$A_{LL}(p_T, \eta_h)$ for single hadron photoproduction at high p_T

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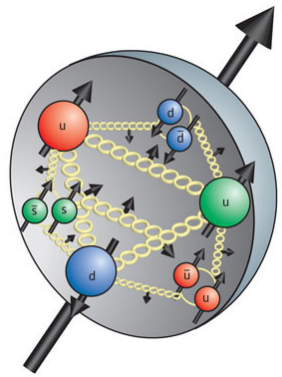
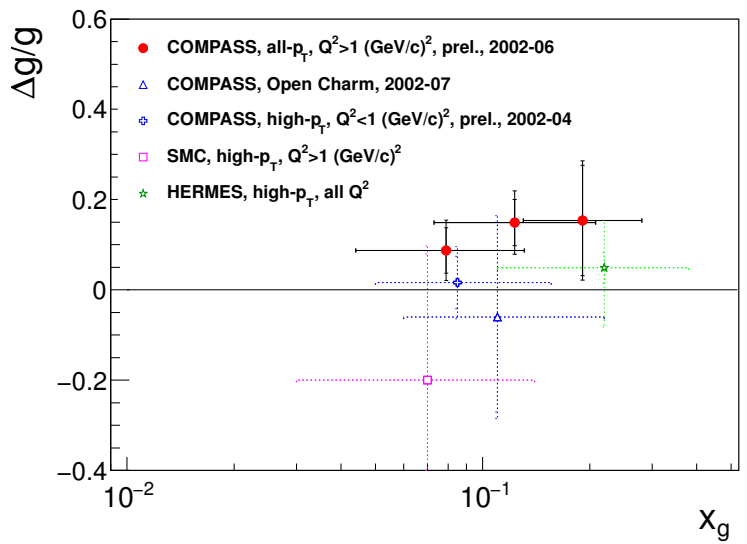
Nucleon Spin Structure

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



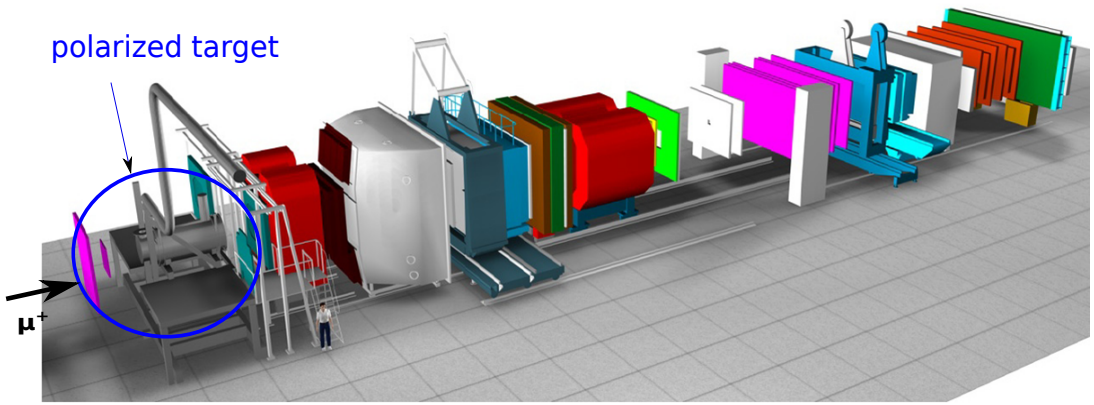
$$\Delta\Sigma \approx 0.3 \;\Rightarrow\; -0.1 \leq \Delta G \leq 0.3 \;\; ??$$

Previous Measurements from longitudinal data:
cf. Malte Wilfert's talk



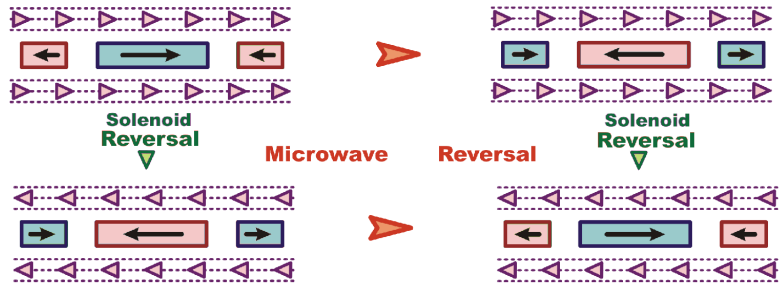
$\Rightarrow$ Purpose: Extraction at NLO of ΔG from $A_{LL}(p_T, \eta_h)$ at high p_T and low Q^2

COMPASS Spectrometer and Target



- μ^+ polarized beam from SPS at 160 or 200 GeV
- 2 stages spectrometer with large acceptance

- polarized target with 2 (2002-2004) or 3 (2006-2011) cells
- 2 types of polarization reversal
- target material:
  - deuterons (^{6}LiD) from 2002 to 2006
  - protons (NH_3) from 2007 to 2011

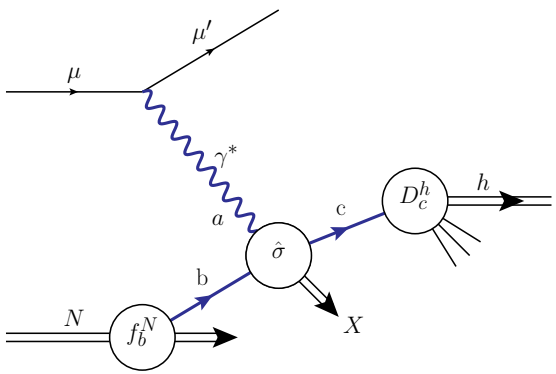


Theoretical Framework

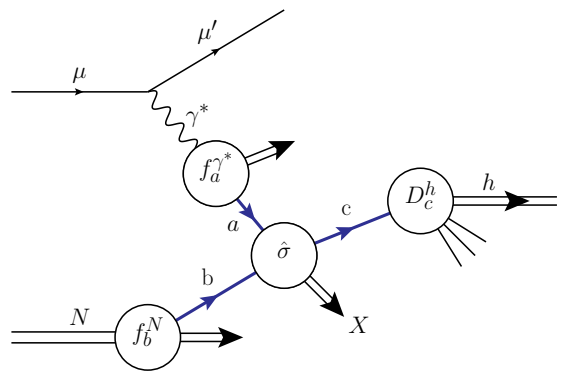
- Collinear pQCD analysis at NLO (EPJC 44 (2005) 533):

$$\frac{d\Delta\sigma^h}{d\sigma^h}(p_T,\eta_h) = \frac{\sum_{a,b,c} \Delta f_a^{\mu} \otimes \Delta f_b^{N} \otimes d\Delta\hat{\sigma}_{a,b\to c,X} \otimes D_c^h}{\sum_{a,b,c} f_a^{\mu} \otimes f_b^{N} \otimes d\hat{\sigma}_{a,b\to c,X} \otimes D_c^h} = \frac{d\Delta\sigma_{dir} + d\Delta\sigma_{res}}{d\sigma_{dir} + d\sigma_{res}}$$

direct γ-contribution



resolved γ-contribution

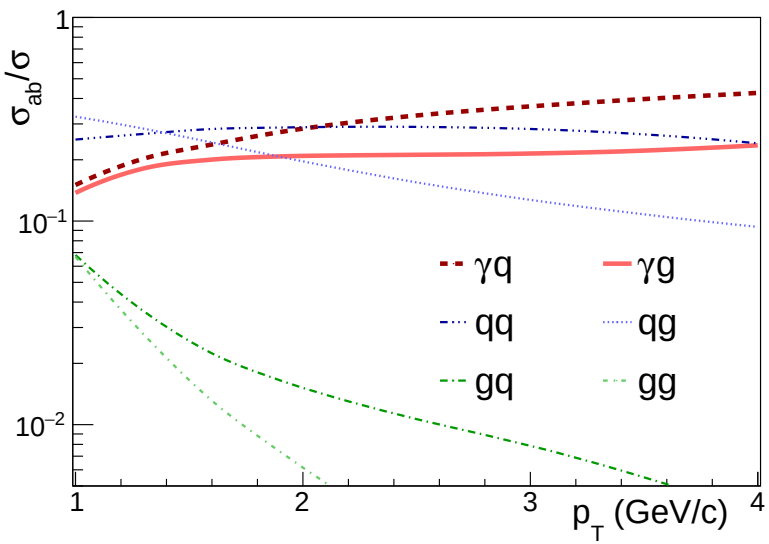


- $\Delta f_a^{\mu}(x_a,\mu_f) = \int_{x_a}^1 \frac{dy}{y} \Delta P_{\gamma\mu}(y) \Delta f_a^{\gamma}(x_\gamma = \frac{x_a}{y},\mu_f)$ allows to take into account both γ-contributions
- Uncertainty for the polarization of the hadronic fluctuation of the virtual photon

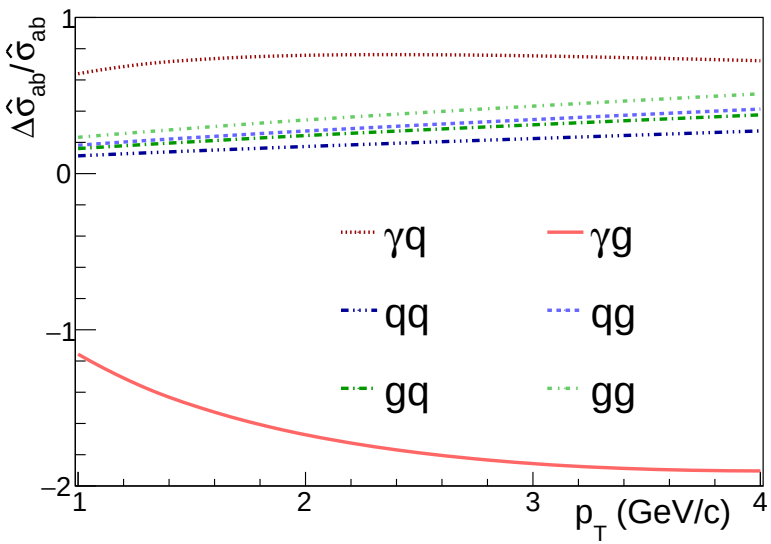
Contributions of the Different Processes at NLO

- Calculations performed with CTEQ6 PDFs and DSS "reloaded" FFs

Unpolarized Cross-sections



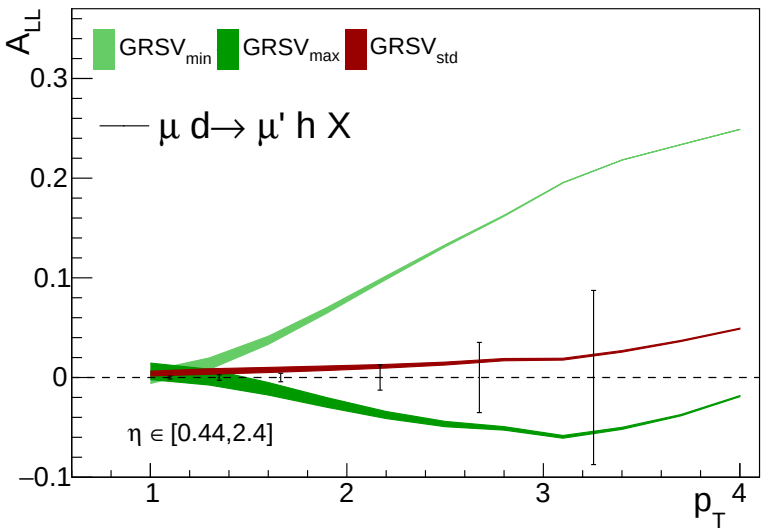
Analysing Power

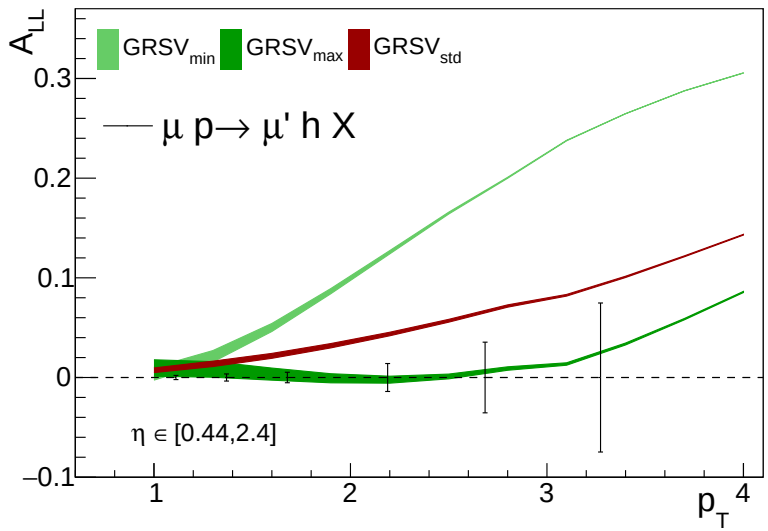


- QCD Compton (γq) dominating over PGF (γg)
- Still a good sensitivity to ΔG through a large magnitude of the PGF analysing power

Theoretical Estimations

- Estimation of COMPASS A_{LL} for deuteron and proton target, with COMPASS error projection (EPJC 44 (2005) 533)

