AERA
The Auger Engineering Radio Array

PIERRE AUGER OBSERVATORY

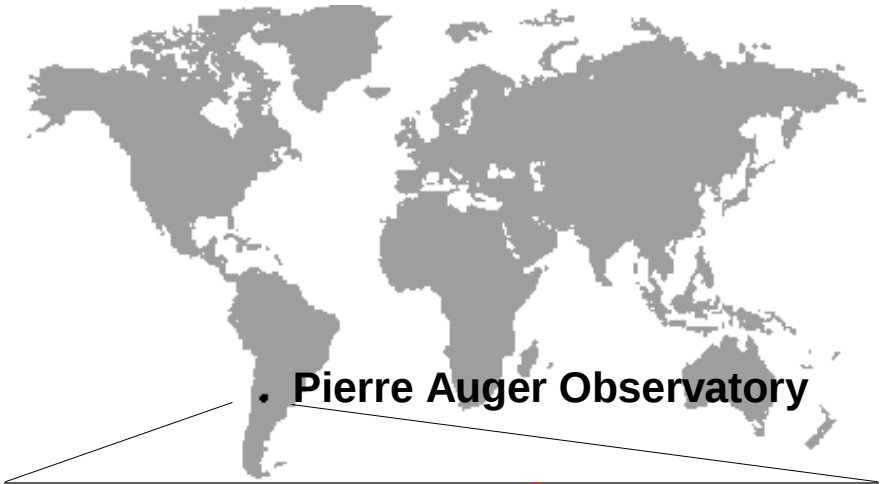
Klaus Weidenhaupt

Vulcano Workshop 2012

AERA Auger Engineering Radio Array

RWTH AACHEN UNIVERSITY

The Pierre Auger Observatory

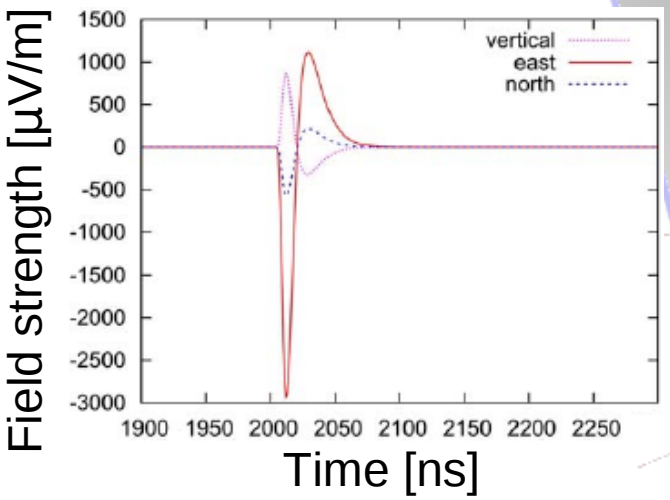


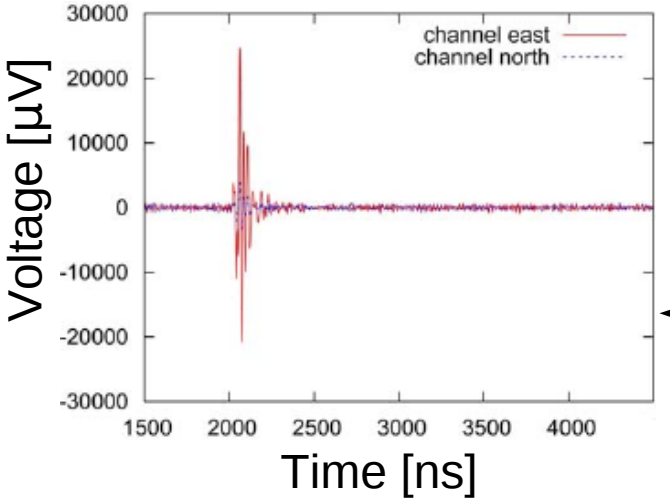
Hybrid Detector

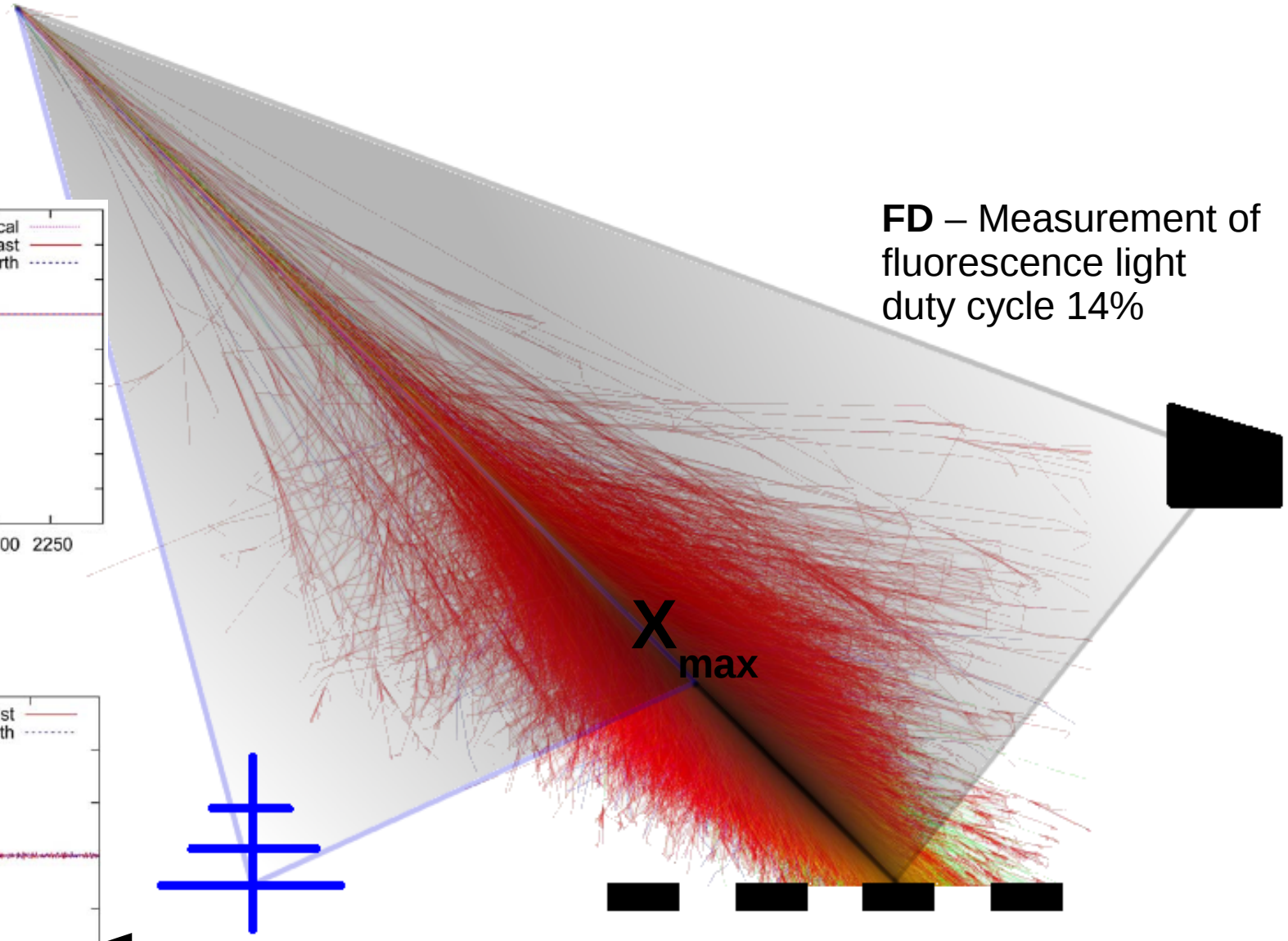
- SD: 1660 water Cherenkov tanks
- FD: 27 Fluorescence Telescopes

Radio Detection of CRs

Coherent radio pulse contains information of shower development







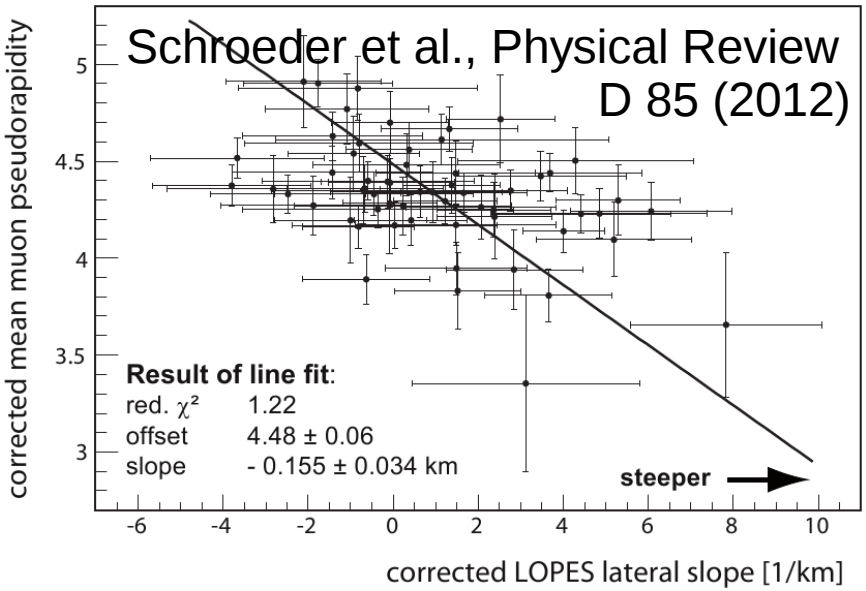
FD – Measurement of fluorescence light duty cycle 14%

Radio Detection duty cycle 100%

SD – footprint of the EAS Duty cycle 100%

Experimental

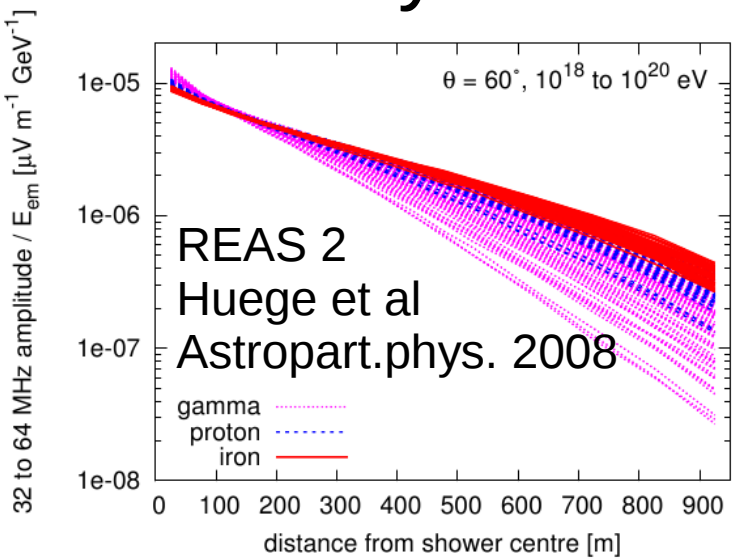
LOPES
LOFAR
CODALEMA

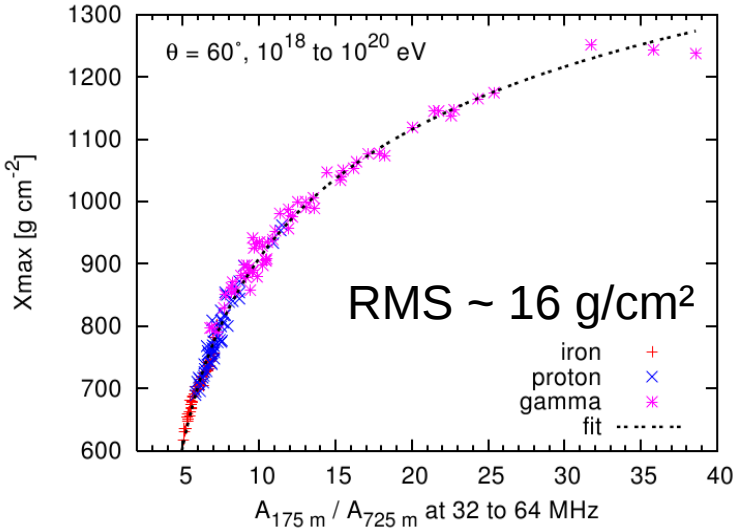


Exp. Evidence for sensitivity of radio emission to longitudinal shower development

