New COMPASS results – nucleon spin structure and diffractive meson production

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A short overview of the experimental programme on investigations of the spin structure of the nucleon and meson spectrocopy of the COMPASS collaboration is given. The experiment is a fixed target experiment performed at the M2 beam line of the CERN SPS using high energy muon and hadron beams. Measurements of polarised deep inelastic muon scattering with longitudinally and transversely polarised nucleons give access to quark helicity and transverse quark distributions as well as to the gluon polarisation. Measurements of diffractive and central production with hadron beams were started to search for exotic mesons and glue balls.

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1. The COMPASS experiment

The COMPASS collaboration is pursuing an extensive experimental programme at the M2 beam line at the CERN SPS. Using a high energy muon beam the longitudinal and transverse spin structure of the nucleon is investigated while hadron beams are being used for the study of meson spectroscopy to search for exotics and glue balls and measurements of polarisabilities. COMPASS is a fixed target experiment using a two stage spectrometer with large acceptance and rate capability to detect the scattered beam and the produced particles [1]. For the muon programme a beam of 160 GeV/c positive muons with an intensity of $2 \cdot 10^8$ per 16.6 s is used. The muon beam is a tertiary beam produced from weak pion and kaon decays and thus is naturally polarised. For each incoming muon the momentum and the trajectory are measured before it impinges on a long solid state polarised target. The target material is LiD (as a deuteron target) or NH_3 (as a proton target) with a polarisation of 50% and 90%, respectively. With hadron beams much shorter liquid hydrogen targets or thin slabs of different materials, e.g. Pb, are used depending of the physics programme. The momenta of the outgoing tracks are measured with the help of two large aperture dipole magnets which are surrounded by tracking detectors. In addition, pion/kaon/proton separation is obtained with the help of a ring imaging Cherenkov detector. Calorimeters are used for electron and hadron identification and thick iron/concrete absorbers for muon identification.

2. Longitudinal spin structure

From 2002 to 2006 the measurements focused on polarised deep inelastic scattering (DIS) on deuterons, while in 2007 first measurements with the proton target were performed. With longitudinal target polarisation the photon-nucleon asymmetry, A_1^d, was measured in a wide kinematic range of the four-momentum transfer squared, Q^2, (0.001 (GeV/c)^2 < Q^2 < 100 (GeV/c)^2) and the Bjorken scaling variable, x ($4 \cdot 10^{-5} < x < 0.7$) [2, 3]. The COMPASS results agree very well with the previous results and improve the precision of A_1^d by an order of magnitude at low x. From the measured asymmetries the spin structure function, g_1, is obtained using the well known spin averaged structure functions. Using COMPASS data with $Q^2 > 1$ (GeV/c)^2 only, a precise value of the first moment, Γ_1^d, is obtained which can be used to extract the contribution of the quark helicities to the nucleon spin, $\Delta\Sigma = 0.33 \pm 0.03(\text{stat}) \pm 0.05(\text{syst})$. This result is in good agreement with the value of $\Delta\Sigma = 0.30 \pm 0.01(\text{stat}) \pm 0.02(\text{evol})$ obtained from a pQCD analysis of the world data for the proton, deuteron and neutron spin structure functions [3]. From semi-inclusive asymmetries a measurement of the valence polarisation is obtained [4] (see fig.1 (left)). Together with the value of Γ_1^d, this result disfavours the assumption of a flavour symmetric polarised quark sea and suggests that $\Delta\bar{u}$ and $\Delta\bar{d}$ have opposite sign.

