Inclusive A_{LL} Measurements at STAR

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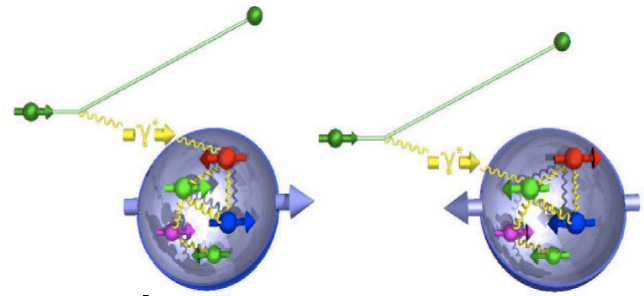
for the STAR Collaboration

LLWI 2009

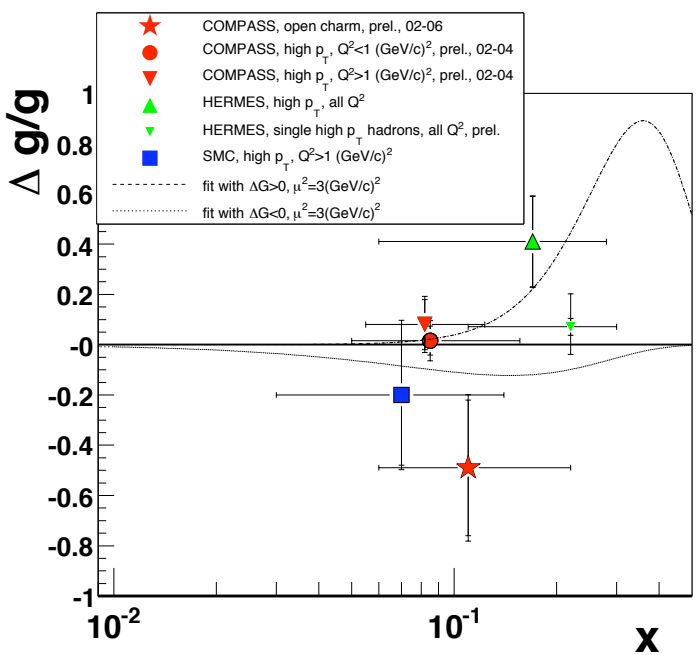
- Introduction
- STAR detector
- Review of Results
- Plans for the Future

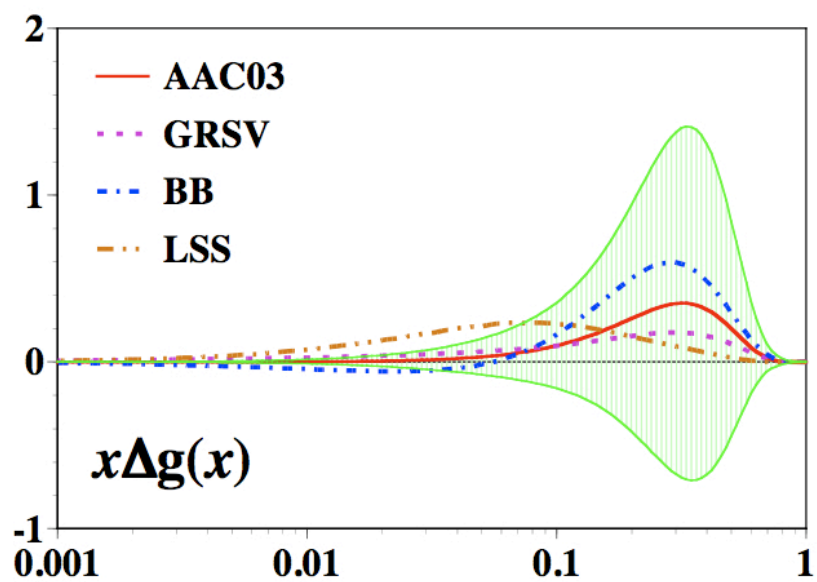
Asymmetries Access Spin Degrees of Freedom

- Polarized DIS determines quark spin contributes ~30% of proton's spin



- Polarized gluon distribution not as well constrained
- Global analyses including pDIS data have large uncertainties ⇒ need direct access to gluons!





Asymmetries Access Spin Degrees of Freedom

Take the asymmetry of proton helicity configurations

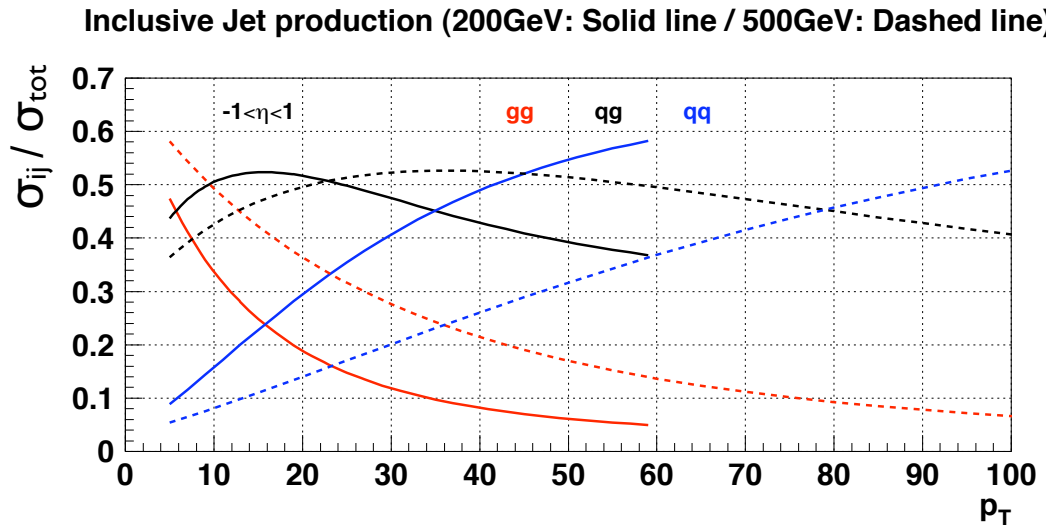
 versus 

In the case of inclusive jets or hadrons:

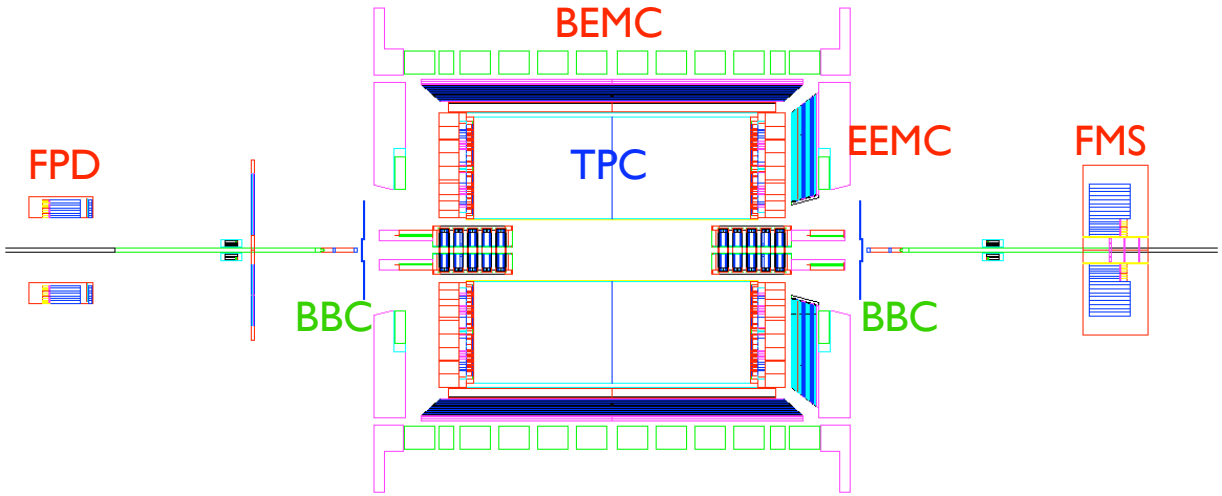
$$A_{LL} = \frac{\sigma^{++} - \sigma^{+-}}{\sigma^{++} + \sigma^{+-}} = \frac{\sum_{a,b,c} \Delta f_a \otimes \Delta f_b \otimes d\hat{\sigma}^{f_a f_b \to f_c X} \cdot \hat{a}_{LL}^{f_a f_b \to f_c X} \otimes D_{f_c}^{h}}{\sum_{a,b,c} f_a \otimes f_b \otimes d\hat{\sigma}^{f_a f_b \to f_c X} \otimes D_{f_c}^{h}}$$

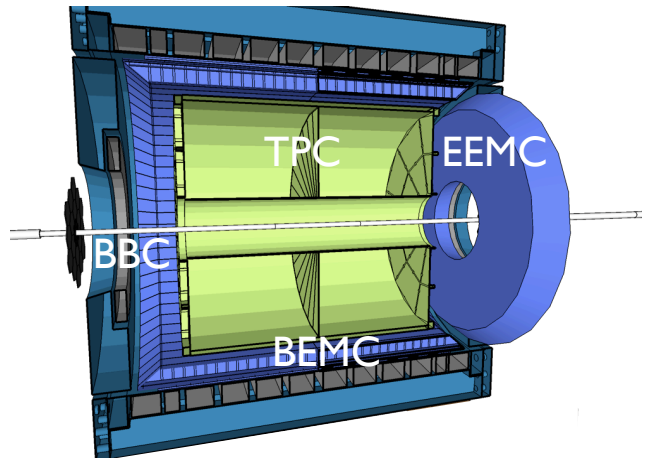
In simplified terms: $A_{LL} \approx a_{gg}\Delta g^2 + a_{qg}\Delta q \Delta g + a_{qq}\Delta q \Delta q'$

At RHIC kinematics, gg and qg scattering dominate



Solenoidal Tracker at RHIC





Beam Beam Counters

- Scintillator annuli
- $2 < |\eta| < 5$
- relative luminosities
- minimum bias trigger

EM Calorimetry

- triggering
- reconstruction of jets / π^0 / γ

Forward Pion Detector	$-4.1 < \eta < -3.3$
Barrel EM Calorimeter	$-1 < \eta < 1$
Endcap EM Calorimeter	$1.09 < \eta < 2$
Forward Meson Spec.	$2.5 < \eta < 4.0$

Time Projection Chamber

- charged particle tracking for jets, π
- $|\eta| < 1.3$
- PID via dE/dx up to 15 GeV/c

Inclusive A_{LL} Measurements

- Reconstruct a piece of final state without considering full event structure
- Larger cross section in our acceptance than correlation or exclusive measurements
- Integrate over multiple subprocesses
- Limited knowledge of initial parton kinematics

Jets

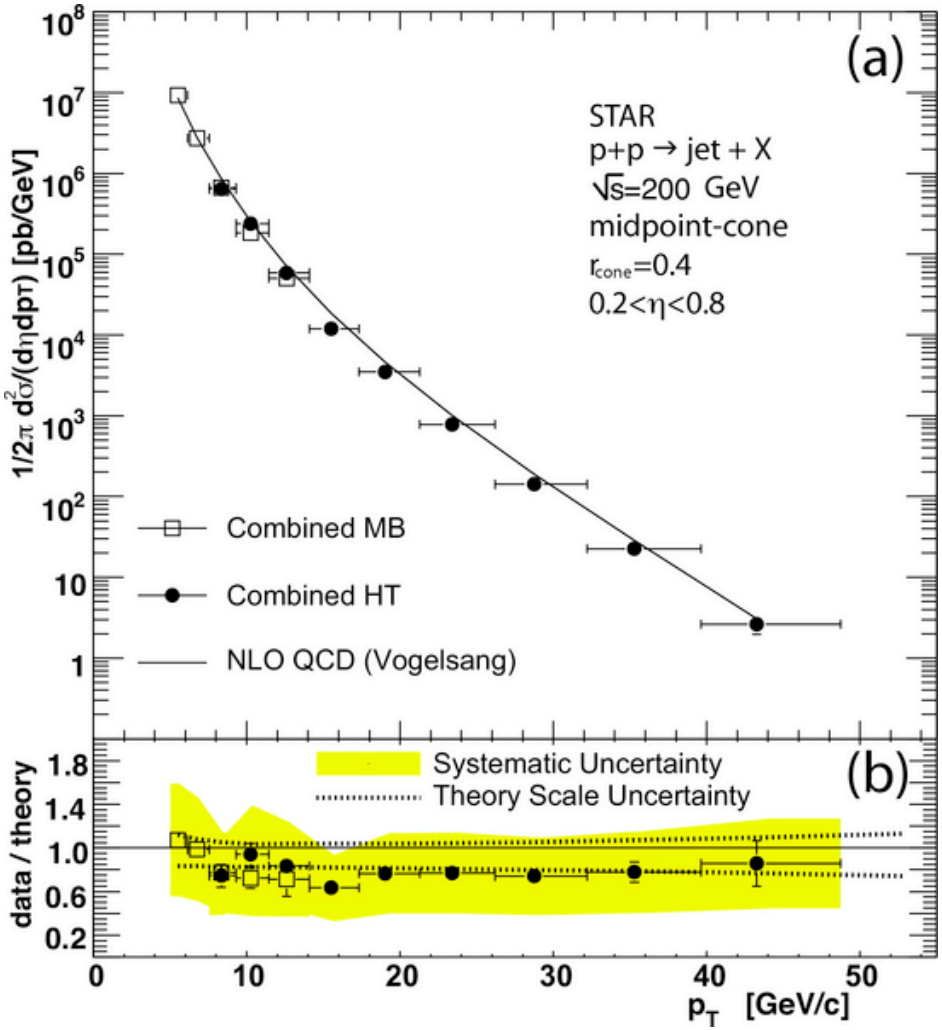
- No fragmentation functions
- Jet definition complicates relation between theory and experiment
- Jet Energy Scale can be a significant uncertainty

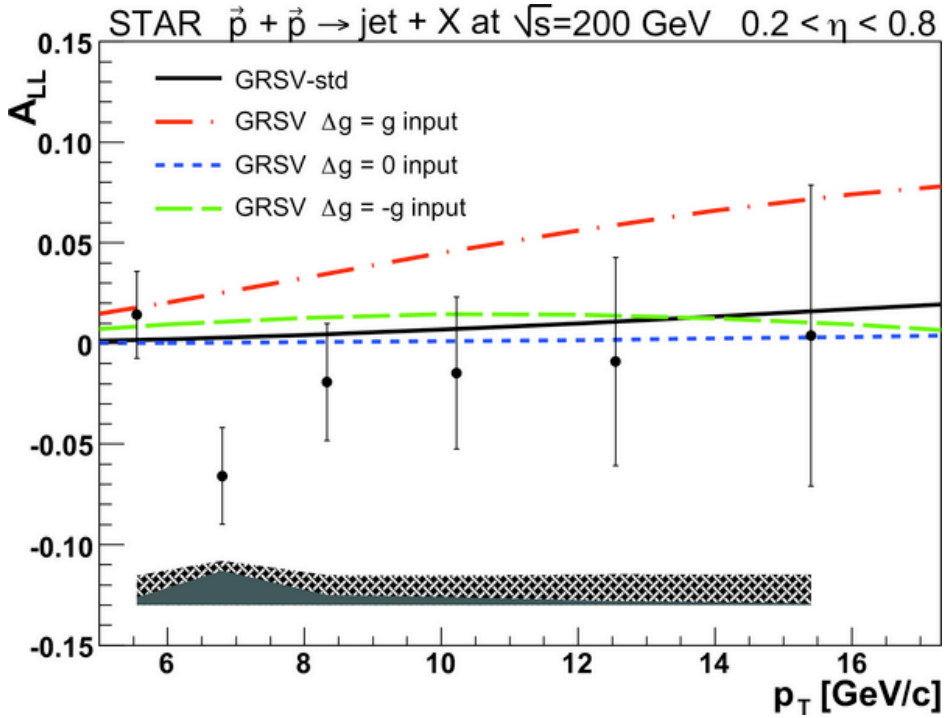
Hadrons

- Need a convolution with FFs
- But this can enable some subprocess selectivity
- Less uncertainty in p_T measurement

2003/04 Inclusive Jet Results

- First jet cross section and longitudinal spin result from STAR





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2005/06 Inclusive Jet A_{LL}

- 2005: Δg over $0.02 < x < 0.2$ smaller than GRSV-STD

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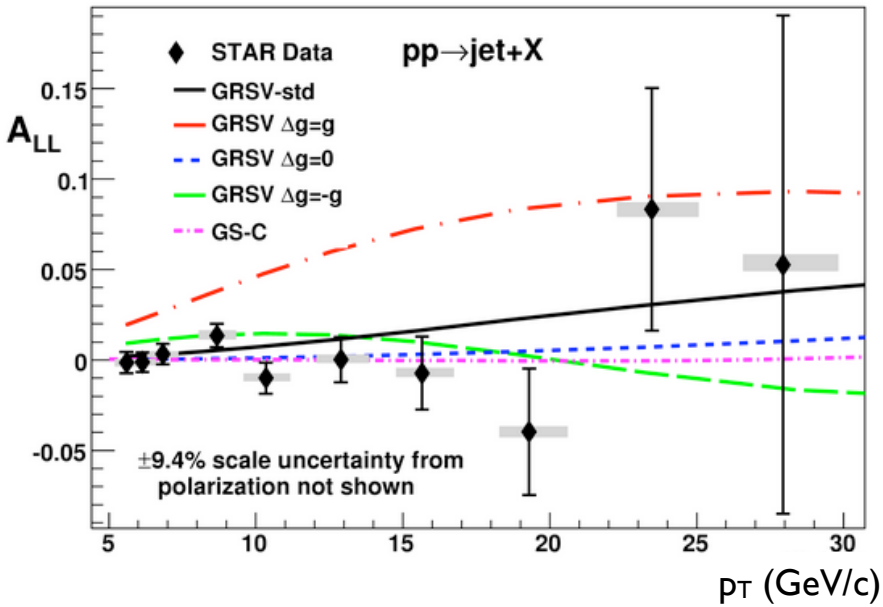

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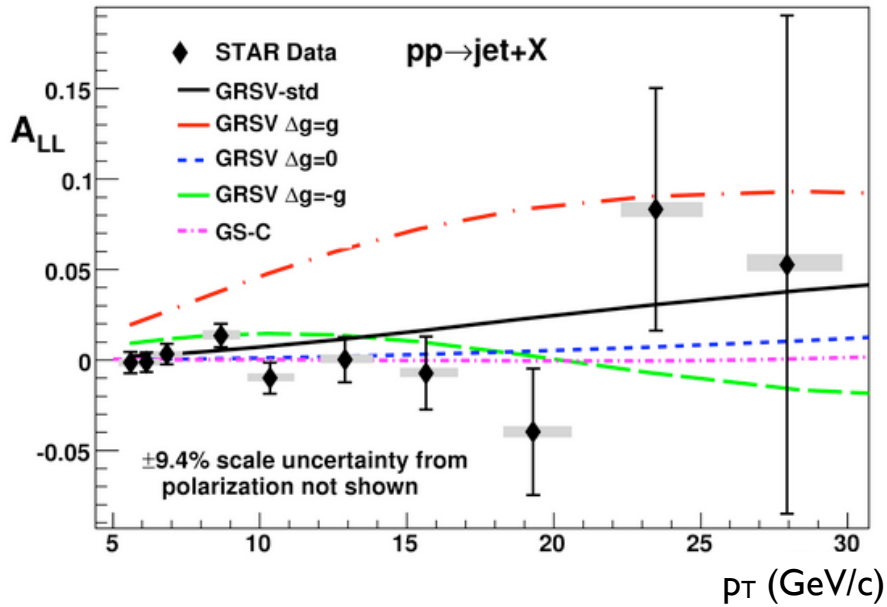

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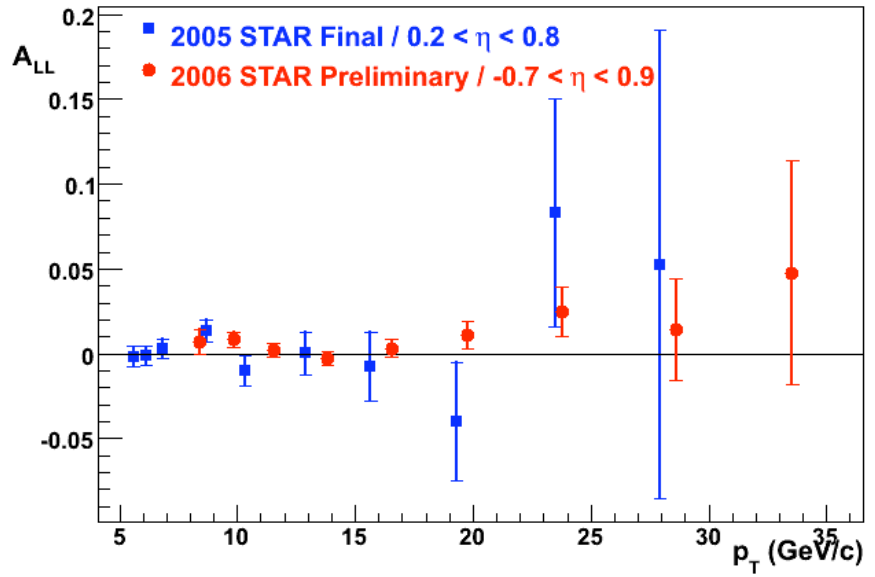

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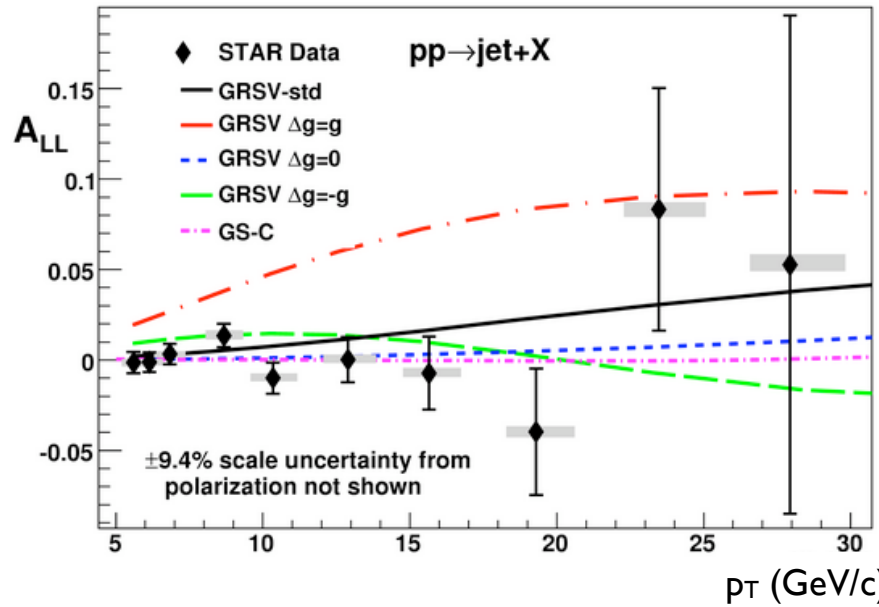

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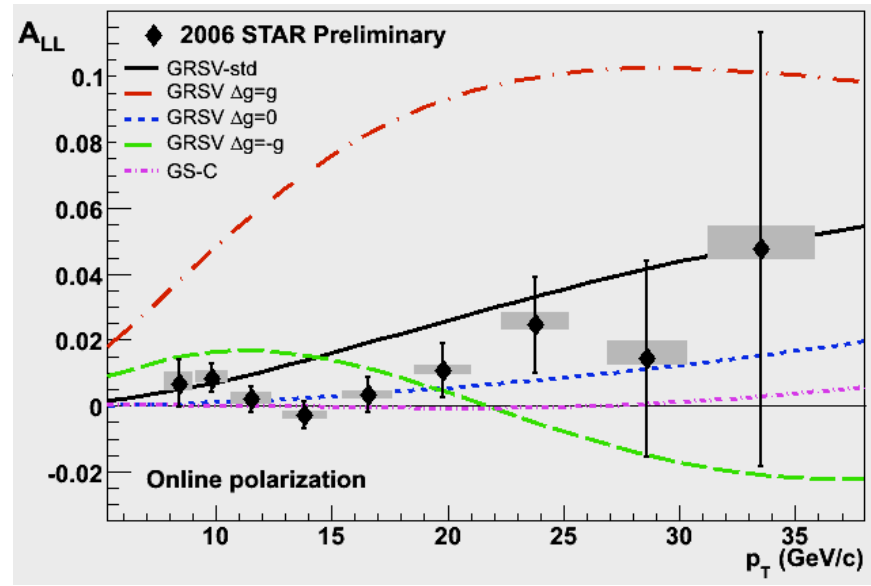

2005/06 Inclusive Jet A_{LL}

- 2005: Δg over $0.02 < x < 0.2$ smaller than GRSV-STD
- 2006: full BEMC, 10x better statistics in some p_T bins
- Confidence levels calculated using available fits and 05+06 data
- Many PDFs with large ΔG ruled out
- Exception: GS Set C, which has $\Delta G \sim 1.0$ but a node in the x range sampled by inclusive jets

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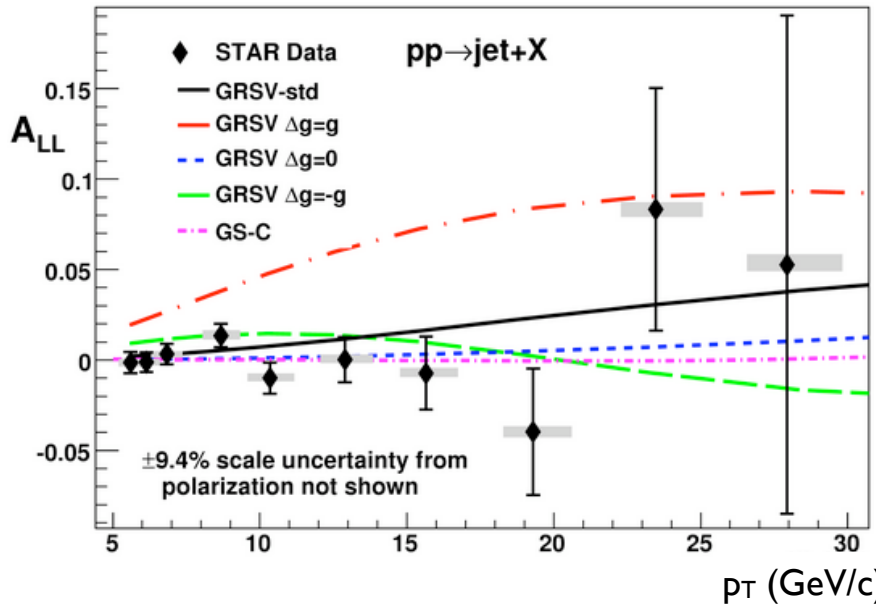

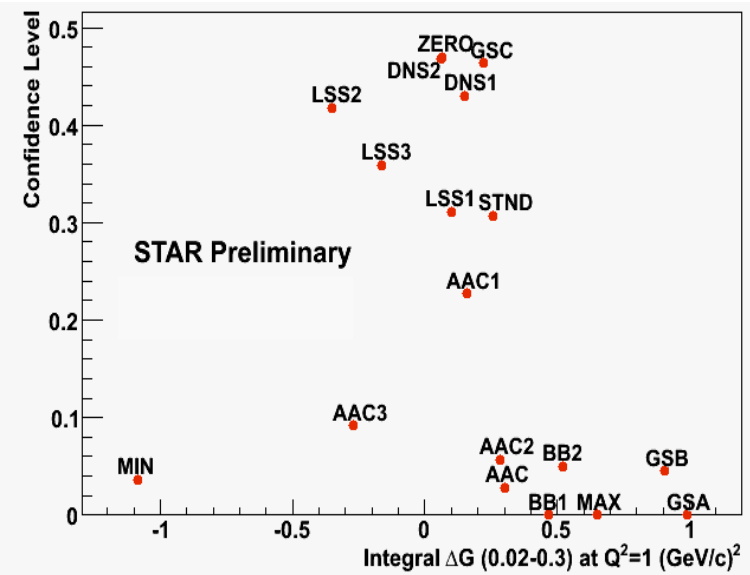

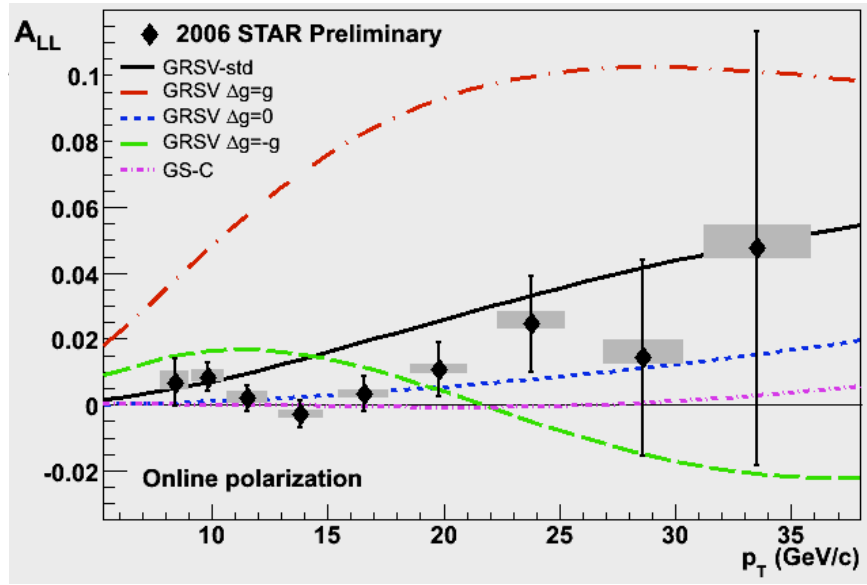

Impact on Global Fits

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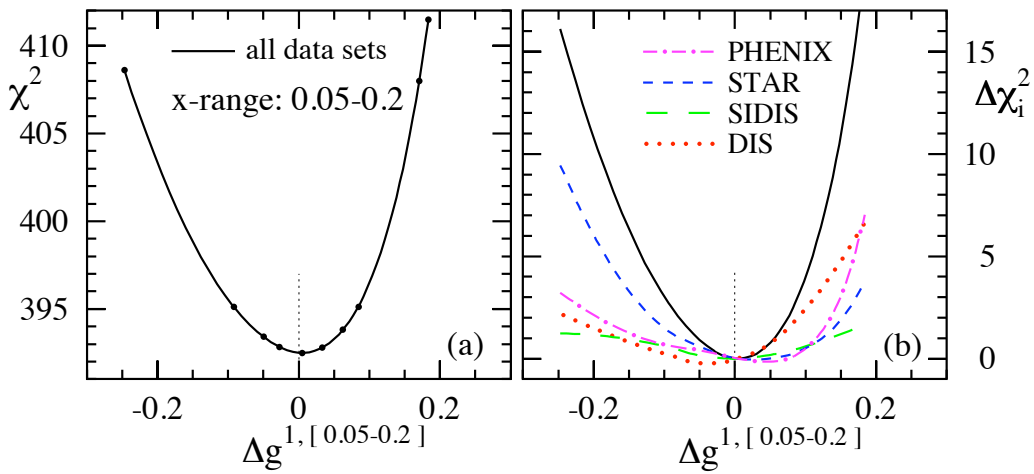

