

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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

Measurement of the $^{230}\text{Th}(n,f)$ reaction cross-section at EAR-1 and EAR-2 of the CERN n_TOF facility

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Abstract

The measurement of the neutron induced fission cross-section of ^{230}Th is proposed to be performed at n_TOF EAR-1 (covering the region at and above the fission threshold) and EAR-2 (covering the resonance and sub-threshold region) using Micromegas detectors. The natural but very rare isotope ^{230}Th , with a half-life of 7.5×10^4 y, is important for the Th-U fuel cycle and very interesting for the investigation of the fission process. Little data exist on the $^{230}\text{Th}(n,f)$ cross-section in the energy range relevant for fast reactors, with many discrepancies among them, while no data exists in the resonance region. Now that the appropriate material has become available at IRMM, highly enriched samples of ^{230}Th can be provided, allowing the measurement of new accurate cross-section data on this reaction from below threshold up to several tens of MeV and in the resolved resonance region.

Requested protons : 6×10^{18} (3×10^{18} in EAR-1, 3×10^{18} in EAR-2)

Experimental Area : EAR-1 and EAR-2



Furthermore, the fine structure in the excitation function at 715 keV has been interpreted in terms of a vibrational resonance in the secondary minimum of the double-humped fission barrier, with $K=1/2$, which could be the head of a rotational band with an effective moment of inertia that is up to 3 times higher than the value of normally deformed actinide nuclei [3]. This structure has also been investigated more recently, within the hybrid model [4]. Further structures have been observed in the data by Meadows [5] and Muir et al. [6], at 1.2 and 1.8 MeV, which have also been measured by Blons et al. [7] and Boldeman et al. [8], with more fine structures, but with cross-section values higher by about 40%. These large discrepancies extend also into the main resonance region at 715 keV.

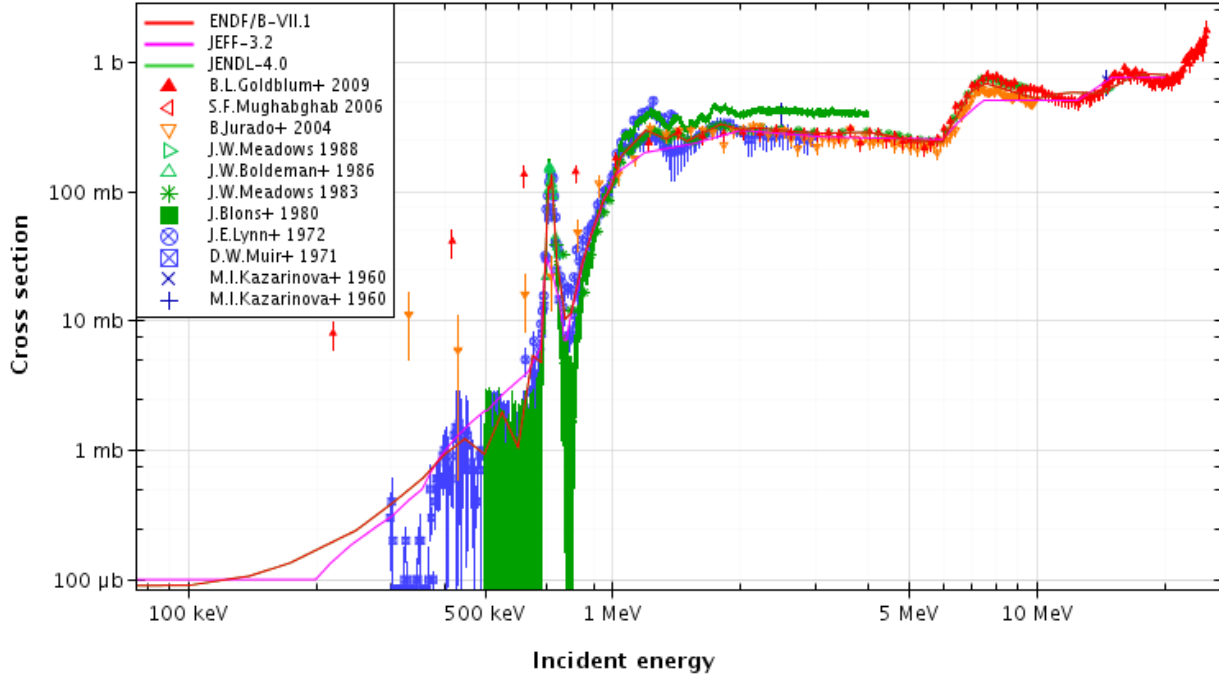


Figure 2. Fission cross-section experimental and evaluated data for ^{230}Th available in literature. No data exist below the fission threshold, with the exception of a single value at the thermal point.

The aim of the present proposal is to collect more accurate experimental data in the energy region close to the fission barrier in order to reveal finer structures of the fission mode and possible spectroscopic information on the states associated with the second well of the fission potential. In addition, accurate and consistent cross-section measurements will be provided in the lower energy region, where no data exist in literature, covering the largest possible energy range. The cross-section values will be deduced relative to the $^{235}\text{U}(n,f)$ and $^{238}\text{U}(n,f)$ reference reactions.

2. Experimental setup

2.1 The Micromegas detectors

For neutron measurements, it is of particular importance to minimise the amount of material present in the beam in order to reduce background related to scattered neutrons, as well as to avoid perturbing the neutron flux. To this end, the microbulk design [9] was developed, based on the Micromegas principle (see Fig. 3). The detectors have performed well both for monitoring the neutron beam and for the measurement of the $^{242}\text{Pu}(n,f)$ [10], $^{240}\text{Pu}(n,f)$ [11] and $^{237}\text{Np}(n,f)$ [12] cross-sections. For this reason, their use is also proposed for the present measurement.

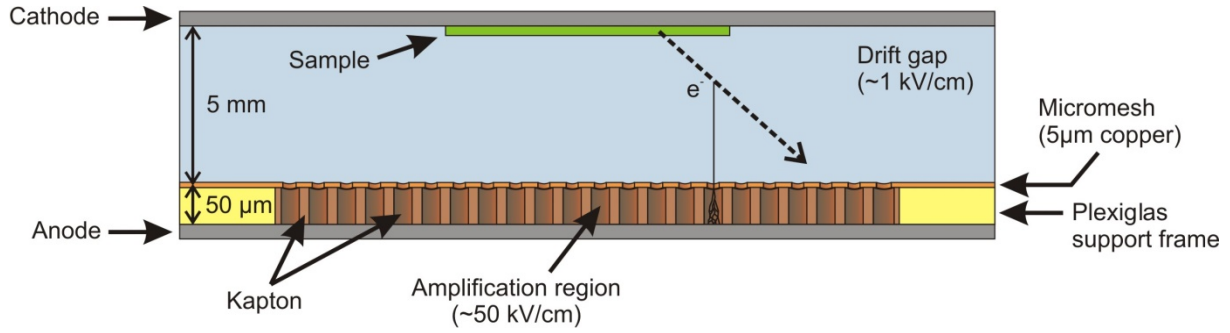


Figure 3: An illustration of the basic principle of operation of a Micromegas detector. An ionising particle emitted from a sample ionises the gas. The ionisation electrons drift towards the micromesh and are multiplied inside the amplification region before being finally collected on the anode. Indicative values are given for the electrical field strength values and dimensions of the two regions.

A chamber that can house up to 10 sample-detector modules is available for the proposed measurements. The chamber will be filled with an Ar:CF₄:isoC₄H₁₀ gas mixture (88:10:2), which is commonly used at CERN and has excellent timing properties due to the relatively high electron drift velocity.

2.2 Samples

The measurements of neutron induced fission cross-sections require the availability of highly enriched samples. The ²³⁰Th samples will be prepared at IRMM, Geel, where there is sufficient quantity of 91.54% purity ²³⁰Th with 8.46% ²³²Th content, in the form of thorium oxide (ThO₂). The contribution of ²³²Th can be accurately subtracted since the ²³²Th (n,f) cross-section is very well-known. Due to the low ²³⁰Th(n,f) cross-section, we propose to use large ²³⁰Th samples. The material will be electro-deposited on an aluminium backing 25 μm thick and 10 cm in diameter, while the deposit itself should have a diameter of 8 cm. A surface density of 100 μg/cm² corresponds to 5 mg per sample, with an activity of 3.8 MBq. We propose to use 6 samples with a total mass of 30.0 mg and total activity of 22.8 MBq (see Table 1).

Table 1. Main characteristics of the requested ²³⁰Th samples

Isotope	Purity [%]	Thickness [μg/cm ²]	Diameter [cm]	Sample Mass [mg]	Sample Activity [MBq]	No. of samples	Total Mass [mg]
²³⁰ Th	91.54	100	8.0	5.0	3.8	6	30.0

Additionally, samples of ¹⁰B, ²³⁵U and ²³⁸U will be used as reference. A preliminary agreement with IRMM to prepare the samples already exists and will be made official upon approval of this proposal.

2.3 Electronics and data acquisition

A setup based on existing electronics from previous fission measurements, consisting of custom-made preamplifiers will be used for fast signal shaping. Incremental improvements have been made over the past few years, adding electronic protection to the pre-amplifier channels to prevent breakage in case of sparks and shielding the preamplifier module to reduce the baseline oscillation observed following the prompt γ -flash. The analogue

detector signals will be input from the preamplifier module into the standard n_TOF Data Acquisition System based on flash-ADCs (12- or 14-bit).

3. Beam request

Due to the low cross-section of the $^{230}\text{Th}(n,f)$ reaction, we propose to perform the measurement using the large (“fission”) collimator available for EAR-1 (8 cm diameter), matching the diameter of the samples. Based on the expected count-rates, we request 3×10^{18} protons on target in order to cover the fission plateau at 1-2% statistical uncertainty and extend the measurement down to about 500 keV (Fig. 3).

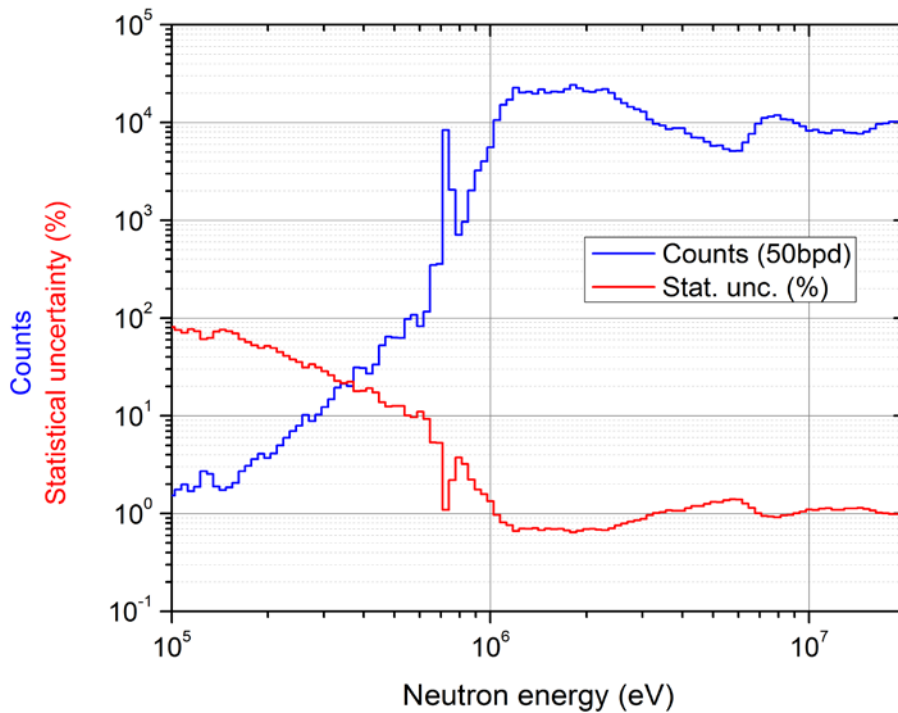


Figure 3. The total expected number of counts for 6 samples, large collimator in EAR-1, at 50 bins per energy decade and 3×10^{18} protons on target.

In order to cover lower incident neutron energies, and especially the resolved resonance region where no experimental data exists, further measurements are needed in EAR-2 with the large 6 cm collimator, where the neutron flux, especially in the thermal region, is about 15 times higher than the corresponding one in EAR-1 with the fission collimator. This makes EAR-2 the ideal facility to provide data for this previously unexplored region. Since there are no previous data, precise count-rate estimates cannot be made. We have used the calculated cross-section from the TENDL library as a “best guess” of the order of magnitude of the cross-section and thus request 3×10^{18} protons on target also for this second part of the experiment in EAR-2 in order to detect several resonances in the resolved resonance region with integrals of at least a few hundred counts or more. In addition to this, the measurement in EAR-2 will also complement the run in EAR-1 in the immediate sub-threshold region, adding significant statistics at energies of a few hundreds of keV.

Thus, the potential of both experimental areas at n_TOF will be exploited to obtain data with high resolution at and above the fission threshold up to high energies (EAR-1) and with reasonable statistics and acceptable resolution in the resonance and sub-threshold region (EAR-2). The measurement in EAR-1 can be performed in parallel with other

measurements using the large collimator. This may also be possible in EAR-2, but specific hardware solutions (e.g. special supports) would likely be required.

4. Summary

The measurement of the $^{230}\text{Th}(n,f)$ reaction cross-section remains a high-priority objective for nuclear technology and Th-U fuel cycle as well as for the study of the fission process and development of theoretical models. The availability of the very rare isotope ^{230}Th at IRMM, Geel, provides the opportunity to perform high-quality measurements at both experimental areas EAR-1 and EAR-2 exploiting their respective features and covering a wide energy range from the thermal region up to the fission threshold and to a few tens of MeV in order to address the uncertainties and discrepancies among the existing experimental data. A preliminary agreement with IRMM to prepare the ^{230}Th samples already exists and will be made official upon approval of this proposal. The sample holder design is ready and the Micromegas detectors and electronics already exist and have been previously used at n_TOF. Radio-protection procedures for the reception and handling of these samples are already in place. Furthermore, the previously developed analysis software could be used without major modifications. In conclusion, this experiment, which will produce high-quality results on a very important cross-section, can be carried out with a reasonable expected duration of about 4-5 weeks in each of the two areas, depending on the beam delivery rate.

Summary of requested protons:

3.0×10^{18} protons on target in EAR-1

3.0×10^{18} protons on target in EAR-2

Total: 6.0×10^{18} protons on target

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