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Clarification of Report UR-597, [redacted]
(Fermilab-PUB-76/76-EXP, Nu-EXP-4)

"Structure in Momentum-Transfer for ($p\pi^-$) Systems Produced in Diffractive Dissociation of Neutrons on Protons."

by

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We wish to clarify that the absolute theoretical predictions for the data displayed in Fig. 2 exceed the observed cross sections by about a factor of two. For the curves in Fig. 2 we used the same normalizations as Babaev et al. (ref. 7), namely, the theoretical predictions normalized to the data from Serpukhov. For absolute predictions see, for example, M. Uehara, Prog. Theoret. Phys. 55, 146 (1976), and references given therein.

#305 PRL

UR-597

[redacted]

Structure in Momentum-Transfer for ($p\pi^-$) Systems Produced in Diffractive Dissociation of Neutrons on Protons.*

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The four-momentum transfer distribution of ($p\pi^-$) systems produced in the neutron dissociation reaction $n + p \rightarrow (p\pi^-) + p$ has substantial structure which depends strongly on the mass and on the angular decay properties of the produced ($p\pi^-$) system. No significant energy dependence is observed in the data for incident neutrons in the momentum range between 50 GeV/c and 300 GeV/c. The results are compared with a Deck-type of model.

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[redacted]inary results of an investigation of neutron diffractive-dissociation into $(p\pi^-)$ systems at Fermilab have been reported previously.[1] Here we wish to examine in more detail the correlation between the decay characteristics of the $(p\pi^-)$ system and its production t-spectrum. In particular, we wish to expand upon the recently noted difference in t-distributions of the $(p\pi^-)$ system for forward and backward Gottfried-Jackson angles of the decay proton.[2] A similar study of this correlation at the ISR in the reaction[3]:

$$p + p \rightarrow p + (n\pi^+) \qquad (1)$$

has revealed an unusually strong interdependence between the $(n\pi^+)$ mass and both the Gottfried-Jackson decay polar-angle (θ) of the neutron, and the momentum transfer to the $(n\pi^+)$ system. This has motivated us to report our findings for the charge-symmetric dissociation process:

$$n + p \rightarrow (p\pi^-) + p \qquad (2)$$

Our data, which span a range of incident momenta between 50 GeV/c and 300 GeV/c, with a mean value of ~200 GeV/c, were obtained in the wide-band neutron beam at Fermilab. The data are essentially bias-free for produced $(p\pi^-)$ masses below 1.5 GeV, and the corrections at large mass-values are straightforward[4]. The results to be presented here are based on the final analysis of ~400,000 triggers, which yielded ~70,000 events as the data base for studying the properties of Reaction (2).[4] The data to be discussed have been corrected for instrumental acceptance, and only statistical errors appear on the measured quantities. (The largest systematic uncertainty is in the normalization and shape of the incident-neutron momentum spectrum. This source of possible error could affect the energy dependence and the absolute cross section for Reaction (2) at $\lesssim$ 15% level.)

Distributions in t, the square of the four-momentum transfer between the incident neutron and the produced ($p\pi^-$) system, when integrated over all values of M, the mass of the ($p\pi^-$) system, exhibit substantial complexity. However, for small ranges of M, the t-spectra can be approximated at low-t by simple exponentials.[1] Results of fitting the data to the form exp(Bt), as a function of M, are displayed in Fig. 1. The range of t-values used for the fits are $0.03\ \mathrm{GeV}^2 < |t| < t_M$, where t_M is the maximum value of $|t|$ (in all cases $t_M > 0.15\ \mathrm{GeV}^2$), for a given M interval, for which the χ^2 for the exponential fit remains acceptable. (The cut off at $|t| = 0.03\ \mathrm{GeV}^2$ arises from the acceptance of the experiment.[4]) Figure 1(a) displays the slope parameter, B, as a function of M for all incident momenta ($\mathbf{p}_{in}$). Near the $p\pi^-$ threshold, the value of B is about twice that found for elastic scattering.[5] Above $M \sim 1.55$ GeV B becomes essentially mass independent. Except for the interesting shoulder near $M \sim 1.35$ GeV,* an effect pointed out recently by Chaloupka,[6] the value of B falls almost linearly between M = 1.08 GeV and M = 1.55 GeV. Figure 1(b) displays, as open circles, the lower-momentum component of the data ($p_{in} < 200$ GeV/c, with $\langle p_{in} \rangle \sim 150$ GeV/c), and, as solid circles, the higher-momentum ($\langle p_{in} \rangle \sim 240$ GeV/c) results. No significant difference is observed between the results in Fig. 1(b). In particular, the shoulder near $M \sim 1.35$ GeV, and the dramatic correlation between B and M appear to be energy independent. The latter result is emphasized further in Fig. 1(c), where we show the variation with incident momentum of the B parameter for M<1.55 GeV. The value of B changes by less than 10% between 100 GeV/c and 300 GeV/c.

