CEE-ZDC event plane simulation study

Li-Ke Liu

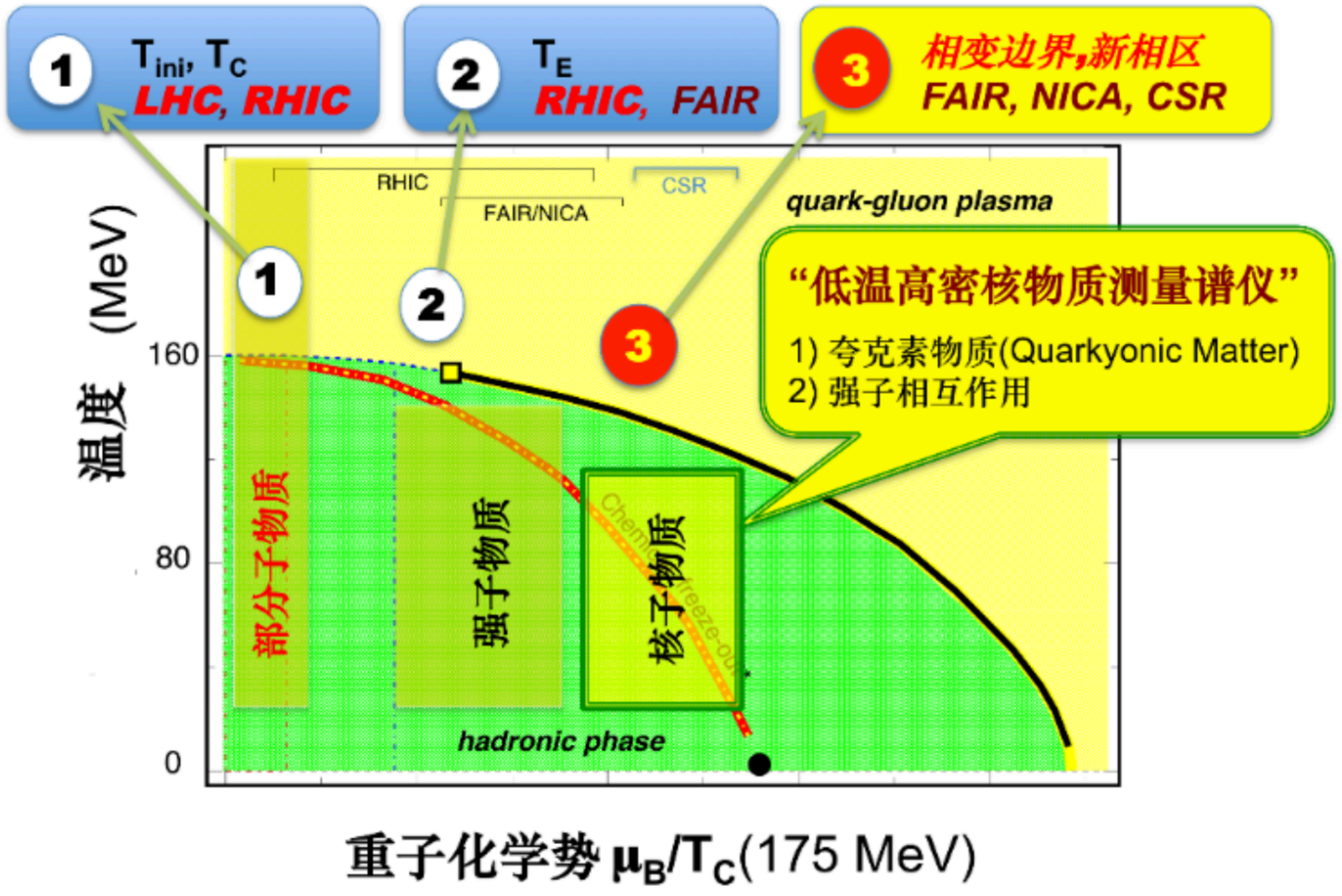
Central China Normal University

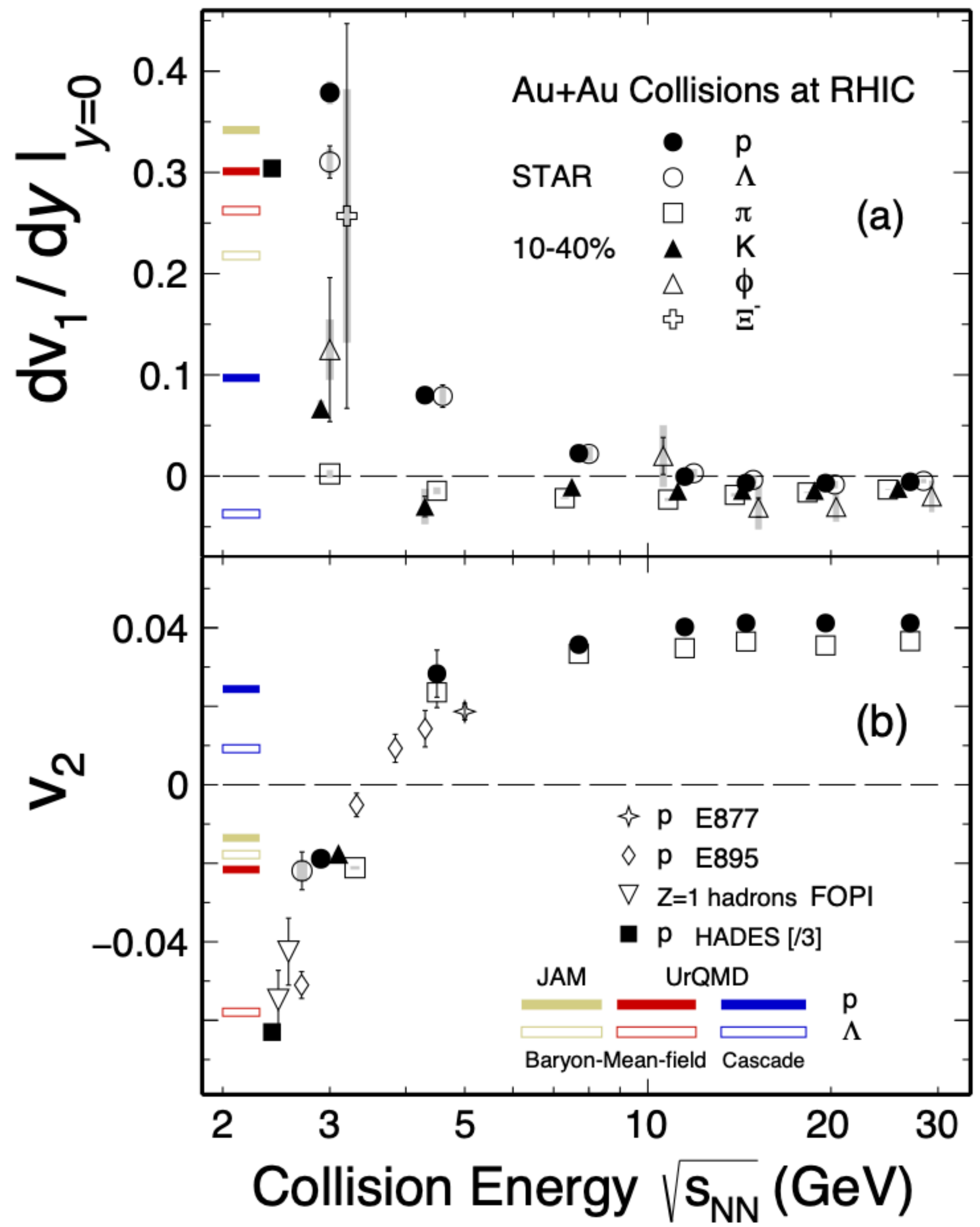
Sep. 16, 2022

Outline

- ZDC Motivation
- Position weight method
- Shift calibration
- 1^{st} order event plane resolution

ZDC Motivation

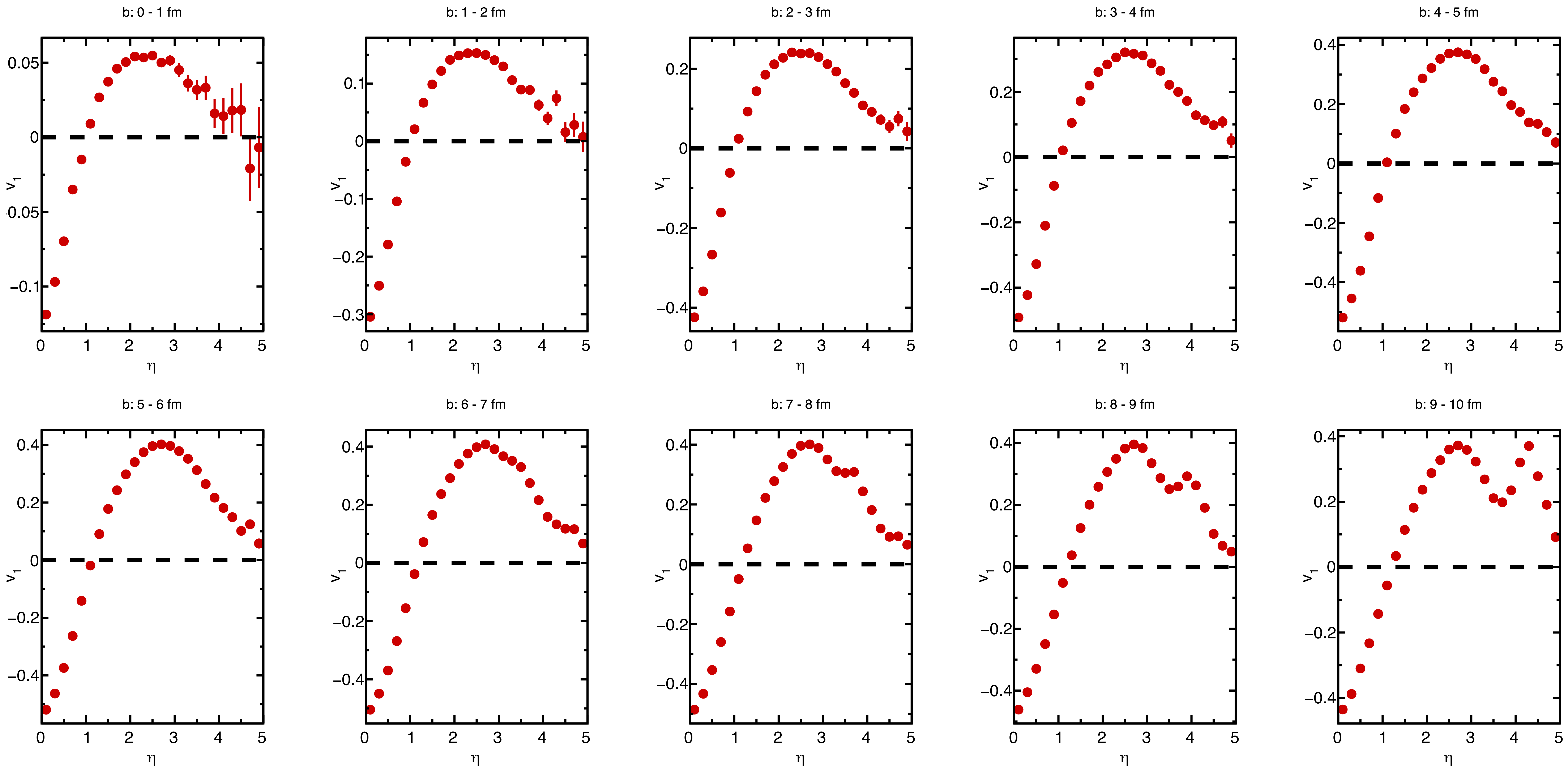




- CEE provides a valuable research opportunity for QCD phase diagram studies in high baryon density region
- ZDC used to determine the event plane, provides basic measurement quantity for collective flow

IQMD Model

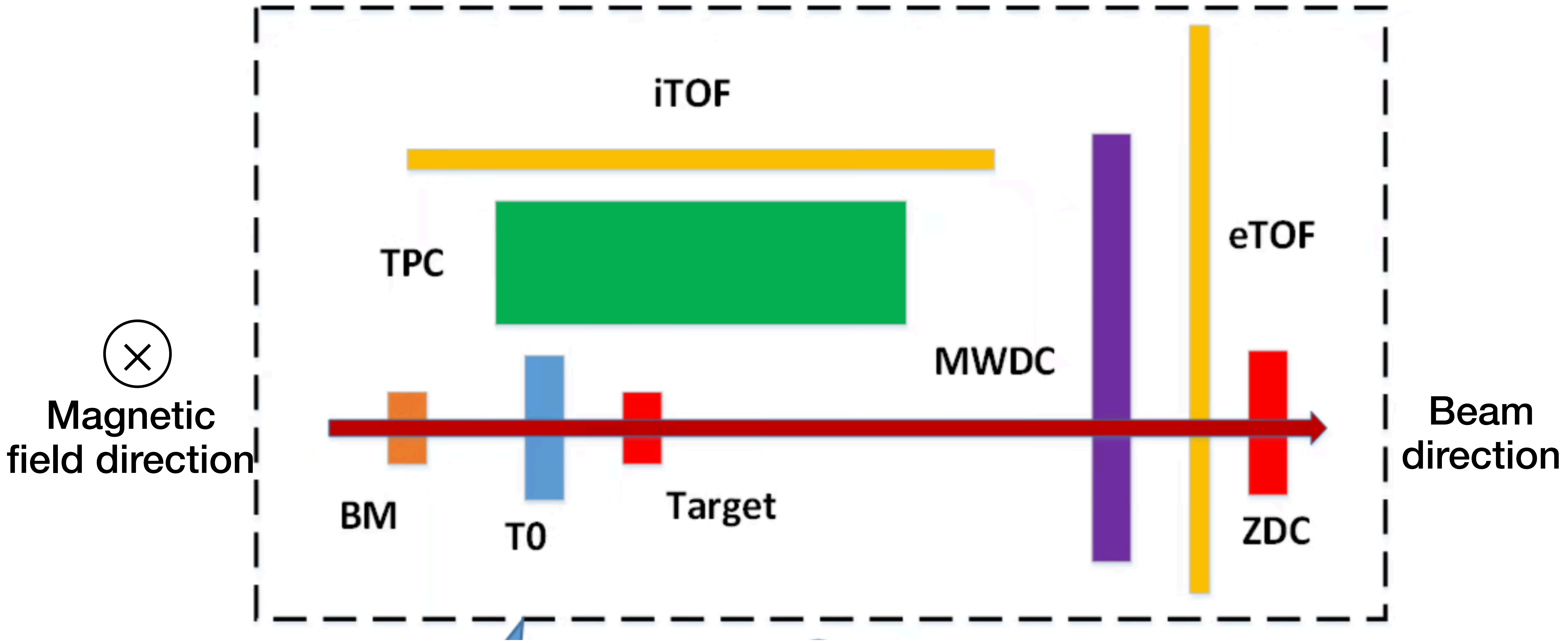
- IQMD 500MeV/u $^{238}U + {}^{238}U$, 1000 events per 0.1 fm (0.1-10 fm), 100,000 events total

