ČVUT
ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

REVIEWER´S ASSESSMENT OF FINAL WORK

I. IDENTIFICATION DATA

Title:	**Advanced Methodology for Radiation Field Decomposition with Hybrid Pixel Detectors**
Author´s name:	Declan Garvey
Type of assignment:	Master Thesis
Faculty:	Faculty of Nuclear Sciences and Physical Engineering (FNSPE)
Department:	Department of Nuclear Reactors (DNR)
Reviewer:	RNDr. František Mráz, CSc.
Reviewer´s affiliation:	Katedra softwaru a výuky informatiky, Matematicko-fyzikální fakulta, Univerzita Karlova

II. ASSESSMENT OF CRITERIA

Work assignment — **demanding**

Assess how demanding the work topic is.

The subject of the thesis is quite complicated. Solving the problems requires extensive study of hardware, software, and machine learning methods. Without a detailed analysis, the results would not be good, and some errors caused by hardware or the environment could not be corrected.

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.

The thesis succeeded in solving all the goals – see below.

Chosen approach to solution — **appropriate**

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

The methodology of the student is excellent. The carefully selected methods are suitable and enable solving all problems from the assignment.

The thesis studies methods for using Timepix particle detectors for analyzing various radiation fields. Timepix particle detectors can register tracks of charged particles of a broad energetic spectrum in extremely fine time and space resolution. Such detectors produce an enormous amount of data that must be processed to extract the properties of the detected particles and measure the particles' spectrum.

After introducing detectors Timepix and Timepix3, the thesis describes possible use cases for the detectors. For the development of methodology and algorithms for radiation field analysis, ground-truth data are needed. Such data were obtained from careful simulations that were validated against real-world measurements in several experiments.

The examined methods comprise Bayesian deconvolution, neural networks, random forests, and XGBoost algorithm. For efficient algorithms, several easy-to-compute features were considered. Similarly, for particle tracking, several methods were examined and compared.

Based on the comparison on simulated datasets, it turned out that the best results in particle classification were produced by Bayesian deconvolution and random forests. Random forests also yield the best results in

particle tracking.

The author subsequently applied the developed methods to the data from three types of experiments. The first was measuring the spectrum of particles in the Danish Centre for Proton Therapy. Here the results confirm the composition of the produced particles and the background measurement.

The second was analyzing data from the Space Application of Timepix based Radiation Monitor. A thorough analysis not only confirmed the expected South Atlantic Anomaly but also enabled obtaining the energy spectrum of the proton field of the Earth's inner radiation belt. While it seems easy, the data were obtained using the older Timepix detectors that do not fully enable the separation of geometrically overlapping particle traces.

The last type of experiment was data from Monopole and Exotic Detector at the Large Hadron Collider in CERN. The achieved results enable to locate and measure properties of interaction points where ions of lead collided and later also protons. Further, the analysis facilitates the separation of the particles from the interaction from the background and also a partial classification of the detected particles.

Professional standard **excellent**

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

The thesis fulfills high standards for scientific work.

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

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

The text of the thesis is well-written, with enough details. The text has only a few minor grammatical errors, like double "always being" on p. i, l. -7, missing "be" between "can" and "constructed" on p. 5, l. -2, "was been" instead of "has been" on p. 15, l. -1, missing comma after "Bayesian formula" on p. 17, l. 8, missing "is" after "This" on p. 18, l. 5, confusion between "affect" and "effect" on p. 22, l. 5 and p. 26, l. 7, wrong word order in "the is histogram normalized" on p. 34, l. 16. should be "the histogram is normalized."

Choice of references, citation correctness **excellent**

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.

The author used extensive recent sources related to Timepix and Timepix3 detectors. The literature used is also suitable for machine learning methods. All the sources are cited correctly.

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 results achieved are excellent and of great importance in developing state-of-the-art analyses of the radiation fields. They will influence future research in the field. The proposed methodology is applicable to similar data, enabling its applications in many other situations.

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I have only one remark concerning the proposed and analyzed machine learning methods. For completeness of the comparison of the used methods, the parameters of the methods should be given. E.g., their architecture and learning parameters should be given when speaking about neural networks. Similarly, other machine learning methods usually have hyperparameters that could strongly influence the results.

From a computer science point of view, the importance and overall value of the thesis contribution could be increased by publishing the code used in the investigations.

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.

In summary, the thesis of Declan Garvey is outstanding. The results achieved are excellent and important for future applications of Timepix detectors. The high quality of the thesis was already acknowledged, as the methods and results were already published in two papers.

Questions for the defense:
1. What were the main parameters for the examined machine learning methods, e.g., the architecture of neural networks and the depth of decision trees in the random forest algorithm?
2. What was the run time of the main methods used – Bayesian deconvolution and random forests?

Suggested grade: **A - excellent.**

Date: 29/05/2023

Signature: František Mráz