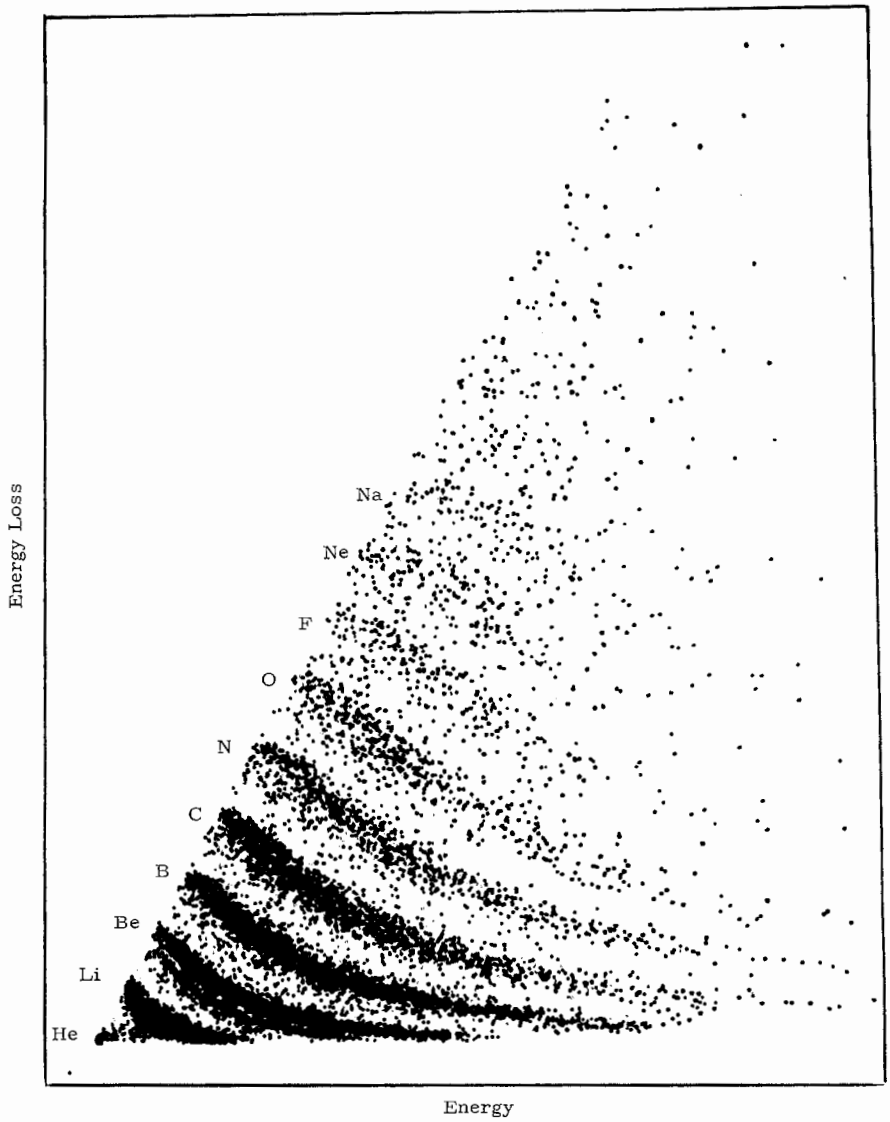
# fermilab report

Fermi National Accelerator Laboratory Monthly Report

May 1977



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

F. T. Cole, Editor R. Donaldson, Assistant Editor

The presentation of material in fermilab report is not intended to substitute for or preclude its publication in a professional journal, and reference to articles herein should not be cited in such journals.

Contributions, comments, and requests for copies should be addressed to the Publications Office.

FERMILAB-77/5 **Fermi National Accelerator Laboratory** 0090.01

THE COVER: The cover is an on-line computer plot of results from Experiment #442 in the Internal Target Area. The ordinate is energy loss of nuclear fragments from protons on Xenon and the abscissa is the energy of the fragments.