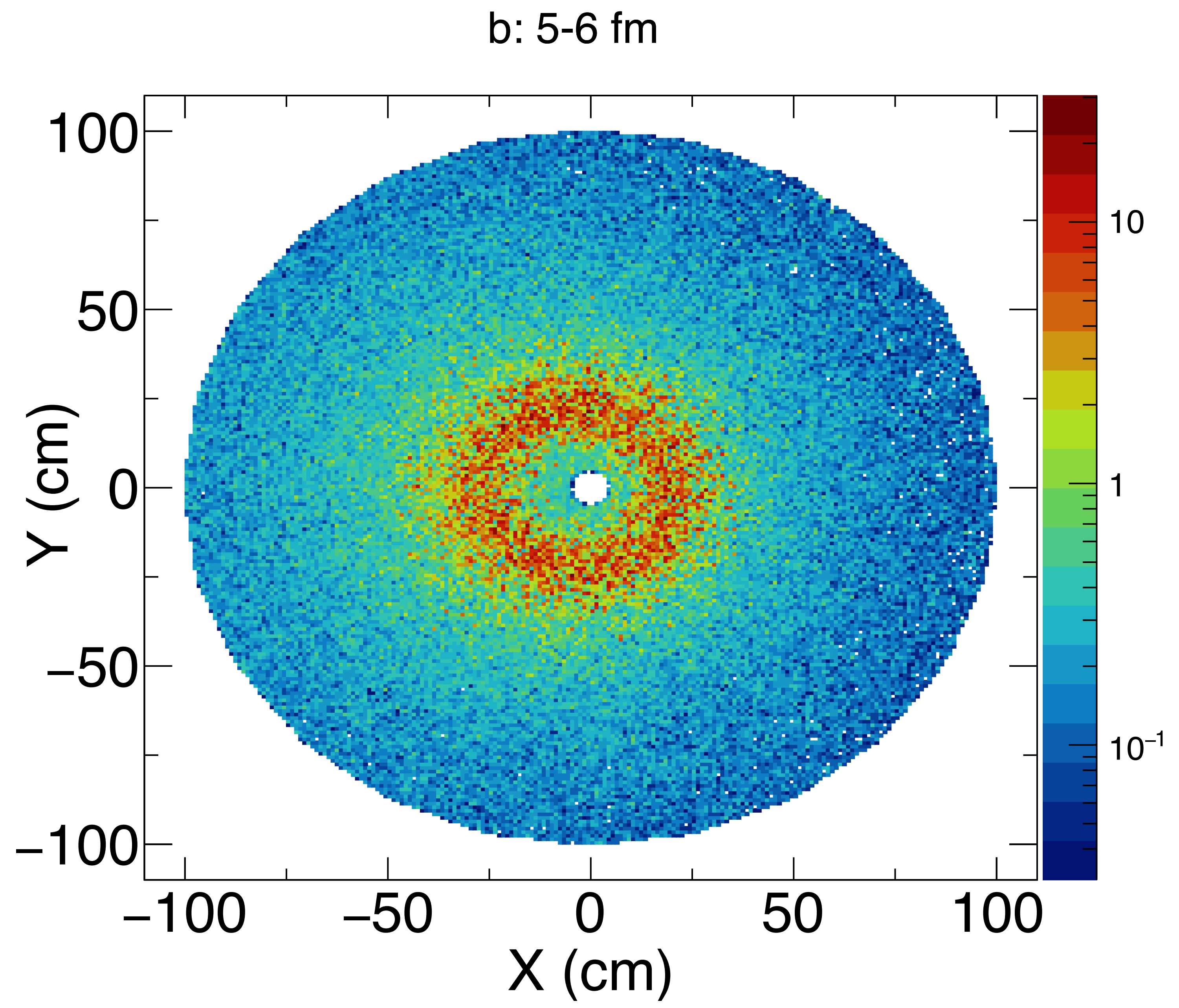


ZDC η: {1.8, 2.1, 2.4, 3.0, 4.8}

- v_1 is positive in the ZDC acceptance, event flow vector does not cancel each other

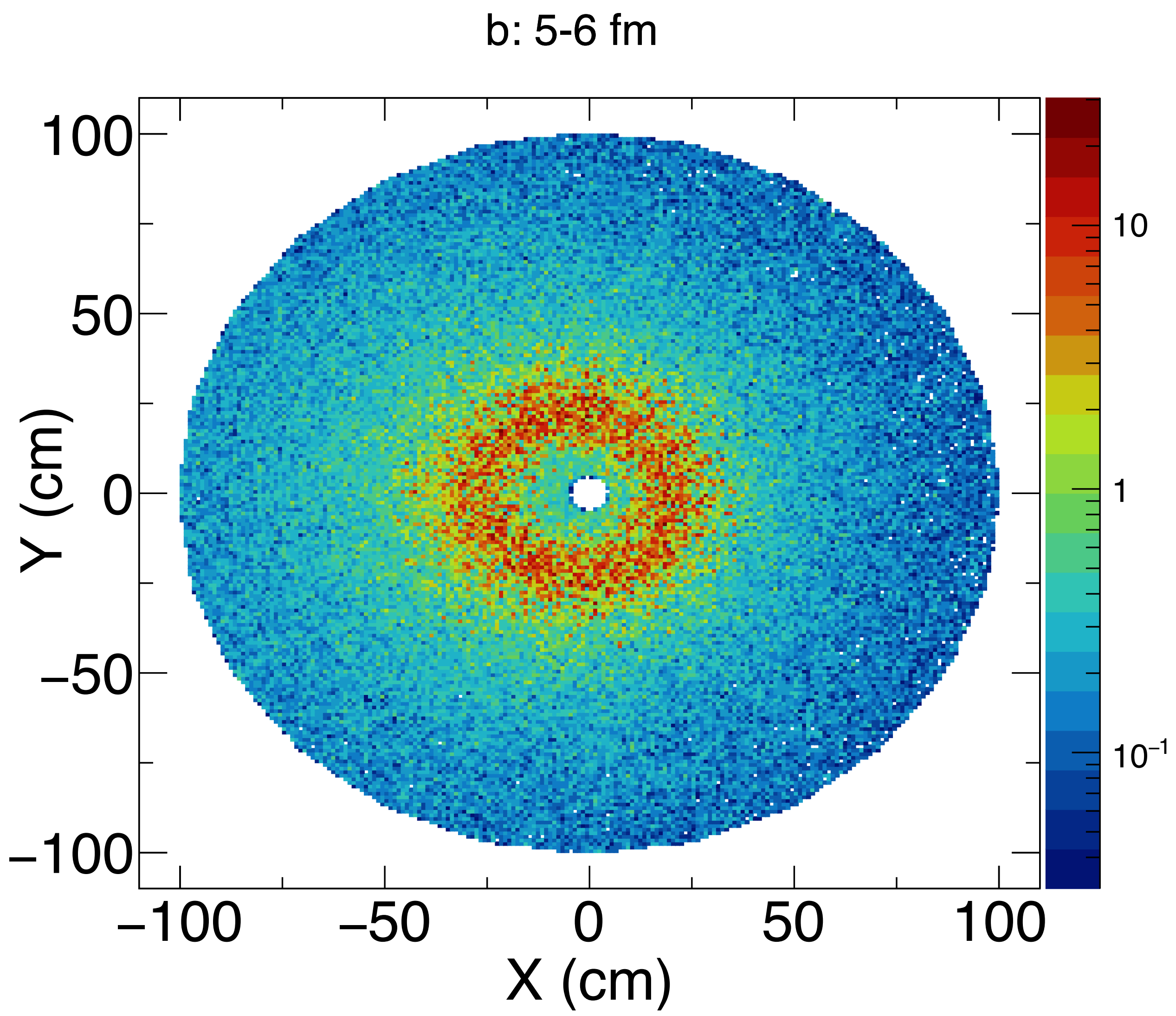
ZDC Space Acceptance





- Since the **magnetic field direction is perpendicular to the beam direction** at CEE, the **acceptance of ZDC is asymmetric**, which cause the reconstructed event plane large deviate with the reaction plane

Event plane reconstruction



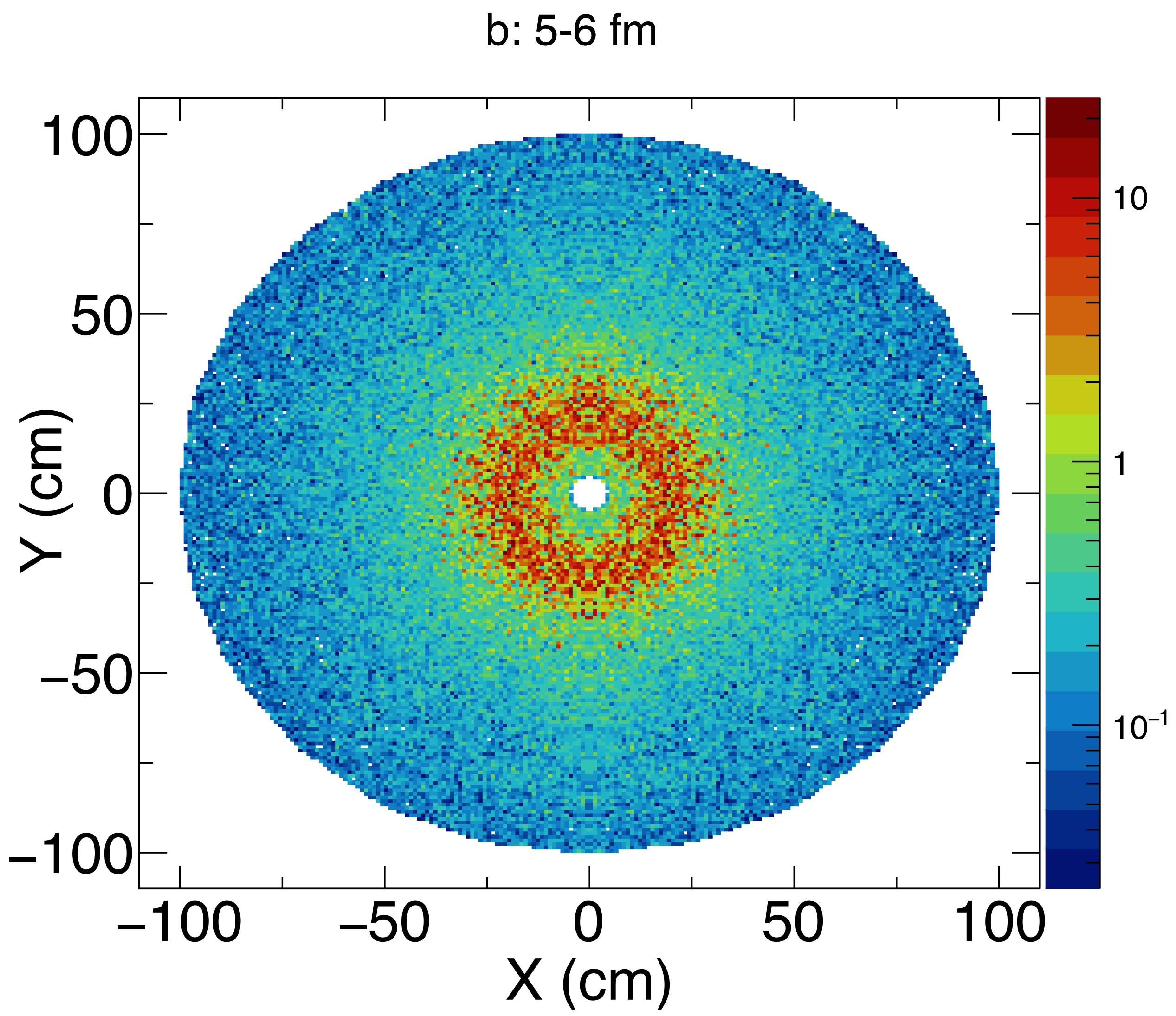
Position weight method

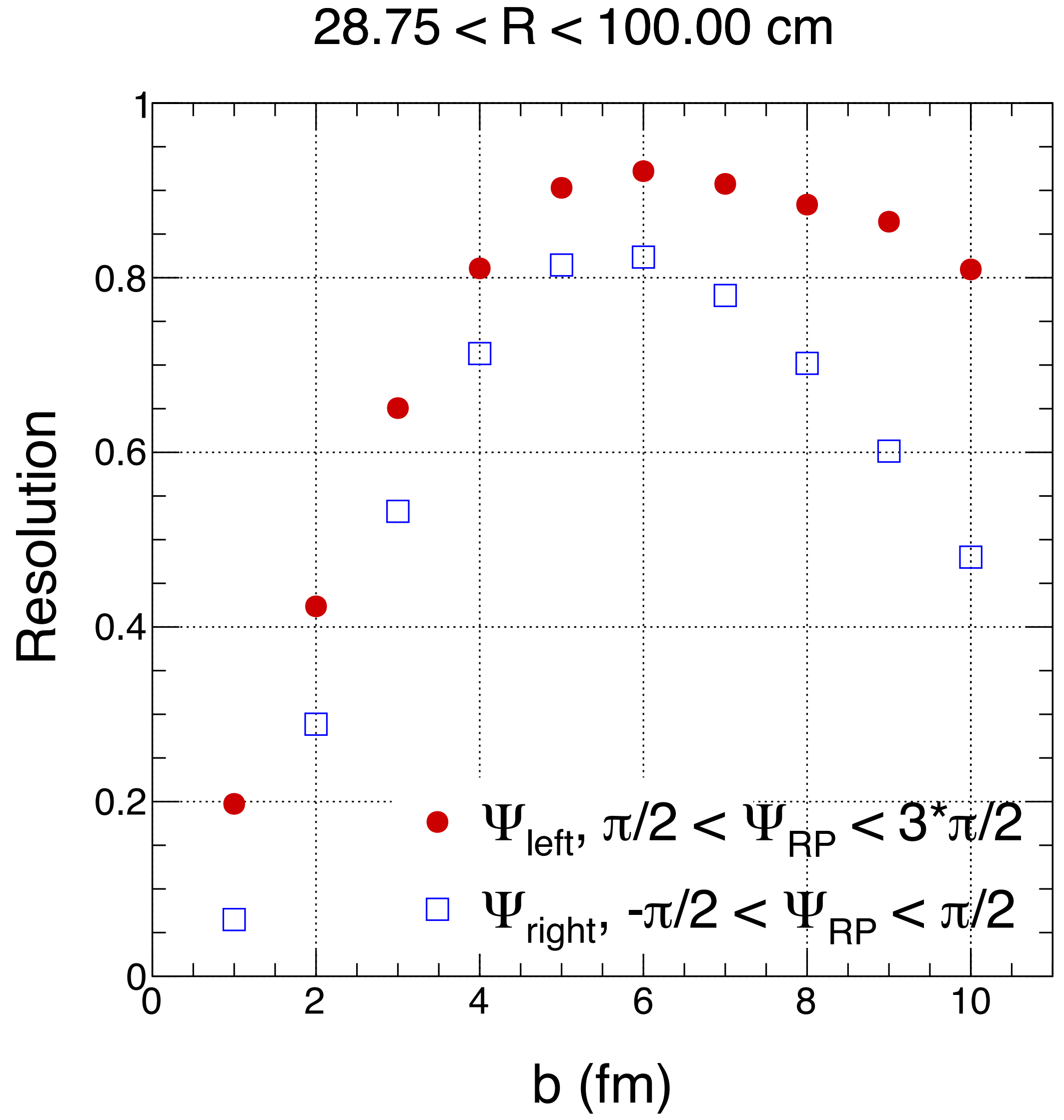
$$\Psi_1 = \tan^{-1}\left(\frac{\sum_i w_i \sin(\phi_i)}{\sum_i w_i \cos(\phi_i)}\right)$$