Now go to ultra high energies...
AERA
EASIER

Theory



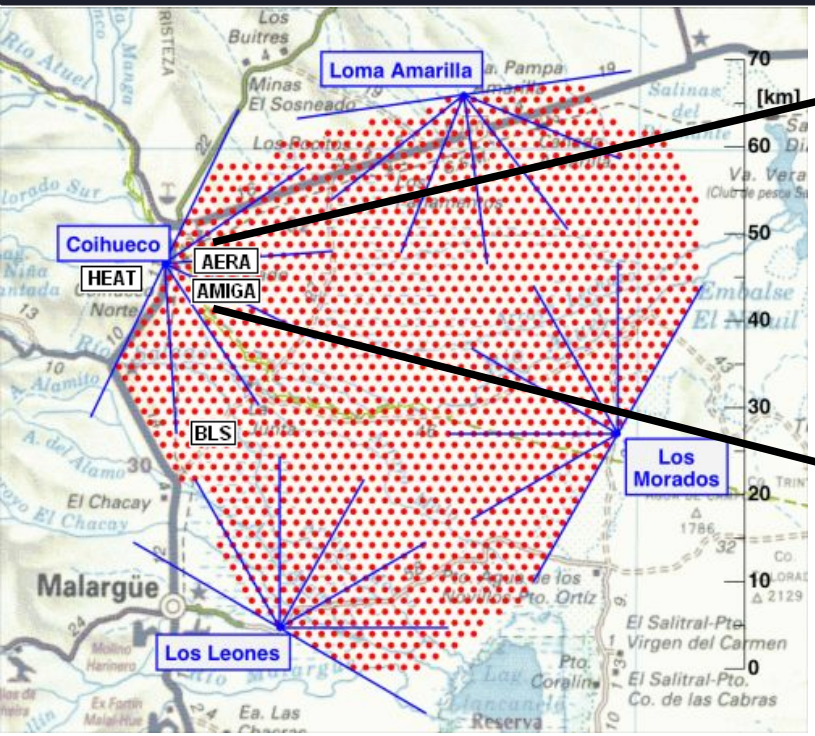


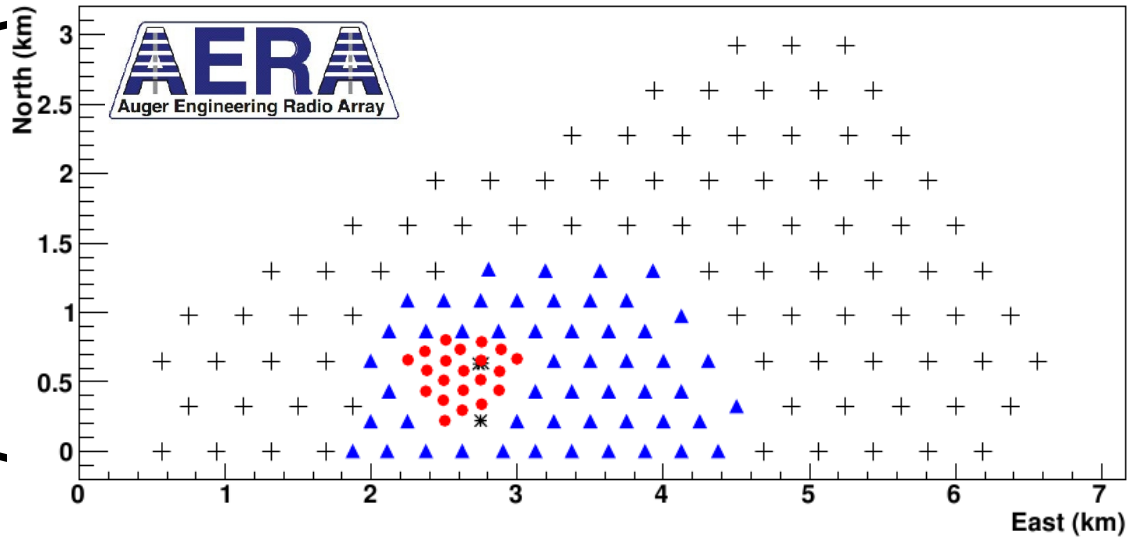
Complement theoretical descriptions
REAS and MGMR → similar results

AERA Objectives

- Selftriggered (standalone) radio detection of UHECRs with $E > 10^{17}$eV
- Detailed studies of radio emission mechanisms
- Determine properties of CR (angular distribution, energy, mass)
- Explore feasibility of RD for future CR experiments

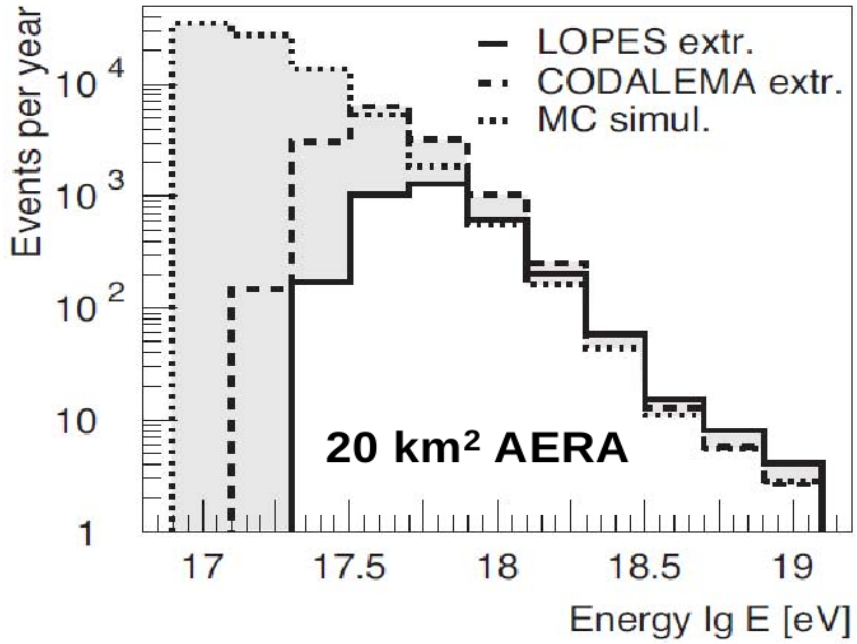
AERA Layout



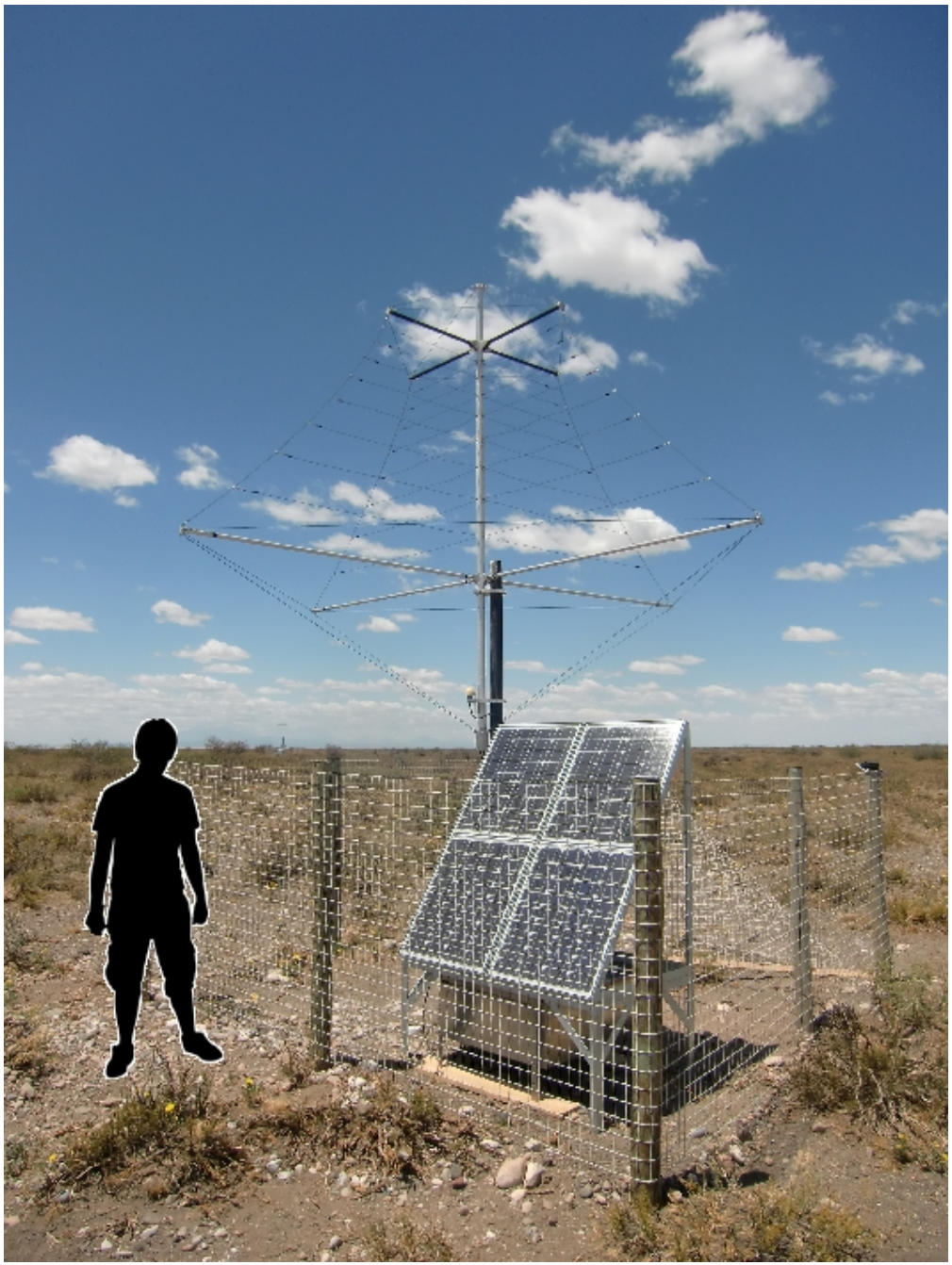


- Dense core (150m spacing) of 24 stations taking data
- 150 stations covering ~20 km² (2012/13)
- Enlarged spacing (375m) in the outer regions
- Overlap with other Auger detector components: SD, FD, HEAT, AMIGA (Infill Array)

