Direction de la Recherche Fondamentale
Institut de Recherche sur les lois Fondamentales de l'Univers
Département de Physique Nucléaire

Saclay, August 30, 2022.

Subject: Opponent's Report on the Dissertation Thesis of Ms. Ingrid Knapová

Ms. Ingrid Knapová presents her manuscript entitled "*Study of gamma decay in ^{168}Er from neutron capture*" to be defended in order to obtain the doctoral degree from Charles University. The research field of the dissertation concerns low-energy nuclear physics. The thesis focuses on the study of nuclear structure properties, in particular on level densities and photon strength functions in the rare-earth nucleus ^{168}Er, produced by the ^{167}Er(n,γ) reaction. Those quantities are important ingredients for calculations of nuclear reactions used in computer simulations of complex multi-physics systems as nuclear reactors and astrophysical environments.

Multi-step cascade gamma-ray cascades following neutron capture from the ^{167}Er(n,γ)^{168}Er reaction, which have been measured with the DANCE detector array at Los Alamos National Laboratory, were analysed and compared to simulated spectra using the code DICEBOX. The work has given valuable insights of the quality of different models for level densities and photon strength functions which will be appreciated by the community. In addition, spins of several individual neutron resonances could be assigned. In a broader context such experimental data provide constraints for the currently ongoing development of theoretical models and calculations of those quantities.

The document is written in English and includes, among others, an introduction, six chapters, a conclusion, a bibliography, and two appendices. The appendices are in the form of journal papers (Physical Review C) with the candidate as first and corresponding author. The chapters provide additional in-depth information on the different aspects covered in the papers. The structure as well as the presentation of the thesis, including the figures, tables, references and numbering are fully compliant with today's standards of a PhD thesis in this field.

The first chapter describes the level density models, both phenomenological models, like the most commonly used Constant Temperature and Back-Shifted Fermi Gas models, and recent progress on microscopic model-based Hartree-Fock-Bogoliubov and Shell-Model Monte Carlo calculations.

Chapter two goes into more detail on the principle of photon strength functions, describing the state of the art on E1, M1 and E2 multipole strength functions, which are the ones of primary interest in this work. Both phenomenological and microscopic models are discussed, in particular the recent work on QRPA-based calculations. Moreover, the low-energy enhancement, for which strong indications have recently been reported in particular, but not only, in the case of rare-earth nuclei, is discussed and modelled as scissors-mode and spin-flip components of the M1 photon strength in the simulations performed in the current work.

The principle of the simulations and the concept of the statistical decay code DICEBOX are discussed in the chapter three. The origin of the statistical properties resulting from Random Matrix Theory and the corresponding fluctuation properties of neutron resonances are then treated in chapter four. These four chapters give the full physics context of the conducted research.

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The core substance of the dissertation is described in the remaining two chapters. Chapter five gives an overview of the experimental setup of the DANCE detector array and the related data analysis procedures, including background and time and energy calibrations. The population of the 109 ns isomeric state of ^{168}Er at 1.094 MeV could be extracted from the experimental data and could be confirmed by simulations when statistical decay was applied above a relatively high excitation energy. The considerations of constructing the experimental sum and multi-step cascade spectra are explained in detail. Spin assignments of neutron resonances in the ^{167}Er(n,γ) reaction could be performed using the prototype multiplicity distribution method.

Chapter six is dedicated to the results and discussion of the quantities defined in the previous chapters. In an impressively extensive study, statistical tests on the resonance neutron widths, resonance energy spacings, and the Δ_3 statistic are compared to simulated level sequences from Gaussian Orthogonal Ensembles. The comparison of the experimental multi-step cascades with the spectra from post-treated simulations of a series of model combinations of level densities and photon strength functions resulted in a selection of models describing reasonably well the experimental data.

The chapters of the thesis form a highly informative supplement to the two papers for the journal *Physical Review C*, which are included as appendices. The identification of new resonances, including several close doublets resolved using a powerful analysis technique, together with the spin assignments and completed by a rigorous missing level estimation, have led to an improved value and precision of the average *s*-wave level spacing which is a crucial calibration quantity for any level density model. Existing phenomenological photon strength function models for dipole radiation could well reproduce the measured spectra, while different theoretical strength functions based on QRPA calculations did not agree with the experimental multi-step spectra. The used detector array and analysis tools have been proven very effective to detect the decay of isomeric states.

In this excellent thesis, Ms. Ingrid Knapová has clearly shown her ability to perform creative scientific work in the field of experimental nuclear physics. Two high-quality papers have been written resuming the results of her thesis work. Therefore, I fully recommend the defence of this thesis.

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