Deconvolution of Neutron TOF Data

Golda K.S.* and R.K. Bhowmik
Inter University Accelerator Center, Aruna Asaf Ali Marg, New Delhi - 110067
** email: golda@iuac.ernet.in*

Introduction

It has been very well established that pre-scission neutron multiplicity is an elegant tool to study the dynamics of heavy ion induced fusion-fission reactions. Neutron Time of Flight (TOF) spectrometers have been extensively used since early eighties to study the fusion-fission dynamics as a 'Clock' for establishing the time scale for nuclear processes [1]. Precise measurement of neutrons which are emitted at different stages (thus giving the clue about the dynamics of such reactions) of reaction between heavy ions in conjunction with the heavy fragments provide exclusive data and a unique possibility to explore the complex nuclear processes involved in heavy ion collision. The disentanglement of time scales of quasi-fission from fusion fission reactions from the shape of the pre-scission neutron multiplicity distribution has added a new dimension to our understanding on reaction dynamics[2].

To be able to acquire such high precision exclusive data, a large array of neutron detectors is currently under development at Inter University Accelerator Centre. It consists of around one hundred 5″ (diameter) × 5″ (length) liquid scintillators at 1meter flight path[3]. Usually large flight path and neutron detectors of short length are used to obtain good spectral resolution. A disadvantage of such facilities is the low efficiency of the detecting system. Since the primary objective of our facility is to measure high-fold neutron-fission coincidences with high statistics to extract the higher moments of the fold-distribution, the geometry of the array has been optimized for high efficiency and good granularity.

A new approach in the analysis of the neutron TOF experimental data has been developed to extract good spectral resolution from high efficient TOF spectrometers with limited flight path. This method will allow performing measurements with higher efficiency owing to the large detector volume and larger solid angle.

Methodology

The energy of neutrons emitted in a typical heavy ion induced reaction follows a Maxwellian distribution. Hence the experimentally measured neutron TOF spectrum has a continuous distribution. In the conventional data analysis method the experimental TOF data is first binned as per the spectral resolution of the detecting system and there after converted into energy by applying proper Jacobian. The energy dependent intrinsic detector efficiency correction is applied to these discrete energy points to construct the final energy distribution. This method can give rise to incorrect shape of the energy distribution if the thickness of the detector is large in comparison with the flight path. As the pre- and post-scission multiplicities are extracted by fitting the energy distribution using moving source approximation[4], an incorrect shape of the energy distribution is a matter of great concern.

In the new method, the experimental TOF data has been binned to get a set of representative points. These representative data points have been converted into energy by considering proper Jacobian. A cubic spline fit to the obtained energy points gives a continuous energy distribution with a resolution of 10keV/channel. This energy distribution has been folded back to get TOF data by adjusting the ordinate to reproduce the experimental TOF spectrum. The incorporation of detector resolution as a result of the finite thickness and response function of the detector are included in the deconvolution procedure. The individual energy points and their errors have been adjusted iteratively to reproduce the best χ^2 fit to the experimental TOF data. The flowchart of the procedures followed is given in Fig. 1.

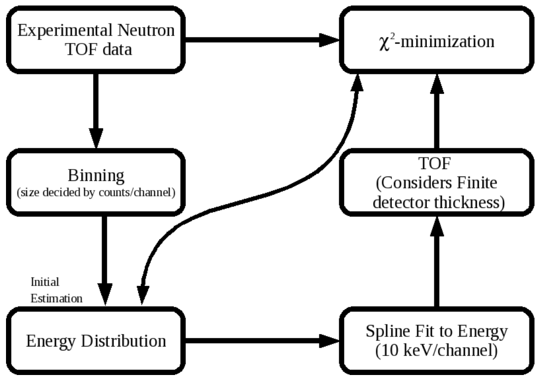

Fig. 1 Flow chart of the data analysis method adapted.

Results and Discussions

To establish the new data analysis method we have made use of the experimentally measured neutron TOF data from the fusion-fission processes induced by ^{12}C+ ^{194}Pt systems at 82MeV [5]. The data collected at 1meter and 2meter flight path by 5″ × 5″ detectors which were placed at the same angles with respect to the respective fission detectors were compared. The time resolution of the detecting system was obtained from the width of the gamma peak. Fig.2 and Fig.3 compares the folded back TOF distribution with the experimentally obtained ones for each of these detectors. We have optimized the initial TOF bin sizes for different flight paths based on the statistics of the data for generating the representative points. Figures show that the folded back TOF distribution very well represents the experimentally measured one.

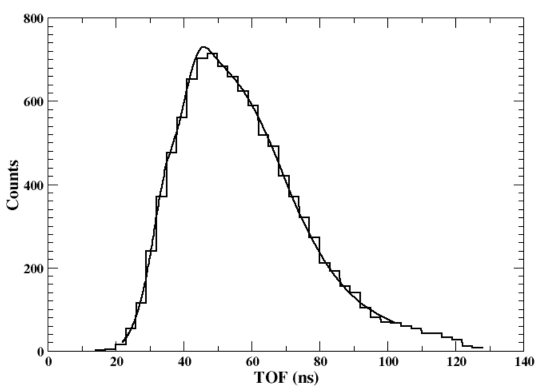

Fig. 2 The folded back TOF (continuous line) is compared with experimental TOF distribution (histogram) for 1m flight path.

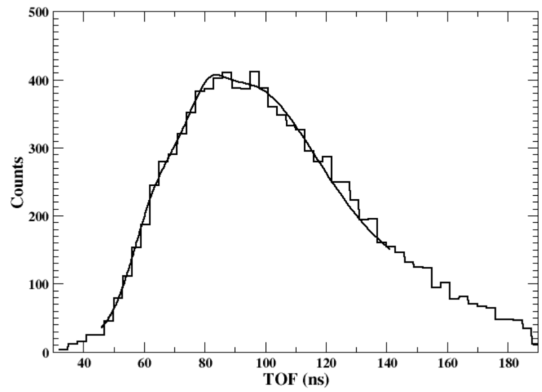

Fig. 3 The folded back TOF (continuous line) is compared with experimental TOF distribution (histogram) for 2m flight path.

The deconvoluted energy distribution obtained from both the detectors match well within the experimental error as shown in Fig.4 which supports the authenticity of the TOF data analysis approach presented here.

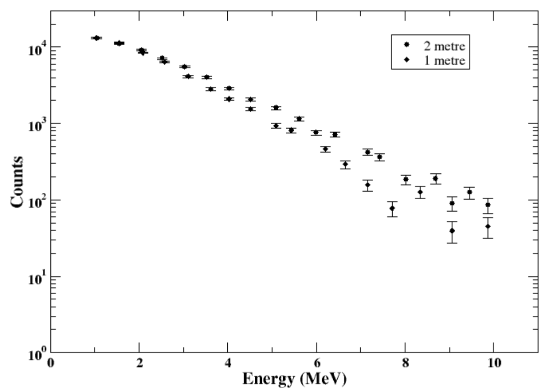

Fig. 4 Neutron energy distribution extracted from 2m & 1m flight path TOF data.

References

[1] D.J. Hinde, et.al. Nucl. Phys, A 452 (1986)550.

[2] L. Donadille et al, Nucl. Phys. A 656 (1999) 259.

[3] R.K. Bhowmik, et.al. Techical Proposal, 1R/S2/PF-02/2007, DST, New Delhi

[4] Th. Keutgen, et.al. Phys. Rev. C 70, 014611 (2004)

[5] Golda K.S., et.al Communicated to DAE-BRNS Symp. Nucl. Phy. 2010