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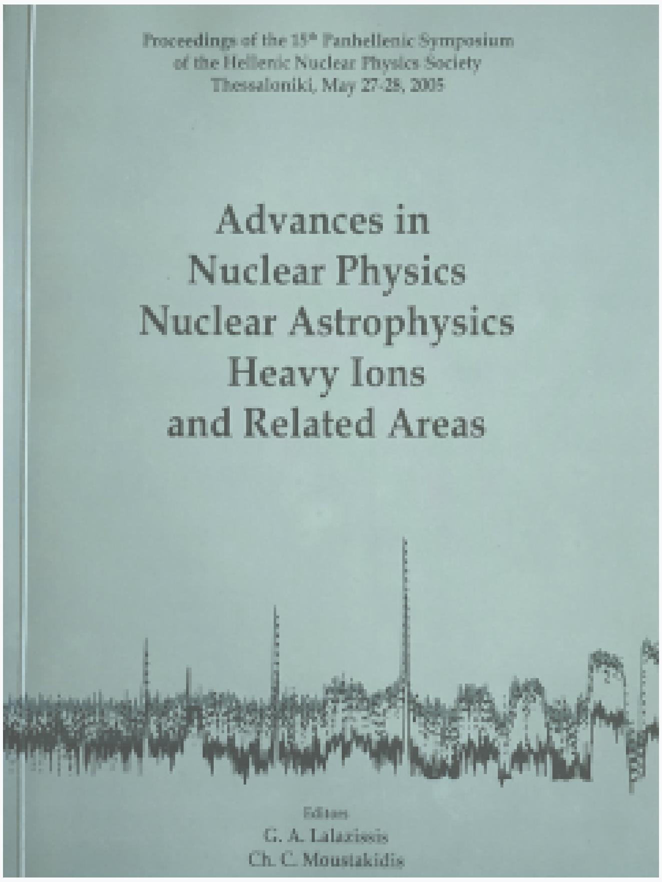

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D. Karadimos[(a)],K. Ioannides[(a)],P. Assimakopoulos[(a)], N. Tsagas[(b)], P. Paulopoulos[(c)],V. Vlahoudis[(d)], P. Cennini[(d)], V. Ketlerov[(d)],V. Konovalov[(d)], K. Stamoulis[(a)],D. Karamanis[(a)], for the n_TOF collaboration

[(a)] *Laboratory of Nuclear Physics University of Ioannina,* [(b)] *Democritus University of Thrace,*[(c)] *Pole Universitaire Leonardo de Vinci,* [(d)] *CERN*

Abstract

The analysis technique applied to the data from the FIC (Fast Induction Chamber) detector at the n_TOF facility is presented here. The measurements took place at the installation of CERN in Geneva. The detector was placed in front of the neutron beam for the determination of the neutron induced fission cross-section of various isotopes of the Th cycle. For the data acquisition, several fADC (flash Analog to Digital Converter) channels were used. This facilitated the detailed off-line analysis of data since all information was stored in the computer. The analysis of the data aimed at the discrimination of fission events. For this end we had to deal with three main issues: (1) The subtraction of the background, (2) the fitting of the pulses and (3) the automation of the process. The analysis pertaining to these issues will be further elucidated here.

1 Introduction

The recently proposed generation of Accelerator Driven Systems (ADS) [2] for energy production has generated the need for comprehensive, high quality nuclear data for the isotopes of the thorium cycle, i.e., ^{230}Th,^{232}Th,^{231}Pa, ^{233}Pa,^{232}U,^{233}U, ^{234}U and ^{236}U. Most of the existing data for these isotopes have been obtained more than two decades ago and compared to data for the uranium-plutonium cycle isotopes employed in conventional fission reactors, i.e. ^{235}U,^{238}U and ^{239}Pu, are of poor quality and rather limited with respect to the energy range covered. Thus, the evaluated files of neutron cross sections, such as ENDF / B - VI / R 5 [3] and JENDL - 3.2 [4], recently published by the IAEA, present serious inconsistencies.

2 The experimental setup

For the ^{232}Th cross-section measurement a FIC (Fast Induction Counter) detector was placed in the forward direction of the neutron beam.^{232}Th, ^{235}U and ^{238}U samples were placed inside the detector as targets. The signal was digitized by means of a flash ADC and was stored in the hard drive of a computer for off line analysis. The measurements were performed at the n_TOF facility during the fission measurement campaign. The FIC was placed in the neutron beam at 185.390 m (distance of the first sample, ^{235}U) from the spallation Pb target, as shown in figure 1. The main chamber was sealed and filled with pure Argon and CF_4 gas at a pressure of 0.8 bar (figure 2). The samples were thin and circular, with radii of 2.6 cm and were deposited on a 100 μm thick Al backing. There were also three off beam positions (i.e. outside the neutron beam) for background measurements. A dummy sample occupied also one in-beam position. The data are analysed using pulse shape analysis techniques, to differentiate fission events. The number of fissions of ^{232}Th nuclei per neutron energy will be determined relative to ^{235}U fissions, for which the cross section is well known.

For the data acquisition four fADC modules CAEN V676 and three multihit TDC modules CAEN-V767 were used. The fADCs recorded the pulse amplitude for each event in steps of 25 ns, thus allowing the reconstruction of the corresponding time and energy of an event recorded by the detector. The TDCs recorded only the time of the events in units of 0.8 ns. The data acquisition was triggered by the PS signal (arrival of a proton pulse). The fADCs recorded the signals in a time window of 100 s and the TDCs inside a 200 ms time window.

3 fADC data analysis

Data are read on an event by event basis. At each event, the proton beam information, the time and the number of the event, the channel and the fADC number and finally the actual content of the fADC's are stored. A typical fADC movie (full content of the fADC) is shown at figure 3 At the beginning of the movie, a strong signal appears, which is mainly due to the gamma rays. We are using this signal for the determination of the neutron Time Of Flight, since this signal defines our tflash, which is the time needed for the gamma rays to reach the detector from the Pb spallation target. The actual neutron TOF is calculated after the peak is fitted using the MINUIT [6] code with the function:

$$Y(t) = Y_0 + A * (1 - e^{-(t-t_0)/t_1}) * e^{-(t-t_0)/t_1} \tag{1}$$

,where Y(t) is the signal function, Y_0 is the background, A the amplitude, t_0 correspond to the shift of the centroid of the peak and t_1, k, t_2 describes the shape of the peak. Because of the high complexity of the function, the initial values for the fitting must be close to the final values in order to obtain convergence. The initial values for Y_0, A, t_0 are calculated for each peak and t_1, t_2 are set to 1,4 and 4,5 respectively. Also the parameter k is set constant to a value k=2,95. The same function is used to fit the gamma flash. For these initial values the 1 is shown at figure 5. The gamma flash is a common feature in all the detectors at the n_TOF facility. Although it is useful to provide a very precise neutron Time Of Flight, the intensity of the signal it produces, is saturating the detector, which is undershooting and until the recovery causes a ripple of the baseline. In order to correct for this effect, we have calculated the average movies, by adding all the movies and dividing with the number of them. This average movie we are fitting to the fADC data with the function:

$$Y(t) = Y_0 + A * avgMovie(t) \tag{2}$$

In order to keep A close to value 1, we have calculated 9 averages (figure 4), corresponding to different beam intensities, since the gamma flash is proportional to the beam intensity. The average movie is subtracted from the actual data after it is fitted to the movie with the average function, using MINUIT [6]. Following this correction of background, the peak identification and fitting of the peaks is performed. All the above described steps of analysis were included in the software, which has been developed. The code has two operation modes. In the first mode it calculates the average movies. In the second mode it proceeds with the pulse shape analysis. A quick overview of the algorithm is described next. First the code reads one event. If there is no error, it then tries to find and fit the gamma flash. If the fitting is successful, the t_{flash} information is stored; else it continues reading the next event. After the location of flash, the code proceeds according to the selected operation mode. In the case where average movies are calculated, the code copies the fADC data to the corresponding array, depending on the beam intensity information and proceeds with the next event. If the code operates in the second mode, will fit and subtract the corresponding average movie. Next it checks the monotony of the data, and if there is a local maximum, it tries to fit the 1 to the data. If the fit converges, then the Time Of Flight is calculated from the centroid of the peak and the signal is subtracted. The subtraction of the signal provides the opportunity to check for double peaks. The Time Of Flight is then stored at a ROOT [5] histogram, with the corresponding error of the fitting. After processing the movie, the code reads the next event and repeats the same steps. The result of this procedure is shown in figure 6.

4 Conclusion

The data from the FIC detector were analyzed with the above described method. Combined with data from the PPAC detector, their analysis will lead to the calculation of the Th, U fission cross sections, after evaluation of the results by the n_TOF group.

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[3] ENDF / B6, OECD NEA Data Bank; IAEA-NDS-110, IAEA Nuclear Data Section, Viena, Austria.

[4] JENDL / Nuclear Data Evaluation Research Group. Japan Atomic Energy Research and Development Agency (JAEA) http://wwwndc.tokai.jaeri.go.jp/

