

Gluon polarization and jet production at STAR

Pibero Djawotho *for the STAR Collaboration*

Texas A&M

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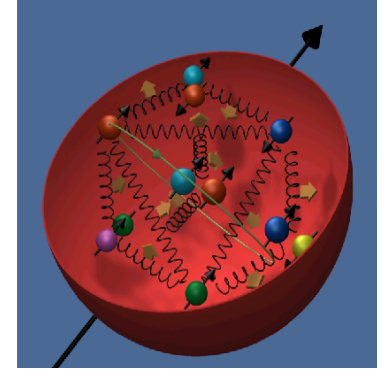


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The proton spin sum rule

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

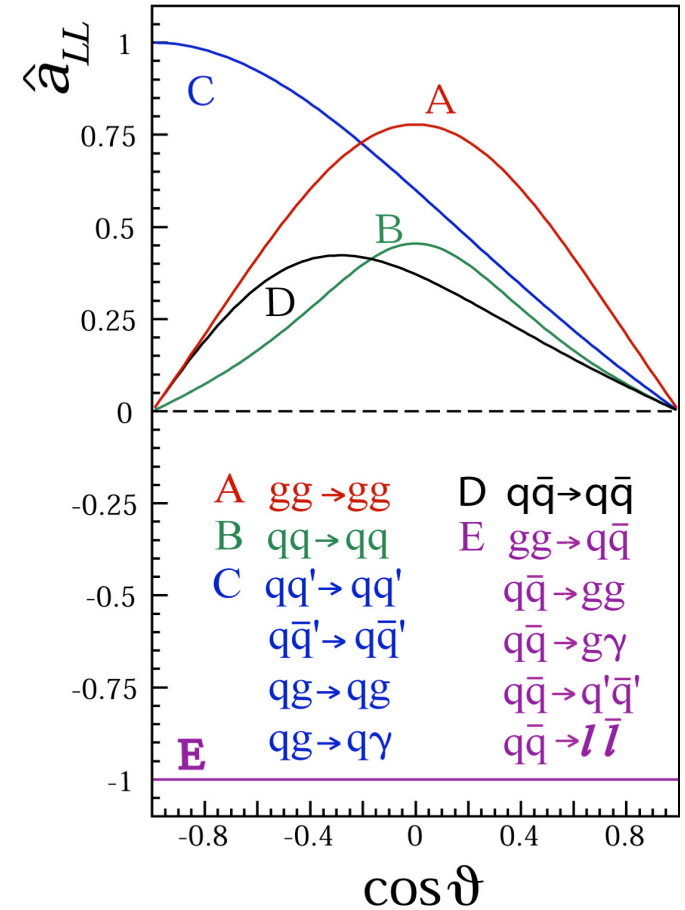
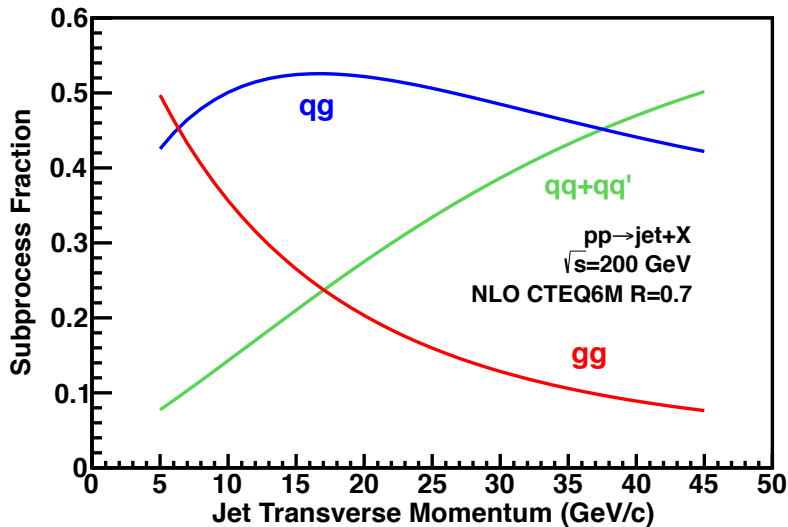
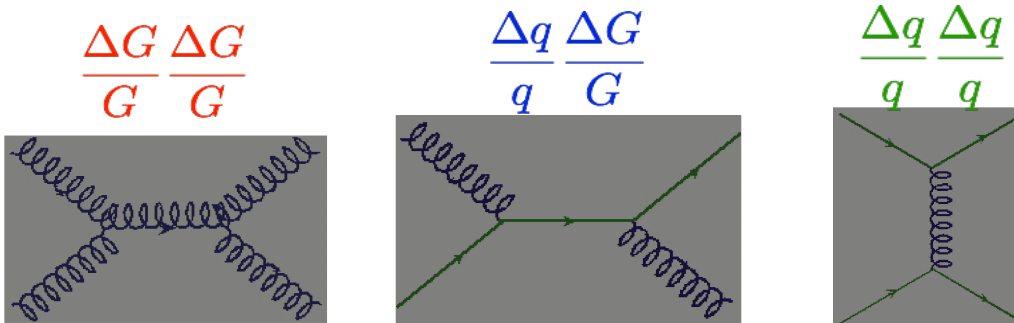


- Quark polarization $\Delta\Sigma \approx 0.3$ from polarized deep inelastic scattering
- Gluon polarization (ΔG) and orbital angular momentum (L) are poorly constrained
- A primary charge of RHIC spin physics \Rightarrow map $\Delta g(x)$

Polarized pp collisions at RHIC

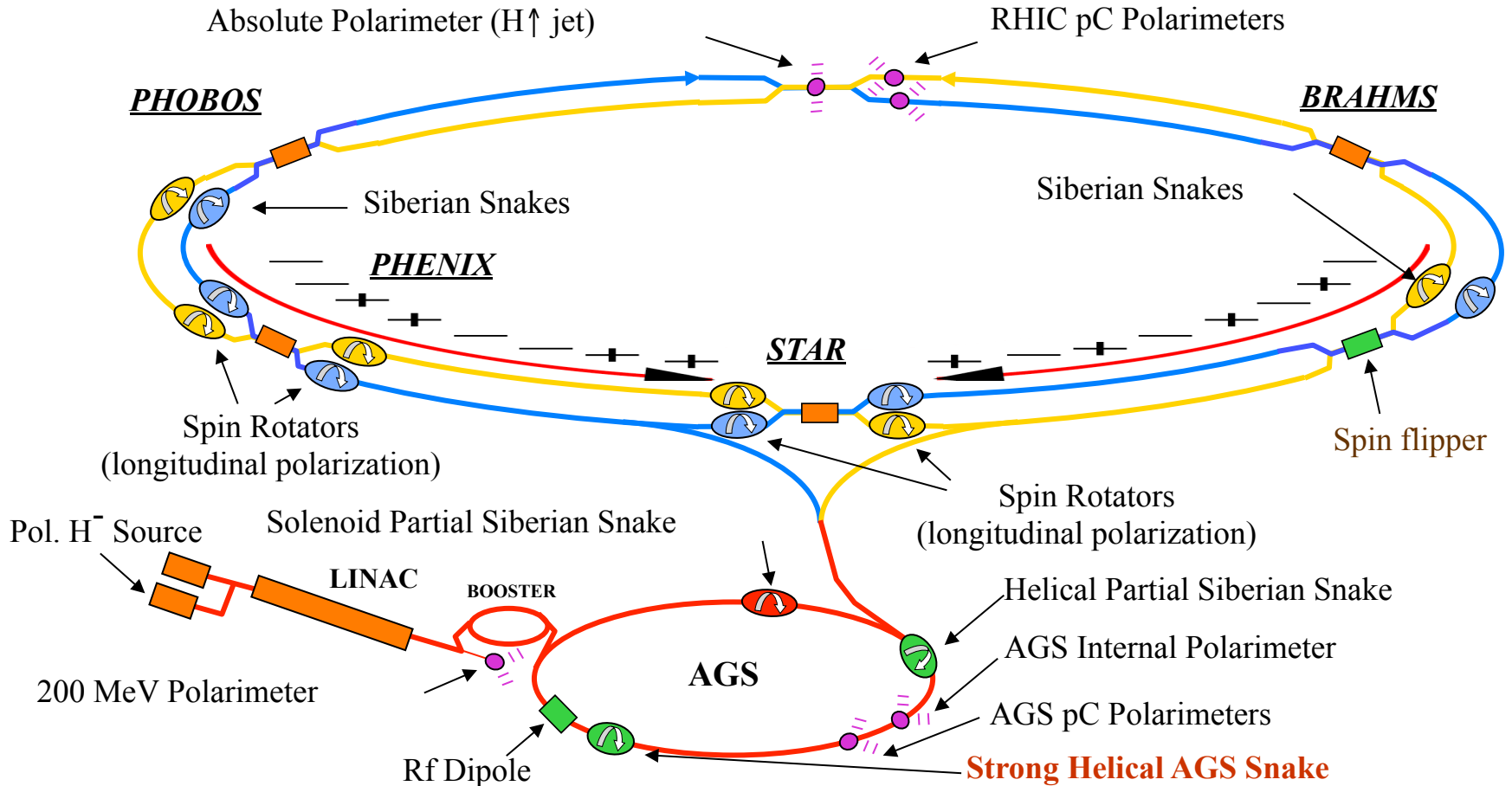
$$A_{LL} = \frac{\sigma^{++} - \sigma^{+-}}{\sigma^{++} + \sigma^{+-}} \propto \frac{\Delta f_a \Delta f_b}{f_a f_b} \hat{a}_{LL}$$

