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Performance of the Intermediate Si tracker at sPHENIX

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Abstract.
sPHENIX is a second-generation RHIC experiment designed to study the quark-gluon plasma and the spin structure of the proton. The Intermediate Silicon Tracker (INTT), a two-layer silicon strip detector, provides precise beam crossing separation and vertex reconstruction using tracklets. In 2024, sPHENIX recorded $\sqrt{s_{NN}} = 200$ GeV collisions, where the INTT operated in triggered mode for Au+Au data and in streaming mode for $p + p$ data. We report the INTT performance, including crossing separation, z-vertex reconstruction, and the first physics result: charged hadron multiplicity in Au+Au collisions, consistent with previous RHIC measurements.

1 Introduction

1.1 Overview of the sPHENIX tracker

The sPHENIX experiment [1] is a newly constructed experiment at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory, designed to investigate the properties of the quark-gluon plasma and to study the spin structure of the proton using polarized beams.

Its tracking system consists of four subsystems. At the innermost radius lies the Monolithic Active Pixel Sensor Vertex Detector (MVTX), which provides high-resolution measurements of the vertex. Surrounding the MVTX is the Intermediate Silicon Tracker (INTT), which enables the separation of individual beam crossings. The main tracking volume is covered by the Time Projection Chamber (TPC), offering precise momentum reconstruction. Finally, the TPC Outer Tracker (TPOT) offers an external space point beyond the TPC, playing a key role in the calibration of space charge distortions that affect the tracking performance.

1.2 Intermediate silicon tracker

The INTT [2] is a key component of the sPHENIX tracking system, situated between the MVTX and the TPC. It consists of two layers of silicon strip sensors arranged in a barrel geometry. Further technical specifications of the INTT are summarized in Table 1.

The primary role of the INTT is to act as a bridge between the MVTX and the TPC, while providing crucial timing information. Its excellent timing resolution enables precise separation of tracks originating from different beam crossings.

In polarized proton-proton collisions at RHIC, where each beam bunch carries a distinct spin orientation, such bunch-by-bunch track separation is crucial for spin-dependent measurements. The INTT uniquely enables this separation, making it indispensable for precision spin physics analyses in sPHENIX.

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Table 1. INTT detector specifications.

Element	Value
Strip pitch (ϕ angle)	78 μm
Strip length (z axis)	16 or 20 mm
Radiation length of one ladder	1.14% $[X/X_0]$
Timing resolution	< 106 ns
Number of ladders	56
Number of channels per ladder	6,656

2 Capability of the crossing separation

Since beam crossing separation is the primary function of the INTT, it is essential to evaluate its performance using collision data. The INTT operated in streaming mode during p+p collisions and in triggered mode during Au+Au data-taking. Figure 1 shows the INTT hit beam

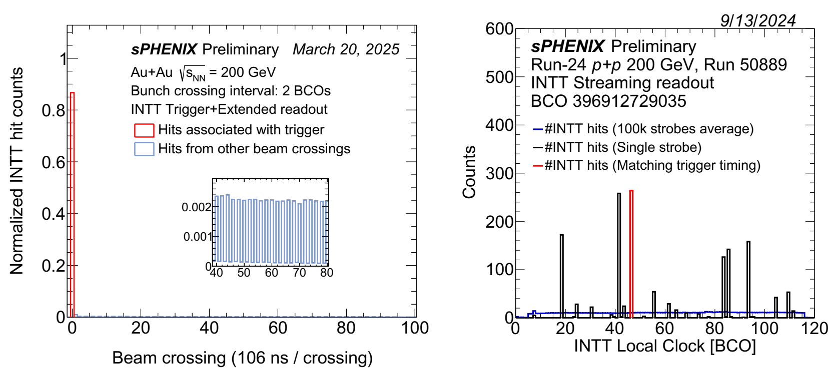

Figure 1. Hit beam crossing distributions measured by the INTT in triggered mode (left, accumulated over many events) and streaming mode (right, for a single strobe). The unit of the BCO on the right panel is 106 ns per crossing, which is the same unit as the left panel.

crossing distributions in both trigger and streaming modes. In triggered mode, beam crossing 0 corresponds to the triggered crossing, whereas all other beam crossings correspond to unbiased samples. Most of the hits are concentrated at the triggered crossing, demonstrating that the INTT hits are well aligned within a single beam crossing. In streaming mode, the INTT records data without a trigger; however, our global timing module can still identify which beam crossing corresponds to the trigger. This capability is essential for matching the streaming tracker with the trigger detectors, even when using unbiased streaming samples. The red peak in the plot corresponds to the triggered crossing, where a clear peak is observed, while unbiased collisions also produce distinct peaks at different beam crossings. These observations indicate that the separation of beam crossings is clearly achieved in both trigger and streaming modes.

