Asymmetries from Semi-inclusive Polarized Deep Inelastic Scattering

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Abstract. The analysis of semi-inclusive data from deep inelastic muon nucleon scattering is presented. The resulting charged hadron asymmetries are used to determine polarized valence and sea quark distributions. In addition, a new approach to derive inclusive asymmetries is discussed.

To investigate the spin structure of the nucleon SMC studies deep inelastic scattering of polarized muons off polarized protons and deuterons. The SMC-NA47 experiment used the M2 muon beam of the CERN SPS at incident energies of 100 and 190 GeV. Data with polarized proton and deuteron targets were taken between 1992 and 1996 (see also [1], [2]). Scattered muons and charged hadrons are detected in an open forward spectrometer and electron-hadron separation is achieved with the help of an iron scintillator calorimeter.

In the standard analysis the spin structure function g_1 is determined from the measured inclusive asymmetry. The produced hadrons can be used in two ways: Firstly, by requiring any hadron in addition to the scattered muon a true deep inelastic scattering is signaled and thus a discrimination between these events and background events like radiative events or elastic electron muon scattering is achieved. Secondly, semi-inclusive asymmetries from positively and negatively charged hadrons can be used to determine the polarized valence and sea quark distributions as a function of the momentum fraction carried by the struck quark, x.

In the first approach a complementary method of determining inclusive asymmetries is being developed. In the standard analysis the measured photon nucleon asymmetry is related to the total cross section by $A^{\gamma\mathrm{N}}_{\mathrm{meas}} = \Delta\sigma_{\mathrm{tot}}/\sigma_{\mathrm{tot}}$ where

$$\sigma_{\mathrm{tot}} = \lambda\sigma_{1\gamma} + \sigma^{\mathrm{el}}_{\mathrm{tail}} + \sigma^{\mathrm{coh}}_{\mathrm{tail}} + \sigma^{\mathrm{qel}}_{\mathrm{tail}} + \sigma^{\mathrm{inel}}_{\mathrm{tail}}$$

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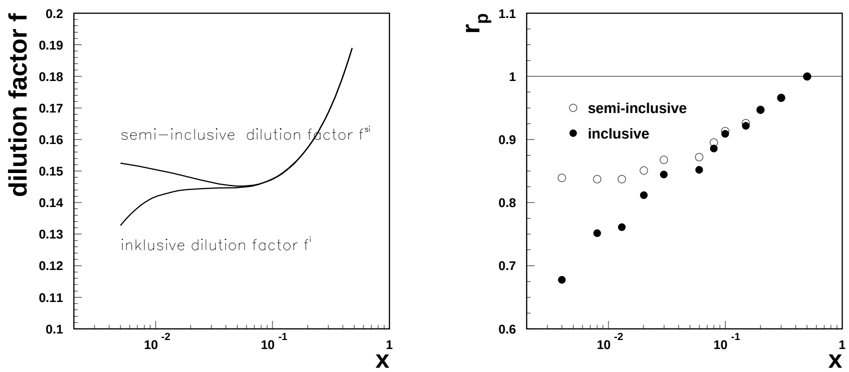

FIGURE 1. Comparison of inclusive and semi-inclusive correction factor for the dilution factor f (left) for the ammonia target and the radiative correction factor $r_\mathrm{p} = \lambda\sigma_{1\gamma}/\sigma_\mathrm{tot}$ for the proton (right).

$$\Delta\sigma_\mathrm{tot} = \lambda\Delta\sigma_{1\gamma} + \Delta\sigma^\mathrm{el}_\mathrm{tail} + \Delta\sigma^\mathrm{coh}_\mathrm{tail} + \Delta\sigma^\mathrm{qel}_\mathrm{tail} + \Delta\sigma^\mathrm{inel}_\mathrm{tail}$$

where σ_tail ($\Delta\sigma_\mathrm{tail}$) is the cross section from radiative tails (elastic, coherent on nuclei, quasielastic and inelastic) and λ is a polarisation independent multiplicative factor for the one-photon cross section $\sigma_{1\gamma}$ ($\Delta\sigma_{1\gamma}$) accounting for vacuum polarisation and vertex corrections.

Thus, the one-photon asymmetry $A_1^{\gamma\mathrm{N}} = \Delta\sigma_{1\gamma}/\sigma_{1\gamma}$ is diluted by these additional processes and corrections have to be applied to determine $A_1^{\gamma\mathrm{N}}$ from

$$A_1^{\gamma\mathrm{N}} = \frac{\sigma_\mathrm{tot}}{\lambda\sigma_{1\gamma}} A^{\gamma\mathrm{N}}_\mathrm{meas} - \frac{1}{D} \cdot \frac{\Delta\sigma_\mathrm{tail}}{\lambda\sigma_{1\gamma}},$$

where D is the depolarisation factor for the virtual photon. An additional dilution is due to the presence of unpolarized nuclei in the target. If an efficient selection of true deep inelastic events is obtained then most of the contributions to σ_tot and $\Delta\sigma_\mathrm{tot}$ vanish and the dilution of $A_1^{\gamma\mathrm{N}}$ is much smaller, giving a more accurate measurement of $A_1^{\gamma\mathrm{N}}$ although the event sample is smaller. The change of the dilution factor f and the radiative correction factor $r = \lambda\sigma_{1\gamma}/\sigma_\mathrm{tot}$ is illustrated in fig.1.

In the SMC spectrometer mainly forward produced charged hadrons with momenta $p_\mathrm{h} > 5$ GeV are detected, that is hadrons with $z = E_h/\nu \approx 0.05$ with ν the energy transfer. Events with a high mass W of the final state contain in general several hadrons with high momenta. High W events are typically found at small x, so that a good acceptance is obtained for $x < 0.1$, whereas in the high x region many hadrons are not detected due to the low momenta at low W. Monte Carlo studies show that more than 80% of the deep inelastic events are found by requiring at least one additional hadron to the scattered muon.

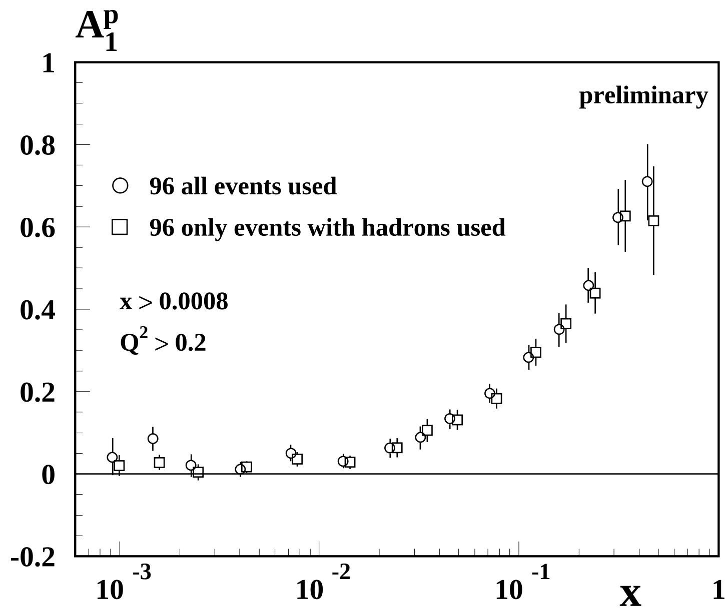

FIGURE 2. Preliminary results for $A_1^{\mathrm{p}}(x)$ obtained with the hadron method (open squares) compared to the ones from the standard analysis (open circles). The error bars are statistical errors.

For part of these hadrons that pass through the calorimeter also the ratio $e = E_{\mathrm{em}}/E_{\mathrm{tot}}$ between the energy deposited in the electromagnetic part to the total deposited energy in the calorimeter is measured. Particles with $e > 0.8$ are labelled electrons, with $e < 0.8$ hadrons.