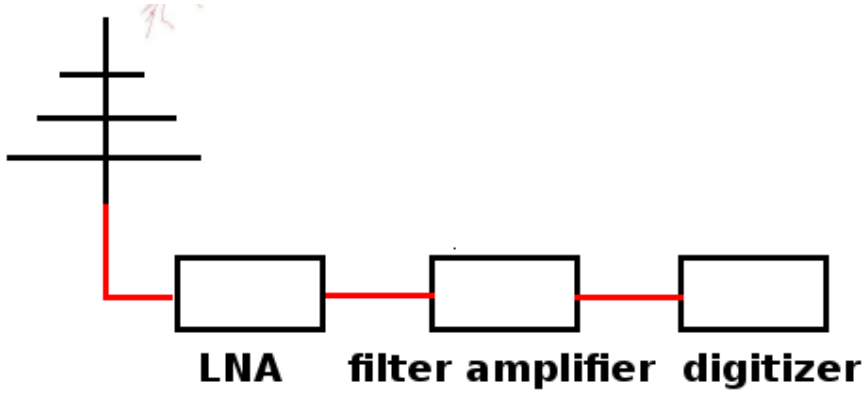
Unique site for detailed studies of EAS and calibration of radio emission



AERA Detector Stations

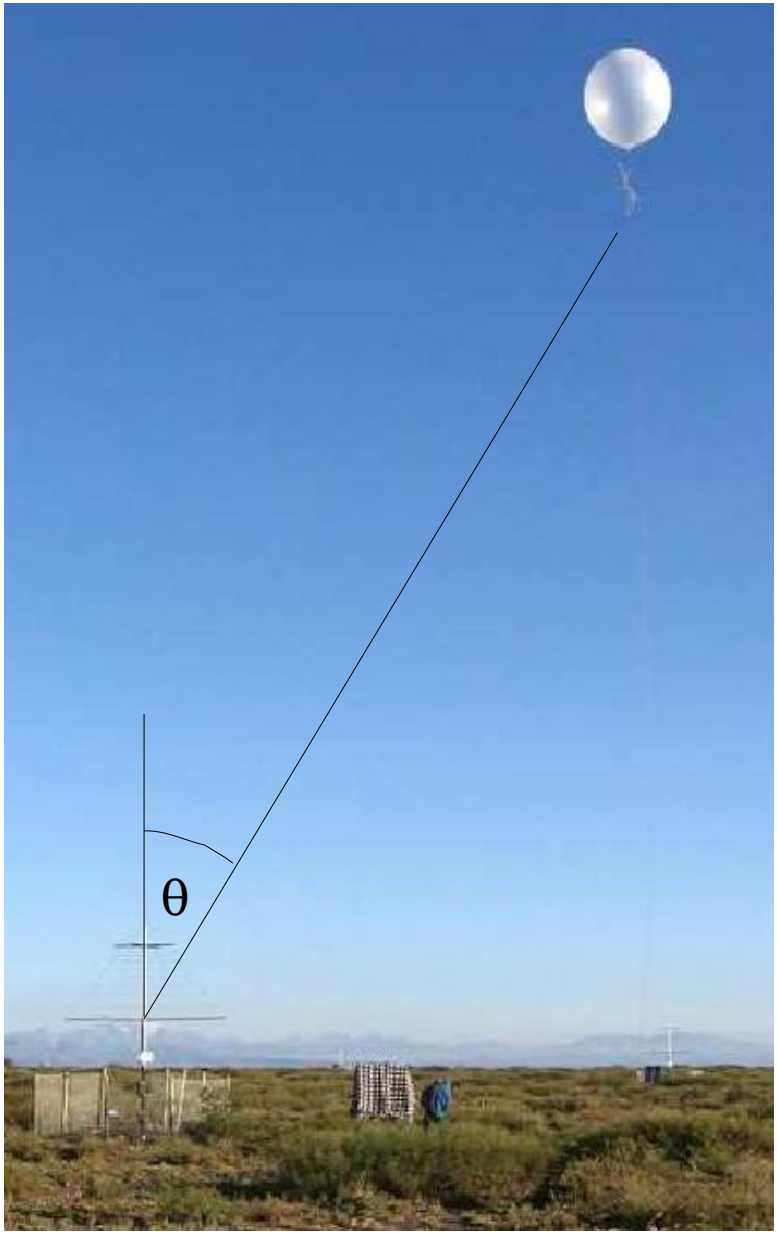


- Dual polarized **L**ogarithmic **P**eriodic **D**ipole **A**ntennas (24 stations)
- Bandwidth: 30 – 80 MHz
- Dedicated digitizer boards
- 200 / 180 MHz sampling
- Optional external trigger