$$w_i = \Delta E \times R$$

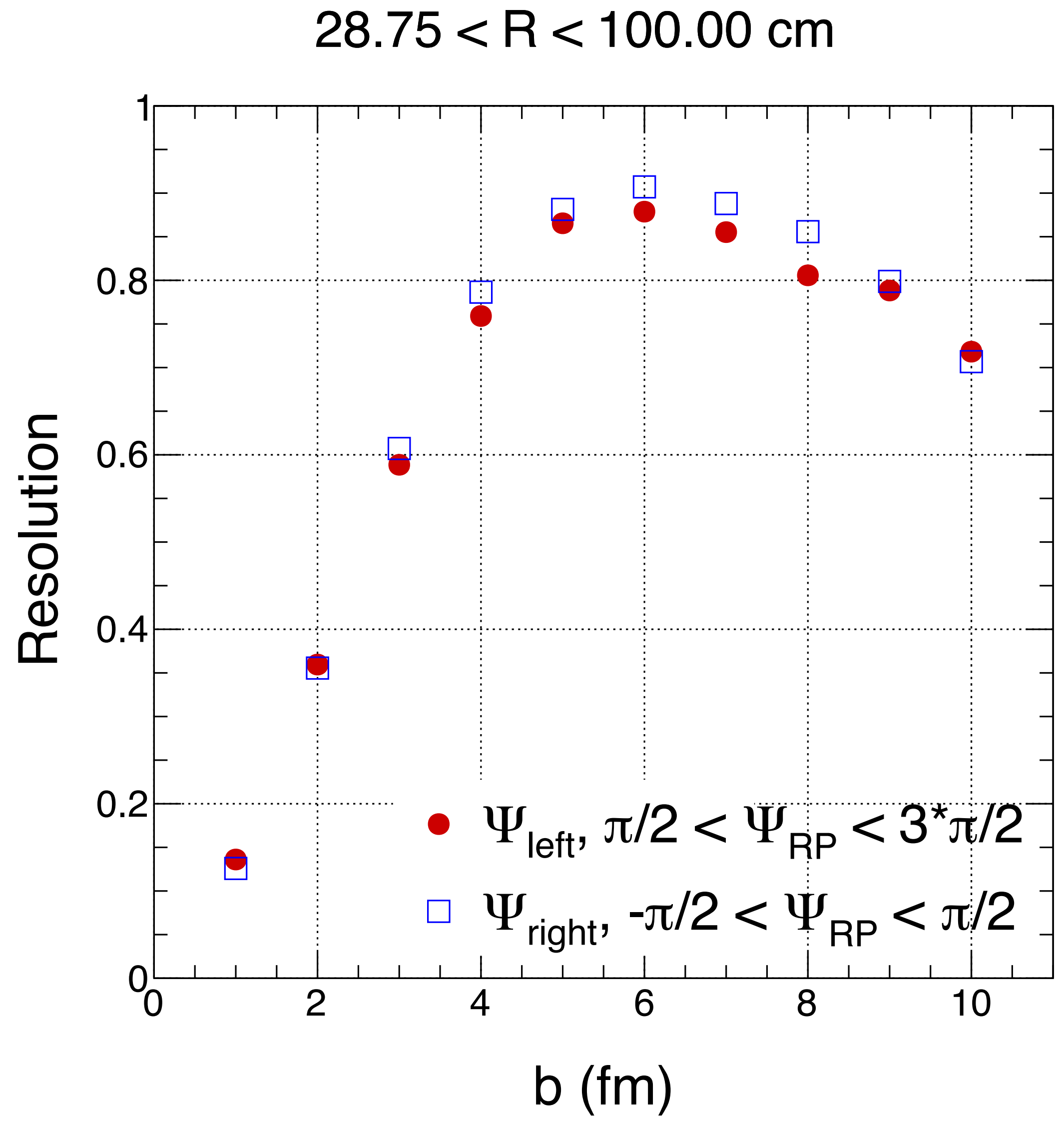
$$R = n(-x, y, \Delta E)/n(x, y, \Delta E), \quad x < 0$$

$$R = 1, \quad x > 0$$

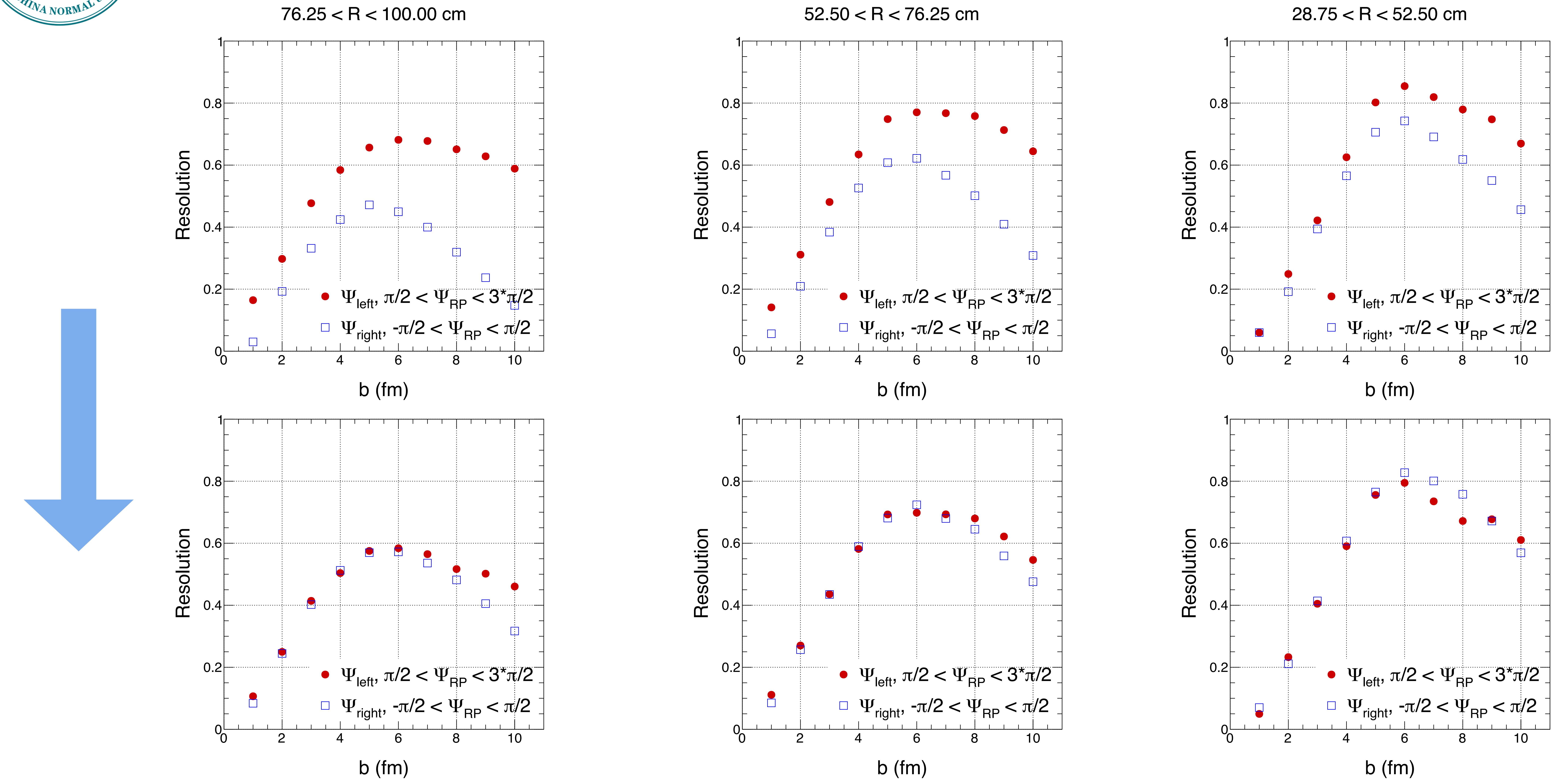




$$R_1 = <\cos(\Psi_1 - \Psi_r)>$$

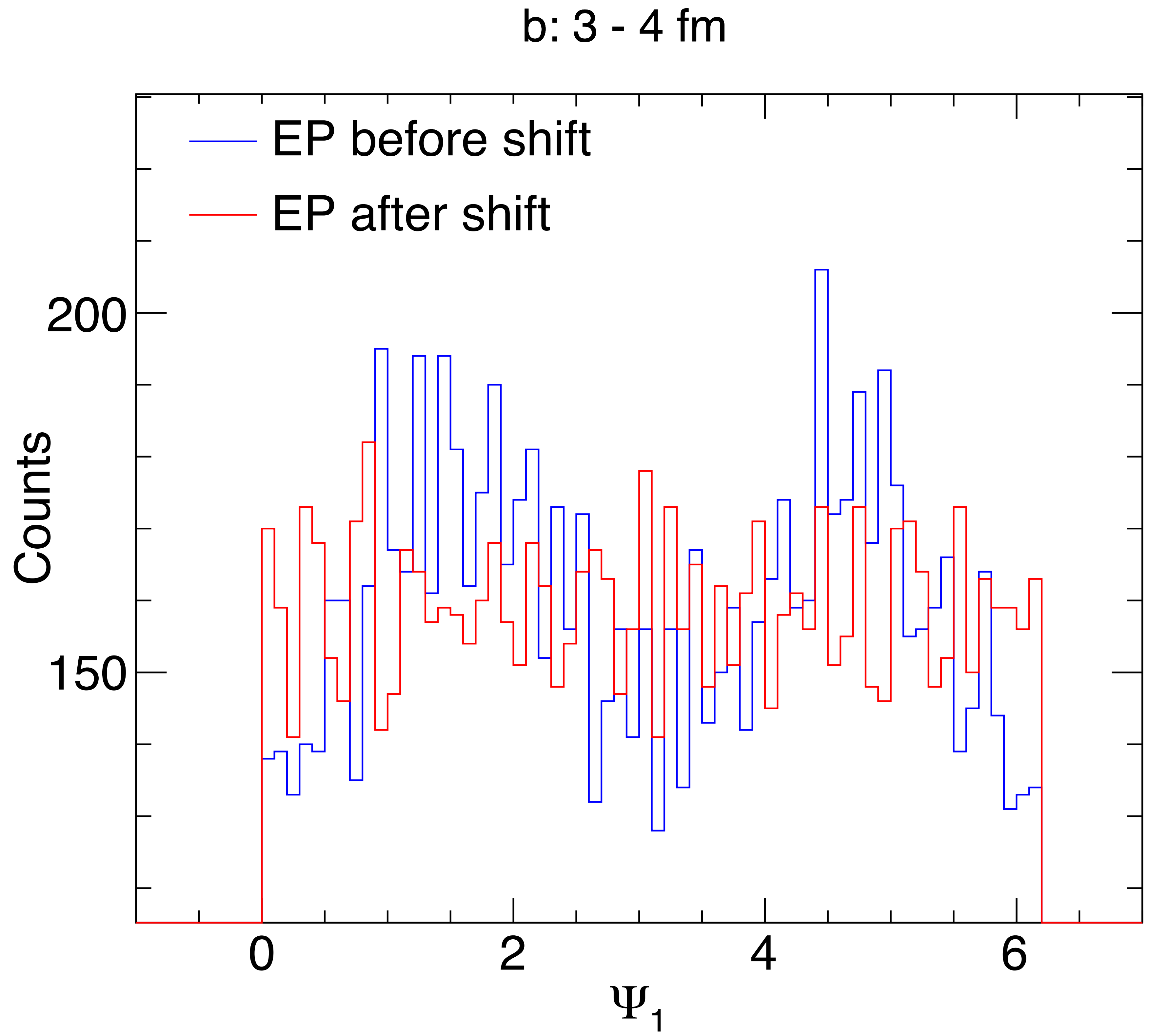


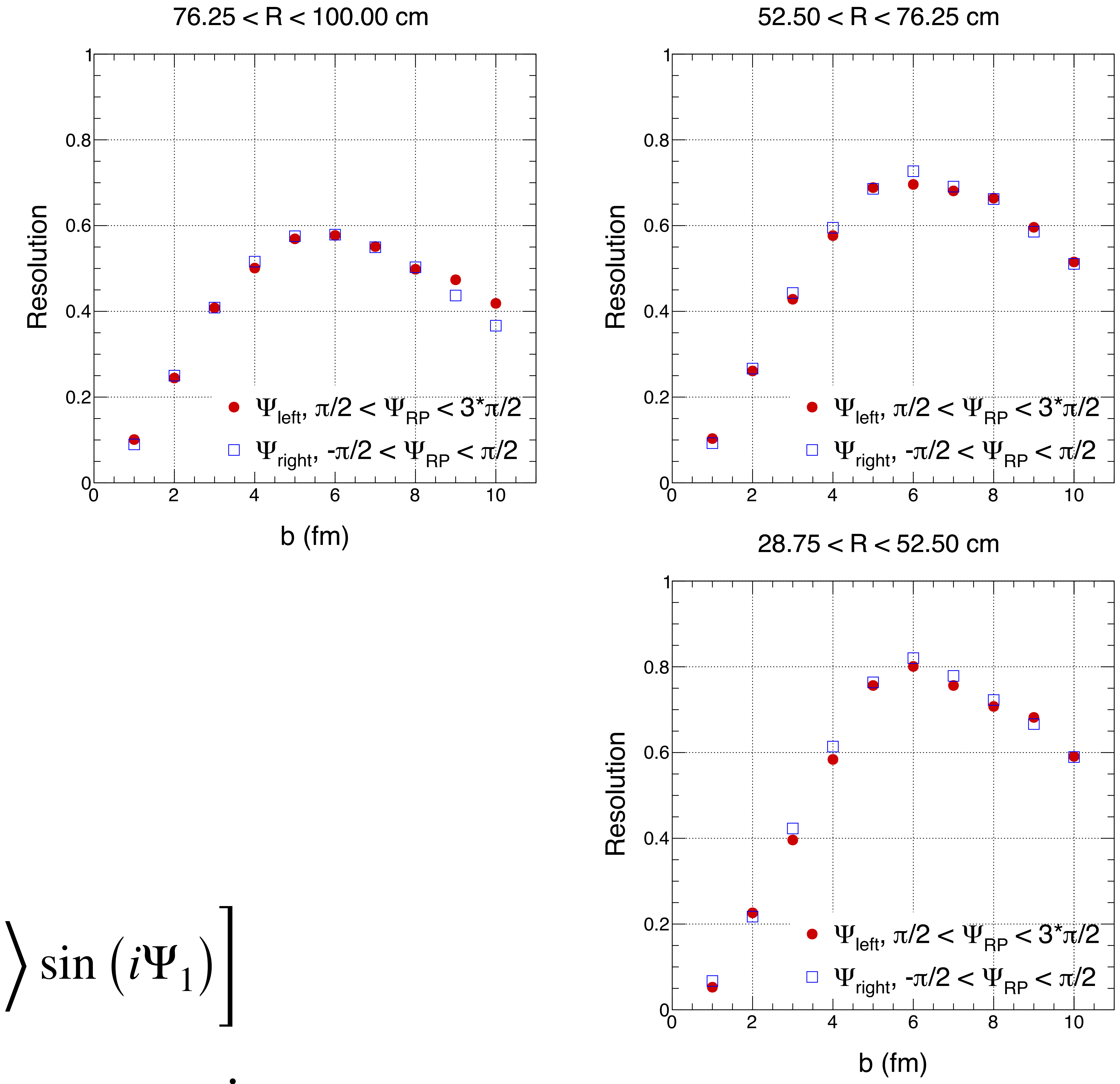
Event plane resolution of sub-rings



- Resolution difference between the left and right sides is largely eliminated with position weight

