Measurement and resonance analysis of the ^{237}Np neutron capture cross section

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The neutron capture cross section of ^{237}Np was measured between 0.7 and 500 eV at the CERN n_TOF facility using the 4π BaF_2 Total Absorption Calorimeter. The experimental capture yield was extracted minimizing all the systematic uncertainties and was analyzed together with the most reliable transmission data available using the SAMMY code. The result is a complete set of individual as well as average resonance parameters [$D_0 = 0.56(2)$ eV, $\langle\Gamma_\gamma\rangle = 40.9(18)$ meV, $10^4 S_0 = 0.98(6)$, $R' = 9.8(6)$ fm]. The capture cross section obtained in this work is in overall agreement with the evaluations and the data of Weston and Todd [Nucl. Sci. Eng. **79**, 184 (1981)], thus showing sizable differences with respect to previous data from Scherbakov *et al*. [J. Nucl. Sci. Technol. **42**, 135 (2005)] and large discrepancies with data Kobayashi *et al*. [J. Nucl. Sci. Technol. **39**, 111 (2002)]. The results indicate that a new evaluation combining the present capture data with reliable transmission data would allow reaching an accuracy better than 4%, in line with the uncertainty requirements of the nuclear data community for the design and operation of current and future nuclear devices.

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I. INTRODUCTION

Neutron capture cross sections of minor actinides have gained importance in the last decade because of their key role in the design and performance of advance reactors and transmutation devices for the incineration of radioactive nuclear waste. At present, the uncertainties on such nuclear data are probably acceptable in the early phases of design feasibility studies, but in many cases the accuracies are not sufficient for the design optimization phase in which economical and safety margins are to be minimized [1–3,21].

In particular, nuclear data for ^{237}Np are of utmost importance because it is the most abundant minor actinide in the spent fuel of a commercial LWR reactor and would be responsible for the largest number of capture reactions among the minor actinides present in the core of an accelerator driven system (ADS). A detailed investigation of the results from previous capture [5–11], fission [6,12,13], and total [6,7,12–14] cross section measurements reveals significant discrepancies between experiments. Indeed, the recommended ^{237}Np evaluations do not result from the combination of several data sets as it is always desirable; instead, individual data sets are selected for each reaction channel and each neutron energy range. In particular, in the resolved resonance region the neutron and capture widths in the JENDL-4.0 evaluation are from a single transmission measurement by Gressier *et al*. [14] while the capture cross section in the unresolved resonance region is directly that from the measurement by Weston and Todd [8]. In the case of JEFF-3.1 and ENDF/B-VII.1 the resonance parameters range only up to 150 eV and are taken directly from the work of Paya [12]. Only recently, a work by Noguere [15] has combined the most recent capture and transmission data; however, high-resolution data exist only up to 100 eV, with only one data set (Weston and Todd [8]) available between 10 and 100 eV. Therefore, the results above 100 eV are based only on transmission.

The n_TOF facility provides the means for high-resolution time-of-flight measurements of capture and fission reactions, and both cross sections have been measured for the case of ^{237}Np using the Total Absorption Calorimeter (TAC) [16] and the PPAC detectors [17], respectively. This paper is devoted to the measurement and analysis of the capture data measured with the TAC, which has provided for the first time capture data with enough resolution to study resonances above the previous 100-eV limit. The details of the experiment and data reduction are given in Secs. II and III, respectively. The resonance and cross-section analysis presented in Sec. IV combines the experimental capture yield with the most reliable transmission data available at the time of this work. The results are discussed and compared to previous evaluations and experiments in Sec. V.

II. CROSS-SECTION MEASUREMENT

A. The n_TOF facility at CERN

The n_TOF (Phase-1) facility [18,19] is part of the fixed target experimental program at CERN. At n_TOF a high-intensity neutron pulse is produced every 2.4 s from spallation reactions induced by a 20-GeV/c proton beam incident on a $80 \times 80 \times 60$ cm^3 lead target. A water layer of 58 mm cools down the target and moderates the initially fast neutron energy distribution.

The result at the irradiation position (185 m) is a high instantaneous intensity neutron beam that covers the energy range from thermal to relativistic energies with a nearly isolethargic distribution between 1 eV and few tens of keV. A neutron flux of 5×10^5 neutrons/cm^2 between thermal and 10 MeV is produced by each proton pulse of the nominal intensity 7×10^{12} protons.

The precise energy dependence of the neutron fluence in the energy range of this work (1–500 eV) was determined from measurements [38] with the ^{6}Li-based silicon monitor *SiMon* that results in an evaluated shape of the neutron flux with an accuracy better than 2% in the region below a few keV. Regarding the spatial profile of the neutron beam, two collimators placed along the neutron beam line provide a nearly symmetric Gaussian-shaped profile at the sample position. In the eV region the width of this Gaussian profile is ∼5 mm, yielding a total diameter of ∼4 cm [20].

The combination of the high intensity and wide energy range of the neutron beam with *state-of-the-art* detectors and