

Particle Transformer for tau lepton pair invariant mass reconstruction for the $HH \rightarrow b\bar{b}\tau\tau$ CMS analysis

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One of the most interesting channels to probe theories beyond the Standard Model at LHC, is the production of a new massive particle, that decays into pairs of Higgs Bosons which, in turn, decay into a pair of b-quarks and a pair of tau leptons. A fundamental discriminant variable to separate HH signal from the backgrounds is the invariant mass of the di-tau system, which can be reconstructed starting from the decay products of each tau lepton. In order to reconstruct the di-tau system in the best possible way, special techniques are needed as the presence of neutrinos from tau decay do not allow for a complete reconstruction of the event. To this end, a Transformer-based architecture (Particle Transformer - ParT) has been implemented to estimate the four-momentum of the neutrinos involved in the decay for a high-resolution reconstruction of the corresponding invariant mass. The regression has been subsequently combined with the classification task for the discrimination of signal events from background ones. ParT can be seen as a graph neural network in which each node consists of a visible particle of the decay's final state while the links represent the connections between them, modeled through pair-wise features. This last input help to enhance the attention mechanism (core of the Transformer class models), which has the purpose of learning the interactions between particles, and improve the model's explainability. ParT showed better results with respect to the most common used algorithm in CMS (SVFit), which is, in addition, extremely CPU consuming.

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