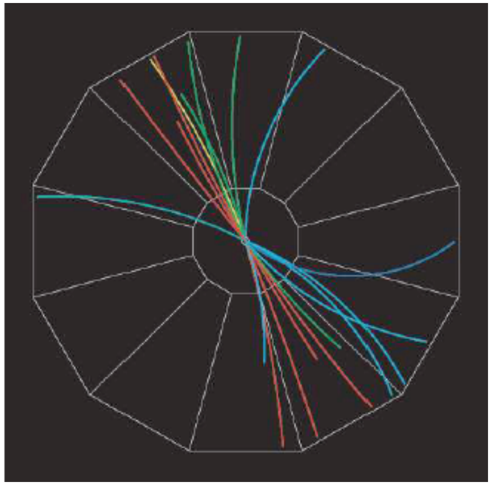


Gluon polarization and jet production at STAR

Pibero Djawotho *for the STAR Collaboration*

Texas A&M

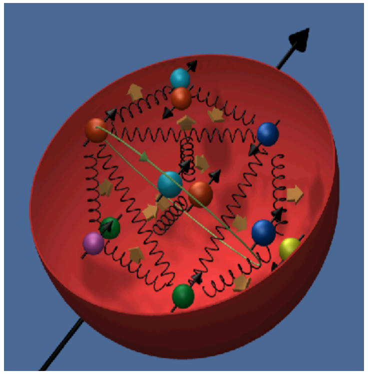
22 October 2012

TEXAS A&M UNIVERSITY

STAR

The proton spin sum rule

$$S = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L$$



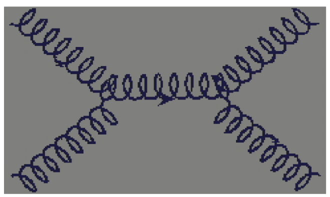
- Quark polarization $\Delta\Sigma \approx 0.3$ from polarized deep inelastic scattering
- Gluon polarization (ΔG) and orbital angular momentum (L) are poorly constrained
- A primary charge of RHIC spin physics $\Rightarrow$ map $\Delta g(x)$

Polarized pp collisions at RHIC

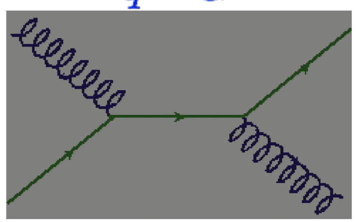
$$A_{LL} = \frac{\sigma^{++} - \sigma^{+-}}{\sigma^{++} + \sigma^{+-}} \propto \frac{\Delta f_a \Delta f_b}{f_a f_b} \hat{a}_{LL}$$

