Overview of radio-detection of cosmic ray air showers and prospects for a larger scale experiment

ECRS 2010, Turku

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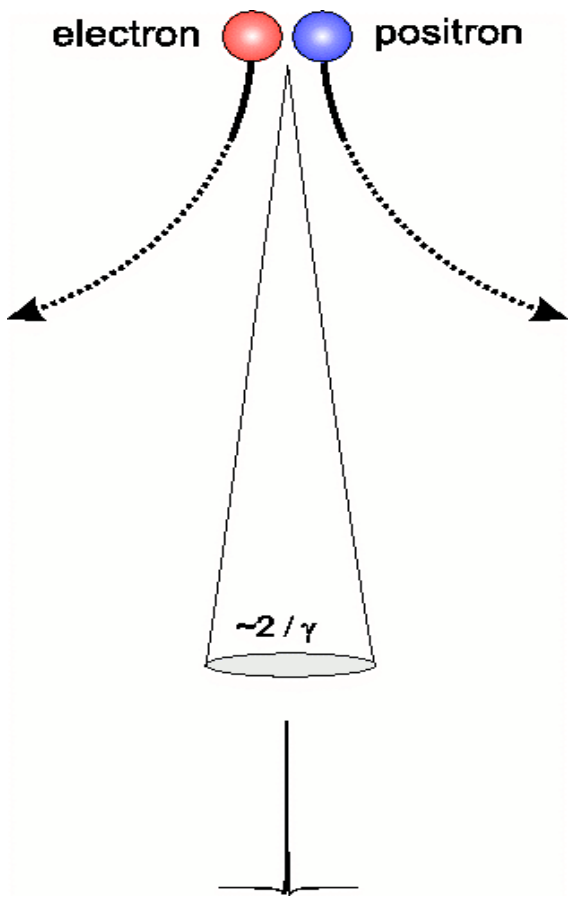
KIT – University of the State of Baden-Wuerttemberg and
National Research Center of the Helmholtz Association

Emission principle

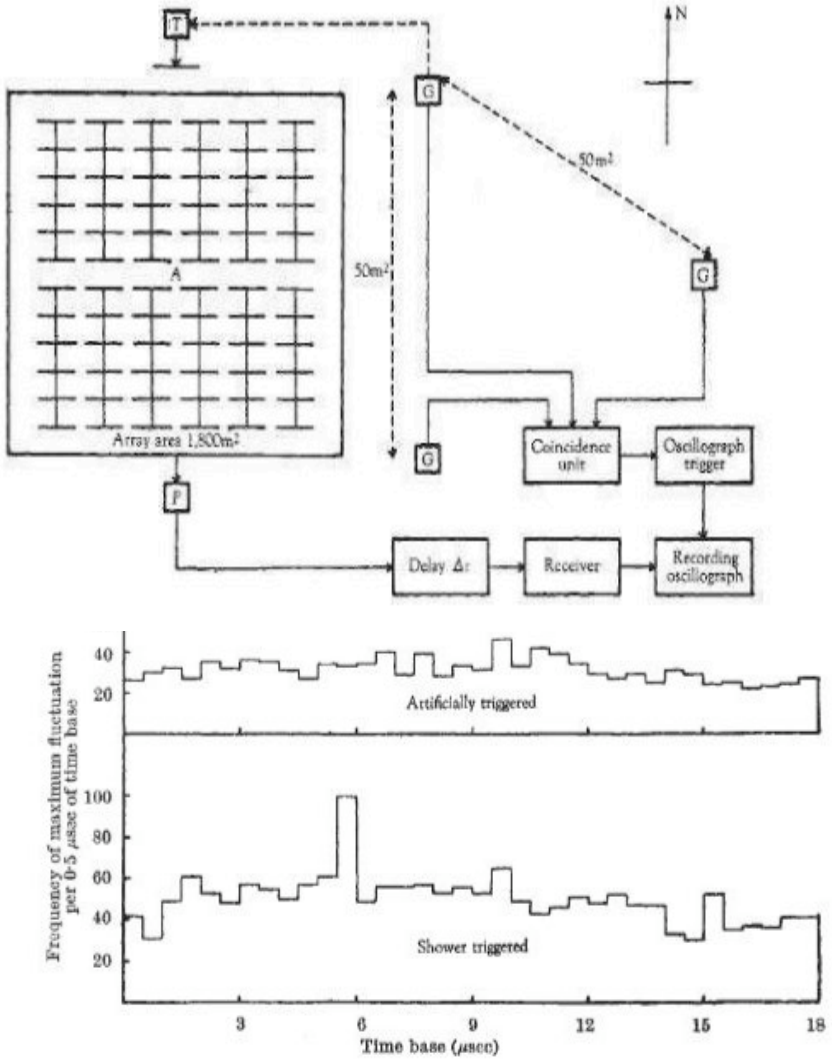


Geo-magnetic emission mechanism :

- e^- and e^+ generated in Cosmic Ray Extensive Air Showers are accelerated in the presence of the earth magnetic field (B) and subsequently emit short radio pulse.
- Radio signal keeps information about the full shower history
- Signal is coherent below 100 MHz
- Simulation codes (REAS, MGMR) can predict pulses compatible with measured one
- Contribution from charge Excess is expected (different behavior than geomagnetic)
- Influence of Cherenkov in air shower is neglected

Radio detection history

- First tries in the 60 with fully analogue processing chain
- Analogue chain worked, but hard analysis
- From this time we have clues on :
  - Influence of the geomagnetic field
  - Amplitude ~ E
  - Amplitude drops exponentially with core distance



Jelley, J.V. & al. . Nature, 1965.

Small size experiment

LOPES:

At KASCADE site good measurement of cosmic ray air showers
Noisy environment (research center)
Antenna taken from LOFAR
Λ-dipole

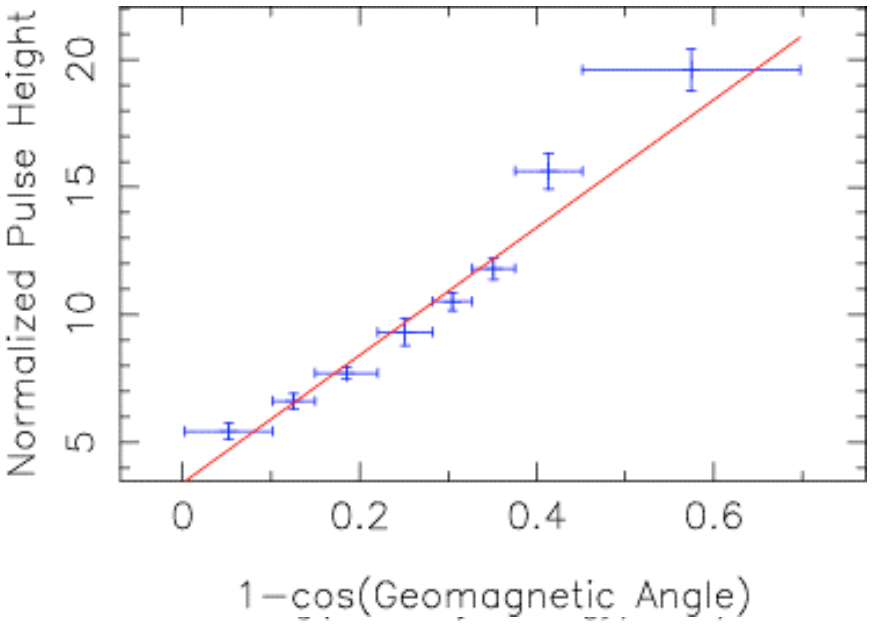
CODALEMA:

At Nancay radio-observatory
Radio quiet
Not a cosmic ray observatory
Active dipole Antenna

