STUDY OF TRANSVERSAL HANDEDNESS IN DIFFRACTIVE PRODUCTION OF PION TRIPLES FROM NUCLEAR TARGETS [a]

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A rather large handedness transversal to the production plane was observed in the diffractive production of $(\pi^-\pi^+\pi^-)$ triples from nuclei by the 40 GeV/c π^-–beam. It was shown that the phenomenon has a clear dynamic origin and resembles the single spin asymmetry behavior.

1 Introduction

Several years ago the concept of jet handedness was introduced as a measure of polarization of parent partons (or hadrons) [1]. For a strong interaction process, parity invariance requires that at least three particles (either spinless or spin-averaged) in a final state or a pair of particles and jet direction were measured in order to build a correlation of final momenta in the fragmentation (or decay) with initial polarization. Namely, from three particle momenta one can construct a pseudovector $n_\mu \propto \epsilon_{\mu\nu\sigma\rho} k_1^\nu k_2^\sigma k^\rho$ $(k = k_1 + k_2 + k_3)$ which gives, when contracted with the initial polarization pseudovector, a scalar component in the strong process. Thus, measuring the asymmetry (handedness) in some component of $\vec{n}$ in the rest frame of the triple and averaging over other components can give an information on the initial polarization in this direction

$$H_i = \frac{N(n_i > 0) - N(n_i < 0)}{N(n_i > 0) + N(n_i < 0)} = A_i P_i, \tag{1}$$

provided the analyzing power A is large enough. The direction i could be chosen as longitudinal (L) with respect to the triple momentum $\vec{k}$ and as transversal ones $(T1$ or $T2)$ perpendicular to the triple production plane or in the plane [b].

In the previous publication [5] the attention was drawn to the fact that in diffractive production of pion triples [6]

$$\pi^- + A \to (\pi^-\pi^+\pi^-) + A, \tag{2}$$

[a] Supported by RFBR Grants No 98-02-16508 and 96-02-17631.

[b] In fact, an idea similar to the handedness was earlier proposed in works [2]. Its application to certain heavy quark decays was studied in Ref. [3]. Similar technique was also studied in work [4].

by π^- beam 40 GeV/c from a nucleus A, a noticeable asymmetry with respect to the triple production plane (transversal handedness H_{T1}) was observed. This paper is devoted to further experimental investigation of this phenomenon. It includes a new information on the dependence of the transversal handedness on the variables:

- Atomic number of the target,
- Transversal momenta of the pion triple,
- Feynmann variable X_F of the leading π^-,
- Invariant mass of the triple,
- Invariant mass of neutral pairs $\pi^+\pi^-$

Also the statistics was considerably increased.

2 Definitions and notation

For reaction (2), let us define the normal to the plane of production of a secondary pion triple $(\pi_f^-\pi^+\pi_s^-)$

$$\vec{N} = (\vec{v}_{3\pi} \times \vec{v}_b) \tag{3}$$

where $v_b = k_b/\epsilon_b$ and $\vec{v}_{3\pi} = k_{3\pi}/\epsilon_{3\pi}$ are velocities of the initial π^- beam and the center of mass of the triple in Lab. r.f. and indices f and s label fast and slow π^-'s. The normal to the "decay plane" of the triple in its center of mass is defined as

$$\vec{n} = (\vec{v}_f^- - \vec{v}^+) \times (\vec{v}_s^- - \vec{v}^+) \tag{4}$$

where $\vec{v}_{f(s)}^-$ or $\vec{v}^+$ are velocities of the fast (slow) π^- or π^+.

The transversal handedness according to (1) is

$$H_{T1} = \frac{N(\vec{N}\vec{n} > 0) - N(\vec{N}\vec{n} < 0)}{N(\vec{N}\vec{n} > 0) + N(\vec{N}\vec{n} < 0)}. \tag{5}$$

Two other components of the handedness connected with $\vec{n}\cdot\vec{v}_{3\pi}$ and $\vec{n}\cdot(\vec{v}_{3\pi}\times\vec{N})$ are forbidden by the parity conservation in the strong interaction.

3 Experimental results and discussion

The transversal handedness (5) was measured for a wide sample of nuclear targets: Be, ^{12}C, ^{28}Si, ^{48}Ti, ^{63}Cu, ^{107}Ag, ^{181}Ta and ^{207}Pb. The total number of selected events of pion triples with leading π^- was about 250,000.

The dependence of H_{T1} on the atomic number A is presented in Fig.1. One can see that the handedness systematically decreases with increasing A, which resembles a depolarization effect in multiple scattering. An argument in this favor is the decrease of the effect as, approximately, inverse nuclei radius.

The value of the asymmetry (5), averaged over all nuclei is

$$H_{T1} = (5.96 \pm 0.21)\% \qquad (6)$$

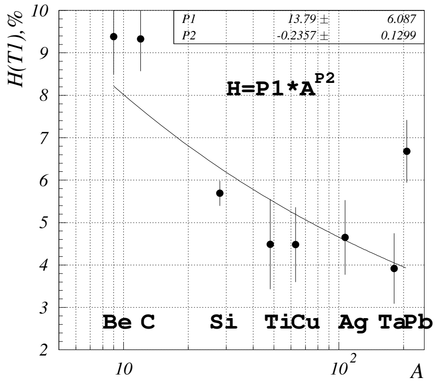

Fig.1. The A-dependence of the handedness.

Statistically, this is highly reliable verification of the existence of correlation of the triple production and decay planes in process (2).

