Measurement of the v_2 in Au+Au collisions at $\sqrt{s_{NN}} = 200 GeV$

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Nara Women's University

Itsuka Omae

Azimuthal anisotropy of charged particles

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

$$v_2 = \langle cos2[\phi - \psi_2] \rangle$$

[INTT]：Event plane angle

[MBD]：Azimuthal angle

- The event plane ψ_2 is determined using the INTT($|\eta| < 1.1$).
- Charged particles with the azimuthal angle ϕ are measured with the MBD($3.51 < |\eta| < 4.61$).
- Measurement of forward v_2
- Autocorrelations are avoided by separating the event-plane and particle measurements in rapidity.

Data set / event selection / Centrality

Data set

- Run 54280 (2024)
- Au+Au
- $\sqrt{s_{NN}} = 200 GeV$
- No magnetic field
- 200k events (to be increase)

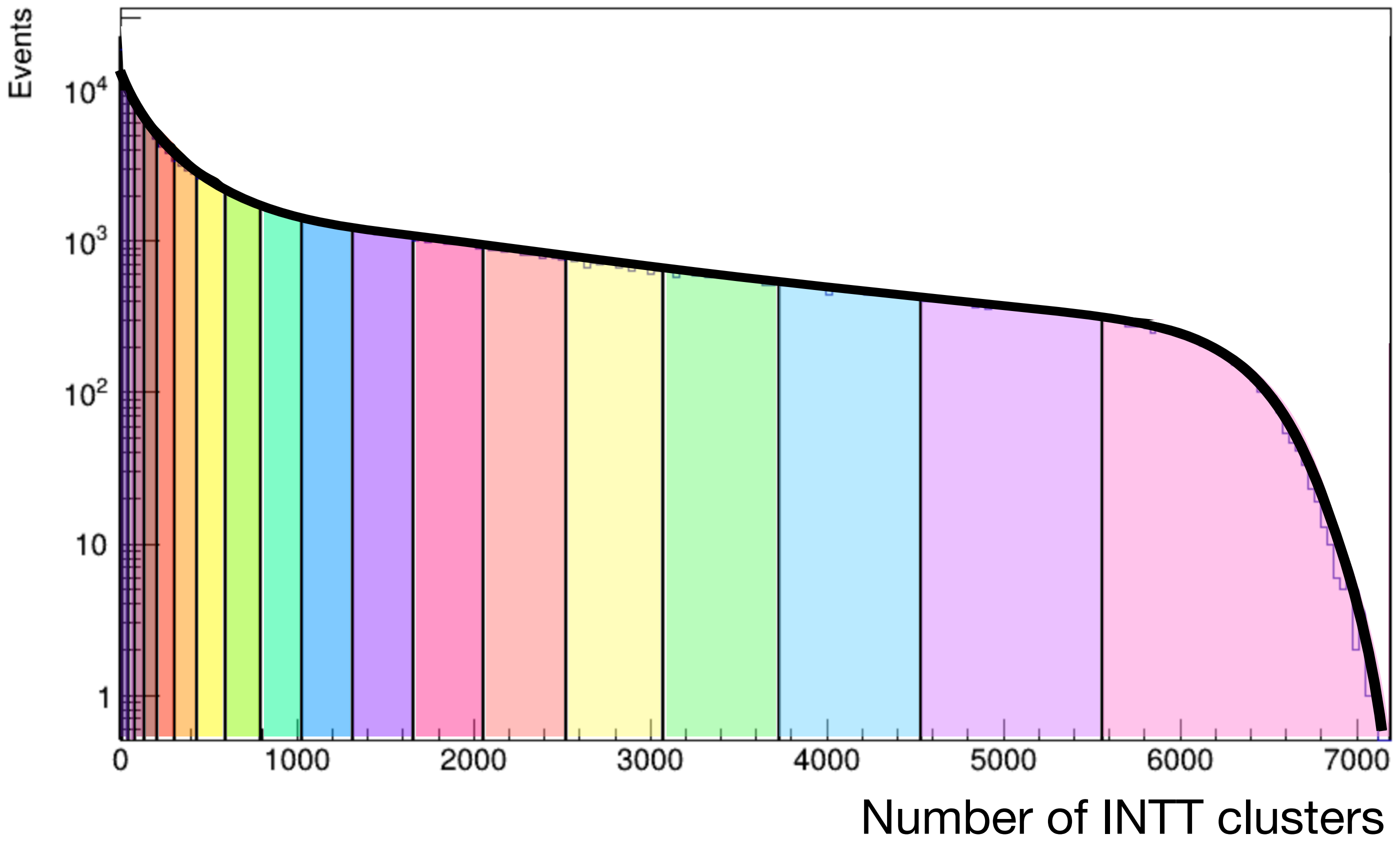
- DST_TRKR_CLUSTER_run2auau_ana464_2024p011_v001-00054280-00000.root
- DST_TRKR_CLUSTER_run2auau_ana464_2024p011_v001-00054280-00001.root

