Longitudinal Double-spin Asymmetries for π^0 Production at Forward Rapidities in pp Collisions at $\sqrt{s}$ = 200 GeV at STAR

Scott Wissink

for the STAR Collaboration

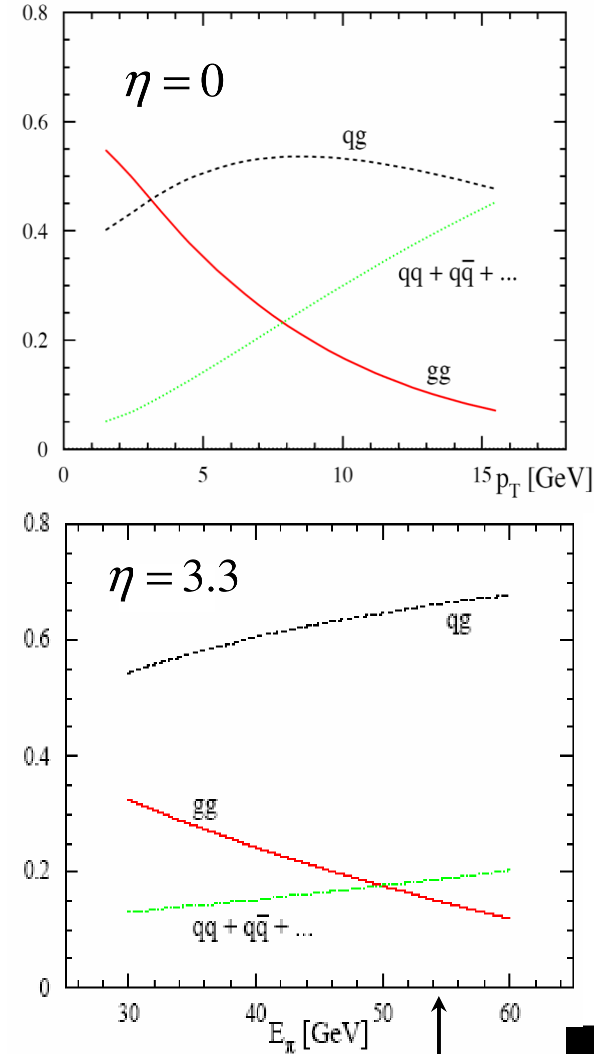
- **Brief motivation**
- **The STAR Endcap EMC**
- **π^0 reconst in the EEMC**
- **Preliminary results**
- **π^0's in FPD, γ's in EEMC**
- **Status and Outlook**

Physics Motivation for Inclusive Spin Studies

The RHIC Spin Program:

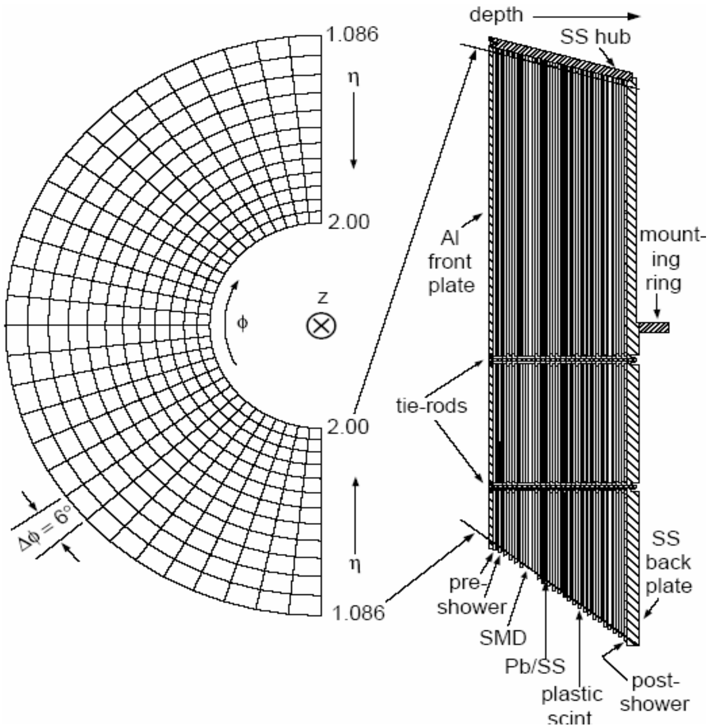
Study **hard partonic scattering** processes in polarized pp collisions, using polarization of one parton to probe helicity preferences of the other

- **For ΔG, strongest constraints to date have come from measurements of double-spin asym. A_{LL} in inclusive jet studies at STAR, π^0 studies at PHENIX, both near mid-rapidity**
- ***Very useful*, to check consistency of data analysis and assumptions of theoretical models, to extract A_{LL} for different outgoing particles, in different kinematics regimes**
- **Probes new ranges in E and p_T → x_g ; fragmentation functions; and alternate mixtures of partonic subprocesses**
- **Often requires new detectors!**

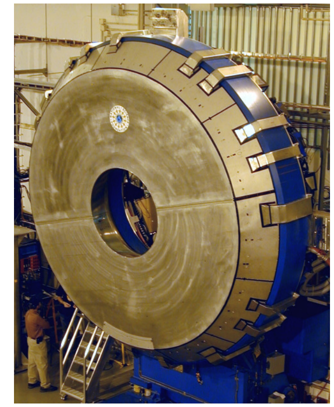


$p_T = 4$!

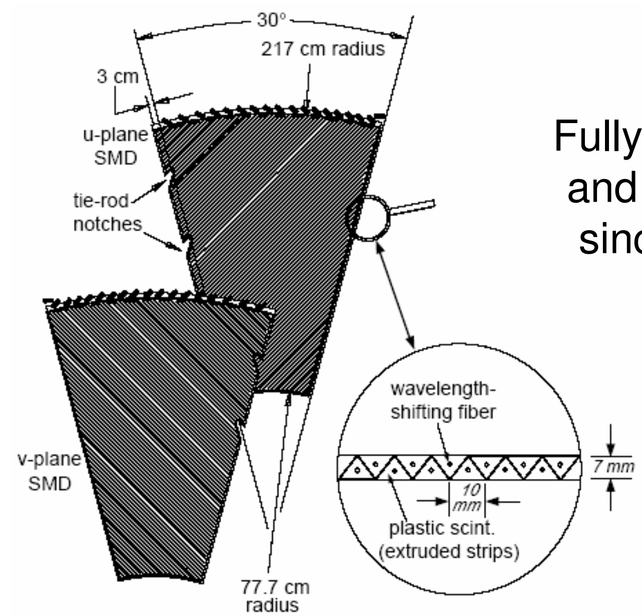
The STAR Endcap Electromagnetic Calorimeter



- Scintillating strip SMD, 288 strips per plane, two planes (*u* and *v*)
- WLS fiber → 16-anode MAPMTs
- "No gaps" between 30° sectors
- ~ 1 mm peak resolution



- Lead/scintillator sampling e.m. calorimeter
- Covers 1.09 < η < 2 over full azimuth
- 720 optically isolated projective towers (~22 X_0)
- 2 preshower, 1 postshower layers, and SMD



Fully installed and working since 2005

Reconstructing π^0's in the EEMC

Basic philosophy: try to maximize π^0 yield by considering *all* combinations of *all* γ candidates, keeping threshold values low even if backgrounds are increased.

