MEASURING TRANSVERSITY WITH SPIN-ONE HADRONS

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We analyze one-particle inclusive DIS in the case when a spin-1 hadron (such as a vector meson) is observed in the final state. We consider only leading order contributions in $1/Q$, but we include transverse momentum of partons. We identify five asymmetries where the transversity distribution $h_1(x_B)$ appears multiplied by new fragmentation functions or moments of them.

To describe the production of spin-one hadrons in DIS we need to introduce two soft correlation functions, describing the quark distribution in the spin-1/2 target and the hadronization of a quark into the final state spin-1 hadron. In leading order in $1/Q$ we are concerned only with the quark-quark correlation functions Φ and Δ. The correlation function Φ has been already widely studied in the literature (see e.g. [1]). The function Δ is defined as (using Dirac indices α and β)

$$\Delta_{\alpha\beta}(k, P_h, S_h, T_h) = \int \frac{\mathrm{d}^4\xi}{(2\pi)^4} \mathrm{e}^{+\mathrm{i}k\xi} \langle 0|\psi_\alpha(\xi)|P_h, T_h\rangle\langle P_h, T_h|\bar{\psi}_\beta(0)|0\rangle. \quad (1)$$

Here, k is the momentum of the quark decaying into an outgoing hadron after being struck by a virtual photon. The vector P_h is the momentum of the outgoing hadron, S_h is its spin vector and T_h is its spin tensor, needed to the full description spin-one polarization [2]. In the hadronic tensor we need the integrated correlation function

$$\Delta(z, \boldsymbol{k}_T) = \frac{1}{4z} \int \mathrm{d}k^+ \; \Delta(k, P_h, S_h, T_h)\Big|_{k^- = \frac{P_h^-}{z}\,;\, k_T = \frac{P_{h\perp}}{z}}, \quad (2)$$

which can be decomposed using 18 different fragmentation functions [3]. Five of them are chiral odd and as such they are possible candidates to connect to the transversity distribution function.

The cross-section of semi-inclusive deep-inelastic scattering is

$$\frac{\mathrm{d}\sigma(l + H \to l' + h + X)}{\mathrm{d}x\,\mathrm{d}z\,\mathrm{d}y} = \frac{\pi\alpha^2}{Q^4}\,\frac{y}{2z}\, L_{\mu\nu}\; 2MW^{\mu\nu}, \quad (3)$$

where x, z and y are the usual scaling variables and $L_{\mu\nu}$ is the lepton tensor. The hadronic tensor $W^{\mu\nu}$ can be written as

$$2MW^{\mu\nu} = 2z\;\mathrm{Tr}\;[2\Phi(x)\,\gamma^\mu\; 2\Delta(z)\,\gamma^\nu]\,. \quad (4)$$

By substituting the full structure of Φ and Δ into Eq. (4) and using the resulting hadronic tensor in Eq. (3), we can calculate the cross section for a transversely polarized target.

From the experimental point of view, it is necessary to reconstruct the spin-one particle momentum and polarization by studying its decay products. For instance, one has to isolate pion couples coming from the decay of primary ρ mesons. The polarization analyzing powers can then be expressed in terms of the azimutal and polar angles of one of the pions. Because of the parity-conserving character of the decay, only tensor polarization analyzing powers are different from zero.

To single out the contributions containing the transversity distribution function a transversely polarized target is needed. Then, azimutal asymmetries can be defined as

$$\langle W\rangle_{UT}(x_B, y, z_h) = \int \mathrm{d}\phi_\pi^\ell \, \mathrm{d}\phi^\ell \, \mathrm{d}^2\boldsymbol{P}_{h\perp} \; W \; \left(\frac{\mathrm{d}\sigma^\uparrow - \mathrm{d}\sigma^\downarrow}{\mathrm{d}\phi^\ell \, \mathrm{d}x_B \, \mathrm{d}z_h \, \mathrm{d}y \, \mathrm{d}^2\boldsymbol{P}_{h\perp}} \right) \quad (5)$$

where ϕ^ℓ is the azimutal angle of the electron scattering plane, ϕ_ρ^ℓ, ϕ_S^ℓ and ϕ_π^ℓ are the azimutal angles with respect to the scattering plane of the outgoing ρ, of the transverse spin of the target and of one of the decay pions, respectively.

The following asymmetries containing the transversity distribution can then be observed:

$$\left\langle \sin(\phi_\pi^\ell + \phi_S^\ell) \right\rangle_{UT} = \frac{4\pi^2\alpha^2 s}{Q^4} \, x_B \; |S_T| \, (1-y) \, |\sin 2\theta_\pi| \sum_a e_a^2 \, h_1^a(x_B) \, H_{1LT}^a(z_\rho) \quad (6)$$

$$\left\langle \frac{Q_T}{M_h} \, \sin(2\phi_\pi^\ell + \phi_S^\ell - \phi_\rho^\ell) \right\rangle_{UT} = \frac{8\pi^2\alpha^2 s}{Q^4} \, x_B \; |S_T| \, (1-y) \, \sin^2\theta_\pi \sum_a e_a^2 \, h_1^a(x_B) \, H_{1TT}^{(1)a}(z_\rho) \quad (7)$$

$$\left\langle \frac{Q_T}{M_h} \, \sin(\phi_S^\ell + \phi_\rho^\ell) \right\rangle_{UT} = \frac{8\pi^2\alpha^2 s}{Q^4} \, x_B \; |S_T| \, (1-y) \sum_a e_a^2 \, \frac{(1 - 3\cos\theta_\pi)}{2} \, h_1^a(x_B) \, H_{1LL}^{\perp(1)a}(z_\rho) \quad (8)$$

$$\left\langle \frac{Q_T^2}{M_h^2} \, \sin(\phi_S^\ell + 2\phi_\rho^\ell - \phi_\pi^\ell) \right\rangle_{UT} = \frac{8\pi^2\alpha^2 s}{Q^4} \, x_B \; |S_T| \, (1-y) \, |\sin 2\theta_\pi| \sum_a e_a^2 \, h_1^a(x_B) \, H_{1LT}^{\perp(2)a}(z_\rho) \quad (9)$$

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\begin{aligned}
&\left\langle \frac{Q_T^5}{4M^2M_h}\ \sin\left(\phi_S^\ell+3\phi_\rho^\ell-2\phi_\pi^\ell\right)\right\rangle_{UT}\\
&= \frac{8\pi^2\alpha^2 s}{Q^4}\ x_{\scriptscriptstyle B}\ \ |S_T|\ (1-y)\ \sin^2\theta_\pi\\
&\quad\times\sum_a e_a^2\left[h_1^a(x_{\scriptscriptstyle B})\ H_{1TT}^{\perp(4)a}(z_\rho)+4\ \left(\frac{M_h}{M}\right)^2\ h_1^{(1)a}(x_{\scriptscriptstyle B})\ H_{1TT}^{\perp(3)a}(z_\rho)\right.\\
&\qquad\left.+\,10\ \left(\frac{M_h}{M}\right)^2 h_{1T}^{\perp(2)a}(x_{\scriptscriptstyle B})\ H_{1TT}^{\perp(3)a}(z_\rho)\right],
\end{aligned}
\tag{10}
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where θ_π is the angle between the direction of the outgoing meson and the direction of the decay pion as measured in the meson's rest frame.

1. See e.g. P.J. Mulders, R.D. Tangerman, Nucl. Phys. B **461** (1996) 197.
2. C. Bourrely, E. Leader, J. Soffer, Phys. Rep. **59** (1980) 95.
3. A. Bacchetta, P.J. Mulders, Phys. Rev. D **62**, 114004.