Transverse Spin Asymmetries at STAR

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Indiana University Cyclotron Facility

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Deep Inelastic Scattering
(DIS2003)

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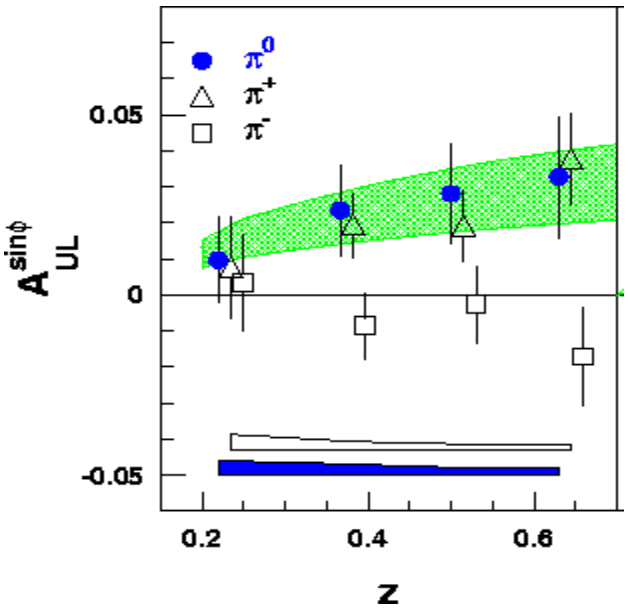
Single-spin asymmetries in π production

HERMES:

$e + p_{\rightarrow} \rightarrow e' + \pi + X$

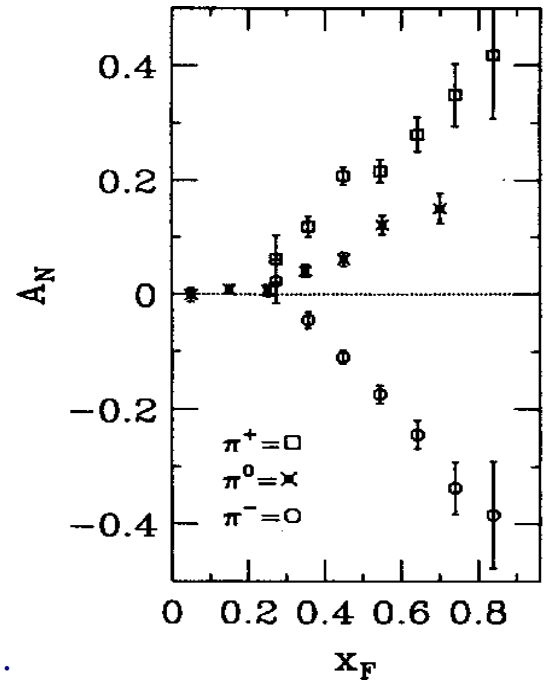


- HERMES Collab., PRD64 (2001) 097101.
- HERMES Collab., PLB 535 (2002) 85.
- HERMES Collab., PRL 84 (2000) 4047.

E704:

$\sqrt{s}$=20 GeV, p_T=0.5-2.0 GeV/c:

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



- π^0 – E704, PLB261 (1991) 201.
- $\pi^{+/-}$ - E704, PLB264 (1991) 462.

Some models:

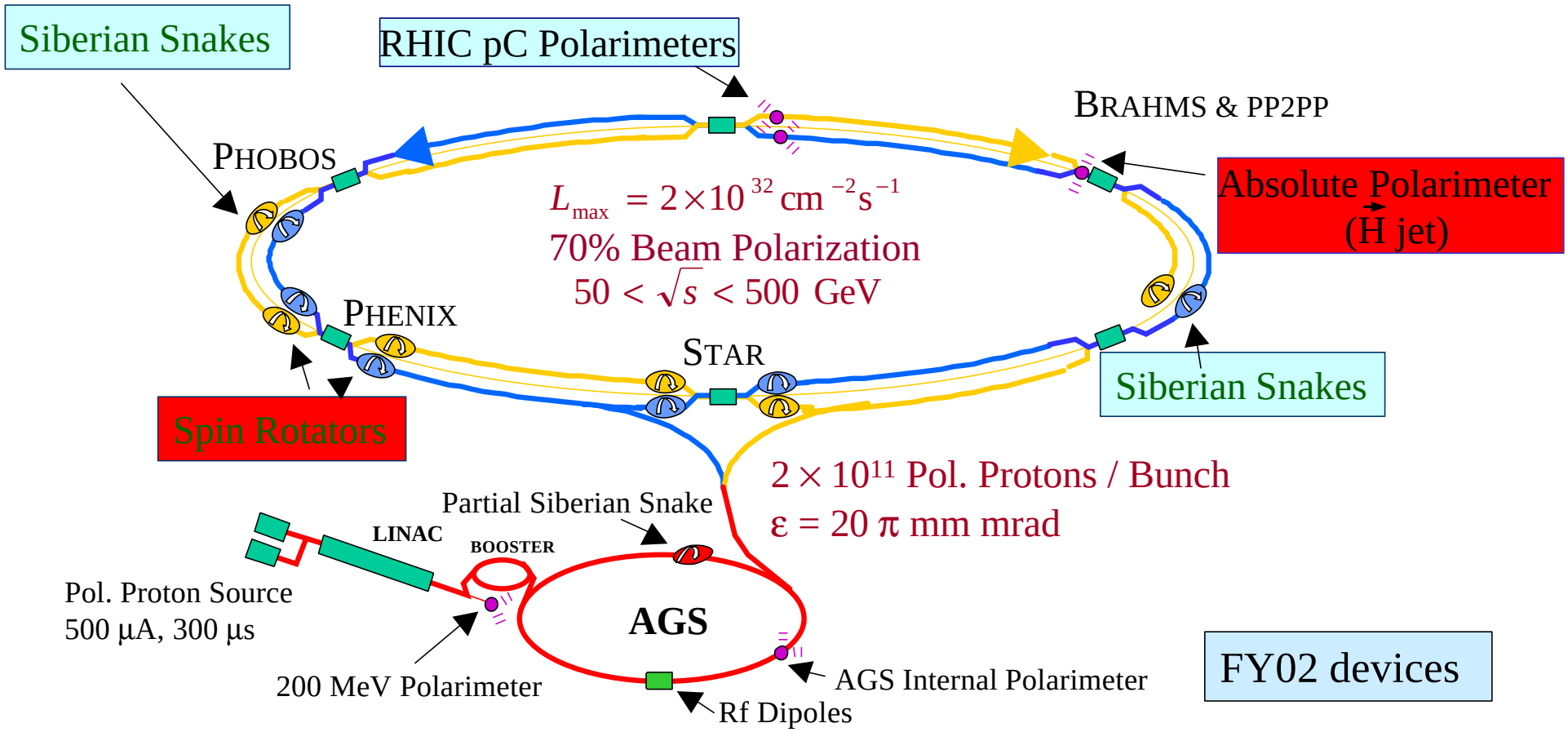
- Transversity structure function + Collins fragmentation function
- k_T in distributions (Sivers approach)
- Higher twist effects

- Anselmino, et al., PLB442(1998)470
- Anselmino, et al., PRD 60(1999)054027
- Qiu and Sterman, PRD 59(1998)014004

- **Measurements of A_N** in $p_{\uparrow} + p \rightarrow \pi^0 + X$ at vs=200 GeV to test model predictions in harder scattering regime (PYTHIA)
- Models also should be able to describe the **cross section**...

