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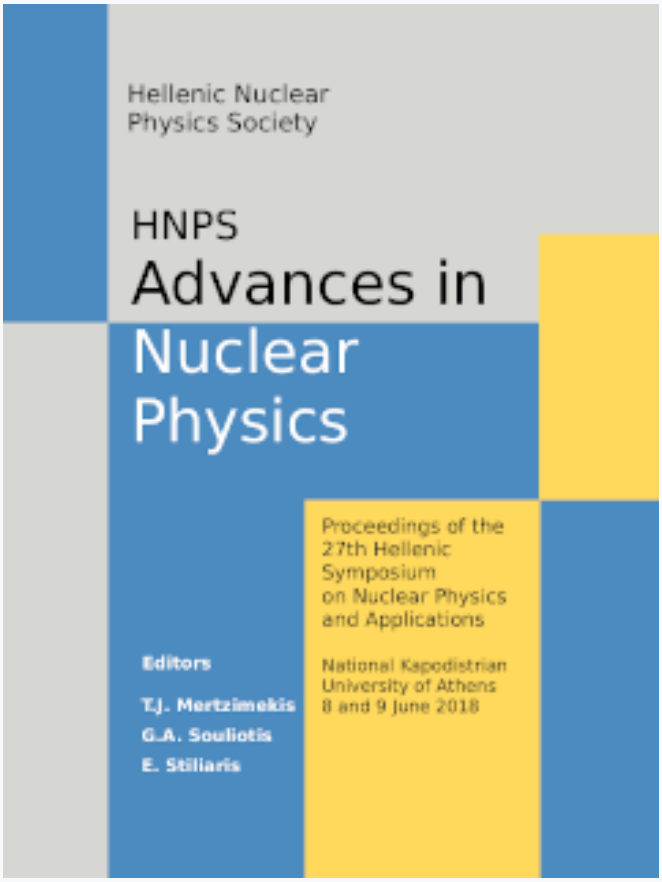

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Development of a pulse reconstruction routine for Transistor-Reset Preamplifiers for (n,xn) measurements using HPGe detectors at the n_TOF facility at CERN *

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Abstract The knowledge of neutron induced cross-sections is essential both for applications as well as for the refinement of nuclear model parameters. Amongst other reactions, (n,xn) are equally important, however the determination of such cross-sections could be limited by current experimental techniques. In this respect, feasibility studies have been performed at the n_TOF facility at CERN concerning the study of (n,xn) reactions by detecting the prompt γ radiation emitted from the residual nuclei an experimental technique which required the use of a Transistor Reset Preamplifier (TRP) set-up. The digital acquisition system at n_TOF is accompanied by a pulse shape analysis framework which lacked the capability of dealing with TRP, therefore a new reconstruction routine had to be developed. A brief description and the first preliminary results are presented.

Keywords HPGe, pulse shape analysis, nTOF, CERN, TRP

INTRODUCTION

The accurate determination of (n,xn) reactions is of great importance for the optimum design and reduction of safety margins of fast reactors since the neutron population is increased by such reactions affecting the available neutron spectrum for fission in the nuclear fuel. In addition (n,xn) reactions are considered to be the most suitable reactions for high energy neutron dosimetry which is justified by the long list of (n,2n) and (n,3n) reactions seen in the High Priority Request List (HPRL).

In most cases the residual nuclei are short-lived with half-lives of the order of ps, which is a limiting factor in using current experimental techniques to measure such cross-sections. A suitable alternative is the use of prompt γ-radiation a technique that was tested in the present work at the nTOF facility at CERN, which features a high instantaneous neutron flux

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produced via spallation of 20 GeV protons impinging on a Pb target. The prompt γ-spectrum can be detected with a high resolution γ-ray HPGe detector, provided that the γ-flash burst that follows the spallation process, does not saturate the read-out system.

The aforementioned saturation was avoided, by employing a transistor-reset preamplifier (TRP) whose response to the charge collection is faster than the typical integration/differentiation preamplifiers. The step-signals of this preamplifier were recorded at high sampling rates of the order of 1 MHz with flash ADCs, which allow the storage of full waveforms. These signals were analysed offline using the pulse reconstruction routine that was developed in the framework of the present work.

DESCRIPTION OF THE ROUTINE

During the feasibility measurements, different types (planar and co-axial) of high purity germanium detectors (HPGe) were used with relative efficiencies ranging from 20% to 35% both with neutron beam and radioactive sources. In the cases were the read-out included a TRP, the pulse recognition routine that will be described, was used.

