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Neutron detection in high γ background using a micromegas detector

J. Pancin[a,*], S. Aune[a], E. Berthoumieux[a], S. Boyer[a], E. Delagnes[a], V. Macary[a], B. Poumarede[b], H. Safa[a]

[a] *CEA Saclay-DSM/DAPNIA, Bat 534/34A, F-91191 Gif-Sur-Yvette, France*
[b] *CEA-DRT/LIST Saclay, France*

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Abstract

The ability of Micromegas to detect neutrons over a wide energy range has already been demonstrated. However, in some nuclear experiments or applications, neutrons come with high photon flux disturbing the detectors. A new project for nuclear waste characterization using photonuclear reactions is under development at the CEA. One of the ideas is to detect the prompt neutrons produced by these kinds of reactions, which are accompanied by a strong γ flash. The micromegas detector has been chosen to detect these neutrons since it is quite insensitive to γ-rays under certain conditions. The configuration of this detector will be presented and its γ insensitivity demonstrated. Results from simulations and experiments will be shown.

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1. Introduction

The SAPHIR facility at CEA Saclay is experienced in radioactive parcel characterization using delayed neutrons [1,2]. An intense γ-ray beam is created by the slowing down of electrons in a copper or a tungsten target. The energy of the electrons is between 12 and 15 MeV with about 10^{12} electrons in one accelerator pulse of 2.5 μs. Photonuclear reactions are induced by the γ-rays on the minor actinides and transuranium elements but also on the impurities of the parcel. The actinide and transuranium quantities are evaluated by measuring the delayed neutrons coming from fission fragments, after the accelerator pulse, using ^{3}He counters placed all around the parcel. Detecting prompt neutrons during the accelerator pulse could be another means to characterize radioactive parcels. However, it would require detectors which are not blinded by the γ-rays flash like ^{3}He counters. A neutron detector based on a Micromegas concept [3] has been realized to detect these neutrons in the huge γ-rays flash. The principle of the detector is presented first. Some simulations have been performed to check the detector characteristics for neutron detection and evaluate its behavior in γ-beams. Some experiments and results are finally reported, showing the detector characteristics.

2. The neutron detector

2.1. Technical description

The Micromegas detector used here is quite similar to the one used for the n_TOF experiment [4]. The inner chamber, filled with a mixture of argon–isobutane or helium–isobutane at atmospheric pressure, has been reused. The detector, placed inside, is a double stage circular chamber with an active surface of 40 cm^2. It consists of a 9.5 mm drift gap and a 100 μm amplification gap. The two gaps are separated by a 5 μm thick nickel micromesh. The amplification occurs between the mesh and a copper printed circuit composed of eight strips of 9 mm wide spaced 100 μm apart. Some spacers insulate the

*Corresponding author. Tel.: +33 1 69082648; fax: +33 1 69085669.
E-mail address: julien.pancin@cea.fr (J. Pancin).

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printed circuit from the micromesh and guarantee the uniformity of the amplification gap. The drift electrode, covering all the detection area, is a 12 μm thick polypropylene foil on which a 100 nm layer of aluminium has been deposited to ensure electrical conductivity.

2.2. Detector principle

Electrons are produced between the drift electrode and the micromesh during the passing of charged particles through the gas. These electrons drift towards the micromesh under the action of the electric field applied in the drift gap (~1 kV/cm). After the micromesh, they are multiplied in the narrow amplification gap (high field with ~30 kV/cm) and this avalanche induces a current on the anode strips. However, a neutron to charged particle converter is necessary to detect the incident neutron. Since only fast neutrons are of interest here, neutron scattering on the nuclei of the polypropylene foil and of the gas is exploited (see Fig. 1). Above the detection threshold, the ionization created by the recoils is detected. For this application, the Micromegas detector is generally filled with He + iC4H10 (3.8%) (For safety reasons, the percentage of isobutane is sufficiently low to have a non-flammable gas).

