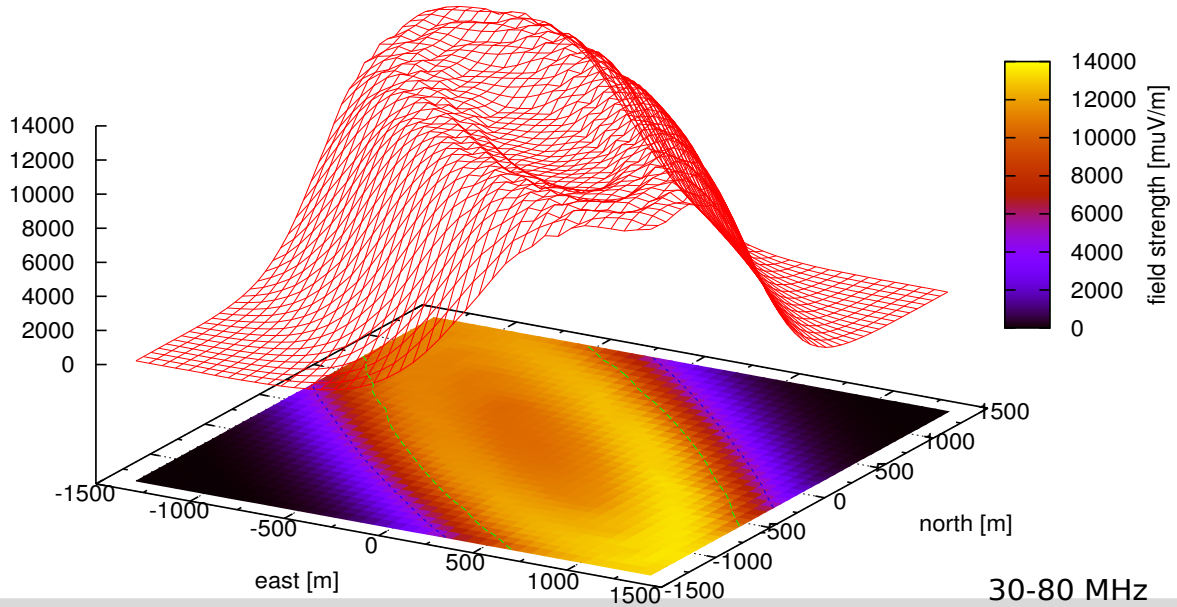
Karlsruhe Institute of Technology

Radio Detection of Horizontal Extensive Air Showers with AERA

Olga Kambeitz | June 11, 2014
on behalf of the Pierre Auger Collaboration

KARLSRUHE INSTITUTE OF TECHNOLOGY (KIT)

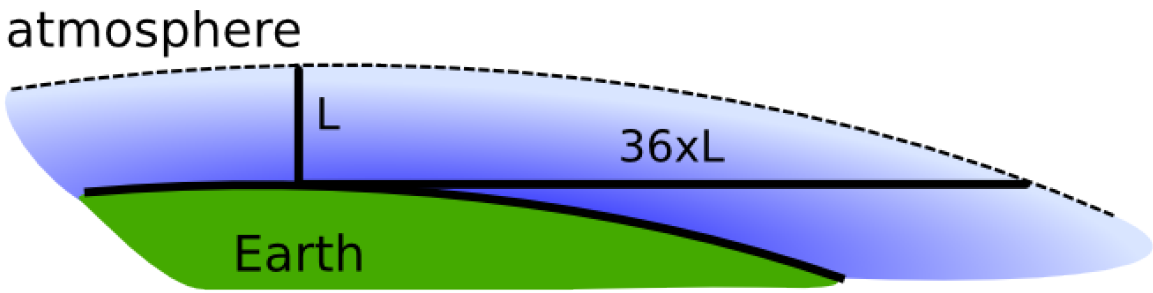


Overview

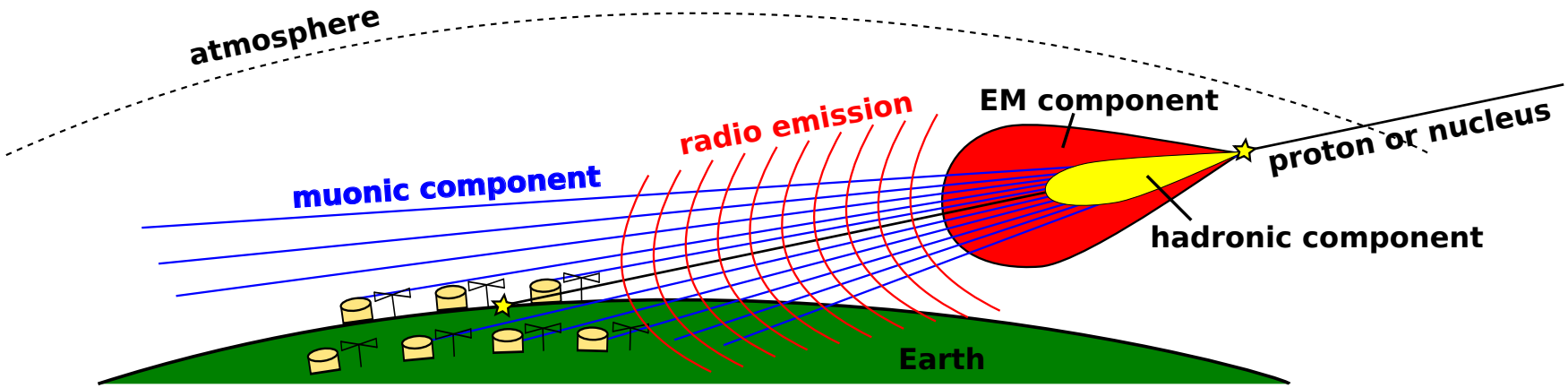
- Motivation to study horizontal showers
- Horizontal events AERA-24 and AERA-124
- Simulation of horizontal events AERA-24 and AERA-124
- Investigation of the vertical component
- Outlook

Horizontal air showers (radio detection)

+ no absorption of radio signal
  $\Rightarrow$ radio signal still detectable if particles showers is absorbed
+ big footprint on ground
  $\Rightarrow$ distance to source
+ radio LDF and wave front shape can help to distinguish between young and old shower
- asymmetry of shower has to be taken into account
- higher background and transient noise
- significant vertical component of the radio signal



