RECEIVED BY TIC JUL 27 1972

United States Atomic Energy Commission
Contract AT(11-1)-3130 (Task B-Experimental)

PROGRESS REPORT
OF A RESEARCH PROGRAM
IN
EXPERIMENTAL HIGH ENERGY PHYSICS

by

Anatole M. Shapiro and Robert E. Lanou, Jr.

1 June 1972

Department of Physics
Brown University
Providence, Rhode Island

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

GG

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

UNCLASSIFIED

PROGRESS REPORT OF A RESEARCH PROGRAM
IN EXPERIMENTAL HIGH ENERGY PHYSICS

Anatole M. Shapiro and Robert E. Lanou, Jr.

Professors of Physics

Principal Investigators

Department of Physics

Brown University

Providence, Rhode Island

AT(11-1)-3130TB

1 June 1972

UNCLASSIFIED

Progress Report of a Research Program
in Experimental High Energy Physics

The Department of Physics of Brown University presents herein a report of the progress made in the experimental program during the present contract year (1 September 1971 - 31 August 1972). This work has been supported by the U. S. Atomic Energy Commission under Contract AT(11-1)-3130 (Task B - Experimental).

This report is divided into five sections:

- I. Data Analysis in Progress;
- II. Experimental Runs in Progress and in Preparation;
- III. Associated Matters;
- IV. Papers Published During the Preceding Year and Papers in Press;
- V. Scientific Personnel Associated with the Experimental Program.

I. Data Analysis in Progress.

A. The Argonne π^+ p Bubble Chamber Experiment - First Stage.

(Widgoff, Shapiro, Massimo, and Fong)

In the first 100,000 pictures of 4.1 GeV/c positive pions taken with the ANL 30" liquid hydrogen bubble chamber, we originally concentrated our efforts on the two-prong and four-prong events. We carefully scanned and rescanned the film for events of all types, but measured and analysed only the above two classes, which constituted 96% of the total.

Recently, considerable interest has developed in observing how well the parton model and other ultra-high-energy models work at lower energies. We have decided to study the single-particle and the double-particle "inclusive" spectra in our events. In order to do this it has been necessary to go back and measure the remaining 4% of the events (approximately 800). These events, although few in number, must be included since they contain a significant fraction of the total number of π^- 's produced in the experiment. One-half of these predominantly six-prong events have been measured and analysed to date.

Various conjectures of limiting behaviour (i.e. the approach of cross sections, properly scaled, to a constant value) as a function of energy have been proposed. Chan Hung-Mo and collaborators¹ have suggested that such behaviour may begin at relatively low energies for reactions of the type $a + b \rightarrow c + \text{anything}$, where the quantum numbers of the combination (abc) are exotic. For $\pi^+ + p \rightarrow \pi^- + \text{anything}$, $abc \equiv \pi^+ p \pi^-$, which has baryon number 1, charge +3, and thus is exotic.

¹Chan Hung-Mo et al., Phys. Rev. Lett. 26, 672 (1971).

Single-particle spectra may be determined as a function of several different variables: P_L (target), the longitudinal momentum of particle c in the rest frame of the target b; P_L (projectile), the same in the rest frame of the projectile a; $x \equiv 2p_L^*/\sqrt{s}$, the Feynman variable, where p_L^* is the longitudinal momentum of c in the overall c.m. system and s is the square of the total energy of a and b in the c.m. system; $P_{\perp}^2$, the square of the transverse momentum of c; and also the "rapidity" variable. We have plotted preliminary results for this reaction in Figures 1, 2, and 3, using the first three variables above, respectively. On these graphs, our data at 4.1 GeV/c is compared with corresponding data² taken at 6 and 22 GeV/c. In Figure 1 limiting behaviour is observed for P_L (target) < 0.4 GeV/c, and in Fig. 2 the same is true for P_L (projectile) < 2.4 GeV/c. This agrees well with the conjecture of Chan Hung-Mo et al.¹. In Fig. 3 near equality is obtained toward the edges of the distribution in the Feynman x, but not in the central region. This analysis is being extended, and the $\pi^+\pi^-$ correlations are being studied in the particularly interesting reaction (among the 800 six-prong events)

$$\pi^+ + p \rightarrow \pi^- + \pi^- + \text{anything}.$$

The two-prong and four-prong results have been reviewed during this year and the results brought up-to-date. A series of papers on this data is being prepared for publication in the Physical Review. The first two (see Section IV, References 163 and 164) are almost ready for final typing and should be submitted within a month. The remaining ones -- π^+p Interactions at 4.09 GeV/c: III. Two-and Three-Body Final States; and -- IV. Inclusive Reactions -- will be ready for submission shortly afterwards.

