HELICITY-FLIP IN NUCLEON DIFFRACTION DISSOCIATION ON SIMPLE AND COMPOSITE TARGETS

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The helicity-flip contribution in nucleon diffraction dissociation on simple and composite targets is discussed. This contribution is responsible for the observed correlations between the t-distributions and the mass and the decay angles of the diffractively excited system.

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In this paper I discuss the effects of helicity-flip in the coherent diffraction dissociation of neutrons into $(p\pi^-)$ systems on hydrogen and nuclear targets:

$$n+p \to (p\pi^-)+p, \tag{1}$$

$$n+A \to (p\pi^-)+A. \tag{2}$$

In both reactions there exists an unusually strong correlation between the t-distributions and the mass and the polar decay angle of the $(p\pi^-)$ system [1]. The purpose of the paper is to show that the helicity-flip effects are responsible for the observed correlation. We shall discuss these effects in the framework of a simple phenomenological model proposed by Humble [2].

In Humble's model the differential cross section is given by an incoherent sum of several terms corresponding to different helicity-flip in the s channel

$$\frac{d\sigma}{dt\, dM\, d\cos\theta} = \sum_{N=0}^{N_{\max}} |F_N(t, M, \cos\theta)|^2, \tag{3}$$

$$F_N(t, M, \cos\theta) = h_N(M, \cos\theta)e^{at}J_N(b_0\sqrt{-t}), \tag{4}$$

where N is net s-channel helicity-flip, M is the mass of the produced diffractive system and θ is the decay angle.

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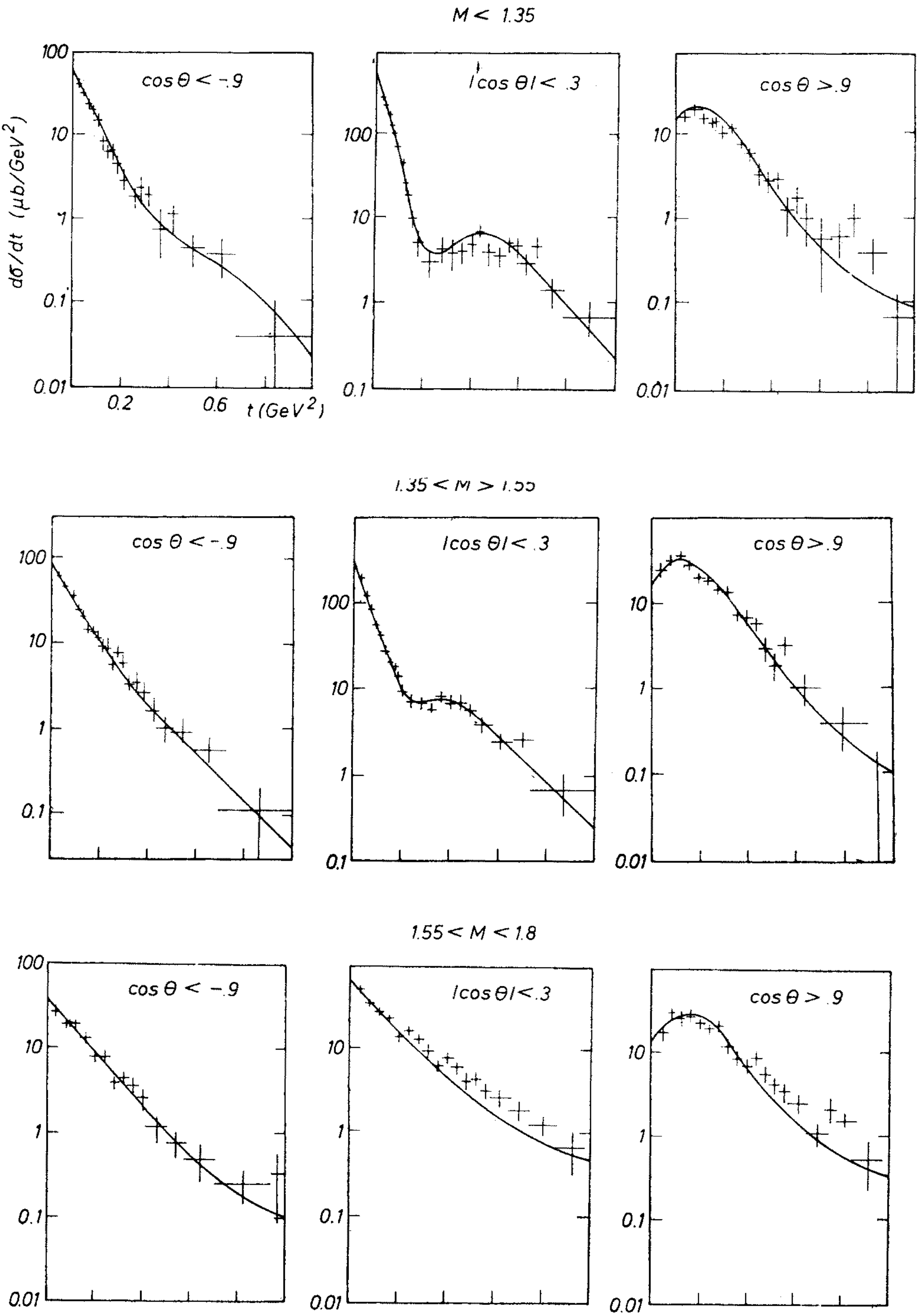