The Pierre Auger Observatory

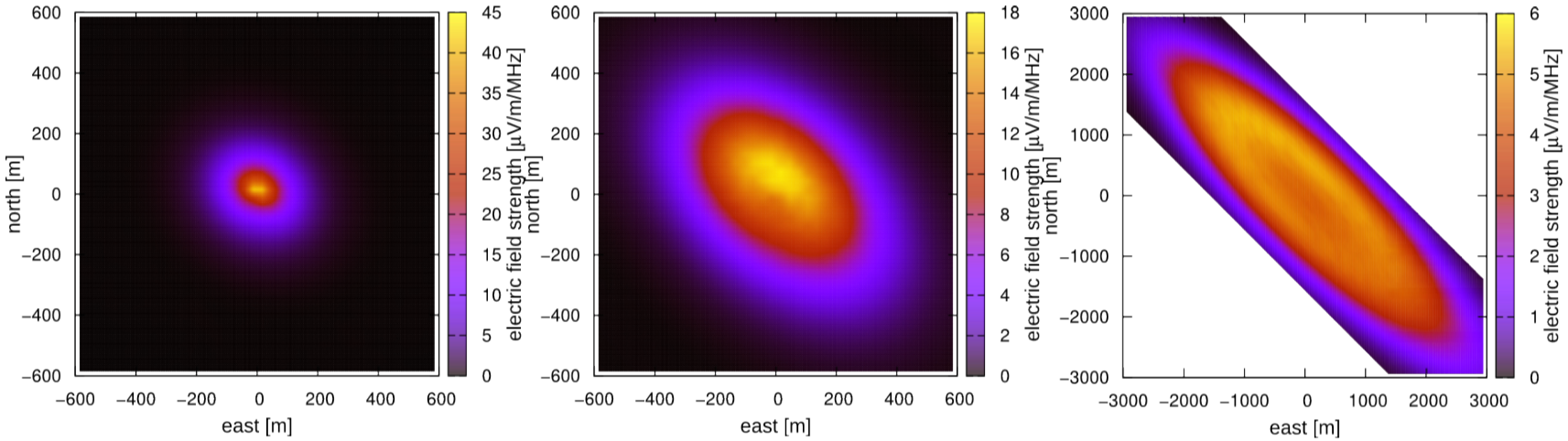


- large area of 3000 km^2
- composition needed for highest energies:
  - vertical showers: muon/electron separation
  - horizontal showers: radio detection and muon detector can help

Motivation

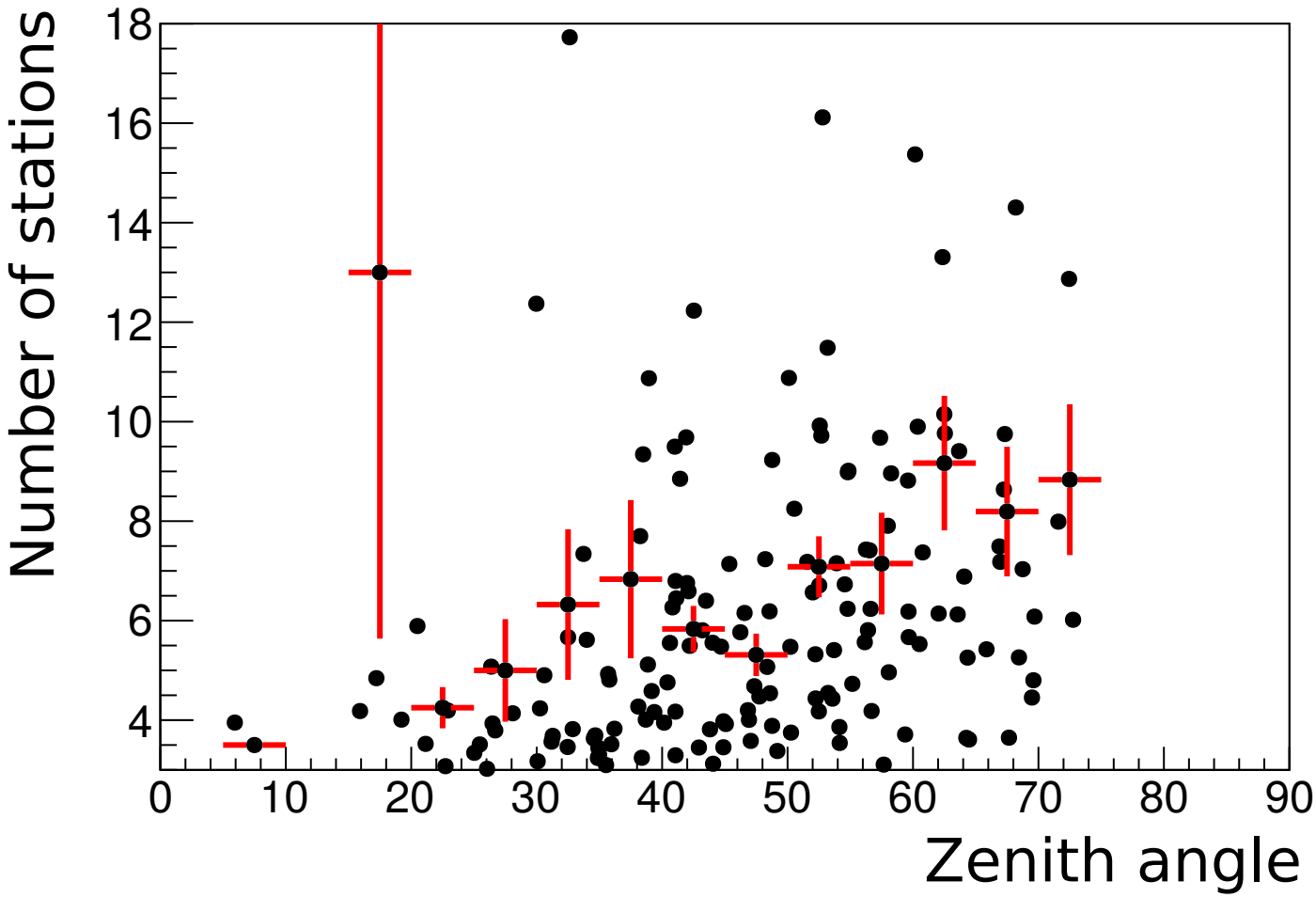
We would like to cover large areas with radio detectors:

- set antennas as far apart as possible to be cost-effective
- radio efficiency is higher for horizontal air showers?



