# *Single-Spin Transverse Asymmetry in Neutral Pion Production at*

PHENIX

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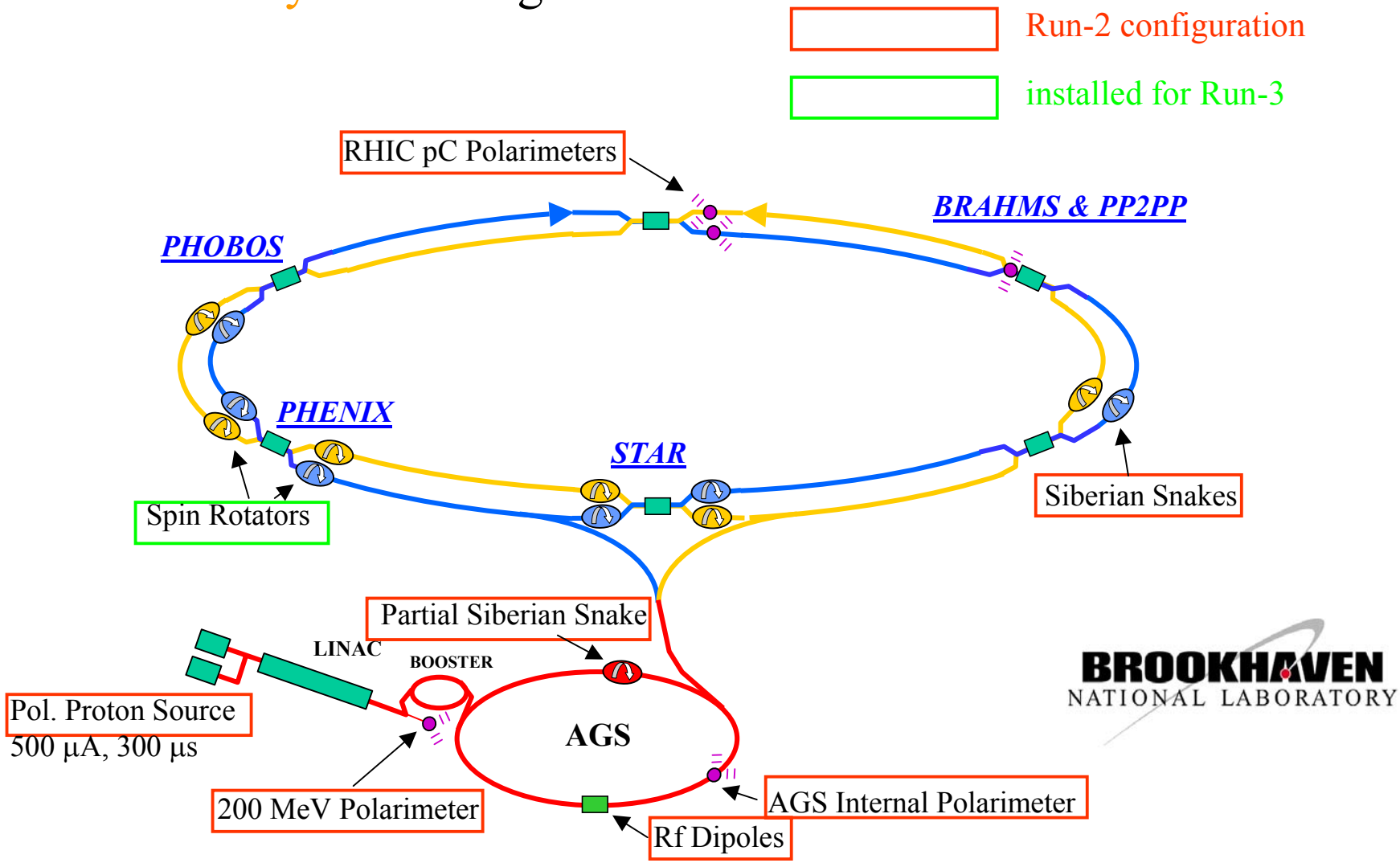
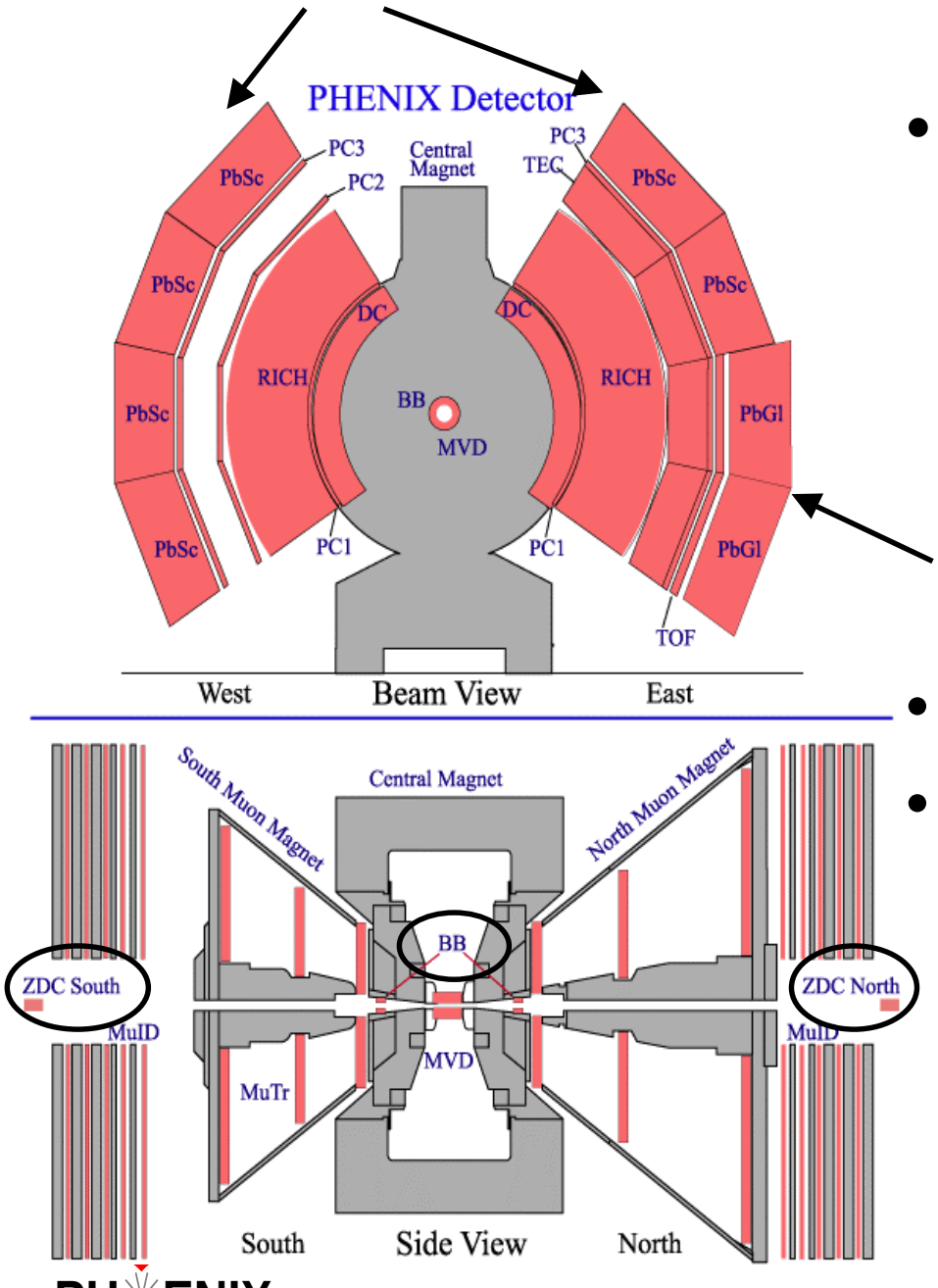
# *Polarized Proton Collisions at RHIC*

"Blue" and "yellow" rings



# PHENIX Detector

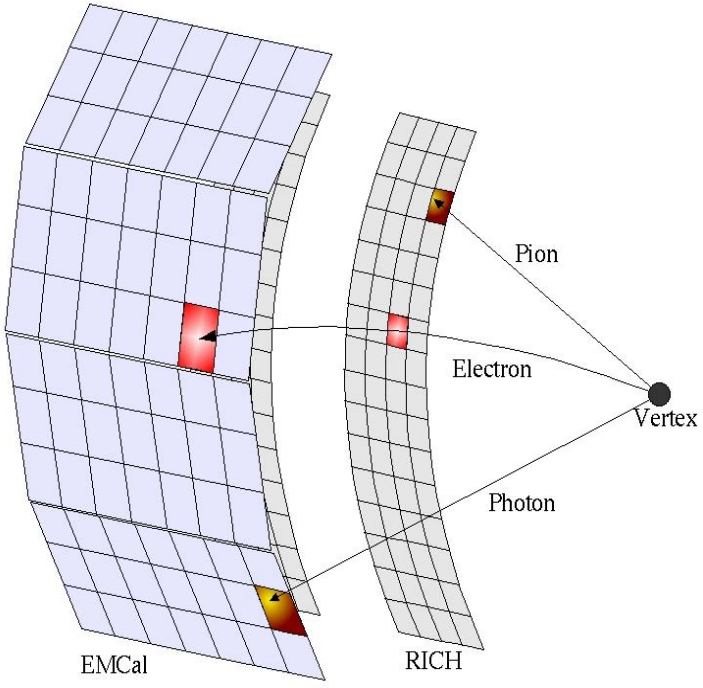



**EMCal PbGl**

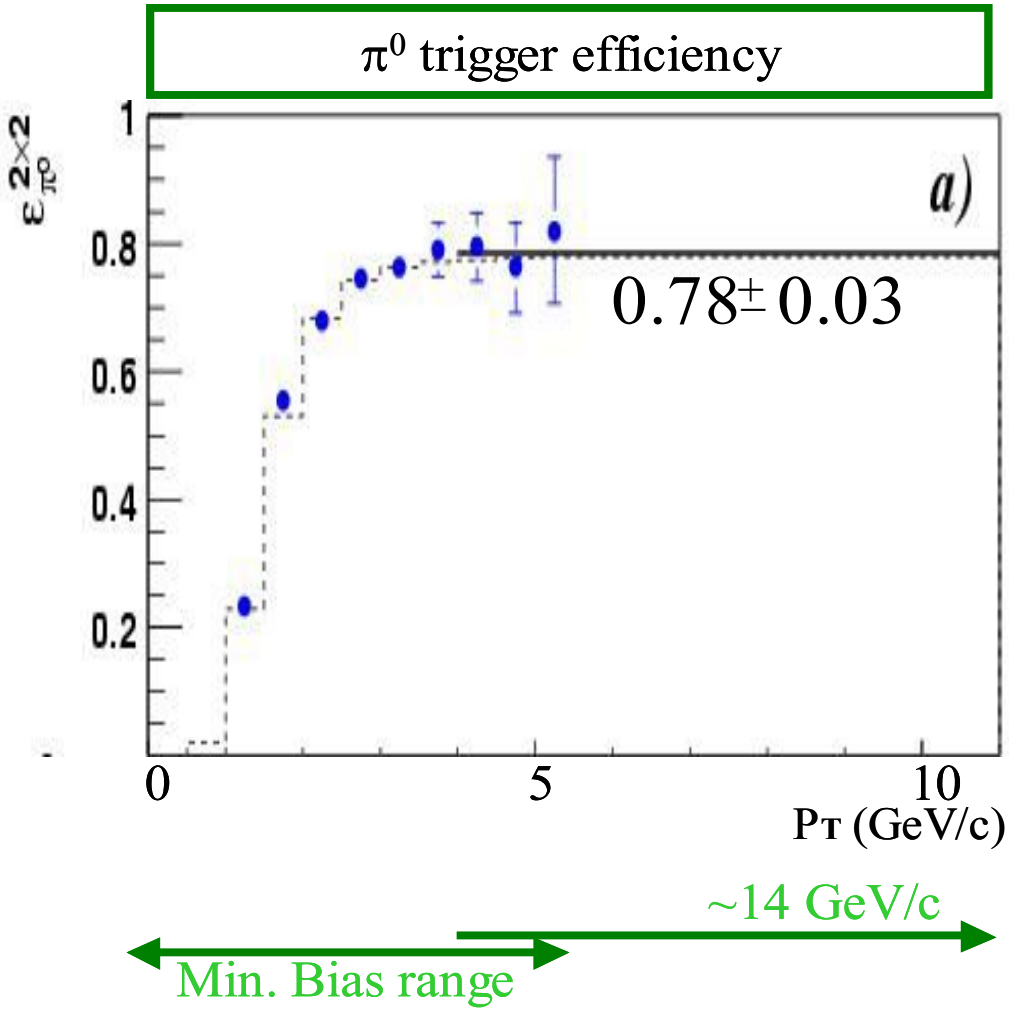
- Central arm spectrometers
  - In the central arms, a fine-grained EMCal equipped with photon triggers enhances $\pi^0$ measurement
- Muon arm spectrometers
- Forward and backward luminosity detectors:
  - BBC (Beam-Beam Counters)
  - ZDC (Zero Degree Calorimeters)