On the one hand, helium is chosen since, as a light gas, it is less sensitive to X-and γ-ray photons. On the other hand, the lighter the nucleus, the larger is the energy transferred from the incident neutron. It is then the recoils of hydrogen coming from the foil and the gas, and the recoils of helium coming from the gas that are mostly detected. The hydrogen nucleus is of particular interest in fast neutron scattering since it can recoil with the entire neutron energy. In the case of helium, the reaction ^{4}He(n,n)^{4}He has a resonance around 1 MeV which increases the reaction rate.

2.3. Electronics and acquisition system

The current from each strip is registered for each 2.5 μs pulse of the electrons accelerator. These accelerator pulses play the role of trigger for the acquisition system. The strips are connected individually to fast current preamplifiers[1] with a 2 ns rise time. These preamplifiers are linked to 1 GSample/s flash digitizer boards[2] interfaced to a LabVIEW acquisition software by a VME-PCI optical link bridge module[3] [5,6]. The whole acquisition system can run with a frequency of 250 Hz. This limitation comes from the PC data transfer rate for the digital representation of the strip current. However, the SAPHIR accelerator can deliver between 1 and 400 pulses per second and we have used it at only 12 Hz.

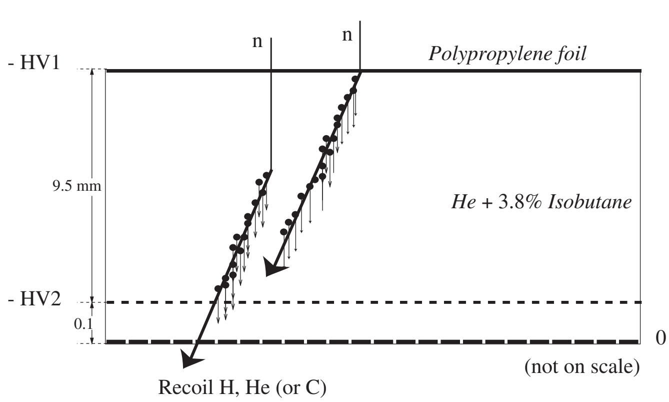

Fig. 1. Micromegas principle for neutron detection.

3. Simulations

3.1. Neutron efficiency

The neutron detection efficiency is evaluated using a Monte-Carlo simulation and the SRIM code (Stopping Range of Ions in Matter) [7]. The different processes of detection (proton recoils from the plastic foil and helium or proton recoils from the gas) are considered. The reaction yield of each process is calculated as a function of the neutron energy using the neutron cross-section from the ENDF data base. The recoils are generated uniformly in depth in the plastic foil and in the drift gap taking into account the differential cross-sections for the angular distribution. The ionization deposited energy in the gas is then calculated using the SRIM code and the recoils depositing less than the threshold energy estimated to 30 keV are discarded. This threshold energy is in fact the threshold energy per strip, which corresponds to a 6 mV amplitude signal. The simulated efficiency as a function of energy is presented in Fig. 2. The carbon recoils from the gas and the plastic foil are not represented since their number is negligible.

3.2. γ-rays sensitivity

One wants to be insensible to γ-rays or at least be able to discriminate γ-rays and neutrons [8]. Like neutrons, γ-rays must be converted before being detected. Obviously, the conversion rate of γ-rays in electrons through photoelectric or compton effects is more important in the surrounding material than in the gas of the detector. However, the deposited electron energy increases with its path inside the gas of the detector and more generally with the drift gap size. The electron and proton stopping powers are plotted in Fig. 3. Electrons deposit at least a factor 10 less than protons in helium. It should be easy to find an adequate gain for the detector permitting sensitivity to n-recoils but not to γ- and X-rays. Nevertheless, a problem could arise at low energy recoils, close to the threshold energy of the detector, where it could be impossible to distinguish a low energy electron having a transversal path in the detector

[1]ZFL-500LN from Minicircuit.
[2]Compatible with CAEN V1729 board.
[3]V2718 from CAEN.