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

Adam Kocoloski
Massachusetts Institute of Technology

for the STAR Collaboration

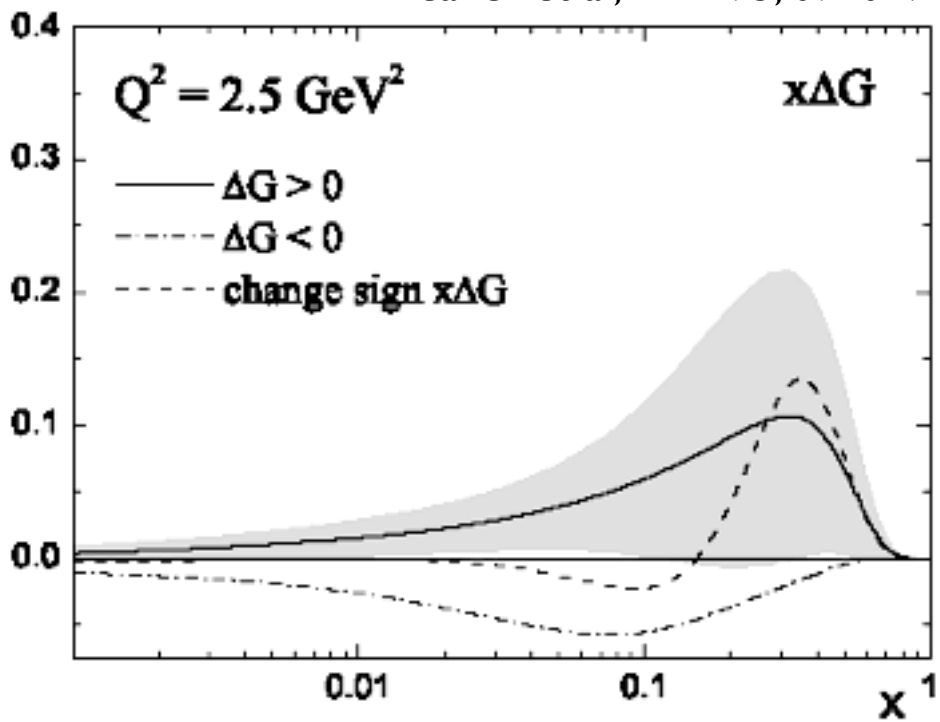
- Introduction
- 2005 Preliminary Result
- 2006 Preliminary Result

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 polarization is a primary goal of RHIC Spin program

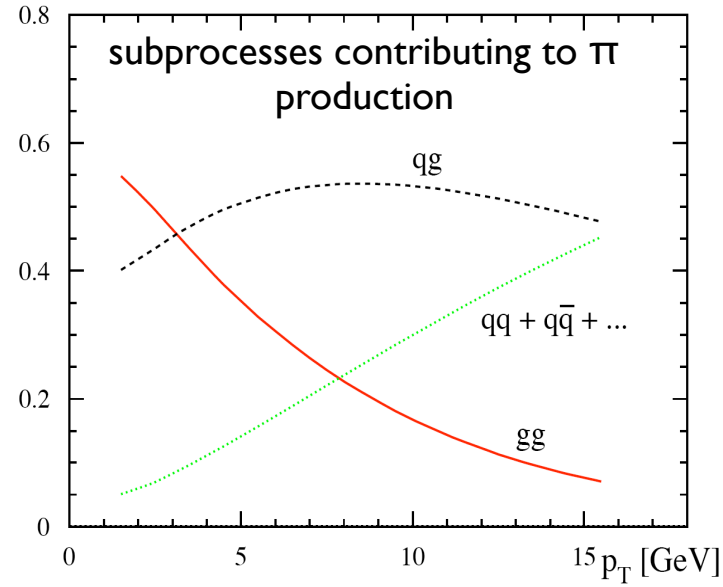
Leader et al, PRD 75, 074027



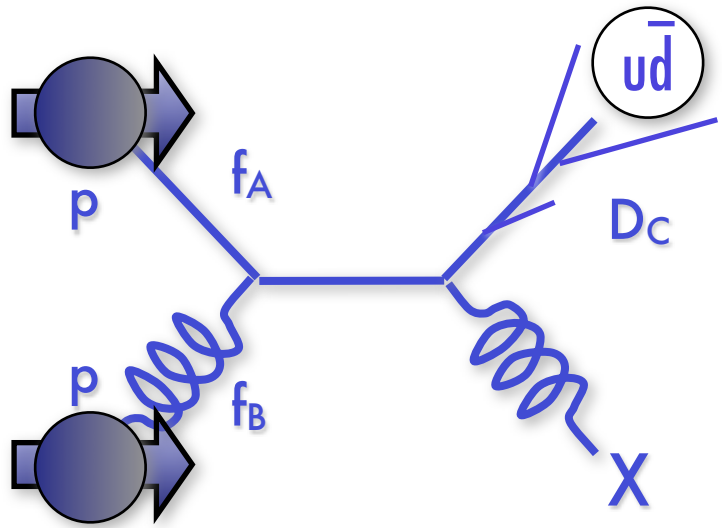
Polarized pp Collisions at RHIC

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

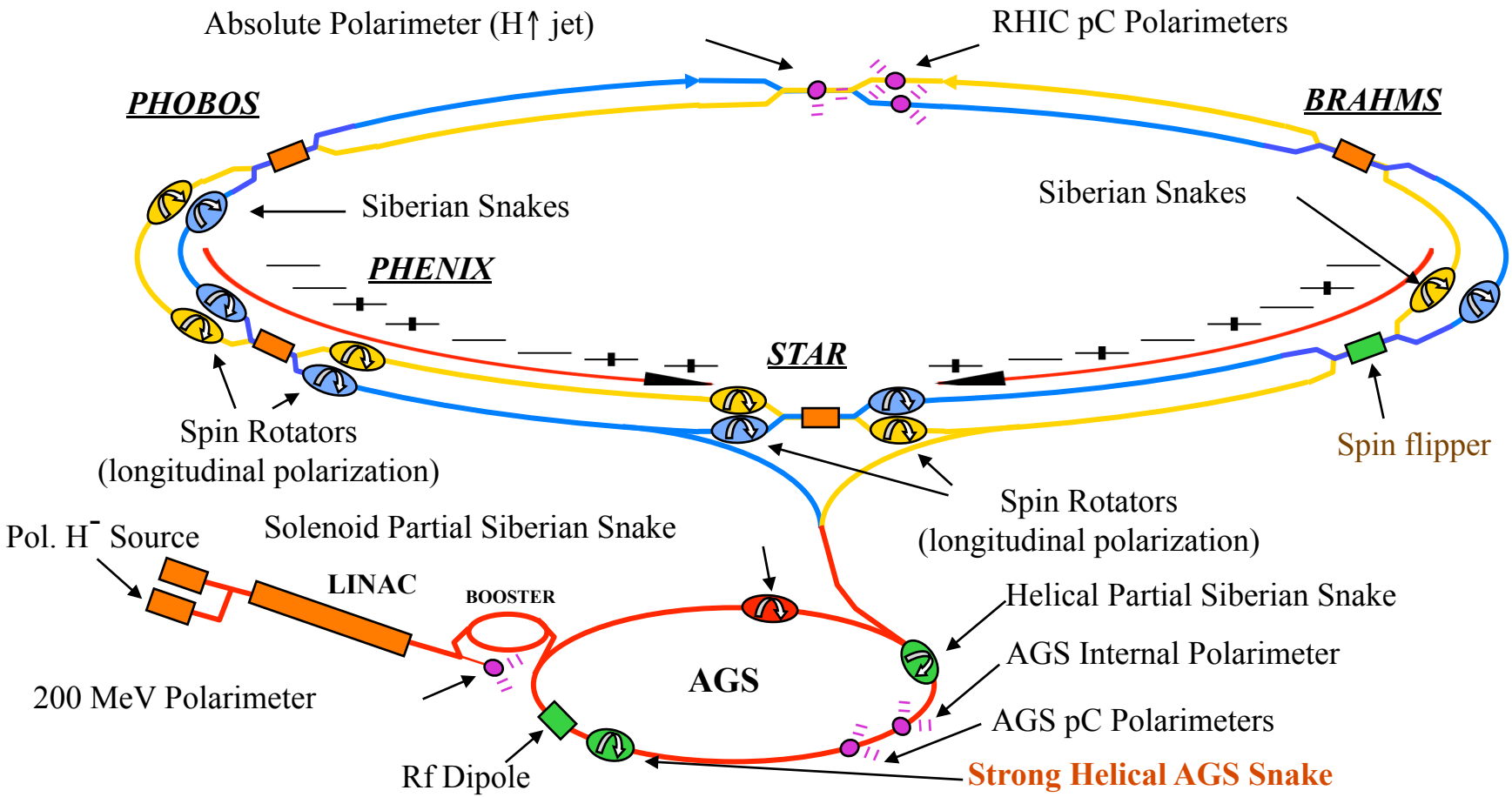
$$A_{LL} = \sum_{f_A f_B f_C} \frac{\Delta f_A \Delta f_B \otimes \Delta\sigma_{AB\to CX} \otimes D_C}{f_A f_B \otimes \sigma_{AB\to CX} \otimes D_C}$$



- 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.



Polarized pp Collisions at RHIC

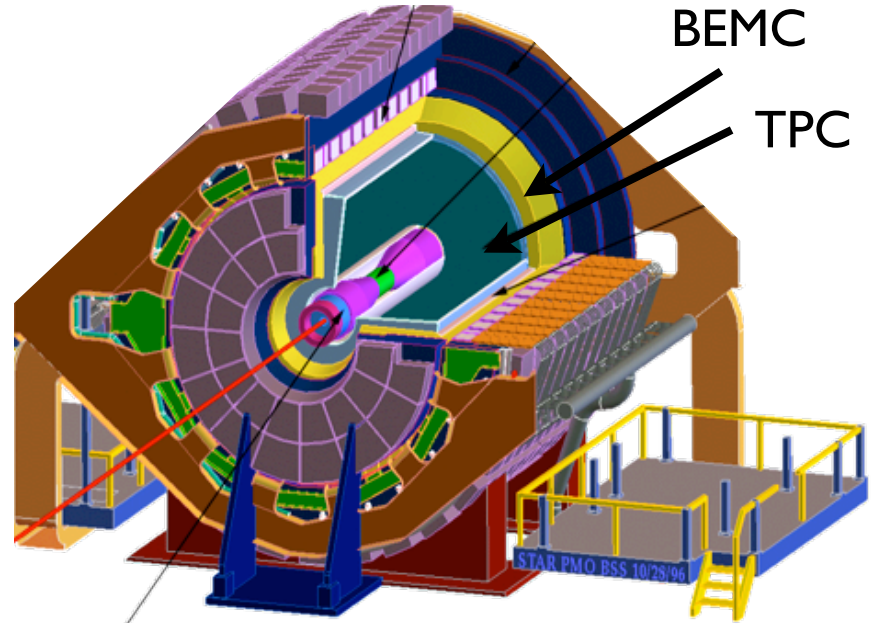


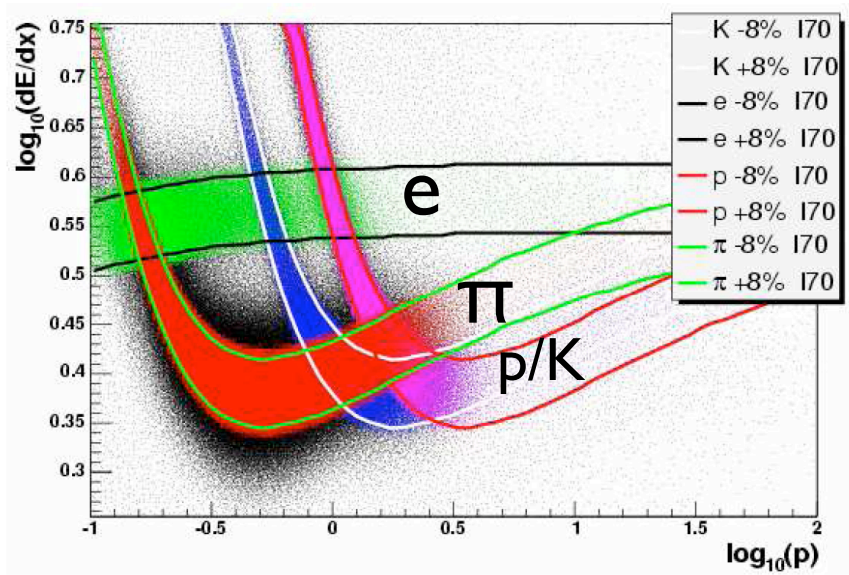
- Spin controlled bunch to bunch -- pattern changes with each fill
- "Siberian snakes" counteract depolarizing resonances
- Rotators at experiments allow for longitudinal spin
- Polarization measured using CNI and H-jet, plus local (transverse) polarimetry at experiments

