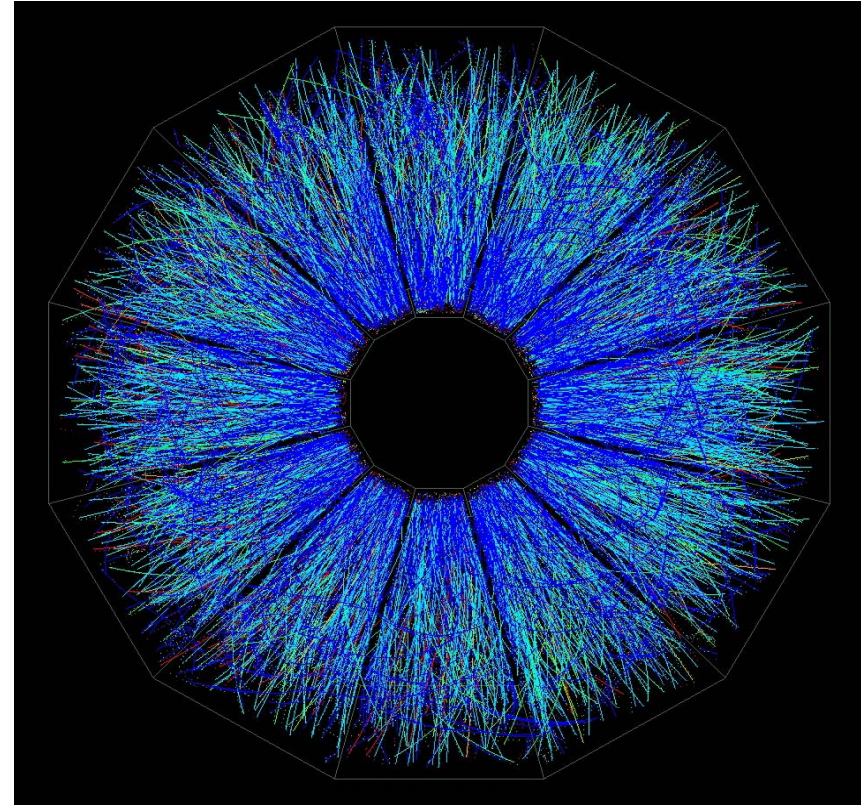


Inclusive Jet Asymmetries from STAR Analysis Update

Stephen Trentalange

for the
STAR Collaboration

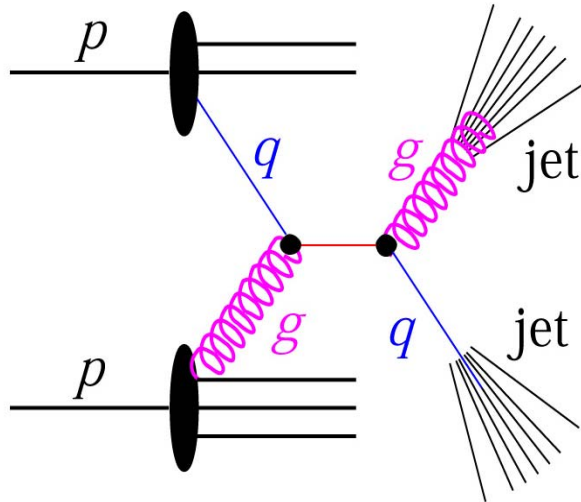


Sensitivity to ΔG from Inclusive Jet Asymmetries

- Polarized proton collisions at RHIC
- Connection with partonic processes
- Detector sensitivity
- Achievable Statistics
- Systematic Errors
- Future Prospects

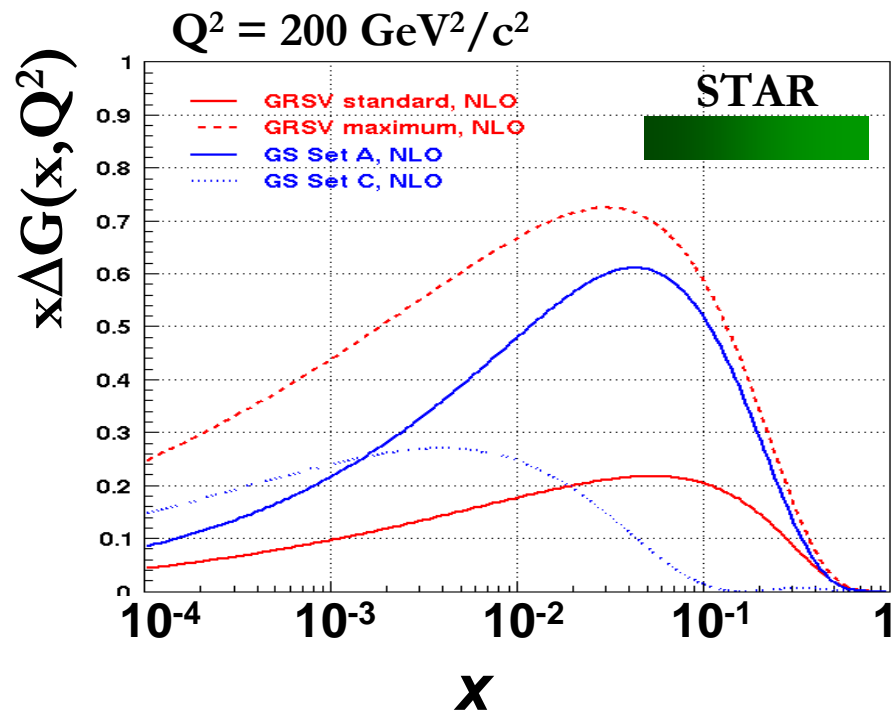


Kinematic Range

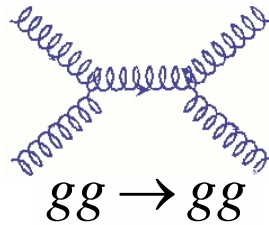


- Polarized proton collisions
- $\sqrt{s} = 200 \text{ GeV}$
- Jet E_T 5-50 GeV
- Pseudorapidity $0 < \eta < 1$

- Large Asymmetry
- Sensitivity to Large ΔG
- Dominant Reaction Mechanism

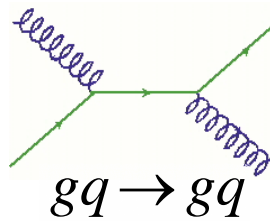


Parton Level Asymmetries



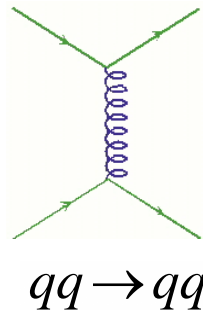
$gg \rightarrow gg$

$$\propto \frac{\Delta G}{G} \frac{\Delta G}{G}$$



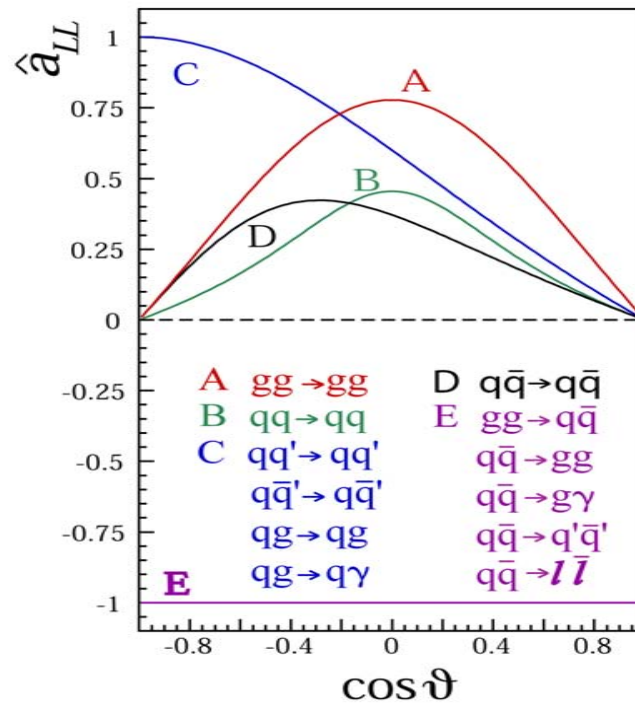
$gq \rightarrow gq$

$$\propto \frac{\Delta q}{q} \frac{\Delta G}{G}$$



$qq \rightarrow qq$

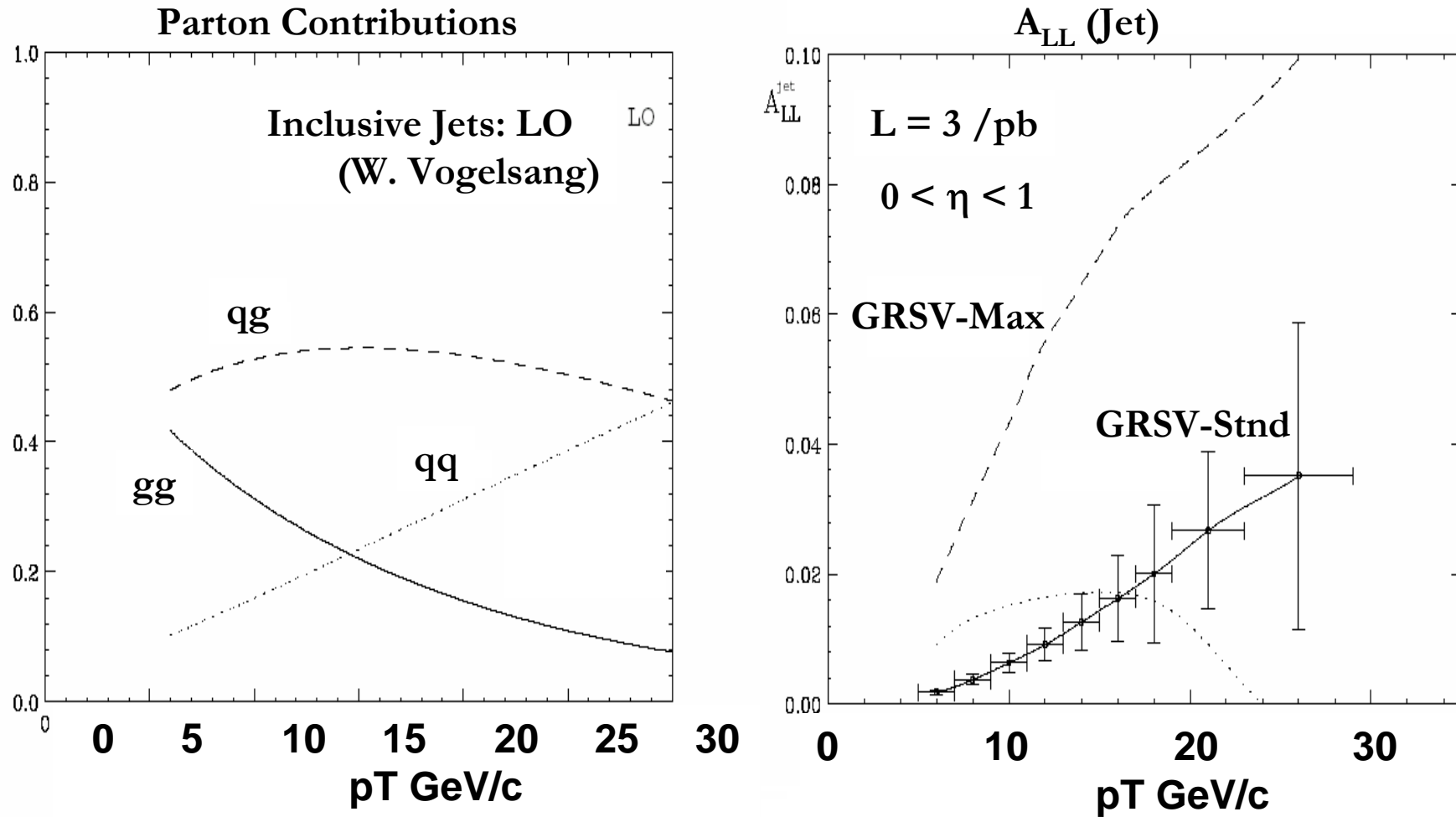
$$\propto \frac{\Delta q}{q} \frac{\Delta q}{q}$$



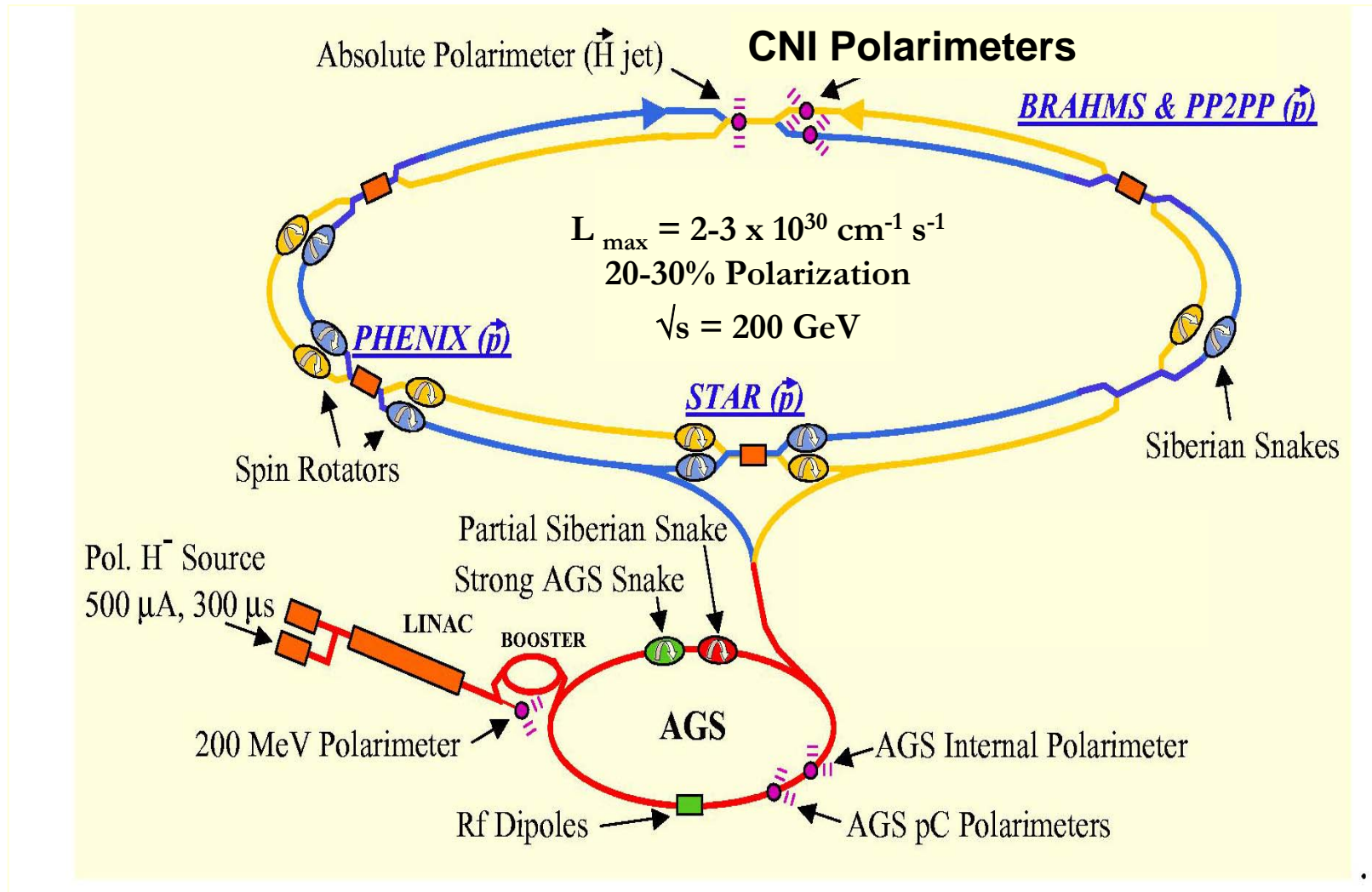
Large asymmetries at mid-Rapidity: Sensitivity to Gluon Polarization



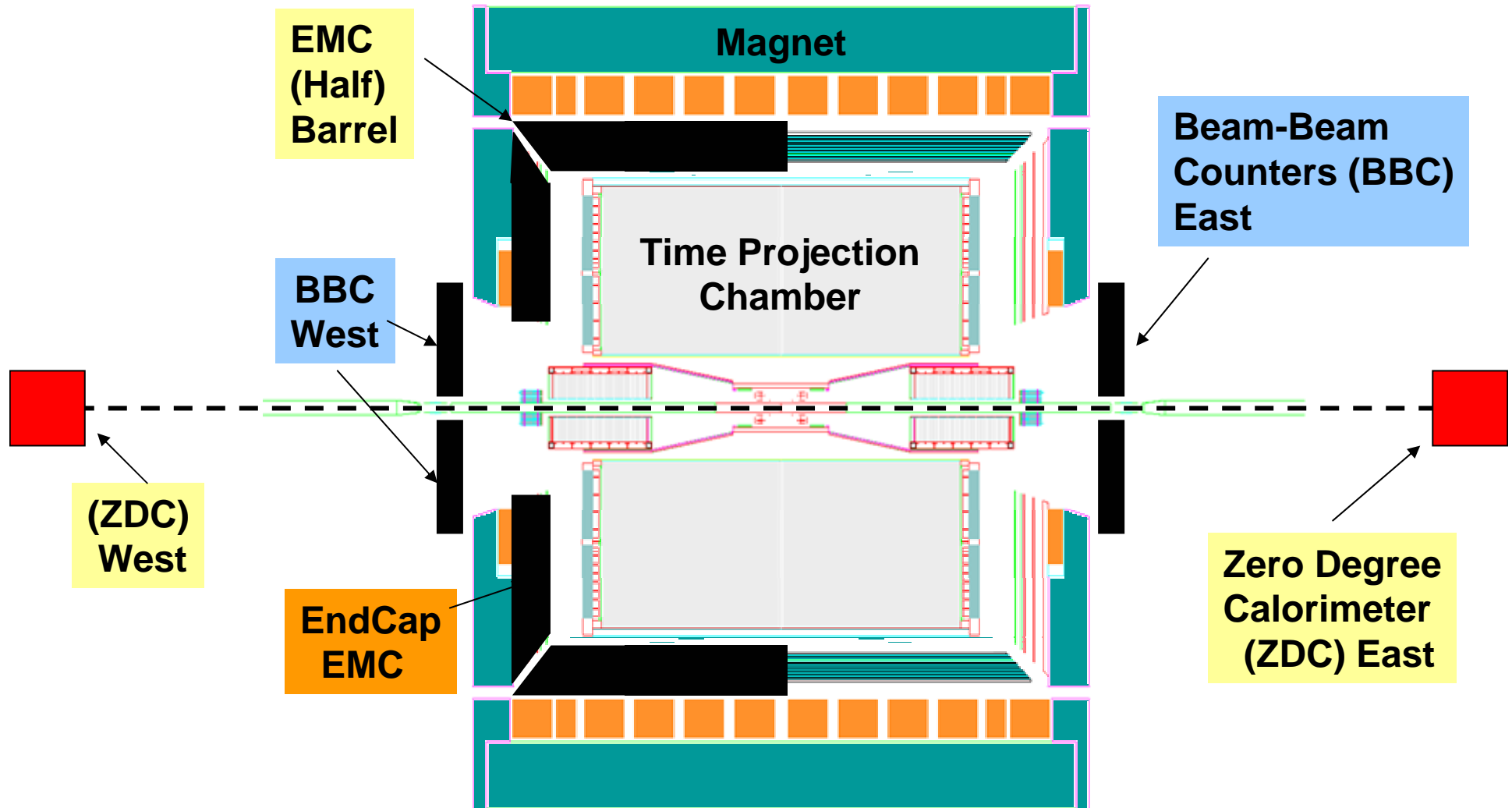
Jet Sensitivity to Gluon Polarization



RHIC: Polarized Protons (2003)



STAR Detector: 2003 Configuration



STAR Beam-Beam Counters

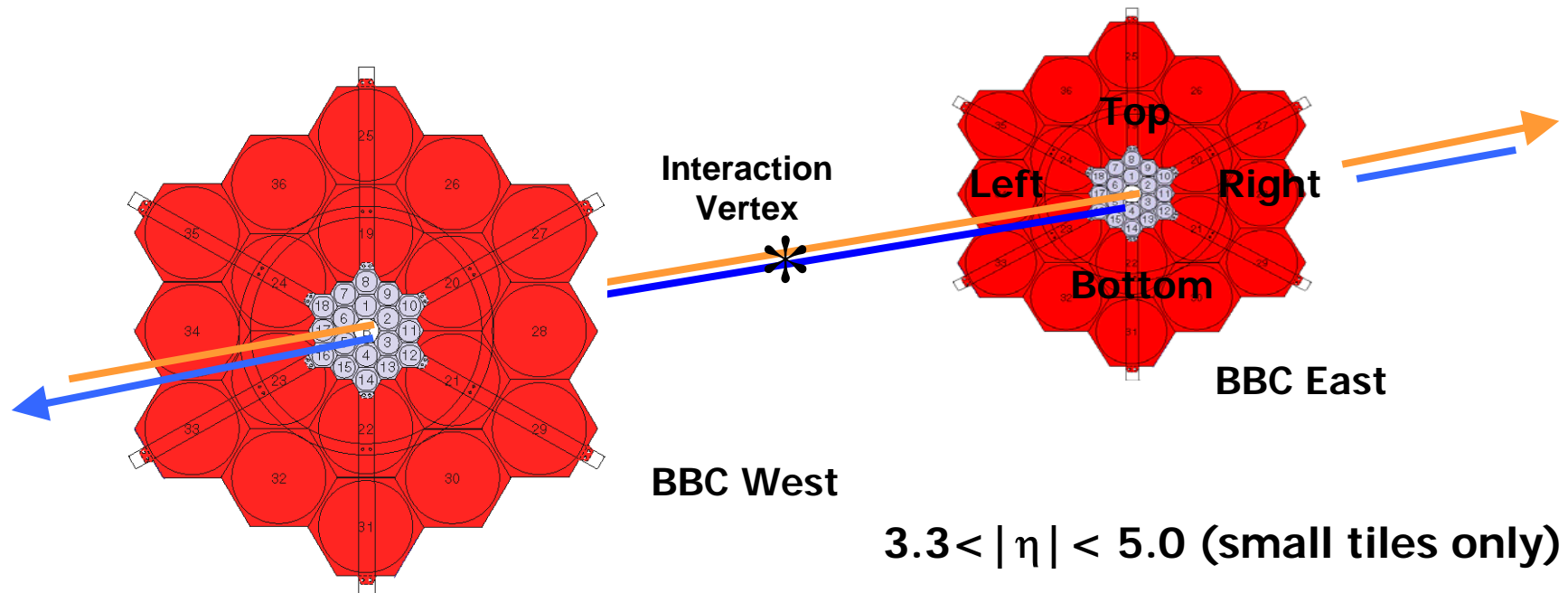
Fast, highly-segmented scintillation counter serves many purposes in STAR:

- Minimum Bias Trigger:
- Absolute Luminosity:
- Relative Luminosity:
- Local Polarimetry

Sensitive to ~50% of total cross section

Van der Meer scan

Fast scalers, updated every beam crossing
e.g., for BBC East, sort data by Yellow beam polarization, sum Blue beam polarizations

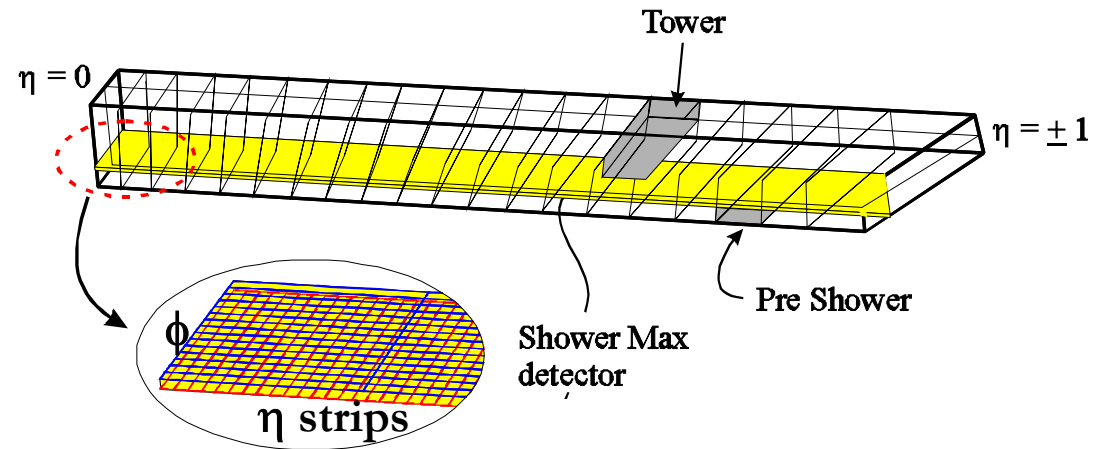


STAR Barrel Electromagnetic Calorimeter

Half Barrel EMC

- Sampling Pb-Scintillator
- $0 < \eta < 1.0$
- Full azimuthal coverage
- 60 modules
 - $(\Delta\eta, \Delta\phi)_{\text{module}} \sim (1.0, 0.1)$
 - 40 towers/module
 - Depth = $21 X_0$
 - $(\Delta\eta, \Delta\phi)_{\text{tower}} \sim (0.05, 0.05)$
 - $dE/E \sim 16\%/\sqrt{E}$
- Shower Max Detector (SMD)
 - Positioned at $\sim 5 X_0$
 - High spatial resolution
 - $(\Delta\eta, \Delta\phi) \sim (0.007, 0.007)$

EMC Module



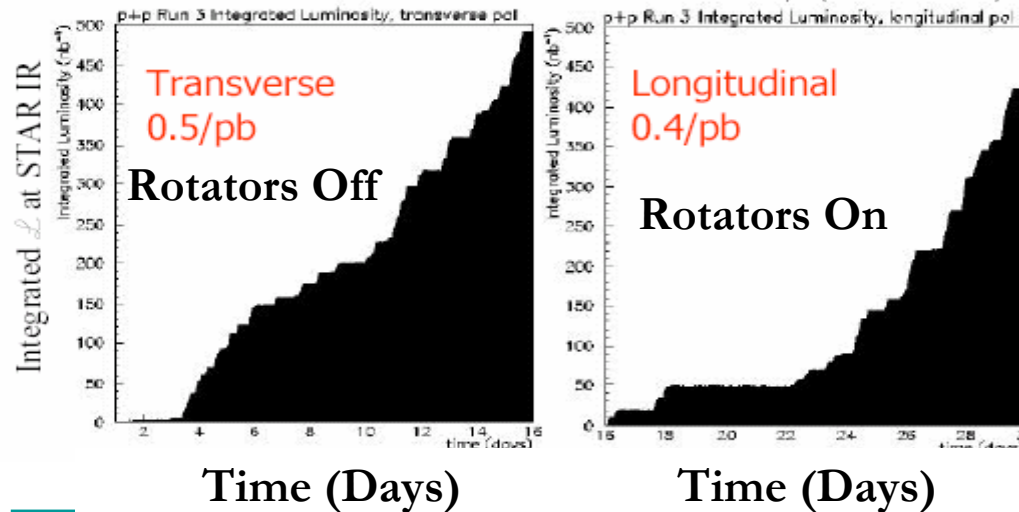
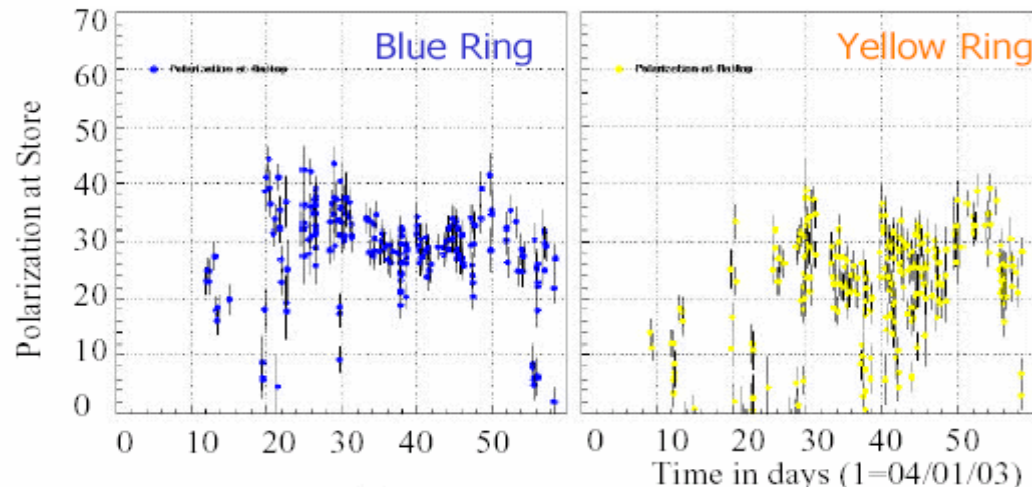
Full Barrel EMC

- Installation in 2005
- Preshower Capability



RHIC Performance During Run 3

RHIC Performance during 2003



Performance in 2003

- Average $P \sim 25\%$
- Instantaneous Luminosity
 $\sim 2-3 \cdot 10^{30} \text{ cm}^{-2} \text{ s}^{-1}$
- CNI Polarimetry
- Yellow ring affected by problem with snake magnet
- Single Week of Longitudinal Polarization

Projections for 2004

- Average $P \sim 40-50\%$
- Instantaneous Luminosity
 $\sim 6 \cdot 10^{30} \text{ cm}^{-2} \text{ s}^{-1}$
- Polarized Gas Jet Target:
(already operational!)

