

Transverse Single-Spin Asymmetries for Jet-like events at Forward Rapidities in p+p Collisions at $\sqrt{s} = 500$ GeV with the STAR Experiment

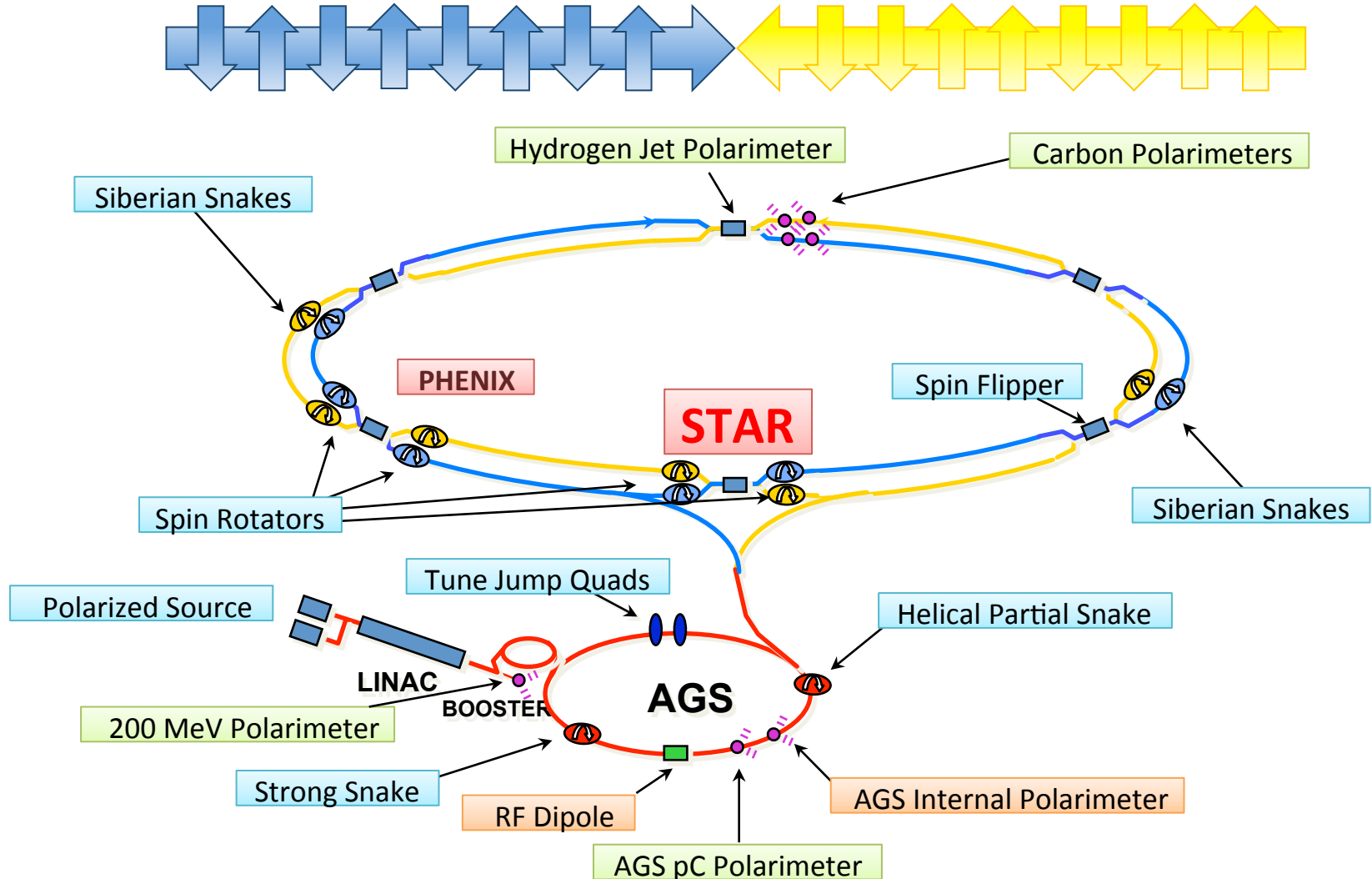
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Texas A&M University

Outline :