Δf : polarized parton distribution functions



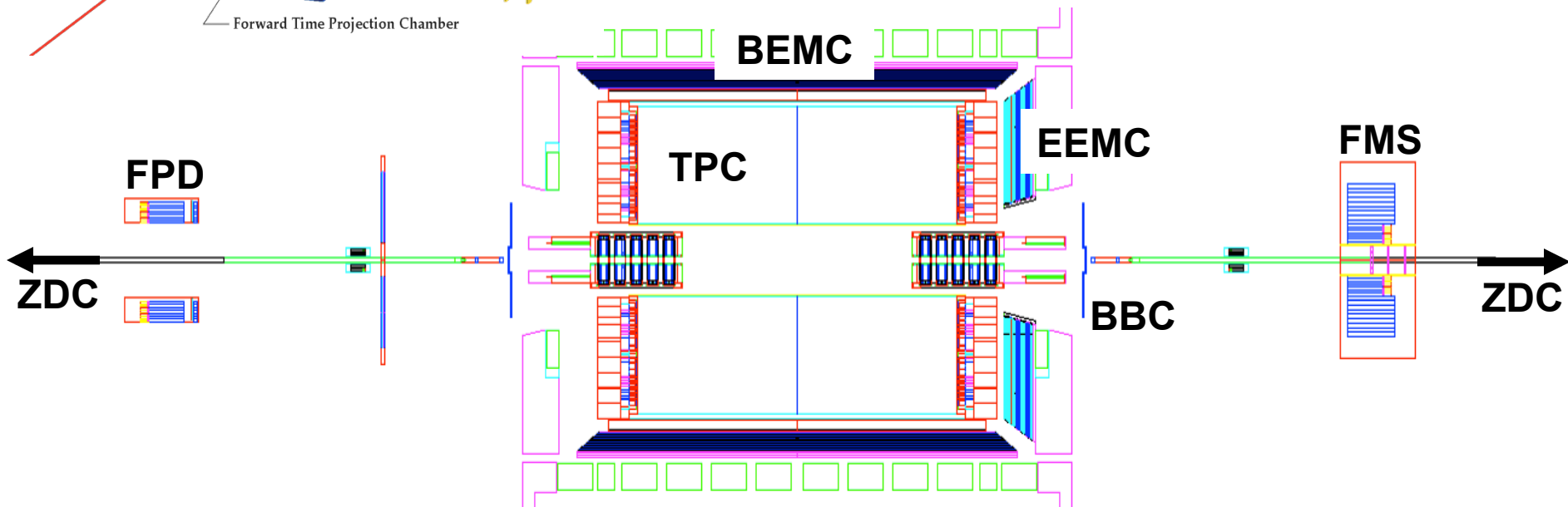
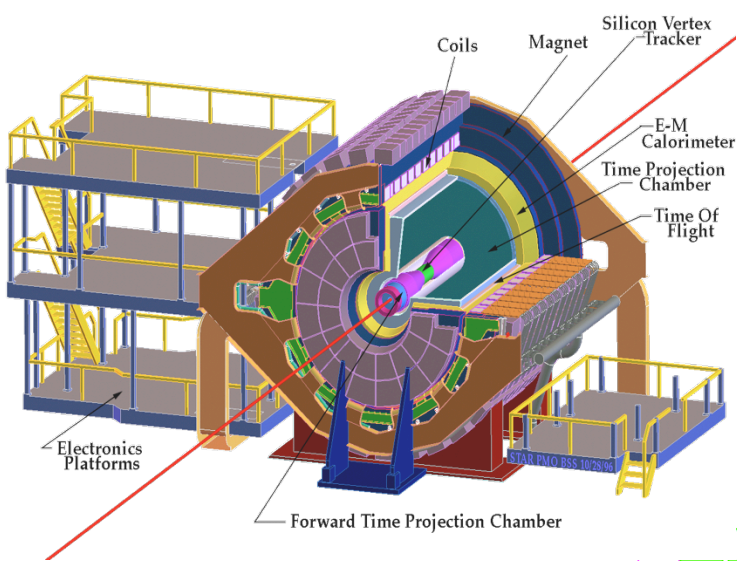
For most RHIC kinematics, **gg** and **qq** *dominate*, making A_{LL} for jets sensitive to **gluon polarization**.

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

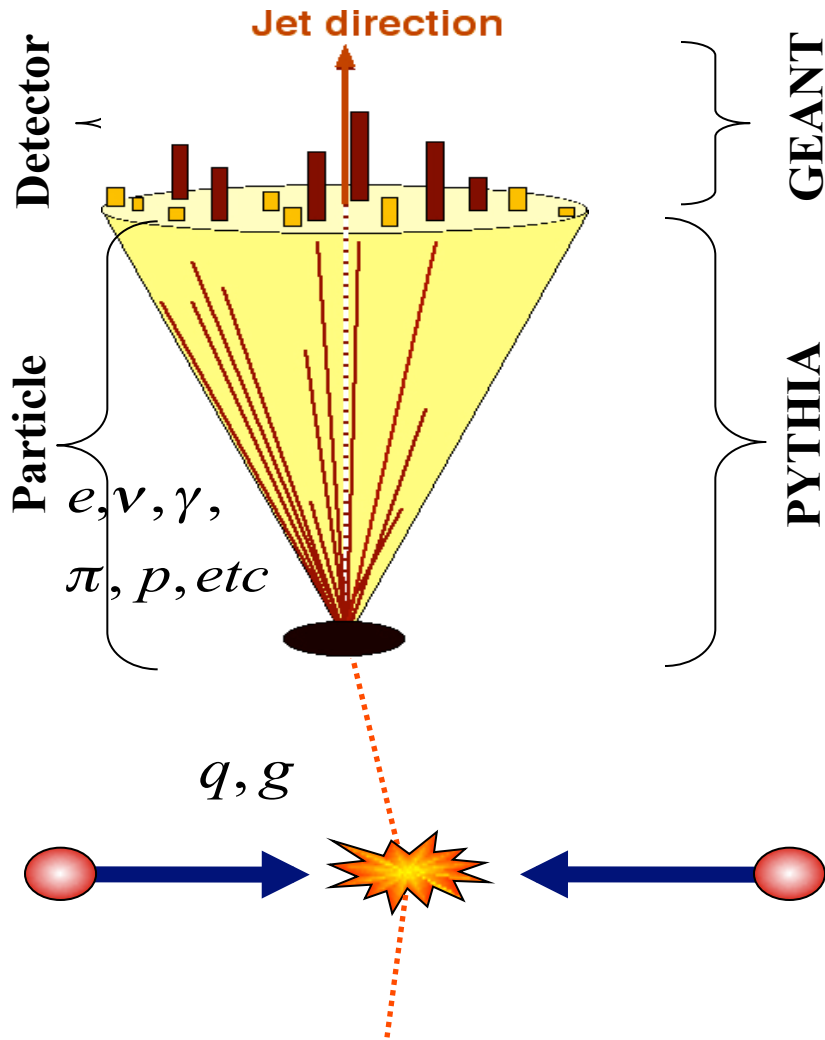
Jet reconstruction in STAR

Data jets

MC jets

Midpoint cone algorithm

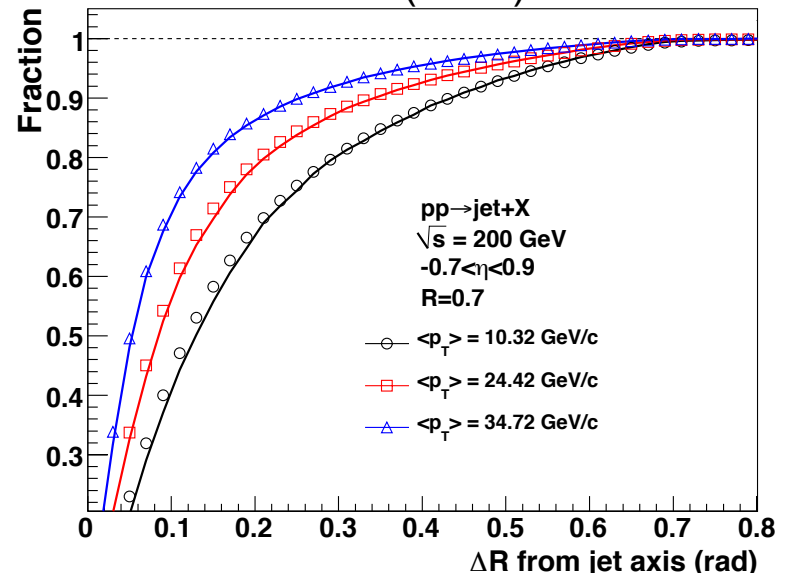
(Adapted from Tevatron II - hep-ex/0005012)