²Crennell et al., Phys. Rev. Lett. 28, 643 (1972).

$$\frac{E}{\sigma_{\text{Tot.}}} \frac{d\sigma}{dP_L(\text{TARGET})}$$

Fig. 1

$$\frac{E}{\sigma_{Tot.}} \frac{d\sigma}{dP_L (PROJECTILE)}$$

Fig. 2

$$\frac{2E}{\sigma_{Tot.}\sqrt{s}} \frac{d\sigma}{dx}$$

Fig. 3

B. The Backward Scattering AGS Spark Chamber Experiment.

(Chen, Massimo, and Lanou)

As we discussed in previous proposals, this is an experiment to measure π^0 and η^0 angular distributions in the backward hemisphere (including 180° point) when produced in π^-p collisions.

The major interest in this experiment arises from its bearing on baryon-exchange processes, Regge-pole models, the determination of some of the parameters of nucleon resonances, and charge-independence tests at high momentum transfer. The principal data used in this study are the high-statistics angular distributions taken at a sequence of energies. Energy dependent trends can be identified and compared to various models. The energy range involved here covers in detail the very sensitive "intermediate energy" region and its highest point overlaps high energy data which exists at isolated points.

Last year we reported the completion in May of the run at the AGS. In that run we accumulated a total of 350,000 pictures taken at 14 incident pion momenta in the interval from 2.0 to 8.0 GeV/c.

Final versions of all of the computer programs are written, tested and in production operation. About 3/4 of the film has been scanned and measured once for π^0 and η^0 candidates. In addition to the remaining film some measuring must be done on higher multiplicity events for a detailed study of the small but important background processes.

Scanning and measuring have progressed at a very slow pace as a result of the reduced number of scanners due to budgetary limitations. By this time we had expected to be finished all of the first scanning and measuring,

instead we have at least two scanner-years more work. As pointed out in Section III, this presents a serious bottleneck.

However, results have been obtained at 4.3 GeV/c and 6.0 GeV/c. The angular distributions at the two momenta are surprisingly similar; they both show a sharp, backward peak and a broad minimum at a u -value of about -0.25 GeV/c. Although the detailed energy dependence of this structure is the prime goal of this experiment and final conclusions must await the completion of all the data at each of our momenta, these early results seem to favor a rather broad minimum. Currently, there is disagreement amongst several published experiments concerning the nature and position of dip-bump structure. The resolution of these differences undoubtedly lies in a complete understanding of experimental resolution and the nature of the background to be subtracted. This experiment is especially well suited to providing this understanding; we are currently embarking on a detailed study in an attempt to resolve the current disagreements.

Using the data at 6.0 GeV/c, and combining it with published data from π^+ elastic scattering, it is possible to make a test of charge independence at large momentum transfer. This is done by using the 180° points. The result is consistent with charge independence. Most of these data appear in the Ph.D. thesis of Dr. George Chen (Ref. 165).

In the next few weeks we expect to combine this data at 4.3 and 6.0 GeV/c, as well as similar data at 2.85 and 3.5 GeV/c, with that of our collaborators (Bari and MIT). The results will be presented at the XVI International Conference on High Energy Physics to be held at NAL in September.

Simultaneously, production on the remaining un-scanned and un-measured

film will hopefully be proceeding at an increased pace if we can return our scanning staff to something closer to full strength.