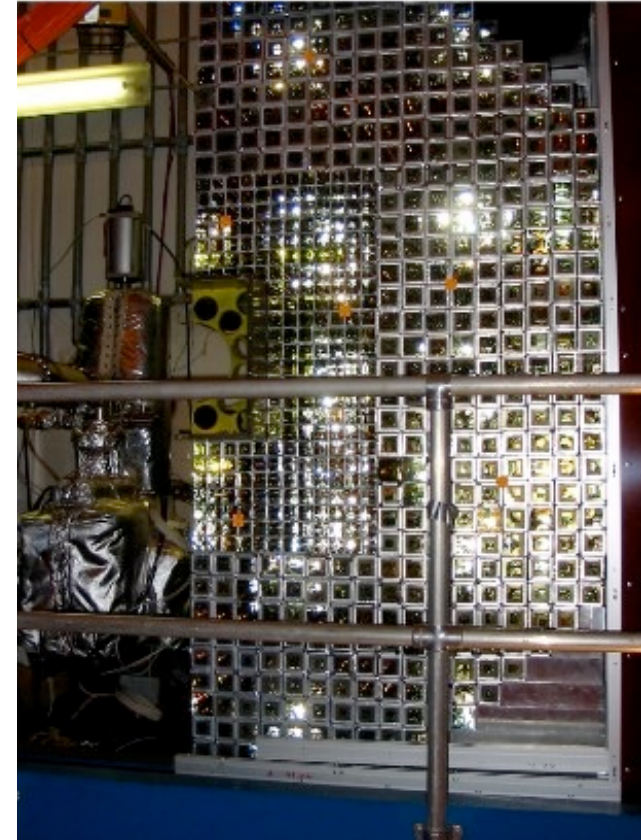
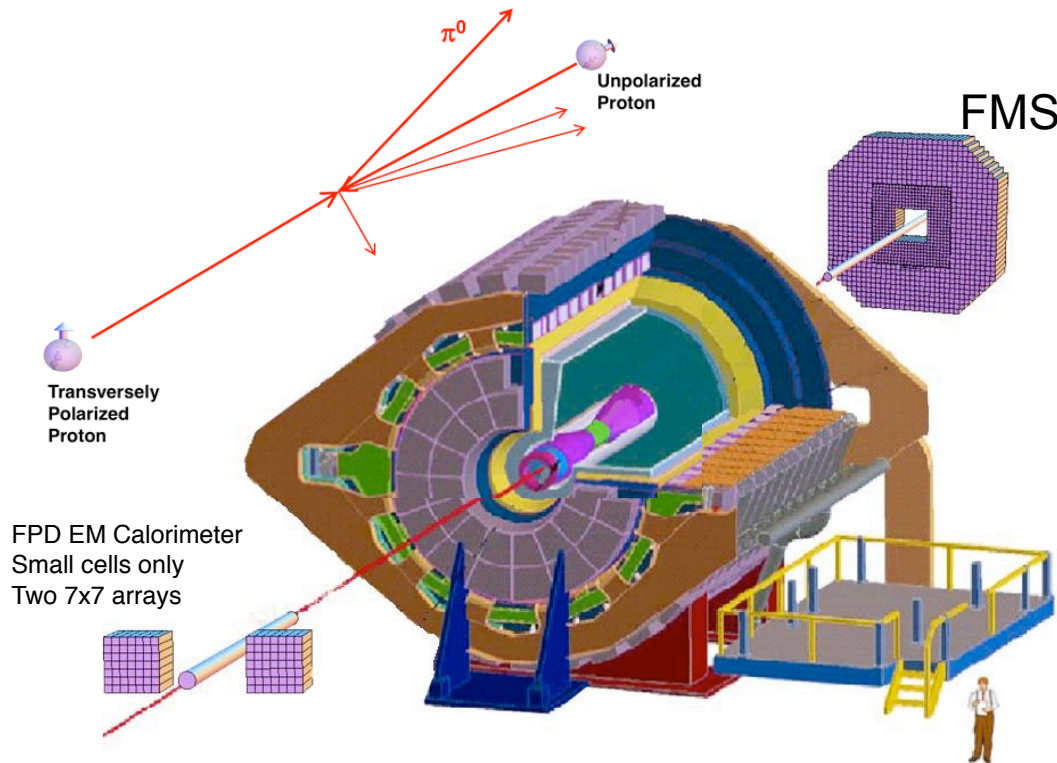
- ✧ Forward Meson Spectrometer in the STAR experiment
- ✧ Transverse Single Spin Asymmetries (TSSA)
- ✧ EM-Jets measured from FMS photons
- ✧ A_N measurements from run-11 at $\sqrt{s} = 500$ GeV

RHIC : the world's first polarized proton collider

Beams: \sqrt{s} 200 - 500 GeV pp; 50-60% polarization for year 2011



Forward ECALs in STAR



Forward Meson Spectrometer (FMS) :

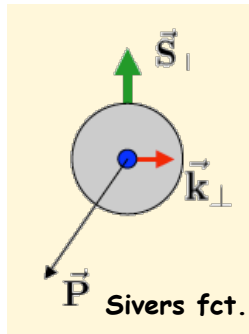
- Pb glass EM calorimeter covering $2.5 < \eta < 4.0$
- Detect π^0, η , direct photons and jet-like events in the kinematic region where asymmetries are known to be large.

TSSA - 2 theoretical frameworks

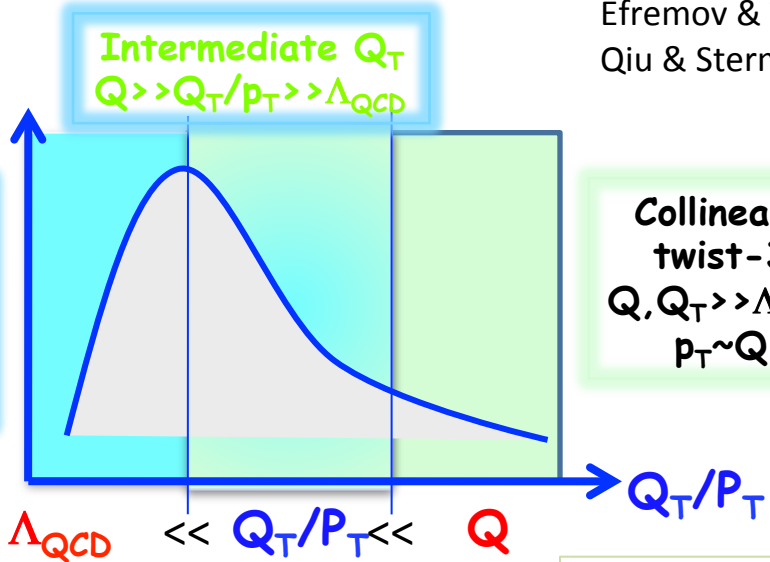
Spin-dependent transverse momentum dependent (TMD) function $S_{T,}(P_{\perp}k_{\perp})$

Brodsky, Hwang, Schmidt, 02

Collins, 02, Ji, Belitsky, Yuan, 02



Transverse momentum dependent
 $Q \gg Q_T \gg \Lambda_{\text{QCD}}$
 $Q \gg p_T$

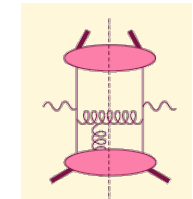


Twist-3 quark-gluon correlations

Efremov & Teryaev: 1982 & 1984

Qiu & Serman: 1991 & 1999

**Collinear/
twist-3**
 $Q, Q_T \gg \Lambda_{\text{QCD}}$
 $p_T \sim Q$



Efremov, Teryaev;
Qiu, Serman

Need 2 scales
 Q^2 and p_{\perp}
Remember pp:
 most observables one scale
Exception:
 DY, W/Z-production

