HADRONIC CHI PRODUCTION AND DIFFRACTIVE CHARM MESON PRODUCTION

John W. Cooper
University of Pennsylvania
Philadelphia, Pa. 19104 (USA)

Abstract

Preliminary results are presented on χ production in 225 GeV/c π^-Be interactions at Fermilab using the Chicago Cyclotron Particle Spectrometer (CYCLOPS). The eye of CYCLOPS is a 147 element Lead Glass array for detection of χ's via the decay $\chi \to \psi + \gamma$. Results on diffractive charmed D meson production from an earlier experiment in the same apparatus are also reported. Hadronic decays of D mesons were detected in coincidence with a prompt muon and a recoil proton from a hydrogen target. D mesons are seen in the channels $K\pi$ and $K\pi\pi$ with identified K_s^o or $K^\pm$.

This is a preliminary report of results from Fermilab Experiment E610 on hadronic χ (3.5) production at 225 GeV/c. The people involved in this Fermilab-Illinois-Pennsylvania-Purdue-Tufts collaboration are listed in reference 1.

The experiment used the Chicago Cyclotron Particle Spectrometer (CYCLOPS) shown in Fig. 1 to detect χ's via

$$\pi^- Be \rightarrow \chi + X$$
$$\quad \hookrightarrow \psi + \gamma$$
$$\qquad \hookrightarrow \mu^+\mu^-$$

The Chicago Cyclotron magnet (7.5 T-m) serves as the analyzing magnet in the CYCLOPS apparatus. Charged tracks are detected with 25 planes of MWPC's and 4 X-Y Drift Chambers. An 18 cell threshold Cerenkov counter separates π's from K's in the range 8-30 GeV/c. Particles which penetrate a 3m steel shield are identified as μ's and the apparatus is triggered on a high mass $\mu^+\mu^-$ pair. The eye of CYCLOPS is a 147 element Lead Glass array shown in detail in Fig. 2. The eye consists of a 2.3 radiation length active converter followed by three planes of proportional tubes (8 mm spacing) for shower position measure-

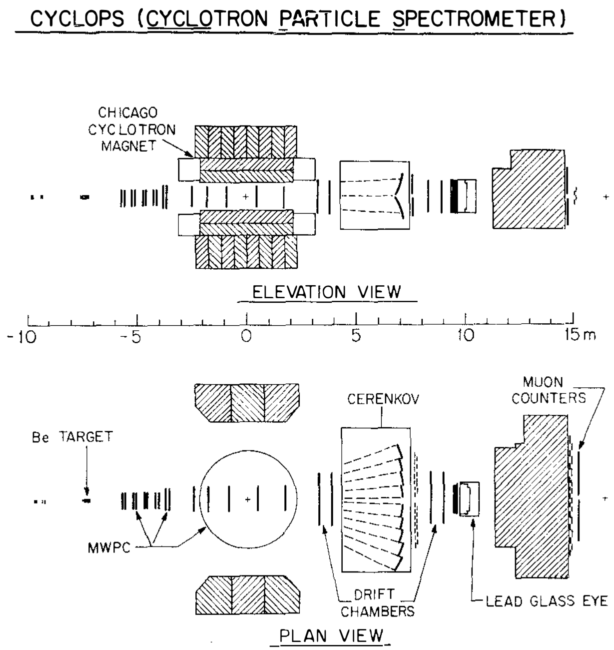


Fig. 1. The CYCLOPS apparatus (elevation view and plan view).

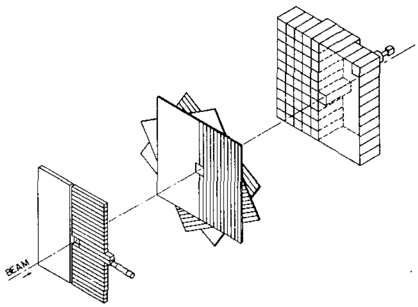


Fig. 2. An exploded view of the CYCLOPS "eye". The active preconverter contains 48 Lead Glass blocks. The proportional tube array (center) has 60° geometry and each plane contains 208 tubes. The final Lead Glass array is 1.5m x 1.5m and contains 99 blocks.

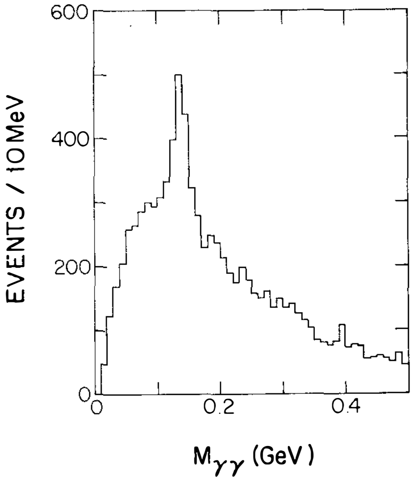


Fig. 3. $\gamma\gamma$ invariant mass

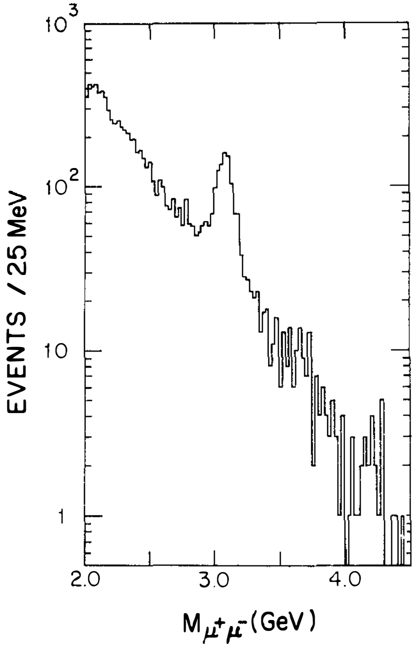
ment and by 18.0 radiation lengths of Lead Glass for the primary energy measurement. In a calibration electron beam this detector achieved a position resolution of $\Delta x = \Delta y \approx 9$mm (FWHM) and an energy resolution of $\Delta E/E \approx 15\%/\sqrt{E}$ (FWHM). With this resolution we expect a reconstructed π^{0} width of 10 MeV (FWHM) and a $\chi(3.5)$ width of 25 MeV (FWHM).

Our present understanding of the CYCLOPS eye is indicated by the γ-γ invariant mass plot in Fig. 3. There is a clear π^{0} peak at 0.135 GeV, but the FWHM is 30 MeV. This larger than expected π^{0} width is due to run to run energy calibration problems which are being intensively studied.

The $\mu^{+}\mu^{-}$ mass spectrum above 2.0 GeV is shown in Fig. 4. There is a ψ peak of about 760 events above background. We take all events in the range 2.95 - 3.25 GeV as ψ events and fix the $\mu^{+}\mu^{-}$ mass at 3.1 GeV. The ψ + γ invariant mass for these "ψ's" is then formed and the result is shown in Figure 5. Photons with $M_{\gamma\gamma}$ in the π^{0} mass range (0.1 - 0.2 GeV) are not used in $\psi\gamma$ combinations, and all the photons used have energies in the range 1-30 GeV. The background curve in

Fig. 5 is formed by taking events with 2.5 < $M_{\mu\mu}$ < 2.75 GeV. We then set $M_{\mu\mu} \equiv$ 3.1 GeV and form the $M_{\mu\mu}$ + γ invariant mass. This background is normalized absolutely by the ratio of "ψ" events to 2.5 < $M_{\mu\mu}$ < 2.75 GeV events.

Fig. 5 shows a clear excess of 50 events above background at ~3.5 GeV. Based on our π^0 width (Fig. 3) we expect a χ mass resolution of about 50 MeV (FWHM) in this preliminary analysis. Our Monte Carlo determined acceptance is 0.4 for the γ once the ψ is detected. We estimated our γ pattern recognition efficiency to be less than 70%. We therefore conclude that the fraction of ψ's produced via an intermediate χ state is greater than 0.29. We do not quote an error due to the preliminary nature of this report.



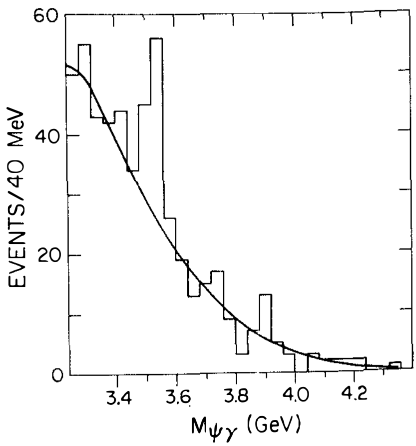


Fig. 5. The ψ + γ invariant mass.

Fig. 4. The $\mu^+\mu^-$ invariant mass.

Now I turn to the subject of diffractive charm production in the reaction $\pi^- p \to M_x^- + p$ at 217 GeV/c. Using an early version of the apparatus in Fig. 1 with a hydrogen target and a recoil proton arm, we restricted the recoil mass M_x^- to the range 2.5 - 7.0 GeV. We then triggered on a single prompt muon to detect charmed D mesons via

$$M_x^- \to D + \bar{D} + X, \quad \bar{D} \to \mu + X, \quad D \to K\pi \text{ or } K\pi\pi$$

The people involved in this Fermilab-Harvard-Illinois-Oxford-Tufts experiment are listed in reference 2.

At the Madison conference we reported[3)] 23 ± 8 D^+ meson events in the channel $K^-\pi^+\pi^+$ and 26 ± 10 events in the channel $K^+\pi^-\pi^-$ with identified $K^\pm$. These mass plots are shown in Fig. 6. Fig. 7 shows the non-exotic $K\pi\pi$ mass where no signal is seen. Our mass resolution in all these plots is 36 MeV, so the D signals appear in a single bin. Since Madison we have also looked for D decays containing a K_s^o. Fig. 8 shows our K_s^o signal and Fig. 9 shows the $K_s^o\pi^+\pi^-$ mass spectrum where we see a peak of 26 ± 8 D^o events at ~1.86 GeV.

In the reaction $\pi^- p \to M_x^- + p \to D\bar{D}\,X\,p$, there are four production cross sections, D^+D^-, $D^o\overline{D^o}$, $D^+\overline{D^o}$, and D^-D^o. We have measured only three numbers, the amounts of D^+ production, D^- production, and $D^o + \overline{D^o}$ production. Therefore we must make one additional assumption to extract a diffractive charm D meson cross

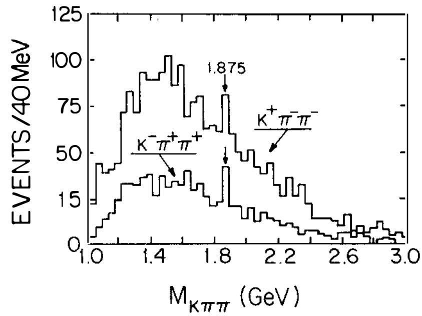


Fig. 6. The exotic $K^+\pi^-\pi^-$ and $K^-\pi^+\pi^+$ invariant mass.

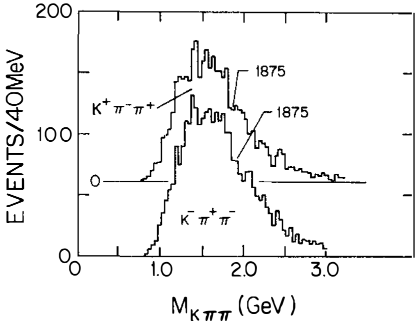
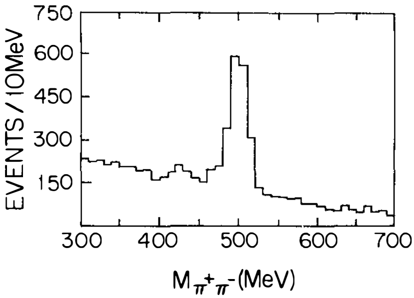


Fig. 7. The non-exotic $K^\pm\pi^+\pi^-$ invariant mass.



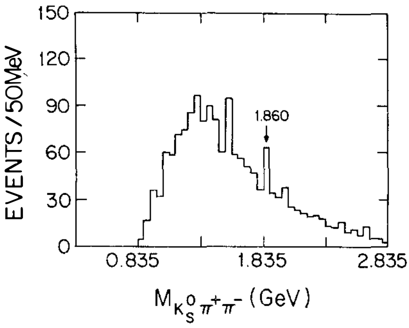


Fig. 8. The $\pi^+\pi^-$ invariant mass distribution for tracks not associated with the primary event vertex.

Fig. 9. The $K_S^0\pi^+\pi^-$ invariant mass.

section. If we try various values for the ratio of $D^0\bar{D}^0$ production to D^+D^- production, we find[4,5,6] the total diffractive $D\bar{D}$ production cross section limits shown in Figure 10. For a wide choice of the ratio $D^0\bar{D}^0/D^+D^-$ the total diffractive $D\bar{D}$ production cross section is 40–50 μb.

