Recent STAR Results from Neutral Pion Production in Polarized p+p Collisions at $\sqrt{s}$ = 200GeV at RHIC.

Alan Hoffman
for the STAR Collaboration

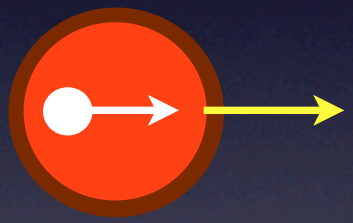
Motivation

How is the spin of the proton distributed?

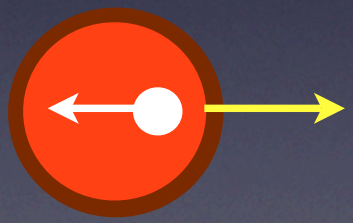
$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma(Q^2) + \Delta g(Q^2) + L_q(Q^2) + L_g(Q^2)$$

$$\Delta g(x, Q^2) = g^+(x, Q^2) - g^-(x, Q^2)$$

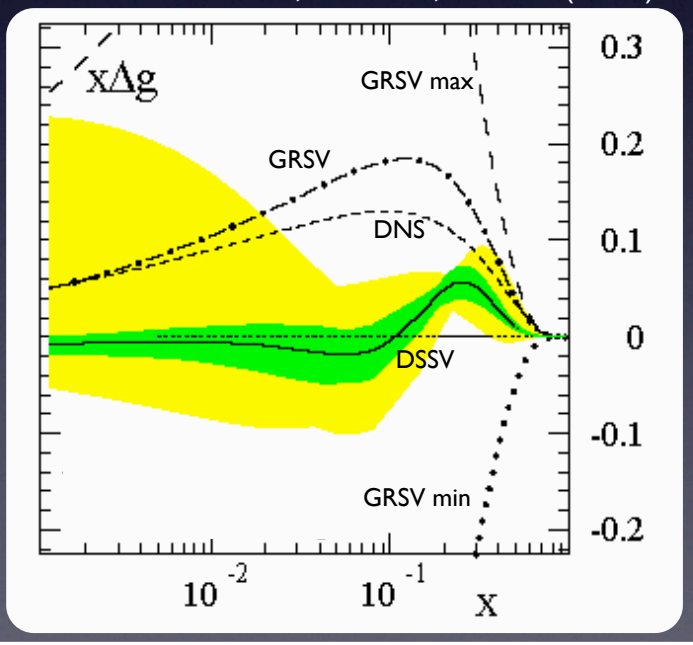
g^+:



g^-:



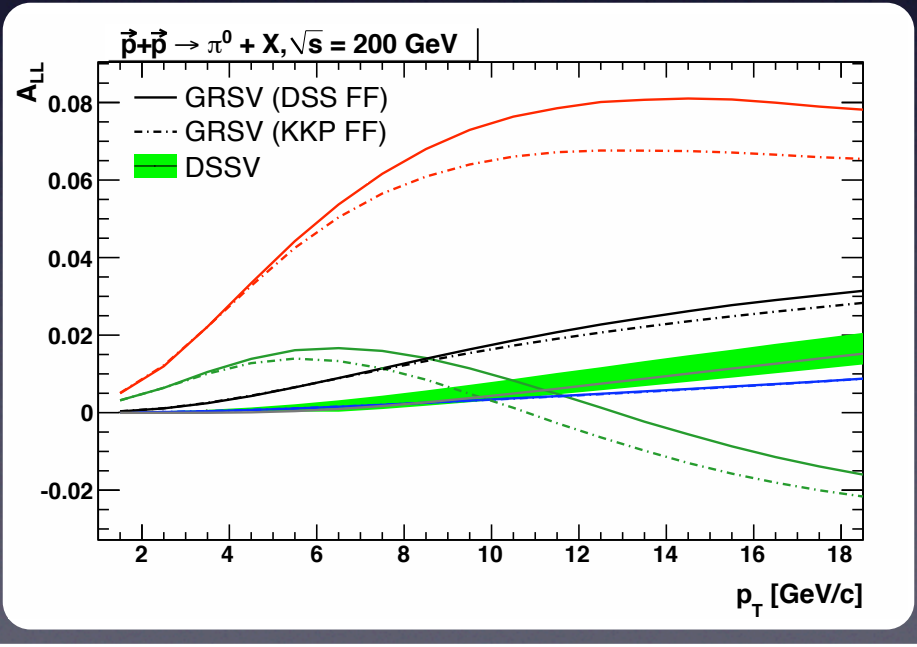
de Florian et al., PRL **101**, 072001 (2008)



Accessing ΔG from A_{LL}

- Polarized p+p collisions give access to the gluon polarization through the observable A_{LL}
- A_{LL} predictions for neutral pion production dependent on fragmentation functions.

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



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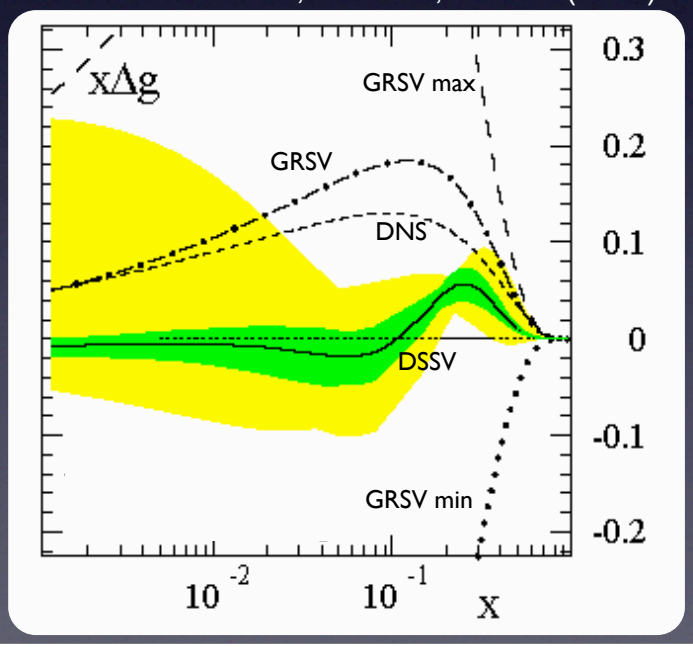
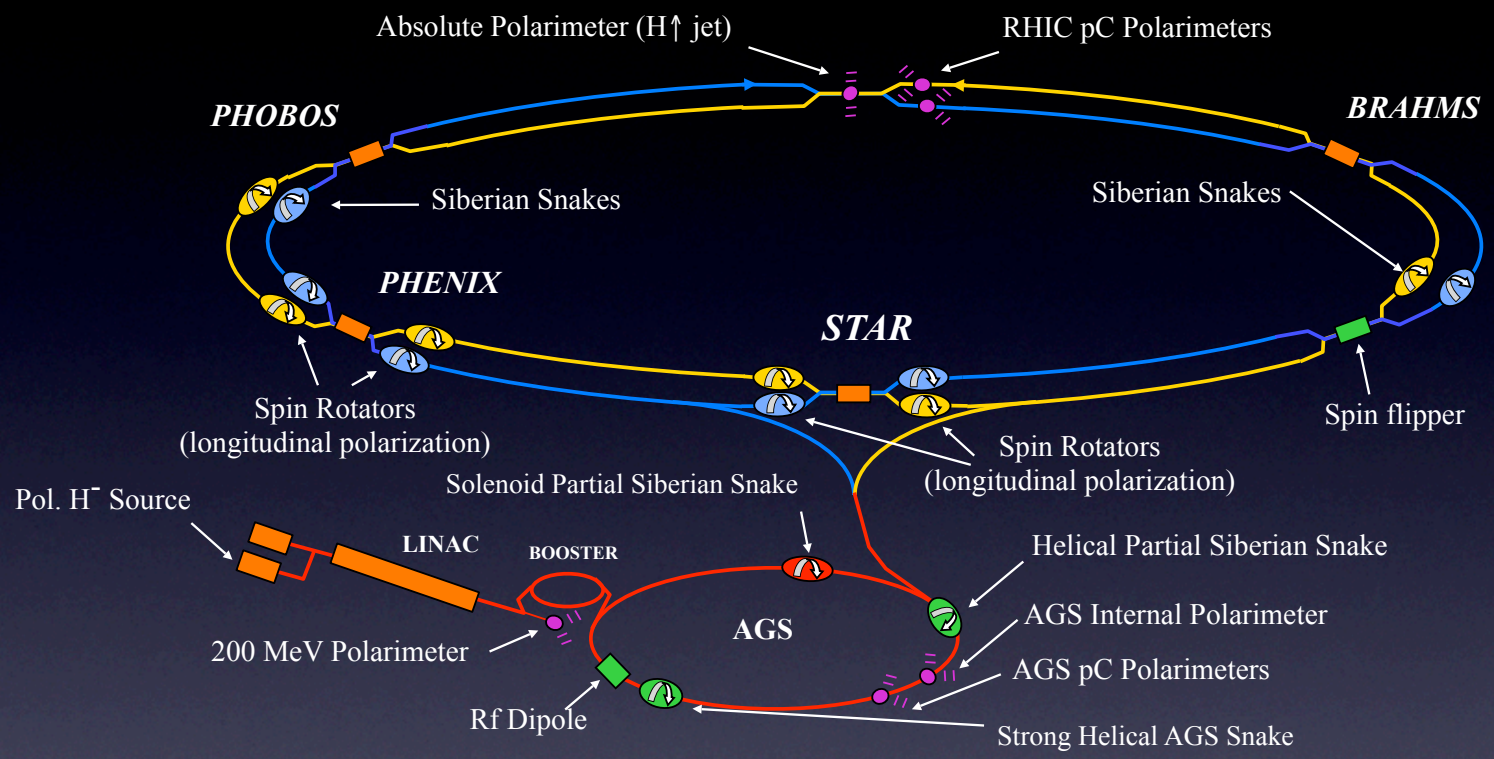


