Signal Noise Filtration of Gamma Tracking Detectors Using Empirical Mode Decomposition Method

Davinder Siwal[1]*, Vinita Suyal[1], A. Prasad[1], S.K. Mandal[1], R.Palit[2], R. Singh[3]
[1]*Departmet of Physics & Astrophysics, University of Delhi, Delhi-110007, INDIA*
[2]*Tata Institute of Fundamental Research, Mumbai-400005, INDIA*
[3]*Amity Institute of NST, Amity University, NOIDA, INDIA*
** email: dev84sonu@gmail.com*

Introduction

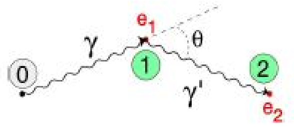
Understanding of nuclear excitation modes is one of the principal aims in nuclear structure studies. These excitations are produced by a nuclear reaction which populates the nucleus with finite excitation energy and angular momentum. If the excitation energy is less than 8MeV then it decays by emitting finite number of gamma rays.

The present accelerator facilities with stable ion beams and the gamma arrays used to study nuclear structure. These arrays are based on Escape Suppression Technique. This technique suppresses the large Compton background and enhances the possibility to detect weak gamma lines. This technique can improve the photopeak efficiency up to around 10% with peak to total ratio around 60%.

The future 4π- gamma arrays will use highly segmented Germanium detectors such as AGATA [1] and DESPEC [2] detectors which will be based on Pulse Shape Analysis (PSA) and gamma tracking algorithms. According to the idea of tracking detector, instead of rejecting gammas that lie in Compton region (using suppression shield), there is a possibility to track those Compton scattering events by finding positions and respective energies deposited. Thus, one can reconstruct the full gamma energy absorption events. In addition to energy reconstruction it also finds the position of localized source by finding emission angle from which finer Doppler correction can be made in the observed peak.

Pulse Shape Analysis

The Compton scattering equation gives one to one relationship between the scattering angle and the energy of the scattered gamma ray as shown in Fig.1 By knowing the scattering angle (θ) the energy of the scattered gamma ray can be calculated using Compton Scattering kinematics. More precise pos-



$$E'_{\gamma} = \frac{E_{\gamma}}{1 + \frac{E_{\gamma}}{m_0 c^2}(1 - \cos\theta)}$$

Fig1. Compton scattering of gamma ray (where symbols have their usual meaning)

-ition information gives better energy resolution in the reconstructed photopeaks.

The gamma tracking detector uses the germanium crystal with high granularity and give two types of signals. One is the core signal which is given by Compton scattered or photopeak gamma events and other are mirror signals which appear in the neighboring segments. By using these signals we can find out the 3-dimensional co-ordinate information of the point of interaction.

The mirror signals in the neighboring segments exist for duration of the transit time of the charge carriers in the main segment. These signals show higher amplitudes when interaction takes place near a main segment. The mirror signal has a poor signal- to-noise ratio due to fewer information carriers and is seriously affected by ohmic currents and thermal noise. Therefore, in order to get good co-ordinate information one needs to perform noise filtration of these signals. The present work reports a new technique based on EMD method to analyze the signal from a planar segmented detector.

Empirical Mode Decomposition

The Empirical Mode Decomposition [3] (EMD) method is a well known technique used for signal decomposition in non linear physics area of research.

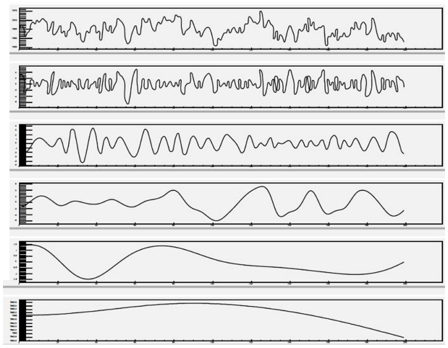
An attempt is made to remove unwanted periodic signal from the mirror signal.

In this technique whole signal is decomposed into a complete set of orthogonal functions known as Intrinsic Mode Functions (IMFs). Each one of these IMFs represents an oscillation mode which is embedded in the whole signal such that the oscillation frequency can be found out by Hilbert transformation. Each IMF satisfies two conditions:

1. In the whole signal, the number of zero crossings and extrema either differ by one or zero.
2. The mean of envelopes defined by local maxima and local minima are zero.

The decomposition method uses the envelope defined by local maxima and minima separately from the given signal. All the maxima and minima are then combined by cubic spline function. If m_1 is the mean of upper and lower envelope, the difference between data set X(t) and m_1 is the first component h_1. Treating h_1 as new data set the same process is repeated until h_1 satisfies IMF conditions. Higher IMFs can be calculated by taking the difference between X(t) and h_1 and repeating the above procedure. The Empirical mode decomposition of mirror signal is shown in Fig.2

Amplitude (Arb Units)



Time (Arb Units)

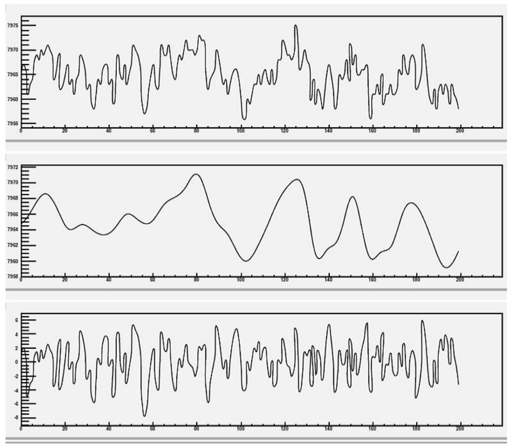
Fig2. First box shows mirror signal and the remaining boxes show the different IMF of mirror signal.

Fig.3 shows the filtered (middle diagram) signal which we can get by removing first two IMF's from the mirror signal

Summary

The analysis shows that EMD method can be used for noise filtration purpose [5] for periodic signals. With this new approach we can explore the position resolution of gamma tracking detectors.

Amplitude (Arb Units)



Time (Arb Units)

Fig3. Actual mirror signal (top), filtered signal (middle), Noise signal (bottom)

Acknowledgment

This work is a part of DESPEC FAIR Collaboration project. One of author (DS) would like to thank Joern Adamczewski-Musch (GSI) for data unpacking in Go4[4] and Jürgen Gerl (GSI) for providing the scanned data. He is also thankful to CSIR and DST for awarding the fellowship and providing funds for GSI trip respectively.

References

[1] http://www-win.gsi.de/agata/reports.html
[2]http://www.gsi.de/fair/experiments/NUSTAR/hispec_e.html
[3] N.E. Huang et.al, Proc. R. Soc. Lond. **A 454**, p903-995 (1998)
[4] http://www-win.gsi.de/go4/
[5] Davinder Siwal et.al, Under Preparation