Forward p+p->π^0+X Cross-Sections at STAR

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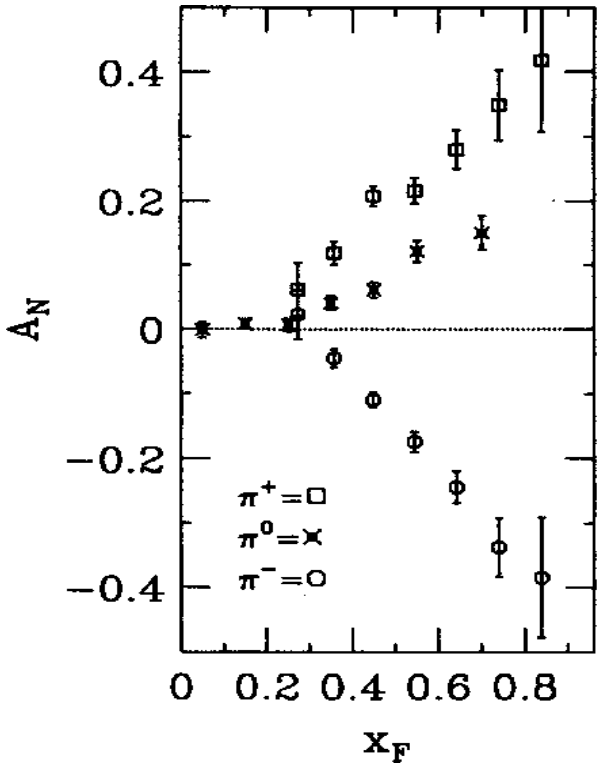
Motivation

- Spin asymmetries in π^0 production: $p_\uparrow + p \rightarrow \pi + X$

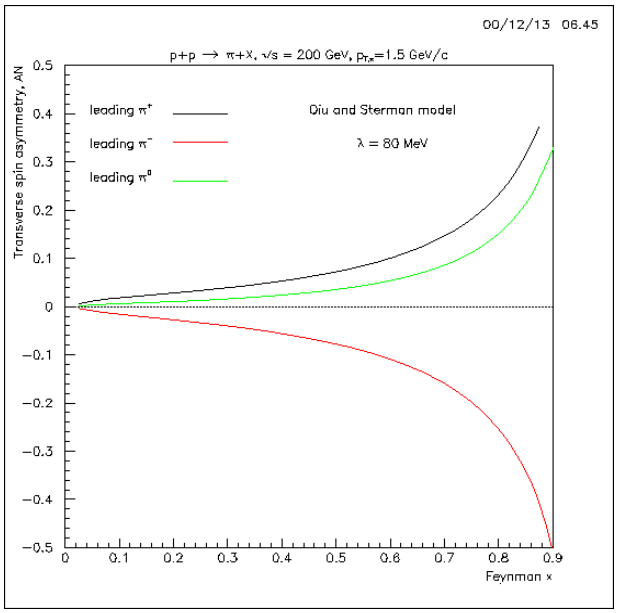
$A_N = 1/P_{beam}(\sigma_{up}(x_F)-\sigma_{dn}(x_F))/(\sigma_{up}(x_F)+\sigma_{dn}(x_F))$

Non-zero A_N measured in E704 at Fermilab at sqrt(s)=20 GeV, p_T=0.5-2.0 GeV/c:



- π^0 - D.L. Adams, et al., Phys. Lett. B261(1991)201.
- $\pi^{+/-}$ - D.L. Adams, et al., Phys. Lett. B264(1991)462.

Predictions by different theorists expect non-zero A_N values, attributed to different dynamics, to persist at RHIC energies: sqrt(s)=200 GeV...



Qiu and Sterman, Phys. Rev. D59 (1998) 014004.

See also:

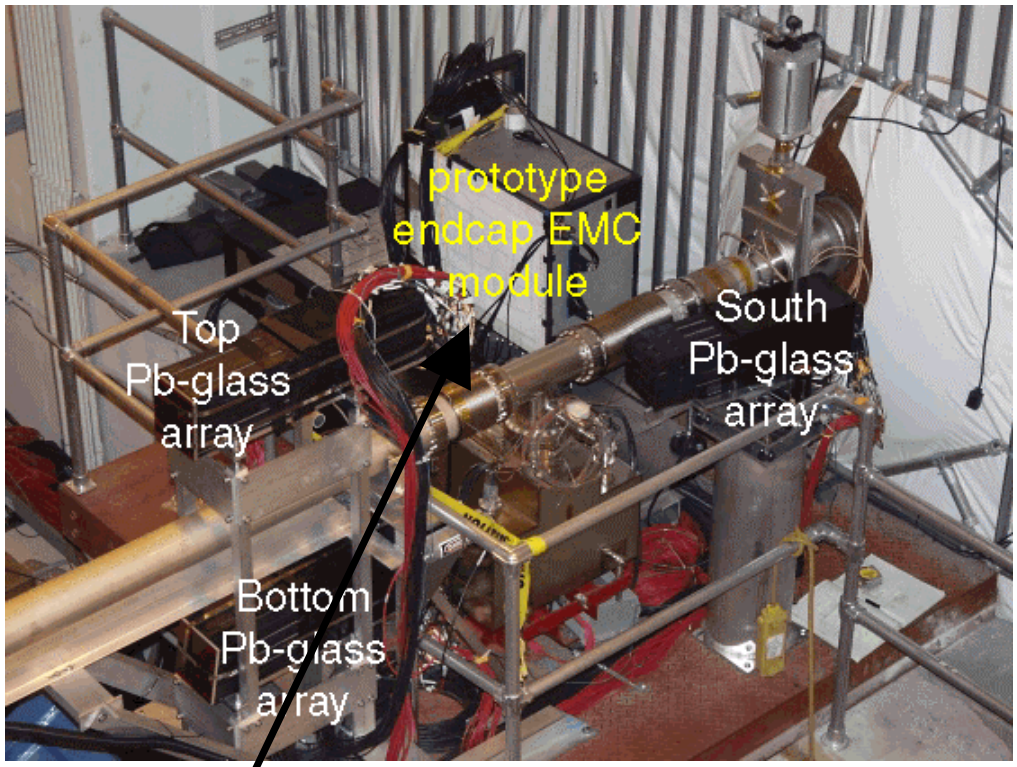
Anselmino, et al., hep-ph/9808426; hep-ph/9901442.

Cross section data could help constrain models which describe E704 data...

Asymmetry analysis on January 2002 data currently underway...

Forward π^0 Detector (FPD)

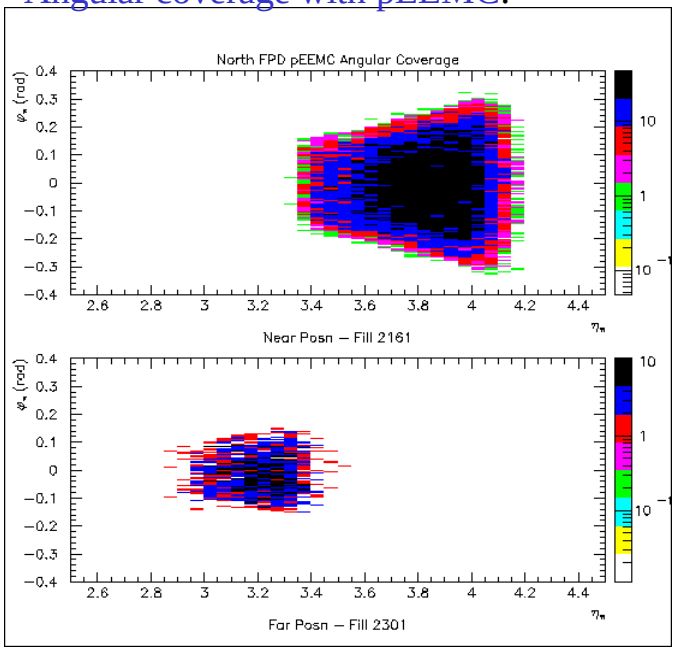
Located east of STAR detector at z=750cm:



Analysis focus on data from prototype of STAR Endcap Electromagnetic Calorimeter (pEEMC)

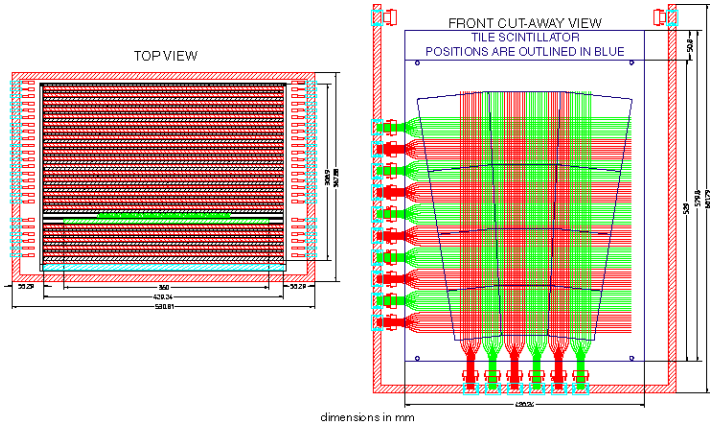
Data collected in "near" and "far" positions…

Angular coverage with pEEMC:



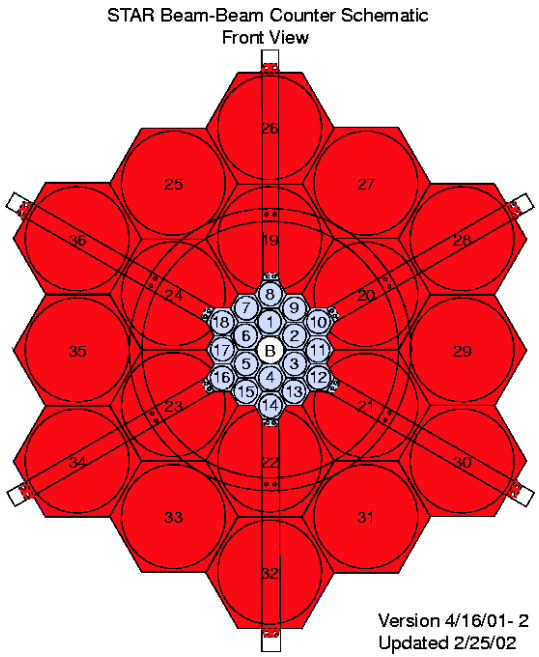
π^0 identification possible with pEEMC:

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



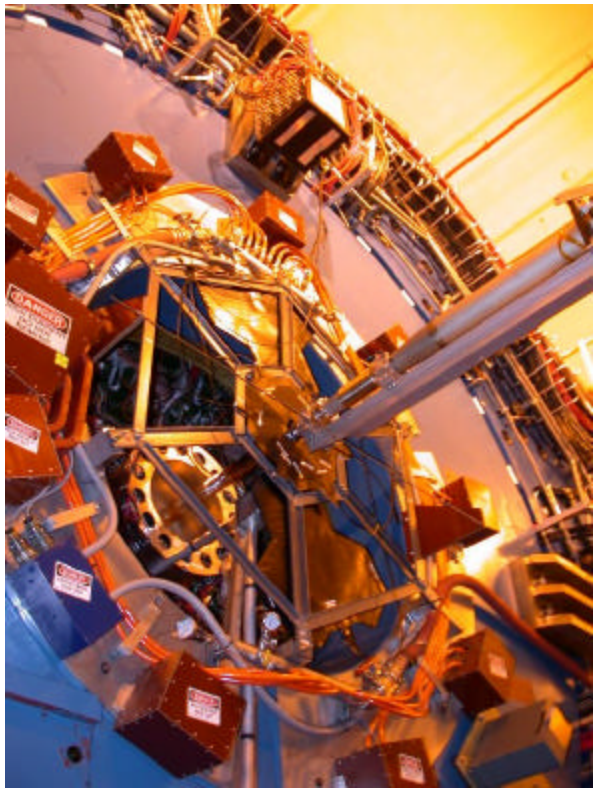
Beam-Beam Counters

Luminosity normalization performed with Beam-Beam Counters (BBC) at STAR…

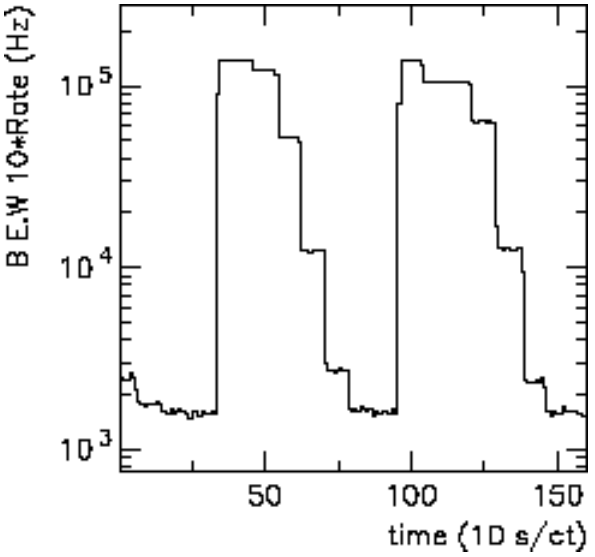


Coincidence between scintillator annuli at z=+/-350cm to define collision at interaction region…