In contrast to the quark helicity contributions to the nucleon spin the gluon contribution cannot be obtained easily from inclusive measurements, see e.g. [3]. Direct access to the gluon distribution is given by the photon-gluon fusion process. In DIS these processes can be tagged either by a hadron pair with high transverse momentum [5] or open charm production [6]. Both channels are being investigated by the COMPASS collaboration. The hadron pair channel yields much higher statistics but suffers from background processes like the QCD Compton process and resolved photon processes [7], while the open charm channel is theoretically very clean but experimentally
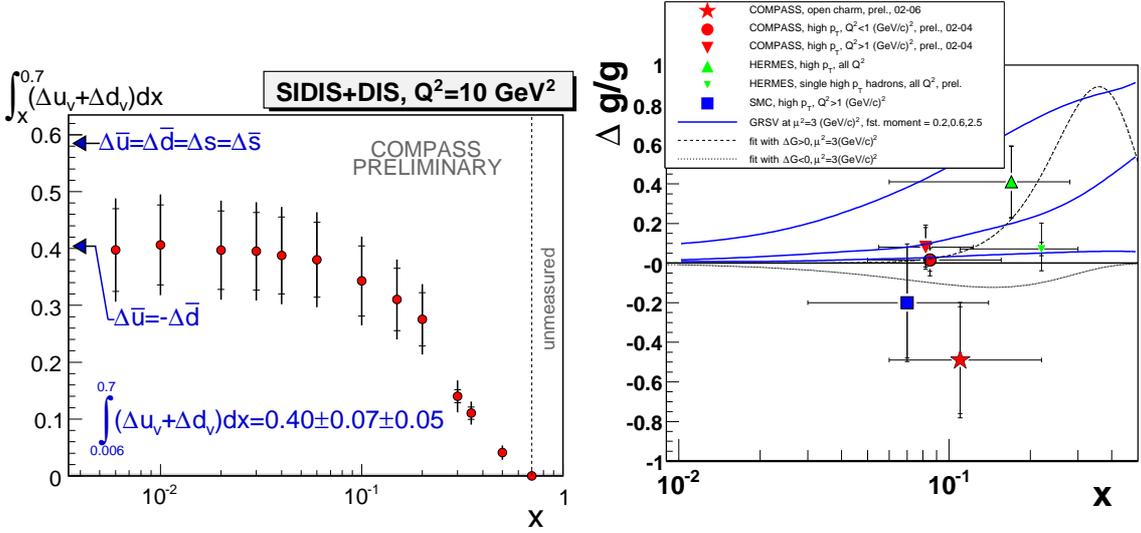
Figure 1: Left: The integral of the polarised valence quark distribution over the range $0.006 < x < 0.7$ as a function of the low x limit, evaluated at $Q^2 = 10 \ (\text{GeV}/c)^2$. Right: Measurements of the gluon polarisation $\Delta G/G$ from open charm and hadron pair production from COMPASS, SMC[9] and HERMES [8] compared to results from QCD analyses [3],[10].

very challenging. Figure 1 (right) summarises the existing results from DIS experiments including the preliminary COMPASS results from open charm production and high p_T hadron pairs. All measurements were done at x around 0.1 and are compatible with a small gluon polarisation, albeit still with large error bars. Note that the open charm point is given at a scale of about 11 $(\text{GeV}/c)^2$ whereas all other data and the curves are given at 3 $(\text{GeV}/c)^2$.

3. Transverse spin structure

About 20% of the data taking with muon beams was done using transverse target polarisation to study the transverse quark distributions. Due to the chiral odd nature of these distributions they are not accessible in inclusive processes but only together with a second chiral odd object, e.g. a fragmentation function, in semi-inclusive measurements. In the COMPASS experiment three channels are studied to extract transversity, single spin asymmetries for hadrons [11] and hadron pair and Λ polarisation. For all these measurements the corresponding fragmentation functions have to be obtained from e^+e^- collider data, e.g. from BELLE. One example is the Collins fragmentation function for hadron production [13]. In single spin asymmetries, in addition to transversity, also distributions and fragmentation processes depending on quark intrinsic transverse momenta or on transverse momenta in the fragmentation process can contribute to the signal, e.g. the Sivers function [14].