# EMCal-RICH 2x2 Trigger

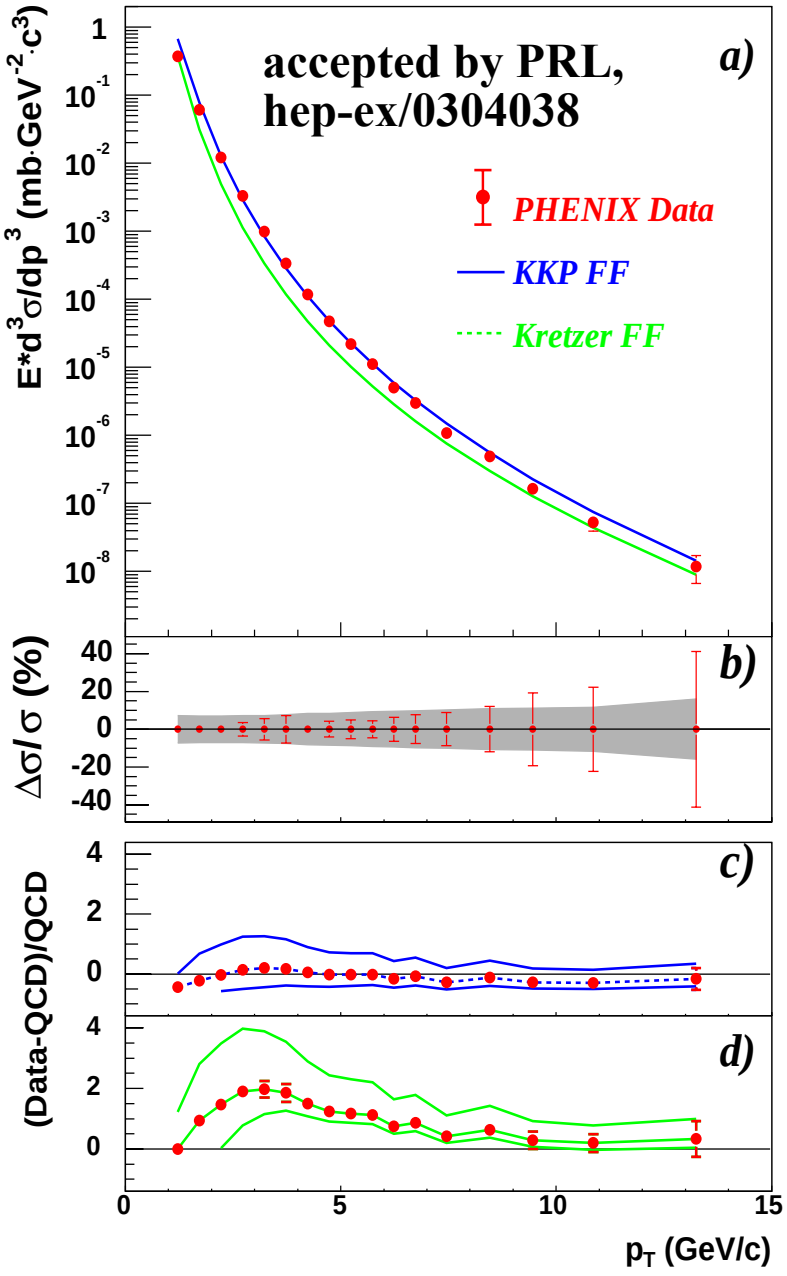
- 2x2 towers non-overlapping sum
- Threshold ~ 0.8 GeV
- Also used in conjunction with RICH to form an electron trigger




2x2 Trigger in 2001-2002 run.



# $\pi^0$ Cross Section from 2001-2 Run

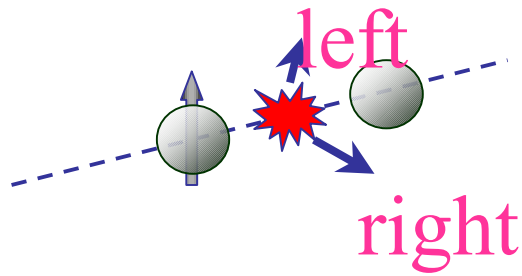



- Statistics cover eight orders of magnitude
- NLO pQCD applies above 2 GeV/c at RHIC
  - Will be able to use in interpretation of spin-dependent results

9.6% normalization error not shown

# *Why Measure $\pi^0$ $A_N$ at PHENIX?*

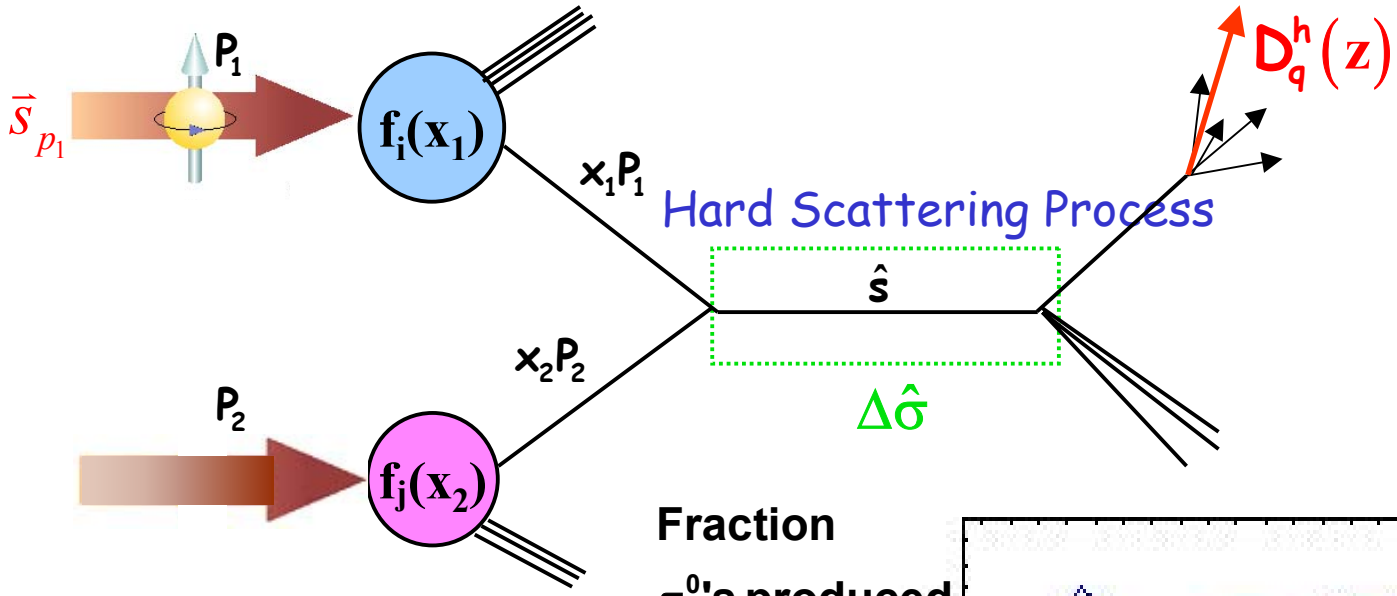
$$A_N = \frac{1}{P} \cdot \frac{\sigma^{\uparrow} - \sigma^{\downarrow}}{\sigma^{\uparrow} + \sigma^{\downarrow}}$$



