Future Polarised DIS Fixed Target Experiments

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New experiments in polarised deep inelastic scattering will mainly concentrate on the measurement of semi-inclusive asymmetries. Especially, the upgraded HERMES experiment at DESY and the newly build COMPASS experiment at CERN will investigate the gluon polarisation via open charm and high p_T hadron pair production, study in detail the flavour decomposition of the quark helicity distributions and measure the tranversity distributions with tranversely polarised targets.

1. INTRODUCTION

The spin structure of the nucleon has been investigated in polarised deep inelastic scattering by a series of experiments at CERN, SLAC and DESY [1]. These experiments were initiated by the discovery of the EMC in 1987 that the contribution of the quark helicities to the proton spin is much smaller than expected originally [2]. The new experiments confirmed the original finding of the EMC also for the neutron that the singlet axial vector current matrix element is about 1/2 to 1/3 of the predicted value of 0.6 [3].

Up to now only the contribution of quark helicities to the nucleon spin was studied. Further insight into the spin structure of the nucleon can be gained by investigating the gluonic contribution and the contribution of angular momentum. In addition a measurement of the decomposition of the quark contribution into the different quark flavours will yield a deeper understanding of the nucleon spin puzzle.

There is a whole list of topics which need more detailed studies:

- The flavour decomposition of the polarised quark distributions can be extracted via the measurement of semi-inclusive asymmetries.
- The gluon polarisation can be measured with the help of open charm production or high p_T hadron pairs.
- Polarised fragmentation functions and spin transfer can be studied by measuring the Λ polarisation in the current and target fragmentation region.
- A new topis is the study of transversity in scattering on a transversely polarised target using the Collins effect. First signal were presented by SMC and HERMES during this workshop [4,5].
- The total angular momentum of quarks might be investigated via deeply virtual Compton scattering.

Further topics on the list refer to the measurement of off-forward parton distributions, vector meson production etc.

The common feature of all these new measurements is the need to detect one or several hadrons in addition to the scattered lepton.

2. MEASUREMENT OF ΔG

Up to now the gluon polarisation has been investigated by indirect methods using NLO analyses of structure function data [1]. They indicate that integral ΔG is positive and of the order of 1 at $Q^2 = 1$ GeV^2 with fairly large errors while the functional form of $\Delta G(x)$ is completely unknown although there are some prejudices that $\Delta G(x)$ is largest around $x \approx 0.1$.

The cleanest channel for a direct measurement of ΔG in polarised DIS is the photon gluon fusion process (PGF) as it depends in leading order on

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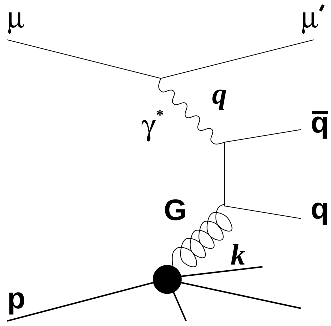

Figure 1. The photon fusion diagramm.

the gluon distribution (see fig. 1). In this context several methods are being discussed to extract $\Delta G/G$:

- Open charm procduction:

$$\gamma\mathrm{N} \to \mathrm{c\bar{c}X} \to \mathrm{D^0X}$$

PGF is signalled by the dectection of charmed particles in the final state, especially by $\mathrm{D^0}$ and Λ_c (close to threshold). The $\mathrm{D^0}$'s are reconstructed via their decay to e.g. $\mathrm{K}\pi$ or $\mu\mathrm{K}\pi$. This process should yield a clear signal directly related to ΔG. Here, the hard scale is given by $2\mathrm{m_c}$.