Electrons may either stem from γ conversion after π^0 decays or from radiative photons. Therefore, additional cuts were developed to remove the latter ones keeping most of the electrons from π^0 decays. Electrons with $z > 0.2$ and $\alpha < 0.004$ for events with $y = \nu/E_\mu > 0.6$ were removed with α the angle between the electron and the photon reconstructed from the muon kinematics. The same cut is applied to particles that could not be identified by the calorimeter due to the limited acceptance close to the muon beam or due to multiple tracks pointing to the same module. It was checked with Monte Carlo simulations that a possible bias for the resulting asymmetries is much smaller than the statistical error and will be included in the systematic error.

The results for A_1^{p} using the 1996 data taken with an ammonia target are shown in fig.2 for $x > 0.0008$ and $Q^2 > 0.2$ GeV^2 and are compared to the results from the standard analysis [1]. Good agreement between the two results is obtained with the statistical error bars lower by a factor 0.6 to 0.9 for $x < 0.01$ for the hadron method (for details, see [3]).

In the second approach polarized quark distributions are determined from semi-inclusive asymmetries using the different weighting of quarks and anti-

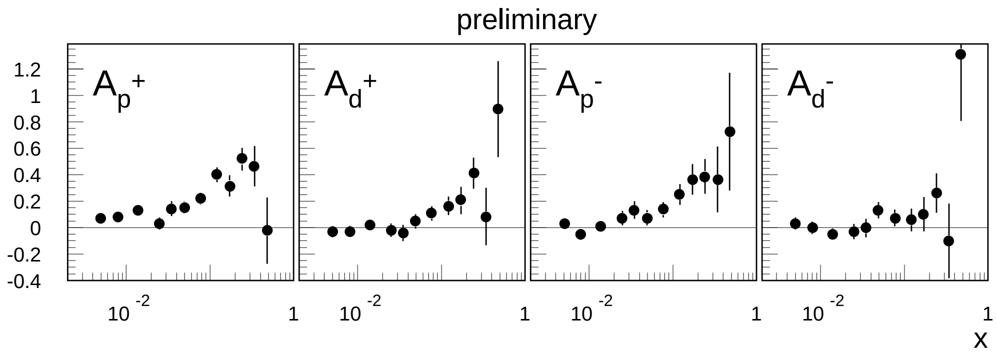

FIGURE 3. Preliminary results for the semi-inclusive photon asymmetries for positively and negatively charged hadrons from proton and deuteron targets as a function of x with statistical error bars.

quarks due to favoured and unfavoured fragmentation functions $D^{\mathrm{h}}_{\mathrm{q}(\bar{\mathrm{q}})}$. In the quark parton model these hadron asymmetries are given by

$$A^{\mathrm{h}}(x,z) = \frac{\sum_{\mathrm{q}} e_{\mathrm{q}}^2 (\Delta q(x) \cdot D^{\mathrm{h}}_{\mathrm{q}}(z) + \Delta \bar{q}(x) \cdot D^{\mathrm{h}}_{\bar{\mathrm{q}}}(z))}{\sum_{\mathrm{q}} e_{\mathrm{q}}^2 (q(x) \cdot D^{\mathrm{h}}_{\mathrm{q}}(z) + \bar{q}(x) \cdot D^{\mathrm{h}}_{\bar{\mathrm{q}}}(z))}$$

with the unpolarized and polarized quark distributions, $q(x)$ and $\Delta q(x)$. Using parametrisations for the unpolarized distributions (GRV94 LO) [4] and the fragmentation functions from [5] the polarized quark distributions can be extracted from a combined analysis of the inclusive [1], [6] and the semi-inclusive asymmetries [7].

From all SMC measurements the asymmetries for positively and negatively charged hadrons were determined using tracks originating from the interaction point of the scattered muon eliminating tracks that were labelled as electrons. To allow the interpretation in the quark parton model a cut of $Q^2 > 1$ GeV^2 and $z > 0.2$ was applied. The resulting asymmetries are shown in fig.3 in the x range from 0.003 to 0.7. The average Q^2 is 10 GeV^2 and the total event sample includes $5 \cdot 10^6$ positive and $3.8 \cdot 10^6$ negative hadrons.

