Purdue University
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COO-1428-433

ANNUAL PROGRESS REPORT

for the period

June 1, 1975 - April 15, 1976

DISCLAIMER

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I. INTRODUCTION

Three counter experiments at ANL have been finished up this year, providing important new results and the doctoral theses for three students, R. L. Dixon, J. M. Fletcher and S. Mudrak. Dixon is currently working at the Cornell Laboratory of Nuclear Studies as a research associate, Fletcher has accepted a position at Sandia Corporation and Mudrak is trying to decide between a high energy physics postdoctoral job and a position in industry.

Charm Search E-357 at FNAL has been successfully assembled and our first extensive data-taking run was completed in January. Our next run begins on April 12. We have demonstrated a sensitivity unmatched at FNAL for detecting charmed decays to hadrons and our mass resolution of about 10 MeV/c^2 at 3 GeV/c^2 has been verified in the strong ψ signal we observe. Planning is also underway to continue this search in our experiment E-472 which has been approved at Fermilab.

Experiment BC61 with the SLAC 40" Hybrid Facility is currently taking pictures after successful demonstrations that the trigger works. The run should finish in early Summer and scanning and measuring with POLLY are proceeding in a routine operational way.

FNAL Experiment E-442, which will study nuclear fragments from proton-nucleus collisions in a heavy atom gas jet at the C-0 straight section, is currently being constructed and installed. Initial running will start this Summer.

The Purdue collaboration involving a study of rare decay modes of mesons using the CERN OMEGA spectrometer has concluded data taking and is in the analysis phase. Another experiment in a similar situation is the 13 GeV/c π^-p exposure in the SLAC 82" bubble chamber. Professor Wen Yen of Indiana University-Purdue University at Indianapolis (IUPUI) is participating as a collaborator in the analysis. Robert DeBonte, whose doctoral research was involved with the 13 GeV/c π-nucleon program, received his Ph.D. last Summer and is currently working with us as a research associate.

II. COUNTER-WIRE CHAMBER EXPERIMENTS AT ANL (E-348, 379, 386)

A little over one year ago the data-taking phase of our spark chamber experiments at ANL was completed. These experiments were designed specifically to study properties of baryon exchange reactions in the incident beam momentum range from 3.0 to 5.5 GeV/c.

Our goals for these experiments have been described in detail in past proposals and progress reports. This past year has seen the labors of previous years come to fruition. We have given several invited papers[1] and seminars[2] on this work and to date have published one paper in Phys. Rev. Letters[3] and prepared a second for that journal.

Support for these experiments in the past fiscal year has been limited to salaries for two Graduate Assistants, Mr. J. M. Fletcher and Mr. S. Mudrak, computing costs, a small amount of travel, and publishing charges.

With the publication of several papers summarizing all this work, we will soon close the door on what has been a very successful venture into experiments using electronic techniques. From our viewpoint, our relation with the ZGS throughout these experiments has proven very productive, giving us an important opportunity to not only do interesting research but also to establish our capability for performing experiments using these techniques.

III. COUNTER EXPERIMENT 357 AT FNAL (SEARCH FOR "CHARM")

This is a preliminary report on a search for narrow resonances (X) decaying into two hadrons, h_1 and h_2, produced in the reaction

$$pN \rightarrow X + \text{anything}$$
$$\hookrightarrow h_1 h_2$$

at 400 GeV/c. The results presented are from the first data-taking run in November-December, 1975, of the FNAL/Michigan/Purdue double-arm spectrometer system installed in the M2 beam line at FNAL. Our experiment (E-357) is one of several performed at FNAL[4,5] to search for new particles resulting from the possible existence of a new quantum number, charm.[6] If the J/ψ particle[7] is a $c\bar{c}$ bound state, a new family of hadrons, some of which should decay into $K\pi$, K^-p, or $\bar{p}K^+$ with a significantly large branching ratio, is expected. Thus far, except for a bump in the $K^-\pi^+$ mass spectrum observed by MSU/OSU/Carleton,[5] the results of charmed particle searches have been negative.[4,8,9]

The plan view of our symmetric, double-arm spectrometer system is shown in Fig. 1. Each arm contains 16 planes of drift chambers, 20 scintillation counters, 3 Cherenkov counters, a BM-109 dipole magnet which bends vertically, and 6 feet of steel plus 18" of concrete to identify $\mu^\pm$. Unambiguous identification of π, K, and p and $\bar{p}$ is obtained for momenta between 7 and 20 GeV/c, and separation of p and $\bar{p}$ from π and K is obtained up to 40 GeV/c. In addition, we detect $\varphi \rightarrow K^+K^-$, $K^o_s \rightarrow \pi^+\pi^-$, and $\Lambda^o \rightarrow p\pi^-$ when their decay products go into a single arm of the spectrometer system. Thus, we can identify $X \rightarrow \pi\pi$, πK, πp, KK, Kp, pp, $\varphi\pi$, φK, and φp in all possible charge states except those with a π^o. The mass acceptance of the system for unambiguously defined particles is $1.5 \leq M_x \leq 4.0$ GeV/c^2 with the rapidity acceptance of $X \rightarrow h_1 h_2$ events confined to $y_{cm} = 0$. The mass resolution varies linearly with M_x; at $M_x = 3$ GeV/c^2, $\sigma_m \simeq 7$ MeV/c^2.

The 400 GeV/c diffracted proton beam was incident on a 10% interaction length CH_2 target divided into seven segments separated by 4" along the beam axis. The trigger for $X \rightarrow h_1 h_2$ was simply a coincidence between the two spectrometer arm signals, each of which, by the coincidence between signals from suitable sets of intra-arm scintillation counters, signified that a charged particle with momentum greater than 7 GeV/c had traversed the arm. For our typical incident flux of 5×10^7 protons per ~ 0.8 sec spill, the two-arm coincidence rate was 250/spill. However, due to computer-induced deadtime, the number of events actually recorded on magnetic tape was $\sim$ 80/spill. During the November-December, 1975, run, approximately 7.7 million triggers were recorded, with $\sim$ 33% having reconstructable tracks in both arms.

The observation of $\varphi \rightarrow K^+K^-$, where both the K^+ and K^- go into the same arm, provides an excellent test of our apparatus and reconstruction procedures. As shown in Fig. 2, the $\varphi \rightarrow K^+K^-$ signal appears as a sharp peak in the K^+K^- mass spectrum with a width consistent with our calculated mass resolution. We estimate the ratio of φ plus anything in the other arm to π^- plus anything in the other arm to be about 10^{-2} for $p_\perp \geqslant 1.4$ GeV/c. Since the branching ratio for $\varphi \rightarrow \mu^+\mu^-$ is 2.5×10^{-4}, it is clear that φ production contributes little to the observed prompt μ to π ratio of $\sim 10^{-4}$ at large $p_\perp$.

Muon pair data were accumulated simultaneously with the hadron pair data in order to experimentally verify the mass scale, mass resolution, and sensitivity of the experiment with the J/ψ particle. Our J/ψ statistics are limited since the beam rate was optimized for hadron running. The hadron trigger rate saturated the data recording capability at $\sim 0.5 \times 10^8$ ppp. No special attempt was made to improve J/ψ statistics at the expense of the hadron data by running with only a μ-pair trigger. The μ-pair effective mass spectrum representing the data taken in November and December is presented in Fig. 3. The J/ψ signal is a sharp peak centered at a mass of 3.095 GeV/c^2. From these data we determine experimentally that our mass resolution is $\sigma_m \sim 7\ MeV/c^2$. Assuming a linear dependence on atomic number, isotropic J/ψ decays, and a momentum dependence given by

$$E \frac{d^3\sigma}{dp^3} \alpha \ (1 - |x|)^{4.3} \ e^{-1.6p_\perp},$$

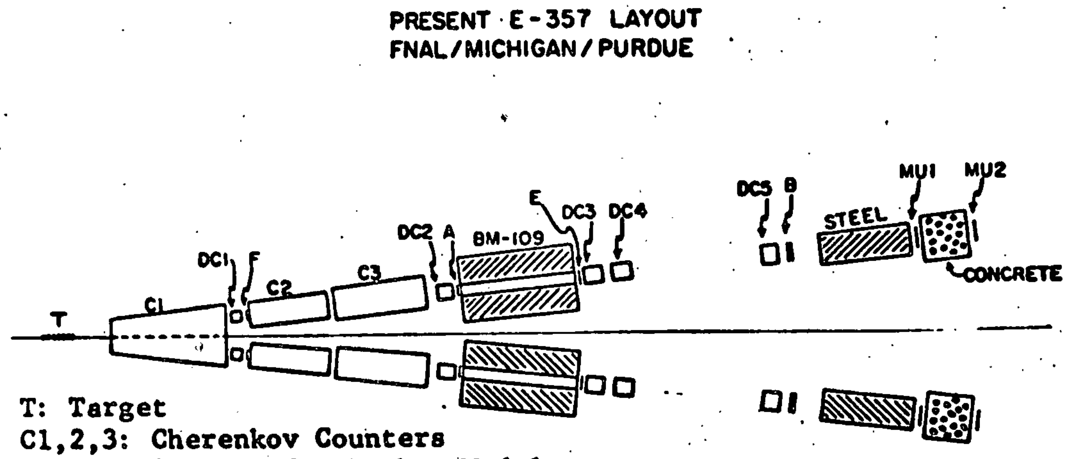
we calculate that $\sigma_{J/\psi} B_{\mu\mu}$ = (9 ± 3)nb/nucleon at 400 GeV/c, in agreement with Snyder et al.[10] who obtained (11 ± 3)nb/nucleon at 400 GeV/c under the same assumptions.

Convinced by our $\varphi \rightarrow K^+K^-$ and $J/\psi \rightarrow \mu^+\mu^-$ signals that we understand the apparatus well, we have investigated the hadron-pair mass spectra. In Figs. 4-8 we show the mass spectra for five of the twenty-one possible combinations of charged π's, charged K's, and p and $\bar{p}$: specifically, $\pi^+\pi^-$, $K^-\pi^+$, π^-K^+, K^-p, and $\bar{p}K^+$. Clear, narrow peaks in the $K^\mp\pi^\pm$ or K^-p and $\bar{p}K^+$ mass spectra would be indications for charmed particles. None of the mass spectra, including those not presented, show any statistically significant narrow structure at the 4 standard deviation level. Since all of these data were collected simultaneously, the $K^-\pi^+$ data may be compared with the π^-K^+ data and the K^-p with the $\bar{p}K^+$ data. In doing this, we find that none of the tantalizing, but nevertheless statistically insignificant, peaks in the $K^-\pi^+$ and K^-p spectra coincide with similarly tantalizing peaks in their respective conjugate spectra. Thus, at this early stage of our experiment we see no evidence for massive narrow resonances decaying into two hadrons.

It is clear from this experiment and others[4,5,8,9] that charmed particles are not easily observable in hadronic effective mass spectra. To obtain upper limits on the cross sections times branching ratio into two hadrons, $\sigma_c B_{h_1 h_2}$, it is necessary to make assumptions about the production mechanism for charmed particles. If we assume that charmed particles are produced with the same momentum dependence as the J/ψ particle, we can calculate upper limits for $\sigma_c B_{h_1 h_2}$ directly in units of $\sigma_{J/\psi} B_{\mu\mu}$. For the data shown in Figs. 5-8, $\sigma_c B_{h_1 h_2}$ ranges from 10 to 40 times $\sigma_{J/\psi} B_{\mu\mu}$ at $M_x = 2.3$ GeV/c^2 and 4 to 8 times $\sigma_{J/\psi} B_{\mu\mu}$ at $M_x = 3.0$ GeV/c^2. Here we have used the criterion that a 4 standard deviation peak in a 20 MeV/c^2 wide mass bin would have been a positive indication of a narrow resonance. These upper limits are set primarily by the large physical hadronic background. If we take our calculated value of (9 ± 3)nb/nucleon for $\sigma_{J/\psi} B_{\mu\mu}$, then the level of sensitivity of our particle search is of the order of 100 nb/nucleon for $\sigma_c B_{h_1 h_2}$.

Our experimental run at FNAL is now less than one-half complete. In the remainder of the run we should be able to at least double the amount of data. The anomolous lepton production observed in several diverse experiments suggests a possible signature for events containing new particles. Therefore, we have proposed an additional experiment at FNAL to search for narrow resonances in two-body hadron mass spectra for events containing a prompt muon. Only minor modifications to our present apparatus are required. This new proposal has been approved, and we hope to start taking data as early as this summer.

We are grateful for the support of the Fermi National Accelerator Laboratory staff and the technical staffs at the University of Michigan and Purdue University. We appreciate the assistance of Professor O. E. Johnson during the November-December, 1975, experimental run.



T: Target
C1,2,3: Cherenkov Counters
DC1,2,3,4,5: Drift Chamber Modules
F,A,E,B,MU1,MU2: Scintillation Counters

Fig. 1. Plan view of the double-arm spectrometer system.

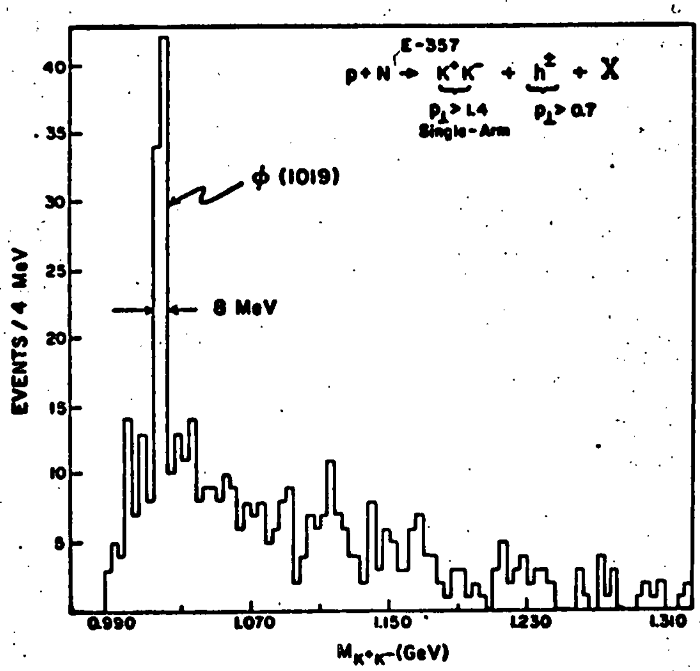


Fig. 2. K^+K^- effective mass spectrum for events in which both the K^+ and K^- go into a single spectrometer arm.

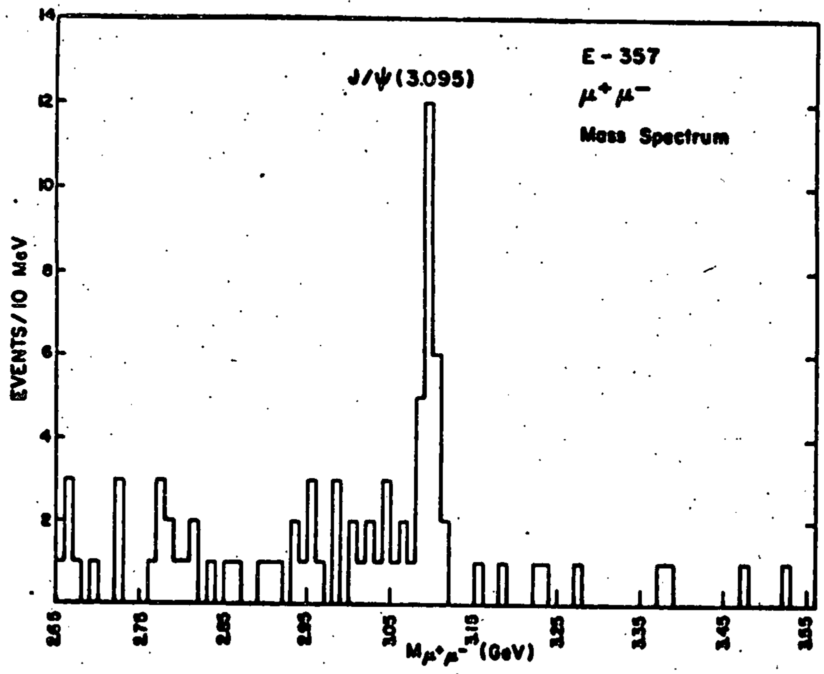


Fig. 3. $\mu^+\mu^-$ effective mass spectrum.

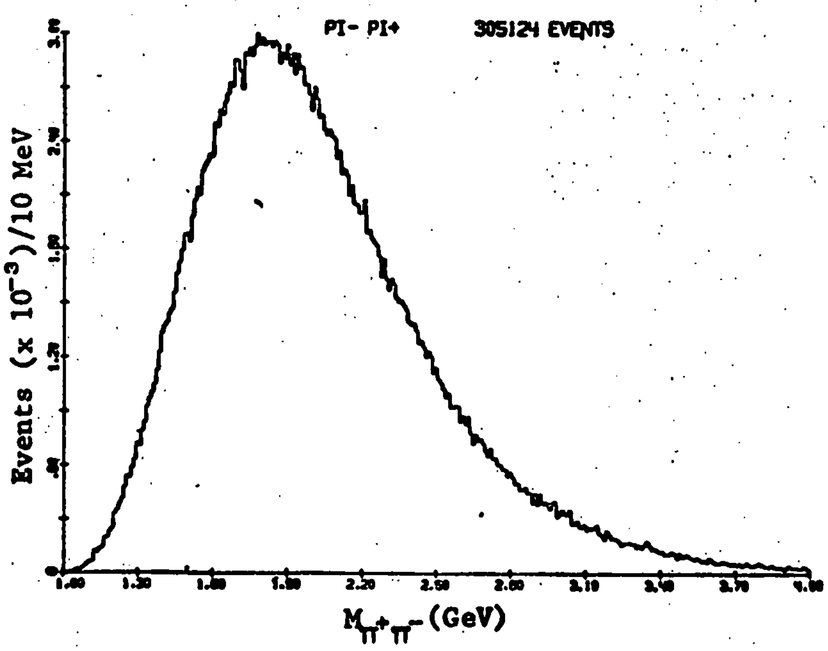


Fig. 4. $\pi^+\pi^-$ effective mass spectrum.

