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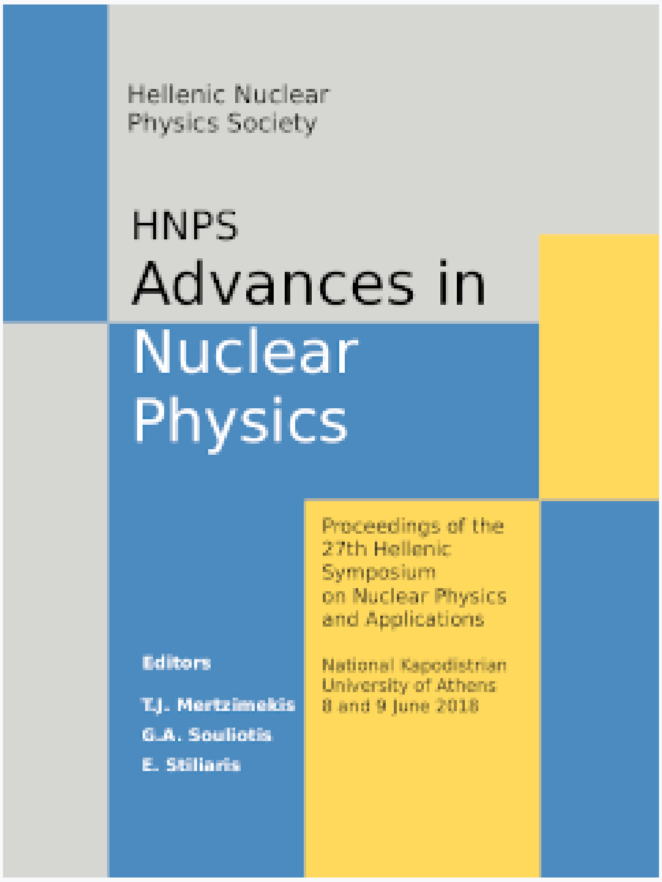

Study of the high energy neutron flux (15-20 MeV) using a BC501A liquid scintillator

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Study of the high energy neutron flux (15-20 MeV) using a BC501A liquid scintillator

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Abstract An experiment was conducted in order to characterize the neutron beam between ~15-20 MeV, at the 5.5 MeV tandem T11/25 Accelerator of NCSR ''Demokritos''. A liquid scintillator, BC501A, was used due to its n-γ discrimination capability and a versatile pulse shape analysis was applied. Offline, the discrimination circuit was tested for tolerance in high counting rates and sensitivity in lowering the limit of the neutron energy monitored through the threshold of the processed signal. The employed circuit proved to be very sensitive to changes in the latter. Neutron spectra at the energies of 14.8, 16.6, 19.2 and 20 MeV were acquired and the unfolding process using the DIFBAS code is currently in progress. Their deconvolution is expected to reveal the extent of the presence of low-energy parasitic neutrons.

Keywords liquid scintillator, pulse shape analysis, d-t reaction

INTRODUCTION AND MOTIVATION

The investigation of neutron-induced reactions is of considerable interest, not only because of their importance to fundamental Nuclear Physics and Astrophysics research, but also for practical nuclear technology, dosimetry, medical and industrial applications. These tasks require accurate nuclear data and higher precision cross sections for neutron-induced reactions. It is thus of importance that the performance of the neutron source is well understood and that the experimental conditions are accurately characterized. In view of the above mentioned remarks, an experiment was conducted in order to characterize the neutron beam between ~15-20 MeV, at the 5.5 MeV Tandem T11/25 Accelerator of NCSR "Demokritos". This characterization is critical for all similar experimental setups in the absence of ToF capabilities. Neutron fields are generally contaminated with photons, which either stem from the neutron source itself, or are produced by interaction of the neutrons with matter in the environment of the source, target, experimental area and the detector itself. Hence, neutron spectrometers oriented to neutron field characterization should either be relatively insensitive to photons, or capable of discriminating photon-induced events. Liquid organic scintillators such as NE213 or BC501A are well suited for spectrometry in mixed fields due to their supreme n/γ discrimination capability. Neutron- and photon-induced events can be separated by means of pulse shape analysis, so that both pulse height spectra can be simultaneously recorded [1-4].

