EPJ Web of Conferences 93, 01050 (2015)
DOI: 10.1051/epjconf/20159301050

Neutron-capture experiment on ^{77}Se with EXILL at ILL Grenoble

Ch. Lorenz[1,a], R. John[1], R. Massarczyk[1,b], R. Schwengner[1,c], A. Blanc[2], G. de France[3], M. Jentschel[2], U. Köster[2], P. Mutti[2], G. Simpson[4], T. Soldner[2], W. Urban[5], S. Valenta[6], and T. Belgya[7]

[1] Institute of Radiation Physics, Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany
[2] Institut Laue-Langevin (ILL), 38042 Grenoble Cedex 9, France
[3] Grand Accélérateur National d'Ions Lourds (GANIL), CEA/DSM - CNRS/IN2P3, B. P. 55027, F-14076 Caen Cedex 5, France
[4] Laboratoire de Physique Subatomique et de Cosmologie, CNRS/IN2P3, UJF, INPG, France
[5] Faculty of Physics, University of Warsaw, ul. Pasteura 5, 02-093 Warszawa, Poland
[6] Charles University, 116 36 Prague 1, Czech Republic
[7] MTA EK Hungarian Academy of Sciences, 1121 Budapest, Hungary

Abstract. The neutron capture reaction at ^{77}Se has been studied with cold neutrons in the course of the EXILL campaign at the high-flux reactor of the Institut Laue-Langevin Grenoble. A simulation of the detector array with Geant4 has been accomplished and evaluated. The detector response has been deduced and measured spectra were unfolded, which have been compared with simulations using γDex to determine strength functions.

1 Introduction

The knowledge about neutron-capture reactions is essential for the transmutation of long-lived nuclear waste. To enable the simulation and optimization of future facilities, nuclear data such as cross sections for capture and scattering of neutrons and fission reactions is necessary. In those processes short-lived isotopes are involved which are experimentally inaccessible. Therefore, nuclear models that can be tested by comparison with data from experimentally accessible nuclei have to be used.

In a cold neutron radiative capture process a highly excited compound nucleus is formed, which then de-excites via emission of γ-rays. Due to high level densities at high excitation energies the γ-ray spectrum exhibits many week transitions in the intermediate part which are not resolvable – the "quasi-continuum". By analyzing the γ-ray spectra, information about strength functions and level densities can be obtained. Furthermore, it might be possible to shed some light on the Axel-Brink hypothesis [1] by investigating coincidence spectra.

In this work a cold neutron capture experiment on ^{77}Se was performed at the high-flux reactor of the ILL Grenoble with the EXILL detector array (see Sect. 2). In a previous work [2] new levels and dipole strength functions for ^{78}Se have been deduced by analyzing the peaks of the spectra. To analyze also the quasi-continuum, it is necessary to know the detector response of EXILL. Therefore, a detector simulation has been developed (see Sect. 3). To determine strength functions, the spectrum fitting method [3] is used. First results are presented in section 4.

2 The EXILL Detector Setup

The EXILL detector array [4] consisted of 16 HPGe detectors comprising 46 crystals. Its geometry is visualized in figure 1. 8 EXOGAM clover detectors were placed perpendicular to the beam axis. 6 single crystal GASP detectors (small dewars) from the INFN Legnaro National Laboratory and 2 clover detectors from the LOHENGRIN fission fragment spectrometer at the ILL (bottom left and right) were positioned at an angle of 45° with respect to the beam axis. The EXOGAM and GASP detectors were equipped with anti-Compton shields. A self-triggering data-acquisition was realized by using digital electronics.

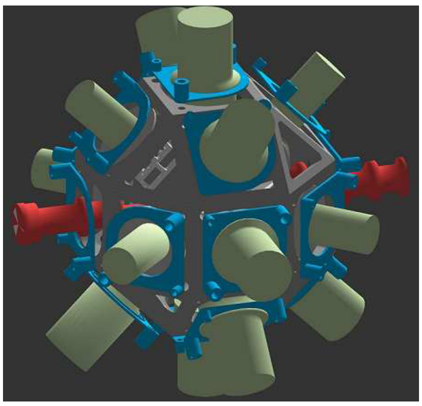

Figure 1. The geometry of the EXILL detector simulation.

[a] e-mail: c.lorenz@hzdr.de
[b] e-mail: r.massarczyk@hzdr.de
[c] e-mail: r.schwengner@hzdr.de

3 The EXILL Simulation

For the detector simulation the Geant4 toolkit [5] is used. It includes detailed descriptions of all 16 detectors and their anti-Compton shields as well as the beam pipe and the aluminum frame that was used to mount the detectors (see fig. 1). A dead layer at the core electrode is also taken into account. An extended source is simulated with

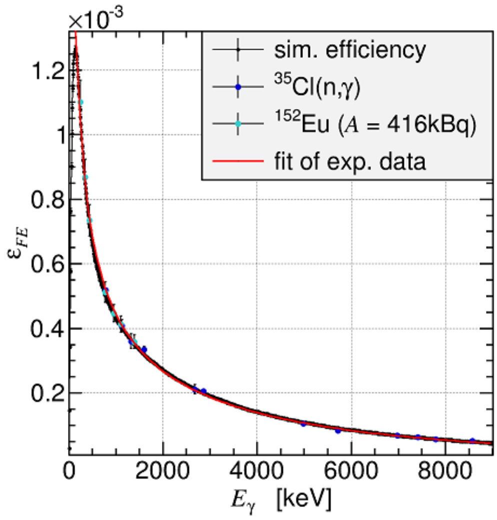

Figure 2. Efficiency of an EXOGAM crystal.

the G4GeneralParticleSource. In figure 2 the comparison of the slope of the simulated and measured efficiency is shown. They agree within 5% in the energy range from 0.2 to 10.6 MeV. Furthermore, the simulation reproduces the escape-to-full-energy peak ratios within the 1σ uncertainties.

4 First Results

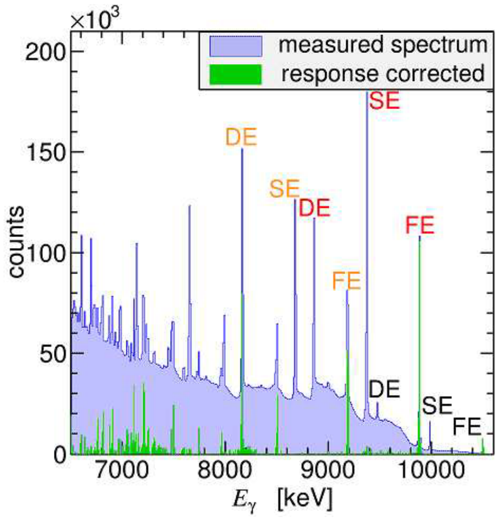

Figure 3. Spectrum of ^{78}Se before and after response correction.

With the EXILL simulation the detector response was simulated in 10 keV steps from 0 to 10.6 MeV. Figure 3 shows the high-energy part of a spectrum of an EXOGAM crystal before and after response correction. One can see that the single-escape and double-escape peaks as well as the Compton continuum are subtracted, whereas the full-energy peaks remain. The response-corrected spectrum is then corrected for efficiency and compared with a statistical γ-cascade simulation using γDex [6]. To ensure the statistical approach of γDex, the simulation and the response and efficiency corrected spectra are binned in 200 keV bins. A preliminary result is presented in figure 4. The slopes in the quasi-continuum are comparable except for an experimental excess at ~ 6 MeV.

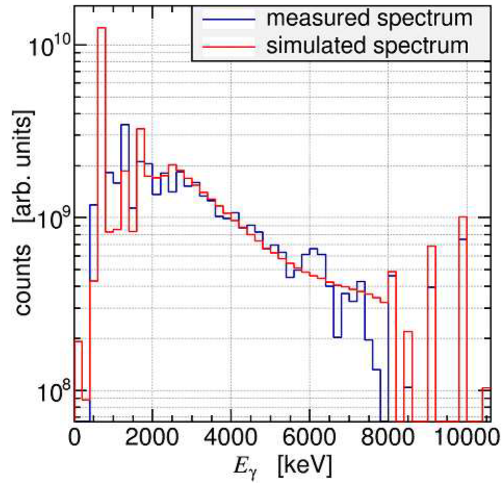

Figure 4. Comparison of the response and efficiency corrected spectrum with the γDex simulation.

5 Outlook

First results of the analysis of the quasi-continuum from the neutron-capture experiment at ILL with the EXILL detector array have been presented. A detector simulation of EXILL has been developed and validated. However, further investigation of the detailed properties of the individual crystals is necessary to improve the simulation. Furthermore, the detector resolution has yet to be implemented. To get more insight into the Axel-Brink hypothesis, strength functions on excited states will be studied using coincidence spectra.

References

[1] D. M. Brink, *Some aspects of the interaction of fields with matter* (PhD Thesis, Oxford University, 1955)

[2] R. John, *Untersuchung von Gammakaskaden und Stärkefunktionen in der Neutroneneinfangsreaktion ^{77}Se(n,γ)* (Diploma Thesis, Technische Universität Dresden, 2014)

[3] G. A. Bartholomew et al., *Advances in Nuclear Physics*, Vol. **7** (Springer US, 1973) 229-324

[4] P. Mutti et al., ANIMMA (IEEE, 2013) 1-6 (2013)

[5] S. Agostinelli et al., NIM-A **506**, 250-303 (2003)

[6] G. Schramm et al., PRC **85**, 014311 (2012)