Need only 1 scale
 Q^2 or p_{\perp}
 But
 should be of reasonable size
 should be **applicable to**
most pp observables
 $A_N(\pi^0/\gamma/\text{jet})$

$\pi^0 A_N$ Measurements at Forward Rapidity

Inclusive π^0 production

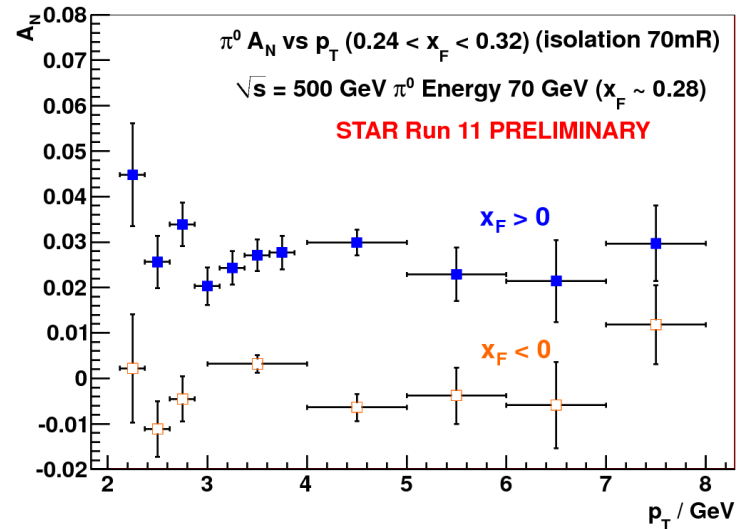
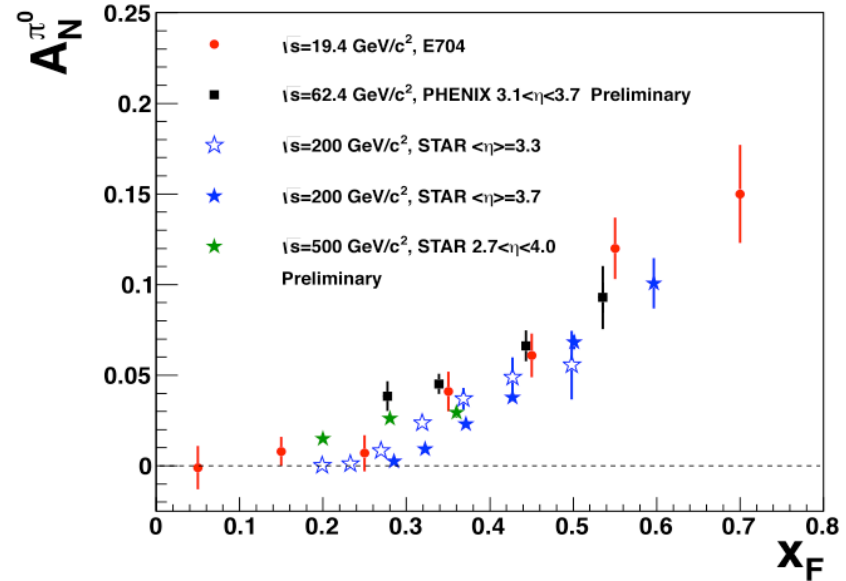
$$p_{\uparrow} + p \rightarrow \pi^0 + X$$

Transverse Single Spin Asymmetry

$$A_N \equiv \frac{\sigma^{\uparrow} - \sigma^{\downarrow}}{\sigma^{\uparrow} + \sigma^{\downarrow}}$$

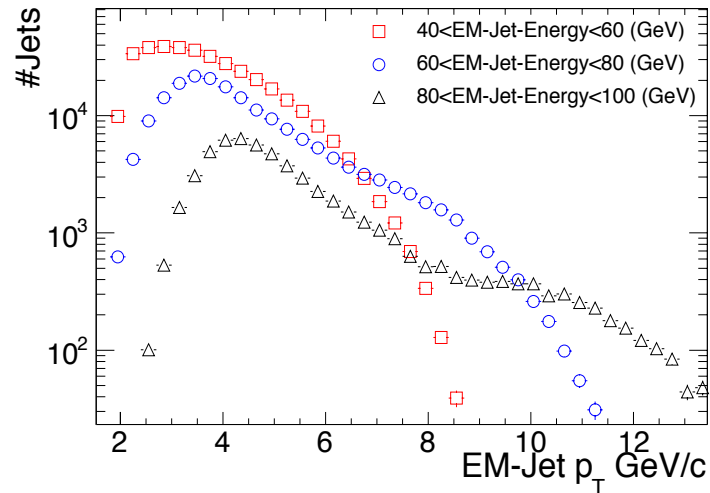
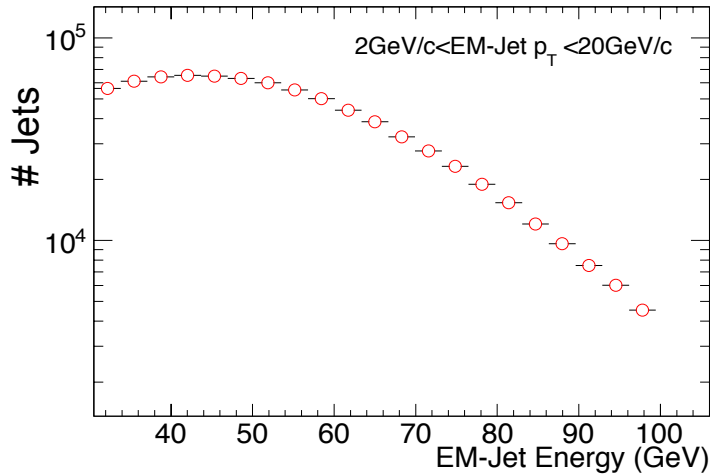
$$x_F = 2p_z/\sqrt{s}$$

- ✧ Rising A_N with x_F
- ✧ A_N nearly independent of \sqrt{s}
- ✧ No evidence of fall in A_N with increasing P_T



CIPANP 2012,
Steve Heppelmann

Run-2011 data



p+p vs = 500 GeV transverse datasets

Jet algorithm : anti-kt

R-parameter : 0.7

$p_T^{\text{EM-Jet}} > 2.0$ GeV/c

FMS photons with $p_T > 0.001$ GeV/c fed into anti-kt

Leading EM-Jets : Multi-photon Jets with highest energy

EM-Jets used to find asymmetry within

$2.8 < \eta^{\text{EM-Jet}} < 4.0$

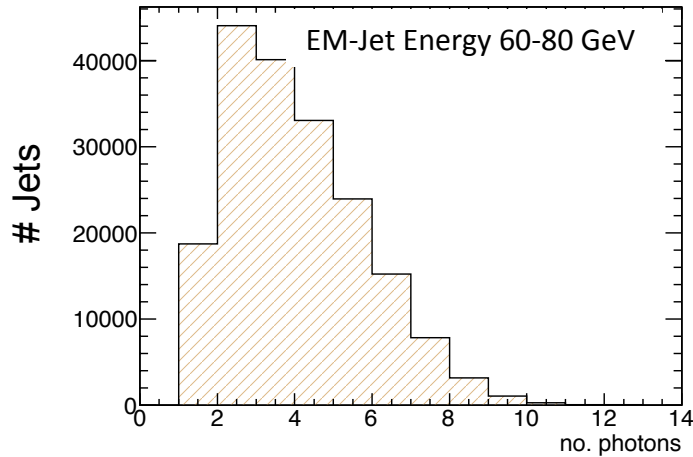
$40 \text{ GeV} < \text{Energy}^{\text{EM-Jet}} < 100 \text{ GeV}$

Structure in EM-Jet p_T :

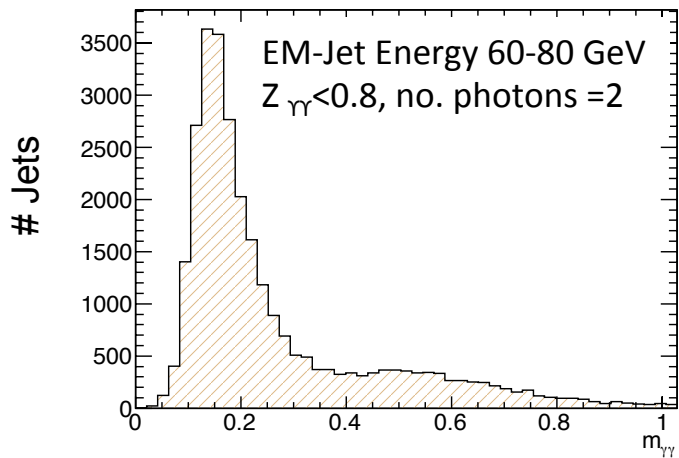
-- Acceptance non uniformity in small and large tower boundary

