Polarised Drell-Yan measurements at COMPASS-II

Elena Zemlyanichkina* **(on behalf of the COMPASS collaboration)**
Joint Institute for Nuclear Research – Joliot-Curie str., bld. 6, Dubna, Moscow region, Russia
E-mail: Elena.Zemlyanichkina@cern.ch

The spin structure of the nucleon including the Parton Distribution Functions (PDFs) is an important subject studied by the COMPASS experiment at CERN (SPS). The transverse momentum dependent parton distribution functions (TMD PDFs) of the proton and deuteron from Semi-Inclusive Deep Inelastic Scattering (SIDIS) have been studied so far. The Drell-Yan (DY) process is a complementary way to access the TMD PDFs, using a transversely polarised target. Studying the angular distributions of dimuons from the DY events produced in the scattering of a 190 GeV$/c$ momentum negative pion beam off a transversely polarised proton target (NH_3) we are able to extract the azimuthal spin asymmetries, each containing a convolution of two PDFs, one from the target quark and one from the beam anti-quark. Disentangling the contributions from these two PDFs we can access four of the eight TMD PDFs needed to describe the nucleon structure at leading order QCD, like the Sivers and the Boer-Mulders functions. The opportunity to study, in the same experiment, the TMD PDFs from both SIDIS and DY processes is unique at COMPASS. An important QCD prediction - the expected sign change in Sivers and Boer-Mulders functions when accessed by DY and SIDIS – will be checked [1, 2].

The COMPASS II Proposal [3] was approved by CERN for the first period of three years including one year for polarised DY; the beginning of the DY data taking with the proton target is scheduled for 2014 and it can be resumed for one more year after 2017. The feasibility of the measurement was proven by several beam tests done so far. One of the major goals of the COMPASS-II experiment is to perform the first ever polarised DY experiment.

The European Physical Society Conference on High Energy Physics -EPS-HEP2013
18-24 July 2013
Stockholm, Sweden

*Speaker.

© Copyright owned by the author(s) under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike Licence. http://pos.sissa.it/

PoS(EPS-HEP 2013)088

The COMPASS experiment is located at the M2 extracted beam line of the SPS/CERN, which delivers to the spectrometer either muon or hadron secondary beams in a momentum range of 50 to 280 GeV$/c$. Such flexibility allows to optimize the extracted π^- beam energy in order to achieve the highest possible Drell-Yan (DY) lepton pair production rate given a fixed acceptance of the experimental set-up. It was found that 190 GeV$/c$ is a good choice for both: useful DY event rate and the accessible kinematical range. There is a small contamination of $\sim 2.5\%$ kaons and less than 2% antiprotons in the secondary π^- beam. The radiation safety conditions (in the area close to the primary production target) and the relaxation time of the COMPASS solid state polarised target limit the intensity of the extracted beam to 1×10^8 particles/second. Taking into account the hadro-production cross-section is large, for such a beam intensity it becomes necessary to prevent the secondary hadrons to overflood the detectors. It is achieved by adding a thick hadron absorber immediately downstream of the target. The optimisation of the absorber has been done using two independent Monte Carlo (MC) packages Fluka and GEANT4. The absorber will be made mainly of aluminium oxide (Al_2O_3) ceramics, surrounded by a stainless steel 'holder'. The total length of the absorber is 220 cm. In order to stop non-interacted beam particles a beam plug made of tungsten will be placed in the center of the absorber along the beam line. In such a measurement it is also very important to have a dimuon trigger. The trigger will be based on two large area hodoscopes with target pointing features.

Assuming a beam intensity of 6×10^7 particles per second, one expects an instantaneous luminosity of $1.2\times10^{32} cm^{-2}$ s^{-1}, which means an event rate of high mass DY events of 800 per day. In 280 days of data-taking the integrated luminosity will be 2900 pb^{-1}, so one will be able to collect 230 000 such events. Running with a transversely polarised ammonia (NH_3) target and a π^- beam, one can assume u-quark dominance annihilation, and study the four azimuthal asymmetries: $A_U^{\cos 2\phi}$, $A_T^{\sin\phi_S}$, $A_T^{\sin(2\phi+\phi_S)}$, $A_T^{\sin(2\phi-\phi_S)}$, which are proportional to the following convolutions of parton distribution functions (PDF), respectively: both Boer-Mulders of an incoming hadron and a target nucleon, the Sivers function of a target nucleon, Boer-Mulders of a beam pion with pretzelosity of a target nucleon, and Boer-Mulders of a beam pion with transversity of a target nucleon. The COMPASS measurement will be probing $x_p > 0.1$, i.e. mostly in the valence quark range, and the theory predictions are for sizeable asymmetries, in the order of 2 to 15%, in this case. Statistical accuracy, expected in the asymmetries, assuming two years of DY data-taking, will allow to do a study in several x and dimuon p_T bins. In Fig. 1 the expected statistical accuracy of the asymmetries is shown together with some theory predictions available for the DY case at COMPASS, from [4].