C. The Argonne π^+p Bubble Chamber Experiment - Second Stage.

(Widgoff, Shapiro, and Fong)

In the second stage of the 4.1 GeV/c π^+p experiment, 395,000 additional good pictures were taken in the spring and winter of 1970. (425,000 more were actually taken, but the data-box readout did not work properly for 30,000 of these, which makes them essentially unusable.) Ninety-two percent of these have been scanned once for all the events that they contain within the central fiducial volume, and about 10% have been double scanned in order to check efficiencies.

The total number of events in this film will be approximately 90,000, of which 35,000 will be of two types: four-pronged, and two-pronged with one or two V^0 decays. As we proposed last year, the 35,000 events of these two types are being studied first. Up to the present time, 29,000 events have been rough-digitized at Brown in preparation for their precision measurement at MIT using the PEPR system; and 23,000 events have been processed through the PEPR system.

The above two types of events were chosen for initial study in order to make an improved measurement of the branching ratios of the A_2 into its main decay modes. The three main modes are known to be roughly in the proportions $\pi^+\pi^-\pi^0:KK^0:76:18:5$, but no systematic measurement of the ratios has yet been made. Also, the above proportions were determined primarily from A_2^- decays, while we shall be studying A_2^+ and A_2^0 decays.

There are two principal reactions for A_2 production in this experiment:

$$\pi^+ p \rightarrow p A_2^+,$$

and

$$\pi^+ p \rightarrow (\Delta^{++} \text{ or } p \pi^+) A_2^0$$

The main decay modes are then

$$A_2^+ \begin{cases} \rightarrow \rho^0 \pi^+, \rho^+ \pi^0 \\ \rightarrow \eta^0 \pi^+ \\ \rightarrow K^+ K^0 \end{cases}$$

$$A_2^0 \begin{cases} \rightarrow \rho^+ \pi^-, \rho^0 \pi^0, \rho^- \pi^+ \\ \rightarrow \eta^0 \pi^0 \\ \rightarrow K^+ K^-, K^0 K^0 \end{cases}$$

Most of the final states in the above channels have four prongs or two prongs plus one or two V^0 's. We can identify all of these and thus determine the branching ratios of the A_2^+ and the A_2^0 with good precision. Mr. R. Simard is pursuing this investigation as part of his doctoral dissertation.

The complete sample of four-prong events will also be used to continue our study of four-body and five-body final states, as discussed in our previous progress reports and renewal proposals. As soon as all of the above events have been measured, we shall proceed with the measurement of the remaining two-prong events and of the six-prong and the handful of eight-prong events, so that as much information as possible will be derived from this film. Of primary interest are the dynamics of the quasi-two-body and the quasi-three-body reactions which predominate at this energy. We shall also investigate the extension of the various inclusive models down to 4.1 GeV/c.

Recently we have started to study the "Prism Plot" analysis technique³ developed by Professor Pless and the MIT bubble chamber group. This technique makes use of a set of variables which help separate a sample of data into

³I. A. Pless et al., MIT Data Analysis - PEPR Programming Note #101 (1971) (unpublished) and Phys. Rev. Lett. 27, 1481 (1971).

its component channels. It appears that this method will aid considerably in the analysis of our data, and if so, it will be vigorously pursued.

II. Experimental Runs in Progress and in Preparation.

A. A $\bar{p}$ -p Bosons (in the T and U-mass region) AGS Spark Chamber Experiment (AGS #527).

(Chen, Massimo, and Lanou)

This experiment, which was reported as approved last year has, for reasons discussed below, been broken into two parts both of which are approved. The two parts are divided into the S-region (AGS #600) and the T and U-region (AGS #527).

The physics of both experiments is very closely related to that of our current backward scattering experiment. Typical reactions are $\bar{p}p \rightarrow \pi^0 \pi^0$, $\pi^0 \pi^0$, $\pi^0 \eta$, $\pi^0 f^0$. The point of the experiment is to study the angular distributions of these reactions as a function of incident antiproton energy. The energy region involved permits the study of the mass range up to 2500 MeV. In this range there are suggestions for at least eight mesons of as yet undetermined quantum numbers. The explicit nature of the quantum numbers in the final states mentioned above, together with an analysis of their angular distributions will permit unambiguous determination of the parameters for many of these heavy mesons. In addition, by crossing symmetry, these final states are closely related to backward meson scattering, the interchange of the roles of the s- and t-channel resonances and Regge trajectories in these processes presents an ideal situation in which to study the predictions of models involving "duality", such as the Veneziano model.

