REVIEWER´S ASSESSMENT OF FINAL WORK

I. IDENTIFICATION DATA

Title:	**Development and validation of new features for the G4SEE radiation effect simulation toolkit**
Author´s name:	**Bc. Eva Fialová**
Type of assignment:	Master Thesis
Faculty:	Faculty of Nuclear Sciences and Physical Engineering (FNSPE)
Department:	Department of Dosimetry and Application of Ionizing Radiation
Reviewer:	Kimmo Niskanen
Reviewer´s affiliation:	University of Jyväskylä, Faculty of Mathematics and Science, Department of Physics

II. ASSESSMENT OF CRITERIA

Work assignment — **average**

Assess how demanding the work topic is.

Given that the toolkit which was developed in this work has been in use for a while and is already beyond testing stage, I find the task of implementing few new features not too challenging. Therefore, I grade this as "average", when assessing the core task of the work. However, student has also covered several other topics in the thesis, such as radiation interaction mechanisms, radiation facility descriptions and also scratching the surface of nuclear- and accelerator based physics. Therefore, I would say that overall it is above average but it doesn't quite fullfill the criteria of demanding.

Fulfilling the assignment — **fulfilled**

Consider whether the work submitted meets the assignment. If necessary, give your comments on items of the assignment not fully answered, or judge whether the scope of the assignment has been broadened. If student failed to fully treat the assignment, try to assess the importance, impact and/or the reasons for the failings.

I understand that the assignment was to develop new features and validate the Geant4-based Single Event Effect simulation toolkit (G4SEE) for simulating radiation effects in electronics. I see this assignment fulfilled. Ideally, in the validation part, the developed features (dose scoring, LET scoring and energy deposition per interaction scoring) would have been validated, at least one of them. However, I can see that it was planned and simulations were performed but the due to the constraints at the test facility, the data was not collected. This is understandable considering the time frame of the thesis work and it does not affect negatively on my assessment.

Chosen approach to solution — **appropriate**

Assess whether student applied a correct approach or method of solution.

The approach is appropriate. Student has compared the simulation results of their implementation with existing solutions correctly in different use cases. Also the comparison as the ratio of different types of LET scoring are presented providing some idea about the uncertainty of the results.
Since SRIM software is the most common tool in the field to assess the deposited energy and LET in the material by radiation, I would have suggested to add that comparison as well. It would have been straightforward to add those to the plots which show LET. It would have further increased the impact of the work.

Professional standard — **average**

Assess the professional standard of the work, application of course knowledge, references, and data from practice.

The work includes some topics which I believe has not been covered during the university courses. Student shows familiarity with the previous work on the topic and provides some discussion about the results. However, discussion could be developed.

Level of formality and of the language used **excellent**

Assess the use of scientific formalism, the typography and language of the work.

This part of the work is at excellent level. Plots are clean and clear. Some graphs could be improved slightly but overall they are good. Especially the in the results part the plots are consistent and clear. Language is professional and typography is adequate.

Choice of references, citation correctness **average**

Assess student´s effort in finding and using study sources for completing their work. Give characteristics of the references chosen. Assess whether student made use of all the relevant sources. Verify whether all items used are properly distinguished from the results obtained by student and their deliberations, whether there are no violations of citation ethics, and whether the bibliography presented is complete and complies with the citation usage and standards.

It is clear that what has been obtained by the student and what is studied previously.
A large fraction of the references are presentation slides. Whereas these presentation might be good sources of information, more scientific sources could have been used in many cases.
Citations are used correctly in the text.
Some entries in the bibliography contain links and some not. These should be made consistent and preferably include links in every entry (if applicable).
Et al. has been used inconsistently.

Further comments and assessment

Give your opinion on the quality of the main results obtained in the work, e.g. the theoretical results, or the applicability of the engineering or programming solutions obtained, publication outputs, experimental skills, and the like.

The main results are useful in the radiation effects field. The implementation of the features will enhance the applicability of G4SEE toolkit for different use cases and lower the threshold for users adopting the tool for their work.

III. OVERALL ASSESSMENT, QUESTIONS TO BE ASKED DURING THE WORK DEFENCE, SUGGESTED GRADE

Summarize those aspects of the work that were significantly influential for your overall assessment. Suggest questions to be answered by student during the defence of the work before the examination board.
Overall, the work is large in volume containing several topics which is a merit on its own. However, it has its advantages and disadvantages. I see that the student will benefit of collaborations with different research groups and it has given them a good perspective of how varied and interdisciplinary is the field of radiation effects in electronics.

On the other hand, from the master thesis point of view, I see this amount of work a bit too much. In my opinion, this thesis suffers from both large data volume and scattered focus points which results in incomplete analysis and loss of “common thread”. For example, I find the silicon carbide section (5.2) a bit unnecessary since it is really not validation of the implemented features. Such section appears to me as a separate study which I believe has been motivated by the collaborators as something which is beneficial for them. Again, I think that it is also beneficial at some level for the student themself but also at the expense of the overall

quality of the thesis. Also, the facility descriptions of PSI and PARTREC presented here could have maybe been omitted since no experimental results were presented. In that way, the document would have been more compact and easier to follow. Also, that would have made some room for additional discussion about the physical mechanisms related to the differences between the results of different LET scoring methods in 4.2. However, some simulations were presented based on the beam energy degraders at the facility so in that sense the inclusion of descriptions are justified.

Another point of criticism is the description of the different LET scoring methods in 4.2. This is one of the key points of the work and therefore I put a lot of weight on assessing this. I was confused and after several reads I was still not sure that what is the difference between the second (Event) and third (Step) options. Are the secondary products included in both of the options or only in the other one and in which one? There are contradicting information about which deposited energies are included in which. In the caption of Fig. 4.2. contradicts with the text above it and also later in the text. This should be made very clear for the reader without any source of confusion. Figure 4.3 nicely compares the LET distributions of different calculation methods, so clarifying the related text would make this chapter very good. Also, I would have hoped to see an examples of the output files in 4.1-4.3 for the different implementations, something similar to Table 3.1.

When looking at the big picture, the student successfully guides the reader starting from MC radiation transport simulations through single event effects (SEE) in electronics and Geant4 based toolkit and its development finishing with the experimental part. Student shows skills to put together variety of topics such as SEE which include several different mechanisms in different technologies. Also, accelerator based electronics radiation parameters are introduced. It is not an easy task and even with some shortcomings here and there, I find this work interesting and overall good quality.

Suggested grade: C - good.

Kimmo Niskanen, PhD
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Date: 29/05/2024

Signature: