π^0 Transverse Single-Spin Asymmetries (A_N)

at $\eta = 4.1$ in p+p Collisions at $\sqrt{s} = 200$ GeV

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For the STAR collaboration

OUTLINE

- Background
- FPD and STAR
- Run 8 Asymmetries
- Conclusions

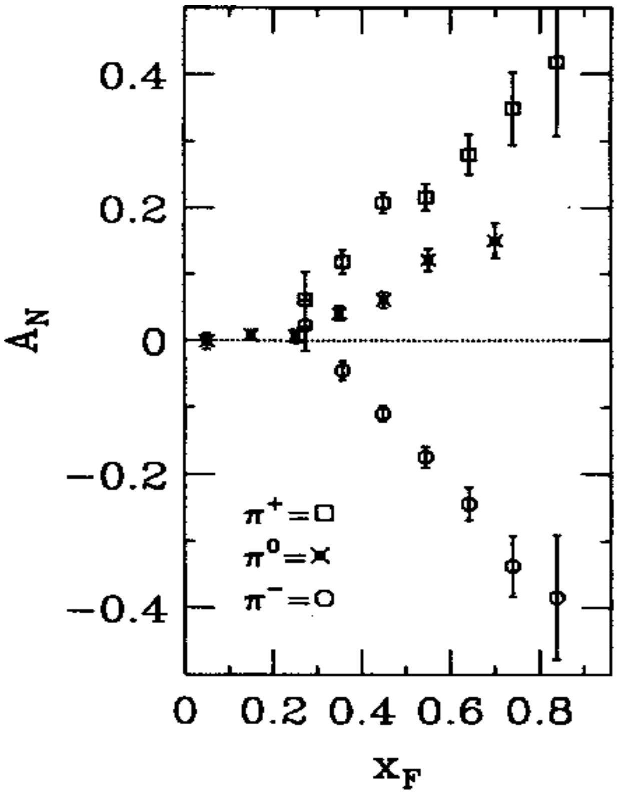
Setting the Stage: pQCD

Early pQCD predictions indicated transverse single-spin asymmetries (A_N) for high transverse momentum particles from p-p collisions should be small

$$A_N \sim \frac{\alpha_s \times m_q}{p_T}$$

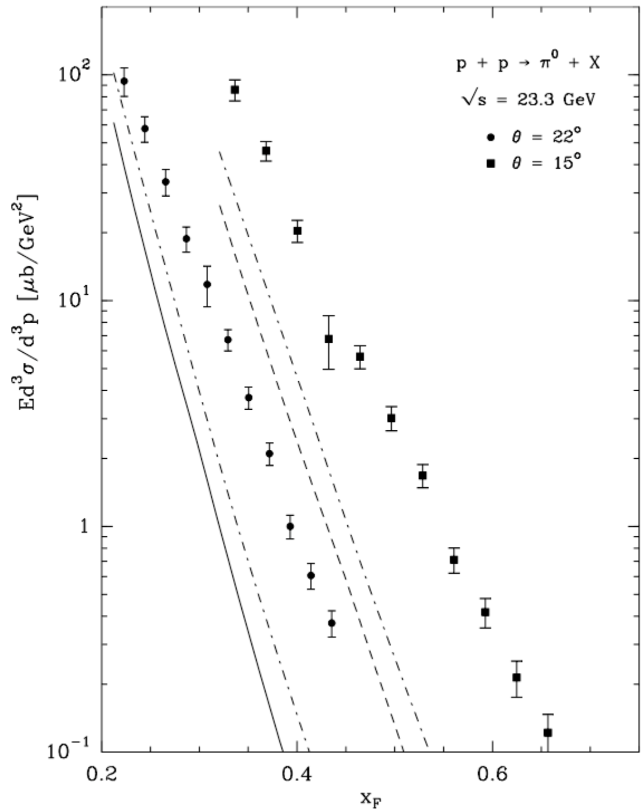
Phys. Rev. Lett. 41, 1689 (1978)

Setting the Stage: E704



Phys. Lett. B 261, 201; 264, 462 (1991)

E704 showed large A_N for large x_F pion production with a $\sqrt{s}$ = 20 GeV polarized proton beam

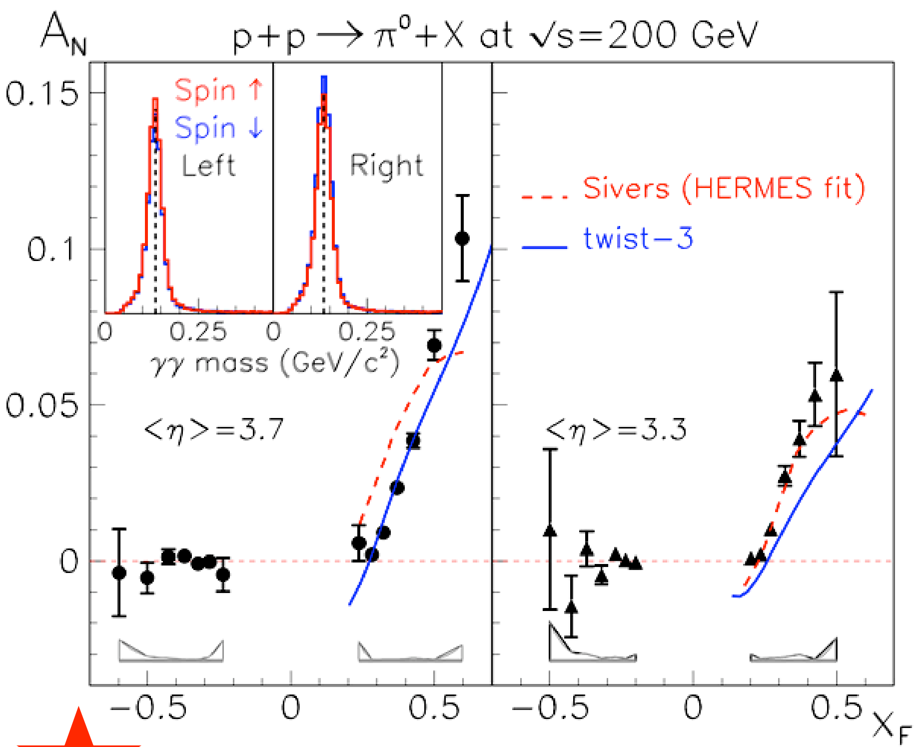


Eur. Phys. Journ. C36, 371 (2004)

However, observed cross-sections for E704 kinematics are large compared to pQCD predictions

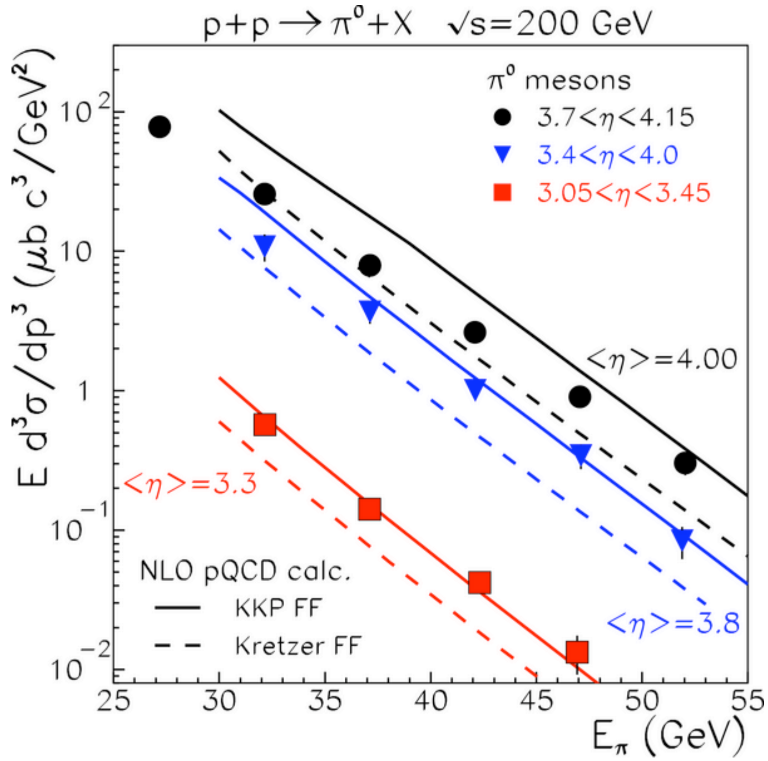
Setting the Stage: STAR

Likewise, STAR has observed large A_N for p+p→π^0+X at forward rapidity



STAR *arXiv:0801.2990v1 [hep-ex]*

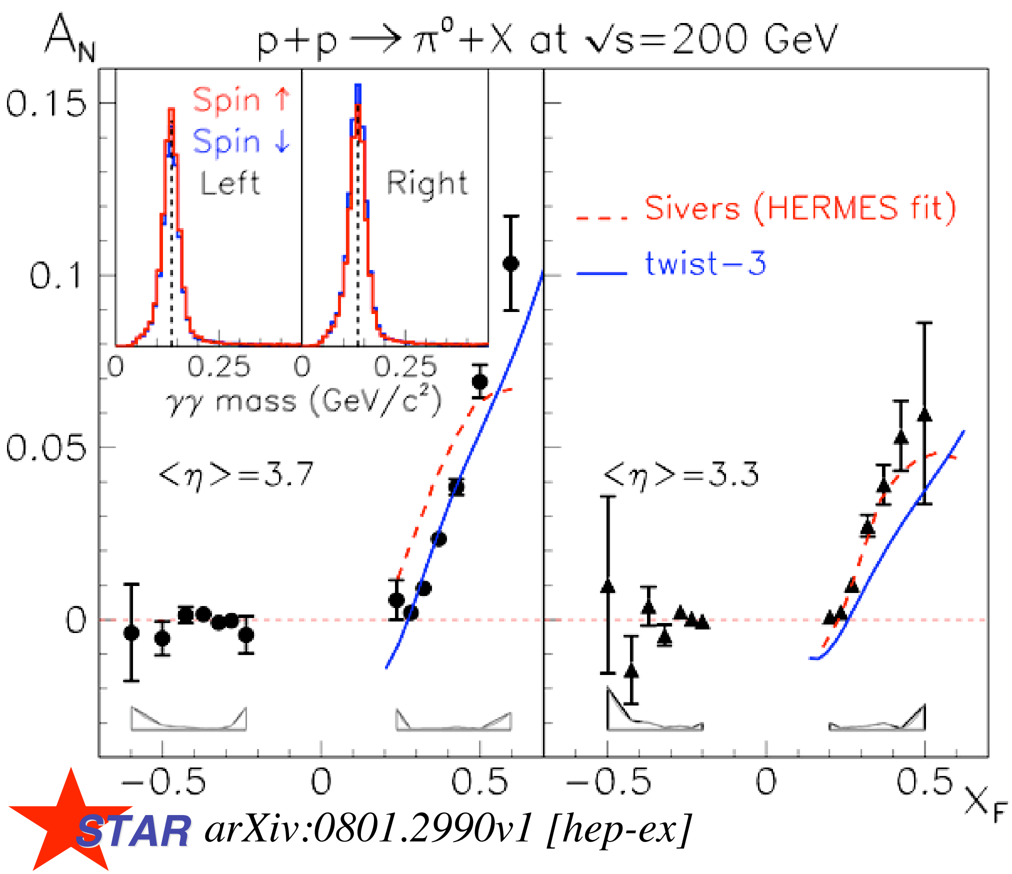
PRL accepted September 2008



In this case, the measurements were taken in a region where the pQCD cross-section provides a reasonable description of the data

