The commissioning status of the intermediate silicon tracker of sPHENIX

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Abstract. The sPHENIX project is a new collider experiment at the Relativistic Heavy Ion Collider (RHIC) in Brookhaven National Laboratory (BNL). It aims to study the Quark-Gluon Plasma and cold Quantum Chromodynamics (QCD) by measuring photons, jets, jet correlations, and the Upsilon family with high precision. To achieve these goals, a precise tracking system is necessary. The tracking system of the sPHENIX detector consists of the MVTX, INTT, TPC, and TPOT. INTT is a two-layer barrel silicon tracker that plays a unique role among the sPHENIX tracking detectors. It is capable of bridging the tracks of MVTX and TPC. In addition, its precise timing resolution enables INTT to associate individual tracks with events to eliminate pile-up events. The INTT barrel installation and cabling were completed in March 2023. We have since commissioned and confirmed the detector responses. The INTT status, and performance evaluated by beam and cosmic rays are described in this proceedings.

1 Introduction

1.1 The sPHENIX experiment

The sPHENIX experiment is a new heavy-ion detector at RHIC proposed by the PHENIX collaboration in 2010 [1]. It seeks to address fundamental questions on the nature of the Quark-Gluon Plasma and cold Quantum Chromodynamics by precisely measuring hard probes, such as jets, jet correlations, Upsilons (Υ_s), and open heavy flavors. Driven by these goals, an excellent tracking system is essential. The cutaway rendering of the sPHENIX detector is shown in Figure 1. Beginning with the innermost tracking detector, the sPHENIX tracking system is composed of the monolithic active pixel sensor vertex detector (MVTX) for superb vertex reconstruction, the intermediate silicon tracker (INTT) providing single-bunch-crossing timing information for track identification, the time projection chamber (TPC) for precise track momentum measurement, and the TPC outer tracker (TPOT) offering an additional space point outside TPC for the TPC-distortion calibration.

1.2 Intermediate silicon tracker

INTT is the second-innermost tracking detector located between MVTX and TPC. The engineering drawing and the cross-section view of INTT are shown in Figure 1, and the specification of INTT is summarized in Table 1. INTT is a two-layer barrel strip tracker, and each

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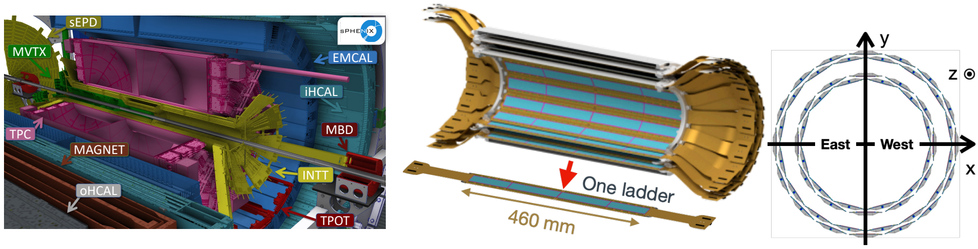

Figure 1: Left: Rendering of the sPHENIX detector. Middle and Right: Schematic and cross-section view of INTT, respectively.

layer consists of two sub-layers. The INTT barrel is made of 56 silicon ladders arranged tangentially in a cylindrical shape around the beam pipe covering pseudorapidity $|\eta| < 1.1$ within the range of z component of collision vertex position (Z_{VTX}) ±10 cm. To achieve hermeticity, sub-layers are staggered in radius, which allows for the alternating ladders to overlap in azimuth [2]. The length and size of the active area of the INTT ladder are 46 cm and 92 cm^2, respectively. The ladder is considered as the combination of two half-ladders read out independently. Similarly, the readout chain of the INTT barrel can be decomposed into north and south sides. Each side of the INTT readout chain consists of four FELIX servers responsible for the data acquisition of one side of the INTT barrel, and each FELIX manages the signal processing of 14 half-ladders [3].

INTT plays a unique role in the sPHENIX tracking system; 1) the hits detected by INTT provide seeds for interpolation of tracking between MVTX and TPC, thus enhances the momentum resolution of reconstructed tracks; 2) the 106 ns operation frequency of the INTT readout chip corresponding to the single beam bunch-crossing of RHIC, the best timing resolution in the sPHENIX tracking system, enables the INTT to associate individual tracks with events, and therefore suppress the event-pileup background [4].

Element	Value	Unit
Strip width	78	μm
Strip length	16 or 20	mm
Radiation length	1.08%	X_0
Sampling rate	9.4	MHz
Layer radius	7.5 and 10	cm
Number of channels per ladder	6656	

Table 1: Specification for the INTT.

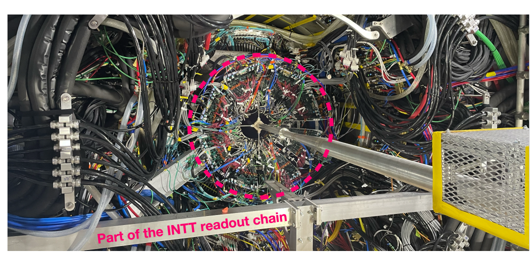

Figure 2: Installation photo of INTT after cabling.

1.3 Missions of the INTT commissioning

The INTT barrel was inserted into the sPHENIX detector on March 1st, 2023. Figure 2 shows a photo of the INTT after installation and cabling. The system testing performed by the INTT group confirmed that 99% of channels of the INTT barrel were in good condition. INTT was ready for the sPHENIX commissioning in April 2023. With more than ten years of preparation, the sPHENIX experiment started commissioning with Au+Au collisions at 200

GeV and cosmic rays in May 2023. Summarized below are the missions of INTT in Run 23 commissioning.

