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Study of diffraction dissociation in 19- and 28-GeV/c pd interactions

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The reaction $pd \to p_{\rm spec} p\pi^- p$ is studied at 19 and 28 GeV/c with data from the Brookhaven National Laboratory 80-in. deuterium-filled bubble chamber. In addition, a separate study is made of the low-momentum pion spectra in selected low-multiplicity events presumed to be associated with either of two isospin-conjugate modes of deuteron fragmentation by a 28-GeV/c beam proton. Our results from these complementary studies are that low-multiplicity channels are dominantly of a diffractive nature; however, significant differences seen in the mass spectra and angular correlations in the slow $p\pi^-$ between the 19- and 28-GeV/c data indicate that asymptotic behavior has not been reached, as least at 19 GeV/c. Neither s- nor t-channel helicity conservation is seen in the excitation of the target neutron into a low-mass $p\pi^-$ system. The $N^*(1.4)$ of missing-mass experiments is shown to be a superposition of nucleon-pion and nucleon–two-pion states.

I. INTRODUCTION

Results are reported from a study of neutron diffraction dissociation events in 19- and 28-GeV/c pd interactions in the Brookhaven National Laboratory 80-in. bubble chamber. The reaction of primary interest in this experiment is

$$p + d \to p_{\rm spec} + p + \pi^- + p\,, \qquad (1)$$

where $p_{\rm spec}$ is the spectator proton. A prominent feature of reaction (1) is the characteristic low-mass enhancement in the system formed by the slow proton with the π^-.[1-3] This effect is normally interpreted as the excitation or diffractive dissociation of the target neutron by the beam proton. Although diffraction dissociation processes have been studied with a variety of beam and target particles at several beam momenta, the data reported here are of special value in that two beam momenta, 19 and 28 GeV/c, and are analyzed in the same experiment. Furthermore, neutron dissociation into two charged particles is simpler to study than the dissociation of a charged particle where a minimum of three charged secondaries must be analyzed.

Diffraction dissociation, an inelastic process, bears many features that are similar to elastic diffractive scattering.[4] These features include little energy dependence, no quantum number exchange, a steep differential cross section, and approximately equal cross sections for the dissociation of a particle and its antiparticle. Elastic scattering of pp, πp, and $\gamma p \to \rho^0 P$ are s-channel helicity conserving, but inelastic diffractive processes, in general, seem to fail to resemble elastic scattering in this respect.[2] Approximate t-channel helicity conservation is expected according to Deck-type models of diffraction dissociation.[5] Our data enable us to study a number of the above features in reaction (1).

The study of the nature of the enhancements in the mass spectra of excited nucleon states has long provided some interesting puzzles. Missing-mass counter spectrometer experiments[6,7] designed to study nucleon excitation have revealed a strong broad ($\Gamma \gtrsim 0.2$ GeV) enhancement in the missing-mass spectrum at 1.4 GeV at small values of squared four-momentum transfer ($-t$). This enhancement may consist of one or more resonant states superimposed on top of a Deck-type threshold background.[8] The effects of a superposition of nucleon-pion and nucleon–two-pion contributions to the 1.4-GeV enhancement are examined in this paper by adding the mass spectrum of neutrons dissociating into $p\pi^-$ to that of protons dissociating into $p\pi^+\pi^-$.

A puzzle relating to the 1.4-GeV enhancement was revealed in a missing-mass spectrometer experiment involving proton-deuteron collisions at 19 GeV/c.[7] As in our experiment, the purpose was to study the proton-neutron interaction, i.e., $p + n \to$ "missing mass" $+ p_{\rm forward}$, where $p_{\rm forward}$ is the proton measured with a downstream spectrometer. The Fermi momentum of the target neutron results in a relatively slight broadening of the missing-mass spectrum, i.e., much less than the 0.2-GeV width of the 1.4-GeV enhancement. However, in the 19-GeV/c pd missing-mass experiment, although the broadening due to the Fermi momentum was barely evident in the data, the peak value of the spectrum shifted down to 1.35 GeV from the expected 1.4 GeV. One possible interpretation of this result was that, for dynamical reasons, the pn interaction results in a missing-mass peak at 1.3 GeV at small values of the squared four-momentum transfer, while the corresponding pp interaction results in a peak at 1.4 GeV. In deuterium, the superposition of the separate pn and pp contributions would result in the observed 1.35-GeV peak. Strong nondiffractive channels could give rise to such an effect.

We carried out a complementary study with our 28-GeV/c pd data to search for gross differences between n and p excitations in deuterium in an effort to explain the peculiar 1.35-GeV enhancement. Two isospin-conjugate modes of deuteron dissociation were examined in the reactions

$$p+d\to(p_{\rm spec}+p+\pi^-+\cdots)+p_{\rm forward} \qquad (2a)$$

$$\to(n_{\rm spec}+n+\pi^++\cdots)+p_{\rm forward}\,. \qquad (2b)$$

The two modes of deuteron dissociation studied are shown in parentheses, with the events selected such that the forward proton, $p_{\rm forward}$, has a momentum which is not less than 3 GeV/c smaller than the beam momentum. Reaction (2a) involves a final state with an observed $p\pi^-$ which may be associated with unseen neutral particles, together with the spectator proton, $p_{\rm spec}$. The second mode of deuteron dissociation, (2b), involves an interaction with the target proton. The forward proton is selected in the same manner in the reactions (2a) and (2b), and the dissociation products, in parentheses, are the isospin conjugates of each other. Reaction (2b) is chosen from two-pronged events, while three- and four-pronged events contribute to reaction (2a). As is explained in Sec. II D 3, the slow secondaries in reactions (2a) and (2b) have low enough momenta, in general, that the positive particles can be identified as either pions or protons according to the ionization of the track in the bubble chamber. If the production mechanism is dominantly diffraction dissociation, which involves only vacuum exchange from the beam proton, then the slow particles in reactions (2a) and (2b) must have identical cross sections and momentum spectra. In a comparison of the π^+ and π^- spectra in these two reactions, any significant differences between the two would indicate strong nondiffractive components in the production mechanism and would perhaps explain the puzzling 1.35-GeV mass enhancement mentioned above.

In Sec. II we describe the manner in which the film data were scanned and measured and how the desired final states were extracted by kinematic fitting procedures and bubble density information. The invariant mass, momentum transfer, and decay angular distributions, as well as cross sections and other information, are given in Sec. III. A summary and conclusions are given in Sec. IV.

II. DATA ANALYSIS

A. Exposures

The deuterium-filled Brookhaven National Laboratory (BNL) 80-in. bubble chamber was exposed to beams of protons at 19 and 28 GeV/c. At each energy some 80 000 pictures have been analyzed. All film taken at 19 GeV/c and half that at 28 GeV/c is 35-mm dark-field, while the remaining 28-GeV film is 70-mm bright-field. The cross section equivalent for all 28-GeV/c events is 2.2 events/μb, and for the 19-GeV events 2.0 events/μb.

B. Scanning

In the 19-GeV/c film all three- and four-pronged events with a stopping proton (the fourth prong is the spectator proton when its momentum $\gtrsim 90$ MeV/c) were scanned for with an efficiency of 91%. In the 28-GeV/c dark-field film such events were required to have a positive, minimum ionizing track within 3° of the beam direction. This maximum angle corresponds to a squared four-momentum transfer to the forward proton of greater than 1 (GeV/c)^2 when the beamlike proton momentum $\gtrsim 20$ GeV/c, which results in a loss of less than 0.5% of the events in reaction (1). About half the 28-GeV/c film was doubly scanned with efficiency 98%. The single-scan efficiency is 91%.

In addition, the 28-GeV/c dark-field film was scanned for two-pronged events which met several criteria: the above 3° cut on a positive track, no stopping proton, and no slow track for which the ionization was inconsistent with the particle's being a π^+. For these events the film was double scanned with 98% efficiency. Cross-section estimates were based on the scanning results from the double-scanned dark field film.

