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Anomaly detection search for BSM physics in ATLAS experiment at LHC

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Traditionally, searches for new physics use complex computer simulations to reproduce what Standard Model processes should look like in collisions recorded by the LHC experiments. These are then compared to simulations of new-physics models (e.g. dark matter, supersymmetry, etc.).
The lack of evidence for new interactions and particles since the Higgs boson's discovery has motivated the execution of generic searches to complement the existing rigorous, model-dependent analysis program. Unsupervised machine learning can offer a new style of analyses which is completely agnostic to types of new-physics models and to any expectations of scientists.
The application of anomaly detection to collider searches is a rapidly growing effort in the high-energy physics community [1]. Machine learning provides an excellent framework for the construction of tools that can isolate events in data solely because of their incompatibility with a background-only hypothesis. Building a tool to perform model-independent classification of collision events involves training on data events, and therefore requires the ability to cope with a lack of labels indicating whether inputs are signal or background. This distinguishes the typical supervised classification problem, where all inputs are labeled with a known origin, from the anomaly detection approach, which makes use of unsupervised (no input labels) or weakly supervised (noisy labels) training.
First application of fully unsupervised machine learning has been reported by ATLAS collaboration [2] where a VRNN is trained on jets in data to define an anomaly detection SR, which selects the X particle based solely on its substructural incompatibility with background jets will be shown.
Moreover we'll review the status of current efforts for Anomaly Detection in Atlas collaboration. In particular, Graph Anomaly Detection (GAD) exploits innovative machine learning algorithms denoted as Graph Neural Networks, which have proved to be more efficient than standard techniques when applied to heterogeneous data naturally structured as graphs.

[1] The LHC Olympics 2020 a community challenge for anomaly detection in high energy physics, Rep. Prog. Phys. 84 (2021) 124201
[2] Phys. Rev. D 108 (2023) 052009

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