

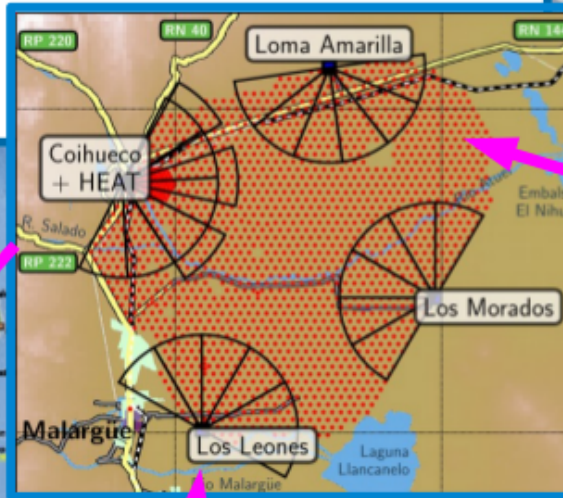


Reconstruction of Horizontal Air Showers with AERA

Marvin Gottowik,

Astroparticle School, Oct 2017

The Pierre Auger Observatory



Surface Detector (SD)

1660 Water Cherenkov stations

1.5 km spacing

3000 km² covered area

Fluorescence Detector (FD)

27 telescopes at

4 sites with 180° view

Radio Detector (RD)

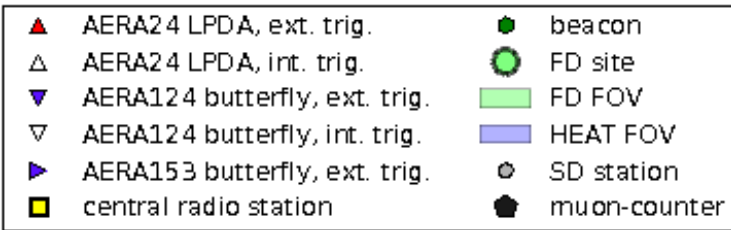
→ AERA



Reconstruction of Horizontal Air Showers with AERA

Gottowik, Marvin | Astroparticle School 2017 | Slide 2

Auger Engineering Radio Array (AERA)



1 km



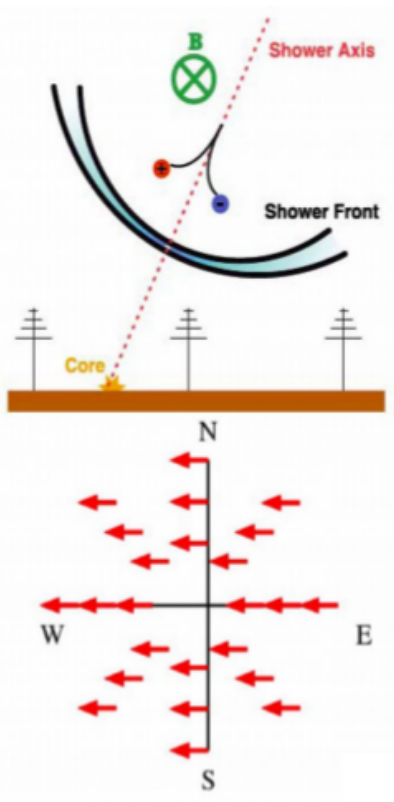
- Build in phases
- Different antenna types and spacings
- 153 stations with 2 antenna (NS, EW)
area of $\sim 17 \text{ km}^2$
- Bandwidth
30 – 80 MHz