STAR detector

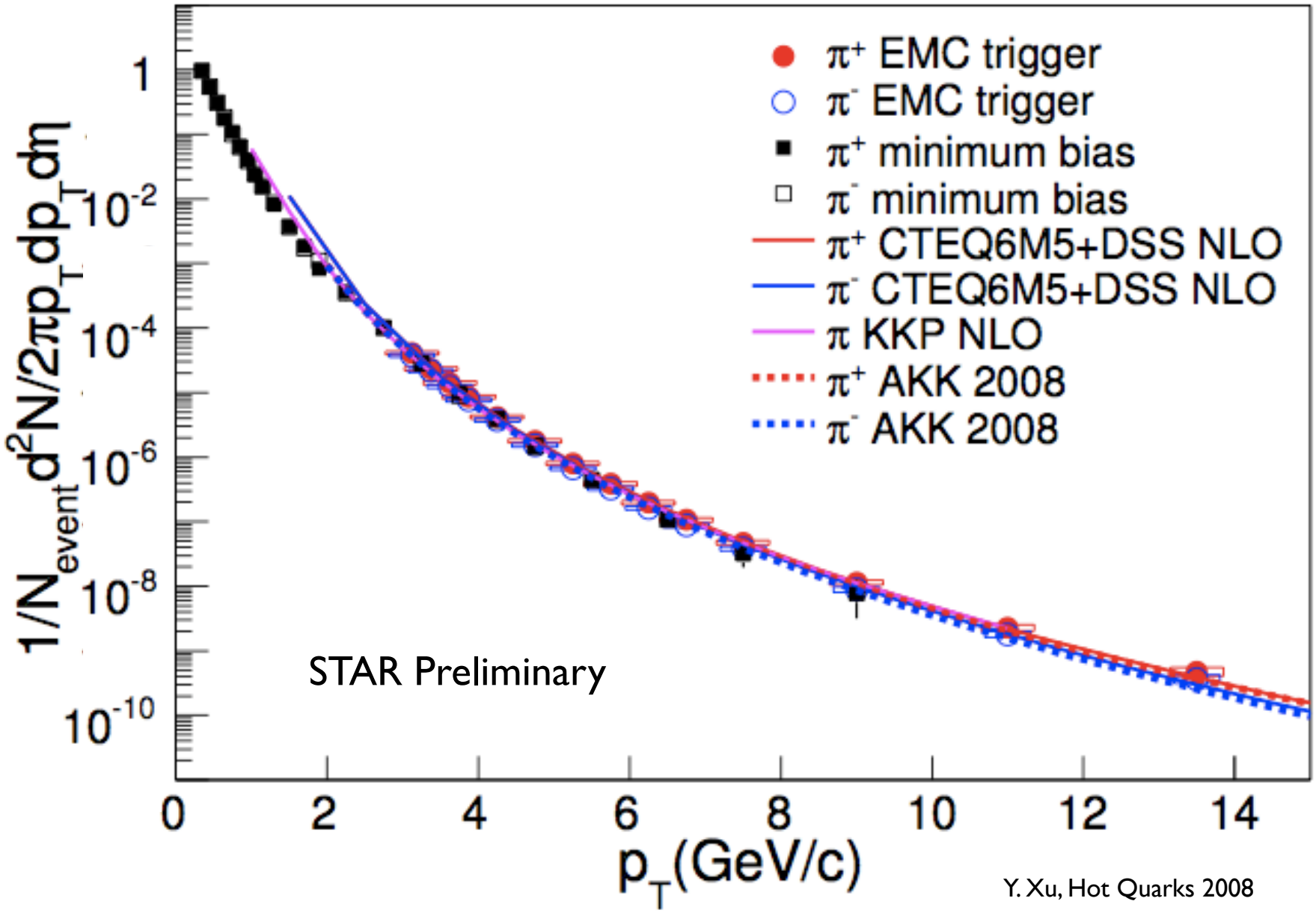
Subsystems of Interest

- 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)