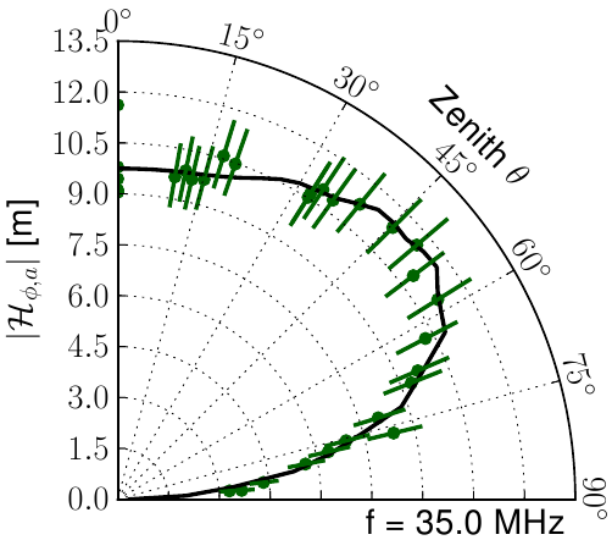


Thorough end-to-end calibration of the entire signal chain

Antenna and Timing Calibration

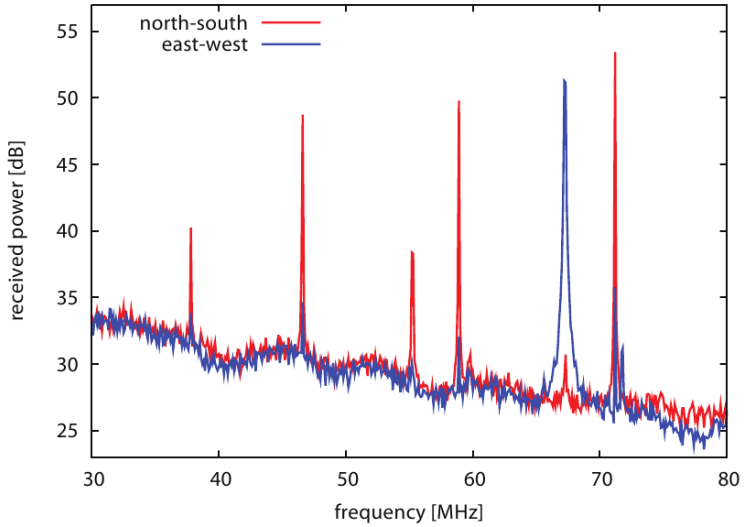


Auger paper on antennas for MHz radio detection to be published

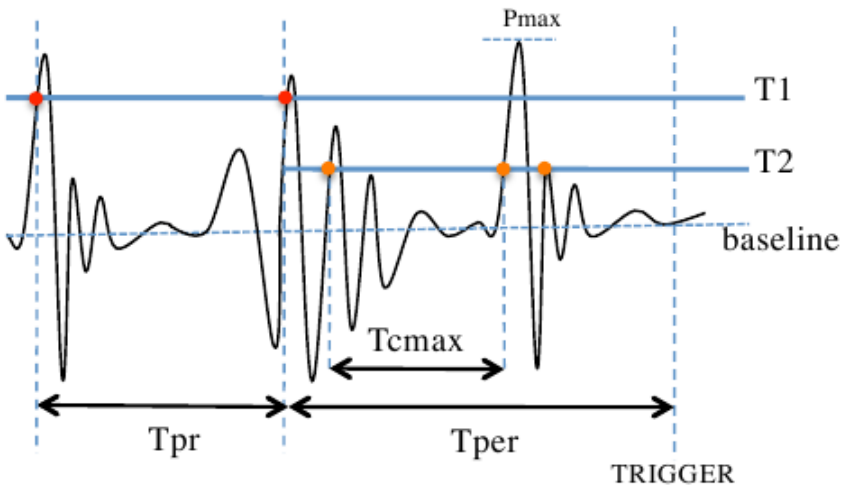


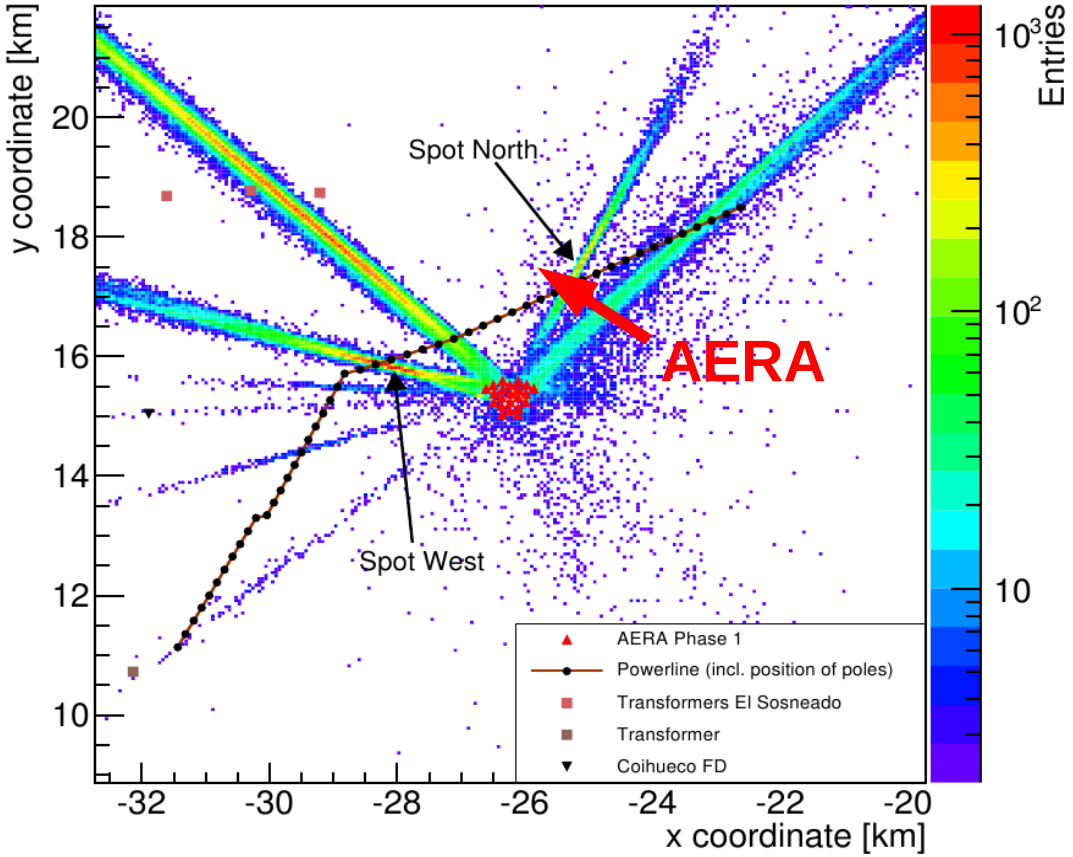
Ongoing development:
Calibration using Octocopter