Shift Calibration





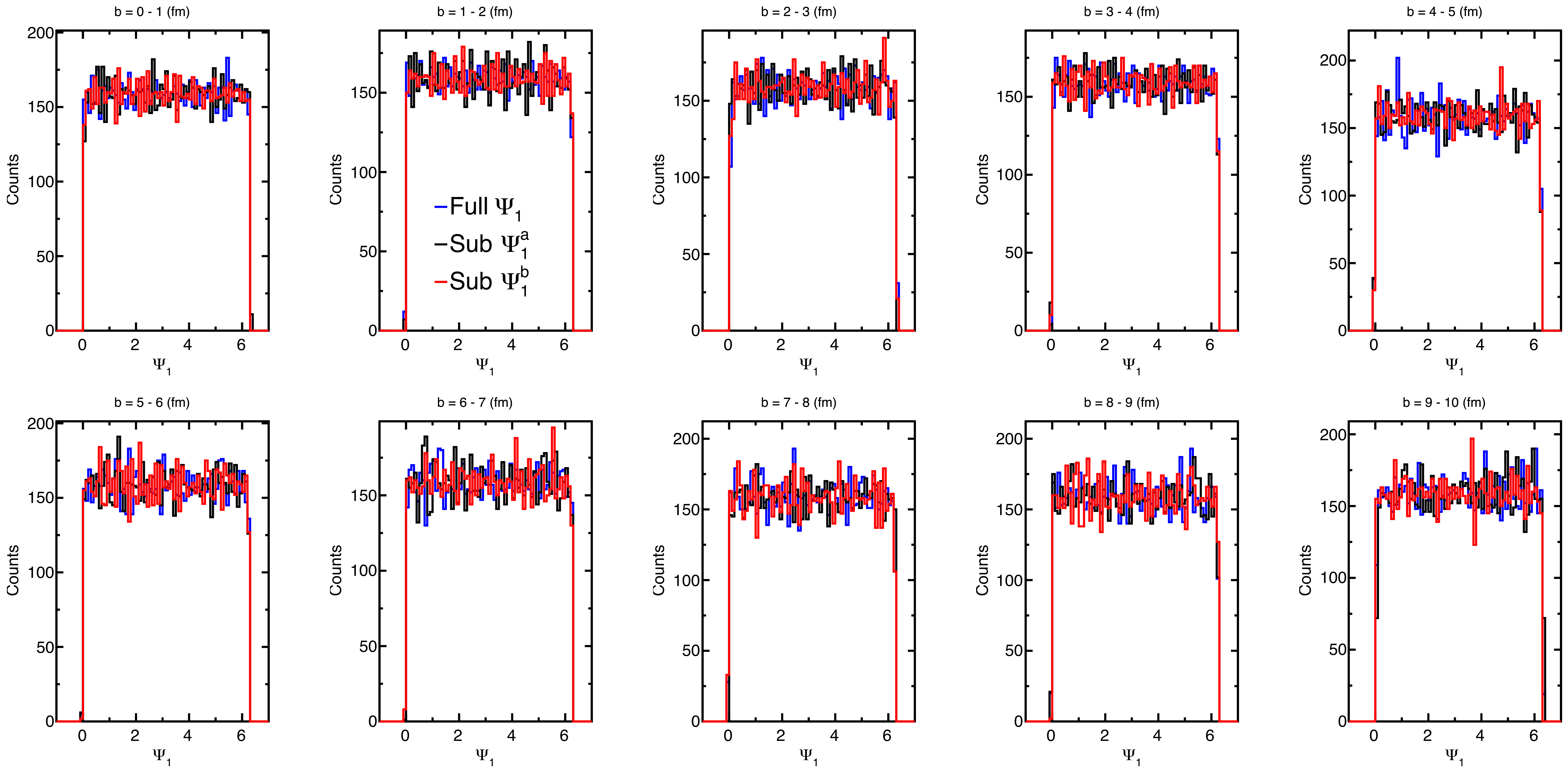
$$\Psi_1' = \Psi_1 + \Delta\Psi_1$$

$$\Delta\Psi_1 = \sum_{i=1}^{20} \frac{2}{i}\left[-\left\langle \sin\left(i\Psi_1\right)\right\rangle \cos\left(i\Psi_1\right) + \left\langle \cos\left(i\Psi_1\right)\right\rangle \sin\left(i\Psi_1\right)\right]$$

- Shift method is applied to further correct the asymmetric acceptance

E877 Collaboration, Phys. Rev. C56

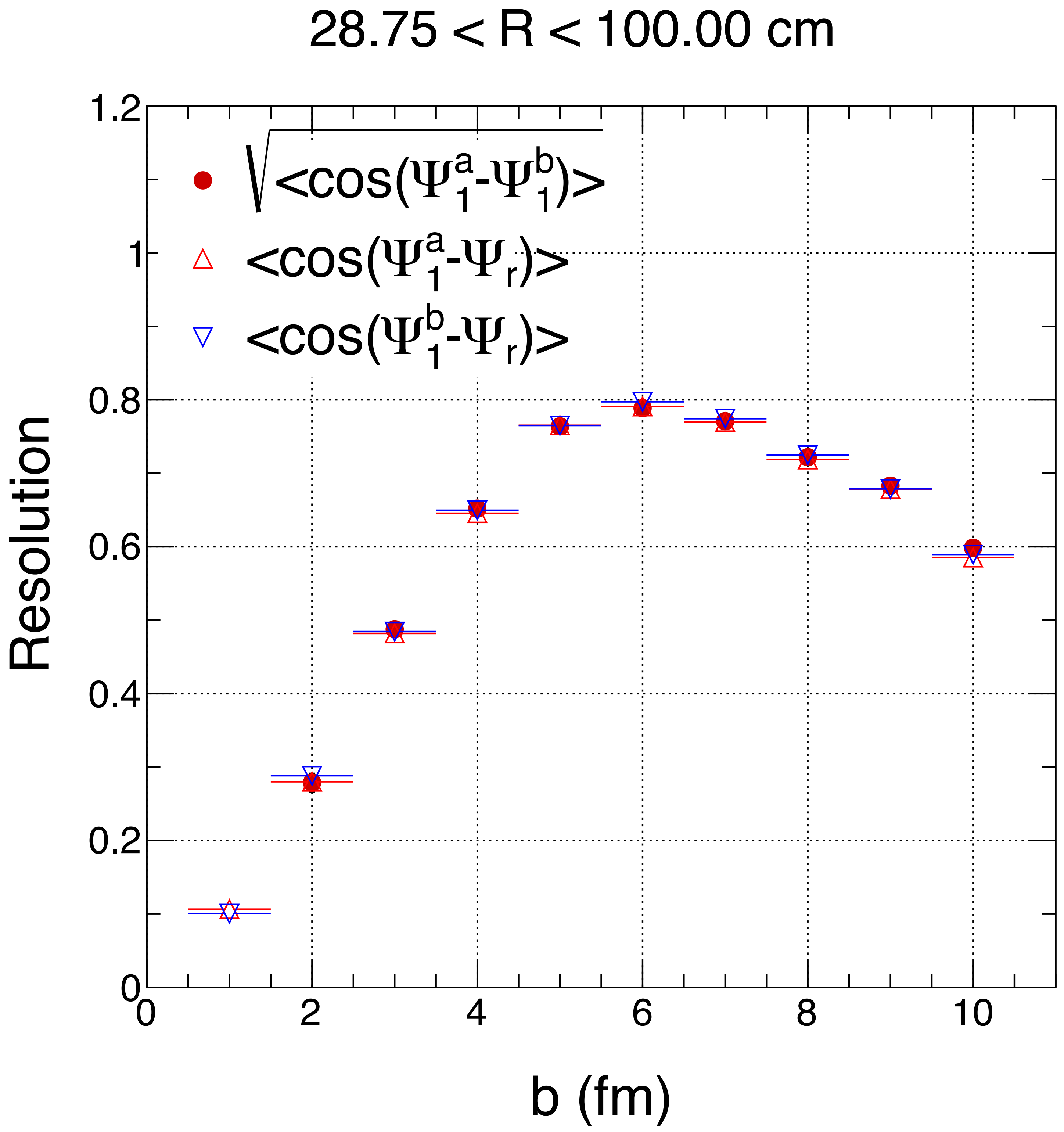
Sub-event plane distribution



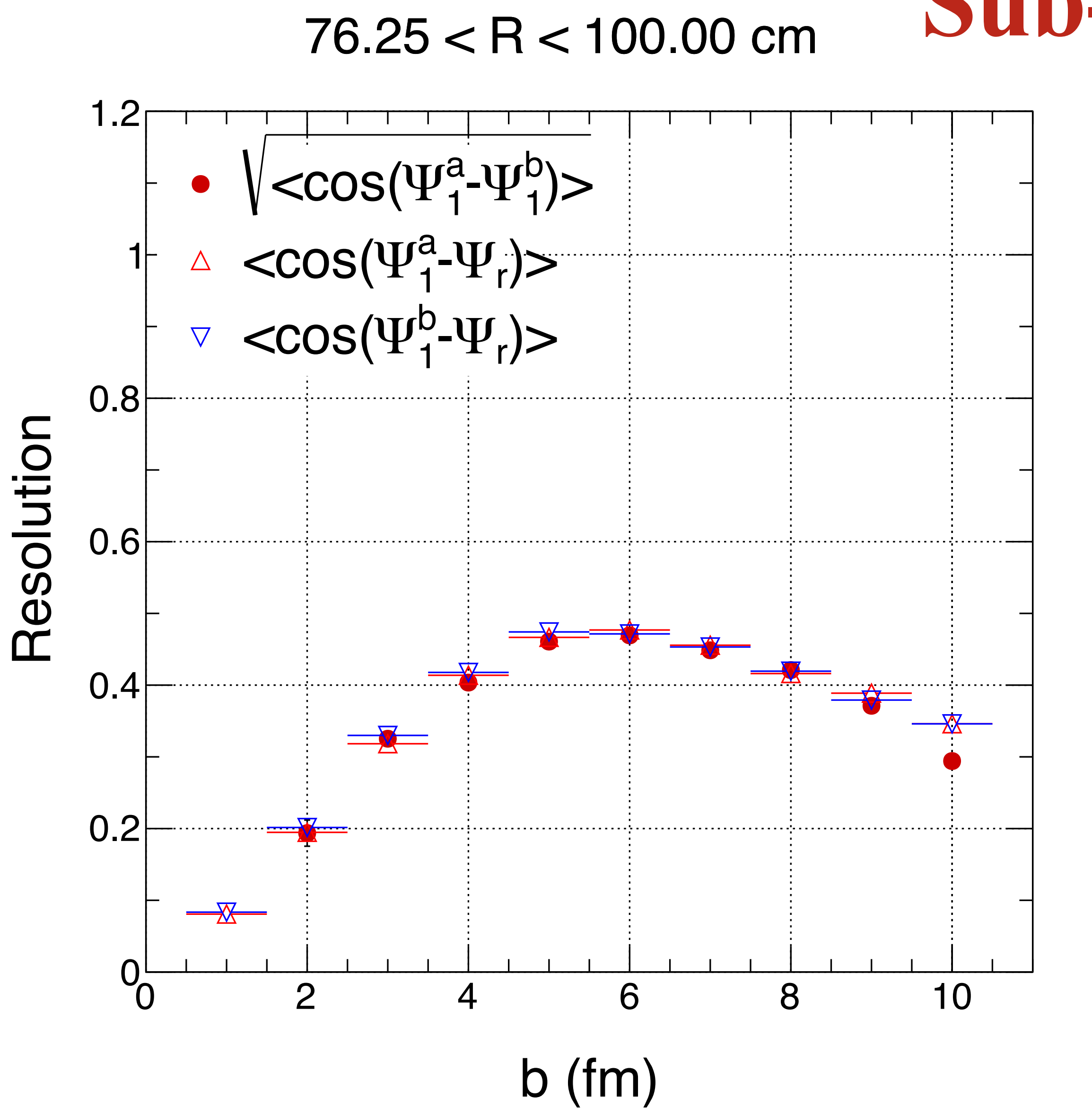
- Divide the full event up into two independent sub-events of equal tracks
- Position weight and shift calibration are applied