The RHIC Complex



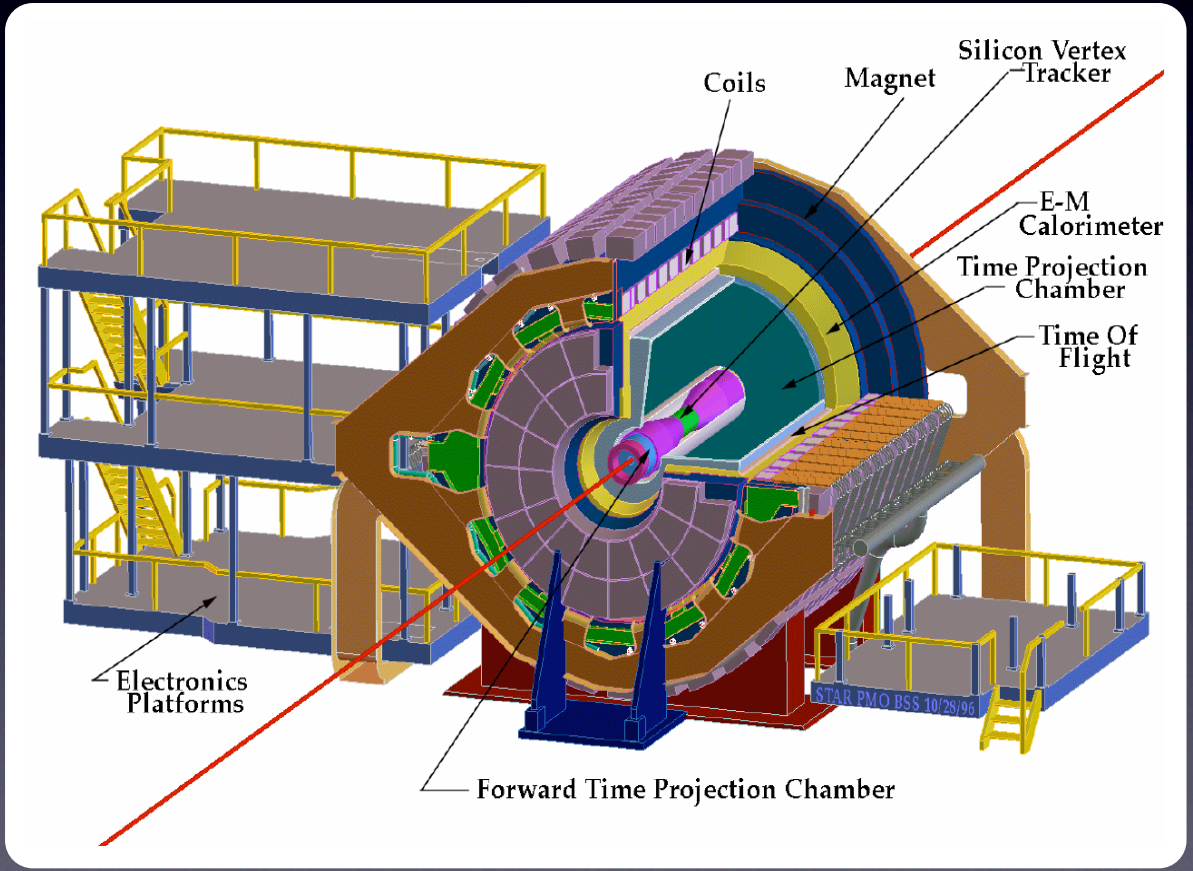
Two rich QCD programs: spin and heavy ion

- Bunch-to-bunch spin control
- Siberian Snakes
- Spin rotators
- Polarimetry

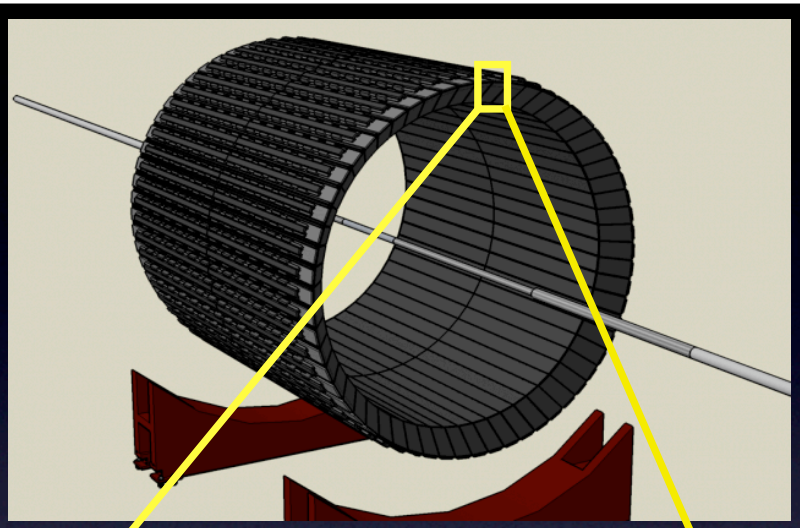
STAR Detector

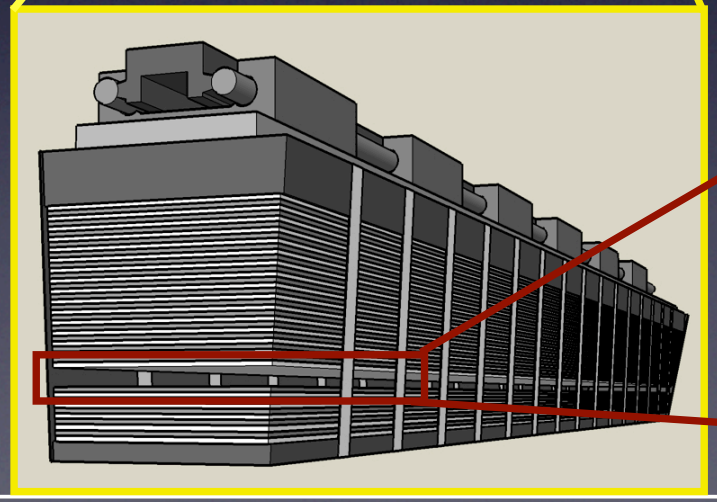
Notable Subsystems:

