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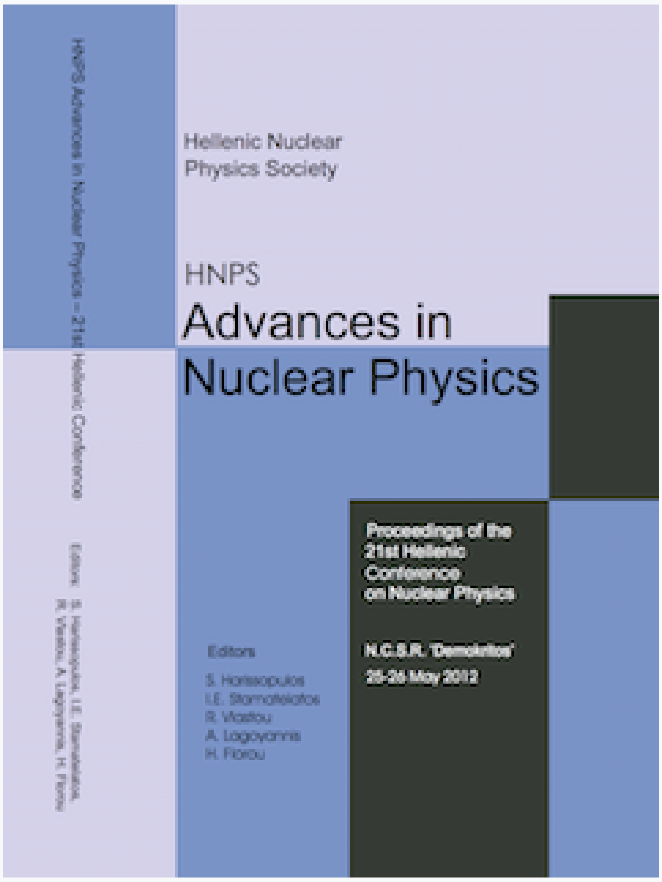

Investigation of the performance of a MicroMegas detector suitable for neutron-induced fission cross-section measurements

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Investigation of the performance of a MicroMegas detector suitable for neutron-induced fission cross-section measurements

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Abstract

The performance of a state-of-the-art MicroMegas detector, suitable for neutron-induced fission cross-section measurements has been examined. Special emphasis was put on the study of the gain and the resolution function.

1 Introduction

Present research related to the nuclear energy production aims to severely reduce the radiotoxicity level of nuclear waste. Furthermore, in the new type of reactors ("fast reactors") the neutron flux will mainly be of high energies (in the unresolved resonance region and up to 20 MeV) where the fission channel is the most intense, so high precision data are required in order to reduce the uncertainties of the reactor design paremeters. The complication of neutron induced fission cross section measurements necessitates new ones with different techniques, in order to improve the accuracy of the evaluations and thus facilitate the subsequent theoretical investigation.

A state-of-the-art MicroMegas detector [1] based on the Micro-bulk technology [2] and developed at CERN, within the context of the n_TOF collaboration

[3,4], was used for the first time for neutron-induced fission cross-section measurements. The experiment took place at the Tandem accelerator facility of NCSR “Demokritos” in Athens. The good energy resolution achieved allowed for the investigation of the performance of the detector.

2 Experimental procedure

The tests were carried out at the 5.5 MV HV TN-11 Tandem accelerator laboratory at NCSR “Demokritos”. The monoenergetic neutron beam was produced via the ^{2}H(d,n)^{3}He reaction. The detector was filled with a mixture of 80% Argon and 20% CO_2 at approximately atmospheric gas pressure and it was open-ended with a constant gas flow of 6-8 NL/h. Good energy resolution was achieved using conventional analogue electronics. Details for the experimental setup can be found in [5].

3 Characteristics and performance of the MicroMegas detector

The MicroMegas detectors used in the present work are low-mass devices especially developed at CERN, with use of the Micro-bulk technique [2]. According to the original version of this method, the mesh and pillars are produced via the chemical attack of a coppered kapton film deposited on an anode of a coppered epoxy. In order to minimize the material in the detector and thus the perturbation of the neutron beam, the coppered epoxy anode was replaced by a thin copper layer. Thus, each microbulk foil is made of a sandwich of 5 μm thick copper mesh - 50 or 25 μm thick kapton pillars - 5 μm thick copper anode. Each microbulk foil is made of a sandwich of 5 μm thick copper mesh - 50 or 25 μm thick kapton pillars - 5 μm thick copper anode.