Fig. 1. Distributions in momentum transfer, as a function of mass and cos θ, for reaction $n+p \rightarrow (p\pi^-)+p$

The parameters a, b_0 and $h_N(M, \cos\theta)$ are obtained from fits to data. Figure 1 shows such a fit to the Fermilab data [1]. It gives $a = 2.5\ \text{GeV}^{-2}$, $b_0 = 1.1$ fm and the parameters h_N (fitted to the differential cross section in each of the phase space regions) are given in Table I.

We have the following comments. For $b_0 = 1.1$ fm, the Bessel function $J_0(b_0\sqrt{-t})$ has its first zero at $t = -0.2\ \text{GeV}^2$. Consequently, the differential cross section $d\sigma/dt$

TABLE I

Strength parameters $h_N^2(\mu\text{b}/\text{GeV}^2)$ for various helicity-flip contributions

M(GeV)	$\cos\theta$	h_0^2	h_1^2	h_2^2
$M < 1.35$	$\cos\theta < -0.9$	60	33	0
$M < 1.35$	$\lvert\cos\theta\rvert < 0.3$	400	40	0
$M < 1.35$	$\cos\theta > 0.9$	15	90	90
$1.35 < M < 1.55$	$\cos\theta < -0.9$	80	100	0
$1.35 < M < 1.55$	$\lvert\cos\theta\rvert < 0.3$	300	100	0
$1.35 < M < 1.55$	$\cos\theta > 0.9$	20	120	120
$1.55 < M < 1.8$	$\cos\theta < -0.9$	32	100	50
$1.55 < M < 1.8$	$\lvert\cos\theta\rvert < 0.3$	60	100	150
$1.55 < M < 1.8$	$\cos\theta > 0.9$	13	120	200

exhibits diffraction minimum at this t-values if zero helicity-flip amplitude dominates (for small values of the mass M and $|\cos\theta|$). With the increasing mass M and $\cos\theta$, helicity-flip amplitudes get stronger, and the differential cross section $d\sigma/dt$ flattens off.

For reaction (2) with the nucleus A as a target the coherent production cross section in the high energy limit is given by (ignoring Coulomb distortion and helicity-flip effects) [3]

$$\frac{d\sigma}{dt\,d\cos\theta} = \left(\frac{d\sigma_0}{dt\,d\cos\theta}\right)_{t=0} \frac{4}{(\sigma_1-\sigma_2)^2}$$

$$\times \left|\int d^2b J_0(b\sqrt{-t})\left(e^{-0.5\sigma_1\int_{-\infty}^{\infty} dz\varrho(b,z)} - e^{-0.5\sigma_2\int_{-\infty}^{\infty} dz\varrho(b,z)}\right)\right|^2, \tag{5}$$

where $\left(\frac{d\sigma_0}{dt\,d\cos\theta}\right)_{t=0}$ is the cross section for elementary reaction (1), σ_i is the total cross section for the collisions of particle n or system ($\text{p}\pi^-$) with a nucleon in the nucleus and $\varrho(b, z) = \varrho(r)$ is the nuclear density.