1 Week FOM Increase (P^4L)
 $x \sim 8-10$

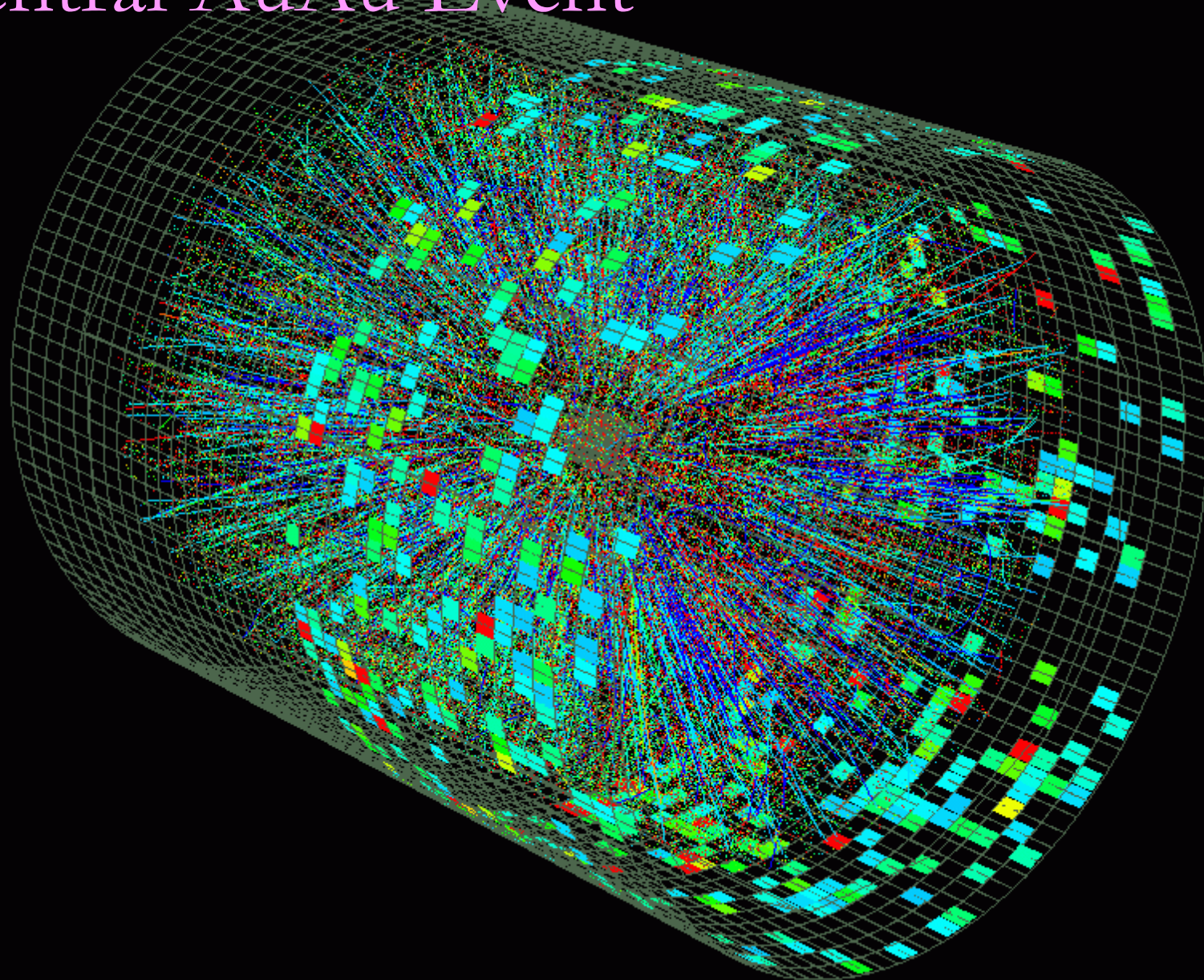


pp Longitudinal Data Set

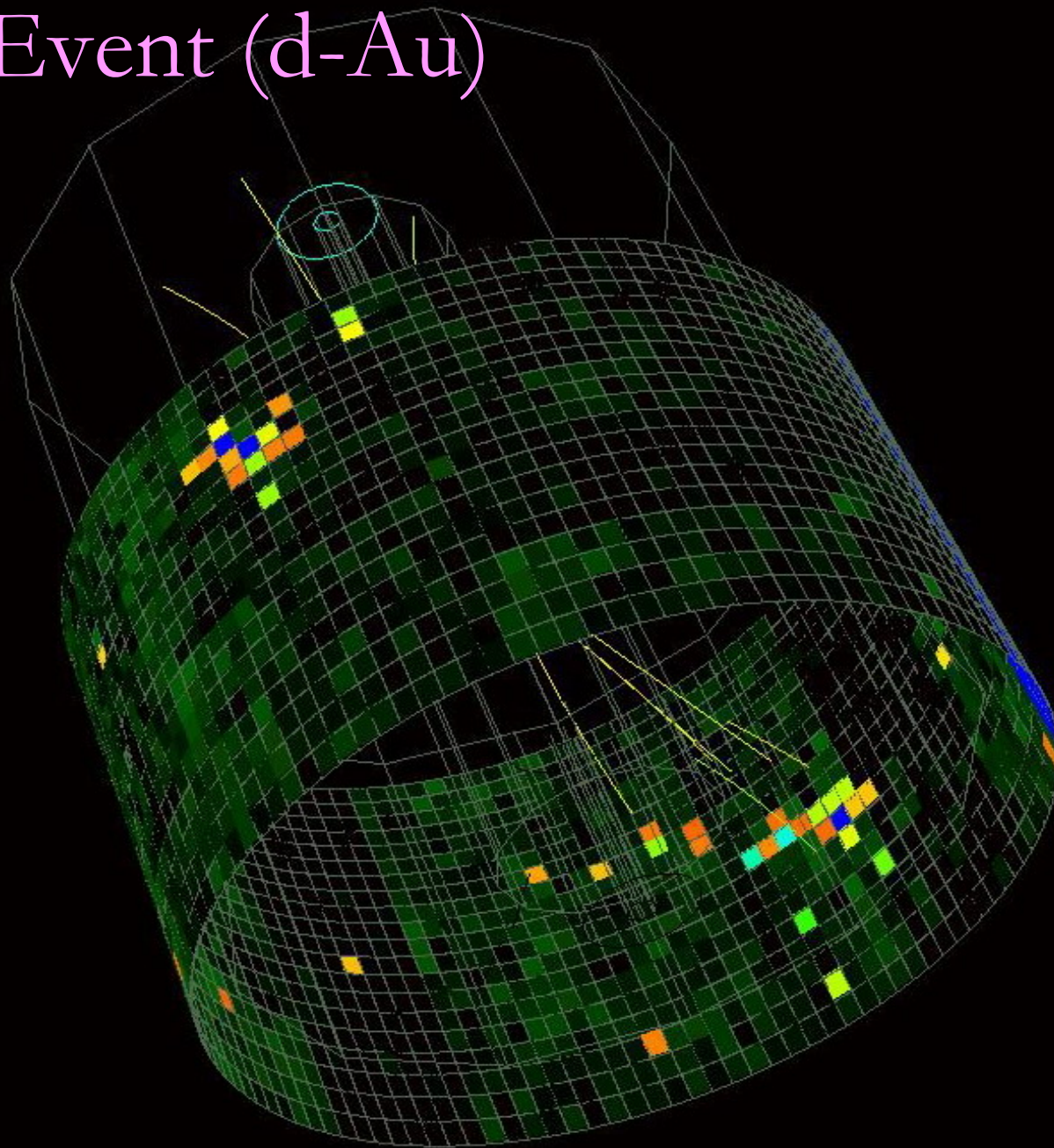
- **May 16- May 30 2003**
- **Ave Polarization / Beam ~0.25**
- **RHIC Delivered Integrated Luminosity ~ 420 nb⁻¹**
- **Full STAR Detectors Sampled ~ 330 nb⁻¹**
- **Recorded Luminosity ~ 180 nb⁻¹**
- **Barrel EMC Covers**
 - **$0 < \eta < 1$ and the Full Azimuth**
- **High Tower Trigger**
 - **Requires Single Tower ($E_T \sim > 2.4$ GeV)**
- **Jet Patch Trigger**
 - **Requires Patch of 1x1 (η, ϕ) $E_T > 7$ GeV**



Central AuAu Event



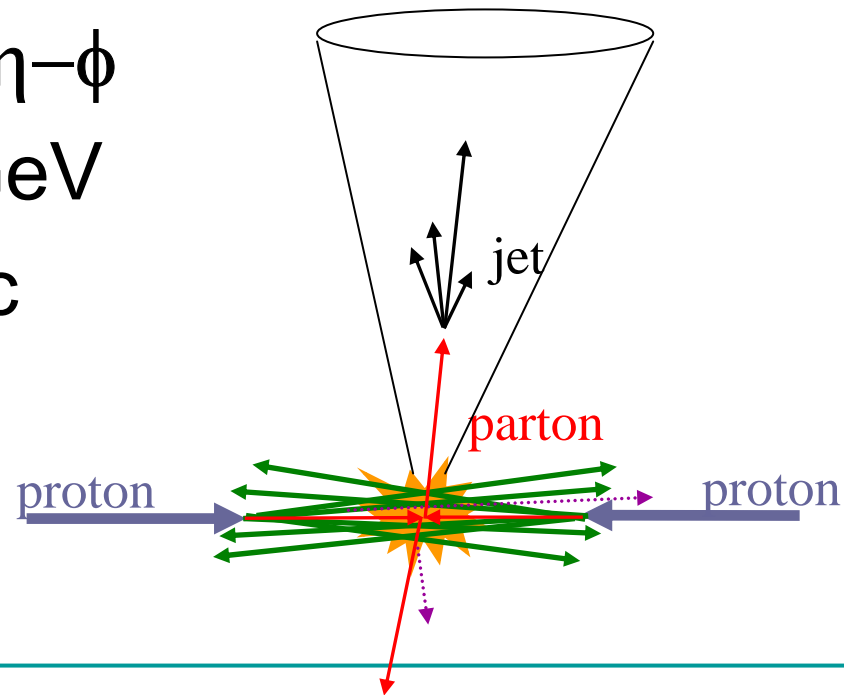
Di-Jet Event (d-Au)



Jet Finder: Charged Jets

For this analysis, Jets are defined as a grouping of one or more (charged) tracks measured in the TPC and satisfying the following requirements...

- Using an Iterative, Midpoint, Cone Algorithm*
- Cone Angle = 0.7 in $\eta-\phi$
- Seed Energy = 0.5 GeV
- p_T Track > 0.1 GeV/c
- $-1.6 < \eta_{\text{tracks}} < +1.6$
- **p_T Jet > 5 GeV**



* Blazey et al hep-ex/0005012 (SNOMASS)

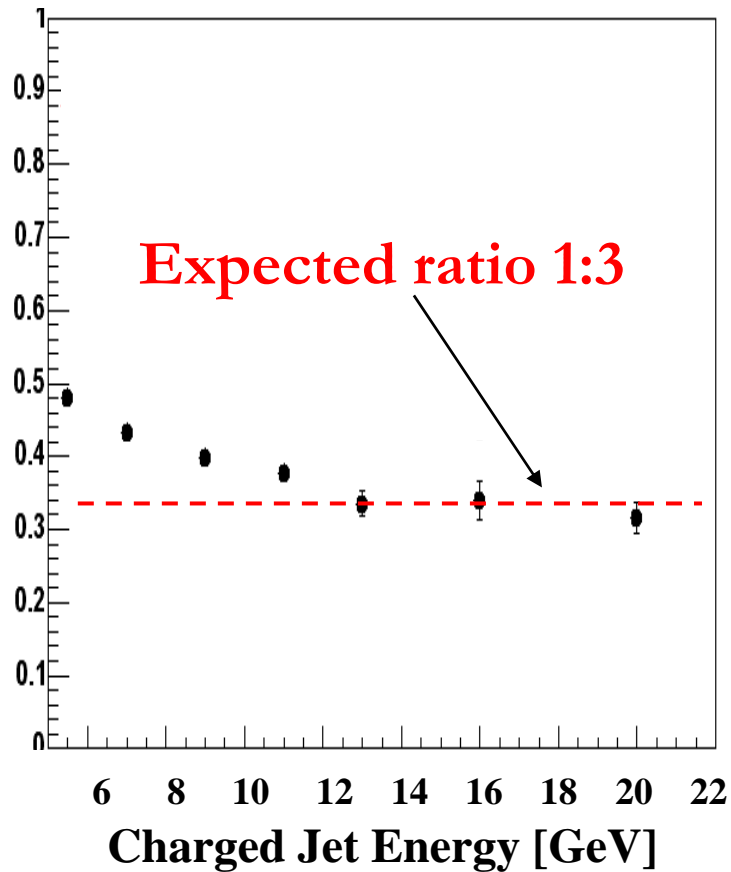
Jet Reconstruction

- Charged Jets: Jet finder uses charged tracks only in jet definition. Sum of track energies is **charged jet energy**
- Neutral energy: Sum neutral energy in EMC using jet cone/direction defined by charged tracks. Define multiplicity in terms of EMC **clusters** (maximum of 2x2 tower hits possible by single particle).
- **Total energy is sum of charged and neutral.**
- Full Jet reconstruction using EMC coming soon.