STAR spin

Polarized Proton Acceleration at RHIC

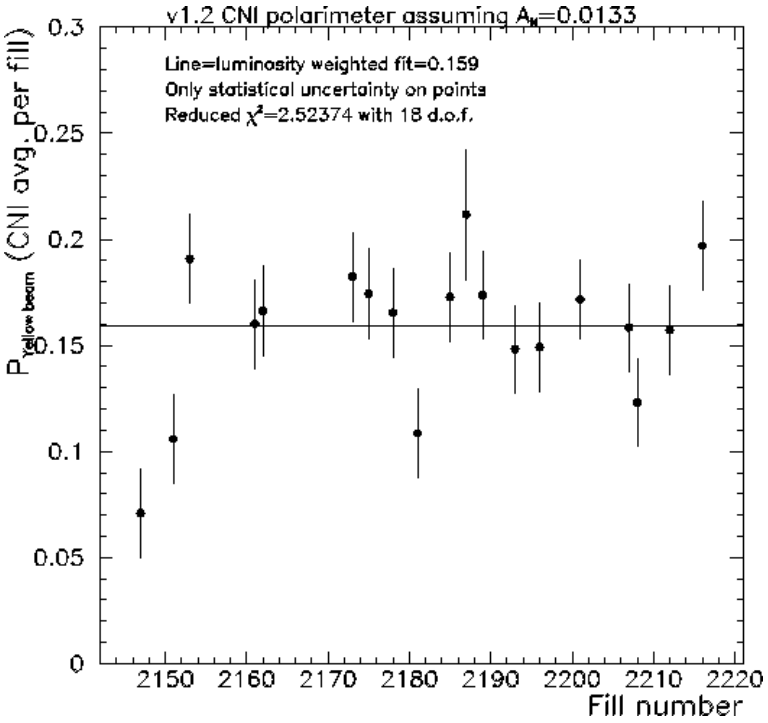


BROOKHAVEN NATIONAL LABORATORY

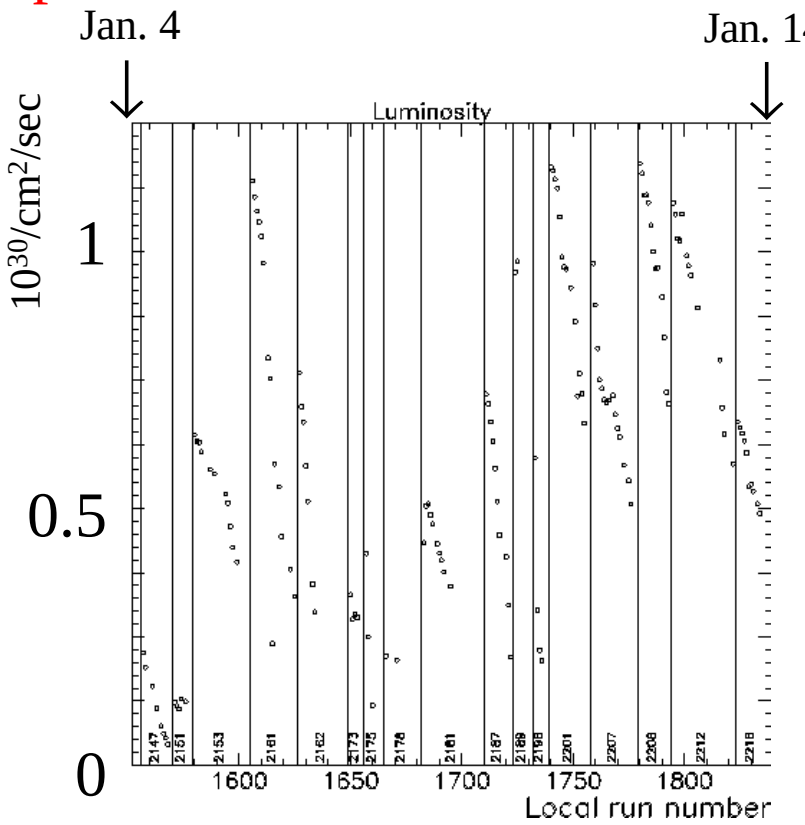
Polarized protons at RHIC

...Data collected at STAR during the first polarized proton run at RHIC in January 2002... At injection, ~47 spin-flips from source to STAR Interaction Region

First collisions of polarized protons ever seen in a collider...



No measurements of A_N(CNI) at 100 GeV.... We assume A_N(CNI)=0.013 at 100 GeV.... $<P_{beam}>$=16% in first part of Jan.



Typical data rate ~300 Hz

Integrated luminosity reported here ~ 0.15 pb^{-1}

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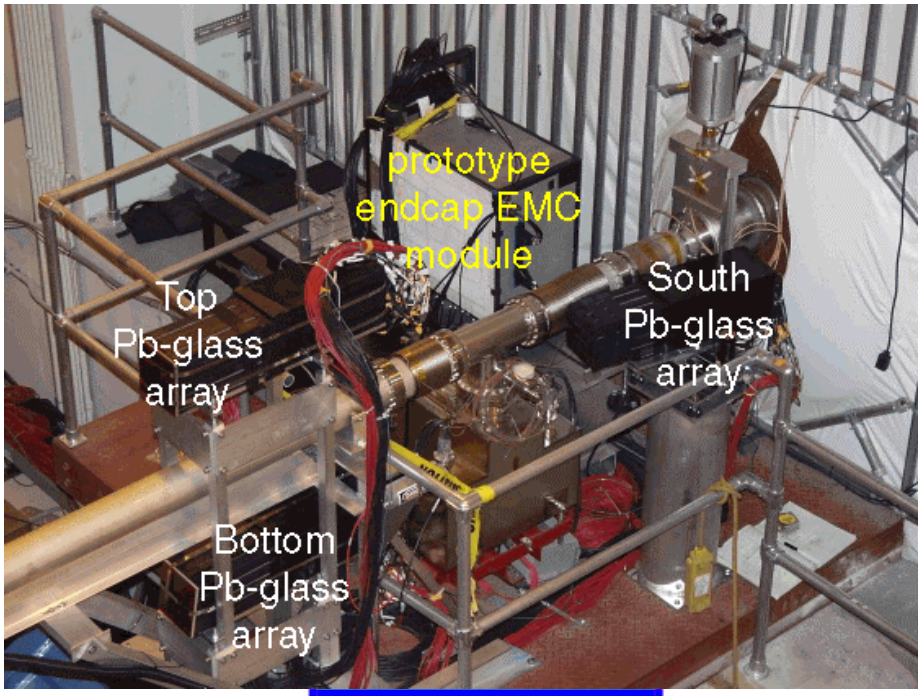
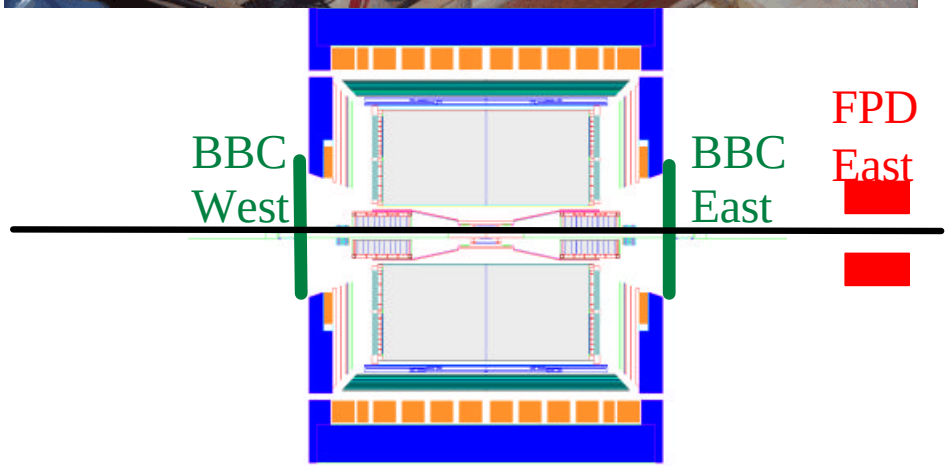
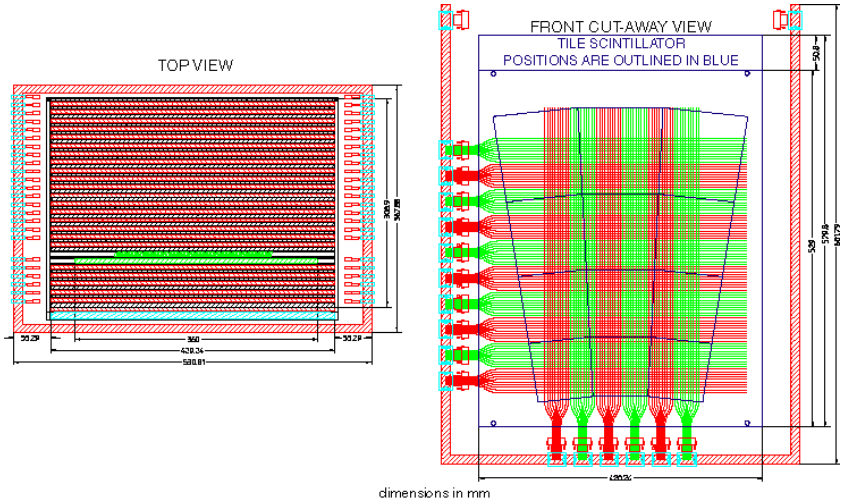
Forward π^0 Detector (FPD) at STAR

Located east of STAR detector at z=750cm:





- Pb-glass detectors provided by IHEP-Protvino
- prototype Endcap EMC module (pEEMC)



π^0 identification with pEEMC:

- 24 layer Pb-scintillator sampling calorimeter (segmented into 12 towers)
- 2 orthogonal planes of finely segmented triangular scintillator strips (Shower-Maximum Detector, or SMD)

Single-spin transverse asymmetries at STAR from four single arm experiments utilizing different technology...

Measurement Details

? FPD Trigger = ~20 GeV electron equivalent deposited in any arm together with BBC E.W coincidence

? Both proton beams polarized—spin sort by polarization direction of one beam only, averaging over other—$x_F>0$

$$A_N = \frac{+/-1}{P_{beam}} \frac{N_{up} - R\,N_{down}}{N_{up} + R\,N_{down}}$$

$N_{up(down)}$ = number of counts with beam polarized up (down)

$$R = \frac{Lumi_{up} * Livetime_{up}}{Lumi_{down} * Livetime_{down}}$$

= spin-dependent yield normalization ratio

P_{beam} = beam polarization

Kinematic ranges:

$\sqrt{s}$ = 200 GeV (DIS:W)

$x_F = p_z/p_{z,max} \sim E_\pi/100$ GeV = 0.2-0.6 (DIS: $z=E_\pi/\nu$)

p_T =1-4 GeV/c

$\eta = -\ln[\tan(\theta/2)]$ = 3.4-4.0 (θ)

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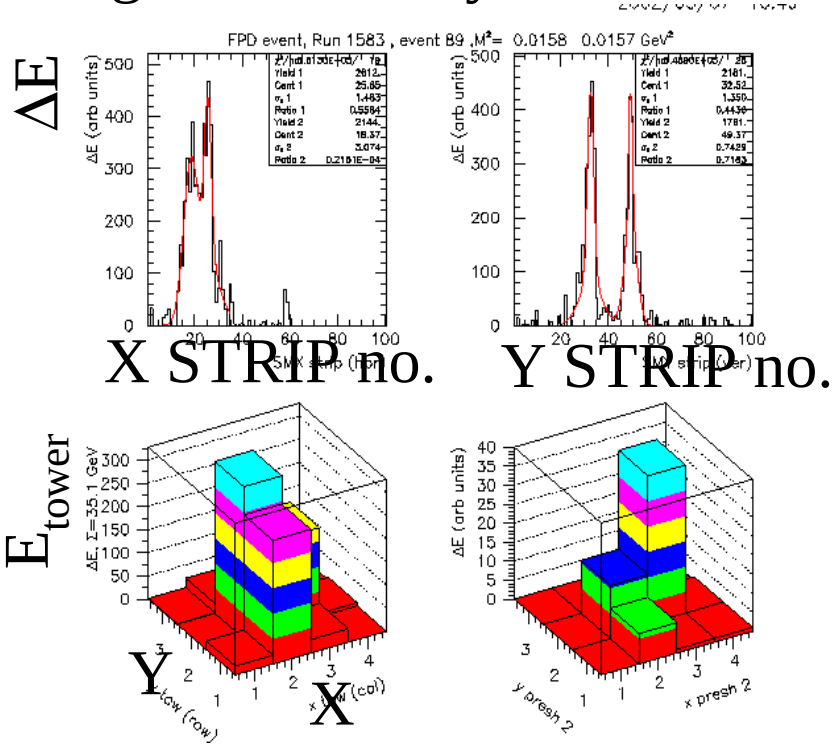
π^0 signal extraction

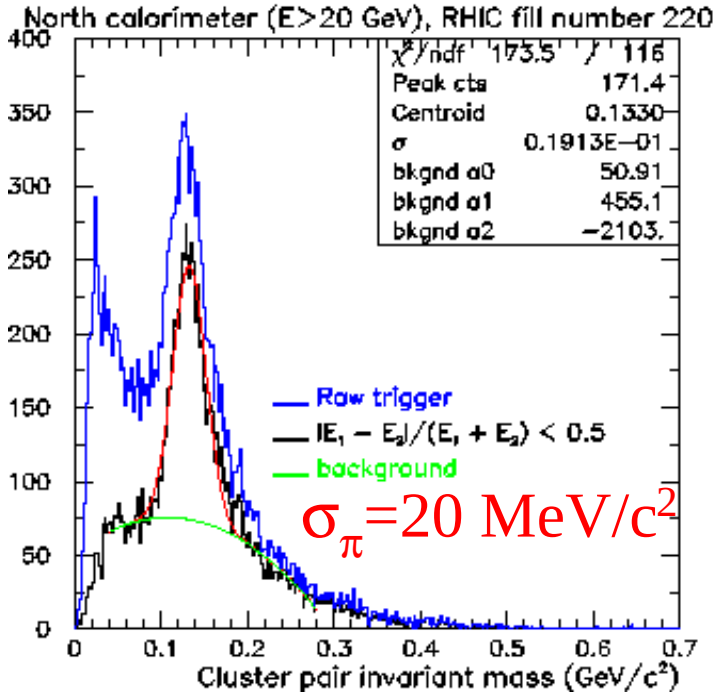
$$M_{\gamma\gamma} = E_{tot}\,\mathrm{sqrt}(1-z_\gamma^2)\,\sin(\phi_{\gamma\gamma}/2)$$
$$\sim E_{tower}\,\mathrm{sqrt}(1-z_\gamma^2)\,d_{\gamma\gamma}/2z_{vertex}$$

- E_{tower}=sum over towers ($\delta E/E=17\%/\sqrt{E}$)
- $d_{\gamma\gamma}$=γ separation from centroid separation of two peaks
- z_γ=|E1-E2|/(E1+E2) from relative yield in two peaks in SMD profile distribution ($\delta E/E=30\%/\sqrt{E}$)
- z_{vertex} = collision vertex

Single event analysis:



Results in π^0 peak:



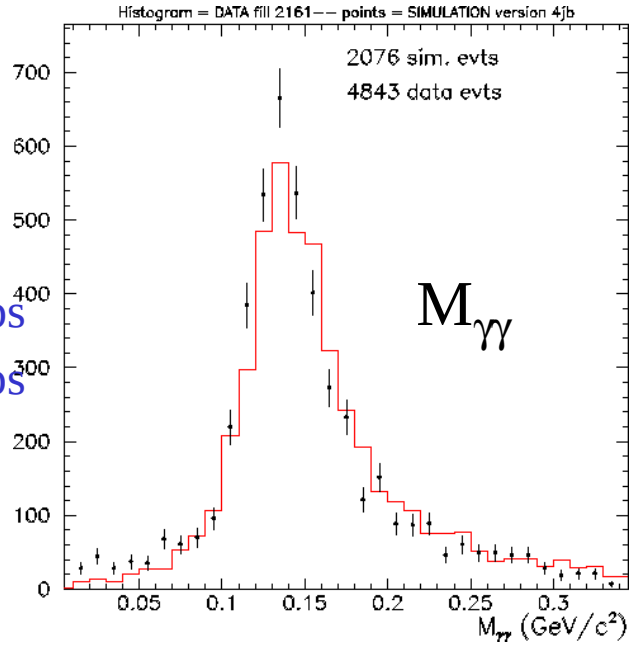
Simulation of pEEMC in STAR

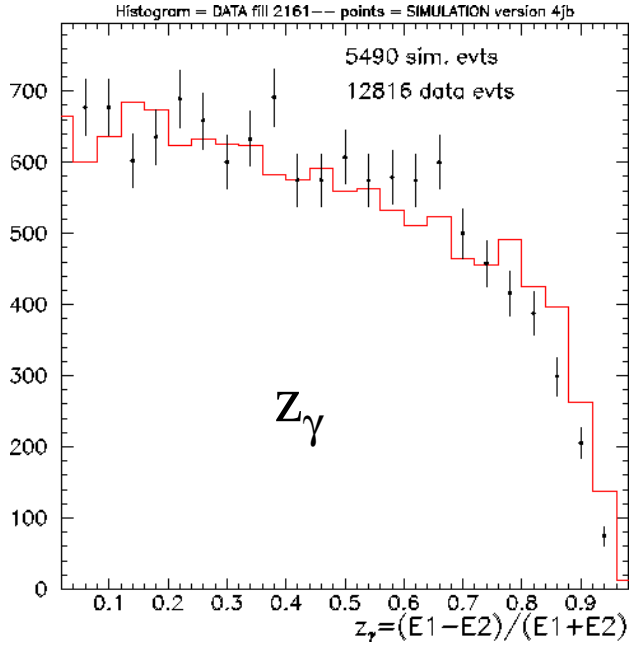
Scheme:

- Events generated with PYTHIA (min bias)
- Events stored if >25 GeV pointing to "box"
- Full PYTHIA record included with events
- GEANT simulation of pEEMC
- Reconstruct using algorithm applied to data

Cuts applied:

- E_{tow}>31 GeV
- 13 < SMD-Y centroid < 90 strips
  12 < SMD-X centroid < 48 strips
- SMD-X or SMD-Y > 1 peak
- z_γ<0.3





