Detection efficiency of the INTT test bench for sPHENIX

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sPHENIX[1)] will start data acquisition in the Relativistic Heavy Ion Collider at Brookhaven National Laboratory from 2023 to study quark-gluon plasma. The Silicon Intermidiate Trackter (INTT),[2)] which is one of the crucial pieces in the detector complex, enables us to perform jet flavor tagging with high precision and low background. INTT inherits the readout electronics from the Forward Silicon Vertex Detector of PHENIX[3)] so that R&D can proceed with low cost in a short period.

In a test-beam experiment at Fermilab,[4)] we confirmed that the prototype of INTT satisfied the essential specifications for position resolution and timing resolution. Detection efficiency was approximately 96%, although almost 100% was expected. In these measurements, the prototype worked using the internal clock (BCO) of 9.4 MHz while the beam arrived independently from BCO. The lower-than-expected detection efficiency can be due to timing mismatch between the beam and BCO, because of which signals of the silicon module were occasionally not detected.

To test the hypothesis, we implemented an external trigger system using the Nuclear Instrumentation Module (NIM) and Computer Aided Measurement And Control (CAMAC) modules and integrated it into the existing data acquisition system (DAQ) (Fig. 1). The silicon module was set between two trigger scintillators. The transverse dimensions of the scintillators were the same as the active area of the silicon module. One scintillator on the top was set along the silicon module, while the other was rotated by 90° longitudinally to restrict acceptance. Coincidence of signals from the two scintillators is treated as a trigger signal. The DAQ stores the following parameters:

- hit information on the silicon module

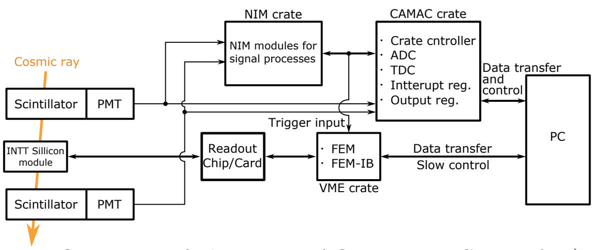

Fig. 1. Overview of the new DAQ system. See Ref. 3) for some of the abbreviations.

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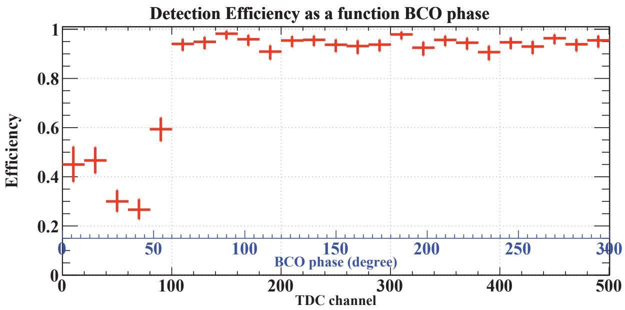

Fig. 2. Detection efficiency as a function of BCO phase with the quality cuts.

- total charge and timing information of the scintillator signals
- the timing difference between the coincidence signal and a BCO pulse, *i.e.*, a phase of BCO.

In the analysis, quality cuts for analog-to-digital converter (ADC) and time-to-digital converter (TDC) distributions of the scintillator signals reject noise-like events. The detection efficiency defined as a ratio of the number of trigger events with INTT hit to the number of the trigger events is calculated after applying the quality cuts as a function of the BCO phase (Fig. 2). Measurement could not be performed for a sixth of the BCO period owing to technical difficulties. A clear drop in efficiency in the first 100 TDC channels was found as expected. The average efficiency excluding and including the dropping region was approximately 94% and 85%, respectively. This low-efficiency condition can be the reason for the 96% efficiency obtained in the test-beam experiments. The efficiency obtained in this study is lower than that in the test-beam experiment because the acceptance restriction was not perfect; consequently cosmic rays could activate the trigger without impingement on the silicon module.

We could also observe a positive correlation between the efficiency and ADC for the bottom scintillator. Requiring higher ADC value to the signal may eliminate cosmic rays, which do not penetrate the silicon sensor. This observation suggests that optimization of the setup can yield a higher detection efficiency.

In summary, we found dependency of the detection efficiency on the BCO phase. It explains the lower efficiency observed in the test-beam experiment. Since RHIC will provide a beam-synced trigger, this timing mismatch cannot be an issue for sPHENIX

References

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