# NALREP

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Monthly Report of the Fermi National Accelerator Laboratory

June 1974

Fermi National Accelerator Laboratory

NALREP is published monthly by the Fermi National Accelerator Laboratory, P. O. Box 500, Batavia, Illinois 60510.

J. R. Sanford, Editor
N. Stiening, Assistant Editor

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NAL-74/7 0090.01

THE COVER: Laura Fermi, wife of the late Enrico Fermi, on the speakers' platform during the Laboratory's formal dedication ceremony on May 11, 1974.

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## THE FILM ANALYSIS FACILITY

At FAF, the Laboratory's Film Analysis Facility, bubble-chamber and spark-chamber photographs are analyzed. Since the fall of 1969, FAF's equipment and personnel have enabled staff physicists to conduct their current research as well as to prepare for the more complex patterns expected from pictures of particle collisions at energies of several hundred GeV. Thus, it was possible for Fermilab physicists, in collaboration with experimenters from other institutions, to participate in the earliest research with 200-GeV protons (Experiment #141A), 300-GeV protons (Experiment #37A), and 200-GeV negative pions (Experiment #137) interacting in the 30-inch bubble chamber. More recently, FAF has analyzed collisions in this chamber in conjunction with those in downstream hybrid detector systems, using wide-gap spark-chamber photographs (Experiment #2B) and proportional wire-chamber data (Experiment #154).

Along with analyses of data from experiments using the 30-inch chamber, a major effort in the Film Analysis Facility will be the analysis of neutrino and hadronic interactions in the 15-foot bubble chamber. Equipment and personnel from the Village will soon be moved to new quarters on the ninth floor of the Central Laboratory.

In the Manual Scanning and Measuring Shop, headed by R. Hanft, film from visual detectors is examined by scanners and measurers working under the direction of physicists. The development of a semi-automatic film measuring machine, the SAMM project, is headed by D. Bogert. Assistance with film analysis computer programs, especially for geometrical reconstruction and kinematic fitting, is provided by J. P. Berge.

To assist the Physics Department in making effective use of this equipment there is a FAF Committee composed of interested Fermilab physicists. The Chairman of this committee acts as coordinator of resources and priorities. L. Voyvodic is FAF Committee Chairman for 1974.

Manual Film Scanning and Measuring

The Laboratory has eight manually operated film projection tables. There are four image-plane digitizers built by the Micrometric Corporation, two of which are on loan from Cornell University. In addition, there is a rebuilt Hermes precision film plane digitizer donated by BNL and three manually operated measuring machines (MOMM's) which were built at the Laboratory. All eight tables are connected to a PDP-9/L computer for recording the scanning and measuring information.

The Micrometric Corp. tables are used for the bulk of the scanning for 30-inch bubble-chamber experiments; they produce a nearly life-size image on the viewing table. These tables have moderate measuring precision, equivalent to approximately a 7.5 μm setting error on the film. The Hermes machine which was not designed for scanning, has higher precision and measures more slowly than the other tables.

To overcome the limitations of commercial equipment and to prepare for pictures expected from the 15-foot bubble chamber, a major effort of the FAF group has been the design and construction of three MOMM's. The optical and mechanical design was carried out by C. Lindenmeyer, who had worked on the design of similar equipment at Argonne National Laboratory for use with their 12-foot bubble chamber.

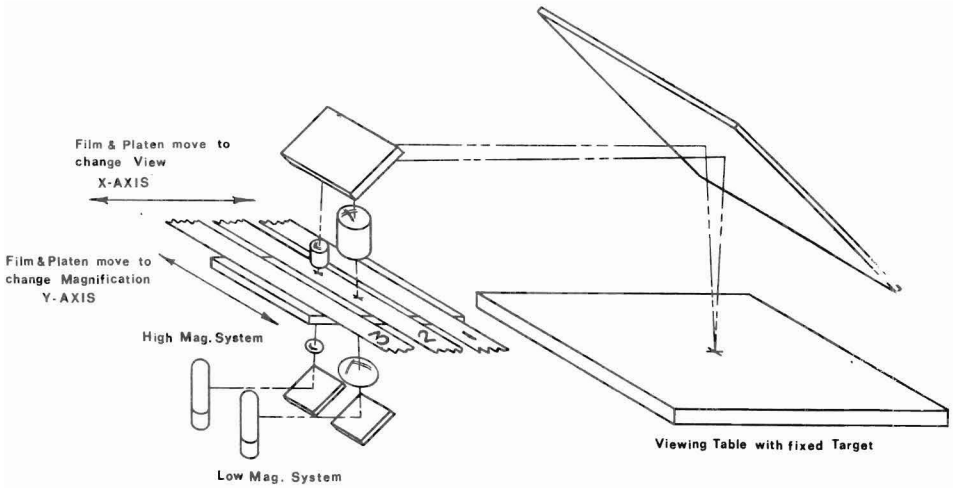



Diagram of the MOMM optical scheme.

The two magnifications available on a MOMM are shown schematically above. The low magnification (~ 15 ×) is similar to that of conventional tables. The high magnification (~ 70 ×) permits detailed viewing of a small region of the film. By moving the film with respect to the fixed projectors, the operator may view all regions of any of the three film strips under either magnification. The film stage has precision X-Y position encoders capable of an accuracy of 1.27 μm least count. By means of a hand controller, the operator can set film images onto a fixed target and digitize film point coordinates into the PDP-9/L logging computer. The setting error is about 2.0 least count. There is a CRT computer terminal at each MOMM so the operator can communicate with the computer.

## The SAMM Project

After examining developments on automatic film measurers at other laboratories, the FAF Committee initiated a project to build a CRT type of

system at Fermilab in 1970. This project is known as SAMM. A PDP-10 computer used to control SAMM was donated by the manufacturer, the Digital Equipment Corporation.

SAMM has three views, with three CRT measuring stations and the means of projecting the film being processed to an operator, who can give helpful assistance to SAMM when confusion arises. The designers of SAMM, with the experiences of other institutions in mind, recognized the fact that fully automatic scanning and measuring of complicated bubble-chamber events is not yet practical, and that an operator is necessary to help in difficult situations.

The PDP-10 control computer for SAMM may only sample one of the three views in a given instant. This is accomplished by means of a special-purpose digital controller, designed and built by the SAMM project group.

SAMM has been designed with 15-foot bubble-chamber pictures in mind, including the special problems which probably will be associated with it. This chamber will produce an image about 3 inches (75 mm) in diameter of a piece of 70-mm film. This is a rather large reduction, and as a result, the bubble images may be as small as 10 μm. Thus, the spot of light passing through the film for measurement purposes must match this size, or the transmitted light signal will be washed out. The achievement of what is believed to be a usefully small spot has been the result of work carried out not only at Fermilab, but originally at Oxford University and other laboratories. The question of optimum signal response from the 15-foot chamber film is, however, one of the questions which the SAMM group will be

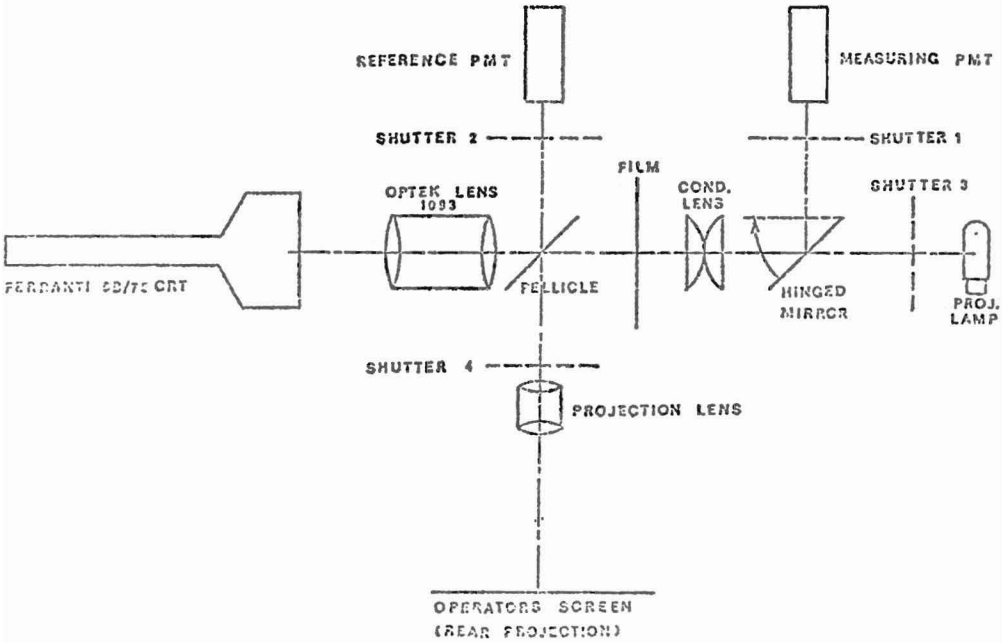



Diagram of one SAMM measuring station. Shutters 1, 2 and 3, 4 are operated in tandem. When one pair is open, the other pair is closed.

studying for some time. Track signals from the 30-inch bubble chamber, on the other hand, can be seen readily by SAMM, and tracks from this chamber have been followed by the computer programs.

The principal elements of a "measuring station" of SAMM are indicated above. Light from the face of the 9-inch CRT is imaged through the OPTEK lens onto the film. About 35% of the light is split out by the "pellicle," a single-surface beam splitter. This light is used as a reference and compared with the signal light transmitted through the film and collected in the measuring photo-tube. This allows the subtraction of any false signal due

to variation in the CRT phosphor. When the operator wants to view the film, the projection lamp is turned on and the image is projected onto a rear projection screen.

As already indicated, SAMM is an amalgam of designs used for previous CRT machines such as the POLLY at Argonne and PEPR at MIT. SAMM can therefore execute two types of computer-controlled scans: 1) a slice scan (a small raster, from POLLY), or 2) element recognition (a line scan at successive angles, from PEPR). Combinations of these types of scan are also possible. SAMM can accept up to four multiple digitizations on a single digitizing sweep.

Initially, SAMM is being programmed to operate in the "road guidance" mode, using four-prong events of 100-GeV $\pi^-$-p interactions from the 30-inch Hybrid #2B experiment. Previous measurements of these tracks on the Micrometric tables will be used to predict "roads" for SAMM's precision measurements of track coordinates and ionization density. The successful demonstration of this phase is expected to be followed by a high statistics experiment on four-prong events from $\pi^-$-p interactions at 250 GeV/c in the 15-foot bubble chamber (Experiment #234). For the longer range, work is progressing on a minimum guidance method in which SAMM is expected to locate and follow all tracks when given only approximate vertex locations.