NEUTRON – GAMMA DISCRIMINATION CIRCUIT

In the present work the liquid scintillator BC501A was implemented. It is a widely used liquid scintillator for neutron monitoring, time-of-flight and neutron spectroscopy measurements, mainly due to its excellent n-γ discrimination capability, high detection efficiency and fast time response. The main processes taking place inside the organic material are fluorescence (a prompt and a delayed one) and phosphorescence. The time difference between these procedures explains why BC501A can effectively discriminate neutrons from gamma-rays [5] .

The pulse shape analysis (PSD) circuit takes advantage of the BC501A's latter ability and counts the actual time difference between the two processes and converts it to an electronic signal. The time relation of the gamma and neutron pulses at the output of the PSD circuit can be monitored with a time-to-amplitude converter (TAC) (start signal from CFD and stop signal from SCA-timing) and an ADC. The block diagram of the electronics is shown in Fig. 1. Since time is counted, gamma rays can be rejected using the discrimination point as a gate to the delayed amplified unipolar signal and subsequently only the neutron energy spectra can be recorded.

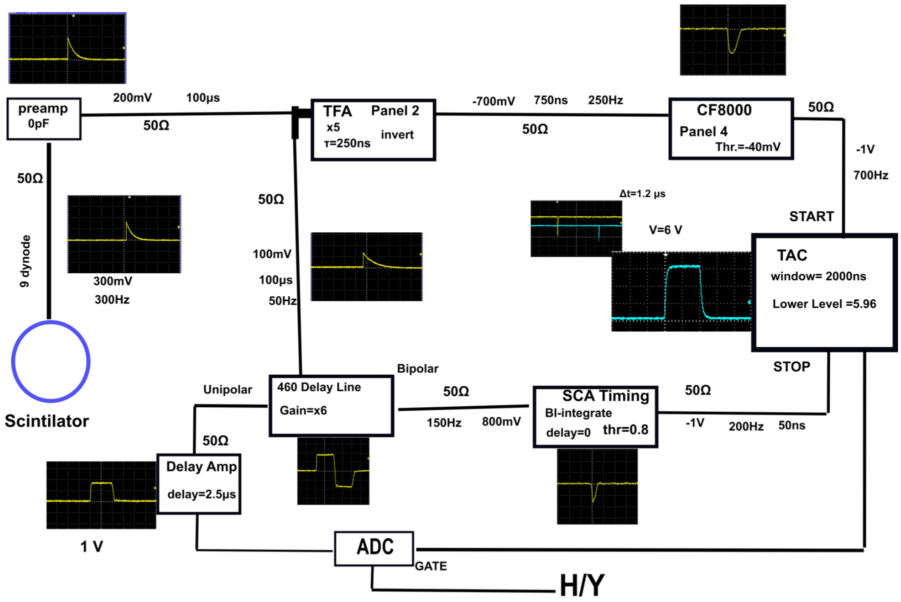


Figure 1 Block diagram for the n/γ discrimination circuit along with the pulses from each unit

PARAMETER TESTS

Time distribution measurements of neutrons and gamma rays, shown in Fig. 2, were obtained in order to determine the maximum counting rate and the minimum pulse height threshold in the SCA (which directly corresponds to the minimum neutron energy that can be recorded). The circuit turned out to be quite insensitive to high counting rates (Figure 3), but very sensitive in the changes of the SCA-timing's lower threshold (Figure 4).

