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Proceedings of the Nineteenth LAMPF Users Group Meeting

Los Alamos National Laboratory
Los Alamos, New Mexico
November 4-5, 1985

Compiled by
James N. Bradbury

MASTER

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Los Alamos National Laboratory
Los Alamos, New Mexico 87545

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PROCEEDINGS OF THE NINETEENTH LAMPF USERS GROUP MEETING

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ABSTRACT

The Nineteenth Annual LAMPF Users Group Meeting was held November 4-5, 1985, 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.

PROGRAM

NINETEENTH ANNUAL LAMPF USERS GROUP MEETING

Los Alamos National Laboratory **November 4-5, 1985**

Chairman: Robert P. Redwine, Massachusetts Institute of Technology

Chairman-Elect: Barry M. Preedom, University of South Carolina

Monday, November 4 **LAMPF Auditorium, Laboratory-Office Building (MPF-1, TA-53)**

MORNING SESSION

Robert P. Redwine, Presiding

8:00 - 9:00 a.m.	Registration
9:00 - 9:15	Welcome and Introductory Remarks - Robert Thorn, Acting Laboratory Director
9:15 - 9:45	Status of LAMPF - Louis Rosen
9:45 - 10:15	Future Directions - Gerald Garvey
10:15 - 10:45	COFFEE BREAK
10:45 - 11:15	LAMPF Operations Report - Donald Hagerman
11:15 - 12:00 p.m.	David Hendrie (Department of Energy) - "Report From Washington"
12:00 - 1:15	LUNCH - Buses to the Laboratory Support Complex Cafeteria

1:15 p.m. **LAMPF Auditorium, Laboratory-Office Building (MPF-1, TA-53**

AFTERNOON SESSION

Barry M. Preedom, Presiding

1:15 - 1:40 p.m.	Annual Users Group Report - Robert P. Redwine, Chairman of Board of Directors
1:40 - 2:25	Hywel White (Brookhaven National Laboratory) - "A ν_μ-e Proposal for LAMPF"
2:25 - 3:10	Martin Cooper (Los Alamos) - "Searching for Muon Number Violation at LAMPF: Current Results and Future Prospects"
3:10 - 3:30	COFFEE BREAK
3:30 - 4:15	John McClelland (Los Alamos) - "NPL Upgrade"
4:15 - 4:45	Paul Lisowski (Los Alamos) - "The WNR Neutron Source"
4:45 - 5:05	David Bowman (Los Alamos) - "New High Resolution π^0 Spectrometer"
6:30 p.m.	**BANQUET AT RANCHO ENCANTADO**
	(Tickets to this event must be purchased in advance)

Tuesday, November 5	WORKING GROUP MEETINGS	LAMPF ROOM
8:30 - 10:00 a.m.		
EPICS (Energetic Pion Channel)	John Zumbro (University of Pennsylvania), Chairman	Auditorium
NPL (Nucleon Physics Laboratory)	George Glass (Texas A&M University), Chairman	A234
SMC (Stopped Muon Channel)	Richard Hutson (Los Alamos), Chairman	D105
10:00 - 10:30	COFFEE BREAK	
10:30 - 12:00 p.m.		
HRS (High-Resolution Spectrometer)	Susan Seestrom-Morris (University of Minnesota), Chairman	Auditorium
P^3 (High-Energy Pion Channel)	William Briscoe (George Washington University), Chairman	A234
Solid-State Physics and Materials Science	Robert Brown (Los Alamos), Chairman	A114
Neutrino Facilities	Thomas Romanowski (Ohio State University), Chairman	D105
12:00 - 1:30 p.m.	LUNCH - Buses to Laboratory Support Complex Cafeteria	
1:30 - 3:00		
LEP (Low-Energy Pion Channel)	Barry Ritchie (University of Maryland), Chairman	Auditorium
Computer Facilities	James Amann (Los Alamos), Chairman	A234
μSR (Muon Spin Rotation)	Mario Schillaci (Los Alamos), Chairman	D105
Nuclear Chemistry	Larry Ussery (Los Alamos), Chairman	A114
3:00 - 3:30	COFFEE BREAK	

3:30 p.m.	LAMPF Auditorium, Laboratory-Office Building (MPF-1, TA-53)
3:30 - 4:15	Toshimitsu Yamazaki (University of Tokyo) - "Japanese Medium Energy Program"
4:15 - 5:00	Henry A. Thiessen (Los Alamos) - "LAMPF II"

Los Alamos

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To the LAMPF Users:

As the LAMPF Director since November 12, 1985, I am taking this opportunity to briefly greet those of you who could not attend the last LAMPF Users Meeting. A distinguished search committee advising the President of the University of California has been in the process of selecting a new Director for Los Alamos National Laboratory to replace Don Kerr who resigned, effective October 1, 1985. This process has led to the selection of Siegfried Hecker as the next Director, effective January 15, 1986. We are looking forward to a happy, productive interaction with the new Laboratory Director whose background is in solid-state physics and metallurgy. The near future should provide a clearer idea of Sig Hecker's views on administrative and organizational matters at the Laboratory.

The realization of what an excellent facility and organization have been developed at LAMPF by Louis Rosen and the MP-Division staff has made the past year a stimulating and pleasant experience for me. The entire community owes them a great debt for their dedication and skill in providing this world-class research capability. I will do my utmost to see that the full resources of LAMPF continue to be made available to conduct the most significant research that is proposed to the facility. As the scale of experiments grow in complexity and cost, research at LAMPF will have to be undertaken in an even more collaborative manner than has been true in the past. We seek to assist you to assemble the research teams required in order to conduct your research.

As a highest priority, I am committed to continue to seek a new facility at LAMPF. As proposed, LAMPF II greatly extends the opportunity for research in nuclear and particle physics. To my mind, a facility such as LAMPF II allows the nuclear physics community the opportunity to accomplish its often stated goal of bringing QCD into nuclear physics. This realization is spreading, and the interest in this physics in the United States, Canada, Japan, and Europe is intensifying. It is probable that we will convene a large LAMPF II workshop this summer to discuss and develop new ideas, and to refine the notions from earlier workshops.

I look forward to seeing you soon, perhaps on your next visit to LAMPF.

Jerry Garvey

Gerald T. Garvey
LAMPF Director

L. Rosen

Talk given at the

NINETEENTH ANNUAL LAMPF USERS MEETING

November 4, 1985

Well, it must have been an occasion similar to this that encouraged Mark Twain to remark that the rumors about his demise are grossly exaggerated. As you have been told by Bob Thorn, I certainly don't intend right now to retire--I have 20 to 30 years before that. I do intend to continue to serve LAMPF, to serve the Laboratory, serve the nation. It looked for quite some time that I might not be here with you this week because our Annual Meeting of the Joint Coordinating Committee for Fundamental Nuclear Properties with our USSR counter parts has been in the works now for six months and we haven't known when we would meet. A month ago, it seemed that this week we would be in Moscow, Leningrad or some place like that. Now it is scheduled for next week. However, not knowing whether I would be here and not wanting to disappoint you by not having a talk (it would be the first one in 20 years I would have missed) I wrote a report--a report on the "History of LAMPF and its Research Programs." I like this report so well that I made it a formal LA-UR. It will be available to each of you, and from that you can see what I had to leave out from the present talk because of the marvelous words spoken by the two previous speakers. I appreciate those words.

About a week ago I gave a talk to all MP Division personnel. It was my annual report to LAMPF stockholders. It was, however, a report on the status of LAMPF, and the status has not changed very much in one week. So those of you who were at my previous talk will be not using their time very effectively if they stay for this one. However, it's too early in the morning for me to eject anyone, so please feel welcome to stay, but don't say I didn't warn you. What I would like to do for the next 30 minutes or maybe 20 minutes, is review very briefly what has happened in the past year and where LAMPF appears to stand at this point in time. I shall follow the outline on the transparencies (Fig. 1)

It is a fact that we have had one of the best, if not the best, years at LAMPF that I can remember, both in terms of the research accomplished and also in terms of new capabilities brought online and of plans being implemented for the immediate future. The far future, I suspect, Gerry Garvey will talk about, and I will try very hard not to get into LAMPF II. You will hear Gerry talk about that. So let's review briefly what has happened.

We addressed scores of experiments during the past year. There's no way I can do justice even to a small fraction of them. However, you know research is the name of the game. I just couldn't report to you on the status of LAMPF without mentioning, and I say it's a random selection--you know random like a Physical Review figure is random--of some of the major research that has happened, by no means all. Then I will mention to you the major facilities additions. This will be a non-random selection. I will tell you of all the major additions that were put into place. I will mention the operational milestones about which much more will be said when Don Hagerman talks to you, and say very little if anything on the progress of LAMPF II. The management issues you now have heard.

All right, what were some of the major research plans? One that certainly stands out is the first actual neutrino-electron scattering data under very difficult and unique conditions. I really mean unique--no other facility in the world, at this time, has had a chance of looking at the cross sections of electron-neutrino scattering on electrons. Data are emerging from this experiment, and they have already provided a partial, but unambiguous, determination of the interference of charged and neutral currents. We have achieved our design performance on the $\mu \to e\gamma$ experiment, the Crystal Box Experiment. Data taking is complete. The data write-up is still in progress. Similarly data taking on parity non-conservation in p-p scattering is complete; and I think here even the write-up is complete. And an experiment which some of you may not have heard of has yielded very interesting results. This is an experiment to study the asymmetry in the charge-exchange scattering of negative pions on polarized hydrogen targets leading to π^0 and a neutron. From that asymmetry it appears that one can say that the Roper resonance is a twin, it's split. Now this is not yet established beyond a reasonable doubt, but if you look at the data, they are very impressive. And I will give you odds that within a year everybody will agree that the Roper resonance is a duet.

Polarized protons on nuclei. This has been a marvelously fruitful research activity, and I will tell you more about that in a few moments. η-meson production near threshold was observed from hydrogen and also from carbon. This is the first time it has been observed near threshold. And we continue with the μ-decay experiment (the Michel-parameter experiment), and μ-catalysis of the d-T reaction. The latter yields the surprising result that one muon can catalyze 170 or 180 DT reactions. Now I'm not suggesting that you go out and buy stock in a company which is proposing to build power plants based on this process. That's a little premature to do even for the entrepreneurs among you. But the physics, the atomic and molecular physics, is exquisite and furthermore, if it turns out for political reasons that the kind of breeder reactors that should be built cannot be built, then one will have to go to electronuclear breeding. In that case, this additional energy source could be very cost-effective in the economic sense of that kind of reactor.

New possibilities for hyperthermia. I'll come back to that. We now have very great industrial interest on a part of Squibb, Squibb Pharmaceutical in particular, to have generators that produce rubidium 87 for cardiovascular diagnostics. It looks like that is the isotope of choice for many such diagnostics. As with the three stars, I have marked the fact that we actually injected a beam into the proton storage ring for the first time. Now we've had and continue to have a large neutrino program here at LAMPF. I suspect Gerry Garvey will tell you that it's not going to stop with the present experiments, those currently under way. Here is the newest addition to this category of experiments, which I'm hopeful will take data before we shutdown in mid-December. It is a neutrino oscillation experiment. You can see that it is somewhat larger than a tabletop experiment as most neutrino experiments are, but these experiments are exceedingly important. They are one of the few areas where you get complete agreement across a spectrum of theoreticians, experimentalists, particle physicists, nuclear physicists, cosmic ray physicists, astronomers, that this kind of research is urgent at this particular time. I have been extremely impressed with the rapidity and professionalism with which all the neutrino experiments have been mounted and with this latest and largest one in particular. It's been a joy to see that experiment go rapidly from bulldozing a tunnel to something which can start taking data perhaps within a month or six weeks from now.

I told you I'd come back to polarization experiments. Many of you are too young to know that there was a time when I was one of the pioneers in polarization experiments, and I still have a very soft spot for that kind of experiment. They can show sensitivities to many aspects of nuclear reactions of phase shifts that no other experiment can show. Well, in the past year or so, they have made one of their major advances. I cannot help telling you briefly the story of being visited about two years ago by the Regents of the University of California. It was my duty to give them a layman's view of why LAMPF is something the University of California should be very proud of, why the research is so important. I started off by telling them that it has now been more than 30 years since the Wood-Saxon potential evolved, and all these decades we thought that the President of the University really had the answer to understanding the interaction of nucleon with complex nuclei. Then I went on to tell them that during the last year, we found out that your President was wrong. Of course this was a joke. However, six months later Saxon resigned. I've never known whether I had anything to do with that; it certainly was completely unintentional. He's a very good friend of mine. You have to be careful with jokes in science.

Anyway, if you look at proton-nucleus scattering you find that as one goes to large momentum transfers, the cross sections, the periodicities, the polarization observables, none of these can be described by the non-relativistic Schrödinger equation approach. In the past year or two it has become apparent that one needs a relativistic component. Whether one can introduce it into the canonical formulation is not clear. But what is clear is that the relativistic Dirac approach seems to give uncanny agreement with data. Here I plot Q, the polarization-transfer variable, which depends upon several polarization observables. The experimental points are shown here (Fig. 2). The solid curve is the Dirac formulation, and you can see how much better that suits the data than does the conventional one. Roy Thaler pointed out to me that it's even more dramatic than is shown here for reasons I'll not take time to go into.

You know I love theoreticians, but at heart I'm still an experimentalist, and I just get very excited about an important experiment which also is simple. Such an experiment was the one performed here within the past year on η production near threshold (Fig. 3). You see you have a negative pion beam. This scintillator detects the pion and serves as zero time for the neutron time-of-flight detectors, which are scintillators. The bismuth germanate detectors look at the gamma rays from the η's in coincidence with the neutrons. The experiment is a little more complicated than that, but it is a beautifully simple experiment. The results are even more beautiful than the schematic of the experiment. Here we have them (Fig. 4)--the first peak comes from the γ rays from π^0, and here that peak is. The target was hydrogen. Then we have the neutrons from this reaction. The two groups of neutrons correspond to η production. Why two groups? Well, one group corresponds to the neutrons going forward in the center of mass and the other backwards, and that's your two groups. No one can possibly take issue with the fact that these people have seen and identified η production at threshold. This is with hydrogen, but similar results emerge when you use a carbon target.

The game right now is quantum dynamics, quarks, and gluons, and we should try, to whatever extent we can, to join that game. I don't think we can do a great deal at intermediate energies until LAMPF II comes into being. But I was intrigued by one experiment that was done here and that took as its starting point the EMC (European Muon Collaboration Experiment) where they use several-hundred-GeV muons to study the electromagnetic structure of nucleons in the form of deuterium and of a complex nucleus in the form of iron. Now, the hypothesis was that the structure factor for a complex nucleus would be the incoherent sum of the structure factors for the nucleons in that nucleus. You don't have to be a great theoretician to suppose that and everybody was looking forward to confirming it. But the data did not confirm that hypothesis. Then the question arose, "What is going on? Is there a communication of quarks from one nucleon to another? What is going on?" Erickson and his coworkers at CERN thought that there was no big deal here. They postulated that the answer lies in classical nuclear physics, in pion condensates. He imagined that in the complex nucleus you achieve a pion condensate and it's this which gives you the extra quarks that give you the anomalous results achieved in this experiment. A group here decided to look at that, and they devised a very ingenious way to do so, using polarization effects. They again used deuterium and iron, and scattered pions from these nuclei, and then measured the transverse and longitudinal response. The experiment is much more complicated than we want to get into here, but I just want to show you the results (Fig. 5). This is the ratio for deuterium and iron of the longitudinal to transverse responses and this curve is what you would get if there was a pion condensate of sufficient magnitude to explain the EMC effect. If there wasn't such you'd get a straight line as a function of excitation energy, and you see that the points very clearly choose a straight line. Well, that's an ingenious experiment carried out in a short time with interesting results.

Now, the muon-catalyzed fusion cycle. Well, there are many complexities if you look at, theoretically, the catalysis of the DT reaction by negative muons. And you can sketch what happens and, if you don't look too closely, this is the kind of dynamics you get (Fig. 6). But if you look more closely, you get something--well, I don't think that you would like me to take the time to explain each of these steps. I just want you to see that sometimes what looks like something that is exquisitely simple, and you can write the answer on the back of an envelope, turns out to be rather complex. Fortunately, we have here at Los Alamos the theoretical competence to attack this problem and try to describe, with considerable success, what actually is going on. Why are there so many fusions catalyzed by a single muon; what are the resonances which give rise to this phenomena?

Now, quickly I would remind you that we've had great success here with hyperthermia, rf hyperthermia, based on rf technology developed for LAMPF. This is now being used throughout the world on animals. That wasn't why some years ago I took some substantial risk to support this kind of program. At that time, we were not permitted to move easily into areas other than the ones designated by the funding agency and by the Congress. Maybe that still is the case, but in any case, looking back I recall getting a memorandum from the then Director (this was 12 years ago) of Los Alamos telling us that this research is inappropriate for MP Division. He cited constraints by the Congress and AEC, but the level of support was modest. You have but one job to give for your country. I show this because Dave Hendrie is here and there is now considerable pressure on him and on the DOE to be more rigorous in supervising the programs at the national laboratories. On the one hand, Congress says, "Thou shalt not micro-manage" and on the other hand they say, "You gotta get these national laboratories under control; they're running away with themselves." Well, one has to use good judgment, one has to use good taste, and one has to use good sense. Since I didn't get into trouble, I must have used one of those. Anyway, this program is now not funded by the Division of Nuclear Physics at all. It's funded by appropriate agencies. It is leading to something of which I think we may be very proud. It is leading to hyperthermia for people, and, at the Fourth People's Hospital in Shanghai, there is a group of surgeons who are experimenting with devices we built here and loaned to them to do hyperthermia on brain tumors that are not completely manageable with surgery. Now Danny Doss and his collaborators have come up with what looks to me like a beautiful concept. You have a tumor, you excise it as much as you can with surgery and then you use hyperthermia to do what you can with the part that could not be excised with surgery. Very often this tumor will recur and what you are faced with now is to go in once again with your hyperthermia, but that means more surgery to get the electrodes in. What is being worked on now is a method for implanting electrodes and a pickup loop in the tumor volume at the time the initial surgery is done. Then if the tumor returns, you use a generator to heat up the appropriate tissue, kill the cancer cells, and go on until the tumor starts to grow again, if it does. This is a non-invasive way to control a very bad situation, especially if it occurs in the brain. The interesting thing is that the technology that is being used to do the phase measurements that tell you the temperature to which you're heating the tumor is the same as the technology we developed here 20 years ago to control the phase of the LAMPF rf system. That is the connection between basic and applied research. It's connection that many people just don't appreciate, and that's why we're doing that here. That's why it is appropriate to carry on such a program in a division that has direct hands-on access to the appropriate technology.

We're doing a lot with medical radioisotopes. I told you Squibb and Sons want a strontium generator, but they're not the only ones. Here are the institutions that are using some of the isotopes we are generating (Figs. 7, 8). The purposes are shown on the slide; you can get access to this if you'd like. These are mostly biomedical agents, but the isotope production activities at this facility have been one of the successes in the practical domain. But that's not the only success. Brookhaven and we now have a commission to build a laboratory that studies the spectroscopy and dynamics of H^- beams. We have been at that kind of study for a long time and you know we use colliding beams. I think all of you are familiar with the way we do these experiments. You may be less familiar with the kind of resolution one can get with an 800-MeV beam.

Our resolutions are in milli-electron volts using an 800-MeV machine. Think about it; it's quite an achievement. For the first time one can get data to look at the theoretical predictions of the three-body problem. It's just quantum mechanics. We ought to understand it. We ought to be able to predict everything, but since it's a three-body problem, we can't. These experiments are a marvelous adjunct to that endeavor.

Harvey Willard was supposed to be here, but since he isn't, I'll give you the part of his talk that I like the most. Gerry Garvey and I recently were in Washington. Gerry is a member of the NSF Review Committee for Nuclear Science, and I too addressed that Committee on the status of nuclear science in the country generally. Harvey Willard, from NSF, gave a talk. I was very much taken with one of his slides. It was this one (Fig.

9). He listed the fundamental studies of which he is most proud. Again it was a selection from many studies. He lists neutrinc-electron scattering and proton-proton scattering; but the point is that of the four or five facilities at which NSF is supporting research of which he is most proud, two of these are LAMPF. I just could not help being proud of that and I thought you would as well. So what are the major facility additions during the past year? There are many: high-intensity H^- ion source; an injector; very much improved low-energy transport; a new switchyard; a new beam stop; a time-of-flight isochronous spectrometer for measuring the masses of neutron-rich low-mass isotopes--the best in the world, it is just now coming to completion; the clamshell spectrometer brought online; and PSR construction completed. Not to be forgotten is that LAMPF was able to attract one of the few funding initiatives that was approved for construction this year. It was the Lab Office Building addition which of coursc we will need desperately as we move further into LAMPF II developments, but these are the major facility additions. The PSR is really a milestone facility; here is the artist's view (Fig. 10). This is the WNR part that remains intact as does this neutrino line which goes down here. That facility will give Los Alamos world class capability for time-of-flight neutron experiments to study nuclear physics, condensed matter physics, and related problems.

What are some of the operational milestones? All the facility modifications worked, and they worked in very short order. That was a minor miracle, I can tell you. We saw three-beam operation: H^-, P^- and H^+. For the first time we showed that we can operate three beams simultaneously. We've achieved 17-mA peak current, and we know we can get nine percent duty factor. The remote handling exercise that we had to go thru in order to replace the beam stop was one of the most difficult that we can ever imagine. Having done that I am not afraid of any challenge that we might have to meet in this area in the future.

What are the operational statistics--what is the bottom line? We provided beam to 129 experiments, about one-third of them were WNR experiments. Sixty-four experiments were completed; again about one-third are WNR. Four hundred fifty-nine participants in LAMPF programs from 98 institutions. One of the things I am most proud of is this transparency (Fig. 11). If we ask what nations were represented at LAMPF by scientists working in one way or another in the '83-'85 period, we get this most impressive list. As I told the group I addressed a week ago, in the age in which we now live, one of the attributes of science is that it is a universal good, an absolute good. It is an area where you can have collaboration across national boundaries, across races, across religions. It is a place where you can have communications among many peoples with differing political and economic ideas on how the world should be run. As we continue in this century and into the next with the severe political problems that beset the world, we must make optimal use of every opportunity to lessen tensions in the world and to create atmospheres of friendship and collaboration. A large national facility such as LAMPF has a very important part to play in this arena. I am very proud that we have, in some measure, been playing that part.

I think you know about the immediate new initiatives underway. I just told you about the neutrino oscillation experiment. There's also underway now a neutrino inelastic-scattering experiment on Line E. We now have funding for a high-intensity polarized ion source. That would make an enormous difference in studying the scattering of polarized neutrons by light nuclei. The nucleon-nucleon problem is still not solved because the neutron-proton part is still not solved. It will also make a large difference in inelastic scattering of polarized protons. We are expanding, improving our nucleon physics laboratory with a neutron time-of-flight facility and a medium range spectrometer. We are in the process of developing support for what will be the ultimate $\mu \rightarrow e\gamma$ experiment; it's quite likely that this experiment will go as far as one can sensibly go. That's a difficult, expensive experiment. Burt Richter, in response to a letter I wrote to him suggesting that he loan or give us a very major component for this experiment--a large superconducting magnet--said he really thinks this experiment is a very important one. It would be a very important contribution to particle-nuclear physics. And we can have the magnet that they now are using at SLAC, but which will go out of use in the next six months. With that dowry, I'm hopeful that we will be able to muster the support and that our friend Dr. Hendrie, here, will urge us on as fast as we can possibly go.

Now, I just want to show you that we have not been dormant in terms of preparing for the future. These are some of the workshops that were held during the past year and these are the people who organized them (Fig. 12). As you'll see in the next slide (Fig. 13), Gerry Garvey has done a fantastic job of organizing and planning and implementing workshops having to do with LAMPF II. That is an absolutely critical activity.

Two or three weeks ago, Professor Yamasaki and his colleagues in Japan put on a marvelous meeting commemorating the 50th anniversary of pion theory. It also, of course, commemorated the late, great Professor Yukawa. It was one of the most inspiring meetings that I have ever attended. I don't know what I was doing there because I'm an experimentalist and they were almost all theorists. During that meeting some of us were summoned by the directors of the Conference who said the press would like to talk with us. We met with them. They said they'd like to have a news conference. You think news conference, 10, 15 minutes, but this was three hours. It started with a dinner, as you see here, and then it was written up in the Japanese newspaper that has the highest circulation, not only in Japan, but in the entire world (Fig. 14). What was it about? It was about the desire in Japan to see implemented a pion-therapy facility. As many of you know, we initiated pion-therapy treatments here at LAMPF. We are not doing it right now, but it is going on at TRIUMF and SIN. This news conference explored how Japan might achieve, in a reasonably short time, the capability to carry on with this work.

One day, many years ago, I was sitting in my office minding my own business when in came a gentleman who said to me, "May I talk with you for a few minutes?" "Yes, of course. Please sit down." He sat down and he said, "Well, I am Nakamura. I was the first student of Yukawa, and Yukawa has sent me here to find out what you are doing with his pi mesons in medicine." We had a long conversation that resulted in Japanese physicians coming here to learn how to treat patients with pions. They treated more patients than anybody else. We treated several hundred, and they treated more than half of these patients. Now they still want such a facility. It occurred to me that it would be marvelous if somehow we could arrange a collaboration where we help them build a pion-therapy facility. In return, might they collaborate with us on a kaon factory? I don't know whether this is sensible, but it just seems like the right thing to do if one can find out how to do it.

I want to thank all of you for listening to this discussion, but more than that, I want to tell you at this point what a pleasure and joy it has been for me to work with this group--so competent and, so dedicated--and, amazingly enough, when the chips are down, really objective. You know there are procedures for adjudicating situations where somebody says he was not given beam time for political reasons, so-and-so knows so-and-so who knows the president, and that's why he got beam time. We imagined this would happen and we set up ways to deal with it. I never had to use that mechanism, and that is a great tribute to all of you and to your dedication to science in general and the pursuit of good physics in this arena in particular. Thank you.

STATUS OF LAMPF

I. *MAJOR RESEARCH ADVANCES (RANDOM SELECTION)*

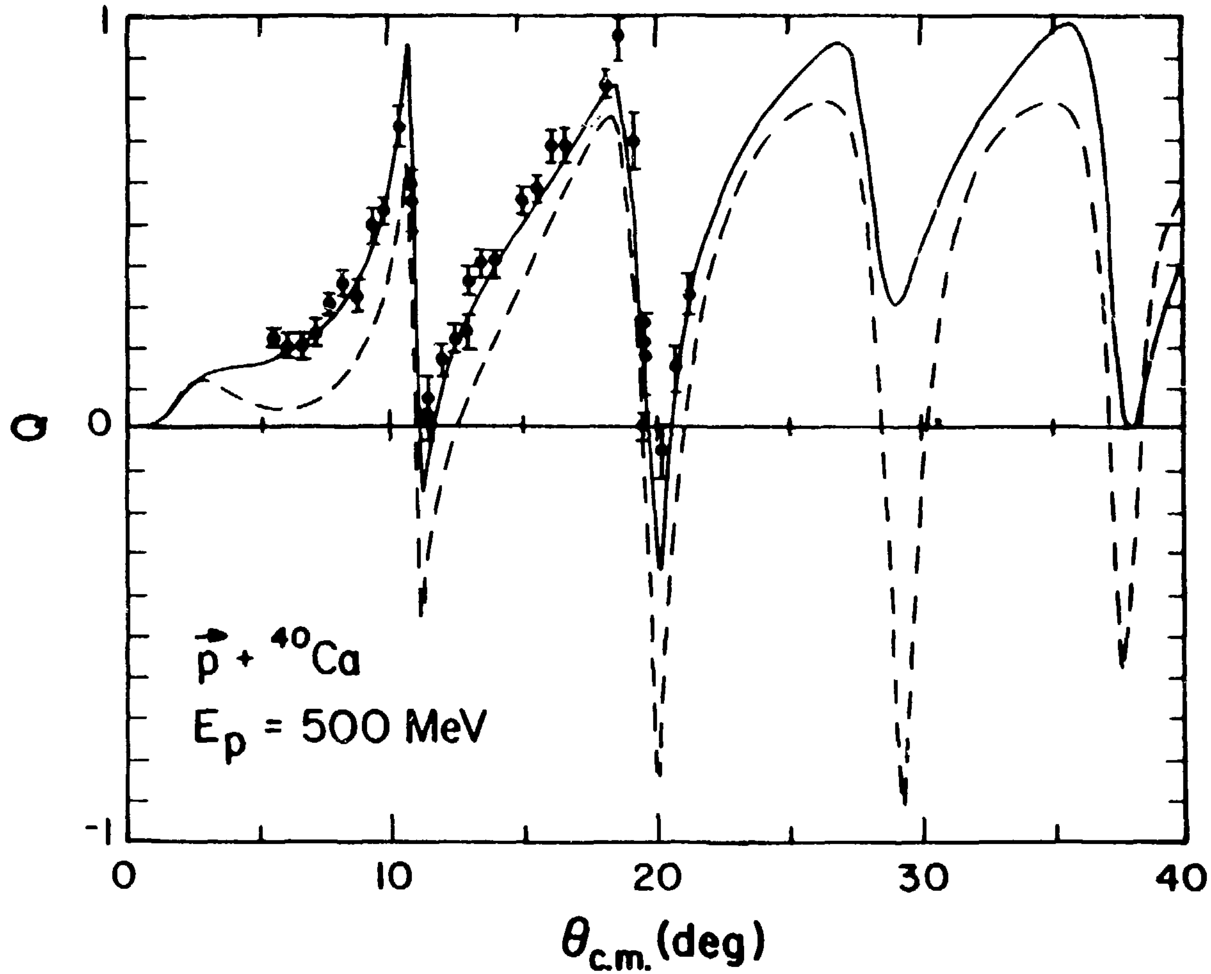
II. *MAJOR FACILITIES ADDITIONS (NONRANDOM SELECTION)*

III. *OPERATIONAL MILESTONES*

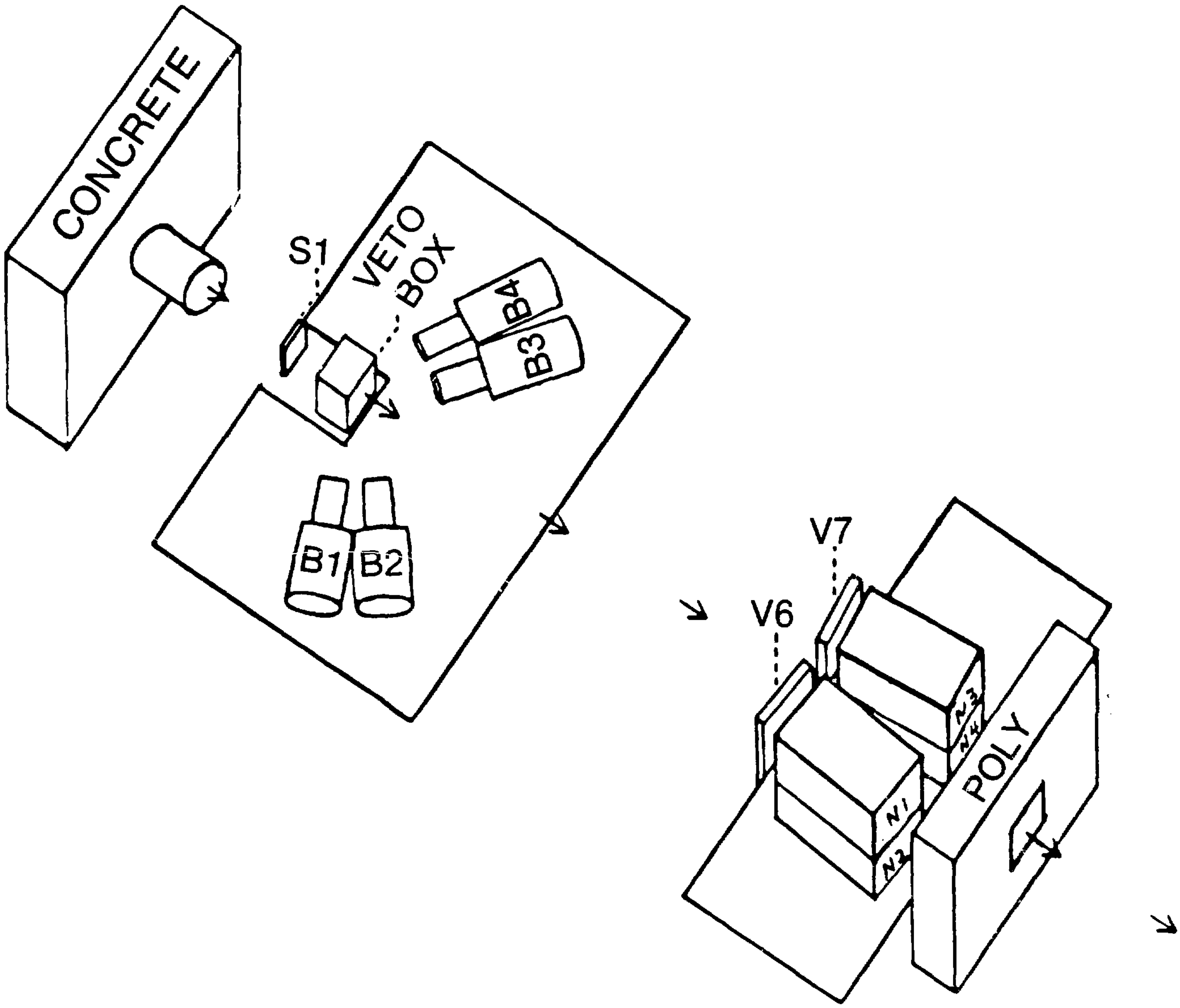
IV. *THE POLITICS OF LAMPF II*

V. *MANAGEMENT ISSUES*

(FIGURE 1)

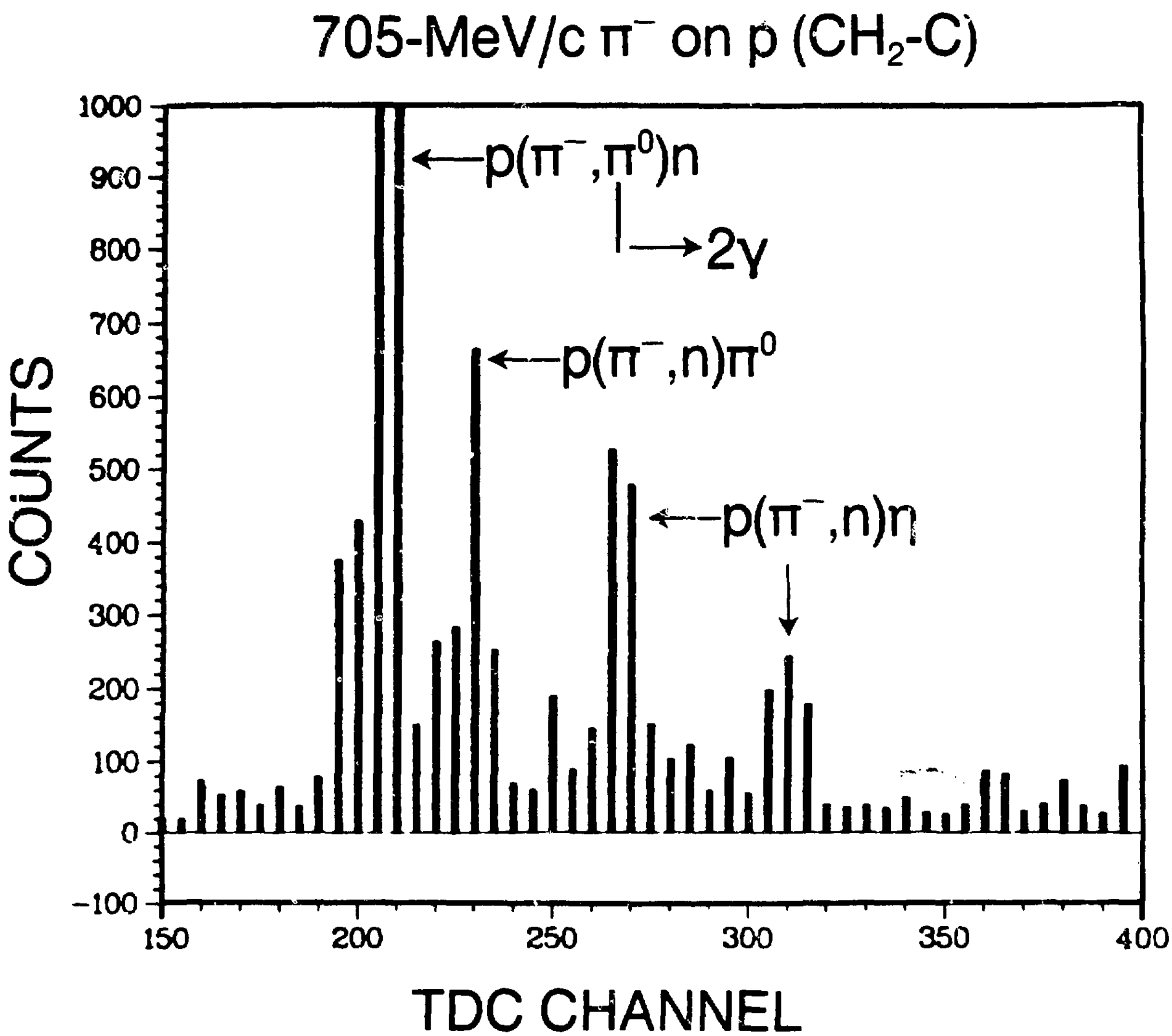


First measurement of the spin-rotation parameter Q for 500-MeV elastic-scattered polarized protons on ^{40}Ca taken with the High-Resolution Proton Spectrometer at LAMPF. The data are compared with full relativistic (solid-line) and nonrelativistic (dashed-line) calculations [see *Phys. Rev. Lett.* **50,** 1443 (1983)].



Schematic of the experimental setup for the test run of Exp. 852.

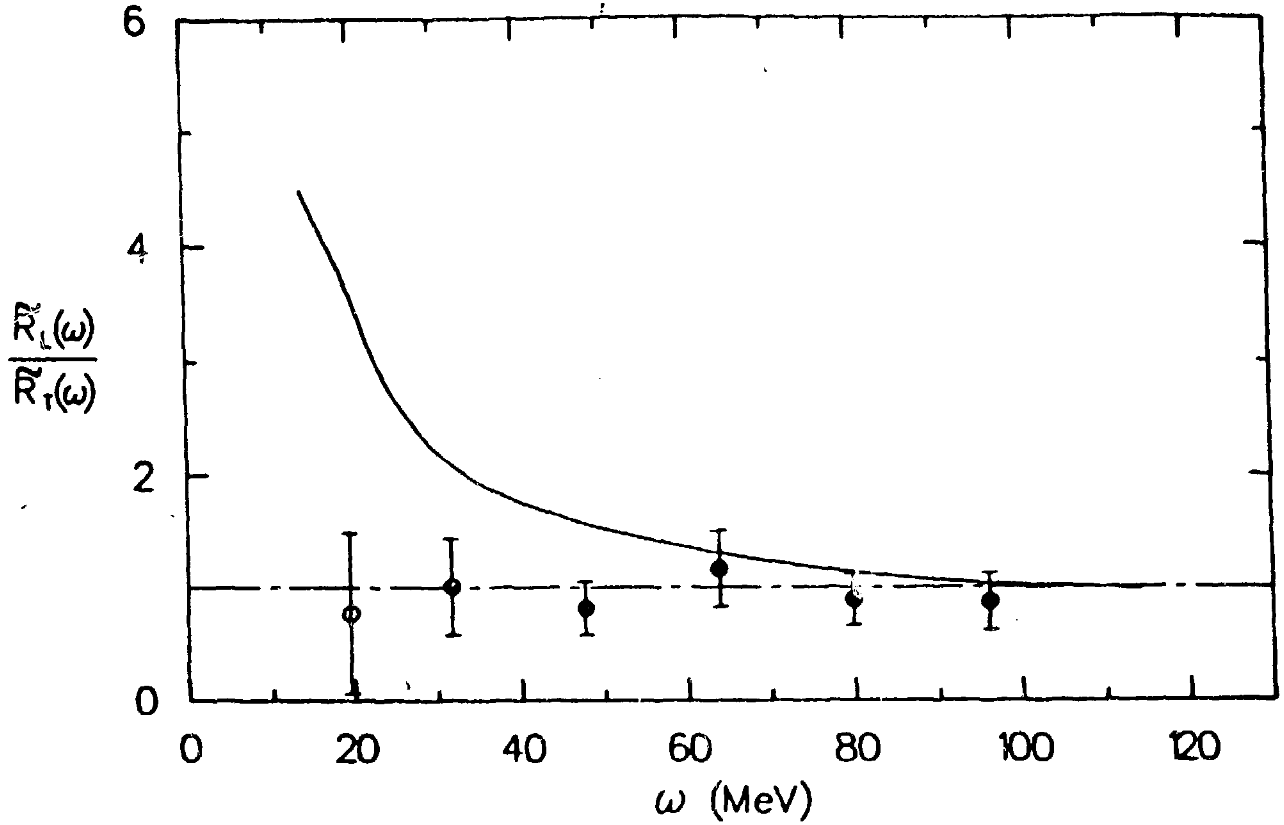
(FIGURE 3)



Neutron time-of-flight spectrum.

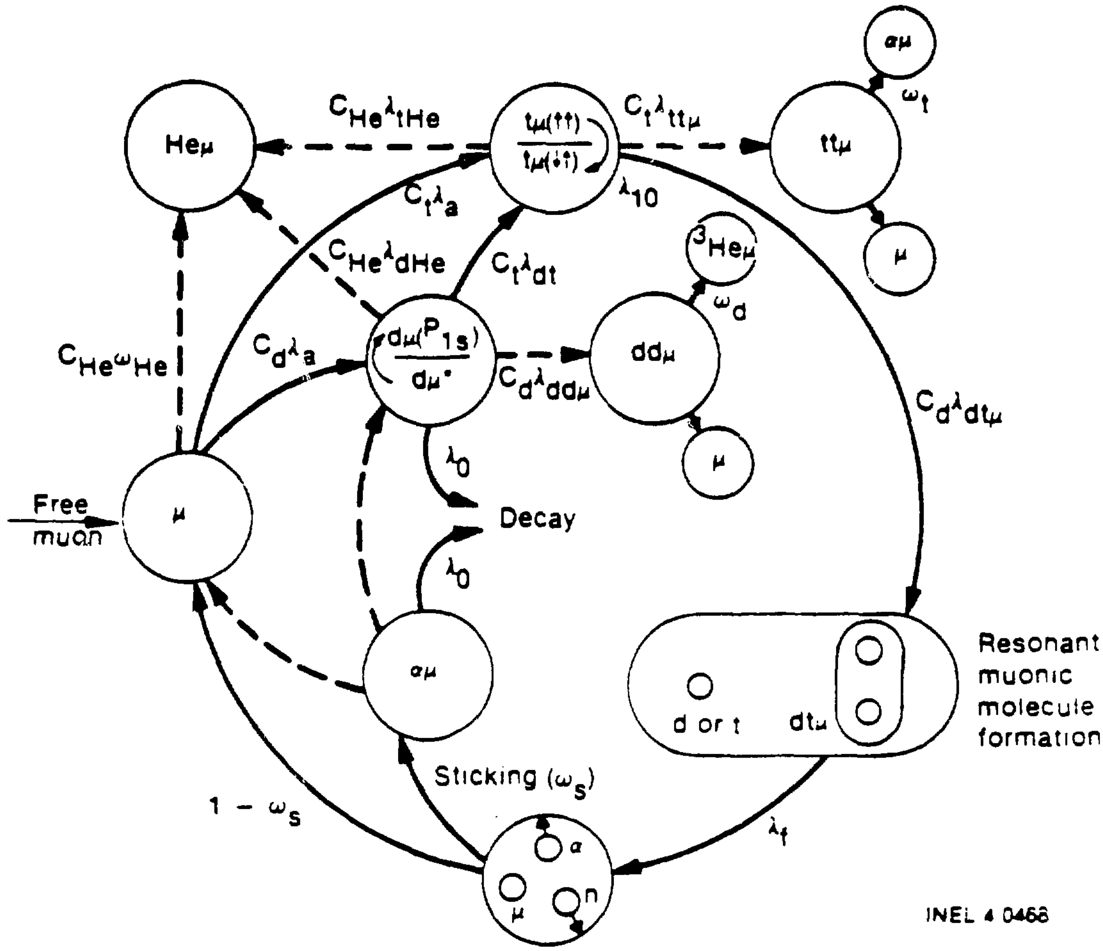
(FIGURE 4)

(FIGURE 5)



Pionic ratio data derived from 500-MeV proton scattering experiments at Los Alamos (ω is the nuclear excitation energy). The curve is the prediction of the pionic enhancement model normalized to reproduce the EMC effect. The experimental ratio of unity indicates no extra pions in lead. The solid curve is at full nuclear density; the dashed curve is at half nuclear density.

Los Alamos



Scheme of processes occurring when a negative muon (μ) stops in a mixture of deuterium (*d*), tritium (*t*), and helium (He) having respective molar fractions $C_d + C_t + C_{He} = 1$. Rates (λ) and sticking probabilities (ω) are defined in the figure.