The cross section for open charm production $\sigma^{\gamma\mathrm{N}\to\mathrm{c\bar{c}}}$ is large for quasi real photons and $\Delta\sigma^{\gamma\mathrm{N}\to\mathrm{c\bar{c}}}/\sigma^{\gamma\mathrm{N}\to\mathrm{c\bar{c}}}$ is largest for photon energies between 30 and 80 GeV. The asymmtry a_LL for the hard subprocess $\gamma\mathrm{g} \to \mathrm{c\bar{c}}$ is about 1 at threshold ($2\mathrm{m_c}$) while $a_\mathrm{LL} = -1$ for large energies. In this case a positive gluon polarisation will leaad to a negative photon nucleon asymmetry:

$$A^{\mathrm{c\bar{c}}}_{\gamma\mathrm{N}} = \langle a_\mathrm{LL}\rangle\langle\Delta G/G\rangle\,.$$

- Hidden charm production:

$$\gamma\mathrm{N} \to \mathrm{c\bar{c}X} \to \mathrm{J}/\psi\mathrm{X}$$

Here the photon gluon process is signalled by the production of a J/ψ which is identified by its decay into a muon pair. While this is a very clean experimental signal the cross section is reduced considerably compared to open charm production. Moreover the relation of the signal to $\Delta G/G$ has to be done via the colour singlet or the colour octet model, a question which is not yet settled in unpolarised DIS.

- High p_T hadron pairs:

$$\gamma\mathrm{N} \to \mathrm{q\bar{q}X} \to \mathrm{2jets\ X}$$

This third method tries to select all PGF events not only the $\mathrm{c\bar{c}}$ production. The transverse momenta of the produced jets give the necessary hard scale.

At the moderate energies of fixed target experiments jets are not available but one can use fast hadrons instead [6]. Selecting oppositely charged high p_T hadron pairs will enhance PGF events, but there is a considerable background especially from the QCD Compton process. Thus the measured asymmetry is given by

$$A^\mathrm{HH}_\mathrm{LL} \approx \langle a^\mathrm{PGF}_\mathrm{LL}\rangle\langle\frac{\Delta G}{G}\rangle\frac{\sigma^\mathrm{PGF}}{\sigma^\mathrm{tot}} + \langle a^\mathrm{COM}_\mathrm{LL}\rangle\langle\frac{\Delta u}{u}\rangle\frac{\sigma^\mathrm{COM}}{\sigma^\mathrm{tot}}\,.$$

The hard asymmtries $a^\mathrm{PGF}_\mathrm{LL}$ and $a^\mathrm{COM}_\mathrm{LL}$ are large in the Q^2 range of the fixed target experiments and have opposite signs.

In addition one has to investigate the contribution due to resolved photons. Thus, the results from this method will be dominated by systematic effects due to large background subtractions. A first attempt to use the method was presented by the HERMES collaboration during this workshop [7].

3. FACILITIES

Up to now the experiments concentrated on inclusive measurements of the spin structure functions g_1 and g_2. This era comes to an end with the present E155X experiment at SLAC [8] where data are being taken for a precise measurement of $g_2^\mathrm{p,d}$. This effort will be continued at Jefferson Lab [9], where a high statistics measurement of the large x behaviour of g_1 and g_2 is being planned using a polarised ^{3}He target.

Several facilities will be available during the next years to measure semi-inclusive properties in polarised DIS:

- HERMES at DESY, which is in full swing measuring semi-inclusive asymmetries, has started a large upgrade program to attack several of the questions listed above.
- The COMPASS experiment is being setup at the CERN 100–200 GeV muon beam and will start data taking in 2000 focussing in the beginning on a measurement of ΔG.
- At MAMI in Mainz, ELSA in Bonn and Jefferson Lab measurements of the GDH sumrule and the generalized GDH sumrule will be continued.

In addition there are plans for future high luminosity maschines where a continuation and extension of the present spin program will be feasible, e.g. the ELFE proposal at CERN or DESY to study polarised DIS and the APPOLON at ELFE and the SLAC real photon beam proposal to investigate photoproduction.

In the following I will concentrate on the HERMES upgrade and the COMPASS experiment.

4. HERMES UPGRADE PROGRAM

The main aims of the upgrade program are

- Particle identification in the full hadron momentum range, i.e. pion, kaon and proton separation,
- Enlarged muon acceptance and improved muon identification,
- Electron acceptance at very small scattering angles,
- Enlarged hadron acceptance covering also negative x_{F}.