All of the equipment was finished and installed in position on the ACS floor last Fall. It is located in a re-designed, separated, antiproton beam with large momentum acceptance but with tagging of individual antiprotons to $\pm 0.25\%$ thus permitting very high mass resolution (Ref. 166). The detector system is one of the more massive and compact we have built consisting of six, high-Z spark chambers totaling ten tons and seventy-two counters arranged in a very convoluted geometry. The electronic logic system which results in an extremely tight trigger is consequently complicated.

Testing of the beam, detector and logic systems began in the Fall. The tests were very successful yielding antiproton fluxes slightly greater than have been achieved before, a 3000:1 rejection of the most troublesome background in the trigger, and a total triggering ratio of the predicted magnitude.

Real data taking began during the winter and we have had sufficient scheduled running time to accumulate slightly more than half (240,000 pictures) of our originally requested pictures.

The quality of the pictures is excellent and some preliminary scanning, measuring, and analysis has been done. These preliminary analyses have shown some interesting features which lead us to request an increase in running time, and consequently the total number of events, from the BNL High Energy Advisory Committee. This request has been approved. The interesting features which prompted this request are that although the total cross-section into all channels is about as expected, the distribution into the different channels (e.g.; $\pi^0\pi^0$, $\omega^0\pi^0$, $\pi^0\gamma$) is different than what one might have expected. Of particular importance is the fact that the simplest channel, $\pi^0\pi^0$, is perhaps a factor two

smaller than an educated guess would have given; this channel had never been measured before for antiprotons in flight. Since we felt that it was important to have adequate statistics in this simplest channel to do a partial wave analysis of the angular distributions, we requested the 600 hours addition which was approved. We propose, at least initially, to measure only those events related to the $\pi^0\pi^0$ channel in this additional film.

It is worth emphasizing here, as was mentioned in Section IB, that the reduced scanning staff is a problem. While the scanning and measuring task is not an unusual or difficult one for either of these experiments we are faced with a bottleneck in manpower. Film is arriving at Brown from this current run at BNL and we still have two scanner-years to go on the backward charge exchange experiment. The addition of two new scanners would go a long way to alleviating this problem.

Mr. R. K. Thornton, whose Ph.D. thesis will contain data from this experiment, has been resident at Brookhaven full-time. One other member of the group will be there essentially full-time this summer.

B. A $\bar{p}$ -p $\rightarrow$ Bosons (in the S-region) AGS Spark Chamber Experiment
(AGS #600).
(Chen, Massimo, and Lanou)

As mentioned in previous section, our $\bar{p}$ -p $\rightarrow$ Bosons experiment has been divided into two parts: one covering the S-region and one covering the T and U-region. This comes about for reasons principally to do with the antiproton intensities available in the momentum ranges needed for the corresponding $\bar{p}$ -p center of mass intervals. In the S-region (this corresponds to incident antiproton momenta less than 600 MeV/c) the intensity of anti-

protons produced directly at those momenta is very low-too low in fact to perform an experiment of the sort we have in mind. Consequently, the intensity must be increased and a way has been found to make an increase to a level which, when combined with greater target length, raises the over-all event rate to a useful level. The elements of this scheme utilize energy degrading and are discussed in a paper by Zeller, Rosenson and Lanou (BNL #16000).

The BNL High Energy Advisory Committee has approved 100 hours for initial tests and running of this experiment.

We have utilized some of this time already in an extensive test of the degrading technique. Aside from the addition of a simple Fitch-type Cerenkov counter, it utilized all of the equipment of AGS #527 without modification. It proved quite successful and enabled us to achieve intensities of more than 100 $\bar{p}$'s per pulse at momenta as low as 450 MeV/c. We are currently studying film taken during this test to determine the resulting rate and the mass resolution; these two factors are important for estimating the total needed running time. We expect to re-build the hydrogen target (i.e., increase the length and area of the target cell) and build two small scintillation counters at the end of AGS #527. This should be a matter of a few weeks and then we will be prepared to run again in the Fall. Incremental costs for this experiment would be in film, spark chamber gas, and subsequent scanning. The hardware, experimental set-up, testing, computer programs, etc. are all identical to experiment #527. This is a unique experiment in a very interesting area of particle physics where previously only low statistics bubble chamber experiments have been done. It represents the possibility of a large reward for a small investment.