LOS ALAMOS NATIONAL LABORATORY

MEDICAL RADIOISOTOPE RESEARCH PROGRAM - COLLABORATIVE RESEARCH STUDIES

<u>Isotope</u>	<u>Institution</u>	<u>Purpose</u>
^{77}Br	University of New Mexico	Tumor detection agents
	Washington University	Estrogen receptive tumor detection
	University of California, Davis	Monoclonal antibody labeling
^{109}CD	Atomic Energy of Canada, Ltd.	Cd/Ag biomedical generator
^{67}Cu	Albert Einstein/Yeshiva University	Protein control of Cu absorption
	California State U., Fullerton	Cu-labeled Bleomycin tumor detection research
	Hospital for Sick Children	
	John Hopkins Medical Institute	Wilson's disease and biological research
	National Institutes of Health	Monoclonal antibody labeling
	New England Nuclear Corp.	
	University of California, Davis	
	University of Saskatchewan	
	USDA, Beltsville, MD	
	USDA, Grand Forks, ND	
	IBM Research Center	
^{52}Fe	University of Nebraska Medical Center	Brain study

(FIGURE 8)

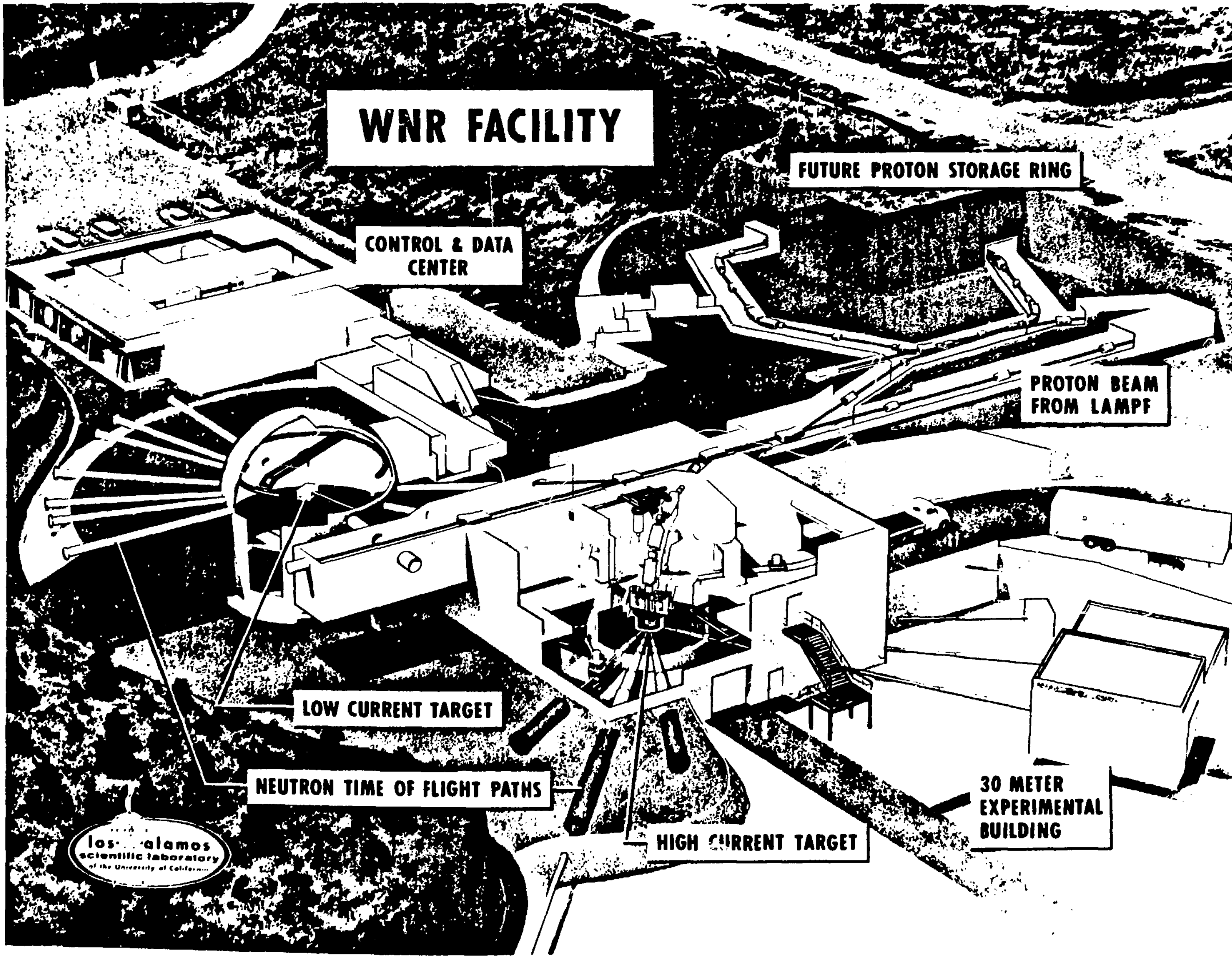
MEDICAL RADIOISOTOPE RESEARCH PROGRAM - COLLABORATIVE RESEARCH STUDIES (2)

Isotope	Institution	Purpose
^{68}Ge	Memorial Sloan-Kettering Cancer Center MRC/Hammersmith Hospital Oak Ridge Associated Universities OFC Des Rayonnement Ionisant University of Chicago Rad. Pro. Serv. University of Liege, Belgium University of Michigan Washington University	Ge/Ga general development, biomedical generator
^{16}Ho	EP-Isolde, CERN	Neutrino mass measurement
^{22}Na	New England Nuclear Corp.	Isotopic composition evaluation
^{82}Sr	E.R. Squibb & Sons MRC/Hammersmith Hospital Squibb/Sloan-Kettering Squibb/Sloan-Kettering/U Texas University of California, Donner Lab University of Liege, Belgium University of Wisconsin	Myocardial studies
^{48}V	California State University, Northridge	Role of vanadium in animal growth
^{127}Xe	Brookhaven National Laboratory	Pulmonary function

(FIGURE 9)

FUNDAMENTAL STUDIES

MEASUREMENT	GROUPS	FACILITY	RESULTS
NEUTRON ELECTRIC DIPOLE MOMENT	HARVARD, WASH, SUSSEX, ILL RUTHERFORD	ILL (REACTOR)	$\leq 4\times10^{-25}$ E-CM
NEUTRINO-ELECTRON SCATTERING	IRVINE, LANL MARYLAND	LAMPF	$(8.9\pm2.9\pm1.5)E_\nu\times10^{-45}\ \mathrm{CM}^2/\mathrm{M}_\mathrm{N}$
ELECTRON-NUCLEUS SCATTERING	AMERICAN, SLAC BONN, CEN ROCHESTER	NPAS	SEE SEPARATE FIGURE
PROTON-PROTON SCATTERING	LANL, ILL, PRINCETON	LAMPF	$(2.4\pm1.1)\times10^{-7}$
	WISCONSIN, ETH	SIN	$(-2.2\pm0.9)\times10^{-7}$
FRACTIONALLY CHARGED PARTICLES	CALTECH	3MV	SEE SEPARATE FIGURE
DOUBLE BETA DECAY	BATTELLE, S. CAROLINA	^{76}GE	$T_{1/2}>1.4\times10^{23}$ Y



WNR FACILITY
FUTURE PROTON STORAGE RING
CONTROL & DATA CENTER
PROTON BEAM FROM LAMPF
LOW CURRENT TARGET
NEUTRON TIME OF FLIGHT PATHS
30 METER EXPERIMENTAL BUILDING
HIGH CURRENT TARGET
scientific laboratory

(FIGURE 10)

COUNTRIES REPRESENTED AT LAMPF 1983 – 1985

Australia
Bangladesh
People's Republic of China
Colombia
Cyprus
Egypt
El Salvador
France
India
Iran
Iraq
Ireland
Israel
Italy
Japan
Lebanon
Malaysia
Mexico
Netherlands
Norway
Republic of China
South Korea
Sweden
Switzerland
United Kingdom
United States
West Germany

(FIGURE 11)

Title of Workshop	Date Held	Name of Organizer(s)
Discussions on Neutrino Physics Proposals for LAMPF II		
First Meeting	July 8-10, 1985	G. Garvey
Second Meeting	July 15-17, 1985	G. Garvey
Workshop on Experimental Proposals for Hyper-Nuclear Physics	Sept. 16-20, 1985	G. Garvey
Discussions of Prototype Proposals of CP Violation for LAMPF II	Sept. 23-26, 1985	G. Garvey
NPL Upgrade Workshop II	Dec. 16-17, 1985	J. McClelland and R. Boudrie
Accelerator Controls Workshop	Oct. 7-10, 1985	S. Brown and P. Clout

(FIGURE 12)

Title of Workshop	Date Held	Name of Organizer(s)
NPL Upgrade Working Group Meeting	Dec. 17-18, 1984	J. McClelland, T. Carey, and M. McNaughton
LAMPF Workshop on Pion Double Charge Exchange	Jan. 10-12, 1985	H. Baer and M. Johnson
LAMPF workshop on Dirac and Approaches to Nuclear Physics	Jan. 31 - Feb. 2, 1985	R. Boudrie and J. Shephard
$\mu \rightarrow e \gamma$ Pre-Collaboration Meeting	March 21-22, 1985	M. Cooper, D. Nagle, C. Hoffman, G. Hogan, and R. Mischke
LAMPF Neutrino Workshop	March 28-29, 1985	R. Burman and G. Garvey
Los Alamos Workshop on Relativistic Dynamics and Quark-Nuclear Physics	June 2-14, 1985	M. Johnson

Discussions to develop an experimental "proposal" to study hard scattering with exclusive reactions with a very hot beam, held at Brookhaven National Laboratory

First Meeting	June 7, 1985	G. Garvey
Second Meeting	July 8-10, 1985	G. Garvey

ガン治療の現状と将来

（左から）坂本教授、ローゼン、ブレーザー、ボートの各所長。右端が司会の中村客員研究員

世界三大研究所長を囲む座談会

アメリカ・カリフォルニア大学付属ロスアラモス中間子物理研究所（LAMPF）所長
ルイス・ローゼン氏

米ペンシルベニア州立大卒。核物理学を専攻。理学博士。一九四四年から六〇年まで、ロスアラモス国立研究所の物理学部長を務め、六四年中間子物理研究所（LAMPF）所長に就任。研究所のあるニューメキシコ州ロスアラモスの出身で、六十七歳。

カナダ・三大学共同・中間子研究所（TRIUMF）所長
エーリック・ボート氏

カナダ・マニトバ大卒。物理学と数学を専攻。理学博士。一九六五年、ブリティッシュ・コロンビア大物理学科教授。七五年から八一年まで同大副学長。八一年、カナダ・三大学共同・中間子研究所（TRIUMF）所長に就任。バンクーバー出身。五十五歳。

スイス国立原子核物理研究所（SIN）所長
ジャン・P・ブレーザー氏

スイス国立工科大（ETH）卒。物理学を専攻。理学博士。卒業後は核物理学、天文学を研究。スイス国内の天文台長、ETH物理学科教授などを歴任した後、一九六八年、スイス国立原子核物理研究所（SIN）所長に就任。チューリヒ出身。六十二歳。

東北大学医学部放射線基礎医学教室教授
坂本　澄彦氏

東京医科歯科大医学部卒。医学博士。昭和五十一年一月から五十四年三月までカナダの三大学共同中間子研究所（TRIUMF）で、パイ中間子の放射線基礎医学研究に従事。現在、東北大医学部放射線基礎医学教室教授。五十二歳。

（司会）
読売新聞社調査研究本部・客員研究員
東海大学理学部教授
中村誠太郎氏

京都大理学部卒。理学博士。中間子論でわが国初のノーベル賞を受賞した湯川秀樹博士の弟子で、素粒子論、核物理学の研究に従事。東大理学部教授などを経て、現在、東海大理学部物理学科教授。本社調査研究本部客員研究員。七十二歳。

(FIGURE 14)

FUTURE DIRECTIONS

Gerald T. Garvey
November 4, 1985
Remarks to the Annual Meeting of the LAMPF Users Group

Director Thorn, visitors from DOE, LAMPF users and staff, ladies and gentlemen:

Thank you Bob for the Laboratory's expression of confidence in me as evidenced by this appointment as the second Director of LAMPF. I regard it a high honor because of the stature and leadership that Louis Rosen brought to the position over the past two decades. It is a position of great responsibility to the Laboratory, to the users of LAMPF, and to the United States nuclear-physics program. I will devote all of my energy to the discharge of this responsibility. I have one advantage that Louis did not have: an advisor who knows the Laboratory intimately and whose skill in communicating the message of nuclear science to the United States Congress is unsurpassed. I plan to seek and rely on Louis Rosen's advice and guidance for a long time.

If you think of the capability that has been built at LAMPF, it represents a staggering resource! LAMPF continues to provide the world's most intense beam of protons above the pion threshold. The fixed experimental apparatus--HRS, EPICS, and the π^0 spectrometer--allow LAMPF to dominate the scientific world in nucleon-nucleon and pion-nucleon research. I must mention that at the moment the π^0 spectrometer is obtaining the only real data that has ever been taken on the $(\pi^{\pm}, \eta)$ reaction on a nucleus. Specialized equipment such as our neutrino detectors and the "crystal box" allow fundamental measurements to be made that lead to further understanding of the Standard Model of the electroweak interaction and its possible extensions.

On the near horizon there is to be a sophisticated magnetic spectrometer, TOFI, designed and constructed by the Los Alamos Isotope and Nuclear Chemistry Division and their collaborators. This device will allow precision measurement of masses of light nuclei far from stability that will challenge physicists to extrapolate present understanding of nuclear structure out to the limits of nuclear stability. That colorful railway system you see down at the far end of LAMPF is part of experiment 645. It will soon be searching for neutrino oscillations at the smallest values of the mixing angle between μ and e antineutrinos that any researchers have heretofore attempted.

On a more distant time scale, the Nucleon Physics Laboratory (NPL) will expand our capability to investigate nucleon-nucleon and nucleon-nucleus physics. Earlier work at Los Alamos has brought this subject into the limelight as it provided the critical phenomenological support for a relativistic description of nucleon-nucleus scattering. Making this description as complete as possible and characterizing the scope of its implications will occupy much of the attention of nuclear physicists over the years to come. I am especially pleased with the interaction between LAMPF and the Los Alamos Physics Division. They are developing a white neutron source at WNR that provides an intense source of neutrons up to 300 MeV. This source will greatly enhance the capability available to the United States nuclear physics community. This afternoon you will hear a great deal more about the new facilities being constructed or proposed at LAMPF. There is enormous vitality at this Laboratory!

Physics never stands still! (Sometimes we manage to go backward.) Surprising discoveries upset our view of the physical world and present challenges and new opportunities. One of the most important observations that has been made on the character of nuclei in my research lifetime is the EMC effect. The observation that the quarks in an iron nucleus have lower momentum than they do in deuterium has potentially startling consequences. Explanations of the EMC effect range all the way from quark deconfinement inside the nucleus, or swelling of hadrons in the nuclear medium to a version that claims the effect is readily explainable by well known meson exchange currents. Clearly, a high priority of nuclear physics is the clarification of this situation and a further investigation of the consequences of quark-gluon structure of hadronic matter. LAMPF as presently configured is not the ideal facility to pursue these investigations. However, Arch Thiessen and his colleagues are designing the nearly ideal facility to open up this area of physics to real investigation.

There is a growing awareness that a facility such as our proposed LAMPF II is far and away the best facility to conduct this research and to lead the nuclear physics community into a systematic investigation of deconfinement. Further, the recent HEPAP report that cites the AGS fixed target program, particularly the study of rare K decays, as one of its four highest priorities shows that a kaon factory is a cost-effective way to investigate the limits of the Standard Model of the electroweak interactions. I have never felt more confident about the scientific necessity of building a kaon factory and believe there is no better site for it than here at Los Alamos. However, for the present the most important issue is that we all become intellectually involved in understanding this new physics and thinking through how it is best pursued. What do we want to learn, and how can we most effectively go about gathering the data we need? This is an issue that I want you to become informed on and then make yourselves heard. I would hope that your graduate courses in nuclear physics include a section on QCD, its impact on hadron structure, and its potential role in nuclear structure. If nothing else, it will serve to show that our conventional picture of the nucleus with nucleons and mesons is far from obvious or trivial.

On a more administrative note, there is a new cast of players both here at Los Alamos and in Washington. I am sure that Dave Hendrie will relate the changes in Washington to you in his talk later this morning. The University of California expects to be naming a new Los Alamos National Laboratory director by early next year. I work on the assumption that the new director will see the case for LAMPF II as a National and Laboratory priority. But what I wish to bring to your attention is that these shifts in leadership represent opportunities for constructive change. I would greatly appreciate hearing from each of you regarding changes that we could make that would enhance your effectiveness in using LAMPF. Over the next two months we will be reviewing all aspects of our activity here at Los Alamos in nuclear and particle physics and will consider input from the user community regarding LAMPF operations in a formal way. I am currently discussing this matter with your executive board. At any rate, I hope that any of you with strong views will share them with me. My Los Alamos telephone number is 505-667-2000.

Thus, as we enter into a new era in nuclear physics, I expect this community of LAMPF users to be in the vanguard of building on the past achievements of nuclear physics, and taking those bold steps that will be required to place our understanding of the behavior of hadronic matter on a firm foundation.

Thank you!

Operation's Report
1985 Users Meeting
Donald C. Hagerman

The past year has been extremely busy at LAMPF with the first half being devoted to a shutdown for major changes in our facility and the second half being devoted to production under the challenging conditions imposed by three-beam operation.

The shutdown work on the accelerator emphasized changes necessary to provide a high-peak intensity beam for the Proton Storage Ring (PSR). These changes included a new H^- ion source and injector system, a new low-energy H^- transport system, and a reconfiguration of the LAMPF switchyard. Performance of the new H^- source and injector system met initial PSR requirements reasonably well in that satisfactory operation was achieved with a 6-mA peak current beam captured in the linac. Improvements are in order on beam availability, increased peak current, and beam emittance and are expected to occur, for the most part, during routine upgrades to this new facility. Rebuilding of the low-energy H^- transport was necessary to accommodate the beam chopping needs of the PSR and to provide appropriate time sharing of the H^- and P^- beams. This rebuilding unavoidably caused some significant changes in the P^- and H^+ transport systems. The switchyard reconfiguration was required so that negative ion beams could be sent either to the PSR or to the NPL/HRS laboratories. Because these two laboratories lie in opposite directions, the switchyard changes were extensive. Twenty-three new magnets were needed, and several old magnets were repositioned. Performance of the new switchyard is gratifying in that commissioning of the new equipment was without difficulty.

In the experimental areas, the major shutdown activity was a complete rebuild of target cell A-6. This work provided new facilities for studies of neutron- and proton-induced radiation damage; it also provided enhanced neutrino fluxes with reduced neutron backgrounds through the addition of a water target and some uranium shielding. A further benefit was a significant reduction in radioactive gas release. This work completes a three-year upgrade program on target cells that are currently in use so that they will operate reliably at the 1-mA level. Other work in the experimental areas included the addition of shielding at HRS that significantly reduced background, installation of a He liquefier system, and a new refrigerator system for the liquid-deuterium neutron-production target in Line B.

In the world of computers, the VAX control system on the accelerator is now essential for many aspects of accelerator operation, and it is displaying many desirable features to operators, programmers, and accelerator physicists. The Data Analysis Center (DAC) was enhanced during the summer by the addition of an 8600 computer; it has proven to be a popular machine. Further enhancements to the DAC are planned for the next year.

Operation of the facility with three primary beams (H^+, H^-, and P^-) has been challenging. Turn-on for the P^- and H^- beams occurred near the end of April; the H^+ beam was added early in May. Some beam-availability problems have been related to the increased complexity introduced by simultaneous production of three beams. It is encouraging that as we gain experience with three-beam operation, beam availability has returned to satisfactory values. We have met our goal of providing a beam to PSR without compromise to the other LAMPF users, except for the appropriate reduction in duty factor. Other beam-availability problems were due to causes beyond our control. For example, this has been an exceptional year for lightning-induced power outages causing significant beam interruptions, particularly on the P^- injector system.

One highpoint of the H^+ beam this year has been the use of a 17-mA peak-current beam in routine production. This level of peak current was part of the original design criteria for LAMPF but never had been used in practice. Higher peak currents are essential for average currents in the 1-mA range while sharing the available duty factor among several different uses of the facility.

Commissioning of the PSR was reorganized under the leadership of Robert Macek late in the summer. Initial performance of the ring was quite promising, but the problems became more difficult as the current was increased and beam spill became more critical. The major LAMPF contribution to this commissioning effort has been related to measurements that characterize the beam coming from LAMPF. Progress on the PSR and its related problems is being made at a gratifying rate; by the time of the next users meeting, the ring should be in routine operation for materials-science research at interesting current levels.

During the next shutdown, which will start late in December, we will continue our upgrade program and perform routine maintenance activities. A buncher-chopper system will be installed on the P^- injector system, which will provide beam pulses separated by 100-ns intervals for neutron experiments requiring time-of-flight information. Activity continues on the optically pumped polarized-ion source with installation of this device now expected prior to the 1988 operating period. In the experimental areas, the new clamshell spectrometer is in routine use and has displayed satisfactory resolution and low pion-energy performance. The Time-of-Flight-Isochronous-Spectrometer (TOFI) is virtually complete, and some research results should be obtained before the shut-down occurs. Construction for the neutrino oscillation experiment is coming along with the tunnel nearly complete, a rail system for moving detectors and plugs in place, and a service building for detector assembly in use. Checkout of the detector array and active shield has been started. The NPL upgrade program is underway; it includes a neutron time-of-flight installation (NTOF) and a new medium-spectrometer (MRS). A High Resolution Atomic Beam facility (HIRAB) may appear as fallout from the Strategic Defense Initiative (SDI) program providing improved facilities for the laser-stripping atomic physics program.

In these upgrade programs, as well as in the operation of the facility, we continue to experience strong budgetary pressures. For upgrades we minimize costs by installing old equipment whenever possible; for example, the old Colorado cyclotron magnet will be used as a switching magnet in the NPL upgrade. Operational costs are almost linearly related to the running time (and the research output) so the only significant adjustment that can be made is by changing the operating schedule; an optimistic schedule has production restarting by mid-June of 1986. Realistically, this date could easily slip several weeks.

LAMPF remains a challenging facility from the operations viewpoint. Competition for personnel from other programs as well as increasing budgetary pressures are foreseen for the next year, making our problems more difficult. However, research results and the potential for significant research results continue at such a high level that operation and improvement of the facility are well worth the effort and cost.

OG 872

NEUTRINO ELECTRON SCATTERING AT LAMPF

D. Hywel White

Department of Physics

Brookhaven National Laboratory

Upton, NY 11973

Talk given at LAMPF User's Meeting Ncvember 2, 1985

The Standard Model

A major accomplishment in elementary particle physics in the last fifteen years has been the success of the electroweak model of Glashow, Weinberg, and Salam in describing the unification of the electromagnetic and weak forces. The theory explains the experimental facts within the precision with which they are known in terms of a single phenomenological parameter. Many deeper uncertainties remain, particularly the origin of the masses of the intermediate vector bosons, but here we shall consider the limits of applicability of the standard model assuming that verifying the theory is a worthwhile goal and that exposing limitations of the theory may cast light on the deeper aspects, which are yet speculative.

The theory is described below from an experimenter's point of view, with heavy emphasis on the observables, including a summary of the present experimental situation. The electroweak interaction is described by the symmetry $SU(2)_L \times U(1)$ implying two independent coupling constants for the two constituent groups g' and g, respectively. The charged current interaction has been known (for some time) in the form of β decay and is well described by the exchange of a W^+ or W^- with equal axial and polar vector coupling constants.

The group SU(2) implies a W° in a triplet coupling with the same strength as the charged W. The U(1) group describes a single boson B° with different coupling to the SU(2) triplet but which is mixed with the W° to give a photon

$$|\gamma\rangle = \frac{g|B^\circ\rangle + g'|W^\circ\rangle}{\sqrt{(g^2 + g'^2)}}$$

and

$$|Z^\circ\rangle = \frac{g|B^\circ\rangle - g'|W^\circ\rangle}{\sqrt{(g^2 + g'^2)}}$$

The electromagnetic coupling of $|\gamma\rangle$ is

$$e = \frac{gg'}{\sqrt{(g^2 + g'^2)}} \quad .$$

The Z° can be written

$$|Z^\circ\rangle = g/\cos\theta_W \; [\sqrt{1/2}|\Phi^\circ{}_1\rangle - \sin^2\theta_W|\Phi_{em}\rangle]$$

with Φ_1°, the eigenstate of the weak triplet and Φ_{em} the electromagnetic eigenstate illustrating the fact that the Z° contains an electromagnetic component as is observed in e^+e^- collisions, for example.

At this stage, there are two neutral particles in the laboratory with coupling constants that reflect the mixing between them. We may define

$$\tan\theta_W = g'/g \text{ and then } \sin^2\theta_W = e^2/g^2 \quad .$$

Symmetry Breaking

When spontaneous symmetry breaking is introduced, for example from a Higgs field, the W and Z acquire mass and the photon becomes massless. Then in a simple version of symmetry breaking with a Higgs doublet gives

$$m_W/m_Z = \cos\theta_W$$

and

$$\sin^2\theta_W = e^2/g^2 = 1 - m_W^2/m_Z^2 \quad .$$

The fact that the Z° mass is different from the W mass allows a solution for the mixing angle θ_W, but to establish the scale of g and g′ we must use a charged current process, for example μ decay. With a charged current coupling constant G_μ, and appropriate phase space factor

$$\frac{1}{\tau_\mu} = \frac{G_\mu^2\, m_\mu^5}{192\pi^3}$$

from the rate of decay of the muon, G_μ can be separated from the phase space contributions. We will be concerned below with radiative corrections to weak processes and muon decay is no exception; the corrections to first order in α are written below together with their numerical values. Then the muon lifetime of 2.197 μsec gives $G_\mu = 1.16635 \times 10^{-5}\ \mathrm{GeV}^1$.

$$(1 - 8m_e^2/m_\mu^2)(1 - 3/5\ m_\mu^2/m_W^2 + \alpha/2\pi(25/4 - \pi^2)(1 + 2\alpha/3\pi\ \ln(m_\mu/m_e)$$

0.99981 0.99159 1.00383

The SU(2)xU(1) theory with symmetry breaking gives an explicit relation for m_W.

$$m_W = \frac{\pi\alpha}{2G_\mu \sin^2\theta_W}^{1/2} = \frac{37.281}{\sin\theta_W}$$

and

$$m_Z = \frac{m_W}{\cos\theta_W} \quad .$$

Radiative Corrections

The masses of W and Z are generated by spontaneous symmetry breaking but with contributions from diagrams like

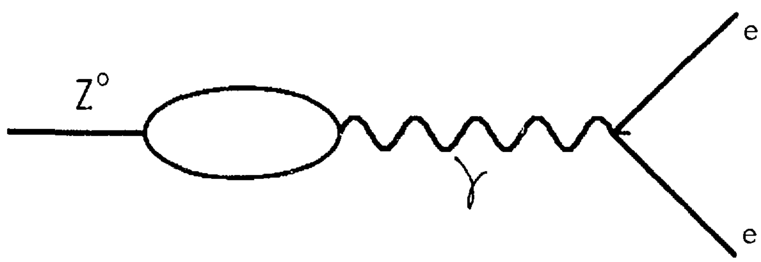


Fig. 1

These diagrams potentially contribute significantly, for example when the SU(2) x U(1) is embedded in the group SU(5) as an attempt at grand unification, then a prediction for $\sin^2\theta_W$ emerges as 3/8. Diagrams like that above contain loops from the grand unifying particles and generate substantial radiative corrections giving

$$\sin^2\theta_W^{exp} = \frac{3}{8} \left(1 - \frac{109\alpha}{18\pi} \ln(m_X/m_W)\right)$$

estimating m_X from the measured value of $\sin^2\theta_W$ gives $m_X \simeq 1.3 \times 10^{14}$ GeV. This approach has the difficulty that the predicted mass of m_X in turn implies a proton lifetime which is in conflict with the upper limits $\tau_p > 2.5 \times 10^{32}$ years from IMB and Kamioka. However, the point remains that the relation between $\sin^2\theta_W$ and the W and Z masses depend on contributions from radiative corrections. Define the sum of radiative contributions to the W mass as $(1-\Delta r)$, then

$$m_W = \frac{37.281}{\sin\theta_w \sqrt{(1-\Delta r)}} = \frac{38.64}{\sin\theta_w}$$

with

$$\Delta r = .069 \quad .$$

The mass of the W determined from the average of UA1 and UA2 is 81.8 ± 1.5 GeV, which yields $\sin^2\theta_w = 0.223 \pm 0.008$. The expression above

$$\sin^2\theta_w = 1 - m_W{}^2/m_Z{}^2$$

can be used to define $\sin^2\theta_w$ as an experimental quantity which gives

$$m_Z = \frac{m_W}{\cos\theta_w} = \frac{77.30}{\sin 2\theta_w} \quad .$$

The measured Z mass from the same two experiments

$$m_Z = 92.6 \pm 1.7 \text{ GeV}$$

gives $\sin^2\theta_w = 0.225 \pm 0.011$. Returning to the definition of e

$$\frac{e^2_{exp}}{g^2_{exp}} = \left(1 - \frac{m_W^2}{m_Z^2}\right) \qquad \left(1 - 2\,\frac{\delta e}{e}\,..\right)$$

experimental quantities $\qquad (1 + \Delta r)$.

e_{exp} is potentially variable depending on the process by which it is measured, that is at the masses of W and Z or in the scattering processes. δe expresses this variation with contributions from leptonic, hadronic, and bosonic loops. Numerically,

$$\Delta r = \underset{\text{leptonic}}{0.033} + \underset{\text{hadronic}}{0.033 \pm 0.003} + \underset{\text{bosonic}}{0.003}$$

The leptonic corrections assume three generations at the known masses. The hadronic corrections similarly assume three generations with a top mass at $\simeq$ 36 GeV. The correction is approximately logarithmically dependent on this mass. Higher mass generations would increase this correction substantially with the error $\pm$ 0.003 reflecting a reasonable uncertainty on the mass of the top quark. The bosonic correction comes from W loops and a contribution from the Higgs. To estimate this correction, a Higgs mass equal to the Z was used, clearly uncertain at this time.

When radiative corrections are calculated for scattering processes, an extra diagram appears.

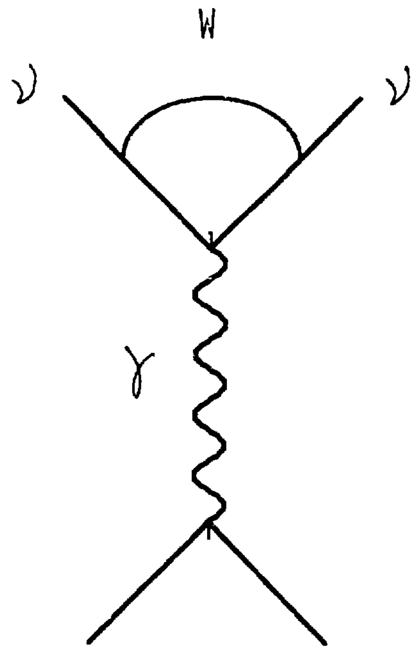


Fig. 2

This term is roughly equal and opposite in sign to the sum of corrections to the mass terms above so that little numerical correction is required for neutral current processes like ν_μ-e scattering, at least in the context of the standard model with the definition of $\sin^2\theta_w$ above.

Scattering from Hadrons

The ratio of scattering of neutrinos from hadrons in the neutral current (Z exchange) and charged current (W exchange) channels depends on $\sin^2\theta_w$. In deep inelastic scattering with four momentum transfer Q^2 to the lepton

$$R_\nu = \frac{\sigma_{nc}}{\sigma_{cc}} = \rho^2_{\nu n}\ [1/2 - \kappa(Q^2)\sin^2\theta_W + \frac{20}{27}\kappa^2(Q^2)\sin^4\theta_W]$$

$$= 0.31$$

$\kappa(Q^2)$ is the radiative correction to the neutral current cross section and is weakly dependent on Q^2; a typical value is 1.006. The charged current cross section has also a radiative correction which is somewhat larger and is included in $\rho_{\nu n}{}^2 \simeq 0.98$. These experiments have the advantage of a copious event rate although the systematic uncertainties have given trouble, which has been reflected in different values of $\sin^2\theta_W$ from different experiments. The analysis assumes that the parton model is applicable to the structure and this may be a concern, although the cross section ratio measurement helps to reduce the systematic uncertainty. A present world average is

$$\sin^2\theta_W = 0.223 \pm 0.008.$$

A conceptually similar measurement is made in $\nu_\mu p$ elastic scattering at Brookhaven. Form factors are measured in electron scattering and in ν_μ quasi elastic scattering. The cross section is then understood with $\sin^2\theta_W$ as a parameter and a possible induced isoscalar contribution. The level of systematic understanding does not make it competitive in accuracy at this time with deep inelastic scattering, but $\sin^2\theta_W = 0.220 \pm 0.016 {}^{+0.023}_{-0.031}$.

The Z° is coupled to e^+e^- and the weak electromagnetic interface may be observed at an e^+e^- collider. Parity violation in the weak interaction induces an asymmetry in the production of μ pairs, which may be expressed as

$$\frac{d\sigma}{d\cos\theta} = \frac{\pi\alpha^2}{2S} R_{\mu\mu} \, (1 + \cos^2\theta + 8/3 \, A_{\mu\mu} \cos\theta) \quad .$$

In a recent experiment at PEP, MAC has quoted $R_{\mu\mu} = 1.001$ and $A_{\mu\mu} = -0.063$. $A_{\mu\mu}$ is subject to radiative corrections of the same general type with a value of 0.0314 ± 0.006. This experiment basically measures the interference of the electromagnetic amplitude with the tail of the Z° and will be expected to improve in accuracy as the C.M. energy of colliders improve. Ultimately, with SLC or LEP, the measurement of the Z° mass will lead to the greatest precision at an e^+e^- collider. Presently, the value of $\sin^2\theta_W$ is typically

$$\sin^2\theta_W = 0.22 \begin{smallmatrix} + \, 0.05 \\ - \, 0.04 \end{smallmatrix} \; .$$

Neutrino-Electron Scattering

ν_e-e scattering, E225, is being measured at LAMPF and this group has an interim publication of their data. The radiative corrections are comparable to the charged current corrections discussed in the section on deep inelastic scattering above. At the present time, this experiment has determined the sign of the interference between the charged and neutral currents (it is destructive) and have a value of $\sin^2\theta_W$

$$= 0.21 \begin{smallmatrix} + \, 0.08 \\ - \, 0.12 \end{smallmatrix} \begin{smallmatrix} + \, 0.05 \\ - \, 0.07 \end{smallmatrix}$$

ν_μ-e scattering is being measured in two experiments, CHARM at CERN and E734 at Brookhaven. The radiative corrections are negligible in these scattering experiments because of the accidental cancellation discussed above. This cancellation depends on the particles that are assumed to contribute to the loops in the diagrams that are considered, so that the fact that the radiative corrections are small is particularly true for the standard model.

In the published literature

$$\text{CHARM} \quad \sin^2\theta_W = 0.215 \pm 0.032 \pm 0.013$$

$$\text{BNL} \quad \sin^2\theta_W = 0.209 \pm 0.029 \pm 0.013 \ .$$

In CHARM II and in further running for BNL, the combined error may be reduced to 0.020.

A New LAMPF Experiment

The preceding discussion underscores the need for a really precise measurement of $\sin^2\theta_W$ in the scattering mode. The measurement of the Z and W masses will provide an alternate determination and the difference in $\sin^2\theta_W$ from the measurement of the masses squared and from scattering is .015 in the standard model. This is near the limit for present (and near future) measurements. So as the statistical precision improves, the systematic understanding of the experiments is becoming a limiting feature.

A group at LAMPF is proposing an experiment that combines excellent statistical precision with the potential for low systematic uncertainty. The proposal is to measure the ratio

$$R = \frac{\sigma(\nu_\mu e)}{\sigma(\nu_e e) + \sigma(\bar{\nu}_\mu e)} \ .$$

In terms of the standard model $SU(2)_L \times U(1)$

$$R = \frac{3}{4} \frac{1 - 4 \sin^2\theta_W + 16/3 \sin^4\theta_W}{1 + 2 \sin^2\theta_W + 8 \sin^4\theta_W}$$

when $\sin^2\theta_W$ increases, $\sigma(\nu_\mu e)$ increases and both $\sigma(\bar{\nu}_\mu e)$ and $\sigma(\nu_e e)$ decrease, the last because the charged and neutral currents interfere destructively. There is an immediate gain, therefore, in measuring this ratio over the measurement of the individual rates. Each reaction has a similar signature, namely that the recoil electron has a small angle to the incident neutrino direction. The $\nu_e e$ cross section is about six times either of the $\nu_\mu e$ cross sections, which are about equal. To measure the ratio, ν_μ must be distinguished from ν_e and $\bar{\nu}_\mu$. The lifetime of the pion is 25ns and the μ 2200 ns. The proposal uses the proton storage ring (PSR) to compress a LAMPF pulse to 270 ns. We show in Fig. 3 a spill from the PSR and the time-dependent neutrino fluxes from the decay chains

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$

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

There are equal numbers of ν_μ, ν_e, and $\bar{\nu}_\mu$ integrated over all three, but within the 270 ns spill the ratio

$$\frac{N_{\nu_e}}{(N_{\bar{\nu}_\mu} + N_{\nu_e})} = 0.06 \ .$$

The Detector

Experiments using a stopped pion source have been considered at LAMPF at least since 1969. The $\nu_e e$ experiment that is presently running demonstrates the feasibility of the idea. The use of the PSR for time separation of ν_μ and $\nu_e, \bar{\nu}_\mu$ has the disadvantage that the available flux is reduced compared to the existing beam stop. More events are required to reach the precision that is required to impact physics in the next decade. It has been recognized at LAMPF that a new detector technology has emerged that makes very large neutrino detectors feasible financially. The detector we refer to is the water cherenkov detector for electrons in which enough cherenkov photons are collected in enough separate phototubes that reconstruction of the energy and direction is possible. A prototype of this technology is operating at Kamioka looking for proton decay in which appropriate energy and angular resolutions have been demonstrated. The number of cherenkov photons produced by a charged particle is

$$N = \frac{2\pi\alpha}{C} \left(1 - \frac{1}{n^2\beta^2}\right) \Delta\Omega \ \delta\nu$$

$n = 1.344$ for water and $\beta \simeq 1$ for electrons. For a typical phototube and water as an absorbing medium $\Delta\nu \simeq 5.7 \times 10^{14}$ sec^{-1}.

Assuming a reasonable quantum efficiency of 0.1 averaged over angle, the number of photoelectrons

$$N_e = f \times 10/\text{MeV}$$

where f is the fractional coverage of photocathode in the detector. The angle of the cherenkov cone

$$\cos\theta = 1/n\beta \ , \ \theta = 41.4° \text{ for } \beta = 1 \ .$$

The radiation length in water is 36 cm and a typical multiple scattering angle for a 20 MeV electron is about 15°. For 25% photocathode coverage a 20 MeV electron yields 50 photoelectrons. The angular resolution is such as to largely preserve the ring structure of the cherenkov light and the number of photoelectrons should produce energy resolution at the 20% level. The cost of the photomultiplier and electronics is a major constituent of the detector and for a point source the optimal distribution of detecting elements is on the surface of a sphere. A highly schematic view of a possible detector is shown in Fig. 4. The proton beam is stopped in the center of an iron hemisphere that is thick enough to absorb the neutron flux from the target. The phototubes are arranged on the surface of a hemisphere of 17 m radius. This gives an effective thickness of about 9 m for the water in which neutrino interactions can be detected; the interaction rate is proportional to this thickness. The cherenkov cone of 41° will occasionally impinge on the area outside the hemisphere, so that phototubes are also deployed on the iron and also on the flat surface. These phototubes also detect light from events in which the angle of scatter of the secondary electron is large enough that the information of the neutrino direction is lost. Cosmic rays also will produce electrons from the decay of muons that shop in the detector that will frequently be detected outside the hemisphere. Signal events will appear to come from the target and a scheme has been suggested to enhance the light coverage for these events by mounting mirrors between the phototubes on the hemisphere and reflecting light back on to the iron hemisphere and collecting these photons there. This scheme will have to be studied carefully to avoid degradation of the cherenkov pattern by additional reflections. The cosmic ray rate is large and a veto will need to be provided. The water outside the hemisphere is envisaged as a suitable medium to detect incoming muons and some of the hadrons.

In Fig. 5 we show two Kamioka cosmic ray events. In the top event, the muon ring is very clear, with a decay electron. In the bottom event, the muon is not visible but the decay electron is obvious. These electrons are approximately the quality of events that would appear in a LAMPF detector of this type. Electrons from decaying stopped muons have the well known Michel spectrum, this spectrum measured at Kamioka is shown in Fig. 6, illustrating the accuracy of the Monte Carlo model of the data. At this level of detail, the experiment seems feasible with a high level of cancellation of systematic effects in numerator and denominator of the cross section ratio. The principal uncertainty is in the energy resolution function because the secondary electron spectrum is different in numerator and denominator so the threshold behavior of the electron detection efficiency must be well known.

Photomultiplier Cost Estimate

The photomultipliers and associated electronics form the single most expensive component of the experiment. As an example, we have chosen the Hamamatsu 20" tube used at Kamioka. The active area of this tube at 25% coverage means that each tube takes care of an area of 0.66 m^2. The table below gives an estimate of the area of the detector components.

Area of outer hemisphere 17 m radius	1,816 m^2
Area of inner hemisphere 7 m radius	308 m^2
Area of plane bottom	754 m^2
This translates into:	
Outside hemisphere (25% coverage)	2,764 tubes
Inside hemisphere (25% coverage)	470 tubes
Plane bottom (10% coverage)	470 tubes

The total number of tubes is 3,694 and at 1.5 K$ per channel this is 5.54 M$. The mirrors on the outer hemisphere focusing on the inner hemisphere give a total of 40% light collection for νe electrons with 60% coverage.

Counting Rate Estimate

It is assumed that the experiment might run for three years with 130 days equivalent for each year. For the geometry of Fig. 3 and 100 μA of beam,

Total number of $\nu_\mu e$ events	14,270
Assume 60 μA is delivered on average	8,560
Electron energy cut at 12 MeV	4,400
85% detector operating efficiency	3,730
80% pattern recognition efficiency	3,000

This translates into an error on $\sin^2\theta_W$ of ± 0.0024.

Background

The residual cosmic ray and beam associated backgrounds are estimated below for the electron range between 10 and 60 MeV. E225 has been used as a model so that these estimates are completely empirical, and may improve with more caareful shield engineering. The numbers of background events are to be compared with 8 $\nu_\mu e$ events/day after all cuts described above.

	Beam Associated	Stopping Cosmic Ray
Background in E225/day	0.5	100
Increase for lower energy threshold: 20 MeV → 10 MeV	1.0	150
Scaling to larger detector Neutrons by inside surface area Cosmic Rays by projected area	50	15000
Reduction for addition 1.5 m Fe m shield	5	15000
Forward angle cut	.25	750
PSR duty factor	.25	2.5×10^{-3}
Scale factor for 60 μA current	.025	2.5×10^{-3}

The beam associated background is dominant and represents a signal/background of 300:1. This may be compared with about 4:1 in the BNL experiment.

Conclusion

We all agree that the standard model of Glashow, Weinberg, and Salam is a good description of the experimental world at the present level of accuracy. The first non-trivial corrections to the theory occur at the one-loop level and because they are different in their contributions to vector boson mass and in scattering, the two classes of measurements offer a serious test of the theory and of the particles that are assumed to contribute via the appropriate loops to the radiative corrections. The difference of the expected radiative corrections at the mass squared of Z and at the Q^2 of neutrino electron scattering is .069, which reflects into an apparent difference in $\sin^2\theta_W$ of .015. A group has been studying an experiment that could yield an accuracy of 0.0025 in $\sin^2\theta_W$ putting this section of the theory to a significant test.

Acknowledgements

In preparing this talk, I have exploited the patience of Bill Marciano, my knowledge of the radiative corrections is almost entirely due to him. Many people at LAMPF have contributed ideas and effort to the exploration of a convincing experimental scenario and detector design. I have borrowed their ideas extensively; some of them are Bob Burman, Herb Chen and the people at Irvine, Roger Carlini, Joey Donahue, and Vern Sandberg. Gerry Garvey has urged us on and continues to do so. I expect that these people and others will produce a detector design that can be used to do this exciting physics.

Neutrino Source

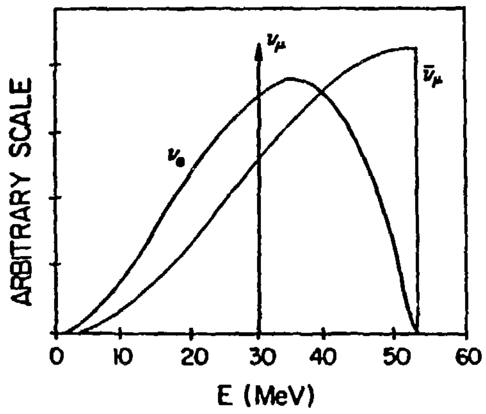
PSR produces pulses of protons of
270 ns duration into a beam stop target

π^+ stop and decay from rest
π^- are absorbed

Decay chains:

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$
$$\hookrightarrow e + \nu_e + \bar{\nu}_\mu$$

Equal numbers of ν_μ, ν_e, and $\bar{\nu}_\mu$.



