Reaction Plane Calibration in Run2024

2023/11/15 INTT Eng MT

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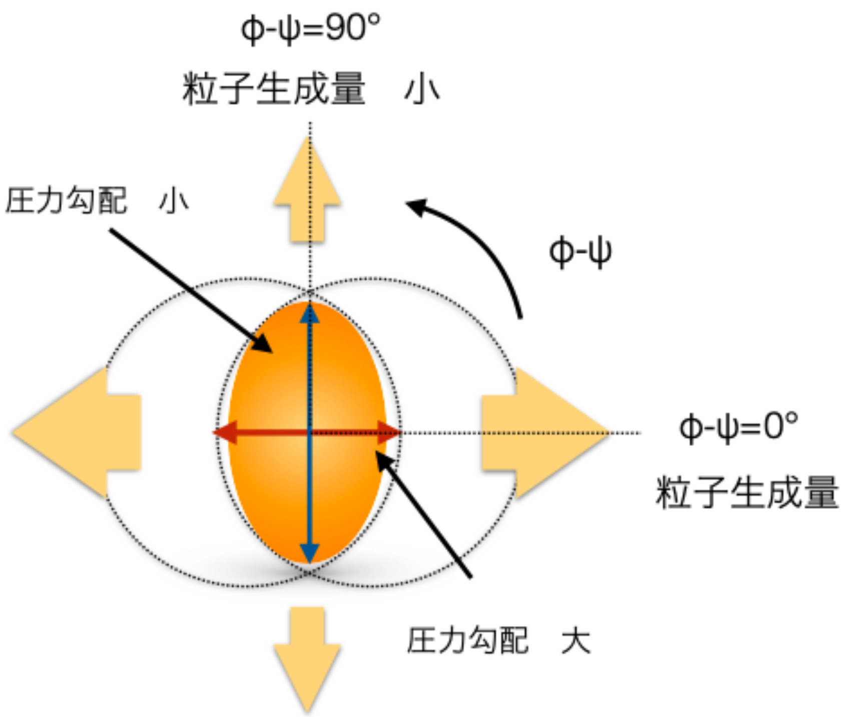
Hydrodynamic behavior of QGP and azimuthal anisotropy of particles (v_2)



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

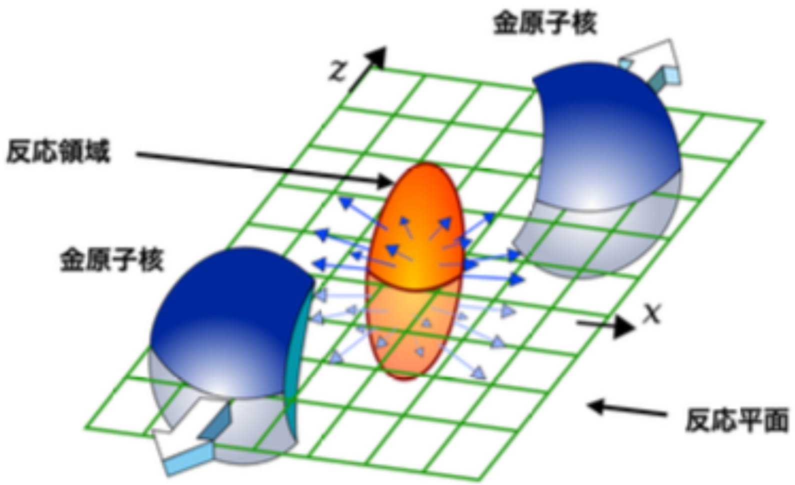
ϕ : Azimuthal angle of the particles produced by the collision

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

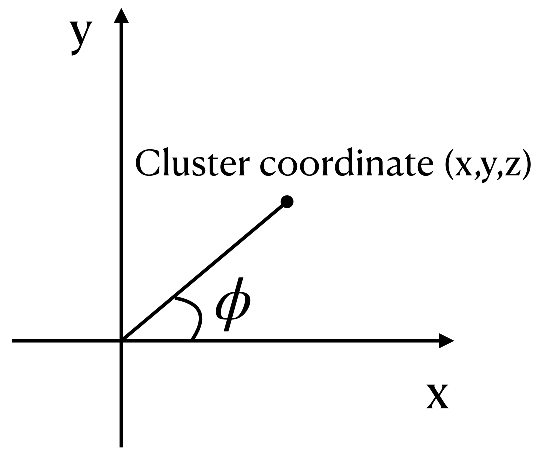
→ Reaction plane angle distribution is distorted due to the effect of detector acceptance, beam doesn't throw center of detector