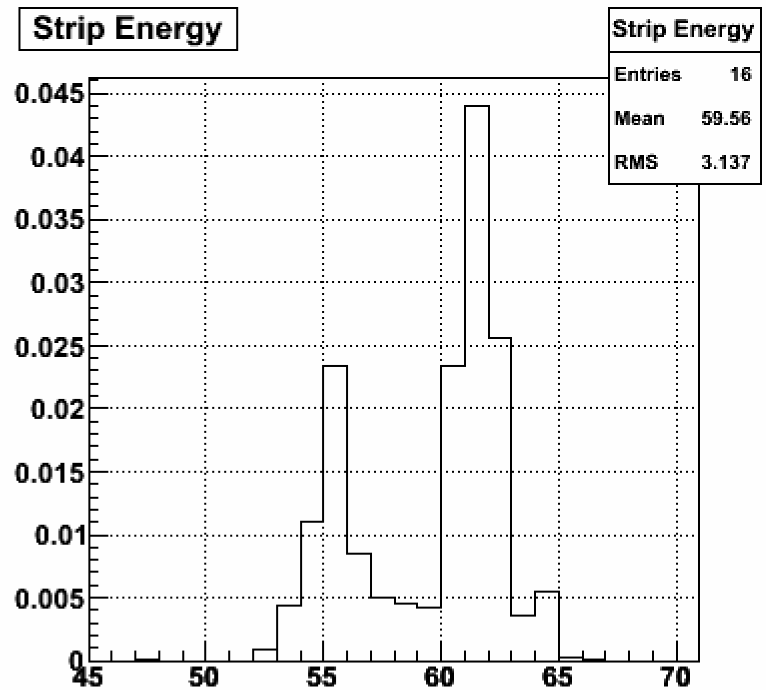
→ Identify neutral pions by determining

$$M_{\mathrm{inv}}^{2} = 2E_1E_2(1-\cos\varphi_{\gamma\gamma})$$

Procedure: clusters ->points -> π0

1. E1 + E2 measured by EMC towers
2. opening angle measured by SMD
3. energy sharing zγγ based on both

SMD seed energy =3 MeV
7 strip energies summed for smd cluster
Point $p_T > 1.5$ GeV
π^0 candidates accepted $1.086 < \eta < 2.0$
Tower ET cut > 3.0 GV * doubleGaussian



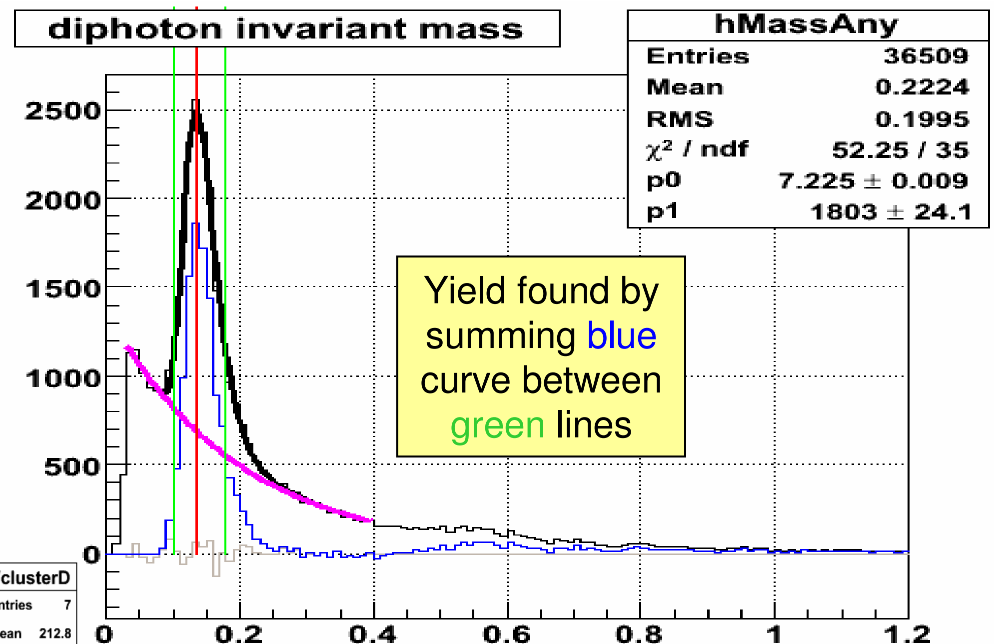
Actual (though not typical) SMD response

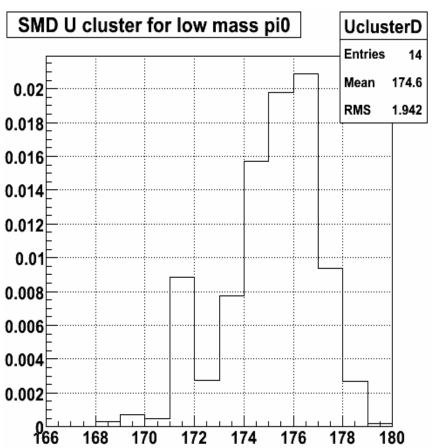
All events require:
Trigger = “High tower” + trigger patch
Event vertex found

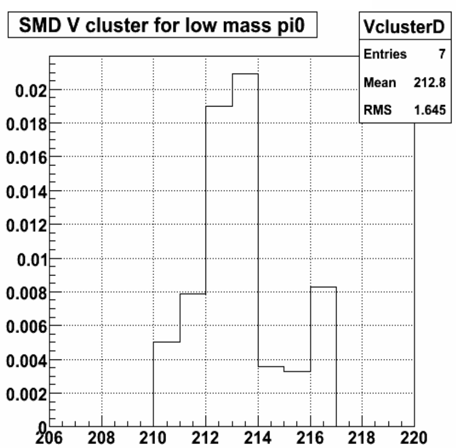
Extracting Yields from Run 6 Data Set

➢347 longitudinal runs from 41 fills
2.2M events, ~320k π^0 candidates
~200k after bkgd subtraction → ~9% reconstruction effic / trigger

➢ Strip-to-strip fluctuations in the SMD response produce a low-mass peak in spectrum – dominates over combinatorics, ***but not reproduced with EEMC SMD slow simulator!***







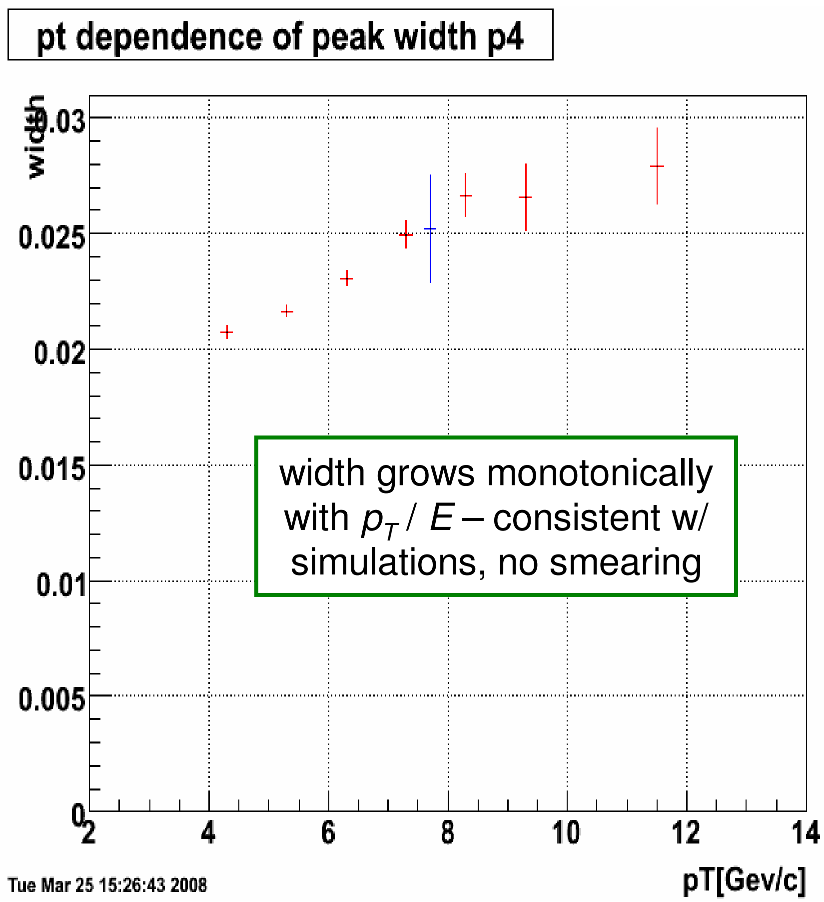
➢ **Adopt a phenomenological approach: Fit π^0 mass spectra using the function**

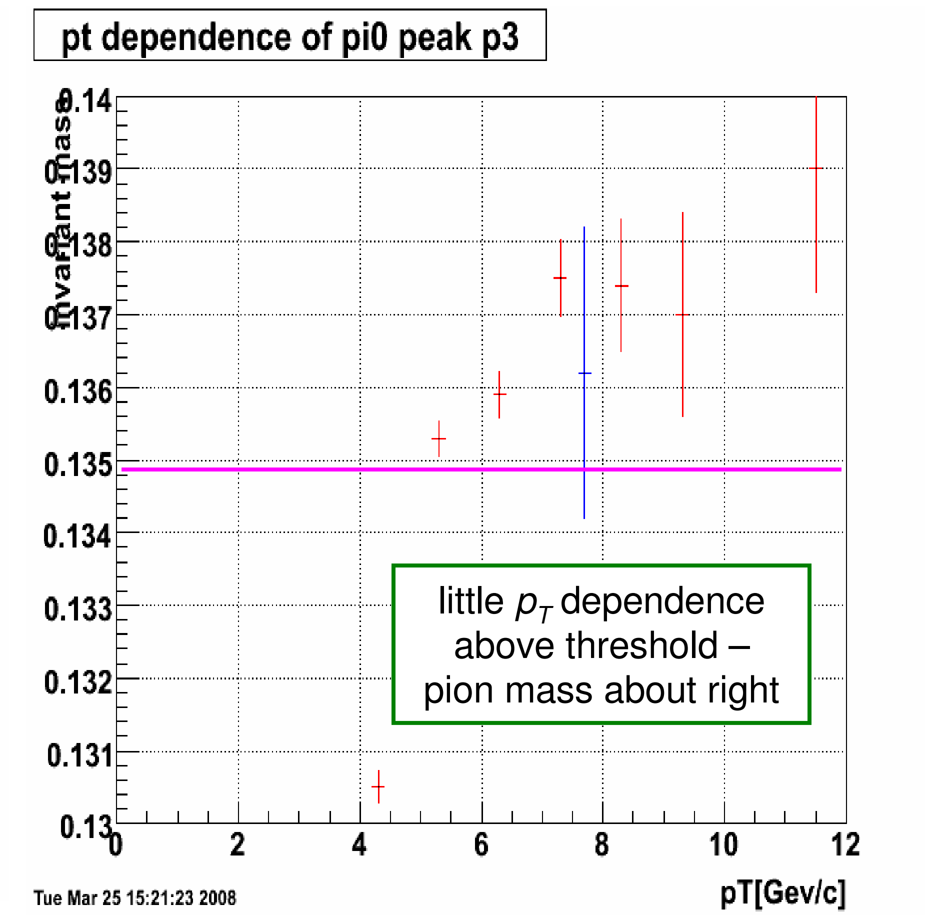
$$y(x) = A_1 e^{-\alpha x} + A_2 \exp\left[-\frac{1}{2}\left(\frac{x-\mu}{\sigma[1+k(x-\mu)]}\right)^2\right]$$

