Using the KASCADE array to study the sensitivity of a single HiSPARC station to shower orientation

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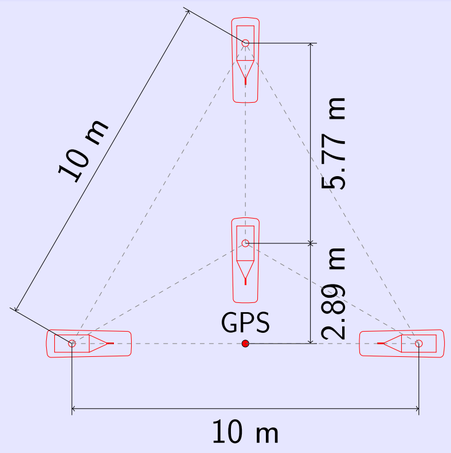
Introduction

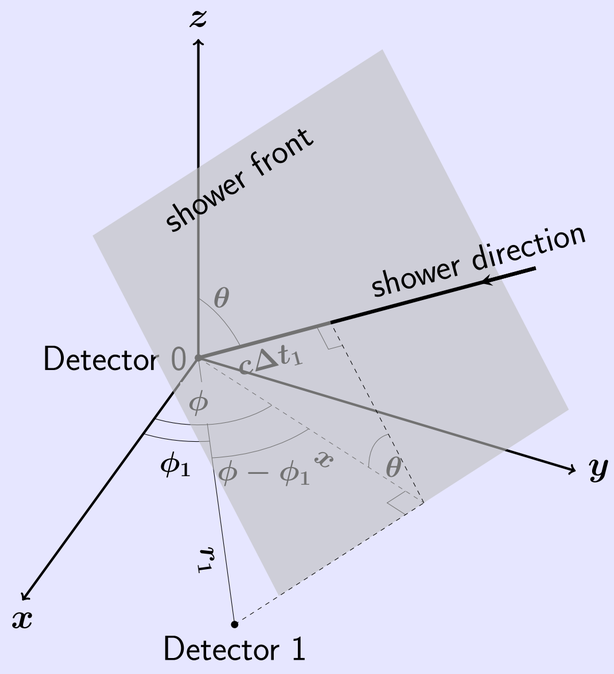
One of the leading questions in astroparticle physics research is: *Where do cosmic rays come from?* To what degree is it possible to reconstruct shower orientation using a single four-detector station? To answer that question, a HiSPARC station has been placed inside the much larger and well-studied KASCADE array in Karlsruhe, Germany. The KASCADE array has been taking data continuously since 1996.

HiSPARC station



A HiSPARC station consisting of four detectors is placed in an equilateral triangle. The electronics must be able to pick up time differences which are only a few nanoseconds. The GPS unit provides an accurate timestamp to individual events.

Angular reconstruction



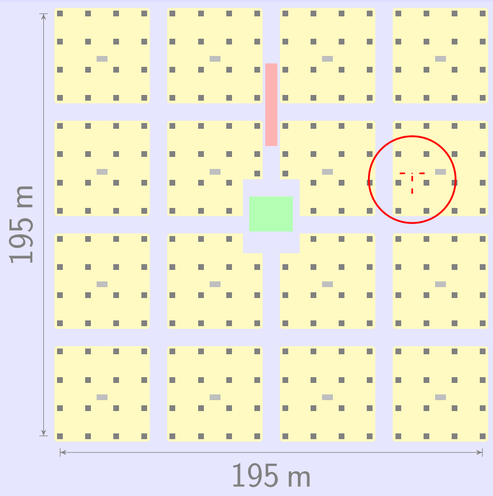
When an inclined shower front passes over the station, it will hit detectors at different times. The shower direction can be calculated using

$$\tan\phi = \frac{r_1\Delta t_2\cos\phi_1 - r_2\Delta t_1\cos\phi_2}{r_2\Delta t_1\sin\phi_2 - r_1\Delta t_2\sin\phi_1}, \quad \text{and} \tag{1}$$

$$\sin\theta = \frac{c\Delta t_1}{r_1\cos(\phi-\phi_1)}. \tag{2}$$

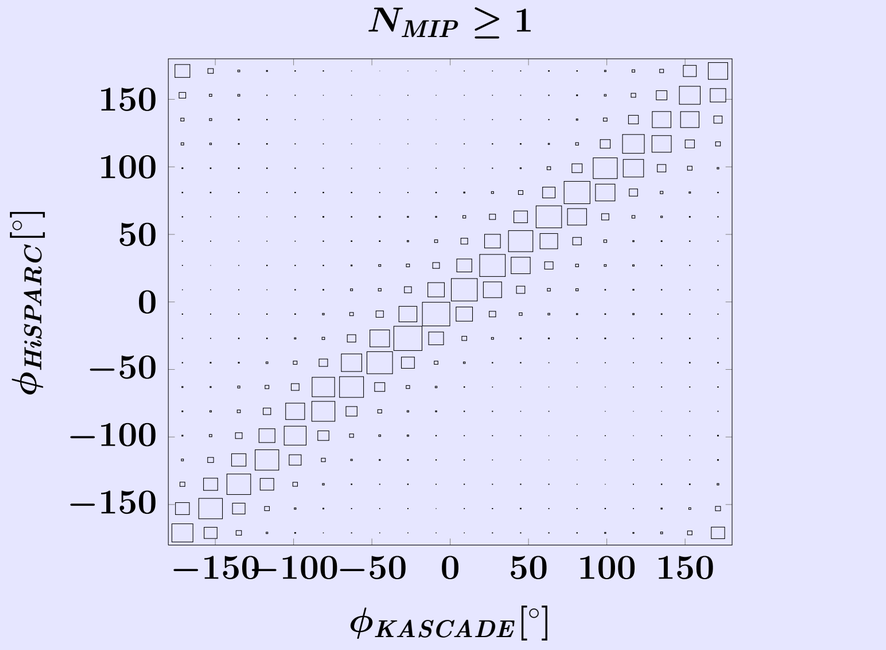
Simulations have shown that it is indeed feasible to reconstruct shower orientation with a single station.

HiSPARC at KASCADE

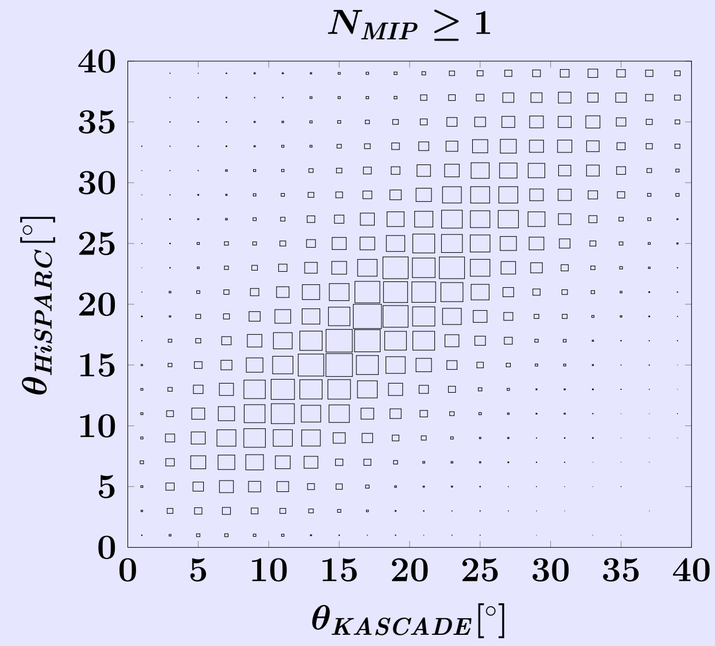


The KASCADE array contains 252 detector huts placed 13 m apart. The HiSPARC station is drawn in red. The KASCADE array is able to pinpoint the direction of the shower to within 0.1°.

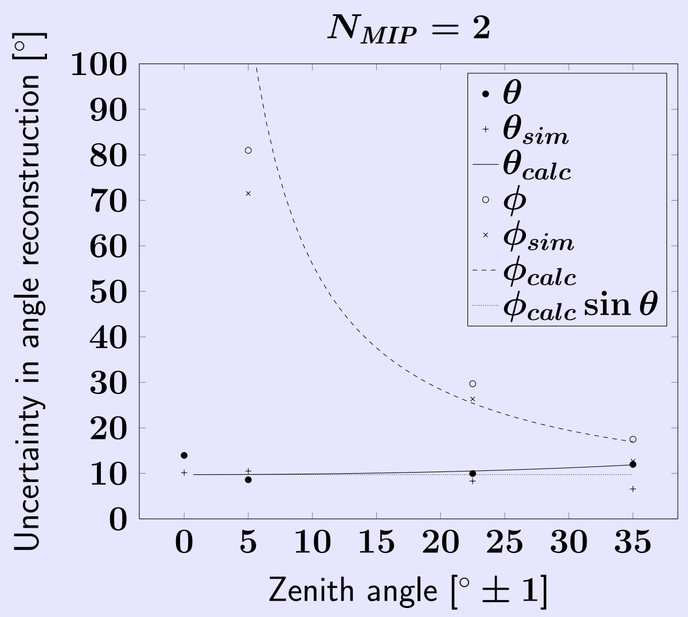
Results



Reconstruction of the azimuthal angle ϕ is accurate within 30° for 68 % of showers.



Reconstruction of the zenith angle θ is accurate within 10° for 68 % of showers.



Azimuthal angle uncertainty increases for small zenith angles. This is largely a geometrical effect. The uncertainty of the *angular distance* $\phi\sin\theta$ is flat and about 10° for 68 % of showers.

Conclusions

A single HiSPARC station is capable of reconstructing shower angles for showers which generate a particle signal in the three corner detectors. Accuracy for zenith angles is ±10°. Accuracy for azimuthal angles is $\pm\frac{10^\circ}{\sin\theta}$. Results from simulation and calculations agree with the experiment.

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HiSPARC