Development of a silicon detector array with large dynamic range

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We have developed an array of strip silicon detectors for the Coulomb beakup experiments with proton-rich heavy nuclei at intermediate energies. The breakup reaction, where the final state consists of one or two protons and the residual heavy charged particle, is an inverse reaction of the radiative proton capture and has been considered one of the most promising methods to extract the reaction rate of the capture process. The extracted rate gives us insight into the nucelosynthesis through the *rp* process, consisting of sequential proton captures on nuclei for producing heavier ones. The array measures the four momentum of each particle in the final state for specifying the excitation energy of the state along with the SAMURAI spectrometer. We plan to build an experimental setup capable of measuring the rates involving nuclei with masses up to 100.

The heaviest case is the breakup of a ^{101}Sb nucleus. The energy deposit of the breakup fragment ^{100}Sn is 50^2 times that of a proton. The dynamic range of the array must be larger than the difference in the energy deposit. The design value for the upper and lower detection limits were set to 1 GeV and 200 keV, respectively, after taking into consideration the possibility of the pile-up of events.

The total number of signal channels becomes more than one thousand for sufficient momentum resolution. In order to effectively treat such a large number of signal channels and to suppress the cost per channel, we need to employ the Application Specific Integrated Circuits (ASIC) technology for the array.

In view of the above requirements, we constructed an array consisting of newly developed preamplifier ASIC providing a large dynamic range by implementing high- and low-gain channels,[1)] another ASIC system called HINP for subsequent pulse shaping,[2)] and the silicon detector developed for the GLAST mission.[3)] The items in the following list were examined for the characterization of the array by irradiating the detector directly at the HIMAC facility .

(1) Linearity in the range from 390 keV to 300 MeV
(2) Cross talk between neighboring strips
(3) Yields of δ rays for the irradiation of heavy charged particles

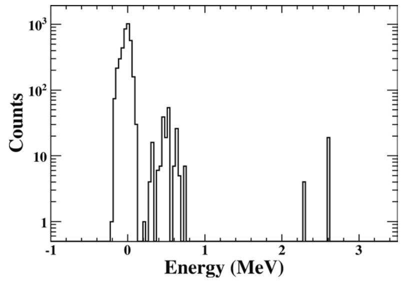

Fig. 1. Energy peak at around 390 keV obtained from the irradiation of a 150-MeV proton beam.

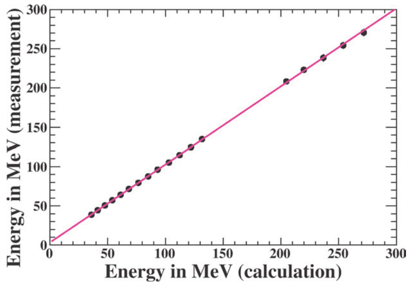

Fig. 2. Measured energy as a function of calculated energy. The slope of the line is 1.

The smallest energy deposit 390 keV was made by a 150-MeV proton beam(Fig. 1). For larger deposits, ^{56}Fe and ^{84}Kr ions were accelerated as primary beams and we selected secondary beams having a mass-to-charge ratio of two. The linear response of the low-gain channel shown in Fig. 2 indicates that the dual gain system of the preamplifier ASIC succeeded in extending the upper limit to higher than 100 MeV, which is the limit of the high-gain channel. The results obtained for the last two items will be used for the estimation of the background rates for the proton detection. The determination of the upper and lower limits is the subject for the next irradiation.

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