Recent STAR Results from Charged Pion Production in Polarized pp Collisions at $\sqrt{s}$ = 200 GeV at RHIC

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for the **STAR** Collaboration

- Introduction

- 2005 Preliminary Result

- 2006 Preliminary Result

Gluon Polarization and the Proton Spin

$$\langle S_z^p \rangle = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + \langle L_z^q \rangle + \langle L_z^g \rangle$$

- Measurements of $g_1(x, Q^2)$ indicate quark spin contribution is small

- $\Delta g(x)$ extracted via scaling violations in pDIS, but uncertainties remain large

- Determination of the gluon is a primary goal of the RHIC Spin program

Leader et al, PRD 75, 074027

$Q^2 = 2.5$ GeV^2 xΔG

—— ΔG > 0
—·—· ΔG < 0
----- change sign xΔG
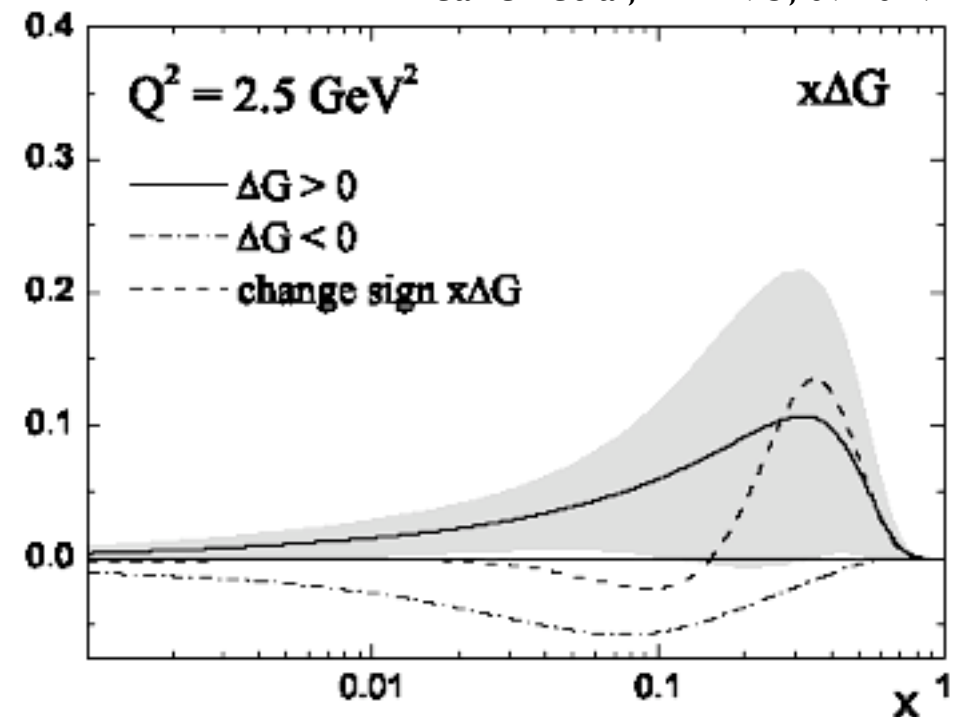
Polarized pp Collisions at RHIC

- Observable is A_{LL}, written using QCD factorization as

$$A_{LL} = \sum_{f_A f_B f_C} \frac{\Delta f_A \Delta f_B \otimes \Delta \sigma_{AB \to CX} \otimes D_C}{f_A f_B \otimes \sigma_{AB \to CX} \otimes D_C}$$

- Δg enters at leading order; precise measurements of unpolarized PDFs used as inputs

- Integrate over a wide range in x and multiple subprocesses with different partonic asymmetries

- Charged pion measurements (particularly π^+) can leverage favored/disfavored fragmentation at high z (fraction of parton momentum carried by π) to improve analyzing power.

subprocesses contributing to π production
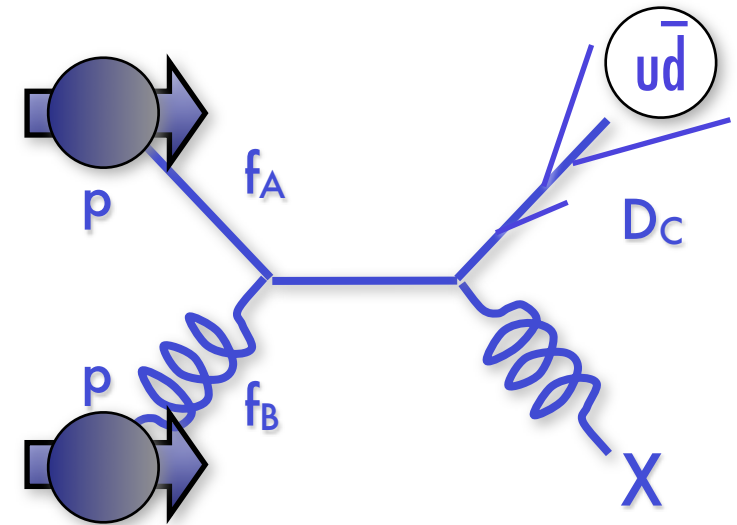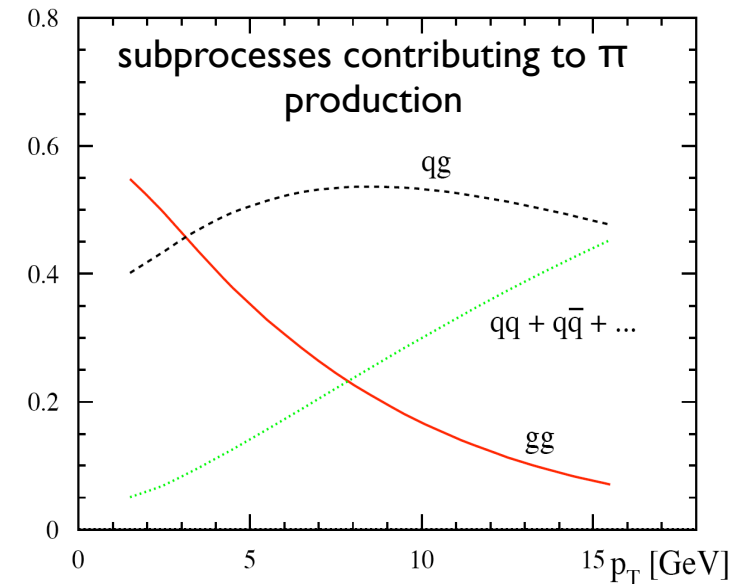
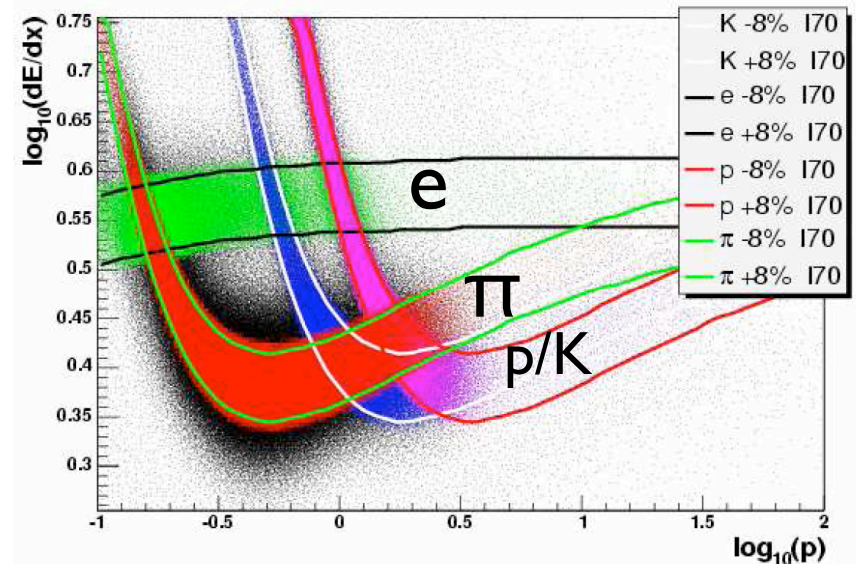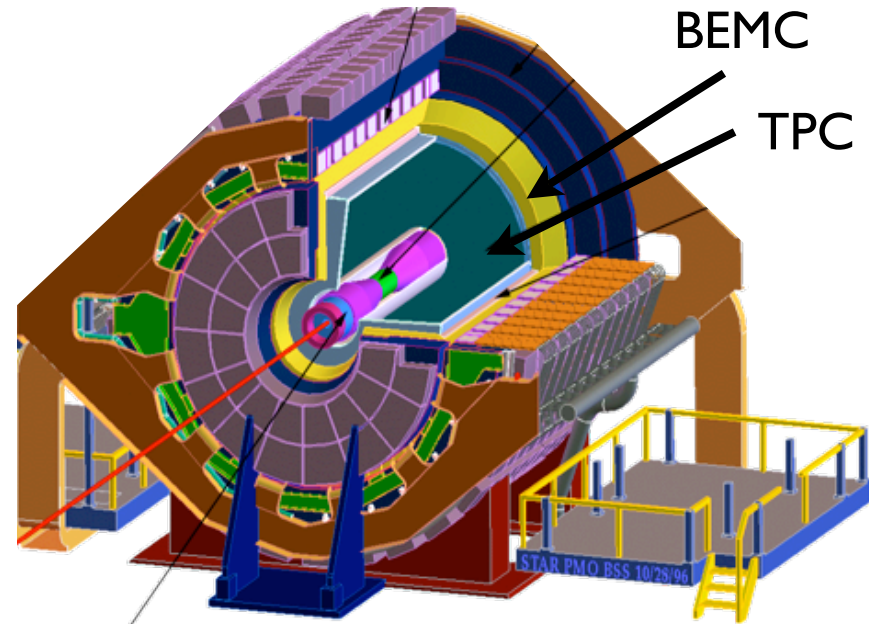# Polarized pp Collisions at RHIC
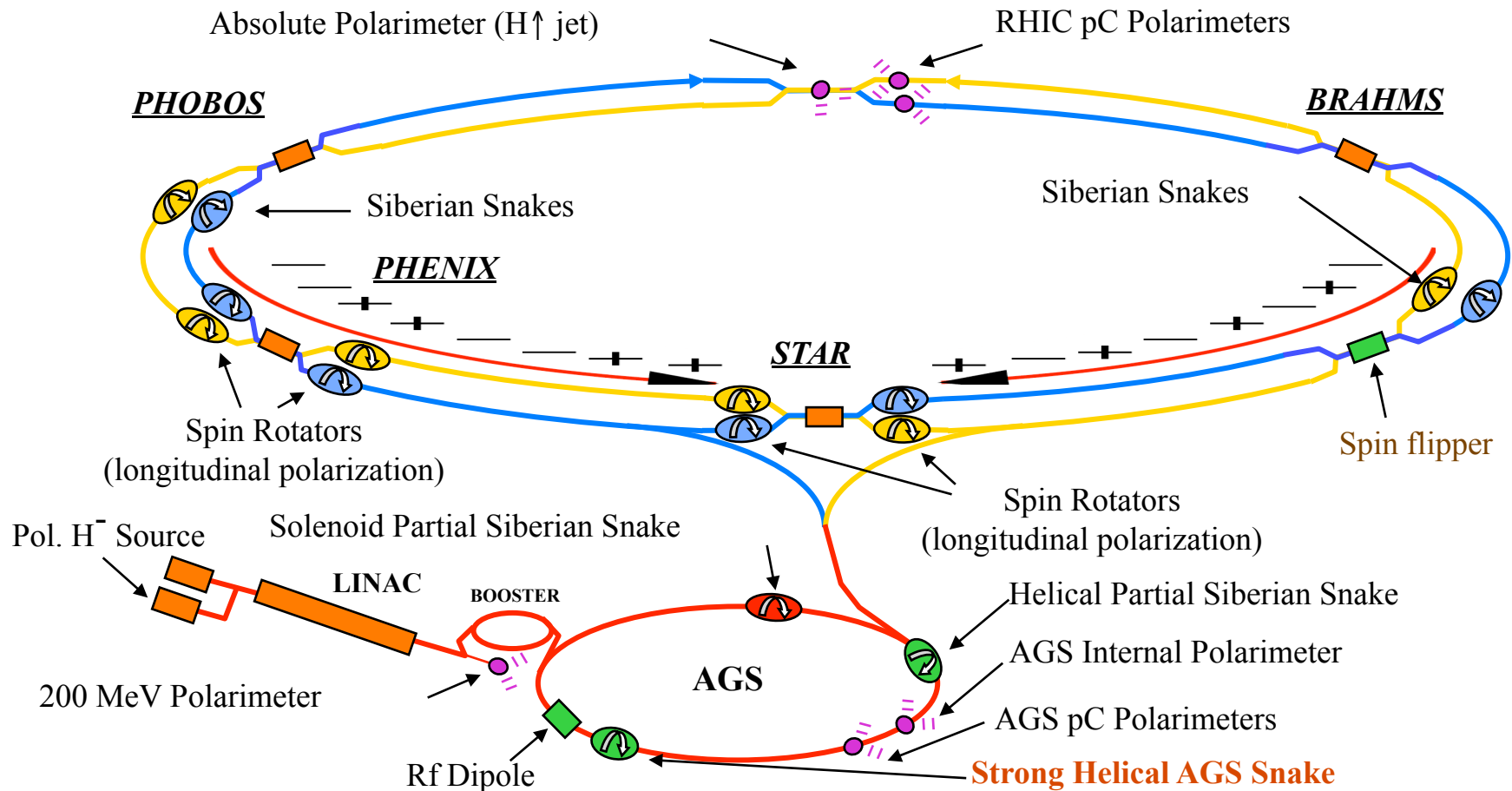
- Spin controlled bunch to bunch -- pattern changes with each fill

- "Siberian snakes" counteract depolarizing resonances

- Rotators at experiments allow for longitudinal spin

STAR detector

Subsystems of Interest

- BBC: relative luminosities, minimum bias trigger

- BEMC: jet patch trigger sums energy over fixed $\Delta\eta \times \Delta\Phi = 1.0 \times 1.0$ patches

- Time Projection Chamber

  - tracking and PID using dE/dx for $|\eta| < 1.3$ and $p_T < 15$ GeV/c

  - 1σ separation between pions and kaons / protons

  - Sophisticated calibrations improve precision at high p_T (arxiv:0807.4303)

