THE LAB E SPECTROMETER AND NEUTRINO EXPERIMENTS†

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When beam began arriving in the Neutrino Area on January 23, the denizens of Lab E trembled in ready anticipation. For the past two years, they have been upgrading their neutrino detector for use with the Tevatron beam in the Quadrupole Triplet Beam Experiment (E-744) and the Dichromatic Beam Experiment (E-652). The present E-744 run could increase by more than an order-of-magnitude the present world's supply of analyzed high-energy (i.e., E > 100 GeV) neutrino and antineutrino events, if the requested 10^{18} protons can be delivered. Besides providing definitive measurements of high Q^2 structure functions, these data should provide a unique sample for searches for anomalous events, like the much-heralded and completely baffling same-sign dimuons suggested from earlier experiments.

The major modifications to the detector are required primarily because of the high instantaneous event rate produced by the Tevatron beam. The improvements include 78 new drift chambers (most are 3 m × 3 m in area) and multihit TDC readout with 10 μs deadtime between events. All of the collaborating institutions (Columbia/Chicago/Fermilab/Rochester) contributed to design and construction. Drift chamber components were produced at Fermilab, Chicago's Fermi Institute, and Columbia's Nevis Labs. Final assembly of the chambers was carried out at Fermilab by a team of technicians from Fermilab, Chicago, and Columbia. The TDC modules were produced at Nevis Labs. This seemingly complicated amalgam of the efforts of many laboratories worked smoothly and efficiently over about a year to produce the system on time and on cost.

A shakedown of the first few components occurred near the end of the 1984 running period. This gave confidence to the basic designs and showed that the goal of 500 μ spatial resolution was surpassed. One by-product of the upgrade is a substantial increase in information content near the interaction vertex as compared with data taken with the spark chambers used previously.

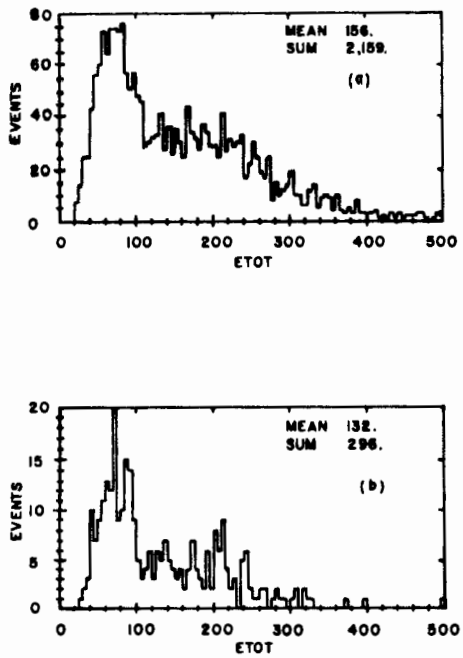
Another modification, under the primary responsibility of the Rochester group, was a new double-veto wall to remove triggers from muons coming through the shield, as well as muons from upstream neutrino interactions. This group also oversaw the installation of a large-area hodoscope to produce the timing information necessary for precision track resolution.

Various other contributions to the upgrade included extension of the target to permit additional chambers to be installed; new chambers installed in the downstream Lab E extension; check-out and calibration of new buffered LeCroy ADC units, replacement

and addition of several 3 m × 3 m target scintillation counters, upgrade of the counter-flasher system, development of new PDP-11 acquisition software, and development of new online monitor software made possible by the Laboratory-supplied VAX 11/780.

By the end of January, the new equipment was 95% installed and intermittent operation of the detector had been carried out using cosmic ray triggers. The experimenters began to see the happy consequences of their preparations with high-energy muons and actual neutrino events when beam arrived on January 23. Amidst the revelry, the E-744 spokesman, Frank Merritt, was heard to proclaim, "It's been a long time coming!"

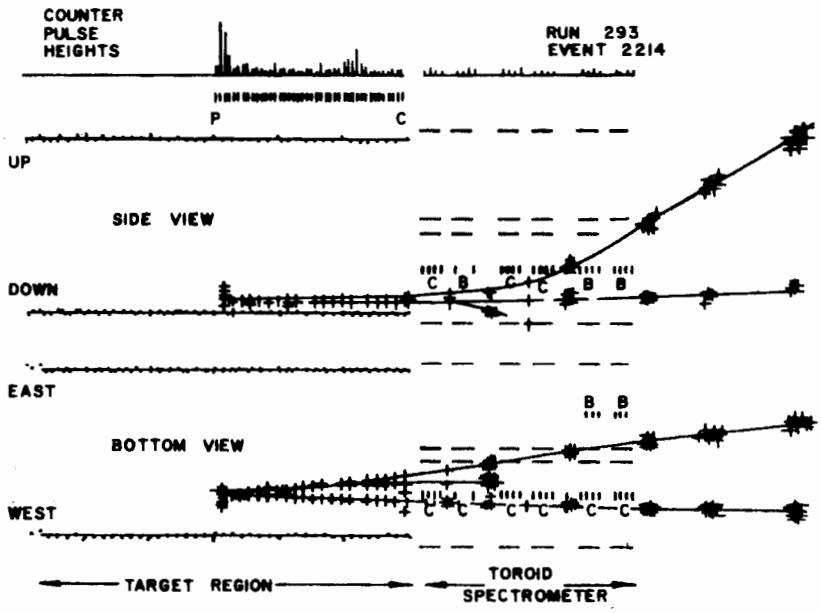
Within approximately one week, data were being taken. These data, treated online, provided important feedback to the Laboratory regarding beam composition, beam steering, etc. The figure below shows the energy distributions for neutrino and antineutrino interactions in the Lab E target as obtained online from



The number of events obtained in a single run versus the total observed energy (ETOT) in GeV for (a) neutrino events and (b) antineutrino events. This is a relatively "hard" spectrum with mean energies of 156 GeV and 132 GeV, respectively, due to the high primary energy of the Tevatron (800 GeV) and the Quadrupole focusing system.

data accumulated over a period of several hours. The spectral shapes, as well as the ratio of antineutrino-to-neutrino events, is qualitatively consistent with expectations. The transverse position profiles of interaction verticies showed that the beam centroid was offset by about 25 cm at Lab E; the Research Division has recently taken steps to rectify this.

Efforts at catching exotic-appearing events online are being made. The following figure shows a trimuon event selected with online software. The figure shows a neutrino interaction vertex about halfway through the detector, with large pulse heights in counters immediately downstream. Following the shower is a sequence of pulse heights at about three times the minimum ionizing level, and three tracks resolved in the target and separated in the magnetized toroid. Two of the muons traverse the entire toroid system while the third exits approximately halfway through the toroid. The two focusing tracks are μ^- and the defocusing track is a μ^+.



A schematic of the Lab E apparatus showing the upstream target region and the downstream toroid spectrometer. The pulse heights observed from scintillation counters imbedded in the steel target are shown at the top of the figure. The drift chamber hits are shown as crosses.

Considerable group effort is being transferred to the off-line analysis system. It is anticipated that major data crunching may begin before the run ends.

To be successful, this run requires an integrated proton flux on target of 10^{18} protons, or about 10^{13} protons per machine cycle. With the 10^{18} protons anticipated in this run, nearly two million high-energy neutrino events would be collected. Several obstacles have appeared which endanger this goal: the ability to extract high intensities in the fast resonant extraction mode, and the total beam available in the machine.

The first problem was formidable, since losses would quench Tevatron magnets when the extracted beam intensity rose above 2×10^{12} protons in a single one-millisecond burst. The Accelerator Division solved this difficulty in short order by extracting four such pulses during the 20 second flat-top without mishap. Additional pulses may feasibly be added if a solution to the quench problem is not found.

At present, the total machine intensity seems to be the limiting factor; typically, slightly less than 10^{13} protons are being accelerated in the Main Ring. This number is substantially less than that routinely achieved in the pre-Tevatron days. With the needs of the slow-spill experiments taken into account, it will be necessary to raise the machine intensity by about a factor of two in order to deliver the requisite protons to the Neutrino Area. Optimism is high that the Accelerator Division will be able to overcome this hurdle.

The physicists in Lab E are genuinely pleased at the progress made thus far. The experiment is taking high-quality data without serious difficulty. They look forward to amassing the large quantity of interactions required for an important step toward an understanding of neutrino interactions.

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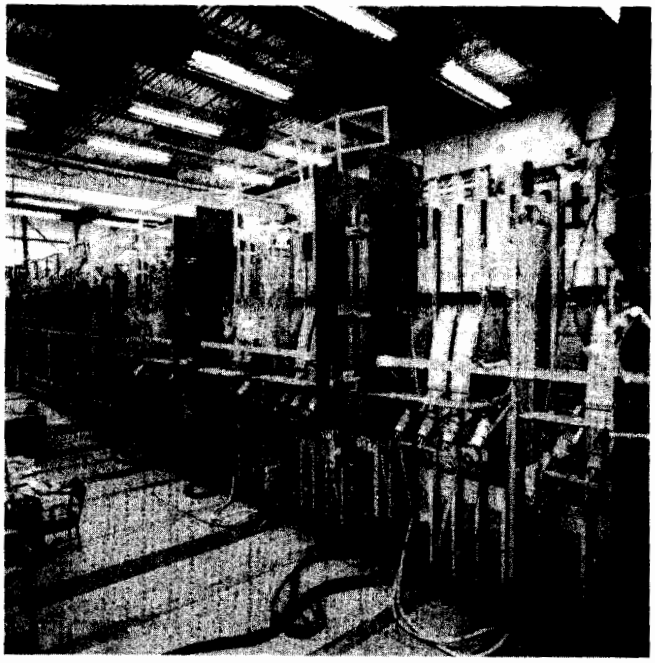

Neutrino detection apparatus viewed from the rear of Lab E.
(Fermilab photograph 79-319-4)