Contribution ID: **817** Type: **Parallel**

Multi-Scale Transformer Encoder for Di-Tau Invariant Mass Reconstruction at CMS

With the discovery of the Standard Model (SM) Higgs boson (H) by the CMS and ATLAS experiments in 2012, the last missing elementary particle predicted by the SM was identified. Since then, extensive measurements of the Higgs boson's properties have been performed across various decay channels. One of the most important is its decay into a pair of tau leptons, the second-most frequent fermionic decay mode after the decay into bottom quarks. In such analyses, the reconstructed invariant mass of the di-tau system plays a crucial role in distinguishing signal (H) from background events. However, due to the presence of neutrinos in the final state, a portion of the energy is lost, leading to an underestimation of the invariant mass. This work proposes a novel Deep Learning (DL) model designed to enhance the reconstruction of the invariant mass by estimating the full four-momentum of each tau lepton before decay, rather than directly regressing the mass. The approach allows for !
a more precise kinematic characterization of the parent particle. The implemented model is a custom transformer encoder —an advanced DL architecture originally developed for Natural Language Processing, now proving its versatility in diverse domains. It takes as input the information from the di-tau products, the reconstructed properties of the two tau leptons, the missing transverse energy (MET), and other key event variables relevant for invariant mass reconstruction. Through learned embeddings, the model extracts meaningful features from each input source, which are then combined and processed using self-attention layers within the transformer encoder. This architecture enables the model to effectively capture correlations between inputs and recover missing contributions from neutrinos, leading to a more accurate invariant mass estimation. The performance of the proposed algorithm is benchmarked against the current standard method used in CMS (SVFit) using simulated H!
$\rightarrow \tau\tau$ events and main background processes. The results demonstrate
the potential of this novel approach in improving mass reconstruction and enhancing Higgs boson analyses.

Secondary track

Author: COLLABORATION, CMS

Session Classification: Joint T08+T16

Track Classification: T16 - AI for HEP (special topic 2025)