C. Reconstruction

The analysis of this experiment was done using two subsets of the events, which were rough-digitized on image-plane digitizers at Vanderbilt University and Brookhaven National Laboratory. After being measured on the Brookhaven Flying Spot Digitizer (FSD), the events were processed through the Brookhaven National Laboratory TVGP-SQUAW chain, with over-all failure rates of 10–15%. Analysis of remeasured events revealed no important biases. Ionization estimates were computed from the FSD digitizations.

D. Selection of events

1. Single-pion events

The detailed study of diffractive single-pion production was carried out in reaction (1). The four-pronged events with measured spectator protons make four-constraint fits. The three-pronged events are fitted by inserting the unseen spectator momentum. This is done by supplying a track with $p_x = p_y = p_z = 0$, $\Delta p_x = \Delta p_y = 30$ MeV/c, $\Delta p_z = 40$ MeV/c. The fits to events with unseen spectator momentum are, therefore, less reliable since events with very-low-momentum π^0's could be included among the fits.

The events of interest for our study, reaction (1), have two protons slow in the laboratory. We choose the slower of the two to be the spectator (whose momentum must be less than 0.3 GeV/c). The reliability of this selection was investigated with a sample of Monte Carlo–generated events. A $p\pi$ system with mass ~1.3 GeV was allowed to decay isotropically in its rest frame, and the proton momentum spectrum from the decaying 1.3-GeV system was compared to that of the spectator proton generated with a Hulthén distribution.[9] In less than 2% of these events is the proton laboratory momentum from the 1.3-GeV system smaller than that of the spectator proton.

2. Possible contamination of single-pion sample

We have estimate an upper limit on the contamination of the sample of events interpreted as $pd \to p_{\text{spec}} p p \pi^-$ from events with one or more slow π^0's. The main background is likely to be the reaction $pd \to (p\pi^-\pi^0)_{\text{slow}} p_{\text{fast}} p_{\text{spec}}$.

Owing to the uncertainty in the net momentum of the observed final-state particles in the three-pronged events, i.e., when the spectator proton is not seen, an event with one or more very-low-momentum π^0's could be kinematically fitted to reaction (1). To understand the magnitude of such an effect, we examined the momentum spectrum of the π^+ in the four-constraint reaction $pp \to (p\pi^+\pi^-)_{\text{slow}} p_{\text{fast}}$ at 28.5 GeV/c.[10] We have assumed that this two-pion-production final state would have a cross section equal to that of the target-neutron dissociation process $pn \to (p\pi^-\pi^0)_{\text{slow}} p_{\text{fast}}$, although the latter reaction has not been measured in our energy region and it is not possible for us to reliably measure it in our experiment. In fact, it is likely that the $(p\pi^-\pi^0)$ production by neutron excitation has a smaller cross section than $(p\pi^+\pi^-)$ production by proton excitation. The nucleon–two-pion systems include $\Delta(1236)\pi$ intermediate states, and the $p\pi^+$ mode of the $\Delta(1236)$ is strongly favored over other combinations by isospin considerations.

Taking the slow $(p\pi^+\pi^-)$ system as a test sample, we compare the transverse momentum distribution of the π^+ in this system with the missing transverse momentum off of the measured charged tracks in our three- and four-pronged events that fit reaction (1). We find that the four-constraint (seen-spectator) events should have not more than a 5% contamination of events with low-transverse-momentum π^0's, based on the shape of the missing-transverse-momentum spectrum in these events as compared with the π^+ distribution in our test sample. However, the same procedure applied to the unseen-spectator events reveals that the imbalance in transverse momentum is sufficiently large that 35% of these events could have a π^0 with a transverse momentum smaller than that of the π^+ in the test sample.

Longitudinal momentum conservation provides an additional constraint to help eliminate background events. In particular, the over-all energy and momentum conservation constraints are such that the longitudinal and transverse momenta of a slow $(p\pi^-)$ system are restricted to a narrow kinematic region which depends on the $(p\pi^-)$ mass. This kinematic region is bounded by a curve described by a quadratic equation with the longitudinal and transverse momenta as variables and the mass of the $(p\pi^-)$ as a parameter in the equation. We compared the kinematic region inhabited by the low-mass $(p\pi^-)$ from the three-pronged events of reaction (1) with the $(p\pi^-)$, with the same mass, that is part of the $(p\pi^+\pi^-)$ in the reaction $pp \to (p\pi^+\pi^-)_{\text{slow}} p_{\text{fast}}$. In this manner, we were able to make a quantitative estimate of the fraction of events that might falsify the final state of interest. We set an upper limit on the π^0 contamination to be ~15% for the whole pd sample and ~10% for events with $|t| < 0.1$ (GeV/c)^2.

