WHAT HAPPENED AT FERMILAB DURING 1977?

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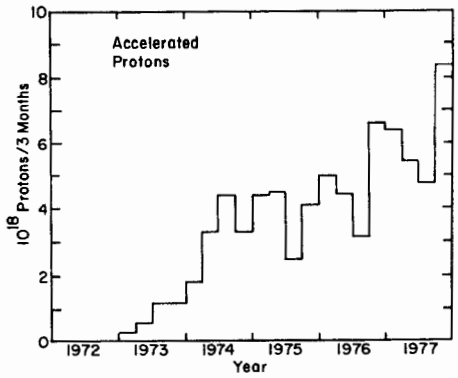
The most exciting development at Fermilab during 1977 was the discovery of the Υ-particle in a dimuon experiment running in the Proton-Center experimental area. Another highlight was the productivity of the 15-foot bubble chamber, in which were taken over 700,000 pictures of neutrino interactions. During the year it was possible to finish data-taking for the experiments that had been in residence since operation of the facilities began. With the removal of these experiments, new activities were initiated. Changes were particularly evident in the M1, M2, and M4 beams in the Meson Area and in Proton-East and Proton-West.

There were two major shutdowns during the calendar year, each about three to four weeks in duration. This pattern of shutdowns is expected to repeat in a similar fashion during 1978. The accelerator was run at 400 GeV, but there were two extended periods of operation at 300 GeV with a 200-GeV front porch. These were arranged at the request of experimenters interested in running with lower-energy proton beams. The beam spill usually included 1.25 sec of slow spill followed by 20 μsec or 2 msec of fast spill for neutrino experiments, depending on the type of focusing system in use. A 20-μsec spill is necessary for effective use of the present pulsed wide-band horn, whereas the longer fast spill is more satisfactory with non-pulsed focusing systems such as the quadrupole triplet or the sign-selected bare-target trains. At times when the neutrino program was not in

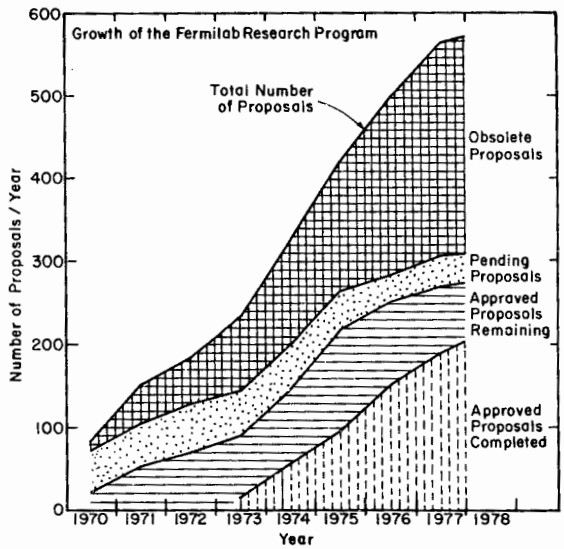
operation, 2 sec of slow spill was available. This chance occurrence provided a bonus to experiments using slow spill which were scheduled at that time.

Overall the accelerator ran well during the year, with a total of 4,800 hours available for high-energy physics research. During the 42-$\frac{1}{2}$ weeks of operation, this meant an average of about 110 hours of beam per week for experiments. Extremes in the quality of operation were noted in January, when the very cold temperatures noticeably affected many facilities adversely, in particular the feeder cables for the accelerator. The most successful month in Fermilab's history was realized in October, when there was a record number of protons accelerated and a record number of hours of beam for experiments. Recently there has been a significant improvement in the number of protons available for experiments, as can be seen in the graph on the right. During the last quarter of the year, the number was larger than in any previous period.



Number of protons accelerated in the Main Ring for each quarter-year since operations began in 1972. A total of 2.5×10^{19} protons were accelerated during 1977.

As shown in the graph on the next page, the rate of completion of experiments is comparable to that in recent years. Underlying this is the feature that the completions have included many significant experiments with large amounts of running time. The number of approved proposals remaining to be run has been reduced below that for previous years.

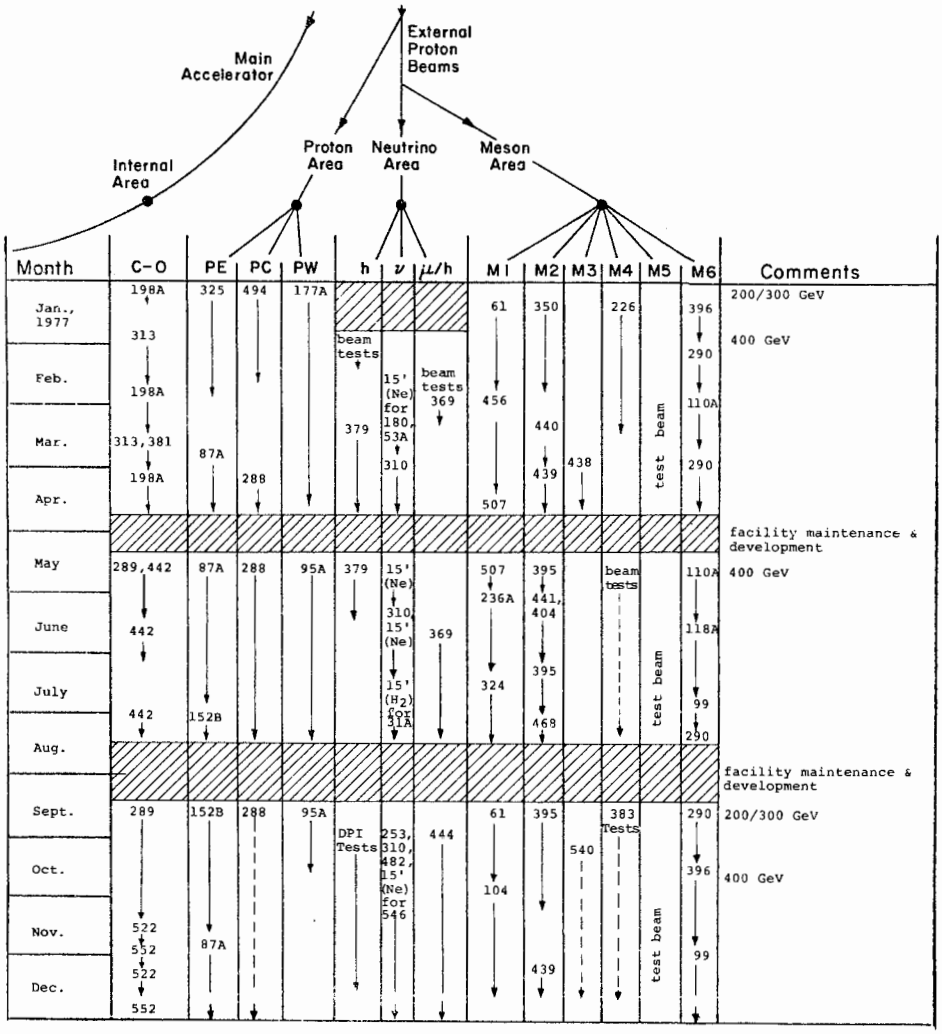


Graphical description of the growth of research at Fermilab. During 1977 a total of 53 proposals were received, 25 were approved, and 29 completed data-taking.

The history of experimental activities at Fermilab during 1977 is given in the figure on page 8. In the table on page 9 are included descriptions of the major activities underway during the year. By using the experiment numbers, it is possible to identify individual activities in the figure and table.

Proton Area

In Proton-Center the apparatus that had previously been used for di-electron and dihadron measurements was converted for study of dimuons. The tuneup of the experiment began in April and by July there was an announcement of the discovery of a new particle, the Υ, with mass 9.4 GeV. Later a second, neighboring particle, the Υ', with mass 10.0 GeV was


External Proton Beams
Main Accelerator
Internal Area
Proton Area
Neutrino Area
Meson Area
Month
C-O
PE
PC
PW
h
ν
μ/h
M1
M2
M3
M4
M5
M6
Comments
Jan., 1977
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
198A
313
198A
313,381
198A
289,442
442
442
289
522
552
522
552
325
87A
288
87A
152B
152B
494
288
288
177A
95A
95A
beam tests
379
379
DPI Tests
15' (Ne) for 180, 53A
310
15' (Ne)
310
15' (Ne)
15' (H2) for 31A
253, 310, 482, 15' (Ne) for 546
beam tests 369
369
444
61
456
507
507
236A
324
61
104
350
440
439
395
441, 404
395
468
395
439
226
beam tests
383 Tests
test beam
test beam
test beam
396
290
110A
290
110A
118A
99
290
290
396
99
200/300 GeV
400 GeV
facility maintenance & development
400 GeV
facility maintenance & development
200/300 GeV
400 GeV

DESCRIPTION OF MAJOR RESEARCH ACTIVITIES IN THE EXPERIMENTAL AREAS DURING 1977.

(The individual experiment numbers are shown in parentheses.)

Proton Area

Discovery of the Υ-states at 9.4 and at 10.0 GeV (288)

High mass hadron pair production from proton interactions (494)

Study of the dimuon continuum produced in proton-nucleon collisions at 200-400 GeV (288, 325)

Continued measurements of p-p elastic scattering with large-t at 200 and 400 GeV (177A)

Continued study of single and diphoton production in proton-nucleon collisions (95A)

Neutrino Area

Study of ν and $\bar{\nu}$ interactions in the 15-ft bubble chamber using a heavy neon/hydrogen mixture (53A, 546) and in electronic detectors (310, 482) with particular interest in multilepton production.

Study of $\bar{\nu}$ interactions in the 15-ft bubble chamber using a heavy neon/hydrogen mixture (180) and using hydrogen (31A)

Search for high-mass, short-lived states produced in 400-GeV proton interactions and decaying into one or more muons and neutrinos (379)

Study of pion dissociation at 215 GeV using a large aperture spectrometer (369)

Production of high-mass muon pairs by pion-nucleon interactions at 225 GeV (444)

Meson Area

Elastic scattering of protons at 300 GeV from a polarized proton target (61)

Continuing measurements to determine the charged kaon form factor (456)

Study of "jet" structure among hadrons produced at large-p_t in hadron collisions (236A, 395)

Measurements of inclusive production of single charged and neutral hadrons produced in hadron collisions (118A, 324, 350)

Continuation of measurements of hadron total cross sections from hydrogen, deuterium and nuclei at the highest available energies (104)

Dimuon production from proton collisions in a magnetized beam dump (439)

Studies of neutral hyperon production and decay: measurement of the Λ^0 magnetic moment (440), Λ^0 production and polarization from p-p interactions (441)

Measurements to yield the charge radius of the neutral kaon (226)

Studies of exclusive production of hadrons: π-p backward scattering (290), associated production (99), ρ^0-production by pions (110A)

Study of diffractive dissociation of charged hadrons from a gas target (396)

Continued study of neutron interactions to include measurements of inelastic cross sections on nuclei (438)

Internal Area

Continued study of p-p and p-d elastic scattering (198A and 552)

Continued measurement of the polarization of recoil protons from p-p elastic and inelastic scattering (313 and 522)

Study of nuclear fragments produced in proton collisions with a target of heavy gas (442)

Measurement of the real part of the p-n and p-p forward scattering amplitudes and study of isobar production (381)

Measurement of proton elastic scattering from gaseous He^4 (289)

