IMPROVED ACCURACY (N,γ) MEASUREMENTS AT N_TOF

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Several aspects related to the quality of the radiative capture measurements at the new n_TOF facility are reviewed following the initial measurements.

1. Introduction

The recently completed n_TOF facility at CERN \(^1\), has been constructed with the aim of obtaining high quality data relevant to the fields of Nuclear Technology, Nuclear Astrophysics and Fundamental Nuclear Physics. The essential features of the installation are the high instantaneous flux, the good energy resolution and the low intrinsic background. In order to fully exploit these characteristics for improved measurements parallel efforts were dedicated to the betterment of the experimental techniques. Some are common to all measurements, as the development of a zero dead time acquisition system based on the continuous digitization of the detector signals, which preserves the full experimental information. Below we restrict to the present status of the radiative capture measurements which are an important part of the planned experimental program at n_TOF.

2. Background and resolution function of the installation

The measurement of small cross-sections requires the minimization of the detector signals unrelated to the capture \(\gamma\)-ray cascades. A fraction of these background signals is generic to the installation, while another fraction is sample specific. At n_TOF considerable efforts were dedicated to the reduction of the installation related background \(^2\).

In fact, the measurements carried out have shown that below \(E_n \approx 100\) eV the observed background in the capture detectors is dominated by sample scattered neutrons which are subsequently captured in the experimental area. For higher energies the background is dominated by sample scattered photons originating at the spallation target. These delayed photons are coming from neutron capture in the Pb target, in the structural materials, and mainly in the H of the water moderator. The level of this background can be reduced by placing the detectors at backward positions (As an example, for a 2x45mm Fe sample an improvement of peak/background of 4 compared to the 90\(^\circ\) position can be obtained). Furthermore due to the very soft energy spectrum of the dispersed photons they are efficiently suppressed by the weighting technique (an additional factor 4 for the mentioned Fe sample).

In the resolved resonance energy region the other important parameter to consider is the time of flight resolution which determines the sensitivity (peak to background ratio) and resolved energy range. According to
FLUKA Monte Carlo simulations of the spallation-moderation process the FWHM resolution ranges from $8 \times 10^{-4}$ at 1 keV to $6 \times 10^{-3}$ at 1 MeV, and the shape of the resolution function exhibits a rather long tail. It is crucial to characterize this shape precisely as a function of the neutron energy in order to allow the extraction of accurate resonance parameters through the use of resonance fitting programs. The analysis of the measured high energy resonances (up to 200 keV) in $^{56}$Fe is being used for this purpose.

3. Detectors

In the initial phase, capture measurements will be carried out using a set of C$_6$D$_6$ liquid scintillator detectors applying the Pulse Height Weighting Technique (PHWT).

Despite the efforts which could be made in order to minimize the neutron beam background, the measured sample itself is a source of intrinsic neutron background through scattering. It is important therefore to minimize the neutron sensitivity of the capture detectors. This dictates, for instance, the choice of scintillator material. The dead material belonging to the detector itself has also to be carefully considered. A set of 0.6 l commercial detectors (BICRON) was developed employing a reduced aluminium canning and removable liquid expansion tubing, allowing a reduction of the neutron sensitivity by a factor 2 with respect to the standard detector. Another set of home-made 1.0 l detectors was developed for more critical applications. The use of C-fiber as canning material, the elimination of the quartz window between scintillator and photo-multiplier (PM) and the elimination of the PM housing reduced the neutron sensitivity by an additional factor 4.

4. Pulse Height Weighting Technique

The technique is based on the application of a pulse height dependent counting weight for each singly registered $\gamma$-ray in order to obtain the required independency of the detection efficiency on the energy and multiplicity distribution of the capture cascades. The weights are very sensitive to the full experimental arrangement including the measured sample itself and therefore the adequate procedure to obtain them is through a detailed Monte Carlo (MC) simulation of the setup. Obviously the resulting cross-sections depend on the quality of the simulation. Measurements have been devoted to determine the accuracy which can be achieved. The well known (and particularly sensitive) 1.15 keV resonance in $^{56}$Fe was chosen for this study. Two different detector setups, one for each type of C$_6$D$_6$ detector, and different Fe and calibration (Au and Ag) sample sizes were employed. The
weight as a function of deposited energy was obtained from Geant4\textsuperscript{5} Monte Carlo simulations. The preliminary results obtained for the $^{56}$Fe 1.15 keV resonance cross-sections from the different measurements indicate that an accuracy better than 2\% can be achieved with the MC weighting functions. This requires also the correction for several systematic deviations affecting the PHWT: 1) the summing of more than one cascade $\gamma$-ray in the detectors, 2) the loss of $\gamma$-rays in the cascade through the conversion electron process and 3) the loss of counts imposed by the noise discriminating electronic threshold. Such corrections have been calculated from a detailed simulation of the experiment including realistic capture cascades obtained from a statistical decay simulation code similar to existing ones\textsuperscript{6}.

5. Conclusions

The first results obtained during the Spring-2002 campaign at n\_TOF confirm the excellent performance of the installation and the related instrumentation, in particular for the \((n,\gamma)\) measurements. The installation related background has been reduced to the level where the sample related background is dominating. Efforts have been dedicated to minimize its influence through improvements of the detector set-up. Additionally the required high degree of accuracy of the PHWT was verified and the resolution function characterized.

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References

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