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). Its aim is to study Quark-Gluon Plasma and cold-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 MVTX, TPC, TPOT, and the Intermediate Silicon Tracker (INTT). 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 and events to eliminate pile-up events. The INTT barrel installation and cabling were completed in March 2023. We have since commissioned and confirmed installation procedures and detector responses. The INTT status, and performance evaluation by beams and cosmic rays are described in this paper.

1 Introduction

1.1 The sPHENIX experiment

The sPHENIX experiment is the first new heavy-ion detector at RHIC since the start of the Large Hadron Collider (LHC). It was proposed by PHENIX collaboration in 2010 [1]. This experiment seeks to address fundamental questions on the nature of the Quark-Gluon Plasma (QGP) and cold Quantum Chromodynamics (QCD) by precisely measuring the 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 sPHENIX detector focusing on tracking system is shown in Figure 1 (left panel). Starting from the innermost tracking detector, the sPHENIX tracking system is composed of the monolithic active pixel sensor vertex detector (MVTX) for superb vertex reconstruction, intermediate silicon tracker (INTT) providing single-bunch-crossing timing information for track identification, time projection chamber (TPC) for precise track momentum measurement, and TPC outer tracker (TPOT) offering an additional space point outside TPC for the TPC-distortion calibration.

1.2 Intermediate Silicon Tracker

The 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

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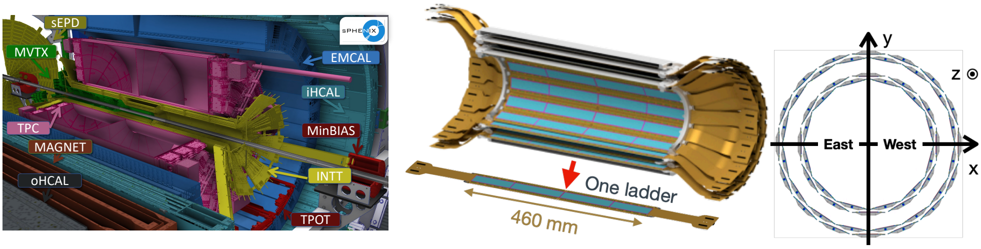

Figure 1: Left: The rendering of the sPHENIX detector focusing on the tracking system. Right: The schematic and cross-section view of INTT.

shown in Figure 1 (right panel), and the specification of INTT is summarized in Table 1. INTT is a two-layer barrel strip tracker, and each 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 vertex ($zvtx$) ± 10 cm. To achieve hermeticity, sub-layers are staggered in radius. The alternating ladders therefore overlap in azimuth [2]. The length and size of the active area of 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 INTT barrel can be broken down into the 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 INTT barrel, and each FELIX manages the signal processing of 14 half-ladders.

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, and enhance the resolution of track reconstruction; 2) the 106 ns timing resolution of INTT readout chip corresponding to the single beam bunch-crossing of RHIC, best timing resolution in the sPHENIX tracking system, enables INTT to associate individual tracks and events, and therefore suppress the event-pileup background [3].

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
# of channels	128	per chip
# of chips	52	per ladder

Table 1: The specification of INTT.

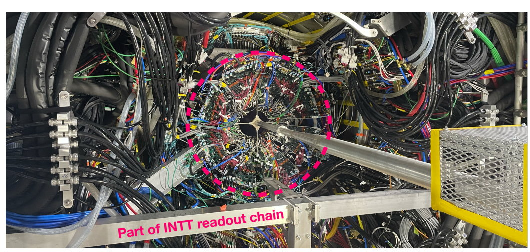

Figure 2: The photo of INTT after cabling.

1.3 Missions of commissioning

The INTT barrel was inserted into the sPHENIX detector on March 1^{st} 2023. The cabling and system testing were conducted afterward. Figure 2 is a photo taken after the INTT cabling. The INTT group confirmed the barrel live-channel efficiency 99%. INTT was ready for the sPHENIX commissioning in April 2023. With more than ten years of preparation, the sPHENIX experiment started the commissioning with Au+Au collisions at 200 GeV and cosmic rays on May 18th 2023. The missions of INTT during Run 23 commissioning are listed below.

- **See the signal with INTT**: The timing synchronization of eight FELIX servers has to be confirmed in the first place. In addition, having cross-check with other detectors is essential to ensure the reliability of INTT data taking.
- **Provide valuable information**: INTT is a silicon-base tracker expected to be capable of offering meaningful information for the calibration of other detectors and RHIC.
- **Search for cosmic tracks**: The geometry of INTT allows a cosmic track to be detected more than four times. The cosmic-track candidate observed by INTT is expected to be reliable and feasibly served as a seed for cosmic-track hunting of other detectors.

