

# Recent Longitudinal Spin Asymmetry Measurements for Inclusive Jet Production at STAR

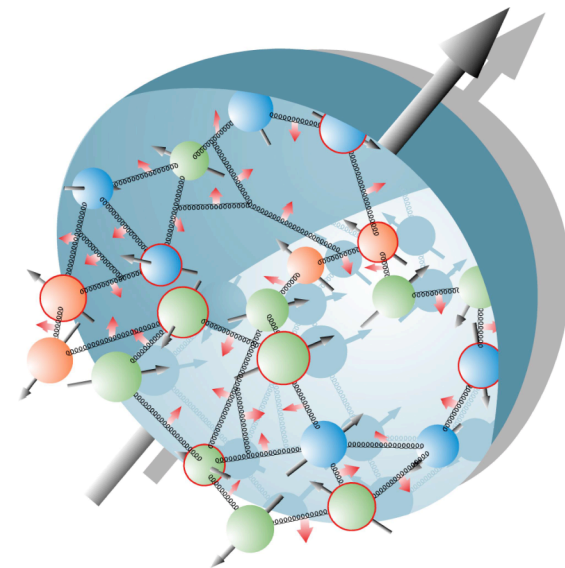
*David Staszak (UCLA) for the STAR Collaboration  
PANIC 2008, Eilat, Israel  
November 9-14, 2008*

## Outline

- \* *Introduction*
- \* *2005 Results*
- \* *2006 Results*
- \* *Summary and Outlook*

# The Proton Spin Structure Puzzle

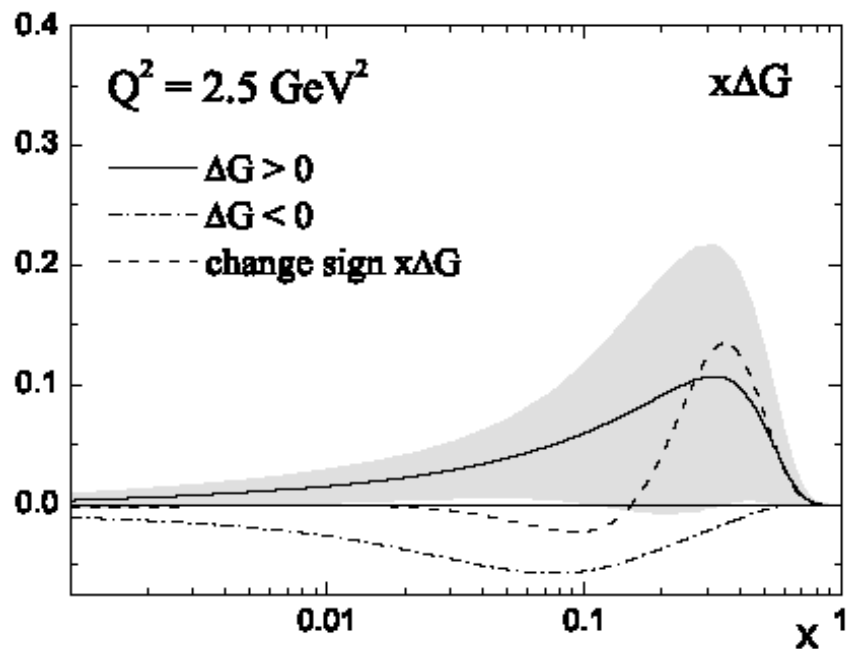
$$\frac{1}{2} = \frac{1}{2} \Delta\Sigma + \Delta G + \langle L_{q,g} \rangle$$



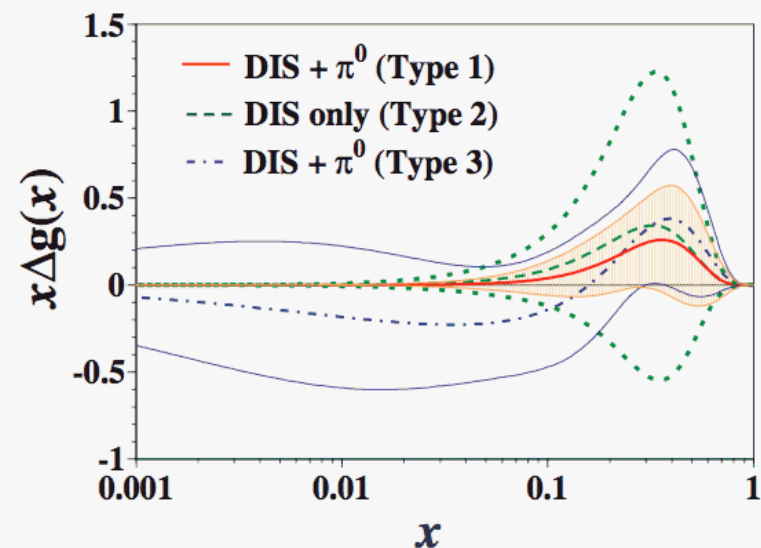
- From polarized-DIS measurements we know quark contribution to 1/2 is small:

$$\Delta\Sigma \approx 20\text{-}30\%$$

- Gluon polarized distributions are not well constrained



Leader et al, PRD 75, 074027 (2007)

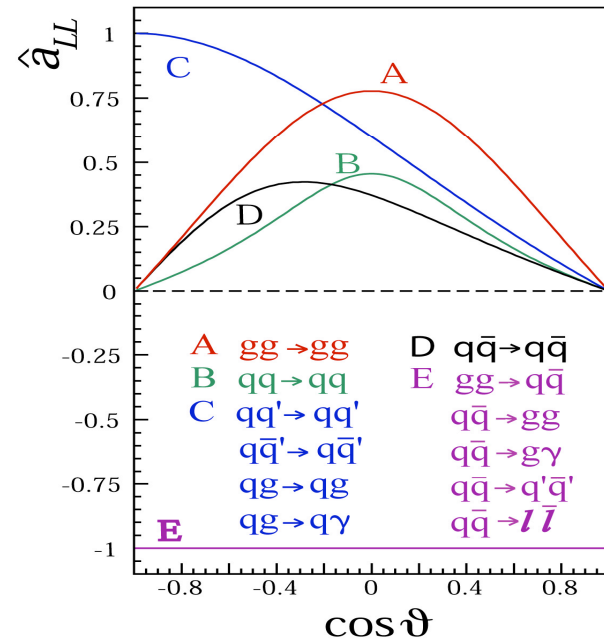
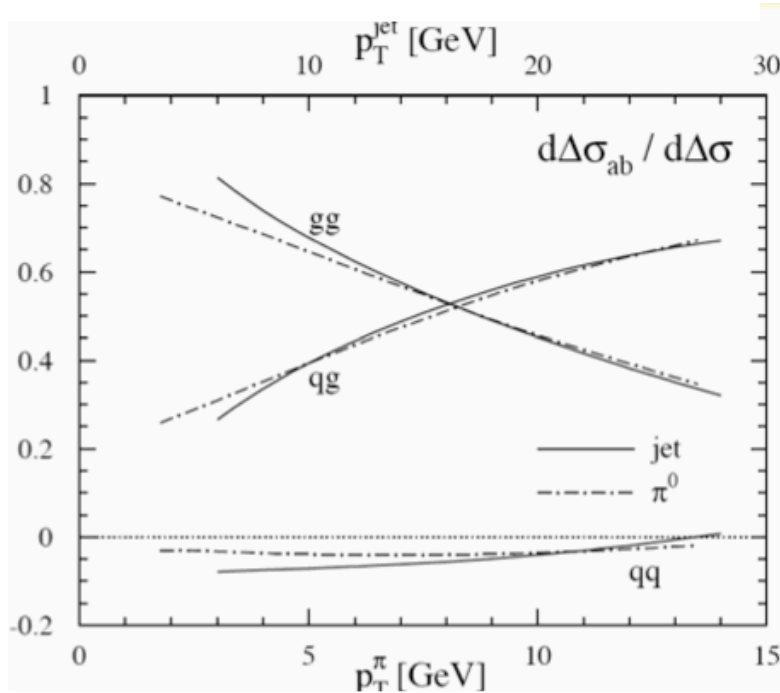
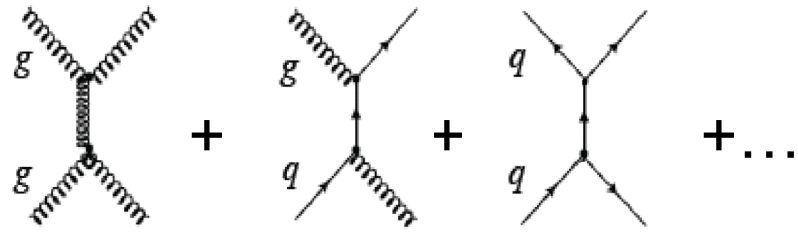


AAC, PRD 74, 014015 (2006)

