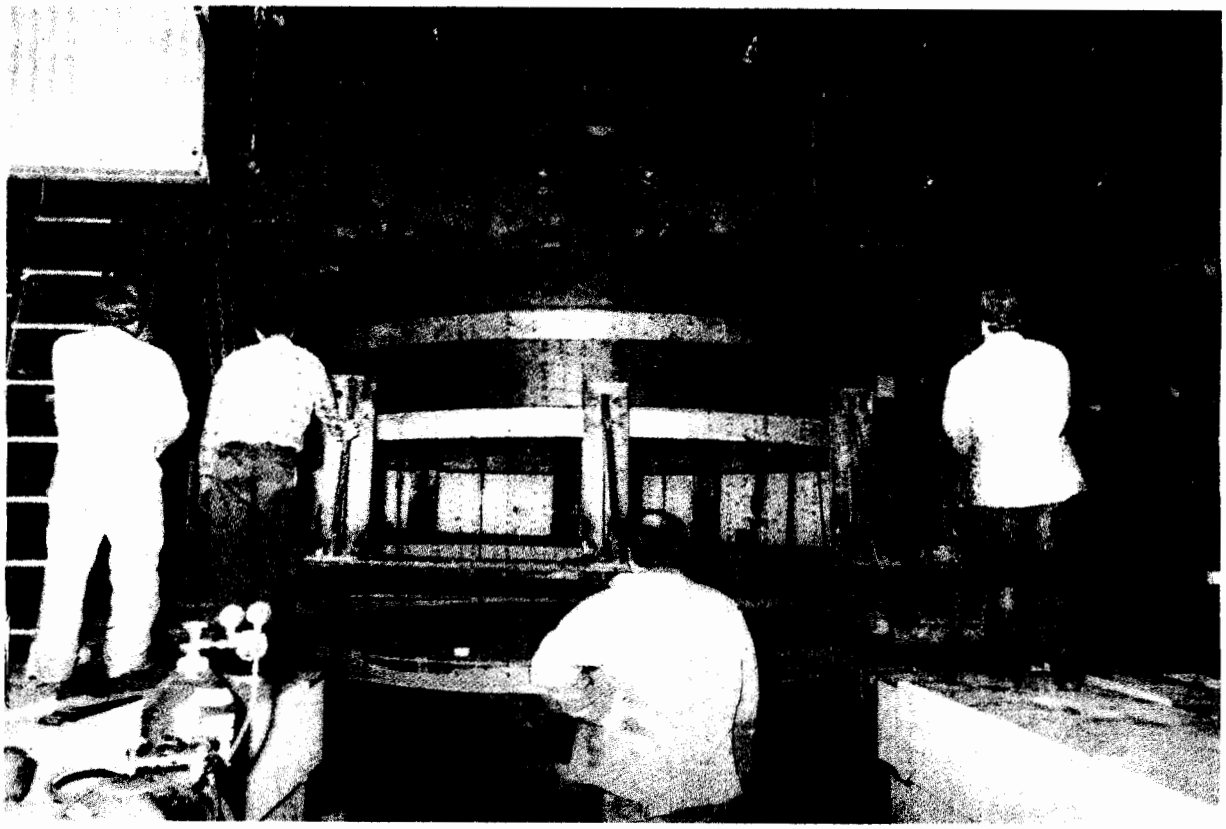
fermilab report

Fermi National Accelerator Laboratory Monthly Report

November 1980



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THE COVER: Superconducting coils being installed on the Chicago cyclotron magnet.
(Photograph by Fermilab Photo Unit)

400-GeV START-UP

William Merz

The resumption of 400-GeV accelerator operation for high-energy physics during the week of November 13 following a facility shutdown of more than 4 months was deemed a resounding success by the Accelerator Division. Beam was available to both Proton and Neutrino experimental areas only a few hours behind the schedule that was drawn up last summer. Several weeks of weekend operation in preparation made the smooth start-up possible. Anticipated problems with the Main Ring and extraction systems did not materialize or were minor enough to be ironed out during the weekend tune-ups. It is hoped that the improvements made in accelerator systems will increase reliability and make the shortened running time even more productive for the experimental program.

ELECTRON COOLING ACHIEVED

Electron cooling of a proton beam was demonstrated at Fermilab early in the morning of October 17. Both longitudinal and transverse cooling have been observed.

This was the culmination of several years of building the electron-cooling gun system and storage ring. The first proposal for this work was made in 1976 by Cline, McIntyre, Mills, and Rubbia.[1] This work is being done as a collaboration of Fermilab with Argonne National Laboratory, Lawrence Berkeley Laboratory, University of Wisconsin, and the Institute of Nuclear Physics in Novosibirsk. The storage ring has previously been used to test stochastic cooling by Argonne and LBL. Electron cooling had previously been observed at Novosibirsk and at CERN.

Electron cooling is an important part of the plan to produce proton-antiproton collisions at 2 TeV in the center of mass in the Fermilab superconducting accelerator. Electron cooling reduces the transverse and longitudinal size of a heavy-particle beam by Coulomb scattering by a parallel electron beam, which carries oscillation energy away from the heavy particles.

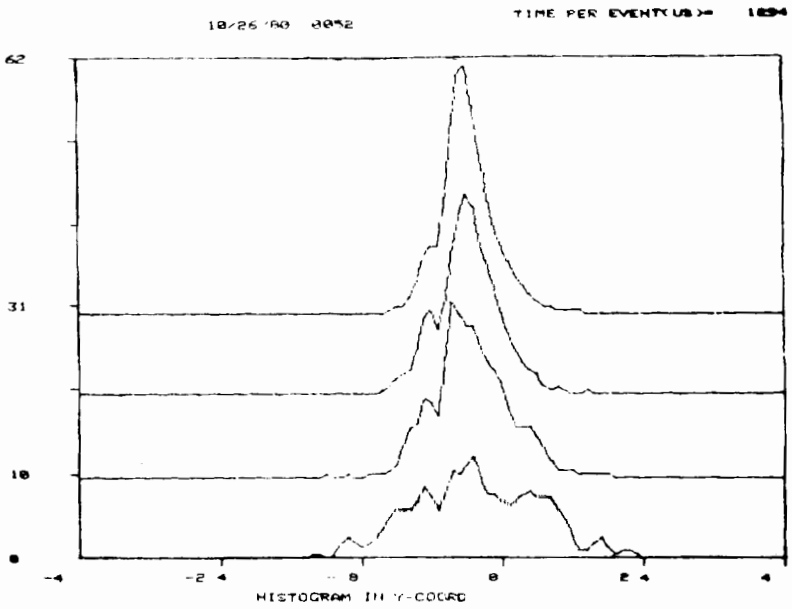
The cooling experiments recently accomplished were carried out with a circulating proton beam injected from the Linac at 115 MeV. Longitudinal cooling was first detected by cooling the proton beam into a very small rf bucket and observing the bunched signal. In later experiments, the drag of the electron beam moved the entire proton beam to the energy corresponding to the rf bucket frequency. The drag force calculated from the electron-beam parameters is in reasonably good quantitative agreement with that observed in these experiments. The momentum spread of the proton beam appears to be reduced by a factor 50.

With the given beam properties, the calculated transverse cooling time is approximately 20 sec, but the observed cooling rate is faster than this, 10 to 12 sec. The best beam lifetime achieved in a series of experiments before the run ended was approximately 1000 sec, consistent with single scattering from the residual gas. Vertical profiles at different times are shown in the figures on the next page.

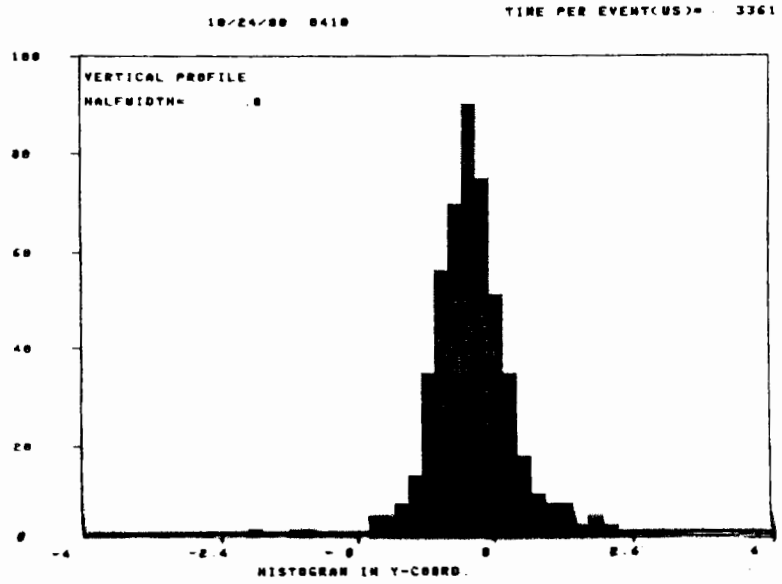
Work is now going on to improve the electron-beam system for another series of experiments.

Reference

[1] D. Cline, P. McIntyre, F. Mills, and C. Rubbia, Collecting Antiprotons in the Fermilab Booster and Very High Energy Proton-Antiproton Interactions, Fermilab Internal Report TM-689, October 1976.



Vertical cooling of a beam.



Histogram of the vertical distribution of a cooled beam.

SUPERCONDUCTING SYSTEMS TESTS

Recent systems tests of the above-ground superconducting magnet string at B12 have given encouraging results for future Tevatron plans.

In the first series of tests, the 20-magnet string was ramped to 4000 amperes continuously over a 4-day period. There were no quenches and no human intervention. This test shows that the cryogenic, quench, and power systems are easily controlled and reliable.

In addition, when the magnet string is first energized after cooldown, the first quench is always at a current greater than 4000 amperes. There is no training needed.

In a second test, the string operated at 4000 A dc for two hours. This can be considered as a test of the colliding-beams mode. It demonstrates that the internal coil splices do not produce significant heating and that there are no short-term creep problems in the coil.

PHOTOPRODUCTION OF CHARMED PARTICLES - EXPERIMENT 87A

Irwin Gaines

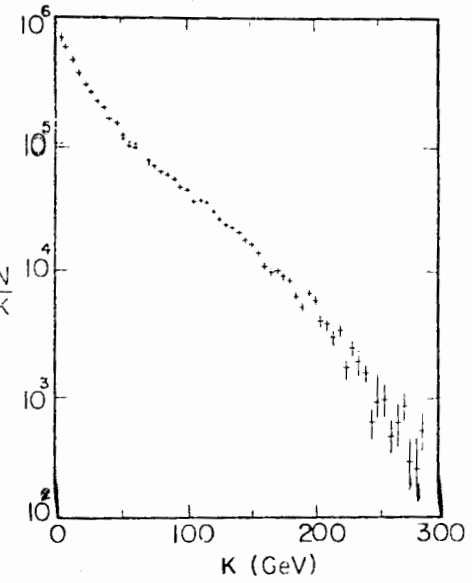
Fermilab experiment 87A has recently reported new results on the photoproduction of charmed mesons and baryons. This article will summarize this work.

Members of the E-87A collaboration are Paul Avery, Joel Butler, Gary Gladding, Maury Goodman, Tom O'Halloran, Jim Russell, Al Wattenberg, and Jim Wiss from the University of Illinois; Morris Binkley, John Cumalat, Irwin Gaines, Mike Gormley, Bob Loveless, and John Peoples of Fermilab; and Maged Atiya, Steve Holmes, Bruce Knapp, Wonyong Lee, and Bill Wisniewski of Columbia University.

The new results on charm particle production come from the Ph.D. theses of Paul Avery (mesons) and Jim Russell (baryons).

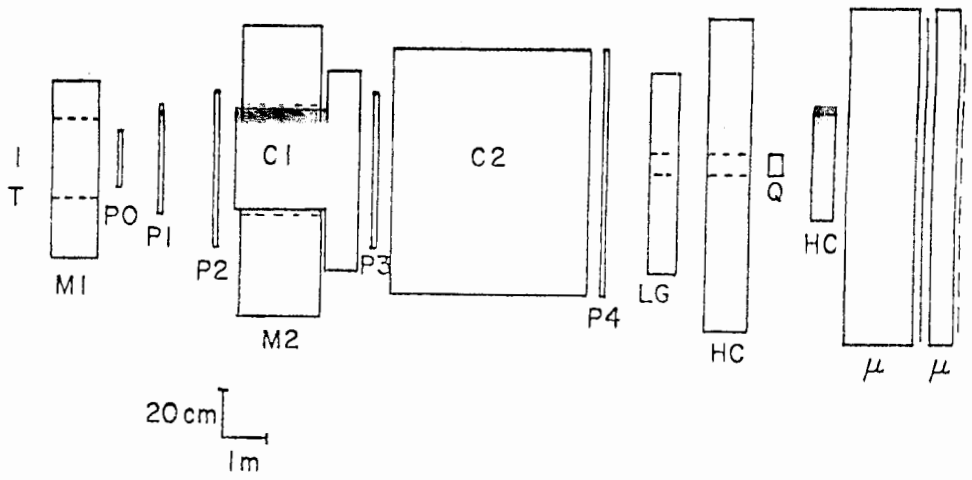
Beam and Apparatus

The experiment was performed in the broad-band photon beam in Proton East. This beam is a 0° neutral beam with the photon-to-hadron ratio enhanced by passing the beam through 35 m of liquid deuterium. This results in the photon-beam spectrum shown below, with large fluxes of high- energy, photons which are important to the charm measurement. The hadronic background (neutrons and K_L^0's) in the beam is less than 1%, but this still represents an important background to charm production.



Momentum spectrum of the broad - band photon beam.

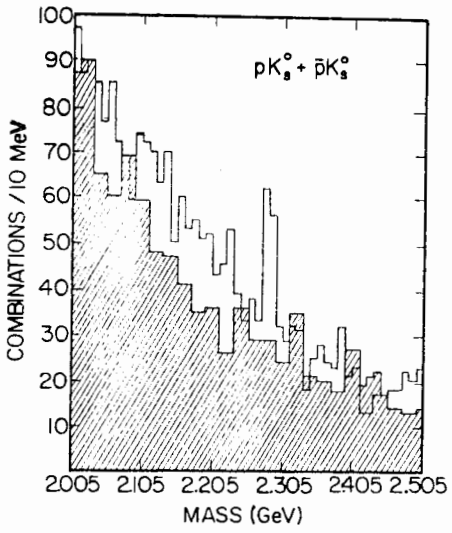
The experimental apparatus is shown in the figure at the top of the next page. It consists of two analyzing magnets (M1 and M2), 5 sets of proportional chambers (P0-P4) each of which measures coordinates in three views, 2 multicell threshold Cherenkov counters (C1 and C2) to identify charged kaons and protons, an array of lead glass (LG) and a steel-scintillator hadron calorimeter (HC) used in triggering, and a muon hodoscope (μ). The data sample consisted over of 30 million events taken from January through May 1978.



Schematic layout of the E-87A apparatus.

Baryon Results

The charmed baryon Λ_c was detected through its decay mode into pK^0_S and $\bar{p}K^0_S$. The mass distribution in the figure below shows a clear Λ_c signal with a mass of 2284±5 MeV/c^2 and a width consistent with the resolution of the apparatus. (The shaded region in the figure represents events produced by the hadrons in the beam.) Equal numbers of events were observed for both the baryon (pK^0_S) and antibaryon ($\bar{p}K^0_S$), which, together with the observed values of Λ_c momentum and p_t, strongly suggests that the charmed particles are produced in baryon-antibaryon pairs. The 55 events in the figure represent a cross section times branching ratio of 3±1 nb/nucleon.



Mass plot of pK^0_S + $\bar{p}K^0_S$ combinations. Shaded region represents hadron-induced background.

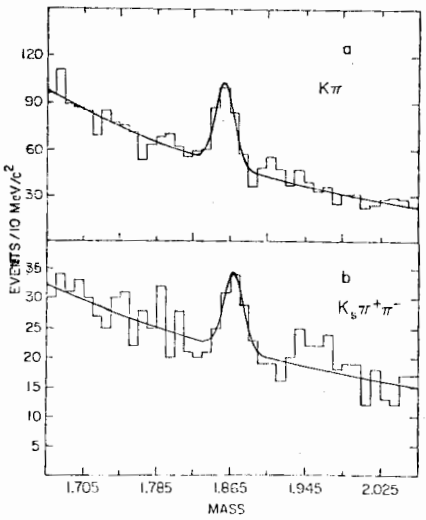
No other decay modes of the Λ_c were seen at the same level of significance, allowing us to put 90% confidence level upper limits on the relative branching ratio (compared to pK^0) of 0.4 for the $\Lambda\pi^+$ decay mode, 1.5 on the $p^\pm K^\mp \pi^\pm$ decay mode, 3.3 on the $pK^0\pi^+\pi^-$ mode, and 3.1 for the $\Lambda 3\pi$ decay mode.

Meson Results

The neutral charmed meson D^0 was observed in both its $K^-\pi^+$ and $K^0_S\,\pi^+\pi^-$ decay modes by requiring it to be produced from the cascade decays of the charged D*: $D^{*+} \to D^0\pi^+$ and $D^{*-} \to \bar{D}^0\pi^-$ and exploiting the known $D^* - D^0$ mass difference of 145 MeV/c^2. The figure below shows the $K^\pm\pi^\mp$ and $K^0_S\,\pi^+\pi^-$ mass distributions subject to the requirement that the $(K\pi)\pi - K\pi$ or $(K_S\pi\pi)\pi - K_S\pi\pi$ mass difference be near 145 MeV/c^2. Clear peaks of 143±20 and 35±13 events are seen at the D^0 mass in the two distributions.

Again, equal numbers of charmed particles and anti-particles are produced. Moreover, after substracting background we find 35±9% of the D's are produced opposite a charged kaon of the appropriate sign to be coming from the decay of an oppositely charmed meson. Both these facts strongly support a pair-production mechanism for charmed-meson production.

These events yield a cross section of 160±70 nb/nucleon for inclusive D^{*+} photoproduction (using the known branching ratios). Inclusive distributions suggest that 24^{+13}_{-6}% of D^0's are produced in D^{*+} decays. We can also put a limit on $D^0/\bar{D}^0$ mixing by looking for D^0 decays into wrong sign kaons, obtaining



Mass plots of a) $K^+\pi^- + K^-\pi^+$ combinations b) $K^0_S\pi^+\pi^-$ combinations subject to the $D^* - D^0$ mass difference cut.

$$\frac{D^0 \to K^+\pi^-}{D^0 \to K^-\pi^+} < 11\% \quad (90\% \text{ confidence level}).$$

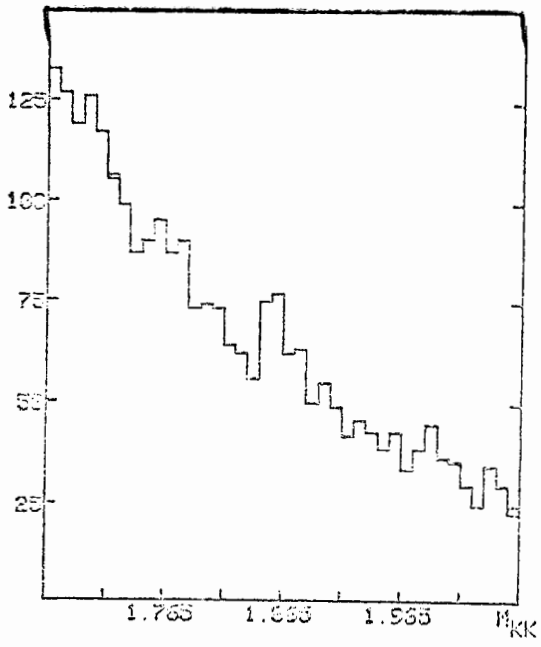
Finally, we can observe the Cabibbo suppressed decay of the D^0 into K^+K^- shown in the graph at the top of the next page, obtaining a branching ratio of

$$\frac{D^0 \to K^+K^-}{D^0 \to \pi^+K^-} = 0.20 \pm 0.09 .$$

Conclusion

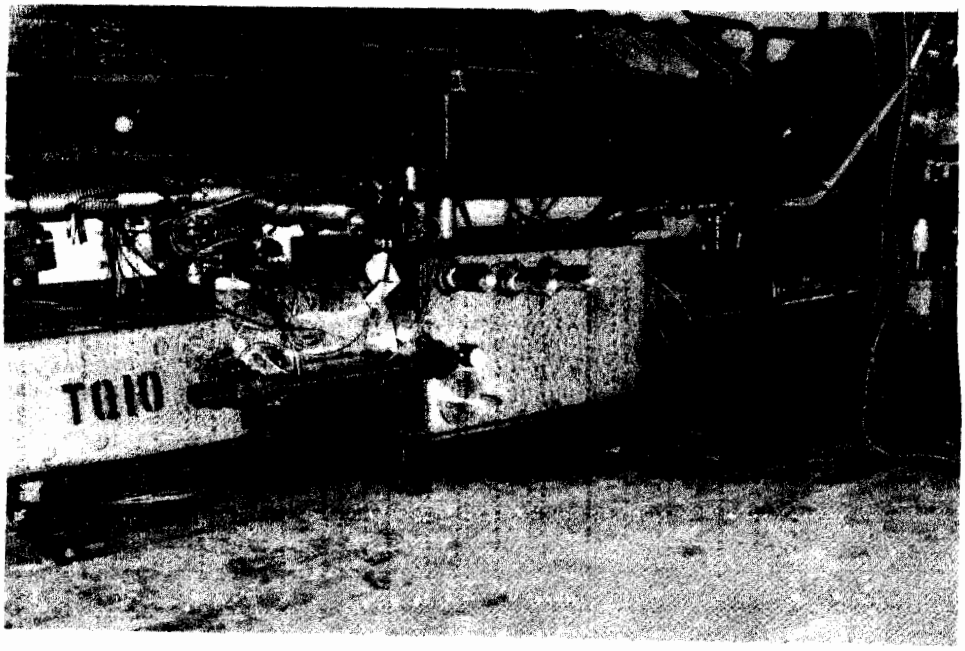
We have seen clear evidence for the photoproduction of both charmed mesons and baryons. Both appear to be pair-produced at a level of a few hundred nanobarns. Other important results

include the mass determination for the Λ_c and the observation of the rare K^+K^- decay mode for the D^0.



$D^0 \rightarrow K^+K^-$

Mass plot of K^+K^- combinations subject to the $D^* - D^0$ mass difference cut.



Superconducting quadrupole installed in the tunnel.
(Photograph by Fermilab Photo Unit)

NOTES AND ANNOUNCEMENTS

SEMINAR SERIES ON PARTICLES AND COSMOLOGY. . .

In order to gain hints of what may happen when the proton-antiproton colliding-ring accelerator begins operation, Fermilab will sponsor a year-long series of seminars devoted to the particle physics connections of cosmology and cosmic rays.

Prof. James Peebles from Princeton University opened the series October 29 speaking on "Cosmology, New Physics and Old." Prof. William Fowler from California Institute of Technology spoke November 5 on "Nucleo Synthesis and Supernova." Future speakers and topics include: Prof. Tom Gaisser, Bartol Research Foundation, University of Delaware, will give four talks December 1-4 and 8-11 on "Particle Collisions Above 10 TeV as Seen in Cosmic Rays;" Prof. David Schramm from the University of Chicago will speak January 14 on "Neutrinos and the Big Bang;" Prof. Malvin Ruderman, Columbia University, will speak on "Elementary Particles and Superdense Matter," February 12; Prof. Gordon Baym, University of Illinois, will deliver the seminar, "How Can We Learn About Particles from Neutron Stars?" on March 11; and in mid-April Prof. Steven Weinberg from the University of Texas will speak on "The Very Early Universe."

MANUSCRIPTS, NOTES, LECTURES, AND COLLOQUIA PREPARED
OR PRESENTED FROM OCTOBER 8 TO NOVEMBER 14, 1980

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

P. R. Avery
Experiment #87A

Photoproduction of the $D^{*\pm}$ (Ph.D. Thesis, University of Illinois)

V. Cook et al.
Experiment #236

A Measurement of the Energy Dependence of the Inclusive Yield of High P_t Events Triggered by a Large Solid Angle Calorimeter (FERMILAB-Pub-80/91-EXP; submitted to Nucl. Phys. B)

C. Wilkinson et al.
Experiment #620

Polarization of Σ^+ Hyperons Produced by 400 GeV Protons (Submitted to Phys. Rev. Lett.)

Theoretical Physics

M. K. Gaillard

CP Violation at High Energies (FERMILAB-Conf-80/65-THY; talk presented at the XX International Conf. on High Energy Physics, Madison, Wisconsin, July 17-23, 1980)

K. T. Chao

The (cc)-($\bar{c}\bar{c}$) (Diquark-Antidiquark) States in e^+e^- Annihilation (FERMILAB-Pub-80/70-THY; submitted to Zeitschrift fur Physik)

R. Migneron and
J. L. Robinson

Baryon Production from Pion Fragmentation in the Quark Recombination Model (FERMILAB-Pub-80/72-THY; submitted to Nucl. Phys. B)

A. Buras

Quantum Chromodynamics and Deep-Inelastic Scattering (FERMILAB-Conf-80/73-THY; talk presented at the XX International Conf. on High Energy Physics, Madison, July 17-23, 1980)

K. M. Bitar	Composite Gauge Fields (FERMILAB-Pub-80/83-THY; submitted to Phys. Rev. D)

Physics Notes

A. Van Ginneken et al.	Beam Induced Quench Study of Tevatron Dipoles (FN-327)

General

D. Ciazynski and P. Mantsch	Typical Problems of the Correction Magnets for Fermilab Energy Saver (Presented to the 1980 Applied Superconductivity Conf., Santa Fe, New Mexico, September 29-October 2, 1980)
H. E. Fisk et al.	Room Temperature Harmonic Analysis of Superconducting Energy Saver Quadrupoles (Submited to the 1980 Applied Superconductivity Conf., Santa Fe, September 29-October 2, 1980)
R. A. Lundy	State of the Energy Doubler (Submitted to the 1980 Applied Superconductivity Conf., Santa Fe, September 29-October 2, 1980)
J. E. O'Meara et al.	A Design Method for Cryostat Supports for the Fermilab Energy Saver/Doubler (Submitted to the 1980 Applied Superconductivity Conf., Santa Fe, September 29-October 2, 1980)
J. R. Orr	Status of the Fermilab Energy Saver/Doubler Dipole (Submitted to the XX International Conf. on High Energy Physics, Madison, July 17-23, 1980)
L. C. Teng	Acceleration, Accumulation and Storage of Polarized Ion Beams (Presented at the 1980 International Symposium on High-Energy Physics with Polarized Beams and Polarized Targets, Lausanne, Switzerland, September 25-October 1, 1980)

A. V. Tollestrup	Care and Training of Superconducting Magnets (Presented to the 1980 Applied Superconductivity Conf., Santa Fe, September 29-October 2, 1980)

Colloquia, Lectures, and Seminars

T. Devlin	"Recent Results on Hyperon Polarization and Magnetic Moments" (Given at DESY, Hamburg; Max Planck Institute, Munich; CERN, Geneva; Imperial College, London; Princeton University, New Jersey)
C. Hill	"Penguins and CP Violation" (Enrico Fermi Institute, University of Chicago, October 29, 1980)
R. Huson	"Super Booster" (Fermilab, November 4, 1980)
D. Jovanovic and T. Kondo	"Report from the Telemark Conference" (Fermilab, October 24, 1980)
H. J. Lipkin	"Magnetic Moments of Baryons, Quarks, and Leptons" (Fermilab, October 10, 1980)
A. V. Tollestrup	"The Care and Training of Superconducting Dipoles" (Fermilab, November 11, 1980)
E. Treadwell	"Evidence for Gluon Radiation in High Energy ν-N Scattering/Results from E-546" (Fermilab, October 17, 1980)

Stages in the fabrication of a superconducting quadrupole. Bare coils are at the right, a finished collared-coil assembly is at the left.

(Photograph by Fermilab Photo Unit)

DATES TO REMEMBER

December 1-4, 1980 December 8-11, 1980	"Particle Collisions Above 10 TeV as Seen in Cosmic Rays," Prof. Tom Gaisser (see page 10).
January 14, 1981	"Neutrinos and the Big Bang," Prof. David Schramm
February 1, 1981	Deadline for proposals for Tevatron experiments with hadron and photon beams in the Meson and Proton Areas to be considered at the June 1981 PAC meeting.
February 12, 1981	"Elementary Particles and Superdense Matter," Prof. Malvin Ruderman
March 11, 1981	"How Can We Learn About Particles from Neutron Stars?" Prof. Gordon Baym
mid April, 1981	"The Very Early Universe," Prof. Steven Weinberg