* The significance of this shoulder is somewhat sensitive to the range of t-values used in the fits.

We next proceed to the study of the correlation between the t-distribution and the Gottfried-Jackson polar-angle (θ) of the decay proton in the rest frame of the ($p\pi^-$) system. Figure 2 displays t-spectra for four intervals in M, and for each M interval three regions of θ. In particular, the ranges of $\cos\theta$ are: $\cos\theta < -0.9$, $|\cos\theta|<0.3$, and $\cos\theta > 0.9$; the mass regions are: $M < 1.30$ GeV, 1.30 GeV $< M < 1.40$ GeV, 1.40 GeV $< M < 1.55$ GeV and 1.55 GeV $< M < 1.80$ GeV. We have remarked that t-distributions, when integrated over $\cos\theta$,* display simple exponential behavior (exp Bt) at small t. The results of Fig. 2 suggest that, although B may be a useful parameter, it probably does not have fundamental significance. We note that, particularly for small M, the character of the t-distribution is strongly dependent on the decay angle of the ($p\pi^-$) system. (The distributions change smoothly between the regions of $\cos\theta$ shown in Fig. 2.) There is no significant dependence of the displayed data on the momentum of the incident neutron (not shown). In fact, our results are in remarkably close agreement with those obtained at the ISR.[3]

The curves in Fig. 2 are based on the prescription for pion and baryon-exchange Deck-calculations provided by A. Babaev et al.[7]**

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*For a fixed $\cos\theta$, the shapes of the t-spectra do not appear to depend on the azimuthal angle of the proton in the Gottfried-Jackson frame.

**A similar formulation, but one including absorption, has been suggested by E. L. Berger.

This model takes into account a neutron-pole term, in addition to the pion and proton-exchange Deck terms used previously.* Also, spin structure of the baryon vertex is included, as is the interference among the three diffractive graphs. The normalizations of the curves in Fig. 2 are the same as given by Ponomarev.[7]

In the region of phase space where pion-exchange dominates, namely $\cos\theta > 0.9$, the model is in excellent agreement with the data. This is true for the differential cross sections shown in Figs. 2(c), (f),(j) and (ℓ), as well as for the azimuthal decay angular distributions (not shown). In addition, at low mass values, where resonance production is unimportant, the t-spectra are again reasonably consistent with the calculation. However, the predictions for the azimuthal dependence disagree with the data for $\cos\theta < -0.9$ (not shown). For central regions of $\cos\theta$, the model fails to reproduce the mass dependence as well as the dramatic structure observed in the data at small t.

The highly peripheral interference minimum in the t-distribution, which moves out to larger values as M increases, and eventually disappears, is a result very much akin to that found by the ISR group.[3] The fact that such an interference pattern has very little energy dependence between 50 GeV/c and ~1100 GeV/c, suggests that the mechanism responsible for the phenomenon must be basic to diffractive dissociation.

We thank E. L. Berger for helpful discussions and suggestions regarding this work.

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*Unlike the calculations used in Ref. 1, small Regge corrections were not applied to the Deck diagrams.

References

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4. J. Biel, Ph.D. Thesis, University of Rochester (1976).

5. A. Melissinos and S. Olsen, Phys. Rep. C 17, 77 (1975).

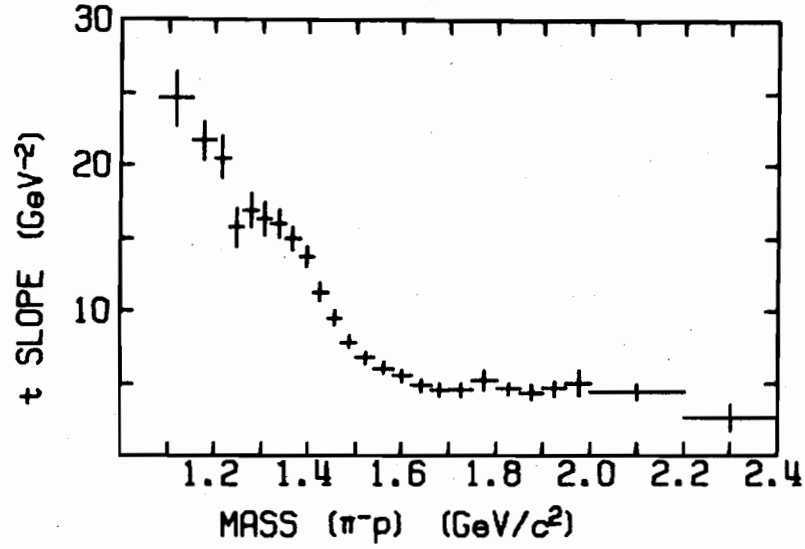
6. V. Chaloupka, SLAC Preprint (1976), submitted to Oxford Conference on Baryon Resonances .

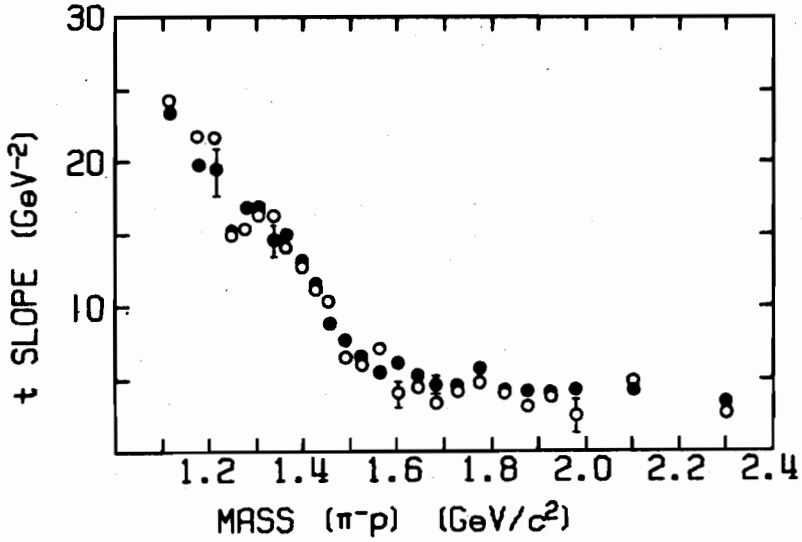
7. A. Babaev et al., CERN Report (June 23, 1976; submitted to Nuclear Physics B).

Figure Captions

1. Slope parameter in t as a function of the mass of the produced ($p\pi^-$) system. Data for all momenta are given in graph (a). (b) contains the results of (a) split up according to incident neutron momentum; open circles are for momenta below 200 GeV/c, solid circles are for data above 200 GeV/c. (c) displays the variation of the B parameter with incident momentum for data with $M < 1.55$ GeV.

2. Momentum transfer distributions as a function of the Gottfried-Jackson angle for different regions of M. Curves are calculations taken from a model proposed in reference 7.


30
20
10
t SLOPE (GeV^{-2})
1.2 1.4 1.6 1.8 2.0 2.2 2.4
MASS (π^-p) (GeV/c^2)


30
20
10
t SLOPE (GeV^{-2})
1.2 1.4 1.6 1.8 2.0 2.2 2.4
MASS (π^-p) (GeV/c^2)

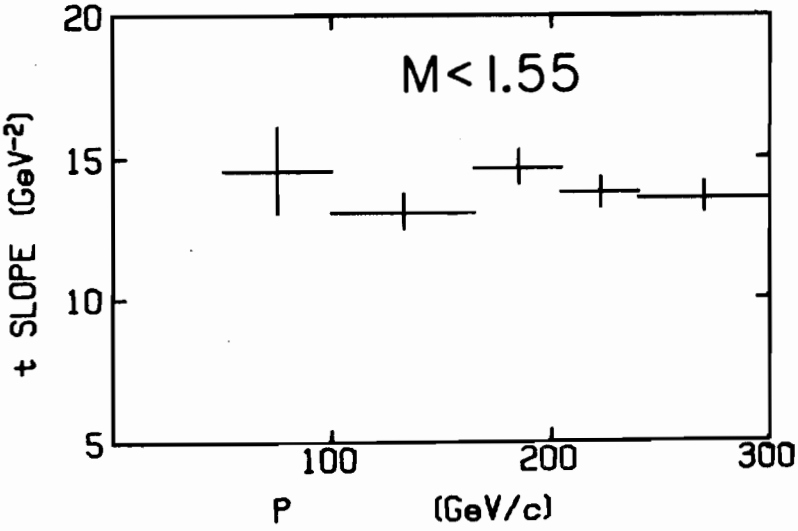

M< 1.55
20
15
10
5
t SLOPE (GeV^{-2})
100
200
300
P (GeV/c)

