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A Study of the $PP \pi^+ \pi^-$ Final State in 8 BeV/c P-P
Interactions*

MASTER

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We report here the preliminary analysis of the four body final state $PP \pi^+ \pi^-$ resulting from P-P interactions at 8 BeV/c. The experiment was performed at Brookhaven National Laboratory in the 80" Hydrogen Bubble Chamber. We have measured events from approximately 2/3 of an available 30,000 frames and have identified 1597 events of the type $PP \pi^+ \pi^-$.

The dominant characteristic of this final state is the strong production of the $N^{*++}(1236)$. This strong production is shown in Figure 1, a Chew-Low plot of the mass of the $P \pi^+$ combinations versus the square of the four momentum transfer (Δ^2) to the $P \pi^+$. For a given $P \pi^+$ combination Δ^2 can be calculated relative to each of the incident protons. We have plotted the mass

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versus the smaller of the two Δ^2 's. The smooth curve superimposed on the mass projection is phase space normalized to the number of combinations. The cross-hatched histogram represents those $p \pi^+$ combinations in which the production cosine, the cosine of the angle between the outgoing $p \pi^+$ system and one of the incident protons, is greater than .96. This selection criterion enhances the N^{*++} peak relative to the background.

Figure 2 shows the invariant mass histograms for the $P \pi^-$ and $P \pi^+ \pi^-$ combinations. The smooth curves are phase space. The $P \pi^-$ spectrum shows some enhancement at the mass of the $N^*(1236)$, the $N^*(1520)$ and the $N^*(1688)$. The $P \pi^+ \pi^-$ mass spectrum shows a large deviation from phase space at the low mass end. We will discuss this deviation in more detail below.

The invariant masses for $P P \pi^+$, $P P \pi^-$, $P P$ and $\pi^+ \pi^-$ are displayed in Figure 3 together with phase space. The baryon number = 2 mass spectra peak towards the high mass end relative to phase space. This peaking is a reflection of the peripheral nature of this final state. We see no particular evidence for resonances in these $B = 2$ mass spectra. Our data shows no enhancement in $p p \pi^+$ at 2520 MeV, the mass of a possible resonance reported by Kidd et al. at an incident proton momentum of 5.5 BeV/c.^{1/} The $\pi^+ \pi^-$ mass is peaked towards the low mass region, reflecting the tendency of the two pions to be headed in the same direction more often than predicted by phase space. We see no obvious evidence for ρ^0 production.

The predominance of the production of the $N^{*++}(1236)$ allows us to treat a subset of the events as the pseudo-three body state $N^{*++} P_b \pi^-$. P_b is the proton not in the N^{*++} . We define the N^{*++} band to be $1.14 \leq M(P \pi^+) \leq 1.32$ BeV. 1036 events satisfy this criterion, 171 have both $P \pi^+$ combinations satisfying the criterion for a total of 1209 combinations. Figure 4 is a Dalitz plot for this pseudo-three body state; the mass squared of $N^{*++} \pi^-$ plotted against the mass squared of $P_b \pi^-$. The $P_b \pi^-$ spectrum continues to peak at the masses of the three resonances mentioned previously. The $N^* \pi^-$ projection shows a strong enhancement at low mass, consisting of two reasonably distinct peaks.

Figure 5 displays the $N^{*++} \pi^-$ spectrum in a different manner. The mass of the $N^* \pi^-$ combinations is plotted against Δ^2 to the N^* . The lower peak, between roughly 1400-1550 MeV, is associated with a low Δ^2 to the N^* . The upper peak, between roughly 1680-1760 MeV, has a much broader Δ^2 distribution. The upper peak may be one of the $N^*(1688)$'s.

The difference between the two peaks relative to Δ^2 to the N^{*++} allows us to isolate the lower peak. The cross-hatched histogram of Figure 5 is for those $N^* \pi^-$ combinations for which the production cosine of the N^{*++} is greater than .96. The histogram contains 486 events, 89 plotted twice. The low mass enhancement may be associated with the peak at about 1400 MeV observed in "missing mass spectrometer" proton-proton inelastic scattering experiments.^{2,3/} Similar structure to what we observe has been reported by Gellert et al. at an incident proton momentum of 6.6

GeV/c⁴/ and by Almeida et al. at 10 GeV/c.⁵/ Both groups attempt to explain the low mass enhancement as a kinematic effect arising from a Deck-type mechanism. The group at 6.6 GeV/c suggest that the peak can be accounted for as due to a kinematic reflection of diffraction scattering; the group at 10 GeV/c suggest that the peak cannot be entirely explained by a simple kinematic calculation.

We have performed a Monte-Carlo calculation in order to determine if our data is consistent with a kinematic interpretation. The calculation was made in accordance with the OPEM diagram in Figure 6. We used a Breit-Wigner function to represent the N^{*++} at the upper vertex, a pion propagator, and the physical π^-p elastic differential cross section at the lower vertex. Qualitatively, for high π^-p invariant mass the π^- is scattered diffractively off of the proton, leading to a low $N^{*++} \pi^-$ invariant mass. Figure 7 shows the curve resulting from the calculation superimposed on the data. Both the calculation and the data are for the N^{*++} production $\cos$ greater than .96. The curve is normalized to the number of combinations. We note that the calculation gives a peak that is somewhat broader than the experimental distribution. At this preliminary stage of our analysis we cannot conclude that the low mass enhancement is either a kinematic effect or a resonance.

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FIGURE 1

FIGURE 2

FIGURE 3

FIGURE 4

FIGURE 5

FIGURE 6

FIGURE 7