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Probing Gluon Polarization in the Proton with Jets at *STAR*

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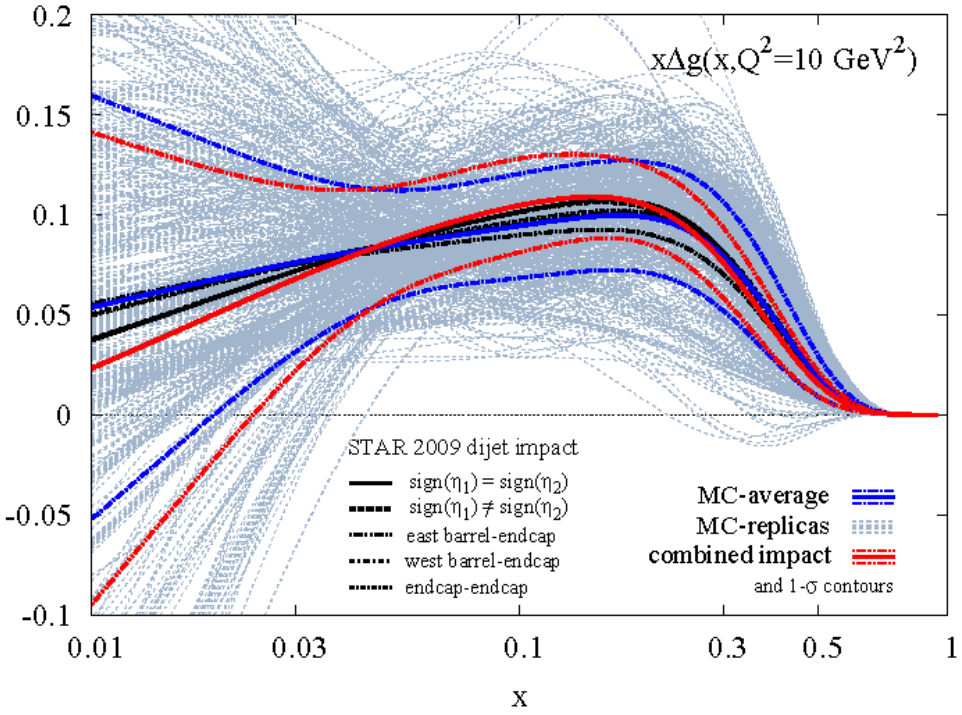
for the
STAR **Collaboration**

PHYSICAL REVIEW D **100,** 052005 (2019)

Longitudinal double-spin asymmetry for inclusive jet and dijet production in *pp* collisions at $\sqrt{s}=510$ GeV

Why 510 GeV *pp* for gluon polarization?



de Florian et al,
arXiv:1902.10548

$$\int_{0.01}^{1} \Delta g(x)dx = 0.296 \pm 0.108$$

- ***STAR*** jet and di-jet measurements in 200 GeV *pp* collisions have provided significant constraints on gluon polarization for $x > 0.05$
  - Even tighter constraints will be coming soon (previous talk!)

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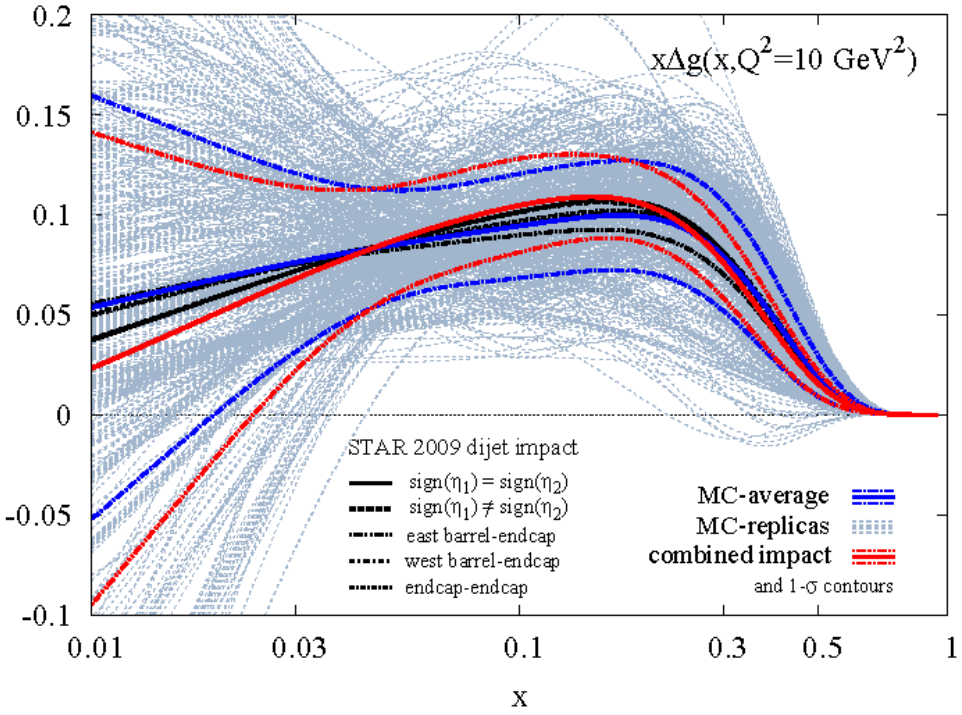

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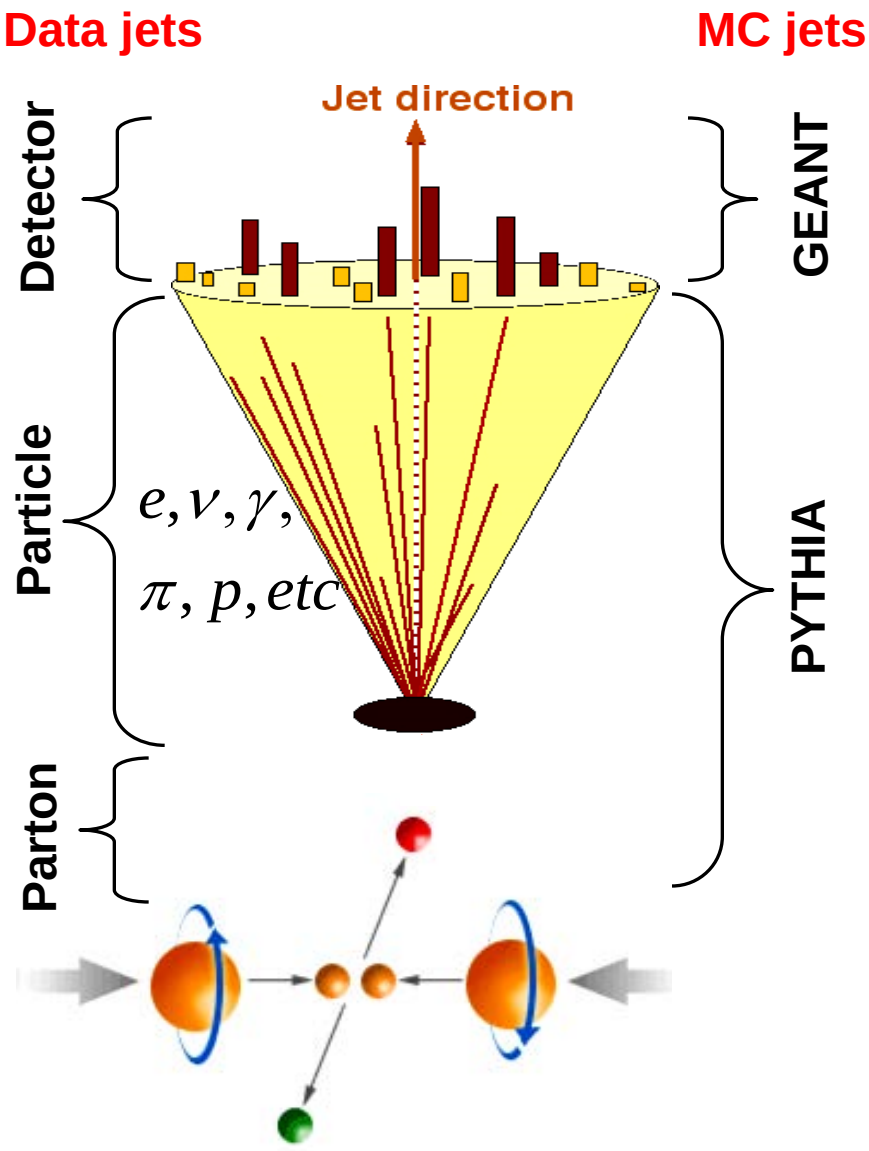
- ***STAR*** jet and di-jet measurements in 200 GeV *pp* collisions have provided significant constraints on gluon polarization for $x > 0.05$
  - Even tighter constraints will be coming soon (previous talk!)
- Must constrain the polarization of the abundant gluons at low x to determine the total contribution to the proton spin
  - 510 GeV *pp* at mid-rapidity extends the sensitivity to $x \sim 0.015$

Jet reconstruction in ***STAR***



Anti-k_T algorithm

Cacciari, Salam, and Soyez, JHEP 0804, 063

- R = 0.5 for 510 GeV pp

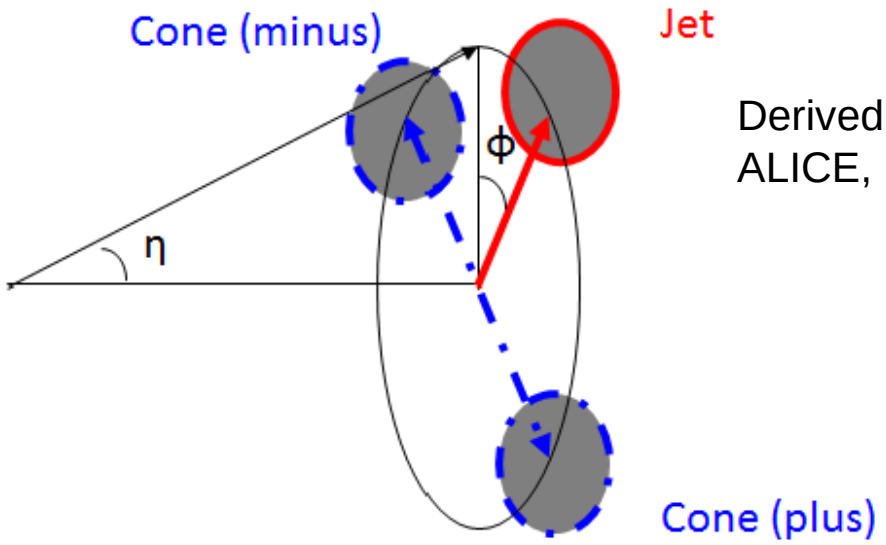
New for this analysis of 510 GeV pp data recorded during 2012

- Jet-by-jet underlying event subtraction
- Modified PYTHIA Perugia 2012 tune to reproduce measured ***STAR*** inclusive charged π cross sections
- Additional technical changes to minimize systematics

Use **PYTHIA** + **GEANT** to quantify detector response

Sjostrand, Mrenna, and Skands, JHEP 05, 026

Off-axis cone underlying event subtraction



Derived from:
ALICE, PRD 91, 112012

- Transverse momentum and energy densities are measured in two off-axis cones, centered ±π/2 away in φ and at the same η as the jet

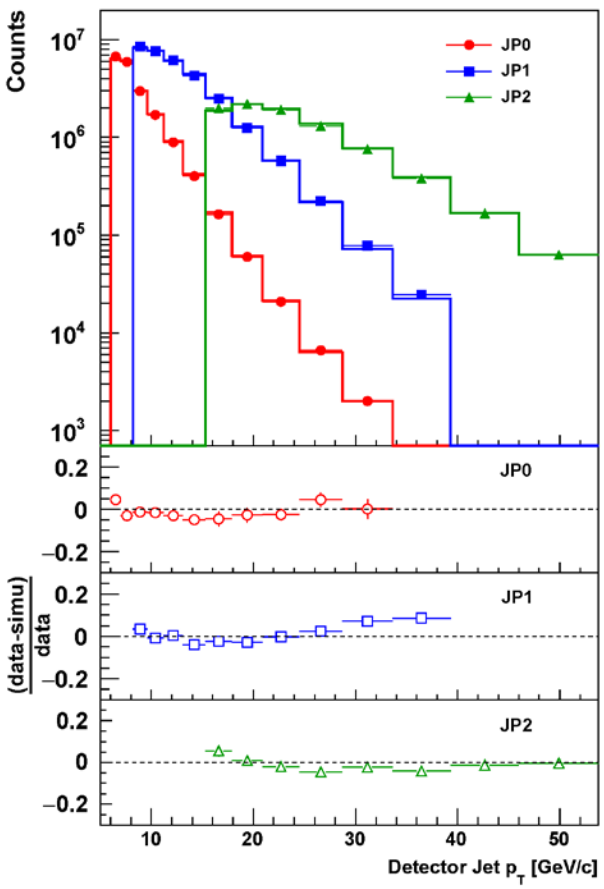
$$dp_T = \frac{\rho_{plus} + \rho_{minus}}{2} A_{jet}$$

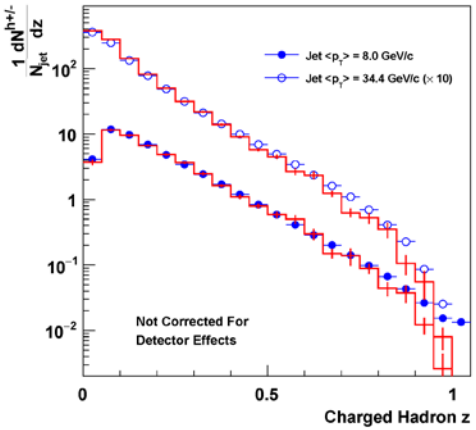
- Proper treatment of the detector acceptance, independent of the jet kinematics
  - STAR has excellent 4-fold symmetry in φ, but not as uniform in η
- Also provides a first-order correction for pile-up effects

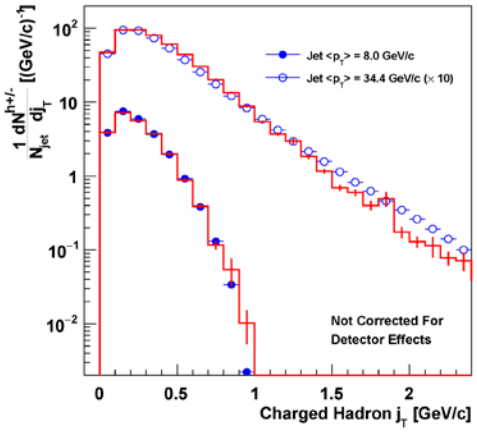
Data – Monte Carlo comparisons

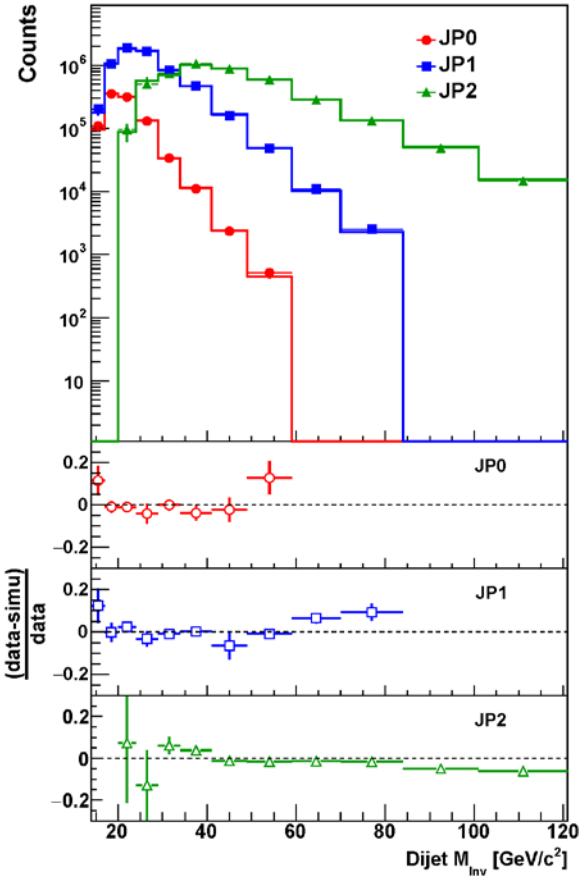
PRD 100, 052005

Data: points. Simulation: histograms.





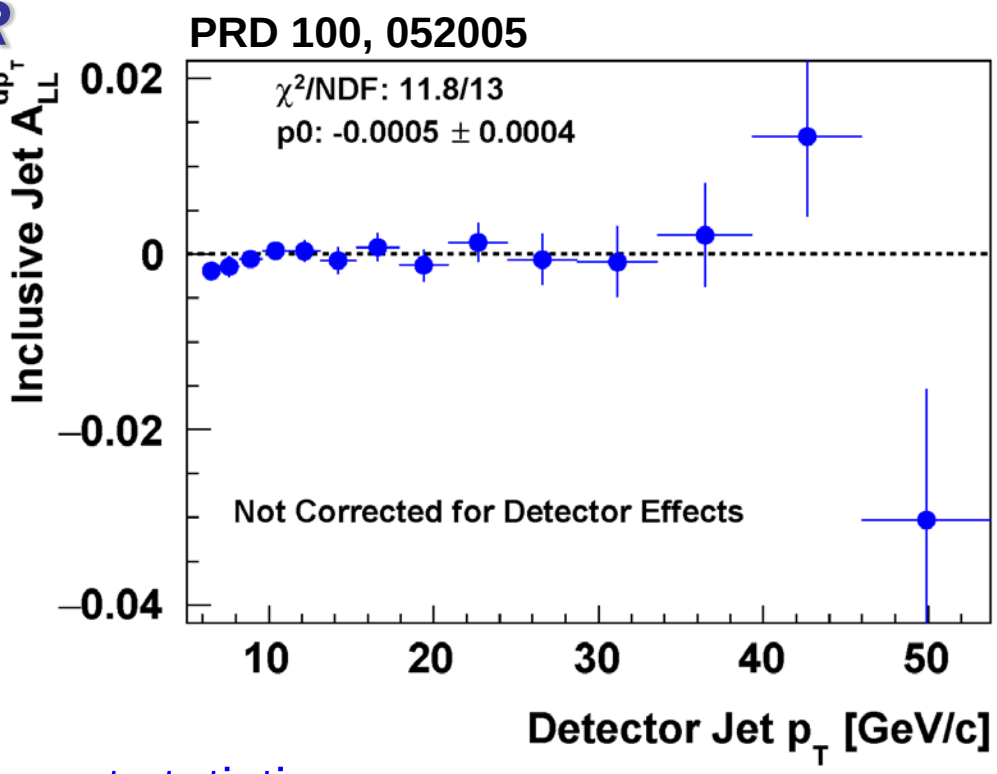




- Jet p_T and di-jet mass spectra for three different triggers
- Jet longitudinal and transverse fragmentation distributions for two p_T ranges
- Jet production in ***STAR*** is **very well understood**

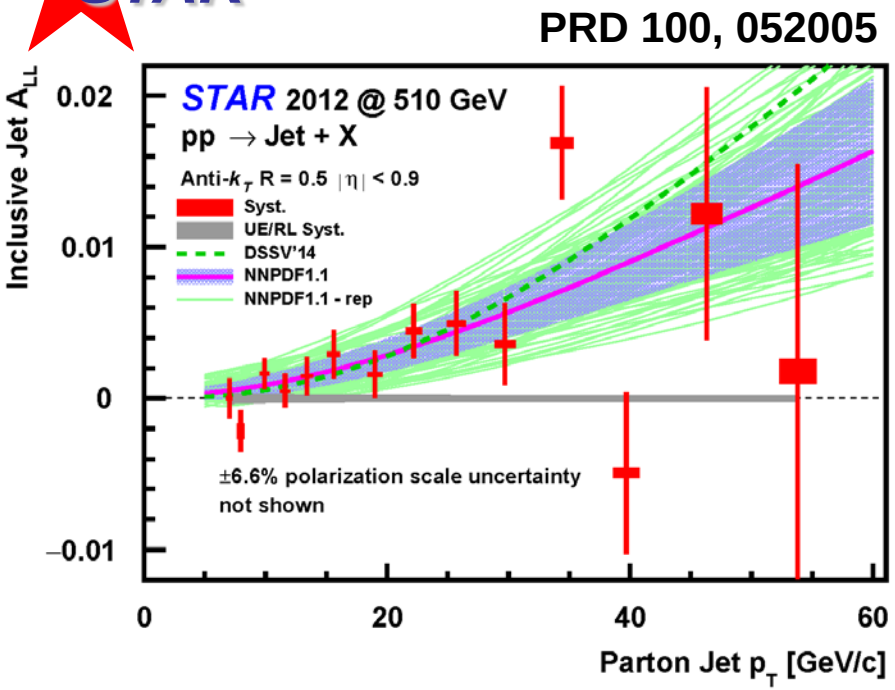
Spin asymmetry in the underlying event?