3. Events selected for deuteron fragmentation study

This sample was selected to look for differences between the production of slow π^-'s and π^+'s from neutron and proton interactions, respectively, in the deuteron fragmentation reactions (2a) and (2b) described in the Introduction. As explained above in part B, the two-, three-, and four-pronged events in the dark field 28-GeV film were required to have a fast forward positive track within 3° of the beam direction whose momentum differed in magnitude by < 3 GeV/c from the beam momentum. Since the momentum of the fast track could not be measured to better than about 10%, we had to make this difference 3 GeV/c to include most candidate events. The fast track selected in this manner may be a positive pion instead of a proton, but it is extremely unlikely since this would require three (including the spectator) slow baryons in the final state.

It is crucial to be able to properly identify the slow particles if a valid comparison of π^+ against π^- in reactions (2a) and (2b) is to be made. To identify the slow particles by ionization, only those with momentum less than 1 GeV/c were analyzed. This cut on the slow proton in the three- and four-prongs, reaction (2a), causes a loss of events compared to the two prongs which involve slow neutrons, reaction (2b), whose momentum we cannot measure. However, requiring the momentum of the fast proton in reaction (2a) to be within 3 GeV/c of the beam momentum has the effect that the momentum distribution of the slow proton (p) falls rapidly as a function of its increasing momentum. The shape of the momentum spectrum of slow protons with momentum greater than 1 GeV/c (i.e., those that cannot necessarily be identified by ionization) can be estimated by extrapolation from the proton spectrum below 1 GeV/c and by comparison with the momentum spectra of the slow protons in the fitted reactions $pd \to p_{\rm spec}(p\pi^-)_{\rm slow}p$ fast and $pp \to (p\pi^+\pi^-)_{\rm slow}p_{\rm fast}$. These considerations lead us to estimate that $(13 \pm 2)\%$ of the slow protons of reaction (2a) are lost by the cut requiring the momentum to be less than 1 GeV/c. We include this correction in our results. The 1-GeV/c cut does not result in an appreciable loss of π^+'s in reaction (2b) since the pion momentum spectrum falls very rapidly with increasing momentum.

III. RESULTS

A. Properties of the nucleon-pion system

In the following discussion, we treat reaction (1) as a quasi-two-body process in which the produced π^- is associated with the low-momentum secondary proton, assuming that we have properly accounted for the spectator proton. Thus, we view reaction (1) as if

$$p + n \to n^* + p_f, \quad n^* \to p_s + \pi^- \qquad (3)$$

where n^* represents the excited state of the target neutron which may or may not be resonant and p_s and p_f are the slow and fast final-state protons, respectively. In this analysis, we arbitrarily assign the π^- to be associated with p_s and do not apply any other criterion for assigning the π^- with either p_s or p_f.

1. Cross sections

The cross section of reaction (1) at 19 and 28 GeV/c is given in Table I. No attempt has been made to introduce any screening corrections. These cross sections are strictly for the proton-deuteron reaction resulting in three final-state protons and a single π^-.

2. Mass and momentum transfer dependence

The invariant mass of $p_s\pi^-$ of reaction (3) is shown in Fig. 1 at 19 and 28 GeV/c for $|t'| < 0.1$ (GeV/c)^2, part (a), and for $|t'| > 0.1$ (GeV/c)^2, part (b) of Fig. 1. The quantity $t' \equiv t - t_{\rm min}$, where t is the squared four-momentum-transfer from the beam to the forward proton, or equivalently, from the neutron to the n^*. $t_{\rm min}$ is the minimum value of t kinematically allowed for a given n^* mass. We find, as shown in part (a), that the $p_s\pi^-$ spectrum is essentially the same at the two beam momenta for $|t'| < 0.1$ (GeV/c)^2, although the 19-GeV/c spectrum appears somewhat broader than that at 28 GeV/c. We note also that at both beam momenta the peak of the n^* spectrum is at a mass of about 1.3 GeV. At $|t'| > 0.1$ (GeV/c)^2, part (b) of Fig. 1, the shapes of the 19- and 28-GeV/c spectra have broadened considerably compared with the shape at $|t'| < 0.1$ (GeV/c)^2. The 1.3-GeV peak has disappeared and there is some indication of resonance production in the 1.2-, 1.5-, and 1.65-GeV mass regions in the 19-GeV/c data. At 28 GeV/c, the peaks at 1.2 and 1.65 are not evident.

