Characterization of a front-end circuit for SAMURAI Si detection system

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An array of silicon strip detectors will be installed between a secondary target and the Superconducting Analyzer for MUltiparticles from RAdioactive Isotope beam (SAMURAI) at RIKEN Nishina Center for experiments performed to study the Coulomb breakup reaction of proton-rich nuclei [1]. The reaction products of the experiment are a proton and the residual heavy particle. The scattering angle must be detected for both particles with high accuracy. Therefore, a total number of silicon-strip electrodes will be more than 600. The large number of signal channels will be handled by an ASIC (Application-Specific Integrated Circuit) system called HINP (Heavy Ion Nuclear Physics) [2].

In order to distinguish an emitted proton and the residual heavy particle in coincidence, a larger dynamic range is necessary than that can be provided by the HINP system. To extend the range, a preamplifier ASIC called DGCSA (Dual Gain Charge Sensitive preAmplifier) has been developed at RIKEN [3]. This article reports the results on the range obtained by using the DGCSA at the input stage of a signal and the HINP at the following stage.

A fastest proton in the experiment will deposit the energy of around 200 keV in the Si detector. The charge equivalent to the energy was injected using a pulser into the system consisting of the DGCSA and the HINP for 30 s with a frequency of 50 Hz. To take into account the effect of the capacitive load attributed to the detector and the cables, a capacitor of 70 pF was placed at the input stage. In similar way, the output pulse heights were recorded for the different amount of the charge in steps of 100 keV equivalent except for the case of 500 keV, where the injection lasted for 60 s to make the corresponding peak dominant. The results are shown in Fig. 1. The lowest peak was generated by the noise. The detection efficiency of less than 100% is indicated for the peak at 752 ch corresponding energy of 100

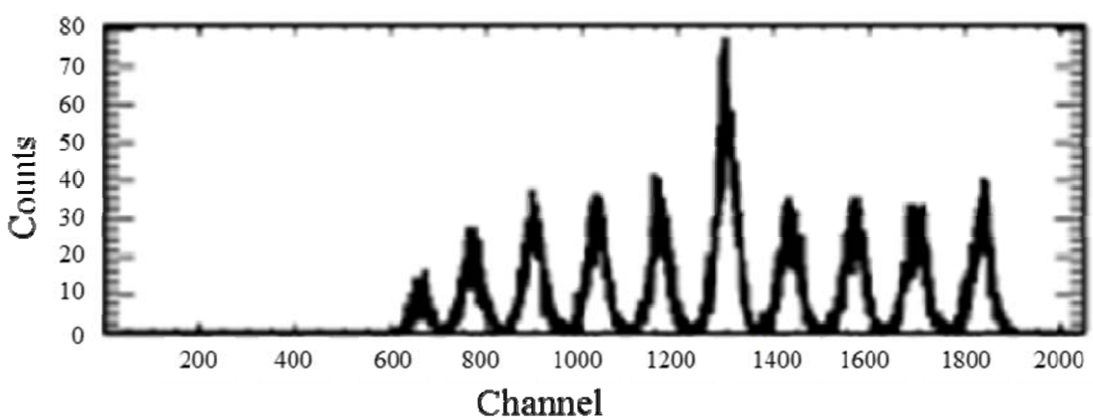

FIG. 1. The output pulse height for the charge injection using a pulser when the capacitive load was 70 pF.

keV because of its smaller counts compared with those for other peaks at larger channels. The result is consistent with the threshold of 762 ch estimated from the 5σ limit of the noise. The detection limit of lower than 200 keV is expected from this result

Another important parameter of the detection system is the higher detection limit of the energy. In order to enlarge the limit, the DGCSA employed a dual-gain system consisting of two charge-sensitive preamplifiers (CSAs). The result shown above was that obtained from the high-gain channel. Identical specifications were adopted for the two CSAs except for an FET that was installed in the high-gain channel. The dual-gain function was implemented by applying capacitive division to the input charge. The charge can be divided asymmetrically in proportion to the capacitance ratio of the two coupling capacitors and hence the range of the dual-gain system can be greater than that of the single-channel system as much as the ratio, if an input impedance of a CSA is negligibly small compared with that of the relevant capacitor.