STAR *Phys. Rev. Lett. 97 (2006) 152302*

Explanations: Sivers Effect



The "Sivers effect" describes the asymmetry as arising from a correlation between the incident proton polarization and parton transverse momentum

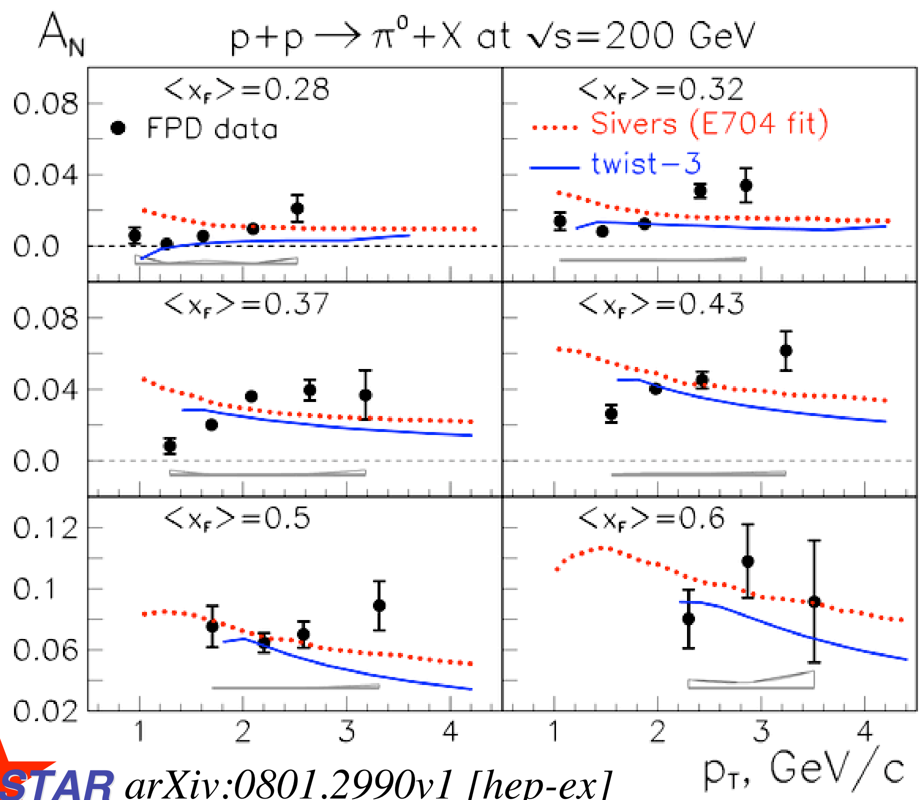
Sivers calculations (as well as twist-3) roughly fit the data in terms of x_F

Sivers effect would give an indirect signature for parton orbital motion

Explanations: Sivers Effect

HOWEVER:

The Sivers calculation expects a *fall-off* with p_T at fixed x_F.

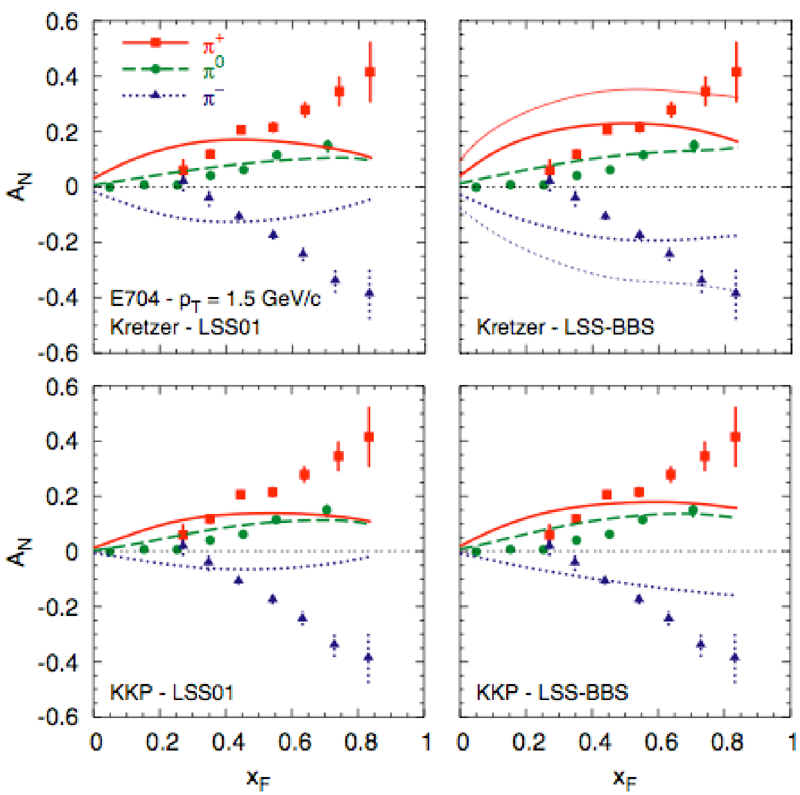


STAR arXiv:0801.2990v1 [hep-ex]

This is NOT indicated in the data

Explanations: Collins Effect

The “Collins effect” describes the asymmetry as arising from spin-dependent fragmentation of transversely polarized scattered quarks



Initially, it was thought the Collins effect would be **suppressed** in the forward region:

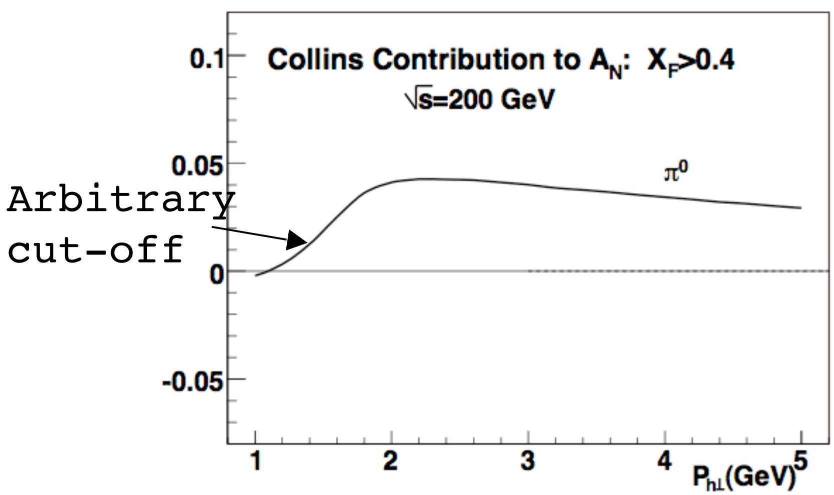
> *“Surprisingly, the intrinsic partonic motion…produces a strong suppression of the transverse single spin asymmetry arising from the Collins mechanism.”*

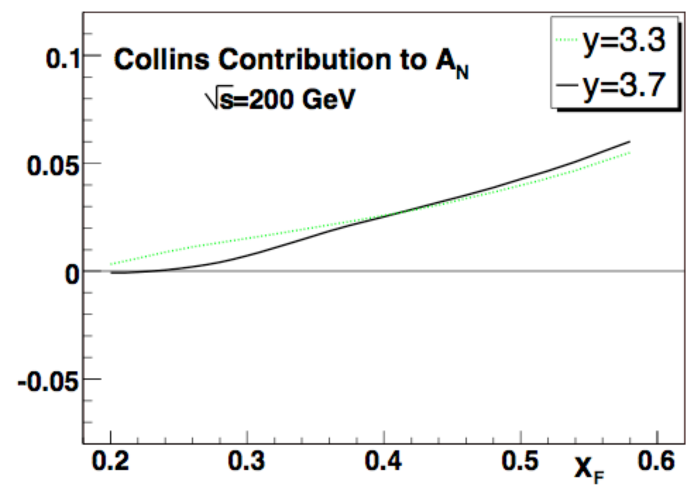
[M. Anselmino et al., Phys. Rev. D 71, 014002 (2005)]

Explanations: Collins Effect

HOWEVER:

Recent investigation revealed a sign error in the previous limits. It now appears that the Collins effect could indeed explain the full behavior.





F. Yuan *arXiv:0804.3047v2 [hep-ph]*

Collins effect would provide a means to constrain the quark transversity.

Explanations: Collins Effect

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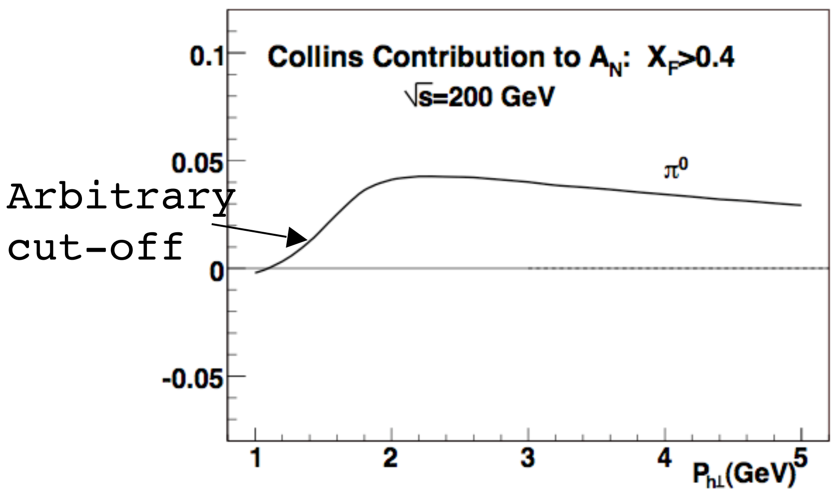
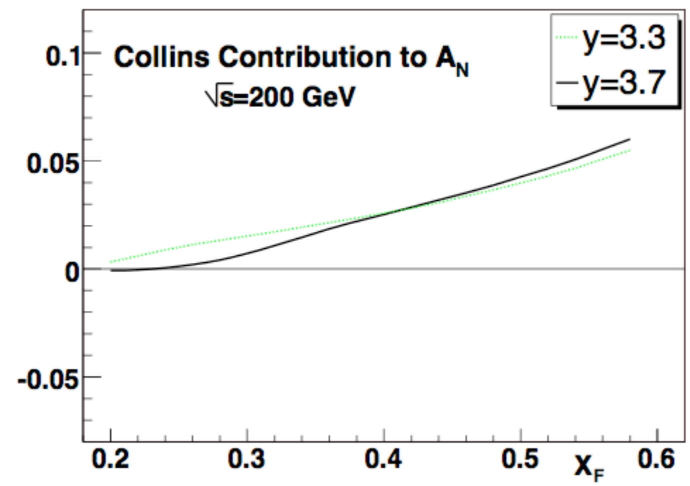


