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Wavefront of the Radio Emission from Air Showers

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We investigated the radio wavefront of cosmic-ray air showers with LOPES measurements and CoREAS simulations: the wavefront is of hyperbolic shape and can be used to reconstruct the shower maximum.

LOPES was a digital, interferometric antenna array at the Karlsruhe Institute of Technology (KIT) at an altitude of 110 m. LOPES consisted of up to 30 antennas on an area with approximately 200 m diameter. It was externally triggered by the KASCADE particle detector array and measured the radio emission of air showers in the effective band from 43 to 74 MHz. Our analysis is based on 316 LOPES events with energies above 0.1 EeV and zenith angles below 45°. In addition, we have made two CoREAS simulations of the radio wavefront for each event, one for a proton and one for an iron nucleus as primary particle.

A hyperbola describes the wavefront shape significantly better than a sphere or a cone. On the one hand, this means that the radio emission cannot be approximated by a static point source at the shower maximum. On the other hand, a conical wavefront expected for a moving point source seems to be a sufficient approximation for axis distances > 50 m.

In first order, the angle between the shower plane and the limiting cone of the hyperbola depends on the distance of the radio array to the shower maximum. This implies dependences on the zenith angle as well as on the atmospheric depth of the shower maximum, Xmax. We exploit this for the reconstruction of Xmax based on the arrival times of the signal in the individual antennas. For the simulations, we obtain a resolution of approximately 25 g/cm². For the measurements, the resolution is only 140 g/cm², since LOPES in its radio-loud environment suffers from significant experimental uncertainties.

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