Fig 1

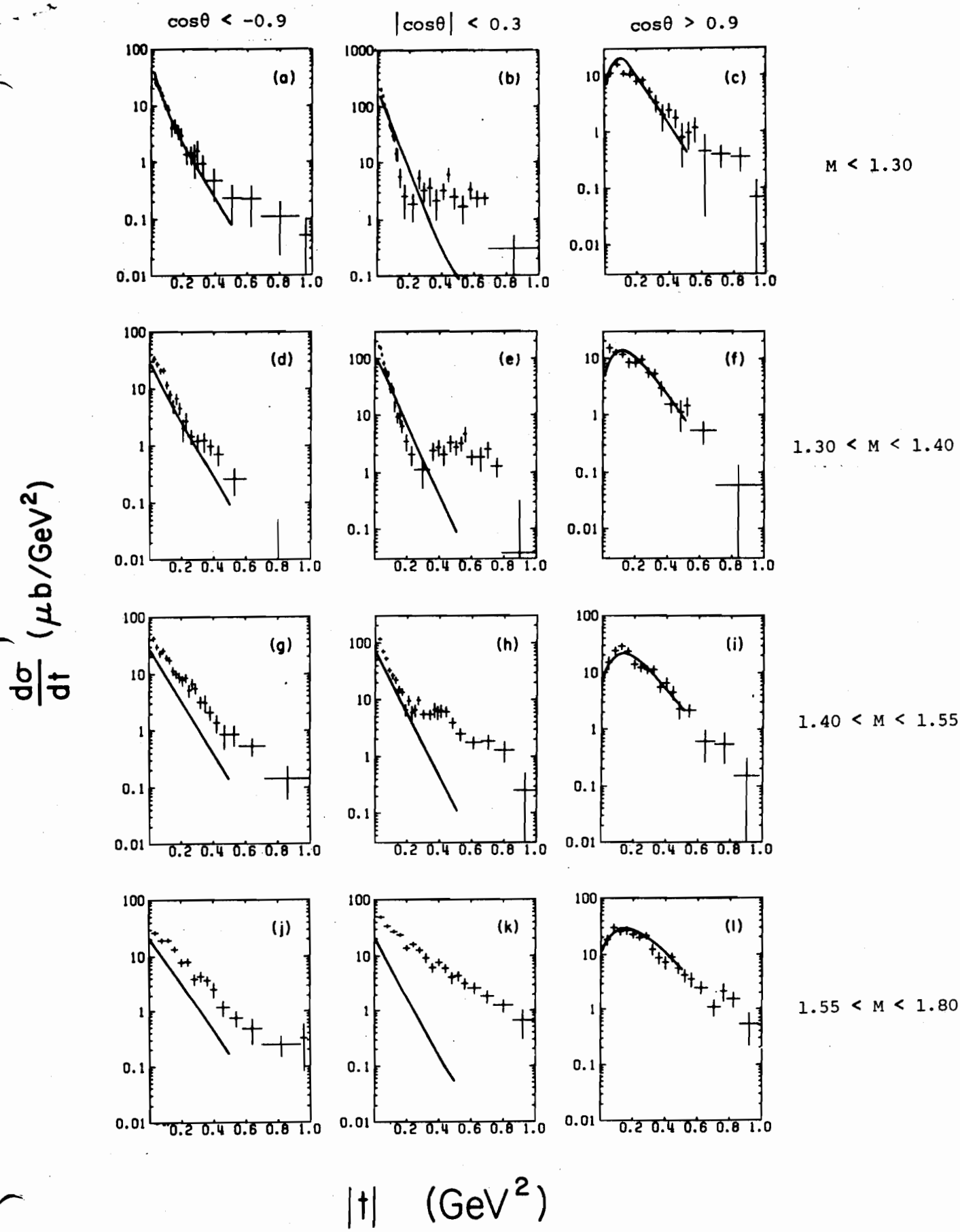

cosθ < -0.9
|cosθ| < 0.3
cosθ > 0.9
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
(j)
(k)
(l)
M < 1.30
1.30 < M < 1.40
1.40 < M < 1.55
1.55 < M < 1.80
dσ/dt (μb/GeV²)
|t| (GeV²)

Fig. 2