ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

REVIEWER'S OPINION OF FINAL THESIS

I. IDENTIFICATION DATA

Thesis name:	Application of Machine Learning for the Charged Higgs Boson Search Using ATLAS Data
Author's name:	**Jiří Pospíšil**
Type of thesis :	bachelor
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Department of Cybernetics
Thesis reviewer:	Karel Smolek
Reviewer's department:	Institute of Experimental and Applied Physics

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment **challenging**

Evaluation of thesis difficulty of assignment.

The aim of the thesis is the application of machine-learning for the selection of events with a charged Higgs boson, produced in the ATLAS experiment at the LHC. The thesis focuses on final states with two same-sign charged light leptons, a hadronically decaying tau lepton and multiple quarks. The final state is rather complex. Therefore, it can be expected the procedure for distinguishing of signal and background events will be complicated. The data acquisition and processing within the ATLAS experiment is rather complex. The application of the data samples provided by the ATLAS collaboration requires mastering many technical details (e.g. related to the data format, SW used with the ATLAS collaboration). Furthermore, the topic of the thesis requires understanding of elements of particle physics terminology and phenomenology. It can be difficult for a student not studying high energy physics.

Satisfaction of assignment **fulfilled**

Assess that handed thesis meets assignment. Present points of assignment that fell short or were extended. Try to assess importance, impact or cause of each shortcoming.

The thesis fulfills all goals specified in the thesis assignment.

Method of conception **correct**

Assess that student has chosen correct approach or solution methods.

The main goal of the thesis is to develop and to optimize the procedure for distinguishing of signal and background events. Due to a high complexity of the analyzed final states with many parameters describing the events, the application of neural networks was an optimal approach to reach aims specified in the thesis assignment.

Technical level **A - excellent.**

Assess level of thesis specialty, use of knowledge gained by study and by expert literature, use of sources and data gained by experience.

The student managed to use programs specific for machine learning and for data analysis used in the ATLAS collaboration. Two neural networks, MLP and TabNet, were implemented. The student successfully processed detailed tuning and optimizations to get optimal results in the signal events selection. He estimated corresponding cross section exclusion limits. I positively evaluate, that his results indicate a higher sensitivity for tbH^+ production than methods published by the CMS collaboration.

Formal and language level, scope of thesis **A - excellent.**

Assess correctness of usage of formal notation. Assess typographical and language arrangement of thesis.

The thesis is well written. The description of the used methods and obtained results is clear and comprehensible, the structure of the thesis is well arranged. There is almost no typo in the text.

I noticed a mistake at the end of the section 2.2: A charged Higgs boson H^+ can decay to an anti-tau lepton and a tau-neutrino, not to an anti-tau lepton and a muon. On the page 5, the correct decay channel of a W^+ boson is an anti-lepton and a neutrino (not an anti-lepton and a muon). In the introductory sections 2.2 and 2.3, it would be advisable to mark antiparticles with a bar above a symbol of a particle. Also, Feynman diagrams in Figures 2.1, 2.2 and 2.3 would be clearer,

if correct particle/antiparticle labels were chosen, as well as if arrows signing a particle momentum orientation in a spacetime were used.

Selection of sources, citation correctness **B - very good.**

Present your opinion to student's activity when obtaining and using study materials for thesis creation. Characterize selection of sources. Assess that student used all relevant sources. Verify that all used elements are correctly distinguished from own results and thoughts. Assess that citation ethics has not been breached and that all bibliographic citations are complete and in accordance with citation convention and standards.

The citations are used properly throughout the thesis. In the Bibliography section, the list of authors for each reference should have the same format (sometimes a first name is missing, sometimes it is fully written, and sometimes only a first character of a first name is written).

Additional commentary and evaluation

Present your opinion to achieved primary goals of thesis, e.g. level of theoretical results, level and functionality of technical or software conception, publication performance, experimental dexterity etc.

All goals of the thesis were achieved. The student obtained nice results, applicable in practice within the ATLAS experiment. I have no serious objection to the thesis.

III. OVERALL EVALUATION, QUESTIONS FOR DEFENSE, CLASSIFICATION SUGGESTION

Summarize thesis aspects that swayed your final evaluation. Please present apt questions which student should answer during defense.

I positively evaluate all aspects of the thesis. The student demonstrated a high level of knowledge in the field of machine learning and the ability to apply his skills within the real experiment in the field of high energy physics.

Question: It is well known that a simulation of so complex object like the ATLAS detector may not reflect fully all real details. For example, I can imagine, that real measurement performance of the detector ATLAS can be slightly different than supposed in the simulation used for the generation of training data. Or, there are several models used for a creation of jets from primary quarks. What could you say about the robustness (sensitivity of neural network training on the quality of simulated input data) of the machine learning method presented in the thesis?

I evaluate handed thesis with classification grade **A - excellent.**

Date: **3.6.2022** Signature: