RHIC (Relativistic Heavy Ion Collider) at Brookhaven National Laboratory (BNL) in the US, is one of two (the other is LHC) currently operating circular accelerators of protons and heavy ions and the only one in which it is possible to collide polarized proton beams. STAR experiment, which began collecting data in 2001, is one of two currently operating detectors at RHIC. The main objective of the STAR experiment is to make progress in understanding of the fundamental properties of elementary particles and their interactions. To the most important achievements of the RHIC experiments belongs the first observation of a new state of matter called quark gluon plasma (QGP) in collisions of heavy ions. QGP is a state of matter that occurs at extremely high energy densities, wherein quarks and gluons behave as free particles. Understanding the characteristics of the QGP allows a better understanding of the processes that occurred in the early stages of Universe just after the Big Bang, which then decided on its evolution. The study of the phase diagram of quantum chromodynamics (QCD), of the initial conditions and the nature of hadronization process in heavy-ion collisions are still the basic objectives of the physics program of the STAR experiment.

In parallel, a program of examining the nature of the proton spin and diffraction processes in proton-proton and / or proton-nucleus collisions is developed. These issues are in the centre of interest of particle physics and are now important elements of the STAR physics program. Interests of our team are concentrated just on these issues.

Physicists from the AGH University of Science and Technology and the Institute of Nuclear Physics PAN participate in the STAR experiment since the beginning of 2012. We participate both in the process of data collection, as well as in their reconstruction and analysis. In addition, we are engaged in software development (algorithms for reconstruction of tracks and Monte Carlo simulation of detectors) as well as in maintenance and upgrade of the Roman Pot detectors designed for the measurement of protons scattered at very small angles relative to the beam axis.

QCD as the theory of the strong interaction is one of the foundations of the Standard Model of elementary particles. It explains the behavior of strongly interacting matter by interactions of point-like quarks through the exchange of gauge bosons called gluons. A strongly interacting matter is responsible for 99% of the mass of the observable universe.

Most of the current knowledge about the structure of the proton comes from lepton-proton deep inelastic scattering (DIS) experiments. In particular, a lot of data on unpolarized proton structure were collected in experiments at the HERA collider. These studies revealed that quarks carry only about 50% of the momentum of a proton, while the remainder is associated with gluons. To obtain a complete picture of the nucleon structure one needs to study the widest possible range of reactions. In hadron-hadron interactions, it is possible to directly access the gluons by the parton-parton scattering and consequently studying the contribution of gluons to the proton spin. Comparison of the results of the DIS experiments and interactions of hadrons allows to test the universality of the description of the structure of hadrons and the hadronization process in the framework of perturbative QCQ (pQCD). In the high-energy limit of pQCD, calculations in which the quarks and gluons are treated as nearly free particles moving collinearly with their parent hadron, and in which hadronic interactions are assumed to factorize into a) parton distribution functions (PDFs) within the initial state hadron, b) partonic hard-scattering cross sections, and c) fragmentation functions (FFs) describing the hadronization of the scattered parton, have had tremendous success in describing hadronic cross sections at high energies over the past several decades. Energies available at RHIC allow to use pQCD to describe the reaction with a high transverse momentum. The relevant perturbative scale in DIS is the photon virtuality squared, whereas in the case of hadron-hadron interactions it is a square transverse momentum of produced jets or particles.

Despite significant progress in understanding of the structure of the nucleon made during the last 25 years, there still remain open two fundamental aspects of its partonic structure. The first concerns a full understanding of the nature of the spin of the nucleon. The second concerns the departure from the currently used "one-dimensional" description of the nucleon by correlating information about individual parton contribution to the nucleon spin with their transverse momentum and spatial distribution.

Another topic belonging to the area of ?? interest of our team are diffractive processes. Diffractive processes are characterized by elastically or quasi-elastically scattered proton in the final state. This effect occurs through the exchange of an object carrying the vacuum quantum numbers called Pomeron. In QCD the Pomeron exchange is described as exchange of gluons in color singlet state. Registration of protons scattered at very small angles at high energies thus enables selection of processes taking place through the exchange of objects composed mainly of gluonic matter. Additionaly the polarized proton beams at RHIC allow testing of the unknown dependence on the spin in the process of diffraction. Particularly interesting are processes with the exchange of two Pomerons in which each of the protons emitts a Pomeron, then both Pomerons interact, producing a system with a mass M_X in the final state. This final state can be resonances, multiparticulate systems, jets, etc.

QCD predicts the existence of bound states of gluons with no constituent quarks, called glueballs. An existence proof and characterization of these compound objects off er unique insight into the strong interaction since the gluon self-interaction is exclusively responsible for the mass of glueballs.

Processes of the central exclusive production (CEP) of particles and resonances by double Pomeron exchange at high energies have recently become active field of research. Measurements at RHIC can be used as tests of theoretical models. It is expected that because of the high energies available at the LHC, when the AFP project (ATLAS) is implemented, the double Pomeron exchange process can be used for measurement of Higgs production and the search for supersymmetric particles.

Implementation of the physics program of our project will enable progress in understanding of the structure of the nucleon spin and the nature of diffractive processes. The results and the experience gained will be useful in future studies at the LHC.