- STAR inclusive jets provide a strong constraint on Δg over $0.05 < x < 0.2$
- Data favor a small gluon polarization over this limited range
- Future measurements must increase the sampled x range and map the x dependence of Δg

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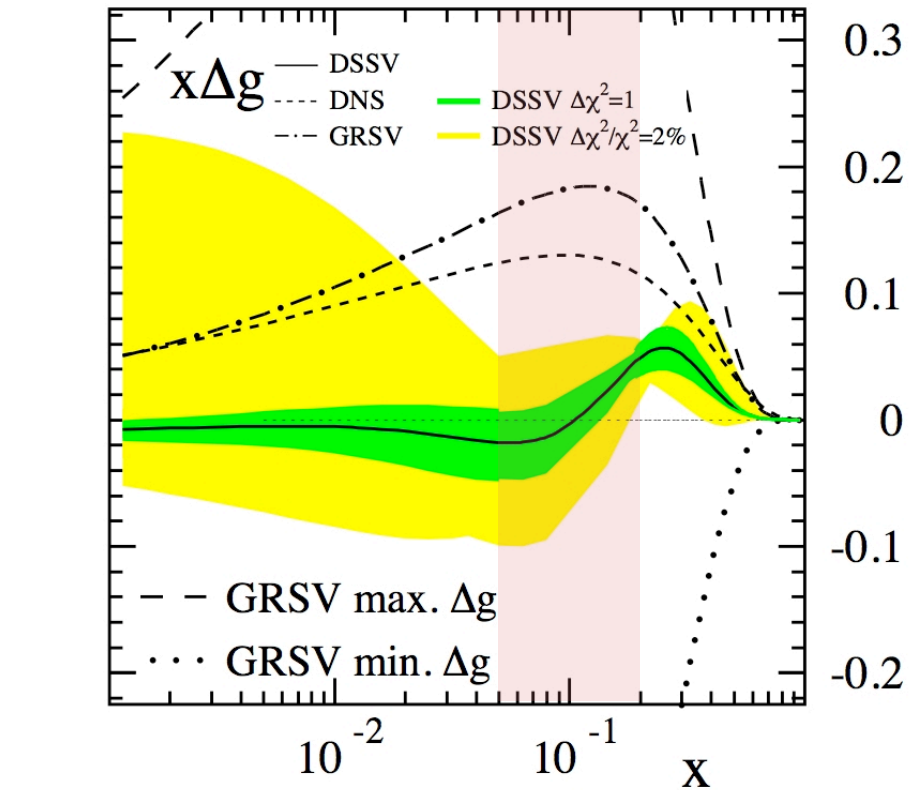

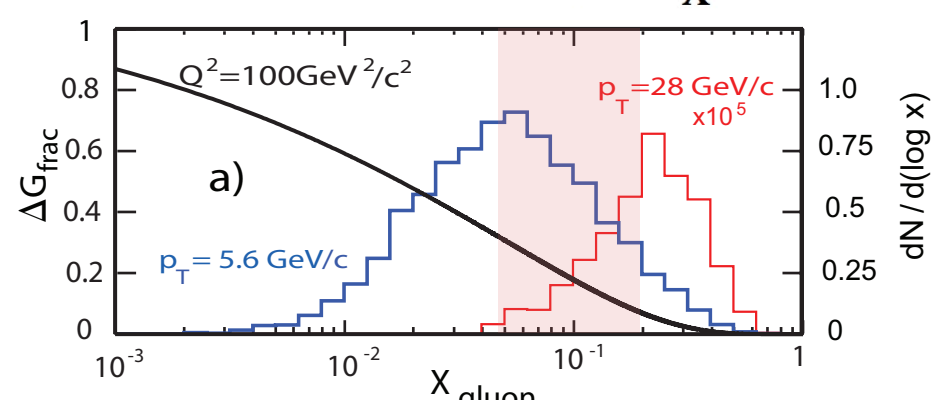

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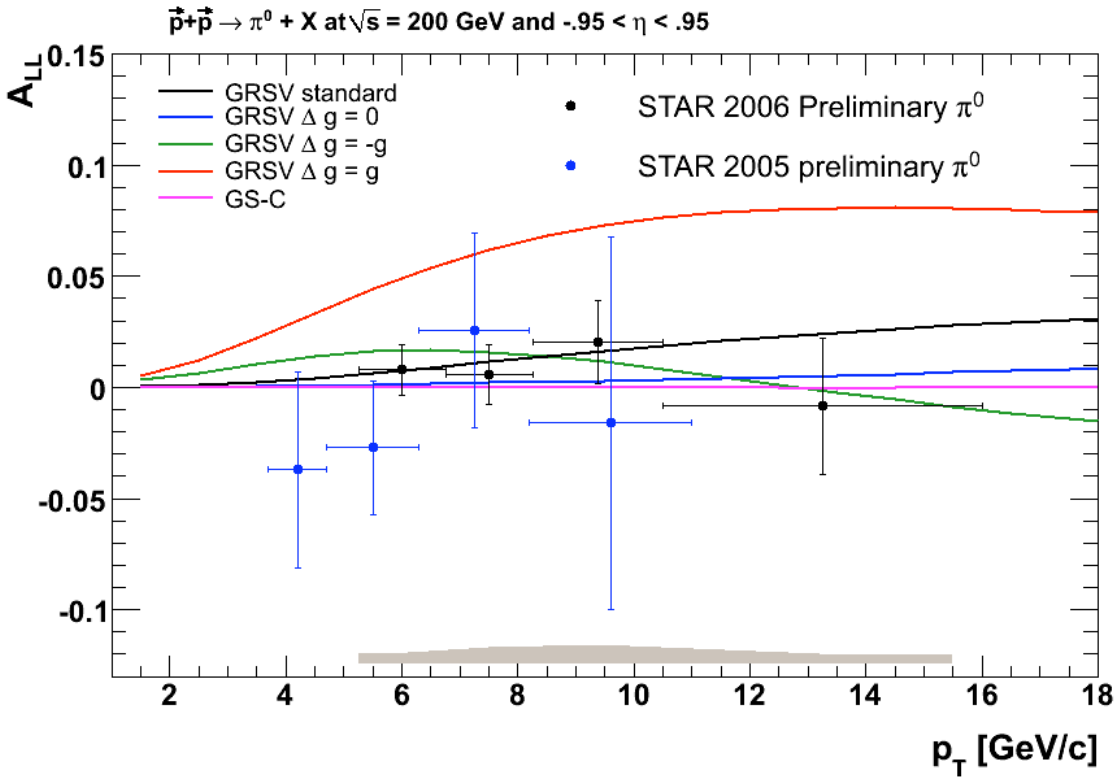
2006 π^0 A_{LL} (mid-rapidity)