On the west side of STAR…



Absolute normalization of BBC from transverse scan of beams…



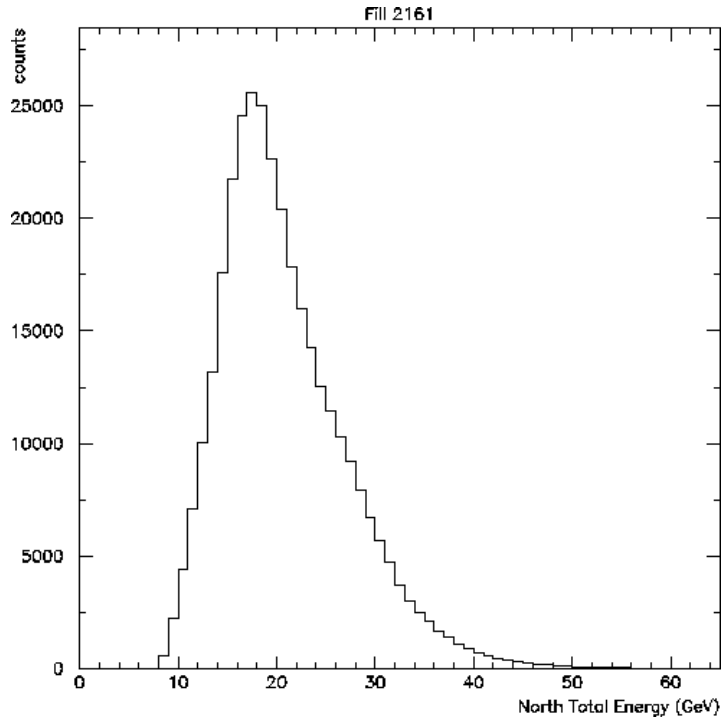
BBC coincidence rate during van der Meer scan

Data Selection

•Data collected at STAR during the first polarized proton run at RHIC in January 2002. N.B. These were the first collisions of polarized protons ever seen in a collider…

•Trigger = ~20 GeV electron equivalent deposited in pEEMC

•Coincidence condition on BBC counters



Kinematic ranges:

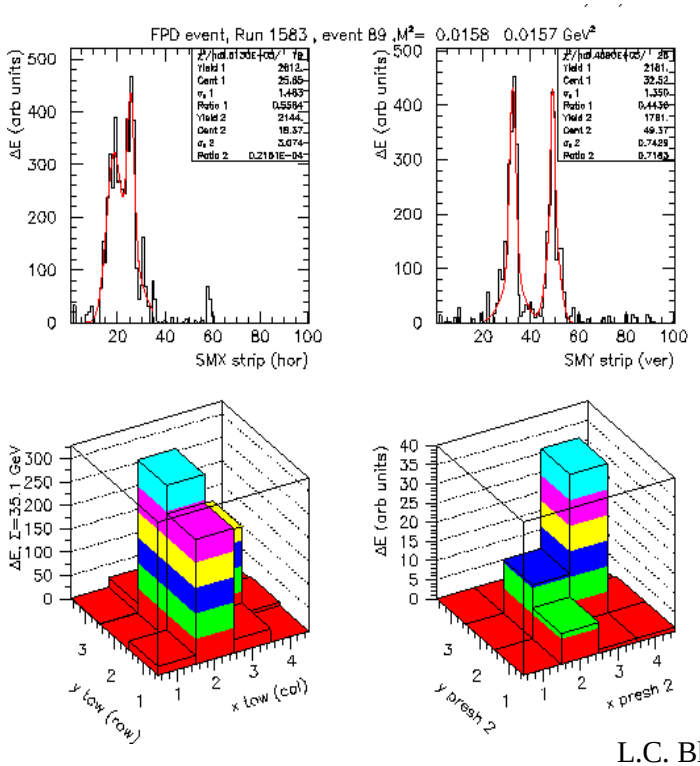
- sqrt(s)=200 GeV
- x_F=0.3-0.6
- η=3.0-4.1

π^0 signal extraction

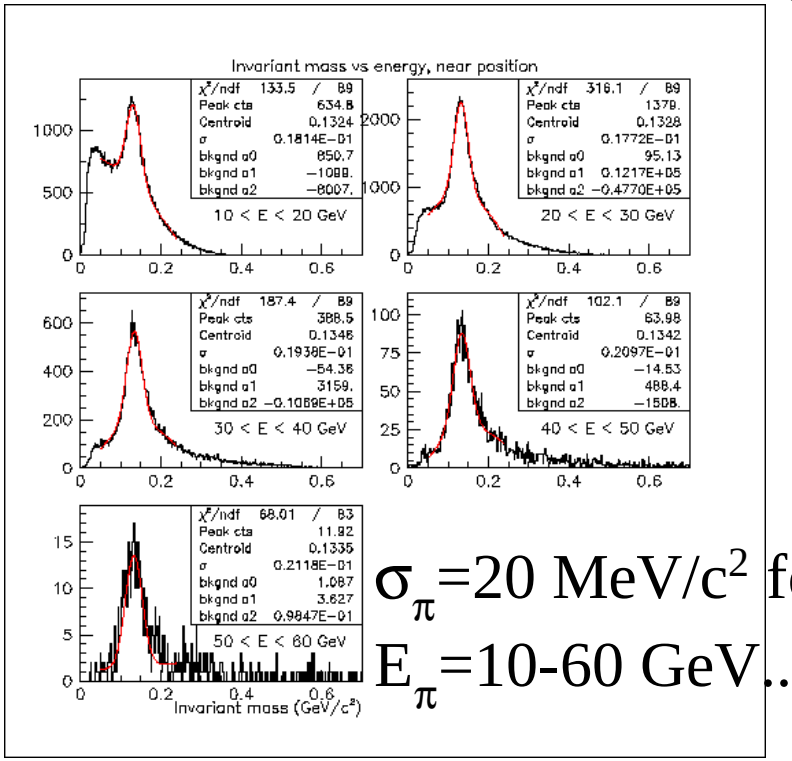
$$M_{\gamma\gamma} = E_{tot}\ \mathrm{sqrt}(1-z_\gamma^2)\ \sin(\phi_{\gamma\gamma}/2)$$

- E_{tot}=sum over towers ($\delta E/E=17\%/\sqrt{E}$)
- γ separation from centroid separation of two peaks
- z_γ=|E1-E2|/(E1+E2) from relative yield in two peaks in SMD profile distribution ($\delta E/E=30\%/\sqrt{E}$)
- Assume Z_{vertex}=750cm

Single event analysis:



Results in π^0 as a function of E_π:



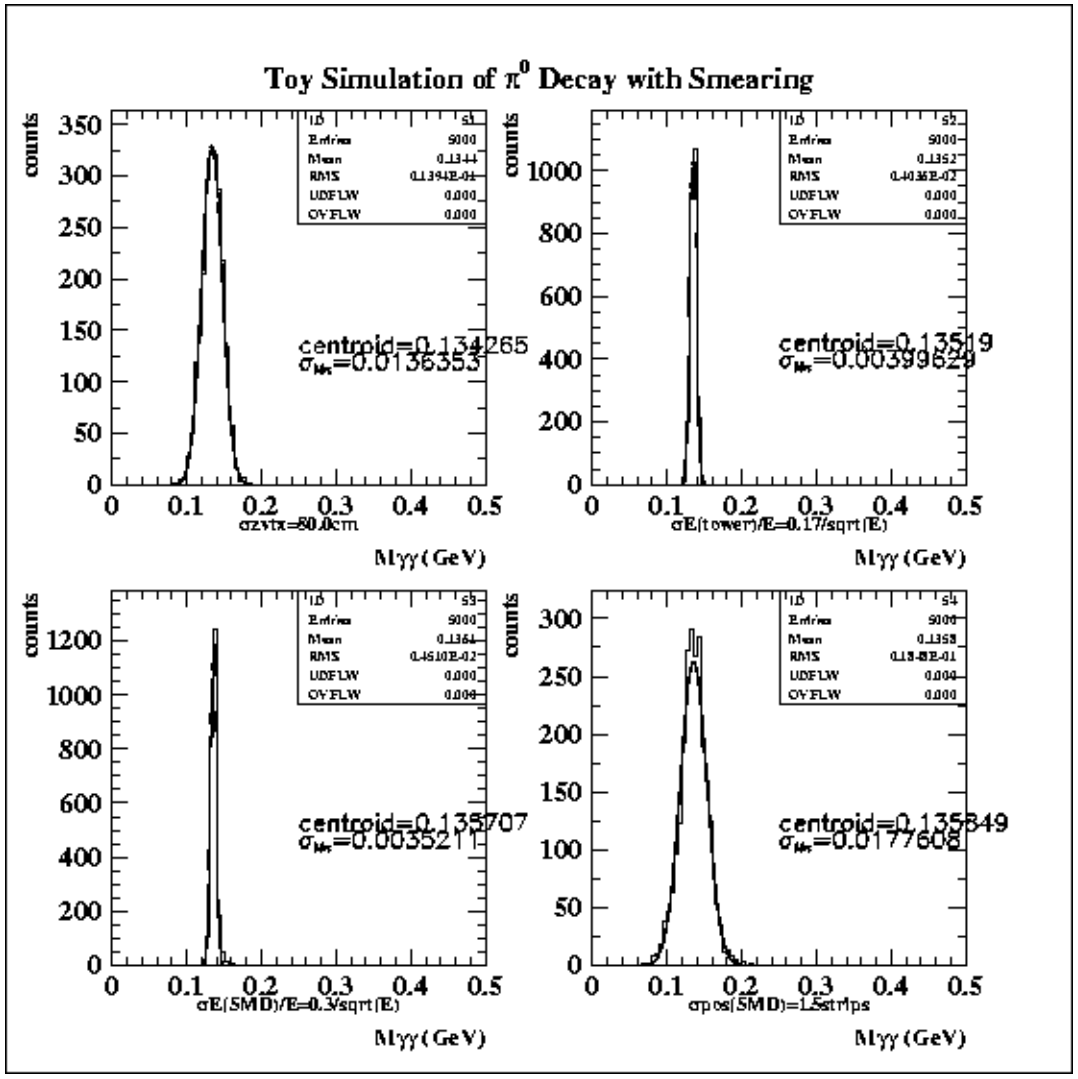
σ_π=20 MeV/c^2 for E_π=10-60 GeV...

Effects of Measurement on Mass Resolution

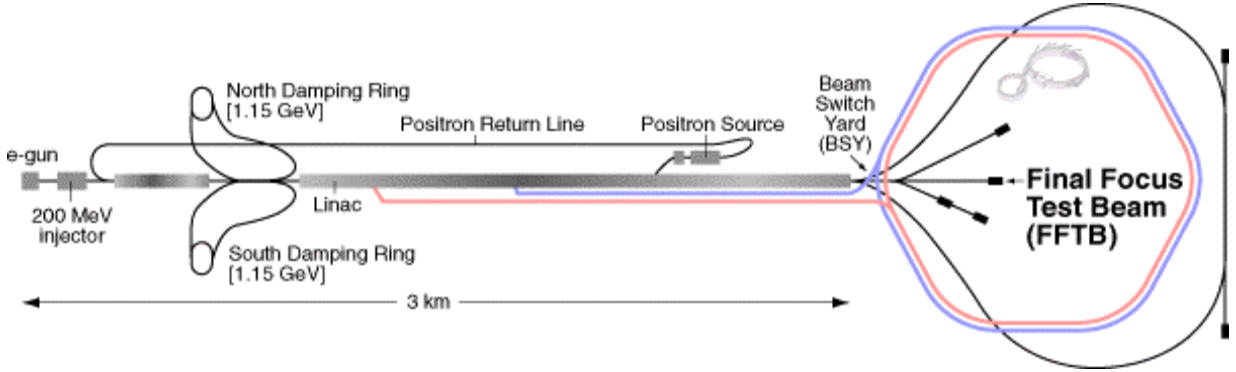
Toy simulation to study effects from the resolution of each aspect of the π^0 measurement:

- Z_{vertex} distribution
- E_{tot} resolution
- $\gamma 1, \gamma 2$ energy resolution
- $\gamma 1, \gamma 2$ position resolution

