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Particle content of inclined cosmic ray air showers for radio signal modeling

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The origin of ultra-high-energy cosmic rays (UHECRs) is still unknown. They are likely produced in powerful cosmic accelerators but, because of their low flux and their deflections when they propagate across the magnetized Universe, it is difficult to collect them with large statistics and to infer their sources. When reaching the Earth, UHECRs penetrate the atmosphere and induce air-showers, which are cascades of secondary particles that emit a radio signal. The reconstruction of very inclined air-showers is a new challenge for next-generation radio experiments such as GRAND, which focus on the detection of UHE particles. To tackle it, we study the electromagnetic particle content of very inclined air showers, which has scarcely been studied so far. The features of the radio signals emitted by very inclined air-showers are significantly different from those of vertical ones; in particular, they present a drastic drop of the geomagnetic emission amplitude. Using the simulation tools CORSIKA and CoREAS, and analytical modeling from physical principles, we explore the energy range of the particles that contribute the most to the radio emission, quantify their lateral extent, and estimate the atmospheric depth at which the radio emission is strongest. We find that the distribution of the electromagnetic component in very inclined air-showers has characteristic features that could impact the reconstruction strategies of next-generation radio-detection experiments.

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