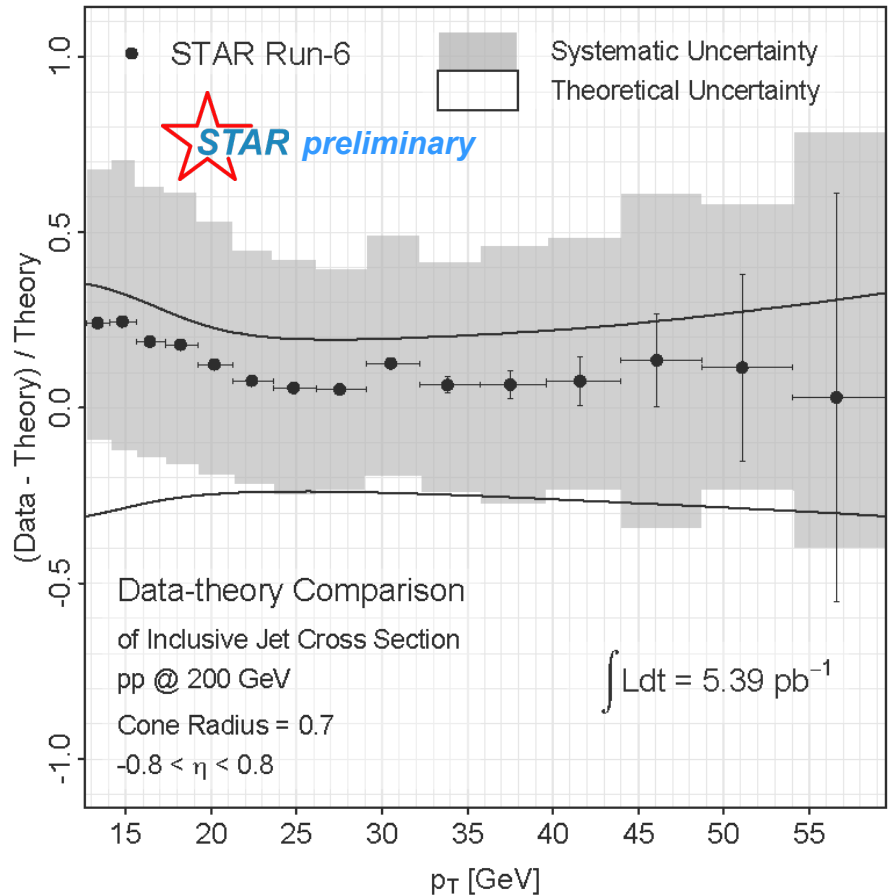
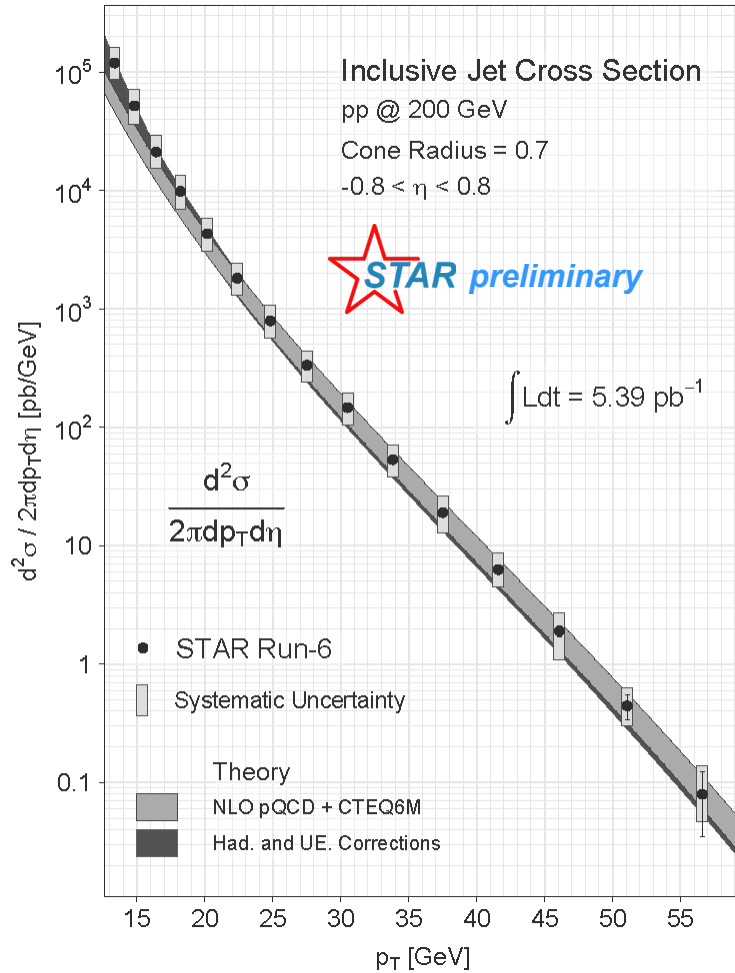
- Seed energy $E_T^{\text{seed}} = 0.5 \text{ GeV}$
- Cone radius $R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.7$
- Split/merge fraction $f = 0.5$

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

PRD **86** 032006 (2012)



2006 inclusive jet cross section

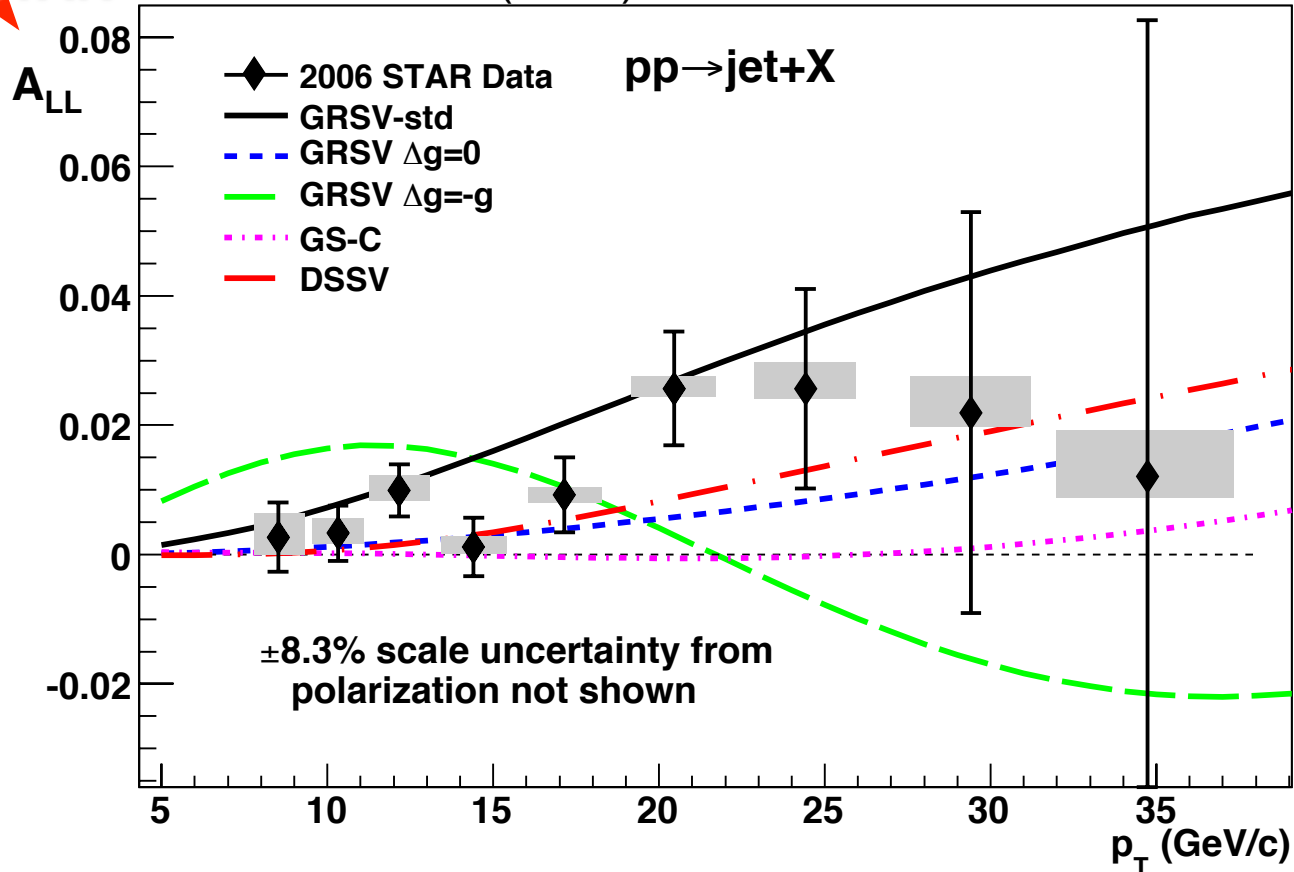


- Data well described by NLO pQCD+Hadronization+Underlying Event

2006 inclusive jet A_{LL}



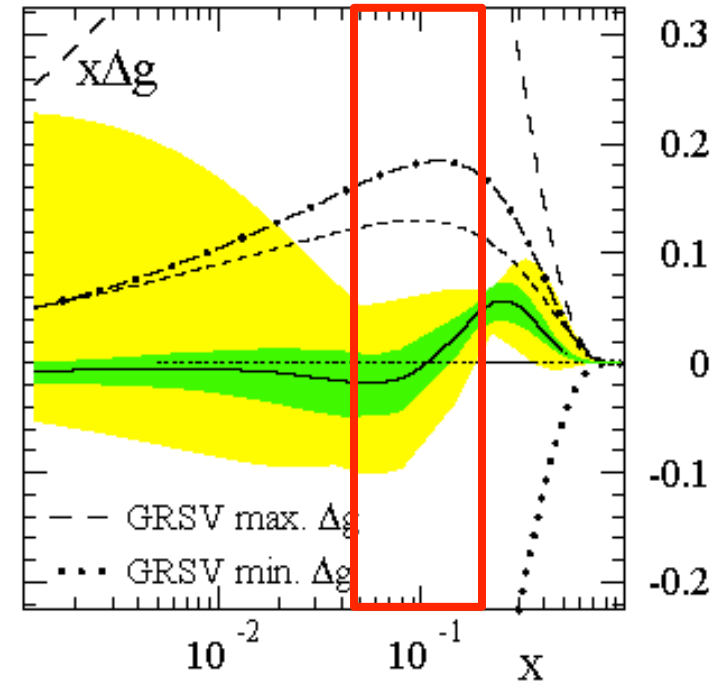
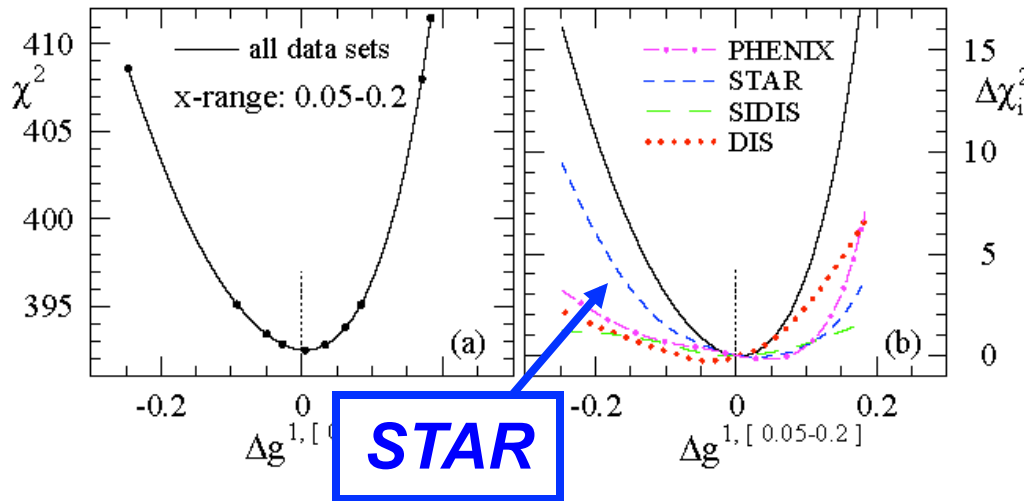
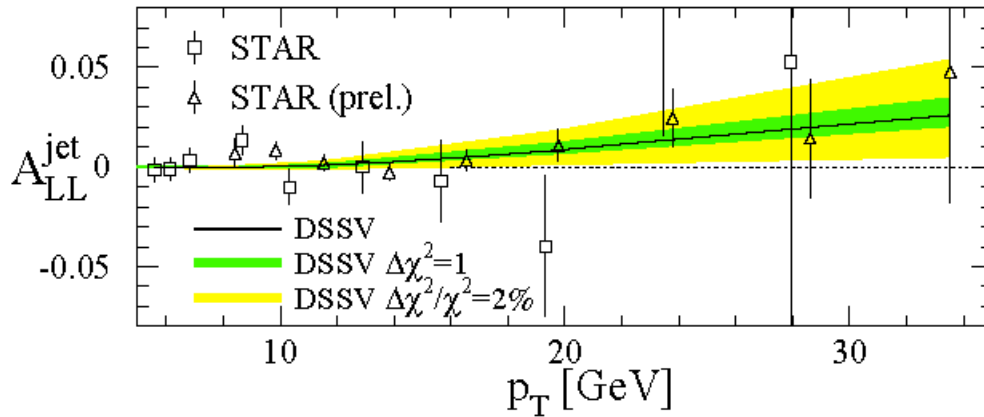
PRD **86** 032006 (2012)



- Sampled 5.5 pb^{-1} at $\sim 57\%$ 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 $x \sim 0.1$

