

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

Alan Hoffman
for the STAR Collaboration

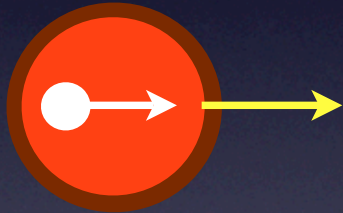
Motivation

How is the spin of the proton distributed?

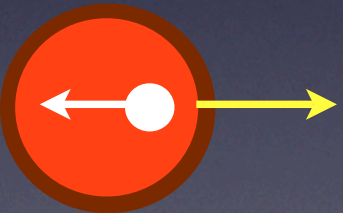
$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma(Q^2) + \Delta g(Q^2) + L_q(Q^2) + L_g(Q^2)$$

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

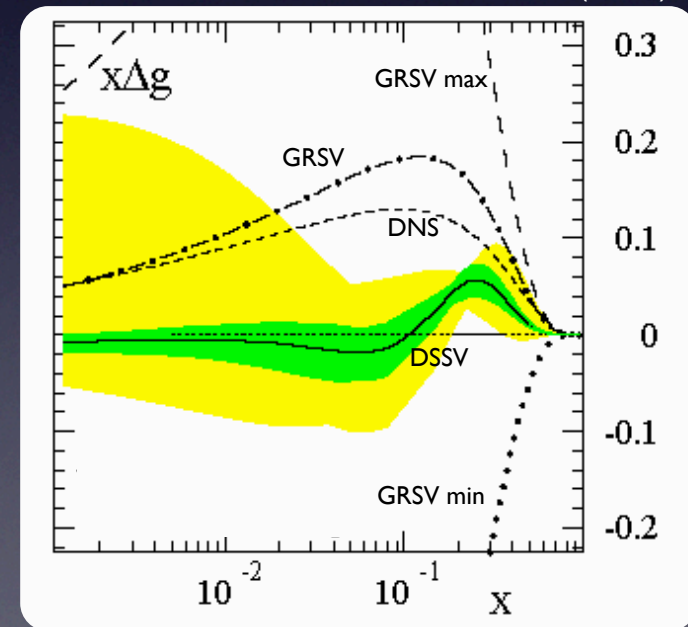
g^+ :



g^- :



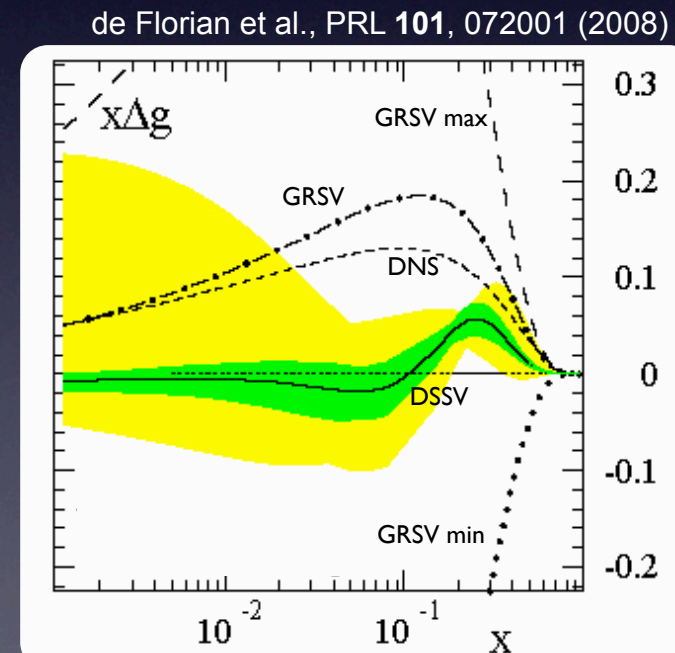
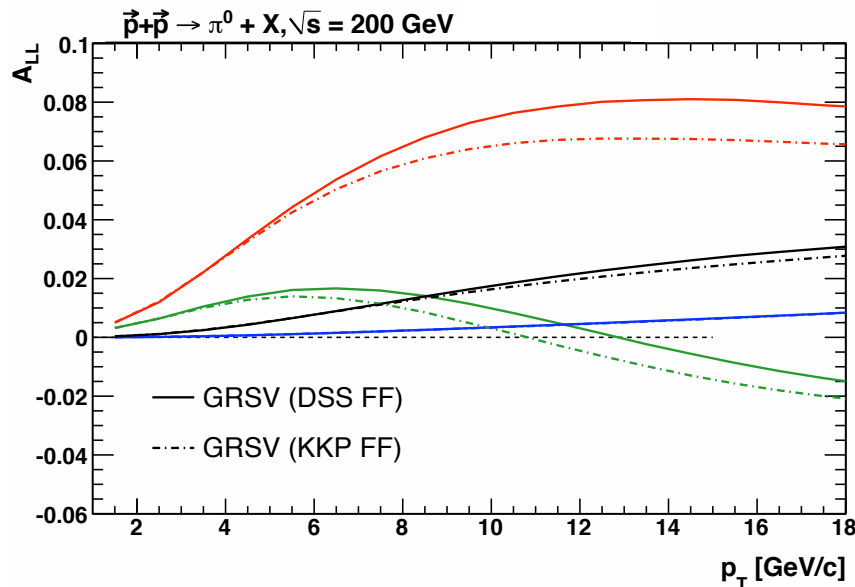
de Florian et al., PRL **101**, 072001 (2008)



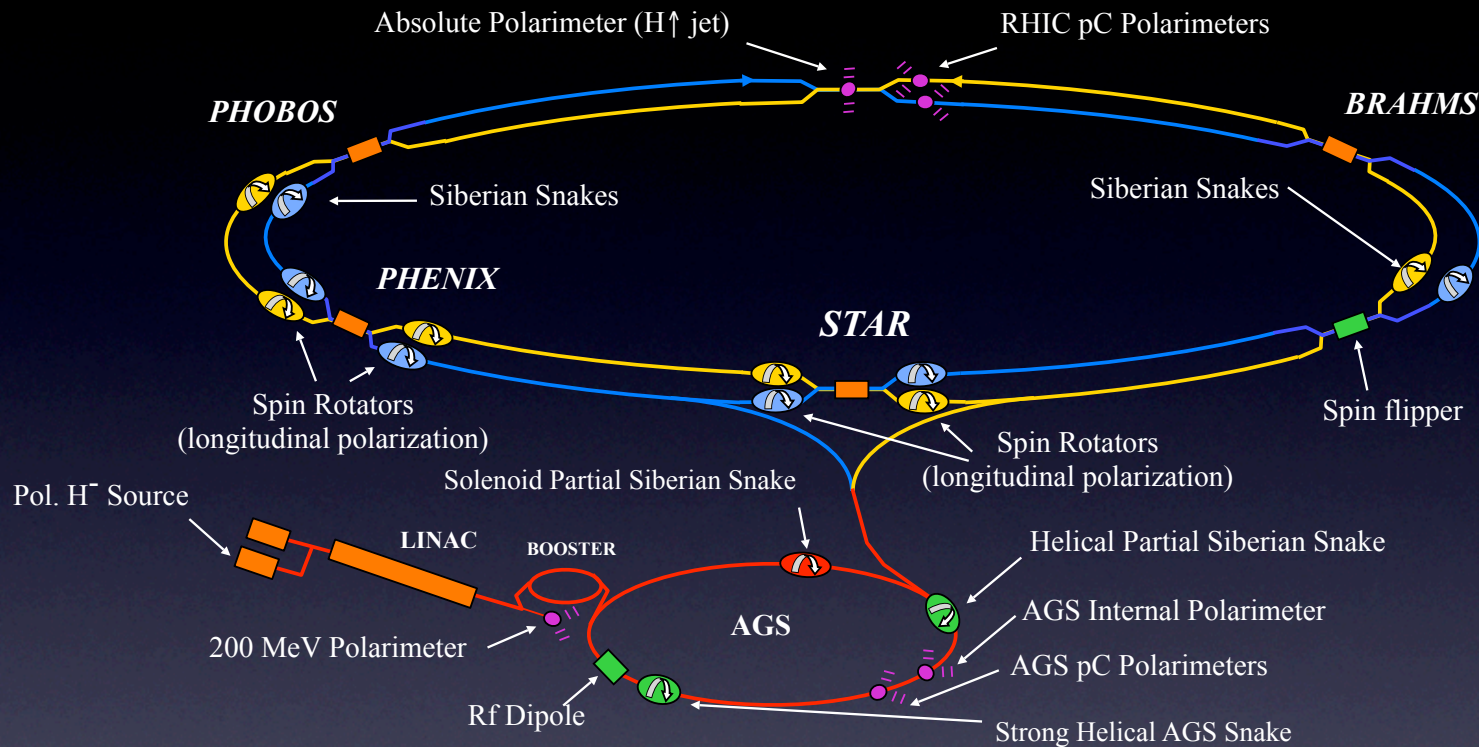
Accessing ΔG from A_{LL}

- 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.

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



The RHIC Complex



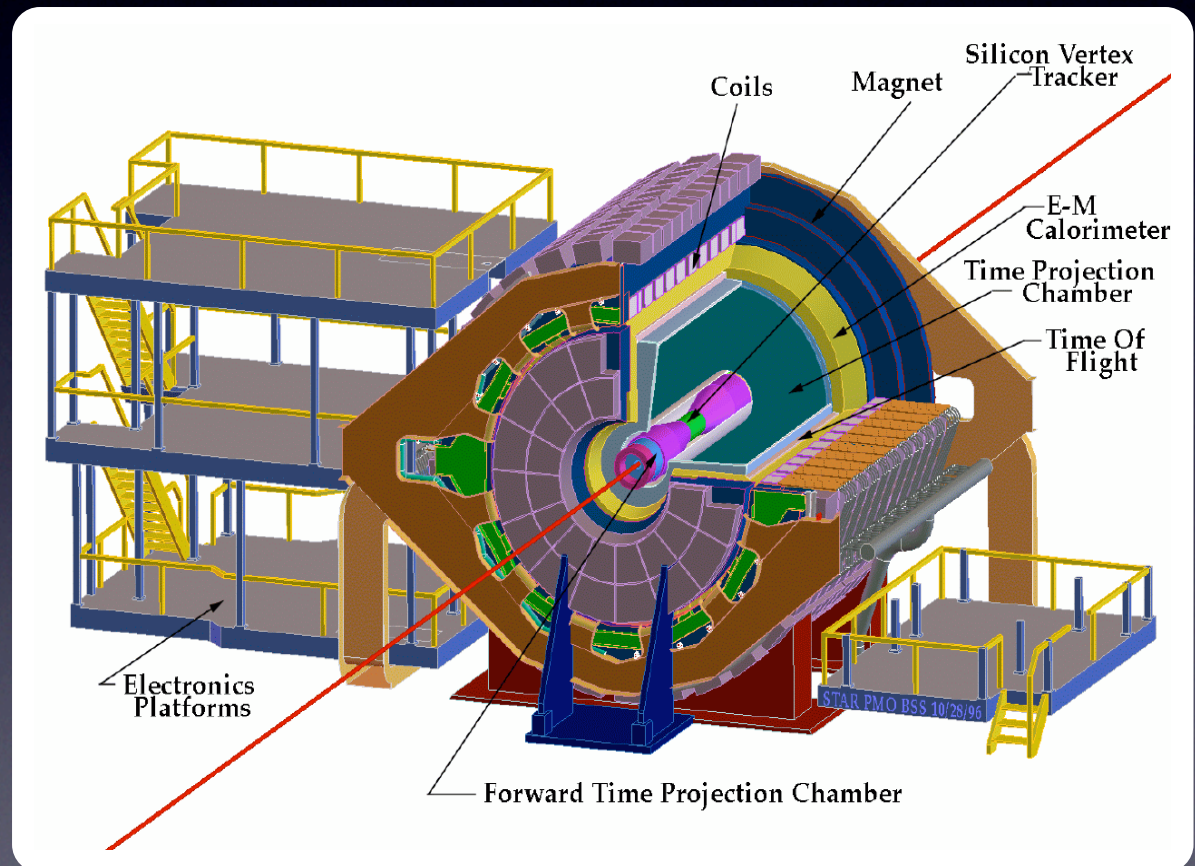
Two rich QCD programs: spin and heavy ion

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

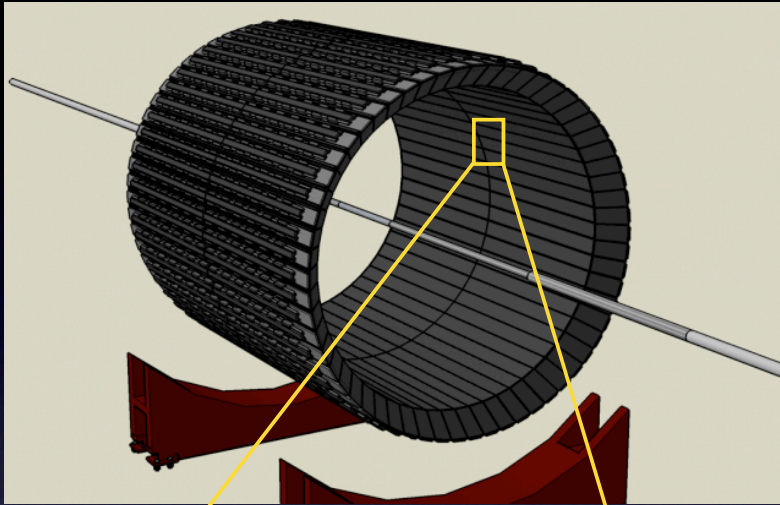
STAR Detector

Notable Subsystems:

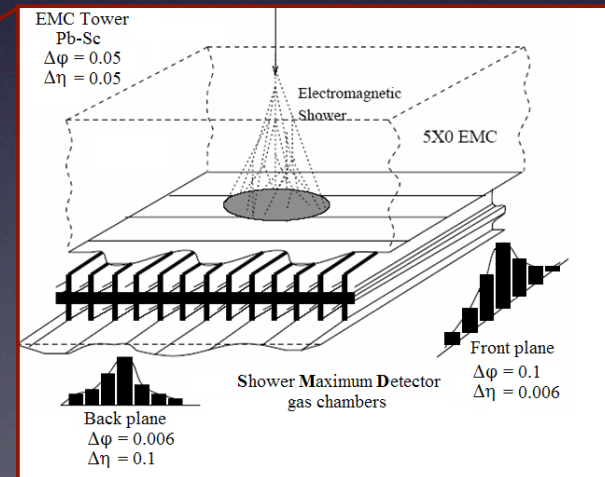
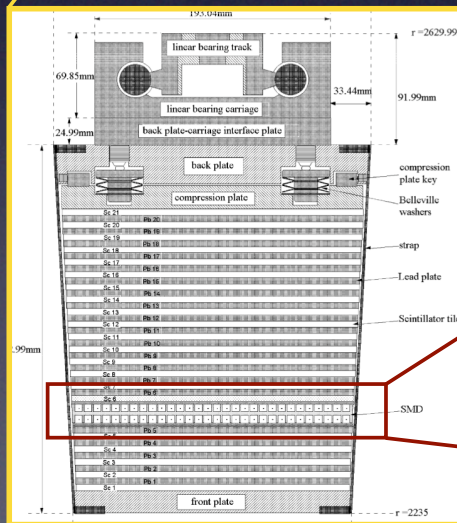
- Beam Beam Counters
 - Triggering and luminosity
- TPC
 - Central tracking and vertexing
- Barrel EMC
 - Triggering and final state reconstruction



Barrel EMC

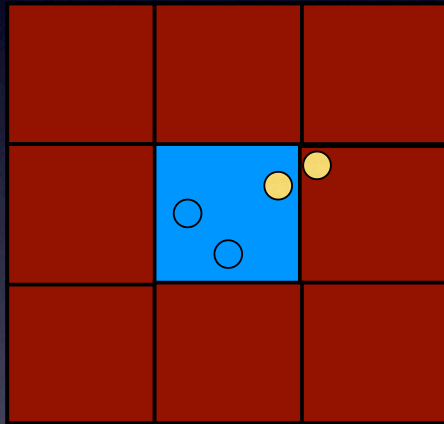


- Lead-scintillator sampling calorimeter ($\sim 20 X_0$)
- 2π azimuthal coverage
- $-1 < \eta < 1$ (Run 6)
- Segmented into 4800 towers, $.05 \times .05$ in η - ϕ
- Shower Max Detector located at a depth of $\sim 5 X_0$



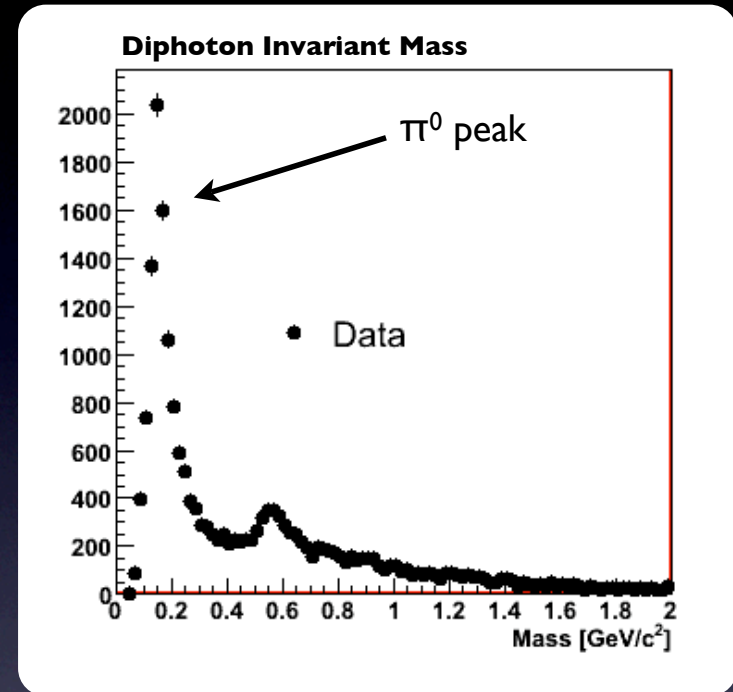
Pion Reconstruction

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



Event Selection

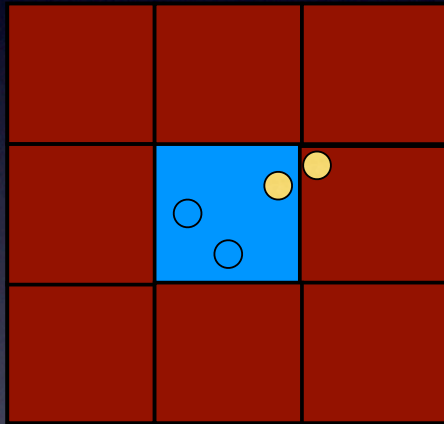
- Found Vertex
- Require good SMD information in both planes
- Veto calorimeter hits with a charged track pointing to tower
- π^0 candidates w/ P_T above $5.2 \text{ GeV}/c$



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

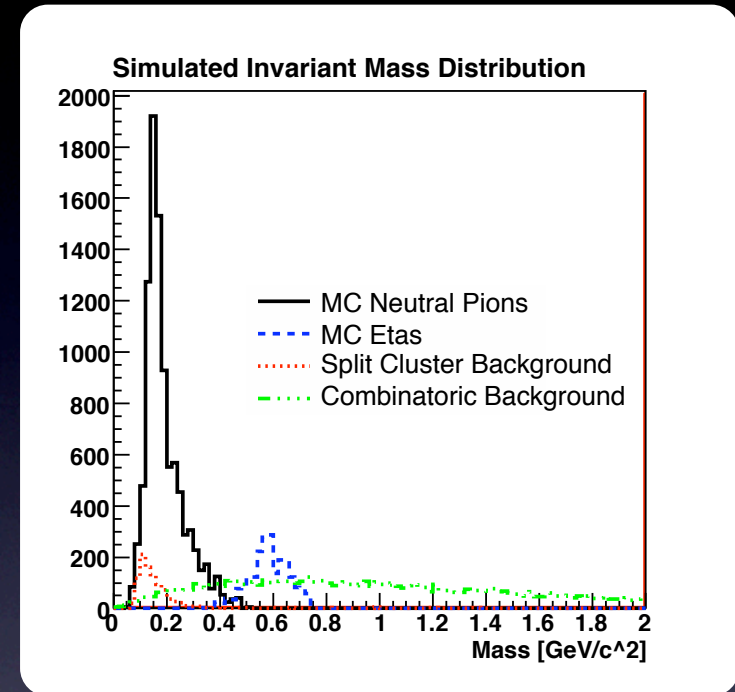
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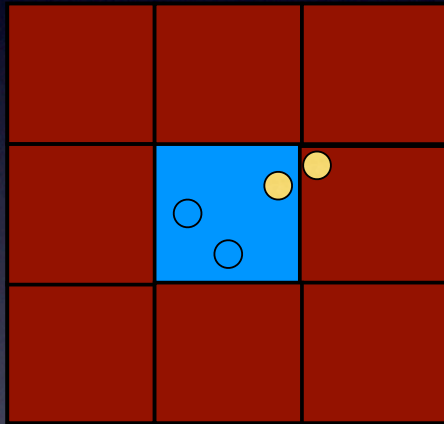
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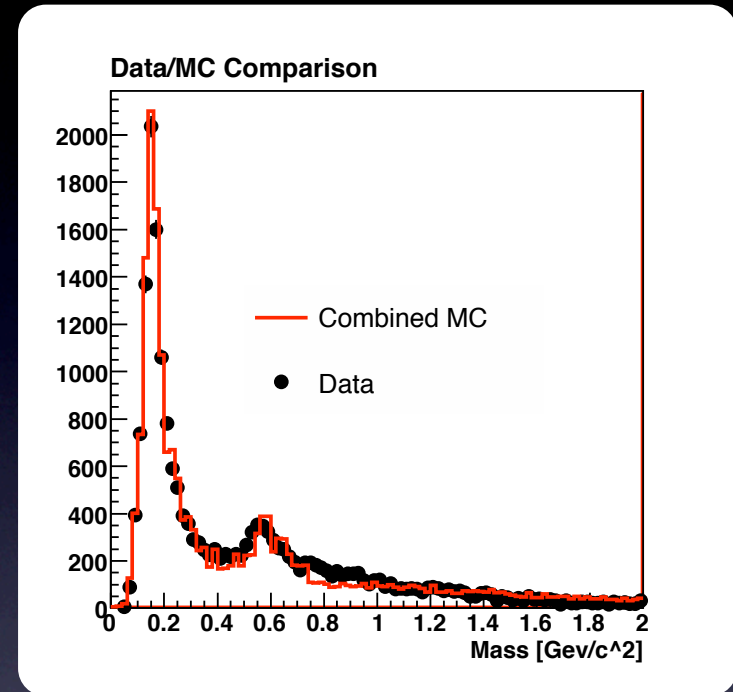
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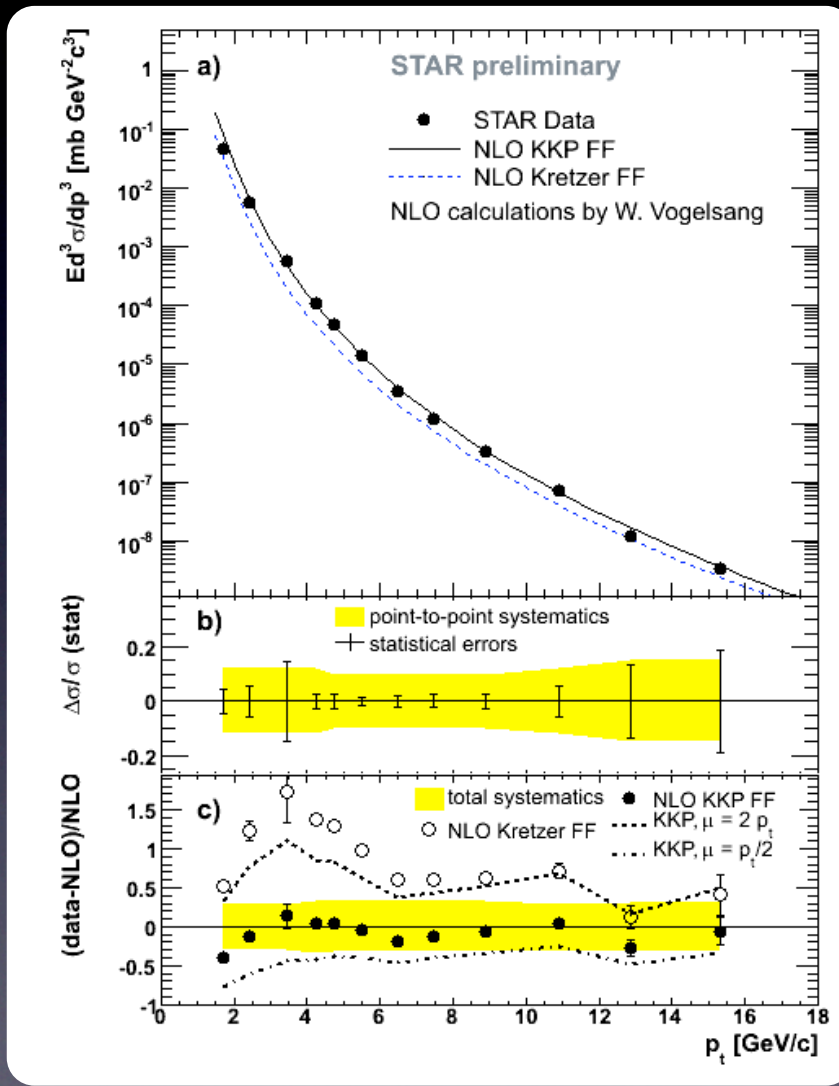
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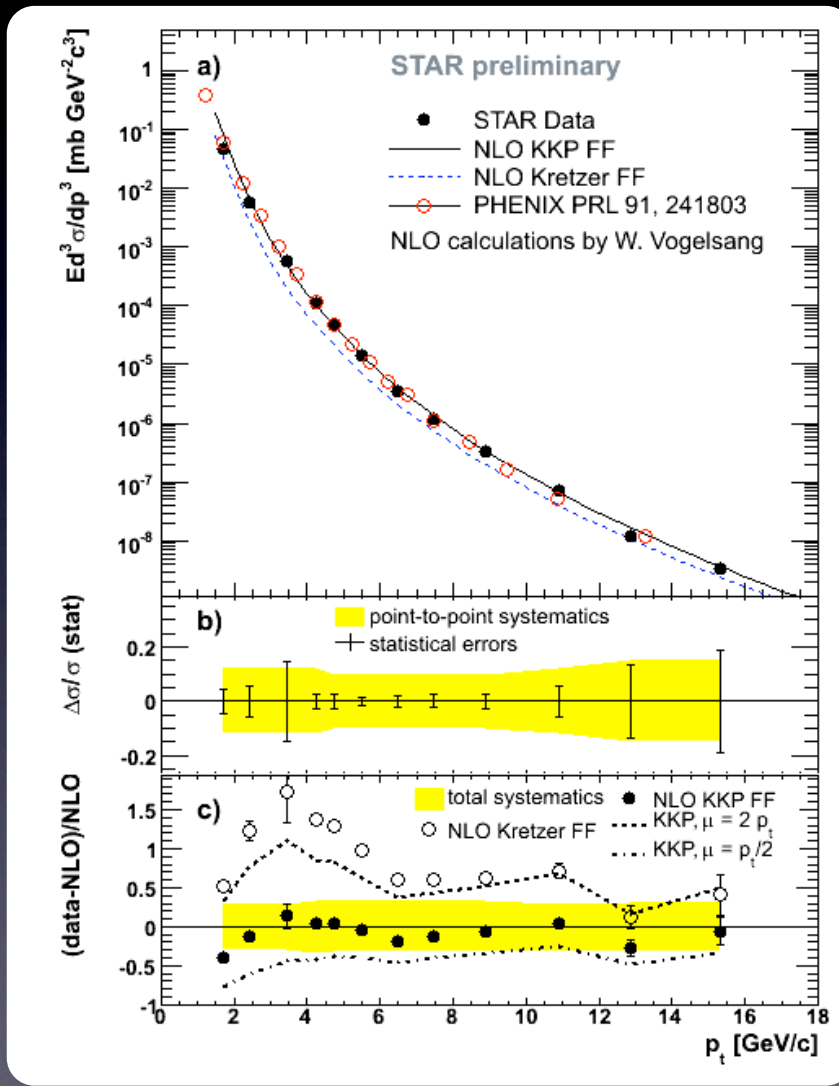
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2005 π^0 Cross Section



- L_{sampled} : 0.4 pb⁻¹ (HT triggers)
44mb⁻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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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

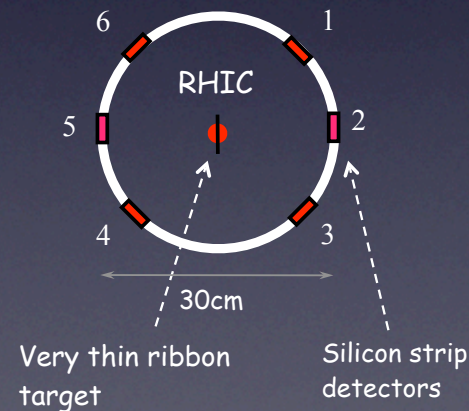
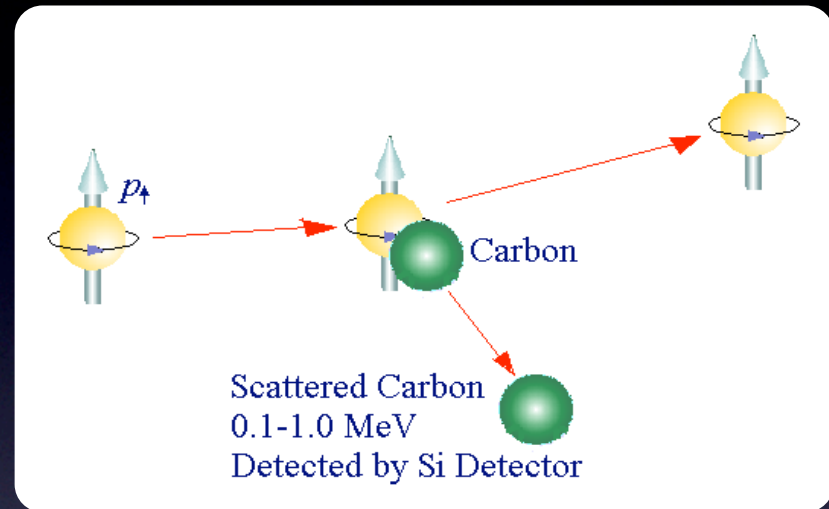
- Polarization
 - Coulomb-Nucleon Interference and H Polarimeters
 - ~55% avg. polarization
- Relative Luminosity
 - Beam-Beam Counters
- Spin Sorted Yields
 - Triggering on desired events
 - Final state reconstruction

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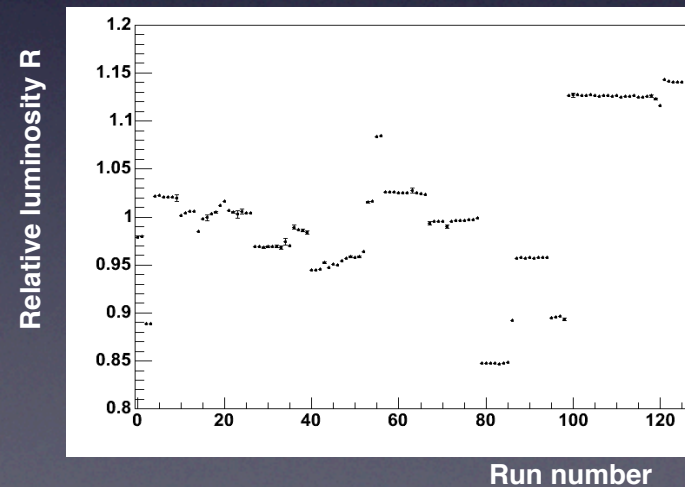
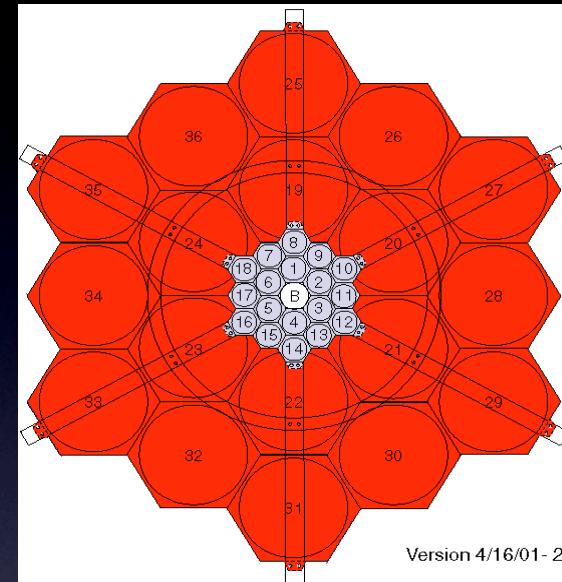


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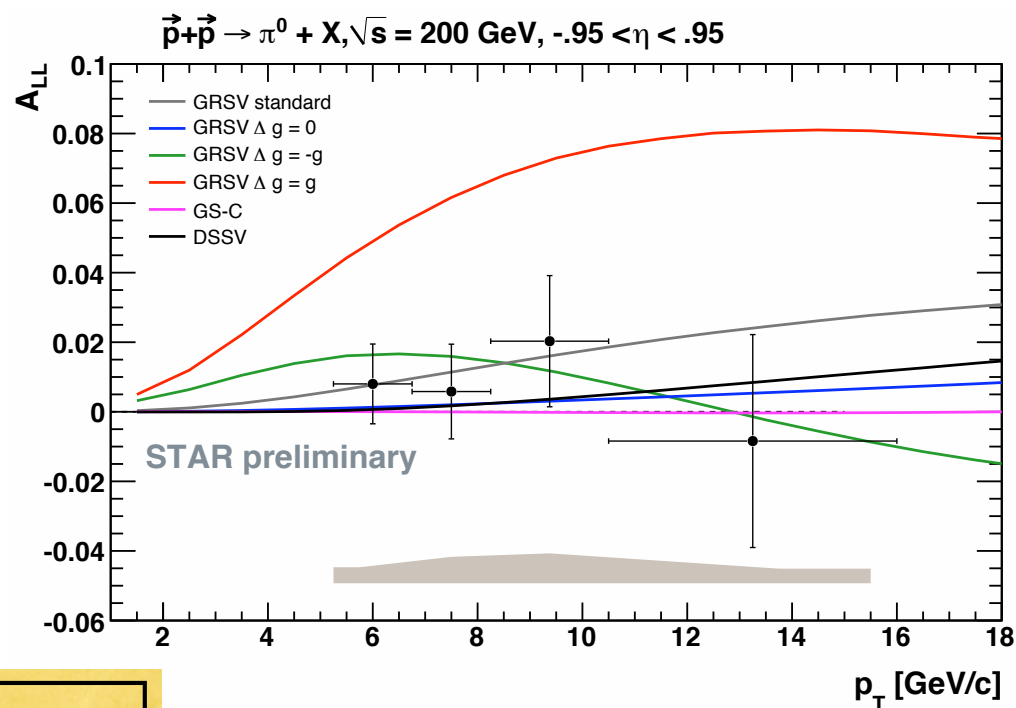
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2006 Preliminary A_{LL}

