Forward Single Spin Asymmetries in Transversely Polarized Proton Collisions at STAR

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For the STAR Collaboration

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OUTLINE

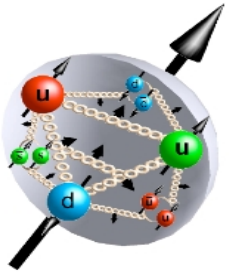
- Transverse Single Spin Asymmetries
- STAR Forward Meson Spectrometer
- $\sqrt{s}$ = 500 GeV data overview and production asymmetries of π^0
- Summary & Outlook

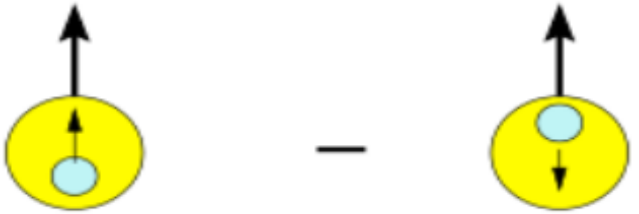
Transverse SSA in hadronic collisions

- Production asymmetry of hadron/jet/direct photon.

$$A_N = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

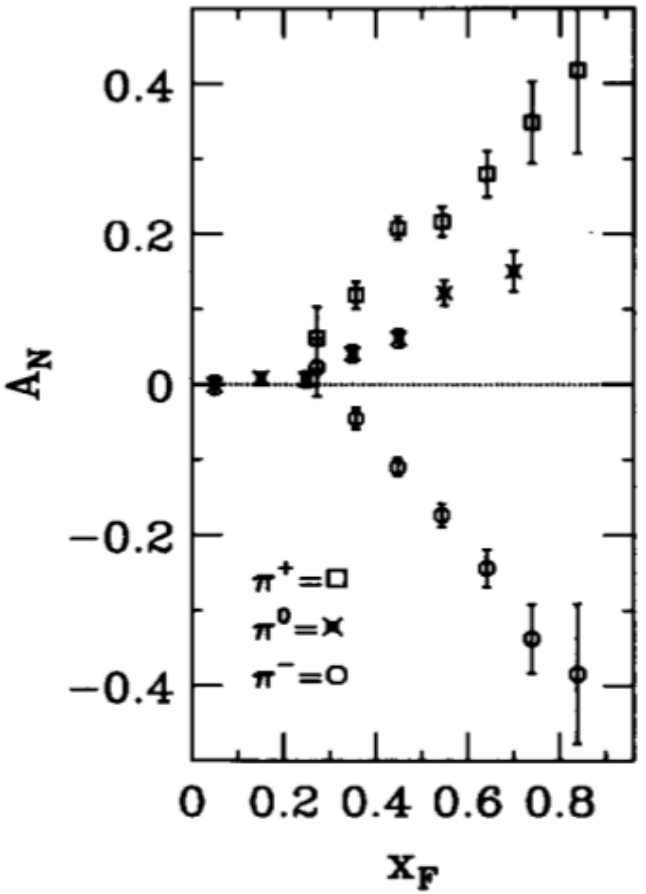
- A promising tool to reveal spin-correlated parton transverse motion and/or parton transversity.



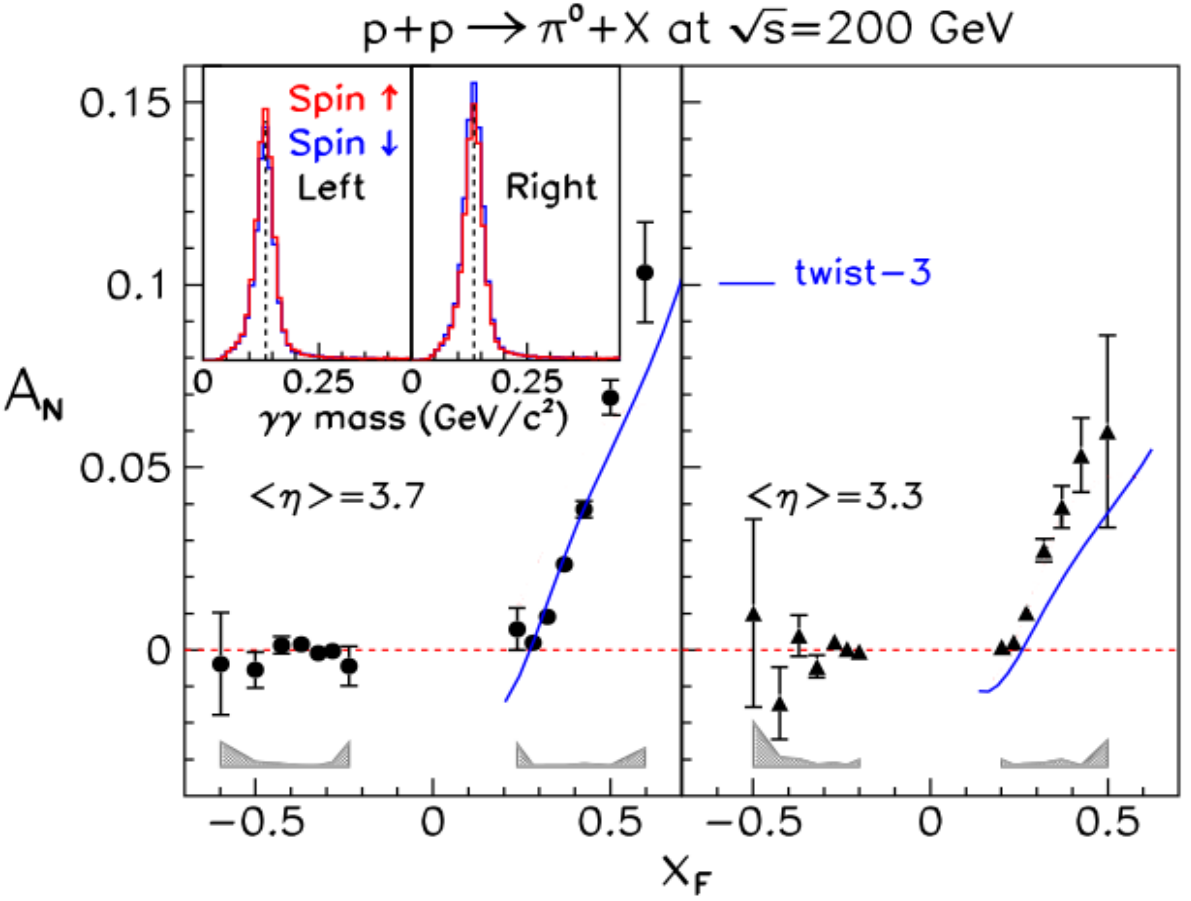


- Test QCD in non-perturbative regime

Transverse SSA in hadronic collisions

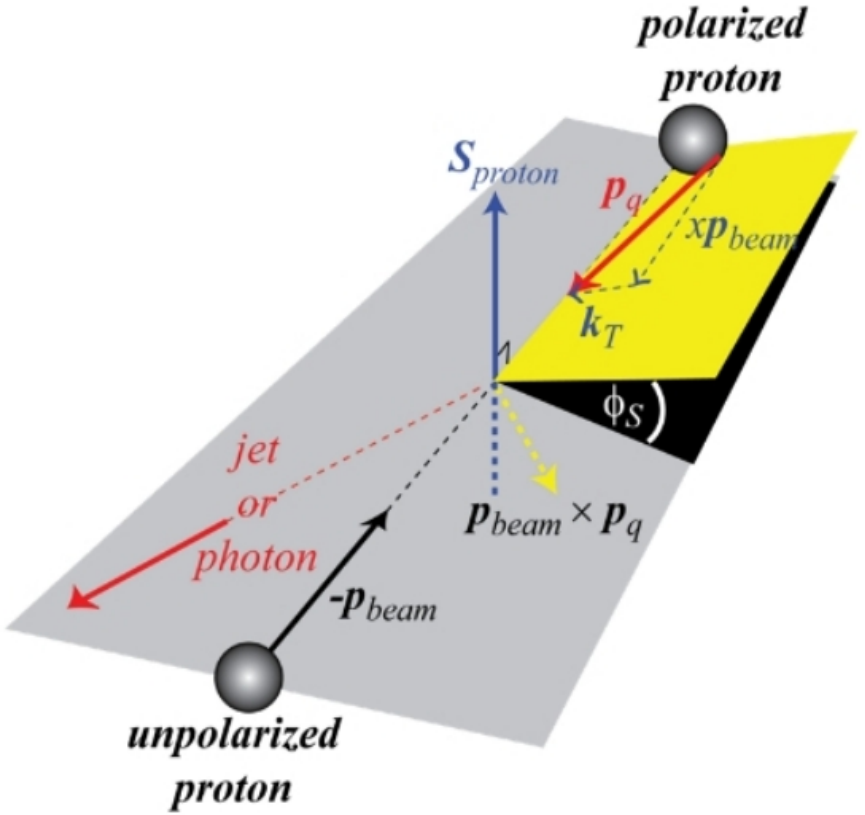


FNAL E704 $\sqrt{s}$ = 20 GeV
Phys.Lett.B.Vol.264,462 (1991)

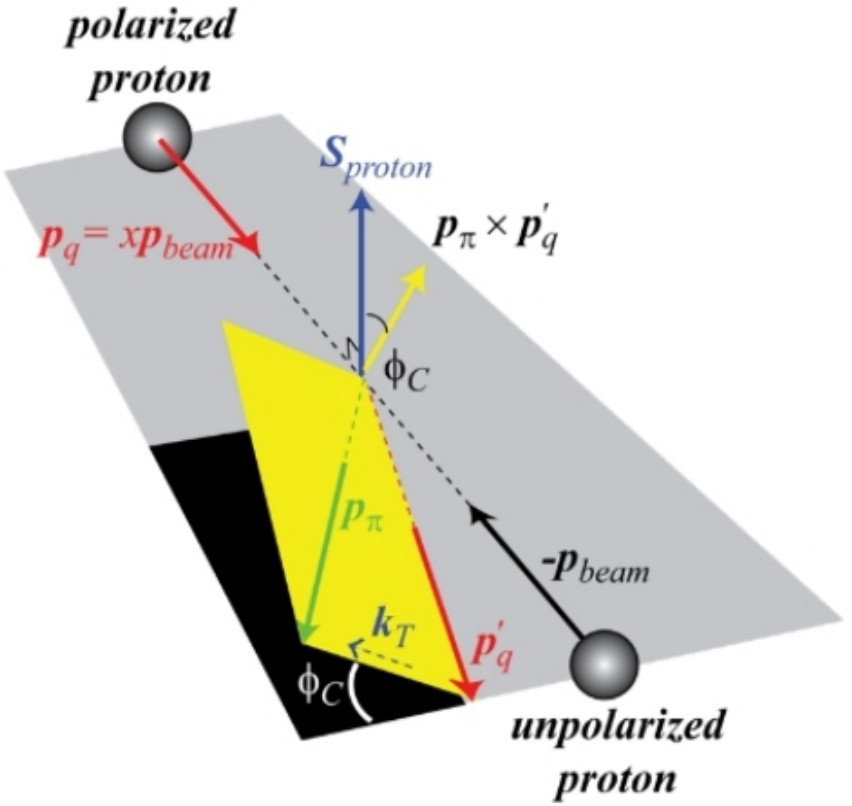


STAR,
data from *Phys.Rev.Lett*. 101,222001 (2008)

Transverse SSA beyond collinear scheme



D.Sivers, Phys.Rev.D. Vol.41,83 (1990)



J.Collins, Nuclear Physics B396 (1993) 161

Transverse SSA beyond leading twist

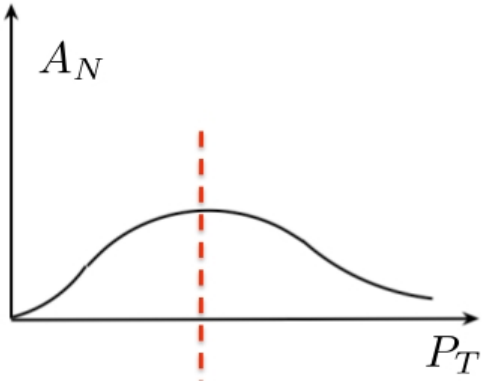
- Low p_T region--

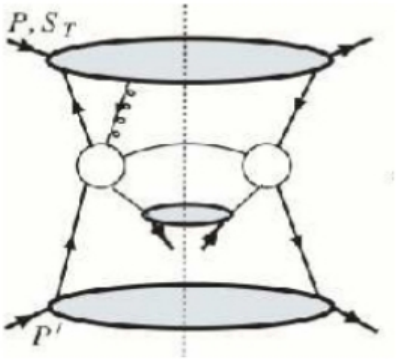
  TMD factorization, non-zero A_N at leading twist. Intrinsic k_T in initial or final state

- High p_T ($p_T \geq Q$) region--

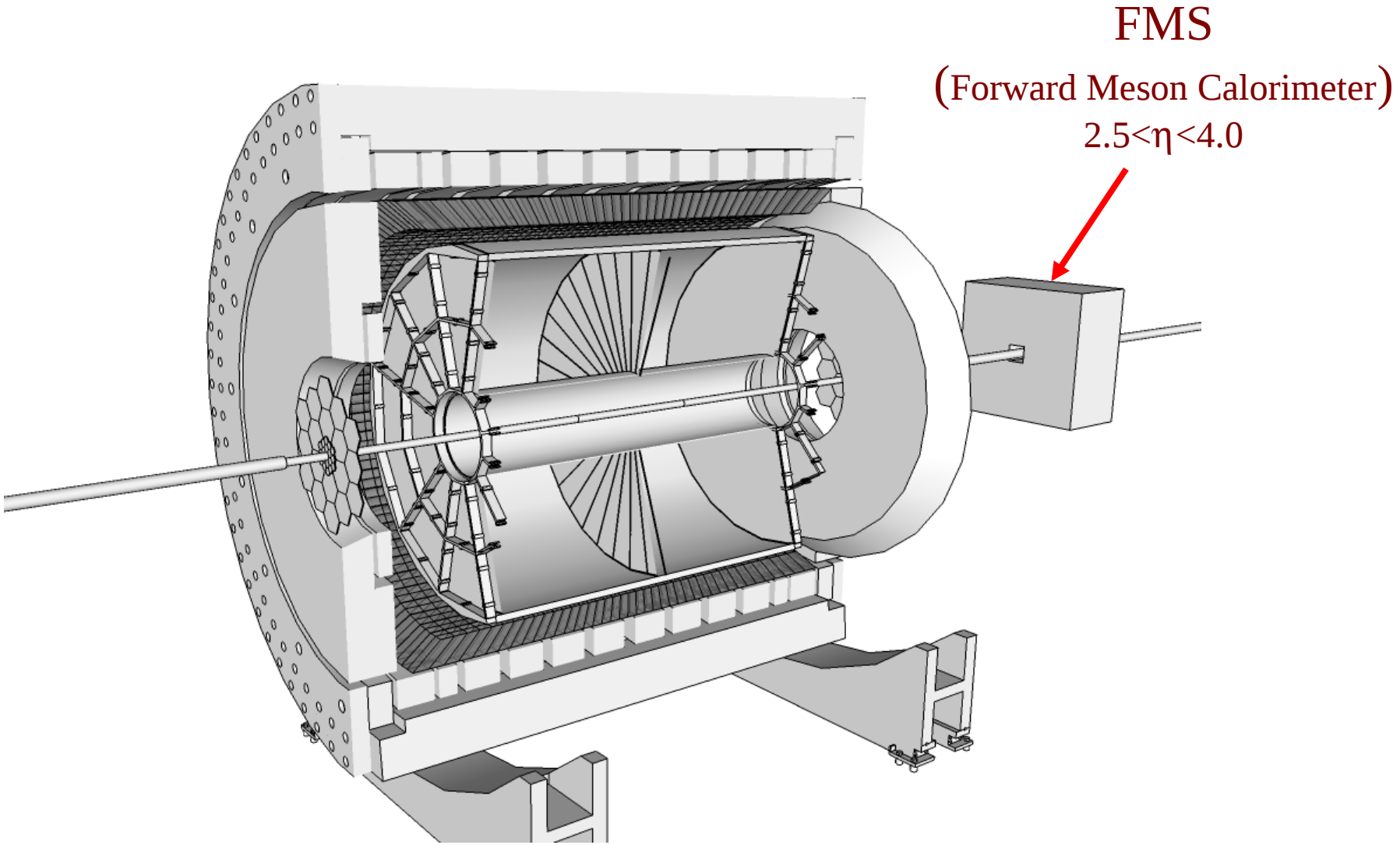
  Collinear factorization, A_N generated by higher twist effects, e.g. initial state quark-gluon correlation

Transition region--
If both factorization schemes work, they should predict the same A_N