Event / INTT cluster selection

- $|Z_{vtx,MBD}| < 20 cm$
- Hot dead channel removed (INTT)
- INTT cluster ADC > 45

Centrality classification

- Events are divided into centrality classes with 5% intervals (0–5%, 5–10%, …), and v_2 is measured for each class.
- In this analysis, the 0–5% centrality class corresponds to the top 5% of events based on the cluster multiplicity measured by INTT.



Determination of Event plane angle ψ_2

Azimuthal angle of each particle is defined as

$$\phi = tan^{-1}\left(\frac{y}{x}\right)$$

(x, y : INTT cluster coordinates)

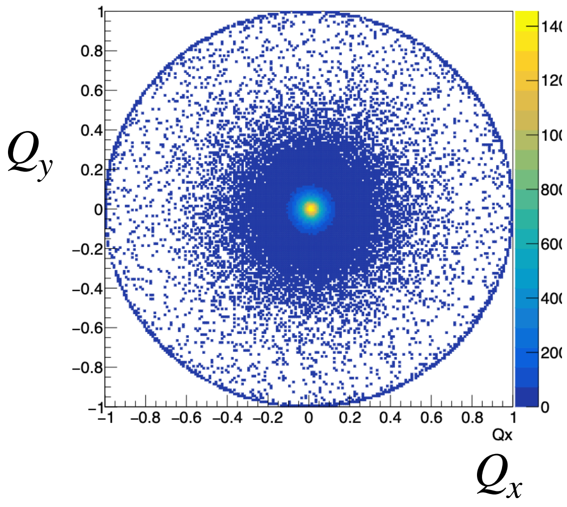
- No magnetic field was applied.
- The ϕ is directly calculated from the x-y coordinates.

Determination of event plane angle ψ_2

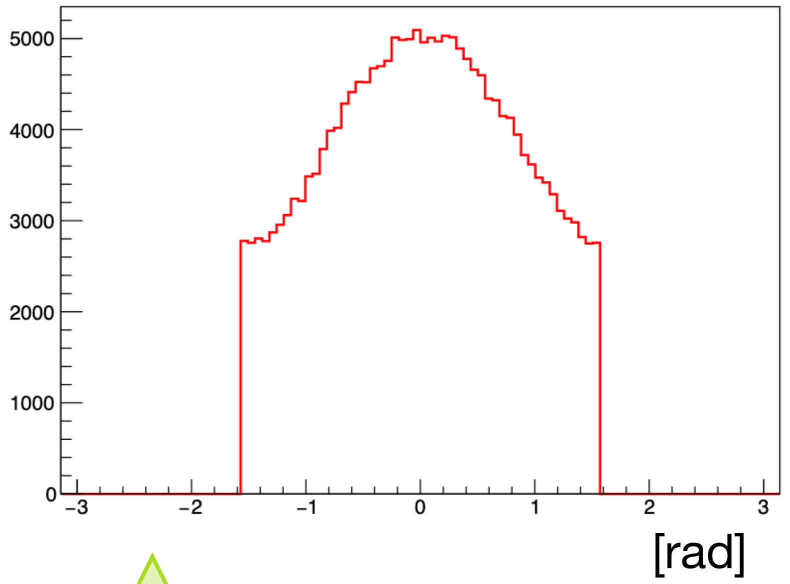
Azimuthal angle of each particle

$$\phi = tan^{-1}\frac{y}{x}$$

$(x, y$: Cluster coordinates)



