Submitted to Palermo Meeting June, 1975
FERMILAB-CONF-75-181-E

Decay Properties of $p\pi^-$ Systems Produced in Neutron Dissociation at Fermilab Energies[ʃ]

J. Biel*, E. J. Bleser†, D. Duke*, T. Ferbel*,
D. Freytag#, B. Gobbi‡, L. Kenah‡, J. Rosen‡, R. Ruchti‡,
P. Slattery*, and D. Underwood*

We have examined the decay distributions of $(p\pi^-)$ systems produced in the reaction $n + p \rightarrow (p\pi^-) + p$ for neutron momenta between 120 GeV/c and 300 GeV/c. Preliminary analysis of decay moments indicates the presence of large helicity-flip amplitudes even for small $(p\pi^-)$ mass values, and does not support the hypothesis that the helicity non-flip $(p\pi^-)$ states are produced peripherally in impact parameter. These results are in approximate agreement with predictions of the Deck mechanism. The experiment was performed at the M-3 neutral beam of Fermilab.

ʃResearch supported by the U. S. Energy and Research Development Administration
*University of Rochester, Rochester, N.Y. 14627
†Fermilab, Batavia, Ill. 60510
#SLAC, Stanford, Calif. 94305
‡Northwestern Univ., Evanston, Ill. 60201

The origin of the observed correlation between the mass M of an inelastic system produced in diffraction dissociation and the square of the four-momentum transferred to that system (t) has been the object of extensive investigation.[1] One model for understanding the t-M interdependence in these highly peripheral reactions is based on the assumption that s-channel helicity amplitudes for small masses ($M \lesssim 1.3$ GeV) are dominantly helicity non-flip.[2] Consequently one expects a steep differential cross section (DCS) for small t and a dip or sharp break near $-t \sim 0.2$-0.3 if the helicity non-flip system is produced peripherally (i.e., near an impact parameter $b \sim 1$ Fermi). The contributions from the helicity flip amplitudes are hypothesized to become more important as the mass and spin of the diffractively produced system increases, thus leading to a substantial broadening of the t-distributions with increasing M values.[2]

In a paper submitted to this conference[3] we displayed the main features of dissociation reaction

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

Here we address ourselves to the decay angular distributions of the $(p\pi^-)$ system in order to study the properties of the dissociation helicity amplitudes for $M < 1.55$ GeV. It is expected that the spin structure for these masses is sufficiently simple to allow an analysis of the $(p\pi^-)$ system production amplitudes. Processes such as reaction (1) have been discussed in the past in the framework of a Deck-like model.[4] In this paper we will also compare our data with the Deck-production model indicated in Fig. 1. The square of a simple Deck-type matrix element can be written as

$$|M|^2 \approx -t_1 e^{2(t_1-\mu^2)} \frac{[\frac{1}{2}(s_{\pi p} - u_1)]^{2\alpha_\pi}}{\alpha_\pi^2} (s_2 - u_2)^2 e^{10t}, \qquad (2)$$

where t_1 and t are four-momentum transfers squared; $s_{\pi p}$ and s_2 are squares of the πp invariant masses as indicated in Fig. 1; u_1 and u_2 are respectively the squares of the four-momentum transfered to the pion from the incident neutron and target proton; $\alpha_\pi = 0.9\ (t_1-\mu^2)$ is the pion Regge trajectory, and μ is the pion mass. The $\pi^- p$ elastic DCS is taken proportional to exp(10t). The decay moments of the $(p\pi^-)$ system were extracted by numerical integration of the above expression.

Figure 2 displays the normalized low-order moments $\langle Y_{LM}\rangle$ versus t for fixed mass in the Gottfried-Jackson (GJ) frame and in the helicity frame. The data are in rough agreement with the trend of the Deck calculation. A similar level of agreement is available for other $(p\pi^-)$ mass values. In Fig. 3 we display the variation of the same $\langle Y_{LM}\rangle$ versus mass at fixed t in the GJ frame. Again, the data only roughly follow the Deck calculations. The moment $\langle Y_{11}\rangle$ in the helicity-frame consists of interference terms proportional to an helicity non-flip amplitude and a unit helicity-flip amplitude. In terms of the s-channel peripheral model discussed above,[2] one therefore expects $\langle Y_{11}\rangle$ in the helicity frame to pass through zero at the t value where the dip in the DCS is observed. Similarly, one also expects a zero in $\langle Y_{11}\rangle$ near $-t \sim 0.6$ where the single helicity-flip amplitudes are predicted to have a zero. The observed absence of these predicted zeroes in $\langle Y_{11}\rangle$ implies that the s-channel peripheral model cannot be the dominant production process.