- Beam Beam Counters
  - Triggering and luminosity
- TPC
  - Central tracking and vertexing
- Barrel EMC
  - Triggering and final state reconstruction

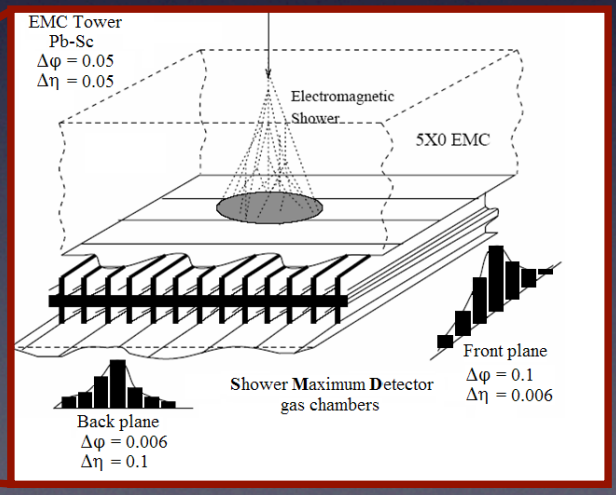


Barrel EMC



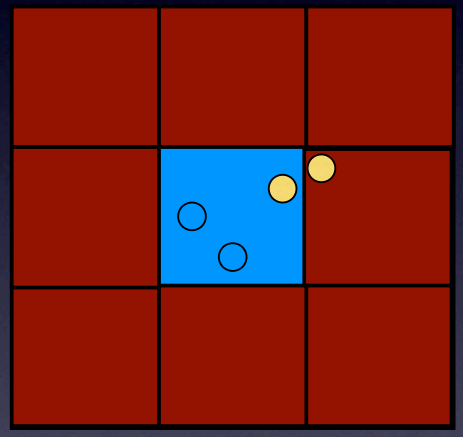


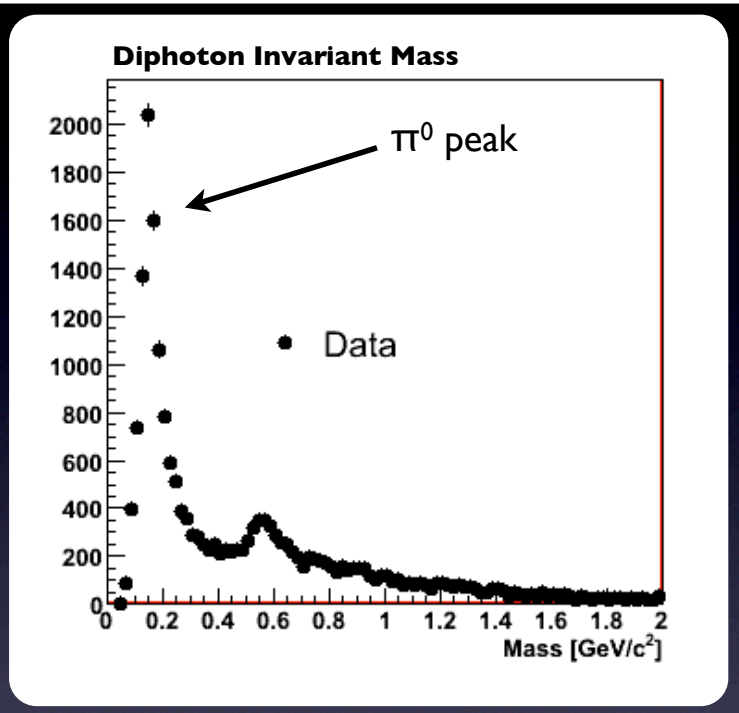
- Lead-scintillator sampling calorimeter (~20 X_0)
- 2π azimuthal coverage
- -1 < η < 1 (Run 6)
- Segmented into 4800 towers, .05 x .05 in η-ϕ
- Shower Max Detector located at a depth of ~5 X_0



Pion Reconstruction

- New trigger for Run 6. Specifically designed to find more π^0s.
- 2 stage trigger: High Tower + Trigger Patch.
- ~3.7 pb^{-1} Triggered Luminosity





Event Selection

- Found Vertex
- Require good SMD information in both planes
- Veto calorimeter hits with a charged track pointing to tower
- π^0 candidates w/ P_T above 5.2 GeV/c

- π^0 invariant mass: $M^2_{inv} = 2E_1E_2(1 - \cos\theta)$
- $-0.95 \leq \eta \leq 0.95$
- $Z_{\gamma\gamma} \leq 0.8$
- $0.08\ GeV/c^2 \leq M_{inv} \leq 0.25\ GeV/c^2$
- π^0 mass spectrum well described by MC simulation of single π^0, single η, and background (more later)

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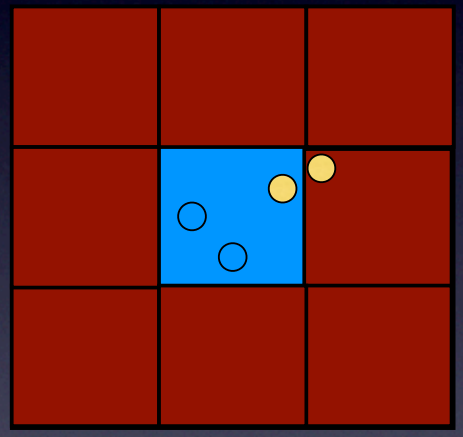

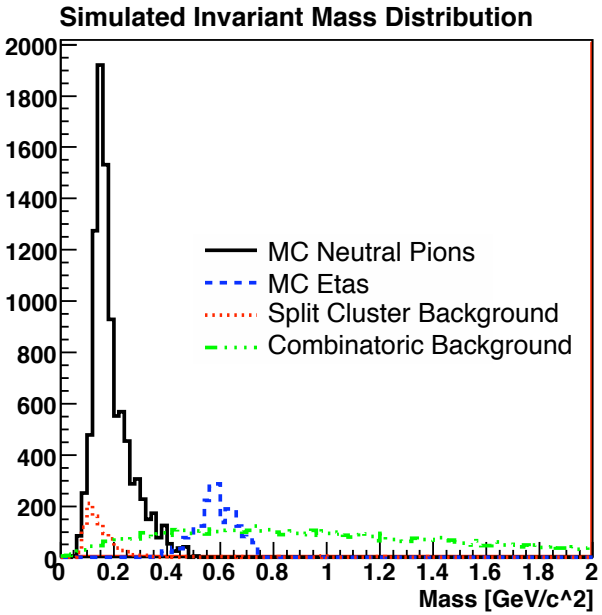

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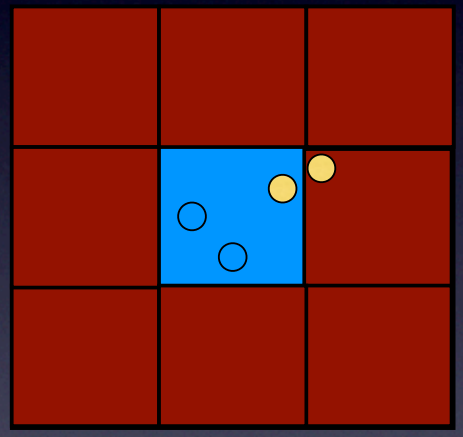

