Reaction Plane Resolution

2023/11/29 INTT Workshop in KU

NWU M2 Manami Fujiwara

Analysis Plan during INTT workshop

Name : Manami Fujiwara
Institution : NWU

- Analysis topic

  Analyze v2 INTT reaction plane with MBD phi

- Current knowledge/status of this topic

  Calibrated INTT reaction plane were calculated
  INTT reaction plane resolution with 2sub - method was calculated

- Goal for the workshop

  1. Calculate v2 using 1M event in run54280
  2. Confirm correlation v2 and resolution with number of intt cluster
  3. Make document, how to get Mbd data from DST

- Milestones to reach to your goal

  1. Get Mbd phi information from DST and add to my ttree for analysis
  2. Write code for v2 calculation
  3. Add function divide by the number of cluster to flattening code and v2 code

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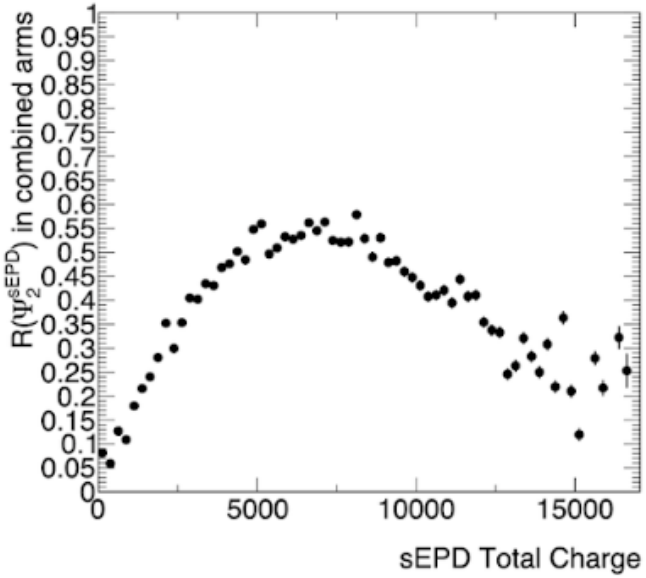
Run and Cut condition

- Run54280
  - Zero field
  - Number of Event : First 1M events (Run54280 has 10M events.)

- Cut Condition
  - Hot Channel (produced by Jeain)
  - BCO Timing
  - |MBD z vertex| < 20
  - INTT Cluster ADC > 45

INTT reaction plane resolution

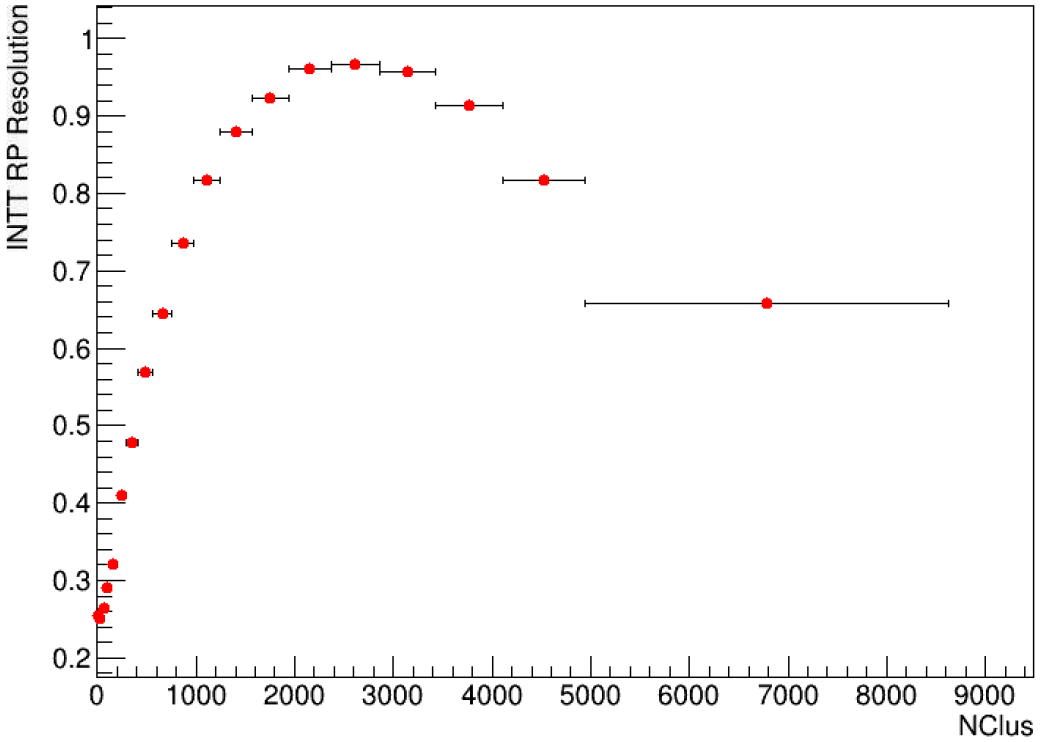
- Calculate the resolution using 2sub-method
  - Suppose that $\sigma_{INTTS} = \sigma_{INTTN}$, the resolution is
  - $\sigma_{INTT} = \sqrt{\sigma^2_{INTTS} + \sigma^2_{INTTN}} = \sqrt{2\langle \cos 2(\psi_{INTTS} - \psi_{INTTN})\rangle}$
  - $\sigma_{INTT} = 0.696062$ (using 1M event)
- Compare with sEPD event plane resolution, it is higher than the maximum of sEPD resolution



sEPD Total Charge vs sEPD event plane resolution
by ejiro
https://docs.google.com/document/d/1hNYyXgFVp3XaeHl82aTlv55webk9-ZO5qKOok26zclk/edit?tab=t.0

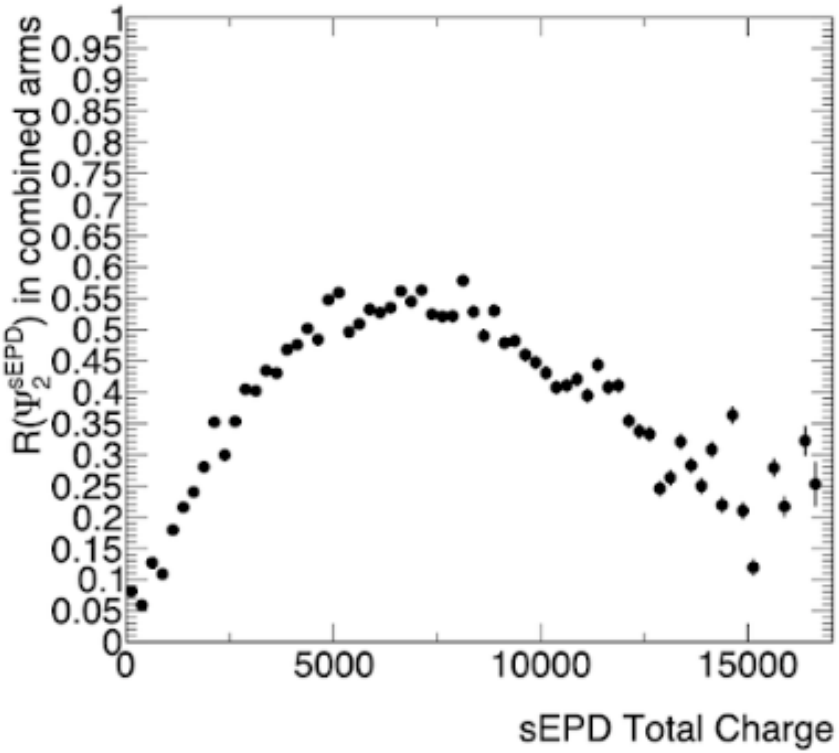
INTT reaction plane resolution

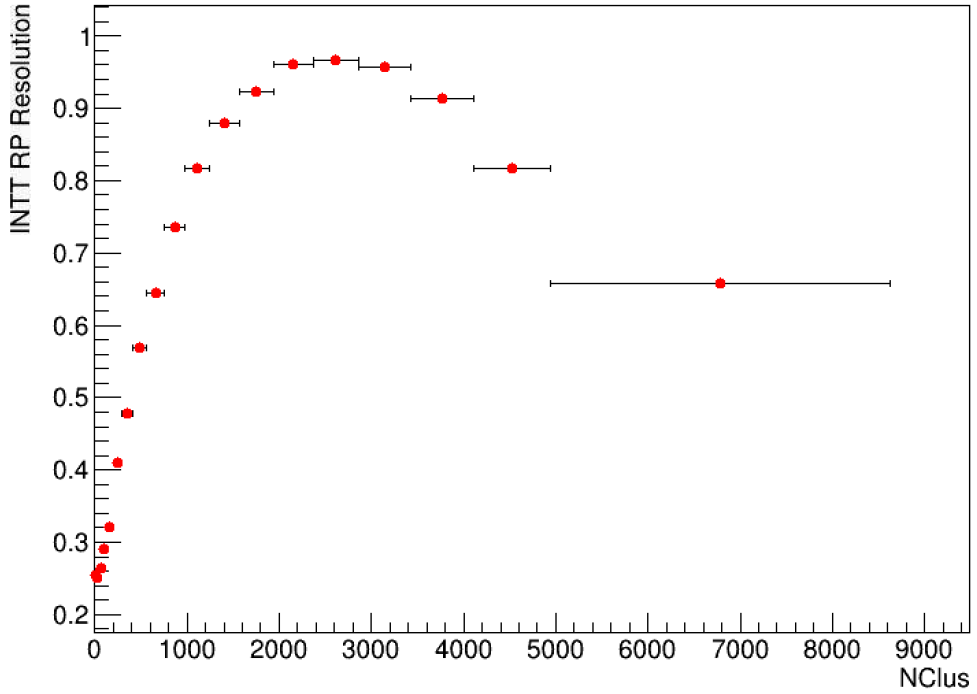
- X axis : number of INTT Cluster
- Y axis : INTT RP Resolution
- X error : range of number of cluster
- Y error : sigma of mean
- $\sigma_{INTT} = \sqrt{\sigma^2_{INTTS} + \sigma^2_{INTTN}} = \sqrt{2\langle \cos 2(\psi_{INTTS} - \psi_{INTTN})\rangle}$



Compare with sEPD RP resolution and INTT RP resolution

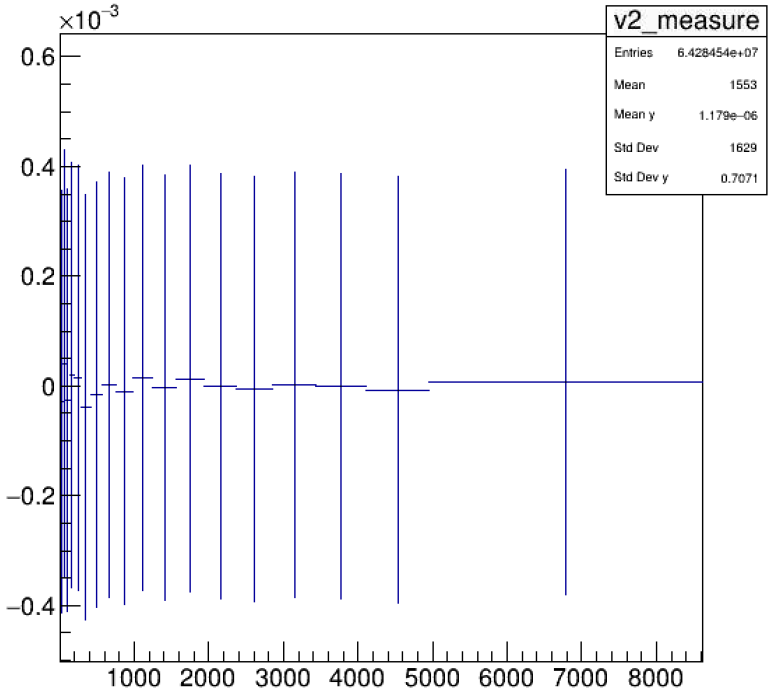
- INTT RP resolution is higher than sEPD RP resolution

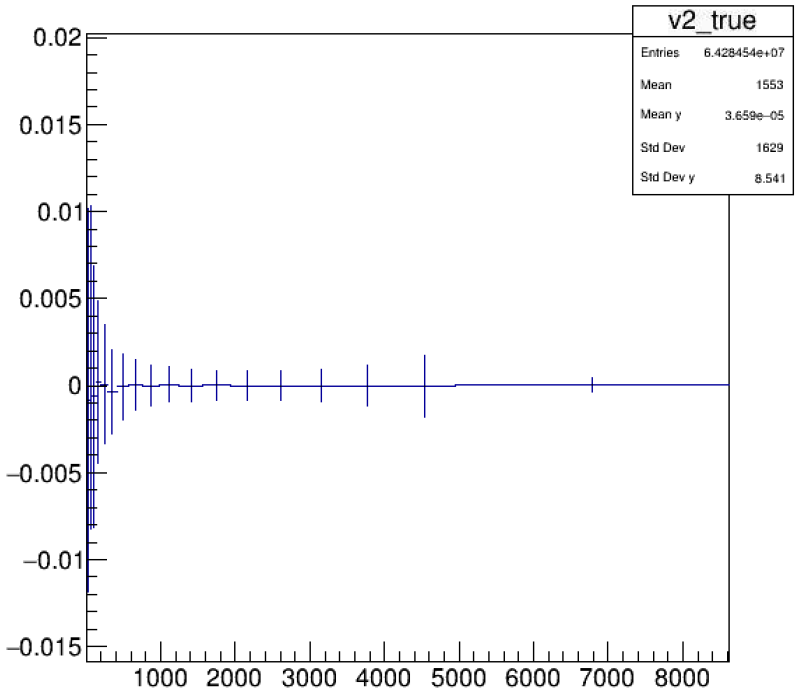




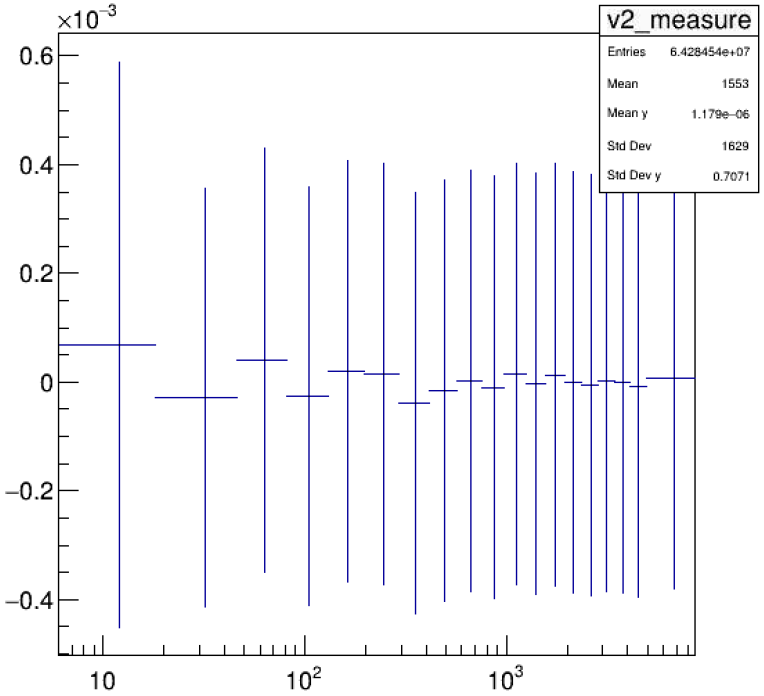
NClus vs v2

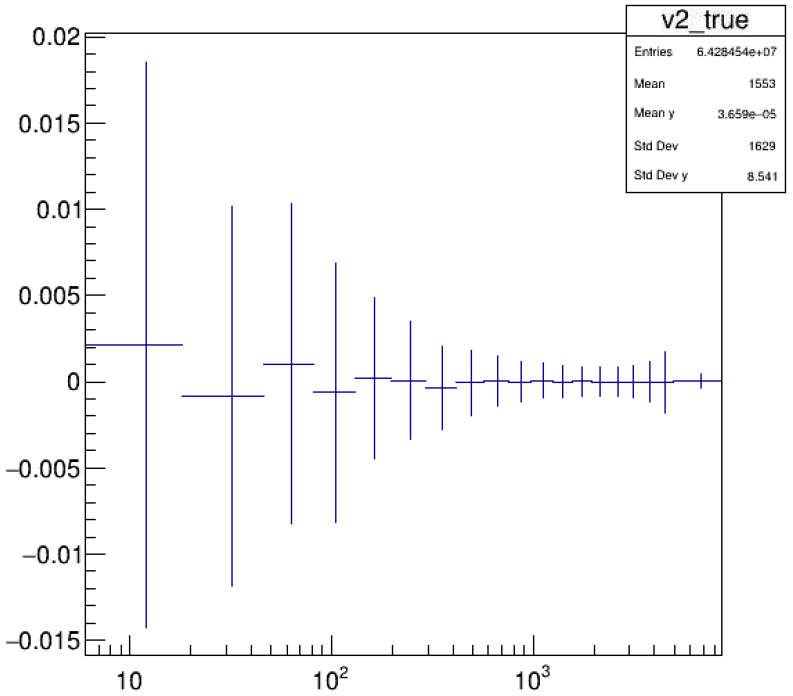
- $v_2^{measure} = \langle \cos(2[\psi_{INTT} - \phi_{MBD}]) \rangle$
- $v_2^{ture} = \dfrac{v_2^{measure}}{\sigma_{INTT}}$