→ 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, and makes ψ_{rec} distribution flat
- $\psi^{flat} = \psi^{rec} + \Delta\psi$
- $\frac{\Delta\psi}{2} = \sum_{k=1} (A_k \cos 2k\psi^{rec} + B_k \sin 2k\psi^{rec})$
  - $A_k = -\frac{2}{k}\langle \sin 2k\psi^{rec} \rangle$
  - $B_k = \frac{2}{k}\langle \cos 2k\psi^{rec} \rangle$

Run and Cut condition

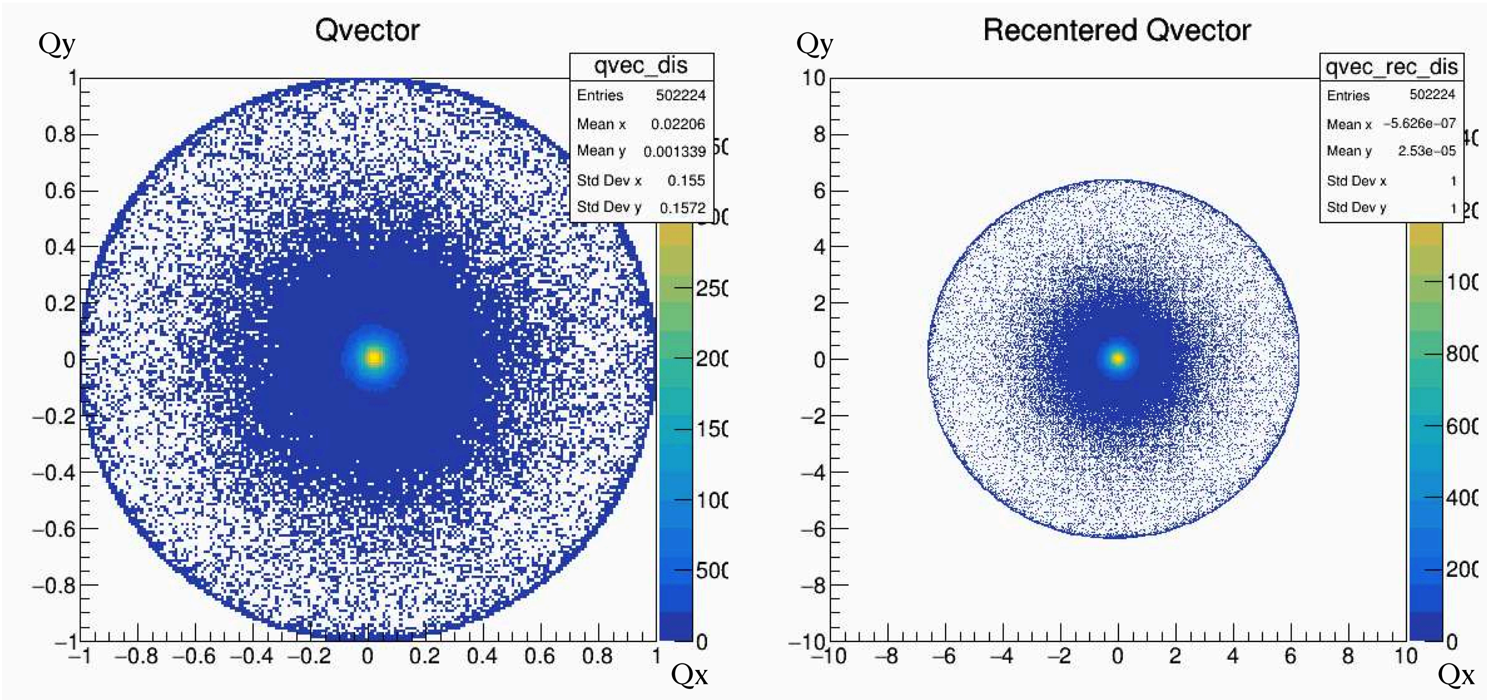
- Run54280
  - Zero field
  - Number of Event : First 1M events (Run54280 has 10M events.)