Timing calibration / monitoring: AERA beacon



Selftrigger



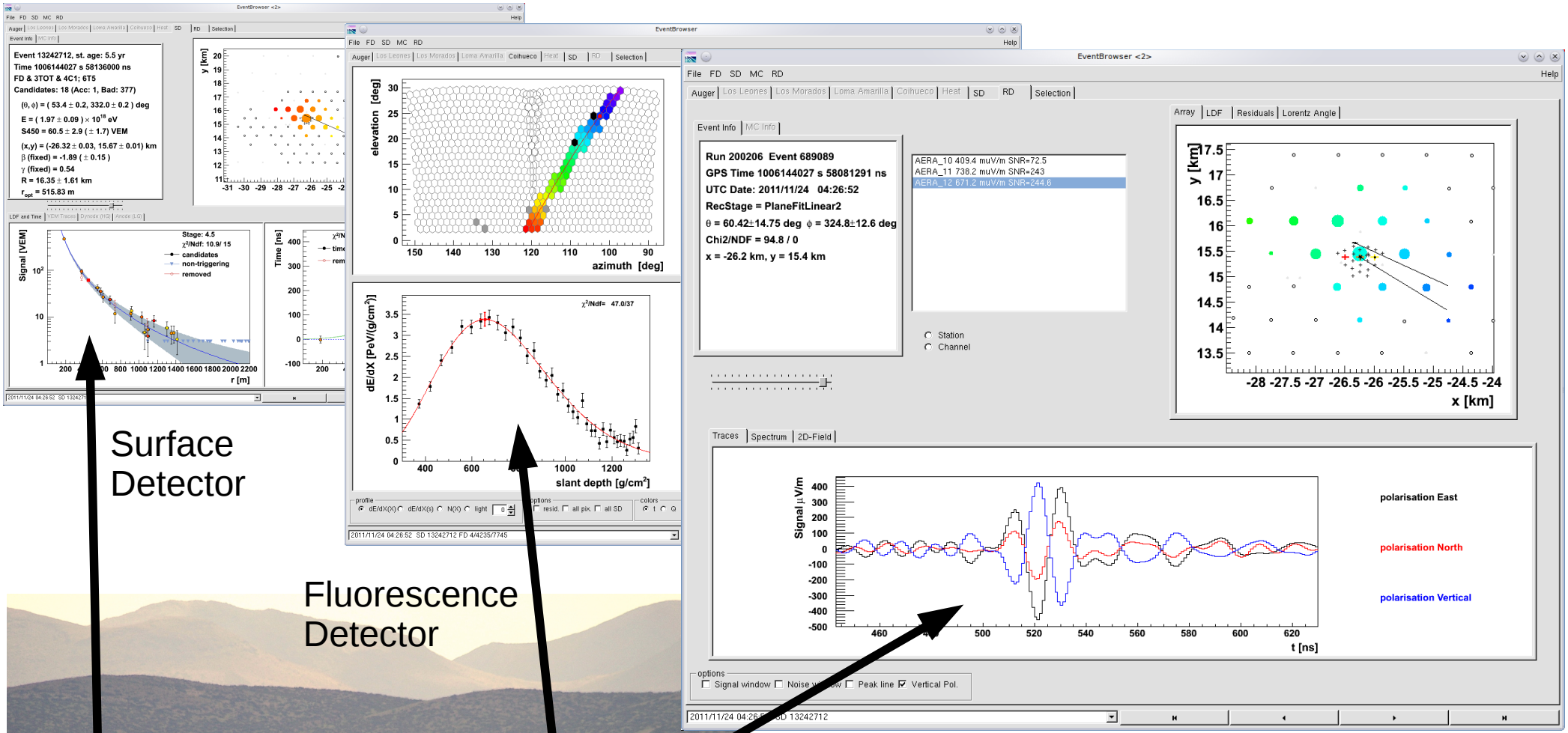


Noise Rejection Strategies

Station level:
- Smart trigger
- notch filter for narrowband signals
- Filtering of periodic signals (100Hz)

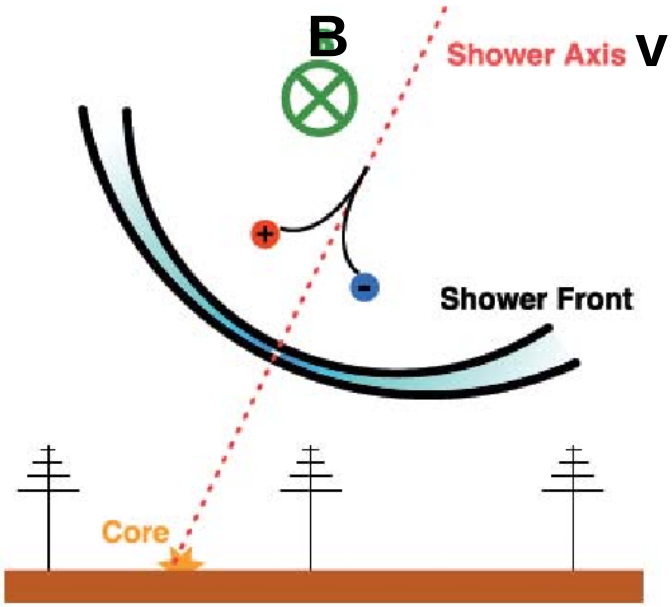
Event level (CRS):
- Reconstruction of source point
- Directional filtering
- Polarization Signature

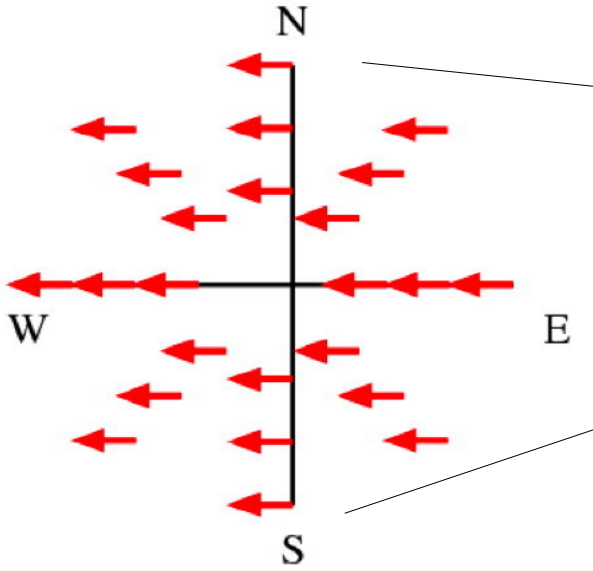
Superhybrid Measurements

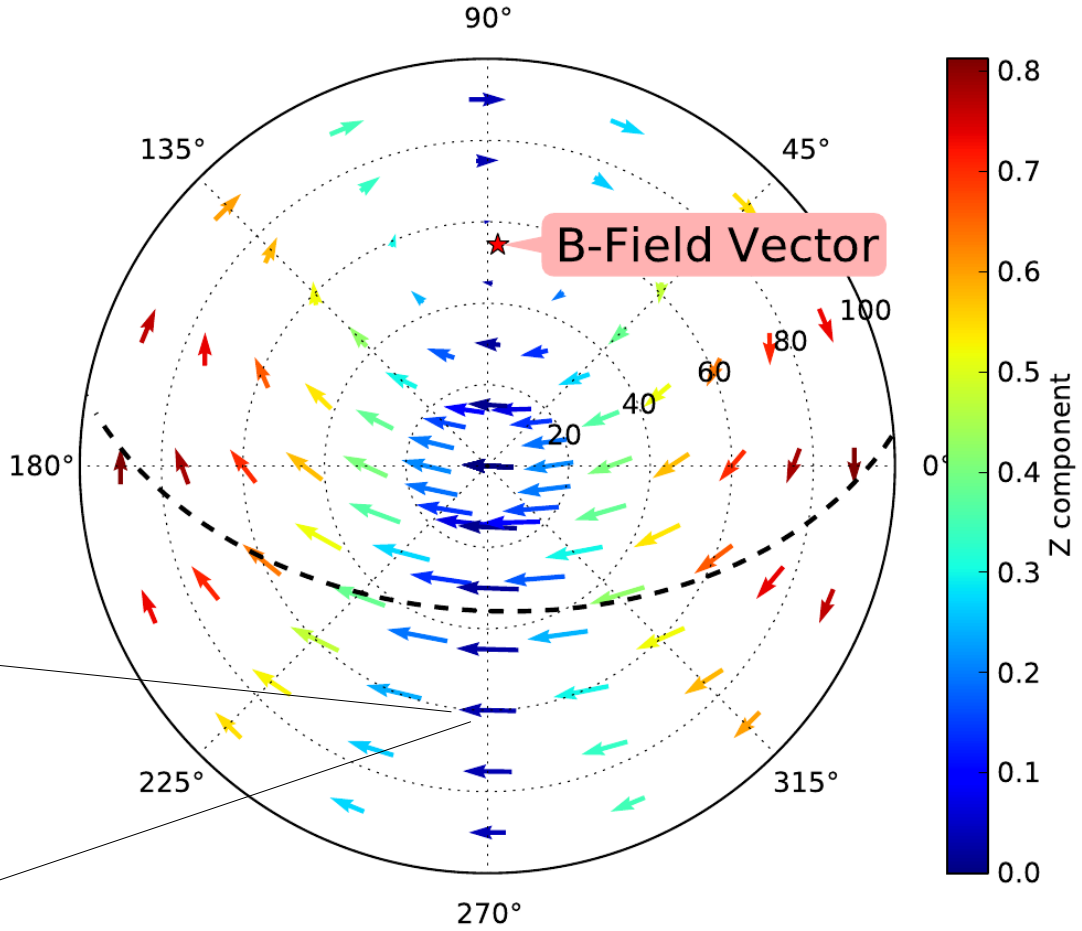


- Several Superhybrid events measured (Radio, Surface Detector, Fluorescence Detector)
- Radio Funcionality integrated in standard Auger reconstruction framework Offline