NClus vs v2


v2_measure
Entries 6.428454e+07
Mean 1553
Mean y 1.179e−06
Std Dev 1629
Std Dev y 0.7071
×10^−3
0.6
0.4
0.2
0
−0.2
−0.4
10
10^2
10^3


v2_true
Entries 6.428454e+07
Mean 1553
Mean y 3.659e−05
Std Dev 1629
Std Dev y 8.541
0.02
0.015
0.01
0.005
0
−0.005
−0.01
−0.015
10
10^2
10^3

Summery

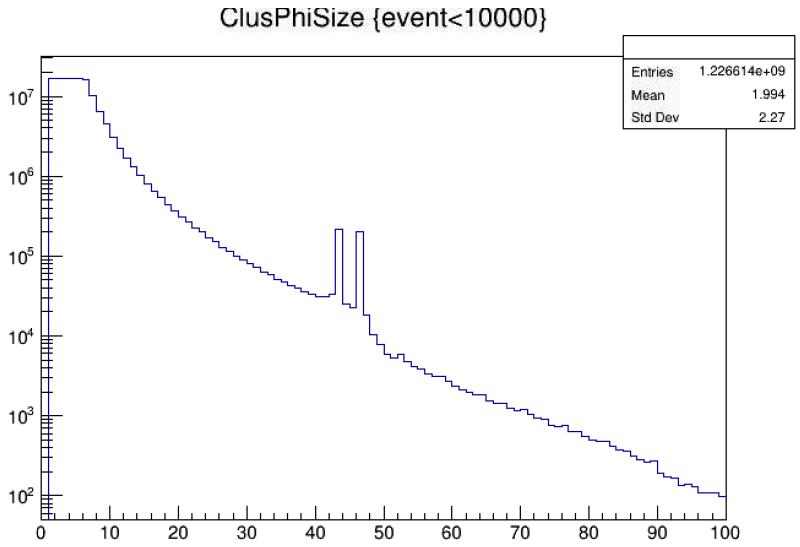
- Confirm correlation with number of cluster and INTT reaction plane resolution
- INTT reaction plane resolution is higher than sEPD resolution
- INTT reaction plane resolution contains auto correlation made by 2-sub method
- 3-sub method (using 3 detector, for example, INTT, MBD south and MBD north) is better

- v2 is close to 0
- I need to debag more

Next to do

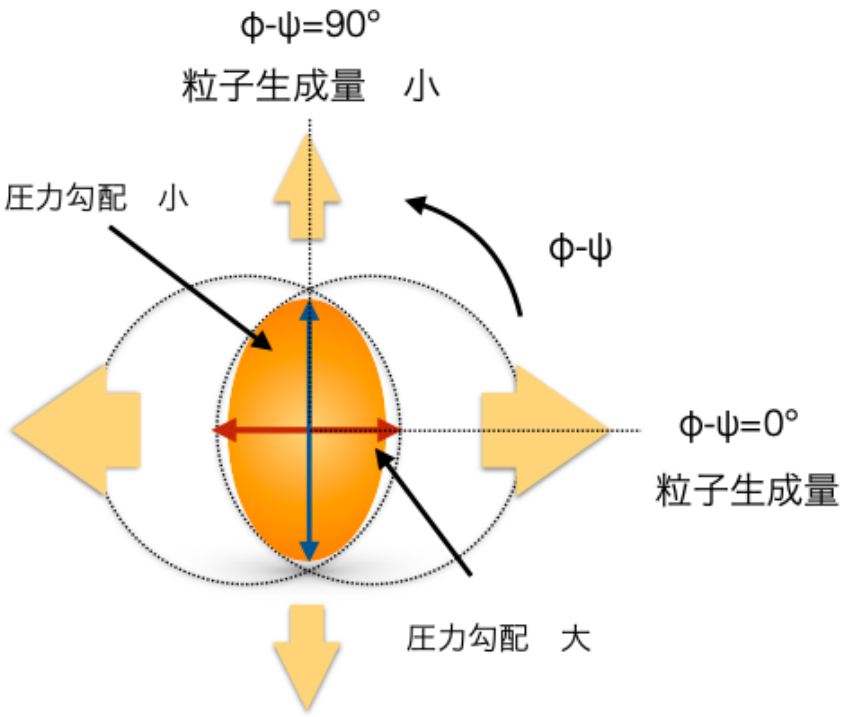
- Debag the code and calcurate correlation with v2 and number of cluster again

- ClusterPhiSize Analysis



Back Up

Hydrodynamic behavior of QGP and azimuthal anisotropy of particles (v_2)



$$\frac{dN}{d(\phi-\psi_2)} \propto 1+2v_2\cos[2(\phi-\psi_2)]$$

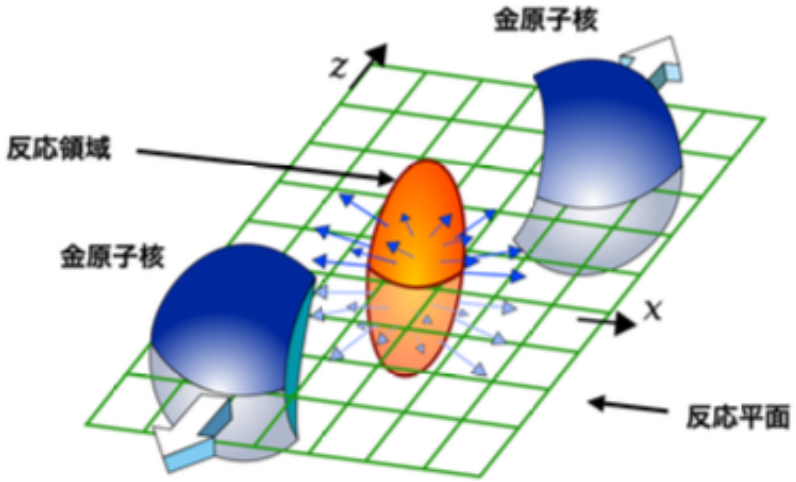
ϕ : Azimuthal angle of the particles produced by the collision

