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ANNUAL PROGRESS REPORT

to

UNITED STATES
DEPARTMENT OF ENERGY

Contract No. DE-AC02-76ER01195

Department of Physics
University of Illinois
at Urbana-Champaign
Urbana, Illinois

Key Personnel: A. Wattenberg
R. O. Simmons

Submitted May 1981

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
DEPARTMENT OF PHYSICS

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I. SUMMARY OF SCOPE AND PURPOSE OF THE PROJECT

Our program in Elementary Particle Physics is carried out at the University of Illinois and at the high energy particle accelerator laboratories operated by the Department of Energy.

During the past five years we have carried out and planned experiments which predominantly studied the production and decay of particles containing charmed quarks. A series of photoproduction and neutron production experiments started with the very early observation of the production of J/ψ by neutrons and by photons at Fermilab. From subsequent experiments using these neutral beams and the basic detecting system, we have reported results on the photoproduction of the Λ_c charmed baryon and the D and D^* charmed mesons. More recent runs are studying the high energy photoproduction of vector mesons including the ψ' . The next experiment in this sequence (scheduled for FY82) will use neutrons to produce a large number of D mesons.

Another series of experiments at Fermilab set out to study the hadronic production of charmed mesons. The Chicago Cyclotron facility was modified with a detector sensitive to various possible production mechanisms. The experiments were a success; clean signals of D mesons were observed to be produced by pions, and also the production of χ_c with the subsequent decay via a γ -ray to ψ were observed. The experiments scheduled for the coming year will have better photon resolution for measuring the decays of χ_c to ψ ; the next experiments will study the production of charmonium states and charmed mesons by protons.

About two years ago, a University of Illinois group joined the collaboration building the Mark III detector at SPEAR to study charmed quark systems and tau leptons. This is a new generation detector which has a program of obtaining more precise measurements of the decays of these particles. It is anticipated that it will require several years to acquire the number of events to give the desired statistical significance.

In the past we have had a neutrino physics program studying the weak interaction. Our long range interest in studying the weak interaction at higher energies has led us to investigate the possibility of an e-P colliding facility in the United States. We also are planning to perform experiments at

increasingly higher energies at Fermilab as they become available. We are collaborating on the Colliding Detector Facility for Fermilab; one of the motivations is the possible production of (weak) intermediate vector bosons by collisions of protons and anti-protons.

The University of Illinois staff is continuing to play a major role in a new generation of fast electronics, namely the so called "FASTBUS" system. The engineers are part of the "Tri-Group" which is responsible for prototype equipment development. The mechanical aspects are being field tested in the fast trigger for Mark III; plans are being made to use a FASTBUS system on the CDF at Fermilab. The complexities of the electronics for large detectors (e.g. the microprocessor trigger for Mark III) have led to our recognizing the need for us to obtain a computer aided design system for electronics for elementary particle physics.

The summary of our present and future programs is in the accompanying lists.

During 1980 major accomplishments include the following:

1. The analysis of data from Fermilab E-369 was completed. We determined the diffractive cross section for production of charmed D mesons in $\pi^- p$ collisions at 215 GeV/c to be 20 μb .
2. Data acquisition for Fermilab E-610 was completed for π^- beryllium at 215 GeV/c. Preliminary analysis of the data shows strong ψ/J and χ peaks.
3. Prototype muon drift tubes are being constructed and tested for the $p\bar{p}$ Colliding Detector Facility. Monte Carlo studies of muon trigger rates, background levels and resolutions are being carried out.
4. The muon proportional counters and associated electronics for the Mark III detector have been shipped to SLAC and tested. The fast trigger will be shipped very soon.
5. The second run looking for the production of η_c has been completed at Brookhaven.
6. The results of the photoproduction of D^* and D mesons has been published. We found for 70 to 200 GeV photons cross-sections of 160 ± 70 nb and 390 ± 190 nb per nucleon respectively.
7. The results of the analysis of $\Lambda_c + K_S^0 p$ and $Kp\pi$ are being published. The cross-section for the photoproduction of the charmed Λ_c baryon is approximately half that of the charmed D meson.
8. The most recent runs on the photoproduction of vector mesons and two particle systems are being analyzed with emphasis on a better determination of the spectrum and detector efficiencies.

9. Our electronic engineering staff is making a major contribution to the development of a new generation of fast electronics needed by elementary particle physicists and others - namely, the development of the so-called "FASTBUS" system.
10. Illinois physicists organized a work study conference on an e-p colliding beam facility for the United States.

During the coming year the major parts of our program will be:

1. A new run is expected for Fermilab E-610. We will take data with 250 GeV/c protons incident on a beryllium target. Analysis of this and our previously acquired pion data should reveal details of the quantum states and production dynamics of charmonium.
2. Construction will proceed on the central muon detector and high P_T trigger system for the $\bar{p}p$ Colliding Detector Facility.
3. The first runs using the Mark III detector with the colliding beams at SPEAR will take place in FY82.
4. In the data from the Brookhaven search for η_c we will also analyze the data for $\pi^0\pi^0$ events.
5. We should be obtaining results from the most recent photoproduction runs studying vector mesons and two particle systems. The results should include the first information on the ψ' nucleon scattering cross-section.
6. E-400 is scheduled to run in FY82. It uses the neutron beam to obtain an improved signal to noise in charmed particle production.
7. Computer links between the Urbana site and the National Laboratory computing facilities will be extended to provide access to sizeable data analysis/reduction facilities. The RJE station to FNAL, which uses an LSI-11 computer and a 4800 baud telephone line, will be completed.

II. PERSONNEL

In this section are listed the names of Senior Staff members and graduate students who are or will be involved in the Elementary Particle Physics Program at the University of Illinois in Urbana-Champaign.

Personnel who are or will be actively engaged in physics experiments in this program are:

1) Faculty members with the rank of Assistant Professor or higher:

Ascoli, G.	Kruse, U. E.
Brown, R. M.	O'Halloran, T. A.
Cui, H.	Sard, R. D.
Eisenstein, B.	Thaler, J. J.
Gladding, G.	Wattenberg, A.
Holloway, L.	Wiss, J.
Koester, L. J.	

2) Senior Staff members holding research or professional appointments (Research Associates, Research Assistant Professors, Research Physicists, or Engineers):

Alverson, G.	Kohlmeier, J.
Cassell, R.	Lesny, D.
Diesberg, M.	Simaitis, J.
Downing, R.	Wisniewski, W.
Fuess, S.	Wray, J.
Karliner, I.	

3) Graduate Students (part time Research Assistants, Fellows, and Programmers):

Becker, J.	Garren, L.	Nater, K.
Bellinger, J.	Graff, T.	Nienaber, P.
Blaylock, G.	Hahn, S.	Olszewski, C.
Budd, H.	Lamm, M.	Plaetzer, S.
Callahan, P.	Li, W.	Schoessow, P.
Filaseta, J.	Lukens, P.	Spadafora, A.

- 4) There are theoretical physicists at the University of Illinois whose main area of interest is Elementary Particle Physics. The interaction of these physicists with the experimentalists is of great value to the High Energy Physics Experimental Program. Members of this group are:

Chang, S. J.

Stack, J.

Goffin, V.

Stone, M.

Jones, L. M.

Sullivan, J.

Kogut, J.

Wyld, H. W.

III. EXPERIMENTAL PROGRAM

A. Technical Accomplishments During the Past Year

A.1. The Mark III Project at SPEAR

(R. Cassell, H. Cui, B. Eisenstein, G. Gladding, J. Thaler, A. Wattenberg, W. Wisniewski, J. Becker, S. Plaetzer, A. Spadafora, in collaboration with groups from SLAC, the California Institute of Technology, the University of California at Santa Cruz, and the University of Washington)

The collaboration undertook the construction of Mark III at SPEAR in order to provide a detector better suited than previous detectors to the study of charmed particles and tau leptons. Specifically it will have more extended range of momenta over which it can distinguish between electrons, muons, pions, kaons, and protons. The Mark III shower detectors are designed to have better efficiency for low energy photons, particularly those below 200 MeV. This, combined with good spatial resolution should allow us to study decays involving several π^0 's. Mark III should have an increased efficiency for tagging D mesons and for identifying and measuring complex decay modes.

The status, as of February 1981, of the various parts of the Mark III detector follows: The magnet has been assembled, and the precision mapping has been completed by a SLAC group. The assembly of the barrel shower detector was completed, and it has been installed in the magnet. The installation of the cabling and associated electronics has been started. The assembly of the main drift chamber, also a responsibility of SLAC, is completed, and it is being tested.

The time of flight counters have been constructed and tested by the group from Seattle, Washington. In the next few months the drift chamber, and the time of flight counter package will be installed inside the magnet-shower detector assembly. The CalTech group has built an inner drift chamber, and it is now being tested. The end cap shower detectors built by Santa Cruz are being tested at SLAC. There have been delays in completing the delivery of some important SLAC electronic units (e.g., "Brilliant ADC's"-"BADC's", programmable HV supplies). We are debugging the system with the units that have been delivered. We hope that these delays will not seriously curtail our

ability to test and calibrate the Mark III detector this spring using cosmic rays while it sits on the apron at the SPEAR West Pit. The June shutdown will be the most convenient time to install Mark III in the pit, both for the Mark III detector and the SLAC program.

The Illinois group has had responsibility for the muon detector, the fast trigger system, and the Monte-Carlo programs and it has shared responsibility with SLAC and Santa Cruz personnel for the gas system. Due to a lack of funds in FY81, we are procrastinating on the purchase of a gas mixing system; we will buy premixed gases this spring and summer. The large storage tanks, manifolds, and monitoring system are partially installed and tested. The proportional counters for the muon system were shipped out to SLAC without any breakage or failures. The electronic system for the muon detectors was completed and tested at Urbana. Subsequent testing and exercising the electronic systems with the counters at SLAC has revealed some electronic failures associated with shipping and/or bad electronic components. Although bad units are replaced, the lack of reliability of some components will require design modifications and replacement of 20% of the boards in the future. Two octants of the muon system (which will not interfere with the rigging of the central detector) are in place on the magnet. They have been attached to a SLAC "BADC" and exercised under computer control. The muon detector and electronics is a working system; however, the fine tuning of the resistive wire technique will be continued in order to improve the axial position resolution.

The electronics that will find circular tracks for the trigger has been completed and is being tested using an LSI-11 computer. We will ship the apparatus to SLAC by the end of February. We have not yet built the electronics for the current division calculation, which provides additional suppression of beam-loss induced events. The existing apparatus will provide an adequate trigger for now (equivalent to the Mark II trigger), and the remainder will be done by the summer.

There are a number of software projects in which we are involved. The Monte Carlo program exists in a complete pre-experiment form. That is, it simulates both the data tapes, or simply the physics results, from a variety of anticipated reactions. Data tapes are being used as input in the development of programs to do pattern recognition and track reconstruction in

the drift chambers, shower reconstruction, etc. We have also written, and are testing, the programs which analyze hits in the muon detector, link them to tracks reconstructed in the drift chamber, and decide whether a muon was actually detected. We have written, and are testing, programs which check that the hardware trigger signals are in agreement with hits in the drift chambers as written onto the data tape. Finally, we are sharing the responsibility for a number of other tasks, including the on-line data acquisition program, monitoring and calibrating programs, and some parts of the off-line analysis system. As various jobs are completed, effort will be shifted to other software projects; in particular much more work will begin on refining the Monte Carlo as soon as tests using the real apparatus reveal more details about the hardware performance.

A.2. Charm Search and ψ/J Production (E-369)

(G. Alverson, G. Ascoli, L. Holloway, L. Koester, U. Kruse, R. Sard, D. Bender, S. Hahn, W. MacKay and E. Smith in collaboration with physicists from Fermilab, Harvard University, Oxford University, and Tufts University)

Fermilab Experiment E-369 is part of our program to study the quantum states and transitions resulting from high energy hadron-hadron collisions. It focuses primarily on the hadronic production of charmed mesons and on the production mechanism of the ψ/J . The apparatus consisted of a large aperture magnet (the former Chicago cyclotron magnet) with multiwire proportional chambers upstream and spark chambers downstream. Additional components included a recoil proton time-of-flight spectrometer, an 18-cell threshold Cherenkov counter, an 80-element lead glass array, and several scintillation counter hodoscopes.

Results were published (T.B.W. Kirk, et al., Phys. Rev. Lett. 42, 619 (1979)) on the observation of photons associated with ψ/J particles. It was concluded that more than half of the inclusive ψ/J cross-section comes from a two-step process involving one of the χ 's ($^3P_{0,1,2}$ charmonium states of positive charge conjugation) as an intermediate state.

Final analysis of the data on the production of charmed mesons has been completed. The theses of D. Bender and W. MacKay are based on these results. The experiment was performed with a 215 GeV/c π^- beam incident on a

liquid hydrogen target. In every event, a recoil proton of small momentum transfer was detected ($0.1 < -t < 0.4 \text{ GeV}^2/c^2$); thus we were observing peripheral production. Clear signals are seen in the channels $D^0 \rightarrow K_S^0 \pi^+ \pi^-$ and $D^\pm \rightarrow K^\mp \pi^\pm \pi^\pm$. Summing all the data gave a total of 83 ± 16 events above background. An investigation of the distributions in the kinematic variables shows that our signal is consistent with a diffractive-type process. We can make no statement about central production since our acceptance is too small in that region of phase space. If we fit our data to a diffractive model we obtain a cross section of $20 \pm 6 \text{ } \mu\text{b}$ for the production of D mesons from protons by $215 \text{ GeV}/c \text{ } \pi^-$. The publication of these results is in progress.

A.3. χ -Production (E-610)

(G. Alverson, L. Holloway, L. Koester, U. Kruse, R. Sard, H. Budd, T. Graff, S. Hahn, W. Li, P. Lukens, P. Schoessow, in collaboration with physicists from Fermilab, University of Pennsylvania, Purdue University, and Tufts University)

Fermilab Experiment E-610 is a continuation of E-369 but with new apparatus that has improved resolution, increased acceptance, and allows a higher rate of data acquisition. One of the principal goals is to confirm and improve the results of E-369 which conclude that a substantial fraction of the inclusive ψ/J cross section involves an intermediate χ state of charmonium. The improved resolution of the photon detector should allow us to resolve separate contributions from the three χ states (3415, 3510, and 3550 MeV/c^2). This is a crucial issue in distinguishing between gluon-gluon fusion and quark-antiquark fusion models. The increased photon acceptance will enable us to reconstruct the decay angular distribution of $\chi \rightarrow \psi/J + \gamma$ in the χ center-of-mass frame. This should allow us to make some conclusions about the spin of the χ 's.

The Illinois group has contributed the following to the new improved Chicago cyclotron magnet spectrometer facility:

- 1) 50 lead glass blocks with photomultiplier tubes and bases
- 2) 15 planes of multiwire proportional chambers with electronic readout (7500 wires)
- 3) 3 planes of proportional tubes with analogue readout (600 tubes)
- 4) LED calibration system for the 150 element lead glass array

Data was taken in the summer of 1980 with 215 GeV/c π^- incident on a beryllium target. A total of four million triggers were accepted which should yield about four thousand ψ /J's and one thousand χ 's. Analysis of the data is in progress.

A.4. Search for the η_c Produced by Pions

(L. Garren, J. Thaler, with physicists from Princeton University and Brookhaven National Laboratory)

We are searching for the η_c , the predicted 1S_0 bound state of two charmed quarks, by looking for the reaction $\pi^- p \rightarrow \eta_c n$ ($\eta_c \rightarrow \gamma\gamma$) at the AGS. We completed the second round of data acquisition in August, 1980. The first round had refuted an earlier claim of observation of the η_c at a mass of 2850 MeV, with a 100 pb cross section. The second round was designed to increase our sensitivity to 1 pb/event.

After the start of this experiment, two experiments at SPEAR reported a likely η_c candidate, the u (2983), observed in the decay $\psi' \rightarrow u + \gamma$. It remains an important task to verify the existence of this particle and to determine its properties vis-a-vis the strong interactions.

We are currently analyzing our data to optimize the calibration of the detector, for mass resolution and background suppression. In addition to $\gamma\gamma$, we are sensitive to $\pi^0\pi^0$ final states. Lynn Garren is analyzing this data and will write her Ph.D. thesis on this subject. Analysis should be complete by the summer.

A.5. Photoproduction of Multi-Hadronic States

(G. Gladding, T. O'Halloran, A. Wattenberg, J. Wiss, M. Lamm)

Based on our previous success in observing the charmed antibaryon, the running of Fermilab Experiment 87A was extended with a considerably improved apparatus. Major improvements in the Fermilab wideband neutral beam detector included the installation of two multicell Cherenkov counters, a 98 element lead glass shower counter, and an upstream wide angle analysis magnet. Although the final data run of the experiment was completed in December of 1978, the shorting out of one of the magnet coils considerably complicated event reconstruction. Final event reconstruction and data reduction was completed in the spring of 1979. Since that time we have published several

major physics results including the first compelling observation of a clear $\rho' (1600) \rightarrow \pi^+\pi^-$, further observations of photoproduced charmed baryons decaying via pKs, and the first observation of photoproduced D's and $D^{*\pm}$'s.

The major analysis effort in FY81 has established the production mechanism for photoproduced charmed mesons. This work is described in detail in the thesis of Paul Avery, and is summarized in J. Wiss's conference talk "Charmed Particle Production by Photons and Neutrinos". We find that the $D^{*\pm}$ is produced by 70 GeV to 200 GeV photons at the level of 160 ± 70 nb/nucleon; while the D is produced at a level of 390 ± 190 nb/nucleon. This ratio of D^* to D production is quite close to the ratio observed in e^+e^- annihilation near threshold. The charmed mesons appear to be photoproduced against charmed antimesons rather than charmed antibaryons. This latter mechanism has been previously suggested in a recent CERN photoproduction experiment. The sharply peaked p_{perp} spectrum (with respect to the incident photon) suggests a diffractive production mechanism with a total charm-anticharm invariant mass very close to threshold. All features of the data appear to be consistent with the predictions of the photon-gluon fusion model.

We expect that all analysis of Experiment 87A will be completed in FY82, as the last graduate student completes his thesis.

A.6 Photoproduction of Vector Mesons and Two Particle Systems

(G. Gladding, A. Wattenberg, P. Callahan, C. Olszewski, in collaboration with a group from Fermilab)

This experiment was performed in the broad band neutral beam at Fermilab with the multiwire proportional chamber magnetic spectrometer used in E87, supplemented with additional detectors. These additions included (1) a liquid hydrogen/deuterium target, (2) a set of 24 scintillation counters and 6 Lucite Cherenkov counters arranged azimuthally around the target in order to detect the recoiling nucleons, (3) a 44 element scintillation counter hodoscope which is capable of determining with a precision of 1 mm the vertical (i.e., bend-plane) positions of forward produced particles prior to their entry into a magnetic field, and (4) a segmented lead-scintillation shower counter situated so as to identify electrons in the "outer detector" (i.e., production angles of 35-100 mrad).

