Silicon trackers for cluster knockout reactions in ONOKORO

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We developed silicon trackers for the cluster knockout reactions toward the ONOKORO[1,2] project at RIKEN, Nishina Center. Particle tracking with a good position resolution is necessary to measure the angle of the emitted particles from the cluster knockout reactions. The multi-channel signals from the silicon-strip detectors were pre-amplified and shaped (50 ns CR-RC circuit) using the ASIC integrated circuits APV25.[3] Each of these ASIC can treat 128 channels. The unit silicon wafers with 7.68 cm width (768 strips) require twelve chips (see Fig. 1), which actually operate 1536 channels. The half (odd) channels were connected to the strip electrodes of the silicon detector by wire bonding, and the other (even) half were used to measure the sync common-mode noises and subtract them from the odd channels. Skipping channels with no signal reduces the number of readout channel. As it does not generate a trigger signal by itself, the basic operation involves synchronizing with external triggers. The output of the shaping circuit was held at the timing of an external trigger and was converted into a serial signal using an analog multiplexer. The serial signal was digitized using an ADC module (ADCM) and the data was acquired by the DAQ based on the TRB3 (TDC Readout Board V3) system.

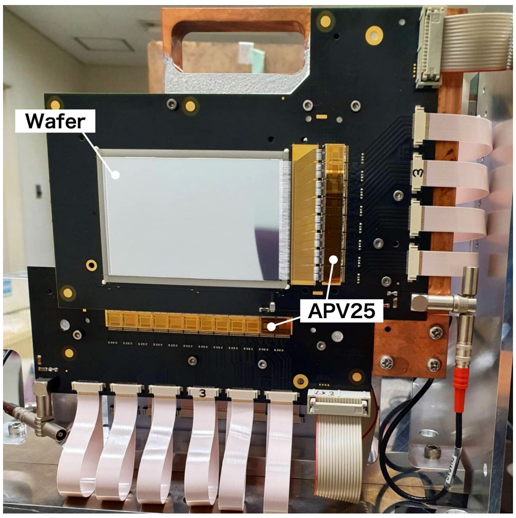

Fig. 1. Silicon detectors mounted for the text experiment at the HIMAC. A silicon wafer with vertical strips is placed in front of that with horizontal strips.

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In August 2021 at HIMAC, we evaluated the responses of the silicon detectors to proton and α beams. Four silicon detectors, two each for measuring the positions in the X and Y directions with 100 μm strips, were installed in the beamline. Figure 2 shows the energy loss spectra of the proton 100 MeV beam and the α particle 230 MeV/nucleon beam in one silicon layer, respectively.

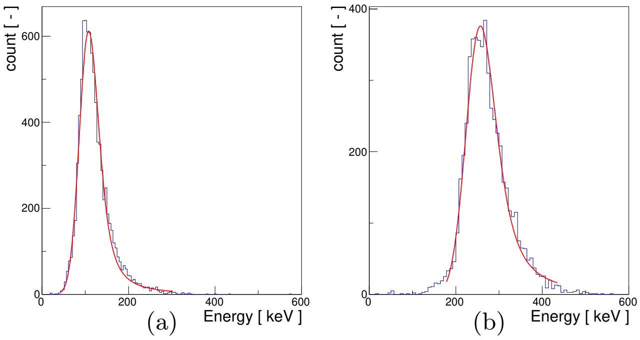

Fig. 2. Energy loss spectrum of (a) 100 MeV proton beam (b) 230 MeV/nucleon alpha-particle beam.

The distribution of small energy loss is known to be a Landau distribution. In (a) with proton beam, the fitting was performed using a Landau function convoluted by a Gaussian. It reproduced the pedestal widths (4.15 keV). In (b), the larger energy loss with the alpha-particle beam provides a rather symmetrical distribution. This result revealed that the responses of the silicon detectors, including the electric circuit, were under control. Moreover, we also evaluated the detection efficiencies. The particles were guaranteed to pass through the detector by detecting them in the same events in the front and back. In a low intensity (1 k cps) condition, 91.4% of the events had a single hit, and 8.10% were double hits. In the double hits, 75.7% were adjacent strips. Events with more than triple hits were 0.47%. Consequently, it was found that it is possible to uniquely determine the hit position with 97.5% in each silicon layer. The high detection efficiency under small energy loss conditions encouraged us to develop the full silicon detector array in the future.

References

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3) L. Jones, APV25-S1 User Guide V2.2 (2001).