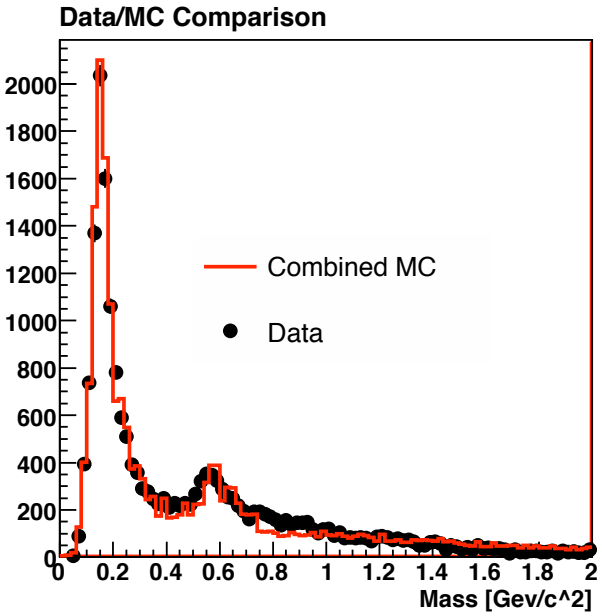

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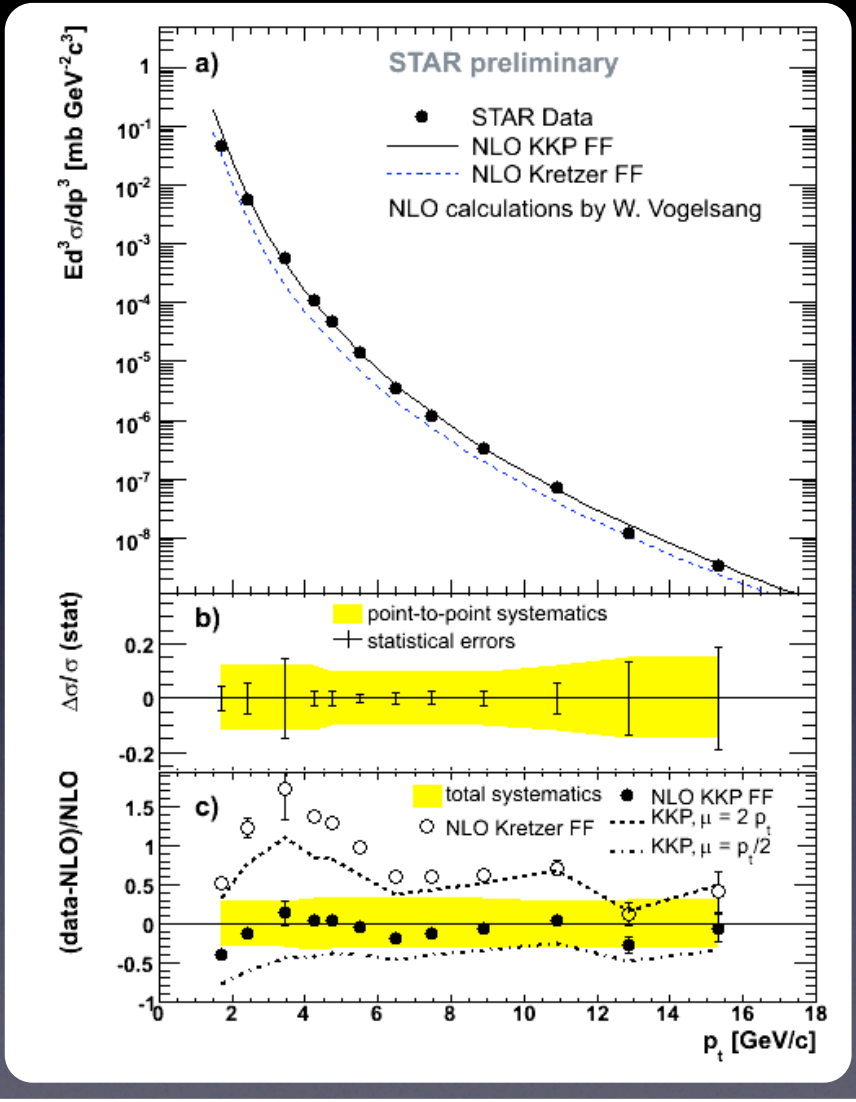
2005 π^0 Cross Section



- $L_{sampled}$: 0.4 pb^{-1} (HT triggers) 44μb^{-1} (MB)
- $0.1 \leq \eta \leq 0.9$; $0 \leq \phi \leq 2\pi$
- Systematics dominated by 5% uncertainty in BEMC energy scale
- Good agreement to NLO pQCD predictions.

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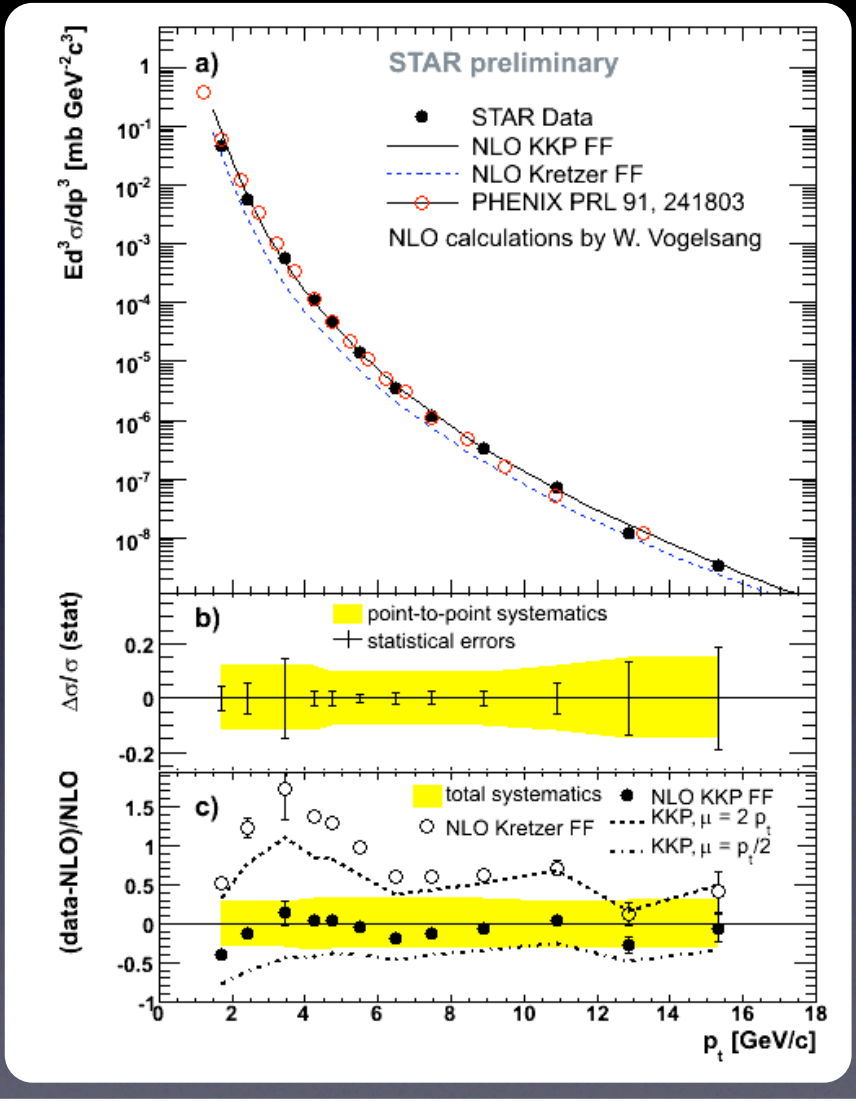