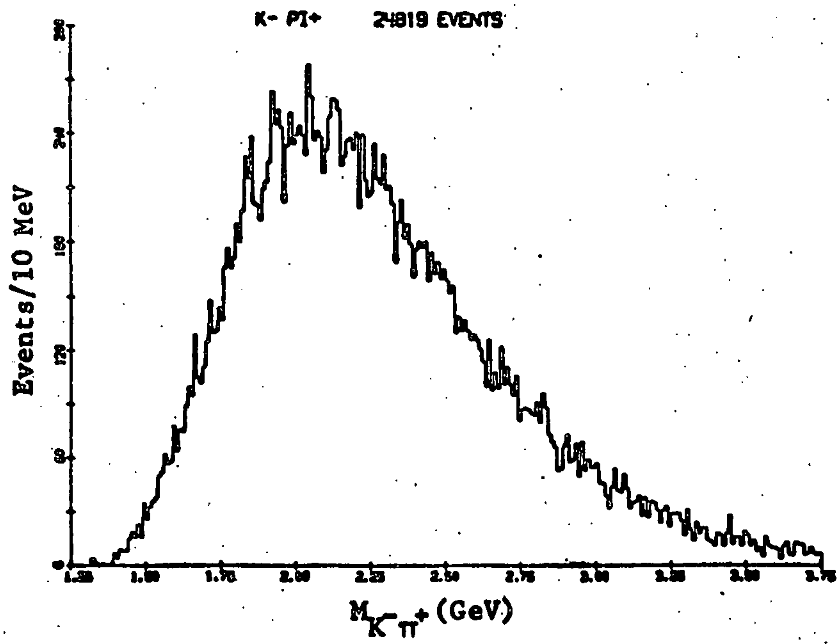


Fig. 5. $K^-\pi^+$ effective mass spectrum.

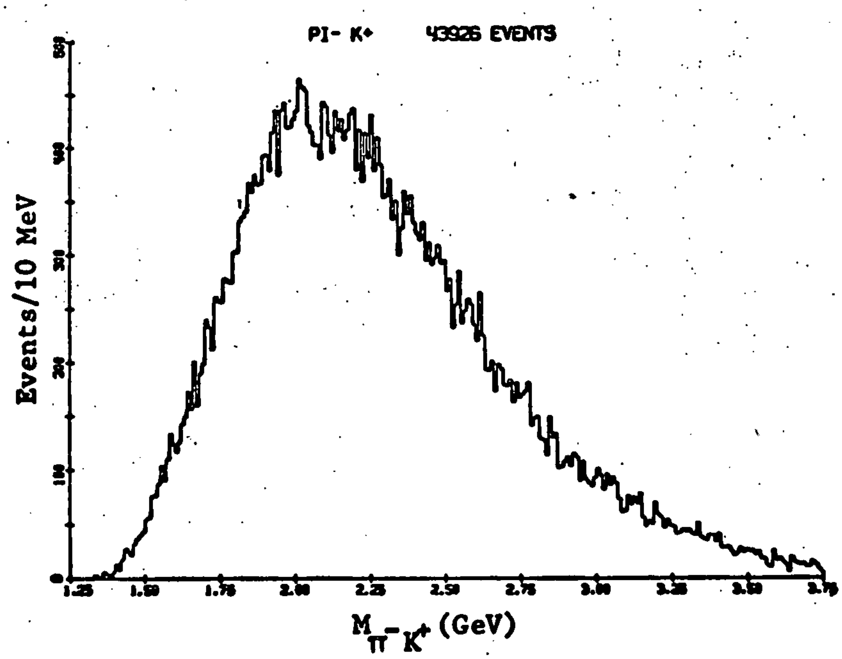


Fig. 6. π^-K^+ effective mass spectrum.

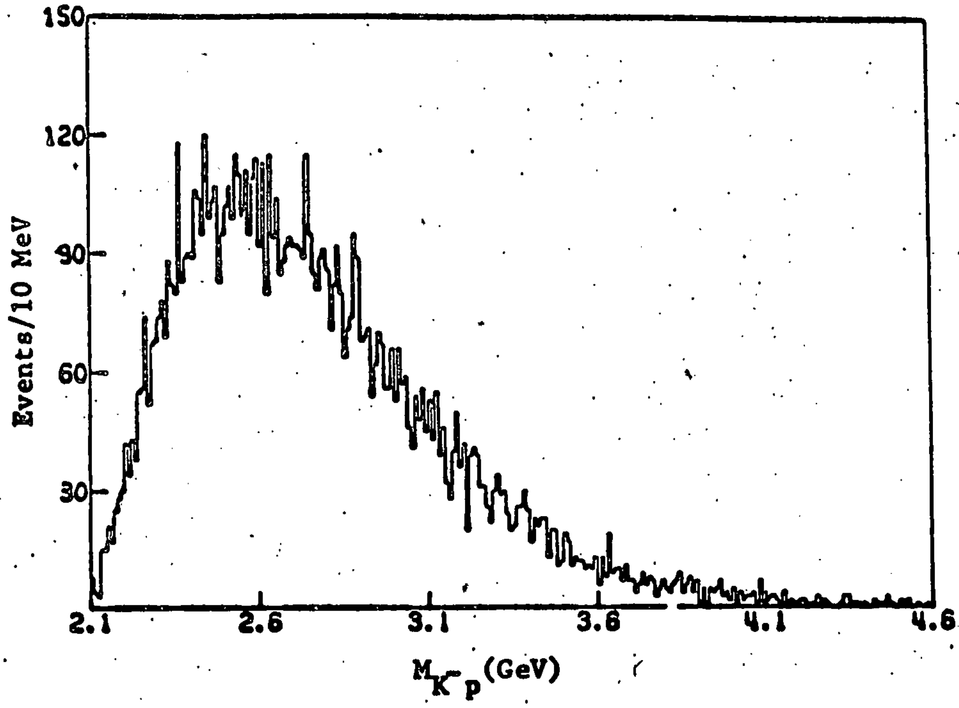


Fig. 7. K^-p effective mass spectrum.

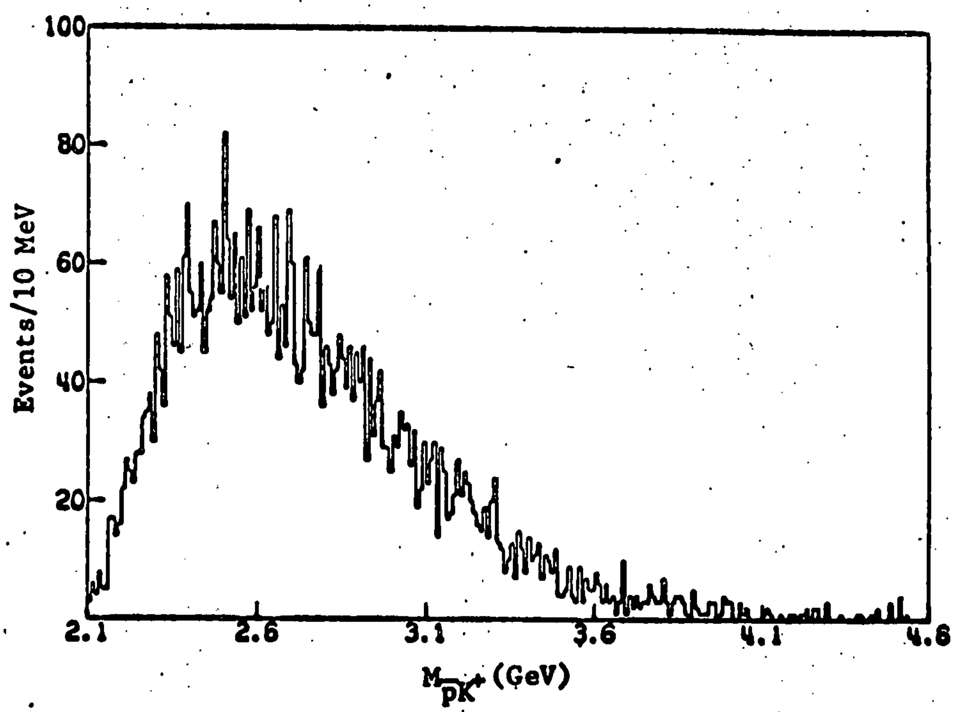


Fig. 8. $\bar{p}K^+$ effective mass spectrum.

IV. EXPERIMENT BC61 (A STUDY OF SOME RARE PION- AND KAON-INDUCED REACTIONS USING THE 40" SLAC HYBRID FACILITY)

A. Introduction

This experiment is an extension of our study of pion-nucleon interactions to the level of 500 events/μb. We are utilizing the SLAC Hybrid Facility with an incident π^+ beam at 11.6 GeV to trigger selectively on final states containing at least a K^- or K^+ or $\bar{p}$ or p with momentum > 5 GeV/c. We are particularly interested in and have a very high acceptance for the reactions

$$\begin{aligned} \pi^+ p \rightarrow\ & \Delta^{++}K^+K^- \\ & \Delta^{++}p\bar{p} \\ & p \text{ (u-channel).} \end{aligned}$$

B. Apparatus

A plan view of the apparatus is shown in Figure 9 and consists of the 40" rapid cycling HBC together with upstream and downstream multiwire proportional chambers and Cerenkov counters. The fast trigger is fairly loose and consists of selecting interactions in which no light appears in the downstream $\check{C}$. The main trigger is a real time software trigger using a Nova computer. When a fast trigger occurs all the information from the wire chambers is read out and examined. Space points are constructed and secondary particle trajectories are found. An event is accepted if there is a secondary particle whose momentum is > 5 GeV and which gives no light in the segmented downstream Cerenkov. The fringe field of the 40" is adequate to provide a good momentum measurement. The on-line algorithm takes between 500 and 1000 μsecs which is a suitable time for adequate bubble growth in the chamber.

C. Progress During 1975-76

All the apparatus was finally put in place during the fall of 1975. The construction and reliable operation of the wire chambers had proved to be the most difficult part and this was responsible for delays in the original schedule. During November and December test data were taken and analyzed to look for systematic biases, etc. The data we took were compared with our own untriggered data which provided an adequate comparison. These data are shown in the attached memo.

Since the test data seemed to be correct, production running started in March, 1976. To date some 30 rolls of film have been accumulated or $\sim 4\%$ of the total experiment. Our measuring system using POLLY is now fully operational and this week has seen the measurement of the first events which will be used in the final analysis. Our collaborators in Toronto are also beginning to measure the new film.

D. Evaluation of the Test Data

The test data evaluated so far indicate that the apparatus is basically functioning correctly. Two problems both connected with the wire chambers have shown up, one of which was unexpected and could cause systematic errors at some level. The first effect is the normal expected inefficiency in each plane which overall reduces the data-taking rate in an unbiased way. The second is the frequent occurrence of high multiplicity in one or more planes, rendering it impossible to reconstruct sensible trajectories in the downstream system. These high multiplicities have features which suggest they are electromagnetic in origin, i.e. delta rays and γ-ray conversion, although the frequency of occurrence is too high. This problem reduces the data-taking rate and may cause a multiplicity dependent bias. This last problem is the only one of any significance and we are studying this problem in detail.

B. Detection System

. General Description

Figure 4 shows the Stage I system which is presently being installed and checked out. It consists of two sets of multiwire proportional chambers (MWPC) for locating the beam particle position and direction, three sets of MWPC's immediately behind the 40" chamber for position and momentum measurement of fast forward secondaries, a beam Cerenkov counter, a large downstream Cerenkov (CANUTE) for identifying and triggering on forward secondaries, followed by a scintillation hodoscope and beam veto. Stage II (not shown) would consist of a large spectrometer magnet and associated drift chambers 8-10 m downstream of the bubble chamber to provide a much cleaner kinematic trigger (1-2% uncertainty in the online momentum measurement of the trigger particle). The downstream aperture of the bubble chamber magnet allows the following emittance angles: a) $+18^{\circ}$, -15° vertical and $\pm 5^{\circ}$ horizontal from the front of the bubble chamber, b) $\pm 32^{\circ}$ vertical and $\pm 11.5^{\circ}$ horizontal from the back of the bubble chamber. The trigger particle must pass through two 1.8 mm stainless steel windows at the rear of the bubble chamber and two 5.6 mm Al windows and 3 m of 30-60 PSIA Freon 12 in the large Cerenkov counter.

The 40" chamber has a central field of 26 kg with ~ 10 kg-m in the region of the downstream MWPC's for online momentum measurement of the trigger particle.

2. Multiwire Proportional Chambers

A set of three multiwire proportional chambers with 2 mm wire spacing is placed in the exit aperture of the bubble chamber magnet. The chambers have a construction which uses honeycomb sandwich plates as high voltage electrodes which also hold the chamber rigid against the mechanical tension of the sense wires. This technique allows the chambers to be sensitive over as much as possible of the available detection area. Using the downstream chambers alone, the momentum of the trigger particle can be measured online to an accuracy of ~ 20%. By also using the two beam MWPC's the online error is reduced to (3-12%/azimuthal scattering angle), depending on the location of the vertex in the bubble chamber.

3. Cerenkov Counters

Beam Counter: Beam particles are identified with a threshold Cerenkov counter, a 1.5 m long rectangular tube filled with 1 atm Freon 12 which puts the K threshold at ≈ 10.5 GeV/c (measured).

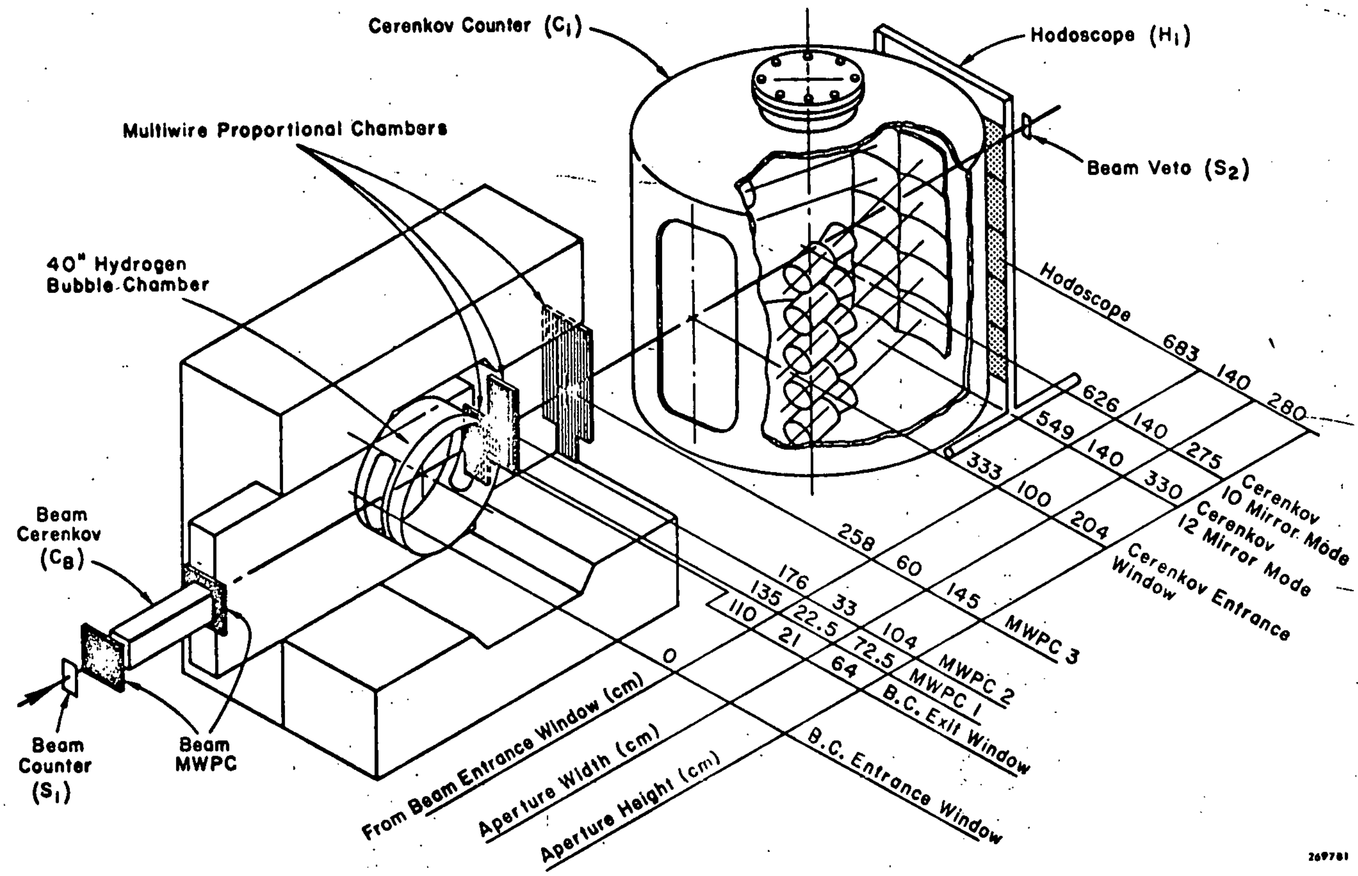


Fig. 9--SLAC 40" BC Hybrid Facility.

DATE: February 21, 1976
SHF MEMO #24

To : Distribution

FROM : D. H. Miller and F. Ogino

SUBJECT: Analysis of four-prong events

In this memo, the results of analysis on four-prong events at 11.6 GeV/c from the December Cycle are presented. Fourteen rolls of four-prong events were measured and processed through TVGP-SQUAW at SLAC. Table-1 shows the statistics of the data for the present analysis.