Only amplitudes A_1 and A_2 are allowed to vary with spin state

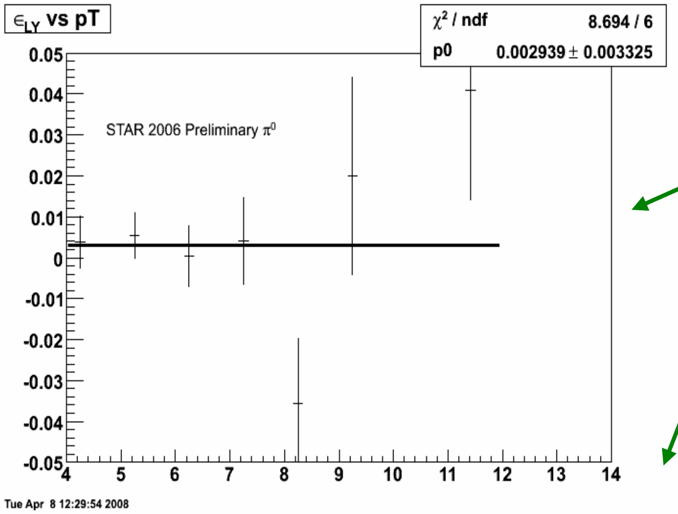
Comparison of peak fit params to Simulations

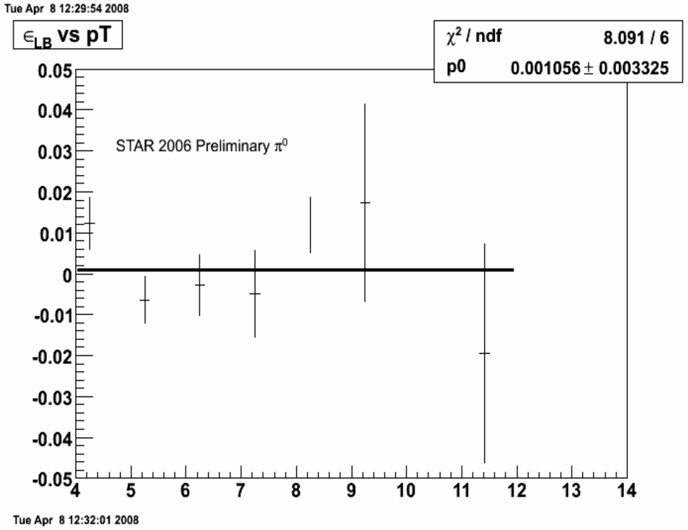
Divide data into 7 p_T bins – look for "smoothness" in fit parameters, compare to MC (blue)





Consistency Checks





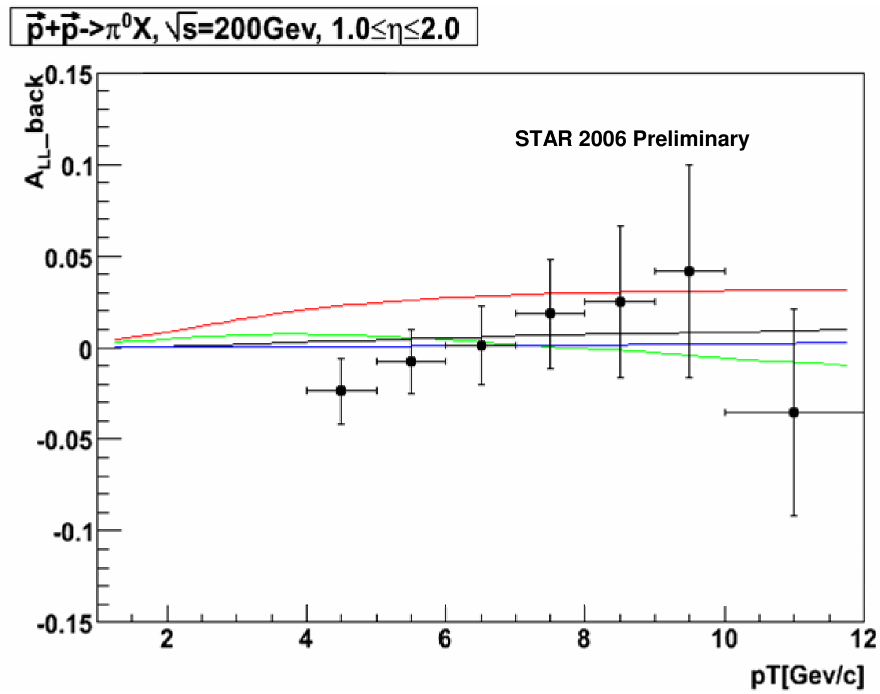
1. Use normalized, spin-sorted yields to calculate longitudinal single-spin asymmetries A_L – **consistent with zero for both Y & B beams.**
2. Estimate sensitivity of A_{LL} to choices in fitting:
   a) vary fitting range (nominally 50-400 MeV) by ±10 MeV at each end
   b) increase complexity of assumed shape of background, adding parameters to vary but keeping normalized χ^2 ~ constant
   c) For each p_T bin, hold the peak parameters μ and σ fixed for the spin-sorted fits, but displaced from 'best' values by 2 x error

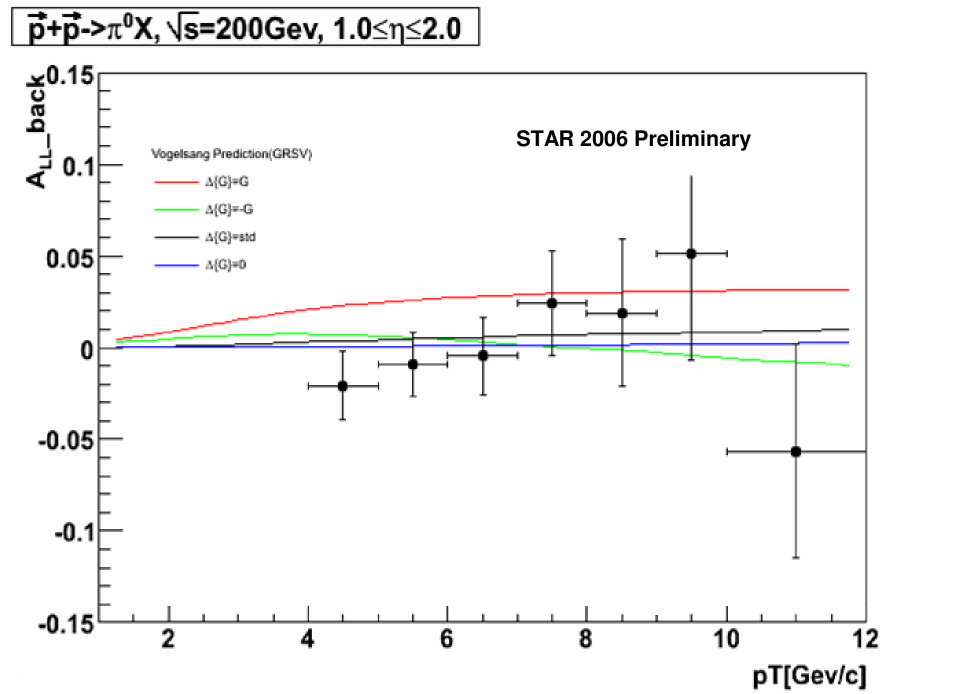
Changes in A_{LL} resulting from a - c were added algebraically to estimate contribution to the total systematic error budget

Correcting for Background – Two Methods

1. Integrate the fitted exponential over the same mass range as for pions, then subtract to calculate $A_{LL}(pion)$

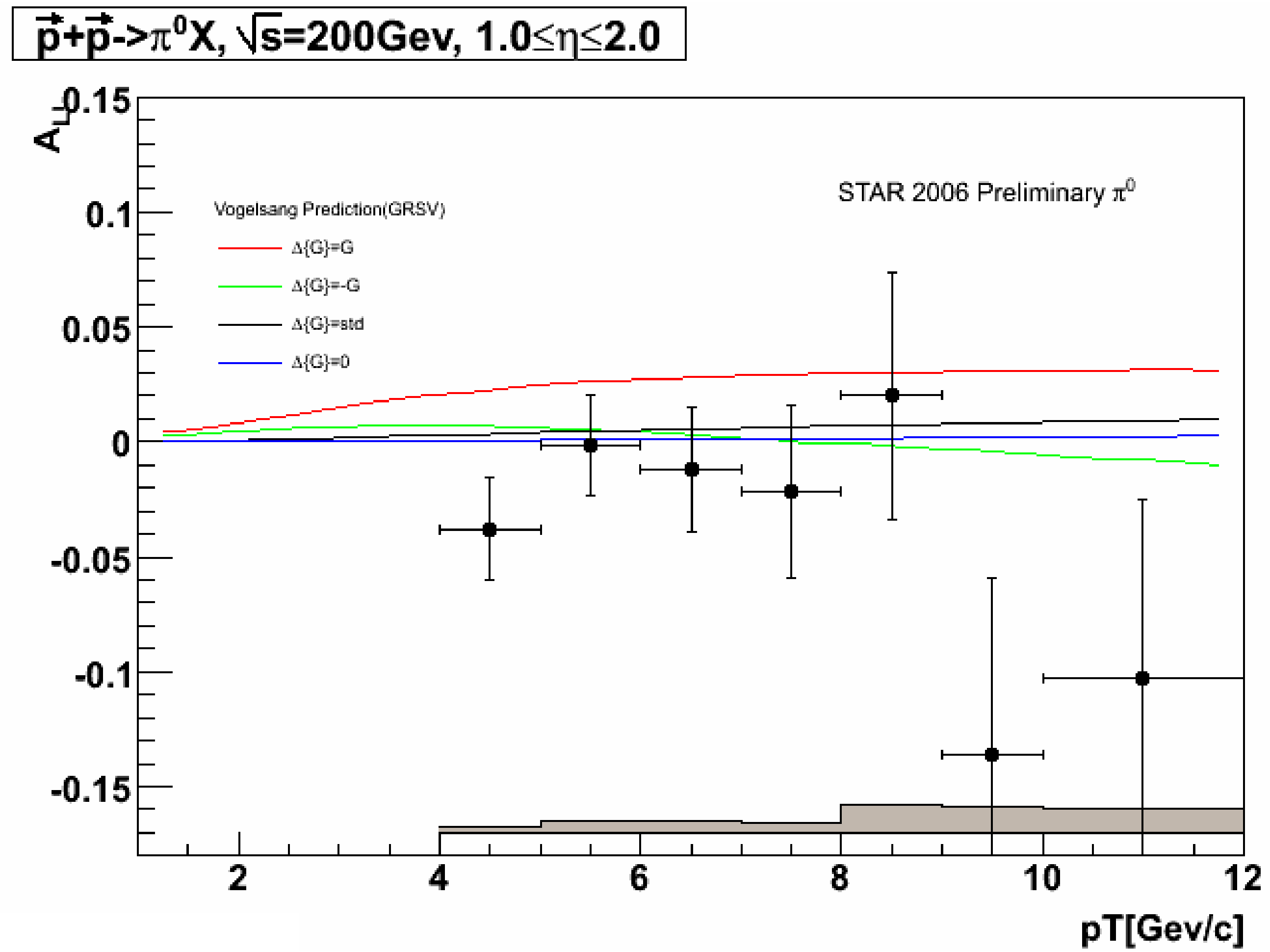
2. Sum yields in sidebands outside π^0 peak, calculate $A_{LL}(bkgd)$ for each, average, then use to correct $A_{LL}(raw) \rightarrow A_{LL}(pion)$





NOTE: Curves are predictions of A_{LL} for π^0's in the EEMC – added here only to set a scale!

Preliminary Result: A_{LL} for π^0's in the EEMC

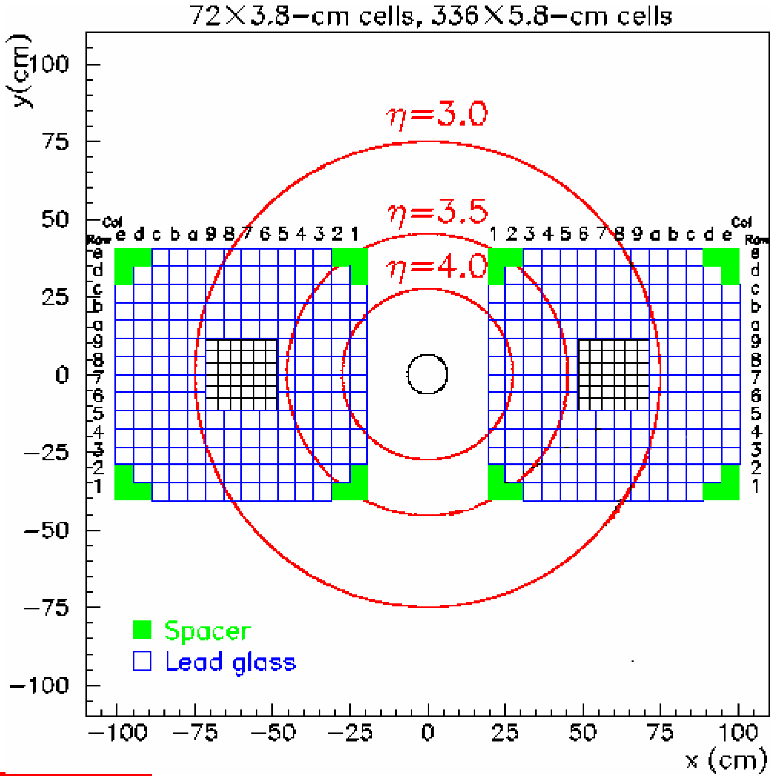


- Negligible dependence on bkgd method – acc't for diff's in syst. error
- Theoretical predictions ~2-3 times smaller than at η=0 → significant loss in physics sensitivity
- ***First measurement of A_{LL} in this η range → consistent with other inclusive results that rule out large ΔG.***
- Systematic errors small and appear to be under control – dominated by assumptions in fitting

