Detector tests for SAMURAI silicon tracker

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This report summarizes briefly the in-beam detector and electronics test for the SAMURAI Si tracker project performed at the NIRS-HIMAC facility (Heavy-Ion Medical Accelerator in Chiba, Japanese National Institute for Radiological Sciences). The aim of the experiment was to study the responses of a double-sided silicon strip detector (Micron TTT2, 300 μm) and a single sided silicon strip detector (Hamamatsu GLAST, 300 μm) with associated electronics in conditions as close as possible to the ones in the upcoming experiments with SAMURAI spectrometer [1] at RIBF facility in RIKEN.

The beam time consisted of a total of 5 shifts with different beams and goals:

- ^{12}C at 400 MeV/u for setting up and checking the system performance.
- ^{56}Fe at 400 MeV/u to produce a cocktail of secondary beams with A/Z = 2 to check linearity and response of the system with wide range of energy deposits. This provides also the energy calibration (access to external sources was limited to a single ^{241}Am source).
- ^{1}H at 150 MeV/u to see if system can detect high energy protons (low energy deposit in thin Si).
- ^{40}Ar at 290 MeV/u to determine possible effects from δ-rays.
- ^{84}Kr at 400 MeV/u to determine possible effects from δ-rays and to see responses from ions closer to A = 100 region at this energy range.

We prepared a high quality vacuum system that could be connected directly to the HIMAC beam lines (standard procedure is to have setup separated by an air gap to ensure safety of the medical facility). This allowed us to be sure to not have any background δ-rays from beam-line windows and thus have conditions as close as possible to those at RIBF. The vacuum requirements, mostly pumping time to reach low enough pressure, limited the amount of possible detector configurations that could be tested.

For TTT detector we used the internal charge-sensitive amplifier (CSA) of the HINP16C chips [2]. The CSAs were run with high gain (0-70 MeV range) for all the beams, except for ^{84}Kr, for which we had to switch to low gain (0 – 350 MeV range). For the GLAST detector we had a 64 channel external dual gain charge-sensitive preamplifier (DGCSP), designed and manufactured at RIKEN, which had simultaneous high and low gain and this was read out with the HINP16C chips in external amplifier configuration.

This was the first time that our readout system (TABS) with two motherboards (total of 512 channels) was run in online conditions and it was found to perform as expected from offline tests. This was also the first time that the system was operated through the RIKEN data acquisition software [3]. Development of the analysis codes for the future setup is still on going process with aim to integrate the Si tracker code to the full SAMURAI setup.

Both detectors and electronics chains were found to be linear over the ranges of energy deposits used. Fig. 1 illustrates A/Z = 2 cocktail from ^{56}Fe fragmentation as observed with TTT2 detector and high-gain of HINP internal CSA.