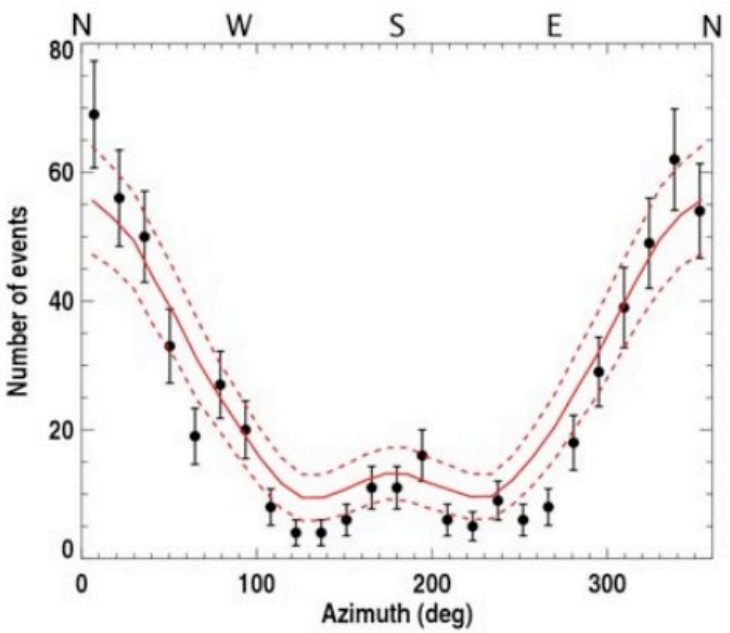
Poster by F.Schroeder on LOPES

Results from small size experiments

LOPES results



CODALEMA results

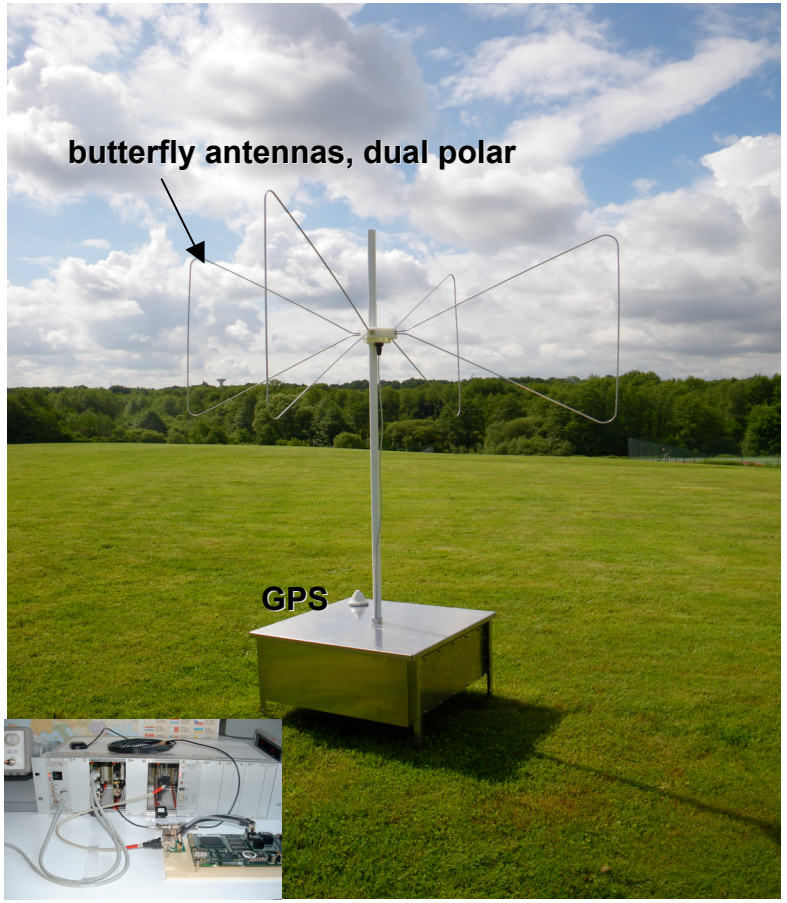


- From LOPES and CODALEMA we know :
  - Radio amplitude drops exponentially with lateral distance.
  - Radio amplitude scales linearly with particle energy.
  - Radio amplitude is strongly correlated with “geomagnetic angle”.
- Problem : LOPES and CODALEMA are small experiments, run out of statistics at ~ 10^{18} eV

LOPES & CODALEMA ARENA 2008

small size experiments : new antennas

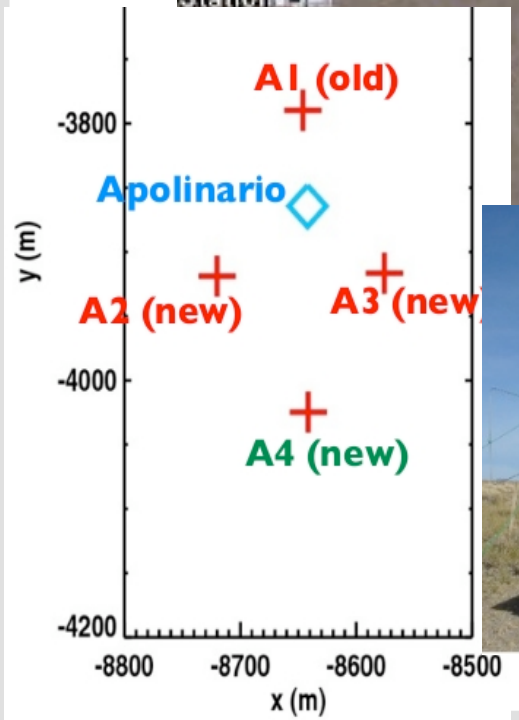
LOPES 3D
3D measurement of electric field vector



CODALEMA Autonomous station
New Antenna, dual polarization test bench for self triggering

LOPES & CODALEMA ARENA 2010

Test setups @ AUGER



Auger is the largest cosmic rays detector
In the Pampa, few human activities= less noise.

Near **B**alloon **L**aunch **S**tation :

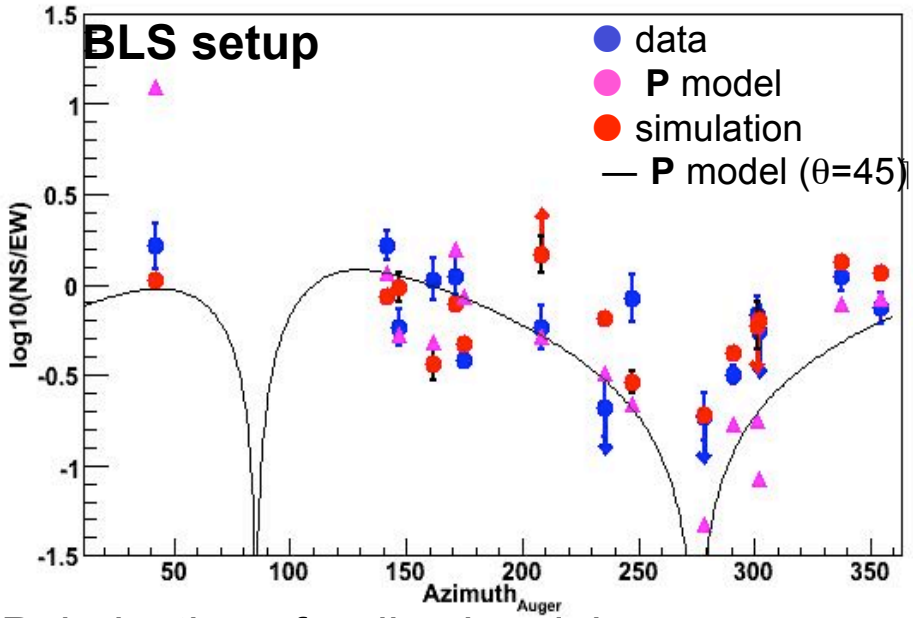
- 4 Wired Antennas
- 7 Autonomous stations
- External trigger
- Noise due to power line

Near **C**entral **L**ASER **F**acility :

- 4 Autonomous stations
- Pure self trigger

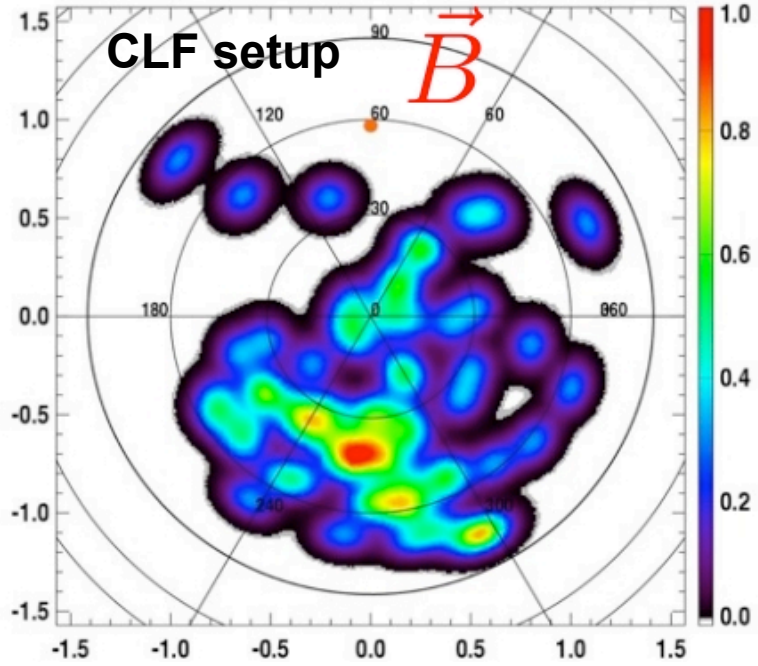
R. Caruso's talk to know more about AUGER

Results from test setup (1)



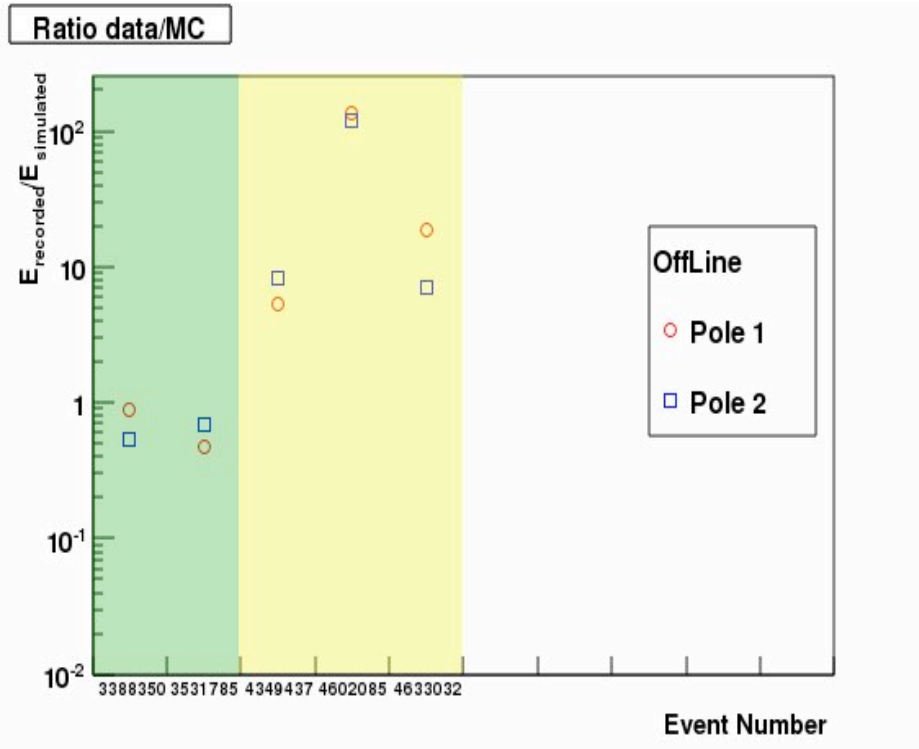
Polarization of radio signal, is consistent with simple geomagnetic model : $\vec{P}_i = \vec{v}_i \wedge \vec{B}$

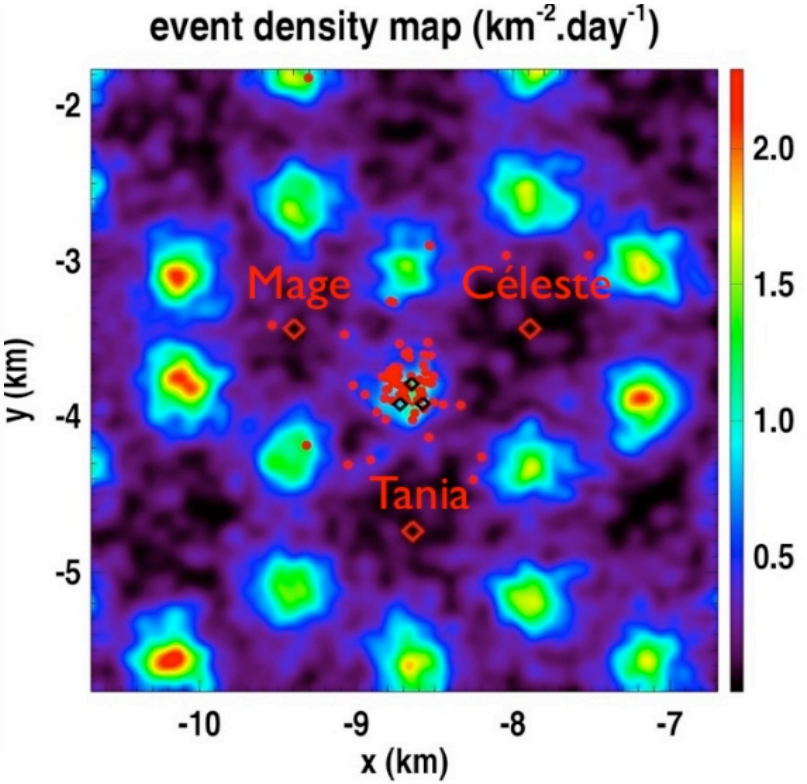
In agreement with geomagnetic emission mechanism.



Events come from south.
Agreement with a geomagnetic mechanism.

Results from test setup (2)



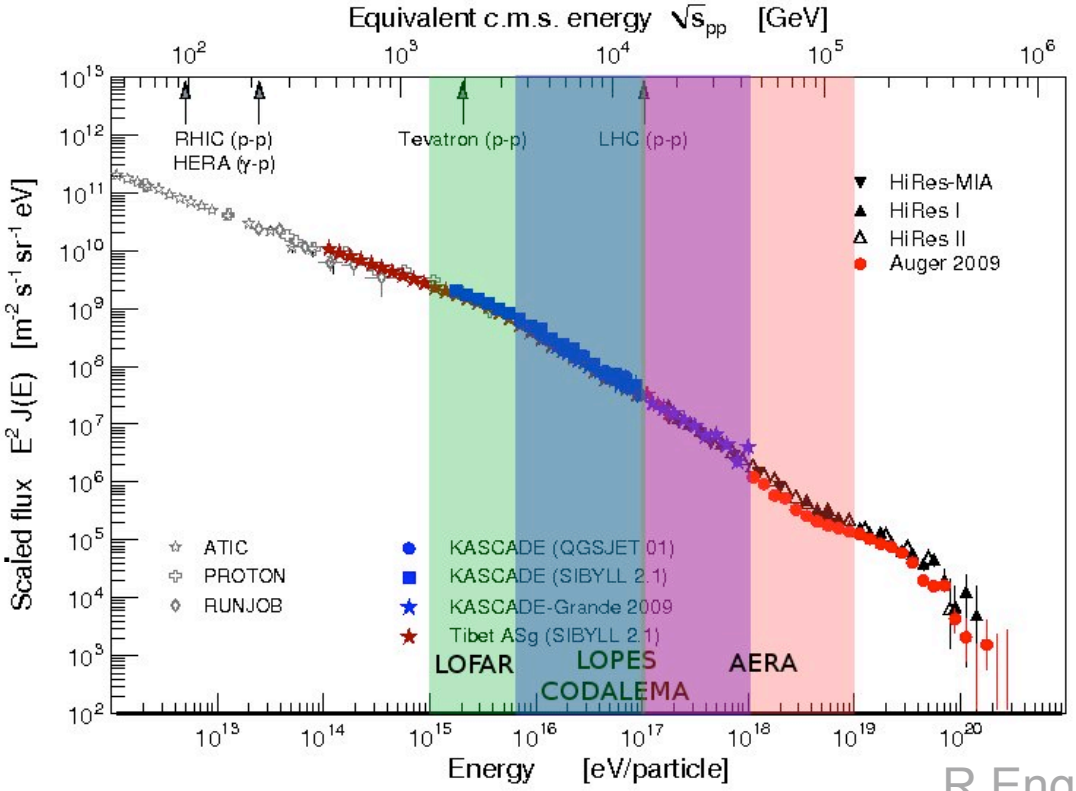


During thunderstorm, high amplitude events, strongly diverging from theoretical prediction

65 self triggered events associated with cosmic rays events close to the CLF

Physics goal of a large scale array

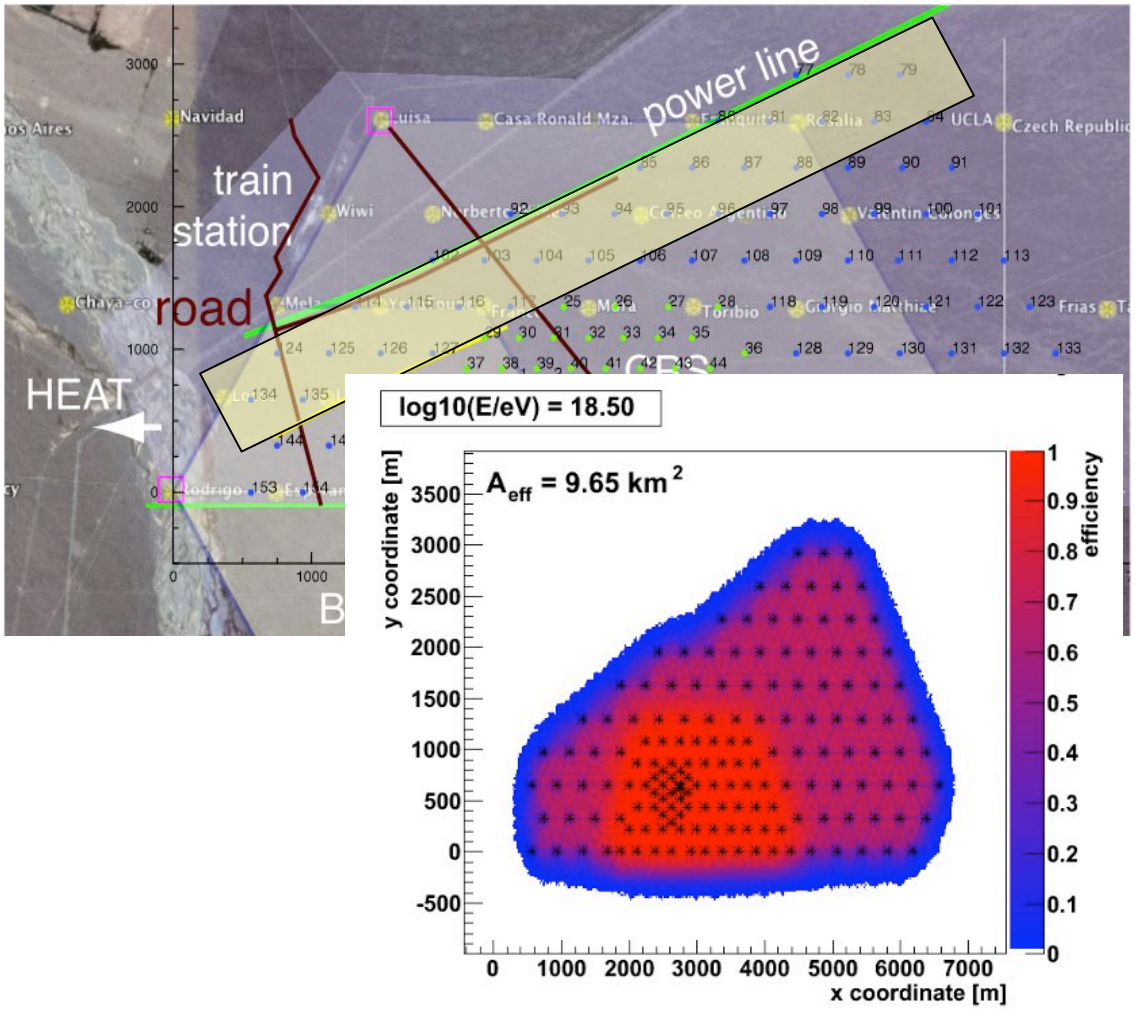
- **Physics goal :**
  - Calibration of the radio emission in air-showers E > 10^{18}.
  - Capability of the radio detection method.
  - Cosmic ray physics in the transition region.
- **Open questions**
  - Radio-emission mechanism?
  - Influence of the primary particle?
- **Challenges**
  - Self triggering.
  - Noise/CR discrimination.
  - Communication



R.Engel

Auger Engineering Radio Array

- In the AUGER infill array
  - AUGER maximum efficiency E>$10^{17.6}$ eV
  - Want to explore up to 10^{19} eV
  - 161 antennas over 20 km²
  - 3 Different grid size 150m, 250m,375m
- Spaces constraint
  - Noise from power line
  - Land's owner
- AERA stage 1 in deployment
  - 20 antennas
  - Wired communication



AERA status

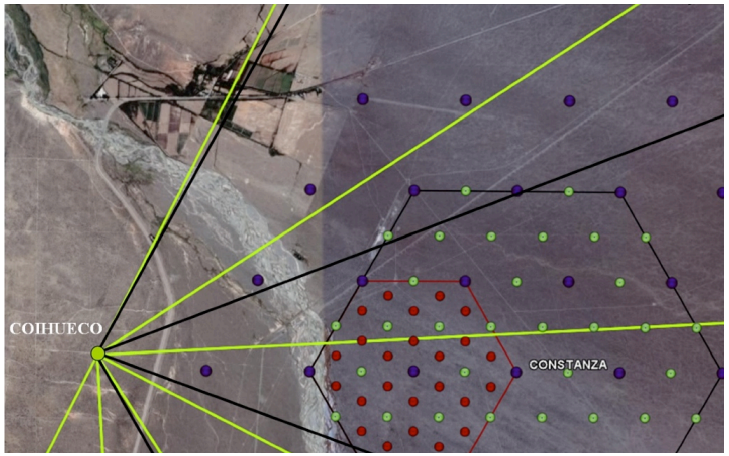
- First Antennas and central station deployed.
- Electronic and data acquisition chain not mounted yet.
- Next on-site operation after the (austral) winter.

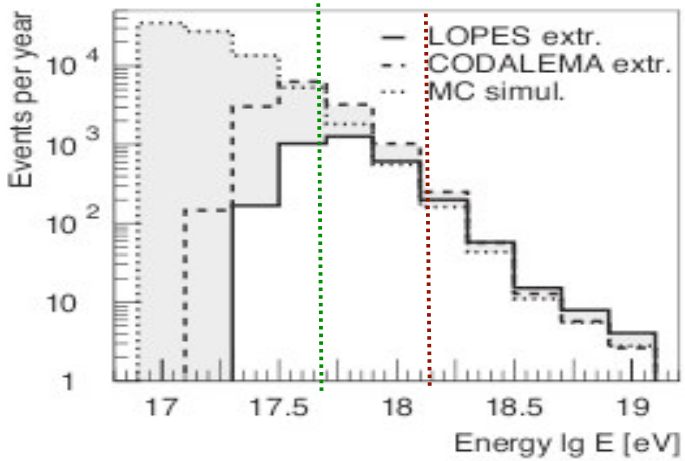
Antennas on the field. →

← Central Radio Station.