Further Forward – π^0's in the STAR FPD's

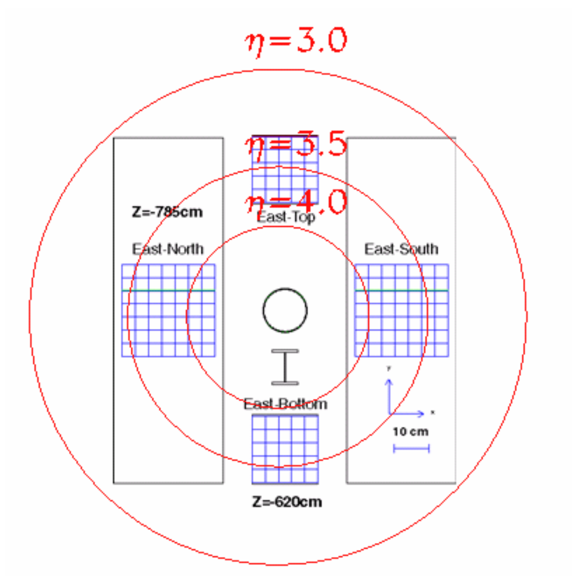
West FPD++

Inner: Two 6x6 arrays of small Pb glass
Outer: Total 168 Large Pb glass cells
Average pseudo-rapidity: 3.25



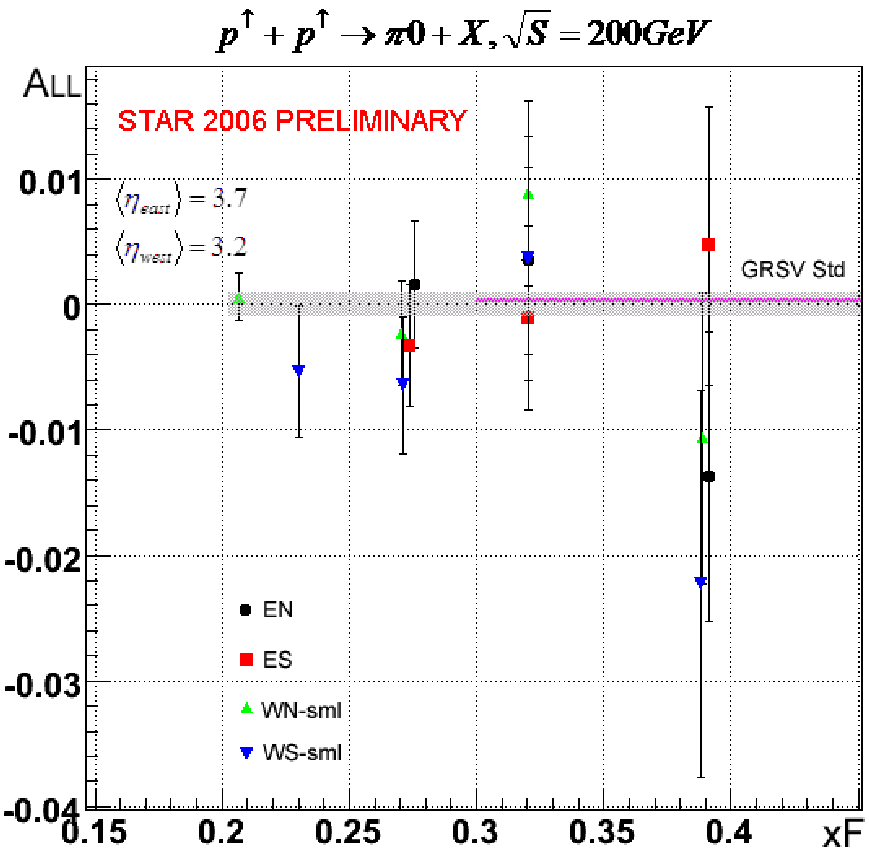
East FPD

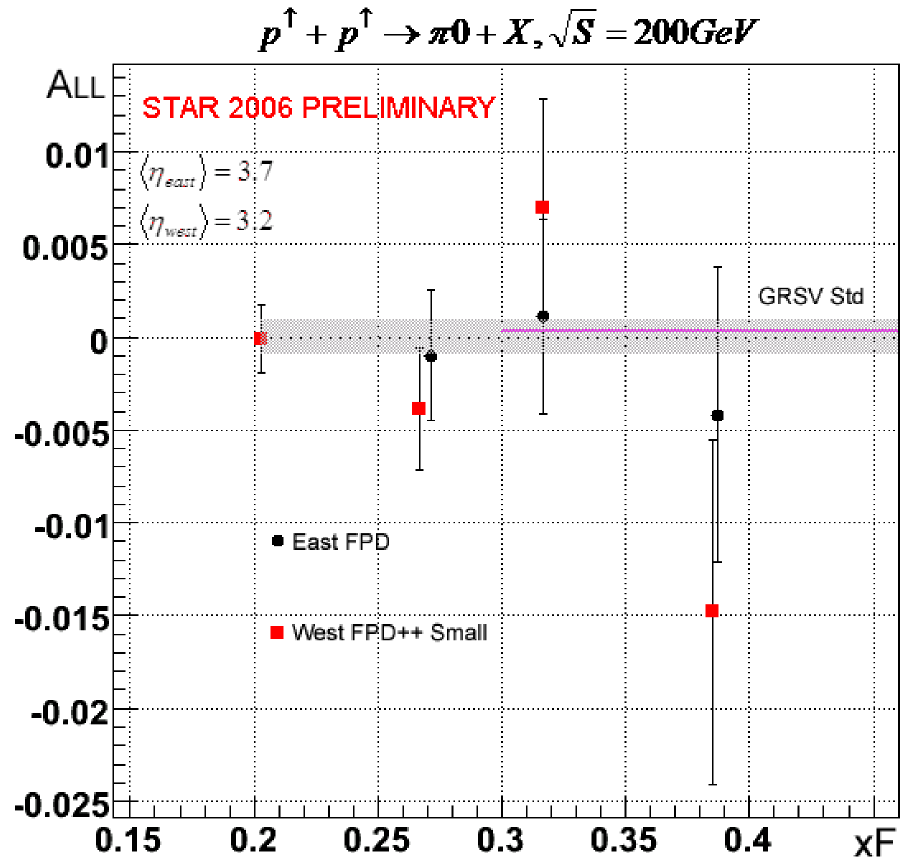
Two 7x7 arrays of small Pb glass (N/S)
Located at "far" position, X-offset 30.7 cm
Average pseudo-rapidity: 3.7



