PROGRESS REPORT ON CONTRACT NO. EY-76-S-05-3509, August 1978

TITLE: Elementary Particle Physics at the Florida State University

This report covers the eleven-month period from 1 September 1977 to 31 July 1978. Because this report is being prepared in the summer between data-taking runs at SLAC and BNL, it is not as polished as usual. However, as you will see, it has been a very busy and exciting period of research.

The experimental efforts during this period fell into three groups: (1) equipment construction in preparation for new experiments to be run at SLAC and BNL, (2) first-phase calibration runs with apparatus at SLAC and BNL, and (3) continuing analysis of experimental data obtained in the previous years.

The theoretical efforts have been concentrated in three broad areas: (1) the study of the interaction of quarks and gluons as described by the theory of quantum chromodynamics, (2) the study of hadron diffraction, and (3) a continuing study of the theory of the gravitational interaction.

The highlight of this period was the very successful international conference held here at FSU in honor of Paul A.M. Dirac, entitled "Current Trends in Field Theories" or "50 Years of the Dirac Equation." (See a copy of the program as Enclosure D.3.) The conference was attended by about 75 people, including a number of outstanding theoretical physicists from Europe and the U.S.A. The proceedings will be published as part of the A.I.P. Conference Series.

I. Logistics

A. Personnel

John R. Albright has been promoted to Full Professor. Research Associate William Morris, who has been working for us full time at BNL, has accepted at staff position at Brandeis University effective July 1, 1978. Fortunately, he will continue to work with us as a collaborator on the BNL-MPS Ξ* experiment. Also, David Gluch (collaborator at FAMU) accepted a position with the Schlumberger Corporation in Houston, Texas.

A search for a new faculty theorist at the Assistant Professor level was put off until next year after the prime candidate declined our offer because he had found higher rank possibilities in Germany.

Norberto Ezquerra completed his Ph.D. Two new graduate students have joined our group: Joe Norton and John Piper. Thus, at present we have 8 graduate students in the program.

B. Facilities

Our most obvious facility upgrades were made in three independent areas: (a) the second K^+ detector for the BNL MPS Ξ* experiment was completed and checked out; (b) the lead-glass wall gamma-ray detector and its associated electronics was completed and used in a first-phase calibration run; and (c) an 8080 microprocessor was completed and programmed for use with one IPD.

II. Experimental Research Program:

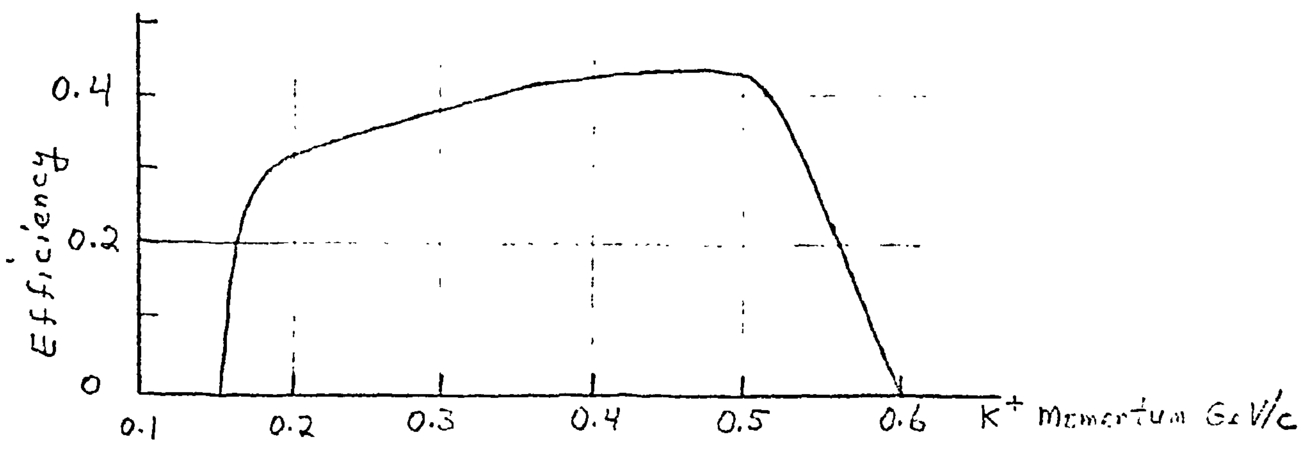
A. Ξ^* Search at Brookhaven National Laboratory Using the Multiparticle Spectrometer (MPS)(Expt. 673)

This is an approved 500-hour experiment where the expected starting date of the preliminary data-taking is in August 1978, with the bulk of the data scheduled to be taken during November and December of 1978. Briefly, the experiment uses a K^- beam with a momentum of about 5 GeV/c and triggers on a slow K^+ so that what remains is a baryon with two units of negative strangeness. To detect the slow K^+ a brass-scintillator sandwich with an active area of 62 cm x 100 cm was borrowed from Imperial College (London). During the past year we completed building and testing a larger K^+ detector, 110 cm x 140 cm, which has 2.5 times the area of the borrowed one. We plan to use both K^+ detectors.

This experiment was approved together with another Ξ^* search experiment proposed by Brandeis and Syracuse universities. Since the other experiment uses a multiplicity trigger at a beam momentum of 2.5 GeV/c, the two experiments are incompatible and cannot take data simultaneously. Since then Syracuse has effectively pulled out because of their commitment to the Cornell intersecting e^+e^- facility; so Brandeis most likely will join our experiment, but so far neither Brandeis nor Syracuse has contributed to the preparation of this experiment. This experiment is in collaboration with BNL. During the past year the major effort for the preparation of this experiment has been made by FSU, mainly in building and testing the new K^+ detector and designing and buying parts for the electronics needed (BNL constructed the electronics under our supervision).

