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

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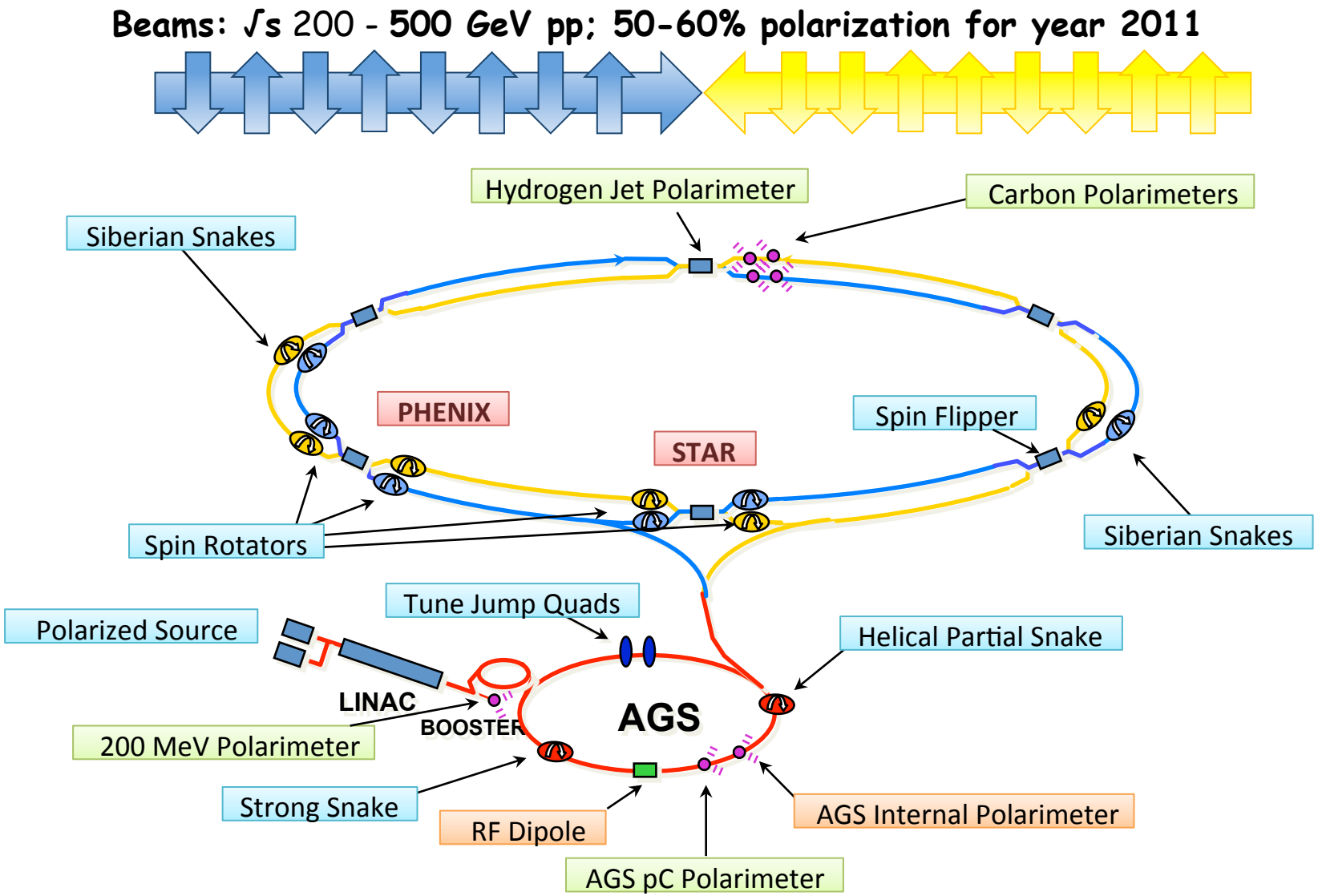
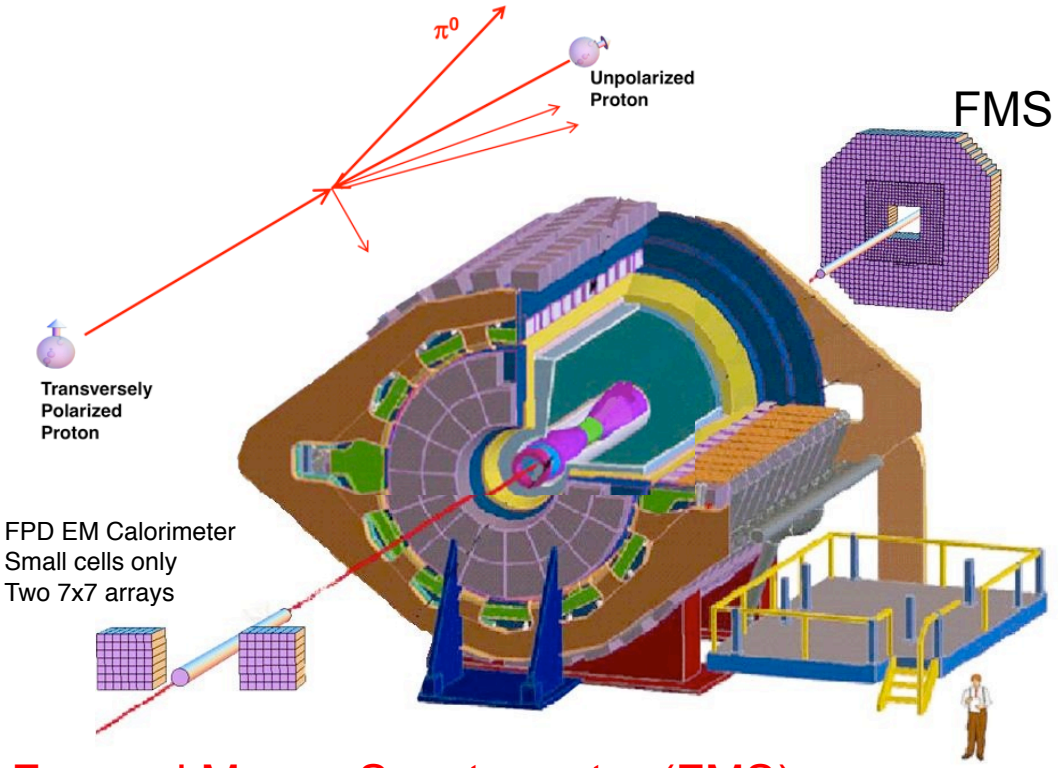
Outline :

- ✧ 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 √s = 500 GeV

RHIC : the world's first polarized proton collider



Forward ECALs in STAR



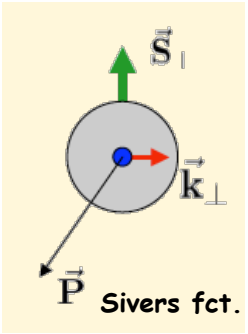
Forward Meson Spectrometer (FMS) :

-- Pb glass EM calorimeter covering 2.5< η <4.0

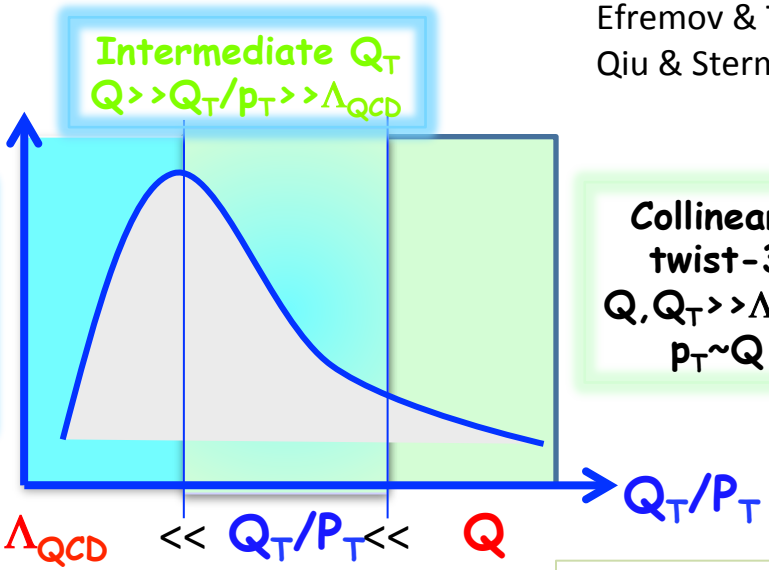
-- Detect π^0,η, direct photons and jet-like events in the kinematic region where asymmetries are known to be large.

TSSA - 2 theoretical frameworks

Spin-dependent transverse momentum dependent (TMD) function $S_T.(Pxk_T)$
Brodsky, Hwang, Schmidt, 02
Collins, 02, Ji, Belitsky, Yuan, 02

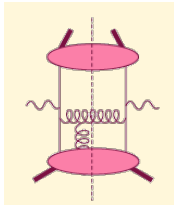


Transverse momentum dependent
$Q >> Q_T >= \Lambda_{QCD}$
$Q >> p_T$



Twist-3 quark-gluon correlations
Efremov & Teryaev: 1982 & 1984
Qiu & Sterman: 1991 & 1999

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



Efremov, Teryaev; Qiu, Sterman

Need 2 scales
Q^2 and p_t
Remember pp:
most observables one scale
Exception:
DY, W/Z-production

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

π^0 A_N Measurements at Forward Rapidity

Inclusive π0 production

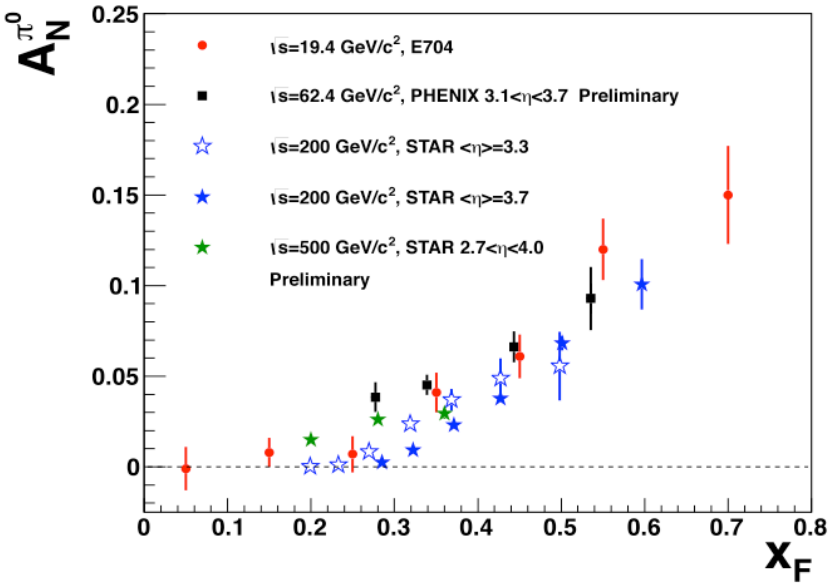
$$p_\uparrow + p \longrightarrow \pi^0 + X$$

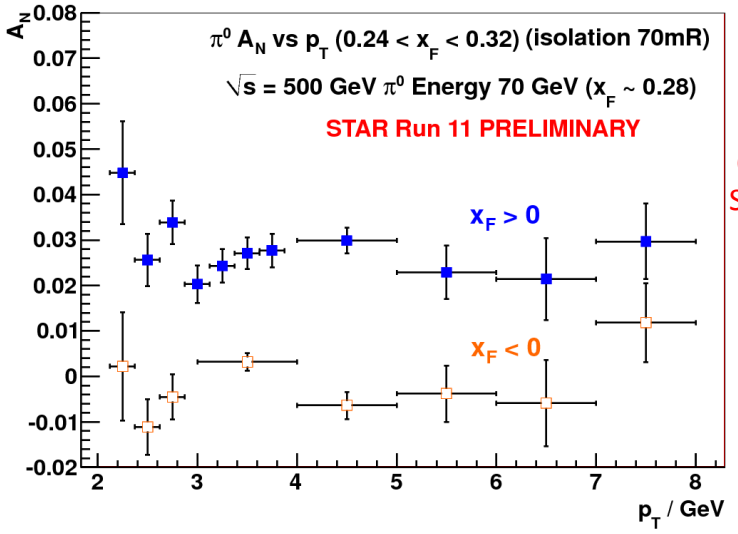
Transverse Single Spin Asymmetry

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

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

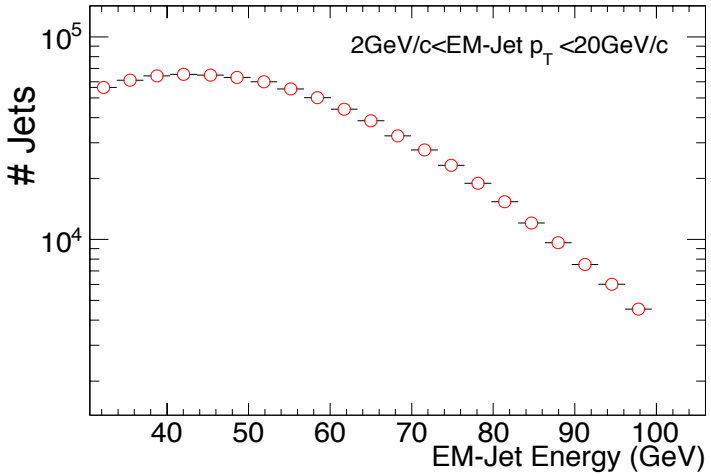
- Rising A_N with X_F
- A_N nearly independent of √s
- No evidence of fall in A_N with increasing P_T

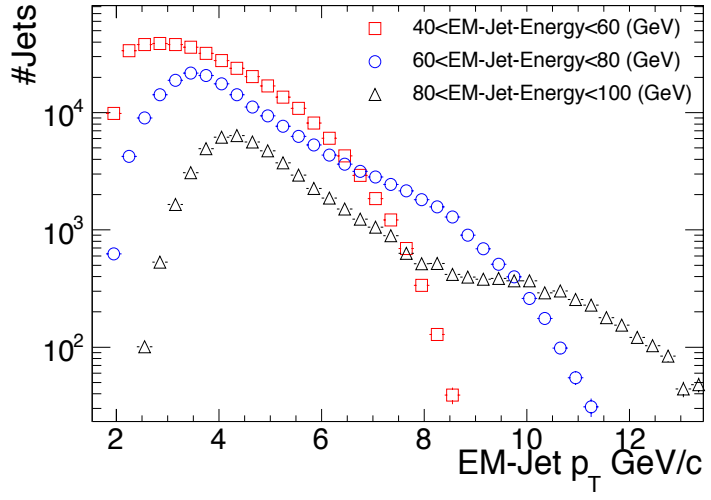




CIPANP 2012, Steve Heppelmann

Run-2011 data





p+p √s = 500 GeV transverse datasets

Jet algorithm : anti-kt

R-parameter : 0.7

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

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

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

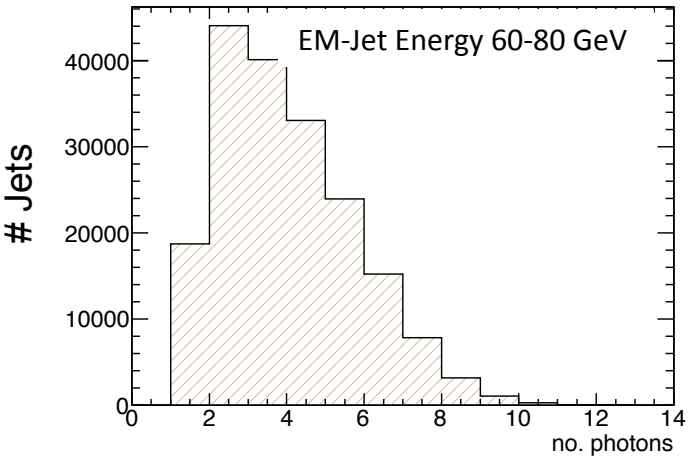
EM-Jets used to find asymmetry within

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

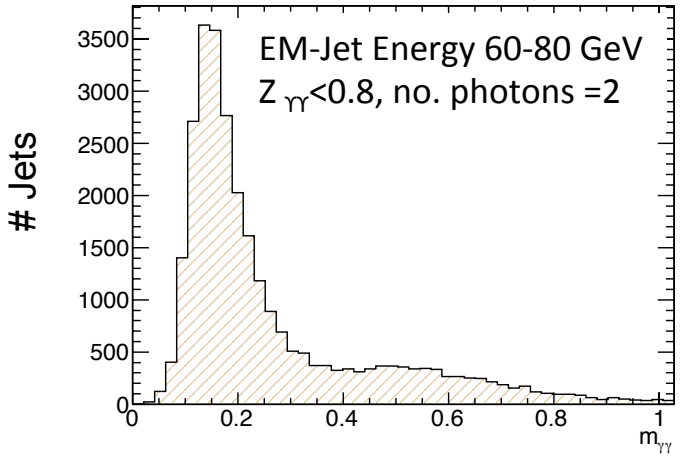
40 GeV < $Energy^{EM\text{-}Jet}$ < 100 GeV

Structure in EM-Jet p_T :
-- Acceptance non uniformity in small and large tower boundary
-- Different trigger threshold influence different p_T region

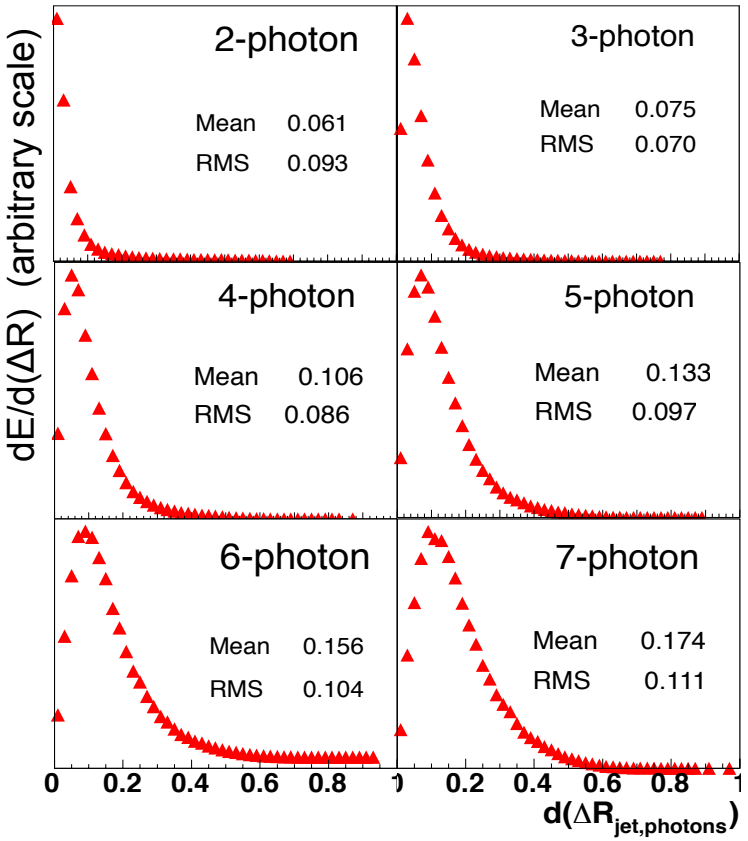
EM-Jet characteristics



No. of photons in leading EM-Jets



ϒϒ invariant mass 2-photon EM-jets



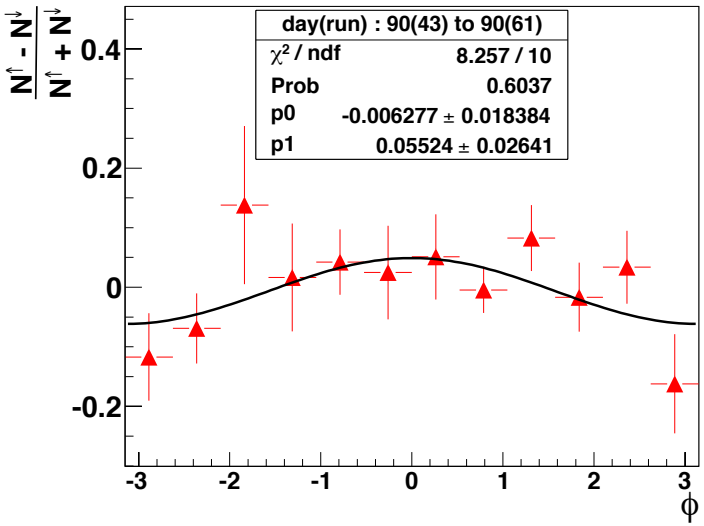
dE/d(ΔR) distribution of EM-Jets

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

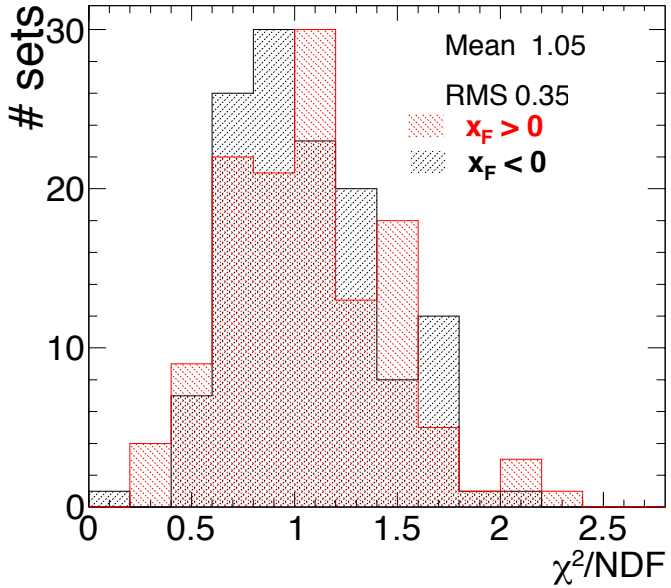
A_N from fits

- A_N is calculated from **p0 + p1 cos(ϕ)** 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

