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Cosmic-ray measurements by reconstructing longitudinal shower profiles for the Cherenkov Telescope Array

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The study of cosmic-ray (CR) composition plays an important role in determining their origin and acceleration mechanism. In the TeV energy range, space experiments perform composition measurements that identify incoming particles and measure the energy accurately. Ground-based experiments can provide a complementary measurement of the mass composition by studying air showers. The depth of the shower maximum, referred to as Xmax, depends on the mass of the primary particle and on its energy. Thus, developing techniques to measure the Xmax of a collection of air showers offer possibilities for the CR composition. The Cherenkov Telescope Array (CTA) is the next-generation ground-based observatory for high-energy gamma-ray astronomy. With several tens of telescopes in the northern and southern hemispheres, CTA will be the most sensitive ground-based observatory for gamma-ray energies.

In this work, we present a novel approach that uses IACTs (Imaging atmospheric Cherenkov telescopes) to reconstruct the shower profile of cosmic-ray and gamma-ray air showers in the TeV range. Using a parametric description of the angular distribution of the Cherenkov light emitted along the shower axis, we propose a novel method for reconstructing the shower longitudinal profile and the Xmax on an event-by-event basis. Preliminary estimates based on a simplified detector geometry indicate that this method provides a resolution on the Xmax of the order of 30 g/cm2 at 100 TeV. We apply our approach to simulated air showers detected by the upcoming Cherenkov Telescope Array. We focus on showers initiated by three different types of primary particles: gamma rays, protons, and iron nuclei.

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