Karlsruhe Institute of Technology

LOPES-3D – studies on the benefits of direct measurements with vertically aligned antennas

ARENA 2014

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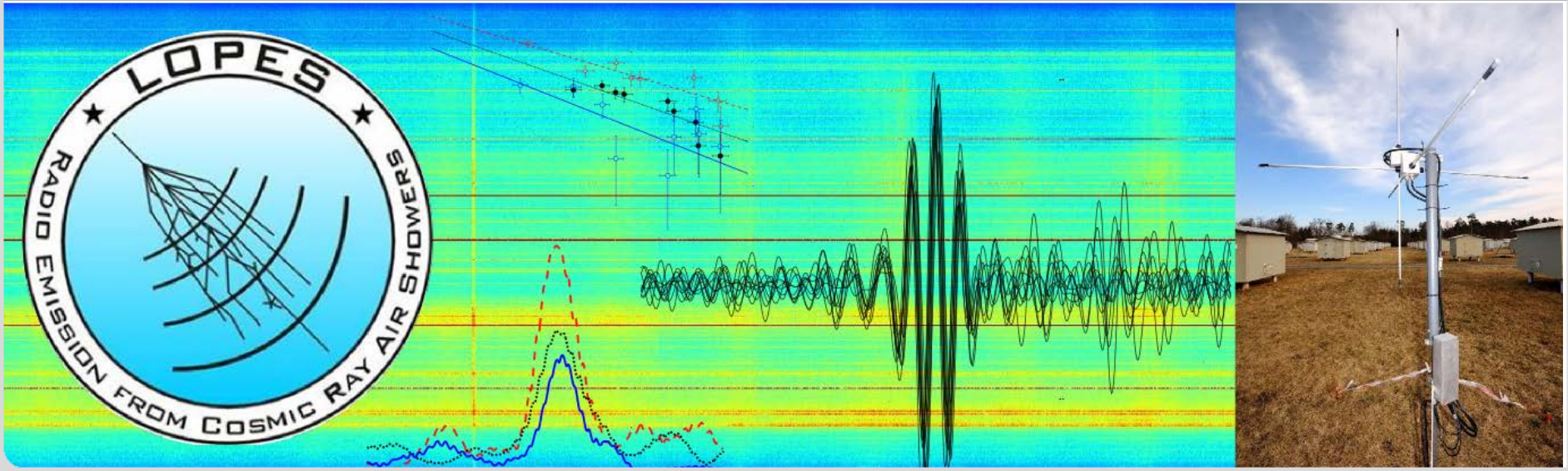
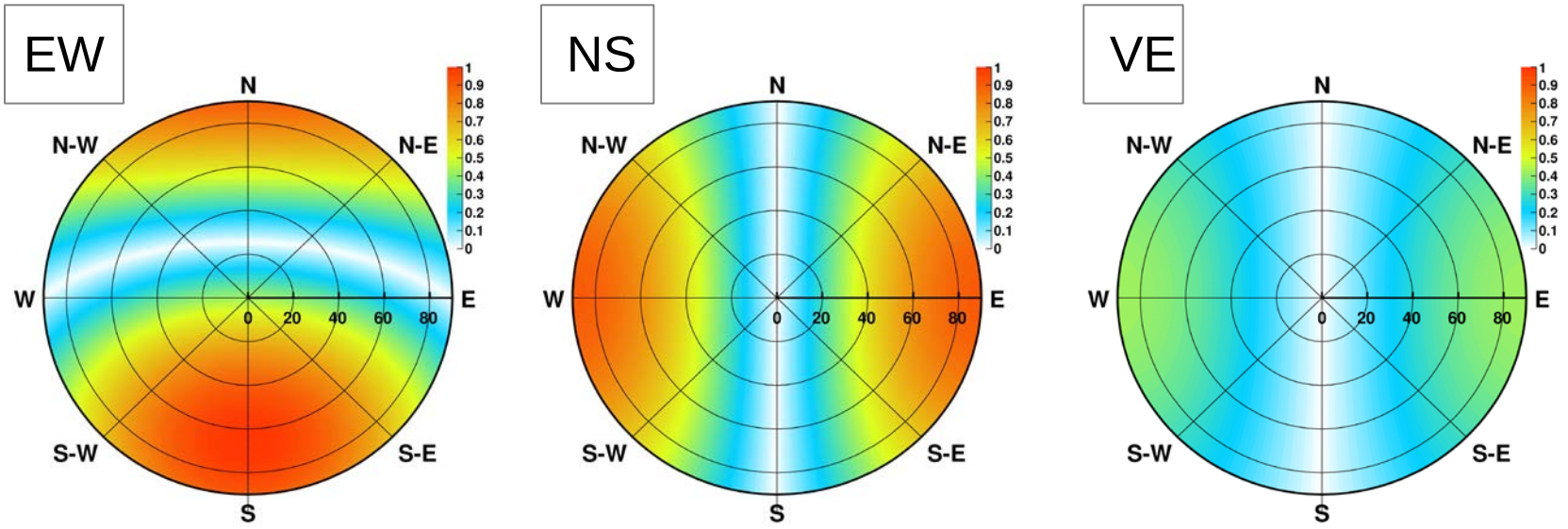


Motivation

- Testing the benefits of additional vertical measurements with focus on
  - Improvement of reconstruction
  - Detection efficiency

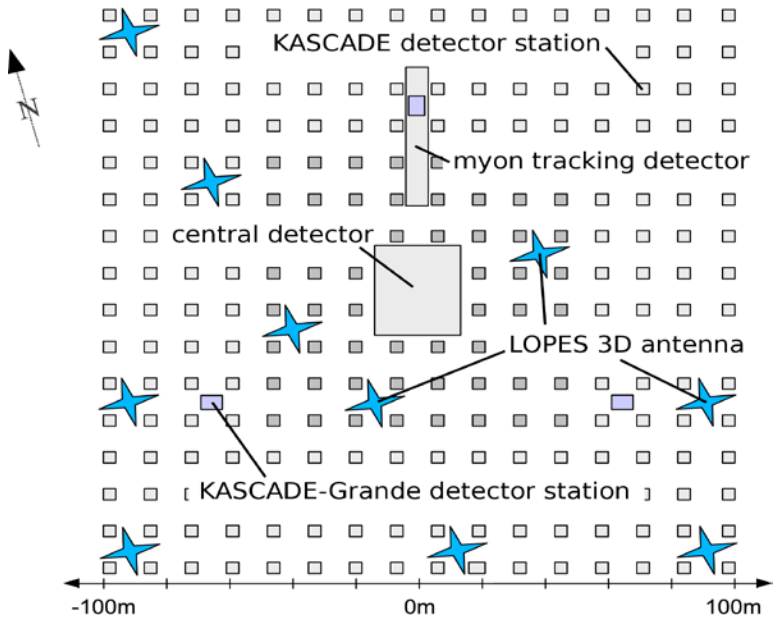


LOPES - the (former) LOFAR PrototypE Station

- Data taking finished beginning of 2013
- At KASCADE-Grande
- 10 - 30 antennas
- Dense spacing ~20 m
- Inverted v-shape + tripole antennas
- Bandwidth 40-80 MHz
- Trigger and air shower information from KASCADE-Grande
- Digital radio interferometer

