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COHERENT PRODUCTION FEATURES IN dp INTERACTIONS AT 11.9 GeV/c

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Abstract.-

The two pion production in coherent dp reactions is studied. The resonance production as well as the d^* effect and the fragmentation processes are discussed. The present results are compared with available coherent $\bar{p}d$ data.

1. INTRODUCTION

In this report we present the study of the reaction $dp \to dp\pi^+\pi^-$ using an 11.9 GeV/c incident deuteron beam. The present data were extracted from ~ 50,000 photographs taken at the 2 meter CERN bubble chamber. The use of deuteron beam on a hydrogen target rather than vice versa affords an easy separation of coherent events from deuteron break-up events having spectator nucleons centered around 5.9 GeV/c laboratory momentum.

The selection of events and the estimation of the $dp \to dp\pi^+\pi^-$ cross section are discussed in Section 2. The general features of this channel are presented in Section 3. Our data are compared with experimental results for $pd \to pd\pi^+\pi^-$ [1,2,3] and $\bar{p}d \to \bar{p}d\pi^+\pi^-$ [4,5,6] reactions at several different incident momenta. Helicity conservation for the proton diffraction dissociation is checked in the s and t channels. The conclusions are given in Section 4.

2. SELECTION OF EVENTS AND CROSS SECTIONS

From about 11,000 measured four prong events we obtained 246 events fitting the reaction

$$dp \to dp\pi^+\pi^- \qquad (1)$$

The scatter plot (not shown) of the proton (P_p) versus the deuteron (P_d) laboratory momenta gives a clear separation between the "coherent" events ($P_d > 7$ GeV/c) and the events with $P_d < 7$ GeV/c and having in addition their P_p centered around 6 GeV/c. These later events (36), almost all ambiguous with deuteron break-up channels having a spectator proton in the final state, have been removed from our analysis. We obtain then finally 210 events which will be used for the present analysis.

As the beam contamination (mainly muons) is unknown, direct cross section calculation cannot be carried out. In order to estimate the cross section of reaction (1) we calibrate our events to the cross section of the 4-constrained fitted events belonging to the reaction

$$dp \rightarrow p_s pp\pi^- \qquad (2)$$

The cross section of the reaction $np \rightarrow pp\pi^-$ at 5.9 GeV/c, including a 5 percent Glauber effect correction, has been reported by W. Gage et al.[7] to be 1.4 ± 0.1 mb. The ratio of 210 coherent events of reaction (1) to 607 events of the reaction (2) gives us the cross section $\sigma = 0.46 \pm 0.09$ mb for the reaction $dp \rightarrow dp\pi^+\pi^-$ at 11.9 GeV/c.

As a further check we also calculated our coherent cross section by using the observed 1-constraint reaction

$$dp \rightarrow p_s pn\pi^+\pi^- \qquad (3)$$

and the cross section $\sigma = 4.75 \pm 0.25$ mb (including 5 percent Glauber correction) reported by A.R. Kirschbaum et al.[8] for the reaction $pn \rightarrow pn\pi^+\pi^-$ at 5.9 GeV/c. We obtain then the coherent cross section $\sigma = 0.40 \pm 0.07$ mb for reaction (1). The combined use of reaction (2) and (3) gives us finally a cross section of 0.42 ± 0.08 mb.

The differential production cross sections $d\sigma/dt_d$ and $d\sigma/dt'_d$ (where t_d is the squared momentum transfer between the incident and outgoing deuteron, and $t'_d = |t_d - t_{min}|$) are shown in Fig.1. Contrarily to experiments using the deuteron as target there are no losses of events with small values of t_d and t'_d. Fitting the exponential behaviour of the differential cross sections for $0.02 < |t_d| < 0.12 (GeV/c)^2$ and for $t'_d < 0.12 (GeV/c)^2$ to the functions $A \exp(-b_d |t_d|)$

and $A' \exp(-b'_d t'_d)$ we obtained the slope parameters $b_d = 19.5 \pm 3.3 (GeV/c)^{-2}$ and $b'_d = 30.3 \pm 2.5 (GeV/c)^{-2}$. As can be seen in Fig.2.a and 2.b, these values are nearly equal to the slopes obtained in $\bar{p}d$ and pd experiments at different incident momenta.

The total channel cross sections for the reactions $pd \to pd\pi^+\pi^-$(1,2) and $\bar{p}d \to \bar{p}d\pi^+\pi^-$(4,5,6) (see Fig.2.c) obtained with deuteron targets are generally calculated by extrapolating the t_d or t'_d distributions above $\sim 0.2 (GeV/c)^2$ using an exponential function. Thus in order to compare our cross section with the available pd and $\bar{p}d$ data we have extrapolated our differential cross sections $d\sigma/dt_d$ and $d\sigma/d'_d$ for $|t_d|$, $t'_d > 0.12 (GeV/c)^2$ by the same method. Then we obtain for both t_d and t'_d extrapolations the $dp \to dp\pi^+\pi^-$ cross section $\sigma = 0.33 \pm 0.08$ mb shown in Fig.2.c.

3. GENERAL FEATURES

The comparison between the triangle plots of the effective masses of the system $d\pi^+$ [$M(d\pi^+)$] versus $p\pi^-$ [$M(p\pi^-)$] and $d\pi^-$ [$M(d\pi^-)$] versus $p\pi^+$ [$M(p\pi^+)$] (Fig.3) shows that reaction (1) is dominated by Δ^{++} and d^{*o} production. The $M(p_{\pi^+})$ mass distributions (Fig.4.a) were fitted with an incoherent mixture of peripheral phase space and a Breit-Wigner function for the $\Delta^{++}(1236)$. The peripheral phase space calculated by a Monte Carlo method was obtained by weighting each event by an $e^{-b_d |t_d|}$ factor using our fitted slope parameter b_d. The best values for the mass and width of the Δ^{++} obtained in this one-dimensional fit were $E_0 = 1.205 \pm 0.007$ GeV and $\Gamma = 0.125 \pm 0.022$ GeV. The low peripheral phase space background accounts for less than 10 percent of the events.

Even though the d^{*o} mass enhancement in the $M(d\pi^-)$ mass distribution (Fig.4.b) is not a real resonance[9], this distribution can be well described

by an incoherent mixture of peripheral phase space and a Breit-Wigner function. The best fit to the $d\pi^-$ mass enhancement was obtained for

$$E_0 = 2.200 \pm 0.012 \text{ GeV}$$

$$\Gamma = 0.149 \pm 0.034 \text{ GeV}$$

These values are very close to those found for the d^{*++} enhancement observed in $\bar{p}d$ experiments[4,6]. The contribution of d^{*0} in our experiment is about 50 percent.

Figure 4.c shows the $p\pi^+\pi^-$ mass $M(p\pi^+\pi^-)$ distribution of the 210 events. As could be seen from the Chew-Low plot t_d versus $M(p\pi^+\pi^-)$, of Figure 5 the low mass enhancement $M(p\pi^+\pi^-) < 1.5$ GeV corresponds almost completely to events with low momentum transfer $|t_d| < 0.12(\text{GeV/c})^2$. This suggest a diffraction dissociation mechanism in which $p \to p\pi^+\pi^-$ or rather $p \to \Delta^{++}\pi^-$.

Excluding the d^* by a simple mass cut $[M(d\pi^-) > 2.4(\text{GeV/c})^2]$ we obtained a subsample of N = 99 events. This sample has been used to check if our data are compatible with t and s channel helicity conservation. If helicity is conserved in the t (or s) channel, the outgoing particles (for instance the π^-) have to show isotropic azimuthal angular distributions about the z axis of the Gottfried-Jackson (or helicity) frame[10]. The z axis are defined in the $(\Delta^{++}\pi^-)$ c.m. system, z_J along the incoming proton and z_H opposite to the outgoing deuteron direction. The y axes of the two frames are defined by the production plane $\vec{d}_{inc} \times \vec{d}_{out}$.

As the Δ production is very important we considered only the experimental distributions of the π^- azimuthal angles φ_J and φ_H, shown in Figure 6. Helicity seems not to be conserved in the t channel. Within our limited statistics, the φ_H distribution is compatible with isotropy.

5. CONCLUSION

We have studied the $dp \to dp\pi^+\pi^-$ reaction at 11.9 GeV/c deuteron incident momentum. By using the known cross sections of the $pd \to p_s pp\pi^-$ and $pd \to p_s pn\pi^+\pi^-$ channels we have estimated the cross section of the $dp \to dp\pi^+\pi^-$ reaction to be 0.42 ± 0.08 mb. We have parametrized by exponential functions the distributions of the four momentum transfer t_d between the incident and outgoing deuteron and of the $t'_d = |t_d - t_{min}|$ quantity. The experimental slopes found here are nearly equal to the values obtained in different pd and $\bar{p}d$ experiments at various incident momenta.

The main features of the $dp \to dp\pi^+\pi^-$ reactions at 11.9 GeV/c are the important $\Delta^{++}(1236)$ ($\sim 90\,\%$) and d^{*0} ($\sim 50\,\%$) production rates. The low mass enhancement of the $p\pi^+\pi^-$ (or rather $\Delta^{++}\pi^-$) system peripherically produced, suggests the diffraction dissociation of the target proton. Using the π^- azimuthal distributions, we attempted to see wether or not these distributions are compatible with helicity conservation in the s or t channel. The statistics is too meagre to drew any definit conclusion. However, within the present statistics, the data are compatible with s channel helicity conservation.

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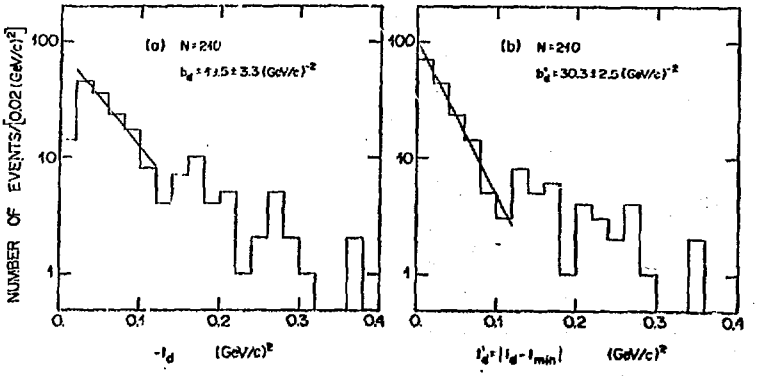

Figure 1

(a) Distribution of the four momentum transfer t_d between the incident and outgoing deuteron ; (b) Distribution of $t'_d = |t_d - t_{min}|$.
The straight lines represent the fits to the exponential functions in the range $0.01 < |t_d| < 0.12$ and $0. < t' < 0.12 (GeV/c)^2$.

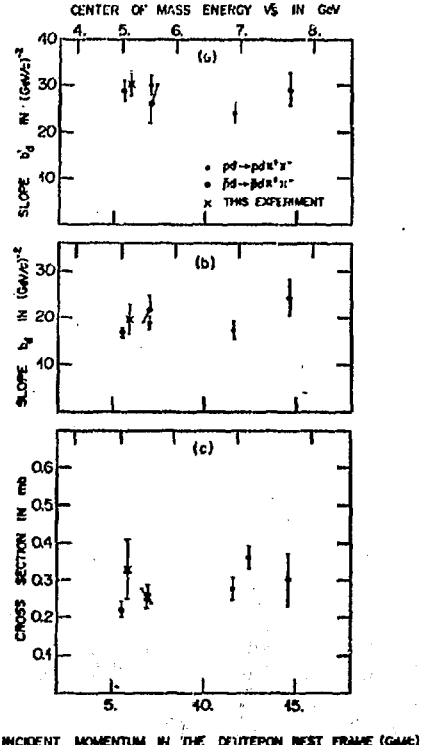

Figure 2

Comparison of the slopes obtained by fitting the t'_d (a) and t_d (b) distributions with $e^{b_d t_d}$ and $e^{-b'_d t'_d}$ functions for the $pd \to pd\pi^+\pi^-$ and $\bar{p}d \to \bar{p}d\pi^+\pi^-$ reactions. Our cross section shown here was obtained assuming an exponential form for the differential cross section as described in the text.

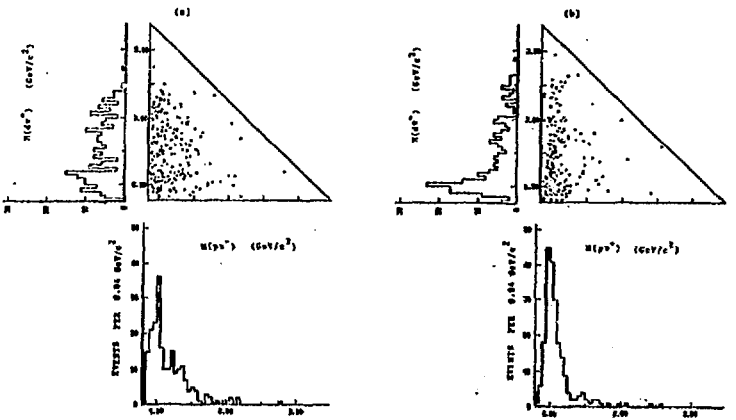

Figure 3

Comparison between the triangle plots : (a) $M(d\pi^+)$ versus $M(p\pi^-)$ and (b) $M(d\pi^-)$ versus $M(p\pi^+)$.

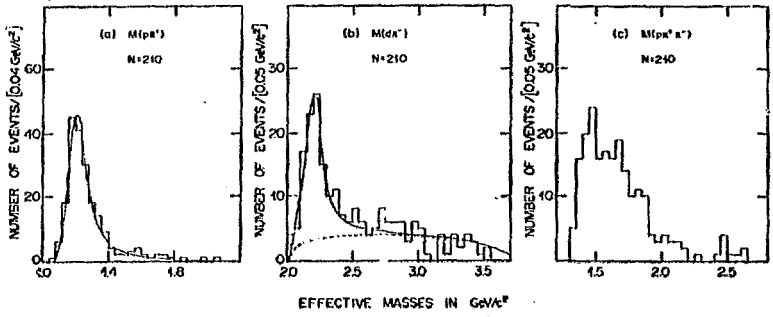

Figure 4

Effective masses distributions obtained from the reaction $dp \to dp\pi^+\pi^-$: (a) $M(p\pi^+)$; (b) $M(d\pi^-)$; (c) $M(p\pi^+\pi^-)$ The solid lines in (a) and (b) represent a fit to an incoherent mixture of peripheral phase space and Breit-Wigner functions as described in the text. The dashed line in (b) represents the peripheral phase space background.

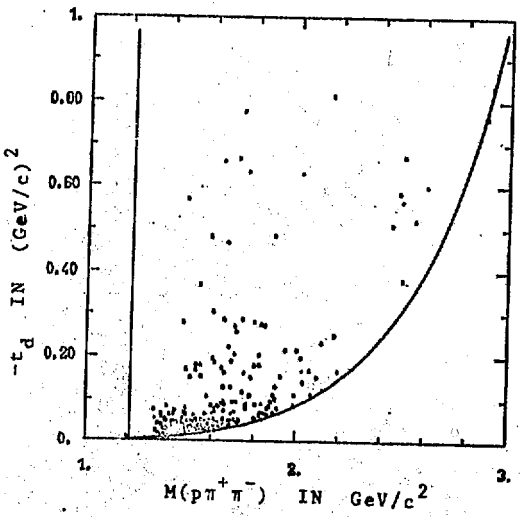

Figure 5

Chew-Low plot $|t_d|$ versus $M(p\pi^+\pi^-)$ for the reaction $dp \to dp\pi^+\pi^-$

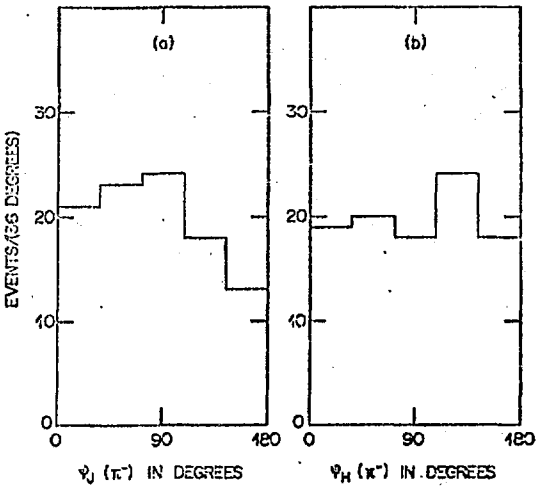

Figure 6

Folded distributions of the azimuthal angle of the outgoing π^- in the (a) Gottfried - Jackson and (b) helicity frames for events outside the d^* band ($M(d\pi^-) > 2.4$ GeV/c^2).