The nuclear density has been taken as [4]

$$\varrho(r) = \varrho_0\left[1+\exp\left(\frac{r-R}{a}\right)\right]^{-1}, \tag{6}$$

$$\int d^3r\varrho(r) = A, \tag{7}$$

where $R = 4.26$ fm and $a = 2.5$ fm for Cu.

The results of the calculation based on Eq. (5) are shown in Fig. 2. The elementary production cross sections $\left(\frac{d\sigma_0}{dt\,d\cos\theta}\right)_{t=0}$ are taken directly from data [1] (Table II).

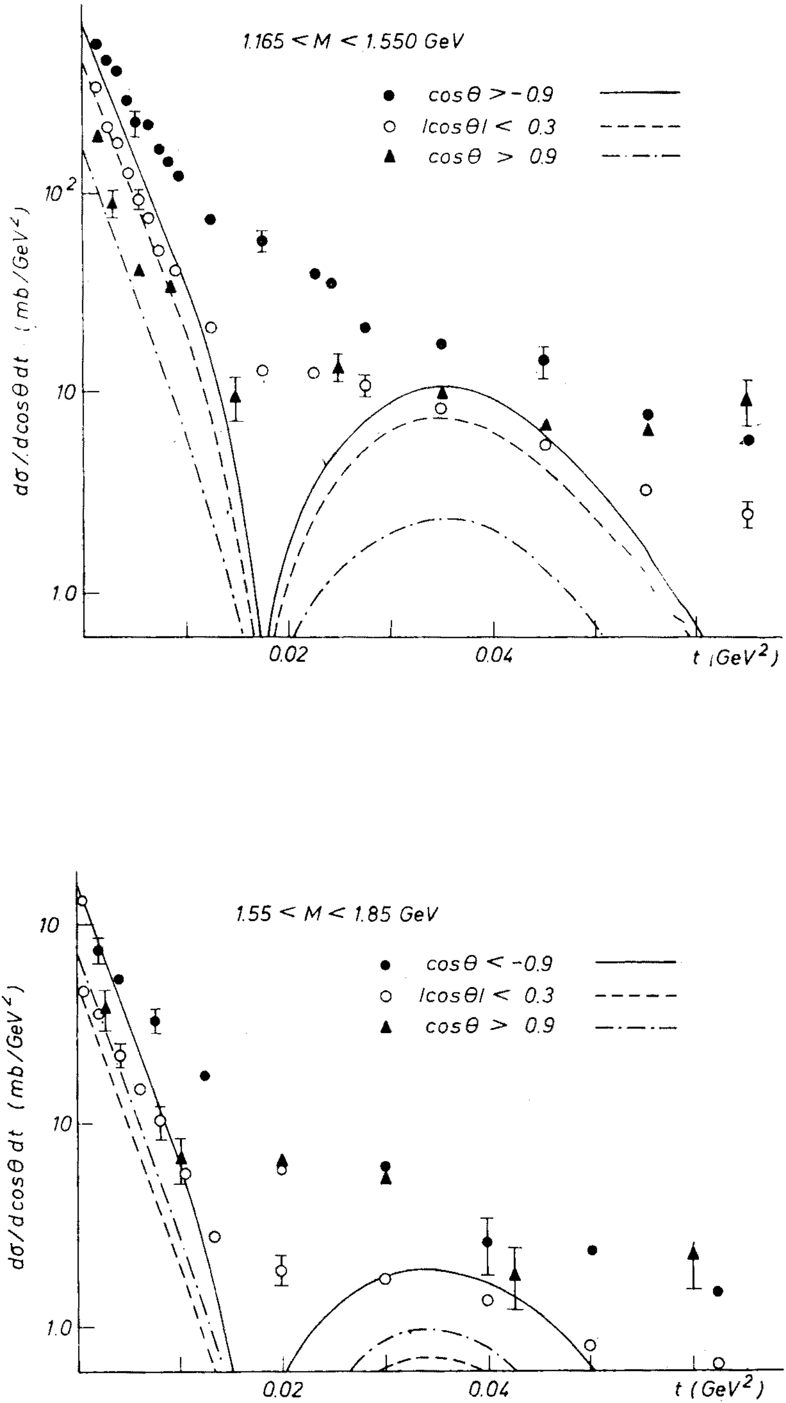

Fig. 2. Differential cross section for coherent production $n+Cu \rightarrow (p\pi^-)+Cu$. The theoretical curves show helicity-non-flip model for $\sigma_1 = \sigma_2 = 38$ mb

