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Evidence For Double Pomeron Exchange At Fermilab Energies

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ABSTRACT

Double Pomeron Exchange (DPE) events from the reaction $pp \to pp\pi^+\pi^-$ at 200 and 300 GeV/c have been identified using the Fermilab 30-inch bubble chamber-wide gap spark chamber hybrid system. Cross sections, distributions in the square of the four-momentum transfer and proton-proton azimuthal angle are in general agreement with theoretical considerations.

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A number of experimental searches[1-5] for the Double Pomeron Exchange (DPE) process have been made in the reactions (1) $pp \to pp\pi^+\pi^-$, (2) $\pi^-p \to \pi^-p\pi^+\pi^-$ and (3) $pp \to ppX$. The existence of a process in which the Pomeron occurs more than once is a crucial ingredient in not only understanding the properties of the Pomeron, but also in elucidating the very notion of the Pomeron[6-9]. Because of the small cross sections involved, such experiments are generally difficult and consequently little is known of the nature of the DPE process.

We present a study of the DPE process based on 396 (633) events of reaction (1) obtained in the Fermilab 30-inch hydrogen bubble chamber-wide gap spark chamber hybrid system[10] at 200 (300) GeV/c. These data result from two measurement passes of a total of 3377 (4153) four-prong events. We have required the identification of a slow proton (up to ~1.4 GeV/c) by ionization and a minimum length of 20 cm for forward-going tracks. Each event was processed through the kinematic fitting program SQUAW and required to give a four-constraint probability > 4%. In addition, all hypotheses giving a Feynman x-value > 0.5 of the π^+ were rejected. This condition is consistent with the observed π^+ x-distribution for $x < 0$, which by symmetry must be identical to that for $x > 0$.

We plot in Fig. 1(a,b) the confidence level distributions (CLD) of "target dissociation" ($m_1 > m_2$, sample A) and "beam dissociation" ($m_1 < m_2$, sample B) events, where $m_1(m_2)$ is the mass of the $P_{fast}\,\pi^+\pi^-$ ($P_{slow}\,\pi^+\pi^-$) system. Possible contamination is evidenced by the nonuniformity of both distributions and likely originates from $pp\pi^+\pi^-\pi^\circ$, $pp\pi^+\pi^-2\pi^\circ$, ..., $pp\pi^+\pi^-n\pi^\circ$ reactions (with respective cross sections σ_1, σ_2, ..., σ_n). Assigning probabilities P_1, P_2, ..., P_n for these

π° multiplicity of 1.5[12], we find the contamination in sample A(B) to be 11±6 (24±9)%, in good agreement with the previously quoted results.

Finally, we have studied a sample of events with complete bubble chamber-spark chamber information. When we utilize the much improved momentum resolution given by the hybrid system[10], we find that 6 out of 26 events in sample A and 13 out of 37 events in sample B must be rejected on the basis of their respective CLD's, indicating contaminations of 23±11% and 35±12% respectively for the combined 200 and 300 GeV/c data. The CLD's of these events with (dashed histogram) and without (solid histogram) spark chamber information are shown in Fig. 1(g,h). Again, these results are consistent within errors with previous results, leading us to conclude that we have identified the sources and magnitude of background in our event sample.

After correcting for contamination, the cross section for reaction (1) with a slow proton at 200 (300) GeV/c is 605±61 (659±63)μb[13]. This correction is based on the results of the three techniques discussed previously. Our value at 200 GeV/c is in good agreement with that of Derrick et al.[14] (680±140μb).

Turning to a discussion of the DPE process, we define the Z variable after Chew and Chew[2,7]: $Z_i = \ln(s/m_i^2)$, where s is the overall center-of-mass energy squared. We further define $t_1(t_2)$ as the square of the four-momentum transfer between the target proton and slow proton (projectile proton and fast proton) and, for the present discussion, DPE events are defined as those satisfying the requirements Z_1, $Z_2 > 2.3$; $|t_1|$, $|t_2| < 0.3$ $(\mathrm{GeV/c})^2$. The CLD's of these events, shown shaded in Fig. 1(a,b), are uniform; however twice as many events are observed in sample B(86) as in sample A(43). Accordingly, we have studied the effects

lower bound on Z_1 and Z_2. The solid curve is our calculation, based on the work of Chew and Chew[7]. Also shown is a second calculation (dashed curve), similar to that of ref. 7, but using Pomeron terms resulting from fits to the triple Regge model[16]. The data compare favorably with both calculations, but are somewhat high when the lower bound on Z is less than $\sim$2.6. This could be due to overlap of singly diffractive events in this region.

This new measurement of the Z dependence of the DPE cross section permits a direct comparison with previous results from the ISR. For example, the 20±4 μb cross section recently reported at the CERN ISR at $s \sim 500$ GeV^2 agrees quite well with our value of 19±6 μb for $Z > 3.0$, where it has been pointed out[17] that the kinematics of the two experiments overlap to a considerable degree.

FIGURE CAPTIONS

Fig. 1. Confidence level distributions for "target dissociation" (A) and "beam dissociation" (B) samples at 200 and 300 GeV/c for: (a,b) all examples of reaction (1) with a slow proton, with background events removed (dashed) and DPE events shaded; (c,d) fake $pp\pi^+\pi^-$ events, with DPE events shaded; (e,f) events fitting $pp\pi^+\pi^-$, but with a visible electron pair, and DPE events shaded; and (g,h) events with complete hybrid data, plotted using only bubble chamber data (solid) and the complete bubble chamber-spark chamber data (dashed).

Fig. 2. (a) Combined t_1- and t_2-distribution for events at 200 and 300 GeV/c satisfying the DPE criteria. The solid curve represents the form $e^{-9|t|}$; (b) distribution of the proton-proton transverse momentum azimuthal angle for the same events as in (a) and for all events of reaction (1) (dashed); and (c) cross sections for the DPE process versus the lower bound on Z_1 and Z_2 compared with calculations based on ref. 7 (solid curve) and ref. 16 (dashed curve).

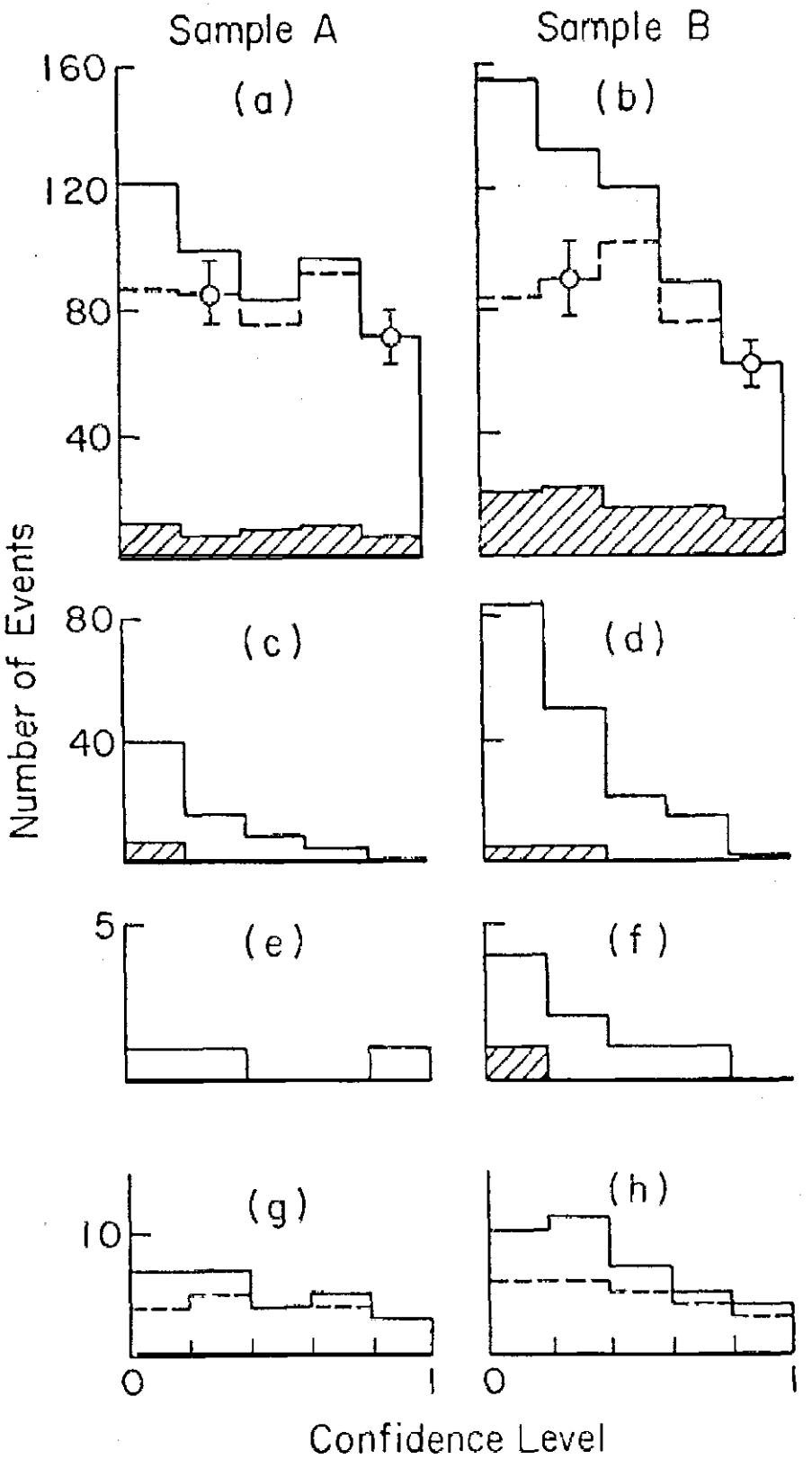
Sample A
Sample B
160
120
80
40
(a)
(b)
80
40
(c)
(d)
5
(e)
(f)
10
(g)
(h)
0
1
0
1
Number of Events
Confidence Level

Figure 1