THESIS SUPERVISOR'S REPORT

I. IDENTIFICATION DATA

Thesis title:	Machine Learning for the Leptoquark Search Using CERN ATLAS Data
Author's name:	Lukáš Viceník
Type of thesis :	bachelor
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Cybernetics and Robotics
Thesis reviewer:	André Sopczak
Reviewer's department:	Institute of Experimental and Applied Physics

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment	**challenging**
How demanding was the assigned project?	
This project has been very challenging, as it required to get familiar also with the specific software used in the ATLAS experiment at CERN, namely root and trexfitter. The machine learning development was also challenging, because the mass of the signal is unknown and thus a range of possible signatures had to be investigated.	

Fulfilment of assignment	**fulfilled**
How well does the thesis fulfil the assigned task? Have the primary goals been achieved? Which assigned tasks have been incompletely covered, and which parts of the thesis are overextended? Justify your answer.	
The goals of the thesis were achieved very well. All tasks have been covered. In addition to the expectation, a mass determination was added, which is a valuable surplus.	

Activity and independence when creating final thesis	**A - excellent.**
Assess whether the student had a positive approach, whether the time limits were met, whether the conception was regularly consulted and whether the student was well prepared for the consultations. Assess the student's ability to work independently.	
The performance was excellent in terms of the research work done. He kept all deadlines, provided more than weekly reports and asked relevant questions which were well prepared. He showed much ability to work independently.	

Technical level	**A - excellent.**
Is the thesis technically sound? How well did the student employ expertise in his/her field of study? Does the student explain clearly what he/she has done?	
The thesis is clearly written and the student showed very good expertise in the machine learning aspects, he also worked efficiently with new tools used in the CERN/ATLAS computing environment.	

Formal level and language level, scope of thesis	**A - excellent.**
Are formalisms and notations used properly? Is the thesis organized in a logical way? Is the thesis sufficiently extensive? Is the thesis well-presented? Is the language clear and understandable? Is the English satisfactory?	
The formalism is very well followed and the thesis is very extensive. The student chose a very detailed substructure for his thesis organization. The English language is very good.	

Selection of sources, citation correctness	**B - very good.**
Does the thesis make adequate reference to earlier work on the topic? Was the selection of sources adequate? Is the student's original work clearly distinguished from earlier work in the field? Do the bibliographic citations meet the standards?	
The references to earlier works are adequate. Sources are cited adequately. The student's work is clearly distinguishable. The bibliographic citations meet the standards.	

Additional commentary and evaluation (optional)
Comment on the overall quality of the thesis, its novelty and its impact on the field, its strengths and weaknesses, the utility of the solution that is presented, the theoretical/formal level, the student's skillfulness, etc.

The thesis project has demonstrated different machine learning approaches to the problem of separating signal and background for the reaction under study. The student presented his thesis results in a CERN meeting and it was well received. The thesis demonstrated that there is potential for further analysis in this research channel. Lukáš has been very able and skillfull in analysis software development for scientific research.

III. OVERALL EVALUATION, QUESTIONS FOR THE PRESENTATION AND DEFENSE OF THE THESIS, SUGGESTED GRADE

Summarize your opinion on the thesis and explain your final grading.
The thesis work met all expectations of the assigned project, in addition the mass reconstructed determination study was added. Lukáš worked very independently and make continuously progress. He mastered the software challenges in the CERN/ATLAS environment. He developed software soundly, which is documented and can be used further.

The grade that I award for the thesis is **A - excellent.**

Minor comments/questions:

1)
Figure 8.11, in the legend, it should be a red line, not a red box.

2)
How are the yellow and green uncertainty bands defined and calculated?

Date: **30.5.2022**

I. IDENTIFICATION DATA

Thesis name:	**Finding a leptoquark using machine learning in data from the CERN ATLAS experiment**
Author's name:	Lukáš Viceník
Type of thesis:	bachelor
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Department of Cybernetics
Thesis reviewer:	Vlasios Petousis
Reviewer's department:	Institute of Experimental and Applied Physics

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment	**challenging**
Evaluation of thesis difficulty of assignment.	
Challeging research using machine learning method. The thesis is providing a new and alternative way of investigation finding leptoquarks using CERN ATLAS data.	

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 assignment is fulfilled in all aspects.	

Method of conception	**correct**
Assess that student has chosen correct approach or solution methods.	
A correct machine learning approach that serves as an improvement of the cross-section limit, for pair production of third generation scalar leptoquark, decaying into a top quark and a τ-lepton.	

Technical level	**B - very good.**
Assess level of thesis specialty, use of knowledge gained by study and by expert literature, use of sources and data gained by experience.	
A good use of algorithms from two machine learning categories implemented and used for tabular data classification, gradient boosting decision trees and deep neural networks, were well deployed to analyze the simulated data for leptoquark masses from 300 to 2000 GeV. A very good use of the data for all available masses which they have combined in order to show that one universal classifier can be used for all leptoquark mass cases.	

Formal and language level, scope of thesis	**B - very good.**
Assess correctness of usage of formal notation. Assess typographical and language arrangement of thesis.	
The thesis is concise and well written. I have no objections about the structure if the individual chapters. Citations are used properly.	

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.	

III. OVERALL EVALUATION, QUESTIONS FOR DEFENSE, CLASSIFICATION SUGGESTION

Overall, I positively evaluate all aspects of this thesis.

I consider the work done is of good quality and could be very useful for the leptoquark research group within ATLAS.

I evaluate handed thesis with classification grade **B - very good.**

Date: **26.5.2022**   Signature: