BRNO UNIVERSITY OF TECHNOLOGY
FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION

Opponent Review of Doctoral Dissertation

Applicant: **Anhelina Tanchak**

Title of Dissertation: Investigation of Pu-239 transmutation for accelerator driven subcritical reactors

Opponent: Ing. Oleg Parlag, PhD.

Opponent's Department: Institute of Electron Physics, National Academy of Sciences of Ukraine

In accordance with the Study and Examination Rules of BUT, in his/her review the opponent will mainly comment on:
a) the topicality of the dissertation,
b) whether the dissertation achieved its given objective,
c) the problem-solving procedure and the results of the dissertation along with the concrete contribution of the doctoral student,
d) the significance for practical application or the progress in the field,
e) formal and language qualities of the dissertation,
f) whether the dissertation fulfils the conditions of Section 47 (4) of the Act,
g) whether the student proved his/her creative abilities in the given research field and whether the work does or does not comply with the standard requirements placed on the dissertations in the given field. The review is not valid without this conclusion.
It is necessary to add a concise commentary to each of the points below.

Ad a) Topicality of the dissertation

The topic of the dissertation is very topical.
Comment:
The dissertation topic holds considerable significance due to the concept of transmuting spent nuclear fuel (SNF). This concept is important in effectively managing nuclear minor actinides and long-lived products from SNF. Additionally, transmutation of plutonium holds significance in mitigating proliferation risks.

Ad b) Objective of the dissertation

The objective of the dissertation was achieved.
Comment:
The main objectives of this dissertation were to calculate cross section of residual products and to demonstrate the feasibility and effectiveness of transmutation process. The final data are presented very well, student provided deep analysys of obtained results. As expected, the results are dominated by radionuclides with short half-lives, that proves effictiveness of transmutation process.

Ad c) Problem-solving procedure and the results of the dissertation and the concrete contribution of the doctoral student

The problem-solving procedure and the results of the dissertation are above average.
Comment:
The results are presented in graphical and tabular form and include a discussion appropriate to the level of the dissertation thesis. As far as the formal requirements are concerned, the submitted thesis meets the level of a doctoral thesis. It is of a good standard, it is clear and comprehensible and is enriched with figures, graphs, equations, and tables. The table presents 66 found radionuclides with half-lives corresponding to units of days, which is a great contribution of the work. However, the comparison between experimental data and theoretical simulations (MCNP v.6.1 and FLUKA codes) highlights the accumulation and creation of radionuclides, following general trends but cross section values have different range, that is explained in thesis.

Ad d) Significance for practical application or progress in the field

The significance for practical application or progress in the field is excellent.
Comment:
Recieved data can to supplement existing data or to contribute new data for plutonium and research for advanced nuclear technologies such as ADS. Demonstrated the effectiveness of transmutation in converting long-lived radioactive isotopes into less hazardous, short-lived isotopes. Additionally, the obtained data can be used to evaluate the accuracy and efficacy of simulation codes for Pu-239 transmutation reactions.

Ad e) Formal and language qualities of the dissertation

Formal and language qualities of the dissertation are excellent.
Comment:
The thesis is written in Englishat a very good level, comprising of 186 pages divided into six chapters. The text draws upon a total of 172 sources, encompassing scientific articles, student scholarly theses, R&D websites, conferences, and subject presentations. It is noteworthy that the language complexity of the work is substantial. It is noteworthy that the language complexity of the work is substantial. Despite the considerable strengths outlined above, the thesis does exhibit a few minor issues that warrant attention: an instance is noted where the equation for calculating reaction rates (Fig. 2.7) is referenced without clear justification for its use, despite a previous mention of the equation; in Figure 6.21, there's an incorrect reference to the nuclear database, as it should be attributed to ENDF rather than EXFORD, as clearly indicated in the picture name; there is a discrepancy where Figure 6.16 is mentioned in the text but not actually included; Figures 6.15 and 6.17 are observed to be truncated on the left side, which limits the display of the full range of data. However, these are a very minor issues which does not impact the excellent overall impression.

Ad f) The dissertation fulfils the conditions of Section 47 (4) of the Act

The dissertation fulfils the conditions of Section 47 (4) *) Act No. 111/1998 Sb. Higher Education Act: YES

((4) Studies are duly finished with a doctoral state exam and dissertation defence, which prove the ability and readiness to work independently in the field of research or development, or in theoretical and creative arts. The dissertation must comprise original and published results or results accepted for publication.*

Ad g) Creative abilities of the student in the given research field. Compliance with the standard requirements placed on the dissertations in the given field.

The doctoral student did prove ~~his~~/her creative abilities in the given research field and the work does comply with the standard requirements placed on the dissertations in the given field.

Comment:

Student provides wide overview of all processes related to given topic. In this dissertation, student used two simulation codes for comparison with experimental data. Additionally, used PHITS code for better understanding spallation and fission reactions on plutonium target.

Overall evaluation:

The dissertation of the student Anhelina Tanchak focuses on investigating high energy proton induced Pu-239 transmutation. The thesis is written in English comprising of 186 pages divided into six chapters. The text draws upon a total of 172 sources, encompassing scientific articles, student scholarly theses, R&D websites, conferences, and subject presentations. It is noteworthy that the language complexity of the work is substantial. The dissertation topic holds considerable significance due to the concept of transmuting spent nuclear fuel (SNF). This concept is important in effectively managing nuclear minor actinides and long-lived products from SNF. Additionally, transmutation of plutonium holds significance in mitigating proliferation risks.

Chapter 1 serves as a valuable resource detailing information about accelerator-driven systems and pertinent nuclear processes relevant to the topic, including nuclear transmutation, spallation reactions, spallation products, and more. In Chapter 2, a broad range of theoretical information is provided on methods for determining fission and spallation products along with their cross sections. Chapters 3 and 4 offer insights into the practical application of software for processing gamma-ray spectra. They delve into the utilization of simulation tools such as MCNP v.1., FLUKA, and PHITS codes for theoretically predicting reactions involving protons with plutonium-239. Chapter 5 outlines the procedural steps involved in conducting an experiment on a thin plutonium target. This encompasses the preparation of the sample before irradiation, the irradiation process itself, transportation of the sample to the γ-ray spectroscopy laboratory, sequential measurement of gamma spectra, and subsequent data processing. Moving on to Chapter 6, which focuses on experimental results and analysis, it is structured into three main sections. Firstly, it showcases the experimental data results, illustrating the reaction rates and cross section values of radionuclides generated within the plutonium target. Secondly, simulation outcomes are presented, incorporating theoretical calculations of spallation and fission reactions using the MCNP v.6.1 code and FLUKA code. Finally, the last subsection concentrates on comparing the experimental data with simulations conducted using the Monte Carlo methodology. The results are presented in graphical and tabular form and include a discussion appropriate to the level of the dissertation thesis. As far as the formal requirements are concerned, the submitted thesis meets the level of a doctoral thesis. It is of a good standard, it is clear and comprehensible

and is enriched with figures, graphs, equations, and tables. The table presents 66 found radionuclides with half-lives corresponding to units of days, which is a great contribution of the work.

The thesis exhibits commendable formal qualities, boasting a logical structure, comprehensive theoretical content, accompanied by relevant illustrations, and a coherent presentation of calculation and simulation results. The student has effectively met the criteria defining a thesis, demonstrating a depth of understanding and contributing valuable insights to the field. The potential significance of the correctly interpreted experimental data cannot be understated, particularly given the scarcity of such results in the domain of nuclear fuel transmutation. The findings hold promise for advancing knowledge within the scientific community engaged in this area of research. The depth of analysis and contribution to the field aligns with the expectations for a doctoral-level thesis. Despite some minor mistakes (as mentioned in section e), I rate the overall professional level of the work positively and I confidently recommend the submission for defence.

Opponent's questions:

1. It's crucial to clarify whether the student conducted all simulations independently or if there was collaboration or guidance from supervisors or other experts. Acknowledging the extent of the student's involvement in the simulation process will provide a clearer understanding of their contributions to the research.
2. It would be purposeful to provide an explanation why FLUKA and MCNP software were chosen for the experiment. While these tools are commonly employed in nuclear physics research due to their robust capabilities and established reliability, it's important to explain why they were selected over alternative software options.
3. Whether further investigation or evaluation of the experiment is warranted. This could involve discussing any limitations or uncertainties in the current findings, proposing potential areas for future research, or suggesting refinements to the experimental setup or simulation methodologies.

I ☒ **recommend** ☐ **do not recommend** **the dissertation for the defence.**

Date: 12.04.2024

Signature: .....[redacted].....