Polarised Drell-Yan measurement in the COMPASS experiment at CERN

Márcia Quaresma[1] for the COMPASS Collaboration

[1]LIP - Laboratório de Instrumentação e Física Experimental de Partículas, Av. Elias Garcia 14-1, 1000-149 Lisboa, Portugal, marcia@lip.pt

DOI: http://dx.doi.org/10.3204/DESY-PROC-2014-04/117

The COMPASS experiment at CERN has been contributing to the description of the nucleon spin structure, namely the transverse momentum dependent parton distribution functions (TMDs), through the Semi-Inclusive Deep Inelastic Scattering (SIDIS) using a muon beam impinging on polarised targets. These TMD functions are also accessible via the transversely polarised Drell-Yan (DY) process, which will be studied in the next COMPASS data taking, starting this Autumn. This process, in which the proton valence region will be explored, will be studied in collisions of a 190 GeV/c negative pion beam with a transversely polarised ammonia target. The QCD prediction that Sivers TMD change sign when accessed through SIDIS or via DY will be checked by the new COMPASS measurement. Considering one year of data taking, the Sivers azimuthal asymmetry statistical error is expected to be less than 2%. In addition to the polarised target, other nuclear targets will give the possibility to study unpolarised DY subjects. The experimental setup will be presented, and predictions and expectations will be discussed.

1 Introduction

The nucleon structure in leading order QCD, taking into account the quarks intrinsic transverse momentum, is described by 8 PDFs for each quark flavour. These so called TMD PDFs are accessible via either the single transversely polarised Drell-Yan measurement or the transversely polarised Semi-Inclusive DIS. The latter has been already measured in COMPASS and published [1]. The DY cross-section is written in terms of angular modulations, each containing a convolution of two PDFs, whereas in the SIDIS cross-section the amplitude of each modulation contains the convolution of one PDF and one fragmentation function. Because of that, DY is considered an excellent tool to access TMD PFDs. In addition, the TMD PDFs are expected to be sizeable in the valence quark region, being this region dominant in the foreseen COMPASS DY measurement regarding the use of a negative pion beam impinging on an ammonia target. Furthermore, the QCD TMD approach is valid in the region Q ($M_{\mu\mu} > 4$ GeV/c^2) $\gg \langle p_T \rangle \sim$ 1 GeV/c, which is also dominate in the COMPASS DY measurement.

The amplitudes present in the DY cross-section are accessed via the measurement of the azimuthal asymmetries between the two oppositely transversely polarised target cells. Each asymmetry contains the convolution of two TMD PDFs, giving access to Sivers, Boer-Mulders, transversity and pretzelosity functions.

The Sivers measurement is the main goal of the first polarised DY data. Theory predicts its sign should change when accessed through DY or SIDIS processes [2]. This is considered a crucial test of the QCD TMD approach. Figure 1 shows the phase space coverage of the two processes in COMPASS. The SIDIS result was extracted from the 2010 data and the DY from a MC simulation. The statistical error selecting just the overlap between the two measurements, i.e. with $Q^2 > 16$ GeV$/c$, is $\sim 1\%$ for both.

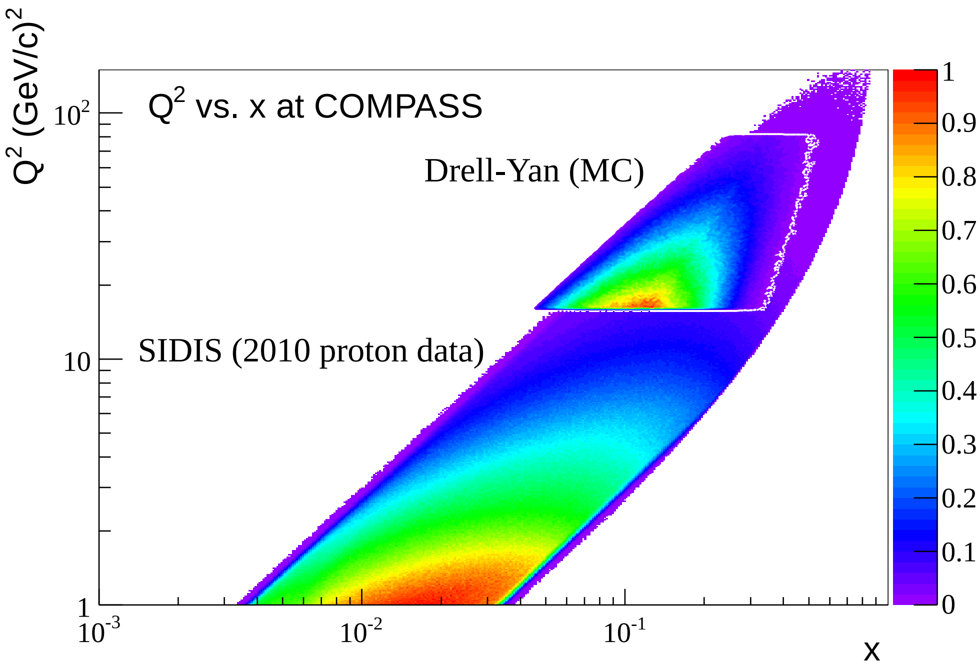

Figure 1: Q^2 versus x phase space coverage at COMPASS. Superposition of the SIDIS 2010 proton data with the DY MC simulation.

In addition to the azimuthal asymmetries measurements, several studies beyond the polarised DY measurement are possible, including the study of the flavour dependent EMC effect [3]. This will be possible by the use of nuclear targets in addition to the polarised ammonia target.

2 Experimental setup and feasibility of the experiment

COMPASS is a CERN experiment located at the end of the SPS M2 beam line. It is a fixed target experiment that consists in a two stage spectrometer giving the possibility to measure a wide angular and momentum range. The spectrometer is equiped with several tracking detectors, one hadron and one electromagnetic calorimeter in each spectrometer stage, two dedicated stations to identify muons and hodoscopes to perform the trigger. A complete description can be found in [4]. For the DY measurement, there is a hadron absorber with a beam plug in its central part, just downstream of the target, to stop the hadrons and the non-interacting beam.

The DY muons will suffer multiple scattering when crossing the absorber and this is responsible for a resolution degradation. Thus a scintillating fibre vertex detector is placed at the beginning of the absorber to improve the spatial resolution of the interaction vertex. Figure 2 shows a sketch of the hadron absorber and the vertex detector. The location of the aluminium nuclear target, necessary for the unpolarised DY studies is also shown. The polarised target is made of two target cells of ammonia which will be oppositely transversely polarised with respect to the beam direction. This polarisation will be reversed several times during the data taking, in order to cancel some systematic errors. A negative pion beam with an intensity of $10^9\pi$/s will be used.

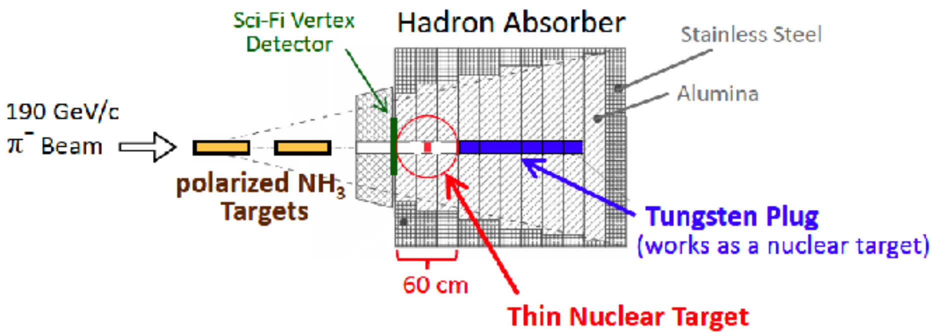

Figure 2: Sketch of the hadron absorber. In blue is visible the beam plug, in red the Al nuclear target and in green the vertex detector.

The DY pilot run has started in October. This is the opportunity to tune the experiment and analysis software before the next year's physics run. Prior to this pilot run, a beam test with a duration of three days was preformed in 2009 with success. At that time, a hadron absorber prototype was used, the trigger was based on calorimeter signals and the negative pion beam had a lower intensity, $1.5 \times 10^7\pi$/s. Now, for the pilot run everything is as it will be next year, which means the optimised absorber is installed, the trigger will be based on hodoscopes with a high efficiency, purity and target pointing capability, and we will have a high intensity pion beam available.

Figure 3 shows the dimuon mass distribution and the Z vertex distribution for the 2009 DY beam test. The J/ψ is visible and both its mass pole as well as the mass resolution are in agreement with the MC simulations. The expected J/ψ yields were confirmed regarding the involved efficiencies. The Z vertex distribution shows the separation between the two target cells and the beam plug, even in the absence of a vertex detector and the optimised absorber.

3 Event rates and statistical accuracy

The expected event rate in the mass region $4 < M_{\mu\mu} < 9$ GeV/c^2 of the polarised DY measurement is expected to be 2000 events/day. Being one year of data taking approximately 140 days, 285000 events are expected. For such a rate, the statistical errors of the asymmetries are expected to be less than 2%.

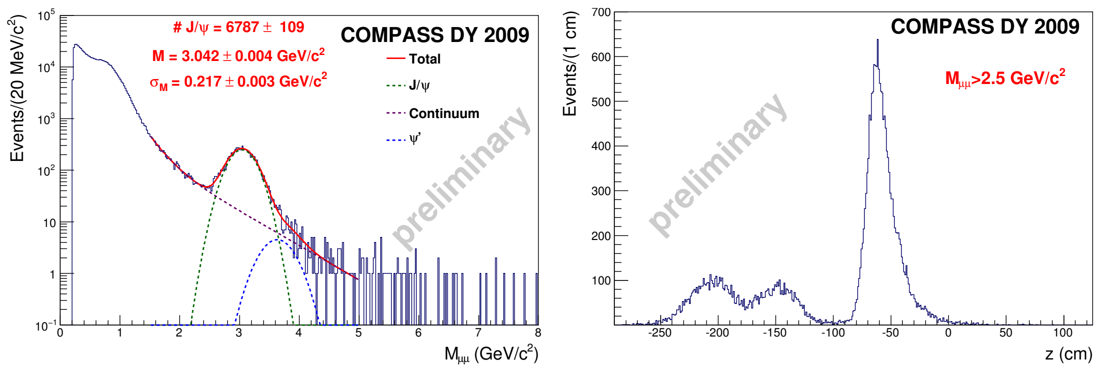

Figure 3: On the left hand side, the dimuon mass distribution is plotted. On the right hand side, the Z vertex distribution is plotted.

4 Conclusions

The DY pilot run has started in the beginning of October 2014 and will last for about two months. This is the opportunity to test the whole concept of the measurement and work out the data taking strategy for the next year's data taking. The main goals for next year are to extract the azimuthal asymmetries, in particular to check the Sivers function sign change when comparing the COMPASS SIDIS results and DY ones. By the use of nuclear targets, COMPASS also aims to contribute to the unpolarised DY studies, namely the EMC effect. Concerning the future, a second year of DY data taking before the Long Shut Down 2 at CERN, taking place in 2019, will be discussed soon. COMPASS will collect the first ever DY polarised data.

Acknowledgments

This work was partially supported by the Portuguese Fundação para a Ciência e a Tecnologia.

References

[1] C. Adolph *et al.* [COMPASS Coll.], Phys. Lett. **B717** 10 (2012).

[2] J.C. Collins, Phys. Lett. **B536** 43 (2002).

[3] D. Dutta *et al.*, Phys. Rev. **C83** 042201 (R) (2011).

[4] P. Abbon *et al.* [COMPASS Coll.], Nucl. Inst. Meth. **A577** 455 (2007).