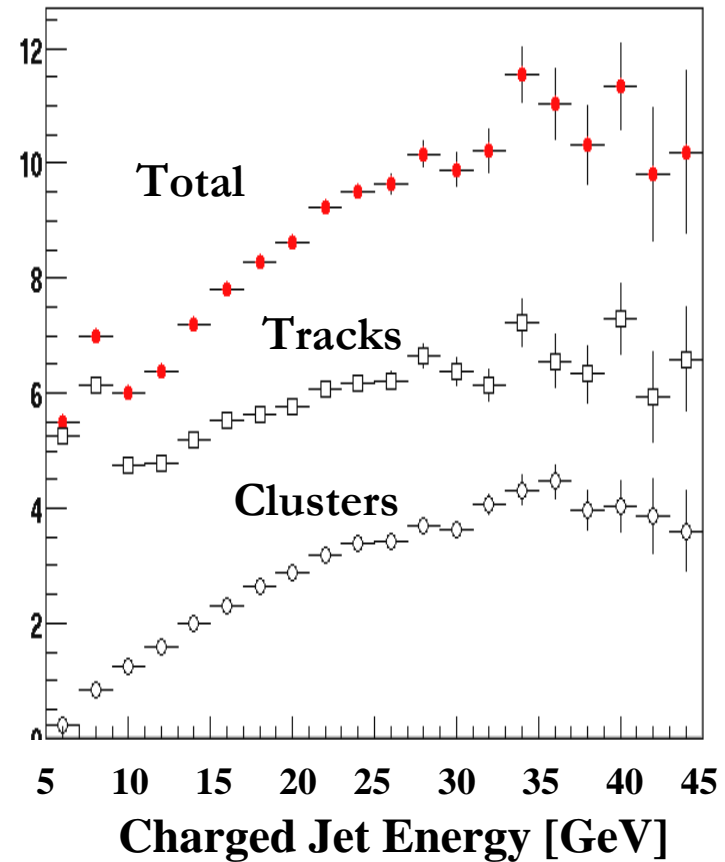


Trigger Bias: Neutral Energy Fraction

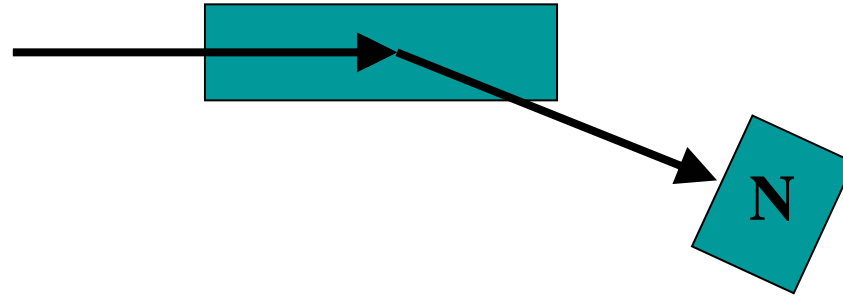
Neutral E_T /Total Jet E_T



Track and Cluster Multiplicities



Double Spin Asymmetries



$$A_{LL} = (\sigma^{++} - \sigma^{-+}) / (\sigma^{++} + \sigma^{-+})$$

$$A_{LL} = \frac{1}{P_A P_B} \cdot \frac{N^{\uparrow\uparrow} / \mathcal{L}^{\uparrow\uparrow} + N^{\downarrow\downarrow} / \mathcal{L}^{\downarrow\downarrow} - N^{\uparrow\downarrow} / \mathcal{L}^{\uparrow\downarrow} - N^{\downarrow\uparrow} / \mathcal{L}^{\downarrow\uparrow}}{N^{\uparrow\uparrow} / \mathcal{L}^{\uparrow\uparrow} + N^{\downarrow\downarrow} / \mathcal{L}^{\downarrow\downarrow} + N^{\uparrow\downarrow} / \mathcal{L}^{\uparrow\downarrow} + N^{\downarrow\uparrow} / \mathcal{L}^{\downarrow\uparrow}}$$

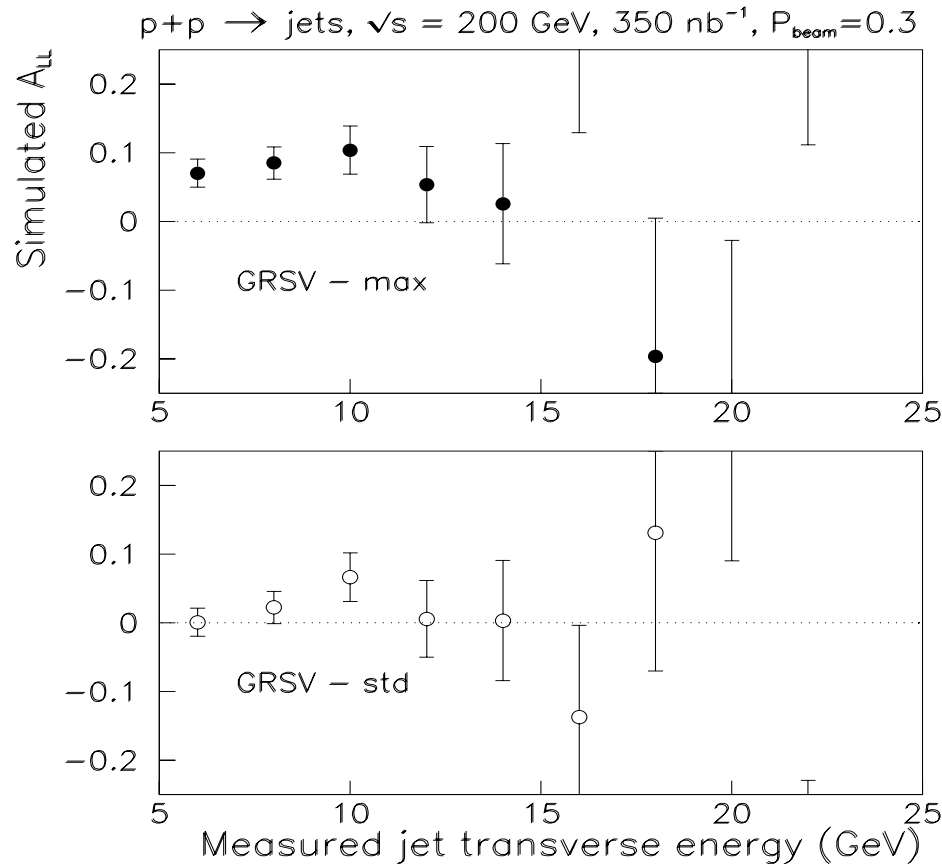
$$\mathcal{R} = \mathcal{L}^{\uparrow\downarrow} / \mathcal{L}^{\uparrow\uparrow} \dots \mathcal{L}^{\downarrow\downarrow} / \mathcal{L}^{\uparrow\uparrow} \dots \text{etc...}$$

Requires luminosity ratios to be measured much more accurately than desired precision on asymmetry.



Inclusive Jet Production

A_{LL} Sensitivity (incl. detector effects)



- Simulation based on Pythia including trigger and jet reconstruction efficiencies

- Assume: Present coverage of EMC (barrel)

$$\Rightarrow 0 < \Phi < 2\pi \text{ and } 0 < \eta < 1$$

- Jet Trigger: $E_T > 5 \text{ GeV}$ over at least one “patch” ($\Delta\eta = 1$) x ($\Delta\Phi = 1$)

- Jet reconstruction: Cone algorithm (seed = 1 GeV, $R = 0.7$)

- Luminosity: 350 nb^{-1}

- Polarization: 0.3

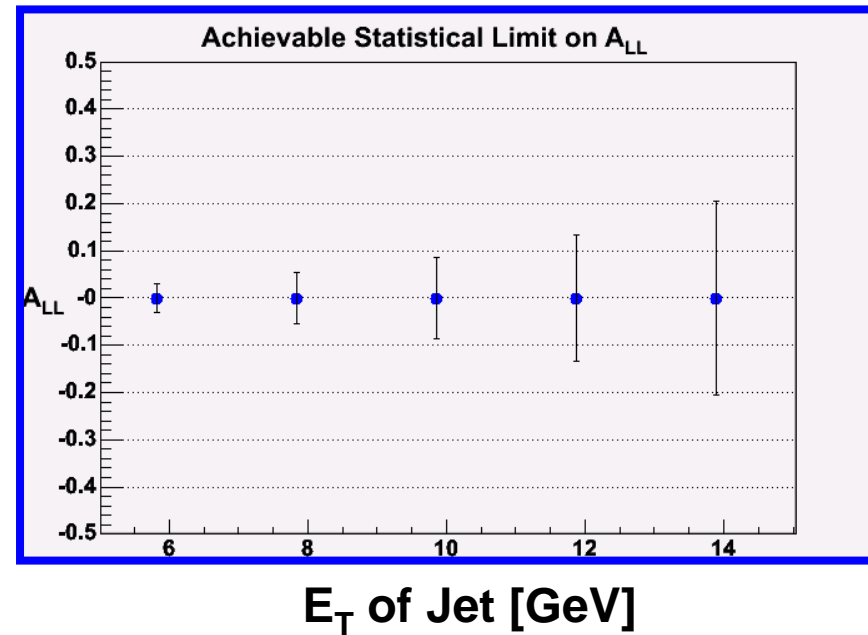
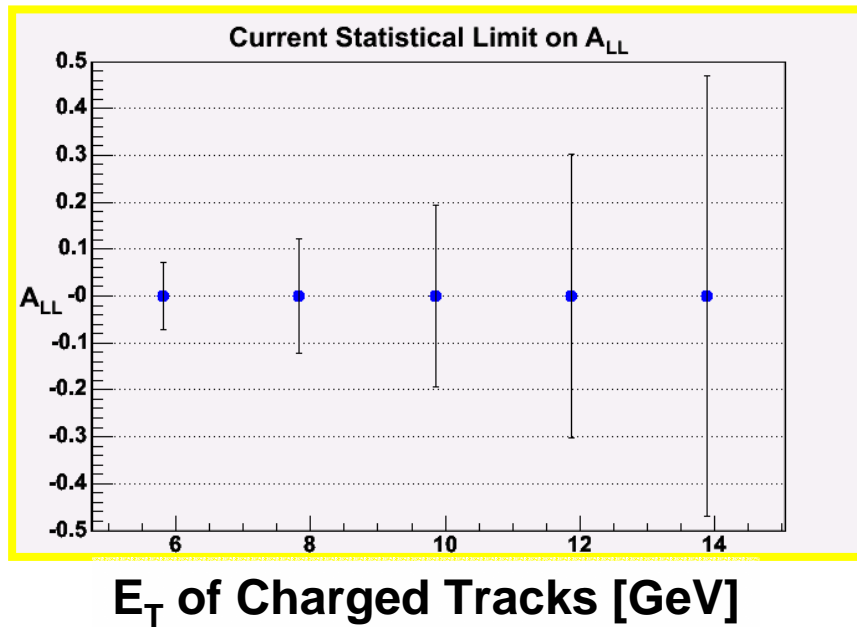
- $\sqrt{s} = 200 \text{ GeV}$

Simulations by Les Bland



Statistical Precision (2003 Data)

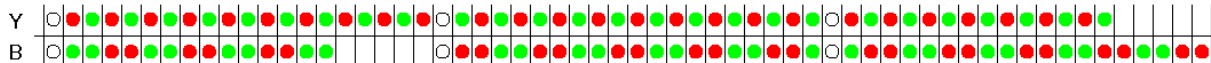
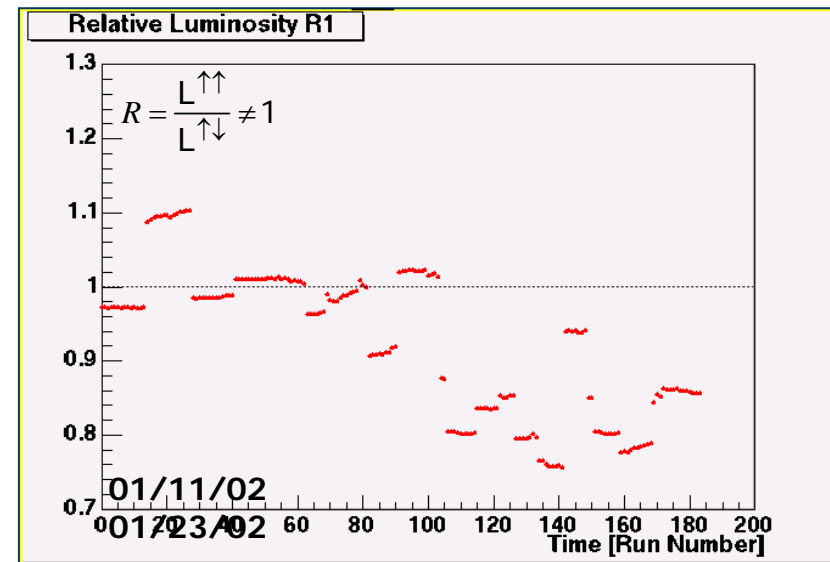
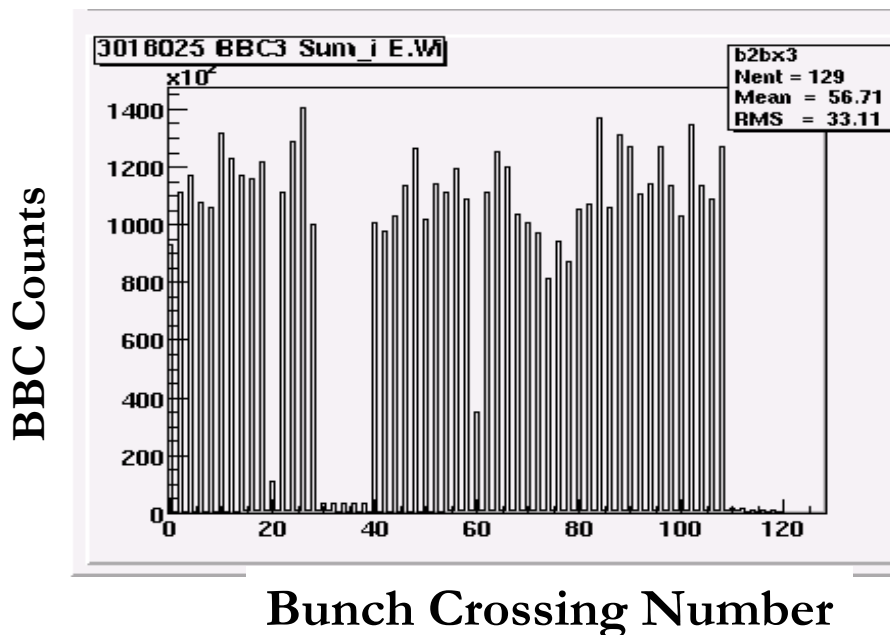
Data	$\sigma(A_{LL})$
TPC Jets	+/- 0.057
EMC+TPC Jets	+/- 0.030



Relative Luminosity Determination

Scaler Board System:

- 24 bit Input Pattern (Fast STAR detectors) recorded for each RHIC Strobe (every 214 ns)
- Relative luminosity for each bunch crossing/polarization combinations
- Beam-gas background determined from 'abort gap' /beam collisions (typically <0.5%)
- Relative luminosity determined to 10^{-4} (30 minutes)



Bunch Polarization Pattern at STAR



Error on A_{LL} from Relative Luminosity Meas. $\sim 10^{-3}$

Transverse Single Spin Asymmetries

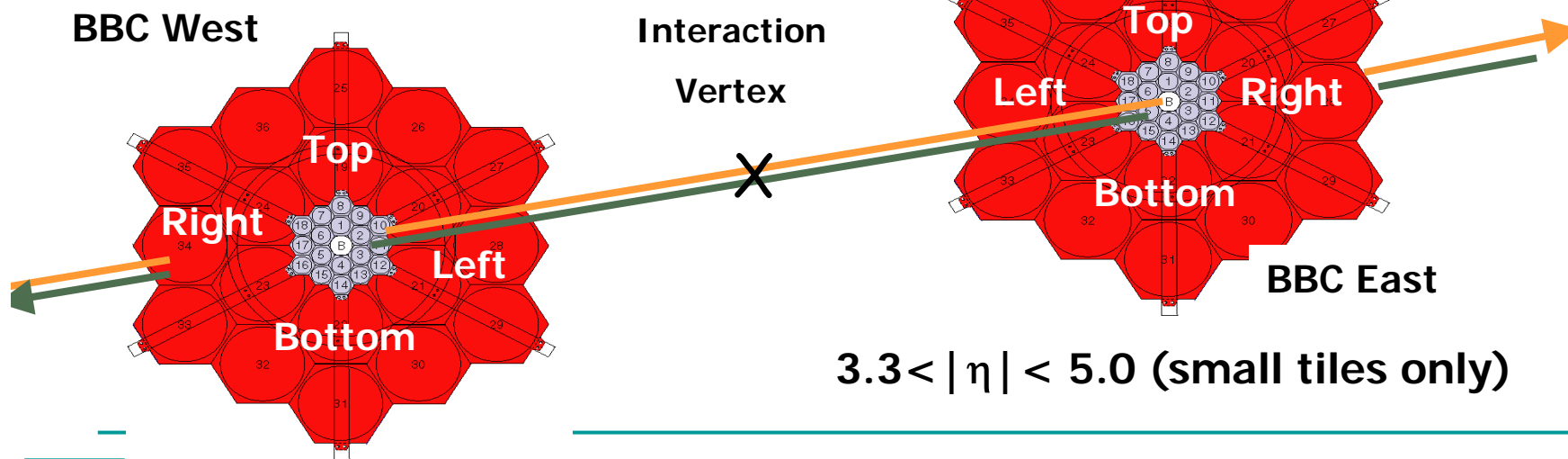
Single spin asymmetries measured for $p+p \rightarrow A + X$, where A – hit(s) in the BBC

$$\mathcal{E} = P_{\text{beam}} \times A_N \approx \frac{\sqrt{N_L^\uparrow N_R^\downarrow} - \sqrt{N_L^\downarrow N_R^\uparrow}}{\sqrt{N_L^\uparrow N_R^\downarrow} + \sqrt{N_L^\downarrow N_R^\uparrow}}$$

