DISSECTING THE PROTON'S SPIN WITH POLARIZED PROTON COLLISIONS AT RHIC*

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The Relativistic Heavy Ion Collider is the world's first polarized proton collider, providing collisions at $\sqrt{s} = 200$ GeV with increasing luminosity since 2002. We report on a program to investigate the polarization of the partons in the proton via hard partonic scattering. Results from 2005 and 2006 for inclusive jets from STAR and π^0s from PHENIX are beginning to provide new significant constraints on ΔG, the first moment of the gluon helicity distribution. Future measurements at $\sqrt{s} = 500$ GeV will enable investigations of the polarization of sea quarks via W production.

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1. Recent progress in RHIC spin

Although named the Relativistic Heavy Ion Collider, the 4 km rings at Brookhaven National Laboratory also comprise the world's first polarized proton collider. Since 2002, protons have been collided at $\sqrt{s} = 200$ GeV with increasing polarization and luminosity, achieving delivery of 45 pb^{-1} at 60% polarization in 2006. Operation of RHIC in this polarized proton mode enables an extensive program to investigate the spin structure of the nucleon [1]. In the following we will discuss recent results already making important contributions to this quest as well as prospects for the future.

It is now well accepted that quarks account for about $\frac{1}{4}$ of the nucleon spin [2]. The remainder must come from gluons and orbital angular momentum of the partons. Deep inelastic scattering provides some sensitivity to the gluon helicity distribution, $\Delta g(x)$, where x is the gluon's fraction of the proton momentum, but there remains a large uncertainty in the magnitude and sign of ΔG, the first moment of $\Delta g(x)$. Polarized pp collisions provide the possibility to directly scatter partons from each other in kinematics

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where the partonic spin dependence is large. In particular, the helicity dependence of gluon–gluon and quark–gluon scattering detected as jets, π^0s and direct photons provide sensitivity to ΔG.

Measurements at both STAR and PHENIX through 2006 have mostly focused on large yield inclusive measurements. RHIC cross sections for inclusive jet [3], π^0 [4, 5] and direct photon [6] production at 200 GeV agree well with next-to-leading order perturbative QCD calculations. Helicity dependent measurements in 2005 [7,8] and 2006 are adding new constraints on gluonic contributions to the proton's spin. In particular, they are showing a preference to parton distribution functions with gluon polarization less than those with significant positive ΔG such as GRSV-std [9]. The existing inclusive data tend to integrate over large x regions and thus do not have strong sensitivity to the shape of $\Delta g(x)$. Due to the dominance of gluon–gluon scattering, the existing data also lack discriminating power for negative ΔG values. Beginning with the 2006 data integrated luminosities are large enough that di-jets, hadron correlations and direct gamma channels can be exploited for their sensitivity to the x dependence and negative values of ΔG.

2. The future of polarized RHIC

With the completion of the current goals for $\sqrt{s} = 200$ GeV over the next few years, RHIC will raise the collision energy to $\sqrt{s} = 500$ GeV. Tests have already demonstrated significant polarization transport to this energy. Measurements at $\sqrt{s} = 500$ GeV will provide access to lower x values for ΔG and to spin dependent flavor differences in the sea via parity violating asymmetries in W production.

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