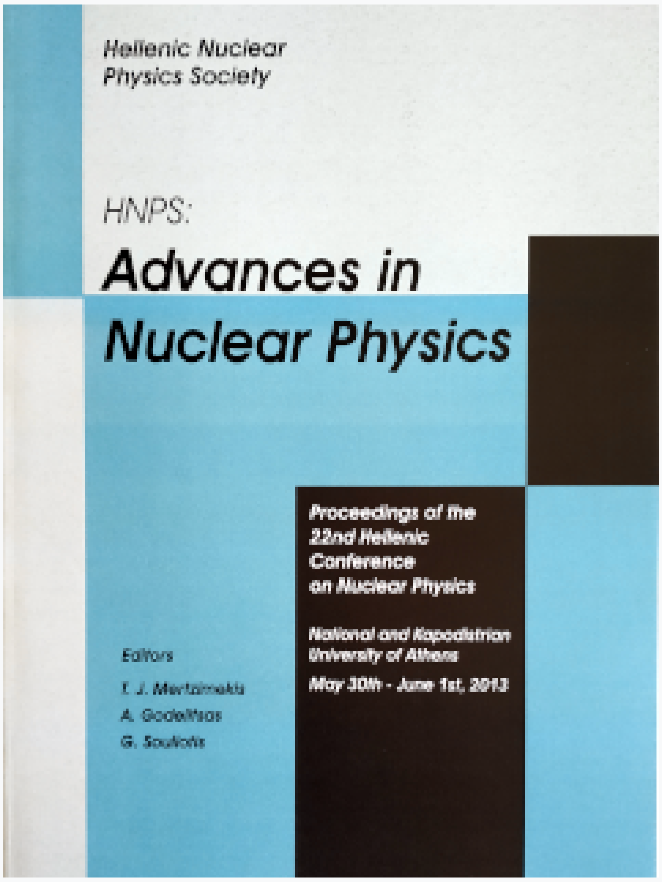
HNPS Advances in Nuclear Physics

Vol 21 (2013)

HNPS2013



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doi: [10.12681/hnps.2008](https://doi.org/10.12681/hnps.2008)

Fission cross section measurements with the MicroMegas detector

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Abstract

A new MicroMegas detector, based on the innovative Microbulk technology, especially developed within the context of the n_TOF collaboration, was used for the first time for fission cross section measurements with monoenergetic neutron beams at the Institute of Nuclear and Particle Physics of the NCSR "Demokritos". The detector assembly was successfully used in the case of the measurement of the ^{237}Np(n,f) cross section while the first results on the performance of the detector as far as the gain and resolution function are concerned are reported.

1. Introduction

The design of the new generation of nuclear reactors aims in the reduction of the radiotoxicity level of nuclear waste through transmutation or partitioning techniques, requires accurate cross section data of neutron induced reactions mainly on minor actinides. Furthermore, in the new type of reactors ("fast reactors") the flux in the fast neutron region will be orders of magnitude larger than in the existing thermal ones. The fission channel is the most intense channel in this region, so accurate data are required in order to reduce the uncertainties of the reactor design paremeters. Discrepancies in the existing data as well as the complication of neutron induced reaction measurements and of the fission process makes new measurements with different techniques necessary in order to improve the accuracy of the evaluations and thus facilitate the subsequent theoretical investigation. In this context, a new MicroMegas detector assembly was set, tested and used for fission cross section measurements with use of monoenergetic neutron beams in the MeV region at the 5.5 MV Van de Graaff Tandem accelerator laboratory of the Institute of Nuclear and Particle Physics of the NCSR "Demokritos". The first results on the measurement of the ^{237}Np(n,f) cross section were very encouraging and are presented.

2. Detector performance

The MicroMegas detector (Micro-Mesh Gaseous Structure) is a gaseous detector [1], introduced in 1996, working as a two stage parallel plate avalanche chamber. The basic feature of this detector is the separation of the gas-filled region between the cathode and anode electrode in two zones by the so-called "micromesh", a thin electrode with holes. The region between the cathode electrode and the micromesh is called the "drift" region, i.e. the region where the ionization of the gas atoms by the incoming radiation takes place and the electrons are drifted by a low electric field towards the micromesh. The region between the micromesh and the anode electrode is called "amplification region" and it is the region where a high electric field is applied (typically 50-60kV/cm) causing electron avalanches and thus the amplification of the signal. The MicroMegas detector has rapidly gained a lot of popularity in nulear and high energy physics experiments, especially because it can be optimized to measure different kinds of radiation by changing the distances between the three electrodes, the voltages applied and the gas mixture and pressure, and also due to the good energy resolution, fast timing properties and resistence to radiation damage. Detection of radiation in neutron beams requires the use of a low-mass detector in order to reduce neutron scattering and additional

γ background from the interaction of the neutrons with the detector material. For this purpose, a state-of-the-art MicroMegas detector bazed on the Micro-bulk technology [2] was developed within the context of the n_TOF collaboration. The amplification region consists of a microbulk foil is made of a sandwich of 5 μm thick copper micromesh - 50 or 25 μm thick kapton pillars - 5 μm thick copper anode (fig. 1).

Figure 1: Left: A schematics of a microbulk, taken from [3]. Right: A photo of the micromesh used in the present work, taken with a microscope.

The microbulks were tested as far as the gain and transparency curves are concerned with use of a monoenergetic ^{212}Po source in order to obtain the optimal settings, showing high resistence to sparks, high gain and good energy resolution [4]. Typical gain and transparency curves for one of the microbulks are shown in fig. 2.

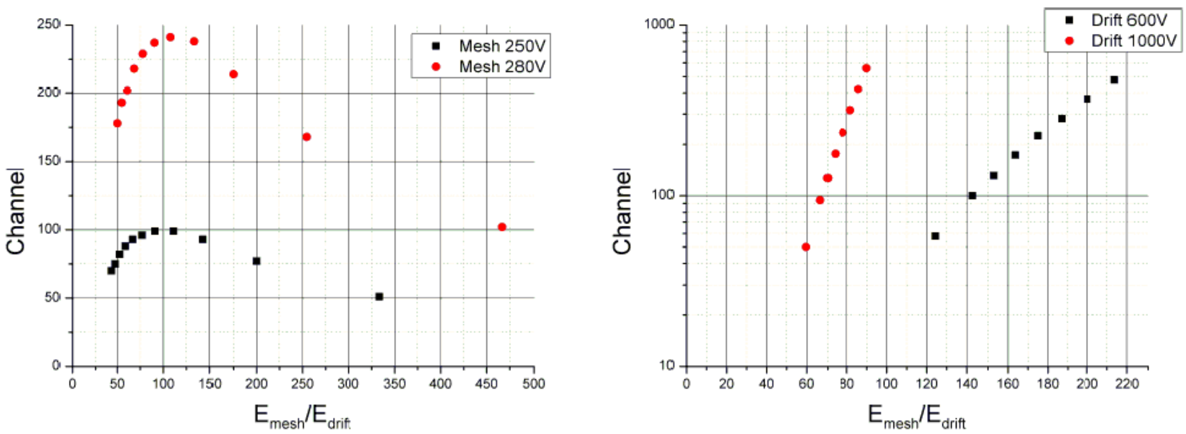

Figure 2: The transparency curve (left) and the gain curve (right) obtained from the testing of one of the microbulks used. The peak at the transparency is reached when E_{mesh}/E_{drift} ~110.

3. The case of the ^{237}Np(n,f) cross section measurement

The ^{237}Np(n,f) reaction cross section was measured with reference to the ^{238}U(n,f) reaction with use of monoenergetic neutron beams in the energy range 4.5-5.3 MeV and the innovative MicroMegas detectors described above. The quasi-monoenergetic neutron beams were produced with the ^{2}H(d,n) reaction. Each actinide target along with the microbulk chosen formed a MicroMegas detector cell, as shown in fig. 3. The target backing served as the drift electrode, the drift region was approximately 1 cm thick, while the amplification region was 25 or 50 μm thick. Three reference targets (two ^{238}U and one ^{235}U target) and one ^{237}Np target were used in the following order: ^{238}U, ^{237}Np, ^{235}U, ^{238}U. The four target-microbulk cells

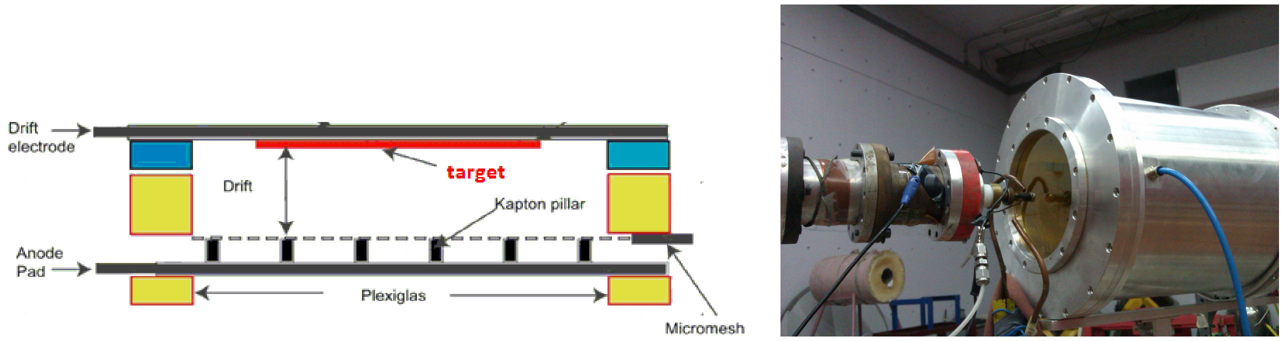

Figure 3: Left: Schematics of a MicroMegas detector with the target under analysis used in this work. The target backing served as the drift electrode. Four target-microbulk cells as the one shown here were used, one for each target. Right: Schematics of the deuterium gas cell and the chamber housing the target-microbulk assebly used.

were put in a big Al chamber with thin kapton entrance and exit windows (fig. 3). The gas of the detector was 80% Argon and 20% CO_2 at atmospheric pressure.