- Here: AERA124,
ext. triggered

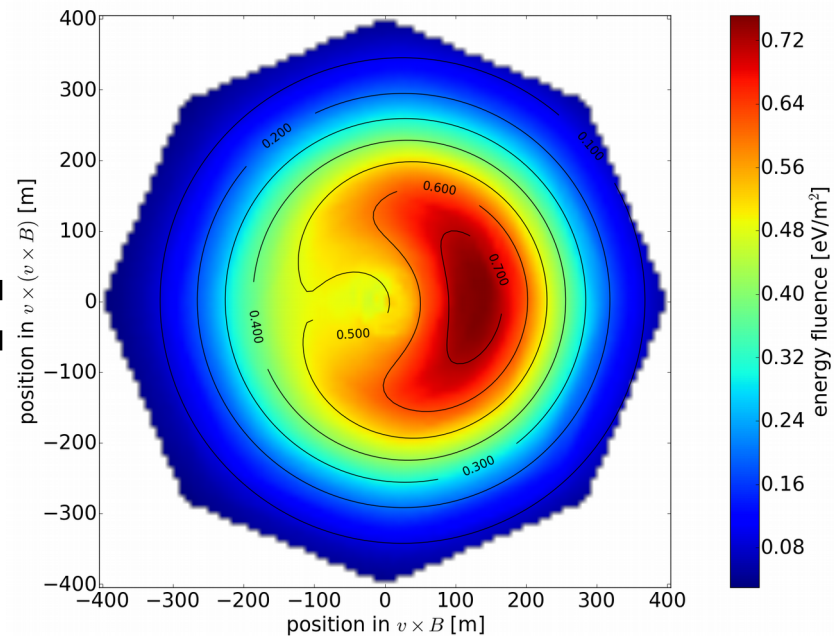
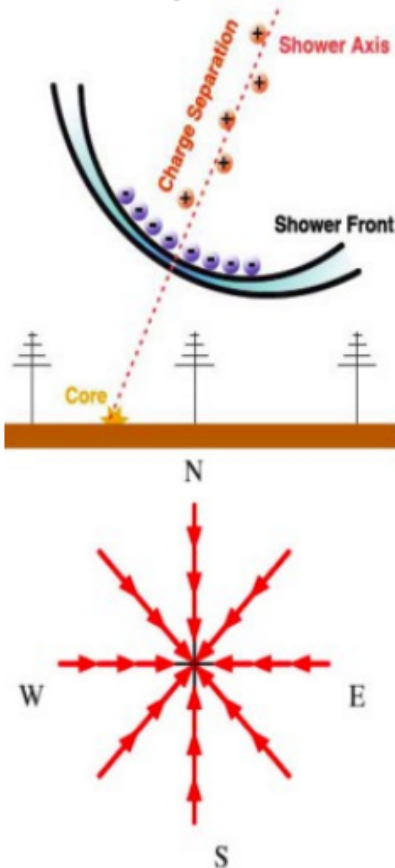


