Detection efficiency of the hit cluster in the sPHENIX-INTT detector

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The sPHENIX experiment at the Relativistic Heavy Ion Collider is currently in operation to study the properties of quark-gluon plasma in detail. The INTermediate silicon Tracker (INTT)[1] is located in the radius of 6 to 12 cm from the collision point. It consists of two barrel layers equipped with silicon strip sensors. Each sensor has a strip width of 78 μm segmented in azimuthal direction. During the development period, we studied the detection efficiency of the INTT using positron beams at ELPH, and the resulting efficiency was >99%.[2] In this report, the detection efficiency of the fully implemented INTT in the sPHENIX is presented under a beam collision circumstance.

To calculate the efficiency, we used the third hit point as a collision vertex for this study, as our setup lacks a third-layer detector, unlike the beam test configurationt.[2] The collision vertex was employed as the substitute of third hit point for the efficiency calculation. The validity of this method was studied using a MC-based detector simulation. The MC data used in this study are given in Fig. 1(b).

The method shown in Fig. 1(a) is conducted as follows:

(1) Obtain the coordinates of clusters in the outer layer within a single event.

(2) Connect the collision point and hit cluster to define the search window of the hit cluster in the inner layer. In this study, the window was varied from +/−0 to 10 strips.

$$\text{window} = 78\ \mu\text{m} \cdot i \quad (i = 1, 2, 3, \dots)$$

(3) Calculate the residual between the straight line and the inner-layer cluster. Count the outer-layer cluster as N_{yes} if the inner cluster exists within the expected range, and count it as N_{no} otherwise. If more than one inner cluster exists within the search window, select the one with the smallest residual. Residuals are also calculated in the Z direction to account for the cluster position in the Z direction. Among these residuals, only the cluster with the smallest χ^2 is selected.

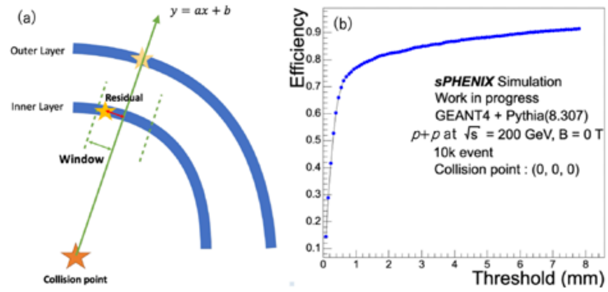

Fig. 1. (a)Method for calculating detection efficiency. (b) Detection efficiency as a function of window size.

The detection efficiency ε is calculated using the following formula:

$$\varepsilon = \frac{N_{\text{yes}}}{N_{\text{yes}} + N_{\text{no}}}$$

The rapidity coverage of the inner and outer barrels does not fully match. For precise evaluation of the detection efficiency, clusters within this region are removed.

Figure 1(b) shows the detection efficiency calculated for each window size. As expected, the detection efficiency increases as the window size expands. However, it increases sharply up to approximately 0.5 mm, which suggests that signals may not be sufficiently captured with smaller windows. In contrast, the detection efficiency saturates at approximately 88% when the window size reaches around 4 mm (51 strips). A possible reason for the loss of inner clusters is the presence of dead space between sensors. The simulation includes this effect, which may act as a physical constraint that limits the maximum achievable detection efficiency. To achieve higher efficiency in the future, we must assess the impact of the dead space quantitatively and apply appropriate corrections.

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