A_{LL} for Forward π^0's in Run 6

Steve Heppelmann and Len Eun

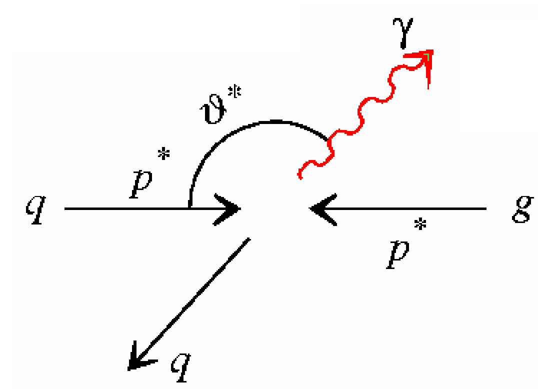




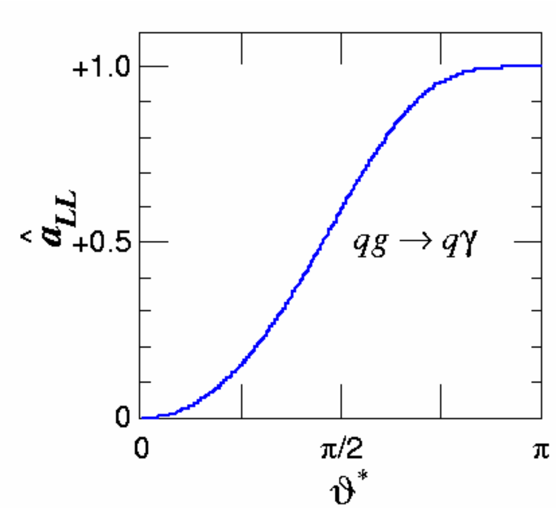
Asymmetries consistent among all detectors – but also consistent with zero at all x_F, in keeping with theoretical expectations.

Even Further Forward … in time

Photon-jet coincidences – still the "Golden channel" !

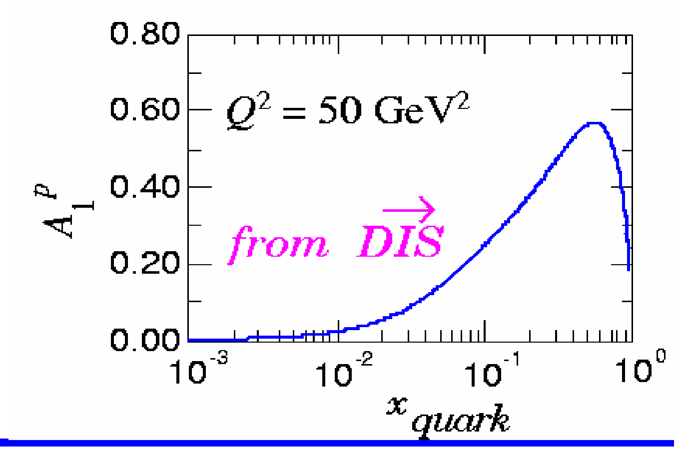


- ✓ Direct photon production dominated (~90% of yield) by a single LO pQCD process: $qg \rightarrow q\gamma$
- ✓ Partonic spin correlation large for this process, esp. when gluon / γ is back-scattered – where cross section peaks!



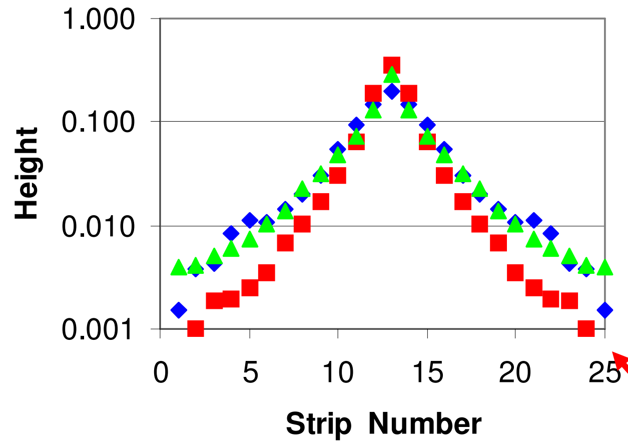
- ✓ 4-mom of γ + direction of coincident jet → can reconstruct *x*'s of initial state partons. Additional information on jet p_T → provides handle on k_T smearing effects
- ✓ Want to use high-*x* quarks (where they're most polarized) to probe low-*x* gluons (where they are most abundant)

→ *Very asymmetric collisions! Outgoing particles boosted into forward direction / to STAR EEMC*



Experimental Challenges

Normalized shower shape in SMD



Most precise tool: use high granularity SMD

- Discriminate against nearby mips (crucial where TPC tracking is no longer efficient)
- Examining shower shape can distinguish between single shower and a nearby pair