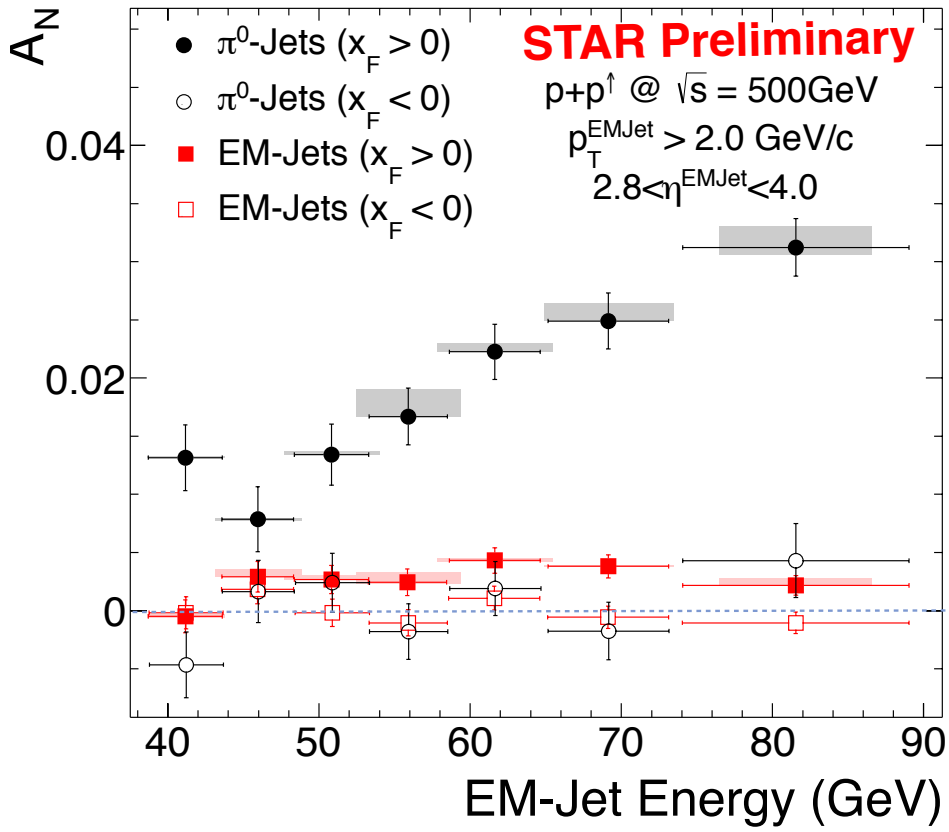


For 2-photon isolated π^0



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

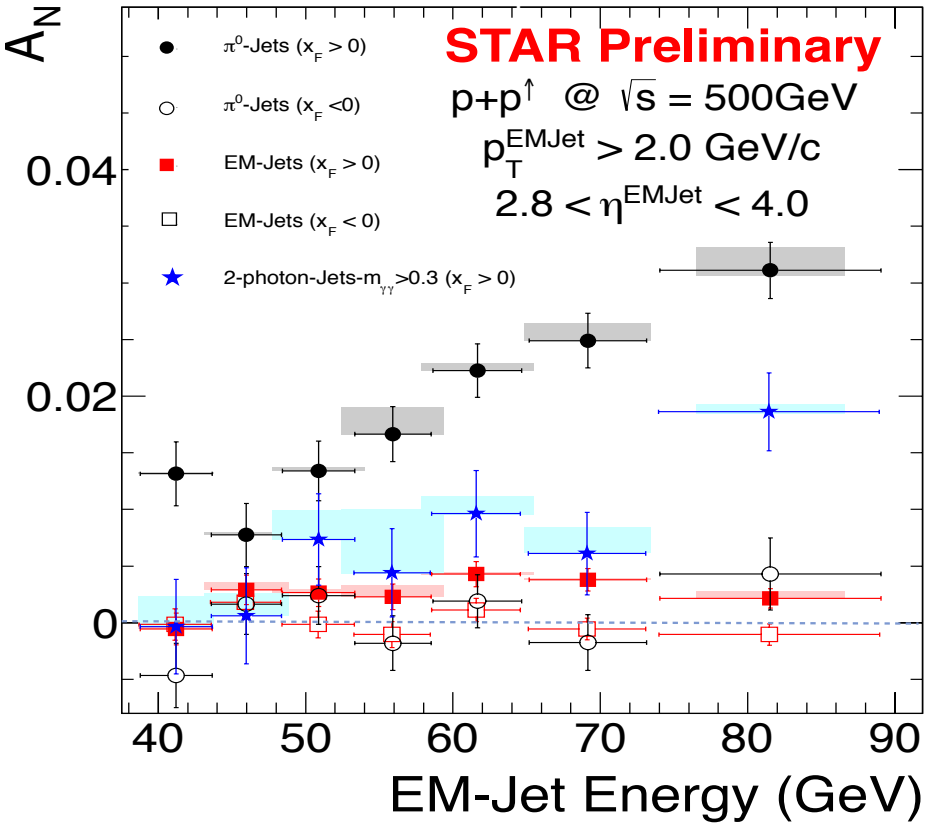
EM-Jets –
with no. photons >2

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

https://indico.triumf.ca/contributionDisplay.pycontribId=349&sessionId=44&confId=1383