$L(R)$ – number of counts in Left (Right) or Top (Bottom) in the BBC East or BBC West (small annuli) counted every bunch crossing by the scaler system

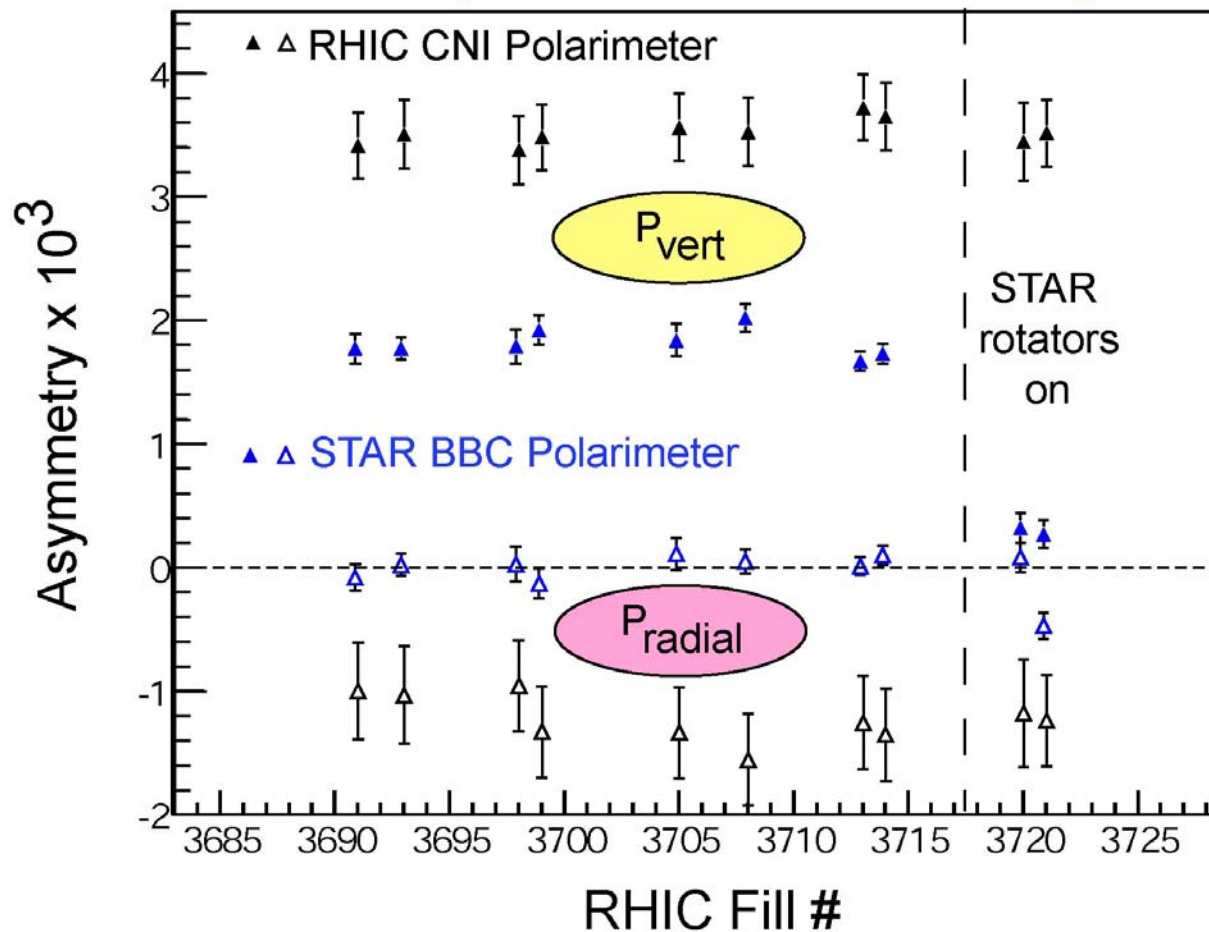
The BBC East and West data sets sorted by beam polarization states:

1. **Polarized Yellow beam** (sum over Blue beam polarization states) heads towards the East
2. **Polarized Blue beam** (sum over Yellow beam polarization states) heads towards the West



Local Polarimetry: Longitudinal Polarization

Blue Beam Spin Rotator Commissioning, 5/03



Radial Polarization Component (Yellow) < (8°)

Systematic Error: A_{LL} in Relative Luminosity

Is $A_{LL} = 0$ in the Relative Luminosity ($R=L_{\uparrow\uparrow}/L_{\uparrow\downarrow}$) measurement?

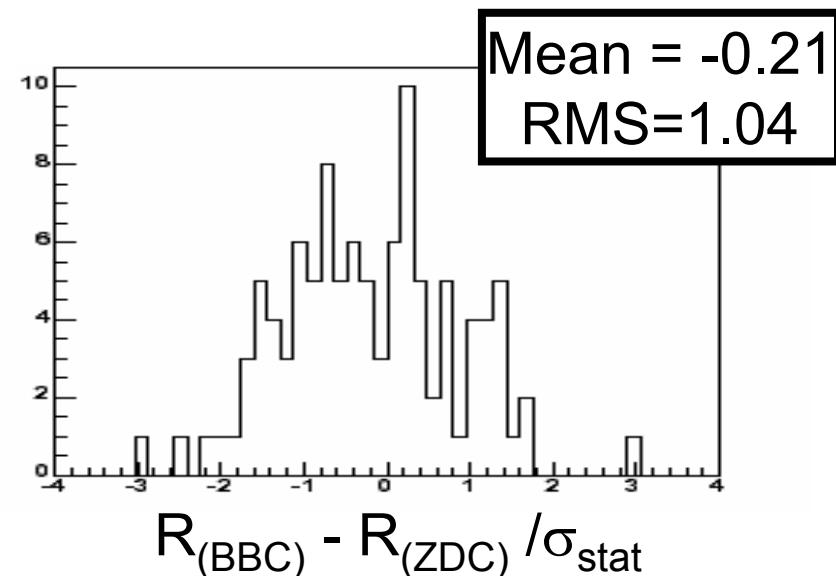
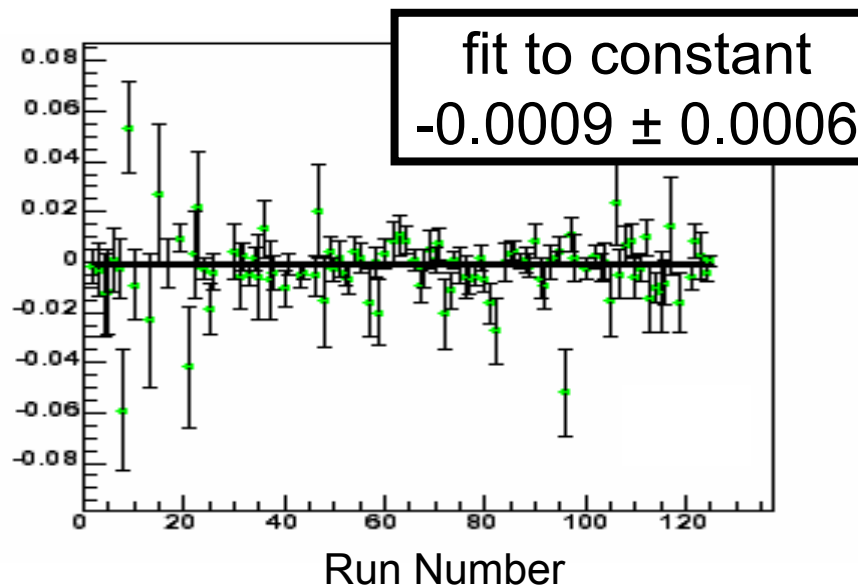
Compare measurements from two different detectors:

BBC sees $\sim 50\%$ of σ_{Total}

ZDC sees $\sim 0.5\%$ of σ_{Total}

($\sim 87\%$ of inelastic, non-single diffractive)

$R(bbc)-R(zdc)$

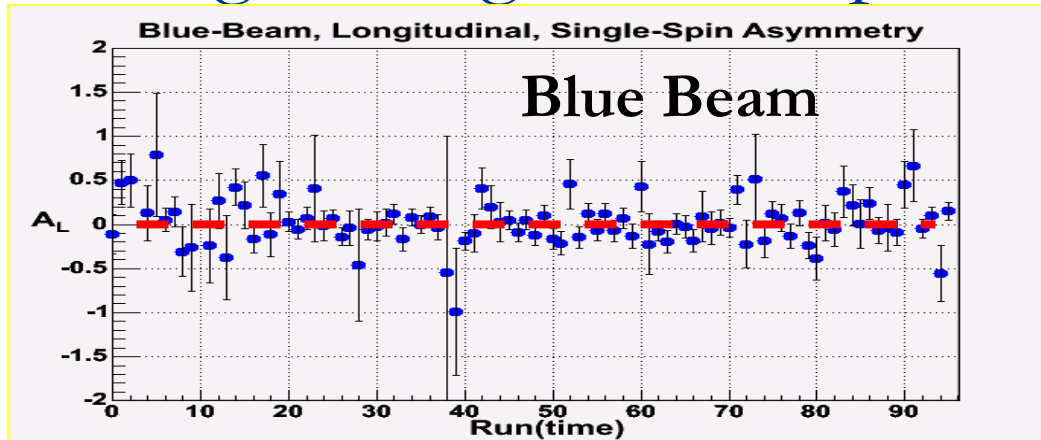


$$\epsilon_{LL}(BBC) - \epsilon_{LL}(ZDC) \sim R_{(BBC)} - R_{(ZDC)} \leq 10^{-3}$$

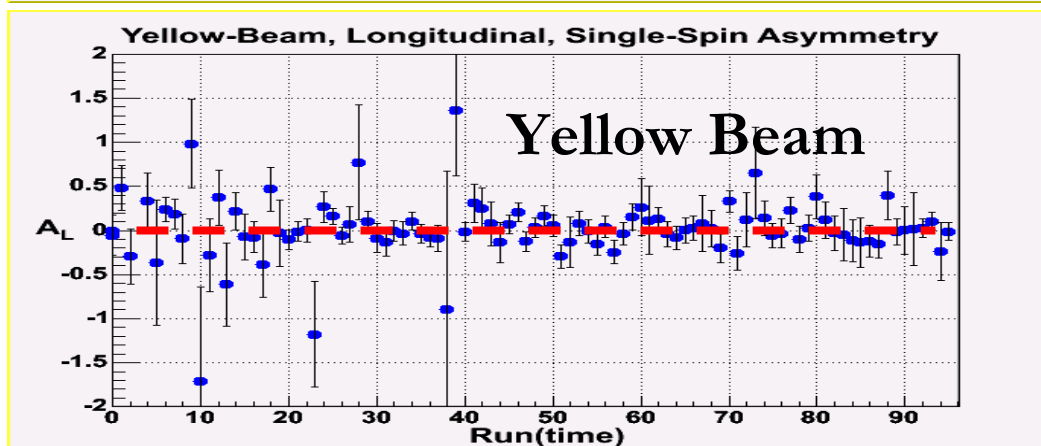


Consistent with zero to within statistical error

Diagnostic Tools: Parity-Violating Single Longitudinal Spin Asymmetries



$$\mu = 0.00066$$
$$\sigma = 0.0156$$
$$\chi^2/\text{dof} = 1.12$$



$$\mu = 0.0215$$
$$\sigma = 0.0163$$
$$\chi^2/\text{dof} = 1.06$$

Run Number

Parity-violating single longitudinal spin asymmetries consistent with 0.

