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Bumblebee: A self-supervised transformer model to learn top quark decay at the Large Hadron Collider

As deep learning methods and particularly Large Language Models have shown huge promise in a variety of applications, we attempt to apply a BERT (Bidirectional Encoder Representations from Transformers) model developed by Google utilizing the infamous multiheaded attention mechanism to a high energy physics problem. Specifically, we focus on the process of top quark-anti top decay reconstruction and demonstrate that the model can learn the decay chain and kinematics with high accuracy via self-supervised learning. The learned decay information can be adapted to downstream tasks such as mass and spin correlation variables reconstruction that are crucial for studying top quark entanglement and search for top/anti-top bound states in high energy collisions. Using decay kinematics that would be reconstructed by the detector at CMS, we tokenize, mask, and take it as input into the model to find the "next"tokens, which we treat as the generated or truth kinematics. As a result, the model learns to effectively "translate"the kinematics measured by the detector at CMS to the true kinematics of the ttbar decay with a preliminary result of 30% improvement in the target region of 340-350 GeV and a 0.95 AUROC score in discrimination from the bound state toponium. In further studies, we hope to increase the scale of this tool and explore its practical applicability in the detector at CMS for reconstruction, as the model can easily be applied to any decay process which gives it huge potential for future studies in the high energy domain.

Focus areas

HEP

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