In order to check the feasibility of the measurement three beam tests were performed in the years of 2007, 2008, and 2009. The radiation conditions in the COMPASS hall were monitored, showing no unexpected effects. The target temperature does not increase significantly with the incident pion beam at the proposed intensity. The relaxation time of the target polarisation is measured to be in the order of thousands of hours. The beam tests have shown no problems with the detector occupancies, even for the planes closer to the hadron absorber, that still detect some amount of punch-through low momentum particles. The number of found J/ψ's, in data collected during a three-day DY beam test at the end of the data-taking period of 2009, is in good agreement with the expected J/ψ yield. Namely, 3170 ± 70 J/ψ events were reconstructed from the experimental date in respect to 3600 ± 600 expected from MC studies. It is also the case for the number of DY events of 84 ± 10 found in the range 4 GeV$/c^2 < M_{\mu\mu} <$ 9 GeV$/c^2$. The combina-

PoS(EPS-HEP 2013)088

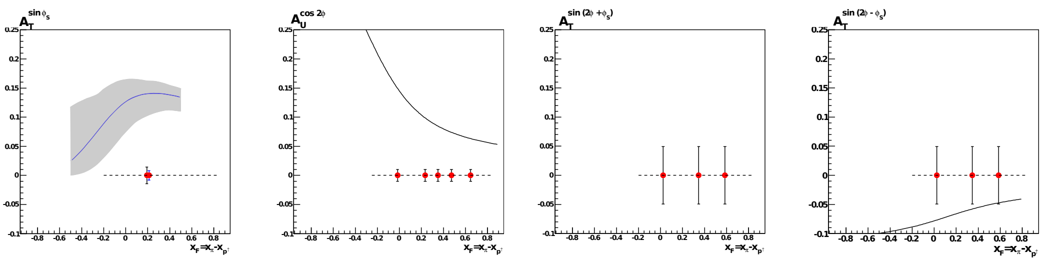

Figure 1: Statistical accuracy of the asymmetries in two years of data-taking, compared to several theory predictions [4] for the Drell-Yan COMPASS case in the dimuons high mass region.

torial background was measured by studying $\mu^+\mu^+$ and $\mu^-\mu^-$ invariant mass distributions. The combinatorial background in the $\mu^+\mu^-$ invariant mass spectrum was calculated according to the formula $N_{BC} = 2\sqrt{N_{\mu^-\mu^-}N_{\mu^+\mu^+}}$. The contribution of the combinatorial background is suppressed by a factor of about 10 with respect to the $\mu^+\mu^-$ invariant mass spectrum at $M_{\mu\mu} = 2$ GeV$/c^2$, so that even in the intermediate mass region 2 GeV$/c^2 < M_{\mu\mu} < 2.5$ GeV$/c^2$ there is a good probability to have a rather clean DY signal. Open-charm decays, i.e. D^0 and $\bar{D}^0$ decays into muons, could also give a contribution, which cannot be avoided or suppressed by using the hadron absorber. The open-charm processes were simulated using PYTHIA and the generated dimuon events were propagated through a GEANT 3 simulation of the experimental apparatus. These MC events were then reconstructed and the obtained distributions were compared with the corresponding ones for the DY process. The contamination of open-charm dimuon events was seen to be negligible in both the high-mass region 4 GeV$/c^2 < M_{\mu\mu} < 9$ GeV$/c^2$ and the intermediate-mass region 2 GeV$/c^2 < M_{\mu\mu} < 2.5$ GeV$/c^2$. The separation of open-charm and DY events is likely to be improved by proper muon angular cuts.

To conclude, one should stress that the expected statistical accuracy will allow to check the universality of transverse momentum dependent (TMD) factorisation approach for the description of single spin asymmetries, i.e. sign changing in Sivers and Boer-Mulders when measured in SIDIS and in DY processes. Not only these two PDFs, but also the transversity and the pretzelosity will be studied as a function of x and dimuon p_T. COMPASS has the potential to become the first effort to access these TMD PDFs of the nucleon in a polarised DY experiment.

References

[1] J. C. Collins, *Leading twist single transverse-spin asymmetries: Drell-Yan and deep inelastic scattering, Phys. Lett.* B **536** (2002) 43 [hep-ph/0204004].

[2] J. Collins, *Rapidity divergences and valid definitions of parton densities*, in proceedings of *LIGHT CONE 2008 Relativistic Nuclear and Particle Physics*, July 7-11, 2008, Mulhouse, France, PoS(LC2008)028 and [arXiv:0808.2665]

[3] F. Gautheron *et al.* [COMPASS Collaboration], *COMPASS-II Proposal,* SPSC-P-340.

[4] M. Anselmino, M. Boglione, U. D'Alesio, S. Melis, F. Murgia and A. Prokudin, *Sivers effect in Drell-Yan processes, Phys. Rev.* D **79** (2009) 054010 [arXiv:0901.3078 [hep-ph]].
B. Zhang, Z. Lu, B. -Q. Ma and I. Schmidt, *Extracting Boer-Mulders functions from p+D Drell-Yan processes, Phys. Rev.* D **77** (2008) 054011 [arXiv:0803.1692 [hep-ph]].
A. N. Sissakian, O. Y. .Shevchenko, A. P. Nagaitsev and O. N. Ivanov, *Polarization effects in Drell-Yan processes, Phys. Part. Nucl.* **41** (2010) 64.

PoS(EPS-HEP 2013)088