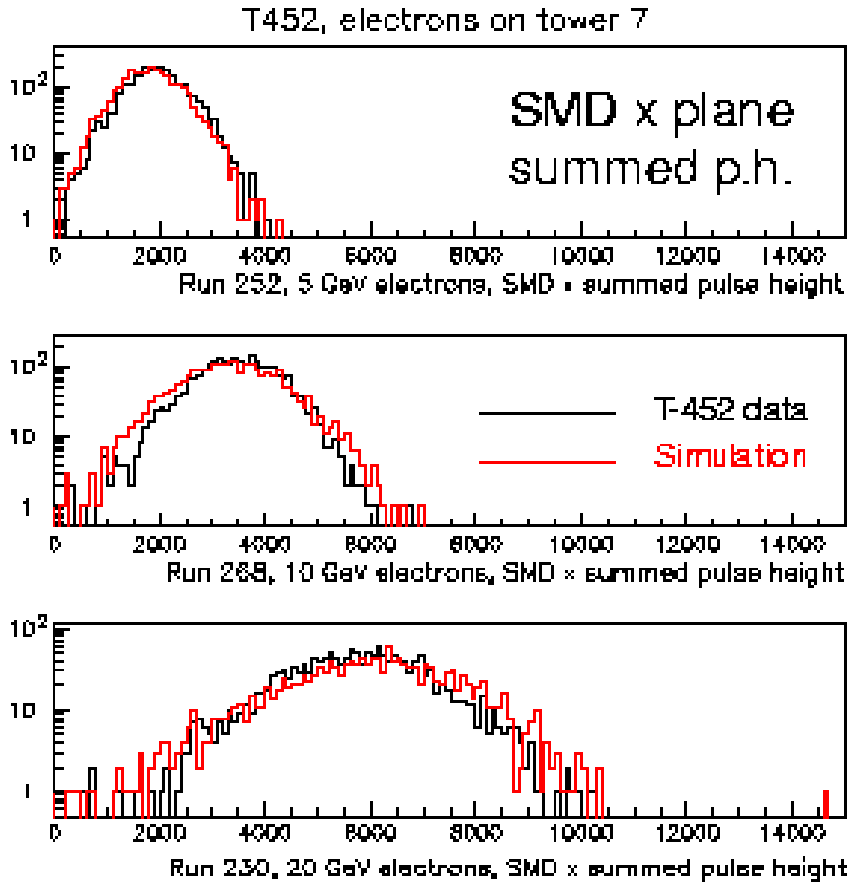
…Resolution driven by measurement of opening angle…



Simulation of SLAC test beam experiment T-452



Single e^- incident on pEEMC gives the following response from SMD strips:



- **GEANT model describes detector response**
- **SMD energy resolution dE/E~30%/sqrt(E)**

Simulation of pEEMC in STAR

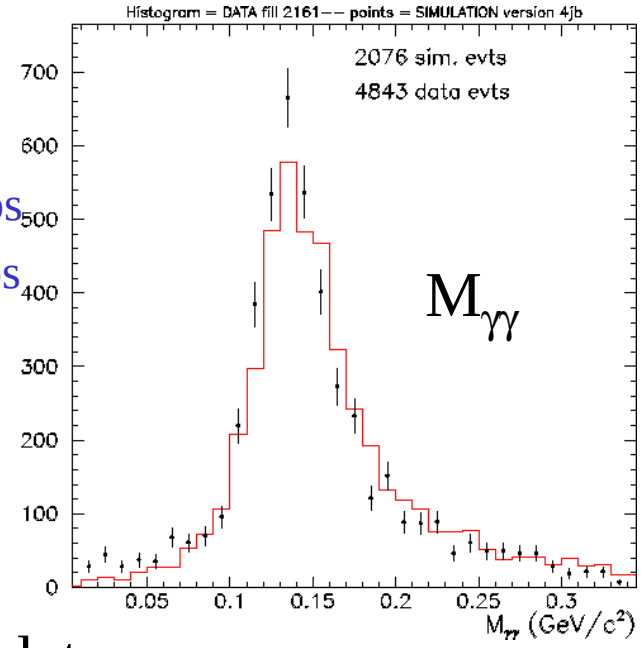
Use simulation for background and efficiency correction…

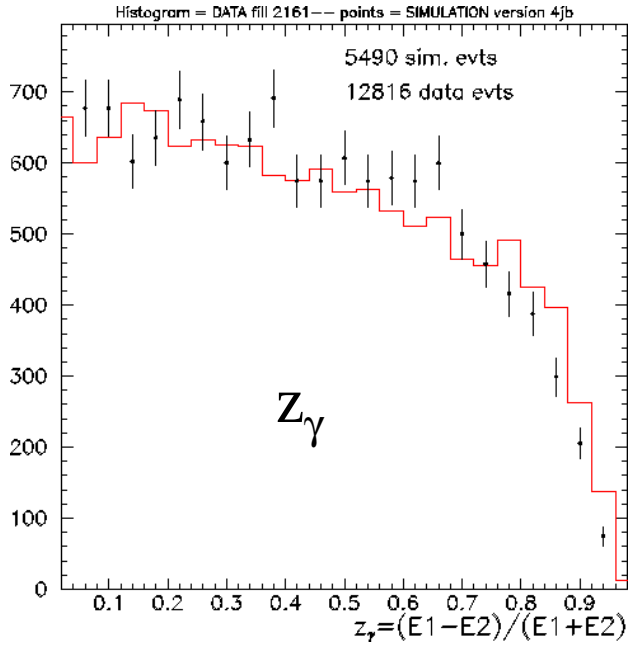
Scheme:

- 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

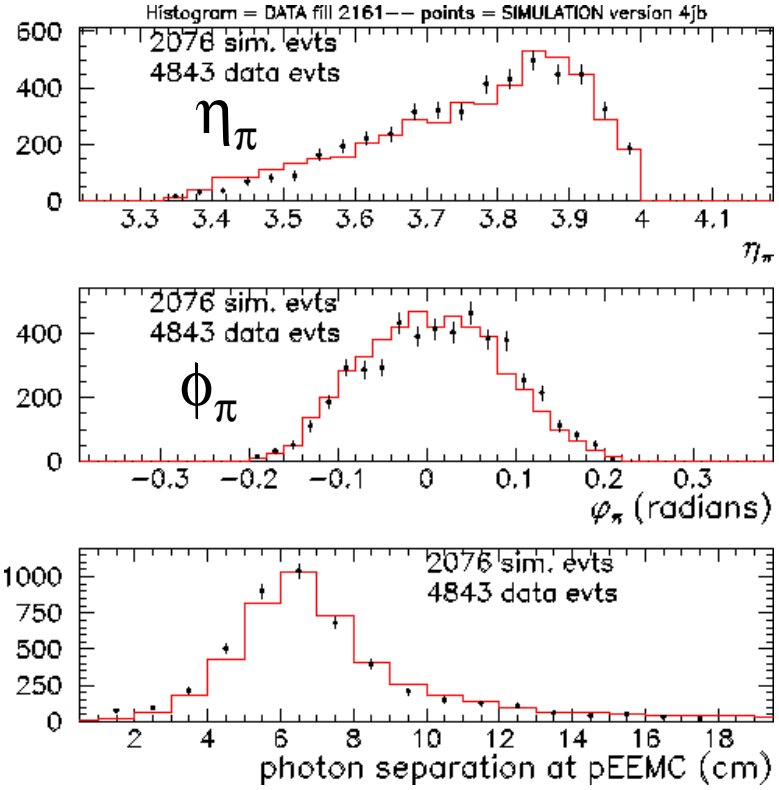




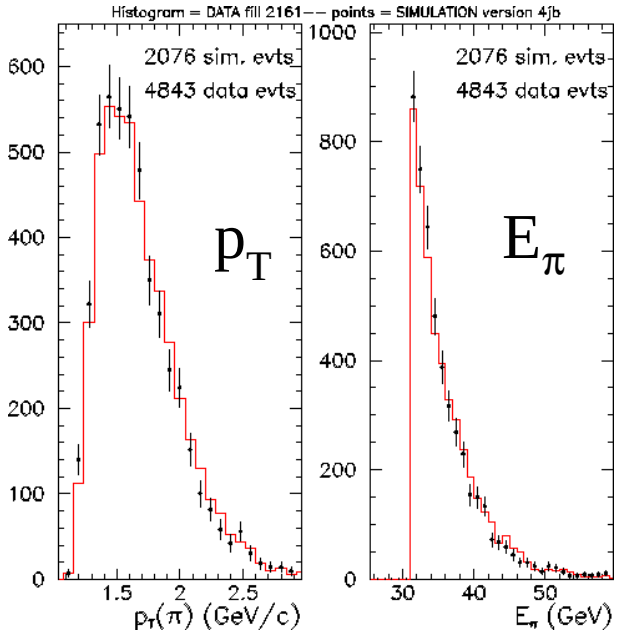
- Histogram = data
- Points = simulation norm. to data

Simulation of pEEMC (cont.)

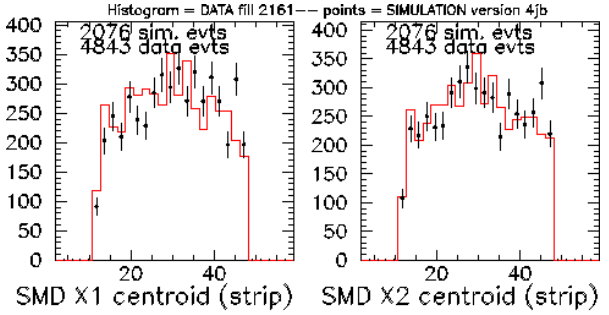
Angular variables:



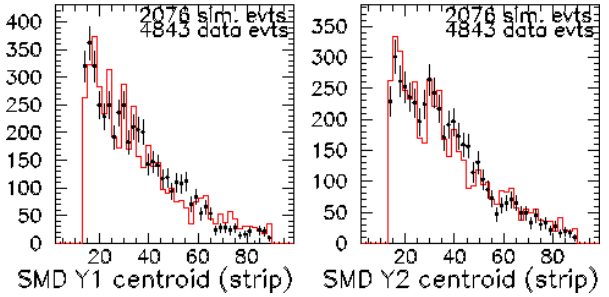
Photon separation at pEEMC



Single photon positions: vertical



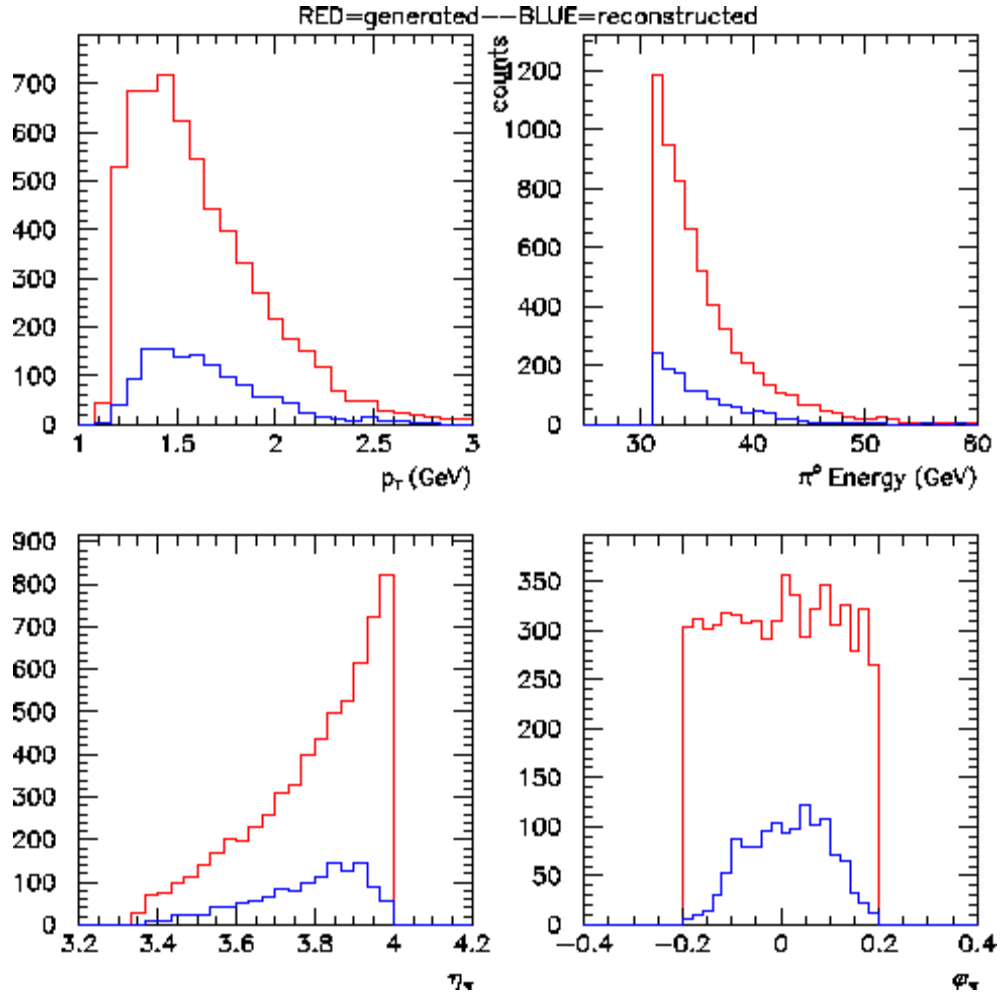
horizontal



Simulation describes data and general features understood…

Efficiency/Acceptance Correction Performed with Monte Carlo Simulation

- Red= π^0 simulated events generated into "box" defined by η and ϕ
- Blue=full PYTHIA simulated events reconstructed with identical fit model and cuts as used for data

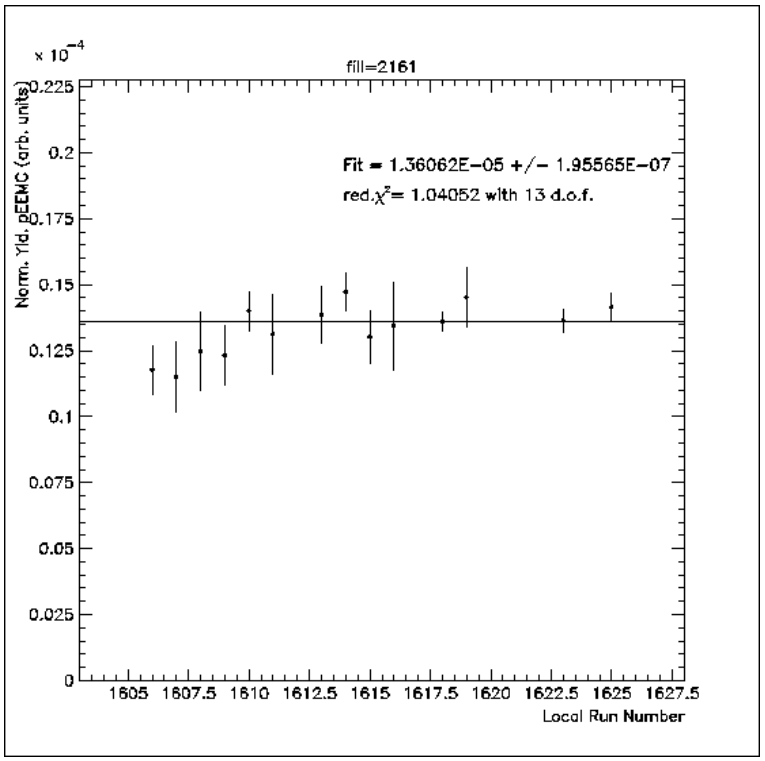


Correction to be performed simultaneously as a function of p_T and η...

Yield Stability

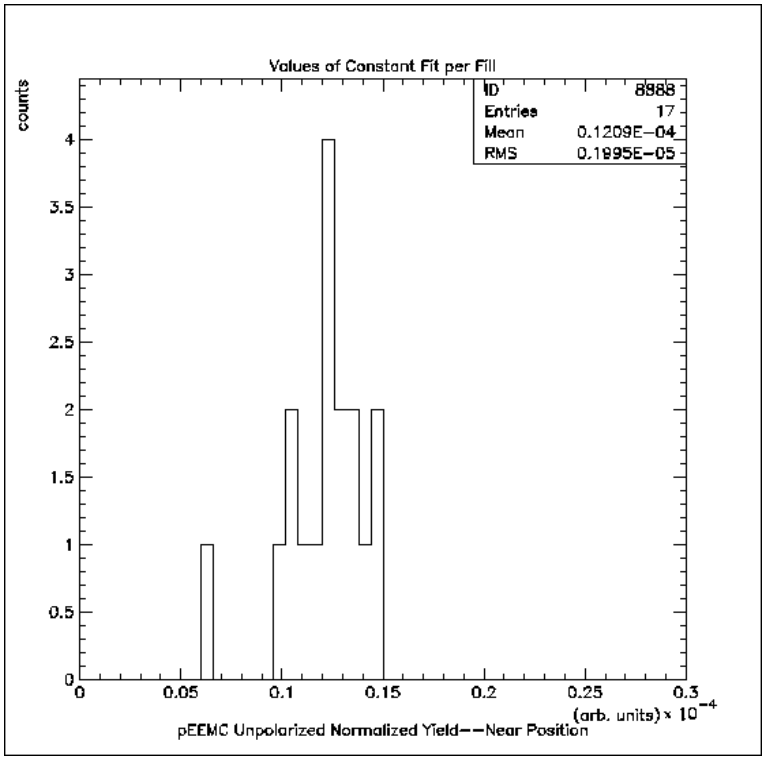
Correct raw yield by BBC coincidence rate and live time…

For fill 2161:



... fit a straight line to the normalized yield...

Fit normalized yields within each fill, and plot the distribution of the values of the fits:

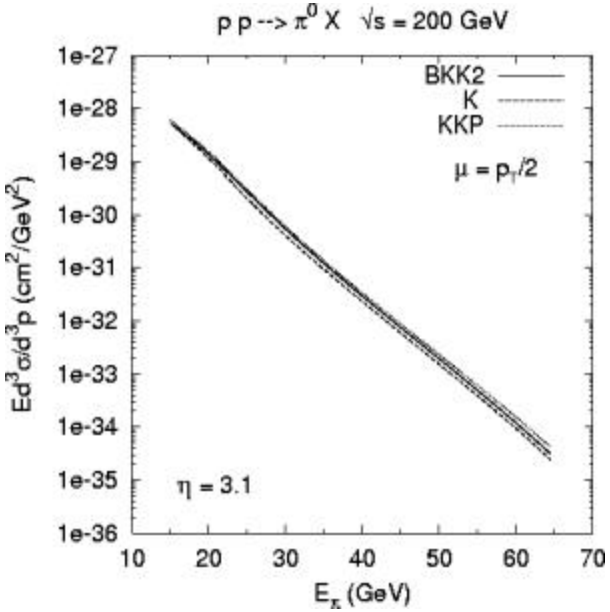


…p^0 yield stable to RMS/mean~15%

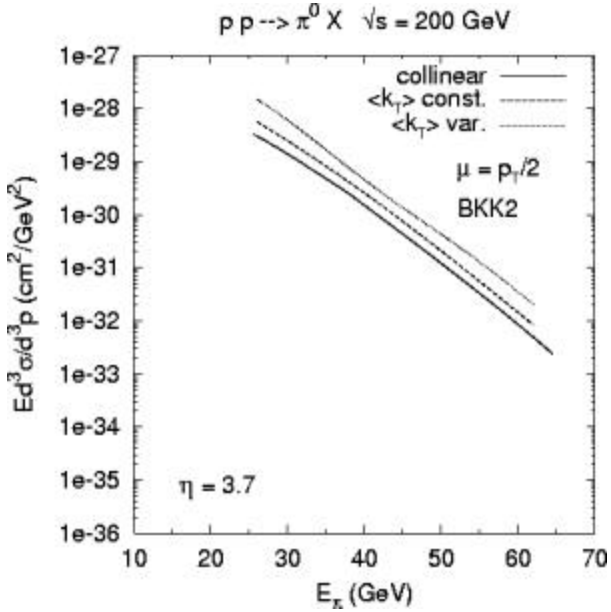
Perturbative QCD Calculations

M. Anselmino, U. d'Alesio, F. Murgia (private comm.):

Different Fragmentation Functions:

