Detection efficiency of the RHIC-sPHENIX-INTT detector

M. Morita,[*1,*4] Y. Akiba,[*1] D. Cacace,[*2] K. Cheng,[*3] H. En'yo,[*1] T. Hachiya,[*1,*4] S. Hasegawa,[*1,*5] M. Hata,[*4] H. Imai,[*1,*6] T. Kondo,[*7] C. Kuo,[*3] H. -S. Li,[*8] R. -S. Lu,[*9] E. Mannel,[*2] C. Miraval,[*2] I. Nakagawa,[*1] Y. Nakamura,[*1,*6] G. Nakano,[*1,*6] Y. Namimoto,[*1,*4] R. Nouicer,[*2] G. Nukazuka,[*1] R. Pisani,[*2] M. Shibata,[*1,*4] C. Shih,[*3] M. Shimomura,[*4] M. Stojanovic,[*8] Y. Sugiyama,[*4] R. Takahama,[*1,*4] W. -C. Tang,[*3] K. Toho,[*10] K. Tsuruta,[*10] M. Watanabe,[*4] and X. Wei[*8]

The intermediate tracker (INTT), consisting of 56 ladders of silicon strip detectors, is a tracking detector of charged particles for the sPHENIX experiment[1] at the Relativistic Heavy Ion Collider. So far, by using test pulses, radiation sources, cosmic rays, and proton test beams at Fermilab, we have confirmed that the performance required of the INTT ladders is mostly fulfilled. After the completion of the research and development of INTT, mass production and detector construction are now in progress.[2]

A silicon detector is expected to have a detection efficiency of almost 100%; however, we obtained an efficiency of 96.5 ± 0.5% from a previous test beam experiment.[3] This low efficiency may have been caused by the missing beam clock information in the experimental data because one cannot confirm whether each hit in the detectors originated from one beam particle without the beam clock information. Thus, the INTT data acquisition (DAQ) system was modified to save the beam clock information and accept an external trigger.

In December 2021, at Research Center for Electron Photon Science, Tohoku University, we performed a new test beam experiment[4] with the mass-produced ladders and the new INTT DAQ system. Three ladders were collinearly placed along the beamline and sandwiched by trigger plastic scintillators. A positron beam with an energy of 1 GeV impinged on these detectors.[3]

The detection efficiency $\epsilon(L_i)$ of the i-th ladder L_i is calculated as

$$\epsilon(L_i) = \frac{N(L_i \cap L_j \cap L_k)}{N(L_j \cap L_k)}, \quad (i,j,k = 0,1,2)(i \neq j \neq k) \tag{1}$$

where $N(x)$ is the number of hits under a condition x.

The events from noisy strips are excluded from the analysis. Hit clusters are formed by merging adjacent hits in a ladder before the calculation of detection efficiency. The strip ID of the hit clusters are determined by the weighted mean of the merged hits with their analog-to-digital conversion (ADC) value. The events in which the beam penetrates all ladders almost perpendicularly are used to evaluate the detection efficiency. The fired strip-ID difference between two ladders are utilized to select such events, as shown in Fig. 1. A smaller absolute value of the difference between the fired strip IDs corresponds to a smaller position difference in the plane perpendicular to the beam axis. The events inside the 2σ region in the fired strip-ID distribution (the region enclosed by dashed lines in Fig. 1) are treated as the coincidence condition in Eq. (1). The mean of the fired strip-ID difference is approximately 4, implying that the position difference between ladders is approximately 320 µm. The width of the distribution is governed by the angular spread of the beam. With the coincidence condition described above, the detection efficiencies of the three ladders are determined to be 99.53 ± 0.02%, 99.39 ± 0.03%, and 99.56 ± 0.02%, respectively. The high detection efficiency of the INTT detector is confirmed, implying that the detector is ready for the day-one experiment of sPHENIX.

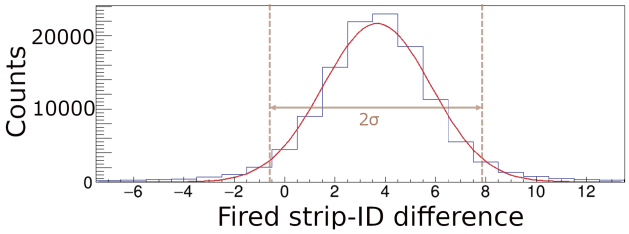

Fig. 1. Fired strip-ID difference between two ladders. The events in the 2σ region (enclosed by dashed lines) are used to evaluate the detection efficiency of each ladder.

*1 RIKEN Nishina Center
*2 Brookhaven National Laboratory
*3 Department of Physics, National Central University
*4 Department of Physics, Nara Women's University
*5 Japan Atomic Energy Agency
*6 Department of Physics, Rikkyo University
*7 Tokyo Metropolitan Industrial Technology Research Institute
*8 Department of Physics, Purdue University
*9 Department of Physics, National Taiwan University
*10 Department of Physics, Tohoku University

References

1) Conceptual Design Report of sPHENIX (2018).
2) I. Nakagawa *et al.*, in this report.
3) A. Suzuki, Master thesis, Nara Women's University (2019).
4) G. Nukazuka *et al.*, in this report.