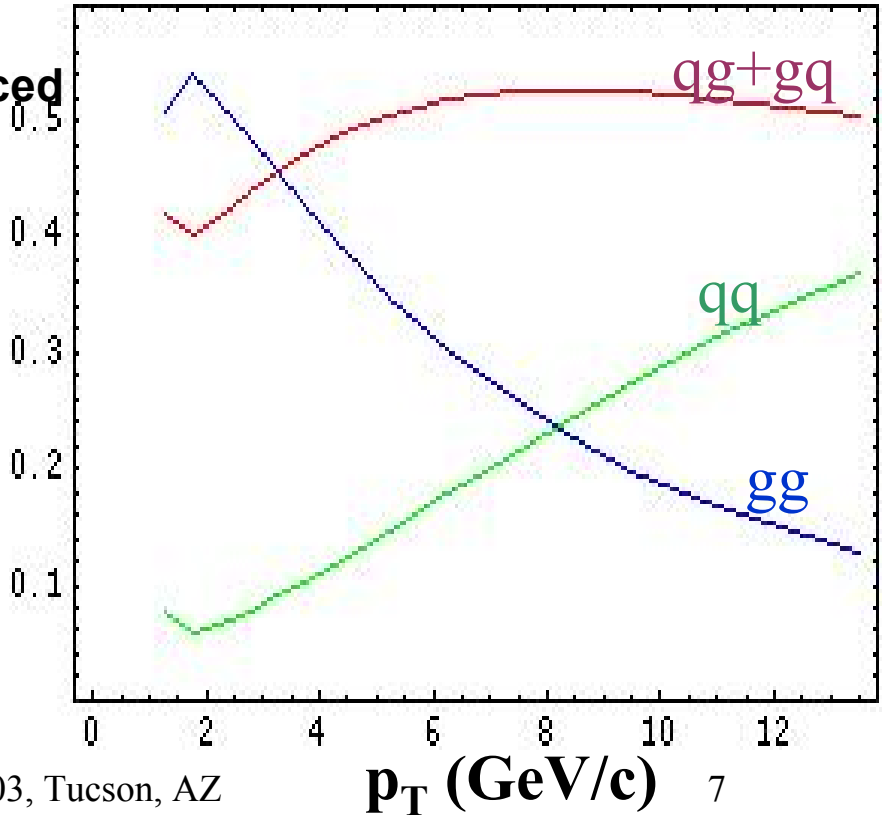

- $\pi^0$ cross section at $\sqrt{s}$ = 200 GeV described by pQCD

  ➡ measuring $\pi^0$ $A_N$ at midrapidity will help to separate contributions from transversity and the Sivers effect to single transverse spin asymmetries in polarized hadron collisions
- Significant asymmetries observed at STAR for forward $\pi^0$'s produced at $\sqrt{s}$ = 200 GeV, $x_{quark} \geq 0.6$ (talk by Y. Wang)
- PHENIX $\pi^0$ $A_N$ measurement explores a different kinematical region: midrapidity, $x_{quark} \sim 0.1$