Δf: polarized parton distribution functions

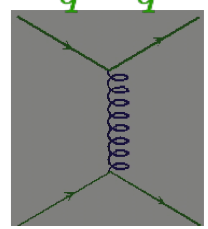
$\frac{\Delta G}{G} \frac{\Delta G}{G}$

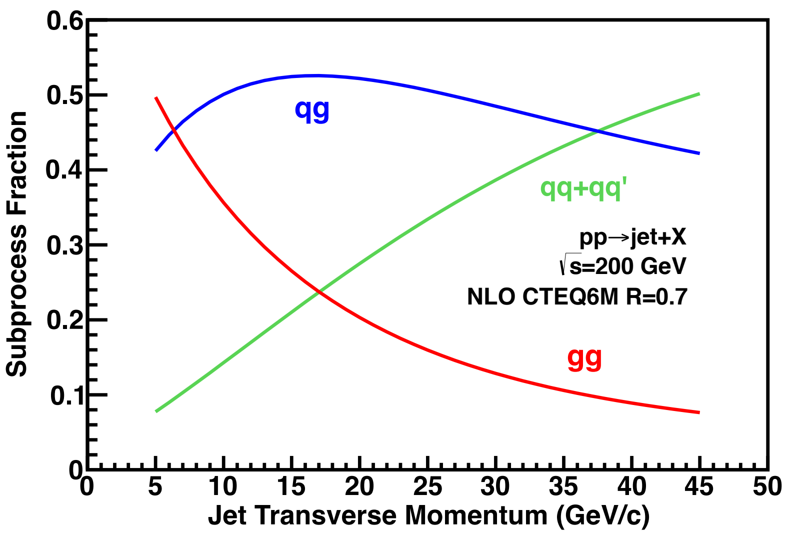


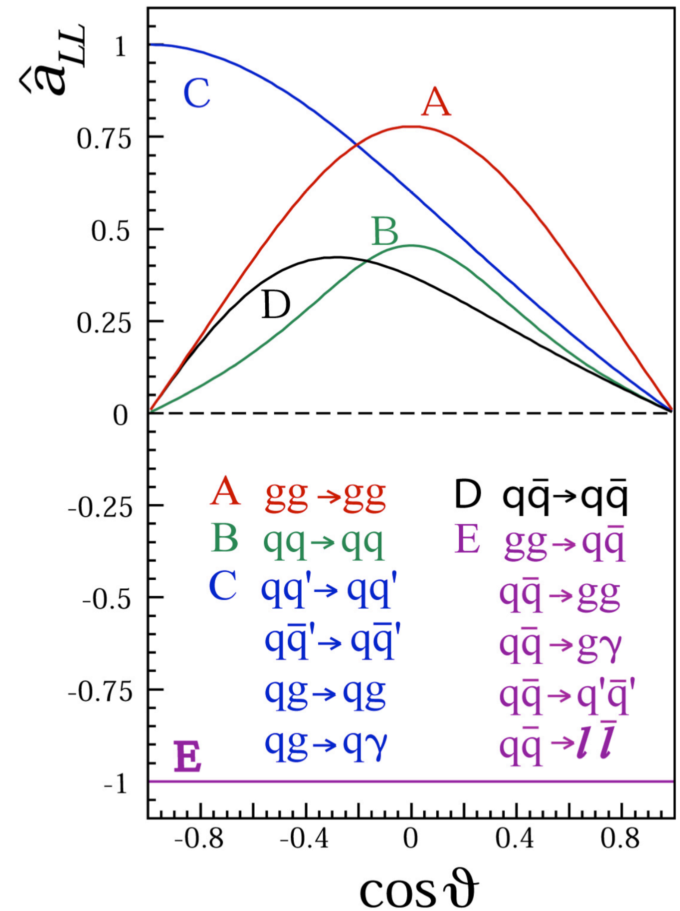
$\frac{\Delta q}{q} \frac{\Delta G}{G}$



$\frac{\Delta q}{q} \frac{\Delta q}{q}$

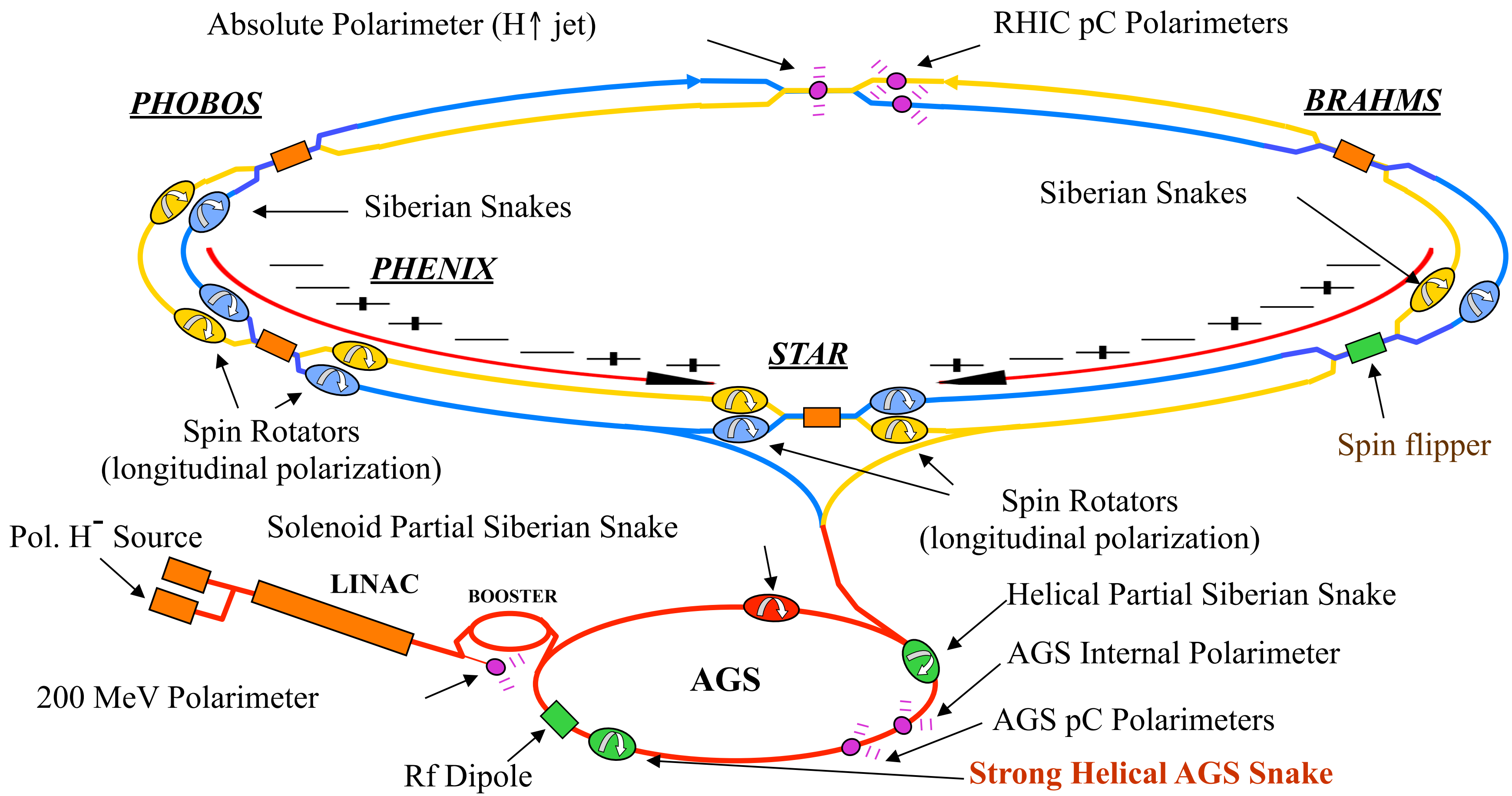






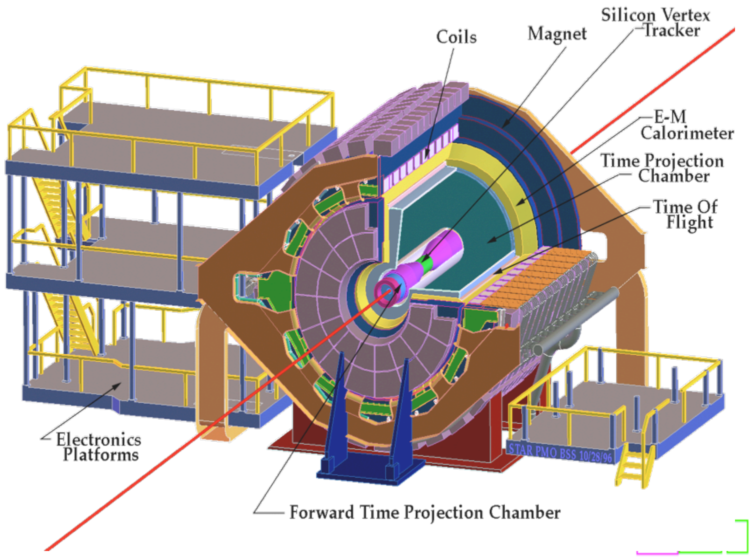
For most RHIC kinematics, ***gg*** and ***qg*** ***dominate***, making A_{LL} for jets sensitive to ***gluon polarization***.

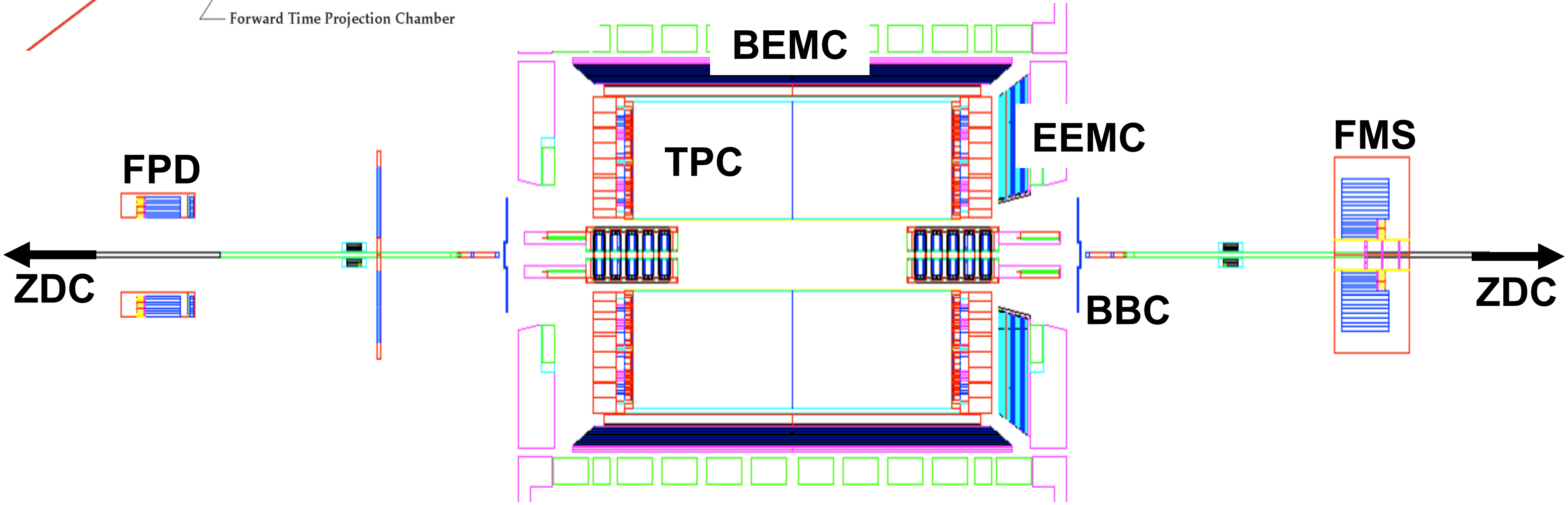
RHIC: The World's First Polarized Hadron Collider



- Spin varies from rf bucket to rf bucket (9.4 MHz)
- Spin pattern changes from fill to fill
- Spin rotators provide choice of spin orientation
- Billions of spin reversals during a fill with little depolarization

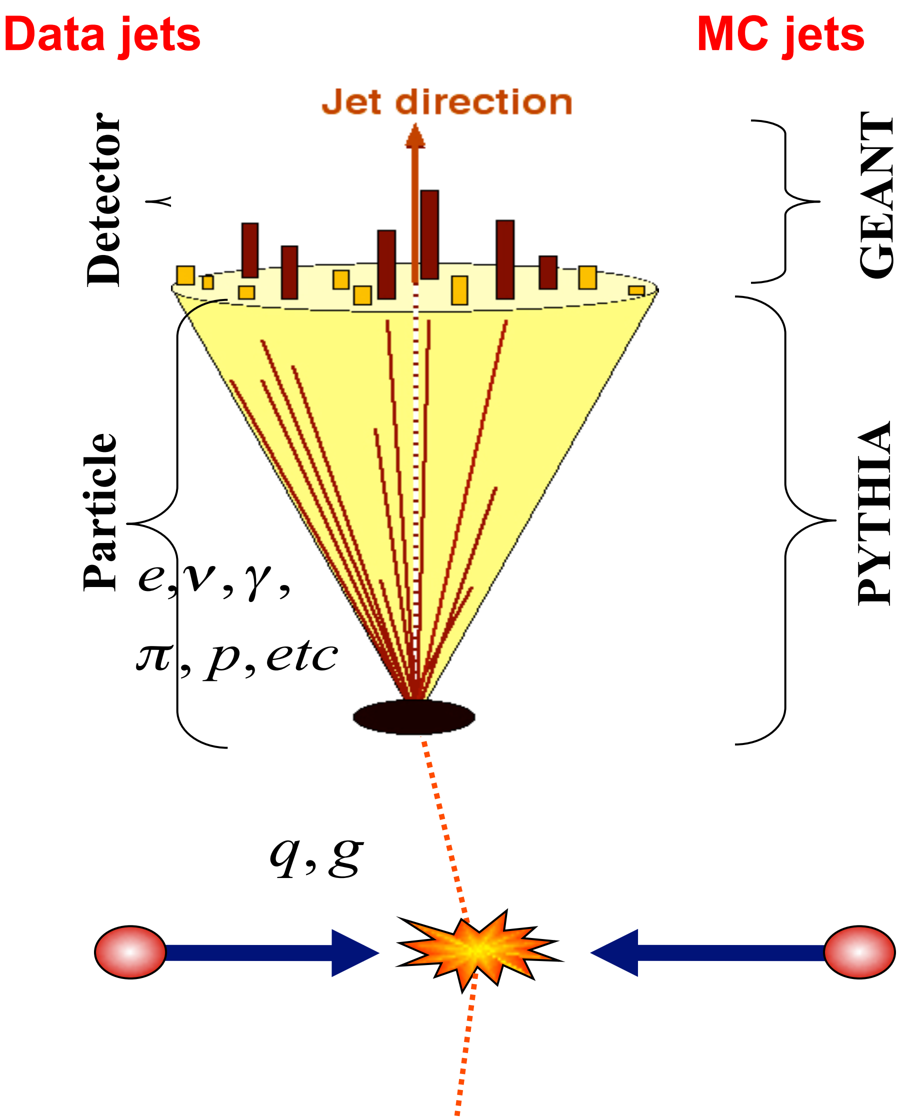
STAR detector in two views





- High precision tracking with the TPC
- Electromagnetic calorimetry with the BEMC, EEMC, and FMS
- Additional detectors for relative luminosity, local polarimetry, and minbias triggering

Jet reconstruction in STAR



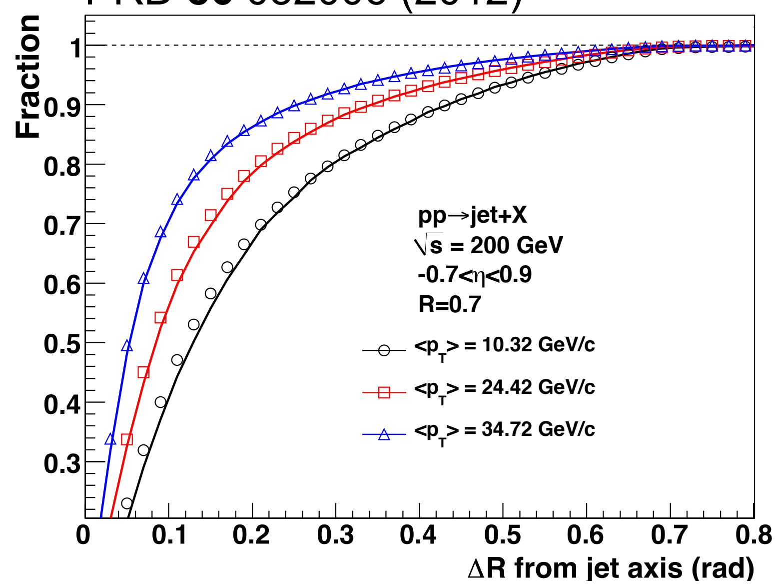
Midpoint cone algorithm

(Adapted from Tevatron II - hep-ex/0005012)