BEMC

TPC

e

π

p/K

Cross Sections

STAR Preliminary

Y. Xu, Hot Quarks 2008

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STAR Preliminary
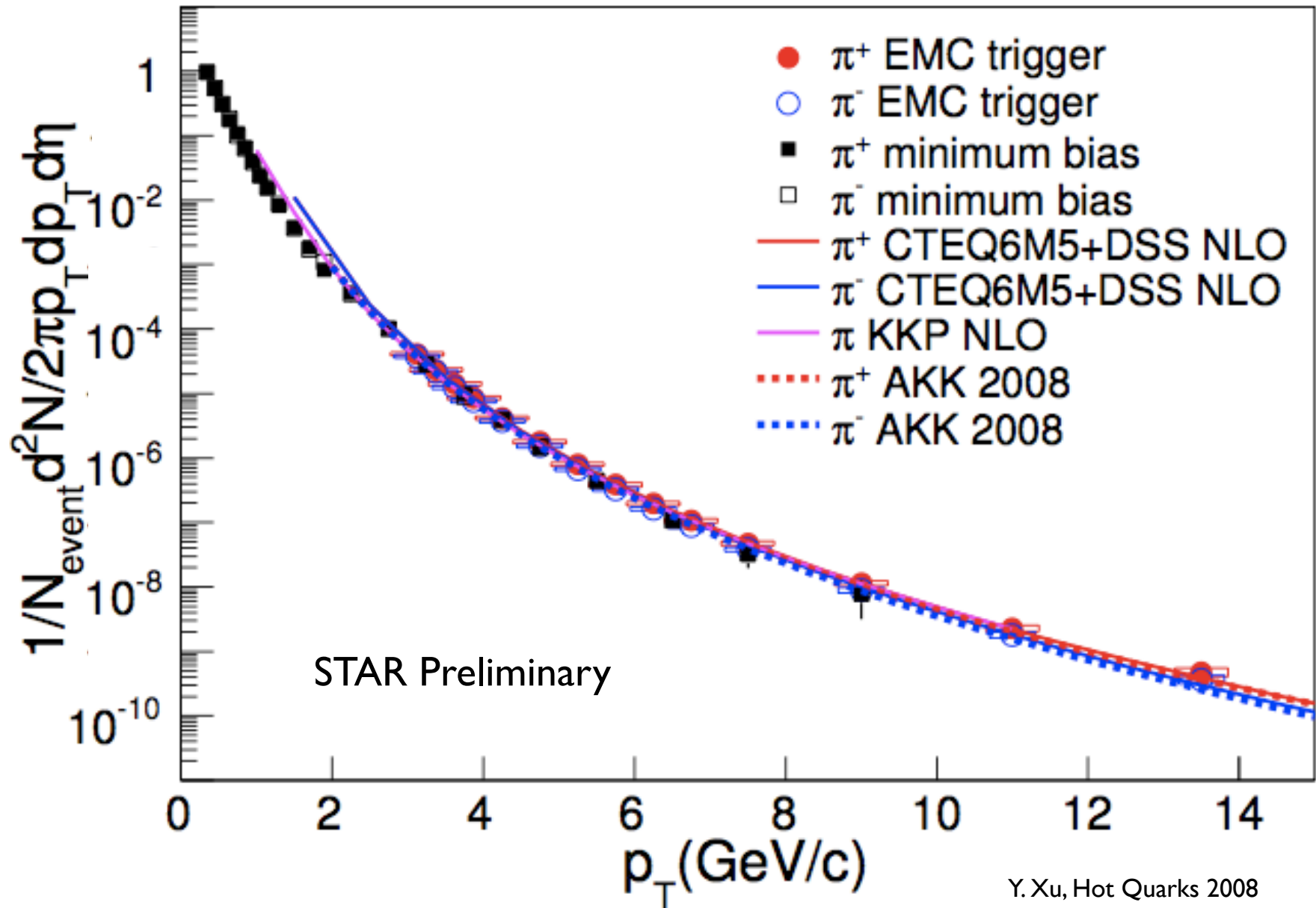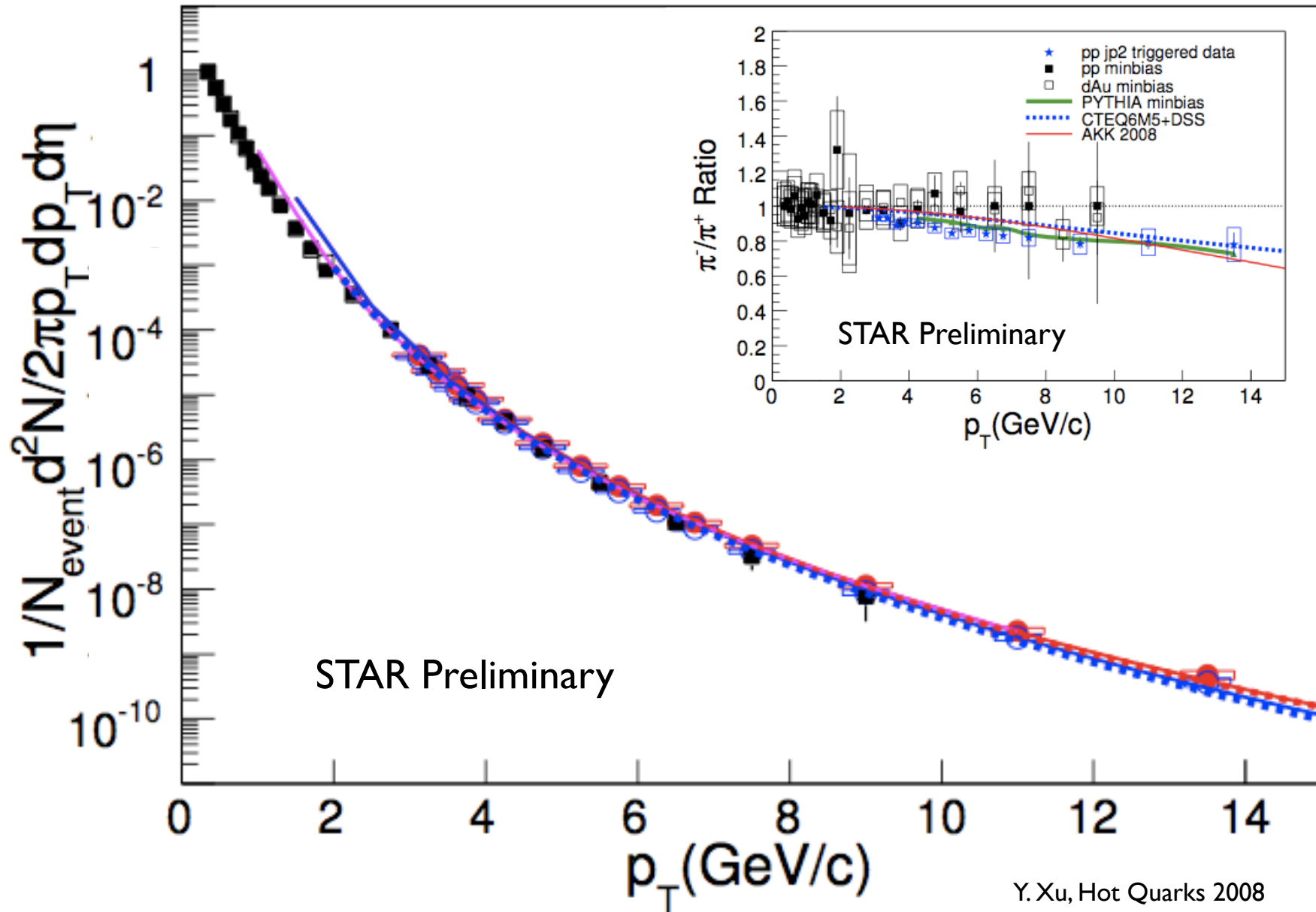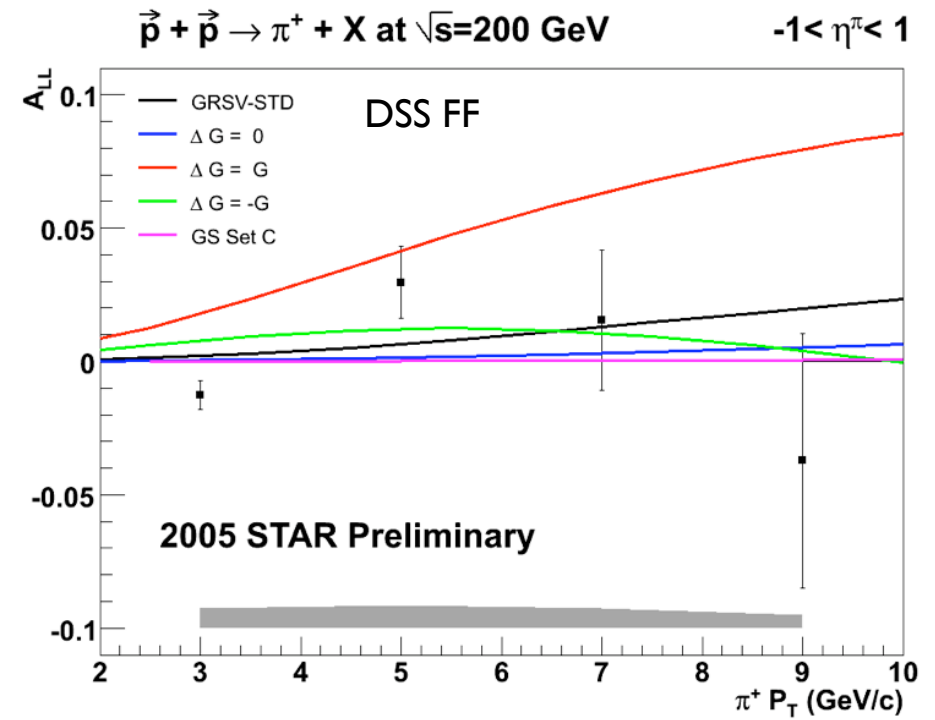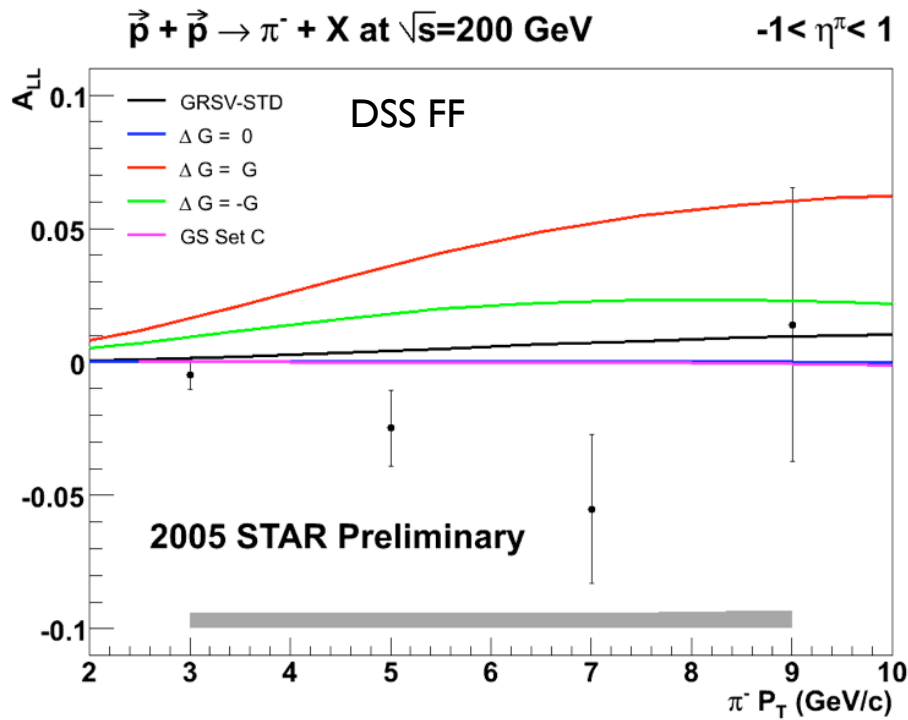
Y. Xu, Hot Quarks 2008