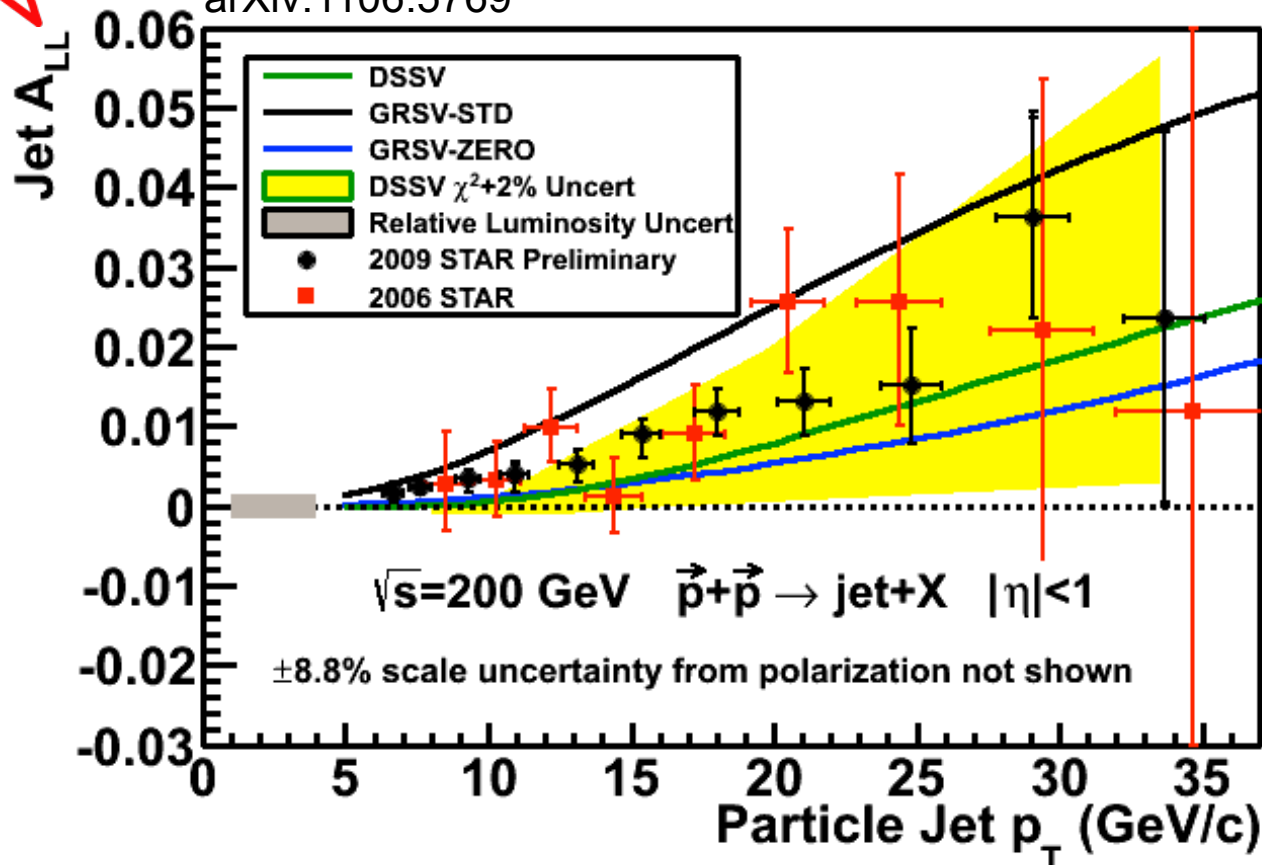
2009 upgrades

- **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

arXiv:1106.5769

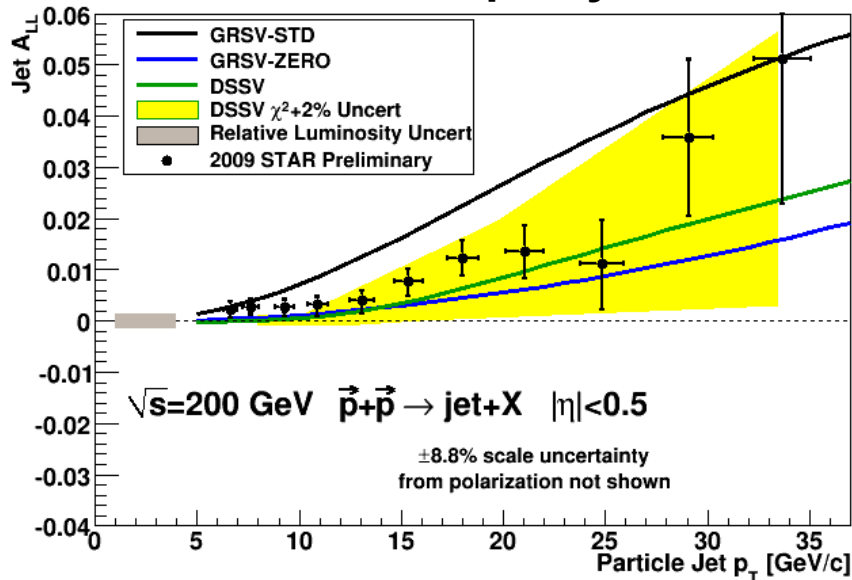


- 2009 STAR data is a factor of 3 (high- p_T) to >4 (low- p_T) more precise than 2006 STAR data
- Results fall between predictions from **DSSV** and **GRSV-STD**
- Precision sufficient to merit finer binning in pseudorapidity

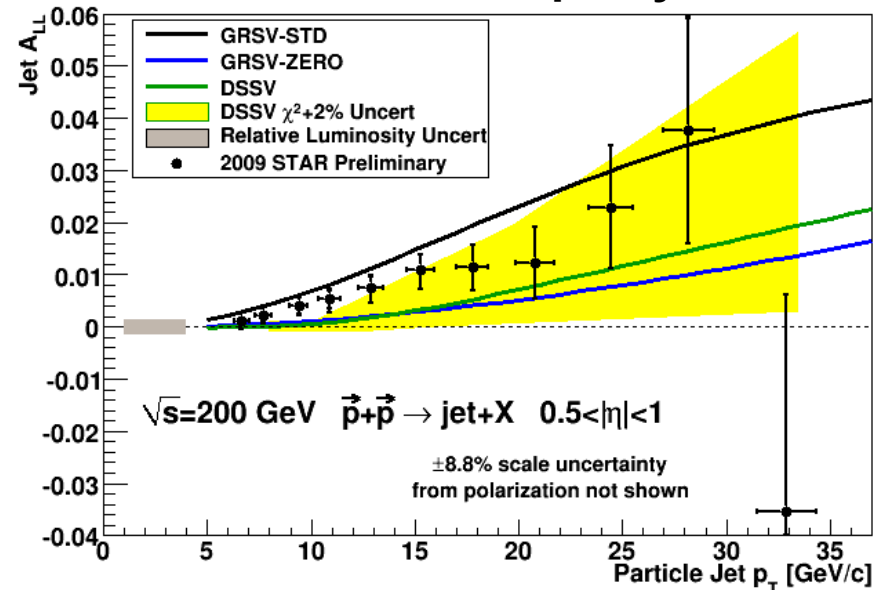
2009 inclusive jet A_{LL}



Mid rapidity



Forward rapidity

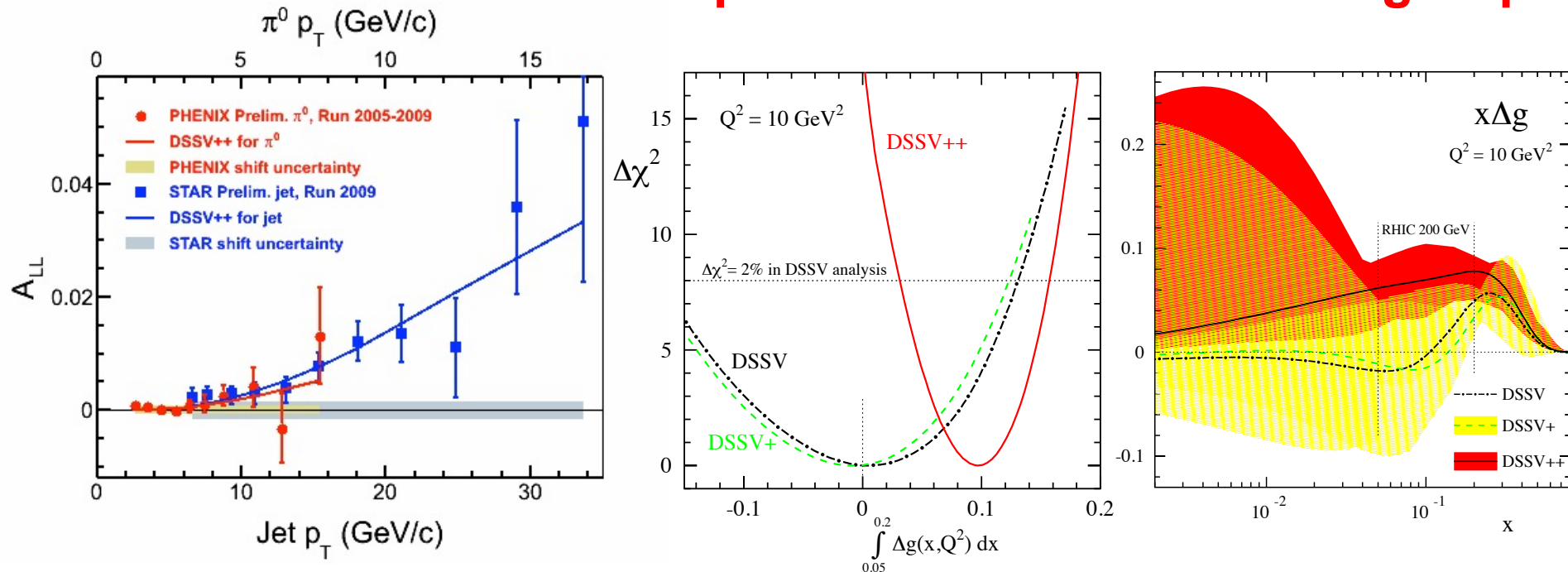


- A_{LL} separated into two pseudorapidity ranges
- Forward jets involve:
 - A larger fraction of quark-gluon scattering with:
 - Higher x quarks that are more polarized
 - Lower x gluons that are less polarized
 - Larger $|\cos(\theta^*)|$, which reduces \hat{a}_{LL}
- A_{LL} falls between the predictions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

New global analysis with 2009 RHIC data

arXiv:1304.0079

Special thanks to the DSSV group!