ψ_2 distribution



For each collision

$$Q_x = \frac{\Sigma_i^N cos(2\phi)}{N}$$: Weighted average of x-coordinate of particles

$$Q_y = \frac{\Sigma_i^N sin(2\phi_i)}{N}$$: Weighted average of y-coordinate of particles

$$\psi_2 = \frac{1}{2}tan^{-1}\frac{Q_y}{Q_x}$$

N : Number of clusters

The ψ_2 distribution is not flat and needs calibration.

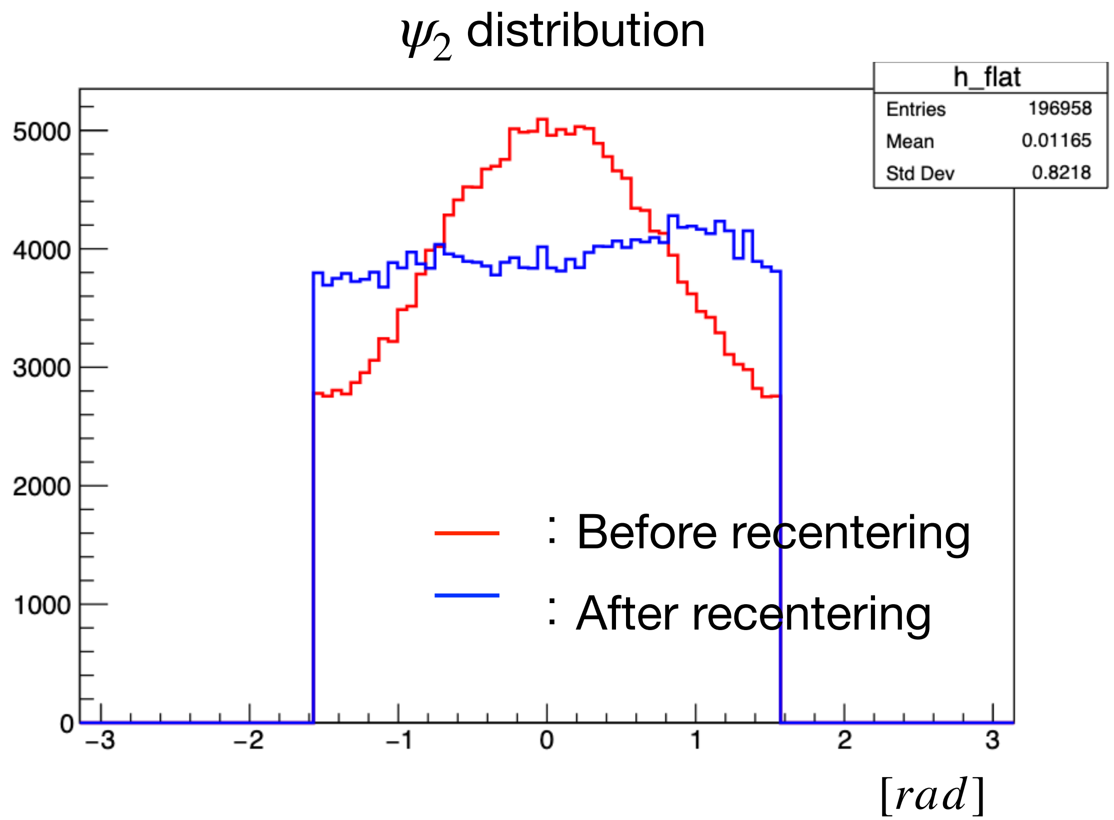
Event plane calibration1 : recentering

The distribution is corrected using the recentering method.

$$Q_x^{rec} = \frac{Q_x - \langle Q_x \rangle}{\sigma_x}$$

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

- σ_x, σ_y : dispersion of Q_x and Q_y distributions
- $\langle Q_x \rangle$ and $\langle Q_y \rangle$: Average of Q_x, Q_y
- $\rightarrow \langle Q_x^{rec} \rangle, \langle Q_y^{rec} \rangle = 0, \sigma_x^{rec}, \sigma_y^{rec} = 1$



- The distribution becomes flatter after recentering, though the small residual distortion remains.

