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Measurement of Collins asymmetries in the inclusive production of pion pairs in electron-positron collisions at BaBar

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Summary. — Transversity distribution describes the quark transverse polarization inside a transversely polarized nucleon. It is the last leading-twist missing piece of the QCD description of the partonic structure of the nucleon. Transversity can be extracted from semi-inclusive deep inelastic scattering (SIDIS) where, however, it couples to a new, unknown fragmentation function, called *Collins function*. We present a measurement of the azimuthal asymmetries in the process $e^+e^- \to q\bar{q} \to \pi\pi X$, where the two pions are produced in opposite hemispheres, based on a data sample collected by the BaBar experiment at a center-of-mass energy of about 10.6 GeV. The Collins function is extracted from the measured asymmetries.

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PACS 13.87.Fh – Fragmentation into hadrons.

1. – Motivation for extraction of Collins function in e^+e^- annihilation

Transversity (h_1) is the less known function [1] among the three parton distribution functions needed for a complete description of the momentum and spin distribution of the quarks inside the nucleon. We can measure h_1 in the SIDIS experiment where, using the factorization theorem, the cross-section is:

$$\sigma^{ep\to ehX} = \sum_q \mathrm{DF} \times \sigma(eq \to eq) \times \mathrm{FF}, \tag{1}$$

with DF the unpolarized Distribution Function (h_1), and FF the Collins Fragmentation Function ($H_1^\perp$). Therefore, to extract h_1 we need to know the Collins FF. The measurement of the Collins function can be done in e^+e^- annihilation, in which we can use two reference frames in order to extract the asymmetries. In the *thrust reference frame* (RF12) (where the thrust axis is the axis that maximizes the longitudinal momentum of

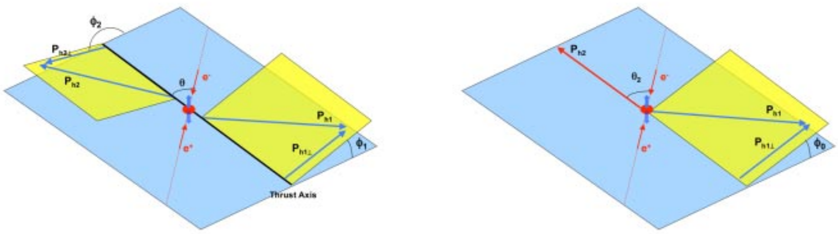

Fig. 1. – (Color online) (a) RF12: θ is the angle between the lepton and thrust axis; $\phi_{1,2}$ are the azimuthal angles between the scattering plane and the transverse momenta $P_{h\perp}$ around the thrust axis. (b) RF0: θ_2 is the angle between the beam axis and the second hadron momenta; ϕ_0 is the azimuthal angle between the plane spanned by the beam axis and the second hadron momenta P_2, and by the first hadron's transverse momenta $P_{1\perp}$.

the event), the differential cross-section is

$$\frac{\mathrm{d}\sigma(e^+e^- \to h_1 h_2 X)}{\mathrm{d}z_1 \mathrm{d}z_2 \mathrm{d}\Omega \mathrm{d}\phi_1 \mathrm{d}\phi_2} = \sum_{q,\bar{q}} \frac{3\alpha^2}{Q^2} \frac{e_q^2}{4} z_1^2 z_2^2 [(1+\cos^2\theta) D_1^{(0)}(z_1) \bar{D}_1^{(0)}(z_2) + \sin^2(\theta)\cos(\phi_1+\phi_2) H_1^{\perp,(1)}(z_1) \bar{H}_1^{\perp,(1)}(z_2)], \tag{2}$$

and in the *second hadron momentum frame* (RF0) is

$$\frac{\mathrm{d}\sigma(e^+e^+ \to h_1 h_2 X)}{\mathrm{d}z_1 \mathrm{d}z_2 \mathrm{d}^2\mathbf{q}_T \mathrm{d}\Omega} = \frac{3\alpha^2}{Q^2} z_1^2 z_2^2 \left\{ A(y)\, \mathcal{F}(D_1(z_1)\bar{D}_1(z_2)) + B(y)\cos(2\phi_0)\mathcal{F}\left[(2\hat{\mathbf{h}}\cdot\hat{\mathbf{k}}_T\, \hat{\mathbf{h}}\cdot\hat{\mathbf{p}}_T - \hat{\mathbf{k}}_T\cdot\hat{\mathbf{p}}_T) \frac{H_1^{\perp}(z_1)\bar{H}_1^{\perp}(z_2)}{M_1 M_2} \right] \right\}. \tag{3}$$

D_1 is the unpolarized Fragmentation Functions (FF), $H_1^{\perp}$ is the Collins FF, $z_{1,2}$ is the fractional energy of the hadron, Q^2 is the center-of-mass energy, and the angles are defined in fig. 1. In conclusion, the Collins asymmetries in e^+e^- annihilation are proportional to $H_1^{\perp}(z_1) \times \bar{H}_1^{\perp}(z_2)$ and, therefore, we can obtain a independent measure of this FF.

2. – Analysis strategy

Assuming the thrust axis as $q\bar{q}$ direction and selecting pions in opposite hemispheres with respect to the thrust axis, we measure the azimuthal angles ϕ_1, ϕ_2, and ϕ_0. In order to select the two jets topology, we require a thrust higher than 0.8. In addition, we select pions coming from the primary vertex with a fractional energy ($z = 2E/Q$) higher than 0.2. The total energy of the events is required to be higher than 7 GeV. After this preselection, we can access the Collins asymmetries by measuring the $\cos(\phi)$ modulation, where $\phi = \phi_1 + \phi_2$ or $\phi = 2\phi_0$ for the two reference frames, of the normalized azimuthal distributions of the selected pion pairs. The asymmetries resulting by these distributions are largely affected by detector acceptance effects, making their measurement unreliable. We therefore perform suitable double ratios of the asymmetries in order to eliminate the detector effects and the first order of radiative effects [2]. In particular we use the ratio of the normalized distributions of unlike sign (R_{UL}) over those of like sign (R_L) pion pairs. Fitting the double ratio with a cosine function

$$\frac{R_L}{R_{UL}} = \frac{N^L(\phi)/\langle N^L\rangle}{N^{UL}(\phi)/\langle N^{UL}\rangle} = P_0 + P_1 \cdot \cos(\phi), \tag{4}$$

the P_1 parameter contains only the Collins effect and higher-order radiative effects.

3. – Study of systematic effects

A crucial point in the measurement of Collins asymmetry is the identification of all the effects that can influence the azimuthal distribution of the pion pairs. We study the influence of the particle identification, the possible dependence of the detector response on the pion charge, the contribution of the charmed hadrons and τ decays to the asymmetry, the polarization of the beams, and other minor effects.

Asymmetry dilution. – The deviation of the thrust axis from the real $q\bar{q}$ direction can lead to a dilution of the measured asymmetries. This effect could be evaluated using a Monte Carlo (MC) sample. However, the Collins fragmentation functions are not defined in our MC generator. Therefore, we simulate the asymmetries applying different weights to the generated angular distribution. We finally fit the reconstructed azimuthal distributions and we compare the resulting asymmetries with the weights introduced in the simulation. We find that, in the RF12 frame, the asymmetry is significantly underestimate, and we apply a correction factor according to the measured value.

4. – Conclusions

An analysis aiming to measure the Collins FF from the azimuthal asymmetries from the inclusive production of pion pairs in opposite jets is presently in progress in BaBar. We expect to have final results with the full BaBar data sample by the end of 2011, with the sensitivity comparable to the measurements published by Belle [3].

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