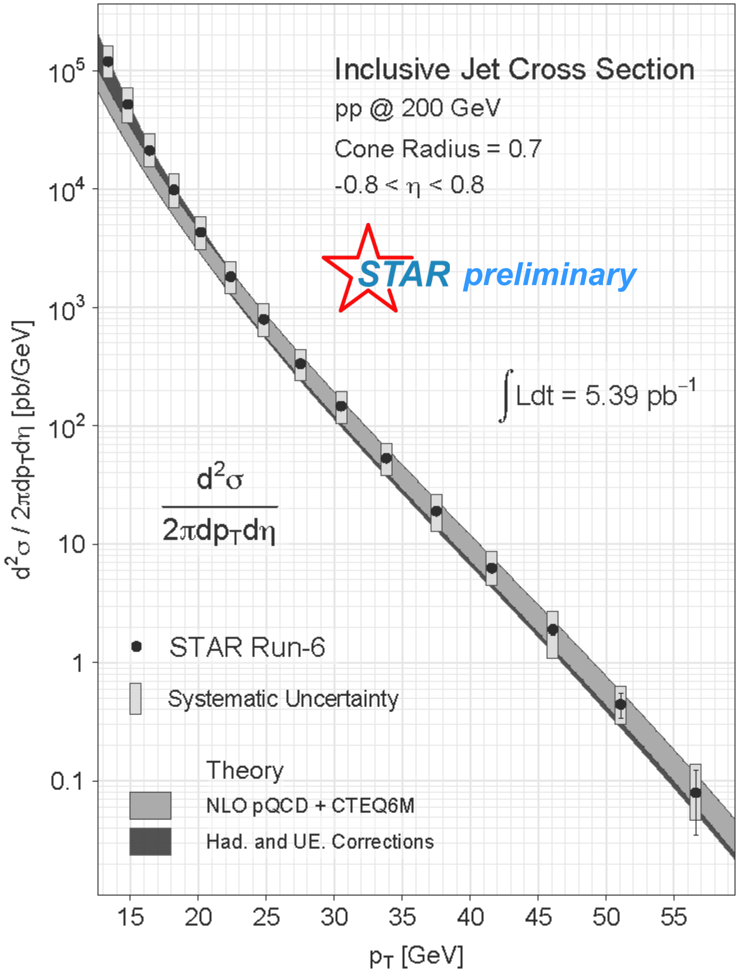
- Seed energy E_T^{seed} = 0.5 GeV
- Cone radius $R = \sqrt{\Delta\eta^2+\Delta\varphi^2} = 0.7$
- Split/merge fraction f = 0.5

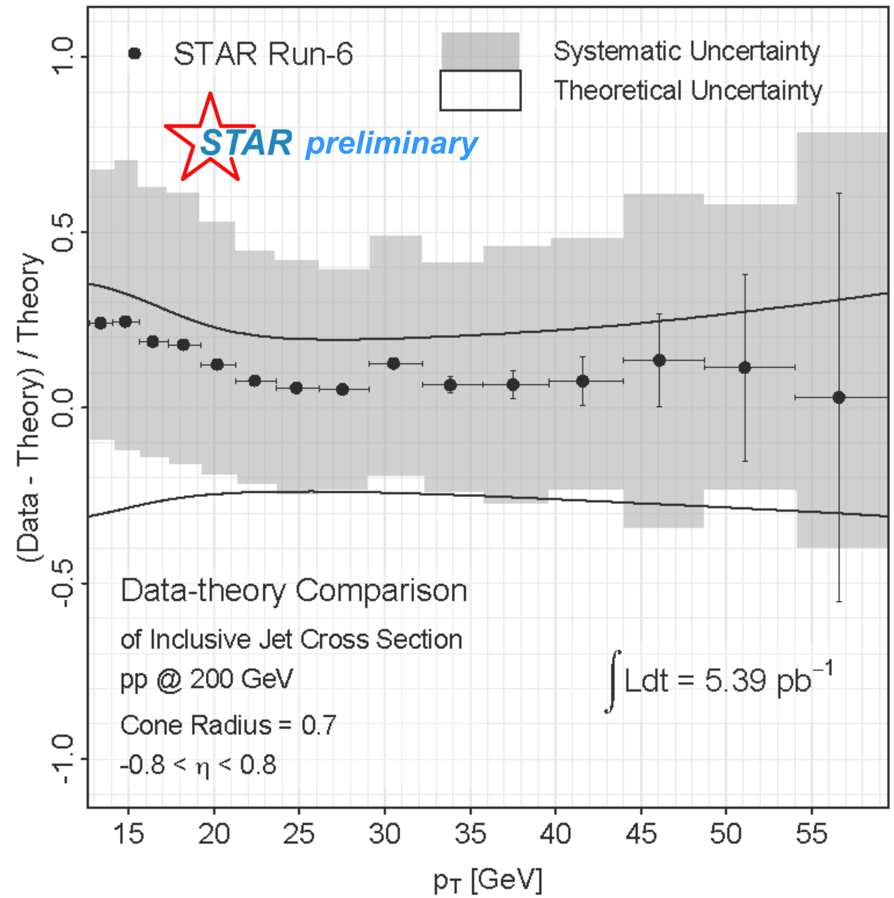
Use **PYTHIA + GEANT** to quantify detector response

PRD **86** 032006 (2012)