Low-gain charge sensitive preamplifiers, energy amplifiers and ADCs composed the data acquisition system of the experiment in an effort to check the performance of the detector, a choice which was rendered possible due to the relatively low neutron flux, resulting a low counting rate of fission fragments. With this setup, the spectra showed good discrimination between the light and heavy mass peaks of the fission fragments. Moreover, tests with a monoenergetic ^{210}Po α-source were carried out off-line, using the same system in order to estimate the optimal detector settings. A typical picture showing a MicroMegas detector assembly used for these tests can be found in Fig. 1.

In order to check the energy deposition of the fission fragments in the active volume of the detector, detailed Monte Carlo simulations were performed with the code FLUKA [6]. The geometry of each MicroMegas-target assembly

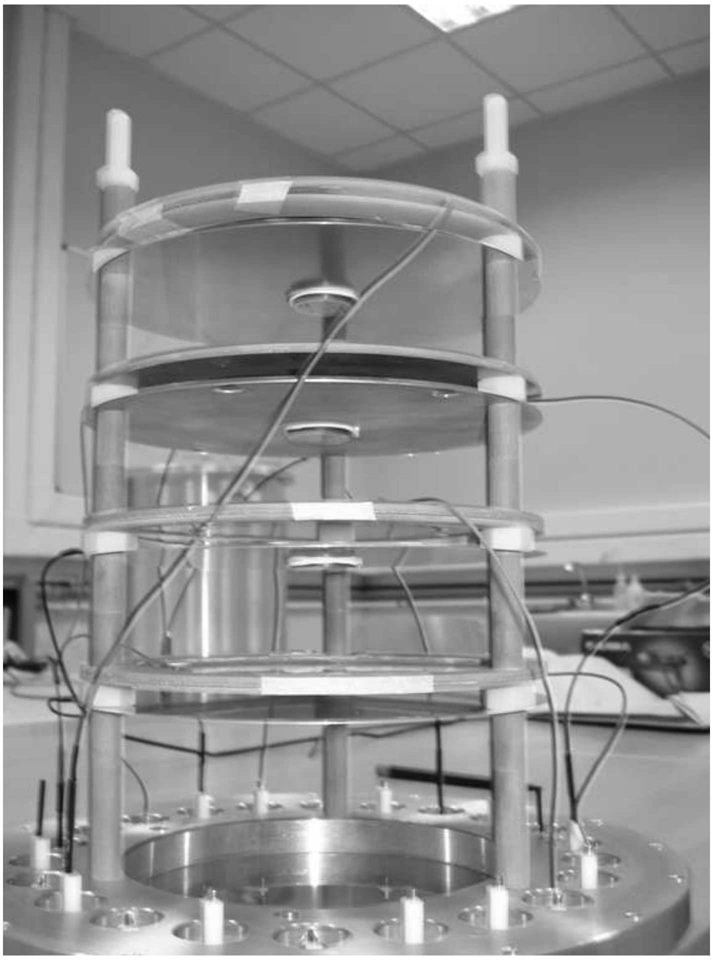

Fig. 1. Photo of the MicroMegas detector assembly.

was implemented, and the energy deposition of alphas and fission fragments in the volume of the gas was scored. The values of the simulated alpha efficiencies agreed with the experimental ones within 2-3 %, thus implying that the geometry was well implemented in the simulations. An external routine was developed in order to create fission fragments based on [7] and [8]. A heavy fission fragment was selected from a gaussian distribution with mean value $\mu \approx 140$ and standard deviation $\sigma = 6.5$, the mass number of the light fragment was calculated by assuming the emission of 1-3 neutrons and an average total kinetic enery of ≈ 174 MeV was distributed to the fission fragments inversely proportionally to their mass. The atomic number Z of the fission fragments was sampled from $\pm$ 5 around the mean value given in [7]. The fission fragments produced by this routine were isotropically distributed in the volume of the target and their energy deposition was scored in the gas of the detector. A typical energy deposition histogram for alphas and fission fragments emitted from a ^{237}Np target can be seen in Fig. 2. The peaks have a width due to the energy straggling during the interaction of the various ions of different energies in the target and the gas of the detector.