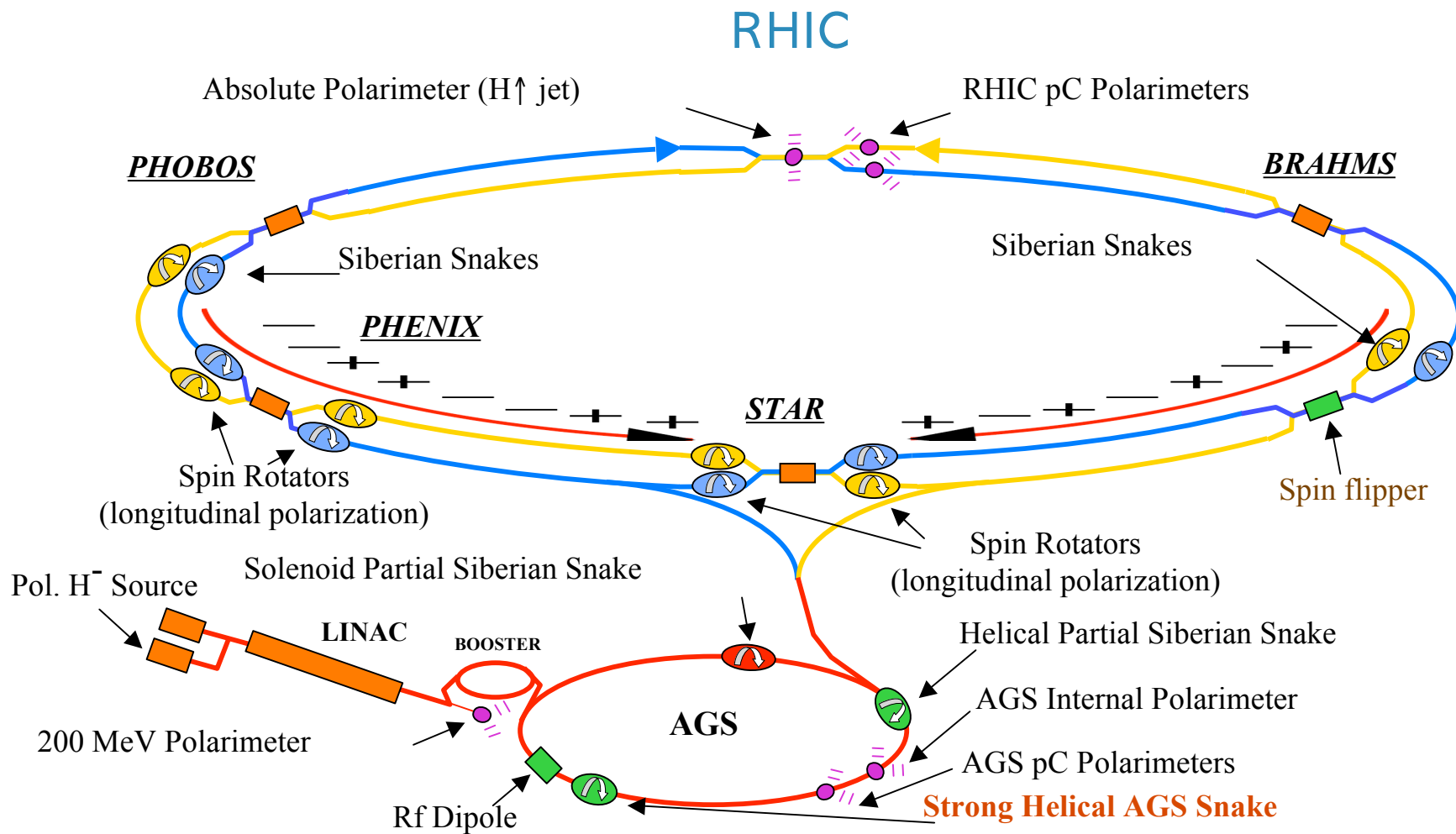
# Accessing $\Delta G$ via $A_{LL}$

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

Several contributing sub-processes:

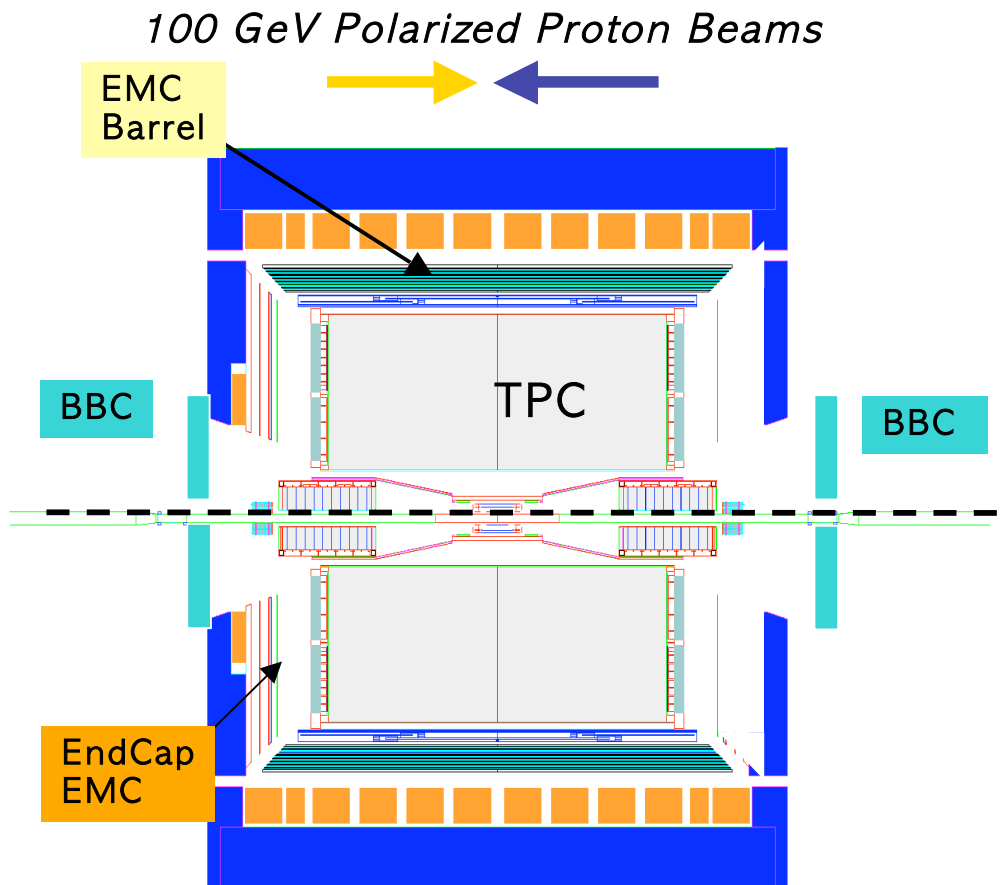


Inclusive Jet Signal: High Cross Section + Avoid fragmentation functions



pp Run Year	2003-2004	2005	2006	2009 (Requested)
Polarization	30-45%	50%	~55% (60% online)	60%
Luminosity	0.3 pb <sup>-1</sup>	2 pb <sup>-1</sup>	5 pb <sup>-1</sup>	50 pb <sup>-1</sup>
FoM = P <sup>4</sup> L	0.01 pb <sup>-1</sup>	0.1 pb <sup>-1</sup>	0.5 pb <sup>-1</sup>	6 pb <sup>-1</sup>

# STAR Detector



## Beam-Beam Counter:

- MinBias Trigger
- Relative Luminosities
- $3.4 < |\eta| < 5$

## Time Projection Chamber:

- Charged Tracks  $P_T$
- $-1.4 < \eta < 1.4$

## EM Calorimeter (Pb/Scintillator):

- Particle Neutral Energy
- Barrel  $0 < \eta < 1$  (2003-2005)  
 $-1 < \eta < 1$  (2006)
- Endcap  $1.09 < \eta < 2.0$

All detectors have full azimuthal coverage

# Jet Reconstruction

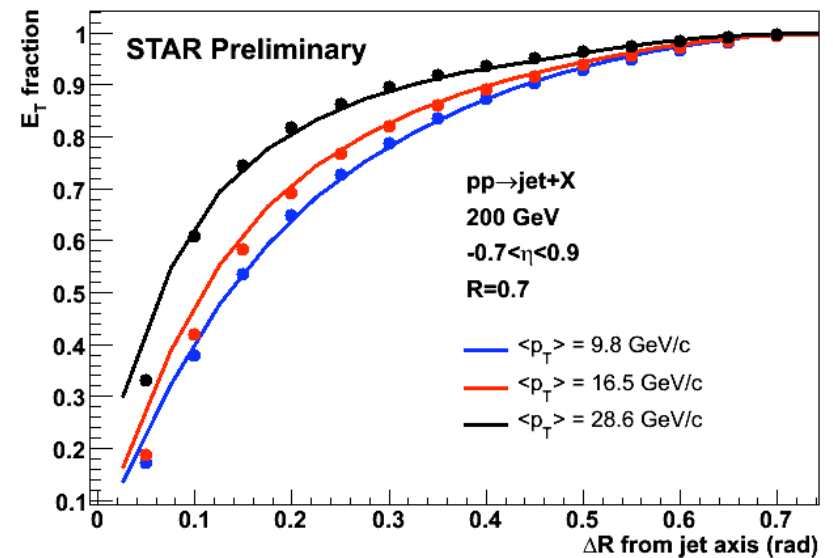
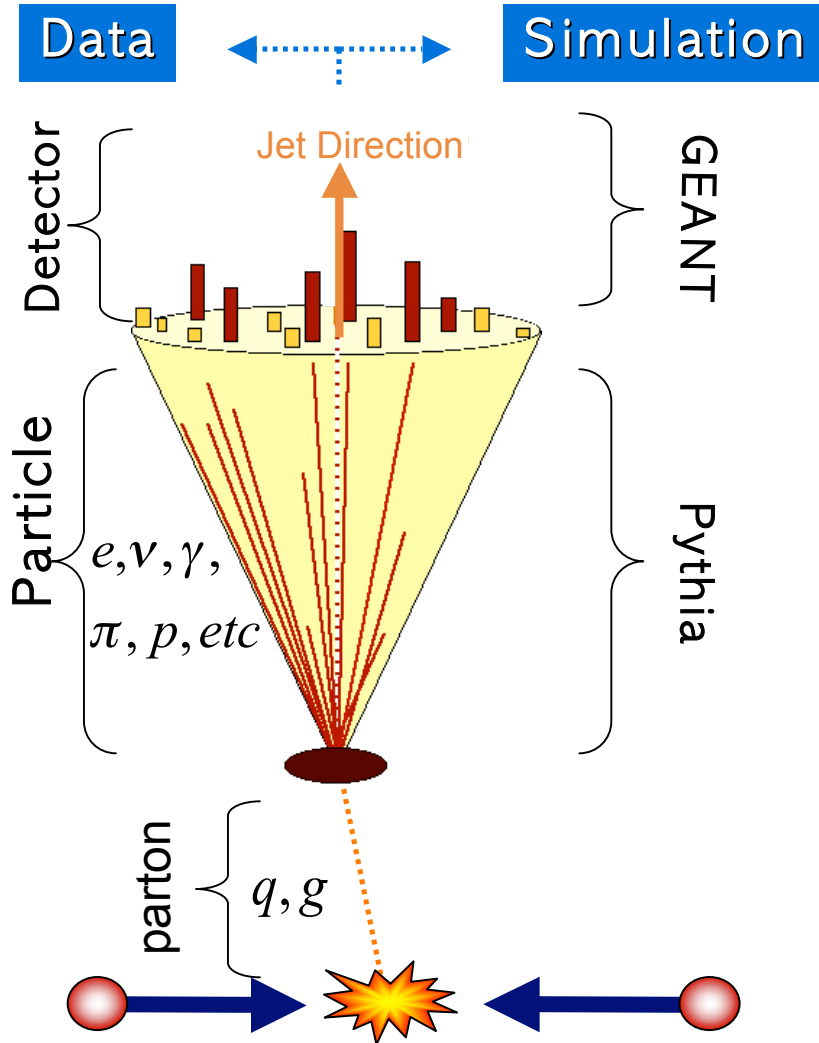
\*(hep-ex/0005012)

## midpoint-cone algorithm\*

- Adapted from the Tevatron
- 0.5 GeV seed energy, split/merge fraction = 0.5
- Cone Radius:

= 0.4 (2003-2005)

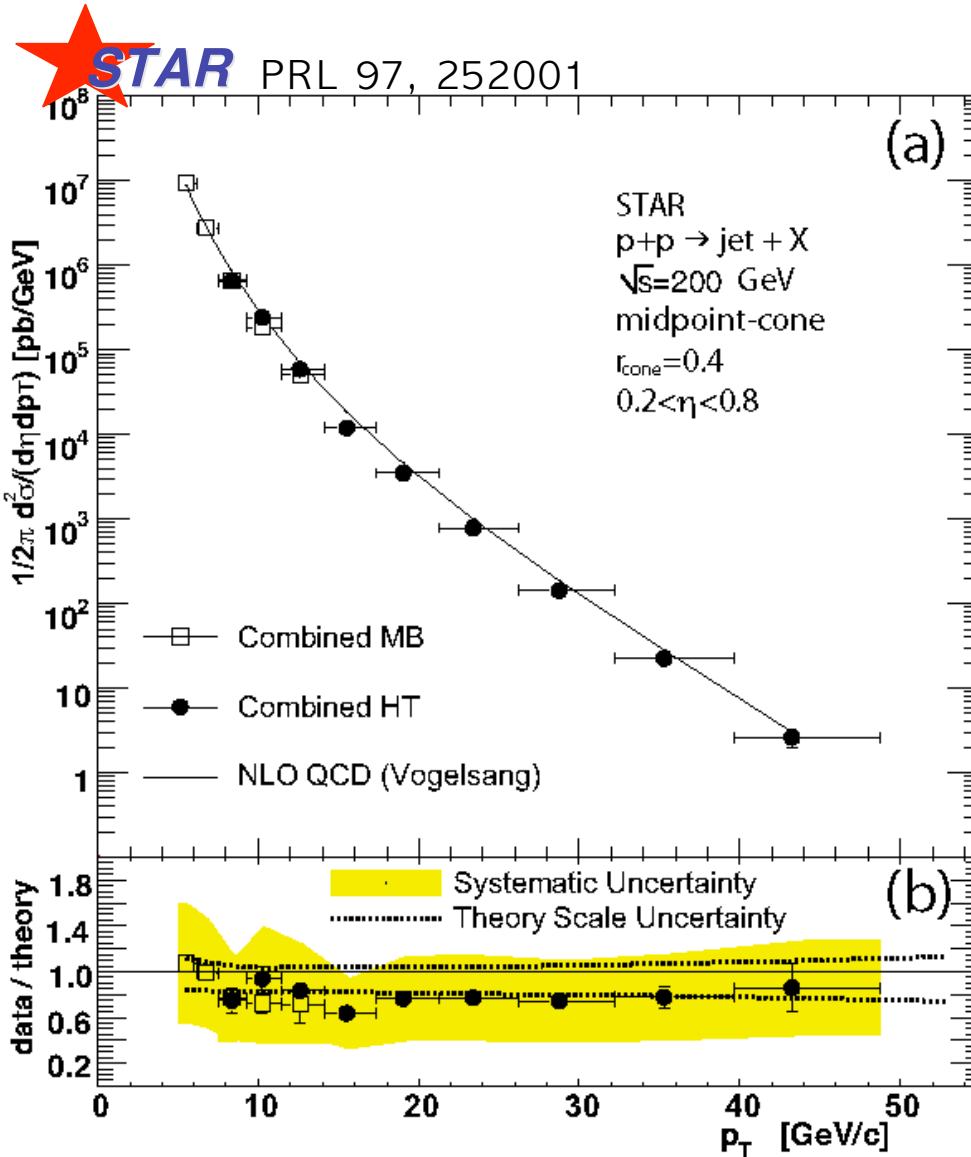
= 0.7 (2006)



## correct data to theory

- Use Pythia+GEANT to quantify detector response
- Estimate corrections to go from “*detector*” to the “*particle*” level

# Inclusive Jet Cross Section



$$\frac{1}{2\pi} \frac{d^2\sigma}{d\eta dp_T} = \frac{1}{2\pi} \cdot \frac{N_{Jets}}{\Delta\eta\Delta p_T} \cdot \frac{1}{\int L dt} \cdot \frac{1}{c(p_T)}$$

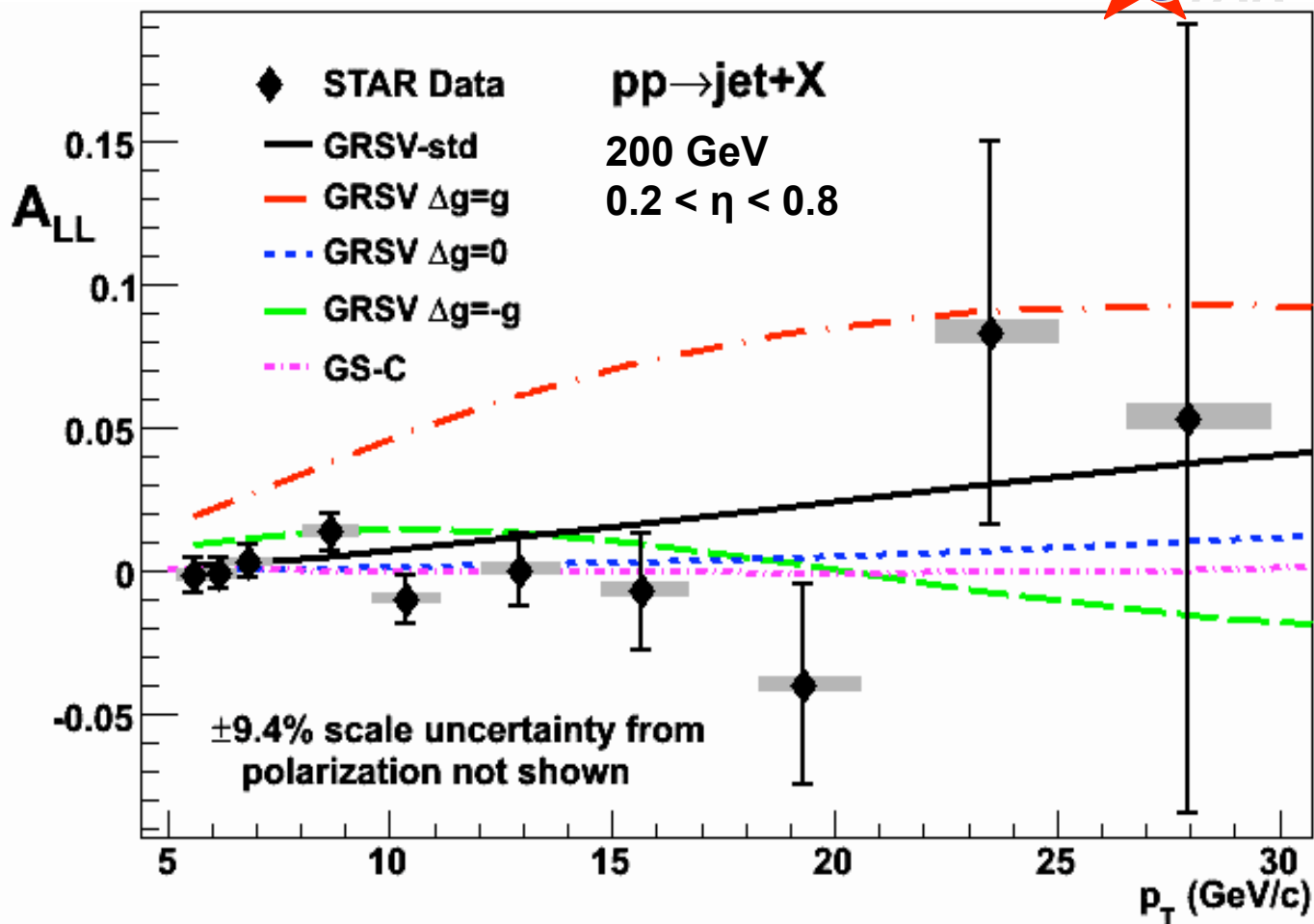
- Agreement within systematics with NLO QCD over 7 orders of magnitude
- MB and HT agree in 3 overlapping bins
- Other channels have shown agreement with pQCD at RHIC:  $\pi^0$ ,  $\pi^+$ ,  $\pi^-$ ,  $K^+$ , photons

⇒ pQCD works here!