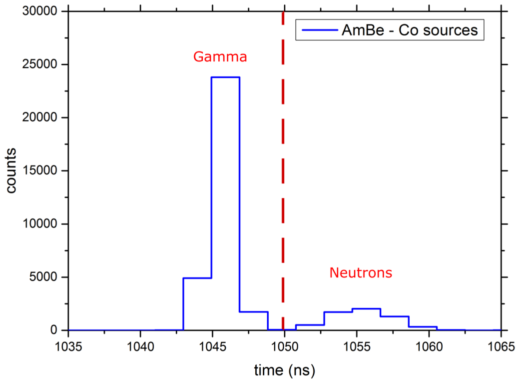
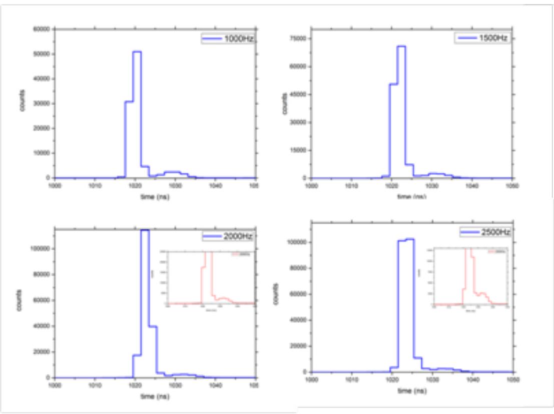


Figure 2: Time distribution measurements of neutrons and gamma-rays counted

Interpreting in terms of energy the afforementioned remark, the elimination -through threshold values- of the gamma rays emitted by ^{60}Co, renders the n/γ separation clear and distinct. Lowering the threshold on the other hand, allows for low energy γ-rays to be recorded and consequently, low energy neutrons, however, this has a severe negative impact in the circuit's discrimination capability, which is depicted as an overlap in time distribution, as shown in Figure 4.



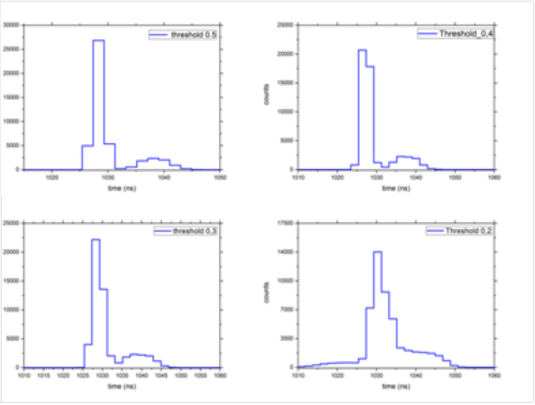


Figure 3: Time distribution for different counting rates (1000-2500 Hz with a step of 500Hz)

Figure 4: Time distribution for four different threshold values (from high to low)

ENERGY SPECTRUM OF AN AmBe SOURCE

An AmBe source is a mixture of ^{241}Am and ^{9}Be in powder form. Three spectra are shown in Fig. 5: A neutron-gamma mixed one, a gated spectrum consisting only of neutrons and the actual AmBe source neutron field, which is the result of deconvolution (using the code

DIFBAS). The continuous form of the recorded neutron spectrum and its difference from the deconvoluted one lies in the form of the source material, which causes changes in the α-particle energies (due to energy losses), within the source, before the reaction $^{9}Be(\alpha,n)$ occurs, along with the fact that the recorded spectrum is always angle-integrated, therefore requires an *a priori* knowledge of the scintillator's light response with energy and needs a proper deconvolution to transform it to actual neutron beam flux vs. energy [6] . The maximum neutron energy emitted by the source is ~11 MeV.

