T 26: Data Analysis, Information Technology and Artificial Intelligence

Time: Monday 16:15–18:30 Location: T-H39

T 26.1 Mon 16:15 T-H39

Investigation of robustness of b-Tagging algorithms for the CMS Experiment — Xavier Coubez[1,2], Nikolas Frediani[1], Spandan Mondal[1], Andrzej Novak[1], Alexander Schmidt[1], and •Annika Stein[1] — [1]RWTH Aachen University, Germany — [2]Brown University, USA

Deep learning as one form of machine learning is utilized for various applications and shows its benefits also in the field of high-energy physics, or more specifically, for jet flavour tagging. However, subtle mismodelings in the simulation could be invisible to typical validation methods. Investigating the response to mismodeled input data is motivated by the later usage of the outputs in physics analyses, as the values for simulation and data are deviating. The vulnerability of b-tagging algorithms used at the CMS experiment is probed through application of adversarial attacks. In this talk, a corresponding defense strategy that improves the robustness, namely adversarial training, will be presented. Comparisons of the model performance and the susceptibility show that this method constitutes a promising candidate to reduce the vulnerability and that this could improve the capability to generalize to data.

T 26.2 Mon 16:30 T-H39

Performance Studies of the Conditional Attention Deep Sets *b*-Tagger for the ATLAS Experiment — •Alexander Froch[1], Manuel Guth[2], and Andrea Knue[1] — [1]Albert-Ludwigs-Universität Freiburg — [2]Université de Genève

The identification of jets containing b-hadrons, called b-tagging, is crucial for most analyses performed at the ATLAS experiment. Several new multivariate techniques have been developed for this purpose. One of these is the Deep-Impact-Parameter-Sets (DIPS) tagger.
The DIPS tagger is a deep neural network based on the Deep-Sets architecture. It uses track information of the particles inside the clustered jets for classification. It is part of a new generation of tagging algorithms currently developed in ATLAS. DIPS itself can distinguish between different jet origins, like light, charm or bottom jets.
Although DIPS already outperforms the currently recommended RNNIP tagger, its high-p_T performance can still be improved further. While the number of fragmentation tracks increases rapidly with p_T, less heavy-flavour tracks are being reconstructed at high p_T. Therefore, it is more difficult for this kind of network to filter the most important tracks.
To further enhance the tagging capabilities of DIPS and fix the issues arising in the higher p_T region, DIPS will be extended with an attention mechanism conditioned on jet kinematics. This new version is the Conditional Attention Deep Sets (CADS) tagger.
The new CADS tagger will be discussed and its performance will be compared to the current best DIPS model.

T 26.3 Mon 16:45 T-H39

Charm tagger shape calibration for BDT-based signal-background discrimination — •Spandan Mondal[1], Xavier Coubez[1,2], Alena Dodonova[1], Ming-Yan Lee[1], Luca Mastrolorenzo[1], Andrzej Novak[1], Andrey Pozdnyakov[1], Alexander Schmidt[1], and Annika Stein[1] — [1]RWTH Aachen University — [2]Brown University, USA

Identification of charm-quark-initiated jets at the LHC is especially challenging. Usage of deep learning based algorithms have enabled several CMS analyses to efficiently discriminate charm jets simultaneously from bottom and light jets. The charm probability scores yielded by such charm tagging algorithms can play a powerful role when used as inputs to a machine learning based algorithm for discrimination between signal and background. However, as jet identification algorithms are trained strictly on simulated jets, a direct usage of charm tagger output values requires calibrating the entire output probability distributions using real jets reconstructed from CMS data. This talk focuses on the calibration of the output discriminator values of charm-tagging algorithms using flavour-enriched selections of jets in data. Additionally, the improvement resulting from a shape calibration approach, over the traditional approach of calibrating efficiencies at fixed c-tagger working points, is exemplified in the context of the resolved VHcc analysis.

T 26.4 Mon 17:00 T-H39

Reduction of the Irreducible Background in the $t\bar{t}H(b\bar{b})$ Analysis at ATLAS, Using a Deep-Sets-Based $b\bar{b}$-Tagger — •Joschka Birk, Alexander Froch, and Andrea Knue — Albert-Ludwigs-Universität Freiburg

The search for the $t\bar{t}H(b\bar{b})$ signal suffers from the large irreducible $t\bar{t}+b\bar{b}$ background. This irreducible background contains the same final-state particles as the signal, including four b quarks. In the background process, a radiated gluon can split into a b-quark pair, which often leads to two b-jets that are very close together. With the currently used b-tagging algorithm, these $b\bar{b}$-jets are often misidentified as a single b-jet.
In order to improve the rejection of these background events, the existing Deep-Impact-Parameter-Sets (DIPS) Tagger is extended with an additional output class dedicated to jets which contain two b-hadrons ($b\bar{b}$-jets). DIPS is part of a new ATLAS b-tagging algorithm, based on the Deep Sets architecture, and has already shown promising performance compared to the RNNIP tagger, which is part of the DL1r tagger that is currently used in ATLAS analyses. Studies of this extended version of the DIPS tagger, including first results of a hyperparameter optimisation, are presented.

