Neutron Pulse-Shape Discrimination and Time – of – Flight Measurements with a Digital Oscilloscope

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Introduction

Neutrons are charge-neutral particles and hence their detection is more complicated than that of charged ones. They are non-ionising radiation and hence their energies have to be measured in an indirect manner. The most common way of doing so is by elastic collision of a neutron with a nucleus of comparable mass and measuring the energy of the recoiling charged nucleus. Therefore, hydrogenous materials constitute most of the neutron detectors.

All neutron-sources usually also emit gamma rays to which the detectors are sensitive. So we need to distinguish neutron events from photons. There are two primary techniques which are used namely Time of Flight (TOF) method and Pulse Shape Discrimination (PSD). Both the methods are widely used and complement each other.

We have already tested our neutron detectors utilising both these techniques using analogue electronics. Moreover we had also generated a preliminary PSD algorithm using the digitised neutron – gamma pulses utilising a digital oscilloscope [1].

The aim of this work is to understand Digital Signal Processing techniques in more detail by testing the applicability of a digital oscilloscope in neutron spectroscopy. We have also utilized DSP for measurement of time differences in a Time of Flight set-up. Later simultaneous measurement of PSD and TOF helped us to complement and test the veracity of the results produced by these methods.

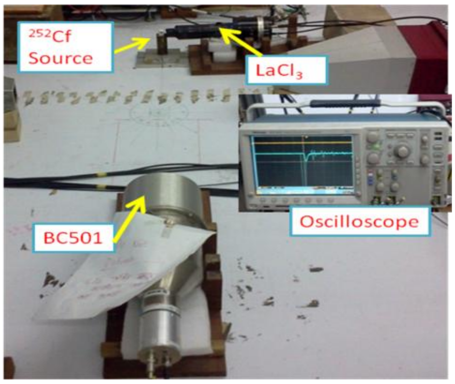

Fig. 1 The experimental set-up

Experimental Details

Our experimental set-up consisted of two scintillators, one of them is a liquid scintillator BC501 detector and the other one is a (1″×1″) $LaCl_3$. The liquid scintillator was placed at a distance of 100 cm from the source. Later the distances were also changed for TOF measurements. The $LaCl_3$ was used to generate start trigger for TOF. So it was kept it close to the ^{252}Cf source. A digital oscilloscope Tektronix DPO4032 was used to acquire the data. Further details of data acquisition have been discussed in Malik et al. [2].

Results and Analysis

We have already verified the suitability of the digital oscilloscope for energy measurement [2] and pulse shape discrimination [1]. Similarly, we have also tested the suitability of a digital oscilloscope for time measurement in nuclear spectroscopy.

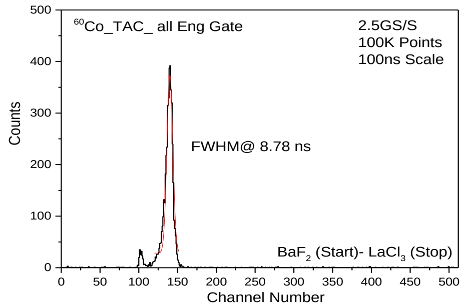

Fig. 1 Preliminary time difference spectrum

Timing measurements

To start with, we have used two scintillators and generated the time difference spectrum using the Delay measurement option from the Automatic Measurement menu of the oscilloscope. Two channels of the oscilloscope corresponded to the two preamplifier signals of the scintillator triggered by the first detector signal (BaF_2 in Fig.1).

Later the time difference spectra were validated by varying the relative delay between the two channels by using a nano-second delay box in the circuit. Reliable linearity of the time differences was observed (Fig.2) from the acquired spectra.

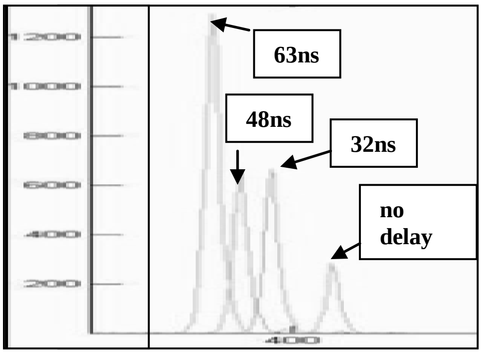

Fig. 2 Shift in peak positions with varying delay

Pulse shape Discrimination

Starting with the algorithm developed earlier [1], several other algorithms were tested to separate out the gamma-neutron mixed events from the liquid scintillator most efficiently. Data were taken with both ^{252}Cf (gamma+ neutrons) as well as ^{137}Cs (gamma) sources. One of the representative spectra is shown in Fig. 3.

Time of flight measurements

TOF data have been collected for three different distances between the source and the neutron detector. The pulse / waveforms of the events from the detector have also been saved simultaneously. This will give us a unique opportunity to do PSD analysis of the pulses corresponding to neutron peak in the TOF spectrum to study the neutron pulses from this detector with more precision.

Future

Combining TOF and PSD analysis, the neutron and gamma pulses can be clearly separated. This will help us to study these pulses more accurately and search for the best fitted functional forms for them to improve accuracy and precision of neutron detection.

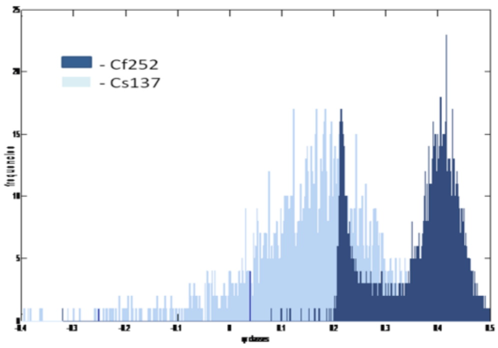

Fig. 3 Overlapping PSD histograms generated with events from ^{137}Cs and ^{252}Cf source

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References

[1] Anirudh Chandra et al., Proc. of the DAE Symp. on Nucl. Phys. 58 (2013) 938.

[2] Tuhin Malik et al., *al.*, contributed to the DAE Symp. on Nucl.Phys. (2014)