# Global analysis of AAC for determining polarized parton distribution functions

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**Abstract.** We report global analysis results for polarized parton distribution functions in the nucleon. The optimum distributions are determined by using spin asymmetry data on polarized lepton scattering on proton, neutron, and deuteron. Their uncertainties are estimated by the Hessian method. As a result, polarized quark distributions are relatively well determined, whereas the polarized gluon distribution has a large uncertainty band. We find that the obtained gluon distribution is compatible with recent $\Delta g/g$ measurements in high-$p_T$ hadron productions.

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## INTRODUCTION

The nucleon spin is one of the fundamental quantities in physics, yet we do not understand its origin. Internal structure of the nucleon spin has been investigated mainly by polarized lepton-nucleon scattering experiments. Polarizations of quarks and gluons are expressed by polarized parton distribution functions (PDFs), and we extract them from the experimental measurements.

The standard method is to obtain the polarized PDFs, which are expressed by a number of free parameters, by a $c^2$ analysis of available polarization-asymmetry data. Among such analyses, we report the results by the Asymmetry Analysis Collaboration (AAC) [1, 2]. In the recent version [2], the polarized PDFs and their uncertainties are obtained by using inclusive deep inelastic scattering (DIS) data. However, these data are not enough to impose considerable constraints on each polarized PDF, especially the gluon distribution. Fortunately, the situation is changing because the RHIC-Spin started producing data and there are reports on the gluon polarization by using semi-inclusive lepton scattering data. In the following, we explain the AAC results [2] and also a comparison with recent $\Delta g/g$ measurements.

## GLOBAL ANALYSIS OF SPIN ASYMMETRY DATA

For probing the internal structure of the nucleon, cross sections for polarized deep inelastic lepton-nucleon scattering have been measured. Their experimental data are shown by the spin asymmetry $A_1$. It is expressed by the ratio of the polarized structure function $g_1$ to the unpolarized one $F_1$, which is usually expressed by $F_2$ and the longitudinaltransverse ratio $R$:

$$A_1(x,Q^2) = \frac{g_1(x,Q^2)}{F_2(x,Q^2)} 2x\,[1+R(x,Q^2)]\,. \tag{1}$$

The unpolarized PDFs of the GRV98 are used for calculating $F_2$, and the SLAC parametrization is used for $R$. The polarized structure function is expressed in terms of polarized PDFs:

$$g_1(x,Q^2) = \frac{1}{2}\sum_{i=1}^{n_f} e_i^2 \left\{ \Delta C_q(x,\alpha_s) \otimes [\Delta q_i(x,Q^2) + \Delta\bar{q}_i(x,Q^2)] + \Delta C_g(x,\alpha_s) \otimes \Delta g(x,Q^2) \right\}, \tag{2}$$

where $\Delta C_q$ and $\Delta C_g$ are coefficient functions.

A polarized PDF, $\Delta f$ $(= \Delta q_i,\ \Delta\bar{q}_i,$ or $\Delta g)$, is defined by a number of parameters at the initial scale $Q^2$=1 GeV$^2$: $\Delta f(x) = [\delta x^\nu - \kappa(x^\nu - x^\mu)] f(x)$, where $f(x)$ is the corresponding unpolarized distribution. This functional form is convenient especially for imposing the positivity condition, $|\Delta f(x)| \leq f(x)$, in the global analysis. Flavor symmetric antiquark distributions are assumed at the initial scale because of the lack of experimental information. The distributions are evolved to experimental $Q^2$ points of the spin asymmetry by the DGLAP evolution equations in order to calculate $\chi^2$ values at the same $Q^2$ points. All the calculations are done in the next-to-leading order (NLO) of $\alpha_s$ and the $\overline{\mathrm{MS}}$ scheme is used. The parameters are determined so as to minimize the total $\chi^2$. Then, the uncertainties of obtained PDFs are estimated by the Hessian method. So far, only the inclusive DIS data are used for the analysis in the AAC analysis. Because there are measurements after the publication [2], an analysis is in progress with JLab, HERMES, and COMPASS data. In future, we need to include other data such as the ones from semi-inclusive DIS and RHIC-Spin.