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Measuring A_{LL} at STAR

$$A_{LL} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} = \frac{1}{P_1 P_2} \times \frac{N_{++} - RN_{+-}}{N_{++} + RN_{+-}}$$

Three Measurements

- Polarization
  - Coulomb-Nucleon Interference and H Polarimeters
  - ~55% avg. polarization
- Relative Luminosity
  - Beam-Beam Counters
- Spin Sorted Yields
  - Triggering on desired events
  - Final state reconstruction

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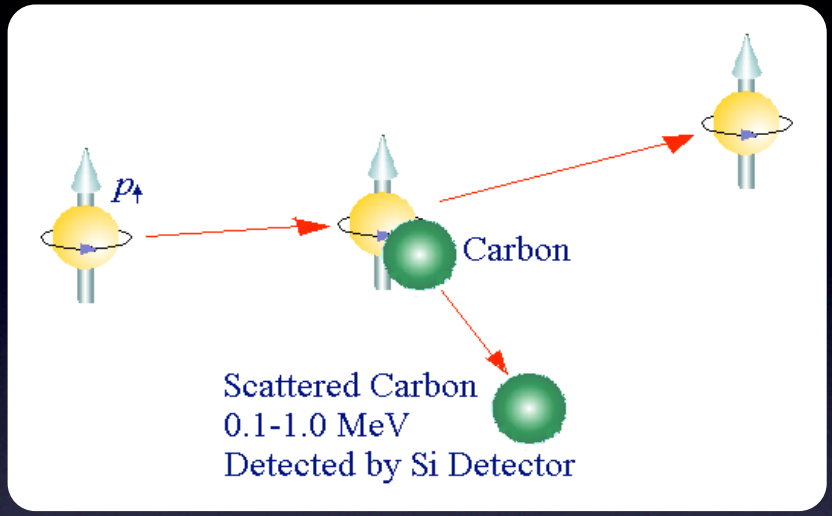

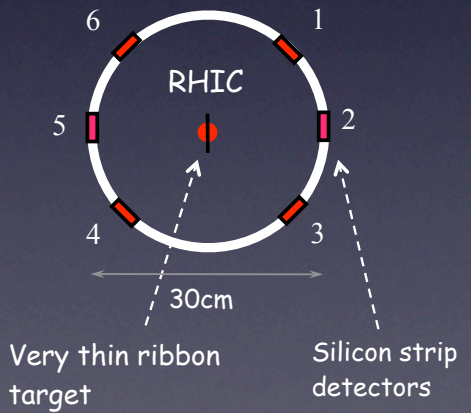

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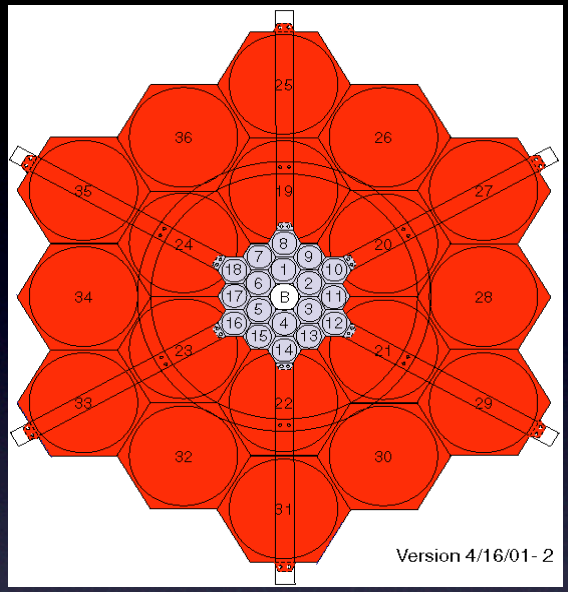
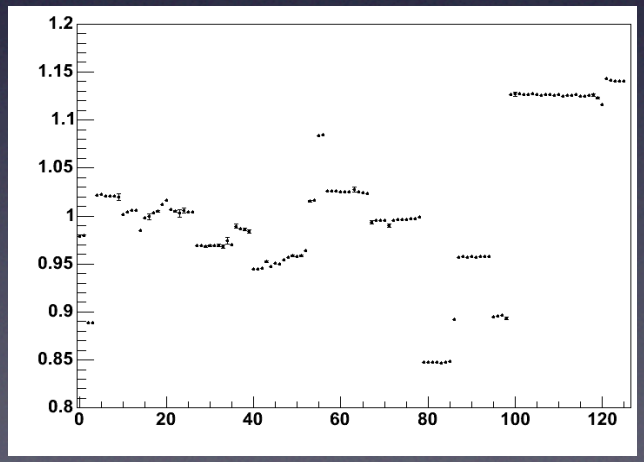
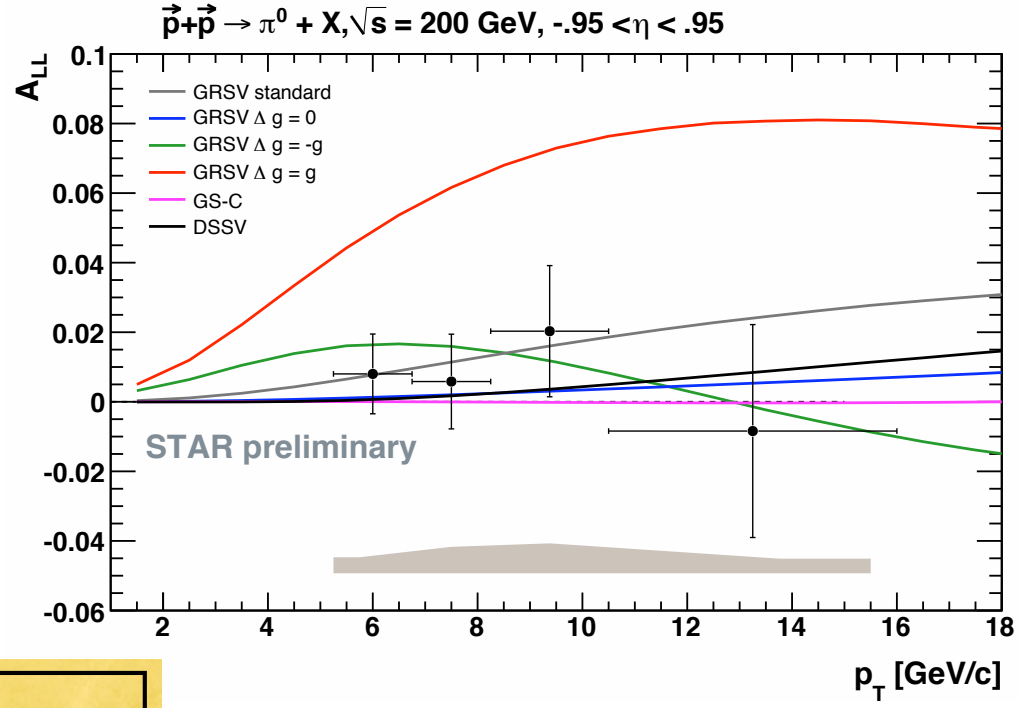




2006 Preliminary A_{LL}

χ^2/ndf for NLO predictions:

GRSV Std:	0.3
GRSV Max:	11.4
GRSV Min:	0.3
GRSV Zero:	0.4
GS-C:	0.5
DSSV:	0.4

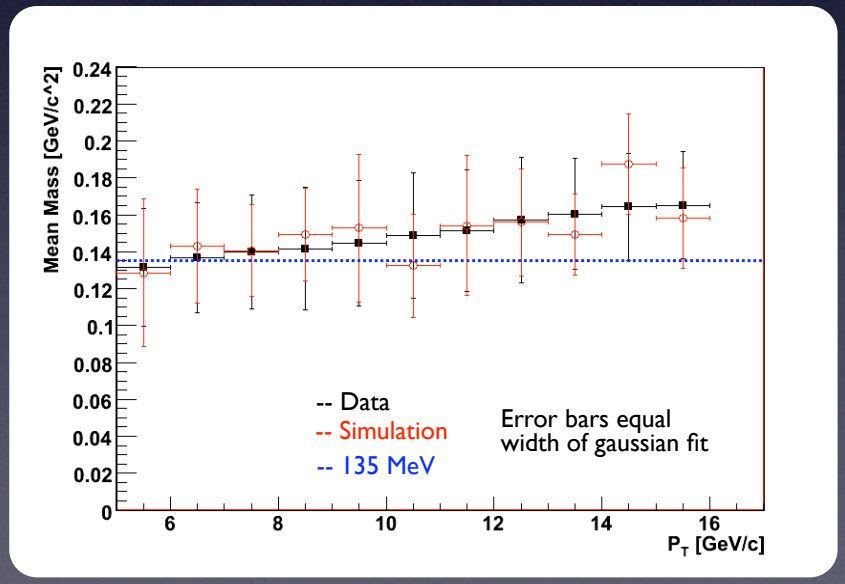


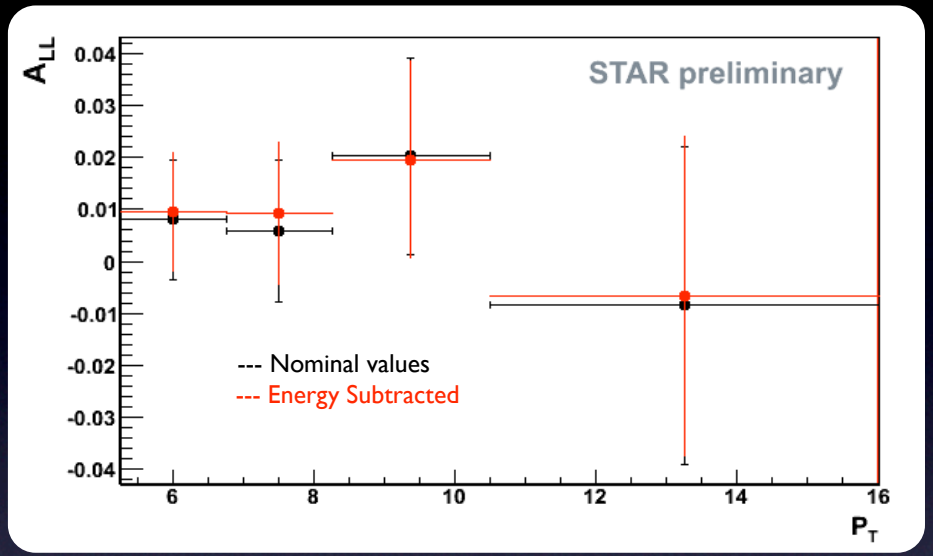
Pt Range [GeV/c]	A_{LL} ± Stat. Err. ± Sys. Error
5.2 - 6.75	0.0080 ± 0.0115 ± 0.002
6.75 - 8.25	0.0058 ± 0.0136 ± 0.004
8.25 - 10.5	0.0203 ± 0.0189 ± 0.004
10.5 - 16.0	-0.0084 ± 0.0306 ± 0.002

$$A_{LL} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} = \frac{1}{P_1 P_2} \times \frac{N_{++} - RN_{+-}}{N_{++} + RN_{+-}}$$

Photon Energy Uncertainty

- Reconstructed pion mass is P_T-dependent.
- Numerous Effects
  - BEMC Resolution
  - π^0 Reconstruction Algorithm
  - Jet Background
- Recreated in Monte Carlo



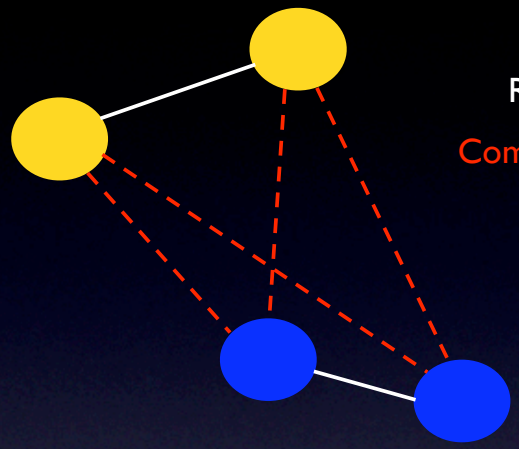


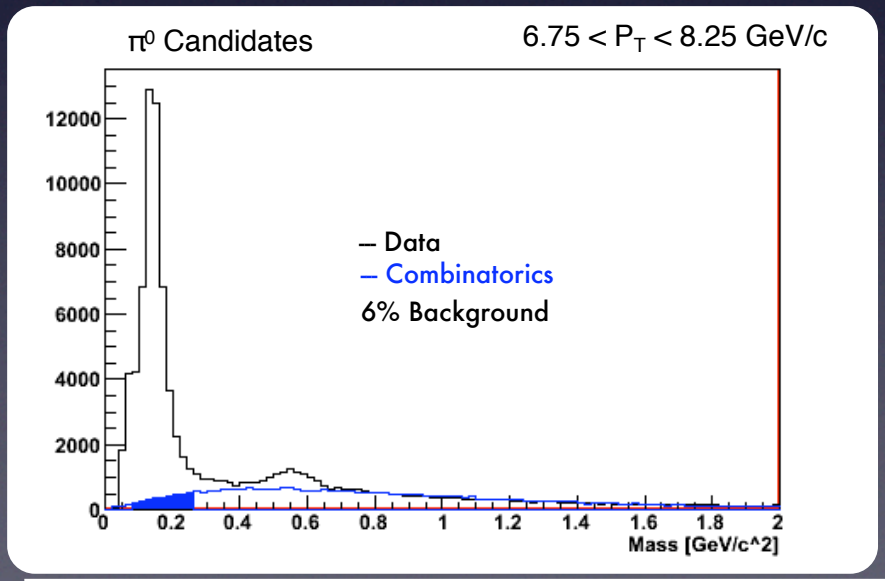
- Effect on A_{LL} consistent with statistical effect
- Uncertainty assigned (equal to observed shift) to be conservative

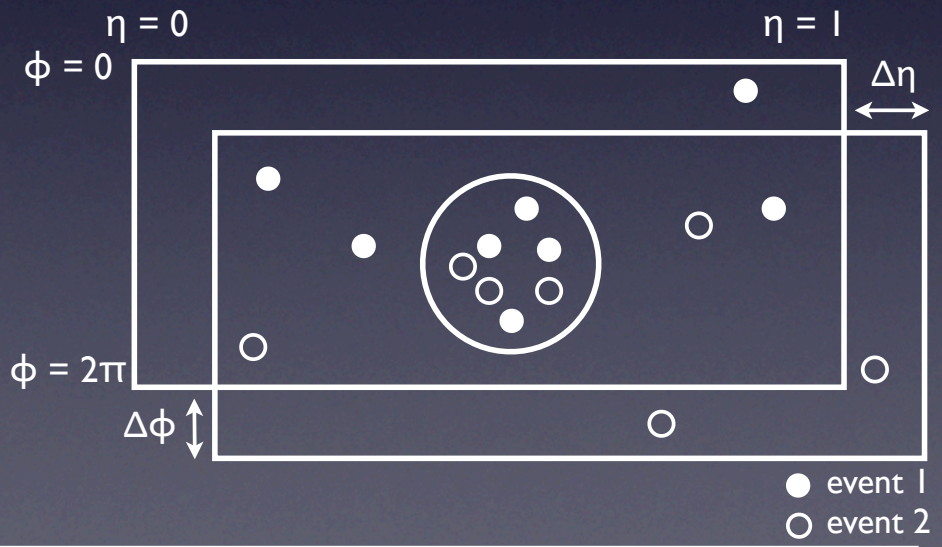
Pt Range [GeV/c]	Error x10^{-3}
5.2 - 6.75	1.5
6.75 - 8.25	3.4
8.25 - 10.5	0.7
10.5 - 16.0	1.5