During the summer of 1977 we at FSU completed the fabrication of all the needed light guides for the new K^+ detector. Assembly and testing started in the fall of 1977. Until July 1978 we had a research associate permanently at BNL, and in addition several of us (including advanced graduate students) have made over 10 trips to BNL. Presently (summer of 1978) we have two advanced graduate students at BNL and another advanced graduate student spends 50% of his time there. The building and testing of the K^+ detector has been an FSU responsibility. In December 1977 one plane (out of 10) was completed and tested in the BNL unseparated beam. The test was successful and work progressed. The new K^+ detector, which has about 300 scintillators, 600 lightguides and 8 brass sheets weighing 1.5 tons, was completed and assembly finished by May 1978. We put the K^+ detector in the unseparated test beam at BNL in June 1978 and tested every plane. The detector worked better than expected; apparently our painstaking effort in polishing, bending and gluing paid off, leading to less light losses than we expected. Presently (July 1978) we have moved the K^+ detector in the Low-Energy Separated beam where separated K^+ mesons at various energies will be detected. As soon as the two-week shutdown is over we will measure the efficiency of K^+ detection as a function of momentum and incident angle.

The other progress that FSU can report is the completion of two programs. The first is a Monte Carlo computer program which calculates the theoretical efficiency of the K^+ detector as a function of angle and momentum using all known decay modes. The efficiency curve is sketched below.



An internal memo titled "Shystar" was written for this program (see Enclosure G.1). This program took 2 man-years to develop and complete. The second program that we (i.e. FSU) did was another Monte Carlo program to simulate the events in the MPS and so position various detectors and chambers to maximize the accuracy and overall sensitivity. Originally we had hoped to be able to have a sensitivity of 1500 events/μb but as a result of our efforts at repositioning the smaller K^+ detector closer to the target, we are now confident that our sensitivity will exceed 2000 events/μb.

<u>A Short Review of the Physics of the Experiment</u>. This experiment will use a K^--beam of about 5 GeV/c and a slow K^+-trigger to fire all the spark chambers in the MPS. Every time a K^- goes in and a K^+ comes out a change of two units of strangeness occurs. This trigger detects most of the cascade resonances, as well as other final states which are not cascade resonances, e.g. Ω^-.

We estimate that this experiment will have a sensitivity of 2000 events per microbarn. This has been verified by our Monte Carlo calculation. The physics background of this experiment is that only two or possibly three cascade resonances are confirmed. Recently three bubble chamber experiments, with sensitivities of the order of 100 events per microbarn, have reported approximately 10 different cascade resonances. Upon looking at these data carefully, it is obvious that most of these claims are statistical fluctuations. In addition, another experiment using the streamer chamber at SLAC has also searched for the cascade resonances with a sensitivity of about 70 events per microbarn; they do have many peaks but they do not have the same masses as those of the bubble chamber experiments. So we say that the field of cascade resonances is very much confused at the present time, and not much is expected to happen in the future, until our MPS experiment runs. SU(3) symmetry predicts the existence of a Ξ^* for each octet and a Ξ^* for each decuplet, so this experiment will provide a good test of this model.

This MPS experiment has been one of the two major projects that our experimental group has undertaken in the past year. This one is a complete departure from our previous type of experiment with bubble chambers, but, when you come right down to it, except for the building of the K^+-detector and the data-taking, the analysis and the computations are very similar to those we have always done in bubble chambers, with the exception that we have eliminated the intermediate film. So we feel quite confident that we can carry this experiment to a successful conclusion.

The Spokesperson of this experiment is S.U. Chung of BNL. Since Dr. Chung is also the Spokesperson for another MPS experiment and is quite busy with that experiment, V. Hagopian has taken on the de facto leadership of this experiment.

In addition, it is appropriate to mention here that a letter of intent, proposing that we use the MPS again when it is upgraded, has been submitted to BNL (see Enclosure E.1).

B. π^+d Using the 40-Inch Bubble Chamber With a Lead-Glass Wall at SLAC (Expt. #BC-67)

This experiment is being done in collaboration with Duke University, the University of Tennessee, Oak Ridge National Laboratory and the State University of New York at Albany. In December 1976 we proposed to use the 40-inch bubble chamber at SLAC and to build a lead-glass wall to be placed behind the bubble chamber in order to trigger on gamma-rays. We requested 40-million bubble chamber expansions and assuming we would get a 5% picture-taking trigger rate it would comprise a 2-million-picture exposure. We got approval, as a first stage, for ten million expansions to be operated in a triggered mode.

Basically, the experiment entails use of the 40-inch bubble chamber at SLAC in conjunction with the lead-glass blocks obtained by SLAC and LBL for use at SPEAR. These lead-glass blocks were used in Mark I and were made available for other experimental users until they are needed again for PEP. We will trigger the camera whenever there is a large deposition of photon energy in a portion of the lead-glass wall; several interesting reactions can be studied in this fashion. In particular we propose to study the following π^+d interactions.

$$
\begin{aligned}
\pi^+ d &\rightarrow \pi^o_{forward}\ \pi^+ pn \\
&\rightarrow \pi^o \pi^o pp \\
&\rightarrow \eta^o \pi^+ pn \\
&\rightarrow \omega^o \pi^+ pn \\
&\rightarrow \pi^o \eta^o pp \\
&\rightarrow \pi^o \omega^o pp \\
&\rightarrow \pi^+ \pi^- \pi^o pp \\
&\rightarrow \rho^+ d \\
&\rightarrow \pi^+ \pi^o \pi^o d \\
&\rightarrow \pi^+ \omega^o d
\end{aligned}
$$

It will be necessary to place wide-angle γ-ray conversion plates in the 40-inch bubble chamber. By using the resolution of the wall we should be able to study reactions with two neutral particles; this opens an essentially unexplored domain. We propose to use 18 to 20 GeV/c incident π^+, which would produce mesonic masses up to 3 GeV/c^2. By concentrating on the reactions which are not dominated by Pomeron exchange, we hope to do a sensitive search for high-mass resonances.

The physics of this experiment should be quite unique in that it will be one of the first bubble chamber experiments to have a very high efficiency for detecting γ-rays and accurate measurement of primary tracks. Not only will we know the position of the γ-rays, but we will also know their energy to within a few percent, allowing us to do fairly good π^o physics. Since a large fraction of the events have π^o's in the final states it is necessary to select out a subsample. We have not quite settled all the details of the triggering, but we can say that using the on-line NOVA computer attached to the 40" bubble chamber some extraordinary triggers can be set up, e.g. we may be able to set for only gammas which come from η or ω, so we could study final states which have η^o or ω^o. We are not quite certain how well we can do with a lot of these triggers, but the first run of 10 million pulses ought to tell us in detail how far we can push this new technique of doing π^o physics.

