Breakup of ^{9}C and ^{66}Se with SAMURAI in RIKEN

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We have performed the first physics experiments with the SAMURAI Si tracker at the RIBF facility in RIKEN. This Si tracker and related electronics were instrumented in collaboration with TAMU, WUSTL, LSU, and the international partners. The initial commissioning experiment in May/June 2018 was Coulomb dissociation and nuclear breakup of ^{9}C→^{8}B+p and ^{9}C→^{7}Be+2p at 157 AMeV for studying the rate of ^{8}B+p→^{9}C reaction chain as possible bypass of the 3α process in stellar environments [1]. This was followed in March 2019 by nuclear breakup of ^{66}Se→^{65}As+p and ^{66}Se→^{64}Ge+2p at 270 MeV/u for studying destruction of waiting point nucleus ^{64}Ge in X-ray burst environments [2].

The Si tracker was built to improve the measurement of the relative angle between the breakup products: the resulting heavy ion and proton(s) immediately after the reaction target. The setup is used in combination with the drift chambers and hodoscopes around the SAMURAI magnet. The Si tracker consists of two sets of two 324 μm thick GLAST type Single-Sided Si Strip Detectors (SSD), each with 128 strips that are 684 μm wide. A pair of SSDs is mounted on same PCB so that the strips on opposite side are in 90 angle, forming a tracking coordinate plane. Each of the SSDs is connected into a Dual Gain Charge Sensitive Preamplifier (DGCSP) inside the vacuum chamber. The DGCSP is an application specific integrated circuit (ASIC) designed in RIKEN which are packaged onto preamplifier boards designed and built by ATOMKI. The DGCSP has total dynamic range from about 200 keV to a little under 1 GeV. Two DGCSP chips per preamplifier board can instrument 16 strips, giving 16+16 outputs (high gain and low gain) for each strip. The resulting 4 x 128 x 2 = 1024 data channels are read with HINP16C chips [3]. The total system consists of two motherboards, each with 512 channels. The readout system for the two motherboards was integrated into the RIBFDAQ as its own device and the data synchronized to the data collected from other parts of the setup.

Fig. 1 gives an example of the setup performance for the protons. The left panel of Fig. 1 shows a comparison between proton calibration data run (multiplicity = 1 in each Si layer) and protons from one run of ^{9}C on ^{208}Pb target, with gates placed on incoming ^{9}C beam, a proton detected in the hodoscope after SAMURAI and with Si multiplicity <7 and that the hit strip in Si was more than 4 strips away from the highest energy of the event (the heavy ion). The right panel of Fig 1 shows accumulated proton spectrum with similar conditions from multiple runs of ^{9}C on ^{12}C. The left panel of Fig 2. shows the ^{9}C beam spot in the second tracker layer and the right panel shows the distribution of protons from the right panel of Fig. 1.

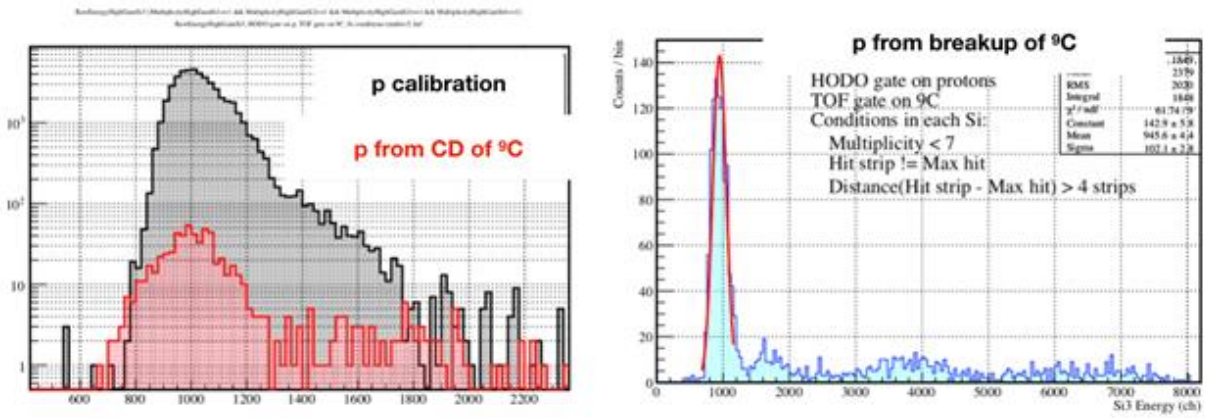

FIG. 1. Left panel: A comparison of energy deposition in one strip from the proton calibration run and one run of Coulomb dissociation of ^{9}C. The calibration data has requirement of multiplicity = 1 in each Si layer whereas the CD data has gates placed on incoming ^{9}C beam, a proton detected in the hodoscope after SAMURAI and with Si multiplicity <7 and that the hit strip in Si was more than 4 strips away from the highest energy of the event (the heavy ion). The right panel shows shows accumulated proton spectrum with similar conditions from multiple runs of ^{9}C on ^{12}C.

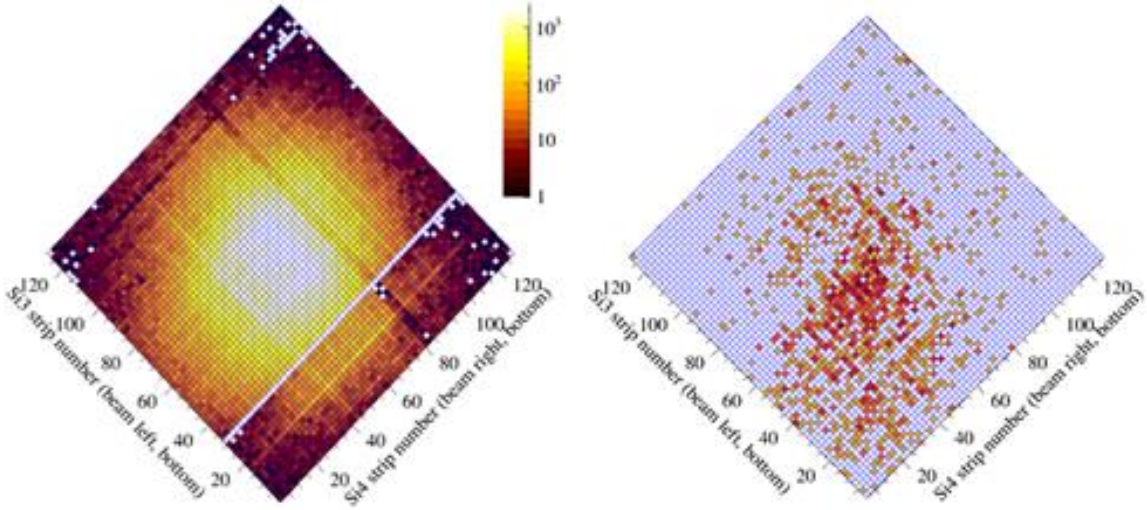

FIG. 2. Left panel: ^{9}C beam spot in the second tracker layer (~60 cm from the target) during nuclear breakup measurement. Right panel: Distribution of protons with same conditions as right panel of Fig. 1. and for the same runs as the left panel.

Data taking for both experiments was successful and the analysis is in progress by the collaboration.

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[3] G.L. Engel *et al.*, Nucl. Instrum. Methods Phys. Res. A**573**, 418 (2007).