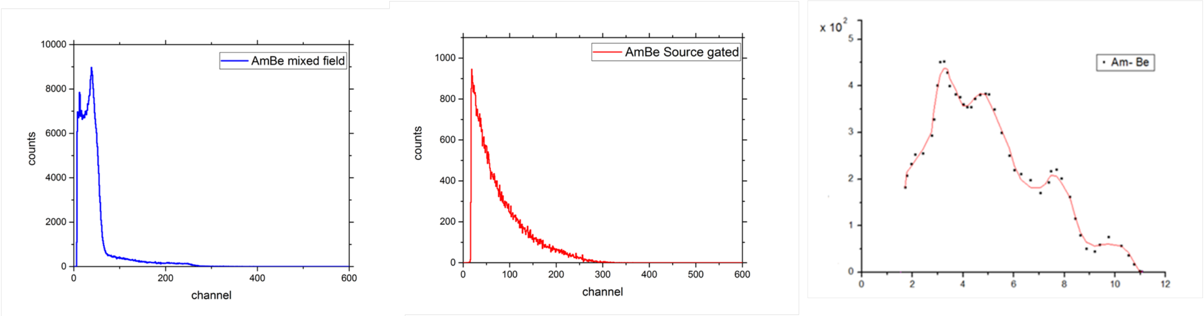


Figure 5: Three different AmBe spectra. The acquired one in the mixed field (left), the gated one (center) and the deconvoluted (right)

EXPERIMENTAL SETUP

In the 5.5 MV tandem T11/25 Accelerator Laboratory of NCSR 'Demokritos' high-energy neutron beams, at energies ~15-20 MeV, were produced by means of the $^{3}H(d,n)^{4}He$ reaction [7]. The corresponding deuteron beam energies obtained from the accelerator, were 1.75-4.5 MeV. The Ti-Tritiated target of 373 GBq nominal activity, consists of a 2.1 mg/cm^{2} Ti-T layer deposited on top of a 1 mm thick Cu backing for good heat conduction.

The BC501A detector was placed at a distance of ~1.5 m away from the target and behind an experimental chamber filled with MicroMegas detectors used for fission cross-section measurements on actinides.

Recorded neutron energy spectra are presented, as shown in Figure 6, along with the ADC's energy calibration (in Figure 7), which is practical linear. The deconvolution using DIFBAS is in progress.

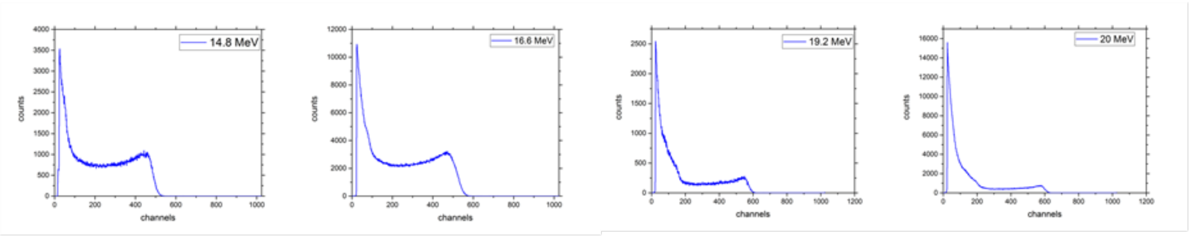


Figure 6: Recorded neutron energy spectra at 14.8, 16.6, 19.2 and 20 MeV

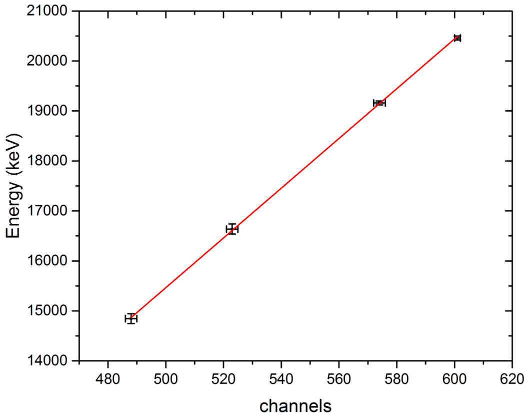


Figure 7: ADC's energy calibration

CONCLUSIONS

The first results of monitoring the high energy neutron beam, along with its low energy components, utilizing a BC501A liquid scintillator seem to be very promising. Gamma rays can be omitted from the recorded neutron spectra, while the latter, even before deconvolution, can directly give a rough estimation of the recorded neutron energies. This information can also be used as an in-beam quick ckeck of the experimental conditions (i.e. beam monitoring). Moreover, the detailed deconvolution using the code DIFBAS, which is still in progress, is expected to reveal the precise neutron energy/flux distribution of the beam and act as an additional, valuable characterization tool in the absence of ToF capabilities.

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