LETTER OF INTENT

Micromegas performance test for (n,α) measurements at n_TOF: ^{33}S(n,α) cross section.

Javier Praena[1], Pierfrancesco Mastinu[2], Samuel Andriamonje[4],
José Manuel Quesada[1], Manuel Lozano[1]
for the n_TOF collaboration
and Ignacio Porras[3]

1) Universidad de Sevilla, Spain
2) Laboratori Nazionali di Legnaro, INFN, Italy
3) Universidad de Granada, Spain
4) CERN, Switzerland

Abstract

Presently, a neutron detector based on the Micromegas concept is running at n_TOF facility at CERN for monitoring purposes. The main goal of the letter is a first (n,α) cross section measurement by using the Micromegas detector. The transmission of the sample and detector allow performing the experiment in parasite mode. In the future a series of (n,α) measurements would be performed at n_TOF of interest in several fields such as nuclear technology, astrophysics, medical physics and material science. We propose to measure the (n,α) cross section of the stable isotope ^{33}S in the energy range from 0.1 keV to 100 keV. The possibility to cover a wider energy rage will be studied.

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1. MOTIVATIONS

The n_TOF facility at CERN has provided important (n,γ) and (n,f) cross sections data of several nuclei with applications in many fields, especially for the development of Accelerator Driven Systems, new generation of nuclear power plants and astrophysics [http://pceet075.cern.ch/]. The main motivation of this Letter of Intent is to open the possibility of (n,α) studies at n_TOF by using a detector yet running for monitoring purposes. As a first case, we propose to perform the ^{33}S(n,α) cross section measurement because of its very low contamination by (n,p) reactions, its high value and its high Q-value. We will try to cover at least the energy range from 0.1 to 100 keV.

Neutron cross sections are of interest in several fields and are required by the most important agencies as NEA and IAEA [1,2]. Requests for a variety of structural materials, neutron absorbers and other nuclear technology applications can be found for the reaction types: (n,p), (n,np), (n,α), (n,2n), (n,t), (n,f) and so on. In case of (n,α) cross sections, many requirements of different accuracies and energy ranges can be found. For example, in fusion technology the ^{22}Ne(n,α) is required for plasma diagnostics in the energy range from thermal to 16 MeV with an accuracy of 20%. In fission technology (n,α) cross sections of the structural materials as ^{nat}Cr, ^{nat}Fe and ^{nat}Ni are required in the energy range from thermal to 8 MeV with a 10% of accuracy. For other elements which form part of the moderation and cooling systems or fuel diluents, e.g. ^{nat}N, ^{15}N, ^{nat}Pb and ^{nat}Bi are required all the neutron cross section including the (n,α) channel in energy range from thermal or 1 eV to 10 or 20 MeV.

In astrophysics the (n,α) cross sections are of great for importance for the nucleosynthesis of the elements. The elements heavier than Fe are believed to be created by successive neutron captures and beta decays (*s*- and *r*-process), whereas the rare proton–rich isotopes are mainly assigned to charge particle reactions (*p*-

process). Measurements of (n,α) cross sections are needed for the *s*-process and for a grid of intermediate to heavy-mass nuclei for constraining the α-nucleus potential used in the statistical models for calculating the complex reaction network of the *p*-process.

In the range between Si and Fe, three neutron-rich isotopes (^{36}S, ^{40}Ar and ^{48}Ca) are believed to be bypass by charge particle capture reactions [3] and formed by neutron induced processes. Concerning the ^{33}S(n,α) cross section, it is of interest for the puzzling origin of ^{36}S, since it is included in one of the paths that it is believed to produce it:

$$^{32}_{16}S(n,\gamma)^{33}_{16}S(n,\gamma)^{34}_{16}S(n,\gamma)^{35}_{16}S(n,\gamma)^{36}_{16}S \xrightarrow[(p,\gamma)]{} {}^{37}_{17}Cl$$

$$\downarrow (n,\alpha) \qquad\qquad (p,\alpha)$$

$$^{30}_{14}Si$$

Auchampaugh *et al* [4] obtained by TOF the Maxwellian Average Cross Section (MACS) of ^{33}S(n,α) as a function of the thermal energy (kT). The value 690±170 mb at kT=30 keV corresponded to an overproduction of the ^{36}S in the Universe. In a later TOF measurement, Wagemans *et al* [5] obtained 227±20 mb, corresponding to an underproduction. A new measurement by the TOF technique at n_TOF could clarify these discrepancies between TOF measurements.