Research on the problems of pattern recognition to make SAMM an automatic measuring system promises to be one of the challenging projects for the next few years at FAF.

Reported by D. Bogert, R. Hanft, and
L. Voyvodic

# PROTON-PROTON INTERACTIONS AT 300 GeV

There are many complementary experimental techniques for studying the properties of strong interactions. The bubble chamber is but one method and has its particular advantages and disadvantages. The exploratory, "first look at new places" aspect of a bubble-chamber experiment is important and exciting. But the bubble chamber can also yield detailed quantitative information of a type that is difficult to obtain in a bias-free way by any other method.

When one first looks at bubble-chamber photographs taken in a new energy range, the visual aspect of the work gives one a feeling of anticipation as a vast, new, unexplored panorama unfolds. But later comes more careful, systematic work. No quarks, monopoles, or other new particles have appeared on our horizon. Instead we have started unraveling the rich and intricate details of the strong interaction. Among the hundreds of exclusive channels kinematically possible at our 23-GeV center-of-mass energy, which one does nature prefer? And why these?

A bubble-chamber experiment is uniquely suited to studying the correlation of a diverse phenomena as a function of $n_c$, the number of charged particles produced in a collision. Since there is no underlying theory of strong interaction dynamics to guide us, it is not known whether $n_c$ is an important parameter, but it may well turn out that such information will provide crucial tests of various models.

This article will describe some of the methods used and results obtained from a particular bubble-chamber experiment: # 37A, the Caltech-Fermilab-Indiana University-UCLA collaboration on studying proton-proton interactions at 300 GeV in the 30-inch hydrogen bubble chamber.

Experimental Problems

There are some special aspects of doing bubble-chamber experiments in a modest-sized volume at these high energies. Approximately 8-1/2 charged tracks are produced from each inelastic collision. On the average, half of these will lie in a cone which is only 2 × 77-mrad wide. This forward cone, with its accompanying close-in $V^0$ decays and secondary interactions, is thus a very complex region, and the best possible spatial resolution in the few centimeters near the primary interaction point are needed to untangle what is occurring.

The particles in the forward cone have high momenta, often in excess of 100 GeV/c. In the short distance available for measurement they are almost indistinguishable from straight lines. Since this is a "bare-chamber" experiment, i.e. one which does not make use of supplementary information obtained from downstream spark chambers, the momenta of forward-hemisphere particles are poorly determined. But since this experiment is a study of pp interactions, center-of-mass symmetry is invoked to circumvent this problem. In high-multiplicity events a portion of the forward hemisphere is cut and the weights on tracks in the corresponding part of the backward hemisphere are doubled. The most serious consequence of the small chamber size is that $V^0$'s have a small probability for decay and gammas and neutrons have a small probability for interaction.

Another problem which has plagued all the high energy 30-inch runs has been track matching. One would like to measure complete high multiplicity ($\gtrsim$ 20 prong) events. We have solved this problem by "brute force." The MOMM tables, one of which is shown on page 9, designed and built in the

K. Schmidt, of the Fermilab Film Analysis Facility, measures a high-multiplicity event for Experiment # 37A on a MOMM table.

Fermilab Physics Department, have very "crisp" optics. One can easily change magnifications from 15 × to 70 × so the complex region around the primary vertex can be studied carefully. For one view the bubble pattern of each track is traced on a piece of paper and then this paper is used to decide which are the corresponding tracks in the other views. After all the matching is done the tracks are measured. The bubble pattern is a unique fingerprint

and all track reconstructions done by this method pass TVGP, the geometric reconstruction computer program. The only drawback is that the process requires very careful work. It takes nearly a day to analyze one event.

Experiment # 37A was done in two phases. Phase I film was obtained in August 1972, with just barely enough time to prepare a multiplicity distribution for the Batavia Conference held in September 1972. This exposure contained 2750 events, 2245 after a fiducial length cut was made. We received the Phase II film nine months later, in June 1973, and had a total sample of 12,356 events, 10,054 after the fiducial cut. Because of the time duration between them, we decided to treat the phases as two separate experiments, and concentrated on somewhat different physics goals in Phase II.