## RESULTS

We analyzed the data of the spin asymmetries $A_1$ in Eq. (1) for the proton, neutron, and deuteron in polarized lepton scattering. The polarized PDFs obtained by the analysis at $Q^2$=1 GeV$^2$ are shown in Fig. 1, where the solid curves indicate the AAC03 distributions and their uncertainties are shown by the bands. In comparison, other analysis results (BB, GRSV, LSS) are also shown in the figure. The valence-quark distributions are well determined; however, the antiquark and gluon distributions have large uncertainties. In particular, the polarized gluon distribution has the huge uncertainty which is much larger

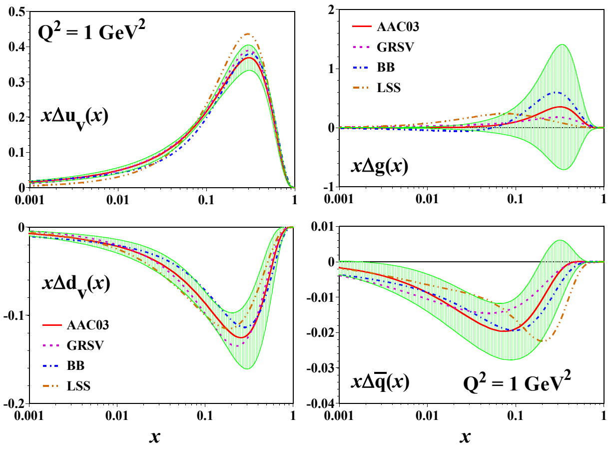


**FIGURE 1.** Polarized PDFs with uncertainties [2].

than the distribution itself. If the uncertainty is taken into account, even $\Delta g(x) = 0$ is allowed at this stage. Although there are variations among the four parametrizations in Fig. 1, they are consistent with each other within the PDF uncertainties. From the PDF determination, we find that the quark spin content is $\Delta\Sigma = 0.21 \pm 0.14$ and the first moment of $\Delta g(x)$ is $\Delta g = 0.50 \pm 1.27$ at $Q^2$=1 GeV$^2$.

The results indicate that it is impossible to determine a reliable gluon polarization at this stage. There are two types of contributions to $g_1$ from the polarized gluon distribution. One is through the NLO coefficient function in Eq. (2), and the other is through the DGLAP $Q^2$ evolution. Current inclusive DIS experimental data are not accurate enough to specify these gluonic effects, which results in the huge gluonic uncertainty. On the other hand, there are reports on the gluon polarization by observing high-$p_T$ hadrons in DIS. The HERMES, SMC, and COMPASS results are shown in Fig. 2 in comparison with the AAC03 gluon distribution with the uncertainty at $Q^2$=1 GeV$^2$. There are also preliminary results on $\Delta g/g$ from the COMPASS collaboration by using large-$Q^2$ and charmed-meson data. We find that the AAC03 curve agrees with three data points in Fig. 2.

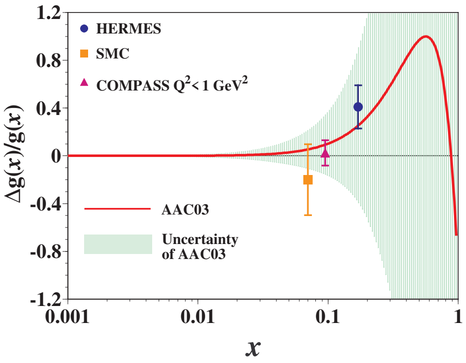


**FIGURE 2.** AAC $\Delta g/g$ in comparison with high-$p_T$ hadron-production data.

After the AAC03 analysis, measurements were reported by JLab, HERMES, and COMPASS collaborations on the spin asymmetry $A_1$. In addition to these DIS measurements, high precision data of $A_{LL}(p^0)$ from PHENIX and $A_{LL}(\text{jet})$ from STAR experiment measured in polarized $pp$ collisions at RHIC are reported at this conference. The AAC03 distributions are compatible with the reported $A_{LL}(p^0)$. These new data should improve the situation on the determination of polarized PDFs. In particular, the RHIC data as well as the high-$p_T$ DIS data can impose considerable constraints on the gluon polarization.

The AAC polarized PDF code is available at the web site [3], and it can be used for calculating the PDFs in a given kinematical point of $x$ and $Q^2$. It is noteworthy that a code is provided also for calculating the PDF uncertainties.

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3. The AAC code for polarized PDFs is available at http://spin.riken.bnl.gov/aac/.