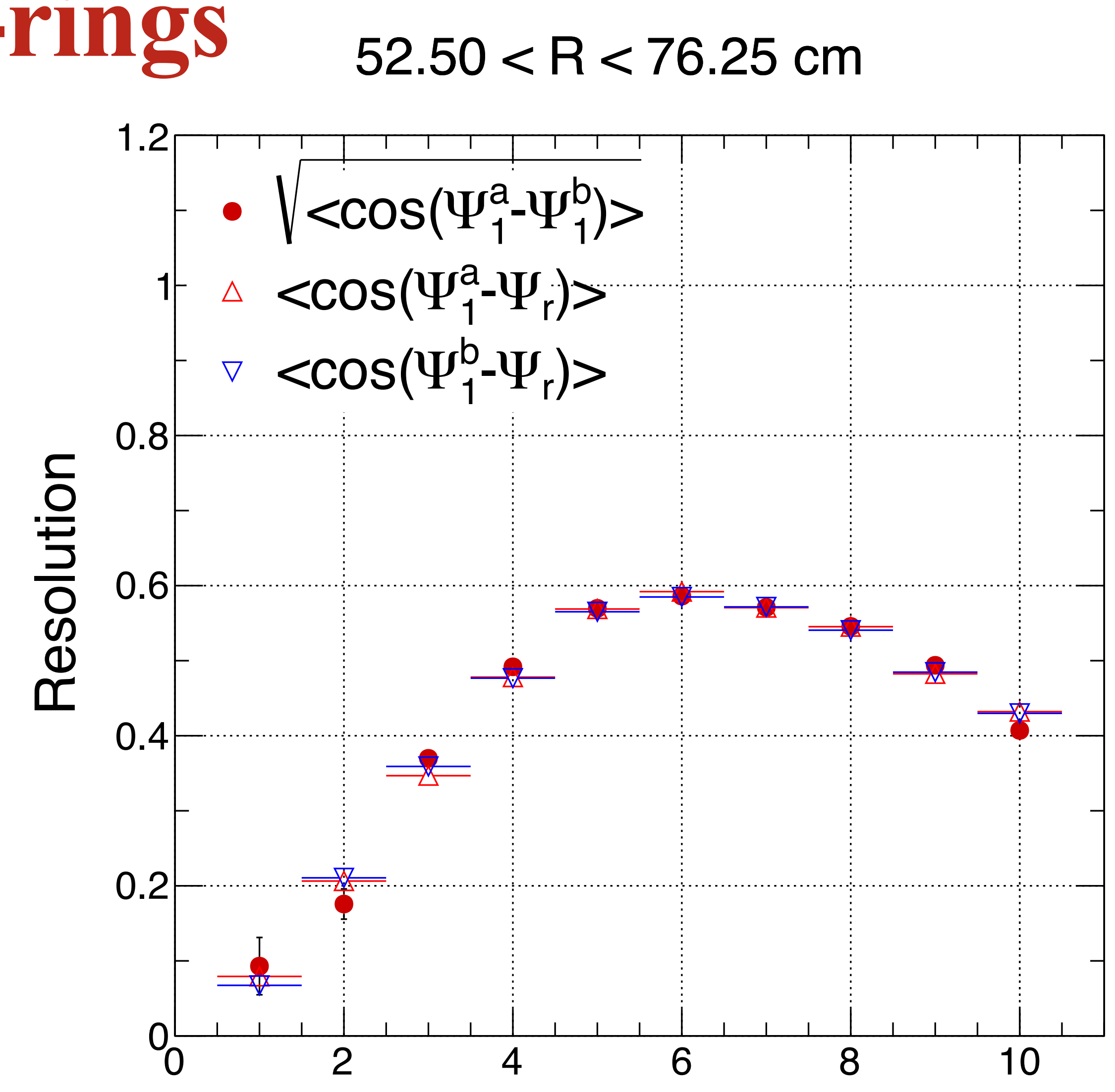
Sub-event plane resolution

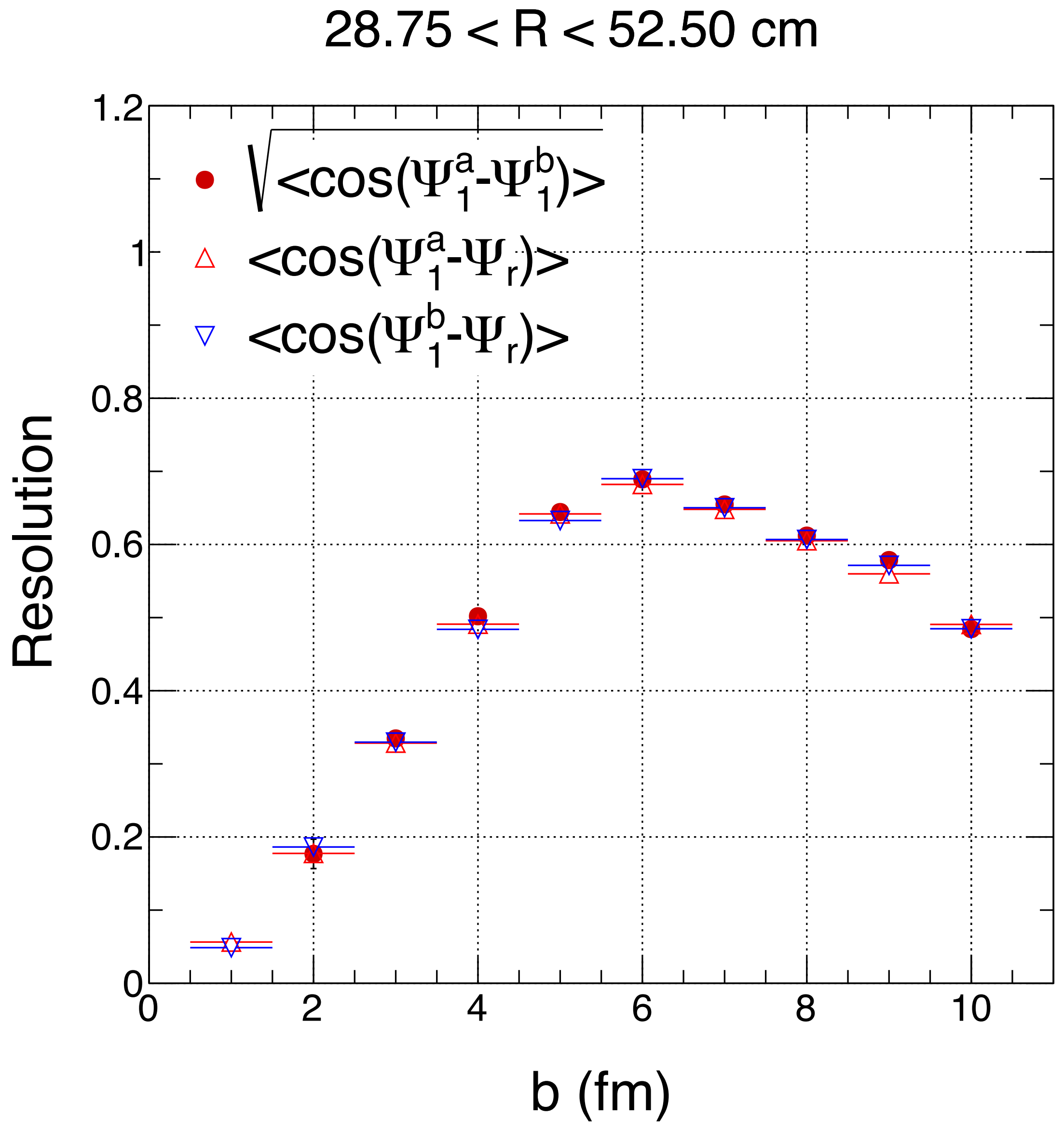
Whole ring



Sub-rings







- Estimating the event plane resolution by correlating two sub-events

$$R_{sub} = \sqrt{< \cos(\Psi_1^a - \Psi_1^b) >}$$

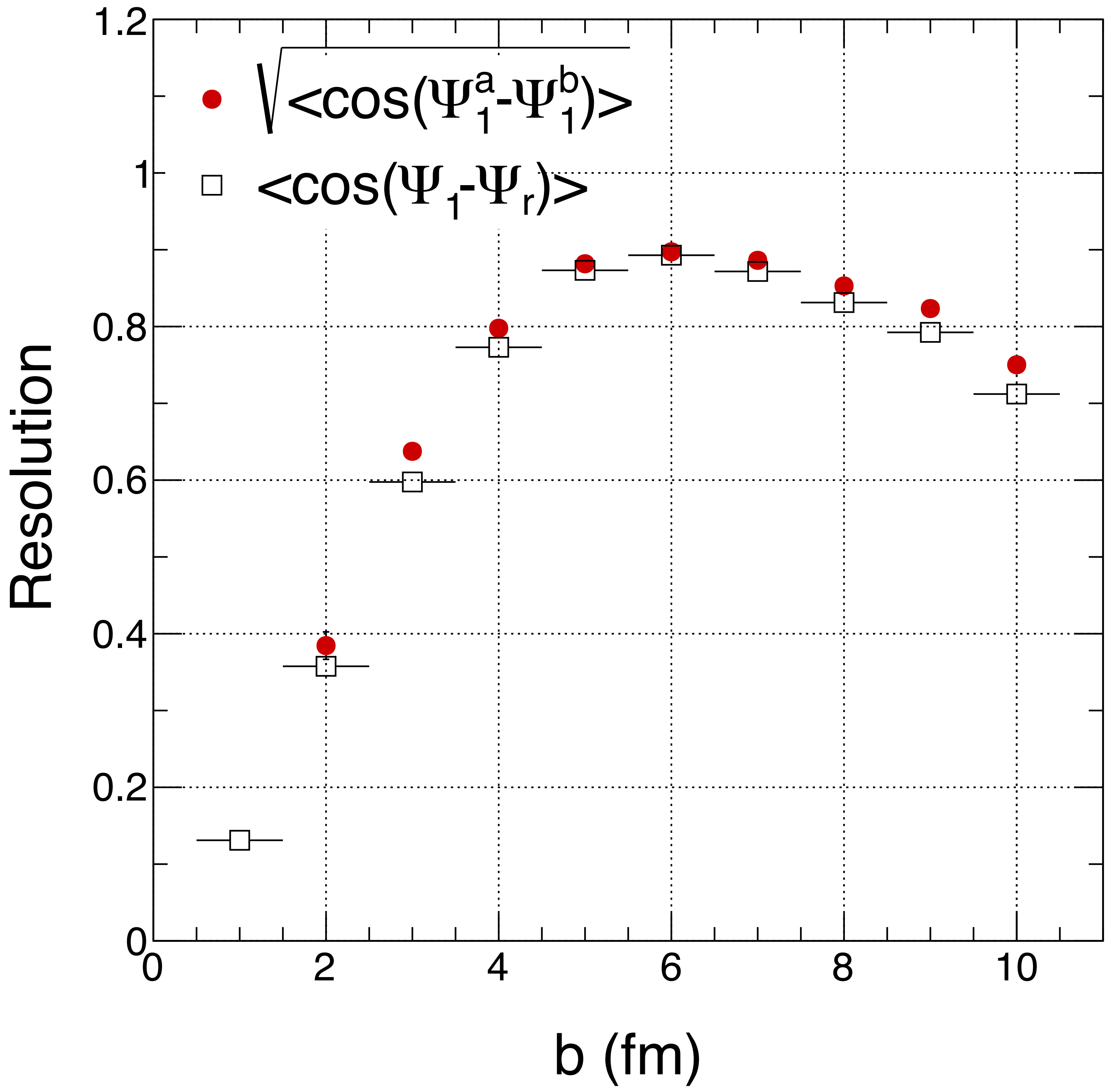
$$R_{sub} = < \cos(\Psi_1^a - \Psi_r) >$$

A. M. Poskanzer and S. A. Voloshin, Phys. Rev. C58, 1671 (1998)

Full-event plane resolution

Whole ring

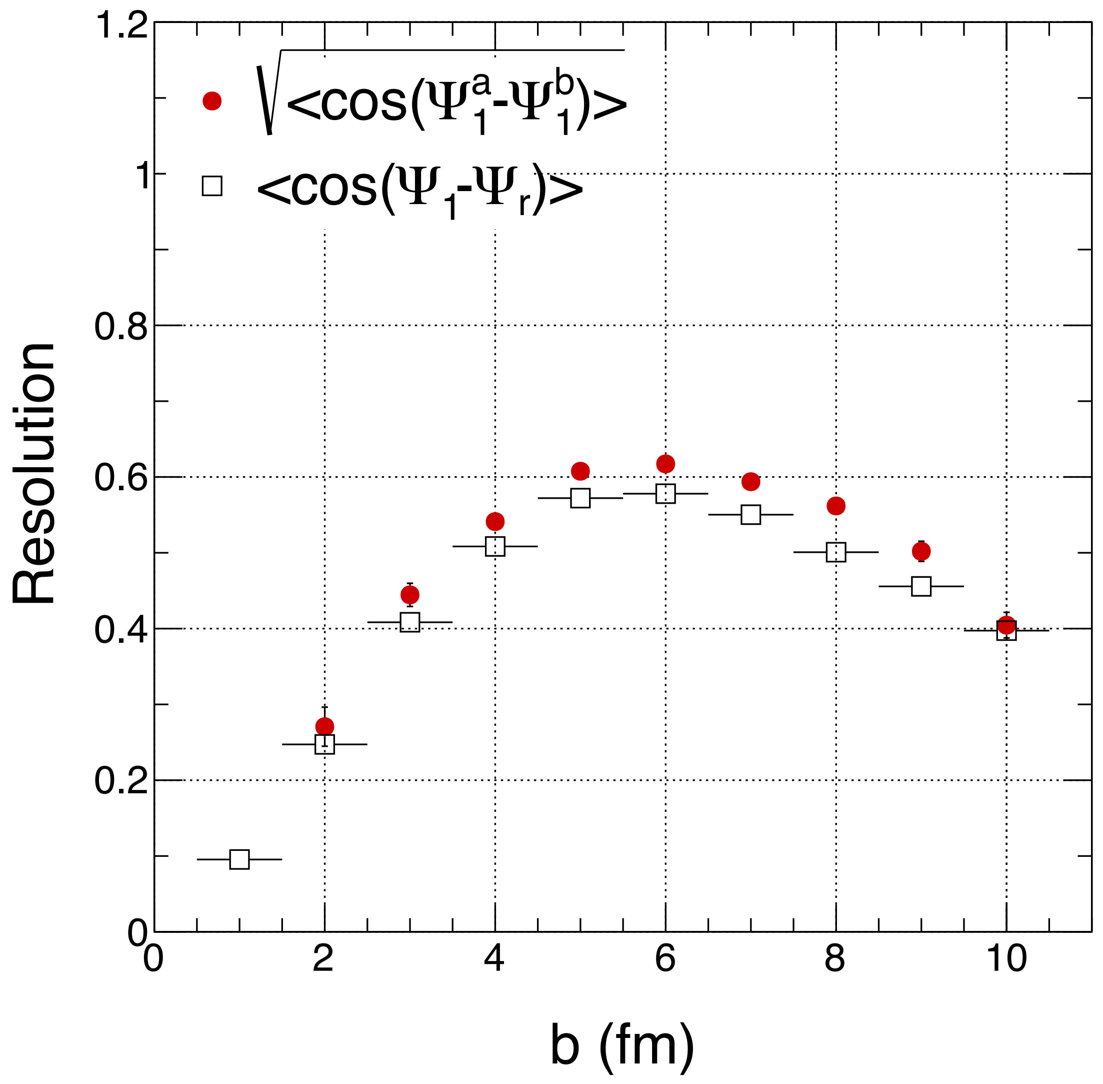
28.75 < R < 100.00 cm



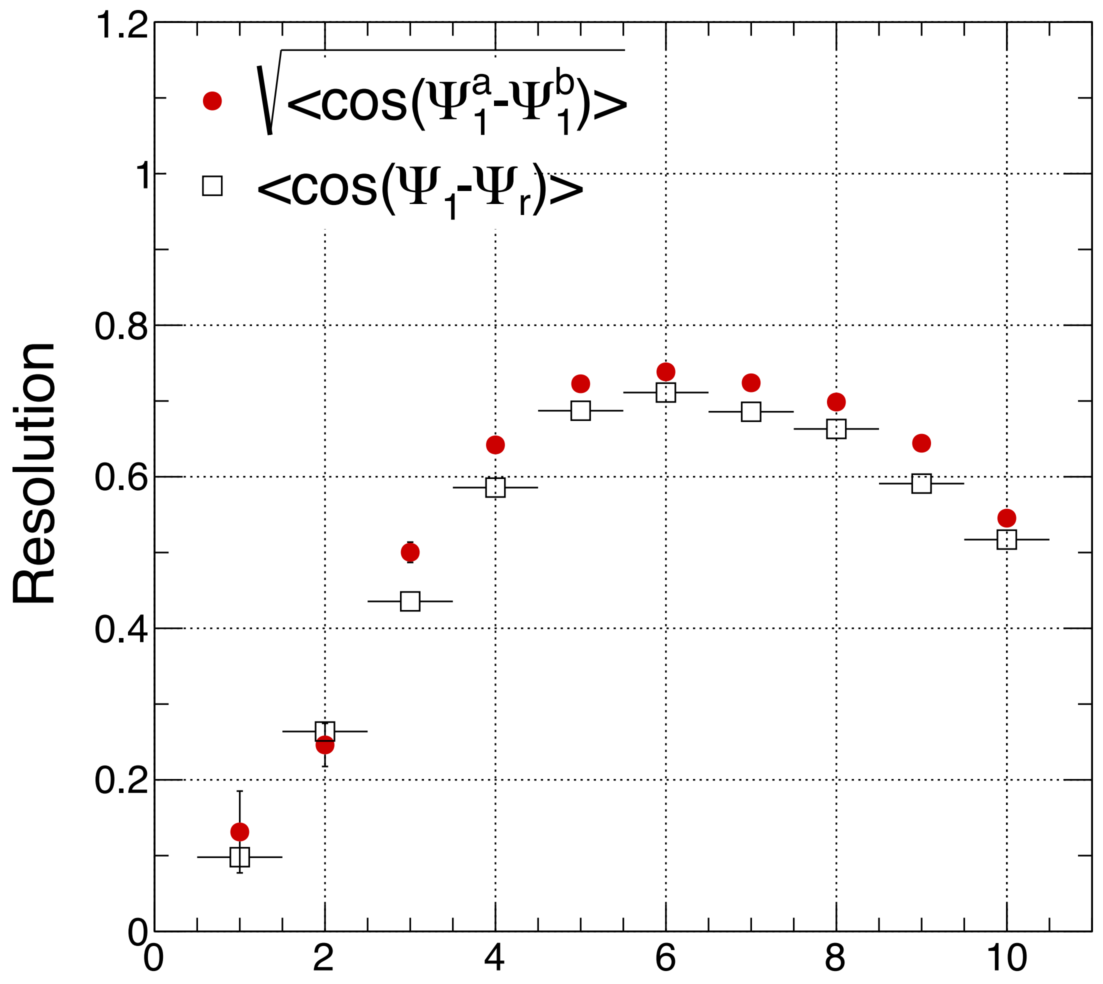
$$R_{full} = <\cos(\Psi_1 - \Psi_r)>$$
$$= \frac{\sqrt{\pi}}{2\sqrt{2}}\chi_1 \exp\left(-\chi_1^2/4\right) \times \left[I_0\left(\chi_1^2/4\right) + I_1\left(\chi_1^2\right)/4\right]$$