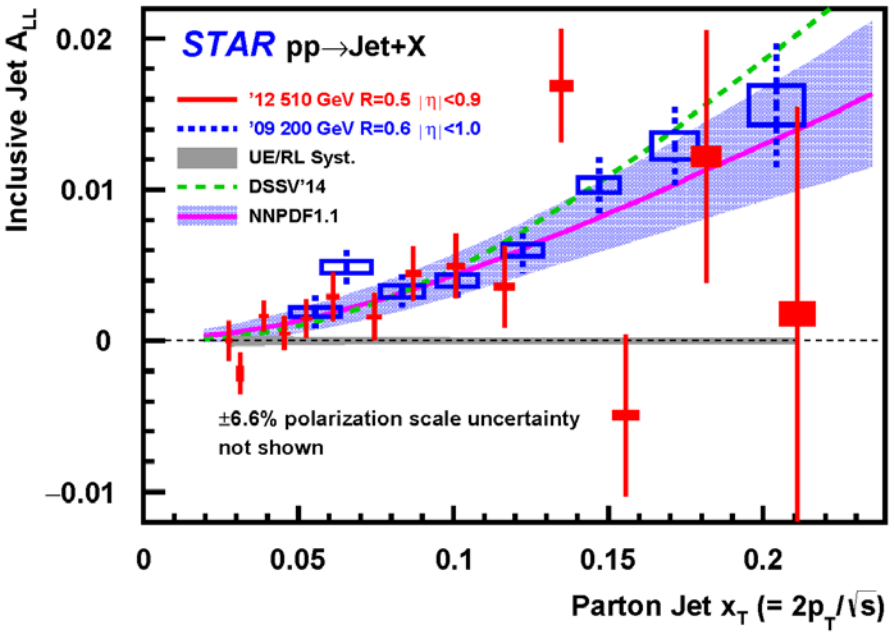
$$A_{LL}^{dp_T} = \frac{1}{P_A P_B} \frac{\langle dp_T \rangle_{++} - \langle dp_T \rangle_{+-}}{\langle dp_T \rangle_{++} + \langle dp_T \rangle_{+-}}$$



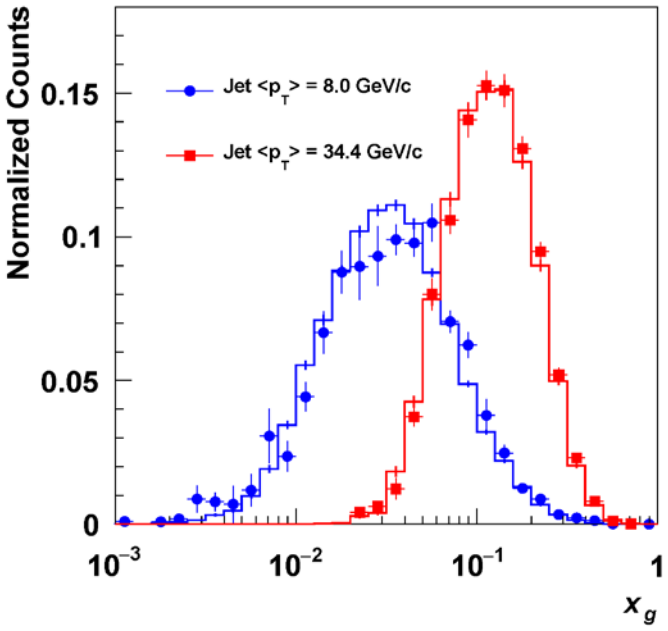
- Consistent with zero for the current statistics
- First ever measurement of A_{LL} for the underlying event
  - Previously assumed – but not measured – to be small
- Limits any underlying event impact on the jet A_{LL} measurement to the ~ 10^{-4} level

STAR 510 GeV inclusive jet A_{LL}





- Consistent with 200 GeV measurements in overlapping region
  - Sensitivity down to $x \sim 0.015$
- Also consistent with recent polarized PDF predictions
- Much reduced systematics compared to previous measurements