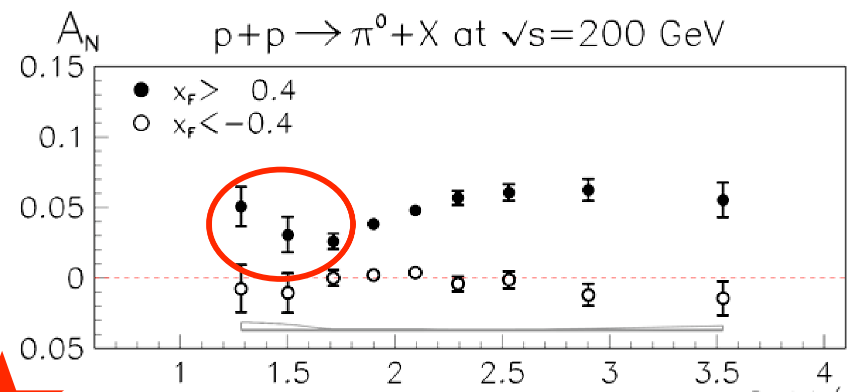


F. Yuan *arXiv:0804.3047v2 [hep-ph]*

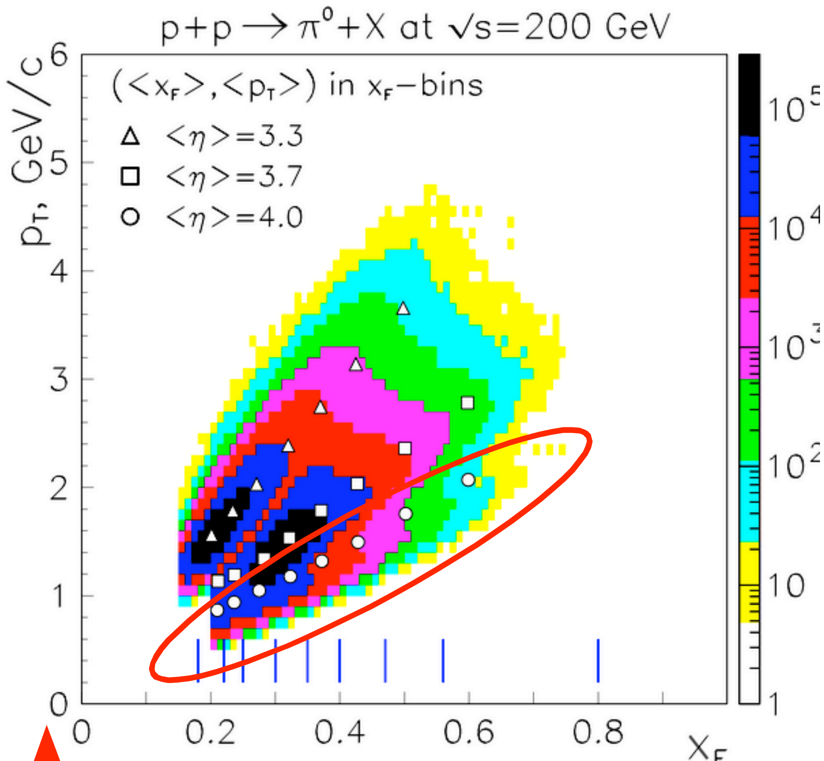
Determining the underlying origin(s) of the large A_N would provide crucial information about proton spin-structure

Lower-p_T at High-x_F?

In addition to the sign of no decline in higher p_T, the previous STAR measurements provided some indication of enhancement at low-p_T, high-x_F.



STAR *arXiv:0801.2990v1 [hep-ex]*



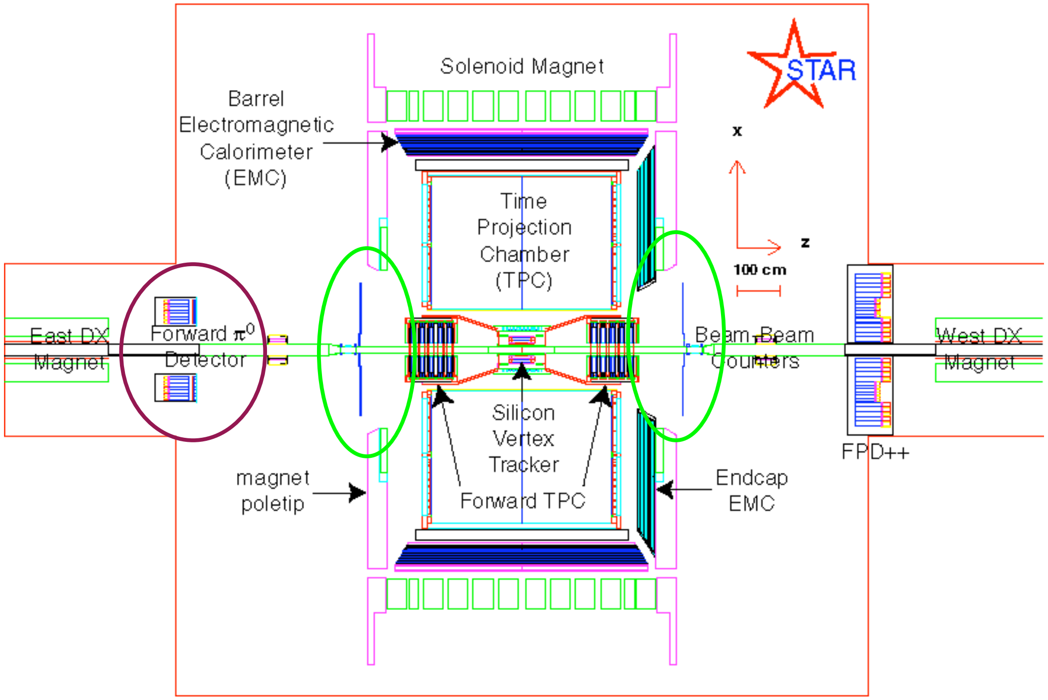
STAR *arXiv:0801.2990v1 [hep-ex]*

Low-p_T, high-x_F ⇒ higher η (~ 4)

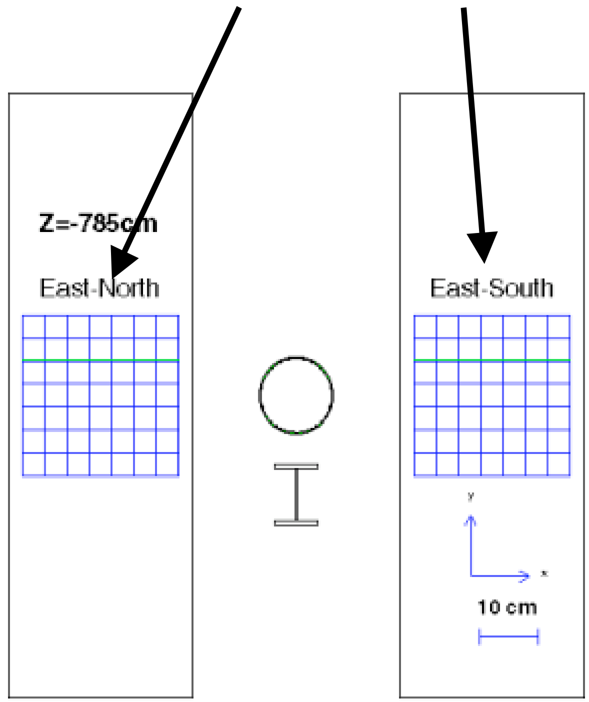
Prior data for this region of interest was dominated by Run-3 and Run-5 statistics.

Forward Pion Detector (FPD) and STAR

STAR Run 6 with FPD



FPD: EN and ES



For Run-8, FPD was placed in the “near position”

Run-8 $\eta \approx -4.1$ while Run-6 $\eta \approx -3.7$

Run-8 FPD Event Cuts

• Transversely polarized p+p runs at $\sqrt{s}$ = 200 GeV (~0.5 pb^{-1} with P ~ 0.44)

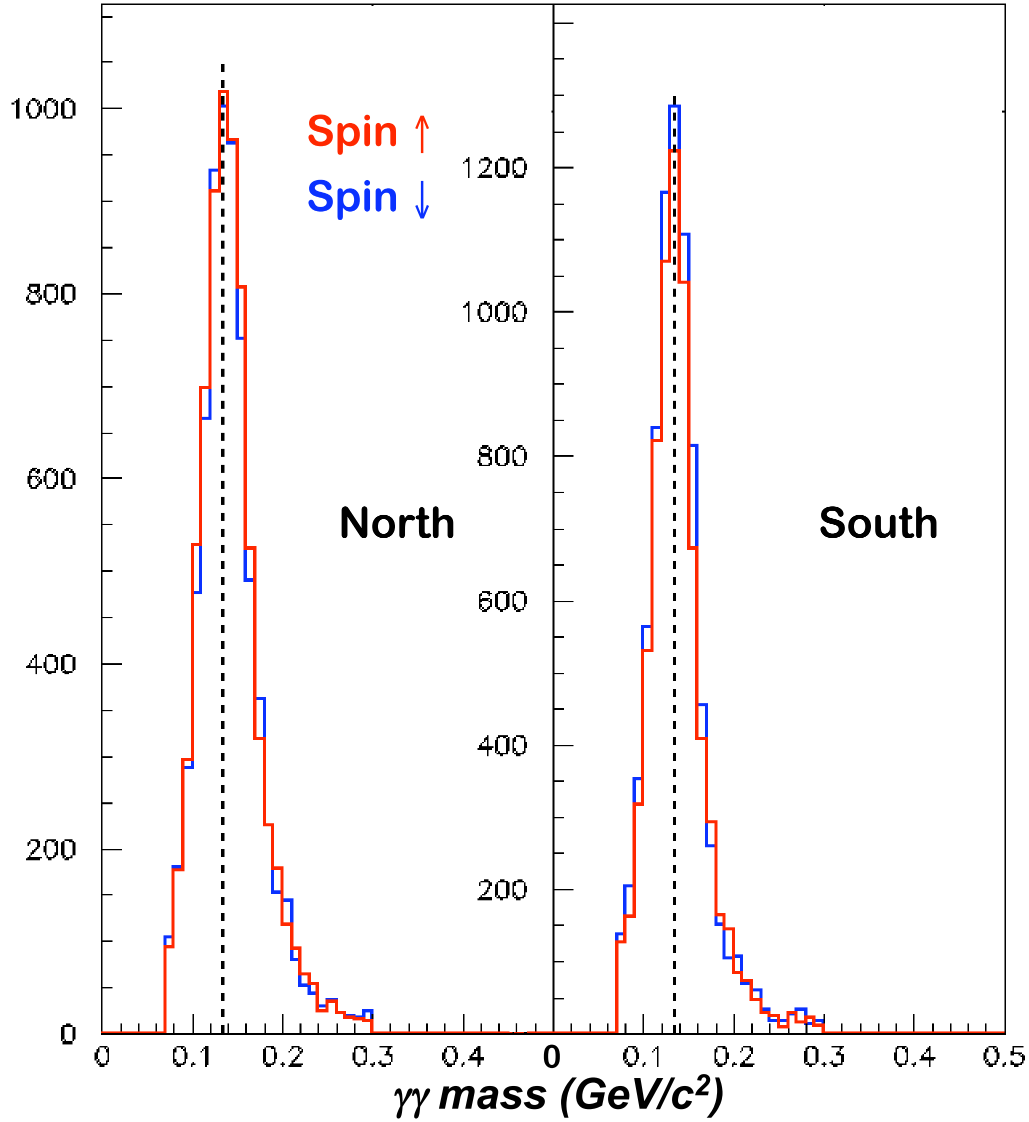
• Hardware trigger: Summed ADC for each module ≥ 125 (nominally 25 GeV)