The output pulse height of the system is shown as a function of the equivalent energy of the input charge in Fig. 2. For the high-gain channel given with red marks, the linearity between the energy and the pulse height degraded at the energy of less than 100 MeV as in the case of the single channel case. On the other hand, the range of the low-gain channel given with blue marks was larger than that was obtained for the high-gain channel about 10 times. The implementation of the dual-gain system successfully increased the range beyond the energy required for the detection of a heavy charged particle with the atomic number of 50. These tests were done at Texas A&M University using the ASICS system built for use with SAMURAI.

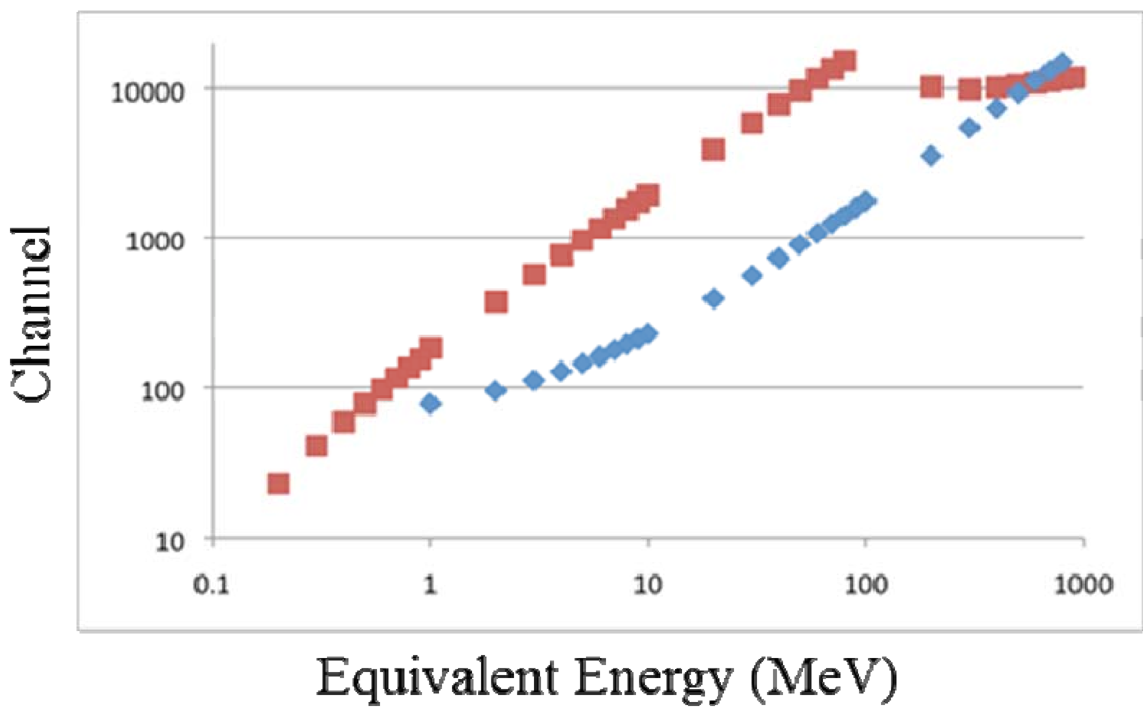

FIG. 2. Output pulse height of the system is shown as a function of the equivalent energy in MeV. The red and the blue marks indicate the results for the high and low gain channels, respectively.

In summary, the system consisting of DGCSA and HINP has been developed as a front-end circuit for SAMURAI Si detection system, which will be used for the Coulomb breakup reaction of proton-rich nuclei. The system is based on the ASIC chip and thus can handle enormous number of signal channels, which is necessary for the accurate measurement of the scattering angles of the reaction products. The lower and higher detection limits obtained for the system allows the coincidence detection of a proton and the residual heavy particle produced by the reaction of nuclei up to ^{100}Sn.

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[3] M. Kurokawa *et al*., RIKEN Acc. Prog. Rep. **44** (2011).