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Machine learning-based analyses using surface detector data of the Pierre Auger Observatory

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The Pierre Auger Observatory, the world's largest detector for studying ultra-high-energy cosmic rays (UHECRs), employs multiple detection techniques to observe the different components of extensive air showers. In order to accurately understand the physics of UHECRs, it is essential to determine their mass composition. Since UHECRs can only be measured indirectly, it is necessary to study mass-sensitive observables, such as the number of muons reaching the ground and the atmospheric depth of the shower maximum. One way to estimate these observables is by analyzing spatio-temporal patterns in the shower footprint recorded by the surface detector (SD) of the Observatory. Given the complexity of this information, the Pierre Auger Collaboration utilizes machine learning (ML) to complement the traditional analytical techniques. With the SD operating nearly 100% of the time, ML algorithms enable the analysis of events with an unprecedented precision. In this work, we summarize the ML-driven analyses conducted at the Pierre Auger Observatory to identify and reconstruct mass-sensitive observables and explores potential applications of ML in other areas. Special emphasis is placed on techniques that utilize the different sub-detector systems of the SD, including the newly installed scintillator detectors from AugerPrime, highlighting their potential for advancing UHECR studies.

Type of Contribution

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