PHOTOPRODUCTION OF CHARMED PARTICLES - EXPERIMENT 87A

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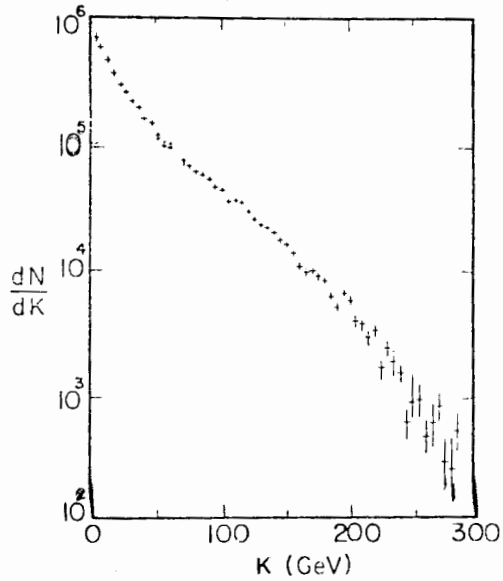
Fermilab experiment 87A has recently reported new results on the photoproduction of charmed mesons and baryons. This article will summarize this work.

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).

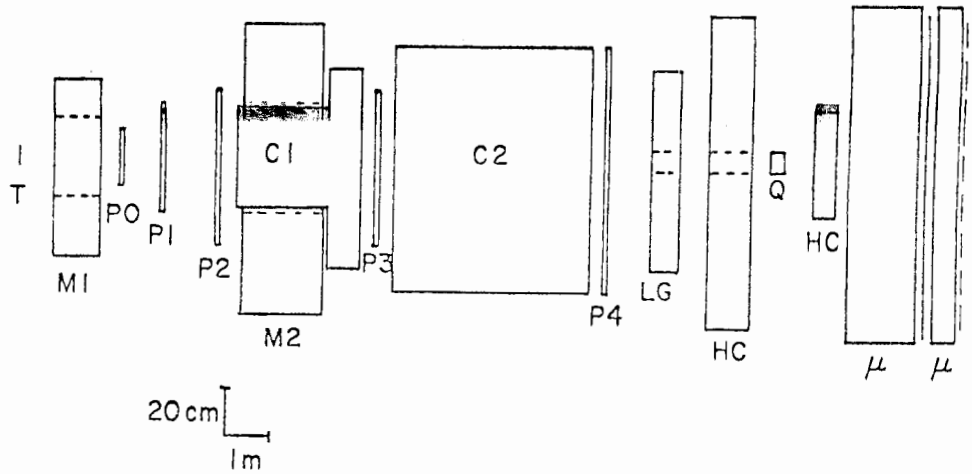
Beam and Apparatus

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.

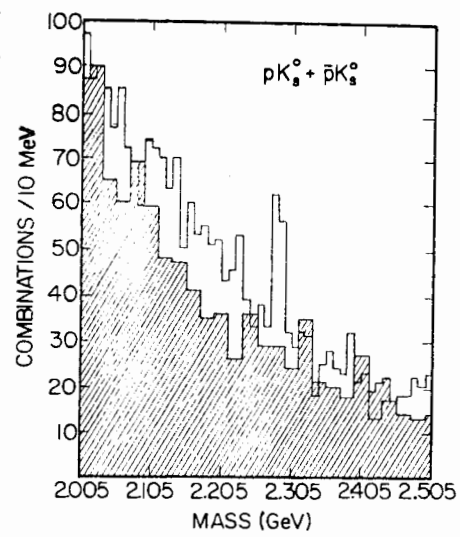


Schematic layout of the E-87A apparatus.

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 $p_\perp$, 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.

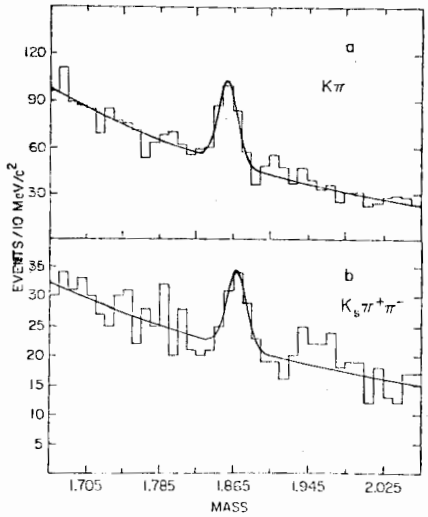
No other decay modes of the Λ_c were seen at the same level of significance, allowing us to put 90% confidence level upper limits on the relative branching ratio (compared to pK^0) of 0.4 for the $\Lambda\pi$ decay mode, 1.5 on the $p^{\pm}K^{\mp}\pi^{\pm}$ decay mode, 3.3 on the $pK^0\pi^+\pi^-$ mode,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



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

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.



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.

Again, equal numbers of charmed particles and antiparticles 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

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

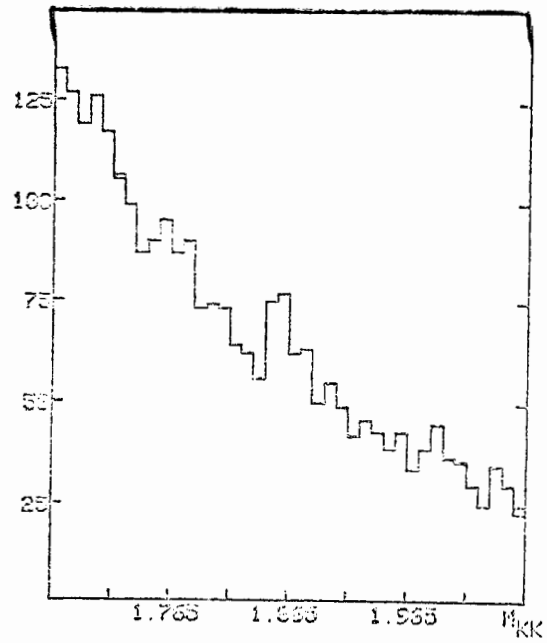
Finally, we can observe the Cabibbo suppressed decay of the D^0 into K^+K^- shown in the graph at the top of the next page, obtaining a branching ratio of

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

Conclusion

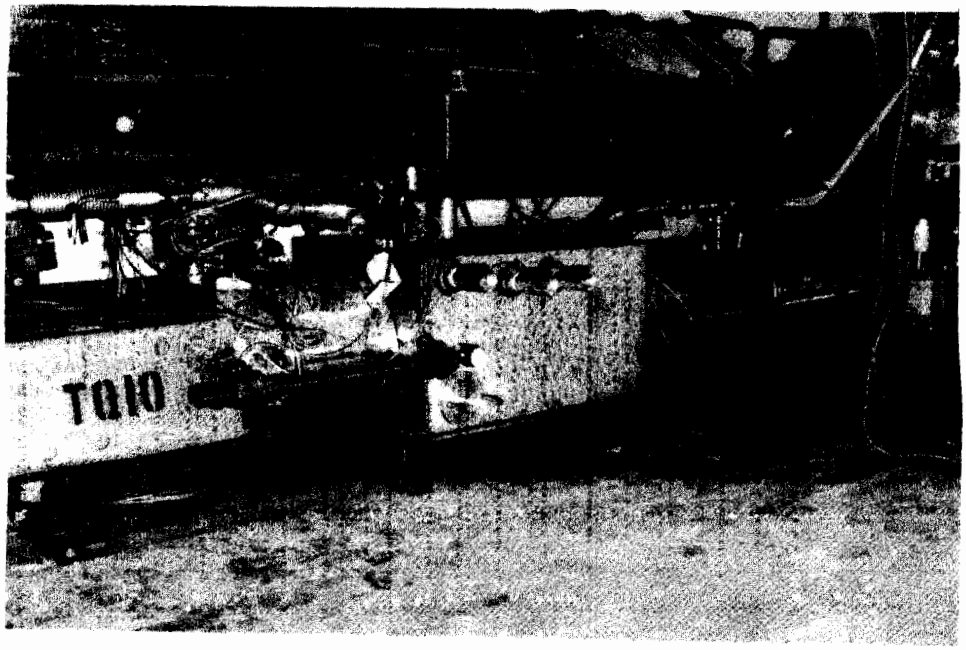
We have seen clear evidence for the photoproduction of both charmed mesons and baryons. Both appear to be pair-produced at a level of a few hundred nanobarns. Other important results

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)