Limit of detection (current experiments): $\approx 2\ \mu\mathrm{V/m/MHz}$ [E. Holt, T. Huege]

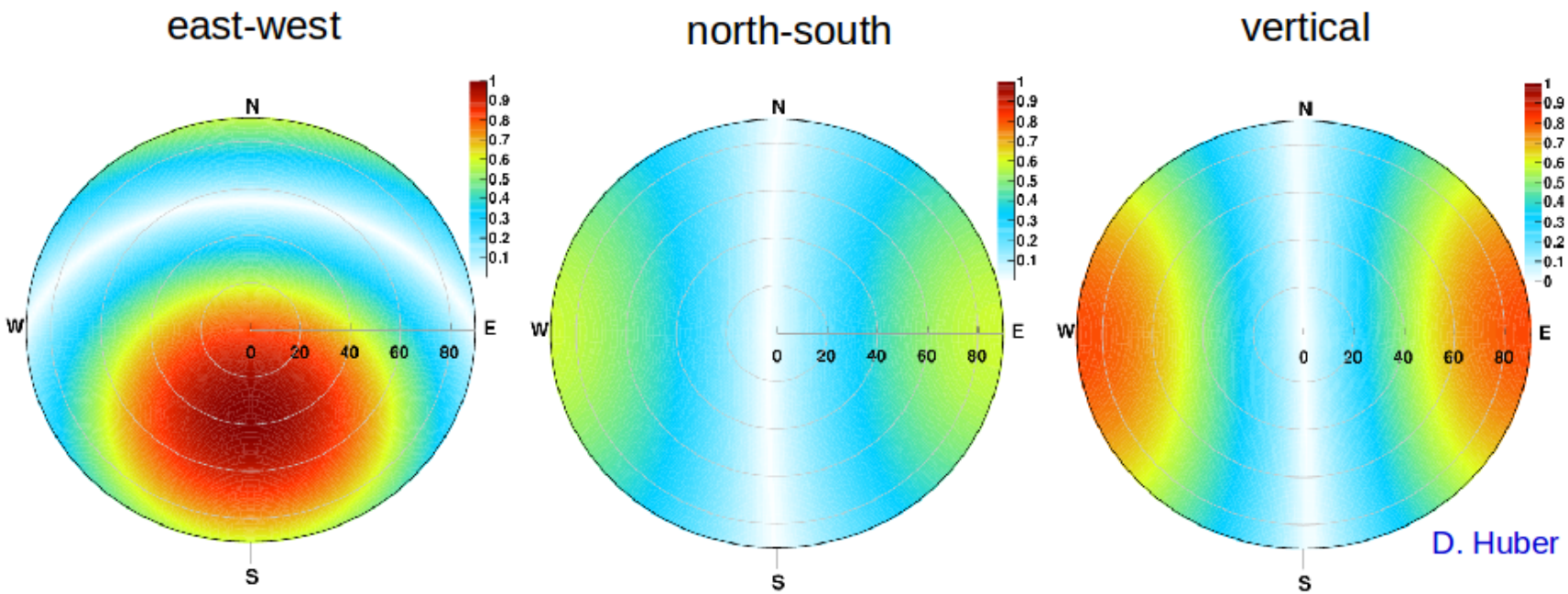
Station multiplicity



Standard AERA reconstruction: RdObserver (see talk by Jens Neuser)

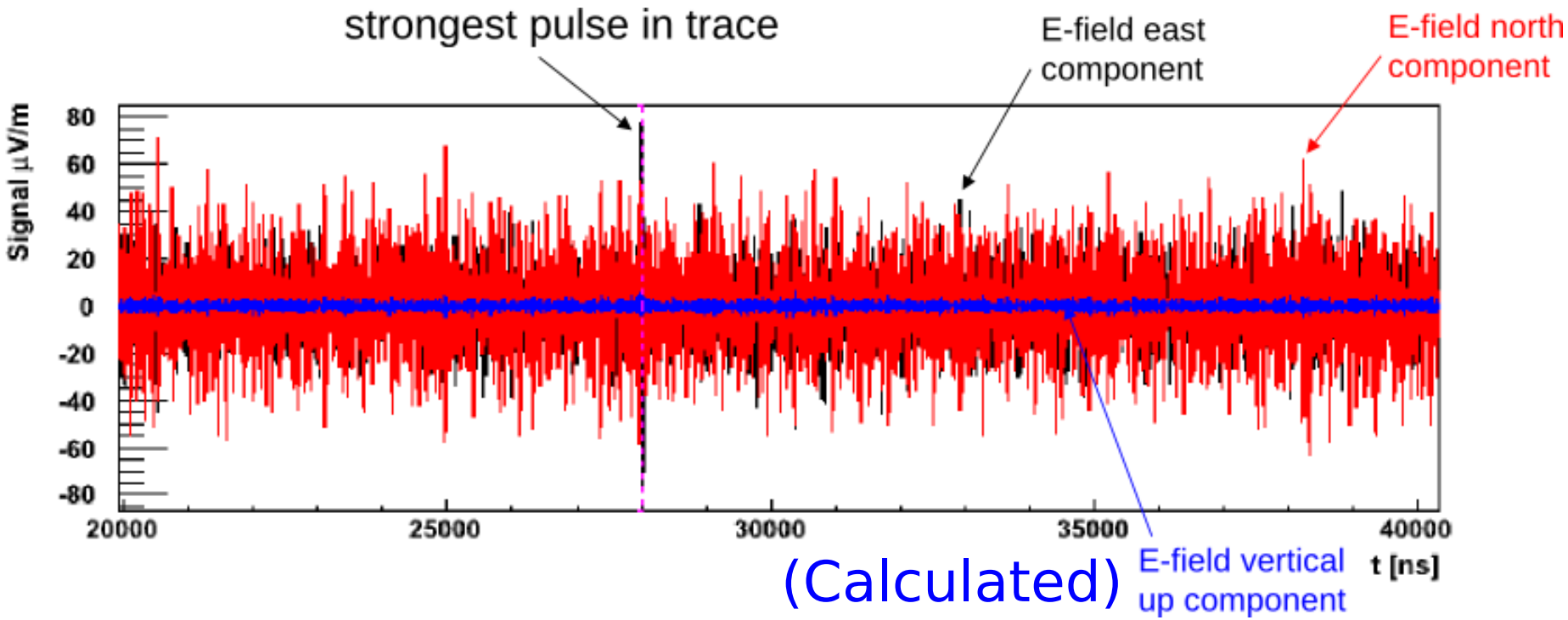
Horizontal air showers and the vertical component

- for horizontal air showers, vertical E-field component can become large
- for **v** x **B**, vertical is actually larger than north-south at AERA site

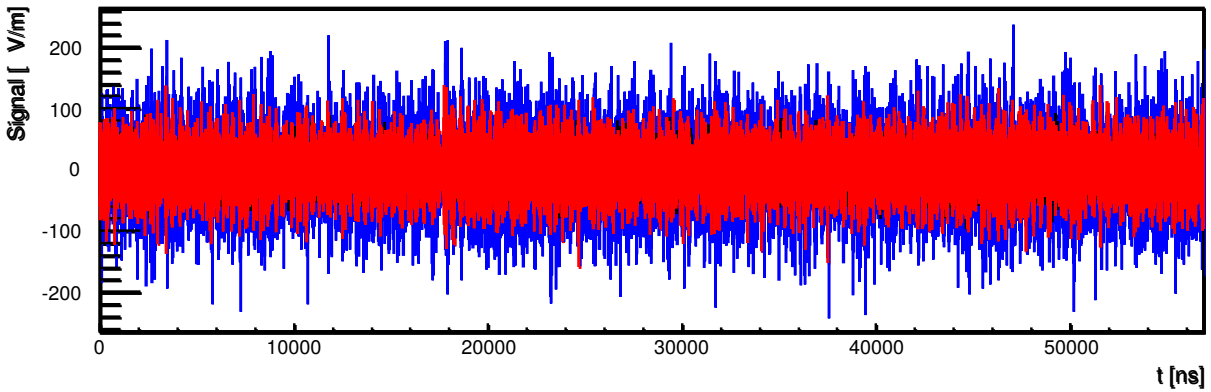


Relative strength of the E-field components for pure geomagnetic radiation.

An AERA trace



A horizontal air showers - AERA trace

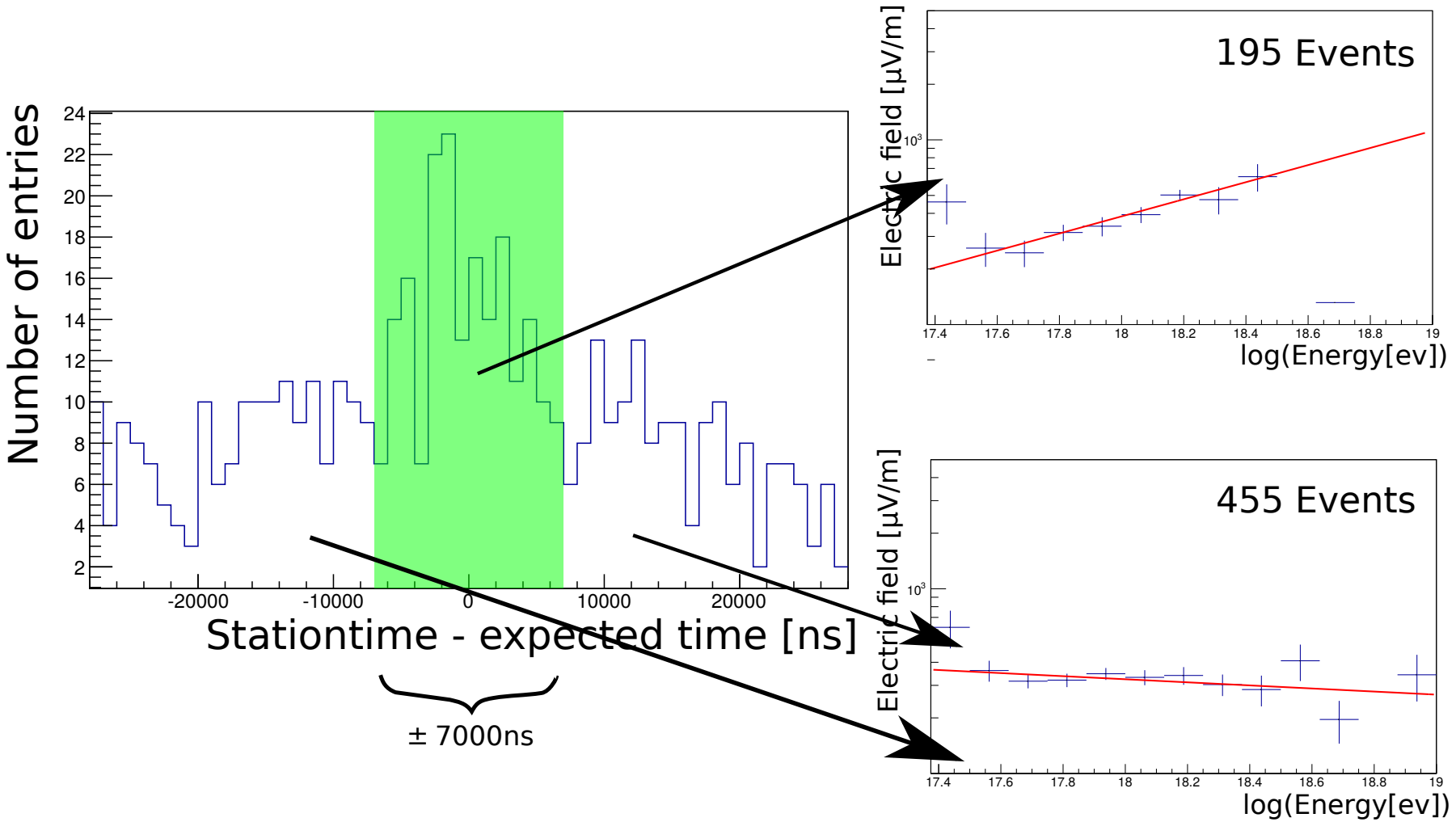


- calculated vertical components blows-up for horizontal events
- search for highest pulse in trace is difficult with magnitude of three components
- standard practice at the moment:
  use east-west and north-south reconstruction of electric field vector

Single pulse selection - Event selection

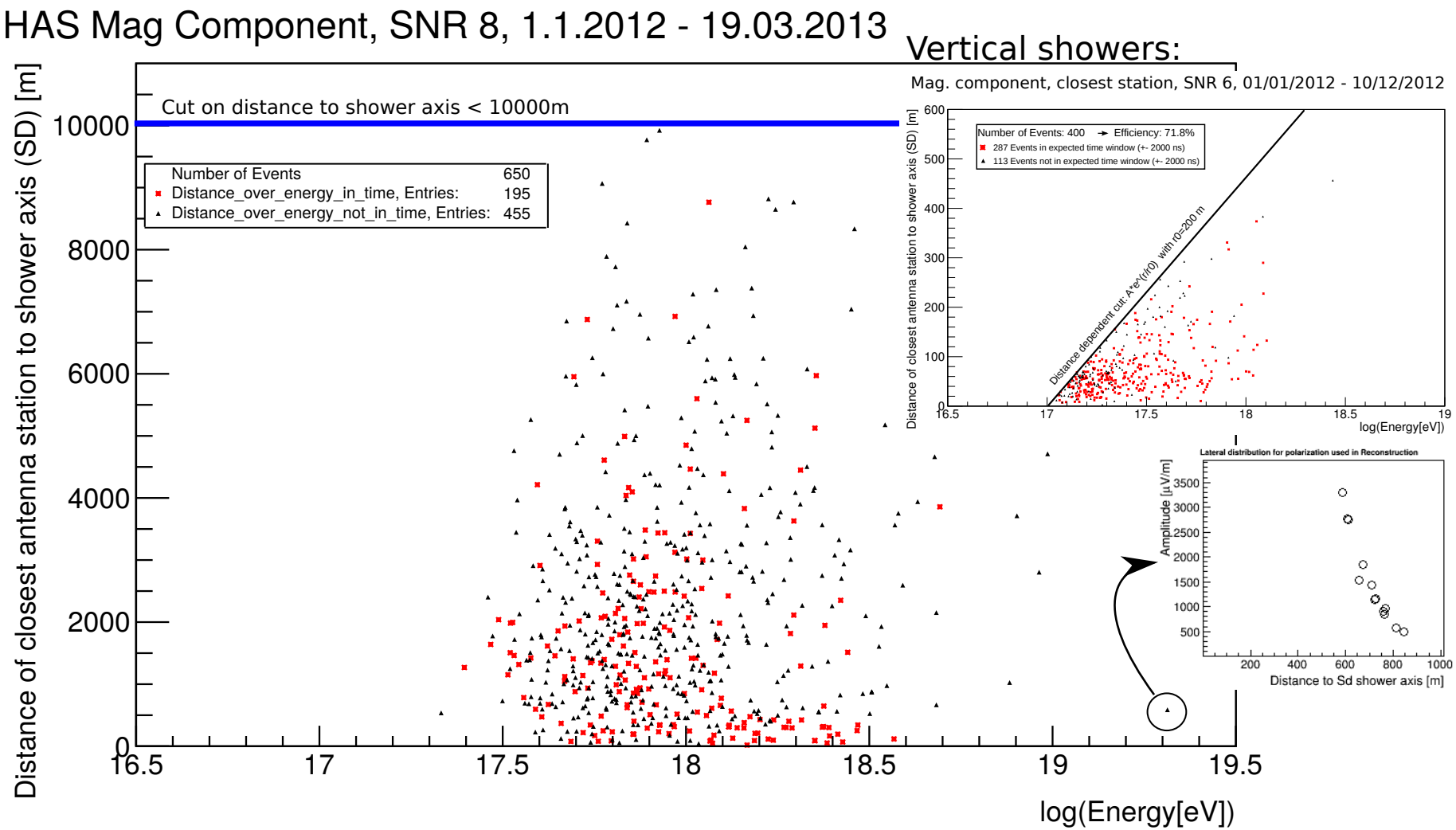
1. take all externally triggered events by surface detector stored by AERA DAQ
   - 2.5 years of data taking
2. no energy cut
3. apply quality cuts of surface detector for horizontal events (ICRC 2013)
   - zenith angle 62° - 80°
4. search for highest pulse in closest AERA station
5. distance of closest station to shower axis of surface detector smaller than 10km

Horizontal events AERA-24 and AERA-124

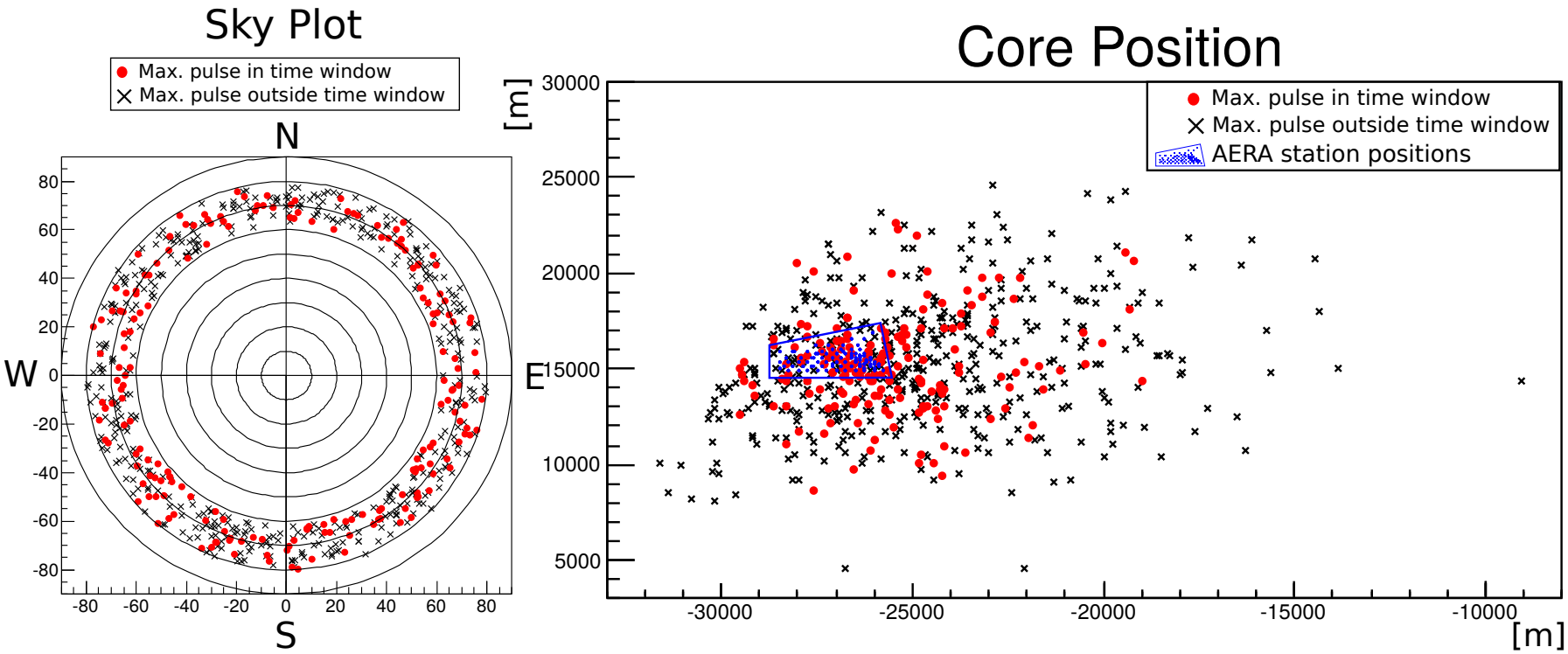


Fit was performed for three closest stations

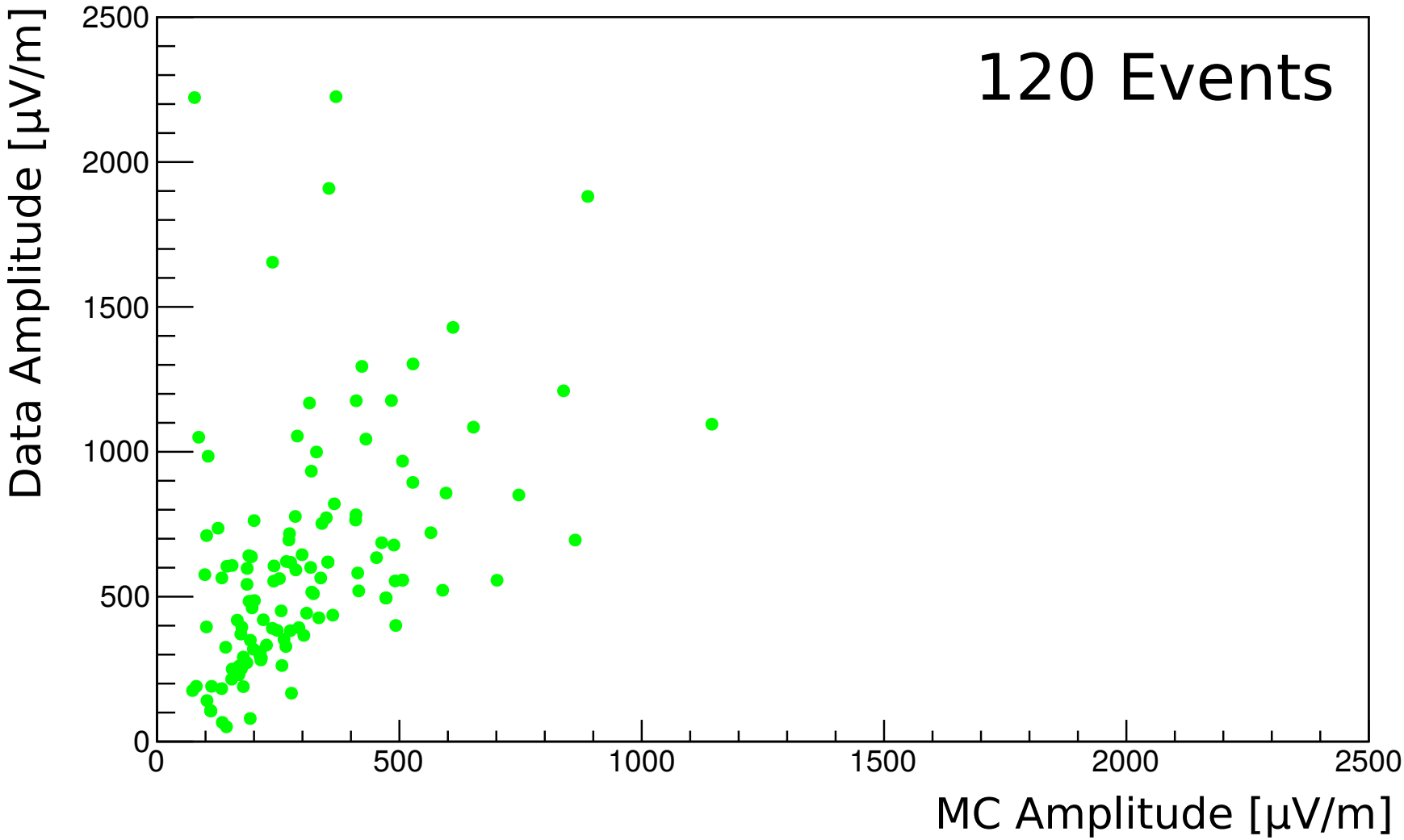
Horizontal events AERA-24 and AERA-124



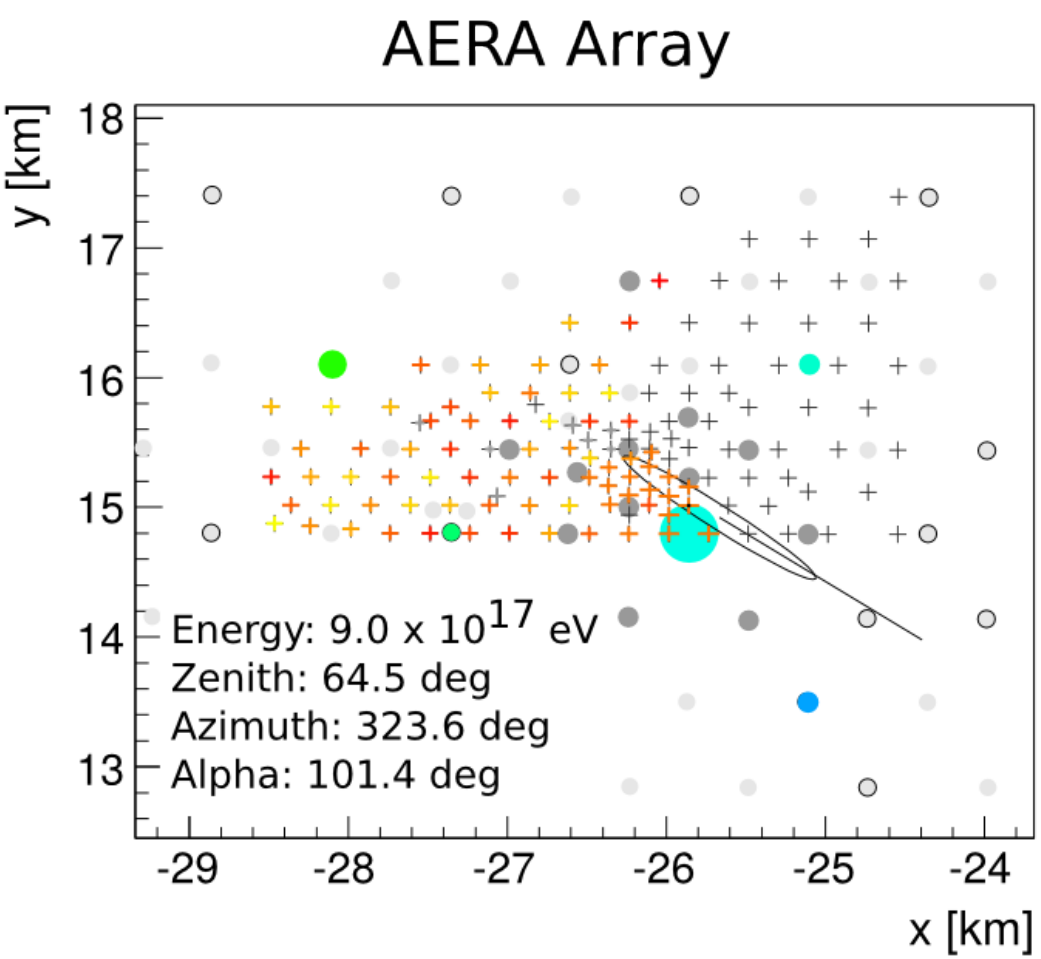
Horizontal events AERA-24 and AERA-124

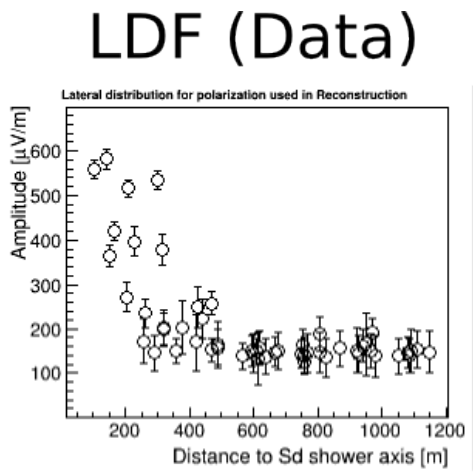


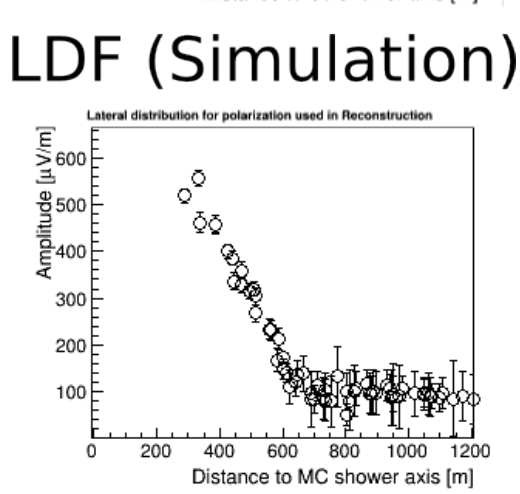
CoREAS simulations of horizontal events AERA-24 and AERA-124



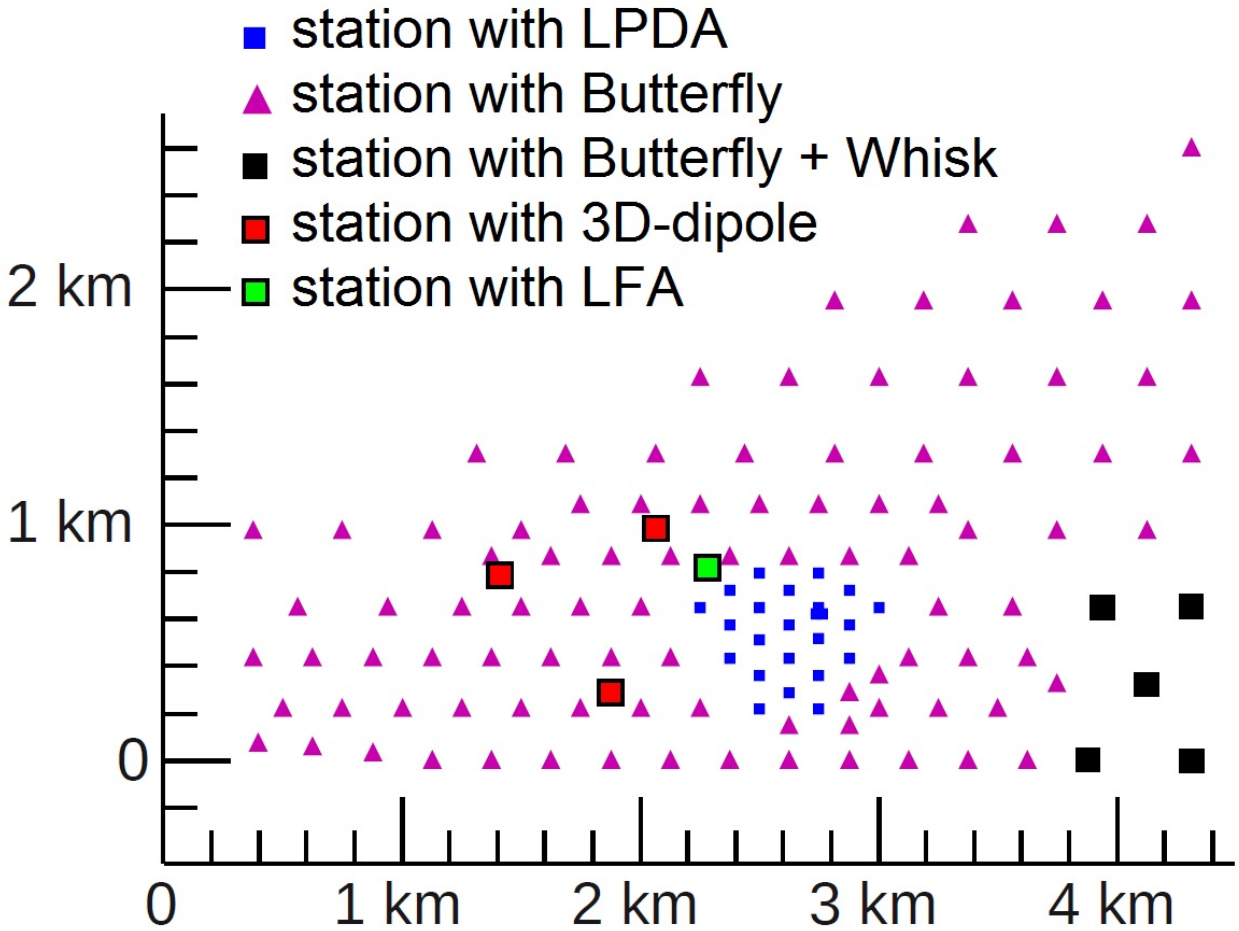
CoREAS simulations of horizontal events - Event Example







Deployment of prototype stations in November 2013



Five Whisk stations and three tripole stations measuring the vertical component

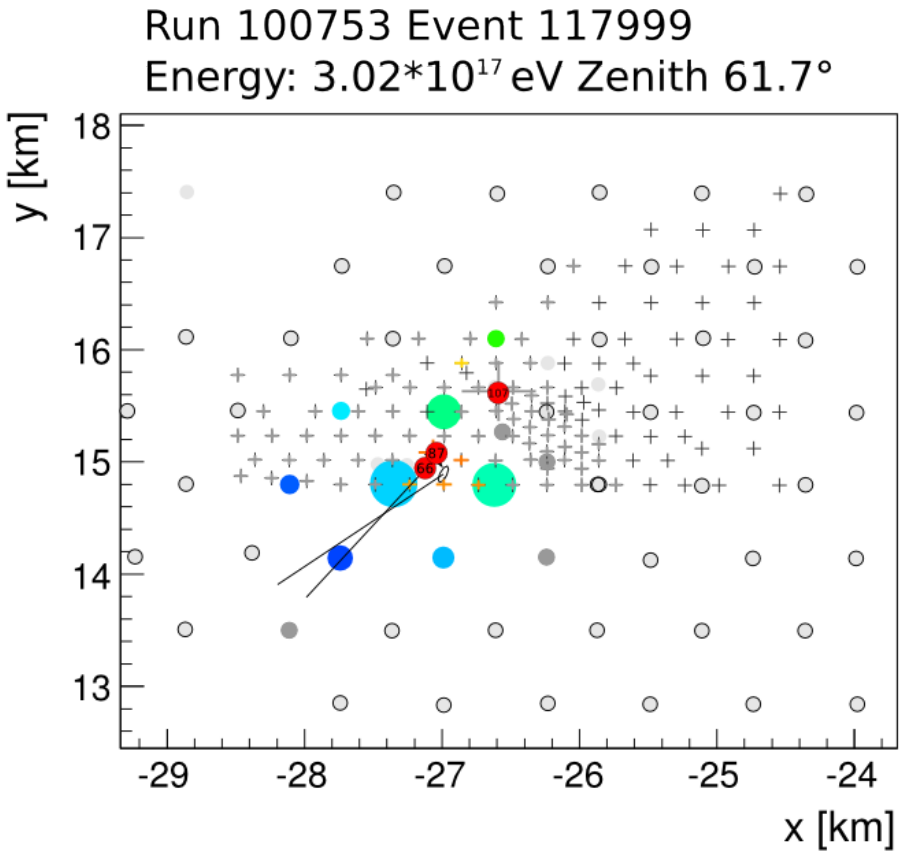
Tripole station

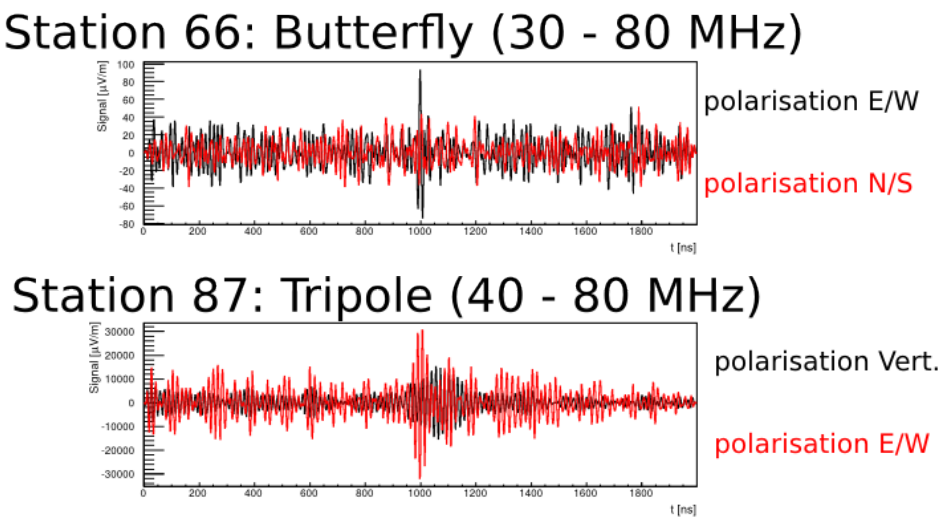
http://www.pinterest.com/astrohap/hapkelschwein/

Frequency range:

- Tripole Station: 40 - 80 MHz (see talk ”LOPES-3D”)

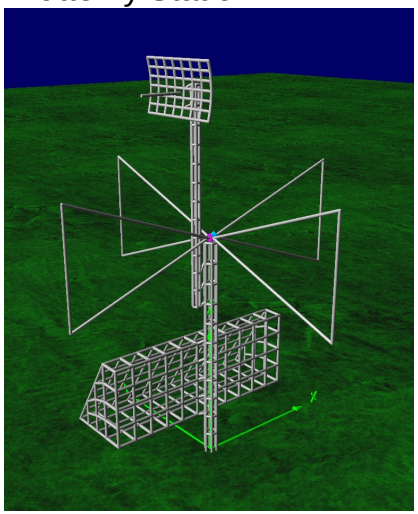
Example Event - Tripole Stations

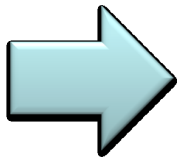


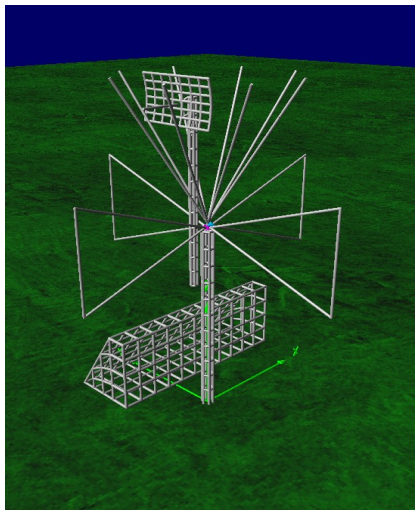


Whisk station

Butterfly Station





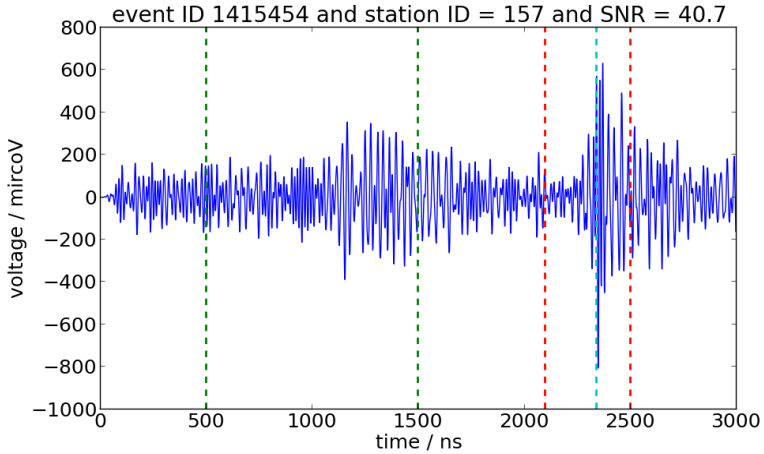


BF + Whisk Antenna

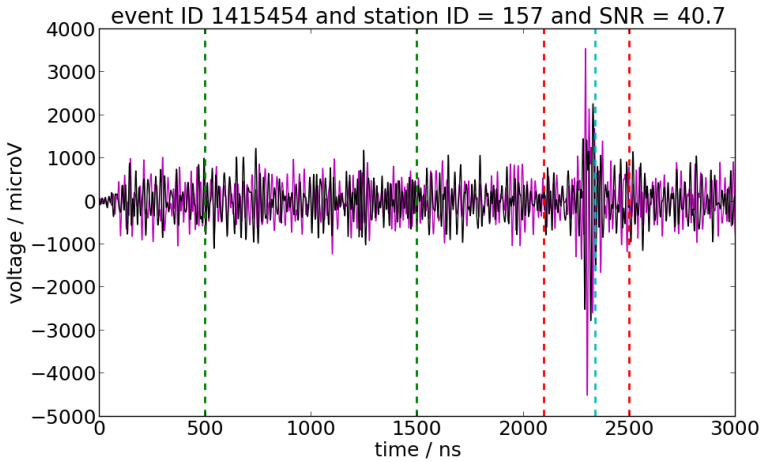
Example Event- Whisk station

Cosmic Ray Candidate

Vertical



NS and EW



	Zenith/°	Azimuth/°	X/km	Y/km	E/EeV
SD	59.04	148.16	-24.43	14.44	1.261

Outlook

The Radio Detection of Horizontal Extensive Air Showers with AERA

- Main motivation:
  1. Big footprint on ground
  2. Mass composition determination
- Ongoing analysis: 195 event candidates with $E > 3 * 10^{17}$ eV and $62° < \theta < 80°$
  $\Rightarrow$ every 4 days one horizontal event which pass quality cut of the surface detector
- make the vertical component measurable
  $\Rightarrow$ eight prototype stations installed

Thank you for your attention!