Silicon tracker array for RIB experiments at SAMURAI[†]

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A silicon tracker for use in front of the SAMURAI spectrometer at the RIBF facility of the Nishina Center of RIKEN, Wako, Japan was designed, built and tested.[1)] The tracker consists of two pairs of single-sided microstrip detectors that determine the (x, y) position at two locations along the beamline after the target. The system provides particle identification from protons up to $Z \sim 50$ heavy fragments with energies 100–350 MeV/nucleon. GLAST-type 325 μm thick detectors were used. The inherent problems stemming from the large granularity, the required very large dynamic range and counting rate were handled using two matched ASICs: a dual-gain preamplifier DGCSP and the HINP16 pulse processing system.

Combining the HINP16 ASICs with the newly developed dual-gain preamplifiers, produces $2 \times 4 \times 128 = 1024$ channels. (Lo/Hi gain $\times$ 4 Si each with 128 channels.) This system yields a very large dynamic range of $\sim 10^4$. It can work in a self-triggering mode or in slave mode where it requires an external trigger and can tolerate very large input capacitance. The large dynamic range, provided by the dual-channel preamplifier, makes it possible to measure a wide range of nuclear charges. Parts of the system were tested with beams from the HIMAC facility in Chiba, Japan, to show that it can measure energy losses from 100 keV (protons) to 600–900 MeV (for heavy fragments up to $Z = 50$), which makes it appropriate for the studies with radioactive ion beams at intermediate energies.

The whole system was used and characterized in two RIBF experiments (NP1412-SAMURAI29 and NP1406-SAMURAI24), using the SAMURAI magnetic spectrometer. The silicon detection system was successfully used to track protons and heavy fragments simultaneously in the breakup of the proton-rich nuclei, (like ^{9}C and ^{66}Se) to reconstruct the reaction vertex, the emerging angles of the particles, the momentum distributions of the protons and the relative energy spectra. We run the system with 1.2×10^3 Hz ^{132}Xe beam rate during the HIMAC test and with 4×10^4 Hz of ^{9}C beam, and we assume that the maximum rate can be higher. However, the damage of the detector may become important. The problem becomes more complex because the center of the detector system takes a larger rate of hits and will lead to local damages. And it is more important for heavier (secondary) beams. This will be addressed by replacing the detectors when necessary.

To achieve the science objectives of the experiments with proton-rich radioactive beams in which we have to measure the proton and the heavy ion remnant, the essential tracking performances are: the atomic number identification, the vertex reconstruction resolution, the angular resolution and the momentum reconstruction resolution. All these are required to determine with a good energy resolution the missing mass spectra. We illustrate these with the case of the proton breakup of ^{9}C at 160 MeV/nucleon. The physics objectives are to disentangle the E1 and E2 contributions to the Coulomb dissociation process on a lead target and to evaluate the astrophysical factor, $S_{18}(0)$ by separating the contribution of the resonance at 918 keV. The resolutions obtained with the silicon system are resulting from the incoming beam phase space characteristics, the strip pitch size (0.684 mm), the distance between target and the first pair of detectors and the distance between the two pairs of detectors. With the 4 silicon detectors used in the configuration presented in the article, the resolution of the longitudinal distance (σ = 35 mm) is sufficient to separate the spurious events induced by the beam in the other materials around the target, as illustrated in Fig. 10(b) of Ref. 1). The angular resolution obtained for the laboratory opening angle is 3.5 mrad and the largest contribution is coming from the proton straggling in the first two silicon layers (straggling in 0.650 mm Si $\approx$ 2.8 mrad). By using these silicon detectors for proton tracking together with the proton drift chambers mounted at the exit of the SAMURAI superconducting magnet, we got for proton momentum resolution: $\Delta P/P \approx 0.065\%$. Considering these resolutions, we expect that at 1 MeV relative energy of p-^{8}B we get the energy resolution of $\approx$100 keV, about 2.5 times better than without the silicon tracker, which is sufficient to determine the cross section at energies below the resonance and to evaluate $S_{18}(0)$ by extrapolation.

This silicon tracker dramatically extends the research opportunities with the SAMURAI spectrometer especially for systems with two or more charged particles, which had been too difficult with the standard detectors equipped in SAMURAI.

† Condensed from the article in Eur. Phys. J. A **58**, 223 (2022)

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Reference

1) A. I. Stefanescu *et al.*, Eur. Phys. J. A **58**, 223 (2022).