- Theory: B. Jager et. al, Phys Rev D70 034010

## 2005 $A_{LL}$ Results

 STAR PRL 100, 232003 (2008)



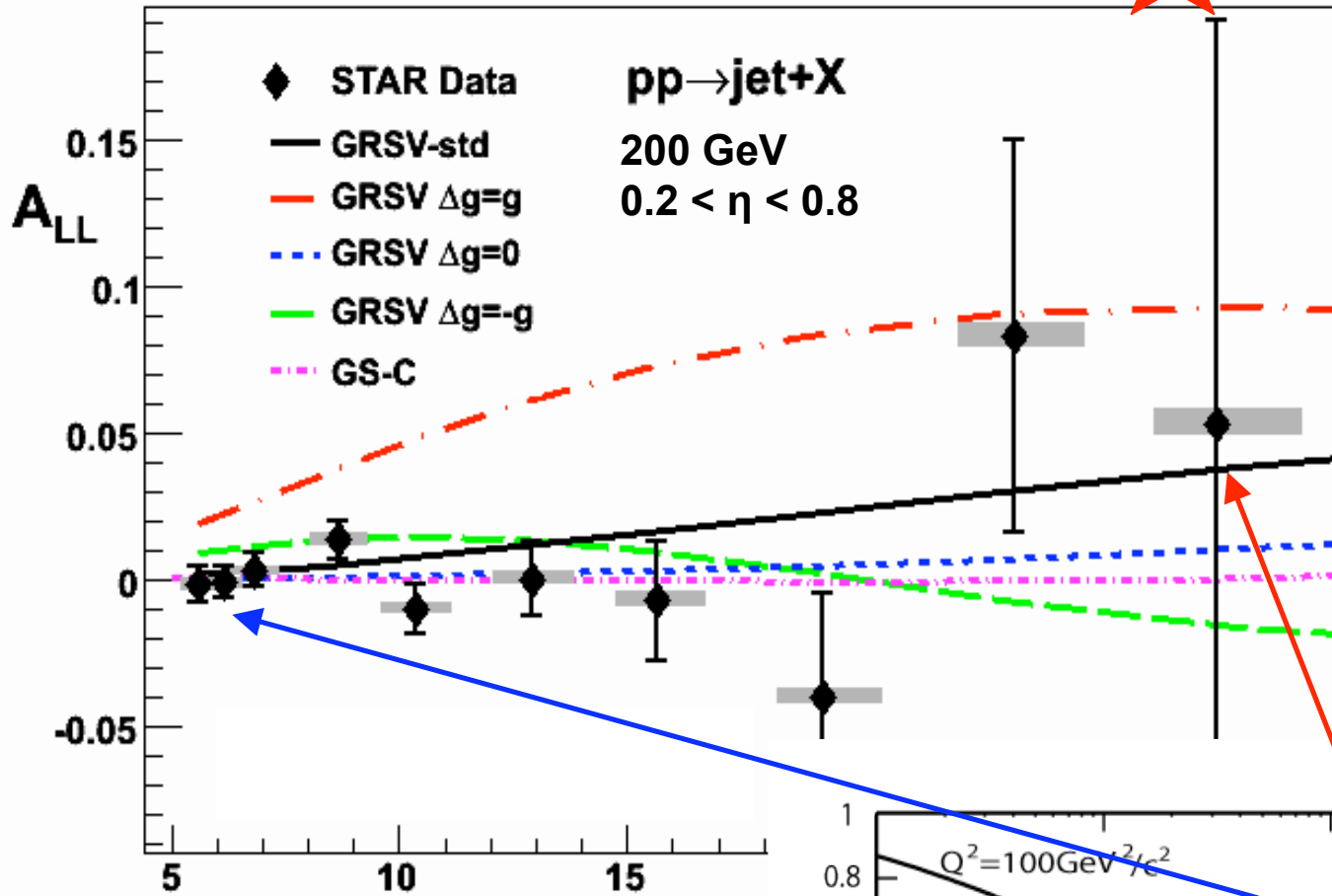
- Error bars are statistical uncertainty only, grey bands are systematic
- Data are compared to predictions within the GRSV framework with several input values of  $\Delta G$ . Model calculations from:

*B. Jager et. al, Phys Rev D70 034010, T Gehrmann et. al, Phys.Rev.D53 6100-6109(1996)*

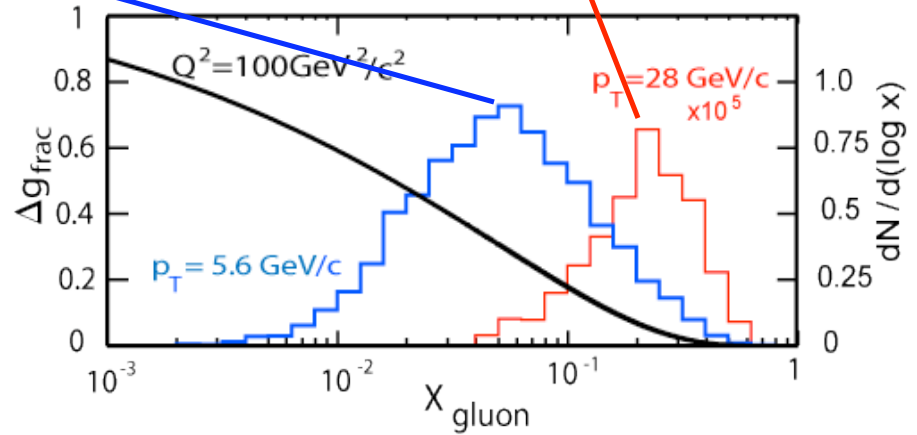


# 2005 $A_{LL}$ Results

**STAR** PRL 100, 232003 (2008)



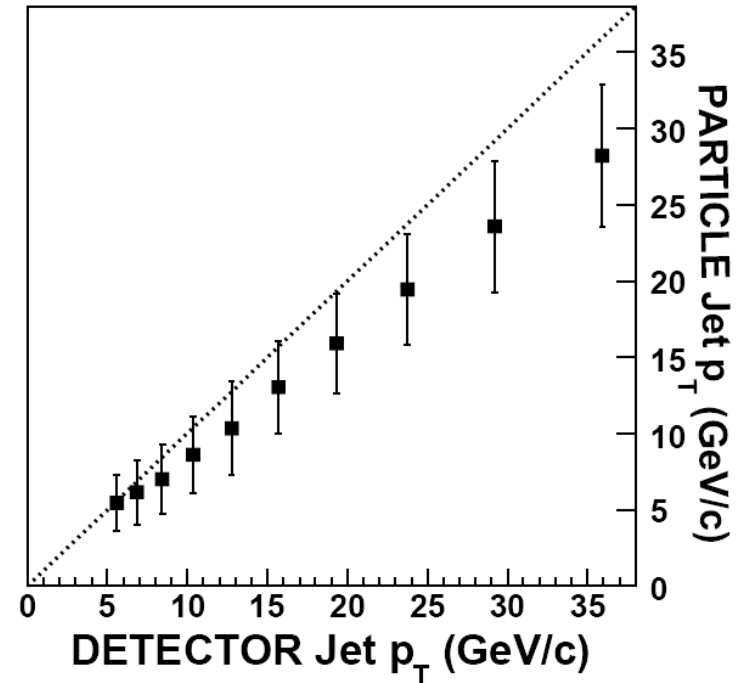
Full  $\Delta G$  Integral not covered by STAR acceptance:  $\sim 0.02 < x < 0.3$



# 2005 $A_{LL}$ Systematics

$A_{LL}$ systematics	( $\times 10^{-3}$ )
Reconstruction + Trigger Bias	2-5 ( $p_T$ dep)
Non-longitudinal Polarization	0.1-0.8 ( $p_T$ dep)
Relative Luminosity	0.94
Backgrounds	0.70
$p_T$ systematic	[-5.4%, +6.7%]

← Leading Systematic



**Trigger Bias:** *The natural interaction mix (gg/qg/qq) can be biased in our sample from our triggers which rely on neutral energy only.*

**Reconstruction Bias:** *25% jet resolution mixed with steeply falling  $p_T$  spectrum means on average that we over-estimate the jet energy.*

**Step 1:** Calculate the bin-to-bin  $p_T$  shifts from Detector (Geant) to Particle (Pythia)

# Trigger and Reconstruction Bias Systematic

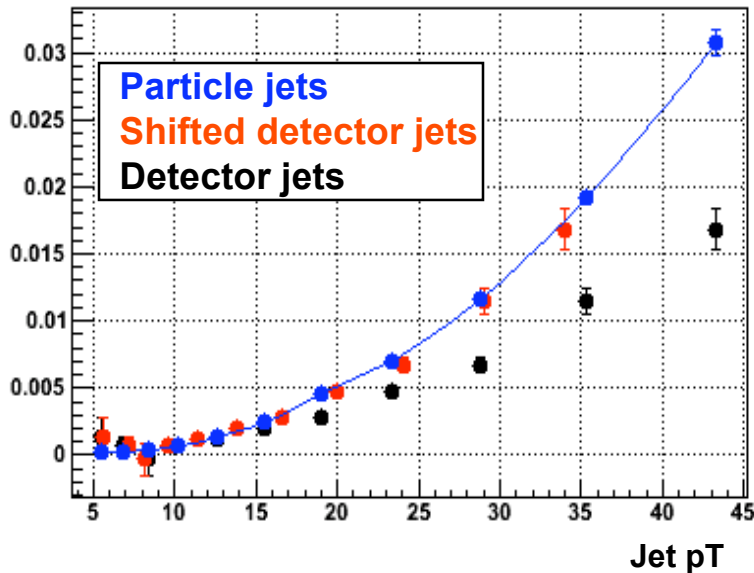
**Step 2:** Combine Pythia partonic information with polarization models of  $\Delta G$ , and calculate:

- $A_{LL}$  (Pythia)
- $A_{LL}$  (Geant + Trigger)

