Detection efficiency of sPHENIX-INTT by cosmic ray measurements and its timing dependence

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INTermediate Tracker (INTT) is one of the three tracking detectors for the sPHENIX experiment, which will be started in April 2023 at the Relativistic Heavy Ion Collider (RHIC) in Brookhaven National Laboratory. It comprises 56 ladders, each comprising two silicon strip sensor modules. One module is divided into 26 cells, and each containing 128 readout strips.

To measure the detection efficiency of INTT, we executed beam tests three times. Although the expected efficiency is approximately 100%, the observed efficiency was $96.0 \pm 0.5\%$ as the result of the second beam test at Fermilab Test Beam Facility (FTBF) in 2019.[1)] The RHIC beam bunches are synchronized with 9.4 MHz clock and so as INTT readout electronics. However, some hits can fall into possible signal processing glitch between subsequent beam clocks (BCO) because the FTBF beam is asynchronous to the RHIC-BCO. To verify the hypothesis, we executed the third beam test at the ELPH facility at Tohoku Univ. in 2021. We upgraded the DAQ system from a nominal Window-based DAQ to a CAMAC-based TDC for the timing measurement of INTT hits w.r.t. the BCO. As a result of this test, we obtained an efficiency of $99.56 \pm 0.06\%$.[2)] Unfortunately, the timing dependence measurement was unsuccessful because we discovered the beam rate exceeded the DAQ processing speed limit, and recorded data were unreliable. Therefore we should measure the detection efficiency and the BCO dependence in low beam rate conditions. The best way is to repeat the measurement with cosmic rays.

For cosmic rays measurement, we put three INTT ladders in a dark box, and two scintillation counters are set above and below the box for external triggers (Fig. 1). The internal clock of the readout electronics is used as BCO. We call the ladders from top to bottom L1, L2, and L3. CAMAC measured the ADC of scintillation counters and BCO timing.

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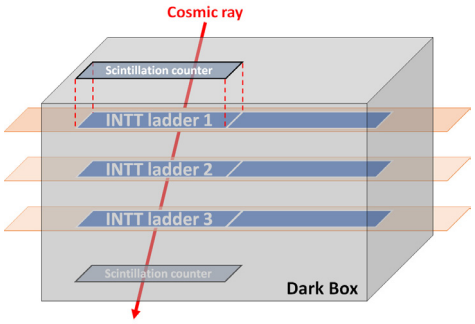

Fig. 1. Setup for cosmic rays measurements.

The efficiency of L2 layer is defined as Eq. (1). Errors were calculated by the binomial distribution.

$$\text{L2 Efficiency} = \frac{\Sigma N(\text{L1}_{\text{hit}} \cap \text{L2}_{\text{hit}} \cap \text{L3}_{\text{hit}})}{\Sigma N(\text{L1}_{\text{hit}} \cap \text{L3}_{\text{hit}})} \quad (1)$$

The observed detection efficiency is $99.54 \pm 0.06\%$, reproducing the 2021 beam test result, by requiring some zenith angle range to be nearly vertical. Then these event samples were classified into 11 relative phase categories w.r.t. BCO, and the efficiency in each phase was evaluated as shown in Fig. 2.

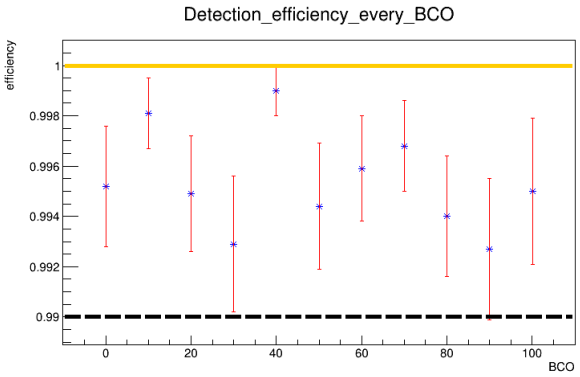

Fig. 2. Detection efficiency of every BCO.

In summary, we confirmed that the detection efficiency of INTT exceeds 99%, and it has no dependence on BCO.

References

1) A. Suzuki, Master thesis, Nara Women's University (2019).
2) M. Morita, Master thesis, Nara Women's University (2021).