C. A Nucleon-Nucleon and Meson-Nucleon Interaction Experiment

Using Counter-Spark Chambers at NAL (NAL #96).

(Chen, Massimo, and Lanou)

This approved experiment is to measure elastic scattering and quasi-two-body elastic scattering of K^+ , K^- , p , and $\bar{p}$ on hydrogen and deuterium (neutron) targets up to 200 GeV/c incident momentum and at $|t|$ values of 0 to 1.5 (GeV/c)^2 .

The spectrometer is of flexible design and can operate either with 15u steradians acceptance and $\pm 0.03\%$ momentum precision up to 200 GeV/c or can be changed to give considerably larger acceptances at lower momenta. It will be equipped with DISC and threshold Cerenkov counters as well as scintillation counters, hodoscopes, and multi-wire proportional chambers. The collaboration assembled to construct and carry out this experiment consists of individual physicists from ANL, Bari, CERN, Cornell, MIT Stanford, and NAL.

At this time last year a full electronic logic system had been designed, some of the electronics had been purchased, prototypes of the hodoscope elements were built, and a preliminary design outline of an executive program had been made for the on-line computer system. During the intervening year we have gone through the first revision of the electronic logic design and have completed the major portion of purchases for Brown's part of the electronics and computer peripherals; more purchases will have to be made during the coming year but can no doubt be accommodated from the current operating budget. A hodoscope composed of twelve of the prototype units were built and tested in a separated, antiproton beam at BNL; it worked very well and we are going

ahead with construction of the next group. The first prototype multiwire proportional chamber, built by the Bari group, was tested by them with our group in a test beam at BNL using a borrowed PDP-11. The test was very successful indicating low noise, strong signal and computer capability. A major effort of the past year has been in the development of a software executive system for the Digital PDP-11, suitable for the data acquisition and on-line analysis problems of Experiment 96. The executive system proper, which supports the swap-in and swap-out of experiment dependent tasks, and priority-ordered input and output of data, was constructed and to a large extent debugged under simulation on a PDP-10, then installed in a local PDP-11 for final testing. The system was installed on the PDP-11 dedicated to Experiment #96 at NAL in early June. Further refinements to the system are continuing on both the local PDP-10 and PDP-11, and on the NAL PDP-11. Although this program has been developed for NAL #96 it is completely general and will not only handle any successive experiments using the single arm spectrometer but is generally applicable to any similarly configured PDP-11-controlled experiment at NAL or elsewhere (Ref. 167, 168, 169).

Professor Massimo and Mr. Levinson (a student, part of whose thesis will contain data from this experiment) have spent week-long periods at NAL during the year. Mr. Levinson is presently in residence at NAL. Travel costs and manpower continue to be a problem for us at NAL.

D. An Experiment to Study "Inclusive" Reactions Using the NAL
Single-Arm Spectrometer (NAL Proposal #118).
(Chen, Massimo, and Lanou)

In February of last year we, together with our Bari and MIT collaborators, submitted a new proposal to the Program Committee for NAL. At this

writing, no action has been taken by the Program Committee on any of these "second wave" experiments for the spectrometer.

We proposed to make an experimental study of the so-called "inclusive reactions" -- they are ones in which some particle or property of the final state is studied without trying to specify what else is happening in the reaction -- these reactions are usually represented by $a + b \rightarrow c + \text{anything}$. More specifically we plan to make an exploratory investigation of these processes by measuring the momentum spectra of final state hadrons over a range of production angles and incident energies with the use of the NAL focussing spectrometer which will be constructed for Experiment #96, as mentioned above. By employing an array of Cerenkov counters in the spectrometer set to be sensitive to different masses, the momentum distribution of protons, π^+ and K^+ can be simultaneously measured. The spectra of final state π^- , K^- , and $\bar{p}$ can be simultaneously measured with reverse magnetic fields. With the use of Cerenkov counters in the incident beam as well, reactions resulting from protons, antiprotons, K^+ mesons, and π^+ mesons can be simultaneously measured over the part of the kinematic range to be covered in this experiment in which the incident intensities are about 10^7 particles per pulse or less.

