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# J/ $\psi$ Polarization Study at RHIC/PHENIX

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# Outline

- **Motivation**
- **Muon angular distribution**
- **PHENIX 2002-2003 years (Run 3) data**
- **Bin by bin background subtraction**
- **Acceptance corrections**
- **Status & future work**

# Motivation for $J/\psi$ polarization study

The measurement of the angular distribution of decay leptons from  $J/\psi$  provides a detailed test of the production mechanism of the quarkonium bound state.

## ❑ Quarkonium production cross section

- Color Singlet Model (CSM): predicted smaller production rates than observed
- Color Evaporation Model (CEM): failed in predicting production ratio of  $c\bar{c}$  states
- Non-relativistic QCD (NRQCD): using cross section to determine model parameters

## ❑ Quarkonium polarization

- CSM: predicts transverse polarization
- NRQCD: **predicts transverse polarization at large  $p_T$**

## ❑ Fixed target experiments

- E537, E672, E771 no significant polarization
- CIP, no polarization at small  $x_F$ , longitudinal polarization at large  $x_F$
- E866: large  $x_F$ , longitudinal; small  $x_F$ , unpolarized or slight transverse

- ❑ **Collider experiment (CDF), small  $p_T$ , unpolarized; large  $p_T$ , longitudinal**  
**This last observation can't be explained by NRQCD theory at large  $p_T$**

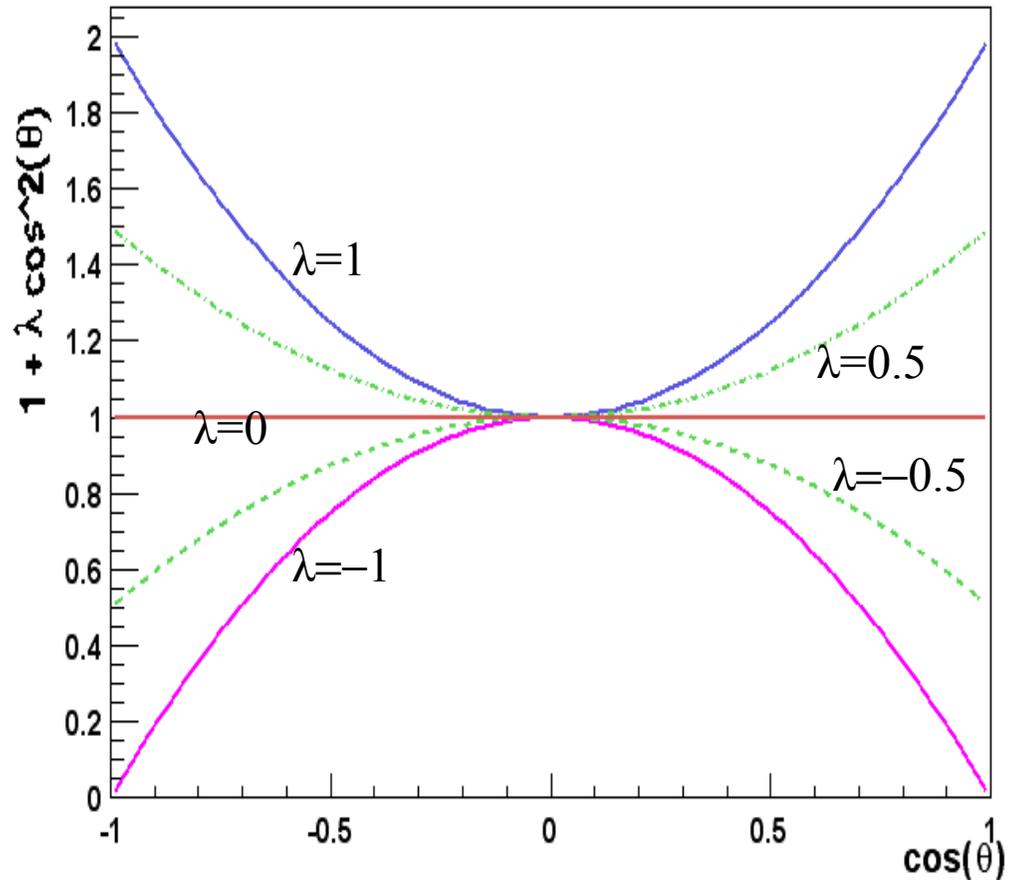
# Angular Distribution Parametrization

Angular distribution of muon pair in the  $J/\psi$  rest frame is commonly parametrized as follows:

