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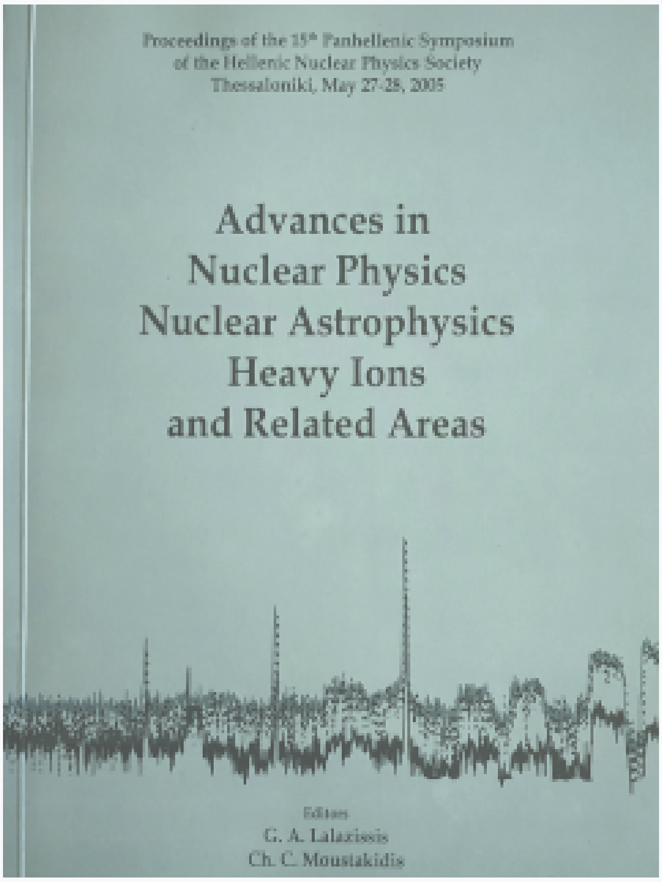

Neutron cross section measurements at the n_TOF facility (CERN)

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Neutron cross section measurements at the n_TOF facility (CERN)

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Abstract

The design of innovative Accelerator Driven Systems (ADS) for incineration of nuclear waste and energy generation requires the complete knowledge of basic cross sections for neutron induced processes. The main goal of the project is to produce, evaluate and disseminate high precision cross sections for the majority of the isotopes relevant to the waste incineration and the ADS design i.e. capture and fission cross sections for the minor actinides, capture cross sections for the main fission products and (n,xn) reactions for structural and coolant materials.

The most recent work, (2003-2004 campaign) took place at CERN, using a Total Absorption Calorimeter (TAC) in neutron capture measurements. The TAC was build at n_TOF facility and consists of 40 BaF_2 crystals, covering an almost 4π geometry. Several targets of special interest have been measured, such as $^{233,234}U$, ^{241}Am, ^{237}Np, ^{240}Pu and samples for reference and background determination as well (^{197}Au, ^{208}Pb, ^{nat}C). Preliminary results of ^{237}Np and ^{240}Pu and ^{234}U will be presented, indicating the good performance of the n_TOF facility, DAQ (Data Acquisition system) and TAC, allowing even more ambitious experiments in the future.

1 Introduction

Nuclear waste is one the main problems for the public perception of the nuclear energy production and for the sustainability of this energy source. For this reason, nuclear waste transmutation has been proposed as a way to reduce substantially the inventory of the long lived component of the nuclear waste, mainly the trans-uranium actinides.

Actinide transmutation is proposed to take place by fission in nuclear systems like critical reactors or subcritical Accelerator Driven Systems (ADS). In most of the scenarios, the use of fast neutron energy spectra and specific fuel compositions, highly enriched in high mass trans-uranium actinides, is proposed.

The currently existing nuclear databases can be used for the conceptual design of the transmutation oriented nuclear devices – critical reactors or ADS – and for the first order evaluation of the impact of the transmutation technology in the nuclear waste management.

However, the detailed engineering designs, safety evaluations and the detailed performance assessment of dedicated transmutation ADS and critical reactors (i.e. with fuels highly enriched in transuranic isotopes) require more precise and complete basic nuclear data, because these data sets are not accurate enough, are incompatible in some cases, do not cover the necessary neutron energy range and the resolution provided is not sufficient. Also the available evaluated cross section files do not agree between themselves as well.