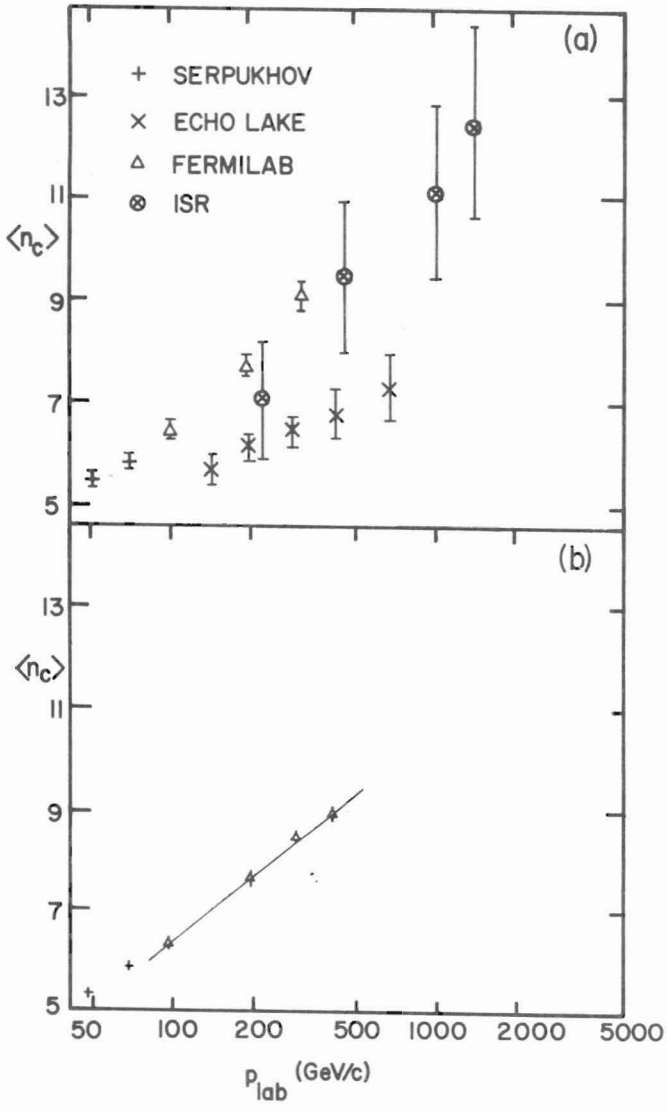
Physics Results

The most straightforward measurement is a determination of $\langle n_c \rangle$, the average number of charged particles per inelastic collision. This number is one of the basic predictions of many strong interaction models, and it has an interesting history. Before the bare-chamber runs started at Fermilab, the only existing information in the > 100-GeV region was from a cosmic-ray experiment. Then the bare-chamber runs at Fermilab began and the Argonne/Fermilab group working at 205 GeV/c were the first to observe that the cosmic-ray measurement was in error and that $\langle n_c \rangle$ really was considerably higher. This was confirmed by us and the Michigan-Rochester group working with 100-GeV/c protons. The situation in September 1972 is

summarized on page 12. The three measurements at 100, 200, and 300 GeV roughly followed a $\ln s$ dependence as predicted by many models. But if one looked more carefully at the data, our measurement of $\langle n_c \rangle = 8.86 \pm 0.16$ was about 1 standard deviation higher than the $a + b \ln s$ fit through the data. So we eagerly awaited our Phase II film to remeasure $\langle n_c \rangle$ with greater precision. This has now been done and the new value is $8.50 \pm 0.12$. Also a 400-GeV measurement has been done by the Michigan-Rochester group and the accuracy of the 100- and 200-GeV points improved. The situation as of the April 1974 Washington APS meeting is also summarized on page 12. Now all four experiments agree very closely with a $\ln s$ dependence.

It is difficult to search for meson resonances by their charged pion decay modes because in the high-multiplicity events there are so many possible combinations of tracks that a resonance can be hidden by background. Since there are only one or two protons per collision, it is easier to search for $(p\pi^+)$ and $(p\pi^-)$ resonances. Other promising avenues to follow in resonance searches are through the systems $K_S^o + K_S^o$, $K_S^o$ + charged particle, $\Lambda^o$ + charged particle.

Protons can be uniquely separated from pions by ionization if their momentum is less than 1.4 GeV/c. We made ionization decisions on all such low-energy tracks in our Phase I film and then looked at the $(p\pi^+)$ and $(p\pi^-)$ effective mass distributions. There was no <u>a priori</u> reason to expect strong-resonance production so we found the strong $\Delta^{++}$ signal quite striking. The average number of $\Delta^{++}$'s, $\langle \Delta^{++} \rangle$, produced per inelastic collision equals $0.13 \pm 0.02$).

