Performance Study of Integrated ΔE-E Silicon Detector Telescope using Lohengrin Fission Fragment Separator at ILL, Grenoble

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Introduction

In depth studies of fission reactions require identification of fission products as well as precise measurement of their energies. Particle identification in these studies is usually done by a telescope in which two detectors are used in ΔE-E configuration for measurement of dE/dX and E. Experiment involving heavy fission fragments demand a ΔE detector with thickness of a few microns. Technological limitations in fabrication of detectors using conventional silicon etching techniques makes fabrication of thin, large area ΔE detectors extremely difficult. We have developed a novel silicon detector telescope in which the ΔE and E detectors are integrated on the same wafer [1]. The device structure and fabrication technology is suitable for fabrication of large area detectors of thickness of a few microns. Since the total detector thickness is more than 300 μm, the detector is rugged to handle and could be used for multidetector system involving large number of detectors.

The performance of the integrated ΔE - E detector telescope has been evaluated for light charged particles [1, 2]. The suitability of the detector for study of heavy fission fragments has been also examined [3]. The performance of the integrated ΔE - E detector telescope for fission fragments has been recently studied in detail using the Lohengrin fission fragment separator at Institute Laue-Langevin (ILL), Grenoble, France. This fission fragment separator can efficiently separate fission fragments according to their mass over charge ratio (A/q). The results of this study are presented in this paper. The results demonstrate the suitability of the integrated detector for identification of fission fragments and their energy measurement.

Experimental

To study the performance of the integrated ΔE–E detector telescope for identification of heavy ions with higher Z (fission fragments) and varying energy, experiments were carried out using Lohengrin spectrometer. Lohengrin provides the facility to select mass number, as well as energy of the particles produced as fission fragments [4]. It separates fission fragments of given A/q ratio onto parabolas by using the combination of a magnetic sector field and a cylinder condenser. The separator has energy dispersion along each parabola (A/q-line) and an A/q-dispersion perpendicular to the parabolas. By a suitable choice of the field strengths most of the particles of a chosen A/q-value, that is of a given parabola, are deflected into an exit slit of 72 cm length and of a variable width (0-18 mm). $^{235}UO_2$ target with Ti baking was used as a source for fission fragments in the present study and the source was placed very near to the core of high flux reactor (thermal neutron flux of 5 x 10^{14} n/cm^2s). For an integer value of A/q, a cocktail beam containing several mass numbers A, each with a kinetic energy E~A are available at a single point of parabola and hence, are incident on the detector surface. Experiments were carried out using two detectors of active area 100mm^2 and 50 mm^2. The ΔE thickness was 10μm. During experiments, the detector was mounted using a custom made arrangement in the vacuum chamber of spectrometer. The data acquisition system comprising of charge sensitive preamplifier, spectroscopy amplifier, coincident logic unit and ADC was used for recording signals in ΔE and E detectors. The detectors were also characterized for the measurement of energy resolution.

Results and discussion

Fig-1 shows the two dimensional spectrum obtained by plotting the energies (in terms of channel numbers) ΔE and E+ΔE = total E (E_T) for a fixed value of A/E_T. We note that for integer A/q ratios there exist several q spots with fission fragments of different mass numbers and energies having same A/E_T. Each such fission fragment is expected to appear in the form of a discrete spot in ΔE –E_T plot (for a fixed A/E_T) at a particular ΔE-E_T corresponding to its respective mass numbers. It is clear from the spectrum that the detector telescope can clearly distinguish each fission fragment having mass numbers A= 80,85,90,95 and 100.

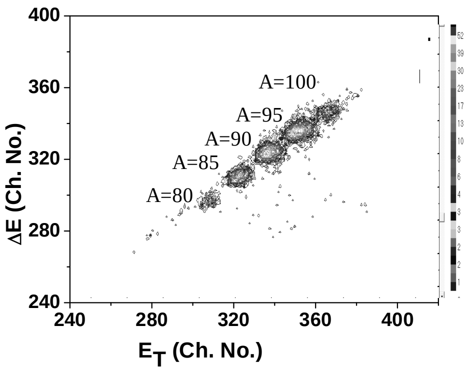

Fig.1 Two dimensional spectrum recorded by the integrated detector for fixed value of A/q=5 and A/E_T=1 MeV/nucleon

The complete scans for fission products for all values of A/E_T are presented in Figure 2 where plots between total energy and energy measured by ΔE detector have been plotted. As can be seen from the plot, each fission fragment is represented by a separate curve and hence can be easily identified even for varying A/E_T. Further, detector has been also characterized for its energy as well as mass number resolution.

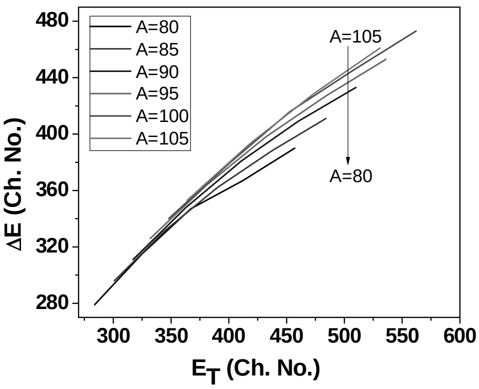

Fig.2. Plot between ΔE and E_T for different fission fragments of fixed A/q but varying A/E_T.

Full energy deposition in the ΔE detector is ensured by placing the telescope at an optimized angle. Incident beams of medium mass fission fragments (A=80 to 136) and of alpha particles from ternary fission of energies 4.7 MeV and 11MeV were used. The detector resolution is calculated by employing a linear relationship between total energy E and channel number of the form E = (a + a′A) X + b + b′A. The mass resolution ΔM is found to be almost constant with a value ~1.35 whereas the energy resolution of ΔE detector is found to be 1.33% and E detector 0.52%.

Conclusions

Performance of integrated ΔE-E detector for fission fragments has been studied using Lohengrin spectrometer. The results obtained demonstrate the suitability of the detector for fission fragment identification and their energy measurement.

References

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