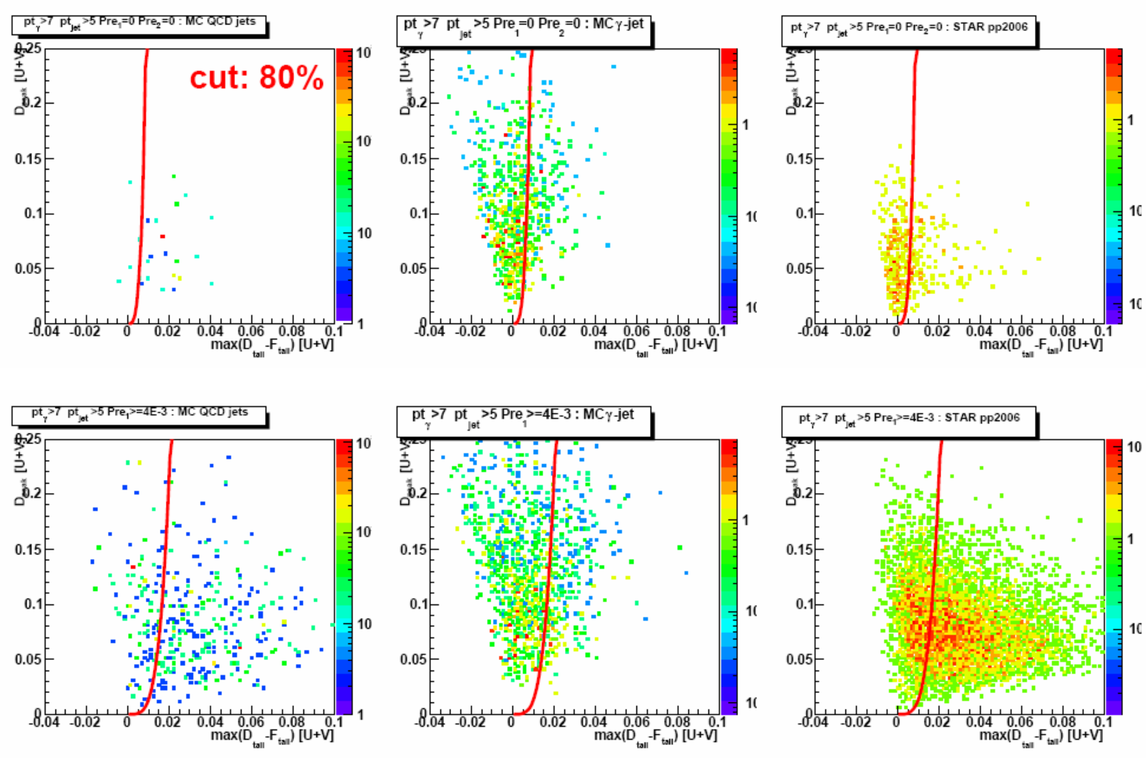
➢ *But only if SMD response is well understood!*

Non-trivial to collect a data sample of isolated photons to compare to simulated response

One idea: **"tag" photons by looking at SMD points that reconstruct to correct η mass**

- Shows clear problem → **EEMC shower profile significantly wider than MC suggests**
- Adjusting GEANT settings, lowering thresholds, increasing sensitivity, not much help
- More radical approach: for each photon in GEANT record, replace simulated SMD strip energies with those stored in a 'library' of empirical responses from η-meson study
- If we can rely on getting shape right → can look for *small deviations* in fit residuals

Status of Isolated Photons in Endcap

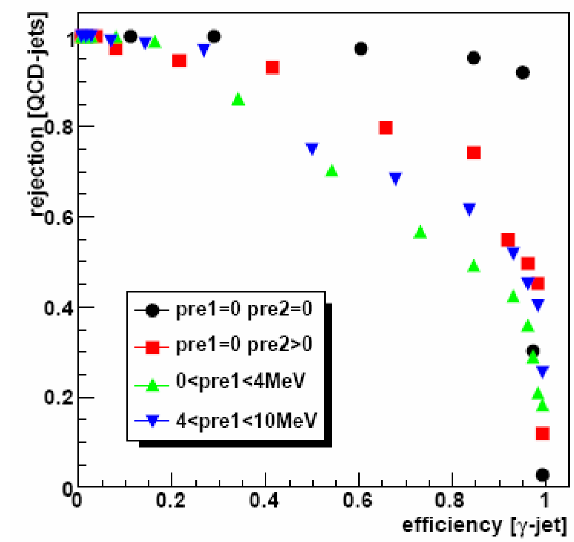


MC "QCD bkgd" | MC γ-jet events | 2006 pp data

"Purity" of photons in data sample strongly correlated with pre-shower response

No energy in either layer → mostly isolated photons

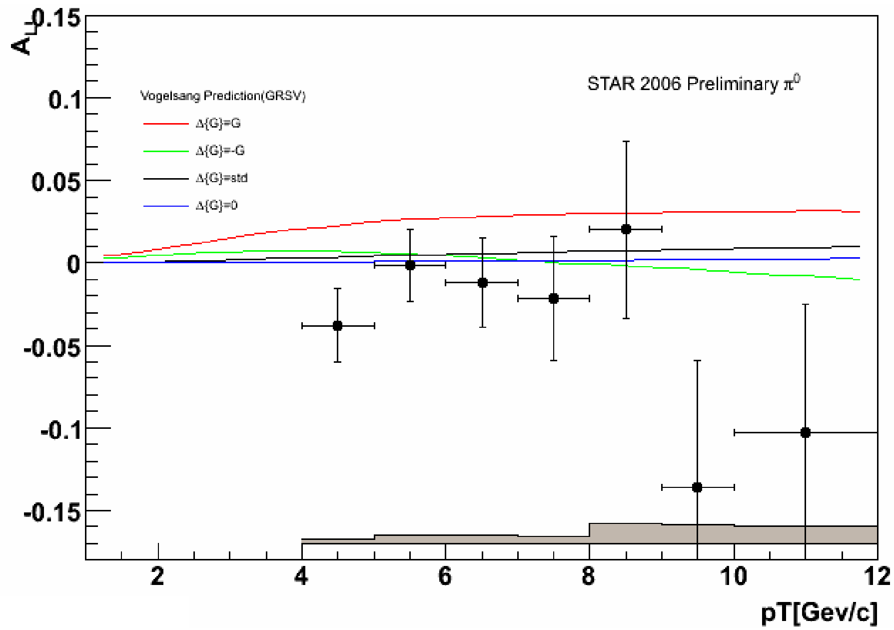
***E(pre1)* > 4 MeV** → nearby photons and/or hadrons



All samples above normalized to 3.1 pb^{-1}. *Sum* of two MC samples agrees with data in *pT, η*, and preshower energy distributions

Summary and Outlook

- **First look at longitudinal double spin asymmetries for π^0's at high η (EEMC and FPD's) → lower x_g.** Statistics not great, A_{LL} expected to be small: but errors under control, results consistent with incl. studies



- **Has forced a detailed look at behavior of <u>all</u> components of EEMC** → critical for future work in extracting A_{LL} for γ-jet coincidences

- **Near-term goals:**
  - See if a "data-driven" MC sample can reproduce low-mass structure in π^0 spectra
  - If so, obtain realistic estimates of reconstruction efficiencies vs p_T, η, $z_{\gamma\gamma}$, etc
  - ***Better handle on background subtraction for A_{LL} , extract π^0 cross section!***