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

- TTree produced by Cheng-Wei

Run54280 RP Calibration

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



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

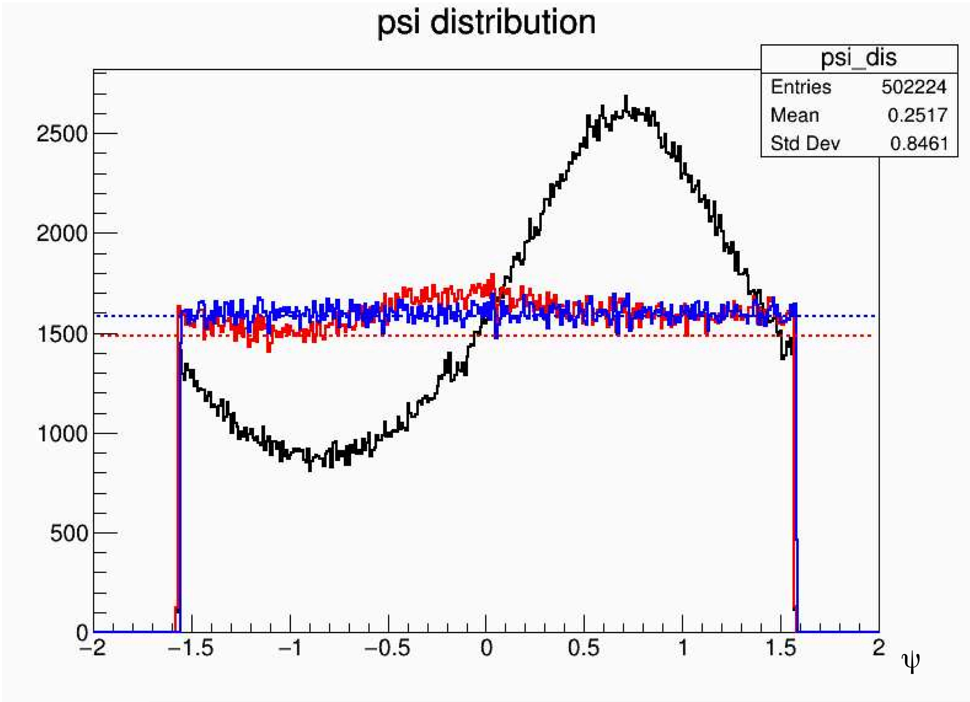
- $Q_x^{rec} = \dfrac{Q_x^{obs} - \langle Q_x^{obs} \rangle}{\sigma_x}$,

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

Run54280 RP Calibration

All INTT

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

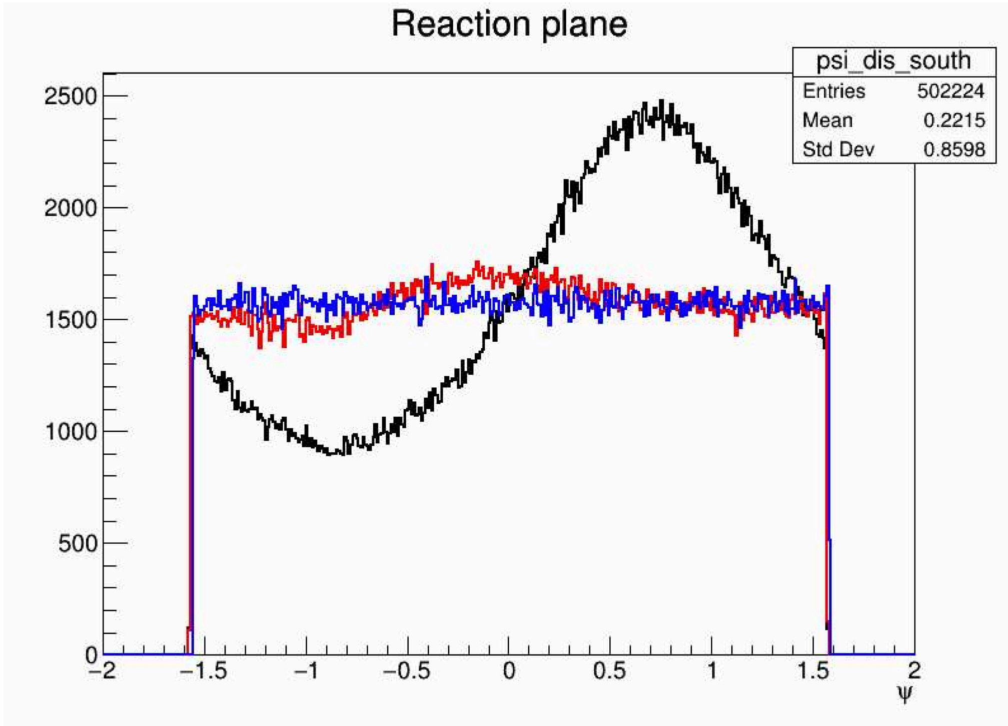


- $\psi^{flat} = \psi^{rec} + \Delta\psi$
- $\dfrac{\Delta\psi}{2} = \sum_{k=1}^{8} (A_k \cos 2k\psi^{rec} + B_k \sin 2k\psi^{rec})$

Run54280 RP Calibration

INTT south

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

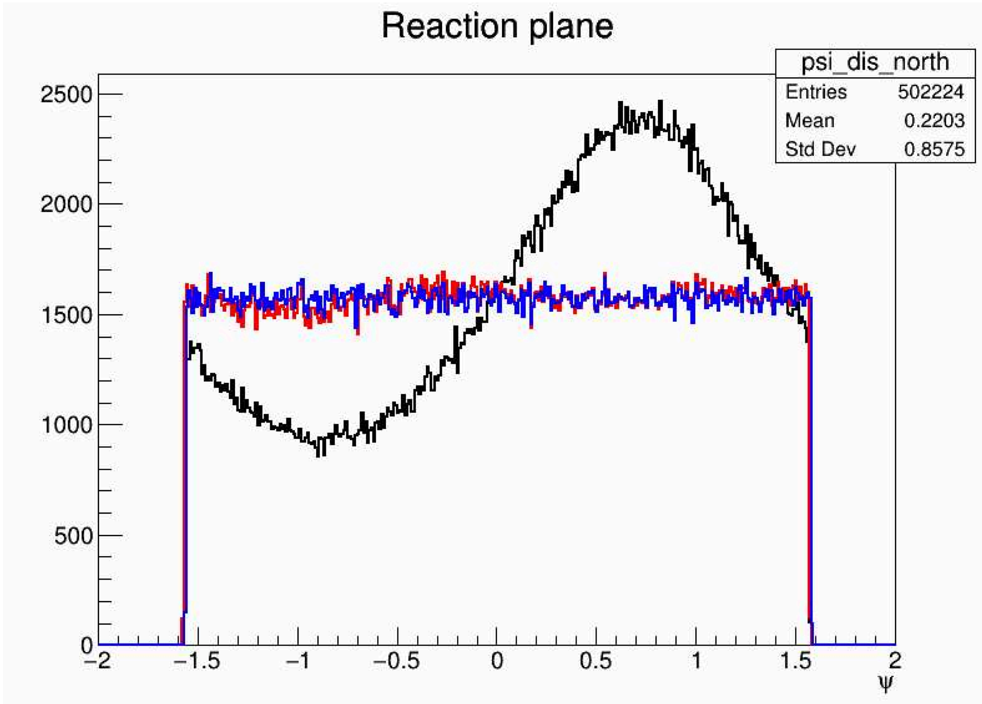


- $\psi^{flat} = \psi^{rec} + \Delta\psi$
- $\frac{\Delta\psi}{2} = \sum_{k=1}^{8} (A_k \cos 2k\psi^{rec} + B_k \sin 2k\psi^{rec})$

Run54280 RP Calibration

INTT north

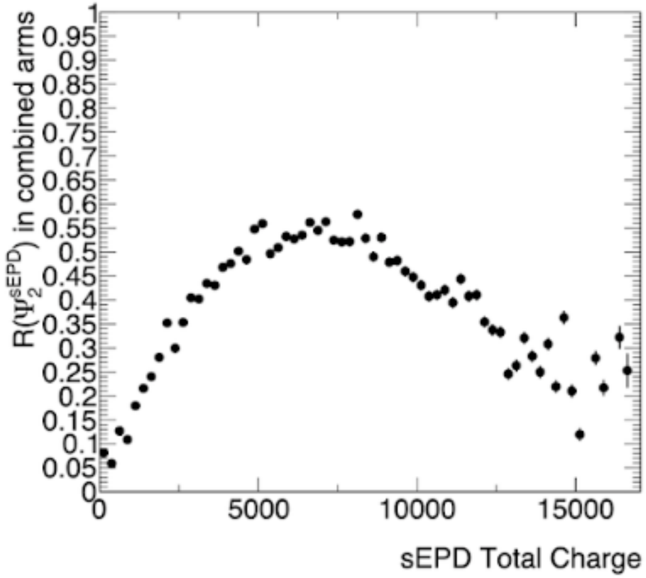
- Using INTT cluster in north
- Black : raw ψ_2
- Red : After recentering ψ_2
- Blue : After flattening ψ_2



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

INTT reaction plane resolution

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



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

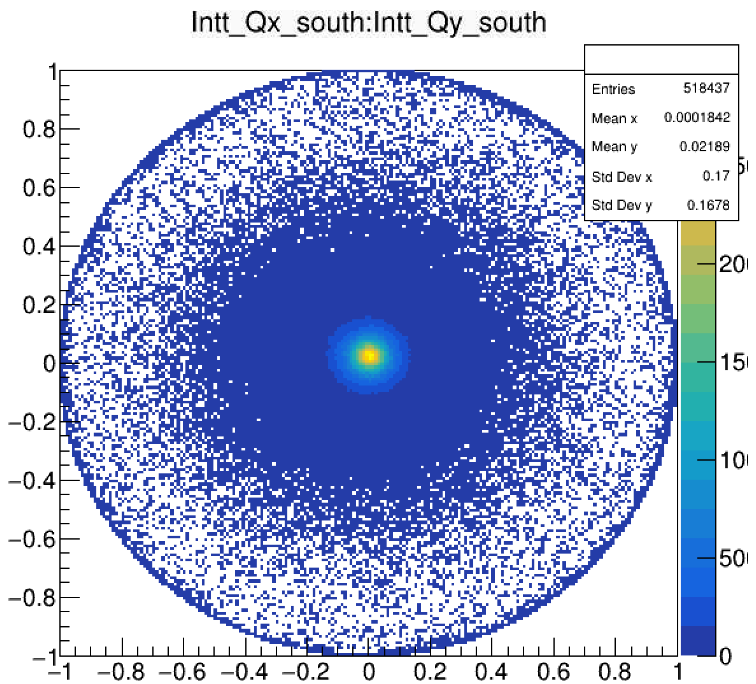
Next to do

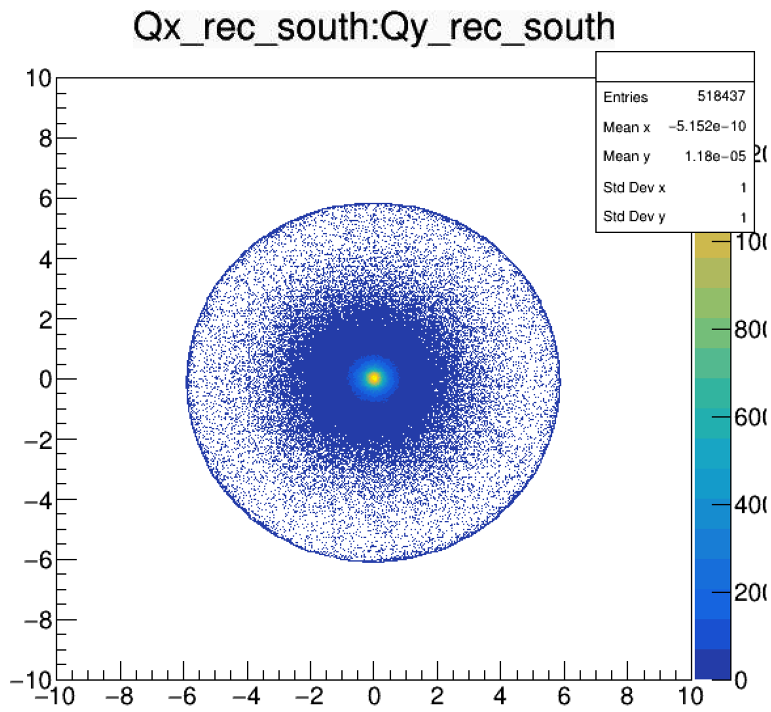
- Calculate v_2 INTT reaction plane with MBD ϕ_{MBD}
- Correlation between INTT multiplicity and v2, INTT multiplicity and INTT reaction plane resolution