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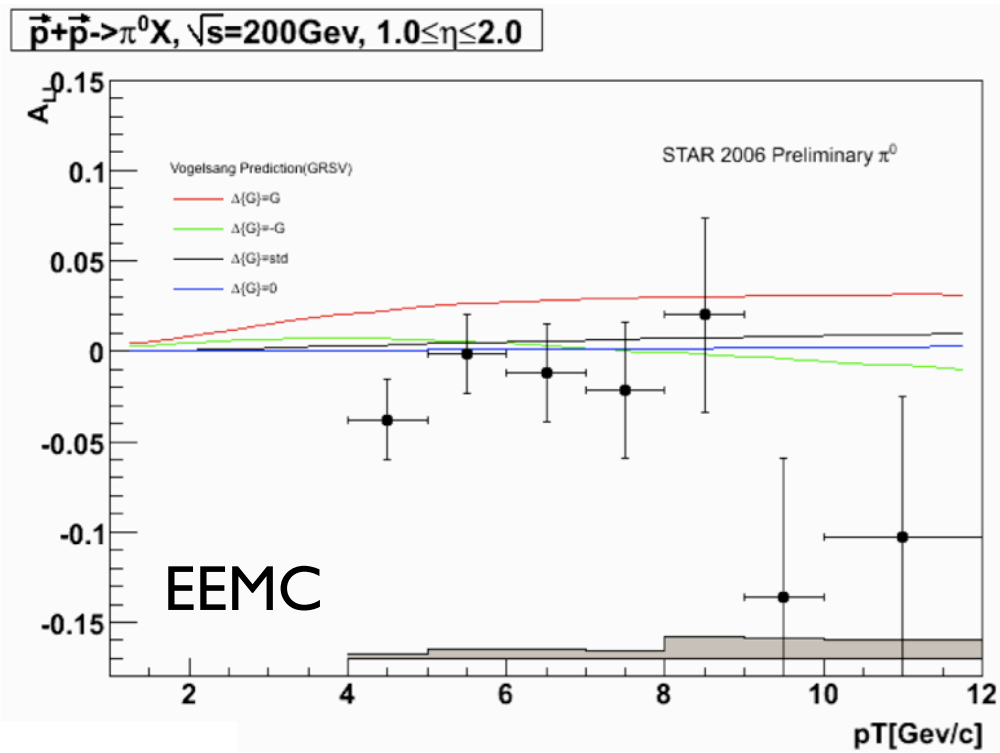
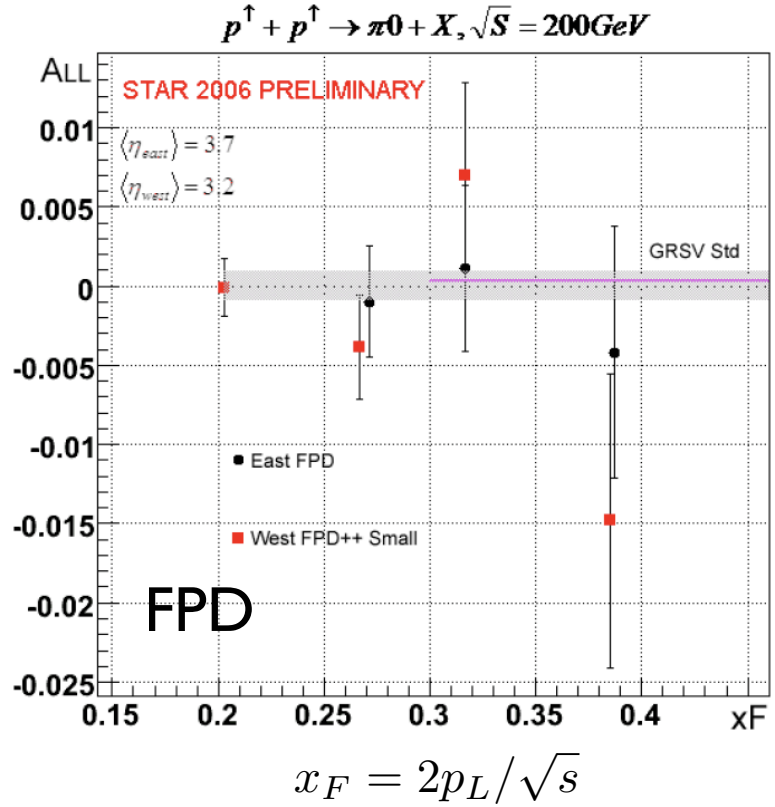
- Pions reconstructed using two photon decay channel in BEMC
- Run 6 results significantly more precise than previous measurements
- GRSV-MAX ruled out

2006 π^0 A_{LL} (forward rapidity)



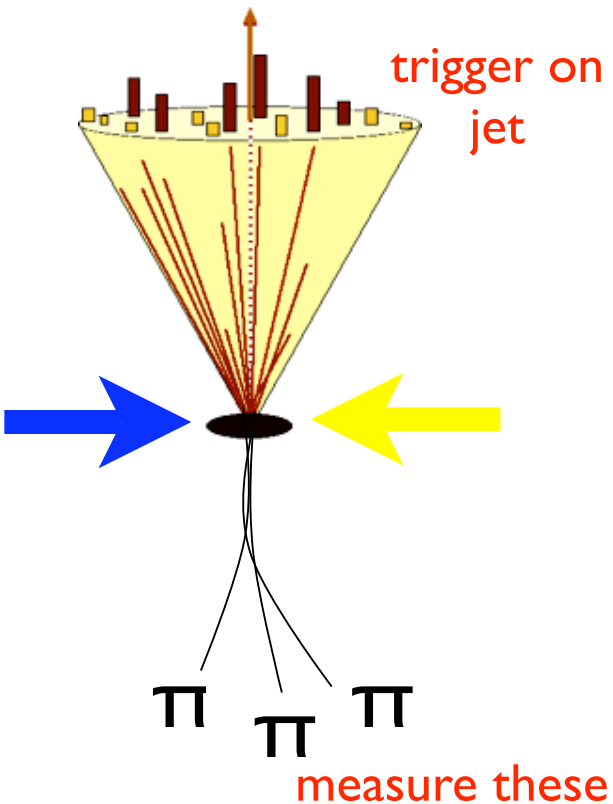


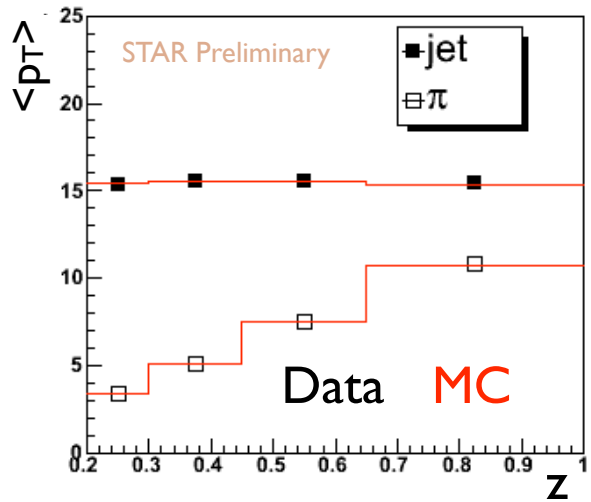
$$x_F = 2p_L/\sqrt{s}$$

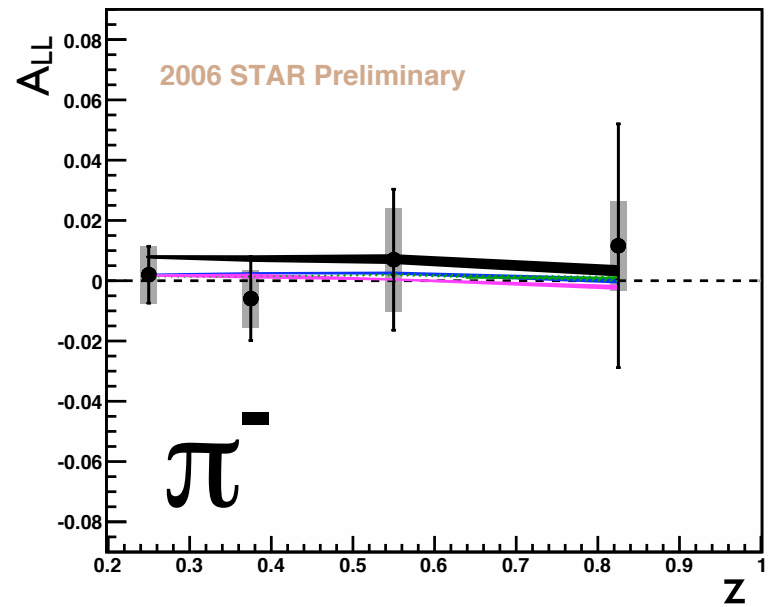
- Probe low-x region where $\Delta g(x)$ is generally predicted to be smaller
- Important baseline measurements for STAR inclusive γ and γ-jet program