	# of measured 4-prongs	ev/μb with 5% correction for CE
Fast Trigger	1390(9 rolls)	0.60
Algorithm Trigger	1527(5 rolls)	4.55

Table-1 4-prongs from December Cycle

The kinematic fits with beam averaging were attempted for the following three hypotheses :

$$\pi^+ p \longrightarrow \pi^+ p\, K^+ K^- \quad (1)$$
$$\pi^+ p\, p\, \bar{p} \quad (2)$$
$$\pi^+ p\, \pi^+ \pi^- \quad (3)$$

Those events satisfying one or more hypotheses were examined at the scanning table to see if :

(a) Ionization is consistent with the prediction calculated from the momentum of track,

and (b) the PWC Y_2 value of the triggering beam track, which is recorded on the lower corner of View 3 of the film, agrees with the y-value of the vertex. This check is referred as Y_2 check hereafter.

The events surviving after these two tests were studied further.

I. Fast trigger events

Table-2 summarizes the results of several cuts on the 4C data. As shown in column 2, approximately 70% of the $K\bar{K}$ events are unique in that there is only one SQUAW fit for each event. The rest of $K\bar{K}$ events were obtained either from Ionization Check or from comparison of SQUAW chi-squared values among different fits. The third block from the top in Table-2 explains why the events were rejected in the Y_2 check. It should be noted that about 50% of events were rejected in the Y_2 check, most of which were $P3\pi$ as expected. The events listed in the last row are used in later analysis. If the 4C event has momentum of the forward going kon or proton greater than 5 GeV/c and if the vertex is inside the fiducial volume ($-40 < VTX < 35$cm), the corresponding hardware data was processed through the FORTRAN version of TRIGGER ALGORITHM program with the full debug printout, from which it was possible to study the cause of algorithm failures. Table-3 presents the results of the Algorithm program for fast triggered events.

Cut \ Channel	$\pi^+ P K^+ K^-$	$\pi^+ P P \bar{P}$	$\pi^+ P \pi^+ \pi^-$	All Channels
Ionization Check	48	11	145	204
Ion + Y_2 check pass	40	7	56	103
(unique SQUAW fit	29	3	44	76
(not unique SQUAW fit	11	4	12	27
Ion + Y_2 check fail	8	4	89	101
Trigger from { another beam	3	2	64	69
Trigger from { another event	4	1	22	27
Trigger from { BC wall int.	1	1	3	5
Ion + Y_2 + Momentum Cut ($P,K > 5$GeV/c)	37	6	3	46
Ion + Y_2 + Mom. Cut + Fid. Vol.	34	6	3	43

Table-2 Cuts on 4C data (Fast Triggers)

The interesting features seen in Table-3 are:

(1) The overall detection efficiency (# of algorithm pass/# attempted) is 28%. The detection efficiency for $K\bar{K}$ channel is only 20%.

(2) Algorithm failures due to high multiplicity hits in one or more planes are very large ; for example, about half of the algorithm failures in $K\bar{K}$ channel are due to high multiplicity hits. Most of the other failures are associated with PWC's inefficiency.

(3) 50% of events that passed the Algorithm were $\pi^+ p \pi^+ \pi^-$ events (non U-channel), which are not useful for physics analysis.

Also shown in Table-3 are the corresponding cross sections. If one includes the acceptance of 70%, the production cross section for $K\bar{K}$ channel is estimated to be 81 μb, which agrees quite well with the previously reported result from the bare bubble chamber experiment.

Channel	$\pi^+ p K\bar{K}$	$\pi^+ p p\bar{p}$	u-channel $\pi^+ p \pi^+ \pi^-$	other $\pi^+ p \pi^+ \pi^-$	all channels
Fast trigger events	34 (56.7μ b)	6 (10 μ b)	3 (5.0 μ b)	53	96
Algorithm pass	7 (11.7 μ b)	3 (5.0μb)	2 (3.3 μ b)	12	24
Algorithm failure	27	3	1	41	72
Reason of failure Multiplicity 0	6	2	1	9	18
Multiplicity high in one or more planes	14	0	0	14	28
Both Mult. 0 and Mult. high	1	0	0	4	5
Trigger momentum low	2	1	0	1	4
No YZU match in one plane	2	0	0	2	4
Mismatching due to missing point	2	0	0	5	7
Others	0	0	0	6	6

Table-3 Algorithm results

Further study on a partial sample of fast triggered events (20 $K\bar{K}$ events out of 34 $K\bar{K}$ events in Table-3) was made using Rob Stevens' program, which enabled us to compare the extended BC track locations with those of observed hits at PWC planes and hodoscope cells. It was found that all events had at least one track for which the predicted hodoscope cell agreed with the observed cell #. This would support our observation that most of the algorithm failures are due to problems with the wire chambers data.

II. Algorithm trigger events

The algorithm triggered events were analyzed in a similar fashion as discussed above and the results are shown in Table-4. Approximately 45% of the 4C events were rejected by the Y_2 check, most of which were random $P3\pi$ events. Some events were lost at this stage due to LED problems and/or T_2 triggers. The cross section for $K\bar{K}$ channel is found to be 12.7 μb, which is consistent with our earlier estimate 11.7 μb from the fast triggered events (Table-2). The u-channel $P3\pi$ events comprise 10% of all $P3\pi$ events. In fact, there are as many useless $P3\pi$ events (75 events) as useful 4-constrained events (83 events) in the final data samples of algorithm triggered events. This result also agrees well with that from fast triggered data.

Cut \ Channel	$\pi^- PK\bar{K}$	$\pi^+ PP\bar{P}$	u-channel $\pi^+ P\pi^+\pi^-$	other $\pi^+ P\pi^+\pi^-$	all channels
Y_2 rejected: no unique fit	--	--	--	--	31
Y_2 rejected: unique fit	14	4	80 (u-channel + other)		98
Y_2 pass and Ion check pass	58 (12.7 μb)	16 (3.5 μb)	9 (2.0 μb)	75	158
unique fit	48	11	9	63	131

Table-4 Algorithm trigger events

III. Mass and Momentum distributions

Using the event sample, we have looked at mass and momentum distributions to check for possible biases. These distributions are shown in Figure-1 for the three possible 4-constraint final states. Within the limited statistics the agreement with bubble chamber data at 13.6 GeV/c is good. The Δ^{++} shows up clearly and the momentum distribution of the triggering particle seems to be as expected.

There is a possible bias at $P\bar{P}$ threshold which is probably due to the momentum cut in the algorithm. This may force us to lower the cut to 4.5 GeV/c, which gives an 8% increase in the picture taking rate.

IV. Summary

The main problems appear to be the severe loss of events due to high multiplicities or inefficiencies in the proportional wire chambers. It is difficult to determine if these losses cause biases in the data, but they probably do.

Another problem is the number of events in which a forward pion was the trigger. We are studying these events to see if it is possible to exclude them by changes in the algorithm. The FORTRAN algorithm has been checked in detail and only minor mistakes have been found. It also handles Monte Carlo data collectly.