Operated by Universities Research Association, Inc., under contract with the United States Energy Research and Development Administration

CONTENTS MAY 1977

The Internal Target Area 1
E. T. Nash

Research Activities During April 1977 9
James MacLachlan

Facility Utilization Summary -- April 1977 13

Beam Utilization By Experiment -- April 1977 14

Manuscripts and Notes Prepared During April and May 1977 17

Dates To Remember

# THE INTERNAL TARGET AREA

E. T. Nash

The Internal Target Area was last discussed in these pages in an article by Drasko Jovanovic in June, 1975. At that time, the additional floor area of the spectrometer room was still being constructed and the spectrometer itself was still being designed. We have now completed successful experimental runs with the spectrometer. In addition, with the passage of time, warm jet targets have supplanted the traditional cold jets. It is therefore an appropriate time to report on progress in the Internal Target Area.

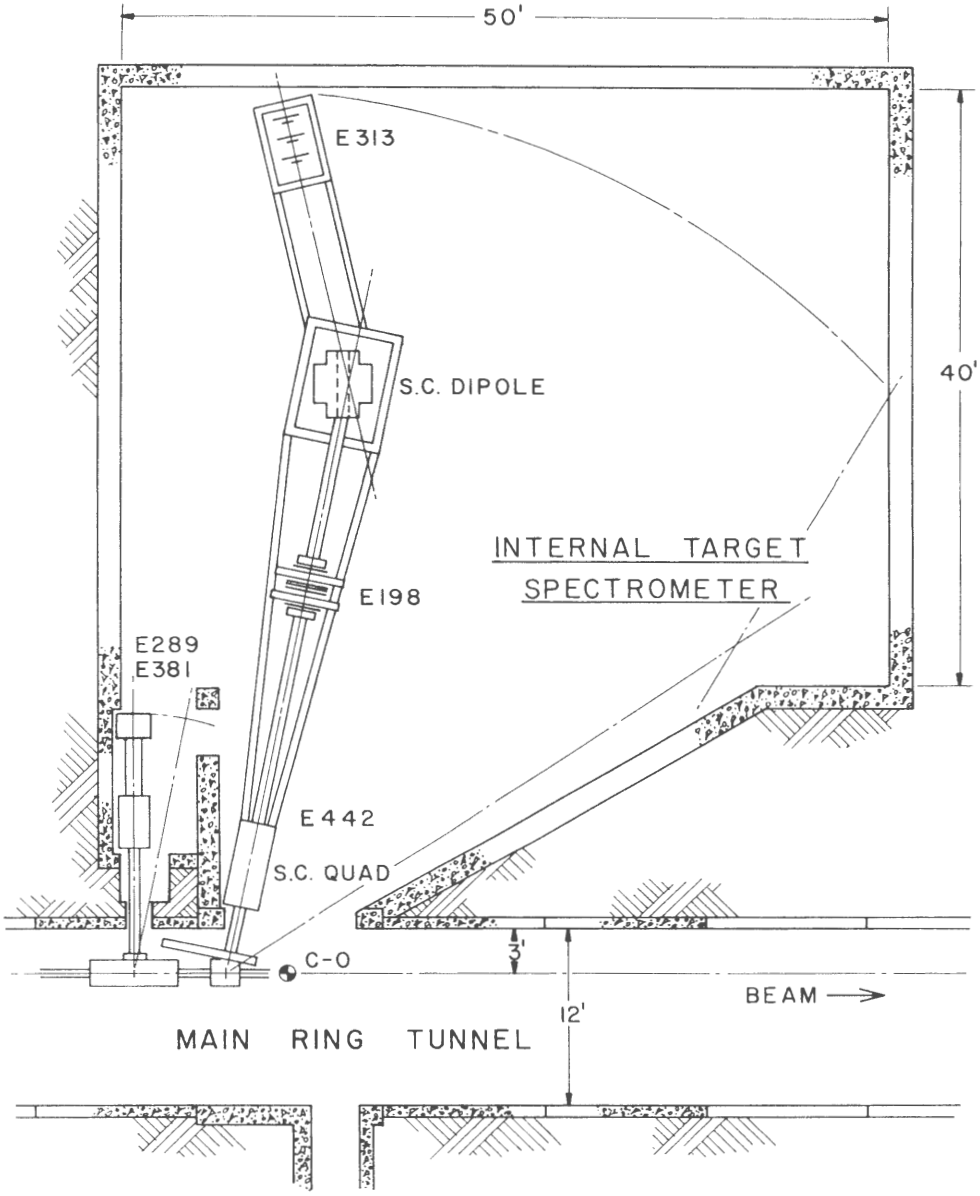
Through the end of 1975 and the first three quarters of calendar year 1976, the spectrometer was being installed and debugged and the only experimental operation was by experiment E321, which we shall discuss later in this report. The installation work on the spectrometer was made difficult by the limited access possible in C0. Now that the spectrometer is operating, the limited access is a continued, though much smaller problem, because everything on the spectrometer is remotely controlled.

