SCIENCES &
BIOENGINEERING SCIENCES

The Research Group
High Energy Physics

has the honor to invite you to the public defence of the PhD thesis of

Alexandre De Moor

to obtain the degree of Doctor of Sciences

Title of the PhD thesis:

Deep learning for Jet Algorithms

Promotor:
Prof. dr. Jorgen D'Hondt

The defence will take place on

Wednesday, December 11, 2024 at 4:30 p.m. in auditorium D.0.08

Members of the jury

Prof. dr. Michael Tytgat (VUB, chair)
Prof. dr. Alberto Mariotti (VUB, secretary)
Prof. dr. Sophie de Buyl (VUB)
Prof. dr. Dominique Maes (VUB)
Prof. dr. Loukas Gouskos (Brown University, USA)
Prof. dr. Pascal Vanlaer (ULB)

Curriculum vitae

Alexandre De Moor obtained the degree of Master of Science in Physics with distinction at the ULB, in 2019. Afterwards, he joined VUB, in 2020, as a PhD student at the Inter-University Institute For High Energies under the promotorship of Prof. dr. Jorgen D'Hondt. During his PhD he studied the development of Deep Learning for jet algorithms for the CMS experiment at CERN. During his PhD, he also assumed leadership responsibilities towards the CMS collaboration as convener of software and algorithm of the flavour tagging group from 2021 until 2023.

Abstract of the PhD research

The development and improvement of deep learning techniques over the past decades have created new opportunities for algorithmic methods in high-energy physics. Particularly, deep learning has led to significant advances in the performance achieved of algorithms for the flavour identification of jets, the structures formed by the fragmentation of a quark or a gluon when produced in a collider such as the CERN Large Hadron Collider.
In this doctoral thesis, we focus on deep learning methods to enhance the performance of jet flavour identification algorithms at the CMS experiment. We aim to extend their capabilities by improving model robustness against changes that may be applied to the variables used by a the algorithms. Additionally, by extending their initial tasks, we enable new opportunities for future research. First, we explore the Transformer architectures in the context of creating deep neural networks that preserve the structure of jets. We establish two models whose performance and computational cost set a new state-of-the-art in the field. Second, we introduce a data-agnostic training method based on adversarial attacks, improving the model's robustness against changes in the distribution of input variables. Enhancing robustness is necessary to improve our models' performance after calibration. Finally, we successfully extend the algorithms' tasks to identify hadronic taus and to estimate jet energy corrections and resolutions. Additionally, we introduce the identification of strange jets, a first for an experiment at the LHC.
Ultimately, this doctoral work results in the creation of a new class of models with improved architecture, training methods, and an expanded scope of what an artificial neural network may achieve. The final model produced, named UParT, serves as the state-of-the-art in jet identification for the CMS experiment at the LHC. With the identification of jets originating from strange quarks being a first for the LHC, new analyses targeting final states containing this type of jet can now be pursued once the new model is calibrated.