Gluon Polarization Measurements at STAR

Matthew Walker
for the STAR Collaboration

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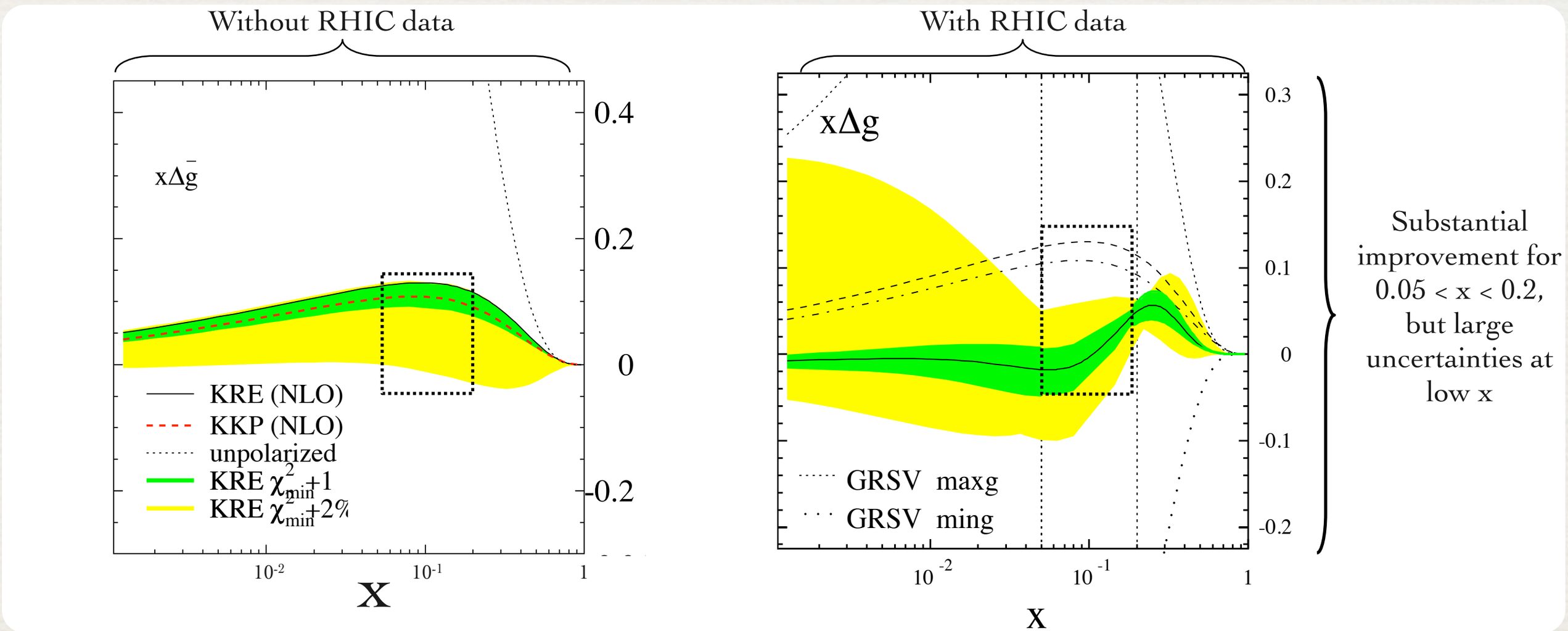
Outline

- Brief theoretical motivation
- Inclusive measurements: Jets and pions
- Correlation measurements: Di-Jets
- Status and Prospects

Theoretical Motivation

- Polarized DIS tells us that the spin contribution from quark spin is only ~30%.

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



D. de Florian et al., Phys. Rev. D71, 094018 (2005).

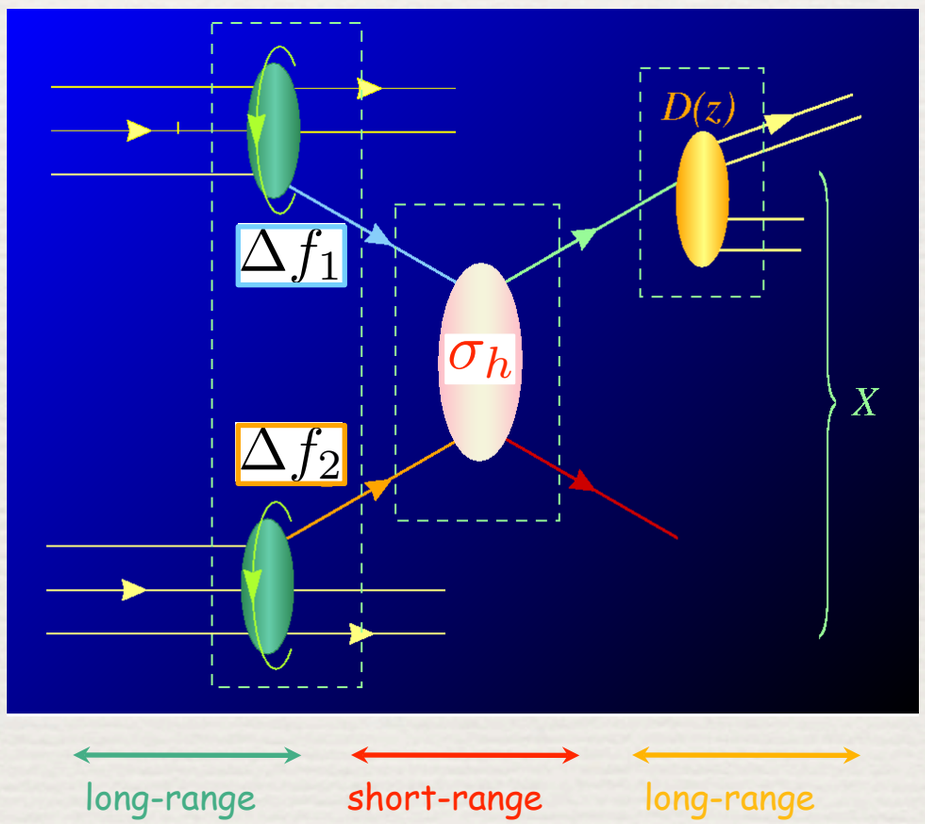
D. de Florian et al., Phys. Rev. Lett. 101 (2008) 072001

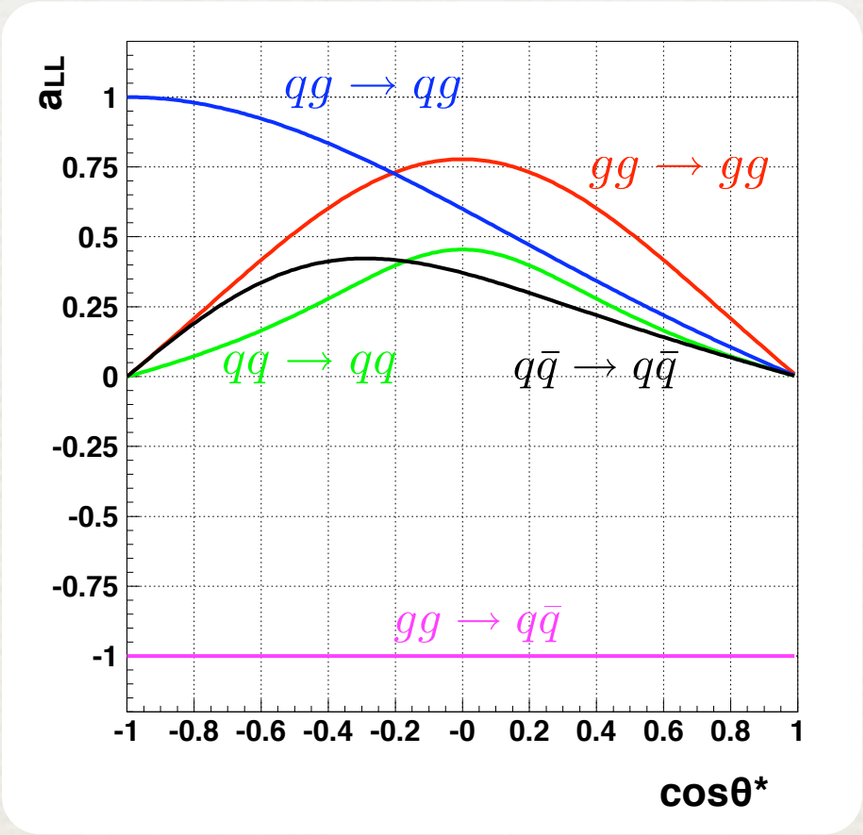
Theoretical Motivation

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

- Extracting gluon polarization

$$A_{LL} = \frac{d\Delta\sigma}{d\sigma} = \frac{\Delta f_1 \otimes \Delta f_2 \otimes \sigma_h \cdot a_{LL} \otimes D_f^h}{f_1 \otimes f_2 \otimes \sigma_h \otimes D_f^h}$$