Radio Emission from Cosmic Ray Air Showers

Geomagnetic Emission

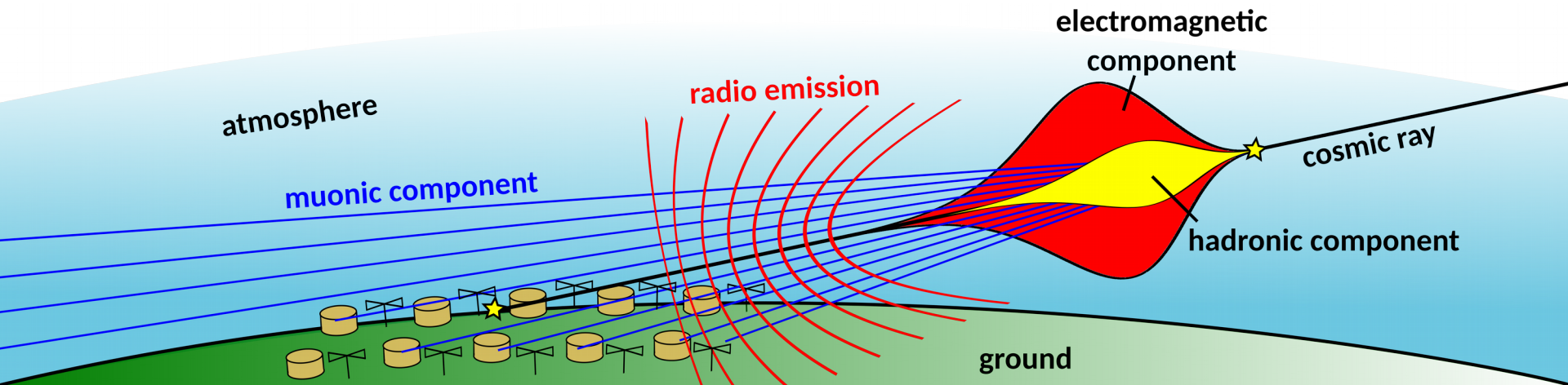


Charge Excess



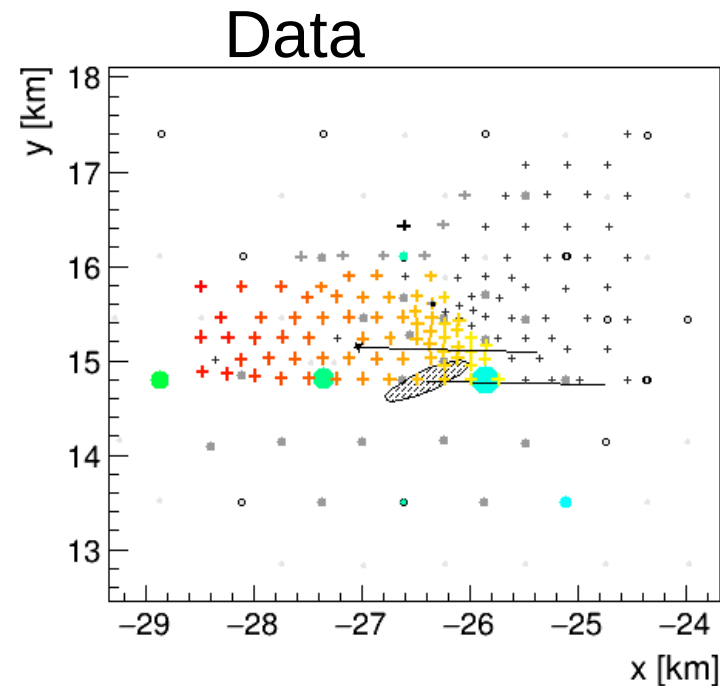
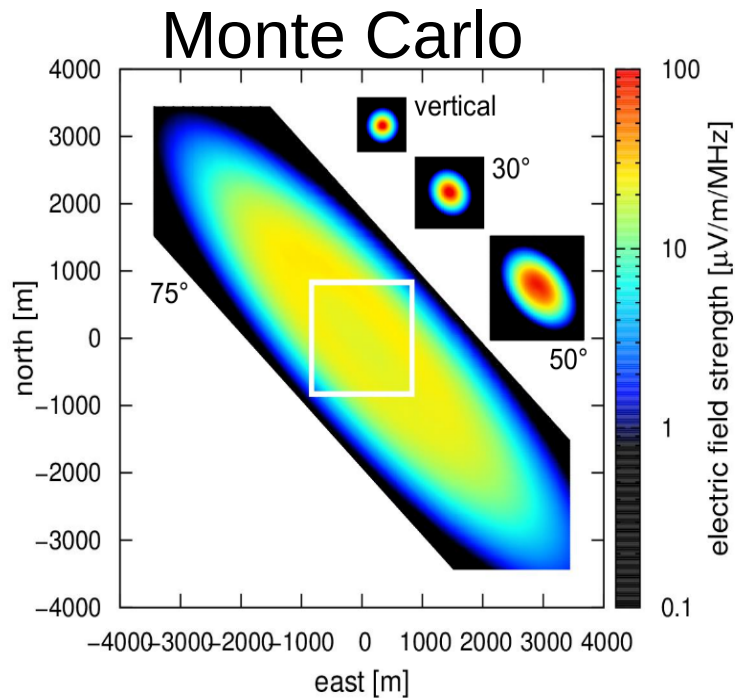
Horizontal Air Shower (HAS)

- Full signal in RD, SD only sees muons
- Challenging reconstruction and MC
- Interesting features
 - e.g. v-search, composition, energy scale



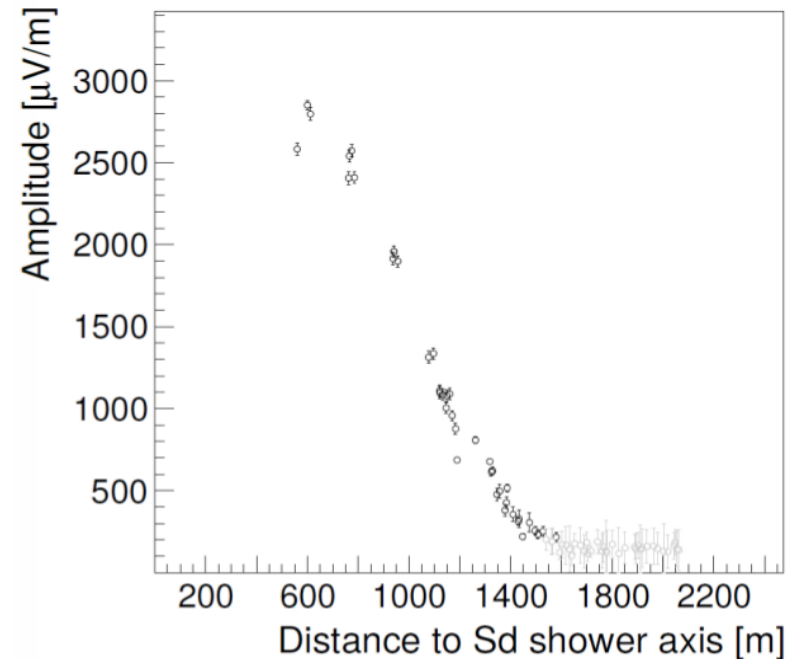
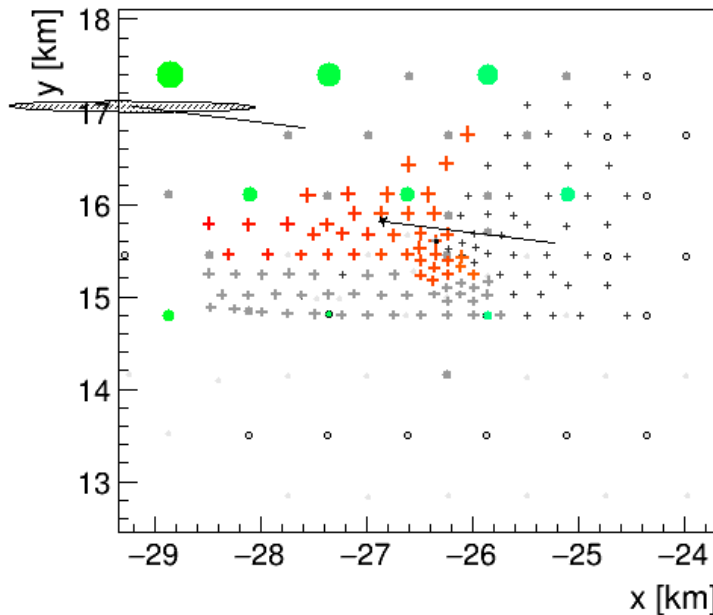
Outline