The purpose of the experiment was to measure the photoproduction cross-sections of few-particle final states. Data were taken in 3 separate modes. Approximately 200 hours of data were taken with a low intensity beam incident on a liquid hydrogen target. The emphasis in this phase of the experiment was to measure the high energy behavior of the fundamental vector meson (ρ , ω , ϕ) cross-sections from protons. An additional 200 hours of data were taken with a moderate intensity beam incident on a liquid deuterium target. The emphasis in this phase of the experiment was to look for new phenomena in final states involving at least one heavy particle (e.g., $\bar{p} + p$, $K^+ + K^-$, ---). An additional 500 hours of data were taken with a high intensity beam incident on a liquid deuterium target. The emphasis in this phase of the experiment was to measure the production of dilepton (e^+e^- , $\mu^+\mu^-$) final states. The main goals here were to obtain good measurements of the s and t dependence of ψ -production, to determine the ψ' -nucleon total cross-section, and to search for new phenomena at large mass. The final 100 hours of data were taken with a high intensity beam incident on a liquid hydrogen target in order to make a measurement of the t dependence of elastic ψ production.

During FY81, we have made significant progress on the analysis of this data. We have completed the charged particle track reconstruction for our entire data sample and are now in the process of making a detailed study of the behavior of our detector in order to be able to make accurate cross-section measurements. In particular, we have measured the energy spectrum of our photon beam using two independent methods, determined efficiencies of the detectors which contribute to our various triggers, developed particle identification analysis for muons and electrons, investigated the use of the recoil detector for identifying elastic events, and developed a program to simulate the Bethe-Heitler production and detection of dimuons and dielectrons in our apparatus.

A.7. Charm Production by High Energy Neutrons

(T. O'Halloran, J. Wiss, M. Diesberg, J. Filaseta, J. Simmons, in collaboration with a group from Fermilab)

Fermilab Experiment 400 was removed from jeopardy in spring 1980, and is presently scheduled to run in the wide band neutral beam facility at Fermilab in October of 1981. Although originally approved in 1975 as a study of particles produced by hadrons in association with the ψ , the present E-400

will primarily be a high statistics study of charmed particles produced by a 300 GeV neutron beam. The beam will be configured as it was for Fermilab E-358 which was performed previously by our collaboration as the first study of neutron ψ production.

Present information on hadronic charm production is somewhat sketchy and contradictory. A single prompt muon signal has been observed in proton proton collisions by several Fermilab experiments. This result is consistent with the central production of charmed mesons at the 20 microbarn level, and their subsequent semileptonic decay with an average 10% branching ratio. This type of experiment has given the best statistical information on the hadronic charm cross section. Unfortunately, because the charmed particles are not explicitly reconstructed, prompt muon experiments must rely on specific production models in order to extract their charm cross sections. In addition, they offer no information on the relative contributions of specific charmed mesons and baryons. Several experiments at Fermilab and CERN have reported the observation of hadronically produced charmed particles decaying into explicit final states. The detectors and triggers used in these experiments have had small acceptances in the central region ($X_F \approx 0$), and thus report on diffractive signals.

Because charm events are such a small fraction of the total hadronic cross section, backgrounds have always been the major problem in obtaining high statistics charm signals. Generally hadronic charm experiments have required a prompt lepton trigger in order to reduce the data to a manageable level and to improve the charm signal to background ratio. Unfortunately, such a trigger substantially reduces the charm yield, as well as biases the charm sample to those events with an accompanying charm semileptonic decay. These biases introduce significant complications in obtaining charm cross-sections and inclusive distributions. For these reasons, E-400 will rely on a different method for charm enhancement and trigger rate reduction.

The E-400 apparatus will be an upgraded version of the E-87/E-400 detector with the major improvement being a small, 2000 wire high resolution proportional chamber installed 10 cm downstream of a longitudinally segmented Be target. This chamber, based on a working prototype by the Sandweiss group at Yale, consists of 9 planes of 400 micron spaced wires and will operate at a pressure of 4 atmospheres. Secondary vertices from charmed particle decays

will be resolved from primary vertices at about the one millimeter level using the high resolution chamber. Hence about half of the accepted D^+ 's, which are known to have a lifetime of about 7×10^{-13} seconds, will have decay vertices separated by more than 3 standard deviations from the primary event vertex. Using backgrounds measured in the high energy data of E-87, which is believed to be primarily neutron induced, we compute signal to background ratios for the $D^+ \rightarrow K^- \pi^+ \pi^+$ in excess of 10 to 1 after applying the previously described vertex cut. Using the 10 microbarn estimate for D^+ production, and a central production model parameterization appropriate to hadronically produced ψ 's, we compute an expected accepted event yield in excess of 10,000 events for a 500 hour run.

Effective signal enhancement using the high resolution chamber requires charmed particles with lifetimes on the order of 10^{-12} seconds. The D^+ is the only currently known charmed particle satisfying this requirement, although strange-charmed baryons may also have lifetimes in this range. Reasonably clean D^0 signals should be obtained in E-400 by taking advantage of the narrowness of the $D^{*+} - D^0$ mass difference peak in the $D^{*+} \rightarrow D^0 \pi^+$ reaction. As demonstrated in E-87, the two magnet spectrometer arrangement will allow us to exploit this technique again by offering excellent acceptance for the soft pion produced in D^{*+} decay.

We will run E-400 with an essentially open trigger for detectable charm. Hence we will accept events with a large energy deposition outside our central calorimeter hole that have at least one kaon or proton candidate with a p_{perp} exceeding 500 MeV/c. The proton or kaon will be identified through our multicell Cherenkov system in conjunction with the M7 trigger processor. The M7 trigger processor, previously used in E-401, is a fast, pipelined computer with a special purpose instruction set designed for rapid track reconstruction. During the 1 second neutron spill, the M7 will insure that tracks failing to fire the Cherenkov counter are above pion threshold and thus are legitimate heavy particle candidates. In the 10 seconds between spills, the M7 will more fully reconstruct the data (which at this point reside on a 64 K solid state memory) and eliminate about 3/4 of the events which fail certain kinematic criteria. The remaining events will then be written on tape.

