Performance test of the silicon tracker for the heavy-ion-proton experiments at SAMURAI

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An essential component of the future setup of the heavy-ion-proton (HI-p) experiments[1)] at SAMURAI will be an array of GLAST-type[2)] single-sided silicon strip detectors (SSDs) situated downstream of the target. These detectors will be used for precise tracking and identification of outgoing protons and heavy residues. Each detector is 325 μm thick and has dimensions of 87.6×87.6 mm^2 with a readout-pitch size of 864 μm. A key feature of the SSDs is their wide dynamic range, which allows for simultaneous detection of protons and heavy ions, which deposit to a single SSD energy ranging from ~100 keV up to several hundreds MeV, respectively. This feature is achieved via custom-designed ASIC dual-gain preamplifiers providing low-gain (LG) and high-gain (HG) readouts coupled to the high-density processing circuit HINP[3)].

A performance test with the SSDs and their new electronics was conducted at the HIMAC facility in Japan, using beams of protons with energies between 150 and 230 MeV as well as heavy-ion beams ^{12}C, ^{84}Kr, and ^{132}Xe (primary and secondary) at a few hundreds MeV/u. Only 32 central strips out of the 128 strips of a single sensor were fully instrumented by the newly designed ASIC preamplifiers, and only those channels were read-out during the experiment.

The results of the performance test are summarized in Fig. 1. Using the secondary beam, obtained by fragmentation of the primary ^{132}Xe at an energy of 200 MeV/u (see PID plot in Fig. 1(A,B)), the response of the LG readout was investigated for a wide range of nuclear charge Z. A good linearity of the LG readout was observed (Fig. 1(D)) along with a deposited-energy dE resolution of $\sigma(dE/E) \approx 1.4\%$, which is close to the designed value. The cross-talk ratio between a fired and a neighbouring strip is found to be ~1% after the add-back analysis combining HG and LG data. Saturation of the LG readout was observed at $dE \gtrsim 650$ MeV, although the reconstruction of even larger dE was possible owing to a certain amount of interstrip hits in which dE is divided between the adjacent strips.

The performance of the HG readout was tested with ^{12}C and proton beams. Good linearity of the HG dynamic range was confirmed. The required detection threshold of $dE \gtrsim 100$ keV for protons can be achieved with the present configuration. The total detection efficiency of protons was found to be above 97%. Thus, it is confirmed that the combined dynamic range of the detector spans from ~100 keV to ~650 MeV, which in perspective would allow the simultaneous detection of protons and Z ≈ 50 heavy ions at RIBF energies.

The design and production of the missing preamplifier circuits is currently in progress and is expected to be completed in 2016. Hence, a sufficient amount of dual-gain readouts will be provided for all four silicon trackers (*i.e.*, $4 \times 128 = 512$ strips) intended for the actual HI-p experiments.

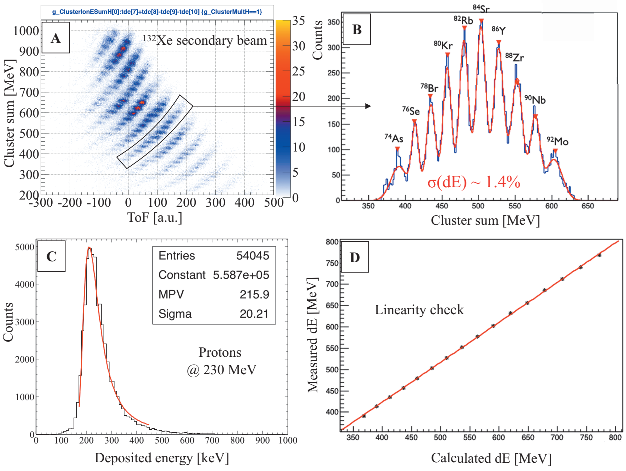

Fig. 1. Performance results of the silicon tracker in the HIMAC test experiment. Figure A: particle identification (PID) of the secondary beam from ^{132}Xe at 200 MeV/u, where dE measured by the SSD (cluster sum after the add-back) is plotted against the time of flight (ToF). Figure B: dE response of the SSD with the indicated resolution $\sigma(dE)$ for the selected species in Figure A and the multiple-gauss fit (red line). Figure C: dE response of the HG readout with respect to 230 MeV protons and Landau fit (red line). Figure D: comparison of the measured and calculated dE response in the SSD (symbols) with a linear fit (red line).

References

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