In Fig. 2 we display the t' distributions for various mass intervals at 19 and 28 GeV/c. These distributions are fitted to the exponential form $e^{-b|t'|}$ for small t' values since the entire t' distribution cannot be fitted with a single exponential; it becomes flatter at large t'. The b parameter is computed for $|t'| < 0.2$ (GeV/c)^2 and $|t'| < 0.4$ (GeV/c)^2 for n^* mass less than 1.4 GeV and greater than 1.4 GeV, respectively. The results at 19 and 28 GeV/c are in very good agreement with each other; the slopes (b) are steep at

TABLE I. Cross section for the reaction $pd \to p_{\rm spec}pp\pi^-$.

Incident momentum	Cross section
19 GeV/c	710 ± 20 μb
28 GeV/c	630 ± 35 μb

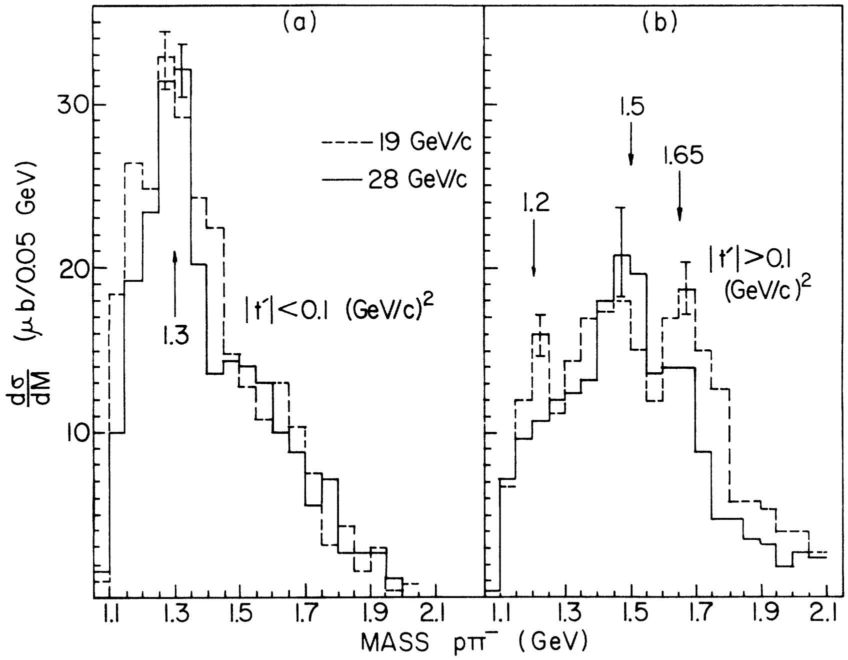

FIG. 1. Distribution of the invariant mass of $p_s\pi^-$ in the reaction $p+n\to p_s+\pi^-+p_f$ at 19 and 28 GeV/c for (a) $|t'| < 0.1$ (GeV/c)^2 and (b) $|t'| > 0.1$ (GeV/c)^2.

low n^* mass and become flatter as the n^* mass is increased. The values of b are plotted in Table II.