Sub-rings

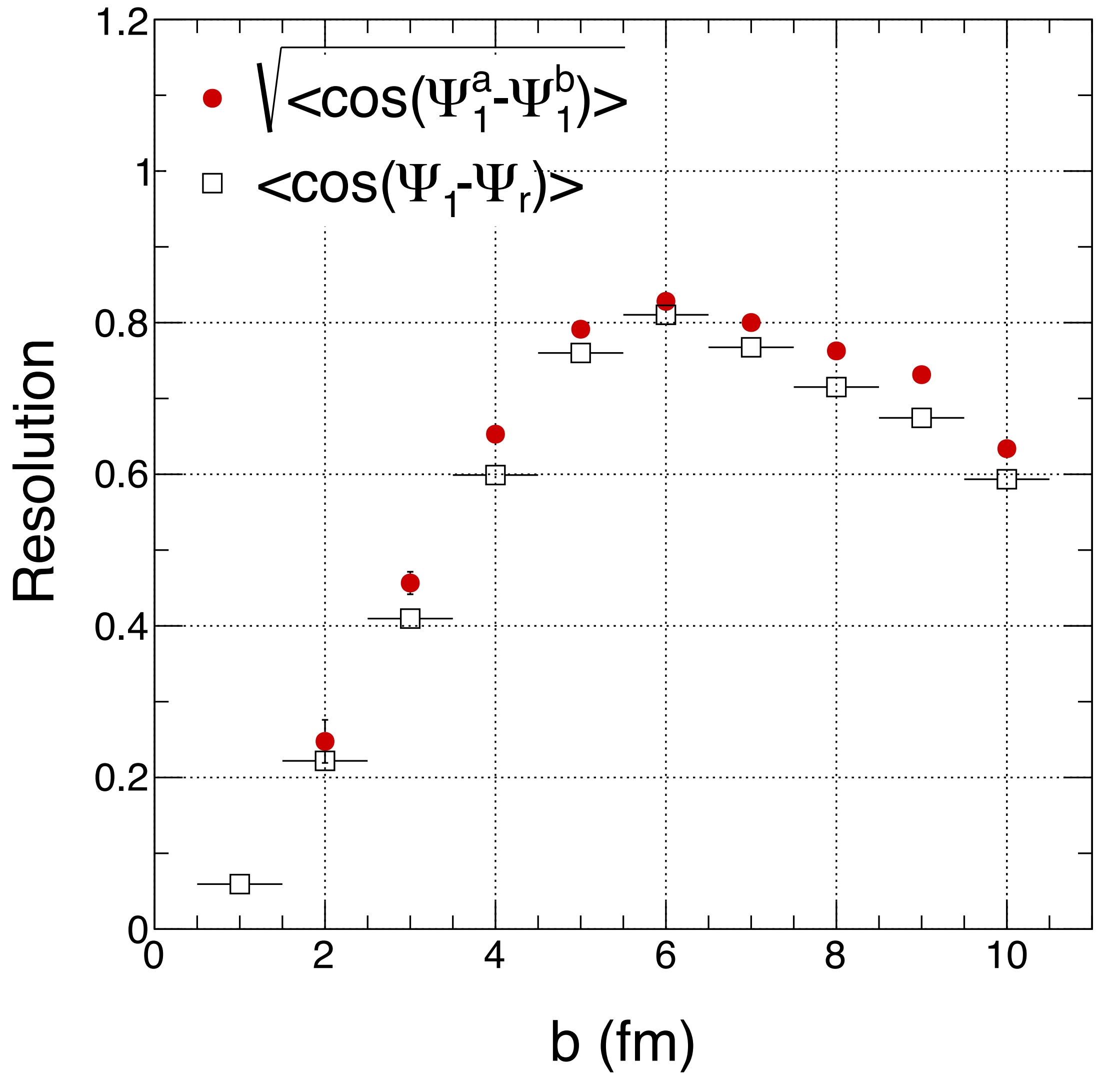
76.25 < R < 100.00 cm



52.50 < R < 76.25 cm

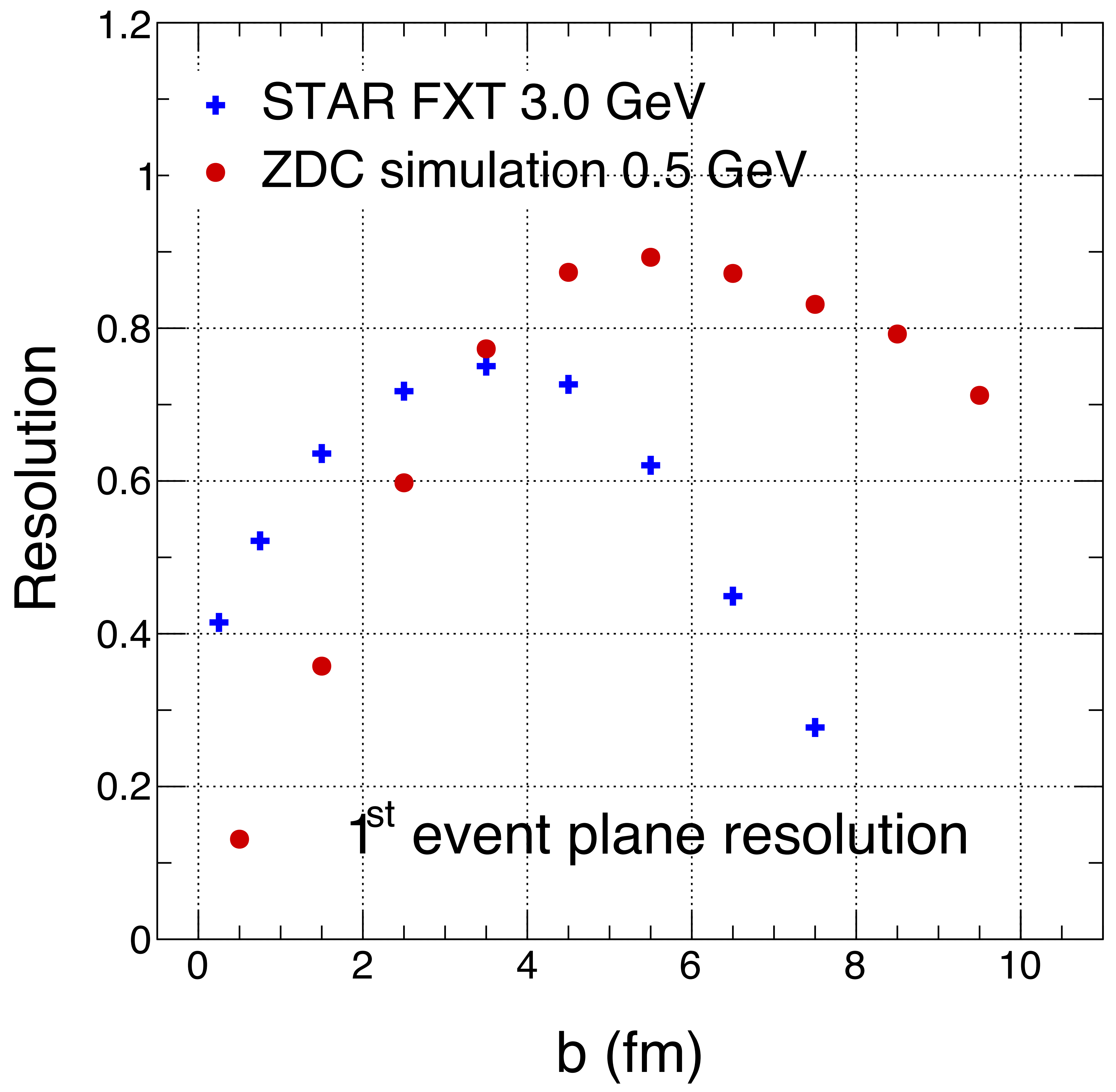


28.75 < R < 52.50 cm



A. M. Poskanzer and S. A. Voloshin, Phys. Rev. C58, 1671 (1998)

ZDC event plane resolution



- Position weight and shift calibration are applied
- ZDC 1st order event plane resolution reach to 90% ($4 < b < 7$ fm)

Summary

1. ZDC event plane simulation study using IQMD (500 MeV/u ^{238}U + ^{238}U) + GEANT

2. Position weight method and shift method well correct the resolution difference between the left and right sides caused by the asymmetric acceptance

3. ZDC 1st order event resolution can reach 90% ($4 < b < 7$ fm), which is an excellent level for similar detectors. It meets the physical requirements of CEE experiment