Our group at FSU took the prime responsibility for the construction of the lead-glass wall. This entailed taking apart the lead-glass wall which was used by the SLAC-LBL group in Mark I and putting it together in a new configuration. This involved the unwrapping, cleaning, and gluing of 88 pairs of lead-glass blocks (each weighing about 50 pounds), and then re-wrapping them as double-block sets.

At the beginning of this report period, September 1977, we had just completed the mechanical-optical construction of the back blocks of the lead-glass wall - 88 double blocks of 20 radiation lengths and 64 single blocks, each with its photomultiplier tube attached and stacked 8 wide and 19 high (i.e., 4' wide and 8' high). In September the installation of the active converter stack of 52 lead-glass blocks 6' wide and 8' high and 4" thick was completed.

During the next eight months: (1) the University of Tennessee and FSU physicists prepared 206 scintillator rods and light guides for the two hodoscope planes. UT wrapped them, attached phototubes, tested each element, and put it all together into hodoscope planes at SLAC.

(2) The housing for the lead-glass wall was designed, constructed, and installed. Air conditioning was installed.

(3) All blocks and hodoscope elements were cabled to J-panels in the housing. The calibrating light emitting diode system - pulser and light fibers to each block - was installed. The Americium and NaI radioactive-source calibrating system was installed.

(4) Tests were made comparing the radioactive sources and the LED pulses for all blocks.

(5) A 9-double-block system with phototubes was constructed as a test section of the wall. This was then put into an electron beam in January 1978 to determine the efficiency of the blocks as calorimeters. For this run C. Frank Rydeen built an LSI 11 on-line system and wrote programs for it to help record data, store them on tape, and plot them on a Tektronix 4010 during the test. In about a month of running, a great deal of experience was gained regarding what to expect when the total system was implemented. Tests were made with various energy electrons and with lead glass and lead slabs in front of the blocks. In addition, a study was made of the effect of changing the frequency spectrum of the light pulses to be used for calibration. Cerenkov radiation and the LED's do not have the same light frequency spectrum.

(6) All cables, digital electronics, power supplies for the 410 phototubes, etc. were gathered and tested. In particular a Large Scale Digitizer (LSD), borrowed from LBL, was studied and tested somewhat. This was to be used to digitize the signals from the phototubes.

(7) Programs for the foreground control and background on-line analysis were written. Testing these had to wait until we got the NOVA computer and beam.

Then about June 10, 1978, physicists and graduate students from all the collaborating universities arrived at SLAC for a short test phase experimental run. During the first week, final construction, cabling, and tests were made of the wall, housing, interlocks, etc. On June 19 the wall system was moved into the bubble chamber building and by June 21 it was mounted on its tracks behind the bubble chamber. Installation of all cables (about 1000 of them) from the wall to the NOVA computer, LSD, and control electronics in Bldg. 233 was completed by June 27. We spent about seven days calibrating, checking out electronics, timing signals, adjusting beam, etc., etc., before any serious bubble chamber operation could be attempted on July 5. Considering the fact that this complex system had never been operated before, in spite of a variety of problems, the commissioning went well. The borrowed LBL LSD became our major weakness. But during this checking out period we also calibrated most of the back blocks using electron beams of known energy. In addition, the bubble chamber crew filled the chamber with deuterium - the first time in 9 years! Of course, there were some problems.

From July 5 through July 12, except for several periods of searching out component failures and power "brown outs" each afternoon, we actually took pictures with 16 GeV/c π^+ mesons into the deuterium-filled chamber - 28K pictures with the data on energy in the lead glass stored but not used as a trigger and 74K pictures with the trigger requirement that there be more than 8 GeV of energy in the lead-glass blocks.

Near the end of July, scanning has begun on some film at each laboratory and the magnetic tapes and the rest of the film were being shipped out of SLAC. We are in the process of unraveling everything in preparation for the full-scale run in October 1978.

C. π^+d at 15 GeV/c in the SLAC 82-Inch Bubble Chamber (BC-38)

This is a continuing experiment which has over 900,000 photographs and over 110,000 measured events. All the data-reduction, starting with scanning, was performed at FSU, with the exception of measuring the non-strange particles on the University of Pennsylvania HPD and the University of Tennessee Spiral Reader. Over 9 papers have already been published. The following represents specific progress on this experiment during the past year or so.

1. Multipion Production. An article is being written on the multipion final states which should be submitted for publication before September 1978. An extensive analysis of the six- and eight-prong events was completed; many partial cross sections and resonance-production cross sections were determined. Modified phase space calculations were performed to fit the data to multipion production. The model and the data agree extremely well. Essentially, the model uses phase space modified by an exponential t distribution of the nucleon (the peripheral model) and each generated event is weighted to make the average $<p_\perp>$ equal to the experimental value. The only fitted parameter is the overall normalization. One surprising determination is the fact that the average number of π^0's for any particular charge configuration is always about 2, whether there are two or seven charged pions. This surprising fact can only be explained as being the result of two competing concepts. The first is isospin which predicts an increasing number of π^0's with increasing number of charged pions,

the second is the kinematical limit of phase space which limits the total number of π's so the number of π°'s decreases with the increase in number of charged pions; the net result is a constant number of π°'s. Also presented in this paper are the 3π, 5π, and 7π coherent production. The partial cross section decreases sharply and exponentially with an increasing number of pions. This is not unusual, but no model has been able to predict such a sharp drop-off.

2. <u>$p\bar{p}$ and K^+K^- Final States</u>. This experiment yielded 143 events of $\pi^+n\rightarrow pp\bar{p}$ and 407 events of $\pi^+n\rightarrow K^+K^-p$. The $p\bar{p}$ and K^+K^- are mainly produced by pion exchange and show some of the known resonances. Upper limits were established for some of the new narrow baryonium states at this energy. A talk on this subject was given at the Washington, D.C., APS meeting (see Enclosure A.1.b).