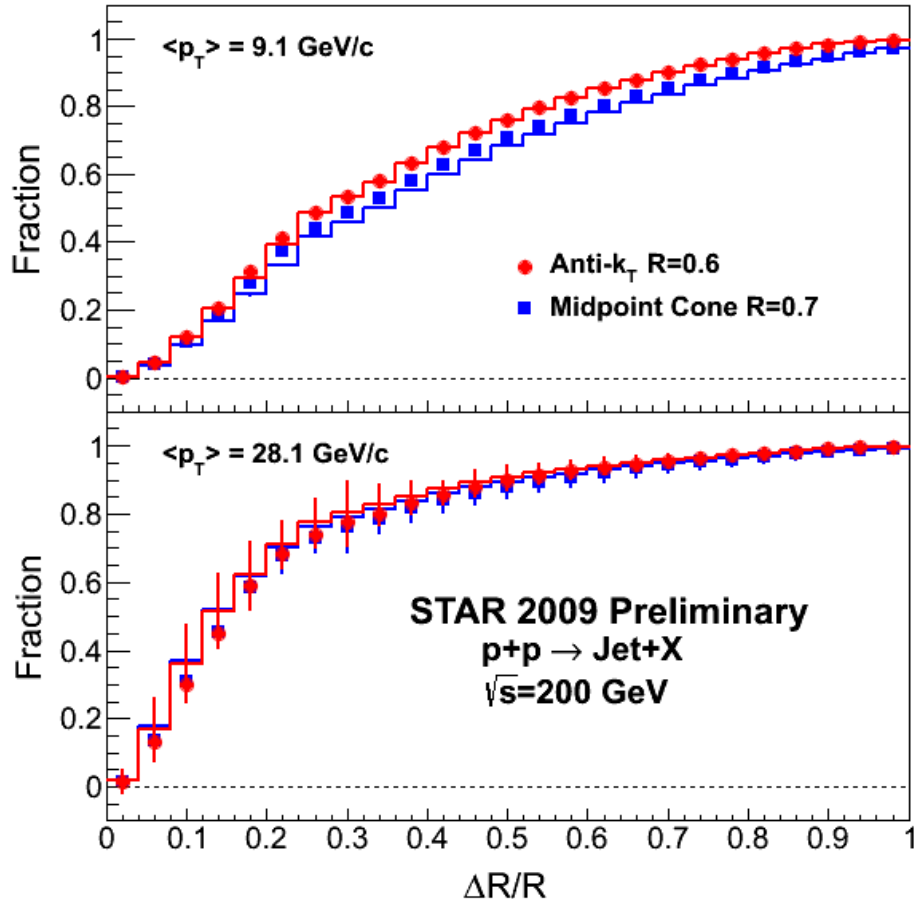


- **DSSV++** is a new, preliminary global analysis from the DSSV group that includes the 2009 RHIC A_{LL} data (STAR inclusive jets and PHENIX π^0 's)

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

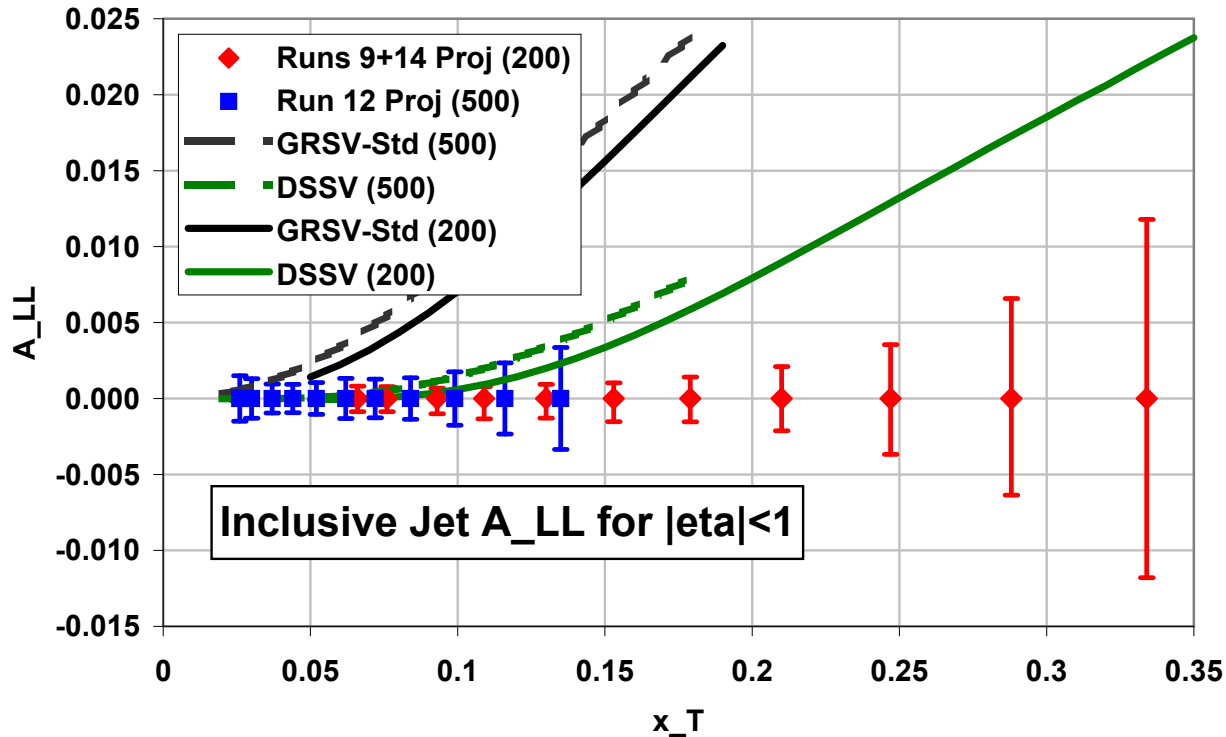
- First experimental evidence of **non-zero $\Delta g(x)$** in RHIC range ($0.05 \leq x \leq 0.2$)

2009: from preliminary towards final



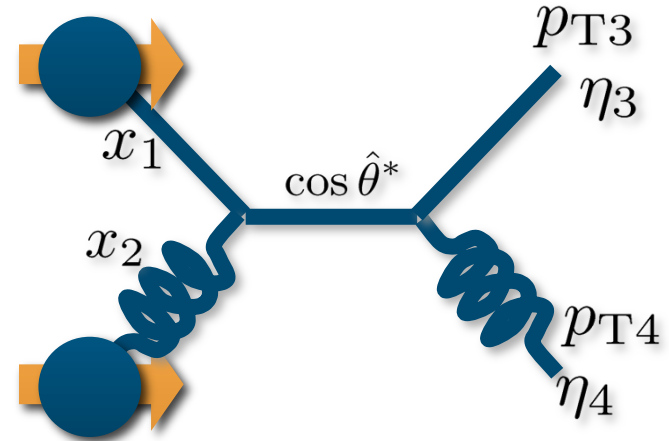
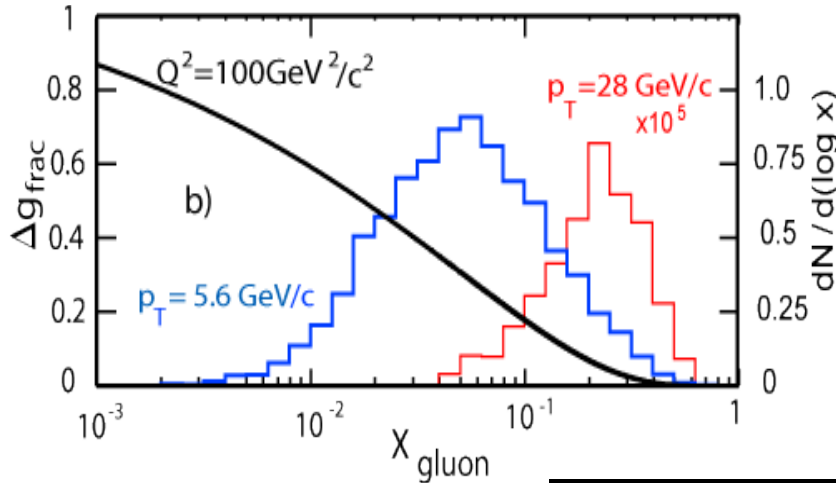
- STAR is switching from the mid-point cone algorithm to the anti- k_T algorithm for the final 2009 inclusive jet A_{LL} measurement:
 - Anti- k_T tends to have a more rigid cone
 - Reconstructed jet energy is less sensitive to nearby underlying event contributions (and pile-up)
- Provides a **significant reduction** in the systematic uncertainties associated with **trigger and reconstruction bias**
- Final results available soon

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

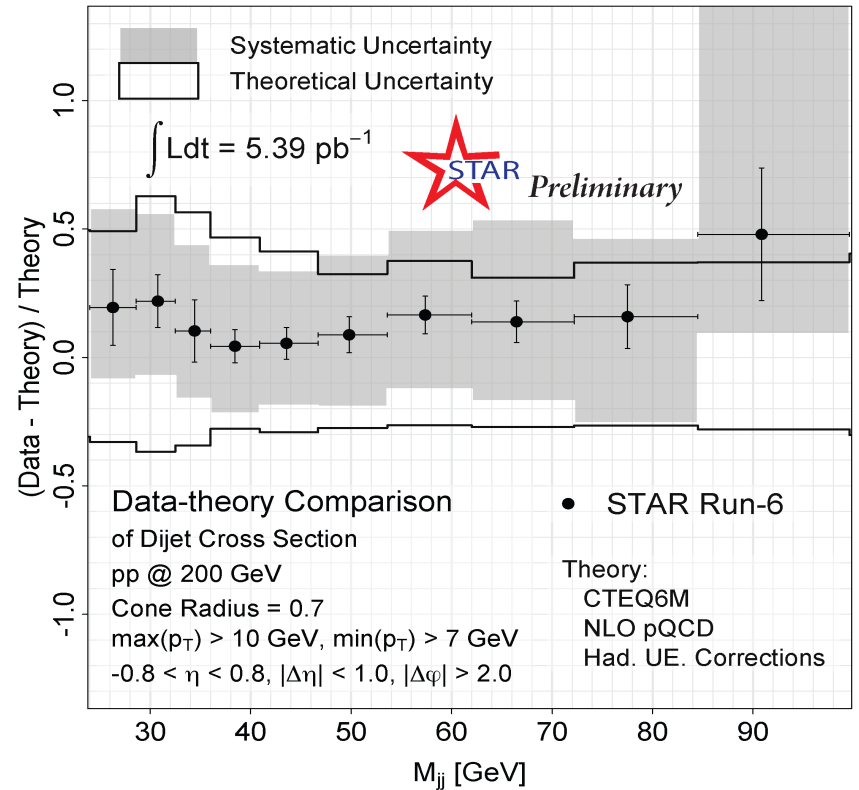
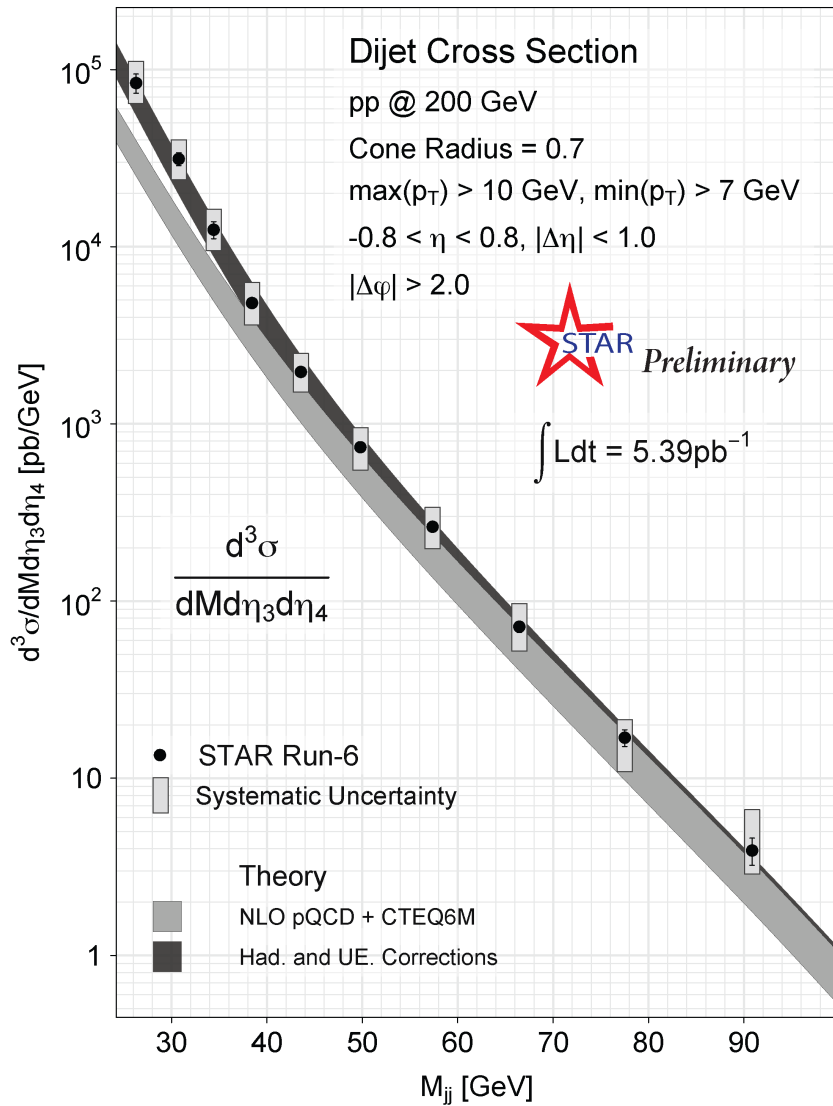


$$x_{1,2} = \frac{1}{\sqrt{s}} \left(p_{T3} e^{\pm\eta_3} + p_{T4} e^{\pm\eta_4} \right)$$

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

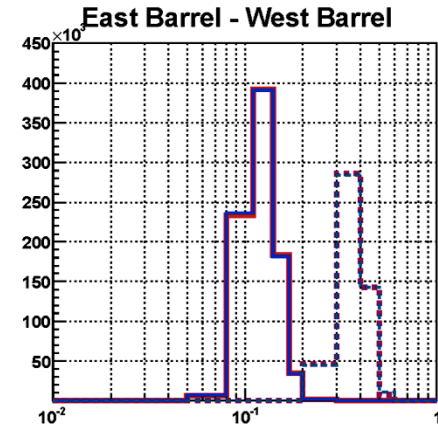
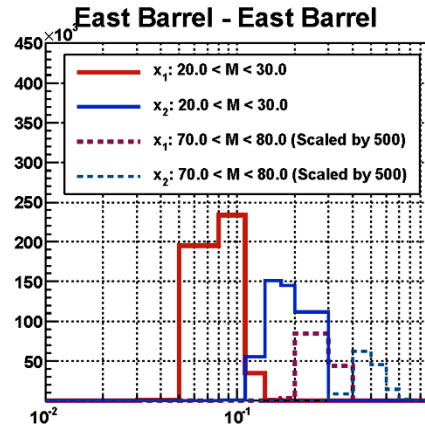
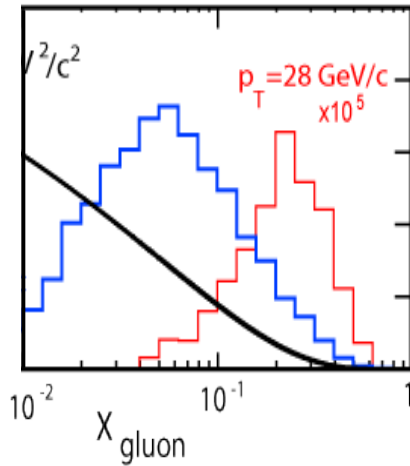
- Inclusive probes at fixed p_T sample broad x range \Rightarrow global analysis needed to disentangle shape of $\Delta g(x)$
- Reconstructing dijet final state (jet p_T and η) provides information on initial parton kinematics ($x_{1,2}$ and $\cos\theta^*$) at LO
- STAR is well suited for correlation 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



