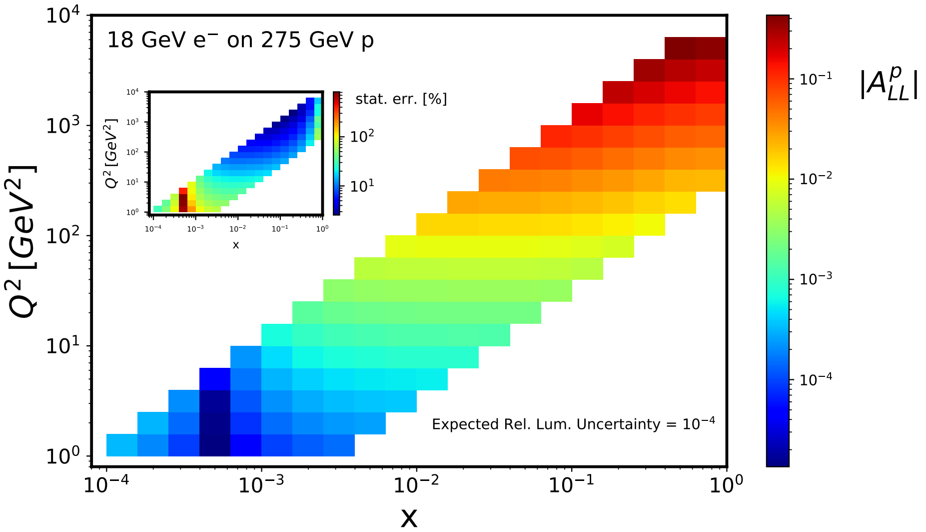
1 Spin physics from inclusive measurements

1.1 Double spin asymmetry measurements

The simulated inclusive data is used to estimate the precision with which spin asymmetries can be measured. As was the case at RHIC, the expectation is that beam polarisations will be flipped at very high frequency, such that any time-dependent instrumental systematics become negligible.



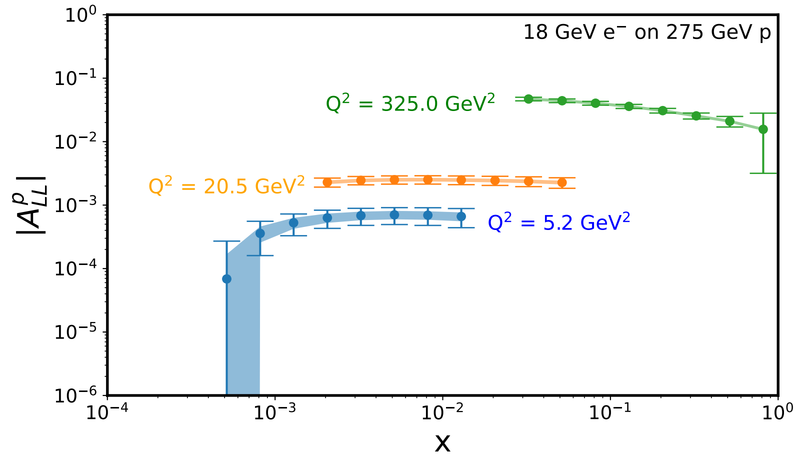


Figure 1: Projected double spin asymmetry A^{ep}_{LL} for inclusive electron-proton measurement versus both x and Q^2 at highest beam energy. The statistical uncertainty is based on an integrated luminosity of 15 fb^{-1} with ATHENA acceptance. The systematic uncertainty estimation includes 1.5% point-by-point uncorrelated systematic uncertainty, 5% normalization uncertainty, and an additional systematic uncertainty of 10^{-4} from relative luminosity.
Upper plot: A^{ep}_{LL} and its uncertainties versus x and Q^2 with ATHENA pseudo-data. The A^{ep}_{LL} values come from the JAM collaboration.
Lower plot: Uncertainties together with A^{ep}_{LL} at three typical Q^2 values with the same condition as upper plot. The error bars show the statistical uncertainties, and the bands represent the systematic one. A^{ep}_{LL} values come from the DSSV collaboration.

