Particle identification using pulse shape discrimination in a nTD silicon detector with a 1 GHz sampling digitizer

K. Mahata,* J. A. Gore, A. Shrivastava,
S. K. Pandit, V. V. Parkar, A. Kumar, and P. Patale
Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA

Introduction

Particle identification using pulse shape discrimination (PSD) in Si detector has drawn considerable interest in recent years [1, and references therein]. It has certain advantages over the conventional ΔE-E technique. PSD technique allows particle identification using a single detector, whereas ΔE-E technique requires two detectors. Hence, use of PSD eliminates the requirement of thin ΔE detectors, reducing the number of electronic channels, cost and complexity. Further, the low energy particles, which are stopped in the ΔE detector, can not be identified using the ΔE-E technique, where PSD technique may still work.

The pulse shape in a Si detector depends on the length of the ionization track and ionization density, thus on mass, charge and energy of the incident ions. The time required to erode the plasma, produced due to ionization along the track, depends on the density of ionization and the electric field strength. The charge, escaping the plasma, move along the electric field towards the electrode. The drift time depends on the drift path and on the electric field strength. If the particles are injected from the rare side, where the electric field is low, both the plasma erosion time and the drift time increases with increasing charge and mass of the incident ions, thus it is more sensitive. However, particle identification using PSD required highly uniform resistivity Si crystal and fast pulse processing. PSD using nTD type Si and fast digitizer is under investigation worldwide. In the present experiment we have investigated the particle identification capability of a nTD Si detector using a indigenously developed FPGA based digitizer.

Experimental Details

The in-beam test experiment was carried out by bombarding ^{7}Li ions on ^{12}C, ^{89}Y and ^{197}Au targets at the BARC-TIFR Pelletron facility, Mumbai. A 500 μm thick 2 cm × 2 cm nTD Si pad detector was mounted in rear side injection mode with 6 mm collimator in one of the moving arm of the 1 m diameter scattering chamber. For comparison, a ΔE (33 μm)-E (300μm) telescope was also kept at the same angle on the other arm. Signal from the nTD Si detector was fed to a PACI preamplifier [2], which provides a charge as well as a current output. The charge output was digitized using a indigenously developed FPGA based digitizer with 1 GHz sampling speed and 12 bit ADC resolution [3]. Digitized samples were recorded for a time interval of 2 μs starting from 500 ns (pre-trigger) before the arrival of a external trigger. The Fig. 1 shows a typical pulse recorded during the experiment. The nTD Si detector and the PACI preamplifier were provided by IPN-Orsay, France. Signals from the ΔE-E telescope were processed using standard analog electronics and acquired using 13 bit peak sensing ADC.

Analysis and Results

The digitized pulses were analyzed offline using ROOT analysis framework. Rise time of the pulses were taken as the time difference between the 10% and 90% of maximum pulse height. A trapezoidal filter was applied to the recorded pulses to get the pulse height, which is related to the energy deposited by the incident particle. Effect of bias voltage in the range 150 V to 300 V was studied to find an optimum operating voltage. The energy and

*Electronic address: kmahata@barc.gov.in

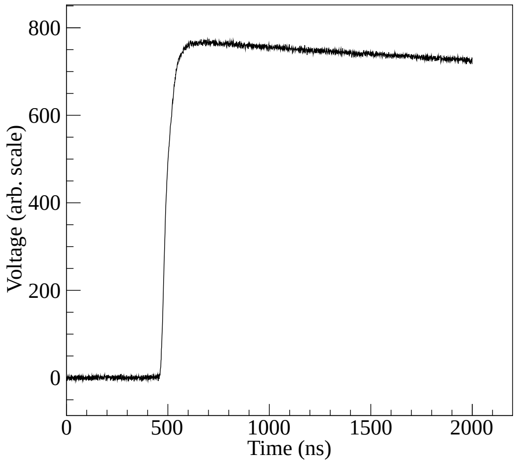

FIG. 1: A typical digitized charge output of the PACI preamplifier using the FPGA based 1 GHz sampling digitizer.

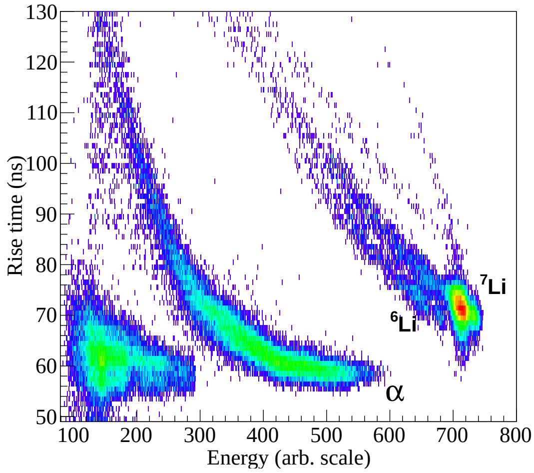

FIG. 2: Energy vs. rise time plot for the different reaction products in ^{7}Li+^{89}Y reaction. Bands corresponding to different particles are marked.

time resolution were found to improve with increasing bias voltage. However, the differences in rise time for different type of particles were found to decrease with increasing bias voltage. The optimum voltage was found to be 225 V, which is less than the full depletion voltage, 300 V. At 225 V bias voltage, the energy and time resolutions (σ) were 125 keV and 1.45 ns, respectively. Fig. 2 shows a two dimensional plot of energy vs. rise time for the reaction products from the reaction of 35 MeV ^{7}Li ions with ^{89}Y target detected using the nTD detector placed at 50° and operated with 225 V bias voltage. Different bands in Fig. 2 correspond to different type of particles. As can be seen from Fig. 2, particles having different Z, i.e. α and Li are widely separated and even a good isotopic separation have been achieved in case of Li isotopes. The lowest band in the Fig. 2 may corresponds to isotopes of Z=1. However, clear identification was not possible for Z=1 band. In case of ^{197}Au target, incident energy of 35 MeV corresponds to below barrier energy and only ^{7}Li band is observed. In case of C target, the beam energy was lowered to 20 MeV and the detector was moved to 20°. Discrete energy α peaks, corresponding to excited states of ^{15}N, were were observed in the high energy part of the α band in addition to the ^{7}Li band in case of C target.

Summary & Conclusion

Pulse shape discrimination capability of a nTD Si detector in rare side injection mode has been studied using a indigenously developed 1 GHz sampling FPGA based digitizer. Effect of bias voltage on PSD has been investigated to determine the optimum bias voltage for particle identification using PSD. Good isotopic separation have been achieved in case of Li ions. Particle identification capability of the nTD Si using PSD technique was found to be comparable to that of the ΔE-E telescope.

References

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