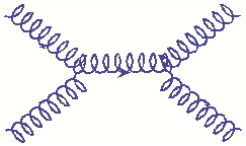
# Leading Hadrons as Jet Tags



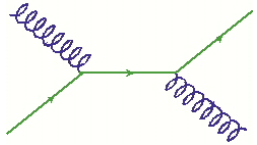

**Fraction $\pi^0$'s produced**



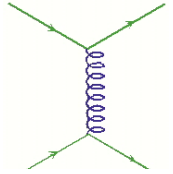

$gg \to gg$



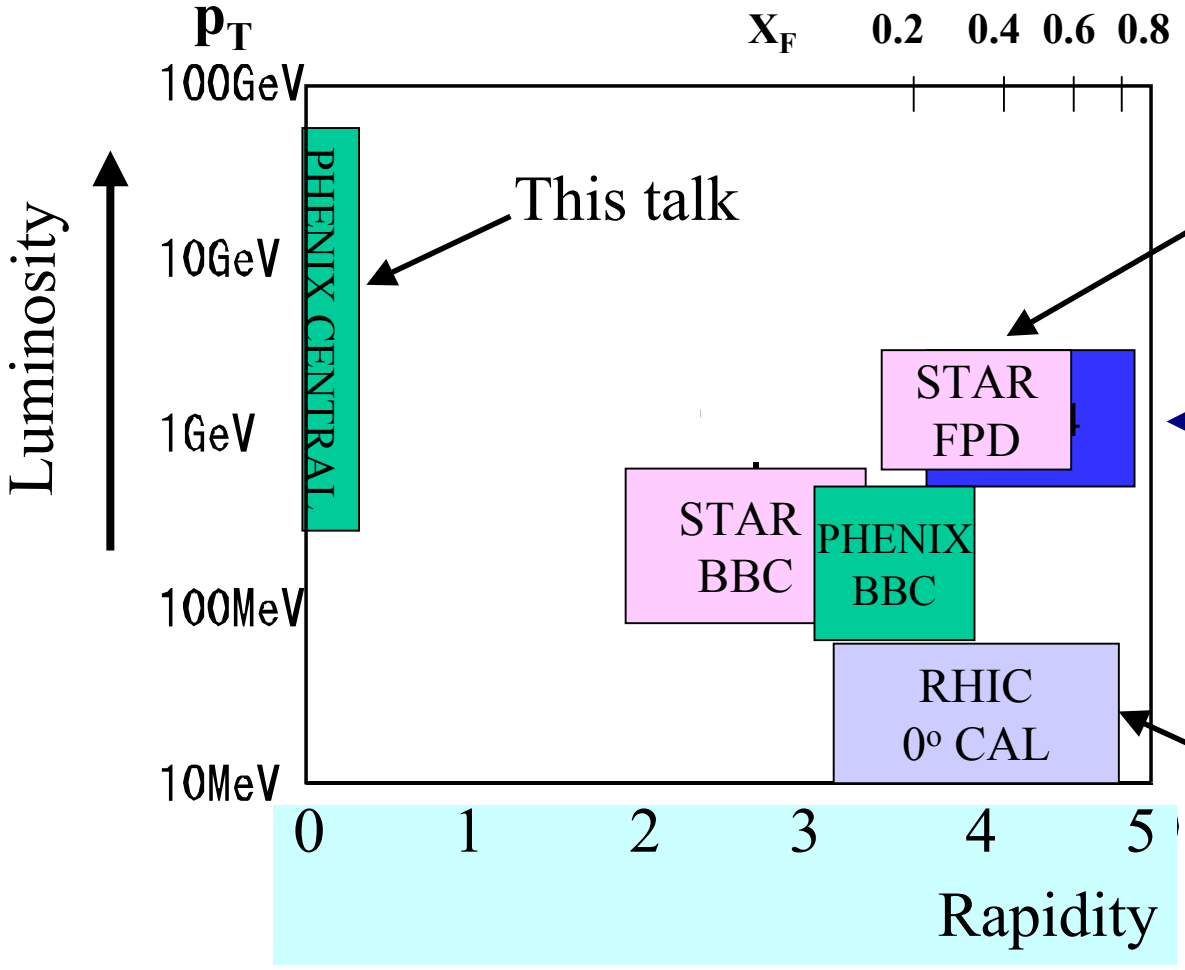
$gq \to gq$



$qq \to qq$



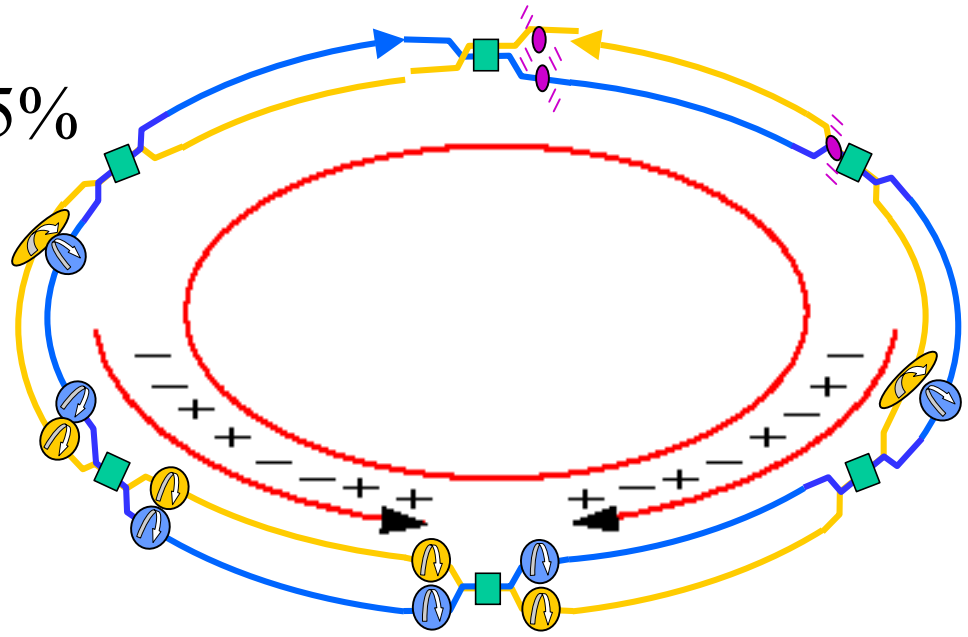
# *Kinematical Coverage for $A_N$ Measurements*




**E704 at Fermilab**
**$\sqrt{s}$=20 GeV,**
**$p_T$=0.5-2.0 GeV/c**
**$\pi^+$, $\pi^-$, $\pi^0$ at high $x_F$**
**Observed asym +10%~+30%**

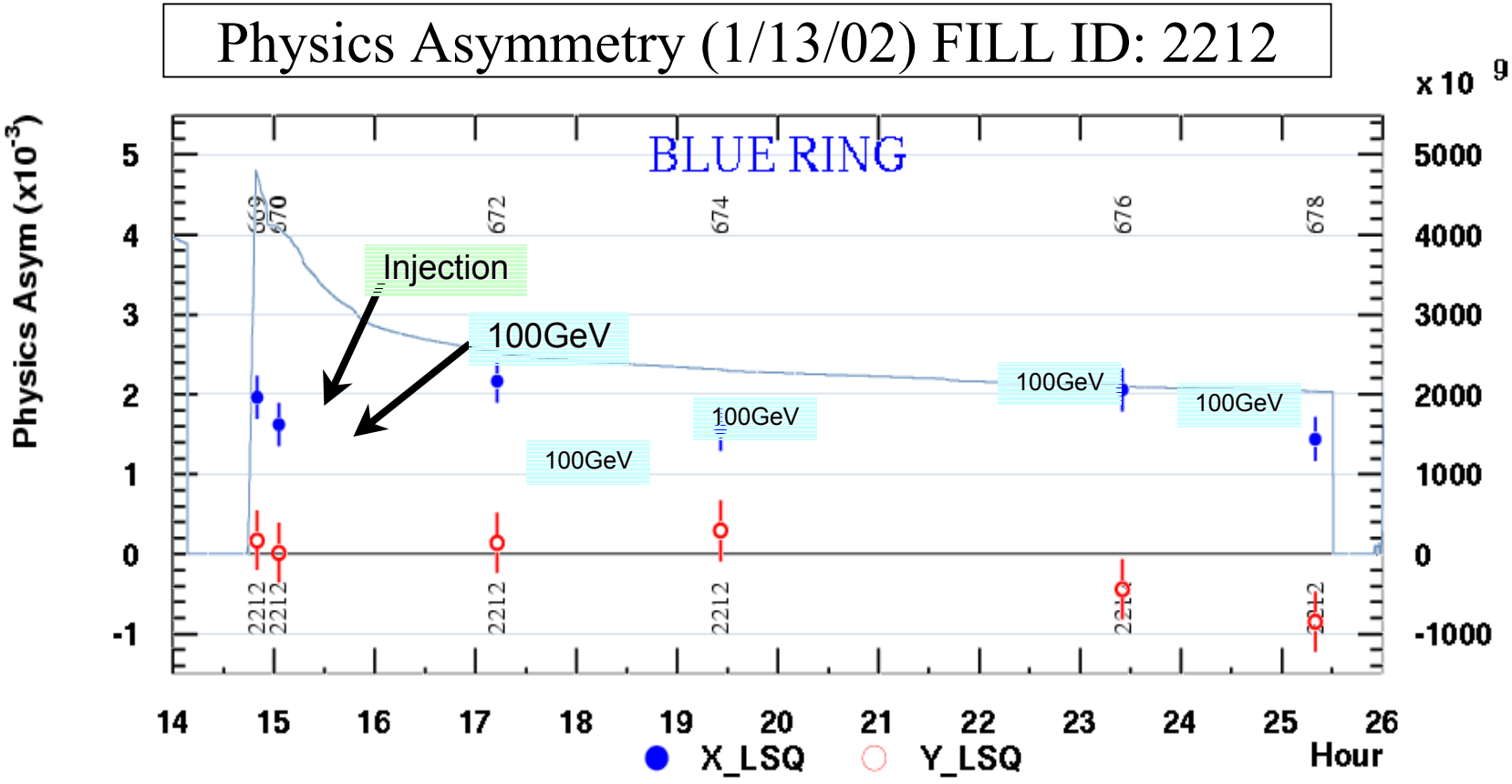
# *2001-2002 Run at RHIC*

- Transversely polarized p+p collisions at $\sqrt{s}$= 200 GeV
- 150 $nb^{-1}$ written to tape
- Average polarization of ~15%
- Single-spin asymmetries *calculated for each beam separately*, averaging over the spin states of the other
  - effectively doubles statistics



Different spin combinations for different crossings aid in canceling systematic uncertainties.