The entire spectrometer is mounted on a rigid frame more than 18 m long, which pivots on tracks about the end closest to the Main Ring. Particles scattered into the spectrometer are initially focused by a superconducting quadrupole doublet built at the Lawrence Berkeley Laboratory. The doublet is followed by a series of proportional chambers built at the University of Rochester. After the first series of chambers, there is a superconducting dipole capable of up to 40 kG magnetic field that is the heart of the

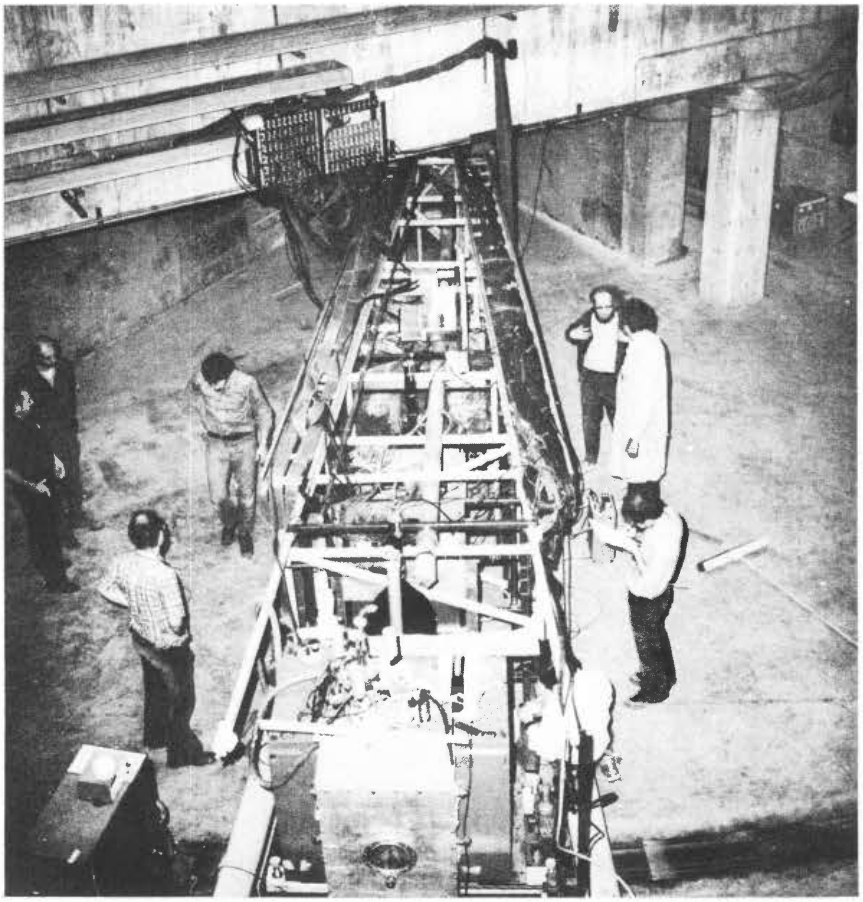
spectrometer, followed by more proportional chambers. Appended at the end and moving with the whole assembly is the Indiana University polarimeter.

This spectrometer, whose mechanical design was done by Chuck Nila and Joel Misek, is a large remotely controlled movable superconducting system. It requires a full-time cryogenic support system. It is located in a radiation area near the Main Ring, so access is rare and it is to some degree a forerunner of the Energy Doubler/Saver, which will have similar problems, although on a far larger scale. During this winter, the spectrometer and the Internal Target Area were ready to take data for more than 95% of the available beam time. The magnets were in a continuous cryogenic state essentially from January until the shutdown in April. This fine record was due to the hard work of Don Mizicko, Joel Misek, Les Oleksiuk, and the technicians of our group. The spectrometer requires 44 liters per hour of liquid helium and the two helium liquefiers were capable of producing up to 60 liters per hour. Operation was difficult in the fall because we had only one liquefier producing less than 35 liters and as a result we were always trying to catch up. But with two liquefiers, we have been able to continue operation even when we had to shut one down for several days for maintenance. When both liquefiers were up there was often sufficient extra liquid to operate the E381 cold jet simultaneously. A layout of the spectrometer is shown on the next page and a photograph appears on page 4.

While the spectrometer was being built, E321, a Columbia-Stony Brook collaboration, ran for p-p inclusive scattering. This experiment also used a warm-jet target, designed and built by the experimenters. This jet used

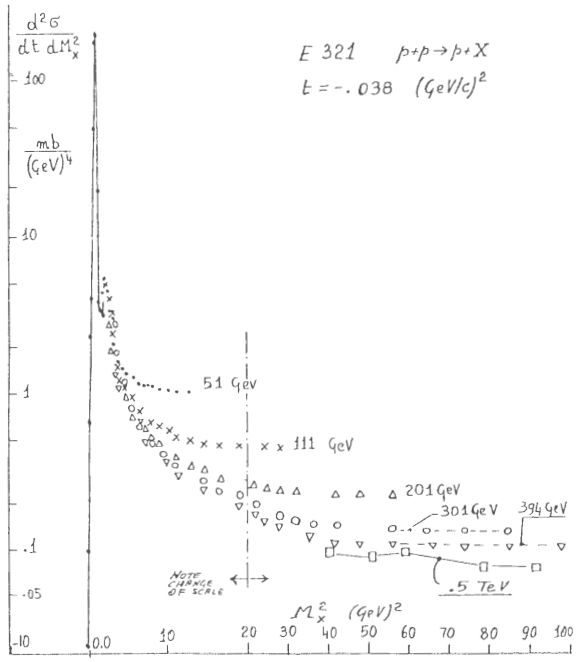



p-p inclusive scattering cross section as a function of energy (E321).



A recent photograph of the spectrometer.

large pumps to pump away the jet particles so that they do not contaminate the accelerator vacuum. Other, more recent warm jets use a very large pumped buffer volume to keep jet particles from scattering back into the accelerator vacuum. The preliminary results of E321, some of which are shown below, show a clear separation into an energy-dependent continuum and a scaling contribution.




p-p inclusive scattering cross section as a function of energy (E321).

Since spectrometer operation began, two experiments, E198 and E313, have completed substantial data-taking with it. Experiment #198 is a series of measurements of p-p elastic scattering in the diffraction-dip region near $|t| = 1.4\ (GeV/c)^2$ as a function of energy. This experiment,

a Rochester-Rutgers-Imperial College of London collaboration, has given a clean measurement of the cross section in the dip. The same collaborators have proposed to carry on their measurements at higher $|t|$ and in p-D scattering.

Experiment #313, an Indiana University experiment, is a measurement of the polarization of the scattered proton in p-p elastic scattering in the region $0.3 < |t| < 1\ (\mathrm{GeV}/c)^2$. Polarization is measured by rescattering from a carbon target. Preliminary results indicate that there are definite polarization effects in elastic scattering. The group has proposed to continue by studying inclusive polarization, where in preliminary testing they have seen significant polarization consistent with and perhaps equally surprising as that seen in $\Lambda^0$ inclusives in the Meson Laboratory.

Both these experiments ran with a warm-jet target. This target was built by Dan Gross; a prototype had been built by Paul Mantsch and Frank Turkot.[1] The last of the cold-jet targets has been phased out with the completion of E381, a Dubna-Fermilab-Arizona-Rochester collaboration to measure p-p and p-D elastic scattering at very low t. This target was built at Dubna and was the third cold-jet target of the Soviet-American collaboration. It used 12 liters per hour of liquid helium. E381 ran while debugging of the spectrometer was being completed in the fall of 1976 and parasitically during the ensuing spectrometer run.

Experiment #381 and E289, now in progress, are follow-ons to E36, E186, and E317. They share a common apparatus located as shown in Fig. 1. The new experiments have higher mass resolution because the ion guide is longer and, in addition, is built to allow more precise surveying.

During the April accelerator shutdown, E289 and other experiments have been set up in the spectrometer are to run until the end of June. We should note that these are purely noncryogenic efforts, which will leave the Internal Target group somewhat free to devote effort to the support of other activities, such as the antiproton cooling ring, the Colliding Beams Department, and the Energy Doubler.

Of these new experiments, E442, a Fermilab-Purdue collaboration, is not a spectrometer experiment, but has detectors set up in the first quadrupole of the spectrometer. The objective of the experiment is to look for fragments of heavy nuclei from proton-heavy nuclei interactions. The experiment uses the spectrometer warm jet to blow heavy gasses such as Xenon into the beam. Preliminary results, such as those shown in the scatter plot on the cover, are very interesting.

