Digital pulse shape analysis for charged particle identification with a nTD silicon detector and 1 GHz sampling digitizer

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Introduction

Digital pulse shape analysis (PSA) for particle identification (PI) using Si detector is currently under investigation worldwide. It has certain advantages over the conventional ΔE-E technique, which is commonly used for PI. While ΔE-E technique require a thin (~ 50 μ) ΔE and a relatively thick (~ 500 μ) E detector, PI can be achieved in a single E detector by utilizing PSA technique. Hence, use of PSA technique eliminates the requirement of thin ΔE detectors. Further, the ΔE-E technique can not be applied for the low energy particles, which are stopped in the ΔE detector, where PSA technique may still work. It is proposed to use the PSA technique in most of the future charged particle detector array (*e.g.* GASPARD, FAZIA [1]) to reduce the number of channels, cost and complexity.

Charged ions while passing through a medium loses most of its energy near the end of the track (Bragg peak). The length of the track (range) and the density of ionization depend on the charge, mass 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. After the plasma is eroded, the charges drift along the electric field towards the electrodes. The drift time depends on the drift path as well as on the electric field strength. As a result, the pulse shape depends on the charge, mass and energy of the incident ion. If the particles are injected from the rear side, where the electric field is low, the heavier ions will be stopped nearer to the entrance creating denser plasma there as compared to the lighter ions. As a result both the plasma erosion time and the drift time will be larger for heavier ions as compared to the lighter ions. Thus the rear side injection make the PSA technique more sensitive. However, particle identification using PSA required highly uniform resistivity Si crystal and fast pulse processing. Earlier we have reported PI for ^{6,7}Li using PSA technique with a nTD Si detector and a indigenously developed FPGA based digitizer [2]. In the present experiment we have extended the measurement for heavier ions.

Experimental Details

The experiment was carried out by bombarding ^{7}Li and ^{12}C ions on ^{12}C,^{27}Al, ^{93}Nb and ^{197}Au targets at the BARC-TIFR Pelletron facility, Mumbai. A 500 μm thick 2 cm $\times$ 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 1.5 m diameter scattering chamber. The nTD Si detector was operated with 225 V bias voltage, which was found to be optimum for PI using PSA in an earlier study [2]. For comparison, a ΔE (33 μm)-E (300μm) telescope was also kept at the same angle on the other arm. Pulses from the nTD Si detector were processed using a PACI preamplifier [3], 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 [4]. Digitized samples were recorded for a time interval of 4 μs starting from 1μs (pre-trigger) before crossing of the threshold. The nTD Si detec-

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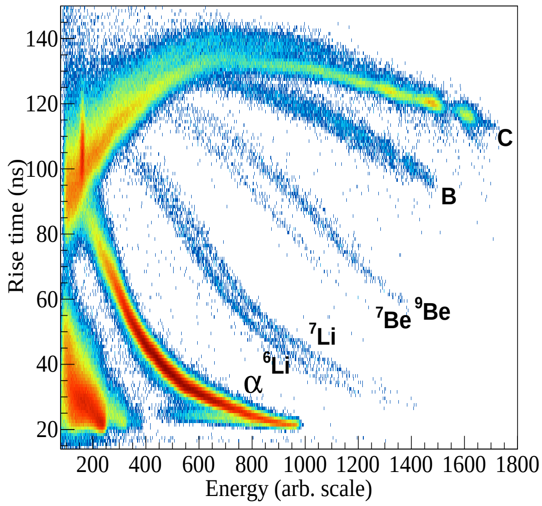

FIG. 1: Energy vs. rise time plot for the different reaction products in ^{12}C+^{27}Al reaction. Bands corresponding to different particles are marked.

tor 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 using ROOT analysis framework. Trapezoidal filters were applied to the recorded pulses to obtain pulse height and the rise time. The width of the Averaging interval of the trapezoidal filter was varied from 8 ns to 512 ns. The difference between the averaging intervals was kept as 256 ns. Height of the pulse after passing through the trapezoidal filter was taken as the energy of the incident ion and the rise time of the pulse was taken as the time difference between the 20% and 80% of maximum pulse height. The pulse height was found to be not very sensitive to the width of the averaging interval. While the 8 ns averaging width found to give better separation for Li isotopes, increasing the width of the averaging interval was found to improve the PI for heavier ions with larger rise time. Fig. 1 shows a two dimensional plot of energy vs. rise time for the reaction products from the reaction of 63 MeV ^{12}C ions with ^{27}Al target detected using the nTD detector placed at 30°. Different bands in Fig. 1 correspond to different type of particles. As can be seen from Fig. 1, good isotopic separation have been achieved in case of Li and Be isotopes. The PI obtained using PSA technique was found be comparable with the ΔE-E technique. The lowest band in the Fig. 1 may corresponds to isotopes of Z=1. However, clear identification was not possible for Z=1 band. It may require still lower operation voltage for isotopic separation in Z=1 band. For the heavier ions (B,C), different isotopes were not populated with sufficient intensities in present reaction. At lower energies all the band merge with each other. At these energies (E/A $\sim$ 1 MeV) the range of the ions are dominated by straggling and the pulse shape become independent of the ion charge and mass. It will be interesting to extend the measurement with higher energy and heavier beams.

Summary & Conclusion

Pulse shape discrimination capability of a nTD Si detector in rear side injection mode has been studied using a indigenously developed 1 GHz sampling FPGA based digitizer. Good isotopic separation have been achieved in case of Li and Be isotopes. Particle identification capability of the nTD Si using PSA technique was found to be comparable to that of the ΔE-E telescope.

References

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