Within the 270 ns spill $\frac{N_{\nu_e}}{N_{\nu_\mu} + N_{\nu_e}} = 0.06$

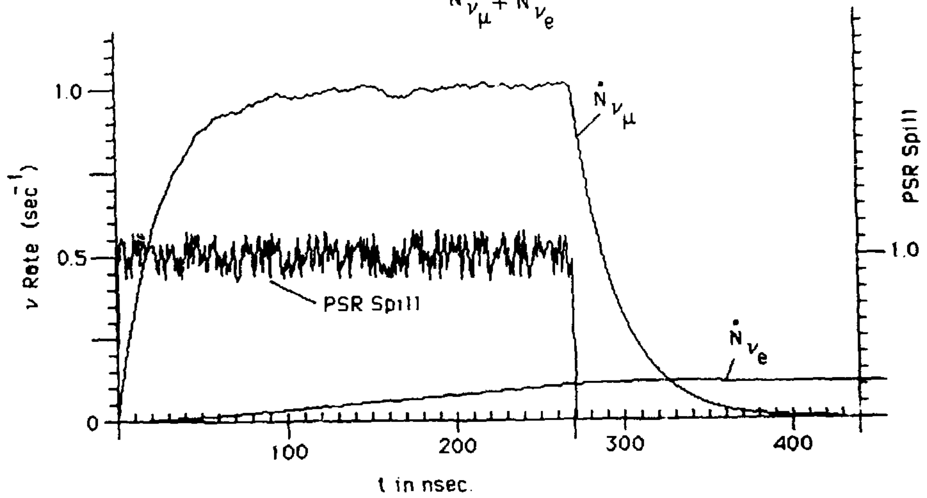


Fig. 3

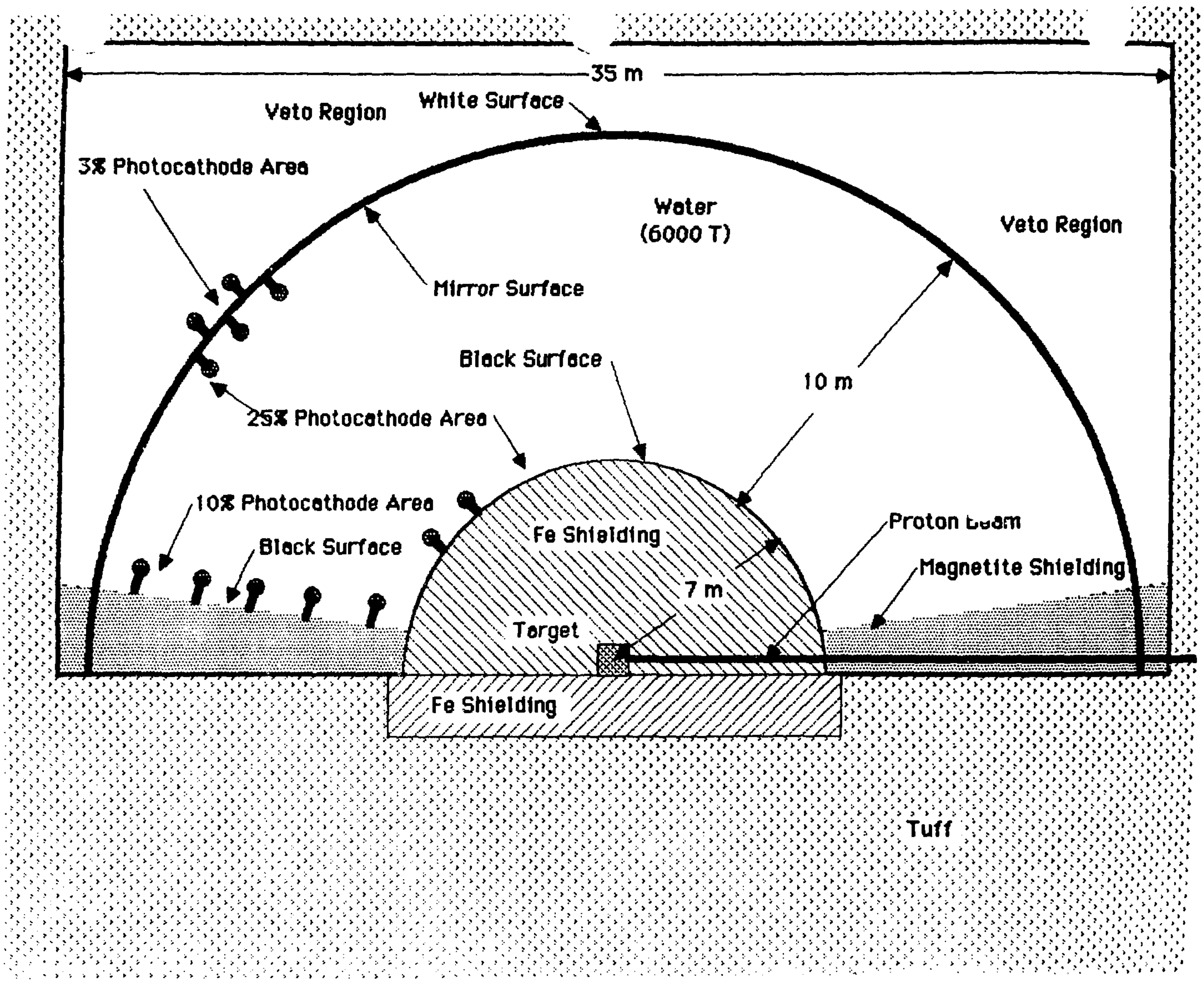


Fig. 4. A version of the Los Alamos neutrino experiment. The steel hemisphere is for neutron shielding, phototubes are mounted on a hemispherical support immersed into water.

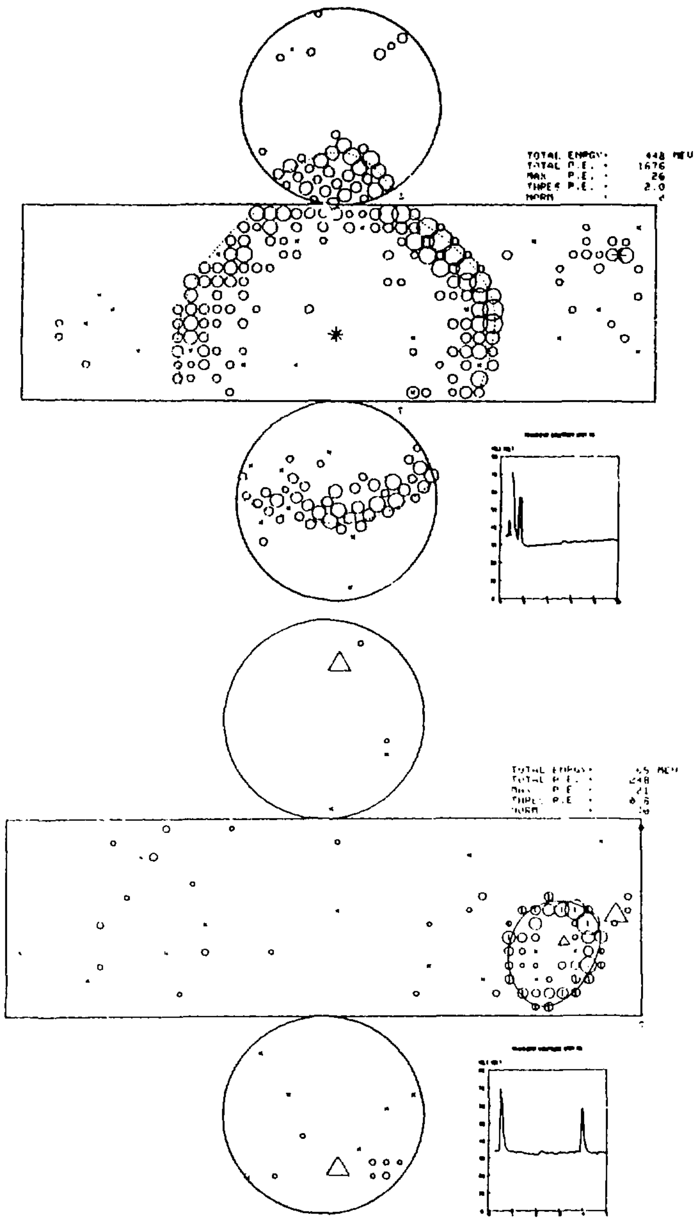


Fig. 5 Examples of two low-energy events as seen in the Kamioka detector. The top event is a stopping muon with it's Michel decay electron seen as the small circle on the right. The second, is a muon decay ($\mu \rightarrow e$) in which only the electron is seen. These are projections of the PMT's hit pattern onto an unrolled cylinder. The "top" and "bottom" of the cylinder are also shown. Particle identification is possible from the diameter and "fuzziness" of the rings. Incident momentum is determined from the number of photoelectrons generated.

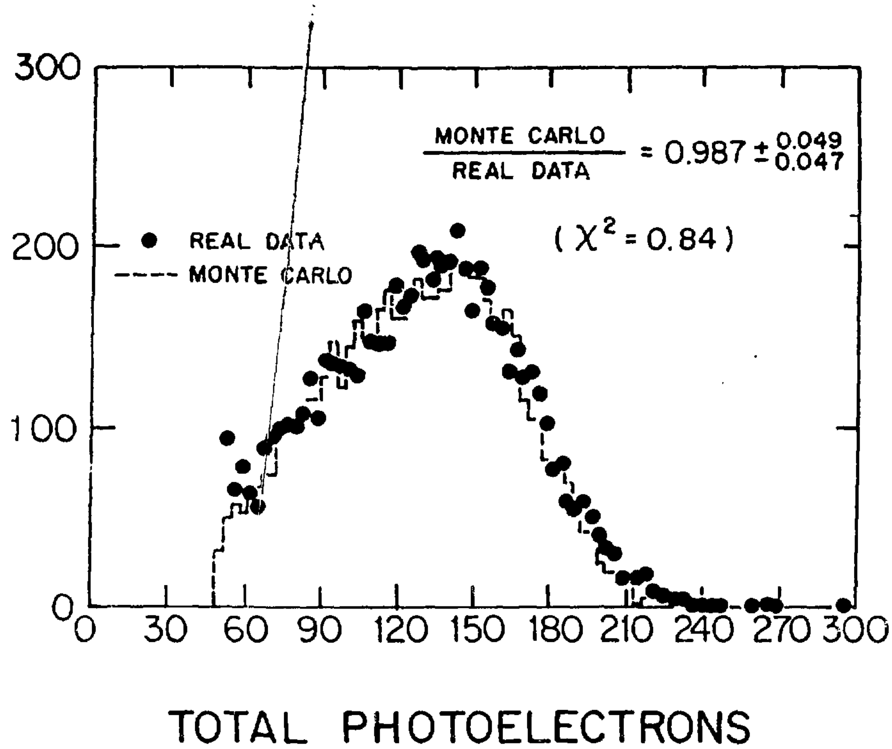


Fig. 6. The Michel electron spectrum as seen by the Kamioka imaging water Cherenkov detector.

SEARCHING FOR MUON NUMBER VIOLATION AT LAMPF: CURRENT RESULTS AND FUTURE PROSPECTS

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The experimental status of rare decays that violate muon number conservation is summarized in Table I. These results represent an international effort in this active field, with experiments at laboratories in the United States, Switzerland, Canada and the Soviet Union. Substantial improvements over the data of two years ago are shown that demonstrate our present knowledge for the four muon processes. As many of these experiments are still running or coming into operation, immanent progress to the level stated in column four is expected. The last column shows that new experiments are being planned now that should yield results around 1990. This paper will focus on the present and future prospects for the decays $\mu^+ \to e^+\gamma$ and $\mu^+ \to e^+\gamma\gamma$ that are being pursued at LAMPF.

The search for processes that violate conservation of muon number remains a subject of high interest because these reactions must occur through processes outside the minimal standard model of weak interactions. In placing the observed fermions in the group representations of the model, the assignments are repeated three times, and the particles are assigned to generations or families in the order of their mass. However, the minimal standard model is aesthetically incomplete because it contains many unknown parameters and the family replication is not explained. The apparent need for an extension to the standard model and the requirement that muon number non-conservation lies outside the model has driven experimentalists to redouble their efforts to find such a process. Furthermore, its non-discovery at increasingly better limits restricts the types of models that can be built. Table II gives some guidance toward the extensions that are most likely tested by individual muon-number non-conserving process. The table is based on the number of weak vertices involved in the process and should not be considered rigorous because uncertainties in the extended model can change the result. The $\mu^+ \to e^+\gamma$ and $\mu^+ \to e^+\gamma\gamma$ decays figure prominently in the table.

All of the muon experiments share several common elements. First, they all hope to identify the sought-after process through the measurement of kinematical variables, i.e. conservation of four momentum. For example, the $\mu^+ \to e^+\gamma$ decay has the signature of back-to-back electrons and photons that are in-time and each of 52.8 MeV. A useful equation for i detected particles of energy E_i and momentum $\vec{p}_i$ is

$$\sum E_i + \left|\sum \vec{p}_i\right| \leq M_\mu . \qquad (1)$$

For neutrinoless decays, the second term (missing momentum) is zero and the equal sign holds. For one unobserved particle, such as a familon, the equality is appropriate. For normally allowed processes with two neutrinos, the full inequality applies. Of course, all decays must come from a single muon, which implies a common vertex and time coincidence.

To reach the very high sensitivities, the second requirement is large number of useful muon decays

$$M = \frac{\Omega_o}{4\pi}\varepsilon RT, \qquad (2)$$

where Ω_o is the solid angle, ε is the detection efficiency, and RT is the stop rate times the running time. Our LAMPF experiments have tried for 50%

acceptance, high efficiency, and the highest stop rates consistent with detector performance. The detectors use low-energy stopped-muon beams and thin targets to achieve their required stopping densities.

A third requirement is good resolution, which stresses technology in high-rate environments and which is needed to suppress backgrounds of either allowed processes or accidental coincidences. The experiments need to be background-free so that sensitivity will improve inversely as the running time, rather than inversely as the square root of the running time when background is present. There are two sources of backgrounds, prompt-allowed processes and random coincidences. These backgrounds are suppressed with good resolution. Table III compares the three experiments at LAMPF since 1975.

Fourth, the data processing of all the experiments is a search for a rare process in a very great number of decays. Hence, a clever trigger is designed to control data encoding and tape writing rates, and sophisticated analysis is used to select any possible candidates.

Finally, in order to understand the detector response, known processes are measured where possible. In the cases of these experiments, the allowed process $\mu^+ \rightarrow e^+\gamma\nu\bar{\nu}$ is measured to prove the instrument can observe what it should.

The Crystal Box collaboration[1] has constructed the large solid angle detector for electromagnetic radiation shown in Fig. 1. The detector consists of an eight plane drift chamber that surrounds the stopping target and provides vertex and directional information. Around the drift chamber is a hodoscope of 36 scintillators used to make the trigger, to provide timing for charged particles, and to give no signal for photons. The final layer is a total absorption calorimeter of 396 NaI(Tl) crystals that measures the energies of the decay products and the shower position of photons. A typical trigger for $\mu^+ \rightarrow e^+\gamma$ candidates would consist of a track in the drift chamber that points at a struck scintillator and greater than 35 MeV in the NaI(Tl) quadrant. In the opposite quadrant of the Box, there would be no scintillator, no close charged particle track in the drift chamber, and 35 MeV in the NaI(Tl) that is deposited within 10 ns of the electron. Better candidates are of higher energy, are more in time, and back-to-back. The best candidates for $\mu^+ \to e^+\gamma$ are within the resolutions listed in Table III of the kinematic requirements.

In order to analyze the data, the instrument must be calibrated and the response functions measured. Briefly, the energy calibrations and line shapes are obtained from detecting the back-to-back π^0 decays produced in the reaction $\pi^- p \to \pi^0 n$. The spectrum obtained is shown in Fig. 2. The timing of the apparatus can be obtained from looking at the radiative decay of the muon $\mu^+ \to e^+\gamma\nu\bar{\nu}$ that is shown in Fig. 3. The resolution of the chamber can be obtained by analyzing the tracks traced back to the target. The target distribution of track origins is shown Fig. 4., where a 1 cm radius hole in the target is easily seen.

The greatest difficulty in the analysis arises from the requirement that the energy calibration be precise. A good analysis will yield the expected number of events for $\mu^+ \to e^+\gamma\nu\bar{\nu}$, but a 1 MeV gain shift (1/3 of the resolution) represents a factor of two in yield. In order to obtain correct gains for 396 crystals, it is necessary to understand pile-up effects and to monitor possible drifts over the months the experiment took data. This paper reports on 60% of the data, where the piled-up events have been removed and the gains stabilized. The final results are not yet available, but a sample analysis will be shown to demonstrate that they are at hand. Because there is background, the results are extracted with a maximum likelihood analysis. The likelihood function that is maximized for the most probable number of $\mu^+ \to e^+\gamma$ events α and $\mu^+ \to e^+\gamma\nu\bar{\nu}$ events β is

$$L(\alpha,\beta) = N^{-N} \Pi \; [\alpha P(\vec{x}) + \beta Q(\vec{x}) + (N-\alpha-\beta)R(\vec{x})], \qquad (3)$$

where P, Q, and R are the probability that each of the N events are a $\mu^+ \rightarrow e^+\gamma$, a $\mu^+ \rightarrow e^+\gamma\nu\bar{\nu}$, or a random event, respectively, as a function of the measure quantities $\vec{x} = (E_e, E_\gamma, \theta_{e\gamma}, \Delta t)$. Figure 5 shows the results for some typical restrictions to the data set processed with Eq. (3). The number of $\mu^+ \rightarrow e^+\gamma\nu\bar{\nu}$ events seen is 960 ± 40, which is reasonably in agreement with what is expected. The number of $\mu^+ \rightarrow e^+\gamma$ events is 4 ± 7, and represents no evidence for observation of the process. Hence, a 90% confidence limit can be set at less than 14 events. The above analysis represents the process $\mu^+ \rightarrow e^+\gamma\nu\bar{\nu}$ rather well. In Fig. 6, the deviations between the Monte-Carlo simulation of the radiative decays and detector response are compared to the data after random background subtraction.

Currently the group is still quoting the numbers presented at the Washington APS meeting[3] though final results should be available within two months. Those 90% confidence limits are $B(\mu^+ \rightarrow e^+\gamma) < 1.4 \times 10^{-10}$ and $B(\mu^+ \rightarrow e^+\gamma\gamma) < 3.8 \times 10^{-10}$. The latter is achieved by a cut analysis, the essence of which is shown in Fig. 7. The scatter plots are of the missing momentum versus the total detected energy (see Eq. (1)) for coincident events. The data shows no evidence of events for zero missing momentum and 105 MeV total energy.

The Crystal Box group has analyzed their $\mu^+ \rightarrow e^+\gamma$ data for the process $\mu^+ \rightarrow e^+\gamma f$, where f symbolizes the family-number-carrying axion named the familon. The signature is events satisfying the equality in (1) in the region of high energy photons and electrons. Backgrounds from radiative muon decay and accidental coincidences are separated using a likelihood analysis in a limited region of the Dalitz plot. The branching-ratio upper limit is 1.2×10^{-8} (90% confidence). This limit can be translated to a mass scale for family symmetry breaking of $>8.6 \times 10^{8}$ GeV. Improvements are made as the inverse square root of the sensitivity, and the experimenters expect to make a further improvement of a factor of 100 in the branching ratio because of increased statistics and a larger sampling region in the Dalitz plot. For comparison, the limits on the mass scale from $\mu^+ \to e^+ f$ and $K^+ \to \pi^+ f$ are 3.6×10^{9} (Ref. 3) and 3×10^{10} (Ref. 4) GeV, respectively. The different reactions are sensitive to different interaction symmetries, and the comparison must be made carefully.

The future of this field at LAMPF is called MEGA, an acronym standing for Muon decays into an Electron and a GAmma ray. The MEGA collaboration[5] was formed in the Spring of 1985 and submitted the experiment proposal to LAMPF last summer. The experiment was approved but awaits final DOE funding approval. Meanwhile, substantial activity has begun at most of the 10 institutions. Our reasons for beginning a new search for $\mu^+ \to e^+\gamma$ are:

1. The search addresses some of the most compelling physics issues of the 1980's, i.e. physics beyond the Standard Model. Many of the possible extensions of the Standard Model would make $\mu^+ \to e^+\gamma$ observable. In many models, the mass scale probed is well above the energies anticipated even at the SSC.
2. MEGA will have a factor of 500 improved sensitivity compared to the Crystal Box, the currently best detector for $\mu^+ \to e^+\gamma$. The factor of 500 improvement is the largest that can be made on any of the reactions that have already been studied at a significant level.
3. $\mu^+ \to e^+\gamma$ is the easiest to tackle at LAMPF. There does not exist a μ^- beam of sufficient intensity to warrant undertaking the $\mu^- A \to e^- A$ conversion experiment, and the cost of a new beam line is prohibitive. Each of the

muon branches has been pushed to where they are background limited, and the technical improvements required for a three particle final state decay are more complex at a low duty factor accelerator.

4. Substantial expertise exists at LAMPF from the μeγI and Crystal Box experiments for detecting this process.

5. New technology employed in this experiment will raise the technical expertise available at LAMPF. MEGA will: (a) be the first with a large cryogenic magnet, (b) demonstrate the ability to take data in a very high intensity environment, (c) employ a multi-crate FASTBUS system, and (d) use low cost micro-computer technology both in data acquisition and replay to achieve five times the computing power of the Data Analysis Center.

6. There is a window of time, for the next five years, when LAMPF has the most intense beam for doing a high sensitivity experiment.

The MEGA apparatus is shown in Figs. 8 and 9. and is designed to find the decay $\mu^+ \rightarrow e^+\gamma$ in a background free experiment if its branching ratio is greater than 10^{-13}. The apparatus is contained in a large magnet that will be obtained from SLAC; it has a 1.5 T field, a clear bore of 1.85 m, and a length of 2.2 m. The central region of the magnet contains the target. The target is a thin planar ellipse, canted at a large angle relative to the beam. This orientation provides adequate stopping power in the beam direction to contain the muons and presents a minimal thickness to the decay products. The anticipated stopping rate is 3×10^7 Hz (average).

The detector is divided into an electron spectrometer and a series of photon pair spectrometers. All of the charged particles arising from muon decay are confined to a maximum radius of 29 cm, leaving the photon detectors in a relatively quiet environment. A low-rate photon arm is essential to the success of the experiment. The design philosophy of the electron arm is to optimize the resolution of the electron detectors without producing photon backgrounds.

The electron arm consists of two parts. The electrons from muon decay first pass through a multiwire proportional chamber (MWPC) with three layers of sense wires at radii of 6, 11, and 14 cm. This chamber is built of the thinnest possible materials to minimize multiple scattering and positron annihilation in flight. The chamber acts as a 180^0 spectrometer to measure the helical paths of the electrons in the uniform magnetic field. The parallel components of the momenta are derived from the measured coordinates of chamber intersections along the beam direction. These measurements are achieved with spiral cathode strips. The wire spacing in the chamber is 1 mm, a pitch that makes the chamber efficient at high rates. The chamber is gated with a short coincidence pulse to limit its sensitivity to the periods of interest.

The very high rate makes a serious pattern recognition problem. A typical event is illustrated in Fig. 10. The key to identifying candidate electrons is that in the end view, they make almost perfect circles. The symmetry in a circle, plus redundancy in the cathode strips, makes for a highly efficient selection of candidates that still rejects useless events. Figure 11 illustrates the expected resolutions from the electron arm.

The second part of the electron spectrometer consists of banks of scintillators arranged in a cylindrical geometry about the beam near the pole faces. The electrons enter the scintillators after at least one revolution in the chamber. The scintillators measure the time of the electron. Electrons trapped in the field for more than eight loops are rejected by their relative time with respect to the photon. Each bank is divided into 100 elements to keep the individual counter rates manageable. After passage through the scintillators, the electrons are stopped in a 4 cm thick annulus of lead.

The photon arm is five concentric pair-spectrometers of essentially identical construction. A blowup of a section of one spectrometer is shown in Fig. 12. Each pair spectrometer is made of lead converters, MWPCs, drift chambers, and scintillators. The converters are divided into three sheets and separated by the MWPCs. Each sheet is thin enough to maintain good resolution (1.2% at 50 MeV). The MWPCs determine in which sheet the incident photon converted, allowing a correction for the mean energy loss in subsequent sheets to be made. The electron and positron from the conversion have the vast majority of their energy measured by the drift chambers as they move along helical paths whose radii are proportional to their perpendicular momenta. The parallel components of momenta are measured with spiral cathodes. Finally, the particles recross the converters into a cylindrical hodoscope of scintillators of 4 cm arc length. These scintillators, with photomultiplier tubes at both ends, measure the time of the photon conversion. Contributions from energy loss straggling and chamber resolution degrade the resolution to 2%. Bremsstrahlung produces a low energy tail for 50% of the spectrum. The expected response function of the pair spectrometer is shown in Fig. 13.

The most serious background for the experiment is a 52.8 MeV electron from normal muon decay in accidental, back-to-back and time coincidence with a 52.8 MeV photon. The most copious source of 52.8 MeV photons comes from internal bremsstrahlung or radiative muon decay ($\mu^+ \rightarrow e^+\gamma\nu\bar{\nu}$.) It is intended to veto these photons by detecting the normally present low-energy electrons with which the photons are associated. These electrons are below 2.5 MeV and follow the field lines to the magnet pole faces. Relevant parts of the pole faces will be lined with scintillators set to veto on these electrons.

The very high instantaneous rates require a sophisticated trigger. The primary trigger relies on the fact that all electrons from muon decay are contained in the central region of the detector. If the trigger requires a photon of at least 42 MeV, the number of firings will be reduced by a factor of roughly 700 relative to the muon stop rate. On average, there will be 36 μs between triggers, which is sufficient time for modern electronics to encode, compact, and read the data into memories. A typical event will contain about 700 data words. The dead time is kept small by employing substantial parallel processing. At the end of a LAMPF macropulse, the data from the events are read into one of 32 micro-processors for further selection. The additional criteria will require that the electron have 49 MeV, pass some restrictions on its relative time to the photon, and be within 10^0 of back-to-back of the photon. The surviving events will be written to tape at a rate of 11/s for further analysis. The remaining analysis will employ the complete calibrations and refined algorithms to sharpen the detector response functions, thus kinematically isolating any $\mu^+ \rightarrow e^+\gamma$ events from all backgrounds. The replay of the tapes will be done with the data acquisition micro-processors.

The parameters of MEGA are summarized in Table III. In almost every category, MEGA makes significant improvements over the previous efforts. The product of these improvements leads to an experiment with an ultimate sensitivity that is 500 times greater than the expected results from the Crystal Box. To dramatize the sensitivity, Fig. 14 displays the 90% confidence limit versus running time that can be achieved with MEGA. The current limit and the curve for the Crystal Box are shown also. In the background free region, the curves drop inversely as the running time, and in the background limited region, they drop inversely as the square root of the running time; the desirability of a background free experiment is clear.

The collaboration has estimated the cost of MEGA to be $2.9 M if the magnet is made available by SLAC. The director of SLAC has just given his approval for the move. If the funding is available to allow for rapid procurement, debugging of the experiment can begin in the Spring of 1988. The collaboration is very enthusiastic about the experiment and is working hard to keep it on schedule.

MEGA is a world class effort to search for muon number non-conserving decays, and compliments experiments at SIN (muon-electron conversion[6]) and at Brookhaven (rare kaon decays[7]) to find a violation of the Standard Model. It is necessary to explore all the possible channels because theory gives very little guidance as to which process will be easiest to observe. Unfortunately, there are so many possible extensions to the standard model, each containing unconstrained parameters, that no definitive predictive power exists. Most of the models introduce new particles of large mass. Therefore, the new experiments will continue to restrict the model builders and give insight on what to expect at the new generation of accelerators.

The author would like to thank all the members of both the Crystal Box and MEGA collaborations for their invaluable assistance (see Refs. 1 and 5.)

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Table I.

90% Confidence Limits for Muon Number Non-conserving Decays.

DECAY	1983	PRESENT	CURRENT EXPERIMENTS	FUTURE EXPERIMENTS
$\mu^+ \to e^+\gamma$	1.7×10^{-10}	1.4×10^{-10}	4×10^{-11}	$\sim 10^{-13}$
$\mu^+ \to e^+e^+e^-$	1.9×10^{-9}	2.4×10^{-12}	8×10^{-13}	
$\mu^+ \to e^+\gamma\gamma$	9.4×10^{-9}	3.8×10^{-10}	7×10^{-11}	$\sim 10^{-12}$
$\mu^-A \to e^-A$	7×10^{-11}	1.6×10^{-11}	7×10^{-12}	$\sim 10^{-13}$
$K^+ \to \pi\mu e$	5×10^{-9}		$\sim 10^{-11}$	
$K_L \to \mu e$	2×10^{-9}		$\sim 10^{-10}$	$\sim 10^{-12}$

All the branching ratios are upper limits given with 90% confidence.

Table II.

Physics Beyond the Standard Model with Rare Decays

Theoretical Uncertainties of the Standard Model	Model Extension	Likely Channel
Unknown number of generations	4+ generations	$\mu A \to eA$, $\mu \to e\gamma$
V − A	Left-right symmetry	$\mu \to e\gamma$, $\mu A \to eA$
More Higgs doublets	Extra doublets − $\Delta S = 0$	$\mu A \to eA$, $\mu \to e\gamma$
	− $\Delta S \neq 0$	$\mu A \to eA$, $K_L \to \mu e$
Gravity	Supersymmetry	$\mu \to e\gamma$, ?
Too many elementary fields	Composite models	$\mu \to e\gamma$, $(\mu \to e\gamma\gamma)$
	Composite models with contact interactions	$K_L \to \mu e$
Many undetermined parameters	Horizontal gauge particles	$K_L \to \mu e$, $\mu \to eee$
Replication of generations	Horizontal gauge particles	$K_L \to \mu e$, $\mu \to eee$
Need for an elementary scalar field	Technicolor	$K_L \to \mu e$, $\mu A \to eA$
Hierarchy problem	Technicolor	$K_L \to \mu e$, $\mu A \to eA$
	Supersymmetry	$\mu \to e\gamma$, ?
Not a unified theory	GUTS	As above according to construction

Table III

Parameters of $\mu^+ \rightarrow e^+\gamma$ Experiments

Property	MEGA	$\mu e \gamma$I	Crystal Box
Fractional electron energy resolution	0.005	0.09	0.08
Fractional photon energy resolution	0.02	0.08	0.08
Photon-electron timing (ns)	0.5	2.0	1.1
Electron position resolution at the target (mm)	2.0	3.0	2.0
Electron angular resolution-including target scattering (deg)	0.6	1.3	1.3
Photon conversion point resolution (mm)	3	76	25
Electron-photon angle (deg)	0.6	3.8	8.0
Photon angle (deg)	10	---	---
Inefficiency of bremsstrahlung veto	0.2	---	0.5
Fractional solid angle times detection efficiency	0.1	0.018	0.2
Muon stopping rate (s^{-1})	3×10^7	2×10^6	5×10^5
Running time (s)	1.2×10^7	1.1×10^6	2×10^6
Branching ratio sensitivity	8×10^{-14}	1.7×10^{-10}	4×10^{-11}
Number of background events with $\pm 2\sigma$ cuts	0.4	~10	~50

All resolutions are FWHM

FIGURE CAPTIONS

1. The Crystal Box apparatus.

2. The response of the NaI(Tl) to back-to-back decays of the π^0 produced in the reaction $\pi^- p \rightarrow \pi^0 n$.

3. The timing response for events from the decay $\mu^+ \rightarrow e^+\gamma\nu\bar{\nu}$. The data satisfy Eq. (1) with finite resolution, and the background events do not satisfy the inequality.

4. The target distribution of track origins. A 1 cm hole in the target is easily seen.

5. A sample likelihood analysis of the most probable candidates that shows the expected number of radiative decays but no evidence for muon number violation.

6. A comparison between the simulation of the radiative decays plus the detector response and the data. The data have the random background subtracted in all but the timing plot. The darkened regions are where the simulation exceeds the data, and the shaded regions are vice-versa.

7. A comparison between Monte-Carlo simulation and the data for $\mu^+ \to e^+\gamma\gamma$ events that shows no evidence for a signal.

8. End view of the MEGA apparatus with an idealized $\mu^+ \to e^+\gamma$ decay shown.

9. A sectioned plan view of the MEGA apparatus with the same idealized $\mu^+ \to e^+\gamma$ event shown that was displayed in Fig. 8.

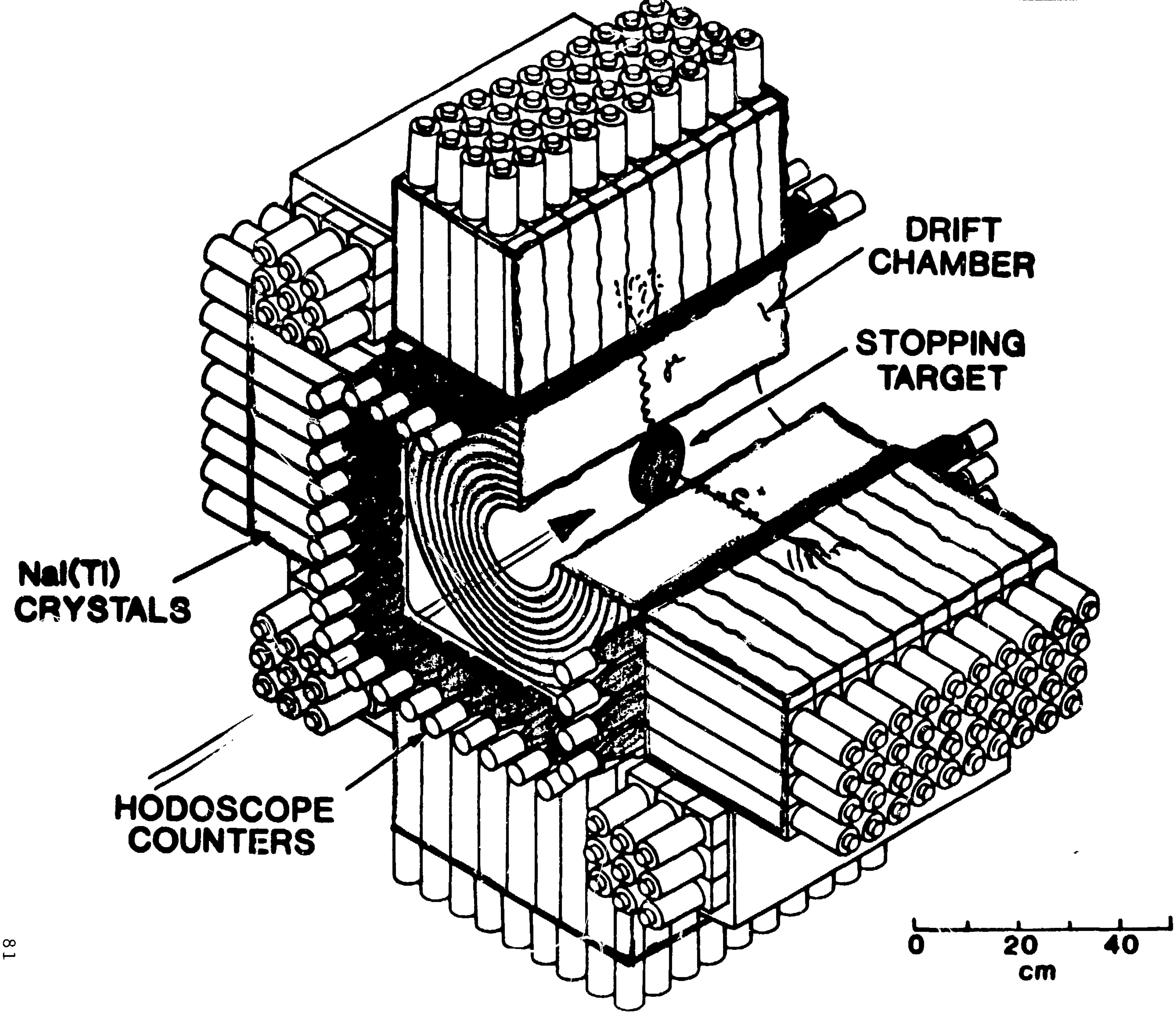
10. A typical event in the electron spectrometer.

11. The expected resolutions from the MEGA electron arm: (a) in energy and (b) in angle. The simulation includes resolutions of the MWPC and multiple scattering in the chambers and target.

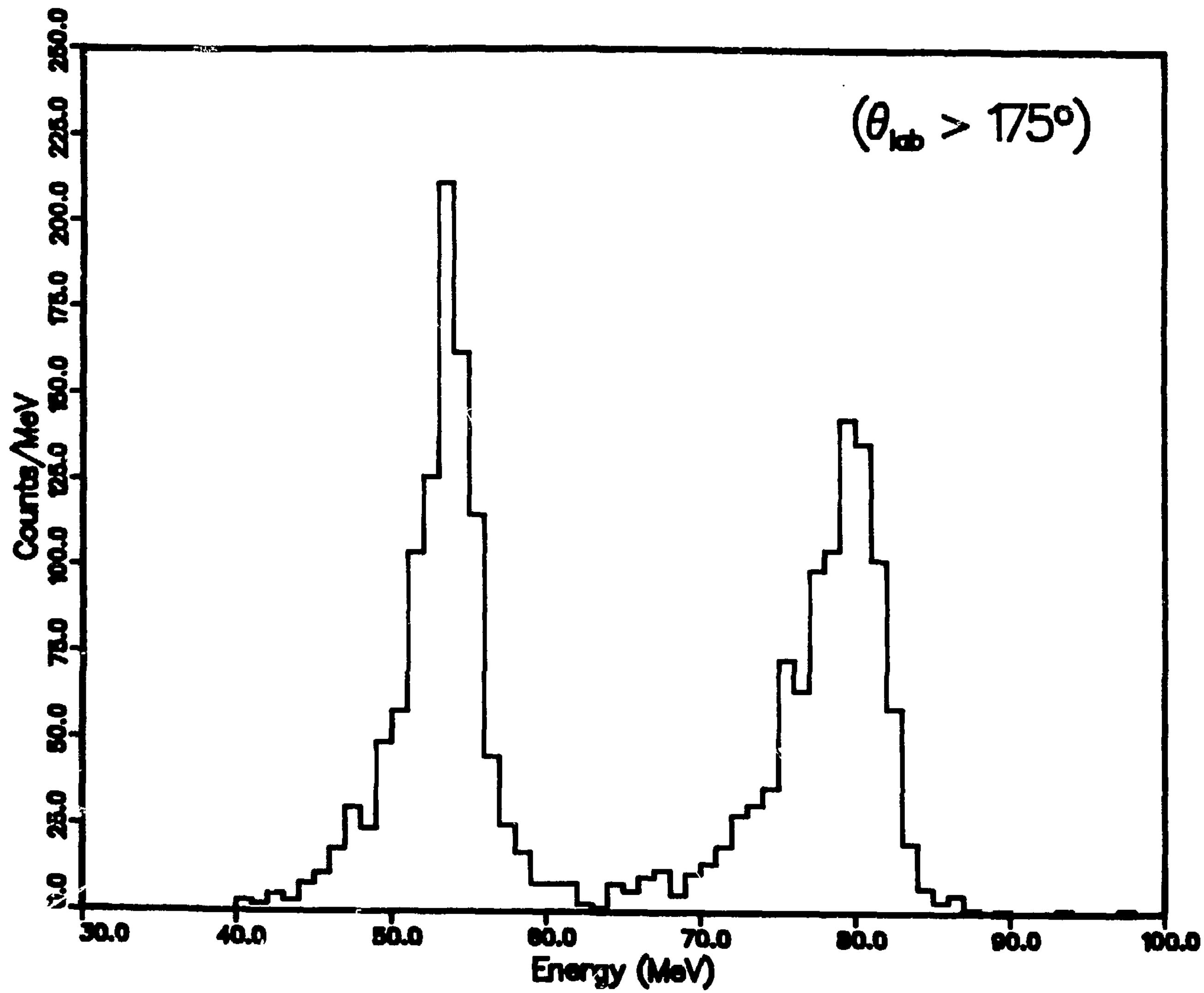
12. A blown up view of one pair spectrometer showing the multiple layers of converters, the chambers, and the scintillators.

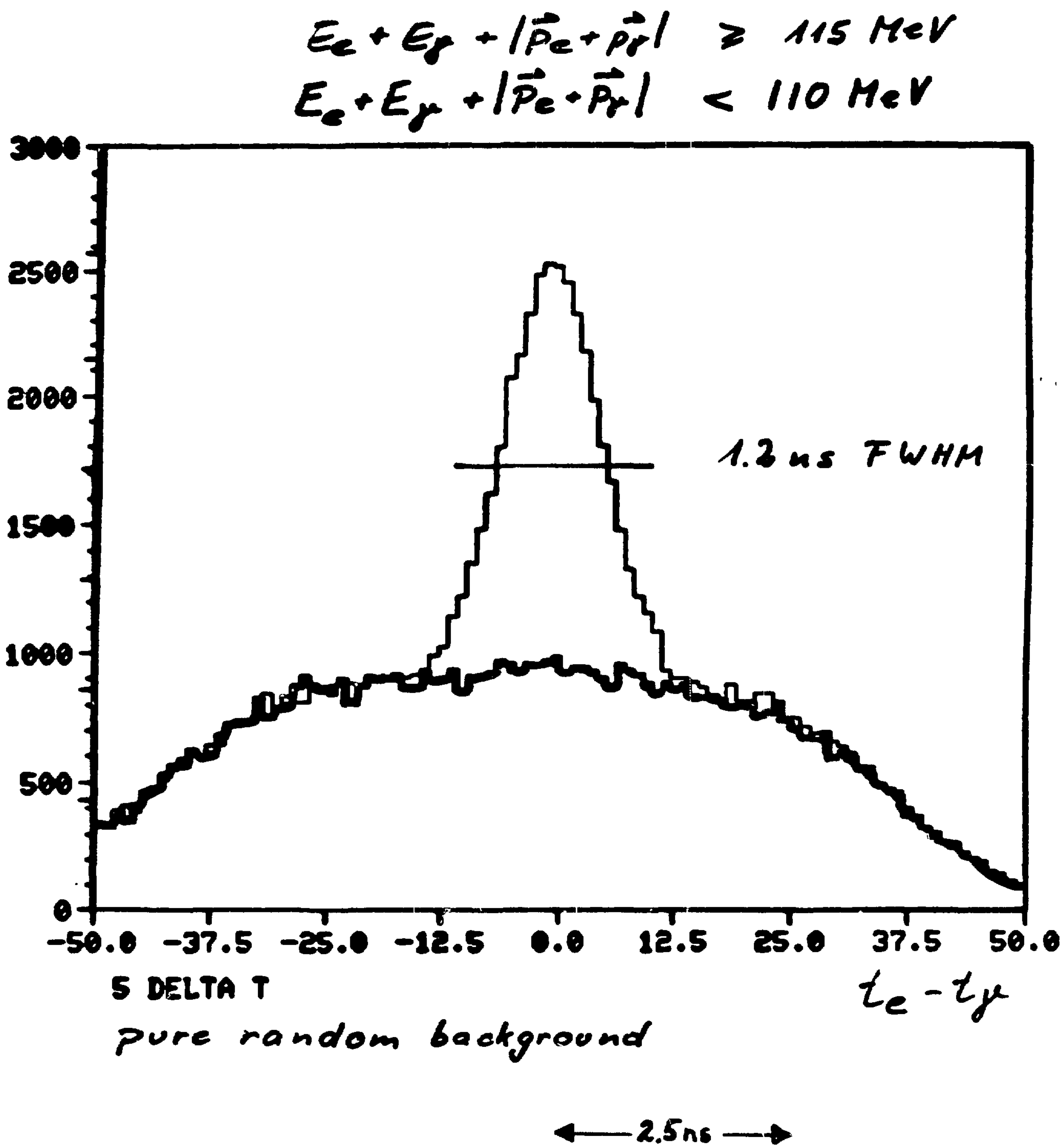
13. The energy resolution expected from the pair spectrometers.