Combinatoric Background

- Modeled by mixing photons from different events (data)
- Careful about event topology
  - Rotating jets
  - Similar in jet η and z vertex
- Background shape fit to the data
- Uncertainty in A_{LL}: 0.5×10^{-3} - 1.6×10^{-3} (P_T dependent)

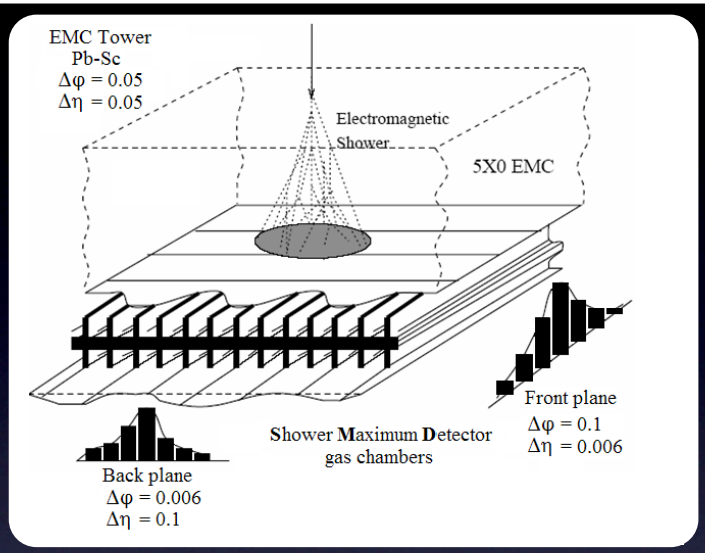


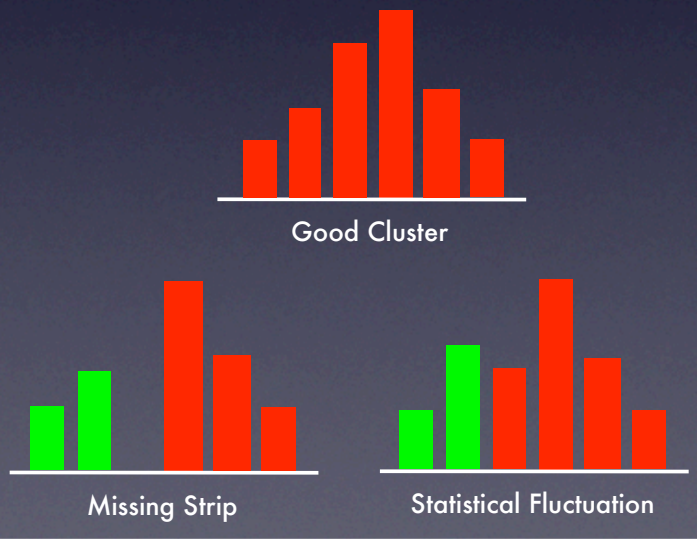


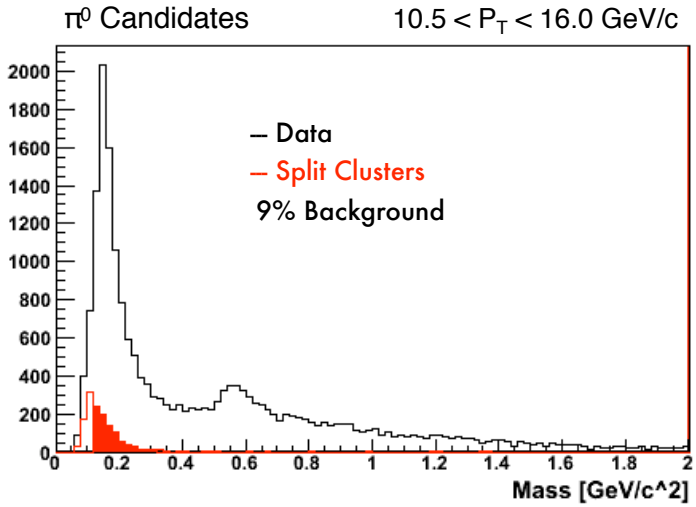


Split Clusters

- Above ~5 GeV/c in pion P_T, rely on SMD to separate and reconstruct decay photons.
- SMD hardware inefficiencies and energy fluctuations lead to 'split' photons.
- False positives at low M_{inv}
- Modeled with single particle MC
- Error: 1.0×10^{-3} - 3.8×10^{-3} (P_T dependent)

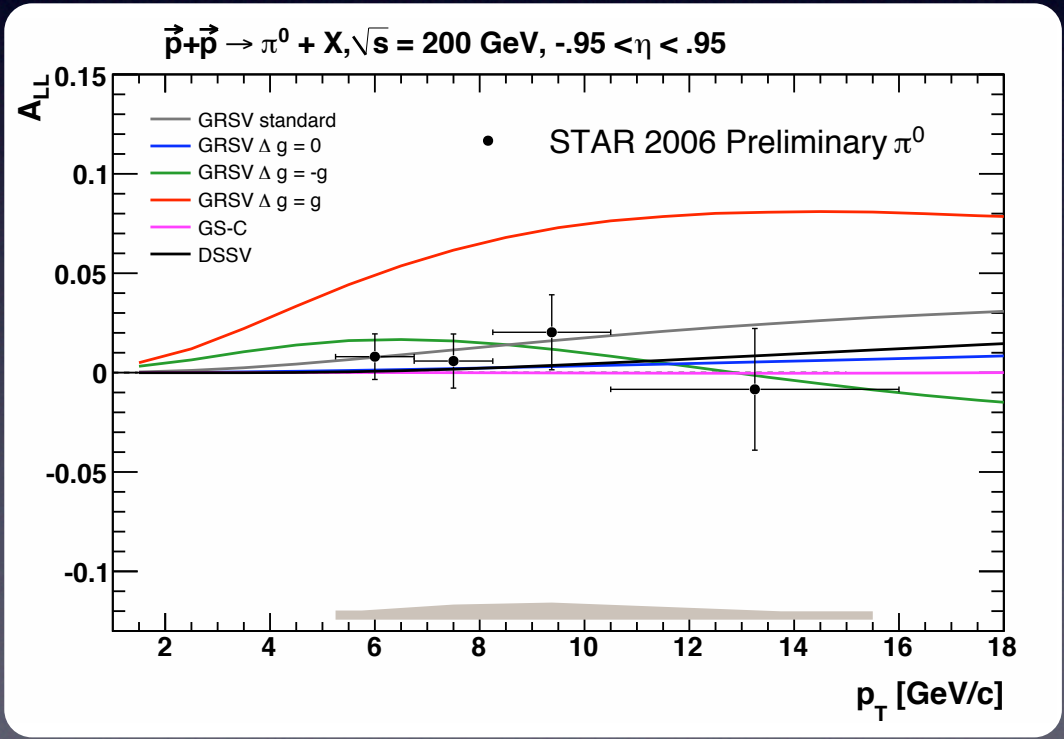






Summary

- Most recent measurement of A_{LL} and the cross section for inclusive π^0 production have been presented.
- Maximum polarization scenario is excluded, measurement cannot at this time distinguish between other scenarios.
- Results consistent with PHENIX 2006 preliminary
- The run 6 π^0 result sees a significant increase in statistical precision as well as a greater reach in P_T compared to run 5.
- STAR is planning for a long pp run in Run 9. Expecting large increase in FOM with 60% polarization and 50 pb^{-1}