Figure-1a $\pi^+ p \to \pi^+ p K^+ K^-$ at 11.6 GeV/c

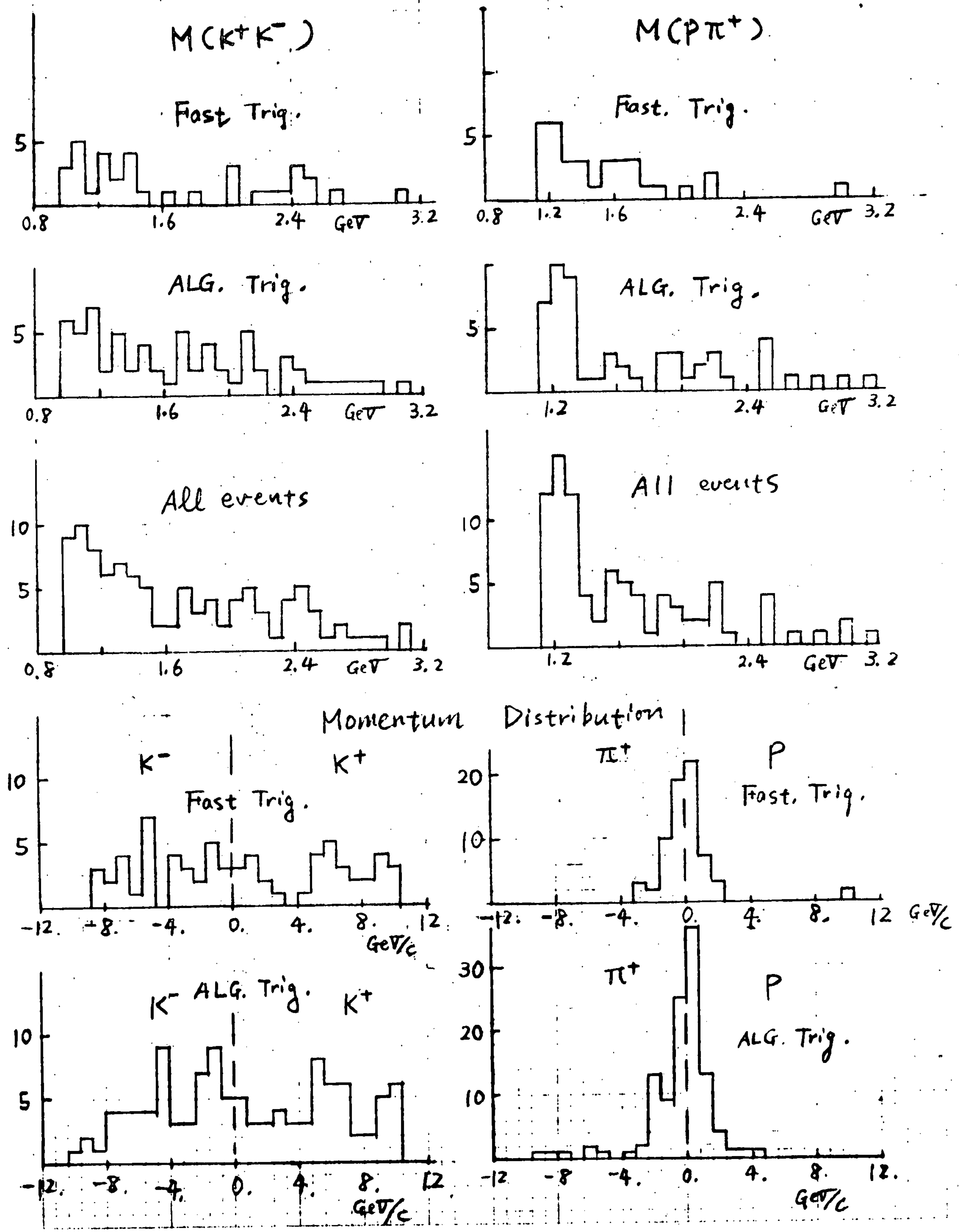
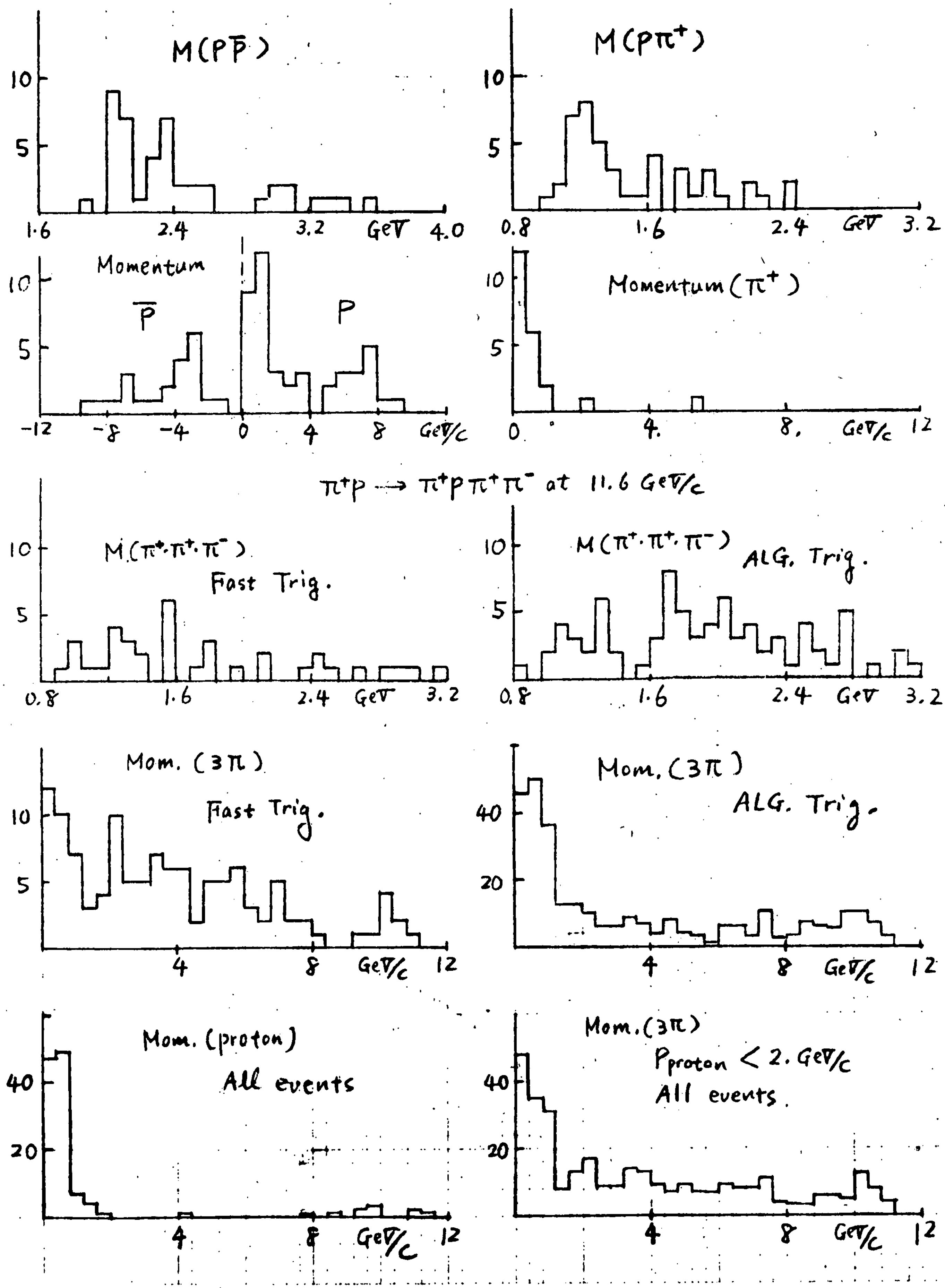


Figure-1b $\pi^+ p \to \pi^+ p p \bar{p}$ 11.6 GeV/c



V. COUNTER EXPERIMENT 442 AT FERMILAB (AN INTERNAL GAS JET EXPERIMENT AT SECTION C-0)

Recent experimental evidence indicates that there is a significant change in the mode of proton-nucleus collisions with increasing energy and that collective motion is initiated by the passage of a fast proton through a heavy nucleus. In E-442, we are investigating heavy fragment production ($4 \leq Z \leq 16$) as a function of angle ($35^\circ \rightarrow 85^\circ$) and incident energy ($20 \rightarrow 500$ GeV) by utilizing a warm jet of various heavy gases in the internal target area of FNAL.

Since E-442 was approved (November 25, 1975) we have purchased and calibrated vacuum equipment; built and calibrated a hot wire anemometer and its associated electronics; carried out several series of measurements of warm jet characteristics with H_2, He, N_2, A, Xe and various (H_2 + Xe) mixtures; and have designed a computer configuration, electronic control assembly and a basic silicon wafer telescope which will be used in tests in a few weeks.

The results of our testing have been encouraging and we are planning to begin assembling the apparatus in mid-May.

VI. STATUS OF AN EXPERIMENT TO STUDY THE RARE DECAYS OF MESONS USING THE OMEGA SPECTROMETER AT CERN

A. Introduction

The experiment to study the rare decays of mesons is a collaboration between Purdue-CERN and several other European groups. This experiment completed data taking in November and December, 1974, using the configuration shown in Figure 10. The intent of the experiment was to accumulate several thousand events/μb of π^- induced interactions containing at least a K^- or a K^+ or a $\overline{p}$ in the final state.