The values of two other asymmetries with respect to correlations $\vec{n} \cdot \vec{v}_{3\pi}$ and $\vec{n} \cdot (\vec{v}_{3\pi} \times \vec{N})$ was found to be comparable to zero from the same statistical material: $H_L = (0.25 \pm 0.21)\%$ and $H_{T2} = (0.43 \pm 0.21)\%$ respectively. This is by no means estonishing, since they are forbidden by the parity conservation in process (2).

A natural question is to what extent the effect observed is due to the kinematics or apparatus influence, in particular, due to acceptance of the experimental setup where the events have been registered. For this aim the Monte-Carlo events of reaction (2) were generated with a constant mass spectrum of the 3π–system in the interval 0.6–2.5 GeV/c^2 and with the exponential decrease of the cross section in $t' = t - t_{min}$ with the slope (for berillium) $40\,(GeV/c)^{-2}$. This events were traced through the apparatus simulation and the same selection of events shows no transversal handedness H_{T1}

$$H_{T1}^{\mathrm{MC}} = (0.20 \pm 0.28)\% \qquad (7)$$

For two other asymmetries, forbidden by the parity conservation, the result was $(0.00 \pm 0.28)\%$ and $(-0.14 \pm 0.28)\%$, respectively. Thus, the effect (6) cannot be explained by the kinematics or apparatus influence.

To understand the nature of the effect observed, the dependence of the handedness (5) on the Feynmann variable X_F of the leading π^-, on the invariant mass of the triple $m_{3\pi}$ and its neutral subsystem $m_{\pi^+\pi^-}$ and on the triple transversal momentum k_T was studied. From Fig.2 one can see that the handedness (5) increases with X_F, which resembles the behavior of the single spin asymmetry (e.g. the pion asymmetry or the Λ-polarization [7]).

The dependence of H_{T1} on the triple invariant mass (Fig.3a) is especially interesting. It clearly indicates two different sources of H_{T1} with comparable contributions: a resonant and a non-resonant one. The resonance contribution is clearly seen at the mass of $a_1(1260)$ and $\pi_2(1670)$ region and by no means is due to a non-zero polarization of the resonances. The non-resonant background could also be polarized, provided that the 3π system is predominantly in a state with the total angular momentum $J \neq 0$, e.g. if a neutral pair $m_{\pi^+\pi^-}$ was predominantly produced from ρ-decay. Some indication of this can be seen from Fig.3b. In this context, the growth of H_{T1} in the region of small $m_{3\pi}$, i.e. in the region of small relative momenta of pions, looks quite intriguing.

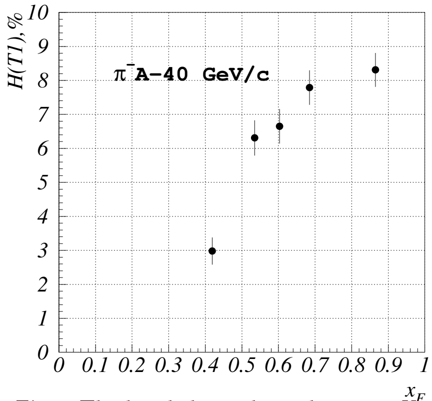

Fig.2. The handedness dependence on X_F of the leading π^-.

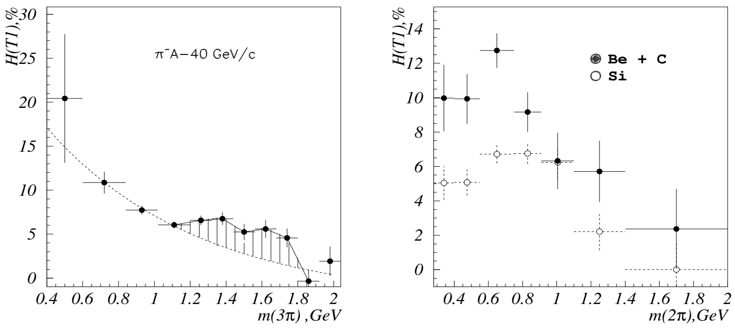

Fig.3. The handedness dependence on $m_{3\pi}$ (a) and $m_{\pi^+\pi^-_f}$ (b).

A complicated picture of the k_T-dependence with a sharp minimum at $k_T = 0.05 - 0.07\,GeV/c$ (Fig.4) reflects by all means the fact of interference of the resonant and non-resonant processes in the triple production. With further increase of k_T the handedness increases which resembles the single spin asymmetry behavior too.

Notice also that in earlier study of reaction (2) at $4.5\,GeV$ for the proton target at the hydrogen bubble chamber no angular dependence of the normal $\vec{n}$ (4) was found just as in the Regge pole exchange model, which provides a reasonable description of that experiment [8].

In conclusion, a rather large handedness transversal to the production plane was definitely observed in the diffractive production of $(\pi^-\pi^+\pi^-)$ triples in the π^-–beam fragmentation region. The phenomenon has a clear dynamical origin and in some features resembles the single spin asymmetry behavior. For a more detailed study, a partial wave analysis of reaction (2) seems necessary.

The authors sincerely thank the participants of the Bologna–Dubna–Milan collaboration whose data were used in the present work.

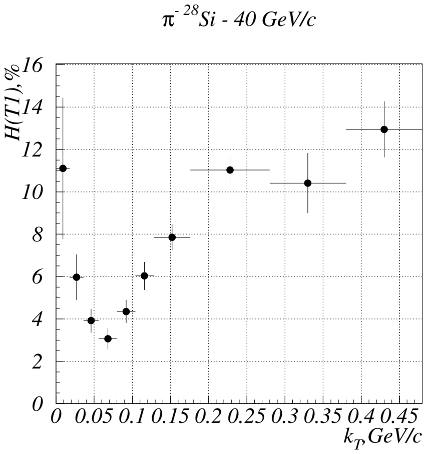

Fig.4. The k_T-dependence of the handedness.

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