This proposal is one of several submitted by sub-groups of the single-arm-spectrometer collaboration and they will constitute the "second wave" of experiments to be performed using the original facility with little or no modification. This should represent a saving in capital equipment costs per experiment. It is hoped that the Program Committee will consider this group of "second wave" experiments at its meeting this August.

E. The Proportional Hybrid System Experiment at NAL

(NAL Experiment #154).

(Widgoff, Shapiro, and Fong)

In the spring of 1971 a collaboration of physicists from nine institutions including Brown proposed to build a set of multi-wire proportional chambers to be used together with the ANL 30" hydrogen bubble chamber at NAL. This proposal was turned down because the designed system was considered to be too large, too expensive, and too untried. NAL recognized, however, that our design had basic advantages over other proposed systems, enabling a wider variety of experiments to be performed. We were thus encouraged to propose a simplified system, which was submitted and then approved as NAL Experiment #154 in August 1971.

This system has two distinct sections -- one section, which extends upstream from the bubble chamber, consists of four 4"x4" proportional chambers and three scintillation counters; the other section, which will be located downstream from the bubble chamber, consists of a series of 12"x12" proportional chambers.

The upstream section will identify each particle entering the 30" chamber as to position, angle (to within $\pm 1.1 \times 10^{-5}$ radians), momentum (to within $\pm 0.04\%$), and time order of arrival. Cerenkov counters in the beam further upstream will identify each particle as a π , K or proton and this information will be incorporated with that from the proportional chambers. The upstream section, after it is made operational, will be turned over to NAL and will become a general facility of the laboratory providing input information to all 30" chamber users.

The upstream section was completely built within a six month period and is currently being installed at NAL. As part of our contribution to the collaboration, the Brown group designed and constructed the scintillation counters and the associated electronics and logic system for the upstream section. The scintillation counter system provides a master gate during which all the wire chamber information is collected and stored. Controlled deadtimes are provided which permit complete storage before new information will be accepted. A record is kept for each master gate of all multi-track problems, such as the arrival of additional particles during the master gate and during the following deadtimes. A complete description of the counter-logic system is now being written up as a Brown Internal Report (Reference 171) and will be distributed to the collaboration. An "Operator's Manual" is also being prepared for the general user.

Special enclosures for the counters were constructed at Brown for the mounting of the counters and in order to provide an explosion-proof atmosphere around them. Because of the large distances between the counters and the presence of the high-voltage power lines nearby, special circuits were built at each counter to send out two signals of opposite polarity for each particle. Another circuit was built to receive these double signals in the control room and convert them into standard NIM pulses for the logic system. In this way we believe that all noise pickup problems should be eliminated.

The large downstream chambers are nearly completed and will be installed during the summer. Recently we have determined that we will be able to build an extra downstream chamber and to set it in position at the end of the chain with a lead plate in front of it. This plate and last chamber will enable us to observe fast forward π^0 's without interfering with the measurements of

the charged outgoing tracks. This development will improve considerably the capabilities of our hybrid system. Such a development did not seem to be feasible last year and this was the only important deficiency of our hybrid system in comparison with the wide-gap-spark-chamber hybrid system.

In our Renewal Proposal last year we described at length some of the interesting physics that we proposed to investigate with our proportional hybrid system. With the addition of the above π^0 detector much more information will be known about each interaction, and more processes can be studied. For example, in the diffraction dissociation of the projectile particle, most of the π^0 fragments as well as the charged fragments will be observed in the downstream system. Because of the very small opening angle between the gamma pairs from each π^0 , both the direction and the energy of the π^0 will be well determined.