- „large“ radio footprints predicted, now **measured**
- Comparison of the signal in data & simulations
- Potential for sparse SD-RD hybrid array



Example Event

- Energy 19.6 EeV
- Zenith 79.2°
- Azimuth 351.7° (East)
- RD Stations 40



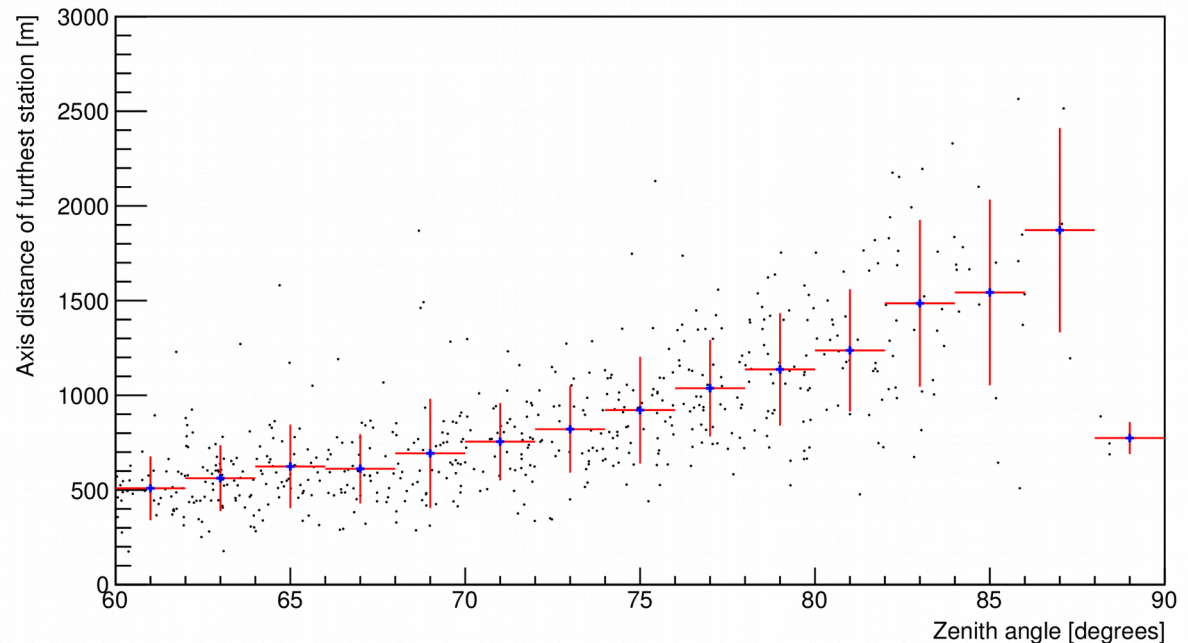
- all antennas on one side of the shower axis
→ no asymmetry from the charge-excess contribution



