EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Proposal to the ISOLDE and Neutron Time-of-Flight Committee

Measurement of the ^{241}Am(n,γ) cross section at low energies at EAR2

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Abstract

The neutron capture cross section of ^{241}Am is an important quantity for nuclear technology applications. At n_TOF, two measurements have already been performed in EAR1 in 2010, one with the BaF_2 calorimeter, and one with C_6D_6 gamma-ray detectors. The obtained results allowed among others to extend substantially the resolved resonance region. Nevertheless, the data acquisition system in use at that time could not completely cover the thermal energy region. In addition, the low neutron energy range suffered from a considerable background due to the high radioactivity of the ^{241}Am sample, and consequently had a large systematic uncertainty. At near-thermal energies, this background is about 90% of the signal. We propose to measure the ^{241}Am(n,γ) cross section in EAR2, taking full advantage of the much more favorable signal to noise (due to radioactivity) ratio, while also extending the low energy limit to include the full thermal peak.

Requested protons: 1.6×10^{18} protons on target
Experimental Area: EAR2

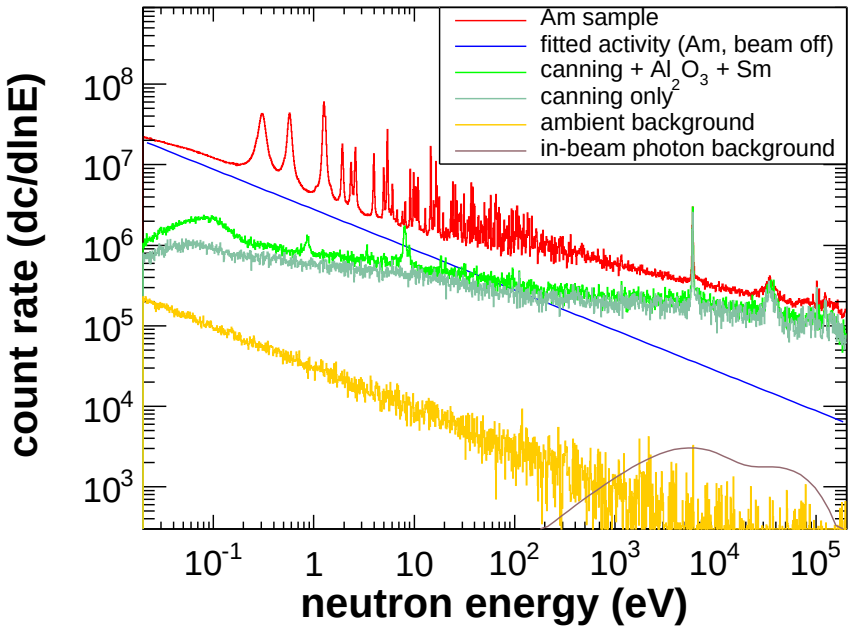

Figure 1: The previously measured ^{241}Am counting spectrum from the C_6D_6 measurement in EAR1 together with the various measured and calculated scaled background components. The count rate is expressed in a width-independent logarithmic equidistant binning. Figure from ref. [3].

1 Introduction

Following an earlier proposal [1], the INTC has approved the measurement of the neutron capture cross section of ^{241}Am. This reaction is of importance for nuclear technology applications and the ^{241}Am measurement was part of the EC-FP7 ANDES project [2]. Following this proposal, two neutron capture measurements were performed at EAR1 of the n_TOF facility: one measurement with C_6D_6 detectors [3] and another one with the BaF_2 total asborption calorimeter (TAC) [4]. The two detector systems are used frequently at n_TOF for capture measurements and have each their own characteristics. The C_6D_6 gamma-ray detectors benefit from a very low sensitivity to scattered neutrons and use the total energy technique to access the capture yield. The BaF_2 TAC is used with the total absorption technique. These two detector systems are expected to give consistent results as has been demonstrated for the capture cross section of ^{197}Au [5, 6].

2 Results from previous n_TOF measurements

While the results of the two EAR1 measurements, using the same sample, seem to be in agreement within the quoted uncertainties, both measurements suffer from a large systematic uncertainty at low neutron energy. This is caused by the large background component due to the radioactivity of ^{241}Am, greatly limiting the final obtained accuracy. The radioactivity of the sample was about 3 GBq, dominated by 60 keV γ-rays, but also including for example 662 and 722 keV γ-rays following the alpha decay of ^{241}Am, and a

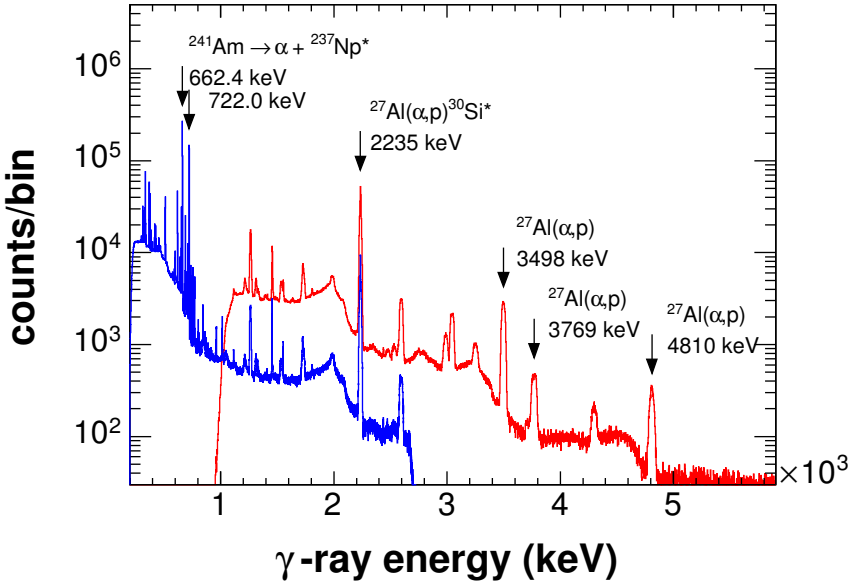

Figure 2: The gamma-ray spectrum of the ^{241}Am sample measured in two energy ranges with a dedicated HPGe setup [7]. Some characteristic gamma rays from α-decay or from α-induced reactions are shown as well.

2235 keV γ-ray from the (α,p) reaction on Al present in the Al_2O_3 matrix immobilizing the $^{241}AmO_2$ sample material. In total in EAR1 the gamma-ray background at thermal energies was about 90% of the signal, as shown in figure 1 where the neutron time-of-flight spectra are shown as a function of corresponding neutron energy for the C_6D_6 system. In figure 2 the radioactivity of the sample is illustrated by its gamma-ray spectrum as measured in a dedicated HPGe setup [7], indicating the most prominent gamma-rays.
Two other time-of-flight experiments, using different samples, have recently been performed. The first is a capture measurement at DANCE, Los Alamos [8]. The second concerns a capture and transmission measurement at GELINA [9] using a sample with $^{241}AmO_2$ in a Y_2O_3 matrix. The capture yield in this case was normalised to the results of the transmission experiments.
In order to improve the n_TOF results in the low energy region, we propose to measure the ^{241}Am(n,γ) cross section again, now in the new experimental area EAR2, which is clearly suited for highly radioactive isotopes like ^{241}Am. The extension of the low-energy region down to subthermal energies, will also allow a comparison with neutron capture measurements with reactor neutrons using differrent techniques.

3 New measurement in EAR2

The availability of EAR2 offers the possibility to do a ^{241}Am(n,γ) measurement with highly improved conditions for background due to radioactivity. Compared to the previous measurements performed in EAR1, there is a substantial increase in the ratio between the capture signal and the radioactivity background of more than a factor 250, due to an increased neutron flux (factor 25) and the smaller time bins for the same energy

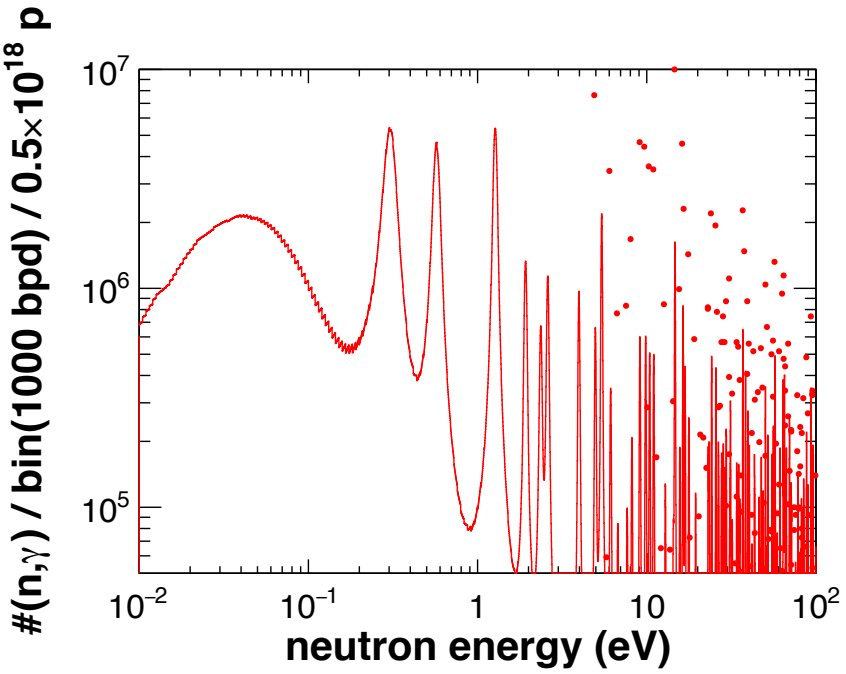

Figure 3: The number of expected (n,γ) reactions in the sample in EAR2. The red dots represent this number integrated over each resonance. The count rate in the detector depends on the final efficiency which is in the range of 3%.

range (factor 10). The reduced energy resolution in EAR2 with respect to EAR1 is less important: the focus of this measurement is on the resolved energy region below 300 eV and in particular the thermal region and the first few resonances below 10 eV. In addition, the currently available data acquisition system covers a time-of-flight window including the full energy range down to thermal energies thanks to a much larger on-board memory. At the time of the previous measurements in EAR1, the longer times of flight and therefore lower energies, were not accessible. A further improvement of this measurement will be the use of a different dummy sample. In the analysis of the data from the dummy used in the previous experiment a large peak identified as Sm was observed. Sm has a very high thermal cross section and is clearly observable at low energies. A radiograph of the dummy sample showed that the Al_2O_3 pellet was broken and apparently glued together, explaining the presence of Sm as a component in the used glue. We will use again the same Am sample from JRC-Geel, which is about 30 mg of $^{241}AmO_2$ immobilised in a Al_2O_3 matrix, and possibly a second, similar, sample from the same batch.

4 Summary of requested protons

We request in total 1.6×10^{18} protons for the ^{241}Am(n,γ) measurement in EAR2. Only 0.5×10^{18} protons are intended to be used with the ^{241}Am sample, the remaining 1.1×10^{18} protons will be used mainly for background and normalisation measurements. The different background components will be measured using among others dummy samples, $^{\mathrm{nat}}$C, and neutron filters. For the absolute normalisation the low-energy saturated resonances

Table 1: Tentative distribution of protons. Note that most of the beamtime will be allocated to background and normalization measurements.

sample	protons $\times 10^{18}$
^{241}Am	0.5
dummy	0.2
empty can	0.1
^{nat}C	0.1
^{197}Au, ^{nat}Ag, ^{nat}U	0.4
neutron filters	0.2
contingency	0.1
total	1.6

of three different isotopes will be used with samples of ^{197}Au, ^{nat}Ag, ^{nat}U. In addition calibrations and radioactive background measurements will be taken without beam. The gamma rays will be detected with a set of 4 C_6D_6 detectors, each of them shielded by 2 mm of lead, like in the case of the previous measurement in EAR1, to reduce the high current in the photomultiplier due to the high rate of the 60 keV gamma rays. Depending on the final experimental configuration, this reduction may also be achieved by increasing the geometrical distance to the sample, in this way also reducing the efficiency of the setup. Upstream the permanent neutron flux monitor SiMon2 will measure the energy dependence of the neutron flux in parallel. The expected number of (n,γ) reactions for the ^{241}Am sample in EAR2 is shown in figure 3 on a binning of 1000 bins per energy decade, together with the number of reactions integrated over each resolved resonance. The resolution of EAR2 is not included in this plot. The efficiency of the final capture setup is assumed to be in the range of 3%, depending on the needed shielding and covered solid angle. The new measurement in EAR2 would be much less sensitive to the high radioactive background. In addition the energy range can now be extended to the full thermal region.

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