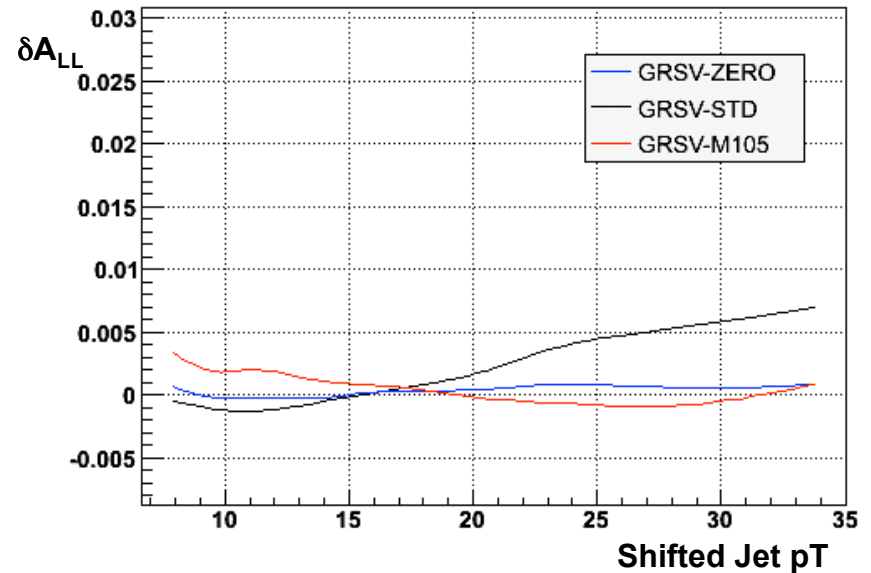
➔ **Trigger + Reconstruction Bias is the difference between  $A_{LL}$  (Pythia) and shifted  $A_{LL}$  (Geant+Trigger)**

- Systematic is conservatively the greatest +/- difference of all models for each pT bin

Asymmetry (JP1, ZERO)

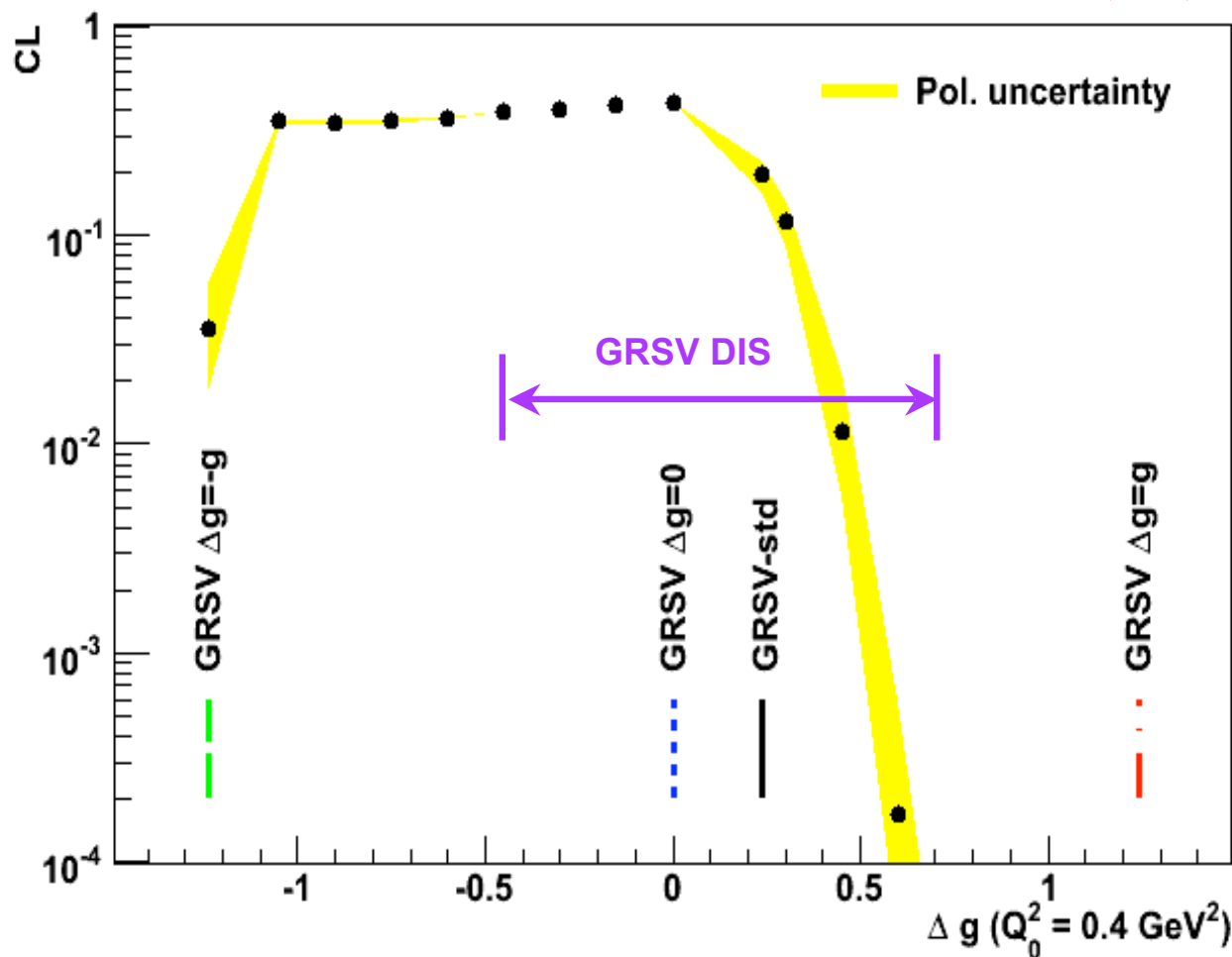


Pythia[ $A_{LL}$ ] - shifted Geant[ $A_{LL}$ ] (JP1 Trigger)



# 2005 GRSV Comparison

\*Theoretical Uncertainties not included



- GRSV provided 15 models of  $\Delta G$  ranging from  $\Delta G = -g$  (MIN) to  $\Delta G = g$  (MAX)

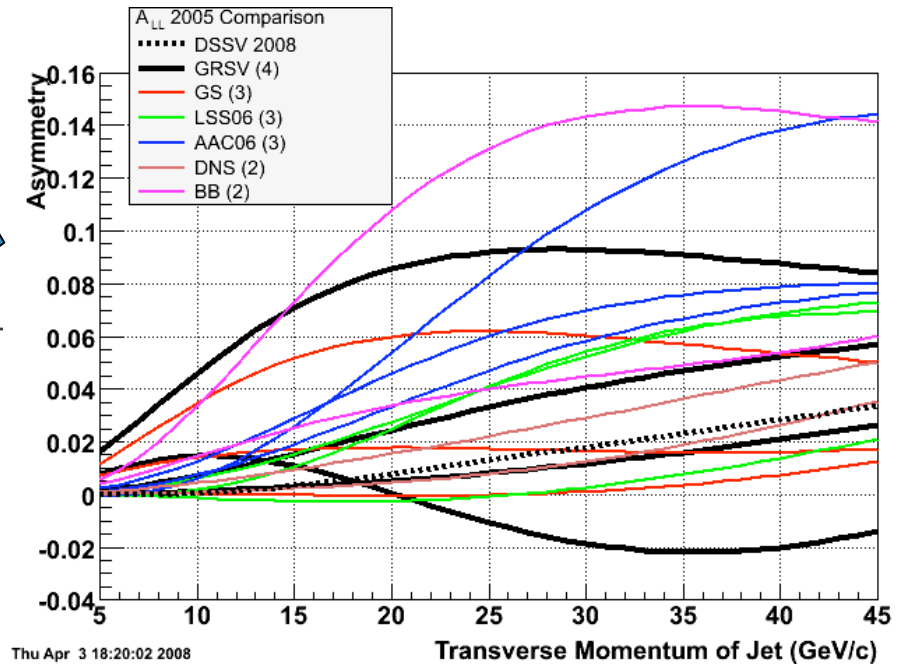
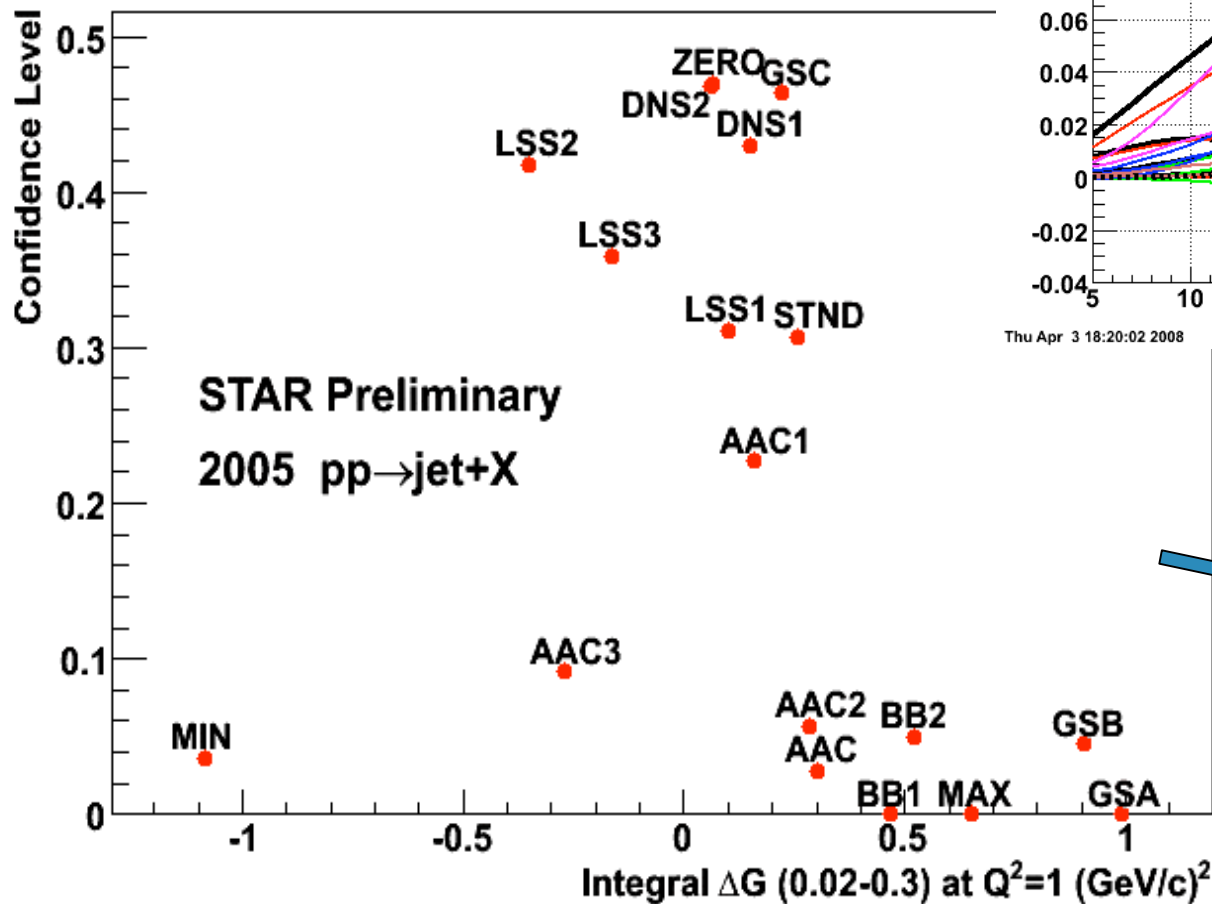
- Within GRSV framework,  $\Delta G$  cannot be much larger than STD