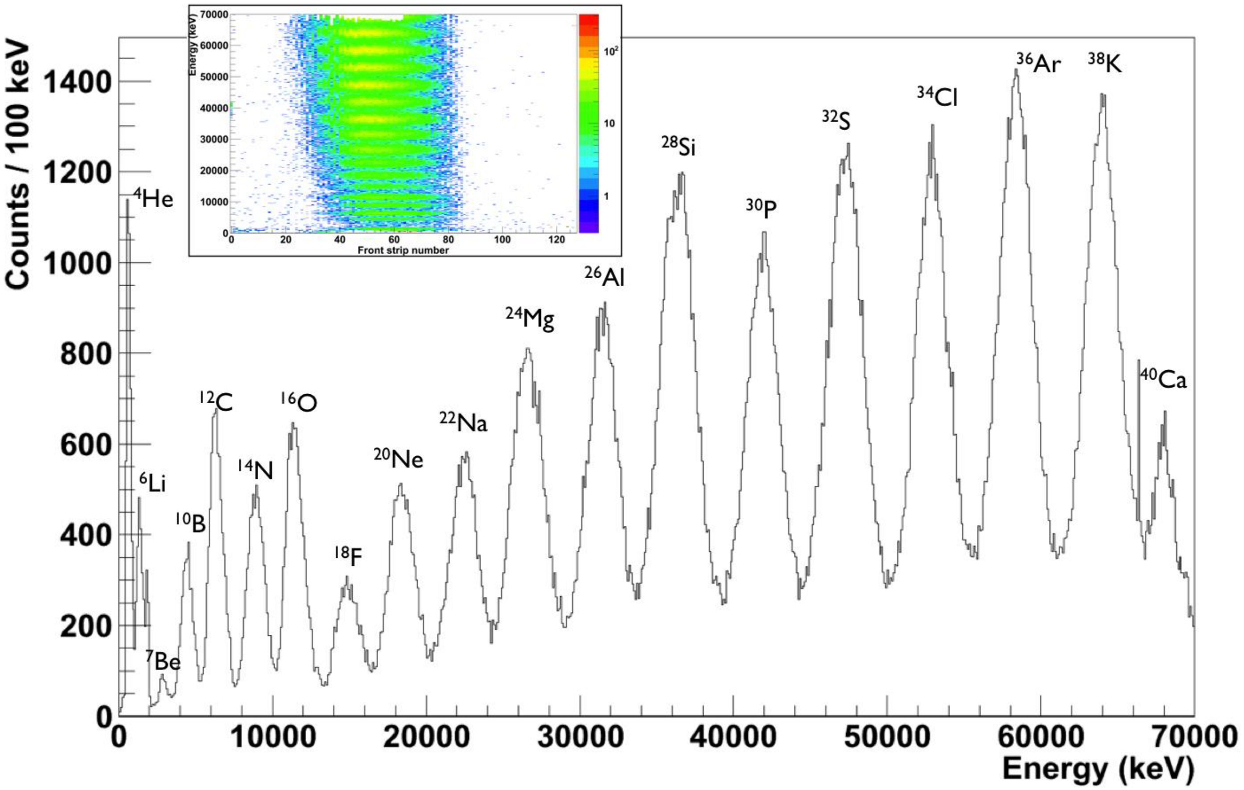

FIG. 1. Energy deposits of A/Z = 2 cocktail from ^{56}Fe fragmentation at 400 MeV/u with TTT2 detector front (junction) side. Inset shows the distribution along different strips.

We observed only a small fraction of the protons with the TTT2 and HINP CSAs. This is not entirely unexpected with the internal CSA of HINP chips as the ~300 keV energy deposit from 150 MeV protons is just at the detection threshold. The few candidates for protons are shown in Fig. 2 with noise like events removed by requiring that $|E_{\text{front}} - E_{\text{back}}| < 100$ keV and that multiplicity of the event is one on both sides. Notably there are only about 3000 counts in the peak, out of over 800 000 events in total. The external RIKEN CSA did yield also only circumstantial evidence about protons as the electronics thresholds were rather high in most of the channels. As a future improvement, the response for high energy protons will be improved by increasing the thickness of the detector from 300 μm to 500 μm and with an upgrade to the HINP chips, lowering the thresholds about factor of two. The combination of higher energy deposit and lower thresholds should yield a good response from high energy protons. The new detectors and improved HINP chips are to be tested in fall 2013.

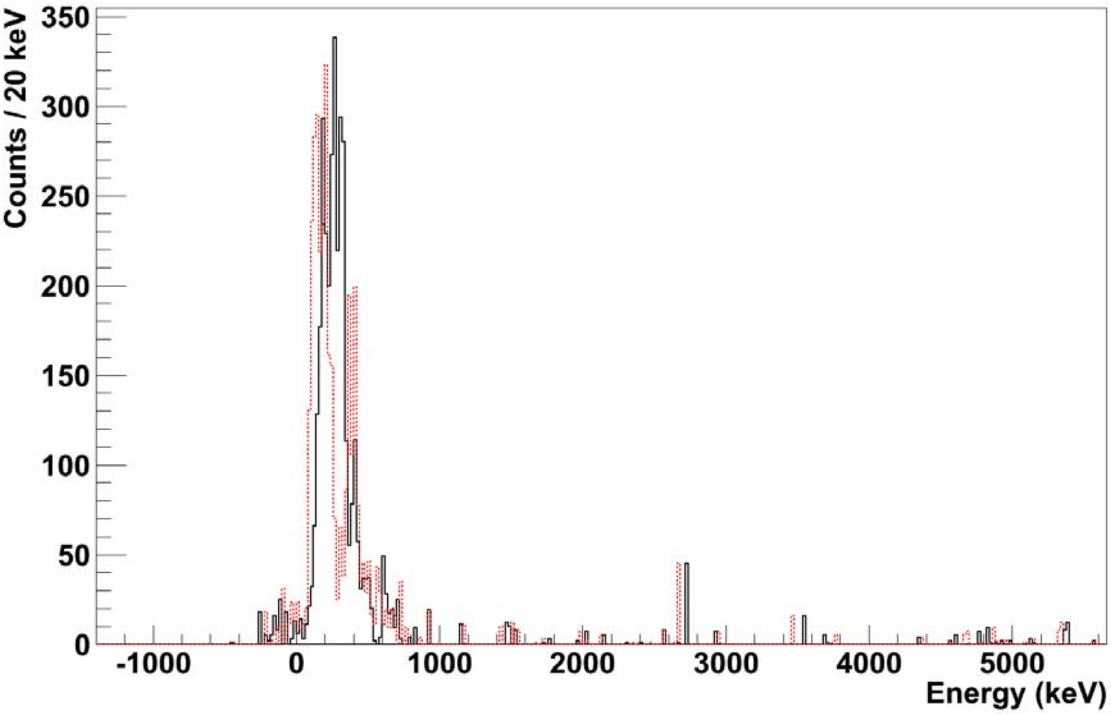

FIG. 2. Most probable candidates as 150 MeV protons as observed with TTT2 detector. The spectrum from front (junction) side is in solid black line and the spectrum from back (ohmic) side is in dashed red line.

To test production of δ-rays we had a set of Pb and Al foils (to simulate a production target and another Si detector at larger distance, respectively) <100 cm upstream in the beam line before the GLAST detector. The TTT detector was located <50 cm behind the GLAST detector. With the present setup, at these distances, we did not observe any significant amount of δ-rays. This is an encouraging result if the final configuration of the SAMURAI setup is built in similar distances and utilizes double-sided strip detectors. Unfortunately the time available did not allow us to test two detectors at a few cm distance to have a measurement in configuration similar to two single-sided detectors (which would be the configuration if two GLAST detectors are combined as position sensitive detector). We have also designed and built a permanent magnet setup that can suppress electrons up to few MeV (as tested with ^{90}Sr source). This magnet fits easily inside normal beam line pipe and can be used if δ-rays are found to be problematic in future.

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