ψ_2 : reaction plane angle

v_2 : value representing the strength of the azimuthal anisotropy

QGP is generated →large v_2 is measured

Reaction plane



- Reaction plane is a plane includes the straight line connecting the center of nucleus and and z axis
- Reaction plane is not controlled, so distribution of reaction plane angle should be uniform distribution

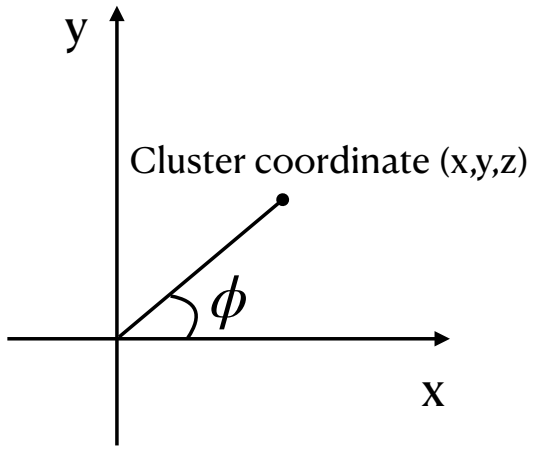
  → Reaction plane angle distribution is distorted due to the effect of detector acceptance, beam doesn't throw center of detector

  → Calibrations to fix the effects

  (re-centering, flattening) are needed

Definition of Reaction plane

- $\phi = \arctan\left(\frac{y}{x}\right)$
- $Q_x^{obs} = \frac{\sum_i \omega_i \cos(n\phi)}{\sum_i \omega_i}$, $Q_y^{obs} = \frac{\sum_i \omega_i \sin(n\phi)}{\sum_i \omega_i}$
- $\psi_n = \frac{1}{n}\tan^{-1}\frac{Qx}{Qy}$



Analysis in the case of n=2, $\omega_i = 1$ using coordinates of INTT cluster

Reaction plane angle ψ is the angle between the reaction plane and the xy-plane.

The reaction plane is a plane that includes the straight line connecting the centers of the nuclei and the beam axis.

Recentering calibration

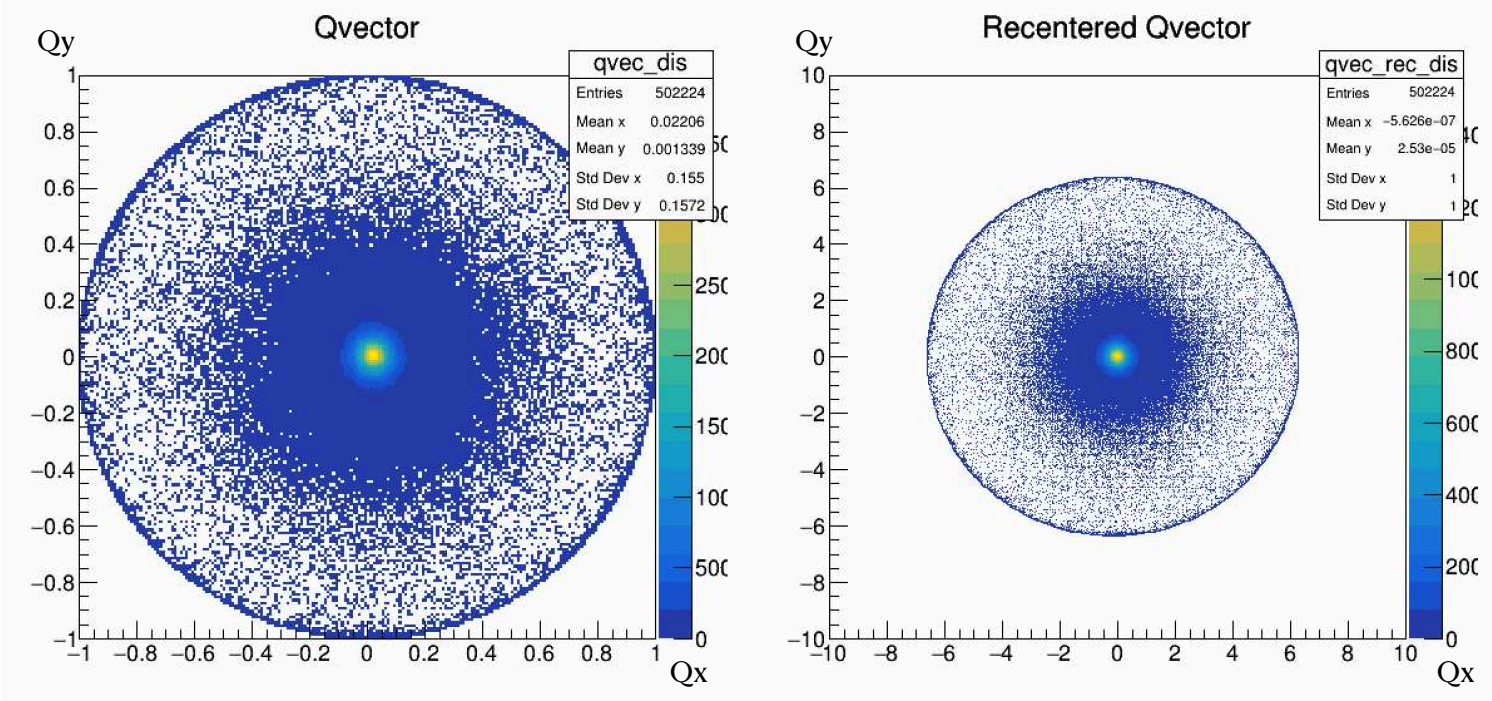
- Recentering calibration revises the effect which made by beam doesn't throw center of detector
- Q_x^{rec} and Q_y^{rec} are defined by following equation using observed $Q_{x,y}$ and $\sigma_{x,y}$
- $Q_x^{rec} = \dfrac{Q_x^{obs} - \langle Q_x^{obs} \rangle}{\sigma_x^{obs}},\ Q_y^{rec} = \dfrac{Q_y^{obs} - \langle Q_y^{obs} \rangle}{\sigma_y^{obs}}$
- $\psi_2^{re-cent} = \dfrac{1}{2} \tan^{-1} \dfrac{Q_x^{rec}}{Q_y^{rec}}$

