Abstract

Understanding the structure of the nucleon remains one of the central challenges in modern hadron physics. The aim of this thesis is to experimentally study the three-dimensional structure of the nucleon in terms of Transverse-Momentum Dependent (TMD) Parton Distribution Functions (PDFs). Experimental validation of the TMD framework has been significantly advanced by data from semi-inclusive deep inelastic scattering experiments. To achieve a more universal understanding of TMD PDFs, it is essential to study them in complementary processes, with the Drell–Yan process playing a particularly important role.

This thesis presents an analysis of Transverse-Spin Dependent Azimuthal Asymmetries in the Drell–Yan process, $\pi^- + \mathrm{p}^\uparrow \to \gamma^* + \mathrm{X} \to \mu^+ + \mu^- + \mathrm{X}$, based on data collected by the Common Muon and Proton Apparatus for Structure and Spectroscopy (COMPASS) Collaboration in 2015 and 2018. The data were obtained using a 190 GeV negative pion beam scattered off transversely polarised NH_3 target.

A key aspect of the analysis is the introduction of a novel weighting method, where asymmetries are weighted by powers of the transverse momentum of the dimuon pair relative to the beam direction. The method of weighted asymmetries has proven to be a powerful tool for probing the transverse structure of the nucleon, allowing direct access to specific k_T^2 moments of the TMD PDFs. In this work, the first k_T^2 moments of the Sivers and Boer–Mulders functions have been extracted. These results represent one of the most significant experimental contributions to the study of TMD physics in recent years, and are expected to remain a key reference until future measurements from facilities such as the EIC and LHCspin become available.