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The Drell-Yan measurement at COMPASS

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Summary. — The Drell-Yan process can be used to access transverse-momentum–dependent parton distribution functions. It provides complementary information to what is known from semi inclusive deep inelastic scattering data. A fundamental test of the factorization theorem in the non-perturbative QCD can be performed as well. The COMPASS experiment offers the possibility to extract TMD PDFs from Drell-Yan data, making use of its large acceptance spectrometer and its unique transversely polarised target. This measurement is described in the COMPASS-II Proposal.

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1. – Transverse-momentum–dependent parton distribution functions of the proton

When one permits non-zero intrinsic transverse momentum $\mathbf{k}_T$ of partons inside the nucleons, at leading order, the proton can be described by eight Transverse-Momentum–Dependent Parton Distribution Functions (TMD PDFs). They are: $f_1(x, \mathbf{k}_T^2)$, $g_{1L}(x, \mathbf{k}_T^2)$, $h_1(x, \mathbf{k}_T^2)$, $g_{1T}(x, \mathbf{k}_T^2)$, $h_{1L}^\perp(x, \mathbf{k}_T^2)$, $h_{1T}^\perp(x, \mathbf{k}_T^2)$, $h_1^\perp(x, \mathbf{k}_T^2)$ and $f_{1T}^\perp(x, \mathbf{k}_T^2)$, where x is the fraction of the proton momentum carried by the partons. The first three functions, when integrated over $\mathbf{k}_T$, give back the commonly known momentum distribution, helicity distribution and transversity function, in the collinear approximation. The TMD PDFs describe the correlation of momentum and spin of partons with the spin of the parent proton if it is either unpolarised or longitudinally/transversely polarised. In the list above, the latter three functions are called, respectively, the Pretzelosity, the Boer-Mulders and the Sivers functions. The Boer-Mulders and the Sivers functions are naively T-odd; as a consequence, QCD factorization predicts that both functions should change their sign when measured in Semi-Inclusive Deep Inelastic Scattering (SIDIS) experiments and in Drell-Yan experiments [2], thus an important test of QCD can be performed: $f_{1T}^\perp(\mathrm{DY}) = -f_{1T}^\perp(\mathrm{SIDIS})$ and $h_1^\perp(DY) = -h_1^\perp(\mathrm{SIDIS})$.

2. – The Drell-Yan process and TMDs

The Drell-Yan process is the annihilation of a quark-antiquark pair coming from two hadrons into a virtual photon which produces a pair of leptons. The azimuthal angular distributions between the lepton and hadron planes, as well as between the lepton plane and spin of the polarised hadron, provide information on the TMD PDFs in the Drell-Yan process. In case of the reaction $\pi^- + p^{(\uparrow)} \to \mu^+\mu^- + X$ with a pion beam scattering on a (polarised) proton, the Drell-Yan cross section is

$$(1)\quad \frac{\mathrm{d}\sigma}{\mathrm{d}^4 q \mathrm{d}\Omega} = \frac{\alpha_{em}^2}{Fq^2}\hat{\sigma}_U \Big\{ \Big(1 + D_{[\sin^2\theta]} A_U^{\cos 2\phi} \cos 2\phi\Big) + |\mathbf{S}_T| \Big[A_T^{\sin\phi_S} \sin\phi_S + D_{[\sin^2\theta]} \Big(A_T^{\sin(2\phi+\phi_S)} \sin(2\phi+\phi_S) + A_T^{\sin(2\phi-\phi_S)} \sin(2\phi-\phi_S)\Big)\Big]\Big\},$$

where $D_{[f(\theta)]}$ are the depolarisation factors, $\mathbf{S}_T$ is the target polarisation vector, F is the flux of incoming hadrons and the A's are the azimuthal asymmetries, $\hat{\sigma}_U$ is the part of the cross section which survives the integration over ϕ and ϕ_S, ϕ and θ are the azimuthal and polar angles of the lepton in the Collins-Soper frame and ϕ_S is the angle of the spin in the proton rest frame. $A_U^{\cos 2\phi}$, $A_T^{\sin\phi_S}$, $A_T^{\sin(2\phi+\phi_S)}$ and $A_T^{\sin(2\phi+\phi_S)}$ give access, respectively, to the Boer-Mulders functions of the incoming hadrons, to the Sivers function of the target nucleon, to the convolution of the Boer-Mulders function of the beam hadron and of the Pretzelosity function of the target nucleon and to the convolution of the Boer-Mulders function of the beam hadron and the transversity function of the target nucleon.

3. – The COMPASS spectrometer

The COMPASS spectrometer gives the possibility to study the Drell-Yan process in $\pi^- + p^{(\uparrow)} \to \mu^+\mu^- + X$ using its unique transversely polarisable NH_3 target and a negative pion beam extracted from SPS at CERN [1]. The spectrometer has a large acceptance up to 180 mrad and it is built around two analysing magnets with tracking detectors (GEMS, MicroMegas, MWPC, Straws, SciFi and Silicon detectors), hadronic and electromagnetic calorimeters. Particle identification is performed by a Rich detector while muon filters provide muon identification. Some upgrades of the COMPASS spectrometer are needed to make it efficient for the future Drell-Yan experiment. The most important one is the insertion of a hadron absorber after the target, to reduce the particle flux and enhance the muon identification. Asymmetries are expected to be quite large in the proton valence region [3], which is well covered by COMPASS acceptance.

4. – Conclusion

The COMPASS experiment has the possibility to give new results in the understanding of the physics of the spin of the proton using single polarised Drell-Yan process, probing the TMD PDFs and testing their factorization approach in QCD.

REFERENCES

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