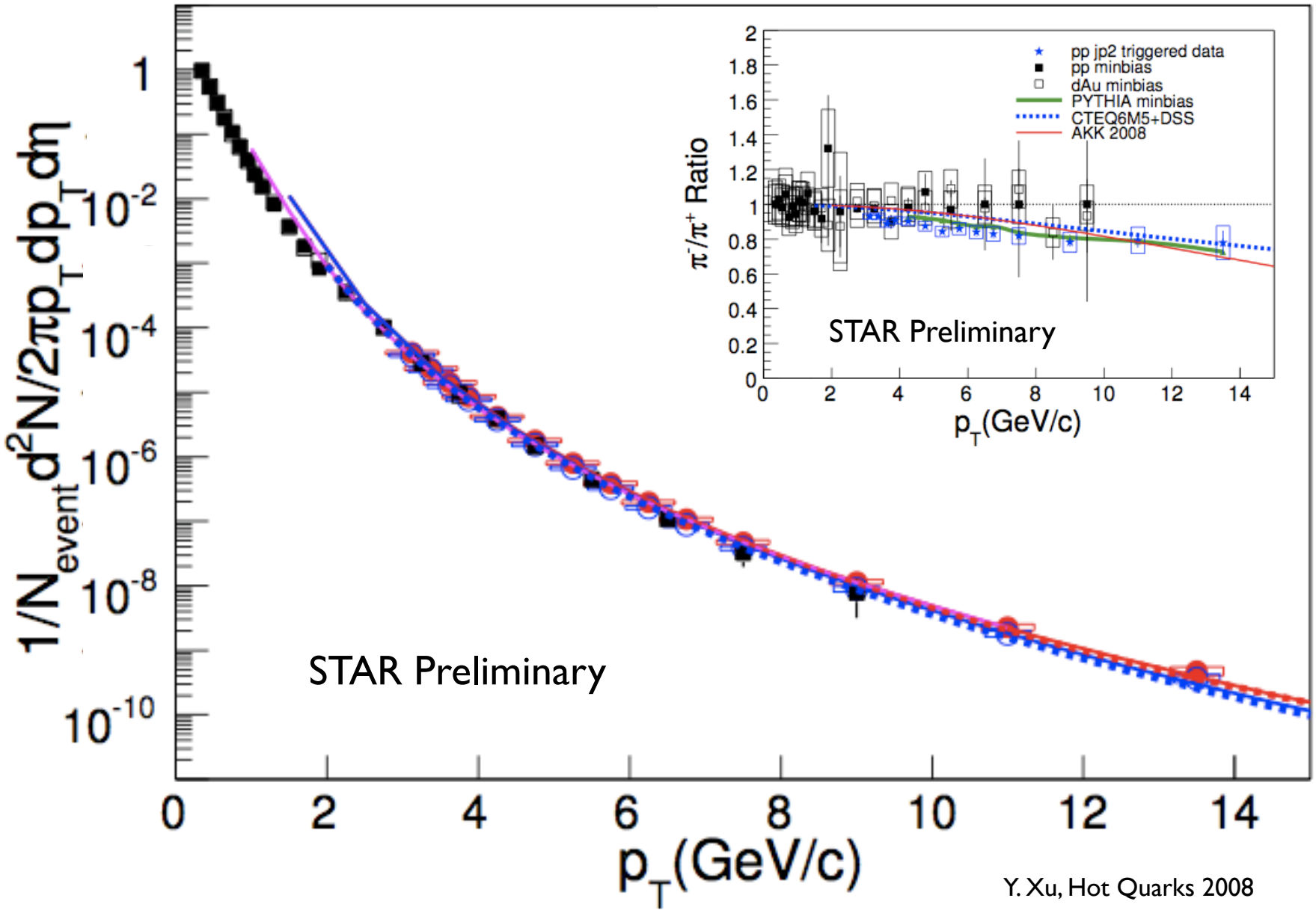


Cross Sections



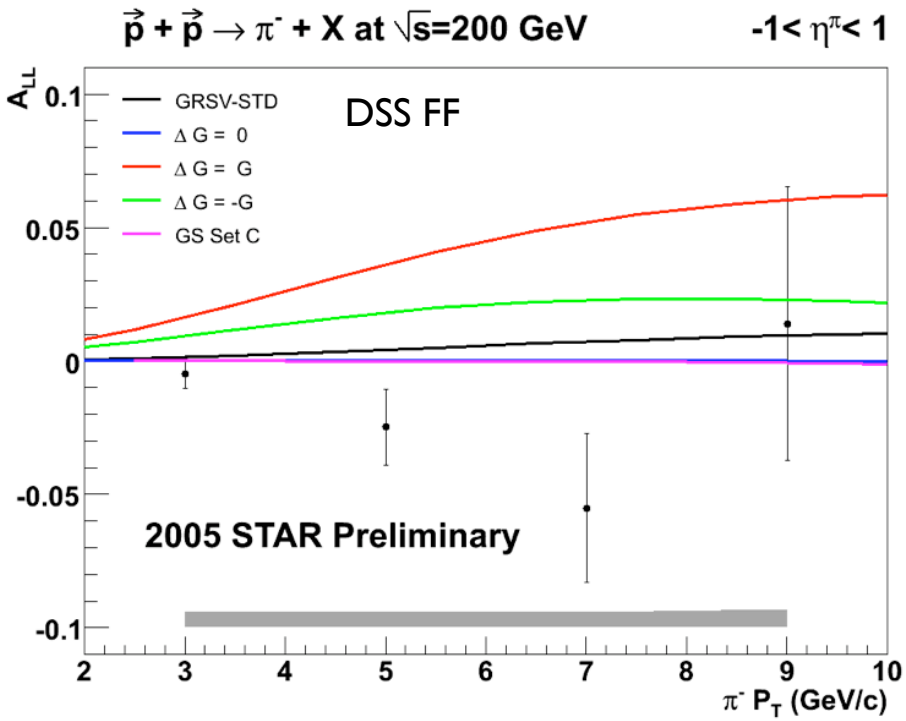
Y. Xu, Hot Quarks 2008

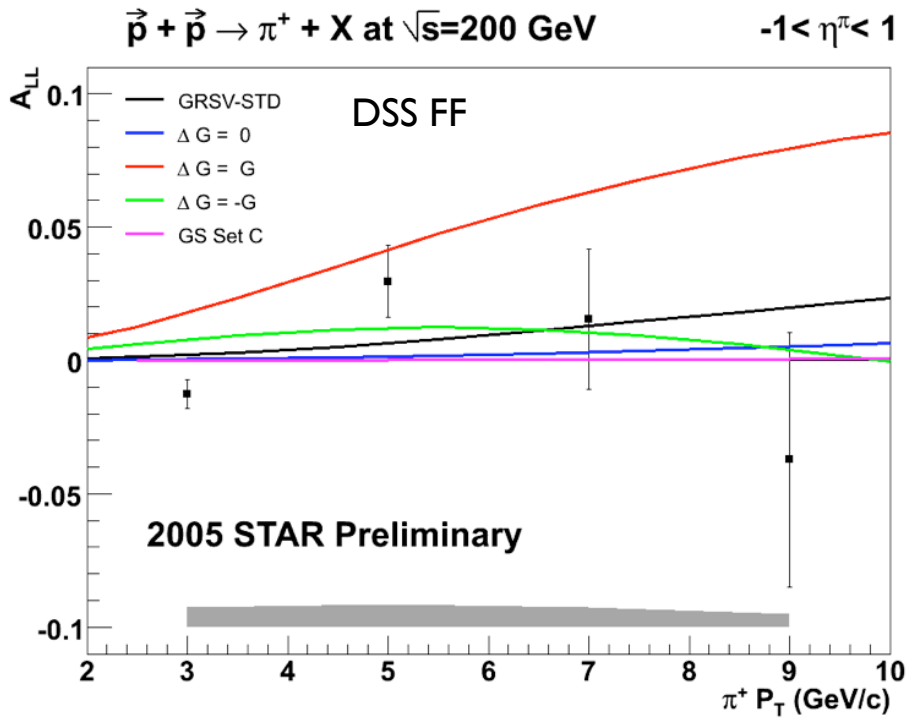
Cross Sections



Y. Xu, Hot Quarks 2008

2005 Inclusive Charged Pion A_{LL}





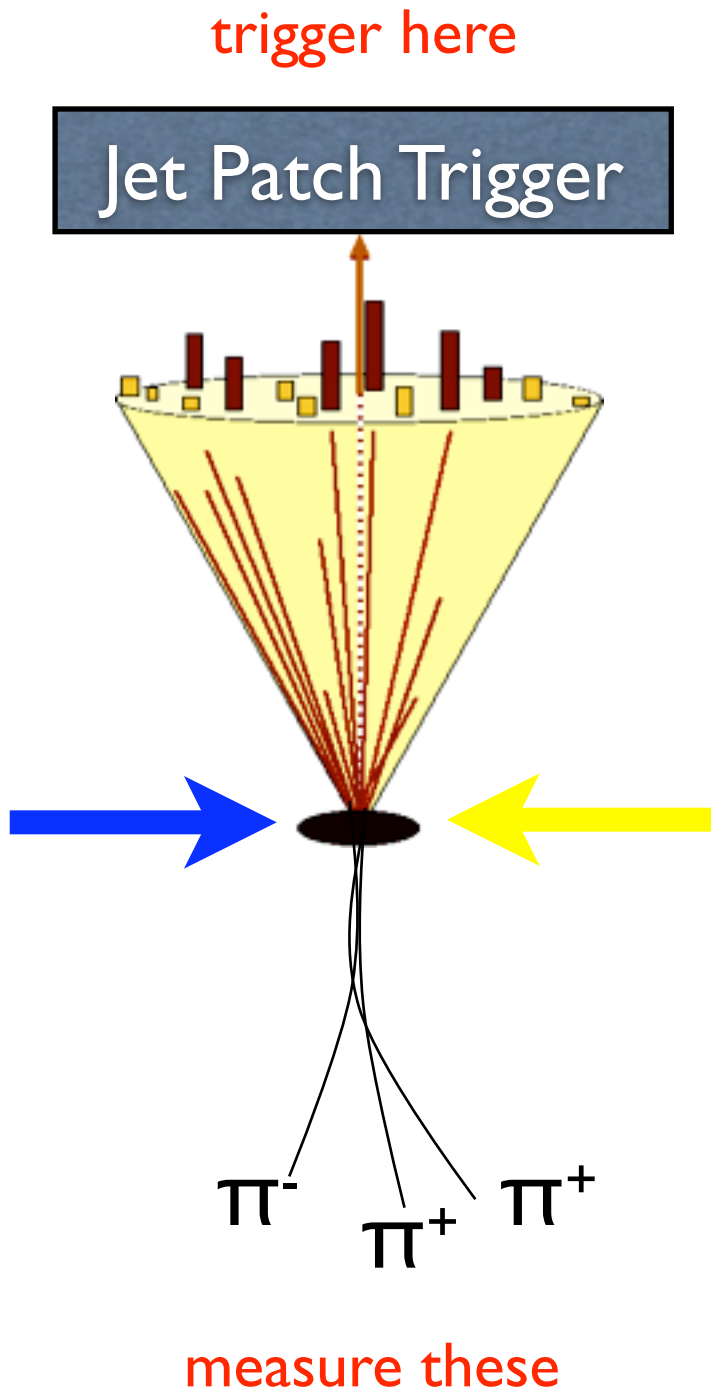
- 1.6 pb^{-1} , 45-50% beam polarizations
- Dominant systematic uncertainty arises from use of jet patch trigger which
  - samples partonic subprocesses in a non-uniform fashion
  - suppresses high-z charged pion fragmentation

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

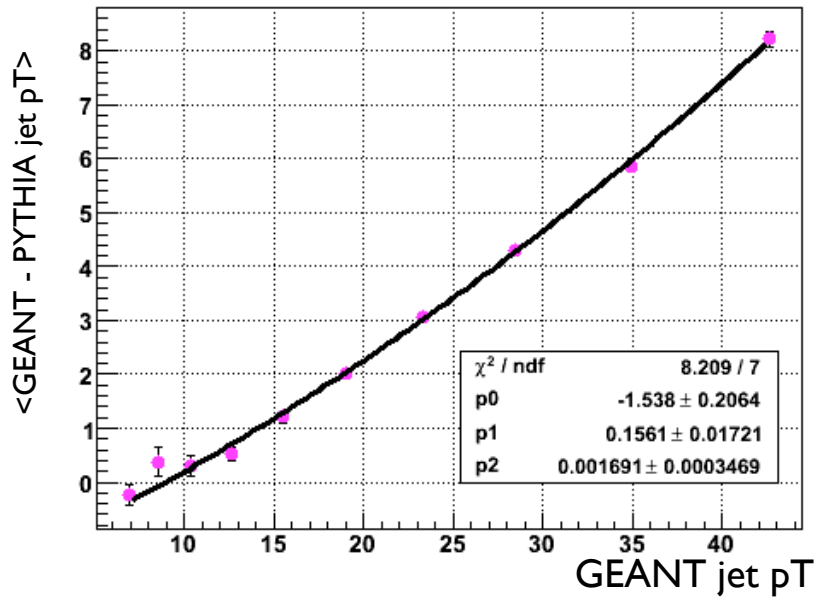
Plan of Attack

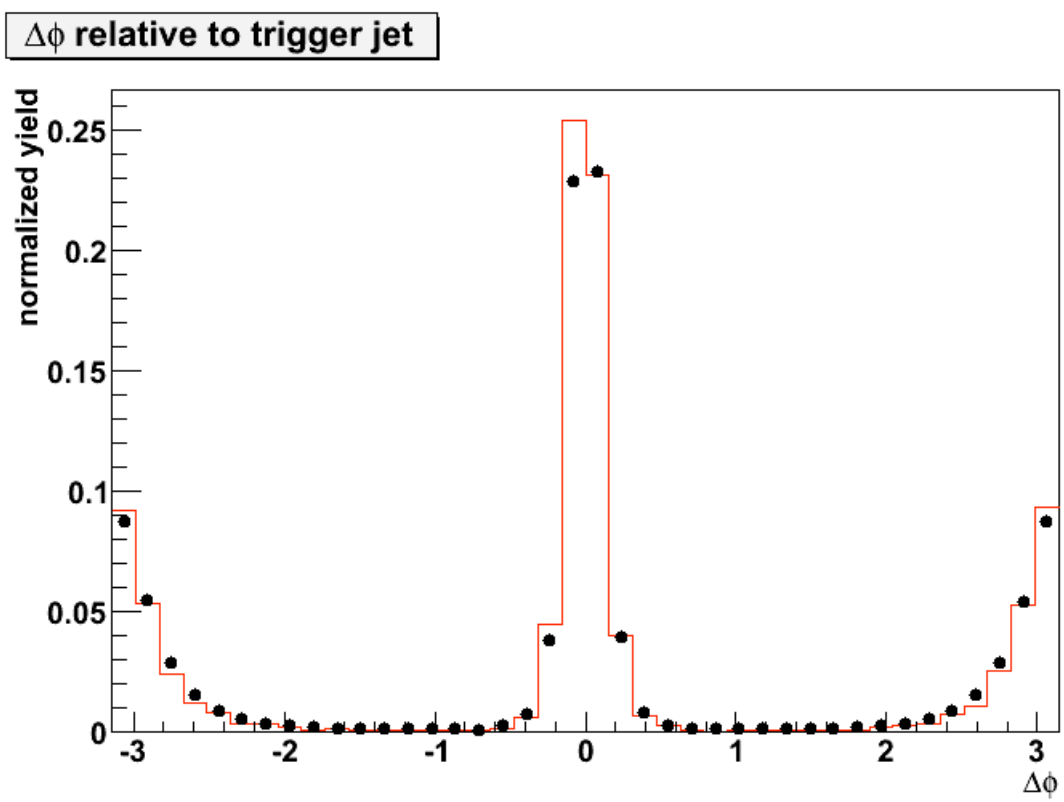
- Limit bias by measuring charged pions opposite a trigger jet
- Plot asymmetry versus $z \equiv p_T(\pi) / p_T(\text{trigger jet})$ to cleanly isolate favored fragmentation

