REVIEWER´S ASSESSMENT OF FINAL WORK

I. IDENTIFICATION DATA

Title:	**Tungsten transport studies via multi-diagnostic approach**
Author´s name:	**Jiří MALINAK**
Type of assignment:	Master Thesis
Faculty:	Faculty of Nuclear Sciences and Physical Engineering (FNSPE)
Department:	Department of Physics (DP)
Reviewer:	Axel JARDIN
Reviewer´s affiliation:	Institute of Nuclear Physics Polish Academy of Sciences (IFJ PAN), Krakow

II. ASSESSMENT OF CRITERIA

Work assignment **demanding**

Assess how demanding the work topic is.

This master project had ambitious objectives, as it implied combining several aspects:
1) modelling of impurity radiation in tokamak plasmas, that the student had to develop almost from scratch based on available literature and databases,
2) understanding and use of tomographic inversion package Tomotok to reconstruct 2D emissivity patterns,
3) use AUG data from different diagnostics (SXR, bolo, AXUV…) and study their validity / applicability,
4) perform the analysis of AUG plasma discharges with W laser blow-off for impurity transport studies,
5) compare the experimental profiles and transport coefficients obtained with the theory or simulation codes.
Therefore, the amount and variety of work to be performed represented a challenge.

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.

Generally, the student fulfilled his assignment in a very satisfactory manner, given the work load and time given to realize the project. The work achieved is considerable, with a manuscript of around 100 pages among which 70 pages of main text and figures. Item 1 was critical for the rest of the project. Different datasets and assumptions were considered and discussed with care, allowing to build the emissivity model successfully. Item 2 was more straightforward given the availability of Tomotok package and the experience of the student on this topic. Item 3 was very challenging since experimental analysis of different diagnostics data often leads to issues with data calibration and validation. Jiri reviewed the available information and the different assumptions with care to determine the reliability of the data to be used. Items 4 and 5 were also fulfilled satisfactorily, though some issues were encountered to obtain consistent transport coefficients over the full range of radius, likely due to the numerous sources of experimental uncertainties involved. Besides, the comparison between experiments and modelling could have been a bit strengthen, with deeper analysis and physical interpretation of the differences obtained, giving perspective for further work. This is fully understandable given the time constraints and the work is overall of good quality.

Chosen approach to solution **appropriate**

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

The solutions chosen to assess the different items were justified:
1) The PEC coefficients of Open ADAS are among the best available datasets to model line emission of impurities in fusion plasmas. Bremsstrahlung could be modelled with analytical solutions, and the choice to discard radiative recombination was wise since trying to include dielectronic recombination in the cooling factor (a term much smaller than line emission) would have been very time consuming and would have impeded the rest of the project, for a limited gain in precision.
2) The Tomotok Python package with Tiknonov regularization and minimization of Minimum Fischer

Information was used for tomography. For the bolometry, as mentioned in the Summary, there is the perspective to use other packages like PyTomo or other algorithms specifically developed for resolving the emissivity around the X-point.
3) The multi-diagnostic approach to collect as much information about tungsten during AUG discharges. The proposed approach to investigate the anisotropy in the region above the X-point was original.
4) The choice to analyse W transport during laser blow-off experiments to extract the transport ratio profile in the steady-state and then derive D and V independently during the signal decay was good.
5) The use of FACIT toolbox for impurity transport modelling.

Professional standard **average**

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

No special comment from this point of view, despite the fact that the manuscript seemed a bit long (100 pages) for a master thesis, and it was sometimes necessary to go back-and-forth between the Chapters "Theory", "Methodology" and "Results" to find the relevant information. I wonder if it would not have been more fluid and easier for readers to organize the chapters by topics "Radiation", "Tomography", "Diagnostics", "W transport", etc. Otherwise it is fine.

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

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

In general the language and scientific formalism are satisfying, though some explanations are sometimes not very clear and the manuscript is not exempt of grammatical mistakes and typos. Nevertheless, it does not affect the general clarity of the document, only in few specific places (see the marked PDF). For example, it could have been useful to define partial cooling factors (W.m3) related to free-free L^ff, free-bound L^fb and bound-bound L^bb contributions to avoid possible confusion with the "emissivity" (W/m3).

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.

References to the literature about impurity diagnostics, transport analysis and textbooks on plasma physics and tokamaks seem perfectly adequate. The choice of sources for codes and databases (ADAS, Tomotok, FACIT, AUG diagnostics) is relevant. The student only forgot to give some reference about the grazing incidence spectrometer and Johann spectrometer of AUG, for which data are used at some point.

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 nature of the work is very good. A significant effort was made to build a model of impurity radiation in tokamak plasmas and use it for W transport analysis on AUG. The use of existing tools to achieve the project goals was made adequately. Some experimental results regarding the multi-diagnostic approach or the anisotropy study above the X-point are very fruitful and should be of interest to the fusion community. It feels like the last analysis of W transport coefficients and comparison with modelling could be pursued deeper if the time and resources were available. As a perspective, completing this work with some validation tools could be welcome, e.g. based on synthetic diagnostics to identify the different sources of uncertainties and refine/explain the results obtained experimentally.

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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.

*** Strengths:
- Quantity of work achieved despite difficulty and variety of the project topics,
- Good reference to existing literature and good use of existing tools (Tomotok, ADAS, FACIT, AUG diagnostics),
- Original studies realized (multi-diagnostic approach, anisotropy analysis above X-point, W transport analysis),
- Overall good quality of the work, results can be useful for the scientific community, the created tool deserves to be developed further.

*** Weaknesses:
- Some explanations are sometimes not clear in the text, some definitions are missing, and there are a few typos.
- The information is sometimes spread between Chapters, due to the choice to separate "Theory", "Methods" and "Results" and the manuscript is quite long (100 pages),
- The final results on W transport coefficients are not as fruitful as one could have hoped (diffusion coefficient negative in some regions and comparison with modelling difficult).

*** Here are some suggestions of questions:
1) Radiative recombination was not included in the modelling of impurity radiation, why? Could it impact significantly the results of this work? Would it be possible to implement this term in the future?
2) Minor comment about tomography: in Eqs. (1.58, 1.59), are the weights w = 0 at the first step of w = 1? And then, w_i = max(w) or w_i = Wmax, where Wmax > 0 is a predefined value?
3) Section 2.2: "A constant anisotropy coefficient η = 3 was chosen for tomographic reconstructions of foil bolometers and η = 3.5 for SXR cameras." What motivated this choice and why this small difference 3 --> 3.5?
4) Figure 3.3: Is the region of high emissivity on the LFS of the wall some physical effect (e.g. erosion spot, W source from LBO...) or more likely some reconstruction artefact?
5) Figures 3.5, 3.6, 3.7: the emissivity distribution in the core seems poloidally asymmetric: LFS with SXR, slightly HFS with bolometry while up-down in AXUV. Is one of them more trustworthy? can you comment on the origin of these asymmetries?
6) Section 3.2. Anisotropy analysis: Could one also consider the hypothesis lambda = mu, i.e. the density of any species is compressed in the same way in this X region? Is there any argument to think that reality should be rather in the region lambda < mu or in the region lambda > mu (i.e. is W more likely to be sensitive to asymmetry sources than the bulk plasma)?
7) Figure 3.28, W profile: What can explain the discrepancy between SXR and bolometry in the plasma core?
8) Figure 3.21, 3.23: How to interpret negative diffusion coefficients found in some regions from SXR and bolo? Can it be caused by some numerical issue, or error propagation in the reconstruction method?

Suggested grade: **B - very good.**

Date: 27/05/2024

Signature: Axel Jardin