Suitability of Digital Signal Processing for LAMBDA spectrometer

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Introduction

In recent past, a Large Area Modular BaF_2 Detector Array (LAMBDA) [1], consisting of 162 BaF_2 detector elements, has been developed in house at Variable Energy Cyclotron Centre (VECC), Kolkata. This detector array along with its dedicated analog CAMAC modules and VME based data acquisition system has been efficiently employed to measure the high energy γ-rays (upto 100 MeV) in a number of recent experiments [2, 3]. The analog electronic system is quite capable of discriminating neutron-gamma events and pile up events by Time-of-Flight (TOF) and Pulse Shape Discrimination (PSD) techniques, respectively. However, the system suffers from three crucial drawbacks; firstly, the charge sensitive QDC, used for extracting the energy information, has a dead time $\sim 7\mu$s; secondly, the analog modules are endowed with drift owing to the change in ambient temperature and line voltages; thirdly, a large number of analog modules are required to accommodate all the detector elements leading to a bulky and importable system; also, high density modules are becoming obsolete day-by-day. Interestingly, a Digital Signal Processing (DSP) system, which directly discretises the time varying pulse from Photo Multiplier Tube (PMT) or any amplifying modules and processes thereafter, is devoid of the above mentioned shortcomings and can be integrated with LAMBDA spectrometer. But the main difficulty lies in the fact that the rise-time of the PMT pulse of the BaF_2 detector is $\sim$2ns and the conventional low sampling-rate ADCs lead to a large uncertainty in time determination.

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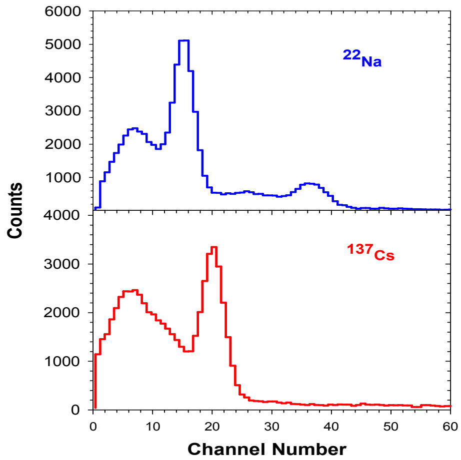

FIG. 1: *Energy spectra for ^{22}Na [Top panel] and ^{137}Cs [Botom panel] sources. The energy resolution was found to be 19.9% at 662 keV.*

In this paper, we report on the preliminary feasibility study of upgrading the LAMBDA spectrometer with DSP system to have a compact, efficient and versatile detector system for high energy γ-ray measurement.

Experimental details

Two BaF_2 detector elements ($3.5\times3.5\times35$ cm^3) of the LAMBDA spectrometer, placed 180° apart, were used for the experiment and conventional lab standard sources (^{22}Na, ^{60}Co & ^{137}Cs) were placed in between them. The time varying pulse from both the detectors were amplified by a fast amplifier and fed to the two channels of a 12 bit VME sampling ADC (V1729). The ADC registered the data in both the channels when the pulse in channel#1 crossed a threshold of -50 mV. The sampling rates of the ADC were 1 GSPS and 2

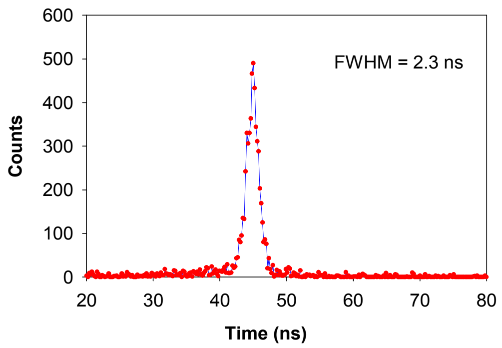

FIG. 2: *Time spectrum for LAMBDA spectrometer obtained using ^{60}Co source. Resolution was 2.3 ns for 1GSPS. The original pulse was delayed for 2 ns for implementing CFD technique.*

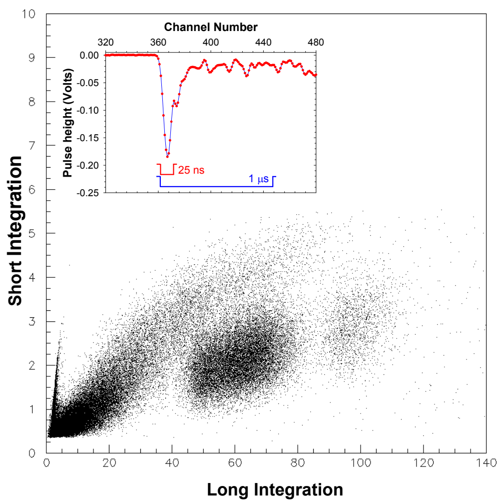

FIG. 3: *PSD spectrum for LAMBDA spectrometer. [inset] A typical sampled pulse from BaF_2 crystal along with the long and short integration window (not in scale)*

GSPS; but in both cases the record length was 2560, implying that the ADC can sample the input pulses for 2560 and 1280 ns when operated in sampling frequency of 1 GSPS and 2 GSPS, respectively.

The energy information was extracted by integrating the digitized pulse for 1 μs (fig. 1). The time information was extracted using the technique used in constant fraction discriminator (CFD); the zero cross-over point was determined by linearly fiting the two points i.e the one above and the other below the zero cross-over point thereby decreasing the uncertainty in estimating the cross-over point. Interestingly, the energy dependent resolution of the BaF_2 detector was found to be consistent with the result previously obtained by using analog electronics[1]; moreover, the energy resolution was found to be nearly independent of the sampling period provided that the integration time remained the same for the two cases. However, the estimated time resolution (fig. 2) was greater than that obtained using analog electronics and fine tunings are being performed using different time extraction techniques[4, 5] to make it better. The pulse shape discrimination (PSD) was also done by integrating the pulse for 1 μs (long integration) and 25 ns (short integration). As can be observed from fig. 3 that intrinsic α-impurities are clearly separated from the γ-band.

Discussion

We have done the priliminary feasibility study of upgrading the LAMBDA spectrometer with a digital acquisition system. The energy information can be extracted using QDC technique and PSD method can be utilised to remove the pile up and α-impurities. However, the difficulty lies in time extraction for which diferent techniques are being studied. We are also investigating the possibility of energy extraction by shaping the digitized pulse. The details will be presented during the symposium.

References

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