Fermilab's Fixed-Target Run a Success

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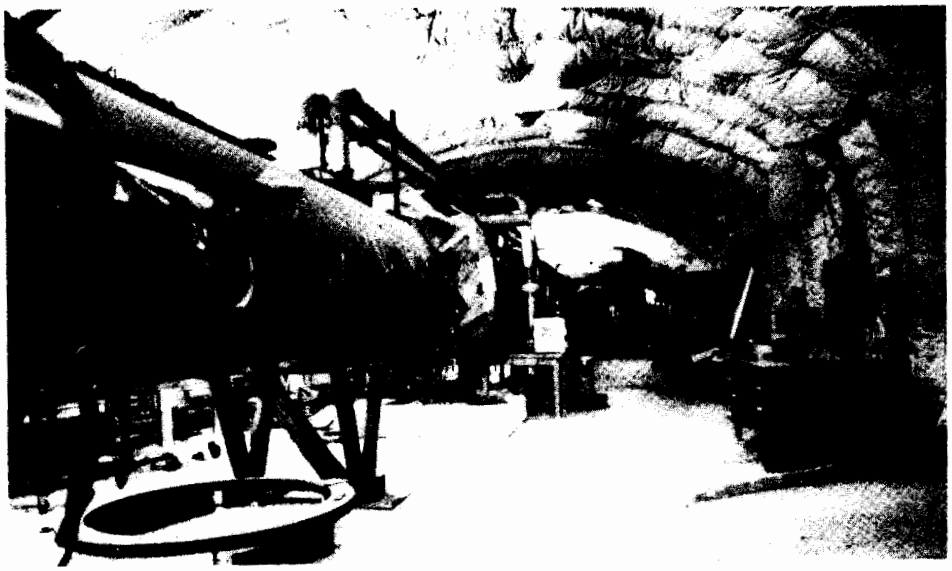
Eight months, 3000 high-energy physics (HEP) hours, and 35,000 data tapes later, Fermilab's most successful fixed-target physics run came to an end in mid-February 1988 with the highest superconducting accelerator intensity recorded at 1.8×10^{13} protons per pulse and the total number of protons accelerated recorded as 2.192×10^{18}. This was the first 800-GeV fixed-target physics run in which the entire complement of experiments and beams that were built as part of the TeV II Upgrade project were operated. In total, 10 experiments were completed, with a total of 15 beamlines serving 16 experiments and a variety of test- and calibration-beam users. This report focuses on the highlights of the run. Reports on each individual experiment will appear in future issues of *Fermilab Report* as the data analysis proceeds.

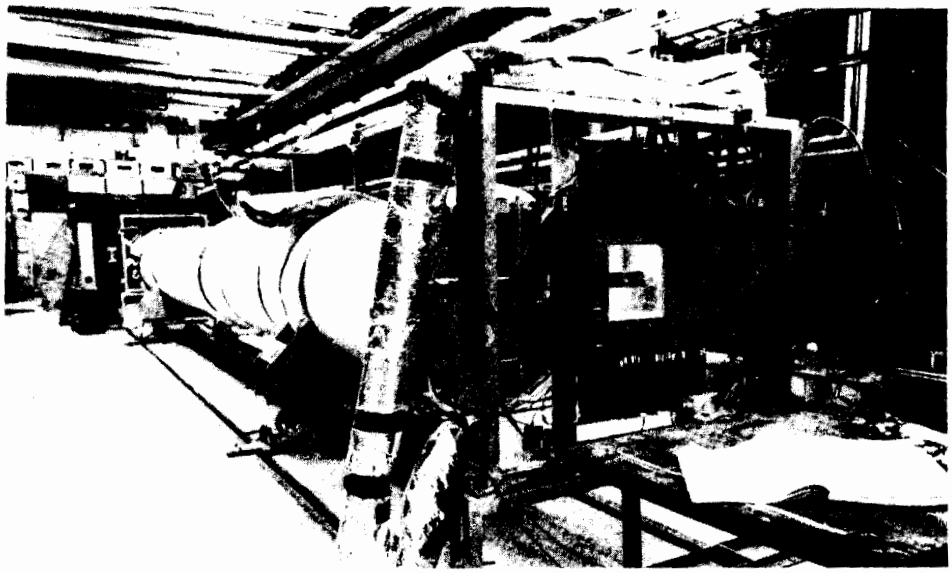
Particle Decays and CP Violation



(Fermilab photograph 88-773-7)

The decay region of Experiment 731's apparatus.

Under the category of particle decays and CP violation, Experiment 731 completed taking data with the goal of measuring the ratio of the CP non-conservation parameters ε'/ε in the neutral kaon system to a precision of ±0.001. They collected 250,000 $K_L \rightarrow \pi^0 \pi^0$ events, 370,000 $K_L \rightarrow \pi^+ \pi^-$ events, with a factor of three more events of the $K_S \rightarrow \pi^0 \pi^0$ and $K_S \rightarrow \pi^+ \pi^-$ variety recorded. The experiment is a collaboration of the University of Chicago; Elmhurst College; Fermilab; Princeton University; and CEN-Saclay (France).



(Fermilab photograph 87-288-11)

The apparatus of E-756 located in the P-Center beamline.

Also in this category was Experiment 756, whose goal is to study the polarization and magnetic moment of the Ω^- hyperon. The experiment accumulated about 82,000 Ω^- events during this run. A polarization signal was observed after a dramatic mid-course change in targeting arrangement. The experiment is a collaboration of Fermilab; the University of Michigan; the University of Minnesota; Rutgers University; and the University of Washington.

Electroweak Interactions

In the electroweak interactions category, Experiment 770 did high-statistics measurements of nucleon structure functions at higher neutrino energies than previously possible, and high-statistics measurements of charm production and the strange quark sea in opposite-sign dimuons. The experiment took 5.3 x 10^{17} protons onto the primary production target, accumulating about 120 same-sign

dimuons, 1.6 million neutrino events, and 0.35 million antineutrino events. The experiment is a collaboration of the University of Chicago; Columbia University; Fermilab; and the University of Rochester.

Another experiment in the electroweak interaction category was E-632, which exposed the 15-ft Bubble Chamber to the wideband neutrino beam. This was the final run of the 15-ft Bubble Chamber. The chamber was filled with a neon-hydrogen mixture and was designed to search for new particles and also study like-sign dileptons in both $\mu\mu$ and μe^+ modes. The experiment took 48,000 neutrino events in fiducial volume and 46,000 neutrino events with holograms. E-632 is a collaboration of the University of California, Berkeley; the University of Birmingham (Great Britain); the Universite Libre de Brussels (Belgium); CERN; Fermilab; the University of Hawaii; Illinois Institute of Technology; Jammu University (India); Max-Planck Institute (Germany); Punjab University (India); Rutgers University; CEN-Saclay (France); Stevens Institute of Technology; and Tufts University.

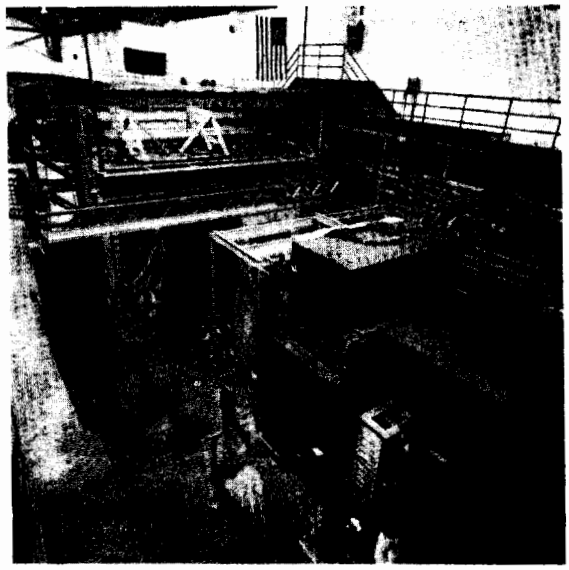
Experiment 733, also in the neutrino beam, completed a study of weak neutral currents and comparing neutral current models with measurements of the Weinberg Angle. They also looked at the production of same-sign dimuon events, primarily the missing transverse energy and possible correlations of that energy with the muon and hadron showers. E-733 also performed a time-of-flight search for weakly interacting massive particles (WIMP). They accumulated 90,000 neutrino events in a 100-metric-ton fiducial volume. Experiment 733 is a collaboration of Fermilab; the University of Florida; Massachusetts Institute of Technology; and Michigan State University.

Also in this category was Experiment 665, in the muon beam, which began a run that will be completed during the next fixed-target running period. Using positive muons, the experiment used three types of target with both 500- and 100-GeV beams and accumulated between 0.5 and 2.5 x 10^{11} muons per target. E-665 is a collaboration of Argonne National Laboratory; the University of California, San Diego; Fermilab; the University of Freiberg (West Germany); Harvard University; the University of Illinois at Chicago; the Institute of Nuclear Physics (Poland); the University of Maryland; Massachusetts Institute of Technology; Max-Planck Institute (Germany); the University of Washington; the University of Wuppertal (Germany); and Yale University.

Experiment E-745, based upon the Tohoku Bubble Chamber, completed a run in which they studied neutrino interactions, charm and heavy quark flavors, and looked for new phenomena such as same-sign dileptons. They accumulated 13,000 neutrino events, with 3000 holograms. E-745 is a collaboration of Brown University; Fermilab; IHEP, Beijing (PRC); Indiana University; Mas-

sachusetts Institute of Technology; Nagoya University (Japan); Oak Ridge National Laboratory; Technion-Israel Institute of Technology, Haifa (Israel); the University of Tel Aviv (Israel); the University of Tennessee; Tohoku Gakuin University (Japan); and Tohoku University (Japan).

Production of Heavy Quarks



(Fermilab photograph 86-782-8)

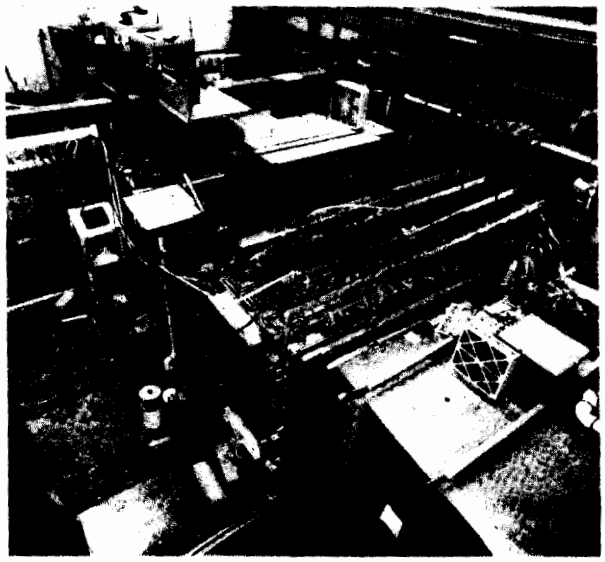
A view of E-687's apparatus.

In the "Production of Heavy Quarks" category, Experiment 687 explored the photoproduction of charm and beauty, especially photo-excited states containing charmed quarks, charmed D mesons and Λ_c baryons, J/ψ and ψ' production, and heavier states containing bottom quarks. The experiment was heavily damaged by a fire which destroyed an electromagnetic calorimeter and other components, but was revitalized with a tremendous effort on the part of the Laboratory and experimenters, and thereby managed to accumulate about 70 million triggers, with 80% of the triggers requiring hadronic energy in the calorimeter. E-687 is a collaboration of the University of Colorado; Fermilab; the University of Illinois; INFN Frascati (Italy); INFN and the Universities of Milano, Bologna, and Pavia (Italy); Northwestern University; and the University of Notre Dame.

E-653 completed a run studying charm and beauty using hadronic production in a hybrid emulsion spectrometer. The goal of the experiment was to search for new charm and beauty ground and excited states (especially baryons), and rare charm decays using 600-GeV pions in emulsion. They accumulated 9.6

million events. E-653 is a collaboration of Aichi University of Education, Kariya (Japan); the University of California, Davis; Carnegie-Mellon University; Chonan National University, Kwangju (Korea); Fermilab; the University of Gifu (Japan); Gyeongsang National University, Chinju (Korea); Jeonbug National University, Jeonju (Korea); Kobe University (Japan); Korea University, Seoul (Korea); Nagoya Institute of Technology (Japan); Nagoya University (Japan); Ohio State University; Okayama University (Japan); the University of Oklahoma; Osaka City University (Japan); Osaka Prefecture, Science Education Institute (Japan); Sookmyong Woman's University, Seoul (Korea); Toho University (Japan); Utsunomiya University (Japan); Won Kwang University, Iri (Korea); and Yokahama National University (Japan).

Another heavy quark experiment was E-769, in the Tagged Photon Lab, which looked at the properties of hadronic charm production, measuring the Feynman x, pt and A dependences of this process with 250-GeV pion, kaon, and proton beams at the same time and in a single apparatus. The experiment accumulated over 500 million triggers with their hadronic transverse energy trigger. E-769 is a collaboration of Centro Brasileiro de Pesquisas Fisicas, Rio de Janeiro (Brazil); Fermilab; Northeastern University; the University of Toronto (Canada); Tufts University; the University of Wisconsin-Madison; and Yale University.



(Fermilab photograph 86-772-5)

The detector for E-769 located in the Tagged Photon Facility.

Experiment 705 completed a study of charmonium and direct photon production with 300-GeV antiproton, proton, and π^{+-} beams. The goals of this experiment include the separation of closely spaced charmonium states with the high-resolution measurements of photons given off in the decay $\chi \rightarrow \gamma\, \psi_{\mu^+\mu^-}$ along with a comparison of the production of direct photons and charmonium states using different beam types, allowing the separation of qq and $\bar{q}$q components of the production process. The experiment accumulated about 100,000 J/ψ events and about the same number of π^{+-} events. E-705 is a collaboration of the University of Arizona; the University of Athens (Greece); Duke University; Fermilab; McGill University; Montreal (Canada); Northwestern University; and Shandong University (PRC).

Hard Collisions and QCD Tests

Although E-706 and E-672 are housed in the same experimental hall and ran simultaneously, they are pursuing somewhat different physics goals. Experiment 706 began a comprehensive study of direct photon production in hadron induced collisions, focusing on the study of the gluon structure functions of hadrons and gluon fragmentation. E-706 analyzed the production of direct photons and their accompanying hadrons in collisions of pions, kaons, and protons with a variety of targets. The experiment accumulated 1.8 million triggers with the positive beam and 2.0 million triggers with the negative beam. The experiment is not complete and will run again during the next fixed-target run. E-706 is a collaboration of Delhi University (India); Fermilab; Michigan State University; the University of Minnesota; Northeastern University; Pennsylvania State University; the University of Pittsburgh; Rajasthan University (India); and the University of Rochester. E-672 is making a study of hadronic final states in association with high P_t jets and high-mass dimuons, namely the production of particles produced in association with the ψ and high-mass dimuons. They accumulated about 6000 J/ψ events with the full E-706 spectrometer and about 2000 J/ψ events with the muon toroid spectrometer only. The experiment is not complete and will run during the next running period. E-672 is a collaboration of the University of Arizona; the California Institute of Technology; Fermilab; Florida State University; George Mason University; the University of Illinois at Chicago; Indiana University; the Institute of High-Energy Physics, Serpukhov (U.S.S.R.); the University of Maryland; the University of Michigan; and Rutgers University.