• Software cuts:

- 2 γ events
- $z_{\gamma\gamma} < 0.7$
- 0.07 GeV < $m_{\gamma\gamma}$ < 0.3 GeV
- E_{total} > 25 GeV
- Fiducial volume cut: 0.5 cell from edge of detector

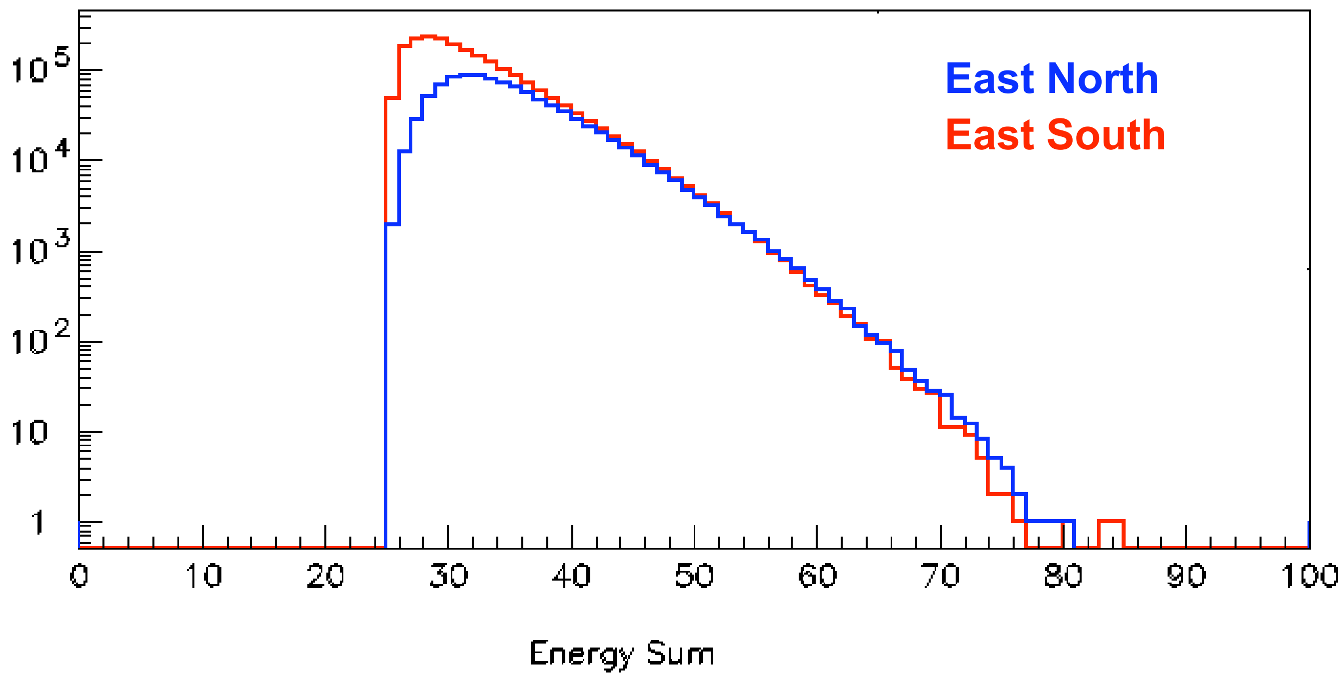
• Number of events passing east and west BBC min-bias conditions (software trigger): EN ~ 0.97 M; ES ~ 2.11 M

Run 8 Energy Calibration



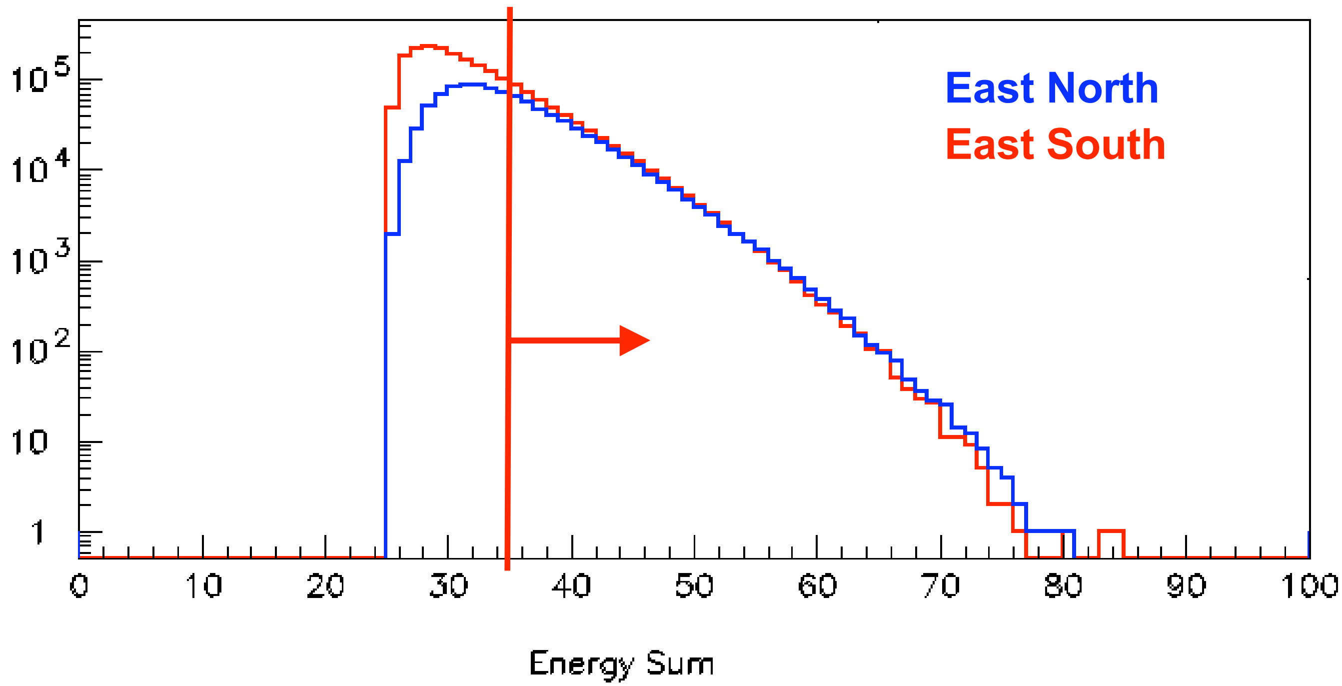
- Channel-by-channel and run-by-run raw ADC's are analyzed for pedestal shift
- Reconstruct π^0, channel-by-channel, correcting to known mass value until convergence for all channels
- Energy-dependent corrections
- Run-dependent corrections

Gain Difference



Due to gain difference between EN & ES, there is large acceptance asymmetry near threshold.

Gain Difference

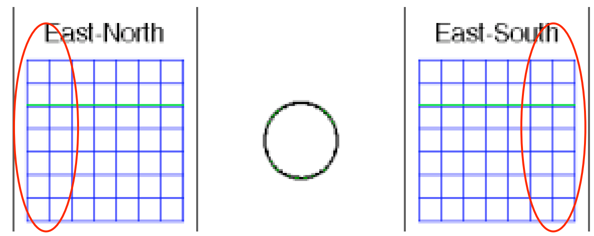


Due to gain difference between EN & ES, there is large acceptance asymmetry near threshold.

We focus on summed energy > 35 GeV

Systematics for A_N

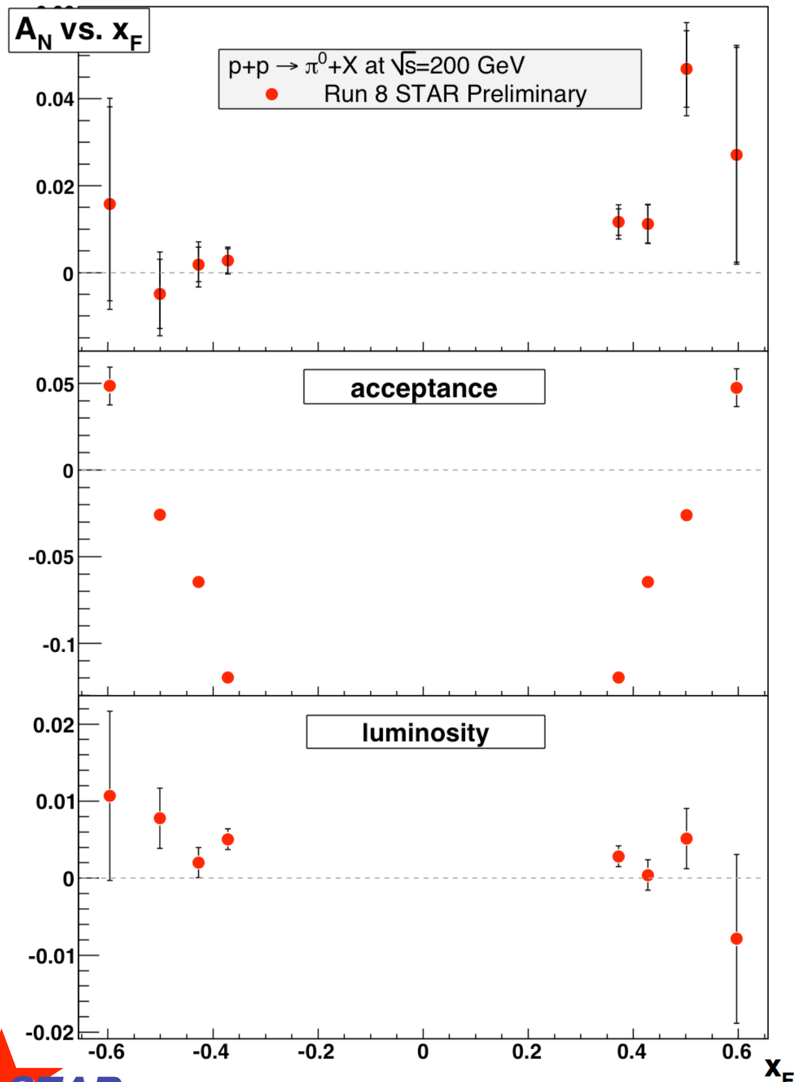
• Consider effects of low statistics far from the beam on gain calibration