-- Different trigger threshold influence different p_T region

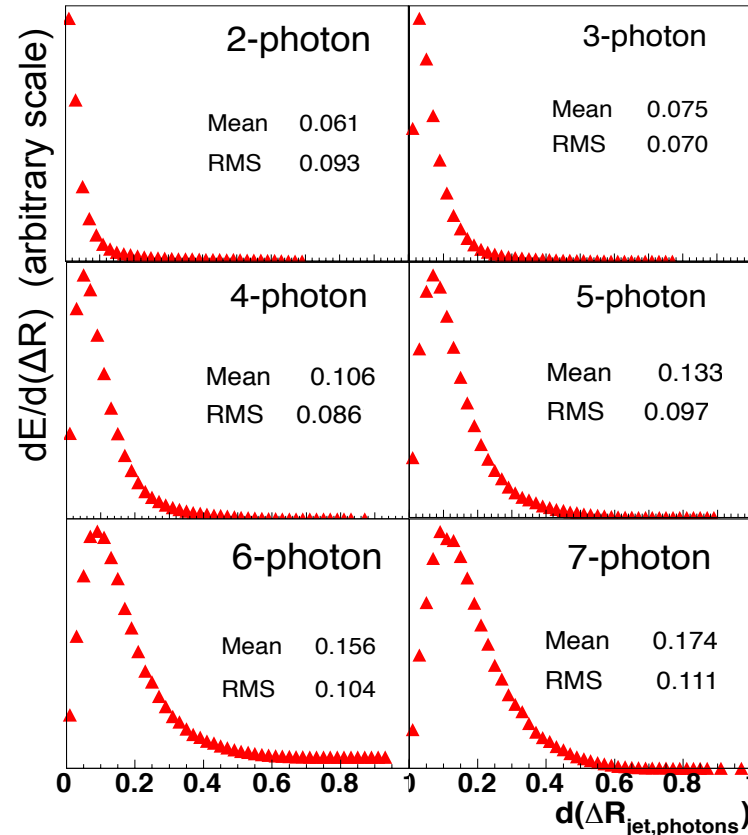
EM-Jet characteristics



No. of photons in leading EM-Jets



$\gamma\gamma$ invariant mass 2-photon EM-jets



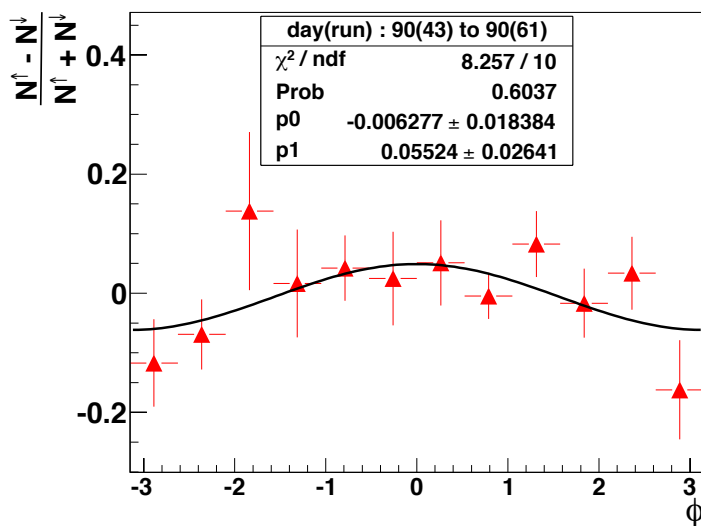
$dE/d(\Delta R)$ distribution of EM-Jets

- ✧ 2-photon jets are mostly π^0
- ✧ Events with more than 2 photons show jet-like energy flow

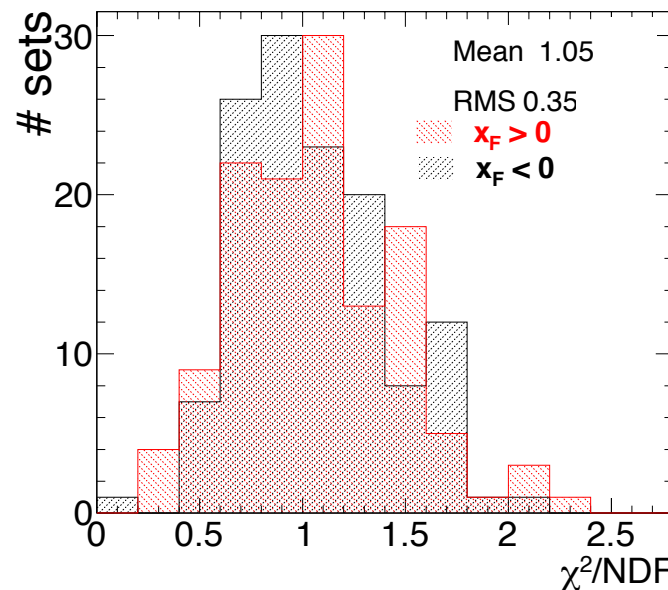
A_N from fits

- ◇ A_N is calculated from $p0 + p1 \cos(\phi)$ fits over each fill
 $p0$ = relative luminosity, $p1$ = asymmetry
- ◇ A_N 's are corrected for polarization values from fill to fill
- ◇ Weighted A_N and χ^2/NDF are calculated over entire fills

EM-Jet Energy = 55-57.5 GeV

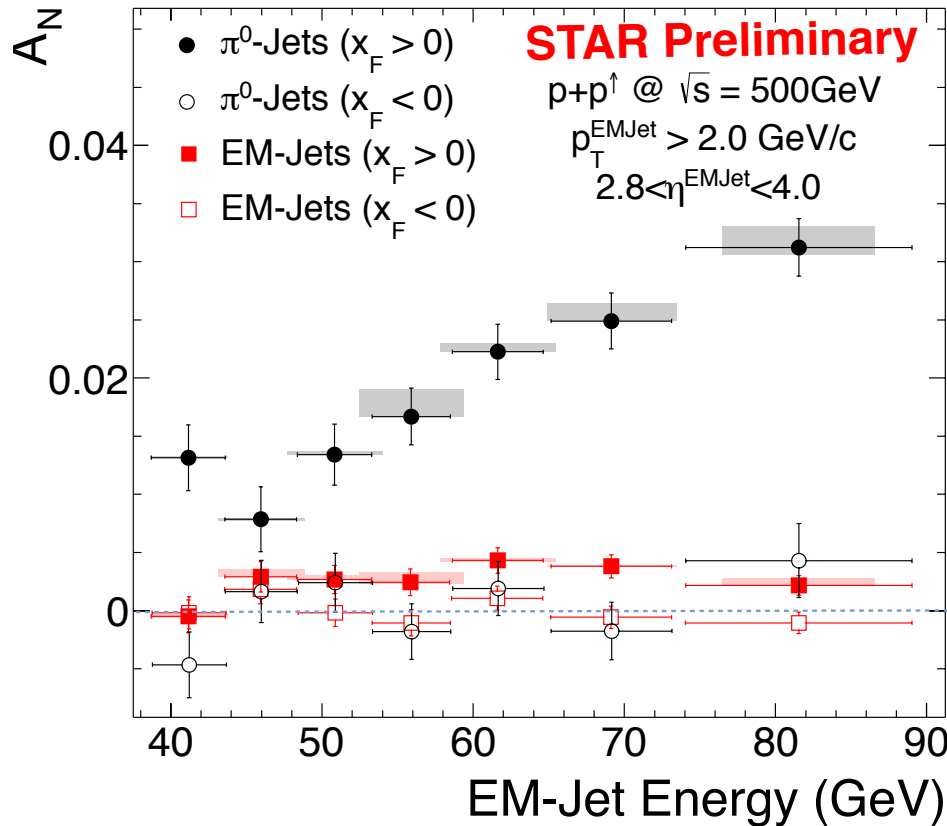


For 2-photon isolated π^0



Individual point and χ^2/NDF from averages over ~ 18 fills

A_N vs. EM-Jet Energy



π^0 -Jets –
 2γ -EM-Jets with
 $m_{\gamma\gamma} < 0.3$
 $Z_{\gamma\gamma} < 0.8$