Increasing Footprint

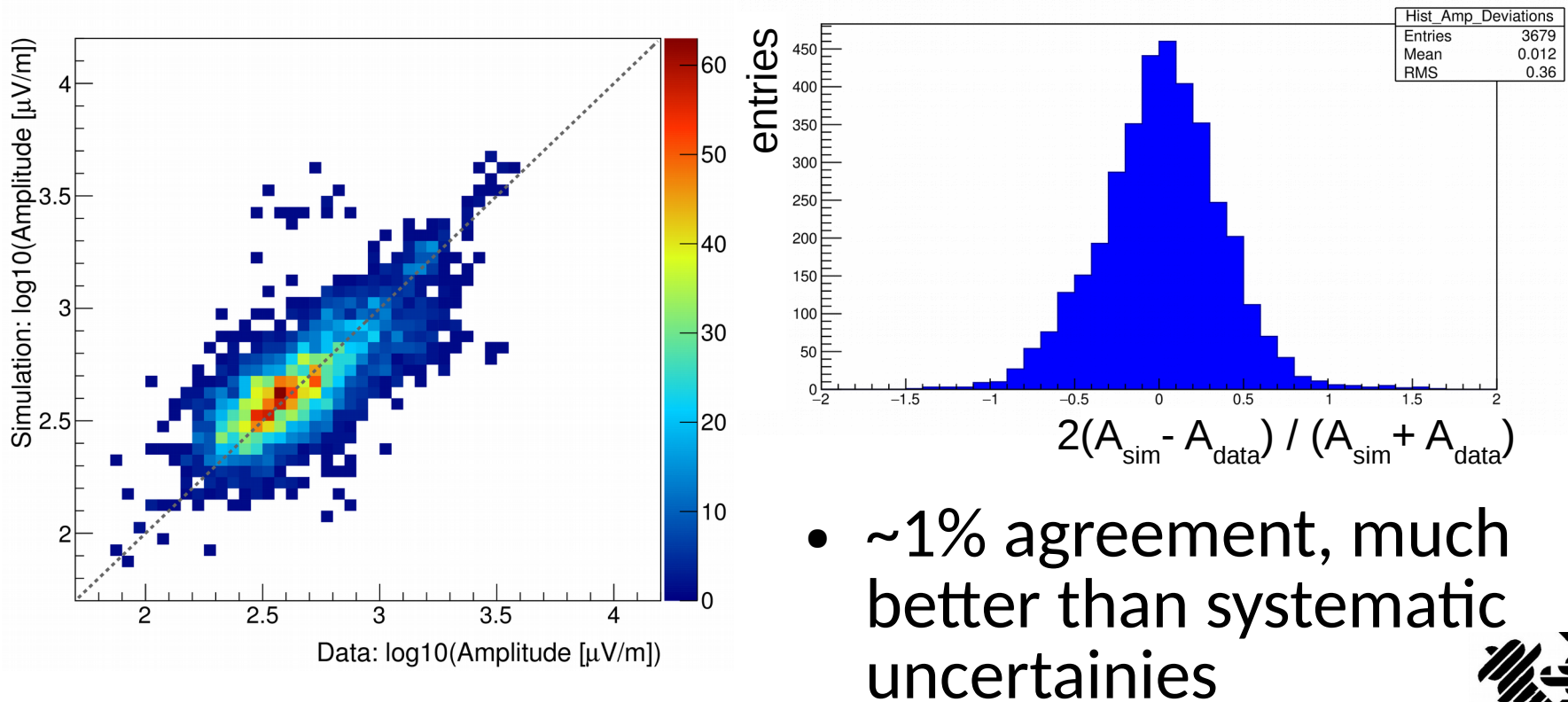
- RD externaly triggered by SD regular array
- 702 events in 20 month data (07/2013 – 02/2015)
- Footprintsizes **in shower plane** increases for higher zenith angles