The ^{33}S(n,α) cross section is also of interest in medical physics. Recently, a research based on Monte Carlo simulations for a new or cooperating target for Boron Neutron Capture Therapy with epithermal neutrons has been performed by Porras [7]. The calculations of Porras show an important increase of the dose and equivalent dose absorbed in water for ^{33}S concentrations of 1% by using the most conservative values for Γ_α of the conflicting available experimental data.

2. EXPERIMENTAL DATA

The available experimental data related with this Letter of Intent are:

- Auchampaugh *et al* [4], 1975: (n,γ) and (n,α) from 10 to 700 keV, TOF.
- Wagemans *et al* [5], 1987: (n,α) from 10 keV to 1 MeV, TOF.
- Koehler *et al* [6], 1995: (n,α) from 10 to 300 keV, TOF.
- Schatz *et al* [3], 1995: (n,α) MACS at kT=25 keV, activation.
- Coddens *et al* [8], 1987: (n,tot) from 10 keV to 2 MeV, TOF.

The measurement of Auchampaugh *et al* [4] was performed at Los Alamos Scientific Laboratory vertical Van de Graaff (LASL) using the TOF technique and by the ^{7}Li(p,n) reaction with thin and thick targets as neutron source. The measurement of Wagemans *et al* [5] was performed at the Geel Electron Linear Accelerator (GELINA) with the TOF technique. The resonance analysis was performed up to 400 keV by combining the data of [5] with the transmission measurement of Coddens *et al* [8] performed at the Oak Ridge Electron Linear Accelerator (ORELA). Some discrepancies can be found between the values of resonance parameters.

The measurement of Koehler *et al* [6] was performed at the LANSCE facility of the Los Alamos National Laboratory for a test of a new (n,p) and (n,α) detector. The TOF technique was used for measuring the cross section from 10 to 285 keV.

3. EXPERIMENTAL SET-UP

We plan to use a Micromegas detector, which is already used for different applications for neutron detection via a neutron/charged particles converter [9]. The Micromegas detector concept is similar to the fast ionization chamber. The detection principle is: a gas volume is separated in two regions by thin micromesh, the first one where the conversion and drift of the ionization electrons occur, and the second one (50-160μm thick) where the amplification takes place (see Figure 1, left side).

The energy deposition of an incident charged particle in the conversion gap (alpha particles create in the $^{33}S(n,\alpha)$ reaction) creates ionization electrons that drift to the micromesh, which acts as cathode. In the amplification region, a high field (40-70 kV/cm) is created by applying a voltage of a few hundreds volts between the micromesh and the anode plane, which collects the charge produced by the avalanche process. The anode can be segmented into strips or pads. The positive ions are drifted in the opposite direction and are collected on the micromesh. The ^{33}S sample will be deposited on the drift electrode by evaporation, drop-deposition, sputtering or simply glued by a silver stick on the drift electrode constituted by thin foil window.

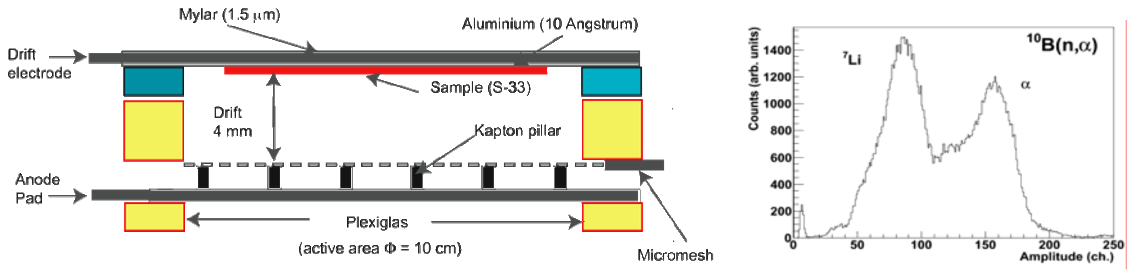

Figure 1: schematic view of the Micromegas detector. The sample position is represented by the red line, on the left side. Amplitude spectrum of the two products of the neutron reaction with a ^{10}B, on the right side.

The main advantages of this type of detector are:

- The possibility to adjust the gain permits to separate the alpha signals from the background noise; for example, the γ-flash produced in the spallation reaction can be minimized or eliminated.
- It is possible to use of low quantity of material, thanks to the new transparent Micro-bulk concept (micromesh + Kapton pillar + anode pad) minimize drastically the neutron background for the measurement.