The first item was attacked with the installation of a dual RICH [10]. Due to the combination of an aerogel with a gas radiator π/K/p separation is achieved in the full momentum range up to 20 GeV. To yield high precision measurements of the Cerenkov rings the RICH is being red by an array of photomultiplier.

The RICH is already installed and was successfully operated in 1998. Currently particle identification is being implemented in the analysis chain.

The new muon filter system has been installed during the last shutdown [11]. It consists out of an iron absorber at the end of the spectrometer followed by a scintillator hodoscope.

The enlarged muon acceptance (for scattering angles above 170 mrad) will be made available by using tracks passing part of the magnet yoke. During the shutdown in May 1999 additional scintillators will be installed covering the region between 140 and 270 mrad behind the spectrometer magnet.

With a forward quadrupole spectrometer [11] the electron acceptance will be extended to smaller scattering angles. This is especially important for quasireal photoproduction events. Up to now only 10% of the scattered electrons were detected by the luminosity monitor. The new spectrometer will add another 16%.

For this, quadrupoles with larger apertures were installed in the last long shutdown. The electrons will be measured using a small vertical driftchamber installed inside the quadrupole. After the successfull test of a prototype chamber the system will be installed in May 1999.

The next topic is the enlarged hadron acceptance [12]. For this purpose a wheel of silicon detectors is being constructed to be positioned right after the target cell. This will enlarge the acceptance to $x_{\mathrm{F}} < 0$. Monte Carlo simulations showed that this improvement is especially important for measuring the Λ decay products. The installation of the system will start in May 1999.

The last project on the list is the recoil detector. It will consist out of a layer of double sided silicon detectors positioned below the target cell. It will be used to measure recoil particles from the target to identify diffractive events and measure tagged structure functions. This year a prototype detector was tested successfully. The installation of the full system is forseen for 2001 provided funding is available.

This upgrade will allow

- To study the flavour decomposition in more detail, e.g. measure strange quark polarisation $\Delta s(x)/s(x)$.
- A measurement of the gluon polarisation with several methods. Using open charm

production and the D_0 decay into πK and $\mu\pi$K a precision of $\Delta G/G$ of 0.44 rsp. 0.40 can be reached with a luminosity of 80 pb^{-1}. The measurement of hidden charm yields $\delta(\Delta G/G)$ of about 0.69. In addition the enlarged hadron acceptance will improve the measurement via high p_T hadron pairs.

- The measurement of the Λ polarisation in the current fragmentation region will yield a significant measurement of the polarised fragmentation function $\Delta D_u^\Lambda / D_u^\Lambda$, while the spin correlation for strange quarks will be studied in the target fragmentation region.

- After 2000, measurements with a transversely polarised target will allow studies of azimuthal spin asymmetries to extract tranversity distributions.

5. THE COMPASS EXPERIMENT

Currently, the COMPASS experiment is being setup at the CERN M2 muon beam line to study polarised deep inelastic muon nucleon scattering. In addition a hadron program is planned e.g. to study charmed baryons and search for glue balls [13].

Compared to the previous muon experiment from SMC COMPASS will have an increased muon beam intensity of $2 \cdot 10^8 \mu/14.4$ s with 100–200 GeV and 80% polarisation. Together with two oppositely polarised target cells of 60 cm length filled with ^{6}LiD or NH_3 a luminosity of about 2 fb^{-1} per year can be reached.

The spectrometer is optimized for large hadron acceptance and particle identification (see fig. 2). To achieve acceptance up to ±180 mrad a new target solenoid is being constructed with a large opening minimizing the multiple scattering for hadron tracks at large angles.

The spectrometer itself consists out of two stages. Each stage has a dipole spectrometer magnet surrounded by tracking chambers followed by a RICH detector, an electromagnetic and a hadronic calorimeter and a muon filter system.

A special feature of the muon beam is the 10% halo of muon tracks surrounding the muon beam up to a radius of 0.5 to 1 m. In addition, scattered muons have to be detected very close and in the muon beam for the measurement of quasireal photoproduction. Thus the tracking system has to be split into three regions.

The beam and scattered muons with very small angles will be measured by scintillating fiber hodoscopes. Small angle tracking will be performed with micromega chambers (stage 1) and GEM detectors (stage 2) while drift (stage 1), proportional (stage 2) and straw chambers will be used for the large angle tracking.

For the first year of data taking the detector will not be complete, especially the RICH in stage 2, the electromagnetic calorimeter electronics and part of the large angle tracking will be missing. Thus the measurements will concentrate on $\Delta G/G$ via quasireal photoproduction.

Using the above mentioned luminosity 82k charm events are expected with 1.2 D^0 per charm event. The D^0's will be reconstructed via their πK decays. Due to MCS in the target it is not possible to reconstruct the decay vertex, thus the large combinatorial background has to be reduced by strict cuts on the D^0 kinematics. This should result in 900 charm events/day with a S:B of 1:3.9. Within 1.5 y with a ^{6}LiD target a precision of $\delta A_{\gamma N}^{c\bar{c}} \approx 0.05$ could be reached translating to $\delta(\Delta G/G) \approx 0.14$ at $\langle x_g \rangle = 0.14$. Using e.g. additional decay channels or $D^\star$ tagging will improve the results.

Alternatively high p_T hadron pairs will be used to extract the gluon polarisation [6]. To reduce the background due to the QCD Compton process a series of cuts (opposite charge, high $p_T > 1$ GeV, opposite azimuth, p_T balance, positive x_F) have to be applied resulting in a good signal to background ratio of about 1:1. Due to the suppression of strangeness in the fragmentation process K^+K^- pairs yield an even cleaner signal.

The gluon polarisation can be studied in the range $0.04 < x_g < 0.2$ for 200 GeV muon energy. With 1 y of data taking a precision of $\delta(\Delta G/G) \approx 0.05$ should be achievable. The error of the gluon polarisation will then be dominated by systematic

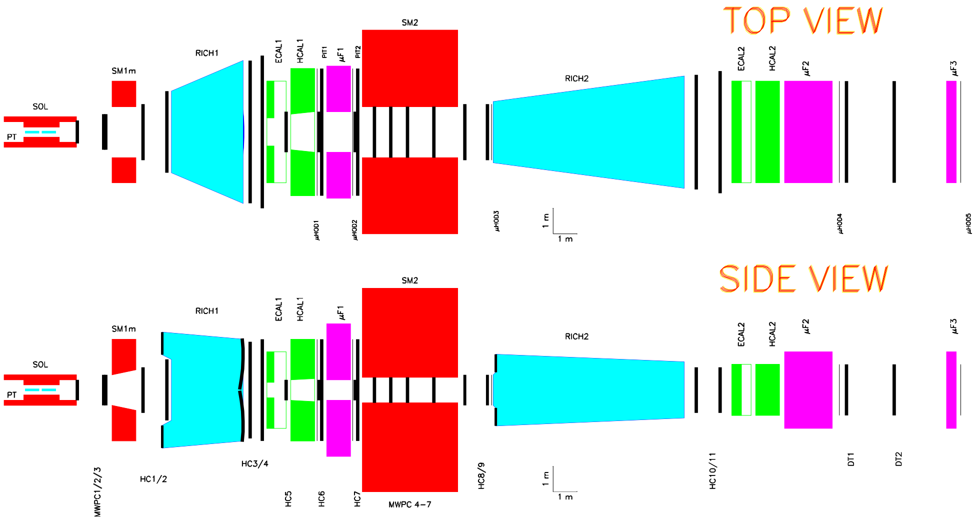

Figure 2. Schematic top and side view of the COMPASS spectrometer

effects for this analysis.

With the described spectrometer, especially with the full setup, all topics discussed in the introduction can be investigated like the flavour decomposition of the quark helicity distributions and polarised fragmentation functions. With a tranversely polarised target azimuthal asymmetries will be measured to extract transversity distributions. The possibility to study deeply virtual Compton scattering is currently being investigated.

6. SUMMARY

During the next years a rich experimental program is going on in fixed target polarised DIS. Experiments at DESY and CERN will do detailed studies of semi-inclusive processes to unravel more of the details of the nucleon spin structure.

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