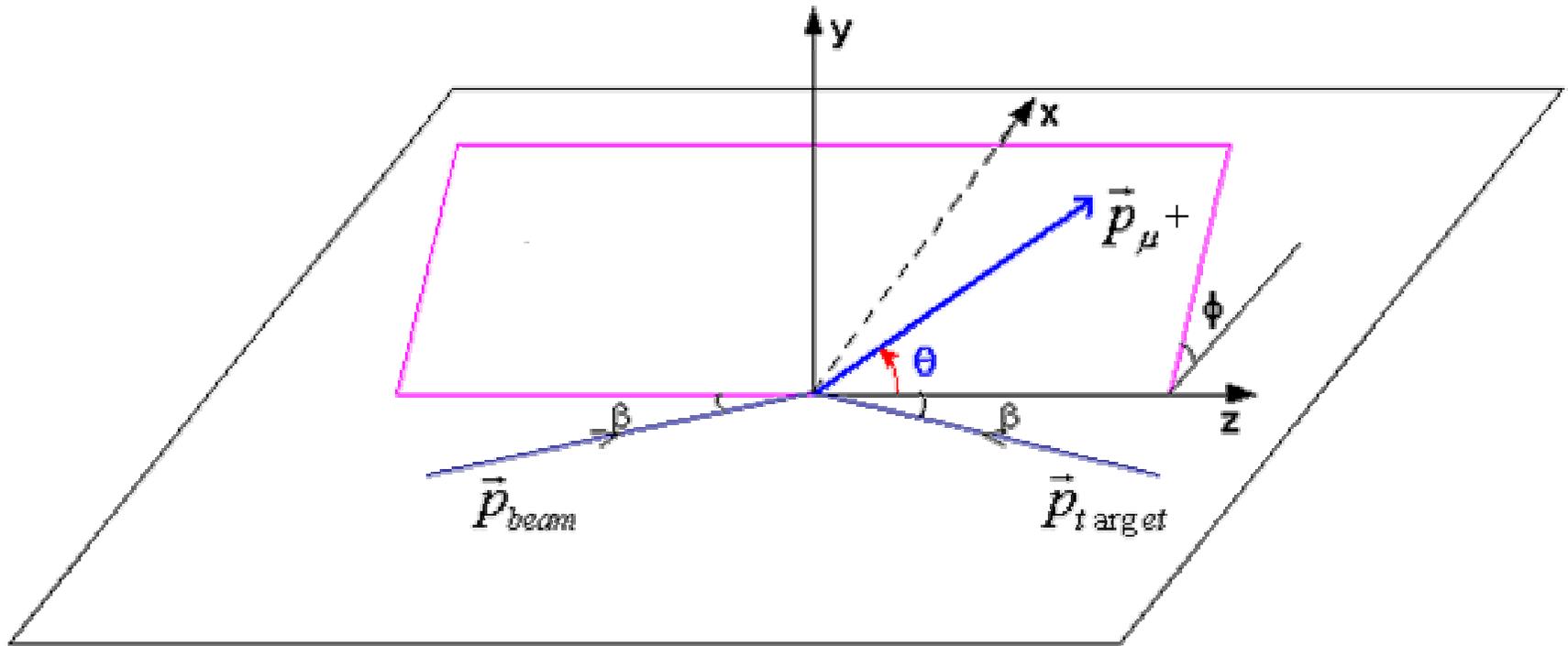
$$\frac{d\sigma}{d\cos\theta} \sim 1 + \lambda \cos^2\theta$$

- $\lambda < 0$  Longitudinal
- $\lambda = 0$  Unpolarized
- $\lambda > 0$  Transverse

$\theta$  is the angle between the  $p_{\mu^+}$  ( $p_{\mu^-}$ ) and the z axis in the  $J/\psi$  rest frame



# J/ $\psi$ Rest Frame (Collins Soper frame)



**Collins Soper Frame:**  $z$  axis along the bisector of the  $\vec{P}_{beam}$  and  $-\vec{P}_{target}$

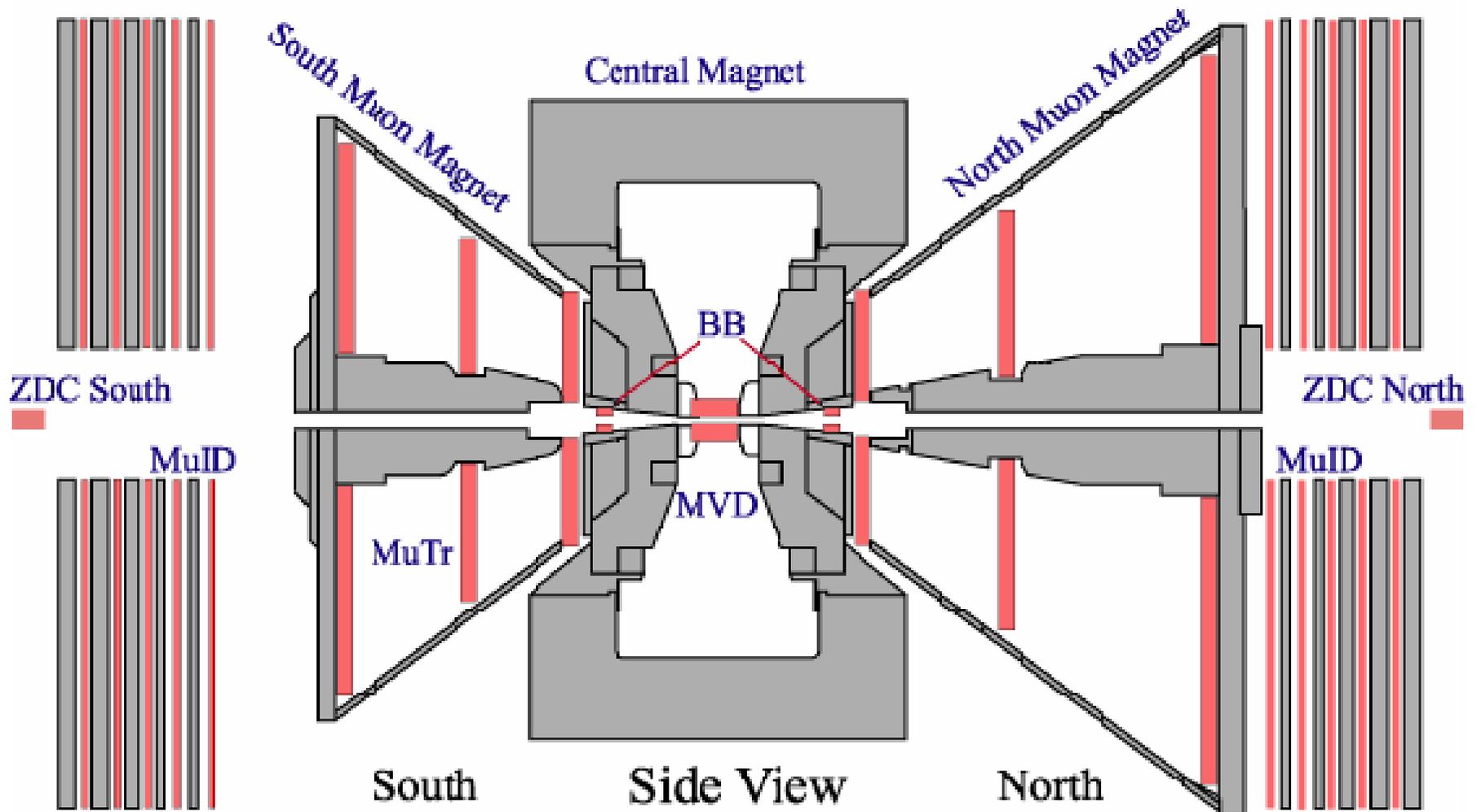
Gottfried-Jackson Frame: choose the  $z$  axis parallel to  $\vec{P}_{beam}$  direction

The two only differ significantly at large  $p_T$

# PHENIX Run 3 Data Sample

- **PHENIX muon arms:**  $J/\psi \rightarrow \mu^+ \mu^-$   
Offers an opportunity to measure charmonium polarization
- **Run Selection:** Run3 d-Au & Run3 p-p data (CCF)
- **Cuts Applied**
  - Vertex selection:  $|z_{\text{vtx}}| < 38\text{cm}$
  - Muon arm acceptance:  
South:  $-2.2 < \eta < -1.2$ ; North:  $1.2 < \eta < 2.4$
  - Single-particle selection:  
 $\chi^2 < 20(\text{d-Au})$  or  $\chi^2 < 15(\text{p-p})$  and  $R_{\text{vert}} < 5\text{cm}$
  - Two particle selection:  $2.65 < M_{\text{inv}}(\text{GeV}) < 3.73$

# Muon Detector for run 3

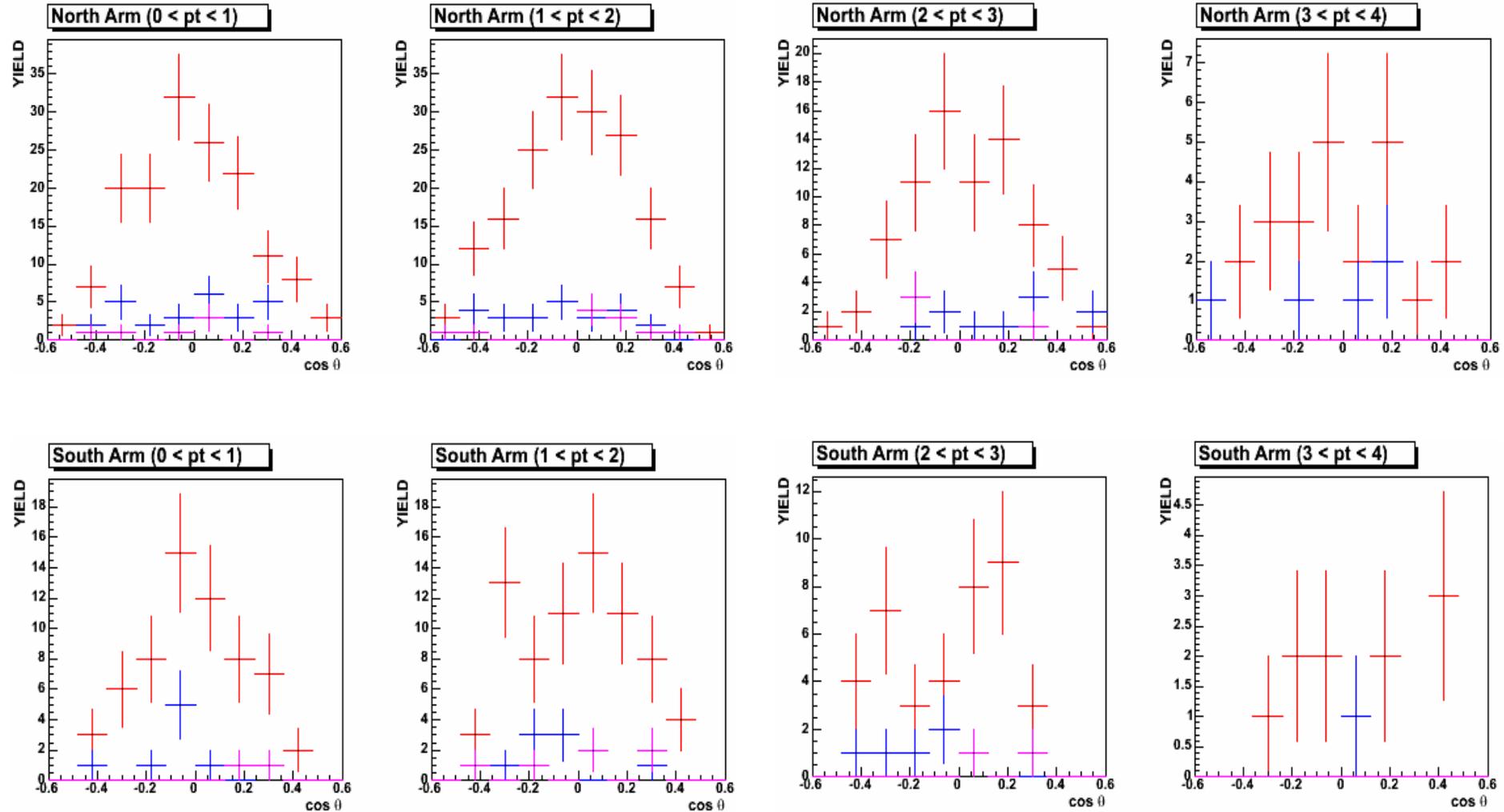


# Bin-by-Bin Background Subtraction

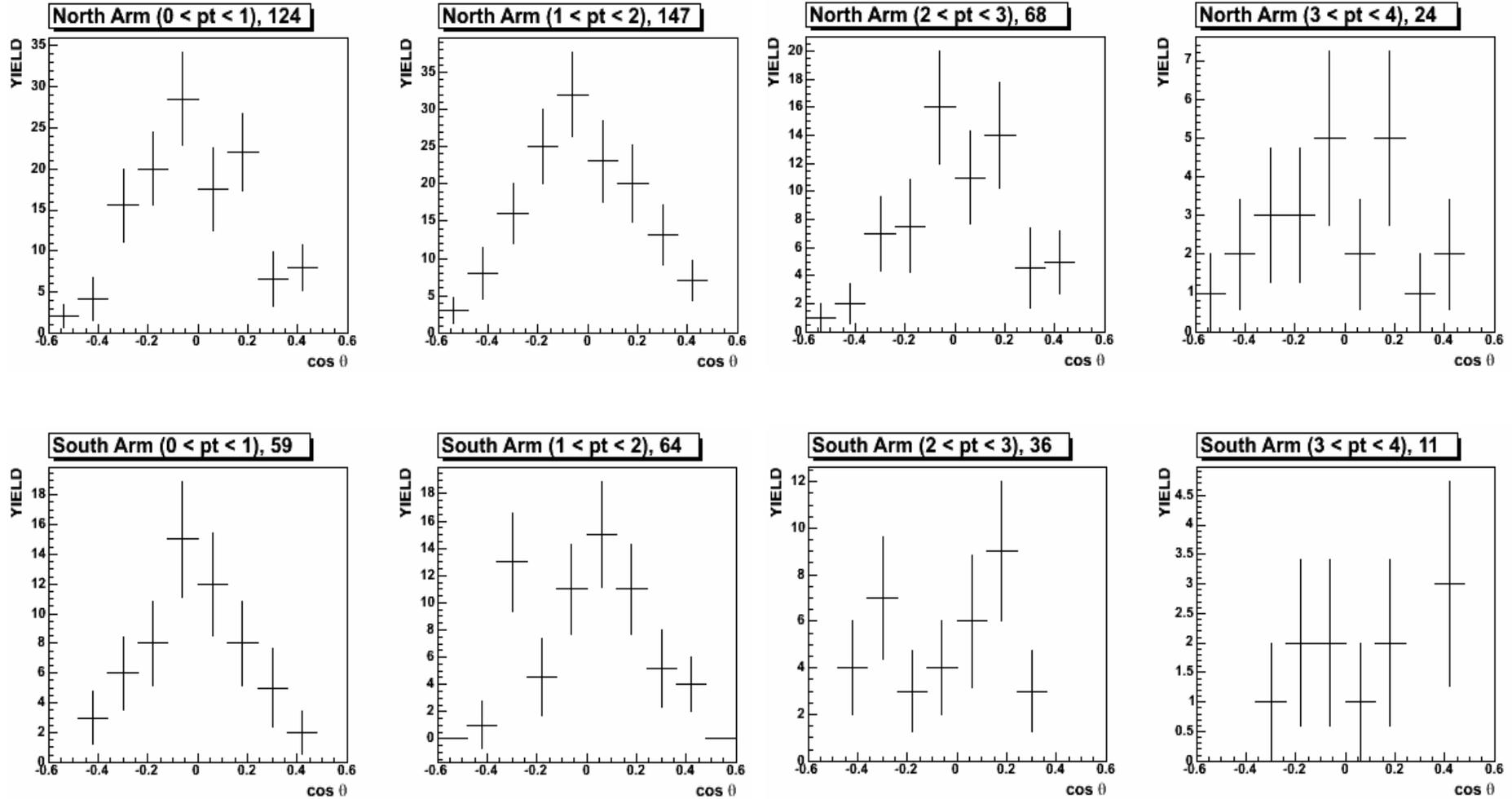
- $\cos\theta$  distributions in small  $p_T$  bins
  - Four  $p_T$  bins from 0 to 4 GeV
  - For all  $(+-)$ ,  $(++)$ , and  $(--)$  pairs.
- Background subtraction is then applied in each  $\cos\theta$  bin. The subtracted bin contents are calculated as follows:

$$N = N^{+-} - 2 \times \sqrt{N^{++} \times N^{--}}$$

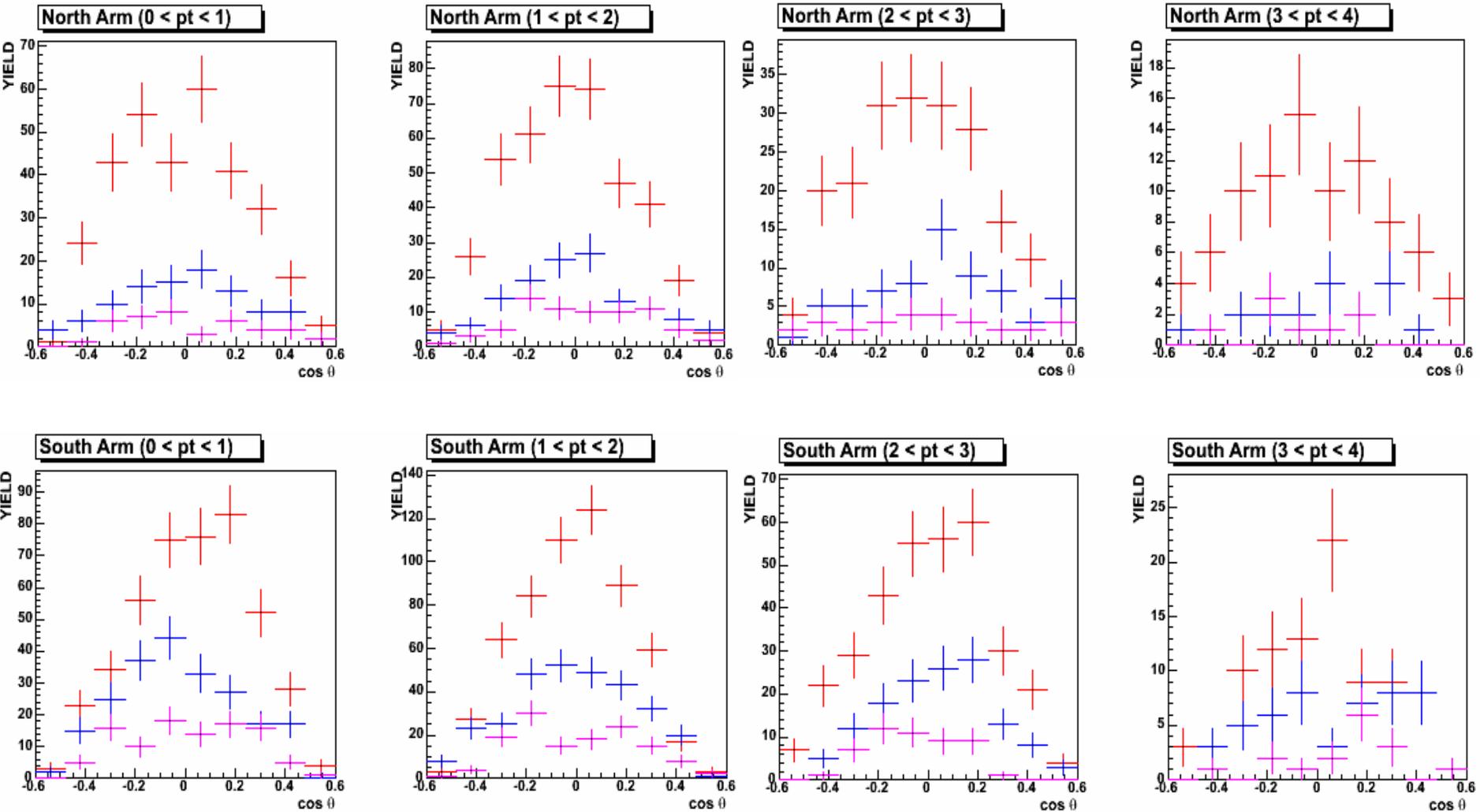
# Run 3 p-p $\cos\theta$ distribution in CS frame in $p_T$ bins