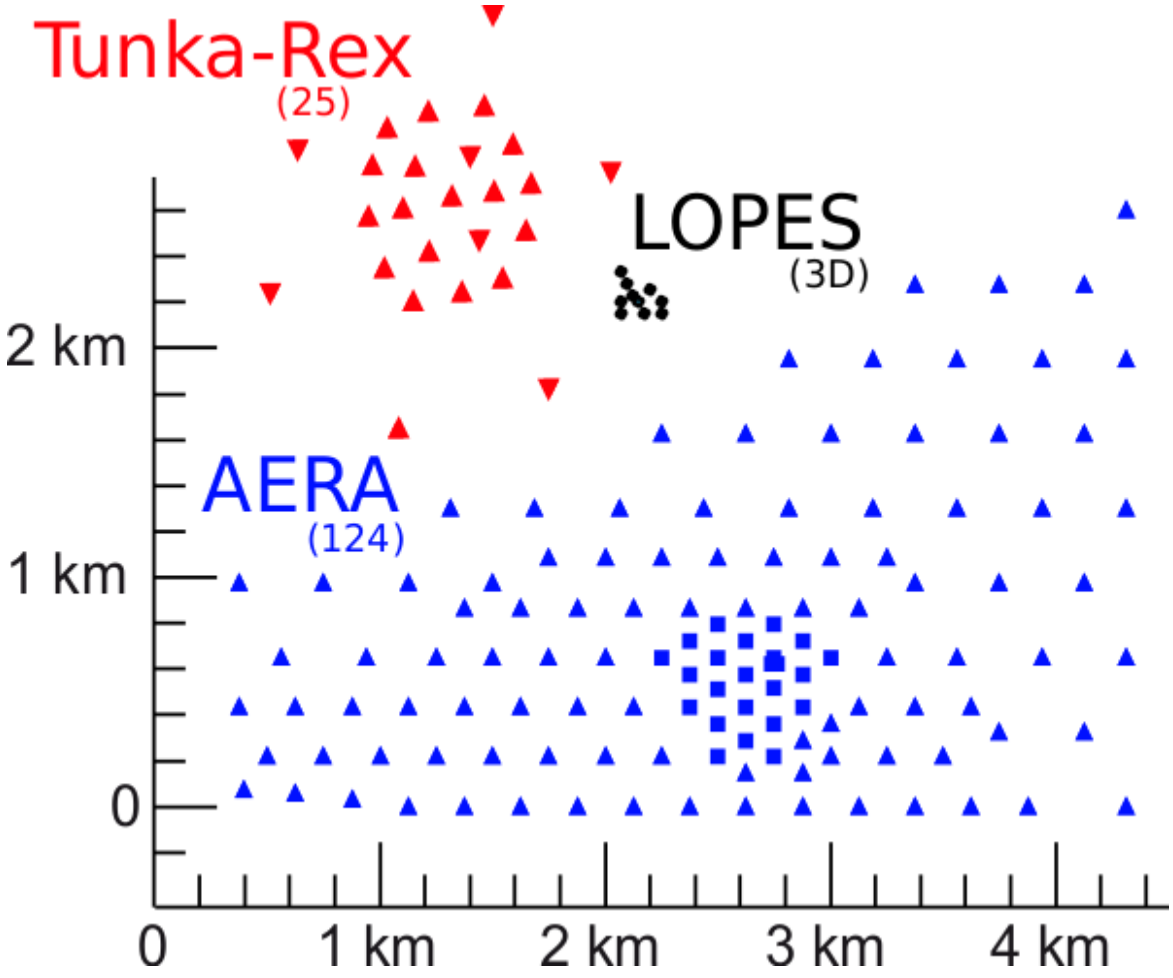
The tripole antenna

- 3 crossed dipoles
- First time cosmic ray measurements with vertical antennas

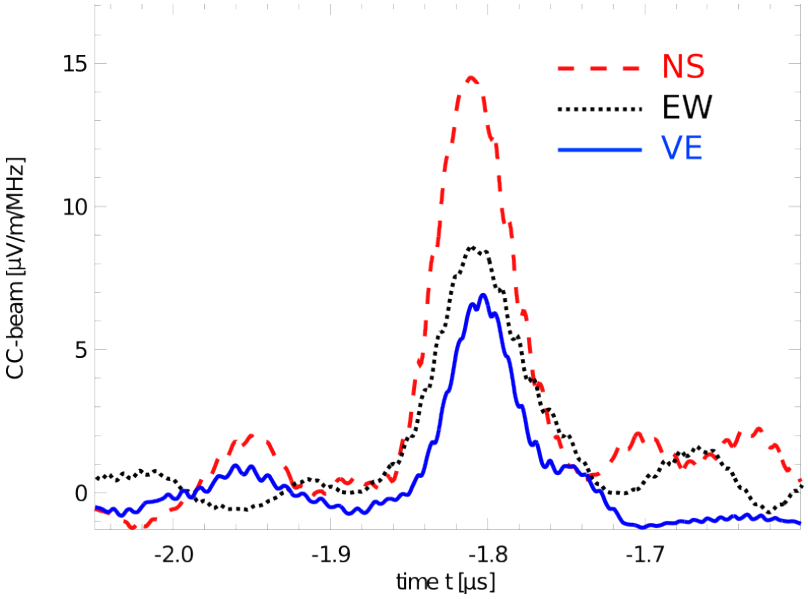


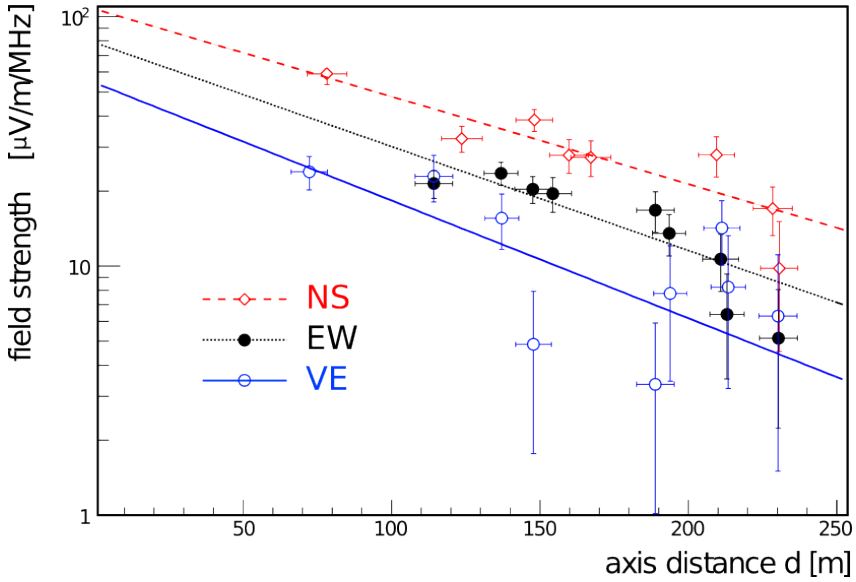
Comparing sizes

- LOPES is a precursor experiment and prototype station
- Development for large scale applications like AERA



Example event





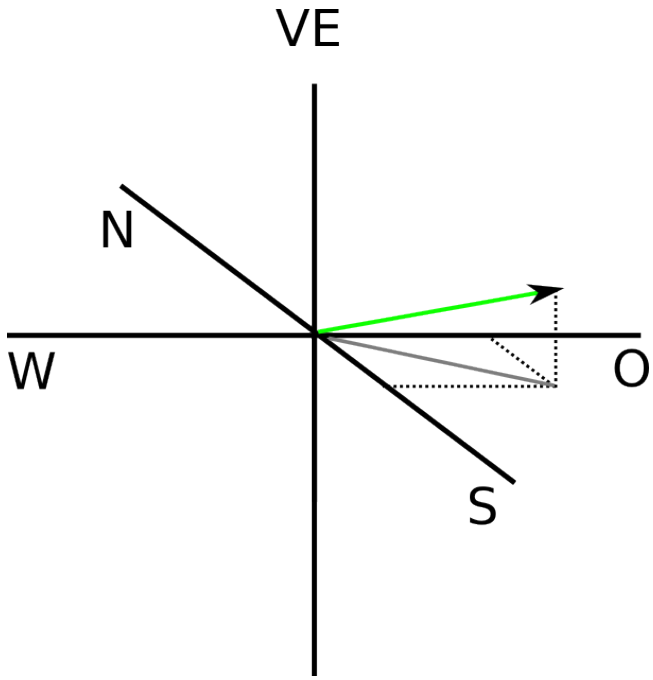
- Azimuth: 334°, zenith: 37°
- Air showers detectable in all components

Measurement and reconstruction of the e-field

- Measurement can be described by scalar product
- Tripole measurements lead to 3 equations
- Plane in which e-field vector is lying is known

→ 2 equations sufficient to determine full e-field vector

- Redundant measurement



$$\vec{E} \cdot \vec{G}_{\mathrm{NS}} = \mathrm{V}_{\mathrm{NS}}$$

$$\vec{E} \cdot \vec{G}_{\mathrm{EW}} = \mathrm{V}_{\mathrm{EW}}$$

$$\vec{E} \cdot \vec{G}_{\mathrm{VE}} = \mathrm{V}_{\mathrm{VE}}$$

How to deal with redundancy ?! Weighted average

- Weigthing schemes principles
  - Calculate e-field vector 3 times
  - Define quality factors for each measurement
  - Multiply the qualitiy factors of the two measurements used to calculate the e-field vector to get the according weighting (w)

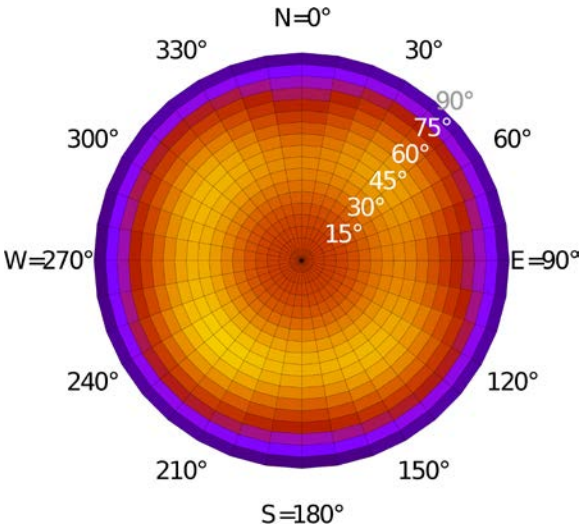
$$\vec{E} \cdot \vec{G}_{\mathrm{NS}} = \mathrm{V}_{\mathrm{NS}}$$
$$\vec{E} \cdot \vec{G}_{\mathrm{EW}} = \mathrm{V}_{\mathrm{EW}} \longrightarrow \vec{E}_{EW,NS},\ \vec{E}_{EW,VE},\ \vec{E}_{NS,VE} \longrightarrow \sum_{i=1}^{3} \frac{\vec{E}_i * w_i}{w_1 + w_2 + w_3}$$
$$\vec{E} \cdot \vec{G}_{\mathrm{VE}} = \mathrm{V}_{\mathrm{VE}}$$

The gain - method

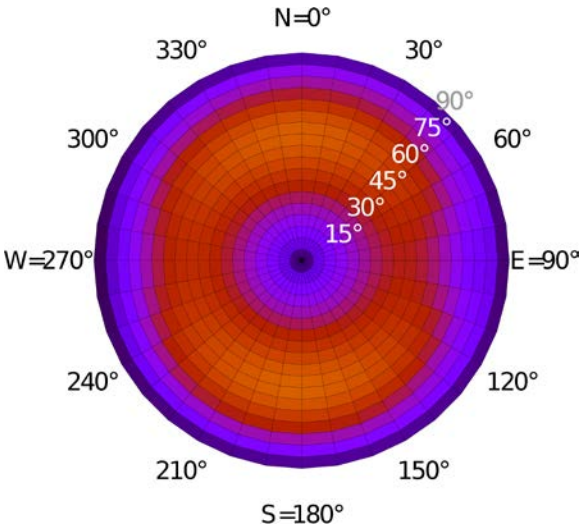
- Using simulated sensitivity of antenna to define qualtity of measurement

→ only looking at detector properties

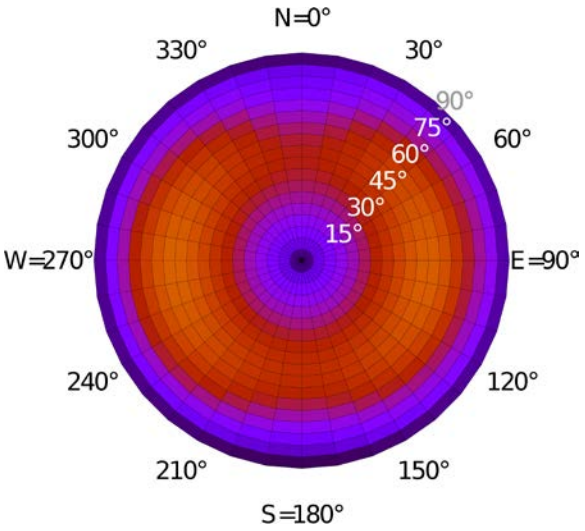
EW-NS



EW-VE



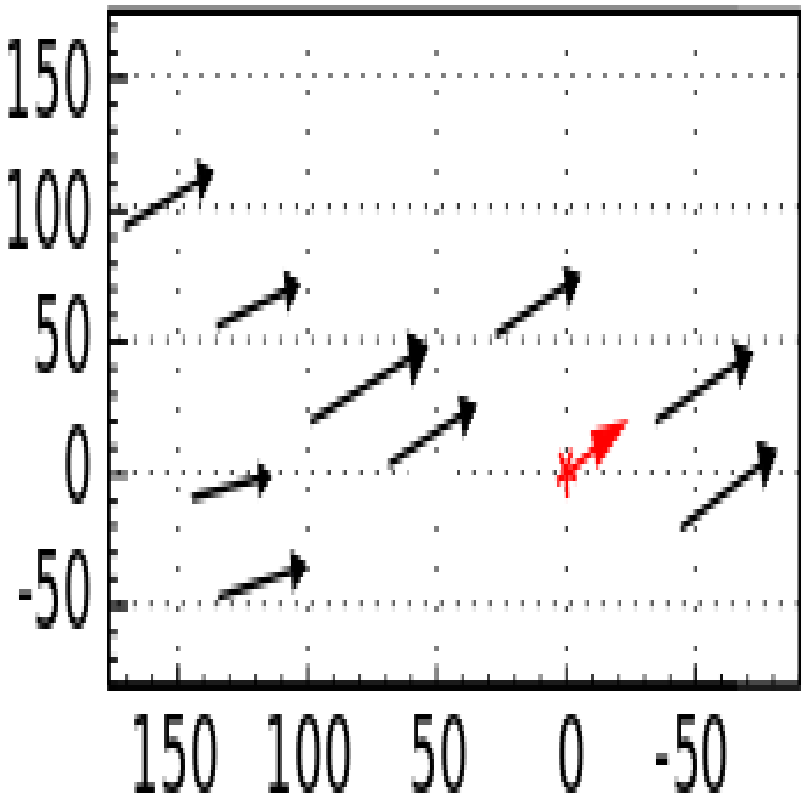
NS-VE



Improvement of reconstruction

- Advanced gain treatment (vectorial effective antenna height)
- Now polarization analyses possible with LOPES

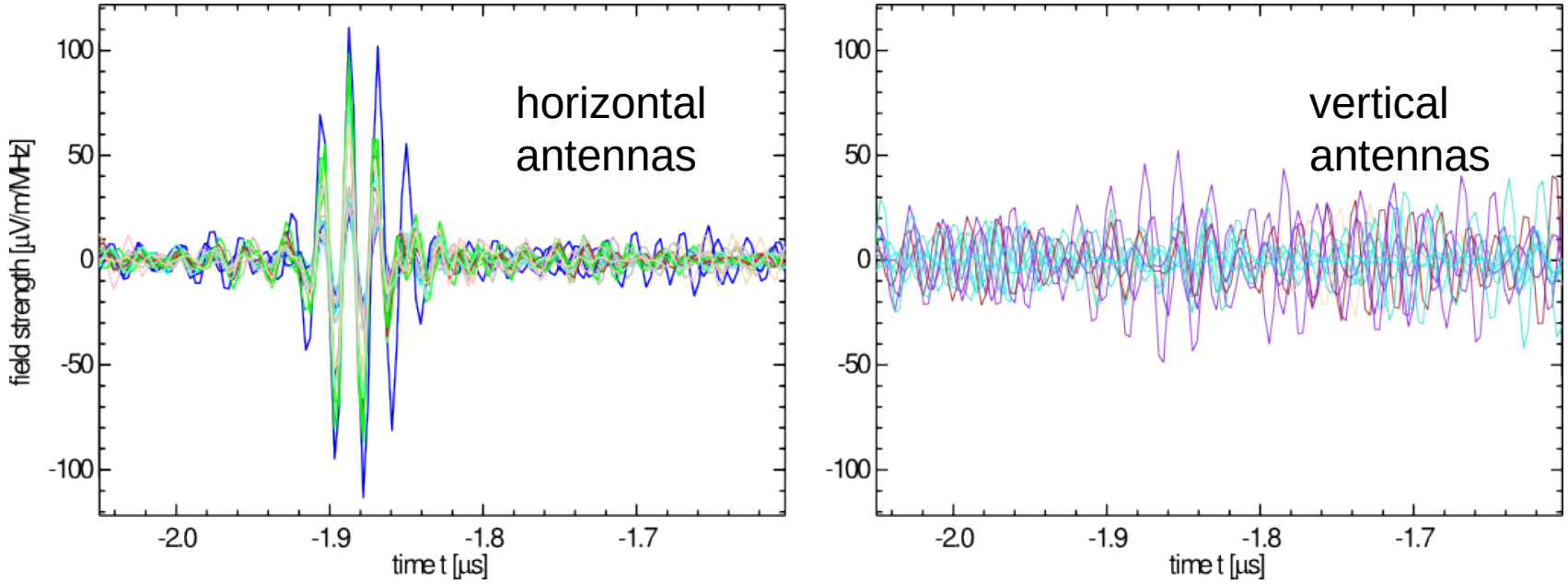
  → 2D lateral distribution function



Measured E-field vectors

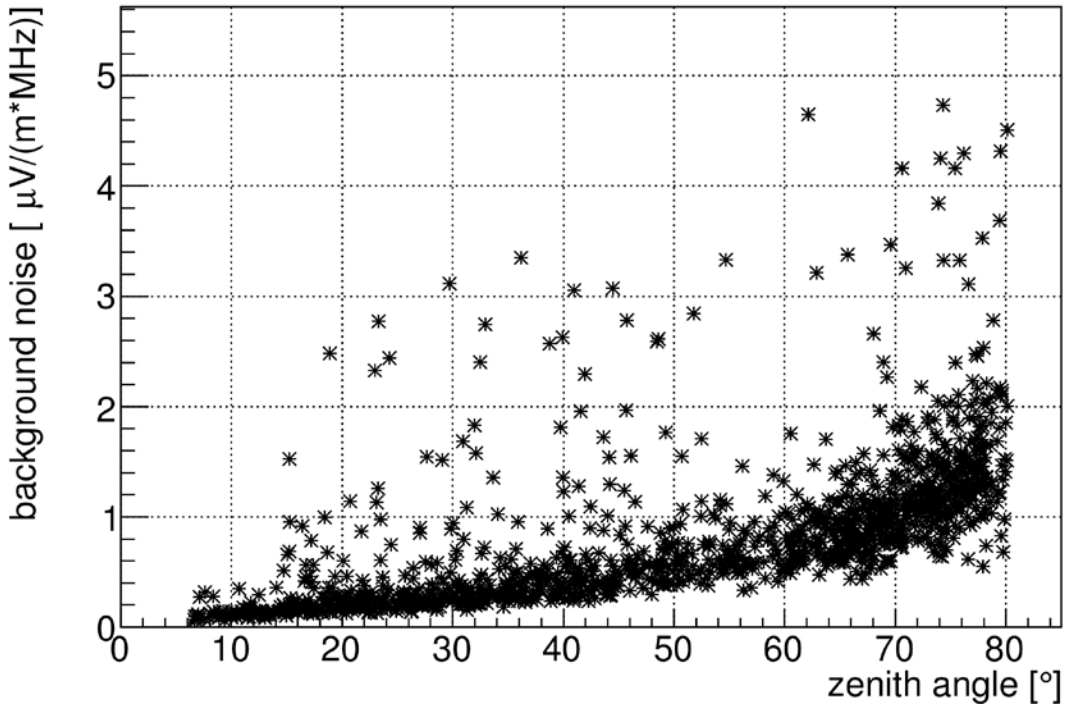
Polarization from v x B model

Measuring with vertically aligned antennas



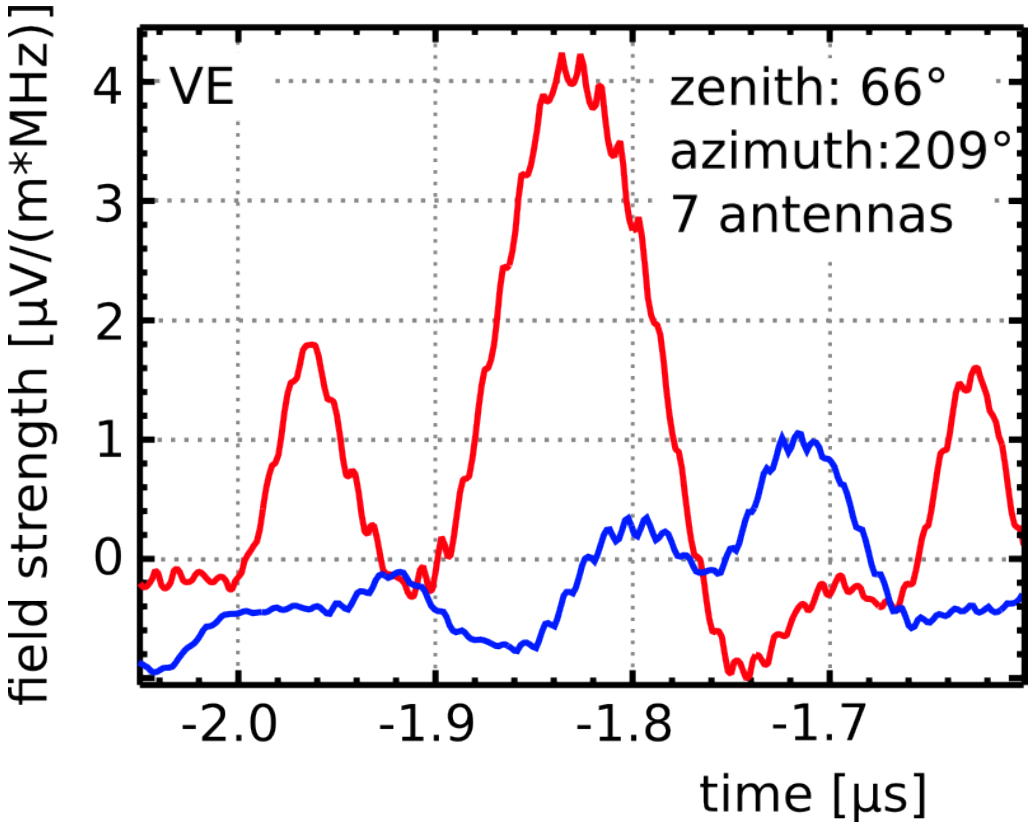
- Same event !!!
- Higher noise present in vertical component

Zenith angle dependence of noise



- Unfortunately increasing noise towards horizon found in the vertical component

Example event (inclined)



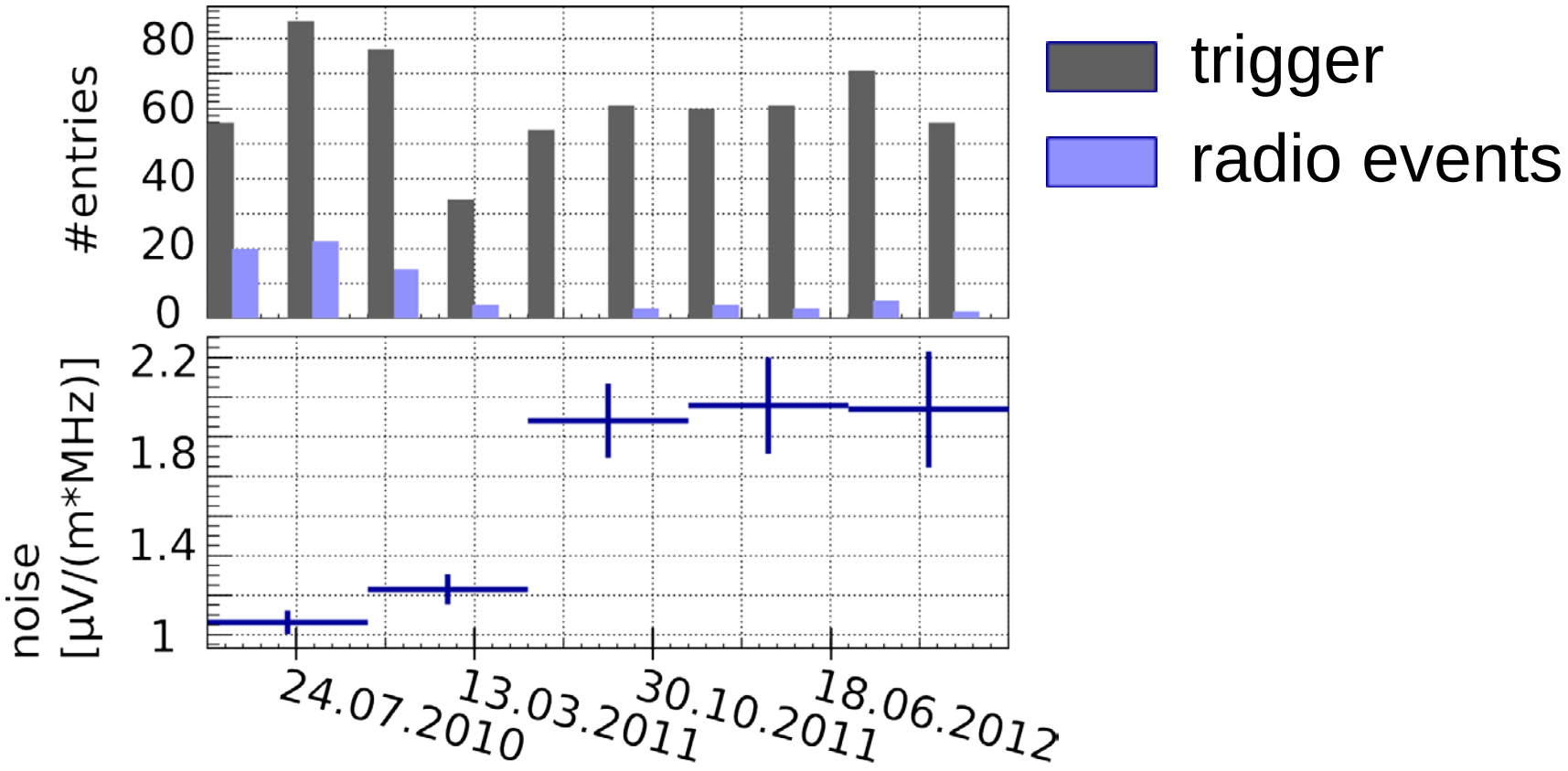
Only horizontal antennas

With vertical antennas

- Only detectable when including VE antennas

Statistics

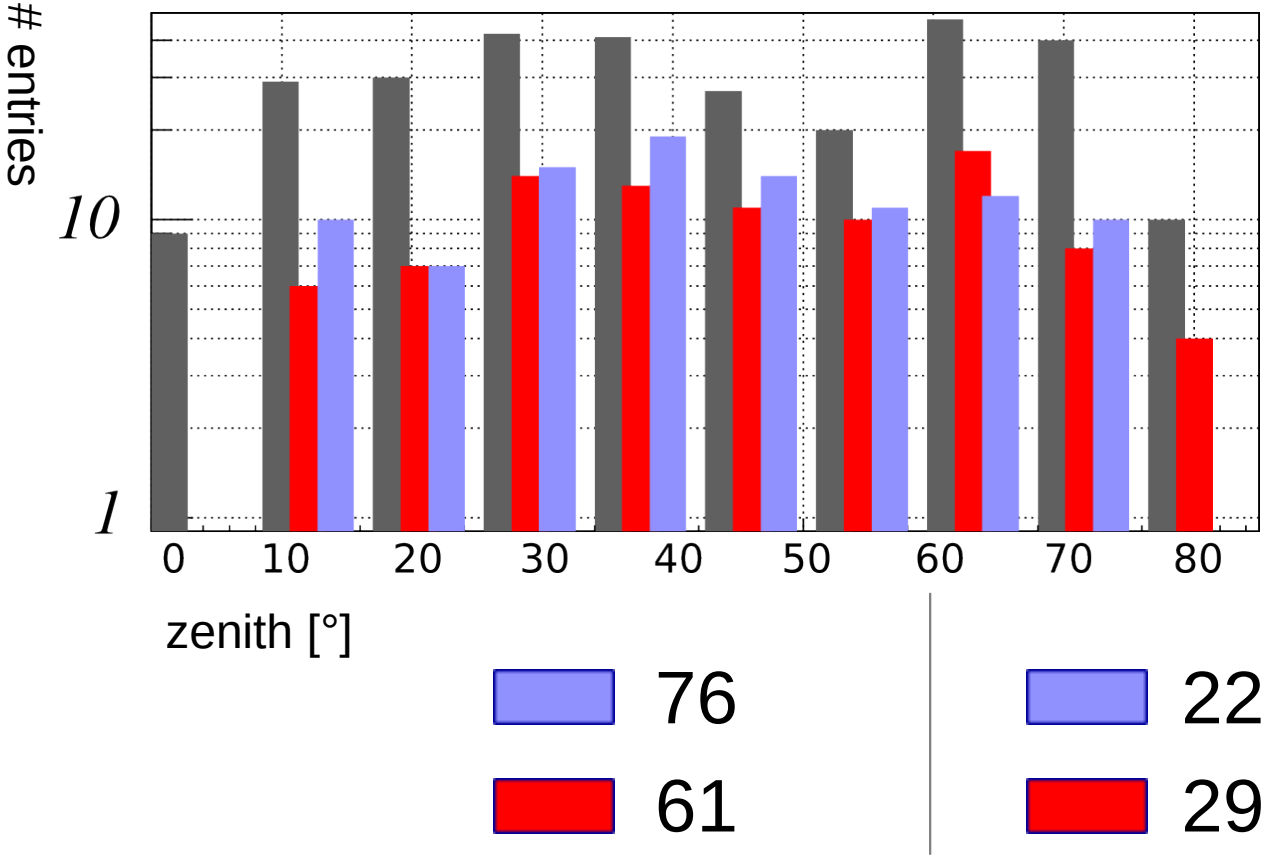
- Decrease in rate caused by increase in background

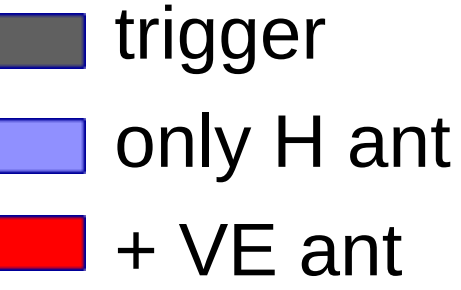


Statistics - the reason ?

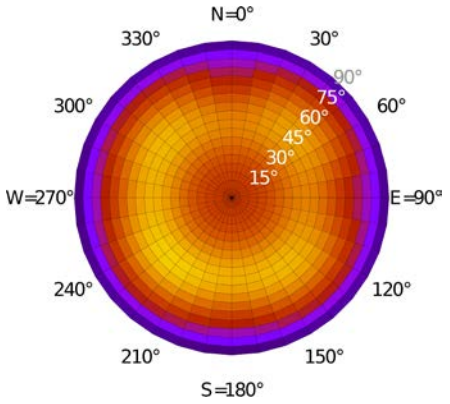
- Large facility built next to the array
- A lot of:
  - Metal
  - Pumps
  - Electronics
  - ...

Reconstructable events





Sensitivity for H ants



Conclusion

- Horizontal antennas sufficient for zenith < 60°
- VE antennas did not improve accuracy of reconstruction (due to background noise)
- VE antennas play role for inclined shower detection
  - Better with less background noise in VE
  - Magnetic field better for VE in Argentina
- Analysis based on e-field vector possible (LOPES)
- Radio (LOPES) sensitive up to 80° zenith
- Universal methods for vertical antennas developed