LA--10956-C

DE87 012707

Proceedings of the Twentieth LAMPF Users Group Meeting

Los Alamos National Laboratory
Los Alamos, New Mexico
October 27-28, 1986

Compiled by
Roberta Marinuzzi

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

CONTENTS

PROCEEDINGS OF THE TWENTIETH
LAMPF USERS GROUP MEETING
Los Alamos National Laboratory
Los Alamos, New Mexico
October 27-28, 1986

Compiled by

Roberta Marinuzzi

ABSTRACT

The Twentieth Annual LAMPF Users Group Meeting was held October 27-28, 1986, at the Clinton P. Anderson Meson Physics Facility. The program included a number of invited talks on various aspects of nuclear and particle physics as well as status reports on LAMPF and discussions of upgrade options. The LAMPF working groups met and discussed plans for the secondary beam lines, experimental programs, and computing facilities.

TWENTIETH ANNUAL LAMPF USERS GROUP MEETING

Los Alamos National Laboratory October 27-28, 1986

Chairman: Barry M. Preedom, University of South Carolina

Chairman-Elect: June L. Matthews, Massachusetts Institute of Technology

Monday, October 27	LAMPF Auditorium, Laboratory-Office Building (MPF-1, TA-53)
	MORNING SESSION
	Barry M. Preedom, Presiding
8:00 - 9:00 a.m.	Registration
9:00 - 9:15	"Research Directions at LANL" - Warren Miller, Deputy Director for Energy Research and Technology
9:15 - 9:45	"LAMPF Status and Future" - Gerald Garvey, Director of LAMPF
9:45 - 10:15	"MP Division Report" - Donald Hagerman, MP Division Leader
10:15 - 10:45	COFFEE
10:45 - 11:15	"Report from Washington" - Wilmot N. Hess, Associate Director for High Energy and Nuclear Physics (DOE)
11:15 - 11:35	"Annual Users Group Report" - Barry Preedom, Chairman of Board of Directors
11:35 - 11:45	"Associated Western Universities Programs" - Donald Walker
11:45 - 1:00 p.m.	LUNCH

1:00 p.m.	LAMPF Auditorium, Laboratory-Office Building (MPF-1, TA-53)
	AFTERNOON SESSION
	June Matthews, Presiding
1:00 - 1:30	"Physics at P^3" - Daniel Koltun (University of Rochester)
1:30 - 2:00	"Physics at HRS" - Gerard Crawley (Michigan State University)
2:00 - 2:30	"Physics at EPICS" - David Ernst (Texas A&M University)
2:30 - 3:00	COFFEE
3:00 - 3:30	"Physics at LEP" - Philip Roos (University of Maryland)
3:30 - 4:00	"Physics at NPL" - David Axen (TRIUMF)
4:00 - 4:30	"Status and Plans for Computer Facilities at LAMPF" - Earl Hoffman (Los Alamos)
4:30 - 5:15	"Concepts for Advanced Hadron Facilities" - Henry A. Thiessen (Los Alamos)
6:30	**BANQUET AT ELDORADO HOTEL - SANTA FE** (Tickets to this event must be purchased in advance)

MORNING SESSION

New Chairman-Elect, Presiding

8:30 - 9:00 a.m.	"Physics at SMC" - Hywel White (Los Alamos)
9:00 - 9:30	"Neutrinos at LAMPF" - Barry Barish (Caltech)
9:30 - 10:00	"Nuclear Chemistry at LAMPF" - Norbert Porile (Purdue University)
10:00 - 10:30	COFFEE

10:30 - 11:30 WORKING GROUP MEETINGS LAMPF ROOM

EPICS (Energetic Pion Channel)	Kalvir Dhuga (New Mexico State University), Chairman	Auditorium
NPL (Nucleon Physics Laboratory)	John Faucett (New Mexico State University), Chairman	A-234
SMC (Stopped Muon Channel)	Martin Cooper (Los Alamos), Chairman	D-105
Nuclear Chemistry	Robert Kraus (Clark University), Chairman	A-114
Neutrino Facilities	Stuart Freedman (Argonne), Chairman	A-144

11:30 - 12:30 p.m.

Computer Facilities	Kok-Heong McNaughton (University of Texas), Chairman	Auditorium

12:30 - 1:30 LUNCH

1:30 - 2:30

P^3 (High-Energy Pion Channel)	Gordon Mutchler (Rice University), Chairman	A-144
LEP (Low-Energy Pion Channel)	James Knudson (Los Alamos), Chairman	Auditorium
HRS (High-Resolution Spectrometer)	Raymond Fergerson (Rutgers University), Chairman	A-234
Solid-State Physics and Materials Science	Robert Brown (Los Alamos), Chairman	A-114

2:30 - 3:00 COFFEE

3:00 p.m. LAMPF Auditorium, Laboratory-Office Building (MPF-1, TA-53)

Robert Redwine, Presiding

3:00 - 3:45	"Some Open Questions in Nuclear Physics" - Ernest Henley (University of Washington)
3:45 - 5:30	Reports from Working Group Chairmen

ADDRESS TO THE LAMPF USERS GROUP

October 27, 1986

G. T. Garvey

Introduction

Good morning, it is a great pleasure to see so many LAMPF users at the 20th annual meeting of the LAMPF Users Group, Inc. (LUGI). We are honored to have several distinguished visitors joining us for the occasion. Among them, Warren "Pete" Miller, the Deputy Director of Los Alamos National Laboratory, and from DOE Headquarters, Clarence Richardson of the DOE Office of Nuclear Physics, and Bill Hess, Associate Director of High Energy and Nuclear Physics.

Bill has recently taken on the very important and difficult task of directing the Department of Energy's effort to keep U.S. nuclear and particle physics at the cutting edge of science. In a time when both Congress and the public are acutely aware of the huge national deficit, it is more difficult than ever to retain the political support required for new large and expensive initiatives. However, it is my firm impression that Bill will be very successful at this job. We feel especially honored that he has come out to LAMPF so early in his tenure. We are to be joined later in the meeting by Ernest Henley, Chairman of NSAC, who will share his insights on the new directions in nuclear physics.

On a personal note, it has been one year since I was appointed Director of LAMPF. This position has proved to be more stimulating and challenging than I had anticipated; the stimulation arises from the vast potential that Louis Rosen has assembled here, the challenge from coordinating the resources to produce outstanding science. Since last I spoke to you, Don Hagerman has been named the new MP-Division Leader. We are working well together and we both trust that your needs at LAMPF are being met. If not, please let us know.

Last May, Los Alamos was indeed fortunate to have attracted Hywel White from Brookhaven to join us. Hywel jointed the Lab as the MP-4 group leader, a position that Darragh Nagle filled with distinction for so many years. He brings a wealth of expertise in particle physics and a genuine savvy in organizing large projects. We will be relying on him a great deal to provide advice on new directions at LAMPF and setting up effective procedures for us to see that our large undertakings are implemented in a timely fashion.

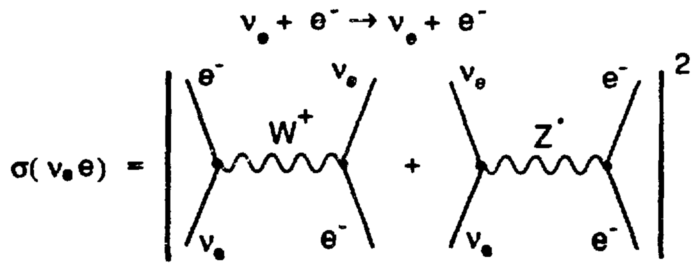
Returning to science, I want to briefly share with you today some of LAMPF's recent research achievements, take a look at what is on our immediate horizon, and finish with a vision of what we all might work towards in the longer-term future.

Samples of Some Recent Achievements

Over the past year E225—a collaboration involving U.C. Irvine, LAMPF, and the University of Maryland has obtained truly significant results. Herb Chen is the spokesman of this experiment that measures electron neutrino-electron scattering. The experiment uses the neutrinos resulting from the stopped π^+ decay chain at the Line A beam stop.

The experiment is important because it allows the unique observation of the interference between the charged weak and neutral weak amplitudes (Fig. 1). The Standard Model (SM) predicts that this interference should be destructive. This is confirmed in E225 as they measure a cross section $\sigma(\nu_e e) = (9.8 \pm 2.7 \pm 1.6)E_\nu$ (GeV) $\times 10^{-42}$ cm^2 The SM predicts $9.2E_\nu \times 10^{-42}$ cm^2 while constructive interface would predict $15.2E_\nu \times 10^{-42}$ cm^2.

Investigations of rare decay processes using the "crystal box" detector have just concluded data taking. We have subsequently offered this excellent photon detection system to others in the U.S. scientific community and are in the process of determining which of three research groups who have expressed interest will receive it. Some of the results obtained at LAMPF with the crystal box that have been completely analyzed at this point are shown in Table I. They are impressive and significant, and please note the results are not all upper limits.



$$\sigma(\nu_e e)_{Exp} = (9.8 \pm 2.7 \pm 1.6)\, E_\nu\, (\mathrm{GeV}) \times 10^{-42}\ \mathrm{cm}^2$$

$$\sigma(\nu_e e)_{MSM} = 9.2\, E_\nu \times 10^{-42}\ \mathrm{cm}^2$$

Figure 1. Feynman diagram of the two amplitudes entering into $\nu_e e$ scattering. The exchange diagram is absent in the case of $\nu_\mu e$ or $\nu_\tau e$ scattering.

Table I
List of the present results obtained with the LAMPF Crystal Box.

Process	*Result*	*Status*
$\mu \rightarrow e\gamma$	$< 4.9 \times 10^{-11}$	Published—*PRL* **56**, 2461 (1986)
$\mu \rightarrow 3e$	$< 3.1 \times 10^{-11}$	Analysis complete—will be part of a *Physical Review* paper
$\mu \rightarrow e\gamma\gamma$	$< 7.2 \times 10^{-11}$	Submitted to *PRL*
$\pi^+ \rightarrow e\nu\gamma$	$\gamma \equiv F_A/F_V$ $= +0.29 \pm 0.12$	Published—*PRL* **57**, 1402 (1986)
$\pi^0 \rightarrow 3\gamma$	Limit $<$ few $\times 10^{-9}$	Analysis essentially complete
$\pi^0 \rightarrow 4\gamma$	Limit available (?) (few $\times 10^{-7}$)	Paper and thesis in preparation
$\mu^+ \rightarrow e^+\gamma$ (familon)	$F > 2.9 \times 10^9$ GeV (scale of symmetry breaking)	Paper in preparation
$\mu^+ \rightarrow e^+\nu\bar{\nu}\gamma$	$\bar{\eta} < 0.086$ (68% CL) ($\bar{\eta} \propto f_S^2 + f_P^2 + f_T^2$)	Analysis complete—will be part of a *Physical Review* article

The TOFI spectrometer has been generating absolutely beautiful data. This excellent system has been principally the responsibility of scientists in the INC Division. It too is an extensive collaboration involving Utah State, Clark, Geissen, Iowa State, and NIKHEF. The project has been very ably led by Dave Vieira. Figure 2 shows some mass spectra which were obtained at the end of the 1985 running cycle. These preliminary measurements greatly improved our knowledge of the masses of extremely neutron-rich isotopes (Fig. 3). In the past year the time resolution and overall system stability has been improved which leads to an improvement in mass resolution of a factor of 2. There are several very interesting issues to be investigated with these measurements but perhaps the most interesting are potentially significant effects due to the onset of deformation in specific regions of the periodic table. Looking at Fig. 4 one can see that in a nucleus like ${}_{10}\mathrm{Ne}^{30}_{20}$ the last proton pair can gain significant energy if the mean field takes on large positive deformation. The same might be true for the last neutron pair in Ne^{30} if it was promoted into the lowest deformed $1f/2p$ orbit rather than remaining in the highest $2s/1d$ orbit. It will be interesting to see what this program of mass measurements reveals. It is clear that it may be extremely desirable to follow up interesting behavior in the ground state masses with more detailed spectroscopic studies of these exotic nuclei; as coexistence of spherical and deformed shapes might occur with a vengeance in this region of neutron and proton numbers.

Coincidence studies of pion-nucleus reactions are just beginning at LAMPF and they are already turning up very interesting effects. Chris Morris and Dieter

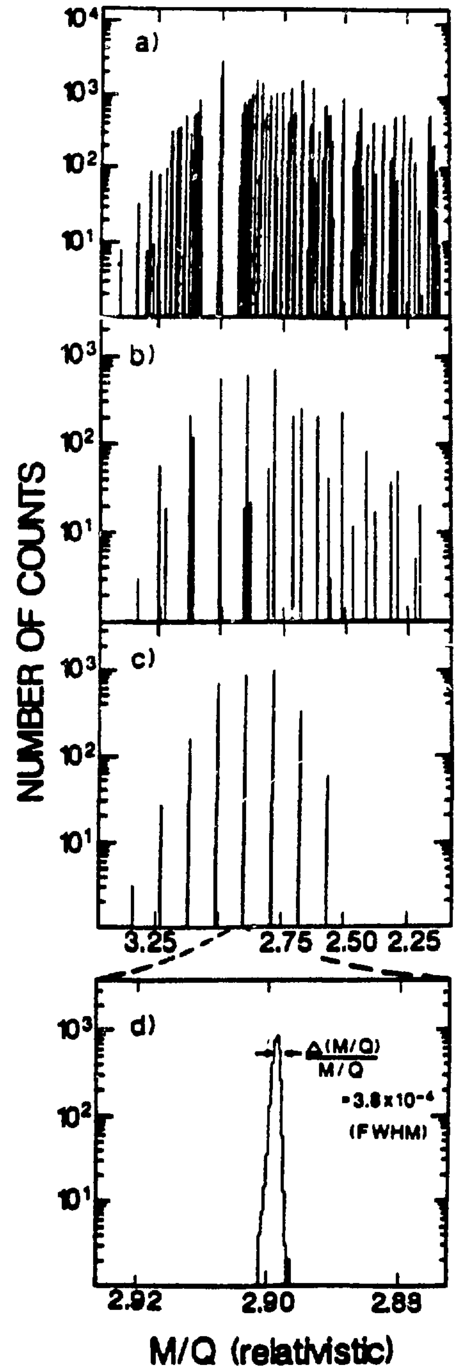


Figure 2. Mass to charge spectra obtained in 8 hours for 800 MeV proton fragmentation of Th. (a) $Z = 6 - 15$, (b) gated on $Z = 11$, (c) gated on $Z = 11$, with a charge of 9, and (d) a blow-up of line associated with ${}^{26}\mathrm{Na}^{+9}$.

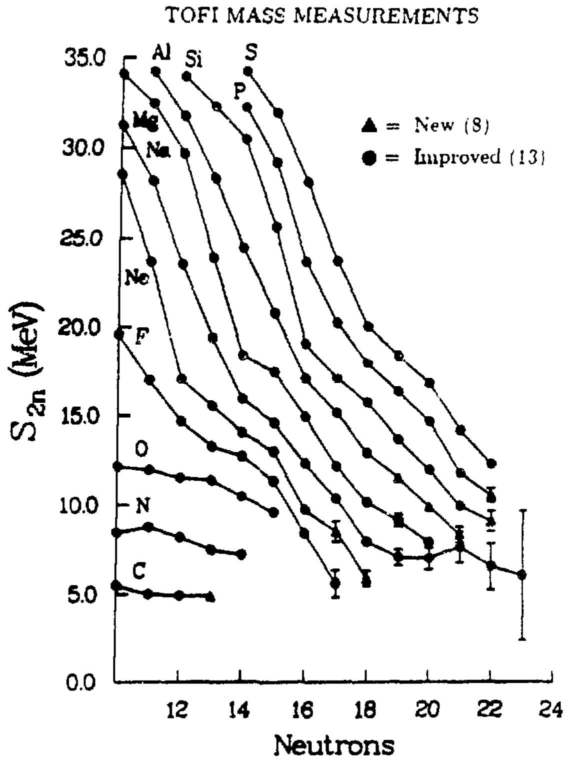


Figure 3. Two neutron separation energies versus neutron number for isotopes of C to S. Open circles indicate an improved measurement of the mass while the triangles indicate masses that have been measured for the first time. The solid points are from G. Audi and A. H. Wapstra, Interim Mass Adjustment, April 1986, private communication.

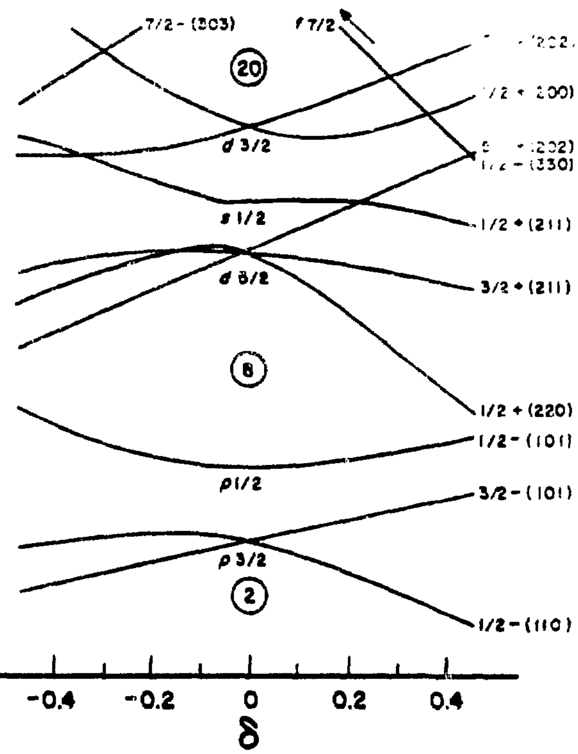


Figure 4. Nilson diagram for the single particle orbits up through N or Z approximately 20.

Dehnhard are the spokesmen for this effort (E998). It is a collaboration between LAMPF, Minnesota, Texas, and Pennsylvania.

A fascinating early result from this work is that while π^+ and π^- inelastic scattering on ^{4}He looks identical (Fig. 5) as it should due to charge independence, the coincident proton spectrum in (π, π', p) looks very different. There is of course no reason why they should be identical as (π^+, π^+, p) is not related to (π^-, π^-, p) via overall isospin conservation. They would only be identical if the pions were exciting states of definite isospin in ^{4}He. If the scattering is quasielastic one would expect $\frac{\sigma(\pi^+, \pi^+, p)}{\sigma(\pi^-, \pi^-, p)} \sim 9$. Figure 6 shows the coincident (π, p) yield as a function of excitation integrated over the angular range (40°-90°). The explanation of the abrupt change of this ratio from 1 just above the ^{4}He breakup energy to a value of the order of 1/9 at excitation energy above that represents a real challenge for theorists studying nuclear reactions. These data may be very important in unraveling pion reaction mechanisms. Further data on heavier systems are to be taken soon.

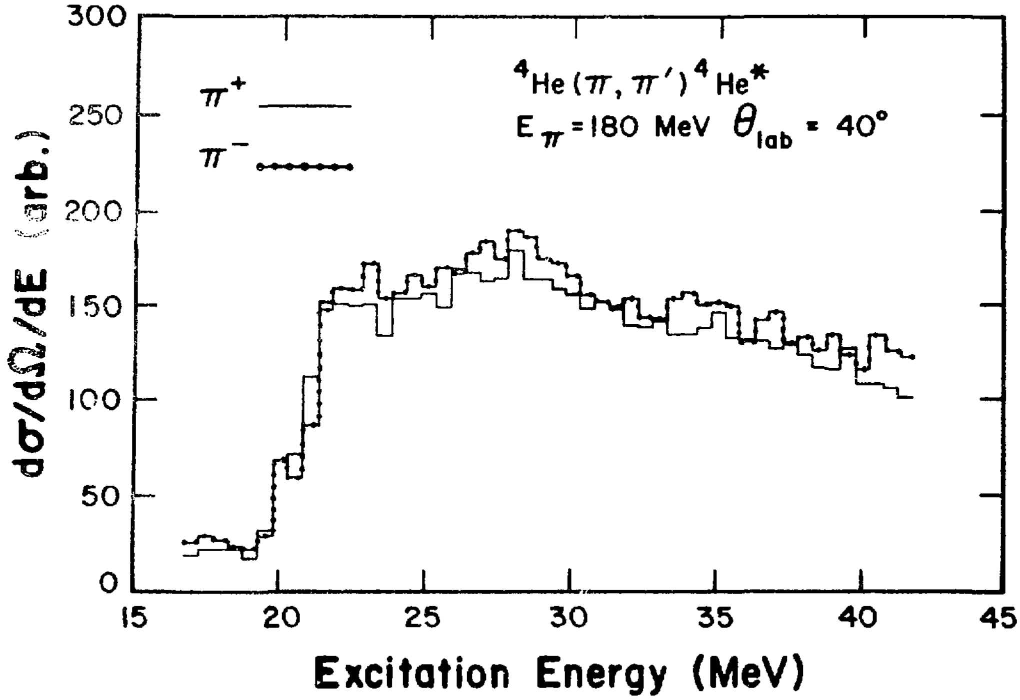


Figure 5. The inclusive π^+ and π^- spectra resulting from ${}^4He(\pi^+,\pi^+)X'$ and ${}^4He(\pi^-,\pi^-)X'$ inelastic scattering.

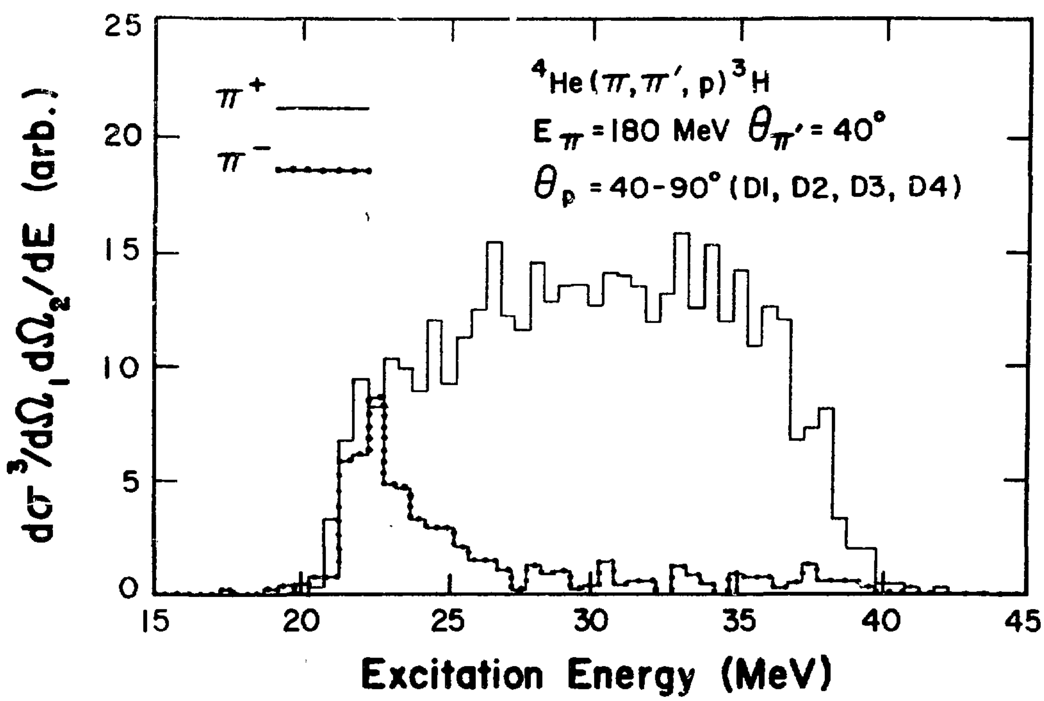


Figure 6. The (π^+,p) and (π^-,p) coincidence spectra resulting from the ${}^4He(\pi^+,\pi^+p)X$ and ${}^4He(\pi^-,\pi^-p)X'$ reactions.

The Near Future

The near future, if anything, looks even more exciting! Our ability to make that future a reality is of course constrained by the available resources. The President's budget for FY1987 represented the first step of an apparently well-conceived plan that provided a vigorous startup ($25M) for the construction of CEBAF and allowed the rest of the nuclear physics program to effectively use existing resources and people. As you are well aware, the previous year, FY1986, was terrible for everyone, including LAMPF, because of G-R-H. This caused us to reduce our working force by 5%. This reduction in force caused the accelerator operations to be less than the very high standard we usually adhere to, and I am sure you noticed this during our summer 86 operating cycle. Though the President's FY1987 budget looked promising, the House of Representatives somewhat reduced (-$7M) that allocation and the Senate was considerably less generous. The Conference Committee has recently completed its work and Nuclear Physics in DOE ended up at $206M, some $18M below the President's budget. This budget will allow us to run a moderately effective program at LAMPF, but it is far from enough to allow Nuclear Physics to develop new facilities in a timely fashion.

Here at LAMPF our near term high priorities are first increased and more effective operation of LAMPF for research (3100+ hours). Completion of the Nucleon Physics Laboratory (NPL) in the most timely fashion possible with existing budgets. The present schedule for the principle components of NPL are as follows. NTOF is coming along very well and experiments are expected in 1987. The Medium Resolution Spectrometer (MRS) and the high intensity polarized ion source are expected to be ready some time in 1988.

The next highest priority is MEGA. This is an experiment to measure $\mu \rightarrow e\gamma$ with a sensitivity of 10^{-14} and it is moving very rapidly. As Director of LAMPF, there are several things that I appreciate about this undertaking in addition to its being a potentially outstanding piece of experimental research. First, it is a tight collaboration including 10 university groups, many of them taking on major responsibility for specific hardware. As you might imagine, organizing and planning such an undertaking is a complex business, but Martin Cooper, ably assisted by Rick Bolton, are doing a superb job of managing that project. Further, by interacting closely with Clarence Richardson and Dave Hendrie at DOE, a real plan has been worked out as to how resources are to be provided for this experiment. I hope to see all our large future undertakings laid out as well as this one.

As many of you know, as our newest high priority proposal, LAMPF is seeking DOE approval and incremental funding to proceed with the construction of a Large Cherenkov Detector[1] (LCD). This large (fiducial volume 7 K tons of H_2O) detector will be used in conjunction with the Proton Storage Ring (PSR) to measure $\sin^2\theta_W$ to an accuracy of better than 1%. The measurement compares the cross section for neutrinos created from pion decay at rest ($\pi^+ \rightarrow \mu^+ + \nu_\mu$, $\tau_{\pi^+} = 2.6 \times 10^{-8}$ sec) to those resulting from μ^+ decay ($\mu^+ \rightarrow e^+ + \nu_e + \widetilde{\nu}_\mu, \tau_\mu = 2.2 \times 10^{-6}$ sec). The time structure of the PSR beam, shown in Fig. 7, allows separation of these two decay modes. Thus, rather than having the very difficult and typical problem of trying to normalize the flux of two different neutrino beams, we simply let nature do the normalization and separate the two components in time. The experiment is costly because of its very large physical dimensions which are required to obtain sufficient counting statistics; however, it appears to be an absolutely fundamental experiment leading to a precise structure independent low-energy determination of $\sin^2\theta_W$.

Also under consideration is an initiative in pion-nucleus physics. One entire day of the August PAC meeting was directed at the subject of future directions in pion physics. Several interesting ideas were put forth but no clear consensus was achieved as to what should be done next. It will take further work and discussion by the interested users to properly define what the next significant step in this area should be.

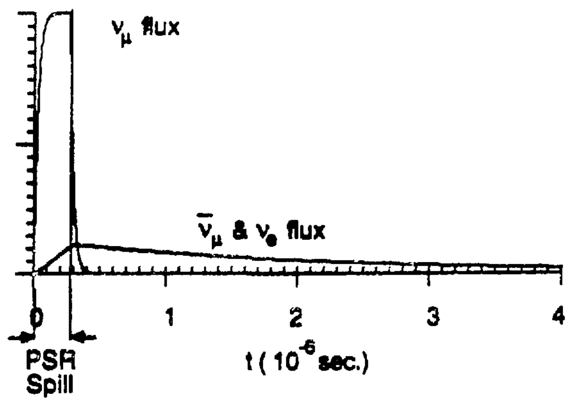


Figure 7. The intensity, as function of time, of neutrinos resulting from π^+ decay and those resulting from the subsequent μ^+ decay. The beam burst creating the π^+ is from the LAMPF-PSR.

A few words about the Proton Storage Ring (PSR) are very much in order at this point. This facility was constructed with a combination of DOE-DP and laboratory funds. It is primarily intended to be used for studies in condensed matter science. LAMPF is committed to providing 12 of its 120 macropulses per second to this facility. The PSR is injected with 800 MeV H^- and should provide 100 μa (6×10^{14} p/sec) at 800 MeV in 12 pulses/sec each with 270 ns duration. On striking a spallation source the 800 MeV protons produce intense beams of thermal and epithermal neutrons. There have been a few very interesting ideas about what nuclear physicists could do with such a neutron source, in particular Dave and Charles Bowman have come up with a notion of how to uncover a rather large number (>100) of neutron resonances which evidence parity violation and then using selected members of this sample to probe for the violation of time reversal invariance.

The Longer-Term Future

Looking to the more distant future, one sees great scientific opportunities in nuclear physics along with some real fiscal and sociological obstacles to the realization of these opportunities. Nuclear Physics stands to make fundamental contributions to the electroweak sector of the standard model if our capability is extended to provide a more than hundred-fold increase in the intensity and purity of beams of kaons, antiprotons, and neutrinos. The definition of the physics program and the required technological improvement and innovation required for the experiments are now underway. Experiments such as MEGA at LAMPF, $K \rightarrow \mu e$ and $K^+ \rightarrow \pi^+ \sum_1 \nu_i \bar{\nu}_i$ at the AGS, measurements of ϵ'/ϵ in K_L decay at FNAL, all challenge the Standard Model with the best available technology and sharpen our awareness of the technological developments that are required to make effective use of higher intensity beams. These experiments will either provide evidence for new physics beyond the SM or lay the technical foundations for the next assaults which will certainly require sizable increases in particle flux.

The avenue to best pursue strong interactions is less clear. The insert below contains statements from three important policy documents generated by representatives of the nuclear science community. These statements make it clear that nuclear physicists wish to relate present-day phenomenological hadronic physics to a more fundamental underlying theory (QCD). This is a noble scientific goal as the matter of which nuclei are made is likely a very special case of QCD, albeit a pervasive one.

—A Long Range Plan for Nuclear Science,
Report by NSAC, 1983—

"One of the greatest challenges facing nuclear physics today is to find and follow the implications of quarks and of QCD in nuclei. This challenge is experimental and theoretical in equal measure. We must design experiments that will reveal the relevant degrees of freedom as clearly and unambiguously as possible; we must attempt to find experimental signatures for models of excitation in which the quark degrees of freedom participate individually, not merely as the underlying structure of nucleons and mesons."

—Report of the NSAC Ad Hoc Subcommittee on a 4 GeV CW
Electron Accelerator for Nuclear Physics, 1984—

"Going beyond our dominant question, we turn here to the general question of exploring the interface of nuclear physics and QCD. The richness of QCD will give rise to a diversity of phenomena requiring study with a corresponding diversity of probes. As is clear from the Long Range Plan, effective exploration of the interface between nuclear physics and QCD necessarily involves, in addition to electromagnetic facilities, consideration of relativistic heavy ion collisions, and of hadronic probes which address complementary fundamental aspects of this interface."

—Brinkman Report, Nuclear Physics Survey, 1984—

"The primary focus of nuclear physics research at CEBAF will be investigations of the microscopic quark-gluon aspect of nuclear matter (the regime of high energies, high momentum transfers, and small distances), using the electron beam to probe the detailed particle dynamics within a single nucleon with surgical precision."

At the recent theoretical symposium[2] honoring Gerry Brown on the occasion of his 60th birthday, it was clear how strongly the viewpoints expressed above have affected nuclear theorists. There were as many talks at the symposium on hadron structure as there were on nuclear structure. A revolution is at hand! Of course, hadron structure can have profound effects on the structure of hadronic matter, for example, recent theoretical work[3] rather convincingly demonstrates that there is a kaon condensate at ~2.7 times nuclear matter density. This condensate serves as a pathway to strange quark matter. Unfortunately, the time scales for this process to occur are too long to be realized in heavy-ion collisions. This state of matter, however, has a large impact on the nature of supernova explosions and the resultant states of the dense core left behind.

We will have to explore and come to understand the consequences of nonperturbative QCD with much greater vigor and precision than we have over the past five years. New facilities for nuclear physics and their proposed research programs should be judged against the standard of how much they will teach us about this new subject. In my mind no facility offers as much potential to investigate hadronic structure and nuclear medium effects as does an advanced hadron facility with an energy of approximately 50 GeV.

References

1. Large Cherenkov Detector—Proposal to the U.S. Department of Energy by the Los Alamos National Laboratory, 1986.
2. Proceedings of the International Conference and Symposium on Unified Concepts of Many-Body Problems—State University of New York at Stony Brook, New York, September 4-6, 1986.
3. D. B. Kaplan and A. E. Nelson, *Physics Letters B* **175**, 57 (1986).

Summary of a Report on MP Division

1986 LAMPF Users Meeting

Donald C. Hagerman

The major goals of MP Division are to participate in the highest possible quality research program to set a world standard for operation and development of an accelerator based research facility, to commission, develop, and operate the LANCE/WNR beam delivery system, and to prepare for a future major facility upgrade.

Major physics initiatives include the MEGA experiment and the NPL upgrade program. MEGA, a measurement of a rare decay mode of the muon, is a collaborative effort of 10 institutions led by a member of MP Division; development and construction of this experiment require careful planning and effective cooperation if the scientific goals are to be met in a timely manner. The NPL upgrade program includes a new optically pumped, polarized ion source, a neutron time-of-flight facility (NTOF), and a new medium-resolution spectrometer (MRS). This upgrade program will make possible continuation of the nucleon-nucleon program, enhance our nuclear physics capabilities, and make possible a significant program in charge-exchange reactions. Other enhancements to our experimental capabilities include a BGO ball detector system and eventually a polarized ^{13}C target.

Other physics programs include the three major spectrometers supported by MP Division (HRS, EPICS, and the Clamshell), charge-symmetry studies using pions, proton-nucleus structure studies, pion-nucleus reaction-mechanism studies, and study of muon catalysis.

Neutrino experiments continue as an important element of the research program with the possibility of a major neutrino detector (LCD) being constructed in a few years for a precise measurement of the $\sin^2\theta_w$. One intriguing offshoot of the neutrino program is a measurement of high-energy events from Cygnus; this measurement is being made through parasitic use of an existing detector complemented by an array of smaller particle detectors.

MP Division is also involved in three significant experiments at high-energy laboratories; two of these are nuclear physics measurements, which require high energies, the third is a particle physics measurement. These off-site programs are important both from the significance of the research and the experience they provide in mounting the sort of experiment that is expected to be the future thrust of medium energy physics.

All of the research programs are collaborative efforts between MP Division, other institutions, and other portions of the Los Alamos National Laboratory. This deep involvement in research is essential if MP Division is to meet its responsibilities in maintaining LAMPF as a world-class facility.

The operation and improvement of the LAMPF facility is driven by the needs of the research program so, in a broad sense, all of the LAMPF users participate in these activities even though nearly all of the work is carried out by MP Division. During the next year increased emphasis will be placed on maintenance and development activities, which will increase beam availability. This need for increased emphasis is a result of some long-deferred maintenance activities and the technical complications resulting from the need to run three beams simultaneously. Accelerator technical problems are primarily connected with the H^- and P^- ion sources and the complex tuning problems introduced the the three-beam operation.

The responsibility for the LANSCE/WNR beam delivery system was assigned to MP Division by the laboratory management early in 1986. This assignment presents a variety of challenging accelerator problems as well as an increased burden of operational responsibilities. The budget for the LANSCE work is separate from the LAMPF budget; by suitable administrative arrangement it is quite plausible that this new assignment will have some synergistic effects, which will be to the financial advantage of both programs. The accelerator-development problems connected with the Proton Storage Ring (part of the LANSCE facility) are of long-range interest to MP Division in that they provide an excellent training ground in circular machine problems—clearly, circular machines will be very interesting to LAMPF personnel when the major facility upgrade occurs. Another common area of interest between LANSCE and LAMPF is that if the LCD experiment is done it will require use of the Proton Storage Ring at quite high currents.

The operating budget for LAMPF is not yet defined in detail; however, it seems probable that we shall be able to provide as many beam hours in FY 1987 as in FY 1986 and possibly a small increase in beam hours may occur; if so, LAMPF operation should resume in June of 1987.

The LAMPF management is contemplating a change from the summer/fall operation used in recent years to a fall/winter schedule. If this occurs, it should provide the users of this facility with better support without increased cost. Because this question impacts all of our users, we have asked them in a recent letter for their evaluation of this proposal.

Annual Report of the Board of Directors to the LAMPF Users Group

October 27, 1986

Barry Preedom

The 1986 Louis Rosen Prize was presented by June Matthews, Chairman-Elect, to Ronald Gary Jeppesen for his thesis entitled, *Observation of Gamow-Teller and Fermi Strength in Light Nuclei Using the 800-MeV (p,n) Reaction.* His advisor was Professor David A. Lind of the University of Colorado. It was announced that last year's Rosen Prize winner, William Burger, was a co-winner of this year's newly established thesis prize of the Division of Nuclear Physics of the American Physical Society.

The results of the election of officers of the LAMPF Users Group, Inc. were announced. The new officers are Chairman-Elect, Stanley Hanna (Stanford University) and Joseph N. Ginocchio (Los Alamos National Laboratory), and R. Jerry Peterson (University of Colorado) as members of the Board of Directors.

During 1986, the Board of Directors had three meetings. Discussions with the new LAMPF management were frank and wide-ranging. Topics included the future of LAMPF with or without LAMPF II, various large projects and their impact on the Users, laboratory support of Users, budgets, and priorities.

The Board of Directors spent a lot of time trying to define the role of the Technical Advisory Panel (TAP). The ability to give in-depth technical advice on specific proposals or programs was of some concern to the new management. According to the By-laws of the LAMPF Users Group, Inc., the members of the TAP are appointed by the Board of Directors from the membership to *collaborate with the staff of LAMPF in devising new experimental facilities and evaluating future developments.* Since the TAP is appointed by the Board of Directors and not the LAMPF management, since not all members have the technical expertise to judge the merits of a specific proposal or device, and since most of the projects brought before the TAP are already in progress, the Board of Directors agrees that the role of the TAP should be more clearly defined. As of this User's meeting, we have asked the working-group chairmen to nominate TAP members who will represent the group by identifying the needs of the group such as upgrades, new spectrometers, technical problems, etc. At subsequent User meetings, these TAP representatives will report back to their working groups. The Board of Directors feels strongly that the TAP (by whatever name), being the only standing committee broadly representative of the Users, should continue to exist.

Housing remains a problem. As most Users know, the Monte Vista Apartments are inadequate in several respects. As of January 1, 1987 the Laboratory has leased twenty units in the Los Alamos Apartment complex nearby. Since these apartments are not associated with the Hilltop House, there will be no late check-in, the Users office will contract for cleaning, and the Laboratory will supply linens and utensils. The Board of Directors has insisted that telephones be in all of the rooms, subsidized by LUGI if necessary.

The subject of U-accounts was taken up by the Board of Directors. They are an administrative headache, but they are very important for Users. There are hidden charges in many of the services and stock purchases. A detailed description of these charges was sent to all holders of U-accounts by Claudette Thiebolt this year. The DOE policy on reimbursable accounts such as U-accounts is presently undergoing a change. The LAMPF management has assured the Board of Directors that they will resist changes that would adversely affect these accounts. The Board of Directors plans to monitor this situation as it develops.

Donald Hagerman, MP-Division Leader, announced a proposed change in the running schedule in his talk. The Board of Directors understands the rationale for not running during the summer, but it is concerned about the problems such a schedule may cause for the university-based Users. Since faculty members usually do not teach in the summer and since undergraduate students and new graduate students usually can come to LAMPF only in the summer, such a schedule may prove unworkable. The Board of Directors asks that all Users respond to Hagerman's request for comments on the proposed change.

Another problem that has reappeared this year is that of open access to LAMPF. Since the decision to build the United States meson factory in Los Alamos, the problem has existed. The necessary security consciousness required for much of LANL is not appropriate for a basic research facility such as LAMPF. The LAMPF and senior LANL management feel as strongly as the Board of Directors about this matter; open access to LAMPF is necessary for it to remain a forefront research laboratory in the international scientific community. Recent attempts to forbid certain foreign nationals from government-identified *sensitive countries* are being vigorously opposed.

Finally, there are a few announcements in the category of quality of life. The Los Alamos YMCA and the LANL Wellness Center welcome LAMPF Users to their facilities. In the September nailing, the various rates charged at the YMCA were listed. The Board of Directors would like to once again remind the Users of the existence of the Users lounge next ro the DAC. This lounge is nicely furnished and can be used at any time. Supplying television sets for the Los Alamos Apartments has been discussed by the Board of Directors, and LAMPF is trying to find some way to provide them.

A plaque expressing appreciation to Donald Walker, Executive Director, of Associated Western Universities, who will be retiring this year, was presented to him by the Board of Directors on behalf of the Users.

PHYSICS AT P^3

Daniel Koltun - University of Rochester

Summary of Talk to the Twentieth LAMPF
Users Group Meeting, October 27, 1986

The kinds of experiment currently running at P^3, or scheduled for the immediate future, can be divided into five categories:

		Exp't. No.
1.	πN: Spin: A + R	806
	$\pi^- p \rightarrow \pi^o n$	849
2.	Charge exchange on nuclei; single (SCX) and double (DCX):	
	Inclusive DCX	978, 957
	DCX at higher energy	(1028)
	SCX on A=3 nuclei	1026
3.	π absorption by nuclei:	
	higher energy and many (charged) particle emission	994
4.	π production	
	$A(\pi^+, 2\pi^+)B^*$	1002
5.	(π,η) in nuclei	852, 934
	broad states of ηA?	(1022)

(The two experiments denoted by parenthesis have tentative approval, conditional on more detailed updates.)

We shall discuss highlights of these experiments in what follows; spokespersons are indicated.

1. πN Experiments

E806 - Barlow, Briscoe, Nefkins, Sadler.

$$\pi^{\pm}p \rightarrow \pi^{\pm}p \quad ; \quad 378 < P_{\pi} < 625 \quad \text{MeV/c}$$

The target is polarized longitudinally, and the polarization components in the scattering plane are measured from the recoiling proton:

$$\vec{P} = P\hat{n} + AP_t\ \hat{s}_f + RP_t\hat{\ell}_f$$

$\hat{\ell}_f$: along recoil, $\hat{s}_f$: $\perp \hat{\ell}_f$, in plane.

P_t = target polarization: expected to be ≃ 80% in HERA target. The extracted values of A,R are expected to have 1-4% statistical accuracy. (P is the transverse polarization, equal to A_N for transverse polarized target - already measured.)

This will be the last of the πN series of cross section and spin measurements, meant to provide complete data for partial wave analysis. The energy range falls between the first two resonances: $\Delta(1232)$ and N(1440) (Roper):

$$1262 < E_{cm} < 1430 \text{ MeV},$$

which is not sufficiently well known. There is hope that complete data sets will help sort out alternate pictures of the "Roper" resonance. For example, in the Chew-Low model, the N(1440) is one of a set of πN states which includes the nucleon N(938) and the Δ. In the quark-bag model, the Δ is a simple spin-isospin excitation of the N, while the N(1440) requires radial excitation. It is likely that not all questions of this sort will be answered by the "on-shell" or phase shift information; "off-shell" experiments involving at least one more particle will also be required. However, the complete on-shell data will also be crucial.

E849 - Fitgerald, Briscoe, Sadler.

$$\pi^- p \rightarrow \pi^0 n$$

Differential cross sections near 0° and 180° are to be measured, for a range of momenta:

$$471 < P_{\pi} < 687 \quad \text{MeV/c}.$$

This will much improve the data available for this CX reaction.

2. Charge Exchange Studies

Several experiments by Gram, Matthews, Rebka.

These follow on a series reported in the 1984 and 1985 LAMPF Progress Reports: Nos. 309, 750, 859.

E865 - An attempt to measure $^3He(\pi^-,\pi^+)3n$, lost its ^3He target in 1985. (Further problems with the target have been reported very recently!) Here one wants good data on a light target, to compare to inclusive π^- scattering.

E957 - Inclusive differential cross section for DCX in p-shell nuclei. This follows onsimilar studies of ^4He, which showed a two-bump structure in the energy of the outgoing pion, possibly indicative of two different kinds of DCX processes. The structure is not seen for ^{16}O. The idea is to see what happens in between, to help explain DCX reactions on light targets in general.

E978 - $^4He(\pi^+,\pi^-p)3p$

This coincidence experiment would explore the details of the ^4He inclusive DCX experiment mentioned above, to try to clarify the reaction mechanisms involved, which lead to the two-bump structure seen.

E1026 - $^3H(\pi^+,\pi^0)^3He$

This SCX study is intended to provide a good data base on a small target, for which rather incomplete and/or poor statistics data exists. The expected cross section accuracies are $\simeq$ 5% relative and $\simeq$ 10% absolute.

E1028 (conditional) - Baer, Burleson, Morris.

Here the intention is to push DCX studies into the energy region

$$300 < T_\pi < 500 \text{ MeV},$$

which has not been previously explored. Some simplification of interpretation may be expected, above the Δ-region. Preliminary SCX studies have been carried out at these energies (see E829, 1985 LAMPF report).

The proposed experiment would study small angle DCX (0° - 8°) on ^{14}C and ^{16}O, looking both at IAS and at nonanalog excitations. (Elastic scattering cross sections on ^{16}O will also be measured at these energies.)

Studies of DCX at lower energies, to analog states, have shown evidence of an interference of two mechanisms: one consists of two successive SCX reactions, passing through the IAS as an intermediate state. The second does not pass through the IAS, and presumably involves some short range structure of nuclear (e.g. correlations) or subnuclear (e.g. Δ, or 6-quark) origin. One would very much like to know what happens above the Δ.

3. π Absorption by Nuclei

E994 - Ransome, Morris.

$$\pi + A \rightarrow \text{charged particles} + X$$

This experiment will push in two new directions at once: first, to study absorption at energies above the Δ-resonance, up to 500 MeV. Second, a newly developed detector will be used to measure correlated multiple charged emissions (mostly protons).

Recent studies of inclusive (π,p) and (π,2p) have given some evidence on the reaction mechanism or mechanisms involved. Although two-nucleon absorption clearly plays an important role, there is less agreement on the evidence for many-nucleon processes, such as direct absorption by clusters in the nucleus, with $N \geq 3$ or 4. It is hoped that the availability of multi-nucleon emission will help sort out the questions raised. Although it is expected that there is useful information in this data, there has not been much thought concerning how to organize this data, and to what it should be compared. There is very little theory available for guidance, other than Monte-Carlo calculations.

This experiment will provide a good example for the development of the new "BGO-Bell" detector - a multi-sector 4π device with Bismuth-Germanate scintilator components.

4. π Production on Nuclear Targets

E1002 - Dropesky, Liu.

Study of (π^+, $2\pi^+$) with nuclear targets, by radioactivity of the final targets, as a function of the energy of the initial π beam,

$$380 < T_\pi < 450 \text{ MeV.}$$

The physical interest here is in the possibility of seeing some "enhancement" of the cross section, at a momentum transfer of 300-450 MeV/c in this energy range, which could indicate the presence of a "precursor" of pion condensation. This "precursor" is non-linear increase of the probability of coupling to pions (relative to that expected from free nucleons) which comes from mixing with spin-isospin nuclear modes of the target.

The problem is tht the expected "enhancement" is relative to other nuclear effects, like optical damping, which complicate the analysis.

5. (π,η) Studies in Nuclei

E852 - Peng et al., are studying η-production in nuclei, trying to see discrete final states. (Preliminary results in the 1985 LAMPF report show the IAS excited in (π^+,η) for ^{3}He, ^{7}Li, ^{9}Be, ^{13}C.)

E947 by the same group is interested in the energy - and target - dependence of this reaction, to see effects of the interaction of the produced η with the host target. This can be considered a study of the η-nucleus optical potential. Note that the absorptive part of this potential should come from $\eta N \to \pi N$, the inverse of the (leading) production process.

E1022 (conditional) Lieb, Liu.

This novel experiment will look for broad "bound" states in the final system of η+A, with widths estimated $\Gamma \geq 10$ MeV. ($\Gamma(\eta) \sim 1$ keV for free η.) The broad structure would represent an "optical bound state" of ~ nuclear optical lifetime, analogous, in a way, to the Σ-nucleus states.

To lower competing backgrounds, the experiment is planned as a coincidence measurement:

$$\pi^+ + {}^{16}O \to p + {}^{15}_{\eta}O$$

with the fast p in coincidence with a π^- from the decay of ${}_{\eta}O$.

In summary - what is new at P^3?

1. πN - on to finishing the program!

2. CX → DCX

   (π,πp) correlations and higher energy.

3. π-absorption

   multinucleon emission,

   new detector development: BGO ball.

4. (π,2π)

   Exploratory.

5. (π,η)

   Exploratory.

Talk Presented at the Twentieth LAMPF Users Meeting, Nov 1986

Physics at the HRS

G.M. Crawley

National Superconducting Cyclotron Laboratory

and

Physics Department, Michigan State University

The high resolution spectrometer at LAMPF was planned during the construction of the accelerator and was actually commissioned in 1976. The principle motivation for HRS was, I believe, to permit a wide range of nuclear spectroscopic measurements at the high proton energies available at LAMPF. However the point I would like to emphasize in my brief remarks today is that not only were these kinds of measurements possible but a wide range of other kinds of measurements have also been made. The ability to remove elastic scattering or any other unwanted but prolific reaction from the counters has proved a very valuable property of the magnet and has led to diverse uses of HRS. In addition, the flexibility of the focal plane detectors including the focal plane polarimeter has allowed a whole range of spin studies which have led to new insights both in reaction theory and in the structure of particular kinds of nuclear states especially spin-flip excitations.

I think that the LAMPF staff and the experimenters using this facility are to be congratulated on their willingness to keep improving HRS as the physics needs arise.

In the brief time available, I cannot hope to cover all the physics carried out at HRS. It has been necessary for me to be very selective. I have therefore chosen to describe a few experiments which illustrate the diversity of the physics program. In addition, I have chosen to emphasize recent experiments or even proposed experiments not only because the earlier experiments are already in the literature, but also because not all of you are perhaps so familiar with the current program.

I regret that I can cover so few of the many excellent measurements carried out at HRS and I hope that people whose favorite experiment is not mentioned will understand my difficulty.

I thought that I should begin with a very brief description of the facility. Fig. 1 shows a drawing of HRS and the main characteristics are listed in Table 1. Let me emphasize the high resolution achieved, viz. about 1 part in 10,000 in energy in real experiments, the solid angle of 3.6msr and the momentum "bite" of 4%. Finally let me stress that the focal plane detectors have undergone many changes including an extensive shielding project last year and that the target area has seen many different kinds of targets including large cryogenic targets.

I have divided the rest of this paper up into 6 sections illustrating the diversity of the HRS physics program and will give an example or two of recent or current work going on in these areas.

1. Few Nucleon Problems:

The ability to make clean measurements with low background even at very forward angles has led to a number of important few nucleon measurements at HRS. These experiments typically involve long runs with a good deal of overhead because of the need for complex cryogenic polarized targets. However such measurements cannot be carried out readily on any other facility.

One recent experiment* of this type[1] used a polarized proton beam to bombard a polarized hydrogen target. The aim of this experiment was to determine the proton-proton spin-dependent scattering amplitudes by measuring the spin asymmetries A_{NN}, A_{LL} and A_{SS} at forward angles in the Coulomb-nuclear interference region. The Coulomb and nuclear amplitudes are of comparable magnitude at such forward angles, and therefore the interference is strong making it easier to extract the nuclear p-p spin-dependent amplitudes. The determination of A_{NN} and A_{LL} were the first measurements of these spin asymmetries in this angular range. They were possible because of the small angle capability of the HRS. This experiment also used a frozen-spin dilution refrigerator to obtain the polarized proton target.

Figure 2 shows preliminary results of the A_{LL} measurements compared with various phase shift analyses. None of the 3 analyses give excellent fits to the data. In particular, the Saclay calculations are in marked disagreement with the measurements over most of the angular range. On the other hand, the measurements are generally in good agreement with forward angle dispersion relations calculations suggesting that analyticity should be more of a constraint on phase shift analyses. Interestingly the dispersion relations and the two phase shift analysis which fit the data better all show "looping" in their Argand diagrams, a feature indicative of a dibaryon resonance whereas the Saclay analysis does not have such resonance behavior.

A somewhat different type of experiment[2] used the HRS to study the $^2H(p,\gamma)^3He$ reaction by measuring the emitted ^3He energy rather than the γ-ray directly. The goal of this experiment was to study meson exchange currents. In particular a calculation by Laget of both the (p,γ) and (p,π°) reactions includes virtual excitation of the Δ resonance. This calculation predicts substantial oscillatory structure for Ay for both of these reactions. In addition widely discrepent cross sections have been published for the $^2H(p,\gamma)^3He$ reaction.

The (p,π°)peak was readily observed but in order to extract the peak from the (p,γ) reaction, a coincidence with γ-rays identified in a Pb glass

Cerenkov counter was needed. By this method the γ-ray peak was clearly identified. (See Fig 3).

The results from the preliminary measurements are somewhat inconclusive. The analyzing power values for both $(\vec{p},\pi^{0})$ and $(\vec{p}\ \gamma)$ reactions are shown in Figs. 4 and 5. While these measurements are generally consistent with Laget's calculations, the quality of the data particularly in the (p,γ) case needs to be improved to determine whether the predicted oscillations are in fact observed.

2. Exotic Searches

There have been a number of searches for exotic (read unexpected or maybe unlikely) phenomena using the HRS. Some of these searches have been successful (see the LAMPF contribution to the EMC effect) and there seems to be general sympathy on the PAC for permitting some small fraction of the time to be used for "wild" ideas.

One recent example is a proposal[3] which aims to search for dibaryon resonances in the cross section and analysis power for the $\vec{p}+d \rightarrow p+x$ reaction in the energy range $1880 \leq M \leq 2350$ MeV.

There are a number of predictions of narrow dibaryon resonances in this energy range (see Table 2) and even a number of claims that such phenomena have been observed (See Table 3) and Fig 6. However a preliminary search over part of this energy range has shown no evidence of such resonance. See (Fig. 7). We await the complete experiment with interest.

(3) Relativistic Scattering Theory

One of the recent exciting developments in intermediate energy physics has been the observation that using a relativistic impulse approximation gives an excellent description of nucleon-nucleus elastic scattering expecially at energies between 500-800 MeV. This statement is expecially true if one considers the spin observables in addition to cross section and analyzing power. Perhaps the classic example is the measurement of the analyzing power A_Y and spin rotation pasrameter Q in the ^{40}Ca (p,p) reaction[4] shown in Fig. 8. This relativistic impulse approximation calculations appear to give better fits, especially to the angular distribution of Q.

More recently, interest has turned to a relativistic description of inelastic scattering. One of the additional advantages of this formulation is that it makes for a more transparent comparison between (p,p') and (e,e').

One example of such a test was the measurement[5] of cross section, analyzing power Ay, the spin rotation parameter Q and other spin transfer parameters for a number of low lying states in ^{58}Ni including the 6^{+} (5.13 MeV) state. The wave function of this state is believed to be mainly (f $7/2^{-1}$ f 5/2) and the charge transition density has been measured previously by electron scattering. (Fig. 9)

The angular distributions of the cross sections, analyzing power and D_{SS} and D_{SL} for the (p,p') reaction at a bombarding energy of 498 MeV are shown in Figs. 10, 11, 12 and 13. On the figures are also shown predictions based on 1) a phenomenological optical potential, optimized to fit only the elastic cross sections and analyzing power (A_y) data, 2) Dirac IA calculations (made by E. Rost, Univ. of Colorado) using transition densities adjusted to fit electron scattering, together with experimental N-N amplitudes and 3) Non-relativistic IA calculations, again using transition densities from electron scattering, and the free N-N matrix of Franey and Love. The DIA and NRIA predictions are thus essentially parameter free. Some of the conclusions from the preliminary results are:

1) The DIA predictions for the elastic cross sections, A_y and Q are superior to the NRIA, and for Q, to the phenomenological potential predictions also.

2) The same is true for the 6_1^{+} inelastic A_y, D_{SS} and D_{SL} observables.

3) For the 6_1^{+} transition densities, based on a pure ($1f_{7/2}^{-1}$ $1f_{5/2}$)

configuration, both the DIA and NRIA calculations require slightly different bound state (BS) radii for best fits to the electron and proton inelastic (6_1^+) data. In both cases R_{BS} (proton) < R_{BS}(electron).

4) An energy dependence of the normalization constant, $N_P^2 = \sigma_{exp}/\sigma_{theo}$ is seen for the Dirac calculations similar to that found for the NRIA below 500 MeV. Thus the relativistic theory does not seem to solve this problem. A plot of normalization factors for several natural and unnatural parity states vs proton energy is shown in Fig. 14.

Another example of a test of a relativistic approach to inelastic proton scattering is provided an experiment recently proposed.[6] The aim is again to accurately measure angular distributions cross sections, analyzing powers and other spin observables, for a number of states in ^{12}C whose wave functions are believed to be fairly well described by Cohen-Kurath 1p shell wave functions. In particular the 12.71,1^+ T=0 and 15.11,1^+ T=1 states and 16.1,2^+ T=1 states will be measured.

Earlier measurements at 398 MeV of cross sections and Ay for some of these states are shown in Fig. 15, and 16 together with three calculations. These calculations are (1) standard (non relativistic) impulse approximations (SIA) (2) The Full Relativistic Impulse Approximation (FRIA) which employs the relationship between upper and lowe components of the bound target nucleon 4- component Dirac spiner characteristic of a free particle and (3) the Dynamical Relativistic Impulse Approximation (DRIA) which attempts to include strong scalar and time-like vector potentials on the target nucleon.

While the Relativistic calculations give a better description of the $\sigma(\theta)$ and $Ay(\theta)$ for the 15.11 MeV state, the SIA calculations appears to do better for the 12.71 MeV state. The hope is that accurate measurements of a wider set of spin observables will provide a more discriminating test of the different theories.

(4) Reaction Mechanism of (p,π^+) Reactions

The mechanism of the (p,π) reaction at intermediate energies is still not well understood. One proposed measurement[7] focuses on the continuum cross section and analysing power in a number of nuclei in attempting to establish a common dominant mechanism for this process.

Another approach[8] focussed on the mechanism for exciting certain states whose wave functions are believed to be known. In particular these measurements plan to establish whether 2 particle -1 hole states are strongly excited in this reaction at 650 MeV. Initially the hope was that the (p,π^+) reaction would be dominated by a simple stripping mechanism and could be used to probe high momentum components of nuclear wave functions.

However, this did not turn out to be true and at present the reaction mechanism is unclear.

There are 4 possible nucleon-nucleon processes which can produce charged pions vig.

$$p+p \rightarrow d+\pi^{+}$$

$$p+p \rightarrow p+n+\pi^{+}$$

$$p+p \rightarrow n+n+\pi^{+}$$

$$p+n \rightarrow p+p+\pi$$

One finds however that the (p,π^{+}) reaction (and the (p,π^{-}) reaction for that matter) is quite selective and in particular selects neutron transitions. This seems hard to understand in a one step nucleon-nucleon model of the reaction mechanism. An alternative explanation is a two step mechanism, where the intermediate state is a strong collective state like the first 2^{+} state in ^{12}C. This experiment, which will examine transitions to particular well understood states, is designed to clarify this question.

5). Nuclear Spectroscopy

One of the important features of HRS , as the name implies, is its ability to carry out high resolution studies of particular states of interest. This feature has been exploited both in transfer reactions like (p,d) and (p,t) and in inelastic scattering to extract transition densities. Let me select just a couple of illustratative examples.

One recently proposed study[9] plans to obtain neutron transition densities (ρ_n) in a number of s-d shell nuclei to compare with the extensive shell model (SM) calculations which exist for this region. These neutron transition densities require a knowledge of the proton transition densities obtained from electron scattering and of course a correct description of the reaction, including the effective interaction. In particular the SM prediction of ρ_n for the second 2^+ state in ^{34}S has a very different shape from that for the first 2^+ state as shown in Figs.17 and 18. Measurement of the cross sections as illustrated in these same figures should clearly differentiate between the case where $\rho_n = \rho_p$ and the SM prediction.

A similar example has been seen in ^{88}Sr (Fig.19) and a proposal[10] exists to test the stability of the measured ρ_n as a function of bombarding energy.

A somewhat different motivation exists for a study[11] of high spin (stretched) states in ^{208}Pb. These transitions peak at large momentum transfer, q which makes them suitable for studying the high q components of the effective interaction. An additional motivation is to study the "quenching" observed for these states in the (p,p') reaction compared to the quenching observed in (e,e'). Various explanations have been suggested to explain this quenching including core polarization, mixing with 2p - 2h states and with the octupole core excitation. The measurements were carried out at a bombarding energy of 318 MeV where the central isoscalar spin independent part of the nucleon-nucleon interaction has a broad minimum. The resolution obtained (and required) was about 40 keV FWHM as shown in the spectrum in Fig.20. The excellent quality of the fits to the elastic scattering cross section, Ay and Q parameter are shown in Figs. 21, 22 and 23. Representative fits to the 14^-, 6.74 MeV and 12^-, 6.43 MeV states are shown in Figs.24 and 25. The quenching factors obtained for some of these states both from (e,e') and (p,p') are shown in Table 4 where the analysis has been done assuming the simple configurations shown in the table. Note that the quenching factors from (p,p') and (e,e') do not agree especially for the 12^- states. However, the two 12^- configurations are allowed to mix 12^- , the agreement becomes much better (see Table 5.) for a value of the mixing parameter α of 0.07.

6). ℓ=o Spin-Flip Excitations

One of the most exciting areas in nuclear physics in recent years has been the observation of the giant Gamow-Teller resonance in (p,n) reactions and later the similar ℓ=o spin-flip transition in the parent nucleus observed in (p,p'). These observations have led to a whole range of theoretical calculations and to the fruitful comparison of both of the hadronic reactions with electromagnetic measurements of similar (M1) transitions.

The work done at HRS[12,13] has been extremely important first in proving definitely that the bumps seen in earlier (p,p') measurements in nuclei like ^{90}Zr and ^{51}V with ℓ=o angular distributions were indeed spin-flip excitations. See Figs 26 and 27. In addition the spin-flip probability measurements at HRS have been extended to higher excitation in a number of nuclei. The surprising result was that significant spin-flip cross section persisted to excitation energies much higher than the bumps seen around 10 MeV. Fig. 28 shows the measured spin-flip cross sections in ^{90}Zr together with a calculation by Esbenson and Bertsch. the agreement is excellent up to 25 MeV excitation energy but it would certainly be interesting to continue these difficult measurements to higher excitation energies.

One other question which need to be answered is the distribution of multipolarity as a function of excitation energy. The different angular momentum transfers can in principle be obtained by multipole decomposition of the angular distribution of the spin flip cross section. An example of an attempt to carry out such a decomposition in ^{90}Zr is shown in Fig. 29 and the preliminary results for 3.5° and 5° are shown in Fig. 30.

From these results and the calculated angular distributions shown in Fig. 31, one sees the importance of measurements at very forward angles in order to identify the interesting ℓ=o transitions. Therefore an attempt is being made to construct a 0° polarimeter for use on the HRS. A preliminary measurement first of the cross section for the 15.11 MeV 1^+, T= 1 state in ^{12}C is shown in Fig. 32. When multiplied by the spin-flip probability, the experimental background essentially goes to zero. (see Fig. 33) The next try will be a heavier mass target and we await the results of these measurements with great interest.

This zero degree polarimeter is an example of the apparatus development which continues at HRS.

I hope that I have given you some appreciation of the diversity of the physics program at HRS and I regret that in the limited time available I could not deal with a larger fraction of the interesting physics being carried out at HRS.

Acknowledgments:

I should like to acknowledge the suggestions made by a number of PAC members and users of HRS in the preparation of this talk particularly John McClelland, Kevin Jones, Norton Hintz, Gerry Hoffman and Charles

Glashausser. However the responsibility for errors and omissions is all my own.

References

* References will generally be given only to the relevant HRS proposals. More extensive references are available there or from the appropriate spokespersons.

1. "Measurements of A_{NN}, A_{LL} (A_{SS} and A_{SL}) in the Coulomb Nuclear Interference Region for $\vec{p}+\vec{p}$ at 650 and 800 MeV." Experiments 583 and 709, Spokespersons: M. Gazzaly and G. Pauletta.

2. "Reaction Mechanism for the $^{2}H(p,\gamma)^{3}He$ Reaction at 800 MeV." Experiment 883, Spokespersons: G.S. Adams and B. Hoistad.