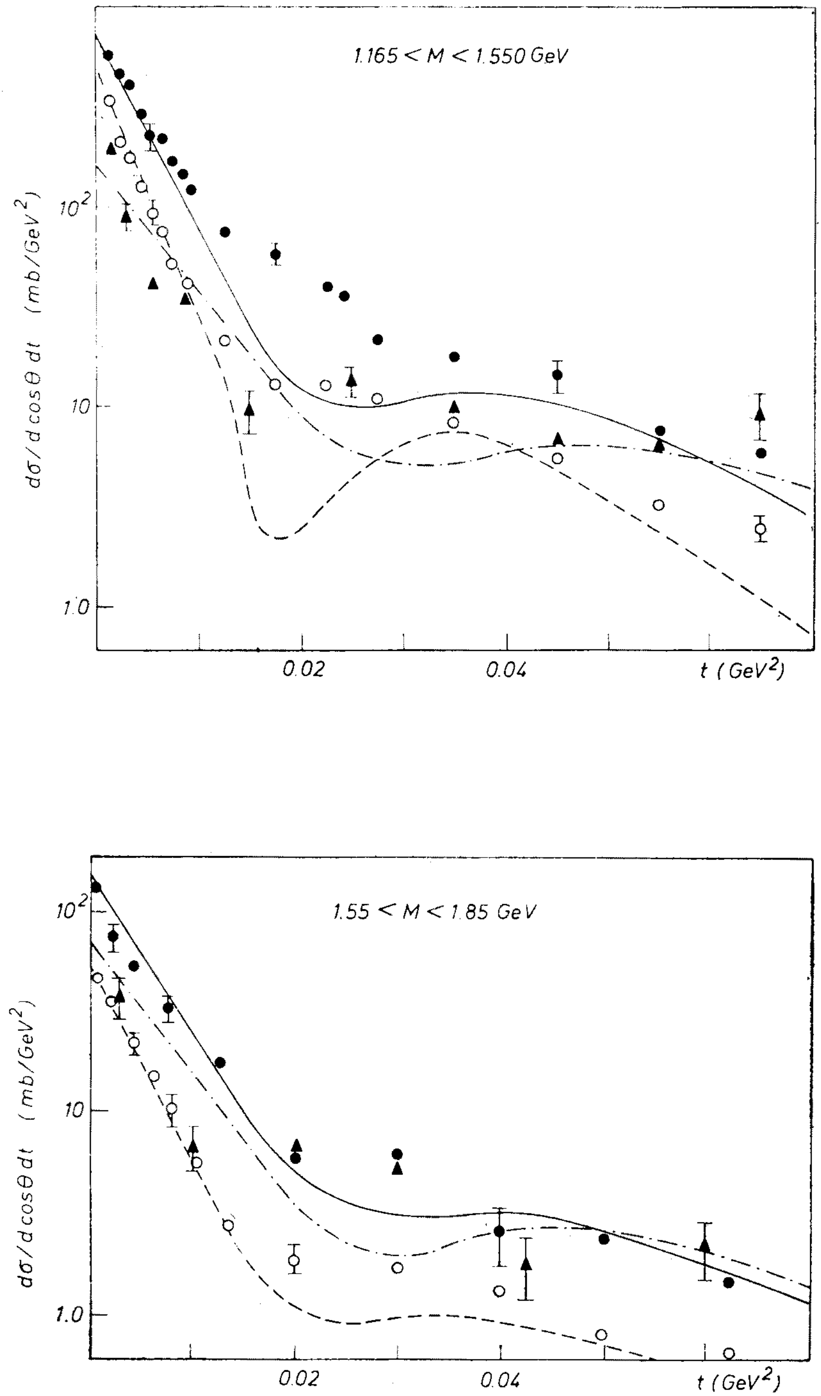

Fig. 3. Differential cross section for reaction $n+Cu \rightarrow (p\pi^-)+Cu$. The curves show helicity-flip model for $\sigma_1 = \sigma_2 = 38$ mb

TABLE II

Elementary production cross section $\left(\frac{d\sigma_0}{dt\, d\cos\theta}\right)_{t=0}$

M(GeV)	$\cos\theta$	$\left(\frac{d\sigma_0}{dt\, d\cos\theta}\right)_{t=0}$ (mb/GeV²)
$M < 1.55$	$\cos\theta < -0.9$	1.4
$M < 1.55$	$\lvert\cos\theta\rvert < 0.3$	1.1
$M < 1.55$	$\cos\theta > 0.9$	0.4
$1.55 < M < 1.85$	$\cos\theta < -0.9$	0.35
$1.55 < M < 1.85$	$\lvert\cos\theta\rvert < 0.3$	0.11
$1.55 < M < 1.85$	$\cos\theta > 0.9$	0.14

The agreement with data is unsatisfactory: the experimentally observed correlation between t-distributions and M, as well as between t-distributions and $\cos\theta$ is absent.

If we include the helicity-flip effects, the differential cross section can be written as follows [5]

$$\frac{d\sigma}{dt\, d\cos\theta} = \sum_N C_N \left| \int d^2 b J_N(q_\perp b) \int_{-\infty}^{\infty} dz \left[b^N \left(-\frac{1}{b}\frac{d}{db}\right)^N \varrho(b,z)\right] \right.$$

$$\left. \times \exp\left[i q_{\parallel} z - \tfrac{1}{2}\sigma_1 \int_{-\infty}^{z} dz' \varrho(b,z') - \tfrac{1}{2}\sigma_2 \int_{z}^{\infty} dz' \varrho(b,z')\right]\right|^2 \tag{8}$$

with