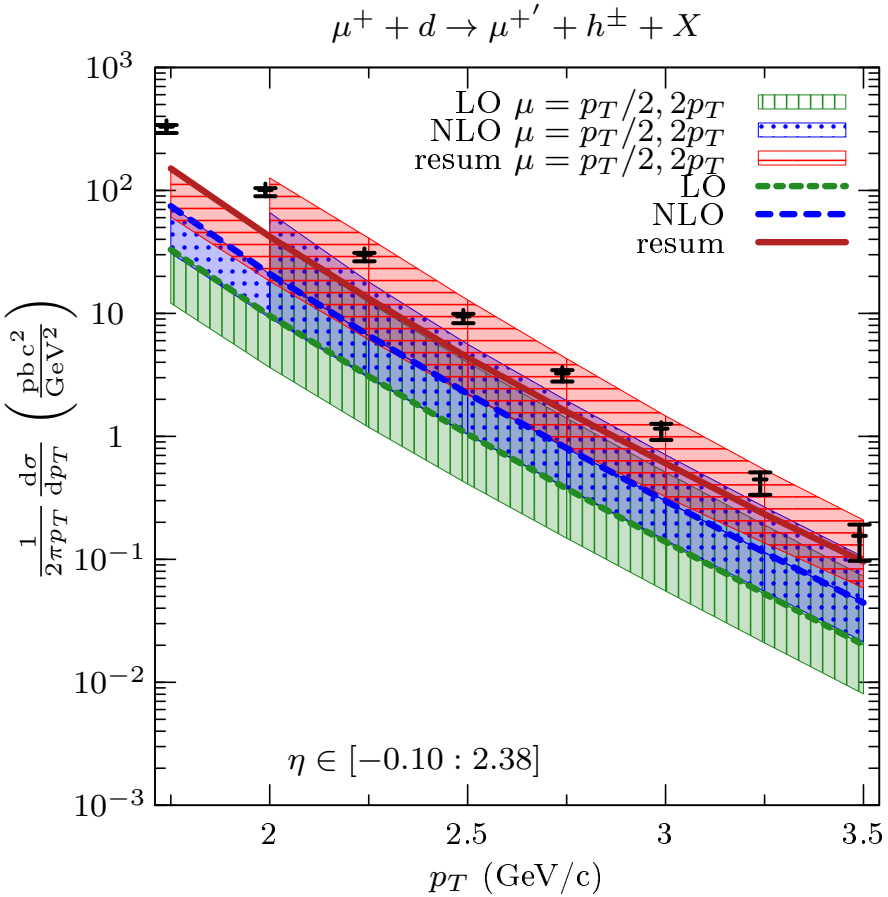




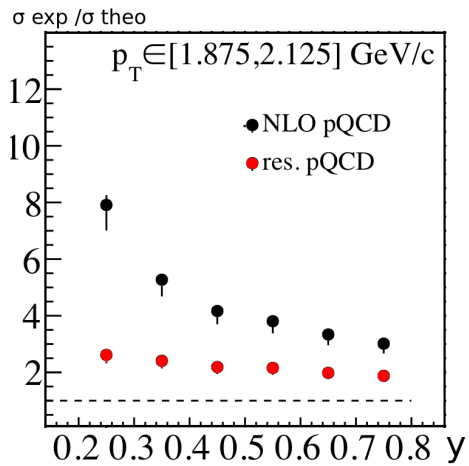
- Small impact of the resolved photon polarized structure uncertainty (only at *low* p_T)
- Discriminating power on ΔG

Unpolarized Cross-sections Preliminary Study

- COMPASS measurement (PRD 88 (2013) 091101)
- Comparison with theoretical calculations with gluon resummation (PRD 88 (2013) 014024)



- close to threshold given a low energy range: $\sqrt{s} \approx 18$ GeV (RHIC: $\sqrt{s} \approx 200$ GeV)
- needs gluon resummation to explain unpolarized cross-section



Systematics Study

- Qualitative study of unphysical asymmetries (supposed to be zero) and comparison of asymmetries from equivalent parts of the data
- Multiplicative uncertainties coming from measurement uncertainties on beam and target polarization and on the dilution factor

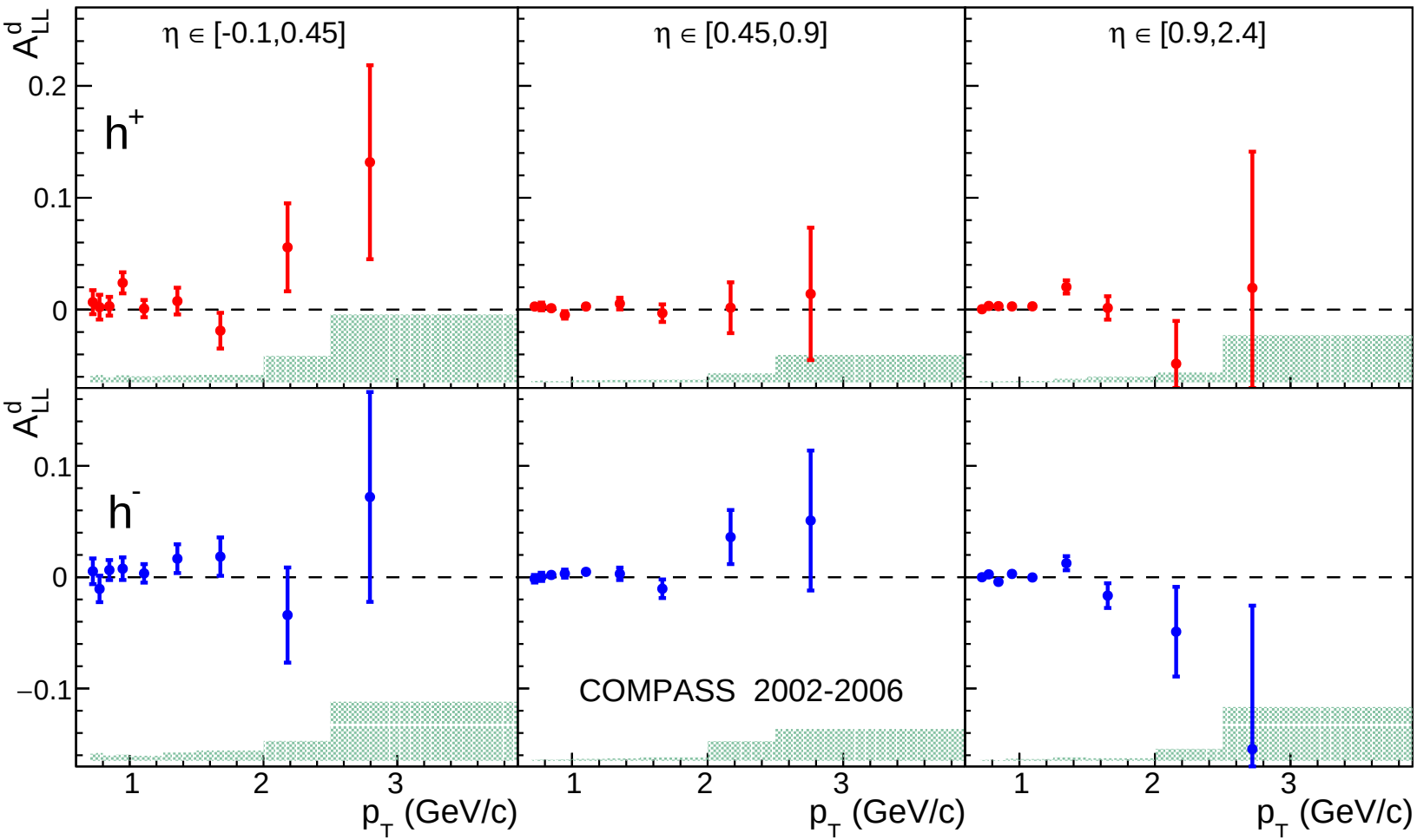
$$\rightarrow \qquad 0.07 \cdot A_{LL}$$