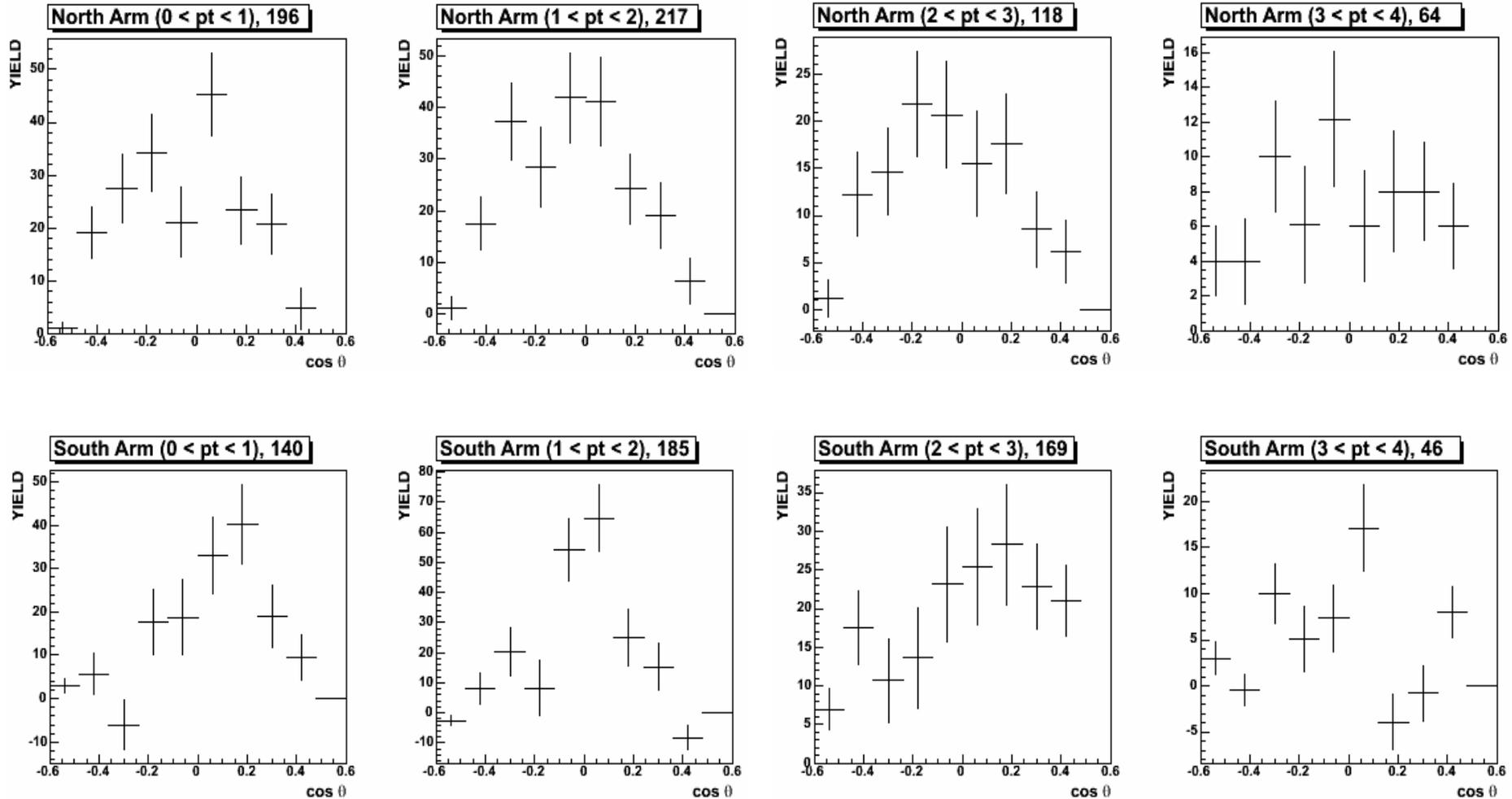
# Background subtracted Run 3 p-p $\cos\theta$ distribution in CS



# Run 3 d-Au $\cos\theta$ distribution in CS frame in $p_T$ bins



# Background subtracted Run 3 d-Au $\cos\theta$ distribution in CS



# Acceptance Correction Procedure

- **Data Hybrid method:** G.Bunce: NIM 172(1980)553  
In the hybrid procedure,  $\cos\theta$  is randomly generated uniformly in the interval  $[-1, +1]$ , while other parameters ( $p_T$  and  $x_F$  distribution) of Monte Carlo events are taken from the data. The Monte Carlo event is then traced through detector.
- It was demonstrated that one needs to use real data  $p_T$  and  $x_F$  distribution to make the angular distribution acceptance correction.

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# Status and future work

## Status

- Had a first look at the angular distribution of PHENIX Run3 p-p and d-Au data.
- The main goal of this study was to develop the procedure to do the bin by bin background subtraction and acceptance correction for PHENIX data.

## Future work

- Do the acceptance correction
- Plot polarization parameter vs  $p_T$  ( $x_F$ )
- Study feed-down contamination from higher  $c\bar{c}$  bound states.