3. <u>Higher-Mass 2- and 3-Pion Final States</u>. Several searches for higher-mass final states were performed using events which had high-$p_{\perp}$ pions. This technique, pioneered by us several years ago during a charm search, has isolated several higher-mass resonances. One paper on the two-pion final state, "Higher-Mass Mesons from 15 GeV/c π^+d Interactions," has been submitted for publication (see Enclosure C.2) and another paper on the 3π state is in draft form and should soon be submitted for publication. The higher-mass states observed so far are N*(1700), ω(1675), a 2π state at 1925 MeV, and possibly another 2π state at about 2350 MeV.

D. <u>250 and 360 GeV/c π^-p Experiment with the 15-Foot Fermilab Bubble Chamber (Expts. #234 and #384)</u>

The film from this experiment is being analyzed in collaboration with Russ Huson's group at the Fermi National Accelerator Laboratory. The exposure was made during October 1974 (Expt. #234) and 46K useful pictures were obtained with an average of 4 tracks per picture - a sensitivity level of about 1.2 events/millibarn. A second exposure of 20K pictures was obtained in February 1977 at 360 GeV/c as the first part of an approved exposure for 200K pictures.

The physics interests in this experiment have been manifold: reports have been published on a search for charm, inclusive strange particle production, a multiplicity study and correlation studies in strange particle events (see Enclosures B.7 and C.3). There are additional reports not yet published but essentially complete on inclusive strange resonance production, search for hadron jets, and an analysis of the two-component model for the pion production process.

During this report period work has continued on a systematic study of π° production at 250 GeV/c. The mean conversion probability for $\gamma\rightarrow e^+e^-$ in the 15-foot chamber is about 0.15 and is thus 0.02 for converting both photons from a π°. Taking advantage of this relatively high conversion probability for a hydrogen bubble chamber, we have gathered data on γ-conversions to make a statistically significant study of π° production versus various charged-particle multiplicities, Mueller's two-particle correlation moment $f_2^{\circ\circ}$ (which is predicted to have different values by the fragmentation model and the critical fluid model) and to compare γ cross section distributions with data at other energies.

Analysis and some measurements are still in progress; so far about 11,000 γ candidates have been measured, of which about 6,000 give 3C fits. A report on these data was made at the Washington APS (see Enclosure A.1.a) and the data will be published during the next few months.

In addition, some work has been done on (1) 4- and 6-prong events in order to collect a significant sample of exclusive events such as $\pi^- p \to (3\pi)p$ and $5\pi(p)$ to study diffraction dissociation; (2) cross section for direct electron pair production by 250 GeV/c π^- mesons; and (3) polarization of Λ's produced at 250 GeV/c.

Regarding the 360 GeV/c, we received a letter from Fermilab after the June 1978 PAC meeting, telling us formally what we already knew, that in view of the backlog of neutrino experiments planned for the 15-foot chamber, they estimated that all approved 15-foot chamber hadron experiments would be delayed for about two years. However, they stated that the approval of the experiment still stands and it would be run when possible.

E. Search for Resonances in $\pi^- p \to \Lambda\bar{\Lambda}(\pi^\pm)+X$ and $\pi^- p \to K_S^\circ K_S^\circ(\pi^\pm)+X$ at 300 GeV/c Using the Fermilab Multiparticle Spectrometer (Expt. #580)

A new proposal (P-580) was submitted to Fermilab in January 1978 to use the Fermilab MPS and the upgraded M6 beam line which will transport π's of 300 GeV/c, to search for narrow and broad resonances with masses up to 22 GeV. The search has been spurred on by the discovery of the T at 9.4 GeV and the T' at 10 GeV. It is likely that a whole family of resonances exists in the mass range around 10 GeV and the study of their properties and comparison with the predictions of the quark model is very important. And *if* the T is associated with a b quark, there may be another whole family associated with a t-quark at a somewhat higher mass range. Our MPS experiment can clearly separate such resonances from background if their $\sigma \cdot B(Res \to VV) \geq 2nb$. This collaboration has strengthened its counter-experience by adding VPI, Notre Dame, and Georgia Tech to the group and by participating in E-110 data-taking on the MPS. S. Hagopian of FSU and J. Poirier of Notre Dame presented this proposal to the Fermilab Advisory Committee on May 16, 1978. It was approved June 23, 1978 and is expected to run in the spring and summer of 1979. It is already scheduled for May 1979. (See Enclosure E.2.)

F. Neutrino Experiment at Fermilab

Last winter our proposal (#521) to put plates in the 15-foot bubble chamber, fill it with deuterium, and expose it to a beam of high energy neutrinos was considered by the Fermilab PAC. The idea of putting plates in the chamber had gained acceptance by the PAC after a common plate design, acceptable to the various plate proposals, had been achieved in October. Unfortunately for us the PAC awarded the experiment to a group which previously had an approved bare chamber neutrino-deuterium run and whose bare run was cancelled because of the advent of the plate proposals.

Fermilab went ahead with the construction of the plate system and the chamber was tested in May-June 1978 with discouraging results. The plate system was removed from the chamber and will be redesigned. Meanwhile, the neutrino-deuterium group is running with a bare chamber. As a result Proposal 521 may be resubmitted to the PAC, because of the physics merits of the plate system

We have recently explored the possibility of joining an already approved neutrino bubble chamber experiment, because there is still much physics to be done. We have measured a small amount of neutrino film on our IPD's and are attempting to reconstruct events to the satisfaction of the Fermilab-Michigan groups. If we are successful then we may join experiment E180 at Fermilab.

R. Diamond, who came to F.S.U. from Michigan, continues to make some contributions to the Michigan neutrino program. He has been working or E180, in particular on distinguishing between anti-neutrino proton and antineutrino neutron reactions in the hydrogen-neon mixture of the 15-foot bubble chamber. (See Enclosures B.4, C.12, C.13, C.14, and G.3.)

