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Title: Characteristics of the lateral distribution of the ultra-high energy cosmic ray initiated air showers observed by the Telescope Array

Ultra-high-energy cosmic rays (UHECRs) are the most energetic particles known in the Universe, yet their origin remains unresolved. Due to their extremely low flux, UHECRs can only be observed through the air shower phenomenon. To measure such events, the Telescope Array (TA) experiment employs both fluorescence detectors (FDs) and surface detectors (SDs). To estimate the energy of the primary UHECR for each detected event, FDs provide a more direct measurement of the energy deposited by shower particles, with the uncertainty in the energy scale evaluated to be approximately ±18%. In contrast, the SD energy is initially derived from a lookup table based on air shower simulations, using the particle density at 800 m from the shower core, referred to as S(800), along with the reconstructed zenith angle. This initial energy estimate is then rescaled through hybrid event analyses. In hybrid event analyses, the initial SD energy estimate is found to be approximately 30% higher than that obtained from FDs. This discrepancy in energy scales depends on the assumed hadronic interaction models, the type of primary particles, and other analysis assumptions. S(800) is determined by fitting particle densities, which are sparsely measured by the SD array, using an empirical formula. Therefore, differences in the lateral distribution of particles could contribute to uncertainties in the SD-based energy scale. In this work, we focus on this aspect by investigating the characteristics of the lateral distribution of particles in air shower simulations with various combinations of interaction models and primary particles, taking detector response into account. Possible effects on data analysis and energy estimation will also be discussed.

Collaboration(s)

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