Title
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Abstract. The spin physics program at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory presents a unique opportunity to study the proton spin structure using hard probes and collider kinematics. In the future, measurements will be made of polarized proton collisions at a center of mass energy of $\sqrt{s} = 500\,\mathrm{GeV}$. At the projected high integrated luminosities of $\sim 800\,\mathrm{pb}^{-1}$ ample W^{+-}-bosons are produced. Measurement of the ratio of decay daughter leptons in the central and forward rapidity regions for opposite helicities of one of the polarized beams allows the dissociation of the proton spin contributions from up and down quark and anti-quark spins. The capabilities with the current detector configurations and future upgrades are discussed.

Keywords: proton spin structure, spin asymmetries
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About 20 years ago, the European Muon Collaboration reported a non-intuitively small inclusive spin structure function in deeply inelastic polarized muon-proton scattering [1]. When combined with hyperon β decay measurements, the conclusion is that the sum of quark and anti-quark spins carry only $\sim 20\%$ of the proton spin. Natural questions then concern how much of the proton spin is carried by gluon spins and by angular momenta, and why is the quark contribution small? Unpolarized deeply inelastic scattering and Drell-Yan measurements have shown strong breaking of $SU(2)$ symmetry in the anti-quark sea [2, 3, 4]. New insights continue to emerge, on quark polarizations in the valence region from measurements [5] at the Thomas Jefferson National Accelerator Facility, on gluon polarization and quark flavor decomposition from semi-inclusive deeply inelastic scattering measurements of (identified) hadrons at the HERMES and COMPASS experiments [6, 7], and on gluon polarization from the ongoing RHIC measurements with longitudinally polarized proton beams at $\sqrt{s} = 200\,\mathrm{GeV}$ [8, 9, 10]. Future high luminosity RHIC beam periods at $\sqrt{s} = 500\,\mathrm{GeV}$ will produce ample $W^{\pm}$-bosons and allow for the direct measurement of the proton spin contributions from up and down quark and anti-quark spins. A detailed description of the RHIC complex and the STAR and PHENIX detectors is given in Ref. [11].

Within the standard model, the quark and anti-quark helicities in $u\bar{d} \rightarrow W^+$ and $d\bar{u} \rightarrow W^-$ are fixed through V-A interaction. W-bosons produced in polarized proton collisions are thus good candidates to study the spin-flavor structure of the proton, in particular through their calculable leptonic decay channels. The participating quark and anti-quark spin distributions are probed at large scale $\sim M_W^2$ and the interpretation needs not rely on knowledge of hadronization processes. Contributions from strange and charm quarks arise mostly from quark mixing and are generally small.

An experimental difficulty is that in $W \rightarrow l\nu$ the neutrino escapes detection. Only the

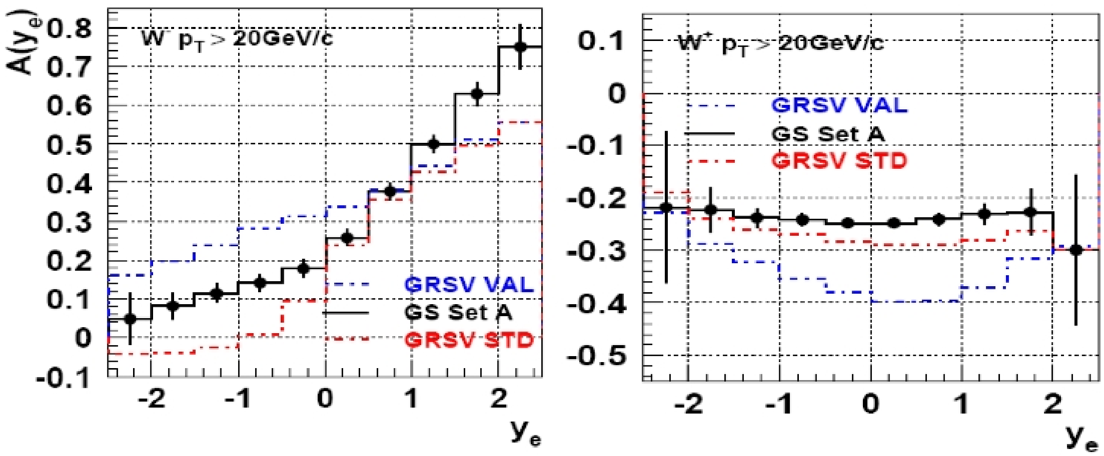

FIGURE 1. The single beam-helicity asymmetry in the weak production of single electrons in proton collisions at $\sqrt{s} = 500\,\text{GeV}$ versus electron rapidity for several commonly used polarized parton distribution functions. The projected uncertainties are for $800\,\text{pb}^{-1}$ and 70% beam polarization.

charged lepton is observed, which complicates kinematic reconstruction of the quark and anti-quark momenta or Bjorken-x. The standard technique of large missing p_T cannot be used to select W-boson production at RHIC, since neither the STAR experiment nor the PHENIX experiment is hermetic. Instead, W-boson production is enhanced by selecting leptons for large p_T where decay contributions from charm, beauty, and Z-boson are less important. Both the kinematic convolution and the p_T selection have been successfully incorporated in advanced theoretical calculations [12]. Figure 1 shows predictions for the single beam-helicity asymmetry in the weak production of single electrons in polarized proton collisions at $\sqrt{s} = 500\,\text{GeV}$ for various polarized parton distribution functions [13] versus electron rapidity, together with the projected statistical uncertainties for the projected $800\,\text{pb}^{-1}$ integrated luminosity and 70% beam polarization at RHIC. The sensitivity of the measurements is different for the central and forward rapidity regions, and is generally better in the forward regions. Future RHIC measurements will cover both regions and have the potential to distinguish between the polarized parton distribution functions, which are all based on deeply inelastic polarized lepton-nucleon scattering data and different assumptions on the polarized quark sea.

To make successful measurements, the PHENIX and STAR experiments will need:

- extended RHIC data collection periods with longitudinally polarized proton collisions at $\sqrt{s} = 500\,\text{GeV}$,
- good charge identification for leptons with large momenta, and
- efficient lepton triggers with high rejection of backgrounds.

STAR and PHENIX currently have the experimental capabilities, but only in the central rapidity region where the sensitivity is limited. In the forward region, where the measurements are most sensitive, PHENIX has successfully proposed a trigger upgrade for its muon arms to achieve the required background rejection. The muon charge discrimination is adequate. STAR is proposing an upgrade to its forward tracking capabilities to be able to discriminate electrons and positrons at high momenta. Its fully commissioned endcap electromagnetic calorimeter provides trigger capability. RHIC has successfully accelerated, stored, and collided protons at $\sqrt{s} = 410\,\text{GeV}$ as part of its development program in 2005. This, together with measured survival of proton polarization, bodes well for future measurements.

In summary, W-bosons in longitudinally polarized proton collisions at RHIC form a unique opportunity to measure the up and down quark and anti-quark spin contributions to the proton spin. With proposed upgrades of the forward tracking system in STAR and the forward muon trigger in PHENIX, and extended data collection at $\sqrt{s} = 500\,\text{GeV}$, decay lepton measurements in the central and forward rapidity regions can be made with sufficient accuracy to discriminate between different flavor scenarios for the polarized quark distributions in the nucleon.

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