As a final check on our results we have examined the 2-body decay channels. Since we see 49 ± 13 $D^{\pm} \to K^{\mp}\pi^{\pm}\pi^{\pm}$ events, we expect to see 6 ± 3 events in $D^{\pm} \to K_S^0\pi^{\pm}$ and we do find 13 ± 5 events. We also see 26 ± 8 $D^0 \to K_S^0\pi^+\pi^-$ events, so we expect to see 25 ± 12 events in $D^0 \to K^{\pm}\pi^{\mp}$, but we find no events in this channel. We are re-examining our analysis of $D \to K^{ch}$ channels in an attempt to resolve this discrepancy.

References

1. Fermilab: D. Bauer, D. Judd, T. Kirk, S. Pordes. R. Raja, and A. Wehmann; Illinois: G. Alverson, H. Budd, T. Graff, S. Hahn, L. Holloway, L. Koester, U. Kruse, W. Li, P. Lukens, R. Sard, and P. Schoessow; Pennsylvania: J. Cooper; Purdue: V. Barnes, C. Davis, A. Garfinkel, and A. Laasanen; Tufts: S. Hossain, R. Milburn, W. Oliver, and R. Thornton.

2. Fermilab: T. Kirk and R. Raja; Harvard: M. Goodman, A. Loomis, A. Sessoms, R. Wilson, C. Tao; Illinois: G. Alverson, G. Ascoli, D. Bender, J. Cooper, L. Holloway, L. Koester, U. Kruse, W. MacKay, R. Sard, M. Shupe, E. Smith; Oxford: J. Davis and T. Quirk; Tufts: R. Milburn and R. Thornton.

3. L.J. Koester et al., High Energy Physics - 1980 (XX International Conference, Madison, Wisconsin), edited by L. Durand and L. Pondrom, A.I.P. Conference Proceedings No. 68, Particles and Field Subseries No. 22, New York, 1981, pg. 190.

4. To extract cross sections we evaluate the $D \rightarrow K\pi$ or $K\pi\pi$ acceptance and the $D \rightarrow \mu$ acceptances via Monte Carlo. These acceptances are relatively independent of whether the D's are produced by $M_x \rightarrow D\bar{D}$ or $M_x \rightarrow D\bar{D}^* \rightarrow D$. We also take into account the probability that our prompt muon trigger came from a $\pi \rightarrow \mu$ decay.

5. We used the branching ratios for $D \rightarrow$ hadrons as reported by R.L. Kelly et al., Rev. Mod. Phys. 52, S1 (1980).

6. We take the $D^{ch} \rightarrow \mu$ and $D^o \rightarrow \mu$ branching ratios from DELCO: W. Bacino et. al., Phys. Rev. Letters 45, 329 (1980).

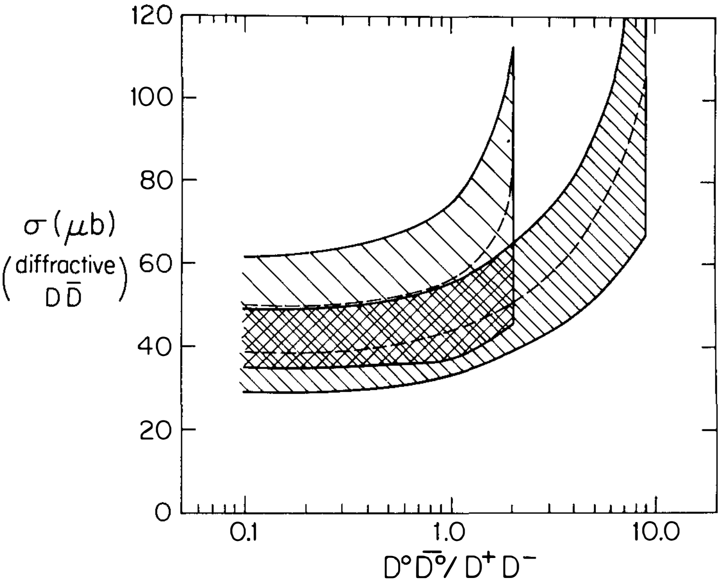


Fig. 10. The total diffractive DD cross section versus the ratio of the D^oD^o cross section to the D^+D^- cross section. The double-shaded curve follows from the DELCO result of $D^{ch} \rightarrow \mu$ branching ratio = 22%, $D^o \rightarrow \mu$ B.R. = 0%. The single-shaded curve follows the DELCO 2σ limit $D^{ch} \rightarrow \mu$ BR = 18%, $D^o \rightarrow \mu$ BR = 4%. The bands represent $\pm$ one std. dev. limits.