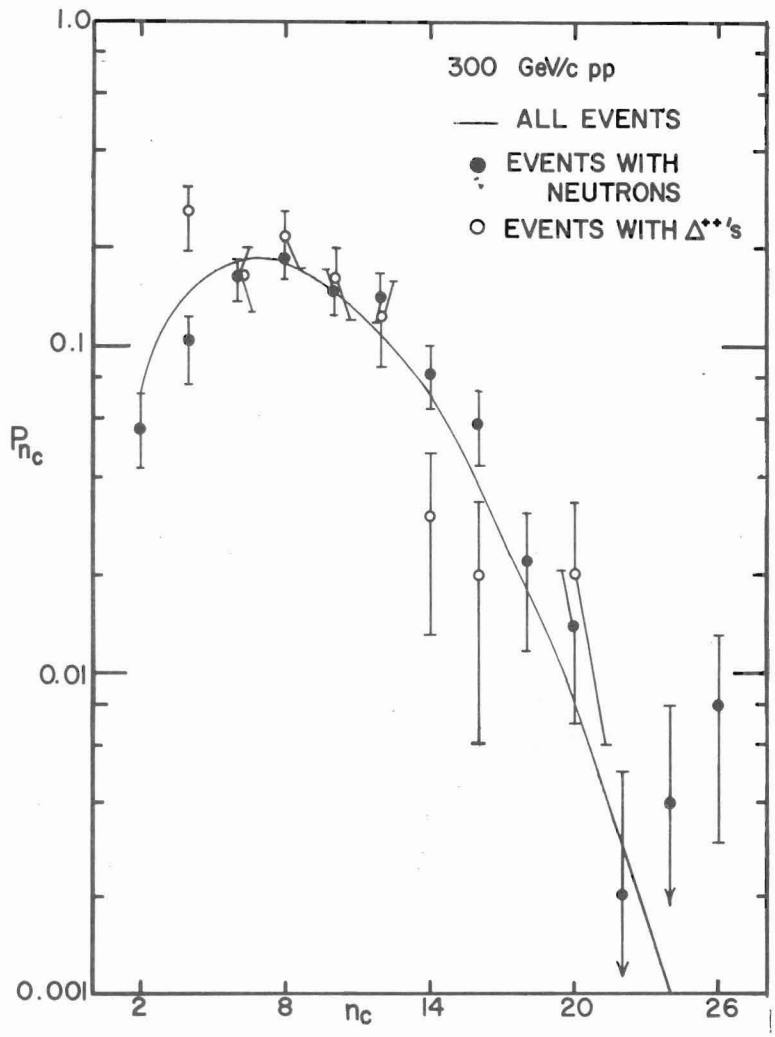



Average charged particle multiplicity, $\langle n_c \rangle$, as a function of beam momentum: (a) at the time of the 1972 Batavia Conference, and (b) at the time of the 1974 Washington APS meeting in April.

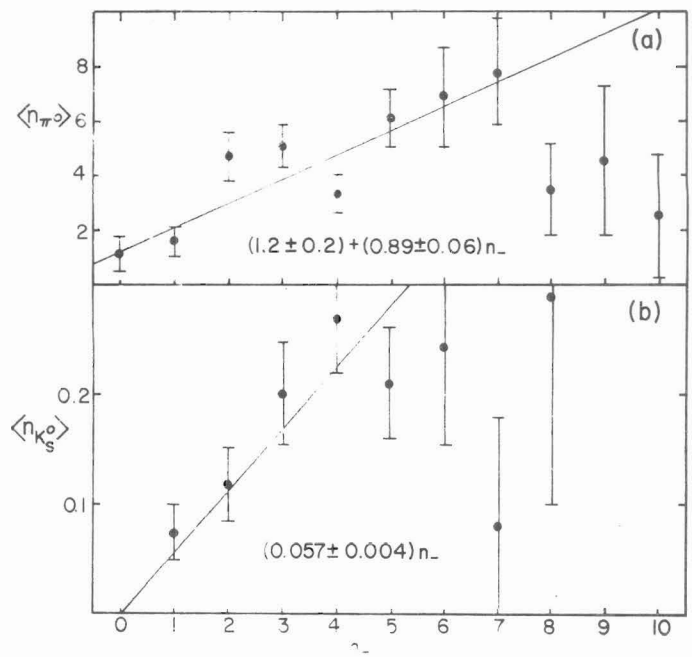
In Phase II we made an attempt to measure inclusive neutron production. This is done by counting the number of inelastic np interactions giving an odd-prong "star" with $n_c \geq 3$ prongs. We then made a number of corrections, the most important being (1) an estimate of the number of 1-prong inelastic events (for which the scanning efficiency is low), (2) a subtraction of $K^o p$- and $\Lambda^o p$-induced odd-prong stars, and (3) a correction for the unobserved portion of the backward hemisphere. The result $\langle n \rangle + \langle \bar{n} \rangle$, the average number of neutrons and antineutrons (since we have no way of distinguishing them) produced per inelastic collision, equals $0.8 \pm 0.2$.

The comparison of $\Delta^{++}$ and neutron production as a function of primary collision multiplicity is shown on page 14. In both cases, production is slightly increasing with multiplicity. One can speculate on the following simple dynamical picture. Within a high-mass blob virtual pions interact with the leading proton. If we assume that there are equal numbers of $\pi^+$'s and $\pi^-$'s, use the pole equation, and ignore off-mass shell, the ratio $\langle n \rangle$ $\langle n \rangle / \langle \Delta^{++} \rangle$ is in rough agreement with the measurement.

Next we discuss some of the work we are doing with $V^o$'s. The symmetry of the pp system means we measure $K_S^o$'s, $\Lambda^o$'s, $\bar{\Lambda}^o$'s (and $\Delta^{++}$'s) only in the backward hemisphere and then correct the cross sections for the full $4\pi$ solid angle. Gammas (assumed to be from $\pi^o$'s) are, of course, seen in both hemispheres. In Phase I we determined that $\pi^o$'s were strongly correlated to $\pi^-$'s and this supported a cluster picture and argued against an independent pion emission model. Phase II data, shown on page 15, confirmed this but in addition showed clearly the dropoff in $\pi^o$ production for very high multiplicity. As shown on page 15, $K_S^o$'s produced in low-multiplicity events are




Primary multiplicity distribution for events with $\Delta^{++}$'s and neutrons.




Average number of $\pi^0$ per inelastic collision as a function of $n_-$, the number of negative tracks (a); (b) average number of $K_S^0$ per inelastic collision as a function of $n_-$.

correlated with the number of negative tracks, so the $K^0$ production may be via $K^0$'s or other clusters.

A small number of events have two $K_S^0$'s. Their effective mass distribution shows a striking enhancement at low $m_{KK}$. This result is preliminary and we are now investigating it further.

Finally we turn to a discussion of the high-multiplicity events. At this time we have measured ~50 events with $n_c \geq 20$ prongs. The number of ways in which these can be looked at is endless; the game we are playing is to find

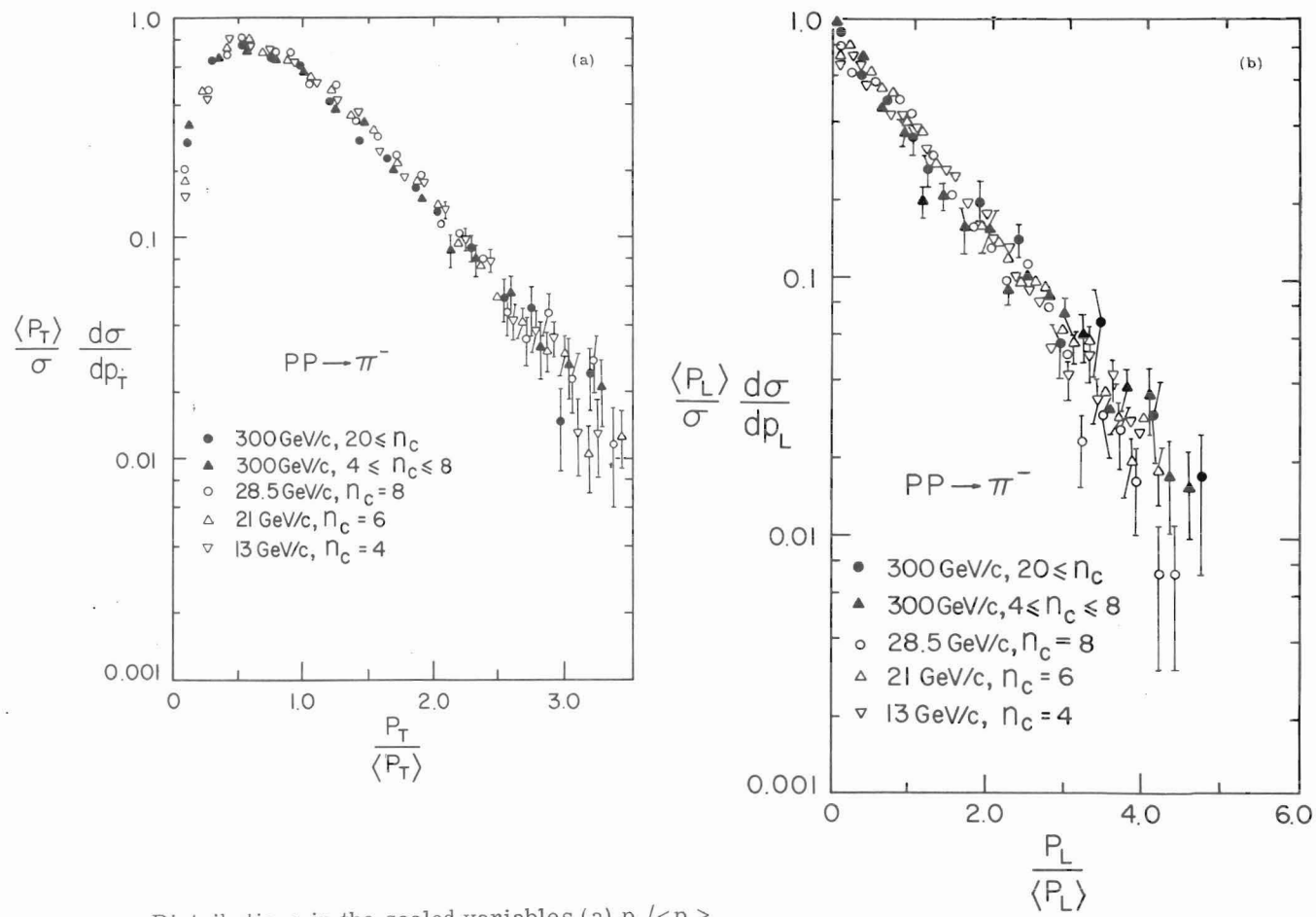
the proper variables to bring out the essential physics of these interactions. One can look for two-body correlations and as already discussed we have observed a strong $\Delta^{++}$ signal in all multiplicities. Another two-body effect we have seen is the "Goldhaber effect" where the effect of Bose statistics causes the angular separation between pions of like charge to be greater than those of unlike charge. This is seen clearly in our high-multiplicity events.

One can look at correlations between more than two particles; i.e., search for clusters. T. Ludlum and R. Slansky from Yale have taken some of our data (and some from the 205-GeV/c experiment) and have concluded that clusters having an average multiplicity of 4 charged particles are produced in these collisions.

An interesting observation has been made by F. T. Dao. He finds evidence for a new kind of scaling illustrated on page 17. The distributions in $p_t$ and $p_L$, even though the values of $\langle p_t \rangle$ and $\langle p_L \rangle$ may differ, appear to have the same shape, independent of multiplicity, charge of produced particle, primary energy, or beam particle.

## Conclusions

What about the future? The next step our group will take is to study pd interactions at 300 GeV in the 30-inch chamber (Experiment #209). We will attempt to answer the question: Is the neutron the same as the proton in high energy strong interactions? We expect the answer to be yes, but it is important to test this in as many ways as possible, and so we will repeat many of our Experiment #37A measurements with deuterium and compare them with the proton results described in this article.




Distributions in the scaled variables (a) $p_t/\langle p_t\rangle$ and (b) $p_L/\langle p_L\rangle$.

It has often been said that bare bubble chamber experiments such as ours only serve a role when an accelerator first operates in a new energy region. This role has certainly been important, first in the search for new particles such as quarks or monopoles, and then in the initial measurement of quantities like $\sigma_{tot}$ or $\langle n_c \rangle$. A picture of how inelastic collisions look is roughly drawn down to the 0.1-mb level.

But I think the bubble chamber has a more lasting role to play. Studies of multi-$V^o$ production, correlation of V's with charged tracks, and detailed analyses of high multiplicities are best done in the bubble chamber. A logical step would be a tenfold increase in statistics in a bare chamber proton-proton experiment, done in the larger 15-foot chamber. This would aid the $V^o$ detection problem.

Reported by E. Malamud

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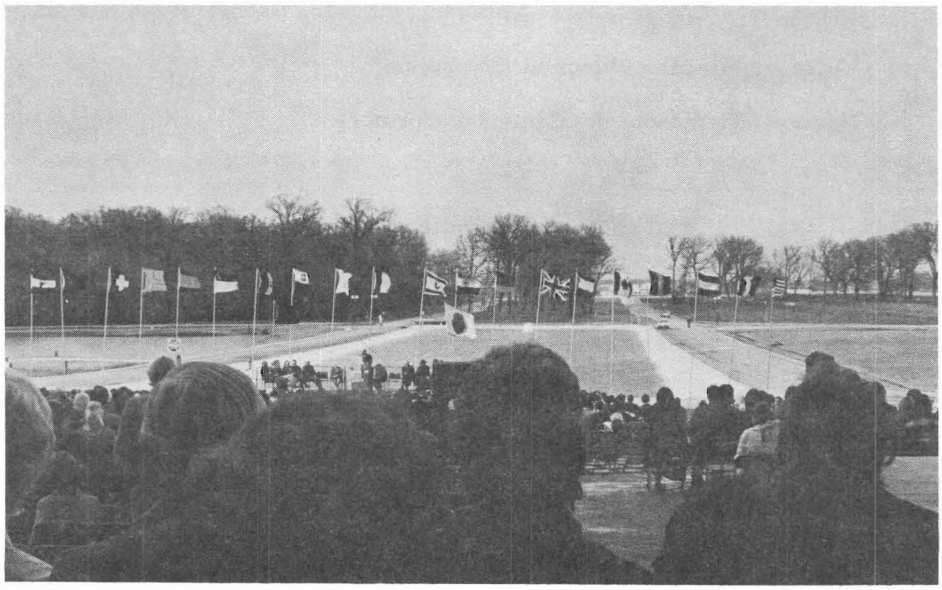
Those who participated in this work are: F. T. Dao, V. Davidson, A. Dzierba, A. Firestone, D. Gordon, R. Hanft, J. Lach, K.-W. Lai, D. Lam, E. Malamud, T. Meyer, F. Nagy, F. Nezrick, C. Peck, R. Poster, J. Schivell, P. Schlein, A. Sheng, and W. Slater. Equally important contributions to these results were made by those who built and operated the Fermilab accelerator, the hadron beam to the bubble chamber, the bubble chamber itself, and the Fermilab Film Analysis Facility.

## NOTES AND ANNOUNCEMENTS

Dedication of the Fermi National Accelerator Laboratory (Fermilab). . .

"I speak for my colleagues who have built this laboratory. We are deeply honored to have the name of Fermi attached to our laboratory. Laura, I pledge in their name that we will do our best to make this a laboratory worthy of the name of Enrico Fermi". . . the promise of Director R. R. Wilson to Laura Fermi at the formal Laboratory Dedication on May 11, 1974.

It was a festive occasion. Special guests attended a Reception and Luncheon in the Atrium of the Central Laboratory, and then took a guided tour of the facilities. They visited the accelerator areas, the Main Control Room, and selected experimental areas. Later in the afternoon, they joined the rest of the Laboratory community for the formal ceremony. A booklet containing reprints of all of the talks will be available later this summer. Some photographs of what went on that day follow on pages 20 and 21; captions are on page 22.



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Upper left: Mrs. Fermi and Mrs. Williams at the Reception

Upper right: Mr. Smyth, Mr. Giacomelli, and Mr. Segrè at the Luncheon

Middle left: Mr. Wilson and Senator Percy view a main ring magnet

Middle right: Mr. Reardon, Chairman Ray, and Mr. Goldwasser in the Main Control Room

Bottom: Tour of the Meson Detector Building

Page 21

Upper left: The speakers' platform, with Mr. Bacher at the podium

Upper right: Mr. Wilson at the podium

Bottom: View from the Central Laboratory

(All photos by Fermilab photographers)

## FACILITY UTILIZATION SUMMARY--MAY 1974

Monday, May 6 saw the end of a ten-week running period in which new records were set for peak accelerated intensity, average intensity, accelerator reliability, and hours of beam time available for high energy physics research. Good performance continued throughout the period, with the final week showing a record 140 hours of beam for high energy physics research at an average intensity of $0.64 \times 10^{13}$ protons per pulse over all magnet cycles. Most of the remainder of the month was devoted to accelerator development for operation at energies of 400 GeV and greater. The initial tests of the series capacitor bank for the main ring pulsed power were carried out during the week of May 6. These tests were very successful, and the Main Ring was pulsed to the 485-GeV excitation level. A brief period of 300-GeV beam was available for experimental use over the weekend of the Laboratory Dedication May 10 to 12. The accelerator was then turned off for maintenance and development work. On May 17 the new main ring pulsed power transformer failed under no-load conditions, frustrating both the remaining tests and the hopes for operation at 400 to 500 GeV tentatively scheduled for late May and early June. Accelerator operation at 300 GeV was therefore resumed on May 25. Considering the length of the shutdown and the scope of development activities, the startup went very smoothly. The 221 hours of beam available for high energy physics research during May represents 74% of the time so scheduled; $6.13 \times 10^{17}$ protons were delivered to the experimental areas.