The pulse recognition was based on the calculation of the first derivative, by differentiating raw time frames, using a step size defined by the user. A typical derivative calculation can be seen in fig. 1, where the top and bottom panel show a raw time frame and its calculated derivative, respectively. The derivative calculation is followed by the determination of the recognition thresholds, which are defined at 3.5 rms. Two consecutive derivative crossing at -3.5rms indicate the presence of a signal while a crossing at +3.5 rms indicates the reset of the TRP.

Prior to determining the attributes of the recognised signals, the baseline of the derivative is calculated. At the previous step, the position in time of the threshold crossings was stored, therefore a linear fit in the derivative was performed in which the points between two consecutive negative threshold crossing were excluded.

The arrival time t_s, which will be assigned as the time of flight of each recognised signal, was calculated as the time where the derivative crossed a threshold which was defined at 5% below the baseline, when moving from the minimum position between the rms threshold crossings to the left of the time frame. The time in which the derivative reached its minimum value was also stored and was assigned as the time in which the raw signal was half-way formed.

Similarly, the time when each pulse ended, was calculated as the time t_e where the derivative reached an amplitude 5% below the baseline, but this time when moving towards greater times from the positions of the minima in the derivative in each recognised signal. The time difference t_w between t_e and t_s, $t_e - t_s$ was assigned as the duration of the pulse. It has to be noted that terms such as rise, decay and width are avoided due to the distinct format of a TRP induced signal.

Finally, the amplitude of each raw signal was calculated as the difference in the recorded amplitude in the raw time frame between t_e and t_s. It has to be mentioned that the reset of the

preamplifier did not differ from a typical signal in terms of the mathematical treatment apart from the fact that it had the opposite polarity.

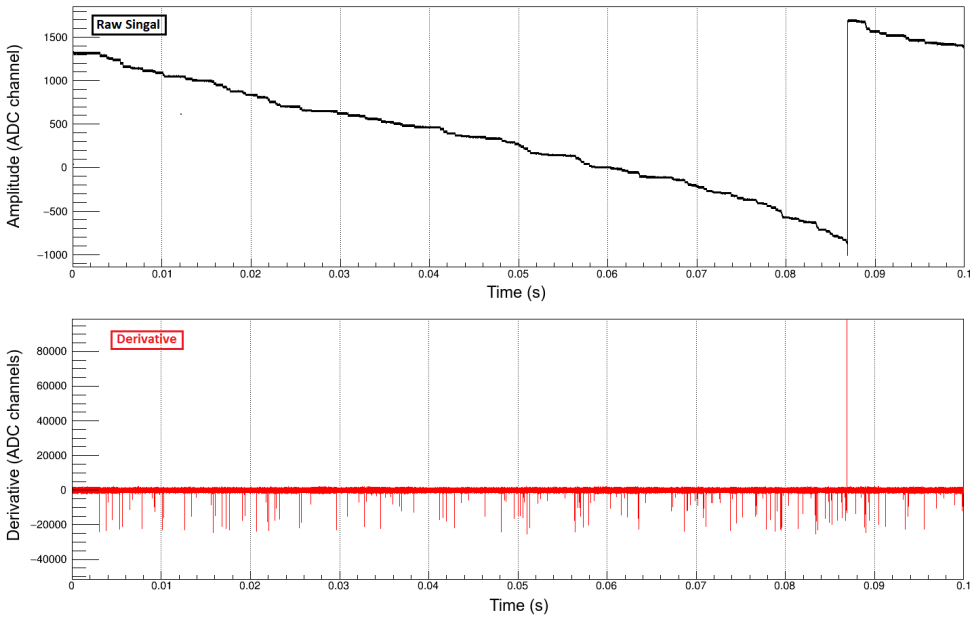

Fig. 1 Raw signal (top panel) detection is based on the calculation of the first derivative (bottom panel). A typical time frame from a 30% relative efficiency HPGe detector is shown during the acquisition of γ-rays from a ^{137}Cs radioactive source.

RESULTS AND DISCUSSION

Several measurements have been performed in which γ-rays induced by neutron interactions or produced by radioactive sources were recorded. Prior to analysing neutron beam data, amplitude spectra were reconstructed from calibration runs using ^{137}Cs and ^{60}Co sources in order to benchmark and check that the developed routine was able to adequately perform. As seen in fig. 2, the reconstructed amplitude spectrum recorded at a distance of 15 cm from the sources with a 35% coaxial HPGe detector, a satisfactory energy resolution of ~1% at 661.7 keV was achieved, given the poorer spectroscopic capabilities of a reset preamplifier. Nonetheless, this value was in complete agreement with the resolution obtained from the same set-up and a typical spectroscopy read-out consisted of a spectroscopy amplifier and a multi-channel analyser.

Time-of-flight spectra were also reconstructed, for neutron induced reactions on a ^{197}Au sample, 1 mm in thickness and 2 cm in diameter. As seen in fig. 3 (left panel), the ^{197}Au(n,tot) resonances at 4.9 and 60 eV incident neutron energies were successfully reconstructed indicating that the developed routine can perform equally satisfactory in beam data as well. Finally, the development of the routine was critical in the feasibility studies of (n,xn) reactions at n_TOF, since it made possible the recognition of γ-rays produced from high energy neutrons at incident energies of hundreds of MeV, as seen in fig. 3 (right panel) .

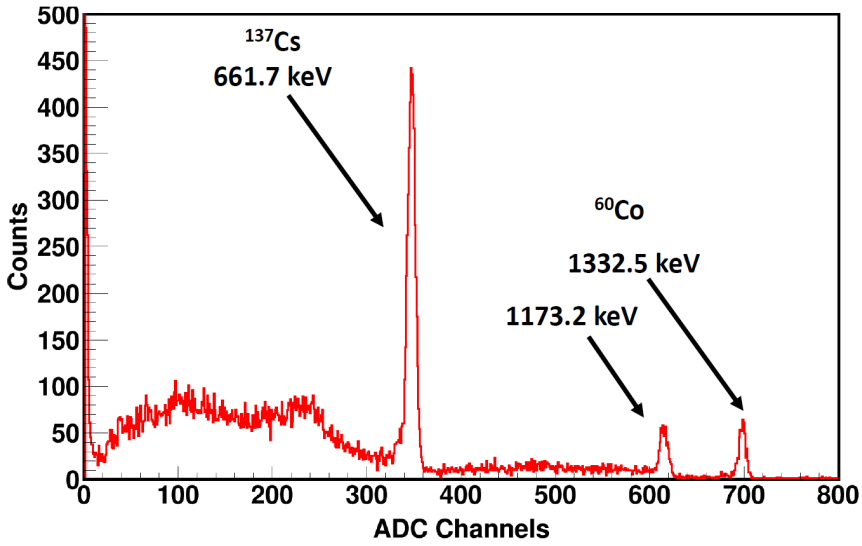

Fig. 2 Amplitude spectra reconstructed from the developed routine in the case of a calibration measurement with ^{137}Cs and ^{60}Co radioactive sources. The obtained 1% energy resolution at 661.7 keV, which was in agreement with the resolution of a spectrum recorded with a typical spectroscopy read-out, was satisfactory.

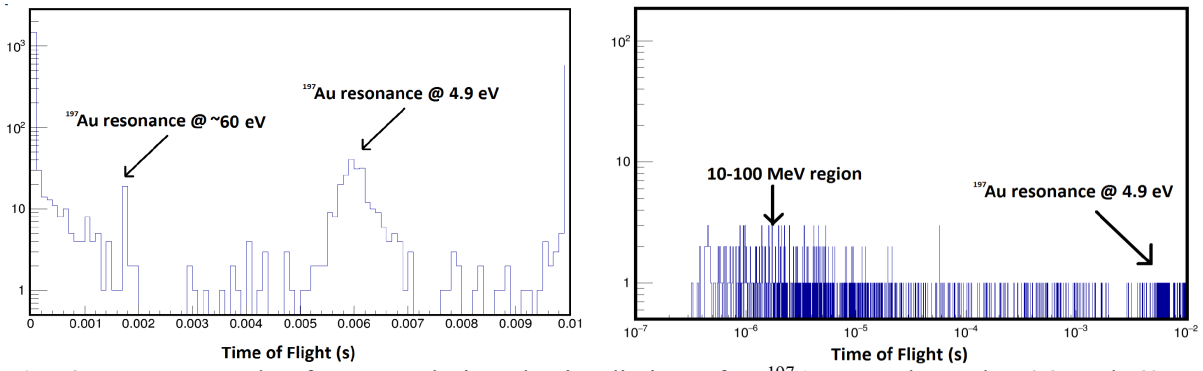

Fig. 3 Reconstructed tof spectra during the irradiation of a ^{197}Au sample. The 4.9 and 60 eV resonances in the ^{197}Au(n,tot) reaction were clearly visible. Promising signals were also reconstructed at neutron energies in the 10-100 MeV region.

CONCLUSIONS

Feasibility studies of (n,xn) reactions at n_TOF, required the use of transistor reset preamplifiers. The pulse shape analysis framework currently used at n_TOF was lacking a routine to deal with TRP signals. In this respect, a new reconstruction routine was developed and benchmarked in calibration and beam runs. First preliminary results indicate a satisfactory energy resolution of 1% at 661.7 keV, comparable to standard spectroscopy read-outs. Finally, ^{197}Au(n,tot) resonances were resolved while γ-rays were reconstructed from neutrons at incident energies in the 10-100 MeV region.

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