- **See the signal with INTT**: The timing synchronization of eight FELIX servers with respect to the trigger has to be confirmed in the first place. In addition, having cross-checked with other detectors is essential to confirm the reliability of INTT data taking.
- **Measure the collision vertex position**: The INTT is expected to perform the measurement of the collision vertex position which needs to be crosschecked with other relevant subsystems.
- **Search for cosmic tracks**: The geometry of INTT allows a cosmic track to be detected over four times as it passes through. The cosmic-track candidate observed by INTT is expected to be reliable and can feasibly serve as a seed for cosmic-track hunting and relative alignment study of other detectors.

2 INTT commissioning

2.1 With beam

The first Au-Au collision was recorded by the sPHENIX detector on May 18th, 2023. The INTT was commissioned shortly after. The first step was to verify the status of eight FELIX servers and ensure their synchronization with the trigger. This was confirmed by correlating the number of clusters of INTT's inner and outer layers as shown in Figure 3. The data taken by all INTT ladders was included in this study, and a linear correlation was observed. It indicates that the silicon ladders and the whole INTT readout chain are synchronized and working as expected. Further cross-check was performed by synchronizing INTT with a sPHENIX forward detector, the minimum bias detector (MBD), and correlating the multiplicities between INTT and MBD, as shown in Figure 3. A positive correlation was observed as well, showing that INTT and MBD are timed in, and able to see the real signal. This marks a significant milestone for the INTT group. Besides the confirmation of detector status, several decent analyses were developed such as the measurement of Z_{VTX}. The Z_{VTX} can be measured by INTT and MBD independently. The tracklet method was employed when the INTT was used to determine the Z_{VTX}. The tracklets were formed by the extrapolations of the hits detected by INTT's inner and outer layers. The Z_{VTX} was then determined by the location of the majority where the tracklets point to, as shown in Figure 3. INTT can perform an independent study and reconstruct Z_{VTX} consistent with that of MBD, as shown in Figure 4. The measured Z_{VTX} value by the two detectors was taken by the RHIC accelerator group to adjust the vertex position afterward.

2.2 With cosmic rays

With cosmic rays, INTT was the first tracking detector to find clear cosmic tracks. The INTT track seeds were provided for other tracking detectors, which assists in the hunting of cosmic tracks. Figure 5 shows a cosmic track observed by the sPHENIX tracking system in a zero magnetic field. It proves that all four tracking detectors are functional and capable of working together. This constitutes a substantial achievement for the sPHENIX collaboration.

3 Conclusion

INTT is a two-layer barrel strip tracker that plays a unique role in the sPHENIX tracking system. Its precise timing resolution is capable of associating individual tracks with events,

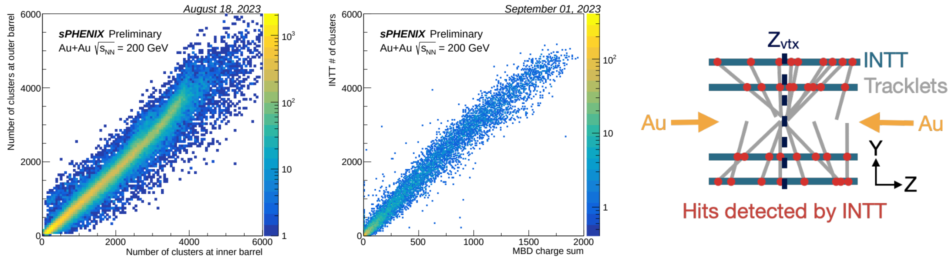

Figure 3: Left: Correlation between the multiplicities of INTT's inner and outer layers. Middle: Correlation between the MBD total charge and the number of clusters of full INTT barrel. Right: Cartoon of the tracklet method for the Z_{VTX} measurement of INTT.

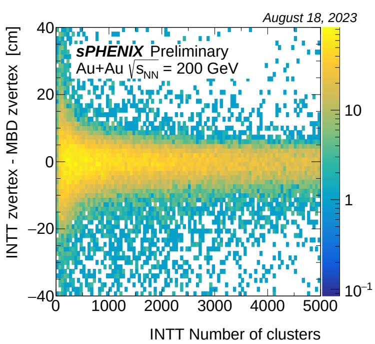

Figure 4: Z_{VTX} difference measured by INTT and MBD as a function of INTT multiplicity.

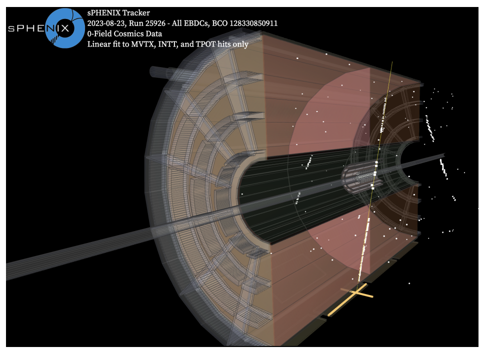

Figure 5: Cosmic track candidate seen by the sPHENIX tracking system in a zero magnetic field.

which is essential to the sPHENIX physics programs. The INTT group performed cabling and system testing after the INTT insertion into sPHENIX. INTT was ready for the sPHENIX commissioning in April 2023, with confirmed 99% live channels. While commissioning with beam, a clear multiplicity correlation was observed between INTT's inner and outer layers, as well as between the INTT and MBD. The commissioning with cosmic rays showed that cosmic track candidates could be observed by the sPHENIX tracking system. INTT was confirmed to be functional well, and all the primary missions of the INTT commissioning were achieved. The INTT commissioning is nearing completion and moving towards the readiness for physics data taking.

References

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