- Histogram = data
- Points = simulation norm. to data

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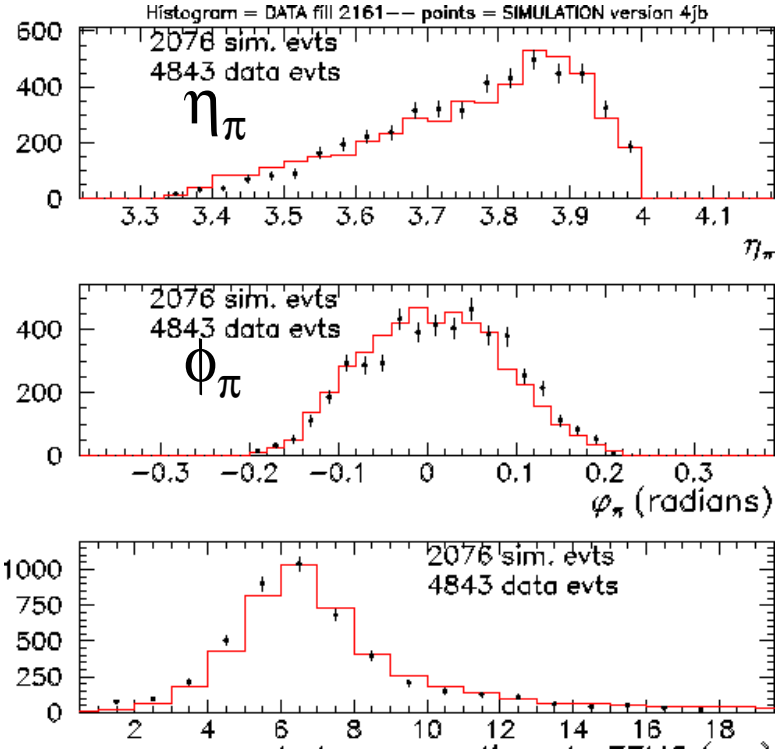
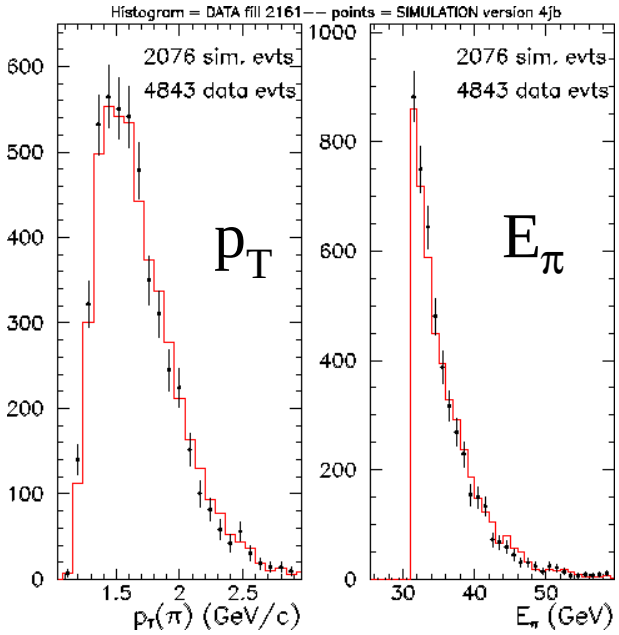
Simulation of pEEMC (cont.)

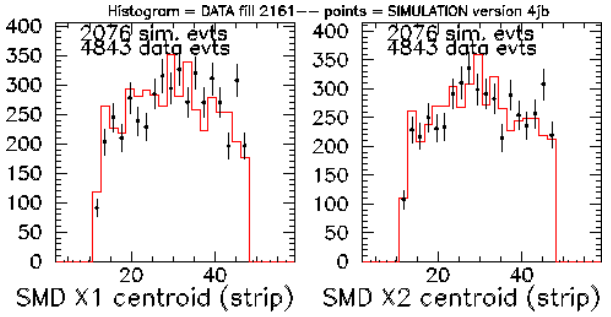
Angular variables:



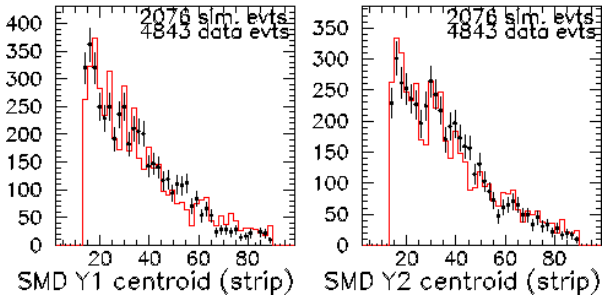
Photon separation at pEEMC (cm)



Single photon positions: vertical



horizontal



PYTHIA+GEANT simulation describes data---p^0 mesons and background from collisions...

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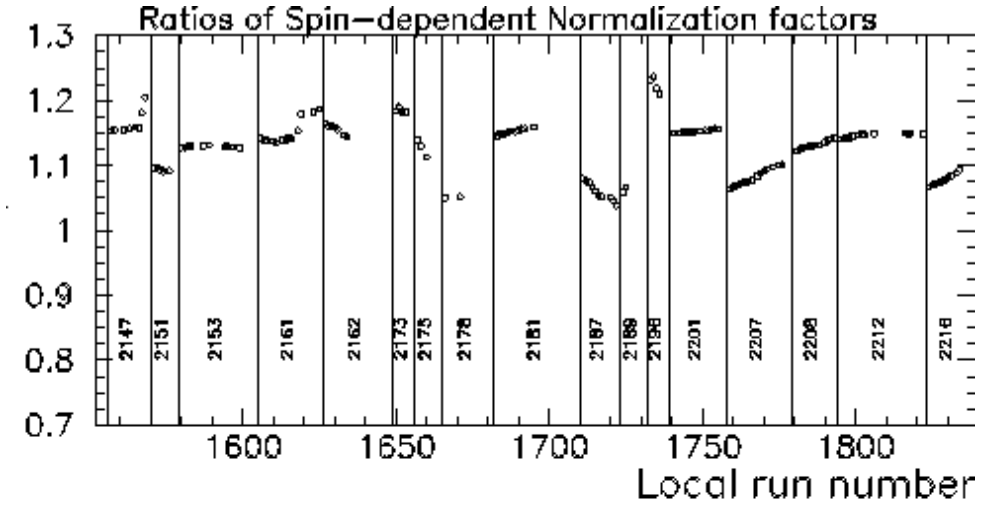
Spin-dependent normalizations

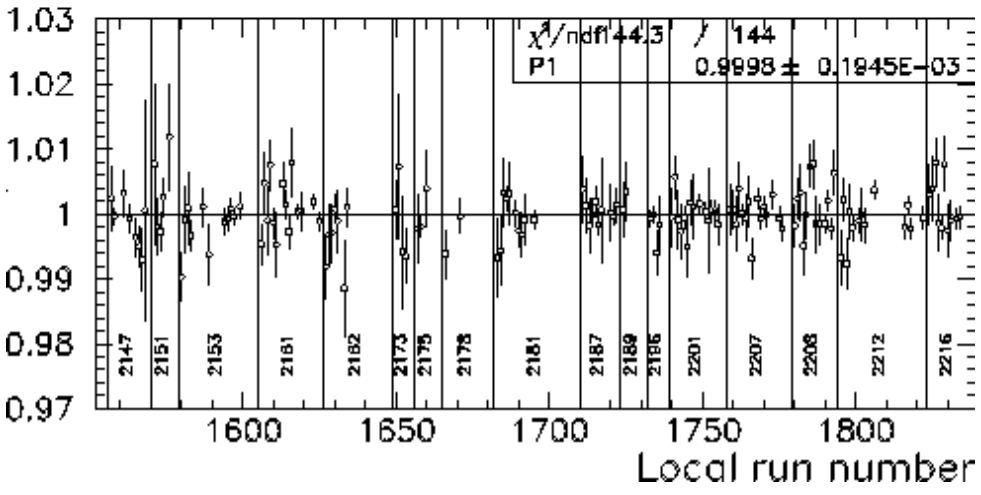
- 55 beam crossings of varying polarization and specific luminosity occurs every 213ns
- Relative luminosity normalization performed with BBC's…

$$\frac{Lumi_{up}}{Lumi_{down}}$$



← Correction on the order of ~1.15...

$$\frac{Livetime_{up}}{Livetime_{down}}$$



← Relative livetime correction stable and consistent with 1.000

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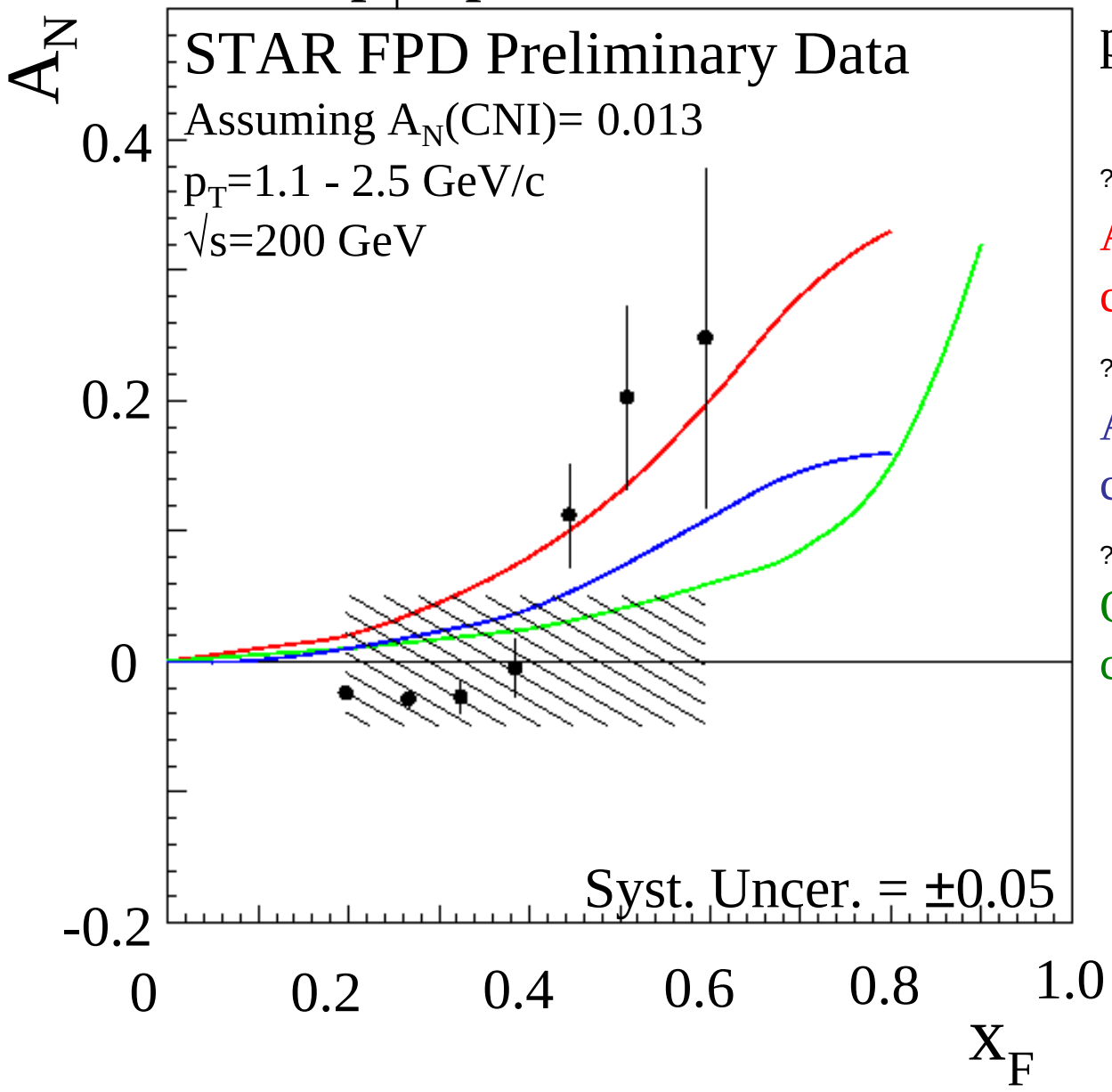
Analyzing power:

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



Theory predictions at p_T=1.5 GeV/c:

- Collins effect
  Anselmino, et al., private communication
- Sivers effect
  Anselmino, et al., private communication
- Twist 3 effect
  Qiu and Sterman, private communication

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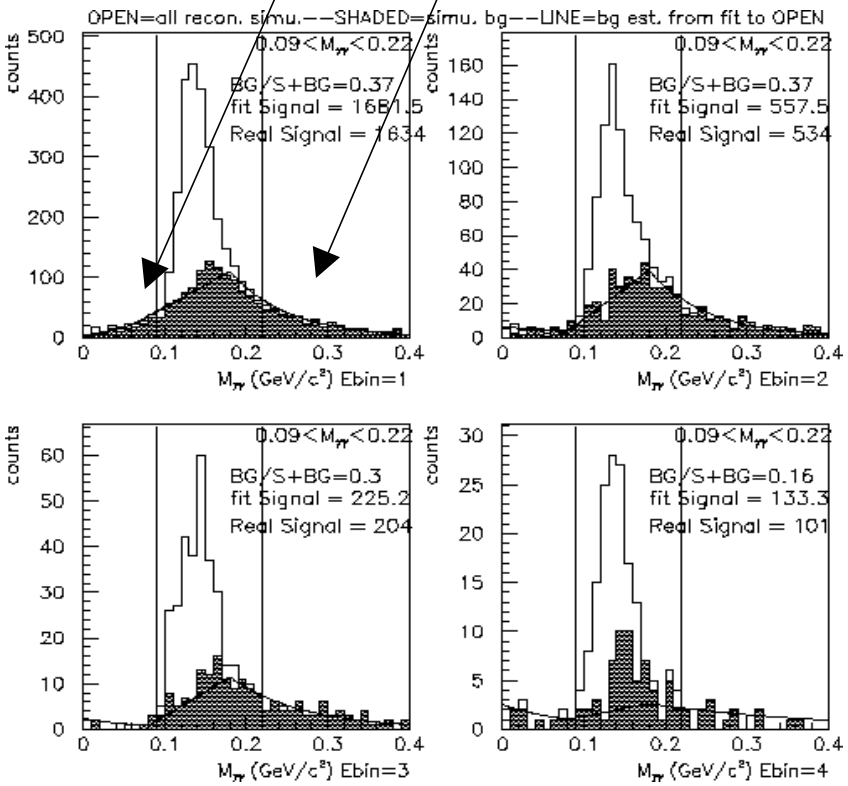
Corrections to Cross Section

Background Correction:

→dominated by jet background and hadronic background

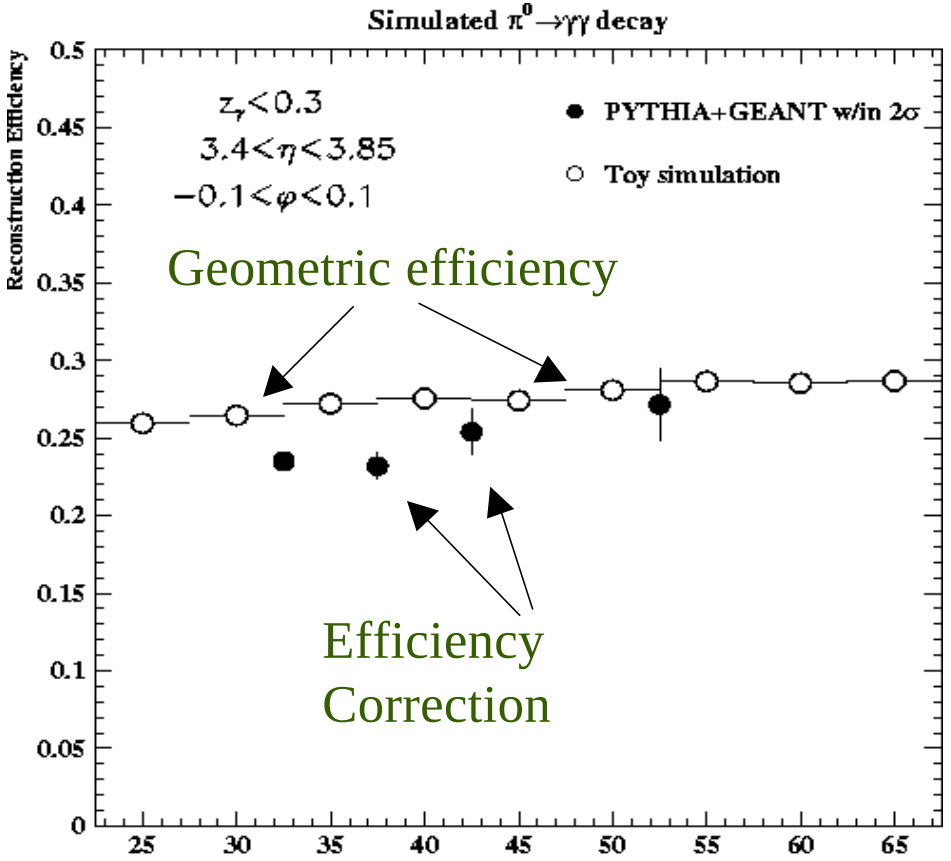


Open = reconstructed simulation

Shaded = background

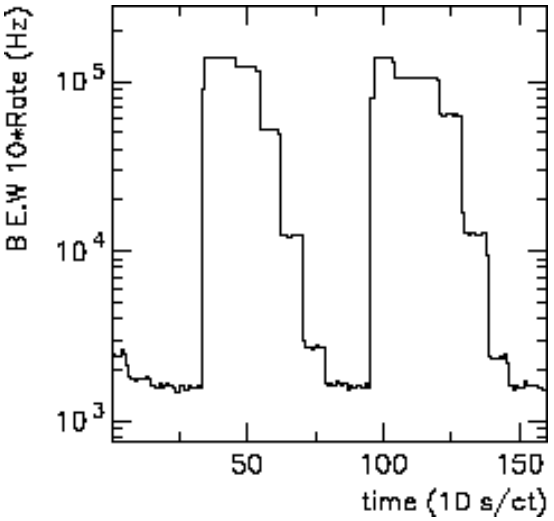
Efficiency Correction:

→dominated by geometry of calorimeter

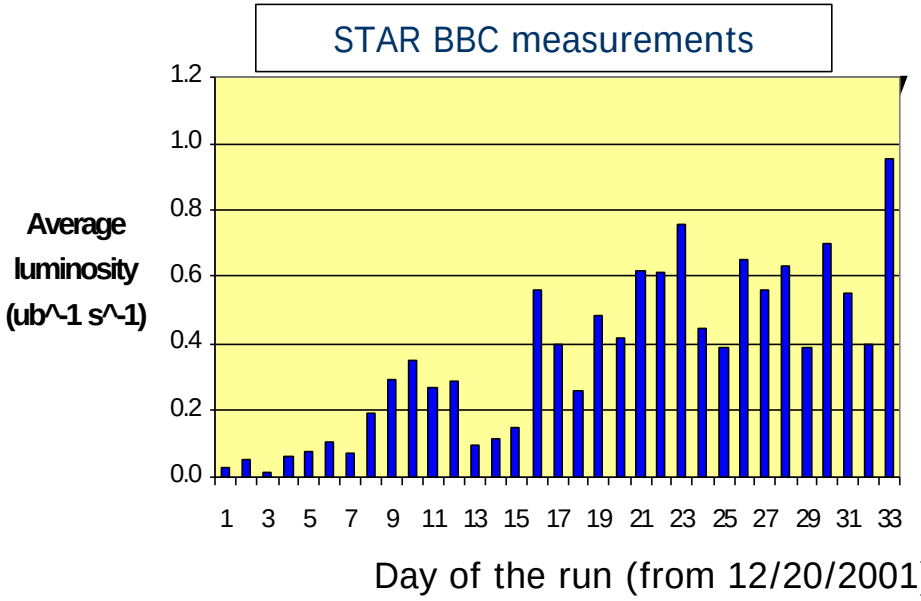


Absolute Luminosity Measurement

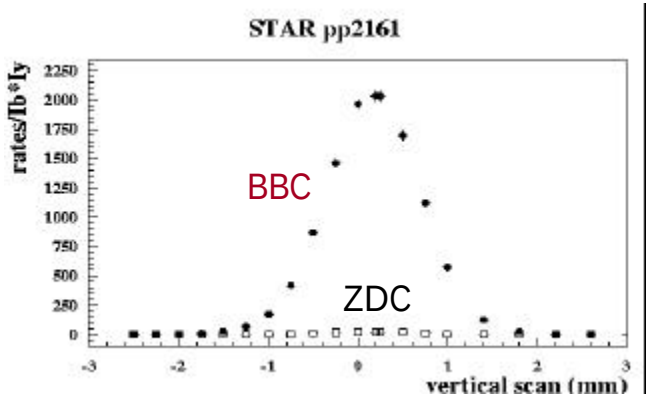
Absolute normalization from BBC E.W:



-BBC E•W coincidence rate vs time during a **Van der Meer scan** that **determines the beam size,** and hence the luminosity, by controlled relative steering of the colliding beams.