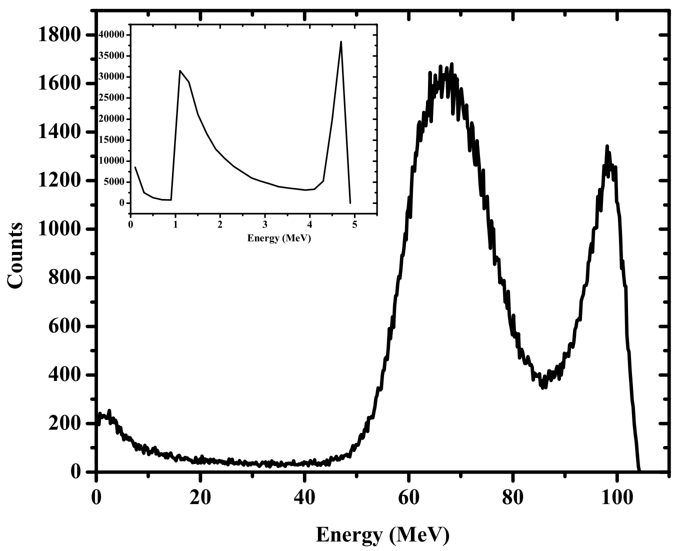

Fig. 2. The simulated energy deposition of the fission fragments in the gas of the detector, produced by an external source routine and emitted isotropically in the ^{237}Np target. The inset contains the simulated energy deposition of 4.8 MeV alphas, emitted isotropically in the ^{237}Np target.

The first interesting result was that, based on the simulated energy deposition of the alpha peak and the heavy and light fission fragment peaks, the calibration of the experimental spectra was made, which turned out to be linear, with a non-linear term 4 orders of magnitude lower than the linear one. This implies that the gain of the detector is practically the same for alphas and fission fragments, despite the large difference in the atomic number and energy of the ions, as well as their production mechanism. The very small non-linear term can be attributed to recombination of electron-ion pairs which turns out to be slightly more intense at the fission fragment tracks. Furthermore, an effort to reproduce the experimental spectrum was made, by applying a response function for the spreading of each bin from the FLUKA simulation histograms. The gaussian response function given in eq. 1 was used,

$$G(H) = \frac{A}{\sigma\sqrt{2\pi}} e^{-\frac{(G(H)-G(H_0))^2}{2\sigma^2}} \tag{1}$$

where G(H) is the number of counts added in channel H due to the spreading of the channel H_0 with a gaussian with standard deviation σ and A is a normalization factor. The comparison of the final convoluted spectrum with the experimental one can be found in Fig. 3 for the alphas and Fig. 4 for the fission fragments. By taking into account that 1) a gaussian response function in such a large energy range is a first order approximation for the behavior of the electronics and 2) the number of counts at the tails of the heavy and light fission fragment peaks of the experimental spectrum are poor, implying that the statistics at these channels do not follow a gaussian distribution, the reproduction of the experimental spectrum is quite satisfactory.

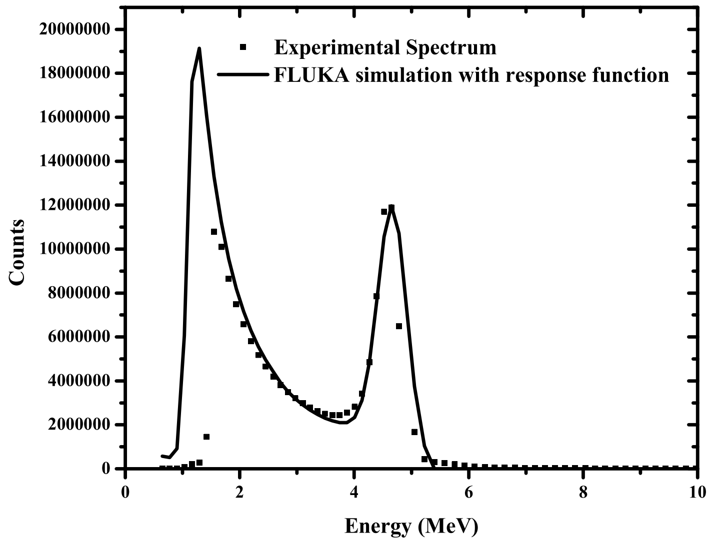

Fig. 3. The comparison of the convoluted with a gaussian resolution function FLUKA histogram with the experimental one for the alphas. The high alpha activity of ^{237}Np caused pile up of the alpha pulses in the detector, which is not taken into account at the FLUKA simulation. A threshold was applied at the low-energy part of the experimental spectrum.