- Study of false asymmetries (dominant systematics) through a *pulls* analysis ($(A_i - \bar{A})/\sigma_{A_i}$ distribution for i sub-sample)

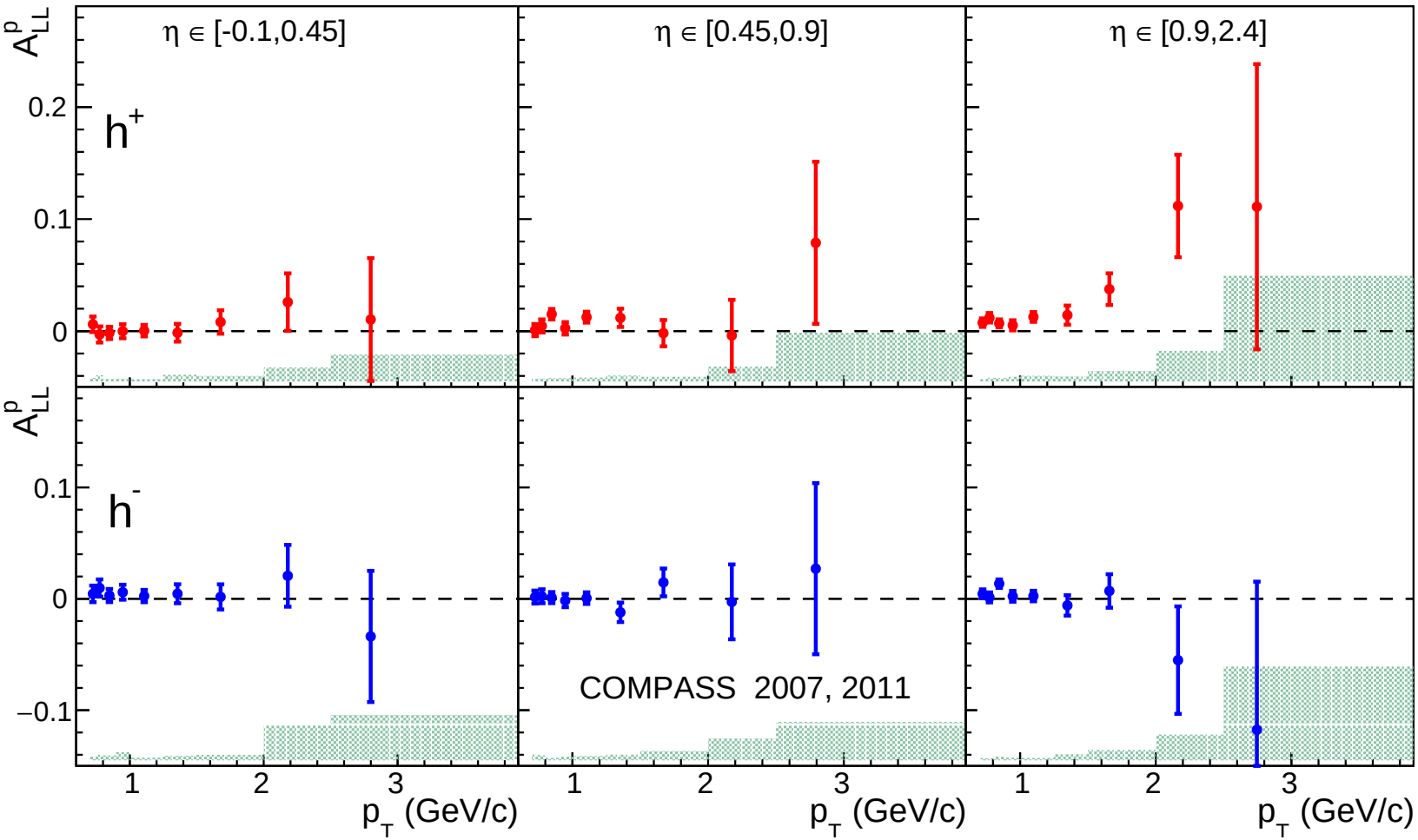
$$\rightarrow \qquad \leq 0.6 \cdot \sigma_{A_{LL}}^{stat}$$

Deuteron Results

- Study performed for 3 bins in η_h to boost the sensitivity to ΔG

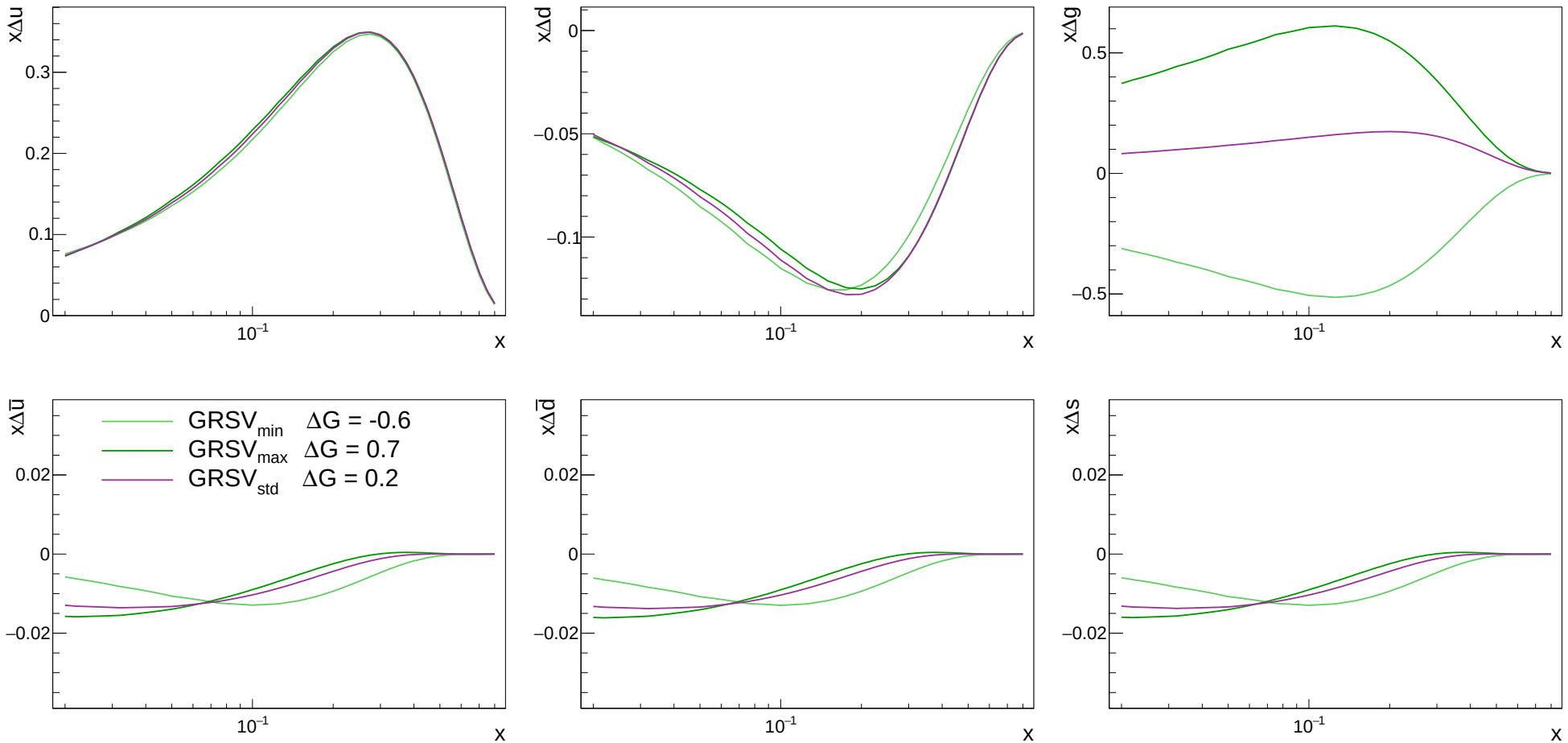


Proton Results



- Asymmetries are compatible with 0
- Interpretations require a comparison with theoretical curves