The neutrons are signed by the detection of the alpha produced by the reaction. An example of (n,α) spectrum obtained for the $^{10}B(n,\alpha)^{7}Li$ reaction, presently used for neutron flux measurements at n_TOF [10], is shown in Figure 1, right side. The separation between the products is shown. The measurement of the $^{33}S(n,\alpha)$ cross section would serve as a first test of the performance of Micromegas for future (n,α) measurements. Indeed, this isotope seems to be a promising candidate for a first (n,α) study because of the no contamination from (n,p) reactions, its relative high cross section and favourable Q-value.

4. BEAM TIME ESTIMATION: PARASITIC MODE.

The sample for the (n,α) measurement with the Micromegas detector should have a diameter around 4-6 cm. The sample will be deposited on the drift electrode constituted by thin conductor foil window (see Figure 1, left side). For a short distance of the drift space (for example 4 mm) the alpha detection efficiency is close to 0.95. The efficiency limitation comes from the possible self-absorption of the alpha particles inside the sample. This problem can be relaxed by increasing the active area of the detector, the diameter of the sample, and by using a stack of Micromegas detectors.

We have chosen for the calculations a diameter of 4 cm with a mass of 25 mg, which corresponds to a layer 10 μm in thickness. The transmission of alpha particles of 3.1 MeV in natural sulphur is more than 99% for 12 μm (SRIM-08 code, http://www.srim.org/). ^{33}S enriched samples are commercially available and we already have a quotation of $276.25 from Trace Sciences International Inc. for a ^{33}S sample (purity >99%) of 25 mg of powder and with a delivering time of 2-3 weeks.

We have calculated the expected (n,α) counting for this sample for a energy resolution of 1000 bins/decade (Figure 2); the large fluctuations are related to the fluctuations of the experimental cross section of Wagemans *et al* [5] used for the calculation. A minimum of 1000 bins/decade is required to obtain sufficient resolution in the resonances, being **3000 bins/decade the optimum** binning. We have determined the requested number of protons so that the statistical uncertainty at the peak of the lowest lying resonances is better than 3%. This corresponds to a total of **10^{18} protons** which would be normally delivered in 3 weeks of beam time (7e12 protons/pulse).

The thin sample allows us performing the (n,α) measurement simultaneously with other cross sections measurements (parasitic mode) since neutron transmission through the sample would be larger than 99% even at the peak of the resonances. Indeed, this measurement would be very similar to the ^{10}B(n,α) that is always running for monitoring purposes and it could be considered as a first test of the performance of Micromegas detector for (n,α) future measurements at n_TOF.

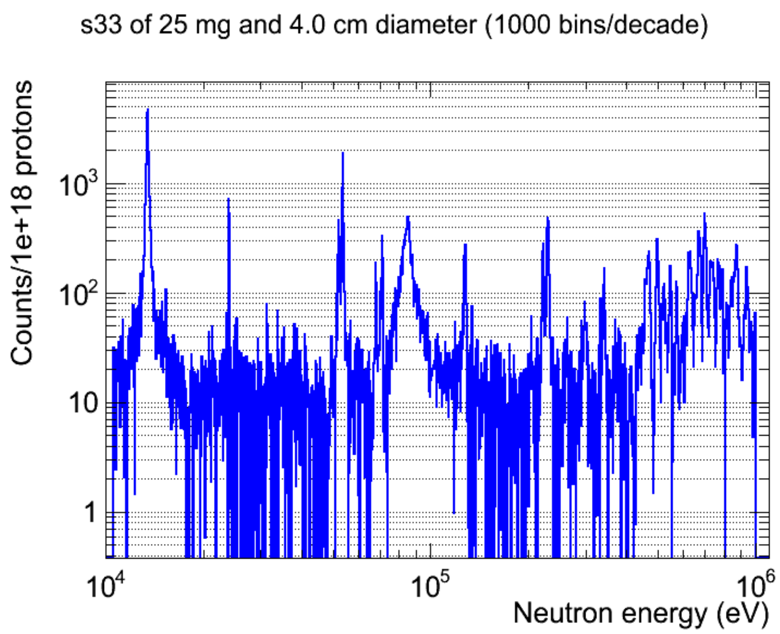

Figure 2: Expected counting based on the experimental data of [5] with a 25 mg and 4 cm diameter ^{33}S sample for a total intensity of 10^{18} protons.

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