In the Meson Area, three experimental groups took data and four others were in various stages of testing. Those taking data were Elastic Scattering #7, Missing Mass #51A, and $K^0$ Regeneration #82. Beam was used for testing by Neutron Backward Scattering #12, Monopole #22, Elastic Scattering #69A, and Photon Inclusive #268. After the Laboratory Dedication the Meson Area remained off for maintenance work, including the repainting of the interior of the Detector Building roof and the installation of the closed-loop target cooling system.

In the Neutrino Area, May 6 marked the end of a 74,000-picture run in the 30-inch bubble chamber for $\pi^+$-p @ 200 GeV #217. During this run the cameras were triggered on three or more positive pion tracks in the chamber. The chamber was shut down upon completion of this run. Muon #98 finished their approved running with hydrogen at +150 GeV/c, having received about $3.7 \times 10^{17}$ protons; they then set up their target to use deuterium. In addition, during early May, the N-5 hadron beam line to the 15-foot bubble chamber was tested and Neutrino #1A began testing their calorimeter with hadrons of known energy. They continued this work after the shutdown period. The 15' Neutrino #45 group tested their flux-monitoring system. Cooldown of the 15-foot chamber proceeded to the point of filling the chamber with hydrogen, but the magnet was not energized and no pictures were taken.

The primary user in the Proton Area during May was Lepton #70, who changed their apparatus from a laboratory angle of 83 mrad to 67 mrad. Photoproduction #87A ran in the early part of the month with the upstream 35-foot section of their liquid deuterium absorber.

In the Internal Target Area, Proton-Deuteron #186, Proton-Proton Inelastic #221, Photon Search #63A, and Particle Search #184 all took data. The #63A and #221 groups completed their data taking during the month.

The facility utilization summary for May is as follows:

I. Summary of Accelerator Operations

| | Hours | |
|---|---|---|
| A. Accelerator use for physics research | | |
| Accelerator physics research | 44 | |
| High energy physics research | 221 | |
| Research during other use | (26) | |
| Subtotal | | 265 |
| B. Other activities | | |
| Accelerator setup and tuning to experimental areas | 83 | |
| Scheduled interruption | 323 | |
| Unscheduled interruption | 67 | |
| Subtotal | | 473 |
| C. Unmanned time | | 6* |
| Total | | 744 |

II. Summaries of High Energy Physics Research Use

| | # of Expts. | Hours | Results |
|---|---|---|---|
| A. Counter experiments | 17 | 1520 | 1520 hours |
| B. Bubble chamber experiments | 1 | 83 | 48,795 pictures |
| C. Emulsion experiments | 0 | - | - |
| D. Special target experiments | 0 | - | - |
| E. Test experiments | 0 | - | - |
| F. Engineering studies and tests | 2 | 73 | 73 hours |
| G. Other beam use | | 98 | 98 hours |
| | 20 | 1774 | |

*Laboratory Dedication

III. Number of Protons Accelerated and Delivered

| | | Protons |
|---|---|---|
| A. Beam accelerated in Main Ring | Total | $7.43 \times 10^{17}$ |
| B. Beam delivered to experimental areas | | |
| Meson Area | | $0.85 \times 10^{17}$ |
| Neutrino Area | | |
| Main beam | | $4.35 \times 10^{17}$ |
| Bubble chamber beam (estimated) | | $0.04 \times 10^{17}$ |
| Proton Area | | $0.89 \times 10^{17}$ |
| | Total | $6.13 \times 10^{17}$ |

## PROPOSALS RECEIVED DURING APRIL AND MAY 1974

| No. | Title | Submitted By |
|---|---|---|
| 294 | Experimental Proposal to NAL Anti-Neutrino Interactions in Deuterium in the NAL 15-ft. Bubble Chamber | B. Roe |
| 295 | A Study of $\pi^+$-d Interactions at 200 GeV/c in the 30-inch Bubble Chamber at NAL | A. Fridman |
| 296 | Study of Electron-Neutrino ($\nu_e$ and $\overline{\nu}_e$) Interactions in a Liquid Neon Bubble Chamber | C. Baltay |
| 297 | Quark Search Using 400-500 GeV (By Measuring Ionization Energy Loss) | L. B. Leipuner |
| 298 | A Proposal to Study Hadron-Nucleus Collisions at NAL Energies Using 30-inch Chamber Filled with Pure Neon | P. K. Malhotra<br>A. Subramanian |
| 299 | Precision Study of High Energy Collisions Induced by Incident 150 GeV/c Pions and Protons | I. A. Pless |
| 300 | Study of Particle Production at High Transverse Momentum Using Hydrogen and Deuterium Targets | J. W. Cronin |
| 301 | Measurements of Hadron-Hadron Elastic Scattering at Large Four-Momentum Transfer Squared | M. Gettner |
| 302 | Test of C at Small Distances | R. Cester-Regge |
| 303 | NAL 15 Foot Hydrogen Bubble Chamber Proposal Diffraction Dissociation of Neutrons on Hydrogen | A. Seidl |
| 304 | Proposal for a Study of the Interaction of High Energy $\pi^{\pm}$ with Uranium | W. D. Walker |