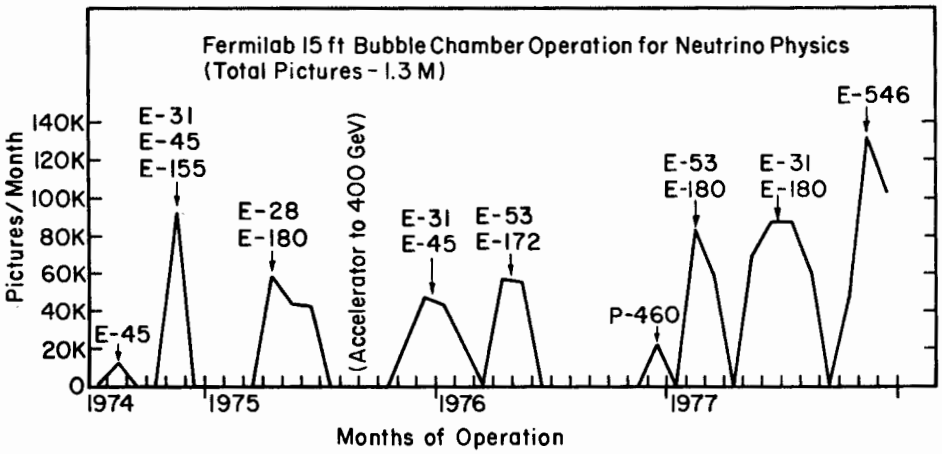
exposed and there was speculation that a third particle might be apparent in the data. During September and October measurements were made of the dimuon continuum produced in proton-nucleon collisions at 200 and 300 GeV using the same apparatus. Accompanying this were studies of production of the Υ at those energies.

During early 1977, measurements of the dimuon continuum were made in Proton-East using a precision spectrometer paired with a simpler spectrometer fashioned from counters installed in holes drilled in adjacent earth. The completion of this dimuon experiment meant the end of a series of experiments by the Chicago-Princeton group that had previously studied high-p_t production of hadrons by protons incident on hydrogen and nuclear targets. Later in the year, Proton-East was used for investigation of photon interactions.

The experimental program originally planned for the Proton-West area was completed during 1977. An experiment studying p-p elastic scattering at large angles was able to make use of 200-GeV beam when that energy was available during accelerator operation with a front porch. The purpose of this work was to study the energy dependence of the elastic-scattering process. The experiment then continued for about three months to collect data at their largest angle with lowest rates. Then later in the year there was a final running period for an experiment which had been studying di-photon production. Since October the Proton-West area has been used for testing or calibrating equipment to be used in other experiments while construction of a new pion beam has continued downstream.

Neutrino Area

As was pointed out previously, the 15-ft bubble chamber was operated very successfully in 1977. This is shown most dramatically in the graph below where there is indication of the historical development of the 15-ft neutrino experimental program. Whereas it was gratifying to see the much-improved performance of the 15-ft chamber, the 30-in. bubble chamber was not able to be run because of insufficient resources to operate both facilities simultaneously.



Graphical description of 15-ft bubble chamber operation for neutrino physics since startup in 1974. The numerals for experiments are given at the time they were run. A total of 717,000 pictures was taken during 1977.

The running during 1977 began with a heavy neon fill for two experiments using incident neutrino and antineutrino beams and the wide-band horn focusing system. During this period, there were two failures of the focusing system. But eventually that system also operated reliably, after it was realized that it was necessary to limit the amount of beam flux per

pulse incident on the horn target. During the summer about 150,000 pictures were taken with a beam consisting primarily of antineutrinos incident on the 15-ft chamber with a hydrogen fill. During this period, the bubble chamber operated almost flawlessly and a new standard of operation was realized--an average of 30,000 pictures per week for several weeks. Later in the fall, the 15-ft chamber was again filled with heavy neon and the External Muon Identifier behind it was supplemented by new chambers and was reconfigured into a double-plane system.

Throughout 1977, electronic detectors to study neutrino interactions were in use in two laboratories. During the fall, a total of over 800 tons of detector was simultaneously employed in the study of neutrino interactions.

While the neutrino experimental program was underway, there were experiments in progress simultaneously using hadron beams in the Muon Lab or in Lab E. A portion of a new neutrino detector in Lab E was used with a fine-grain calorimeter to study proton interactions with outgoing muons and hadrons, and with missing energy. This experiment was motivated by a search for charmed particles produced in hadron interactions. In the spring it benefited from several weeks of running with a long flattop when the neutrino focusing system and bubble chamber were undergoing repairs.

Later during the summer, the muon beam was used with hadrons. An experiment was set up to use the cyclotron spectrometer for studies of pion dissociation. The targeting for that beam was accomplished using a new target station located in the decay pipe for the neutrino beam. During the fall, the same spectrometer was used again but for study of dimuon production by positive and negative pions and by antiprotons. The main goals

of this experiment included a search for new particles decaying into two muons and test of a dimuon production model, which predicts that π^- produce them more readily than do π^+. The experiment relied on beam intensities provided by the quadrupole triplet train. Thus it was possible for a program of neutrino physics using that focusing system to be run in parallel with this experiment.

Meson Area

One of the main goals of 1977 was the completion of experiments in the M1, M2, and M4 beams that had been in residence since the Meson Area was first operated. Consequently, the inside of the Detector Building completely changed in appearance during the year. In the M1 beam, there were activities completed that enabled the removal of experimental apparatus used by five groups. Areas of physics explored in the process of completing these experiments included measurement of elastic scattering from a polarized-proton target, determination of the kaon form factor, study of hadron-jet phenomena, inclusive-scattering studies, and measurements of hadron total cross sections. The last experiment listed had waited for two years for needed improvement of the proton transport to the Meson Area to 400 GeV and for increase of the M1 beam energy. Thus measurements of charged-hadron total cross sections have now been made at the highest available Fermilab energies.

In the neighboring M2 beam, there was completion of running and removal of equipment belonging to two groups. The photon detector previously used for measurement of pion charge exchange ended its service in

M2 with a study of inclusive π^o and η^o production. Further, another hadron-jet experiment was installed, completed, and removed. The neutral-hyperon spectrometer there provided data for four separate experiments. It resides at the end of the M2 beam.

During the year, the shielding for the M2 beam was significantly increased; with this came the ability for an experiment located in a cave inside the Detector Building to use 10^{11} protons per pulse. This increase in intensity is a factor of 100 improvement over previous normal operating levels of the beam. The experiment studied dimuon production using an apparatus with large acceptance.

In M4, there was not only a change of experiments but a significant change in the beam. Early in the year the apparatus originally used for experiments to study K^o regeneration was still in use to study K_S^o-electron scattering or to measure the charge radius of the neutral kaon. The completion of this work then signified the end of an impressive series of neutral-beam experiments. During 1977, the beam was changed to a charged beam. The first experiment to use this new beam has been for study of inclusive production of K_S^o from K^--p interactions. Data-taking for the experiment was commencing as the year ended.

In the M6 charged beam, the Laboratory and the experimenters have been burdened with a large backlog of commitments, which at present seem to extend to the middle of 1978. The apparatus in use there includes the Single Arm Spectrometer and Multiparticle Spectrometer facilities, as well as one experimental setup for study of pion backward scattering and another

for measurements of hadron dissociation. It is hoped that during the first half of 1978 the major commitments to experiments in that beam line will be able to be fulfilled.

Internal Area

The primary research interests in the Internal Target Area have been centered around use of the superconducting spectrometer and associated warm gas-jet target. The operation of the spectrometer has depended on use of two liquefiers that regularly supply liquid helium for the superconducting magnets. A total of four experiments involving two groups have used the apparatus for studies of proton elastic and inelastic scattering. Residing at times in the vacuum chamber for the spectrometer were detectors used to identify nuclear fragments produced in collisions of protons with heavy gasses. This experiment used the spectrometer whenever liquid helium was unavailable.

Other activities in the Internal Area have included completion of two additional experiments involving the US-USSR collaboration, which has been active since the first beam was available in the Main Ring in 1972. The last experiment of this series included study of proton-helium scattering using a gaseous helium target.

A Final Reflection

In answer to the frequent question about what has happened recently at Fermilab, there is often initial silence. With that silence come memories of experiences with the experimental program and anticipation of results to come from analysis of data. Verbal description or pages of prose will never appropriately match the significance of what happened.