- Asymmetries for jettier events are much smaller

A_N vs. EM-Jet Energy



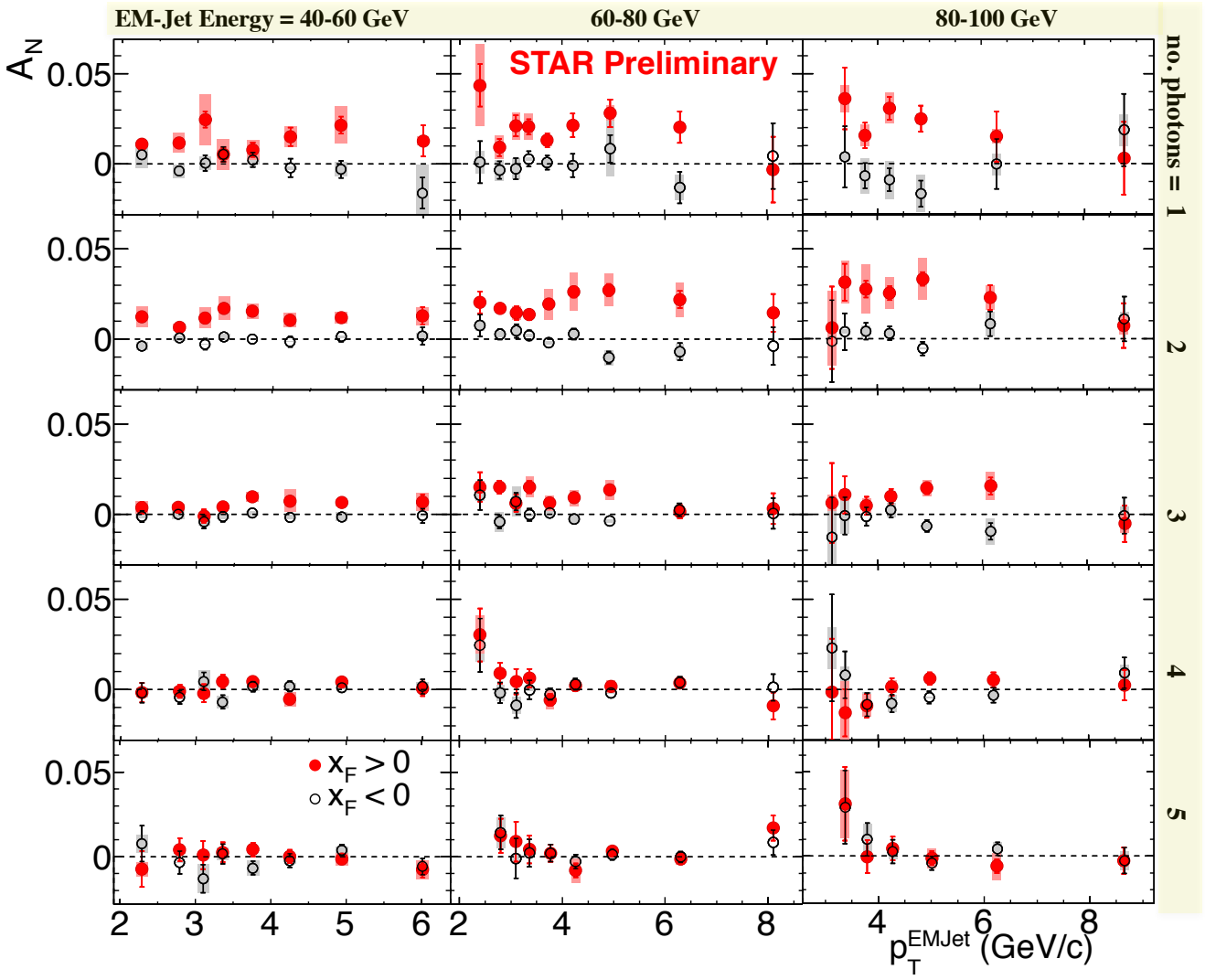
π^0-Jets –
2γ-EM-Jets with
$m_{\gamma\gamma}$ <0.3
$Z_{\gamma\gamma}$ <0.8

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

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.pycontribId=349&sessionId=44&confId=1383
✧ Asymmetries for jettier events are much smaller