Experiment 704's initial goals, using polarized protons and antiprotons, are to study the spin dependence of the interactions $\bar{p}$p and pp in a global way. This is a straightforward experiment which will measure the difference in the total cross section $\bar{p}$p and pp between the states with helicities of target and beam

parallel and antiparallel. The experiment took preliminary test 200-GeV proton beam polarization data with Coulomb nuclear interference and Primakoff polarimeters. They also tested antiproton beam and performed electromagnetic calibrations of their detector. They will run during the next fixed-target physics run. E-704 is a collaboration of Argonne National Laboratory; CEN-Saclay (France); Fermilab; the Institute of High Energy Physics, Serpukov (U.S.S.R.); KEK-National Lab for High-Energy Physics (Japan); Kyoto University (Japan); Lab. A. Physique des Particules, Annecy-le-Vieux (France); Los Alamos National Laboratory; Lawrence Berkeley Laboratory; Northwestern University; Rice University; the University of Texas at Austin; and Universitat Degli Studi di Treste (Italy).

Experiment 711 completed a run studying the angular and energy dependence of constituent scattering through measurements of the reaction $p+N \rightarrow h_1+h_2+X$ where h_1 and h_2 are both high transverse momentum hadrons, roughly back-to-back in the pN center-of-mass system. By determining the angular distribution and mass dependence of the cross section of the di-hadron system, the experiment will try to extract the angular and energy dependence of the underlying hard constituent scattering. Using 800-GeV protons, a luminosity of 0.5 - 1.0 x 10^{37}, and a variety of targets, they studied the $h^+ h^-$ mass to 13 GeV and the angular distribution to a mass of 12 GeV. The experiment is a collaboration of the University of California, Davis; Fermilab; Florida State University; and the University of Michigan.

Experiment 772 completed a precise measurement of the A dependence of the Drell-Yan process for 800-GeV protons on targets of deuterium and calcium. Emphasis was placed on the kinematic region $M \geq 4$ GeV and $x_f \geq 0.2$, where one is most sensitive to beam-valence-quark, target-antiquark annihilation. In the mass range of 5-14 GeV, they accumulated 500,000 dimuons with a variety of targets. E-772 is a collaboration of Fermilab; the University of Illinois at Chicago; Los Alamos National Laboratory; Rutgers University; the University of Texas at Austin; SUNY/Stony Brook; and the University of Washington.

The conclusion of this run begins a year-long period in which the Collider Detector at Fermilab comes back online for a 10-month physics run with a full complement of standard reconstruction packages ready to analyze the data that will be accumulated. But the fixed-target areas will by no means be idle during this time frame because a number of beamline and fixed-target detector upgrade projects necessary in preparation for the June 1989 fixed-target run are planned and have already begun. Most importantly, the analysis of the 35,000 data tapes accumulated during the run will proceed. This will put a tremendous load on

Fermilab's computing facilities. But given the fact that Fermilab's new large-scale scientific computer will begin to arrive and be installed in early summer, this computing load will be alleviated. According to Jack Pfister, Associate Head of the Computing Department responsible for central computing, there have been major upgrades to the VAX Cluster recently, but the new Amdahl 5890 computer is the largest major increment of general-purpose computing capacity in the last four years. The added capacity is on the order of twice the entire Cyber complex. Another help will be the use of Advanced Computer Program parallel processor systems as part of the offline data reconstruction packages. This combination promises the kind of computing power necessary to meet the data crunching demands of fixed-target users.

(Fermilab photograph 86-773-5

The apparatus for E-772 located in the M-East beamline.