# Performance evaluation of electron tracking using INTT and a calorimeter for the sPHENIX experiment

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The sPHENIX experiment, conducted at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory, began in May 2023 and is scheduled to run until the end of 2025. Its main objective is to investigate the properties of the quark-gluon plasma (QGP), which is a state of matter formed at extremely high temperatures or energy densities.

The sPHENIX detector[1)] includes several tracking subsystems: the Monolithic Active Pixel Sensor (MAPS)-based Vertex Detector (MVTX), Intermediate Tracker (INTT), and Time Projection Chamber (TPC). Among them, the TPC serves as the primary tracking device, providing high momentum resolution for charged tracks and enabling particle identification. Precise momentum measurements are particularly required to reconstruct the dielectron decay channel of the $\Upsilon$ and $\rho$ mesons.

Separating different $\Upsilon$ states requires a transverse momentum ($p_\mathrm{T}$) resolution of less than 1%.

The 2024 run is the first physics data-taking run of sPHENIX, and commissioning and operating TPC posed significant challenges. Although the problems were eventually resolved, much data was collected without TPC. Therefore, developing alternative tracking methods that do not rely on TPC is essential.

Previous studies using only INTT or both MVTX and INTT have shown that these tracking methods yield a $p_\mathrm{T}$ resolution of approximately 10% at 1 GeV/$c$, which is insufficient for many physics analyses.

To improve this resolution, we have begun exploring a tracking method that incorporates calorimeter information. The $p_\mathrm{T}$ of charged particles is determined by the curvature of their trajectories in a magnetic field. Thus, an accurate $p_\mathrm{T}$ measurement requires a sufficiently long lever arm between detector layers. The distance between the INTT and electromagnetic calorimeter is about 9 m. This configuration is expected to achieve a $p_\mathrm{T}$ resolution of 1%–2%, which is sufficient for identifying electrons and hadrons.

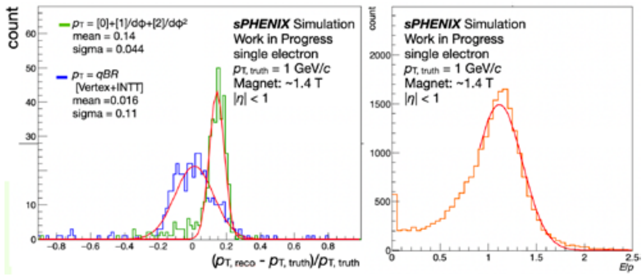

Fig. 1. Results of the $p_\mathrm{T}$ resolution and $E/p$ distribution.

This study aimed to demonstrate that track reconstruction without the TPC can achieve adequate performance for physics measurements.

In this study, the reconstructed transverse momentum $p_\mathrm{T,reco}$ was calculated as

$$p_\mathrm{T,reco} = C_1/\mathrm{d}\phi + C_2/\mathrm{d}\phi^2, \quad (1)$$

where d$\phi$ represents the difference in azimuthal angle between INTT and calorimeter. The coefficients $C_1$ and $C_2$ are arbitrary constants determined using a single-particle gun simulation under realistic experimental conditions.

As the first step, we used a simulation of single electrons with 1 GeV/$c$ momentum to determine $C_1$ and $C_2$. Subsequently, using Eq. (1), we reconstructed $p_\mathrm{T}$ and evaluated the $E/p$ ratio with the new algorithm.

The left-hand plot in Fig. 1 shows the $p_\mathrm{T}$ resolution results. The blue line represents the previous method (vertex + INTT), whereas the green line represents the new method (INTT + calorimeter). These results show that incorporating the calorimeter significantly improves the resolution, from 10% to 4%. However, the target of 1% resolution has not yet been achieved. Because the calorimeter cluster positions have not been calibrated, this suggests that further improvement may be possible with proper calibration. Additionally, the right-hand plot in Fig. 1 shows that the $E/p$ distribution peaks are near 1, supporting its usefulness in distinguishing electrons from hadrons.

Reference

1) Technical Design Report of sPHENIX (2019), `https://indico.bnl.gov/event/7081/`.

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