Finally, in Fig. 4 we display the (preliminary) results of an amplitude analysis of the data. $\langle Y_{LM}\rangle$ are negligible for $L > 4$ and (in the GJ frame) for $M > 2$. Therefore spins up to $J = 5/2$ and helicity-flips ±1 saturate the moments. The $M \leq 2$ cutoff in $\langle Y_{LM} \rangle$ is a consequence of Pomeron exchange in the s_2 subchannel of Fig. 1. However, amplitudes calculated from the Deck expression (2) do not agree even with the signs of the results in Fig. 4. Thus we conclude that the simple Deck mechanism also does not agree in ultimate detail with our data. The presence of S^1 and P^3 states is inconsistent with the Morrison rule.[5]

We thank E.L.Berger and G.Fox for helpful discussions.

References

1. See, for example, the following:

J. Bartsch et al., Phys. Letters 27B, 336 (1968); B. Y. Oh and W. D. Walker, Phys. Letters 28B, 564 (1969); M. S. Farber et al., Phys. Rev. Letters 22, 1394 (1969); H. I. Miettinen and P. Pirila, Phys. Letters 40B, 127 (1972); the review of J. Rushbrooke, Proc. III Intl. Colloquium on Multiparticle Dynamics, Zakopane (1972), A. Bialas et al., eds; H. Lubatti and K. Moriyasu, Lett. Nuovo Cimento 12, 97 (1975).

2. See, for example, G. Kane, Acta Phys. Pol. B3, 845 (1972), and S. Humble, CERN Report Th. 1827 (1974).

3. J. Biel et al., paper submitted to this conference.

4. See the recent comprehensive review of E. L. Berger, ANL Report ANL-HEP-PR-75-06 (1975).

5. D.R.O.Morrison, Phys. Rev. 165, 1699 (1968).

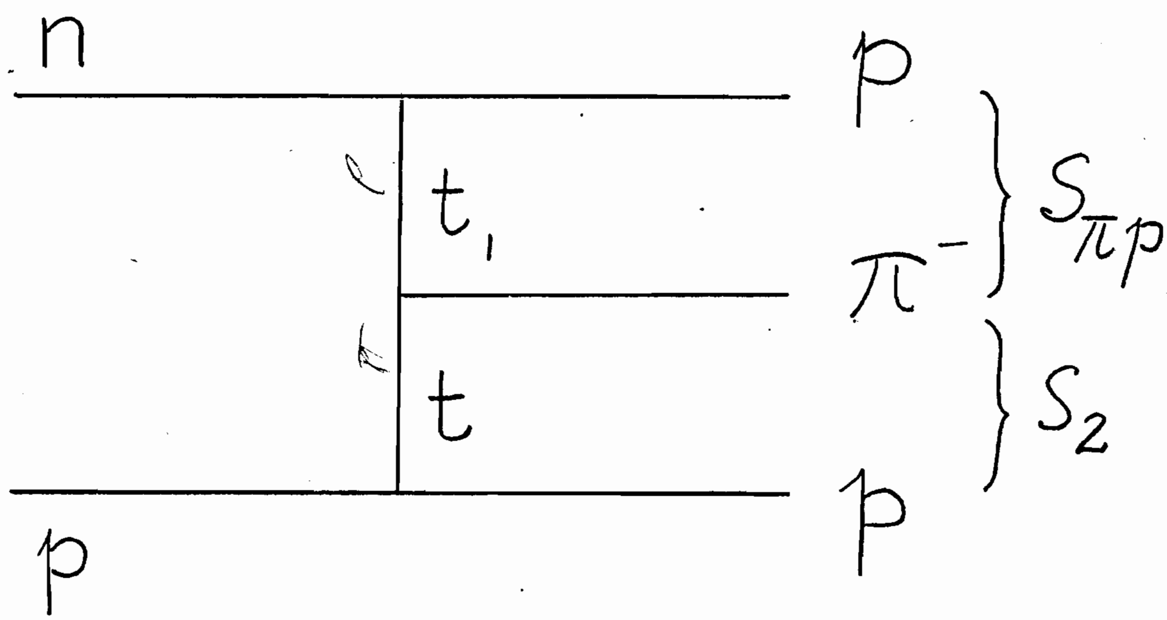
Figure Captions

1. The simple π-exchange Deck diagram for reaction (1). (Nucleon exchange has not been considered in this report.)

2. The average $<Y_{LM}(\theta,\phi)>$ moments as a function of $|t|$ for the $p\pi^-$ mass interval 1.300 - 1.375 GeV. The solid curves are predictions of equation (2). The dashed curves correspond to equation (2) but without the $(-t_1\, e^{2(t_1-\mu^2)})$ factor in front of the expression. The latter can be thought of as a Deck model with additional absorption.

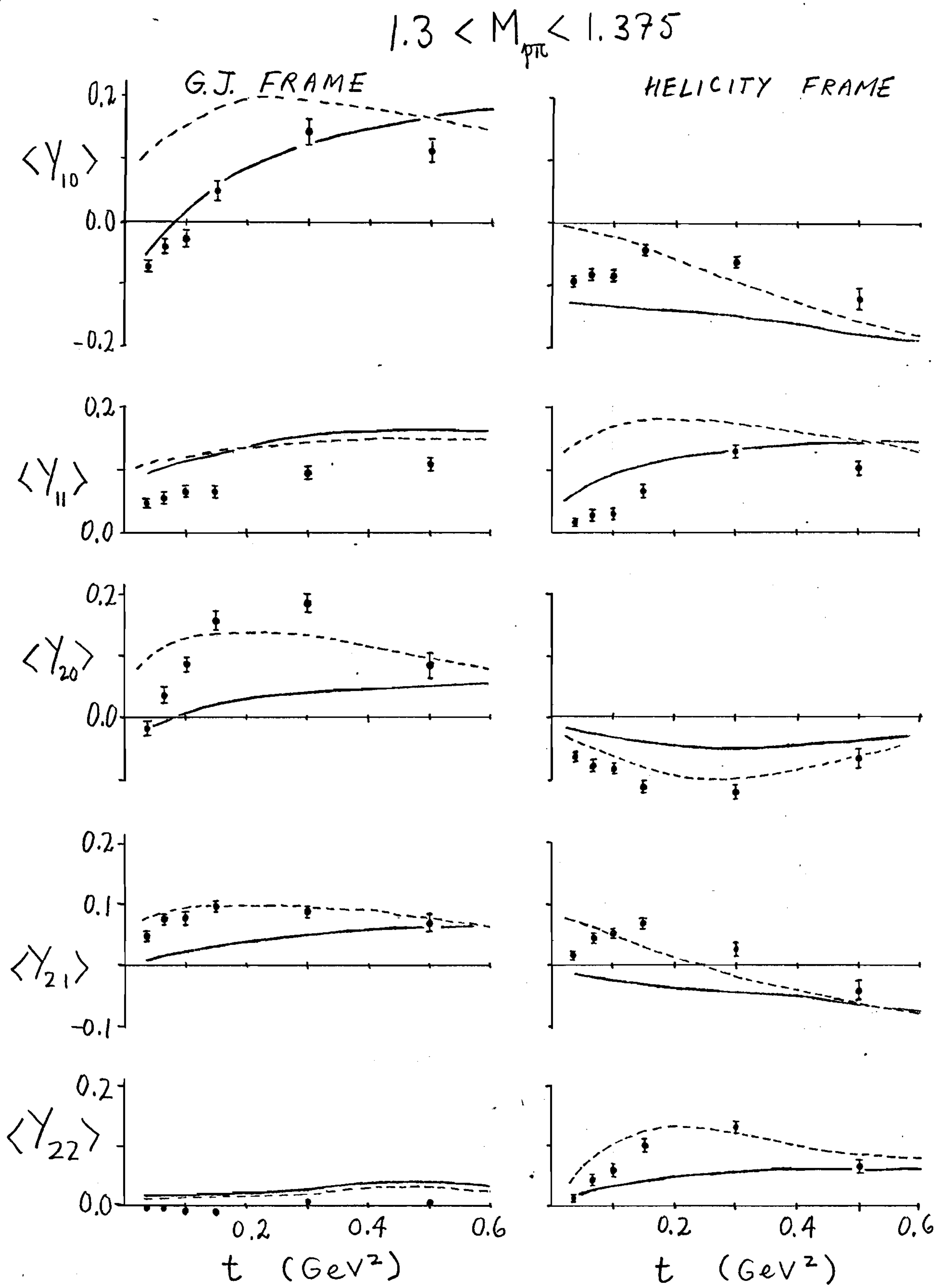
3. The low order $<Y_{LM}(\theta,\phi)>$ moments as a function of $p\pi^-$ mass for the $|t|$ interval 0.08 to 0.12 GeV^2. The solid curves are predictions of equation (2). The dashed curves correspond to equation (2) but without the $(-t_1\, e^{2(t_1-\mu^2)})$ factor in front of the expression. The latter can be thought of as a Deck model with additional absorption.

4. Preliminary t-channel helicity amplitudes for the $p\pi^-$ mass range 1.3 - 1.375 GeV compared with Deck model predictions. The amplitudes are specified through the orbital wave (L), the total spin (J), and the helicity flip ($\Delta\lambda$) as $L^{2J}_{2\Delta\lambda+1}$. There is an ambiguity in the overall sign of the amplitudes. There is also an overall ambiguity in the relative parity of all even and odd states, e.g., the amplitudes labeled S^1, D^3, F^5 can be relabeled respectively as P^1, P^3, D^5 and vice versa.



Deck Diagram

Fig. 1



1.3 < M_pπ < 1.375
G.J. FRAME
HELICITY FRAME
⟨Y10⟩
⟨Y11⟩
⟨Y20⟩
⟨Y21⟩
⟨Y22⟩
0.2
0.1
0.0
-0.1
-0.2
0.2
0.4
0.6
t (GeV²)

Fig. 2

G. J. FRAME 0.08<t<0.12

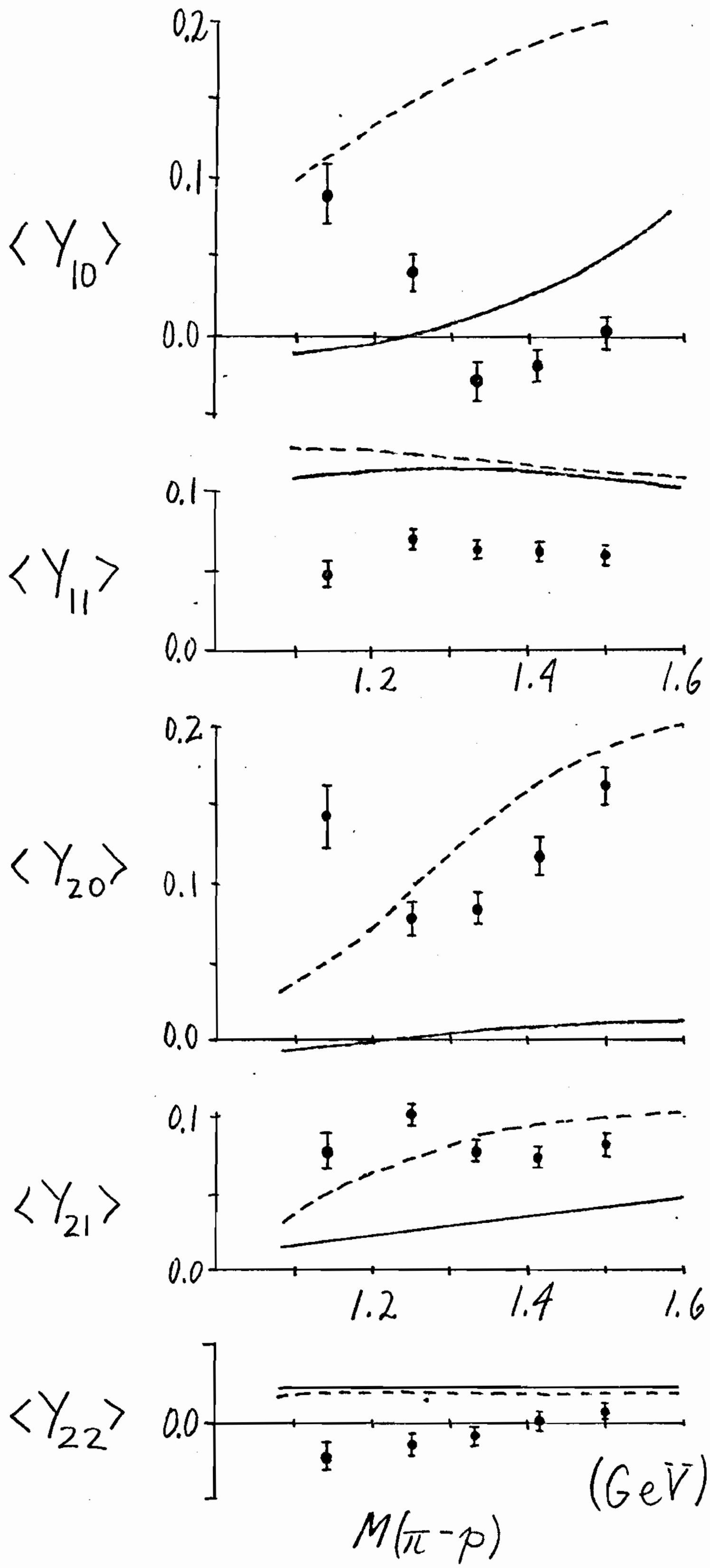


Fig.3

t - CHANNEL HELICITY AMPLITUDES
(PRELIMINARY)
$1.3 < M_{\pi^- p} < 1.375$

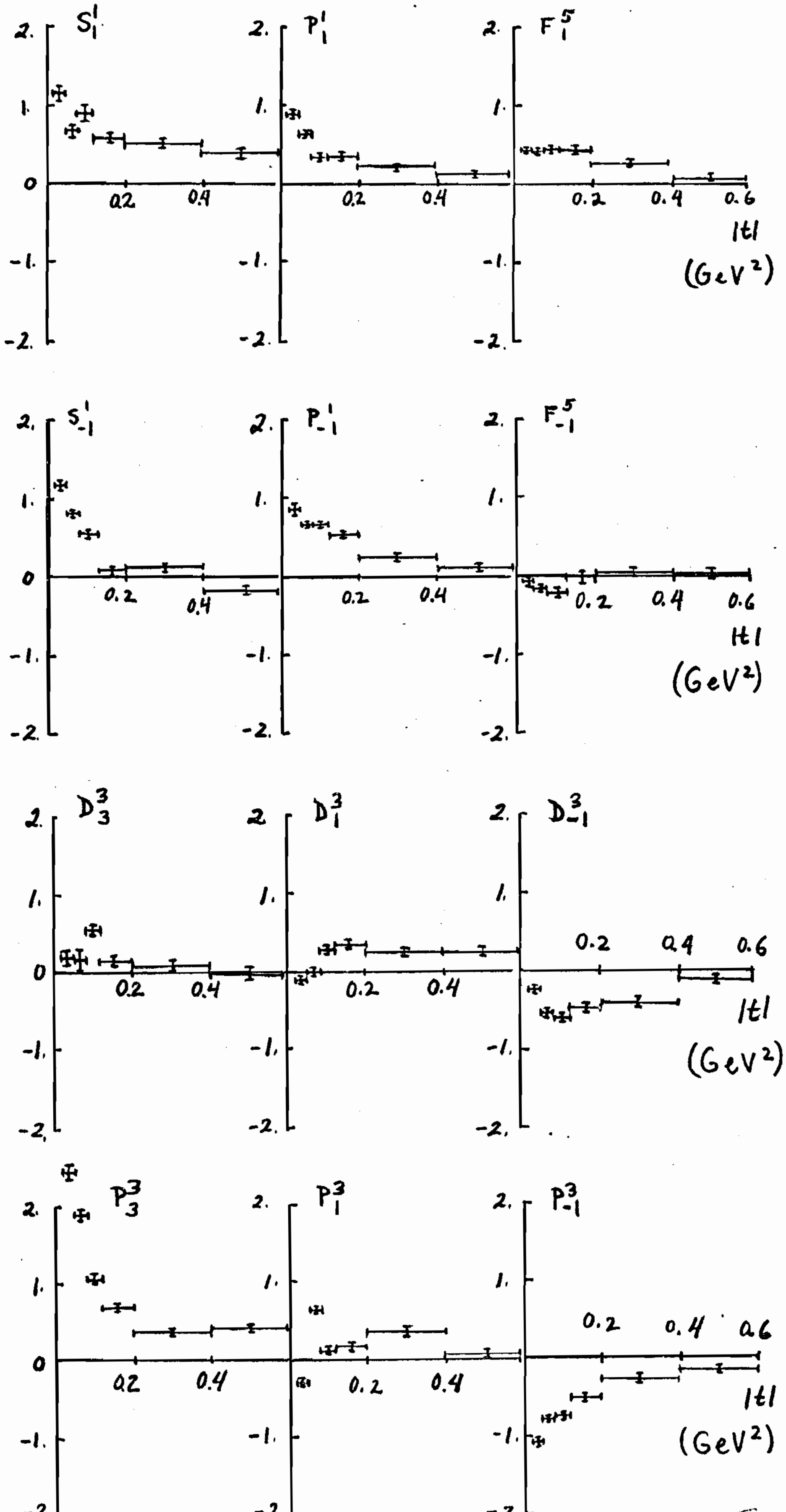


Fig. 4