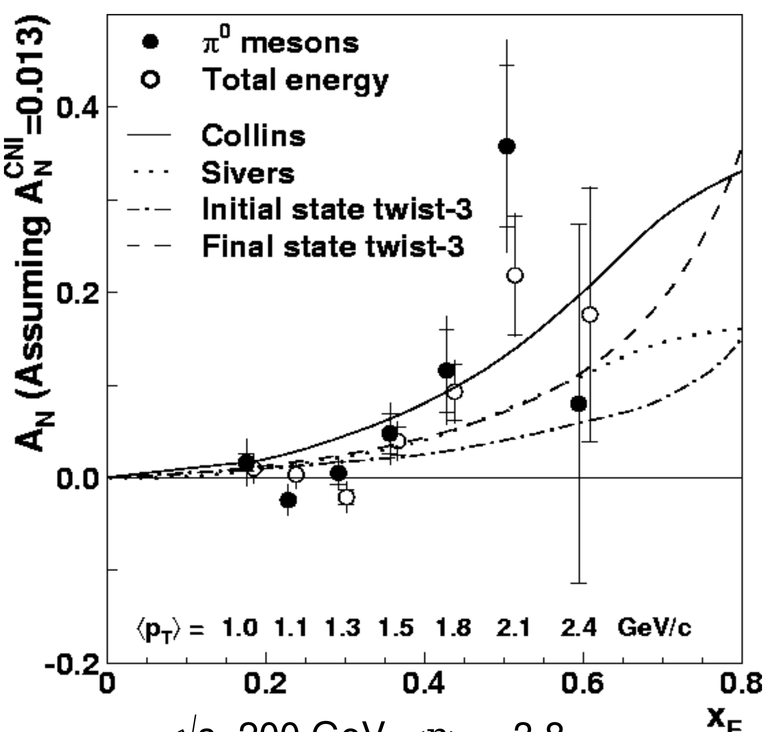
Transverse Single Spin Asymmetry and Cross-Section for Forward Direct Photon Production at STAR

Len K. Eun
For the STAR Collaboration
DNP 2011, East Lansing, Oct. 2011

Transverse Single Spin Asymmetry

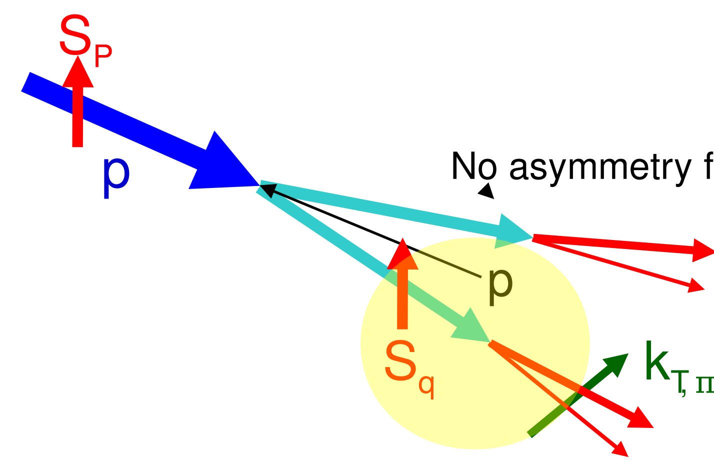
Large Transverse Single Spin Asymmetry(SSA) in forward meson production persists up to RHIC energy.

PRL 92, 171801 (2004)

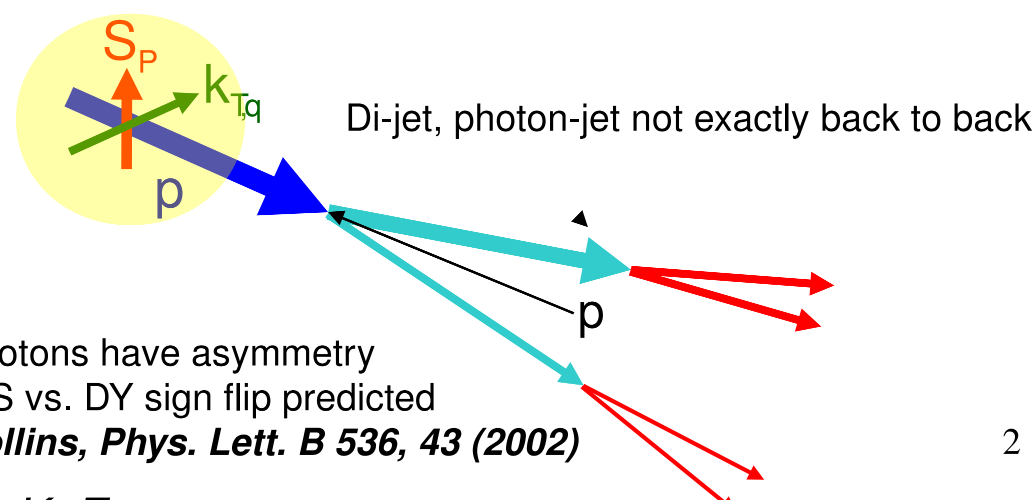


$\sqrt{s}$=200 GeV, <η> = 3.8

• **Collins effect**: asymmetry comes from the transversity and the spin dependence of jet fragmentation.



• **Sivers effect**: asymmetry comes from spin-correlated k_T in the initial parton distribution



Photons have asymmetry
DIS vs. DY sign flip predicted
Collins, Phys. Lett. B 536, 43 (2002)