[5] ROOT. An Object Oriented Data Analysis Framework. http://root.cern.ch/

[6] MINUIT - CERN Program Library entry D506, CERN, Geneva 1994

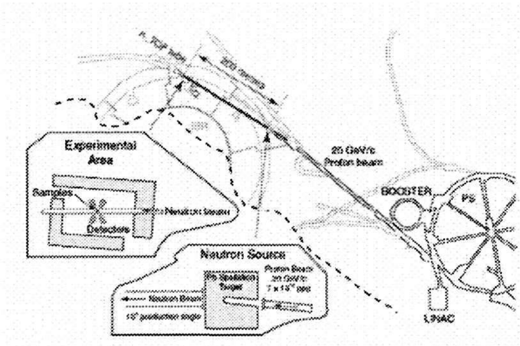

Fig. 1. The n_TOF facility

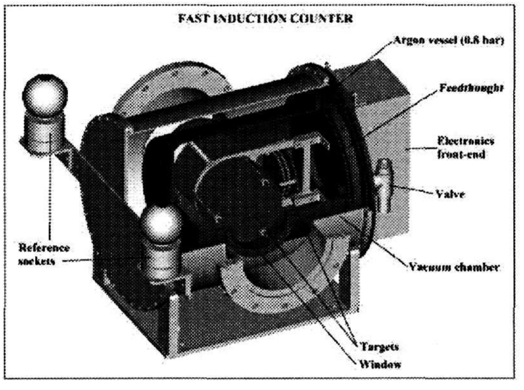

Fig. 2. Artistic rendering of the FIC detector

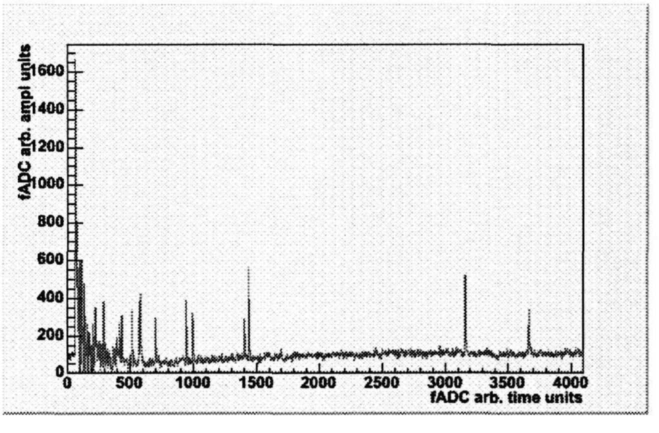

Fig. 3. The content of the fADC for one event, movie

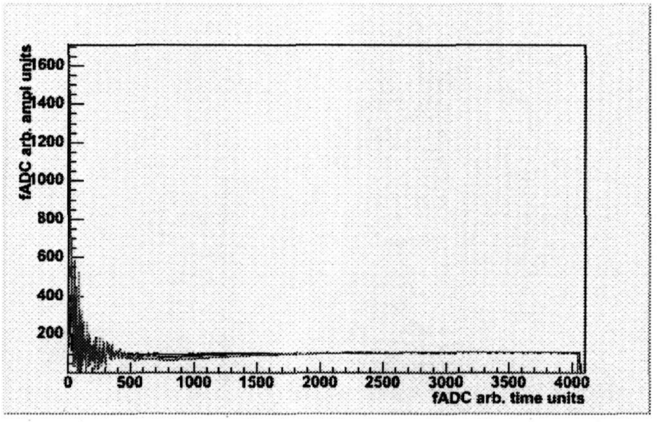

Fig. 4. The Average Movies.

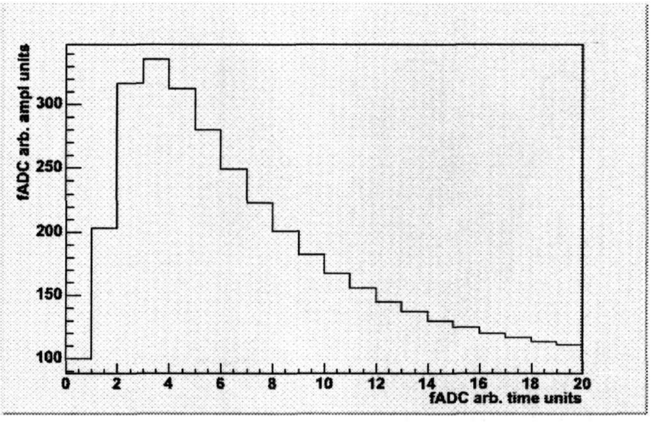

Fig. 5. The signal function

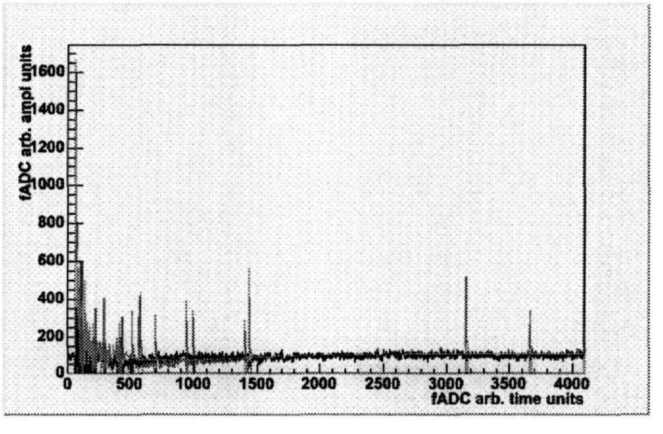

Fig. 6. Results from average movie subtraction and fitting