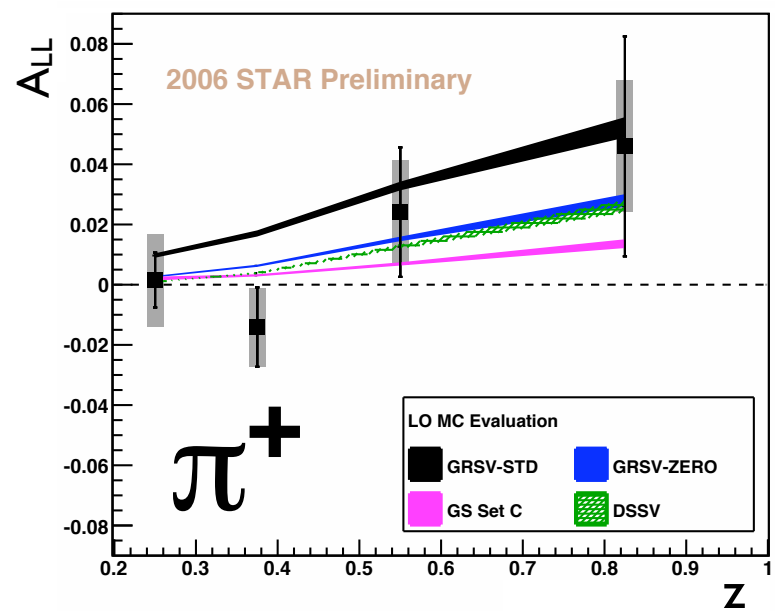
2006 $\pi^{+/-}$ A_{LL}

- EM trigger used to select events; $\pi^{+/-}$ in trigger jet biased towards soft fragmentation
- Require jet, pion back-to-back in ϕ
- Plot asymmetry versus $z \equiv p_T(\pi) / p_T(\text{trigger jet})$ to cleanly isolate favored fragmentation









The Future

- x-dependence of Δg: correlation measurements
  - Di-Jet/Hadron production: all three (LO) QCD-type subprocesses contribute
  - γ-jet: One dominant underlying (LO) process with a large partonic a_{LL} at forward rapidity
  - Small cross section for γ-jet: efficient reconstruction and background subtraction are essential
  - Both measurements can be readily incorporated into a global analysis
- increase sampled x range
  - correlations over wide rapidity range
  - 500 GeV data ($x \cong 2\, p_T/\sqrt{s}$)

$$\frac{M}{\sqrt{s}} = \sqrt{x_1 x_2} \qquad \eta_3 + \eta_4 = \ln\frac{x_1}{x_2}$$

$$x_{1\,(2)} = \frac{1}{\sqrt{s}}\left(p_{T_3} e^{\eta_3(-\eta_3)} + p_{T_4} e^{\eta_4(-\eta_4)}\right)$$

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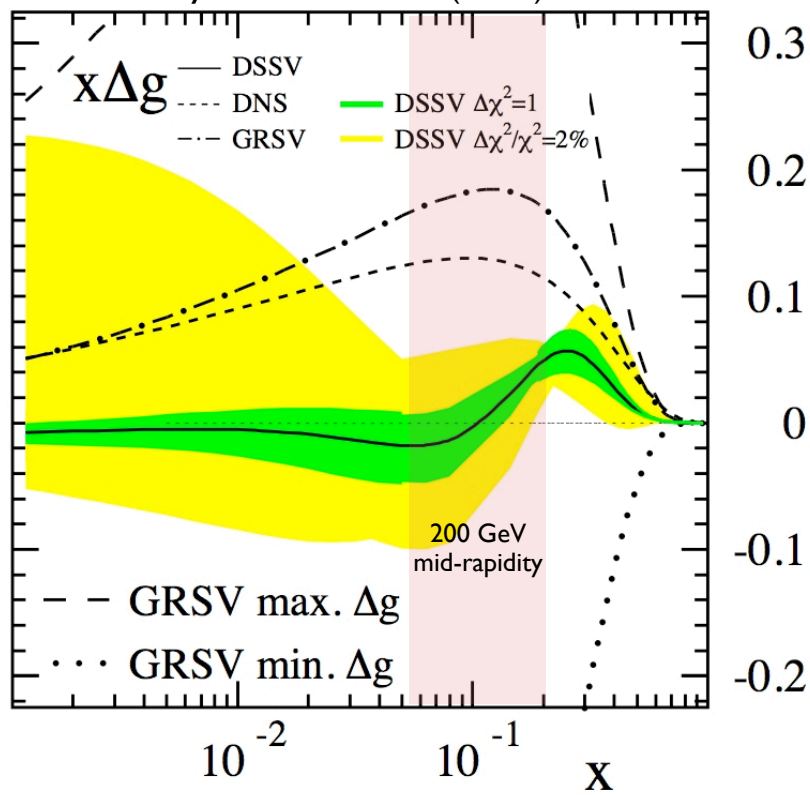

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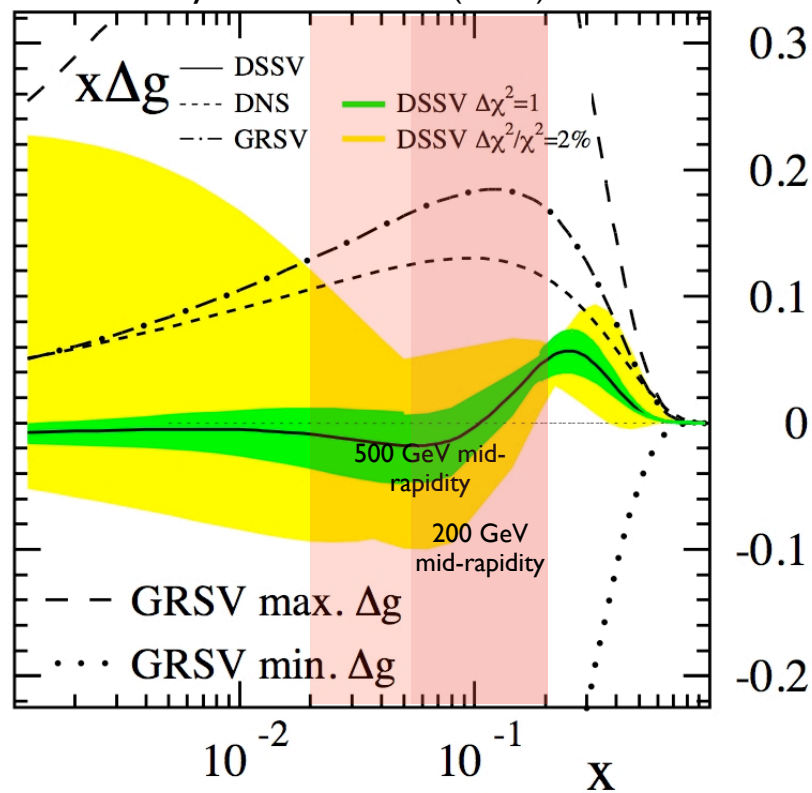

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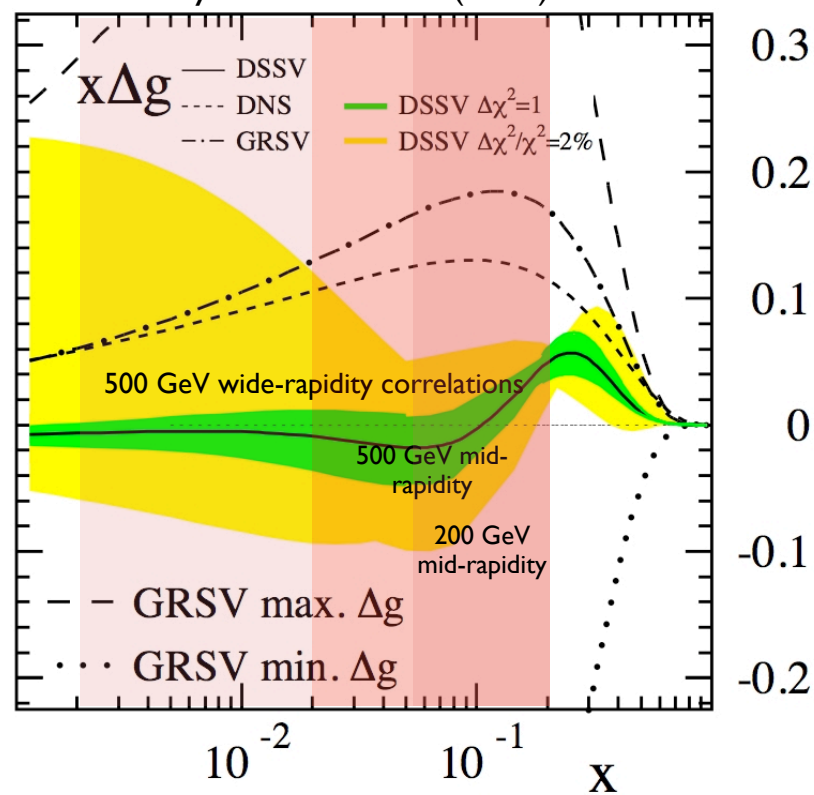
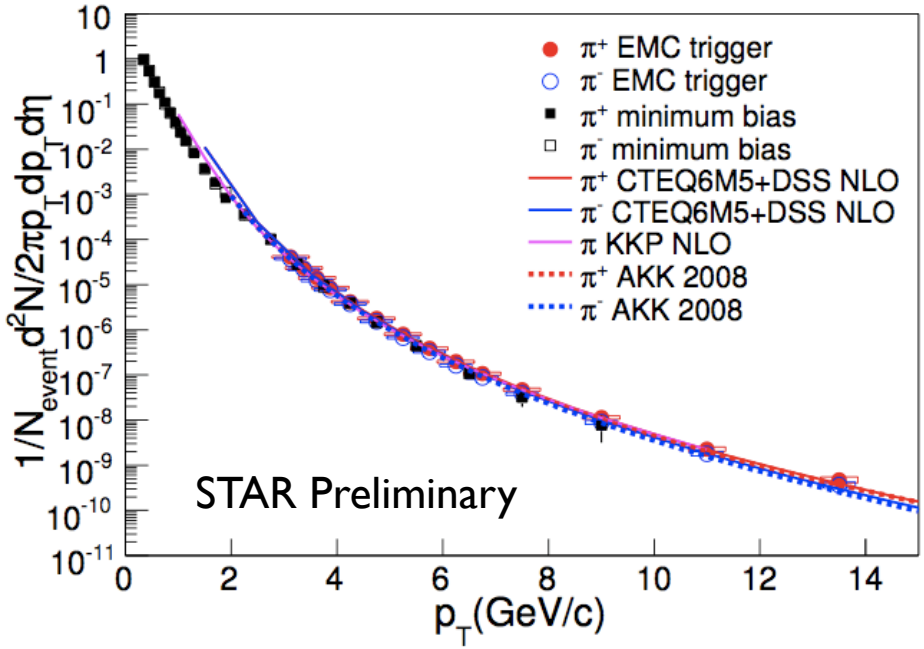


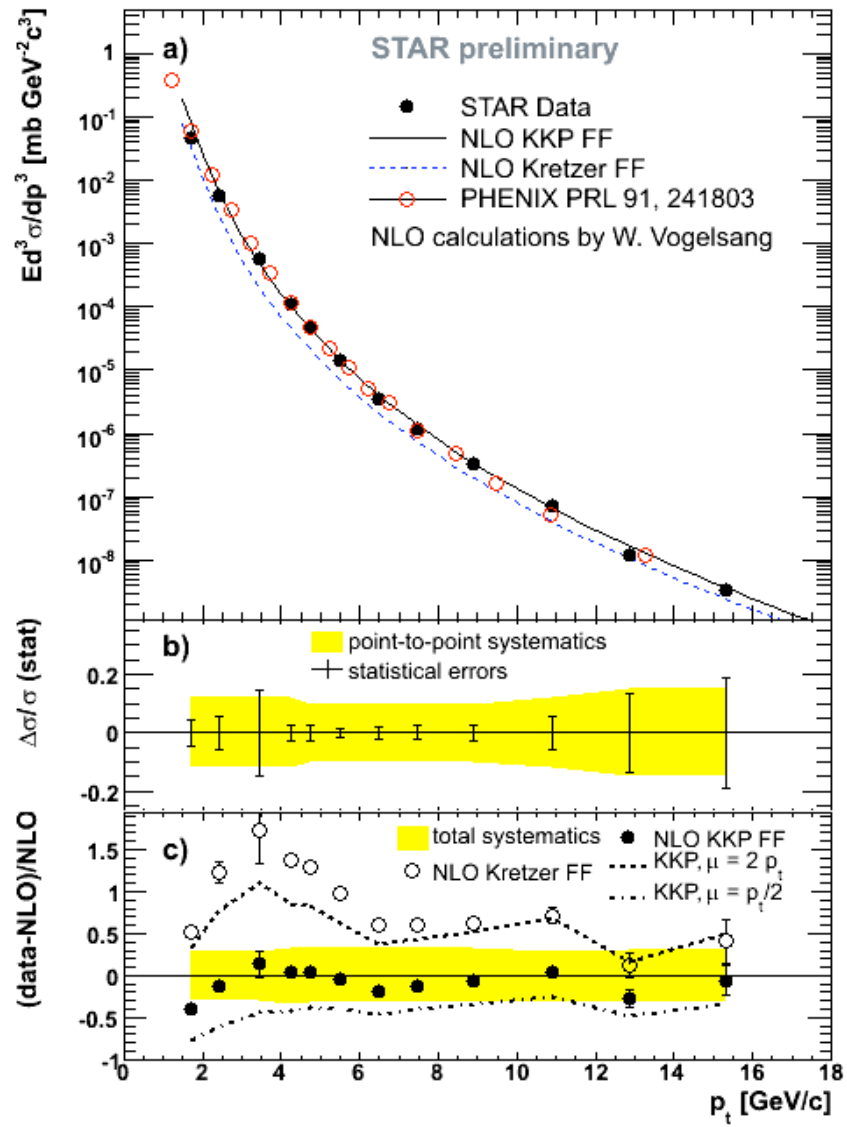
Summary

- STAR has a robust program of inclusive A_{LL} measurements at $\sqrt{s}$ = 200 GeV
- These measurements have had a significant impact on our understanding of Δg
- Correlation measurements will allow STAR to better constrain parton kinematics and map the x-dependence of Δg
- RHIC 500 GeV running combined with STAR's wide rapidity coverage enable asymmetries that will sample the gluon polarization at small x

Backup

2005 Pion Invariant Yields





- Good agreement between data and NLO calculations over several decades
- Charged pion cross section made possible by advanced TPC calibrations (arXiv:0807.4303-physics)