A_N for different # photons in EM-Jets

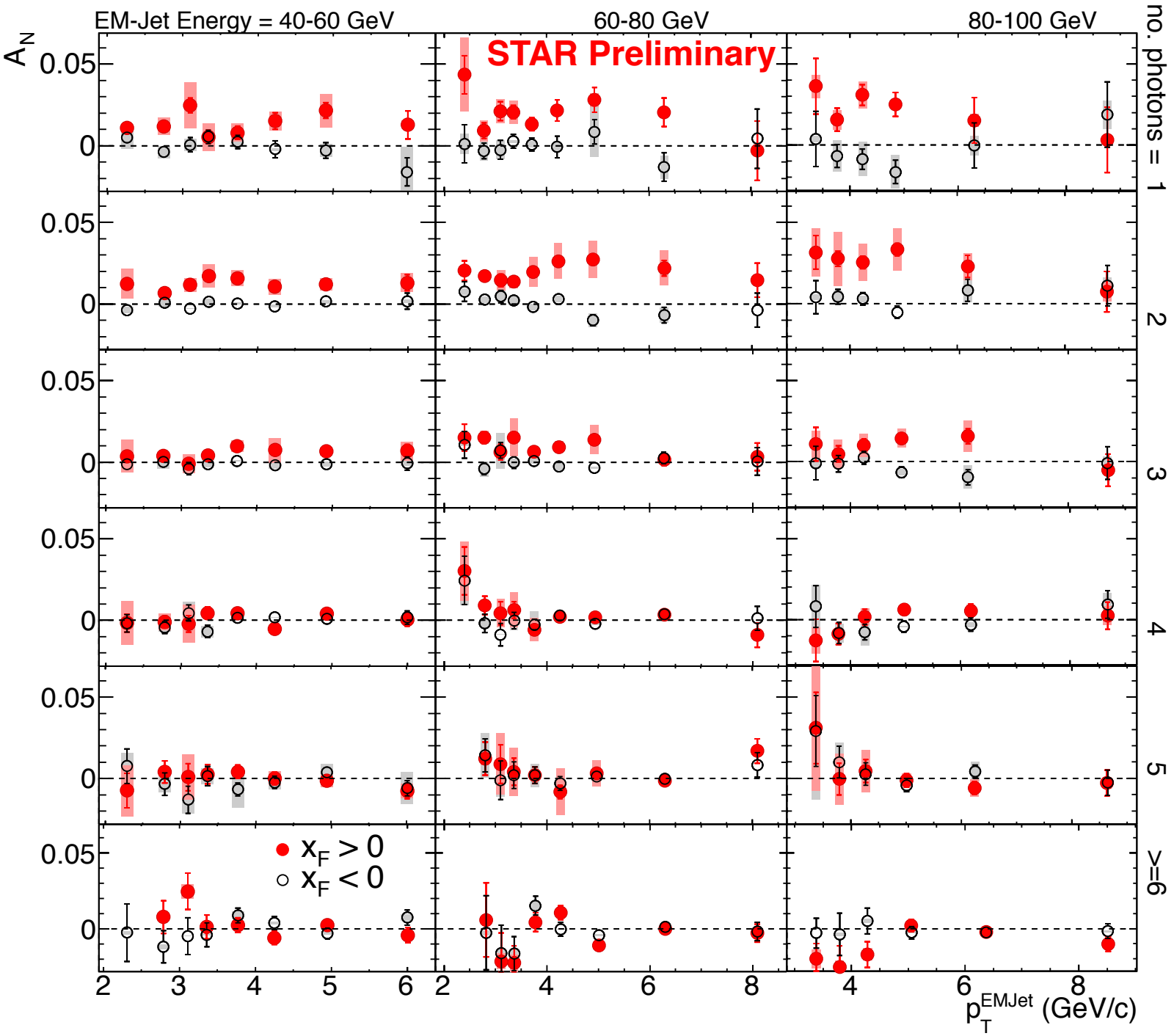


- 1-photon events, which include a large π^0 contribution in this analysis, are similar to 2-photon events
- Three-photon jet-like events have a clear non-zero asymmetry, but substantially smaller than that for isolated π^0's
- A_N decreases as the event complexity increases (i.e., the "jettiness")
-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

Summary

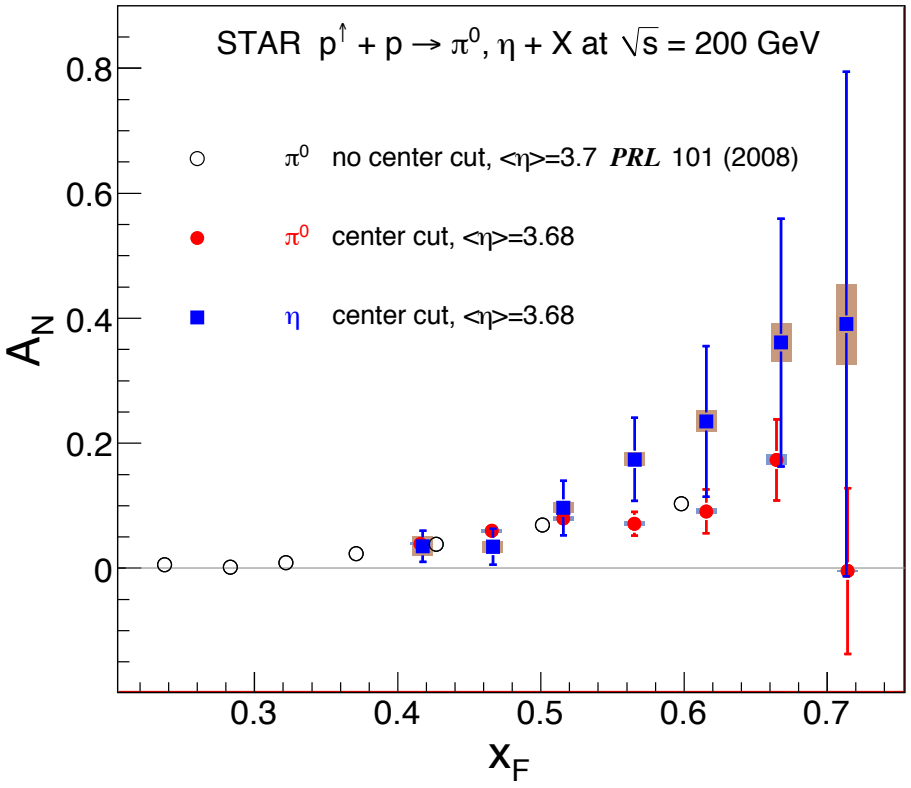
- ✧ EM-Jets are reconstructed from photons detected in the FMS at STAR.
- ✧ Jets with isolated π^0 have large asymmetry as seen before.
- ✧ Three-photon jet-like events have a clear non-zero asymmetry, but substantially smaller than that for isolated π^0's.
- ✧ A_N decreases as the event complexity increases(i.e.,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