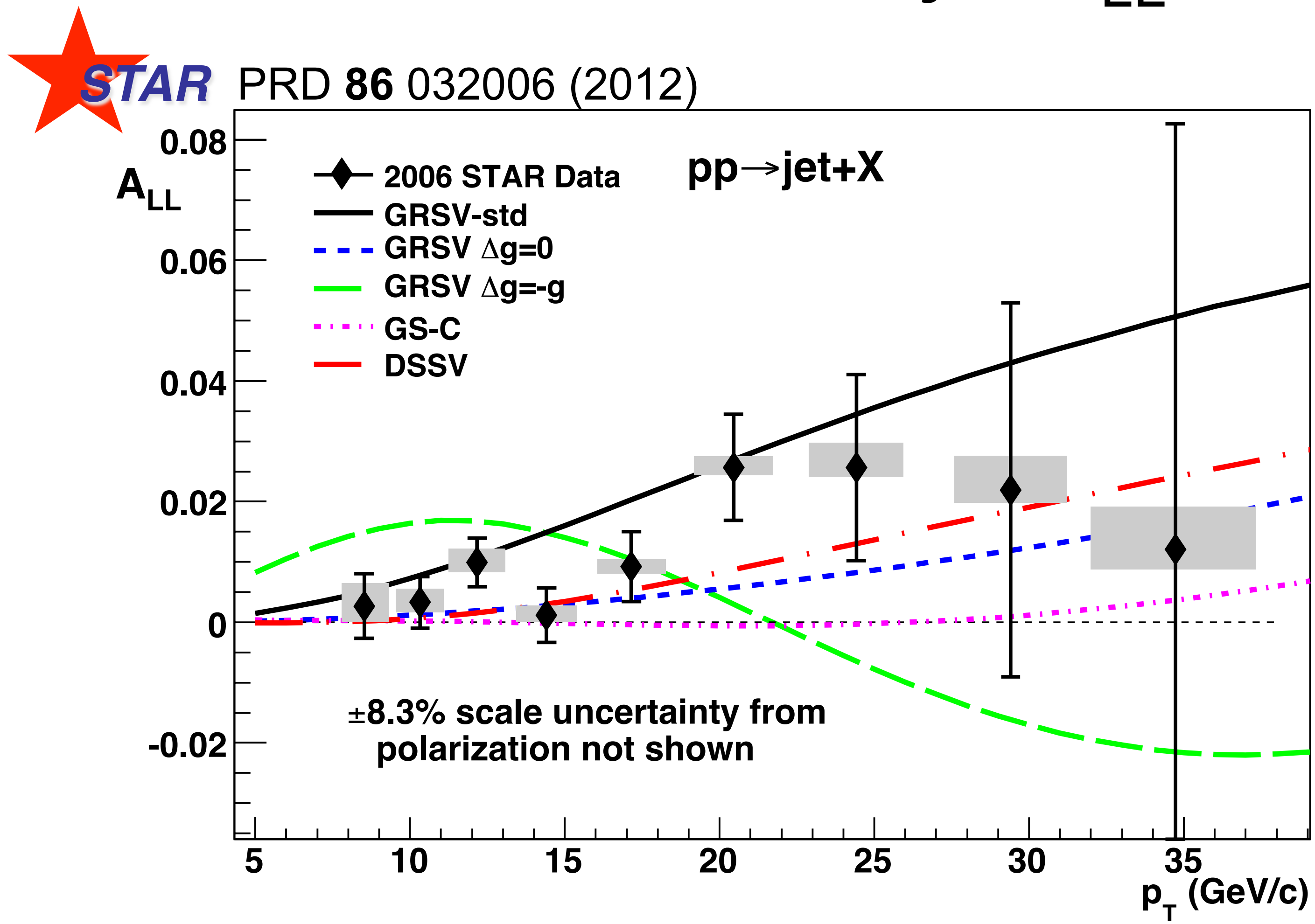
2006 inclusive jet cross section





- Data well described by NLO pQCD+Hadronization+Underlying Event

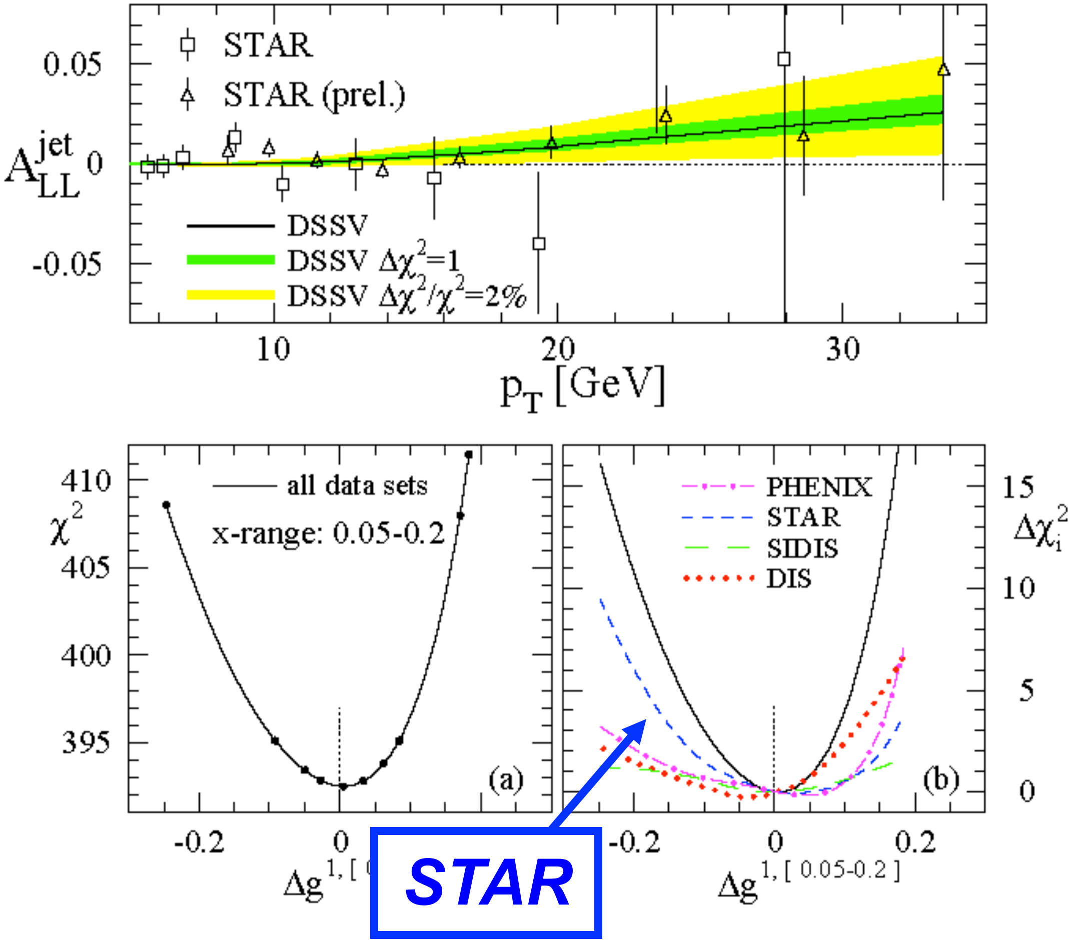
2006 inclusive jet A_{LL}

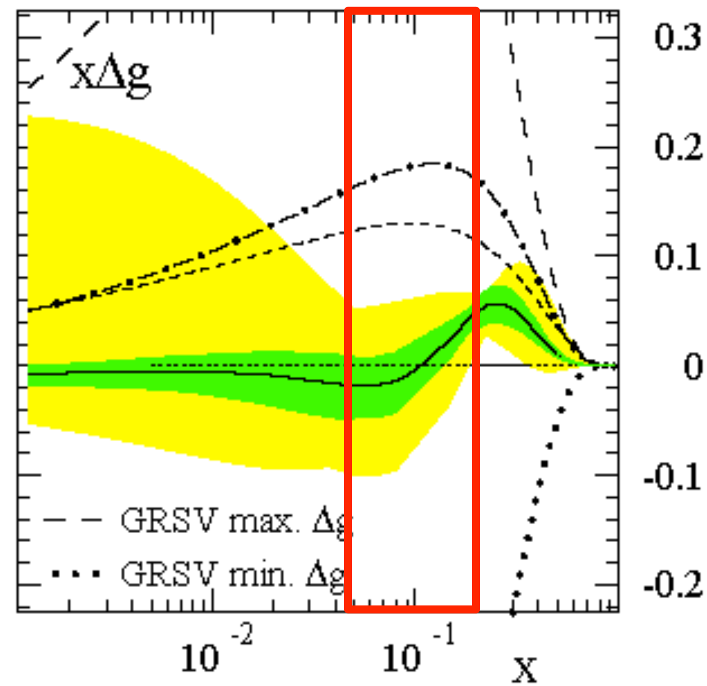


- Sampled 5.5 pb^{-1} at ~57% average beam polarization
- STAR data rule out several previous models of gluon polarization

DSSV – First Global Analysis with Polarized Jets

de Florian et al, PRL **101** 072001 (2008)



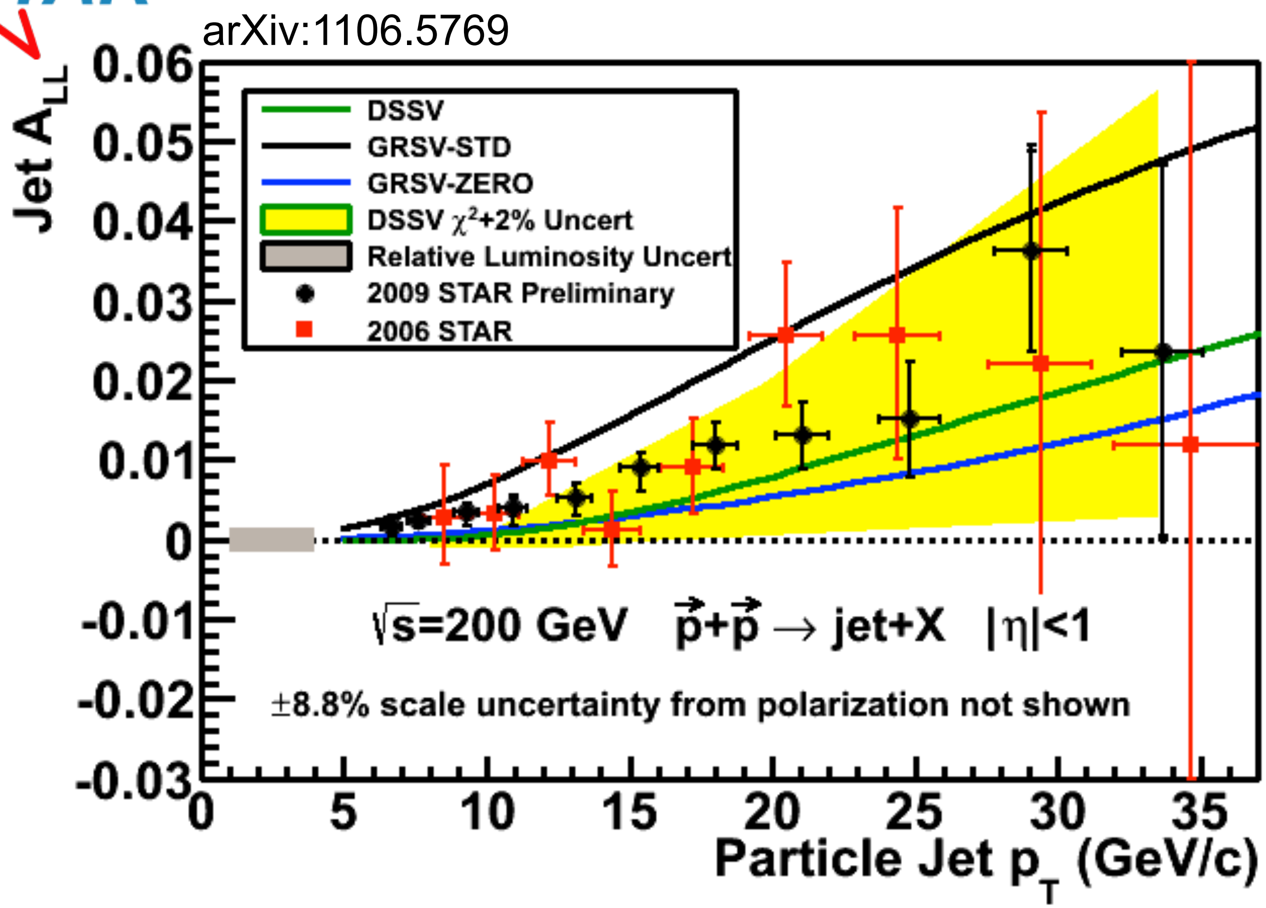


- First global NLO analysis to include DIS, SIDIS, and RHIC pp data on equal footing
- Finds node in gluon distribution near x ~ 0.1

2009 upgrades

- 2009 jet patch trigger upgrades
  - Overlapping jet patches and lower E_T threshold improve efficiency and reduce trigger bias
    - Net increase of 37% in jet acceptance
  - Remove beam-beam counter trigger requirement:
    - Trigger more efficiently at high jet p_T
    - Measure non-collision background
  - Increased trigger rate enabled by DAQ1000
- Improvements in jet reconstruction
  - Subtract 100% of track momentum from struck tower energy (2009) instead of MIP (2006)
  - Overall jet energy resolution improved from 23% to 18%
  - Switching to anti-k_T algorithm for *final* result
    - Reduces sensitivity to underlying event effects
- Collected 4 times the figure-of-merit of 2006
  - Sampled 20 pb^{-1} at 58% average beam polarization

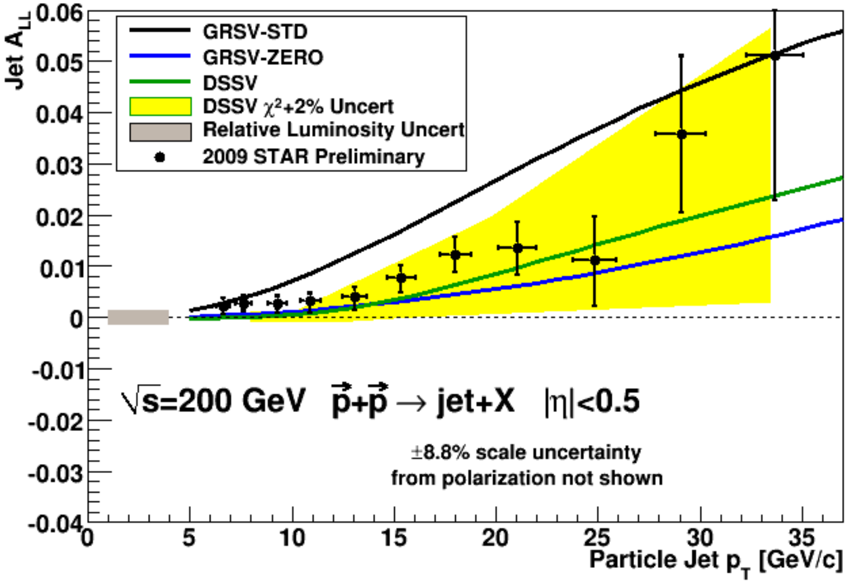
From 2006 to 2009



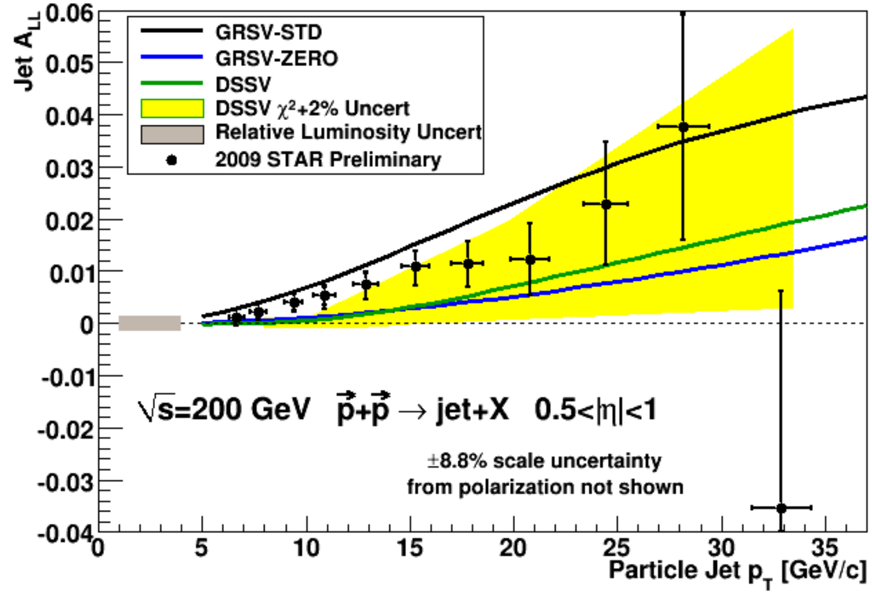
- 2009 STAR data is a factor of 3 (high-p_T) to >4 (low-p_T) more precise than 2006 STAR data
- Results fall between predictions from **DSSV** and **GRSV-STD**
- Precision sufficient to merit finer binning in pseudorapidity

2009 inclusive jet A_{LL}

Mid rapidity



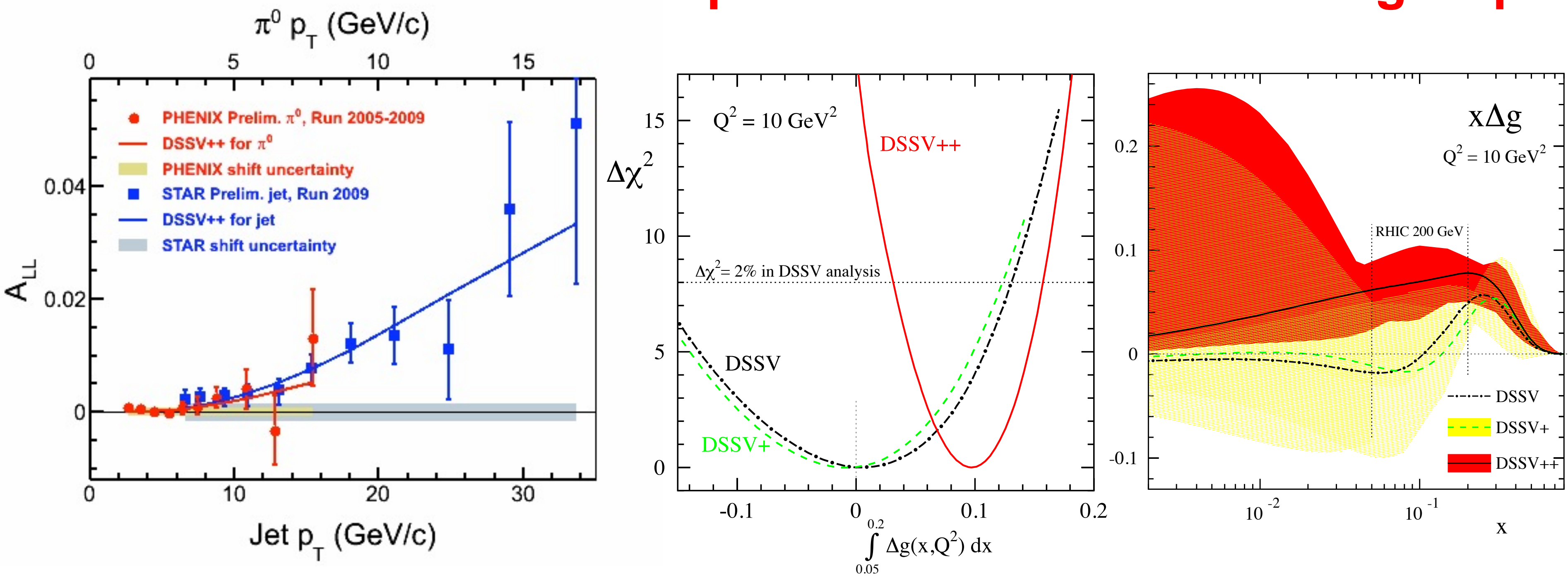
Forward rapidity



- A_{LL} separated into two pseudorapidity ranges
- Forward jets involve:
  - A larger fraction of quark-gluon scattering with:
    - Higher *x* quarks that are more polarized
    - Lower *x* gluons that are less polarized
  - Larger $|\cos(\theta^*)|$, which reduces $\hat{a}_{LL}$
- A_{LL} falls between the predictions from **DSSV** and **GRSV-STD**

New global analysis with 2009 RHIC data

Special thanks to the DSSV group!

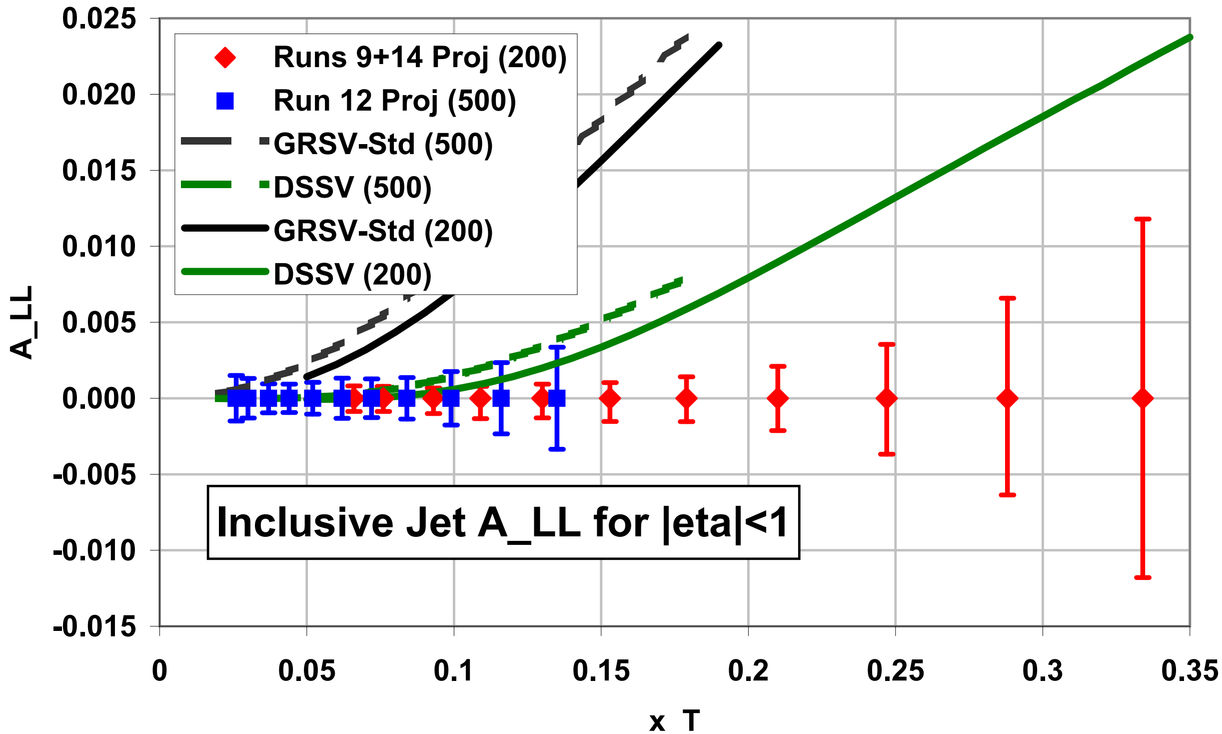


- **DSSV++** is a new, preliminary global analysis from the DSSV group that includes the 2009 RHIC A_{LL} data (STAR inclusive jets and PHENIX π^0's)

$$\int_{0.05}^{0.20} \Delta g(x, Q^2 = 10\ \mathrm{GeV}^2)\,dx = 0.10^{+0.06}_{-0.07}$$

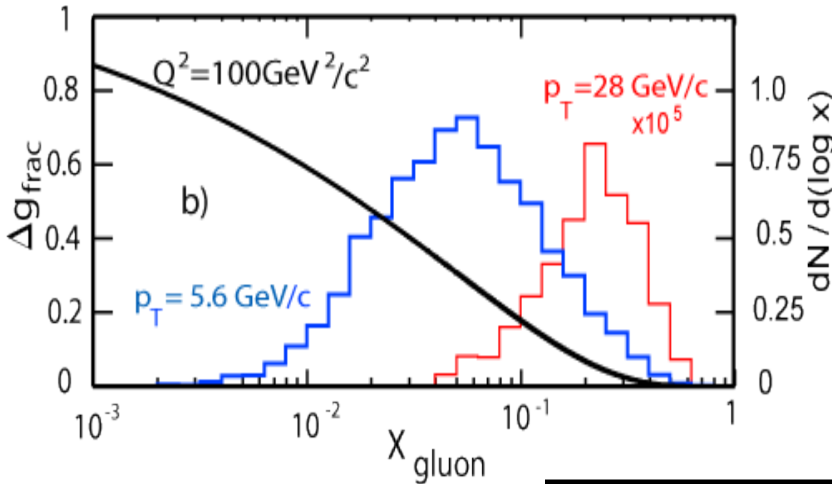
- First experimental evidence of **non-zero Δg(x)** in RHIC range ($0.05 \le x \le 0.2$)