Fermilab's primary responsibility in E-400 includes the construction of the high resolution proportional chamber and the upgrade of the M7 trigger processor. Construction of the high resolution chamber has begun at Fermilab and should be completed toward the end of FY81. The M7 upgrade is already underway, and software for the M7 is being rapidly developed.

Illinois is responsible for the upgrade of the high speed data acquisition system (ACE), increasing the size of the present solid state memory to 64K, and the construction of the high resolution chamber's latch registers. The design modifications for the ACE system and memory upgrade are presently under discussion with our engineers. The latch register design is essentially a copy of the E-610 design and will require primarily packaging modifications. Board loading for the latch registers will commence shortly in parallel with our other E-400 activities.

In addition to the electronics responsibilities, Illinois has several detector upgrade projects including the construction of a two foot long multicell Cherenkov counter (C0) with a pion threshold of 3 GeV, the construction of a set of 120 proportional tube muon counters, and the upgrade of our shower counter system. The design of C0 which will greatly improve our kaon-proton separation capabilities, and will allow pion-heavy particle separation for low momentum particles in our outer detector, is nearly complete and most of the photomultiplier tubes have arrived. The proportional tube muon counters are very similar to those built at Illinois for the Mark III project and construction will commence shortly. The nature of the shower counter upgrade is presently unclear but may involve the construction of a proportional tube system sitting immediately upstream of our present 98 element lead glass array. The proportional tube system would be similar to that employed by E-610 and would serve to greatly disentangle the shower recognition problems expected for high multiplicity hadronic final states. The installation of a shower counter proportional tube system appears to be contingent on obtaining low cost proportional tube amplifiers and ADC's.

A.8. A Measurement of Neutrino and Anti-neutrino Elastic Scattering and Single-pion Production

(R. M. Brown, T. O'Halloran, S. Fuess, P. Nienaber, in collaboration with Columbia University)

This experiment consisted of several runs at Brookhaven National Laboratory which yielded 671K pulses of anti-neutrino beam and 213K pulses of neutrino beam. The apparatus consisted of Al spark chambers and the events were automatically measured by the University of Illinois. The elastic scattering measurements and analysis are now complete and a paper is now in preparation. The results may be summarized in two ratios:

$$R_1 = \frac{\sigma(\bar{\nu} + p \rightarrow \bar{\nu} + p)}{\sigma(\nu + p \rightarrow \nu + p)} = 0.45 \pm 0.18$$

$$0.33 < Q^2 < 1.0$$

$$R_2 = \frac{\sigma(\nu + p \rightarrow \nu + p)}{\sigma(\nu + n \rightarrow \mu^- + p)} = 0.13 \pm 0.04$$

$$0.25 < Q^2 < 1.0$$

The results are consistent with

$$\sin^2 \theta_w = 0.26 \pm 0.08 .$$

The measurement of the single pion production by neutrinos and anti-neutrinos has now been completed and the analysis will be concluded during the spring of 1981.

A.9. Illinois-Columbia Neutrino Proposal at Fermilab

(T. O'Halloran, J. Wiss, S. Fuess, M. Lamm)

We propose to construct a highly segmented, fully active neutrino target which will offer unparalleled resolution in both the direction and energy of hadrons produced by high energy neutrinos. This detector will probably complement another group's more conventional calorimeter detector and will be used in the Fermilab neutrino program. We hope to use this device to study the interaction of the tau neutrino (ν_τ) with matter using the neutrinos emerging from a beam dump. This device can also be used in wide band neutrino running in order to separate the charm contributions to ν induced dimuon events from the contributions from bottom production. The latter study provides information on the charm content of the nucleon, in much the same way

as the charm dimuon contribution has provided information on the strangeness content of the nucleon. This more modest and detailed proposal has been submitted as a Fermilab Tevatron proposal and we are awaiting Fermilab's response.

A.10. Electron-Proton Interactions

(T. O'Halloran, J. Wiss, M. Lamm)

We have initiated a proposal for the construction of a 10 GeV electron ring which will interact with the Tevatron at Fermilab. Several workshops sponsored by Columbia University or the University of Illinois have been held and it is our intention to submit a final proposal in collaboration with several other universities for the construction of a detector and electron ring capable of observing lepton-proton interactions using polarized and unpolarized electrons and positrons at momentum transfers of $Q^2 = 10^4 \text{ GeV}^2$. In order to get a reasonable counting rate we are proposing a 10 GeV ring with a luminosity of $4 \times 10^{31}/\text{cm}^2\text{sec}$. The proposal is being prepared in collaboration with accelerator physicists from Argonne, Brookhaven, and Fermi National Laboratories and physicists from several universities in addition to the National Laboratories.

A.11. Colliding Beam Studies at Fermilab

(G. Ascoli, R. Brown, R. Downing, B. Eisenstein, L. Holloway, J. Bellinger, G. Blaylock, in collaboration with physicists of the Colliding Detector Facility group)

Colliding beams of protons and antiprotons will become a reality at Fermilab within a few years. The expected luminosity is of the order of $10^{30} \text{ cm}^{-2}\text{sec}^{-1}$ at a center of mass energy of 2000 GeV. The beams are suitable for studying strong interactions where the expected cross section is about $50 \times 10^{-27} \text{ cm}^2$ and for searching for rare processes, e.g. production of $W^\pm$ and Z^0 vector bosons, where the cross section is of the order of 10^{-33} to 10^{-32} cm^2 . New phenomena are eagerly anticipated.

In the past year the Illinois group has concentrated its efforts in two areas: the central muon detection system and the FASTBUS electronics system.

The purposes of the central muon detection system are to provide precise position measurements of muons which penetrate the central electromagnetic and

hadron shower calorimeters and to provide a signal suitable for triggering on potentially interesting events containing muons. A double layer of drift tubes with a single layer of scintillation counters has been designed. The drift tubes are constructed with customized aluminum extrusions 4 x 15 x 400 cm with plastic extrusion inserts which carry field shaping conductors. An initial shipment of the aluminum and plastic extrusions has been received, and a prototype module is being constructed and tested. A module will consist of 28 tubes in two double layers separated by 30 cm. A layer of plastic scintillator lies in between. Drift times will be measured with time to amplitude converters with subsequent analogue to digital conversion. Charge division measurement of the Z-coordinate is being contemplated.

In order to reduce background, coming mainly from low P_T muons, an electronic triggering scheme is being designed which requires a coincidence between two muon tubes, one in each double layer, which point back to the beam intersection region. Low P_T muons, having been strongly bent by the central solenoidal magnetic field, will not be able to satisfy this coincidence requirement. An effective cutoff of about 5 GeV/c P_T obtains.

Control of the muon detection will be directed from an LSI-11 microcomputer interfaced through the FASTBUS system. Hardware and software efforts for this are described in Section IV.

B. The Experimental Program for the Coming Year

B.1. The Mark III Project at SPEAR

(R. Cassell, H. Cui, B. Eisenstein, G. Gladding, J. Thaler, A. Wattenberg, W. Wisniewski, J. Becker, S. Plaetzer, A. Spadafora, in collaboration with groups from SLAC, the California Institute of Technology, the University of California at Santa Cruz, and the University of Washington)

During FY82 we will be taking data, using Mark III with the SPEAR colliding beams. The initial runs will probably be at the ψ and/or ψ' resonances in order to acquire an appreciable number of events with clean topologies. These events will be used to complete the calibration of the pulse heights and timing in the various components of the detector.

During the following years, we intend to study a large variety of problems. The first runs following the ψ studies will probably be at the 3.77 GeV resonance in order to obtain a sample of tagged D mesons. Using the D mesons, we wish to determine whether the Cabibbo angle for the c to s quark transitions is the same as the Cabibbo angle for the s to u quark transitions. Specifically, the semi-leptonic decay ratio $(D \rightarrow \pi e \nu)/(D \rightarrow K e \nu)$ would give us the vector part of the Cabibbo angle for semi-leptonic decays. By also measuring the ratio $(D \rightarrow \rho e \nu)/(D \rightarrow K^* e \nu)$, we can get information about the axial vector part of the Cabibbo forbidden non-leptonic transitions $D \rightarrow KK$ and $D \rightarrow \pi\pi$. Better data are necessary to study the $\Delta I = 1/2$ rule and the extent to which there is a sextet enhancement in the non-leptonic decay. There are theoretical predictions, including QCD corrections, for the ratios of various non-leptonic decays.

The situation on the F mesons is very uncertain at the present time. We need to find an energy for the e^+e^- beam which will give us a useable signal for the F meson. One of the interesting questions is whether the relative lifetime of the F is the same as the D^+ or the D^0 meson. Another question is, what is the branching ratio of the F to $\tau\nu$?

Last year results were published on the observation of the charmed baryons from e^+e^- machines. There is very little information on the rich excited state spectrum of the charmed baryons. Also the higher baryon states which contain both charmed and strange quarks have not yet been observed.

There remain interesting questions regarding the tau lepton decays. For example, one would like to know the value of the Cabibbo angle for tau decays - specifically the ratio of $(\tau \rightarrow K\nu)/(\tau \rightarrow \pi\nu)$. We believe our muon detector will be very helpful in allowing us to eliminate the $\tau \rightarrow \mu\nu\nu$ events which might be confused with the decays of interest.

From the above, it is obvious that there is a very interesting and extensive program of measurements for the Mark III detector. Obviously, there is the possibility that new phenomena or theoretical developments will introduce other significant and exciting experiments into our program.

B.2. χ -Production (E-610)

(G. Alverson, L. Holloway, L. Koester, U. Kruse, R. Sard, H. Budd, T. Graff, S. Hahn, W. Li, P. Lukens, P. Schoessow, in collaboration with physicists from Fermilab, University of Pennsylvania, Purdue University, and Tufts University)

An additional data acquisition run at Fermilab is planned for the fall of 1981. This run will use 250 GeV/c protons as incident beam particles instead of pions as in the previous run of E-610. The comparison of data from the two different runs should allow us to make significant tests of charmonium production models. If the gluon-gluon fusion model (C. E. Carlson and R. Suaya, Phys. Rev. D18, 760 (1978)) is correct then we should be able to extract the gluon distributions function of the proton.

New superconducting coils are being installed in the Chicago cyclotron magnet replacing the old conventional ones. E-610 will be the first experiment to use the magnet in this configuration. Additional minor modifications and additions to the apparatus will be made in order to improve the performance and reliability of the spectrometer facility. An additional scintillation counter hodoscope will be installed behind the present muon hodoscope. It is expected that the rate of unwanted background triggers will be significantly reduced by this addition.

Analysis of the new data, as well as of the old data, will continue.

B.3. Photoproduction of Vector Mesons and Two-Particle Systems

(G. Gladding, A. Wattenberg, P. Callahan, C. Olszewski, in collaboration with a group from Fermilab)

We expect to complete the analysis for most of the topics contained in this experiment during FY82. Since we cannot know, at this time, the exact nature of these results, we will just give our best estimates of the possibilities in the following paragraphs.

From the low intensity hydrogen data, we expect to obtain approximately 200,000 elastic ρ 's, 3000 elastic ω 's, and 2000 elastic ϕ 's in the energy region from 50+150 GeV with momentum transfer squared, t , from 0+0.6 GeV². The preliminary analysis has demonstrated clean signals in all channels. Precise cross-section measurements depend on careful investigation of trigger biases, acceptance calculations, and K_L^0 and/or neutron beam contamination. We also expect approximately 250 $\psi \rightarrow \ell^+ \ell^-$ events.

It is difficult for us to make many predictions concerning the moderate intensity deuterium data since it is the sample that we have studied the least. However, preliminary analysis does show a clean ϕ signal (estimate $\approx$ 10,000 events) in the $K^+ K^-$ final state. We project a sensitivity of 100 events/nb in the high mass region.

Most of our analysis effort has been focussed on the high intensity hydrogen and deuterium data. We expect our first publications will be presentations of the results of our analysis of this data sample. Preliminary analysis, which makes use of the recoil detector information has demonstrated that we can cleanly separate elastic from inelastic events for $0.15 < t < 1.0$ GeV/c². Consequently, we expect to be able to use the approximately 300 $\psi \rightarrow \ell^+ \ell^-$ events from the hydrogen data to make an accurate measurement of the elastic t -slope. Previous results in the literature have varied from 1.8+2.9 GeV². Preliminary results from our sample of approximately 2500 $\psi \rightarrow \ell^+ \ell^-$ events from deuterium have indicated a cross-section which increases as the photon energy increases from 50+300 GeV. In order to make an accurate determination of this rise, we are in the process of making several checks for systematic effects. We have made an accurate measurement of our photon energy spectrum using both a total absorption counter in the beam in special runs, as well as our entire forward detector to observe $e^+ e^-$ pairs during our normal data-taking runs. We are also in the

process of comparing our data for dilepton masses $> 1.2 \text{ GeV}/c^2$ with the prediction made using the hypothesis that all such production is due to the Bethe-Heitler process. We are confident that when all such checks have been completed, we will be able to present the best measurement of ψ photoproduction to this date. In addition, we will be able to use our sample of approximately 30 $\psi' \rightarrow \ell^+ \ell^-$ and $\psi' \rightarrow \psi \pi^+ \pi^-$ events to make the first determination of the ψ' nucleon scattering cross-section.