2 Facility and Detection system main features

2.1 n_TOF facility

Neutron Time of Flight (n_TOF) [1] , is a facility that has been recently built at CERN – Geneva. Neutrons performed their first flight during November 2000 and since then several campaigns occurred, with different detector arrangements operated, along with some upgrades of the facility. The main characteristics concerning the proton beam, the lead spallation target and the neutron beam are the following:

<u>Proton beam</u>

- Proton beam momentum : 20GeV/c
- Intensity: 7 x 10^{12}p/pulse (dedicated) or 4 x 10^{12}p/pulse (parasitic)

- Repetition frequency: 1 pulse/2.4sec

Spallation module

- Material: Lead
- X,Y,Z dimensions: 80 x 80 x 60 (cm^3)

TOF tube

- Total length: 199.607m (mostly stainless steel)
- Internal diameter: [80 – 40] cm
- Two collimators used for beam modification

The neutrons produced from the spallation reaction in the lead target, 'travel' for a distance of 185.6m and reach the experimental area. Beam flux is monitored using several different techniques, such as silicon monitor, fission chamber and Au activation. All these methods along with simulation results are shown in figure 1.

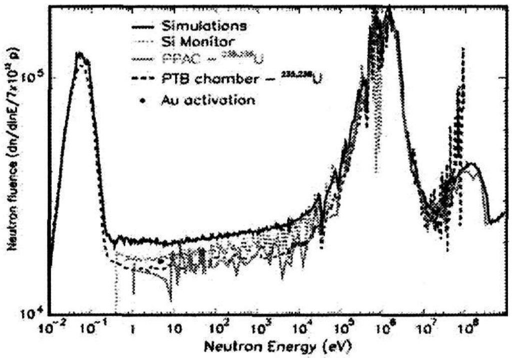

Fig. 1. Neutron beam flux resulted from different detectors and simulations

Beam profile was also another major issue, if we consider that a possible misalignment of the beam will lead to a different portion of neutrons that hit the targets, which furthermore will impact the cross section determination. The beam profile was determined with two different detectors, one solid state nuclear track detector (CR-39) and a gas detector (micromegas) [2],[3].

2.2 *Total Absorption Calorimeter (TAC)*

TAC consist of 40 BaF_2 crystals, forming a sphere, covering an almost 4π geometry (two wholes allow the entrance and exit of the neutron beam pipe). Detection efficiency is above 90%, while the energy resolution had an average value of 14% for 662KeV. Several radioactive sources were used for the energy calibration of the crystals (^{137}Cs, ^{60}Co, ^{88}Y and Pu/C) performed once a week or during a beam stop. A drawing of the TAC as it is in real is shown in figure 2.

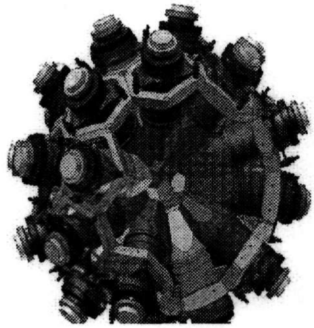

Fig. 2. Schematic view of TAC

3 Experimental

All targets measured at n_TOF are assembled in the same way: the radioactive material is sandwiched between two thin Al layers (total mass < 75 mg) and canned inside a 0.35 mm thick Ti canning with ISO 2919 certification (requested by the safety regulations at CERN). Their isotopic purity has been determined by γ -ray spectrometry and is more than 98% in all cases. For capture measurements with a 4 cm diameter neutron beam spot, the instantaneous flux amounts to 10^5neutrons/cm^2/pulse for neutron energies between 0.1eV and 20GeV.

The capture cross section measurements at n_TOF have been done relative to the standard capture cross section $^{197}Au(n,\gamma)$. For this reason, several independent monitors were used permanently for a proper normalization between the $^{197}Au(n,\gamma)$ and main measurements.

The Data Acquisition system (DAQ) [4] used in the measurements reads 54 channels of high performance flash ADCs [5] . Each channel has 8 Mbytes memory and was operated at a sampling rate of 500Msamples/s, thus allowing to record full history of TAC, Silicon and Fission Chamber (FIC) detectors. After zero suppression and data formatting, the raw data are sent to CERN's massive storage facility CASTOR [6] via several Gigabit links. In parallel, specially designed pulse shape analysis routines run on a PC farm and extract from the digitized detector signals the necessary information for the data analysis.

4 Results

The capture data for ^{237}Np and ^{240}Pu and ^{234}U have been taken during the period between August and October 2004. The data analysis is at an early stage. However, a simple analysis of the raw data with full statistics has given promising results. In the resolved resonance region, a large number of resonances are observed with good statistics. Raw data for ^{237}Np and ^{240}Pu, are shown in fig. 3. In the unresolved resonance region, a more detailed study and subtraction of the background is required, mainly due to the Ti canning effect as it is obvious from figures 4 and 5. However, clear capture signals are visible in the TAC energy deposition spectra. The background due to the empty Ti canning and other minor sources has been measured with high statistics and will be subtracted from the main measurement, thus leading to an accurate value of the capture cross section up to 100KeV.

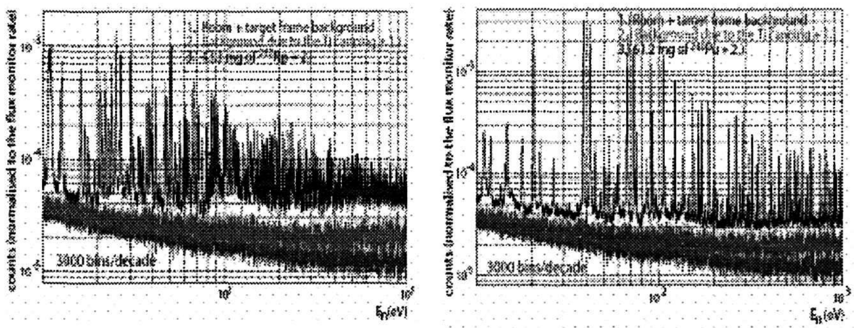

Fig. 3. Raw data from both Np and Pu (n,γ) measurements in the resolved resonance region between 10eV and 1keV along with the background due to the Ti canning and the empty TAC (without any sample in the beam)

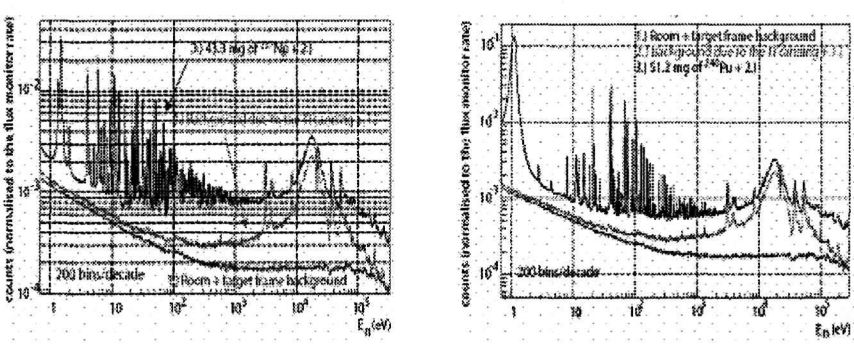

Fig. 4. Raw data from the Np and Pu (n,γ) measurements in the energy range between 0.7eV and 300keV, along with the background due to the Ti canning and the empty TAC (without any sample in the beam).

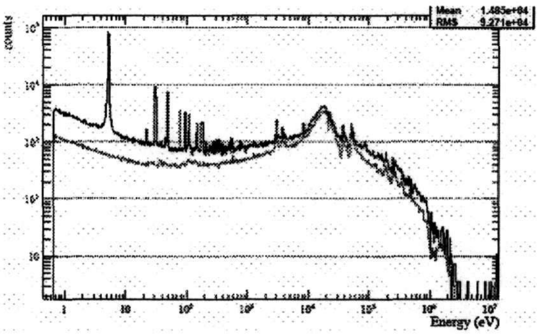

Fig. 5. Raw data from the $^{234}U(n,\gamma)$ measurement in the energy range from 0.7eV up to several MeV, along with the background due to the Ti canning.

5 Conclusions

The neutron capture cross section measurements of several isotopes have been performed at the n_TOF facility at CERN. A high performance Total Absorption Calorimeter made of 40 BaF_2 crystals was used for this purpose. The raw data for ^{237}Np, ^{240}Pu and ^{234}U are promising in the resolved resonance region, where a large number of resonances has been observed with good statistics for both isotopes. Furthermore, the capture events can be clearly distinguished from the background at neutron energies up to 100KeV, thus allowing to conclude that it will be possible to extract the capture cross section up to 100KeV after a careful background subtraction.

All ^{237}Np, ^{240}Pu and ^{234}U measurements are clear experimental validation of the good performance of the n_TOF facility, data acquisition system and TAC and allow the design of even more ambitious experiments in the near future.

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