Understanding the spin of the proton is one of the central pillars of the EIC physics programme. Historically this question has been approached through the helicity-dependent collinear quark and gluon distributions in the proton, following the spin sum rule:

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_{Q+G}, \tag{1}$$

where $\Delta\Sigma$, ΔG, L_{Q+G} are the contributions from the quark/anti-quark spin, the gluon spin and the parton angular momentum respectively. The numerous existing data from fixed-target polarized lepton DIS experiments and polarized proton-proton experiments, provided us good knowledge on $\Delta\Sigma$, ΔG in the range 0.005<x<0.6. The EIC measurements with unprecedented precision and wider kinematic coverage will lead to a revolution in our understanding of nucleon spin structure. In particular, the inclusive DIS measurements will drastically reduce the uncertainties on $\Delta\Sigma$ and ΔG in the range of x<0.05.

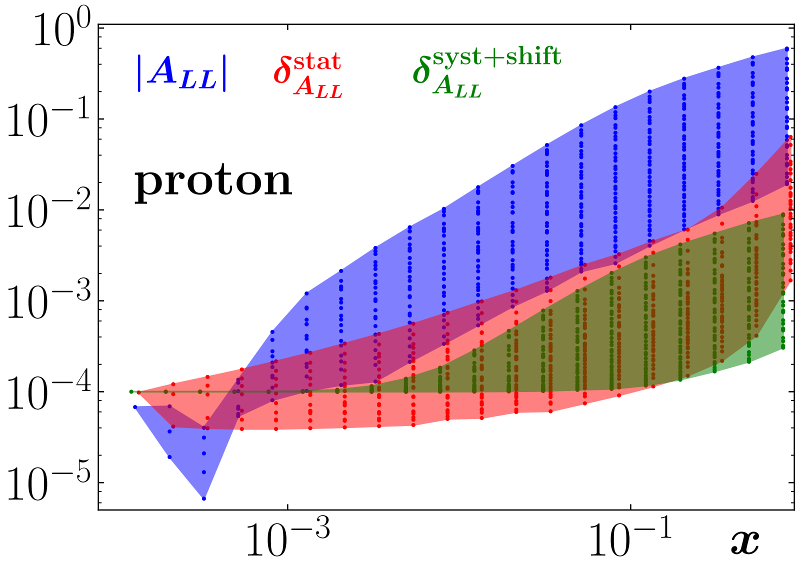


Figure 2: Projected uncertainties (statistical and systematic) of A^{ep}_{LL} versus x bins with ATHENA pseudo-data. Each point represent the corresponding value in that bin. The points at same x correspond to different Q^2 bin. The A^{ep}_{LL} asymmetry is provided by JAM Collaboration.

The basic ingredient of these studies is through the double spin asymmetry A_{LL}, which can be derived from inclusive NC DIS data with different beam polarizations. Given that the asymmetries are small, large luminosities are required for these studies, such that spin decomposition through inclusive measurements is a medium-term target for ATHENA. Fig. 1 shows the projected double spin asymmetry from JAM collaboration and the statistical uncertainty for inclusive electron-proton measurement for covered x and Q^2 ranges with an integrated luminosity of 15 fb^{-1} at highest energy. The systematic uncertainty estimation includes 1.5% point-by-point uncorrelated systematic uncertainty, 5% normalization uncertainty, and an additional systematic uncertainty of 10^{-4} from relative luminosity. The conservative 5% normalization uncertainty includes contributions from electron beam polarization (2%), proton polarization (2%), uncertainty related with pion contamination (3%, assuming 90% electron purity), and 1-2% on detector effects. Fig. 2 shows the systematic and statistical uncertainties for ATHENA pseudo-data versus x bins. The points at same x correspond to different Q^2 bin. As can be seen, the shift uncertainty from relative luminosity dominates at very low x region (10^{-4}) and is comparable or even larger than the projected A_{LL} value by JAM.

