SLAC-PUB-1657
LBL-4292
September 1975
(T/E)

DIFFRACTIVE NUCLEON DISSOCIATION BY $\pi^{\pm}$ AT 14 GeV/c AND A COMPARISON WITH p p AT 1400 GeV/c*

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ABSTRACT

Data is presented on the reactions $\pi^{\pm}p \to \pi^{\pm}p\pi^{0}$ and $\pi^{\pm}p \to \pi^{\pm}n\pi^{+}$ from the SLAC hybrid bubble chamber triggered on a fast forward pion. Diffractively produced resonance structure is observed, closely resembling that seen in $pp \to pn\pi^{+}$ at ISR energies.

INTRODUCTION

We have performed an experiment using 14 GeV/c π^{+} and π^{-} in a hybrid hydrogen bubble chamber in order to study the diffractively dissociated proton final state. In this paper we consider the reactions

$$\pi^{\pm}p \to \pi^{\pm}(p\pi^{0}) \qquad (1a)$$

and

$$\pi^{\pm}p \to \pi^{\pm}(n\pi^{+}) \qquad (1b)$$

where the bracketed di-particle system is of low mass recoiling against a fast forward pion with the same charge as the beam. These reactions have the particular advantage that the $N\pi$ system is relatively simple and the spin-parity states present may in principle be obtained from a study of their angular distributions. We also compare the excitation spectrum with that found in $pp \to p(n\pi^{+})$ at an equivalent beam energy of 1400 GeV/c on the CERN ISR.

In this experiment the SLAC 40" bubble chamber lamps were flashed when a downstream magnetic wire chamber spectrometer showed a scatter with recoil mass above 1.1 GeV had occurred. Experimental details may be found in Ref. 1. These measurements were used off-line with the film digitizations to provide mass resolution of 15-40 MeV for the diffractive systems of reaction (1). Equivalent sensitivities, e, for $\pi^{+}(\pi^{-})$ are 89 (40) events/μb when the events are weighted by the inverse of their geometrical acceptance (average weight ~ 1.8), and by e^{-1}.

RESULTS

The excitation spectra for reactions (1) show evidence for $\Delta^{+}(1236)$, a peak at ~ 1350 MeV, and structure at ~ 1650 MeV. These latter structures will be discussed later. Here we describe the lower mass region.

We may describe the angular distributions in terms of unnormalized moments

*Work supported by the U.S. Energy Research and Development Administration.

(Presented at the Annual Meeting of the Division of Particles and Fields, American Physical Society, Seattle, Washington, August 27-29, 1975)

$$Y_\ell^m = \frac{1}{e} \sum_{i=1}^{Nevt} Y_\ell^m (\theta_i , \phi_i) w_i = \sigma < Y_\ell^m > \qquad (2)$$

for a given mass and $t_{\pi \to \pi}$ region, where θ_i and ϕ_i are angles in the $N\pi$ t-channel or Gottfried-Jackson[2] analysis system.

The Δ^+ is expected to be produced by ρ exchange with the Stodolsky-Sakurai[3] mechanism. The decay distribution $1+3 \sin^2\theta \sin^2\phi$ leads to a Y_2^2 moment which we use to identify the Δ:

$$\frac{d\sigma_\Delta}{dtdm} = -\sqrt{\frac{160\pi}{3}} < Y_2^2 > \frac{d\sigma}{dtdm} . \qquad (3)$$

This quantity is shown in Fig. 1 for the average of π^+ and π^- cross sections of reaction (1a) in the Δ region. The superimposed curve is the form suggested by Kane[4] for this process, which gives a satisfactory description. The total $\Delta \to p\pi^0$ cross section is 26.5±5 μb.

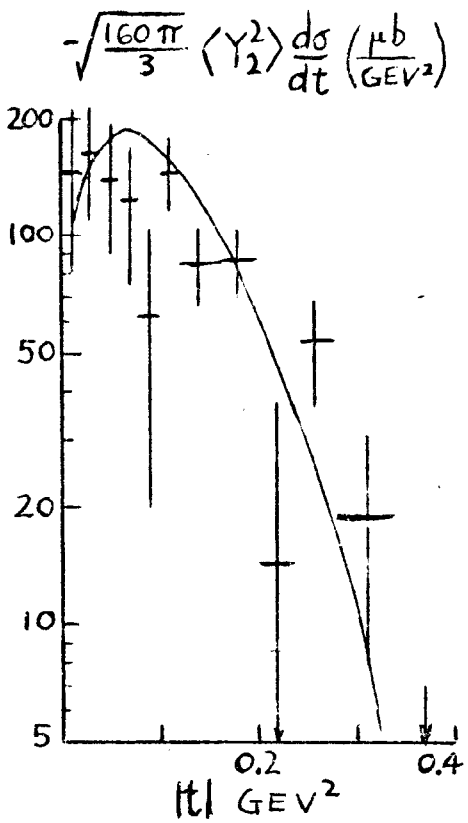

Fig. 1. Deduced $\Delta(1236)$ t distribution, averaged for π^+ and π^- data.

The angular distribution in the Δ region shows a forward-backward asymmetry in the Jackson system such that Y_1^0 changes sign between π^+ and π^- excitation. We have previously shown[5] that this requires the presence of a $J^P=1/2^-$ state (s wave pion) produced by I=0 exchange and interfering with the Δ. We may isolate this Δ-s interference by using the differences of Y_1^0 moments in the π^+ and π^- data. The sum of the Y_1^0 moments will then represent the s-p interference terms where the p-wave was $J^P = 1/2^+$ (produced by I=0 exchange). Figure 2a,b shows half the Y_1^0 differences and sums as functions of t for reactions (1a). It is clear that the projection of the s wave state on the Δ has a sharp t dependence ($d\sigma_\Delta/dt$ is relatively flat for $|t| \lesssim 0.1$ GeV^2). Fig. 2a indicates an amplitude slope of 17±5 GeV^{-2}. Figure 2b suggests that the p-wave state has a relatively flat t dependence.

In Fig. 2c we show the mass spectrum for reactions (1a) averaged over beam charge to remove Δ-s interference, for the t region $0.01 < |t| < 0.12$ GeV^2, where the s-wave is strong. In Fig. 2d we show the averaged $\bar{Y}_1^0$ moment for the same t cut. Both distributions show peaks at ~ 1350 MeV. $\bar{Y}_1^0$ however may pass through zero near the 1470 MeV

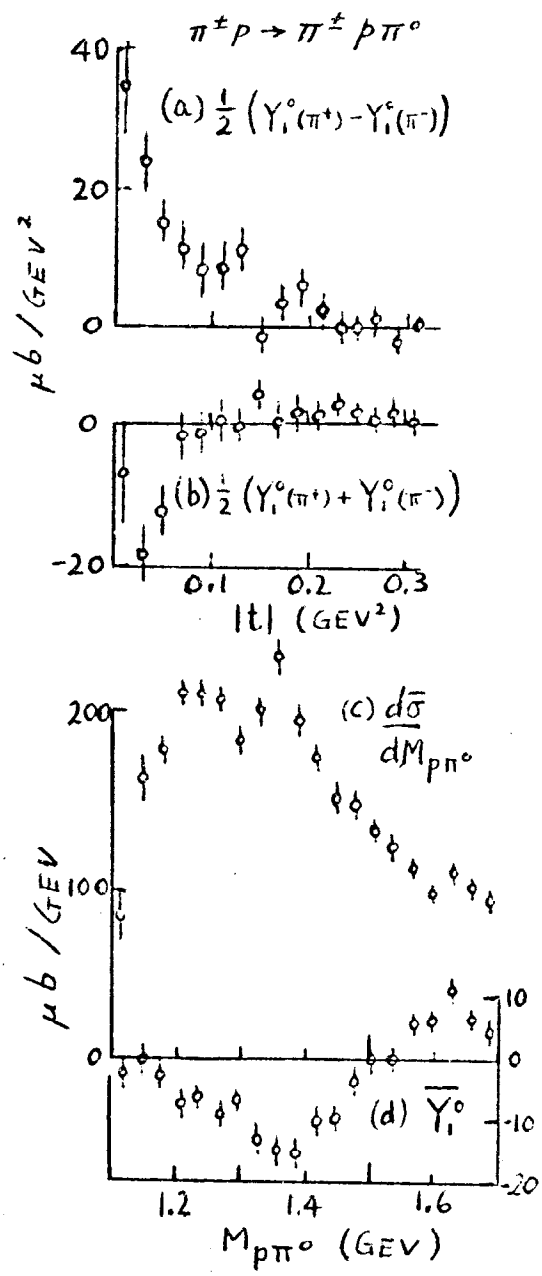

Fig. 2(a,b) Y_1^o difference and sum t distribution for 1.15 < $Mp\pi^o$ < 1.3 GeV(c) mass spectrum for 0.01 < $|t|$ < 0.12 GeV^2 (d) same for Y_1^o average.

resonance value. These results suggest that the p wave diffractive component is strongly skewed to lower masses than seen in πp elastic scattering, in agreement with the conclusion of Lissauer et al.,[6] who studied the reaction $K^+n \to K^+ p\pi^-$ at 12 GeV/c.

COMPARISON WITH ISR RESULTS

The complexity of the angular distributions at higher $N\pi$ mass requires a more detailed analysis which has not been completed. We therefore turn to a comparison of the observed spectrum with that observed in the reaction

$$p\ p \to p\ (n\pi^+) \qquad (4)$$

by a group at the CERN ISR.[7] In both that data and ours a striking change of mass structure is observed if the data is plotted for decay polar angle in the Jackson system forward or backward. In Fig. 3 the histogram shows the ISR data on reaction(4) taken at CM energy W = 53 GeV, equivalent to a beam momentum of ~ 1400 GeV/c (histogram). The points show the average π^+ and π^- cross sections from our data on reaction (1b) at W = 5.3 GeV. The pp data have a cut 0.05 < $|t|$ < 0.8 GeV^2 while the π^+p data have 0.05 < $|t|$ < 0.5 GeV^2.

The results are strikingly similar, especially since the data have independent absolute normalizations (the relative uncertainty is ~ 25%). It appears that the same production mechanism is involved, although the lower energy data has a greater background under the peaks and more Δ^+ signal. This is a remarkable confirmation of the expected energy and particle independence of the diffractive process.