To extract the valence quark distributions $\Delta u_{\mathrm{V}}(x)$ and $\Delta d_{\mathrm{V}}(x)$ and the sea quark distribution $\Delta \bar{q}(x)$ additional assumptions are needed. Firstly, $\Delta \bar{u}(x) = \Delta \bar{d}(x) = \Delta \bar{q}(x)$ is used due to the limited statistics of the data set. Secondly, to constrain the polarized strange quark distribution $\Delta \bar{s}(x) = \Delta s(x) \sim s(x)$ is assumed with the integral $\int (s(x) + \bar{s}(x)) \mathrm{d}x = -0.1$ in the range $0.003 < x < 1$ fixed to the value from the inclusive analysis [8]. The effect of this assumption on $\Delta u_{\mathrm{V}}(x)$, $\Delta d_{\mathrm{V}}(x)$ and $\Delta \bar{q}(x)$ is negligible due to the low sensitivity of the measured asymmetries to the strange distribution as 80% of the hadrons are pions. Also, possible Q^2 dependences of the asymmetries are neglected by using $A(x, Q^2_{\mathrm{meas}}) = A(x, 10\,\mathrm{GeV}^2)$.

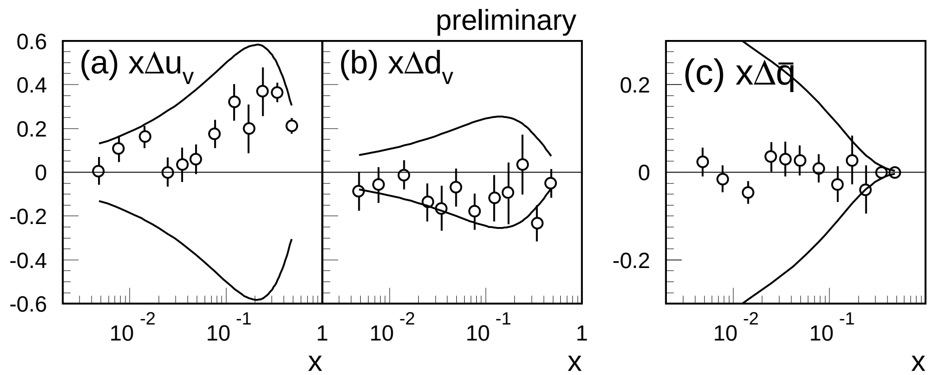

FIGURE 4. Preliminary results for the polarized quark distributions (a) $x\Delta u_{\rm V}$, (b) $x\Delta d_{\rm V}$ and (c) $x\Delta\bar{q}$ as a function of x at $Q^2 = 10$ GeV^2 with statistical error bars. For the curves, see text.

The preliminary results for the polarized quark distributions $x\Delta q(x)$ are shown in fig.4 compared to $\pm xq(x)$ [4]. The valence quark distributions are positive for $\Delta u_{\rm V}(x)$ and negative for $\Delta d_{\rm V}(x)$ with a polarization of about 50% (-50%), respectively. The non-strange sea quark distribution is consistent with zero over the measured range. For the integrals $\int_{0.003}^{0.7} \Delta q \mathrm{d}x = \Delta q(0.003, 0.7)$ in the measured range

$$\begin{aligned} \Delta u_{\rm V}(0.003, 0.7) &= 0.88 \pm 0.11(\text{stat.}) \pm 0.06(\text{syst.}), \\ \Delta d_{\rm V}(0.003, 0.7) &= -0.48 \pm 0.15(\text{stat.}) \pm 0.05(\text{syst.}), \\ \Delta\bar{q}(0.003, 0.7) &= -0.01 \pm 0.05(\text{stat.}) \pm 0.01(\text{syst.}) \end{aligned}$$

are obtained. The extrapolation to $x = 1$ leads to negligible contributions, while the extrapolation towards low x is currently under investigation.

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