In-beam Calibration of CsI(Tl) Detectors Using ^{12}C + ^{12}C Reaction

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Introduction

CsI(Tl) detectors are used extensively for detection of charged particles [1–3] due to their intrinsic ability to discriminate between various charged particles like α-particles, protons and projectile like particles. The light output of these detectors is composed of two components, a fast component (decay time of $\sim 0.6\mu s$) and a slow component (decay time of $\sim 3.0\mu s$). Different exciting particles have different intensities of these components and this property is used for particle discrimination. CsI(Tl) crystals can be synthesised in large sizes and in any shape to meet the requirement of experiment. The readout of these detectors can be taken directly from Si photodiode coupled to the crystal, thus, avoiding the use of large photomultiplier tubes inside the scattering chambers.

Although, these detectors have a disadvantage that, the amount of light produced by these scintillators depends on the energy, charge and mass of the particle interacting with the scintillator. So, their light response in not a linear function of energy and also particle type dependent. Therefore, it is not possible to extrapolate the calibration done for low energy alphas using standard ^{229}Th α-source to higher energies. Most of heavy ion induced fission reacions yield α-particles with energy upto 30 MeV and protons of energy upto 20 MeV but the known α sources can provide discrete α-particles of energy upto 8 MeV. So, an in-beam calibration of CsI(Tl) detectors is essential in order to perform α-particles spectroscopy where the energy of α-particles can reach upto 30 MeV. The in-beam calibration can be done using $^{12}C(^{12}C,\alpha)^{20}Ne$ reaction [1]. This reaction yields discrete α-particles corresponding to various excited states of ^{20}Ne.

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Experimental Setup

Sixteen CsI(Tl) crystals with dimensions of 2cm×2cm and 3mm thick were used for the detection of charged particles emitted during the fission of ^{210}Po compound nucleus populated through reaction ^{12}C + ^{198}Pt. The front surface of the CsI(Tl) crystals was covered with a $2\mu m$ Mylar foil, aluminized on both the sides. These 16 crystals were again grouped in set of four to form a complete detector. The experiment was performed in the scattering chamber of NAND facility at IUAC, New Delhi. After the experiment, the CsI(Tl) detectors were calibrated using the ^{229}Th α-source and then by the reaction ^{12}C + ^{12}C at energies of 30 MeV and 25 MeV. The ^{12}C target was 100μg/cm^2 thick and sandwiched on 50 micron thick Ta foil to stop the beam from contaminating the data. During the in-beam calibration run, the detectors were moved to the forward angles to take care of the kinematic energy spread. The data were taken in event by event mode and 2D particle identification plot (PID) [4] from CsI(Tl) were used to separate α-particles from other contaminations.

Data Analysis

The projected 1D alpha energy spectra from one of the CsI(Tl)crystals is shown in fig. 1.

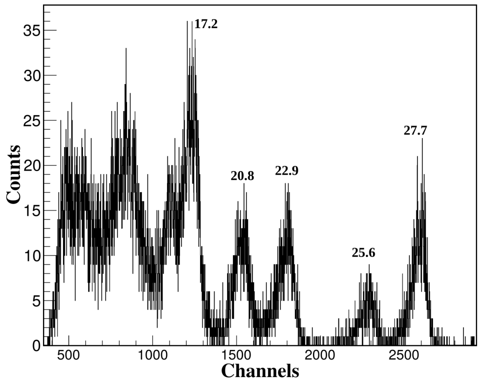

FIG. 1: Projected alphas from $^{12}C(^{12}C,\alpha)^{20}Ne$ reaction. Marked values are in MeVs

Energies of α-particles corresponding to various excited states of ^{20}Ne were calculated and these energies were corrected for energy loss in the Ta foil using the SRIM software [5]. Kinematic corrections were also applied to these energies. In order to approximate the energies of peaks in fig. 1, initial calibration of this spectra was done using ^{229}Th source. The measured energy calibration curve for a CsI(Tl) upto 30 MeV α-particles is shown in fig. 2(a). From this figure, it can be inferred that a linear function is not adequate to fit the points indicating a non-linear energy response of this detector. Fitting with a second order polynomial $(a_1 + a_1 * x + a_2 * x^2)$ is sufficient to explain the response of CsI(Tl) detector upto energy of 30 MeV. The calibration parameters obtained were used to calibrate the alpha energy spectra obtained from the reaction ^{12}C + ^{198}Pt, shown in fig 2(b).

Summary

The non-linearity of the light output of the CsI(Tl) detector in the energy region from $\sim$ 5 to 30 MeV has been measured for α-particles. The α-particles response from $\sim$ 5 to 8 MeV was measured using a ^{229}Th source and the response at higher energies was measured with α-particles emitted from the reaction $^{12}C(^{12}C,\alpha)^{20}Ne$ populating discrete states in ^{20}Ne. A second order polynomial can be used as a calibration function to fit the alpha energy spectra upto 30 MeV energy.

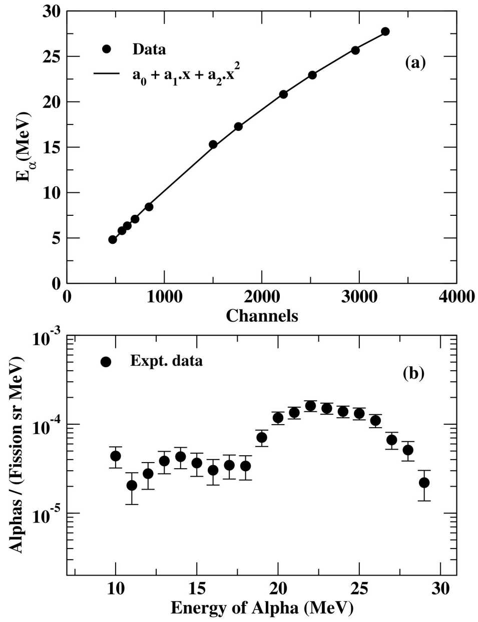

FIG. 2: (a) Calibration curve for a CsI(Tl) crystal. Calibration parameters obtained are $a_0 = -0.68136$, $a_1 = 0.011953$ and $a_2 = -1.0116 \times 10^{-06}$. (b) Calibrated alpha energy spectra.

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References

[1] K. Kapoor, et al., Phys. Rev. C **96**, 054605 (2017).

[2] K. Ramachandran, et al., Phys. Rev. C **73**, 064609 (2006).

[3] J. P. Lestone, et al. Phys. Rev. Lett. **67**, 1078 (1991).

[4] A. Jhingan, et al., Nucl. Intr. Meth. A **786**, 51-58 (2015).

[5] J.F. Ziegler, J. Biersack, U. Littmark, The Stopping and Range of Ions in Matter, Pergamon Press, 1985, www.SRIM.org.