Geomagnetic Radio Emission

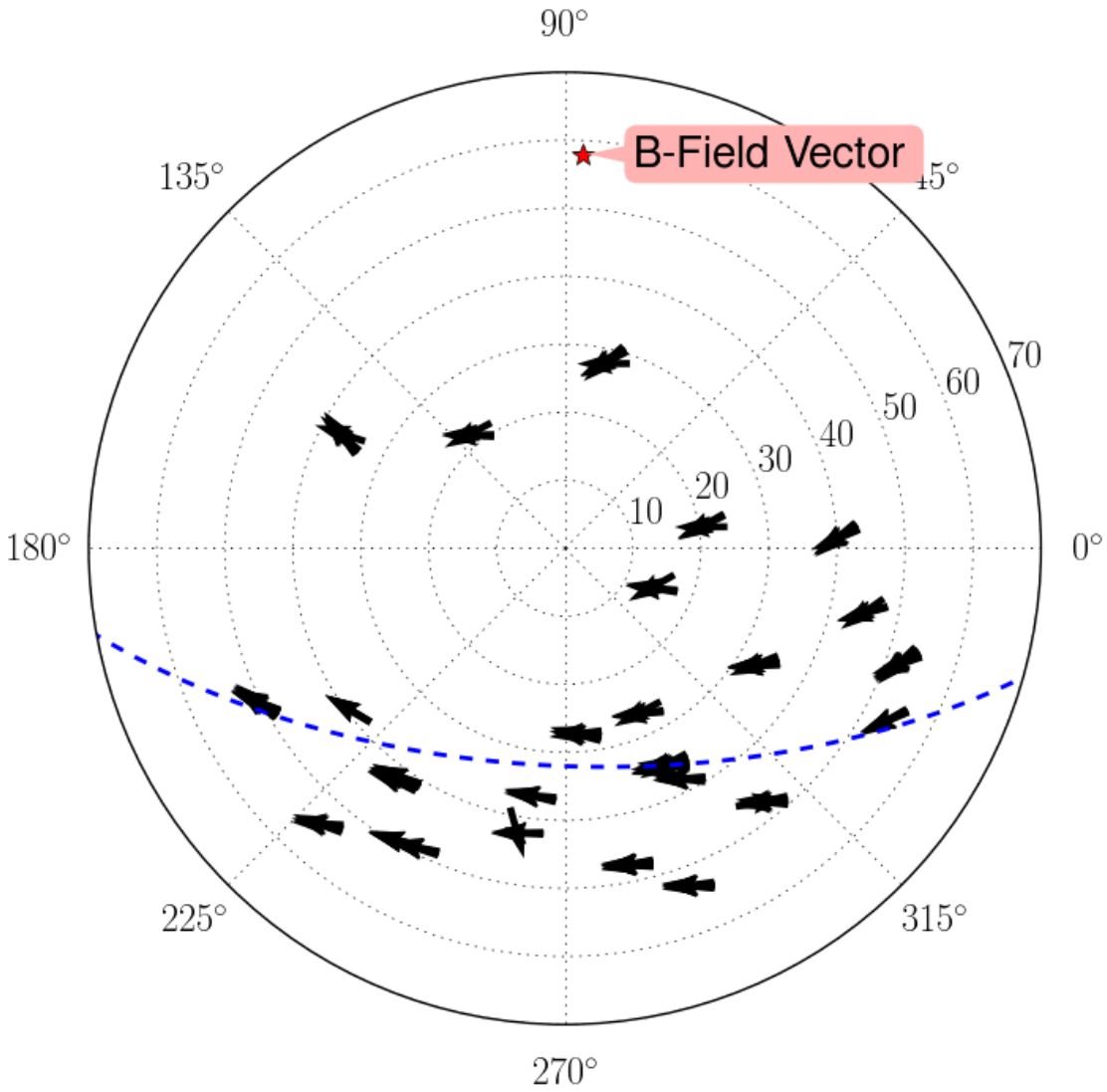






Expected polarization due to **v x B**

Polarization Radio Events

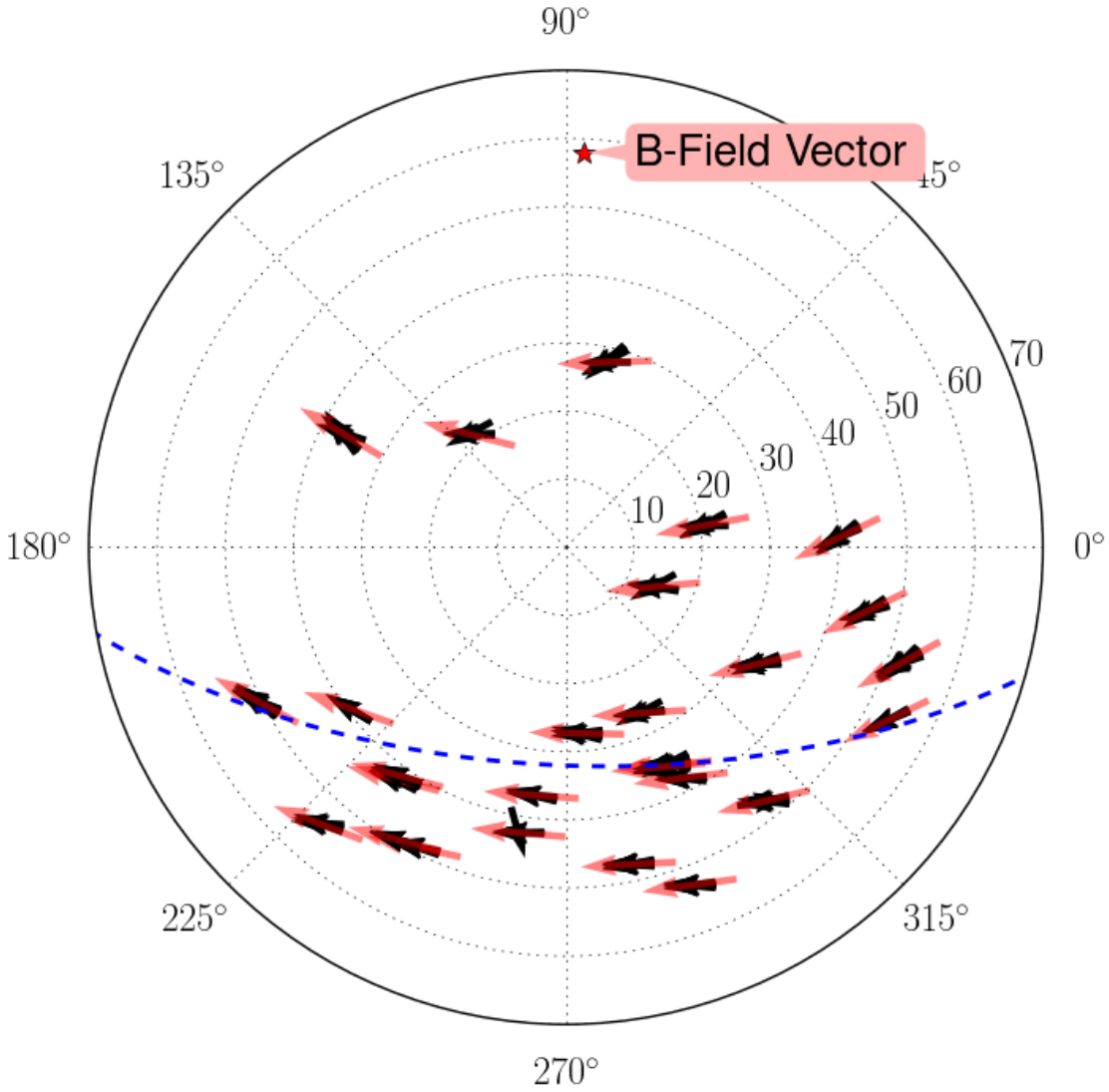


Skyplot with EW and NS components of the measured E-Field vector

Radio Events recorded in coincidence with Auger Surface Detector

- Event selection
  ≥ 3 selftriggered stations
  zenith < 55°
  no thunderstorms
- Anisotropy in arrival direction
- All stations of one event measure approximately equal polarization