14. The branching ratio sensitivity as function of running time for MEGA and the Crystal Box.

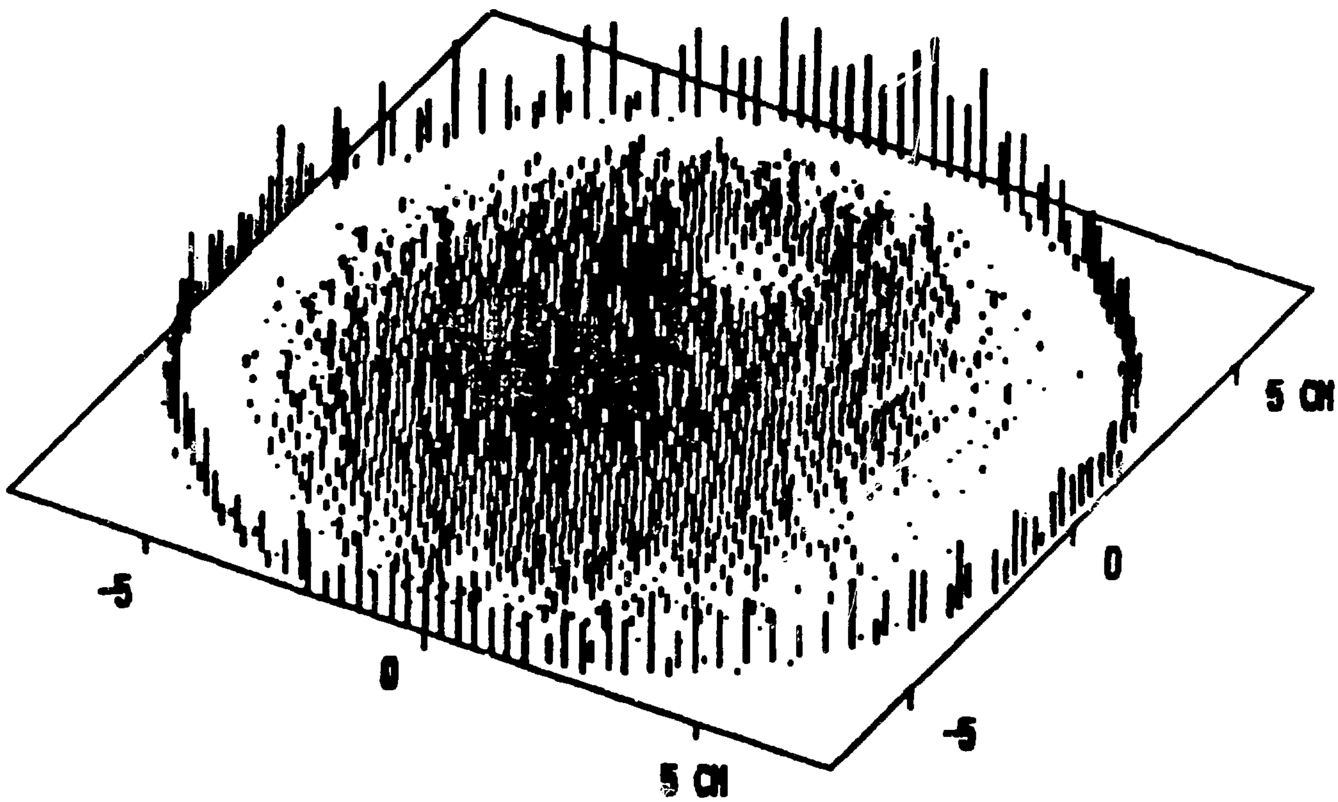

DRIFT CHAMBER
STOPPING TARGET
NaI(Tl) CRYSTALS
HODOSCOPE COUNTERS
0
20
40
cm

Detected Photon Energies for $\pi^0 \rightarrow \gamma\gamma$

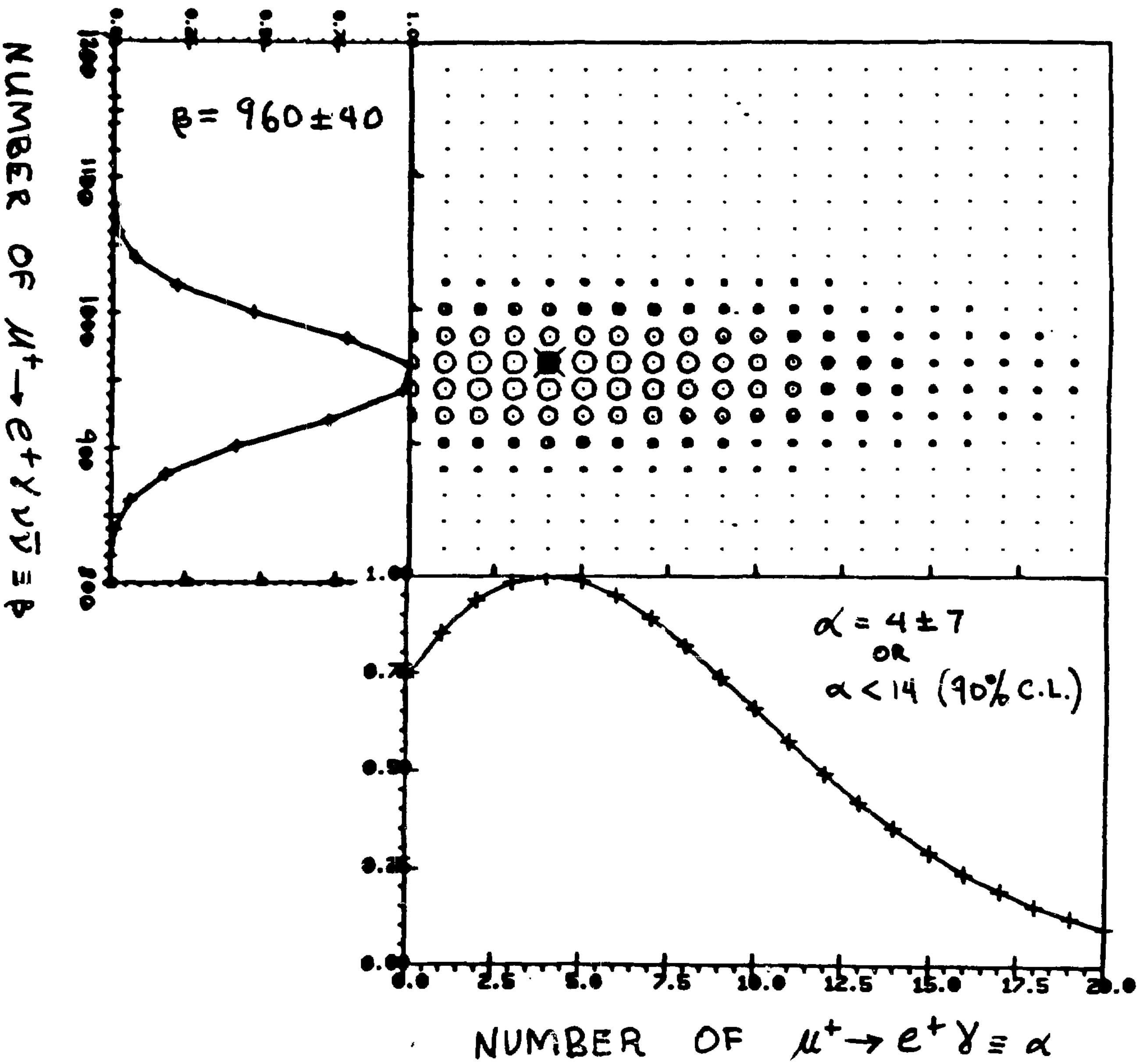



$E_e + E_\gamma + |\vec{p}_e + \vec{p}_\gamma| \geq 115$ MeV
$E_e + E_\gamma + |\vec{p}_e + \vec{p}_\gamma| < 110$ MeV
3000
2500
2000
1500
1000
500
0
-50.0
-37.5
-25.0
-12.5
0.0
12.5
25.0
37.5
50.0
1.2 ns FWHM
5 DELTA T
$t_e - t_\gamma$
pure random background
2.5 ns

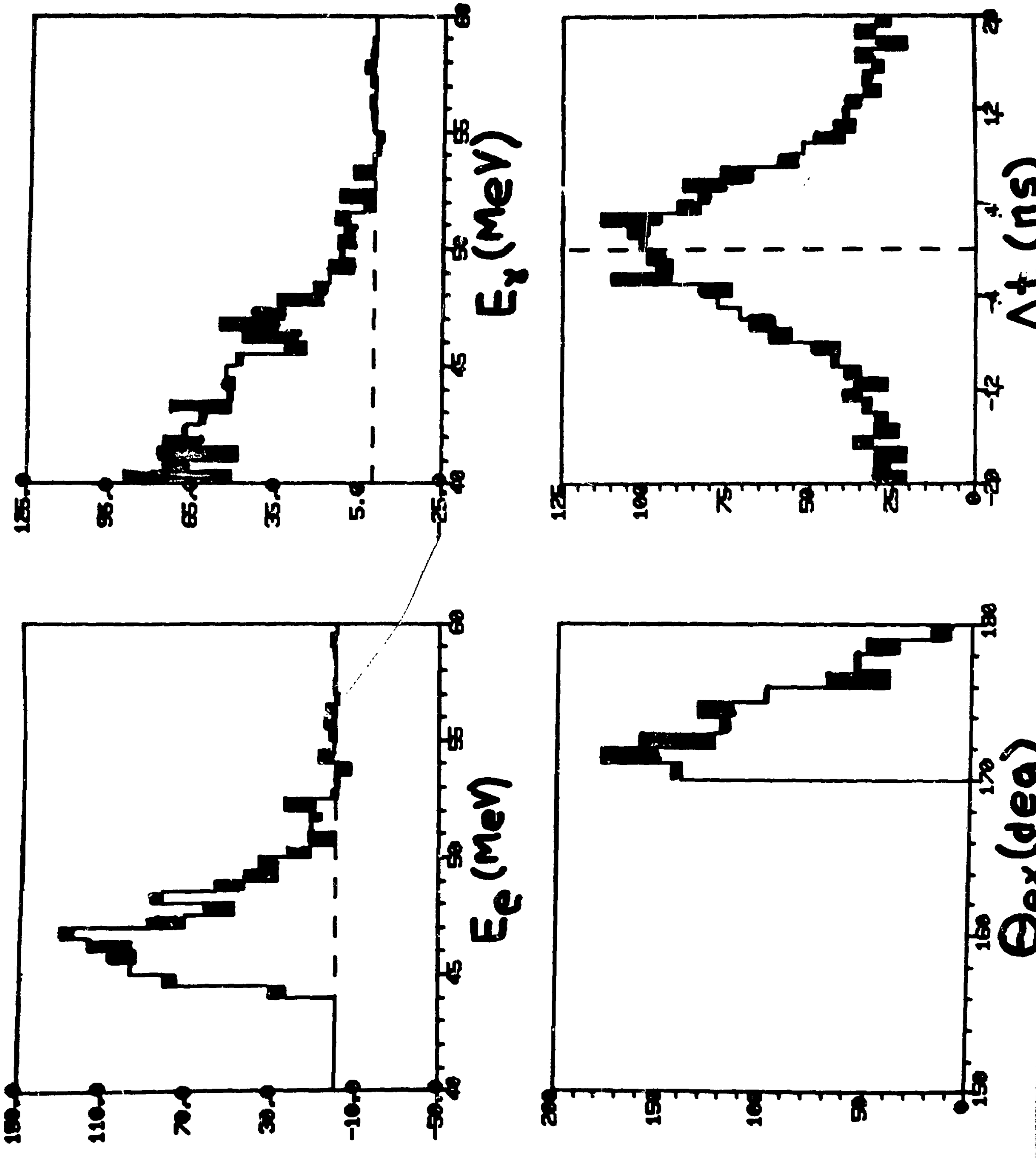
TARGET DISTRIBUTION



MAXIMUM LIKELIHOOD ANALYSIS

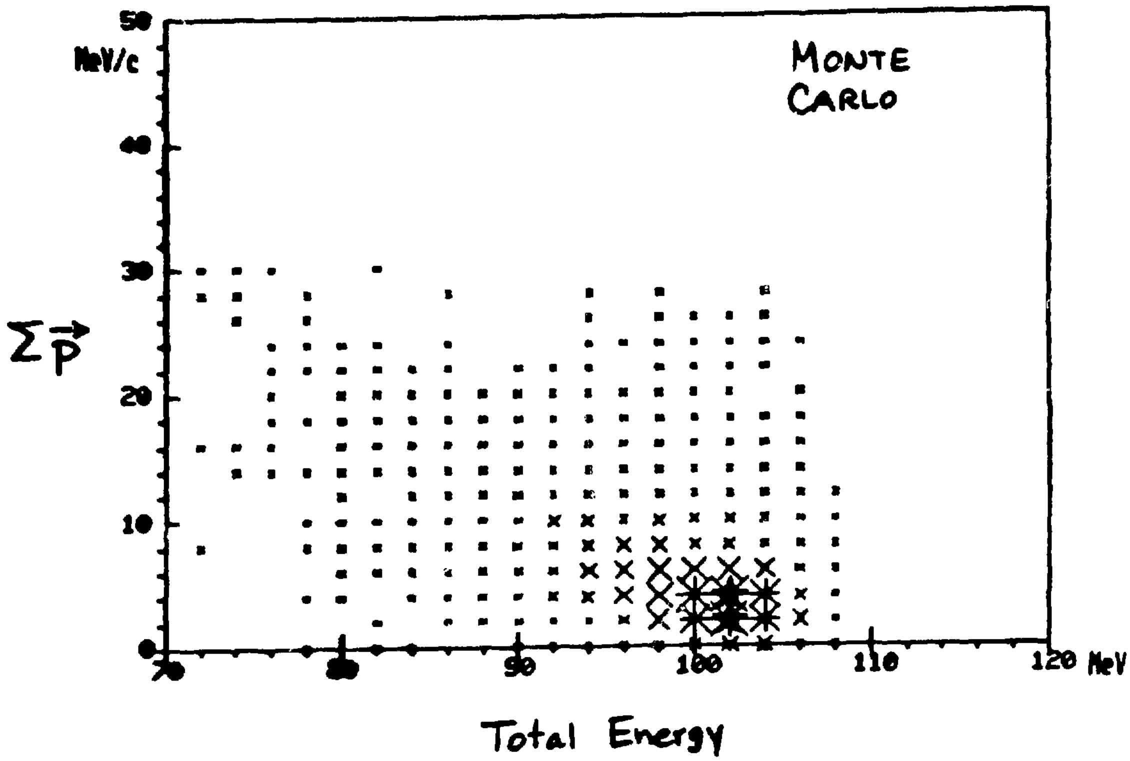


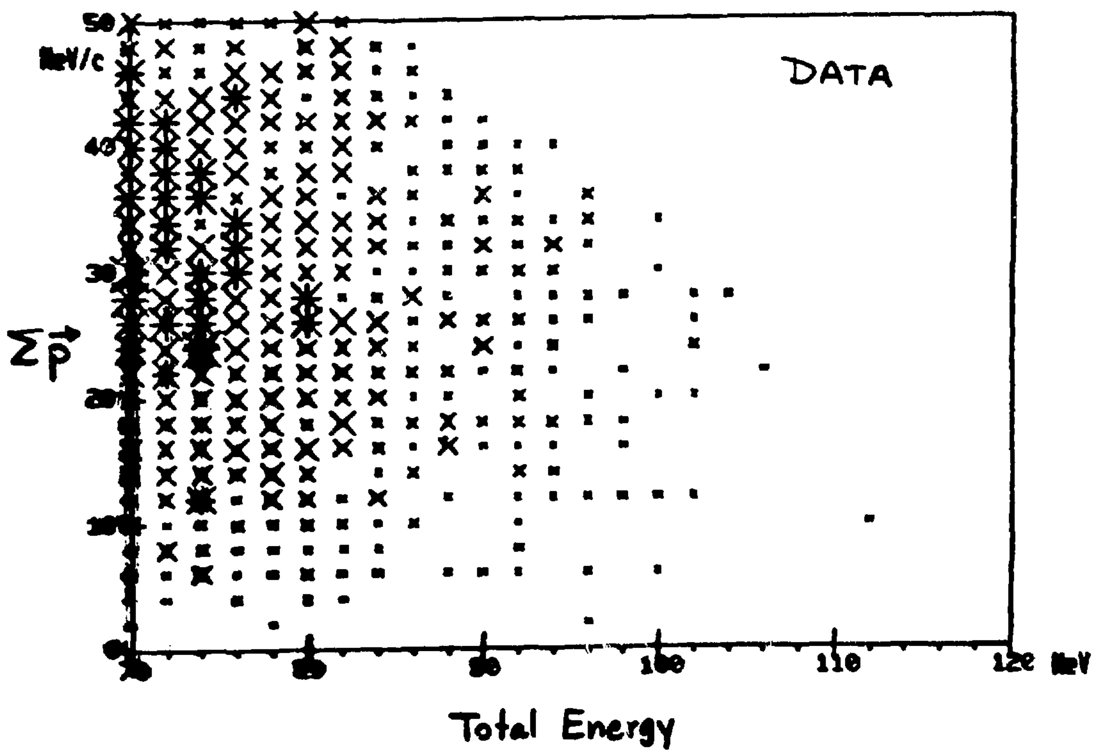
$$\frac{\mathcal{L}(\alpha,\beta)}{\mathcal{L}(0,0)} = \frac{1}{N^N \mathcal{L}(0,0)} \prod \left[\alpha P(\vec{x}) + \beta Q(\vec{x}) + (N-\alpha-\beta) R(\vec{x})\right]$$

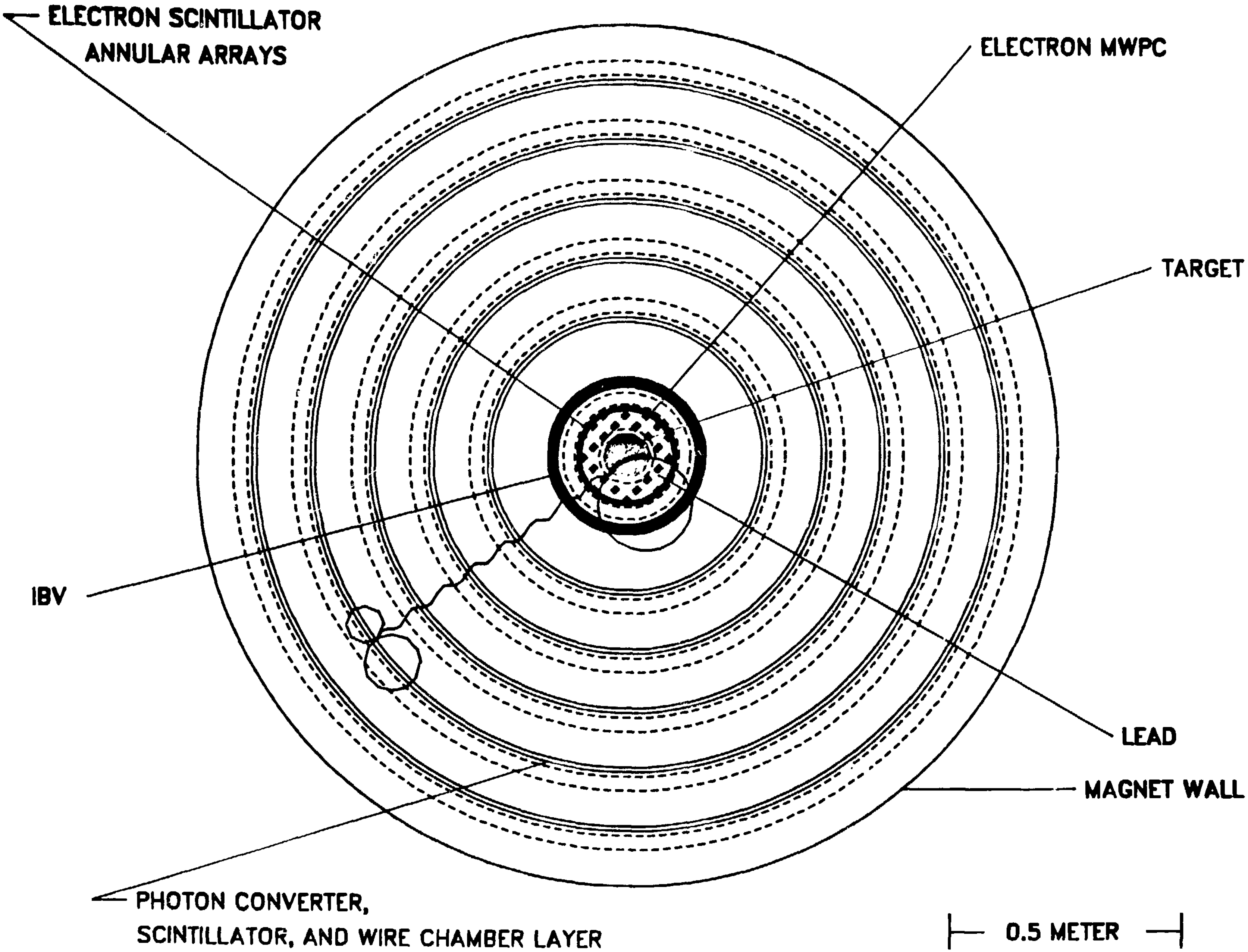


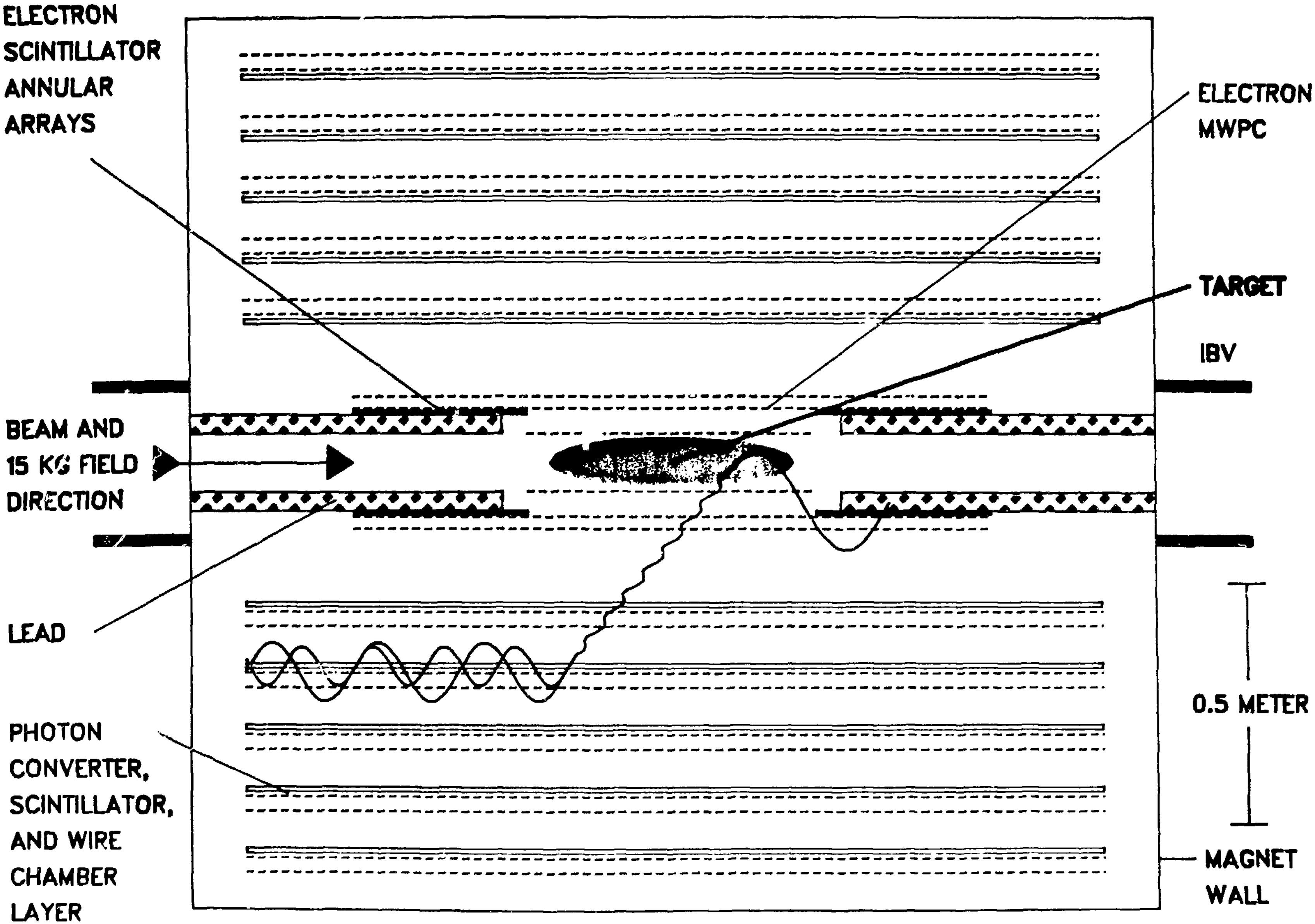
E_e (MeV)
E_γ (MeV)
Θ_eγ (deg)
Δt (ns)

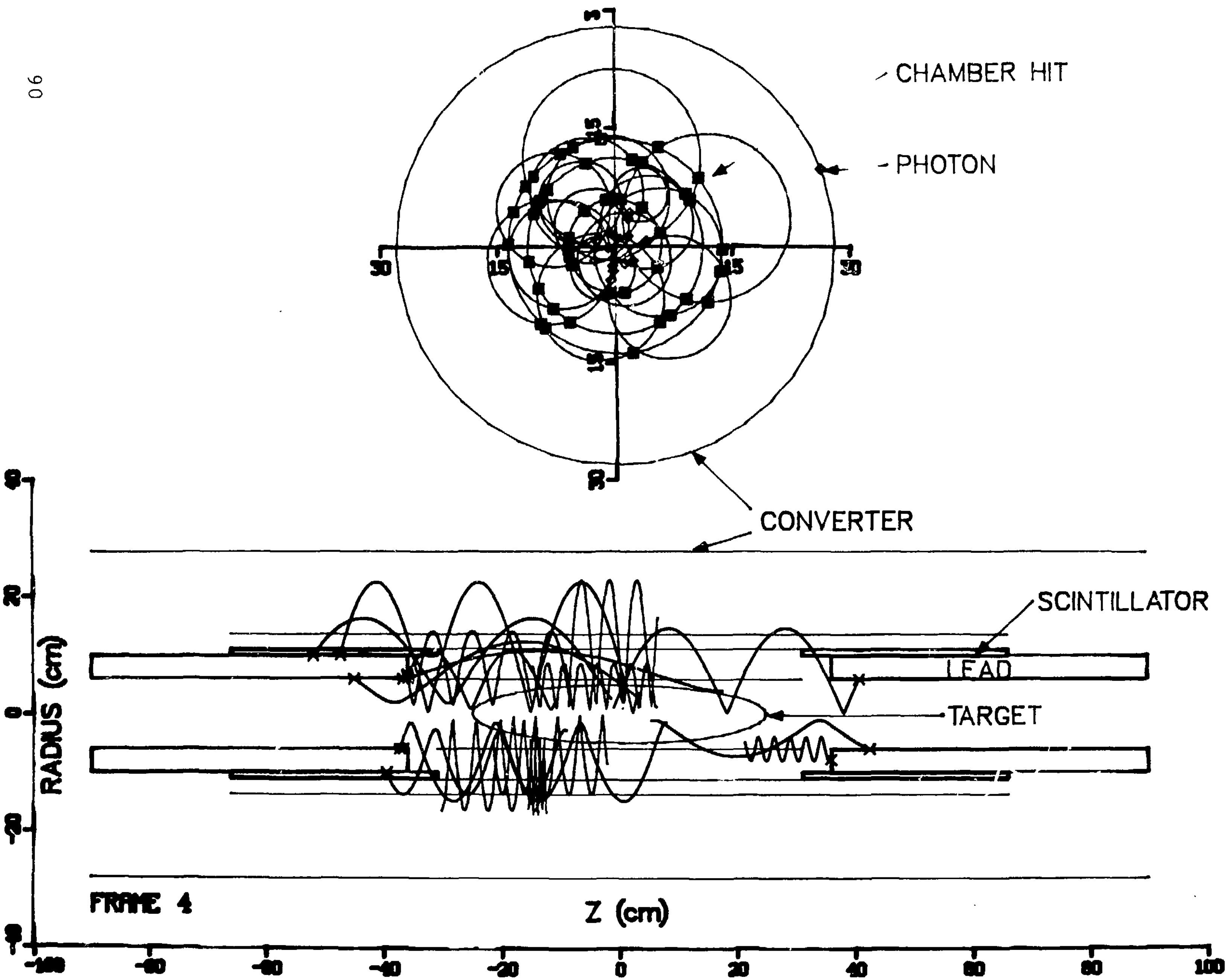
$\mu \to e\gamma\gamma$ Events

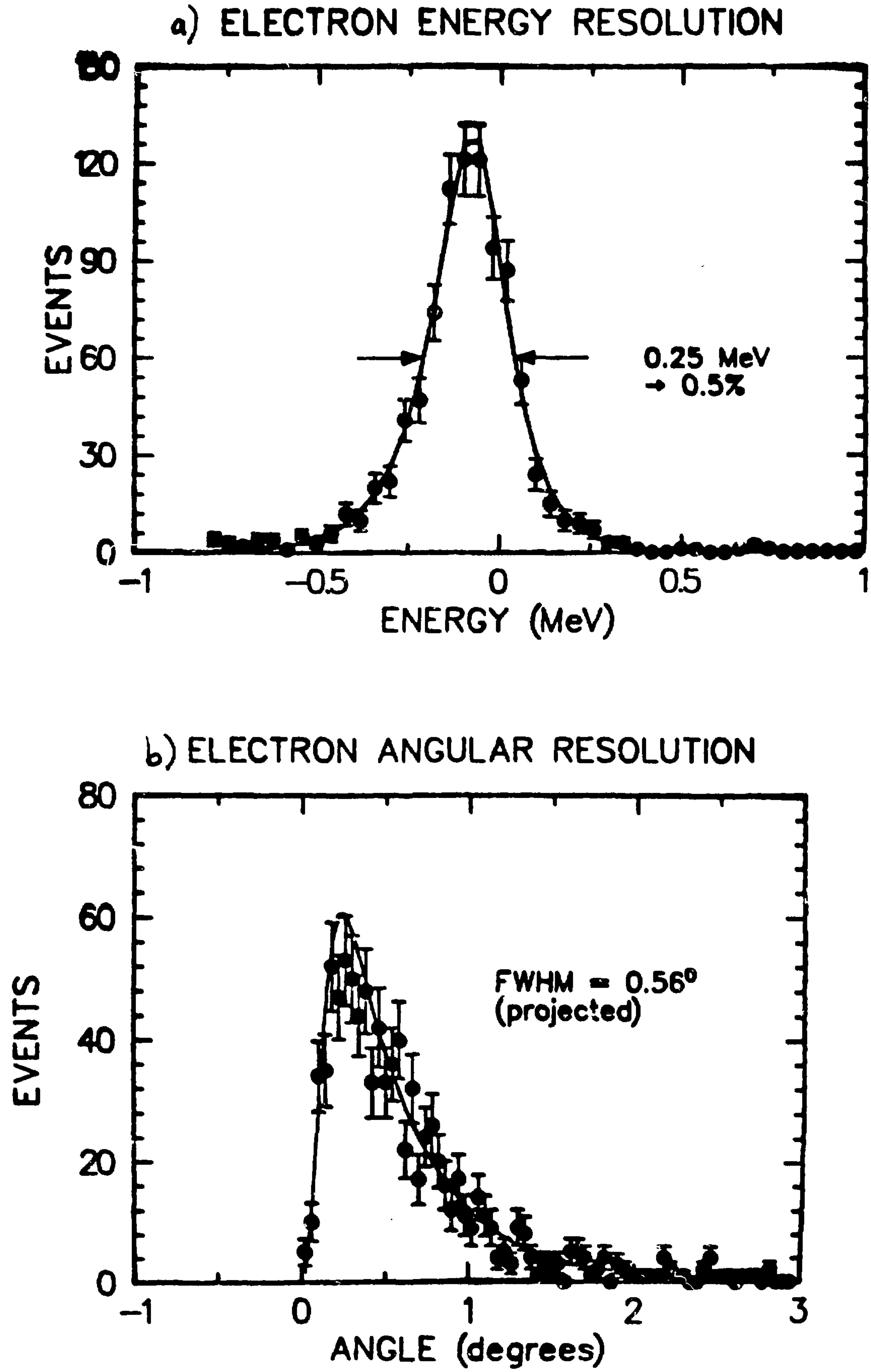


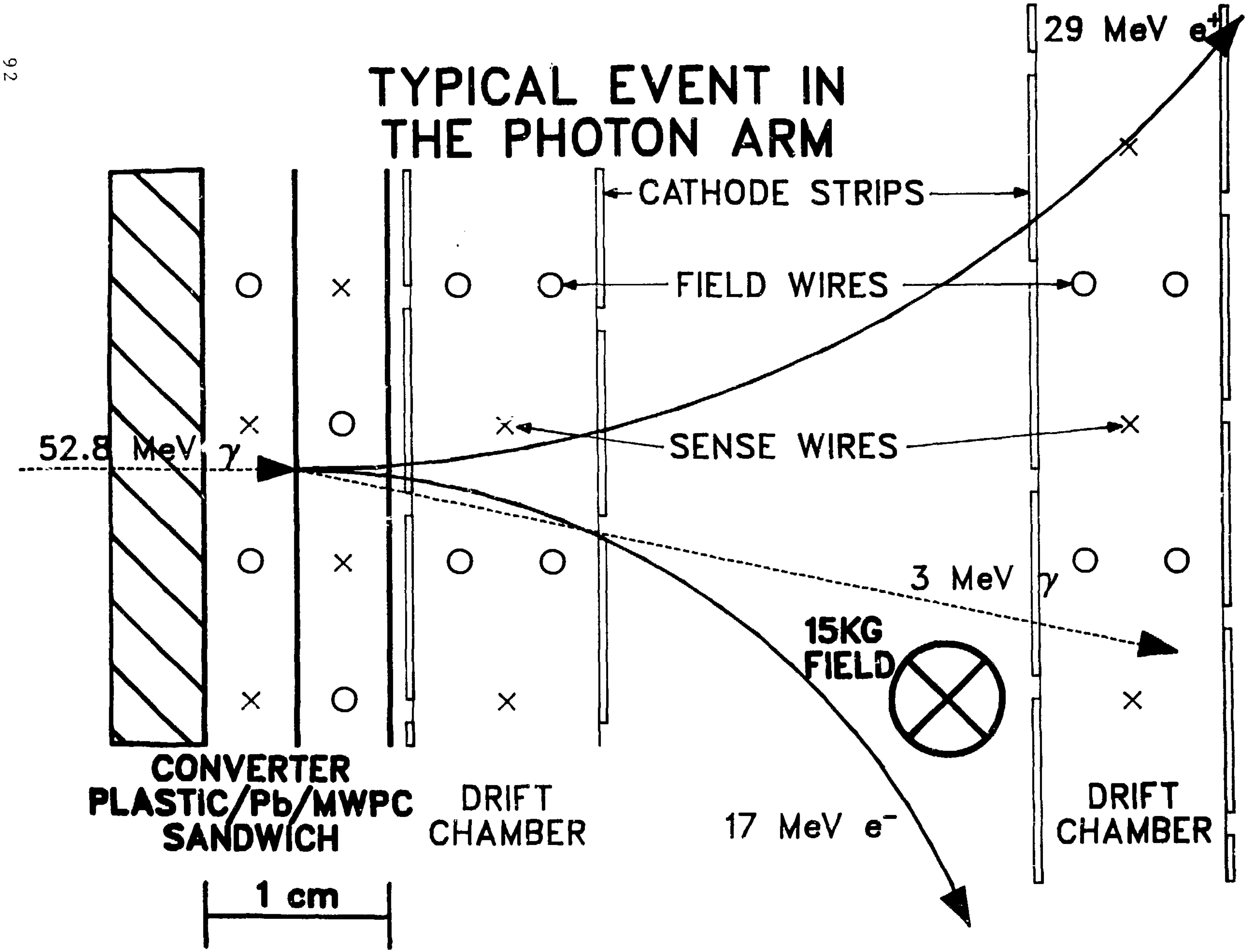


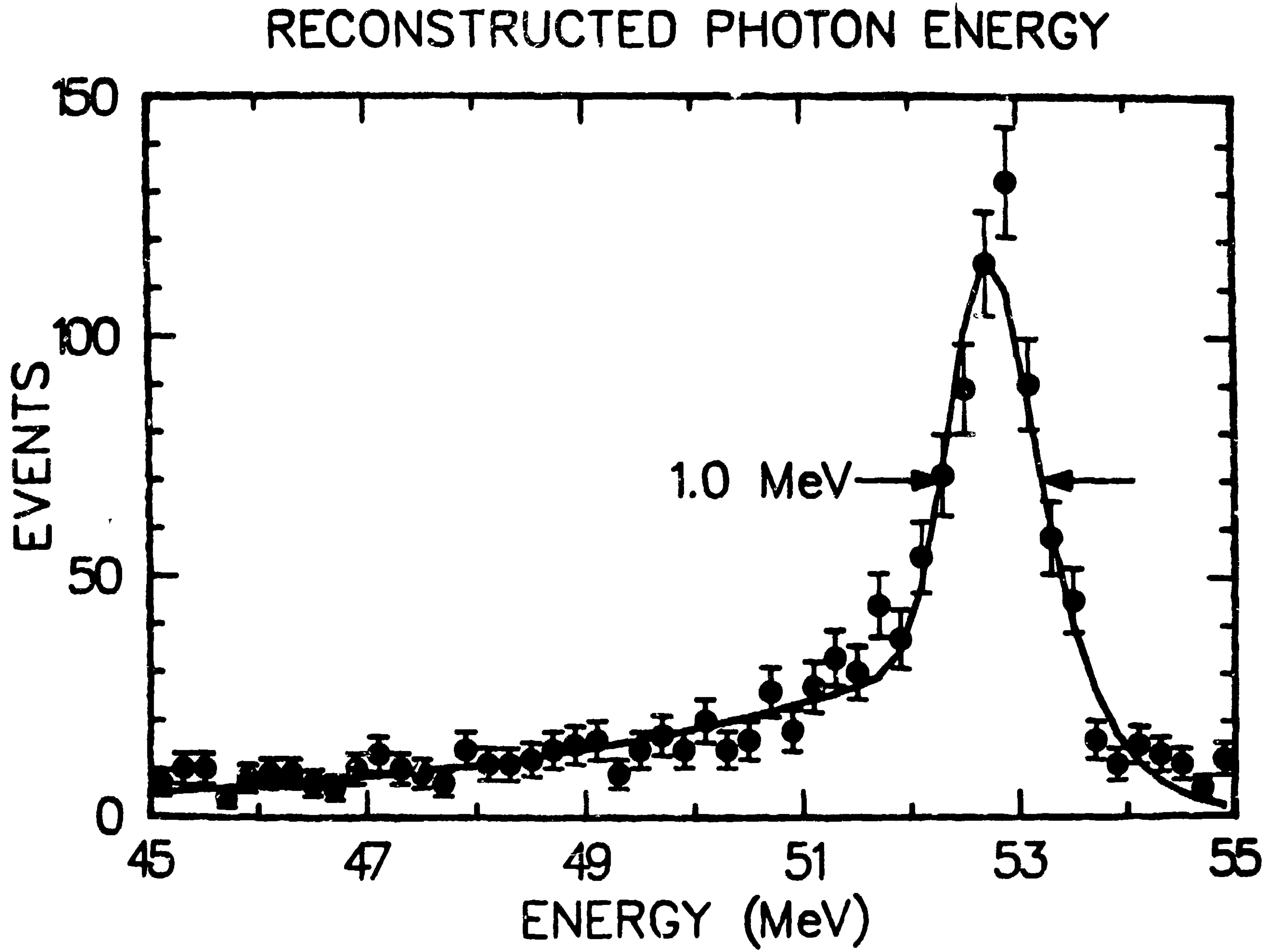

ELECTRON SCINTILLATOR
ANNULAR ARRAYS
ELECTRON MWPC
TARGET
IBV
LEAD
MAGNET WALL
PHOTON CONVERTER,
SCINTILLATOR, AND WIRE CHAMBER LAYER
0.5 METER


ELECTRON SCINTILLATOR ANNULAR ARRAYS
ELECTRON MWPC
TARGET
IBV
BEAM AND 15 KG FIELD DIRECTION
LEAD
0.5 METER
PHOTON CONVERTER, SCINTILLATOR, AND WIRE CHAMBER LAYER
MAGNET WALL

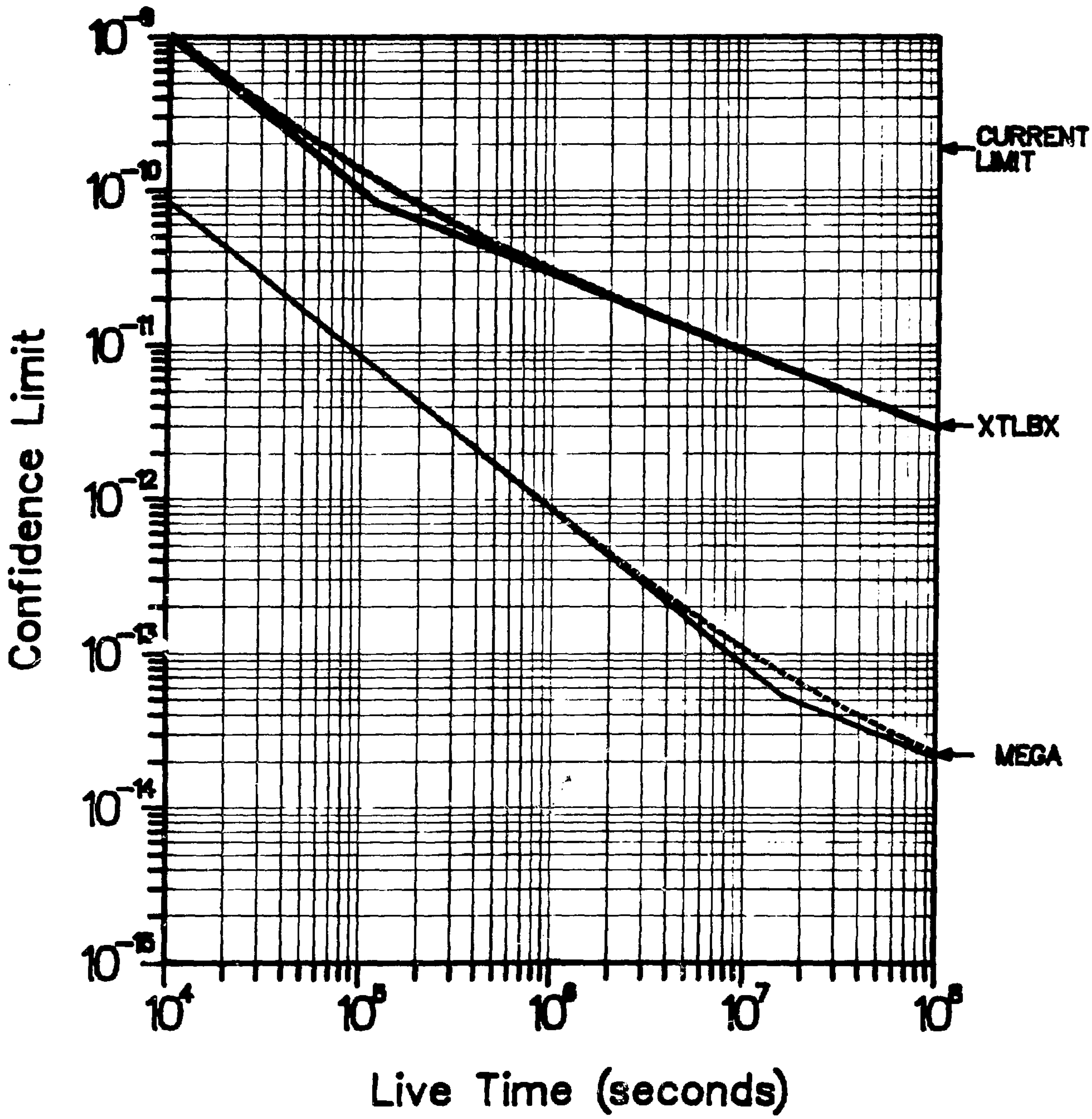

CHAMBER HIT
PHOTON
CONVERTER
SCINTILLATOR
LEAD
TARGET
RADIUS (cm)
Z (cm)
FRAME 4
-100
-80
-60
-40
-20
0
20
40
60
80
100


a) ELECTRON ENERGY RESOLUTION
EVENTS
ENERGY (MeV)
0.25 MeV
→ 0.5%
b) ELECTRON ANGULAR RESOLUTION
EVENTS
ANGLE (degrees)
FWHM = 0.56°
(projected)


TYPICAL EVENT IN
THE PHOTON ARM
29 MeV e+
CATHODE STRIPS
FIELD WIRES
SENSE WIRES
52.8 MeV γ
3 MeV γ
15KG
FIELD
CONVERTER
PLASTIC/Pb/MWPC
SANDWICH
DRIFT
CHAMBER
17 MeV e−
DRIFT
CHAMBER
1 cm


RECONSTRUCTED PHOTON ENERGY
EVENTS
ENERGY (MeV)
1.0 MeV
0
50
100
150
45
47
49
51
53
55

90% Confidence Limits



NPL Upgrade

by

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LAMPF has embarked on a major three year development program to upgrade the Nucleon Physics Laboratory (NPL) to both enhance ongoing experimental programs and to provide facilities for new physics research in nucleon charge-exchange reactions.[1] My talk concentrates on the new physics opportunities presented by this upgrade with a brief description of the experimental facilities.

Studies of the nucleon charge-exchange reaction (p,n) and (n,p) with good resolution will now be possible in the energy range of 200-800 MeV and are expected to provide a unique new probe of nuclear structure and nuclear response functions. The theoretical framework exploited in the (p,p) program at the HRS can now be turned to focus on purely isovector phenomena, thus eliminating the dominant isoscalar excitations present in (p,p) scattering. The presence of complementary (p,p), (n,p) and (p,n) data over the intermediate energy range available at LAMPF could prove to be essential in attacking fundamental open questions in nuclear structure physics.

It would be ludicrous to presume that the important physics results could be predicted at this time, however, certain obvious experiments are natural starting points for a nucleon charge-exchange program. Scattering to discrete final states will allow one to test or calibrate the isovector parts of the effective nucleon-nucleon interaction in this unexplored energy range. Giant resonances have long been a rich source of nuclear structure; it will now be possible to concentrate on isovector giant resonances and sum rules in a very detailed fashion. The structure of the continuum and the general nuclear response can be explored. Decomposition of very specific parts of the interaction become possible when complete polarization transfer measurements are performed. The consequences of the Dirac approach to nuclear reaction theory can be investigated in the isovector sector. In the following sections, I will spend some time exploring these issues in more detail.

The Effective Interaction

At small momentum transfers, the major contribution to Gamow-Teller (GT) and isobaric analog (IA) transitions are the central part of the spin-flip and nonspin-flip interaction respectively. Measurements of 0° (p,n) cross sections to these two classes of states provides a powerful tool to map out the ratio of these parts of the effective interaction. These can be compared to interactions based on nucleon-nucleon phase shifts which are virtually the only source of information on these important terms at the present time from 200 to 800 MeV. Figure 1 shows the present status of theory and experiment for this ratio in this energy range. Below 200 MeV this ratio is well determined from 0° (p,n) studies at IUCF. The points at 318 and 800 MeV are from recent (p,n) results from WNR at LAMPF[2] and will be discussed in more

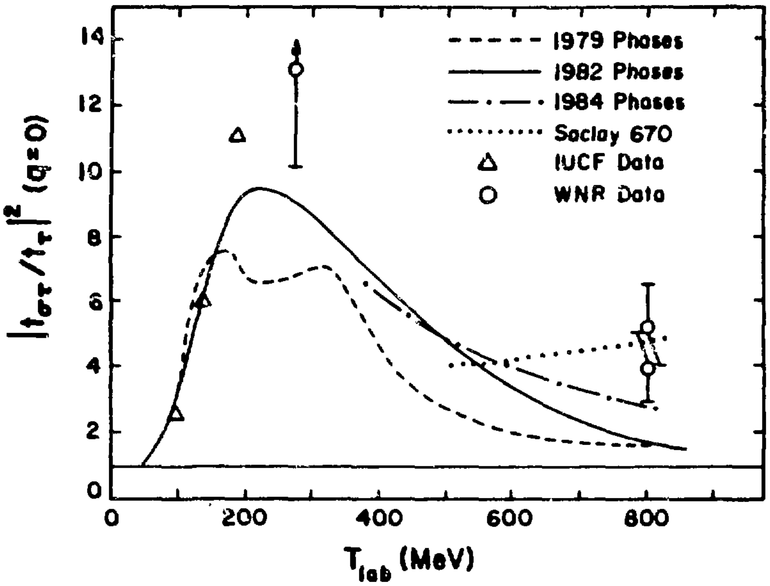

Fig. 1. Energy dependence of spin-flip to nonspin-flip isovector amplitudes at q = 0.

detail in the talk by P. Lisowski. Results from the new TRIUMF facility should be available soon from 200 to 500 MeV. As can be seen from the figure, this ratio of the effective NN interaction which drives the nucleon-nucleus reaction process exhibits a strong energy dependence on spin (actually on nonspin-flip as it is t_τ which is changing most). These first data seem to bear this out and demonstrate that the nucleon charge-exchange reaction may have more sensitivity in determining this energy dependence than NN experiments. This tunable nature of the selectivity of the nucleon probe has an important impact on our ability to investigate specific features of the nuclear response function.

By selection of particular final states, the momentum dependence of various terms of the effective interaction can be mapped to investigate modification of the NN interaction in the nuclear medium. Medium modifications are expected to be significant up to 400 MeV. The technique of complete sets of polarization transfer (PT) observables used in $(\vec{p},\vec{p}')$ can be applied to the charge-exchange reaction. In the plane wave impulse approximation (PWIA) it has been shown[3] that for unnatural-parity transitions

$$\begin{aligned}
\sigma D_{nn} &= X_T^2\ (C^2+B^2-F^2)-X_L^2E^2 \\
\sigma D_{pp} &= X_T^2\ (C^2-B^2+F^2)-X_L^2E^2 \\
\sigma D_{qq} &= X_T^2\ (C^2-B^2-F^2)+X_L^2E^2
\end{aligned} \tag{1}$$

Where C,B,E,F are the coefficients of the two-body NN scattering amplitude defined by

$$M_{12}(q) = A(q)+B(q)\sigma_{1n}\sigma_{2n}+C(q)(\sigma_{1n}+\sigma_{2n})+ E(q)\sigma_{1q}\sigma_{2q}+F(q)\sigma_{1p}\sigma_{2p} \tag{2}$$

with

$$\begin{aligned}
\sigma &= X_T^2[C^2+B^2+F^2] + X_L^2E^2 \\
X_L^2 &\sim |\langle I'|\vec{\sigma}\cdot\vec{q}e^{i\vec{q}\cdot\vec{r}}|I\rangle|^2 \\
X_T^2 &\sim |\langle I'|\vec{\sigma}\times\vec{q}e^{i\vec{q}\cdot\vec{r}}|I\rangle|^2
\end{aligned} \tag{3}$$

the D_{ii}'s are the diagonal PT observables and $X_{L(T)}^2$ is the longitudinal (transverse) response function. Evident from Eq. 1 is that linear combinations of the PT observables are directly related to specific pieces of the NN effective interaction if the nuclear structure is known. By looking at different multipolarities the nucleus acts as a filter to investigate different regions of momentum transfer. The nondiagonal PT observables have been shown to be related to composite current ($J \otimes \sigma$) operators previously only accessible in beta decay.[4,5]

Giant Resonances and the Continuum

Once the selectivity of discrete final states is given up, PT measurements may be the only way to regain any measure of exclusivity. In Fig. 2 an example of this is shown for $^{12}C(\vec{p},\vec{p}')$ at 397 MeV (Ref. 6). In the top half of the figure the spectrum of low-lying states is shown containing strong natural-parity $\Delta S=0$ states as well as weaker unnatural- and natural-parity states known to have sizable $\Delta S=1$ contributions. The bottom of the figure shows the product of yield and spin-flip probability ($S_{nn} = \frac{1-D_{nn}}{2}$).

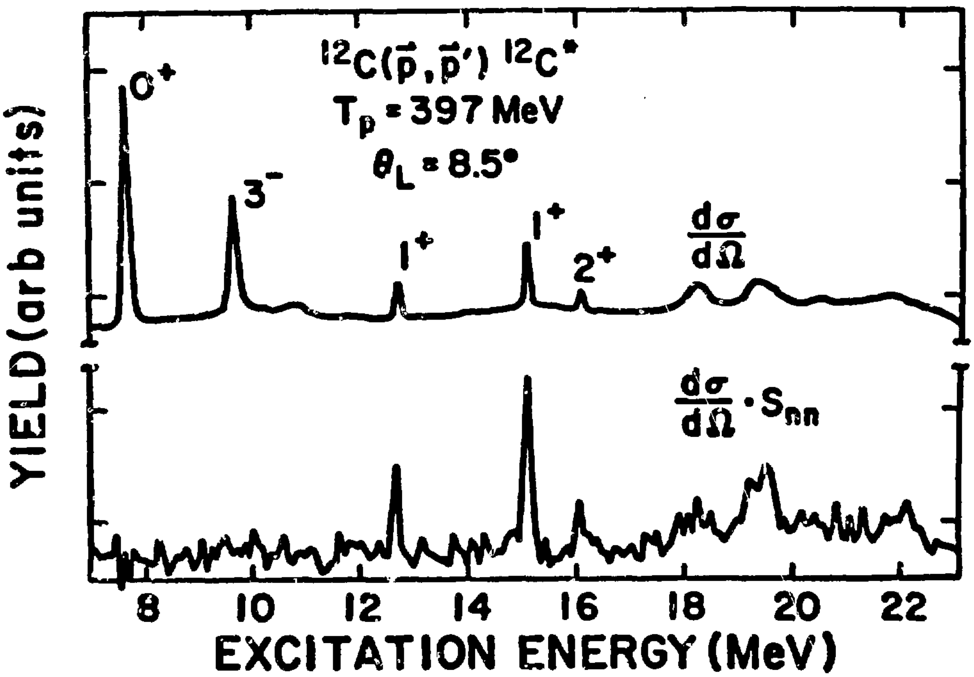

Fig. 2. $^{12}C(\vec{p},\vec{p}')$ yield and spin-flip cross section at 397 MeV.

Virtually a complete suppression of the strong 0^+ and 3^- $\Delta S=0$ states is seen while the 1^+ and 2^+ $\Delta S=1$ states are enhanced. This is a general feature of spin-flip measurements; S_{nn} is directly related to the amount of $\Delta S=1$ present in the transition. In fact the general definition gives

$$S_{ii} = \frac{\sigma(SF)}{\sigma(NSF)+\sigma(SF)} = \frac{\sigma(SF)}{\sigma}$$

$$\sigma D_{ii} = \sigma(1-2S_{ii}) = \sigma(NSF)-\sigma(SF) \tag{4}$$

where $\sigma(SF)$ and $\sigma(NSF)$ denotes spin-flip and nonspin-flip cross sections along the i-axis. This technique has been used for S_{nn} in the $(\vec{p},\vec{n})$ reaction at IUCF[7] for identification of GT strength. Significant dependence of S_{nn} on J^π in general makes this a powerful tool for spin-parity decomposition of isovector giant resonances and continuum background. Love and Klein[8] have pointed out a very interesting effect associated with spin-flip measurements in the continuum as a function of bombarding energy. They have shown that the transverse spin-flip at 0° is simply related to the ratio of transverse (V_t) to longitudinal (V_ℓ) isovector parts of the interaction by

$$D_{nn} \sim \frac{-1}{1+(V_t/V_\ell)^2} \tag{5}$$

In a $\pi+\rho$ picture, V_ℓ will be nearly zero at about 0.7 fm^{-1} while V_t remains large, thus forcing D_{nn} toward zero and destroying its sensitivity to spin-flip transitions. This q dependence of V_ℓ is supported by the two-body t-matrix based on phase shift analysis[9] and occurs at Q_{pn}~50 MeV for IUCF energies. Inasmuch as D_{nn} is a powerful tool for addressing the problem of missing GT strength, sensitivity to $\Delta S=1$ at high excitations is essential.

Since the effective momentum transfer at a given Q value decreases as the bombarding energy is increased, one might expect the problem of poor sensitivity to improve with increasing energy. Figure 3 shows the ratio of V_t/V_ℓ vs. Q_{pn} for 120, 160, and 500 MeV incident energy protons. It is apparent from this figure that a great deal of sensitivity is gained by going to higher energy.

Perhaps some of the most promising theoretical results in charge exchange reactions are RPA calculations of the continuum.[10,11] The calculations shown in Fig. 4 are due to Osterfeld, Cha, and Speth and represent a microscopic analysis of 200 MeV ^{90}Zr (p,n) spectra in the RPA model. The overall quality of the fit is remarkable over a large range of excitation and angle. There is now much less ambiguity in background subtraction insofar as the "background" is now due to multistep processes or ground state correlations not

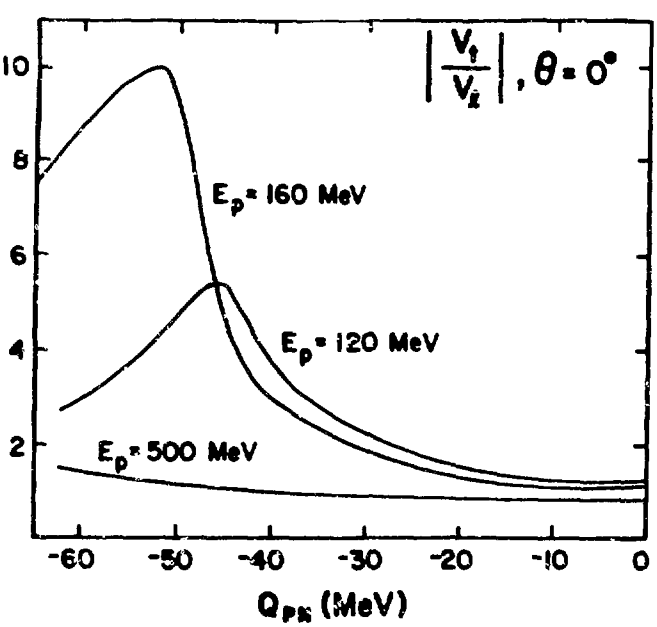

Fig. 3. Ratio of transverse to longitudinal coupling vs. Q_{pn} for various bombarding energies.

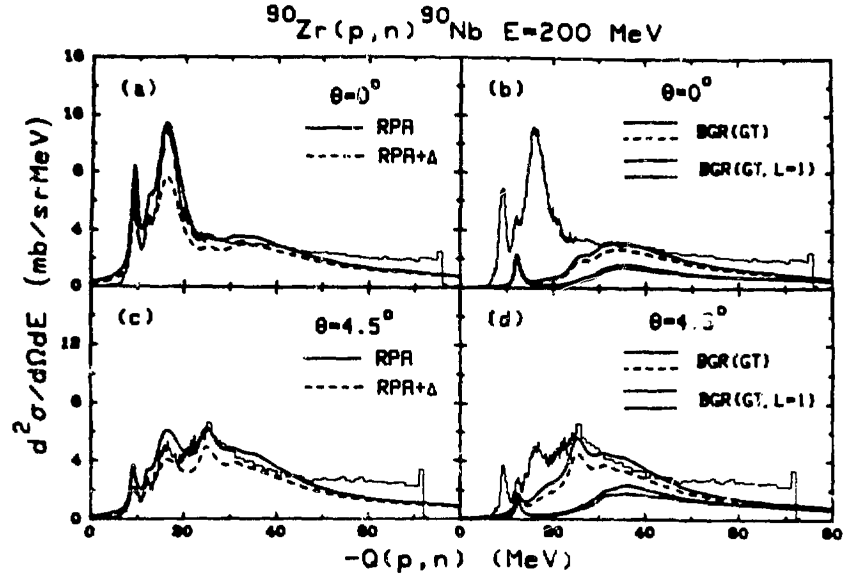

Fig. 4. RPA cross section calculation for 200 MeV ^{90}Zr (p,n).

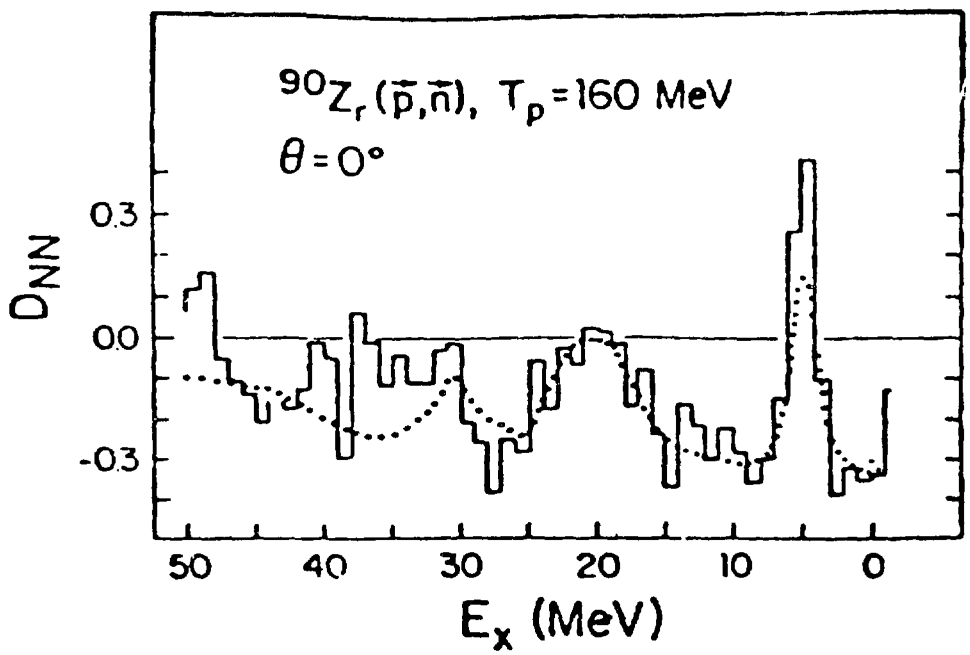

Fig. 5. RPA D_{nn} calculation for 160 MeV ^{90}Zr $(\vec{p},\vec{n})$.

incorporated in the RPA calculation. Figure 5 shows a similar comparison for 160 MeV ^{90}Zr$(\vec{p},\vec{n})$ D_{nn} by Love and Klein. The general features of the spectrum are well reproduced up to $Q_{pn} \approx 40$ MeV. Noticeable at high excitation is the trend of D_{nn} to -0.1 which remain constant above 45 MeV, reflecting the greater sensitivity to the noncentral parts of the force and the dominance of transverse coupling. All of these calculations include only 1p1h contributions and fall short of a precise fit to the data. There are good indications[12] that inclusion of 2p2h contributions will improve the situation by removing GT strength from the low-lying states and spreading it to higher excitations, providing detailed information on quenching of Gamow-Teller strength and perhaps the role of the delta. It is expected that in the near future precise calculations of the continuum will be available for detailed interpretation of charge-exchange data.

Given this type of theoretical framework, comparison of (n,p) and (p,n) spectra will be essential for interpretation of the GT sum rule

$$S_\beta^- - S_\beta^+ = 3(N-Z) \qquad (6)$$

where the S_β^- strength is derived from the (p,n) reaction and S_β^+ from (n,p). The good fits obtained by Osterfeld, Cha, and Speth to (p,n) spectra indicate that the minimal sum rule (i.e. $S_\beta^+ \approx 0$) is satisfied without inclusion of Δ admixtures to the wave function. The 2p2h admixtures into the ground state wave functions, however, can create S_β^+ strength and destroy the minimal sum rule achieved in the calculations. Hence knowledge of S_β^+ is essential to any conclusions about the importance of the Δ, thus demonstrating the importance of (n,p) measurements in conjunction with (p,n).

Another interesting feature associated with higher bombarding energies involves differential absorption in transverse and longitudinal modes. To the extent that the longitudinal part of the interaction is mediated by π exchange while transverse goes by ρ exchange, the different ranges of the two parts allow a preferential enchancement of longitudinal modes as the absorption increases (short range correlations modify this behavior somewhat). This implies that it is possible to suppress the purely transverse 1^- strength at higher energy thereby increasing sensitivity to GT strength. Calculations have been done which bear this out.* In fact the ratio of distortion factors for longitudinal to transverse almost doubles in going from 120 MeV to 800 MeV. This provides an additional selectivity for investigating the nuclear response.

Absorption also plays an important role in sensitivity to the isovector monopole resonance in that sampling of the interior node is suppressed thereby enhancing the probability of observing it at higher energies.

Referring back to Eq. 1 it is possible to take the alternate view that the effective interaction has been calibrated and proceed to extract nuclear structure information from complete PT measurements. This approach was taken in a recent HRS experiment[13] to obtain the ratio of longitudinal to transverse response functions for quasi-free scattering in a heavy target and comparing that to essentially free NN scattering. It was found that there were no changes in this ratio in going from ^2H to Pb. This is in contrast to recent theoretical calculations based on enhancements of the pion field within the nucleus used to explain the so-called EMC effect.[14] A comparison of the HRS

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*Information provided by Amir Klein, University of Georgia, 1985.

data and this calculation using the value of g′ needed to fit the EMC data (0.55) and the more traditional value (0.7) are shown in Fig. 6. The details of this analysis are an entire talk on its own, but I will give some brief comments on its connection with charge-exchange reactions.

The driving term in these calculations is a purely isovector effect due to the enhancement of the longitudinal $\vec{\sigma}\cdot\vec{q}$ or pion part of the interaction. Corrections to the $(\vec{p},\vec{p}')$ experiment had to be made in order to subtract out the isoscalar part of the interaction seen by the proton. This amounted to a factor of 2-3 reduction in the sensitivity of the $(\vec{p},\vec{p}')$ reaction to this isovector effect. This factor is readily recovered in the $(\vec{p},\vec{n})$ reaction since it is purely isovector in nature. Systematic investigation of this is warranted based on uncertainties in the momentum dependence of the effect.[15]

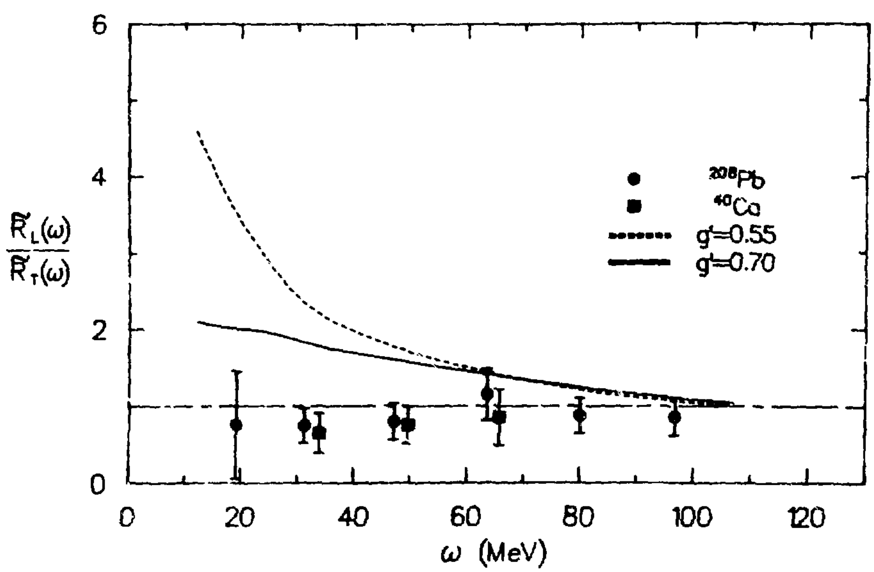

Fig. 6. Ratio of longitudinal to transverse isovector response functions normalized to the free NN values. Calculations include the enhanced nuclear pion field use to explain the EMC effect.

Reaction Theory

LAMPF is considered the birthplace of intermediate energy relativistic theory. It was motivated by the complete breakdown of the standard nonrelativistic theories in fitting elastic spin observables. Relativistic treatments based on the Dirac theory were found to provide a remarkably good description of these data. It has been pointed out[16] that in (p,p′) scattering, only the isoscalar part of the relativistic optical potential is probed and that the isovector parts are largely untested. PT measurements in the (p,n) reaction to the IAS would provide the required complementary data. Large differences between relativistic and nonrelativistic impulse approximation have been calculated for these spin observables.[17]

Microscopic inelastic calculations are now becoming available. The general conclusions of Eq. 1 remain intact so that detailed comparisons of various approaches can be made in the isovector sector when general (p,n) PT observables become available.

Experimental Facilities

The major upgrades to the NPL facility include a Medium Resolution Spectrometer (MRS), a 600 m Neutron Time of Flight path (NTOF), and a high intensity polarized ion source.

In December of 1984, a workshop for the NPL Upgrade Working Group was held at LAMPF. Fifty participants representing twenty universities and national laboratories met to review the upgrade proposal and to lay down criteria for the physics programs being proposed. Two parallel sessions were held during that meeting, MRS and NTOF.

The MRS design now under consideration is a QD(-D) system by H. Enge shown in Fig. 7. The design is intended to satisfy the criteria established at the workshop and detailed in Table I. The important criteria is ~1 MeV of energy resolution at 800 MeV over a limited region of the focal plane, a large acceptance and range for NN and light nucleus proton scattering, and a large target volume for (n,p) applications. The initial stages of the (n,p) program will involve movement of the MRS to the neutron hall of Area B (BR) and replacement of the liquid deuterium neutron production target with a lithium

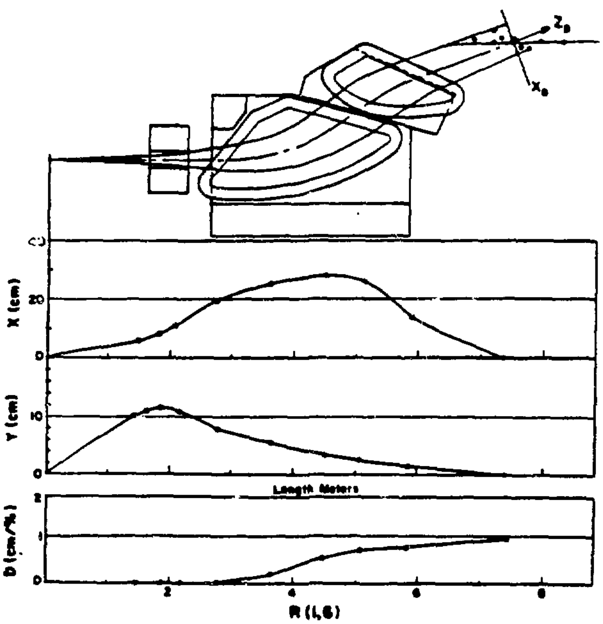

Fig. 7. Medium Resolution Spectrometer design.

target to produce a nuclear physics grade neutron beam using the 0° Li(p,n) reaction. This will provide the source for the MRS in the (n,p) mode.

Neutron energy resolutions of 1-2 MeV in the (p,n) reaction require the long flight path offered by NTOF. Figure 8 shows the energy resolution for 200-800 MeV neutrons vs. flight path for an overall timing resolution of 1 ns. The neutron detector system is based on a polarimeter shown in Fig. 9 being developed by P/MP divisions for use in $(\vec{p},\vec{n})$ studies at IUCF. It consists of three planes of liquid scintillator where the front plane provides the source of free hydrogen in the scintillator for the elastic n+p analyzing reaction and two rear planes serve as catchers to map the polar and azimuthal distributions of scattered events. Some modification for higher incident neutrons will be incorporated.

δT vs D for Time Resolution δt = 1.0 nsec

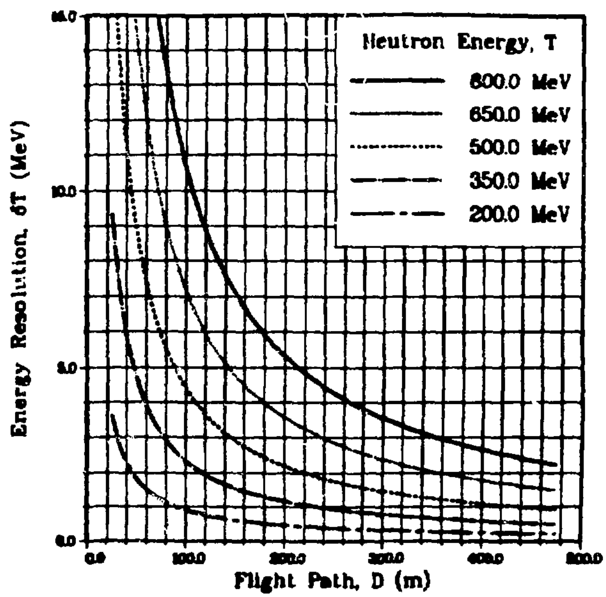

Fig. 8. Neutron energy resolution vs. flight path for 200-800 MeV neutrons with an overall timing resolution of 1 ns.

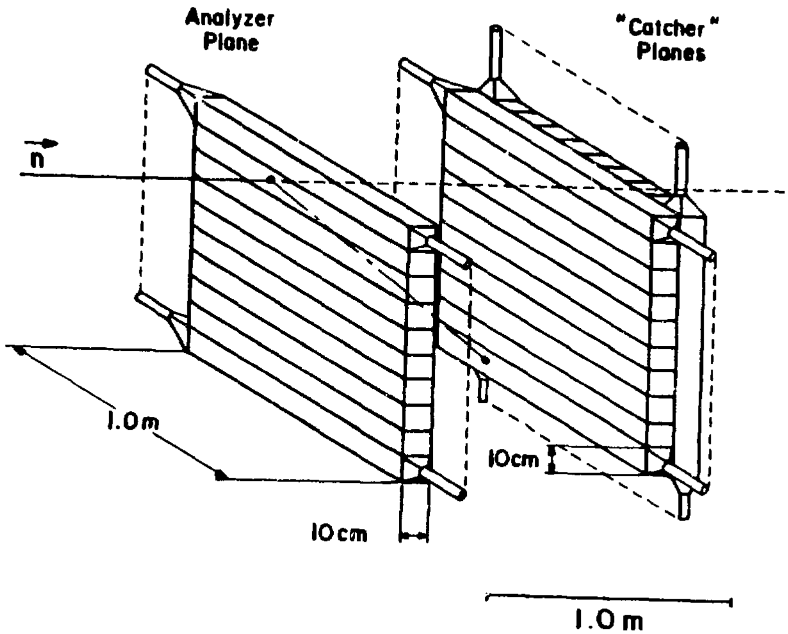

Fig. 9. Neutron polarimeter design.

The vitality of the nucleon charge-exchange program at LAMPF depends on the implementation of the high intensity optically pumped polarized ion source now underway. A factor of a hundred over existing intensities is expected (10 nA → 1 μA average). This is needed given the small solid angles subtended by detectors in NTOF and the double-scattering nature of the (n,p) facility. Along with the new source comes a 100 ns buncher for wrap around rejection in NTOF.

This proposal has been favorably reviewed by the Program Advisory Committee, the Technical Advisory Panel, the LAMPF Board of Directors, and the Experimental Area Development Committee. A management team has been established and a scheme for funding the project has been devised. User Advisory Panels have been formed to provide input from the scientific community and serve as a board of review for plans and options. Preliminary estimates indicate a cost of six million dollars for the new polarized source, MRS, NTOF, and associated beam line modifications. Some early phases of NTOF are expected in 1987, MRS and the new source in 1988. Beam line modifications for MRS and NTOF are planned for early 1986. A second workshop is scheduled for December 16-17 of this year at LAMPF for detailed consideration of the project.

Acknowledgments

This presentation represents the contributions of many people interested in the nucleon charge-exchange program at LAMPF. In particular, I wish to thank N. Auerbach, A. Bacher, C. Goodman, A. Klein, G. Love, and J. Speth for their valuable contributions.

TABLE I

OPERATIONAL REQUIREMENTS

Energy Resolution: (@ 800 MeV)	0.5 MeV over ±20 MeV of acceptance ($\Delta\Omega$~10 msr) 5.0 MeV over ±150 MeV of acceptance ($\Delta\Omega$~15 msr)
Solid Angle:	10-15 msr
Target Area:	25 cm^2
Momentum Acceptance:	±20%
Maximum Momentum:	1.9 GeV/c
Angular Resolution:	±2 mr
Angular Range:	0-160°
Overall Length:	9 m
Instrumentation:	Wire chambers at focal plane for ray tracing Focal plane polarimeter Front chambers for (n,p) application (large target area) Polarized target interface Second arm interface

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THE WNR NEUTRON SOURCE

LAMPF USERS MEETING
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ABSTRACT

The Weapons Neutron Research (WNR) facility is a versatile pulsed neutron source used in a wide variety of research programs. In this talk the WNR Facility and the experimental program are described with emphasis on the potential of the WNR for studying nuclear physics issues.

INTRODUCTION

The Weapons Neutron Research (WNR) facility[1,2,3] has been operational since 1977 as a pulsed spallation neutron source at Los Alamos National Laboratory. At the WNR part of the 800 MeV proton beam from the Clinton P. Anderson Meson Physics Facility (LAMPF) has been used to either provide a white neutron source for nuclear physics and condensed matter research or for proton induced reaction studies.

At present, the facility is being substantially upgraded. The Proton Storage Ring (PSR), which came on line in 1985, is providing greatly increased intensity, improved time structure, and a better duty factor for neutron experiments in the thermal and epithermal energy range. Formally, this part of the facility served by the PSR has been renamed the Los Alamos Neutron Scattering Center or LANSCE. The LANSCE is entirely devoted to experiments using moderated neutrons, including condensed matter neutron scattering studies and low-energy neutron physics. For nuclear physics experiments requiring neutrons with energies greater than a few hundred keV, an additional target area is being constructed which will take advantage of multiplexed operation and forward angle flight-paths to greatly enhance the neutron flux over that previously available. This new target area together with an existing low-current target room constitute the WNR facility. This talk concentrates on the WNR operating characteristics and discusses its potential for investigating several forefront nuclear physics issues.

FACILITY DESCRIPTION

The WNR/LANSCE Facility is only one of several target areas located at LAMPF. Because the first stage of acceleration operates at 201 MHz, the LAMPF proton macropulse has a sub-structure consisting of narrow micropulses separated by 5 ns. The beam from LAMPF to the WNR facility can be provided either as macropulses, sections of macropulses, or as macropulses which have been chopped to leave micropulses with a minimum separation of 360 ns. After acceleration, the proton beam is deflected from LAMPF using a pulsed magnet and transported directly to the target area bypassing the PSR.

The layout of the entire facility is shown in Fig. 1. There are three experimental areas, the LANSCE, formerly called target-1, a high-current area fed by the Proton Storage Ring (PSR), target-2, a low-current, low-return room with an external proton beam capability, and target-4, a high-intensity fast-neutron nuclear physics target area. The WNR facility consists of target-2 and target-4. Target-4 is not shown in Fig. 1.

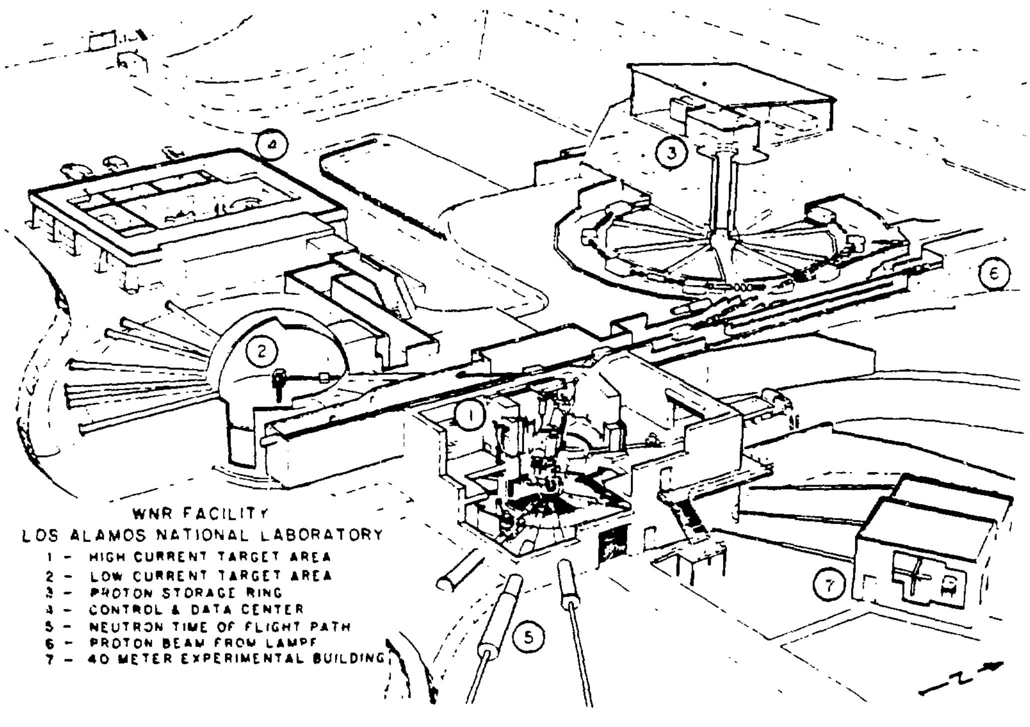

FIGURE 1 The layout of the WNR/LANSCE facility. The beam from LAMPF enters from the right. The target-4 area is not shown, but is located to the south of the complex along the proton beam line from LAMPF and on an extension of the beam line into the low-current targets, respectively.

The existing low-current target, labelled as target-2 in Fig. 1, is shielded for up to 100 nanoamperes of proton beam current. This room is designed to reduce room return by having a low-mass floor and a 6-meter wall-to-center spacing. Because of the flexibility of design, many different kinds of experiments have been performed in this area. Most recently, theoretical predictions of target-moderator neutron output for the LANSCE target system have been tested[5] and a variety of proton-induced reaction studies[6] have been carried out. By removing the beam pipe and allowing the proton beam to pass through the air, it is possible to have an external proton beam in the center of the room for various test set-ups and irradiations. One example of this has been a recent set of beam-pulse timing tests which measured the proton micro-pulse width to be 132 ps FWHM.

In order to provide a dedicated source of fast neutrons for Nuclear Physics experiments, a new white-source facility is under construction to the south of target-2. A plan view of this area is shown in Fig. 2. and a layout of the planned time-of-flight yard is shown in Fig. 3. In the design, there are three important features. First, the flexibility of the existing target-2 arrangement will be maintained by using an 8^{o} bending magnet to elevate the new white-source flight paths above those of target-2. Second, a high-resolution small-angle (p,n) experimental facility previously located along Line-D at WNR, can be operated simultaneously with the white source in this

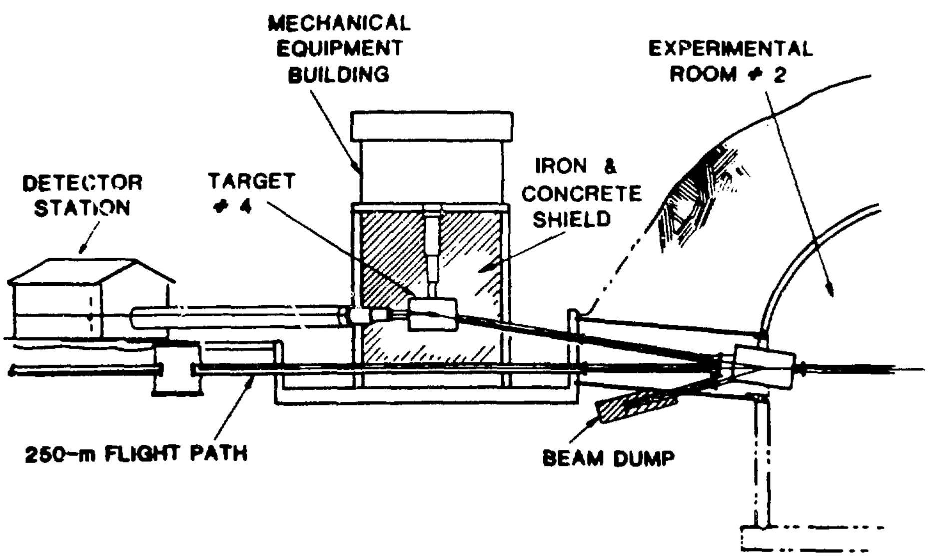

FIGURE 2 A side view of WNR Target-4. The proton beam is deflected 8^{o} up into Target-4 from Target-2. The target changer for high resolution (p,n) experiments is located in the magnet. For (p,n) measurements at angles between 8^{o} and 16^{o}, the proton beam is bent down into the beam dump.

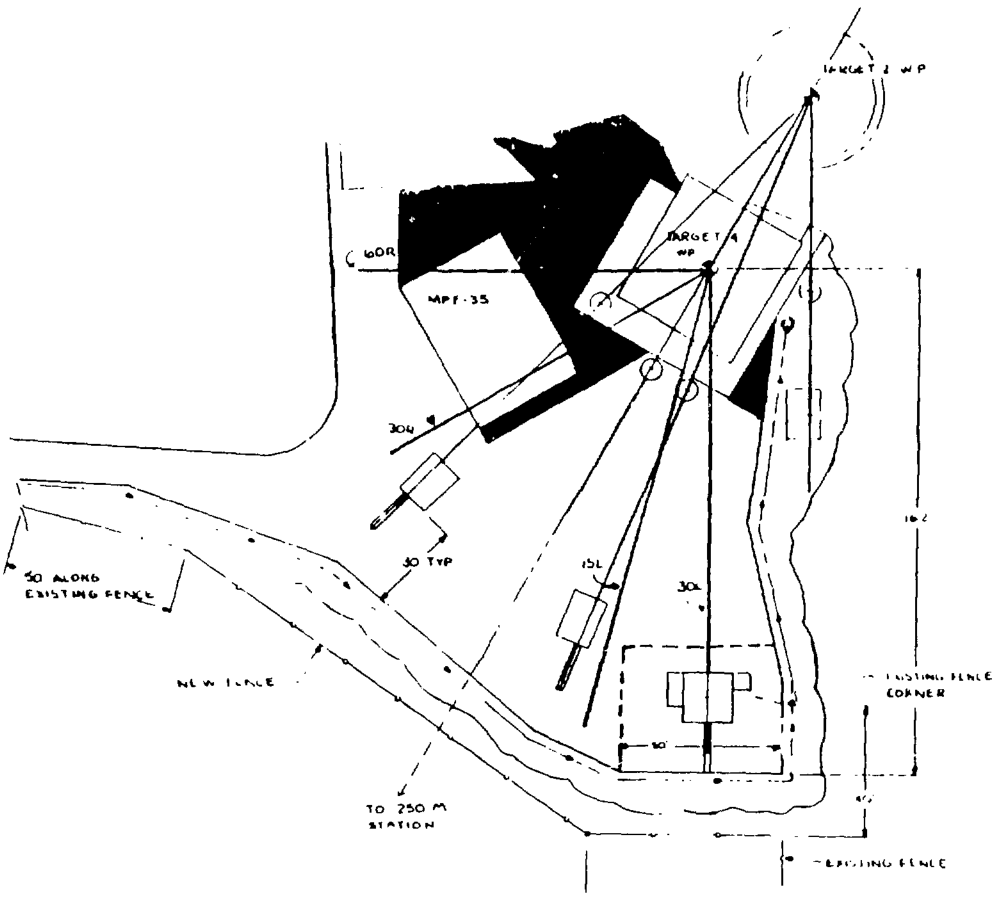

FIGURE 3 The layout of the WNR Target-4 and the time-of-flight yard. The detector station located on the 30° (right) flight path is planned for (n,γ) experiments, the one on the 15° (left) for (n,p) experiments, and the one at 30° (left) is planned for defense related studies.

area. Third, the neutron flight paths for the new facility will view the production target at forward angles instead of at 90° as in the old target-1 arrangement, thus providing a source extending to nearly 800 MeV with increased neutron intensity above about 10 MeV.

Target-4 will have seven penetrations to permit experiments to view the production target at angles ranging from 15° to 90°. The neutron source strengths at angles of 30° and 112° are shown in Fig. 4. These results were computed from measured thin-target cross sections[6] for 15-cm thick targets. Comparing 30° and 112° results for copper shows that the source strength for forward angles remains nearly constant out to 500 MeV; furthermore, there is more intensity for neutrons with energies greater than about 10 MeV. In order

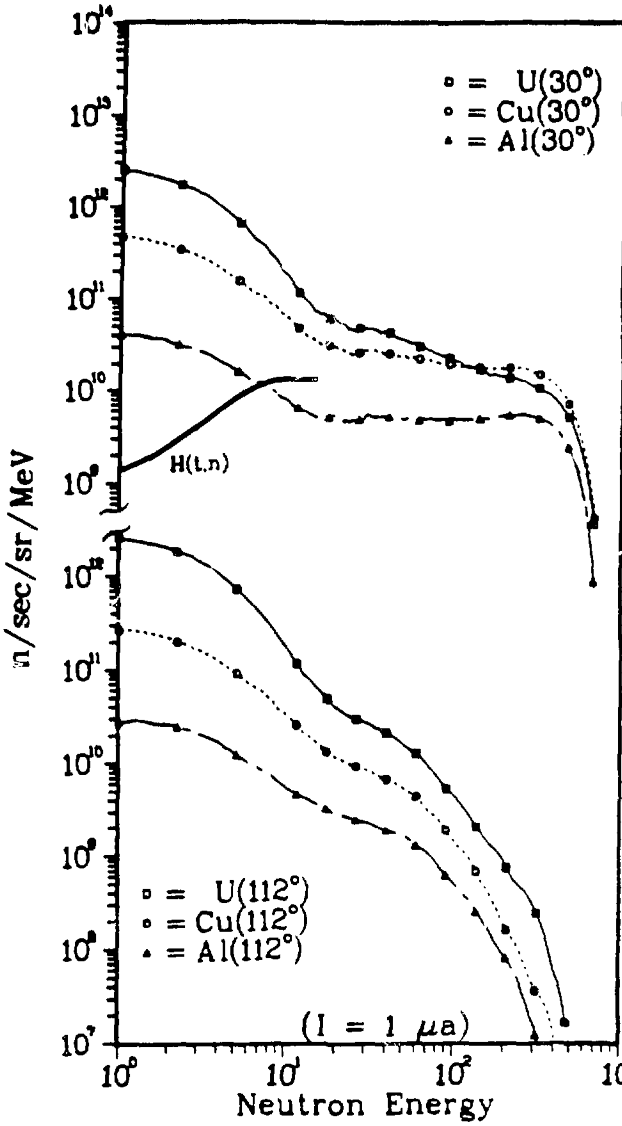

FIGURE 4 Calculated neutron source strengths for angles of 90° (top) and 112° (bottom) for 1 microampere of 800 MeV proton beam incident on 15-cm thick targets of different materials.

to relate the WNR neutron intensity to that from Van de Graaff type accelerators, the solid curve in Fig. 4 gives the yield for the most intense laboratory source of monoenergetic neutrons, the H(t,n) reaction. Here the calculation[7] was performed using a typical pulsed triton beam current of 0.5 microampere. Other parameters used in the calculation are given in Ref. 1.

Target-4 construction began in late May of 1985 with four flight paths planned for implementation in time for experiments during the 1986 LAMPF

Cycle. Those flight paths are a 250-m flight path for high-resolution medium energy (p,n) reaction studies, a 30^{o} flight path for fast-neutron capture and gamma-production experiments, a 15^{o} flight path for neutron-induced charged-particle experiments and a 30^{o} flight path for defense related measurements.

EXPERIMENTAL PROGRAM

A white neutron source[8] such as the WNR has several advantages for performing neutron induced reaction studies. Among those are the ability to perform several experiments simultaneously, a source strength comparable to or greater than many monoenergetic sources, and the ability to measure in one experiment a broad incident neutron energy range with excellent energy-to-energy normalization built in. The disadvantages of such a source are that it is generally necessary to perform experiments using time-of-flight to determine the incident neutron energy and that the experimental arrangement may be more complex than is needed for a single-use, monoenergetic source experiment.

There are many interesting and important physics issues that can be studied at the WNR facility with the white neutron source and the primary proton beam. Among those are studies of radiative capture, charge exchange reactions, preequilibrium and non-equilibrium reactions, elastic and inelastic neutron scattering and tests of nucleon-nucleon scattering and reaction models. Both because of lack of time and because the plans at WNR call for specific experiments to be carried out during the next LAMPF cycle, I plan to discuss only the first two of these topics.

Radiative capture has long been one of the richest areas for investigation of the collective excitation of nuclei. At energies which can be explored by Van de Graaff accelerators, many studies with protons have been made. It is well established in the energy range below 30 MeV, that radiative capture is dominated by E1 radiation which takes place either through a direct process or by the excitation of the giant dipole resonance. For higher order multipole excitations such as E2, neutrons have a distinct advantage over protons because the direct capture part of the interaction is suppressed due to the small effective charge of the neutron. Therefore fore-aft asymmetries which result from the interference of E1 and E2 amplitudes can be used to investigate collective isoscaler and isovector strengths. This is not the case for proton capture where the fore-aft asymmetry is attributed almost entirely to the interference of E1 and non-collective E2 direct capture. Definitive measurements of resonance shape, momentum transfer dependence, and decay modes are needed. These can be provided over the entire range of interest with sufficient energy resolution and intensity for the first time ever at the WNR. At incident neutron energies substantially above 30 MeV, the physics of the capture process is quite different, and measurements at WNR would be the first using medium energy neutrons. One model[9] of the capture process at such energies suggests that meson-exchange, direct capture, and resonance capture processes all play a part. Of particular interest would be the comparison of proton and neutron capture because theory suggests that the three amplitudes contribute differently for the different probes and thus the relative contributions could be determined. As an example of the power of the white source technique for this type of experiment, Fig. 5 shows the total collection of $^{40}Ca(n,\gamma_0)$ data at 90^0. Those data have been obtained at several laboratories world-wide and are the result of many man-years of effort. In Fig. 5, the crosses represent the data obtained at the WNR in approximately 48 hours of data collection using the old white source in target-1, and are roughly equivalent to the entire world's supply prior to the measurement. When the new source is in operation at full capability, capture gamma ray experiments will have an additional factor of approximately 100 in source strength.

