Fundamental measurements of the proton's sub-structure using high-energy polarized proton-proton collisions

Bernd Surrow
Massachusetts Institute of Technology

Understanding the structure of matter in terms of its underlying constituents has a long tradition in science. A key question is how we can understand the properties of the proton, such as its mass, charge, and spin (intrinsic angular momentum) in terms of its underlying constituents: nearly massless quarks (building blocks) and massless gluons (force carriers). The strong force that confines quarks inside the proton leads to the creation of abundant gluons and quark-antiquark pairs (QCD sea). These 'silent partners' make the dominant contribution to the mass of the proton. Various polarized deep-inelastic scattering measurements have shown that the spins of all quarks and antiquarks combined account for only 25% of the proton spin.

New experimental techniques are required to deepen our understanding on the role of gluons and the QCD sea to the proton spin. High energy polarized proton-proton ($p + p$) collisions at RHIC at Brookhaven National Laboratory provide a new and unique way to probe the proton spin structure using very well established processes in high-energy physics, both experimentally and theoretically.

A major new tool has been established for the first time using parity-violating W boson production in polarized $p + p$ collisions at $\sqrt{s} = 500\,\mathrm{GeV}$ demonstrating directly the different polarization patterns of different quark flavors, paving the path to study the polarization of the QCD sea. Various results in polarized $p + p$ collisions at $\sqrt{s} = 200\,\mathrm{GeV}$ constrain the degree to which gluons are polarized suggesting that the contribution of the gluons to the spin of the proton is rather small, in striking contrast to their role in making up the mass of the proton.