Experiment #289 is a Soviet-American collaboration to investigate p-He scattering. A new Soviet built warm helium jet has been installed and is being tested. There are special problems with helium leaked into the accelerator because it is difficult to pump and interferes with leak detection. For this reason, there is not only a buffer volume, but extensive differential pumping in the straight section and permanent leak-detector mass spectrometers installed at each end of C0.

The advent of the spectrometer has given new impetus to the Internal Target Area, with greatly increased competition for beam time. We expect this vigorous experimentation with internal targets to continue.

Reference

[1] P. Mantsch and F. Turkot, Fermilab Internal Reports TM-582 and TM-586, June 6, 1975, and June 18, 1976.

## RESEARCH ACTIVITIES DURING APRIL 1977

James MacLachlan

In April, the accelerator provided 400-GeV beam for high-energy physics research for 305 hours, or 77% of the 396 hours scheduled. A total of $1.28 \times 10^{18}$ protons were accelerated. From April 1 to April 13, the Main Ring was ramped with a 2-second flattop with a resultant accelerator cycle of about 15 seconds. From April 13 until April 18, the flattop length was 1 second and the accelerator cycle was about 11 seconds. On April 19, a 23-hour period of accelerator studies at 450 GeV was started. Beam was accelerated for about 13 hours of this period. After careful orbit and tune measurements, both slow and 2-msec spills were set up on a 1/2-second flattop, and nearly 8 hours of beam at more than $5 \times 10^{12}$ were delivered to the Neutrino Area. The accelerator was shut down the morning of April 20 for the start of a 3-week facility maintenance and development period. The total number of protons accelerated during the month was atypically low, not only because of the shutdown and the long cycle time, but also because extraction losses limited the permissible Main-Ring intensity. The losses that existed at the beginning of the month were slowly reduced, so that average intensity increased from about $1.3 \times 10^{13}$ protons/pulse up to $1.6 \times 10^{13}$ protons/pulse after midmonth. No single solution to the problem was found, although the electrostatic septa remain under suspicion and were replaced during the shutdown.

The Accelerator Division started an extensive program of improvements which includes preparation for $H^-$-ion injection into the Booster by

moving the present preaccelerator column back over a foot and putting new magnets in the 200-MeV line, changing the Booster control system and modifying several Booster rf cavities to provide higher accelerating voltage, replacing bad 13.8-kV Main-Ring feeders and paralleling of some of the most heavily loaded cables, the start of a 200-MeV cooling ring, and a penetration to the Booster for the "backward" injection line into the Main Ring. The shutdown period has also provided for extensive preventative maintenance of electrical and mechanical systems in both the accelerator and experimental areas. High-energy physics is scheduled to resume Wednesday, May 11.

For the first two weeks in April, the priority experiment was Particle Search #379 in the Neutrino Area. A 400-GeV diffracted proton beam was brought into Lab E by the N5 beam line where the experimenters looked at high-mass states produced in a target calorimeter with a downstream toroidal magnet spectrometer for muons. During the third week of April, they moved the toroids off center to look at the most forward muon production. Neutrino #310 ran with a 2-msec spill and the sign-selected bare target train set for antineutrinos. During the third week of running, this experiment was given the highest priority and the accelerator flattop was cut to 1 second to allow improved repetition rate. The experiment received about $8 \times 10^{17}$ protons on target at an average intensity of about $10^{13}$ protons/pulse; they were recording about 1 trigger per 5 to 6 beam pulses. Efforts to increase this rate by raising the accelerator intensity were defeated by the extraction losses mentioned above. During the 450-GeV tests on April 19-20, both Particle Search #379 and Neutrino #310 received beam for about $7\frac{1}{2}$ hours.

Both experiments recorded some data, although the intensity in the fast spill for Neutrino #310 averaged only a little over $5 \times 10^{12}$ because there was not adequate time to tune up extraction.

Photoproduction #401 began chamber tests, rate studies, beam tuning, etc. at the beginning of the month in Proton East. In a few days before the shutdown, they took some test and calibration data with all their apparatus working at some level and expect to return after the shutdown in a data-taking condition. Di-Lepton #288 started testing their extensively reworked di-muon setup about April 7, and they also closely approached the data-taking stage by the end of the running period. p-p Elastic #177A ended a run that had extended almost continuously from October 1976. The experiment is now complete; the last two months of the run were devoted to increasing statistics in their highest t-range, -10 to -15 $(GeV/c)^2$.