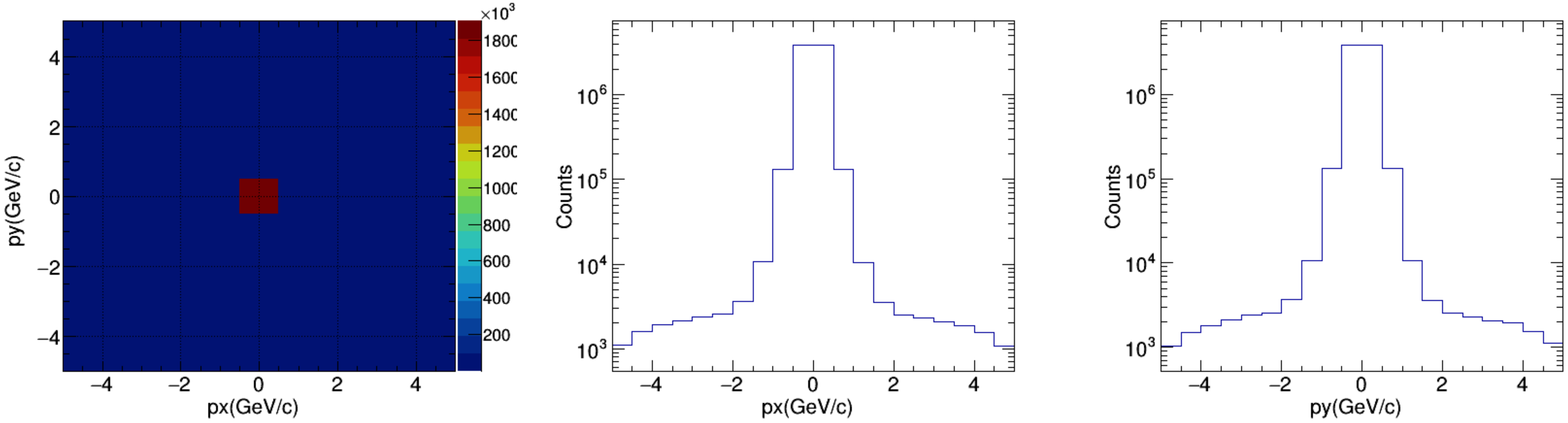
BACKUP

ZDC Acceptance from IQMD model

Random rotation

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$$

Momentum Space

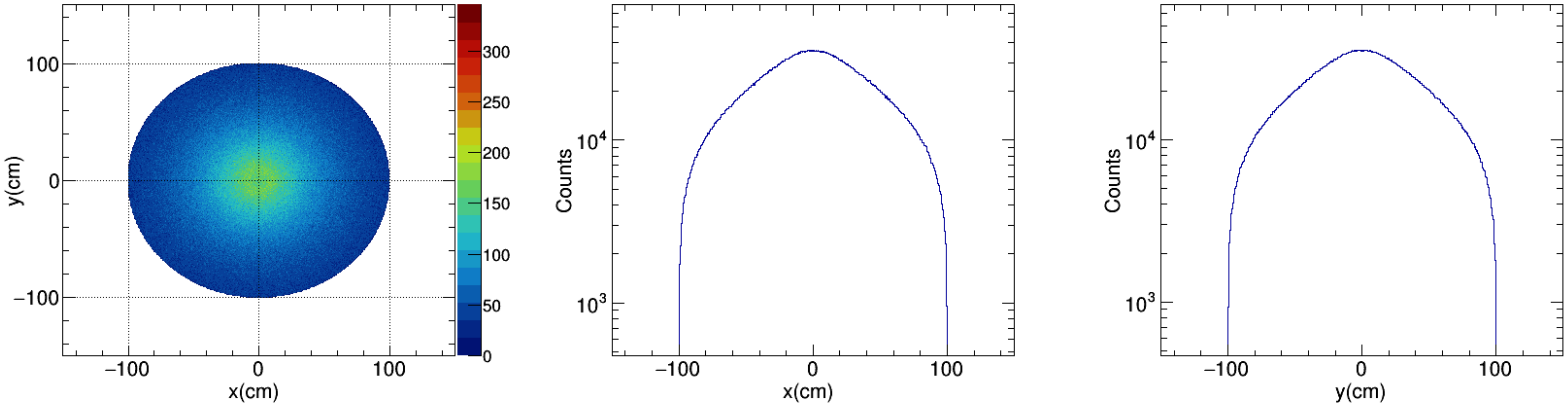


Coordinate Space

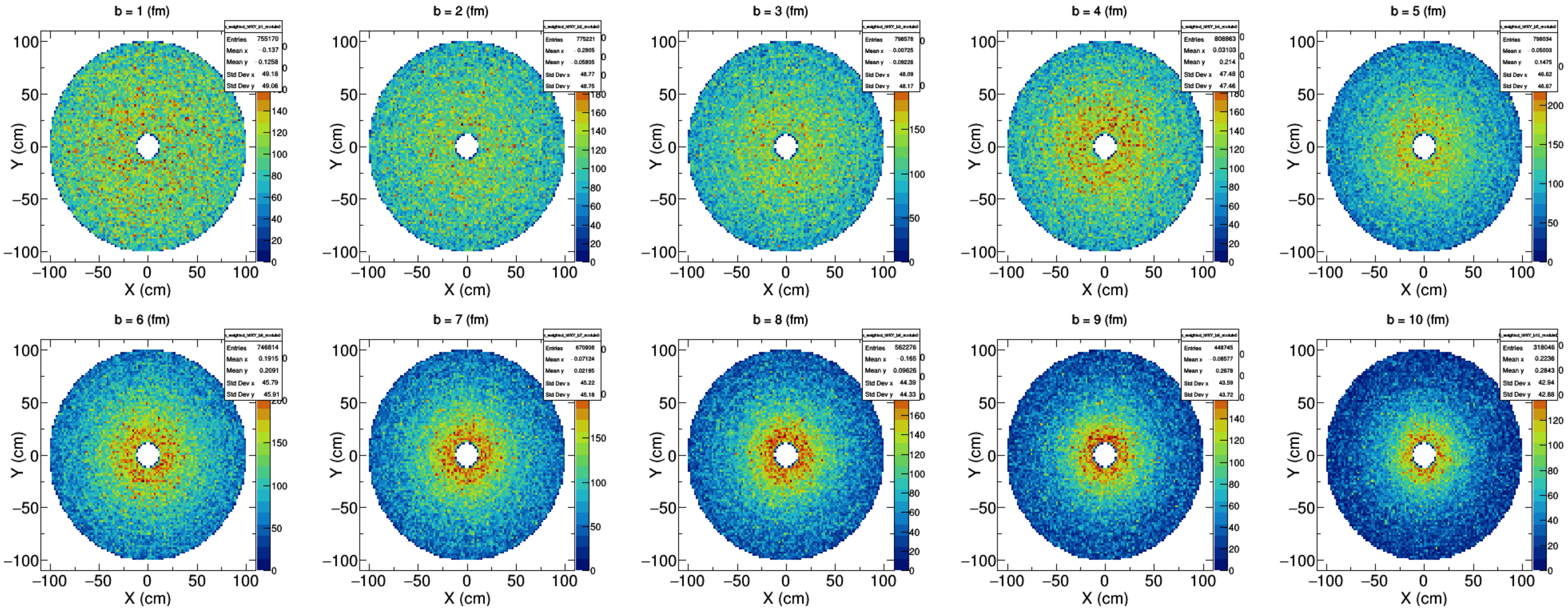
$X/Z = p_x/p_z$

$Y/Z = p_y/p_z$

Z = 299 cm



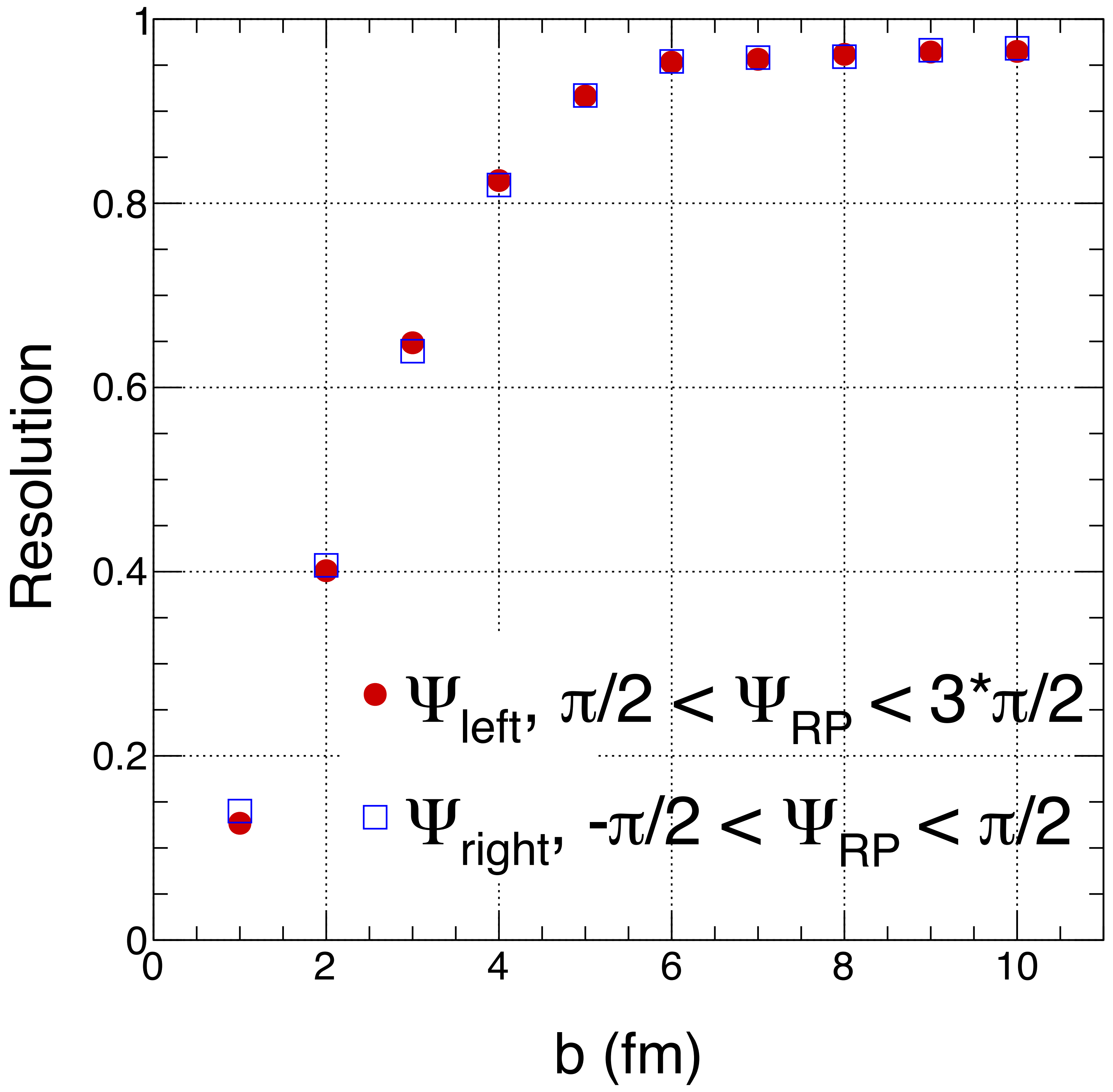
ZDC Acceptance without magnetic field



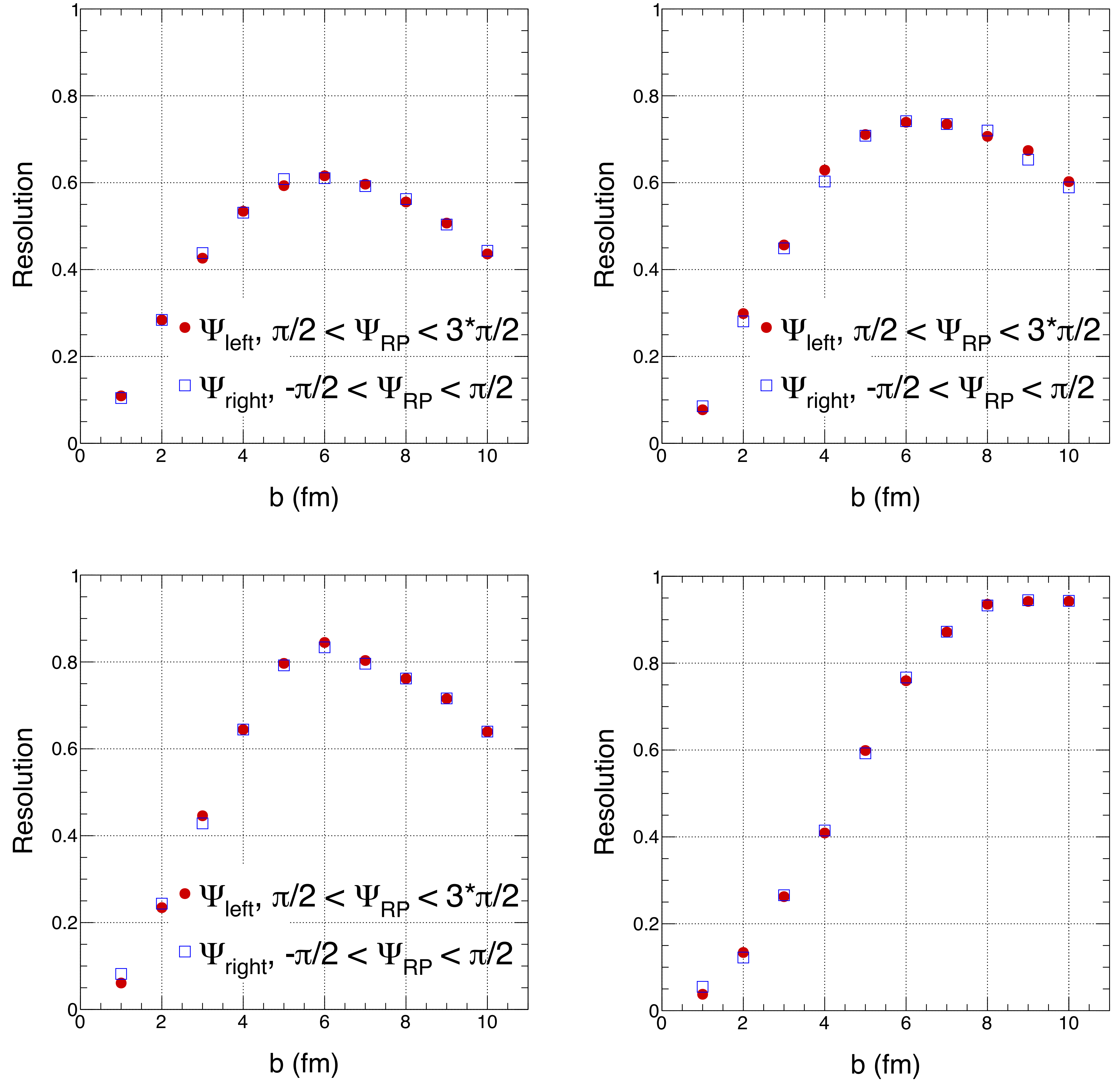
- The ZDC acceptance is isotropic and uniform in the simulation without the magnetic field

ZDC resolution without magnetic field

Whole ring



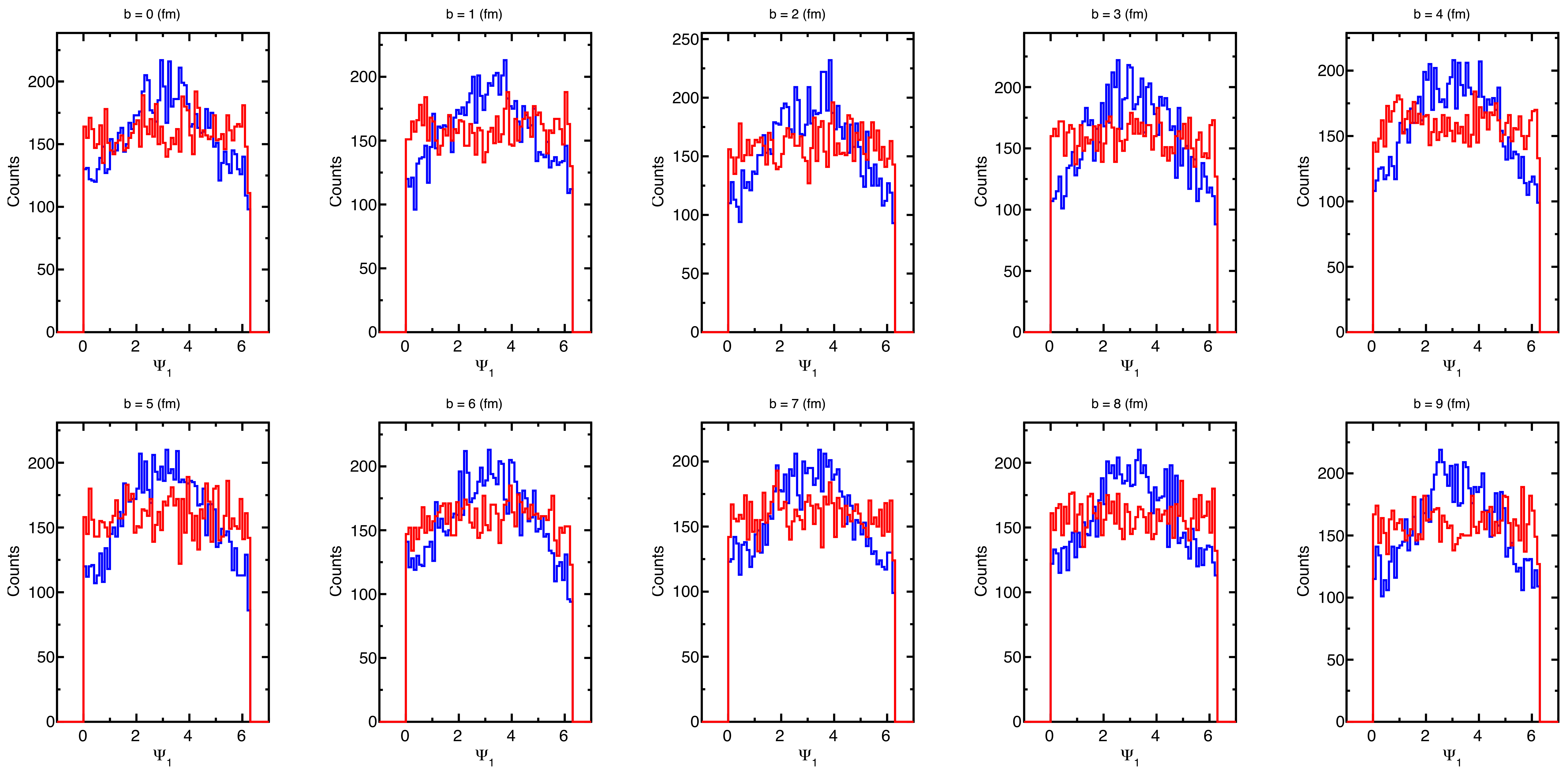
Four sub-rings



EP distribution Wo position weight

$$\Psi_1 = \tan^{-1}\left(\frac{\sum_i w_i \sin(\phi_i)}{\sum_i w_i \cos(\phi_i)}\right)$$

$$w_i = \Delta E$$



— —: Reaction plane
— —: Event plane

- Use the 1st order event flow vector to reconstruct event plane

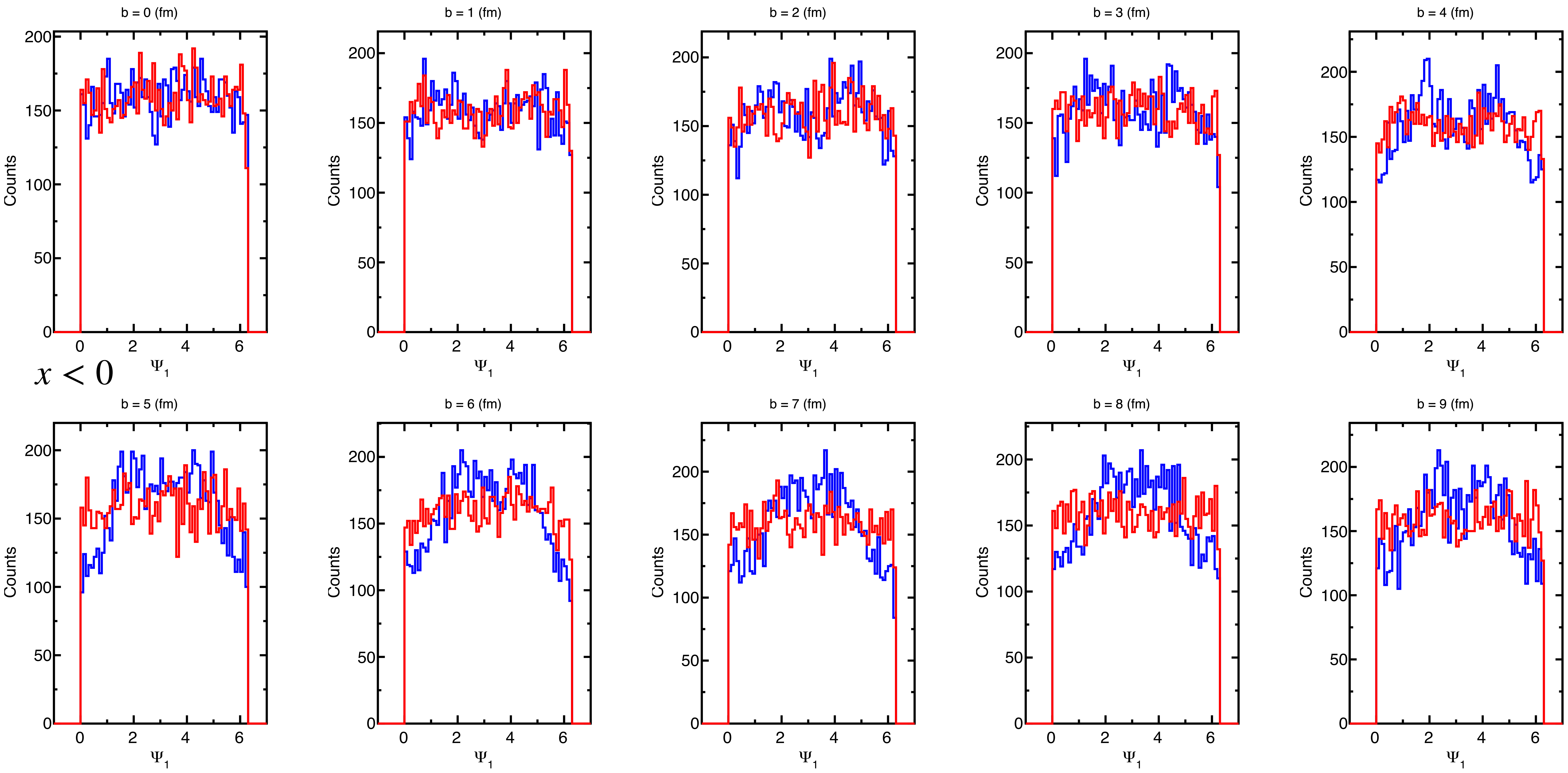
EP distribution W position weight

$$\Psi_1 = \tan^{-1}\left(\frac{\sum_i w_i \sin(\phi_i)}{\sum_i w_i \cos(\phi_i)}\right)$$

