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Referee report on Ph.D. thesis entitled:

Evaluation of the NEMA characteristics for the Modular J-PET Scanner

by

Faranak Tayefi Ardebili

The intersection of nuclear physics and medicine has witnessed significant advancements over the years. Medical practices now leverage principles derived from nuclear physics, incorporating devices and materials from nuclear physics measurements. A notable illustration of this integration is found in Positron Emission Tomography (PET), a cutting-edge medical imaging technique. PET relies on physics phenomena, such as the annihilation of emitted positrons, and utilizes detectors primarily designed for measuring nuclear reactions.

The focus of this thesis centers precisely on the symbiosis between nuclear physics and medical imaging. Authored by Ms. Faranak Tayefi Ardebili, the primary objectives of the thesis are twofold: to assess the performance of the Modular Jagiellonian Positron Emission Tomograph (J-PET) and to compare the results against the standards set by the National Electrical Manufacturers Association (NEMA). Furthermore, the thesis consists of a description and execution of the Monte Carlo simulation process, the sensitivities analysis, experimental measurements, and a comparison of the J-PET parameters obtained from simulation and experimentation with other commercial PET devices.

Structured into ten chapters, the thesis begins with a succinct abstract outlining the key findings and culminates in an overview that encapsulates the overall results. This research significantly contributes to the evolving landscape where nuclear physics converges with medical applications.

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The first chapter is the introductory part of the thesis. It shortly presented the importance of the main topic and introduced the concept of the J-PET device. The second chapter (Chapter 2) covers the general information about Positron Emission Tomography. One can find here the physics principles that stand behind this method. The author introduces the description of the interaction of the gamma-ray with matter, devices used for photon detections, and the principle of operation of the PET device.

Moreover, one can find here the description of the various types of coincidence events that can occur during measurements and possible methods of PET image reconstructions. Chapter 3 gives, in detail, technical information about the J-PET device. One can also find information about the software used for data acquisition and data analysis of the measured gamma radiations.

The next chapter (chapter 4) introduces the readers to the NEMA standards, such as sensitivity, scatter fraction, and spatial resolution. Chapter five describes the J-PET simulation package GATE, based on the Geant4 framework. The author also includes descriptions of the events cuts used during the data analysis in this chapter. Chapter six is dedicated to the comparison of the NEMA standard to simulations. The next chapter presents the characteristic measures of the J-PET apparatus. The author includes a description of the used sources, details about the measurement process, and data selection criteria. In chapter 8, one can find the analysis of the measured data. Have been included here sensitivity and resolution analysis. The next chapter (chapter 9) compares the J-PET with other commercially available PET devices. The last chapter consists of the thesis summary and possible new developments that can be applied in the device to reach parameters closer to commercial PET scanners. I have to stress that a very good idea was introduced in the last chapter of this thesis, “The Prospects,” which presents the future possible development of the J-PET device and how these changes can improve similar measurements.

I have the following comments/questions about the way conducted by author analyzes, or interprets results:

- In the thesis the author mixed Polish and English language: using the words “Rozdział”, “Rysunek” and “Tabela” where in the text is Chapter, Figure or Fig., Table.

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- In Table 2.1 for ^{44}Sc the decay mode should be e^{+}?
- There is no Figure 3.3.
- I don't understand how was completed 200seconds of simulations (page 61).
- Table 6.2 In the last row percent sign should be added.
- Why the range for the sinogram was set to +/-2cm? What is the reason for exactly this value (pages 66 & 127)?
- Why the linear fit of the background was used (Figure 6.7).
- In Figure 6.8 the connection of the points was done by, in my opinion, a strange function that gives an artificial effect (NECR count rate – line between 3 and 4).
- In Figure 7.14 the multiplicity reaches the value 20 – what causes that? I see two different slopes from 1 to 8 and from 8 to 20.
- Why the two histograms in Figure 7.20 (Right) have the same height? The cuts should not reduce the height of the red histogram?
- Why the uncertainty of y was not considered (page 125)?

Ms. Faranak Tayefi Ardebili's doctoral dissertation, composed in English, exudes a commendable simplicity and clarity that made the reading experience thoroughly enjoyable. While I don't possess the full expertise to evaluate the language used in the thesis comprehensively, I must note that I encountered a handful of minor editorial mistakes. It's worth mentioning that these errors, though present, are of minimal consequence in the context of the thesis's overall scope.

I must stress that information on the author's contribution to the described work was very important and allowed me to evaluate the real contribution of the author in the J-PET project.

The author actively engaged in all facets of the experimental process, including the assembly of the detector, the preparation of simulations, hands-on measurements, and meticulous data analysis. I believe he gained a lot of experience in dealing with PET scanners and has a deep understanding of the topics. Moreover, Ms. Faranak Tayefi Ardebili is a coauthor of four publications that touch precisely the problems described in the thesis.

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In summary, I believe that the presented thesis makes a fine and valuable contribution to the test of the J-PET apparatus. The process of obtaining characteristic parameters is very well described in detail. What is worth underlining the steps of these measurements are presented from the simulation thru data analysis to comparison with other results (here commercial scanner). The output shows that in some cases the new device reaches similar parameters as the commercial one but some of them should be improved. In my opinion, the thesis is a summary of the characteristics of the J-PET device and is a crucial step for the future development of this device to finally reach commercial applications.

The author constantly proves throughout the text her good knowledge of experimental nuclear physics. In my opinion, it is very important to consider the discussion of the future possible enhancements of the J-PET device, which can improve the obtained result.

In conclusion, Faranak Tayefi Ardebili's dissertation delivers valuable and original results. It not only meets all the formal prerequisites expected of a doctoral thesis but also convinces me to endorse its public defense.