G. K^-d at Low Energy

The study of baryon resonances with $S = -1$ produced a paper (see Enclosure B.8) and a Ph.D. dissertation (see Enclosure F.1). In both of these studies attempts were made at settling existence, spin and parity of a possible $\Sigma(1620)$. In each case, the data can be fitted without any resonance in this vicinity. If one nevertheless includes a resonant partial wave, the lack of any high degree of polarization in the Λ of the final state prevents any firm assignment of parity. The enclosures present the results: total cross sections, differential cross sections and polarization for $K^-n\to\Lambda\pi^-$. Enclosure B.8 also deals with nonimpulse protons from $K^-d\to\Lambda\pi^-p$ and presents data on the production of the $\Lambda N(2130)$.

H. ISIS

The device known as ISIS (Identification of Secondary particles by Ionization Sampling) is a part of the downstream detection system for use with the 30-inch bubble chamber at Fermilab. ISIS is to be a box 1m x 1m x 3m filled with A-CO_2 mixture with sense wires that measure the relativistic rise in ionization. By so doing one can hope to distinguish pion from kaon from nucleon in the energy range from 10 to 70 GeV.

The MIT group built a prototype ISIS (called CRISIS, for Cleverly Reduced ISIS) with dimensions 1m x 1m x 1m. During the fall of 1977 it was moved to Fermilab and tested with live beam. FSU contributions to this project include calculations pertaining to the distribution of pulse heights to be expected, development of Monte Carlo techniques to sample the distributions of Landau and of Blunck and Leisegang, as well as going to Fermilab to help with the installation and tests, both for ISIS and for the array of lead glass blocks to be used as a detector of forward gamma rays. Results of the testing were presented at the 1978 Washington Meeting (see Enclosure A.1.c).

Our involvement with this project was based on our short-range plan to continue our hadron bubble chamber experiments with the Fermilab 30" hybrid system at presently available energies and our long-range plan to propose use of this facility when the Fermilab accelerator reaches 1000 GeV. In view of the approval of Fermilab Proposal #580 (see Section E above) we have decided that in view of our limitations in funds and personnel we cannot continue participation in the current 30" hybrid program. We do expect to continue some minimal assistance due to our long-range interests.

I. Software Development

Improvements were made to HYDRA to fit 4- and 6-pronged events at high energy, where the number of constraints is reduced since $E \approx p$ (mass negligible). About 2,300 4- and 6-pronged events were measured on SAMM, the semi-automatic measuring machine at FERMILAB. A portion of these measurements were track-matched at FSU using the RESUPX CRT plotting-editing program which was modified for these events.

Software for the EMR-Microprocessor-CRT measuring table system was debugged and preparations made to scan and measure SLAC 40-inch bubble chamber film. A calibration program was written and stored in read-only memory in the microprocessor. It was used to calibrate IPD2. A basic scan/measure program was written for the microprocessor/EMR computer and is being debugged.

J. Progress on Construction Projects

(1) We have finished the design and construction of an 8080 microprocessor development system. It is configured as follows:

8080	μproc. in an inhouse designed frame
36K	RAM memory
8K	ROM memory
1	cassette recorder
1	terminal
1	floppy disc
1	line printer

The 8080 software permits a LINK mode which ties the system to the campus Cyber and gives us the additional power of using the PLM Cross Compiler, the Intel Cross Assembler, or the Lawrence Livermore BASIC Cross-Compiler. After cross-assembling or cross-compiling a program on the Cyber it is then downloaded to the 8080 development system, tested and blown in Read Only Memory, for use in the Distributed Intelligence Bubble Chamber measurement system.

(2) The Distributed Intelligence Bubble Chamber Measurement (DICBM) system design is finished and construction is complete for one IPD; a second IPD is nearly complete. The remaining two IPD's should be converted within two months. The DICBM system is merely an 8080 μproc. on each IPD linked via an 8080 communications processor to the new 6050. This permits each table autonomy in collecting data, calibrating optics and executing diagnostics. The 6050 is thus relieved of any data aquisition or computational function that can be relegated to the 8080 on each table, thereby permitting the 6050's power to be dedicated to each IPD on a polled basis. The software is presently adaquate for collecting data for the SLAC experiment, and is rapidly being upgraded.

(3) The four computer terminals were constructed and are now being used. The last terminal constructed was an intelligent terminal. Any more terminals that are constructed will be the intelligent type as they are faster and easier to construct.

(4) The IPD's are being converted to dual magnification as needed.

(5) The plan to outfit one table with Invar platen mounts was delayed because we had difficulty in locating a source of Invar stock in the size needed to make the platen mounts. The Invar was recently delivered, however, and we are now proceeding with this project.

(6) The microprocessor-based CAMAC system is nearing completion. The processor has been constructed, and the Interface to CAMAC and the U-type controller have been designed. The Interface and controller are now being constructed.

(7) The 6050 memory expansion was delayed because of the unexpected contribution it was necessary for us to make to the construction of the LSI-11 data acquisition system for the test beam facility at SLAC. However, we are continuing the project and plan to finish during this next contract period.

(8) In order to test the lead-glass wall in the test beam at SLAC it was necessary to construct an LSI-11 CAMAC based data acquisition system. SLAC provided most of the hardware and some software. However, it was our responsibility to rewrite the data acquisition software and make the system work, which we did.

The final system was a rather general pulse height analysis system permitting the user to define parameters at will and to some extent redefine the experimental configuration without rewriting the software. It has since become a part of the SLAC test beam facility.

III. Particle Theory Program:

The Particle Theory Program has been spotlighted this year by the Dirac Conference and by an endeavor to add a tenure-track faculty position, which will continue into next year.

The serious theme of the Dirac Conference with its particle theory speakers (t'Hooft, Wilson, Sakurai, Ellis, Ne'eman, Dyson, Gell-Mann, Wouthuysen, Teitelboim, K. Johnson, Politzer, Kogut, Wilczek and Halpern) helped us to properly celebrate the famous equation of Dirac during its 50th year and his 75th. It also helped to (unofficially) inaugurate our new $1.5 million teaching building adjacent to the other two buildings in our Physics complex (Physics Research and Tandem Research). The proceedings will appear in the A.I.P. Conference Series, hopefully on a timely basis (i.e. fall 1978).

The possible tenure-track position in particle theory would be the first addition to the faculty since 1967 (we lost a position in 1972 when Kretzschmar resigned). As the matter was left unresolved this year we look forward to concluding it in the near future. The addition of a faculty member would represent a great boost for our program.

A. Diffraction Dissociation and Strong Absorption (P.K. Williams)

The paper "Inelastic Diffraction and Factorization Properties in the Direct and Crossed Channels" has been published (see Enclosure B.10). Here we introduce a simple phenomenological framework based on approximate factorization properties in the direct and crossed channels. Observed gross features of diffraction become related to gross features of diffractive states. From the observed slope-mass correlation it emerges through this framework that crossed-channel factorization is broken; increasingly massive diffractive states become increasingly transparent and strong absorption for these states weakens to vanishing.

Some further work will proceed in the context of eikonal models or generalized vector dominance models, to which this model bears some resemblance; to incorporate strong absorption in a self-consistent way and to calculate it explicitly; to work out further consequences and to further compare with data, especially on ψ, ψ'... T... photoproduction, nuclear absorption phenomena and strong absorption weakening.

Diffraction phenomena are coming once again to the forefront, due to new sets of data and to some theoretical progress. Generally, however, the theorists have clouded the picture with a bewildering variety of slightly different approaches, while the experimentalists have cleared some things up with better data or set new goals for theory. We simply do not understand the nature of the Pomeron in all its manifestations, and that is what makes it interesting.

B. W → Hadron Jets (P.K. Williams and BNL Collaborators)

During the period July 18-29, 1977, I participated in the Isabelle workshop at BNL. A paper "Considerations on W → Hadron Jets" was published in the workshop proceedings (see Enclosure B.11). Further work along these lines may include a careful calculation of W-Hadron signal and expected background rates in pp collisions, in the context of asymptotically free theories of quarks and gluons. During the period July 31 - Sept. 1, 1978, this work will continue at BNL where I will be a Research Collaborator.

C. Phenomenology of Quarks and Partons (P.K. Williams, F. Amiri)

We are reviewing the phenomenology of hadronic constituents with the idea of applying it to hadronic production processes. This work will continue as a thesis project.

D. Quantum Chromodynamics and the Production of Heavy Particles (J.F. Owens, E. Reya)

In conjunction with M. Glück of the University of Mainz, Mainz, West Germany, we have studied J/ψ production in hadronic reactions. The theory of quantum chromodynamics predicts that there are two components to the J/ψ production mechanism - quark-antiquark annihilation and gluon-gluon fusion. An excellent description of the data was obtained and it was found that the presence of both of the predicted mechanisms was crucial. The results of this study have been published in Physical Review D (see Enclosure B.6). A shorter version of this paper also was published in the proceedings of the 1977 Division of Particles and Fields Meeting (see Enclosure B.15).

The same model discussed above has also been applied to the hadronic production of the Υ. Predictions were given for the cross section energy and x_F dependences as well as for the cross section beam ratios. This paper has been published in Physical Review D (see Enclosure B.13).

E. Detailed Quantum Chromodynamic Predictions for High-p_T Processes (J.F. Owens, E. Reya)

In conjunction with M. Glück of the University of Mainz, Mainz, West Germany, the role of quantum chromodynamics (QCD) in high-p_T hadron production has been investigated. By including all of the QCD predicted subprocesses an excellent description of the single particle inclusive production data can be obtained in the region $p_T \gtrsim 4.5$ GeV/c and $\sqrt{s} \gtrsim 50$ GeV. Predictions for the s, p_T, and θ dependences are given for single meson production. This paper has been accepted for publication in Physical Review D (see Enclosure C.6).

F. Q^2 Dependence of Parton Fragmentation Functions (J.F. Owens)

Quantum chromodynamics (QCD) is a theory of interacting quarks and gluons. In this model quarks do not exist as free particles and, in particular, can not be separated from the parent hadron. If a quark or gluon undergoes a violent collision in some process, it is thought to fragment into various hadrons. This process is described by the parton fragmentation functions. In this paper I studied the QCD predictions for the Q^2 dependent scaling violations expected for these fragmentation functions. The results were then used in subsequent high-p_T calculations. This paper has been published in Physics Letters B (see Enclosure B.14).

G. Parton Transverse Momentum Effects and the Quantum Chromodynamic Description of High-p_T Processes (J.F. Owens, J.D. Kimel)

The previously discussed high-p_T calculation showed that the QCD predictions for single particle inclusive reactions were in good agreement with the data in the region $p_T \gtrsim 4.5$ GeV/c and $\sqrt{s} \gtrsim 50$ Gev. By including the effects due to the internal transverse motion of the hadronic constituents (partons) the region of agreement can be significantly enlarged. This paper has been accepted for publication in Physical Review D (see Enclosure C.7 for paper and A.1.d for abstract).

H. Transverse Momentum Distributions for T and Dimuon Production in Quantum Chromodynamics (J.F. Owens)

The lowest-order QCD diagrams for both T and dimuon production do not give rise to any large transverse momentum contributions. However, higher order diagrams involving, for example, gluon bremsstrahlung do give such contributions. The effects of these terms have been studied in this paper. It was found that for pp interactions the transverse momentum distribution of the T is broader than that for the $\mu\mu$ continuum. Furthermore, the difference is predicted to increase with energy. Both of these predictions are in agreement with the experimental data. Predictions are also given for π^+, π^-, K^+, K^-, and $\bar{p}$ beams. This paper has been submitted to Physical Review D (see Enclosure C.8 for paper and A.1.e for abstract).

I. Reaction $K^- n \to \Lambda + \pi^-$ from 1550 to 1650 MeV (W.A. Morris, J.R. Albright, A.P. Colleraine, J.D. Kimel, J.E. Lannutti)

This collaborative effort between the experimental and theoretical groups, the results of which were published during the past year, is discussed in detail in the experimental section (see Enclosure B.8).

IV. Gravitation Theory Program:

A. Gravitation (P.A.M. Dirac, L. Halpern, R. Parsons)

The work on varying G has been developed during the past few years on the assumption of continuous creation of matter. There are grave difficulties with this assumption, some of which were brought to our attention by Prof. Runcorn during his visit to Tallahassee last year, so we have decided it must be given up.

With conservation of mass, to account for the continual increase in the mass of the observable universe one must suppose that the velocity of recession of the galaxies is continually decreasing, so that more and more galaxies are continually appearing within our view. We are led to a different model for the universe, which is in agreement with a model that was proposed jointly by Einstein and de Sitter in 1932. The natural microwave radiation fits in very well with this model.

There was a conference held in Tallahassee in April 1978, in connection with the celebration of the 50th anniversary of the Dirac Wave Equation for the Electron. It was attended by many high-energy physicists and Dirac spoke about the new cosmological theory there. The report of this conference will be published (see Enclosure D.3)

Dirac had previously spoken about a preliminary version of the theory at the Coral Gables Conference on High-Energy Physics in January 1978. (See Enclosure C.12.)

Dirac has continued to develop this theory and has written a paper about it which has been submitted to the Royal Society (see Enclosure C.1).

Van Flandern's calculations on the motion of the moon, in which he compares observations in atomic time with observations in ephemeris time, are in contradiction to the new theory. However, with newer data and revised calculations, Van Flandern now believes that his earlier results may be wrong.

There is some support for the new theory provided by Shapiro's radar ranging of the nearer planets, but it is not very strong because the errors are about as big as the effect being observed. But we may soon have a much more accurate result from the Viking-lander on Mars.

L. Halpern worked on a formalism in which a general relativistic gravitational theory can be based on a different local invariance group than the Poincaré group. His first publication on this subject appeared in General Relativity and Gravitation, Volume 8, Number 8 (1977), page 623. The progress he has made in this work since is presented and summarized in the detailed version of the lecture presented at the meeting in honour of Dirac's 75th birthday (see Enclosure D.3). This paper will be printed in the Proceedings of the meeting. The formalism results in families of modified cosmological gravitational theories some of which may be adaptable to

Dirac's Large Number Hypothesis. A lecture on the subject will also be presented at the Conference on Group Theory and Mathematical Physics (Austin, September 11-16, 1978). R. Parsons worked on a critical analysis of the solution in spherical symmetry for Dirac's last work and also on the mathematical foundations of the formalism suggested by Halpern.

ENCLOSURES TO THE PROGRESS REPORT

for the period 1 September 1977 to 31 July 1978

A. Papers Presented at Meetings

1. APS Washington, D.C., Meeting, April 1978; Bull. Am. Phys. Soc., Vol. 23, No. 4 (1978).

   a. "Neutral Pion Multiplicity Distributions in $\pi^- p$ Interactions at 250 GeV/c," by P. Hays, J. Albright, R. Diamond, S. Hagopian, J. Lannutti, et al.; p. 510.

   b. "Study of the Reactions $\pi^+ n \to ppp$ and $\pi^+ n \to K^+ K^- p$ at 15 GeV/c," by V. Hagopian, J. Albright, S. Hagopian, J. Lannutti, et al.; p. 598.

   c. "Fermilab CRISIS," by V. Kistiakowsky, F. Barreiro, J. McManus, T. Stoughton, B. Wadsworth, R. Yamamoto, A. Shapiro, G. Koizumi, J. Albright, et al.; p. 619.

   d. "Parton Transverse Momentum Effects and the Quantum Chromodynamic Description of High-p_T Processes," by J.F. Owens and J.D. Kimel; p. 579.

   e. "Quantum Chromodynamic Predictions for Hadronic Upsilon Production," J.F. Owens; p. 580.

B. Papers Published

1. "The Mathematical Foundation of Quantum Theory," by P.A.M. Dirac, in the book Mathematical Foundations of Quantum Theory, Academic Press, 1978.

2. "The Relativistic Electron Wave Equation," in Proc. of the 1977 European Conference on Particle Physics, p. 17, Budapest, Hungary, 1977.

3. "Annahmen und Voreingenommenheit in der Physik" (German translation of "Basic Beliefs and Prejudices in Physics"), aus Naturwissenschaftliche Rundschau, Band 30, Heft 12, Seite 429 (Dez. 1977).

4. "Diffractive Production of Vector Mesons in High Energy Neutrino Interactions," Fermilab-LBL-Hawaii-Michigan Collaboration, Phys. Rev. Lett. 40, 1226 (1978).

5. "Regge Cuts and the Spin Dependence of Inclusive Λ Production," J.F. Owens, Nucl. Phys. B131, 209 (1977).

6. "Gluon Contribution to Hadronic J/ψ Production," M. Glück, E. Reya, and J.F. Owens, Physical Rev. D17, 2324 (1978).

7. "Inclusive Production of Neutral Strange Particle in 250 GeV/c π^-p Interactions," D. Bogert, R. Hanft, R. Harris, F.R. Huson, S. Kahn, J.F. Albright, S. Hagopian, P. Hays, and J.E. Lannutti, Phys. Rev. D16, 2098 (1977). Copies attached to last year's Progress Report.

8. "Reaction $K^-+n\rightarrow\Lambda^0+\pi^-$ from 1550 to 1650 MeV," W.A. Morris, J.R. Albright, A.P. Colleraine, J.D. Kimel, and J.E. Lannutti, Phys. Rev. D17, 55 (1978). Copies attached to last year's Progress Report.

9. "Charm Effects in Deep Inelastic Muon-Proton Scattering," M. Glück, J.F. Owens, and E. Reya, Phys. Lett. 72B, 326 (1978). Copies attached to last year's Progress Report.

10. "Inelastic Diffraction and Factorization Properties in the Direct and Crossed Channels," P.K. Williams, Phys. Rev. D17, 909 (1978). Copies attached to last year's Progress Report.

11. "Considerations on $W\rightarrow$ Hadron Jets," S.U. Chung, V. Flaminio, E.A. Paschos, F.E. Paige, T.L. Trueman, and P.K. Williams, Proceedings of 1977 Isabelle Summer Workshop, Brookhaven Nat. Lab. Pub. BNL50721, p. 224 (1978). Copies attached to last year's Progress Report.

12. "Conclusions from the Extended Gauge Principle of Dirac's Equation," L. Halpern; Springer, Lecture Notes in Mathematics 570: Differential Geometrical Methods in Mathematical Physics, p. 355 (1977). Copies attached to the Progress Report of the year before last.

