Wavelet analysis for particle identification using CsI(Tl) detectors

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Introduction

Heavy-ion fusion evaporation reactions are used commonly to study the high-spin states of nuclei. In these experiments, different charged particles, like, alpha and proton are emitted from the excited compound nuclei. Different exotic nuclei with quite low cross-sections can be populated in the charged particle emission channel. These isotopes remain the focus of the contemporary nuclear structure studies. Large array of Compton suppressed High-Purity Germanium (HPGe) clover detectors coupled to a 4π-charged particle detector array will be an efficient tool to study isotopes produced with low cross-sections through charged particle emission channels [1]. In addition, large segmentation of the 4π-charged particle detector array will improve the resolution of the gamma rays from the thin target experiments through better estimate of the momentum of the recoils [2].

The thallium-activated cesium iodide (CsI(Tl)) crystal coupled with a light guide and photodiode is one of the compact size detector system being used in various 4π charged particle detector arrays (CPDA) [2, 3]. This detector is capable of discriminating various particles based on their pre-amplifier pulse shape. A 4π charged particle array containing eighty CsI(Tl) detectors will be used along with Indian National Gamma Array (INGA). A number of detectors from the array have been tested to evaluate their performance using digital data acquisition system.

To identify the low cross-section reaction channels, it is required to discriminate between the signals obtained from γ, α, p and other charged particle channels. Thus particle identification (PID) is one of the most important parameters in these kind of experiments. The rise time of this processed signal will be different for different particles and hence can be used for particle identification. The present work reports PID based on the wavelet transform of the pre-amplifier signals [4]. This will help in the optimization of the DSP algorithm for the CPDA.

Experimental Details and Results

^{60}Co and ^{239}Pu sources were placed in front of the CsI(Tl) detectors, placed inside a vacuum chamber. The pre-amplifier signal was fed into one of the channels of the 100 MHz Pixie-16 system [5]. The pulse shapes were stored in the digitizer with trace length of 5 μsec. Fig. 1 shows two such pre-amplifier pulses, first pulse showing the interaction of α in CsI(Tl) and the second pulse showing the interaction of γ in CsI(Tl).

The baseline of the pre-amplifier signal is first brought to zero level. Then the modified pre-amplifier signal is normalized. The wavelet transform then decomposes the normalized signal over dilated and translated wavelets. The wavelet transform of a signal f(t) is defined as

$$W_f(a,b) = <f, \psi_{a,b}> = \int f(t)\frac{1}{\sqrt{a}}\phi(\frac{t-b}{a})dt \quad (1)$$

where ψ is the wavelet function. Here, the 'Haar' wavelets have been used. $f(t)$, a and b are the normalized preamplifier signal, scale and shift respectively. A scale function $P(a)$

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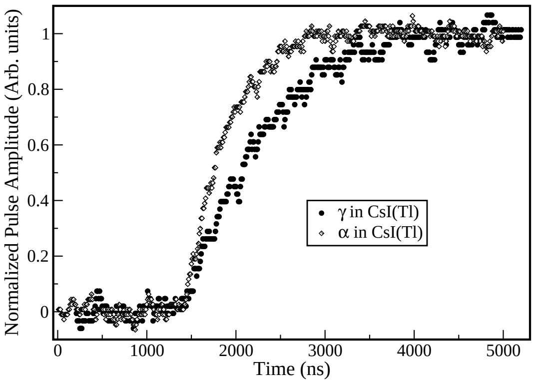

FIG. 1: Pre-amplifier pulses, one from the interaction of α in CsI(Tl) and the other from the interaction of γ in CsI(Tl).

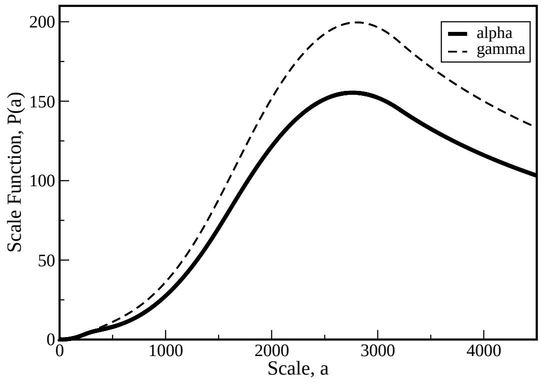

FIG. 2: Plot of scale function versus scale for alpha particles and gamma rays.

defined as

$$P(a) = \frac{1}{(1+n_b)} \Sigma_{j=0}^{n_b} |W_\psi^s(a, b_j)|^2 \qquad (2)$$

is the energy of the wavelet transform of the signal at a specific scale and with different shifts. As evident from the Fig. 2, the scale functions provide a good separation between α-particles and γ-rays. The scale functions of 1000 normalized signals each for α and γ have been used to determine the two discrimination parameters $f1 = P(a)|_{a=1024}$ and $f2 = \frac{P(a)|_{a=4096}}{P(a)|_{a=1024}}$. Figure. 3 shows the scatter plot for alpha particles and gamma rays with f2 vs f1.

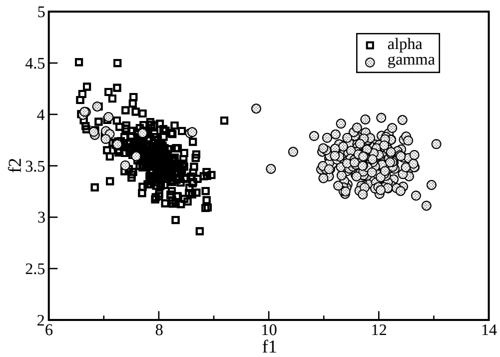

FIG. 3: Plot of f2 versus f1 for alpha particles and gamma rays.

Summary and Conclusion

The wavelet transform has been successfully utilized for the alpha-gamma discrimination in CsI(Tl) detectors. In-beam experiments are planned in future to test the performance of the wavelet technique in obtaining the PID and compare its figure of merit with that of the rise time differentiation technique of the pulses.

References

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