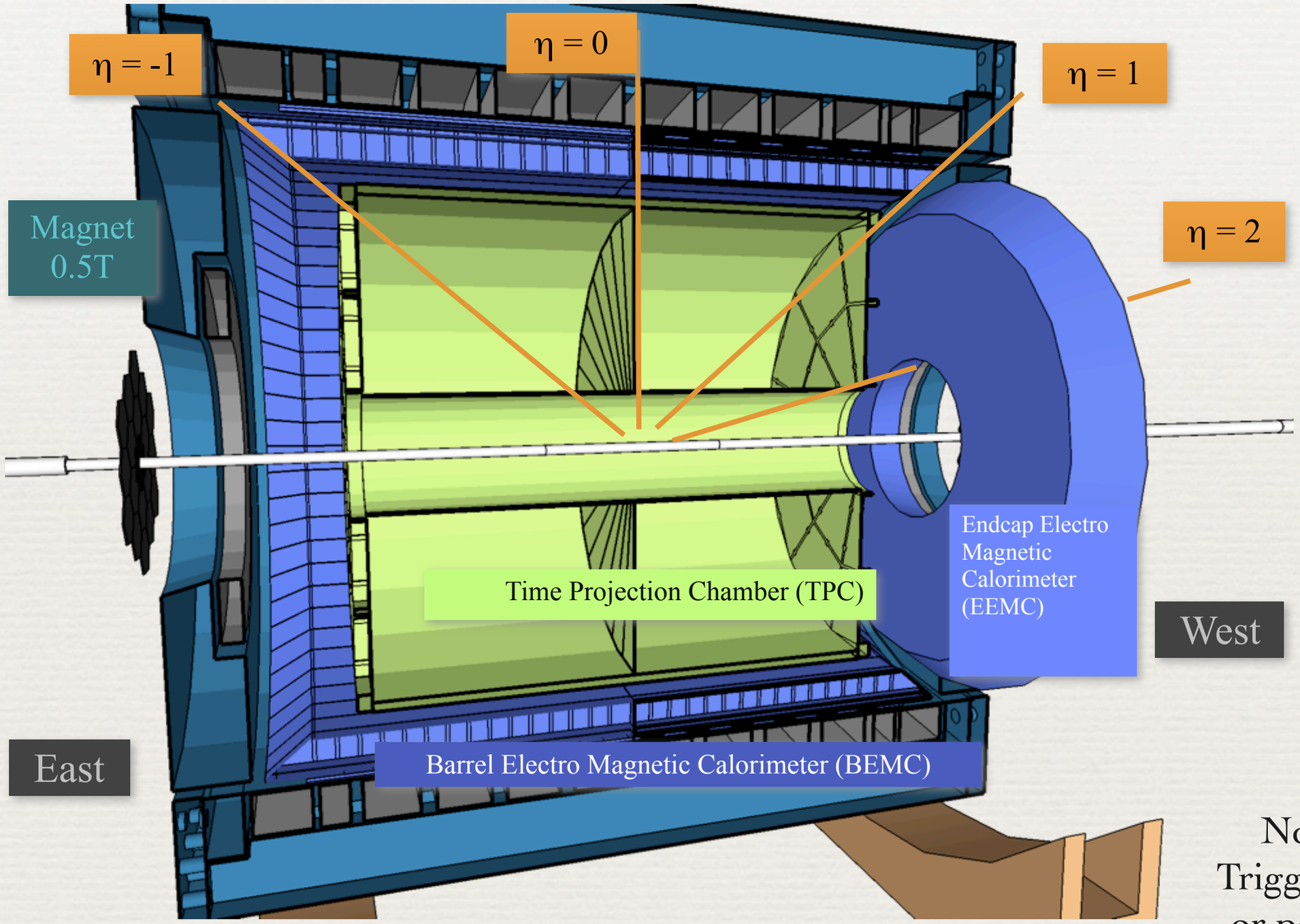




Extract $\Delta g(x,Q^2)$ using a global fit

$$\Delta G(Q^2) = \int_0^1 \Delta g(x, Q^2)dx$$

STAR Detector

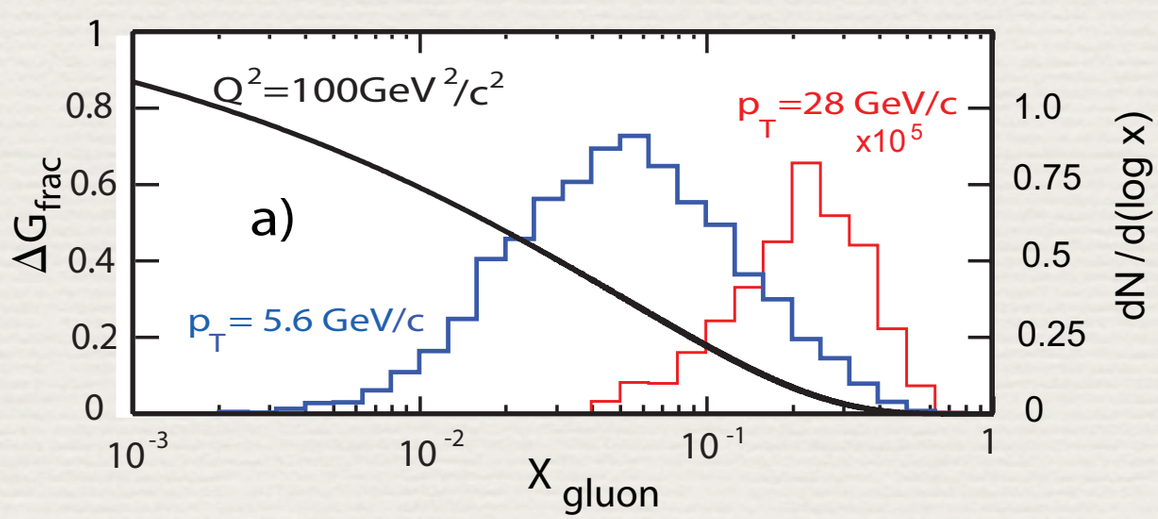


Not shown:
Trigger detectors
or polarimeters

Inclusive Measurements

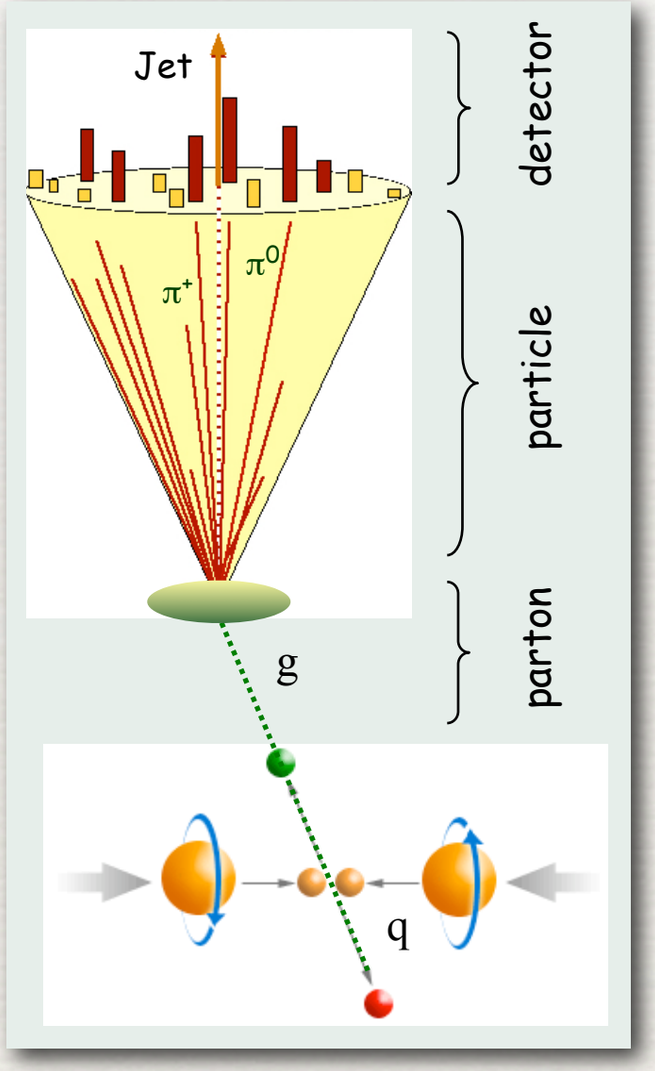
- Inclusive measurements have:
  - High statistics
  - Simple triggers
  - Simple reconstruction
  - Multiple subprocesses contribute
  - Wide range of x_{gluon} in each reconstructed bin

$$A_{LL} = \frac{1}{P_B P_Y} \frac{(N_{++} + N_{--}) - R(N_{+-} + N_{-+})}{(N_{++} + N_{--}) + R(N_{+-} + N_{-+})}$$



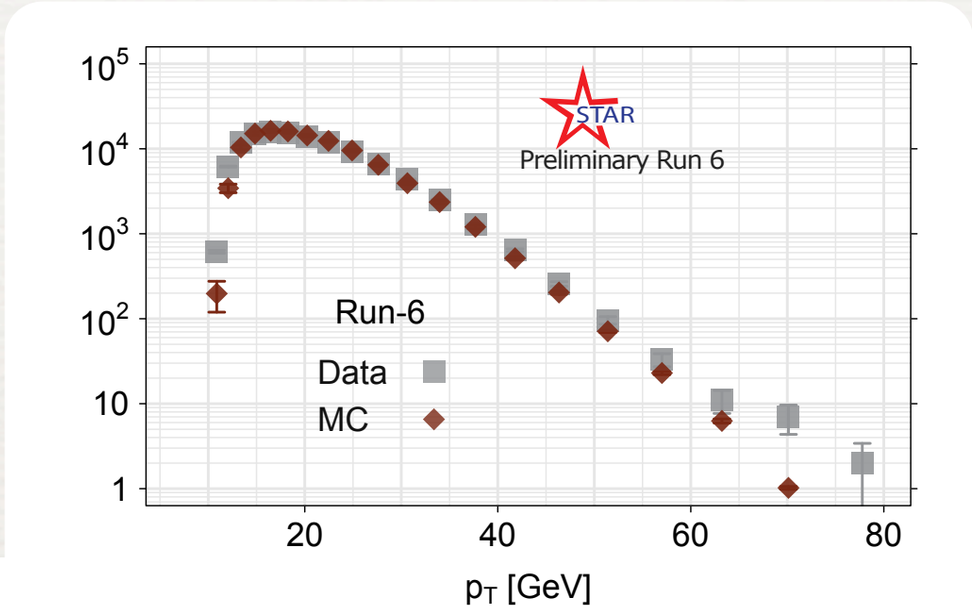
Inclusive Jets

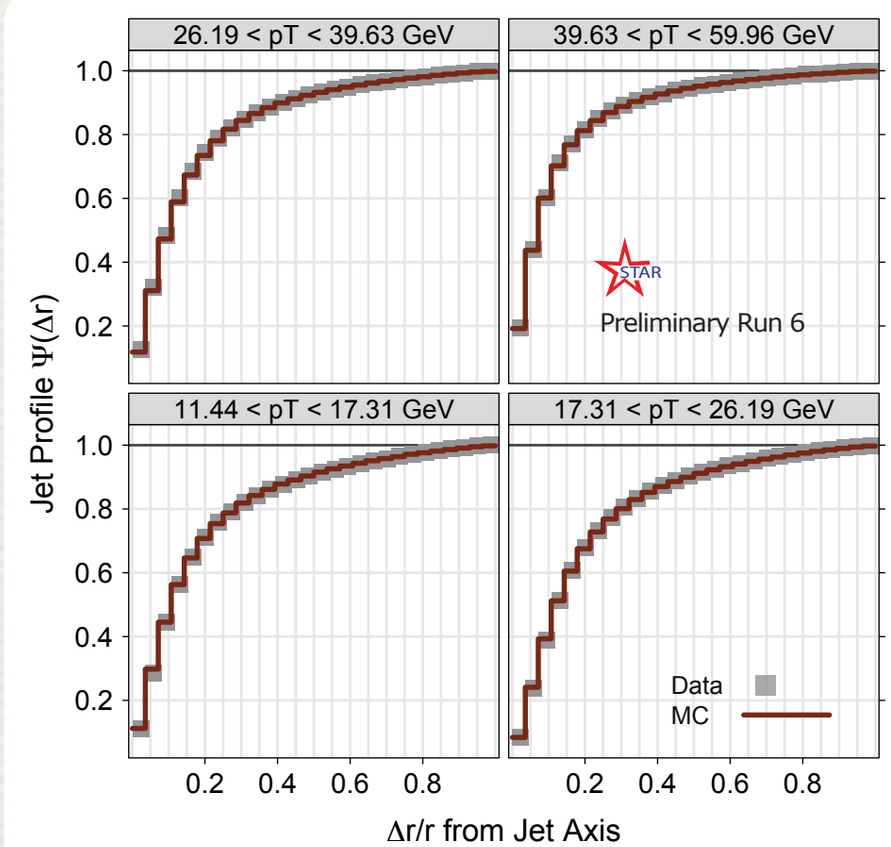
- STAR is well suited for Jet measurements with large acceptance (2π in azimuth)
  - TPC provides charged tracking ($|\eta| < 1.3$)
  - B/EEMC provide electromagnetic energy reconstruction ($-1 < \eta < 2$)
- Jets reconstructed using a midpoint cone algorithm

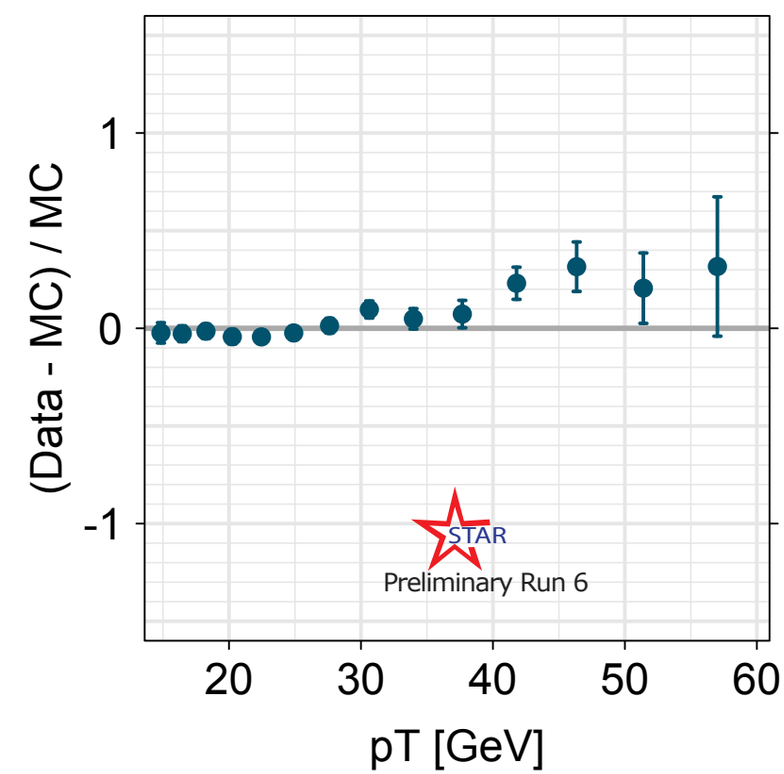


Inclusive Jets

- Shape comparison between Run 6 Data and simulation shows good agreement
- Motivates use of correction based on PYTHIA MC