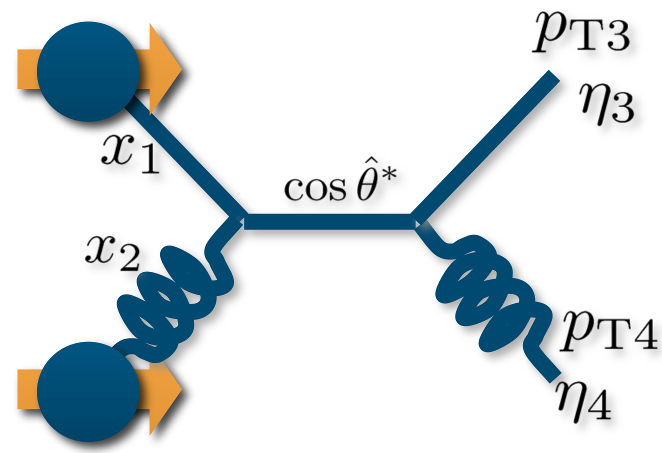
Projected sensitivity for future inclusive jet A_{LL}



- 500 GeV collisions sample smaller $x_T=2p_T/\sqrt{s}$
- Projected statistical uncertainties
- Expected asymmetries are quite small
  - Control of systematics (esp. relative luminosity) will be important

Correlation measurements



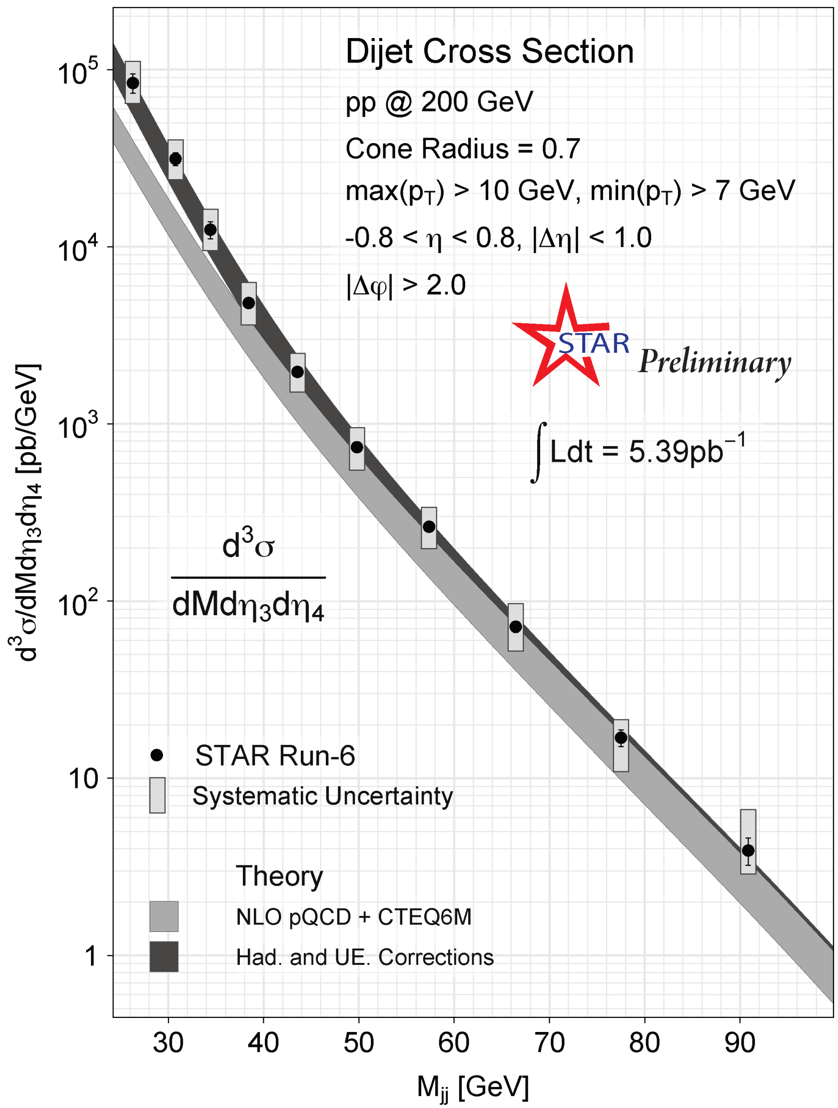


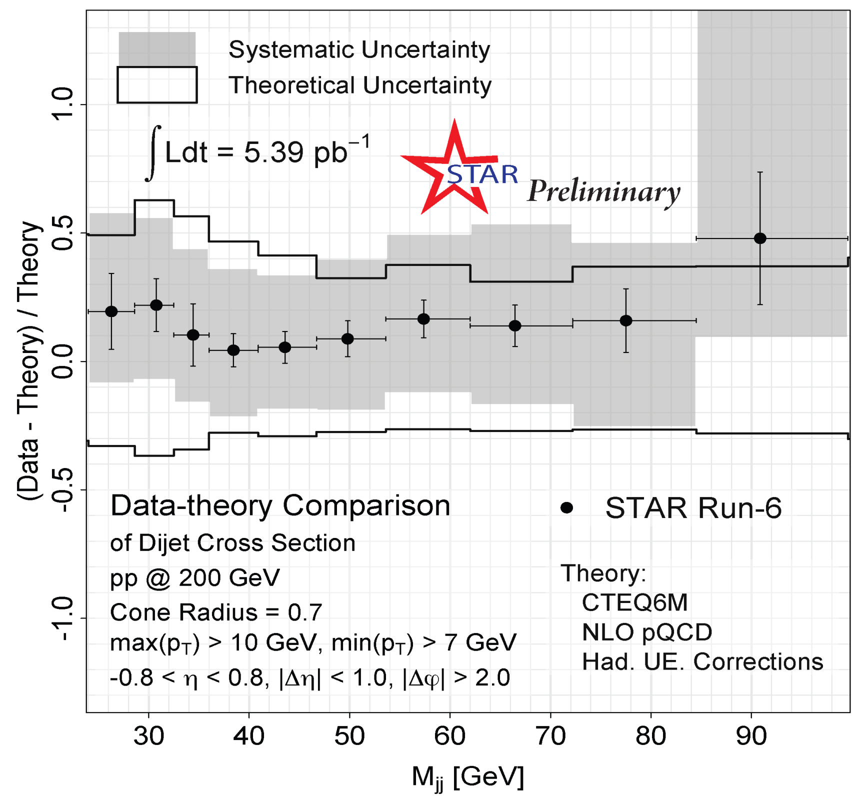
$$x_{1,2} = \frac{1}{\sqrt{s}}\left(p_{T3}e^{\pm\eta_3} + p_{T4}e^{\pm\eta_4}\right)$$

$$\left|\cos\theta^*\right| = \tanh\left|\frac{\eta_3 - \eta_4}{2}\right|$$

- Inclusive probes at fixed p_T sample broad *x* range ⇒ global analysis needed to disentangle shape of $\Delta g(x)$
- Reconstructing dijet final state (jet p_T and η) provides information on initial parton kinematics ($x_{1,2}$ and cosθ*) at LO
- STAR is well suited for correlation measurements and full jet reconstruction with its large acceptance

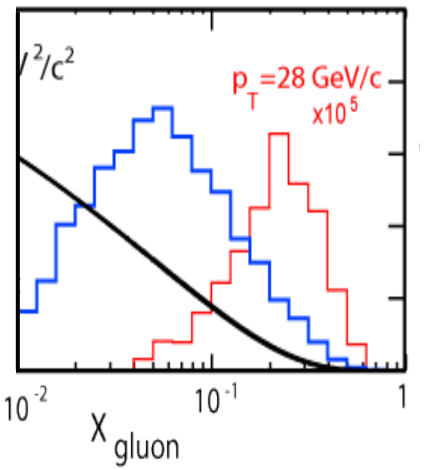
2006 dijet cross section

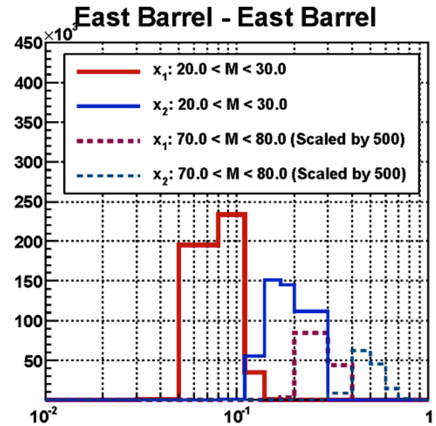


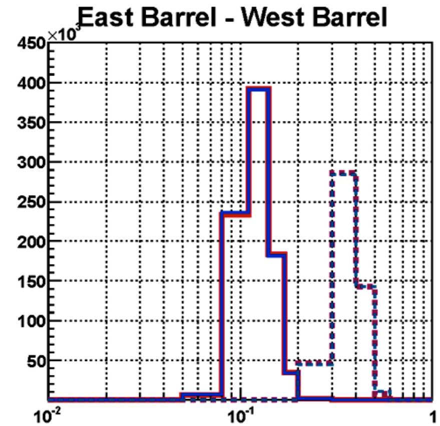


- Data shows good agreement with NLO pQCD + CTEQ6M including Hadronization + Underlying Event Corrections

2009 dijet partonic coverage







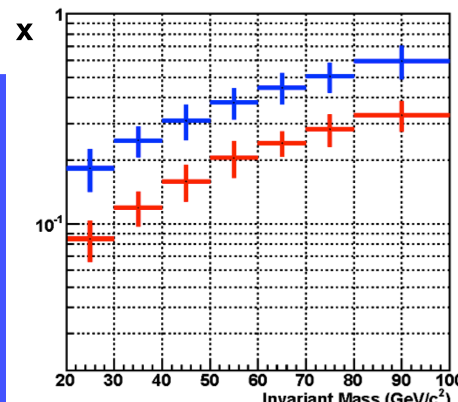
$$x_1 = \frac{1}{\sqrt{s}}\left(p_{T,3}e^{\eta_3} + p_{T,4}e^{\eta_4}\right)$$