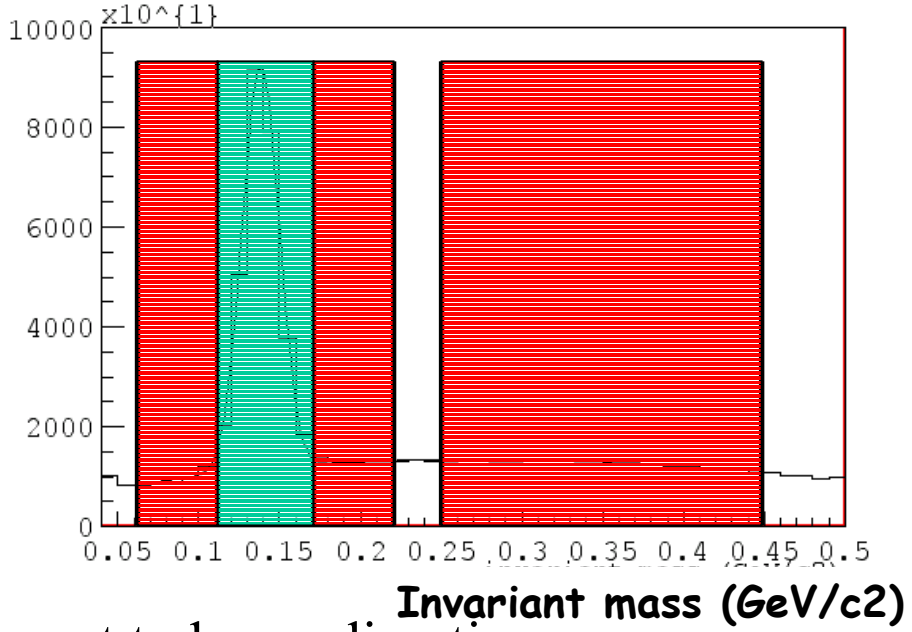
# *Polarization Measurements*




- X asymmetry (physics) and Y asymmetry (false) are plotted as a function of the beam lifetime
- Measurements are carried out at injection, right after ramp-up, two hours each at 100 GeV

# Calculating $\pi^0 A_N$

$$\frac{dN}{d\phi} \propto 1 + A_N P \sin\phi$$




- Look for left-right asymmetry with respect to beam direction

$$A_N P = \frac{N_L - N_R R_{acc}}{N_L + N_R R_{acc}}$$

$R_{acc}$ = relative acceptance of left and right detectors

- OR look either on left or right side and compare $\pi^0$ production for + and - spin states

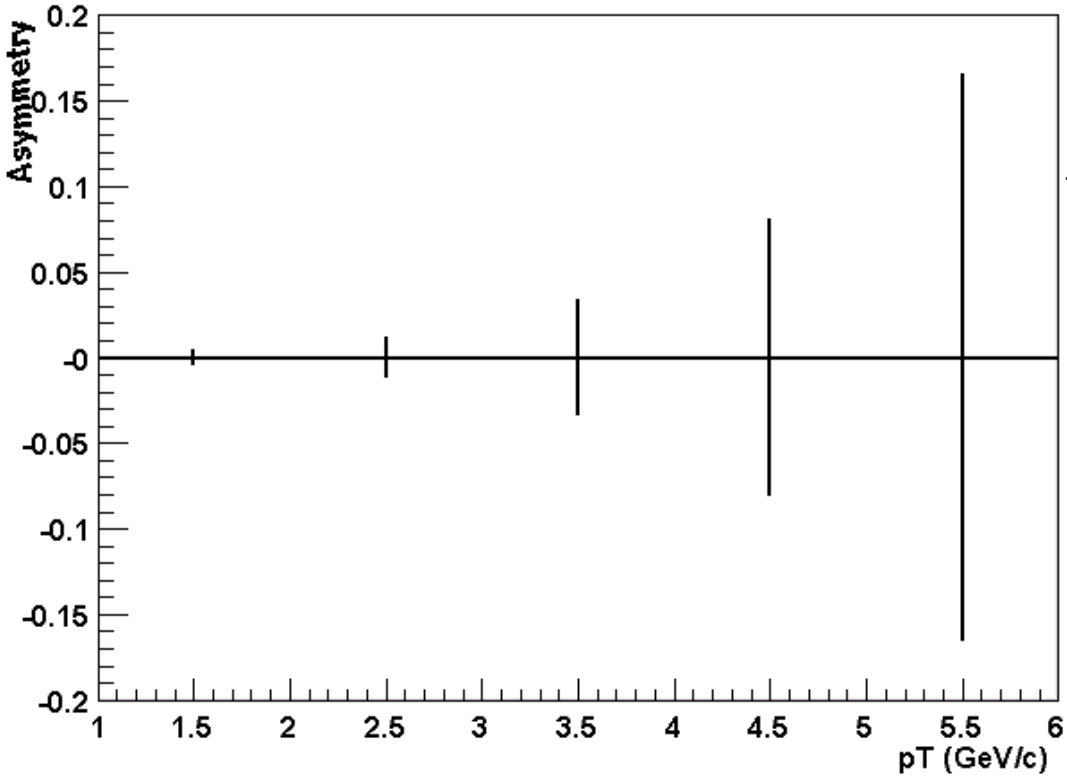
$$A_N^L P = \frac{N_L(+) - N_L(-) R_{lumi}}{N_L(+) + N_L(-) R_{lumi}}$$

$R_{lumi}$ = relative luminosity of + and - spin states

*Important check of systematic errors (more later)*

# *Statistical Sensitivity*

- ~600M minimum bias triggers sampled
- We have statistical sensitivity to the magnitude of asymmetries seen at larger $x_F$; better sensitivity in lower $p_T$ bins
- Measurement of single-spin transverse asymmetry for midrapidity neutral pion production at PHENIX may offer insight on transversity and the Sivers effect




Asymmetries ~0.1 or greater have been seen for higher $x_F$

# *Systematic Errors and Outlook*

Systematic errors are currently being evaluated in the following ways:

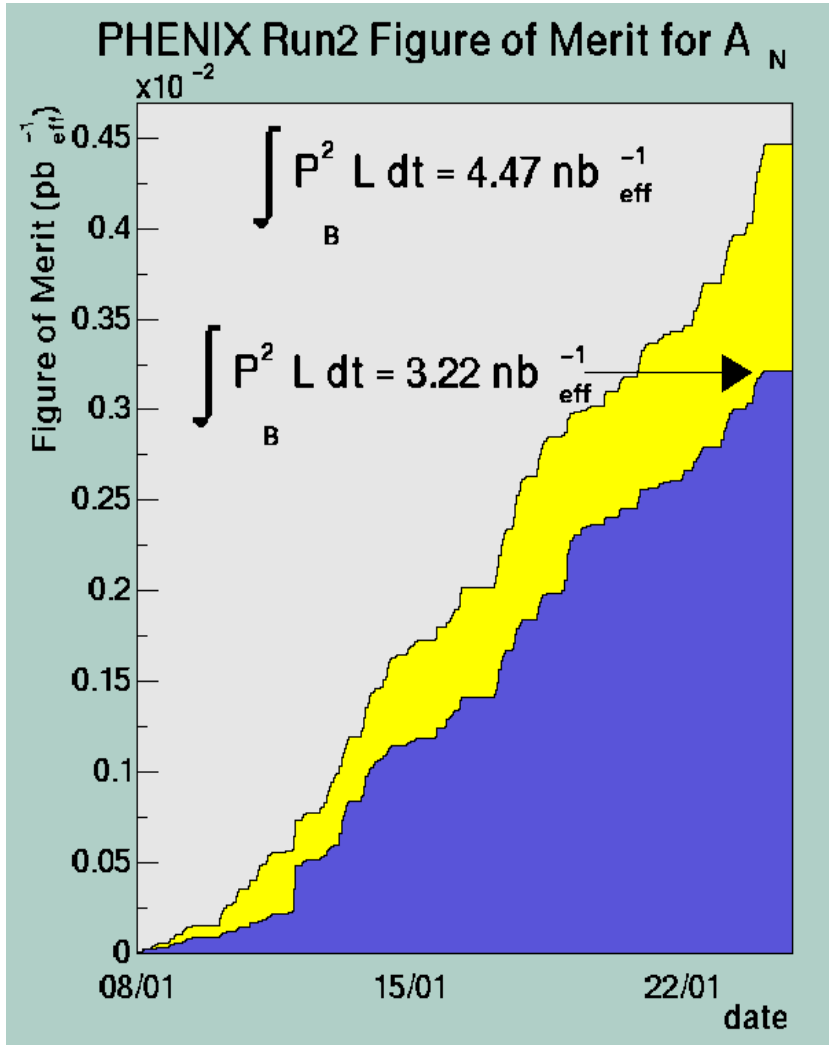
- Compare independent measurements for two polarized beams
- Compare results for left and right sides of detector
- Compare minimum bias and triggered data samples
- Measure asymmetry of background
  - Immediately outside the $\pi^0$ mass peak
  - In the mass region between the $\pi^0$ and the $\eta$
- Examine store-by-store consistency of asymmetry values
- Calculate asymmetries using more than one method

***Results expected soon!***

# *Extra Slides*

# *2001-2002 p+p run*

- **Luminosity**
  - integrated luminosity 0.15 $pb^{-1}$
  - L = $1.5\times10^{30}$ $cm^{-1}sec^{-1}$ at max
- **Polarization – transverse**
  - $<P_{yellow}>$=17 %, $<P_{blue}>$=14 %
- **Cross section measurement**
  - $\pi^0$, J/$\psi$, …
- ***$A_N$* measurement** (analysis ongoing …)
  - central arm (mid-rapidity, $x_F \sim 0$)
    - $\pi^0$, charged hadrons, J/$\psi$, …
- **Systematic studies**
  - relative luminosity study
  - local polarimeter development at IP12



# *Formulas being used for calculation*

Luminosity formula: gives results for left and right sides of the detector separately

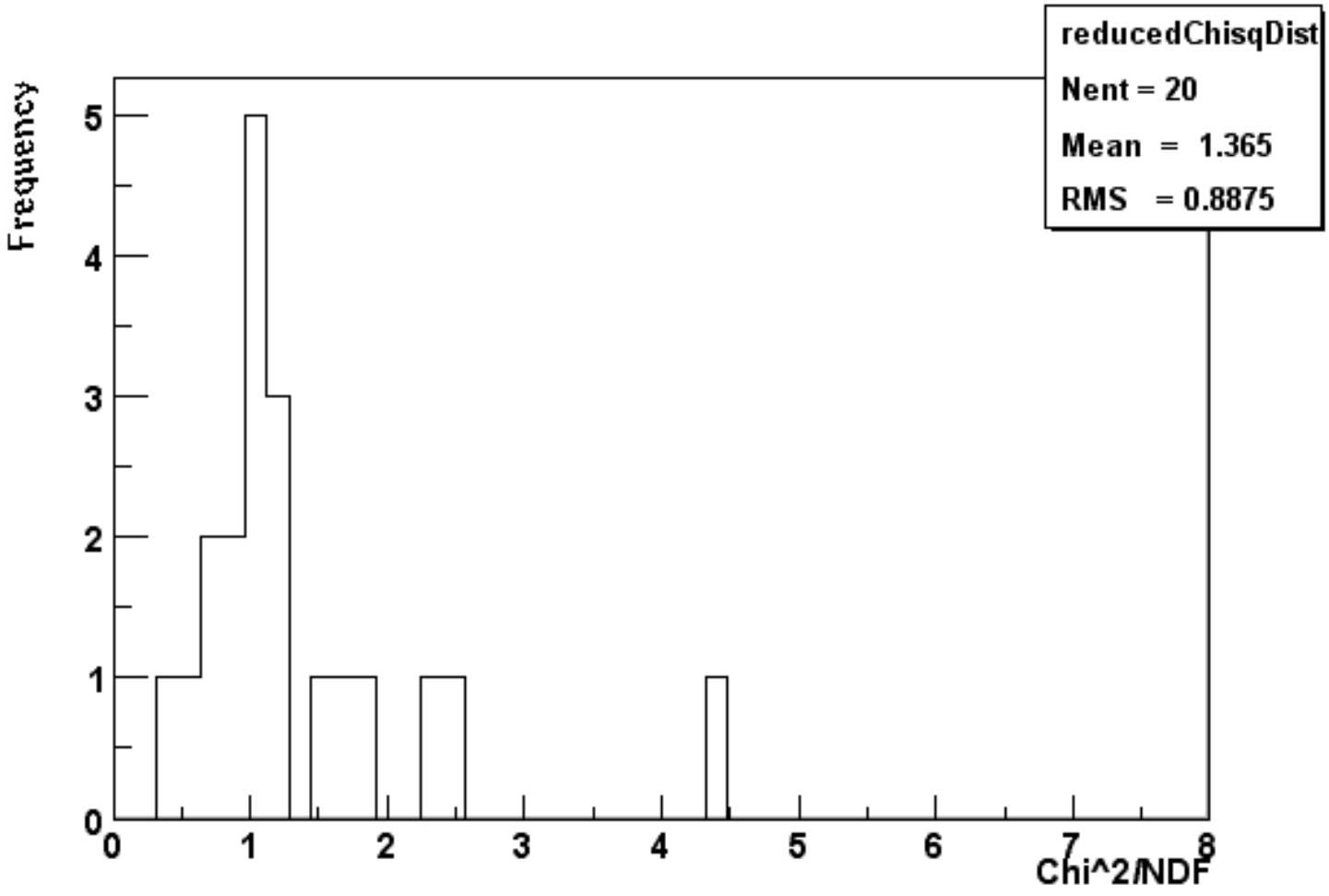
$$A_N^{BlueLeft} = \frac{1}{P^{Blue}} \frac{\left( \frac{N^{Blue+Left}}{L^{Blue+}} - \frac{N^{Blue-Left}}{L^{Blue-}} \right)}{\left( \frac{N^{Blue+Left}}{L^{Blue+}} + \frac{N^{Blue-Left}}{L^{Blue-}} \right)}$$