All above mentioned channels were investigated using the deuteron data. All measured asymmetries are compatible with zero, which is interpreted as a cancellation between the u and d quarks in the deuteron as sizeable effect were observed by the HERMES collaboration using a polarised proton target [12]. The results for the x, z and p_T dependences of the Collins asymmetries obtained from part of the 2007 COMPASS transverse proton data are shown in fig. 2. Here, z is the fractional
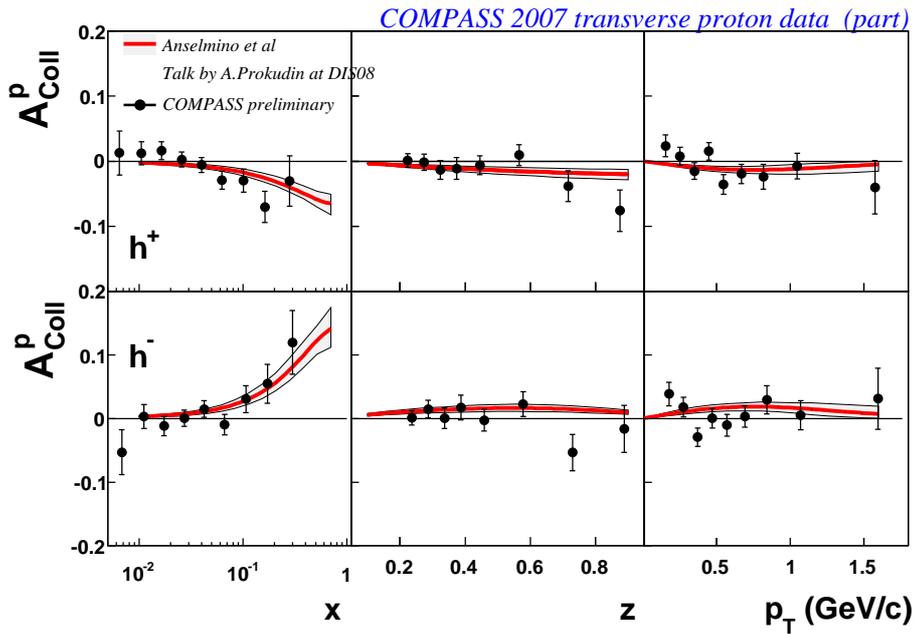
Figure 2: Collins asymmetries A^p_{Coll} from part of the COMPASS proton data vs. x, z and p_T compared to predictions from [15].

hadron energy. Good agreement with the expectation [15] on the basis of the COMPASS deuteron, the HERMES proton and the BELLE data is observed. For the Sivers asymmetries the situation is much less clear. There is an indication that the effects observed in the COMPASS measurements are smaller than expected from the HERMES results but an analysis of all 2007 data is necessary before any firm conclusion can be drawn. The combined deuteron and proton data will also allow to perform a flavour separation of the u and d quark contributions.

4. Meson spectroscopy

In 2008 the first long data taking with a 190 GeV/c pion beam was performed to investigate diffractive and central meson production with a liquid hydrogen target. Before, only a short pilot data taking was done in 2004 with a Pb target. Here, the focus was on the measurement of the pion polarisability via Primakoff scattering. In parallel, also data on diffractive meson production were taken. Figure 3 (left) shows as an example the invariant mass spectrum for exclusive three pion production at high momentum transfers with three well-known prominent resonances clearly visible. A detailed partial wave analysis yields also a small contribution from an exotic 1^{-+} wave (see fig. 3 (right)). A preliminary value for the mass of $(1660 \pm 10^{+0}_{-64})$ MeV/c^2 and a width of $(269 \pm 21^{+42}_{-64})$ MeV/c^2 is obtained [16].

5. Outlook

The COMPASS collaboration plans to continue the data taking with hadron beams in 2009 to do detailed studies of diffractive and central production also with proton beams. The analysis of

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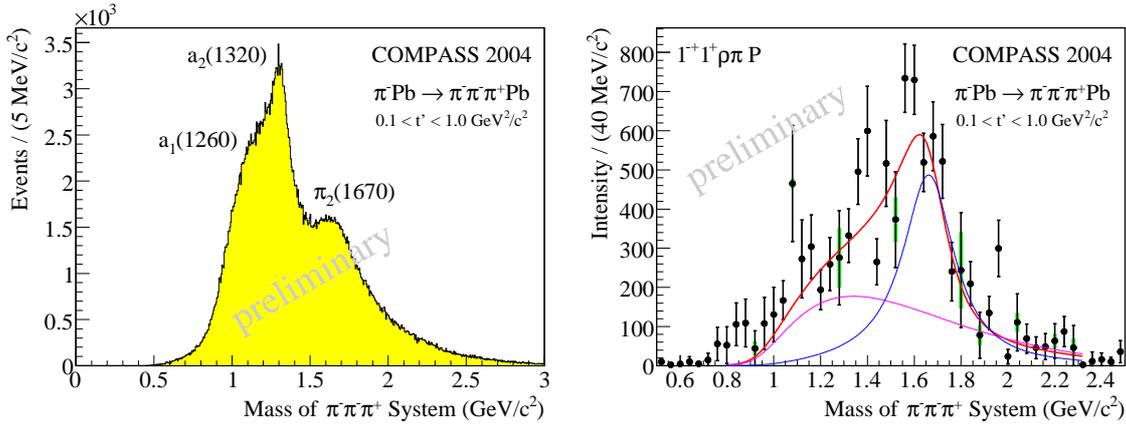
Figure 3: Left: Invariant mass spectrum for exclusive three pion production. Right: Intensity of the $1^{-+}1^{+}\rho\pi$ P wave.

the 2007 and 2008 is in full swing. In addition, a proposal for a COMPASS phase II is being prepared which will also include new physics topics like deeply virtual Compton scattering and Drell-Yann processes.

References

[1] COMPASS, P. Abbon et al.,*Nucl. Instr. Meth. A* **577** (2007) 455.

[2] COMPASS, V.Yu. Alexakhin et al., *Phys. Lett. B* **647** (2007) 330.

[3] COMPASS, V.Yu. Alexakhin et al., *Phys. Lett. B* **647** (2007) 8.

[4] COMPASS,M. Alekseev et al., *Phys. Lett. B* **660** (2008) 458.

[5] A. Bravar et al., *Phys. Lett. B* 421 (1998) 349.

[6] M. Glück et al., *Z. Phys. C* **39** (1988) 569.

[7] COMPASS, E.S. Ageev et al., *Phys. Lett. B* **633** (2006) 25.

[8] HERMES, A. Airapetian et al., *Phys. Rev. Lett.* **97** (2000) 2584; P. Liebig, *AIP Conf. Proc.* **915** (2007) 331, arXiv:0809.1803.

[9] SWMC, B. Adeva et al., *Phys. Rev. D* **70** (2004) 012002.

[10] M. Glück et al., *Phys. Rev. D* **63** (2001) 094005.

[11] COMPASS, E.S. Ageev et al., *Nucl. Phys. B* **765** (2007) 31.

[12] HERMES, A. Airapetian et al., *Phys. Rev. Lett.* **94** (2005) 012002; M. Diefenthaler, arXiv:0706.2242.

[13] J. Collins, *Nucl. Phys. B* 396 (1993) 161.

[14] D. Sivers, *Phys. Rev. D* **41** (1990) 83.

[15] A. Prokudin, *Effects of intrinsic parton motion in SIDIS* in proceedings of *DIS08*, London (2008), to be published.

[16] Q. Weitzel, *Meson production from diffractive dissociation at COMPASS* in proceedings of *the 10th Int. workshop on Meson Production*, Krakow (2008), to be published.