Event plane calibration2 : flattening

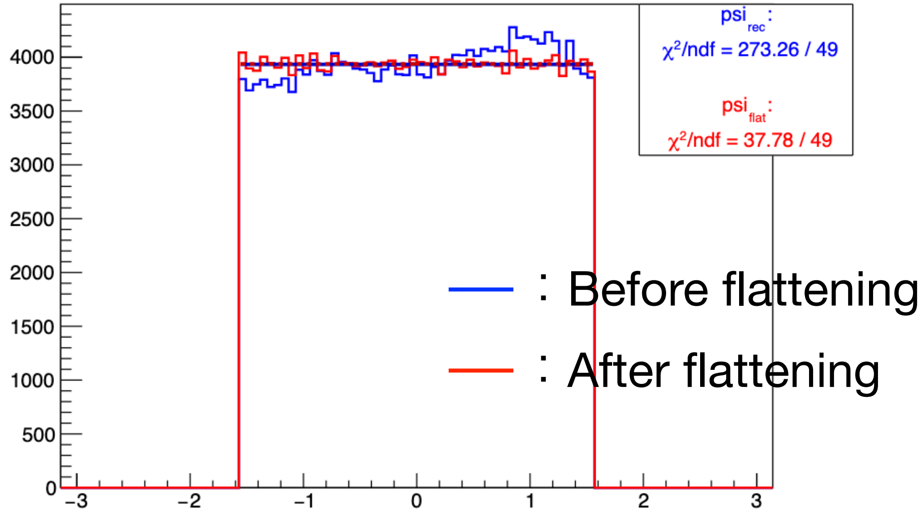
- Residual distribution after recentering are corrected using a Fourier-series-based flattening method.