*GRSV DIS best fit = 0.24*  
 *$1\sigma = -0.45$  to  $0.7$*

*GRSV: PRD 63, 094005 (2001)*

# Comparison with additional global analyses

Additional parameterizations of  $\Delta G$  of polarized-DIS data with corresponding predictions for  $A_{LL}$  vs.  $p_T$



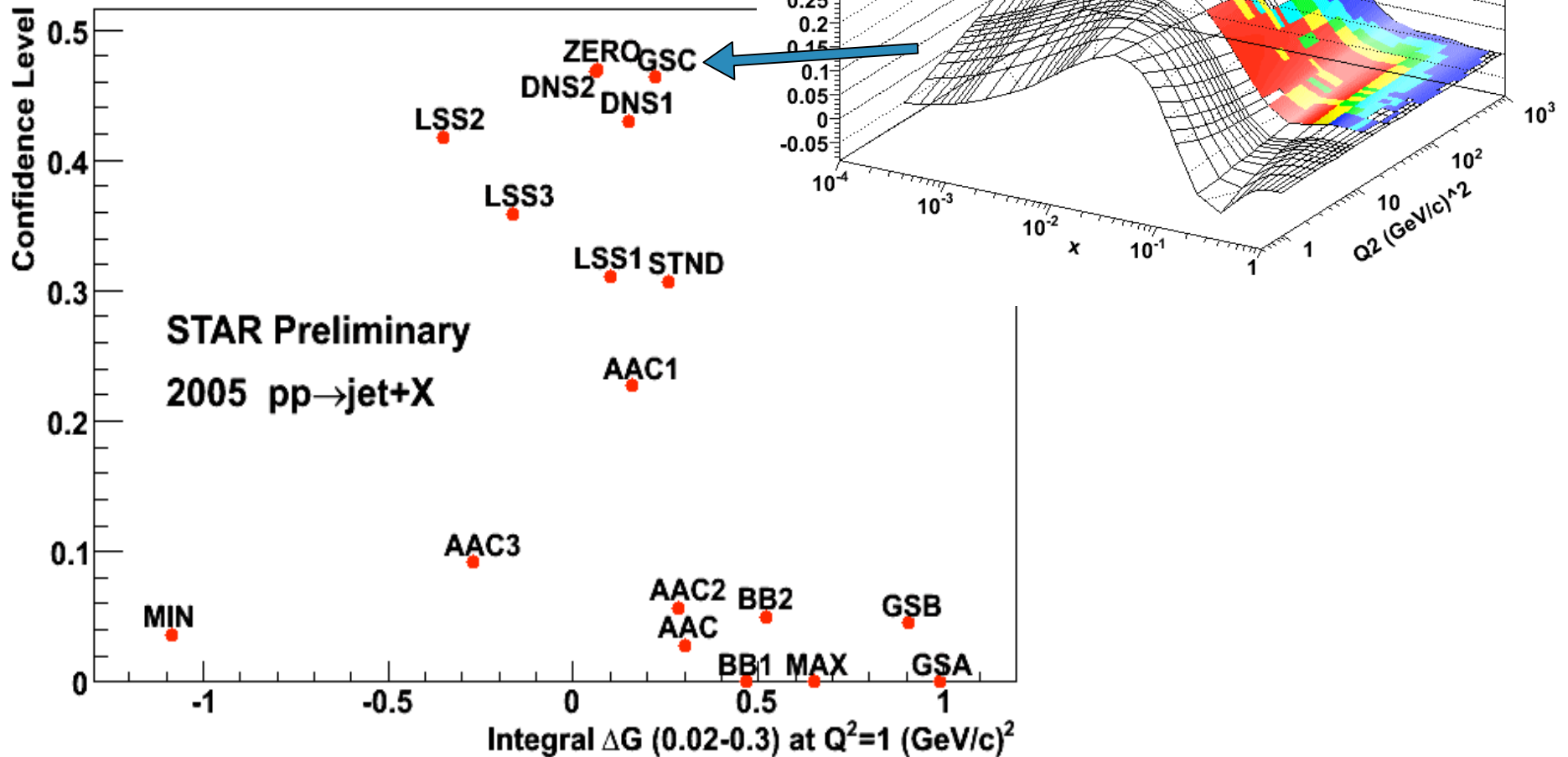
Thu Apr 3 18:20:02 2008

STAR data excludes a range of models with  $\Delta G$  larger than GRSV-STD

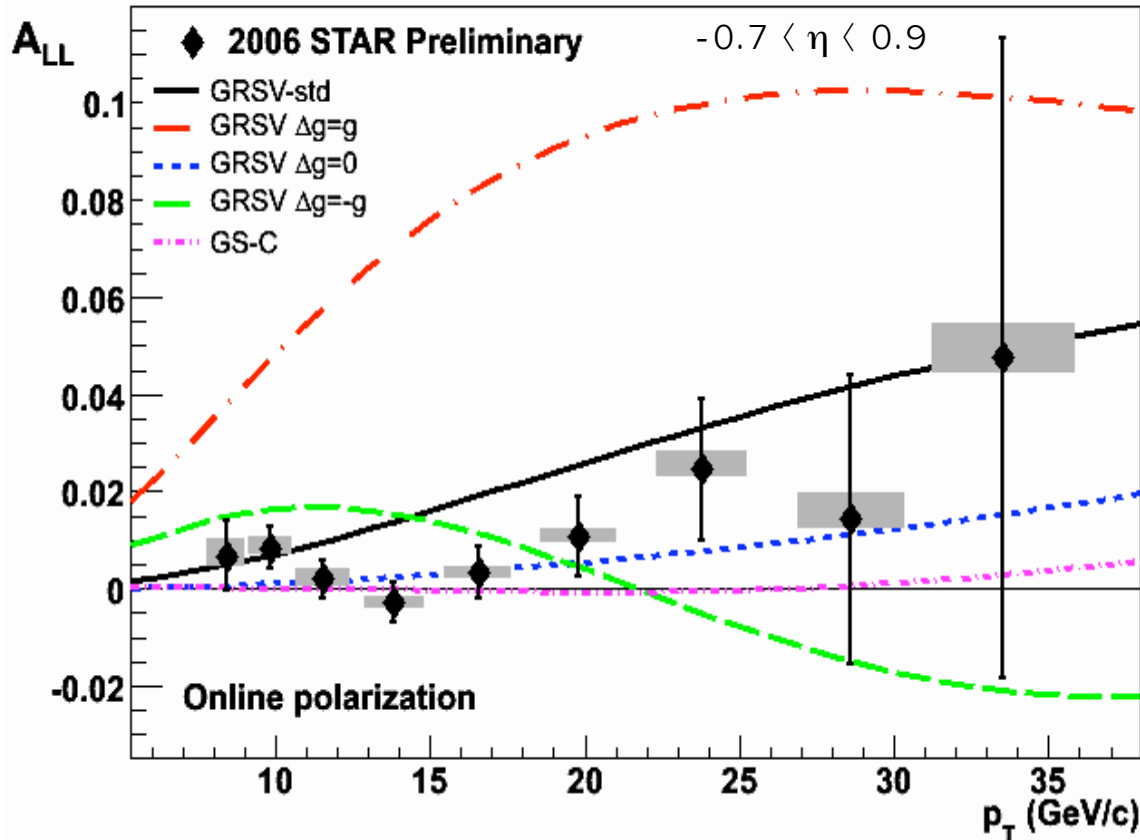
# Comparison with additional global analyses

GS-C is an example of a model which has a large integral that we are not very sensitive to in our  $x$  and  $Q^2$  range