In the Meson Area, Form Factor #456 completed its data taking in the M1 line on April 13, bringing its total data to just over the 4000 high-quality $K^-e$ scatters at 250 GeV that had been set as a goal. Some of the same equipment and experimenters are involved in High Energy Channeling #507 which set up in the E456 location and took preliminary data for the last week of the April running. n-N Inelastic #438 was also completed in the M3 line and that line has been put in standby status. The experiment measured inelastic cross sections on a variety of nuclear targets. The pion backward-scattering experiment in M6W, E290, reached the data-taking stage during the month after several weeks of setup and PWC tests. The magnetized-iron beam-dump experiment in M2, Multi-Muon #439, worked on their trigger

rates and shielding to increase their intensity capability. The experiment took data easily at approximately $3 \times 10^9$ diffracted protons/pulse. During a high-intensity test of the M2 line, the targeting angle of the primary proton beam was reduced as many as $1.5 \times 10^{10}$ protons/pulse were transported down the M2 line without problems for the beam line or surrounding areas. The M4 line was off for the entire month for its conversion to a charged beam line for the benefit of Inclusive K-Short #383.

p-N Scattering #198A was the sole user at the Internal Target Area using the superconducting recoil spectrometer. The experiment completed its running with three weeks of solid data taking.

# FACILITY UTILIZATION SUMMARY -- APRIL 1977

## I. Summary of Accelerator Operations

| | | | Hours | |
|---|---|---|---|---|
| **A. Accelerator use for physics research** | | | | |
| Accelerator physics research | | | 60.6 | |
| High energy physics research | | | 305.0 | |
| Research during other use | | | (14.7) | |
| | | Subtotal | | 365.6 |
| **B. Other activities** | | | | |
| Accelerator setup and tuning to experimental areas | | | 2.3 | |
| Program interruption | Scheduled | 257.0 | 259.1 | |
| | Ad hoc | 2.1 | | |
| Unscheduled interruption | | | 92.0 | |
| | | Subtotal | | 353.4 |
| **C. Unmanned time** | | | | |
| | | Total | | 719.0* |

## II. Summaries of High Energy Physics Research Use

| | # of Expts. | Hours | Results |
|---|---|---|---|
| A. Counter experiments | 11 | 2288.4 | 4 expts. completed |
| B. Bubble chamber experiments | - | - | - |
| C. Emulsion experiments | 1 | - | 1 stack in progress |
| D. Special target experiments | 1 | - | 1 target irradiation |
| E. Test experiments | - | - | - |
| F. Engineering studies and tests | - | - | - |
| G. Other beam use | - | - | - |
| | 13 | 2288.4 | |

## III. Number of Protons Accelerated and Delivered ($\times 10^{18}$ ppp)

| | | | | |
|---|---|---|---|---|
| A. Beam accelerated in Main Ring | | | | 1.28† |
| B. Beam delivered to experimental areas | | | | |
| Meson Area | | | 0.27 | |
| Neutrino Area | | | 0.82 | |
| | Slow Spill | 0.02 | | |
| | Fast Spill | 0.80 | | |
| Proton Area | | | 0.03 | |
| | | Total | | 1.12 |

*One hour lost in changeover to CDT

†Includes $0.02 \times 10^{18}$ accelerated to 450 GeV.

## BEAM UTILIZATION BY

| | Beam | Run Dates | Hours |
|---|---|---|---|
| MESON AREA | | | |
| Nuclear Chemistry #81A | M0 | 4/7 | - |
| Backward Scattering #290 | M6W | 4/1-4/19 | 250.2 |
| n-N Inelastic #438 | M3 | 4/1-4/18 | 248.5 |
| Multi-Muon #439 | M2 | 4/1-4/19 | 278.7 |
| Form Factor #456 | M1W | 4/1-4/13 | 169.5 |
| High Energy Channeling #507 | M1W | 4/14-4/19 | 111.6 |
| NEUTRINO AREA | | | |
| Neutrino #310 | N0 | 4/1-4/20 | 266.0 |
| Particle Search #379 | N5 | 4/1-4/20 | 266.5 |
| Emulsion/$\nu$ #536 | N0 | 4/1-4/20 | - |
| PROTON AREA | | | |
| p-p Elastic #177A | PW | 4/1-4/18 | 135.3 |
| Di-Lepton #288 | PC | 4/7-4/19 | 98.0 |
| Photoproduction #401 | P1 | 4/2-4/19 | 180.7 |
| INTERNAL TARGET | | | |
| p-N Scattering #198A | C0 | 4/1-4/19 | 283.4 |
| HOURS FOR EXPERIMENTS | | | 2288.4 |