$$w_i = \Delta E * R$$

$$R = n(-x, y, \Delta E)/n(x, y, \Delta E), \quad x < 0$$

$$R = 1, \quad x > 0$$

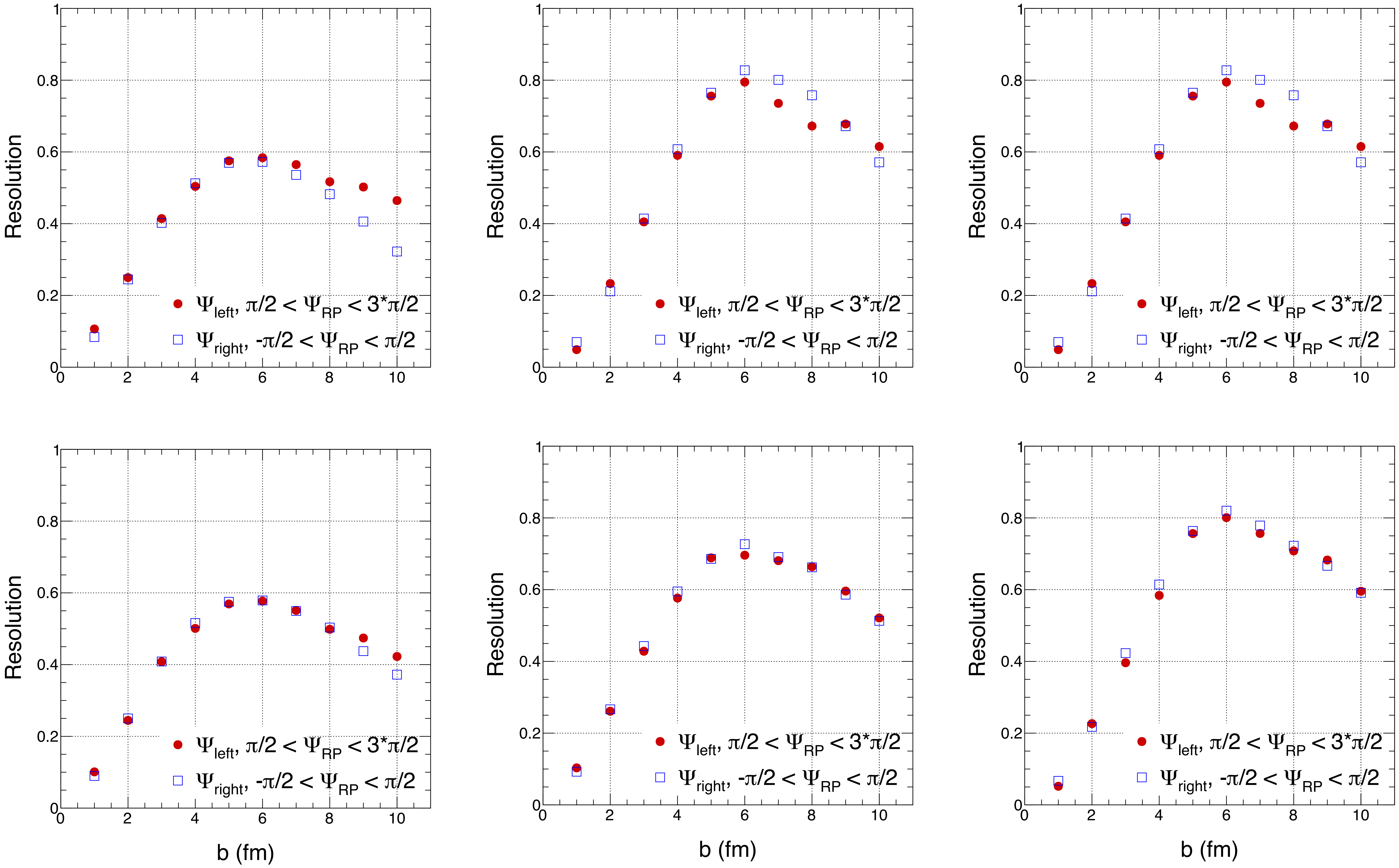


— —: Reaction plane
— —: Event plane

- Use the 1st order event flow vector to reconstruct event plane

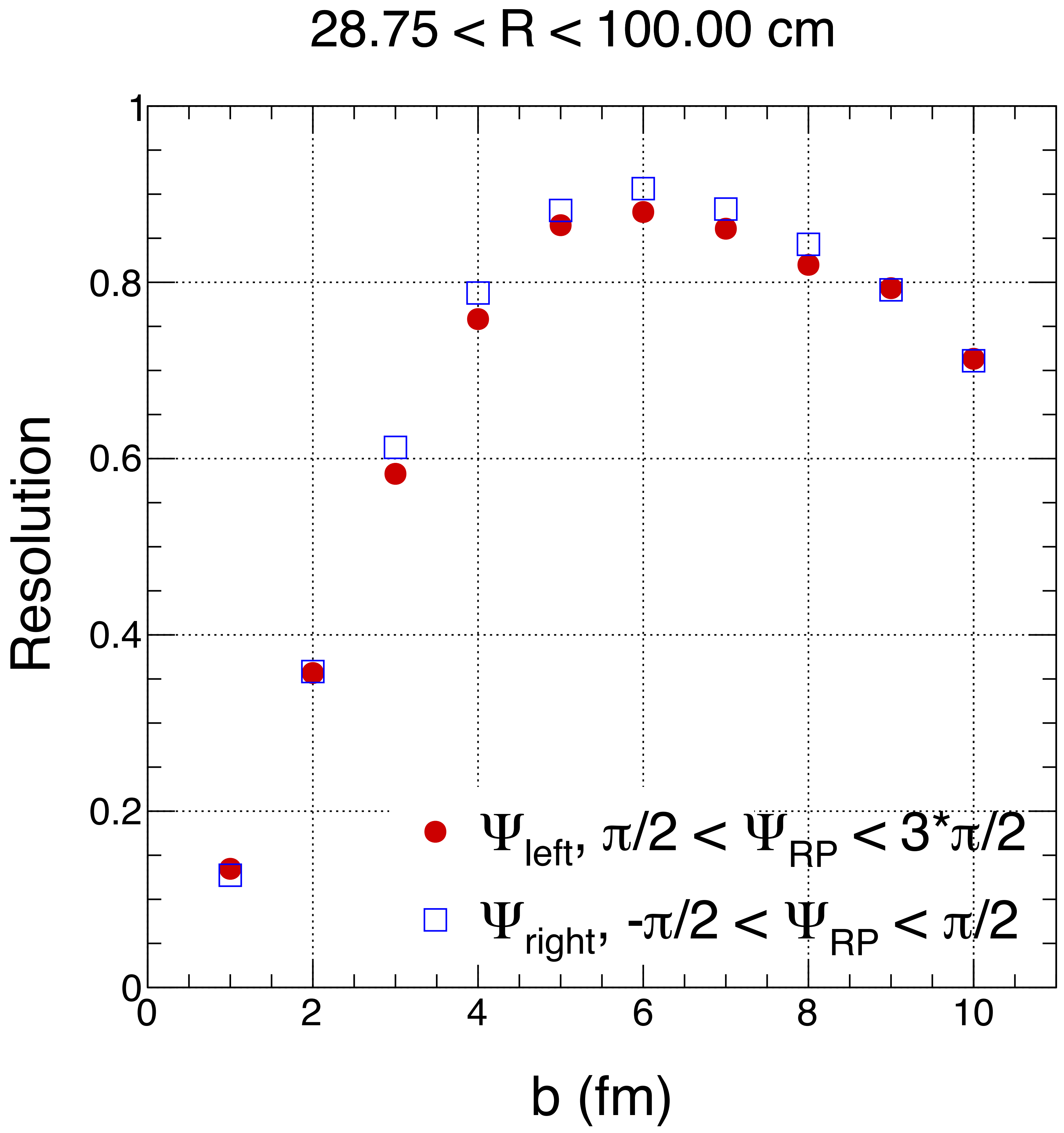
Shift calibration

76.25 < R < 100 cm | 52.50 < R < 76.25 cm | 28.75 < R < 52.50 cm

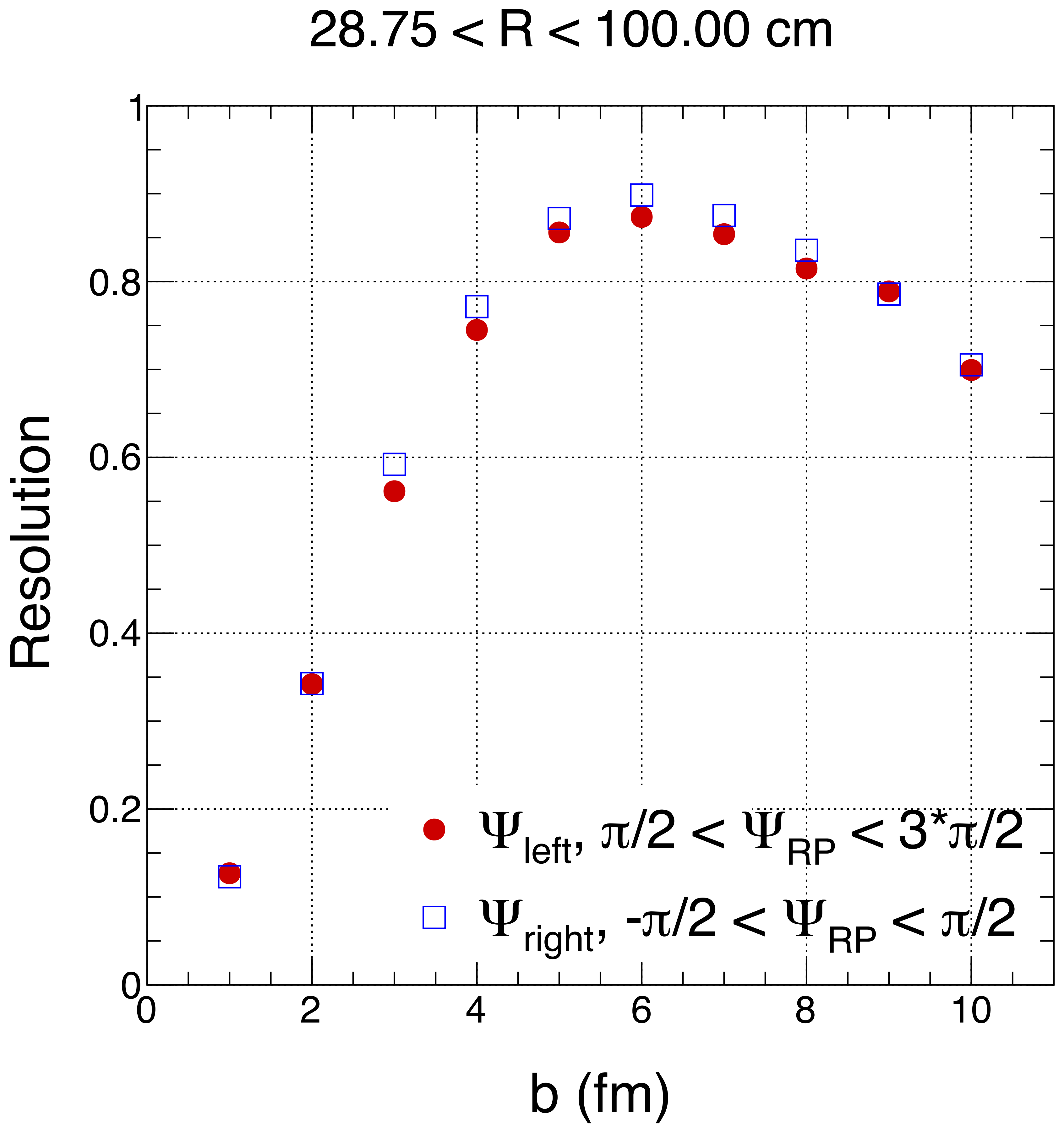


Energy smearing effect

Without Energy smearing effect

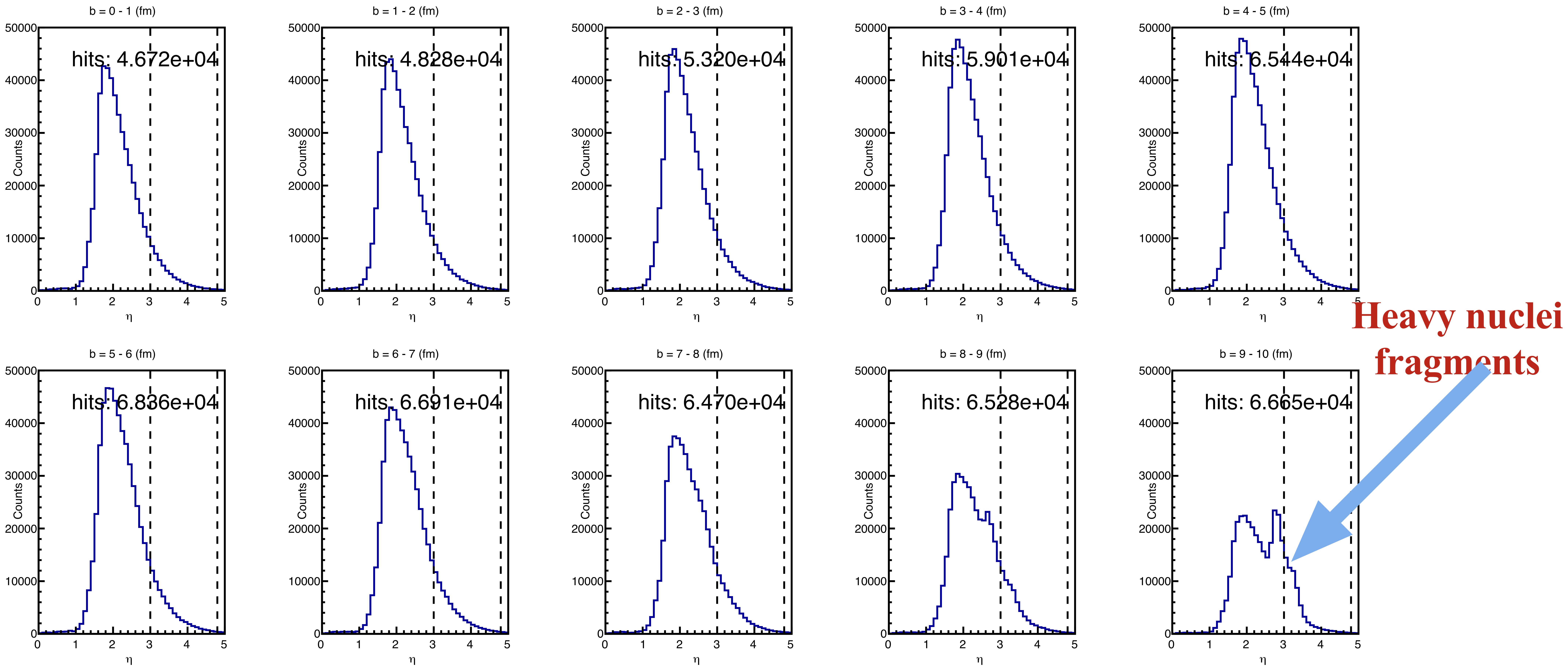


With Energy smearing effect $1.0 - 1/3 * (r/5.5)^2$



- The energy smearing effect has little effect on the resolution

ZDC hits Vs. η



Mass distribution within η [3, 4.8]