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COMPASS experiment – the study of the three-dimensional and spin structure of the nucleon

The structure of strongly interacting particles, like the nucleons and mesons, is provided by the theory of strong interactions – Quantum Chromo-Dynamics (QCD). In the QCD properties and the internal structure of the nucleons and mesons are determined by the interactions between their elementary constituents, quarks and gluons (commonly referred to as 'partons').

The objective of the project are experimental studies of the nucleon three-dimensional and spin structure in terms of its elementary constituents, which situates this project in the new domain of QCD studies that surpass one-dimensional picture commonly used previously. The description of the three-dimensional structure is provided either by the TMD formalism (Transverse Momentum Dependent distributions) or alternatively by the GPD formalism (General Parton Distributions). Both approaches are complementary and also describe correlations between longitudinal momentum of partons (along the nucleon momentum) and their transverse degrees of freedom; parton transverse momenta (in the TMD approach) or parton positions in the plane perpendicular to the momentum of the nucleon (in the GPD approach). In addition, both formalisms correlate parton distributions with the nucleon spin. In particular, they allow us to investigate the role of the total and orbital angular momenta of quarks and gluons in explaining the nucleon spin ½. The problem is known since about 30 years as the 'nucleon spin puzzle' and still is not completely solved. While the total contribution of quarks spin to the nucleon spin is by now well established to be about 30%, the present knowledge about the role of the gluon spin and of the orbital angular momenta of quarks and gluons is still limited. Another interesting topic related to the nucleon three-dimensional structure is the so called 'nucleon tomography', which refers to correlations between partons spatial distributions in the transverse plane to the momentum of the nucleon and their longitudinal momenta.

In this project the TMDs and GPDs will be studied by measuring various azimuthal and spin-dependent asymmetries for three processes: deeply virtual exclusive meson or photon muoproduction (for the GPD program), semi-inclusive polarised deep inelastic muon scattering resulting in the production of hadrons with high transverse momenta (for the TMD program) and Drell-Yan production of di-muon pairs in scattering of pions off transversely polarised protons (also for the TMD program). These studies will be carried out in the framework of the COMPASS Collaboration by scattering high energy muons or π^- mesons off polarised and unpolarised nucleons. The COMPASS apparatus consists of a high precision forward spectrometer and either unpolarised, longitudinally or transversely polarised target. It is located at the unique CERN SPS M2 beam line that delivers hadron or naturally polarised $\mu^\pm$ beams in the energy range between 50 and 280 GeV. High energy muon or hadron beams and large (1.2 m long) polarised targets used at COMPASS provide a unique tool allowing us to study the nucleon structure in a kinematical region not accessible elsewhere. With the versatile experimental setup and comprehensive studies of the nucleon structure and of hadron spectroscopy the COMPASS experiment can be considered as a **'QCD laboratory'** .

The results of this project will improve considerably our knowledge in the domain of research for the three-dimensional nucleon structure. They will make a significant contribution in verifying basic predictions of the Quantum Chromo-Dynamics (QCD), such as e.g. the (limited) universality of parton distributions or QCD evolution of TMDs. They will also improve precision of parameterisations of TMD and GPD models describing the nucleon structure. Presently COMPASS is the only European experiment devoted to the study of the nucleon spin structure and it is complementary to experiments at the two American facilities: Jefferson Laboratory and RHIC complex.

Polish groups from NCBJ, WUT and UW participated in COMPASS experiment since its beginning and have made significant contributions to its accomplishment. The present project, which is realised in the framework of COMPASS Collaboration, is a part of the new phase of the experimental program that is realised since 2012 following the CERN approved proposal 'COMPASS-II proposal'. The project is realised in terms of 'Memorandum of Understanding for the Upgrade and Operation of the COMPASS Experiment (NA58)' signed by CERN and representatives of Polish groups.