B.4. Charm Production by High Energy Neutrons

(T. O'Halloran, J. Wiss, M. Diesberg, J. Filaseta, J. Simmons, in collaboration with a group from Fermilab)

Construction of E-400 should be completed at the end of FY81. We should run in the beginning of FY82. Significant data analysis of E-400 should be completed by the spring of 1983. We are presently looking into the possibilities of incorporating major portions of the E-400 detector into a first round Tevatron experiment.

B.5. Lepton Interactions at High Energies

(T. O'Halloran, J. Wiss)

The neutrino program at the University of Illinois is at the proposal stage. We have already submitted a proposal to Fermilab for the fully active neutrino target assembly. We are in the process of preparing an additional proposal to Brookhaven National Laboratory which will search for neutrino oscillations. Our future effort in the study of neutrino interactions will depend on the decisions of the Fermilab and Brookhaven laboratory directors.

We believe that the ultimate goal of the neutrino program will be the study of electron-proton scattering via colliding beams at energies and luminosities which will allow a detailed study of charged current and neutral current interactions with polarized electrons and positrons. Such a program represents an extension into a new frontier and should be a part of the national high energy program. In collaboration with other universities and national laboratories, we are preparing a proposal which will be submitted to Fermilab.

B.6. Colliding Beam Studies at Fermilab

(G. Ascoli, R. Brown, R. Downing, B. Eisenstein, L. Holloway,
J. Bellinger, G. Blaylock, in collaboration with physicists of the
Colliding Detector Facility group)

We will continue with the construction and testing of the central muon
detector modules. A total of 48 modules is needed. The design of a muon
detector for the angular range 30° to 50° will be started.

IV. OPERATIONS AND DEVELOPMENT OF COMMON FACILITIES

A. Technical Accomplishments During This Year

A.1. Data Acquisition Systems

(R. Brown, R. Downing, J. Kohlmeier, V. Simaitis, J. Wray, D. Lesny, K. Nater, S. Abraham, B. Jackson)

The FASTBUS project has absorbed a significant amount of the efforts of the software group during FY81. Members of the staff are on the Software Working Group for FASTBUS and also are working on specific applications which we expect to be useful for the CDF experiment. Some specific areas where work has been done are:

1. The Fermilab design of a Unibus Processor Interface (UPI) has been reviewed in detail, and specific suggestions for additions and changes were made.
2. A macro language (FSDMAC) based on PDP-11 Macro has been designed and implemented to use in writing the micro-code for the Fast Segment Driver portion of the UPI.
3. A Fastbus Diagnostic Language (FDL) has been designed and implemented for diagnosing FASTBUS problems. (Design philosophy is similar to that used in Camac Diagnostic Language at Fermilab.)

In similar veins,

4. The Fermilab Camac Diagnostic Language has been installed in our LSI-11 computers and made available to the engineering staff for debugging Camac systems.
5. A Blackbox Diagnostic Language (BDL) using a similar approach on LSI-11's has been designed and implemented for the University of Illinois Blackbox Data Acquisition crates.

A.2. Computer Operations

(R. Brown, J. Wray, D. Lesny, K. Nater, S. Abraham, J. Scaman)

In FY81 the PDP-10 computing system was operational and available for timesharing and batch use for approximately 8000 hours. Actual CPU usage during FY80 was a little over 3000 hours; about 4000 hours usage is expected for FY81. The new Data Products line printer, replacing the 8 year old original printer which was becoming somewhat unreliable, was installed and has

proved very satisfactory.

In addition to the use of the DEC-10 for some batch operations, approximately thirty terminals are available for time sharing users. Up to 16 of these can be in use at any one time; in the last year about 30,000 hours of terminal use were logged. In addition, 4 remote BBX stations in department laboratory rooms are available for data acquisition equipment development and checkout.

During the year more complete support of graphics was implemented, and growing use of graphics terminals was noted.

Three LSI-11's now have direct access to the memory of the DEC System-10. These systems are used for development of programs to be used (1) by experimenters in controlling equipment during experiments, (2) for ASCII file transfers at 300 or 1200 baud between the DEC-10 and computers at FNAL or SLAC, and (3) one of them has been programmed for use in an RJE configuration with the FNAL Cyber 175 computers. The DEC-10 is used in all of these operations to provide large disk storage space, fast line printer output and more sophisticated editor and file manipulation capabilities.

The additional exploration of the LSI-11's as peripheral processors did not lead to combinations which overcame the problems we noted in last year's report. The overhead in moving data into an area to be accessed by the PDP-11 seems to overshadow any advantage to be gained.

One new use of an LSI-11 system initiated during the year was providing computational support for staff members at a conference. A magnetic tape containing a large number of Monte Carlo generated events was generated on the DEC System-10. That tape and an LSI-11 with a small tape unit, a DECwriter for output, and a floppy disk for program storage were taken to the Snowmass e-p Machine Study. A number of questions which normally could not be treated until after the conference were answered in a matter of minutes or hours. Staff members felt that this facility contributed significantly to the study results.

A.3. Engineering Systems

(R. Brown, R. Downing, J. Kohlmeier, V. Simaitis)

A fast trigger processor for the Mark III experiment at SLAC has been constructed. This system was packaged in FASTBUS hardware. The building of approximately 150 FASTBUS modules and 10 air-cooled crates has provided an early test for the FASTBUS mechanics. Minimal problems were encountered during construction and several minor modifications were suggested and implemented by the FSDG.

B. Plans for Facilities for Coming Years

B.1. Data Acquisition Systems

(R. Brown, R. Downing, J. Kohlmeier, V. Simaitis, J. Wray, D. Lesny, K. Nater, S. Abraham, B. Jackson)

Continued development of the FASTBUS hardware and software is expected during FY82. By the end of FY81 initial tests of the FNAL UPI hardware and software will be complete. Additional tuning of those components will continue in FY82 with specific considerations of the needs of the Colliding Detector Facility.

