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Machine Learning driven improvements for the high-mass MSSM search in the di-tau final state with CMS

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The search for high-mass Higgs bosons within the Minimal Supersymmetric Standard Model (MSSM) framework represents one of the most compelling flagship analyses of the CMS experiment at the Large Hadron Collider (LHC). The $\tau^+\tau^-$ decay channel provides enhanced sensitivity at high masses due to large branching ratios, but significant challenges arise from Standard Model backgrounds, such as $Z \to \tau^+\tau^-$ and jets misidentified as hadronically decaying taus (τ_h). To address these challenges, advanced machine learning (ML) techniques are being developed to improve the sensitivity of the analysis. A boosted decision tree (BDT) is employed to correct mismodeling in simulations where jets are incorrectly reconstructed as τ_h, while systematic ML-driven optimization is being studied to develop an orthogonal discriminant for improving signal-to-background separation. These methods, applied to the data collected between $2022 - 2024$, will lead to more accurate background modelling in high-mass MSSM Higgs boson searches. By incorporating high-dimensional parameter spaces into the analysis, these methods enable more robust and reliable estimates, increasing our confidence in the outcomes of the search. This work underscores the potential of ML approaches to tackle complex challenges in collider physics and sets a strong foundation for future explorations of beyond-the-Standard-Model phenomena.

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