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

$$2\Delta\psi = \sum_{k=1}^{N} (A_k cos2k\psi^{rec} + B_k sin2k\psi^{rec})$$

$$A_k = -\frac{2}{k}\langle sin2k\psi^{rec}\rangle$$

$$B_k = \frac{2}{k}\langle cos2k\psi^{rec}\rangle$$



ψ^{rec} : ψ after recentering

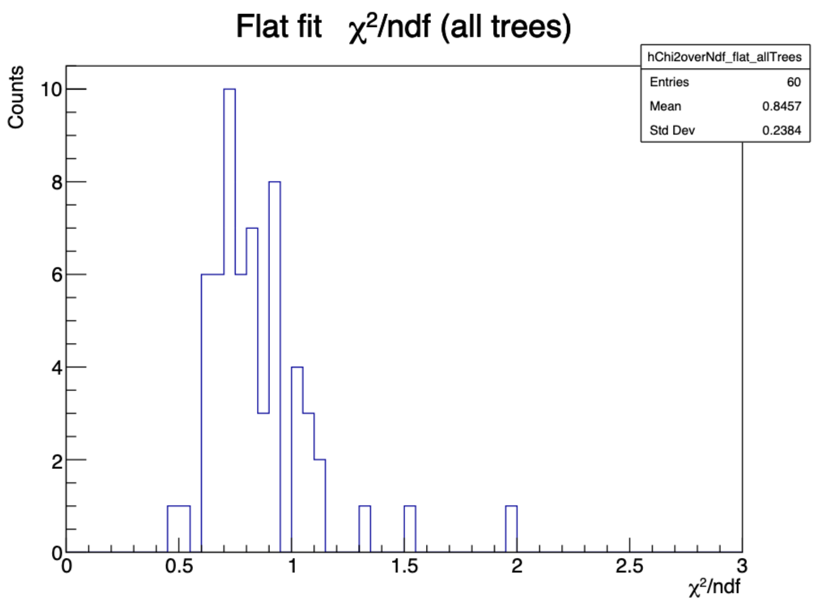
ψ^{flat} : ψ after flattening

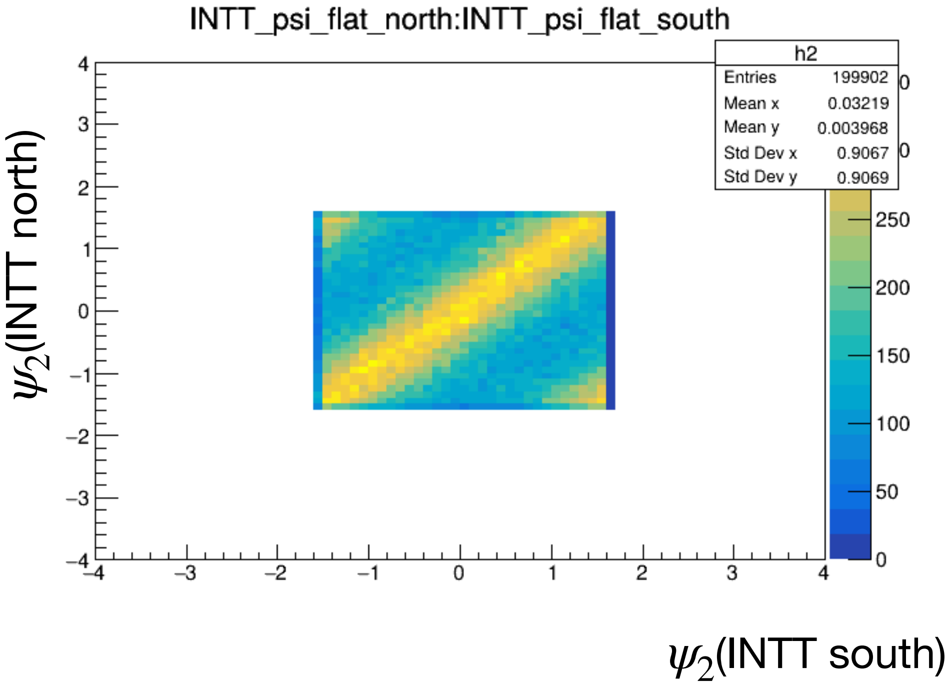
$\Delta\psi$: Residual distribution in the event plane angle

N : Flattening parameter = 8

A constant fit shows that the χ^2 after flattening is smaller than that before flattening.
The calibration bring the distribution closer to uniform, enabling its use for the v_2 measurement.