2005 Inclusive Charged Pion A_LL

- 1.6 pb^{-1} , 45-50% beam polarizations

- Dominant systematic uncertainty arises from use of jet patch trigger which

    - samples partonic subprocesses in a non-uniform fashion

    - suppresses high-z charged pion fragmentation

2006

- Significant improvements in FOM

  - 50% ⇒ 60% beam polarizations

  - 1.6 pb^{-1} ⇒ 5.4 pb^{-1}

  - BEMC η acceptance [0,1] ⇒ [-1,1]

- But ... increased JP trigger thresholds result in strong fragmentation bias for charged pions in trigger jet

Plan of Attack

- Limit bias by measuring charged pions opposite a trigger jet

- Plot asymmetry versus z ≡ p$_T$(π) / p$_T$(trigger jet) to cleanly isolate favored fragmentation

trigger here

Jet Patch Trigger

π^- π^+ π^+

measure these
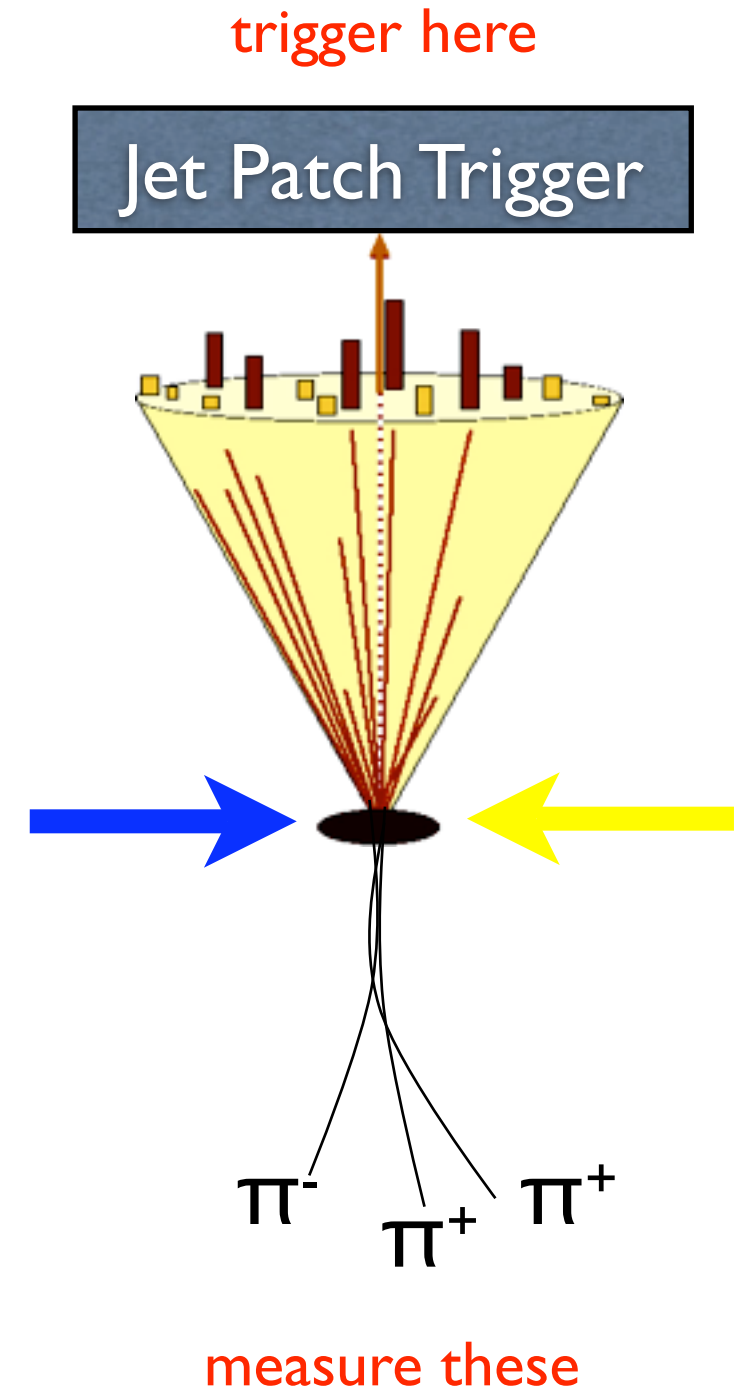
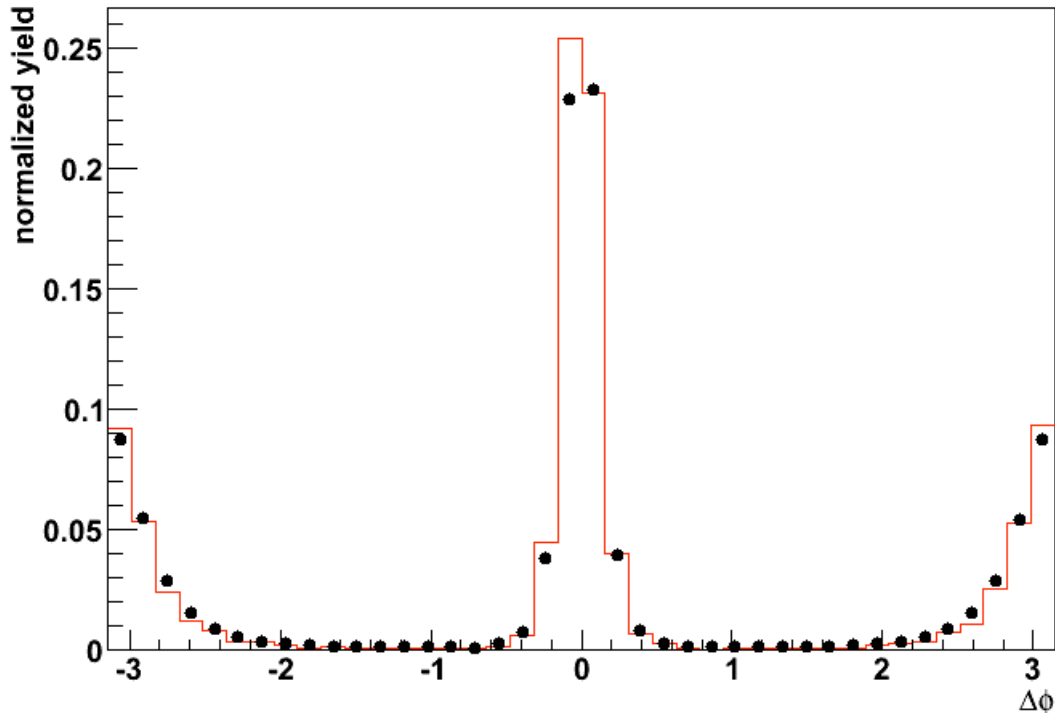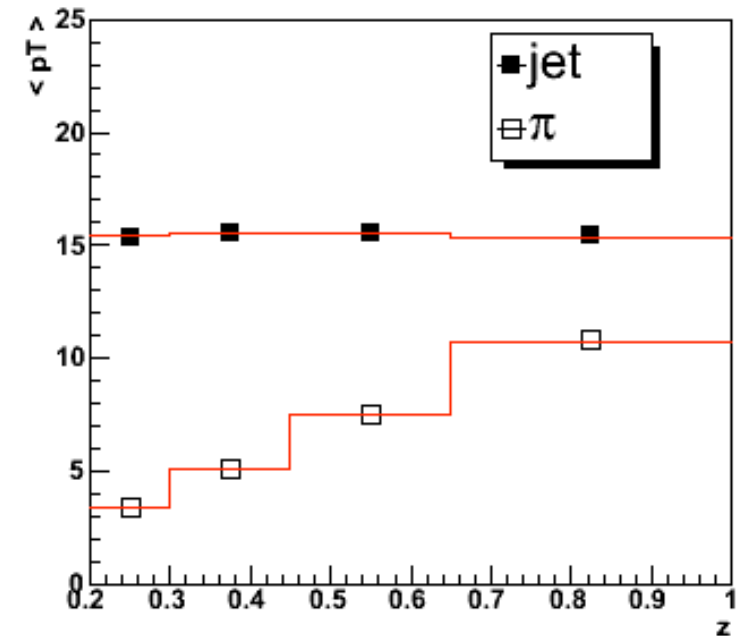# Details of the Measurement

- select $|\phi(\pi) - \phi(jet)| > 2.0$ (~41%)

- Correct measured jet p_T before calculating z using function derived from PYTHIA and GEANT jet comparison