3. "A Systematic Search for Narrow Dibaryons in the $\vec{p}+d\to p+x$ Reaction." Experiment 951, Spokespersons: K. Seth and M. Arturo.

4. "First Measurement of Spin Rotation Parameter Q in Proton-Nucleus Scattering at Intermediate Energies." A. Rahbar et al. Phys. Rev. Letters 47, 1811(1981).

5. "A Test of the Dirac Treatment of Proton-Nucleus Inelastic Scattering." Experiment 896, Spokesperson: N. Hintz.

6. "Tests of a New Relativistic Impulse Approximation for Inelastic Proton Scattering at 500 MeV." Experiment 939, Spokespersons: J.R. Shepard, J.B. McClelland and T.A. Carey.

7. "Pion Production in the Continuum with Polarized Protons." Experiment 1013, Spokesperson: K. Seth.

8. "Cross Sections for the (p,π^+) Reaction on ^{12}C, ^{13}C and ^{14}N." Experiment 1000, Spokespersons: D. Dehnhard, S.J. Seestrom-Morris and K.W. Jones

9. "Microscopic Structure of s-d Shell T=1 Nuclei." Experiment 919, Spokespersons A. Saha and J.J. Kelly.

10. "Inelastic Scattering of 500 MeV Prolonged Protons from ^{88}Sv." Experiment 902, Spokespersons: F.W. Hersman and K. Seth

11. "Determination of Neutron Transition Densities in ^{208}Pb by Inelastic Scattering of 318 MeV Protons." Experiment 686, Spokesperson: N. Hintz.

12. "Spin Excitations in ^{90}Zv." Experiment 837, Spokespersons: C. Glashausser and S. Nanda

13. "Spin Excitations in ^{40}Ca and ^{48}Ca." Experiment 907, Spokespersons: C. Glashausser, K. Jones and S. Nanda

14. "Development of Zero-Degree Spin Flip Measurements at HRS." Experiment 891, Spokespersons: S.K. Nanda and J.B. McClelland.

TABLE I

SPECIFICATIONS OF THE HRS AND LINE C

Incident Proton Beam:	1. Energy variable in steps from 113-800 MeV
	2. 0.1-π-cm-mrad phase space for 96% of the beam and 0.3-π-cm-mrad phase space for 99% of the beam
	3. Momentum spread of $\Delta p/p = 0.26\%$
	4. Maximum average proton current of 100 μA
	5. 50-100-nA average polarized proton current
	6. Maximum dispersion at full phase space = 40 cm/%
QDD Spectrometer:	1. Central radius of curvature = 3.5 m
	2. Solid angle = 3.6 msr
	3. Maximum induction = 19 kG
	4. Momentum acceptance = 4%
	5. Momentum resolution = $\pm 1.5 \times 10^{-5}$
	6. Angular resolution = ±0.8 mrad
	7. Range of scattering angles = 10-168° and 0-10° with reduced intensity
	8. Flight path ≈ 19.5 m
	9. Dispersion $\langle \Delta x/\Delta p \rangle$ = 18.25 cm/%

Table 2. Some Theoretical predictions for narrow dibaryons.

Authors	Model	J^{π} (I)	Mass (MeV)
Fredriksson	$q^2q^2q^2$	0^-	1876 - 2018
Ericson	$\pi^- nn$	1^+ (2)	≈ 2018
McGregor	πNN	0^+ (1)	2020
		1^- (1)	2060
Mulders	q^4q^2	0^-, 2^- (0)	2110
	q^5q	0^-, 2^- (0)	2370, 2433
	q^4q^2	0^-, 2^- (0)	2405, 2427
	q^4q^2	1^+, 3^+ (1)	2466

Table 3 Some recent 'claims' and 'non claims' for narrow dibaryons.

Authors	Lab.	Masses (widths) MeV	Reaction (Incident Energy)
Yuldashev	Tashkent	1922(4),1940(10),1954?	$\pi^- + {}^{12}C \rightarrow pp+X$ (4.4 GeV)
Trojan	Dubna	1936(<10),1962(<10)	$np \rightarrow pp\pi^-$
Ward	BNL	~ 1980?, ~ 2040?	$\pi^- + d \rightarrow \pi^+ + X$ (0.6 GeV)
Siemiarczuk		2020 (45), 2130 (20)	$d + p \rightarrow p + (pn)$ (3 GeV/c)
Baranov	Dubna	2024	$\pi^- + {}^{12}C \rightarrow pp + X$ (5 GeV)
Tatischeff	Saclay	2124(20),2189,2240(16)	$p + {}^3He \rightarrow d + X$ (0.93 GeV)
Julien	Saclay	2220 (<10)	$p + Cu \rightarrow \pi^+ + X$ (350 MeV)
Saudinos	Saclay	2044 (3)	$p + p \rightarrow d + \pi$ (350 MeV)
Schwille	Bonn	2015 (<10)	$\gamma + d \rightarrow pp + \pi^-$(<520 MeV)

TABLE 4. Quenching Factors[a)] - Pure Configurations

	(p,p') previous analysis[c)] $E_p = 135$MeV	(e,e') present analysis	(p,p') present analysis $E_p = 318$MeV
14^- 6.74 MeV $i^{-1}_{13/2}\ j_{15/2}$	.50	.551	.616
12^-_1 6.43 MeV $i^{-1}_{13/2}\ j_{15/2}$	.80	.570	.805
12^-_2 7.06 MeV $h^{-1}_{11/2}\ i_{13/2}$	.20	.483	.389

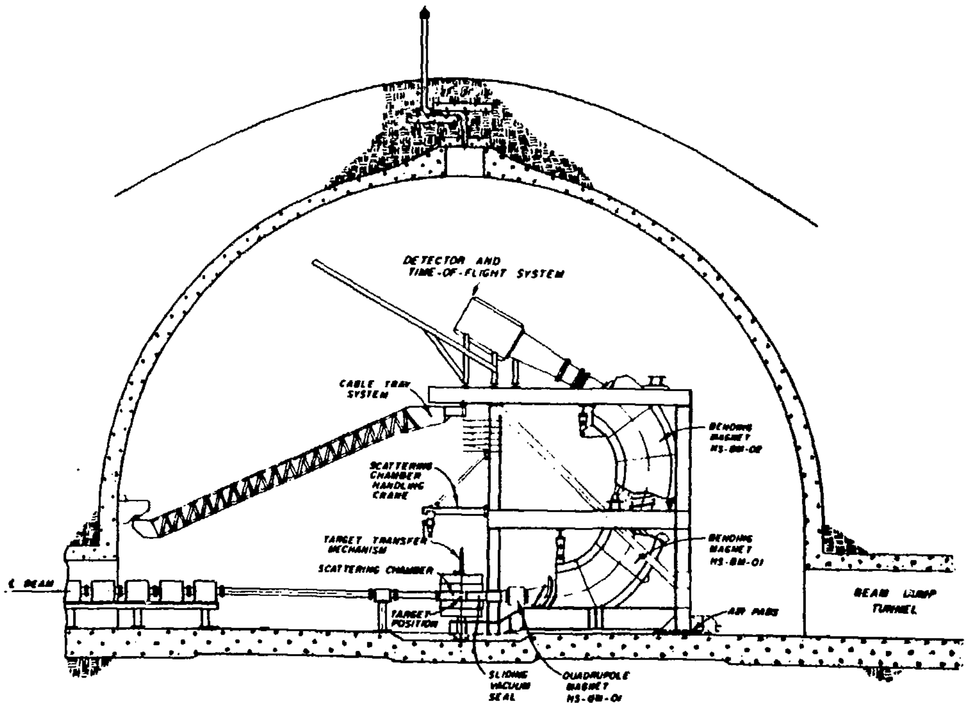
a) Quenching Factor = $\sigma_{exp}/\sigma_{theo}$ where σ_{exp} is the measured cross section maximum, σ_{theo} is the predicted maximum cross section.

TABLE 5 Quenching Factors[a)] for Mixed Configuration (α = 0.07)

12^- Calculations

	(e,e') this work	(p,p') E_p = 318 MeV
12^-_1 6.43 MeV	0.771	0.760
12^-_2 7.06 MeV	0.453	0.399

a) The quenching factor is defined in the footnote to Table 4



SECTION HRS FACILITY

0 5 10
GRAPHIC SCALE
IN FEET

Fig. 1.

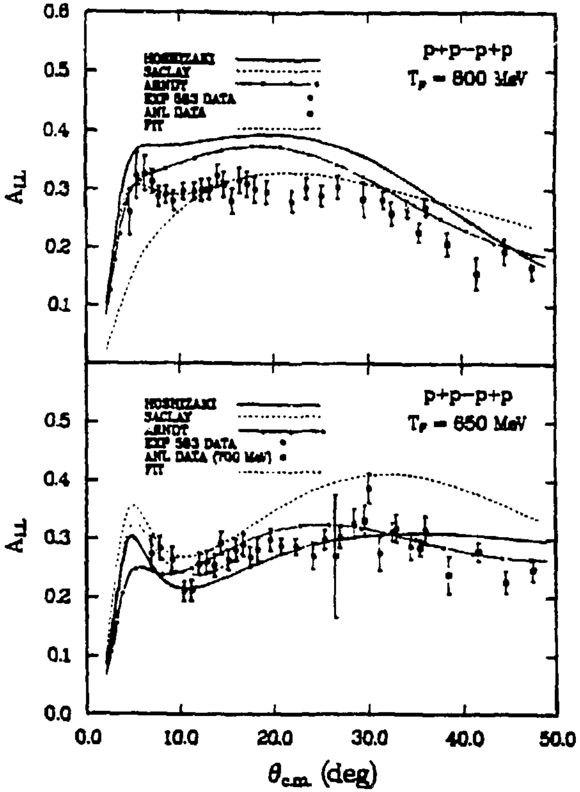


Fig 2. Preliminary data for A_{LL} at 800 MeV and 650 MeV. Some recent Phase Shift Analysis predictions are also shown.

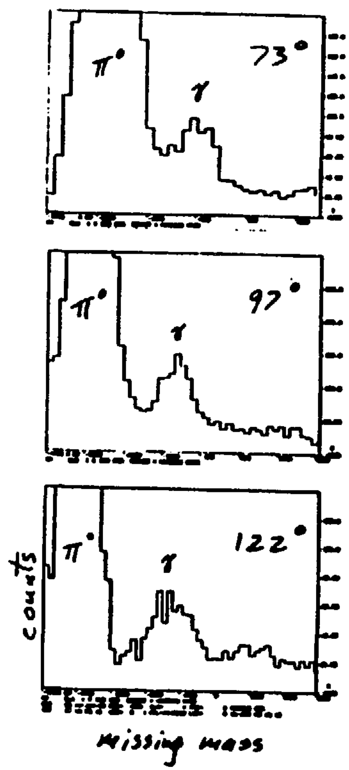


Fig 3. Coincidence spectrum of $^2H(\vec{p},{}^3He)\gamma$ reaction. The $\pi°$ and γ ray peaks are labelled.

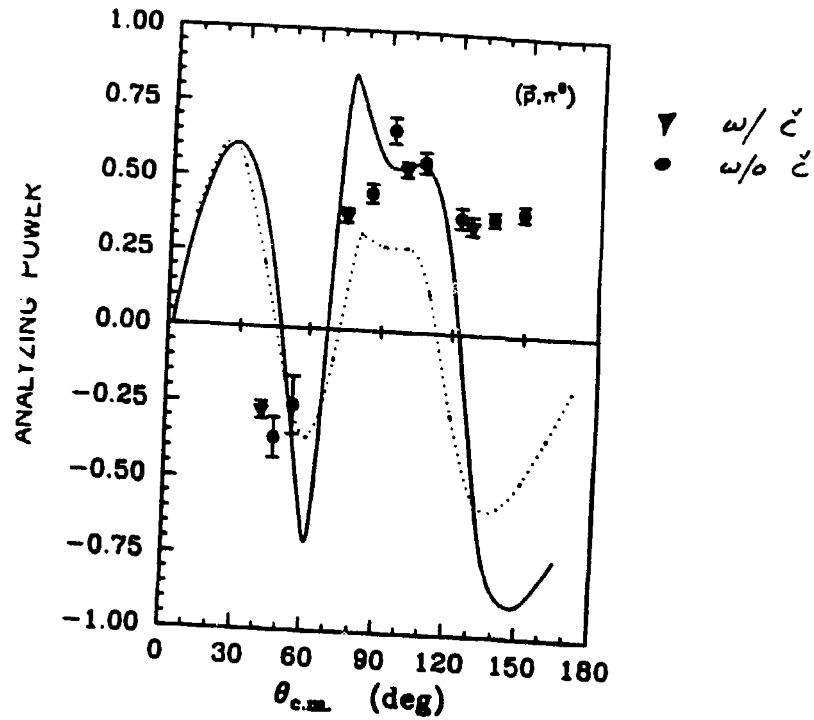


Fig 4. Analyzing Power measurements for the $^2H(\vec{p},\pi°)$ Reaction compared with Laget's calculations. The solid line includes Fermi motion, the dotted line does not.

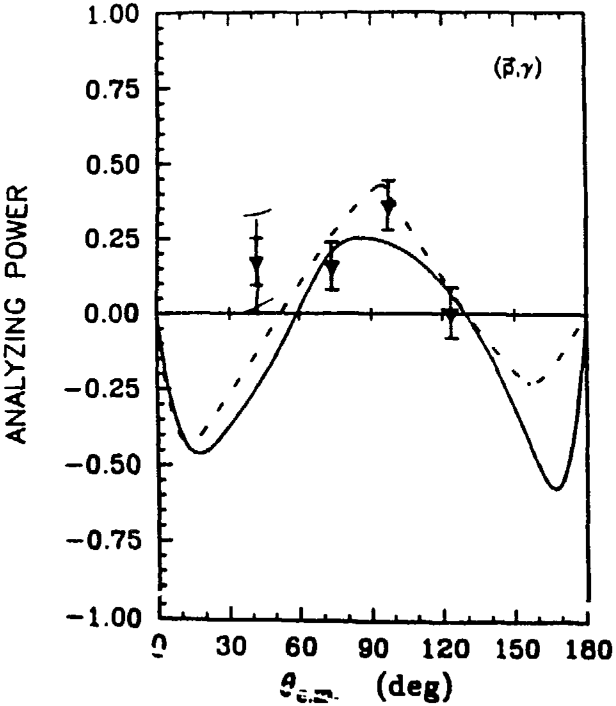


Fig 5. Analyzing Power measurements for the $^{2}H(\vec{p},\gamma)^{3}He$ reaction, compared with Laget's calculations. The solid line includes Ferm' motion, the dashed line does not.

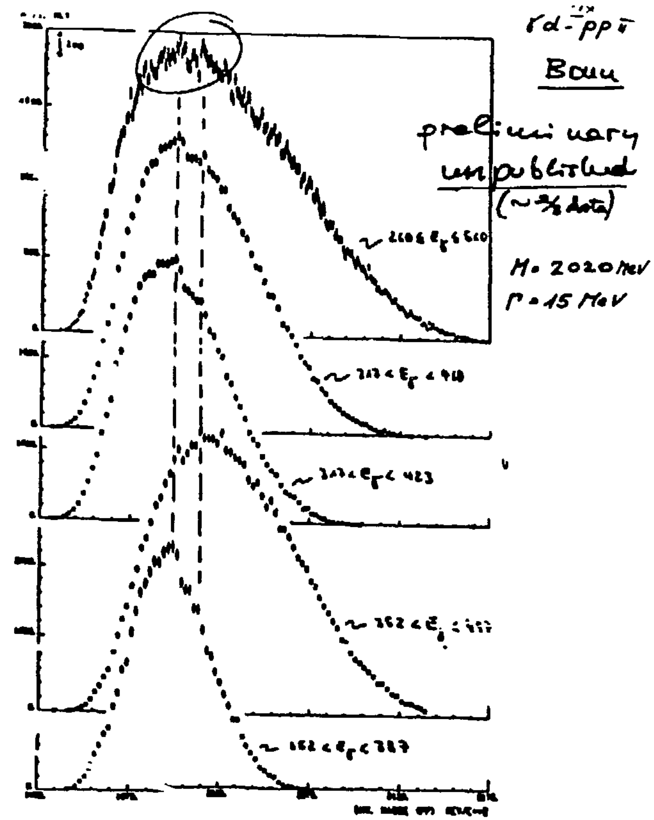


Fig 6. Missing mass for reaction γd→ppπ

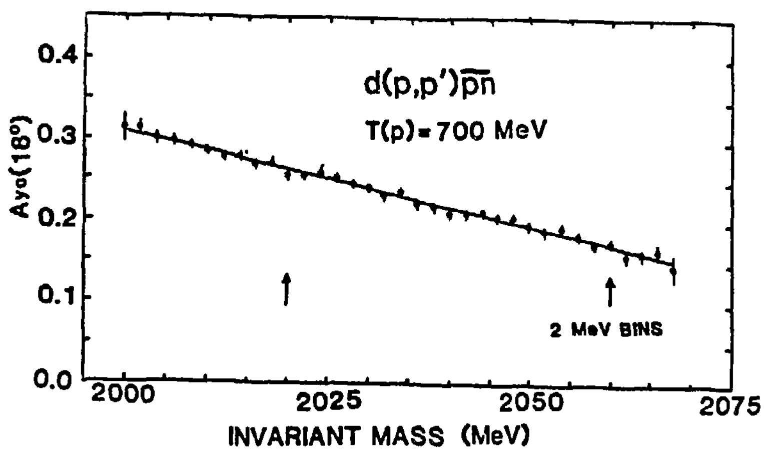


Fig 7. **Analyzing power, $A_{yo}(18°)$ for the reaction $\vec{p} + d \rightarrow p + X$ in the invariant mass region 2000 to 2070 MeV. Note that there are no structure at either 2020 MeV ($^1S_0$) or 2060 MeV ($^3P_1$).**

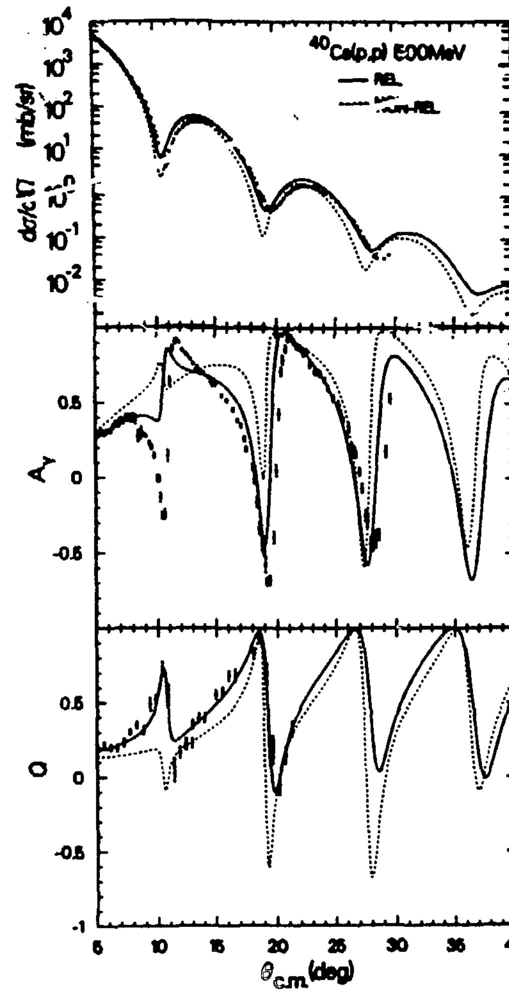


Fig 8. Angular distributions of cross section, analyzing power and spin rotation parameter for the reaction $^{40}Ca(p,p)$ compared with relativistic and non-relativistic calculations.

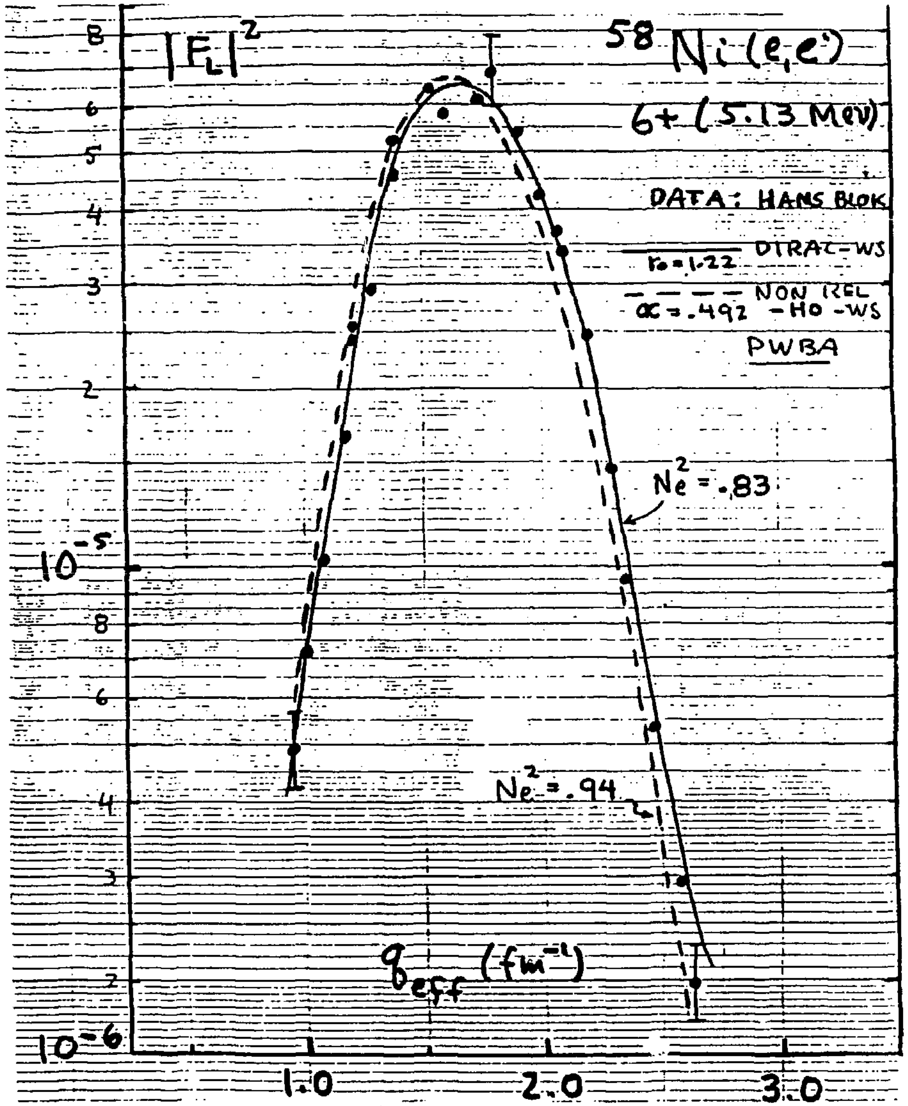


Fig 9. Form factor for ^{58}Ni(e,e') E_x = 513 MeV 6^+ state. Dirac and non-relativistic plane wave Born approx. predictions are also shown.

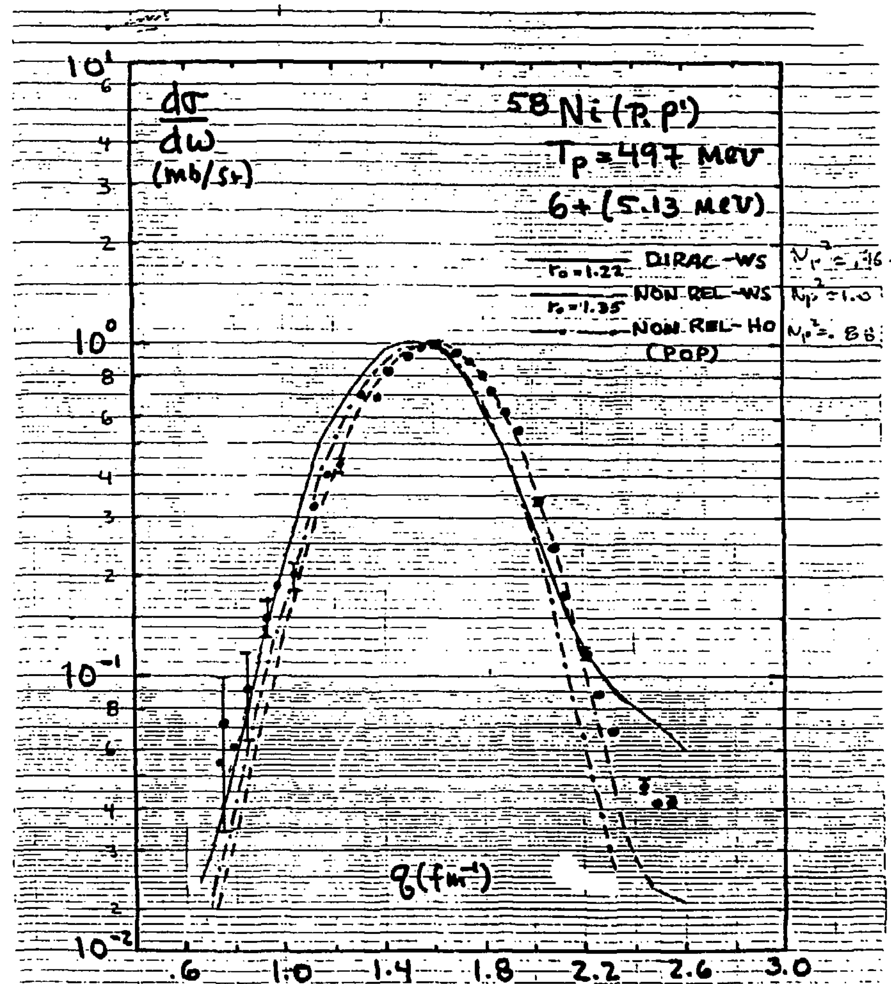


Fig 10. Inelastic cross section to 6_1^+ state for ^{58}Ni(p,p') at T_p = 497 MeV. The Dirac-WS (Woods-Saxon) (solid line) the non-relativistic impulse approx.-harmonic oscillator (NRIA-H_o) and HO calculations used transition densities to fit electron data. The NRIA-Woods-Saxon (WS) calculation used a density adjusted to fit (e,e') cross sections.

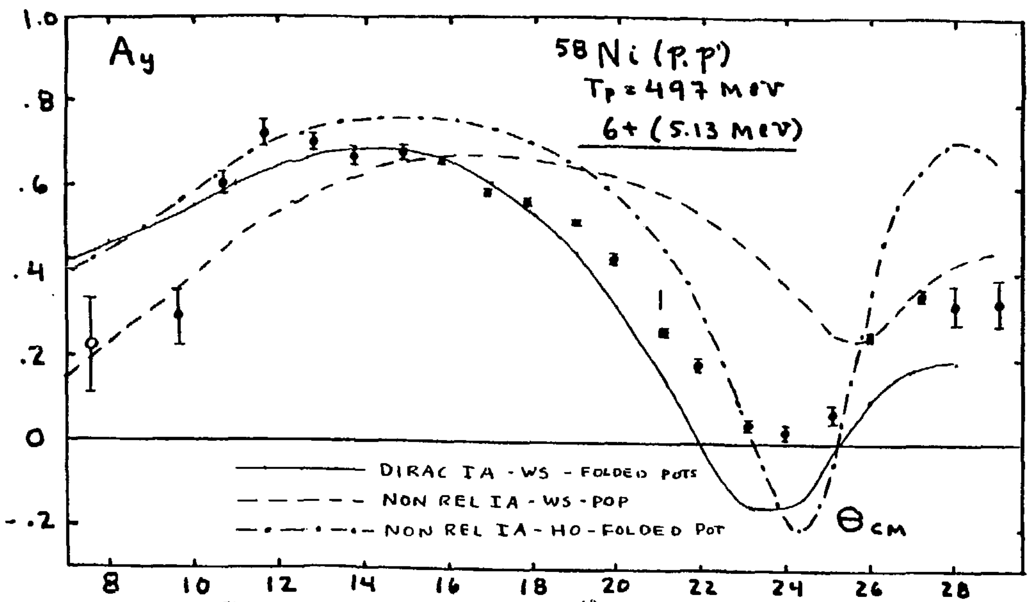


Fig 11. Inelastic analyzing power, A_y for $^{58}Ni(p,p')(6_1^+)$ at T_p = 497 MeV. In the Dirac IA-WS calculation (solid line) the distorting potential was calculated in the IA and transition densities adjusted to fit electron scattering. NRIA calculations are also shown using both phenomenological (POP) (dashed line) and IA generated (folded) (dot-dashed line) distorting potentials. Transition densities used in the NRIA were adjusted to fit (e,e) data.

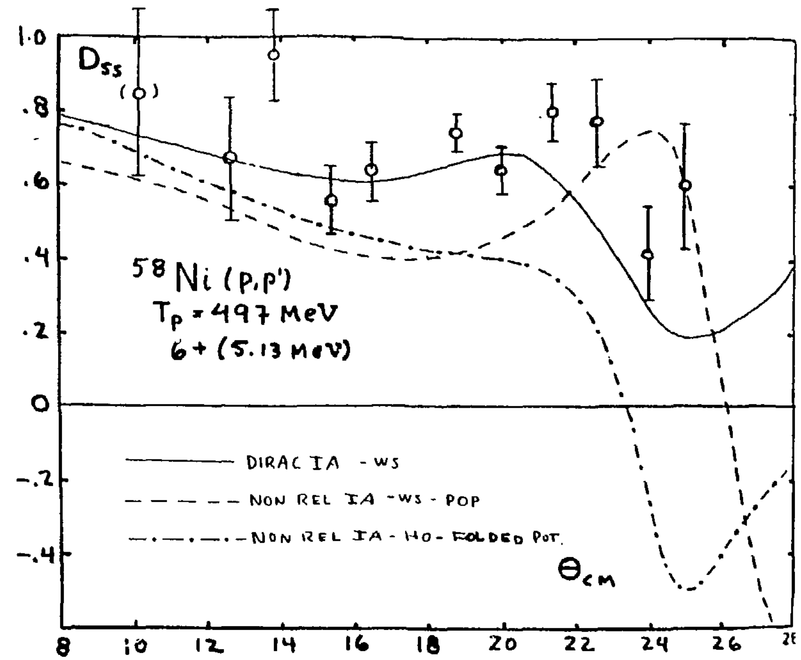


Fig 12. Same as Fig 11. but for D_{SS} parameter

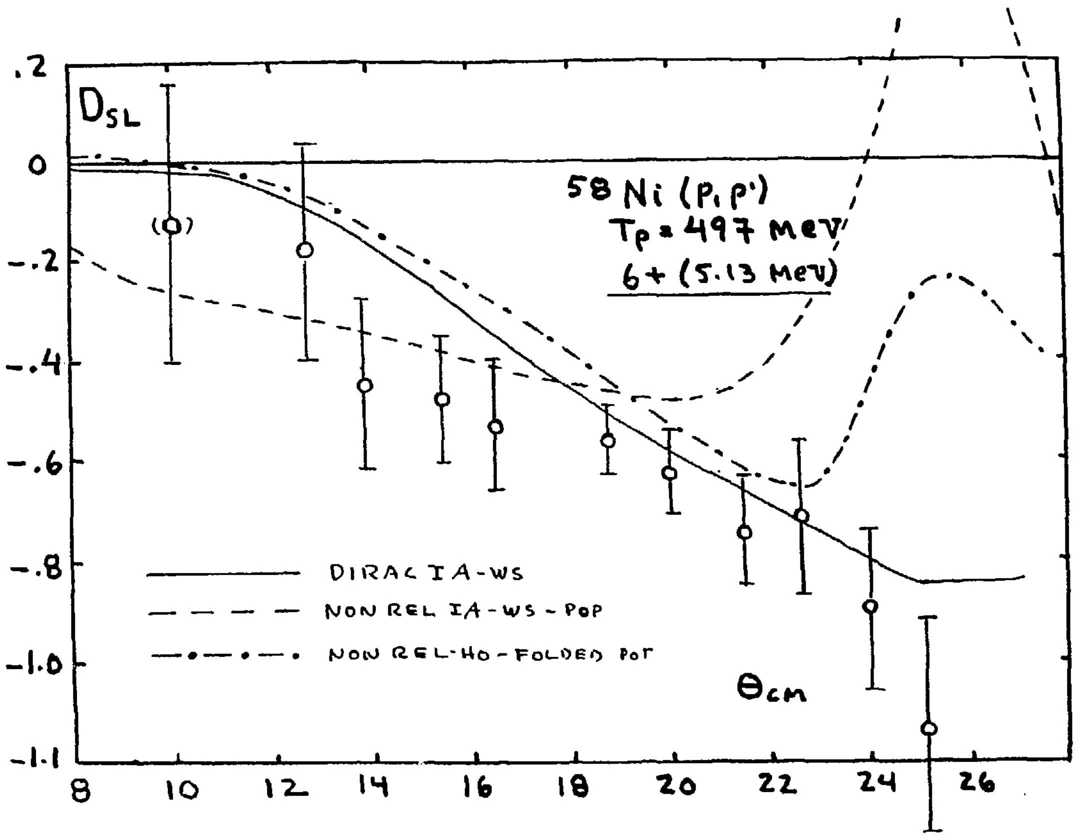


Fig 13. Same as Fig 12. but for D_{SL} parameter.

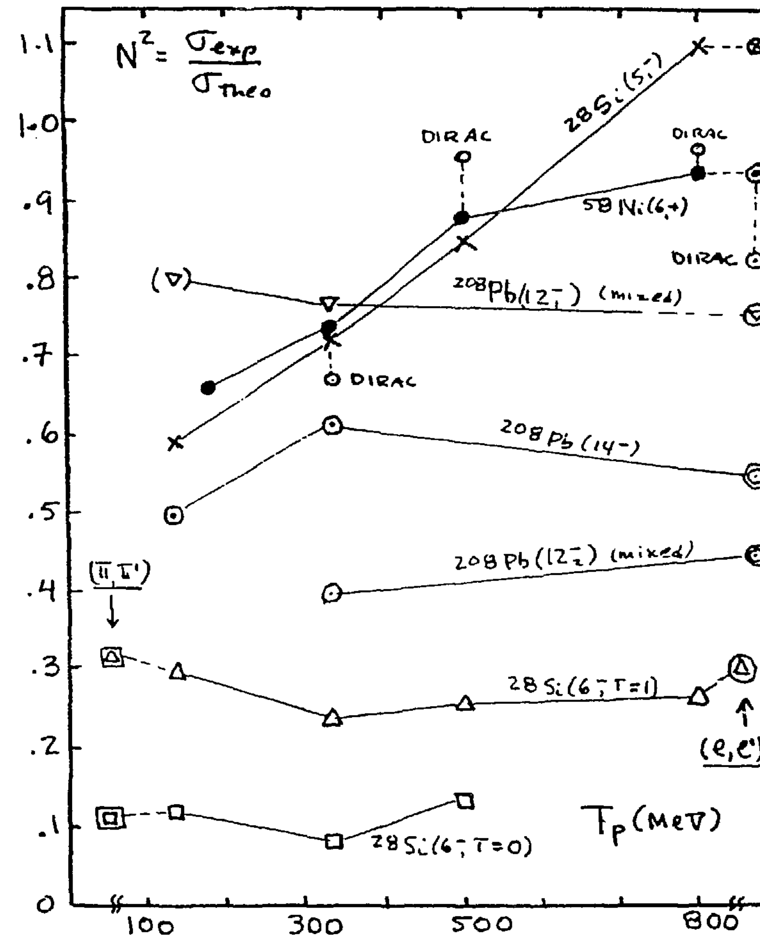


Fig 14. Plot of $N^2 = \sigma_{exp}/\sigma_{Theo}$ vs proton energy for several high-spin stretched (or nearly stretched) configuration states in ^{28}Si, ^{58}Ni and ^{208}Pb. The theoretical cross sections were calculated in the NRIA (except those labelled "Dirac") using 1p - 1h transition densities adjusted to fit electron scattering. Normalization constants, N^2, for electrons and pions are shown on the far right and left.

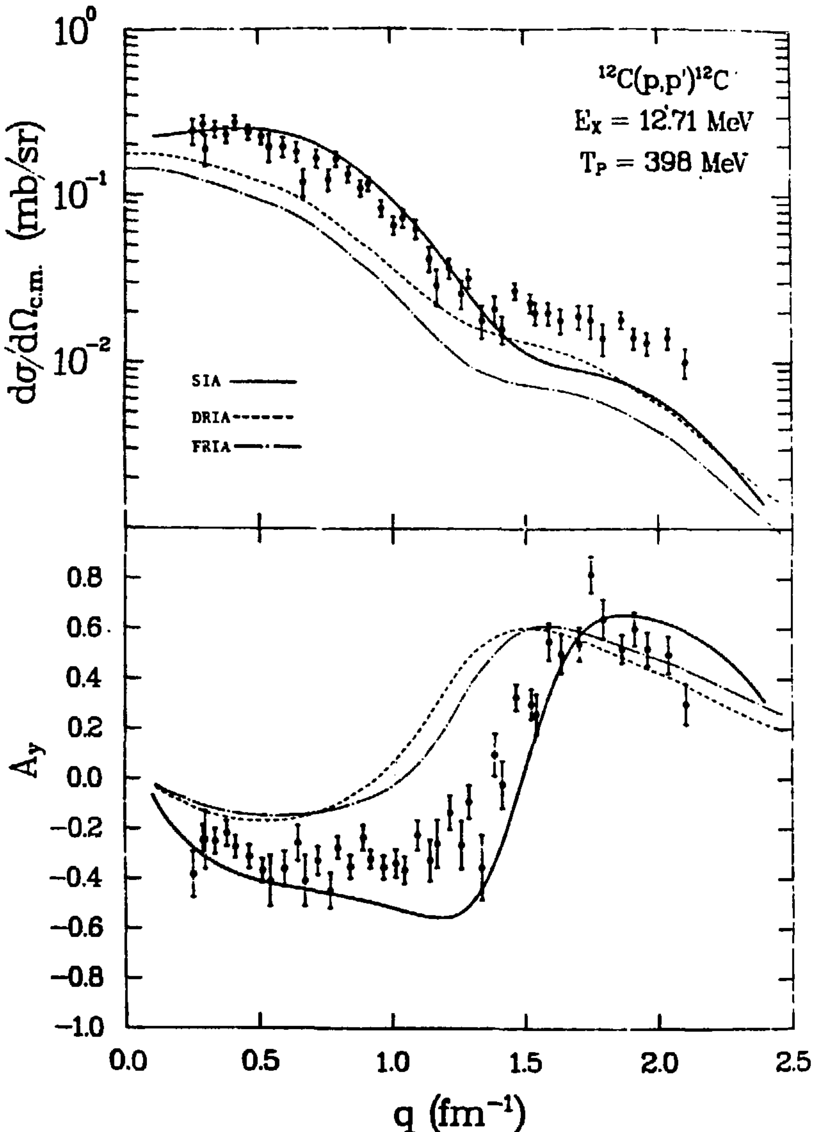


Fig 15. Angular distributions of cross section and analyzing power for the ^{12}C (p,p') reaction exciting the 1271 MeV 1^+ T=0 state. Three calculations are shown; the standard non-relativistic Impulse Approximation (SIA); the Dynamic Relativistic Impulse Approximation (DRA) and the Free Relativistic Impulse Approximation (FRIA).

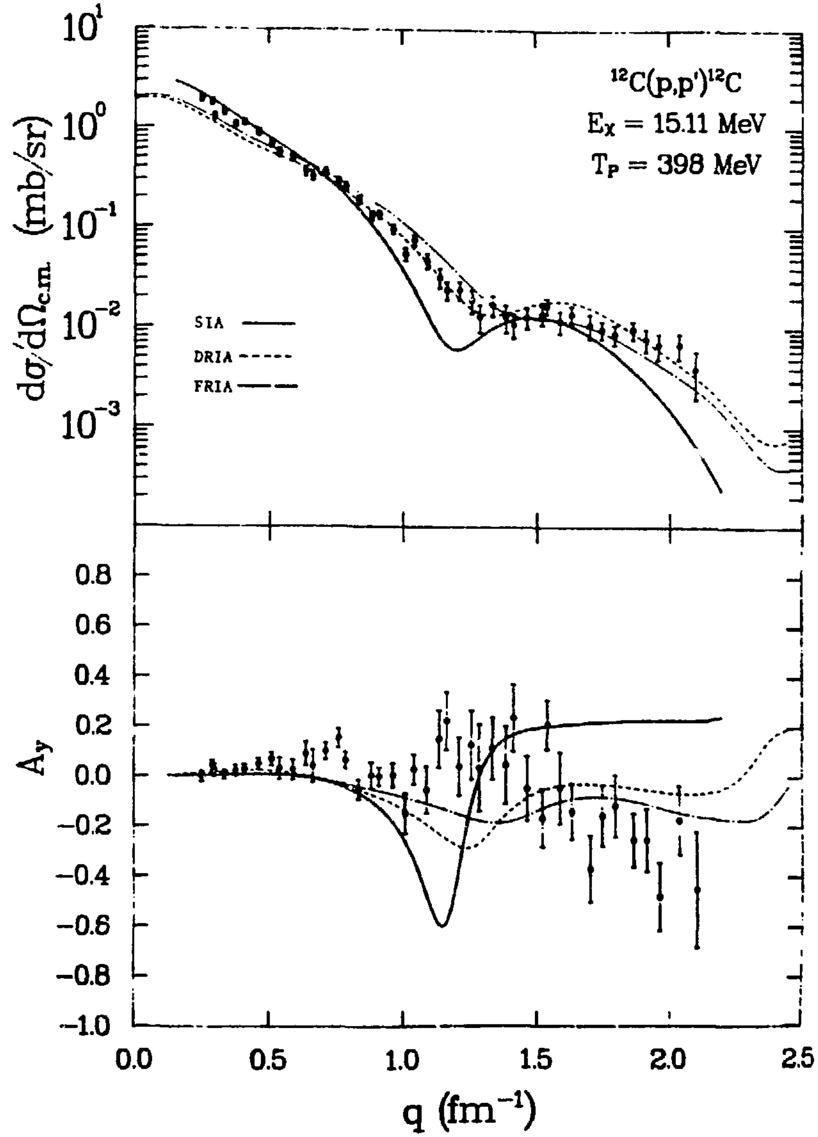


Fig 16. Same as for Fig 15. for 15.11 MeV 1^+ T=1 state of ^{12}C.

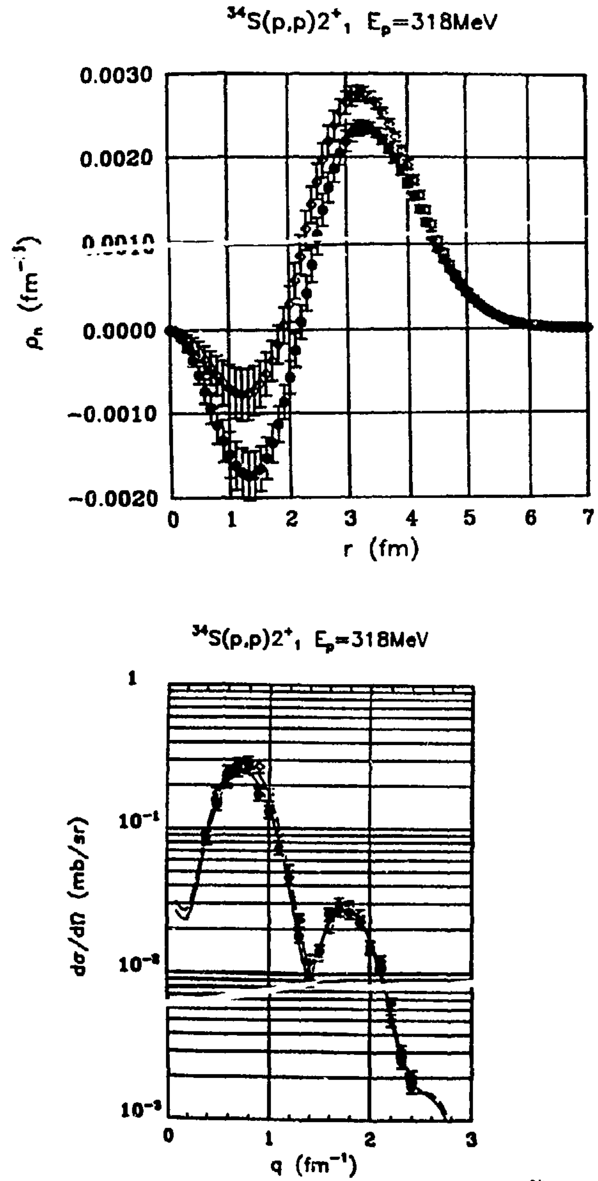


Fig 17. Neutron transition densities for 2_1^+ state in ^{34}S and predicted cross section angular distributions for these transition densities in the (p,p') reaction.

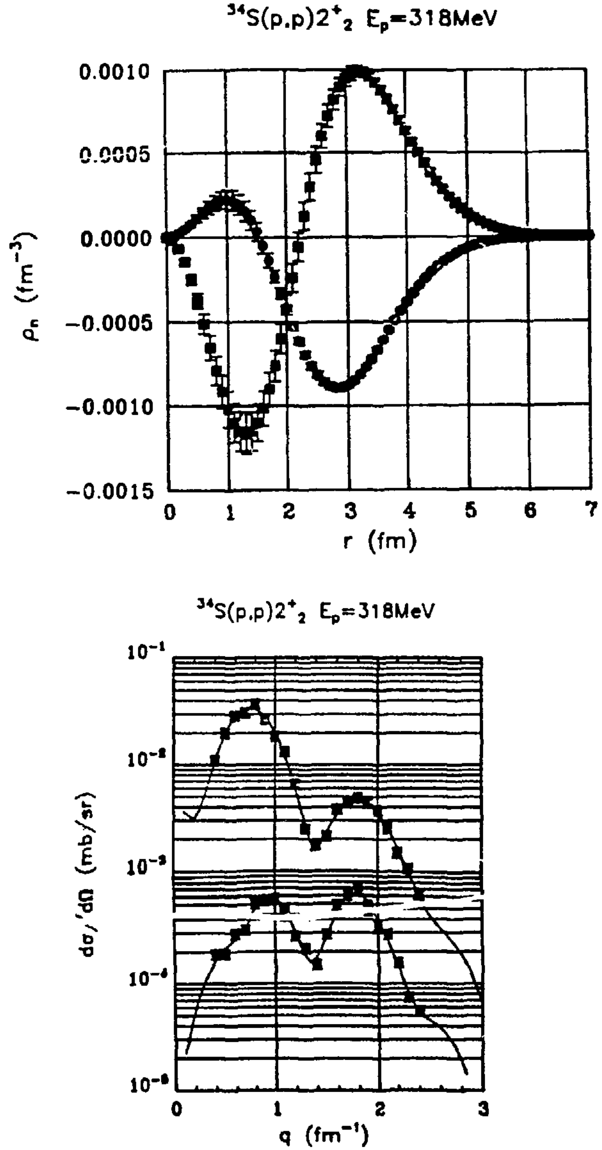


Fig 18. Same as Fig 17. for 2_2^+ state in ^{34}S.

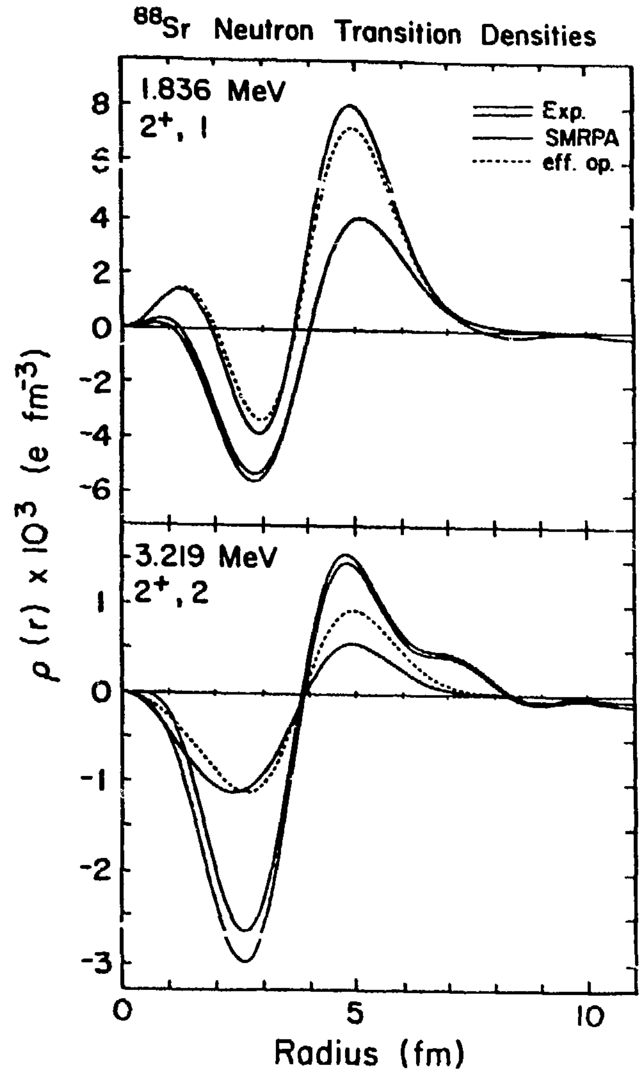


Fig 19. Experimental and theoretical neutron transition densities extracted from the ^{88}Sr (p,p') reaction to two different 2^+ states.

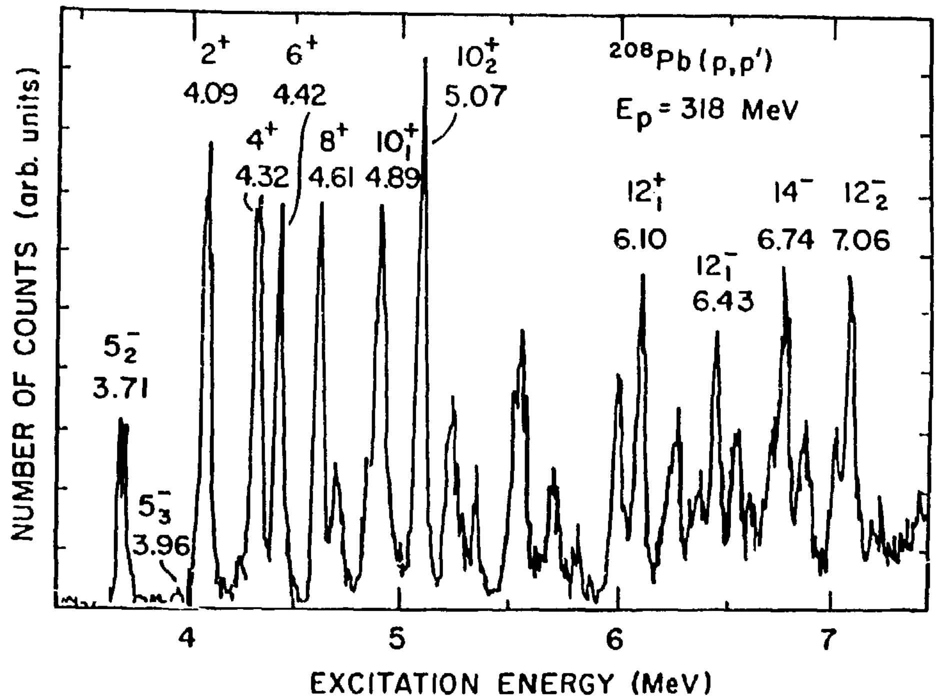


Fig 20. ^{208}Pb (p,p'), Ep=318 MeV spectrum taken at θ_{Lab}=28°.

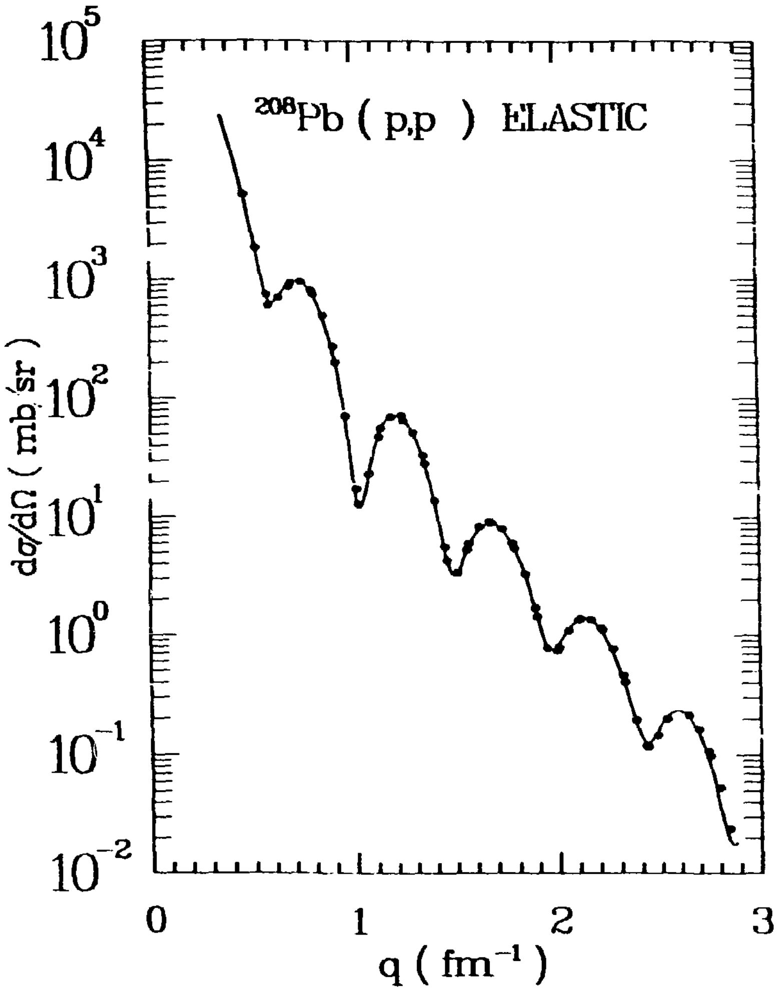


Fig 21. The experimental differential elastic cross section for the Ep=318 MeV ^{208}Pb (p,p') reaction. The fit was generated using a fitted set of optical parameters.

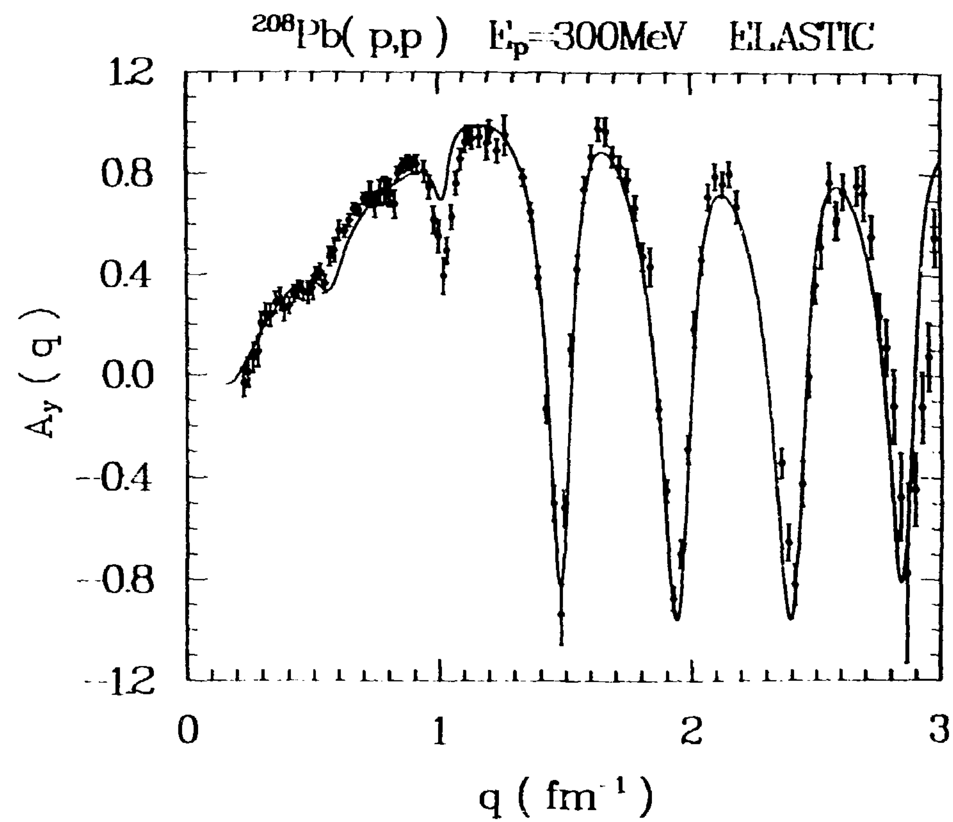


Fig 22. Same as for Fig 21. for Ay at 300 MeV.

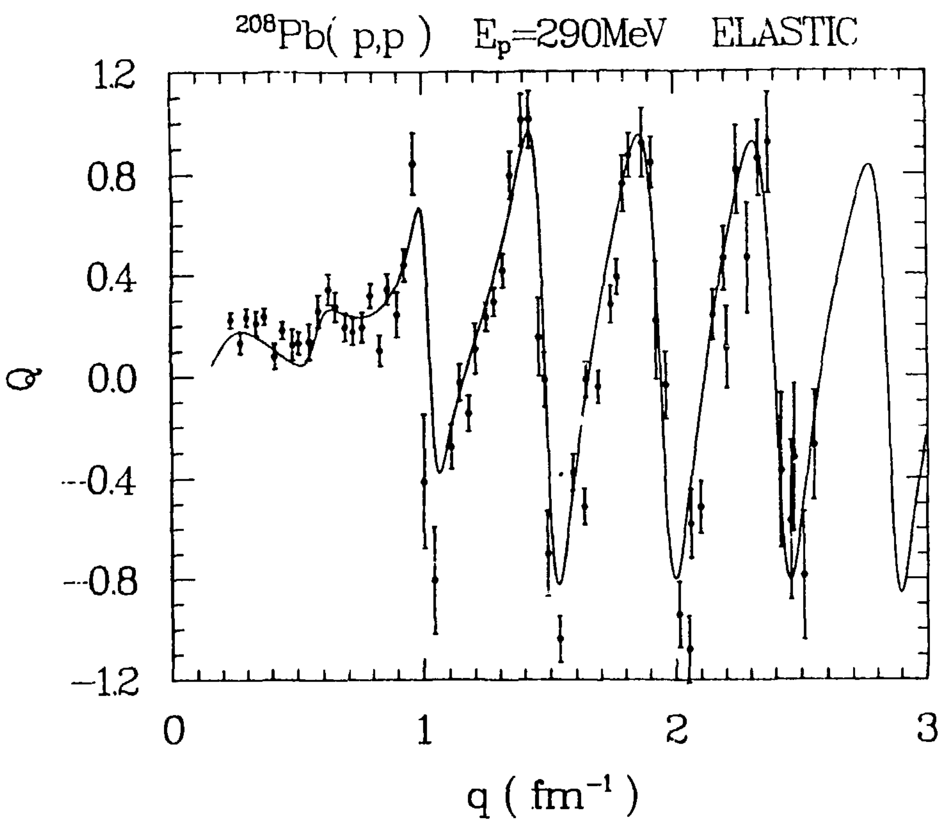


Fig 23. Same as for Fig 21. for Q at 290 MeV.

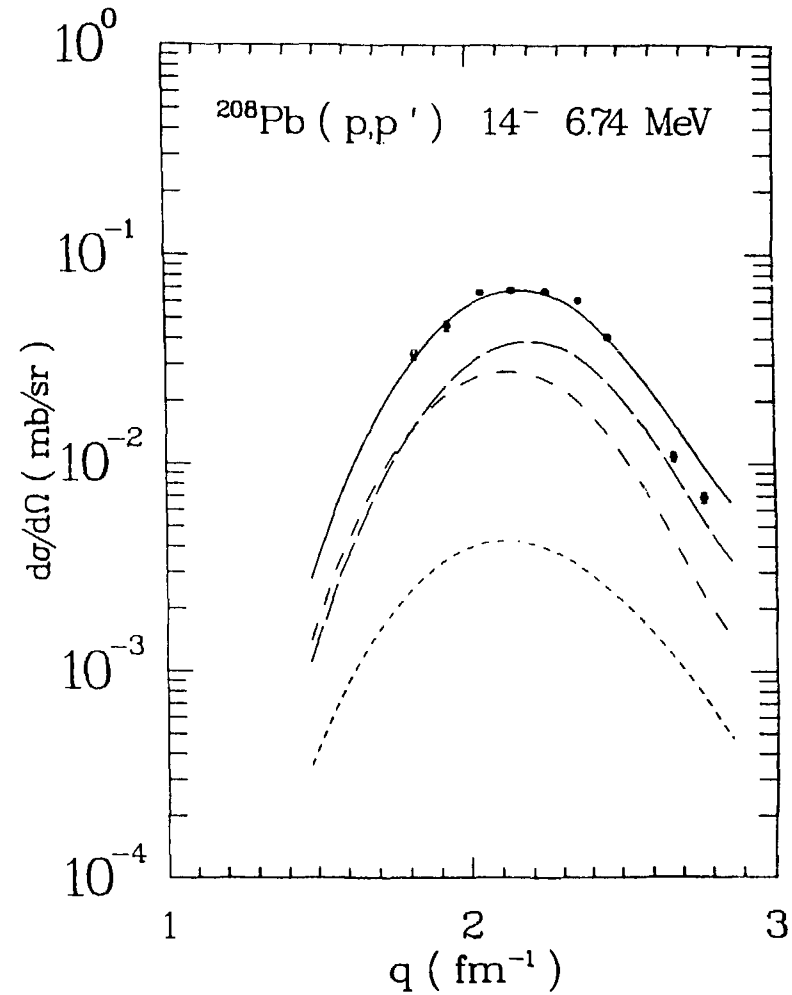


Fig 24. The experimental differential cross section for the $E_p = 318$ MeV ^{208}Pb(p,p') 14^-, 6.74 MeV state. The solid line is the fit in the DWIA with the full N-N interaction. The broken lines are the predicted cross sections from purely central (short dash), spin-orbit (long dash) and tensor (medium dash) parts of the N-N interaction.

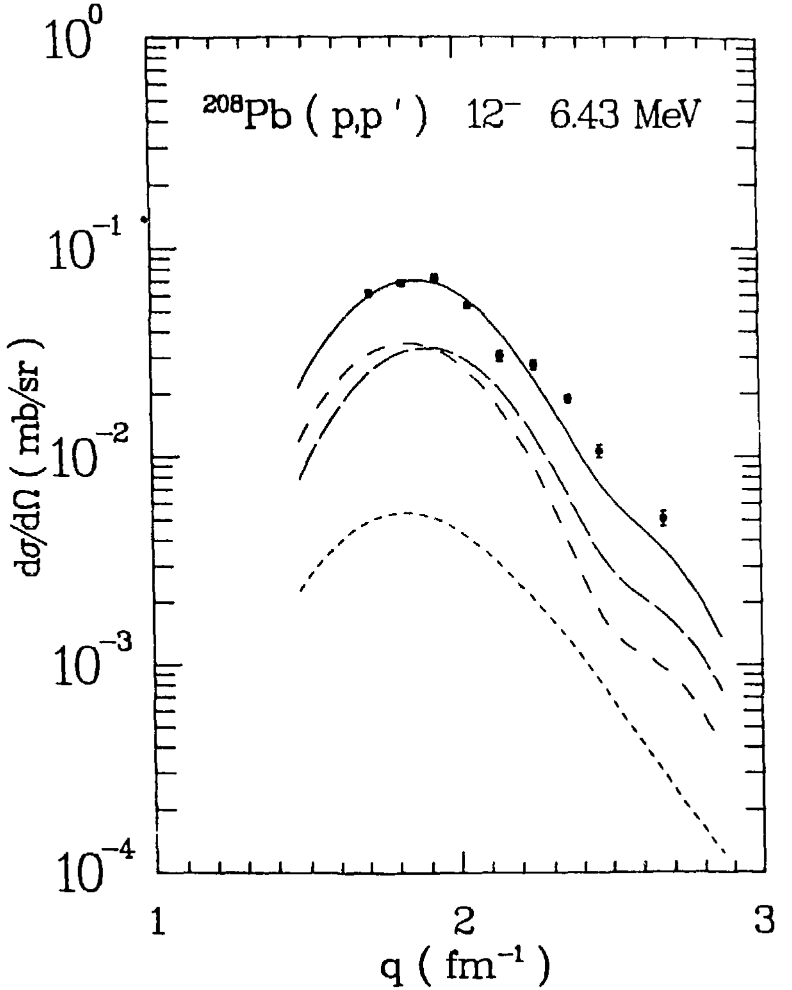
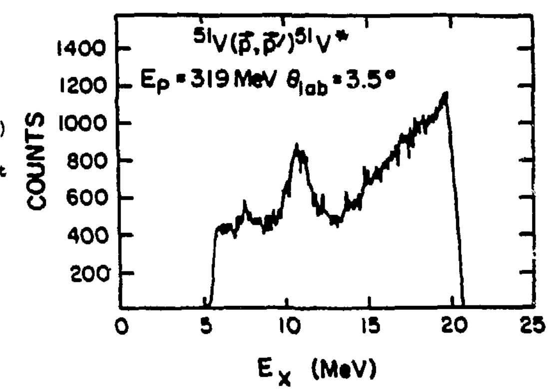


Fig 25. The experimental differential cross section for the E_p = 318 MeV ^{208}Pb(p,p') 12^-_1, 6.43 MeV state. The DWIA calculation uses a neutron $(i^{-1}_{13/2}, j_{15/2})_{12^-}$ configuration. The notation is the same as for Fig. 24.

Fig 26. Spectrum of the ^{51}V(p,p') ^{51}V reaction at 319 MeV at 3.5°.



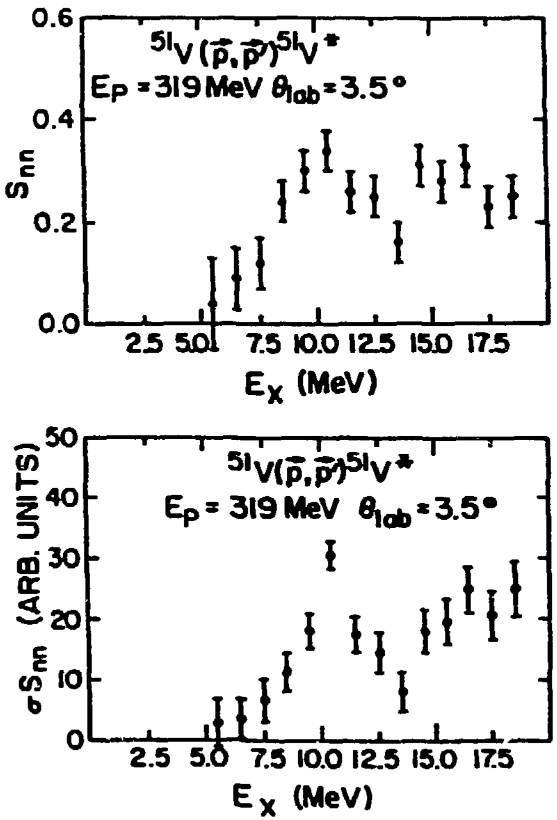


Fig 27. Preliminary values of the spin-flip probability S_{nn} and the spin-flip cross section σS_{nn} at 3.5° for the $^{51}V(p,p')^{51}V^*$ reaction at 319 MeV.

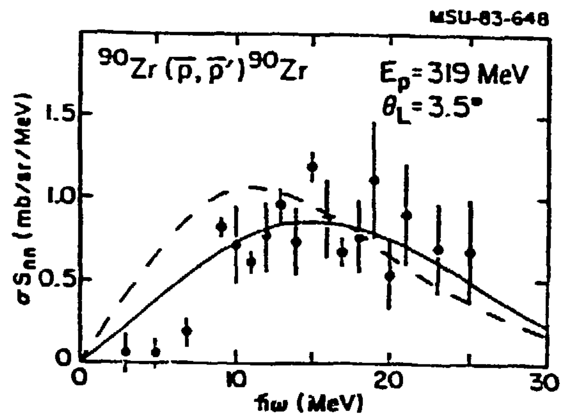


Fig 28. The solid line is the spin-flip cross section for ^{90}Zr predicted by Esbensen and Bertsch

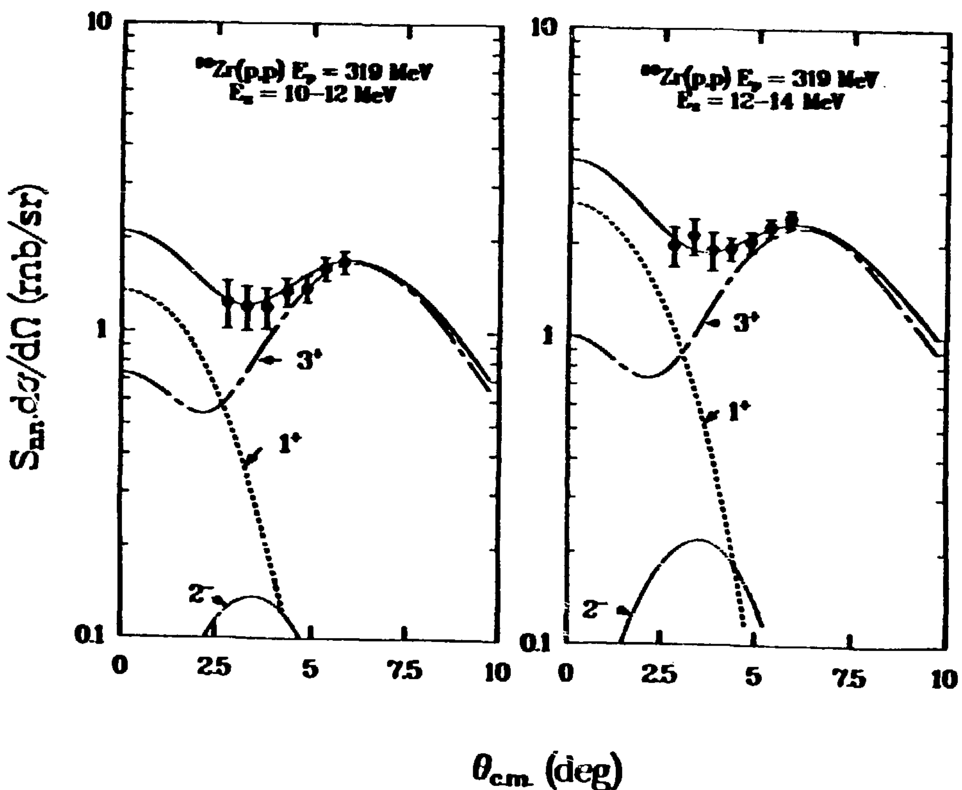


Fig 29. Experimental spin-flip cross section angular distributions for two different spectrum slices compared with DWIA predictions for different multipoles.

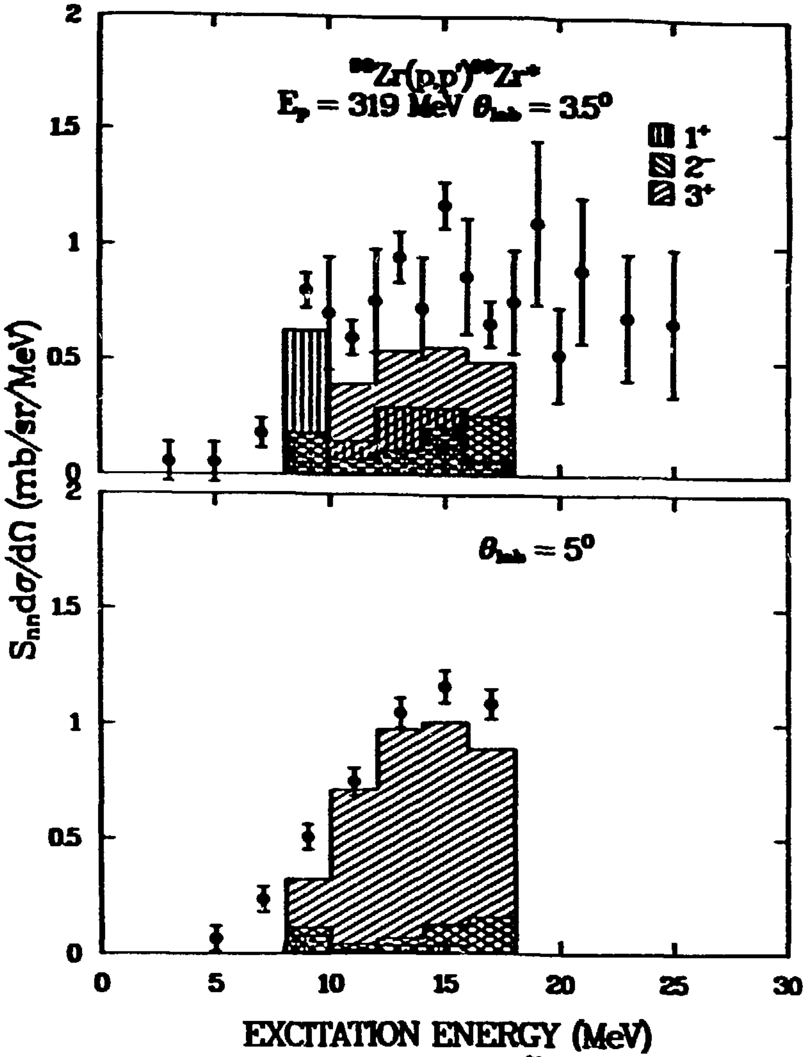


Fig 30. Spin-Flip Cross section (i.e. S_{nn}) for the ^{90}Zr(p,p') reaction at 3.5° and 5° at 319 MeV. The histograms represents contributions from different spin excitation multipoles.

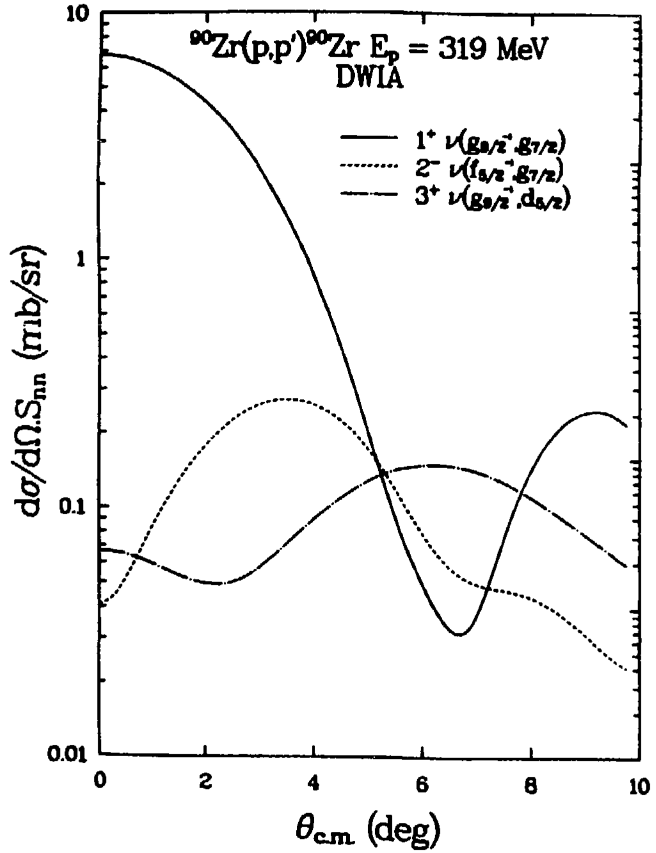


Fig 31. DWIA predictions for the spin-flip cross sections for low multipole spin excitations for the $^{90}Zr(p,p')$ reaction at 319 MeV.

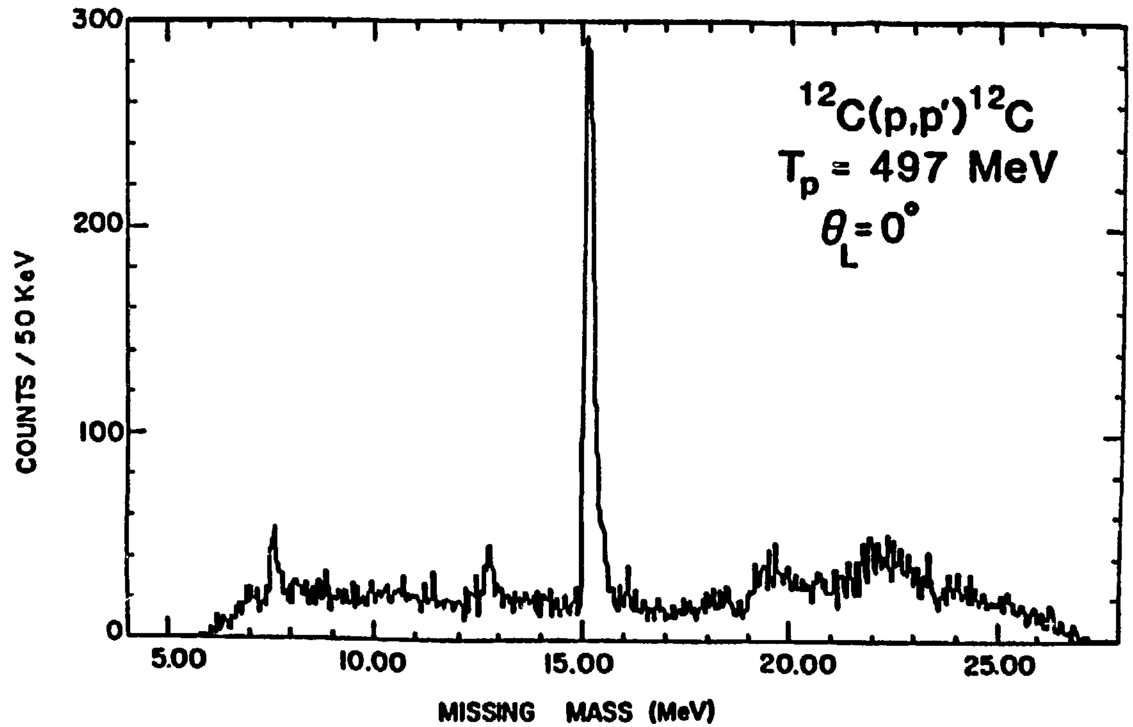


Fig 32. Spectrum of the $^{12}C(p,p')$ reaction at 0° at 497 MeV.

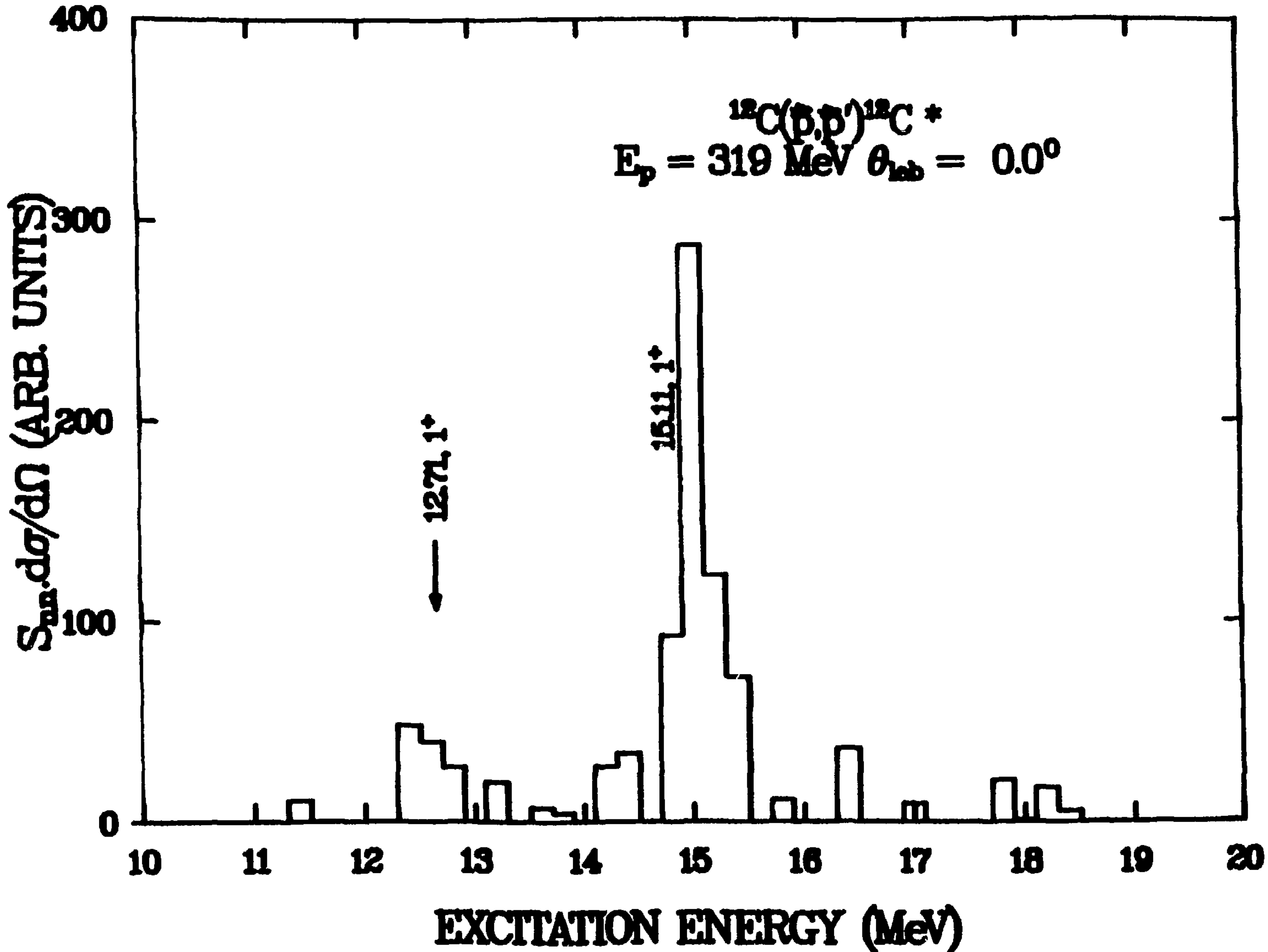


Fig 33. Coincidence spectrum of $^{12}C(p,p')$ reaction at 0° with spin-flip required.

LEP PHYSICS PROGRAM

P. G. Roos
Department of Physics and Astronomy
University of Maryland, College Park, MD 20742

I. Introduction

This talk will be a very brief survey of the experiments carried out over the past couple of years and those to be carried out during the next year or two. The LEP channel is a versatile channel covering the energy range from ~10 MeV to ~300 MeV $\pi^{\pm}$ with adequate quality (e.g., energy resolution, phase space, and beam contamination) and flux to address a wide range of physics questions. Unlike some channels the program is not dominated by the presence of a single major instrument. As a result we have a balanced and interesting program which addresses essentially all aspects of pion-nucleus physics in this energy range.

In this talk I will discuss the recent experiments by grouping them under four broad classifications. I will attempt to discuss the physics goals of the various experiments, and what I (personally) see as present limitations and, where possible, future directions.

II. Major Equipment

Although I said that the program is not dominated by a single instrument, there are two devices which are used on a majority of experiments at LEP. In Fig. 1 is shown a schematic diagram of the π^0-spectrometer which is capable of providing π^0-energy resolutions in the range of 2.5 to 5 MeV. The use of this instrument has constituted a significant fraction of the running time at LEP and has provided a number of interesting results, as I will discuss in Sec. IV.

The other major device is the Clamshell spectrometer, shown schematically in Fig. 2. Some of the parameters of the spectrometer are indicated in the figure. This large acceptance spectrometer, commissioned in 1984, has already been used for a wide variety of experiments ranging from elastic scattering to double-charge exchange. One of the major limitations of the device is the relatively low p_{max}, thereby excluding its use for proton detection.

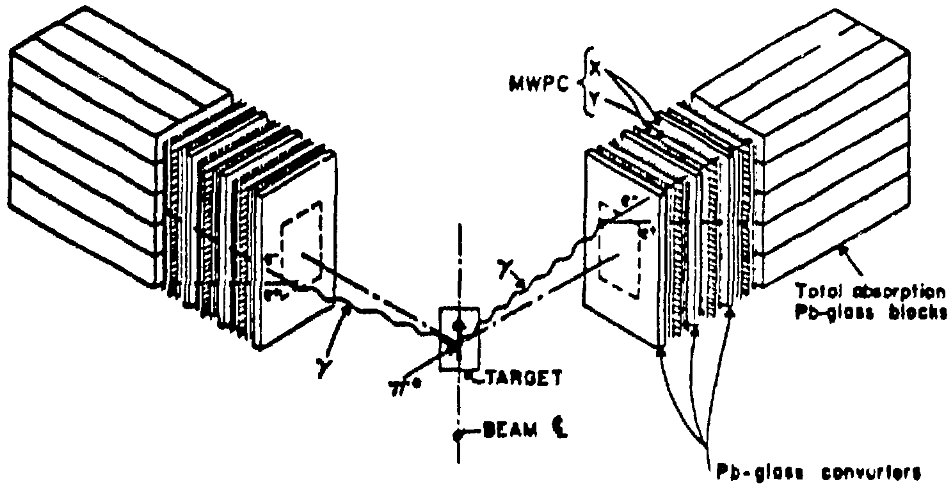


Fig. 1. Schematic of π^0-Spectrometer

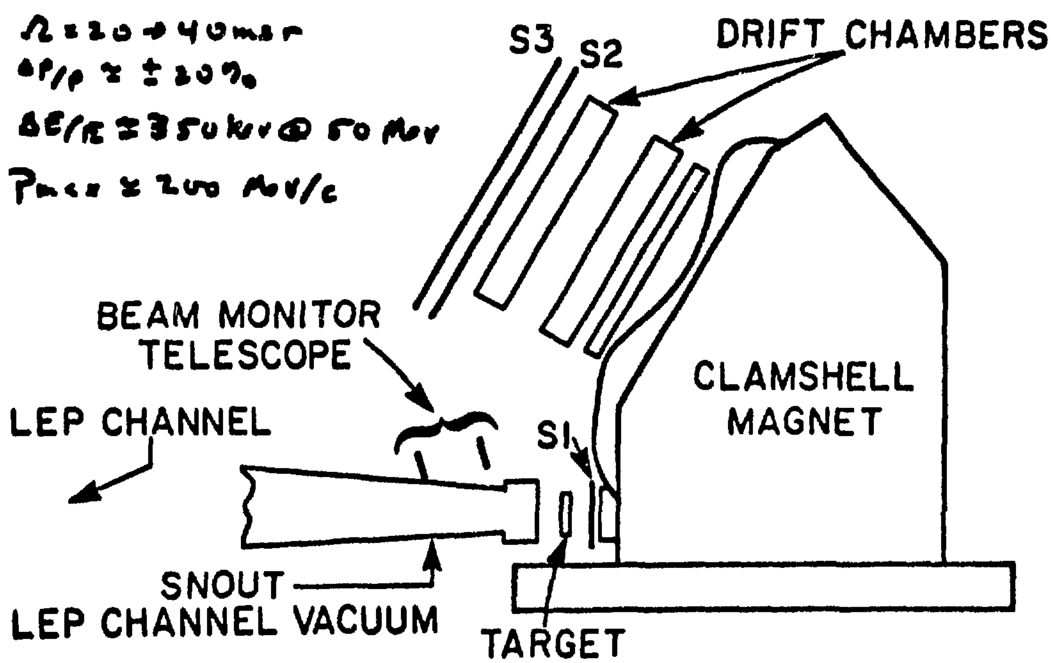


Fig. 2. Schematic of Clamshell Spectrometer

III. Elastic/Inelastic Scattering

A. Elastic Scattering

The Clamshell spectrometer provides major new capabilities in terms of energy resolution and acceptance for carrying out studies of elastic and inelastic $\pi^{\pm}$ scattering. The elastic scattering measurements led by VPI [Exp. #814; Blecher (VPI&SU)] have measured $\pi^{\pm}$ elastic scattering on ^{58,60,64}Ni over the energy range 30 to 80 MeV to examine the isospin dependence of the π-nucleus optical-model potential. An example of the excellent data[1] which were obtained with the new spectrometer is shown in Fig. 3, along with optical-model predictions based on the MSU potential. Below 65 MeV one finds the MSU potential does relatively well and at least qualitatively reproduces the measured isospin dependence. Extrapolation of the MSU potential to 80 MeV fails to reproduce the experimental data.

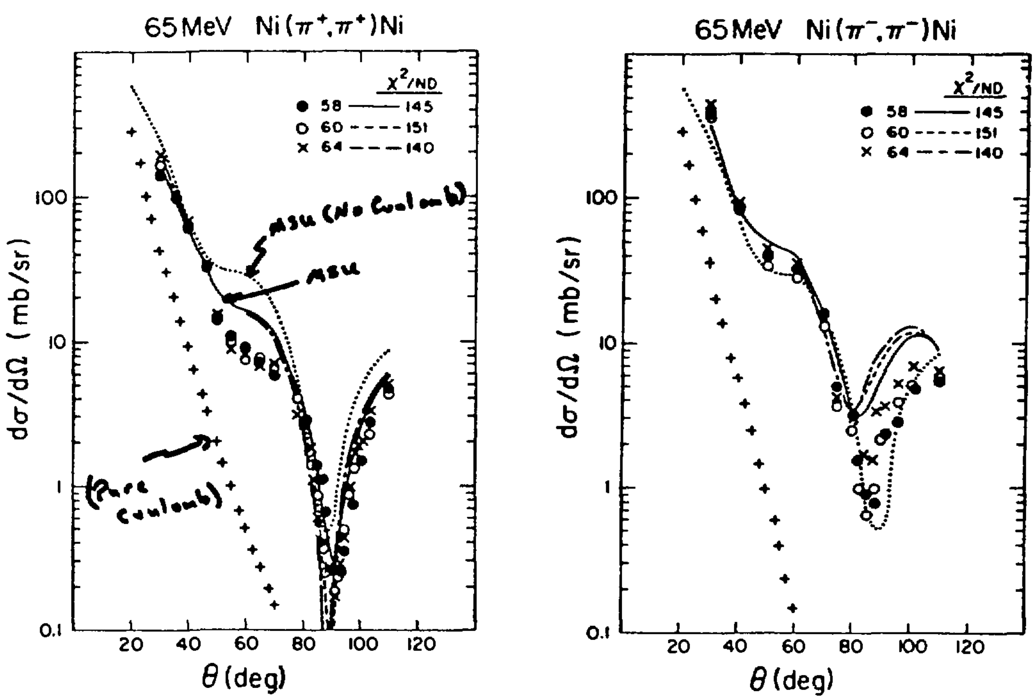


Fig. 3. $\pi^{\pm}$ elastic scattering data taken with the Clamshell spectrometer (Ref. 1).

Elastic $\pi^{\pm}$ scattering data have also been obtained on ^{40}Ca [Exp. #983; Blecher and Wright (VPI&SU)] at 20 and 30 MeV to test modifications to the optical potential used to reproduce the anomalous widths measured in pionic atoms. Preliminary results indicate that these modifications significantly improve the fits to the elastic scattering data. Low-energy elastic scattering studies such as these provide a more stringent test of the optical model potential and should better define the pionic atom potentials.

Now that we finally have a device capable of providing high quality elastic scattering data with excellent efficiency, I am concerned that the data are too often ignored. Not only do elastic scattering studies in themselves provide useful information on the π-nucleus interaction, they also are the source of distorted waves used in any distorted wave treatment of the various reactions I will discuss in the remainder of my talk. I see no one providing either the theoretical interpretation of the present results, or a global analysis which is essential for the distorted wave analyses. It seems to me essential that these deficiencies be removed before any major program in elastic scattering goes forward, in spite of the excellent instrument.

On a more fundamental level, a high-precision study of elastic $\pi^{\pm}$ scattering from deuterium between 30 and 80 MeV is proceeding at the present time [Exp. #767; S. Whisnant (U. South Carolina)]. These results will examine charge symmetry, as well as provide a testing ground for three-body calculations of $\pi^{\pm}+{}^{2}H$. The lowest energies will severely test the inclusion of Coulomb effects in the calculations.

B. Inelastic Scattering (Discrete States)

Several studies of inelastic scattering were carried out in 1985, all in the energy range 30 to 80 MeV, where elastic scattering data exist. Initial measurements of the excitation of excited 0^{+} states (${}^{12}C$, ${}^{28}Si$, and ${}^{90}Zr$) have been carried out [Exp. #860; Preedom and Whisnant (U. South Carolina)]. This is a study of the reaction mechanism; e.g., the importance of coupled channels effects. In an attempt to learn more about the reaction mechanism and/or the isospin selectivity of low-energy pions, measurement of the excitation of the T=0 and 1, 1^{+} levels in ${}^{12}C$ [Exp. #811; Ritchie (ASU)] and various levels in ${}^{13}C$ [Exp. #813; Kraushaar and Peterson (U. Colorado)] have been made. These states have already been studied at resonance energies. Depending on the outcome of this work we should obtain new information of the low-energy reaction mechanism, its isospin selectivity, and if everything worked out well, the effective π-nucleon interaction. Future work will depend heavily on the results obtained by these experimenters.

I would like to make an additional comment concerning the usefulness of low-energy pion inelastic scattering. Although the argument is often made that due to their transparency low-energy pions sample the full nucleus, one pays an important price. At low energies the momentum transfer is small, so that the spacial resolution of the reaction is poor. As a result, even though one samples the interior of the nucleus, the data more reflect the average of the transition density over the full nucleus. This may still provide useful information, but one must appreciate the limitations of low-energy inelastic scattering in terms of the detail which will be learned.

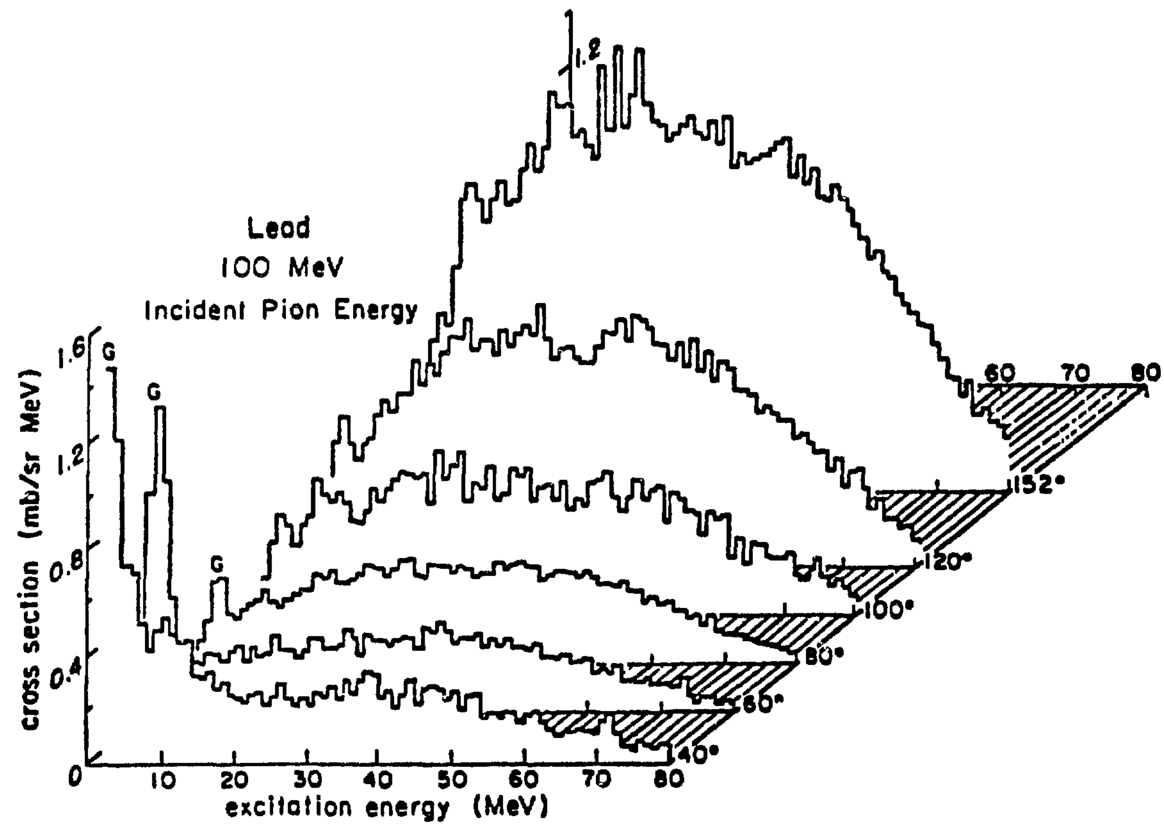


Fig. 4. Pb(π^+,π^+) inelastic scattering at 100 MeV (Ref. 2).

C. Inelastic Scattering (Continuum)

Finally, there is one measurement of the quasifree pion continuum for 100 MeV π^- on C, Ca, Sn, and Pb proceeding this fall [Exp. #967; Halpern (U. of Washington) and Tieger (MIT)]. Although, generally, I believe that adequate data for the pion continuum exist, there is a paucity of π^- data at lower energies. This experiment is very specific in terms of providing a test of a simple model of the reaction. In particular, it will examine effects of the neutron excess and Coulomb potential in increasing the π^- yield over that of π^+. An example of earlier 100 MeV π^+ data[2] taken by the same group is shown in Fig. 4. The Clamshell is well suited for such measurements and there may be future specific studies which will be worth pursuing.

IV. Single Charge Exchange (SCX)

A great deal of interesting physics information has already been provided with the $(\pi^{\pm},\pi^0)$ studies carried out in previous years. I remind you of the systematic studies[3] of the isobaric analog state (IAS) transitions as a function of energy and A. In Fig. 5, I show an example of such studies for ^{14}C indicating the minimum at 0° near 50 MeV. The low-energy SCX data quite nicely reflect the elementary process $(\pi^+ + n \rightarrow \pi^0 + p)$ demonstrating the relative transparency of low-energy pions. I also remind you of the resonance studies and the discovery of the isovector monopole resonance.[4] However, in this talk I will concentrate on more recent studies.

A. Recent "Conventional" Experiments

A study of the fundamental process $\pi^- + p \rightarrow \pi^0 + n$ has been carried out in the range 10 to 40 MeV where the phase shifts are poorly known [Exp. #882; Bowman, Fitzgerald, and Heusi (LANL)]. These data should improve our knowledge of the associated scattering length. Another approved experiment is the measurement of the $A(\pi^-,\pi^0)$ branching ratio with stopped π^- [Exp. #975; Leitch and Liu (LANL)]. These data, to be taken with the π^0 spectrometer, will dramatically improve our knowledge of the charge exchange branching ratio.

There have been some continued studies of the IAS transition, but it is clear that one's ability to think of new measurements to do with the present π^0-spectrometer is limited. One would now like to carry out studies of non-analog transitions which should help shed light on the double-charge exchange reaction. This requires a significant improvement in the energy resolution. Thus, I see a limited role for the present π^0-spectrometer in nuclear spectroscopy measurements of this type. A new, improved π^0-spectrometer is needed to continue in this direction.

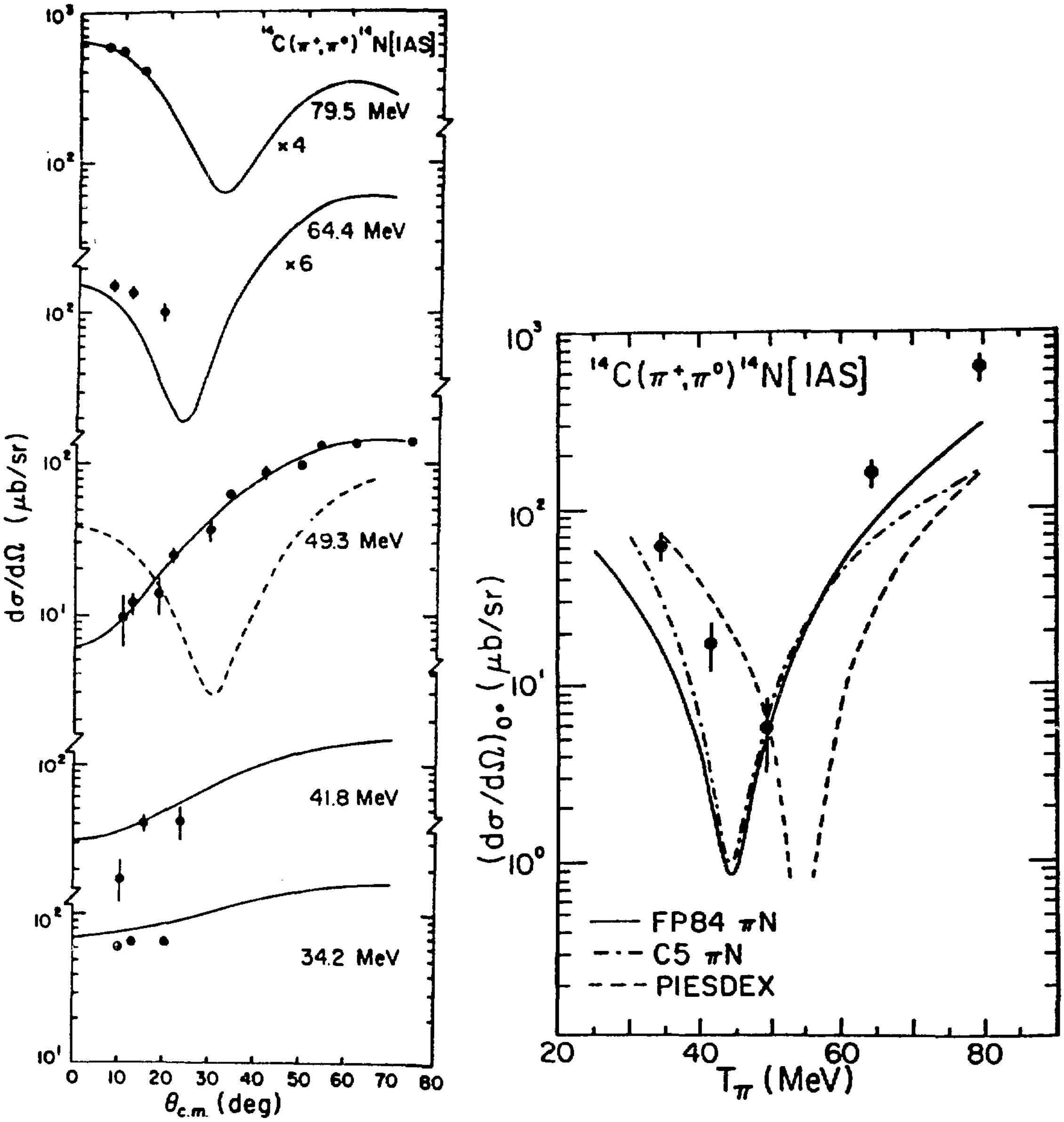


Fig. 5. $^{14}C(\pi^+,\pi^0)^{14}N$ (IAS) angular distributions and 0° excitation function.

B. Polarized Targets

New directions in SCX with the present π^0-spectrometer have been provided by the use of polarized targets. A proposed $^{165}\overrightarrow{Ho}(\pi^+,\pi^0)$ IAS experiment at 165 MeV [Exp. #899; Knudsen and Bowman (LANL) and Comfort (ASU)] expects to be able to extract the neutron deformation to ~5% from an asymmetry measurement.

In another approved experiment analyzing powers for the $\overrightarrow{^{13}C}(\pi^+,\pi^0)$ IAS reaction are to be measured [Exp. #1023; Comfort (ASU) and Kyle (NMSU)] at 165 MeV. This would be a study of the reaction mechanism with the hope of providing information on the effective π-N interaction or the Δ-spreading potential depending on one's viewpoint.

C. Coincidence Measurements

We are now progressing into the next generation of SCX experiments with the present device. Several coincidence experiments with the π^0-spectrometer have been done or proposed. Measurements of the $^{16}O(\pi^+,\pi^0p)^{15}O$ reaction have been carried out on LEP at 245 MeV. This experiment was motivated by the SIN studies of Kyle et al.[5] of $^{16}O(\pi^\pm,\pi^\pm p)^{15}N$. Results from the SIN experiment are shown in Fig. 6. In the lower panel are shown the ratios of the $(\pi^+,\pi^+p)/(\pi^-,\pi^-p)$ cross sections for various angle pairs. One observes large deviations from the expected impulse approximation value of about 9. These ratios have been explained by Hirata, Lenz, and Theis[6] as arising from Δ-N knockout terms as indicated by the diagrams in the middle of the figure. The results of their calculations are indicated by the solid lines in the figure. The two Δ-N knockout diagrams have relatively little effect on (π^+,π^+p) (~8%) but produce large effects in (π^-,π^-p) due to destructive interference at the quasifree peak. The same theory predicts constructive interference for (π^+,π^0p). Thus, the measurements of $^{16}O(\pi^+,\pi^0p)^{15}O$ provide another test of the reaction theory with an addition isospin component in the Δ-N interaction.

Results for this experiment[7] are shown in Fig. 7. Although the $p_{1/2}$ and $p_{3/2}$ shells cannot be separated within the experimental resolution, one can clearly separate the total p-shell strength. In the lower panel are shown the ratios $(\pi^+,\pi^+p)/(\pi^+,\pi^0p)$ which again show a significant deviation from the impulse approximation, although not specifically that predicted by the model. Data of this type should aid in the refinement of such theoretical models.

The same group has also carried out measurements of $^3He(\pi^\pm,\pi^0p)$ [Exps. #920,921; Gilad (MIT) and Piasetzky (Tel Aviv)]. These have the same reaction dynamics motivation. Note that $^3He(\pi^-,\pi^0p)$ cannot occur in a single step and should provide a more stringent test of theoretical models.

A coincidence experiment with nuclear structure goals is $^{13}C(\pi^\pm,\pi^0p)$ at 165 MeV [Exp. #976; Bowman (LANL) and Pocanic (Stanford)]. In particular,

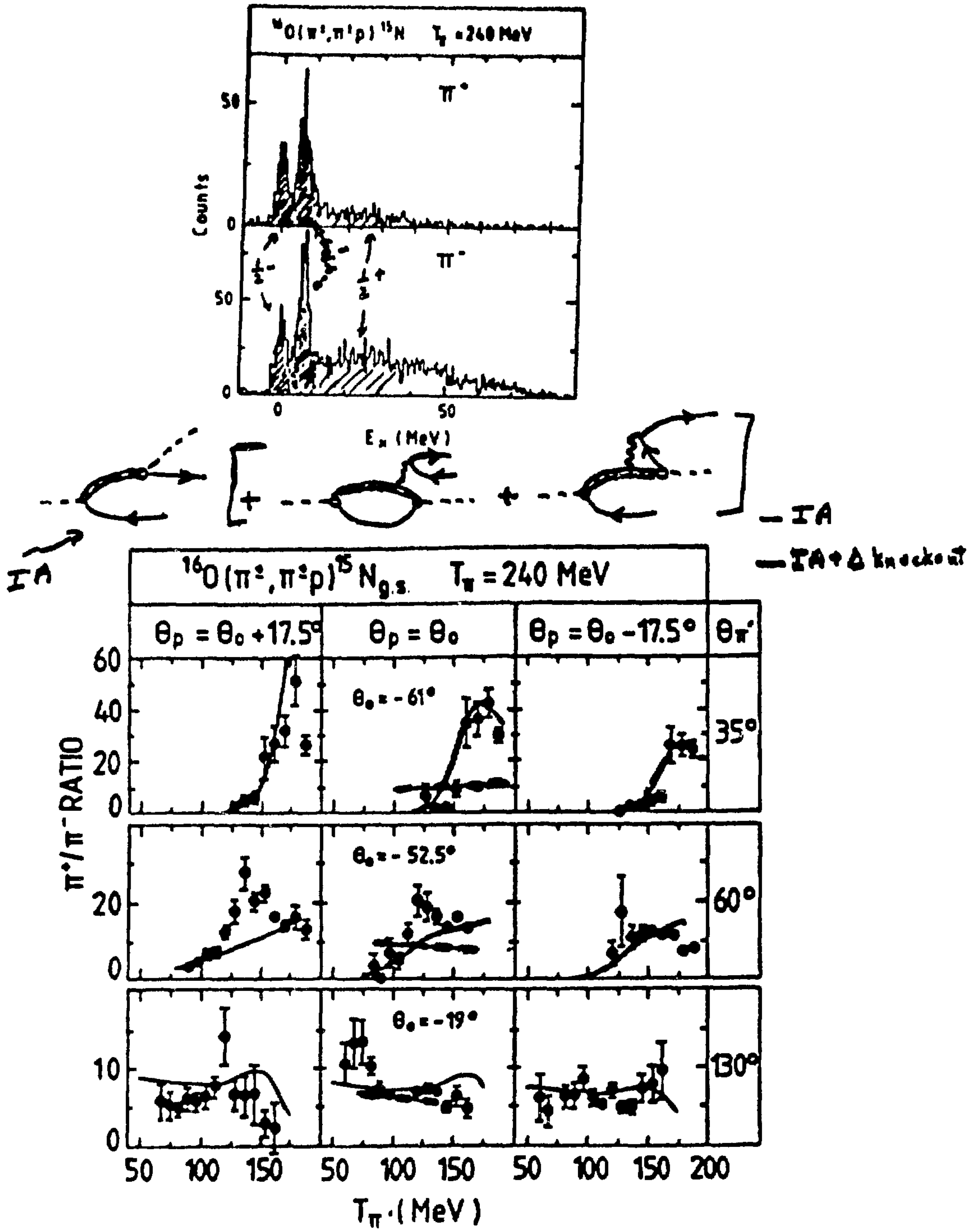


Fig. 6. Comparison of $^{16}O(\pi^+,\pi^+p)$ and $^{16}O(\pi^-,\pi^-p)$ at 240 MeV.[5]
Top: Excitation energy spectra. Middle: Diagrams including Δ-N knockout.[6]
Bottom: Ratio of cross sections at various angle pairs. Dashed curve is impulse approximation prediction and full curve is that of Ref. 6.

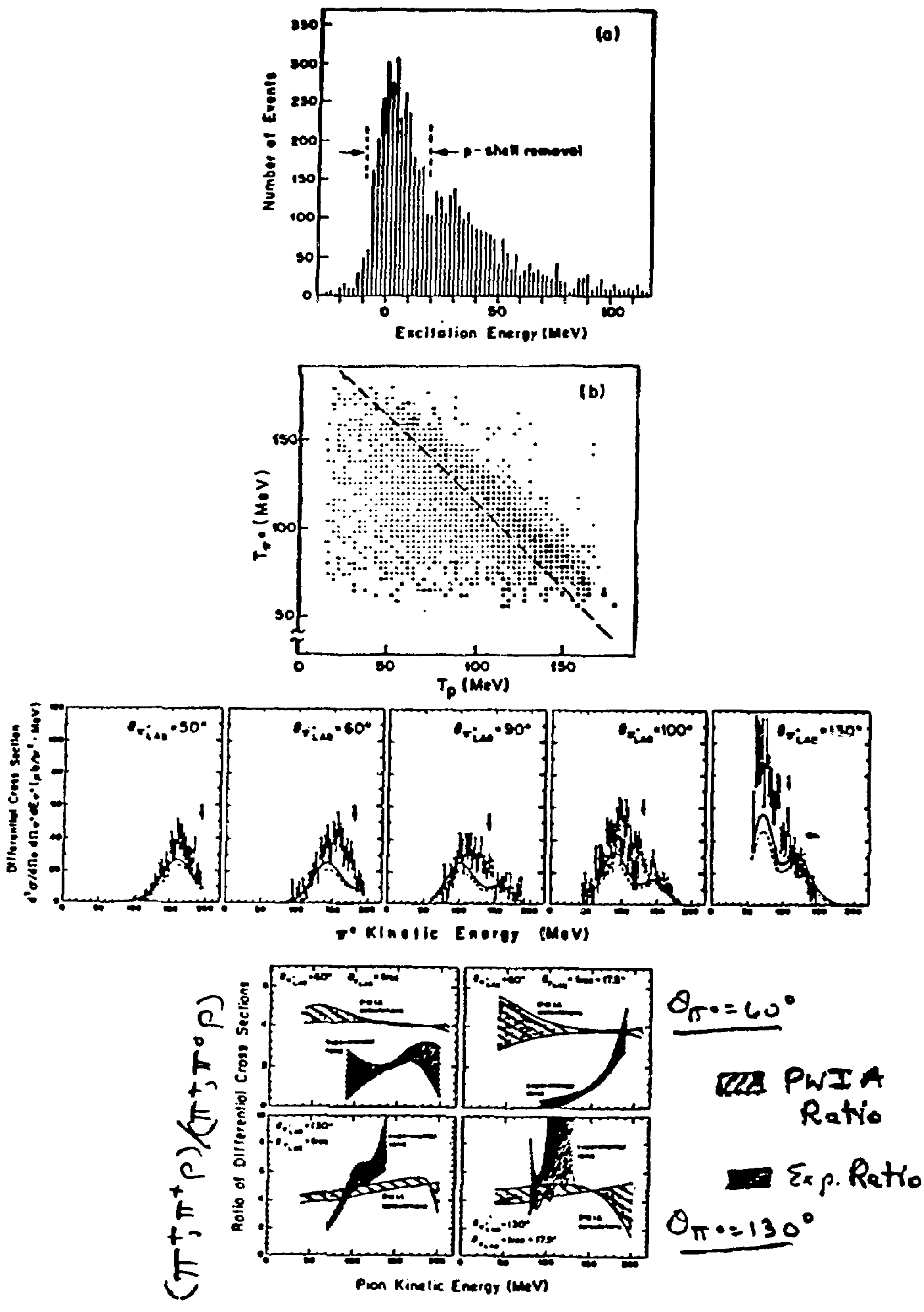


Fig. 7. Results for $^{16}O(\pi^+,\pi^0p)$ (Ref. 7). Top: Excitation energy spectrum and two-dimensional contour plot. Middle: p-shell knockout cross sections for various π^0-angles. Bottom: Ratio of cross sections (π^+,π^+p) to (π^+,π^0p).

they will examine the decay of the isovector giant dipole resonance region populated by SCX. Angular correlation data for the decaying protons will provide multipolarity information. Using both π^+ and π^- the experimenters will be able to separate the T=1/2 and 3/2 components and hope to obtain information on the isospin splitting and particle-hole structure of the isovector dipole resonance.

The above coincidence studies are providing new directions for the LEP program.

V. Double Charge Exchange (DCX)

With the commissioning of the spectrometer a modest program in DCX has begun. Initially there was a great deal of wild enthusiasm based on predictions of a six-quark bag model. As I have already shown, the single-charge exchange reaction to the IAS has a deep minimum at 0° around 50 MeV. Naively one expects the DCX reaction proceeding sequentially through two analog state transitions to also have a very deep minimum at 0°. In fact, the simplest sequential DWIA calculations do give a deep minimum. Gerry Miller's six-quark bag calculation,[8] on the other hand, gives rise to a maximum at 0°, something which was suggested by relatively poor statistics data[9] at TRIUMF.

The above sequence of events led quickly to an experiment to measure the $^{14}C(\pi^+,\pi^-)^{14}O$ double isobaric analog state transition (DIAS) near 50 MeV [Exp. #884; Leitch (LANL) and Piasetzky (Tel Aviv)]. They obtained the excellent data[10] shown in Fig. 8 which clearly showed that the angular distribution had a maximum at 0°.

To shorten a rather lengthy story, there are now several theoretical calculations which describe the data reasonably well. The crucial ingredient is the inclusion of non-analog intermediate states, as is schematically indicated in the lower part of Fig. 8. I should point out that inclusion of these non-analog transitions introduces different two-nucleon correlations compared to the sequential process. In that sense the six-quark bag model also provides a different set of two-nucleon correlations. Estimates by Gibbs indicate that the range of the two-nucleon correlations ivolved in low-energy DCX is significantly shorter than that involved at higher energy. As a result some theorists believe low-energy DCX to be the more interesting region for the study of nucleon-nucleon correlations.

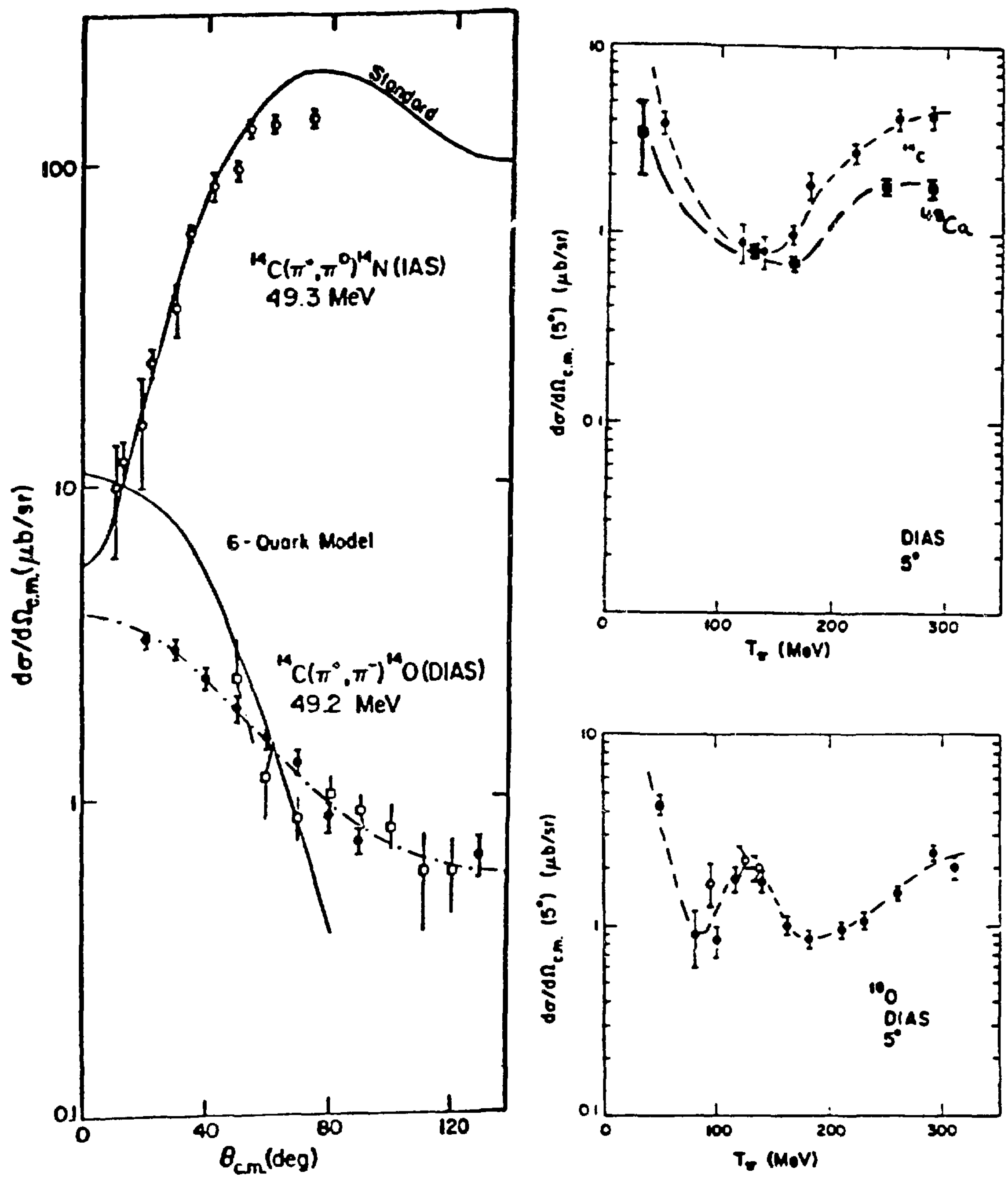


Fig. 8. DCX angular distribution and excitation function data for the DIAS transition.

Since the initial excitement several more systematic studies of low-energy DCX have been underway. DIAS transitions for ^{48}Ca and ^{90}Zr have been measured in the energy range 30 to 80 MeV to examine the dependence on energy and mass [Exp. #1001; Baer and Leitch (LANL) and Piasetzky (Tel Aviv)]. The 5° excitation function is presented in Fig. 8, showing the rise in cross section at low energy.

The small cross section for ^{48}Ca compared to simple estimates based on neutron pairs led to another experiment to measure the DIAS on ^{42,44}Ca at 35 MeV [Exp. #1020; Leitch (LANL) and Piasetzky (Tel Aviv)]. Although a similar suppression was observed at resonance energies, systematic data on the dependence of the DIAS on neutron excess at low energies provides useful results for testing reaction models.

Again, from the standpoint of testing our understanding of the DCX reaction, excitation function data have been obtained for ^{24}Mg and ^{42}Ca [Exp. #952; Seth (Northwestern U.)].

Finally, there has been one study specifically of non-analog DCX. Cross sections for $^{12}C(\pi^+,\pi^-)^{12}O$ (g.s.) have been measured at 60 and 90 MeV [Exp. #927; Faucett (NMSU) and Zumbro (U. Penn.)]. They find that the non-analog transition is comparable in magnitude to the DIAS. Just to emphasize this, in Fig. 9, I show $^{48}Ca(\pi^+,\pi^-)$ spectra at two energies. Clearly at 30 MeV the non-analog transitions are as large as the DIAS. This is perhaps not so surprising in light of the suppression of SCX at these energies.

What is unclear is where to go next. Random surveys of various nuclei and energies are not necessarily useful, at least based on experience at EPICS where a large amount of data has not led us to an understanding of the DCX reaction mechanism. From a theoretical standpoint, we are in need of detailed DWIA calculations for both analog and non-analog transitions in which non-analog intermediate states are included. Perhaps such calculations will at least provide a qualitative understanding of the changing role of the DIAS versus non-analog transitions. In addition, such calculations should provide guidance to the experimentalists on what studies may be most useful.

Without additional theoretical guidance the experimentalists must select xperiments based on such things as nuclear structure (e.g., looking at the two-nucleon correlations predicted by a shell-model calculation for various

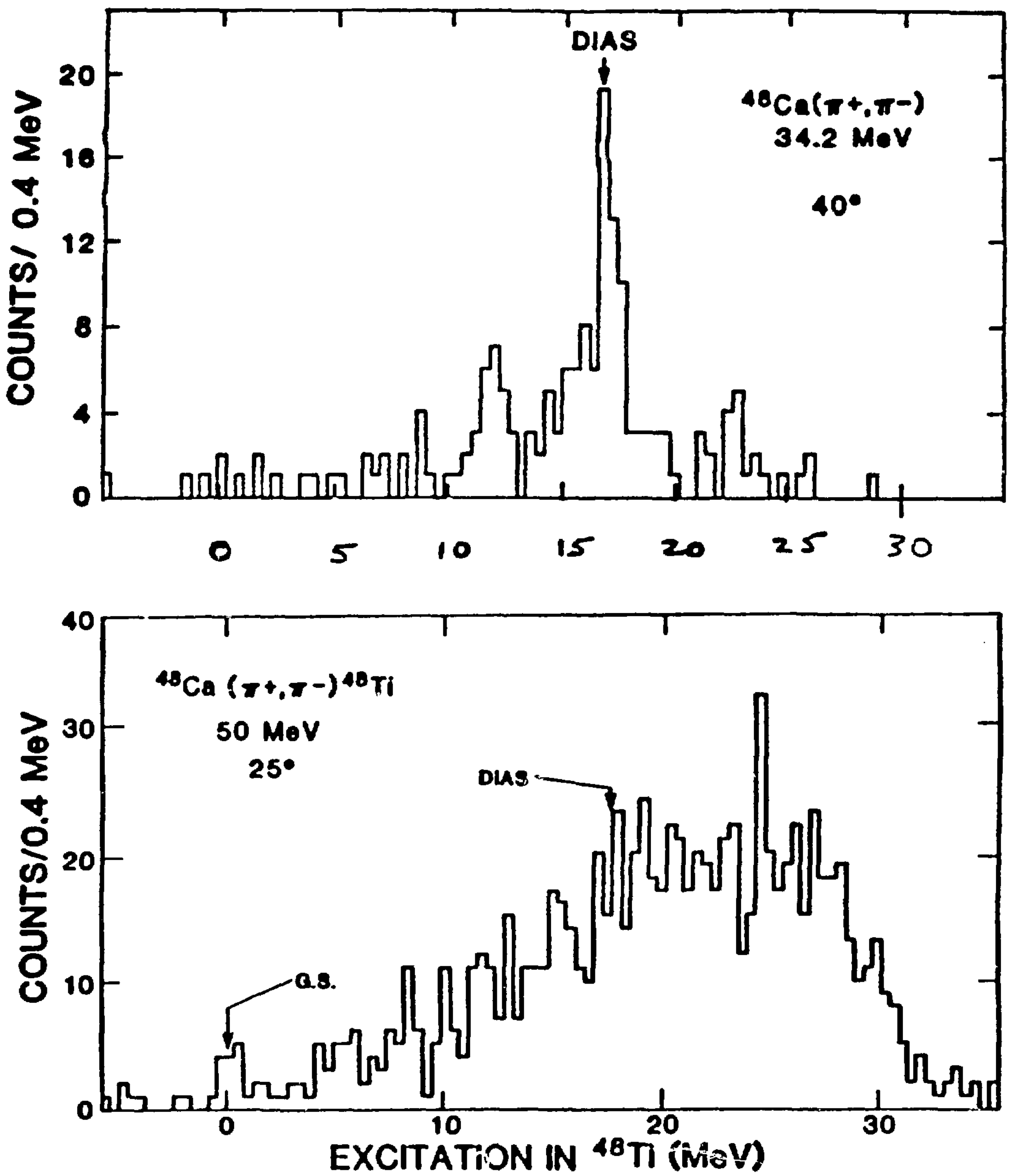


Fig. 9. DCX spectra for ^{48}Ca at 34.2 and 50 MeV.

transitions) and guidance from the work already carried out at EPICS.

VI. Pion Absorption

As a final area of research at LEP, and one of crucial importance in π-nucleus physics, I will discuss pion true absorption. At the fundamental level we have a study of $\pi^+ + d \rightarrow 2p$ at 10 to 30 MeV [Exp. #828; Ritchie (ASU) and Minehardt (UVa)]. This reaction has already been measured from 30 MeV to resonance energies at LEP with good accuracy. This new experiment hopes to provide high quality measurements of the total cross section and angular distribution at low energies far from the Δ-resonance. These data will provide a test of various three-body models.

At low energies pion absorption represents the major component of the reaction cross section, and thereby plays an important role for any π-nucleus reaction. At present our understanding of this important process could, at best, be described as poor -- others might say non-existent. Currently, many (including myself) believe that the absorption has two components: (1) absorption on two nucleons, preferentially those with the quantum numbers of a deuteron, and (2) multinucleon (N>2) absorption perhaps through sequential Δ-production as predicted by Oset et al.[11] Just to indicate the regions populated by these processes, I show in Fig. 10, data from Burger et al.[12] on $^{58}Ni(\pi^+,2p)$ at 160 MeV taken some time ago at LEP. The excitation energy spectra in "^{56}Co" are shown for three angle pairs, the 75°/-75° pair corresponding to the quasideuteron angles. The low-excitation energy region falls off rapidly with angle and is indicative of a two-nucleon mechanism. The higher excitation energy region falls off more slowly, becoming flat around 160 MeV. This region contains some final-state interaction protons, but present experiments suggest that a major part comes from multi-nucleon (N>2) absorption.

If one accepts this hypothesis then we can separate the study of pion absorption into two areas: (1) a study of the two-nucleon absorption by restricting attention to the low-excitation energy region, and (2) the study of multi-nucleon precesses by studying the high-excitation energy region. These two areas require rather different instrumentation. For (1) one would like equipment with sufficient energy resolution to resolve various nuclear states. In that way one could use the nucleus as a filter to isolate specific compon-

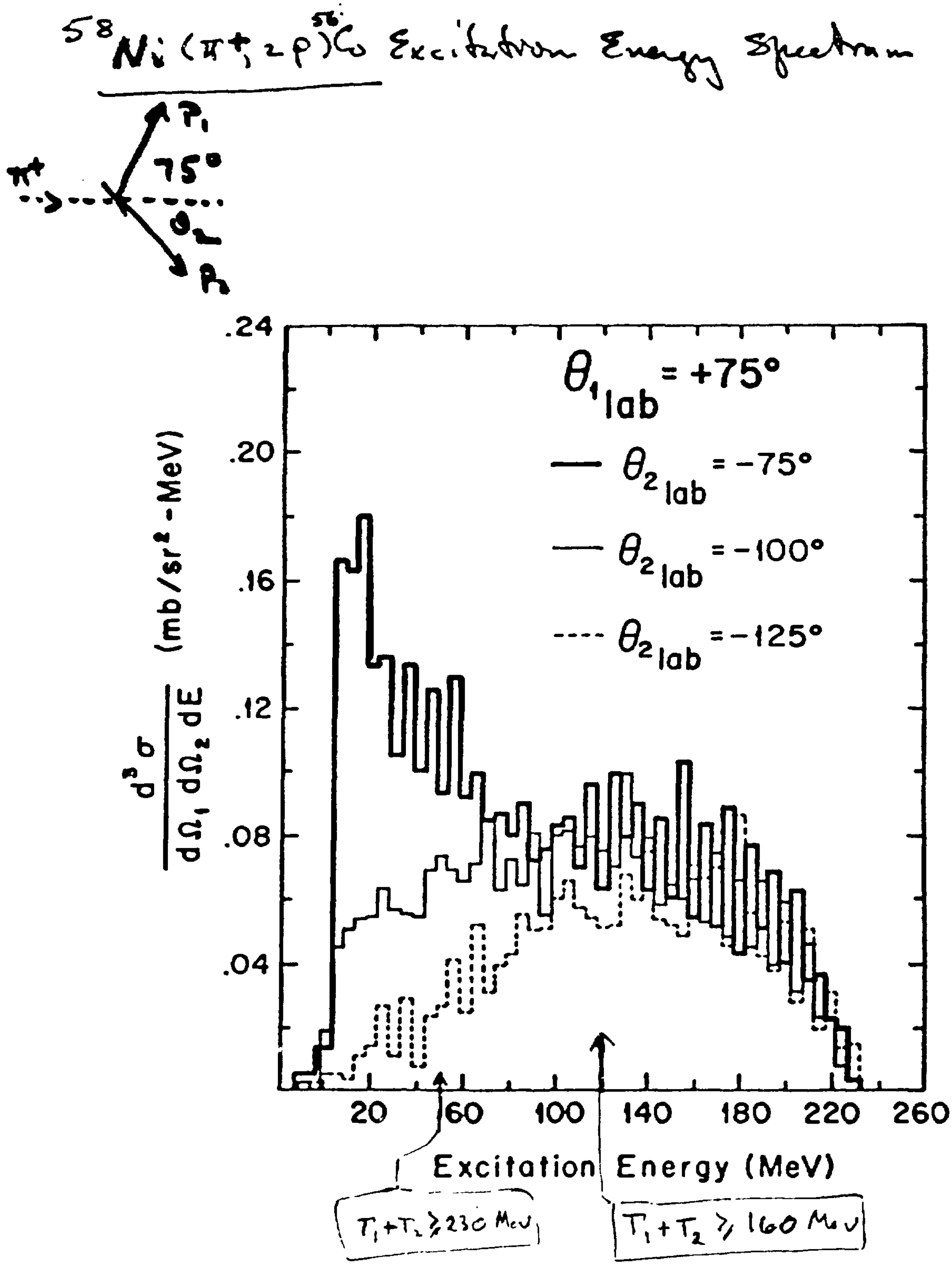


Fig. 10. Excitation energy spectra for $^{58}Ni(\pi^+,2p)$ at 160 MeV.[12]

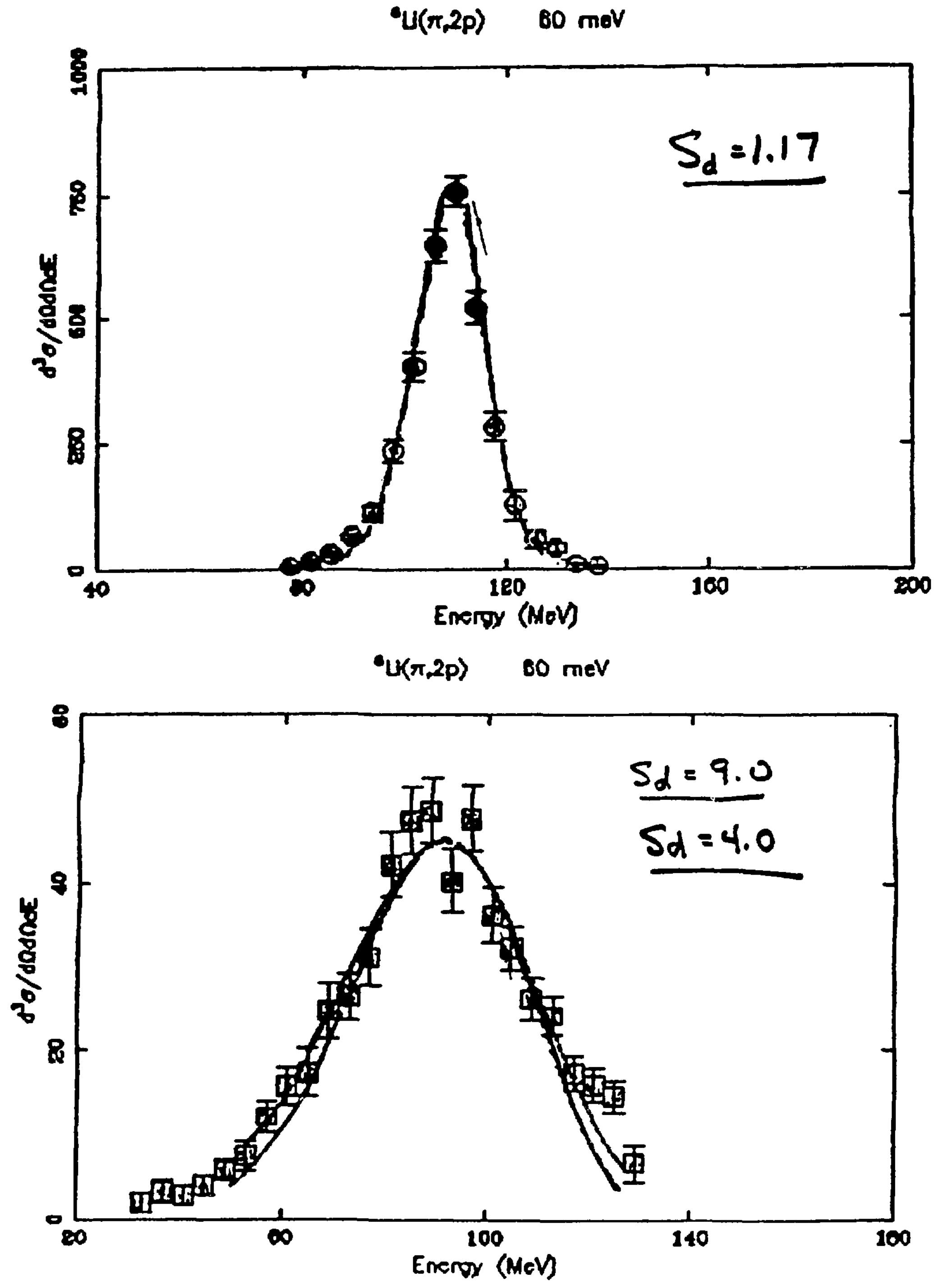


Fig. 11. Energy sharing distributions[13] for $^6Li(\pi^+,2p)$ at 60 MeV (top: g.s., bottom: 25 MeV excitation). The curves are DWIA quasideuteron calculations.

ents of the reaction. For (2) one needs a large acceptance device (~4π) which can measure multi-particle final states and provide total yields for various final states.

A good program in pion absorption would attack both aspects since they are clearly interrelated. I am pleased to say that this is just what is proceeding at LEP.

In one experiment the $^{6}Li(\pi^{+},2p)$ reaction is being measured as a function of energy from 30 to 100 MeV. Also, an initial measurement of $^{10}B(\pi^{+},2p)$ will be carried out [Exps. #948,966; Ritchie (ASU)]. This experiment will have sufficient energy resolution to separate individual states or groups of states. The results will provide a test of various two-nucleon reaction models (e.g., the DWIA quasideuteron model) in terms of energy dependence and angular dependence for two-nucleon components in the low-density region of the nucleus (^{4}He g.s. transition) and the high-density region (^{4}He excited state transitions). To demonstrate that a simple factorized quasideuteron DWIA calculation is not adequate even for ^{6}Li, I show data for $^{6}Li(\pi^{+},2p)$ at 60 MeV[13] in Fig. 11. The curves are DWIA calculations which clearly reproduce the shape, but the magnitudes as indicated by the deuteron spectroscopic factors are too large. This is particularly true of the excited state.

From the other standpoint a ($\pi^{\pm}$,X charged particle) study for several nuclei and energies will run this year using a BGO ball which covers approximately 3π sr [Exp. #993; Ransome (Rutgers) and Morris (LANL)]. This experiment will provide new information on the charged-particle multiplicity and have sufficient energy resolution to define the final state, or at least how much energy is lost through the production of neutrons. This is an ambitious experiment, well worth the effort due to its importance in π-nucleus physics. Almost certainly more ambitious will be the analysis and understanding of the results. This will benefit from the input of many physicists to understand how best to present the results to elucidate the underlying physics.

VII. Conclusions

This talk has been an overview of the physics going on at LEP. I believe that overall the program is interesting, healthy, and attacking many of the important areas of pion-nucleon physics. I am pleased to note that at least in several areas the physicists have proceeded to the next generation of experiments which hopefully will greatly improve our knowledge of reaction dynamics and nuclear structure.

References

1. B. Fick *et al.*, Phys. Rev. C 34, 643 (1986).
2. K. A. Aniol *et al.*, Phys. Rev. C 33, 208 (1986).
3. There have been a number of papers, too numerous to detail here.
4. J. D. Bowman *et al.*, Phys. Rev. Lett 50, 1195 (1983); and subsequent publications.
5. G. Kyle *et al.*, Phys. Rev. Lett. 52, 974 (1984).
6. M. Hirata, F. Lenz, and M. Thies, Phys. Rev. C 28, 785 (1983).
7. S. Gilad *et al.*, Phys. Rev. Lett. 57, 2637 (1986).
8. G. Miller, Phys. Rev. Lett. 53, 2008 (1984).
9. I. Navon *et al.*, Phys. Rev. Lett. 52, 105 (1984).
10. M. J. Leitch *et al.*, Phys. Rev. Lett. 54, 1482 (1985).
11. E. Oset, Y. Futami, and H. Toki, Nucl. Phys. A448, 597 (1986).
12. W. J. Burger *et al.*, Phys. Rev. Lett 57, 58 (1986); W. J. Burger, Ph.D. thesis, MIT, 1985.
13. R. Rieder *et al.*, Phys. Rev. C 33, 614 (1986).

PHYSICS AT THE NUCLEON PHYSICS LABORATORY

Talk given to the LAMPF Users' Meeting
October 27, 1986

David Axen
Department of Physics
University of British Columbia
Vancouver B.C. Canada V6T 2A6

The experimental program at NPL is extremely diverse and is evolving rapidly. I would like to illustrate this diversity and rapid evolution by listing the experiments in progress. I would like to concentrate on the nucleon-nucleon experiments, stressing the evidence which indicates that complete determination of the inelasticities for all the nucleon-nucleon amplitudes will be necessary; that is, measurements of the spin and energy dependence of all the pion production amplitudes. Several 4π detectors are in existence for studying multi-particle final state reactions. I would like to describe the ASTERIX experiment[1] at CERN that has studied proton-antiproton annihilation at rest, using the modified DM1 detector from ORSAY. I would also like to describe some of the techniques developed for an amplitude analysis of the three particle final state. These techniques are very computer intensive. Finally I would like to show that a program of studying multiparticle final state reactions with a 4π detector would lead directly to a very interesting set of experiments at the Advanced Hadron Facility.

The experiments in the queue at NPL are listed in Table 1. The proton-proton and neutron-proton elastic scattering experiments rely completely on the variable energy polarised beam and polarised targets. The atomic physics group has developed a dedicated laboratory. The (p,d) elastic scattering experiments, by the UCLA group, that measure a complete set of spin observables will be completed perhaps within the next year. Two new facilities, the neutron time-of-flight facility and the medium resolution spectrometer are being developed. The neutron time-of-flight facility will be commissioned next year and the medium resolution spectrometer the following year. The specifications of these two facilities are described in a LAMPF report LA10278-MS available from the MP10 group office.

In the nucleon-nucleon program a large experiment (E770) measuring spin correlation parameters in free np scattering, by the Argonne group, has been completed and is being analysed. The measurement of A_{nn} is expected to be completed this year. The elastic nucleon-nucleon program up to 800 MeV will be essentially complete when these two experiments are analysed and the results included in the phase shift analysis.

The nucleon-nucleon elastic cross-sections are smooth functions of energy, devoid of any resonances. Above about 325 MeV the phase shifts become inelastic and there is speculation that the inelastic components might have resonant structure. If such structure exists it could be evidence for quark effects at low energies. Total cross-section difference measurements are a very sensitive probe of inelasticities and, as seen in Figure 1, the structure is well established in the proton-proton[2] case. A previous experiment at the ZGS indicated even larger effects in the neutron proton system. Experiment 960 is a check of this result.

There has already been one experiment (E815) here at LAMPF to study pp → np π^+ between 500 and 800 MeV which is now being analyzed. The reaction is analysed using the Silbar model[3] in which the reaction proceeds through the intermediate delta which then decays to a pion and a nucleon. Two of the collaborators, David Bugg and Rick Shypit, also participated in a previous TRIUMF measurement[4] at 500 MeV. In Figure 2 the measured spin observables, plotted as a function of the decay angle of the intermediate delta, show interesting angular distributions. The energy range in that experiment was not adequate to reach the maximum of the delta resonance. If interesting effects are found when the analysis of the LAMPF experiment is completed and the total cross section difference measurements free np scattering confirm the Argonne results, there will be a strong motivation for a complete study of the inelastic channels.

Experiment 1029 is a proposal to study pion production in the proton-proton system using the large angle spectrometer and the medium resolution spectrometer in coincidence.

The detector for studying proton-antiproton annihilation at rest is shown in Figure 3. Low energy antiprotons are stopped in the central gaseous hydrogen target. Surrounding the gas target and separated from it by a six micron thick mylar foil is an X-ray drift chamber. The X-rays from the atomic cascade process as well as the energy lost by charged particles are measured in this chamber. Outside the drift chamber are seven cylindrical multiwire proportional chambers. Near the outer edge is a thin lead foil with 3% conversion efficiency for gamma rays. Position sensitive gamma detectors are mounted on the end caps and the whole apparatus is contained in an eight kilogauss solenoidal magnetic field.The x-ray drift chamber has 90 sense wires, the charge collected at each end is time digitized for position, pulse shape and energy determination. The multiwire proportional chambers consist of central longitudinal anode wires with the inner and outer cathodes spiralled in opposite senses for determination of the longitudinal co-ordinates. The anodes give the (r,ϕ) co-ordinates. The total number of wire is 23,772. The readout system could be triggered on X-ray detection and on the track multiplicity. The maximum data taking rate was of the order of 60 events per second. The average record length varied between one and four kilobytes and the average time for tracking the events was 40 milliseconds per event on a mainframe computer with a speed of 13 mega instructions per second.

The identification of pions and kaons by differential energy loss in the X-ray drift chamber is shown in Figure 4. Below about 400 MeV/c there is no ambiguity. The missing mass squared for two charged prong events without gamma detection is shown in the Figure 5. The peaks due to single missing neutral pions, as well as to eta and omega decaying in their all neutral modes, are clearly visible. The spectrum is dominated by decays with multiple neutral pions in the final state. Events with a missing mass squared less than 0.4 were fitted to the hypothesis $\bar{p}p \rightarrow \pi^+, \pi^-, \pi^0$. This is a one constraint fit. Those with a χ square less than 1.0 were accepted for the amplitude analysis.

The Dalitz plot for these accepted events is shown in Figure 6. The charged rho bands are very evident, while decay to the neutral rho from the P state is forbidden by G-parity. The f^0 band is also very evident.

The density of points on the Dalitz plot is completely determined by the reaction dynamics or in other words all the information about the reaction is contained in this plot. In the amplitude analysis the annihilation is assumed to proceed through a series of two body annihilations, i.e. the annihilation goes to a dipion state plus a third pion. The dipion subsequently decays to two pions, each of momentum q and relative orbital angular momentum l. The third pion is emitted with orbital angular momentum L with respect to the dipion and momentum P in the lab system. The possible initial proton-antiproton states are listed in Table 2 with all possible intermediate dipion states and the statistical and kinematical factors for the decay process shown. Resonant intermediate states are represented by Breit-Wigner amplitudes.

The detector does not completely cover 4π and is not of uniform efficiency. To incorporate these factors a Monte Carlo data set for decay to three pions was generated with a phase space distribution. This set will ultimately be digitized using the measured detector geometry and efficiency. In the results shown below, this step is not complete and an idealized geometry has been used and the efficiency factors set equal to unity. The Monte Carlo data was then tracked with the same program as the real data. A Monte Carlo Dalitz plot for each of the channels listed in Table 2 was generated in which each event has been weighted by the appropriate kinematical and statistical factor. Finally, the coefficients for each amplitude are determined by χ-squared minimisation. In order that the error be dominated by the statistical error of the data and not the Monte Carlo sample, the Monte Carlo sample should be approximately ten times larger than the data sample.

A Dalitz plot constructed from the Monte Carlo Dalitz plots, weighted by the dynmical factors for each channel and the amplitudes determined from the χ-squared minimisation, is shown in Figure 7. Comparison of the actual data and the simulated data is best done by comparison of the projection on to the diagonal axis as shown in Figures 8 and 9. This comparison only demonstrates that the technique converges. The data taking on this experiment was completed in July of this year. We are still determining all the detector alignments and efficiencies before finalizing the Monte Carlo program. The procedure must be repeated with the final Monte Carlo and the complete data set to obtain publishable amplitudes.

A series of reactions that could be studied using the same 4π detector in a negative kaon beam at the Advanced Hadron Facility are listed in Table 3. The numbers in the second column indicate the quality of fit that could be obtained if the directions of the neutral particles are determined and if the velocity of one of the neutrals is measured by time-of-flight. Most data on kaon-nucleon inelastic processes have been obtained in bubble chambers. Statistics are typically 1000 events per momenta at steps of 25 MeV/c. With a 4π detector one could obtain easily 100 or 1000 times more data including polarisation data if a polarised target were used. The physics objectives are also well defined as in the proton-antiproton annihilation case. The observed resonances fit well into octets and decuplets of the quark model with orbital angular momentum. There are four missing [70-] L=1 members while the [56+] L=2 spectrum is very incomplete. If QCD is correct these states must be there and a 4π detector is the detector necessary to find them.

In conclusion I would like to say that a complete study of the nucleon-nucleon inelastic reactions will be necessary. A 4π detector is essential. The techniques for data acquisition and analysis have all been explored but there are intestesting challenges in developing fast triggers and readout systems. Computers are becoming large enough and fast enough to handle the Monte Carlo calculations for amplitude analysis. The nucleon-nucleon inelastic channels, where the final state multiplicities are low, are an interesting first set of measurements. The next step is an interesting set of experiments at the Advanced Hadron Facility.

References

1. S. Ahmad et al., "Physics at LEAR with Low-Energy Cooled Antiprotons", Eds. Ugo Gastaldi and Robert Klapish (Plenum Publishing Corporation 1984) 253.

2. J.P. Stanley et al., Nuc. Phys. A403 (1983) 525.

3. J. Dubach et al., J. of Phys. G8 (1982) 475.

4. C.E. Waltham et al., Nuc. Phys. A433 (1985) 649.

List of Tables

List of Figures

TABLE 1

NPL PROPOSAL SUMMARY Aug 86

Exp	subject		pri	line	En.	hrs	PAC	notes
961	A_{nn} in np→np	Nrthclff	H	BR	800	1250	Aug85	buncher
960	$\Delta\sigma_{L,T}(n,p)$	Johnson	H-	BR	5-800	2440	Aug85	buncher,PPT
588	γH^-, long-lived states	UNM	H-	EPB	800	100	Feb85	
818	2,3-spin in pd→pd	Igo	H-	EPB	800	1300	Jan84	PDT+Scylla+Janus
965	N calibration	Dunphy	M	BR	3,5,800	336	Aug85	buncher
832	$^{12}C(p,p'\gamma)^{12}C^*$	Funsten	M	EPB	≤500	288	Feb86	
866	ν expt calibration	Donahue	M	EPB	800	0	Feb86	
Cannot run immediately:								
876	K_{ij}, np→np	McNghtn	(H)	BR			Aug84	OPPIS
881	Pb, ^2H quasi-free	McClllnd	(H-)	NTOF	3-500		Aug84	
958	$^{90}Zr(p,n)^{90}Nb$	Hoffmann	(H-)	NTOF	500	232	Aug85	
823	A(n,p)		(H-)	BR			Jan84	MRS in BR
739	P-A, np→np	Nrthclff	(M)	BR	800		Jul82	unpol beam
847	np charge symmetry	Nrthclff	D	BR	800		Jan84	OPPIS
1029	A(p,pπ) A(p,dπ)	Maryland	D	MRS	800		Aug86	MRS+LAS

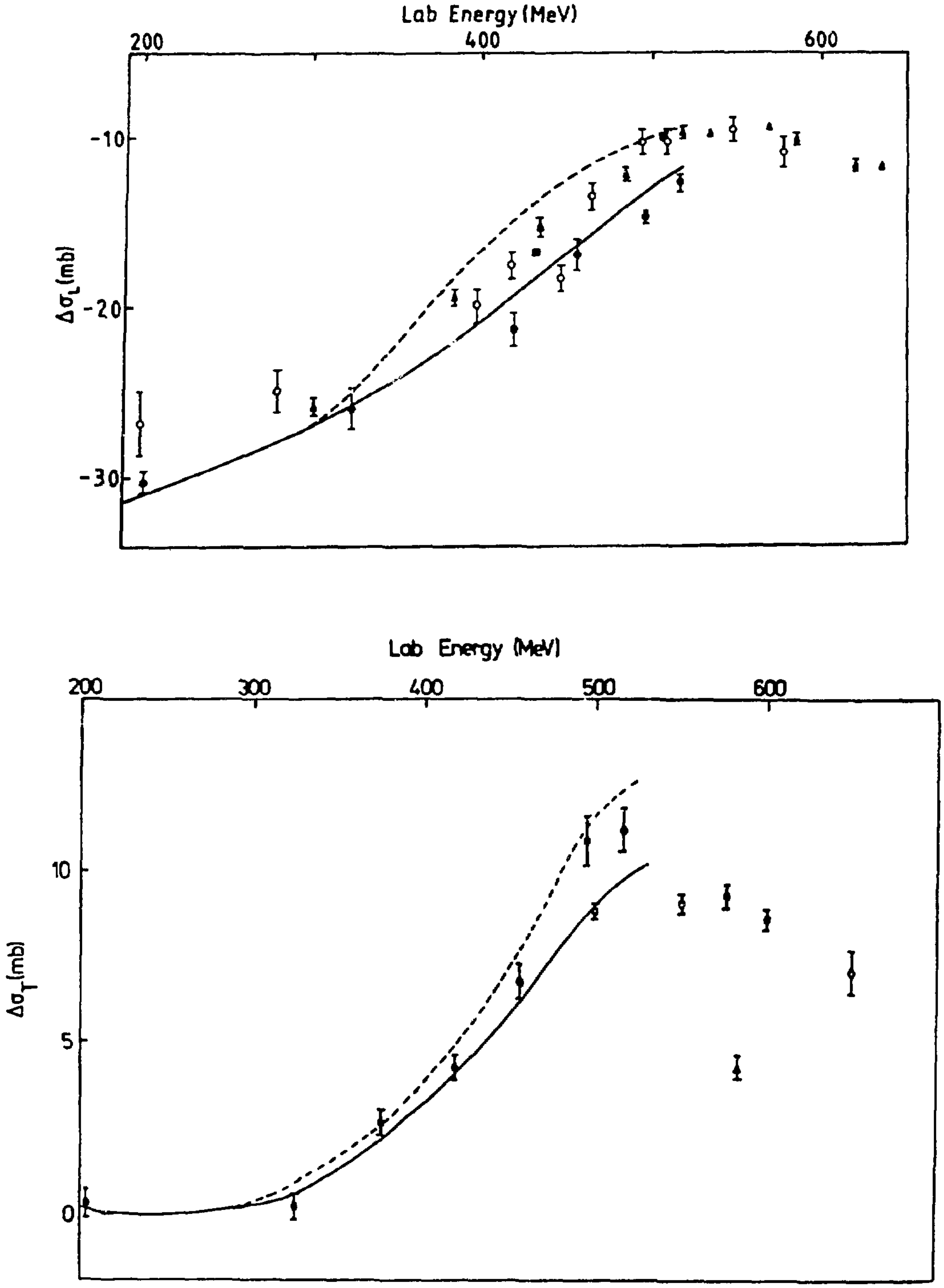
TABLE 2

$\bar{p}p$ state $^{2I+1,\,2S+1}L_J$	$J^{PC}I^G$	Angular Mom Dipion ℓ	Angular Mom Orbital L	Dipion Resonance	Amplitude and Phase	Dipion Isospin $\pi^+\pi^0$	Dipion Isospin $\pi^+\pi^-$	Dipion Isospin $\pi^-\pi^0$	Dynamical Factor	Parameters
$^{31}S_0$	$0^{-+}1^-$	0	0	$\epsilon\,\pi^0$		0	1	0	1	5
				$S^*\pi^0$		0	1	0		
				$\pi^+\pi^-\pi^0$	X_1	0	1	0		
		1	1	$\pi^+\pi^-\pi^0$		−1	0	1	$q\,.\,p$	
				$\rho^\pm\pi^\mp$	$X_3\ \phi_3$	−1	0	1		
		2	2	$\pi^+\pi^-\pi^0$		0	1	0	$(q\,.\,p)^2-(1/3)\,q^2p^2$	
				π^0f^0	$X_2\ \phi_2$	0	1	0		
$^{13}S_1$	$1^{--}0^-$	1	1	$\pi^+\pi^-\pi^0$	$X_5\ \phi_5$	1	1	1	$q\times p$	3
				$\rho\,\pi$	X_4	1	1	1		
$^{11}P_1$	$1^{+-}0^-$	1	0	$\pi^+\pi^-\pi^0$	$X_7\ \phi_7$	1	1	1	q	3
				$\rho\,\pi$	X_6	1	1	1		
		1	2	$\pi^+\pi^-\pi^0$		1	1	1	$p\,(p\,.\,q)-(1/3)\,p^2q$	
				$\rho\,\pi$		1	1	1		
		3	2	$\pi^+\pi^-\pi^0$		1	1	1		
$^{33}P_1$	$1^{++}1^-$	1	0	$\pi^+\pi^-\pi^0$	$X_9\ \phi_9$	−1	0	1	q	7
				$\rho^\pm\pi^\mp$	X_8	−1	0	1		
		1	2	$\pi^+\pi^-\pi^0$		−1	0	1	$p\,(p\,.\,q)-(1/3)\,p^2q$	
				$\rho^\pm\pi^\mp$		−1	0	1		
		0	1	$\epsilon\,\pi^0$		0	1	0	p	
				$S^*\pi^0$		0	1	0		
				$\pi^+\pi^-\pi^0$	$X_{10}\ \phi_{10}$	0	1	0		
		2	1	$\pi^+\pi^-\pi^0$		0	1	0	$q\,(p\,.\,q)-(1/3)\,pq^2$	
				π^0f^0	$X_{11}\ \phi_{11}$	0	1	0		
		3	2	$\pi^+\pi^-\pi^0$		−1	0	1		
$^{33}P_2$	$2^{++}1^-$	1	2	$\pi^+\pi^-\pi^0$	$X_{15}\ \phi_{15}$	−1	0	1	$(q^-\times p^+)\,.\,p^+-(q^+\times p^-)\,.\,p^-$	7
				$\rho^\pm\pi^\mp$	X_{13}	−1	0	1		
		3	2	$\pi^+\pi^-\pi^0$		−1	0	1		
		2	1	$\pi^+\pi^-\pi^0$	$X_{16}\ \phi_{16}$	0	1	0	$q\,(q\times p)$	
				π^0f^0	$X_{14}\ \phi_{14}$	0	1	0		

TABLE 3

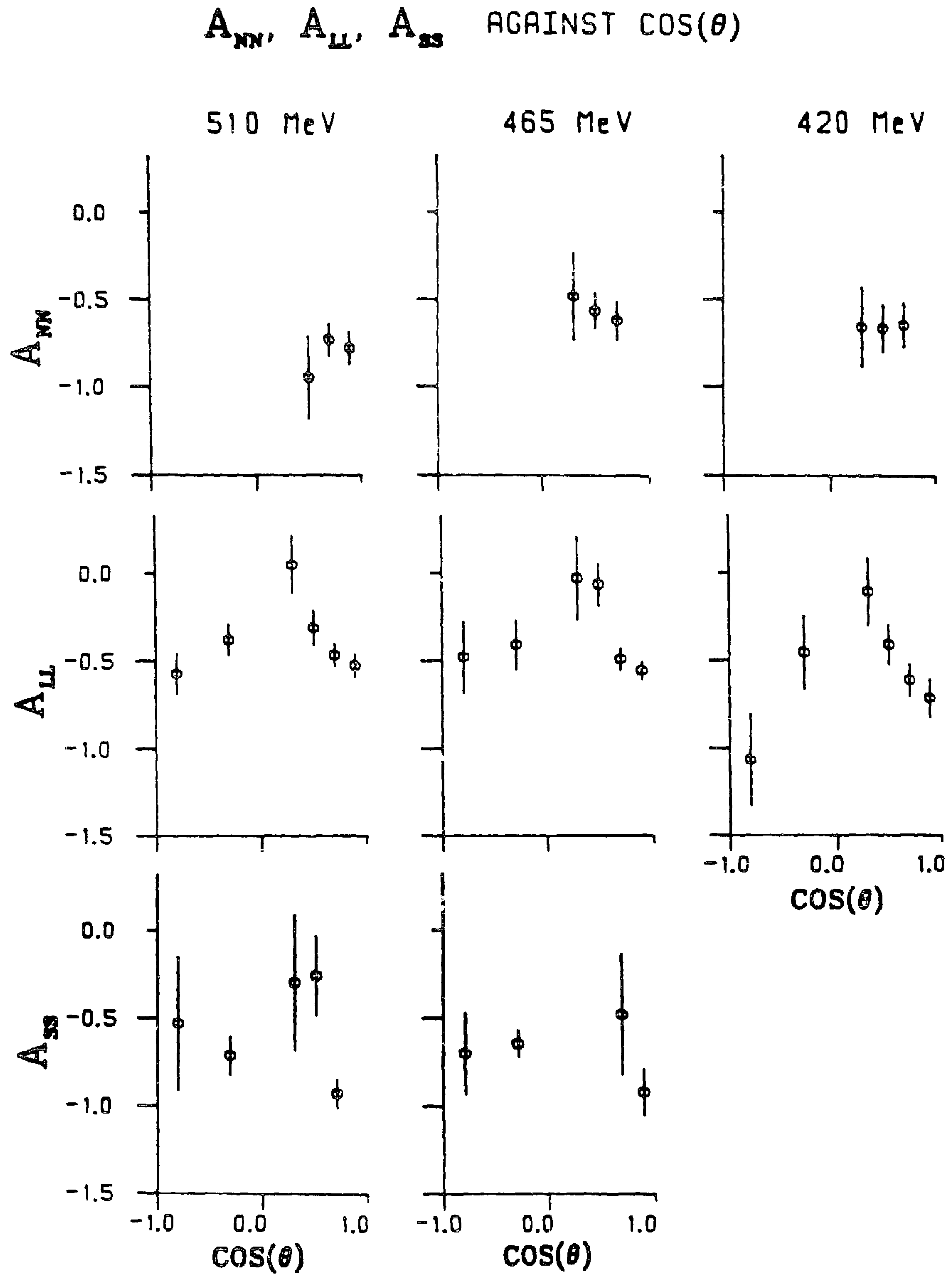
$K^-p \rightarrow K^\circ n$	3C
$\rightarrow \Lambda^\circ \pi^\circ$ (or η°)	3C
$\quad \hookrightarrow \pi^- p$	
$\rightarrow \Sigma^+ \pi^-$	3C
$\quad \hookrightarrow n\pi^+$ or $p\pi^\circ$	
$\rightarrow \Sigma^- \pi^+$	3C
$\quad \hookrightarrow n\pi^-$	
$\rightarrow \Sigma^\circ \pi^\circ$ (or η°)	3C
$\quad \hookrightarrow \Lambda^\circ \gamma$	
$\rightarrow K^- \pi^+ n$	2C
$\rightarrow K^\circ \pi^\circ n$	2C
$\rightarrow K^- p \pi^\circ$	2C
$\rightarrow K^\circ \pi^- p$	2C
$\rightarrow \Sigma^\pm \pi^\mp \pi^\circ$	2C
$\rightarrow \Sigma^\circ$ (or Λ°)$\pi^+\pi^-$	2C
$\rightarrow \Sigma^\circ$ (or Λ°)$\pi^\circ\pi^\circ$	2C
$\rightarrow \Xi^- K^+$	3C
$\quad \hookrightarrow \Lambda^\circ \pi^-$	
$\rightarrow \Xi^\circ K^\circ$	3C
$\quad \hookrightarrow \Lambda^\circ \pi^\circ$	
$\rightarrow \Lambda^\circ$ (or Σ°)ω	2C

FIGURE 1



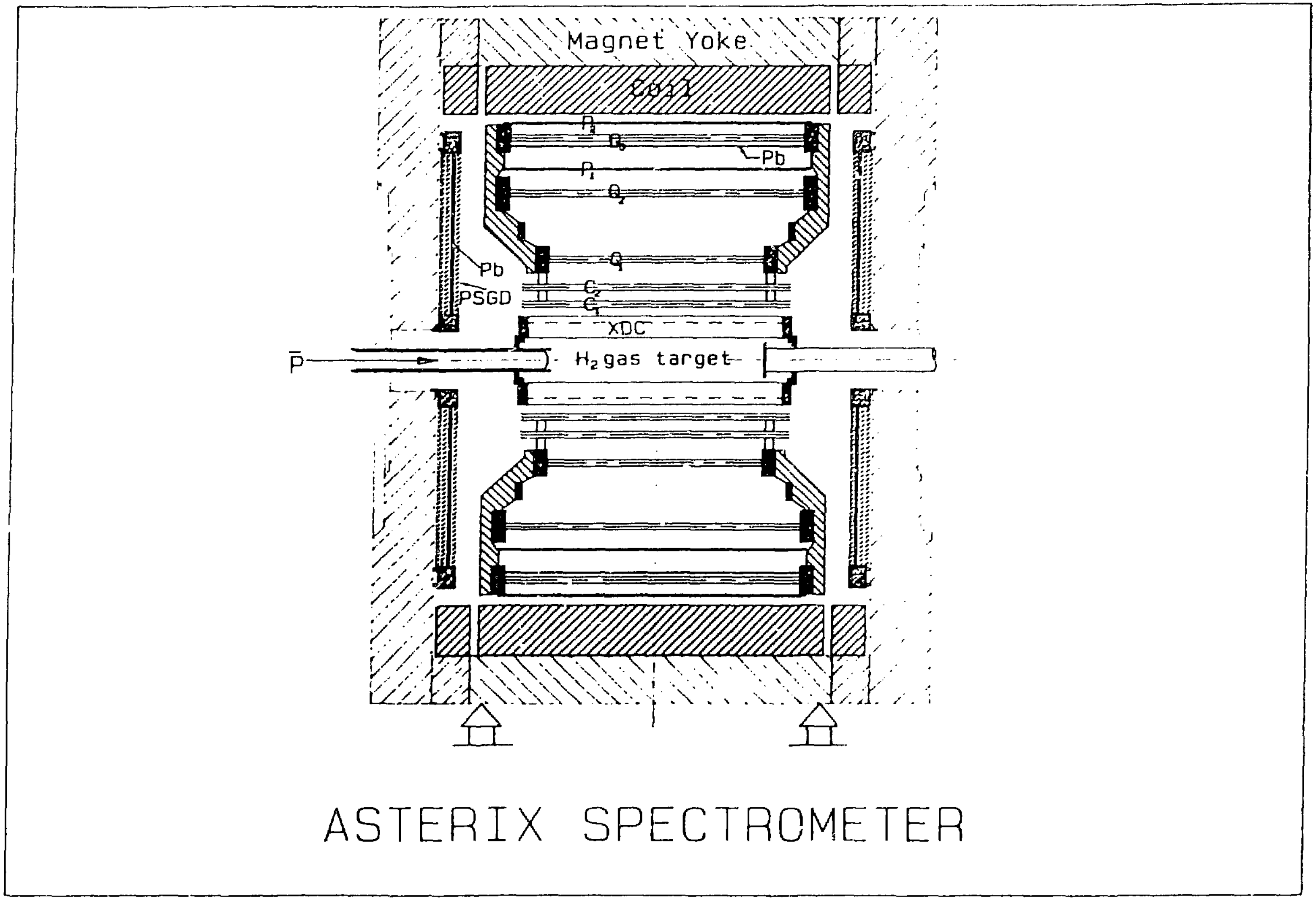
Proton-proton total cross-section differences with the spins aligned parallel and perpendicular to the beam direction.

FIGURE 2



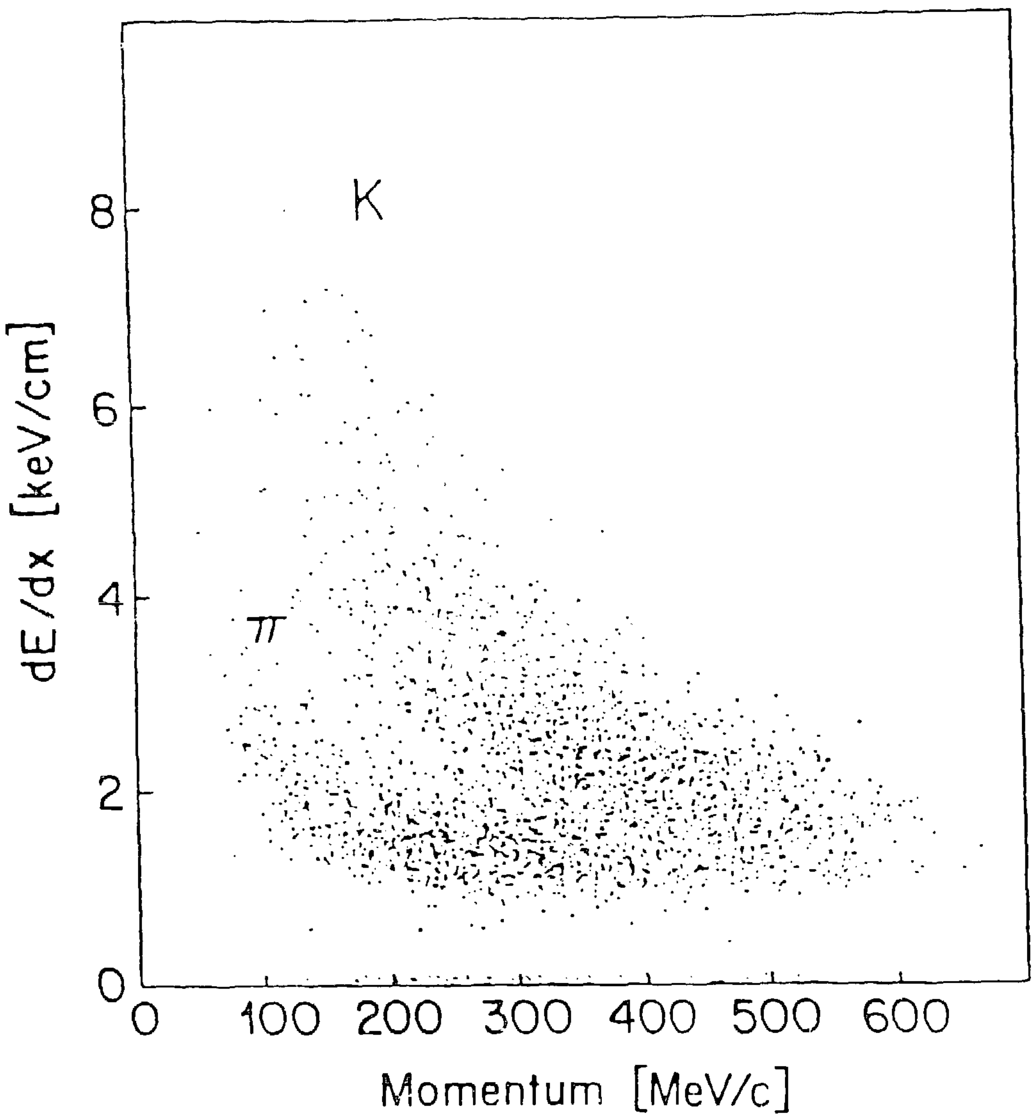
Proton-proton spin correlation parameters A_{nn}, A_{ll}, and A_{ss} as a function of the Gottfried-Jackson angle, i.e., the polar angle of the decay pion in the delta rest frame with respect to the incident beam.

FIGURE 3



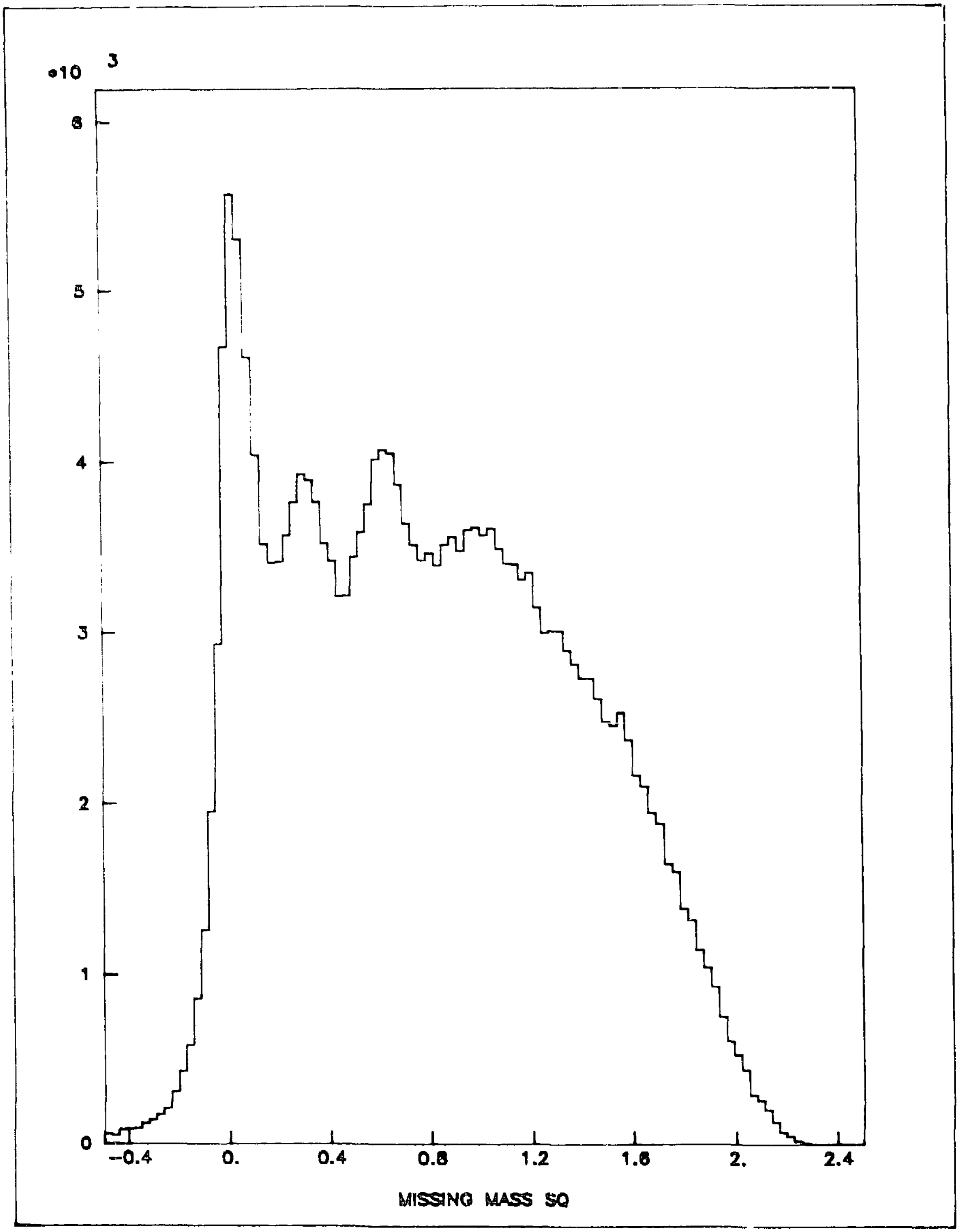
Schematic view of the ASTERIX detector.

FIGURE 4



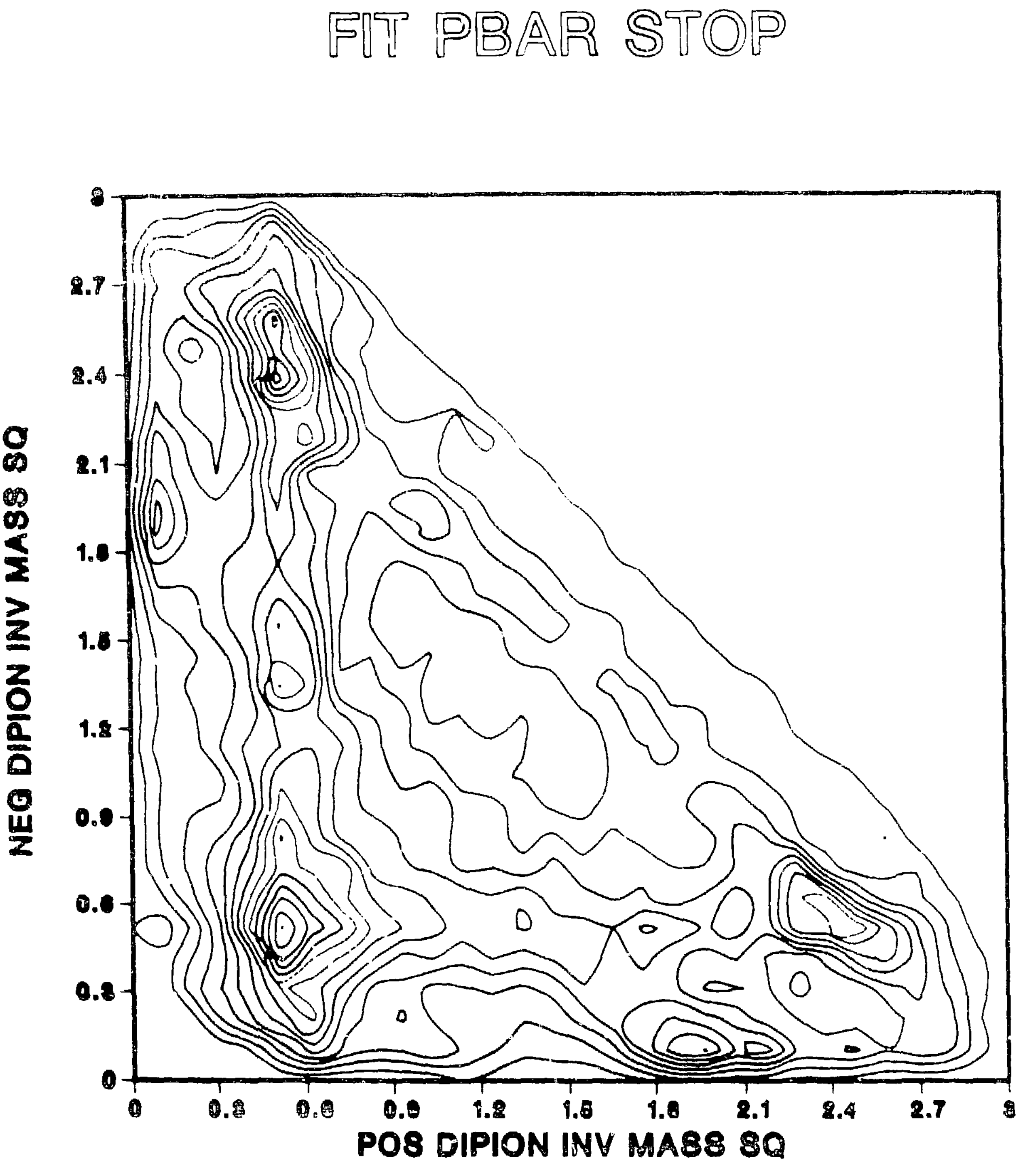
The differential energy lost by charged particles in the X-ray drift chamber.

FIGURE 5



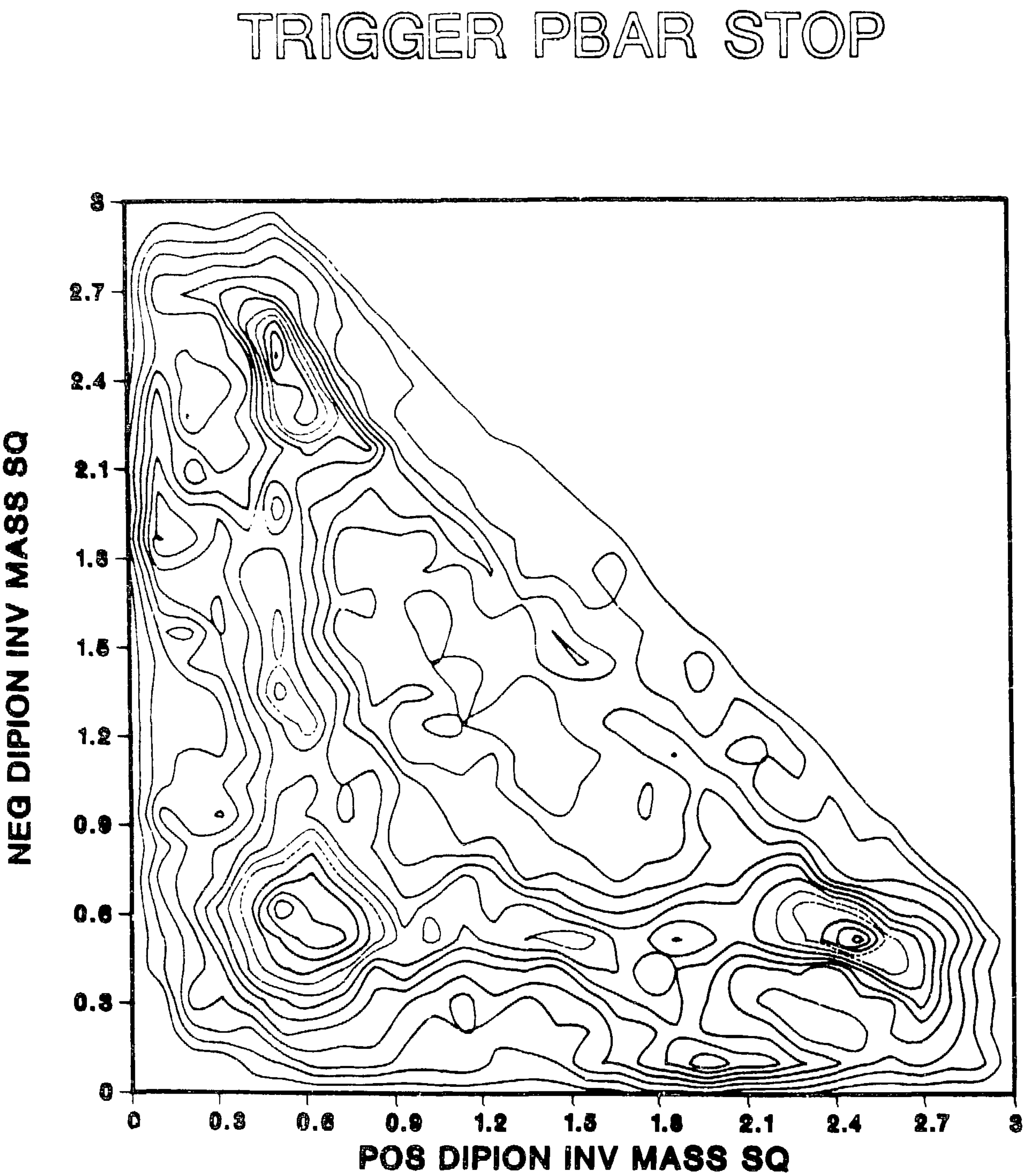
The (missing mass)^2 for the two prong events.

FIGURE 6



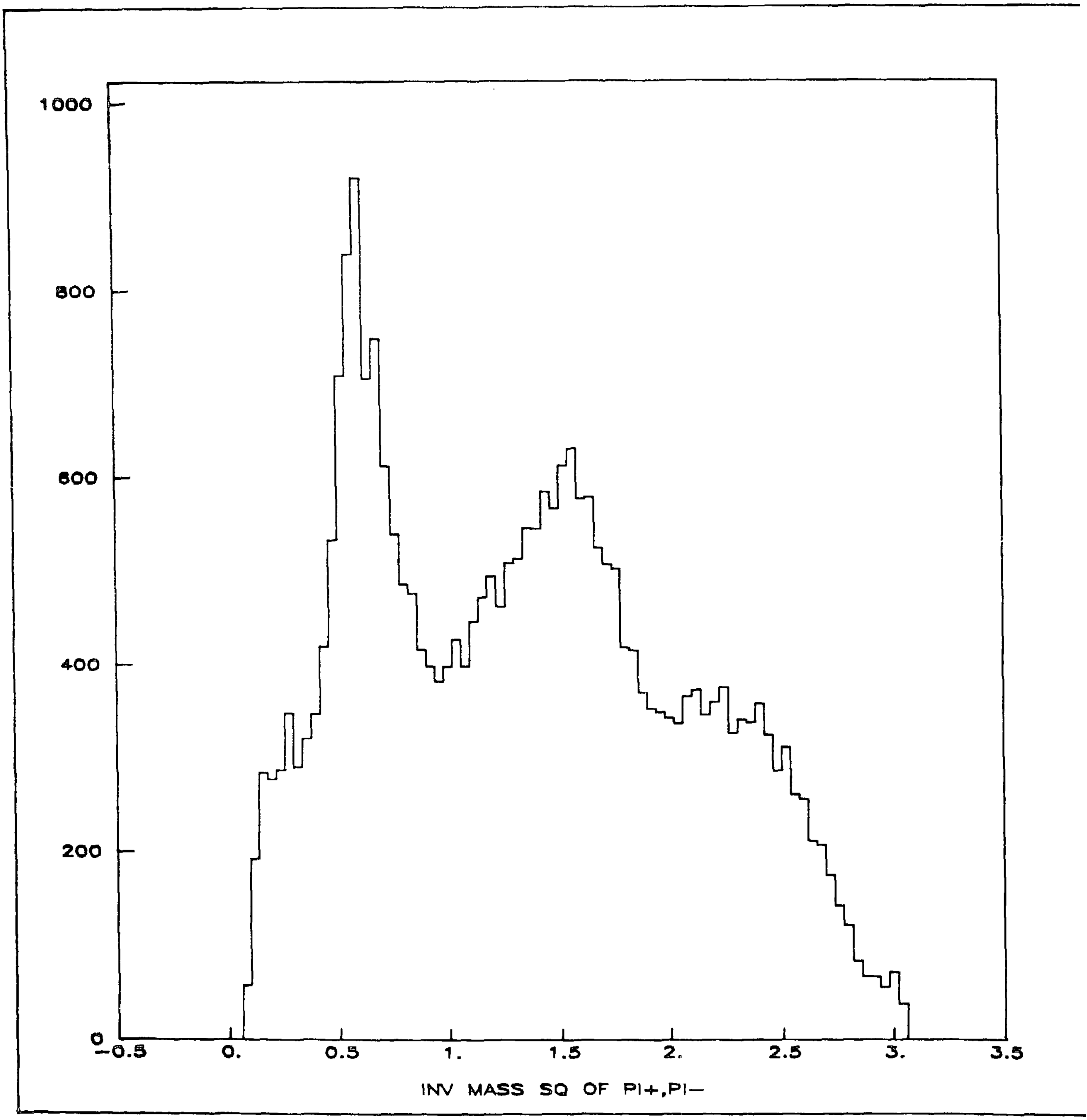
The Dalitz plot constructed from the experimental data for proton-antiproton annihilation to three pions.

FIGURE 7



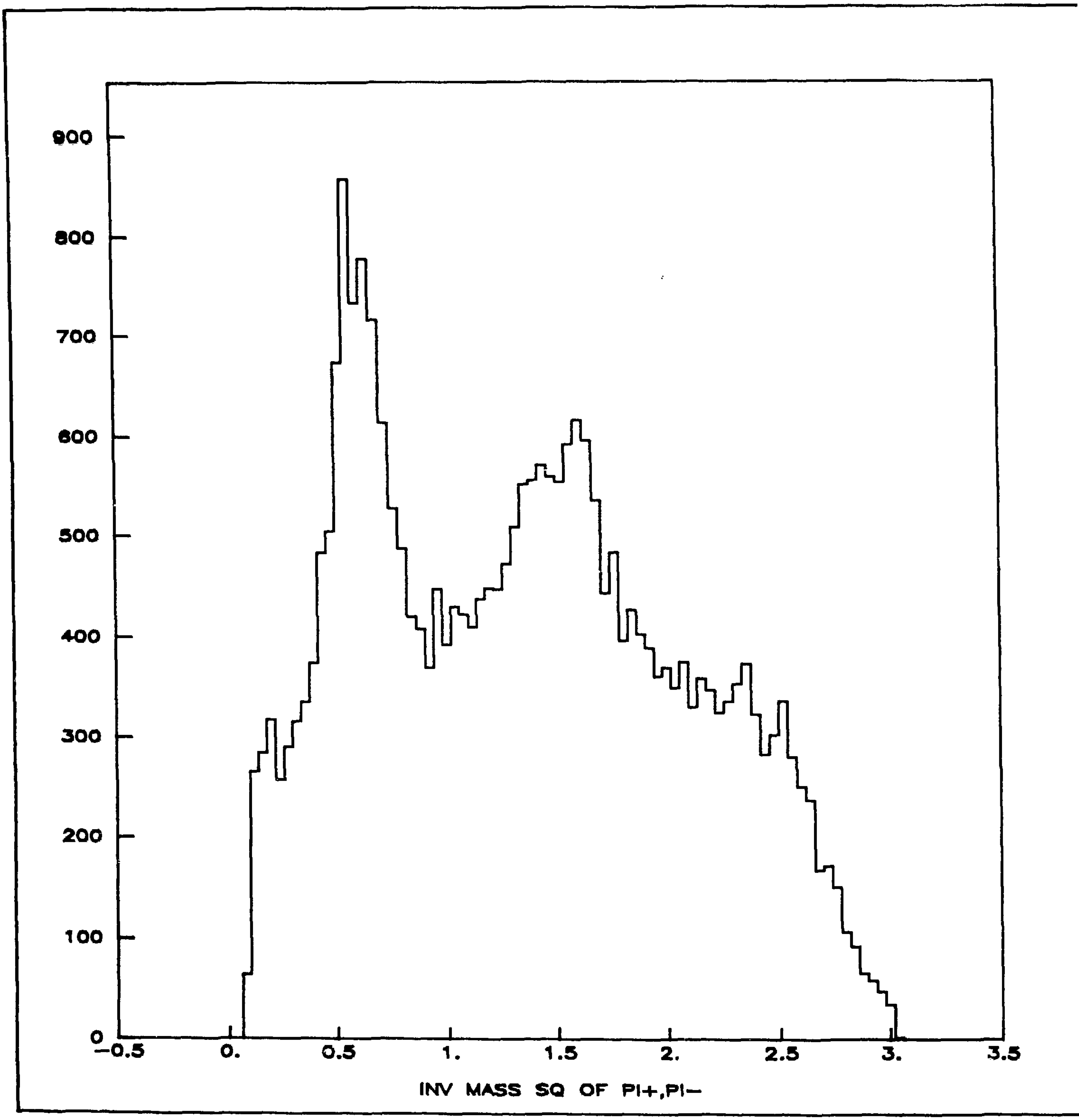
The Dalitz plot constructed with the Monte Carlo data set weighted by the dynamical and statistical factors listed in Table 2 and the amplitudes from the χ-squared minimisation.

FIGURE 8



The (invariant mass)^2 of the (π^+,π^-) dipion intermediate state from Figure 6.

FIGURE 9



The (invariant mass)^2 of the (π^+,π^-) dipion intermediate state from Figure 7.

Status and Plans for Computer Facilities at LAMPF

Earl W. Hoffman

Summary

I want to briefly discuss the current status of computer resources provided at LAMPF for the support of Medium Energy Physics research and to give you our thoughts and plans for the near future. The areas I will discuss are data acquisition, data analysis, and computer maintenance.

Data Acquisition

During the past two years we have replaced all LAMPF-supplied data-acquisition computers with MicroVAX II or VAX 11/750 computers.

Current LAMPF-supplied systems are:

EPICS	VAX 11/750
HRS	"
NPL	"
P3E	MicroVAX II
P3W	"
SMC	"
LEP	"
NTOF	"
BR (New system)	"
TEST CHANNEL (Future)	"

and some users have purchased VAX systems that are connected onto our network. These include Yale, E-465, HIRAB, CYGNUS, and P-DO. A number of advantages accrue with the use of VAXs, including a larger memory space, the same operating system as is used in the DAC, and DECNET compatibility.

In general each system also has a 6250/1600/800 bpi tape drive capable of writing a 2400 foot tape at 6250 bpi in 15-20 minutes, a 1600/800 bpi unit and a 70 MB disk. A typical configuration for data acquisition is shown here:

MicroVAX II
5 MB memory
6250/1600/800 bpi tape drive
1600/800 bpi tape drive
70 MB disk
Microprogramable Branch Driver
Printer
Terminals and console
VMS/DECNET/FORTRAN

Perhaps the most significant enhancement in the past year has been the completion of a DEC Local Area Network that allows our DEC computers to communicate with each other using the DECNET software.

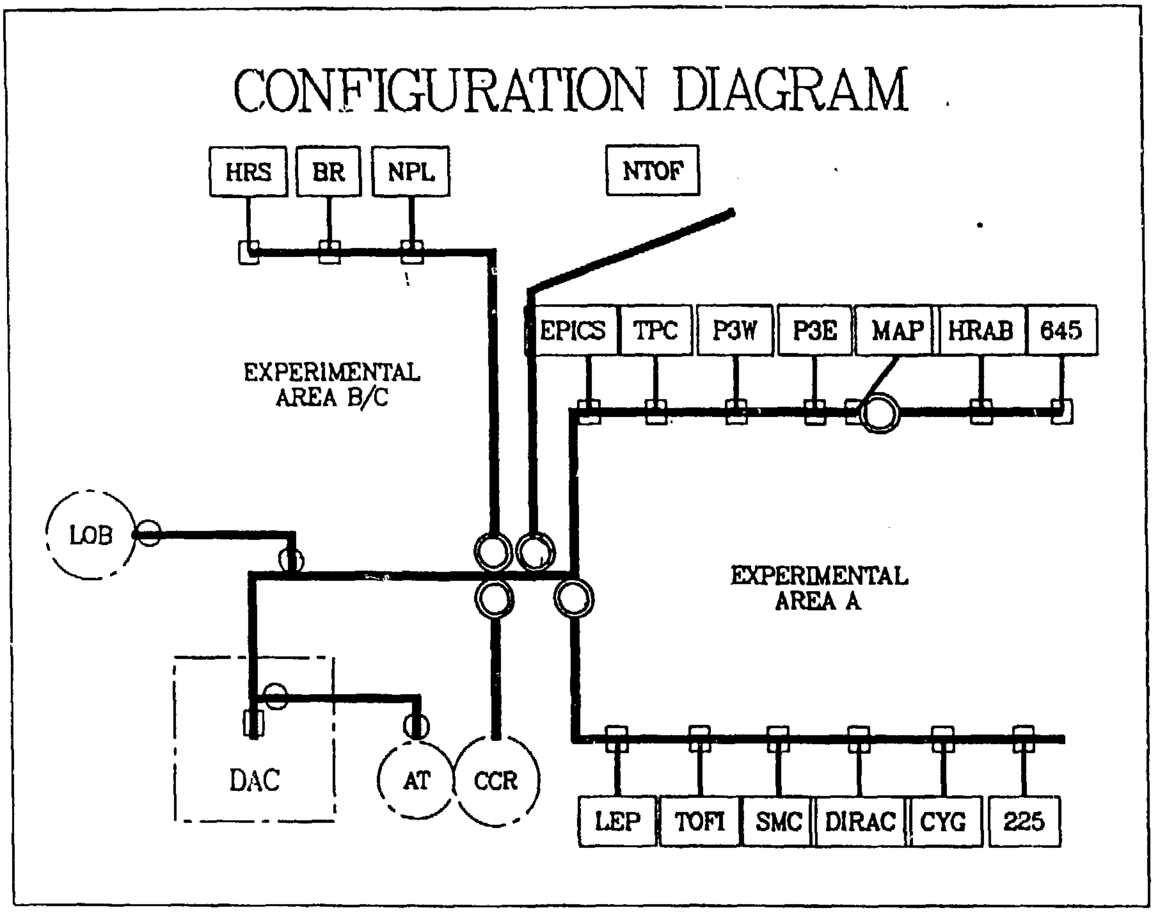


Diagram of the LAMPF Local Area Network.

We have 20 computers on this LAN now and AT division has 9 DEC computers and numerous SUN and Xerox workstations attached to an extension of this network.

The principle advantages of this communications capability are the electronic transfer of files between machines and the ability to interactively work on any machine from any terminal in the network provided that the appropriate accounts and passwords are known.

This network may temp one to try to use the DAC resources as part of one's experiment. I remind you that we have not promised that the DAC will be available on a continuous basis and that anyone foolish enough to design an experiment to require on-line access to the DAC may be quite disappointed.

LORD and SERF have been replaced with a single PDP 11/44 which will be used to maintain PDP codes for the near term. This 11/44 will be available for use by LAMPF users as required. We anticipate terminating support of the RSX version of Q code in two years (Jan. 1, 1989). Q is the LAMPF supported data acquisition code in general use here. Note that we are supporting both PDP and VAX data acquisition this year but requests for the PDP systems has been very light. We expect to eliminate most of our PDP systems in the coming year.

VAX-based Q is considered stable and in a maintenance mode. Bugs will be repaired as found. For RSX Q, only serious problems with broad implications will be addressed. Our current efforts are directed toward exploring the data acquisition needs of larger experiments such as MEGA where FASTBUS and multiprocessor systems become useful. Our intent is to develop those areas that appear to offer advantages to other experiments.

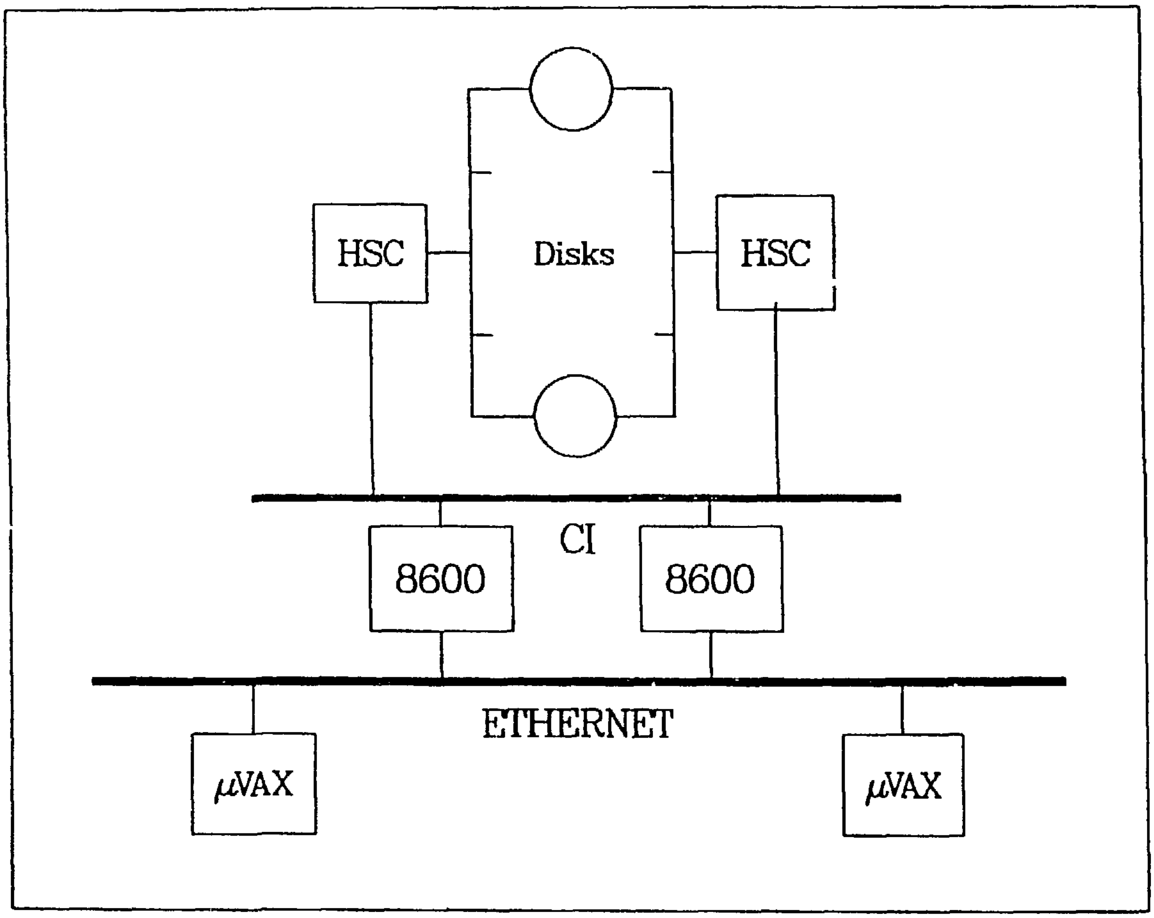
Plans for this year include the extension of the LAN to the LOB for the immediate expansion of our terminal network capabilities. Note however that a LAN in the LOB offers other advantages. Computers (even PCs) may be connected to share the common paths and we expect to provide tape spooling to the DAC from a tape drive in the LOB. We intend to acquire a MicroVAX for the test channel to provide support there as well as to provide a computer for development work prior to the time that a channel data acquisition becomes available for an experiment. Disks, tapes, terminals, and hardcopy devices are under continual review in search for appropriate support for experiments.

The computer maintenance section is finding that the current times are both a blessing and a curse. On the one hand we have eliminated much of our older equipment that was expensive (both in time and money) to maintain. On the other hand, our maintenance people find that it is a continual challenge to learn the details of each new system that we add. VAX computers, Q-bus, 6250-bpi tapes, laser printers, Selanar terminals, and Ethernet bridges, repeaters, DEQUNAs and transceivers are all new equipment in the past couple of years.

Data Analysis Center

Our analysis facilities have grown to:

two VAX 8600 cpus
11.6 GB disk storage
5 6250/1600 tape drives
8 1600/800 tape drives
128 terminal ports
13 laser printers
6- and 8-pen plotters
XNET connection to CCF
ARPANET connection and consequently BITNET
24 dial-in lines (8 at 1200/2400 baud)
4 dial-out lines



The current data analysis facilities hardware configuration.

Planned upgrades this year include:

one 8650 upgrade (20% increase in capacity)
2.4 GB of disk storage (20%)
Extend LAN to LOB
Direct BITNET connection

We have discovered that a proper match of cpu capacity to disk space is crucial to a smooth operation when one is near total saturation. The current system is reasonably well balanced but we expect fluctuations in user demand to cause periodic discomfort. I appeal to each of you to work with us in a spirit of camradarie to get our work done in as pleasant an atmosphere as is possible. MP-1 is here to help you and we tend to do a better job of it when we enjoy the results!

Another future feature is the plan to use the data acquisition computers as a computational "farm" after the accelerator enters the next shutdown. Some batch jobs submitted to the DAC computers will be "farmed" to the data acquisition computers by way of the LAN. Since we have nearly as much computing power in the counting houses as we have in the DAC, we should have a very large thru put for batch jobs during this next shut down.

To assist users in the preparation of high quality documentation, we are in the early stages of providing a TeX typesetting environment throughout the LAMPF site. LN03 laser printers have already replaced the Qumes and are heavily used as line printers. TeX is now available with output to the LN03 printers and macros that generate the Laboratory's memo-heading and letter-heading are available. We will continue to provide TEDI but as new printers move into our environment, they are unlikely to be available to TEDI.

In addition, support for printing LANL standard graphics META-files on the LN03 printers exists. As yet we have no support for electronically integrating text and graphics but C-Division is working on such a capability for TeX.

We support the following selected set of software packages on the DAC computers. This set is necessarily restricted by the limited personnel available for support. Many other packages exist in unsupported form.

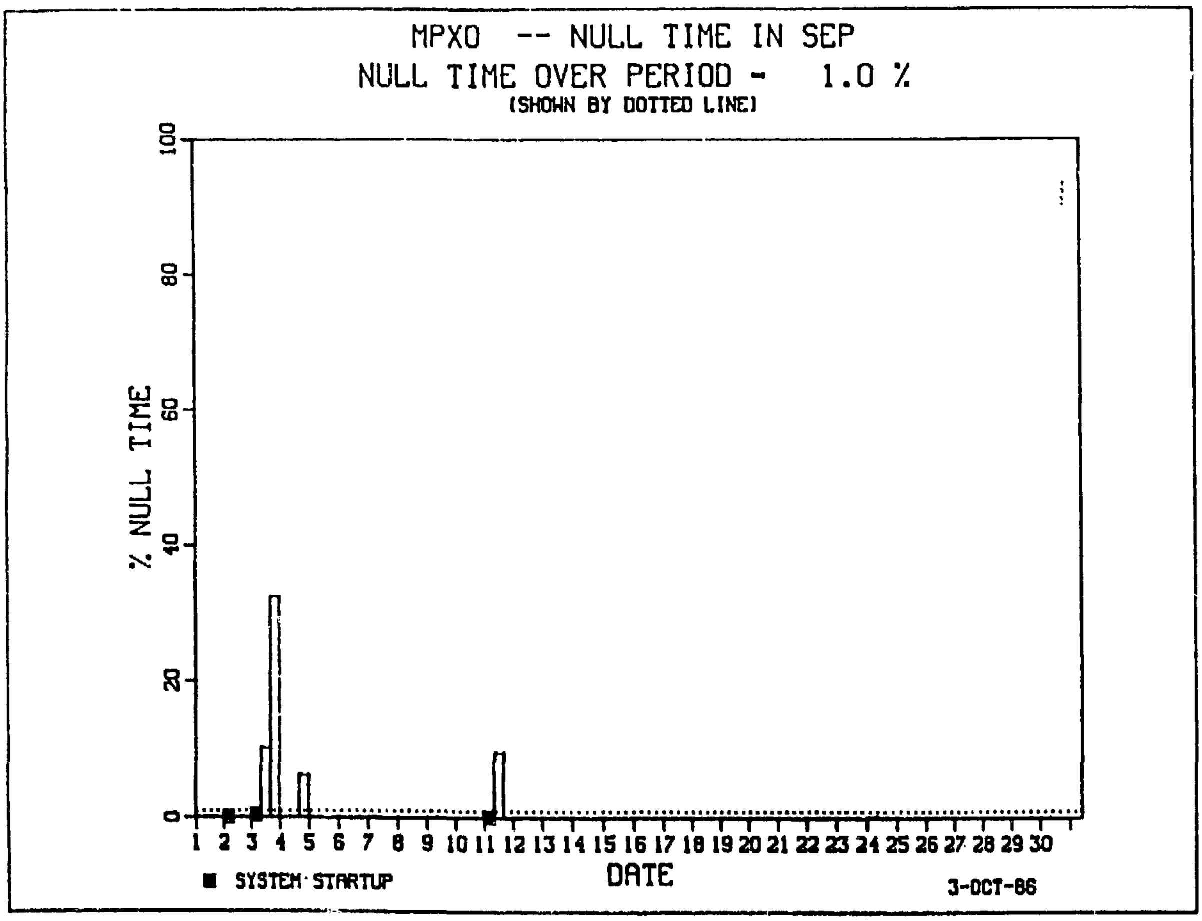
Disspla (graphics)
Mapper (graphics)
GKS (graphics)
DECalc (spreadsheet)
Ingres (database)
Datatrieve (database)

Macsyma (symbolic math)
CALOUT (communications)
BASIC (interpretive language)
PASCAL
FORTRAN
RSX (compatibility mode)
Eunice (UNIX emulator)
CMS/MMS (code management)

We have no support for project management software or expert system software. Needs in this area or required improvements in other areas should be communicated to the working group chairperson.

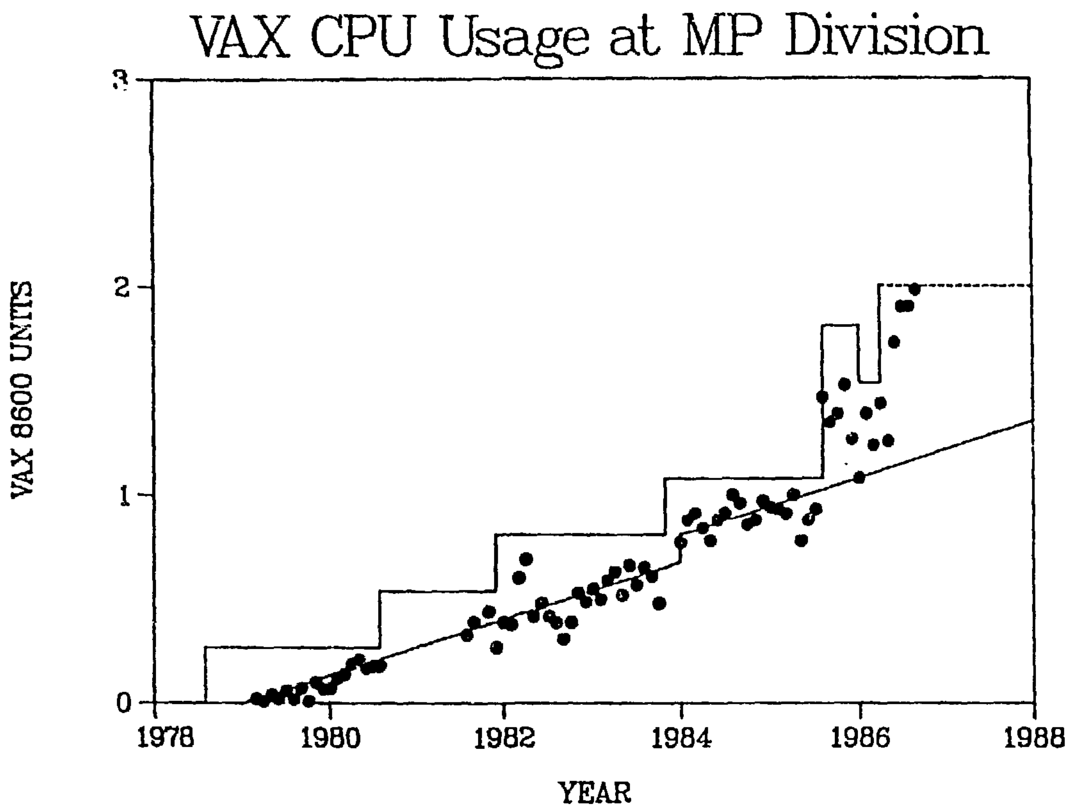
Performance

July, August, and September set utilization records on the DAC computers.



A histogram of unused cpu time on MPX0 during September. Each bin corresponds to 8 hours of 8600 time.

The 99% utilization in September demonstrates an all-time peak in thru-put and the relatively good response seen by interactive users coupled with the relatively abundant disk space (after the great space wars of this summer) have made the past couple of months a paradise for users (or at least for MP-1).



The historical record of VAX usage in MP Division. The right hand point was 99% use of 2 VAX 8600 computers in September of this year. The upper "stair step" line is the available capacity.

VAX CPU USAGE FOR SEPTEMBER 1986

The following summarizes CPU usage for the MP VAXes for September. The CPU hours are in VAX 8600 units.

A breakdown of time used in the batch queues is also included in this report. About 75% of the total time was used from batch.

GROUP	CPU HOURS	% CPU USED	TAPE MOUNTS	COMMENTS
MP-DOU	820.	61.	372	
MP-10	235.	18.	602	
MP-4	82.	6.	243	
SYSTEM	55.	4.	207	
T-5	53.	4.	1	
MP-3	26.	2.	45	
P-00	14.	1.	14	
MP-DO	13.	1.	1	
MP-13	12.	1.	1	
MP-1	11.	1.	3	
MP-7	4.	0.	4	
MP-14	4.	0.	1	

As we see here, experimental physics continues to occupy the bulk of cpu cycles with the outside users (MP-DOU), MP-10 and MP-4 using 85% of the 8600s in September.

Staffing

The level of support for computing continues be stable. In the Q section supporting data acquisition we have:

Will Foreman
Tom Kozlowski
Mike Oothoudt
Jim Amann (MP-10)

Tony Gonzales and Elvira Martinez also assist the data acquisition effort through their support of the VMS systems on the data acqisition computers. Our goals are maintenance of Q, support of experiments, and investigation of new areas in data acquisition.

and in the DAC:

Gail Anderson
Tony Gonzales
Sharon Lisowski
Elvira Martinez
Connie Tregellas
Russell Ragan (joined us this morning!)

The current staffing level in the DAC is adequate to operate the facility and to provide some user support in areas such as consulting, file backup, resource distribution, and some system development.

As most of you know, Martha Hoehn transferred to MP-7 a few months ago. Martha spent the past three years contributing to the development of the DAC and for the past two she was responsible for its operation, expansion and planning for the future. The excellence of our current operation owes much to her dedication and concern. I thank Martha for her contributions of the past few years.

The computer maintenance section consists of:

Kelly Blount
Boyd Cummings
Leon Guerin
Jerry Maestas
Jim Santana
Andy Steck

These gentlemen stand ready to help you 24 hours a day. Our present schedule is to have everyone on site during normal working hours and to have one person on call during the rest of the week. We can generally respond within an hour during off-hours but your patience is requested for those late-night emergencies.

We have been able to reduce staffing in this area during the past two years due to the increased reliability of the equipment and the increased skill of the maintenance personnel. In addition, increased in-house repair of faulty components has helped reduce the cost of this effort.

In two weeks MP-1 will move from this building to the new addition to the DAC. The data acqusition section will be available at their old phone numbers and we will continue to maintain a consultant in the DAC for the benefit of the users working there. As an aside, the electronics drafting effort will move to trailers located on the west of the DAC and the cabie shop operation will move into the new building also.

User Needs

Significant procurements and implementations (>$50k) require preparation and planning before users see the benefit. While we spend much of our effort attempting to anticipate the needs of the community, your assistance by informing us of your needs, well in advance ($\geq$ 1 year), tremendously improves our ability to help you. Asking for immediate changes in standard procedures at 5:05 p.m. is very difficult for us to respond to in a way satisfactory to either you or to us.

While our goal is to bring you as much computing resource as possible within our allotted funds, it is also your responsibility to use that resource wisely. This means educating yourselves to use it effectively and not depending on LAMPF to educate each of you. In addition you have a responsibility to try to avoid wasting resources such as disk space and cpu time. Since we do not directly charge for these facilities, it is particularly important that we be aware of waste. I believe that working together we can accomplish the physics goals of your research while enjoying the experience at the same time.

Muonium and MEGA

D. Hywel White

Los Alamos National Laboratory

I have restricted myself to muonium and MEGA partly in self defense and partly because the other physics, μSR and muon catalysis, is usually discussed in other subcommittees of the Program Advisory Committee. Here we shall give an overview of the physics that is done at LAMPF using muonium as a vehicle to probe particle properties, and a similarly general treatment of MEGA and its motivation. This article is not intended to be other than an introduction to these topics, and for definitive treatments we refer the reader to Refs. 1 and 2.

In the simplest terms we can describe the leptons by the table below.

ν_e	ν_μ	ν_τ
e	μ	τ

There are three families, each with a charged and neutral member. The interactions of these families are identical as far as we know, in spite of the fact that the widely differing masses of the charged members seems to imply a different interaction somewhere that gives rise to these differences. The neutrino masses are certainly small by usual experimental standards, although the assumption that the neutrino mass is zero has no experimental or theoretical foundation. There is no incontrovertible evidence that the neutrino mass is non zero either from direct measurement, observation of neutrino oscillations, or double beta decay. The interaction of these particles with each other or with hadrons is described by the standard minimal electroweak model even though this model contains enough unexplained parameters that it is clear that this description must be incomplete.

The conventional wisdom in minimal models is that there are no direct transitions (horizontal) between families either in the quark sector or among the leptons. In the quark sector corresponding elements in the families mix, especially the d and s quarks, so that decays that involve apparent conversions between corresponding members of families are described by mixing rather than direct transitions. Since there is such similarity between the quark and lepton families it is tempting to make a correspondence between the two and search for mixing between the leptons. A straightforward way of demonstrating either horizontal transitions or mixing is by the observation of the reaction

$$\mu \rightarrow e + \gamma$$

and of course we shall return to this later when we discuss MEGA.

For neutrino oscillations to occur the neutrinos from different families must mix, so searches for neutrino oscillations are motivated in part by the possibility that this mixing occurs. An alternate approach to the lepton problem is the study of the static properties of the charged leptons, and muonium is a fine way to probe the muon. Muonium is a bound state μ^+e^- (μ^-e^+) with a lifetime limited by the lifetime of the muon. This atom should be completely described by Q.E.D. after inclusion of known radiative corrections.

A relatively intense low-energy muon beam is produced from pions, which stop and decay in a target. The pions that decay near the surface produce muons that can escape the target even though the kinetic energy of the muon from two-body decay is only 4 MeV. This muon beam is transported in the channel and electrostatic separation can be provided to make the contamination from pions and particularly electrons manageable. In order to produce muonium further degradation of the energy is accomplished with an absorber in the beam. Muonium production is enhanced when the velocity of the muon corresponds to the velocity of electrons in the muonium production target, an energy of about 4 keV for the muons. The muon picks up an electron fairly readily, so that at this energy the ratio of μ^+e^-/μ^+ is approximately one. Muonium is detected in this beam by passing it through a sweeping B field and subsequently detecting positive muon decay through the Michel electrons after stopping the muonium in a foil. A thin Al foil has been used here for the electron pickup target, but recently there have been developments at TRIUMF and elsewhere that have used composite materials to enhance production of thermal muonium. The interest in thermal muonium is in the potential for observing muonium for long periods in vacuum. Some of the muonium that is produced in the electron pickup process is in the 2S state. This state is metastable, and so this part of the beam may be used for Lamb-shift measurements as we shall discuss below. In fact, about 10% of the atoms are in this state giving a typical production efficiency for 2S atoms of about 4×10^{-3}

In Fig. 1 is shown a schematic of an experiment at LAMPF in which a measurement of the hyperfine structure interval $\Delta\nu$ in muonium was made.The energy of the triplet and singlet states as a function of B field is shown in the Breit-Rabi diagram of Fig. 2. The hyperfine energy of the system of muon and electron has three terms. At zero B field this energy comes from the interaction of the spin of the muon with that of the electron. As the B field increases there are contributions to the energy splitting of the system that come from the interaction of the electron moment with the B field and a similar term for the muon moment. Of course the major effect of the B field is due to the electron moment, with a much smaller effect from the muon moment; the spin-spin interaction is independent of B field. The very uniform B field in this experiment is generated by a solenoid with the axis parallel to the direction of the muon beam. The two branches in the Breit-Rabi diagram are primarily selected by the orientation of the electron spin; because the incident muon is longitudinally polarized from pion decay, the spin-spin splitting is effectively modified by the muon spin direction. The frequencies of transition of the Zeeman transitions are slightly different then and are labeled ν_{12} and ν_{34}. Early measurements at LAMPF measured the level splitting at small B field but more recently the energy shifts have been measured at high field by a resonance technique.

The muon beam is counted by integrating the beam in the scintillator S1 in Fig. 1 and comes to rest in the krypton gas in the pressure vessel forming muonium a fraction of the time. The B field is made very uniform to maintain the width of the resonance lines, examples of which are shown in Fig. 3. These widths are about equally due to the muon lifetime and broadening due to r.f. power. The two lines are measured almost simultaneously by switching the r.f. frequency at about 10Hz. The determination of the central position of this Lorentzian is limited by statistics to about 1 in 3000. The two transitions can be used to measure both $\Delta\nu$ and μ_μ/μ_p because

$$\Delta\nu = \nu_{12} + \nu_{34}$$

μ_μ/μ_p is proportional to the difference in the frequencies ν_{12}, ν_{34} with the constant of proportionality involving known constants and the proton NMR frequency measured in the same B field.

The expression for the hyperfine frequency shift is

$$\Delta\nu^{th} = [16/3\, \alpha^2\, c\, R\, (\mu_\mu/\mu_p)]\,[\,[1 + m_e/m_\mu]^{-3}\,[1 + \varepsilon_{QED}]]$$

The ratio of the magnetic moment of the muon to the proton from the same experiment is

$$\mu_\mu/\mu_p = 3.183\ 345\ 47\ (95) \quad .$$

Then

$$\Delta\nu^{th} - \Delta\nu^{exp} = 0.4 \pm 1.8 \text{ kHz} \ .$$

This can be seen to show good agreement with the predictions of Q.E.D. or it can be viewed as a determination of α. It is compared with other ways of determining α, in the summary below.

α^{-1} =	137.035 988 (20)	μ^+e^-
=	137.035 993 (10)	$g_e - 2$
=	137.035 981 (12)	ac Josephson

It is perhaps remarkable that not only is there agreement between these disparate methods but that the precision of determination of α is similar.

The second class of muonium experiments that we wish to discuss is the measurement of the Lamb shift, the energy difference between the $2S_{1/2}$ and $2P_{1/2}$ states. The naive theory has these states degenerate, but the corrections to the energy of these states are substantial; the energy levels are shown in Fig. 4. and the corrections to the splitting are listed below.

	Value MHz	
Spin orbit energy	1085.8	
Vacuum Polarization	-26.9	
Reduced Mass	-14.6	
Relativistic Recoil	3.2	
Total	1047.6	
Experiment	1054 ± 22	LAMPF
	$1077\ ^{+12}\ _{-15}$	TRIUMF

The experimental measurements of the Lamb shift are more precise in the case of hydrogen but the magnitude of some of the corrections is appreciably different, and in some cases more certain. There is not a structure-dependent correction in the case of muonium because the muon is thought to be a point particle in contrast to the proton. The reduced mass correction is greater, although completely calculable, as is the relativistic recoil term.

The experiment has an additional requirement compared to the hyperfine splitting experiment that we have just described. The transition that is to be observed is that from the $2S_{1/2}$ to $2P_{1/2}$ state. In order to observe this transition it is necessary to prepare the beam in the 2S state. As we remarked above, about 10% of the muonium is made in this metastable state but the state is quenched by collisions in gas and it is necessary for the muonium to be in vacuum very soon after the electron pickup. The apparatus in Fig. 5 is designed to determine the production rate in the aluminum foil with muonium existing in vacuum during observation. The method depends on the fact that if the transition from the $2S_{1/2}$ to $2P_{1/2}$ state is induced then the $2P_{1/2}$ state decays immediately to the ground state with the emission of the Lyman-alpha photon at 1241Å. This photon is detected in the phototubes in the apparatus of Fig 5 in coincidence with μ^+ decay after the de-excited muonium stops in the foil at the end. In Fig. 6 is shown the spectrum of the Michel decay electrons from the stopped muon, in coincidence with the Lyman-alpha photon. The spectrum with gas in the apparatus is also shown giving indication that the muonium is quenched when gas is present. The 2S state can also be quenched by a static electric field. In Fig. 7 is shown the signal from 2S quenching as a function of the electric field from the electrodes in the apparatus. Finally, in Fig. 8 is shown the signal from the decay to the ground state after the 2S - 2P transition is induced by an r.f. field determining the Lamb shift of these two states.

Now that the technology of producing thermal muonium is established another experiment becomes possible; a search for the transition $(\mu^+e^-) \rightarrow (\mu^-e^+)$. This transition is heavily forbidden in the standard model; both muon number and electron number have to change by two units. It has been suggested that lepton number may be multiplicative, but the suggestion was rejected in the simplest form after experiments on the character of neutrinos in muon decay and in electron collider experiments on muon production. However, some models remain, which rely on some coherence in the two lepton transitions. The independent search for the simultaneous transition of both leptons remains an interesting experiment in its own right. This experiment must be done on muonium in vacuum, and the experimental signature that has been proposed is to observe the x rays from μ^- capture in a heavy element. This target is mounted inside the Crystal Box shown in Fig. 9. The Crystal Box consists of a large-solid-angle array of NaI counters and it has been verified that the energy threshold can be lowered enough so that the x rays from uranium can be observed. Muonium (μ^+e^-) is made as in these previous experiments; the beam is swept with a B field to remove charged particles and the Crystal Box is operated in coincidence with the incident μ^+ signal with the x rays providing a signal that a μ^- has been captured. It is expected that in a recently completed run, the coupling constant for the transition $(\mu^+e^-) \rightarrow (\mu^-e^+)$ can be limited at about G_F.

Muonium and MEGA

MEGA[3] is an experiment that is proposed to search for the reaction

$$\mu \rightarrow e + \gamma \ .$$

There is no experimental evidence at present that there is any interaction that allows transition between families either for leptons or in the quark sector. It is true that families as defined by strong interactions seem to be different eigenstates compared to those defined by weak interactions and this allows effective transition between families in the quark sector through weak decays. In the lepton sector there has been no observation of transitions between lepton families either as evidenced by mixing between corresponding eigenstates or by apparently weak but direct transitions. The intermediate vector boson W only causes transitions between members of the same family, and the Z similarly does not induce horizontal transitions in the standard model. A great deal of attention is being paid at present to models in which there is an assortment of particles up to very high masses with the assumption that we only observe that subset with low mass. The symmetry that gives rise to family conservation may then be a consequence of the fact that horizontal transitions are mediated by particles of very high mass and are correspondingly weak and not absolutely forbidden. This point of view represents a prime motivation to search for small violations of family number conservation and $\mu \rightarrow e + \gamma$ is an excellent reaction to do this. In order to be quantitative, we must assume a coupling constant to the horizontal transition inducing particle and then the transition rate is determined by the mass of the mediating particle with little more profound than the uncertainty principle indicating a mass dependence of $\sim m^{-4}$. In fact the muon lifetime (or $G^2{}_F$) is characteristic of the electromagnetic coupling α modified by the mass of the W to the fourth power. A diagram illustrating the kind of transition that would allow $\mu \rightarrow e$ transitions is shown in Fig. 10. A heavy neutrino couples to the muon neutrino and also subsequently to the electron neutrino violating lepton family number conservation. Each of these transitions would be proportional to $(m_{\nu x} - m_{\nu\mu})^2$. If the mixing between the muon and electron neutrinos and ν_x is unity and the mass of ν_x is 70 Mev then the expected branching ratio for $\mu \rightarrow e + \gamma$ is 10^{-16}.

The principle of the experiment is straight forward and based on the two-body kinematics of the reaction. The μ^+ are stopped in a very thin target and the decay particles are detected in two separate components of the apparatus shown in Fig. 11. This is made possible by the large volume of B field in which the electron is restricted by the B field and the photon is detected outside the electron chamber in a series of concentric pair spectrometers of 0.1 radiation length thickness. Crucial to background rejection is the energy resolution of the detector; the back-to-back character of the signal events and their relative timing all contribute to the ability to reject unwanted events. A principal background comes from the reaction

$$\mu^+ \rightarrow e^+ + \gamma + \nu_e + \bar{\nu}_\mu \ .$$

The energy spectrum of this background photon is shown in Fig. 12 and the rejection of the low-energy photons is a problem in the trigger for the experiment as well as in the final analysis. A hard-wired trigger processor is envisaged to accomplish substantial separation of these events in real time before recording takes place. Unfortunately, all muon decays eventually produce a positron, which in turn produces a sea of one-half-MeV photons, which form an accidental background to be removed by multiple coincidences in the layers of the photon arm. The attainable lower limit for the rate for the two-body reaction depends critically on the irreducible background level. In Fig. 13 is shown the limit in the experiment as a function of the muon run time at a rate of 3×10^7 μ^+/s, assuming that the background is maneageable.

If there are no phenomena discovered in the near future to add to our understanding of the standard model then decay experiments like MEGA will be a way in which we can understand a minimal level of applicability of the model. Of course observation of the reaction $\mu \rightarrow e + \gamma$ will be a triumph, and will be a substantial constraint on the way in which our understanding is extended.

REFERENCES

1. H. Orth and V. W. Hughes, "Muonium," Proceedings of the Workshop on Fundamental Muon Physics: Atoms, Nuclei and Particles, Los Alamos National Laboratory report, LA-10714-C (January 1986) p. 62.

2. V. W. Hughes and T. Kinoshita, Muon Physics I, V. W. Hughes and C. S. Wu, Eds., Academic Press, NY, (1977), p. 11.

3. MEGA Proposal, LAMPF Experiment # 969, spokesman, M. D. Cooper.

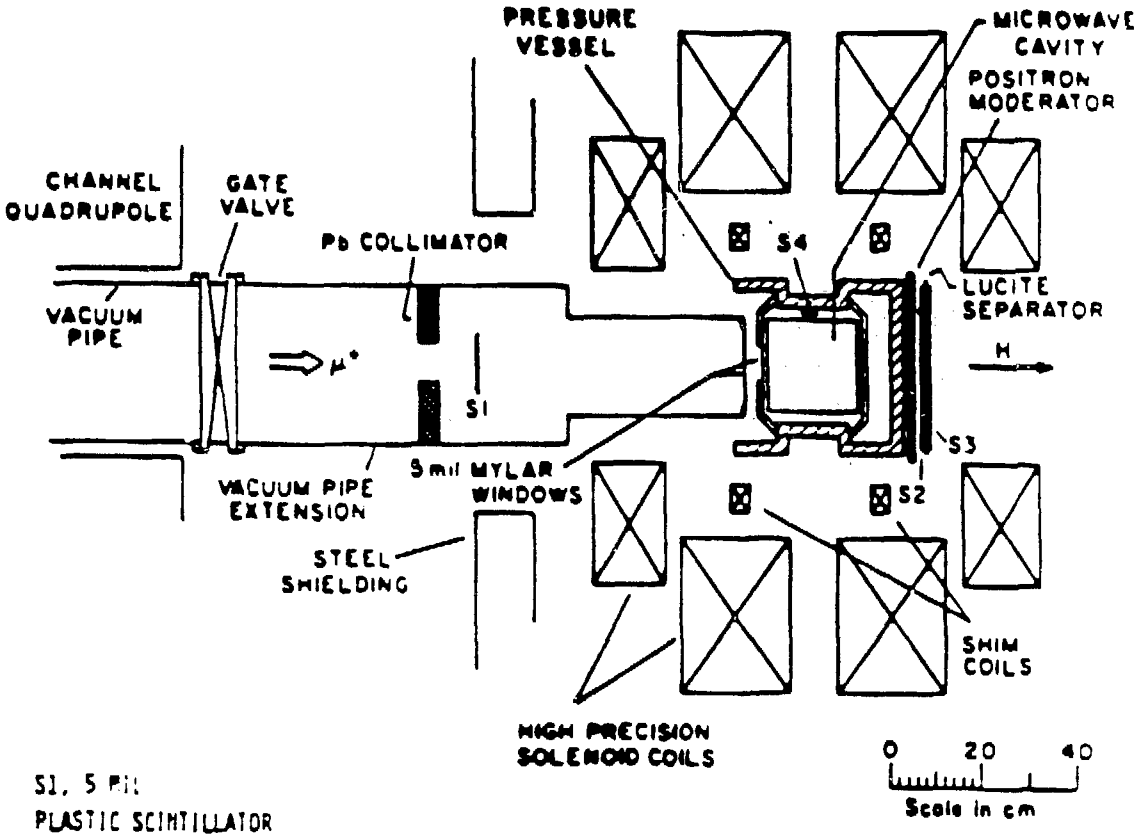


Figure 1. Experiment at LAMPF in which the latest precision measurement of the hyperfine structure interval $\Delta\nu$ in muonium was made.

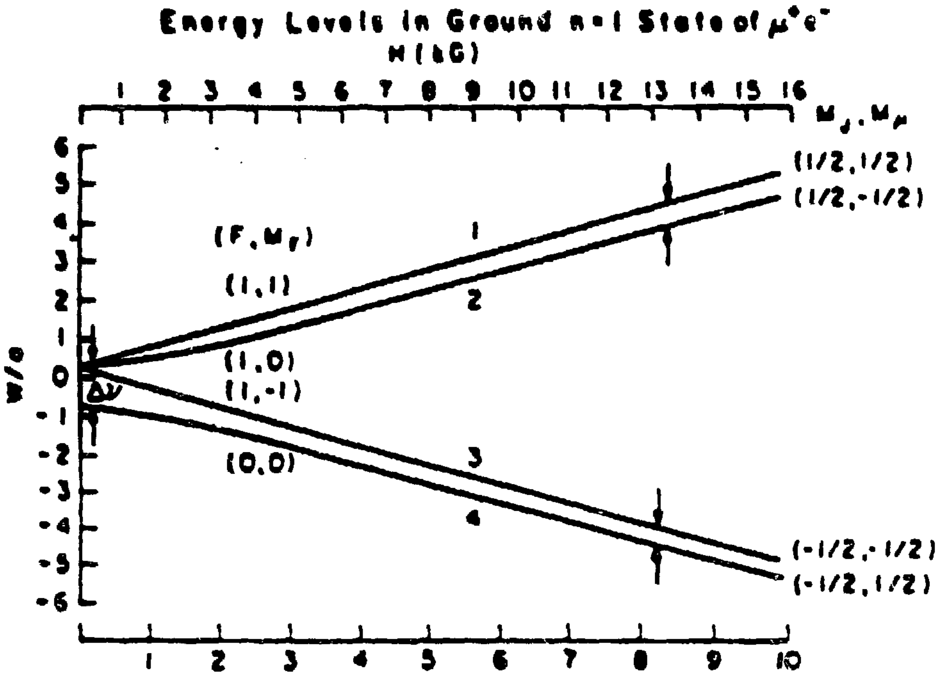


Figure 2. Breit-Rabi energy level diagram for the ground state of muonium.

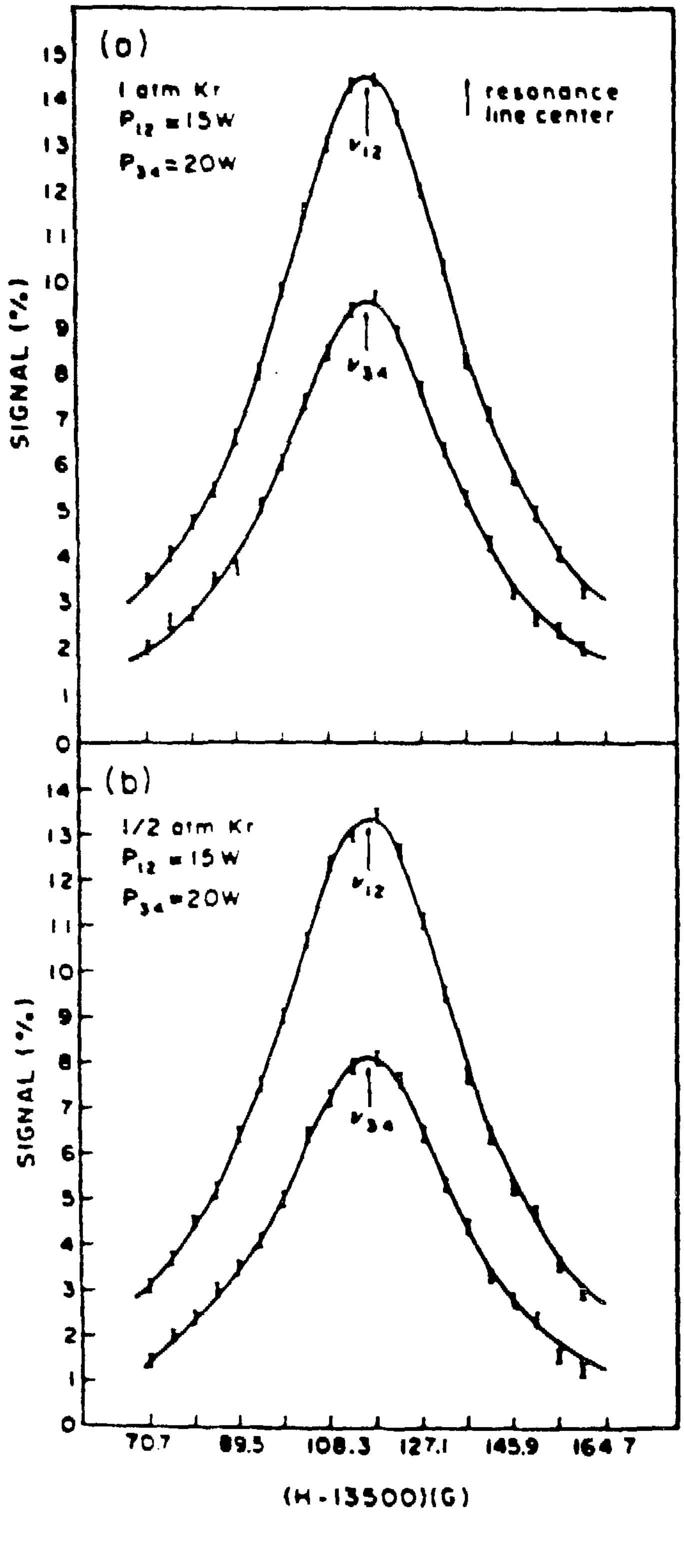


Figure 3. Fitted resonance lines from the experiment shown in Fig. 1.

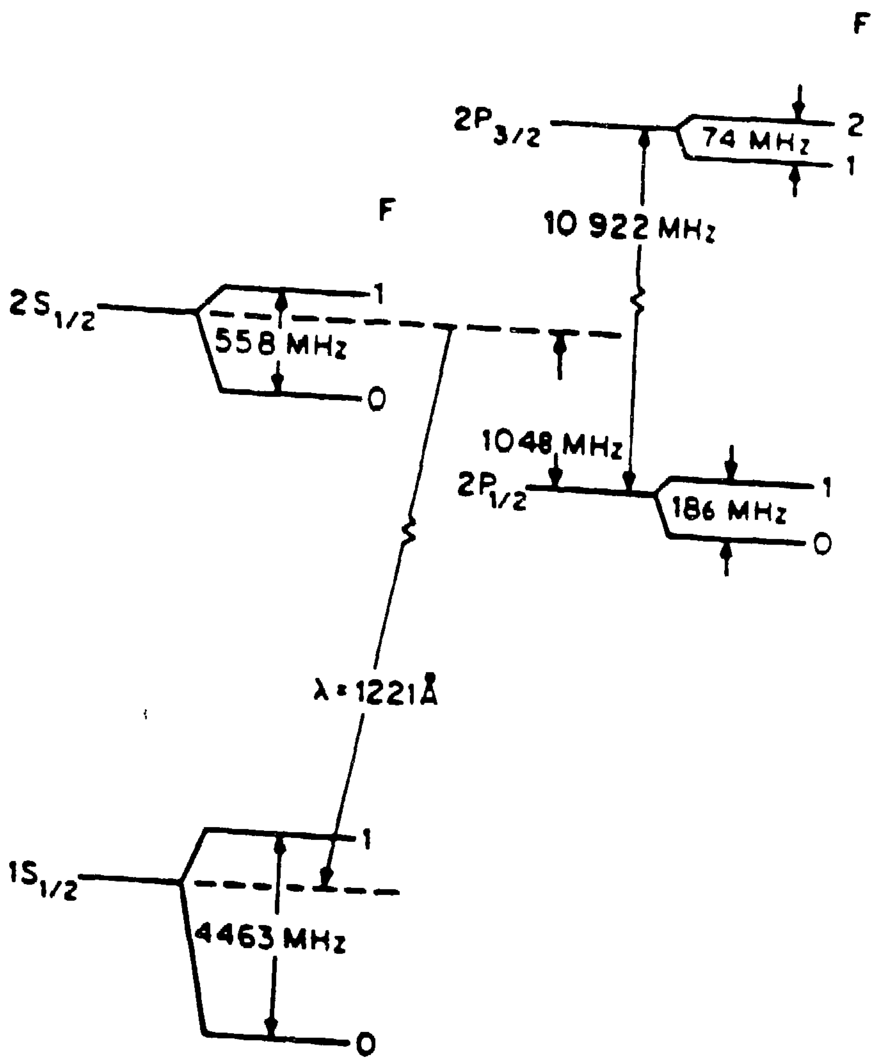


Figure 4. Energy level diagram of the n=1 and n=2 states of muonium.

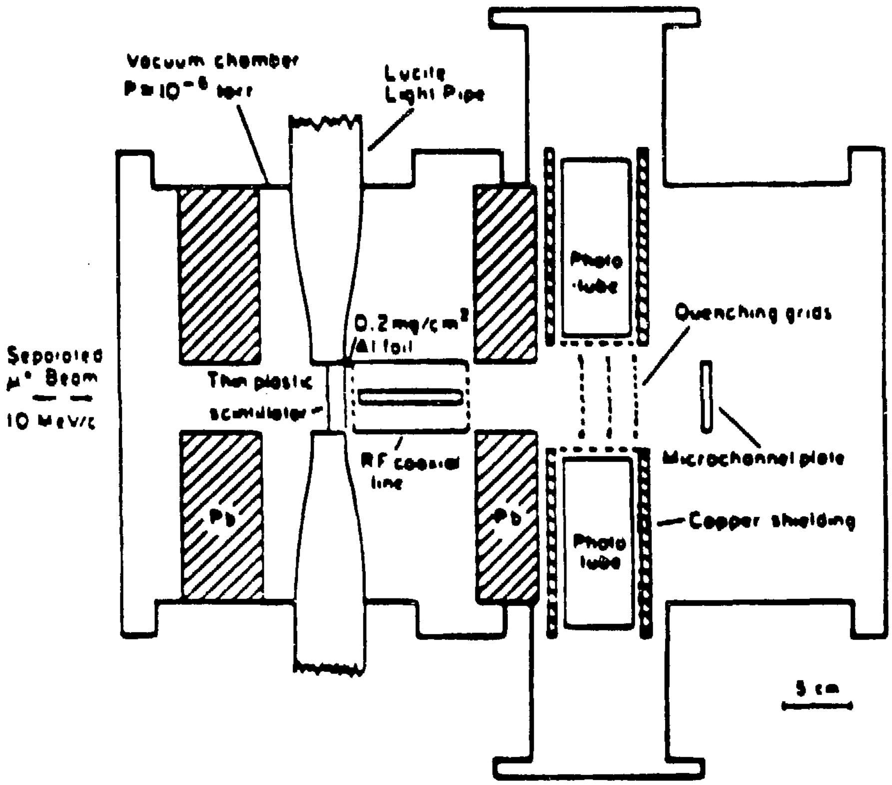


Figure 5. Experimental apparatus used in muonium Lamb shift measurement.

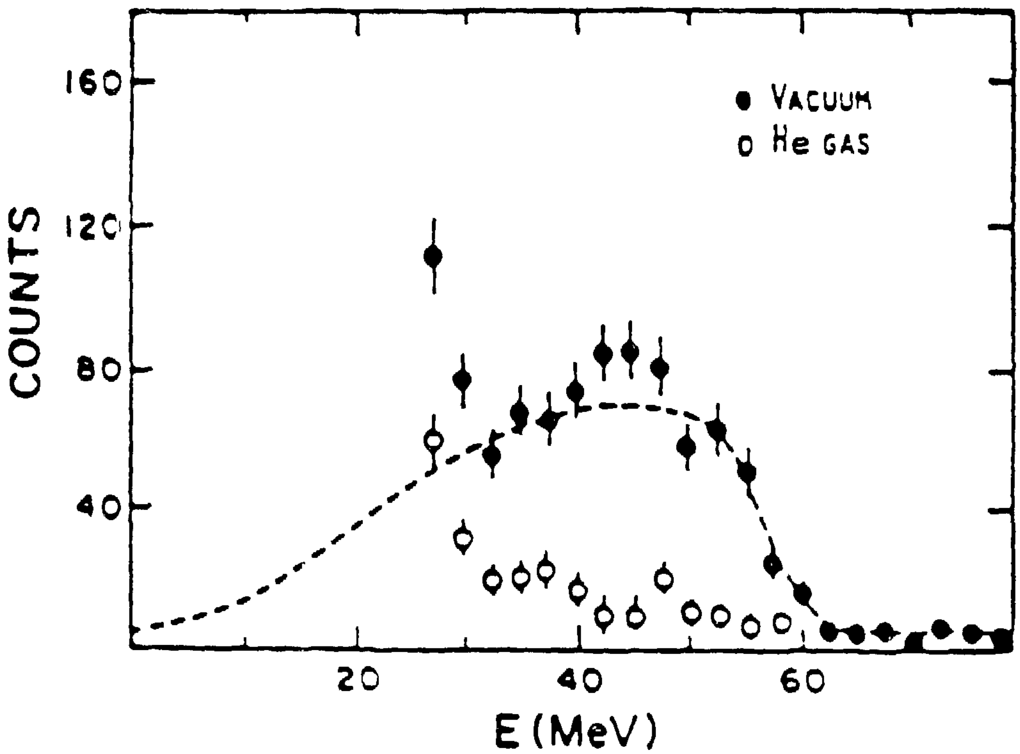


Figure 6. Measured NaI spectrum indicating muonium formation.

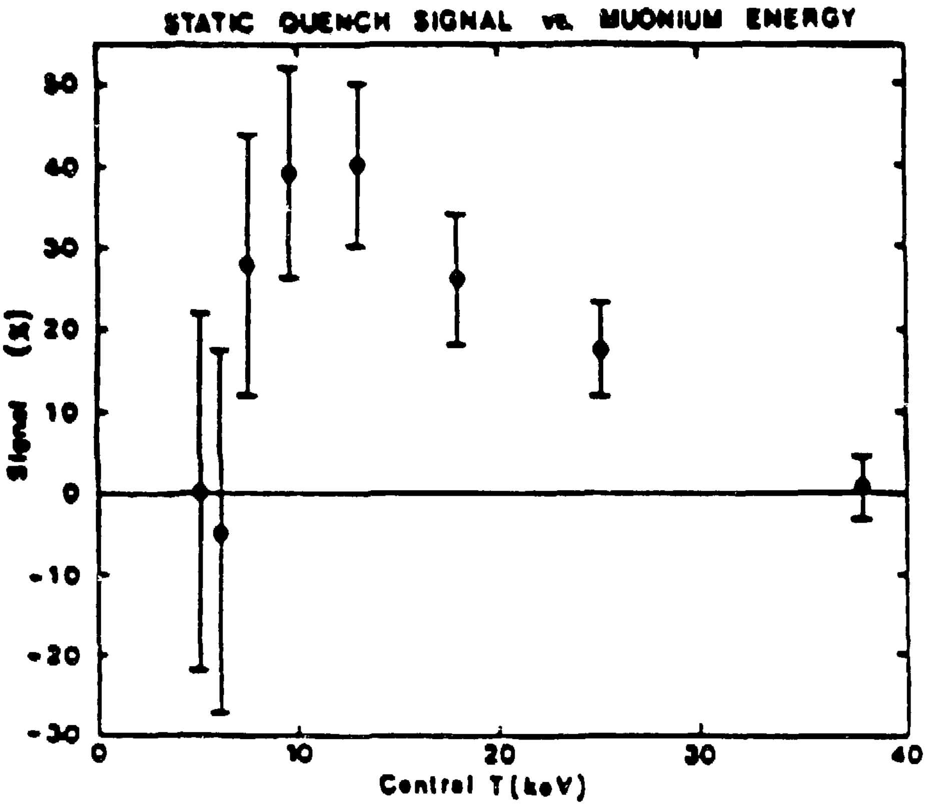


Figure 7. Observation of the static electric field quenching of muonium in the 2S state in the experiment indicated in Fig. 5.

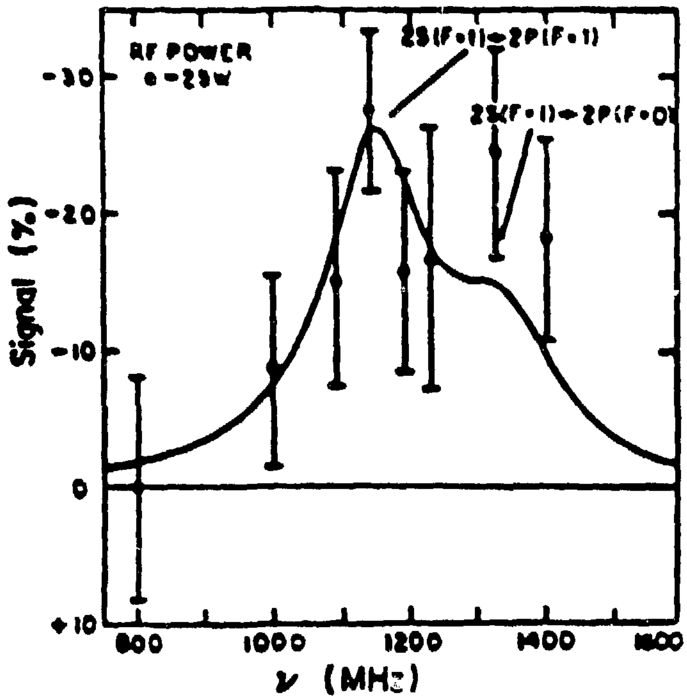


Figure 8. Observation of the rf-induced 2S→2P transitions, which determine the muonium Lamb shift in the experiment indicated in Fig. 5.

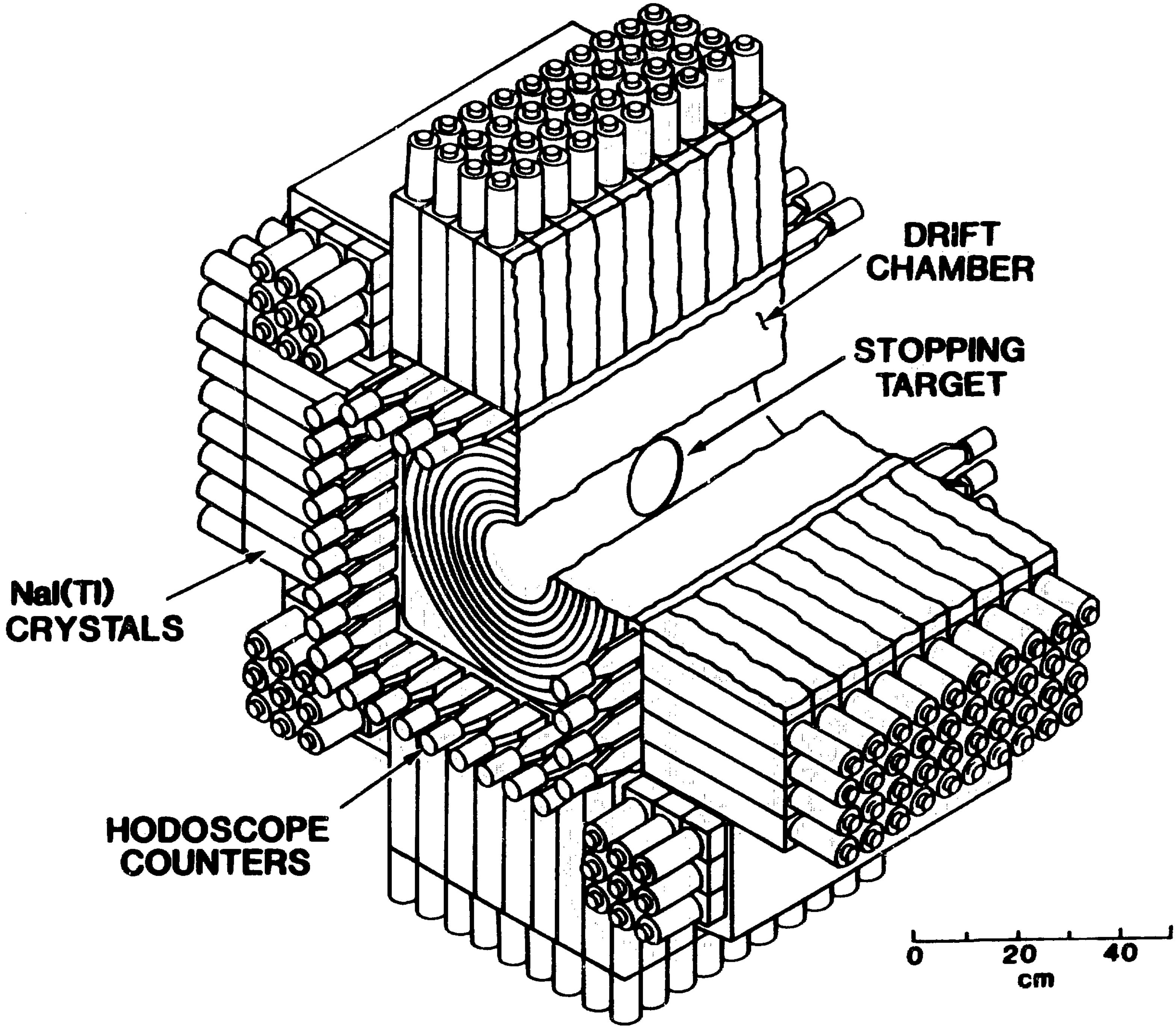
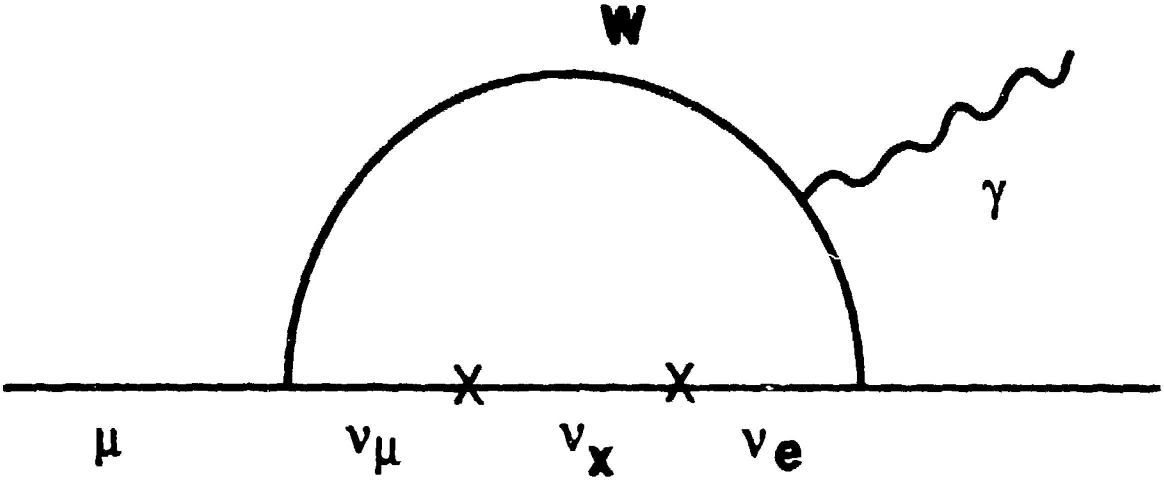


Figure 9. Cutaway diagram of the Crystal Box detector.



$$B \sim \frac{U^*U\,(m_{\nu_x} - m_{\nu_\mu})^2\,(m_{\nu_x} - m_{\nu_e})^2}{M_W^4}$$

Figure 10. A diagram that might contribute to the transition from $\mu \to e$. The particle ν_x couples both to electron antineutrinos and muon neutrinos; if the coupling is at the weak level then the transition is inhibited by the mass of ν_x as shown above.

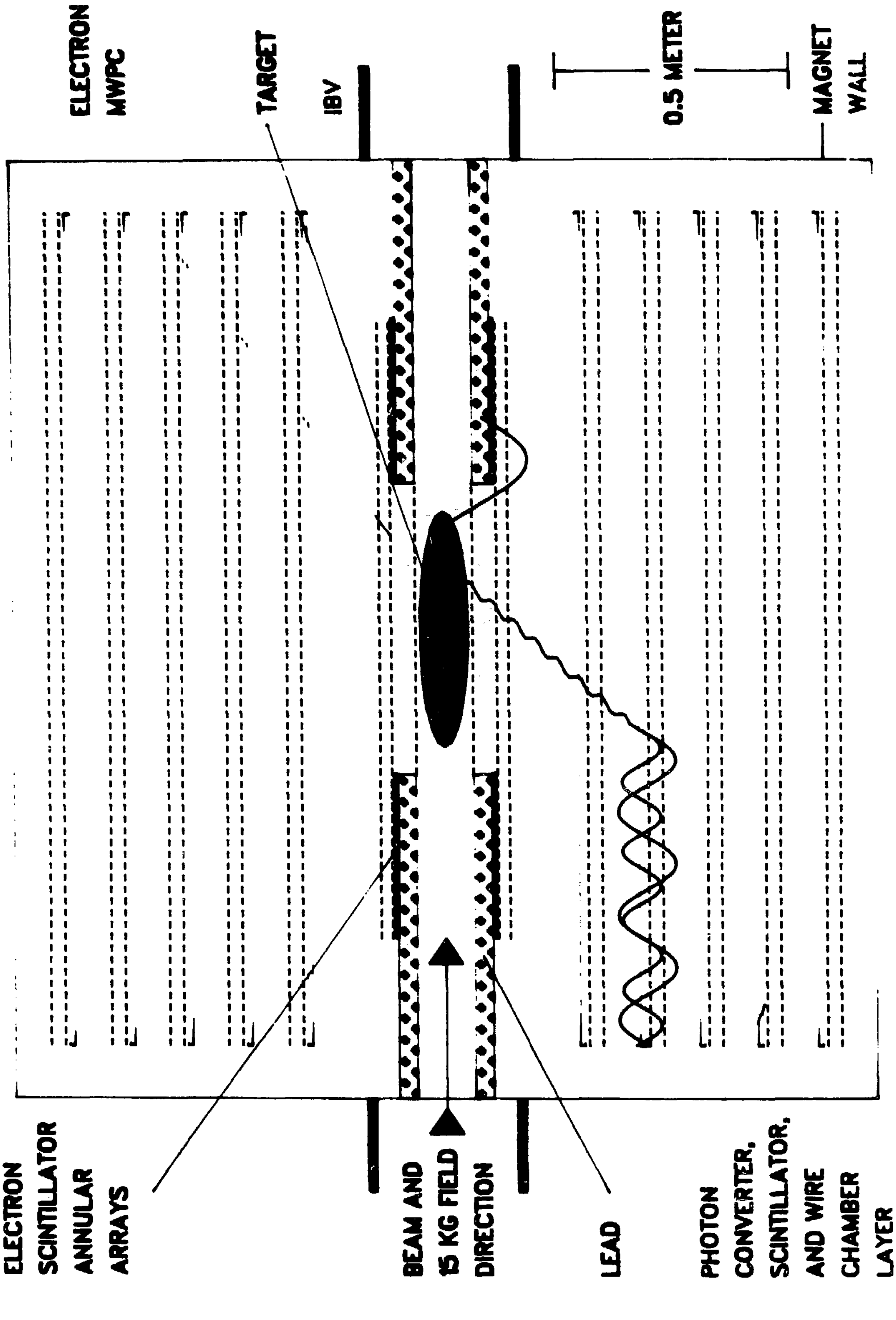


Figure 11. A section through the experiment MEGA. Muons are stopped in the target and electrons from the decay are detected in the electron MWPC. Photons from the decay $\mu \to e + \gamma$ are detected in the photon converter and the momenta of both the photon and electron are measured.

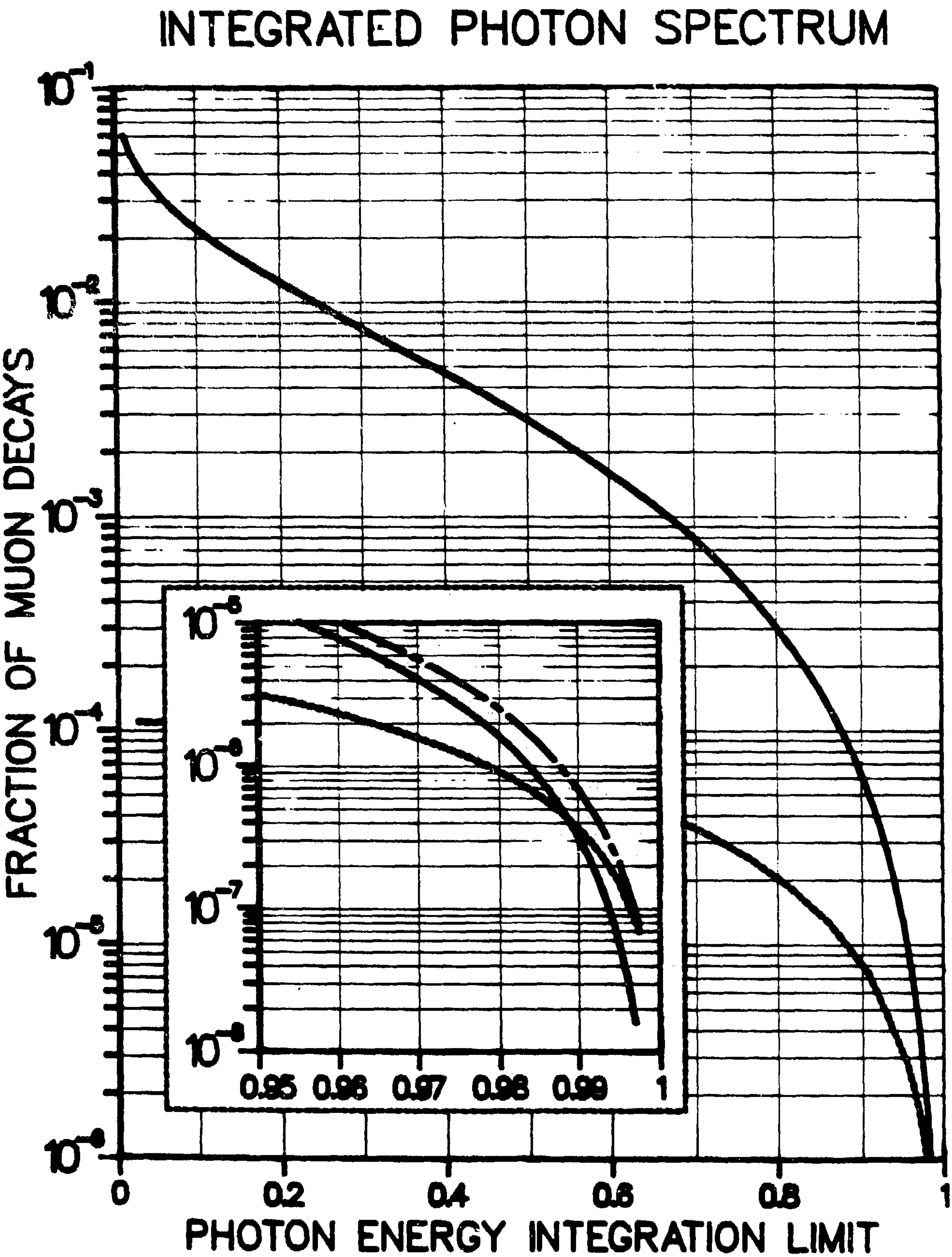


Figure 12. The principal background to $\mu \to e + \gamma$ is expected to be from the normal decay with a hard radiated photon. The spectrum of these photons is shown.

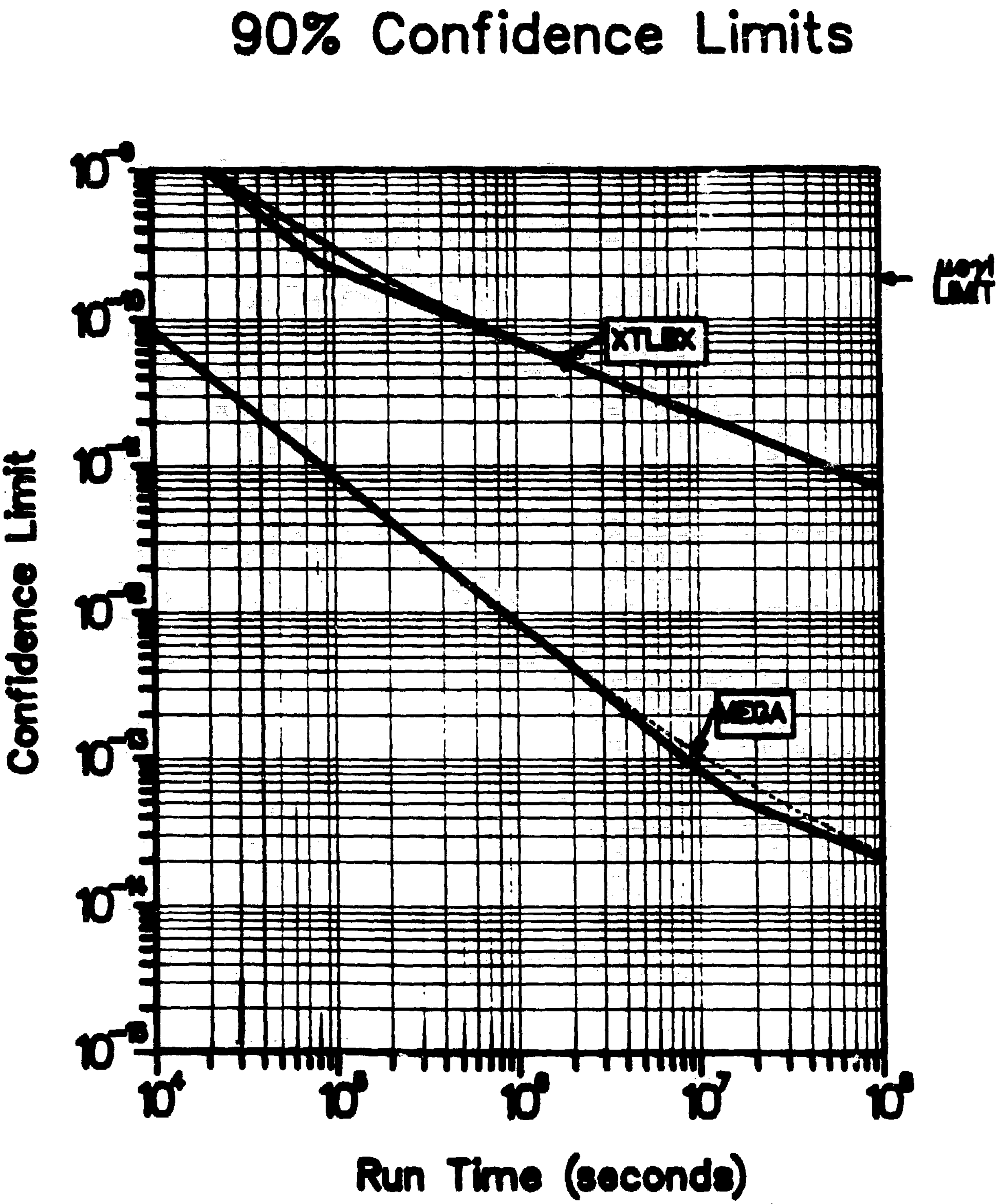


Figure 13. The limit to the branching ratio for $\mu \to e + \gamma$ as a function of the running time, given the expected value of the background.

Nuclear Chemistry at LAMPF

Norbert T. Porile

Department of Chemistry, Purdue University, W. Lafayette, IN

The nuclear chemistry activities at LAMPF currently involve 12 experiments that can be grouped into three categories: (1) atomic mass measurements with the TOFI spectrometer, (2) pion-nucleus interactions, and (3) cosmochemistry. The experiments are summarized in Table 1.

A. Atomic Mass Measurements with the TOFI Spectrometer

The overall goal of the TOFI project is to perform, in a systematic fashion direct mass measurements of light nuclei far from stability and thus identify general, as well as isolated, trends in nuclear structure. In Experiment 870, the masses of the neutron-rich isotopes with Z=4 to 9 are being measured in a systematic fashion using the TOFI (Time-of-Flight Isochronous) Spectrometer. Obtaining the masses of these nuclei will aid in the general understanding of this region of deformed neutron-rich nuclei as represented by the heavy sodium isotopes beginning with ^{31}Na. Of special interest to nuclear structure studies are the predictions by various theoretical models that several new ''deformed'' neutron magic numbers at N=10, 14 and/or 16 should exist since the large N to Z asymmetry of these nuclei make them susceptible to deformation. Discovery of new neutron magic numbers would permit the study of the phenomenon of mutual support of magicities far from the valley of β-stability in the light Z region. Mutual support of magicities is the term used to identify the strong correlation between proton and neutron binding energies that is especially noticeable in nuclei near double shell closures. Finally, this experiment will more clearly define the location of the neutron drip line as well as test the many models that predict the masses for this region.

The first results of this experiment have yielded the masses of 21 nuclides, 8 of which (^{19}C, $^{27-28}Ne$, $^{32-34}Al$, ^{36}Si and ^{37}P) were measured for the first time.[1] Comparing the 13 masses which have been remeasured with their previous measurements, good agreements is found in all cases except ^{30}Na and ^{31}Mg. Figure 1 shows the two-neutron separation energies derived from the data. In general, the masses are reproduced by sd shell model calculations, with the exception of ^{31}Na and ^{32}Mg which indicate that neutron excitations into the $f_{7/2}$ shell occur. Improvements in detector and electronic technologies will permit higher precision mass measurements out to more neutron-rich nuclei.

In Experiment 872, mass measurements will be extended to the Z = 13-17 region. It is planned to measure the masses of the following previously unmeasured nuclides: $^{32-37}Al$, $^{35-39}Si$, $^{37-41}P$, $^{39,41-43}S$, and $^{42,44,45}Cl$. In addition, the masses of nine other isotopes in this region will be determined with improved precision and accuracy. Three new isotopes are expected to be discovered, ^{38}Al, ^{40}Si, and ^{46}Cl but with too few data to permit a determination of mass. These measurements will provide data for evaluation of effects on the mass surface caused by microscopic structures such as shell closures at N=20 and N=28 and subshell gaps at N=14 and Z=14.

Experiment 1024 is an adaptation of the TOFI spectrometer to the measurement of lifetimes of neutron-rich fragments. Beta-delayed neutrons will be used as a very selective decay signature for these nuclides. The measurements consist of recording the arrival time of each ion identified by the TOFI spectrometer and the arrival time of each neutron in a high efficiency neutron counter surrounding the ion deposition point. In effect, delayed coincidences between ions and neutrons will be recorded. Below fluorine, lifetimes out to the limit of neutron stable nuclides should be measurable. It is hoped to determine lifetimes of more than 40 neutron-rich light nuclides in this experiment.

Without additional data collection time, the experiment also provides data on delayed neutron emission probabilities (P_n) and will identify those nuclides which undergo beta-delayed multi-neutron emission. These decay data will be acquired simultaneously with the mass information for which TOFI was designed. Both facets of the experiment will provide fundamental information about nuclides with unusual numbers of protons and neutrons. The lifetimes and P_n values of very neutron-rich nuclides are needed for more thorough tests of models used to predict these quantities. Ultimate applications for the models (and for some of the later measurements) include astrophysical calculations - particularly for r-process nucleosynthesis.

B. Pion-Nucleus Interactions

The pion-nucleus program encompasses a number of different studies. Experiment 975 is a study of pion single charge exchange (SCX) with stopped negative pions. Negative pions will be stopped in ^{45}Sc, ^{35}Cl, ^{31}P, and ^{27}Al. The emerging π^o's, which will have an energy between 1 and 5 MeV depending on the target nucleus, will be detected with the LAMPF π^o Spectrometer. The results will allow the determination of the strength of the isovector pion-nucleon interaction in nuclei. This information can be used to: 1) determine the origin of the large repulsion of the s-wave isoscalar pion-nucleon interaction in nuclei, and 2) investigate the competition between pion absorption and SCX at energies of pionic atom levels. An improved knowledge of the s-wave pion-nucleus interaction, provided by the proposed studies, will also lead to a constraint on various pion-nucleus charge exchange models proposed for the energy domain 30 to 80 MeV, where the s- and p-wave interference is important.

Experiment 999 involves a measurement of forward-angle nonanalog (0^+(g.s.) $\to 0^+$(g.s.) double charge exchange (DCX) cross sections for ^{128}Te and ^{130}Te in the Δ_{33} resonance region. The DCX cross section of these two reactions will provide information regarding possible differences in the structures of these nuclei. As there is a relation between the neutrinoless $\beta\beta$-decay rate and the forward-angle DCX cross section, the measured cross sections can be used to set a tighter limit on lepton number violation.[2] Furthermore, the extent to which the nuclear structure of these nuclei differs will have important implications on the understanding of the ratio of $\beta\beta$-decay rates of these two nuclei. These measuremments also provide a global test of the A-dependence of the nonanalog DCX cross sections.

(π,2π) reactions between 350 and 500 MeV are ideal for studying N$\Delta \to \Delta\Delta$ transition in nuclei, and, for testing existing meson-exchange and/or quark models for the nucleon-nucleon interaction. A similarity between the calculated excitation functions for inclusive pion production and pion production leading to particle-bound states has been noted (Figure 2). This observation, if confirmed by experiment, opens the possibility for studying the double-Δ nuclear dynamics with efficient nuclear chemistry techniques.

The energy dependence of the total cross section of the (π^+,2π^+) reactions to all particle-bound states in aluminum, vanadium, and copper will be determined in Experiment 1002. These activation measurements will provide a critical test of whether DWIA calculations, when extended to include nuclear medium effects, can properly account for both the energy dependence and the (N,Z) dependence of the A(π^+,2π^+)B* cross sections. So far, there are no systematic data available addressing this question; this study will provide such data. The cross sections for the reactions ^{27}Al(π^+,2π^+)^{65}Ni (9.4 min), ^{51}V(π^+,2π)^{51}Ti (5.8 min), and ^{65}Cu(π^+,2π^+)^{65}Ni (2.5 h) will be determined at 350, 400, and 450 MeV by measuring the yields of the radioactive products.

Experiment 1022 is a search for a new form of matter – the η-mesic nucleus. Recent theoretical calculations by Haider and Liu[3] predict the existence of nuclear bound states of the η meson in nuclei with mass number greater than eleven. An experiment to search for the η-mesic nucleus $^{15}_{\eta}O$ by studying the reaction $\pi^+ + {}^{16}O \rightarrow p + {}^{15}_{\eta}O \rightarrow p + \pi^- + (pX)$ at a pion laboratory momentum of 640 MeV/c is planned. The coincidence between the prompt proton (observed with Bismuth-Germanate detectors) and the π^- (detected with the large-acceptance spectrometer) that comes from the decay of the η-mesic nucleus will be measured. Theoretical estimates indicate that a high-energy π^- is a unique signature for the existence of the η-mesic nucleus.

The discovery of this new nuclear species will create a new avenue to study the not-well-understood η meson and to access the domain of high-energy nuclear spectroscopy.

C. Cosmochemistry

Experiment 1003 proposes to study the production of long-lived radionuclides by stopped negative muons. The goal of the experiment is to determine the production of 0.7-million-year Al-26 from silicon in several silicate targets. The results of this experiment will be used to help interpret measurements of Al-26 and 1.5-million-year Be-10 in terrestrial samples. The Al-26 in natural samples are made by nucleons and muons generated by the cosmic rays in the earth's atmosphere. The production of nuclides by the nucleon component of the cosmic rays is fairly well known and additional measurements are presently being made using spallation neutrons at the LAMPF beam stop under Experiment 691. The production of Al-26 from silicon by muons is not well known. The Stopped Muon Channel at LAMPF will be used to determine the production of Al-26 by stopped negative muons in several matrices, such as pure quartz and natural silicate minerals.

References

1. D. J. Vieira et al., submitted to Phys. Rev. Lett.

2. A. Fazely and L. C. Liu, Phys. Rev. Lett. 57, 968 (1986).

3. Q. Haider and L. C. Liu, Phys. Lett. B172, 257 (1986); Phys. Rev. C (in press).

4. Y. Ohkubo, Institute of Physical and Chemical Research (RIKEN), Japan, private communication.

Fig. 1. Two-neutron separation energy versus neutron number for isotopes of carbon to sulphur. Open circles indicate nuclei which have been remeasured, triangles represent nuclei whose mass has been measured for the first time, and the solid points are taken from the literature. Error bars are indicated where they are larger than the symbol size.

Fig. 2. The calculated (DWIA) energy dependence of the cross sections for the inclusive reactions $^{27}Al(\pi^+,\pi^+\pi^+)X$ and for the reaction $^{27}Al(\pi^+,\pi^+\pi^+)^{27}Mg$ (particle-stable states) (Reference 4).

Table 1. Current Nuclear Chemistry Experiments at LAMPF

I. Atomic Mass Measurements with TOFI Spectrometer

Exp. 752 - ''Tuneup of the Time-of-Flight Spectrometer for Direct Atomic Mass Measurements,'' D. J. Vieira, spokesman, TTA/Nucl. Chem.

Exp. 870 - ''Search for New Magic Numbers - Direct Mass Measurements of the Neutron-Rich Isotopes with Z = 4 to 9,'' J. M. Wouters, spokesman, TTA/Nucl. Chem., scheduled for Sept./Oct., will complete this year.

Exp. 872 - ''Direct Atomic Mass Measurements of the Neutron-Rich Isotopes in the Region Z = 13 to 17 Using the TOFI Spectrometer,'' D. S. Brenner, spokesman, TTA/Nucl. Chem., test run scheduled for Nov./Dec., complete in 1987.

Exp. 1024 - ''Lifetime Measurements of Extremely Neutron-Rich Nuclei by Delayed Neutron Counting at TOFI,'' R. A. Warner, spokesman. Approved by PAC at August, 1986 meeting.

II. Pion-Nucleus Interactions

Exp. 975 - ''Single Charge Exchange with Stopped Negative Pions,'' M. J Leitch and L. C. Liu, co-spokesman, LEP/LEP, waiting to be scheduled, need separator on LEP, hope to run in 1987.

Exp. 999 - ''Study of Pion Double Charge Exchange Reactions $^{128}Te(pi^+,pi^-)^{128}Xe$ (g.s.) and $^{130}Te(pi^+,pi^-)^{130}Xe$ (g.s.),'' A. Fazely and L. C. Liu, co-spokesman, EPICS/EPICS, scheduled to run Sept. 26 - Oct. 17, will complete this year.

Exp. 1002 - ''Energy Dependence of the (pi^+, $2pi^+$) Reaction in Complex Nuclei,'' B. J. Dropesky and L. C. Liu, co-spokesman, P3/Nucl. Chem., scheduled to run Nov. 26 - Dec. 1, will complete this year.

Exp. 1022 - ''Studies of Eta-Nucleus Bound Systems,'' B. J. Lieb and L. C. Liu, spokespersons. Approved by PAC at August, 1986 meeting.

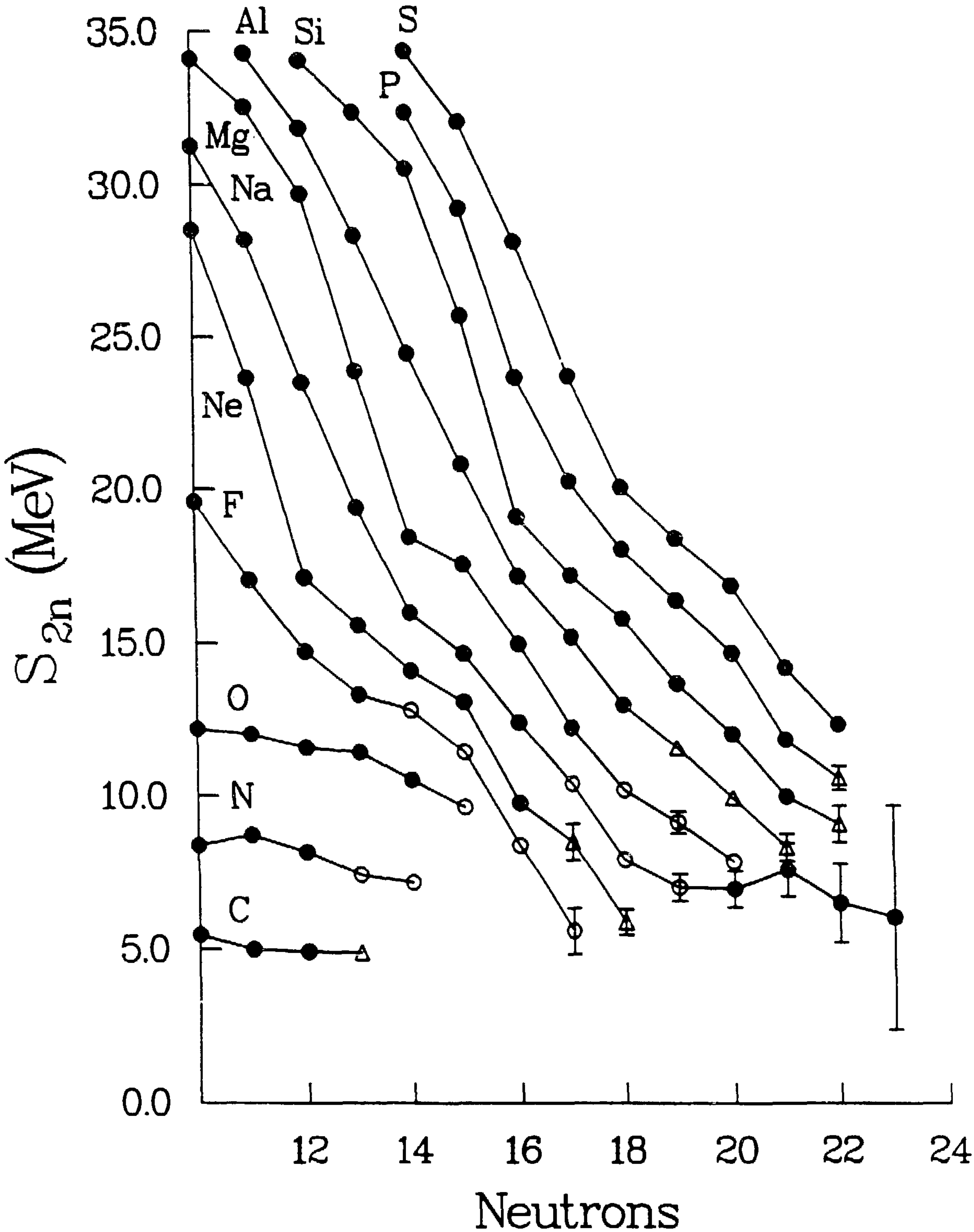
III. Cosmochemistry

Exp. 690 - ''Simulation of Cosmic-Ray Produced Gamma Rays from Thick Targets,'' R. C. Reedy, spokesman, EPB/Nucl. Chem.

Exp. 691 - ''Simulation of Cosmic-Ray Production by Nuclides by Spallation Produced Neutrons,'' R. C. Reedy, spokesman, RADAMAGE-1/Nucl. Chem., plan to run in 1987.

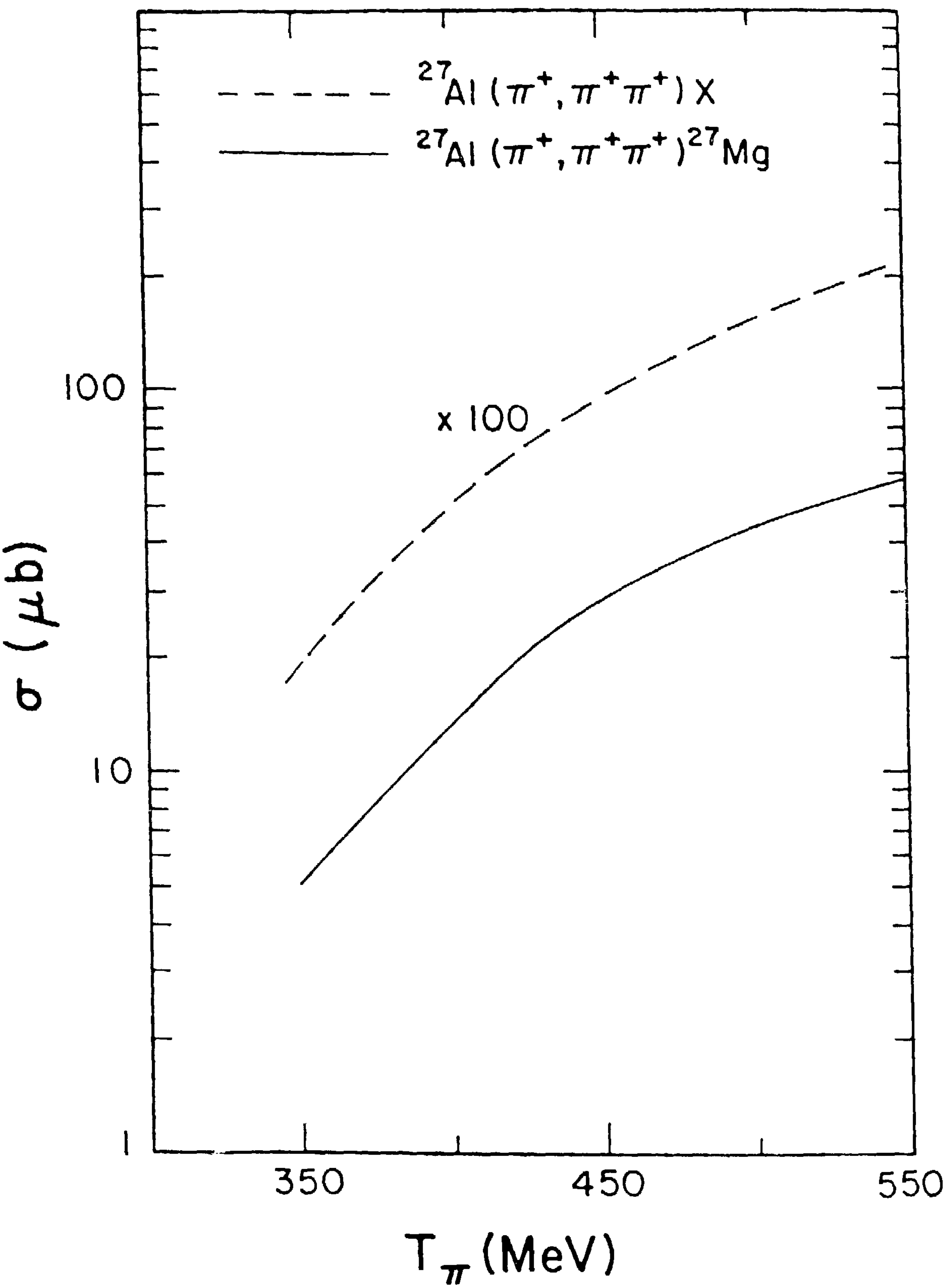
Exp. 692 - ''Ge Detector Low-Level Radiation Damage Equilibration Experiment,'' R. C. Reedy, spokesman, TTA/Nucl. Chem.

Exp. 1003 - ''Production of Long-Lived Radionuclides by Stopped Negative Muons,'' R. C. Reedy, spokesman, SMC/Nucl. Chem., approved last PAC, first of two runs scheduled for Oct. 6-10, second run to be completed in 1987.



35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
S_{2n} (MeV)
Al
Si
S
P
Mg
Na
Ne
F
O
N
C
12
14
16
18
20
22
24
Neutrons

Fig. 1



$^{27}Al(\pi^+,\pi^+\pi^+)X$
$^{27}Al(\pi^+,\pi^+\pi^+)^{27}Mg$
x 100
100
10
1
σ (μb)
350
450
550
T_π (MeV)

Fig. 2

Some Open Questions in Nuclear Physics

Ernest M. Henley
Institute for Nuclear Theory, Department of Physics, FM-15
University of Washington, Seattle, Washington 98195

There is no way that I can hope to do justice to the wealth of interesting nuclear physics that remains to be carried out; you will have to settle for a much more modest approach, namely one that builds in some of my biases and omits many interesting topics. If your favorite subject is not mentioned, I ask you forgiveness.

There are two ways I thought of approaching the subject I was asked to present. The first one was to do so through the nature of the probe that is used, e.g., heavy ions, light ions, electrons, neutrinos, etc. The second one was through the properties that are being investigated. I chose the latter, but the talk inevitably mixes the two approaches. Even so, the topic does not easily lend itself to a coherent approach.

I. NUCLEAR STRUCTURE

One of the important uses of nuclei is as laboratories for exploring basic features of the physical laws and forces of nature. The advantages of this laboratory are tremendous: easily varied mass, charge, angular momentum, and isospin are among them. However, in order to be able to use nuclei as advertised, it is necessary to have as complete a picture as possible of nuclear structure. Electron scattering is a primary tool for doing so, and the advent of d.c. beams allows coincidence experiments to be used in gaining the necessary knowledge. Lower energy (e.g., 400 MeV - 1 GeV) electrons will continue to be needed to provide us with some of the required knowledge.

In addition to nucleons and collective degrees of freedom, we have degrees of freedom which result when an excited nucleon is present in the nuclear medium. The best known and most easily accessible resonance is the $\Delta(1232)$, which is readily excited by pions, but what about other N^*'s in nuclei such as $N^*_{3/2}(1520)$, $N^*_{1/2}(1535)$, or still higher resonances. Can they be studied? Will models used for describing the $\Delta(1232)$ in nuclei be applicable here as well, or will we be faced with surprises?

It is interesting that we do not yet fully understand the structure of the lightest nuclei, e.g., ^{3}He and ^{3}H. Although a number of suggestions have been made, it is not at all clear that there is a satisfactory explanation of the binding energies and elastic electron scattering form factors. These nuclei offer the simplest ones to explore 3-body forces, but are these the answers to the puzzles? The understanding of these nuclei is very important if they are to be used to study quark-gluon degrees of freedom through higher energy electron scattering experiments.

The importance of two-body correlations in nuclei is well known. Pairing forces and seniority are examples of its consequences. Numerous attempts have been made to study these correlations in electron scattering and double charge exchange reactions with pions. However, to-date, two-body correlations remain elusive because of the difficulty of isolating them in experimental studies. Are the short-range correlations merely an indication of six quark and nine quark bags? Future coincidence studies with electrons may shed light on this aspect of nuclear structure.

The relative ease of producing hypernuclei with kaonic beams, for instance, allows us to study the effects of an impurity in nuclei. Can the substitution of a Λ for a neutron be understood with baryon-meson degrees of freedom alone, or are quarks required? The Pauli exclusion principle is different for the two cases and should allow a distinctive test to be carried out, since the Λ contains up and down quarks as well as a strange one. If quark degrees of freedom are involved, it suggests that more than color singlet nucleons and mesons will be required for an accurate description of nuclei. Thus, a detailed study of this question is of high interest and may give us insight into the importance of quark degrees of freedom in nuclear structure. A prime example where the question of the Pauli principle can and has been studied is ^{5}He, in which the binding is reduced on the quark picture because an up and down quark must be in a p-state (see Fig. 1), if a common center-of-mass applies to quark motion as it does for nucleons. If the quark picture is correct, but color singlet baryons are formed, as expected, does it mean that the whole Λ has to be in a p-state (see Fig. 1c) rather than just one up and one down quark? The experimental binding of the Λ in $^5_\Lambda$He is reduced compared to expectation (it is only 3.1 MeV), but the explanation of the small separation of the Λ may be different than the use of quark models.

The finding of some narrow Σ^- hypernuclei has given us further insights into nuclear structure. Will narrow Ξ^- and even Ω^- hypernuclei also be found? Double $\Lambda\Lambda$ hypernuclei are not only of interest in their own right but also for investigating the nature of the Pauli principle further. An example is the reaction ^{7}Li $(K^-, K^+)_{\Lambda\Lambda}{}^7$H, for which the occupations for three pictures are shown in Fig. 2. Of course, the study of all these hypernuclei also gives us new information about the forces between hyperons and nucleons or other hyperons.

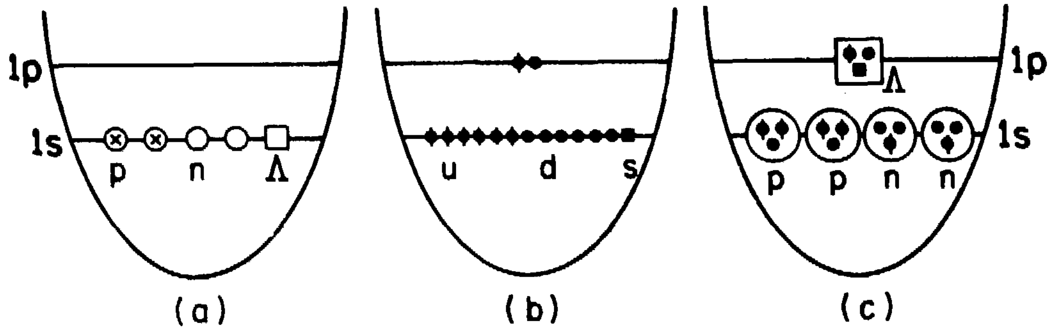


Fig. 1. $^5_\Lambda$He structure for (a) a baryon picture, (b) a quark picture and (c) a baryon quark picture.

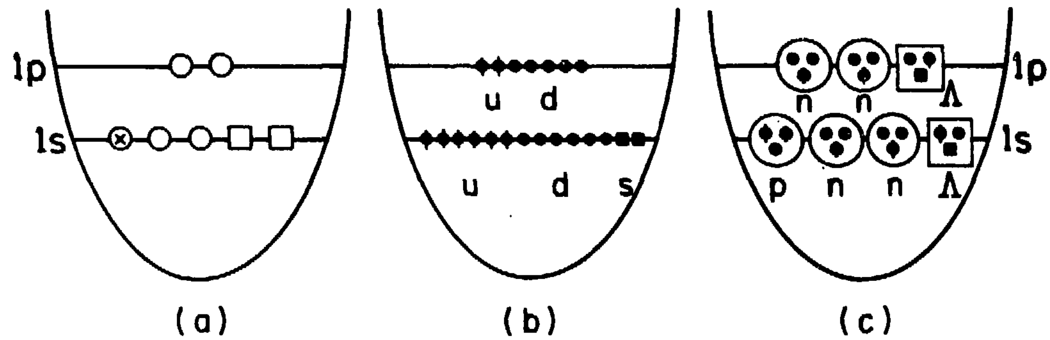


Fig. 2. $_{\Lambda\Lambda}{}^7$H structure for (a) a baryon picture, (b) a quark picture, and (c) a baryon-quark picture.

I will outline some other questions which I find intriguing and which will undoubtedly be studied in the future:

1) Are there special giant resonances at higher energies which remain to be discovered? Can all these resonances be built on excited as well as ground states, as is the case for the giant dipole?

2) If there is an island of relative stability at $N \sim 183$, $Z \sim 114$, can these superheavy nuclei be studied? Can they be formed by bombarding very heavy nuclei with heavy ions? What happens as Z becomes very large, $Z \gtrsim 173$? A variety of phenomena have been predicted.[1] Are the predictions correct?

3) What happens under other extreme conditions for nuclei? Very high angular momenta are being studied. What about nuclei far from the valley of stability? What about nuclei under very high pressures, temperatures, or densities? Do new states of

matter exist under these conditions? How are they best produced and studied? I will return to this subject anon.

II. QUARKS AND GLUONS

Traditional nuclear degrees of freedom include N's N^*'s, and mesons, as well as collective degrees. However, it is now generally agreed that the basic underlying theory of strong interactions is QCD. How do the degrees of freedom associated with this theory manifest themselves in nuclei? Are there critical experiments to be carried out that will help elucidate the answer to this question? There are a multitude of open questions in this realm.

1) Are high momentum transfers required to study the quark-gluon degrees of freedom? Since quarks and gluons are expected to occur at short distances, I believe that the answer to this question is positive. At small momentum transfers, furthermore, the corresponding wavelength is probably sufficiently large to average over the interesting domain. However, high precision experiments will show them up even here.

2) Can we find experiments to observe them and to quantitatively measure their effects? Are electrons and neutrinos the probes of choice for doing so? Is the nucleon-antinucleon system a source of information? I believe that the answer to both of these questions is positive. For one thing with high energy electrons one can probe to short distances, and experiments at SLAC at ~ 15 GeV have shown that results can be interpreted most simply in terms of almost free quarks. That is, for deep inelastic scattering, we have (see Fig. 3)

$$\sigma \propto \sum_i \phi_i(x)dx \; , \tag{1}$$

$$x = Q^2/2\,M\nu \tag{2}$$

where the incoherent sum is over quarks, ϕ_i is the probability of finding quark i with a fractional momentum xp where x is the Bjorken scaling variable and p the momentum of the target (see Fig. 3). In Eq. (2) M is the mass of the target, Q is the 4-momentum transfer and ν is the energy lost by the electron. On the other hand, we know that for electrons of energies less than about 1 GeV, the cross section can be obtained in terms of meson and baryon degrees of freedom. The region between 1 and 10 GeV is thus of great interest, since quark degrees of freedom must enter and confinement effects must also play an important role.

3) Is it necessary to understand the quark-gluon structure of the nucleon in order to understand the nuclear one? My own belief is yes, because nuclei are primarily composed of nucleons.

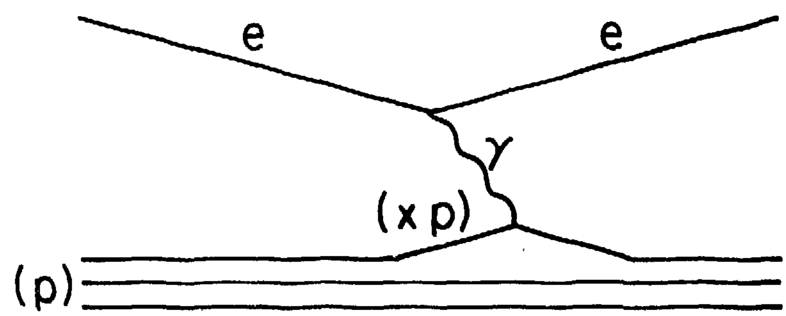


Fig. 3. Deep inelastic electron nucleon or nucleus collision. The symbols in parentheses represent momenta.

4) What is the role of constituent quarks? They are used successfully in nonrelativistic descriptions of baryon properties. But their properties, and their masses in particular, are not well determined. Do the masses of the constituent quarks depend on the process being studied, e.g., the wavelength of the probe?
5) What is the role of gluons in nuclei? High energy experiments show that they carry about 50% of the momentum of a nucleon, but they play no role in low energy quark models of nucleons and nuclei. Is there participation through glueballs? Do they exist and do they have a role in nuclei?
6) Does the equivalent of ^{4}He, the H particle exist? Is it stable? Calculations differ in their predictions; they give a mass smaller than the masses of two Λ's by anywhere from 60 MeV to some tens of negative MeV. The H can be produced in a variety of ways; one of them is the kaonic double charge exchange reaction

$$K^- +^3 He \rightarrow K^+ + n + H$$

Another is

$$\bar{p} + p \rightarrow H + \bar{H}$$

7) What is the role of the sea quarks in the nucleon and nuclei? Can their presence be made manifest? Is the Drell-Yan process at lower energies suitable for doing so?
8) To what degree are quarks and gluons required for an accurate description of nuclei and nuclear interactions at low and medium energies?
9) Can many of the puzzles of nuclear physics be understood by means of quark-gluon degrees of freedom? For example, are these degrees the explanation for the $N - N$ force at short distances, nucleon-nucleon correlations, and the ^{3}H - ^{3}He problems alluded to earlier.
10) It is reasonably clear that confinement is a highly nonlinear many-body problem. Can we solve this problem and will it lead to new insights for nuclear physics such as

the difference between free nucleons and those bound in nuclei and the different role of quarks and gluons in nuclei vs nucleons?

III. QUARK-GLUON PLASMA

I talked earlier about nuclei at extremes of temperatures and densities. These are of particular interest because one expects new states of matter to occur. Pion condensation has been predicted at sufficiently high densities when the chemical energy is lowered for this state. The main point, however, is that nucleons such as we know them may disappear under these conditions (see Fig. 4), and we may form an extended sea of gluons and quarks, a color-conducting plasma contained in a much larger domain than a nucleon. Such a plasma would allow us to gain considerable insights into confinement and deconfinement, nucleon stability, the equation of state at high temperatures and pressures, the conditions inside a neutron star, and perhaps the conditions at the earliest stages of the formation of our universe.

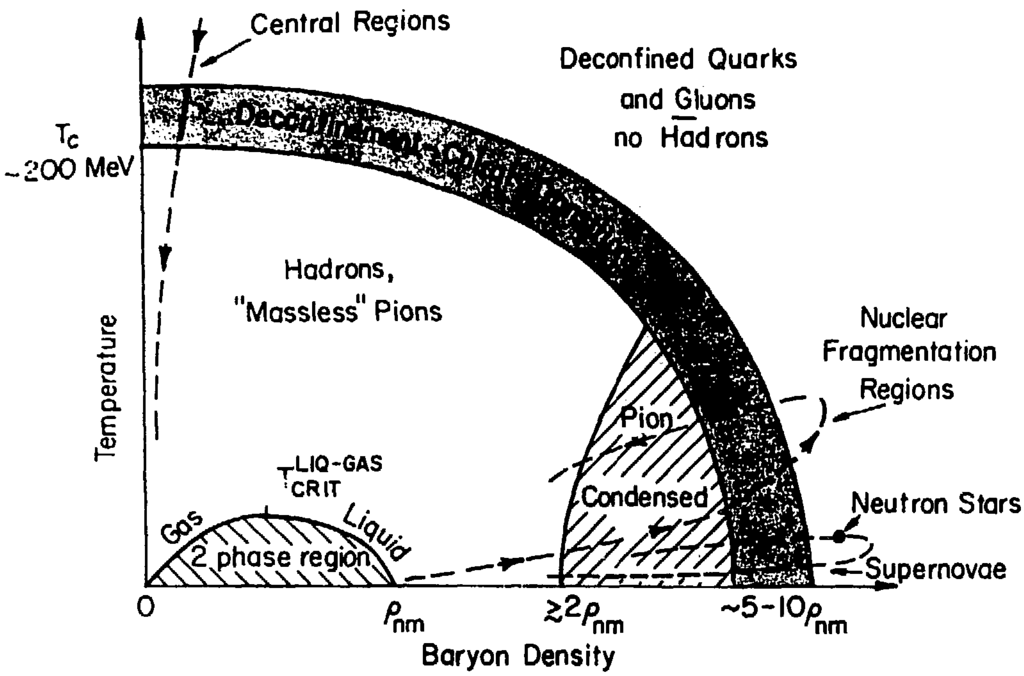


Fig. 4. Phase diagram of Nuclear Matter Temperature is plotted vs. net baryon density for an extended volume of nuclear matter in thermal equilibrium. From "RHIC and Quark Matter" (BNL 51801).

What is the basis for these expectations? First of all, high energy collisions have shown that quarks and gluons can be emitted by hadrons and that they "rehadronize" in jets. Thus, it is clear that confinement as such is not absolute, i.e., we can form new hadrons out of old ones. Furthermore, calculations starting from either end, i.e., normal nucleons under conditions of higher and higher temperatures and quark-gluon plasmas under conditions of decreasing temperatures yield pictures which meld at roughly T_c = 200 MeV and densities corresponding of 0.5-1 GeV/fm^3. Moreover, lattice gauge theory calculations produce about the same result and predict a phase transition at these critical parameters (see Fig. 5). Theorists speculate that a second phase transition will occur at even higher densities into a plasma with chiral symmetry.

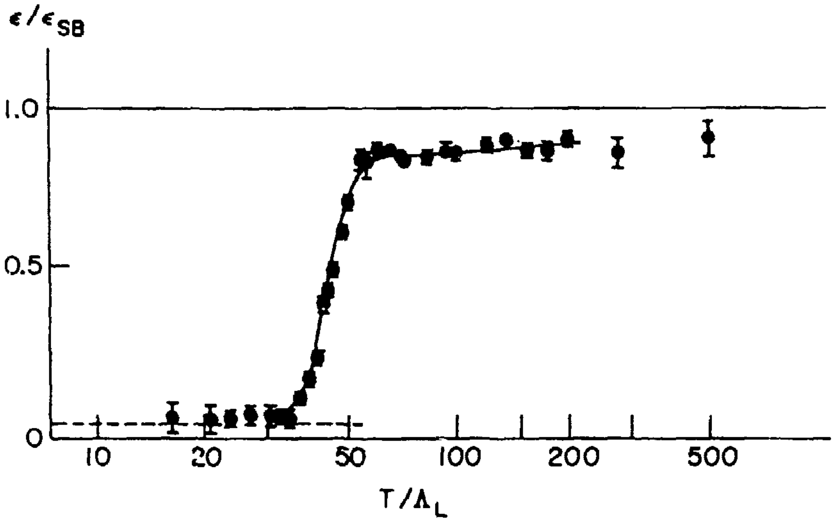


Fig. 5. Lattice calculation of the energy density of the Yang-Mills system for SU(2) color group, as a function of the temperature. The energy density ϵ is normalized to the ideal gas form ϵ_{SB} calculated on the same lattice. The lattice scale, Λ_L, is approximately equal to 5 MeV. Taken from "RHIC and Quark Matter" (BNL 51801).

The study of these plasmas will be difficult, but should constitute a rich new tapestry with fascinating new phenomena which are bound to increase our understanding of hadrons and many-body forces and effects.

How does one expect to produce the required conditions? Lower energy and a few high energy heavy ion collisions give us some insight into the energy deposition and stopping power in such collisions. The picture that emerges is as follows. Beyond an energy when the heavy ions manage to stop each other, they begin to pass through each other and thus acquire some transparency (see Fig. 6). At these higher energies, it is known that in head-on collisions, one forms three localized regions of phase space. There are two fragmentation regions corresponding to two "nuclear regions" recoiling from the collision area and a central "rapidity" region. In the latter region, the baryon density is small, but many pions are emitted from this region. It corresponds to a region of low density but very high temperature, resembling somewhat conditions which must have existed just after the big bang. On the other hand, the fragments carry away a

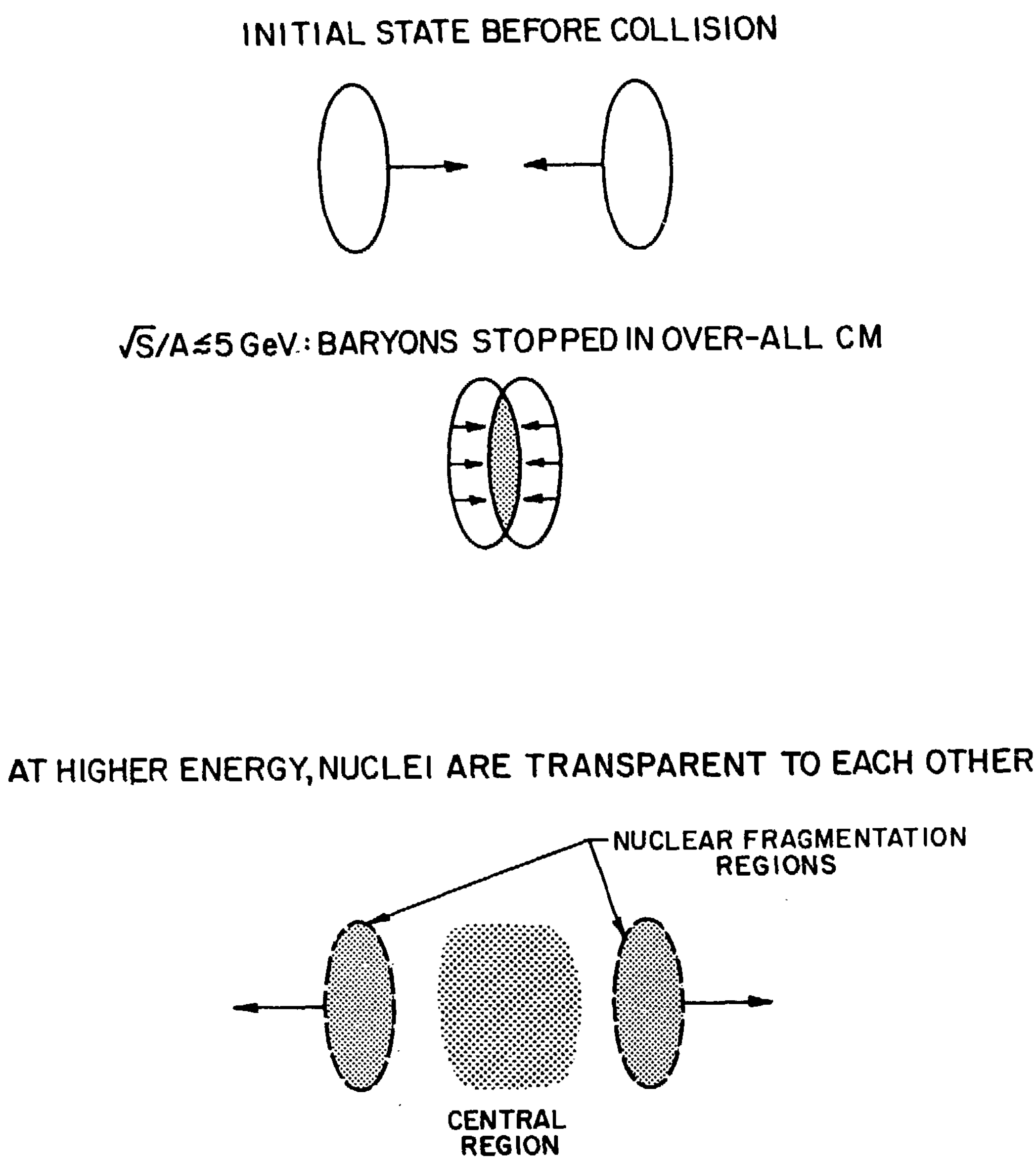


Fig. 6. Schematic illustration of nuclear transparency in high energy collisions at zero impact parameter. From "RHIC and Quark Matter" (BNL 51801).

large baryon density. The prediction is that, for energies in the transparency region, the energy density in the fragments depends only on the size of the colliding nuclei, and increase with A as $0.15(2A^{1/3} - 1)$ GeV/fm^3 (see Fig. 7). Thus, two separate domains can be studied. There is every expectation that a gluon plasma will be formed, but will it be a phase transition or will it be a gradual process? The answer to this question is clearly related to the stability of nucleons in nuclei and nuclear matter under a variety of conditions. Their study should give us insight into normal nuclear matter as well as such matter under extreme conditions.

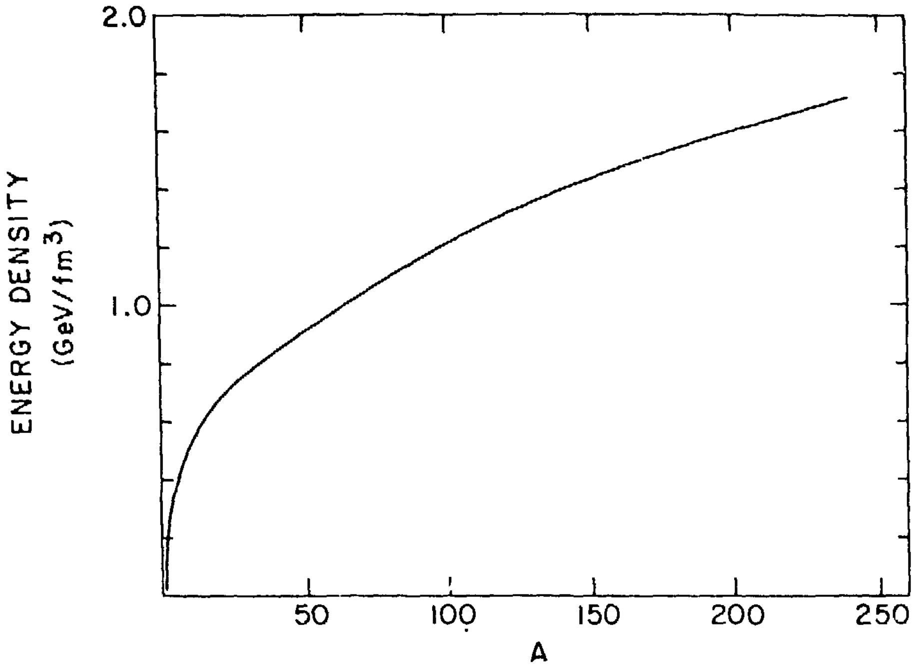


Fig. 7. Predicted energy density in the fragmentation regions as a function of the atomic mass number (A) of the colliding nuclei. From "RHIC and Quark Matter" (BNL 51801).

IV. SYMMETRIES

The importance of symmetries in delimiting and ultimately determining the basic laws of nature is well known. The nucleus is a superb laboratory for determining and examining symmetries; it has been utilized for this purpose in the past, and will continue to be so used in the future. Searches for axions, related to strong CP conservation is but one example. Another one, more closely related to basic dynamics, is its use in determining the energy production cycle in the sun through the associated neutrino flux which reaches the earth.

Dynamical symmetries which have been discovered in nuclei include charge symmetry and independence. Quite recently further light has been shed on this symmetry.[2] It remains of interest because it is an example of an approximate symmetry for which the symmetry-breaking mechanism can be studied. It is now known that this symmetry-breaking is not purely electromagnetic in origin, but includes a QCD mechanism. Is this mechanism the same one responsible for the W- and Z-masses? Can we gain some insight into this mechanism through studies of charge symmetry breaking?

Another dynamical symmetry which has been discovered in nuclei is that associated with the intermediate boson approximation. There appears to be a higher dynamical symmetry present in nuclear structure. What is it about nuclear forces which gives rise to this higher symmetry?

Parity nonconservation was discovered in the beta decay of nuclei. Although many details of the electroweak theory were obtained in the study of particles and at high energies, nuclear physics has contributed its share. Indeed, parity nonconservation in nuclear reactions has led to a much enhanced understanding of the nonleptonic weak interactions. This has occurred through studies in a host of nuclei with a variety of clever detection techniques for the parity violation. Moreover, the low energy experiments can be understood on the basis of nucleons and mesons. However, in order to understand the basic weak force between nucleons which is required for this purpose, one was forced to make use of quarks and QCD.[3] Indeed, we have here one example where quarks are required for low energy nuclear studies. Are they required here, in particular, because the weak interactions are of extremely short range? Moreover, there remains the need to develop a consistent formalism for explaining the low energy, the medium energy (800 MeV) and the high energy (6 GeV/c) data. So far, the approaches that have been successful are different and cannot easily be connected. Will other medium and higher energy experiments shed further light on this aspect of the weak interactions?

Nuclei can also be used to test the "standard model" of the electroweak theory itself. If there are more Z's and W's, for example, one should be able to see deviations in careful experiments, such as those with electrons. In addition, it may well be that the weak parity-violating interactions of several GeV electrons with nuclei will be helpful in providing further insights into confinement and quark distribution functions. We have already noted the sensitivity to quarks of the weak interactions. Parity violation in electron scattering occurs through the interference of photon and Z^0 exchange (Fig. 8). Since the Z^0 exchange is of short range, parity violation experiments at several GeV may indeed be helpful in determining quark distributions in nucleons and nuclei.

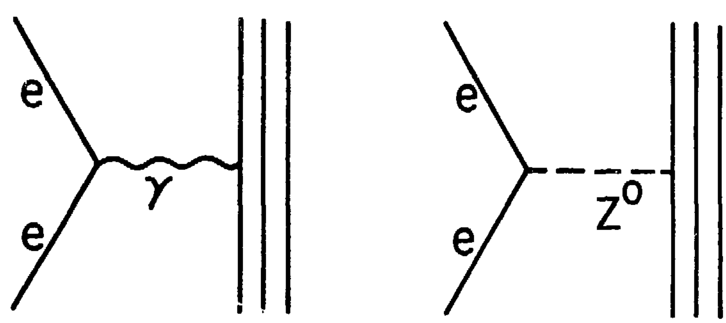


Fig. 8. Interfering diagrams for photon and Z^0 exchanges in electron scattering.

Other tests of the standard model become possible with an accelerator which can produce reasonable neutrino beams. An example is muon and electron neutrino scattering on electrons. The standard theory makes very definite predictions which can be tested; also the ratio of neutrino to antineutrino scattering allows a precise determination of the Weinberg angle through its proportionality to $\sin^2 \theta_W$.

Despite the fact that CP nonconservation was discovered almost 20 years ago, it remains a puzzle. Time reversal is directly related to CP through the CPT theorem. The best determinations of T invariance in the strong interactions have been made in nuclear tests and show that T holds to better than 10^{-3}. Even better determinations occur through studies of the dipole moments of nucleons and nuclei. The neutron dipole moment is less than 10^{-11} of $e < r_n >$, i.e., $d_n < 4 \times 10^{-25}$ e-cm. Heavier nuclei can be studied via their neutral atoms, and such studies are underway.

There is a strong belief that there exist higher symmetries than those which describe the electroweak [SU(2) x U(1)] and strong [SU(3)] interactions. Grand unified theories have been postulated and suggest that at least these interactions become unified at a very large mass scale [$\sim 10^{15}$ GeV]. These theories couple quarks and leptons as well as lepton families; they thus predict unstable neutrinos and protons. Studies of the proton lifetime have already shown its stability to better than 10^{32} years. Similarly $n\bar{n}$ oscillations, for free and bound neutrons have limited the oscillation time to 10^8 sec.

Neutrino oscillations are predicted if neutrinos have masses and interact. Such neutrino oscillations have been sought at reactors, but have not been seen. They set stringent limits on the neutrino mixing angles and electron neutrino masses. Further work is required if the neutrino masses are very small, as now expected. A further test of lepton conservation is double beta decay without neutrinos. It is necessary to distinguish between Dirac and Majorana massive neutrinos. Experiments already carried out limit Majorana neutrino masses to be less than about 20 eV.

I believe that the above examples demonstrate that nuclei are useful laboratories for the studies of symmetries and basic dynamical laws of nature.

V. RARE DECAYS

Although it is not strictly nuclear physics, I cannot conclude this talk without discussing rare decay modes of those mesons and leptons which can be produced with "nuclear" accelerators. I include here so-called kaon factories. The reason for including these decays is that they complement lower energy experiments.

As an example, consider the decay of a muon to an electron and photon. Muons are produced with ease at meson factories and family lepton number conservation can and has been tested at such facilities. Searches for $\mu \rightarrow e\ \gamma$ ($R < 1.7 \times 10^{-10}$), $\mu^+ \rightarrow e^+e^+e^-$($R < 2.4 \times 10^{-12}$) and muon conversion to an electron in nuclei ($R < 2 \times 10^{-11}$ have not discovered any of these decays.[4] These measurements test various GUTs; other accurate measurements of the muon decay parameters test the standard electroweak interaction theory.

The kaon is of particular interest because it contains a strange quark and is the only system in which CP nonconservation has been observed. The rare decays of the kaon test superstrong theories and allow insights into CP nonconservation. The decay of $K_L \rightarrow \mu^+e^-$ tests lepton family conservation, as does $K^+ \rightarrow \pi^+\mu^-e^+$. The decay $K_L \rightarrow \pi^0e^+e^-$ is CP forbidden at the one photon and one Z^0 level, and its rate is sensitive to the CP-violating mechanism. The decay $K^+ \rightarrow \pi^+\nu\bar{\nu}$ tests the standard model in a situation where there are no final state radiative corrections. With improved kaon beams it is also possible to enhance directly our understanding of the properties of the K^0 system through studies of the decay of K_L and K_S. Time reversal invariance can also be studied in the decay of the $K^+ \rightarrow \pi^0\mu^+\bar{\nu}$ through searches for the triple correlation of the spin of the muon and momenta of the pion and muon, i.e., $< \vec{\sigma}_\mu > \cdot \vec{p}_\pi \times \vec{p}_\mu$.

VI. CONCLUSION

This has been a somewhat rambling talk covering some highlights of some open problems in nuclear physics. Although the coverage has been somewhat lopsided and biased, I hope that I have managed to give you a flavor of the excitement which there is in the field at the present time and some further insights into a few aspects thereof.

References

1. For refs. see e.g. *Quantum Electrodynamics of Strong Fields*, ed. W. Greiner (Plenum, NY 1983).
2. R. Abegg *et al.*, Phys. Rev. Lett. 56, 2571 (1986).
3. B. Desplanques, J.F. Donoghue and B.R. Holstein, Ann. of Phys. 124, 449 (1980).
4. W.W. Kinnison *et al.*, Phys. Rev. D 25, 2846 (1982); W Bertl *et al.*, SIN Jahrsbericht 1984 (unpublished); D.A. Brayman *et al.*, Nucl. Phys. A434, 469c (1985).

MINUTES OF THE 1986 HRS WORKING GROUP MEETING

In Attendance: R. Fergerson (chair), K. McNaughton, J. Amann, M. McNaughton, D. Adams, G. Hoffmann, C. Glashausser, K. Jones, A. Wang, E. Stephenson

Report on Software/Electronics

Dr. Amann reported on the installation of the Starburst Auxiliary Crate Controller for use primarily in Focal Plane Polarimeter (FPP) experiments. This device makes an improvement of 30-40% in event rejection efficiency for small angle FPP analyzer scattering before the events are passed to tape.

Report on Hardware/Scheduling

Dr. Jones reported that there will be a large block of 800 MeV time which will be available during the next year since there is a 1000 hour 800 MeV experiment scheduled for EPB and only 260 hours worth of approved 800 MeV HRS experiments.

Dr. Jones also reported on the development of a cooled gas target suitable for angles $>8^\circ$. A recent run with this target produced a resolution of 140 keV at 800 MeV with a 20 mg/cm^2 Oxygen target. A variety of gases can be used as targets and the thickness can be adjusted to suit experimental needs.

Issues Raised from the Floor

The new LAMPF policy of a source "burn" every two days was discussed with the opinion expressed that additional time be allocated to experiments to take this regular downtime into account. In addition, the quality of the P^- beam during recent experiments when the low frequency buncher was in operation was discussed. Huge intensity and position fluctuations were observed which make it impossible to run most HRS experiments.

Dr. McNaughton asked a question concerning the determination of $\hat{l}$-type spin component when the new P^- source comes online. Since then it will no longer be possible to make quench measuremnets, he proposed that orthogonal mixtures of s- and $\hat{l}$-type polarizations be run when this occurs. The possibility of, instead, adding an additional polarimeter to Line C was discussed. The objection to this latter suggestion was that the new polarimeter would not provide the necessary additional information needed at 800 MeV to determine the $\hat{l}$-type polarization component because, at the convenient places to put an additional polarimeter, the precession angle between polarimeter and HRS target is a multiple of π.

Election Results:

Dr. Sirish Nanda of the University of Minnesota was elected to be the new chairman of the HRS working group by acclamation. It was also unanimously decided to nominate Dr. Gianni Pauletta of the University of Texas for the LAMPF TAP.

Raymond Fergerson
Rutgers University

October 30, 1986

MINUTES OF THE MATERIALS SCIENCE WORKING GROUP

ATTENDEES:

R. D. Brown, Chairman
H. Borden, MP-3
J. Cost, MST-5
H. Frost, MST-5
C. Hansen, MP-13
S. Lin, MP-3
R. Livak, MST-5
R. Reedy, ESS-8
W. Sommer, MP-13

The meeting of the Materials Science Working Group featured the description of several experiments in progress, as well as planned, together with a description of some new experimental equipment.

R. Brown described Experiment #930; the study of radiation effects in permanent magnet materials. It was pointed out that these magnets are of use in accelerators, and that it is consequently important to determine their resistance to radiation. Both the SmCo and NdFeB magnet families are being investigated. Preliminary results were shown for small NdFeB magnet samples irradiated at the Omega West reactor. The samples were irradiated at 77 C and 153 C, each irradiation occuring in helium gas. A graph of the normalized open circuit magnetization vs. fluence was shown. Following 8×10^{16} n/cm^2 at 77 C, the magnetization had fallen to about 62% of the pre-irradiation value, while at the same fluence at a temperature of 153 C, the magnetization was about 24% of the pre-irradiation value. Further work is planned to examine the effects of magnetic operating point on the degradation of the larger magnet samples. Also to be examined are the effects of sample chemistry and metallurgical processing.

Some results from Experiment #932, Radiation Damage in Magnetically Soft Crystalline and Amorphous alloys, were described. The degradation of low-field magnetic permeability was described in terms of changes in the short-range order and pinning of domain walls. An equation was presented which described the decay of permeability in terms of the above two processes, and the fit of this equation to the experimental data was shown. Data is now being analyzed from the run made this summer on larger toroids of the materials tested previously. Previous tests showed that following about 3×10^{17} n/cm^2, the permeability of the MetGlas decayed only slightly, while that of the Mumetal decreased markedly, making the MetGlas beneficial at higher fluences. This summer's work appears to bear out this conclusion for the larger toroids.

The results of power deposition measurements at the A-6 radiation effects facility were described, and shown to be in good agreement with calculations performed earlier by D. Davidson.

W. Sommer summarized some of the major accomplishments during 1985, when the present radiation effects facility was constructed. Experiments run that year included #769 (Proton Irradiation Effects on Candidate Materials for the German Spallation Neutron Source), which produced interesting results on the changes in strength of several aluminum base alloys. The dosimetry experiment #936, indicated that gradients in the neutron flux were minimal over distances of about 15 cm in the neutron inserts.

Turning to 1986 work, Experiments #986 and #987 are attempting to evaluate changes in mechanical and physical properties in ceramics and graphites, respectively. Both are collaborations with staff at Julich, Germany, where the results are of interest for the European Fusion program. Experiment #1014, done in collaboration with Riso Laboratory in Denmark, will examine changes in properties of copper and copper alloys following spallation neutron irradiation. The property changes will be compared with those produced by fission neutrons and by 800-MeV protons. Experiment #943 aims to study changes in the microstructure of Al, Mo, and 316 stainless steel, both by actual irradiation and by calculation of the expected changes.

It has recently been demonstrated that helium filled sample cannisters can be run for periods of several months at elevated temperatures with temperature deviations of only about 10 C. This represents a new capability for the facility. In response to questions from the attendees, it was reported that at present the only means for rapid retrieval of samples is the rabbit insert, in which the samples are limited to less than 7 mm in length and several mm in diameter. Several of the attendees expressed an interest in being able to retrieve larger samples quickly.

Ron Livak (MST-5) was elected as the chairman of the Materials Science Working Group for 1987.

Computer Facilities Working Group Minutes

Kok Heong McNaughton

October 28, 1986

Attendees: *Earl Hoffman* MP-1
Kok Heong McNaughton University of Texas
Tom Kozlowski MP-1
Mike Oothoudt MP-1
Gail Anderson MP-1
John Zumbro University of Pennsylvania
James Harrison MP-1
Mike Leitch P-2
Gary Hogan MP-4
Edward Stephenson Indiana University
Bob Redwine MIT
Michael Sadler ACU
Donald Isenhower ACU
Jerry Black ACU
Jay Wightman UCLA
Tony Gonzeles MP-1
Bill Briscoe GWA
Robert Eisenstein University of Illinois
Mary Burns MP-1
Martha Hoehn MP-7
David Adams UCLA
Lu He MP-4
Rusty Ragan MP-1
Jiri Bystricky UCLA

George Burleson NMSU
Jim Knudson MP-7
Mike McNaughton MP-13

Election of New Chairman

There were no volunteers for this position. Kok Heong McNaughton was re-elected for another year as Chairman of this Working Group.

Nomination of TAP Representative

Mike Oothoudt, our TAP representative for the past three years, has completed his term. Tom Kozlowski was nominated as our new TAP representative for 1987-1989.

Networking

Tony Gonzales gave an update of the Network connections between computers within LAMPF. All the counting house computers are now connected to the network either with co-axial cables or fiber-optic cables. Users can communicate between these computers via ethernet.

In addition, the two 8600's are connected to the CCF computers via XNET. Through the CCF computers, a user can communicate with the outside world via ARPANET and BITNET.

Terminal services to the LOB offices were discussed. The present Micom system will eventually be replaced and the change will be transparent to users.

Methods of file transfer were discussed. Between computers at LAMPF, files can be transfered using the simple COPY[1] command. There are several phone lines to enable users to dial up other computers. Some of the DAC-

[1]The remote node name must include Account and Password if the accounts on the two machines are not identical and the file or directory is protected.

supported software for this mode of file transfer are: CALOUT, COMLINK and KERMIT.

Unlike a year ago, users now do not need an account on the CCF machines to use the ARPANET and BITNET gateways, though the use of this facility is at the moment rather unsatisfactory. Support for its usage is minimum and there is no good documentation. It was reported that one can send electronic mail and ASCII files with BITNET but not binary files. There is a move toward having a BITNET connection directly from LAMPF rather than through CCF.

A file exists[2] which gives, among other informations, the BITNET and ARPANET addresses of many known computers in the world.

Judging from users' response, it is apparent that we have many experts among our users who have a lot to contribute to the group not only in networking but also in many other ways. The Chairman urged that users should look upon the LAMPF Computing Facility News as a way to communicate their expertise by contributing articles to this publication.

Data Acquisition and μ VaX II

Mike Oothoudt gave a short presentation of the status of LAMPF data acquisition support. The Q section, consisting of Mike Oothoudt, Will Foreman and Tom Kozlowski, will be moving to MPF-24 beginning November 13. They will keep the same phone numbers. They are now spending 25% of their time in general data acquisition support and 75% of their time with the MEGA experiment.

The data acquisition computers have all been changed to either VAX-750's or μ VAX II's. By January 2, all counting house PDP11's will be salvaged. A PDP 11/44 will continue to serve some users at the DAC for a while. μ VAX II's have now been in use for about a year and the initial problems, which include bad CPU boards, sequence of bus ordering, and bad DEQNAS[3] have been solved. Recurring problems with tape drives[4], are still being worked on.

---

[2] USER$DISK:[NETWORKS]ADDRESSES.TXT.

[3] Ethernet controller.

[4] KENNEDY 9400's are particular culprits.

Account management was briefly discussed. For ease of management, it is preferable to establish one user account on each of the data acquisition computers. Any experiment running on that computer will be given a subdirectory of this account. That means there is no protection between one experiment and another. Some users prefer to have their own account, thinking that this will make their files more secured. But there is really no guarantee on such *open* systems so that files that were there one week may not be there the next. Users were advised to treat these systems as volatile and to be responsible for their own backups.

Offline usage of data acquisition computers was discussed. All the data acquisition computers together make up a computing power equivalent to the two 8600's. If we can put these computers to use during the beam shut down period, it will double our output. One way is to encourage users to sign up for the use of these computers for data analyses. Another way is to *farm* out batch jobs to these computers. This is being looked into.

Counting house computing facilities upgrade was discussed. Some users would like to have LN03 laser printers or some way of getting good pictures to stick in their logbooks. Some users feel that one tape drive is sufficient. Some prefer increased disk space. The Q section welcomes users' feedback.

TeX Typesetter and Formatter

TeX is a VAX-supported typesetter and formatter which is becoming increasingly more important and widely used by the scientific community. Gail Anderson gave a presentation introducing highlights of this new facility to the uses. Users are encouraged to familiarize themselves with TeX since support for Tedi is gradually decreasing and is likely to be unavailable for the next generation of output devices. In addition, TeX produces a device-independent file which can be shipped from one institution to another whereas Tedi is local to LANL.

Documentation, help and consultation are available to users who wish to learn how to use TeX or LaTeX[5]. The input text files can be prepared using any standard editors. They must contain specific macros that TeX

[5]This report was prepared using LaTeX.

or LaTeX interprates as typesetting commands. The output goes to LN03 printers.

C-Division has developed a macro giving the LANL logo for use in memos. A similar logo for LAMPF can also be developed. Future features in TeX include the ability to incorporate a meta file[6] so that users can plot graphs and diagrams directly into their report, without having to cut and paste. Another future feature is routing output to PostScript printers.

User's Input

There were no complaints from the users. Mike Leitch thanked the Q section for their continual support with data acquisition. One user wanted to know if there will be upgrade to the MBD which, in his opinion, is old technology. The answer is no. Earl Hoffman asked what would people want if we have some money for upgrading the Computing Facilities. The consensus is increasing CPU power by upgrading the 8600's to 8650's, with appropriate parallel disk space increase.

[6]Of the type generated by MAPPER.

MINUTES OF THE SMC WORKING GROUP

The stopped muon channel (SMC) working group met in room D105 of the LAMPF office building from 10:30-11:30 a.m. on October 28. The meeting was conducted by the chairman, Martin Cooper (MP-4). Other attendees were O. Kieth Baker (MP-3), Marvin Blecher (VPI), Martha Hoehn (MP-7), Gary Hogan (MP-4), Mike Oothoudt (MP-1), Mike Paciotti (MP-3), Robert Reedy (ESS-8), and Carol Wilkinson (MP-4).

Martha Hoehn discussed channel utilization for 1986 and 1987. The 1986 usage was broken down as follows: Yale-36%, μSR-25%, catalysis-18%, channeling-12%, radio-nuclides-6%, and changeovers-3%. It is expected that in 1987 the μSR usage will go to zero and MEGA will use less than 1000 hours. There are currently only about 1300 hours of approved time at SMC outside of MEGA. The running schedule presented by Don Hagerman called for roughly 3300 hours in 1987-88. This apparent under-utilization of the channel underscores the need for good proposals to be submitted to the PAC.

Channel upgrades were discussed. Mike Paciotti told the group that a pion source of 5 times the intensity available in cave B had been developed near the output of BM03. The spot size was 3-4 cm (FWHM). Its major disadvantage was that high radiation levels at this location meant that setup time was limited for personnel. Gary Sanders related through Martin Cooper that the spin rotator was finished and available to experiments. The Crystal Box separator is also free. It was decided not to accept the recommendation of Martha Hoehn that the magnet sign conventions be brought into accordance with LAMPF standards because there were too many magnets and too much time invested in known tunes to take the chance of mistakes. The working group requests that detailed records be made available on the magnet polarities and voltages. The current disk space on the computer seems to be adequate if a starting experiment can fit one tape of information besides a normal size Q system. The counting house still leaks, and the working group finds it unreasonable to have a counting house that leaks during rain storms. The LAMPF administration is urged to solve the problem.

Martin Cooper discussed the impact of MEGA. Rigging for the MEGA magnet should commence in December, and may require the roll up door outside of cave B to be open for significant periods. Any user of area A who might be adversely affected by environmental changes due to this operation are encouraged to contact Lew Agnew or Martin Cooper. The pit for the magnet in cave B is now complete. A new door to cave C will be required to give access around MEGA. MEGA will construct a platform at the 14 foot level for electronics and cryogenics that will have access from ground level and the catwalk. The platform will be outside the radiation safety interlock system during normal running. A plan is being formulated for the space to the east of area A to accommodate both MEGA cryogenics and potential cave C users.

MEGA has requested a re-organization of the counting house and cable plant to ease its cabling problems. The plan would put MEGA in the east end of the counting house and others in the center. The patch panels and cable trays will be cleaned and improved. Users are requested to give input regarding the type of cables they want on the patch panel and their preferred location in the counting house to Jim Little of MP-1.

In view of the big impact of MEGA on the SMC, the working group recommended that Martin Cooper be appointed to the TAP. Martin Cooper will also stay on as SMC working group chairman.

R E P O R T
of the
1986 LAMPF Nuclear Chemistry Users Group

Chairman: Robert H. Kraus, Jr. 28. October 1986

In Attendance:

	NAME	INSTITUTION/AFFILIATION
1.	Dean Cole	LANL - INC-11
2.	Bruce Dropesky	LANL - INC-11
3.	Xizhang Feng	Peoples Republic of China, LANL - INC-11
4.	Qamrul Haider	LANL - INC-11
5.	Robert Kraus, Jr.	Clark University
6.	Lon-Chang Liu	LANL - INC-11
7.	Janet Mercer-Smith	LANL - INC-11
8.	Norbert Porile	Purdue University
9.	Robert Reedy	LANL - ESS-8
10.	Kamran Vaziri	Utah State University
11.	David Vieira	LANL - INC-11
12.	John Warren	Lakehead University, Canada
13.	Jan Wouters	LANL - INC-11

MINUTES:

We began the Nuclear Chemistry Users group meeting with presentations from three very diverse groups of user.

I. Report by Dr. Janet Mercer-Smith

Dr. Mercer-Smith spoke on the work being undertaken by the biomedical section of INC-11 and their collaborators at LAMPF. The biomedical section is involved with several areas of work including: the production of radioisotopes for use in nuclear medicine research. These radioisotopes are used here at Los Alamos as well as being shipped around the world. 2) Target irradiation at LAMPF in which new applications for various radioisotopes are being studied. 3) Research into biomedical radioisotope generators in which short-lived radioisotopes are generated from longer lived parents. 4) Radiolabeling research using LAMPF-produced isotopes in which complexation of radioisotopes by organic molecules is studied. 5) Finally, animal biodistribution and in vivo stability of new radiopharmaceuticals is studied using techniques including gamma-ray imaging. The biomedical section utilizes the live animal rooms at LAMPF, these are the only NIH approved live animal rooms for radioactive materials available at the laboratory.

II. Report by Dr. Quamrul Haider

Dr. Haider spoke on the theoretical work involving mesonic reactions being performed at LAMPF. Although Dr. Haider and colleague Dr. L.C. Liu are involved in several efforts (primarily bound states of eta-mesic nuclei, self-consistent models of gluon exchange, and excited resonances) the focus of his talk was on the theoretical description of pion double charge exchange reactions. The results of the theoretical work have been published in Physical Review and the signature of this reaction will be examined in experiment 1022 at LAMPF.

III. Report by Mr. Kamran Vaziri

Mr. Vaziri spoke on the most recent experiment completed by the TOFI group, the results of which have been submitted to the Physical Review Letters. The TOFI collaboration has measured 21 neutron rich masses in the region from carbon (Z=6) to phosphorus (Z=15). Eight of these masses represent masses of nuclides measured for the first time and the other 13 are refinements of previously measured masses. The list of collaborators on the TOFI project includes scientists from 6 U.S. and 3 foreign universities and research facilities.

IV. Business matters:

The group voted unanimously to recommend Jan Wouters to the LAMPF Board-of-Directors as a TAP representative. Jan has extensive knowledge of technical aspects of various experiments at LAMPF experiments and is intimately familiar with the LAMPF facility as a whole.

The group also voted unanimously for Lon-Chang Liu as the 1987 LAMPF Nuclear Chemistry Users Group chairman.

The Nuclear Chemistry Users Group also discussed the possible change of the LAMPF beam cycle presented by the LAMPF staff. In general, most members were mildly in favor of the proposed schedule, however, the proposed 3-cycle transition next year was an important factor since several outside collaborators have already made long range plans for working at LAMPF during the summer of 1987 anticipating the beam to be available.

NPL Working Group meeting notes

October 28, 186

Chairman: J. A. Faucett

Secretary: George Glass

Participants

David Axen	TRIUMF
R. L. Boudrie	MP-10
Howard Bryant	UNM
O. van Dyck	M?-DO
J. A. Faucett	NMSU
G. Crawley	MSU
Will Foreman	MP-1
G. Glass	Texas A&M
Charles Goodman	U. of Indiana
G. W. Hoffmann	U. of Texas
James Knudson	MP-7
Kok Heong McNaughton	U of Texas
Mike McNaughton	MP-13
G. S. Mutchler	Rice U.
Matthew Murray	MP-10
L. C. Northcliffe	Texas A&M
Peter Riley	U. of Texas
P. G. Roos	U. of Maryland
Sudhir Sen	U. of Texas
Hal Spinka	Argonne Nat'l Lab.
Dick Werbeck	MP-7

Olin van Dyck presented a detailed description of the P^- buncher system. He showed the layout of the two bunchers with respect to the Cockcroft-Walton accelerator and the linac. The first buncher (the Dome buncher) packs the beam such that about 40 to 50% lands up in one peak. The second buncher (the ground level buncher) repeats the process and results in 1% of the remaining beam to be in one peak with extremely small proportion ($\leq 0.1\%$) of the beam in the side peaks (i.e., within ±10 ns of the main peak). Overall beam loss from the main peak is less than 40% when the system operated properly. He pointed out that when the polarized source is mistuned, then some very significant beam polarization dependent intensities result.

The chopper, due to be installed next year, will further remove that part of the beam that falls between the 100 ns main peaks. Eventually the chopper will be used to chop every second main peak in order to provide 200 ns separation, as would be necessary for NTOF beam experiments at low energy.

Mike McNaughton discussed next year's anticipated running schedule in EPB and BR. He pointed out that with the energy requirements of experiment 960, efficient utilization of EPB might predicate doing experiments other than experiment 818 at the lower energies. Lower energies to be run by experiment 960 are 500, 580, 650, and 733 MeV. He raised the possibility of doing experiments with polarized protons or with deuterium (as in experiment 818) at these lower energies. Presently there are no users of EPB at energies other than 800 MeV scheduled for this time. However, it was pointed out that NTOF could make some heavy demands on this beam line and could create a serious shortage of beam time for already existing experiments in both BR and HRS in that NTOF will require ~100 nA of unpolarized beam.

Dick Boudrie illustrated how the NPL upgrade, namely the "Swinger" package and the NTOF, with a 600 m flight path, fits into the overall LAMPF running schedule. The "Swinger" should be ready by Spring of 1987 whereas the flight path should be able to take beam in the fall of

1987. In addition the MRS is expected to be available in the fall of 1988.

Jim Knudsen described the progress being made in the HIRAB arm of the NPL upgrade. Construction of the major new structures should be completed sometime in November 1986. He also described some plans for obtaining a very narrow beam divergence ($\lesssim$ 1 μrad). The plan calls for throwing away about 90% of the beam using slits.

The subject of a modified distribution of the machine's duty factors was brought up. Experimenters were asked whether they prefer to have a larger duty factor at the lower energy operation in exchange for lower duty factor 800 MeV running. This trade-off is required by constraints on the cost involved in running at a higher duty factor.

The possible scheduling of beam away from the summer months was brought up and discussed. Experimenters were encouraged to respond to this schedule change by letting Don Hagerman know their preferences.

The committee suggested Peter Riley and George Glass as future TAP committee members.

The next chairman for the NPL Working Group will be George Glass (Texas A & M).

MINUTES - EPICS WORKING GROUP MEETING

Kalvir Dhuga - Chairman

October 28, 1986

Attendees:

John Zumbro, University of Pennsylvania
Mohini Rawool, New Mexico State University
George Burleson, New Mexico State University
Kalvir Dhuga, New Mexico State University
David Oakley, University of Texas (Austin)
Jerry Peterson, University of Colorado
June Matthews, Massachusetts Institute of Technology
Ali Fazely, Louisiana State University
David Ernst, Texas A & M University
William Briscoe, George Washington University
Michael Sadler, Abilene Christian University
Terry Black, Abilene Christian University
Daniel Strottman, Los Alamos National Laboratory (T-9)
Mikkel Johnson, Los Alamos National Laboratory (MP-DO)

Meeting was called to order at 10:30 a.m. David Oakley was nominated by John Zumbro for the next chairman of the EPICS Working Group, he as elected chairman.

John Zumbro presented evidence of slit scattering when the EPICS spectrometer is set-up for "zero" degree measurements. He will gladly supply further information for anyone interested.

MP-10 staff were thanked for the excellent tutorials that were held during the summer. They may organize another one next year. MP-10 requests feedback on software/hardware and personnel support at EPICS.

Mikkel Johnson informed the meeting of the formation of a task force to define and evaluate various future directions on pion-nuclear physics. A report will be published. A workshop may be arranged.

Meeting adjourned at 11:30 a.m.

MINUTES OF THE LOW ENERGY PION (LEP) WORKING GROUP MEETING
James N. Knudson, Chair

The meeting began with a discussion of the proposed running schedule for 1987 and 1988 that was presented to the Users Group by Don Hagerman. There appeared to be no strong opinions, either for or against the plan, expressed by the members of this Working Group.

Nominations for TAP and the PAC were solicited. The Board of Directors has indicated that the TAP representatives will, in future, work with the Working Groups that they represent. One nomination for the TAP will be forwarded to the Liaison Office. Phil Roos reminded the Working Group that his term on the PAC expires after the February meeting, and that members of the Working Group should seriously consider their nominations to the PAC. Any nominations received by the chairman outside of this meeting will also be forwarded.

Users of the LEP channel are reminded that the size of the queue of active experiments is growing short. An examination of the list of active experiments shows that about 1600 hours of PAC approved time remains to be scheduled, although experiment E1023 (740h) will not run in 1987. Barring extreme problems with equipment, experiment E899 will request about 600h of time at the February PAC meeting, giving about 1500h of running at LEP for 1987. This is less than was scheduled for all of 1986. Users are therefore encouraged to submit new proposals for consideration in February.

Several elements of the channel are scheduled to receive attention from MP-7 during the upcoming shutdown.

Jaws: The inoperative solid-angle jaws CL01 and CL02 will be fixed. The problem appears to be bearing failure. The asymmetry in the momentum jaws CL06A and CL06B will be investigated, but no action will be taken unless clear and documentable improvements can be made.

- NMR: MP-7 plans to replace the current NMR system if a suitable system can be found. One problem being encountered is that many systems now available do not have the 1kG-20kG range that the present system possesses.
- Degraders: Some problems with the degrader wheels have been encountered recently where the wheels were left in some state not related to what the indicator lights would have the user believe. Joey Donahue (MP-7) mentioned that the P^3 system is inherently more reliable than the LEP system, and that an upgrade of the control system will be considered. Users desiring more positions on the wheels as well should contact MP-7.

Some items from last years agenda were discussed. Dick Boudrie of MP-10 discussed the digital-to-analog magnet controllers. These will probably be ready for the 1987 running. Computer readout of the channel settings is now available from the LEP VAX, where a command file puts the readings into a disk file. No software is yet available that would put these readings onto a users Q tape, but this should not be difficult in principle. Computer control of channel elements is not available, but should be feasible.

In other business, Jerry Peterson brought up the possibility of compiling a Users Guide for the channel. Dick Boudrie indicated that one possibility would be the use information put together for the Clamshell Spectrometer Tutorial that was held in September.

Gerry Garvey came by to discuss the possibility of holding a workshop to consider the future of pion-nucleus physics at LAMPF. Members of the Working Group strongly recommend that such a workshop be held, to be organized by the users of the three pion channels at LAMPF.

The Working Group also strongly recommends that future meetings of the LEP and P^3 Working Groups not be held in parallel sessions.

James Knudson of Los Alamos will continue as chairman of the Working Group for 1987.

Attendees:

R.L. Boudrie	LANL, MP-10
Jerry Peterson	Univ. of Colorado
J.B. Donohue	LANL, MP-7
P.C. Minehart	Univ. of Virginia
R.P. Redwine	MIT
P.G. Roos	Univ. of Maryland
James Tinsley	Arizona State Univ.
Martha Hoehn	LANL, MP-7
J.N. Knudson	LANL, MP-7

Minutes of the P^3 Working Group

Gordon Mutchler, presiding

28 October, 1986

Attendees:

Terry Black	ACU
Bill Briscoe	GWU
Gerald Garvey	Los Alamos
Donald Isenhower	ACU
Andi Klein	MP-4
Derek Lane	ACU
Mike Leitch	P-2
June Matthews	MIT
John McGill	MP-13
Alireza Mokhtari	GWU
Gordon Mutchler	Rice
B. M. K. Nefkens	UCLA
Mike Oothoudt	MP-1
Gerry Phillips	Rice
Chandra Pillai	UCLA
Sayed H. Rokni	Utah State
Michael Sadler	ACU
Dick Werbeck	MP-7
Jay A. Wightman	UCLA

The meeting of the P^3 working group was called to order by Gordon Mutchler. Michael Sadler was elected chairman of the the group for 1986-87. TAP nominees were Bill Briscoe, Peter Gram and Ben Nefkens.

Gerald Garvey challenged the group to come up with ideas for new thrusts in pion-nucleus and pion-nucleon physics and mentioned the task force which is preparing a preliminary report on this topic. He also solicited ideas for upgrades of the P^3 channel.

June Matthews responded with a desire to include experimentalists on the task force. She described the effort as a valuable enterprise but not a substitute for a workshop which should be held in the near future.

Three specific desires for upgrades of the P^3 channel were voiced. Ben Nefkens expressed the desire for beams of reasonable intensity with momenta higher than 700 MeV/c. Mike Leitch described the need for better beam resolution at the higher momenta in the eta production experiments. The need for a proton separator for the higher momentum π^+ beams was also stated.

John McGill responded to the last requests, saying that a dispersed beam was being developed for the channel which would give a resolution of $\Delta p/p = 0.2\%$. New jaws or a thinner A-2 target will be required to achieve this resolution. The target could be changed on a maintenance day, depending on the needs of the experimenters in P^3 and SMC. It was noted that some experiments in SMC, particularly the muon-catalyzed fusion experiment, also want a thinner A-2 target. December development is being planned for this project. John also desbribed how the large phase space of the P^3 channel would make proton separation difficult, requiring a separator several meters long.

June Matthews inquired about the status of absolute momentum calibration of the channel and the linearity of the bending magnets at the higher momenta. Ben Nefkens made a proposal urging LAMPF management to support:

1) higher momentum beams in the channel,

2) better proton separation,

3) improving the momentum resolution, and

4) a new measurement of the absolute momentum at the upper end.

The proposal was approved unanimously by the members present. Bill Briscoe, the present TAP represntative for P^3, was asked to convey this proposal to the TAP.

The need to repair the MS01 readout was expressed by Mike Leitch. The need for new pots on the magnet controls was stated by Bill Briscoe. A request was made by Mike Sadler to modify the MAG program to include the actual shunt setting for the slits, along with the opening in cm, in the readout.

Dick Werbeck commented that the queue for approved experiments waiting to run in P^3 has been reduced to 3000 hours approved, 1000 hours conditional. Approximately 2500 hours were provided to experiments this year. He also mentioned the possibility of a new running schedule with a Fall startup, with 1987 being a transition year. The pros and cons of summer running were discussed by the group. It was noted that experiments in P^3 usually require considerably more staging than experiments in other channels. Students gain a great deal of practical experience while participating in this effort and are often necessary to complete the setup in a timely fashion. A proposal was made by Michael Sadler asking the LAMPF management to preserve some running time during the summer months to accomodate university schedules and to facilitate student involvement. The proposal passed 15 to 1.

Neutrino Facilities Working Group Meeting,
October 28, 1986

Participants:

B. Barrish
T. Bowles
R. Burman
R. Carlini
J. Donahue
S. Freedman (Chairman)
D. Lee
K. Lesko
T. Romanoski
V. Sandberg
E. Smith
N. Thompson
H. White

Minutes:

J. Donahue reported on the early results of Experiment E866. This effort is directed toward an accurate (≈7%) calibration of the neutrino flux from beamstop sources. A mockup of a beamstop using slabs of various materials (primarily copper and water) sandwiched between active plastic scintillator detectors is used to measure the pion and muon production ratio to protons of various incident energies. The neutrino flux is inferred from the pion and muon flux. The measured contamination from negative pions is used to estimate the flux of electron antineutrinos, an important consideration for beamstop neutrino oscillation experiments. The early indication is that water in the beamstop increases neutrino production, but the enhancement may be smaller than expected from calculations.

R. Burman summarized the results from E225 a measurement of electron-neutrino scattering from electrons. The experiment is nearly completed but much of the data is not yet analyzed. The measured crossection is $\sigma = (9.8 \pm 2.7 \pm 1.6)E(\mathrm{GeV})10^{-45}\mathrm{cm}^2$ in good agreement with the Standard Model. Data collection ends with this cycle and the final result is expected in the near future.

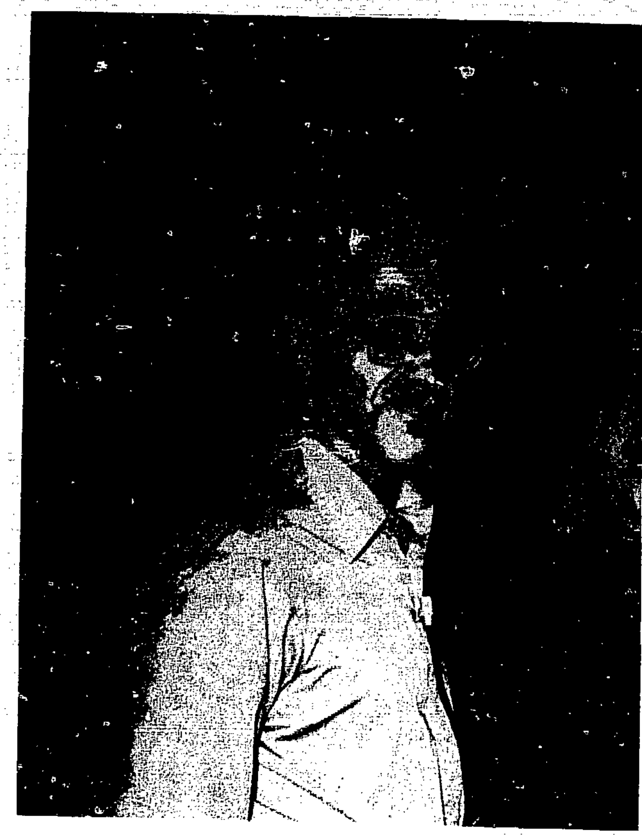
T. Romanoski discussed the status of E645 a search for neutrino oscillations. The experiment searches for an electron antineutrino signal. The contamination of electron antineutrinos produced from negative pions which decay is expected to be smaller than 10^{-3} relative to muon antineutrinos. The experiment is now taking data but a large part of the passive cosmic ray shielding (a significant amount of steel overburden) is not yet completely installed. Beam associated backgrounds probably from fast neutrons have been observed and additional shielding of the beamstop may be required. Significant background rejection is required if E645 is to put significant limits on neutrino oscillation parameters.

H. White discussed a new proposal for a "Large Cherenkov Detector" to measure $\sin^2\theta_W$ to better than one percent. This experiment relies on a new source of neutrinos which would incorporate the beamstop of the proton storage ring. This exciting proposal represents a significant escalation in the scope of neutrino experiments at LAMPF.

Roger Carlini was elected to serve as Chairman of the Neutrino Facilities working group for 1987.

Louis Rosen Prize Winner Presentation:
Gerald Garvey, Louis Rosen, Ronald Jeppesen, June Matthews, and Barry Preedom

Daniel Koltun



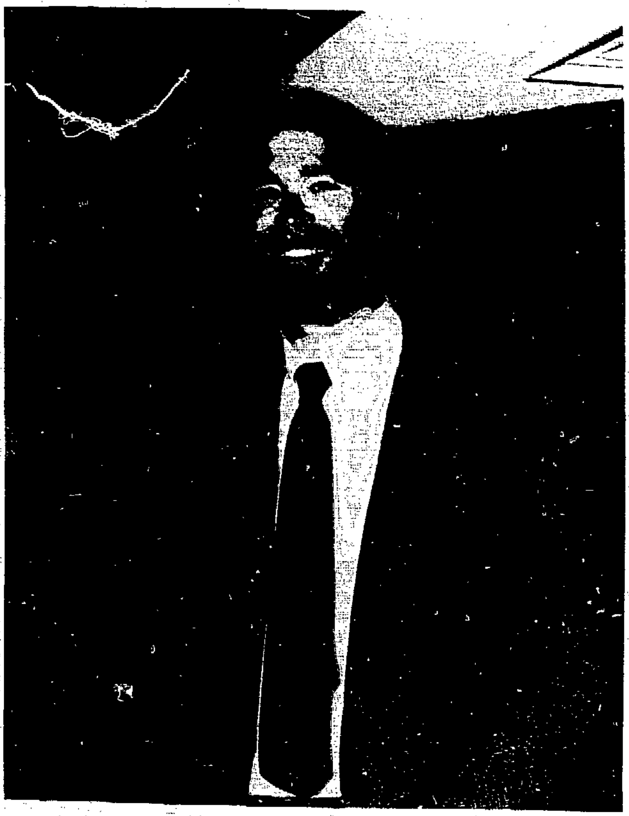
Ernest Henley

Philip Roos

Earl Hoffman

James Bradbury and Donald Hagerman

David Axen

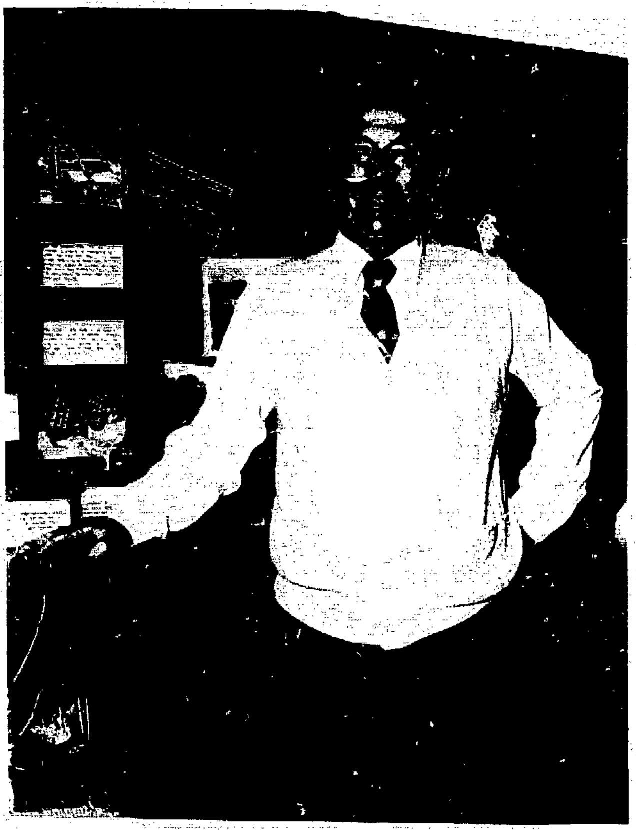


Robert Redwine

Wilmot "Bill" Hess

Donald Hagerman

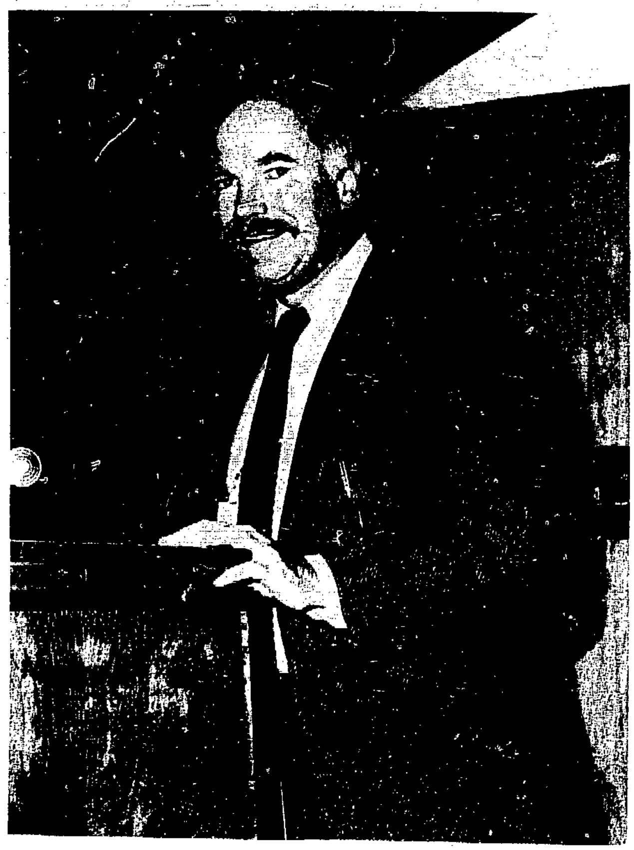
Donald Walker and Barry Preedom



Louis Rosen

Gerard Crawley

Warren "Pete" Miller



Gerald Garvey

ATTENDEES
20TH LAMPF USERS MEETING
OCTOBER 27 AND 28, 1986

LEWIS AGNEW
LOS ALAMOS NATIONAL LABORATORY
MPDO MAIL STOP H850
LOS ALAMOS NM 87545

JOHN C ALLRED
LOS ALAMOS NATIONAL LABORATORY
MPDO MAIL STOP H850
LOS ALAMOS NM 87545

JAMES F AMANN
LOS ALAMOS NATIONAL LABORATORY
MP10 MAIL STOP H841
LOS ALAMOS NM 87545

NAFTALI AUERBACH
SCHOOL OF PHYSICS
TEL AVIV UNIVERSITY
TEL AVIV 69978 ISRAEL

DAVID AXEN
TRIUMF UNIVERSITY OF BC
4004 WESTBROOK MALL
VANCOUVER BC
CANADA V6T 2A3

HELMUT W BAER
LOS ALAMOS NATIONAL LABORATORY
MP4 MAIL STOP H846
LOS ALAMOS NM 87545

OLIVER KEITH BAKER (STANFORD)
LOS ALAMOS NATIONAL LABORATORY
MP3 MAIL STOP H809
LOS ALAMOS NM 87545

BARRY BARISH
CALIFORNIA INSTITUTE OF TECHNOLOGY
248 LAURISTEN LABORATORY
PASADENA CA 91125

MARVIN BLECHER (VIRGINIA STATE)
TRIUMF
4004 WESBROOK MALL
VANCOUVER BC
CANADA V6N 2E2

RICHARD L BOUDRIE
LOS ALAMOS NATIONAL LABORATORY
MP10 MAIL STOP H831
LOS ALAMOS NM 87545

J DAVID BOWMAN
LOS ALAMOS NATIONAL LABORATORY
MP4 MAIL STOP H846
LOS ALAMOS NM 87545

JAMES N BRADBURY
LOS ALAMOS NATIONAL LABORATORY
MP3 MAIL STOP H844
LOS ALAMOS NM 87545

WILLIAM J BRISCOE
GEORGE WASHINGTON UNIVERSITY
PHYSICS DEPARTMENT
725 21ST STREET NORTHWEST
WASHINGTON DC 20052

ANDREW BROWMAN
LOS ALAMOS NATIONAL LABORATORY
MPDO MAIL STOP H848
LOS ALAMOS NM 87545

ROBERT D BROWN
LOS ALAMOS NATIONAL LABORATORY
MP7 MAIL STOP H840
LOS ALAMOS NM 87545

RONALD BROWN
LOS ALAMOS NATIONAL LABORATORY
P3 MAIL STOP D449
LOS ALAMOS NM 87545

HOWARD C BRYANT
DEPARTMENT OF PHYSICS/ASTRONOMY
UNIVERSITY OF NEW MEXICO
ALBUQUERQUE NM 87131

GEORGE BURLESON
PHYSICS DEPARTMENT
NEW MEXICO STATE UNIVERSITY
LAS CRUSES NM 88003

MARY J BURNS
LOS ALAMOS NATIONAL LABORATORY
MP1 MAIL STOP H810
LOS ALAMOS NM 87545

ROBERT L BURMAN
LOS ALAMOS NATIONAL LABORATORY
MP4 MAIL STOP H846
LOS ALAMOS NM 87545

ED D BUSH JR
LOS ALAMOS NATIONAL LABORATORY
MP8 MAIL STOP H826
LOS ALAMOS NM 87545

KENNETH B BUTTERFIELD
LOS ALAMOS NATIONAL LABORATORY
Q2 MAIL STOP J562
LOS ALAMOS NM 87545

THOMAS A CAREY
LOS ALAMOS NATIONAL LABORATORY
P2 MAIL STOP D456
LOS ALAMOS NM 87545

ROGER D CARLINI
LOS ALAMOS NATIONAL LABORATORY
MP14 MAIL STOP H847
LOS ALAMOS NM 87545

JOSEPH CARLSON
LOS ALAMOS NATIONAL LABORATORY
T5 MAIL STOP B283
LOS ALAMOS NM 87545

DONALD R F COCHRAN
LOS ALAMOS NATIONAL LABORATORY
MPDO MAIL STOP H830
LOS ALAMOS NM 87545

D WAYNE COOKE
LOS ALAMOS NATIONAL LABORATORY
MP3 MAIL STOP H844
LOS ALAMOS NM 87545

MARTIN D COOPER
LOS ALAMOS NATIONAL LABORATORY
MP4 MAIL STOP H846
LOS ALAMOS NM 87545

GERARD M CRAWLEY
MICHIGAN STATE UNIVERSITY
NATIONAL SUPERCONDUCTING
CYCLOTRON LABORATORY
EAST LANSING MI 48824 1321

JOEY B DONAHUE
LOS ALAMOS NATIONAL LABORATORY
MP7 MAIL STOP H840
LOS ALAMOS NM 87545

BRYON DIETERLY
PHYSICS DEPARTMENT
UNIVERSITY OF NEW MEXICO
ALBUQUERQUE NM 87131

THOMAS DOMBECK
LOS ALAMOS NATIONAL LABORATORY
P3 MAIL STOP D449
LOS ALAMOS NM 87545

KALVIR S DHUGA (NEW MEXICO STATE)
LOS ALAMOS NATIONAL LABORATORY
MP10 MAIL STOP H841
LOS ALAMOS NM 87545

BRUCE J DROPESKY
LOS ALAMOS NATIONAL LABORATORY
INCDO MAIL STOP J519
LOS ALAMOS NM 87545

ROBERT EISENSTEIN
NUCLEAR PHYSICS LABORATRY
UNIVERSITY OF ILLINOIS
23 STADIUM DRIVE
CHAMPAIGN IL 61820

DAVID ERNST
TEXAS A AND M UNIVERSITY
PHYSICS DEPARTMENT
COLLEGE STATION TX 77843

JOHN A FAUCETT (NEW MEXICO STATE)
LOS ALAMOS NATIONAL LABORATORY
MPDO MAIL STOP H831
LOS ALAMOS NM 87545

ALI FAZELY (LOUISIANA STATE)
LOS ALAMOS NATIONAL LABORATORY
MPVC MAIL STOP H831
LOS ALAMOS NM 87545

XI-HANG FENG (CHINA)
LOS ALAMOS NATIONAL LABORATORY
INC11 MAIL STOP.H824
LOS ALAMOS N 87545

RAYMOND FERGERSON (RUTGERS)
LOS ALAMOS NATIONAL LABORATORY
MP10 MAIL STOP H841
LOS ALAMOS NM 87545

WILL M FOREMAN
LOS ALAMOS NATIONAL LABORATORY
MP1 MAIL STOP H828
LOS ALAMOS NM 87545

STUART J FREEDMAN
PHYSICS DIVISION
ARGONNE NATIONAL LABORATORY
9700 CASS AVENUE
ARGONNE IL 60439

ROBERT W GARNETT
PHYSICS DEPARTMENT
NEW MEXICO STATE UNIVERSITY
LAS CRUCES NM 88003

GERALD T GARVEY
LOS ALAMOS NATIONAL LABORATORY
LAMPF/DIR MAIL STOP H836
LOS ALAMOS NM 87545

AVIGDOR GAVRON
LOS ALAMOS NATIONAL LABORATORY
P2 MAIL STOP D456
LOS ALAMOS NM 87545

DONALD GEESAMAN
PHYSICS DEPARTMENT
ARGONNE NATIONAL LABORATORY
ARGONNE IL 60439

EDWARD F GIBSON
PHYSICS DEPARTMENT
CALIFORNIA STATE UNIVERSITY
6000 J STREET
SACRAMENTO CA 95819

JOSEPH GINOCCHIO
LOS ALAMOS NATIONAL LABORATORY
T5 MAIL STOP B283
LOS ALAMOS NM 87545

CHARLES GLASHAUSSER
RUTGERS UNIVERSITY
DEPARTMENT OF PHYSICS/ASTRONOMY
BOX 849
PISCATAWAY NJ 08854

GEORGE GLASS (TEXAS A AND M)
LOS ALAMOS NATIONAL LABORATORY
MPVC MAIL STOP H831
LOS ALAMOS NM 87545

TERRY J GOLDMAN
LOS ALAMOS NATIONAL LABORATORY
T5 MAIL STOP B283
LOS ALAMOS NM 87545

CHARLES D GOODMAN
INDIANA UNIVERSITY CYCLOTRON FACILITY
MILO B SAMPSON LANE
BLOOMINGTON IN 47405

STEVEN J GREENE
LOS ALAMOS NATIONAL LABORATORY
MP10 MAIL STOP H841
LOS ALAMOS NM 87545

DONALD C HAGERMAN
LOS ALAMOS NATIONAL LABORATORY
MPDO MAIL STOP H850
LOS ALAMOS NM 87545

QUAMRUL HAIDER
LOS ALAMOS NATIONAL LABORATORY
INC11 MAIL STOP H824
LOS ALAMOS NM 87545

STANLEY HANNA
STANFORD UNIVERSITY
PHYSICS DEPARTMENT
STANFORD CA 94305

JAMES F HARRISON
LOS ALAMOS NATIONAL LABORATORY
MP1 MAIL STOP H810
LOS ALAMOS NM 87545

JU HE (CHINA)
LOS ALAMOS NATIONAL LABORATORY
MP4 MAIL STOP H846
LOS ALAMOS NM 87545

ROBERT H HEFFNER
LOS ALAMOS NATIONAL LABORATORY
P10 MAIL STOP K764
LOS ALAMOS NM 87545

LEON HELLER
LOS ALAMOS NATIONAL LABORATORY
T5 MAIL STOP B283
LOS ALAMOS NM 87545

ERNEST HENLEY
PHYSICS DEPARTMENT FM 15
UNIVERSITY OF WASHINGTON
SEATTLE WA 98195

WILMOT N HESS
ASSOCIATE DIRECTOR FOR HIGH ENERGY
AND NUCLEAR PHYSICS
XR 20 GTN
US DEPARTMENT OF ENERGY
WASHINGTON DC 20545

ROBERT E HILL
LOS ALAMOS NATIONAL LABORATORY
MP2 MAIL STOP H812
LOS ALAMOS NM 87545

MARTHA V HOEHN
LOS ALAMOS NATIONAL LABORATORY
MP7 MAIL STOP H840
LOS ALAMOS NM 87545

CYRUS M HOFFMAN
LOS ALAMOS NATIONAL LABORATORY
MP4 MAIL STOP H846
LOS ALAMOS NM 87545

EARL W HOFFMAN
LOS ALAMOS NATIONAL LABORATORY
MP1 MAIL STOP H828
LOS ALAMOS NM 87545

GERALD HOFFMANN
PHYSICS DEPARTMENT RLM 5 208
UNIVERSITY OF TEXAS
AUSTIN TX 78712

GARY E HOGAN
LOS ALAMOS NATIONAL LABORATORY
MP4 MAIL STOP H846
LOS ALAMOS NM 87545

E BARRIE HUGHES
HANSEN LABORATORIES
STANFORD UNIVERSITY
STANFORD CA 94305

RICHARD L HUTSON
LOS ALAMOS NATIONAL LABORATORY
MP3 MAIL STOP H844
LOS ALAMOS NM 87545

DONALD ISENHOWER
ABILENE CHRISTIAN UNIVERSITY
PHYSICS DEPARTMENT
ACU STATION BOX 7646
ABILENE TX 79699

JOHN J JARMER
LOS ALAMOS NATIONAL LABORATORY
MP7 MAIL STOP H840
LOS ALAMOS NM 87545

NELSON JARMIE
LOS ALAMOS NATIONAL LABORATORY
P3 MAIL STOP D449
LOS ALAMOS NM 87545

MIKKEL B JOHNSON
LOS ALAMOS NATIONAL LABORATORY
MPDO MAIL STOP H850
LOS ALAMOS NM 87545

KEVIN W JONES
LOS ALAMOS NATIONAL LABORATORY
MP10 MAIL STOP H841
LOS ALAMOS NM 87545

W WAYNE KINNISON
LOS ALAMOS NATIONAL LABORATORY
P3 MAIL STOP D449
LOS ALAMOS NM 87545

ANDI KLEIN
LOS ALAMOS NATIONAL LABORATORY
MP4 MAIL STOP H846
LOS ALAMOS NM 87545

JAMES N KNUDSON
LOS ALAMOS NATIONAL LABORATORY
MP7 MAIL STOP H840
LOS ALAMOS NM 87545

DANIEL S KOLTUN
PHYSICS AND ASTRONOMY
UNIVERSITY OF ROCHESTER
ROCHESTER NY 14627

THOMAS KOZLOWSKI
LOS ALAMOS NATIONAL LABORATORY
MP1 MAIL STOP H828
LOS ALAMOS NM 87545

ROBERT H KRAUS JR
LOS ALAMOS NATIONAL LABORATORY
INC11 MAIL STOP H824
LOS ALAMOS NM 87545

JACK J KRAUSHAAR
NUCLEAR PHYSICS LABORATORY
UNIVERSITY OF COLORADO
BOULDER CO 80309

DAVID M LEE
LOS ALAMOS NATIONAL LABORATORY
MP13 MAIL STOP H838
LOS ALAMOS NM 87545

MICHAEL LEITCH
LOS ALAMOS NATIONAL LABORATORY
P2 MAIL STOP D456
LOS ALAMOS NM 87545

MELVIN LEON
LOS ALAMOS NATIONAL LABORATORY
MP3 MAIL STOP H844
LOS ALAMOS NM 87545

SHAOFEI LIN (CHINA)
LOS ALAMOS NATIONAL LABORATORY
MP3 MAIL STOP H844
LOS ALAMOS NM 87545

DAVID A LIND
NUCLEAR PHYSICS LABORATORY
UNIVERSITY OF COLORADO
BOULDER CO 80309

JIAN-YANG LUI (CHINA)
LOS ALAMOS NATIONAL LABORATORY
MP8 MAIL STOP H826
LOS ALAMOS NM 87545

LON-CHANG LIU
LOS ALAMOS NATIONAL LABORATORY
INC11 MAIL STOP H824
LOS ALAMOS NM 87545

DUNCAN W MACARTHUR
LOS ALAMOS NATIONAL LABORATORY
Q2 MAIL STOP J562
LOS ALAMOS NM 87545

DONALD R MACHEN
SCIENTIFIC SYSTEMS INTERNATIONAL
3491B TRINITY DRIVE
LOS ALAMOS NM 87544

FESSEHA G MARIAM
LOS ALAMOS NATIONAL LABORATORY
MP5 MAIL STOP H805
LOS ALAMOS NM 87545

JUNE L MATTHEWS
DEPARTMENT OF PHYSICS 26 435
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE MA 02139

JOHN A MCGILL
LOS ALAMOS NATIONAL LABORATORY
MP13 MAIL STOP H838
LOS ALAMOS NM 87545

EDWARD K MCINTYRE
DEPARTMENT OF PHYSICS
BOSTON UNIVERSITY
BOSTON MA 02215

KOK-HEONG MCNAUGHTON (U OF TEXAS)
LOS ALAMOS NATIONAL LABORATORY
MPVC MAIL STOP H831
LOS ALAMOS NM 87545

MICHAEL MCNAUGHTON
LOS ALAMOS NATIONAL LABORATORY
MP13 MAIL STOP H838
LOS ALAMOS NM 87545

RALPH C MINEHART (U OF VIRGINIA)
STANFORD LINEAR ACCELERATOR CENTER
STANFORD UNIVERSITY
PO BOX 4349
STANFORD CA 94305

RICHARD E MISCHKE
LOS ALAMOS NATIONAL LABORATORY
MP4 MAIL STOP H846
LOS ALAMOS NM 87545

SHEKHAR MISHRA
PHYSICS DEPARTMENT
UNIVERSITY OF SOUTH CAROLINA
COLUMBIA SC 29208

DAVID C MOODY
LOS ALAMOS NATIONAL LABORATORY
INC11 MAIL STOP J514
LOS ALAMOS NM 87545

C FRED MOORE
PHYSICS DEPARTMENT RLM 5 208
UNIVERSITY OF TEXAS
AUSTIN TX 78712

CHRISTOPHER L MORRIS
LOS ALAMOS NATIONAL LABOARATORY
MP10 MAIL STOP H841
LOS ALAMOS NM 87545

JOEL M MOSS
LOS ALAMOS NATIONAL LABORATORY
P2 MAIL STOP D456
LOS ALAMOS NM 87545

GORDON S MUTCHLER
T W BONNER NUCLEAR LABORATORY
RICE UNIVERSITY
HOUSTON TX 77251

DARRAGH E NAGLE
LOS ALAMOS NATIONAL LABORATORY
MP4 MAIL STOP H832
LOS ALAMOS NM 87545

BERNARD M K NEFKENS
PHYSICS DEPARTMENT P J01
UNIVERSITY OF CALIFORNIA
LOS ANGELES CA 90024

MICHAEL M NIETO
LOS ALAMOS NATIONAL LABORATORY
T8 MAIL STOP B285
LOS ALAMOS NM 87545

JAN K NOVAK
LOS ALAMOS NATIONAL LABORATORY
MP7 MAIL STOP H840
LOS ALAMOS NM 87545

MICHAEL A OOTHOUDT
LOS ALAMOS NATIONAL LABORATORY
MP1 MAIL STOP H828
LOS ALAMOS NM 87545

GIANNI PAULETTA (U OF TEXAS)
LOS ALAMOS NATIONAL LABORATORY
MP10 MAIL STOP H841
LOS ALAMOS NM 87545

SEPPO PENTTILA (U OF TURKU)
LOS ALAMOS NATIONAL LABORATORY
MP7 MAIL STOP 840
LOS ALAMOS NM 87545

ROY JERRY PETERSON
UNIVERSITY OF COLORADO
NUCLEAR PHYSICS LABORATORY
CAMPUS BOX 446
BOULDER CO 80309

GERALD C PHILLIPS
T W BONNER NUCLEAR LABORATORY
RICE UNIVERSITY PO 1892
HOUSTON TX 77251

LEO PIILONEN
LOS ALAMOS NATIONAL LABORATORY
MP4 MAIL STOP H844
LOS ALAMOS NM 87545

NOBERT PORILE
DEPARTMENT OF CHEMISTRY
PURDUE UNIVERSITY
WEST LAFAYETTE IN 47907

BARRY PREEDOM
PHYSICS DEPARTMENT
UNIVERSITY OF SOUTH CAROLINA
COLUMBIA SC 29208

JACK RAPAPORT
LOS ALAMOS NATIONAL LABORATORY
P3 MAIL STOP D449
LOS ALAMOS NM 87545

MOHINI W RAWOOL (NEW MEXICO STATE)
LOS ALAMOS NATIONAL LABORATORY
MPVC MAIL STOP H831
LOS ALAMOS NM 87545

GLEN A REBKA JR
PHYSICS DEPARTMENT
UNIVERSITY OF WYOMING
LARAMIE WY 82071

ROBERT P REDWINE
PHYSICS DEPARTMENT 26 447
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE MA 02139

CLARENCE R RICHARDSON
DIVISION OF NUCLEAR PHYSICS
ER 23 GTN
US DEPARTMENT OF ENERGY
WASHINGTON DC 20545

PETER RILEY
PHYSICS DEPARTMENT
UNIVERSITY OF TEXAS
AUSTIN TX 78712

BARRY G RITCHIE
PHYSICS DEPARTMENT
ARIZONA STATE UNIVERSITY
TEMPE AZ 85287

B LEE ROBERTS
PHYSICS DEPARTMENT
BOSTON UNIVERSITY
BOSTON MA 02215

SAYED ROKNI (UTAH STATE U)
LOS ALAMOS NATIONAL LABORATORY
MPVC MAIL STOP H831
LOS ALAMOS NM 87545

THOMAS A ROMANOWSKI
PHYSICS DEPARTMENT
SMITH LABORATORY
OHIO STATE UNIVERSITY
COLUMBUS OH 43210

PHILIP ROOS
PHYSICS AND ASTRONOMY DEPARTMENT
UNIVERSITY OF MARYLAND
COLLEGE PARAK MD 20742

LOUIS ROSEN
LOS ALAMOS NATIONAL LABORATORY
MPDO MAIL STOP H832
LOS ALAMOS NM 87545

RICHARD D RYDER
LOS ALAMOS NATIONAL LABORATORY
P9 MAIL STOP H807
LOS ALAMOS NM 87545

MICHAEL SADLER
PHYSICS DEPARTMENT
ABILENE CHRISTIAN UNIVERSITY
ACU STATION BOX 7646
ABILENE TX 79699

BIJAN SAGHAI
CEN SACLAY
DPHN HE
BP NO 2 91190 GIF SUR YVETTE
FRANCE

VERNON D SANDBERG
LOS ALAMOS NATIONAL LABORATORY
MP4 MAIL STOP H846
LOS ALAMOS NM 87545

SUDHIR SEN
UNIVERSITY OF TEXAS
PHYSICS DEPARTMENT
AUSTIN TX 78712

E BROOKS SHERA
LOS ALAMOS NATIONAL LABORATORY
PDO MAIL STOP D434
LOS ALAMOS NM 87545

TOMI SHIMA
LOS ALAMOS NATIONAL LABORATORY
MPVC MAIL STOP H831 (ARGONNE)
LOS ALAMOS NM 87545

ELTON SMITH (OHIO STATE UNIVERSITY)
LOS ALAMOS NATIONAL LABORATORY
MPVC MAIL STOP H831
LOS ALAMOS NM 87545

HAROLD M SPINKA JR
ARGONNE NATIONAL LABORATORY
BUILDING 362 HEP
ARGONNE IL 60439

THOMAS G SQUIRES
ASSOCIATED WESTERN UNIVERSITIES INC
142 EAST 200 SOUTH 200
SALT LAKE CITY UT 84111

EDWARD STEPHENSON
INDIANA UNIVERSITY CYCLOTRON FACILITY
2401 MILO B SAMPSON LANE
BLOOMINGTON IN 47405

GERARD STEPHENSON JR
LOS ALAMOS NATIONAL LABORATORY
PDO MAIL STOP D434
LOS ALAMOS NM 87545

DANIEL D STROTTMAN
LOS ALAMOS NATIONAL LABORATORY
T9 MAIL STOP B279
LOS ALAMOS NM 87545

NOBUYUKI TANAKA
LOS ALAMOS NATIONAL LABORATORY
MP10 MAIL STOP H841
LOS ALAMOS NM 87545

HENRY A THIESSEN
LOS ALAMOS NATIONAL LABORATORY
MP14 MAIL STOP H847
LOS ALAMOS NM 87545

JAMES R TINSLEY
PHYSICS DEPARTMENT
ARIZONA STATE UNIVERSITY
TEMPE AZ 85281

JOHN ULLMANN
LOS ALAMOS NATIONAL LABORATORY
P3 MAIL STOP D449
LOS ALAMOS NM 87545

GORDON J VAN DALEN
UNIVERSITY OF CALIFORNIA (RIVERSIDE)
DEPARTMENT OF PHYSICS
RIVERSIDE CA 92521

OLIN B VAN DYCK
LOS ALAMOS NATIONAL LABORATORY
MPDO MAIL STOP H848
LOS ALAMOS NM 87545

W JOSEPH VAN DYKE
LOS ALAMOS NATIONAL LABORATORY
MP8 MAIL STOP H826
LOS ALAMOS NM 87545

DAVID J VIEIRA
LOS ALAMOS NATIONAL LABORATORY
INC11 MAIL STOP H824
LOS ALAMOS NM 87545

DONALD I WALKER
ASSOCIATED WESTERN UNIVERSITIES
142 EAST 200 SOUTH #200
SALT LAKE CITY UT 84111

ANGEL T M WANG (UCLA)
LOS ALAMOS NATIONAL LABORATORY
MPVC MAIL STOP H831
LOS ALAMOS NM 87545

JOHN WARREN (LAKEHEAD UNIVERSITY)
1016 47TH STREET
LOS ALAMOS NM 87544

GEERT WENES
LOS ALAMOS NATIONAL LABAORATORY
T5 MAIL STOP B283
LOS ALAMOS NM 87545

RICHARD D WERBECK
LOS ALAMOS NATIONAL LABORATORY
MP7 MAIL STOP H840
LOS ALAMOS NM 87545

D HYWEL WHITE
LOS ALAMOS NATIONAL LABORATORY
MP4 MAIL STOP H846
LOS ALAMOS NM 87545

CAROL A WILKINSON
LOS ALAMOS NATIONAL LABORATORY
MP4 MAIL STOP H846
LOS ALAMOS NM 87545

MAHLON T WILSON
LOS ALAMOS NATIONAL LABORATORY
ATDO MAIL STOP H811
LOS ALAMOS NM 87545

RICHARDS WOODS
LOS ALAMOS NATIONAL LABORATORY
LANSCE MAIL STOP H807
LOS ALAMOS NM 87545

JAN WOUTERS
LOS ALAMOS NATIONAL LABORATORY
INC11 MAIL STOP H824
LOS ALAMOS NM 87545

JOHN D ZUMBRO (PENNSYLVANIA)
LOS ALAMOS NATIONAL LABORATORY
MP10 MAIL STOP H831
LOS ALAMOS NM 87545

LAMPF USERS GROUP NEWS

1987 BOARD OF DIRECTORS OF THE LAMPF USERS GROUP, INC.

The Board of Directors consists of a Secretary/Treasurer and seven members elected by the LAMPF Users Group, Inc., whose interests they represent and promote. They concern themselves with LAMPF programs, policies, future plans, and especially with how Users are treated at LAMPF. Users should address problems and suggestions to individual Board members.

The Board also nominates new members to the Program Advisory Committee (PAC).

The 1987 membership and term expiration dates are listed below.

1988	June Matthews (Chairman) Massachusetts Institute of Technology
1989	Stanley Hanna (Chairman-Elect) Stanford University
1987	Barry Preedom (Past-Chairman) University of South Carolina
	James Bradbury (Secretary/Treasurer) Los Alamos National Laboratory
1988	Joseph Ginocchio Los Alamos National Laboratory
1987	Charles Goodman Indiana University
1987	Gerald Hoffmann University of Texas
1988	R. Jerry Peterson University of Colorado

TECHNICAL ADVISORY PANEL (TAP) OF THE LAMPF USERS GROUP, INC.

The TAP provides technical recommendations to the Board of Director and LAMPF management about the development of experimental facilities and experiment support activities. The TAP has 12 members, appointed by the Board of Directors, serving 3-year staggered terms. The Chairman of the Board of Directors seves as TAP chairman. The TAP membership and term expiration dates are listed below. The members shown below are the 1986 TAP members. The 1987 members will be chosen in the Spring of 1987.

1988	Gary Adams Rensselaer Polytechnic Institute
1986	William Briscoe George Washington University
1987	J. David Bowman Los Alamos National Laboratory
1988	Peter Doe University of California
1988	Ralph Minehart University of Virginia
1986	Michael A. Oothoudt Los Alamos National Laboratory
1987	Roy J. Peterson University of Colorado
1987	Robert E. Pollock Indiana University
1986	Gary Sanders Los Alamos National Laboratory
1988	Harold Spinka Argonne National Laboratory
1988	Edward J. Stephenson Indiana University
1986	Charles Whitten University of California

1987 WORKING GROUP CHAIRMEN

High-Resolution Spectrometer (HRS)
Sirish Nanda
University of Minnesota

Neutrino Facilities
Roger Carlini
Los Alamos

Stopped-Muon Channel (SMC)
Martin Cooper
Los Alamos

Nuclear Chemistry
Lon-Chang Liu
Los Alamos

Energetic Pion Channel and Spectrometer (EPICS)
David Oakley
University of Texas

High-Energy Pion Channel (P^3)
Michael Sadler
Abilene Christian University

Nucleon Physics Laboratory (NPL)
Upgrade/Medium-Resolution Spectrometer
George Glass
Texas A&M University

Computer Facilities
Kok-Heong McNaughton
University of Texas

Solid-State Physics and Materials Science
Ron Livak
Los Alamos

Low-Energy Pion Channel (LEP)
James Knudson
Los Alamos

LAMPF PROGRAM ADVISORY COMMITTEE (PAC)

The Program Advisory Committee (PAC) consists of about 25 members appointed for staggered 3-year terms. Members advise the Director of LAMPF on the priorities they deem appropriate for the commitment of beam time and the allocation of resources for development of experimental facilities. The PAC meets twice each year for one week during which all new proposals that have been submitted at least two months before the meeting date are considered. Old proposals, and the priorities accorded to them, also may be reviewed.

Terms Expiring in 1987

Eric G. Adelberger
University of Washington

Gerard M. Crawley
Michigan State University

William R. Gibbs
Los Alamos

Wick Haxton
Los Alamos

Stanley B. Kowalski
Massachusetts Institute of Technology

Philip G. Roos
University of Maryland

Benjamin Zeidman
Argonne National Laboratory

Terms Expiring in 1988

Hall L. Crannell
Catholic University of America

David J. Ernst
Texas A&M University

James L. Friar
Los Alamos

Daniel S. Koltun
University of Rochester

W. Gary Love
University of Georgia

Norbert T. Porile
Purdue University

. Hywel White
os Alamos

Terms Expiring in 1989

Paul T. Debevec
University of Illinois

Ralph G. Korteling
Simon Fraser University

Robert McKeown
California Institute of Technology

John W. Negele
Massachusetts Institute of Technolo

James R. Shephard
University of Colorado

Daniel D. Strottman
Los Alamos

LAMPF USERS GROUP, LUGI

Board of Directors

The LAMPF Users Group, Inc. (LUGI), Board of Directors (BOD) met on February 14, July 15, and October 26, 1986. All meetings were chaired by Barry Preedom: selected topics of discussion are provided below:

There were 161 registrants for the 1986 Annual Users Meeting. The papers presented at the meeting and the minutes of the workshops are given in the proceedings.

The Program Advisory Committee (PAC) met in February and August 1986. For these two sessions 50 new proposals were received. The breakdown follows:

HRS	10
EPICS	17
LEP	9
Nuclear Chemistry	1
NPL	1
SMC	2
P^3	6
Material Science	3
Neutrino	1

The BOD selected Ronald Gary Jeppesen (University of Colorado) as the recipient of the Louis Rosen Prize for 1986 with his thesis "Observation of Gamow-Teller and Fermi Strength in Light Nuclei Using the 800 MeV(p,n) Reaction."

The following workshops are scheduled to be held at LAMPF.

Photon and Neutral Meson Physics at Intermediate Energies
January 7-9, 1987

International Workshop on Hadron Facility Technology
February 1-5, 1987 (Held in Santa Fe)

Pion-Nucleus Physics: Future Directions and New Facilities at LAMPF
August 17-21, 1987

Annual Users Meeting
November 9-10, 1987

Exp. 1016

INELASTIC PION SCATTERING FROM ^{27}Al and ^{28,29}Si

Spokesmen: M. Burlein, H. T. Fortune, University of Pennsylvania
University of Pennsylvania: R. Gilman, J. O'Donnell, J. D. Zumbro, M. Burlein, H. T. Fortune
New Mexico State University: K. S. Dhuga
Los Alamos: C. L. Morris
University of Texas: C. F. Moore, M. J. Smithson
University of Texas & Ben-Gurion University: S. Mordechai

We propose to measure inelastic $\pi^{\pm}$ scattering on ^{27}Al and ^{28,29}Si. We intend to measure M_n and M_p for E2 and E4 transitions. This experiment will improve our understanding of how the addition of a valence particle or hole to the doubly closed d5/2 sub-shell of ^{28}Si polarizes the core.

Exp. 1017

INTERFERENCE EFFECTS IN NONANALOG PION DOUBLE CHARGE EXCHANGE

Spokesmen: K. S. Dhuga, New Mexico State University
H. T. Fortune, University of Pennsylvania
University of Texas: M. A. Bryan, J. W. McDonald, C. Fred Moore, S. Mordechai, D. S. Oakley, M. J. Smithson
University of Pennsylvania: M. Burlein, R. Gilman, J. O'Donnell, J. D. Zumbro, H. T. Fortune
New Mexico State University: G. R. Burleson, K. S. Dhuga, J. A. Faucett, M. W. Ravool
Los Alamos: C. L. Morris

At present, the most complicated microscopic models of pion double charge exchange (without phenomenological ρ^2 terms) include at most sequential plus Δ-nucleon-interaction diagrams. If these microscopic models can explain the forward minima observed in T=1 analog double charge exchange angular distributions, the models would also require similarly shaped angular distributions to occur for nonanalog double charge exchange. We propose to search for such phenomena in the $^{16}O(\pi^+,\pi^-)^{16}Ne$(g.s.) reaction.

