ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

REVIEWER'S REPORT OF MASTER THESIS

I. BASIC INFO

Title:	**Runaway electrons**
Author:	**Bc. Martin Štencel**
Level:	Master thesis
Faculty:	Faculty of Electrical Engineering (FEL)
Department:	Department of Physics
Reviewer:	Ing. Miroslav Horký, Ph.D.
Affil. of reviewer :	Institute of Atmospheric Physics, Czech Academy of Sciences

II. SCORING

Selected topic and tasks	**Harder than usual**

The tasks of the thesis are harder than it is usual for the level of Master thesis. To fulfill given tasks one needs to combine knowledge of higher level math (not taught at standard courses at CTU), numerical simulations, and relativistic physics. Since these topics are not usually covered within courses at the FEE CTU, I consider that the student had tasks which were more difficult than it is average.

Tasks fulfilment	**Fulfilled**

The student fulfilled tasks completely. Beside the given tasks he made also additional simulations analyzing how the number of generated electron-positron pairs changes with increasing velocity of the beam.

Approach used to fulfill tasks	**Partially acceptable**

Approach used in the first theoretical part is not bad at all, however sometimes would be more useful to explain the equations more to make them understandable for a reader unfamiliar with the thesis' topic. In the second part of the thesis, the approach was not chosen very well. At first the chosen computational tool is not well suitable for such numerical simulations. In the thesis, the author states that simulations took long time. When I see the chosen parameters for simulations I would say, that the choice of regular programming language such as Fortran or C would be better for performing such a simulation. Author's reasons to choose the Matlab program (e.g. that it contains mathematical function) are not relevant, since for regular programming language there are many libraries of mathematical functions. Also the way how the author presented velocity phase space is unusual. Much better would be to calculate velocity distribution function from all simulated particles. Another issue is using inconsistent description – for instance sometimes author refer to initial energy of beam in MeV, sometimes the velocity in gamma dimensionless parameter is used, and even sometimes velocity in SI units is used. It would be much better to be consistent.

Scientific level	**B**

The scientific level of the thesis is high. Runaway electrons are hot topic in plasma physics and thus the thesis covers actual problems in plasma physics. Nevertheless, there are minor issues which would need to be improved. For example in introductory part there are some contradictory statements (see final comments for details).

Formal and language style	**D**

The formal quality of the thesis is poor. There are a lot of typos, missing words, as well as author's style of writing might lead to misunderstanding of some parts. Also the chosen division to sections and subsections is not good, some subsections are only one paragraph long which is quite unusual. Also the length of two main parts is unbalanced. The introductory part is too long comparing to the part describing author's own work. Total length of the thesis would be fine if the two main parts would be well balanced. From my reading I have an impression that the author did not let someone to do proofreading of the thesis.

References, citations	**D**

Author used appropriate relevant references however they are not well cited. Sometimes the citation is missing (for instance equation 55 called Bethe-Heitler formula or the description of the numerical methods and many other places). The

biggest problem of references is their inappropriate listing in the end of the thesis. In some references there is written affiliation of author instead of journal name so the papers can be hardly identified. Beside this issue author refers to pdf versions using links to private cloud instead of using doi link.

Additional comments

As a part of the thesis author wrote program in Matlab to simulate generation of electron-positron pairs by runaway electrons. Since it is written in Matlab and thus the simulation is quite slow, it can be hardly used for scientific purposes (such as performing longer and larger simulations). But it can be well used for teaching purposes which is also very good by-product of this thesis.

III. QUESTIONS AND SUMMARY

Regarding the drawbacks mentioned above I have following question for defence.

- Subsection 2.1 is called Inertial confinement and in the first sentence we read that plasma is not confined. So I would like to ask why is it called confinement?
- What was the reason to choose Runge-Kutta algorithm? Did author try other different algorithms like Boris-Buneman scheme which might be faster than Runge-Kutta?
- Regarding Fig. 18 – could the author plot two distribution functions from these data? One distribution in dimensionless gamma scale and second in a linear scale such as fraction of speed of light?
- Regarding the result in Fig. 23 – Why only five simulations were chosen? Can the author comment the evolution of increase in number of generated pairs? The gamma scale is not linear and thus it seems for me and from these only five points that the dependence is exponential. If so, is the increasement really negligible?

The thesis covers runaway electrons, which is up-to-date problem in plasma physics. It occurs in both space plasmas and laboratory (tokamak) plasmas. Runaway electrons in tokamaks are considered as threat because they can damage equipment of the tokamak so ways how to decelerate them are subject of current research. This thesis deals with numerical simulations of one possible mechanism how the runaway electrons can lose their energy which is generation of electron-positron pairs. From this point of view the thesis is a real contribution to the field of plasma physics and I can highly score the selected topic and obtained results. However, as mentioned above, the thesis contains a lot of typos, hardly understandable sentences, and generally it is not clearly written and people who are not from the field of plasma physics must not understand it well. Summarizing all these facts and picking up mainly high scientific level of the thesis I **can recommend** the thesis for defence with proposed classification mark **C.**

Datum: 23.8.2017 Podpis: