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## **LOPES-3D – studies on the benefits of direct measurements with vertically aligned antennas**

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The LOPES experiment was a radio interferometer built at the existing air shower array KASCADE-Grande in Karlsruhe, Germany. The last configuration of LOPES was called LOPES-3D and consisted of ten tripole antennas. Each of these antennas consisted of three crossed dipoles east-west, north-south and vertically aligned. With this, LOPES-3D had the unique possibility to study the benefits of additional, direct measurements with vertically aligned antennas in the environment of the well understood and calibrated particle detector array KASCADE-Grande. The measurements with three spacial coincident antennas led to a redundant reconstruction of the E-field vector. Thus, several methods to exploit the redundancy were developed and tested. Furthermore, for the first time, the background noise could be studied polarization- and direction dependent. With LOPES-3D it could be demonstrated that radio detection reaches a higher efficiency for inclined showers and that the vertical component gets more important for the measurement of inclined showers. In this contribution we discuss the development of different weighting schemes for the best combination of the three redundant reconstructed E-field vectors. Furthermore we discuss the influence of these weighting schemes on the ability to reconstruct the showers in radio and on the geometry reconstruction. We show an estimate of the radio efficiency for inclined showers with focus on the benefits of measurements with vertically aligned antennas and we present the direction dependent noise in the different polarizations.

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