Predicting the Sign of A_N

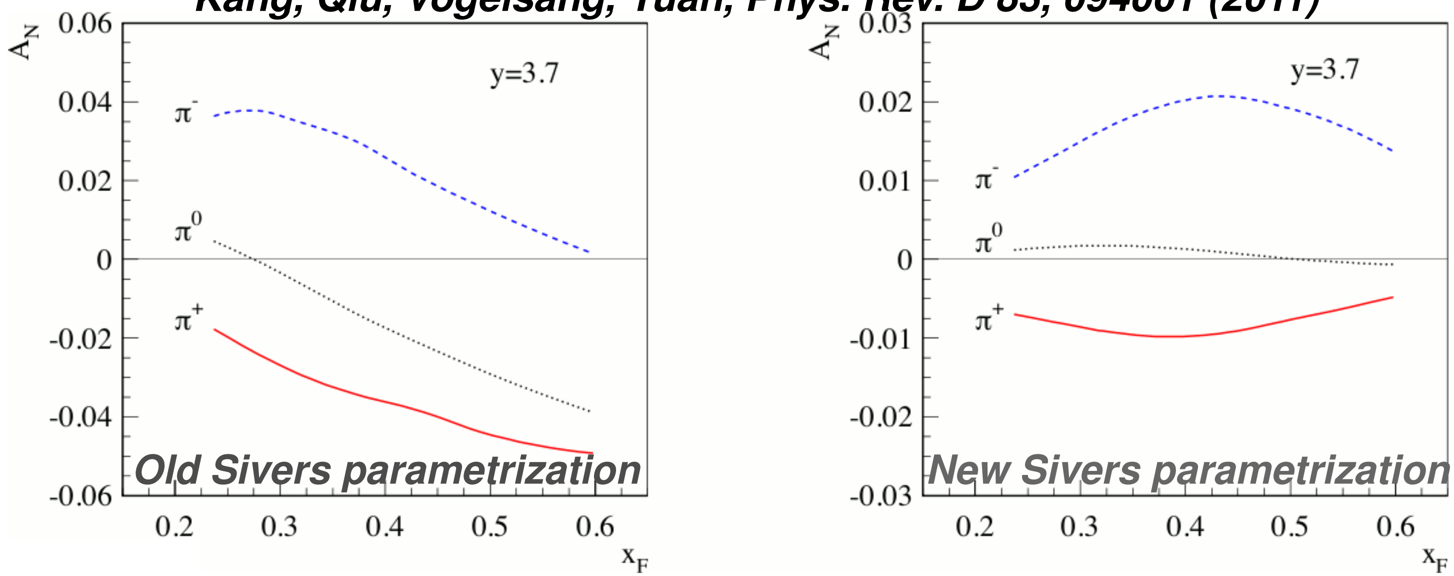
Based on the Sivers function extracted from DIS (HERMES) results, pQCD based theories predict the sign of A_N for the Sivers effect in p+p to be the opposite of what has been observed for π^0, π^+, π^- and η final states at RHIC.

Sivers Effect in p+p Extracted from SIDIS

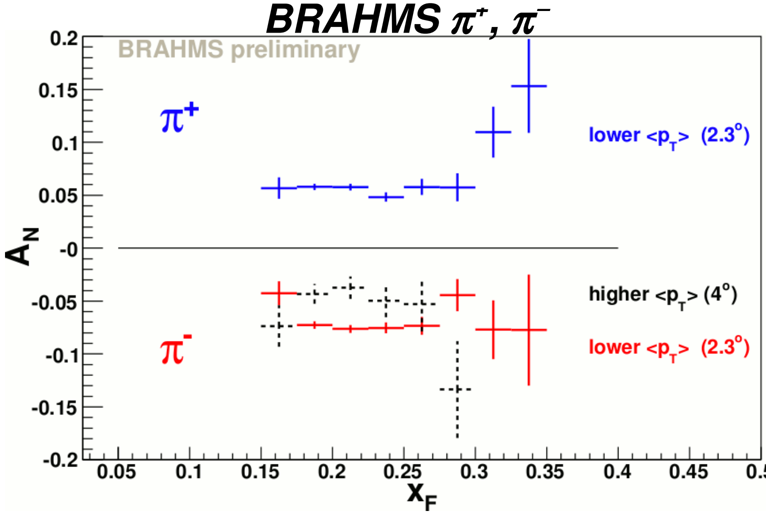
π^0, π^+ : Negative

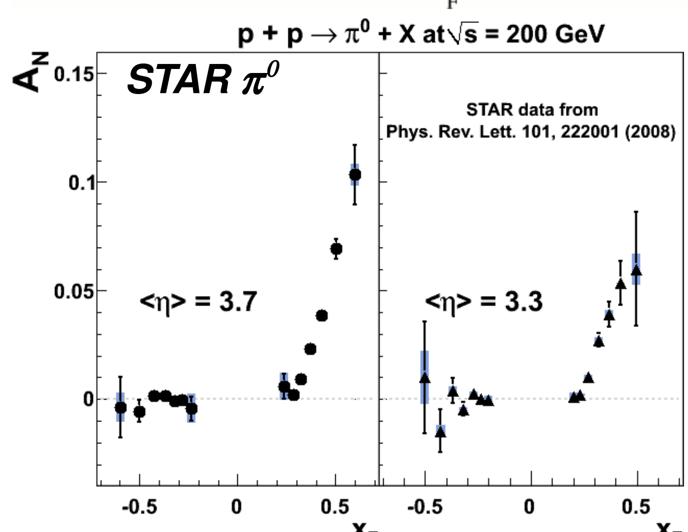
π^- : Positive

Kang, Qiu, Vogelsang, Yuan, Phys. Rev. D 83, 094001 (2011)



BRAHMS π^+, π^-





At RHIC (STAR, PHENIX, BRAHMS)

π^0, π^+, and η : Positive

π^- : Negative

Possible Sources of Discrepancy

The quark-gluon correlation function used for p+p is obtained by taking a k_T moment of the Sivers function extracted from SIDIS.

1. The derivation of ETQS function from the Sivers function might be wrong.

→ ***The k_T structure of the Sivers function from SIDIS is understood only for low k_T***