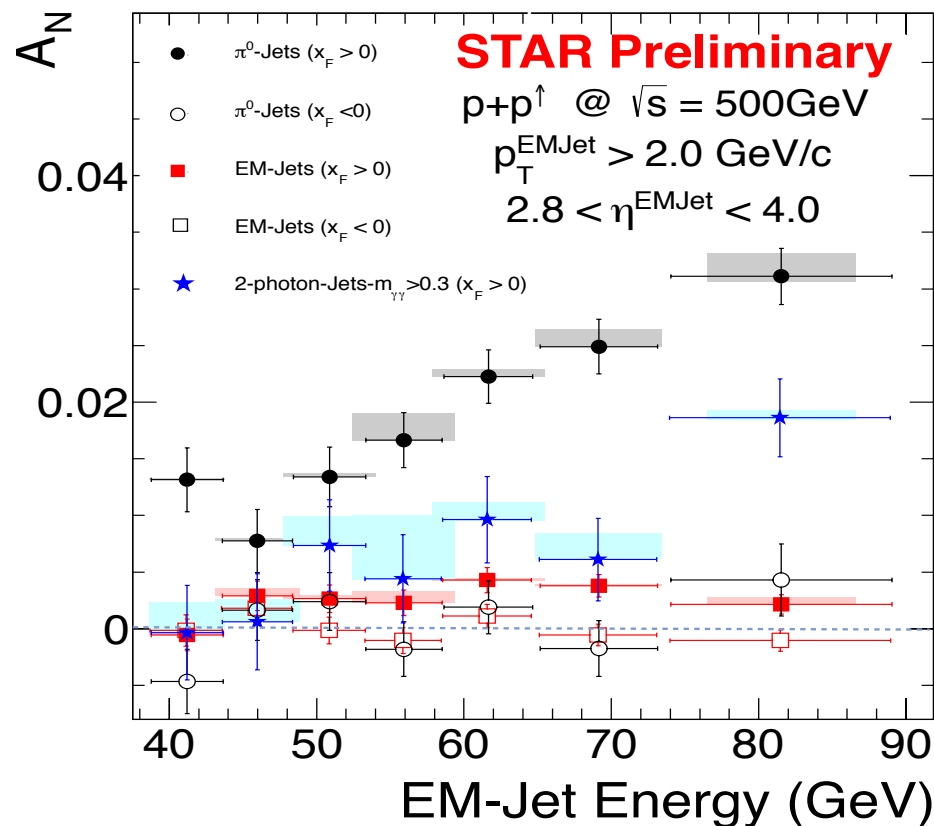
EM-Jets –
 with no. photons > 2

✧ Isolated π^0 's have large asymmetries consistent with previous observation (CIPANP-2012 Steven Heppelmann)

<https://indico.triumf.ca/contributionDisplay.py?contribId=349&sessionId=44&confId=1383>

✧ Asymmetries for jettier events are much smaller

A_N vs. EM-Jet Energy



π^0 -Jets –
 2 γ -EM-Jets with
 $m_{\gamma\gamma} < 0.3$
 $Z_{\gamma\gamma} < 0.8$

2 γ -EM-Jets (η + continuum) –
 with $m_{\gamma\gamma} > 0.3$

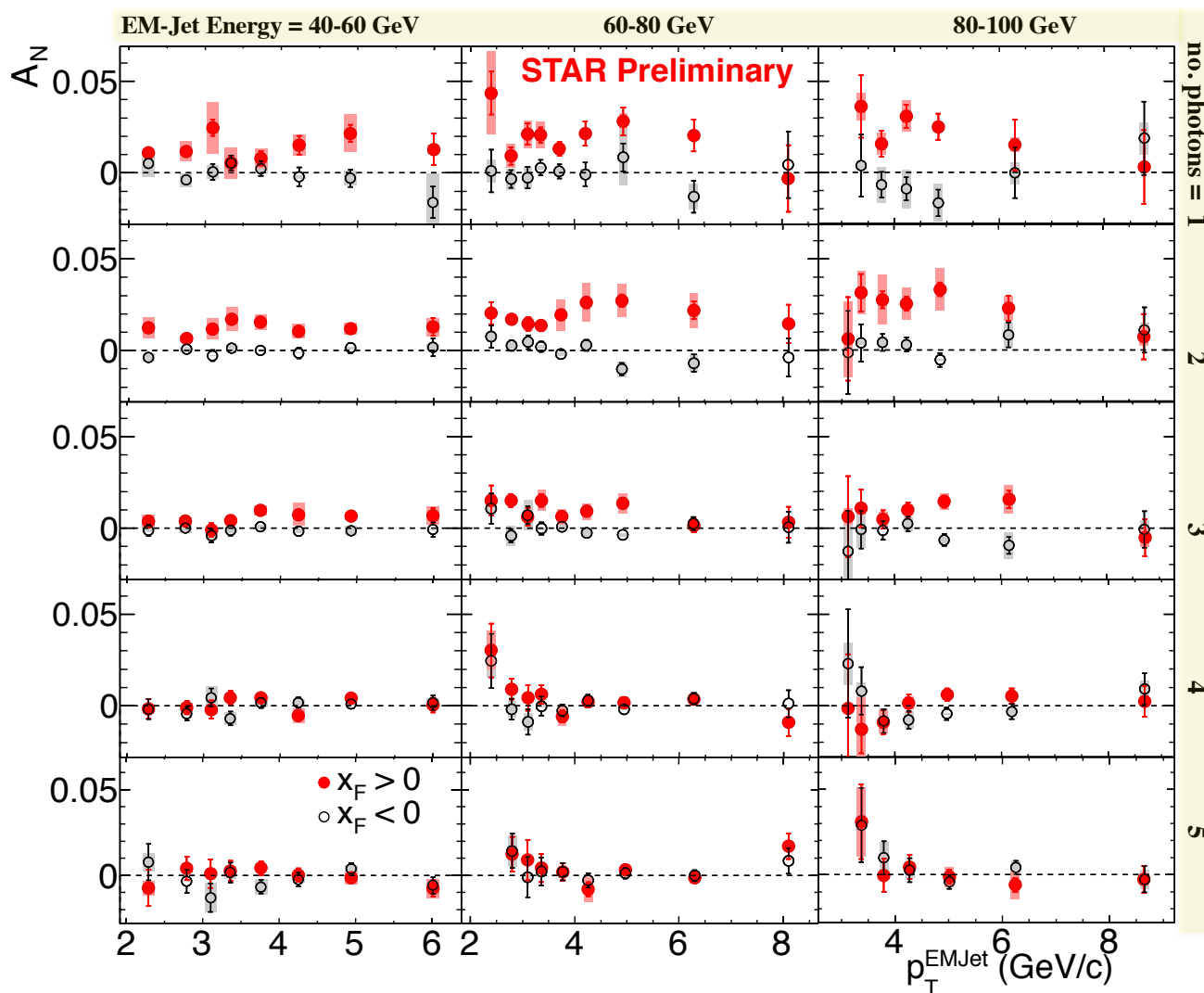
EM-Jets –
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A_N for different # photons in EM-Jets