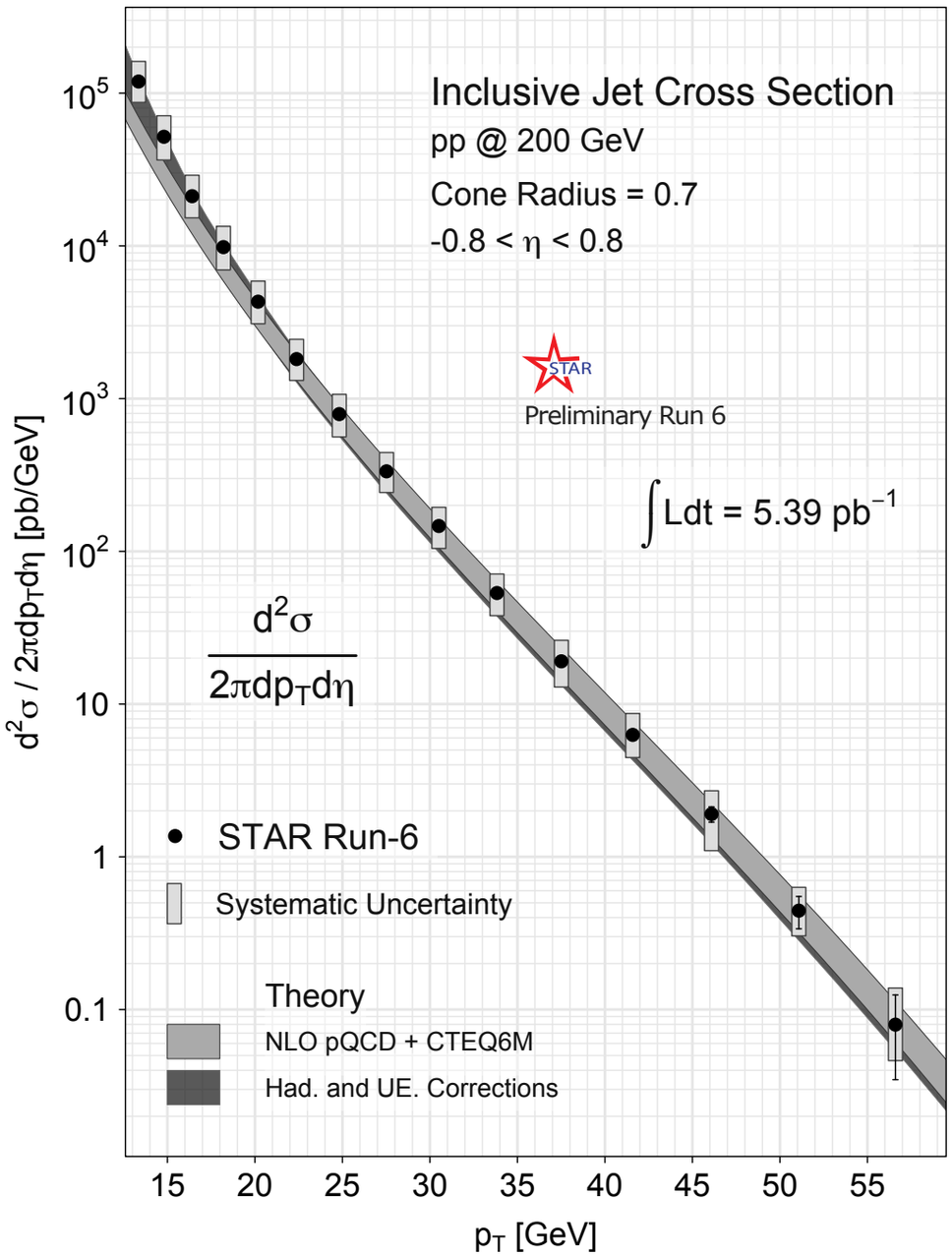


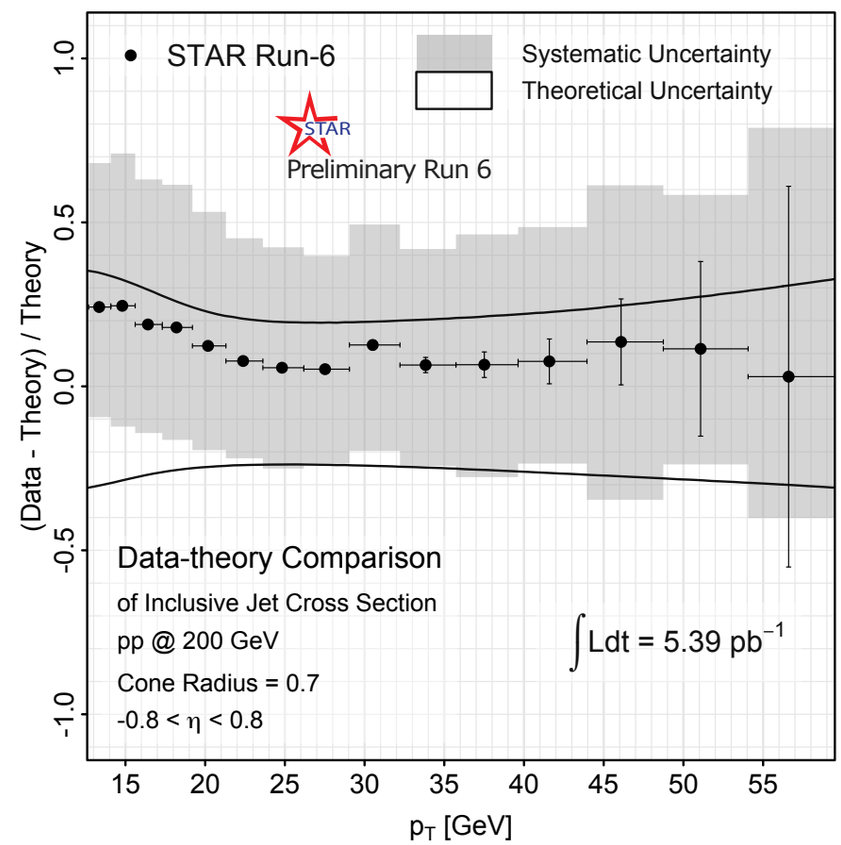




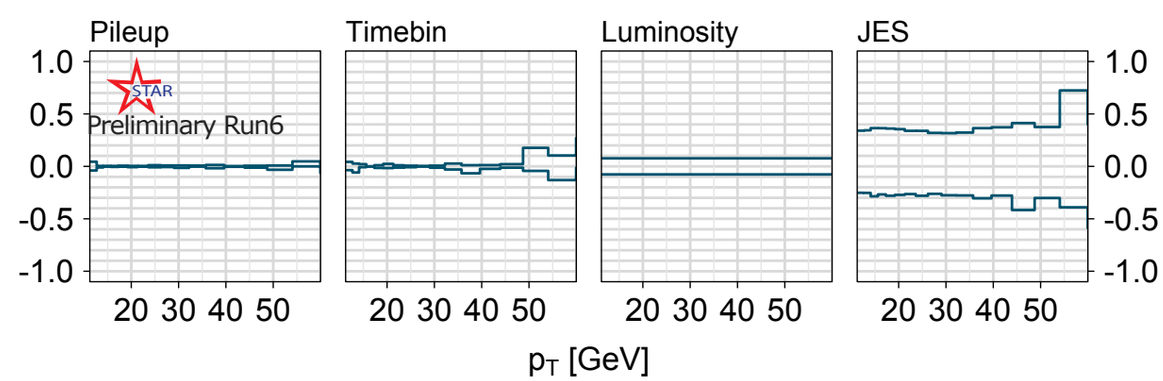
MC: Pythia 6.4 + Geant 3

Inclusive Jets

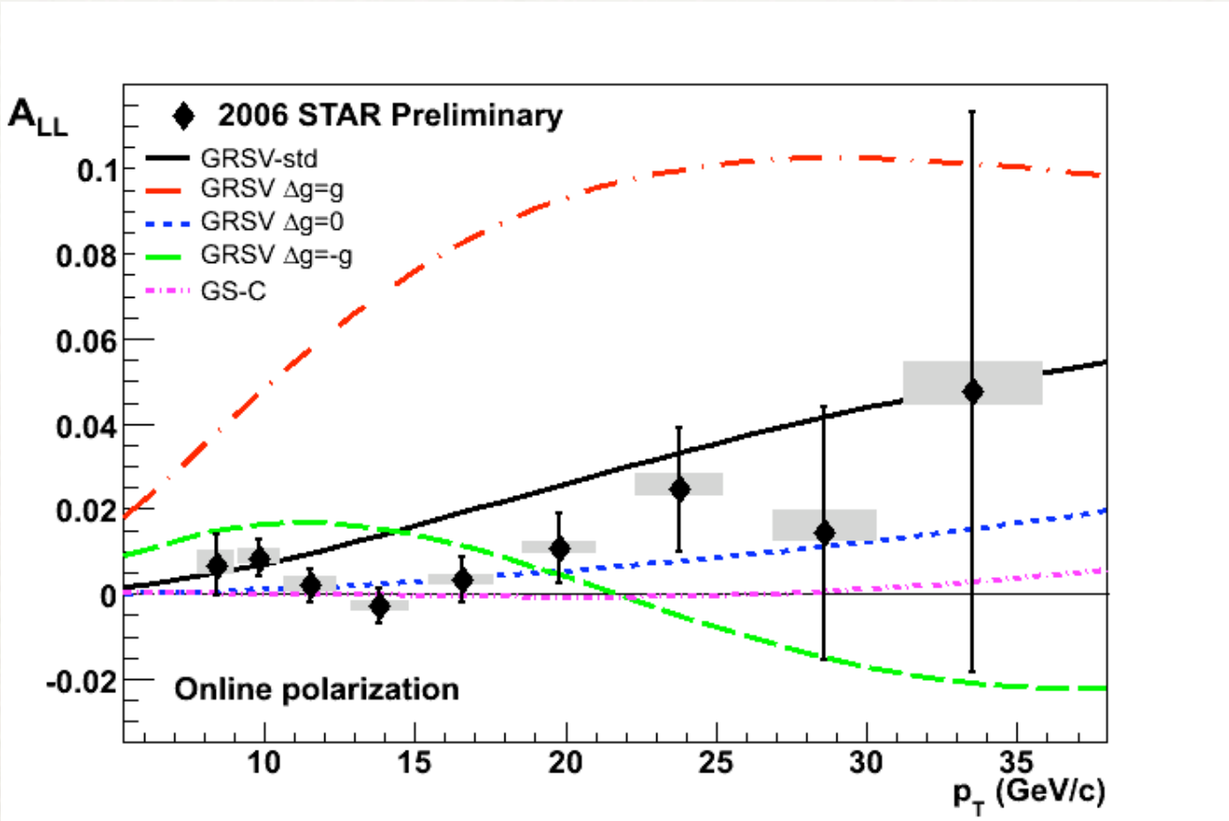


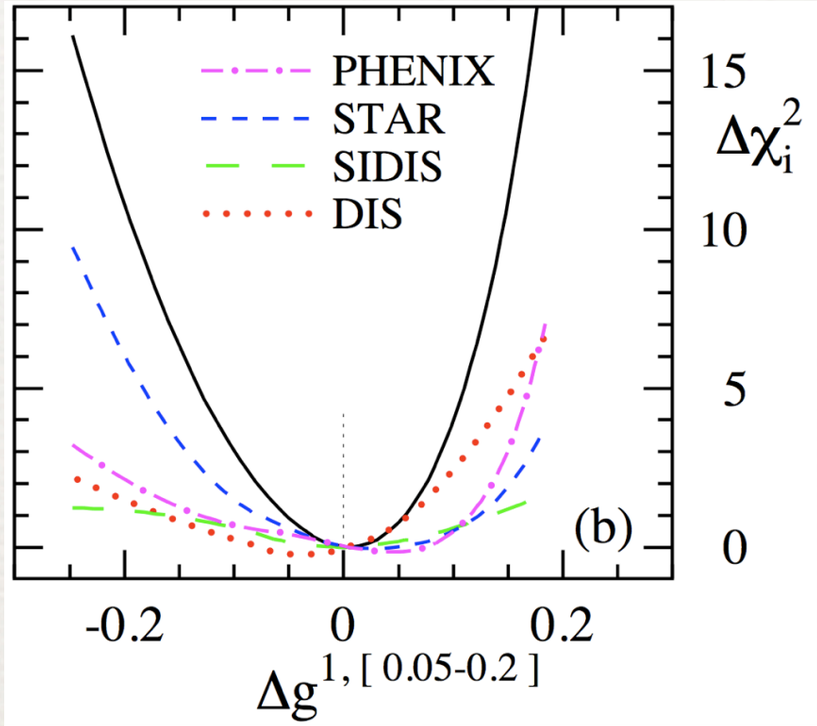


- Data agrees well with NLO pQCD calculation after hadronization and underlying event correction is applied



Inclusive jets





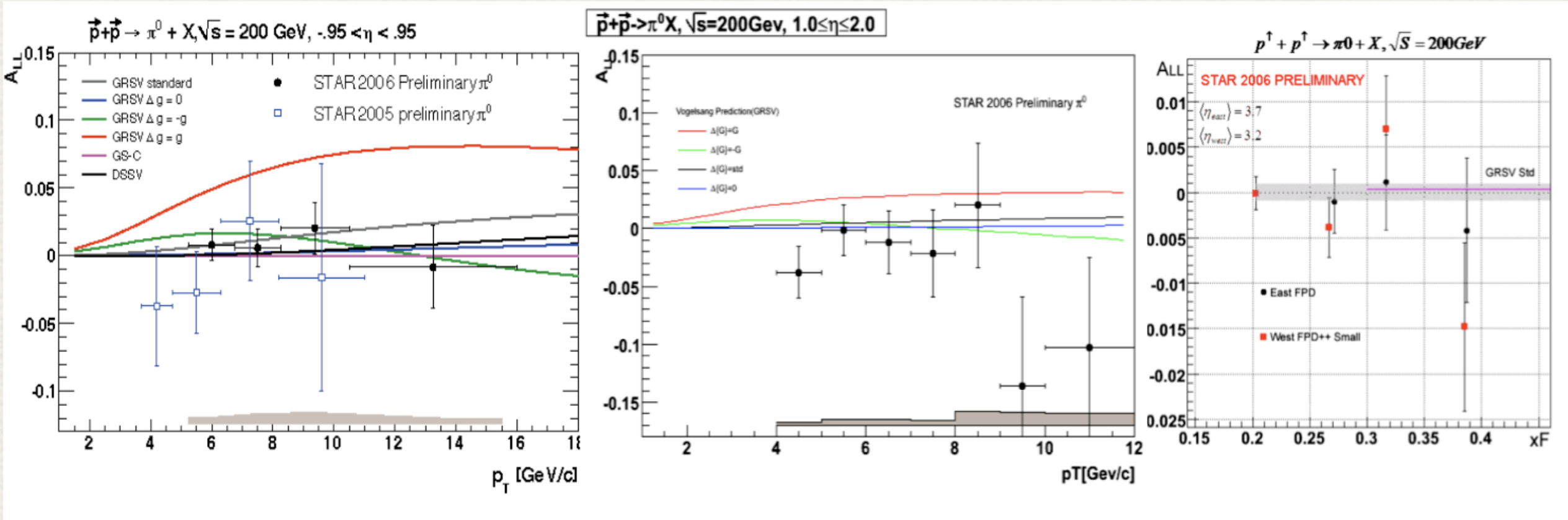
D. de Florian et al. PRL 101 (2008) 072001.