3. The 1.4-GeV enhancement in counter spectrometer experiments

As discussed in the Introduction, the 1.4-GeV enhancement is the most striking characteristic structure seen in missing-mass counter spectrometer experiments performed to study nucleon excitation. To study this effect, we add the $p_s\pi^-$ distribution from our 28-GeV pd data to the $p_s\pi^+\pi^-$ spectrum from a corresponding sample of 28.5-GeV pp data for the reaction

$$p+p\to(p_a\pi^+\pi^-)+p_b\,.$$

Events are chosen such that $|t'|<0.1$ (GeV/c)^2 in reaction (3). A similar cut is made in reaction (4) where there are two final-state protons, p_b is like p_f and p_a is like p_s of reaction (3). These mass distributions are shown in Fig. 3, where the $p_a\pi^+\pi^-$ spectrum is arbitrarily normalized to have an area equal to that of the $p_s\pi^-$ mass spectrum. It is clear that the sum of the two distributions yields a broad low-mass enhancement peaking at 1.4 GeV, just as seen in the missing-mass pp experiments. Our procedure gives a plausible description of the 1.4-GeV enhancement in terms of nucleon-pion and nucleon-two-pion contributions. A more accurate analysis for proton dis-

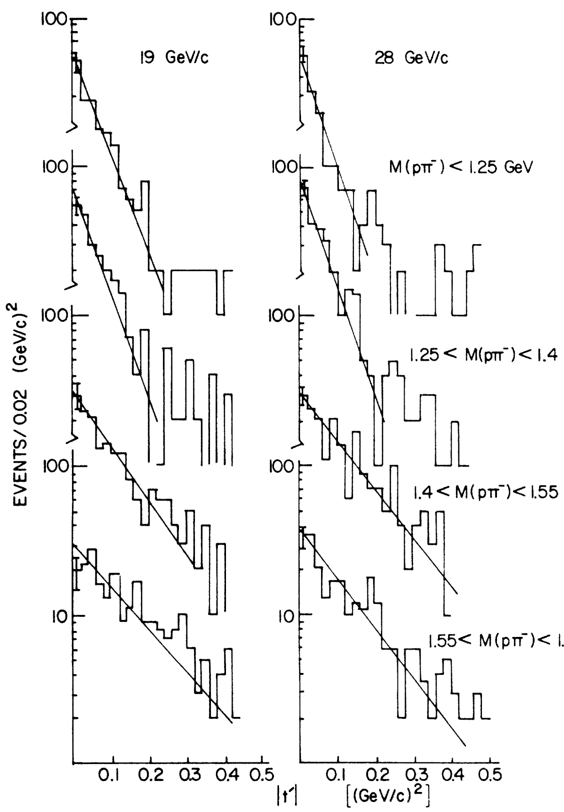

FIG. 2. Distribution of t' at 19 and 28 GeV/c for the indicated $p_s\pi^-$ mass intervals in the reaction $p+n\to p_s+\pi^-+p_f$. Straight line fits correspond to the numbers in Table II.

TABLE II. Slope parameters from fits to $d\sigma/dt, \propto e^{-b|t'|}$.

$p\pi^-$ Mass interval (GeV)	$\|t'\|$ interval [(GeV/c)^2]	Slope parameter b [(GeV/c)$^{-2}$] 19 GeV/c	28 GeV/c
<1.25	<0.2	15.4±1.4	17.1±1.3
1.25–1.40	<0.2	16.2±1.1	17.1±1.1
1.40–1.55	<0.4	8.6±0.6	7.8±0.6
1.55–1.80	<0.4	6.7±0.4	7.6±0.5

sociation would have to include all the constituent states which are not easily detectable without observing the neutrals as well as the charged particles. For example, proton dissociation would include $p\pi^0$, $n\pi^+$, $p\pi^+\pi^-$, $p\pi^0\pi^0$, and $n\pi^+\pi^0$, plus contributions from the higher multiplicity states, which are known to contribute very little at mass near 1.4 GeV.[11] Morrison has also noted the compound nature of the 1.4-GeV enhancement.[3]

4. Angular correlations in the n^* system and tests of s- and t channel helicity conservation.

Polar and azimuthal angular distributions of the $p_s\pi^-$ in the n^* system of reaction (3) are studied and displayed in Fig. 4 for values of $|t'|<0.1$ (GeV/c)^2. These angles are computed in t-channel (Jackson) frame and in the s-channel (helicity) frame.[12] Separate plots are shown for n^* mass less than and greater than 1.4 GeV for both the 19- and 28-GeV/c data. Also shown in an asymmetry quantity $R=(F-B)/(F+B)$, where we divide each plot down the middle and F and B, respectively, denote the "forward" and "backward" contributions in each plot. The lack of symmetry in the polar angle plots, particularly for mass greater than 1.4 GeV, is indicative of the interference

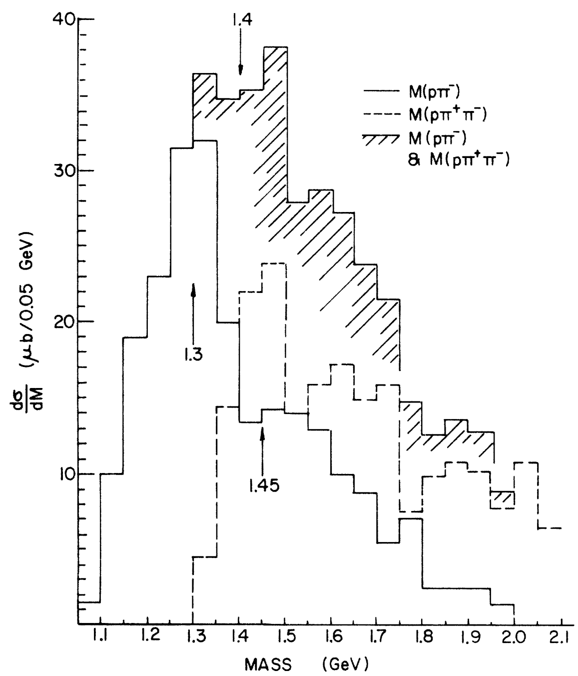

FIG. 3. Distributions of the $p_s\pi^-$ invariant mass in the reaction $p+n\to p_s+\pi^-+p_f$ and the $p_a\pi^+\pi^-$ invariant mass in the reaction $p+p\to p_a+\pi^++\pi^-+p_b$, and their sum, for $|t'|<0.1$ (GeV/c)^2 at 28 GeV/c. The pp data are normalized to the same cross section as the pn data.

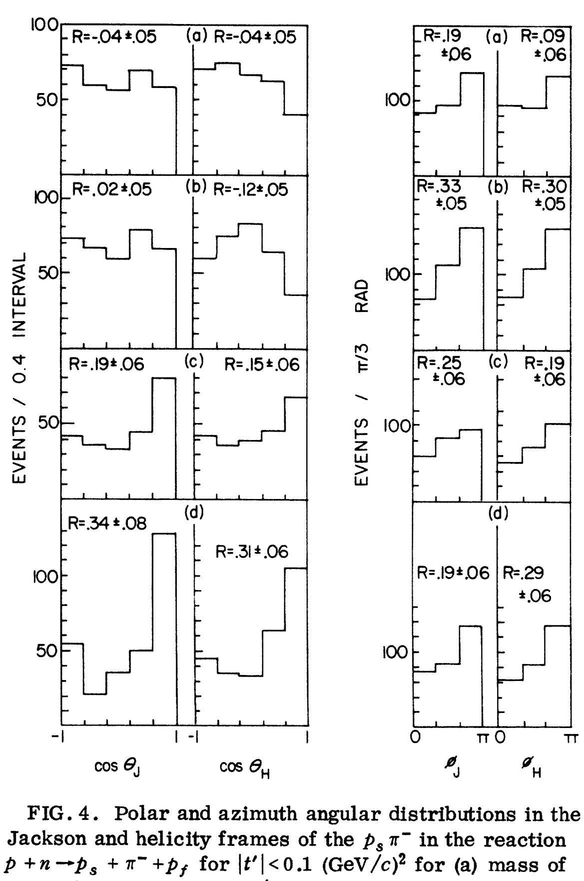

FIG. 4. Polar and azimuth angular distributions in the Jackson and helicity frames of the $p_s\pi^-$ in the reaction $p+n\to p_s+\pi^-+p_f$ for $|t'|<0.1$ (GeV/c)^2 for (a) mass of $p_s\pi^-<1.4$ GeV at 19 GeV/c, (b) mass of $p_s\pi^-<1.4$ GeV at 28 GeV/c, (c) mass of $p_s\pi^->1.4$ GeV at 19 GeV/c, and (d) mass of $p_s\pi^->1.4$ GeV at 28 GeV/c.

between different angular momentum states. Also, it is seen that the azimuthal distributions are not flat and therefore inconsistent with either s- or t-channel helicity conservation. The quantity R is seen to change between 19 and 28 GeV/c in most of the distributions.

B. Deuteron fragmentation study; comparison of π^+ and π^- spectra

Table III shows results of the study of the π^+-π^- comparison described in the Introduction for reactions (2a) and (2b). We described the isospin-conjugate reactions (2a) and (2b) and the fact that the π^+ and π^- spectra must be identical if the deuteron was excited by only vacuum exchange from the beam proton. Various regions in the longitudinal and transverse laboratory momentum spectrum, $p_\parallel$ and $p_\perp$, are compared. All measurements are made for $p_\parallel < 1.0$ GeV/c and $p_\perp < 1.0$ GeV/c. The over-all agreement is very good. The worst agreement is when $0.0 < p_\parallel < 0.5$ GeV/c and $p_\perp < 0.5$ GeV/c, where the number of the π^-'s is almost two standard deviations higher than the number of π^+'s. Our statistics are not large enough to draw any firm conclusions, but it is clear that there are no gross discrepancies between these spectra. The peculiar mass shift of the 1.4-GeV enhancement down to 1.35 GeV in the pd missing-mass experiment described in the Introduction is not verified by any significant evidence of π^+-π^- asymmetry in our data.

TABLE III. Corrected numbers of events for reactions 2(a) and 2(b).

$p_{\parallel\,\mathrm{lab}}$ interval (GeV/c)	$p_\perp$ interval (GeV/c)	Number of π^- [reaction 2(a)]	Number of π^+ [reaction 2(b)]
<0	<0.5	35± 7	35± 7
0–0.5	<0.5	120± 14	89± 11
0–0.5	>0.5	9± 4	7± 3
0.5–1.0	<0.5	32± 7	45± 7
0.5–1.0	>0.5	12± 4	15± 4
all	all	204± 24	187± 16

IV. SUMMARY AND CONCLUSIONS

As in numerous other experiments performed to study diffractivelike inelastic processes, we find that the excitation of a target neutron into a low mass $p\pi^-$ at beam momenta of 19 and 28 GeV/c has many of the properties of elastic diffraction scattering (see Introduction) except for the fact that s-channel helicity is not conserved.[1-4] We find that t-channel helicity is not conserved either. Our studies of deuteron fragmentation at 28 GeV show no significant evidence of nondiffractive components in the data. On the other hand, there are differences in the mass spectra and angular correlations between the 19- and 28-GeV/c data for single pion production that would indicate that the energy-independent behavior expected of diffraction dissociation in reaction (3) is not the only mechanism at these momenta. It will be of interest to study the behavior of this simple final state at much higher energies to see if single diffraction, reaction (3), takes over completely. Comparing 19 and 28 GeV/c shows that asymptotic behavior has not been reached at 19 GeV/c.

One might expect isospin-$\frac{1}{2}$ N^* resonances to show clearly in the dissociation of a neutron into $p\pi^-$ at high energy. Instead, we see the typical low-mass Deck-type[8] threshold enhancement and only marginal evidence for N^* resonances at 1.5 and 1.65 GeV. The 1.4-GeV enhancement, at low t, of counter spectrometer experiments is clearly revealed as a superposition of the threshold nucleon-pion peak at 1.3 GeV and the slightly higher threshold nucleon-two pion peak at about 1.45 GeV The position of the peak in the mass distribution of $p\pi^-$ is seen to occur at about 1.3 GeV/c for $|t| \leq 0.1$ (GeV/c)^2 and to become flatter and move to larger mass values as $|t|$ is increased.

Our comparison of the π^+ with the π^- spectra associated with neutron and proton fragmentation at 28 GeV/c shows no difference in the manner in which these states are excited. However, this was a search for gross effects and we cannot know that differences will not be seen in more thorough investigations.

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