Contribution ID: **78** Type: **Presentation**

Modified Matrix Elements for Enhanced Decorrelation in Boosted Resonance Identification, Regression, and Calibration

Wednesday 17 August 2022 11:20 (15 minutes)

Identifying highly boosted resonances, including top quarks, electroweak bosons, and new particles, has become a core topic of research at the LHC. Advances in machine learning have further accelerated interest in boosted resonance identification. However, as machine learning algorithms become more powerful, so too have the correlations of the algorithms with jet kinematics, like mass and momentum. This complicates their use in measurements and searches which, for example, might leverage smoothly falling backgrounds. A number of decorrelation methods have been used previously, including brute-force decorrelation, modifications to ML training loss functions, or modifications to the samples themselves, such as weighted trainings, or trainings with several resonance masses. In this work, we introduce a novel decorrelation method for jet substructure algorithms constructed by modifying sample matrix elements to create "flat" mass and momentum distributed resonances. As the samples have no intrinsic resonance features, ML algorithms are intrinsically decorrelated jet kinematics. This new decorrelation approach is highly versatile and can be applied to boosted object identification, jet mass regression, and jet mass scale calibration. Moreover, this approach allows for robust decorrelation of advanced AI algorithms, where other approaches struggle, such as graph-based interaction networks and transformers. We present this work in the context of tagging Z' resonances decaying to jets and Higgs to tau leptons. Lastly, we show even better performance with modifications to the training architecture, including a KL divergence-weighted loss, and contrastive learning.

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Session Classification: Taggers