3 Z vertex reconstruction

The INTT consists of two barrel layers. Clusters from the inner and outer barrels are combined to form tracklet pairs, from which the z-vertex distribution is reconstructed by accumulating multiple events. Figure 2 shows the z-vertex correlation between the INTT and MBD

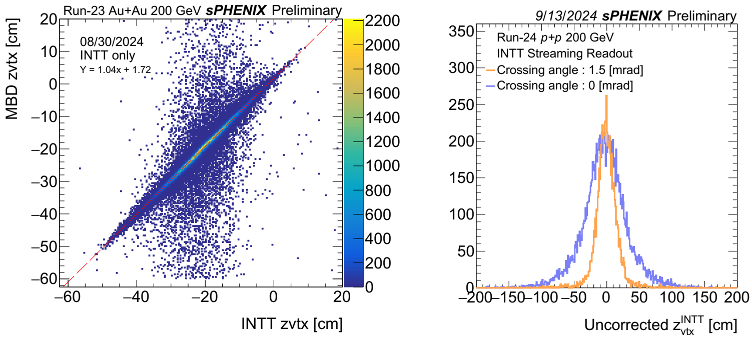

Figure 2. The z-vertex correlation between the INTT and MBD (left), and comparison of the INTT z-vertex at different beam crossing angles (right).

on the left panel and the z-vertex distributions measured by the INTT at different beam crossing angles on the right panel. Although the MBD and the INTT were not fully calibrated at that time, a clear linear correlation is observed between them, indicating that the data quality is reliable and that the detectors are well synchronized. This provides a solid benchmark for advancing the physics analysis. The right plot shows the z-vertex distribution reconstructed by the INTT for different beam crossing angles. The z-vertex range is broader at zero crossing compared to non-zero crossing angles, in excellent agreement with expectations. These results demonstrate that the tracklet-based method for reconstructing the z-vertex is well-tuned and further confirm the reliability of the INTT data.

4 Charged hadron multiplicity measurement

The INTT data have been validated through several quality assurance procedures and beam test [3], enabling the first physics measurements with the detector. One of the initial physics results obtained with the INTT is the charged hadron multiplicity, which provides a measure of entropy production in heavy-ion collisions [4]. The multiplicity is determined by counting tracklets, formed from pairs of clusters with small angular separation in the two INTT layers. The analysis follows the reconstruction methods previously employed by the PHOBOS and CMS collaborations [5, 6]. The left panel of Fig. 3 presents $dN_{\mathrm{ch}}/d\eta$ as a function of η in the range $|\eta| < 1.1$, covering centralities from 0–3% to 45–50% in Au+Au collisions. The vertical extent of each box represents the full combined uncertainty. For comparison, PHOBOS measurements [6] in the same centrality classes are shown as blue open squares, with the shaded area representing the total uncertainty. The right panel of Fig. 3 shows the average $dN_{\mathrm{ch}}/d\eta$ at mid-rapidity, normalized by the number of participant pairs, as a function of the number of participating nucleons. The reconstructed $dN_{\mathrm{ch}}/d\eta$ agrees well with previous RHIC measurements [6–8], marking the transition from detector commissioning to physics data production.

5 Summary

The INTT plays a central role in the tracking system of sPHENIX, providing precise timing information that enables the separation of individual beam crossings. We have presented its

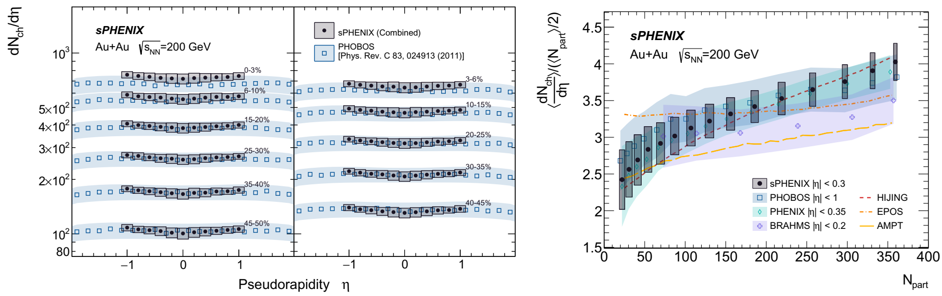

Figure 3. $dN_{\mathrm{ch}}/d\eta$ as a function of η in the range $|\eta| < 1.1$, for centralities from 0–3% to 45–50% in Au+Au collisions, compared with PHOBOS results [6] (left), and average $dN_{\mathrm{ch}}/d\eta$ at mid-rapidity, normalized by the number of participant pairs, as a function of the number of participating nucleons, compared with previous RHIC measurements [6–8] (right).

performance in both trigger and streaming modes, demonstrating that the beam crossing separation is clearly achieved in collision data. The INTT also provides reliable Z-vertex reconstruction using tracklet-based methods, with results consistent with expectations for different beam crossing angles. Furthermore, the first physics measurement, the charged hadron multiplicity in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV, has been obtained. The $dN_{\mathrm{ch}}/d\eta$ shows excellent agreement with earlier RHIC results. These achievements mark the successful transition of the INTT from detector commissioning to physics analysis and establish a strong foundation for upcoming precision measurements with sPHENIX.

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