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Improved Neutron Capture Cross Section Measurements with the n_TOF Total Absorption Calorimeter

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The n_TOF collaboration operates a Total Absorption Calorimeter (TAC) [1] for measuring neutron capture cross-sections of low-mass and/or radioactive samples. The results obtained with the TAC have led to a substantial improvement of the capture cross sections of ^{237}Np and ^{240}Pu [2].

The experience acquired during the first measurements has allowed us to optimize the performance of the TAC and to improve the capture signal to background ratio, thus opening the way to more complex and demanding measurements on rare radioactive materials. The new design has been reached by a series of detailed Monte Carlo simulations of complete experiments and dedicated test measurements. The new capture setup will be presented and the main achievements highlighted.

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I. INTRODUCTION

The Total Absorber Calorimeter [1] at the n_TOF facility [3,6] is used to measure neutron capture cross sections of low mass and/or radioactive samples, due to its high detection efficiency, its reasonable energy resolution and its segmentation in 40 crystals, which allows to differentiate capture events from the background events, while keeping a high detection efficiency values.

In order to improve future capture measurements, a new design of the experimental setup has been performed, with the purpose of improving the capture signal to background ratio. This new configuration is based on the minimization of the amount of materials intercepting the beam inside the calorimeter and the use of neutron absorbers placed around the materials which are present in the beam line outside the calorimeter, thus reducing the background from the neutron beam interaction with those materials.

In addition, the TAC operates with an internal spherical neutron absorber surrounding the samples. Such an absorber reduces the amount of neutrons scattered in the sample that reach the crystals (neutron sensitivity). A new central neutron absorber with improved absorption capabilities has been designed as well.

II. DESIGN OF THE NEW EXPERIMENTAL CONFIGURATION

Different sources of background have been identified in the standard experimental configuration by analyzing background dedicated measurements (see Fig. 1) and by performing detailed Monte Carlo simulations with the MCNPX [4] and GEANT4 [5] codes. The main source of background is due to the interaction of the neutron beam with the various materials present in the beam line. The two main sources are:

1- Neutrons captured at or scattered elastically in the materials inside the TAC: vacuum windows and the Ti capsule surrounding the radioactive samples.

2- Neutrons scattered in the vacuum windows outside the TAC, which can be moderated inside the concrete walls of the experimental area, and then captured in the walls or in the TAC crystals, producing a γ-ray background in times corresponding to lower energy neutrons.

A schematic view of production mechanism of these sources of background is presented in Fig. 2.

The same Monte Carlo codes used to identify these sources of background have been employed to perform the design of the new configuration. The concept behind the new configuration is the replacement of the small but massive Ti capsule of the samples by a long (1.5 m) canning. In this way, the largest amount of the materials intercepting the neutron beam are moved outside the TAC and only a thin Al layer sample backing is left inside the TAC.

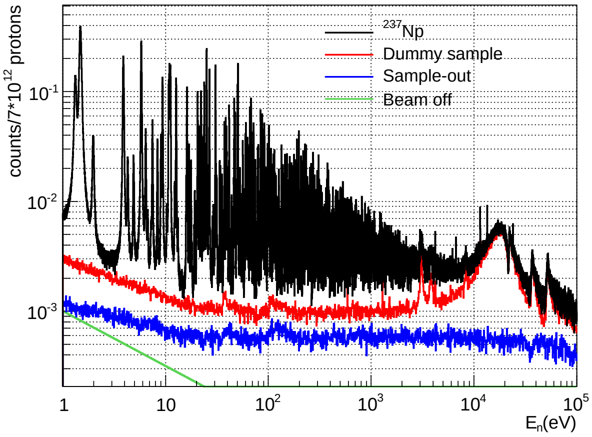

Fig. 1. (Color online) Number of counts detected by the TAC in a ^{237}Np measurement and dedicated background measurements.

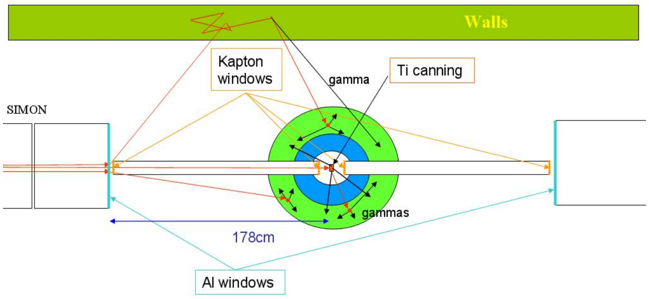

Fig. 2. (Color online) Schematic view of the standard configuration and main mechanisms of background production.

The vacuum windows outside the TAC are surrounded by neutron absorbers in order to minimize the fraction of neutrons that are first scattered along the beam line, and then absorbed in the concrete walls or inside the TAC. A schematic view of this new configuration is presented in Fig. 3.