EXPERIMENT -- APRIL 1977

Activities

data: 1 target exposed to 400-GeV protons

tests & data: 30 and 50 GeV/c $\pi^+ p \rightarrow p\pi^+$ with forward and backward magnetic spectrometers

data: complete; neutron inelastic cross sections on various complex nuclei

tests & data: high mass multi-muon states produced by 400-GeV protons on a magnetized iron beam dump

data: complete; form factor of the $K^-$ meson by $K^- e$ scattering at 250 GeV/c

tests & data: channeling of +35 GeV/c and +250 GeV/c hadrons by a cooled single crystal of Germanium

data: antineutrino events in an iron scintillator targets calorimeter with a downstream toroidal muon spectrometer

data: 400-GeV protons on a variable density target calorimeter with a downstream toroidal muon spectrometer

data: emulsion stack in an antineutrino beam produced by the sign selected bare target train

data: complete; p-p elastic scattering at 400 GeV, $-10 \leq t \leq 15$ $(GeV/c)^2$ with a two-arm spectrometer

setup & tests: high-mass dimuon states with a two-arm spectrometer and beryllium absorber

setup & tests: production of high mass states by a broad band photon beam

data: complete; p-p scattering up to 270 GeV and $|t| = 2 (GeV/c)^2$

At the right, construction of the concrete pad for the cooling-ring experiment (see NALREP, December 1976) is taking place. It will be covered by a prefabricated steel-frame building. Protons of energy 200 MeV will be brought from the linac through the proton-radiography port, visible at the lower left of the new ring.

At the left of the photograph beyond the West Gallery, we see the rearrangement of the booster shielding berm that is taking place as part of the construction of a backward injection line that will join the Main Ring at F17.

## MANUSCRIPTS AND NOTES PREPARED DURING APRIL AND MAY 1977

Copies of preprints with Fermilab publication numbers can be obtained from the Publications Office or Theoretical Physics Department, 3rd floor east, Central Laboratory. Copies of some articles listed are on the reference shelf in the Fermilab Library.

### Experimental Physics

| | |
|---|---|
| T. Devlin et al.<br>Experiment #8 | Inclusive Production of Neutral Strange Particles at 300 GeV: Triple Regge Behavior (Submitted to Nucl. Phys. B) |
| B. C. Barish et al.<br>Experiment #21A | Observation of Trimuon Production by Neutrinos (Submitted to Phys. Rev. Lett.) |
| C. Chang et al.<br>Experiment #26 | Dimuon and Trimuon Final States in Deep Inelastic Muon Scattering (Submitted to Phys. Rev. Lett.) |
| R. K. Adair et al.<br>Experiment #48 | A Determination of the Neutron-Proton Ratio in Primary Cosmic Rays |
| J. Roehrig et al.<br>Experiment #82 | Coherent Regeneration of $K_S$'s by Carbon as a Test of Regge Pole Exchange Theory |
| H. L. Anderson et al.<br>Experiment #98 | Measurement of the Proton Structure Function from Muon Scattering (Submitted to Phys. Rev. Lett.) |
| P. Stix et al.<br>Experiment #'s 138 and 252 | Transverse-Momentum Properties of Multi-Pion Systems Produced in High-Energy Collisions |
| S. Csorna et al.<br>Experiment #218 | Inclusive Neutral Particle Production in $\pi^-d$ Interactions at 205 GeV |
| C. Bromberg et al.<br>Experiment #260 | Observation of the Production of Jets of Particles at High Transverse Momentum and Comparison with Inclusive Single Particle Reactions |
| J. R. Biel<br>Experiment #305 | A Study of the Dissociation Reaction $n + p \rightarrow p\pi^- + p$ for Neutron Momenta Between 50 GeV/c and 300 GeV/c (Ph. D. Thesis, University of Rochester) |
| A. Benvenuti et al.<br>Experiment #310 | Observation of a New Process with Trimuon Production by High Energy Neutrinos |