Flattening

- Flattening calibration revises $\Delta\psi$, the distortion in ψ_{rec} distribution, by fitting with a Fourier expansion. It makes ψ_{rec}distribution flat
- $\psi^{flat} = \psi^{rec} + \Delta\psi$
- $\frac{\Delta\psi}{2} = \sum_{k=1} (A_k \cos 2k\psi^{rec} + B_k \sin 2k\psi^{rec})$
  - $A_k = -\frac{2}{k}\langle \sin 2k\psi^{rec} \rangle$
  - $B_k = \frac{2}{k}\langle \cos 2k\psi^{rec} \rangle$

Run54280 RP Calibration

- Left : Before recentering
- Right : After recentering
- The circle in plot is made by high multiplicity events



- $Q_x^{obs} = \langle \cos(2\phi) \rangle,$
- $Q_y^{obs} = \langle \sin(2\phi) \rangle$

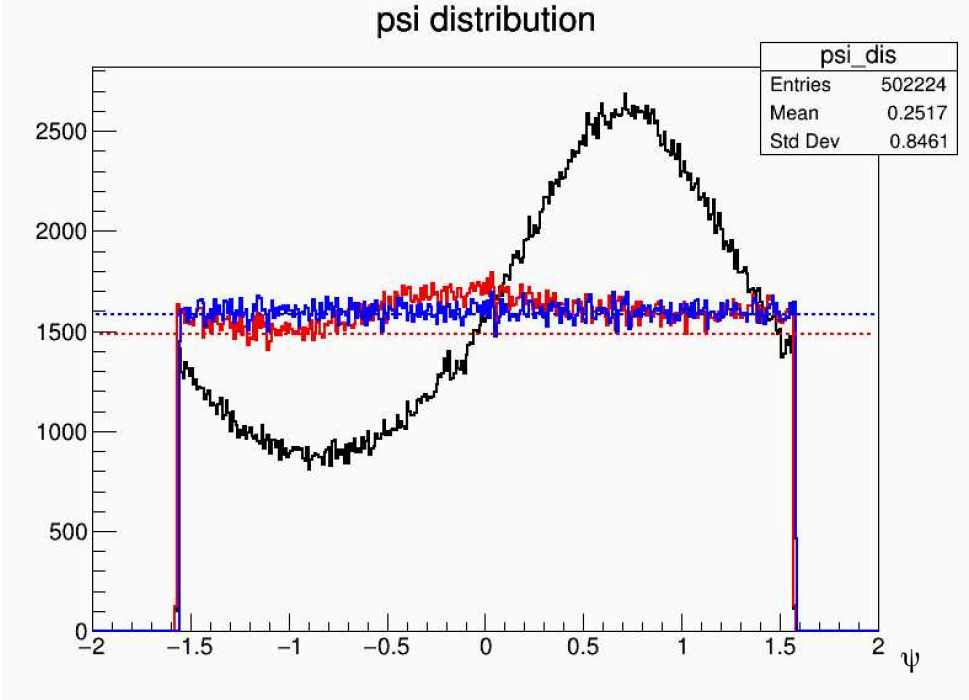
- $Q_x^{rec} = \dfrac{Q_x^{obs} - \langle Q_x^{obs} \rangle}{\sigma_x},$