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

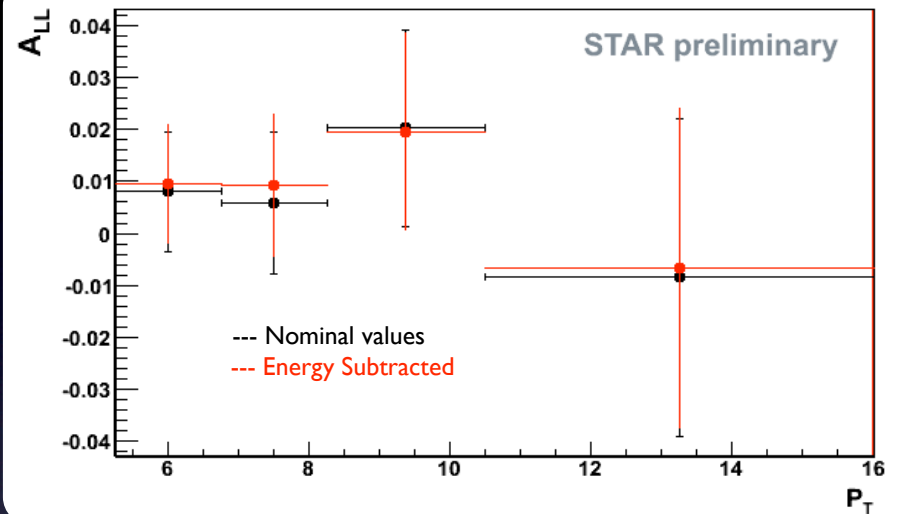
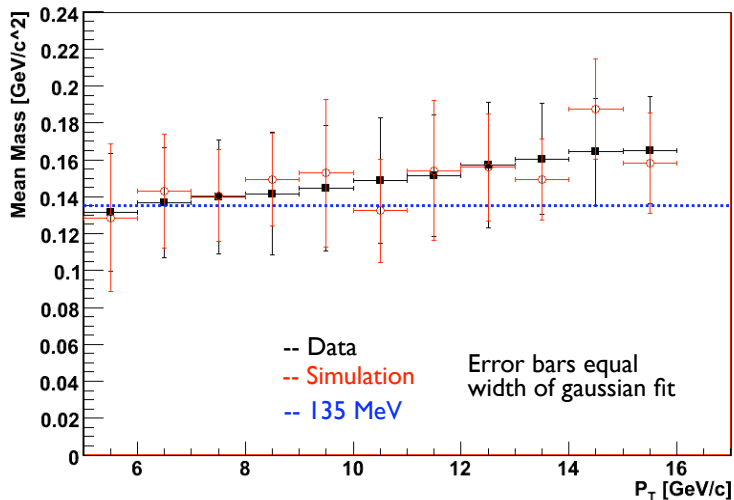


Pt Range [GeV/c]	$A_{LL} \pm \text{Stat. Err.} \pm \text{Sys. Error}$
5.2 - 6.75	$0.0080 \pm 0.0115 \pm 0.002$
6.75 - 8.25	$0.0058 \pm 0.0136 \pm 0.004$
8.25 - 10.5	$0.0203 \pm 0.0189 \pm 0.004$
10.5 - 16.0	$-0.0084 \pm 0.0306 \pm 0.002$

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

Photon Energy Uncertainty

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

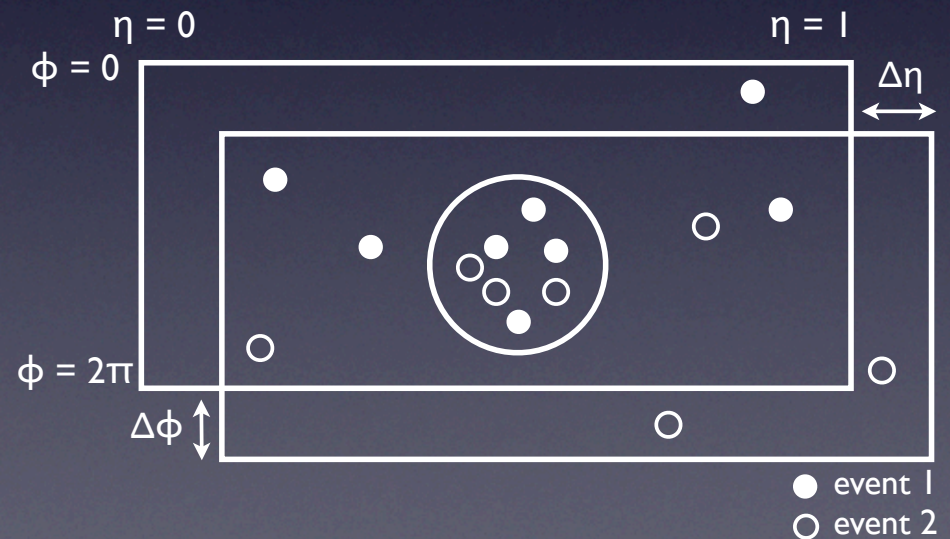
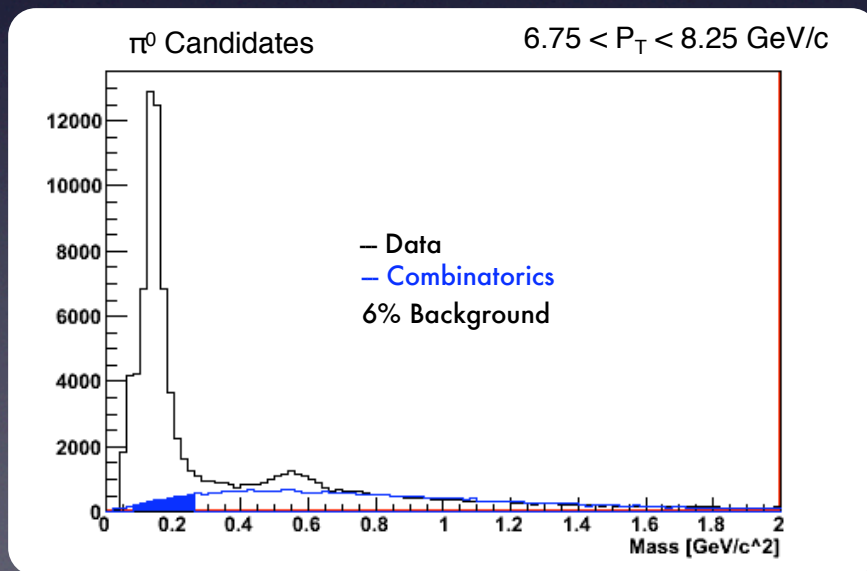
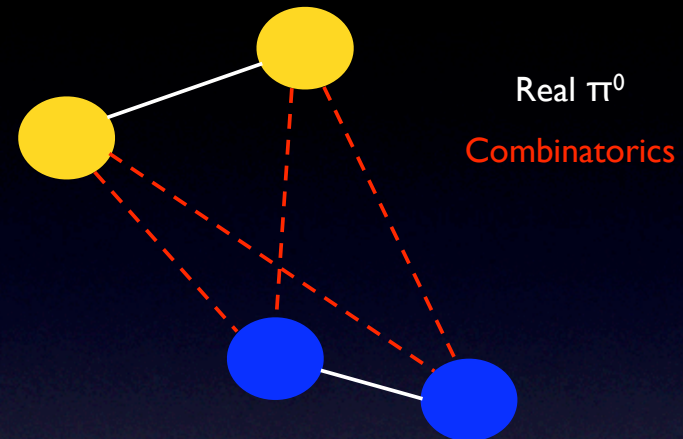