13. "Hadronic Υ Production, Parton Distributions, and QCD," J.F. Owens and E. Reya, Physical Rev. D17, 3003 (1978).

14. "On the Q^2 Dependence of Parton Fragmentation Functions," J.F. Owens, Phys. Lett. 76B, 85 (1978).

15. "Gluon Contribution to Hadronic J/ψ Production," M. Glück, J.F. Owens, and E. Reya, AIP Conference Proc., Particles and Fields - 1977, No. 43 (1978), p. 467.

C. Papers Submitted for Publication

1. "The Large Numbers Hypothesis and the Einstein Theory of Gravitation," P.A.M. Dirac; submitted to Proc. Royal Soc. London.

2. "Higher Mass Mesons from 15 GeV/c π^+D Interactions," W.M. Bugg, G.T. Condo, T. Handler, E.L. Hart, H.O. Cohn, S. Hagopian, V. Hagopian, J.E. Lannutti, and B. Wind; submitted to Nucl. Phys.

3. "Two-Particle Correlations Involving Neutral Strange Particles," R. Harris, D. Bogert, R. Hanft, F.R. Huson, S. Kahn, W. Smart, N.N. Biswas, J.M. Bishop, N.M. Cason, V.P. Kenney, W.D. Shephard, J.R. Albright, S. Hagopian, P. Hays, and J.E. Lannutti; accepted by Phys. Rev. D.

4. "On the Gravitational Analogue of the Magnetic Monopole," L. Halpern; accepted, pending minor modification, for publication by Foundations of Physics. A fire destroyed the manuscript which was reconstructed. Copies attached to the Progress Report of the year before last.

5. "Gravitational and Inertial Effects of Superconducting Shielding," L. Halpern and J. Perk; accepted by Physica. Copies attached to Progress Report of three years ago. Publication was in hands of second author.

6. "Detailed Quantum Chromodynamic Predictions for High-p_T Processes," J.F. Owens, E. Reya, and M. Glück; to be published in Physical Rev. D.

7. "Parton Transverse Momentum Effects and the Quantum Chromodynamic Description of High-p_T Processes," J.F. Owens and J.D. Kimel; accepted for publication in Physical Rev. D.

8. "Transverse Momentum Distribution for Υ and Dimuon Production in Quantum Chromodynamics," J.F. Owens; submitted to Physical Rev. D.

9. "Λ and K° Production in p↑p Interactions at 12 GeV/c," R.L. Eisner, W.J. Fickinger, J.A. Malko, J.F. Owens, et al.; submitted to Nucl. Phys. B. Copies available later.

10. "Gravitation as Broken Group Symmetry," L. Halpern; submitted to Phys. Rev. Lett.; also appears as SLAC preprint.

11. "General Relativistic Gravitation as the Theory of Broken Symmetry of Intransitive Groups of Transformations," L. Halpern; to appear in Austin Conf. Proc. and as SLAC preprint.

12. "The Variation of G," P.A.M. Dirac, in New Frontiers in High Energy Physics, Coral Gables Conference Proceedings, January 1978. Copies available later.

13. "The Monopole Concept," P.A.M. Dirac; to be published in International Journal of Theoretical Physics.

14. "Inclusive Neutral Strange Particle Production from High Energy νp Charged-Current Interactions," Fermilab-LBL-Hawaii-Michigan Collaboration; submitted to Phys. Rev. D.

15. "Inclusive Negative Hadron Production from High Energy $\bar{\nu}$ Nucleus Charged-Current Interactions," Fermilab-IHEP-ITEP-Michigan Collaboration; submitted to Phys. Rev. D.

16. "An Experimental Study of Inclusive Hadron Production in High Energy Neutrino Proton Interactions," Fermilab-LBL-Hawaii-Michigan Collaboration; submitted to Phys. Rev. D.

D. Books

1. "Proceedings of the Workshop Meeting on the Measurement of Cosmological Variations of the Gravitational Constant," held Nov. 12-14, 1975; a F.S.U. Book, Univ. Presses of Florida, Gainesville, 1978.

   In this book there are two articles by our members.

   a. "The Large Numbers Hypothesis and the Cosmological Variation of the Gravitational Constant," P.A.M. Dirac, p. 3.

   b. "Two Methods for Measuring the Variation of the Gravitational Parameter, G, Using Superconducting Technology," L. Halpern and C. Long, p. 87.

2. "Directions in Physics," P.A.M. Dirac; lectures delivered during a visit to Australia and New Zealand, 1975 (J. Wiley and Sons, New York, 1978).

3. "Current Trends in the Theory of Fields," edited by J.E. Lannutti and P.K. Williams; to be published by the American Institute of Physics as part of Conference Series. Program of conference provided here.

   Articles by group members are:

a. "Gravitational Theories Generated by Groups of Transformation and Dirac's Large Number Hypothesis," L. Halpern.

b. "Consequences of Varying G," P.A.M. Dirac.

E. Proposals

1. Proposal for utilization of the upgraded, all-drift-chamber MPS, S.U. Chung, J.R. Bensinger, V. Hagopian.

2. Proposal to search for narrow and broad resonances in $\pi^-p \rightarrow \Lambda\bar{\Lambda}(\pi^\pm)+X$ and $\pi^-p \rightarrow K^o_S K^o_S(\pi^\pm)+X$ at 300 GeV/c using the Fermilab Multiparticle Spectrometer, FSU Internal Report No. 16 (1978).

F. Ph.D. Dissertation

1. "A Study of K^-d Interactions in the Energy Region between 1500 and 1600 MeV," Norberto Ezquerra, F.S.U. publication FSU-HEP-780316 (1978).

G. Internal Reports

1. "SHYSTAR. A First Report." A program to calculate K^+ detector efficiencies. By R.N. Diamond, FSU Internal Report No. 15 (1977).

2. "High-$p_\perp$ Two-Jet Cross Sections and Tests of Parton Distribution Functions," by J.F. Owens; FSU Preprint FSU-HEP-780609 (1978).

3. "E180 - Comments on $\bar{\nu}P$, $\bar{\nu}n$ Cross Sections," UMBC-FSU 77-9.

Reprints + Preprints Remain