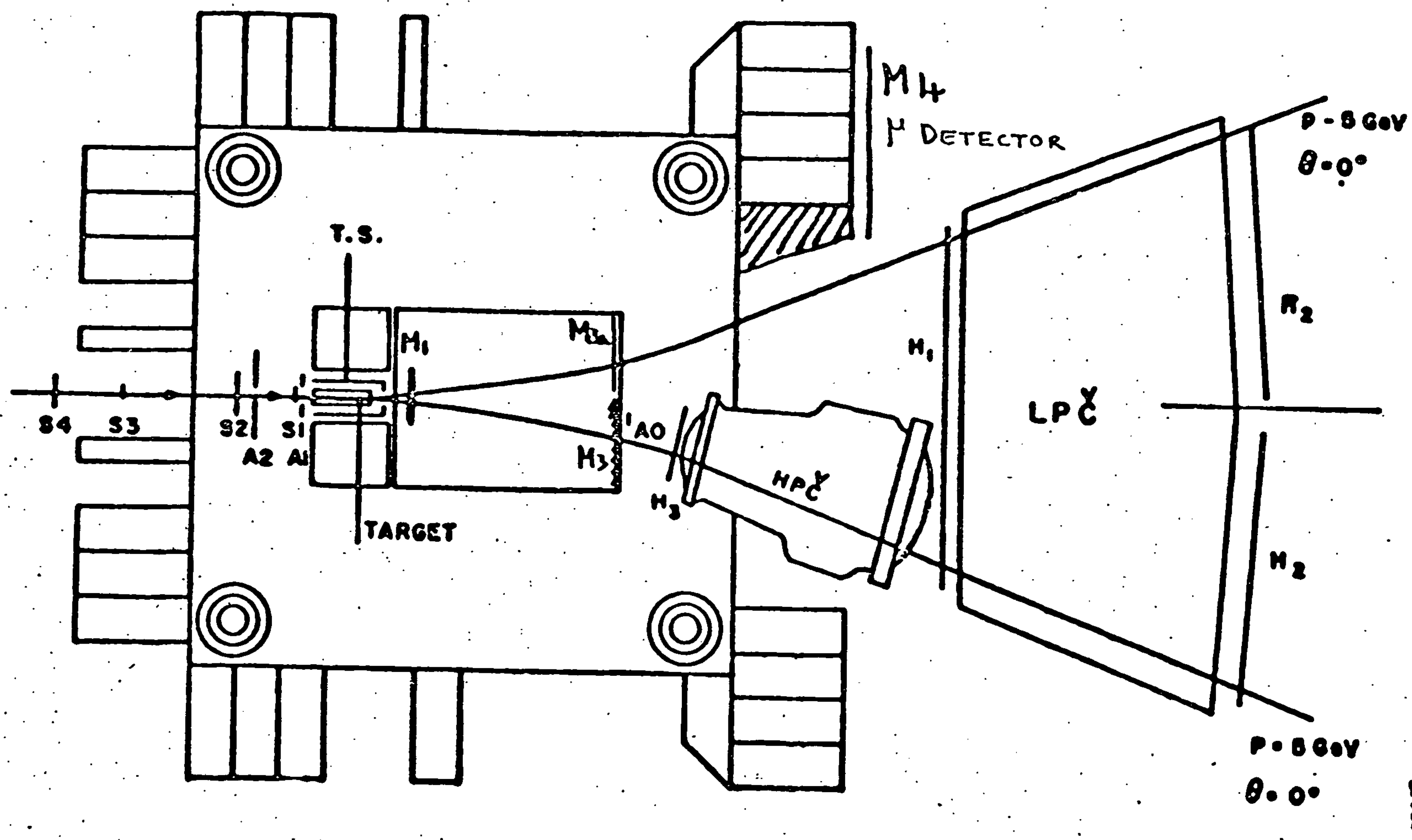

M4
μ DETECTOR
T.S.
M1
M3a
H1
R2
LPC
AO
H3
HPC
H2
S4
S3
S2
S1
A2
A1
TARGET

FIG. 10

B. Summary of the Data Taken

Approximately 2500 events/μb were obtained with an incident beam momentum of 10 GeV/c. This sensitivity has already been corrected for the acceptance of the trigger. In addition, 1000 events/μb were obtained at 16 GeV/c. The thrust of the 10 GeV experiment is to study production of mesons and their subsequent decays into rare modes involving kaons or antiprotons. In particular, although a wide variety of interactions was accepted by the trigger, the reactions

$$\pi^- p \rightarrow nK^+K^-$$
$$\qquad\quad n p \bar{p}$$
$$\qquad\quad pK^+K^-\pi^-$$

had a very high acceptance up to masses of 3 GeV in the meson system. Although the trigger for the 16 GeV data was similar, the emphasis was placed on a search for charmed mesons decaying into final states containing a $K^{\pm}$ or $\bar{p}$.

C. Progress in 1975-76

Much work was done in the early part of the year to ensure that the pattern recognition was working correctly, and, for example, that Λ and K^o decays were being found with high efficiency. In addition, a great deal of work was done with ~ 10% of the data to understand and correct systematic effects. These effects ranged from energy loss corrections for slow particles to spatial corrections for heavily ionizing particles.

Late in 1975 this work was completed with satisfactory geometry and kinematic fits being obtained. The main data processing was then started with the following results.

Momentum	
10	All geometry finished. Kinematic fitting well under way.
16	All geometry finished. All kinematics finished.

Since the year has been consumed with data reduction, no publications have yet resulted from this work.

Comments on the Collaboration

The collaboration has proceeded smoothly during all the experiment. Difficulties have been experienced at Purdue because of the tight restrictions on foreign travel funds. The current level of funding does represent the absolute minimum necessary to ensure the Purdue contribution to the experiment is adequate.

VII. 13 GeV/c $\pi^- p$ EXPERIMENT IN THE SLAC 82" HYDROGEN BUBBLE CHAMBER

The πN experiment consists of three parts:

	# Pictures	Events/μb	# Events	Status
$\pi^+ p$	755,000	35	600,000	completed
$\pi^+ d$	250,000	9	100,000	completed
$\pi^- p$	500,000	25	460,000	85% completed (est. 1/9/76)

all exposed in the SLAC 82" bubble chamber. In addition, a triggered experiment in the SLAC Hybrid Facility of 500 events/μb in selected $\pi^+ p$ channels at 13 GeV/c is well under way.

1. Measuring

Scanning, measuring and fitting events in the $\pi^- p$ film operates in a real time mode. With exposure optimization of one event per frame, the data reduction facility is capable of processing 1000 events per SMP week. Currently the staff of five measurers is shared between the 82" $\pi^- p$ film (SMP's) and the $\pi^+ p$ 40" film (POLLY). Since August, 1975, 100,000 events have been measured, bringing the total to 350,000 processed $\pi^- p$ two- and four-prong events. An additional 50,000 events will have been analyzed before $\pi^- p$ measuring is terminated this summer, corresponding to 85% of the potential data sample.

2. Program

The primary objective of the 13 GeV/c program is to explore the structure of diffractive enhancements and resonant states in terms of current exchange models, utilizing the charge symmetric $\pi^{\pm}$ sister beams.

3. Projects in progress

3.1 Baryon states:

(1) $\pi^{\pm}p \rightarrow \pi^{\pm}N^{*+}$: We are analyzing the production of low-mass πN enhancements in terms of diffractive excitation and isovector exchange. A preliminary spherical harmonic decomposition suggests strong P, D and F states for $m(\pi N) < 1.4$ GeV. Low-mass πN enhancements are of major importance in two-prong final states as illustrated for our new $\pi^- p$ data in Figs. 11b and 11c.

(2) $\pi^- p \rightarrow \pi^o \Delta^o$, $\pi^+ p \rightarrow \pi^o \Delta^{++}$: These reactions are mediated by isovector exchange and are important not only in isolating the exchange mechanisms but also through specifying the behavior of the I=1 exchange component of N^* excitation. Evidence for the $\Delta^o(1236)$ and $\Delta^o(1650)$ are given in Fig. 11d.

(3) $N^*(1700) \rightarrow \Delta(1236)\pi$: A strong $N^{*+}(1700)$ signal is apparent in Fig. 12b and substantially contributes to the Δ^{++} peak observed in Fig. 12c. We have discussed this resonance in the $\pi^+ p$ data and are extending our analysis with the $\pi^- p$ experiment where background effects are less serious.

(4) $\pi^- p \rightarrow (\pi^+\pi^+)N^{*o}$: Excitation by pion exchange and correlated spin studies of both I=3/2 and I=1/2 states will be carried out and compared with similar analyses which we have made with our $\pi^+ p$ data.

3.2 Boson states:

(1) $\pi^{\pm}p \rightarrow A^{\pm}p$: We have shown that $A_3^+ \rightarrow f^o\pi^+$, 2^-S wave decay undergoes a phase change with mass of the $(f\pi)$ system. Our result, in

direct contrast to the A_3^-, has been confirmed by a CERN group. We will analyze the A^- region in a detailed comparison with the A^+ region at a single energy; the A^- is shown in Fig. 12a.

(2) $\pi N \rightarrow \pi\pi N$: Dipion resonant states are clearly apparent in Fig. 11a. These data, along with the $\pi^+ p \rightarrow \pi\pi\Delta$ events, will be combined in a multichannel phase-shift analysis with our hybrid 40" results on $\pi^+ p \rightarrow KK\Delta$.

(3) $\pi^- p \rightarrow (B,R)^- p$, $(KK\pi)^- p$, etc.: We will continue our studies of high-mass bosons and rare final states in terms of specific decay channels.

4. General comments

These projects will be carried out contemporaneously with currently developing experiments. A significant portion of the analysis will involve a collaboration with Indiana University-Purdue University at Indianapolis.