- Effect on A_{LL} consistent with statistical effect
- Uncertainty assigned (equal to observed shift) to be conservative

P_T Range [GeV/c]	Error $\times 10^{-3}$
5.2 - 6.75	1.5
6.75 - 8.25	3.4
8.25 - 10.5	0.7
10.5 - 16.0	1.5

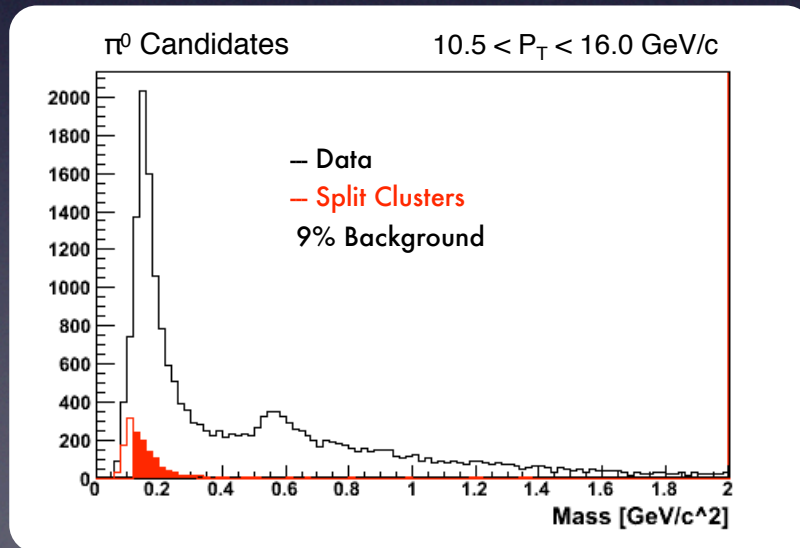
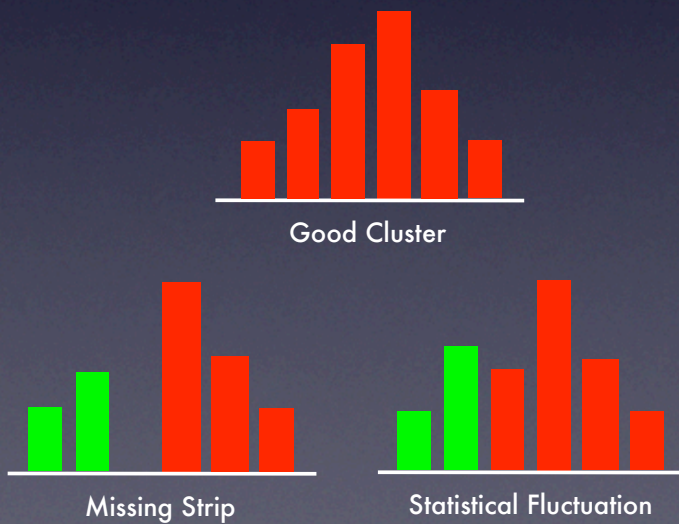
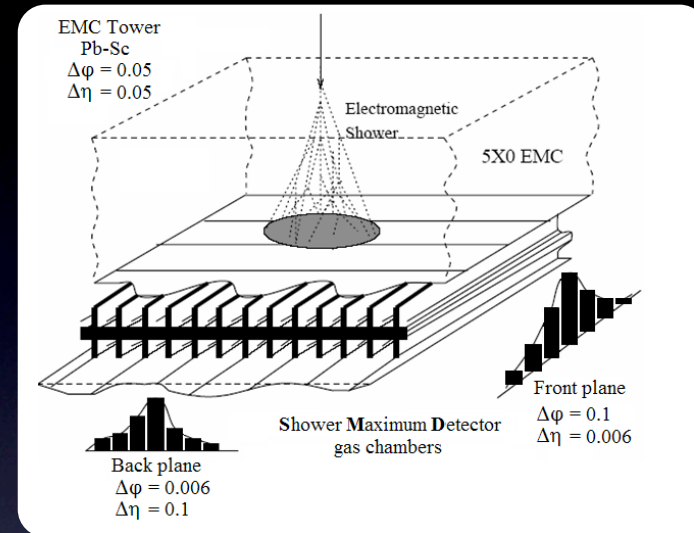
Combinatoric Background

- 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} : $0.5 \times 10^{-3} - 1.6 \times 10^{-3}$ (P_T dependent)



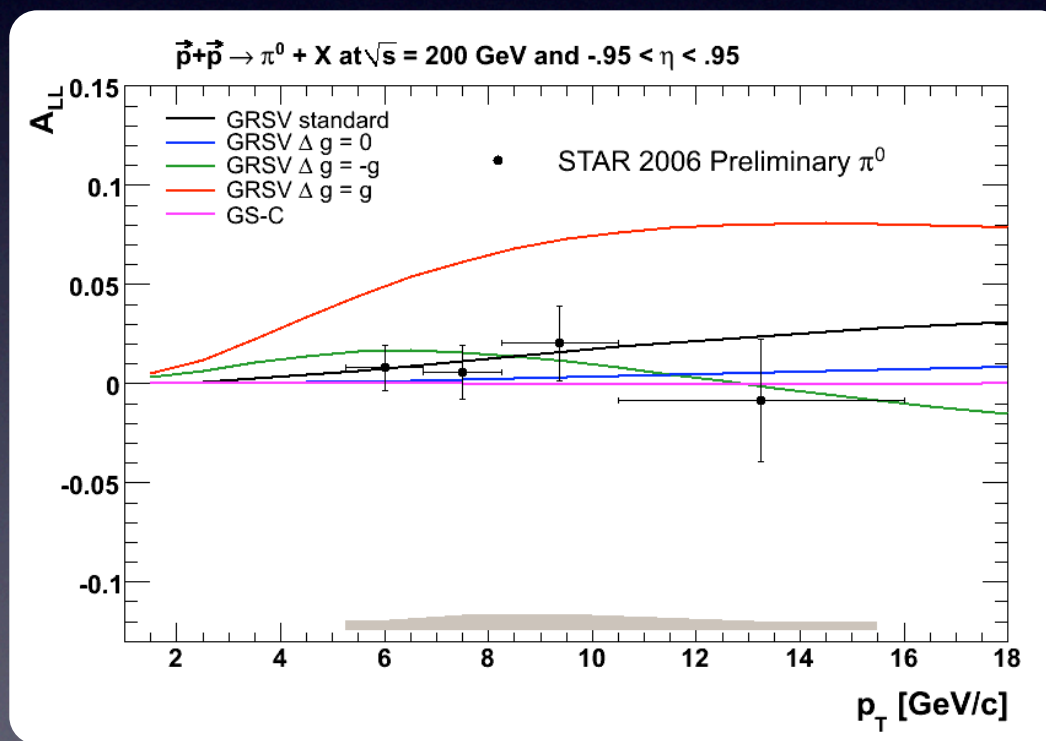
Split Clusters

- 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: $1.0 \times 10^{-3} - 3.8 \times 10^{-3}$ (P_T dependent)



