MIP measurement for mass production of sPHENIX-INTT ladder with a positron beam

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The sPHENIX experiment will start in 2023 at the Relativistic Heavy Ion Collider in Brookhaven National Laboratory. Intermediate Tracker (INTT) is one of the three tracking detectors used in the experiment, which consists of 56 ladders of silicon strip detectors. A half ladder is divided into 26 cells which consist of two types of silicon sensors with different strip lengths, and each cell includes 128 read-out FPHX chips.[1)]

In 2021 at ELPH, Tohoku University, we performed a test beam experiment to evaluate the performance of mass production ladders.[2)] We used the γ-ray beamline at the facility, and irradiated a positron beam with a momentum of about 1 GeV. Three halves of a ladder were used, and two scintillators were installed upstream and downstream of them, respectively.

We evaluated the performance of silicon sensor by detecting Minimum Ionizing Particles (MIP). The noise contamination to the MIP region in the energy deposit spectrum is crucial to achieve good signal-to-noise ratio. The FPHX read-out chip converts the height of the signal generated by the sensor into a 3-bit ADC. As a preparation of the signal AD conversion process, the 8-bit DAC threshold values (called DAC value) are preset with approximately 4 mV step. When the signal is processed, a corresponding DAC value is assigned and set in a data stream as a 3-bit ADC data. The ADC value relates to energy loss of a traversing charged particle. It is important to observe the entire energy deposit spectrum with a good resolution though, it is not possible by using the built-in 3-bit ADC of FPHX chip. A series of sequential measurements were executed to scan through the full DAC range by setting the DAC to cover only narrow range but fine pitch in one measurement.

In the data analysis, events which have too many hits away from the beam spot were removed. Only hits on a single strip were analyzed. A hit with the highest ADC value was excluded from the full ADC spectrum reconstruction event samples because the hit could be an overflow value. We reconstructed ADC distribution of a cell in the upstream ladder obtained from 8 runs. Then the distribution was normalized by the number of entries in two overlapping bins, shown in Fig. 1(a). Then we took the average over each overlapping bin, letting each ADC distributions of narrow region connect smoothly with the spectrum of adjacent region. It was performed in order from the smallest ADC configuration to obtain one energy deposit spectrum.

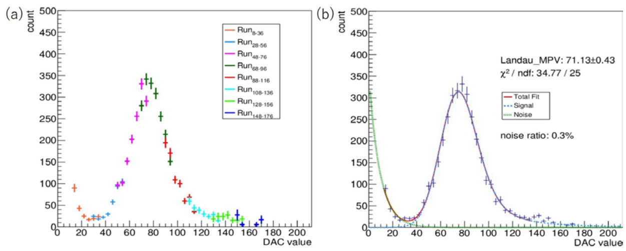

Fig. 1. (a) The ADC distribution obtained from 8 runs by normalizing entries in overlapping bins. (b) The energy deposit spectrum with the fitting results.

We applied the Landau-Gaussian convolution function[3)] to reproduce the peak shape of the MIP region, and an exponential function to express the noise contribution. The Landau most probable value indicates the peak value corresponding to the energy loss of the MIP. We fitted the energy deposit spectrum with a sum of their functions and succeeded in reproducing the experimental data, shown in Fig. 1(b).

The fitting result shows the Landau MPV was 71.13 ± 0.43 at the operation bias voltage of 50 V. The noise contamination in the MIP region from 40 to 136 is estimated to be about 0.3%. Therefore the mass production ladder is almost noiseless in the MIP region.

In summary, we obtained one exact energy deposit spectrum from measurements with 8 different ADC configurations. The experimental spectrum was well reproduced by the sum of the convolution function and the exponential function. Also, the noise contamination in the MIP region is about 0.3%. This means that the DAC threshold value can be set low, leading to high detection efficiency.

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