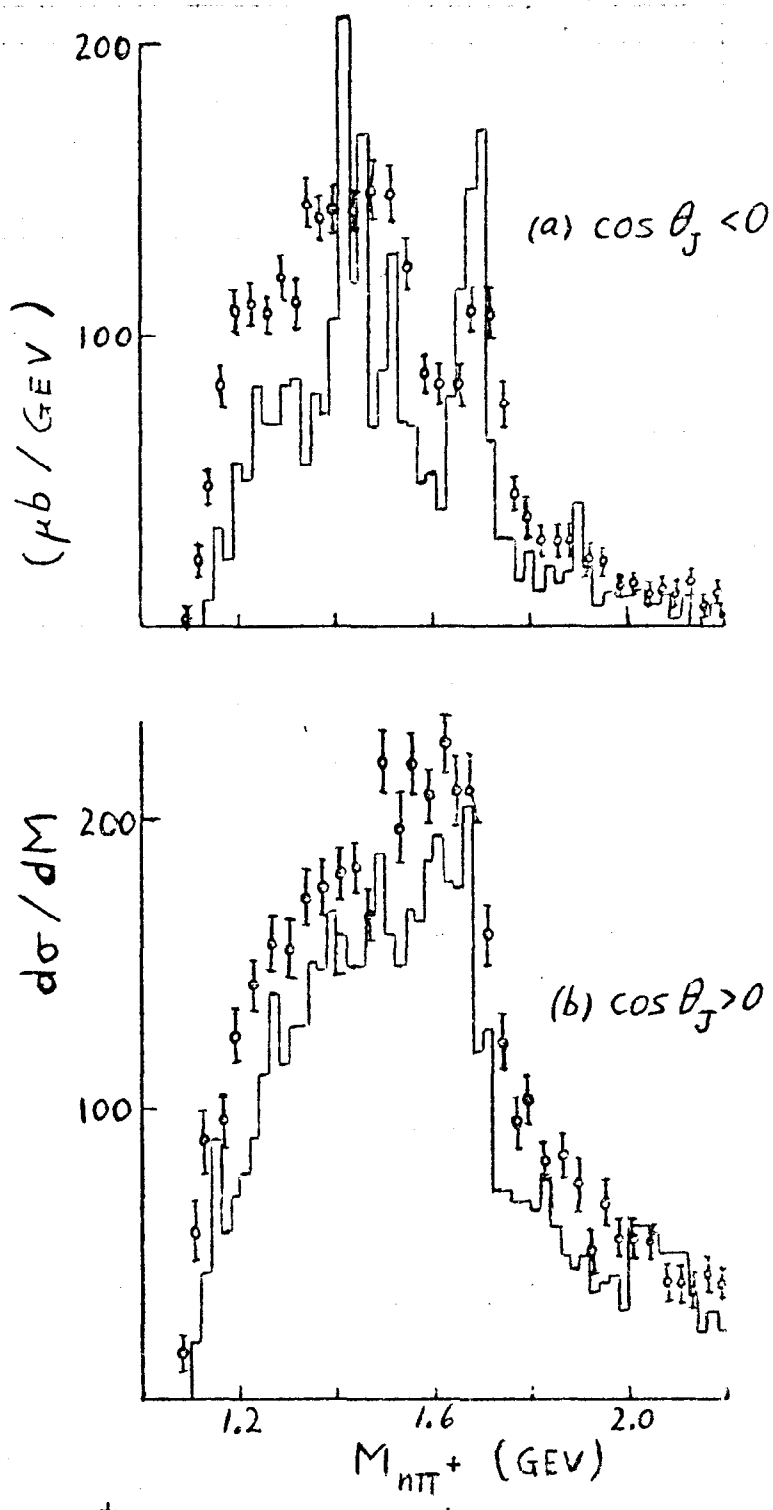

Fig. 3 Mass of $n\pi^+$ system in $pp \to p(n\pi^+)$ at W = 53 GeV (histogram) compared with $\pi^\pm p \to \pi^\pm(n\pi^+)$ at W = 5.3 GeV (circles). (a) Backward decay (b) forward decay. Note that the pp cross sections are for excitation of either proton.

The factorization hypothesis leads one to expect that the Pomeron exchange components of the inelastic spectrum should be in a constant ratio with the elastic scattering, independent of energy and exciting particle, after a factor two reduction in the pp inelastic data because of pp symmetry. The pp/πp elastic ratio is 1.85[1,8,9], so for complete Pomeron dominance the pp data of Fig. 3 should be a factor 3.7 larger than πp. Clearly in most regions the data fail this test, indicating either a large non-diffractive component in the πp case or a breakdown of factorization. In the 1700 MeV mass region the signal above background may still satisfy the factorization relation.[10] We note that a similar test was successful for both reactions at 16 GeV/c,[11] and that Webb et al.,[12] concluded that the cross section for pp $\rightarrow$ pN*(1688) at W = 45 GeV was comparable with that at p_{LAB} = 30 GeV/c.

CONCLUSIONS

We have shown that the low mass Nπ system in $\pi p \rightarrow \pi(N\pi)$ contains, in addition to resonances obeying the Morrison-Gribov Rule[12], a $J^P=1/2^-$ state which peaks sharply at low t values. The P_{11} state furthermore shows an intensity peak strongly skewed to masses below predictions using elastic πp phase shifts.

The excitation spectrum observed is remarkably similar to that observed in the reaction pp $\rightarrow$ p(nπ^+) at 10 times the CM energy.

We wish to thank the SLAC BC Operations Group, under R. Watt, the Experimental Facilities Group under L. Keller, and our data analysis staffs, particularly J. Brown, D. Feick and R. Aintablian, for their willing help. In addition we thank J. Murray and R. Gearhart for the beam design.

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