→ cone opening angle



Simulations

- Similar reconstruction of simulations with real noise from the event time

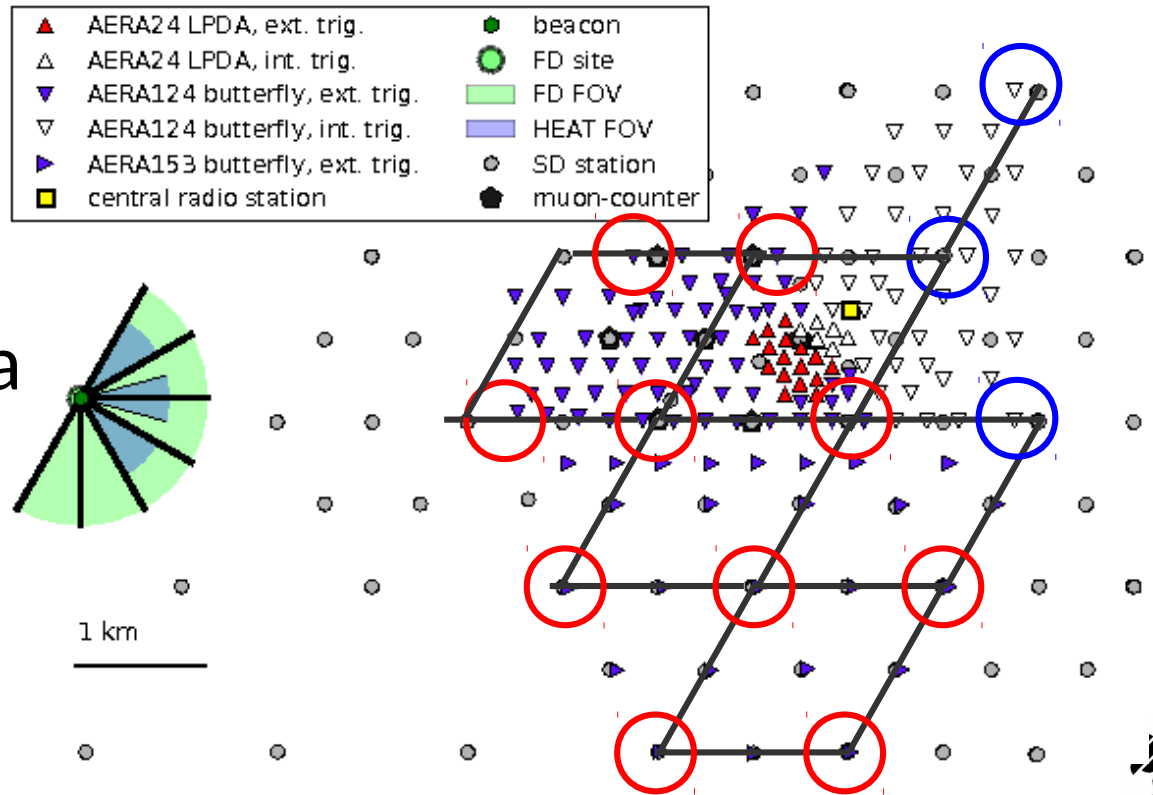


- ~1% agreement, much better than systematic uncertainties



AERA 1500m Array

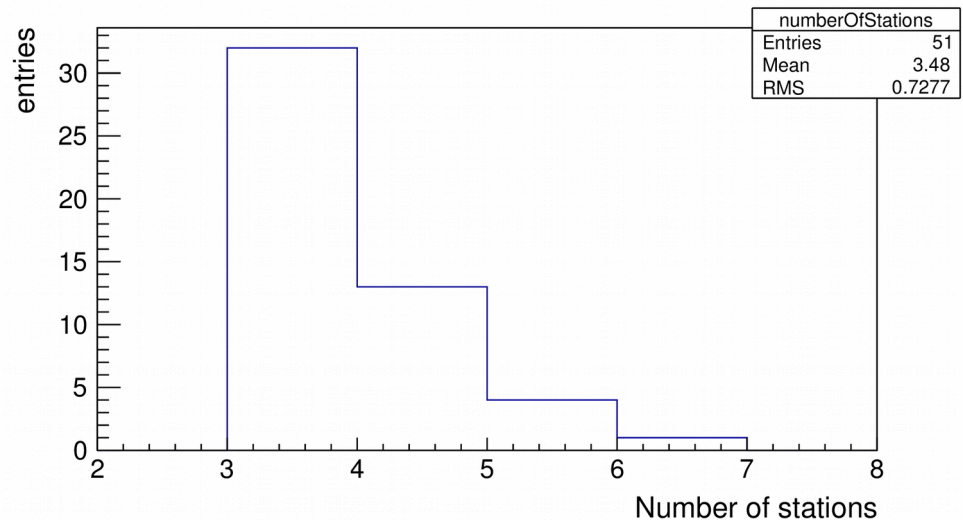
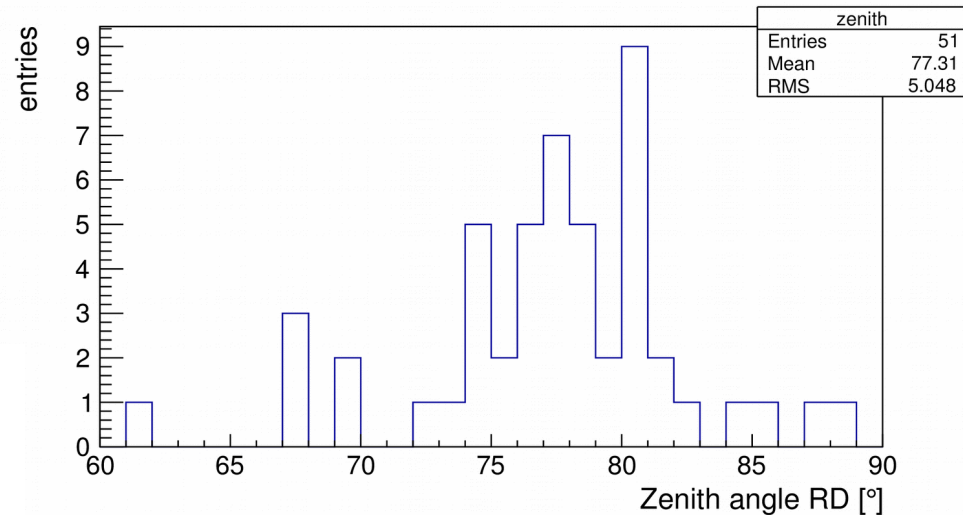
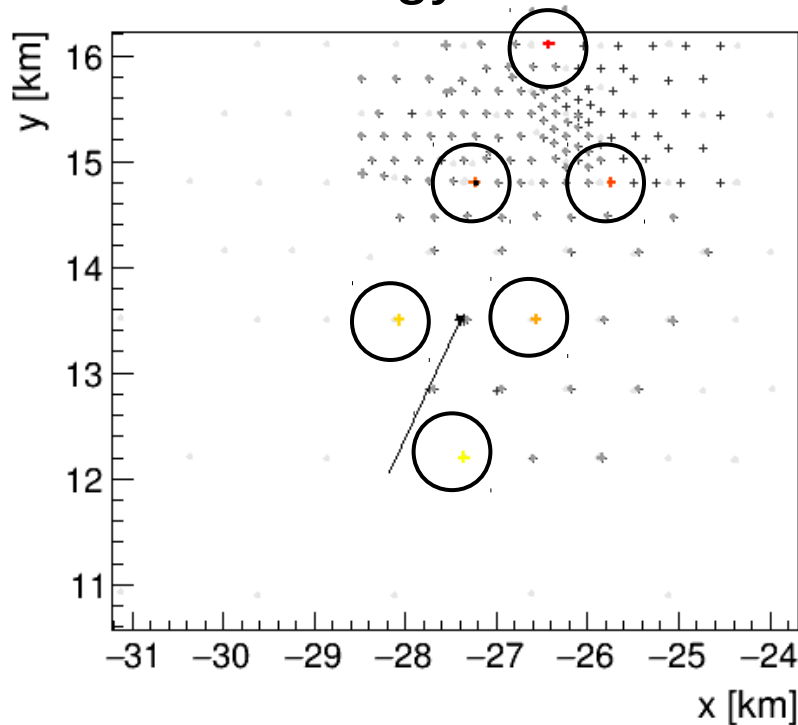
- Only select stations on a 1500m grid
 - 10 ext. trig.
 - 3 int. trig.
- 51 Events found in 18 month of data (03/2015 – 10/2016)



Quick look into the data...

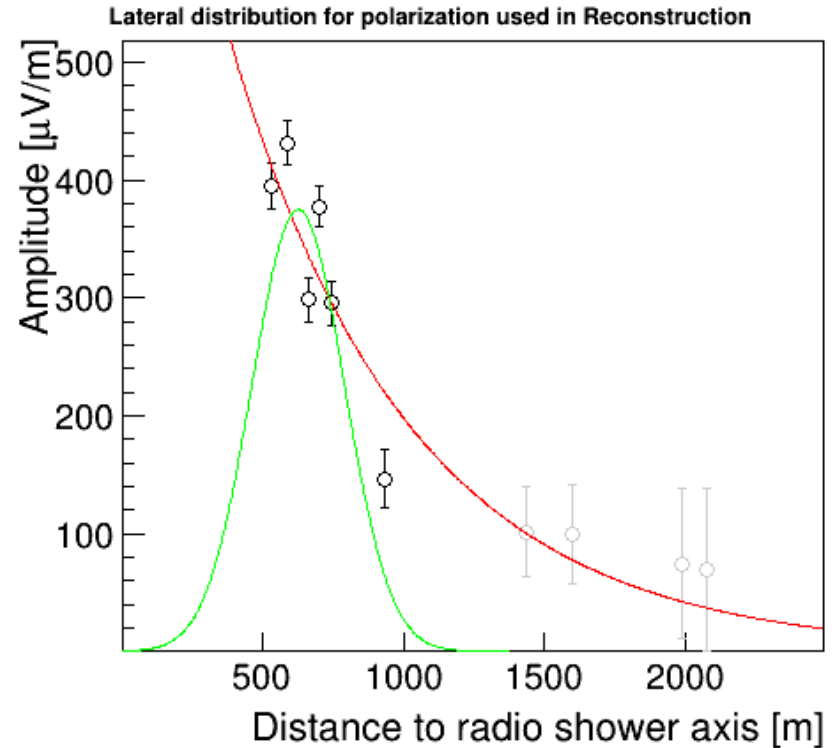
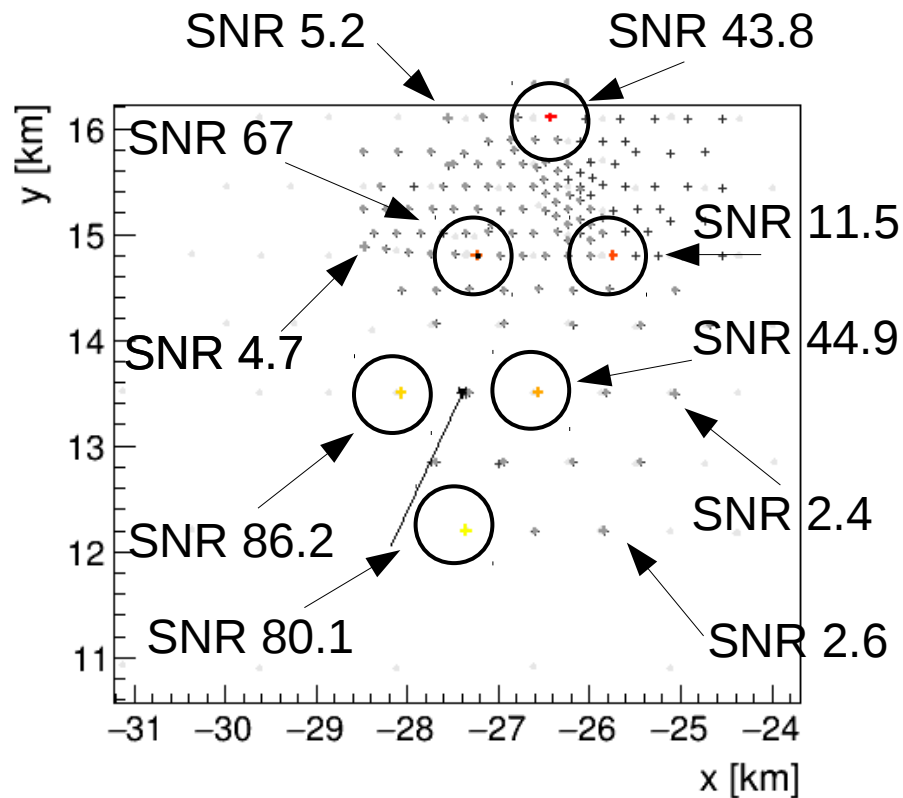
- $\Theta > 60^\circ$
- Up to 6 stations