GS-C Polarized Gluon Structure Function



# 2006 $A_{LL}$

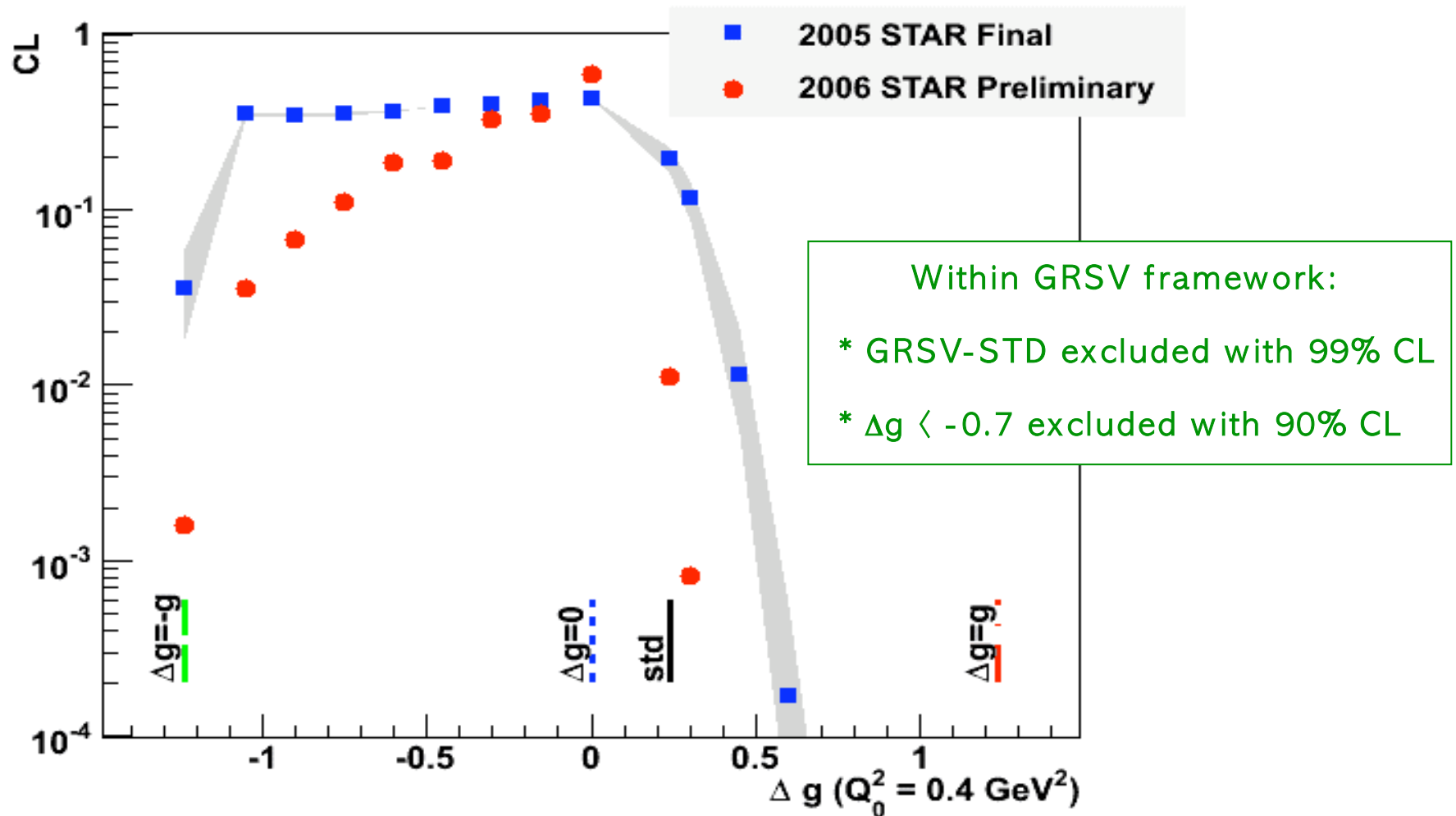


$A_{LL}$ systematics	(x 10 <sup>-3</sup> )
Reconstruction + Trigger Bias	[-1, +3] (p <sub>T</sub> dep)
Non-longitudinal Polarization	~ 0.03 (p <sub>T</sub> dep)
Relative Luminosity	0.94
Backgrounds	1 <sup>st</sup> bin ~ 0.5 else ~ 0.1

p <sub>T</sub> systematic	±6.7%
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- Full Barrel instrumented, Endcap towers included in jet finding
- Increased trigger thresholds from 2005 → better statistics at high p<sub>T</sub>
- 4 pb<sup>-1</sup> (more data still being analyzed), 60% Polarization (online polarization)

## 2006 GRSV Comparison

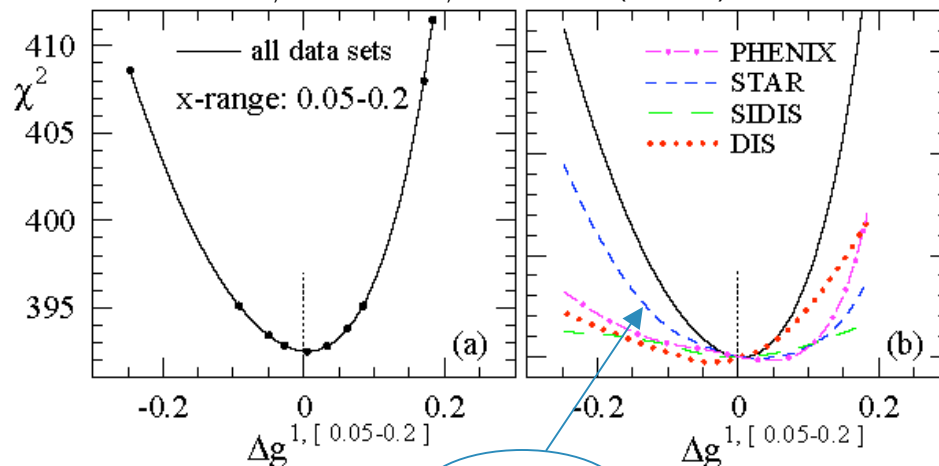




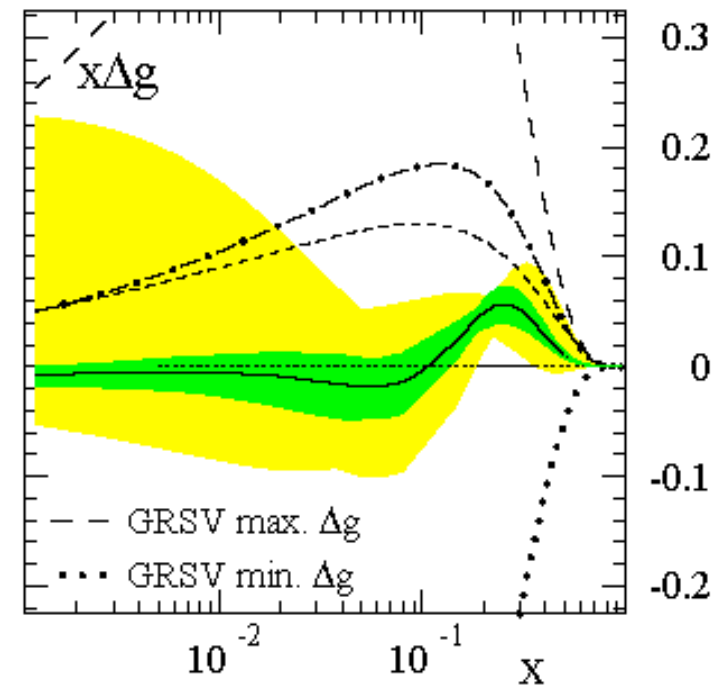
## Summary and Outlook

- pQCD calculations of the inclusive jet cross section agree with STAR data
- 2005 and 2006 inclusive jet  $A_{LL}$  significantly constrain  $\Delta G$  for  $0.02 < x < 0.3$ 
  - Contributions in this range are not large and can be negative
  - Large contributions at  $x < 0.02$  are still allowed
- Correlation measurements at STAR di-Jet and gamma-Jet are a next important step towards pinning down  $\Delta G$  (see B. Surrow this session)
- **The first global analysis to include RHIC pp data (STAR jet  $A_{LL}$ , Phenix  $\pi^0 A_{LL}$ ) with DIS and SIDIS:**