A_{LL} systematics	(x 10^{-3})
Reconstruction + Trigger Bias	[-1,+3] (p_T dep)
Non-longitudinal Polarization	~ 0.03 (p_T dep)
Relative Luminosity	0.94
Backgrounds	1st bin ~ 0.5 else ~ 0.1
p_T systematic	± 6.7%

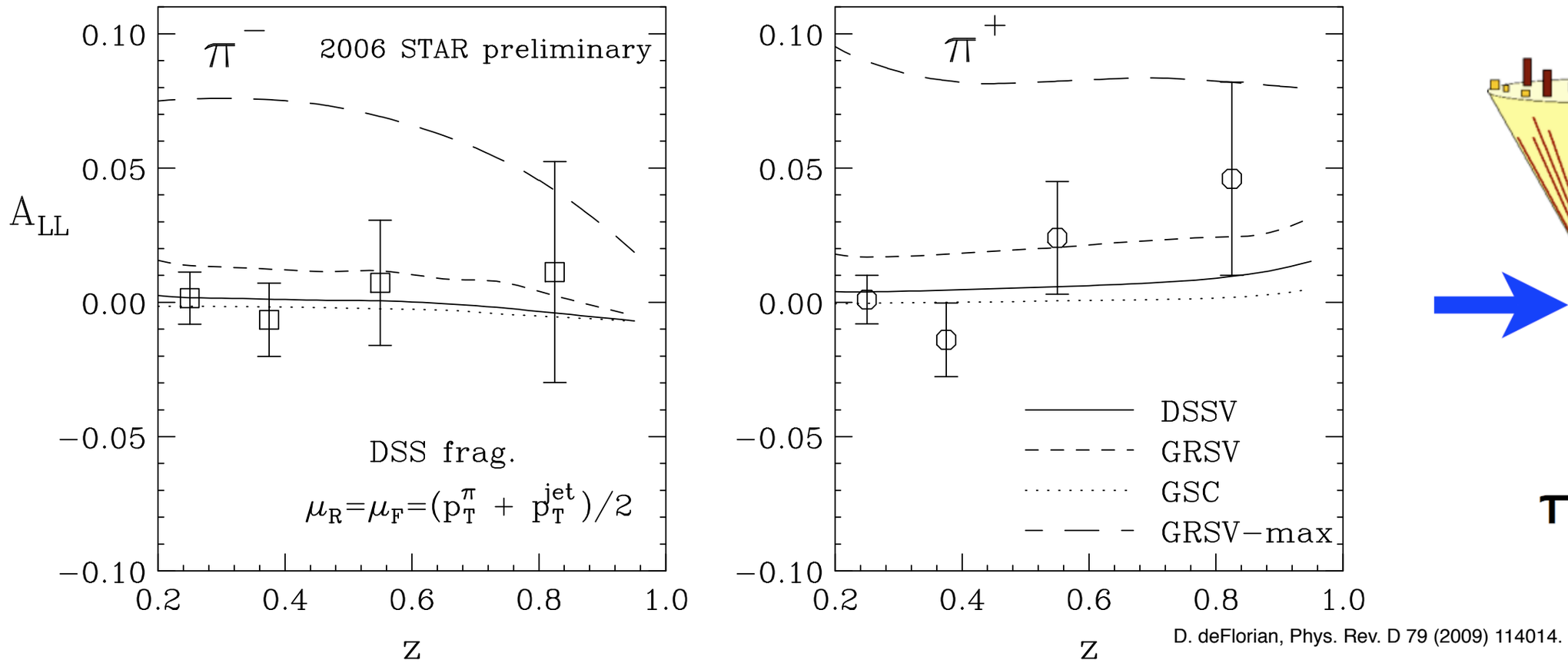
- Run 6 results: GRSV-MAX/ GRSV-MIN ruled out, a gluon polarization between GRSV-std and GRSV-zero favored

Neutral Pions

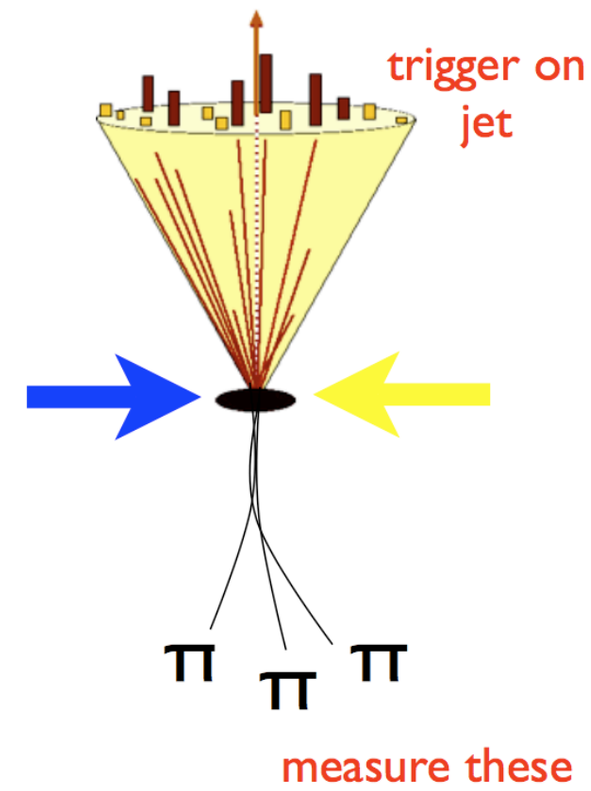
- STAR is able to measure neutral pions over a wide pseudorapidity range using its electromagnetic calorimeters
- Forward rapidity collisions dominated by qg collisions with a low x gluon
- GRSV-Max ruled out by Run 6 result



Charged Pions



D. deFlorian, Phys. Rev. D 79 (2009) 114014.



- Comparison of $A_{LL}(\pi^+)$ to $A_{LL}(\pi^-)$ can give the sign of $\Delta g(x,Q^2)$
- Calculating A_{LL} as a function of z alleviates problems of trigger bias

Correlation Measurements

- Reconstructing multiple physics objects (di-jets, photon/jet) provides information about initial parton kinematics
- Adds information about the shape of $\Delta g(x,Q^2)$
- STAR well suited for correlation measurements with its large acceptance

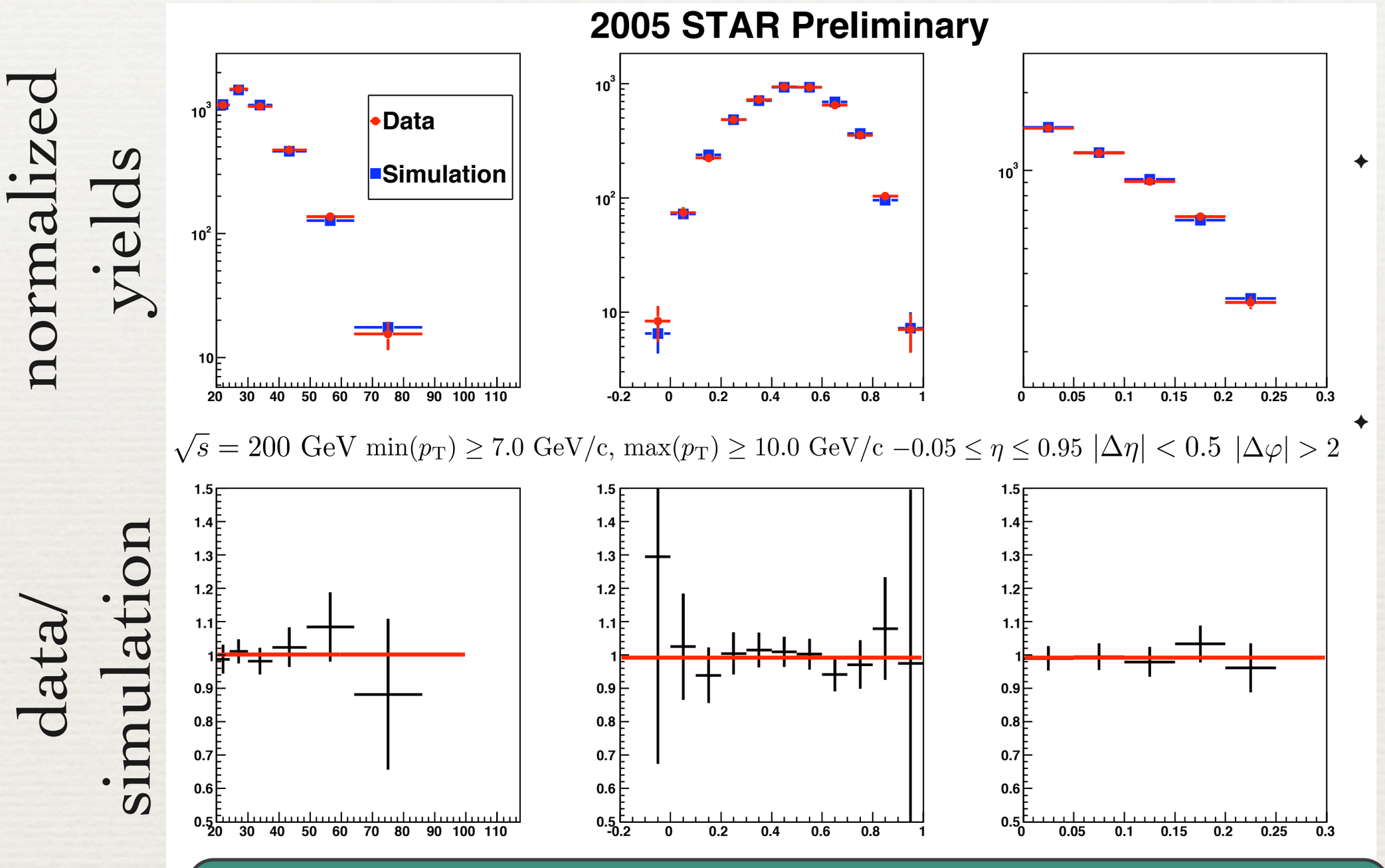
$$x_1 = \frac{1}{\sqrt{s}}(p_{T3}e^{\eta_3} + p_{T4}e^{\eta_4})$$

$$x_2 = \frac{1}{\sqrt{s}}(p_{T3}e^{-\eta_3} + p_{T4}e^{-\eta_4})$$

$$M = \sqrt{x_1 x_2 s}$$

$$\eta_3 + \eta_4 = \ln\frac{x_1}{x_2}$$

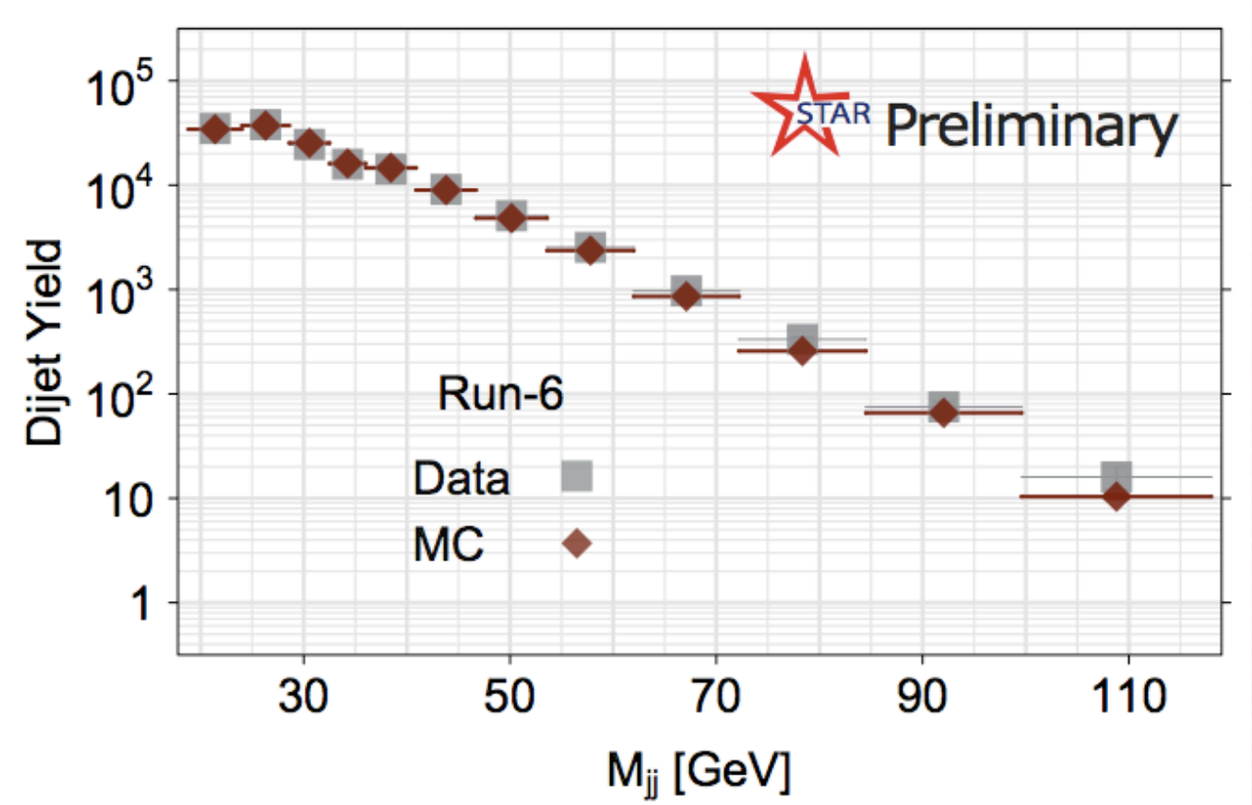
Di-Jets



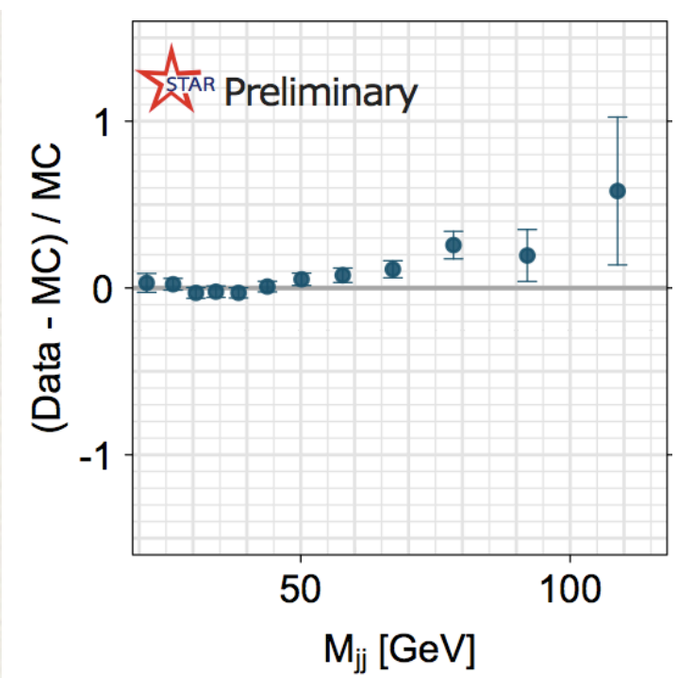
- Run 5 di-jet data shows good agreement with simulations
- Asymmetric p_T cut applied to the jets for comparison with more stable NLO calculations

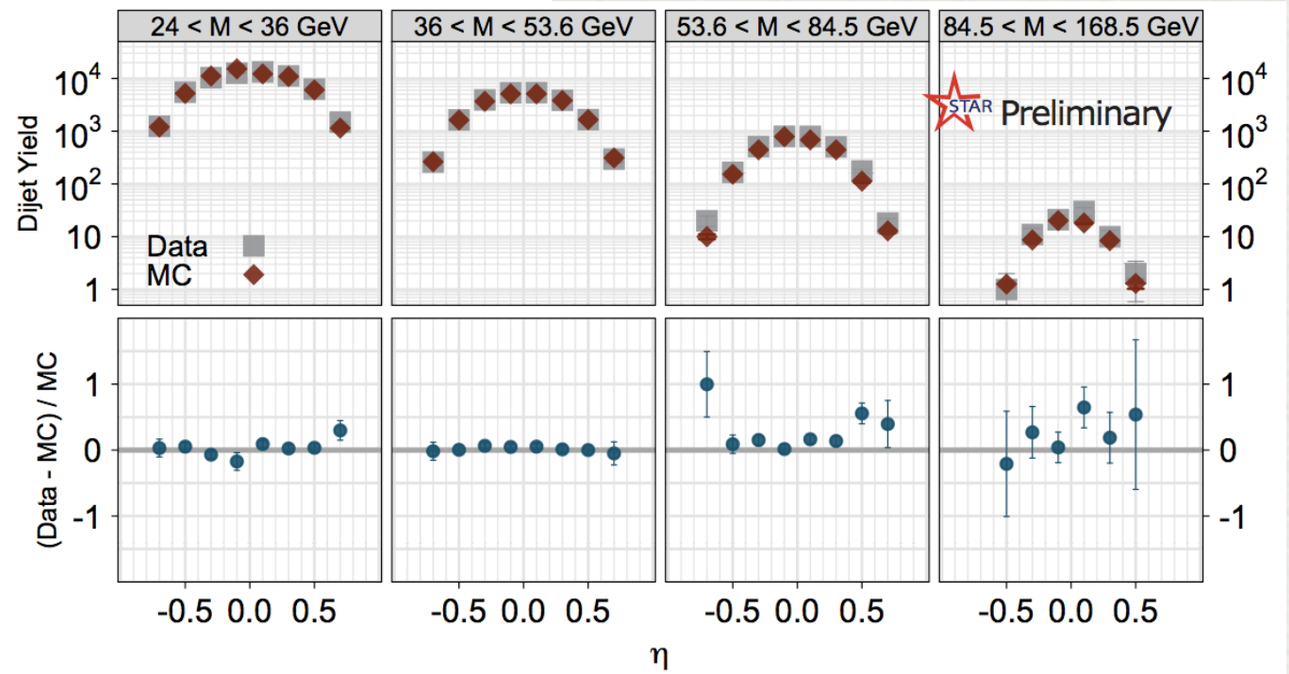
$$M = \sqrt{x_1 x_2 s} \qquad \eta_{34} = \frac{\eta_3 + \eta_4}{2} = \frac{1}{2}\ln\frac{x_1}{x_2} \qquad \cos\theta^* = \tanh\frac{\eta_3 - \eta_4}{2}$$

Di-Jets Run 6



- Run 6 data and simulation agreement is good
- Run 6 cross section and asymmetry analyses are progressing

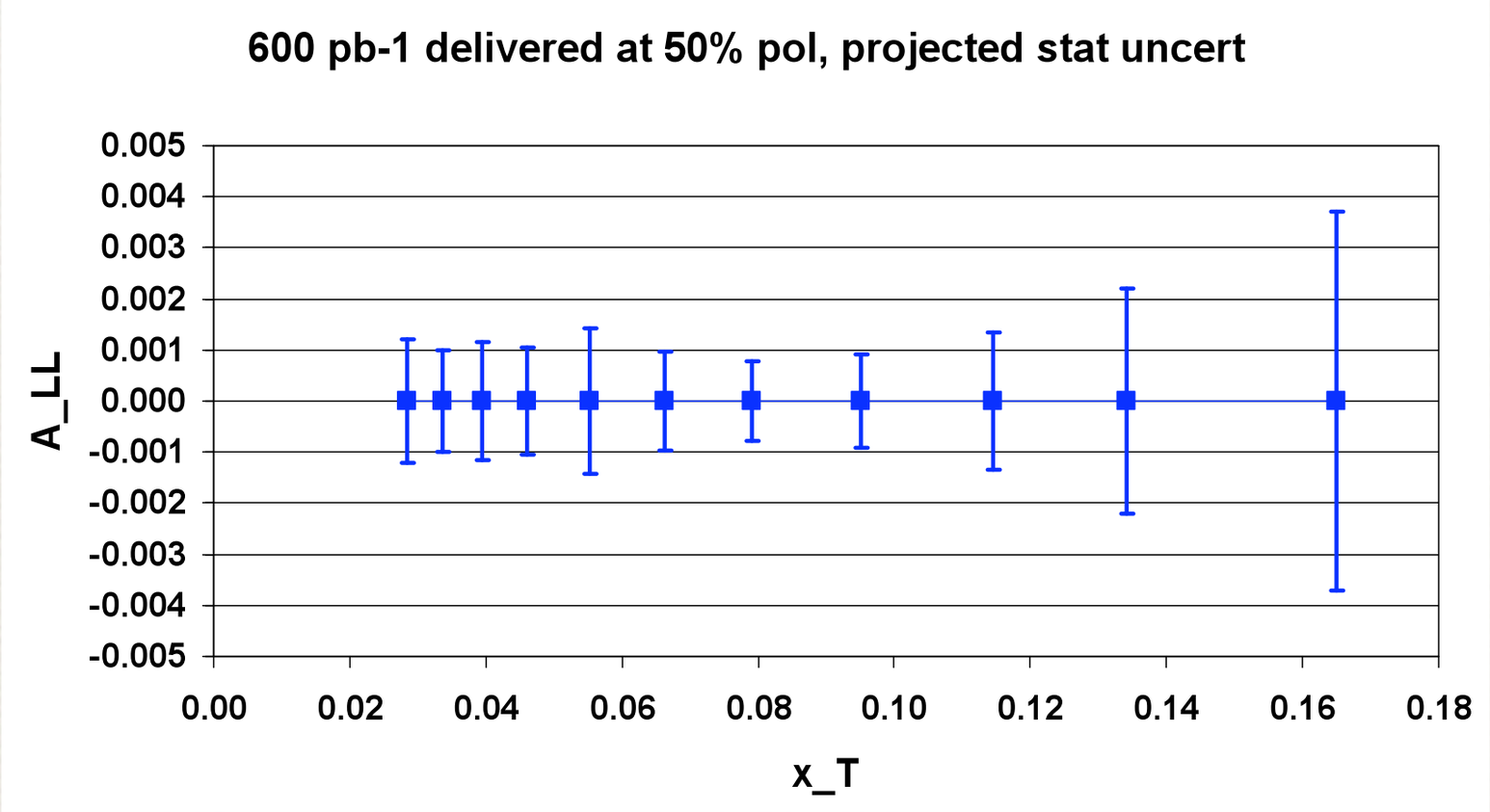




$\max(p_T) > 10.0$ GeV
$\min(p_T) > 7.0$ GeV
$-0.8 < \eta < 0.8$
$|\eta_3 - \eta_4| < 1.0$
$|\Delta\varphi| > 2.0$