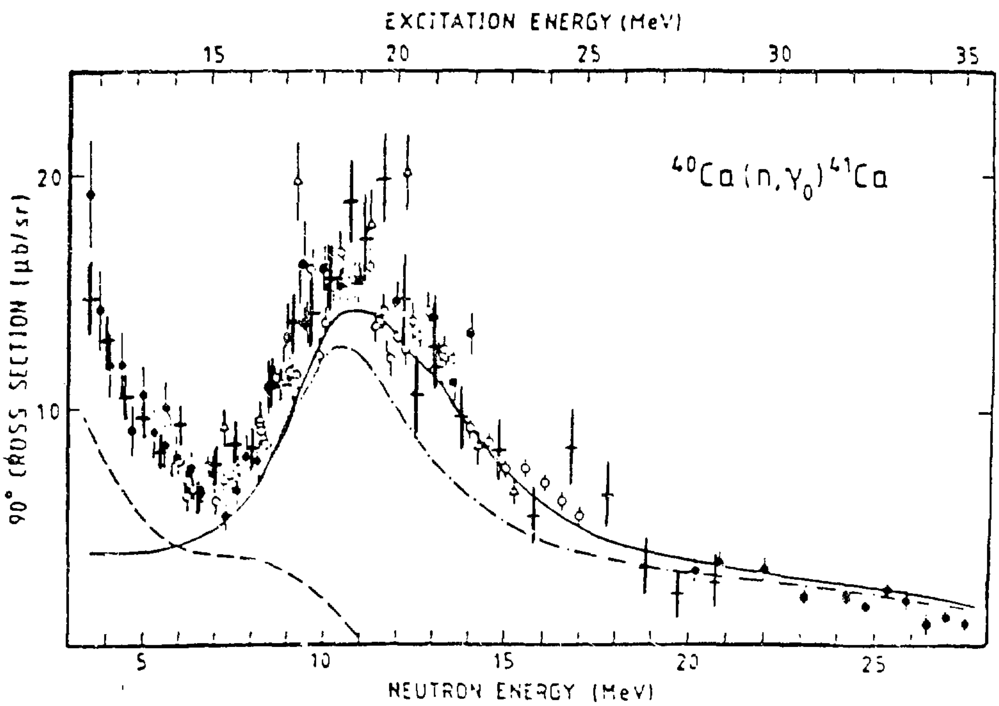

FIGURE 5 The 90^o cross section for $^{40}Ca(n,\gamma_0)$. The crosses represent recent data taken at the WNR facility.

The second area of nuclear physics research which is being emphasized at the WNR is the study of hadronic charge exchange reactions. These processes are governed by the isovector part of the interaction between projectile and nucleus which in the impulse approximation is taken to be the nucleon-nucleon t-matrix. Near 200 MeV, and at small momentum transfer, the spin-flip component of the nucleon-nucleon t-matrix is strongly enhanced over the non-spin-flip component, a relationship predicted to gradually decrease with increasing energy as may be seen in Fig. 6. Furthermore, the t-matrix amplitudes can be shown to be related in a simple way to measured cross sections using the impulse approximation. This property has been heavily exploited at IUCF energies to determine Gamow-Teller (GT) strength distributions in nuclei by integrating the strength associated with 0 $\hbar\omega$ spin excitations. The result is that only about two-thirds of the strength expected from the model-independent sum rule $S_{\beta}^{-} - S_{\beta}^{+} = 3(N-Z)$ is obtained. Several competing explanations of this descrepancy have been put forward. They range from conventional nuclear physics explanations such as that by Bertsch and Hamamoto[10] that 2p-2h nuclear wave-function admixtures may smear the strength over a broad range of excitations, to the possibility of delta isobar-hole admixtures[11] which could shift the missing strength to an excitation region of about 300 MeV. Some calculations[12] include both effects

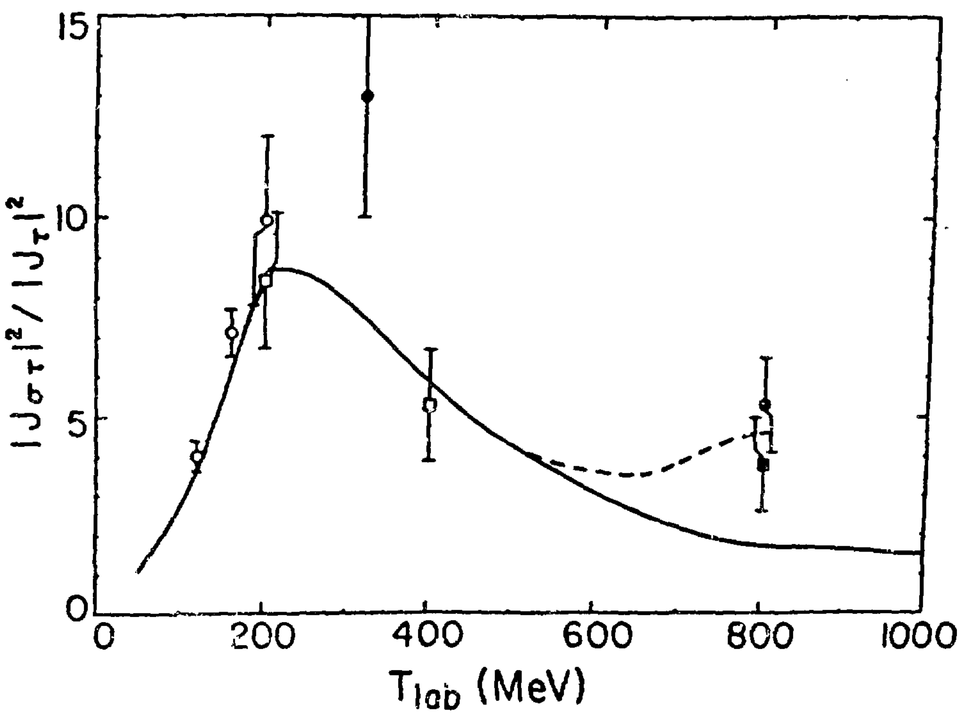

FIGURE 6 The ratio of isovector spin flip to non-spin flip strength as calculated by the impulse approximation and compared to experimental data. The solid and dashed curves are predictions computed using the Love-Franey interaction, and Saclay 670 phase shift solutions, respectively. The WNR (p,n) results are the solid circles. The open circles are lower energy (p,n) results from IUCF and the open squares are (^{3}He,t) results from Saclay.

and predict that all of the GT strength is present in (p,n) reactions, but is spread throughout the continuum in such a way that measurements of the unpolarized cross section cannot detect it. Recent (p,n) measurements[13] at 800 MeV from the WNR have extended our observation of Fermi and Gamow-Teller strength to an energy regime better suited to analysis by the impulse approximation and have provided some interesting results related to the nucleon-nucleon t-matrix, but have as yet have not provided any information concerning the missing GT strength. The new data shown in Fig. 6 indicates that the spin-flip - isospin-flip ratio is considerably larger than predicted both at 318 MeV and at 800 MeV, so that studies near 800 MeV will be nearly as selective as at 200 MeV and thus be quite useful in aiding our understanding of the missing GT strength. Additional measurements will be possible in the new experimental area with better energy resolution, increased beam current, and an angular distribution range extending to 18^{o}, all of which will allow experiments to provide additional insight into the question of the missing GT strength as well as to investigate other interesting processes such as excitation of giant resonances. As an example of the quality of data which is possible, the results shown in Fig. 7 show the first observation of discrete nuclear transitions at 800 MeV in a (p,n) reaction[13] as obtained with the

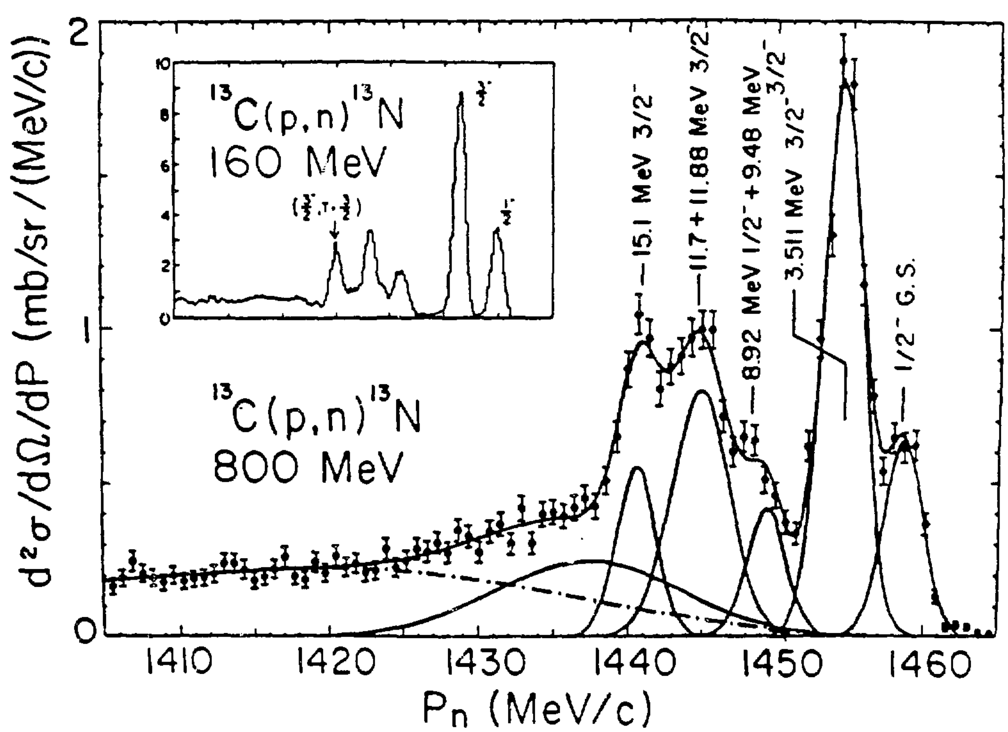

FIGURE 7 Spectrum of neutrons from the $^{13}C(p,n)^{13}N$ reaction at E_p = 800 MeV. The flight path was 213 meters and the time resolution 530 ps giving an energy resolution of 2.7 MeV. The IUCF results at 160 MeV are shown in the inset.

previously existing 213-m flight path at WNR (now being replaced by the 250-m flight path described above). Other data badly needed to help resolve the question of missing GT strength could come from measurements at WNR of the (n,p) reaction. The (n,p) reaction has several distinct advantages over the (p,n) reaction and these studies will be pursued in an experimental program which will be complementary to the one presently underway at TRIUMF and to the one proposed at LAMPF. At medium energies the (n,p) reaction is even more selective than the (p,n). In the case of (n,p), $\Delta T_3 = +1$ so that only T+1 analog states will be excited in N > Z nuclei, the Clebsch-Gordon coupling and coefficient insures a larger cross section for a given amount of GT strength, smaller Q-values imply both that the $q = 0$ approximation will be better met and the escape widths will be narrower. These features have been used to suggest that the (n,p) reaction is the best candidate for studying the isovector monopole resonance[14], so far observed conclusively only in (π^-, π^0) reactions, as well as for shedding additional light on the question of missing GT strength by looking for S_β^+ strength and by comparing (n,p) cross sections[15] with (p,n) cross sections available from IUCF near 200 MeV. At present our plans for (n,p) measurements at WNR involve only a simple detection scheme[16] which should give $\Delta E/E$ of about 1%, similar to that obtained at Crocker Nuclear Laboratory. That resolution will be sufficient to study (n,p) reactions for a wide range of nuclei and be useful for incident neutron energies as high as 200 - 300 MeV.

SUMMARY

By spring of 1986 the WNR will be operational with greatly enhanced fast-neutron capabilities including the addition of a multi-use white-neutron source and a 250-m flight path for (p,n) reaction studies. This facility will be heavily used by the Los Alamos staff for a variety of basic and applied research, but proposals from outside collaborators or groups from other National Laboratories wishing to conduct experiments at the WNR are encouraged.

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JAPANESE MEDIUM ENERGY PROGRAM

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7-3-1 Hongo, Bunkyo-ku, Tokyo 113, Japan

1. INTRODUCTION

Most of the present research activities on meduim energy nuclear and particle physics in Japan are based on the proton synchrotron facilities at KEK (National Laboratory for High Energy Physics). The KEK PS complex consists of a 500 MeV rapid cycling booster synchrotron of 20 Hz repetition and a 12 GeV main ring. The design concept underlying was to facilitate parasitic uses of the 500 MeV beam while accelerating protons to 12 GeV in the main ring, because the main ring requires only a quarter (9 pulses) of the booster beam in a cycle of 2.4 sec.

After the successful operation of the KEK PS in 1975, three parasite projects using the booster beam were established. i) A pulsed neutron scattering facility (KENS) for condensed matter research, ii) a pulsed meson facility for meson science (BOOM), and iii) a medical project using protons and neutrons. I will talk about the meson science project at the booster synchrotron as well as various nuclear/particle programs at the 12 GeV PS, and at the end I will mention future plans.

2. PULSED MESON FACILITY BOOM

The pulsed meson facility, called BOOM, is being operated by the University of Tokyo. It utilyzes 500 MeV protons of sharp pulses of 50 nsec width and 50 msec interval. The averege proton beam current is 2 μA. The duty factor is 10^{-6}!! Before we started this project in 1978, most people had believed that such a beam would be useless, in particular, in view of the coming meson factories, but we thought it would create new fields in meson science because shaply pulsed muon beams should permit i) measurements of μ-e decay time spectra and thus of muon spin relaxation functions in a very wide time range and ii) applications of extreme external conditions such as pulsed r.f., laser, magnetic field, etc.

In a few years after the first muon beam from the superconducting channel in 1980, a number of experiments have been accomplished. They all have proved the unique characteristics of the pulsed beam. Progress reports are presented in annual UT-MSL NEWSLETTER's [1]. Typical examples are listed below.

a) Muon spin relaxation in a wide time range.
   - Long-lived muonium in water [2].
   - μ^+ quantum diffusion in Cu at low temperatures [3].
   - Dynamics of solitons in trans polyacethylene $(CH)_n$ created and probed by μ^+ [4].

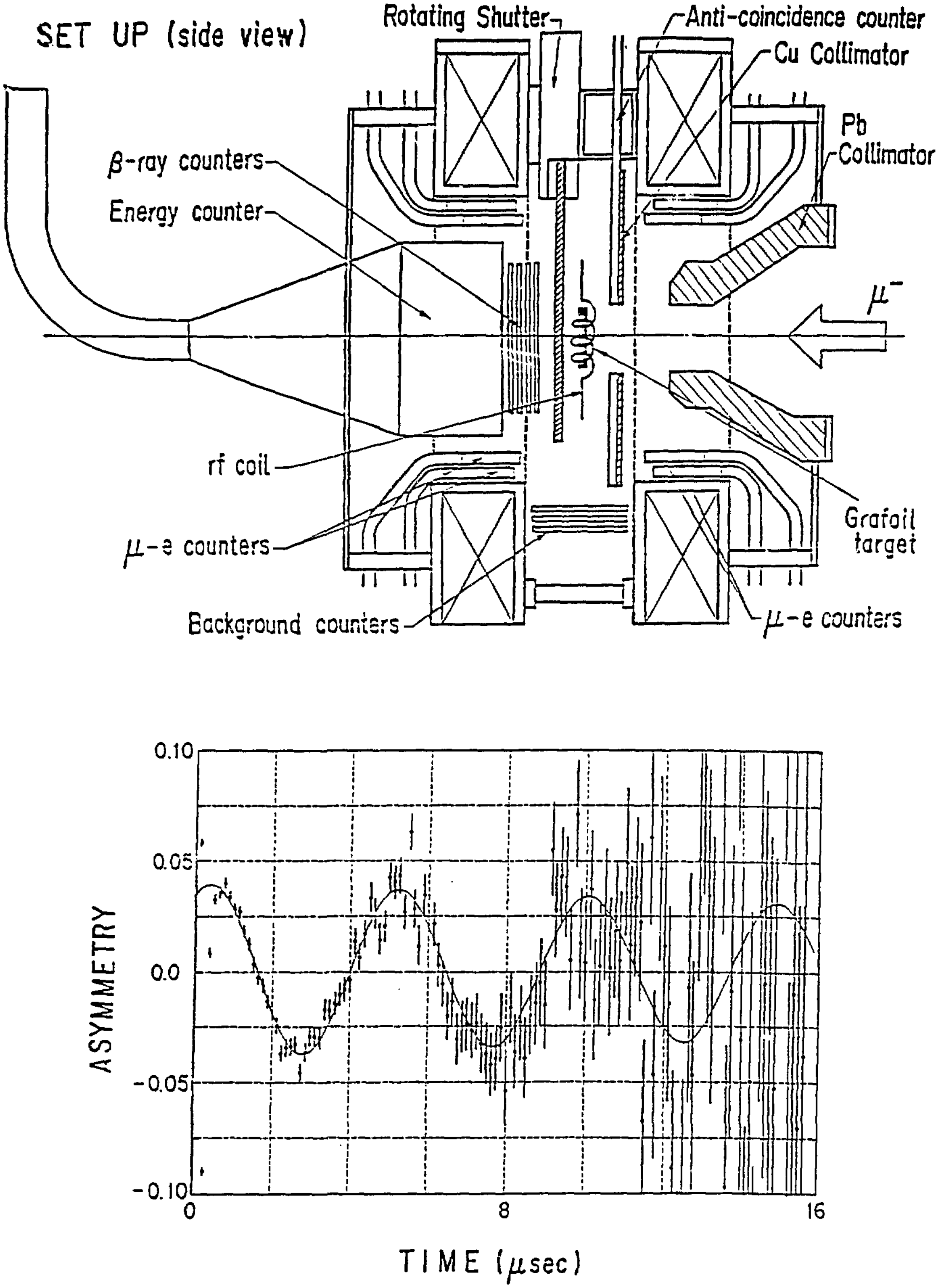

Fig.1 Application of μ^- spin resonance technique to the determination of the average polarization of ^{12}B after muon capture [6]. (Upper) Experimental set up at BOOM. (Lower) Time differential pattern of the μ^- spin due to H_1 at the resonance.

b) Magnetic resonance of muon spin

Decoupling spin resonance of diamagnetic muons in alkali halides to identify chemical reactions from transient muonium radical to diamagnetic muon [5].

Determination of the average polarization of ^{12}B after muon capture by the magnetic resonance technique [6].

Following the first phase of operation we are planning more ambitious scientific programs fully utilyzing the advantage of the pulsed beam.

3. PROGRAMS AT THE KEK 12 GeV PS

The present KEK PS is unique together with the BNL AGS in providing kaon beams. So far, most of the KEK PS programs depend on the following secondary beams.

- K2: Separated, 1-2 GeV/c, K^+, K^-, π^+, π^-, $\bar{p}$
- K3: Separated, 0.5-1 GeV/c, K^+, K^-, $\bar{p}$
- K4: Separated, 0.4-0.8 GeV/c $\bar{p}$
- π1: 4-8 GeV/c, π and others
- π2: 1-4.3 GeV/ ., π and others
- πμ: 0.1-0.5 GeV/c, π, μ

The following are some of recent achievements.

1) Heavy neutrino search in K^+ decay using a high resolution magnetic spectrometer [7].
2) Search for right-hand current in $K^+ \rightarrow \mu^+\nu$ decay [8].
3) Hypernuclear spectroscopy from K^- absorption at rest [9].
4) Resonance like structure in $p\bar{p} \rightarrow K^+K^-$ [10].
5) Hadron-nuclear reactions with invariant mass spectrometer "FANCY" [11].
6) Observation of a new pseudoscalar resonance in π^-p charge exchange reactions [12].

The KEK PS offers unique playgrounds to nuclear/partile physicists in the border region between nuclear and particle physics. With the precious beams of KEK we can attack important problems in particle physics to go beyond the standard model. As well we can study quark confinement problems in nuclei. The following are recently approved experiments at KEK, which aim at such fundamental problems.

E137 (T. Inagaki) Search for rare decay $K^0_L \rightarrow \mu e$ with a sensitivity of 10^{-11}.
E117, E130 (T. Yamazaki) Hypernuclear spectroscopy for both Λ and Σ from stopped K^- using a large superconducting spectrometer.
E140 (O. Hashimoto and T. Shibata) Hypernuclear spectroscopy using (π^+,K^+) reactions.

It is needless to say that all the KEK facilities are open to international collabotation.

4. FUTURE PLANS

As a next step we are planning to build a high intensity booster synchrotron, which will not only provides medium energy protons of a few 100 μA range to pulsed neutrons, pulsed mesons, and others, but also be used as a

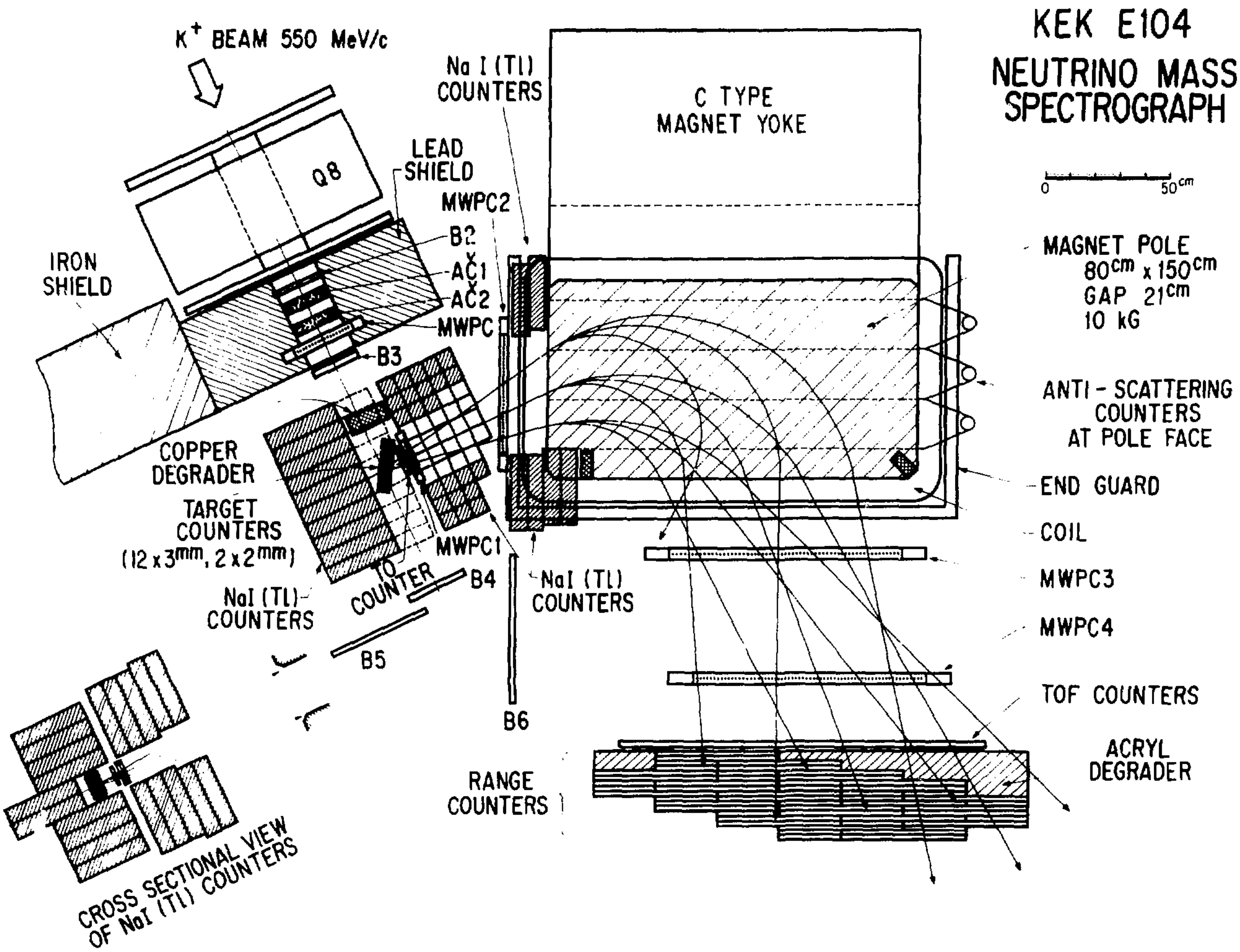

Fig.2 Experimental set up for high resolution, broad range spectroscopy of pions, muons and electrons from stopped K^+ and K^-. This apparatus has been used for heavy neutrino search [7], RHC search [8] and also for a new type of hypernuclear spectroscopy [9].

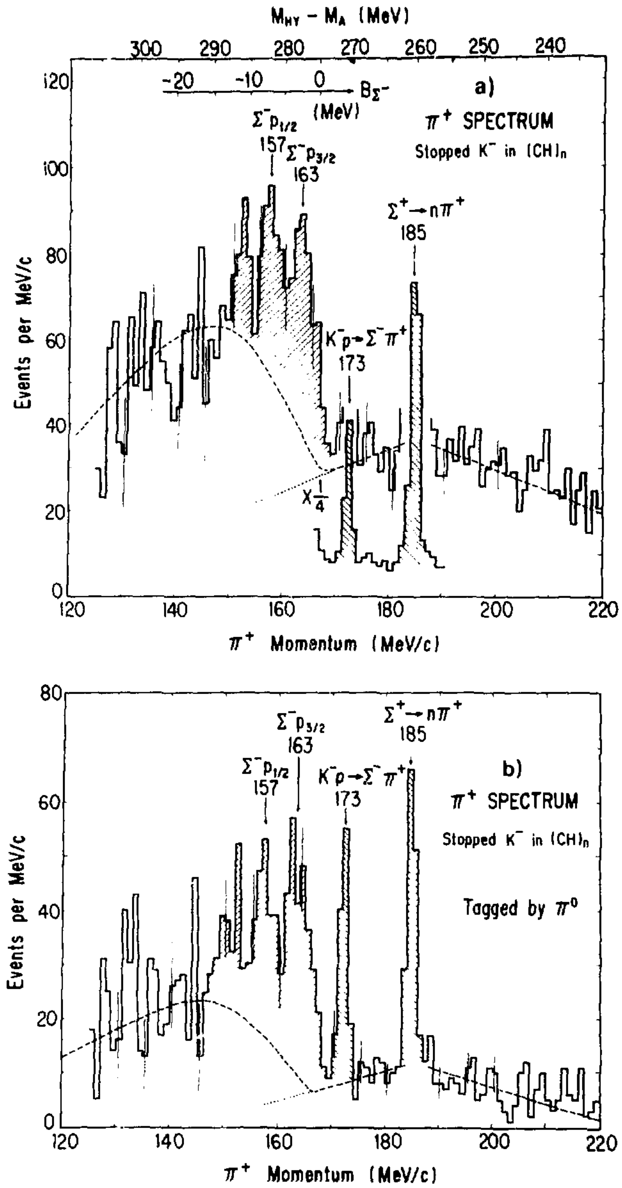

Fig.3 *An example of spectrum from (stopped K^-, π^+) on plastic scintillator $(CH)_n$. Three peaks of Σ^- are revealed. The promising feature of this method will be extended to heavier nuclei by making a large acceptance superconducting spectrometer.*

high intensity injector to the present PS. We hope to get 100 times more neutrons and muons and 10 times more K mesons.

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MINUTES EPICS WORKING GROUP MEETING

Chairman: John Zumbro — November 5, 1985

Chris Morris showed the group a list of experiments that had run or were scheduled to run this year (Cycles 42, 43, and 44) at EPICS.

FIGURE 1

EXPERIMENT
$\pi^{\pm}$-Nucleus $\pi^{\pm}$-d
$\pi^{\pm}$-T ^{208}Pb giant resonance ^{28}Si,^{16}O giant reasonance (gas target) ^{4}He (gas target) ^{208}Pb low-lying state ^{39}K ^{22}Ne (gas target) N=28
$^{44}Ca(\pi^{+},\pi^{-})$ $^{48}Ca(\pi^{-},\pi^{+})^{48}Ar$ mass measurement $^{42}Ca(\pi^{+},\pi^{-})$ $^{208}Pb(\pi^{+},\pi^{-})$ $^{58}Ni(\pi^{+},\pi^{-})$ $^{56}Fe(\pi^{+},\pi^{-})$

Progress and improvements during the 1985 (current) running cycles were discussed, and include:

1) Improved performance of the channel, primarily in the stability of the magnets, due primarily to elimination of problems with the shunts.

2) Increased wire chamber efficiency for the EPICS rear chamber, by the addition of left-right (LR) hardware that now provides redundant information from rear chambers.

3) Changes in reading LR signals from front chambers which improves reliability and the ability to diagnose problems.

4) This is the second year of data acquisition using Q on a VAX (VMS operating system), and the system was greatly enhanced by having a VAX 11/750 as opposed to the 11/730 used last year.

Work planned for the shutdown was discussed and includes:

1) Re-alignment of the spectrometer's quadrupole triplet,

2) Install new front chamber box,

3) Look at repositioning energy degrader,

4) Improve radiation shielding.

Jim Amann reported that 11M Q-data acquistion has been frozen and would no longer be supported by MP Division. Again the improved reliable and increased response time of the VAX 11/750 over the VAX 11/730 was emphasized and that μ- VAX's would be installed in LEP, P^3, and SMC counting houses during the next shutdown.

Steve Greene presented results from floating wire measurement of the EPICS dipoles done during the last shutdown. This work will soon be submitted to NIM for publication. Results from the measurements were also compared to the zero-degree measurements of the output of the EPICS channel and the energy calibration of the channel was discussed.

Kalvir Dhuga will be the next chairman of the EPICS working group.

EPICS WORKING GROUP - ATTENDEES

James Amann, LANL, MP-10
Andrew Browman, LANL, MP-DO
George Burleson, New Mexico State University
Ben Clausen, University of Colorado
William Cottingame, LANL, AT-2
Kalvir S. Dhuga, New Mexico State University
William Fickinger, Case Western Reserve University
Donald Geesaman, Argonne National Laboratory
Edward Gibson, California State University
Steven Greene, LANL, MP-10
Martha Hoehn, LANL, MP-1
Jerry Peterson, University of Colorado
Mike Plum, LANL, MP-10
Robert Redwine, Massachusetts Institute of Technology
Keith Robinson, Case Western Reserve University
Susan Seestrom-Morris, University of Minnesota
John Zumbro, University of Pennsylvania

MINUTES HRS WORKING GROUP MEETING

Chairman: Susan Seestrom-Morris November 5, 1985

In attendance were:

LANL:	J. Amann
	R. Boundrie
	S. Greene
	K. Jones
	J. McClelland
	S. Pentilla
	M. Plum
U of Minn.	S. Seestrom-Morris
U of PA	J. Zumbro
UCLA	A. Ling
Indiana U	G. Walker

The meeting was called to order by Susan Seestrom-Morris. Nominations were invited for the position of Chairman for 1986. Ray Fergerson was nominated (in absentia) and elected by acclamation. Nominations were invited for candidates to the Technical Advisory Panel. Ed Stephenson (IUCF), Fred Moore (Texas), and Kevin Jones (LANL) were nominated. Ed Stephenson was selected as the HRS candidate for the TAP. Nominations were invited for candidates to replace outgoing members of the HRS PAC. A. Bacher (Indiana), C. Olmer (IUCF), V. Madsen (Oregon) and J. Shepard (Colorado) were nominated. A. Bacher and J. Shepard were elected as candidates.

Jim Amann reported on the status of data acquisition and replay computers and software. MP-10 will no longer support RSXIID/M systems. Rules and documentation will be distributed to spokespersons of active and proposed experiments. Users are strongly urged to abide by the MP-10 rules for use of the MPIOREP account on the cluster machines. It was suggested that spokespersons take an active role in the supervision of graduate students, especially new students, who are doing replay. Problems initializing data tapes (recycled) on the Kennedy 9400 6250 bpi drives were noted and discussed. The propagation of unsupported software is discouraged.

Kevin Jones reported on the status of HRS. HRS has run with good efficiency during Cycles 41-44. Problems due to the MBD observed at the end of Cycle 41 have not recurred. The general status of the LC and HRS instrumentation was discussed. A workshop for graduate students (and other users) will be held prior to the beginning of Cycle 45. All users are encouraged to attend! Because of commitments to the NPL upgrade, it may be necessary for MP-10 to reduce its level of support at HRS in the forthcoming cycles.

M I N U T E S

Working Group Meetings on
Tuesday, November 5, 1985

from

Gordon S. Mutchler
RICE UNIVERSITY

HIGH ENERGY PION (^{3}P)CHANNEL WORKING GROUP, W. J. Briscoe, Chairman

The meeting was brought to order by W. Briscoe. The first order of business was the election of a new chairman. G. S. Mutchler was nominated and elected. Nominations were then requested for membership to the TAP and PAC. These nominations were passed on to the Users Liason Office.

D. H. Fitzgerald reported on the performance of the crossed field electrostatic sperators for the ^{3}P beam. Neither is installed at this time. The 5-foot separator is operational and the 10-foot separator is being rebuilt. His calculations show that below 600 MeV/c the 10-foot separator alone should work well to improve the π^+/p ratio. However, at 700 MeV/c, if you try to transport the full ^{3}P phase space, the separators will provide little improvement. Even if both separators are used in series, he would not expect better than a factor of two improvement over the current π^+/p ratio of 1:40 using suitable absorbers. Furthermore, this would cause severe space limitations in the ^{3}P cave.

M. Oothoudt passed out a memo detailing MPl's future level of support for PDP-11 computers, the RSX-11M operating system and the RSX-11MQ data acquisition/replay system. These systems will be supported through 1988, but no further development work will be done. All LEEP counting houses will be upgraded to VAX computers (either VAX 11/750 or Microvax II) over the next two years.

Several experimental groups then gave short ($\sim$15 min) reviews of their P^3 experiments. The speakers and their topics were:

J. Matthews - Inclusive Double Charge Exchange in Light Nuclei

J. L. Peng - Report on the η Experiment

A. R. Mohktari - $\pi^{\pm}p$ Asymmetry Measurements-Elastic Scattering

J. A. Wightman - $\pi^{-}p$ Asymmetry Measurements-Charge Exchange

Helmut Baer - (π^{-},π^{o}) on ^{7}Li, ^{40}Ni

Helmut Baer had the following to report about the P^3 Facility. The π^{o} spectrometer is now available in P^3. An overhead cable tray and a patch panel have been installed to service the spectrometer. He estimates that it can be installed for an experiment in about 3 days. As a result of their running, his group have the following observations. They find that using the standard tunes, the $\Delta p/p$ achieved is larger than is claimed. Specifically they found that the best resolution they could obtain was $\Delta p/p=0.8\%$. It was noted that this is with the long production target. They also checked the surveyed beam line and found it to be at $0.3^{o}\pm0.20$, which they felt was good agreement with 0^{o}. Finally, they reported that they had developed a program to determine the π^{+}/p ratio to 5% using $C^{12}(\pi^{+},\pi N)^{11}C$ aetivation techniques. This program is available on the VAX as ACTP. The program includes π^{+} and proton $^{12}C\rightarrow^{11}C$ cross sections. It can be used to calculate the π^{+} flux from 30 MeV-550 MeV from the β^{+} count rate of, for example, a plastic scintillator activated in the beam.

ATENDEES P^3 WORKING GROUP:

W. J. BRISCOE, GEORGE WASHINGTON UNIVERSITY
C. J. SEFTOR, GEORGE WASHINGTON UNIVERSITY
J. A. WIGHTMAN, UCLA
J. C. PENG, LANL
M. E. SADLER, ABILENE CHRISTIAN UNIVERSITY
JERRY PETERSON, COLORADO
BEN CLAUSEN, COLORADO
JOSEF SPETH, LANL
EARL HOFFMAN, LANL, MP-1
DICK WERBECK, LANL, MP-7
DAN FITZGERALD, LANL, MP-13
CAS MILNER, LANL
MARTHA HOEHN, LANL, MP-1
KEITH ROBINSON, CASE WESTERN RESERVE
BILL FICKINGER, CASE WESTERN RESERVE
W. WAYNE KINNISON, LANL
D. BARLOW, UCLA
S. ADRIAN, UCLA
H. BAER, LANL, MP-4
CHANDRA PILLAI, UCLA
ALIREZA MOKHTARI, GEORGE WASHINGTON UNIVERSITY
GORDON MUTCHLER, RICE

NEUTRINO WORKING GROUP

Minutes of Meeting on November 5, 1985, AT LAMPF

Thomas A. Romanowski, Chairman

Attendees

Robert Burman	Ta-Yung Ling
Roger Carlini	Darragh Nagel
Thomas Dombeck	Thomas Romanowski
Ali Fazely	Vernon Sandberg
Stuart Freedman	Elton Smith
Gerald Garvey	Hywell White

The progress of on-going neutrino experiments at LAMPF was discussed (see attached reports). Gerald Garvey, the newly appointed Director of LAMPF, remarked on the future of the neutrino physics at LAMPF. Hywel White of Brookhaven National Laboratory presented a proposal for $\nu_\mu e$ scattering an experiment for LAMPF (summary of the proposal is included). Nominations for the new members to the Physics and Technical Advisory Committees were solicited. Stuart Freedman of Argonne National Laboratory was elected to become chairman of this group for next year.

The future of the Stopped-pion Neutrino Facility and the $\nu_\mu e$ scattering experiment was discussed by Gerald Garvey. The estimated cost of this facility, which will use PSR beam and the detector, is $10-15M, and DOE appears to be interested in a "good" proposal. The time scale for developing this neutrino facility and the detector is six years from now. Plans are to submit the proposal to DOE and the Policy Advisory Committee (PAC) at LAMPF in this calendar year and secure funding for this project in FY87.

At present some support for prototyping of the detector is designated by both MP and Physics Divisions. The development of this facility will require a strong input and commitment from the Users, and those who are interested in joining the effort should contact Roger Carlini at LAMPF (FTS 843-6645) as soon as possible. There is still an ample opportunity to contribute innovative ideas to the development of the proposal.

The on-going experiments at LAMPF would greatly benefit from the increase of the proton-beam intensity and longer running period as compared to the presently contemplated one.

E-645 - STATUS REPORT

The Argonne National Laboratory, California Institute of Technology, Louisiana State University, Los Alamos National Laboratory, and Ohio State University collaboration reported on the progress of the experiment searching for neutrino oscillations in both appearance ($\bar{\nu}_e + p \rightarrow e^+ + n$) and disappearance modes. The goal of the experiment is to reach sensitivities on $\Delta^2 m = 0.01$ and that on $\sin^2\theta = 10^{-3}$. To achieve these sensitivites, 150 days of beam time is required. The detector is modular; proportional drift chamber planes (12 × 12 ft.) are interspersed among planes composed of liquid scintillation counters. The total mass of the detector is 20T. The detector is protected from cosmic rays by a cylindrical shield and a detector cart, which supports the detector and also serves as a shield. The shielding of the detector is complete over 4π solid angle and is made of six-inch-thick liquid scintillator on the outside and five-inch-thick layer of lead shot on the inside. The detector assembly will be placed in a tunnel with an overburden of 2500 $^{gm}/_{cm^2}$, which will provide an additional shielding factor for cosmic rays. The tunnel is located at the end of line A.

The tunnel and the service line has been completed. The detector also has been assembled. The shield is now ready to be filled with liquid scintillator. The calibration of the detector is now in progress and cosmic ray tracks have been observed.

STATUS REPORT ON E-225

The University of California, Irvine, Los Alamos, University of Maryland collaboration reported on the first observation of electron neutrino elastic scattering from electrons, $\nu_e e \rightarrow \nu_e e$. In the E-225 experiment, neutrino-electron scattering events appear as single electron-recoil tracks in a 15-ton detector located at the LAMPF line-A beam stop. The neutrino detector is composed of 160 large plastic scintillator counters and 208,000 plastic flash chamber tubes; it is surrounded by a four-layered, 4700-wire, active veto system and by 2500 tons of passive steel shielding. Events are expected to be concentrated in a 16°-angular cone about the incident neutrino direction, and indeed the observed angular distribution shows a pronounced forward peak. Data through October 1984 will soon be published. After cosmic-ray background subtraction, we observed 63 ± 17 events, of which 51 ± 17 events are attributed to ν_ee scattering. The resulting cross-section, [8.9 ± 3.2 (stat) ± 1.5 (syst)] $E_\nu \times 10^{-45}$ cm^2/MeV, agrees with standard electro weak theory and begins to show the effect of Z° - $W^\pm$ interference. Additional data taken through July 1985 has increased our event sample to approximately 100 events; we expect to continue to take ν_ee data at the beam stop through 1986.

UPDATE ON E-764

Much of the effort during this last year was spent improving the neutrino detector shielding to reduce the low energy beam associated neutron background and the neutral cosmic rays. In this regard 1500 tons of magnetite were added around the bulk iron shield and additional concrete over the detector house. At present, the neutron rate is two orders of magnitude lower than last year, and the cosmic ray backgrounds are less than one in ten days for the oscillation experiment and one in one hundred days for the charged muon final states.

About five per cent of our anticipated running time was gathered during the run cycle ending in October. Many candidate muon events were observed on-line and are currently being analyzed off-line. No neutrino oscillation candidates in our signal region have been observed.

STOPPED PI NEUTRINO SOURCE

This experiment proposes a one per cent absolute measurement of $\sin^2\Theta_W$ using 100 μA of PSR beam. This measurement is well into the region of radiative corrections and is, therefore, complementary to the measurements of M_Z and M_W, which will be conducted at SLC and LEP. Since $\sin^2\Theta_W$ is defined from the quantities M_Z and M_W, a rigorous test of its universality requires an independent low momentum transfer measurement. After all radiative corrections are made, the level to which the values agree is a significant test of the standard model. The proposed 9,000-ton imaging water Cherenkov detector is of unique design in that by placing the beam stop and neutron shield in the center of the detector the $1/r^2$ flux loss in very high tonnage detectors is avoided.

Neutrinos will be generated from the decay of stopped pions and muons. Since the π^- are absorbed on nuclei in the beam stop, the resulting decay producing neutrinos come from

$$\pi^+ \rightarrow \mu^+ + \nu_\mu \text{ and } \mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu .$$

The PSR's short beam spill (270 ns) allows a time separation of the neutron spectra. The ν_μ, $\bar{\nu}_\mu$ and ν_e from a beam-stop source are produced in equal numbers but have different spectral shapes. The most accurate measurements of $\sin^2\Theta_W$ to date have involved the ratio of $\nu_\mu e$ to $\bar{\nu}_\mu e$ scattering. This experiment will measure the ratio of $\nu_\mu e$ to $(\bar{\nu}_\mu e + \nu_e e)$ scattering, but the events will be taken concurrently, thereby, reducing the systematic errors associated with experiments that must retune their beams for anti-neutrinos. The elastic $\nu_\mu e$ and $(\nu^-_\mu e + \nu_e e)$ cross sections depend on ρ and $\sin^2\Theta_W$, and if we assume the standard model (ρ=1) one obtains the relationship

$$R = \frac{\sigma(\nu_\mu e)}{\sigma(\bar{\nu}_\mu e) + \sigma(\nu_e e)} = 3/4 \; \frac{(1-4\,\sin^2\Theta_W + 16/3\,\sin^4\Theta_W)}{(1 + 2\sin^2\Theta_W + 8\sin^4\Theta_W)},$$

which is very sensitive to $\sin^2\Theta_W$ around its actual value. By taking the partial derivatives we observe that a one per cent measurement uncertainty in R causes a 0.6% uncertainty in $\sin^2\Theta_W$. The quantity R is measurable because the short beam spill (270 ns) from the PSR allows a time separation of ν_μ and $(\nu^-_\mu + \nu_e)$ in a beam stop source.

There appears to be sufficient rate such that after all off-line analysis we will be left with 3,000-4,000$\nu_\mu e$ events. This would result in a one per cent statistical error on $\sin^2\Theta_W$. Systematic errors induced by beam associated neutrons, cosmic rays, and neutrino nuclear interactions have been estimated to be very small. This experiment is in the process of forming a collaboration. We expect to submit a proposal to DOE and the LAMPF PAC before the end of the year. Interested persons should contact Hywel White at Brookhaven National Laboratory (FTS 666-4318) or Roger Carlini at Los Alamos National Laboratory (FTS 843-6645).

LOW ENERGY PION (LEP) WORKING GROUP

B. Ritchie, Chairperson/J. Knudson, Chairperson-Elect

Attendees:

H. Baer, Los Alamos National Laboratory
R.L. Boudrie, Los Alamos National Laboratory
J.D. Bowman, Los Alamos National Laboratory
J. Faucett, New Mexico State University
D. Fitzgerald, Los Alamos National Laboratory
E. Gibson, California State University at Sacramento
K. Jones, Los Alamos National Laboratory
J. Knudson, Arizona State University
M. Leitch, Los Alamos National Laboratory
R. Loveman, University of Colorado
J. McGill, Los Alamos National Laboratory
R.G. Peterson, University of Colorado
G. Phillips, Rice University
B. Preedom, University of South Carolina
B. Ritchie, Arizona State University
S. Seestrom-Morris, University of Minnesota
R. Werbeck, Los Alamos National Laboratory

The working group elected James Knudson (Arizona State) to the chair for the upcoming year.