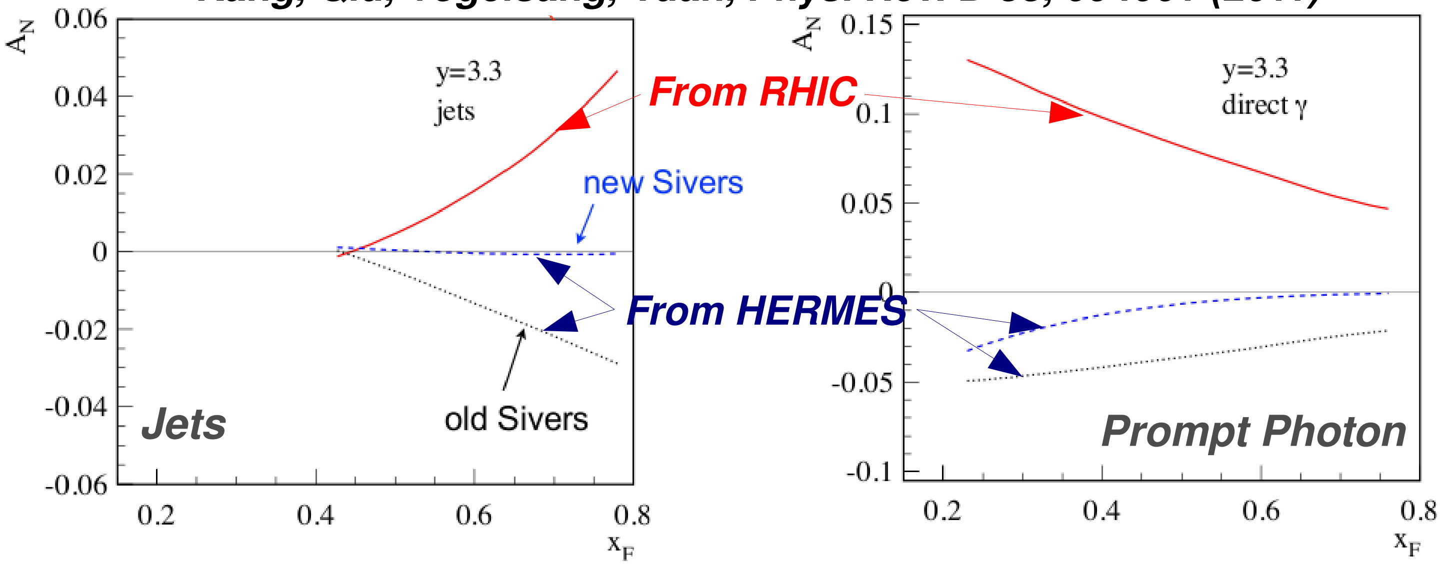
→ ***SIDIS and RHIC focuses on different regions of x_{bj}***

2. The A_N observed in p+p might be dominated by the Collins effect.

→ ***Recent STAR measurement did not see Collins effect (N. Poljak, PANIC 2011)***

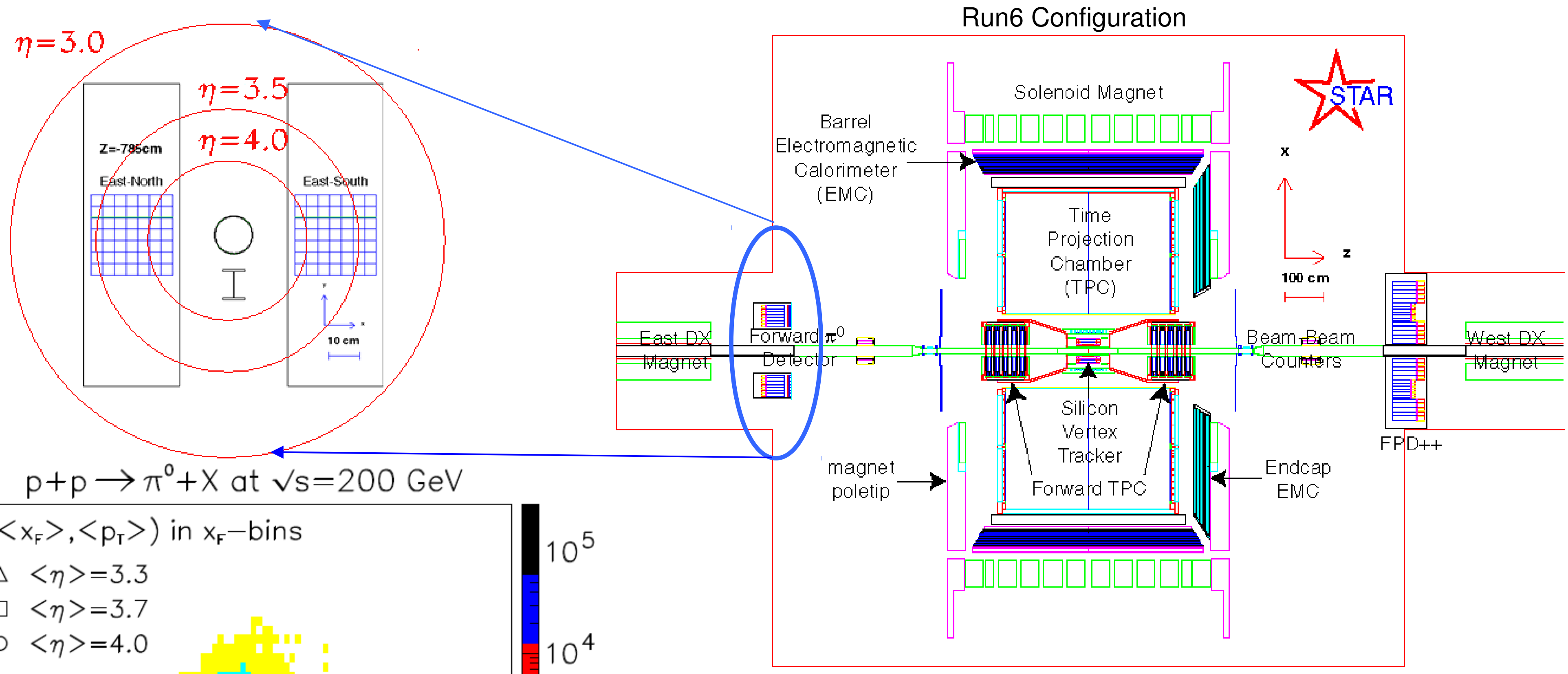
→ ***Measure the A_N for final states without Collins effect: prompt photons and jets.***

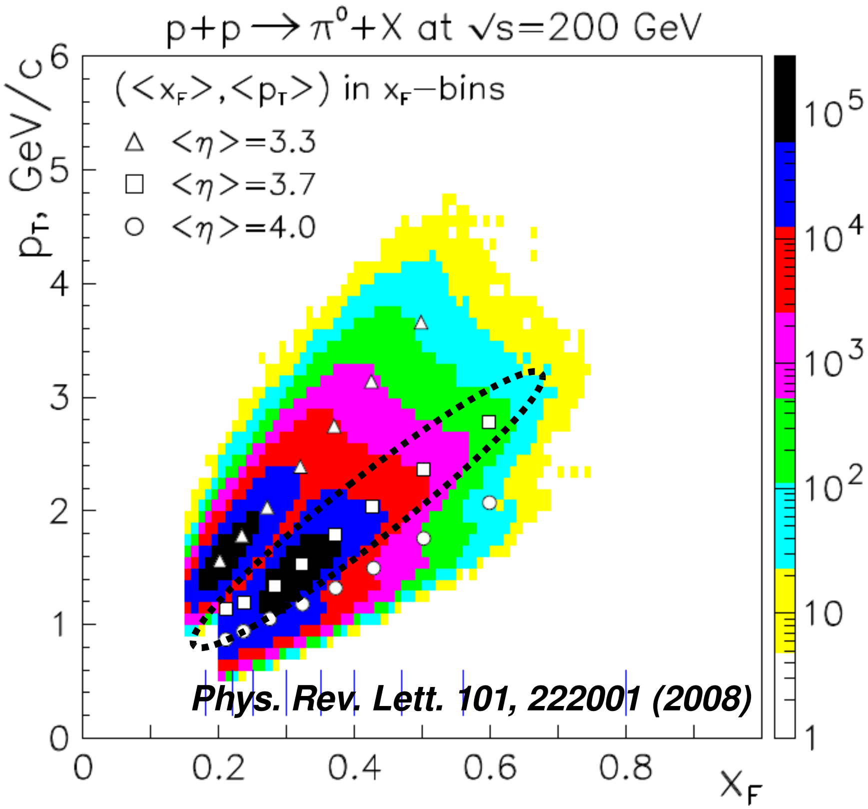
Kang, Qiu, Vogelsang, Yuan, Phys. Rev. D 83, 094001 (2011)



What is the sign of jet and prompt photon A_N in p+p?

STAR Forward Pion Detector (FPD)



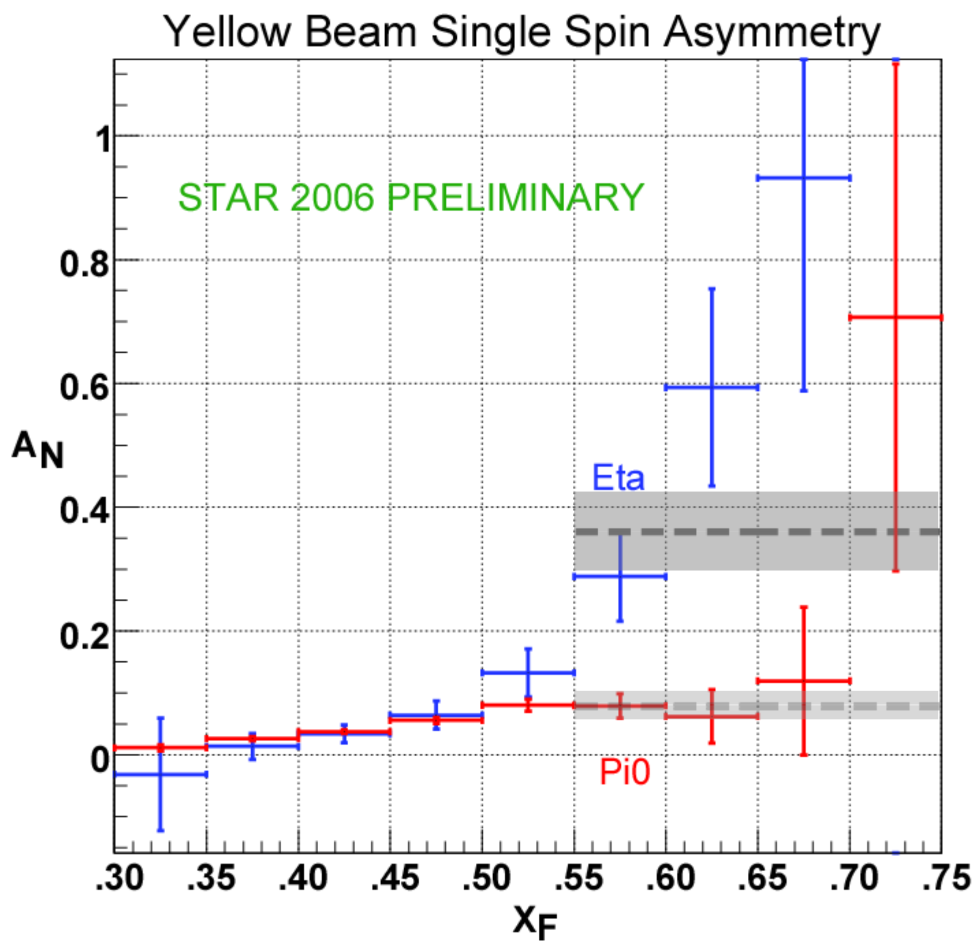


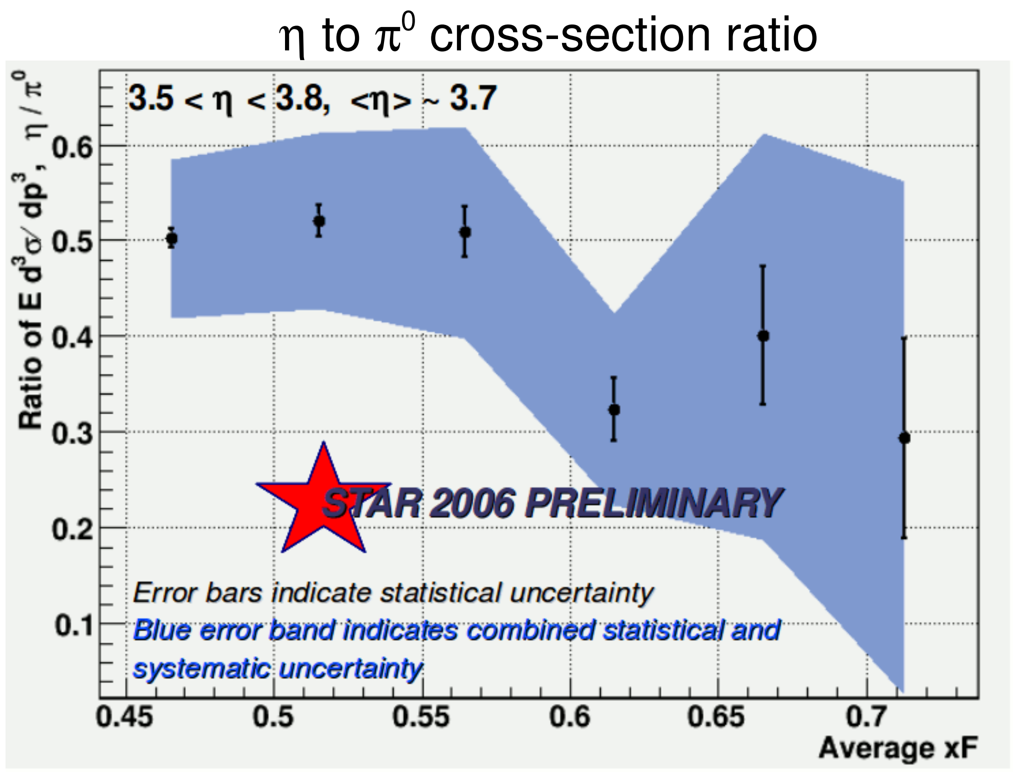
- FPD is a Pb-glass calorimeter in the very forward region of STAR. During RHIC run 2006, it was located on the east side of the STAR TPC.