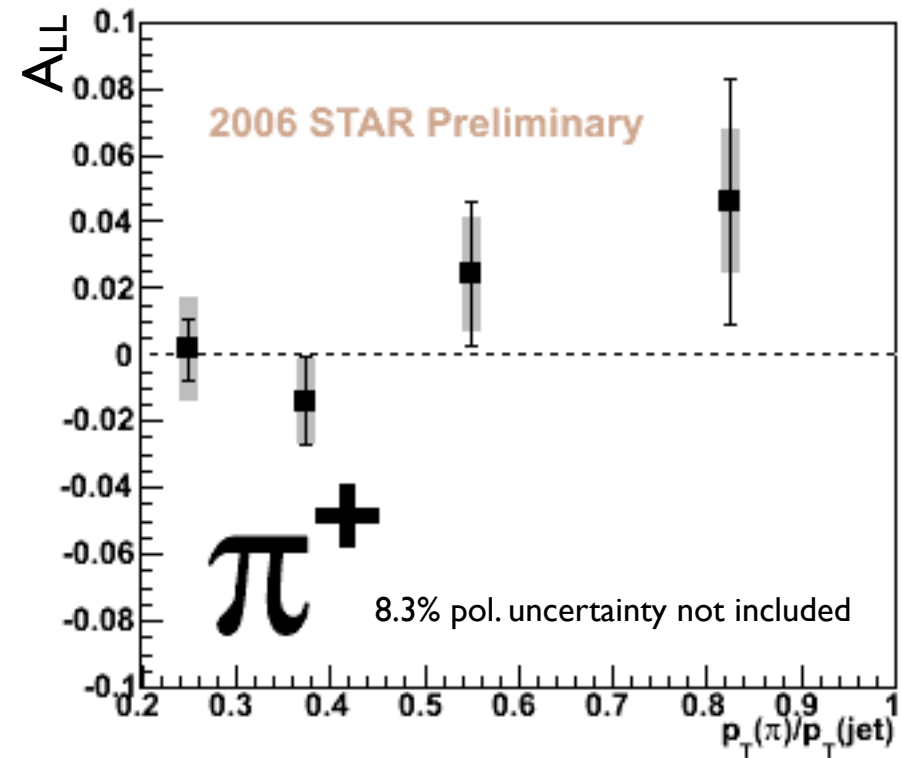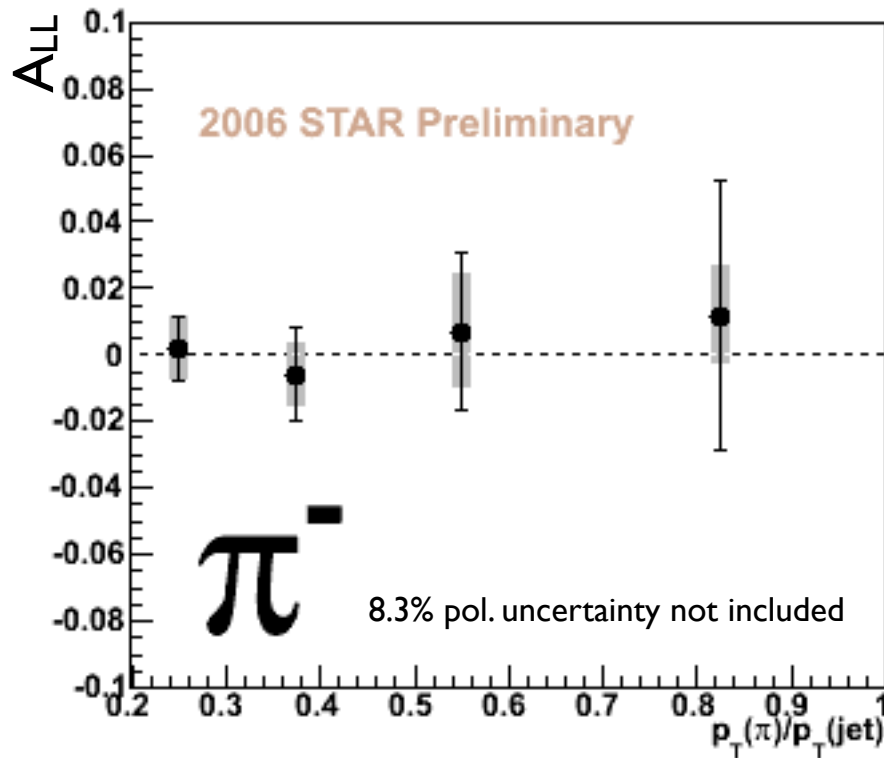χ^2 / ndf : 8.209 / 7
p0 : -1.538 ± 0.2064
p1 : 0.1561 ± 0.01721
p2 : 0.001691 ± 0.0003469
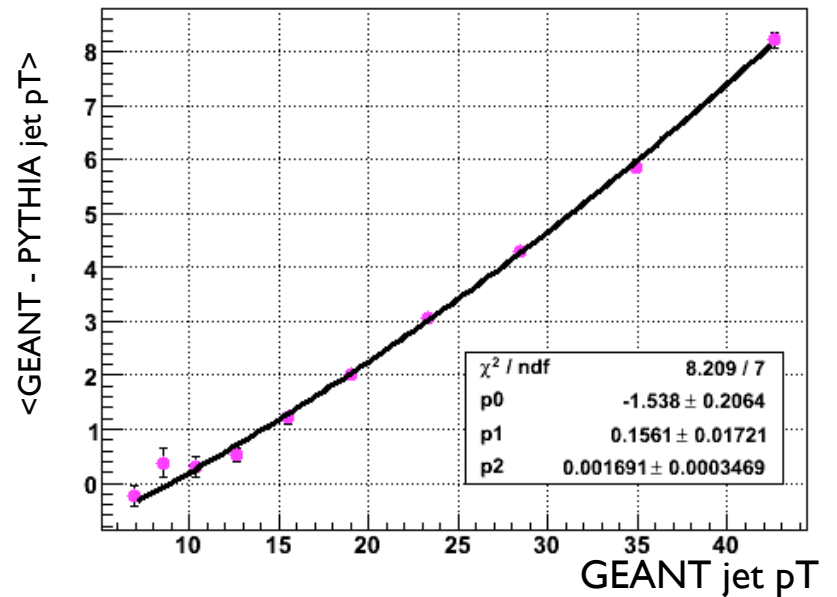
$\Delta\phi$ **relative to trigger jet**

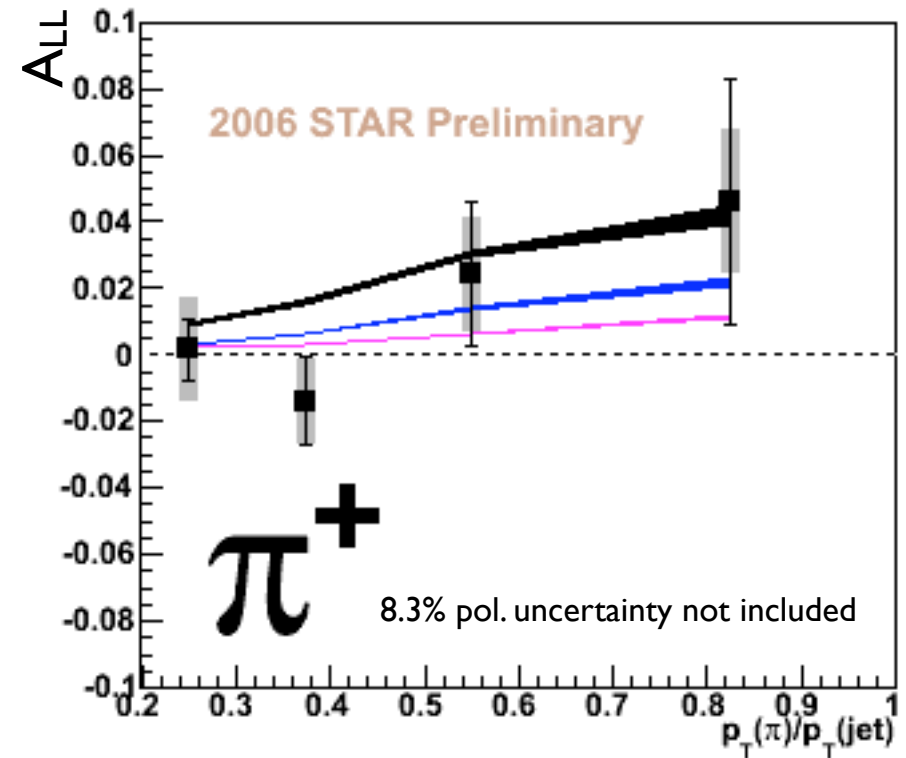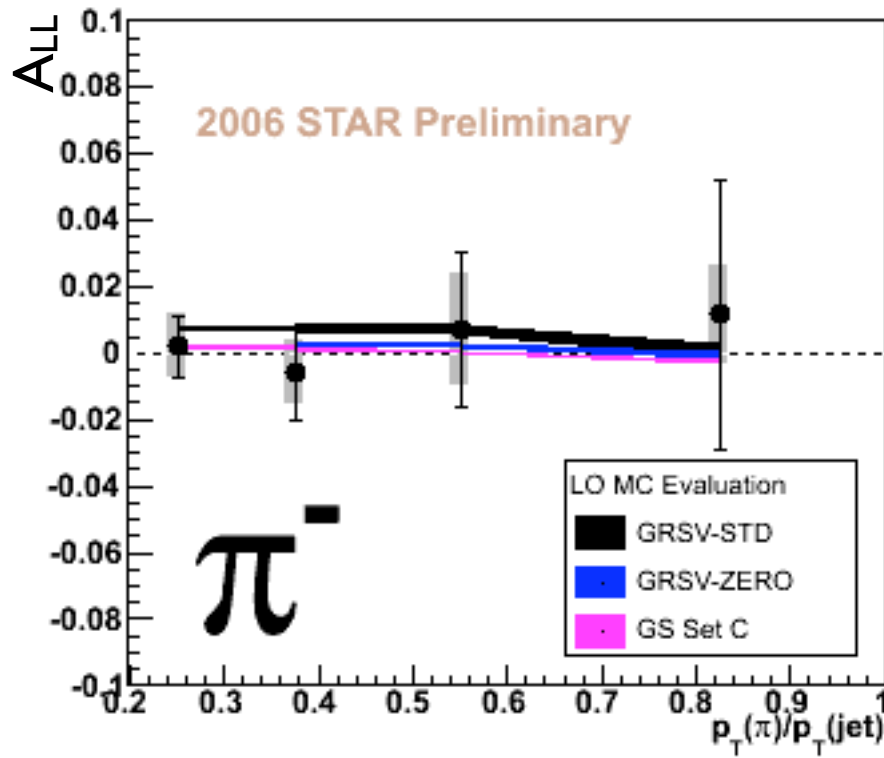**JP Data / Monte Carlo comparison, $\pi +$**

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2006 Result

- Conservative systematic uncertainties are evaluated for

  - Trigger bias (6 - 15 x 10^{-3})

  - PID background contamination (2 - 10 x 10^{-3})

  - Uncertainty on the jet p$_T$ shift (3 - 16 x 10^{-3})

 - Non-longitudinal components, relative luminosity (small)

Comparison to LO MC

- Full NLO pQCD predictions are not yet available for this measurement

- These curves generated by sampling a_{LL} and parton distribution functions at kinematics of PYTHIA event.

- π^+ offers significant sensitivity at high z
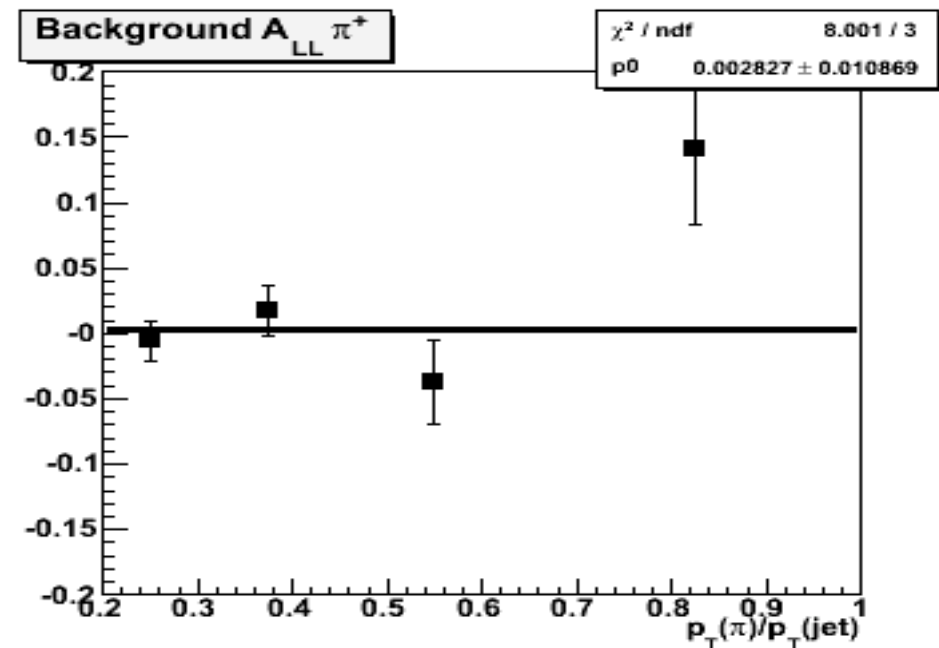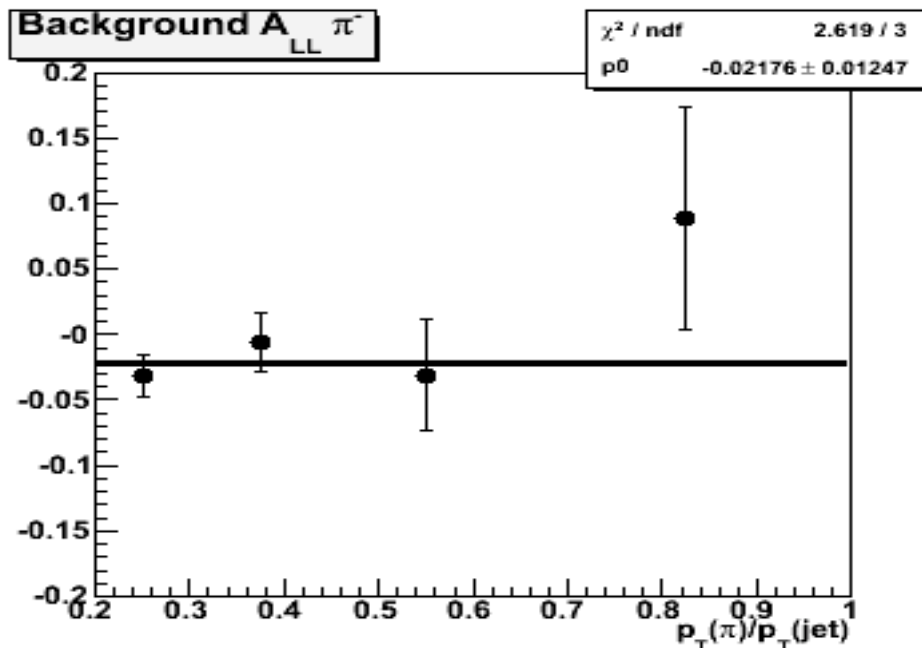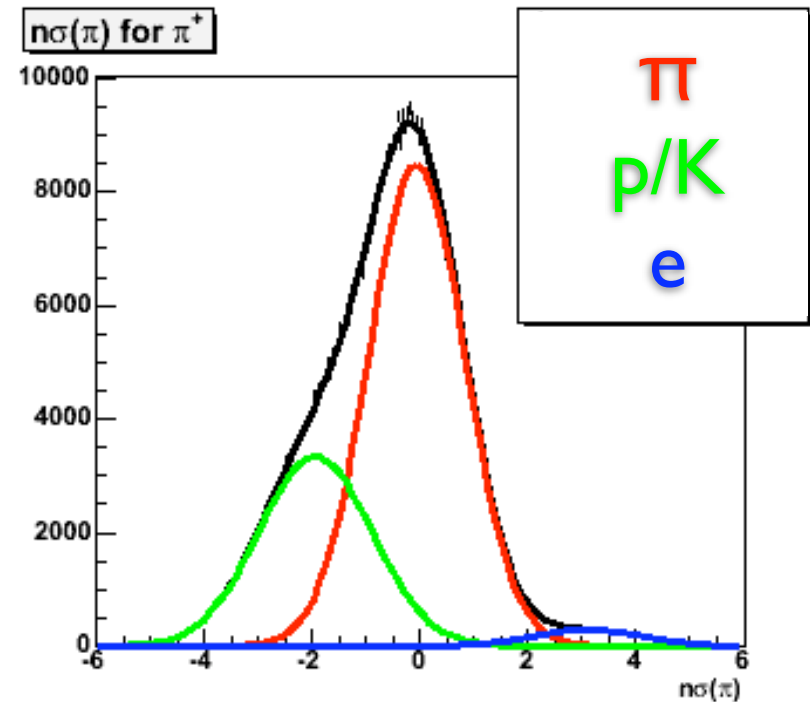
Trigger Bias

- Jet patch trigger samples subprocesses non-uniformly

- Traditionally, LO MC evaluation of A_{LL} is used to assign model-dependent systematic

- This measurement integrates over a wide range in jet p_T, so triggered dataset samples different kinematic range too

- Factor out the difference in $<$jet $p_T>$ by reweighting the Monte Carlo

- Bias assigned assuming GRSV-STD
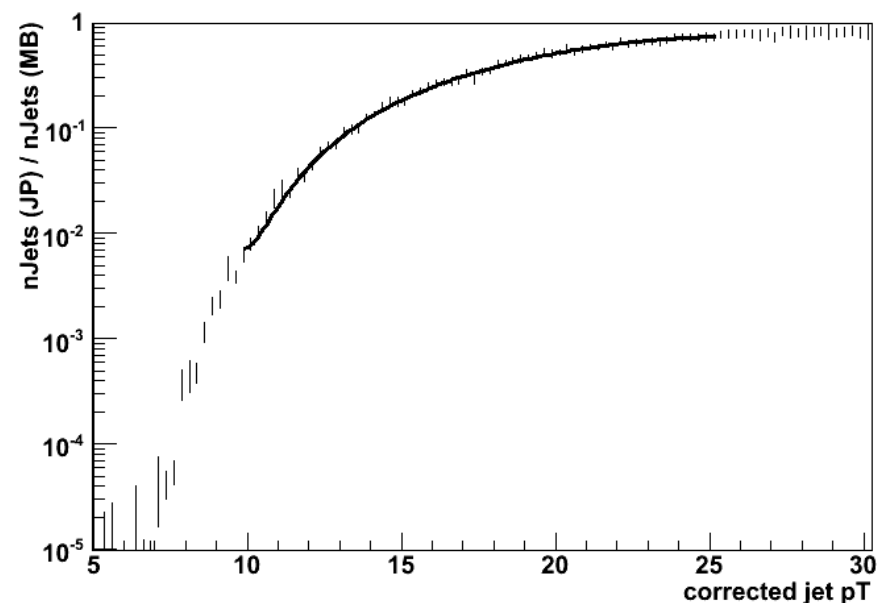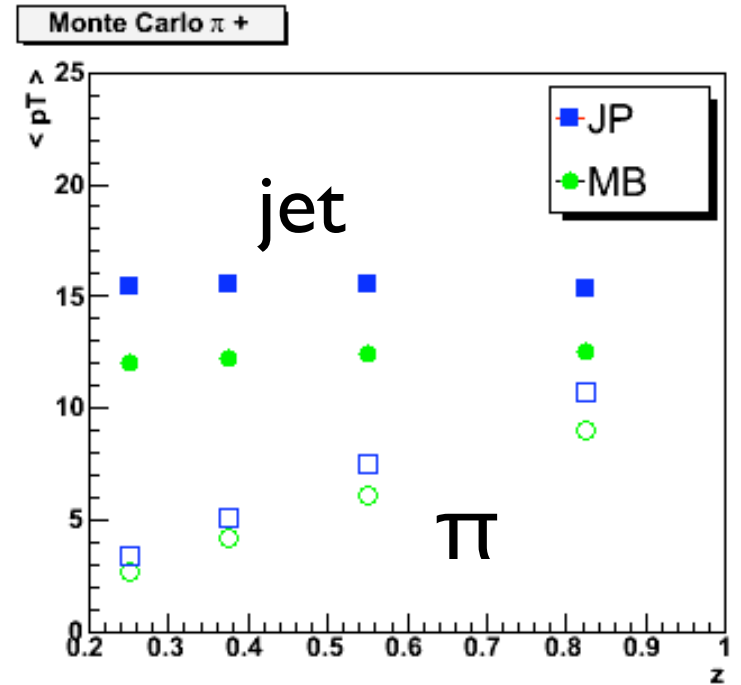
PID Background Asymmetry

- use triple Gaussian fits to estimate p/K background at 10%

- Select sideband starting at -2σ and calculate its A$_{LL}$

- Systematic assigned as

$$\delta A_{LL} = f_{bg} \times (A_{LL}^{meas} - A_{LL}^{bg})$$

nσ(π) for π$^+$

π
p/K
e

Background A$_{LL}$ π$^-$

χ² / ndf	2.619 / 3
p0	-0.02176 ± 0.01247

P$_T$(π)/P$_T$(jet)

Background A$_{LL}$ π$^+$

χ² / ndf	8.001 / 3
p0	0.002827 ± 0.010869

P$_T$(π)/P$_T$(jet)

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Summary

- 2005 result: first spin asymmetry for inclusive charged pion production at STAR

- 2006 measurement focuses on charged pions opposite a trigger jet to minimize fragmentation bias

- Measurement versus z allows favored fragmentation to improve π^+ analyzing power at high z

- Theoretical predictions for this A_{LL} are forthcoming, and future RHIC runs will allow for additional precision at high z

Backup

Jet p_T shift uncertainty

- Measurement uses ratio of π p_T and corrected jet p_T

- Jet p_T corrections have an associated uncertainty -- check for bin migration effect on A_{LL}

- Conservative evaluation limited by statistical uncertainties