| | |
|---|---|
| R. Raja<br>Experiment #311 | A General Theorem for Inclusive Reactions (FERMILAB-Pub-77/28-EXP; submitted to Phys. Rev. Lett.) |
| R. Raja<br>Experiment #311 | Experimental Evidence for the General Theorem in 100 GeV/c $\bar{p}p$ Interactions (FERMILAB-Pub-77/29-EXP; submitted to Phys. Rev. Lett.) |
| R. Raja et al.<br>Experiment #311 | Inclusive $\rho^0$ and $f^0$ Production in 100 GeV/c $\bar{p}p$ Interactions (FERMILAB-Pub-77/34-EXP; submitted to Phys. Rev. Lett.) |
| D. A. Garbutt et al.<br>Experiment #418 | Nuclear Size Dependence of Inclusive Particle Production (Submitted to Phys. Lett.) |

Theoretical Physics

| | |
|---|---|
| R. B. Pearson | Estimates of the Ground State Eigenvalue of the Two-Dimensional Spin 1/2 X-Y Model (FERMILAB-Pub-77/18-THY; submitted to Phys. Rev. B) |
| C. H. Albright and<br>R. E. Shrock | Antineutrino Anomalies and Right-Handed Currents (FERMILAB-Pub-77/19-THY; submitted to Phys. Rev.) |
| B. W. Lee and<br>R. E. Shrock | Natural Suppression of Symmetry Violation in Gauge Theories – Muon and Electron-Lepton Number Non-conservation (FERMILAB-Pub-77/21-THY; submitted to Phys. Rev. D) |
| B. W. Lee et al. | The Strength of Weak Interactions at Very High Energies and the Higgs Boson Mass (FERMILAB-Pub-77/22-THY; submitted to Phys. Rev. Lett.) |
| R. Savit | Topological Excitations in U(1) Invariant Theories (FERMILAB-Pub-77/23-THY; submitted to Phys. Rev. Lett.) |
| H. D. I. Abarbanel | Self-Consistent $\beta$-Functions in Asymptotically Free Massless Field Theory (FERMILAB-Pub-77/25-THY; submitted to Nucl. Phys.) |
| C. Quigg | Issues in Charmed Particle Spectroscopy (FERMILAB-Conf-77/27-THY; submitted to XIIth Recontre de Moriond, Flaine-Haute Savoie, France, March 6-18, 1977) |

| | |
|---|---|
| B. W. Lee and S. Weinberg | SU(3) × U(1) Gauge Theory of the Weak and Electromagnetic Interactions (FERMILAB-Pub-77/31-THY; submitted to Phys. Rev. Lett.) |
| K. O. Mikaelian | Gravitational Collapse and Angular Momentum Loss to Neutrinos (FERMILAB-Pub-77/32-THY; submitted to Phys. Rev. Lett.) |

General

| | |
|---|---|
| G. Hartmann et al. (Results from tests done in Proton Area last summer) | High Energy Cosmic Ray Electrons: A New Measurement Using Transition Radiation Detectors |
| J. Lach | Hadron Elastic Scattering - An Experimental Review (FERMILAB-Conf-77/38-EXP; invited talk presented at XIIth Recontre de Moriond, Flaine-Haute Savoie, France, March 6-18, 1977) |
| D. C. Carey and D. Drijard | Monte Carlo Phase Space with Limited Transverse Momentum (FERMILAB-Pub-77/43-EXP/THY; submitted to J. Comput. Phys.) |

Physics Notes

| | |
|---|---|
| N. A. Filatova et al. Experiment #456 | Selection Units in K-e Scattering Experiment at 250 GeV (FN-303) |
| S. C. Snowdon | Mechanical and Thermal Stresses in Superconducting Accelerator and Beam Line Magnets (FN-304) |
| A. G. Oganessian et al. | An Unconventional Transition Radiation Detector (FN-305) |

## DATES TO REMEMBER

| | |
|---|---|
| May 27, 1977 | Third Colliding Beam Experimental Workshop. This workshop will be held in Curia II at 1:30 p.m. Progress on beam storage, beam structure studies, interaction scheme design, and background studies will be described and discussed. |
| June 18-24, 1977 | Summer meeting of the Fermilab Program Advisory Committee. |

DR. DRAGKE JOVANOVIC
RESEARCH DIVISION
CL-2W
FERMILAB