In addition, members of the staff will continue their work on the FASTBUS Software Working Group projects.

B.2. Computer Operations

(R. Brown, J. Wray, D. Lesny, K. Nater, S. Abraham, J. Scaman)

The use of the DEC System-10 is expected to run at about 4000 hours of CPU usage. The addition of the new memory to the System, long delayed by the need for engineering time, will make possible some experimental design and data analysis which previously could only be done remotely on the SLAC or FNAL central computers.

Additional areas:

1. Studies on the impact of obsolete hardware and software on the users of the DEC System-10 and the costs of upgrading will be done. By the end of FY82 software obsolescence is expected to cause noticeable problems in compatibility of languages (e.g., FORTRAN).
2. Studies of the Group's growing needs for Computer-Aided-Design will be undertaken, and the use of the DEC System-10 in that operation will be evaluated. Areas to be considered include printed circuit board design, mechanical design, and experimental equipment layouts. The need for additional graphics capabilities will be evaluated.
3. Although FASTBUS Diagnostic Language, Blackbox Diagnostic Language, and the macro-driven micro-code assembler for the UPI will be essentially finished during FY81, continuing developments are expected in those areas.

4. In addition, normal program development will be done for data analysis for new experiments.

B.3. Engineering Systems

(R. Brown, R. Downing, J. Kohlmeier, V. Simaitis)

Work will continue on developing the standard protocol and interface I.C.'s for FASTBUS. We plan on specifying a design and having a limited number of these devices produced. Several types of general purpose modules will be designed to test these I.C.'s in a system environment.

We also plan on developing several general purpose modules in the FASTBUS standard. This will allow experimenters to have access to off-shelf hardware just as in NIM, CAMAC, and our internal BLACKBOX system.

During the first quarter of FY82 we will finish and install the new data acquisition system for FNAL Experiment 401 (see III. B.3.).

Work will continue on developing FASTBUS electronics for use in the CDF at Fermilab. This group has an on-going commitment to this experiment for the next several years.

C. FASTBUS Hardware Studies During This Year

(R. Downing)

Preliminary discussions have taken place with I.C. gate-array manufacturers about interface and control chips. A tentative design is awaiting resolution of certain FASTBUS protocol details by the FSDG. If these minor problems can be resolved in the next few months, the design can be hardened. Hopefully some large experiment, such as the CDF at Fermilab, can commit a large amount of hardware to these I.C.'s and amortize the set-up charges over several thousand pieces.

R. Downing has been a member of the FSDG's sub-committee on architecture - the TRI-GROUP. This small group of people has had the major responsibility for devising and checking the system protocol. It has also mainly been this group, along with some people from the software and mechanics group, that has been writing and editing the FASTBUS document.

This research group has made significant contributions to the FASTBUS effort early in the prototyping phase. First, the Mark III trigger was entirely packaged in FASTBUS mechanics. This apparatus uses eight air-cooled chassis and approximately 150 printed circuit boards. The major contribution here was in providing a relatively large construction project to test the ease and flexibility of the packaging. As a result of this project, a minor mechanical change was recommended and approved by the mechanics group. The forced-air-cooled mechanics package, having been Mark III field tested, is now in excellent shape for others to use.

A major general purpose module, the Segment Interconnect, has been designed by the University of Illinois. This device is critical in the implementation of the FASTBUS approach to interconnecting parts of systems. All proposed protocols must be able to be implemented in this device. Having the Segment Interconnect design during the committee's deliberation has been extremely useful in finding logical errors in the protocol.

Besides the SI design here, we are also cooperating with SLAC in the design of the SNOOP module. This device allows detailed diagnostics to be performed on the system. The SNOOP will be one of the most useful general purpose tools for system designers and later for experimenters to use in monitoring and fault finding while running experiments.

monitoring and fault finding while running experiments.

The FASTBUS work has pointed out one serious problem which large boards and complex system design is causing. That problem is the amount of lead time required to build these devices. Not only has the engineering time risen, but the amount of time to convert those engineering drawings to real equipment has risen even more. It is clear that we need to rapidly bring our design and prototype capabilities up to what is currently being used by the electronics industry. A significant investment should be made as rapidly as possible in computer aided design (CAD). This will allow the engineer to at least halve the design phase. It will also reduce by a factor of three (maybe more) the time to lay out these large boards. The human designer is almost at a breaking point when it comes to laying out and verifying the connection between 200 to 250 integrated circuits. For example, the first pass layout of the SNOOP (~250 I.C.'s) took an extremely experienced layout person 12-14 weeks. Another 6-8 weeks is required to convert this design to the photographic artwork to construct the board.

The new technologies will allow us to do better experimental work; however, we must begin to obtain the tools to make this conversion. CAD systems are absolutely necessary if we are to continue to advance our hardware and make our engineers and technicians more productive.

The High Energy Group also has a significant effort in developing FASTBUS software. The details are contained in Sections A and B above.

D. FASTBUS Hardware Studies for the Coming Years

(R. Downing)

The work on the FASTBUS protocol integrated circuits will be closely coordinated with the work at the national laboratories (SLAC, Fermilab, etc.) and also with the Fast System Design Group as a whole. This is necessary to insure the widest acceptance possible.

The circuits will be three designs. The first circuit will be a bus interface I.C. organized as a byte wide transceiver with parity checking generation, logical address recognition, and certain broadcast, geographic address, and "T" pin selection modes. Four of these circuits will facilitate the user's connection to the 32 bit Address-Data Bus.

Two other circuits will be required to implement general purpose slave logic and a position of master logic. These designs will probably be done with smaller gate-arrays rather than the bus transceiver chip. Based on current design proposals, the two protocol chips will be in the new 44 leadless JEDEC chip carrier. The bus transceiver package will probably be the 68 leadless JEDEC chip carrier. The chip carriers offer the best electrical properties, packing density, and thermal management in what will probably be the most common packaging standard of the mid-80's and beyond.

We plan to continue our FASTBUS effort both in building experimental equipment for this research group and providing those designs of general purpose FASTBUS equipment for the entire high energy physics community. This will be possible through our continued involvement with FASTBUS committee work and prototype equipment development.

V. PUBLICATIONS SUBMITTED OR PUBLISHED AND PAPERS
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