The σ results obtained are shown in Fig. 5. These values are the result of the gas multiplication variations for the different isotopes and variations in the response of the electronics and show the expected increasing trend with respect to energy. Nevertheless, the resolution σ/E of the alpha peak seems to be much better than the resolution for the fission fragment peaks. This could be partially attributed to 1) the different ionization density of the alphas and fission fragments which makes the gas multiplication of the initial ion pairs sensitive to different factors of the detector geometry, 2) possible different transparency properties for alphas and fission fragments and 3) the non-linearities of the electronics in such a wide energy deposition range which can cause a deterioration of the resolution function. All these factors, along with the possible influence of the oxygen content in the target and of parasitic neutrons will be further investigated in a future work.

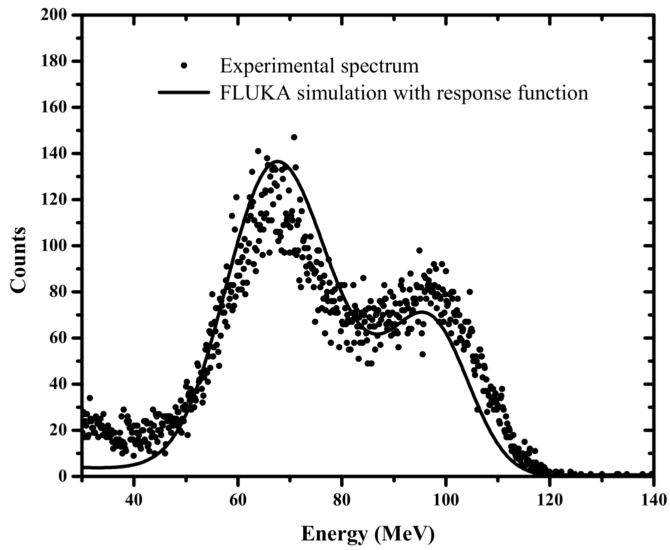

Fig. 4. The comparison of the convoluted with a gaussian resolution function FLUKA histogram with the experimental one for the fission fragments.

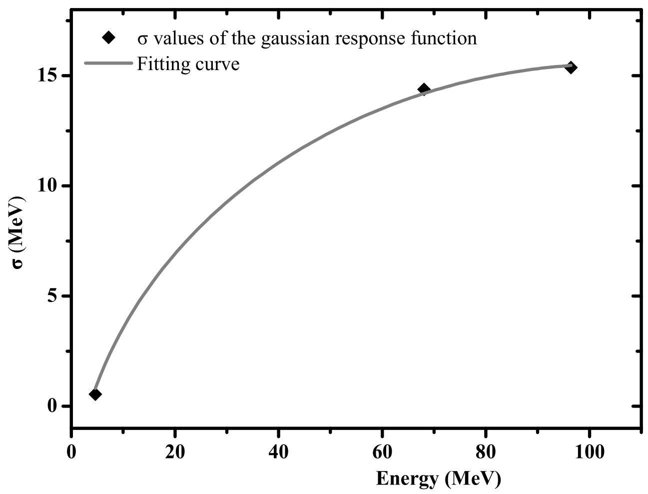

Fig. 5. The σ values deduced from the convolution of the alpha, heavy and light fission fragment peaks. The fitting curve is of the form $\sigma = A + B\sqrt{E + CE^2}$.

4 Results and conclusions

The performance of a new MicroMegas detector as far as the gain and resolution function are concerned was presented, both for alphas and fission fragments from the ^{237}Np(n,f) reaction. The detector, despite the unavoidable non-linearities of the electronics, showed a high linearity in the gas multiplication for a wide energy deposition range of alphas and fission fragments. The resolution is much better at the alpha peak of approximately 5 MeV than that of the fission fragments even if their energies are 1 order of magnitude higher and this effect can be explained by the different ionization density and deviations in the response of the electronics.

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