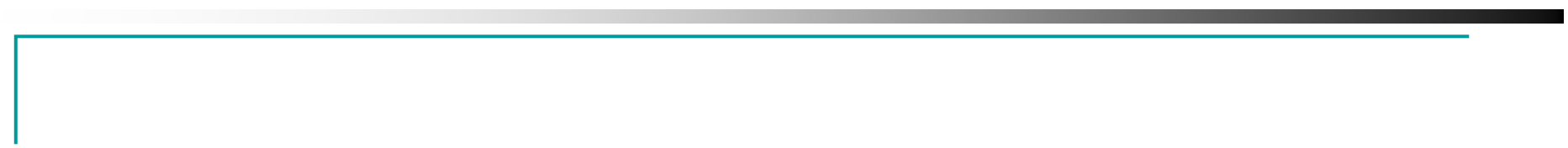


Conclusions

- Inclusive Jet asymmetry measurement (2003)
 - Statistical Error Estimate: $3 \cdot 10^{-2}$
- Progress in Systematic Errors

- Prospects for 2004: 1 week run @ Pol $\sim 50\%$
 - Statistical Error Estimate: $1 \cdot 10^{-3}$
 - Improvement of Systematic Uncertainties



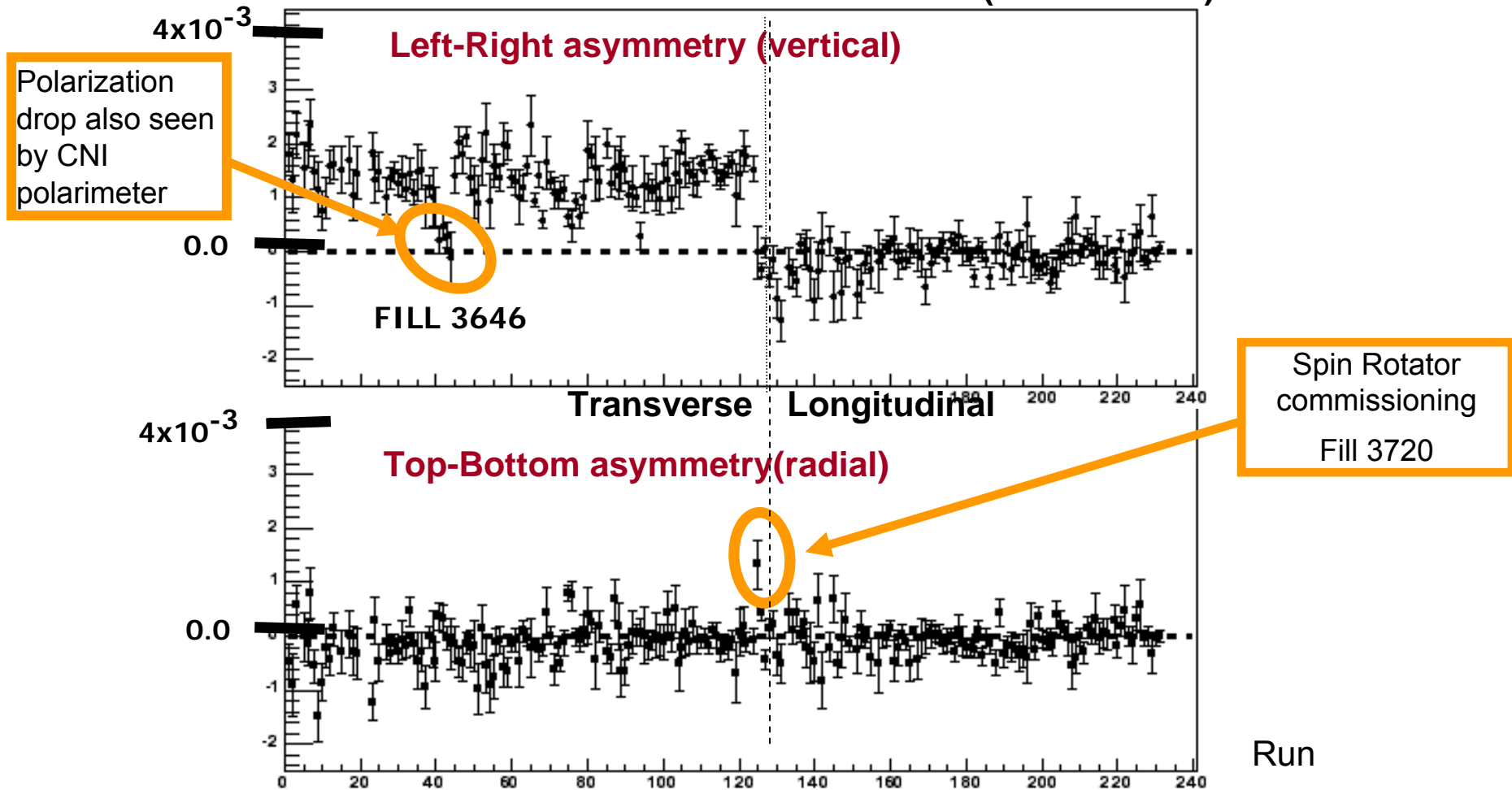


End



Local Polarimetry: Longitudinal Polarization

BBC East (Yellow beam)



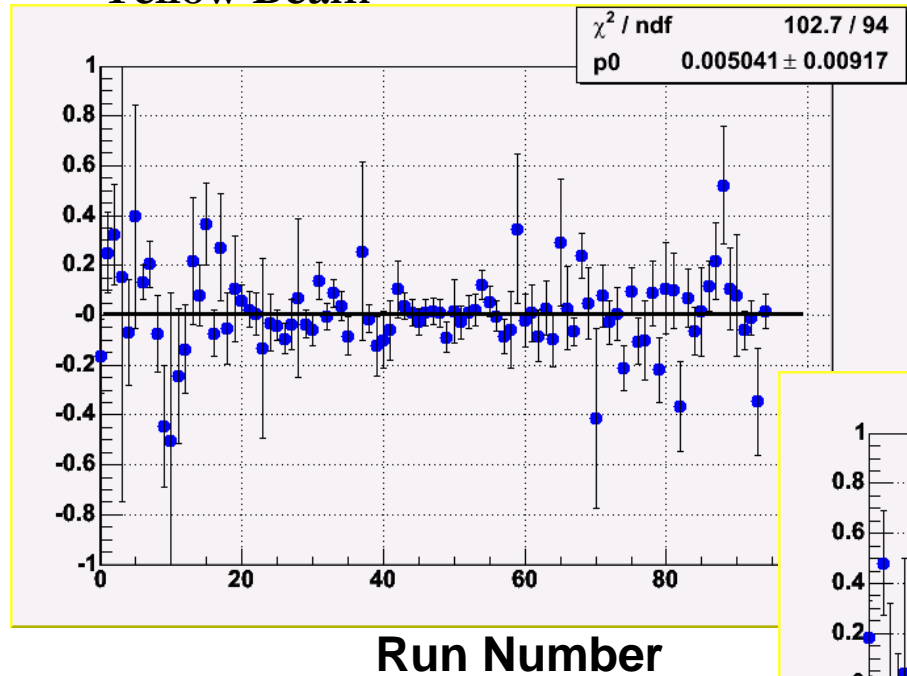
Physics behind the BBC asymmetry is being studied. More information available from the scaler data (dependence on pseudo-rapidity and multiplicity)



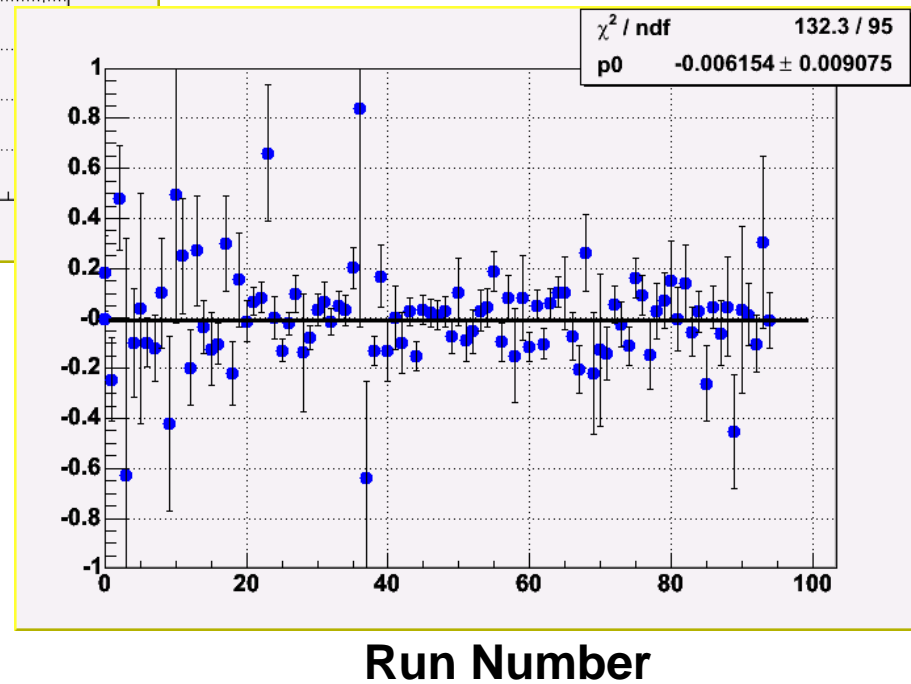
Radial Polarization Component (Yellow) $< (8^\circ)$

Systematic Errors: Single Spin Asymmetries

Yellow Beam



Blue Beam



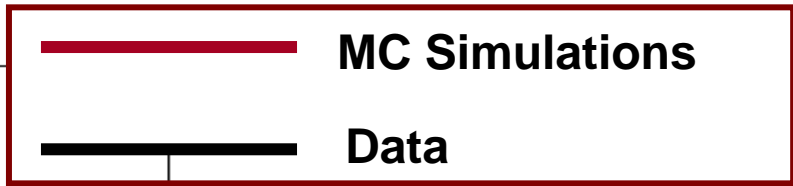
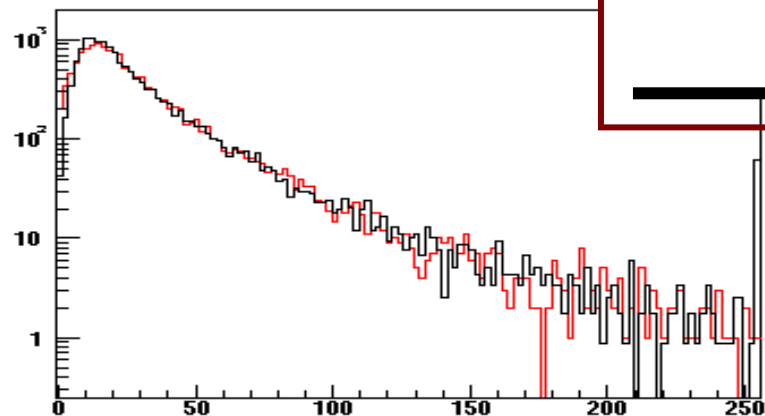
Systematic Error $< 9 \cdot 10^{-3}$



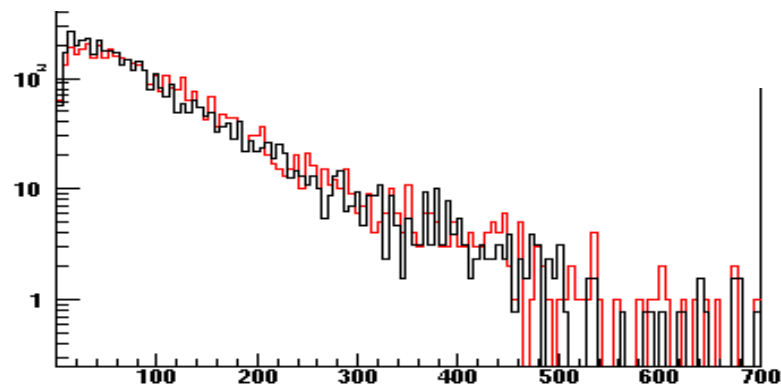
Systematic error estimate from $A_L < 9 \cdot 10^{-3}$

BBC Monte-Carlo Simulations

ADC (Single PMT)



ADC (PMT Sum)



Simulation of detector includes vertex smearing, photoelectron resolution, timing resolution, etc...

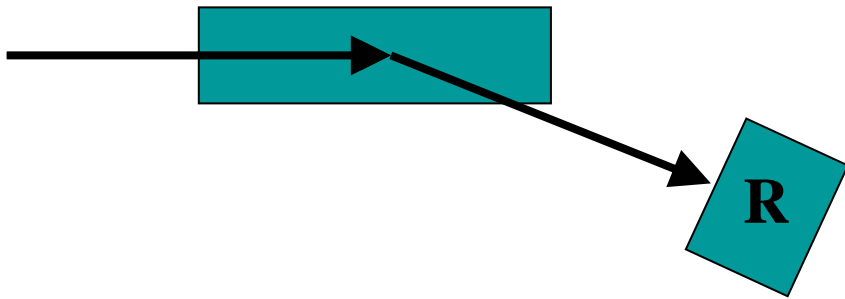
Sensitive to single charged tracks (π^+)
...sees positive transverse asymmetry
as in E704, E925 results.

BBC East shown, BBC West looks similar,
both for the data and MC

Simulation describes the data

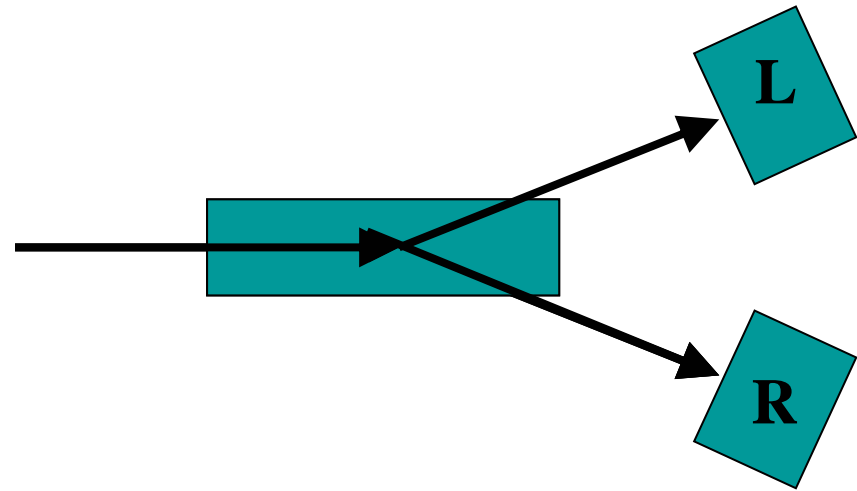


Single Spin Asymmetries



$$A_N = \frac{1}{P_B} \cdot \frac{R^\uparrow / \mathcal{L}^\uparrow - R^\downarrow / \mathcal{L}^\downarrow}{R^\uparrow / \mathcal{L}^\uparrow + R^\downarrow / \mathcal{L}^\downarrow}$$

$$\mathcal{R} = \mathcal{L}^\downarrow / \mathcal{L}^\uparrow \quad \text{Luminosity Ratio}$$



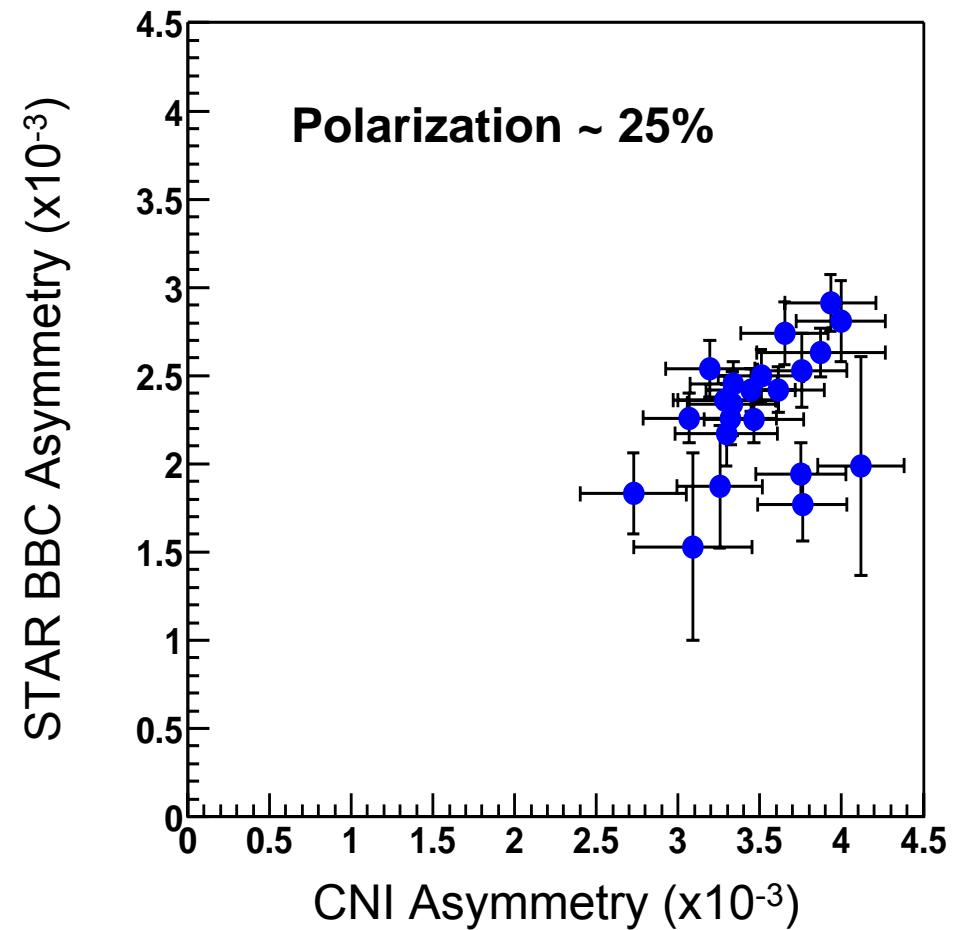
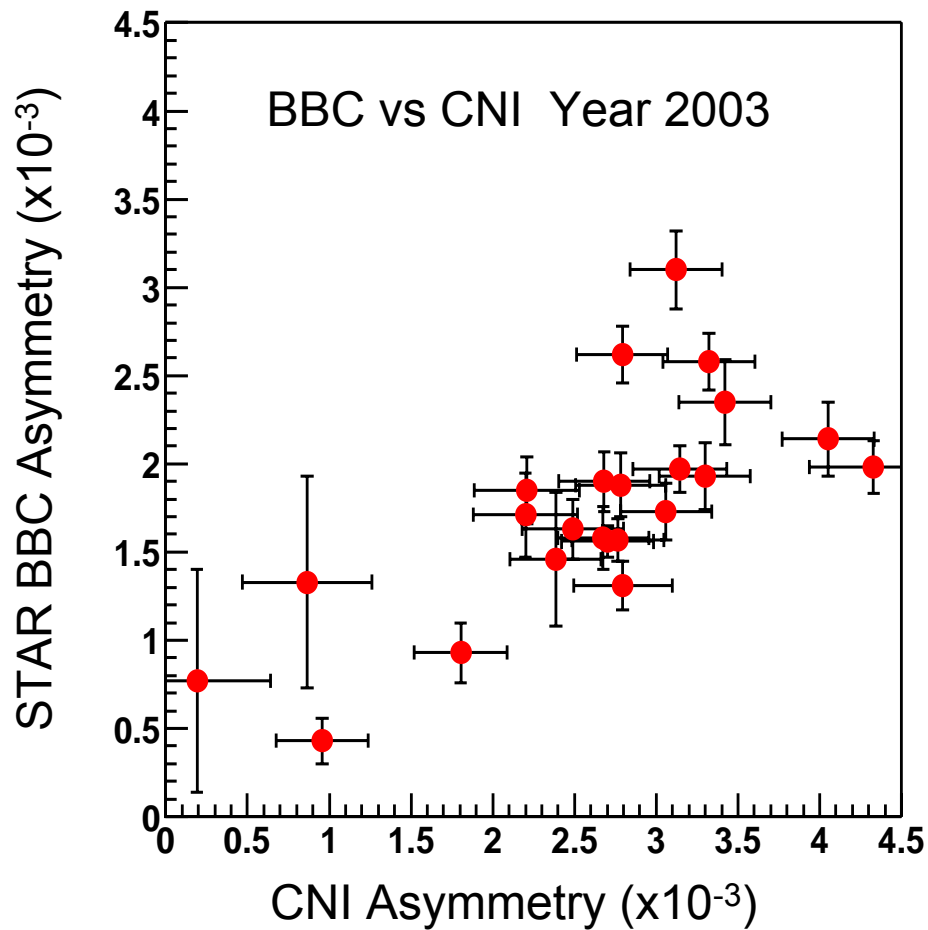
$$A_N = \frac{1}{P_B} \cdot \frac{\sqrt{R^\uparrow L^\downarrow} - \sqrt{R^\downarrow L^\uparrow}}{\sqrt{R^\uparrow L^\downarrow} + \sqrt{R^\downarrow L^\uparrow}}$$

Insensitive to Luminosity or
Acceptance Ratios

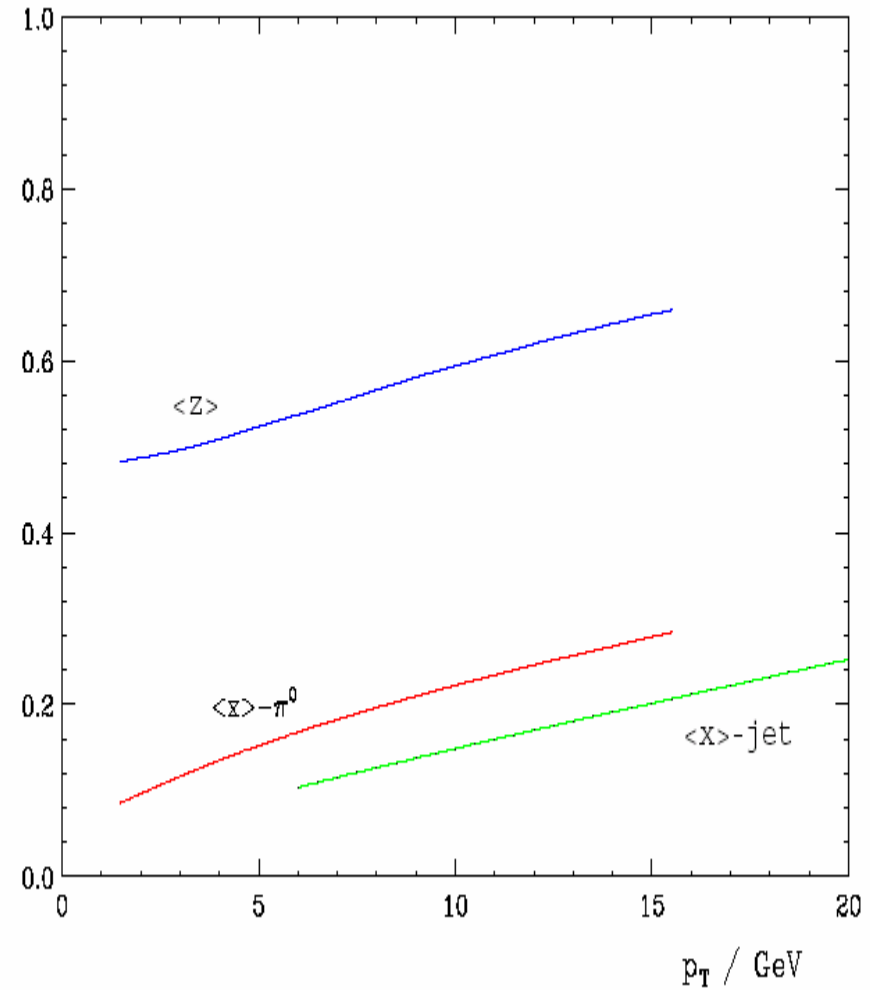
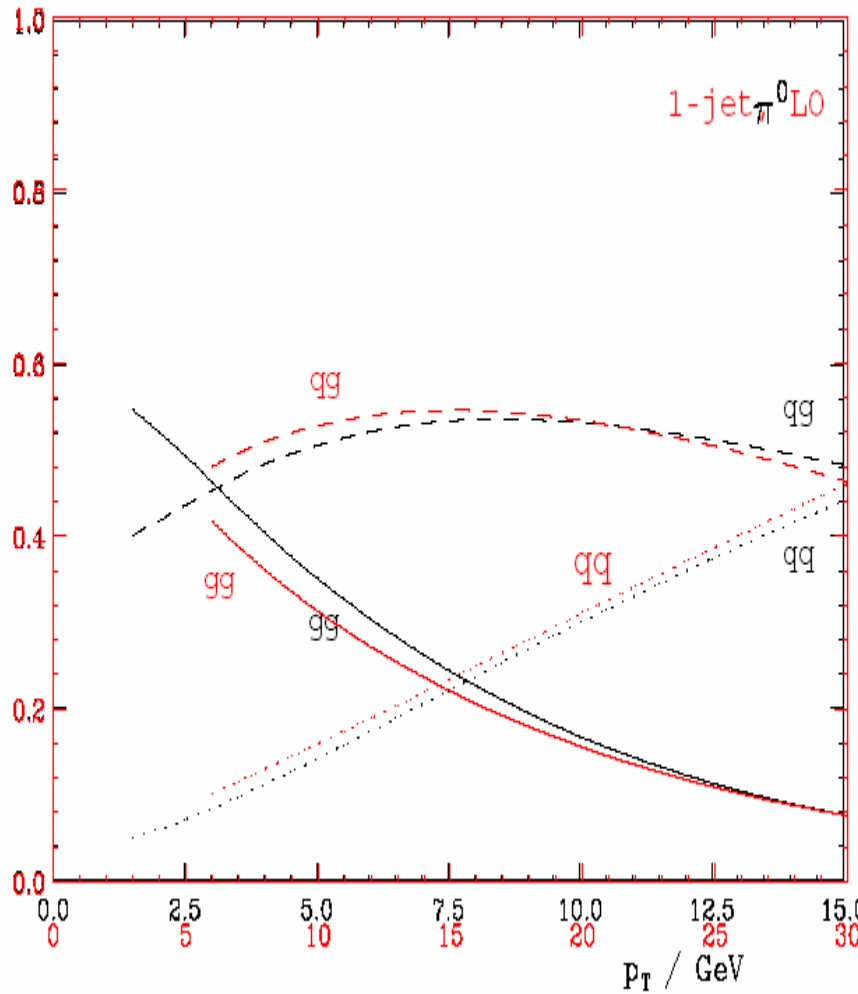
BBC Spin Asymmetries: 2003 Run

Yellow Beam

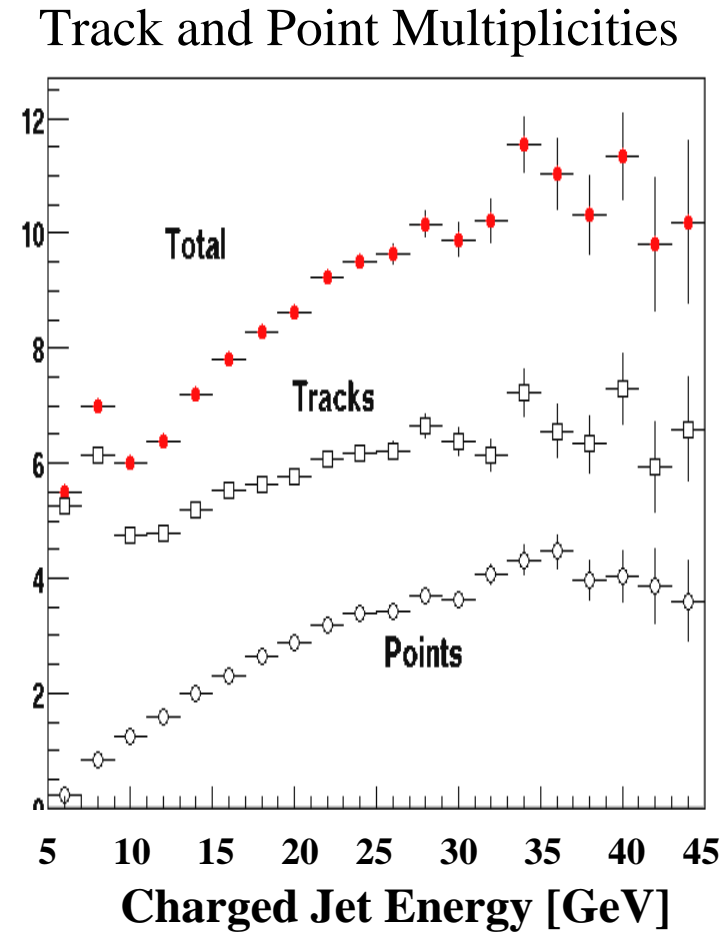
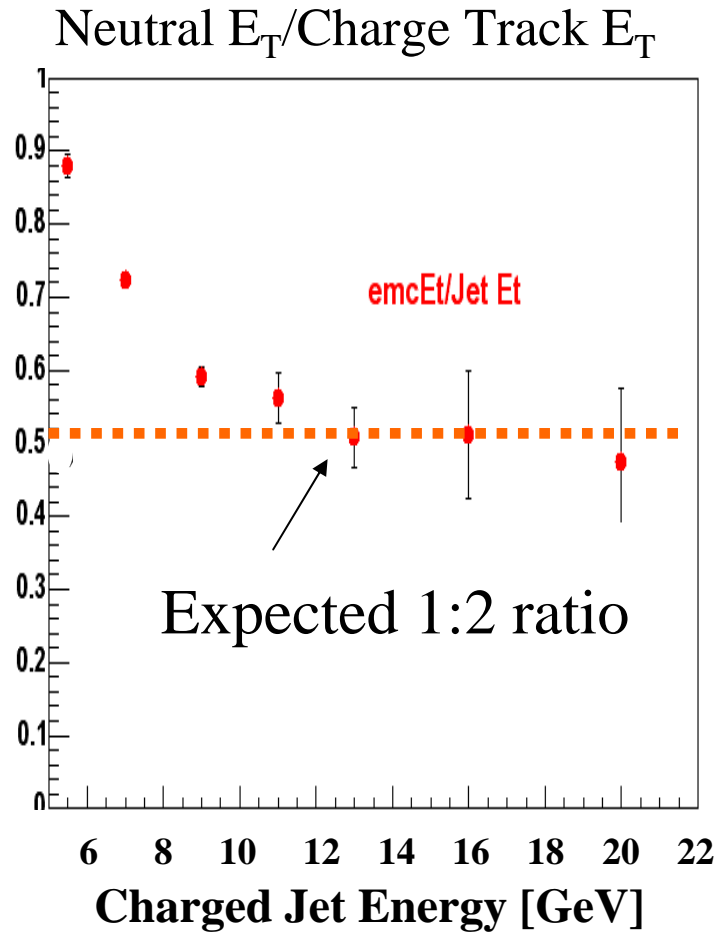
Blue Beam



