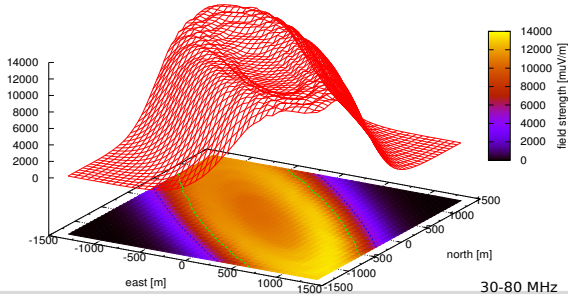


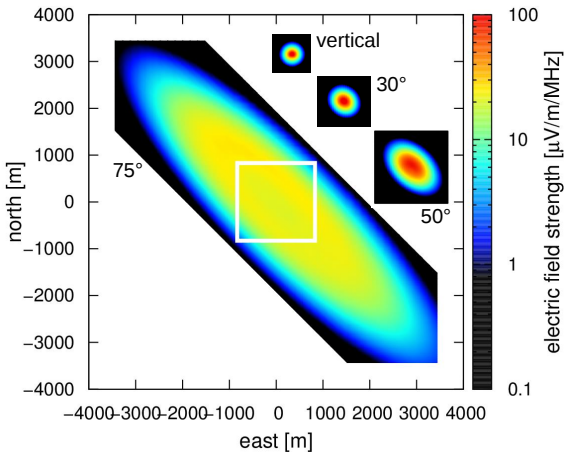
Measurement of horizontal air showers with the Auger Engineering Radio Array

Olga Kambeitz | June 10, 2016
for the Pierre Auger Collaboration

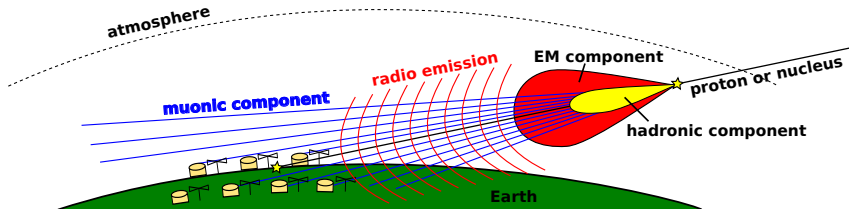
KARLSRUHE INSTITUTE OF TECHNOLOGY (KIT)



Expectations



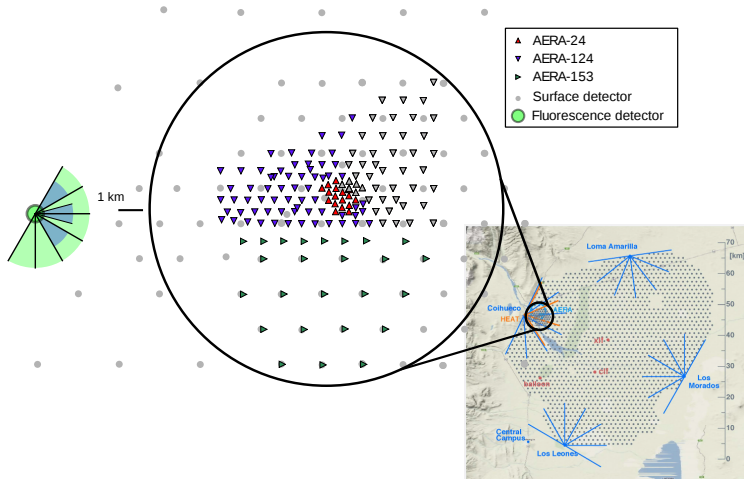
- Simulations predict: the radio footprint of horizontal air showers is large \Rightarrow increase antenna distance



The Pierre Auger Observatory:

- area of 3000 km² size
- measurement of composition for highest energies:
 - vertical showers: muon and electron separation by surface detector
 - horizontal showers: radio detection to determine the electromagnetic component

AERA- Auger Engineering Radio Array



■ 153 antenna stations on 17 km^2

Motivation

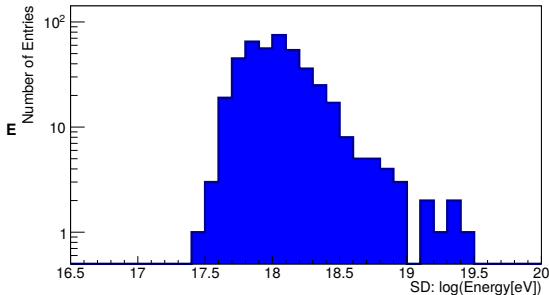
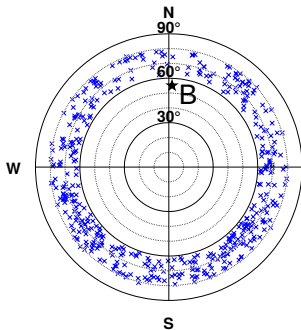


Horizontal Air Showers



Outlook

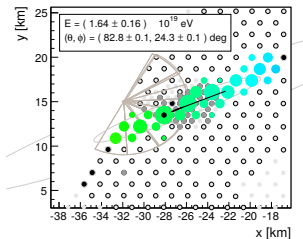




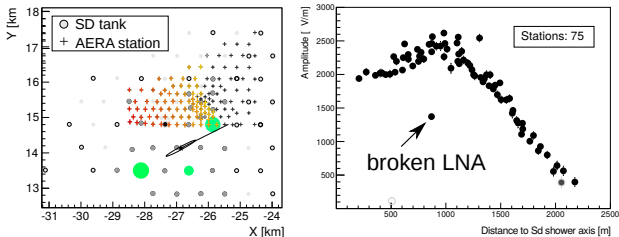
- 427 high quality horizontal radio events selected (January 1, 2012 to August 15, 2015)
- triggered and reconstructed by 1.5 km grid of surface tanks
- cut on zenith angles of 62° to 80°

Event Example: Data

SD HAS



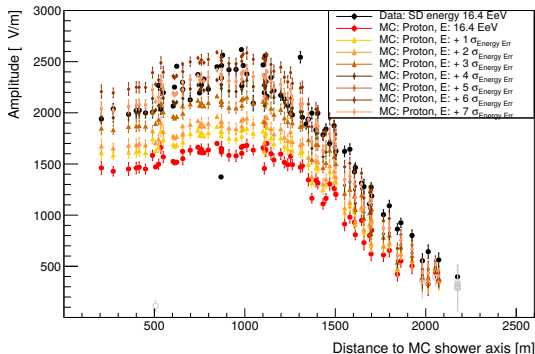
AERA



Event Example:

Simulation - Data Comparison

Proton simulation of shown event: variation in primary energy

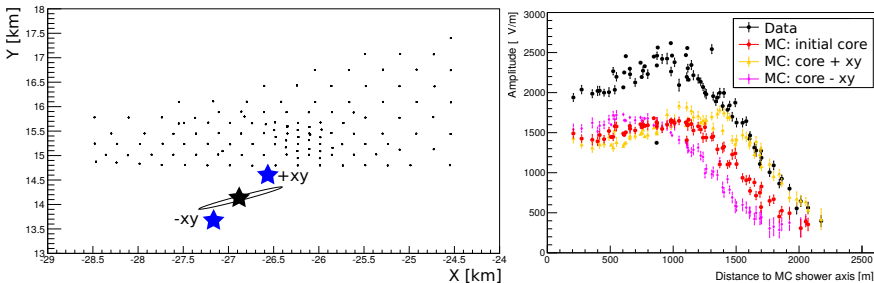


- the shape of the lateral distribution function is described very well by CoREAS simulations
- the radio amplitude changes with the primary energy
- proton and iron show same shape

■ If detector uncertainties are understood, very good energy estimator!

Event Example: Simulation - Data Comparison

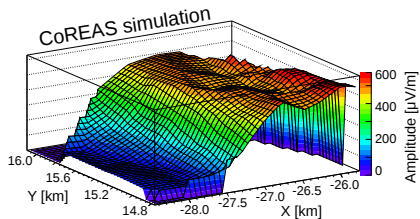
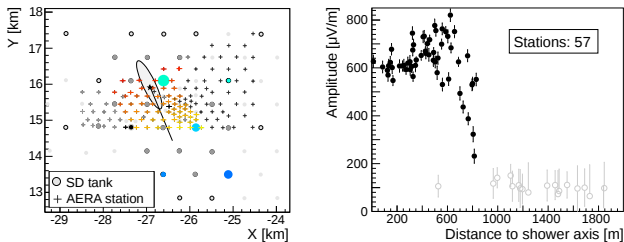
Proton simulation of shown event: variation of core position



- Leaving the core uncertainty ellipse shifts the edge of the radio lateral distribution function \Rightarrow initial core estimation fits
- If detector uncertainties are understood, very good core estimator!

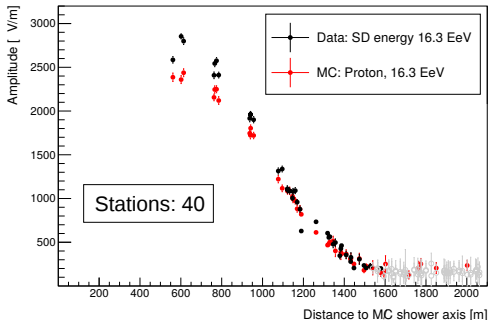
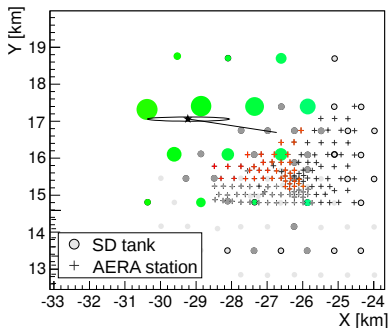
Event Example: Shower Footprint

AERA Data



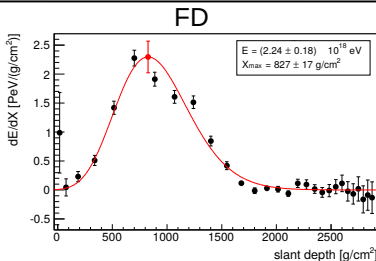
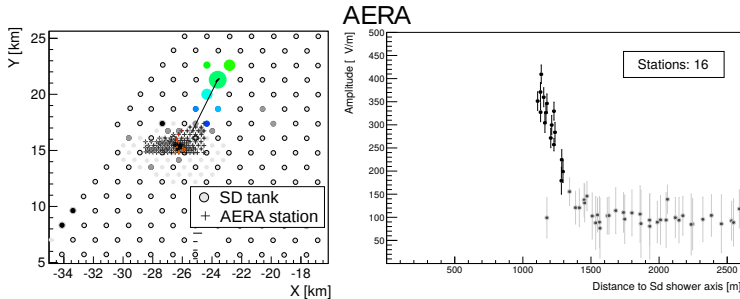
■ Amplitude, asymmetry and shape reproduced by CoREAS!

Event Example: High Energy Event



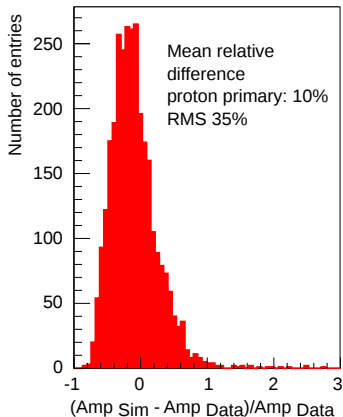
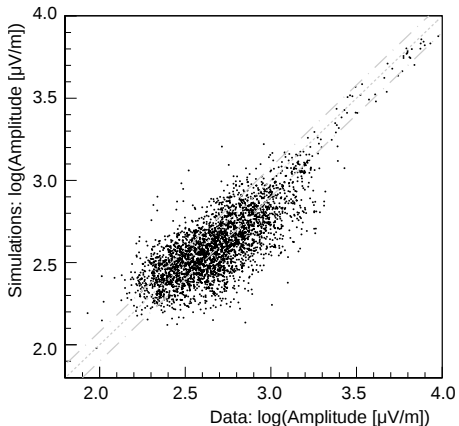
- 27 events with energy > 10 EeV!

Event Example: Core far away



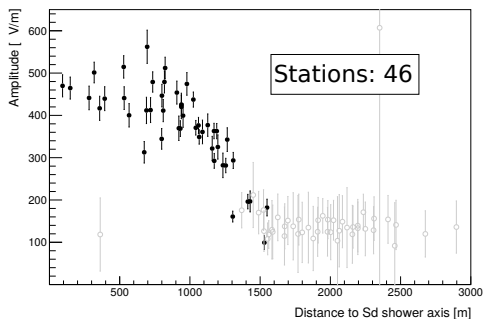
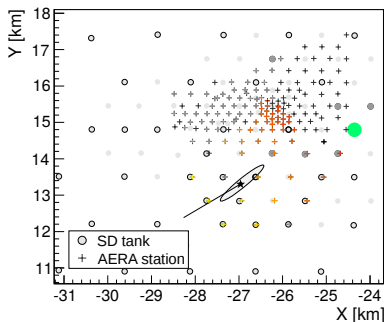
Comparison of measured and simulated amplitudes

427 Events/3065 AERA stations



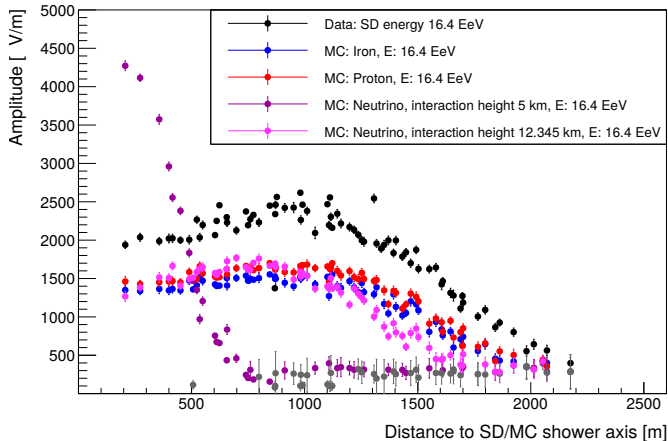
- Systematic shifts and uncertainties need further investigated!

AERA-153 - Grid Size up to 750 m



- 750 m grid okay! 1.5 km grid possible! Single station analysis?

Neutrino Induced Air Showers



- Young neutrino induced showers can be distinguished from old neutrino induced showers

Measurement of horizontal air showers with the Auger Engineering Radio Array

■ Results:

- 1 427 high quality events with $62^\circ < \theta < 80^\circ$
- 2 Big footprint on ground
- 3 Characteristic shape of LDF

⇒ Radio signal of horizontal air showers understood

■ Outlook:

- 1 energy and core determination
- 2 sparse antenna array well suited for horizontal air shower measurements
- 3 detection of neutrino induced air showers possible

⇒ Physics of horizontal air showers in reach,
but need more studies in sensitivity and systematics