Back Up

Run54280

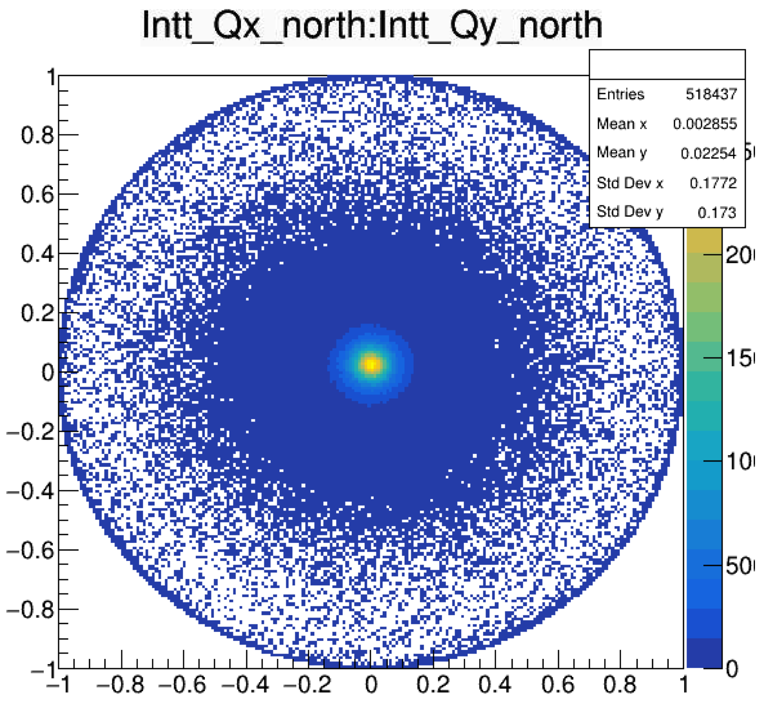
- Q vector in south

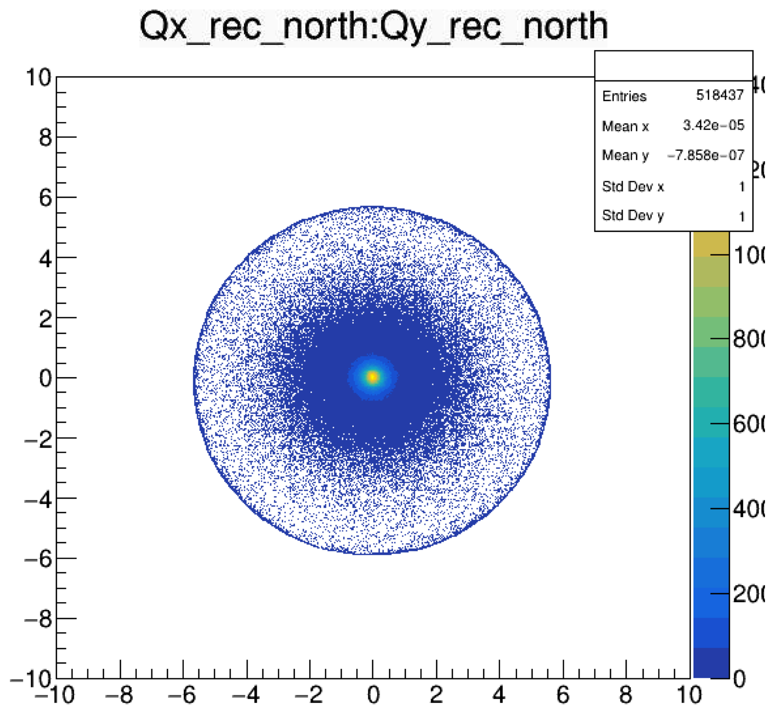




Run54280

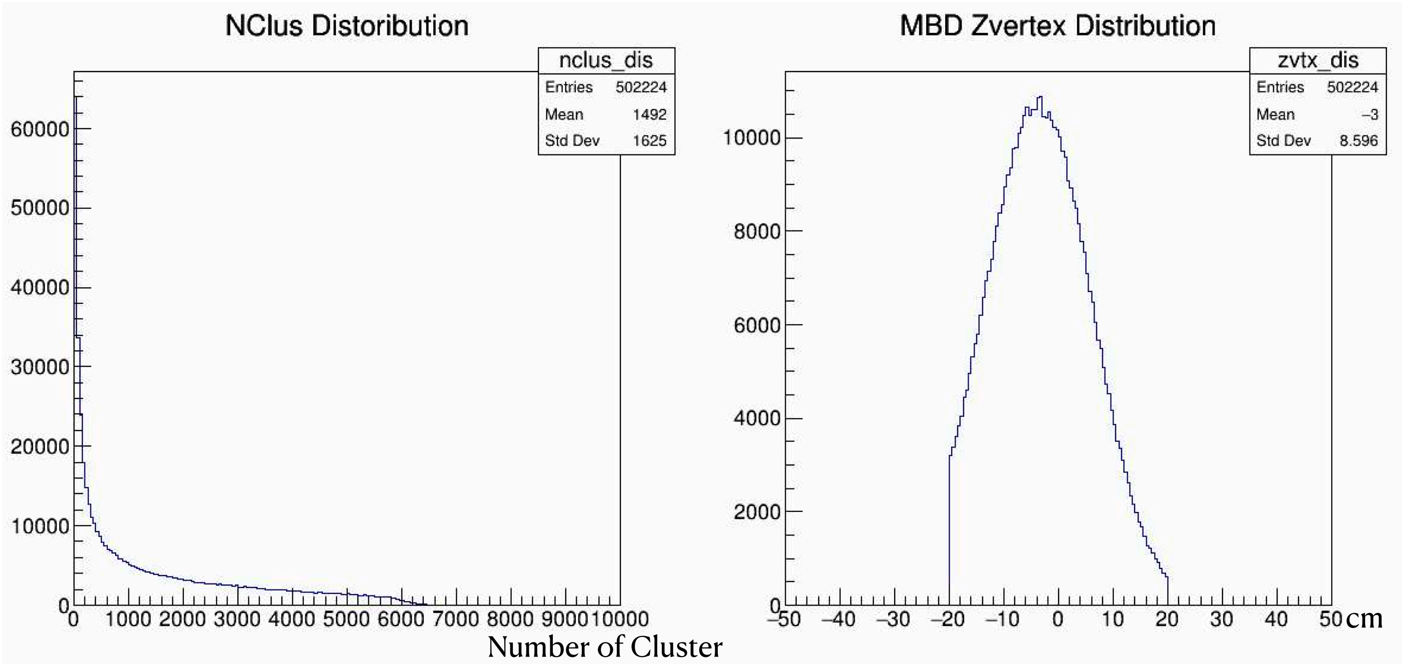
- Q vector in north





Run54280

- MBD z vertex was spread to compare with run2023.



Proof of $\sigma_x^{rec} = 1$

- $(\sigma_x^{rec})^2 = \dfrac{\sum^N Q_x^{rec} - \langle Q_x^{rec} \rangle}{N}$
- $\langle Q_x^{rec} \rangle = 0,\ Q_x^{rec} = \dfrac{Q_x - \langle Q_x \rangle}{\sigma_x}$
- $(\sigma_x^{rec})^2 = \dfrac{1}{N} \sum^N \left(\dfrac{Q_x - \langle Q_x \rangle}{\sigma_x} \right)^2$
- $\sigma_x^2 = \dfrac{1}{N} \sum^N (Q_x - \langle Q_x \rangle)^2$
- $\therefore \sigma_x^{rec} = 1$