1.2 Impact on proton helicity distributions

Fig. 3 shows the impact of ATHENA inclusive data in constraining the $\Delta\Sigma$ and ΔG through a global fit by DSSV collaboration.[1] Similar as done for Yellow Report, the $\sqrt{s}$=45 GeV pseudo-data is included as the baseline global fit. This extended version of NLO DSSV14 baseline is then

[1]With thanks to I. Borsa (Buenos Aires University).

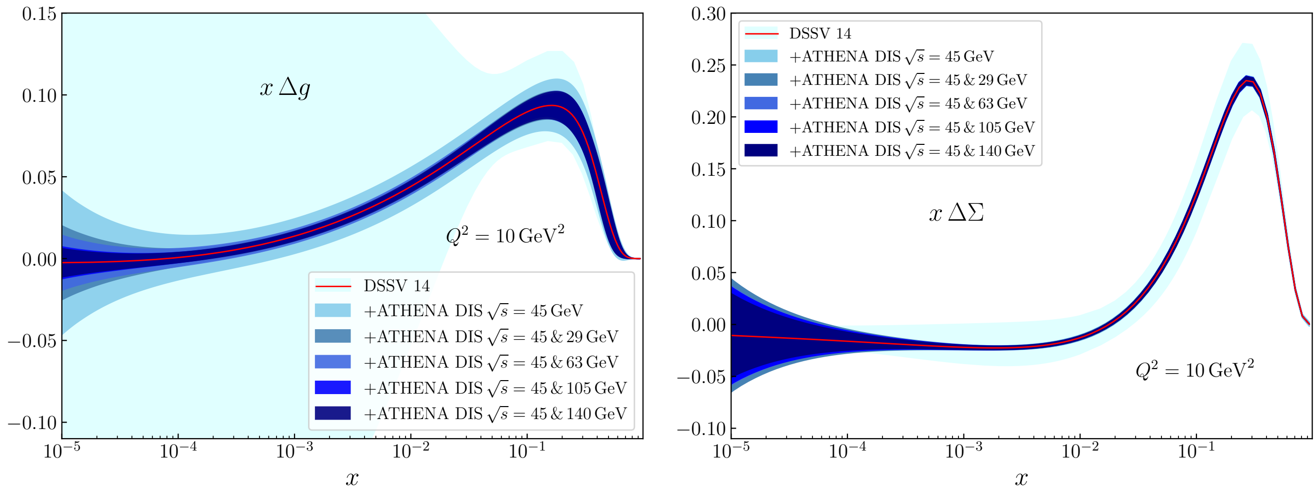


Figure 3: Impact of ATHENA on the understanding of the proton spin through helicity distributions from DSSV global analysis. Left: gluon distribution. Right: singlet quark distribution.

reweighted with the inclusion of other 4 energy data. As indicated in the figure, the uncertainty on the gluon helicity is significantly reduced relative to the DSSV14 [1,2] in the small x region (x<0.05) after including the projected ATHENA NC DIS data. The ATHENA data also provide significant constraints on the quark and anti-quark spin contribution $\Delta\Sigma$ in the intermediate x region. The ATHENA pseudo-data includes a sample of $L = 100\ fb^{-1}$ with the beam energies 10 GeV x 275 GeV ($\sqrt{s}$ = 105 GeV) which produces the highest peak luminosity in a year of running, and other beam energies are scaled based on projected luminosity for equal running time.

Fig. 4 shows the impact of ATHENA inclusive data (same as above for DSSV fit) in constraining the truncated moments $\Delta\Sigma$ and ΔG versus x_{min} through a global analysis by JAM collaboration [3].[2] This JAM global QCD analysis at NLO level includes all existing DIS A_{LL} data and inclusive jet A_{LL} data in pp collisions at RHIC. Here the positivity constraints is particularly studied [4] in the upper and lower rows of figure 4. Similar as DSSV, over all a significant constraint from ATHENA data is seen for the gluon helicity distribution with an uncertainty reduction of about 80% at low x. For the quark singlet case, the reduction is about 50%.

References

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[2]With thanks to Y. Zhou (South China Normal University).