With use of low-gain charge sensitive preamplifiers, energy amplifiers and ADCs an effort to check the energy resolution of the detector was made, thanks to the relatively low neutron flux, resulting in a low counting rate of fission fragments. The heavy and light FF peaks were easily distinguished, as shown in fig. 4 and the alpha particles were lying in the first part of the spectrum, well separated from the FF peaks.

Details on the experiment and the analysis procedure can be found in [5]. The cross section results on the ^{237}Np(n,f) taking ^{238}U as a reference are in agreement with previous data. The ^{238}U(n,f) cross section (with ^{235}U as reference target) was severely lower than the evaluations (this cross section is considered as a standard up to 30 MeV), and this is due to the extra FF counts in the ^{235}U spectra induced by neutrons with lower energies mainly due to parasitic (d,n) reactions on the collimation system and/or the gas cell materials. Thus, the ^{235}U, a fissile target with high cross section down to thermal energies was not used as a reference target. A very interesting result, shown for the first time from this work, was that the calibration of the experimental spectra bazed on the alpha particle peaks, the heavy and light FF peaks turned out to be linear, despite the large energy range and the differences in the ionization properties of these particles. An investigation of the resolution function of the detector, bazed on the reproduction of the experimental spectrum was made, by assuming a gaussian resolution function to spread each bin from Monte Carlo simulation histograms [6]. The reproduction was good, and the resolution function obtained was of the form $\sigma = A + B\sqrt{E + CE^2}$. The resolution σ/E of the alpha peak seems to be much better than the resolution for the fission fragment peaks and this can be attributed to many factors as for example the different ionization density of the alphas and fission fragments or the different behavior of electronics in such a wide energy range.

4. Conclusions

An innovative MicroMegas detector assembly was tested and used in fission cross section measurements with monoenergetic neutron beams at the Institute of Nuclear and Particle Physics of the NCSR "Demokritos". The results on the ^{237}Np(n,f) cross section measurement agreed with existing data. The cross section measurements with this detector will be expanded to other neutron energy ranges (for example below 2 MeV with the ^{7}Li(p,n) reaction) and other actinide targets. Furthermore, additional investigation on the resolution function of the detector and the factors affectioning it in the case of alphas and fission fragments is needed and will be done in future works.

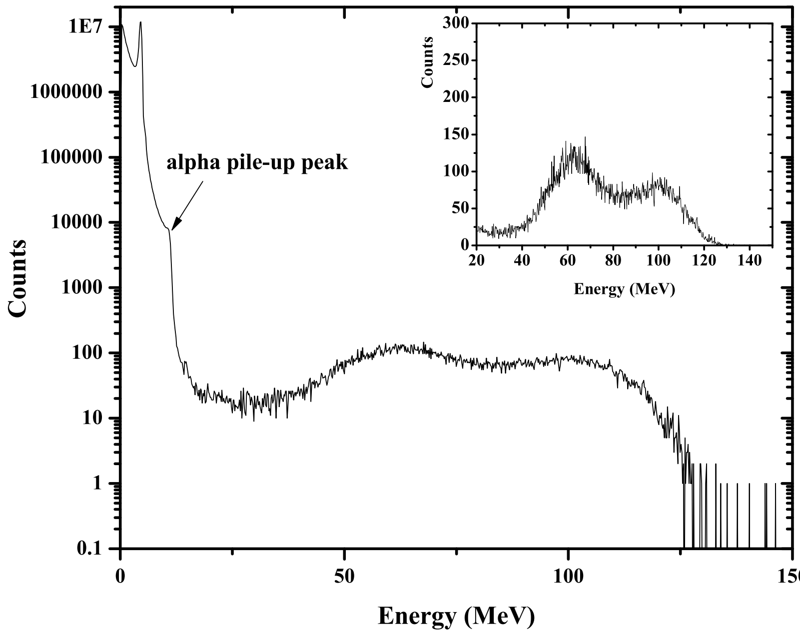

Figure 4: A typical spectrum obtained for the ^{237}Np target in logarithmic scale. The high alpha activity is causing pile-up effect, however orders of magnitude lower than the main peak. The inset contains the same spectrum zoomed at the fission fragment pulses, in a linear scale. The picture is taken from [5].

5. Acknowledgements

This research has been co-financed by the European Union (European Social Fund - ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: Heracleitus II. Investing in knowledge society through the European Social Fund.

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