Investigation of reduction in background counts of clover detector

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Introduction

The peak-to-total ratio [1] can be improved by increasing the full energy peak (FEP) counts and/or by decreasing the background counts. It is notable that FEP counts will be effected by mode of operation, while background counts will be effected by both modes of operation and suppression cases. It would be interesting to know if the reduction in background is caused more by active suppression or by addback process. We introduce a simple formalism to investigate the reduction of background counts for different cases - single crystal or addback mode with active or passive suppression [2]. A more sophisticated formalism for modeling a general composite detector had been presented in a series of six recent papers by the author [3].

Formalism and Results

A. Considerations with total background

If we consider the case of single crystal mode (sc) for a clover detector with passive suppression (P), where b and p are the background counts (including escape peak counts) and the sum of all FEP counts in the spectrum, respectively, then the peak-to-total ratio (r) for this case is given by

$$r^P_{sc} = \frac{p}{p+b}. \tag{1}$$

For the addback mode ($adbk$) with passive suppression (P), the peak-to-total ratio is given by

$$r^P_{adbk} = \frac{p+\alpha}{(p+\alpha)+(b-\beta)}, \tag{2}$$

$$= \frac{p+\alpha}{p+b-(\beta-\alpha)}. \tag{3}$$

where β is the number of counts removed from the background while α is the number of counts from background which is added back to the FEPs due to the addback process. It should be noted that there are cases where multiple background counts from the single crystal mode spectrum correspond to a single count in the addback mode spectrum so that $\beta > \alpha$. In the case of active suppression (A), the peak-to-total ratio from the clover spectra in single crystal and addback modes are respectively given by

$$r^A_{sc} = \frac{p}{p+b-\kappa}, \tag{4}$$

and

$$r^A_{adbk} = \frac{p+\alpha}{p+b-(\beta-\alpha)-\kappa}, \tag{5}$$

where κ is the number of counts removed from the background due to the active suppression.

From the above equations, the fractional change in background counts (say F_{bkd}) due to addback only is $-\frac{\beta}{b}(=\frac{(b-\beta)-b}{b})$ and is $-\frac{\kappa}{b}(=\frac{(b-\kappa)-b}{b})$ due to active suppression alone. The value of F_{bkd} due to both addback and active suppression is $-(\frac{\beta+\kappa}{b})$. The effects due to addback and active suppression can be quantified from the values of F_{bkd}. Lower values of F_{bkd} mean better performance of the detector system.

Using a radioactive ^{11}Be beam, we performed an experiment at TRIUMF with seven TIGRESS detectors and BAMBINO detector [2]. The β^- decay of ^{11}Be ($\tau_{1/2} = 13.81(8)$ sec) produces high energy gamma-rays up to 7974 keV, which was used to get the high energy data. From the ^{11}Be coincidence data, values of F_{bkd} have been extracted and are shown in

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figure 1. The experimental value of $\frac{\beta}{\alpha}$ is found to be 3.970(1).

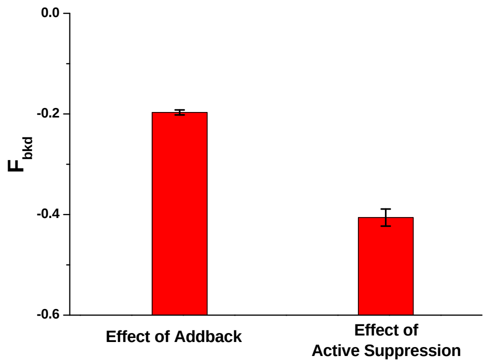

FIG. 1: F_{bkd} from ^{11}Be coincidence data.

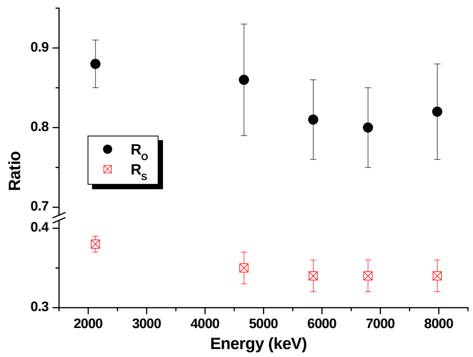

FIG. 2: Variation of the ratios R$_O$ and R$_S$ as a function of gamma energy.

Comparing the experimental values of F_{bkd} for different cases, we observe that the reduction of background counts is more due to the active suppression than the addback process. A possible explanation is - with increasing gamma-ray energy, the probability of full energy peak absorption decreases while the possibility of scattering of gamma-rays out of the TIGRESS detector increases. This causes the decrease in the value of β. The increased number of escaping events detected by the escape suppression shield causes an increase in the value of κ. As a result, with increasing gamma-ray energy, β/b decreases while κ/b increases.

B. Considerations with background due to escape peaks

Let us define the following two ratios R_O and R_S for a gamma-ray of energy E_γ:

$$R_O(E_\gamma) = \frac{area\ of\ SEP\ and\ DEP\ (Addback\ mode,\ E_\gamma)}{area\ of\ SEP\ and\ DEP\ (Single\ crystal\ mode,\ E_\gamma)}$$

$$R_S(E_\gamma) = \frac{area\ of\ SEP\ and\ DEP\ (Active\ suppression,\ E_\gamma)}{area\ of\ SEP\ and\ DEP\ (Passive\ suppression,\ E_\gamma)}$$

Similar ratios considering peak-to-total ratios have been sucessfully used for performance comparisons in our recent works [2, 3]. In figure 2, we have showed the variation of the ratios R$_O$ and R$_S$ for several gamma energies. Due to large errors, the behaviour seems to be independant of energy. The average values of ratios R$_O$ and R$_S$ are 0.8 and 0.35, respectively. These results show that that the escape peaks are decreased more due to active suppression compared to addback mode. Same result is also observed earlier when we considered the total background counts, indicating the generality of the observation for the TIGRESS detector.

References

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