• Consider effects of yields under the π^0 mass peak by implementing tighter mass cut

• Total systematic combines these effects in quadrature

Run 8 Asymmetries



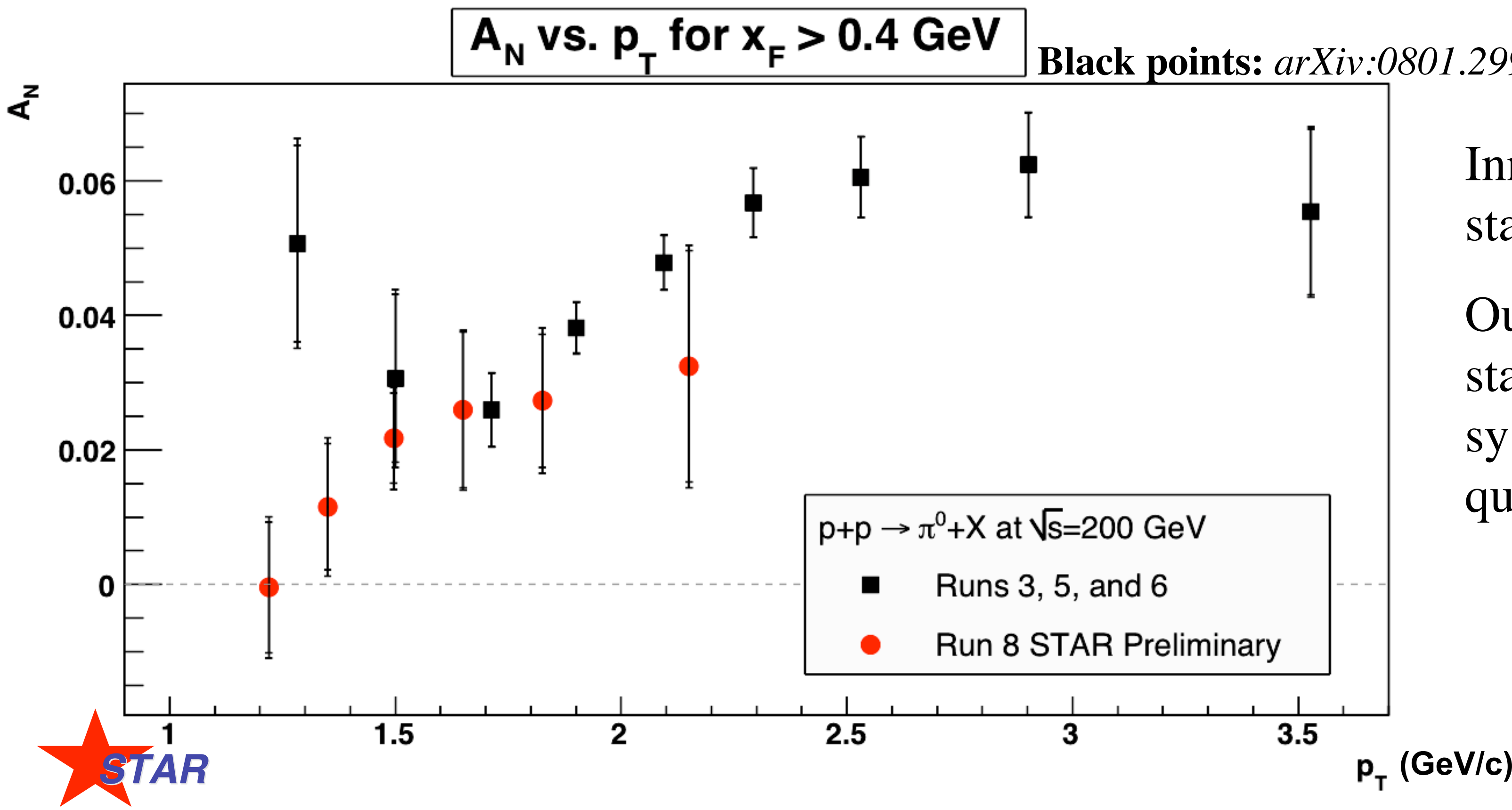
$$A_N = \frac{1}{P} \times \frac{\sqrt{N_\uparrow \times S_\downarrow} - \sqrt{N_\downarrow \times S_\uparrow}}{\sqrt{N_\uparrow \times S_\downarrow} + \sqrt{N_\downarrow \times S_\uparrow}}$$

Note: Still some lingering acceptance issues from gain differences, but small

Errors shown account for remaining acceptance asymmetry

Results for $x_F < 0$ are consistent with zero in all cases

Comparison to Previous Runs



Black points: *arXiv:0801.2990v1 [hep-ex]*

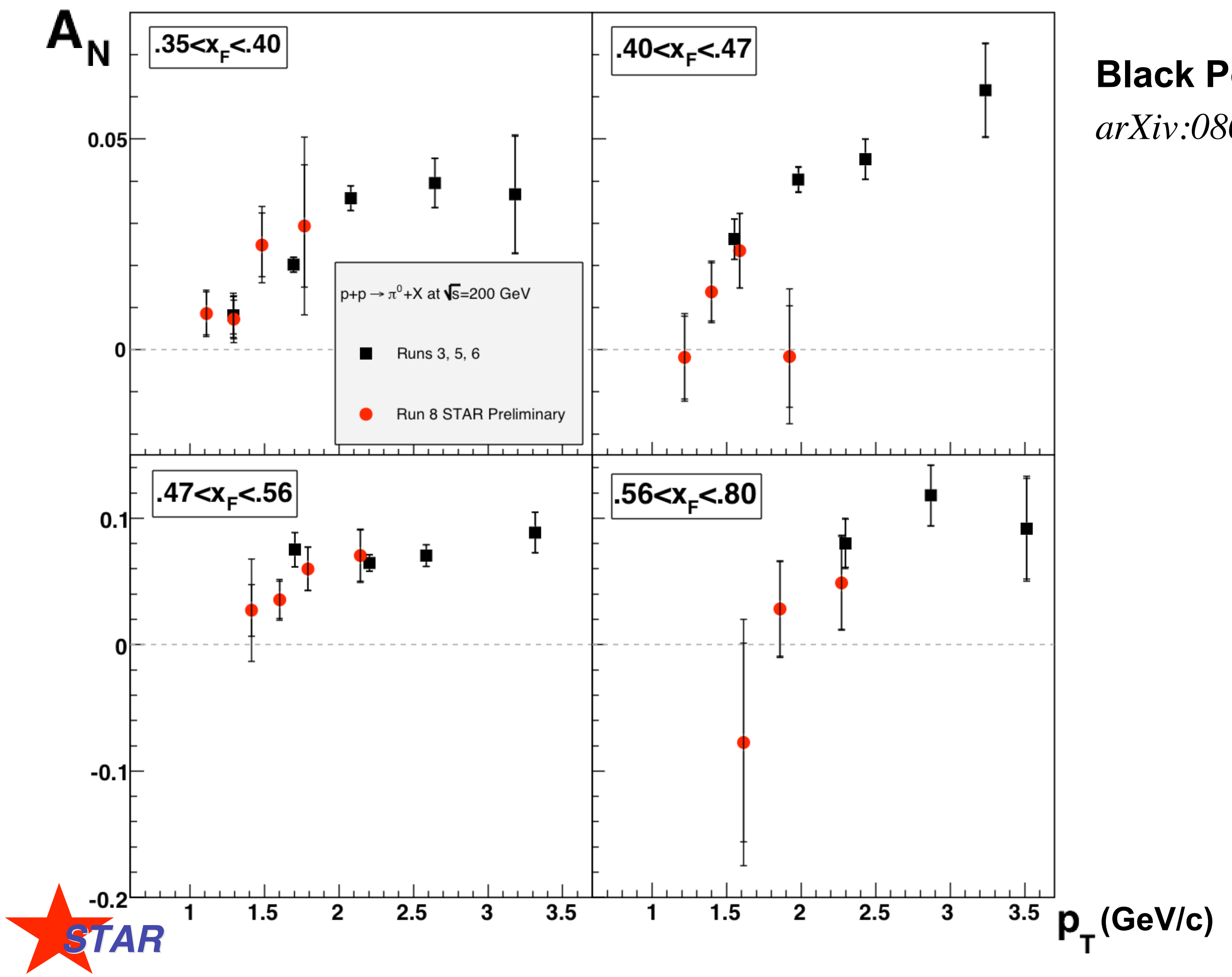
Inner errors: statistical

Outer errors: statistical and systematic in quadrature

Run 8 is mostly consistent with **previous results**.

However, Run 8 shows A_N continuing to fall at low p_T

Comparison to Previous Runs



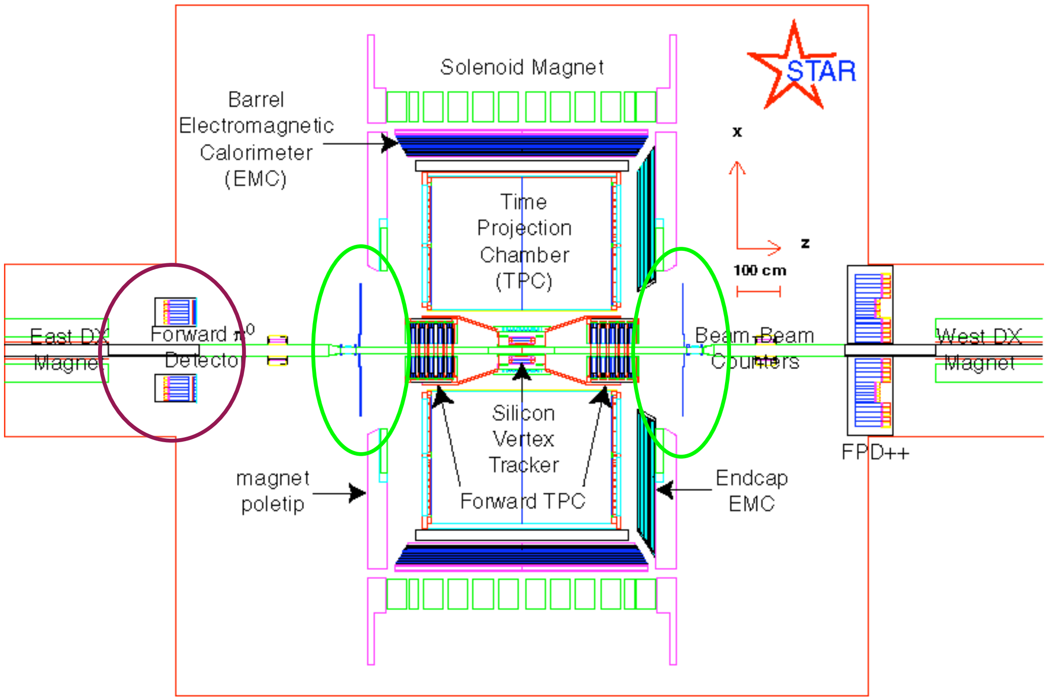
Black Points:

arXiv:0801.2990v1

FPD and STAR

Remember that the results shown so far included a BBC coincidence requirement in software.