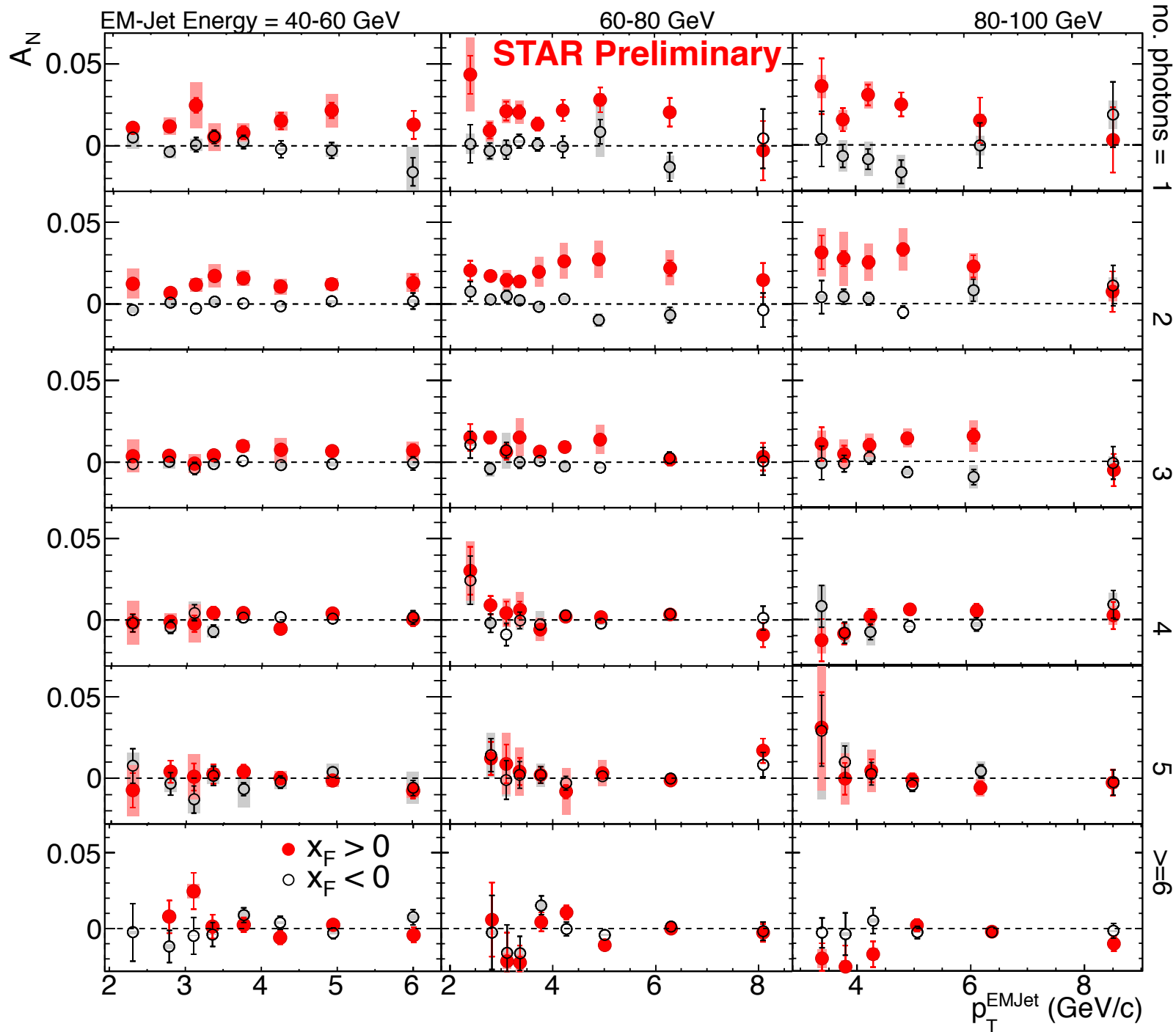


- ✧ 1-photon events, which include a large π^0 contribution in this analysis, are similar to 2-photon events
- ✧ Three-photon jet-like events have a clear non-zero asymmetry, but substantially smaller than that for isolated π^0 's
- ✧ A_N decreases as the event complexity increases (i.e., the "jettiness")
- ✧ A_N for #photons >5 is similar to that #photons = 5

Summary

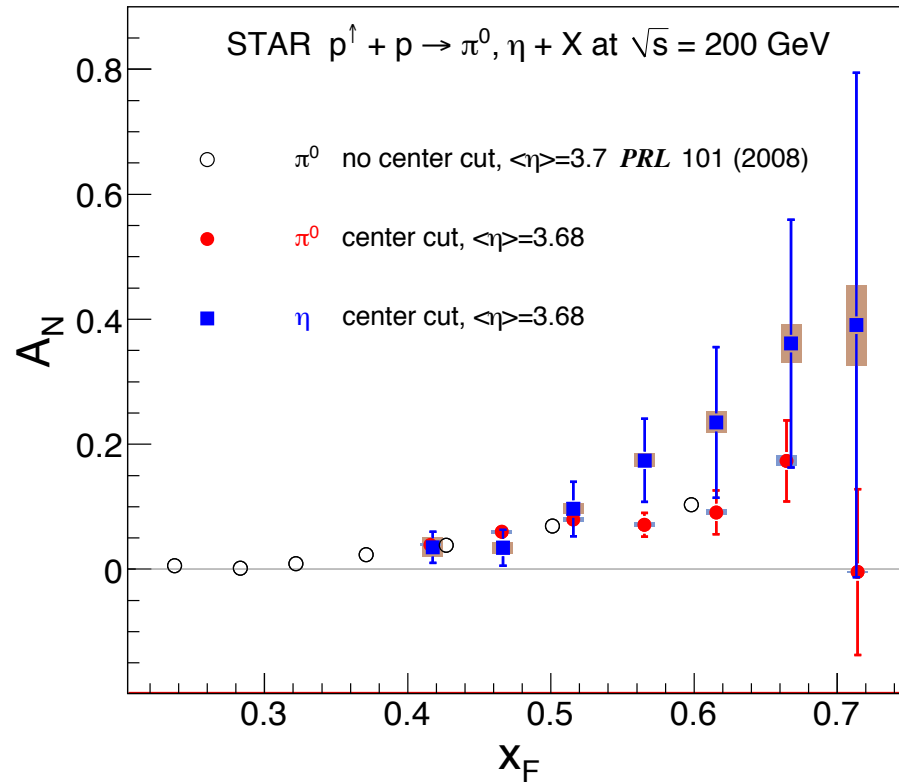
- ✧ EM-Jets are reconstructed from photons detected in the FMS at STAR.
- ✧ Jets with isolated π^0 have large asymmetry as seen before.
- ✧ Three-photon jet-like events have a clear non-zero asymmetry, but substantially smaller than that for isolated π^0 's.
- ✧ A_N decreases as the event complexity increases (i.e., the "jettiness").

Backup slides

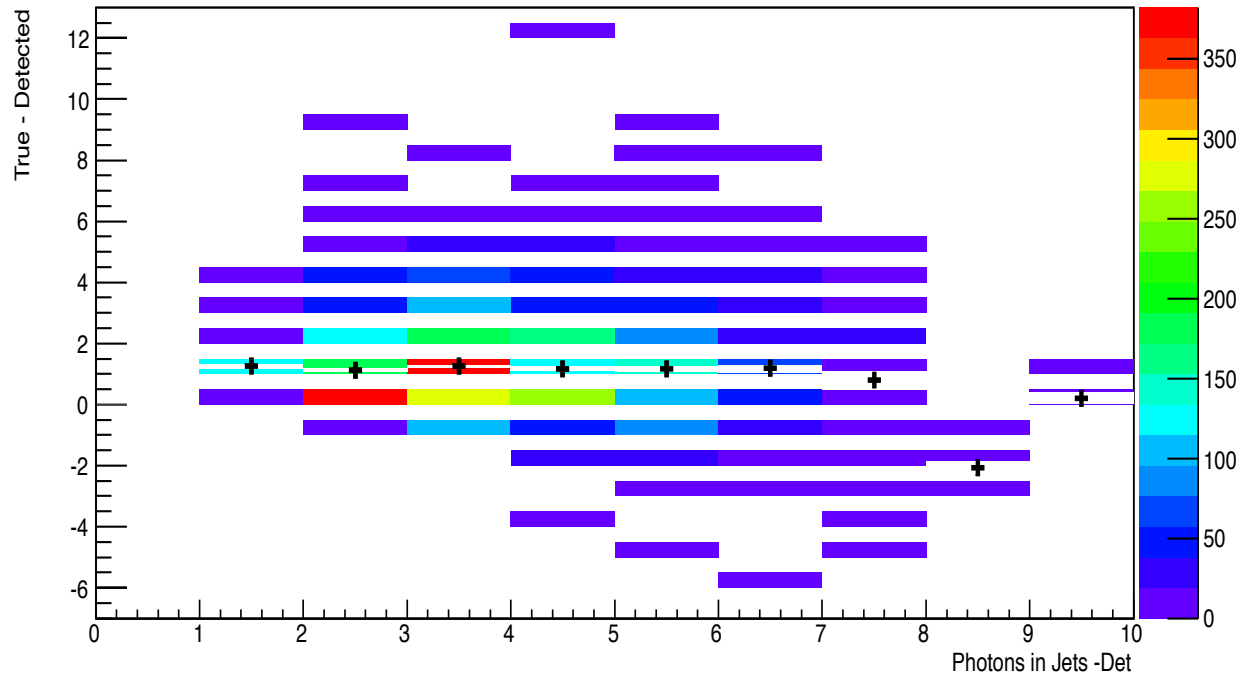


Transverse Single-Spin Asymmetry and Cross-Section for π^0 and η Mesons at Large Feynman- x in $p^\uparrow + p$ Collisions at $\sqrt{s} = 200$ GeV

PRD 86-051101



PYTHIA simulations



Systematics arising from intermixing of event classes

Proton productivity increase 2006-2014 (projected)