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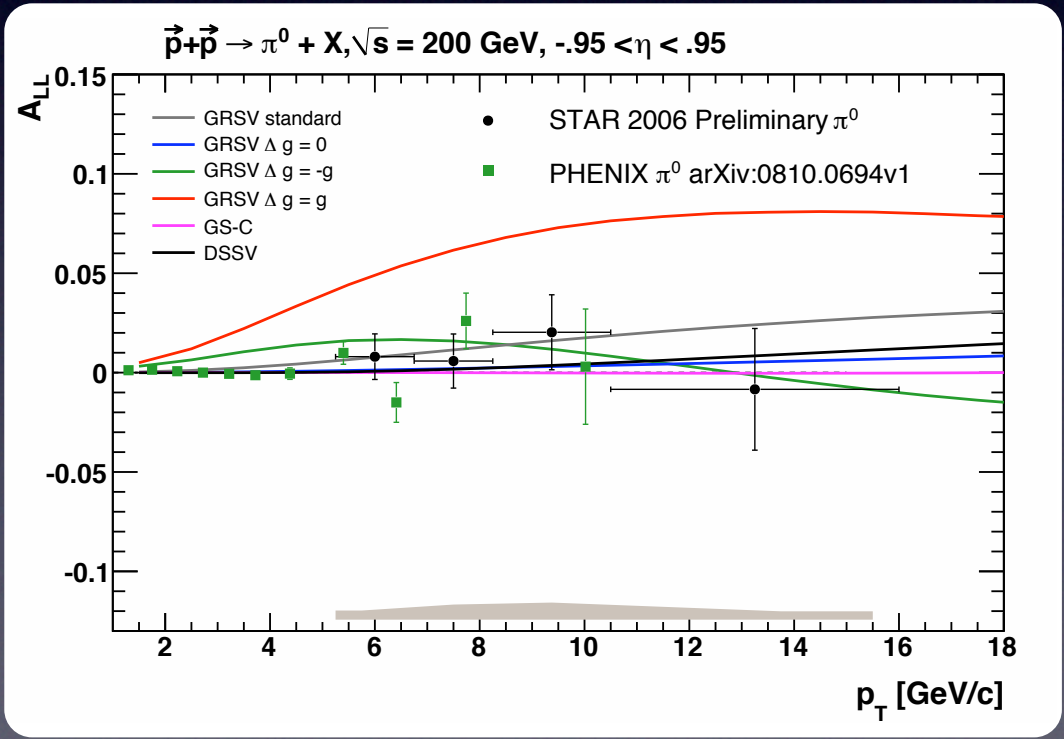

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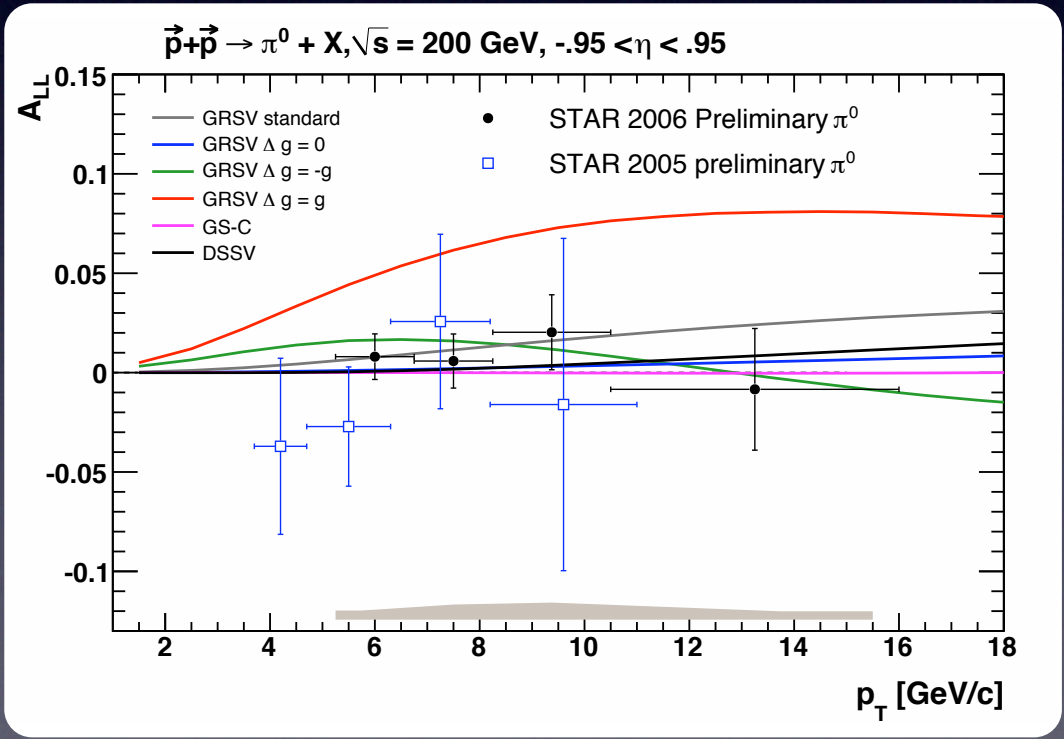
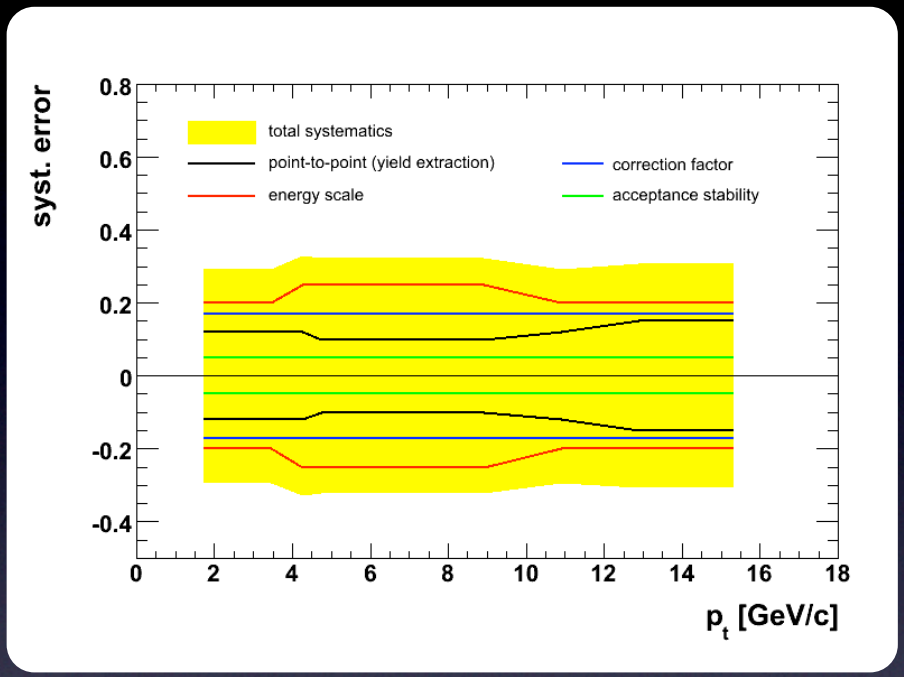


Backup

Systematics Summary

Run 5 Cross Section Measurement:

- Point-to-Point (yield extraction, background subtraction)
- Energy Scale (5% uncertainty on BSMD gain calibration)
- Correction Factor (variation of cuts, uncertainty in SMD gain (to a large extend built into MC, additional uncertainties included in systematics), statistical limitation of MC dataset)
- Acceptance Stability (changes in electronics status, modeling in MC)



Systematic Errors Assigned in Run 6 π^0 A_{LL} Analysis (all errors x10^{-3})

- Non-Longitudinal Beam Components: 0.9
- Photon Energy Uncertainty: P_T Dependent from 0.7 to 3.4
- Backgrounds (from split clusters and combinatorics): P_T Dependent from 1.1 to 4.1