Fig. 11

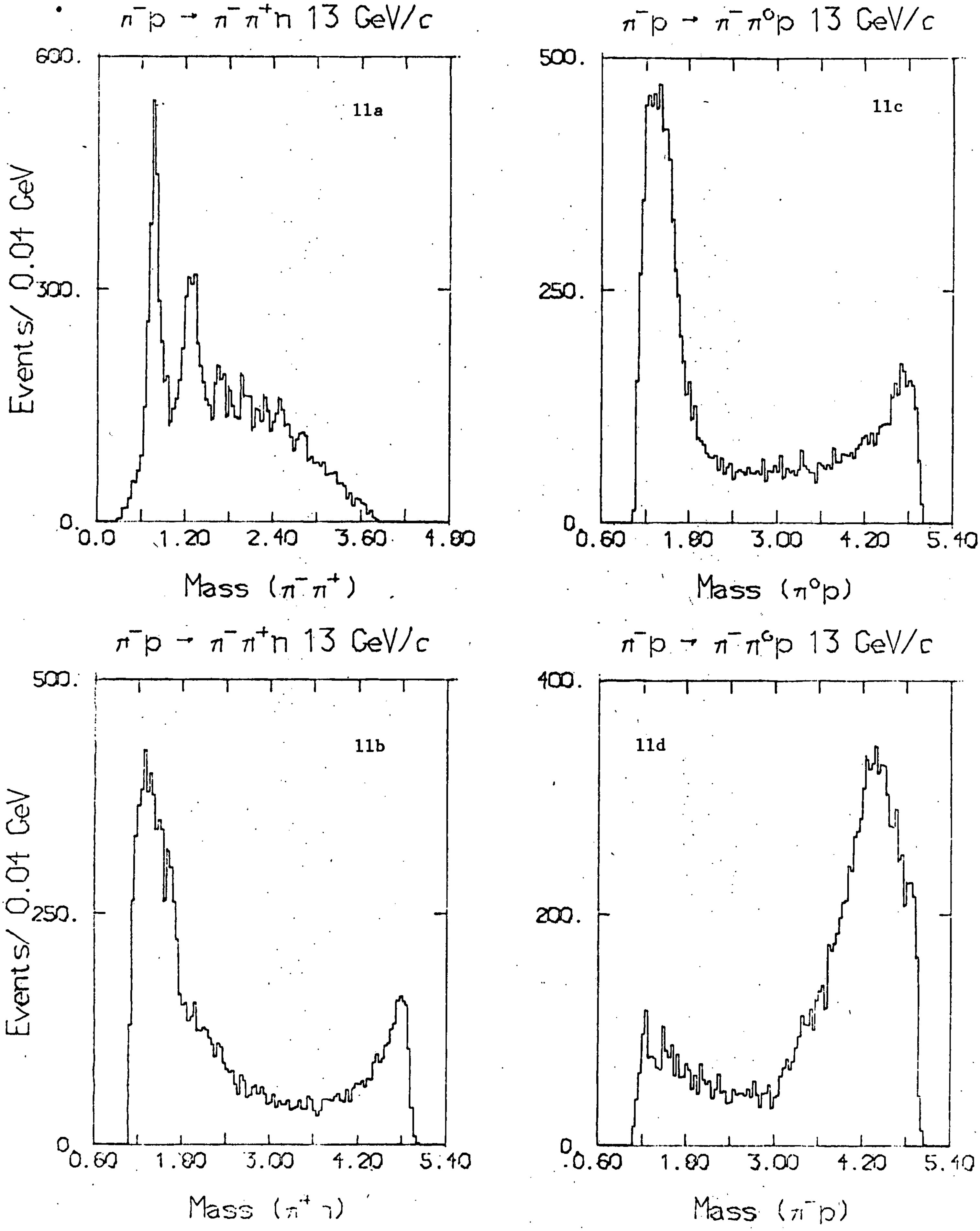
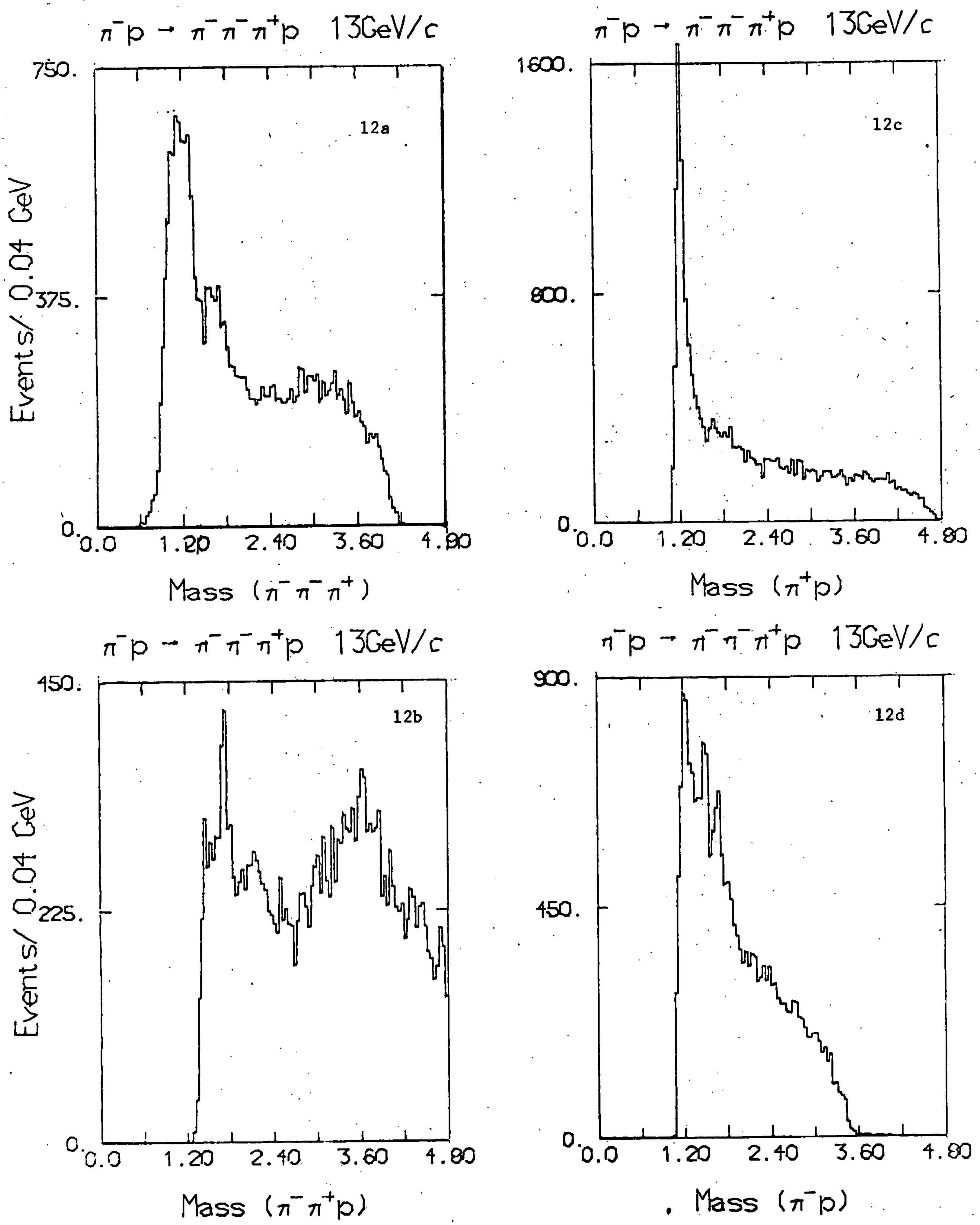

π⁻p → π⁻π⁺n 13 GeV/c
11a
Events/ 0.04 GeV
600.
300.
0.
0.0
1.20
2.40
3.60
4.80
Mass (π⁻π⁺)
π⁻p → π⁻π⁰p 13 GeV/c
11c
500.
250.
0
0.60
1.80
3.00
4.20
5.40
Mass (π⁰p)
π⁻p → π⁻π⁺n 13 GeV/c
11b
Events/ 0.04 GeV
500.
250.
0
0.60
1.80
3.00
4.20
5.40
Mass (π⁺n)
π⁻p → π⁻π⁰p 13 GeV/c
11d
400.
200.
0
0.60
1.80
3.00
4.20
5.40
Mass (π⁻p)

Fig. 12


π⁻p → π⁻π⁻π⁺p 13GeV/c
12a
Events/ 0.04 GeV
750.
375.
0.
0.0
1.20
2.40
3.60
4.80
Mass (π⁻π⁻π⁺)
π⁻p → π⁻π⁻π⁺p 13GeV/c
12c
1600.
800.
0.
0.0
1.20
2.40
3.60
4.80
Mass (π⁺p)
π⁻p → π⁻π⁻π⁺p 13GeV/c
12b
Events/ 0.04 GeV
450.
225.
0.
0.0
1.20
2.40
3.60
4.80
Mass (π⁻π⁺p)
π⁻p → π⁻π⁻π⁺p 13GeV/c
12d
900.
450.
0.
0.0
1.20
2.40
3.60
4.80
Mass (π⁻p)

VIII. POLLY AND THE DATA ANALYSIS SYSTEM

POLLY is currently operational and turning out events completely through the geometric reconstruction stage at the rate of about 15-20 events/hour. Our girls are all trained and operate the system routinely. The present event rate will increase significantly in the next few months as various tuning of the software and hardware is accomplished.

The quality of track measurements is gratifying. The precision appears to be two to three times better than for SMP's. As the film arrives from the SLAC 40" Hybrid Facility (BC61) over the next few months we will scan and measure it with dispatch.

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