Backup slides

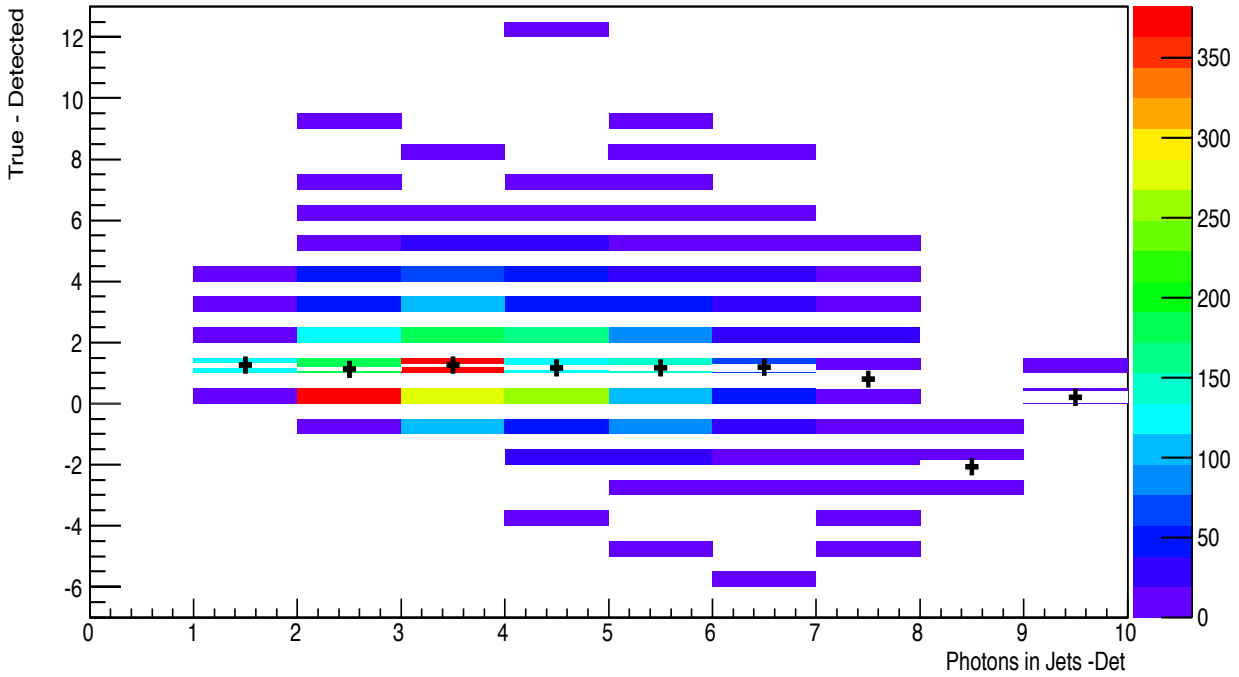

EM-Jet Energy = 40-60 GeV
60-80 GeV
80-100 GeV
STAR Preliminary
A_N
no. photons = 1
2
3
4
5
>=6
$x_F > 0$
$x_F < 0$
p_T^{EMJet} (GeV/c)

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

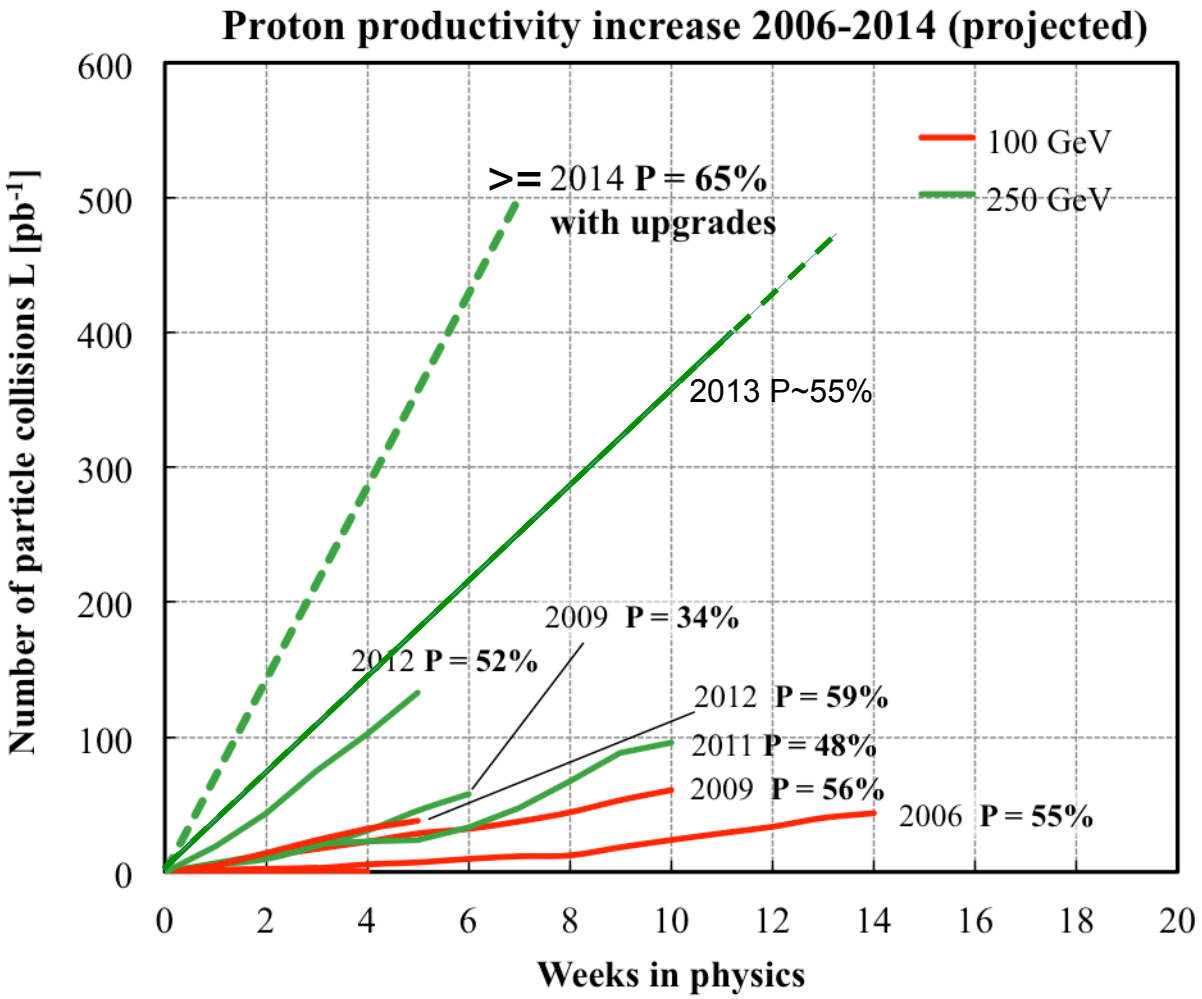
PRD 86-051101



PYTHIA simulations



Systematics arising from intermixing of event classes


Proton productivity increase 2006-2014 (projected)
Number of particle collisions L [pb-1]
Weeks in physics
100 GeV
250 GeV
>= 2014 P = 65%
with upgrades
2013 P~55%
2012 P = 52%
2009 P = 34%
2012 P = 59%
2011 P = 48%
2009 P = 56%
2006 P = 55%
0
100
200
300
400
500
600
0
2
4
6
8
10
12
14
16
18
20