The system as it is being developed can be used with incident beams of pions, kaons, or protons, of either sign of charge, at various incident momenta. Experiments will most likely be carried out with all these particles in due course. An initial run of 20,000 pictures will be made as soon as possible, with the incident beam determined to be most feasible under the then-current operating conditions of the accelerator. We expect that these pictures will be taken sometime during this fall. The entire collaboration will then proceed to analyze rapidly two basic quantities: the elastic scattering $d\sigma/dt$, and the momentum and angle spectra of all secondary particles. We expect to be able to do this and to present significant results in the order of one to two months. This will be a demonstration that our entire hybrid system, from the hardware through to the geometry and kinematics programs, is working well. Upon the successful completion of this demonstration, a schedule of pictures for each member of the collaboration will be decided upon.

The development of the final set of analysis programs has already begun and these should be ready by this fall. All of the Brown group, and most of the other physicists in the collaboration, will spend a considerable amount of time this summer at NAL testing out the system and preparing for the first 20,000 pictures.

III. Associated Matters.

Professor Massimo has been invited to participate in the XVI International Conference on High Energy Physics to be held September 6-13, 1972 at NAL and the University of Chicago.

Professor Lanou has been invited and will participate in the physics portion of the Intersecting Storage Accelerator (Isabelle) Summer Study to be held at Brookhaven this June. He also received an invitation to participate in the Philadelphia Conference on Meson Spectroscopy. He will complete a two and a half year tour of duty on the BNL High Energy Advisory Committee this December but has been asked by the BNL Physics Department to remain as a Consultant to the Laboratory.

Professor Shapiro also received an invitation to participate in the Philadelphia Conference on Meson Spectroscopy.

Professor Widgoff may attend sessions of the XVI International Conference on High Energy Physics as an alternate invitee, while working on the hybrid experiment at NAL.

IV. Papers Published During the Preceding Year and Papers in Press.

163. D. G. Fong, S. Pitluck, A. M. Shapiro, and M. Widgoff, " π^+p Interactions at 4.09 GeV/c: I. Five-Body Final States," (in preparation for submission to the Physical Review).
164. D. G. Fong, J. T. Massimo, S. Pitluck, R. Reasenberg, A. M. Shapiro, and M. Widgoff, " π^+p Interactions at 4.09 GeV/c: II. Four-Body Final States," (in preparation for submission to the Physical Review).
165. George T. Chen, Ph.D. Thesis, "Backward πN Charge Exchange at 4.3 GeV/c and 6.0 GeV/c," Internal Report #121 (unpublished).
166. R. E. Lanou, Jr., M. Marx, F. Posa, L. Rosenson, and R. K. Thornton, "A Separated Antiproton Beam with Momentum Tagging," Internal Report #122 (unpublished).
167. J. T. Massimo and B. Nelson, "SPEX (Spectrometer Executive): General Structure," Internal Report #123 (unpublished).
168. J. T. Massimo and B. Nelson, "SPEX (Spectrometer Executive): Programmer's Manual," Internal Report #124 (unpublished).
169. L. J. Levinson, J. T. Massimo and B. Nelson, "SPEX (Spectrometer Executive): Auxiliary Programs," Internal Report #125 (unpublished).
170. B. N. Kendall, R. E. Lanou, Jr., J. T. Massimo, A. M. Shapiro, and collaborators, "Measurement of the Branching Ratios of the Eta-Zero Meson," (in preparation for submission to Il Nuovo Cimento).
171. D. G. Fong and A. M. Shapiro, "The Scintillation Counter Telescope and Master Gate Logic for the Proportional Hybrid System," Internal Report #126 (unpublished).
172. Anatole M. Shapiro and Robert E. Lanou, Jr., "Progress Report of a Research Program in Experimental High Energy Physics," (unpublished).

V. Scientific Personnel Associated with the Experimental Program.

A. M. Shapiro	-- Professor
R. E. Lanou, Jr.	-- Professor
J. T. Massimo	-- Associate Professor
M. Widgoff	-- Associate Professor (Research)
D. G. Fong	-- Research Associate
G. T. Y. Chen	-- Research Associate
L. Levinson	-- Graduate Research Assistant
R. Simard	-- Graduate Research Assistant
S. Subbarao ¹	-- Graduate Research Assistant
R. Thornton	-- Graduate Research Assistant

1. Supported by Teaching Assistantship during academic year.