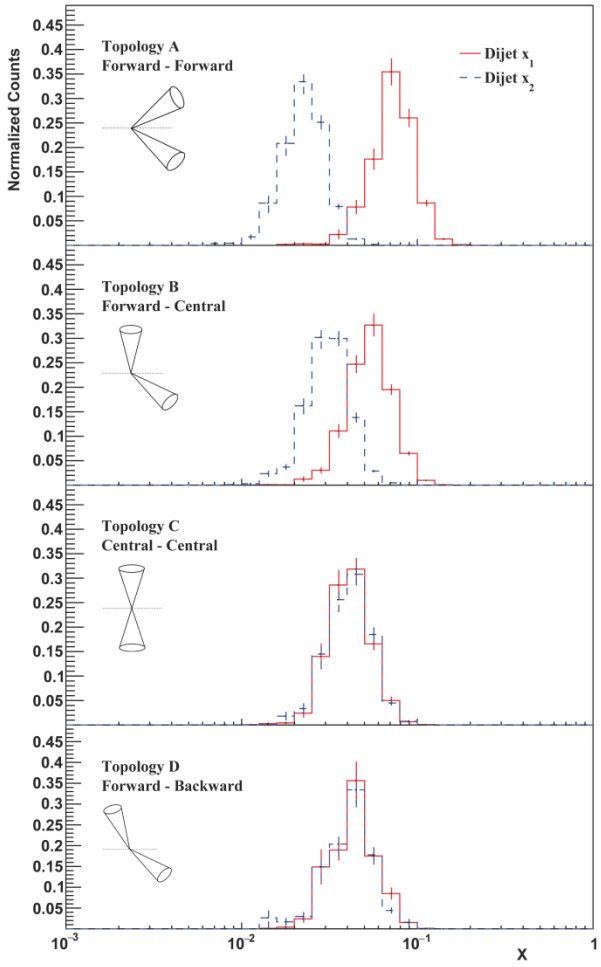
STAR 510 GeV di-jet A_{LL}

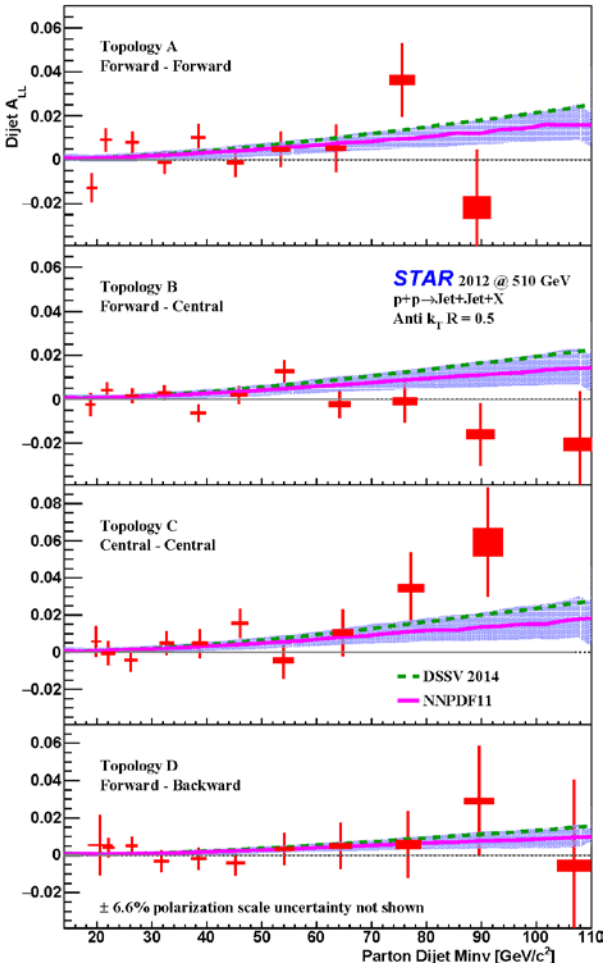
STAR PRD 100, 052005

$$x_1 = \frac{p_{T,3}\, e^{+\eta_3} + p_{T,4}\, e^{+\eta_4}}{\sqrt{s}}$$

$$x_2 = \frac{p_{T,3}\, e^{-\eta_3} + p_{T,4}\, e^{-\eta_4}}{\sqrt{s}}$$