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

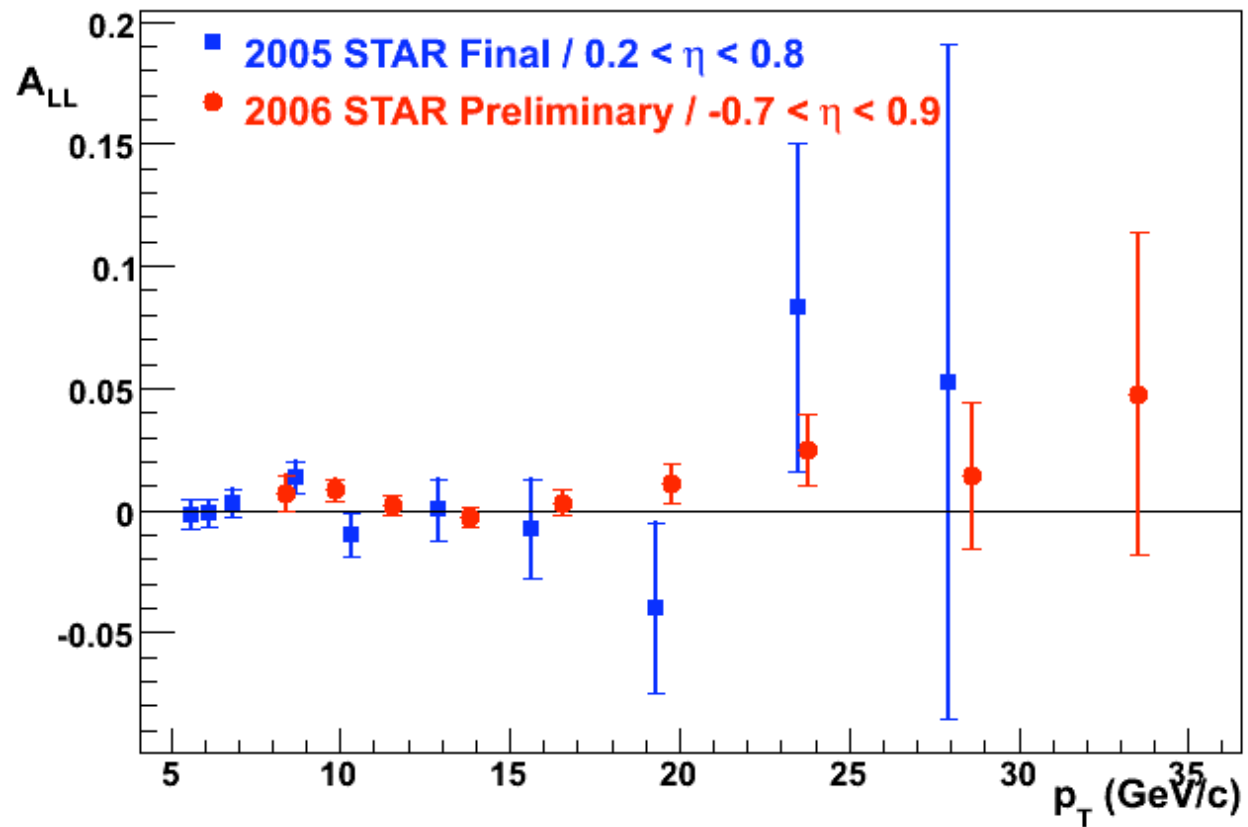


STAR

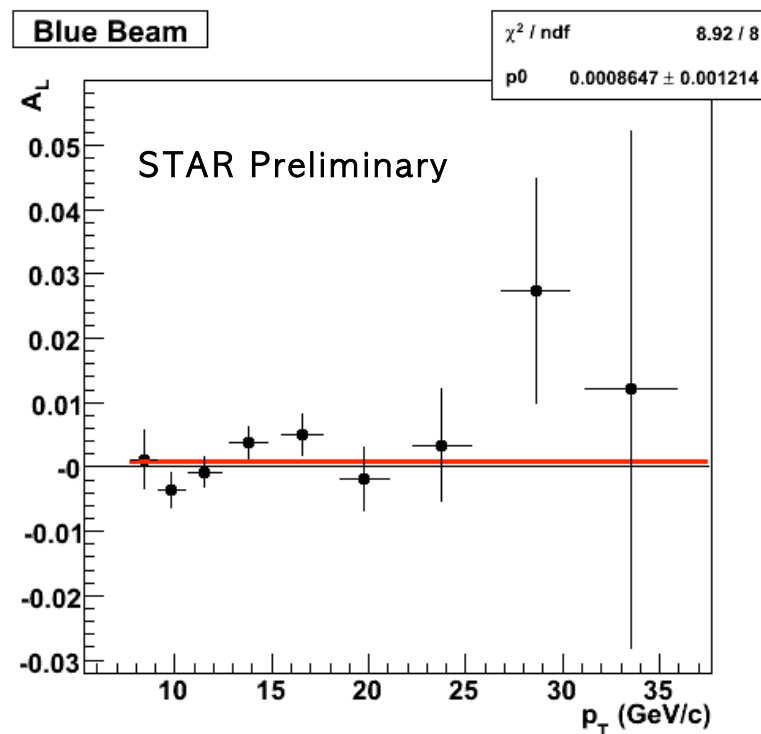
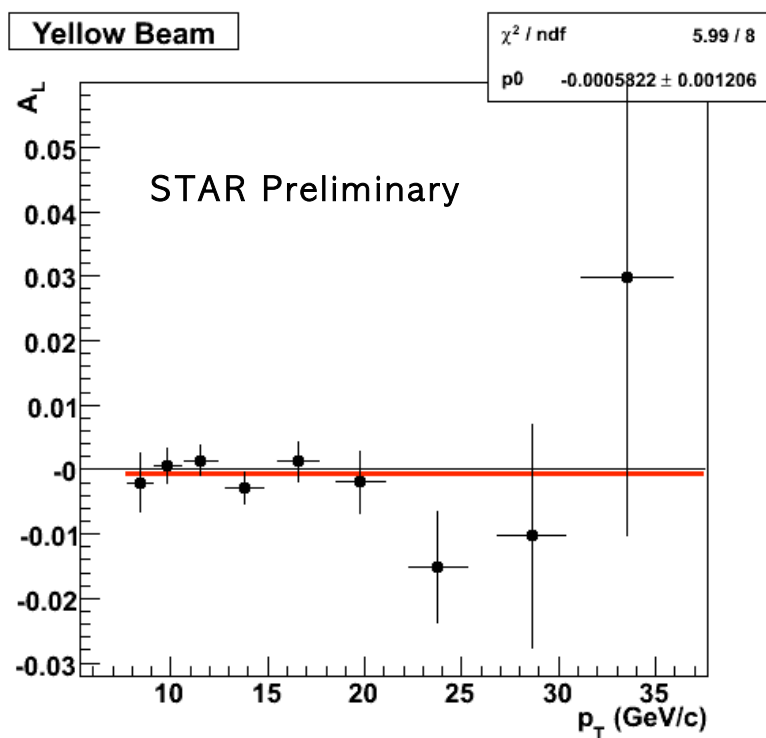


## Backup Slides

## 2005 and 2006 Comparison



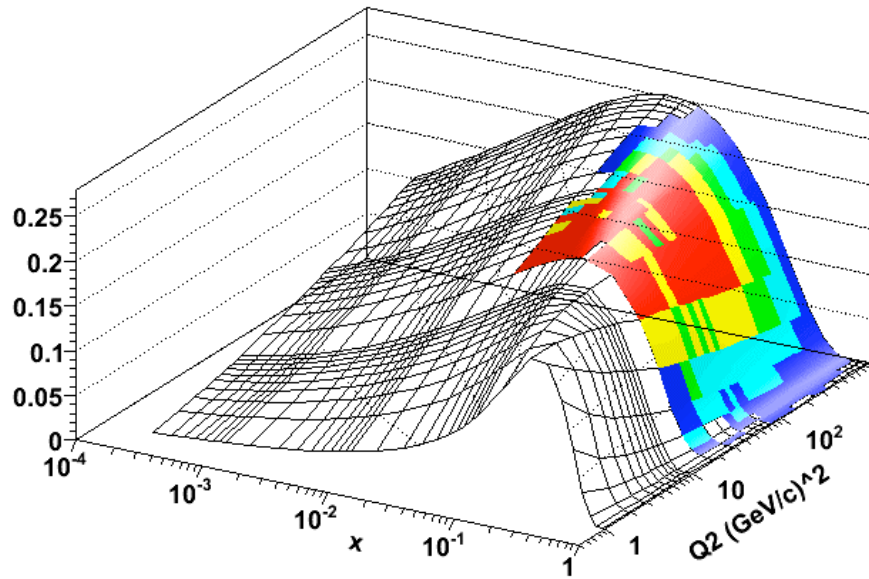
# Single Spin Asymmetries



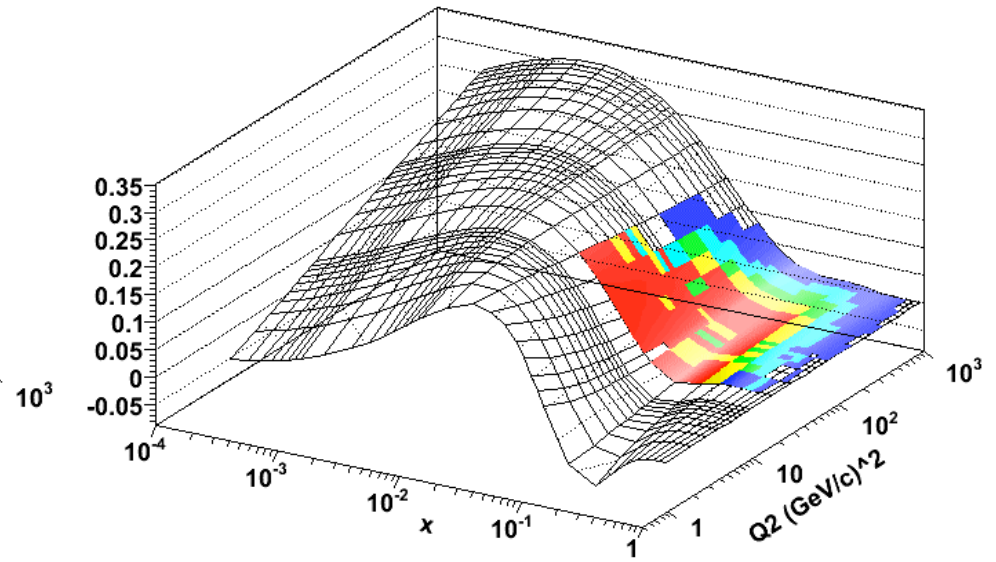
- Longitudinal single spin asymmetries are consistent with zero, as expected

# STAR 200 GeV pp jet sensitivity for a sub-sample of models

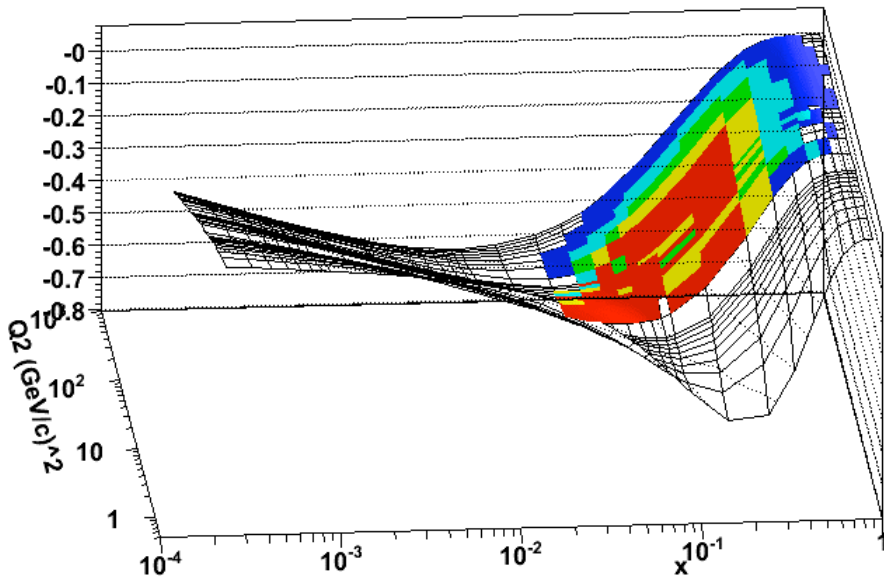
GRSV-STND Gluon Polarized Structure Function



GS-C Gluon Polarized Structure Function



GRSV-MIN Gluon Polarized Structure Function



DSSV 2008 Gluon Polarized Structure Function