The new configuration was tested in the n_TOF 2009 campaign. The preliminary results are presented in Fig. 4, where the new background rate (in red) is compared to the previous background with (in green) and without (in blue) the Ti capsule. Besides the important background reduction achieved over the neutron energy range of interest, it can be observed that the new configuration allows the extension of the energy range to higher

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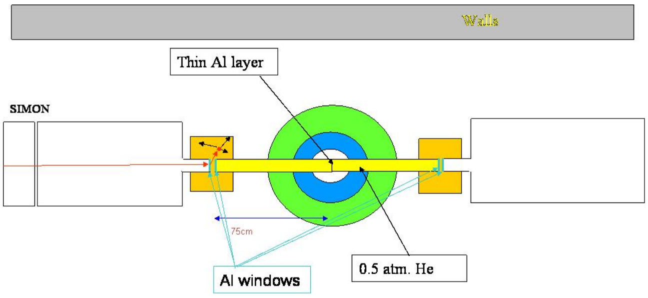

Fig. 3. (Color online) Schematic view of the new experimental setup.

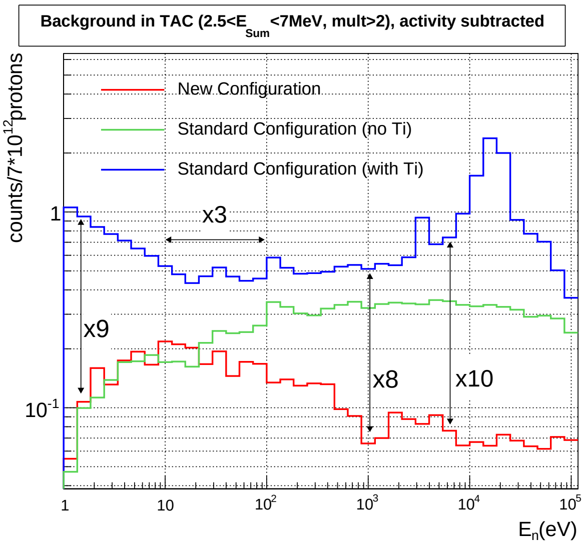

Fig. 4. (Color online) Preliminary experimental results showing the background reduction factors of the new configuration at different neutron energies.

energies because of the removal of the Ti canning, which presents a very strong resonance at 20 keV.

III. DESIGN OF THE NEW INTERNAL NEUTRON ABSORBER

Neutrons scattered in the sample can be captured in the detector crystals, leading to a source of background which follows the same resonant structure as the cross section of interest. In order to minimize this effect a neutron absorber is placed at the centre of the TAC, surrounding the samples. The neutron absorber has to absorb as many neutrons as possible and be at the same time as much transparent to gamma radiation as possible. A new neutron absorber has been designed by Monte Carlo simulations and constructed. The absorber material used in the past was based in a ^{6}Li salt [7]. The Monte Carlo simulations predict that a better performance could be achieved by a 5% weight ^{10}B doped polyethylene. The best possible absorber material found has been ^{6}LiH, but can not be used at CERN due to its high toxicity, flammability, and its classification as strategic material.

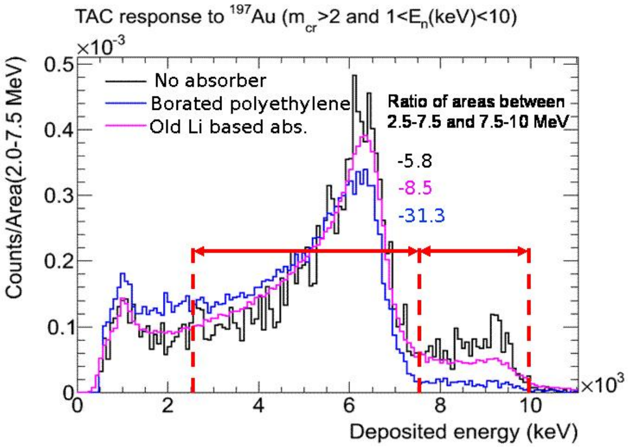

Fig. 5. (Color online) Spectrum of deposited energy in the TAC for neutron capture on ^{197}Au measured with the new central neutron absorber compared with the spectra obtained with the old absorber and without absorber.

The new neutron absorber was tested in the 2009 n_TOF campaign, and the preliminary results are presented in Fig. 5. The figure shows the spectrum of deposited energy in the TAC corresponding to ^{197}Au(n,γ) events induced by neutrons in the range from 1 – 10 eV. The three different spectra correspond to the response of the TAC without absorber (in black), with the ^{6}Li salt absorber (in magenta) and with the new ^{10}B doped absorber (in blue). The counts between 2.5 and 7.5 MeV correspond to real capture events, while the counts above 7.5 MeV are mainly background due to elastically scattered neutrons. The number of detected neutrons (*i.e.*, above 7.5 MeV) is strongly reduced by the new central absorber, while the amount of capture evens remains nearly constant.

IV. CONCLUSIONS

A new low background experimental setup for capture measurements with the TAC has been designed and constructed. The new setup employees a long sample container whose windows are placed inside a neutron shielding outside the TAC to avoid neutrons scattered at the windows entering the TAC, and a new internal neutron absorber. Specific characterization measurements were performed in 2009 with this new configuration. The preliminary data analysis shows that the background in the new configuration is about one tenth than in the standard configuration. The neutron sensitivity was also reduced to about one fourth of the old neutron absorber configuration and about one sixth of the non absorbent configuration. This will allow us to reduce the uncertainty in the next capture measurements and to extend the neutron energy range of the measurement to higher energies.

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