Dick Boudrie (MP-10) discussed progress made on the Clamshell Spectrometer in the past year. The biggest improvement has been in the sliding vacuum seal of the scattering chamber, allowing spectrometer angles to be set from either direction of rotation. A spectrum of ^{93}Ni π^+ elastic scattering demonstrating a spectrometer resolution of 360 keV was shown. The observed resolution is very strongly sensitive to the setting of the channel quadrupole QM03 and extreme care must be taken in setting this quad. A list of projects planned for the upcoming year was presented:

- -installation of cable patch boards
- -installation of digital-to-analog magnet controllers
- -install bellows vacuum seal for the Lawson-Rush probe
- -design a remotely-insertable ISICS
- -improvement of the trigger logic
- -improved beam monitoring
- -computer (VAX) control of magnets and slits
- -design an interface to a BGO ball
- -design of a liquid deuterium target
- -design of a turbopump package for spectrometer vacuum

Dan Fitzgerald (MP-13) gave a presentation on the status of low energy beams and separated beams. The reproducibility of beams of 10 - 20 MeV depends strongly on the magnet cycling procedure. The recommended procedure is to cycle each supply three times from zero current and allow plenty of time to fully saturate at maximum current before coming down to the desired setting. One person should at least supervise all channel settings so that a consistent ramping rate is achieved.

The 5-foot separator was fully scheduled for the 1985 running season after a disaster in early May necessitated extensive repair. The separator ran at about 80% availability with electrostatic fields of up to 400kV. It was noted that the device does not lend itself well to muon spin rotation. The separator is not a turnkey device, and requires operator training plus a fair amount of coddling while in use. An operator's manual is in preparation.

In light of the difficulties encountered at LEP in obtaining reproducible beams and in the strong dependence seen between the quadrupole settings and observed channel resolution, the working group strongly recommended that the present analog magnet controllers for the channel be replaced with digital-to-analog controllers as now employed by MP-10 at EPICS.

Dave Bowman (MP-4) gave a report on the use of the sampling grid scintillator. This flux monitor worked as expected and allows a user to make a 2% absolute flux measurement in 2 shifts' time. In order to make particle identification possible at beam energies in excess of 40 MeV, micro-chopped H^+ beam at a low duty factor is required. Since the hardware for producing such beam has been removed, the working group strongly recommends that hardware to produce beam suitable for time-of-flight measurements (ie., single micropulses at regular intervals within the macropulse) be developed.

Mike Oothoudt (MP-1) sent a message reminding users that RSX-11M support will end in January 1989, and that the PDP-11s will be removed from counting houses in January, 1987. MicroVAX-IIs and 6250-bpi tape drives are being ordered for all counting houses.

In other business, LEP users are warned that the momentum jaws are now closing at $\Delta p/p = -0.13\%$. The culprit appears to be the upper jaw. This asymmetry implies that the central momentum of the channel is not the value given by the dipole fields.

Suggestions for the TAP and the PAC were discussed and forwarded to the Users Liasion Office.

MINUTES OF THE NPL WORKING GROUP MEETING

November 5, 1985

Chairman: George Glass
Secretary: John Faucett

John Faucett was elected chairman for 1986.

Dick Boudrie discussed the progress being made on the MRS magnet designs.

Dick Werbeck discussed shutdown activities, particularly regarding the NPL upgrade. The line B switcher (Colorado cyclotron) will be installed and the line B tunnel extended. The trailers to the east of Area B will be moved to make way for NTOF building.

John McClelland spoke on NTOF. The magnets have been procured. It has been determined that the optional flight path is about 0° relative to an E-W line, with an incline of about 1/2°. EPB will have a temporary counting house north of Area B during construction.

Will Foreman discussed developments in the Q system and procurement of micro VAXes for the NPL upgrade. Line BR's computer system was discussed.

Mike McNaughton spoke on the new H^- chopper/buncher and the new polarized ion source.

The proposed new EPB-BR counting house was discussed. Approximately 1600 square feet will be needed to accommodate two computers, two sets of polarized target electronics, MRS electronics, and electronics for the EPB and BR experiments.

ATTENDEES NPL WORKING GROUP MEETING:

R. L. BOUDRIE, LANL, MP-10
J. B. MCCLELLAND, LANL, MP-10
WILL FORMAN, LANL, MP-1
TOM KOZLOWSKI, LANL, MP-1
KOK HEONG MCNAUGHTON, UNIVERSITY OF TEXAS
MIKE MCNAUGHTON, LANL, MP-13
HAL SPINKA, ARGONNE NATIONAL LABORATORY
L. C. NORTHCLIFFE, TEXAS A & M
L. AGNEW, LANL, MP-7
JOHN FAUCETT, NEW MEXICO STATE
MOHINI RAWOOL, NEW MEXICO STATE
HOWARD BRYANT, UNIVERSITY OF NEW MEXICO
SEPPO PENTTILO, LANL, MP-7
T. S. BHATIA, TEXAS A & M
EARL HOFFMAN, LANL, MP-1
GORDON MUTCHLER, RICE
KENNETH JOHNSON, ARGONNE NATIONAL LABORATORY
G. A. REBKA, WYOMING
G. GLASS, TEXAS A & M
G. GARVEY, LANL, DAD-NPPP

MINUTES SMC WORKING GROUP MEETING

Chairman: Richard Hutson November 5, 1985

Attendees: See list attached

Dick Werbeck summarized SMC beam usage for 1985 and the anticipated usage for 1986. In 1985, approximately 3500 hours of beam were available, 32% used by crystal box, 25% by μ SR, 21% by Yale, 15% by muon catalysis, and the remainder by other experiments. In 1986, it is anticipated that approximately 3000 hours of beam will be available with the time to be divided roughly between μ SR (25%), muon catalysis (25%), Yale (20-40%), and the other experiments (10-30%).

Martin Cooper stated that the MEGA experiment will use very little beam before 1988, but that they might ask for as much as 50% of the available beam time in 1988 and as much as possible in 1989. He also stated that, to prepare for the installation of the MEGA magnet in the SMC south cave, they will probably request that the crystal box be removed after the first running cycle in 1986. Concern was expressed about the effects of dust and vibration generated as a pit is dug in the south cave in preparation for MEGA equipment installation.

Gary Sanders reported on the development of the 10-foot separator to be used as a spin rotator for μSR experiments. The schedule calls for shipment of high voltage power supplies from the vendor on December 15, 1985, acceptance tests in January, 1986, and beginning of conditioning of the spin rotator in February or March. The rotator is then to be tested on line during the summer running period. A cost breakdown for the rotator system showed expenditures of $163K for the custom-made high voltage power supplies and $30K for miscellaneous fabrication costs incurred in mechanical refurbishment of the old Argonne separator being used as the rotator.

Mike Oothcudt reported that a micro Vax II will be installed at SMC sometime around March 1986. This will be the standard SMC computer. However, the PDP-11 will remain in place for 1986. Experimenters will be able to use either computer, but a switch from one computer to the other will take about one day by the computer maintenance section of MP-1; so, the SMC scheduling committee will have to be informed as to which computer an experiment will use in order to avoid scheduling bottlenecks created by the need for computer changeovers.

Gail Anderson asked about any new and unusual needs for DAC services in the near future. Cy Hoffman said that the crystal box experiment usage of the DAC will decrease over the next few months. Martin Cooper stated that the MEGA experiment usage will involve mainly code development and some experiment simulations, but that the bulk of the MEGA computing will be done with their dedicated computer.

Gary Sanders suggested that MP-1 look into the acquisition of VAX-based electronics design codes since the currently available PC-based codes have very limited capabilities.

Martin Cooper pointed out that MP-1 will be tying into BITNET to allow the transfer of large files between LAMPF and other laboratories.

Gail said that ETHERNET lines are in place, and that, as soon as Micro Vaxes are installed in the various counting houses, there can be file transfer between the DAC and the counting house VAXes.

Martin Cooper was elected chairman of the SMC Working Group for 1986.

ATTENDEES:

RICHARD HUTSON, LANL, MP-3
DICK WERBECK, LANL, MP-7
ROBERT REEDY, LANL, INC-11
CY HOFFMAN, LANL, MP-4
MARTIN COOPER, LANL, MP-4
GAIL ANDERSON, LANL, MP-1
GARY SANDERS, LANL, MP-13
K. P. ARNOLD, YALE UNVIVERSITY
BILL W. MAYES, UNIVERSITY OF HOUSTON
JIM BRADBURY, LANL, MP-3
LARRY PINSKY, UNIVERISTY OF HOUSTON
VIRGIL HIGHLAND, TEMPLE UNIVERSITY

From: R. Brown
D. Davidson

Minutes of the November 5, 1985 Solid State Physics and Materials Science Working Group

Walt Sommer reviewed the design of the new radiation damage facility at the A-6 beam stop. Several viewgraphs of sample holders were shown to indicate what has already been done using the facility. In particular, a sample holder for transmission electron microscopy samples was shown which should allow the disks to be cooled without coming into contact with the cooling water. Several viewgraphs were shown of sample holders for tensile samples in the proton beam line. It was pointed out that samples irradiated in the proton beam receive about 200 w/cm^3, while those irradiated in the spallation neutron flux receive about 6 w/cm^3 at one milliamp beam current.

Dorothy Davidson reviewed experiment #936, which has the objective of determining the secondary neutron and proton spectra at the radiation damage facility. Viewgraphs of the rabbit irradiation system were shown, and it was emphasized that access to the system was quite easy. The rabbits are capsules about 1 cm in diameter and about 1.7 cm high, and are inserted and removed by helium gas. Preliminary measurements have not revealed any variation in neutron flux just above or below the beam center line. The neutron flux decreases by about a factor of 25 when one moves radially outward by about 25 cm. Dosimetry runs have been made at two locations of the insert, and several runs have been made for experiment #691 using the rabbit facility.

David Farnum showed atomic resolution micrographs of tungsten irradiated in the proton beam, taken using his field ion microscope. Areas of the polished tips were shown which exhibited individual vacancies, and sections of a depleted zone were also shown. The latter involved taking micrographs every five atom spacings into the tip. The depleted zone was revealed to be of large cross-section at one level, breaking up into smaller regions as more atomic layers were removed. A graph of the atomic vacancy concentration as a function of proton irradiation fluence was shown, indicating that the atomic fraction of vacancies increases from about 10^{-4} to 10^{-2} as the proton fluence increases from 10^{17} to 10^{20} protons/cm^2.

Wolfgang Lohmann reviewed the extensive series of irradiations which he has conducted at the new radiation effects facility. Motivated by the German SNQ project, a variety of materials has been irradiated. Tungsten alloys were of interest for neutron production, while aluminum alloys were considered for cladding, as was Zircalloy. Sintered aluminum product was considered for beam windows. Initial experiments were run last year using the isotope production facility to allow proton irradiation of aluminum and aluminum alloy samples. Results from these irradiations indicated softening of these samples. Since the temperature can now be controlled in the new proton irradiation inserts, it was decided to repeat these irradiations together with irradiation of some tungsten samples. An early run encountered difficulty when the interlocks failed to withdraw the insert when the water supply ran low. A second irradiation is now under way. Additional samples, primarily tungsten, are being irradiated in a helium cooled atmosphere. Samples will be tensile tested, and additional samples will be examined using TEM and small angle neutron scattering to characterize the microstructure. This work will be done in Germany. Two experimental rigs have been developed which will allow in-situ testing of tensile, creep, and thermal fatigue samples in the proton beam. Prior to inserting either of these rigs, the load cell and stepping motor are being checked to determine their resistance to radiation. This experiment is now being run in one of the neutron inserts.

Bob Brown discussed planned experiments on radiation damage to optical mirrors for use in the free electron laser. It was pointed out that interaction of the electron beam with a graphite scraper will result in neutron and gamma fluxes. Metal mirrors are most likely susceptible to only the neutron damage, but the dielectric multi-layer stacks are also susceptible to ionization damage. It is planned to gamma irradiate samples using a ^{60}Co gammacell to determine changes in reflectance and damage threshold. Additional irradiations will be conducted in the radiation effects area where the samples will receive both a spallation neutron and a gamma flux. At present, the funding from the free electron laser project is questionable, due to recent program cuts.

Jim Cost reviewed experiment #932, which examines the decay of magnetic permeability in magnetically soft materials. Materials such as Mumetal are in use in the beam line current monitors at LAMPF, but suffer from rapid degradation of permeability when subjected to scattered radiation. Earlier tests have shown that when irradiated with spallation neutrons to a fluence of $3x10^{17}$ n/cm^2, the permeability of crystalline Mumetal drops from about 25000 to about 5000, equal to that of amorphous Metglas 2605S-3. This fluence was achieved in less than 2 days at the neutron radiation effects facility. Continuing the irradiation to a fluence of $3x10^{19}$ n/cm^2 showed that the permeability of the Metglas samples leveled off at about 2000, while the permeability of the Mumetal samples decreased to one. Further irradiations are planned for 1986 to demonstrate this effect on 15 cm diameter toroids of both samples. Additional efforts are underway to increase the permeability of the Metglas by improving the heat treatment.

Bob Brown described the experiment which will be run in 1986 to study the effects of proton and neutron irradiation on the crack propagation rates in alloy 718. This alloy is particularly important at LAMPF as it is used for the beam line windows at A-6. A stepped-plate design failed in September, 1984. It has since been replaced by a hemispherical design which reduces the stresses by about a factor of five. This experiment will provide better knowledge of how cracks propagate in alloy 718 and an opportunity to better determine how the microstructure of this precipitation hardened alloy is affected by proton irradiation.

Robert Brown will remain chairman of the Solid State Physics and Materials Science working group for 1986.

Attendees:

J. Bradbury	MP-3
R. Brown	MP-7
J. Cook	MST-14
J. Cost	MST-5
D. Davidson	MP-3
H. Donnert	Kansas State University
K. Dowler	MST-14
D. Farnum	MP-13
R. Livak	MST-5
W. Lohmann	MP-13
D. Parkin	CMS
R. Reedy	INC-11
W. Sommer	MP-13
J. Yu	MP-3

NUCLEAR CHEMISTRY WORKING GROUP

Larry E. Ussery, Chairman

Bob Kraus was elected to be the Working Group Chairman for 1986. Professor Ralph G. Korteling was nominated as a replacement for Victor Viola on the nuclear chemistry subcommittee of the PAC. Bruce D. Wilkins was recommended for the TAP.

Dave Vieira presented an update on the TOFI spectrometer project. During the last year significant progress has been made in the following areas: 1) the completion of the transport line and the characterization of its performance; 2) the assembly, mapping, and trimming of the spectrometer dipole magnets; 3) installation of the spectrometer. It is anticipated that the spectrometer will be turned on by November 12th. The spectrometer will be trimmed for optimum performance using sources of alpha-particle activity. Experiment 752, in which the masses of neutron-rich nuclei in the Z=10-12 region are to be measured, will commence after the optimization of the spectrometer. The TOFI collaboration gratefully acknowledges MP Division (particularly MP-8, MP-1, and MP-11) for their technical assistance in carrying out this project.

Quamrul Haider described the theoretical work that he has been doing with Lon-Chang Liu during the last year. They have investigated the possibility that nuclear bound states of the η meson could be formed during the process of a nuclear reaction. It has been found that an η-mesic nucleus can exist and can be used to extract information on the η-N interaction in nuclei. The η meson has no charge, and therefore these bound states of the η cannot be caused by the Coulomb force. The force must be an attractive, strong interaction between the η and the nucleons in the nucleus.

Anzhi Cui described a new ^{44}Ti- ^{44}Sc radioisotope generator on inorganic material. The isotope ^{44}Sc may have some potential as a scanning agent for nuclear medicine. Previously developed ^{44}Ti- ^{44}Sc generator systems have used organic resins as adsorbent. Anzhi Cui and Harold O'Brien have found a suitable inorganic resin Polyan HT (a commercial form of polyantimonic acid) which can be used as the adsorbent for a ^{44}Ti- ^{44}Sc generator system. This material gives good separation of ^{44}Ti and ^{44}Sc. The recovery of ^{44}Sc can reach 70% and the breakthrough of ^{44}Ti can be reduced to about 5×10^{-7} under the appropriate conditions.

Louis Rosen has been a strong supporter of the nuclear chemistry program at LAMPF during his tenure as Director, and we would like to gratefully acknowledge his support and wish him well in his future ventures.

ATTENDEES

Los Alamos National Laboratory

Gil Butler
Bruce Dropesky
Gregg Giesler
Jane Grisham
Quamrul Haider
Lon-Chang Liu
Robert Reedy
Will Talbert
Larry E. Ussery
Dave Vieira

Other Institutions

Anzhi Cui, Institute of Atomic Energy, Beijing, China
Robert Estep, Florida State University
Bob Kraus, Clark University/INC-11
Kamran Vaziri, Utah State University

Minutes of Computer Facilities Working Group
November 5, 1985 at 1:30 pm
Room A234

Attendees:

James Amann, Los Alamos National Lab (Chairman)

(Give list of other attendees with institutions)

The first order of business was to elect a new chairperson for next year. James Amann nominated Kok Heong McNaughton and Earl Hoffman seconded. The nomination was passed.

Mike Oothoudt continues as the group's representative in the TAP.

Martha Hoehn reported on DAC usage for 1985. This year, we have added more CPU capabilities by acquiring a new Vax 8600 with 12 mega bytes memory. MPFGO has been moved to CCR. Other additions are a 6250 bpi tape drive, new disks, several laser printers, an expanded tape library, and network to experimental areas which links counting house computers (both Vaxes and some PDP's) to the DAC computers.

We are using approximately 70% of the VAX CPU capability at MP division. A brief report of the Vax 8600 performance was given. It is suggested that users try to minimize disk access to optimize the 8600 performance. A breakdown of scratch disk usage was discussed.

DAC 1986 projections include addition of MicroVaxes, another 6250 tape drive, additional disks, terminal network, upgrade memory for the 8600 and 2400 baud dial in.

Gail Anderson reported on her search for new graphics terminals. We have been using VT100s adapted with graphic boards from Digital Engineering which went out of business. This necessitated new terminal search. The criteria for these terminals include VT100 and 4010 graphic compatibility and emulation, particularly with keyboards similar and compatible with EDT keypad functions. In addition, features such as resolution better than 640*480, printer and video output lines and line lengths of 80/132 columns are preferred.

Several of the terminals evaluated are now available at the DAC. They include a Qume 311GX, two Selanar 100 XLs and a Cleveland Codonics. Graphic output from one of these terminal was compared with a similar one from a VT100.

The advantages of these new terminals are softer touch keyboards, better crosshair cursor control, greater resolution, pan/zoom capability and programmable keys. Future projections include looking into the purchase of some simple color terminals. Gail needs input from users in this.

Mike Oothoudt gave an update of Q support. MP1 support for RSX-11M will end on Janaury 1, 1989. There will be no new Q development, but fixes to bugs and quirks will continue along with additional work needed on QAL in VMS native mode.

PDP11's in the counting houses will be gradually phased out, to be replaced by MicroVaxes, 4 of which are on order. In addition 6250 tape drives are being investigated for the MicroVaxes. These will be installed by about March 1986, but the PDP11s will be left in place so that experiments running in 1986 can use either computer. The computer maintenance crew must be give at least 1 day notice for the switch. The PDP11s will be salvaged around January 1987.

The advantages of a MicroVax II over a PDP11/45 were discussed. A breakdown of cost in acquiring a MicroVax II system was also presented. Assuming existing peripherals, such a system would cost around $30,000, which includes software and documentation. Software changes in converting from an existing RSX-11M to VMS system were briefly discussed. The change from RSX-11D to RSX-11M is more difficult than the change from RSX-11M to VMS.

Future trends include exploring Fastbus possibilities.

Network communication both internal and external to LAMPF were discussed Many users are interested in having some sort of network to the outside, including to other countries. Don Geesaman of Argonne National Laboratory moved that the committee explore the implementation of BITNET as soon as possible. Martin Cooper seconded the motion. The motion was passed.

The meeting was adjourned at 2:55 pm.

ATTENDEES COMPUTER FACILITY WORKING GROUP:

MIKE OOTHOUDT, LANL, MP-1
RAY POORE, LANL, P-9
RON NELSON, LANL, P-9
EARL HOFFMAN, LANL, MP-1
DEAN MCMILLAN, LANL, P-9
DON MACHEN, SSI
TOM KOZLOWSKI, LANL, MP-1
FRANK NAIVAR, LANL, MP-1
MARTIN COOPER, LANL, MP-4
BILL MAYES, UNIVERSITY OF HOUSTON
BOB REDWINE, MIT
JOHN ZUMBRO, UNIVERSITY OF PENNSYLVANIA
MIKE PLUM, LANL, MP-10
GEORGE BURLESON, NEW MEXICO STATE
DON GEESAMAN, ARGONNE NATIONAL LABORATORY
WILL FOREMAN, LANL, MP-1
LARRY PINSKY, UNIVERSITY OF HOUSTON
HAL BUTLER, LANL, MP-DO
HARALD JOHNSTAD, FERMILAB
KOK HEONG MCNAUGHTON, UNIVERSITY OF TEXAS
MIKE MCNAUGHTON, LANL, MP-13
GERRY MAESTAS, LANL, MP-1
TONY GONZALES, LANL, MP-1
GAIL ANDERSON, LANL, MP-1
JAMES F. HARRISON, LANL, MP-1
JAMES AMANN, LANL, MP-10

Robert Thorn

Louis Rosen

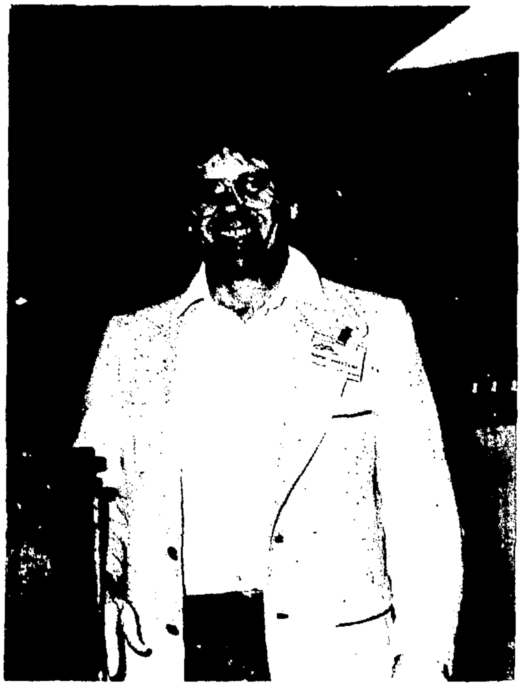
Robert Redwine, June Matthews, Barry Preedom, George Burleson, and Don Geesaman

Josef Speth, Toshimitsu Yamazaki, Jen-Chieh Peng, and Arch Thiessen

Gerald Garvey

Donald Hagerman

David Hendrie and Robert Redwine



Barry Preedom

Hywel White

Peter Barnes and Louis Rosen holding the Louis Rosen Prize Plaque

June Matthews

Martin Cooper

Paul Lisowski

Toshimitsu Yamazaki

LEFT: Arch Thiessen and
June Matthews

Lew Agnew and Don Grisham

ATTENDEES
19TH LAMPF USERS MEETING
NOVEMBER 4 AND 5, 1985

LEWIS AGNEW
LOS ALAMOS NATIONAL LABORATORY
MP7 MAIL STOP H840
LOS ALAMOS NM 87545

JOHN C ALLRED
LOS ALAMOS NATIONAL LABORATORY
MPDO MAIL STOP H850
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JAMES AMANN
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KLAUS PETER ARNOLD
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RICHARD L BOUDRIE
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ALI FAZELY
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MPVC MAIL STOP H831 (LOUISIANA STATE)
LOS ALAMOS NM 87545

RAYMOND FERGERSON
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WILL M FOREMAN
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DADEP/NPPP MAIL STOP H836
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M MAGDY GAZZALY
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1986 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 1986 membership and term expiration dates are listed below.

1987	Barry Preedom (Chairman) University of South Carolina
1988	June Matthews (Chairman-Elect) Massachusetts Institute of Technology
1986	Robert Redwine (Past-Chairman) Massachusetts Institute of Technology
	James Bradbury (Secretary/Treasurer) Los Alamos National Laboratory
1986	George R. Burleson New Mexico State University
1986	Donald Geesaman Argonne National Laboratory
1987	Charles Goodman Indiana University
1987	Gerald Hoffmann University of Texas

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

The TAP provides technical recommendations to the Board of Directors 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 serves as TAP chairman. The TAP membership and term expiration dates are listed below. The members shown below are the 1985 TAP members. The 1986 members will be chosen in the Spring of 1986.

1986 William Briscoe
George Washington University

1987 J. David Bowman
Los Alamos National Laboratory

1985 Harold A. Enge
Massachusetts Institute of Technology

1987 Gerald Hoffmann
University of Texas

1985 Richard Hutson
Los Alamos National Laboratory

1985 Christopher L. Morris
Los Alamos National Laboratory

1986 Michael A. Oothoudt
Los Alamos National Laboratory

1987 Roy J. Peterson
University of Colorado

1987 Robert E. Pollock
Indiana University

1985 Thomas A. Romanowski
Ohio State University

1986 Gary Sanders
Los Alamos National Laboratory

1986 Charles A. Whitten
University of California

1986 WORKING GROUP CHAIRMEN

High-Resolution Spectrometer (HRS)
Raymond Fergerson
Rutgers University

Neutrino Facilities
Stuart Freedman
Argonne National Laboratory

Stopped-Muon Channel (SMC)
Martin Cooper
Los Alamos

Nuclear Chemistry
Robert Kraus
Clark University

Energetic Pion Channel and Spectrometer (EPICS)
Kalvir Khuga
New Mexico State University

High-Energy Pion Channel (P^3)
Gordon Mutchler
Rice University

Nucleon Physics Laboratory (NPL)
Upgrade/Medium-Resolution Spectrometer
John Faucett
New Mexico State University

Computer Facilities
Kok-Heong McNaughton
University of Texas

Solid-State Physics and Materials Science
Robert Brown
Los Alamos

Muon-Spin Relaxation
Mario Schillaci
Los Alamos

Low-Energy Pion Channel (LEP)
James Knudson
Arizona State University

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 the development of experimental facilities. the PAC meets twice each year for 1 week during which time all new proposals that have been submitted at least 2 months before the meeting date are considered. Old proposals, and the priorities accorded to them, also may be reviewed.

<u>Terms Expiring in 1986</u>

David Axen
TRIUMF

Barry Barish
California Institute of Technology

Dietrich Dehnhard
University of Minnesota

Frieder Lenz
SIN

Harold M. Spinka, Jr.
Argonne National Laboratory

Victor E. Viola, Jr.
Indiana University

Larry Zamick
Rutgers University

<u>Terms Expiring in 1987</u>

Eric G. Adelberger
University of Washington

Gerard M. Crawley
Michigan State University

William R. Gibbs
Los Alamos

Wick C. Haxton
University of Washington

Stanley B. Kowalski
MIT

<u>Terms Expiring in 1987 (Continued)</u>

Philip G. Roos
University of Maryland

Benjamin Zeidman
Argonne National Laboratory

<u>Terms Expiring in 1988</u>

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Catholic University of America

David J. Ernst
Texas A&M Univrsity

James L. Friar
Los Alamos

Daniel S. Koltun
University of Rochester

W. Gary Love
University of Georgia

Norbert T. Porile
Purdue University

Willem T. H. Van Oers
Univesity of Manitoba

D. Hywel White
Brookhaven National Laboratory

LAMPF USERS GROUP, LUGI

Board of Directors

The LAMPF Users Group, Inc. (LUGI), Board of Directors (BOD) met on March 10, July 9, and November 3, 1985. All meetings were chaired by Robert Redwine; selected topics of discussion are provided below.

There were 172 registrants for the 1985 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 1985. For these 2 sessions 70 new proposals were received. The breakdown follows.

HRS	13
EPICS	19
LEP	15
NUCLEAR CHEMISTRY	1
NPL	5
SMC	4
P^3	6
SOLID STATE PHYSICS AND MATERIALS SCIENCE	7

The BOD selected William J. Burger (MIT) as the recipient of the Louis Rosen Prize for 1985 for his thesis "An Experimental Study of Pion Absorption in ^{58}Ni at T_π =160 MeV." Since Dr. Burger was out of the country at the time the award was presented to his advisor, Robert Redwine, and forwarded to him.

The following workshops are scheduled to be held at LAMPF.

Nuclear Physics Laboratory Upgrades
December 16-17, 1985

Fundamental Muon Physics: Atoms, Nuclei, and Particles
January 20-22, 1986

Physics with Polarized Nuclear Targets
February 6, 1986

Quark/Gluon Phenomena in Nuclear and Particle Physics
February 7-8, 1986

Annual Users Meeting
October 27-28, 1986

Exp. 954

ISOSPIN AMPLITUDES FOR GIANT RESONANCES IN ^{58}Ni AND ^{64}Ni

Spokesman: R. J. Peterson (University of Colorado)
University of Colorado: B. L. Clausen, J. J. Kraushaar, R. L. Loveman, R. J. Peterson, R. A. Ristinen, J. L. Ullmann
Los Alamos: R. L. Boudrie, N. S. P. King, C. L. Morris
University of Minnesota: S. J. Seestrom-Morris

The giant quadrupole state in nickel lies above the neutron and proton separation energies by very different amounts in ^{58}Ni and ^{64}Ni. This allows a sensitive test of the role of nuclear binding energies on the apparent isospin content of the excitation of that resonance. We propose to excite the GQR in both isotopes with π^+ and π^- scattering at 164 MeV on the EPICS system to measure isospin amplitudes.

Exp. 955

SEARCH FOR EXPERIMENTAL PROOF OF THE EXISTENCE OF LOWER COMPONENTS IN THE NUCLEAR WAVE FUNCTION

Spokesman: G. W. Hoffmann, R. L. Ray, and M. L. Barlett (University of Texas), and J. Jarmer (Los Alamos)
University of Texas: G. W. Hoffman, R. L. Ray, M. L. Barlett, G. Pauletta, J. Lumpe, D. Ciskowski, M. Purcell, C. Milner
Los Alamos: J. Jarmer, N. Tanaka, J. Amann, J. B. McClelland, K. Jones, C. Morris, J. McGill
Argonne National Laboratory: D. Hill
New Mexico State University: G. Burleson, G. Kyle, K. Dhuga, J. Faucett
University of Minnesota: N. Hintz, M. Gazzaly, S. Seestrom-Morris
Ohio State University: B. C. Clark
IBM: R. L. Mercer
Rutgers University: R. W. Fergerson, C. Glashausser

We present results of preliminary calculations which indicate that some of the spin observables for elastic scattering of 500-MeV polarized protons from a polarized ^{13}C target are qualitatively sensitive to relativistic aspects of nuclear structure (large scalar and vector binding fields, and lower components of the relativistic target wave function). We propose to construct a polarized ^{13}C target and perform an experiment at HRS (using the focal-plane polarimeter) to demonstrate the existence (or nonexistence) of such relativistic effects. Preliminary experimental considerations are discussed.

Exp. 956

MICROSCOPIC STRUCTURE OF THE CALCIUM ISOTOPES

Spokesman: J. Kelly (University of Maryland) and A. Saha (University of Virginia)
University of Virginia: J. Laksanaboonsong, B. Norum, A. Saha
University of Maryland: N. Chant, J. Kelly, R. Roos, H. Seifert
University of Minnesota: S. Nanda

We propose to measure inelastic cross sections and analyzing powers for the scattering of 320-MeV protons by the calcium isotopes ^{40,42,44,48}Ca, complementing similar extant and proposed electron-scattering experiments. Electron-scattering data for predominantly longitudinal isoscalar transitions in a self-conjugate nucleus, such as ^{40}Ca, almost completely determine the nuclear-structure information required to interpret complementary hadronic reactions. The proton-scattering data for ^{40}Ca will be used to determine an empirical effective interaction whose form is guided by nuclear matter theory. This procedure has already been applied to similar ^{16}O data.

Once the empirical effective interaction has been obtained, neutron transition densities can be fitted to the proton-scattering data for nearby isotopes. Our technique employs a linear expansion of the radial dependence that is nearly model independent. This technique has been applied to data for ^{18}O and other nuclei. Such a detailed microscopic analysis of the neutron radial transition densities will elucidate the nuclear-structure relationships among the calcium isotopes.

Exp. 957

INCLUSIVE PION DOUBLE CHARGE EXCHANGE IN LIGHT p-SHELL NUCLEI

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University of Wyoming: G. A. Rebka, Jr., D. Roberts

We propose to study the inclusive double-charge-exchange processes (π^+,π^-) and (π^-,π^+) for three light p-shell nuclei (^6Li, ^7Li, ^9Be) at three incident energies in the vicinity of possible Δ-resonance production in the nuclei (120, 180, and 240 MeV). For $T_{\pi^+} = 120$ MeV and $T_{\pi^-} = 180$ and 240 MeV, we expect to measure the doubly differential cross section at 3 angles (25, 80, and 130°), and at 9 or 10 energies for each angle, judiciously spaced over the allowed spectrum of the outgoing pion. For $T_{\pi^+} = 180$ and 240 MeV the cross section will be measured at five angles (25, 50, 80, 105, and 130°). Most of these measurements should have 5% accuracy limited by systematic uncertainties and normalization; some will have an accuracy limited to 10% by the counting statistics. Measurement, calibrations, and tests will be completed in 460 h and will use the same spectrometer-detector system that was successful in measuring $^4He(\pi^\pm,\pi^\mp)$, $^{12}C(\pi^\pm,\pi^\mp)$, $^{16}O(\pi^\pm,\pi^\mp)$, $^{40}Ca(\pi^\pm,\pi^\mp)$, $^{103}Rh(\pi^\pm,\pi^\mp)$, and $^{208}Pd(\pi^\pm,\pi^\mp)$ cross sections.

Exp. 958

STUDY OF THE $^{90}Zr(\vec{p},\vec{n})^{90}Nb_{g.s.}$ (IAS) CHARGE-EXCHANGE REACTION AT 500 MeV

Spokesmen: *G. W. Hoffmann (University of Texas) and J. B. McClelland (Los Alamos)*
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Los Alamos: J. B. McClelland, T. A. Carey, K. Jones
Ohio State University: E. Sugarbaker
IBM: R. L. Mercer

We propose to use the new Neutron Time-of-Flight Facility (NTOF) to obtain high-quality data for 500-MeV $^{90}Zr(\vec{p},\vec{n})^{90}Nb_{g.s.}$ (IAS) excitation of the isobaric analog of the ground state of ^{90}Zr. High-quality cross-section, analyzing-power, and spin-rotation data will be obtained over the laboratory angular range 0-15°, with statistical accuracy $\leq\pm1$-2%, $\leq\pm0.01$-0.03%, and $\leq\pm0.05$-0.2%, respectively. The data will be used to test relativistic and nonrelativistic microscopic descriptions of the reaction in terms of the isovector parts of the (effective) nucleon-nucleon interaction and the neutron excess distribution. A total of 1082 h of beam time is requested.

Exp. 959

INELASTIC PION SCATTERING FROM ^{20}Ne

Spokesmen: *S. Mordechai and C. F. Moore (University of Texas) and H. T. Fortune (University of Pennsylvania)*
University of Texas: S. Mordechai, C. F. Moore, P. A. Seidl, J. K. Brown
University of Pennsylvania: R. Gilman, J. D. Zumbro, H. T. Fortune, M. Burlein
Los Alamos: C. L. Morris
New Mexico State University: K. S. Dhuga, G. R. Burleson, J. A. Faucett, G. S. Kyle
University of Indiana: L. C. Bland

We propose to measure π^+ and π^- scattering on ^{20}Ne. Evidence for the validity of a single one-step direct reaction mechanism to describe pion inelastic scattering has been presented in recent studies of pion inelastic scattering on various nuclei. However, in several cases the standard distorted-wave impulse approximation (DWIA) calculations show a large disagreement with the forward-angle data for inelastic scattering. The measurement of pion inelastic scattering to low-lying natural-parity states of well-known structure in ^{20}Ne will provide valuable information about the reaction mechanism and the contribution of coupled-channel effects and higher order processes to the total inelastic cross section.

Exp. 960

MEASUREMENT OF $\Delta\sigma_L$ AND $\Delta\sigma_T$ IN FREE NEUTRON-PROTON SCATTERING BETWEEN 300 AND 800 MeV

Spokesmen: *G. Burleson (New Mexico State University), K. F. Johnson (Argonne), and L. C. Northcliffe (Texas A&M University)*
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Los Alamos: J. J. Jarmer
New Mexico State University: M. Beddo, G. Burleson, J. Faucett, G. Kyke, M. Rawool
Texas A&M University: T. S. Bhatia, G. Glass, J. C. Hiebert, R. A. Kenefick, L. C. Northcliffe
University of Montana: R. Jeppesen
Washington State University: G. E. Tripard

The measurement of the total cross-section differences $\Delta\sigma_L$ and $\Delta\sigma_T$ for parallel and antiparallel longitudinal- and transverse-spin states, respectively, is proposed using free neutron-proton scattering at seven energies between 300 and 800 MeV. These will be the first measurements of these quantities at intermediate energies using a polarized neutron beam. It will check the quasi-free measurement of $\Delta\sigma_L$ (pn) made at the Argonne ZGS that used a polarized proton beam and a deuterated polarized target. The experiment proposes to use the new beam buncher that will allow the use of time of flight for neutron energy identification.

Exp. 961

MEASUREMENT OF THE SPIN-CORRELATION PARAMETER $A_{NN}(\theta)$ FOR n-p ELASTIC SCATTERING AT 800 MeV

Spokesman: *L. C. Northcliffe (Texas A&M University)*
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Los Alamos: D. Fitzgerald, J. J. Jarmer
New Mexico State University: G. Burleson and graduate student
University of Montana: R. H. Jeppesen
Washington State University: G. E. Tripard
Argonne National Laboratory: K. Johnson, I. Ohashi, H. Spinka

A measurement of the spin-correlation parameter $A_{NN}(\theta^*)$ for n-p elastic scattering at 800 MeV is proposed. The LAMPF primary proton beam will be chopped and bunched. A vertically polarized neutron beam ($P \sim 0.5$) obtained by precession of the polarized neutrons given by longitudinal polarization transfer from the LAMPF polarized proton beam bombarding a liquid-deuterium target would be scattered from a vertically polarized hydrogen target. The recoil protons would be detected in a multiwire-proportional-chamber (MWPC) array and the conjugate neutrons would be detected in a neutron-bar-counter (NBC) scintillator hodoscope. The background coming from quasi-free n-p scattering in nonhydrogenous target components would be distinguished by a test of the coplanarity of the incident beam and the scattered nucleons and by the measured opening angle between the scattered neutron and recoil proton. The angular range to be covered would be $40° < \theta^* < 165°$.

Exp. 962

TARGET MASS DEPENDENCE OF THE ISOVECTOR CONTRIBUTION TO THE GIANT QUADRUPOLE RESONANCE

Spokesperson: S. J. Seestrom-Morris (University of Minnesota)
Los Alamos: C. L. Morris, K. W. Jones
University of Texas: C. F. Moore
University of Minnesota: S. Nanda, D. Dehnhard, S. J. Seestrom-Morris
University of Colorado: J. Ullmann, R. J. Peterson

We propose to measure cross sections for excitation of the giant quadrupole resonance (GQR) in ^{138}Ba and ^{238}U using π^+ and π^- scattering at 162 MeV. Measurements of π^+ and π^- scattering to the GQR in ^{40}Ca, ^{118}Sn, and ^{208}Pb have shown that the ratio of the neutron to proton matrix elements M_n/M_p is a steadily increasing function of A and that the increase is faster than that predicted by the hydrodynamical model. The present experiment is intended to extend the A dependence to a heavier target, ^{238}U, and to add a target intermediate in mass to tin and lead.

Exp. 963

EXPERIMENTAL INVESTIGATION OF MUON CATALYSIS

Spokesmen: A. N. Anderson [Idaho National Engineering Lab. (INEL)], S. E. Jones (Brigham Young University), and M. Leon (Los Alamos)
INEL: A. N. Anderson, A. J. Caffrey, C. D. Van Siclen
Los Alamos: J. N. Bradbury, J. S. Cohen, P. A. M. Gram, M. Leon, H. R. Maltrud, M. A. Paciotti
Brigham Young University: S. E. Jones

Many unexpected and intriguing effects in muon catalysis were discovered in LAMPF Exp. 727. Our understanding of muon catalysis is demonstrably incomplete, motivating further research with the addition of new experimental techniques. We will explore the dependencies of the rates for $dt\mu$-mesomolecular formation and $d\mu \rightarrow t\mu$ transfer on target temperature, density, and tritium fraction; determine the effects of varying the ortho-paradeuterium ratio; test predictions that the *effective* alpha-sticking fraction depends on electron-recombination processes; and measure the alpha-sticking coefficient directly.

Exp. 964

STUDY OF (π^-, p) AND (π^+, p) REACTIONS WITH EPICS

Spokesmen: G. S. Blanpied (University of South Carolina) and J.-P. Egger (Université de Neuchâtel)
Arizona State University: B. G. Ritchie
Drexel University: B. H. Wildenthal
Los Alamos: C. L. Morris
Michigan State University: B. A. Brown
Université de Neuchâtel: E. Bovet and J.-P. Egger
University of South Carolina: G. S. Adams, G. S. Blanpied, C. S. Mishra, B. M. Preedom, C. S. Whisnant

Our first study using the EPICS facility to measure the (π^+,p) reactions has yielded positive, interesting results. Peaks from ^{24}Mg (π^-,p) in the region of bound states with cross sections comparable to those from (π^+,p) have been observed at $T_\pi = 120$ MeV, $\theta_p = 25°$. Smaller cross sections are indicated in ^{12}C, ^{27}Al, ^{40}Ca, and ^{58}Ni. We propose to investigate the angular distribution of the bound states from ^{24}Mg $(\pi^\pm,p)$ and ^{23}Na $(\pi^\pm,p)$. A measurement of ^{50}Cr $(\pi^-,p)^{49}$Ti at 25° is also proposed. A total of 254 h using the EPICS facility is requested for this phase of the experiment.

Exp. 965

TEST AND CALIBRATION OF DETECTOR FOR SOLAR NEUTRONS AND GAMMA RAYS

Spokesmen: E. L. Chupp and P. P. Dunphy (University of New Hampshire)
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Argonne National Laboratory: K. Johnson, T. Shima, H. Spinka, R. Stanek
New Mexico State University: M. Beddo, G. Burleson, J. Faucett, G. Kyle
Texas A&M University: G. Glass

Testing of a prototype design for the detection of solar-flare neutrals from satellites is proposed using neutrons of up to 800-MeV kinetic energy. Accelerator testing is necessary to verify calculations of detector efficiency, energy response function, self-gating effects, and directional properties. Neutrons produced from a proton beam scattering in an LD_2 target in the Line BR area will be used. We propose to accomplish absolute efficiency and energy measurements by scattering the neutrons elastically from an LH_2 target and gating on the scattered protons. Relative efficiency, self-gating, and direction could be determined using the direct neutron beam.

Exp. 966

PION ABSORPTION ON QUASI DEUTERONS IN $^{10}B\,(\pi^+,2p)$

Spokesman: B. G. Ritchie (Arizona State University)
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University of South Carolina: G. S. Adams, G. S. Blanpied, C. S. Mishra, B. M. Preedom, C. S. Whisnant
University of Virginia: R. C. Minehart
Virginia Polytechnic Institute and State University: M. Blecher

An angular distribution for $^{10}B(\pi^+,2p)^8Be$ (g.s.) at 30 MeV will be measured. The results will provide important information on the applicability of an approach to understanding pion absorption in terms of a cluster model in which absorption proceeds on a deuteron-like structure within the cluster. Boron-10 should provide strong support for this model if the observed angular distribution shows lobes about the angles predicted by using quasi-deuteron kinematics rather than a peak at those angles. Such behavior would be consistent with a cluster model of the boron nucleus as a $l = 2$ deuteron orbiting a ^8Be core Nine shifts at the LEP channel are requested to investigate the feasibility of making this measurement if this experiment follows Exp. 948.

Exp. 967

INCLUSIVE π^- SCATTERING AT 100 MeV ON CARBON, CALCIUM, TIN, AND LEAD

Spokesmen: I. Halpern and D. R. Tieger (University of Washington)
University of Washington: I. Halpern, M. Khandaker, T. Murakami, D. Rosenzweig, D. W. Storm
University of Washington and MIT: D. R. Tieger

We propose to measure the inclusive scattering of *negative* pions at 100 MeV on four targets well spaced in mass number. For each target we shall obtain energy spectra at six angles from 40 to 140°. The experiment will be performed in the LEP channel using the Clamshell spectrometer to detect the scattered pions.

Model calculations that we have recently carried out for *positive* pion inclusive scattering reproduce most of the basic features of the observed data. The extension of these calculations to negative pions shows that one must expect substantial enhancements of π^- over π^+ cross sections in heavy nuclei. These enhancements arise from the neutron excess and especially from Coulomb effects. However, they are not in accord with available data. The discrepancy appears to be sufficiently critical to the understanding of pion interactions with nuclei to warrant a π^-/π^+ comparison with an instrument that is capable of showing the π^- spectrum shapes over a wide range of angles.

Exp. 968

STUDY OF INELASTIC SCATTERING OF $\pi^{\pm}$ FROM ^{7}Li AND ^{14}C AT LOW ENERGIES

Spokesmen: F. Irom (Los Alamos) and R. J. Peterson (University of Colorado)
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University of Colorado: B. L. Clausen, J. J. Kraushaar, R. A. Loveman, J. Mitchell, R. J. Peterson, R. A. Ristinen

We propose to study the inelastic scattering of π^+ and π^- from ^{7}Li and ^{14}C at beam energies of 50, 65, and 80 MeV using the LEP Clamshell spectrometer. The ^{7}Li studies will use the three collective isoscalar transitions to examine *s*- and *p*-wave interference in the π-nucleon amplitudes with the least Coulomb effects. The ^{14}C studies will use the wide array of spin and isospin modes known from other studies to examine this interference. For both targets, the data proposed will make possible a refined isospin analysis of optical-model methods successful to higher pion energies.