Prospects-Inclusive Jets

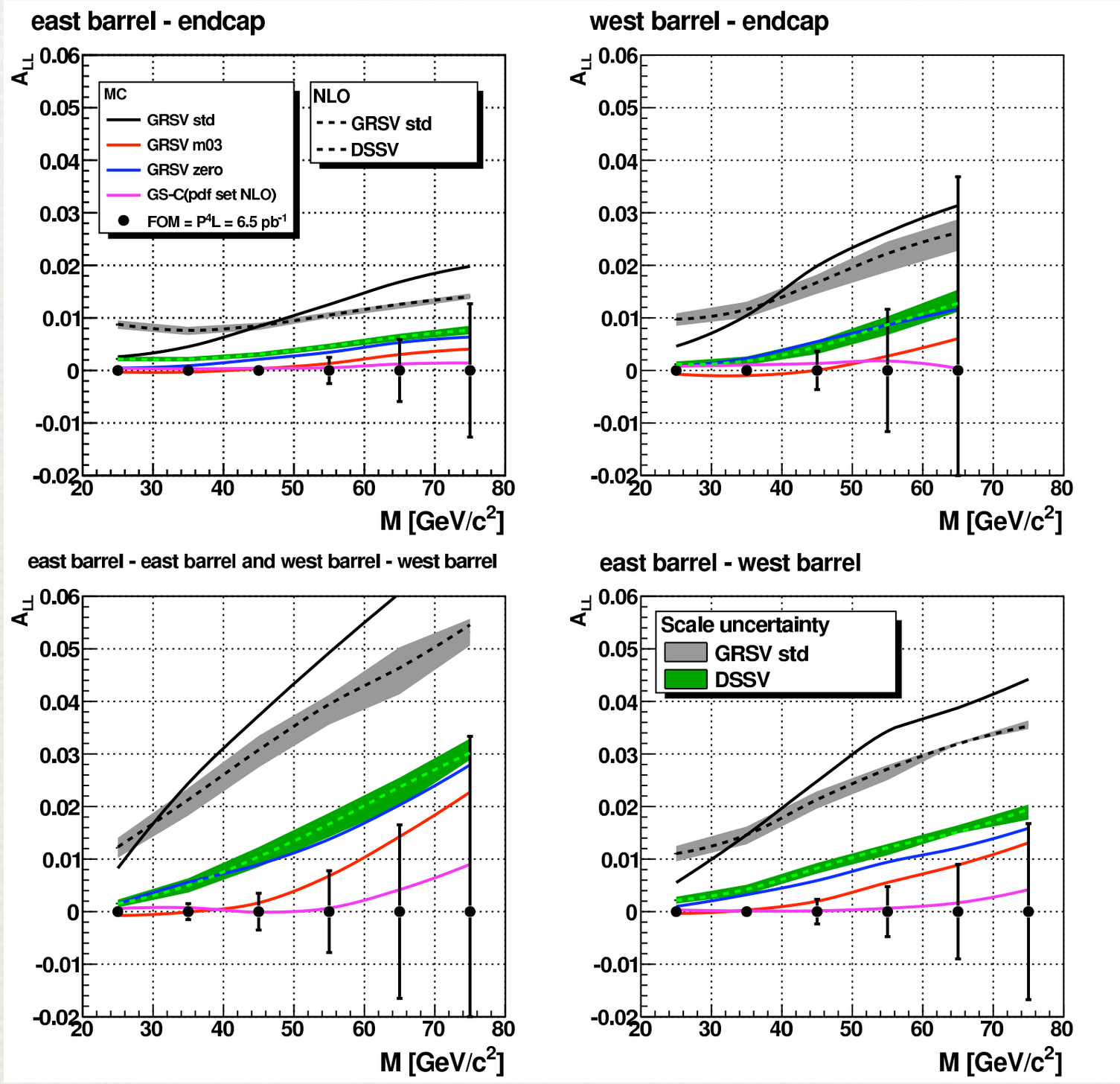
- First look at 500 GeV data in Run 9
- Future 500 GeV runs will significantly surpass statistical precision of current constraints



Prospects: Di-Jets 200 GeV

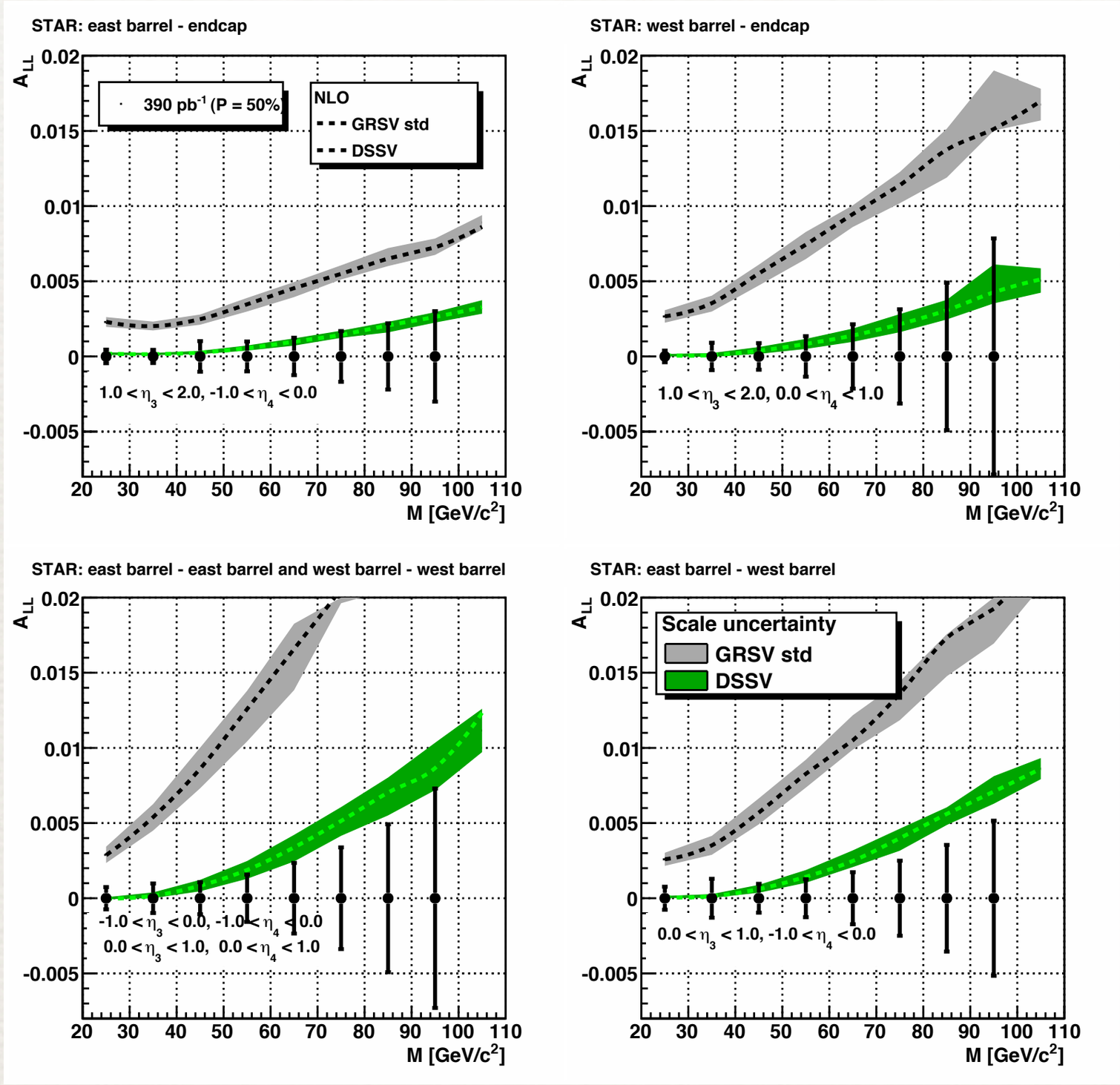
200 GeV Projections for 50 pb^{-1} at 60% polarization

- Run 9 produced approximately 22 pb^{-1} at 55% polarization (FOM 2.0 in Run 9 vs 0.6 in Run 6)
- Higher statistics and analysis of different event topologies should provide much tighter constraints on $\Delta g(x,Q^2)$



Prospects: Di-Jets 500 GeV

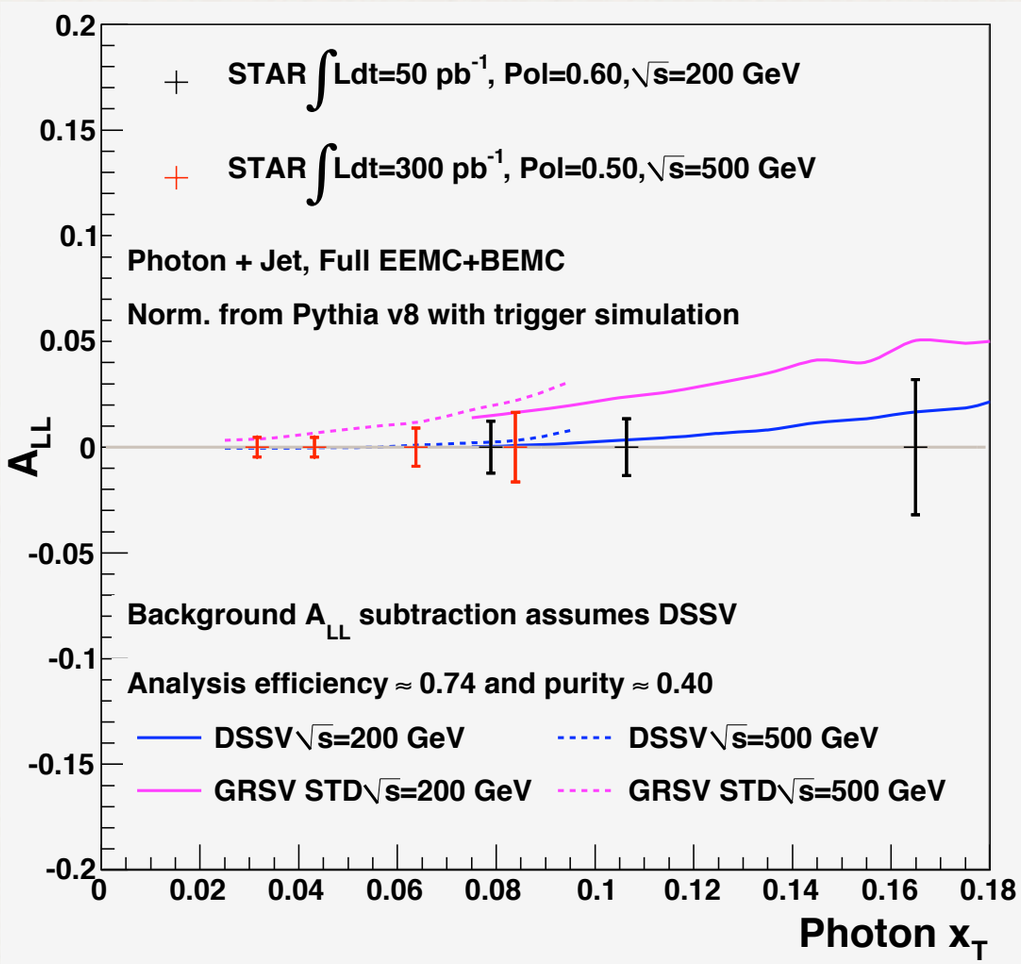
500 GeV Projections for 390 pb^{-1} at 50% polarization

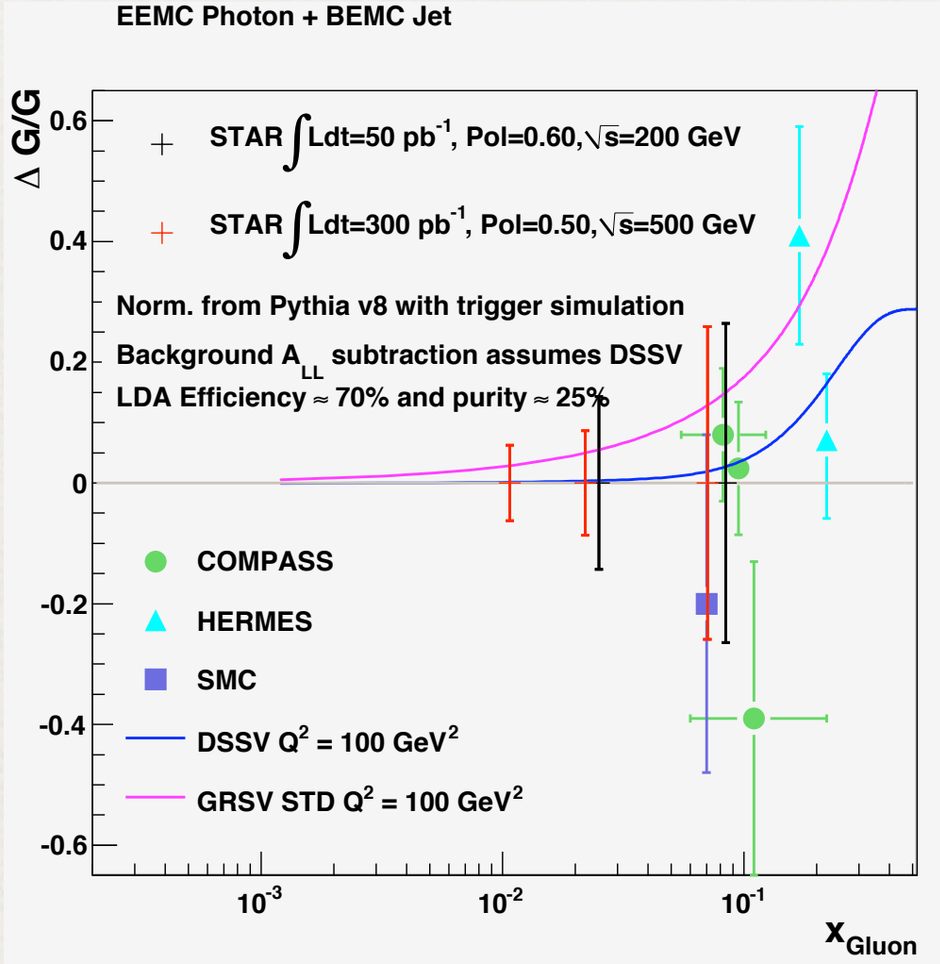


- Dijets at 500 GeV can access the gluon polarization at lower x
- Expectations are for smaller asymmetries
- Larger luminosities should improve statistical uncertainties

Prospects-Prompt Photons

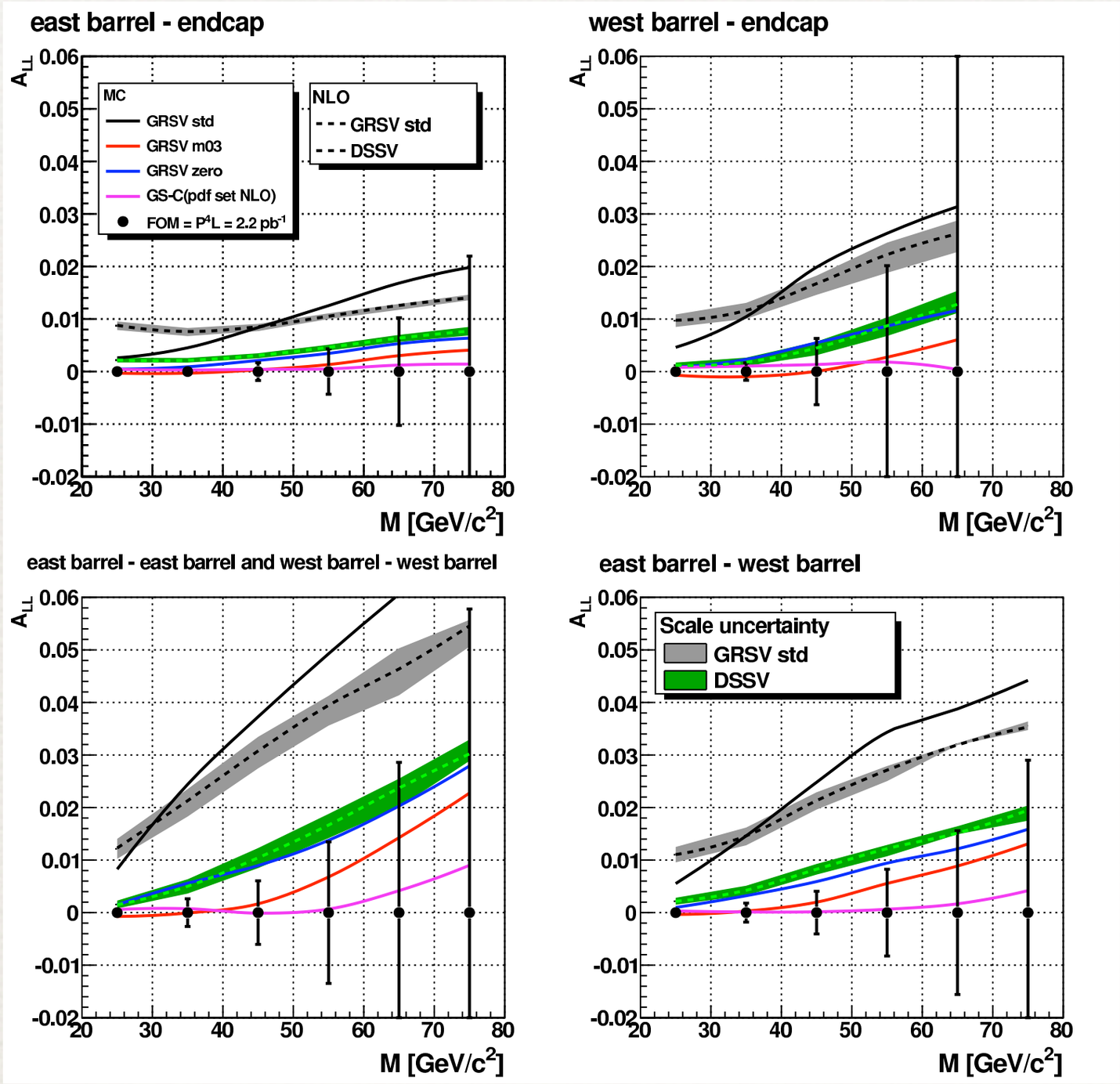
- Material removed before Run 9 significantly reduces conversion backgrounds
- Forward photons measure lowest x
- Correlation with mid-rapidity jet provides cleanest identification of initial parton kinematics





Summary

- 2006 results improved precision at mid-rapidity and new techniques used to limit systematics
- First global analysis including RHIC Spin data suggest small gluon polarization ($0.05 < x < 0.2$)
- Correlations measurements provide constraints on parton kinematics
- Run 9 provides the largest 200 GeV data sample to date and first look at lower x with first 500 GeV data

Backup

Dijet Run 9 Projected