Polarized Parton Distribution Functions with Estimate of Uncertainties

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Experimental data on the structure function $g_1(x, Q^2)$ have been accumulated with the proton, deuteron and ^{3}He targets. We study parameterization of the polarized parton distributions (pol-PDFs) [1] in the leading order (LO) of α_s and in the next-to-leading order (NLO) with estimate of uncertainties.

The polarized distributions are provided with a number of parameters at Q^2=1 GeV^2 ($\equiv Q_0^2$). Considering the positivity condition and the helicity retention property following functional form is proposed for the pol-PDFs:

$$\Delta f_i(x, Q_0^2) = A_i\, x^{\alpha_i}\, (1 + \gamma_i\, x^{\lambda_i})\, f_i(x, Q_0^2)\,, \tag{1}$$

where $f_i(x, Q_0^2)$ is an unpolarized parton distribution (GRV98). The subscript i denotes the type of the parton distribution: $f_i \in \{u_v, d_v, \bar{q}, g\}$. The parameters A_i, α_i, γ_i, and λ_i are determined by fitting available experimental data on the inclusive spin asymmetry A_1 from experiments: EMC, SMC, SLAC (E130, E142, E143, E154, E155) and HERMES, where A_1 is expressed with the structure function g_1 and other known functions and g_1 is expressed as linear combination of pol-PDFs Δf_i. The first moments of Δu_v and Δd_v are fixed by the semi-leptonic decay data by assuming the SU(3) symmetry, so that the number of free parameters is reduced from 16 to 14.

The χ^2 minimization is performed by using the CERN library subroutine MINUIT with the following definition,

$$\chi^2 = \sum (A_1^{data} - A_1^{calc})^2 / (\sigma_{A_1^{data}})^2 \tag{2}$$

comparing theoretical asymmetries A_1 with the experimental data weighted by square inverse of the error in each points. As a result, we obtain the minimum χ^2: χ^2/d.o.f=322.6/359 for the LO and χ^2/d.o.f=300.4/359 for the NLO.

The uncertainties of pol-PDFs can be estimated from the errors of the parameters. However, previous attempts to quantify the uncertainties on the pol-PDFs have been rather unsatisfactory. This is due to that extracting the uncertainties of pol-PDFs is not easy because there are strong correlations between pol-PDFs of different flavors and from different values of x and Q^2. We present preliminary results from an effort to quantify the uncertainties in polarized parton distribution functions.

[1] Y. Goto, N. Hayashi, M. Hirai, H. Horikawa, S. Kumano, M. Miyama, T. Morii, N. Saito, T.-A. Shibata, E. Taniguchi, and T. Yamanishi, hep-ph/0001046, Phys. Rev. D 62 34017 (2000).