Exp. 1018

STUDY OF MEDIUM MODIFICATIONS WITH LARGE-ANGLE PION-NUCLEUS SCATTERING ACROSS THE RESONANCE REGION

Spokesmen: K. S. Dhuga and John A. Faucett, New Mexico State University
New Mexico State University: K. S. Dhuga, J. A. Faucett, G. R. Burleson
Los Alamos: R. L. Boudrie, S. J. Greene, C. L. Morris, S. Seestrom-Morris
University of Texas: C. F. Moore, A. Williams, J. McDonald
University of Pennsylvania: J. D. Zumbro

We have analysed large-angle pion elastic data on ^{12}C and ^{16}O with standard first-order optical models using matter distributions deduced from electron scattering. We show that these models reproduce only the qualitative features of the data. However, much better agreement can be achieved with the same models provided the matter distributions are modified in a suitable way. At this stage it is not clear whether these corrections are applicable to all nuclei or indeed if they apply at energies other than on resonance. In order to address these questions we propose to measure π^+ elastic excitation functions (at 175 deg) on ^6Li, ^{28}Si and ^{58}Ni in the energy range 100 to 250 MeV, in steps of 15 MeV. We also request time to measure π^+ angular distributions at large angles on ^6Li (at 180 MeV), ^{28}Si (at 130, 180, and 226 MeV) and ^{58}Ni (at 162 MeV). The total data production time requested is 294 hours.

Exp. 1019

INVESTIGATION OF LOW-ENERGY DOUBLE CHARGE EXCHANGE ON ^{40}Ca

Spokesmen: J. A. Faucett, New Mexico State University
J. D. Zumbro, University of Pennsylvania
New Mexico State University: K. S. Dhuga, J. A. Faucett, M. W. Rawool
University of Pennsylvania: R. Gilman, J. D. Zumbro
Los Alamos: C. L. Morris, M. A. Plum

Double charge exchange data on T=1 nuclei to isobaric analog states for incident pion energies from 50 to 100 MeV are similar in shape and magnitude. The sparse data for T>1 nuclei show similar patterns except that the cross section magnitudes are somewhat smaller. Data for the T=0 nucleus ^{12}C, which is for a non-analog transition, also show the same pattern as the analog transitions, and the cross sections are a factor of 4 smaller than those of the T=1 cases. In order to obtain information on the possible isospin- and A-dependences, we propose to measure an angular distribution and an excitation function for DCX on ^{40}Ca. Our total time request is 335 hours.

Exp. 1020

LOW-ENERGY PION DOUBLE-CHARGE EXCHANGE ON ^{42}Ca and ^{44}Ca

Spokesmen: M. J. Leitch, Los Alamos
E. Piasetzky, Tel Aviv University
Los Alamos: M. J. Leitch, J. C. Peng, H. W. Baer, R. L. Burman, F. Irom
C. L. Morris
Tel Aviv University: E. Piasetzky, Z. Weinfeld
Argonne: R. Gilman
Virginia Polytechnic Institute: D. H. Wright

We propose to measure the differential cross sections for pion double-charge exchange on ^{42}Ca and ^{44}Ca near 50 MeV. The cross sections for T=1 nuclei up to ^{26}Mg are roughly A-independent. If this A-independent trend is used to extrapolate to the cross section for ^{42}Ca then the measured cross section for ^{48}Ca is about a factor of two smaller than this ^{42}Ca prediction despite the large pair counting factor of (N-Z)(N-Z-1)/2 = 28 for ^{48}Ca. The proposed measurements of DCX on ^{42}Ca and ^{44}Ca will help to identify the mechanisms responsible for suppressing the DIAS strength in ^{42}Ca compared to the light T=1 nuclei and/or the large quenching of the DIAS transition as a function of the number of excess neutrons.

Exp. 1021

ELASTIC SCATTERING OF ≈ 325 MeV PROTONS FROM ^{28}Si, ^{58}Ni AND ^{208}Pb

Spokesman: D. C. Cook, University of Minnesota
University of Minnesota: N. M. Hintz, M. Gazzaly, M. Franey, T. Mack
University of Texas: G. Pauletta, M. Barlett, G. W. Hoffmann

We propose to measure the cross section and analyzing power of the elastic, and low-lying collective states in ^{28}Si, ^{58}Ni and ^{208}Pb at a bombarding energy near 325 MeV from lab angles 4° - 38.5° in 1.5° intervals. The primary purpose of this experiment is to obtain more reliable optical potentials for these isotopes so that existing data in this energy region can be better analyzed. In particular, the analysis of the 6^+, 5.13 MeV state in ^{58}Ni will benefit from this additional information. Also, the analyzing power data obtained for the low-lying collective states will provide a test of the DWIA near 325 MeV.

Exp. 1022

STUDIES OF ETA-NUCLEUS BOUND SYSTEMS

Spokesmen: B. J. Lieb, George Mason University
L. C. Liu, Los Alamos
George Mason University: B. J. Lieb
Los Alamos: B. J. Dropesky, R. J. Estep, Q. Haider, L. C. Liu,
P. A. M. Gram, S. J. Greene, C. J. Morris
College of William and Mary: J. M. Finn, H. O. Funsten,
C. F. Perdrisat, V. Punjabi
Virginia State University: C. E. Stronach

We propose to conduct a search for a new form of matter - the η-mesic nucleus. Recent theoretical calculations by Haider and Liu predict the existence of nuclear bound states of the η meson in nuclei with mass number greater than eleven. We propose an experiment to search for the η-mesic nucleus $^{15}_{\eta}$O by studying the reaction $\pi^+ + {}^{16}O \rightarrow p + {}^{15}_{\eta}O \rightarrow + \pi^- + (pX)$ at a pion laboratory momentum of 640 MeV/c. We will measure the coincidence between the prompt proton (observed with Bismuth-Germanate detectors) and the π^- (detected with the large-acceptance spectrometer) that comes from the decay of the η-mesic nucleus. Theoretical estimates indicate that a high-energy π^- is a unique signature for the existence of the η-mesic nucleus.

Exp. 1023

ANALYZING POWER MEASUREMENTS FOR THE (π^+,π^0) REACTION ON A POLARIZED ^{13}C TARGET

Spokesmen: J. Comfort, Arizona State University
G. Kyle, New Mexico State University
Arizona State University: B. Ritchie, 1 postdoc and students
New Mexico State University: G. Burleson, K. Dhuga, J. Faucett, and
students
Los Alamos: H. Baer, J. D. Bowman, J. Jarmer, S. Penttilä
University of Maryland: N. Chant, P. Roos, 1 postdoc

Stanford University: S. Hanna
University of Texas: G. Hoffmann
TRIUMF: G. Smith

We propose to measure the analyzing power of the $^{13}C(\pi^+,\pi^0)$ reaction to the $1/2^-$ isobaric-analogue ground state of ^{13}N. Data will be obtained at the delta resonance energy of 165 MeV and at angular settings near 25°, 45°, and 65°. A polarized ^{13}C target will be used. This proposal is intended to initiate a new program of measurements of pion scattering and reactions from polarized nuclear targets. In combination with cross-section data, analyzing-power measurements can provide new and unique information on the relative phases of the spin-independent and spin-dependent terms in the effective pion-nucleon interaction within the nuclear medium. The data from the proposed measurements will be compared with predictions from models of pion-nucleus interactions. They will enable a better understanding of these models and may provide unique insights into the spin dependence of the delta-nucleus interaction.

Exp. 1024

LIFETIME MEASUREMENTS OF EXTREMELY NEUTRON-RICH NUCLIDES BY DELAYED NEUTRON COUNTING AT TOFI

Spokesman: R. A. Warner, Pacific Northwest Laboratory
Clark University: D. S. Brenner, R. H. Kraus,
Los Alamos: G. W. Butler, D. J. Vieira, J. A. Wouters
Utah State University: G. Lind, K. Vaziri
University of Munich: K. E. G. Lobner
Pacific Northwest Laboratory: P. L. Reeder, R. A. Warner
Iowa State University and Ames Laboratory: F. S. Wohn
University of Giessen: H. Wollnik

Lifetimes of more than 40 very neutron-rich light nuclides will be measured using the TOFI spectrometer at LAMPF. Beta-delayed neutrons will be used as a very selective decay signature for these nuclides. The measurements consist of recording the arrival time of each ion identified by the TOFI spectrometer and the arrival time of each neutron in a high efficiency neutron counter surrounding the ion deposition point. In effect, we will be recording delayed coincidences between ions and neutrons. Below fluorine, we expect to measure lifetimes out to the limit of neutron stable nuclides. Without additional data collection time, the experiment also provides data on delayed neutron emission probabilities (P_n) and will identify those nuclides which undergo beta-delayed multi-neutron emission. These decay data will be acquired simultaneously with the mass information for which TOFI was designed. Both facets of the experiment will provide fundamental information about nuclides with unusual numbers of protons and neutrons. Together they will strengthen our knowledge of the mass surface for light nuclides and will provide important data leading to improved theoretical models of nuclear beta decay. The lifetimes and P_n values of very neutron-rich nuclides are needed for more thorough tests of models used to predict these quantities. Ultimate applications for the models (and for some of the later measurements) include astrophysical calculations - particularly for r-process nucleosynthesis. The light element studies proposed here will produce data for some of these tests as well as provide experience for later experiments at higher Z.

Exp. 1025

PION ELASTIC AND INELASTIC SCATTERING FROM POLARIZED ^{13}C

Spokesmen: G. R. Burleson, New Mexico State University
D. Dehnhard, University of Minnesota
New Mexico State University: J. A. Faucett, K. S. Dhuga, G. S. Kyle
Los Alamos: S. J. Greene, J. J. Jarmer, C. L. Morris, N. Tanaka
S. Penttila, M. Plum, S. Seestrom-Morris
University of Minnesota: S. Chakravarti, M. A. Franey, S. K. Nanda
University of Texas: G. W. Hoffmann, C. F. Moore
University of Pennsylvania: H. T. Fortune, J. D. Zumbro
Arizona State University: J. R. Comfort

We are proposing to make measurements of the asymmetry parameter A_y from $\pi^{\pm}$ elastic and inelastic scattering over an angular range of 30° to 100° from a polarized ^{13}C target at EPICS. The elastic scattering results should be sensitive to spin-dependent effects in the pion-nucleus interaction, such as the Δ-nucleus spin-orbit interaction. The inelastic results will be sensitive to the relative mixture of spin-flip and non-spin-flip contributions to the transitions. This will give new information about the pion-nucleus interaction that is not available from experiments with unpolarized targets, since the former measures the interference between amplitudes and the latter measures squares of amplitudes. The target system will be assembled principally from polarized target elements available at LAMPF; additional work will be necessary for installation at EPICS. The experimental beam time requested is one running cycle, taken to be 1200 hours.

Exp. 1026

A STUDY OF THE $^3H(\pi^+,\pi^0)^3He$ REACTION

Spokespersons: P. A. M. Gram, Los Alamos
J. L. Matthews, M.I.T.
G. A. Rebka, University of Wyoming
Glasgow University: R. O. Owens
Los Alamos: P. A. M. Gram
Massachusetts Institute of Technology: E. R. Kinney, J. L. Matthews, T. Soos, M. Wang
University of Wyoming: G. A. Rebka, Jr., D. A. Roberts

We propose to measure the differential cross section for the $^3H(\pi^+,\pi^0)^3He$ reaction at $T_{\pi^+} \approx$ 150, 200, 250, and 290 MeV and center-of-mass angles between 40° and 140°. The measurement will be performed by detecting the recoiling ^3He particles with a magnetic spectrometer.

Exp. 1027

DEVELOPEMENT OF A HIGH ENERGY POLARIMETER BASED ON COULOMB-NUCLEAR INTERFERENCE AND MEASUREMENT OF THE SPIN-AVERAGED SLOPE PARAMETER FOR PP ELASTIC SCATTERING BETWEEN 1.1 AND 1.5 GeV/c

Spokesman: G. Pauletta, University of Texas
University of Texas at Austin: M. Barlett, D. Ciskowski, G. Hoffman, G. Pauletta, M. Purcell
University of Udine: R. Garfagnini, L. Santi
University of Minnesota: M. Gazzaly, N. Hintz, S. Nanda
LAPP Annecy: K. Kuroda, A. Michalowicz
University of Trieste: A. Penzo
Los Alamos: N. Tanaka

We propose to use the HRS to develop a polarimeter based on Coulomb-Nuclear interference which will be used to monitor the polarization of the new high energy polarized proton beam at Fermilab. At the same time, we propose to measure the energy dependence of the pp elastic spin-averaged slope parameter between 1.1 and 1.5 GeV/c. This energy dependence is sensitive to the existence of resonance effects but existing data from different laboratories are not in agreement.

Exp. 1028

MEASUREMENTS OF DOUBLE-CHARGE-EXCHANGE AND ELASTIC SCATTERING ON ^{14}C AND ^{16}O AT ENERGIES ABOVE THE Δ RESONANCE

Spokesmen: H. V. Baer, C. L. Morris, Los Alamos
G. R. Burleson, New Mexico State University
Los Alamos: H. V. Baer, M. J. Leitch, J. A. McGill, C. L. Morris
New Mexico State University: G. R. Burleson, K. S. Dhuga, J. A. Faucett, G. S. Kyle
University of Pennsylvania: H. T. Fortune, M. Burlein, T. O'Donnel J. D. Zumbro
Tel Aviv University: E. Piasetzky
University of Texas: C. F. Moore
Argonne: B. F. Zeidman, R. Gilman
Texas A & M: D. J. Ernst

We propose to measure forward angle (π^+,π^-) double charge exchange (DCX) scattering at 300, 425, and 500 MeV at the P^3 channel. The transitions to be studied are the double analog transitions in ^{14}C and the nonanalog ground state transitions in ^{16}O. The goal of this proposal is to study short range N-N dynamics in nuclei using the DCX reaction. At the higher pion energies a more quantitative analysis appears feasible than at the lower pion energies previously employed. We also propose to measure elastic π^- scattering on ^{16}O at 500 MeV at angles 20° to 60°. Measurements will be made with the modified LAS spectrometer and a modified P^3 channel.

Exp. 1029

STUDY OF PION PRODUCTION ON LIGHT NUCLEI WITH INTERMEDIATE ENERGY PROTONS

Spokesmen: P. G. Roos, N. S. Chant, University of Maryland
University of Maryland: N. S. Chant, B. S. Flanders, J. D. Silk, P. G. Roos, and 2 students
Los Alamos: R. Boudrie, K. Jones, J. McClelland

Coincidence measurements are proposed for the possible $p+A \rightarrow p+\pi+X$ and $p+A \rightarrow d+\pi+X$ reactions on targets of $^{1,2}H$, $^{3,4}He$, and ^{12}C. Our intent is to study the effects of the nuclear medium on the pion production process. Effects which are expected to play a role include off-shell effects, Fermi motion, Δ-propagation and both initial and final state interactions. Initial measurements proposed herein will be carried out at 800 MeV at a limited number of angle pairs in order to survey the phase space available to the production process. Protons and deuterons will be detected with the Medium Resolution Spectrometer (MRS), presently under construction, in coincidence with pions detected using the Large Acceptance Spectrometer (LAS). The proton energies available at LAMPF, in conjunction with the large acceptance of these two spectrometers, are well suited to pion production studies. Cross section measurements are proposed for two MRS angle and three LAS angle settings. Several momentum bites are required for each angle setting in order to adequately sample the regions of three-body and four-body phase space.

For the beam energy and chosen angle pairs the $(p,p\pi^+)$ reactions, which we expect primarily to populate four-body phase space, will be dominated by intermediate Δ^{++} production. The $(p,p\pi^-)$ production, taking place on the neutrons will be significantly smaller in magnitude and may thus allow one to examine other contributions to the production process. The $(p,d\pi^+)$ reactions (at the chosen angles) leave the residual nuclei with low recoil momenta and are expected to have large yield to specific residual states. Such studies of the three-body phase space serve principally to explore the role of Fermi motion. Finally the $(p,d\pi^-)$ reaction offers the possibility of isolating final state interactions through the charge exchange process.

Exp. 1030

PRELIMINARY SEARCH FOR RECOIL FREE Δ PRODUCTION IN THE $^{208}Pb(p,^3He)$ REACTION

Spokesman: N. M. Hintz, University of Minnesota
University of Minnesota: M. Gazzaly, D. Cook, M. Franey, A. Mack
University of Texas: G. Hoffmann, M. Barlett, G. Pauletta
Los Alamos: C. Morris

We propose a preliminary study of the $^{208}Pb(p,^3He)$ reaction around T_p = 500 Mev to search for a collective $(N^{-1}\Delta)$ resonance near E_x = 300 MeV. The $(p,^3He)$ reaction has an experimental advantage, over (p,d) and (p,t) reactions, in that the elastic protons do not occur on the HRS focal plane near the critical momentum transfer ($q \approx 0$) region where the Δ-mode is expected. The $(p,^3He)$ reaction also allows $\Delta T = 1$ as needed.

Exp. 1031

HIGH SPIN STATES IN THE (p,t) REACTION

Spokesman: N. M. Hintz, University of Minnesota
University of Minnesota: D. C. Cook, M. Gazzaly, M. Franey, A. Mack
University of Texas: G. Hoffmann, G. Pauletta, M. Barlett

We propose to study the (p,t) reaction on ^{60}Ni and ^{208}Pb at low residual excitation to search for high-spin ($J \approx$ 6-12) pair-hole states. The population of these states is favored over low spin states by momentum match consideration at intermediate (200-400 MeV) proton energies. We expect to obtain data on both valence (or top shell) hole states as well as on deep pair-hole states up to 20 MeV excitation.

Exp. 1032

π^+ AND π^- ELASTIC SCATTERING ON TRITIUM AND ^{3}He AROUND 78°

Spokesmen: B. M. K. Nefkens, University of California at Los Angeles
B. L. Berman, George Washington University
University of California: D. B. Barlow, R. S. Kessler, G. J. Kim, B. M. K. Nefkens, C. Pillai, J. W.Price, J. A. Wightman,
George Washington University: S. D. Adrian, B. L. Berman, W. J. Briscoe, A. Mokhtari, A. M. Petrov, C. J. Seftor, M. F. Taragin
Ruder Boskovi Institute Zagreb: I. Slaus and students
Abilene Christian University: M. E. Sadler and students

We propose to measure the absolute differential cross sections for the elastic scattering of π^+ and π^- on ^{3}H and ^{3}He at T_π = 100, 140, 180, 200, 220, 260, and 295 MeV in the region of the non-spin-flip dip around $\tilde{\Theta}_\pi$ = 78° using the EPICS facility. Calibration measurements are planned using $\pi^\pm$ elastic scattering on p, d, and ^{4}He. The target cells are the special LAMPF-UCLA high-pressure gas targets consisting of thin-walled aluminum cylinders--the same ones used in our recently completed Experiment #905.

The purposes of the investigation are:

I. To measure the proton matter form factor of tritium and the neutron matter form factor of ^{3}He at four momentum transfers squared t between t =

1.5 and 5.4 fm^{-2}. These matter form factors will be compared with the magnetic form factors measured with electron scattering to investigate directly the magnitude of meson-exchange currents.

II. To investigate the validity of charge symmetry via new measurements of the supperratio

$$R = d\sigma(\pi^{+3}H)d\sigma(\pi^{-3}H)/d\sigma(\pi^{+3}He)d\sigma(\pi^{-3}He)$$

and the "simple" charge-symmetric ratios

$$r_1 = d\sigma(\pi^{+3}H)/d\sigma(\pi^{-3}He) \text{ and } r_2 = d\sigma(\pi^{-3}H)/d\sigma(\pi^{+3}He).$$

In the angular region of this experiment these ratios are important for helping to choose between different hypotheses that have been advanced for explaining the observed deviation of the superratio from 1.0. This deviation implies a violation of nuclear charge symmetry because Coulomb interactions are unable to explain the measured values of R.

III. To probe the applicability of different π^--nucleus interaction models such as: a) the new DWBA code by D. Ernst et. al., b) the first-order optical potential in momentum space by R. Landau, c) the Glauber model by Mestre, and d) the multiple-scattering approach by Gibbs and Gibson.

RESEARCH PROPOSAL ABSTRACTS

Prop. 1033 Study of the Excitation of Giant Resonances in Pion Charge Exchange and the Proton-Neutron Density Distributions in Nuclei

Spokesmen: F. Irom and J. D. Bowman
Participants and Institutions:

Los Alamos National Laboratory

A. Bergmann	J. D. Bowman
F. Irom	J. N. Knudson
A. Shariv	

University of Colorado

J. J. Kraushaar	R. A. Loveman
R. J. Peterson	D. Prout
R. Ristinen	

Stanford University
D. Pocanic

We propose to use the pion single-charge-exchange reactions, $^{40}Ca\ (\pi^{\pm}, \pi^{\circ})$ and $^{32}S(\pi^{\pm}, \pi^{\circ})$ to measure ratio of the maximum (π^{-}, π°) cross sections to the maximum (π^{+}, π°) cross sections for the analog states of the isovector electric giant-dipole resonance in energies below and above (3,3) resonance. In previous studies on ^{40}Ca at 165 MeV we have seen that the (π^{-}, π°) cross section is 1.69 times the (π^{+}, π°) cross section. This is contrary to one might expect from charge symmetry, that is that the cross section for (π^{-}, π°) cross section should be equal to (π^{+}, π°) cross section for T=0 nuclei. We plan to measure this ratio for energies below and above (3,3) resonance to examine the role of the pion mean-free-path for this breakdown of the charge symmetry.

Prop. 1034 Measurement of Light Fragment Emission Spectra From Pion True Absorption

Spokesman: R. A. Loveman
Participants and Institutions:

University of Colorado

J. T. Brack	M. R. Braunstein
B. L. Clausen	J. J. Kraushaar
R. A. Loveman	R. J. Peterson
R. A. Ristinen	K. Vaziri

We propose to measure at LEP the inclusive spectra of light fragments following pion interactions with Ag at 160 MeV. A 'hot spot' model developed initially to describe heavy ion interactions has been applied to pion true absorption. This experiment will provide a conclusive test of the applicability of this model to pion true absorption by examining a wide range of ejectiles. If the model proves valid for this broad set of data, as it did for the limited set of existing data, then the understanding of the dynamics of the hot spot as provided by this model will be a crucial part of the understanding of pion true absorption.

Prop. 1035 Two- and Three-Spin Measurements in pp-pp

Spokesman: M. McNaughton
Participants and Institutions:

Los Alamos National Laboratory

M. McNaughton	S. Penttila

University of California, LA

D. Adams	J. Bystricky
E. Gulmez	G. Igo
A. Ling	M. Moshi
M. Nasser	

Texas A & M University

G. Glass	L. Northcliffe

University of Texas

B. Kielhorn	K. McNaughton
G. Pauletta	P. Riley
S. Sen	

We propose to measure 12 spin dependent parameters in pp elastic scattering at 733 MeV. Angular coverage would be 50 to 80° cm; accuracy would range from ±0.01 to ±0.04. The apparatus used (in EPB) would be identical to that used in exp. 818, except for a change of target material. The time requested is the same as that approved for exp. 960 in BR.

Prop. 1036 The Analyzing Power in the $^{9}Be(p,\pi\pm)$ Reactions at 800 MeV and Its Relation to the Free Pion-Nucleon Scattering Data

Spokesmen: B. Höistad and G. S. Adams
Participants and Institutions:

Renselear Polytechnic Institute

G. S. Adams	P. Stoler
D. Tedeschi	

University of Minnesota
M. Gazzaly

The Gustaf Werner Institute, Uppsala
B. Höistad

Los Alamos National Laboratory

J. A. McGill	K. Jones

University of Texas, Austin
G. Pauletta

Angular distributions of the analyzing power for the $^{9}Be(p,\pi^{+})\,^{10}Be$ and $^{9}Be(p,\pi^{-})^{10}C$ reactions will be measured at 800 MeV. A phenomenological comparison, based on a model for pion emission from the target nucleus, will be made between the analyzing power from the (p,π) reaction and polarization data from pion nucleon scattering. A link between data from the (p,π) reaction and πN is indicated by recent (p,π) data obtained at 650 MeV. The aim of the present measurements is to confirm or dismiss the hypothesis that the analyzing power in the (p,π) reaction at high energies can qualitatively be understood from on shell pion nucleon scattering data.

Prop. 1037 Study of the $(p, 2\pi^+)$ Reaction in Al at 750 MeV

Spokemen: X. Feng and B. J. Dropesky
Participants and Institutions:

Los Alamos National Laboratory
X. Feng B. J. Dropesky

This is a proposal to carry out a relatively simple activation experiment to measure the cross section for the $(p,2\pi^+)$ reaction in aluminum at 750 MeV yielding 21-hour ^{28}Mg. We propose to irradiate a high-purity Al foil (10 mil) for about 40μAh (20μA for 2 hours) in an available isotope production stringer during a beam development period. The experiment requires radiochemical separation and purification of the magnesium fraction from the dissolved target and counting of the characteristic 1.342 MeV γ ray of ^{28}Mg with our calibrated Ge(Li) γ-ray spectrometer.

Although this $(p,2\pi^+)$ reaction is energetically possible at 750 MeV, we expect the cross section to be small because of the high probability of final state interactions by the produced pions. But we estimate we can measure down to about 10 nanobars, and therefore, we consider the experiment feasible.

Prop. 1038 Pion Inelastic Scattering from ^{48}Ti, ^{52}Cr, and ^{56}Fe at 180 MeV: A Study of Anomalously Shaped Angular Distributions

Spokesman: D. S. Oakley
Participants and Institutions:

Los Alamos National Laboratory
C. L. Morris

University of Texas
C. F. Moore S. Mordechai
M. J. Smithson D. S. Oakley
M. A. Bryan A. Williams

University of Pennsylvania
H. T. Fortune M. Burlein

A recent experiment has measured angular distributions from pion-nucleus scattering at $T_\pi = 180$ MeV and found several angular distributions to not compare with the shape predicted by the known ℓ-transfer. A possible uncertainty, however, has been introduced by an elastic impurity in the EPICS beam arising from the installation of a new collimator in 1984.

Because of the importance of the theoretical interpretations of these findings, we propose to remeasure these states at a later date when the collimator problem is remedied.

Prop. 1039 ^{208}Pb$(\pi, \pi' p)^{207}$Tl Coincidence Measurement Near the Giant Resonance Region: An Investigation of Structure and Charge Symmetry

Spokesmen: D. S. Oakley and C. L. Morris
Participants and Institutions:

University of Texas
C. F. Moore — S. Mordechai
D. S. Oakley — M. J. Smithson

University of Minnesota
D. Dehnhard — M. Jones

Los Alamos National Laboratory
C. L. Morris

Louisiana State University
A. Fazely

The reaction $^4He(\pi, \pi' p)^3He$ near the GDR region has recently been measured at EPICS and the π^+ channel was seen to be an order of magnitude higher than the π^- channel. Measurements of the Giant Quadrupole Resonance in ^{208}Pb have yielded ratios of π^- to π^+ cross sections that are unexpectedly large. A possible explanation of both of these anomalies involves isospin violations. We propose to measure the proton decay of the ^{208}Pb GQR in coincidence with $(\pi^\pm, \pi^\pm)$ in order to investigate these processes.

Prop. 1040 Spin Variable Measurements for the $(\vec{p}, n')$ Inclusive Reaction on Several Nuclei

Spokesmen: G. W. Hoffmann and C. Goodman
Participants and Institutions:

University of Texas, Austin
M. L. Barlett — D. Ciskowski
G. W. Hoffmann — M. Purcell
G. Pauletta — L. Ray
W. Thirion

IUCF
C. Goodman

Los Alamos National Laboratory
T. A. Carey — K. Jones
N. King — J. B. McClelland
T. N. Taddeucci

University of Colorado
D. Lind — J. Shepard

Ohio State University
E. Sugarbaker

Ohio University
J. Rapaport

We propose to use the Neutron Time of Flight Facility (NTOF) to measure spin-depolarization data (D_{NN}) on ^{1}H, ^{2}H, ^{12}C, ^{40}Ca, ^{90}Zr and ^{208}Pb at 0 degrees and one larger angle at 800 MeV for inclusive $(\vec{p}, \vec{n})$ spectra spanning the energy loss range from the IAS and Gamow-Teller (GT) peaks through the region of quasifree delta production. Along with these data we automatically get the corresponding analyzing power data. We will also measure analyzing power data in 5° steps from 0 - 30° without the corresponding D_{NN} at 800 MeV, 650 MeV, and 500 MeV. The inclusive data will encompass the quasielastic and quasifree Δ-production regions and will complement existing inclusive $(\vec{p}, p')$, (p,n'. n,p') , (^{3}He,t'), (e,e'), and inclusive

γ-absorption data which exhibit the same two-body quasifree excitations and (1) will shed light on the isovector part of the reactive content of the p + A optical potential, (2) may be sensitive to the delta-nucleon (Δ-N) interaction in the nuclear medium, (3) may help in the determination of medium modifications to the isovector part of the free nucleon-nucleon (N-N) interaction, (4) may provide important constraints upon the various N-N isobar models (or other N-N inelastic models), and (5) may provide insight which leads to an understanding of some of the other inclusive data.

Prop. 1041 Study of the $^{13}C(\vec{p}, \vec{n})$ Reaction at 500 MeV

Spokesmen: G. W. Hoffmann and D. Ciskowski
Participants and Institutions:

University of Texas, Austin

M. L. Barlett	D. Ciskowski
G. W. Hoffmann	M. Purcell
G. Pauletta	L. Ray
W. Thirion	

IUCF

C. Goodman

Los Alamos National Laboratory

T. A. Carey	K. Jones
N. King	J. B. McClelland
T. N. Taddeucci	

University of Colorado

D. Lind	J. Shepard

Ohio State University
E. Sugarbaker

Ohio University
J. Rapaport

We propose to use the Neutron Time of Flight Facility (NTOF) to measure cross section ($d\sigma/d\Omega$), analyzing power ($A_y(\theta)$), and spin-depolarization-rotation (D_{ij}) data for the $^{13}C(\vec{p}, n)$ reaction at 500 MeV. Continuous differential cross section and analyzing power angular distributions will be measured between 0° - 20° laboratory scattering angle with statistical (absolute) uncertainties ± 1-2% (± 0.01-0.02) respectively. Spin depolarization (D_{NN}) and spin-rotation (D_{LL}, D_{LS}, D_{SS}, and D_{SL}) data will be obtained at 0°, 2°, 5°, 8°, 12°, and 16° with statistical uncertainty $\Delta D = \pm 0.05$. A total time of 1017 hours is requested.

Prop. 1042 A Proposal to Extend p + ^{40}Ca, ^{208}Pb, 500 and 800 MeV Data to Large Momentum Transfer

Spokesmen: G. W. Hoffmann and L. Ray
Participants and Institutions:

University of Texas, Austin

M. L. Barlett	D. Ciskowski
G. W. Hoffmann	M. Purcell
G. Pauletta	L. Ray
W. Thirion	

Los Alamos National Laboratory

J. F. Amann	K. Jones

University of Minnesota

M. Gazzaly	N. Hintz

Using the HRS we will extend the 500 and 800 MeV $\vec{p}$ + ^{40}Ca and ^{208}Pb elastic scattering cross sections and analyzing powers to regions where the cross sections are ~ 3 x 10^{-7} mb/sr with at least 10% statistical accuracy. These new data will provide information regarding the energy, momentum transfer and target mass dependence of the systematic breakdown seen in comparisons of microscopic scattering models with previous large angle data. A total time of 300 hours is requested, with 150 hours at each energy.

Prop. 1043 A Dependence of Non-Analog DCX at Low Energies

Spokesmen: H. T. Fortune and J. D. Zumbro
Participants and Institutions:

University of Pennsylvania

H. T. Fortune	J. D. Zumbro
M. G. Burlein	J. M. O'Donnell
S. Weiser	P. Kutt

Los Alamos National Laboratory

C. L. Morris

New Mexico State University

K. S. Dhuga	G. R. Burleson
M. Rawool	

We propose to measure low-energy cross sections for the non-analog DCX reactions ^{40,44}Ca(π^+, π^-)^{40,44}Ca(g.s.) at one angle and 3-5 energies for each target. Energy interval to be searched is 30-80 MeV. We would like to use these data, combined with earlier data for ^{12}C, to determine the A dependence for low-energy non-analog DCX. With that information, we should be able to explain (we hope) the confusing situation for DIAS DCX.

We remind the reader that at resonance energies, it has turned out that non-analog DCX is much simpler and easier to understand than is analog DCX. We expect the same to be true here.

Prop. 1044 Double Charge Exchange to Excited 0^+ States

Spokesmen: H. T. Fortune and M. B. Burlein
Participants and Institutions:

University of Pennsylvania

H. T. Fortune	J. D. Zumbro
M. G. Burlein	J. M. O'Donnell
S. Weiser	P. Kutt

Los Alamos National Laboratory
C. L. Morris

New Mexico State University

K. S. Dhuga	G. R. Burleson
M. Rawool	

University of Texas, Austin

M. J. Smithson	S. Mordechai
A. Williams	J. McDonald
M. Bryan	C. F. Moore

Argonne National Laboratory
R. Gilman

We propose to measure cross sections for excited 0^+ states in $^{56}Fe(\pi^+, \pi^-)$ DCX at 164 MeV, using a "thin" DCX target and taking data at two angles – 5° and 15°.

Prop. 1045 Low-Energy Pion Double Charge Exchange on N=28 Isotones

Spokesmen: H. W. Baer, M. J. Leitch and E. Piasetzky
Participants and Institutions:

Los Alamos National Laboratory

M. J. Leitch	J. C. Peng
H. W. Baer	R. L. Burman
A. Klein	C. L. Morris

Tel Aviv

E. Piasetzky	Z. Weinfeld

Arizona State University

J. Comfort	J. Tinsley

Virginia Polytechnic Inst.
D. H. Wright

We propose to measure the differential cross section for pion double charge exchange on ^{50}Ti, ^{51}V, ^{52}Cr, ^{54}Fe at 35 MeV. Together with the available data at this energy on the $^{42,44,48}Ca$ isotopes the measurements will allow future insight into the large observed irregularity of the double- isobaric-analog transitions as a function of the neutron excess number, and will help reveal the mechanisms responsible for the phenomena. Our current understanding is that it has to do with one of the central questions of nuclear dynamics: the short-range part of the N-N correlations.

Prop. 1046 Neutron Emission from Pion Absorption Near the $\Delta_{3/2,3/2}$ Resonance

Spokesmen: R. D. Ransome
Participants and Institutions:

Los Alamos National Laboratory
K. W. Jones J. A. McGill
C. L. Morris

Arizona State University
J. R. Comfort B. G. Ritchie
J. Tinsley

New Mexico State University
G. S. Kyle

Rutgers University
R. W. Fergerson C. Glashausser
R. D. Ransome

University of Colorado
R. A. Loveman

University of Pennsylvania
J. D. Zumbro

University of Texas, Austin
C. F. Moore

University of Virginia
P. C. Gugelot

We propose to measure the energy spectrum of neutrons emitted in coincidence with two protons for π^+ absorption in ^{208}Pb and ^{12}C. Data will be taken for π energies of 100 and 200 MeV.

Prop. 1047 Search for Low Lying Magnetic States in an $f_{7/2}$ Shell Nucleus

Spokesmen: N. M. Hintz
Participants and Institutions:

University of Minnesota
B. Bayman D. C. Cook
M. Gazzaly N. M. Hintz
M. Franey A. Mack
S. Nanda

University of Texas
M. Barlett G. Hoffman
G. Pauletta

Rutgers University
L. Zamick

We propose to search for predicted low lying ($E_x \leq 7$ MeV) magnetic multipole states ($\lambda = 1,3,5,7$) in ^{48}Ti by measuring A_y and the spin flip cross section, σs_{nn} in (p,p′) near 325 MeV. Such states are predicted in the $f^{\,n}_{7/2}$ configuration model for nuclei between N, Z = 20 and 28, and are expected to possess an appreciable fraction of the single particle strength. The low lying M(1) states in the $f_{7/2}$ region bear a close resemblance to the recently discovered "scissor modes" in the deformed region. The experiment would be the first to test the predictions of the simple $f^{\,n}_{7/2}$ model for the little known magnetic excitations of multipolarity, $\lambda > 1$.

Prop. 1048 A Complete Measurement of Elastic Observables from ^{58}Ni with $\simeq$ 325 MeV Protons

Spokesmen: D. C. Cook
Participants and Institutions:

University of Minnesota

N. M. Hintz	M. Gazzaly
A. Hack	

University of Texas

G. Pauletta	M. Barlett
G. W. Hoffmann	

We propose to measure the cross section, analyzing power, and spin rotation parameter Q on ^{58}Ni at a proton bombarding energy near 325 MeV. A_y will be measured from 4° - 38.5° at 1.5° intervals. We will obtain Q by measuring D_{SS}, and D_{LS}, from 4° - 29.5° in 1.5° intervals. The short term goal of this experiment is to extablish the most successful way to treat the optical potential phenomenologically. This will help us in the analysis of ^{58}Ni(p,p′) inelastic cross section data taken previously at this incident energy. The longer term goal is to understand whether effects due to the nuclear medium, or relativistic effects, or both are contributing to the present difficulties in reproducing elastic spin observables in this energy regime. Also, the cross sections and analyzing powers obtained for the strong collective states will provide a further test of the distorting potential and available N-N interactions.

Prop. 1049 Operational Test of a He-Jet System for Transporting Short-Lived Nuclei Produced at LAMPF

Spokesmen: W. L. Talbert, M. E. Bunker
Participants and Institutions:

Los Alamos National Laboratory

M. E. Bunker	W. L. Talbert
J. W. Starner	R. J. Estep

We propose to install a He-jet target chamber in the LAMPF main beam in Area A6 and study its operational characteristics. Ultimately, the He-jet system would be used to transport to an isotope separator the short-lived radionuclides far from stability produced in high-energy proton-induced reactions. There are several hundred unknown radioisotopes far from stability, not available at any other facility in the world, that could be isolated for study with such a system.

The principal objectives of the present experiment will be (1) to establish that our He-jet target-chamber design provides efficient transport of reaction products under the extreme radiation conditions posed by the 1-mA beam; and (2) to establish that the uranium targets will remain intact for weeks under 1-mA bombardment.

The target chamber will be mounted in the radiation effects area of A-6 on the end of the movable vertical stringer, outside the main vacuum line. The diagnostic equipment will be located in the new staging area. A He-jet capillary transport line will be installed between the target chamber and a heavily-shielded collection chamber located on the staging-area floor. The target chamber, which is to be water cooled, is sufficiently thin that it will not perturb downstream experiments. Thus, our experiment will be parasitic in the sense that it will not normally compete for beam time.

Prop. 1050 A Search for Double-Dipole Excitation Using Pion Double Charge Exchange

Spokesmen: M. J. Smithson, S. Mordechai and C. L. Morris
Participants and Institutions:

University of Texas
M. J. Smithson, S. Mordechai, C. F. Moore, D. S. Oakley, J. W. McDonald, M. A. Bryan, A. L. Williams

Los Alamos National Laboratory
C. L. Morris

University of Pennsylvania
J. D. Zumbro, H. T. Fortune, M. G. Burlein, J. M. O'Donnell, S. Weiser

New Mexico State University
K. S. Dhuga, G. R. Burleson, J. A. Faucett, R. W. Garnett

We propose to use pion double charge exchange to look for double-dipole excitation in ^{40}Ca, ^{90}Zr and ^{208}Pb at $T_\pi = 290$ MeV. The measurements will be at two angles, at a forward angle of 5° and at around 25°, the second peak of the theoretical angular distribution for the double dipole. Our primary aim is to detect these previously unseen modes of nuclear excitation. We have chosen closed-shell nuclei for this study because giant dipole resonances have minimum width (FWHM $\simeq$ 4 MeV) in these nuclei. Static coupled-channel impulse-approximation calculations show that the cross section for exciting the dipole increases by about a factor of 2.5 for ^{40}Ca as the incident pion energy is increased from 165 to 290 MeV. Thus we propose to make the measurements at the highest possible energy at EPICS. The requested running time of 12 days is based on the predicted peak cross section for the double dipole, 0.6, 0.8, and 0.5 μb/sr for ^{40}Ca, ^{90}Zr and ^{208}Pb, respectively, at $T_\pi = 290$ MeV.

Prop. 1051 Measurement of M1 and M2 Strength in ^{140}Ce and Comparison with Other Experiments

Spokesmen: F. T. Baker
Participants and Institutions:

Los Alamos National Laboratory
K. Jones

University of Georgia
F. T. Baker A. Sethi

Rutgers University
R. Fergerson C. Glashausser
A. Green

University of Minnesota
S. Nanda

Orsay
L. Bimbot

Michigan State University
C. Djalali

Previous measurments using (e,e′), (p,p′), and scattering of polarized tagged photons disagree regarding the relative M1 and M2 strengths present in the excitation-energy range of 7.5-11 MeV. The proposed experiment will be able to simultaneously measure both strengths without the usual uncertainties associated with the underlying natural-parity backgrounds; this will be achieved by measuring the spin-flip cross section which is approximately zero for this background. In addition, data will be taken up to about 40 MeV excitation to extend our survey of the spin response of nuclei to heavier targets. Attention will also be paid to the data for the non-spin-flip spectrum with the goal of deducing the strengths of giant resonances of natural parity.

Prop. 1052 Calibration of the LAMPF Neutron Time-of-Flight Facility Detector System Using a Tagged Neutron Beam

Spokesmen: J. B. McClelland and T. A. Carey
Participants and Institutions:

Los Alamos National Laboratory
T. A. Carey N. S. P. King
J. B. McClelland T. N. Taddeucci

Ohio State
E. Sugarbaker L. Rybarcyk

University of Texas
D. Ciskowski G. Hoffmann

Indiana University
C. Goodman

University of Colorado
D. Lind J. Shephard

Ohio University
J. Rapaport

We propose to measure integral and differential efficiencies as well as position resolution and systematic effects for the newly developed Neutron Time-of-Flight (NTOF) neutron detector array using a tagged neutron beam for neutron energies $50 < T_n < 750$ MeV. Early in the commissioning phase of NTOF the integral efficiency of the detector system will be needed to perform cross section measurements in the (p,n) reaction. Differential efficiencies, position resolution, and cross-talk systematics for the new array will be essential in understanding the system in the polarimeter mode.

Prop. 1053 Feasibility Study for Detecting Gamma Rays in Coincidence with Scattered Protons at the HRS

Spokesmen: H. Funsten, R. Fergerson, J. Comfort, S. Nanda
Participants and Institutions:

Los Alamos National Laboratory
K. Jones

Arizona State University
J. Comfort J. Tinsley

Rutgers University
R. Fergerson C. Glashausser

William and Mary
H. Funsten V. Punjabi

Virginia State University
C. Stronach

George Mason University
J. Lieb

University of Minnesota
S. Nanda

Florida State University
H. Plendl

University of Mississippi
J. Reidy

We propose to test the feasibility of performing gamma-ray correlation experiments at the LAMPF HRS spectrometer by using BGO scintillation counters placed close to the target to detect the gamma rays. If successful, a variety of correlation experiments between gamma rays and the effects of various Line C collimator settings and tunes as well as shielding arrangement and detector placement on the BGO randoms rate. We do not ask for Line X control.

Prop. 1054 Ultrahigh Precision Measurements on Muonium Ground State: Hyperfine Structure and Muon Magnetic Moment

Spokesmen: V. W. Hughes, G. zu Putlitz and P. A. Souder
Participants and Institutions:

Los Alamos National Laboratory
F. G. Mariam

University of Heidelberg
K. P. Arnold H. J. Mundinger
G. zu Putlitz

Syracuse University
P. A. Souder

William and Mary
M. Eckhause P. Guss
J. Kane

Yale University
S. Dhawan V. W. Hughes
S. Kettell Y. Kuang
B. Matthias B. Ni
R. Schaefer

An ultrahigh precision measurement of the muonium hyperfine structure interval $\Delta\nu$ and of the magnetic moment ratio μ_μ/μ_p is proposed at LAMPF with the goal of determining $\Delta\nu$ to 5 ppb and μ_μ/μ_p to 50 ppb, which correspond to improvement factors of 5 to 10 over present experimental values. The microwave magnetic resonance spectroscopy method will be employed, using the intense and pure subsurface μ^+ beam from SMC, a large homogeneous solenoid, and a line-narrowing method involving a chopped μ^+ beam.

Prop. 1055 Total and Differential Cross Sections for $\pi^+ d \rightarrow pp$ Below 20 MeV

Spokesmen: R. C. Minehart and B. G. Ritchie
Participants and Institutions:

Arizona State University
J. Comfort — B. G. Ritchie
J. Tinsley

University of South Carolina
G. S. Blanpied — B. M. Preedom

University of Virginia
R. M. Marshall — R. C. Minehart
L. C. Smith

Virginia Polytechnic Inst.
D. H. Wright — M. Blecher

The total and differential cross sections for $\pi^+ d \rightarrow pp$ will be measured at energies of 10, 15, and 20 MeV. Uncertainties will be reduced to 5% for the total cross section. The low energy beams will be transported through the LEP channel to the LAMPF electrostatic separator located in the LEP cave at the exit of the channel. The techniques will be similar to those used in Exp. 828. During that experiment the separator was quite effective but the electron and muon contamination before the separation was so large that the pions made up only about 10% of the beam on target at 10 MeV. The precision of our measurement of this fraction was only about 30%. In the new experiment we intend to measure the pion flux to about 3%. In addition we plan to do further development on the 10 MeV beam to increase both the pion fraction and the absolute pion flux. The results from this experiment will provide a check on the only measurements available at these energies for the energy dependence of the total cross section (those by Rose), which have large absolute uncertainties and will test the theoretical predictions for s-wave pion production at very low energies. 400 hours of beam time in the low energy pion channel are requested.

Prop. 1056 The $^{10}Be(\pi^+, \pi^-)^{10}C$ Reaction

Spokesmen: J. D. Zumbro
Participants and Institutions:

Los Alamos National Laboratory
C. L. Morris

University of Pennsylvania
M. G. Burlein — H. T. Fortune
J. O'Donnell — J. D. Zumbro

New Mexico State University
K. S. Dhuga

Argonne National Laboratory
R. Gilman

University of Texas
C. F. Moore

We propose to measure the cross section for the $^{10}Be(\pi^+, \pi^-)^{10}C$(DIAS) reaction at 292 MeV and a laboratory angle of 5° with a statistical precision of approximately 5 percent. This measurement will permit us to decide between a pure $A^{-7/3}$ dependence for the T=1 analog transitions and a two-amplitude model in which the analog amplitude squared is $A^{-10/3}$. (Standard $A^{-10/3}$ is already known not to work for T=1 targets.)

Prop. 1057 Study of Pion Double Charge Exchange Reactions $^{76}Ge(\pi^+,\pi^-)^{76}Se(g.s)$, $^{82}Se(\pi^+,\pi^-)^{82}$ Xe(g.s.), $^{100}Mo(\pi^+,\pi^-)^{100}Ru(g.s.)$

Spokesmen: A. Fazely and L. C. Liu
Participants and Institutions:

Los Alamos National Laboratory
S. J. Greene L. C. Liu
C. L. Morris

University of Pennsylvania
M. Burlein H. T. Fortune
J. D. Zumbro

University of New Mexico
B. Dieterle C. Leavitt

New Mexico State University
K. S. Dhuga R. Garnett

Louisiana State University
A. Fazely

University of Massachusetts
S. J. Rokni

University of York
D. Watson

We propose to measure forward-angle nonanalog 0^+(g.s.) $\rightarrow$ 0^+(g.s.) double charge exchange (DCE) cross sections for ^{76}Ge, ^{82}Se and ^{100}Mo in the Δ_{33} resonance region. As there is a relation between the neutrinoless $\beta\beta$-decay rate and the forward-angle DCE cross section, the measured cross sections can be used to set a tighter limit on lepton number violation. Furthermore, the nuclear structure information obtained from these measurements will help in better understanding strengths of neutrinoless $\beta\beta$-decay rates for these nuclei. These measurements also provide a global test of the A-dependence of the nonanalog DCE cross sections.

Prop. 1058 Study of the Isovector Monopole Interior Transition Density

Spokesmen: S. H. Rockni, R. A. Loveman and J. D. Bowman
Participants and Institutions:

Los Alamos National Laboratory
J. D. Bowman D. Fitzgerald
A. Klein

University of Colorado
R. A. Loveman R. J. Peterson

Stanford University
D. Pocanic B. King

Utah State University
S. H. Rokni

We propose an experiment to demonstrate that in the interior of the nucleus the Isovector Monopole Resonance transition density has the opposite sign from the nuclear surface. In the energy region between the peak of the (3,3) resonance and 500 MeV, the pion mean free path changes from the 0.7 fm to 3 fm, so that the reaction changes from surface peaked to a regime where the interior of the nucleus is probed.

We propose to measure the ratio of maximum cross section for the Isovector Monopole Resonance (IVM) to the Giant Dipole Resonance (GDR) in the ^{60}Ni(π^-, π^0) reaction at beam energies 300, 365, 425, and 500 MeV. The measurements will cover a range of momentum transfers well beyond the first minimum of the IVM and GDR. A detailed analysis of the energy dependence of the IVM to GDR ratio will be made to determine the radius at which the IVM transition density crosses zero.

Prop. 1059 90° Spin Correlation, A_{SL}, and Deuteron Vector Polarization for $\vec{p}\,\vec{p}, \rightarrow \vec{d}\,\pi$ at 733 MeV

Spokesmen: G. Glass and L. Northcliffe
Participants and Institutions:

Los Alamos National Laboratory
N. Tanaka

University of California, LA
D. Adams D. Barlow

University of Minnesota
M. Gazzaly

Texas A & M University
G. Glass H. Hiebert
R. Kenefick S. Nath
L. Northcliffe

University of Montana
R. Jeppesen

University of Texas
K. H. McNaughton G. Pauletta
S. Sen P. Riley

ANL/NMSU
M. Rawool

University of Udine
L. Santi

Washington State University
G. Tripard

We propose to measure the spin correlation parameter A_{SL} and the vector polarization of the deuteron in the reaction $\vec{p}\,\vec{p} \rightarrow \vec{d}\,\pi$ at one energy 733 MeV and at 90 ° cent of mass by taking the advantage of a spectrometer system already setup to measure elastic pd scattering.

Prop. 1060 Measurement of the π^-/π^+ Cross Section Ratio for the Giant Quadrupole Resonance in ^{90}Zr, ^{118}Sn and ^{208}Pb at 65 MeV

Spokesmen: J. J. Kraushaar and R. J. Peterson
Participants and Institutions:

Los Alamos National Laboratory
C. L. Morris J. L. Ullmann

University of Colorado
J. J. Kraushaar R. A. Loveman
R. J. Peterson R. A. Ristinen

Arizona State University
B. Ritchie J. R. Tinsley

It is proposed that the cross sections for the π^- and π^+ excitation of the giant quadrupole resonances in ^{90}Zr, ^{118}Sn and ^{208}Pb be measured at a pion energy of 65 MeV with the Clamshell spectrometer on the LEP beamline. At energies nearer to the (3,3) resonance, π^- to π^+ ratios for the excitation of the GQR have been found to range from 2 to 3 for ^{118}Sn and ^{208}Pb. These values are considerably larger than those given by the standard hydrodynamic model. Several explanations that have been put forth can be critically tested by the use of low energy pions, where the increase in wavelength and mean free path length will deemphasize the contribution of the neutron-rich nuclear surface.

Prop. 1061 Polarization Transfer and Analyzing Power Measurements for the ^{15}N(p,n)^{15}O Reaction at E_p = 500 MeV

Spokesmen: J. R. Shepard and T. N. Taddeucci
Participants and Institutions:

Los Alamos National Laboratory
R. Byrd, T. A. Carey
N. S. P. King, J. B. McClelland
T. N. Taddeucci

Colorado School of Mines
J. A. McNeil

Ohio State University
E. Sugarbaker, L. J. Rybarcyk

Indiana University
C. D. Goodman

University of Colorado
D. A. Lind, R. A. Loveman
J. R. Shephard, C. D. Zafiratos

Ohio University
J. Rapaport

University of Texas
G. W. Hoffman, M. L. Bartlett
D. Ciskowski

Simon Fraser University
R. G. Jeppesen

We propose to measure a complete set of polarization transfer observables for the ^{6}Li(p,n)^{6}Be(g.s.) and ^{15}N(p,n)^{15}O(g.s.) reactions at 500 MeV. In addition, we propose to measure the analyzing power for the ^{15}N(p,n) reaction to judge its suitability as a polarized neutron source reaction for polarimeter and neutron spin processor calibrations.

^{15}N is of interest because of its simple description as a closed shell $\pm$ 1 nucleus. In spite of this simple model description, surprising variations in (p,n) cross section magnitudes relative to cross sections for other p-shell nuclei have been observed. Similar cross section anomalies have also been observed for nuclei such as ^{13}C and ^{39}K, which have led to speculations about required modifications of the Gamow-Teller transition operator. A larger body of data, including polarization transfer measurements (for $E_p \leq 200$ MeV), seems to contradict some of these speculations, however. Thus, no convincing explanation of the cross section magnitudes has yet been given for this and related transitions and additional experimental information is clearly needed. The measurements proposed here, in conjunction with data from other probes such as (e,e′), will provide stringent tests of the nuclear structure involved. These measurements will make it possible to isolate for the first time specific structure contributions such as the transverse and longitudinal spin responses. The ^{6}Li measurements to be made in parallel with the ^{15}N measurements will provide a calibration of the reaction model with a classic, well-understood Gamow-Teller transition.

Prop. 1062 Study of Pure Fermi and Gamow-Teller Transitions in the $^{14}C(p,n)^{14}N$ Reaction

Spokesmen: E. Sugarbaker and T. N. Taddeucci
Participants and Institutions:

Los Alamos National Laboratory
R. Byrd   T. A. Carey
N. S. P. King   J. B. McClelland
T. N. Taddeucci

Ohio State University
L. J. Rybarcyk   E. Sugarbaker

Indiana University
C. D. Goodman

University of Colorado
D. A. Lind   J. R. Shepard

Ohio University
J. Rapaport

University of Texas
G. W. Hoffman   M. L. Bartlett
D. Ciskowski

We propose to measure 0° cross sections for the $^{14}C(p,n)^{14}N$ reaction at bombarding 350, 500, 650, and 800 MeV, and the analyzing power and 0° polarization transfer at 500 MeV. This reaction provides a unique opportunity to study the isovector spin-flip and non-spin-flip components of the effective nucleon-nucleon interaction. The special feature of this particular reaction is that the ^{14}N(2.31 MeV) state populated via a pure Fermi (F) $0^+ \rightarrow 0^+$ transition is separated by 1.6 MeV from its nearest neighbor, populated via a Gamow-Teller $0^+ \rightarrow 1^+$ transition. This reaction thus provides the best experimental opportunity with which to cleanly resolve F strength in a (p,n) reaction in this energy range. The ratio GT to F 0° cross sections can be related to $|J_{\sigma\tau}/J_\tau|$, the ratio of effective isovector interaction strengths at $q = 0$. Experimental results between 200-450 MeV from IUCF and TRIUMF have revealed significant discrepancies with calculated values for the interaction-strength ratio based on a free NN t-matrix. The proposed measurements will provide a quantitative description of $\Delta S=1$ and $\Delta S=0$ transitions in an energy range for which no precise data currently exist. Empirical values for the ratio of GT to F cross sections will be very useful in the interpretation of future (p,n) data obtained at LAMPF.

At 0°, the resolved IAS transition also provides a source of neutrons having the same polarization as the incident proton beam, thus permitting an accurate absolute calibration of the neutron polarimeter. Determination of the polarimeter effective analyzing power for both transverse components will require measurements with N and S incident proton polarization. Such measurements in conjunction with a neutron spin processor will also provide an exacting test of the operation of this device.

Prop. 1063 The Relative $\Delta S=1/\Delta S=0$ Spin Response in ^{40}Ca

Spokesmen: L. Bimbot and G. Glashausser
Participants and Institutions:

Los Alamos National Laboratory
K. W. Jones

University of Georgia
F. T. Baker

Rutgers University
D. Beatty F. Fergerson
C. Glashausser A. Green

Orsay
L. Bimbot M. Morlet
A. Willis

University of Minnesota
S. K. Nanda

The spin-flip probability S_{nn} will be measured for inelastic scattering from ^{40}Ca at 800 MeV over the angular region from about 3° to 10°. The excitation energy ω will extend to about 45 MeV. The cross section σ, the analyzing power A_y, and the spin-flip cross section σS_{nn} will be measured over the same range. The main goal is to determine the nuclear response in the spin transfer ($\Delta S=1$) channel relative to the response in the channel without spin transfer ($\Delta S=0$); this is directly related to S_{nn}. The results will test the accuracy of a similar determination of this relative response for ^{40}Ca as measured in Experiment 903 with 319 MeV protons. A surprising enhancement of the nuclear response was observed at some angles at ω near 40 MeV in Exp. 903; the $\Delta S=1$ response was 80% or more of the total response. The requested time is 196 hours.

Relationship to other approved experiments: This experiment is essentially the same as the ^{40}Ca portion of Exp. 903 of our group which has been completed; the only difference is that it is being run at a different energy, 800 MeV instead of 319 MeV.

Prop. 1064 Pion Scattering from ^3H and ^3He Near 180° in the Region of the Δ_{1232} Resonance

Spokesmen: W. J. Briscoe, B. L. Berman, and B. M. K. Nefkens
Participants and Institutions:

George Washington University
W. J. Briscoe, B. L. Berman
A. Mokhtari, M. F. Taragin

University of California, LA
B. M. K. Nefkens, C. Pillai
J. A. Wightman, G. Kim
D. B. Barlow

Abilene Christian University
M. E. Sadler, D. Isenhower

Ruder Boskovic Institute
I. Slaus

We propose to measure the four differential cross sections for the back-scattering of charged pions from ^1H and ^3He to a precision of 3 to 5%. These cross sections will be normalized to those for ^3H and ^2H measured under the same experimental conditions. The measurements will be performed for incident pion energies between 140 and 260 MeV and angles from 160° to 180°. The target cells were used successfully in Exp. 905; a new sample changer will be built for this experiment. The sample masses will be determined by direct measurement.

Because of the vanishing of the spin-flip amplitude at 180°, the use of a polarized target is not needed to determine the non-spin-flip scattering amplitude (independent of the spin-flip amplitude and the relative phase). In this experiment, we will obtain this information for the paired and unpaired nucleons in both of the three-body nuclei. In a simple view, differences between pairs of these four quantities would indicate charge symmetry ascribable either to medium effects (three-body forces) or to isospin non-conservation in the pion-nucleon reaction mechanism. Equality of these quantities, on the other hand, is a strong indication that the charge asymmetry observed in previous measurements is ascribable to the spin-flip part of the cross section.

The momentum-transfer dependence of the form factors will be measured up to the very large value of 12 fm^{-2} in this experiment. This makes it possible for us to explore any differences in the form factors for ^3H and ^3He where such differences (if they exist) would be roughly a factor of five larger than in the non-spin-flip dip.

Prop. 1065 Simulations of the Production of Cosmogenic Nuclides in Meteorites by Galactic-Cosmic-Ray Protons

Spokesmen: A. J. Englert
Participants and Institutions:

San Jose State University
P. A. J. Englert

Los Alamos National Laboratory
R. C. Reedy

University of Hannover
R. Michel

Max Planck Institut fuer Chemie
F. Begemann H. Weber

University of Cologne
P. Dragovitsch U. Herpers

Institute for Reactor Development
P. Cloth D. Filges

Institute for Crystallography and Petrography
P. Signer R. Wieler

Institute for Middle Energy Physics
W. Woelfli

Racah Institute of Physics
D. Fink M. Paul

University of Pennsylvania
J. Klein R. Middleton

Rutgers University
G. F. Herzog

Lawrence Livermore Laboratory
M. Caffe R. C. Finkel
B. Hudson C. Velsko

University of California, SD
J. R. Arnold K. Marti
K. Nishiizumi

University of Arizona
D. J. Donahue T. Jull

A large variety of stable and radioactive cosmogenic nuclides is produced by the interaction of galactic cosmic radiation with extraterrestrial matter. Measurements of those cosmogenic nuclides provide the only source of information on the past history of the galactic cosmic ray fluxes and on the irradiation history of individual extraterrestrial objects, provided that there exist reliable models describing cosmogenic nuclide production processes. For the complete description of the depth dependent production of cosmogenic nuclides in meteorites the existing models are in need of improvement. To alleviate the problem the irradiation of small spherical meteorite models with 800 MeV protons to simulate the cosmit ray interaction is proposed.

The meteorite models are spherical objects of radii between 10 and 25 cm, made of material that resembles the average common meteorite composition and density. The meteorite models provide locations within their structure that allow the exposure of pure elements and chemical compounds during irradiation. The spheres will be moved within the proton beam such that the isotropical exposure in space is simulated. Thus, the model body will produce the secondary particle cascade under proton bombardment that will produce cosmogenic nuclides within the materials exposed. These materials will be retrieved and analyzed for their cosmogenic nuclide content by instrumental or radiochemical methods.

Thin targets of the same elements and compounds exposed within the meteorite model will be irradiated separately and/or simultaneously upstream of the model in order to determine the primary proton production rates.

The combination of thin and thick target bombardments will allow the deconvolution of primary and secondary nucleon spectra as a function of location in the models and energy. Further, information will be obtained on depth profiles of the production rates of cosmogenic stable and radioactive nuclides. These data will provide a basis for the interpretation of cosmogenic nuclide production in meteorites, especially with respect to their irradiation histories.

Prop. 1066 The Exotic Nucleus Helium-9 and Its Excited States

Spokesmen: K. K. Seth
Participants and Institutions:

Northwestern University
K. K. Seth R. Soundranayagam

University of Massachusetts
B. Parker

In a recent experiment the ground state of the exotic nucleus, ^{9}He was identified and its mass was measured. It was found that not only is the ground state width quite small, $\leq$ 600 keV, (it is unbound by only $\sim$ 1.1 MeV), but there is evidence that the widths of several excited states are also quite small. It is proposed to make a good resolution, good statistics study of the ^{9}Be$(\pi^+,\pi^-)^9$He reaction at $T(\pi^+) \approx 200$ MeV at θ(lab) = 5° and 25° in order to firmly establish the existence of these excited states, measure their widths and hopefully J^π in a few favourable cases. Comparison will be made with the predictions of recent 'no core' shell-model calculations.

Prop. 1067 Study of Pion Induced DCX on ^{88}Sr

Spokesmen: K. K. Seth
Participants and Institutions:

Northwestern University
K. K. Seth R. Soundranayagam

University of Massachusetts
B. Parker

Basic understanding of the mechanism of pion double charge exchange reactions (π^+,π^-) appears to be now at hand. This is primarily due to the excellent experimental data obtained in the resonance region for a large number of analog and non-analog transitions and due to the efforts of several theoretical groups. However, all the experiments to date are confined to studies in light nuclei with $A \leq 60$, and it is indeed an open question whether the existing models will have any success for heavier nuclei. It is proposed to make a detailed study of the DCS excitation of the 17.2 MeV analog state in the ^{88}Sr(π^+,π^-) ^{88}Zr reaction. Excitation function at $\theta = 5°$ will be measured in the range 130 MeV to 292 MeV and angular distributions will be measured at $T(\pi^+)$ = 180 MeV and 292 MeV. At 180 MeV, the non-analog g.s. transition will also be measured at $\theta = 5°$.

Prop. 1068 Analog DCX on ^{42}Ca at 50 MeV

Spokesmen: K. K. Seth
Participants and Institutions:

Northwestern University
K. K. Seth R. Soundranayagam

University of Massachusetts
B. Parker

Interesting and unexpected systematics has been recently revealed in double analog transitions in pion induced DCX at low energies, $T(\pi) \approx 50$ MeV. In marked contrast to the $\sim A^{-10/3}$ decrease of forward angle DCX cross sections at the resonance energies, it is found that at 50 MeV the DCX cross sections for ^{14}C, ^{18}O, and ^{26}Mg targets are nearly identical. What is even more surprising, an exploratory measurement made by us shows that the 50 MeV forward cross section for even ^{42}Ca is nearly the same as for the lighter targets. It is now proposed to make a good statistics measurement of $^{42}Ca(\pi^+, \pi^-)^{42}Ti$ (g.s.) angular distribution at $T(\pi) = 50$ MeV in the range of $\theta = 20° - 100°$. It is believed that such a measurement will provide important constraints for the theories of low energy DCX which are being currently developed.

☆U.S. GOVERNMENT PRINTING OFFICE: 1987-774-894