Transverse SSA measurement at STAR



Transverse SSA measurement at STAR

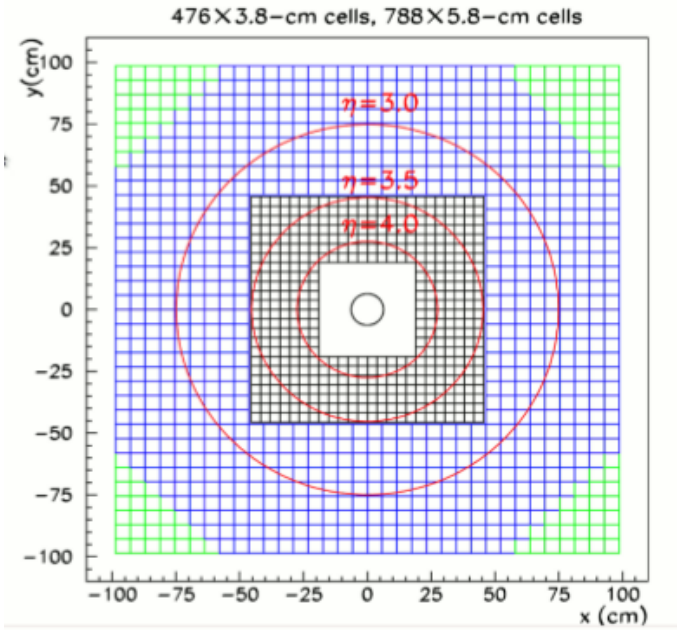
- Forward Meson Spectrometer

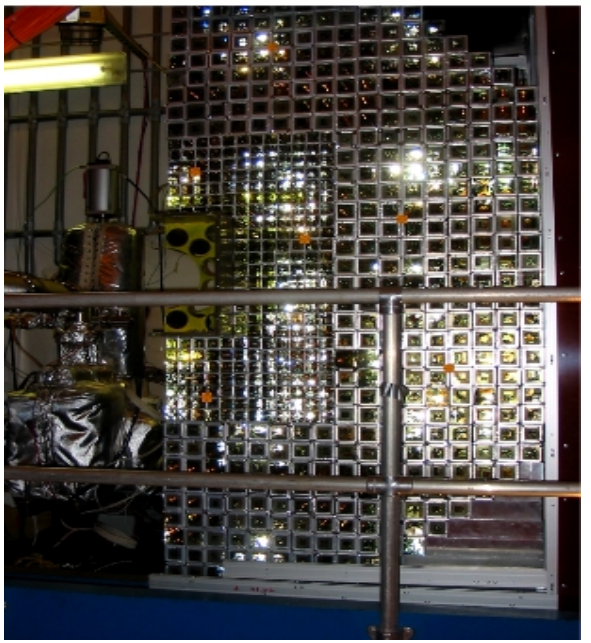
  Pb-glass EMCal, collects Cherenkov light

  Greatly extends STAR EM coverage

  Capable of measuring π^0,η, jets,etc.

  788 large cells / 476 small cells





Data overview

FY2011 Run

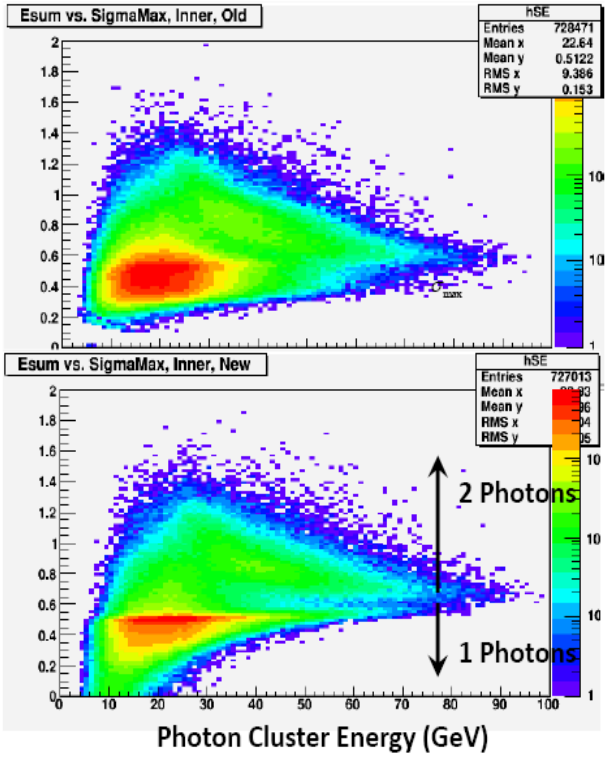
- Data taken at $\sqrt{s} = 500$ GeV with transversely polarized proton collisions.
- Online analysis performed during commissioning run.
- 22.4 pb^{-1} of data were retained after QA. Pol. ~ (40%,50%).
- Jet Patch triggered data were analyzed with preliminary calibrations.

More data can be restored...

Data overview –single/double γ separation

log(Energy) weighted cluster moments provides π^0/ γ separation up to ~80 GeV

σ_{max}

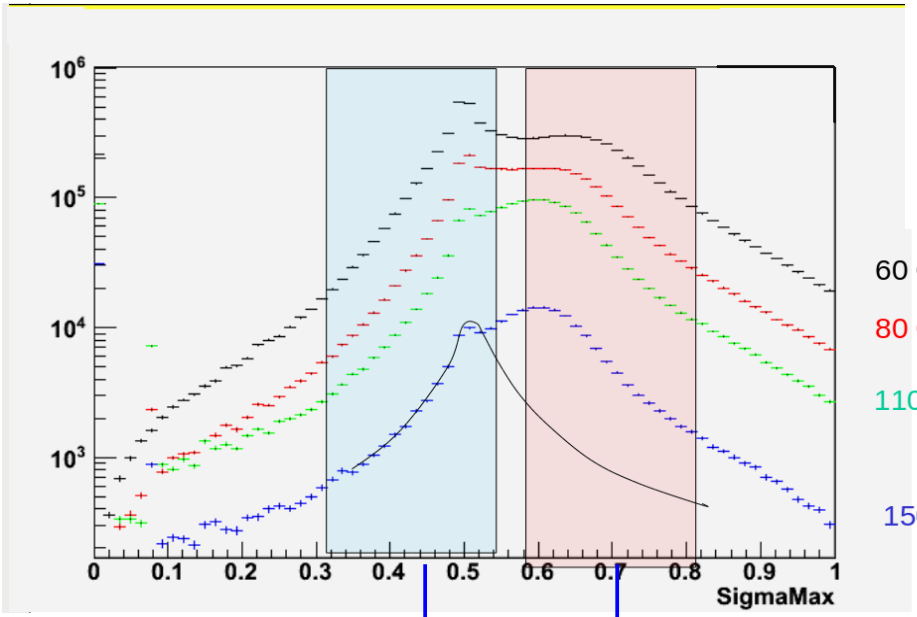


Old algorithm with Energy weighted moments

Improved algorithm with log energy weighted moments

Provides clearer separation Between π^0 and single photon. Clusters up to ~80 GeV.

σ_{max}



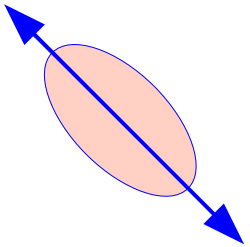
60 GeV

80 GeV

110 GeV

150 GeV

$$\sigma_{max} \equiv Max\ Eigenvalue\ of \begin{bmatrix} \sigma_x^{\,2} & \sigma_{xy} \\ \sigma_{yx} & \sigma_y^{\,2} \end{bmatrix}$$



$$\sigma_x = \sqrt{\frac{\sum_i log(E_i + E_{offset}) \cdot (\bar{x} - x_i)^2}{\sum_i log(E_i + E_{offset})}}$$

$$\sigma_y = \sqrt{\frac{\sum_i log(E_i + E_{offset}) \cdot (\bar{y} - y_i)^2}{\sum_i log(E_i + E_{offset})}}$$

$$\sigma_{xy} = \sigma_{yx} = \sqrt{\frac{\sum_i log(E_i + E_{offset}) \cdot (\bar{x} - x_i)(\bar{y} - y_i)}{\sum_i log(E_i + E_{offset})}}$$

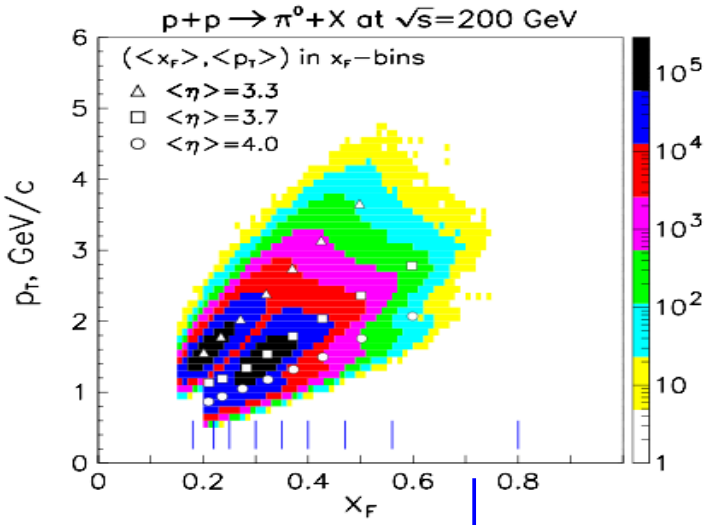
1-photon clusters

2-photon clusters

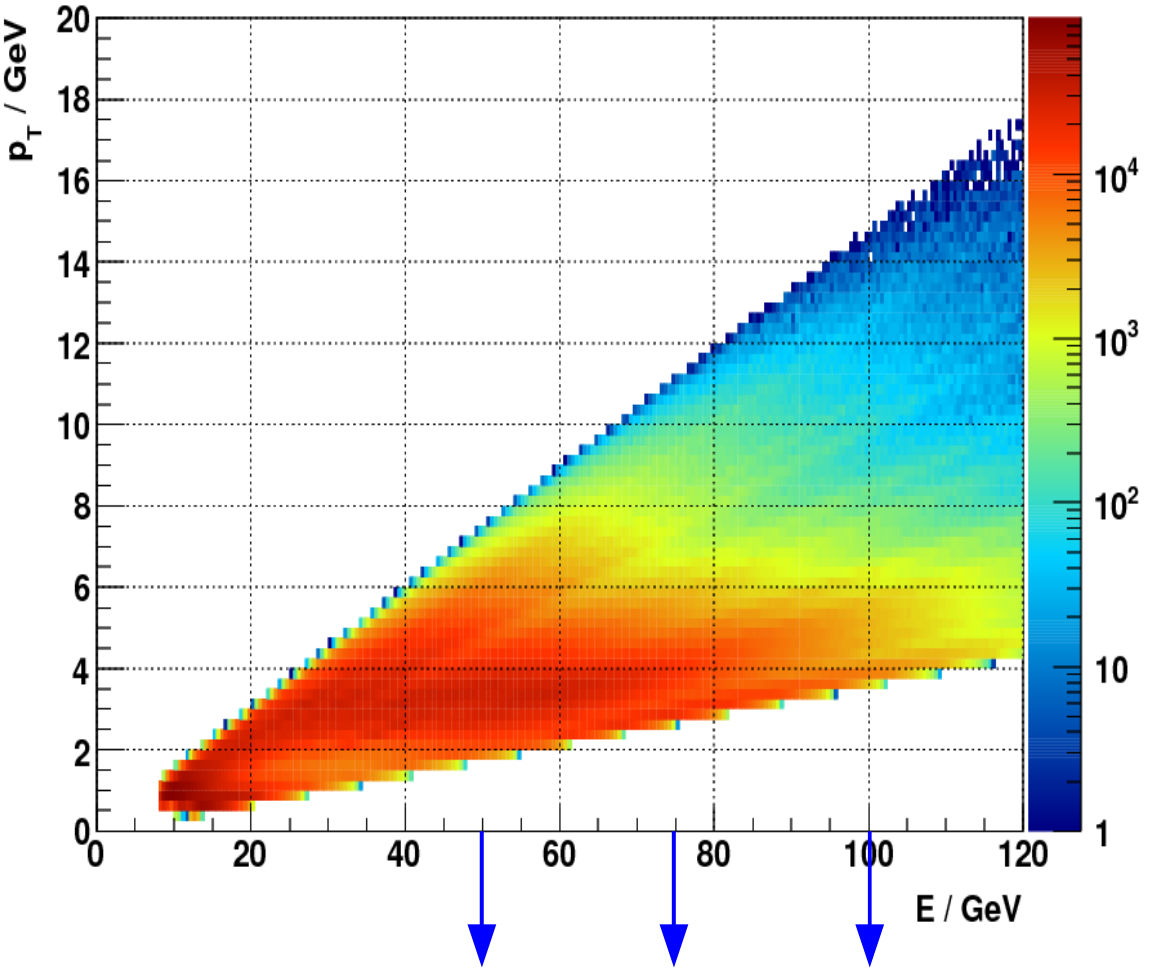
Data overview –kinematic acceptance

2-photon pair mass
$0.07\text{GeV} < m_{\gamma\gamma} < 0.27\text{GeV}$

Pseudorapidity (2.6, 4.0)

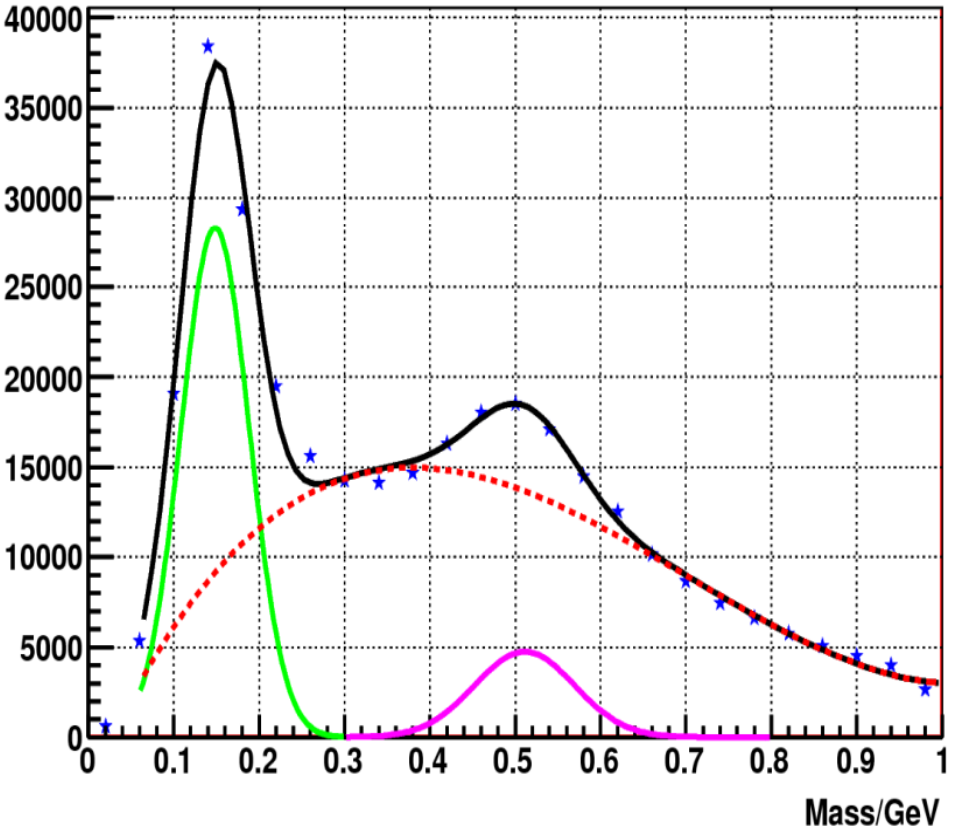


STAR 2006 FPD
Phys.Rev.Lett. 101,222001 (2008)

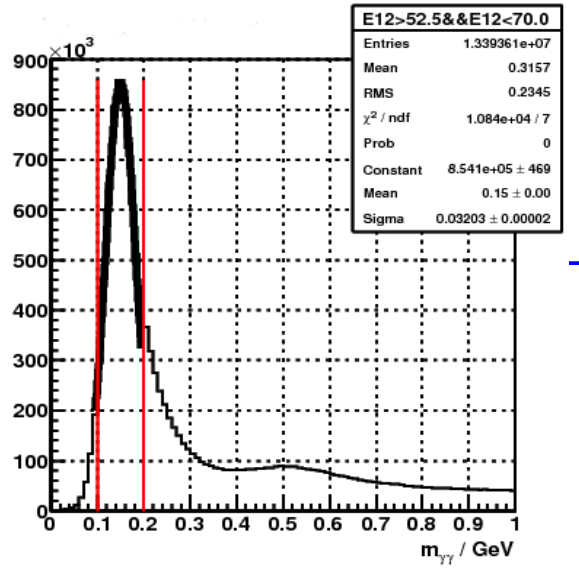


$x_F \approx E/250 =$ 0.2 0.3 0.4

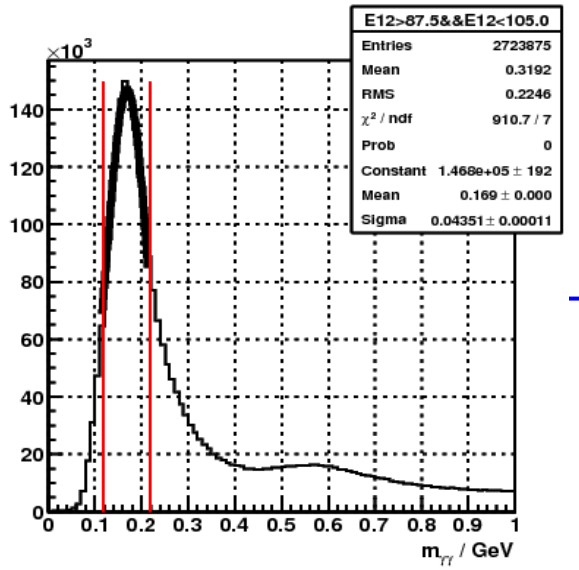
Data overview –2-photon invariant mass



FMS 2011 data
@35 GeV
Pseudorapidity (3.0,3.4)