Pions Compared to Jets

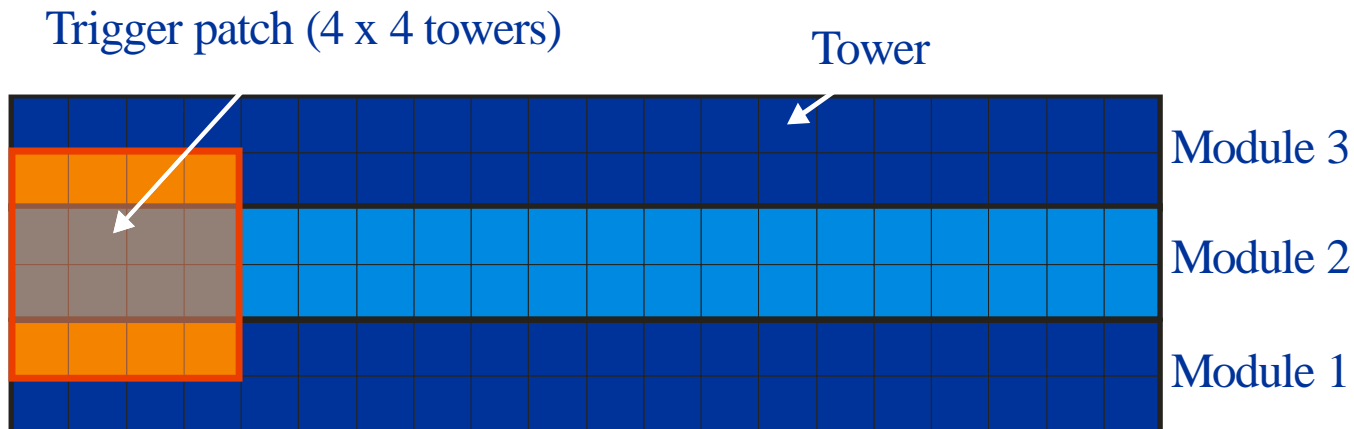


Trigger Bias: Neutral Energy Fraction



EMC (L0) Trigger

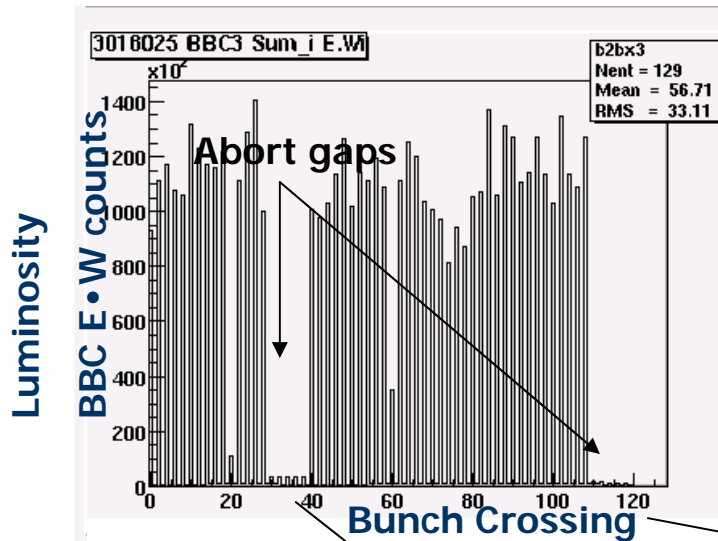
- **High- p_T trigger (High Tower)**
 - Photons, electrons and π^0
 - Highest tower in patch
 - 150 trigger patches
 - 4 x 4 towers
 - $(\Delta\eta, \Delta\phi) \sim (0.2, 0.2)$
 - Highest tower in patch (HT)
 - 0.2 GeV energy resolution
- **Jet trigger (2003)**
 - Sum of Patches in $(\Delta\eta, \Delta\phi) = (1.0, 1.0)$
 - 6 Patches in Barrel



Luminosity Monitoring and Relative Luminosity

Scaler Board System:

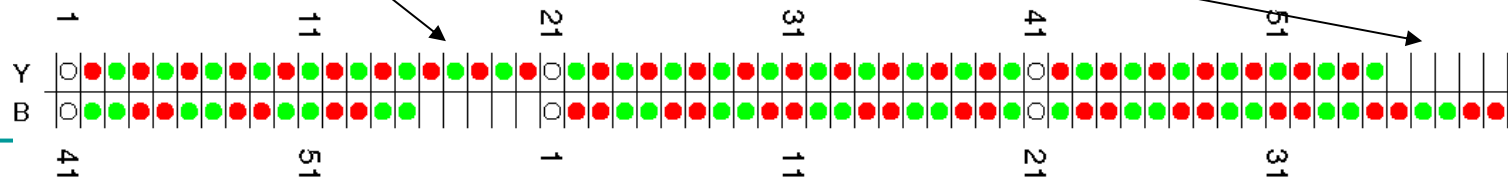
- Each scaler board has 24 input bits = 7(bunch crossing) + 17(physics inputs) -> $2^{17} = 10^5$
Example: one physics bit is the **"luminosity" bit, a coincidence between a signal from the BBC's on either side of the STAR magnet.**
- Input bit pattern (information from fast STAR detectors) is recorded for each RHIC strobe received (every 107 ns).



- BBC's are used to determine the relative luminosity of bunch crossings with different polarization directions.
- Beam-gas background is measured by counts observed in the abort gaps.

Polarization pattern at STAR:

Spin Up ● Spin Down ● Unpolarized ○



Stephen Trentalange UCLA DIS04

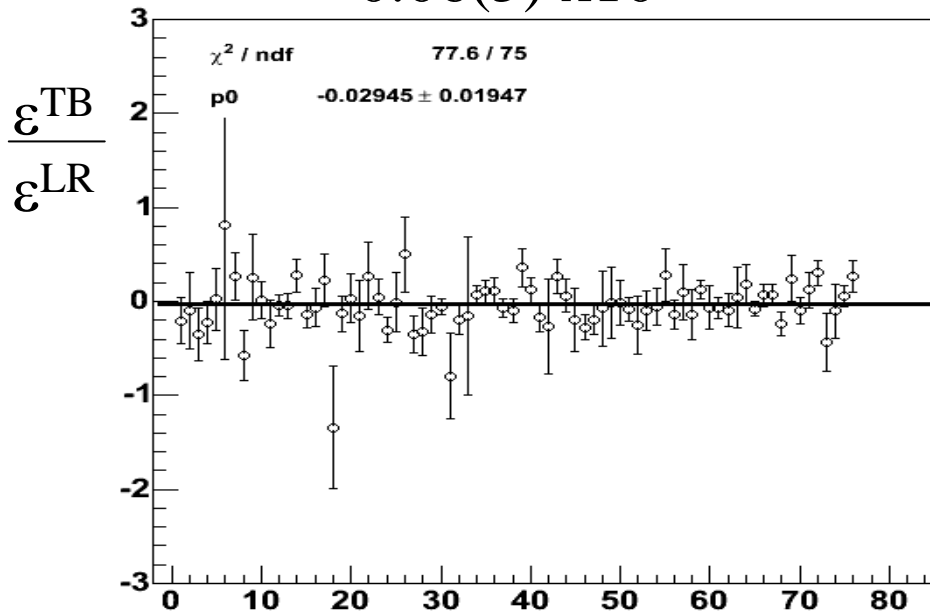


1. Vertical pol. component

$$\epsilon_{\text{BBC}}^{\text{LR}} = A^{\text{BBC}} N_x P_y \langle \cos\phi \rangle \neq 0$$

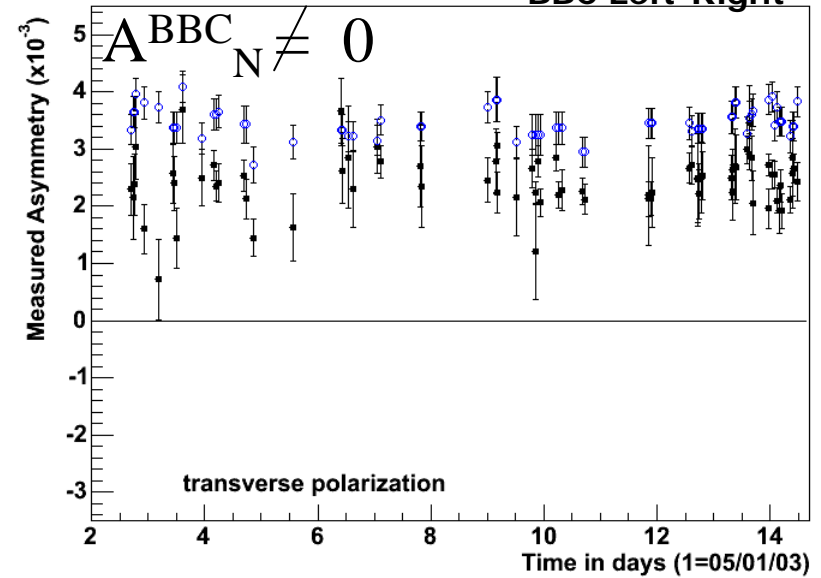
2. Radial pol. component

$$\epsilon_{\text{BBC}}^{\text{TB}} = A^{\text{BBC}} N_x P_x \langle \sin\phi \rangle = -0.06(5) \times 10^{-3}$$

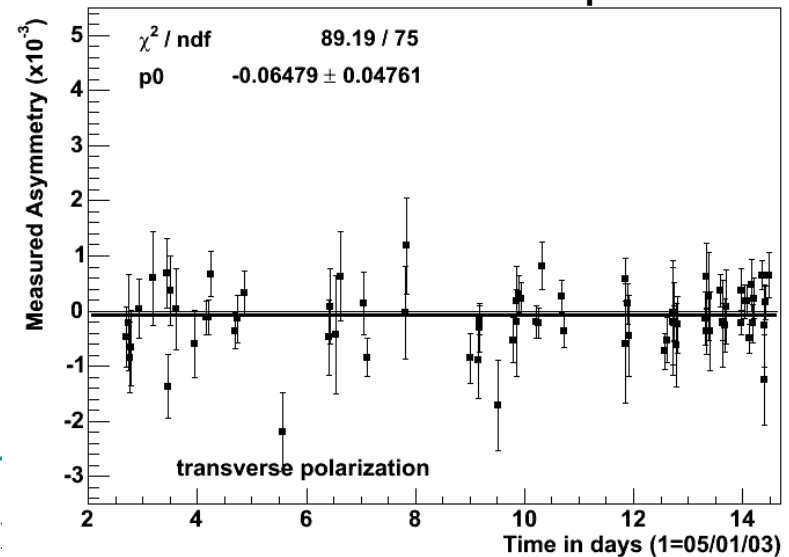


$$\frac{\epsilon_{\text{TB}}}{\epsilon_{\text{LR}}} = 1.15 \frac{P_x}{P_y} = -0.03(2) \quad X^2/\text{NdF}=1.0$$

CNI - ONLINE
BBC Left-Right

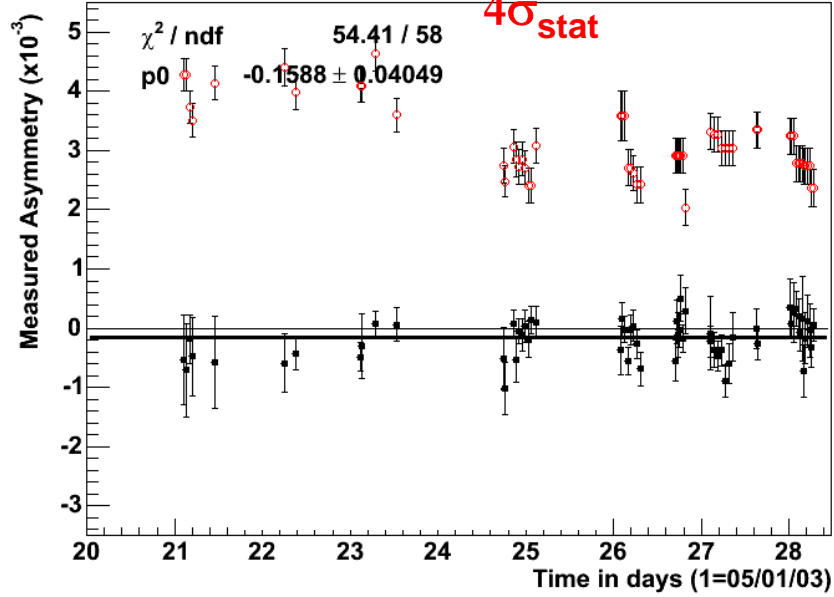


BBC Top-Bottom

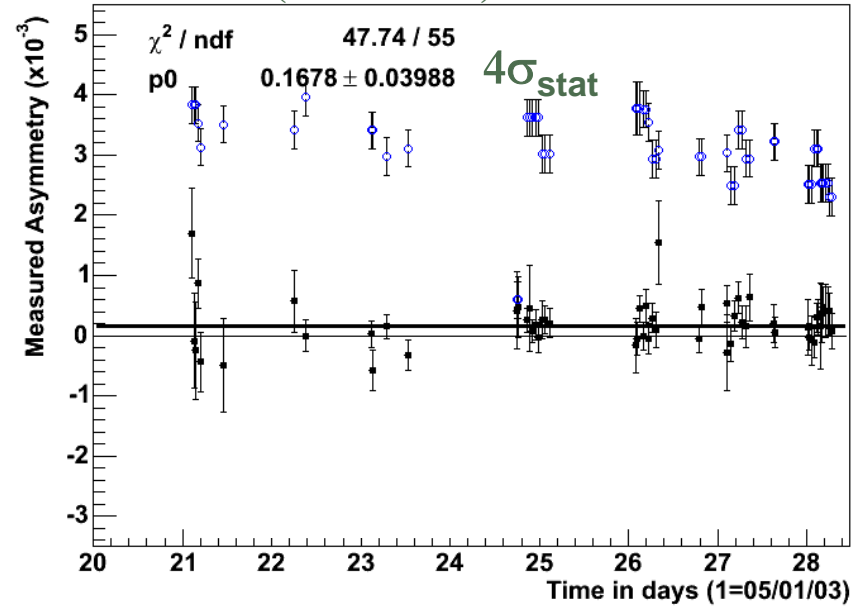


Rotators ON - longitudinal beam polarization at STAR IP

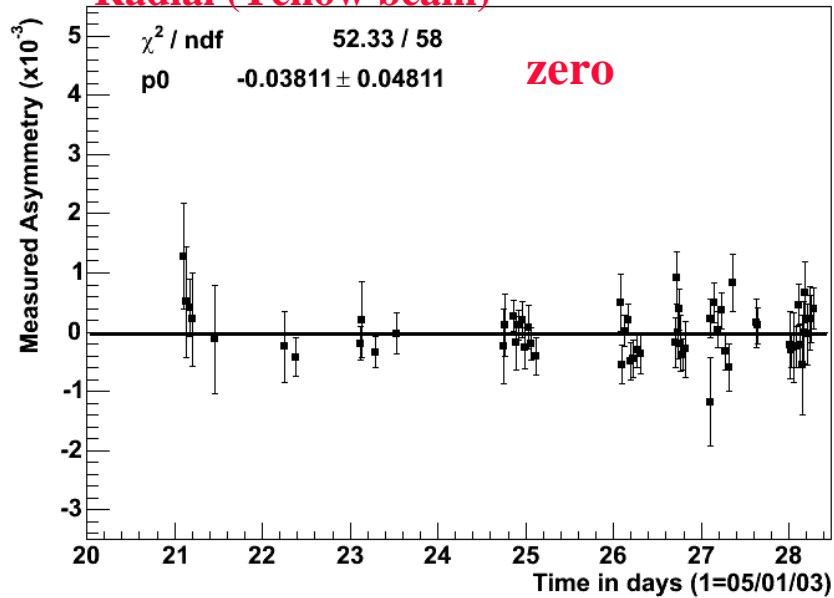
Vertical (Yellow beam)



Vertical (Blue beam)



Radial (Yellow beam)



Radial (Blue beam)