Constant fit and χ^2/NDF evaluation



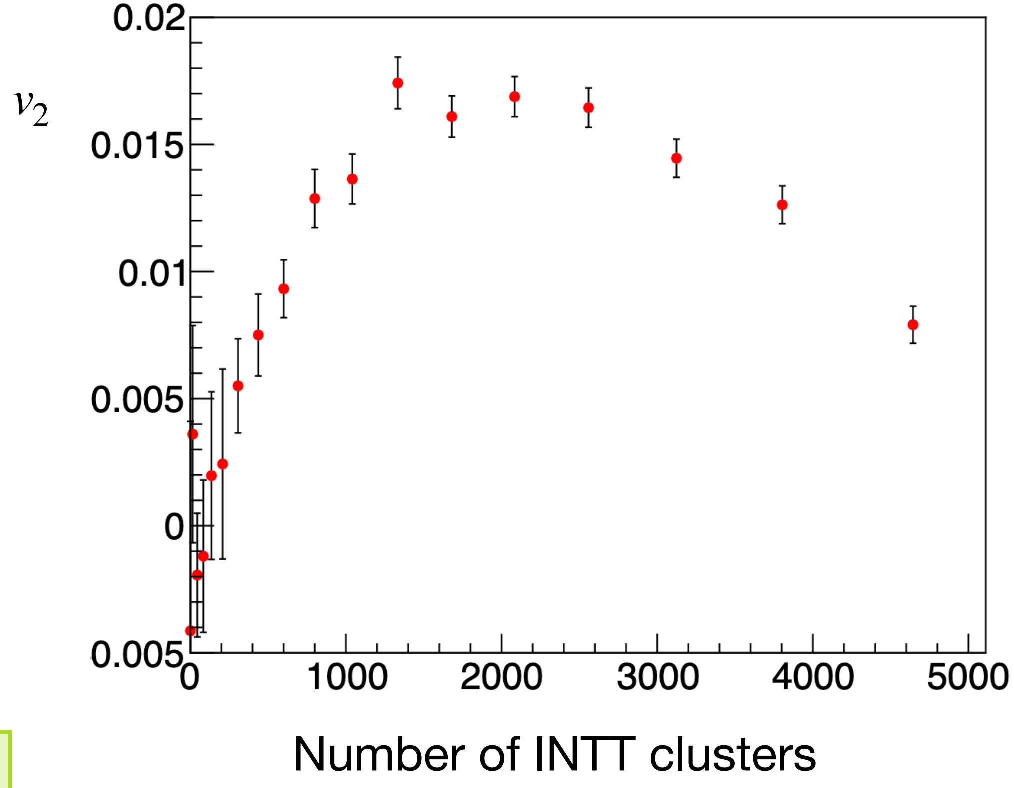


- For all centrality classes, the χ^2/NDF from a constant fit to the event plane angle distribution is close to unity after calibration.
- A positive correlation is observed between the ψ_2 determined by the INTT south and north sides.
- → The v_2 measurement is feasible for all centrality classes.

Raw v_2

$$v_2 = \frac{\sum_{i=0}^{127} q_i cos(2[\phi_i - \psi_2])}{\sum_{i=0}^{127} q_i}$$

- q_i : The number of particles detected by a single PMT
- ϕ : Azimuthal angle of the PMT
- ψ_2 : Event plane angle
- v_2 : elliptic flow coefficient



The v_2 value reaches to the maximum in the 30-35% centrality class.

Event plane resolution correction

- The measured v_2 is affected by the finite resolution of the event plane determination.
- To account for this effect, v_2 is corrected using the event plane resolution factor C_{reso}.
- The INTT event plane resolution is evaluated using three detectors: INTT, MBD south and north.

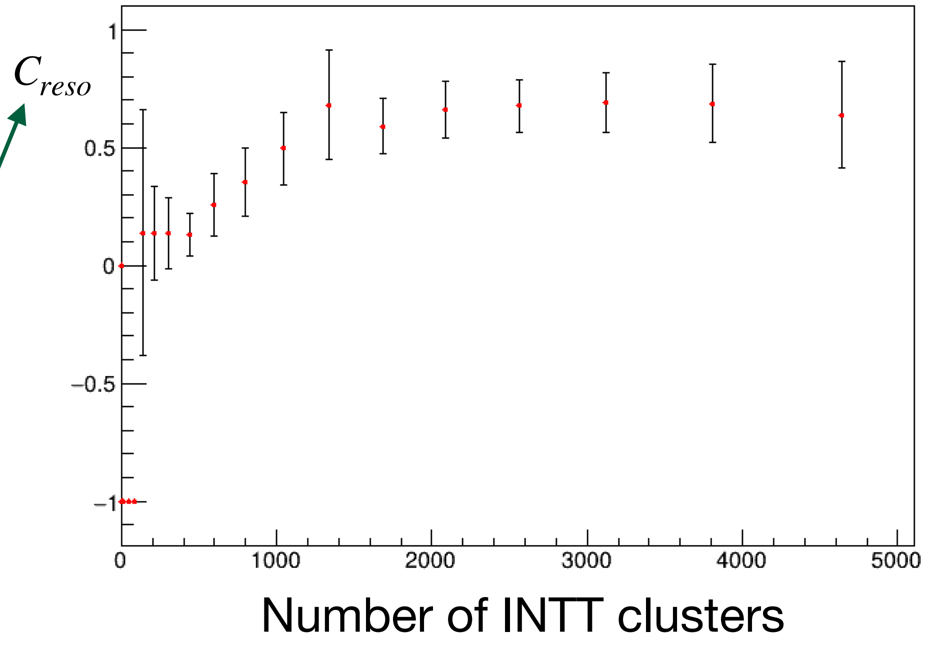
$$C_{reso} = \sigma_{\mathrm{INTT}} = \sqrt{\frac{\left\langle cos\left\{2\left(\psi_{\mathrm{INTT}} - \psi_{\mathrm{MBDS}}\right)\right\}\right\rangle \left\langle cos\left\{2\left(\psi_{\mathrm{INTT}} - \psi_{\mathrm{MBDN}}\right)\right\}\right\rangle}{\left\langle cos\left\{2\left(\psi_{\mathrm{MBDS}} - \psi_{\mathrm{MBDN}}\right)\right\}\right\rangle}}$$

ψ_{INTT} : Event plane angle determined using INTT

ψ_{MBDS} : Event plane angle determined using MBD south

ψ_{MBDN} : Event plane angle determined using MBD north

Event plane resolution of INTT



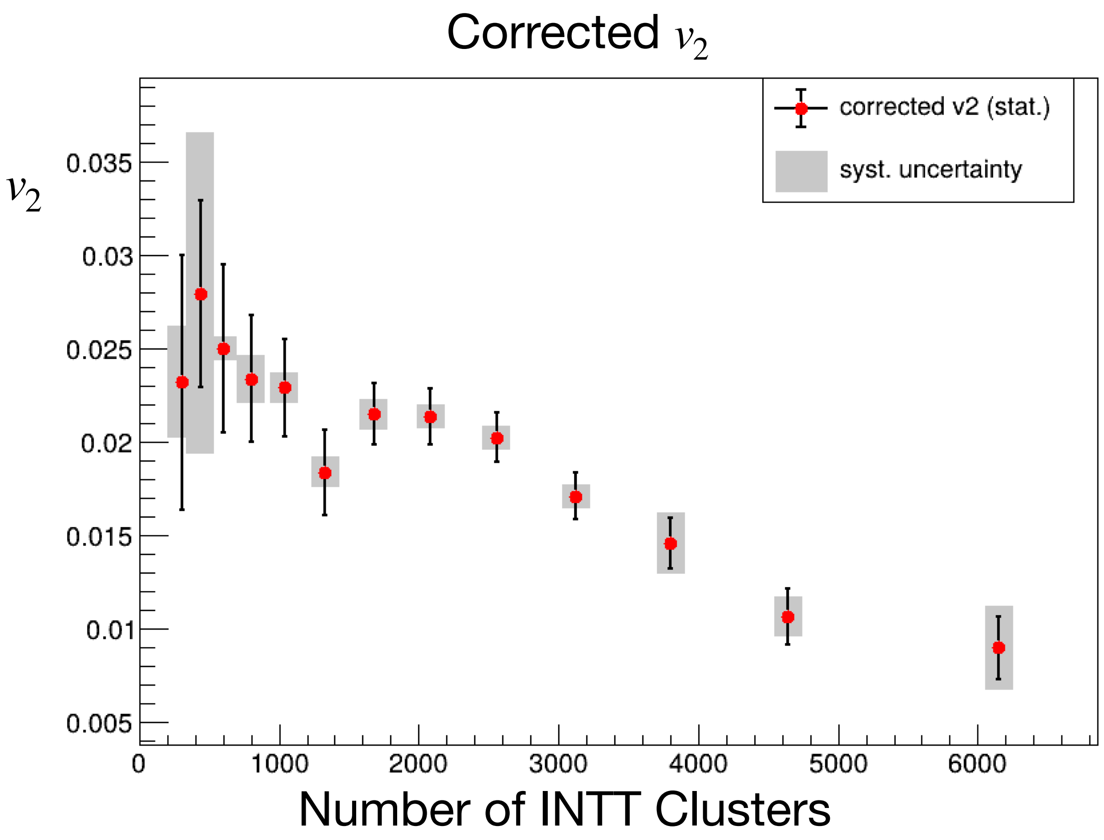
The event plane resolution increases with cluster multiplicity and saturates around 30–35% centrality.