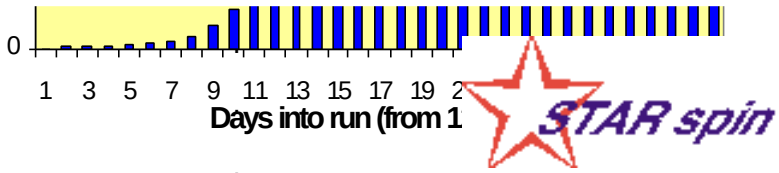
Scaler info sent to RHIC to enable MCR to steer beams at STAR



- RHIC delivers 10^{30} cm^{-2} s^{-1}
- Integrated luminosity recorded@STAR ~0.3 pb^{-1}

From simulations: BBC "sees" 53% of tot pp cross section,

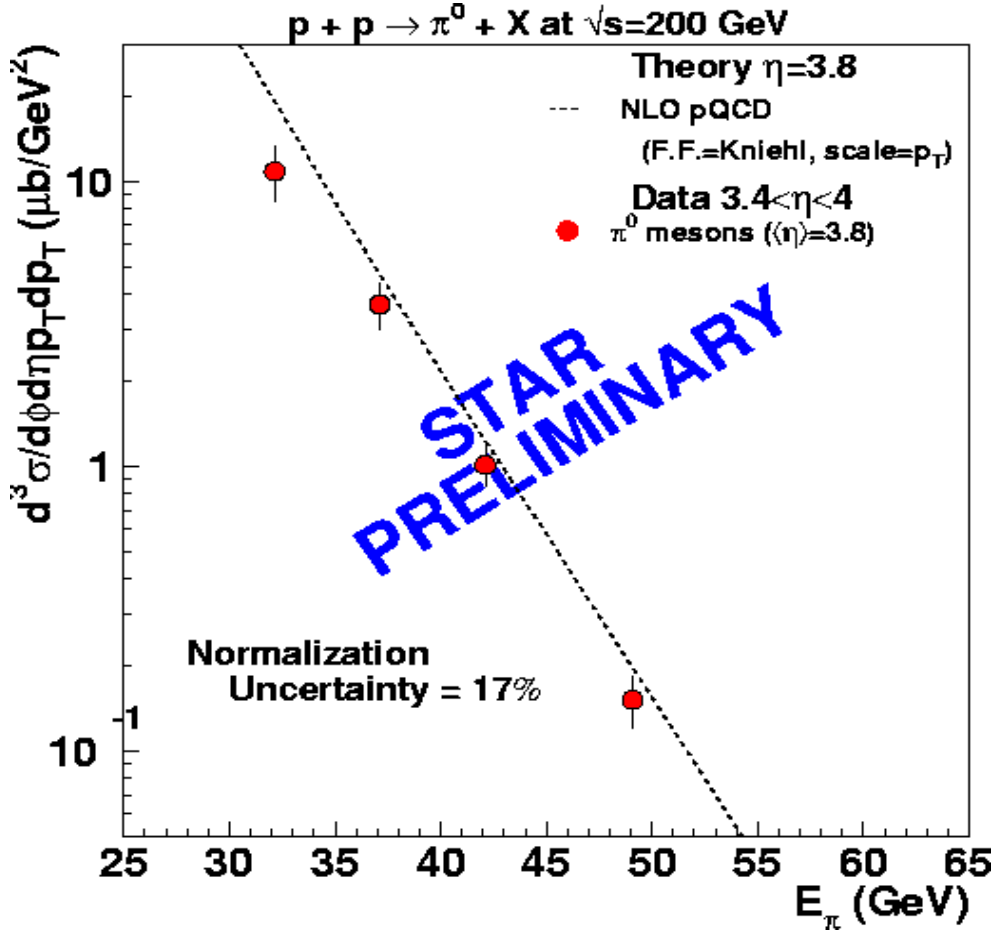
Rate of 27 kHz ~ Luminosity of 10^{30} cm^{-2} s^{-1}



J. Kiryluk (UCLA), A. Drees (BNL)

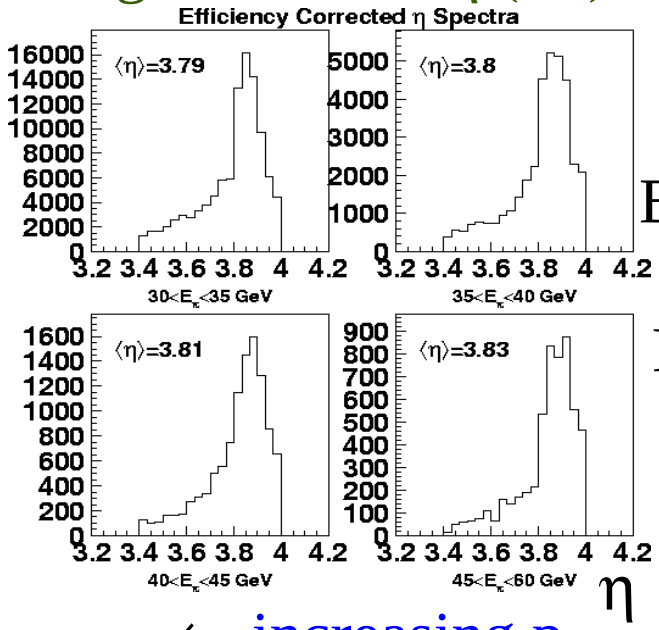
Differential Cross Section

No prior data exist at these kinematics...



...Theoretical uncertainties presently not included...

Data collected over angular bite of η (~θ):



Beam ⊗ Pipe

NLO – W. Vogelsang, private comm.

← increasing p_T...

The data are in fair agreement with NLO pQCD calculation...

Summary

Data from first year polarized proton running at STAR
→First observations of polarized proton collisions ever seen in collider environment....

- Analyzing power is an increasing function of x_F, and is sizable, consistent with model predictions based on E704 data
- Cross section for π^0 production in fair agreement with NLO pQCD calculations. No prior data exist at STAR forward kinematics...

Second polarized proton run at RHIC
happening as we speak...
Stay tuned...