THE NEUTRINO AREA IN 1977 AND 1978

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The last Fermilab Report article on the Neutrino Area, written by Richard Lundy, appeared in January 1977. The purpose of this article is to chronicle what has happened since that date, during 1977 and most of 1978, which corresponds roughly to my tenure as head of the Neutrino Department. The work reported here was done in large part by a very dedicated group of people who have worked very hard to plan, field, and carry out a very large number of significant experiments in both weak and strong interactions. This group of people includes both my colleagues on the staff of the Neutrino Department and the large group of users who utilize the facilities of the department. Without both groups, the research discussed here would not have been possible.

These two years have been ones of solid accomplishments utilizing the increased intensities that have become available from the accelerator. In the 20-month period from January 1977 through August 1978, the Neutrino Department targeted 2.30×10^{19} protons for an average of 1.15×10^{18} protons protons/month. When this monthly number of protons is divided into protons per pulse using a standard 100-hour operating week and a 10-second repetition rate, the average intensity per pulse is 8×10^{12} protons. With these protons we took 825,000 pictures in the 15-ft bubble chamber for neutrino physics, completed two major neutrino counter experiments and started two more, completed three hadron experiments, and completed two major muon experiments. Each of these will be discussed separately below.

15-Ft Bubble Chamber

After several years of shifting operation in the bubble chamber area between the 15-ft chamber for neutrino physics and the 30-in. chamber for hadron physics, a decision was made to operate only the 15-ft chamber and to complete as many neutrino experiments as possible. Experiment #53, a Columbia-BNL collaboration took 103 K pictures in the 64% Ne mixture with the 2-horn neutrino beam. Experiment #180, a Fermilab-ITEP-IHEP-Michigan collaboration, took 186 K pictures in the 64% Ne mixture with both the 2-horn antineutrino beam and the sign-selected bare-target beam. Experiment #31, an Argonne-Carnegie Mellon-Purdue collaboration, took 147 K pictures in H_2 using the 2-horn antineutrino beam with the plug. This experiment marked the first successful use of the plug, which is used as a dump for the wrong-sign mesons and the proton beam to produce an antineutrino beam with smaller neutrino contamination. Experiment #546, a Fermilab-Berkeley-Hawaii-LBL-Washington-Wisconsin collaboration, took 375 K pictures in a 47% Ne mixture using the triplet neutrino beam. This experiment marked the first use of the two-plane external muon identifier (EMI) necessary to aid in their search for dimuon events. A prototype internal picket fence (IPF) was also installed to test the design and usefulness of this device, whose purpose to aid in reducing background in the EMI signals by tagging the time of the event inside the fiducial volume of the chamber. It also allows a time correlation to be made with the EMI, as well as the usual spatial correlation. In May 1978 an engineering test was made of an internal plate system to assess its usefulness in detecting

neutral pions produced in neutrino interactions. Although the mechanical design was acceptable and the concept of plates being easily introduced and removed was successful, turbulence near the top of the chamber did not allow the production of pictures of acceptable quality for physics use. This design is currently being reassessed for changes that will reduce this problem. After the plate tests, the 15-ft chamber returned to production runs for physics and took 97K pictures for E380, a Columbia-BNL collaboration, in the 64% Ne mixture using the new dichromatic neutrino beam built for E356, a neutrino counter experiment.

During this period, the 15-ft bubble chamber can truly be said to have come into full operation. In July 1977, a milestone of 1,000,000 total pictures since initial operation in July 1974 was reached. At this time, the count stands at 1.532×10^6. The record for one month was 131K pictures taken in November 1977 during E546.

Neutrino Counter Experiments

The main efforts in the neutrino counter experiments have centered around multimuon studies and in the preparation of the next generation of a total cross section experiment with a new target and dichromatic beam.

The champion proton user was E310, a Fermilab-Harvard-Pennsylvania-Rutgers-Wisconsin collaboration, with their new NEULAND detector in Lab C. They used 7.2×10^{18} protons with the triplet neutrino beam, the sign-selected bare target antineutrino beam, and the sign-selected bare target beam. The sign-selected bare target beam is a new beam built for this experiment. It is used primarily to produce a beam of antineutrinos

with very little neutrino contamination. The NEULAND detector in Lab C was set up with targets of three different densities and used primarily for multimuon studies.

At the same time, E310 and E546 were using the triplet beam; E482, a Cal Tech-Fermilab-Northwestern-Rochester-Rockefeller collaboration, was set up in Lab E, studying multimuon production by neutrinos in their apparatus, which had targets of two different densities.

During a short period of time in the fall of 1977, when the accelerator was running at 300 GeV/c, E253, a VPI-Oxford-Maryland-NSF collaboration, took some preliminary data on neutrino-electron scattering. When the accelerator returned to 400 GeV/c operation, they were precluded from further operation by the muon background encountered. This problem will, it is hoped, be corrected by the installation of a magnetized toroidal muon spoiler in Enclosure 100. This spoiler will be tested and the main running of this experiment will begin in October, 1978.

The summer of 1978 was used to bring into operation the new 350-GeV/c dichromatic neutrino beam and the new 1100-ton neutrino target in Lab E. Experiment #356, a Cal Tech-Fermilab-Rochester-Rockefeller collaboration, successfully operated the new dichromatic beam at 200 GeV/c and 300 GeV/c for neutrinos and conducted tests at 200 GeV/c and 250 GeV/c for antineutrinos. In addition to the beam itself, a new beam-monitoring system was installed in the decay pipe. This system gives readouts of secondary beam intensity and profiles on a pulse-by-pulse basis and allows secondary-particle ratios to be determined while operating the dichromatic

beam for neutrino physics. In Lab E itself, the full 1100-ton neutrino target was brought into operation. It consists of 650 tons of steel-scintillator spark-chamber target followed by 450 tons of magnetized-steel toroids also instrumented with scintillation counters and spark chambers to operate as a neutrino target. In total, 2.5×10^{18} protons were targeted in this shakedown period. The main running for E356 will begin in the spring of 1979.

Muon Experiments

During this period, two major muon experiments have been completed, E203 and E448. During the spring of 1978, E203, a Berkeley-Fermilab-LBL-Princeton collaboration, ran with the new distributed-target muon spectrometer for 4.4×10^{18} protons (with the triplet target train serving as the muon beam front end) carrying out a search for rare muon-induced processes. At the same time, E448, a Harvard-Fermilab-Chicago-MIT-Michigan State-Tufts collaboration, ran in the Chicago cyclotron spectrometer with a muon shadowing experiment using nuclear targets.

Hadron Experiments

In addition to the previously discussed neutrino and muon experiments the Neutrino Department has also operated a highly successful hadron-physics counter-experiment program. E379, a Stanford-Cal Tech-Rochester collaboration, ran in Lab E using a beam of 10^6, 400 GeV/c protons from the N7-N5 beam line for 1250 hours. They performed a beam-dump particle search for 1 and 2 muon final states. This group will return as E595 and continue their work with protons and extend it to pions during 1979. As part

of the E379 apparatus, the toroidal spectrometer designed for E356 was used for muon momentum analysis.

Two hadron experiments were run in the Chicago cyclotron spectrometer. E369, a Fermilab-Illinois-Harvard-Max Planck-Tufts collaboration, performed a search for charmed particles. They ran for 1000 hours with a beam of 10^6, 225 GeV/c π^- produced from a new target located 200 ft from the end of the neutrino decay pipe.

Experiment #444, a Princeton-Chicago collaboration, ran for 1100 hours in the Chicago cyclotron spectrometer using a beam of 10^7, 225 GeV/c π^+ and π^- using the triplet train as a front end and the muon beam with absorber removed for beam transport. This experiment performed a measurement of high-mass muon pairs.

Operations in the Immediate Future

At present, the Neutrino Department is preparing for an operating period that will feature a new horn beam with a 2-msec spill and the 15-ft bubble chamber filled with deuterium. The horn beam has been improved with a new horn featuring a wider neck to improve reliability and a transformer to stretch the horn current pulse. Many previous horn failures have been traced to high stresses in the narrow neck and the beam-induced failures caused by missteered proton beams. The new design corrects both problems. The transformer will make possible better operation of the EMI/IPF on the 15-ft bubble chamber and simultaneous operation of a large number of neutrino counter experiments along the neutrino beam line.

Finally the 15-ft bubble chamber will operate with a deuterium fill. The procurement of this fill has taken several years because of the large quantity of liquid deuterium involved and consists of the national supply of liquid deuterium for bubble-chamber usage. At the same time E545, a SUNY, Stony Brook-Tufts-Maryland-IIT-Tohoku collaboration, is running in the 15-ft bubble chamber. E253, previously mentioned, will run in the Wonder Building; E531, an Ohio State-McGill-Toronto-Ottawa-Japanese and Korean collaboration, will perform a study of weak decay lifetimes of neutrino-induced particles in a tagged-emulsion spectrometer in the Wonder Building; E553, a Cornell-Pittsburgh-Fermilab-Houston-Sydney-York-Lund collaboration, will search for short-lived particles produced by neutrinos using a hybrid emulsion-visual detector in Lab C; and E564, a Fermilab-ITEP-IHEP-Cracow-JINR-Kansas-Washington collaboration, will perform an experiment on the direct detection of short-lived particles from neutrino interactions in nuclear emulsions inside the 15-ft bubble chamber. This lineup of five simultaneously operating neutrino experiments will set a new record. E390, an Argonne-Carnegie Mellon-Purdue collaboration, will run later in the 15-ft bubble chamber with deuterium fill with the horn set for antineutrino operation. E594, a Fermilab-MIT-Michigan State-Northern Illinois collaboration, will begin setup in Lab C.