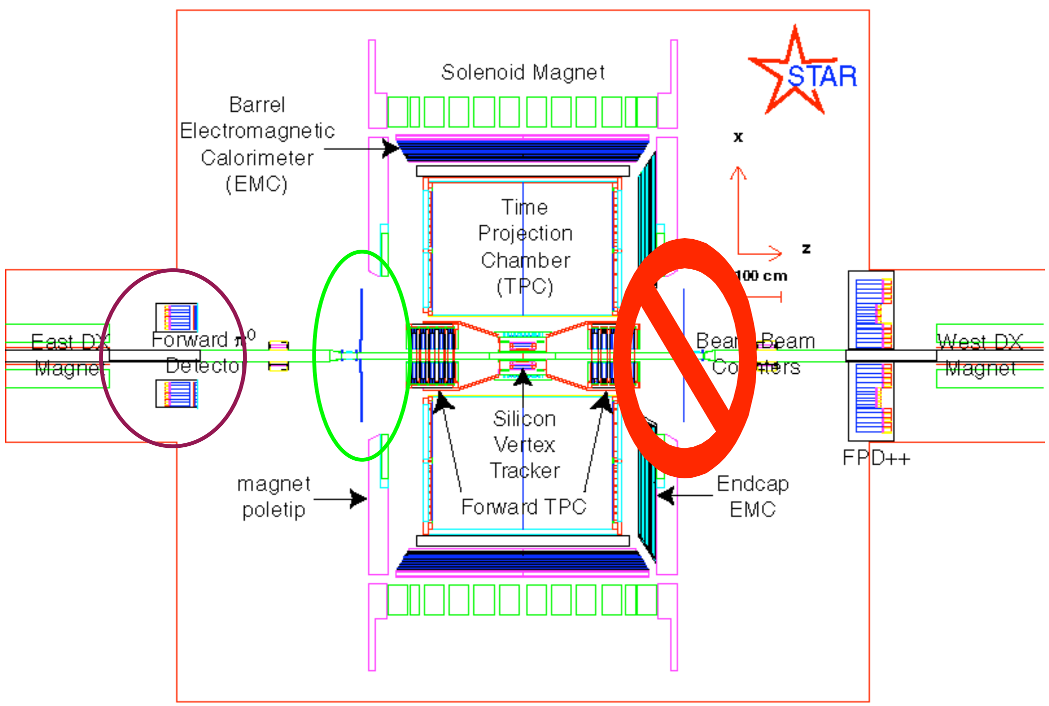
STAR Run 6 with FPD



This leads to a nearly pure **non-singly diffractive (NSD)** event sample.

FPD and STAR

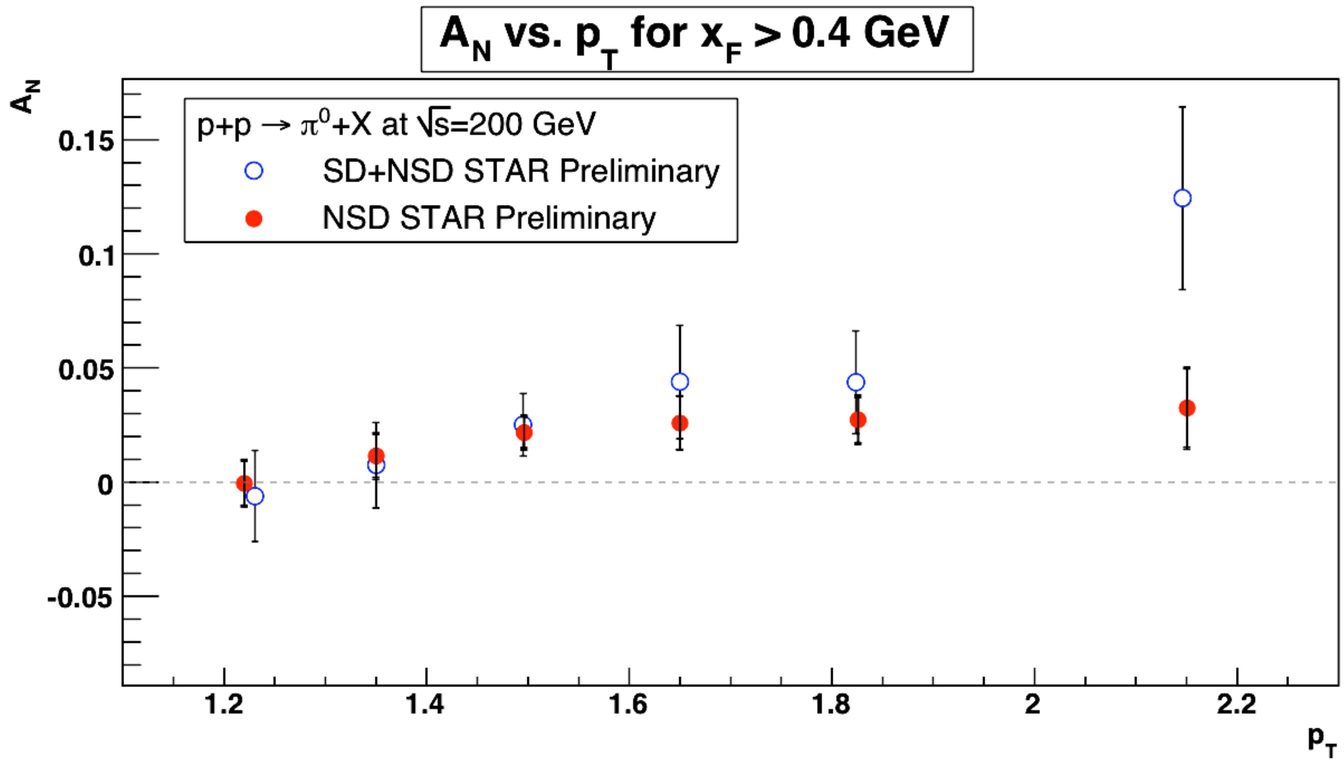
STAR Run 6 with FPD



Since no hardware BBC coincidence was required, we can also look at the events passing the east BBC and ***failing*** on the west side.

This leads to an event sample that contains a mixture of **singly-diffractive and non-singly diffractive (SD+NSD)** processes.

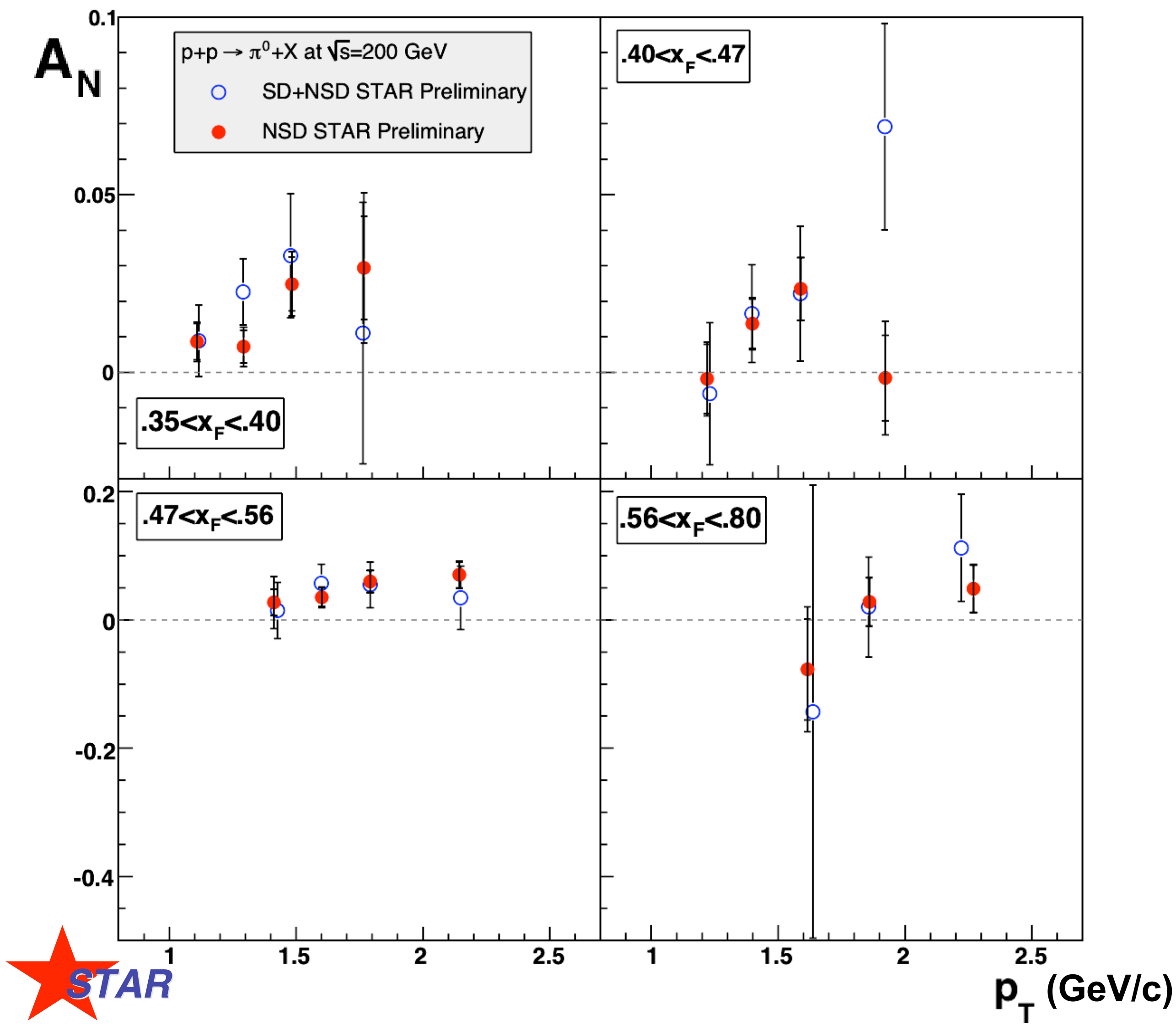
Single-diffractive Enhanced Event Sample



Results for the two different event samples are consistent

- Red points: (nearly pure) non-singly diffractive
- Blue open points: mixture of non-singly diffractive events from West BBC inefficiency and singly diffractive events,
- Non-collision backgrounds in the SD+NSD event sample are still under investigation. Systematics are no greater than statistics.

Single-diffractive Enhanced Event Sample

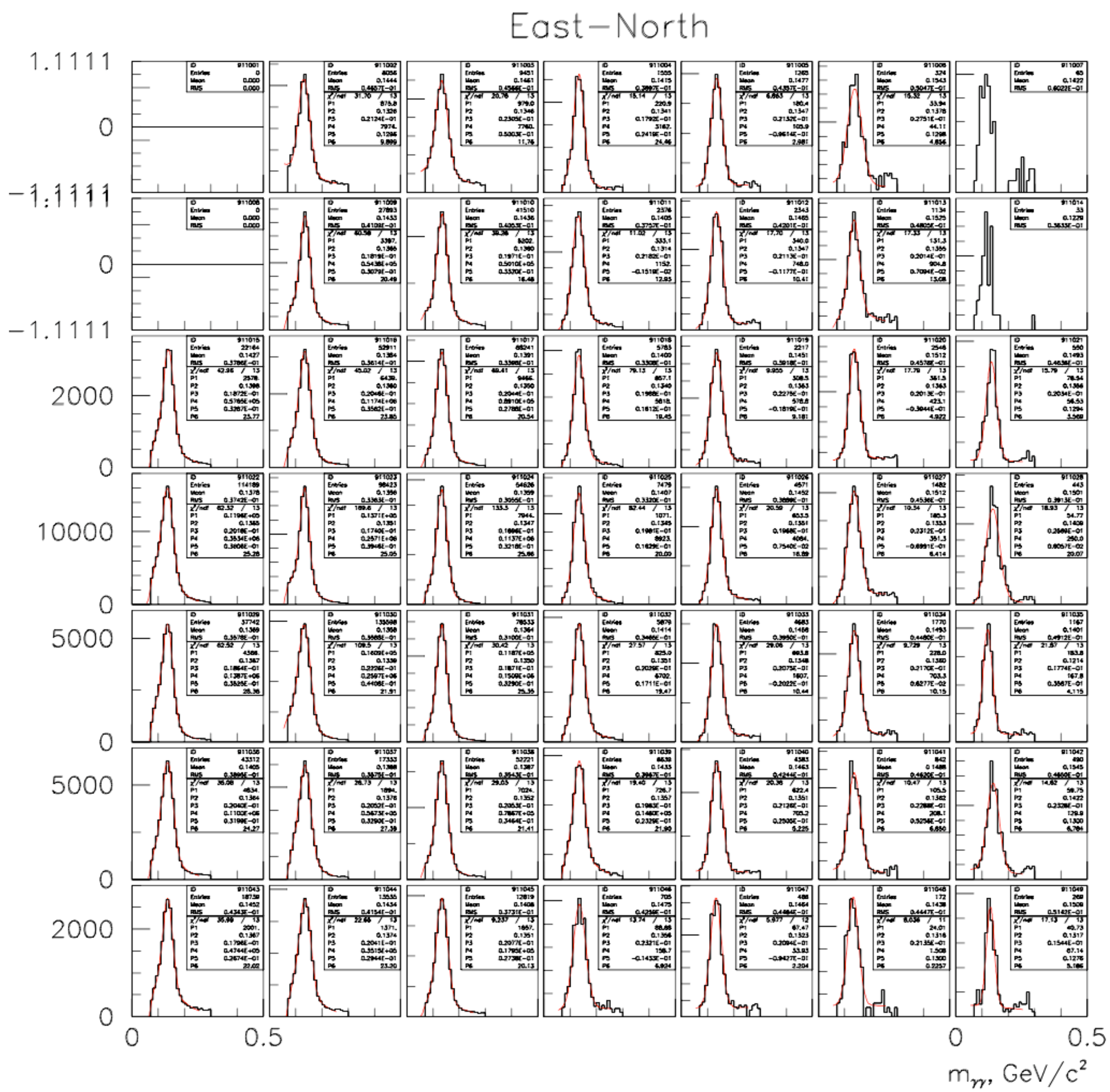


Conclusions

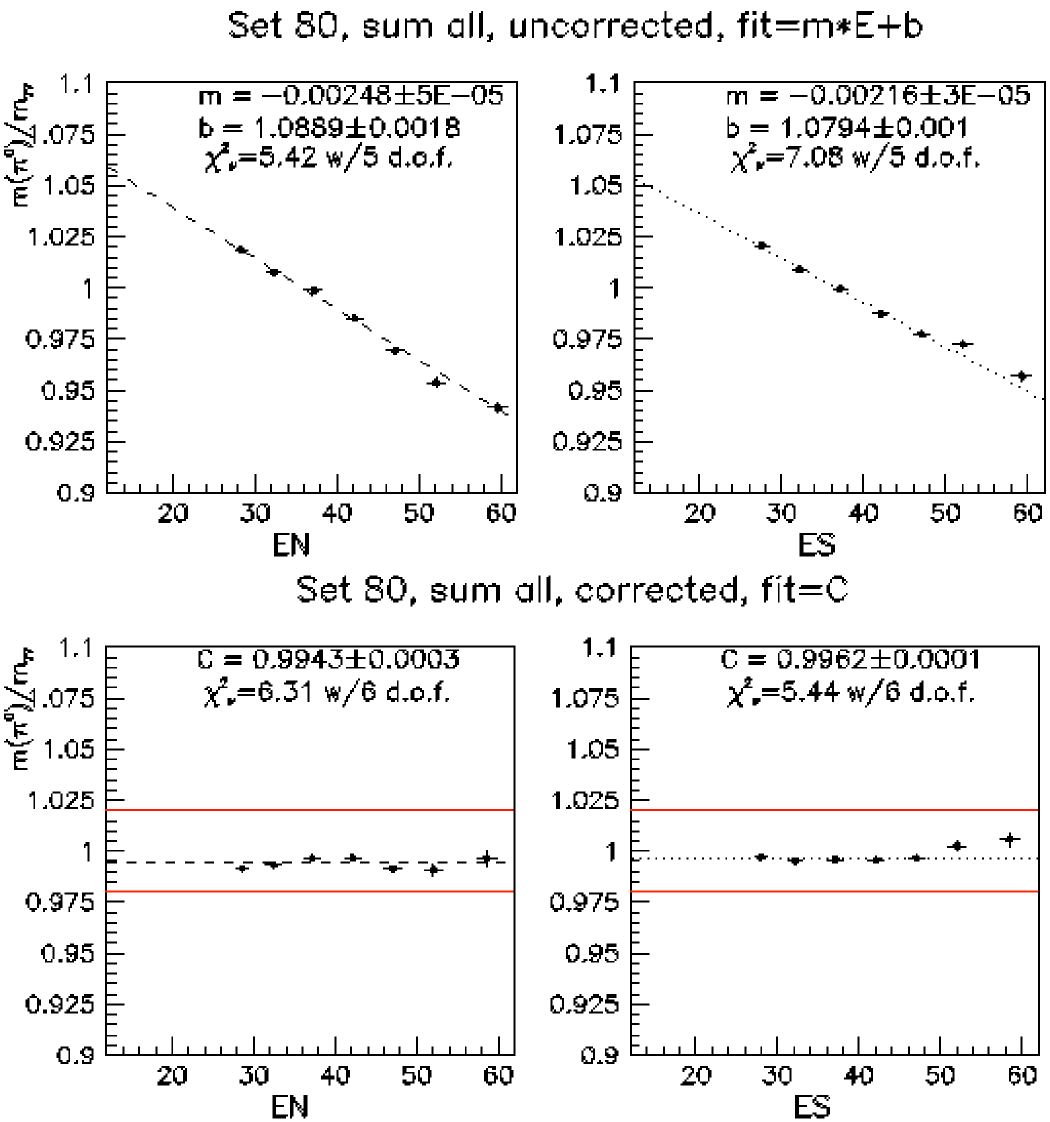
- Run-8 A_N for $p+p \rightarrow \pi^0+X$ at forward rapidity are mostly consistent with previous results
- However, data from Run-8 suggest A_N at large x_F continues to fall with lower p_T
- Results from analysis of an event sample that contains a mixture of single-diffractive and NSD events are consistent with the results for non-singly diffractive events

Back-up Slides

Run 8 Calibration



Run-8 FPD Calibration

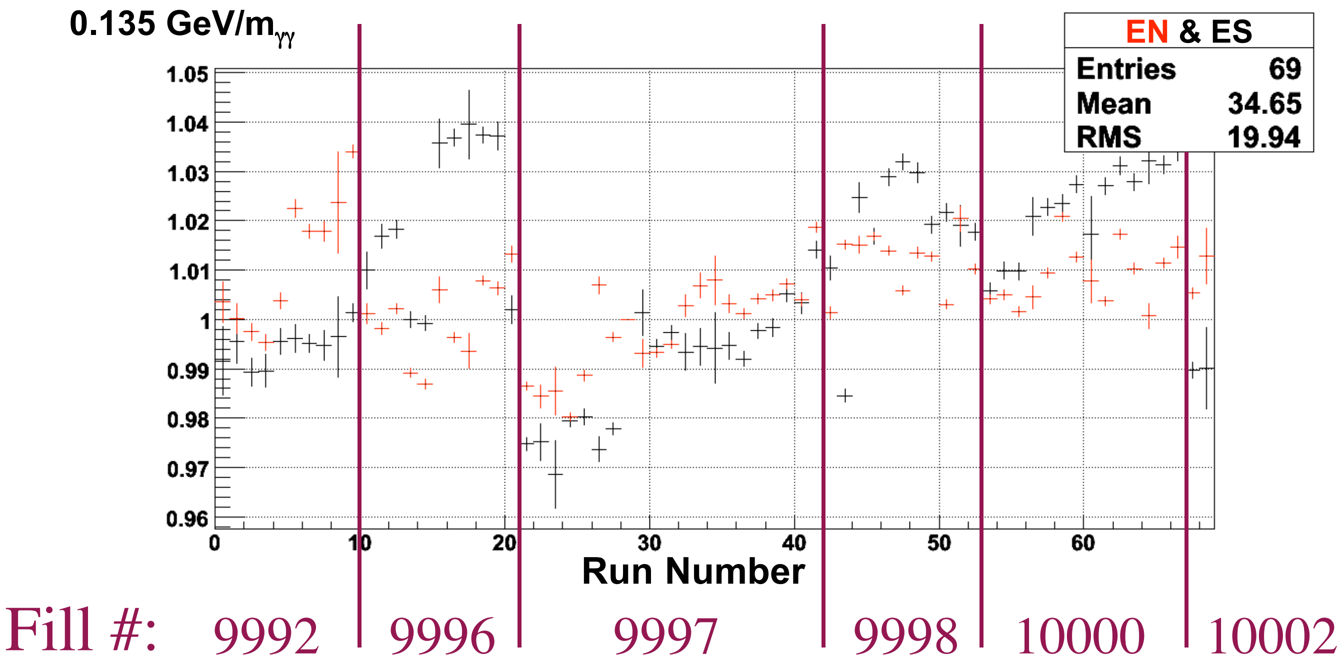


Energy-dependent calibration

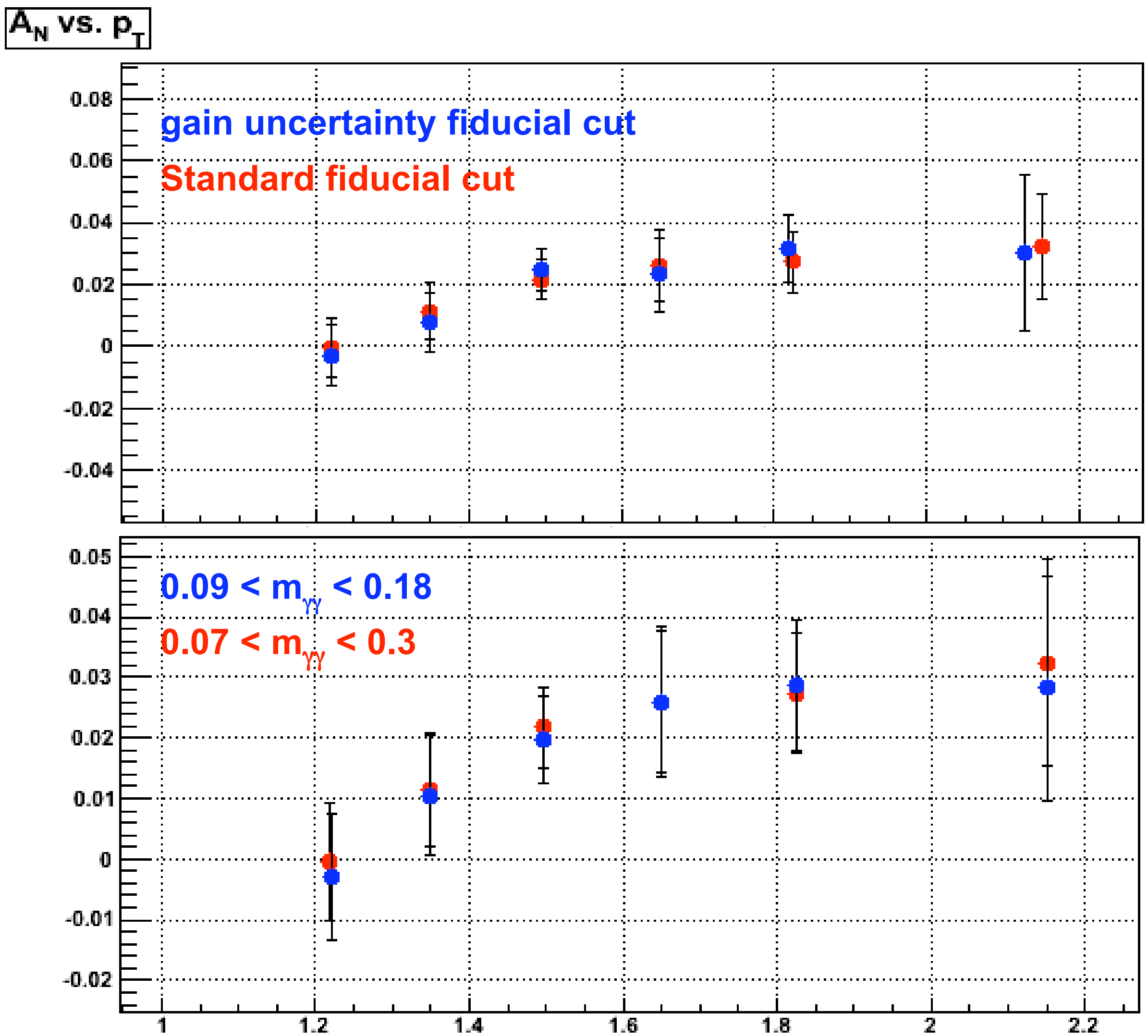
Run-8 FPD Calibration

• Channel-by-channel and run-by-run Raw ADC's are analyzed for pedestal shift

• Reconstruct π^0, channel-by-channel, correcting to known mass value until convergence for all channels



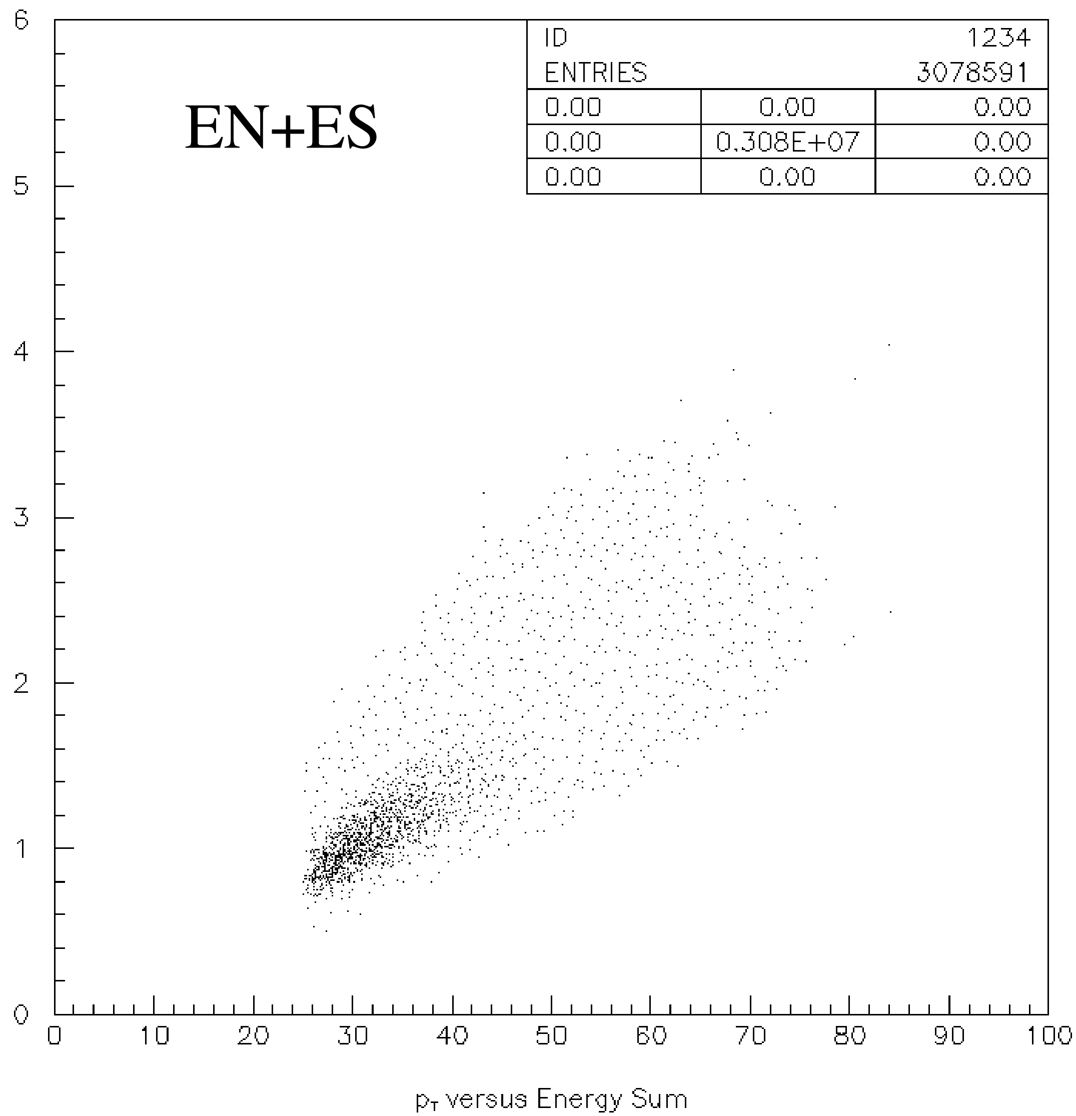
Systematic Uncertainty



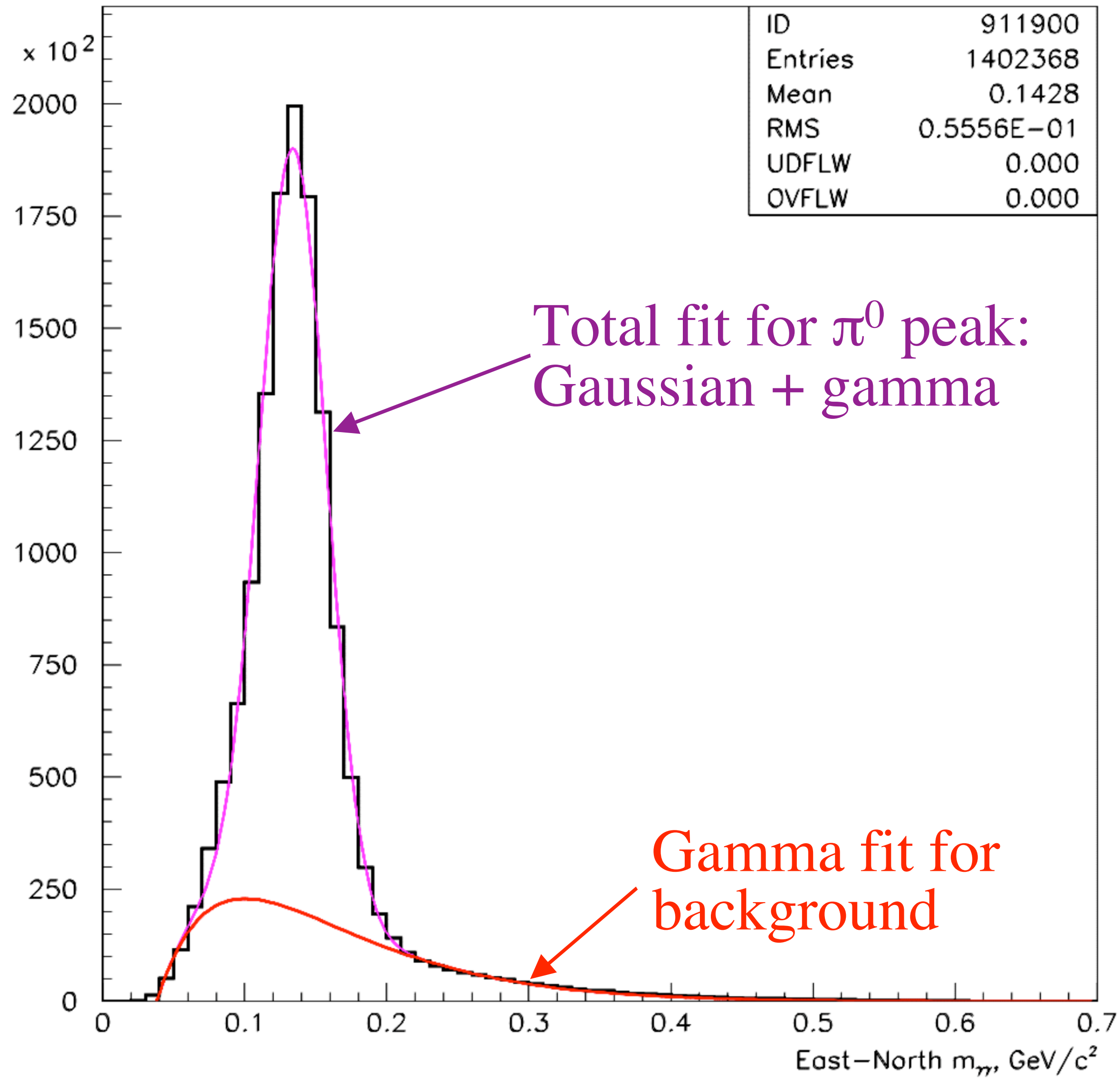
Gain calibration uncertainty

π^0 yield uncertainty

p_T vs. Summed Energy



Background Fit



Background Trigger Rage