- Each of the two main modules, placed on either side of the beam pipe, contained 49 Pb-glass cells and PMT channels.

π^0 and η Meson A_N & Cross-Sections

Previously, STAR has released preliminary results for the A_N of π^0 and η mesons and η to π^0 cross-section ratio at high x_F. The measurements were made based on the data taken by the FPD during RHIC run 2006 p+p collisions at $\sqrt{s}$=200GeV.





These results, <u>along with the new measurements of the absolute cross-sections</u> for the two mesons, are being prepared for publication.

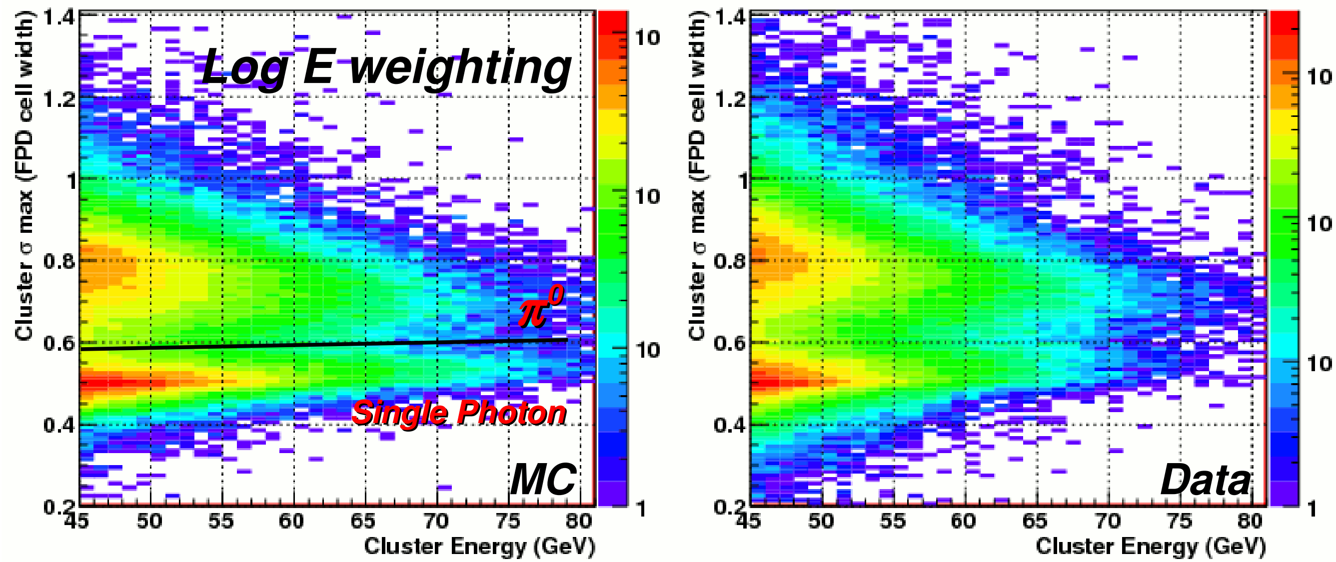
π^0-γ Separation at High x_F

In order to understand the high energy π^0, a new analysis technique was employed to improve the π^0-γ separation at high x_F where cluster merging occurs (x_F > ~0.55).

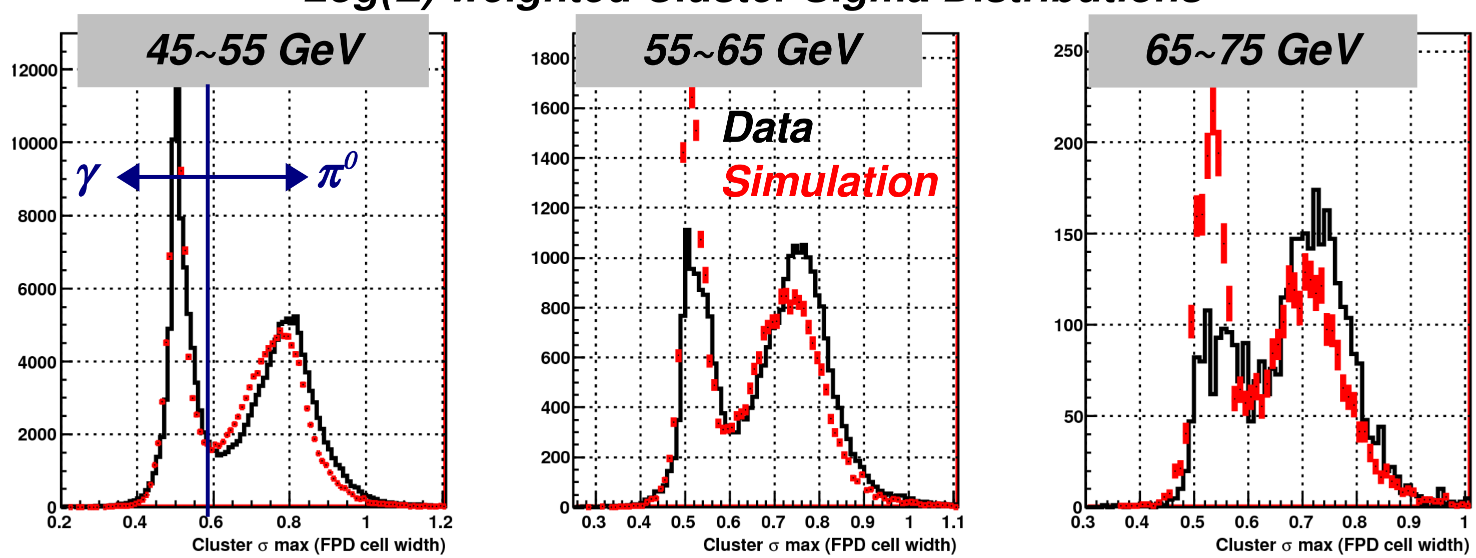
1 or 2 photon cluster?

→ ***The second moment of Log(energy) as a function of cluster energy.***

→ ***Reliably separate π^0 and γ up to 75 GeV, and possibly higher.***



Log(E) weighted Cluster Sigma Distributions

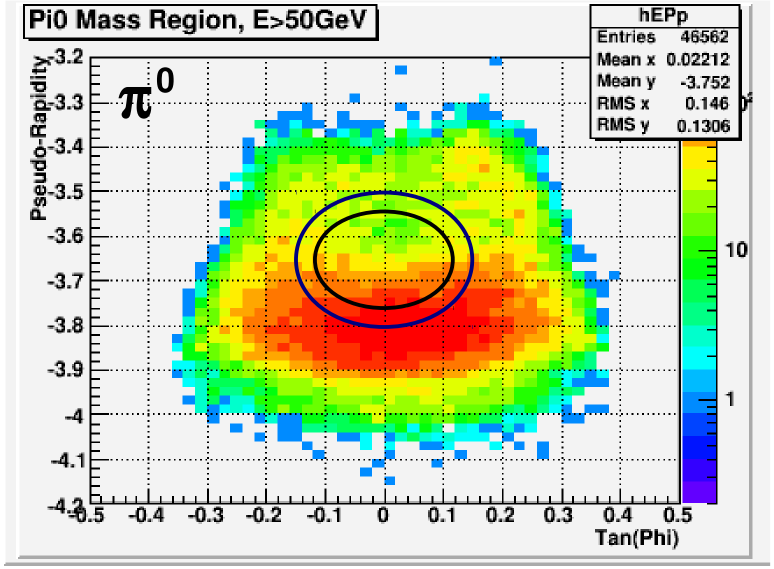


→ ***A sample of high energy single photons (and perhaps electrons and hadrons) largely free of merged π^0 contamination.***

Single Photon Event Selection

Use run 2006 data set that was used for the high x_F π^0 and η cross-section and A_N measurement.

→ ***200 GeV p+p, ~6.8 pb^{-1}, 56% average polarization***

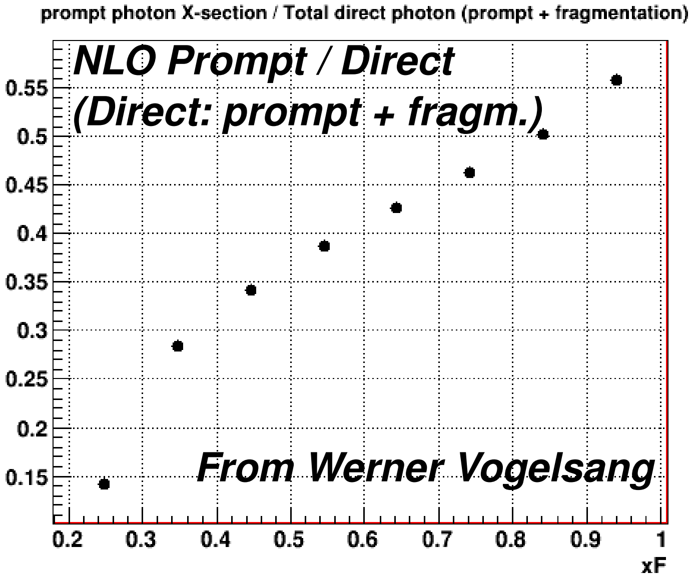


1. One and only one photons reconstructed in the detector.

2. Apply $\eta-\varphi$ cut that requires the photon be in the center of the detector.

For photons: $\tan^2(\phi_\gamma)+(\eta_\gamma+3.65)^2<0.125$

For π^0 and η: $\tan^2(\phi_{\pi^0})+(\eta_{\pi^0}+3.65)^2<0.15$



A substantial part of the photon sample is expected to be π^0 and η decay photons.

→ ***We know their cross-section and A_N.***

We cannot separate fragmentation photons from prompt.

→ ***Assume small Collins effect for fragmentation photons***

There can also be ***hadronic showers misidentified as photons***, and other mesons decaying into photons.

Data Driven Background Subtraction

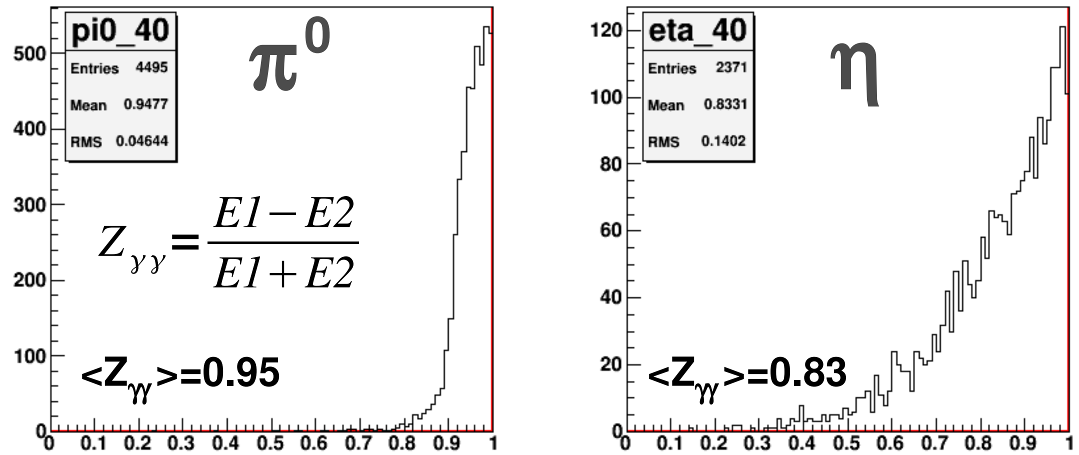
π^0 and η backgrounds

→ *Requires a large openeing angle*

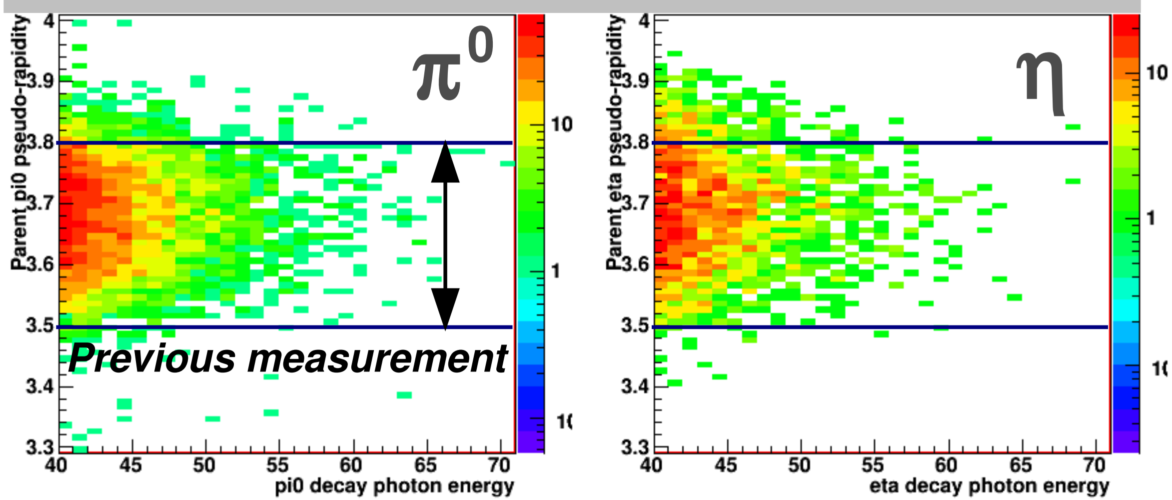
→ *The decay has to be very asymmetrical*

→ *The kinematics of the parent meson is very similar to that of the observed photon*

$Z_{\gamma\gamma}$ distributions of background producing parent



Pseudo-rapidity vs. E of background producing parent



The single photon η–φ cut is inside of what was used for the π^0 and η measurements.

→ *The kinematics of the background producing mesons is similar to previous measurements*

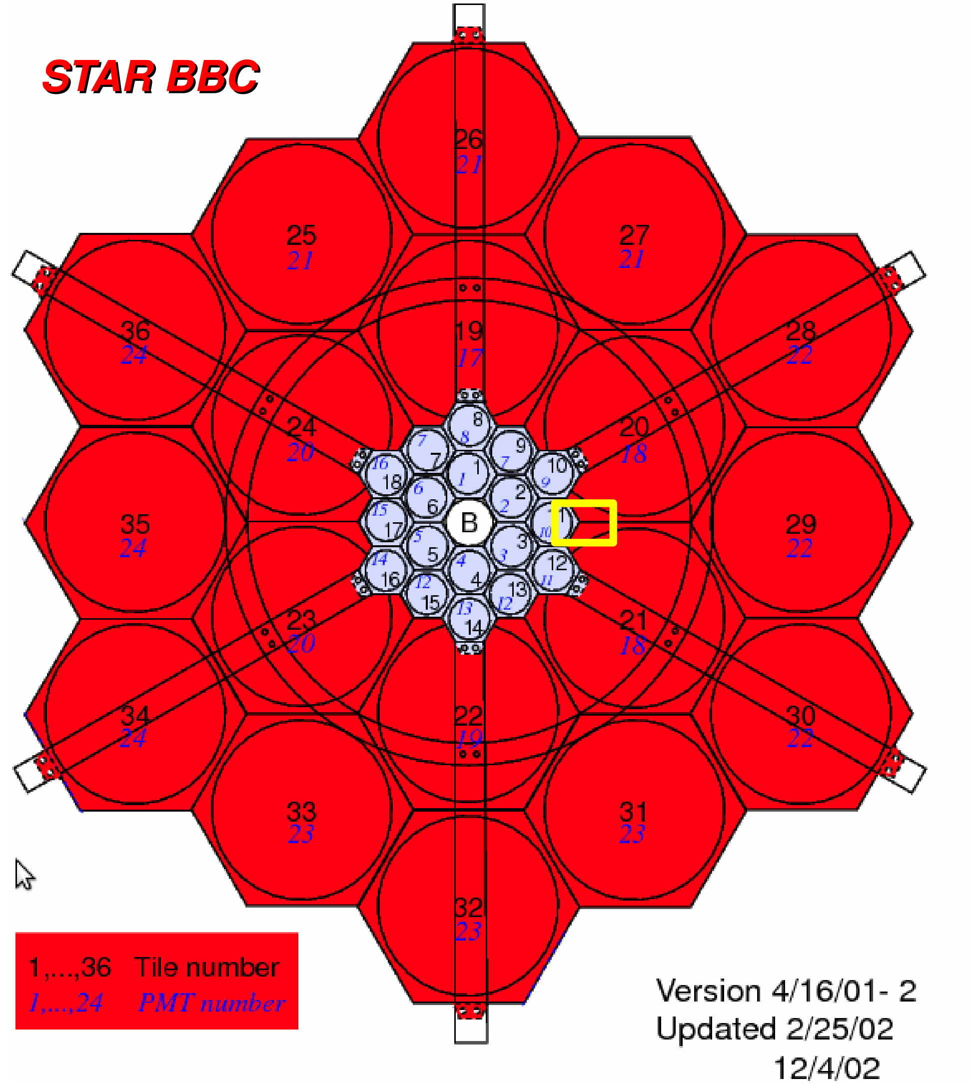
→ *We can rely on the previous measurements to estimate the π^0 and η background photons without having to extrapolate.*

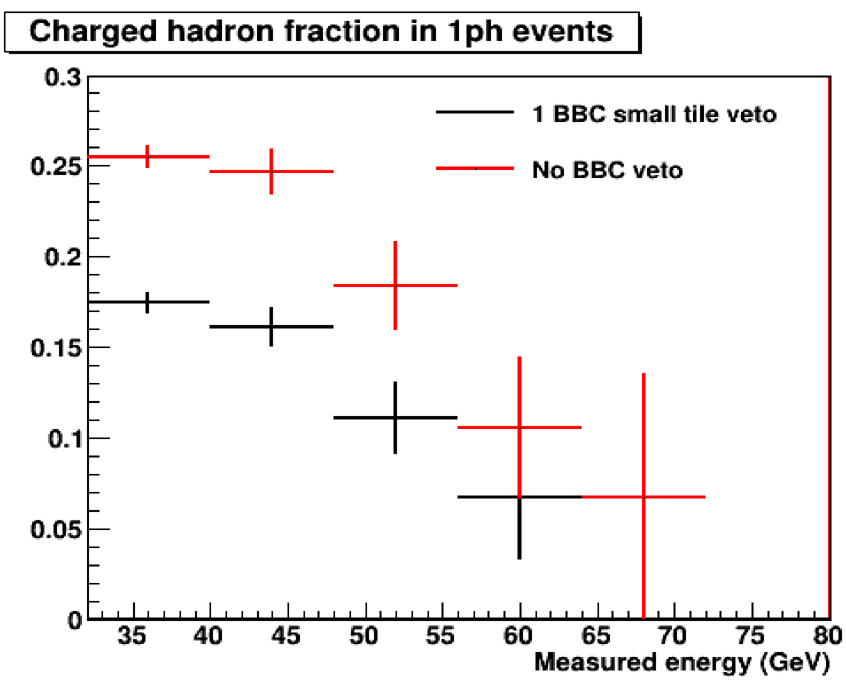
STAR BBC as Charged Particle Veto

The STAR Beam Beam Counter (BBC) fully shadows the FPD. BBC detects charged tracks. → Charged particle veto.

Due to calibration, only inner tiles can be reliably used → Reduces the overlap.

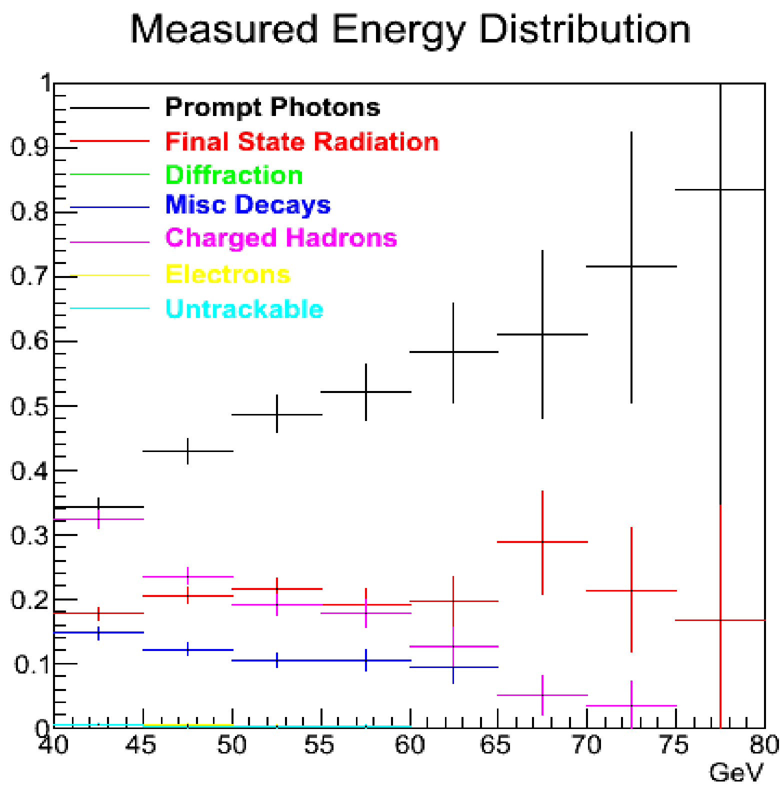
One BBC small tile veto → Up to ~40% suppression of charged tracks in the FPD.





The asymmetry of the unknown mixture of charged hadrons cannot easily be estimated.
→ Partial veto is still useful for the purpose of measuring the spin asymmetry of the photon sample.

Composition of the Remaining Photons



<u>Based on *Pythia 6.222 + Geant* simulation,</u>

Once we subtract the π^0 and η decay backgrounds and apply BBC veto, the largest remaining backgrounds are,

1. Hadronic showers misidentified as photons

2. Photons from non-π^0/η mesons (mostly ω)

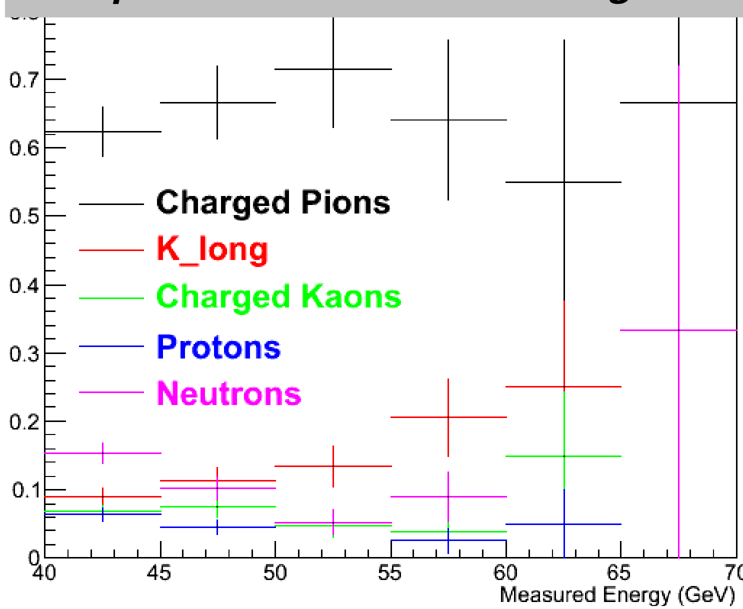
<u>However, we cannot simply rely on these estimates.</u>

1. This version of Pythia does not have the full spectrum of "fragmentation photons".

2. The simulation has not been tuned to reproduce the yield ratio between the single photons and π^0.

3. The simulation of the hadronic response of the FPD needs to be better understood.

Composition of Hadronic Background



Outlook

1. The much improved π^0-γ separation at high x_F allows us to quantify the neutral background that dominates the direct (prompt + fragmentation) photon cross-section and A_N measurements. The run 2006 FPD data, previously used for π^0 and η measurements, is being analyzed for this purpose.

2. By making the measurement in a similar kinematic region as the previous π^0 and η cross-section and A_N measurements, we can get a handle on two of the largest background sources.

3. Our current simulation has important discrepancies with the data in particle yield. Therefore background estimations for the hadrons and misc. decays need to be tied with yield measurements in data.

4. We need to make sure the hadronic response of our Pb glass calorimeter is well simulated before we can reasonably predict the hadronic background.

5. The potential contribution from electrons from heavy flavor decay has not been estimated. This requires more work on the simulation.