$$Q_y^{rec} = \frac{Q_y^{obs} - \langle Q_y^{obs} \rangle}{\sigma_y}$$

Run54280 RP Calibration

All INTT

- Black : raw ψ_2
- Red : After recentering ψ_2
- Blue : After flattening ψ_2

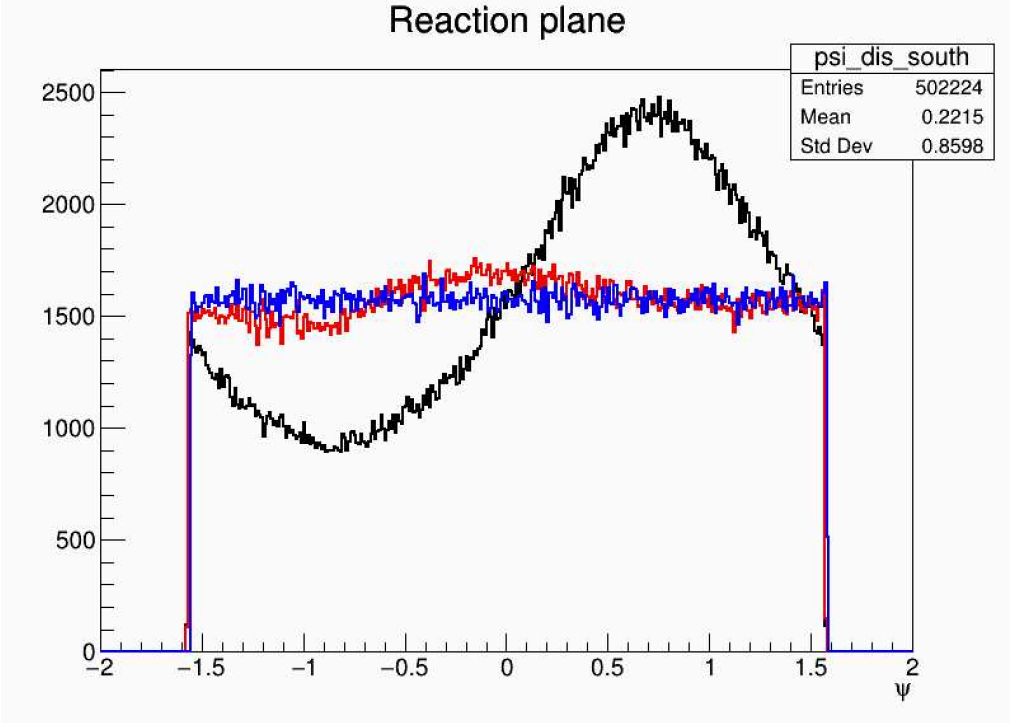


- $\psi^{flat} = \psi^{rec} + \Delta\psi$
- $\frac{\Delta\psi}{2} = \sum_{k=1}^{8} (A_k \cos 2k\psi^{rec} + B_k \sin 2k\psi^{rec})$

Run54280 RP Calibration

INTT south

- Using INTT cluster in south
- Black : raw ψ_2
- Red : After recentering ψ_2
- Blue : After flattening ψ_2



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Run54280 RP Calibration

INTT north

- Using INTT cluster in north
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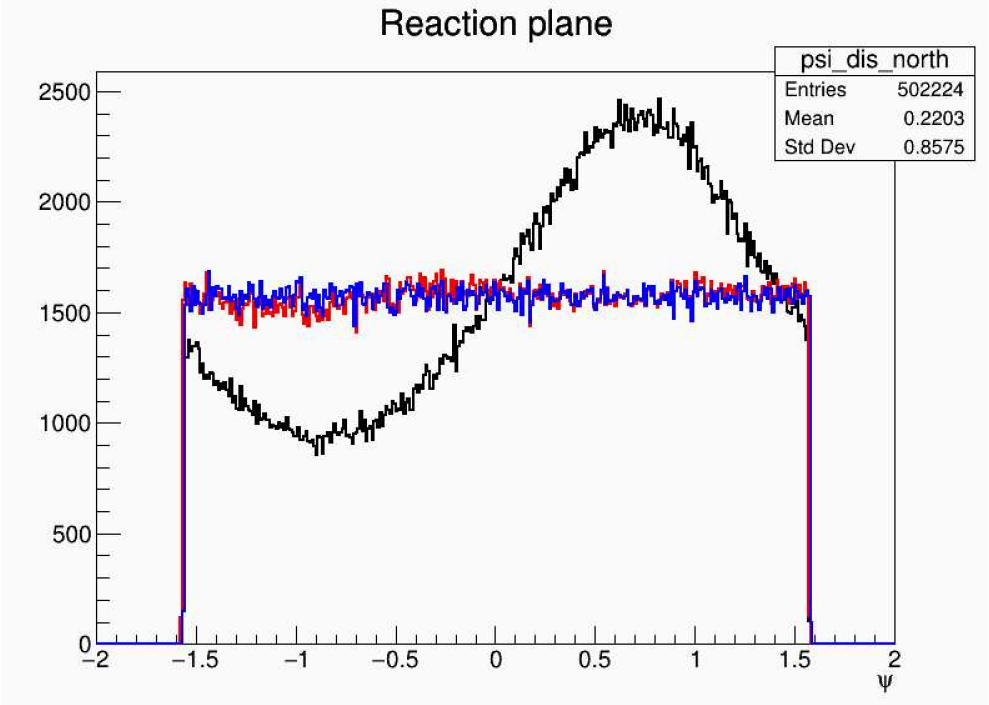
- Red : After recentering ψ_2
- Blue : After flattening ψ_2