PDFs Used in the Comparison



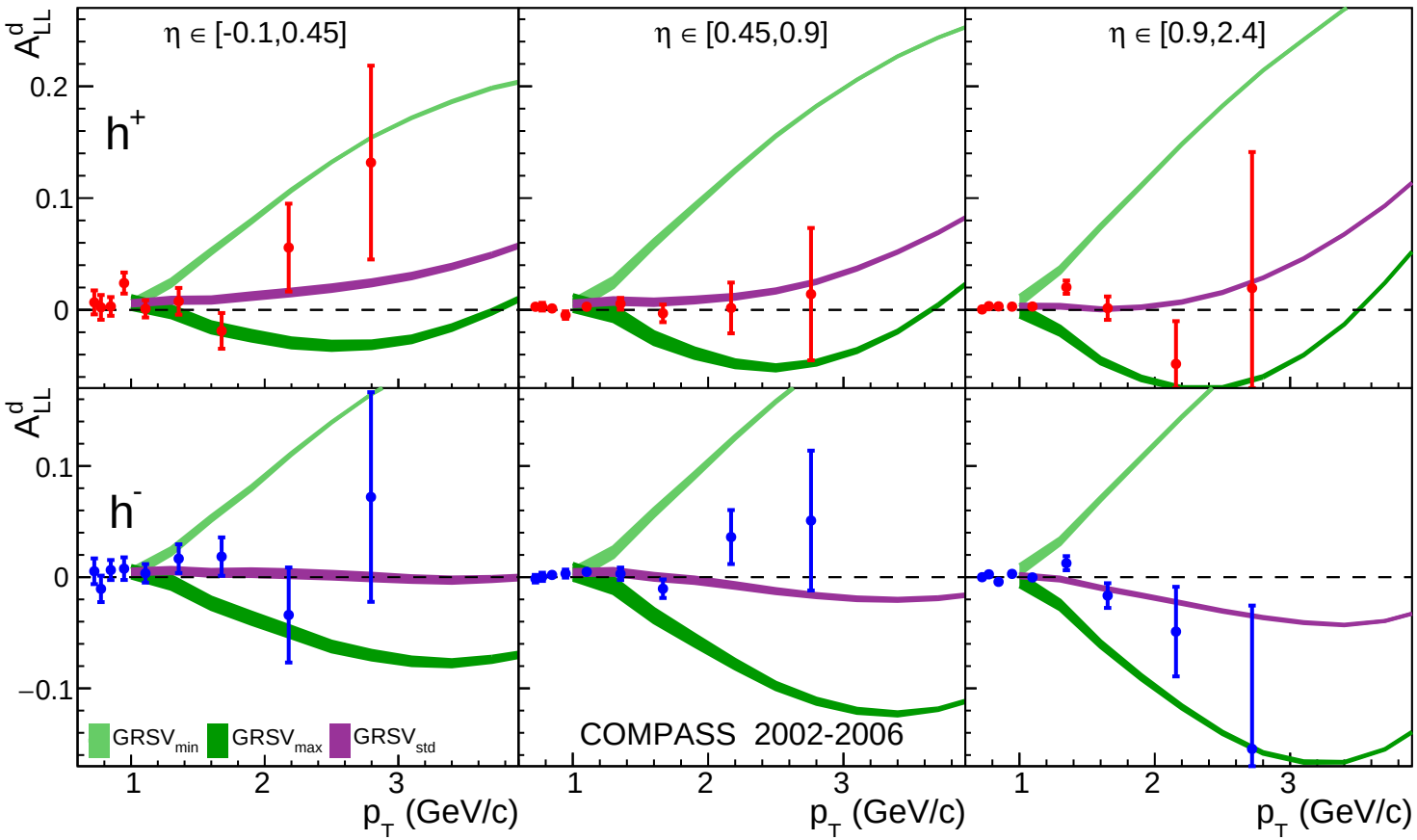
Polarized PDFs for $Q^2 = 3$ GeV^2

ΔG computed with a truncation for $x_g \in [0.05, 0.2]$

- Only the gluon distribution distinguishes these different parametrizations

Deuteron Results with Theoretical Comparison

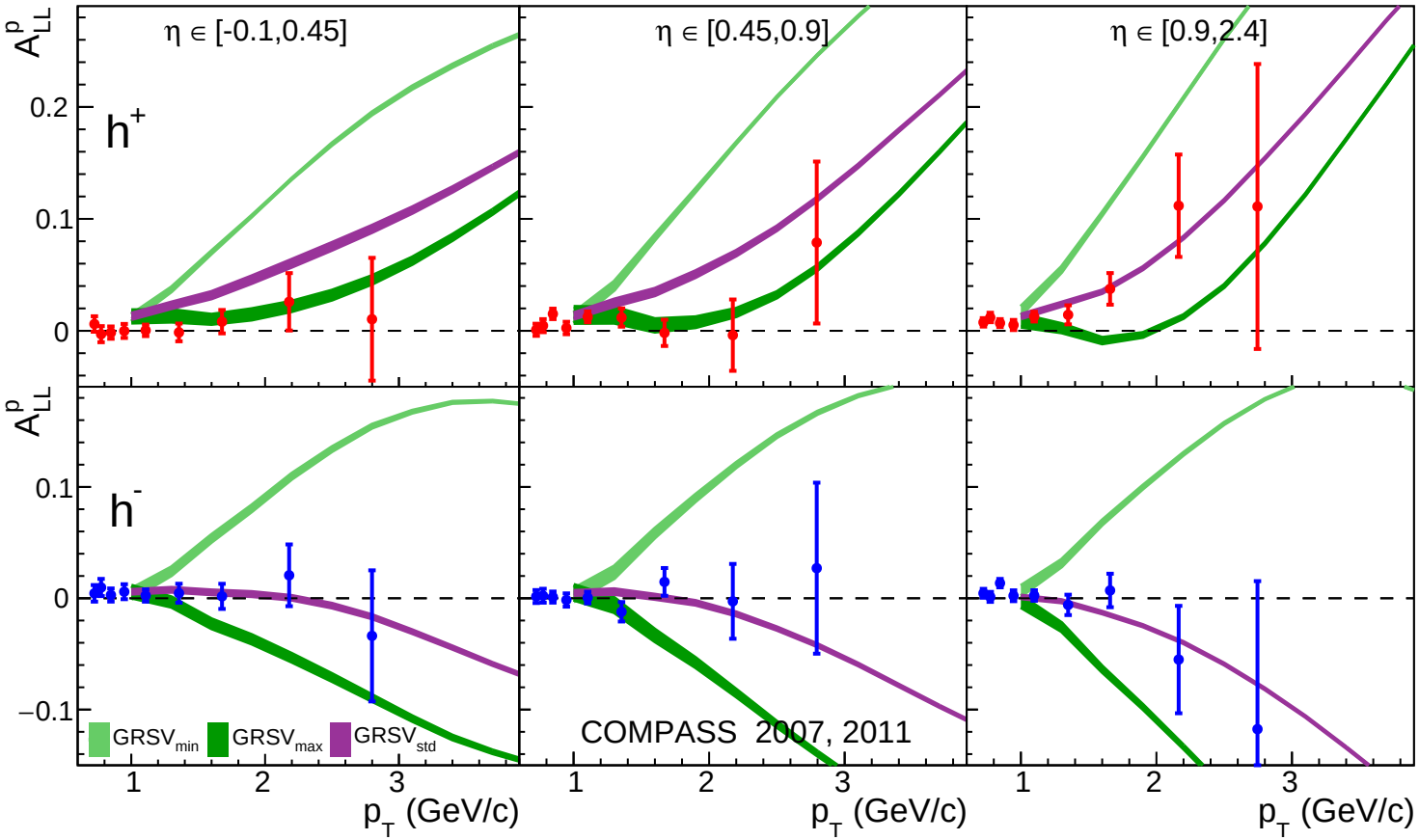
- Theoretical asymmetries are computed at NLO without gluon resummation



- Results tend to settle close to GRSV_{std} parametrization

$\rightarrow$ Strictly positiv ΔG ($\int_{0.05}^{0.2} dx_g \Delta g_{GRSV_{std}}(x_g, \mu^2 = 3) = 0.2$)

Proton Results with Theoretical Comparison



- Some difficulties to match results and predictions for proton data and h^+ yield at low η_h
- Resummation are expected to dilute the asymmetries by 60-80%

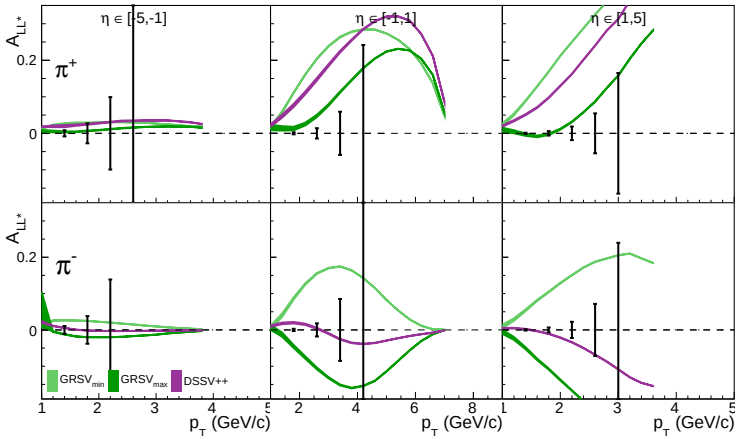
Calculations for EIC

- Longitudinally polarized e-beam with $E_e = 3 - 15$ GeV
- Longitudinally polarized p-beam with $E_p = 20 - 250$ GeV
- SIDIS cross-sections for charged pion yields
- Calculations for backward ($\eta_h \in [-5, -1]$), central ($\eta_h \in [-1, 1]$) and forward ($\eta_h \in [1, 5]$) rapidities
- Statistical uncertainty projection for 5 fb^{-1} integrated luminosity and polarisations $P_e \approx P_p \approx 0.7 - 0.8$
- Calculation of double longitudinal asymmetries (same as COMPASS):