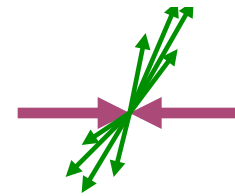
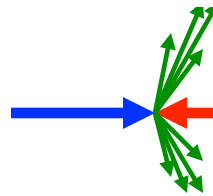
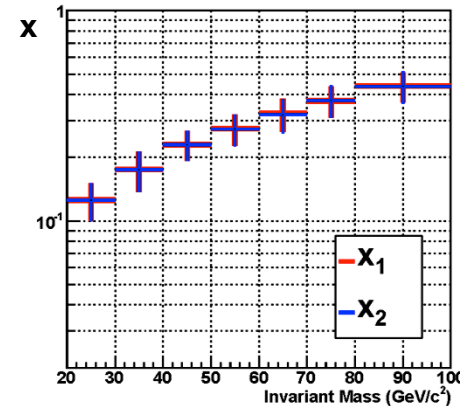
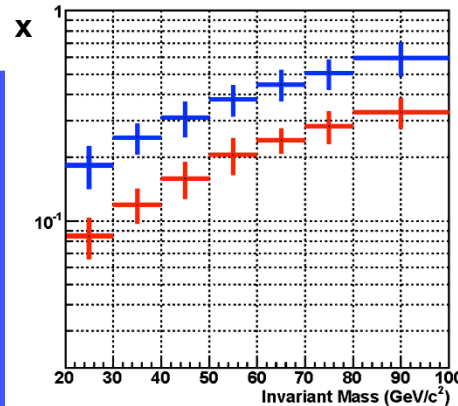
$$x_1 = \frac{1}{\sqrt{s}} (p_{T,3} e^{\eta_3} + p_{T,4} e^{\eta_4})$$

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

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

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

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



2009 dijet A_{LL}

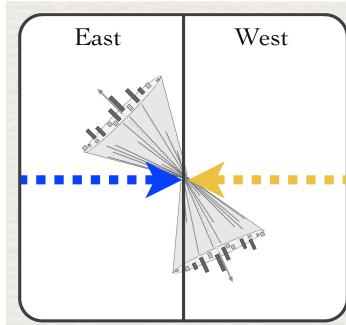
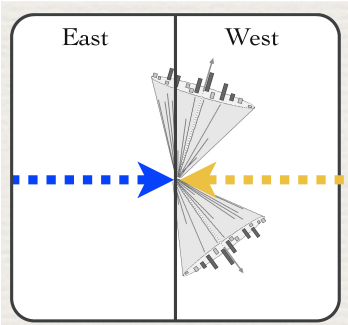
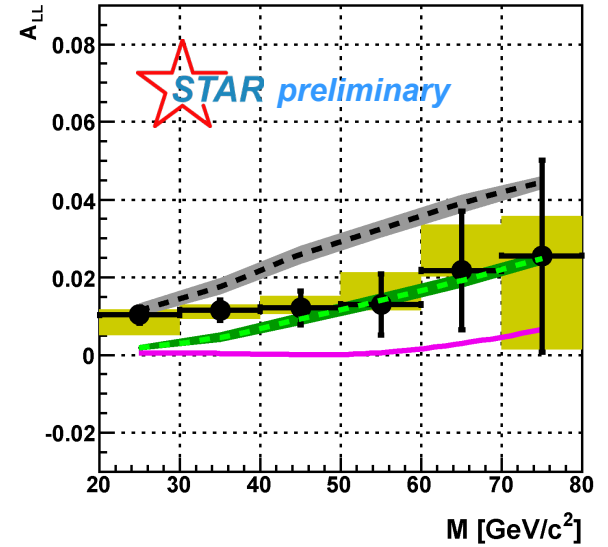
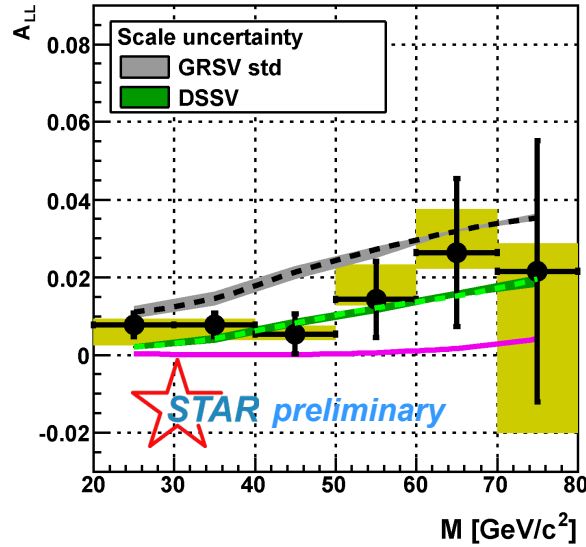
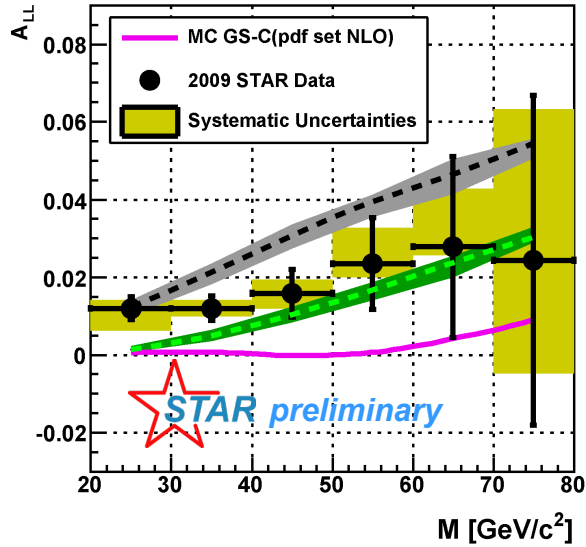


arXiv:1107.0917

East - East and West - West Barrel

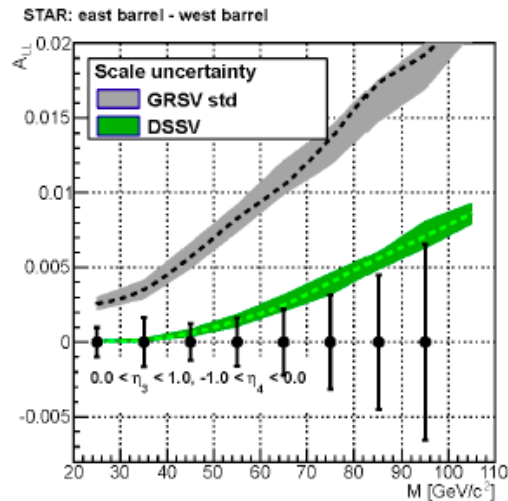
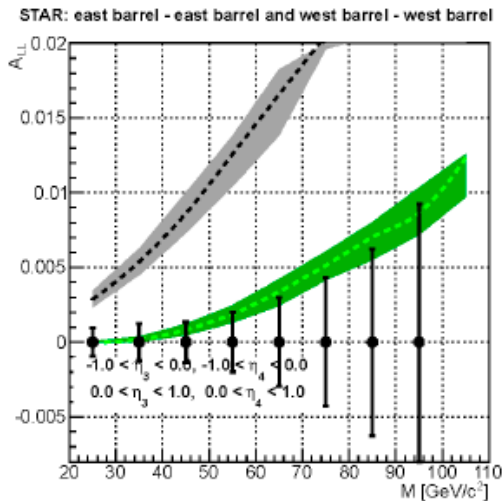
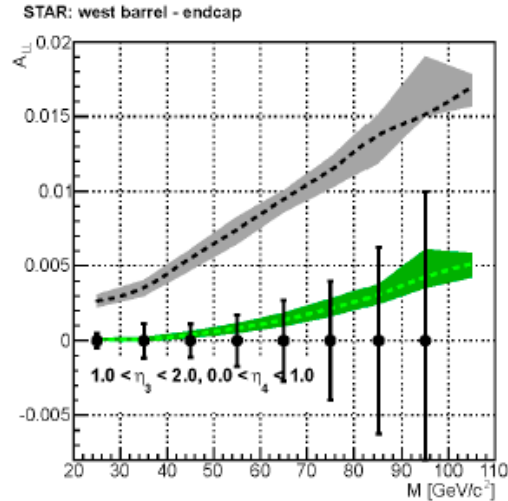
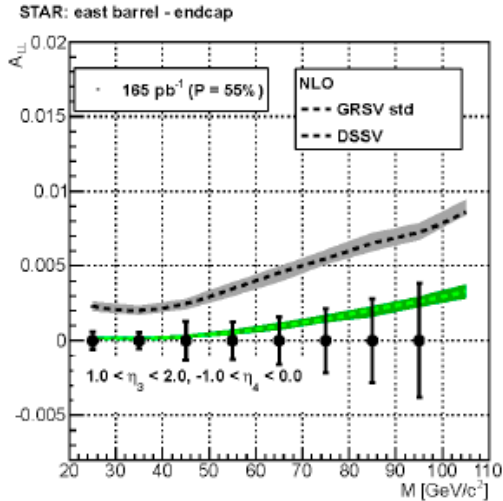
East Barrel - West Barrel

Full Acceptance



- 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 ongoing 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 ($0.05 \leq x \leq 0.2$)
- STAR will provide additional high-precision measurements of inclusive jet and dijet A_{LL} during the next few years