2 INTT commissioning

2.1 With beams

The sPHENIX detector started to take beam data on May 18th 2023, we have since commissioned INTT. The first step of INTT commissioning is to confirm the status of eight FELIX servers and ensure their synchronization with each other. This step was confirmed by correlating the number of clusters of inner and outer INTT layers, as shown in Figure 3 (left panel). The data taken by eight FELIX servers was included in this study, and the linear correlation was observed. It indicates that the silicon ladders and the full INTT readout chain are synchronized and working as expected. Besides, INTT is able to see the real signal from the collisions. Further cross-check was performed by synchronizing with a sPHENIX forward detector, the minimum bias detector, MBD, and comparing the multiplicities between INTT and MBD, as shown in Figure 3 (middle panel). A positive correlation was observed as well, representing that INTT and MBD are timed in, and both detectors are able to see the real signal. It is one big step for the INTT group! Besides the confirmation of detector status, several decent analyses were developed aiming at providing useful information to the sPHENIX collaboration such as the measurement of $zvtx$. The $zvtx$ can be measured by INTT and MBD independently. For INTT, the tracklet method was employed which first forms the tracklets by the extrapolations of the hits detected by INTT inner and outer layers. The $zvtx$ is then determined by the majority where the tracklets point to, as shown in Figure 3 (right panel). INTT is able to perform independent study and reconstruct $zvtx$ with the resolution compatible with that of MBD, as shown in Figure 4. The consistently measured $zvtx$ value between the two detectors was taken by the RHIC accelerator group for adjusting the vertex position afterward.

2.2 With cosmic rays

In the sPHENIX commissioning with cosmic rays, INTT is the first tracking detector found clear cosmic tracks. The INTT track seeds were provided for other tracking system, assisting in the hunting of cosmic tracks. Figure 5 shows a cosmic track observed by full sPHENIX tracking system in zero field. It is ~~a~~ proof that all four tracking systems are ~~all~~ functional and capable of working together, which is a huge milestone ~~to~~ the sPHENIX collaboration!

3 Conclusions

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 and events,

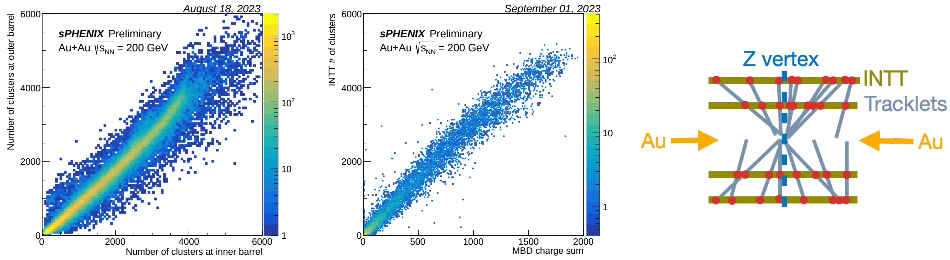

Figure 3: Left: The correlation between the multiplicities of INTT inner and outer layers. Middle: The correlation between the MBD total charge and the number of clusters of full INTT barrel. Right: The cartoon of tracklet method for *zvtx* measurement of INTT.

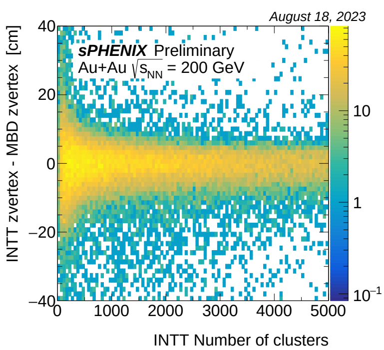

Figure 4: The *zvtx* difference measured by INTT and MBD as a function of INTT multiplicity.

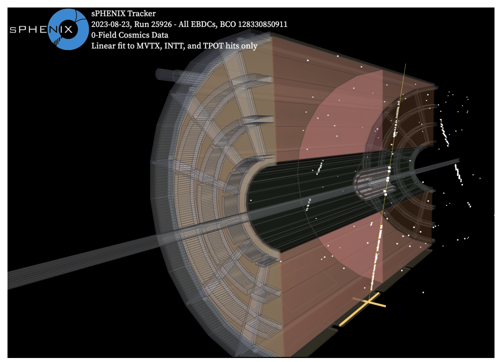

Figure 5: The cosmic track candidate seen by full sPHENIX tracking system in zero field.

which is essential to the sPHENIX physics programs. The INTT group performed cabling and system testing after the insertion of INTT into sPHENIX. INTT was ready for sPHENIX commissioning in April 2023, with a confirmed 99% live-channel efficiency. In the commissioning with beams, a clear multiplicity correlation was observed between the INTT inner and outer layers, as well as between the INTT and MBD. With cosmic rays, the cosmic track candidates were seen by full sPHENIX tracking system. INTT was confirmed to be in good shape, and all the primary missions of INTT commissioning were achieved! The INTT commissioning is nearing completion and moving towards the readiness for physics data taking!

References

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