Polarization Radio Events



Skyplot with EW and NS components of the measured E-Field vector compared to theoretical vectors (v x B)

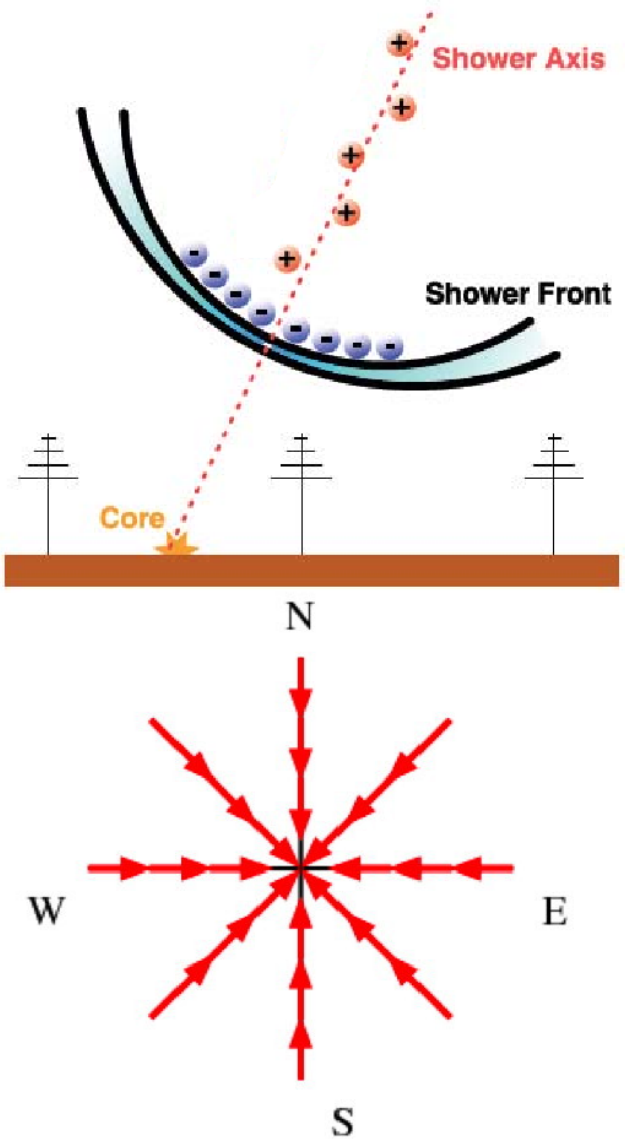
Radio Events recorded in coincidence with Auger Surface Detector

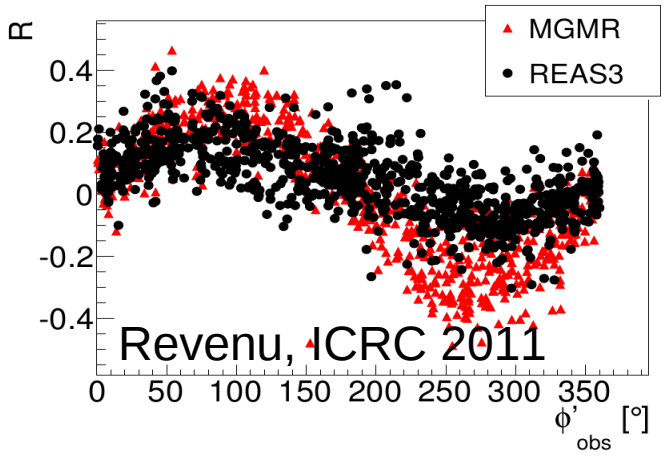
- Event selection
  ≥ 3 selftriggered stations
  zenith < 55°
  no thunderstorms
- Anisotropy in arrival direction
- All stations of one event measure approximately equal polarization
- Polarization signature characteristic for geomagnetic emission

Dominating geomagnetic emission

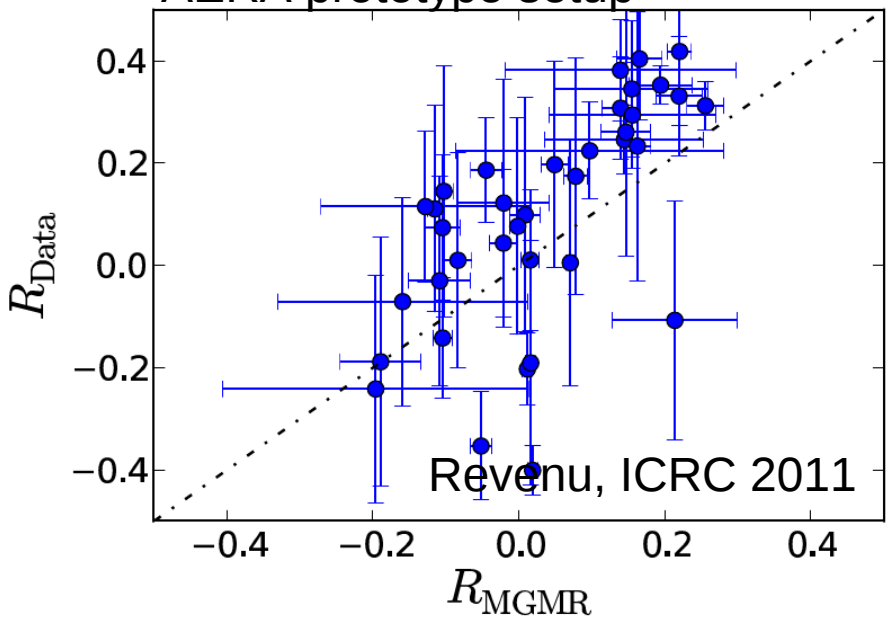
Charge Excess Contribution

$$R = \sum_{i=1}^{N} E_{x'}(t_i)\, E_{y'}(t_i) / \sum_{i=1}^{N} (E_{x'}^2(t_i) + E_{y'}^2(t_i))$$





AERA prototype setup



- Better agreement of data and simulation by inclusion of charge excess contribution
- Upcoming publication on emmission mechanisms based on polarization measurements of AERA data

Summary / Outlook

- Extensive R&D of hardware for MHz radio detection
- End to end calibrated radio detector stations ideally situated within the well calibrated Auger Observatory
- Successfull selftriggering of CRs confirmed by Auger baseline detectors
- Contribution to understanding of radio emission mechanisms

- Deploy 20 km² of radio detector stations in 2012/13
- Determine sensitivity to mass composition
- AERA 300 – 300 km² of radio stations