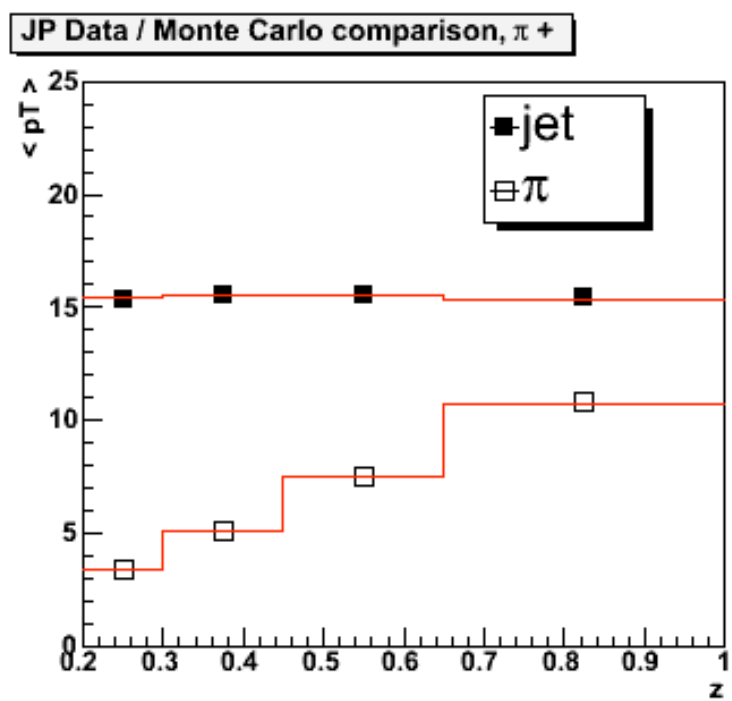


Details of the Measurement

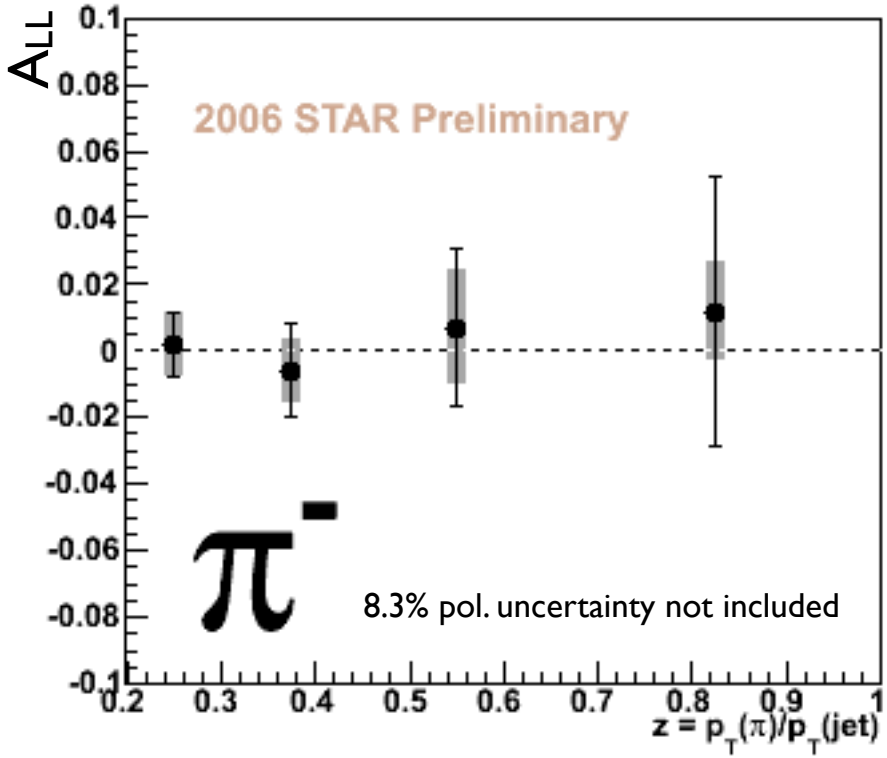
- select $|\phi(\pi) - \phi(\text{jet})| > 2.0$ (~41%)
- Correct measured jet p_T before calculating z using function derived from PYTHIA and GEANT jet comparison

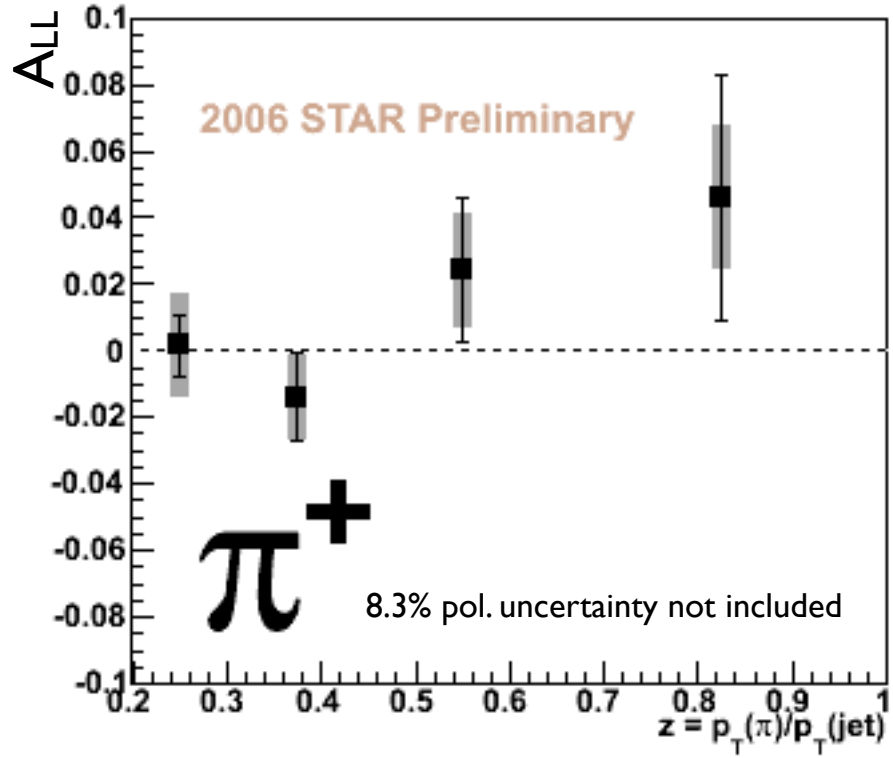






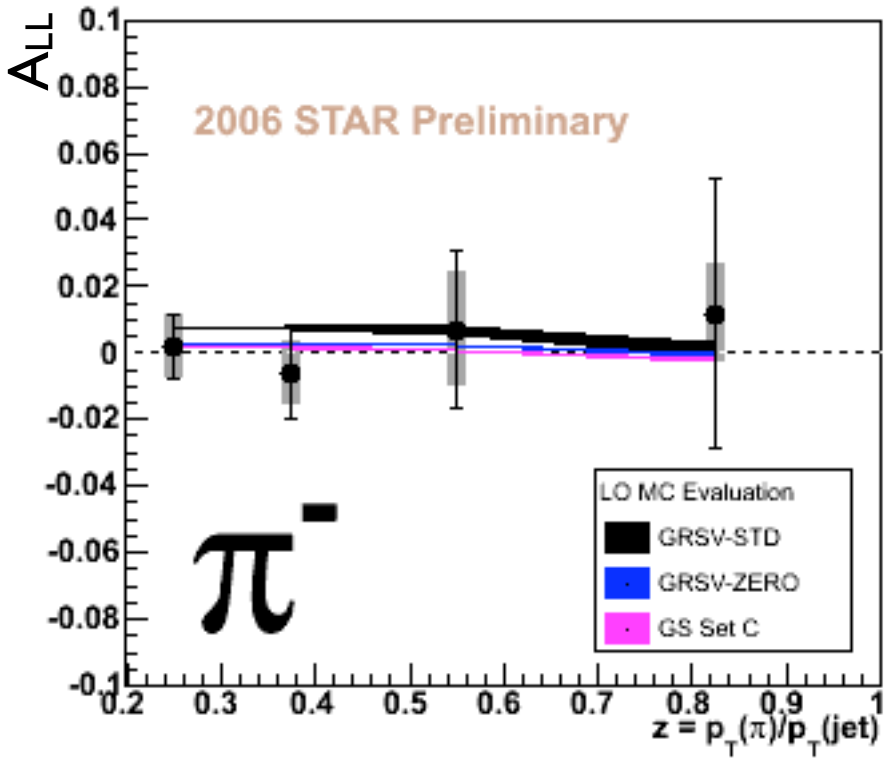
2006 Result

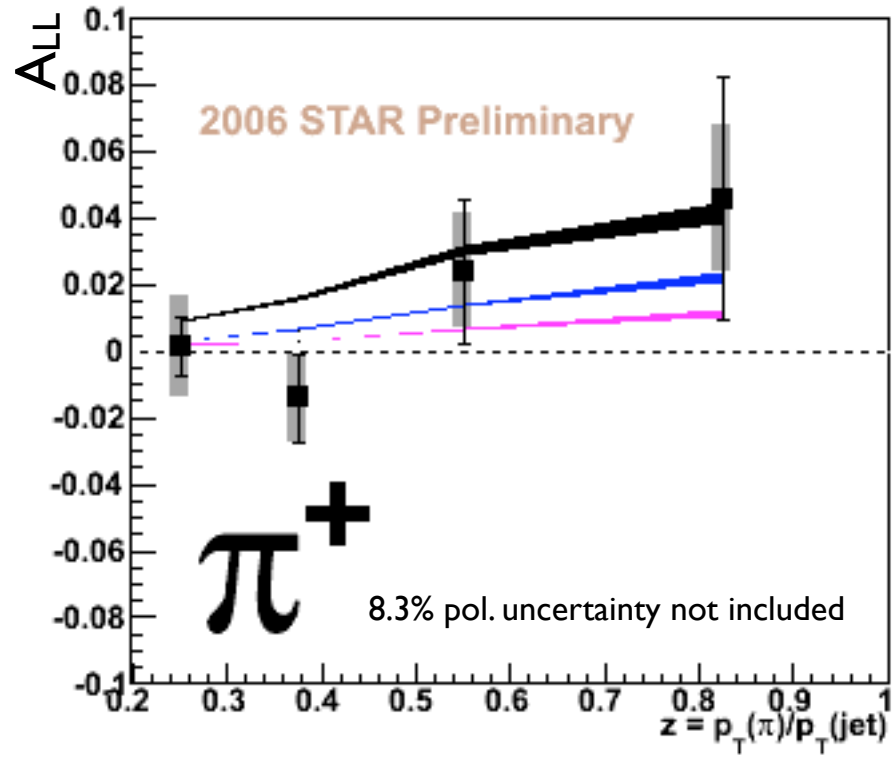




- Conservative systematic uncertainties are evaluated for
  - Trigger bias (6 - 15 x 10^{-3})
  - PID background contamination (2 - 10 x 10^{-3})
  - Uncertainty on the jet p_T shift (3 - 16 x 10^{-3})
  - Non-longitudinal components, relative luminosity (small)

Comparison to LO MC

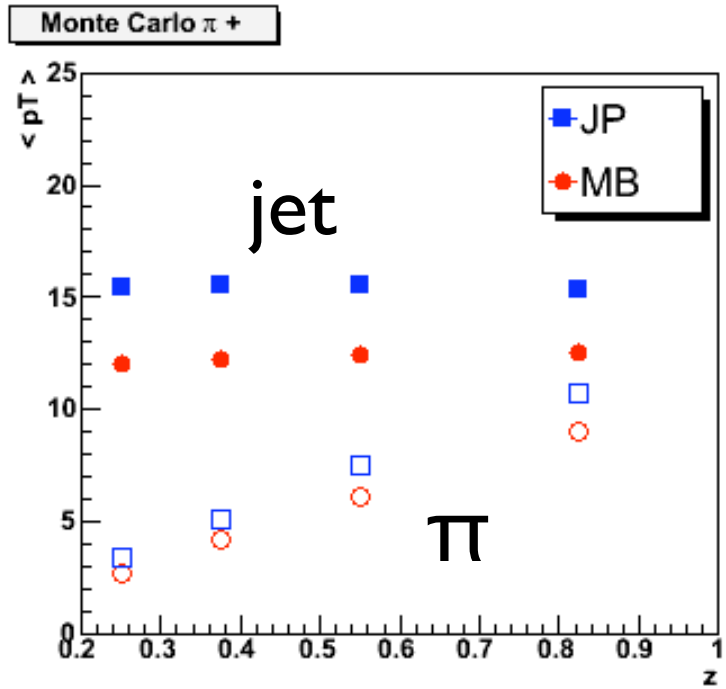


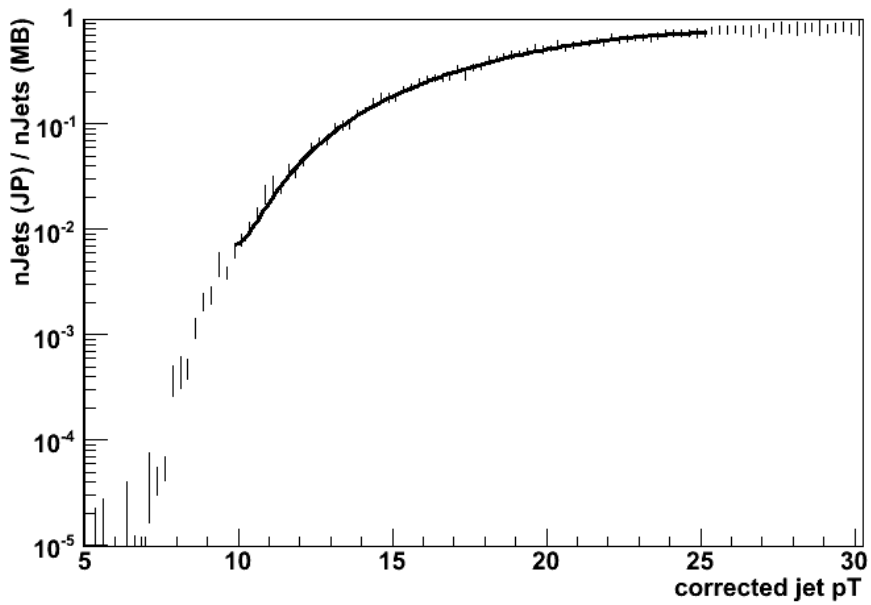


- Full NLO pQCD predictions are not yet available for this measurement
- These curves generated by sampling a_{LL} and parton distribution functions at kinematics of PYTHIA event.
- π^+ offers significant sensitivity at high z

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

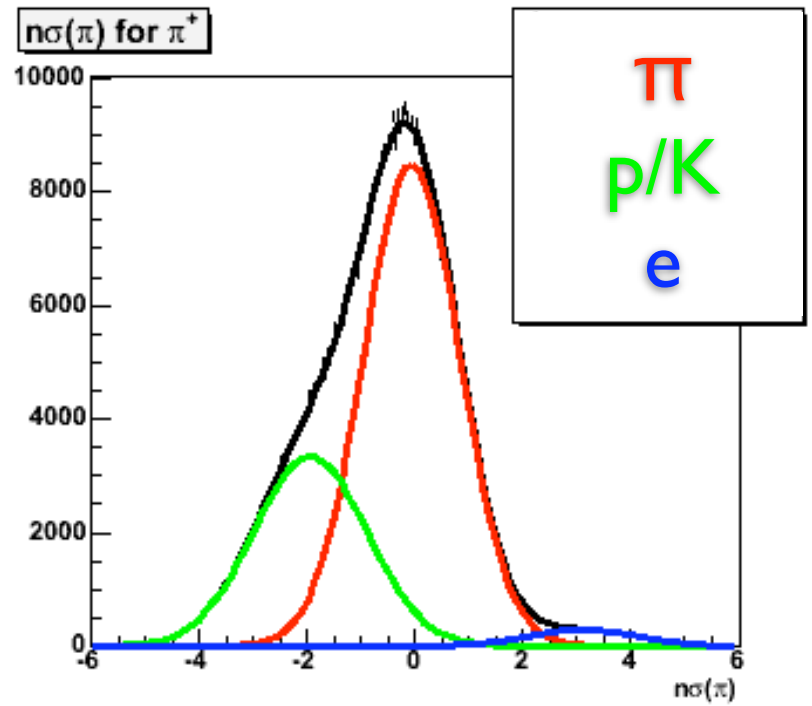


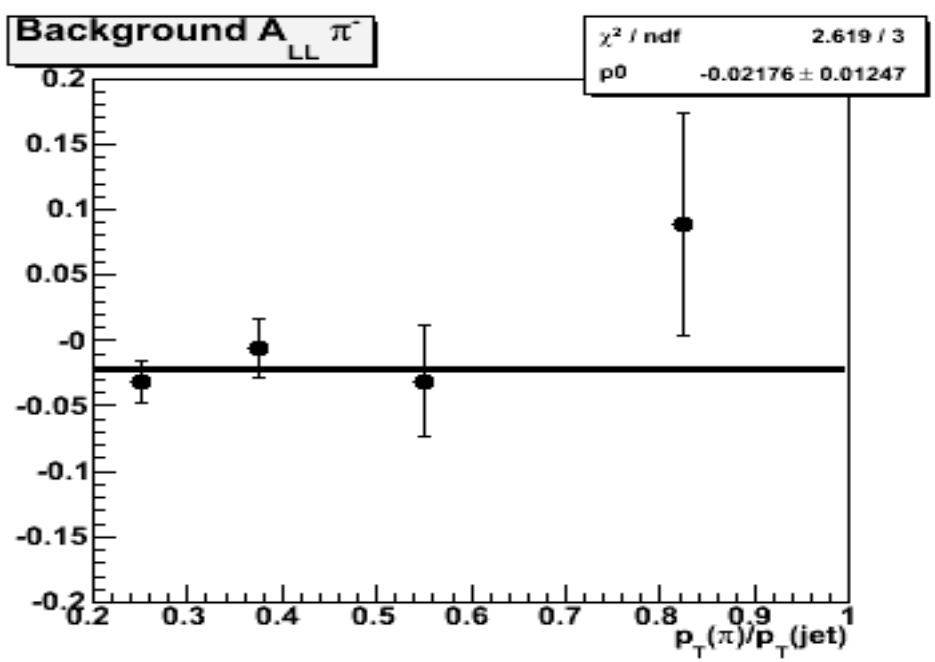


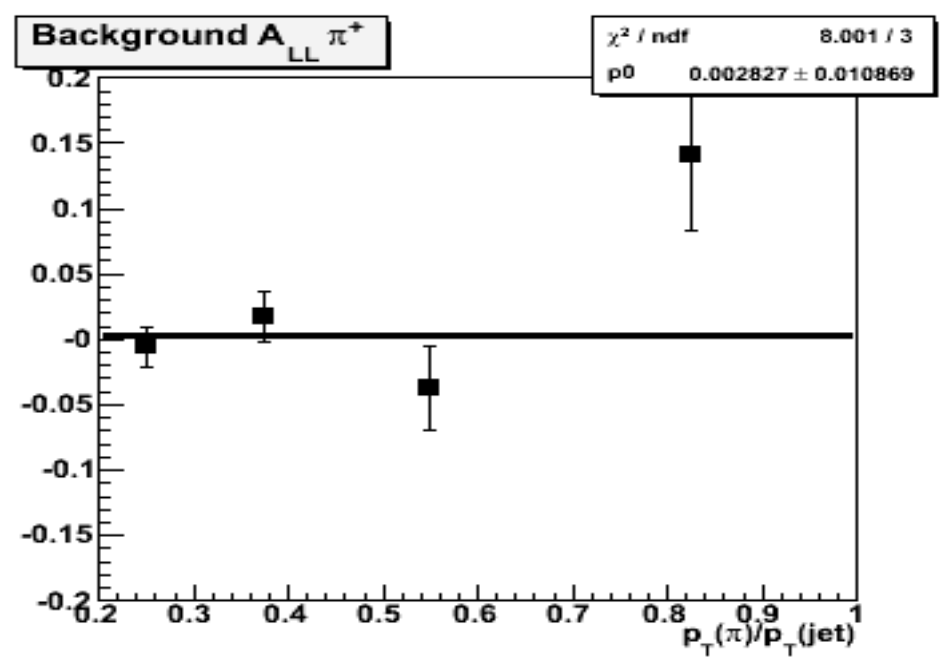
PID Background Asymmetry

- use triple Gaussian fits to estimate p/K background at 10%
- Select sideband starting at -2σ and calculate its A_{LL}
- Systematic assigned as

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







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