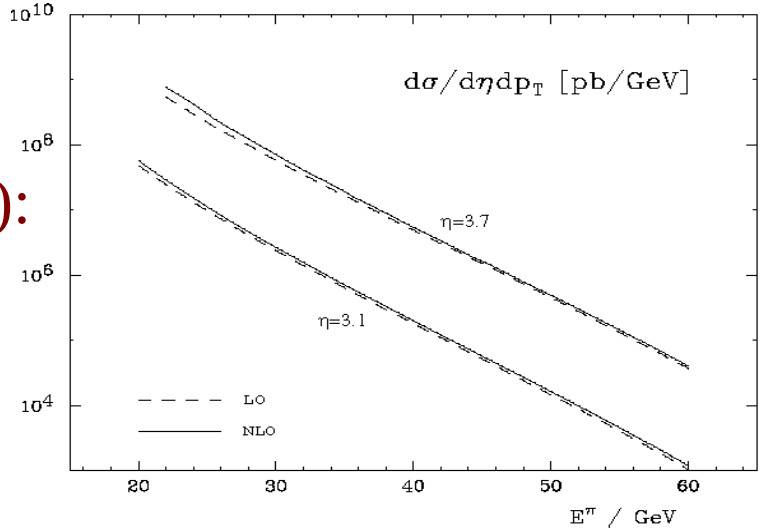


Different k_{perp}:



W. Vogelsang (private comm.):

Leading order and Next-to-leading order:



Data to be compared with theoretical pQCD calculations…

Summary:

Well on our way to extracting differential p^0 cross-section…

- Signal extraction—robust
- Livetime/luminosity correction—yields stable to ~15%

Simulations describe signal and background well:

- Background shape/magnitude—amount of background dependent on z_γ cut, correction to be performed, systematic uncertainty to be estimated

Efficiency/acceptance correction— size of correction dependent on z_γ cut, correction to be performed vs. p_T and η, syst. uncertainty to be estimated

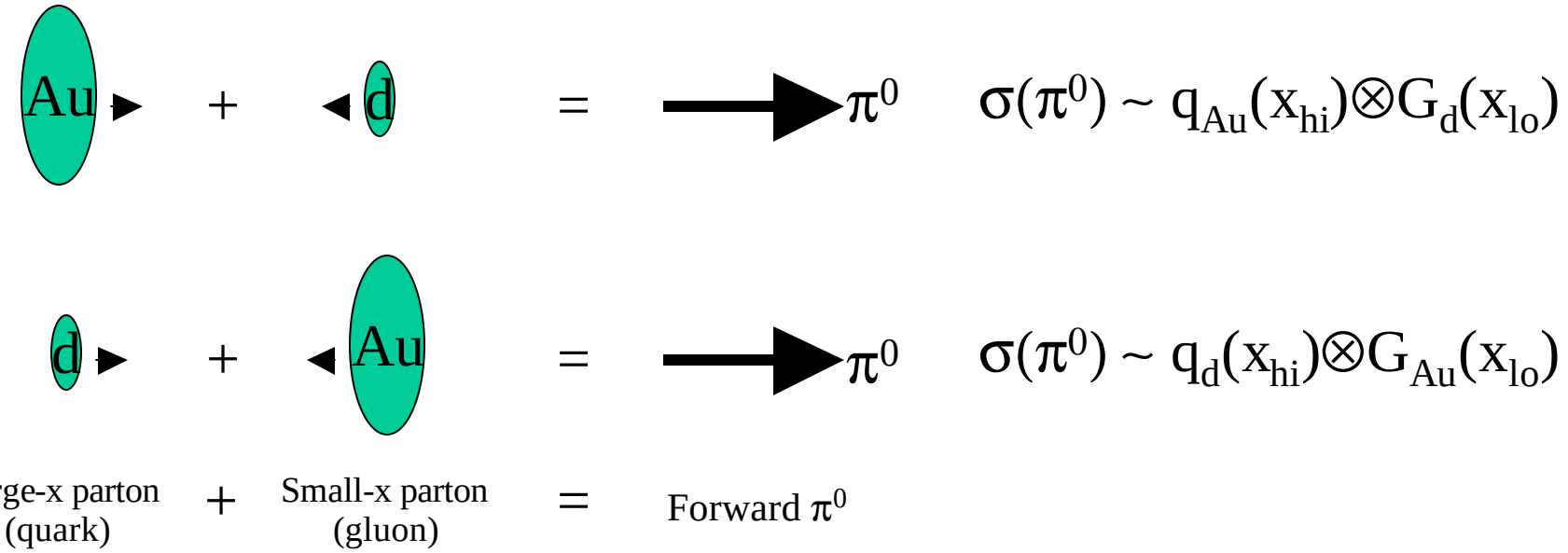
- Absolute angle uncertainty from beam position monitors from accelerator physicists—transverse position to ~few mm
- Absolute energy scale from π^0 mass—effect from uncertainty on absolute knowledge of z-vertex <1%, stability to be determined
- Absolute normalization uncertainty from comparison of van der Meer scan with estimated Beam-Beam Counter acceptance of $\sigma_{tot}(pp)$

Outlook

•Gluon saturation in heavy nuclei?

A. Dumitru and J. Jalilian-Marian, Phys. Rev. Lett. 89 (2002) 022301.

Naïve picture… neglecting Final State Interactions: Look at ratio of cross sections for forward π^0 production in d+Au collisions when the π^0 is along the direction of the d beam and when the π^0 is along the direction of the Au beam:



...Understanding p+p collisions baseline for understanding d+Au collisions in future...