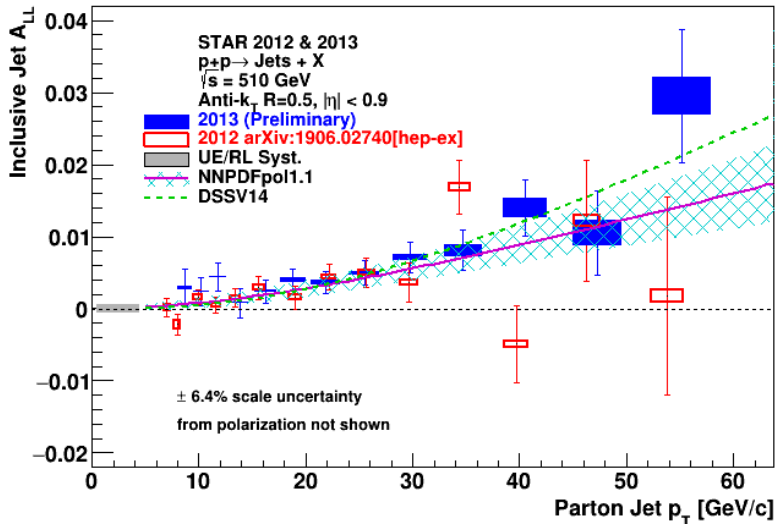
$$M = \sqrt{x_1 x_2}\,\sqrt{s}$$

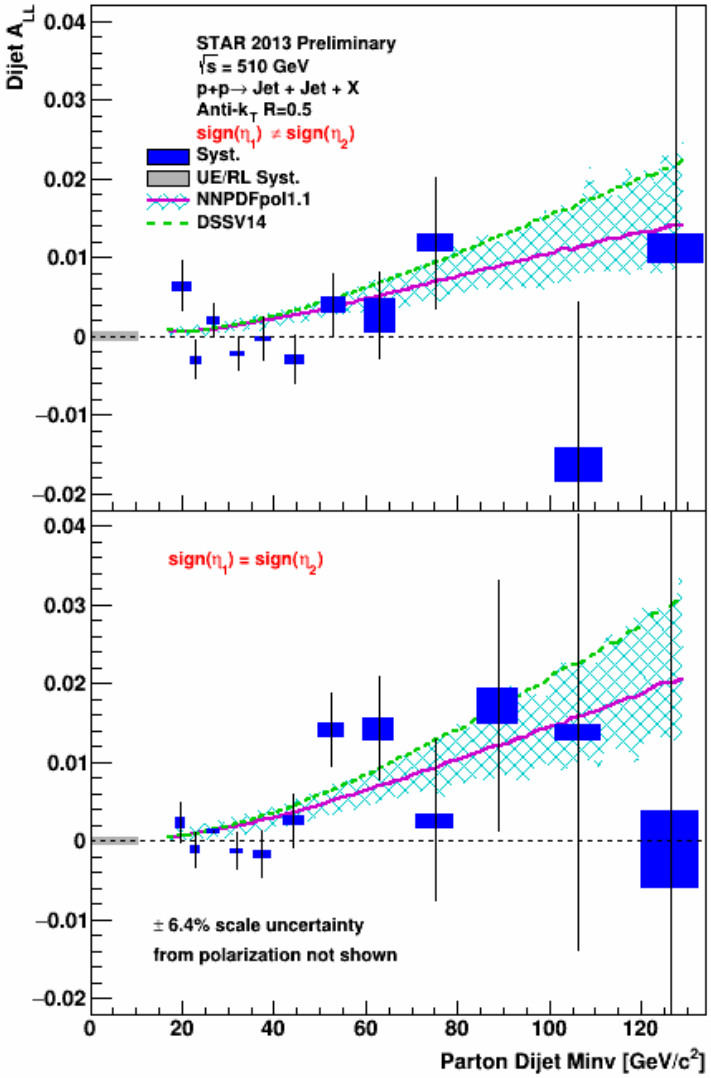




- Di-jets sample much narrower ranges of *x* values than inclusive jets
- Use to constrain the shape of $\Delta g(x)$
  - Minimize extrapolation errors outside the sampled region