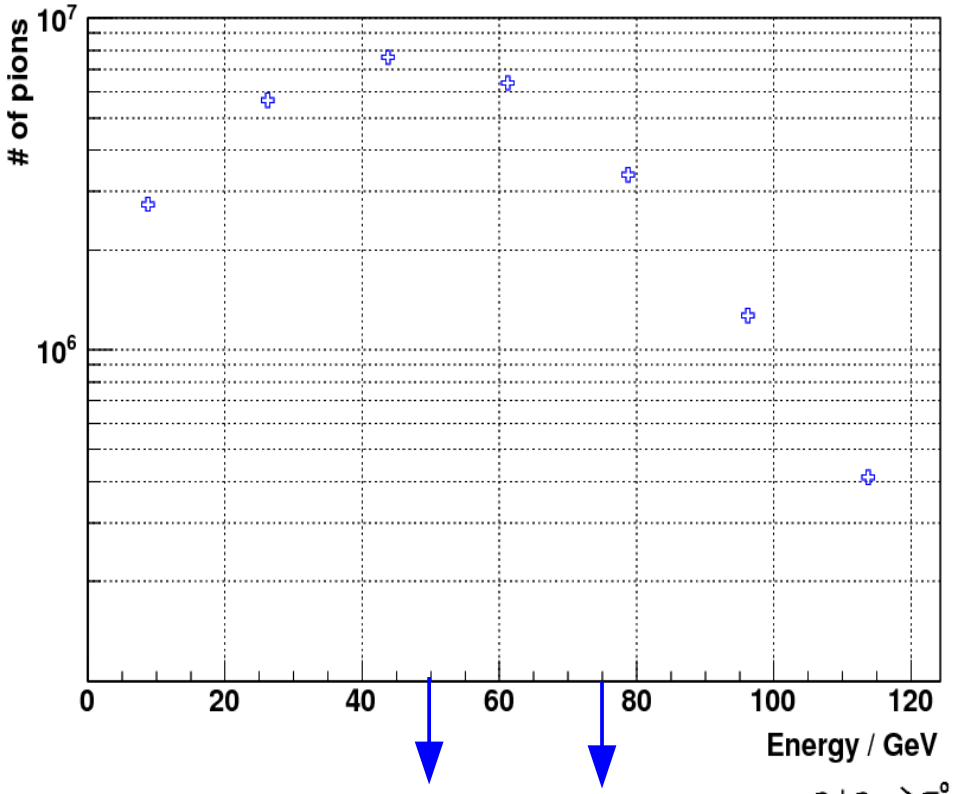


60GeV

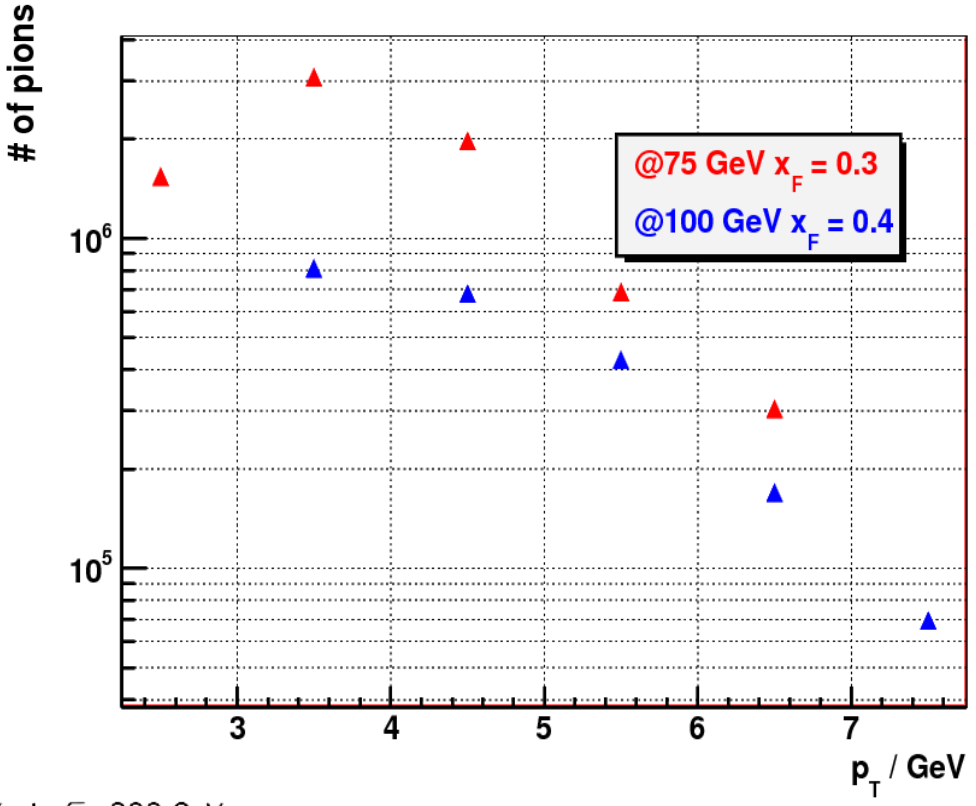


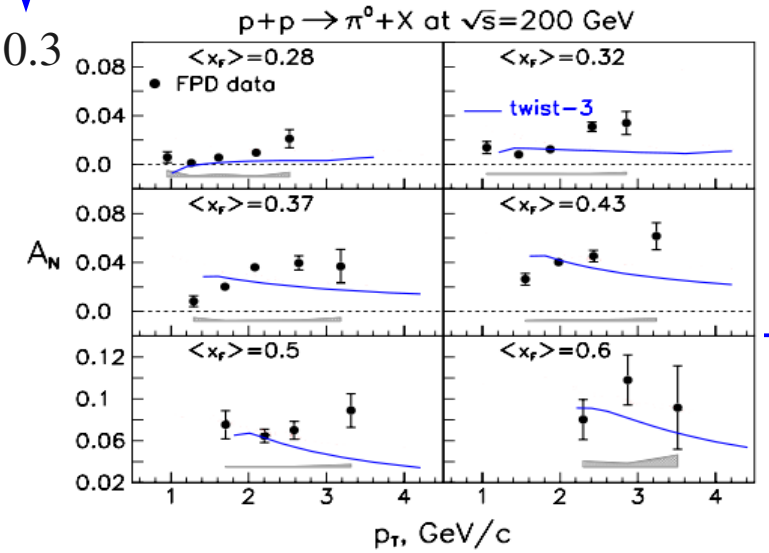
90GeV

Data overview –estimate π^0 candidate yield



$x_F \approx$ 0.2 0.3





STAR 2006 FPD data from *Phys.Rev.Lett.* 101,222001 (2008)

Raw asymmetry – π^0 candidates

Yield asy. = [N(up) – N(down)] / [N(up) + N(down)] = R_{lumi} + Pol.*$A_N \cos(\varphi)$

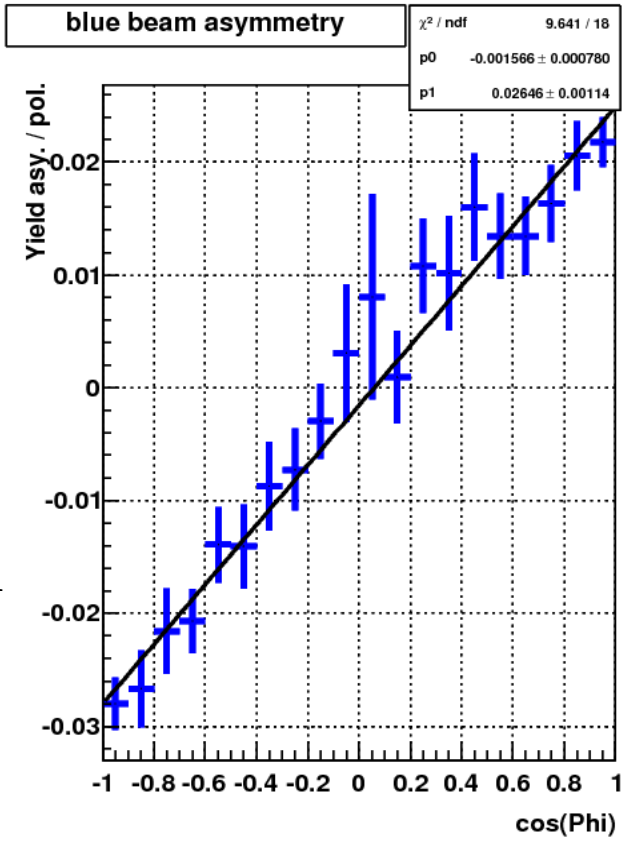
$$R_{lumi} = \frac{L_{up} - L_{down}}{L_{up} + L_{down}}$$

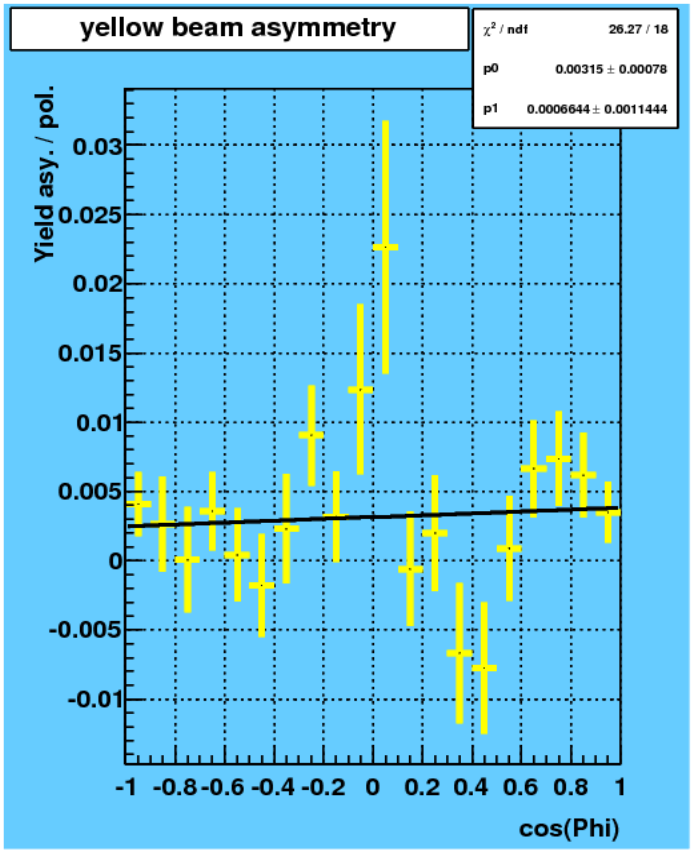
A_N calculated by assuming 50% beam polarization

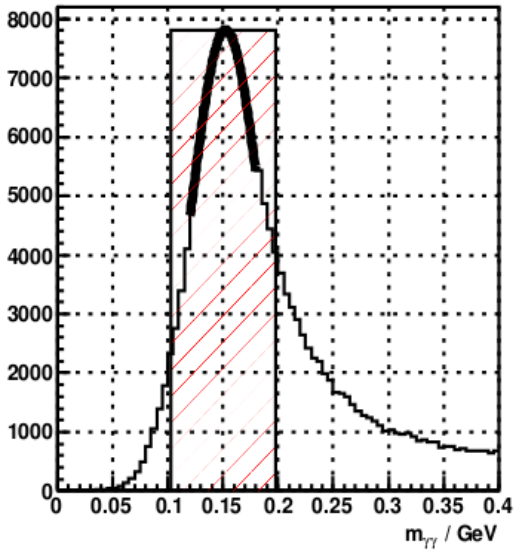
@75 GeV ($x_F = 0.3$)

blue beam (positive x_F) $A_N = 0.026 \pm 0.001$

yellow beam (negative x_F) $A_N = 0.0007 \pm 0.001$







0.1 GeV mass window, A_N reported for di-photon events within the window

Summary & Outlook

- p_T dependence of SSA provides critical test of TMD factorization and Twist-3 scheme in transition region.
- STAR has taken a large data sample @500 GeV polarized pp collisions, with large detector acceptance.
- Nonzero single spin asymmetries of π^0 candidates have been observed.
- Further efforts in calibration and background study are needed to investigate x_F and p_T dependence of SSA.