Exp. 969

MEGA — SEARCH FOR THE RARE DECAY $\mu^+ \rightarrow e^+\gamma$

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University of Chicago: S. C. Wright
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Stanford University: E. B. Hughes, M. W. Ritter
Texas A&M University: C. Gagliardi, R. E. Tribble
University of Virginia: K. O. H. Ziock
University of Wyoming: A. R. Kunselman
Yale University: P. S. Cooper

The proposed experiment will search for the rare decay $\mu^+ \rightarrow e^+\gamma$ with a branching ratio sensitivity of better than 10^{-13}. The resolutions of the detector elements are sufficient to make the kinematic signature of the candidate events background free. This sensitivity will improve the limits on the decay by a factor of 500 over the expected results of the Crystal Box. Observation of this decay would violate conservation of separate muon and electron number. Searches for $V + A$ contributions to the radiative decay of the muon and for the rare decay $\mu^+ \rightarrow e^+\gamma\gamma$ will be made concurrently in a parasitic mode.

Exp. 970

MEASUREMENT OF THE DELTA-NUCLEUS INTERACTION BY PION INELASTIC SCATTERING TO THE 1^+ DOUBLET IN ^{12}C

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Los Alamos: C. L. Morris, R. L. Boudrie
University of Texas at Austin: C. F. Moore, P. A. Seidl
University of Colorado: R. J. Peterson

We propose to measure cross sections for the $T = 0$ and $T = 1$, 1^+ doublet in ^{12}C. Measurements will be made at several angles near the maximum in the angular distributions for both π^+ and π^- at seven incident pion energies from 180 to 295 MeV. These measurements will extend earlier measurements made at lower energies.

Exp. 971

MEASUREMENT OF THE SPIN-ROTATION PARAMETER Q FOR THE 200-MeV $\vec{p} + {}^{208}Pb$

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University of Texas at Austin: M. Barlett, G. Hoffmann, G. Pauletta, L. Ray
Los Alamos: J. McClelland
Indiana University Cyclotron Facility: E. Stephenson, S. Wissink
MIT: C. Horowitz
Ohio State University: B. Clark

We propose to measure the spin-rotation parameter Q on ${}^{208}Pb$ at 200 MeV over the angular range 3-30° (lab). The total time requested is 110 h: 61 h with $\hat{s}$-type incident beam and the rest with $\hat{\ell}$-type beam. These data will provide information on the reliability of relativistic Pauli-blocking calculations that differ markedly from impulse approximation predictions at this energy. The data will also constrain other calculations of media modifications at this energy.

Exp. 972

LOW-MOMENTUM DELTA PRODUCTION VIA THE REACTION ${}^{13}C(\pi^+, p){}^{12}C_\Delta$

Spokesmen: *C. L. Morris and J. A. McGill (Los Alamos)*
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University of Texas: C. F. Moore, G. W. Hoffmann, M. L. Barlett, P. A. Seidl, G. Pauletta
University of Minnesota: N. M. Hintz, S. Seestrom-Morris, S. K. Nanda, M. Gazzaly

We propose to measure the differential cross section for the production of a $\Delta_{3,3}$ resonance in ${}^{12}C$, with very low momentum relative to the residual $A = 11$ nucleus. We will employ the momentum-matching reaction ${}^{13}C(\pi^+,p)$, detecting the proton at a small angle (~15°) in the Large-Aperture Spectrometer (LAS). An array of BGO crystals in close proximity to the ${}^{13}C$ target will detect the decay products of the highly excited (~300-MeV) ${}^{12}C$ residual nucleus.

Exp. 973

SEARCH FOR NARROW RESONANCES IN THE $B = 2$ MISSING-MASS SPECTRUM FROM p + He REACTIONS AND IN THE EXCITATION FUNCTIONS OF THE pp PION PRODUCTION

Spokesmen: *M. Gazzaly (University of Minnesota), G. Pauletta (University of Texas), and N. Tanaka (Los Alamos)*
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University of Udine, Italy: R. Garfagnini, L. Santi
University of Minnesota: M. Gazzaly, N. Hintz, S. Nanda, S. Seestrom-Morris
Los Alamos: K. Jones, C. Morris, N. Tanaka
University of Virginia: L. C. Smith, R. Whitney

We propose to search the missing-mass spectra of the ${}^3He(p,d)mm$, ${}^4He(p,t)mm$, and ${}^4He(p,{}^3He)mm$ reactions for $B = 2$ resonances. The first two reactions will select the same $I = 1$ resonances and the third will select $I = 0$ ones. In addition, we wish to verify the existence of a narrow structure in the $p + p \to d + \pi^+$ reaction near threshold and to search for a possible resonance in pp pion production near 800-MeV incident proton energy. The proposal actually comprises two distinct experiments that can be considered separately, but since the motivation and experimental equipment are common to both we feel it is appropriate to present them for consideration under one heading. Both experiments will use the HRS in Line C. To measure excitation functions, the beam energy will be varied by making use of existing variable-thickness degraders upstream of the bending magnets.

Exp. 974

A SEARCH FOR NARROW RESONANCES IN THE $B = 2$ SYSTEM USING THE $^{3}He(\pi^{+},p)mm$ AND $^{2}H(\pi^{+},\pi^{+\prime})mm$ REACTIONS

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University of Udine, Italy: R. Garfagnini, L. Santi
University of Minnesota: M. Gazzaly, N. Hintz, S. Nanda, S. Seestrom-Morris
Los Alamos: K. Jones, C. Morris, N. Tanaka
University of Virginia: R. Whitney

We propose to search for narrow resonance structure in the $B = 2$ system by making use of the $^{3}He(\pi^{+},p)mm$ and the $D(\pi^{+},\pi^{+\prime})mm$ reactions. EPICS will be used in both cases. For the first reaction, we will scan the missing-mass spectrum for $I = 1$ resonances in the exit channel; for the second, we will measure an excitation function to search for $I = 1$ resonances in the entrance channel. Should we succeed in locating them, we will then search the missing-mass spectrum for transitions to $I = 0$ analog resonances. We also request time for a preliminary study of double charge exchange (DCX) on deuterium to evaluate the effort of searching for $I = 2$, $B = 2$ resonances.

Exp. 975

SINGLE CHARGE EXCHANGE WITH STOPPED NEGATIVE PIONS

Spokesmen: *M. J. Leitch and L. C. Liu (Los Alamos)*
Los Alamos: A. Cui, B. J. Dropesky, G. C. Giesler, F. Irom, M. J. Leitch, L. C. Liu, C. J. Orth, L. E. Ussery

We propose to study pion-nucleus single-charge-exchange (SCX) reactions induced by stopped negative pions. These studies will allow us to determine the strength of the isovector pion-nucleon interaction in nuclei. This information can be used (1) to determine the origin of the large repulsion of the *s*-wave isoscalar pion-nucleon interaction in nuclei, and (2) to investigate the competition between pion absorption and SCX at energies of pionic atom level. 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 from 30 to 80 MeV where the *s*- and *p*-wave interference is important. Negative pions will be stopped in ^{45}Sc, ^{35}Cl, ^{31}P, and ^{27}Al. The emerging π^{0}'s, which will have an energy between 1 and 5 MeV depending on the target nucleus, will be detected with the LAMPF π^{0} spectrometer. The event rates are very high because of the increased solid angle of the π^{0} spectrometer at very low energies and the large fraction of interactions for stopped π^{-}

Exp. 976

STUDY OF THE CHARGED-PARTICLE DECAY OF THE GIANT DIPOLE RESONANCE EXCITED BY PION SINGLE CHARGE EXCHANGE ON ^{13}C

Spokesmen: *J. D. Bowman (Los Alamos) and D. Pocanic (Stanford University)*
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Los Alamos: H. W. Baer, J. D. Bowman, F. Irom
Arizona State University: J. R. Comfort, J. N. Knudson, B. G. Ritchie

Proposed is a study of the decay modes of the isovector giant dipole resonance (GDR) in the $A = 13$ system and of the GDR strength on the $A = 12$ and 14 systems. The proposed experimental method makes use of the unique selectivity of the $(\pi^{\pm},\pi^0)$ in exciting the isovector electric giant resonance, combined with the detection of outgoing protons leading to discrete final states. From the spectra and angular distributions of coincident protons in $^{13}C(\pi^+,\pi^0p)^{12}C$ we shall confirm the multipolarity of the observed GDR and extract information on the particle-hole structure and on the isospin splitting of the GDR in ^{13}C. For the latter goal inclusive measurements of $^{13}C(\pi^{\pm},\pi^0)$ are needed. By also measuring inclusive reactions $^{14}C(\pi^{\pm},\pi^0)$ and using the existing photonuclear data, this study will completely determine the GDR isospin splitting in the $A = 13$ and 14 systems. The $^{12}C(\pi^{\pm},\pi^0)$ measurements will be performed for the purpose of sum rule strength calibration.

Exp. 977

MEASUREMENT OF WOLFENSTEIN PARAMETERS FOR PROTON-DEUTERON ELASTIC SCATTERING AT 800 MeV

Spokesman: *G. Igo (UCLA)*
UCLA Collaboration

The Wolfenstein parameters D_{NN}, D_{LS}, D_{SS}, D_{LL}, and D_{SL}, have been measured at 800 MeV in Exp. 540, and D_{NN} was remeasured in Exp. 545. The results of the measurements made of the observable D_{NN} of these two experiments are in good agreement with one another, generally. However, the behavior of D_{NN} at small $|t|$ is very unexpected. Further, a concurrent measurement of D_{NN} in p-^{12}C elastic scattering is clearly anomalous. These observations taken together suggest the thesis that the data taken in this region may be incorrect. In this proposal we ask for beam time to completely remeasure these observables (11 angles, $\theta_{lab} \leq 28°$). We require a measurement of D_{NN} for carbon at each angle as a consistency check on the proton-deuteron measurement. Since the p-carbon data has its own intrinsic value, we will also complete the measurement of the Wolfenstein parameters for proton-carbon elastic scattering at 800 MeV.

Exp. 978

A COINCIDENCE MEASUREMENT OF PION DOUBLE CHARGE EXCHANGE: $^4He(\pi^+,\pi^-p)3p$

Spokespersons: *P. A. M. Gram (Los Alamos), J. L. Matthews (MIT), and G. A. Rebka, Jr. (University of Wyoming)*
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MIT: E. R. Kinney, J. L. Matthews, R. P. Redwine, T. Soos, S. A. Wood
University of Wyoming: G. A. Rebka, Jr., D. A. Roberts

We propose to investigate the $^4He(\pi^+,\pi^-p)3p$ process at $T_{\pi^+} = 240$ MeV to elucidate the mechanism of the pion double-charge-exchange reaction. Pions will be detected using the same magnetic spectrometer used in our previous measurements of $(\pi^{\pm},\pi^{\mp})$ cross sections. Coincident protons will be observed in an array of counter telescopes comprising silicon detectors and plastic scintillators. We request 460 h for setup, tests and calibrations, and coincidence measurements at one outgoing pion angle.

Exp. 979

A SEARCH FOR $T = 2$ DIBARYON PRODUCTION IN THE $d(\pi^+,\pi^-)X$ REACTION

Spokesmen: *C. L. Morris and J. A. McGill (Los Alamos)*
Rutgers University: C. Glashausser
Los Alamos: K. W. Jones, C. L. Morris, J. A. McGill
University of Texas: G. W. Hoffmann, C. F. Moore, G. Pauletta
University of Minnesota: M. Gazzaly, S. J. Seestrom-Morris

Recent calculations suggest the presence of a relatively narrow 1^+, $T = 2$ dibaryon resonance near the pion decay threshold. We propose to search for the existence of such $T = 2$ dibaryon resonances in the two-baryon system using the $d(\pi^+,\pi^-)X$ reaction. Negative pions will be detected using the Clamshell spectrometer at LEP. Background from quasi-free processes such as $\pi^+ + n \rightarrow \pi^+ + \pi^- + \pi p$ will be eliminated by detecting the expected three charged decay products of $X(pp\pi^+)$ in a 2π BGO ball detector currently being developed.

Exp. 980

AN INVESTIGATION OF THE NEAR STABILITY OF ^{6}H AND ^{7}H

Spokesman: *K. K. Seth (Northwestern University)*
Northwestern University: M. Artuso, G. Garino, B. Parker, K. Seth, M. Sethi, R. Soundra

The possible existence of superheavy isotopes of hydrogen is of fundamental importance both to nuclear physics and astrophysics for reasons as diverse as, for example, the existence of three-body forces and the stability of neutron stars. A highly respected group of Russian investigators has recently claimed that ^{6}H is nearly stable (unbound by ~ 2.7 MeV only) and that it has a width of 1.8 MeV. This is a tremendously exciting claim that must be verified by independent experiments. In 1978 we proposed (Exp. 460) investigation of the stability of ^{6}H and ^{7}H by means of the (π^-,π^+) reaction on ^{6}Li and ^{7}Li. The experiment was approved but could not be successfully done in the time approved. We propose to do the definitive experiment now.

Exp. 981

DO BOUND STATES OF REAL PIONS EXIST?

Spokesman: *K. K. Seth (Northwestern University)*
Northwestern University: M. Artuso, G. Garino, B. Parker, K. Seth, M. Sethi, R. Soundra

It has been conjectured for a long time that polyneutrons can be induced to form a bound state in the presence of a real pion. We propose to search for the formation of the entity $(nn\pi^-)$ by means of the pion double-charge-exchange reaction $\pi^- + d \rightarrow \pi^+ + (nn\pi^-)$. We believe that we can measure the formation of the $(nn\pi^-)$ system at a level that is a factor of ~ 200 better than that achieved ever before.

Exp. 982

THE MEASUREMENT OF LIGHT FRAGMENTS FROM PION TRUE ABSORPTION

Spokesman: *R. A. Loveman (University of Colorado)*
University of Colorado: J. J. Kraushaar, R. A. Loveman, J. H. Mitchell, R. J. Peterson, R. A. Ristinen, J. L. Ullmann

We propose to measure the inclusive spectra of light fragments following pion interactions with ^{181}Ta at resonance energy. These fragments would include particles as light as α's and as heavy as beryllium and perhaps boron. This would be the only measurement of this kind for energetic pions and would complement the inclusive proton spectra that already exist for this target energy combination. Comparisons will be made with the predictions of several models of pion absorption.

Exp. 983

$\pi^{\pm}$-TIN AND π^{-}-LEAD ELASTIC SCATTERING AT ENERGIES BETWEEN 30 AND 65 MeV

Spokesmen: M. Blecher and D. Wright, VPI and SU
University of South Carolina: G. Blanpied, C. Whisnant, B.M. Preedom
Los Alamos: R.L. Burman, M. Leitch
Arizona State University: B. Ritchie

We propose to measure elastic scattering of positive and negative pions from ^{116,124}Sn, and ^{208}Pb at energies of 30, 50, and 65 MeV, using the Clamshell spectrometer. Energy resolution $\lesssim$ 500 keV has been achieved with this spectrometer making the experiment feasible.

Exp. 984

PION SCATTERING TO 8^{-} STRETCHED STATES OF ^{60}Ni

Spokesman: R. J. Peterson, University of Colorado
University of Colorado: J. T. Brack, B. L. Clausen, J. J. Kraushaar, R. A. Loveman, R. J. Peterson, R. A. Ristinen, J. L. Ullmann
University of Virginia: R. A. Lindgren
Los Alamos: M. A. Plum

We propose to use EPICS with 162 MeV π^{+} and π^{-} beams to measure inelastic scattering cross sections to ten known 8^{-} states of ^{60}Ni, lying between 8.3 MeV and 16.1 MeV in excitation. The data for the T=2 levels will be analyzed to yield fractions of the isoscalar and isovector M8 sum strength. Data to the T=3 levels, expected to be purely isovector, will be analyzed to gain insight on the origin of the splitting of a single-particle excitation into six physical states.

EXP. 985

SEARCH FOR MUONIUM TO ANTIMUONIUM SPONTANEOUS CONVERSION

Spokesmen: V. W. Hughes, Yale University
J. R. Kane, College of William and Mary
H. Orth, Yale University
Heidelberg University: M. Gladisch, G. ZuPutlitz
Los Alamos: M. Cooper, C. Hoffman, G. Hogan, F. Mariam, R. Mischke, L. Piilonen, V. Sandberg
College of William & Mary: M. Eckhause, P. Guss, J. Kane
Yale University: K. P. Arnold, F. Chmely, V. Hughes, S. Kettell, Y. Kuang, J. Markey, B. Matthias, B. Ni, H. Orth, R. Schaefer, K. Woodle
University of Mississippi: J. J. Reidy

A search for muonium → antimuonium conversion at the level of sensitivity in the coupling constant of $G_{M\bar{M}} = G_F$ is proposed. The experiment will utilize a low energy muonium beam in vacuum and the LAMPF NaI crystal box to detect coincident muonic x rays.

EXP. 986

SPALLATION NEUTRON IRRADIATION OF NON-OXIDE CERAMICS FOR FIRST-WALL FUSION REACTOR APPLICATION

Spokesman: J. Linke, KFA-Jülich
KFA-Jülich: B. A. Thiele, K. Koizlik, J. Linke, G. Wolf

Five ceramic materials - improved versions of SiC - and three metallic materials - W, W-26 Re and TZM - are proposed for the irradiation test in the Los Alamos Meson Physics Facility (LAMPF). Because of its excellent radiation damage resistance at high temperatures, good chemical stability and reasonable mechanical and physical properties SiC is believed to have a good potential - which must be developed - as candidate ceramic for radiatively cooled first wall structures of fusion devices. The ceramics proposed for the irradiation are developed with regard to increased thermoshock resistance of bulk SiC bodies. Post irradiation thermoshock and bending tests should demonstrate how the improved properties of those specially tailored silicon-carbides are affected by irradiation.

EXP. 987

FAST NEUTRON IRRADIATION SCREENING TEST OF POLYCRYSTALLINE GRAPHITES UNDER FIRST-WALL FUSION CONDITIONS

Spokesmen: W. Delle, J. Linke, W. Lohmann, KFA-Jülich,
W. F. Sommer, Los Alamos
KFA-Jülich: L. Binkele, W. Delle, G. Haag, J. Linke, W. Lohmann
Los Alamos: R. D. Brown, W. F. Sommer

Three grades of polycrystlalline graphites, which have been investigated with respect to their homogeneity, low impurity content and thermal shock resistance - EK 98, FP-219 and 5890 PT - are proposed for the irradiation test under fusion conditions in the Los Alamos Meson Physics Facility (LAMPF).

EXP. 988

DOUBLE-ISOBARIC-ANALOG RESONANCE IN HEAVY NUCLEI

Spokesmen: R. Gilman, University of Pennsylvania, C. L. Morris,
Los Alamos
University of Pennsylvania: M. Burlein, H. T. Fortune, J. D. Zumbro
New Mexico State University: G. R. Burleson, K. S. Dhuga, J. Faucett,
M. Rawool
Los Alamos: S. J. Greene, C. L. Morris
University of Texas: C. F. Moore, S. Mordechai, D. S. Oakley,
M. J. Smithson

Interesting results have emerged from our recent study of the properties of the double-isobaric-analog resonance of ^{208}Pb(gs). The state is observed with a greater than expected width at a higher than expected excitation energy. We propose to study the properties of three additional double-isobaric-analog resonances, of ^{138}Ba(gs), ^{209}Bi(gs), and ^{238}U(gs).

EXP. 989

INVESTIGATION OF ENERGY AND MASS DEPENDENCE OF LARGE-ANGLE PION-NUCLEUS ELASTIC SCATTERING ACROSS THE RESONANCE REGION

Spokesman: K. S. Dhuga, New Mexico State University
New Mexico State University: G. R. Burleson, K. S. Dhuga, J. A. Faucett
Los Alamos: R. L. Boudrie, W. B. Cottingame, S. J. Greene, C. L. Morris, Z. F. Wang
University of Minnesota: D. Dehnhard, S. Seestrom-Morris
University of Pennsylvania: J. D. Zumbro
University of Texas: J. Garza, J. McDonald, C. F. Moore, S. Mordechai, A. Williams

We propose to measure π^+ elastic scattering on ^{6}Li and ^{28}Si (at 115, 162, and 226 MeV) and on ^{58}Ni at 162 MeV, over the angular range 115 to 180°, using the large-angle scattering setup at EPICS. Forward-angle measurements in the range 20 to 120° are also requested. These include π^+ elastic measurements on ^{6}Li (at 115, 162, and 226 MeV), on ^{12}C and ^{28}Si at 115 MeV, and a partial distribution on ^{40}Ca at 163 MeV, using the standard scattering setup. From the complete angular distribution data, we expect to extract the energy dependence of the higher-order terms in the optical potential and also, be in a position to investigate any mass dependent features pertinent to large-angle pion-nucleus scattering. The total data production time requested is 360 hours.

EXP. 990

PION SINGLE CHARGE EXCHANGE ON THE DEUTERON

Spokesmen: R. A. Loveman, R. J. Peterson, University of Colorado, M. A. Moinester, Tel-Aviv University
University of Colorado: J. T. Brack, B. L. Clausen, J. J. Kraushaar, R. A. Loveman, R. J. Peterson, R. A. Ristinen, J. L. Ullmann
Los Alamos: H. Baer, J. D. Bowman, F. Irom
Case Western Reserve University: W. Fickinger, K. Robinson
George Washington University: W. Briscoe
Catholic University: H. Crannell, D. Sober
Tel-Aviv University: M. A. Moinester

We request 690 hours of beam time with the π^0 spectrometer on the LEP beam line to measure angular distributions at three energies (65, 143, and 256 MeV) and two eight-point excitation functions at fixed q for the $D(\pi^+,\pi^0)2p$ and $D(\pi^-,\pi^0)2n$ reactions. The three beam energies are those at which precise comparisons of π^+ and π^- elastic scattering on the deuteron are complete and the greatest differences are found between π^+D and π^-D total cross sections. We will maintain an accuracy of ±2% in the charge asymmetry measurements for the spin-isospin-transfer channel to complement the total and elastic scattering work. The data will comprise the first thorough study of pion-induced spin and isospin scattering, examining the modifications of the elementary reaction mechanism in the simplest of nuclear environments.

EXP. 991

CONTINUATION OF THE INVESTIGATION OF THE ENERGY, MASS, AND CHARGE DEPENDENCE OF PION-NUCLEUS ELASTIC SCATTERING NEAR 180°

Spokesman: G. R. Burleson, New Mexico State University

New Mexico State University: G. R. Burleson, D. S. Dhuga, J. A. Faucett
Los Alamos: R. L. Boudrie, W. B. Cottingame, S. J. Greene, C. L. Morris, Z. F. Wang
University of Minnesota: D. Dehnhard, S. Seestrom-Morris
University of Pennsylvania: J. D. Zumbro
University of Texas: C. F. Moore, S. Mordechai

In previous work, we have measured excitation functions for $\pi^\pm$ scattering on ^{12}C, ^{16}O, and ^{40}Ca near 180°, over portions of the energy range 100 to 300 MeV. A region of large $\pi^\pm$ differences was found near 150 MeV, with indications of another such region above 200 MeV for higher masses. The energy variation of these excitation functions is in qualitative (but not quantitative) agreement with new predictions of models of pion-nucleus scattering, as well as with new calculations of the classical scattering of light from strongly-absorbing spheres (which also give qualitative agreement with experimental angular distributions). The data suggest that the cross section near 180° varies roughly as $\sim R^{-4}$ above ~200 MeV, an unexpected result, but not enough data are available to establish this. We wish to take more data to verify this feature, if it exists, as well as to search for additional $\pi^\pm$ differences, which we feel will give useful information about the pion-nucleus amplitude, because of the opposite signs of the Coulomb distortion. To do this, we propose additional measurements of pion scattering on ^{40}Ca and ^{28}Si near 180°.

EXP. 992

EXCITATION FUNCTIONS FOR MAGNETIC TRANSITIONS IN ^{24}Mg AND ^{28}Si

Spokesman: M. A. Plum, Los Alamos

Los Alamos: C. L. Morris, M. A Plum
University of Colorado: R. J. Peterson
New Mexico State University: K. S. Dhuga
University of Minnesota: S. J. Seestrom-Morris
University of Pennsylvania: J. D. Zumbro

We propose to measure π^+ scattering excitation functions for 1^+ states in ^{24}Mg and ^{28}Si. Measurements will be for beam energies of $T_\pi = 100$, 130, 160, 190, 220, 250, and 280 MeV, with one angular distribution per nucleus at 160 MeV. Results will be used to determine the extent of Fermi motion contributions to the π-N reaction mechanism.

EXP. 993

STUDY OF π ABSORPTION BELOW THE $\Delta_{3/2,3/2}$ RESONANCE REGION

Spokesmen: R. D. Ransome, Rutgers University, C. L. Morris, Los Alamos
Rutgers University: C. L. Glashausser, R. Fergerson, R. D. Ransome
Los Alamos: K. W. Jones, J. McGill
University of Pennsylvania: J. D. Zumbro
University of Texas: C. F. Moore
New Mexico State University: G. S. Kyle
Arizona State University: B. G. Ritchie

We propose to measure the cross section for π^+ and π^- absorption on ^{12}C, ^{58}Ni, and ^{208}Pb, in which the final state includes two or more free protons. Data will be taken for π energies of 50, 100, 150, and 200 MeV. The energy and angular distributions of the outgoing protons will be measured using a large solid angle BGO detector.

EXP. 994

STUDY OF π ABSORPTION ABOVE THE $\Delta_{3/2,3/2}$ RESONANCE REGION

Spokesmen: R. D. Ransome, Rutgers University, C. L. Morris, Los Alamos
Rutgers University: C. L. Glashausser, R. Fergerson, R. D. Ransome
Los Alamos: K. W. Jones, J. McGill
University of Pennsylvania: J. D. Zumbro
University of Texas: C. F. Moore
New Mexico State University: G. S. Kyle
Arizona State University: B. G. Ritchie

We propose to measure the cross section for π^+ and π^- absorption on ^{12}C, ^{58}Ni, and ^{208}Pb, in which the final state includes two or more free protons. Data will be taken for π energies of 200, 300, 400, and 500 MeV. The energy and angular distributions of the outgoing protons will be measured using a large solid angle BGO detector.

EXP. 995

ENERGY DEPENDENCE OF π^+ AND π^- SCATTERING TO LOW-LYING STATES IN ^{208}Pb

Spokespersons: S. J. Seestrom-Morris, University of Minnesota,
C. F. Moore, University of Texas
Los Alamos: C. L. Morris
University of Texas: C. F. Moore, M. J. Smithson

University of Minnesota: N. M. Hintz, M. A. Franey, S. J. Seestrom-Morris
University of Pennsylvania: J. D. Zumbro

We propose to measure angular distributions for π^+ and π^- scattering to low-lying collective states in ^{208}Pb at T_π = 120 and 250 MeV. These data will be used to identify π-nucleus reaction mechanism effects that could explain the energy-dependent values of M_n/M_p extracted for the Giant Quadrupole Resonance in ^{208}Pb. In particular, emphasis will be placed on obtaining high quality data for the 2_1^+ and 3_1^- states over a large angular range. Since the proton matrix elements extracted for the GQR vary with pion energy and are much smaller than expected, the comparison of proton matrix elements for these states with the electromagnetic values is extremely important.

EXP. 996

A SEARCH FOR THE ^{5}Li + π^- STATE IN ^{5}He

Spokesman: J. D. Zumbro, University of Pennsylvania
Los Alamos: K. W. Jones, C. L. Morris, J. F. Amann
University of Pennsylvania: R. Gilman
University of Minnesota: S. J. Seestrom-Morris
University of Texas: C. F. Moore

We propose to investigate the ^{7}Li(p,^{3}He)^{5}He reactions in the region of excitation energy equal to m_π and near zero momentum transfer. A measurement of $\frac{d^2\sigma}{d\Omega\, dp}$ which is enhanced in the region of excitation energy equal to m_π would indicate the existence of a state in ^{5}He which is made up of a π^- bound to ^{5}Li. If such a state(s) is observed, we propose to measure $\frac{d\sigma}{d\Omega}(E_\tau)$ to determine the width and excitation energy of this state(s).

EXP. 997

SPIN-FLIP CROSS SECTION FOR INELASTIC PROTON SCATTERING FROM ^{12}C AND ^{16}O AT 319 MeV

Spokesmen: F. T. Baker, University of Georgia, C. Glashausser, Rutgers University, K. Jones, Los Alamos
University of Georgia: F. T. Baker
Rutgers University: E. Donaghue, R. Fergerson, C. Glashausser, A. Green
Los Alamos: K. Jones
University of Minnesota: S. Nanda

Orsay: L. Bimbot

The spin flip cross section σS_{nn} will be measured for ^{12}C and ^{16}O at 319 MeV at the HRS over the excitation energy region from about 10 MeV to 41 MeV from 3° to 18° with good statistics. The targets are important both for fundamental physics and for experimental reasons. We will look for evidence of M1 strength due to ground state correlations and for evidence of spin-flip dipole resonances. Data are needed also to subtract contaminants from ^{40}Ca and ^{48}Ca spectra and to measure the sensitivity and systematic errors in the extraction of spin excitation strengths via the spin-flip method.

EXP. 998

THE $^4He(\pi,\pi'p)^3He$ REACTION - A TEST OF CHARGE SYMMETRY

Spokesmen: C. L. Morris, Los Alamos, D. Dehnhard, University of Minnesota
University of Minnesota: D. Dehnhard, S. K. Nanda, S. J. Seestrom-Morris
Los Alamos: C. L. Morris
University of Texas: C. F. Moore, M. Bryan
University of Pennsylvania: J. D. Zumbro

Comparisons of photo-proton and photo-neutron breakup of ^4He have provided evidence for a large violation of charge symmetry in the ^4He system. In a recent review of this body of data Calarco, Berman, and Donnelly conclude that while the ratio of cross sections, $R=\sigma(\gamma,p)/\sigma(\gamma,n)$, is nearly two at the peak of the giant dipole resonance, the best available calculations do not predict significant deviations from unity. Precision cross sections have recently been measured for $\pi^{\pm}$ inelastic scattering from ^4He. In contrast to the photonuclear studies, the results of this experiment appear to be consistent with a small amount of isospin mixing induced by the Coulomb force. The measured ratio, $R_\pi=\sigma(\pi^+)/\sigma(\pi^-)$, is 1.03 at the peak of the dipole. We propose to measure decay protons in coincidence with $(\pi^{\pm},\pi^{\pm\prime})$ to resolve this apparent discrepancy.

EXP. 999

STUDY OF PION DOUBLE CHARGE EXCHANGE REACTIONS $^{128}Te(\pi^+,\pi^-)^{128}Xe(g.s.)$ AND $^{130}Te(\pi^+,\pi^-)^{130}Xe(g.s.)$

Spokesmen: A. Fazely, Louisiana State University, L. C. Liu, Los Alamos
Louisiana State University: A. Fazely
Los Alamos: R. J. Estep, S. J. Greene, F. Irom, L. C. Liu
Ohio State University: E. Smith, M. Timko

We propose to measure forward-angle nonanalog $0^+(g.s.) \rightarrow 0^+(g.s.)$ double charge exchange (DCE) cross sections for ^{128}Te and ^{130}Te in the Δ_{33} resonance region. The DCE 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 DCE cross section, the measured cross sections can be used to set a tighter limit on lepton number violation. Furthermore, the extent to which the nuclear structure of these nuclei differs will have important implication on the understanding of the ratio of $\beta\beta$-decay rates of these two nuclei. These measurements also provide a global test of the A-dependence of the nonanalog DCE cross sections.

EXP. 1000

CROSS SECTIONS FOR THE (p,π^+) REACTION ON ^{12}C, ^{13}C, AND ^{14}N

Spokespersons: D. Dehnhard, S. J. Seestrom-Morris, University of Minnesota, K. W. Jones, Los Alamos
Los Alamos: J. F. Amann, K. W. Jones, C. L. Morris
University of Pennsylvania: J. D. Zumbro
University of Minnesota: D. Dehnhard, M. Gazzaly, S. Nanda, S. J. Seestrom-Morris
Rutgers University: R. W. Fergerson

We propose to measure cross sections for the reaction (p,π^+) on the targets ^{12}C, ^{13}C, and ^{14}N a proton energy of 650 MeV. Our objective is to measure the relative strengths with which 4^- (^{14}C) and $9/2^+$ (^{13}C, ^{15}N) states of differing structure are populated. Such a comparison may yield new information on the (p,π^+) reaction mechanism.

EXP. 1001

STUDY OF DOUBLE-ANALOG TRANSITIONS AT PION ENERGIES 20 TO 80 MeV

Spokesmen: H. W. Baer, 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. Morris
Tel-Aviv University: E. Piasetzky
Arizona State University: J. R. Comfort, J. N. Knudson
University of Pennsylvania: R. Gilman
Virginia Polytechnic Institute: D. H. Wright

We propose to extend low-energy measurements of double-analog transitions along three lines of investigation: (1) DIAS measurements on ^{48}Ca and ^{44}Ca. We propose to complete the angular distribution measurements on ^{48}Ca at 35 MeV and to measure ^{44}Ca at the same energy. These data are necessary to separate the (N-Z) and A-dependence. Since there appears to be a strong energy dependence in the DIAS we also propose measurements on ^{48}Ca at 50 and 65 MeV; (2) Extend the measurements on ^{14}C to 20 MeV and complete the 65 and 80 MeV measurements. ^{14}C is our test case for DIAS transitions because we are able to measure the angle-integrated cross section, σ_{DIAS}, vs. T_π and $d\sigma/d\Omega_{DIAS}$ vs. Θ over a broad range of angles and energies between 20 and 80 MeV. These data will provide a basis for the study of N-N correlations in DCX, and will serve as the foundation for extending our understanding to DCX on other nuclei; (3)

DIAS transitions in heavy nuclei. The first measurements will be of the DIAS transition in $^{90}Zr(\pi^+,\pi^-)$ at 40 MeV. In addition, exploratory runs are proposed for ^{120}Sn and ^{208}Pb to determine the feasibility of such measurements; (4) The DIAS transition in ^{58}Ni at 30 or 50 MeV (depending on feasibility). This is the heaviest stable T=1 nucleus and its measurement will complete the T=1 systematics.

EXP. 1002

ENERGY DEPENDENCE OF THE $(\pi^+,2\pi^+)$ REACTION IN COMPLEX NUCLEI

Spokesmen: B. J. Dropesky and L. C. Liu, Los Alamos
Los Alamos: A. Cui, B. J. Dropesky, R. J. Estep, G. C. Giesler, L. C. Liu, C. J. Orth

We propose to investigate the energy dependence of the total cross section of the $(\pi^+,2\pi^+)$ reactions to all particle-bound states in aluminum, vanadium, and copper. 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 $A(\pi^+,2\pi^+)B^*$ cross sections. There is considerable theoretical interest in the energy dependence of $(\pi,2\pi)$ cross sections in heavy nuclei because this reflects some new aspects of Δ dynamics. So far, there are no systematic data available addressing this question; our study will provide such data. The cross sections for the reactions $^{27}Al(\pi^+,2\pi^+)^{65}Ni$(9.4 min), ^{51}Ti(5.8 min), and $^{65}Cu(\pi^+,2\pi^+)^{65}Ni$(2.5 h) will be determined at 350, 400, and 450 MeV by measuring the yields of the radioactive products.

EXP. 1003

PRODUCTION OF LONG-LIVED RADIONUCLIDES BY STOPPED NEGATIVE MUONS

Spokesman: R. C. Reedy, Los Alamos
UC San Diego: J. R. Arnold, K. Nishiizumi
University of Cologne: P. Englert
University of Pennsylvania: J. Klein, R. Middleton
UCSD & Physical Research Laboratory, India: D. Lal
Los Alamos: R. C. Reedy

A small number of targets will be irradiated with stopped negative muons in the Stopped Muon Channel. 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.

EXP. 1004

MEASUREMENTS OF η-MESON MASS IN FREE SPACE AND IN NUCLEI

Spokesmen: J. C. Peng and J. E. Simmons, Los Alamos, spokesmen
Los Alamos: J. D. Bowman, F. Irom, J. Kapustinsky, M. J. Leitch, T. K. Li, J. C. Peng, J. E. Simmons

We propose to measure the mass of η meson with the neutron time-of-flight technique and with the NaI spectrometer detecting $\eta \rightarrow 2\gamma$ decay. The reaction $\pi^- p \rightarrow \eta n$ will be used in these measurements. The NaI spectrometer will also provide a calibration of the beam momentum through the measurement of $\pi^0 \rightarrow 2\gamma$ decay from the $\pi^- p \rightarrow \pi^0 n$ reaction.

After the mass of η meson in free space is measured, we propose to use the NaI spectrometer to measure the mass of low energy η mesons produced in a nucleus. The purpose is to search for any possible η mass shift in nuclei.

EXP. 1005

RELATIVISTIC EFFECTIVE MASS RENORMALIZATIONS OF CONTINUUM POLARIZATION OBSERVABLES

Spokesman: J. M. Moss, Los Alamos
University of Colorado: J. R. Shepard
Los Alamos: T. A. Carey, K. W. Jones, J. B. McClelland, J. M. Moss, L. Rees, N. Tanaka
Indiana University Cyclotron Facility: A. D. Bacher
RCNP, Osaka, Japan: H. Sakai
Massachusetts Institute of Technology: C. Horowitz

We propose to measure complete sets of Wolfenstein parameters for inclusive 500-MeV (p,p′) scattering from ^2H and ^{40}Ca in the vicinity of the quasi-elastic peak at θ_L = 10°, 18.5°, and 22.5°. The objective is to search for evidence of relativistic effective mass effects on the polarization observables. Comparison of ^2H and ^{40}Ca under identical conditions yields the bulk nuclear matter effect with minimal model or experimental uncertainty.

A newly developed model by Horowitz and Iqbal provides justification as well as specific predictions for the experimental observables. It also makes clear the features of continuum scattering measurements which make them complementary to elastic and inelastic scattering for tests of Dirac-based theories.

EXP. 1006

A SEARCH FOR A NARROW RESONANCE IN THE B=2 SYSTEM USING THE $\pi^+ d \to p+p$ REACTION

Spokesmen: G. Pauletta, University of Texas, M. Gazzaly, University of Minnesota, N. Tanaka, Los Alamos.
University of Texas: M. Barlett, G. Hoffmann, G. Pauletta
University of Udine: P. Cauz, R. Garfagnini, L. Santi
University of Minnesota: M. Gazzaly, N. Hintz
Los Alamos: C. Morris, N. Tanaka

We propose to verify the existence of narrow resonance structure reported near threshold of the $pp \to d\pi^+$ reaction by measuring an excitation function for the inverse reaction at low pion energies. We propose to use the LEP channel to measure the excitation function with a resolution of $\lesssim$ 300 keV and a total uncertainty of $\lesssim$ 1.3% between 20 and 40 MeV incident pion energy. This resolution and precision should be more than adequate to reveal the narrow structure reported at S=2.04 GeV in the inverse reaction.

EXP. 1007

COMPARISON OF NSF-MINIMUM IN $\pi^{-3}H$ AND $\pi^{+3}He$ ELASTIC SCATTERING

Spokesmen: B.M.K. Nefkens, UCLA, and W. J. Briscoe, George Washington University
UCLA: S. D. Adrian, D. B. Barlow, A. D. Eichon, G. J. Kim, B.M.K. Nefkens, C. Pillai, J. A. Wightman
George Washington University: B. L. Berman, W. J. Briscoe, A. A. Mokhtari, M. Taragin
Abilene Christian University: M. E. Sadler
Ruder Boskovic Institute, Zagreb: I. Slaus

We propose to measure the absolute differential cross sections for the elastic scattering of π^- on ^3H and π^+ on ^3He at T_π = 100, 140, 180, and 220 MeV in the region of the non-spin-flip-dip around θ_π = 75° using the EPICS facility. Some measurements are planned as well for π^+ on ^3H and π^- on ^3He. The target cells are the LAMPF-UCLA pressurized gas cylinders, the same as the ones used in our recently completed Exp. #905.

EXP. 1008

STUDY OF THE MASS AND ENERGY DEPENDENCE OF LOW ENERGY PION SINGLE CHARGE EXCHANGE AT 180°

Spokesmen: F. Irom and J. D. Bowman, Los Alamos
Los Alamos: H. W. Baer, J. D. Bowman, F. Irom, M. J. Leitch
Tel-Aviv University: E. Piasetzky
University of Colorado: B. L. Clausen, R. A. Loveman, R. J. Peterson
Utah State University: S. R. Rokni
Arizona State University: J. N. Knudson

We propose to measure the energy and mass dependence of the 180° pion single charge exchange cross section to the isobaric analog state for ^{7}Li, ^{14}C, ^{39}K, and ^{120}Sn at pion energies 35, 50, 65, and 80 MeV.

EXP. 1009

PION SCATTERING FROM ^{206}Pb--HOW FAR CAN PIONS PROBE INTO THE NUCLEAR INTERIOR?

Spokesman: F. W. Hersman, University of New Hampshire
University of New Hampshire: J. R. Calarco, J. Connelly, J. H. Heisenberg, F. W. Hersman, J. Wise
University of Minnesota: S. Seestrom-Morris
University of Maryland: J. Kelly
University of Florida: J. Carr

We propose to measure cross sections for charged pions scattering inelastically from ^{206}Pb. Theoretical studies indicate that, of all nuclei, ^{206}Pb can exhibit the most significant qualitative and quantitative differences between neutron and proton transition densities. The large size of the nucleus will allow the most precise determination of the penetration of the pion probe into the interior, and its potential utility as a quantitative probe of neutron densities. This experiment is part of an electron-proton-pion-multiprobe study, with the electron experiment complete.

EXP. 1010

MEASUREMENTS OF SPIN-FLIP CROSS SECTION ANGULAR DISTRIBUTIONS FOR E_X < 40 MeV IN ^{124}Sn

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Angular distributions of spin-flip cross sections will be measured for inelastic scattering of 319 MeV protons from ^{124}Sn. The objective of the experiment is to deduce the multipole composition for the excitation region 4 MeV < E_X < 41 MeV as a means of searching for "missing" M1 strength. It is hoped to determine L=0, 1, and 2 components of the $\Delta S=1$ spectrum; in order to do this, data will be acquired over an angular range of 2.5° - 12.5°.

EXP. 1011

NON ANALOG DCX - SYSTEMATICS IN HEAVY NUCLEI

Spokesman: K. K. Seth, Northwestern University
Northwestern University: M. Artuso, B. Parker, K. Seth, R. Soundranayagam

From the data taken for non-analog g.s. to g.s. DCX transitions in N=Z nuclei with A $\leq$ 40 it has been concluded that $\sigma(5°)$ is proportional to $A^{-4/3}$. A model, involving double - Δ excitation, has been proposed to explain these observations. We point out that from the present experimental data, essentially limited to a subset of very special nuclei, it is very risky to draw general conclusions about the A-dependence of the non-analog cross sections. We propose to make good statistics measurements of $\sigma(5°)$ for the non-analog (π^+,π^-) ground state transitions for ^{88}Sr and ^{208}Pb targets. We believe that these measurements can establish the true trend of the data and can provide more discriminating tests of the theoretical models.

EXP. 1012

STUDY OF ANALOG DCX ON ^{88}Sr

Spokesman: K. K. Seth, Northwestern University
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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 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 DCX excitation of the 17.2 MeV analog state in the ^{88}Sr$(\pi^+,\pi^-)^{88}$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.

EXP. 1013

PION PRODUCTION ON THE CONTINUUM WITH POLARIZED PROTONS

Spokesman: K. K. Seth, Northwestern University
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In a recent experiment on ^{6}Li it has been found that both differential cross sections and analyzing powers for pion production in the continuum show remarkable similarity to those measured for transitions to discrete nuclear states. It is suggested that these measurements shed light on the common dominant mechanism for pion production in nuclei. It is proposed to measure $\sigma(\Theta)$ and $A_{y0}(\Theta)$ for pion production in the continuum from a series of nuclei in order to put the present observations on a firmer basis and to perhaps provide an insight into the pion production mechanism that has eluded us so far.

EXP. 1014

PROTON, SPALLATION NEUTRON AND FISSION NEUTRON IRRADIATION OF COPPER

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LAMPF 800 MeV proton, spallation neutron and fission neutron (Risø DR-3) radiation damage in copper will be analyzed to provide basic information concerning the role of helium and displacement damage generated during irradiation in microstructural evolution.

Irradiations will be carried out in the temperature range 250°C-400°C. Spallation neutron and fission neutron irradiations will be carried out to fluences of up to ~ 0.5 dpa. Direct proton beam irradiation will produce ~ 3 dpa in beam-centre for a single run cycle; lower dose specimens will be obtained further out on the Gaussian intensity profile.

Post-irradiation examination at Risø will be made using transmission electron microscopy, small angle neutron scattering and positron annihilation techniques. The microstructural observations will be complimented by post-irradiation mechanical tests.

EXP. #1015

LAMPF CHERENKOV DETECTOR

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This experiment proposes to measure $\sin^2\Theta_w$ to an accuracy of better than ±0.002 (±1%). This measurement is well into the region of radiative corrections and is, therefore, complementary to the measurements of m_z and m_w, which will be conducted at SLC and LEP. A rigorous universality test of $\sin^2\theta_W$ requires an independent low momentum transfer measurement. After all radiative corrections are made, the level to which the values of $\sin^2\theta_W$ agree is a significant test of the standard model.

The neutrinos will be generated from the decay of stopped pions and muons. Since the π^- are absorbed on nuclei in the beam stop, the resulting neutrinos come only from the decay processes

$$\pi^+ \rightarrow \mu^+ + \nu_\mu \text{ and } \mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu.$$

The ν_μ, $\bar{\nu}_\mu$ and ν_e from a beam stop source are produced in equal numbers with known spectral shapes. The short beam spill (270 ns) from the proton storage ring (PSR) allows a time separation of ν_μ from $\bar{\nu}_\mu$ and ν_e events. This experiment will measure the ratio of $\nu_\mu e$ to $(\bar{\nu}_\mu e+\nu_e e)$ scattering, and the events will be recorded concurrently, thereby avoiding the systematic errors associated with experiments that must retune beams for antineutrinos.

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