Neutral pion double helicity asymmetry

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A major goal of the RHIC Spin program is to determine the gluon spin distribution in the proton. The quark spin contribution to the proton spin ($\Delta \Sigma$) is only about 25%1) and so the remaining spin must be carried by the gluon spin ($\Delta G$), or by the gluon and quark orbital angular momentum ($L_g$ and $L_q$, respectively):

$$S_p = \frac{1}{2} = \frac{1}{2} \Delta \Sigma + \Delta G + L_q + L_g$$

written in units of $\hbar$.

At RHIC, $\Delta G$ can be probed directly through measurements of the double helicity asymmetry in polarized $p+p$ collisions, in this case for neutral pions:

$$A_{LL} = \frac{1}{P_B P_Y} \frac{N_{++} - RN_{+-}}{N_{++} + RN_{+-}}$$

where $P_B$ and $P_Y$ are the polarizations of the two proton rings at RHIC, $N$ is the yield of neutral pions, $\pi^0$, $++$ and $+-$ indicate same and opposite helicity combinations of the two beam helicities, and $R$ is the relative luminosity, defined as $R = L_{++,+}/L_{++,\pm}$, which is required to normalize differences in the luminosity $L$ between RHIC proton bunches.

In 2009, RHIC PHENIX recorded 14 pb$^{-1}$ with an average polarization of 56%. The $\pi^0 A_{LL}$ was measured, and found to be consistent with previous results. The combined results from 20052), 20063) and 20094) are plotted in Fig. 1. The systematic uncertainty from relative luminosity in 2009 was larger than in previous years, and for the lowest $\pi^0$ transverse momentum, $p_T$, was larger than the statistical uncertainties.

The combined data set are shown in Fig. 1 and Fig. 2 compared to several theoretical expectations based on fits to the world polarized scattering data. In the case of1), the RHIC 2005 and 2006 $\pi^0$ data are also included. In fits that do not use RHIC data, such as GRSV5), LSS6) and BB7), there is large uncertainty in $\Delta G$ and therefore in the expected $\pi^0 A_{LL}$. Fits including some RHIC data, such as DSSV$^{(1)}$ and NNPDF$^{(2)}$ find a smaller range of possible $\Delta G$. These data therefore offer significant constraint on $\Delta G$. Recently, the RHIC 2009 data have been included in an updated version of DSSV$^{(3)}$, and indicate that the gluon spin contribution to the proton spin is about the same size as that of the quarks.

References

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