# Reaction plane determination INTT at sPHENIX

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The sPHENIX Experiment started operation in May 2023 at the Relativistic Heavy Ion Collider (RHIC) in Brookheaven National Laboratory. One of the main purposes of the sPHENIX is to study the quark gluon plasma (QGP). QGP is a high-temperature state where quarks and gluons are no longer confined inside hadrons. Au + Au collisions at a nucleon-nucleon center-of-mass energy $\sqrt{s_{\rm NN}} = 200$ GeV were collected for Run 2023 and 2024.

When the QGP is produced in non-central nucleus-nucleus collision, elliptic anisotropy ($v_2$) is observed because the number of particles that are produced by the collision varies depending on the azimuthal angle to the pressure gradient. Figure 1 (left) is the concept of elliptic flow. It shows that particle production is maximal along the event plane direction ($\phi-\psi_2 = 0°$) and minimal in the direction perpendicular to it ($\phi - \psi_2 = 90°$). $v_2$ is calculated by $v_2 = \langle\cos(2(\phi-\psi))\rangle$ where $\psi$ is the reaction plane (RP) angle and $\phi$ is the azimuthal angle of the particle.

The Intermediate Tracker (INTT) is one of the tracking detectors in the sPHENIX experiment. The INTT that covers a pseudorapidity range of $|\eta| < 1.1$ and the full azimuth consists of two barrel-shaped layers located in the radius of 7 to 10 cm from the beam axis. sPHENIX Event Plane Detector (sEPD) covers $2.0 < |\eta| < 4.9$ is a detector to determine event plane.

To measure $v_2$ at forward rapidity, the RP should be determined at a different rapidity by the INTT. If the $v_2$ and RP are measured at the same rapidity, $v_2$ signal is swept out by a significant auto-correlation between the $v_2$ and RP. Observed RP angle $\psi_2^{obs}$ is determined by

$$\psi_2^{obs} = \frac{1}{2}\tan^{-1}\frac{\sum_i \sin(2\phi_i)}{\sum_i \cos(2\phi_i)}, \qquad (1)$$

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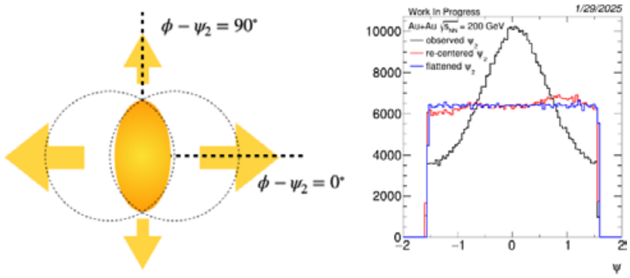


Fig. 1. Left: Elliptic flow illustration showing azimuthal anisotropy relative to the event plane ($\psi_2$), with maximum particle yield at $\phi - \psi_2 = 0°$ and minimum at $90°$. Right: Observed (black), re-centered (red), and flattened (blue) reaction plane distributions.

where the i represents each cluster of the INTT and $\phi_i$ is the azimuthal angle of the i-th cluster.

Black line in Fig. 1 (right) shows the observed $\psi_2^{obs}$ distribution, determined using the 200 GeV Au + Au data without the magnetic field. The $\psi$ distribution should be flat because the RP is randomly oriented. There is a strong oscillation that supposes to be caused by the effects of detector acceptance and the beam offset from the center of the INTT barrels. These detector effects need to be corrected for further analysis. The red line in the Fig. 1 (right) shows re-centered $\psi$ distribution ($\psi_2^{rec}$) in which the beam effect has been corrected.[1)] $\psi_2^{rec}$ is calculated by subtracting the mean of the $\psi_2^{obs}$ distribution from $\psi_2^{obs}$ for each event and dividing it by the standard deviation of the distribution. $\psi_2^{rec}$ still has a non-flat distortion effect which is caused by the detector acceptance. To correct the distortion effect, the flattered $\psi_2^{flat}$ is determined by

$$\begin{aligned}\psi_2^{flat} &= \psi_2^{rec} + \Delta\psi \\ \Delta\psi &= \sum_{k=1}^{8}(A_k\cos 2k\psi_2^{rec} + B_k \sin 2k\psi_2^{rec}) \qquad (2)\\ A_k &= -\frac{2}{k}\langle\sin 2k\psi_2^{rec}\rangle,\ B_k = \frac{2}{k}\langle\cos 2k\psi_2^{rec}\rangle\end{aligned}$$

where k represents the harmonic order in the Fourier series expansion, which in this analysis sums up to the 8th order in this analysis. The blue line in Fig. 1 (right) shows that the RP has bean successfully calibrated by correcting the distortion effect.

Reference

1) I. Selyuzhenkov, S. Voloshin, Phys. Rev. C **77**, 034904 (2008).

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