T 26.5 Mon 17:15 T-H39

High-p_T *b*-tagging using track classification in the ATLAS experiment — Beatrice Cervato, Markus Cristinziani, Gabriel Gomes, Vadim Kostyukhin, •Katharina Voss, and Wolfgang Walkowiak — Center for Particle Physics Siegen, Experimentelle Teilchenphysik, Universität Siegen

In the ATLAS experiment the search for new physics beyond the Standard Model is of particular interest. In many theories, new physics processes result in the production of energetic b-quarks, fragmenting to high-p_T jets in the detector. Many successful b-jet identification algorithms suffer from the jet energy increase due to higher multiplicity of fragmentation tracks, reduced track reconstruction efficiency and, looking ahead to the High-Luminosity LHC, increased pile-up. As b-tagging algorithms typically use properties of the track-in-jet ensemble, the increased multiplicity of fragmentation tracks in energetic jets inevitably decreases the b-tagging efficiency at high p_T. A b-tagging algorithm, based on a multivariate technique, particularly suited for very energetic events, is presented. The multiplicity problem is solved by considering only those tracks, which are most likely to stem from a B-hadron decay. These are identified through a multi-class multivariate track classification algorithm, considering heavy flavour, fragmentation and other tracks from material interactions, as well as pile-up tracks.

T 26.6 Mon 17:30 T-H39

Exploration of neural network architectures for Flavour Tagging algorithms at the LHCb experiment — •Vukan Jevtic[1], Quentin Führing[1], Christoph Hasse[3], Niklas Nolte[2], and Claire Prouvé[1] — [1]Experimentelle Physik 5, TU Dortmund — [2]MIT — [3]CERN

The LHCb detector at the LHC is specialised for measurements of B meson decays, which open a window into the nature of weak interactions through measurements of rare decays and charge parity (CP) violation. In the Standard Model, CP violation is enabled through a complex phase of the Cabibbo-Kobayashi-Maskawa quark-mixing matrix. B meson mixing refers to the property of neutral B mesons to oscillate between two states of matter, B_q^0 and $\overline{B^0}_q$, with different quark contents (i.e. different flavours).
The reconstruction of the flavour at the time of the B meson production is a difficult but indispensable component of measurements of time-dependent CP violation at LHCb. In this talk new approaches to Flavour Tagging via full-event-interpretation techniques will be presented by the example of recurrent neural networks and deep sets.

T 26.7 Mon 17:45 T-H39

Regression of Missing Transverse Momentum (MET) with Graph Neural Networks — •Nikita Shadskiy[1], Matteo Cremonesi[2], Jost von den Driesch[1], Lindsey Gray[3], Ulrich Husemann[1], Yihui Lai[4], and Michael Wassmer[1] — [1]Institute of Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT) — [2]University of Notre Dame — [3]Fermilab — [4]University of Maryland

Neutral particles that are only interacting weakly, like neutrinos, which are known from the standard model, or other, still unknown, particles in theories beyond the standard model, can be measured indirectly using the missing transverse momentum (MET). Analyses which search for specific invisible particles or expect such particles in their final state need well reconstructed MET. The reconstruction of MET is sensitive to e.g. experimental resolutions, mismeasurements of reconstructed particles or pileup interactions and is therefore a challenging task.

This talk will give an overview about a new approach to reconstruct MET with graph neural networks using information from particle flow (PF) candidates. Particle flow is an algorithm used by the CMS collaboration to reconstruct particles by combining information from different detector parts. Using graphs is a more intuitive way to describe the topology of an event because it has the advantage to be permutation invariant. Thus, the order of the PF candidates is irrelevant. The graph neural network is optimized to predict a weight for each PF candidate. These predictions are then used to weight the contribution of each PF candidate in the calculation of MET.

T 26.8 Mon 18:00 T-H39

Studies of machine learning inspired clustering algorithms for jets — Amrita Bhattacherjee[1], Debarghya Ghoshdastidar[1], •Siddha Hill[2], and Stefan Kluth[2] — [1]TUM Informatik — [2]MPI für Physik

We study several machine learning inspired hierarchical clustering algorithms algorithms to cluster the particles of hadronic final states in high energy e+e- collisions into jets. We compare their performance against well known algorithms such as JADE or Durham. Performance indicators are physically motivated such as angular distance or energy difference of matching jets at parton, hadron or detector level. We also study new performance indicators derived from computer science clustering theory.

T 26.9 Mon 18:15 T-H39

Improvement of the Jet-Parton Assignment in $t\bar{t}H(b\bar{b})$ Events using Symmetry-Preserving Attention Networks — •Daniel Bahner, Andrea Knue, and Gregor Herten — Albert-Ludwigs-University, Freiburg, Germany

The associated production of a Higgs boson and a top-quark pair allows for a direct measurement of the top-Higgs Yukawa coupling, which can be sensitive to Beyond Standard Model physics. In the studies presented, the process of interest is the semileptonic decay of the $t\bar{t}$-pair accompanied by a $b\bar{b}$-pair resulting from the most prominent Higgs decay. In this topology, at least four b-jets and two light jets are expected. This Higgs decay channel suffers from irreducible background due to $t\bar{t} + b\bar{b}$ production. Furthermore, the full reconstruction of this final state proves difficult because of the ambiguities in assigning the jets to their original parton, which is called combinatorial background.

In the latest publication, a Boosted Decision Tree was used for the jet-parton assignment. In the studies presented in this talk, a novel Symmetry-Preserving Attention Network is exploited (suggested in arXiv:2106.03898). The training was performed and evaluated on two different samples: In the first sample the full detector simulation with Geant4 and the new ATLAS b-tagging algorithm *DL1r* was used and in the second sample the Delphes framework was used. The performances of the networks and possible future improvements will be presented.