ČVUT
ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

SUPERVISOR'S ASSESSMENT OF FINAL WORK

I. IDENTIFICATION DATA

Title:	Development of a script for the calibration of individual optical modules in the segmented calorimeter of the SuperNEMO experiment
Author´s name:	Bc. Filip Koňařík
Type of assignment:	Master Thesis
Faculty:	Faculty of Nuclear Sciences and Physical Engineering (FNSPE)
Department:	Department of Nuclear Reactors (DNR)
Supervisor:	Mgr. Miroslav Macko, Ph.D.
Supervisor´s affiliation:	Institute of Experimental and Applied Physics, Czech Technical University in Prague (IEAP CTU in Prague)

II. ASSESSMENT OF CRITERIA

Work assignment and topic motivation — **demanding**

Assess how demanding the assigned topic is. Brief introductory word on motivation for choosing the topic.

The field of double beta decay (DBD) is gaining increasingly more attention by particle physicists in the recent years. In 1990s and 2000s, several very successful experiments managed to measure half-lives (for several isotopes) of very rare two-neutrino double beta decay (2νββ). In the most common version of this transition, two neutrons bounded in the nucleus are simultaneously transformed into two protons by emission of two electrons and two electron antineutrinos. However, the biggest goal of DBD experiments is to search for lepton number violating, beyond the Standard Model process called neutrino-less double beta decay (0νββ). One of the biggest challenges for each of the experiments searching for 0νββ is the background suppression. In order to maximize the sensitivity, the detectors must be placed underground, the materials for detector construction have to be carefully chosen to be radiopure and the state of the art techniques for radon suppression must be implemented. Each of the experiments searching for 0νββ need to deal with 2νββ as an inseparable source of background. This is because all the candidate isotopes for 0νββ also undergo 2νββ. The neutrinos from 2νββ fly through the detector without any interaction and, therefore, the detector detects only two electrons from both, the 2νββ and the 0νββ. Luckily, 2νββ and 0νββ differ in the energy spectra – kinetic energy of two electrons from 0νββ is always the same - the Q-value of the decay (delta-peak shaped), while 2νββ forms a continuous shape in the lower values. In the (hypothetical) ideal experiment, with perfect (0%) resolution 2νββ and 0νββ should be perfectly separated and distinguishable. However, if we consider the effect of the resolution, the spectra of 2νββ and 0νββ are smeared and they overlap. The better the resolution is, the smaller the overlap is.

The thesis of Filip Koňařík was dedicated to development of calibration script for the SuperNEMO detector. It is a complex task because energy of electrons in the SuperNEMO detector is measured by several hundreds of plastic scintillator segments, so-called optical modules (OMs). Each of the OMs must be calibrated individually. The SuperNEMO detector is unique in the field of DBD for having a multiwire tracking detector filled with gas. This complicates the task further because, on the way to the OMs, the electrons lose energy in the collisions with the gas. Furthermore, the collection of the light in the OMs is not a linear function of the energy and correction of these so-called "optical effects" need to be performed. I consider the master thesis task given to Filip Koňařík as demanding because it requires to properly combine deep knowledge of the physics of plastic scintillator, tracking gas detectors, the interaction of the charged particles with matter and advanced software methods to develop a model which would be suitable for a large number of relatively diverse OMs.

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Fulfilling the assignment **fulfilled**

Consider whether the work submitted meets the assignment topic. Comment, if necessary, on items of the assignment not fully answered, or mention whether the scope of the assignment has been broadened. If student failed to fully treat the assigned topic, try to assess the importance, impact and/or the reasons for failings.

The task given to Filip Koňařík was to primarily develop a plausible model for correction of electron energy losses and then combine it with already existing correction of optical effects in OMs developed by group at University of Bordeaux. Original expectation was to obtain a phenomenological model based on the simulations. Filip Koňařík completed this task sooner than it was expected and, therefore, he was asked to improve the model, based on the fundamental principles: Bethe-Bloch model of energy losses of electrons in matter. Based on this improvement, Filip Koňařík managed to shrink the number of parameters of the model from original five (phenomenological model) to only one (Bethe-Bloch based model). Moreover, the Bethe-Bloch model was based on the parameter with physical interpretation – pressure in the tracking gas. This allowed to independently confirm the correctness of the model. Filip Koňařík managed to successfully combine his model of electron energy losses with the model of relatively complicated optical effects in the OMs. He integrated all these results into a complex software package which will be used for the calibration by the whole collaboration. Finally, he also managed to provide first estimation of the OM resolutions which sparked a lot of interested among the collaborators. Based on all the aforementioned reasons I consider the assignment more than fulfilled.

Student´s effort and independent approach to the topic solution **excellent**

Assess whether student displayed constant effort while investigating the problem, whether they regularly consulted the issues and whether they attended consultations well prepared. Assess student´s creativity and independence.

Filip Koňařík approached his thesis task with lot of interest, curiosity and with high degree of independence. He managed to familiarize himself with new topics (e.g. the Bethe-Bloch theory of electron interaction with matter) very quickly and with my minimal intervention. He often familiarized himself with particular topics beyond my knowledge as a supervisor. This helped him to not only contribute to the research by fulfilling planned tasks but also to actively propose better solutions. He also successfully applied the knowledge acquired in his master program for the good of the project. The use of the downhill simplex method to optimize the loss function was one of the suggestions which were proposed by Filip Koňařík himself. I conclude that Filip Koňařík was always active and well prepared for the consultations. He showed a high degree of independence and, therefore, I evaluate his effort as "excellent".

Professional standard **excellent**

Give your opinion on the professional standard of the work, application of course knowledge, references, and data from student´s practice.

As mentioned in the previous section, Filip Koňařík was able to work independently and propose solutions based on the knowledge acquired during his master courses and beyond. His first experimental estimations of the OM resolutions drew lot of attention in the collaboration. The collaboration even held a special videocall dedicated to this strategical result where Filip Koňařík received a lot of feedback and praise on his results from the experts in calorimetry within the collaboration. The software which Filip Koňařík developed will be used in following years by the whole collaboration for the regular energy calibration of the detector. I consider the professional standard of the results and the outputs including the thesis as "excellent".

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

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

The thesis is well written with minimal number of typographic errors. I consider that the formatting of the thesis fulfils the highest standards. Filip Koňařík managed to write the thesis in English language which made it accessible for the whole collaboration. I consider the level of formality and the language level as "excellent".

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Choice of references, citation correctness **excellent**

Give your opinion on student´s effort in utilizing references in their investigation. Characterize the choice of references and say whether all relevant sources were utilized. Verify whether all resource facts were properly distinguished from student´s own findings and results, whether there was no breach of citation ethics, and whether all reference citations are complete and agree with the citation usage and standards.

I appreciate the number of references which Filip Koňařík cited in his thesis. The references follow the proper citation ethics. It is easy to distinguish the author´s original work from the content which was taken and (properly) cited from other authors.

Further comments and assessment

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

Except for the brilliant thesis, I would also like to mention some other achievements of Filip Koňařík connected to the thesis preparation. Filip Koňařík regularly (cca. once per two months) presented his work during the regular analysis video meetings of the SuperNEMO collaboration. In 2022, he received two financial awards. One from Josef Hlávka foundation and the other one was a CTU funded stipend named "Scholarship Support for Gifted students". He received both for his extraordinary results connected to his master thesis project.

In 2022, Filip Koňařík presented his work at international conference "Matrix Elements for the Double beta decay Experiments" (MEDEX´22) in form of 25-minute talk. Furthermore, in 2023, he co-authored a poster presented at large international conference named "Topics in Astroparticle and Underground Physics 2023" (TAUP 2023). For both conferences he also prepared proceedings.

In June 2024, he will present a poster at the large international conference "Neutrino 2024" summarizing his final results from the thesis. At the same time, he is preparing an article which we plan to submit before the end of 2024. In my opinion, the scientific output of Filip Koňařík is extraordinary for the master student and I dare to say more appropriate for a student of doctoral level.

III. OVERALL ASSESSMENT AND SUGGESTED GRADE

Summarize all aspects of the work most influential for the overall assessment. If adequate, write questions to be answered by student during the defence of their work before the board.

As it was mentioned in the previous sections, the question of energy calibration and the energy resolution is a strategic question for each DBD experiment. The work of Filip Koňařík received a lot of attention and positive feedback in the (international) SuperNEMO collaboration. Filip Koňařík profited from interaction with the best experts in the experimental particle physics and this fact left a clear positive mark in his work. I consider the thesis clearly written with minimal number of typographic mistakes. I suggest accepting the thesis for a defence.

I suggest to evaluate the thesis with a grade: A - excellent.

Date: 27.5.2024

Signature:

Miroslav Macko (supervisor)