Polarized Drell-Yan measurements in COMPASS

C. Quintans (LIP-Lisboa), on behalf of the COMPASS collaboration

COMPASS is a SPS/CERN fixed target experiment dedicated to studies of the spin structure of the nucleon. At leading twist, if the intrinsic transverse momentum of the quarks k_T is taken into account, 8 parton distribution functions are needed to fully describe the nucleon – the so-called transverse momentum dependent (TMD) PDFs. Functions $f_{1T}^{\perp}(x, k_T^2)$ (Sivers), $h_1^{\perp}(x, k_T^2)$ (Boer-Mulders), and $h_{1T}^{\perp}(x, k_T^2)$ (pretzelosity) are examples of such TMD PDFs.

In COMPASS, the semi-inclusive deep inelastic scattering (SIDIS) of 160 GeV/c muons on a transversely polarized solid state target has been studied in recent years, as the means to access the Sivers PDF, as well as the transversity PDF [1].

A complementary way to access TMD PDFs is from the study of Drell-Yan (DY) processes, where a quark from the target annihilates with an anti-quark from the beam. The produced virtual photon will convert into a pair of leptons detected in the final state. In this case, the spin asymmetry is proportional to a convolution of 2 PDFs. Given the T-odd character of both Sivers and Boer-Mulders functions, the sign of these TMDs is expected to be reversed when observed from SIDIS or from DY. The verification of this sign change is considered a very important test of non-perturbative QCD (see slide 1).

The multipurpose spectrometer of COMPASS offers the possibility to study TMD PDFs from both SIDIS and DY processes, thanks to the availability of both muon and pion beams of suitable energies (150 to 200 GeV). Other important aspects are the COMPASS unique polarized target; and the 2-stages spectrometer, that allows for a good identification of muons, with a wide angular acceptance.

Studies of COMPASS acceptance for DY events have shown that the experiment probes the valence quarks region ($x > 0.1$) which, according to theory predictions, is also the best to measure spin asymmetries. The experiment has the possibility to make such DY measurement very soon, using a π^- beam and a transversely polarized ammonia (NH_3) target. The u-quark Sivers PDF, as well as a model dependent extraction of transversity and Boer-Mulders functions can be achieved. In the longer term, the possibility of having an anti-proton beam extends the physics possibilities further, giving access to a model independent extraction of both Sivers and transversity functions. The so-called J/ψ-DY duality, arising from the fact that at relatively low energies the $q\bar{q}$ annihilation process becomes an important J/ψ production mechanism, presents itself as an interesting option to access PDFs, given the much larger J/ψ cross-section as compared to DY.

Short beam tests performed in COMPASS in 2007/2008 have proved the feasibility of the measurement, while showing the necessity to use an hadron absorber and a beam plug downstream of the target, in order to reduce the combinatorial background (see slide 2). Assuming a beam intensity of 6×10^7 pions/second, and a data-taking period of 280 days, spin asymmetries can be extracted, with an expected precision of 1 to 2%, depending on the number of x_F bins. This statistical accuracy seems to be enough to distinguish between most of the theory predictions presently available (see slide 3). COMPASS can be the first experiment to measure polarized Drell-Yan effects. A physics proposal for this future measurement is in preparation [2].

References

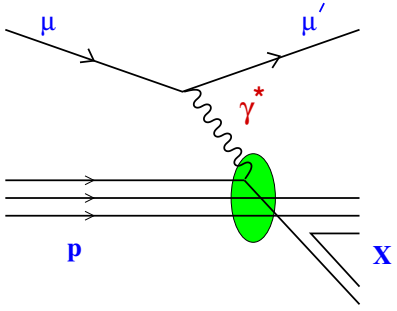
[1] PRL 94 (2005) 202002; NP B 765 (2007) 31-70; PL B 673 (2009) 127-135.

[2] CERN-SPSC-2009-003

Accessing PDFs in COMPASS

TMD PDFs, like Sivers, can be accessed both from semi-inclusive DIS (SIDIS) and from the Drell-Yan process (DY).

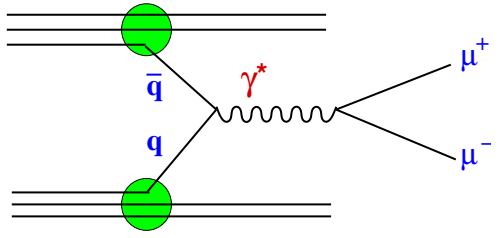
SIDIS



The spin asymmetry is given by the convolution of structure functions with fragmentation functions:

$$A_{Sivers} \propto \frac{\sum_q e_q^2 f_{1T}^{\perp(1)}(x) D_q^h(z)}{\sum_q e_q^2 f_1(x) D_q^h(z)}$$

DY



The spin asymmetry is proportional to a product of structure functions. For unpolarized beam and transversely polarized target:

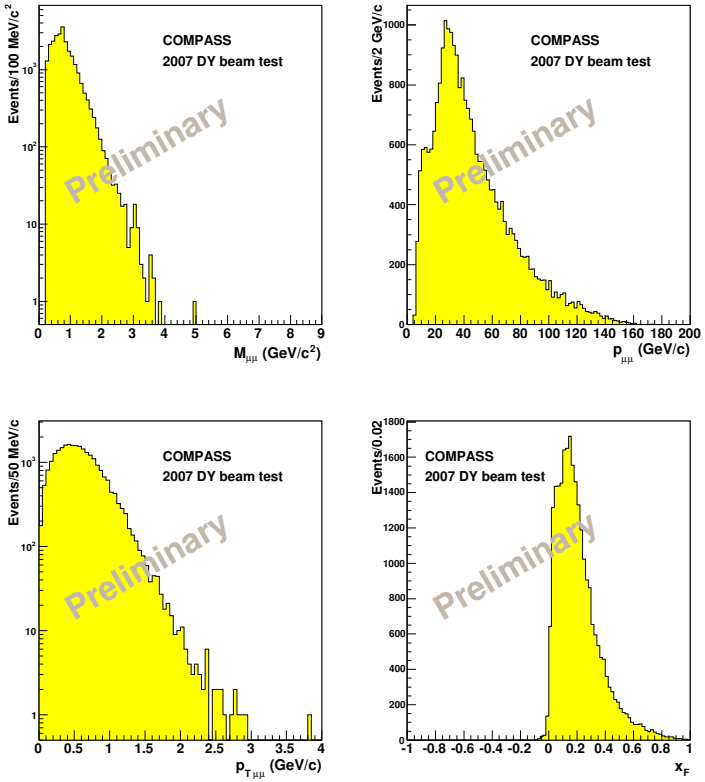
$$A_{Sivers} \propto 2\frac{\sum_q e_q^2 \bar{f}_{1q}(x_1) f_{1Tq}^{\perp(1)}(x_2)}{\sum_q e_q^2 \bar{f}_{1q}(x_1) f_{1q}(x_2)}$$

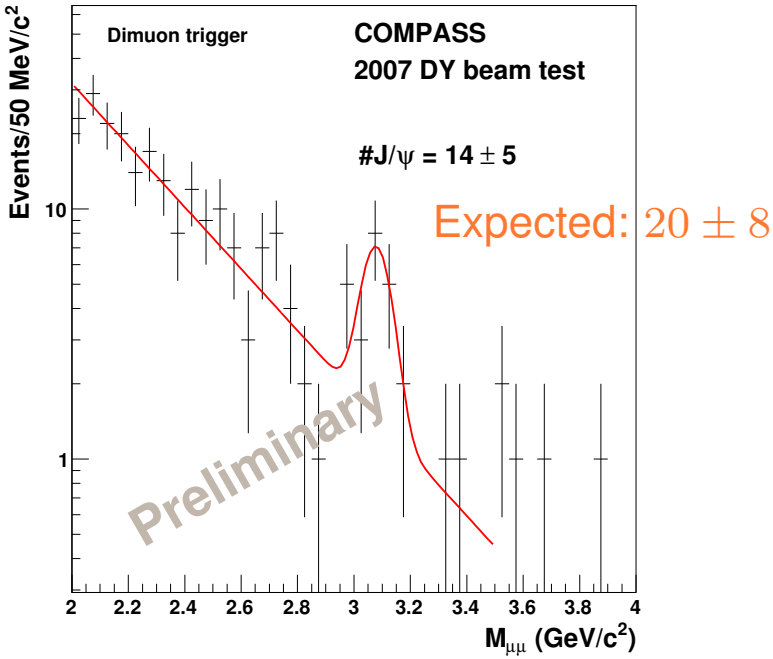
Change of sign between DY and SIDIS – important test of non-perturbative QCD:

$$f_{1T}^{\perp}(DY) = -f_{1T}^{\perp}(SIDIS) \qquad h_1^{\perp}(DY) = -h_1^{\perp}(SIDIS)$$

Drell-Yan beam tests in COMPASS

In 2007 and 2008, short Drell-Yan beam tests were performed, to check the feasibility of the measurement. In 2007, with a π^- beam of 160 GeV/c on a NH_3 target, and without hadrons absorber: ≈ 90000 dimuon events (< 12 hours data-taking).





The future proposal includes an hadrons absorber, for optimal background reduction.

Asymmetries expected precision

Predictions for the Sivers asymmetry in the COMPASS phase-space, for the mass region $4. < M < 9.$ GeV/c^2, compared to the expected statistical errors of the measurement:

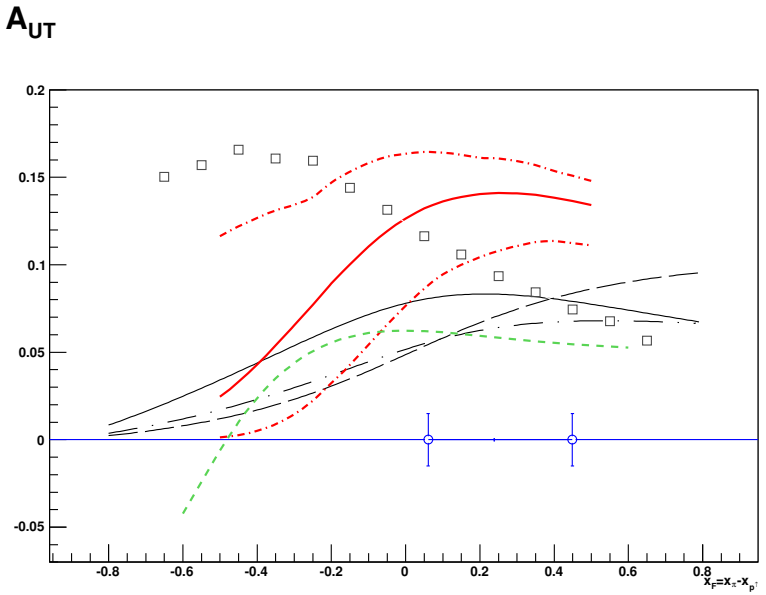
– solid and dashed: Efremov et al,
PLB612(2005)233;

– dot-dashed: Collins et al,
PRD73(2006)014021;

– solid, dot-dashed: Anselmino et al,
PRD79(2009)054010;

– boxes: Bianconi et al, PRD73(2006)114002;

– short-dashed: Bacchetta et al,
PRD78(2008)074010.



Assuming 2 years of data-taking, and depending on the number of bins, the expected statistical error in the asymmetries measured is:

$$\delta A^{\sin(\phi_{S2}-\phi)} \approx 1-2\%$$