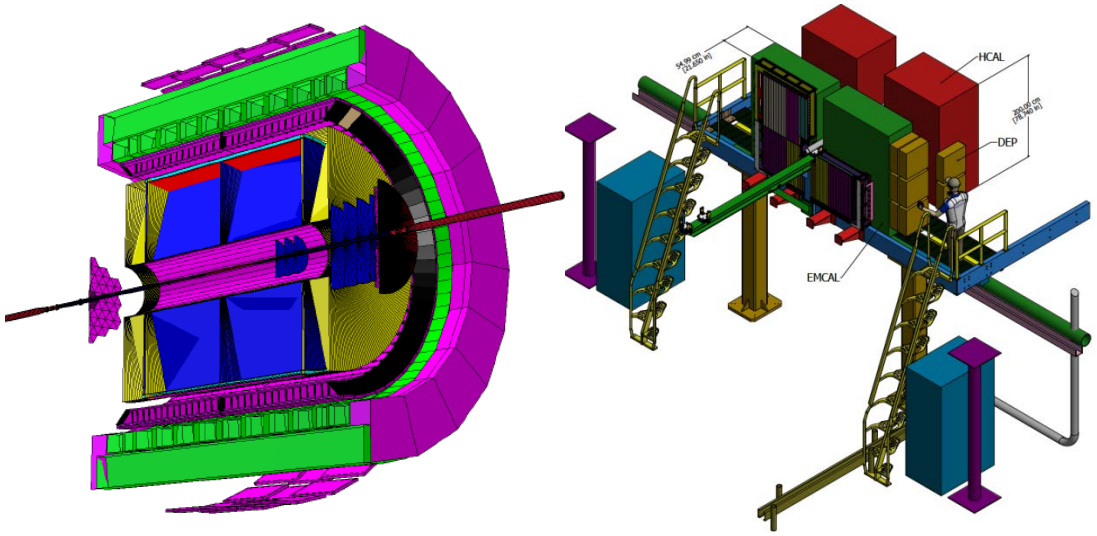
Additional 510 GeV data from 2013

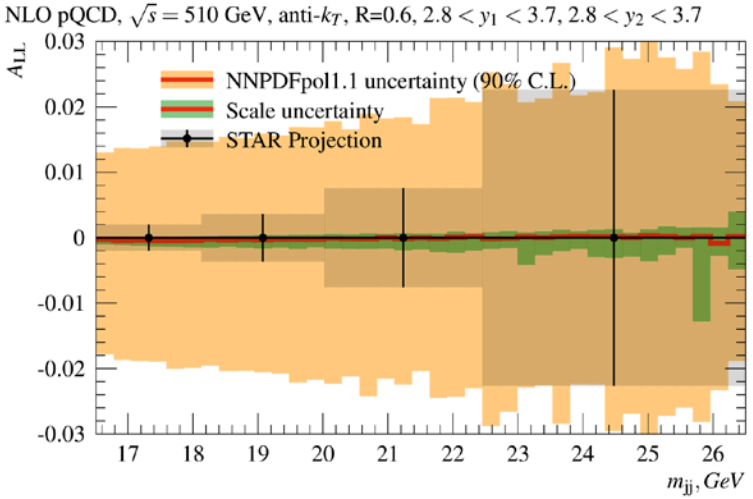




- Recorded over 3 times the sampled luminosity during 2013 as during 2012
  - Also optimized trigger for di-jets
- Preliminary inclusive jet and di-jet A_{LL} are consistent with the 2012 results
- Systematic uncertainty evaluations are underway for final results
- Also analyzing di-jets with at least one at intermediate rapidity to push lower in x

Next step: the ***STAR*** Forward Upgrade





- ***STAR*** is adding a **Forward Upgrade** with tracking, electromagnetic, and hadronic calorimetry at $2.5 < \eta < 4$
  - Will take first data in late 2021 or early 2022
- Di-jets with both jets at $\eta \sim 3$ probe **gluon polarization down to *x* ~ 0.001**
  - Dramatic extension of the level arm
  - Important to optimize detectors and longitudinal spin running at EIC

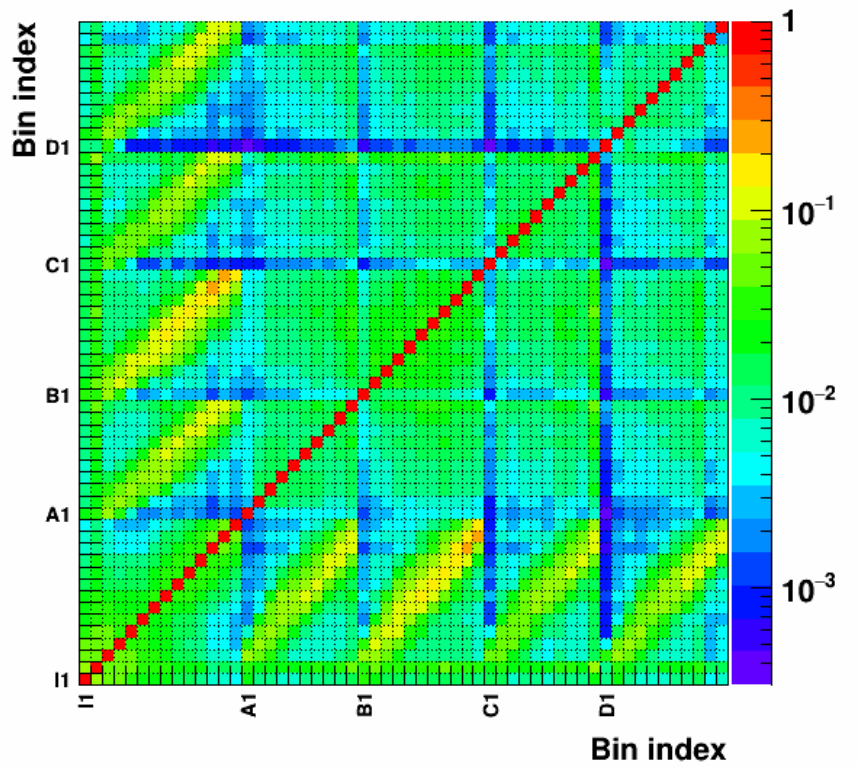
Conclusions

- ***STAR*** inclusive jet and di-jet A_{LL} measurements are providing **new, essential information regarding gluon polarization**
- The recent 2012 and upcoming 2013 measurements with 510 GeV *pp* collisions probe gluon polarization down to ***x* ~ 0.015**
- 510 GeV di-jet data with at least one jet at intermediate rapidity, which are still under analysis, will extend the reach **below 0.01**
- Within the next few years, the ***STAR* Forward Upgrade** will extend our sensitivity to gluon polarization all the way to ***x* ~ 0.001**

- **Stay tuned!**

Correlations

STAR PRD 100, 052005



- The 2012 inclusive jet and di-jet A_{LL} measurements are derived from the same event ensemble
- There are statistical and systematic correlations between the various measurements
  - Largest correlations (> 0.2) are statistical
  - Occur between inclusive jets with p_T and di-jets with $M \sim 2\ p_T$