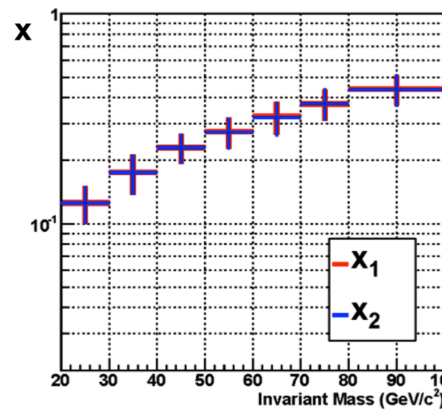
$$x_2 = \frac{1}{\sqrt{s}}\left(p_{T,3}e^{-\eta_3} + p_{T,4}e^{-\eta_4}\right)$$

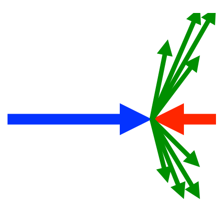
$$M = \sqrt{x_1 x_2 s}$$

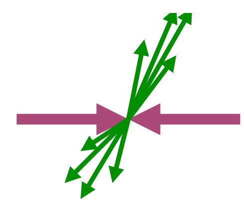
$$y = \frac{1}{2}\ln\frac{x_1}{x_2} = \frac{\eta_3 + \eta_4}{2}$$

$$|\cos\theta^*| = \tanh\frac{|\eta_3 - \eta_4|}{2}$$



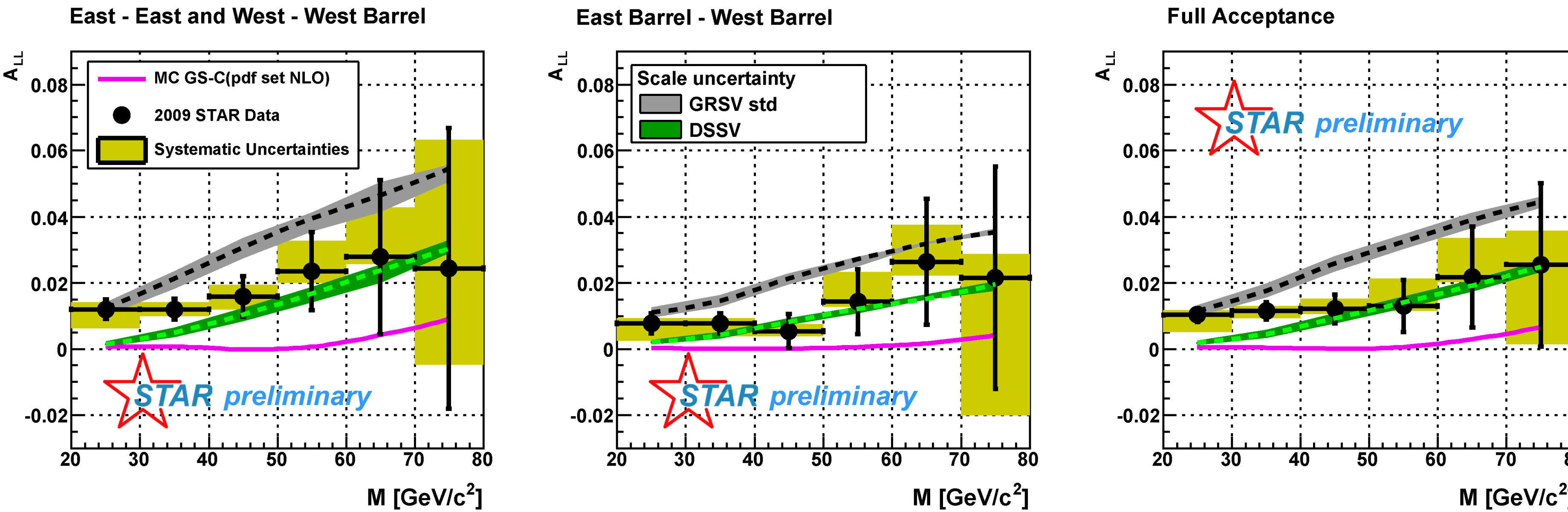






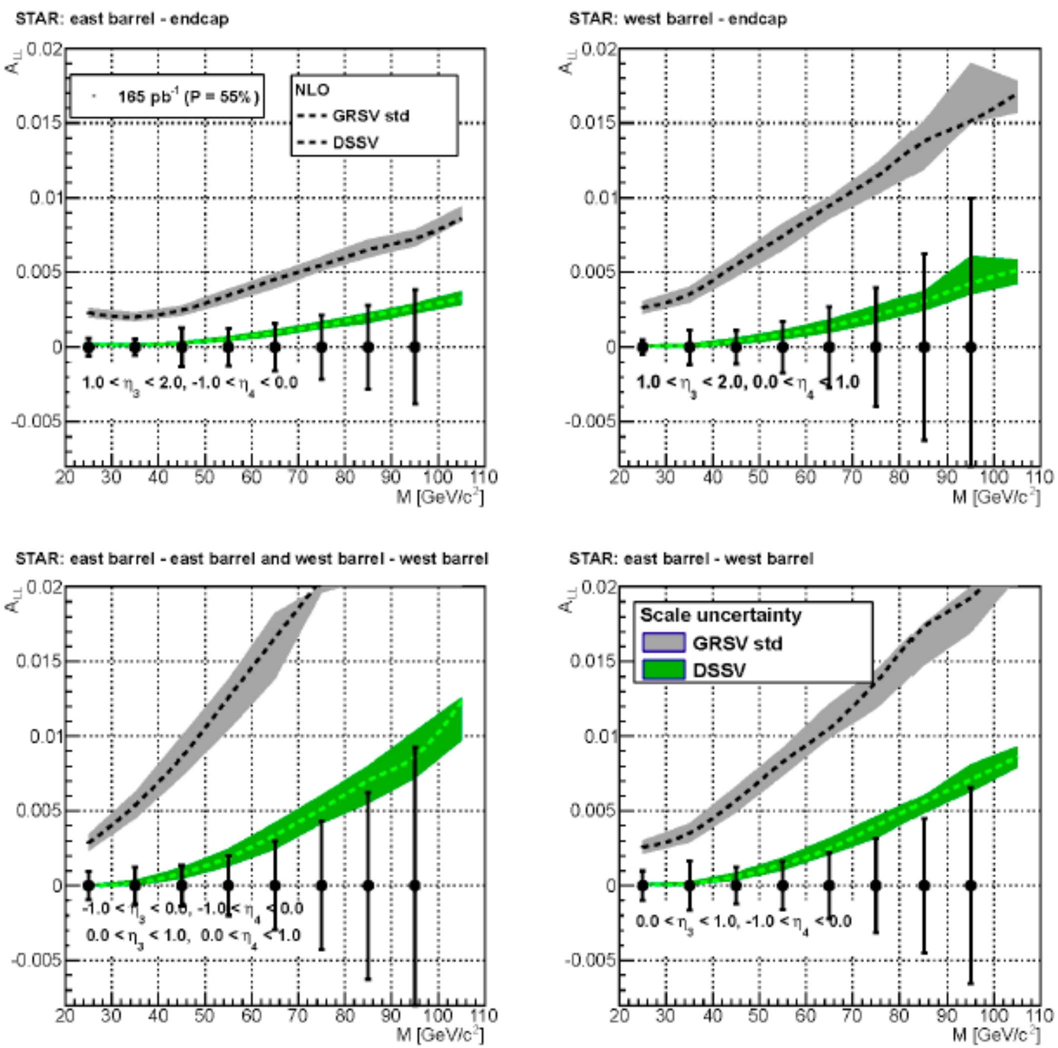
2009 dijet A_{LL}

arXiv:1107.0917



- STAR data fall between predictions of **DSSV** and **GRSV-STD**

Projected sensitivity for dijet A_{LL} at 500 GeV



$$x_1, x_2 = \frac{M}{\sqrt{s}} \exp\left(\pm \frac{\eta_3 + \eta_4}{2}\right)$$

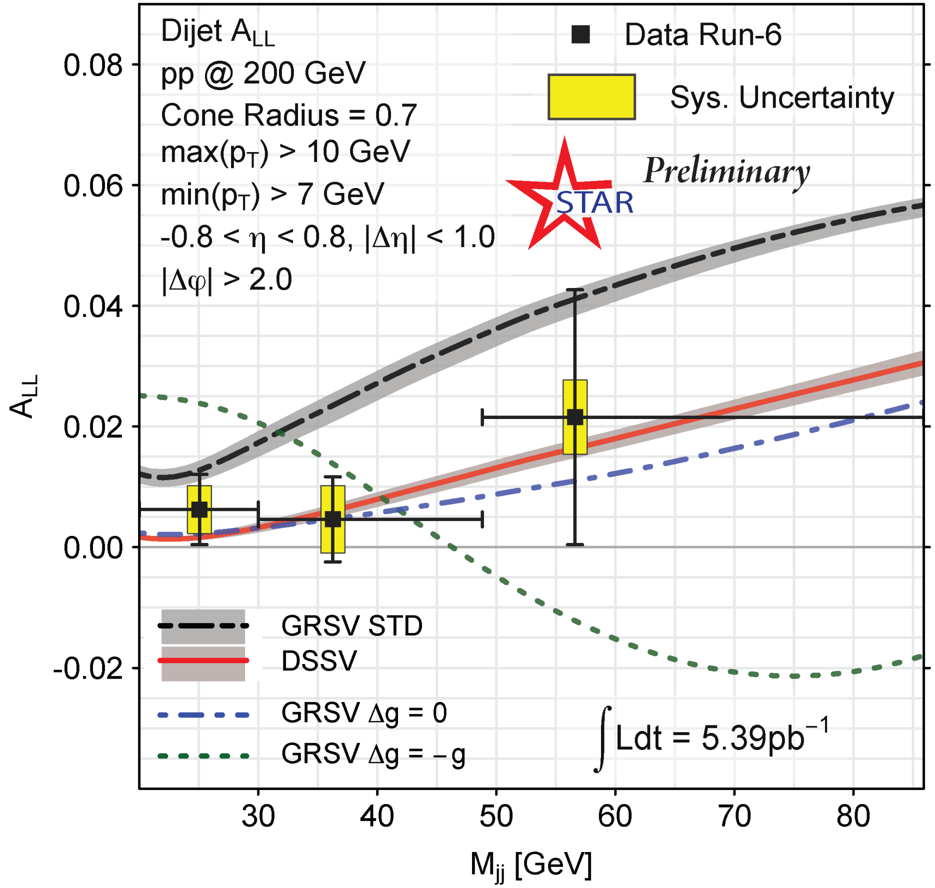
- Higher energy accesses lower x_g
- Expect smaller A_{LL}
- Projections show expected sensitivity for the upcoming 2013 run