Plans for 1000-GeV Improvements

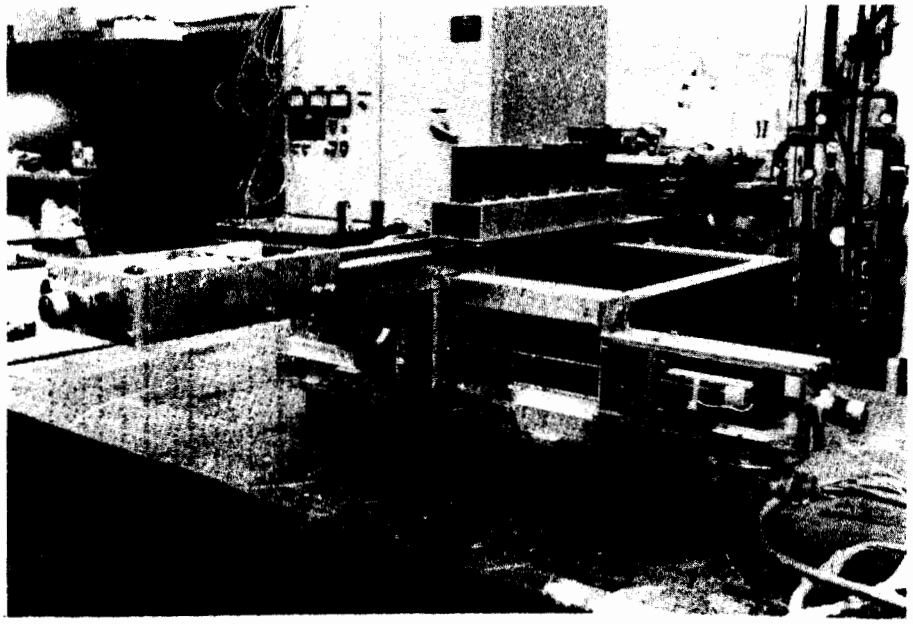
The 1976 Aspen Summer Study did a very good job in layout of the necessary changes in the Neutrino Area for 1000-GeV/c operation. Most of the departmental work since then has concentrated on detailed design of the various changes. T. B. W. Kirk has completed a tentative design for a new

800-GeV/c muon beam to be built between the present Neutrino and Proton Areas--finally a Muon Area after all these years of sharing the Neutrino Area. S. Mori has calculated several possible shielding upgrades, featuring an iron core for the main neutrino shield. L. Stutte has begun detailed design of a 750-GeV/c dichromatic beam. Design work has started on a lengthened target area for the dichromatic beam.

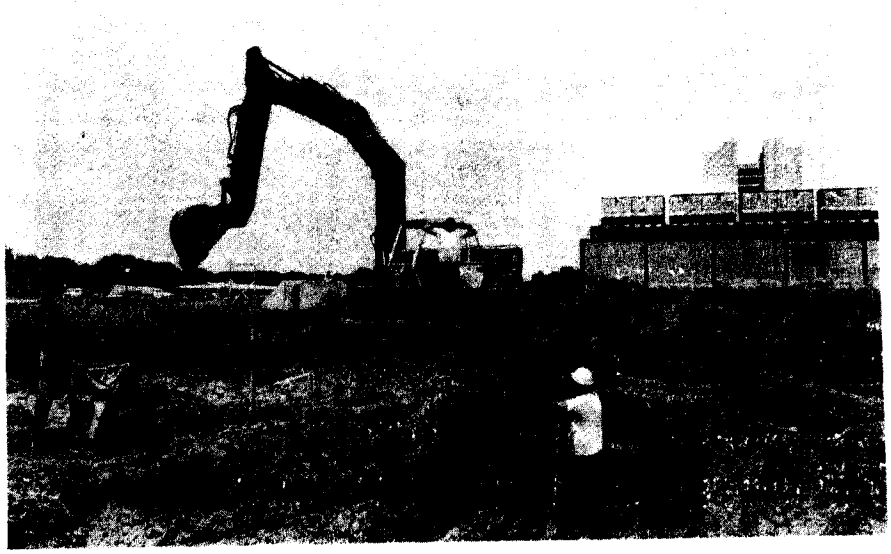
Conclusion

As can be seen from the above recitation of accomplishments, the Fermilab Neutrino Department has a solid record for the years 1977 and 1978 and need not bow to anyone for the amount of physics it has produced. The future looks bright. One major next-generation neutrino experiment has been successfully brought into operation. Another one is in preparation. The 1000-GeV upgrade will expand our facilities and give us beams that cannot be equalled anywhere.

As a retiring department head I would like to take this opportunity to thank everyone who has made this possible. I have thoroughly enjoyed my association with the Neutrino Department staff, of which I remain a member, and with the many fine and dedicated users whom it has been my pleasure to serve over the last two years.



A target positioner for pion beams in the new High-Intensity Laboratory.
(Photograph by Fermilab Photo Unit)



Construction work for the reverse-injection line into the Main Ring.
(Photograph by Fermilab Photo Unit)