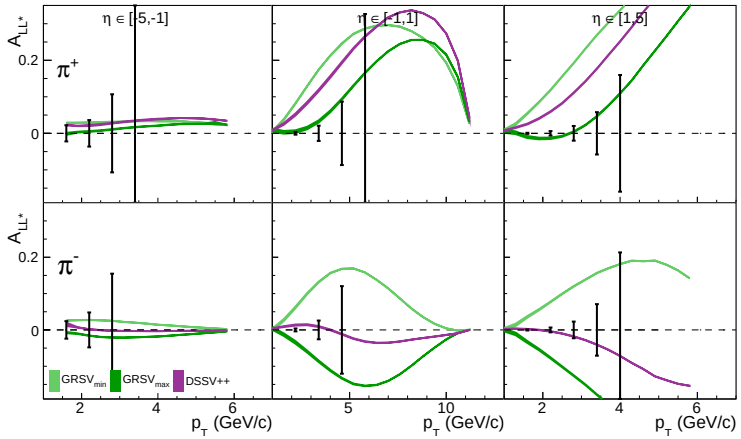
$$A_{LL*} = \frac{\sigma(\overleftarrow{e}, \overrightarrow{p}) - \sigma(\overleftarrow{e}, \overleftarrow{p})}{\sigma(\overleftarrow{e}, \overrightarrow{p}) + \sigma(\overleftarrow{e}, \overleftarrow{p})}$$

Theoretical Expectations for EIC for $E_e = 3$ GeV

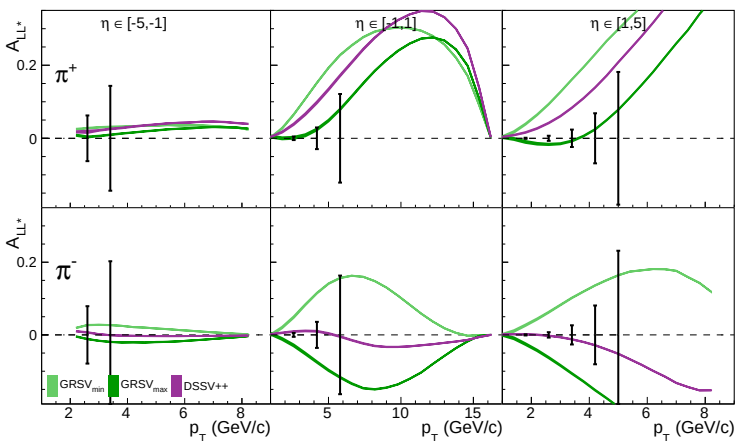
$E_p = 20$ GeV, $\sqrt{s} = 16$ GeV



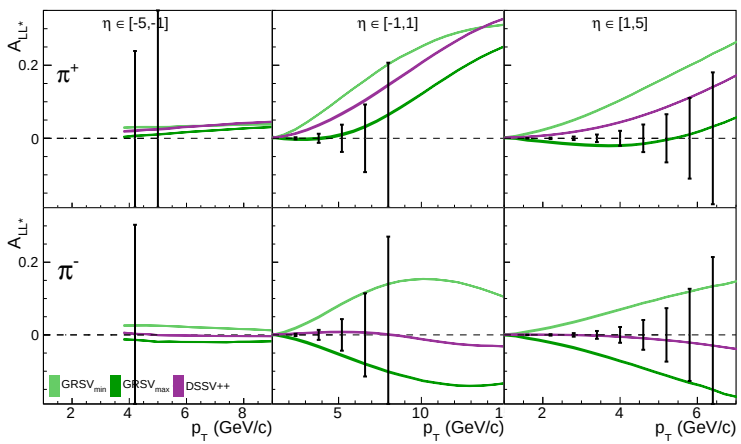
$E_p = 50$ GeV, $\sqrt{s} = 25$ GeV



$E_p = 100$ GeV, $\sqrt{s} = 35$ GeV



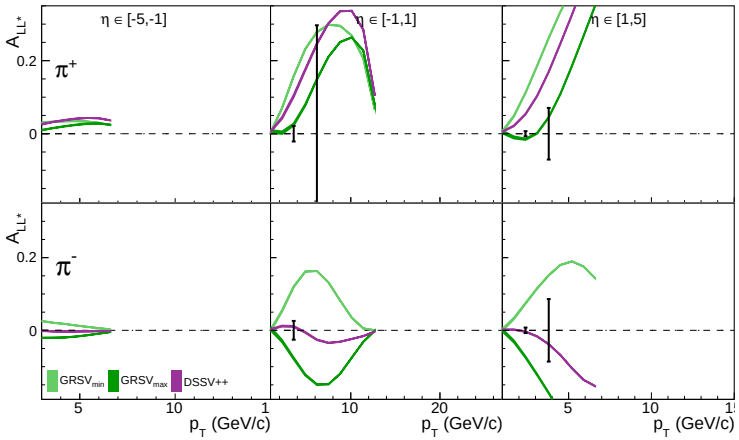
$E_p = 250$ GeV, $\sqrt{s} = 55$ GeV



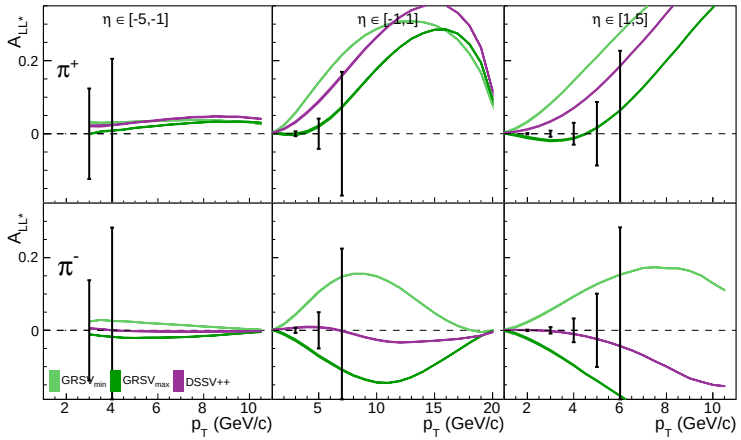
- Backward region out of reach of the measurements

Theoretical Expectations for EIC for $E_e = 10$ GeV

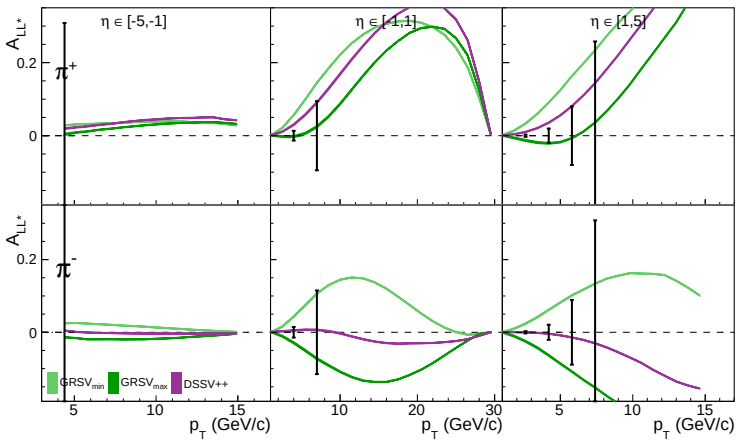
$E_p = 20$ GeV, $\sqrt{s} = 28$ GeV



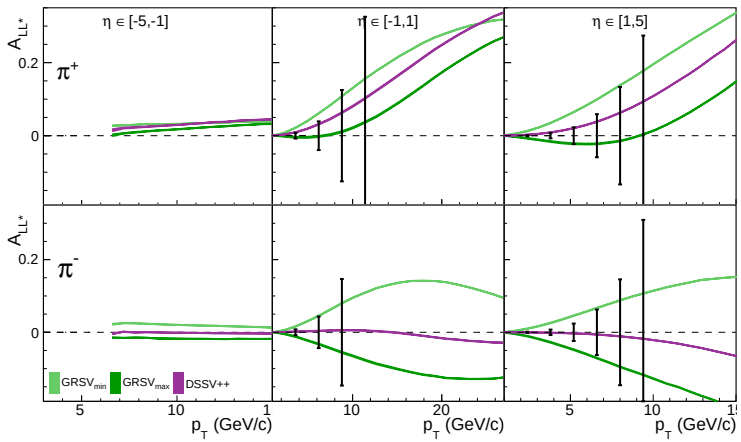
$E_p = 50$ GeV, $\sqrt{s} = 45$ GeV



$E_p = 100$ GeV, $\sqrt{s} = 63$ GeV



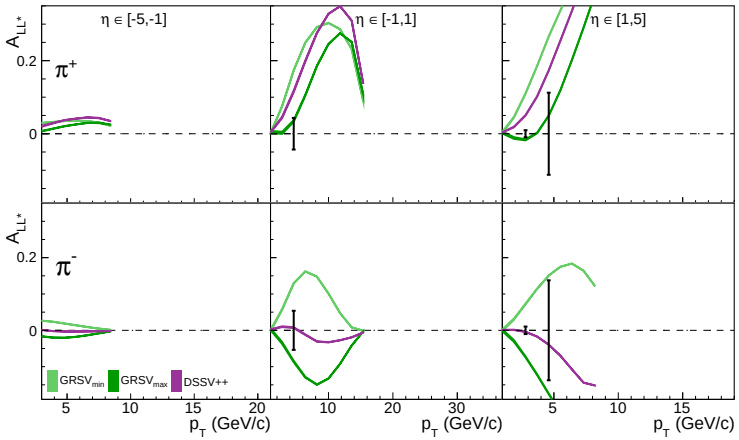
$E_p = 250$ GeV, $\sqrt{s} = 100$ GeV



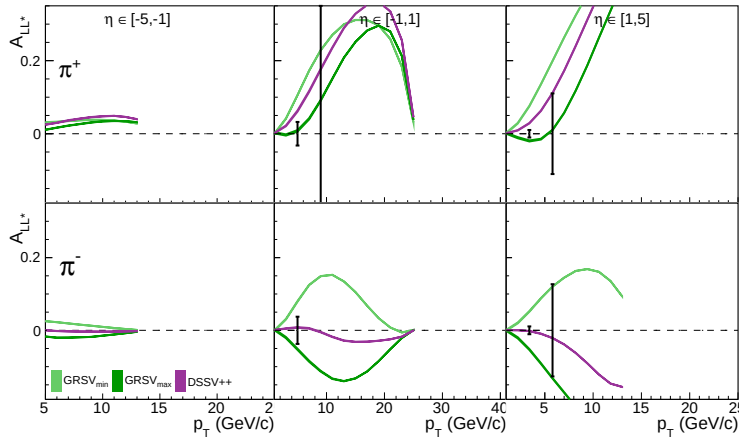
- Possibilities to probe ΔG or at least check theoretical models for a polarized collider for central and forward rapidities

Theoretical Expectations for $E_e = 15$ GeV

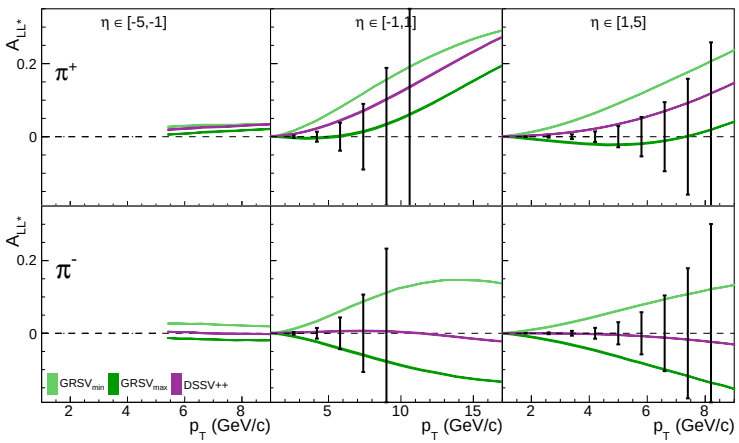
$E_p = 20$ GeV, $\sqrt{s} = 35$ GeV



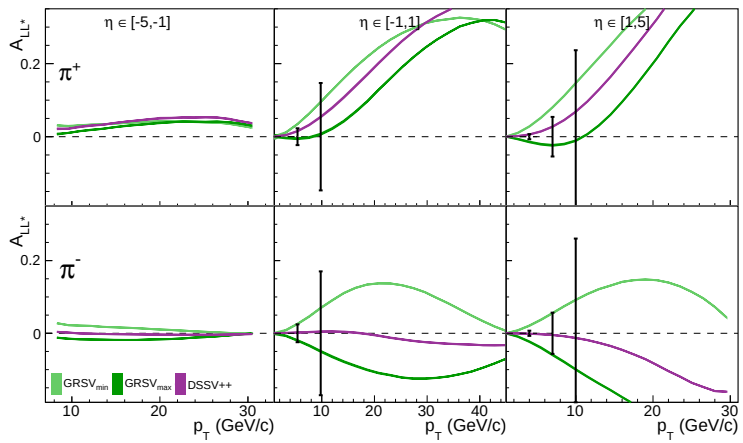
$E_p = 50$ GeV, $\sqrt{s} = 55$ GeV



$E_p = 100$ GeV, $\sqrt{s} = 77$ GeV



$E_p = 250$ GeV, $\sqrt{s} = 122$ GeV



- No possibility to probe ΔG because of high statistical uncertainties at high p_T.

Outlook

- Conclusive results for all COMPASS data

$\rightarrow$ Final interpretation and inclusion in fits pending for resummation calculation

- Analysis to extract asymmetries for identified hadrons (π, K) is in progress

- The same kind of SIDIS analysis for EIC is only possible for low electron beam energies ($E_e \lesssim 10$ GeV, $\sqrt{s} \lesssim 60$ GeV)

$\rightarrow$ Hard to probe spin structure for low-x_g