Clover detectors set-up for the study of beta decay spectroscopy

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Introduction

The beta decay spectroscopy is conventionally studied using HPGe detectors. These HPGe detectors, with a typical volume of 100 cc, have very low photo-peak efficiency compared to the Clover detectors which have active volume 470cc. The primary advantage of using Clover detectors over conventional Ge detectors is the increased photo-peak sensitivity in add-back mode for gamma energies above 1 MeV. The clover detector consists of four closely-packed n-type hyper-pure germanium crystals in a common cryostat [1,2]. The signal from all four crystals may be added together to obtain the total pulse height for an incident gamma ray that scatters from one crystal to one or more of the other three crystals. This is so called add-back mode increases the photo efficiency of a Clover. The add-back efficiency is superior to the sum of the four individual's efficiencies.

We have set up a gamma-spectrometer comprising of two Clover detectors, to study β-decay spectroscopy using CIRUS reactor at BARC. In the present setup the gamma rays in singles mode can be measured with higher efficiency, and the γ-γ coincidence technique can also be used. The testing and characterization of the experimental set up has been carried out. The performance of the set-up is reported in this paper.

Experimental Setup

The experimental set up comprised of two Compton suppressed Clover detectors each having intrinsic photo peak efficiency ~ 0.2. Both the detectors are placed at a distance of 25 cm from the source, and the angle between them is 180°. The standard NIM modules are used to process energy and timing signals from Compton- suppressed Clover detectors. The shaping time of the spectroscopy amplifiers can be adjusted to 2μs, 3μs, and 6μs. The timing signals from individual crystals of each Clover detector are 'OR'ed, followed by 'VETO' from the Anti Compton Shield (ACS) signal, to get 'A_{coinc}' signal. The master gate for data acquisition system is generated OR'ing both 'A_{coinc}' signals from individual detectors. CAMAC based Data Acquisition System is used in the set up. BARC made13-bit, CM-88 ADCs are used to digitize the energy and the TAC signals. Data read out and buffering are accomplished by BARC-made CC-2000 Crate Controller. The multi-parameter data acquisition program LAMPS [3] is used for data acquisition.

Results and discussions

The characterization of the set-up, Energy resolution, Peak to total ratio, full energy peak detection efficiency, and add-back factor has been carried out. The γ-ray spectra were obtained in list mode using ^{60}Co and ^{152}Eu radioactive sources. The energy resolutions and The Peak-to-total ratio P/T of both the Clover detector in direct and add-back modes determined for shaping time of 6μs are given in **table.1**. In the add-back mode we get a resolution of ~ 2.5 keV at 1332 keV, which is slightly more than that of individual crystals in direct mode. The Peak-to-total ratio improves to ~ 0.40 in add-back mode compared to the value 0.21 measured in the direct mode for individual crystals. The measured timing resolution of the Clover detectors was 15ns. The Full Energy Peak (FEP) detection efficiency of the set-up is shown in **Fig.1**. the direct The FEP detection efficiency in direct mode and add-back mode has been normalized.

Clover 1 (SN 77)		
	FWHM (keV) at 1332 keV	Peak to total ratio
Crystal 1	2.13	0.20
Crystal 2	2.04	0.21
Crystal 3	1.97	0.21
Crystal 4	2.07	0.21
Add-back mode	2.43	0.41
Clover 2 (SN 78)		
	FWHM (keV) at 1332 keV	Peak to total ratio
Crystal 1	2.31	0.19
Crystal 2	1.99	0.21
Crystal 3	1.99	0.19
Crystal 4	2.25	0.21
Add-back mode	2.52	0.38

Table.1. The energy resolutions and Peak-to-total ratio P/T of both the Clover detector in direct and add-back modes

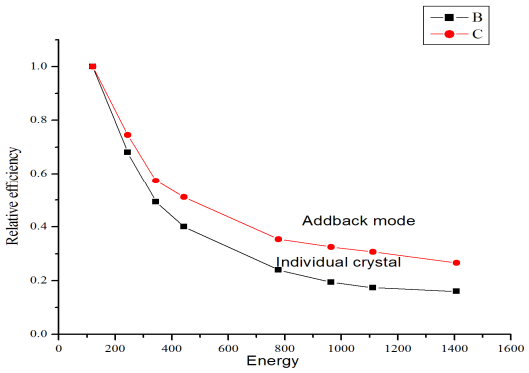

Fig.1. The normalized gamma ray detection efficiency as a function of energy.

The FEP detection efficiency for Eγ > 300 keV clearly shows an enhancement in add-back mode over the sum of FEP detection efficiency of all four crystals in the direct mode. The FEP detection efficiency in add-back mode increases with energy due to the add-back factor F. The add-back factor F, which is a measure of the enhancement in the Full Energy Peak (FEP) efficiency of a gamma-ray of energy Eγ, is defined as the ratio of the FEP detection efficiency in the add-back mode to that in the direct mode. The add-back factor for both the clover detectors is shown in **Fig.2.**

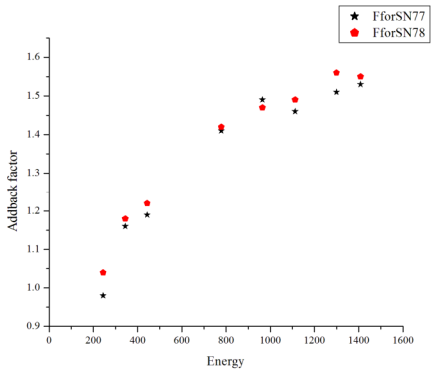

Fig.1. The add-back factor as a function of energy.

The β^-decay of ^{139}Ba has been studied using the present set up. The radioactive sources of ^{139}Ba were obtained from the ^{138}Ba(n,γ)^{139}Ba reaction from Pneumatic Carrier Facility at CIRUS reactor, BARC. The experimental results are submitted in this symposium [4].

Summary

The testing and characterization of the gamma-spectrometer comprising of two Clover detectors to study β-decay spectroscopy has been reported in this paper. The set-up is planned to up-grade with two more Clover detectors in future.

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References

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