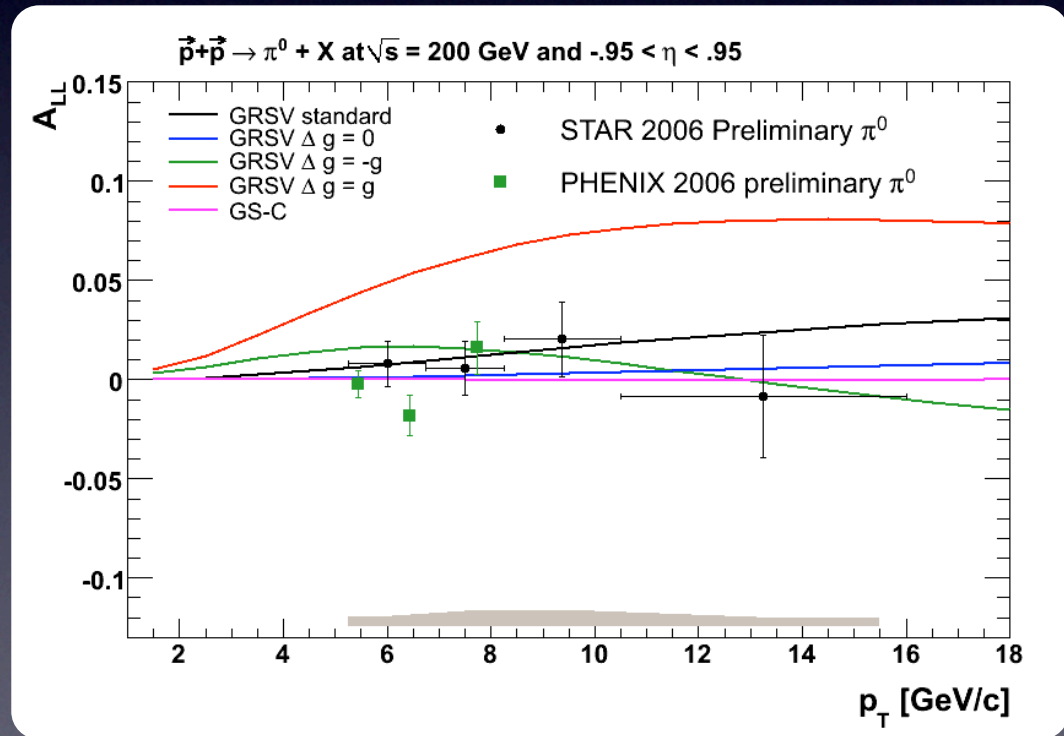
Summary

- 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}



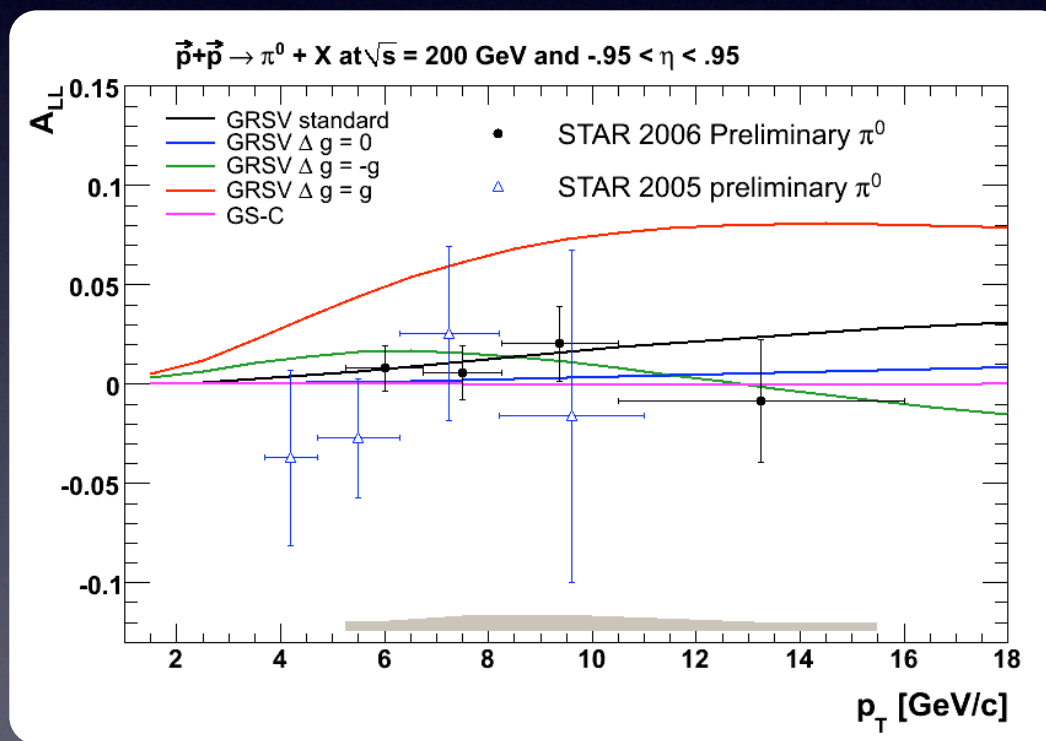
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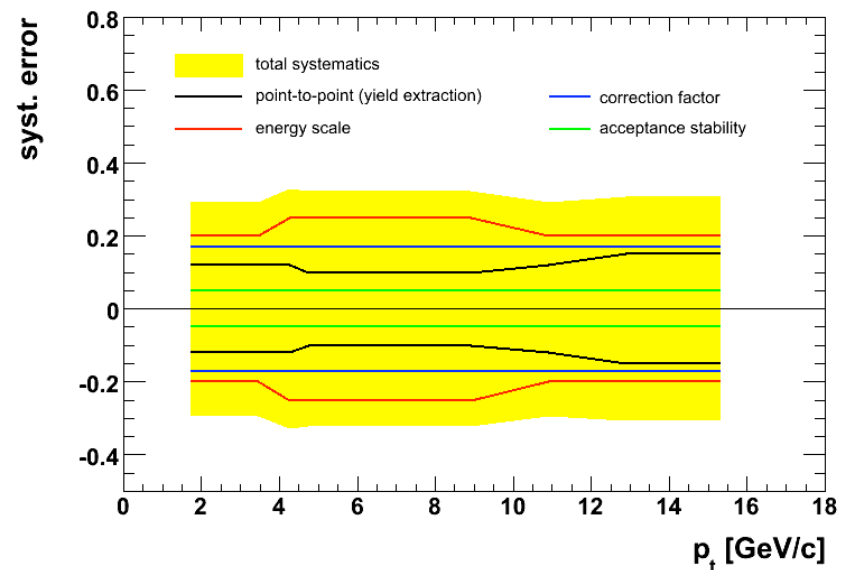


Backup

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 extent 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 $\times 10^{-3}$)

- 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