Square root formula: cancels effects of detector and luminosity asymmetries to first order

$$A_N^{Blue} = \frac{1}{P^{Blue}} \frac{\sqrt{N_{Left}^{Blue+} N_{Right}^{Blue-}} - \sqrt{N_{Right}^{Blue+} N_{Left}^{Blue-}}}{\sqrt{N_{Left}^{Blue+} N_{Right}^{Blue-}} + \sqrt{N_{Right}^{Blue+} N_{Left}^{Blue-}}}$$

# *Sample $\chi^2$ Distribution*

Fit to a constant asymmetry across all stores.
20 entries for 2 beams * 2 triggers * 5 $p_T$ bins



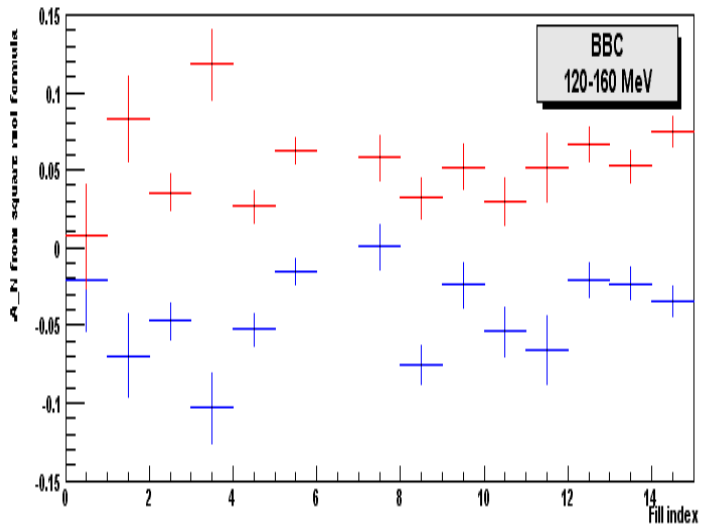
# *Luminosity and Detector Asymmetries*

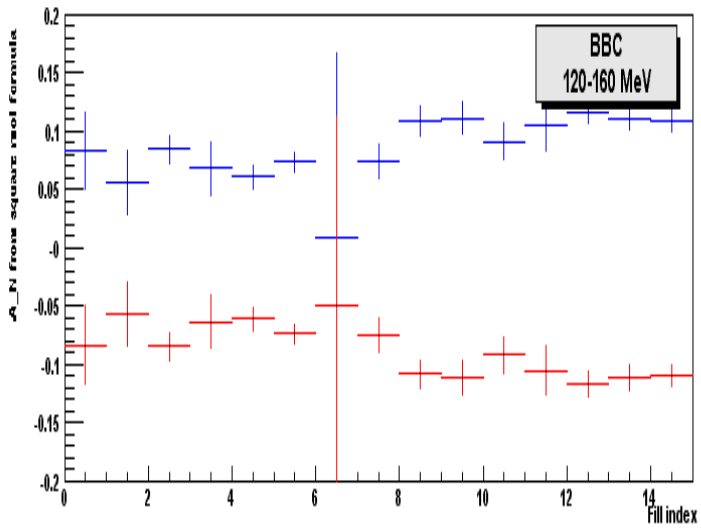
BBC

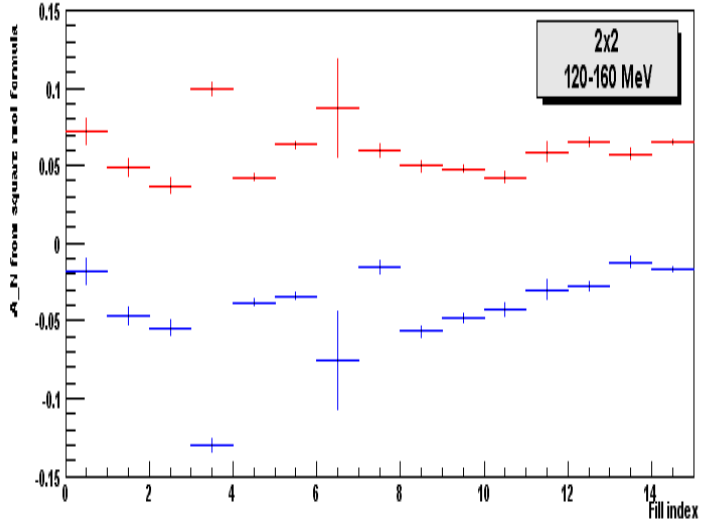
Blue

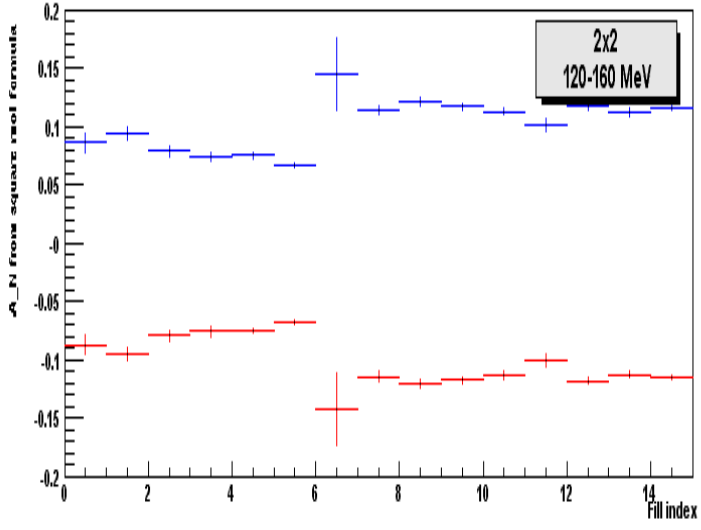
Yellow

2x2




Luminosity asymmetry vs. fill

Detector asymmetry vs. fill

# *E704 Results*

$$A_N = \frac{1}{P} \cdot \frac{\sigma^{\uparrow} - \sigma^{\downarrow}}{\sigma^{\uparrow} + \sigma^{\downarrow}}$$

FNAL E704