Corrected v_2

$$v_2 = \frac{v_2^{measured}}{C_{reso}}$$

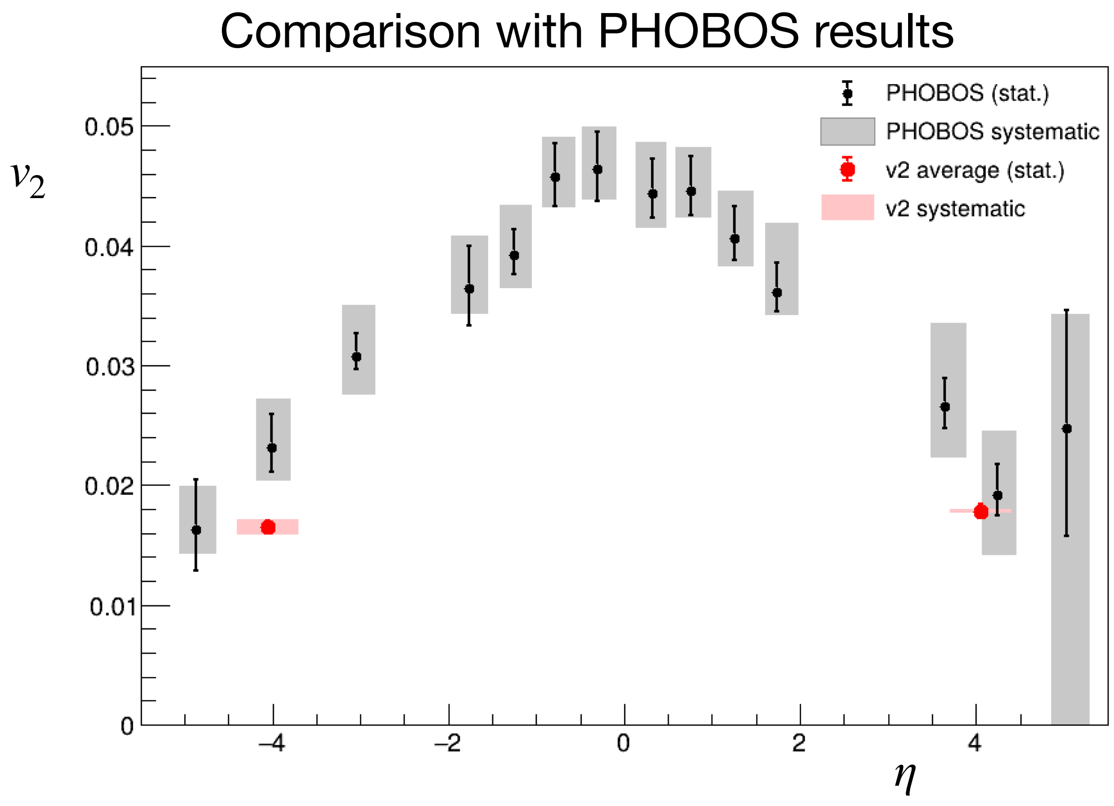
$v_2^{measured}$: Raw v_2

- v_2 deceases as collisions become more central.
- The systematic uncertainty is estimated by taking the v_2 value calculated using both MBD south and MBD north as the reference.
- The v_2 values obtained using MBD south only and MBD north only are compared to this reference, and the larger deviation is assigned as the systematic uncertainty.



Comparison with PHOBOS results

- Weighted-average v_2 from sPHENIX for each centrality class
- $\eta > 0$: MBD north , $\eta < 0$: MBD south
- The systematic uncertainty is evaluated from the deviation of v_2 when the event plane is determined using INTT north only or south only.



Results:

- One side agrees with PHOBOS
- The other side shows a discrepancy, possibly related to background or low- p_T effects (under investigation).

$$\langle v_2^{north} \rangle \approx 0.0178 \pm 0.0006$$
$$\langle v_2^{south} \rangle \approx 0.0165 \pm 0.0005$$

(Centrality range：0–70%)

Summary

- We performed the v_2 measurements in the forward and backward region using Au+Au data taken in 2024 under zero magnetic field condition.
- The event plane was determined with the INTT, and after applying calibration procedures, the event-plane distribution became flat.
- For each centrality class, the measured v_2 was corrected using the INTT reaction plane resolution. The v_2 value decreased toward more central collisions.
- A comparison with the PHOBOS results showed agreement within uncertainties in one side, while a discrepancy was observed on the other side.

Next to do

- Further investigations on the systematic uncertainties.
- Plan to use sPHENIX official centrality.
- Next: measure mid-rapidity v_2 and compare with Ejiro's measurement.
- I would like to show these results at the JPS meeting (March 23, 2026).