SD energy: 1,9 EeV



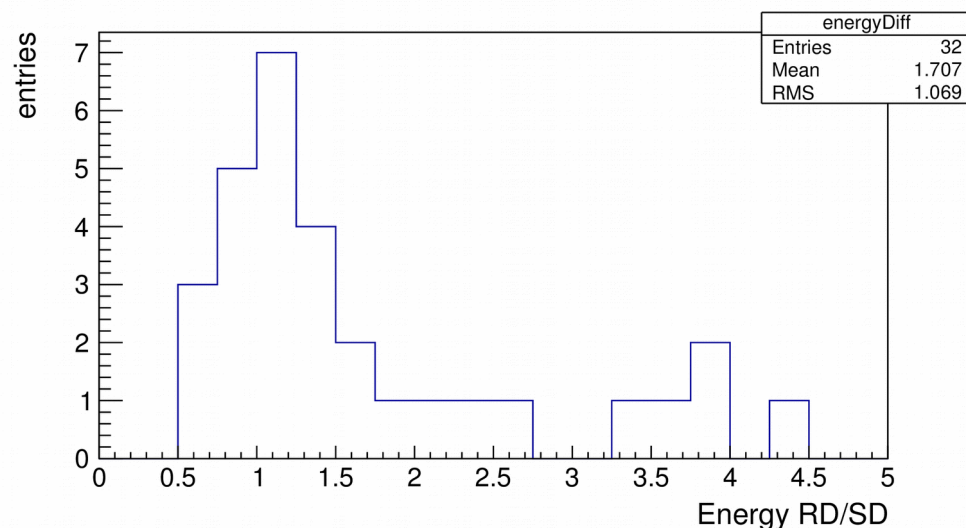
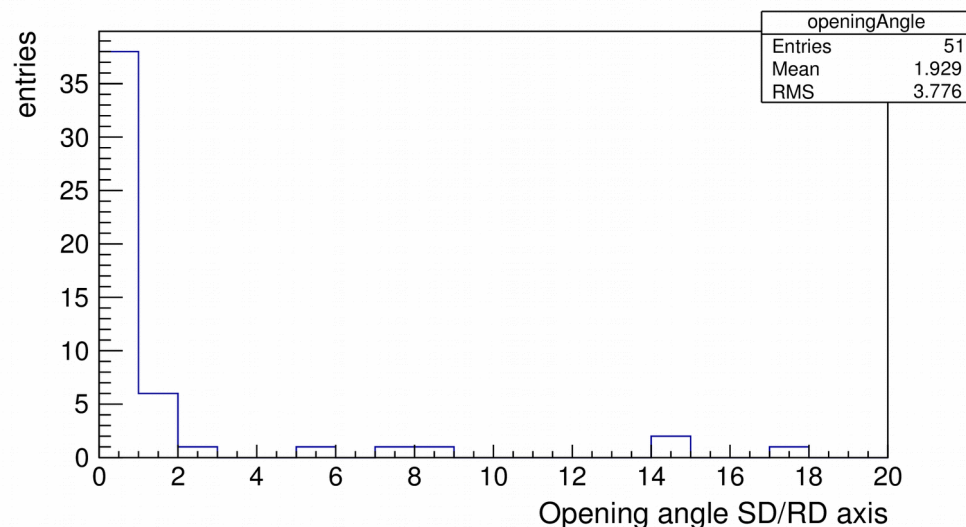
Quick look into the data...

- $\Theta > 60^\circ$
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Shower Reconstruction

- Accurate reconstruction of shower direction
- „problems“ with energy estimation
 - Reconstruction designed for vertical showers
→ optimize
- Fully efficient for $E > 10 \text{ EeV}$ and $\Theta > 65^\circ$



Summary

- HAS: large radio footprints on ground
→ grid spacing $\sim$ km sufficient
→ Sparse RD grid works for high energy and zenith angle
- Simulated amplitudes agree well with data