$$C_N = \left[\frac{1}{|t|^N} \frac{d\sigma_0^N}{dt\, d\cos\theta}\right]_{t=0} = \left(h_N \frac{1}{N!} (b_0/2)^N \right)^2, \tag{9}$$

where N is the helicity transfer in the reaction. The elementary helicity-flip amplitudes can be taken from our fit to reaction (1) as summarized in Table I. The results obtained in this way are shown in Fig. 3. The agreement with the data is better than in Fig. 2. We see that multiple scattering theory of Glauber [6] with helicity-flip contributions in elementary process included discribes the main features of the coherent diffractive production on nuclei. It has been found that the helicity-flip amplitudes are responsible for the variation of t-distributions with mass M and $\cos\theta$ both in elementary and nuclear diffraction dissociation.

Diffractive production on nuclei is more peripheral than corresponding elastic reaction. This is due to the fact that multiple scattering effects are stronger in the former than in the latter case. This mechanism gives the difference between the slopes of the t spectra ($\exp(180t)$ for $p+Cu \to p+Cu$, and $\exp(265t)$ for $n+Cu \to (p\pi^-)+Cu$ for $|\cos\theta| < 0.3$ and $M < 1.35$ GeV) and between the position of the minimum in the $d\sigma/dt$ cross section ($t = -0.027$ GeV^2 for $p+Cu \to p+Cu$ and $t = -0.017$ GeV^2 for $n+Cu \to (p\pi^-)+Cu$.

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