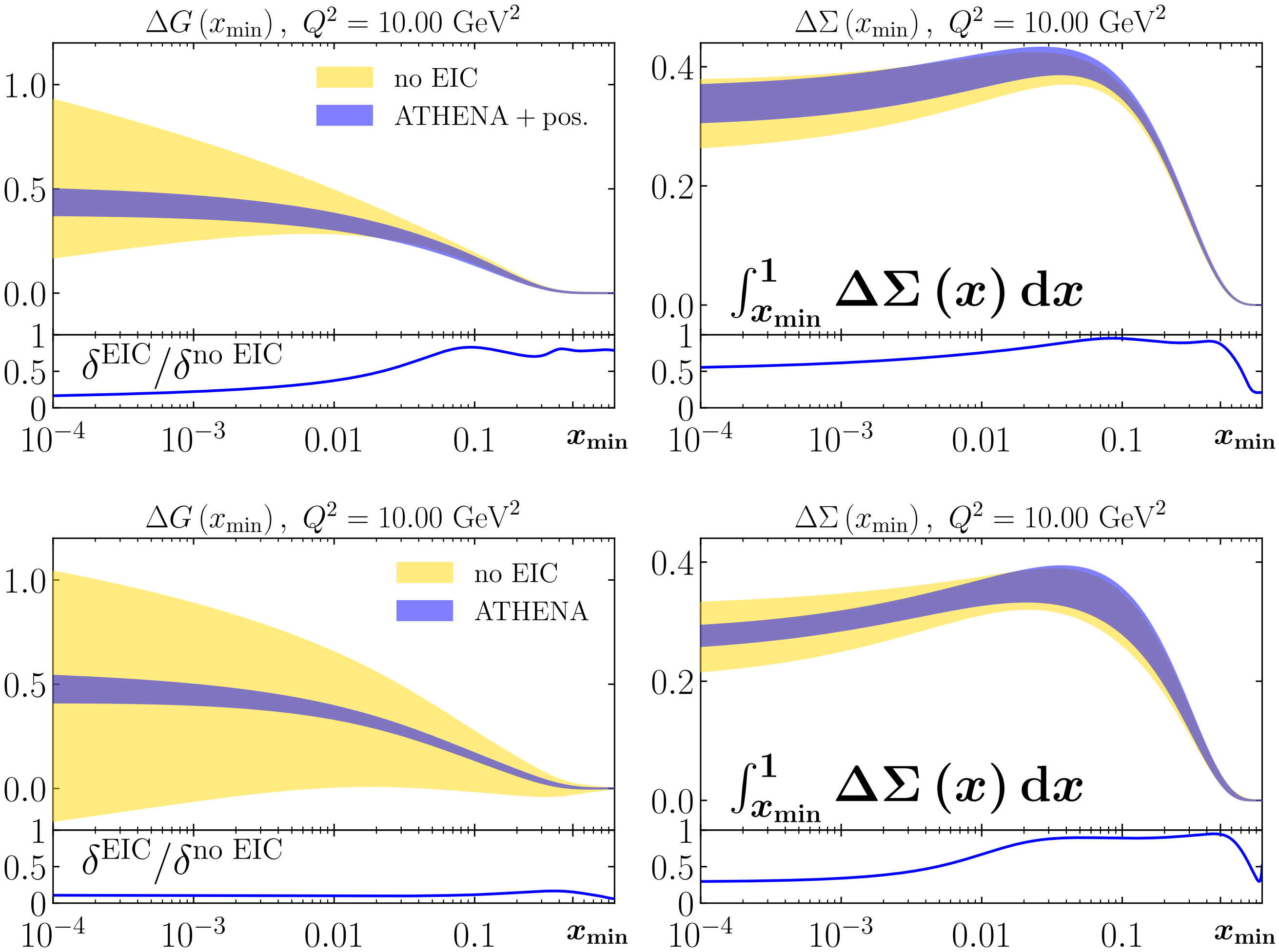

Figure 4: Impact of ATHENA on the understanding of the proton spin through truncated moments of gluon and quark singlet helicity distributions versus x_{min} from JAM global analysis.
Left column: gluon distribution. Right column: singlet quark distribution.
Upper row: with positivity constraint. Lower row: without positivity constraint.