Summary

- STAR inclusive jet and dijet cross sections are in good agreement with NLO pQCD calculations when hadronization and underlying event effects are included
- STAR inclusive jet A_{LL} from 2006 provides significant constraints on gluon polarization in NLO global analyses
- 2009 STAR inclusive jet A_{LL} is factor of 3 (high-p_T) to >4 (low-p_T) more precise than 2006 results
  - First experimental evidence for **non-zero gluon polarization** within the RHIC range
- STAR will provide additional high-precision measurements of inclusive jet and dijet A_{LL} during the next few years

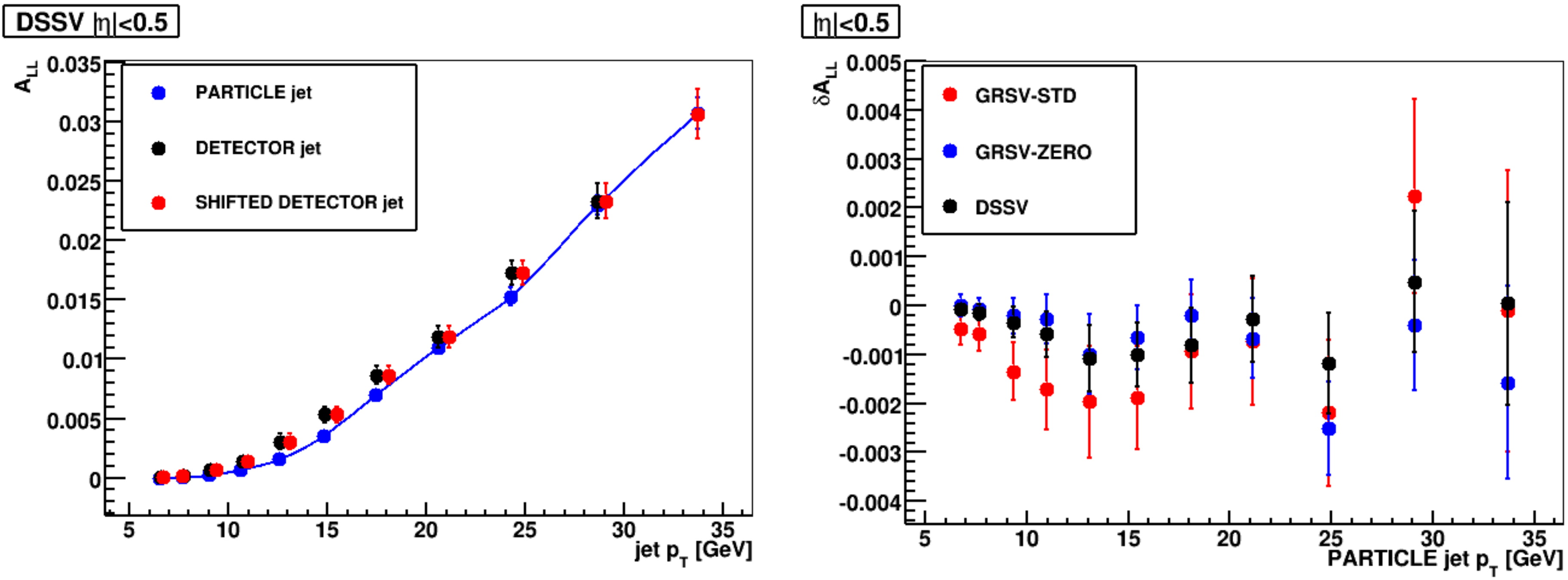
BACKUP

2006 dijet A_{LL}



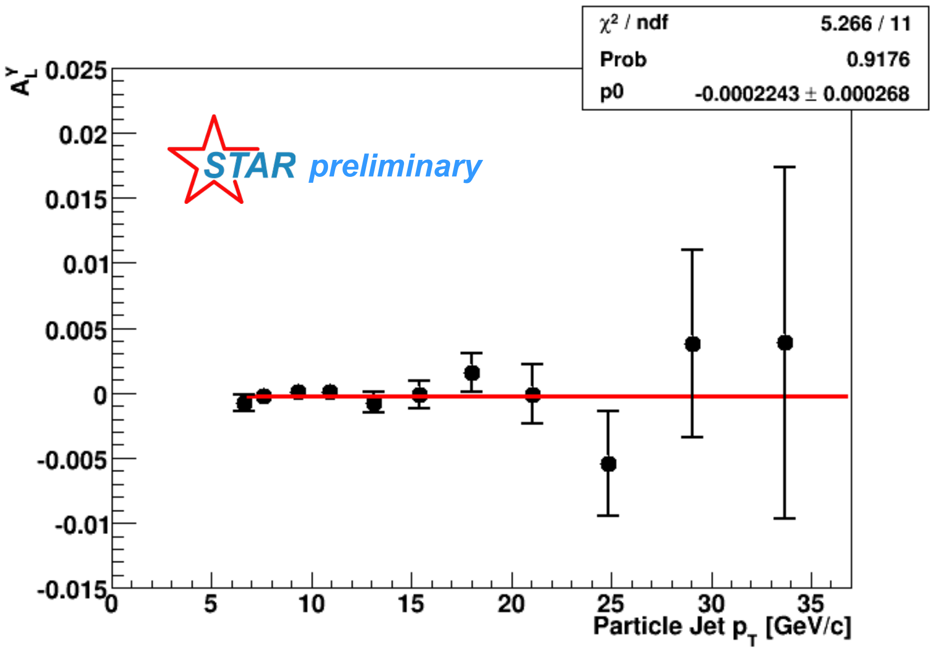
- Systematic uncertainties show effects on trigger of different theory scenarios
- ±8.3% scale uncertainty from beam polarization not shown

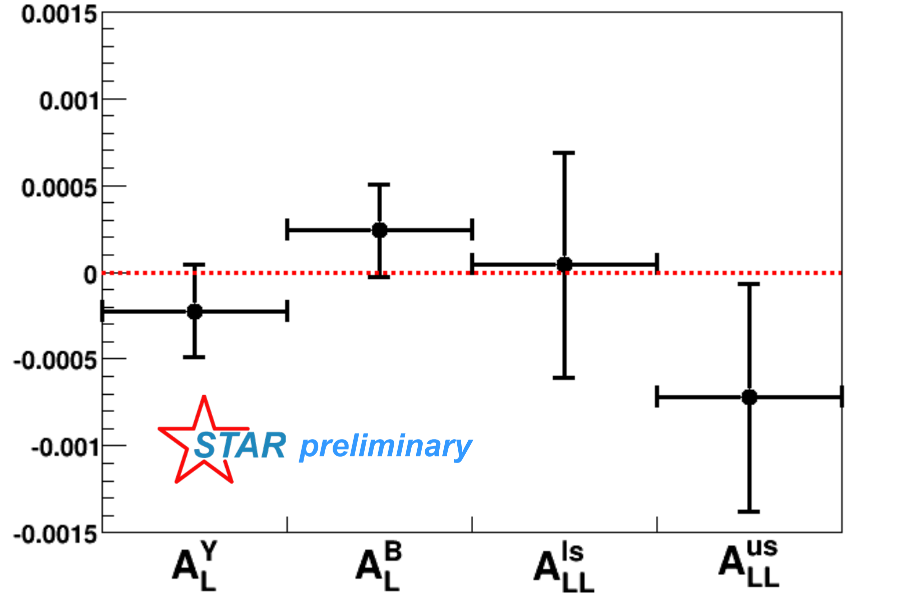
Trigger and reconstruction bias



1. Calculate PYTHIA A_{LL} at PARTICLE jet p_T
2. Calculate GEANT A_{LL} at DETECTOR jet p_T
3. Move GEANT A_{LL} from DETECTOR jet p_T to appropriate PARTICLE jet p_T
4. Calculate δA_{LL}=(PYTHIA-GEANT) A_{LL} $\Rightarrow$ trigger and reconstruction bias

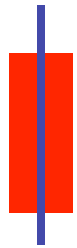
Relative luminosities



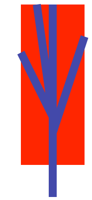


- Relative luminosities are calculated using the beam-beam counters (BBC)
- Relative luminosity systematic from comparisons of BBC and zero-degree calorimeter (ZDC) rates
- Preliminary estimated systematic for A_{LL} (±0.0015) very conservative
- False asymmetries from jet data are consistent with zero

Improvements in jet reconstruction



- 2006 treatment: Subtract MIP from EMC tower when charge track passes through
- Allows to see EM energy emitted very close to charge track
- Makes reconstruction susceptible to fluctuations in charge hadron showering
- Major contribution when jet energies are larger at detector level than particle level



- 2009 treatment: Subtract total charged track momentum from EMC tower when passing through
- Reduces ability to see EM energy emitted close to charge track
- Significantly reduces response to fluctuations from charge hadron showering
- Reduces average difference between jet energies at the detector and particle level

Improves overall jet energy resolution 23% to ~18%