- $\psi^{flat} = \psi^{rec} + \Delta\psi$
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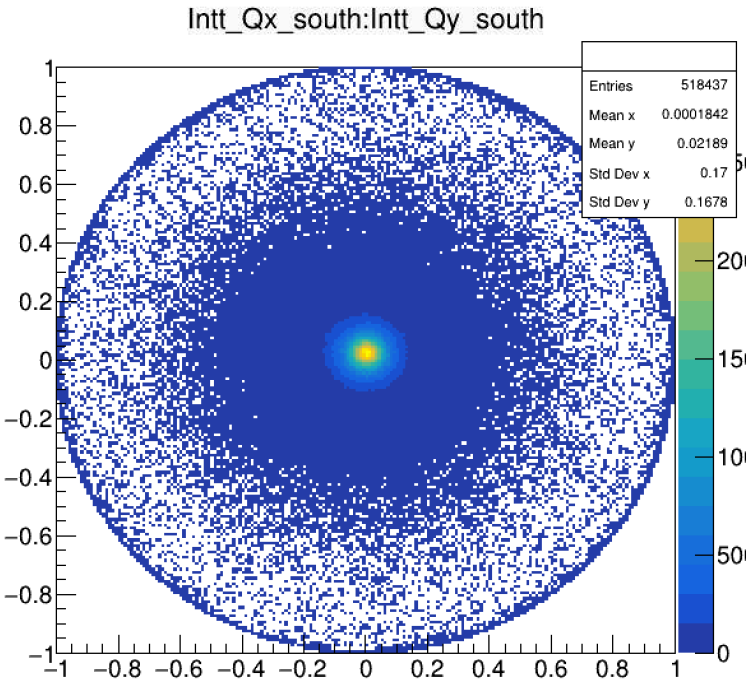
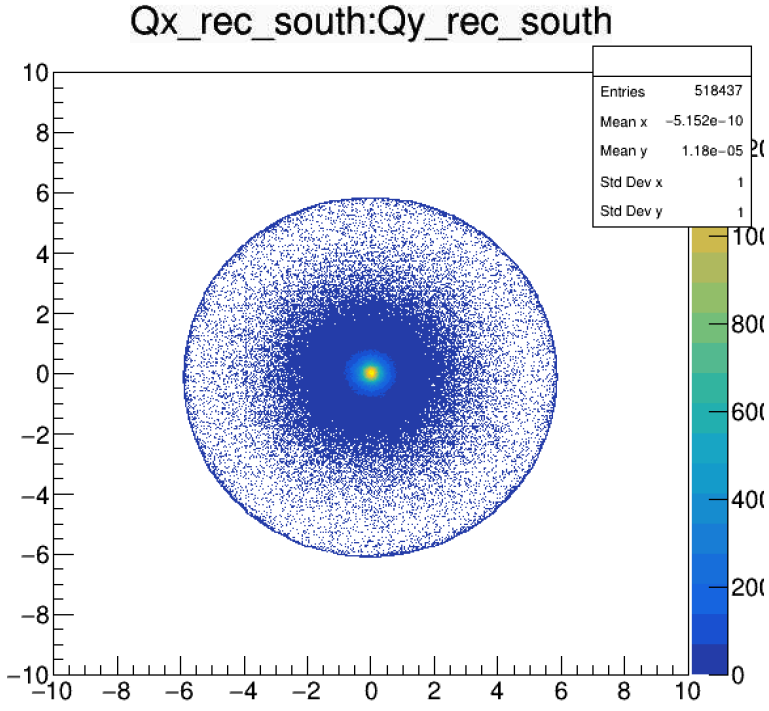
Run54280

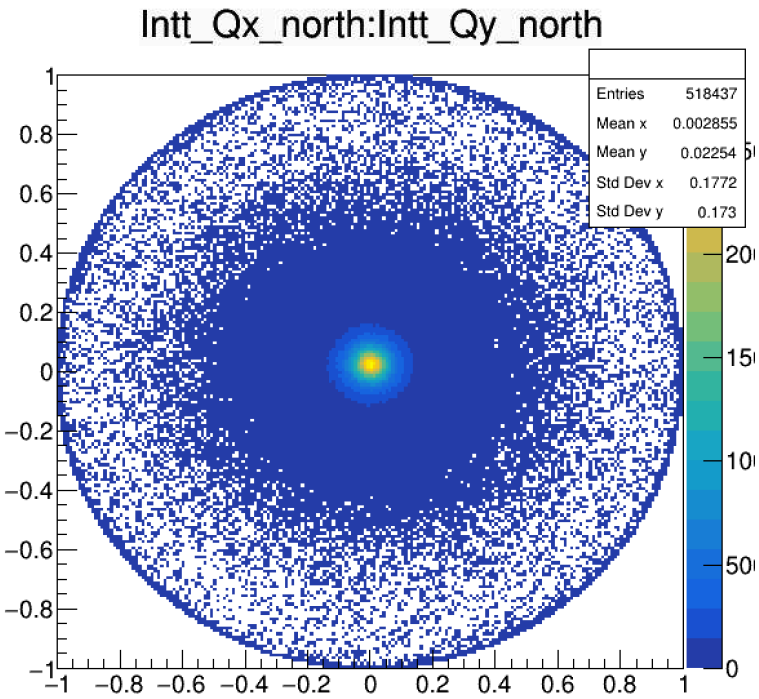
- Q vector in south

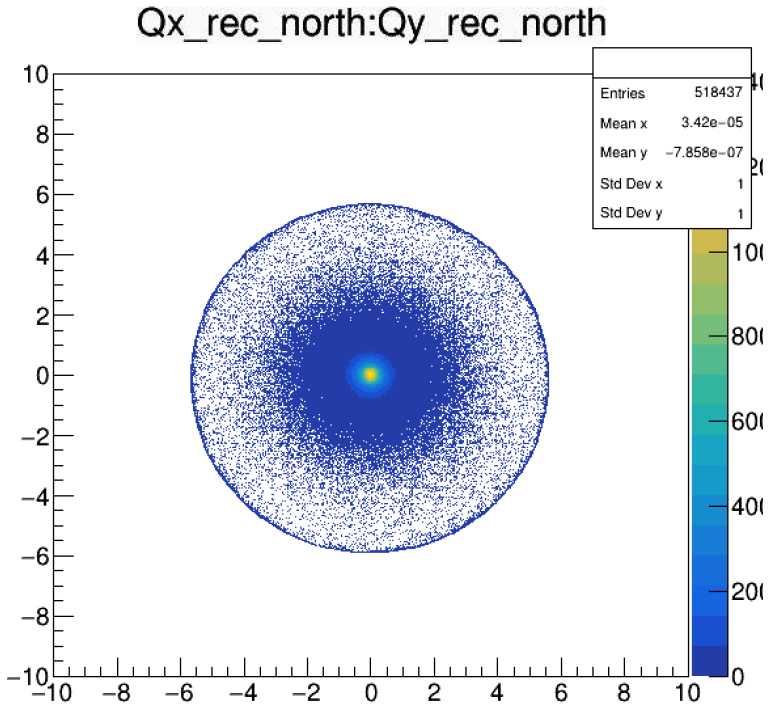




Run54280

- Q vector in north





Run54280

- MBD z vertex was spread to compare with run2023.