Toward a super hybrid detector @ AUGER

- AERA is in the infill array, good sensitivity lg(E)> 17.6
- AERA is located near Fluorescence detector at Cohueco. Possibility to see super hybrid events (surface detector + radio + fluorescence)
- >2000 events per year over $10^{17.5}$ eV, also detected by AUGER infill array





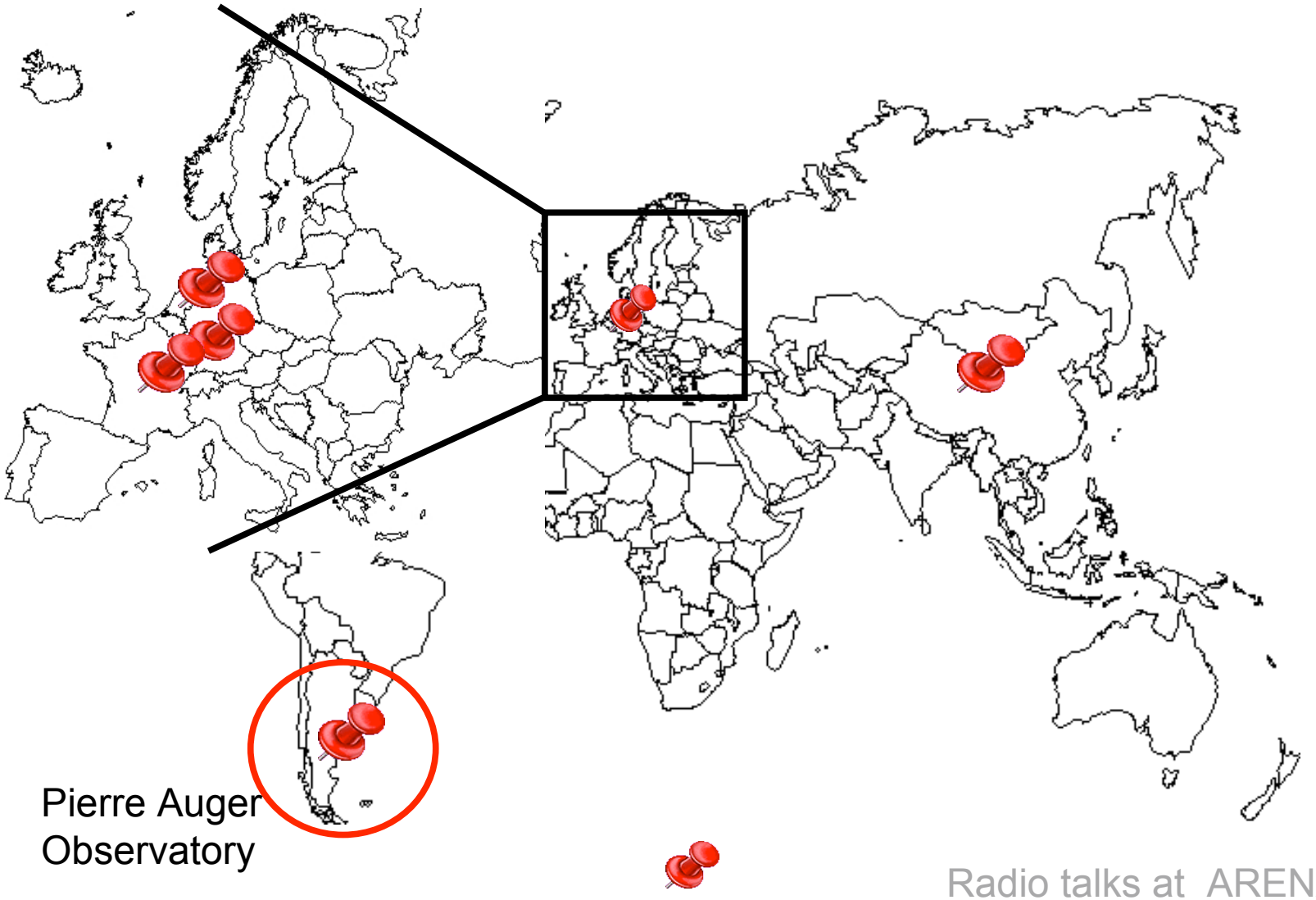
Infill Maximum efficiency

Auger Maximum efficiency

Conclusion and outlook

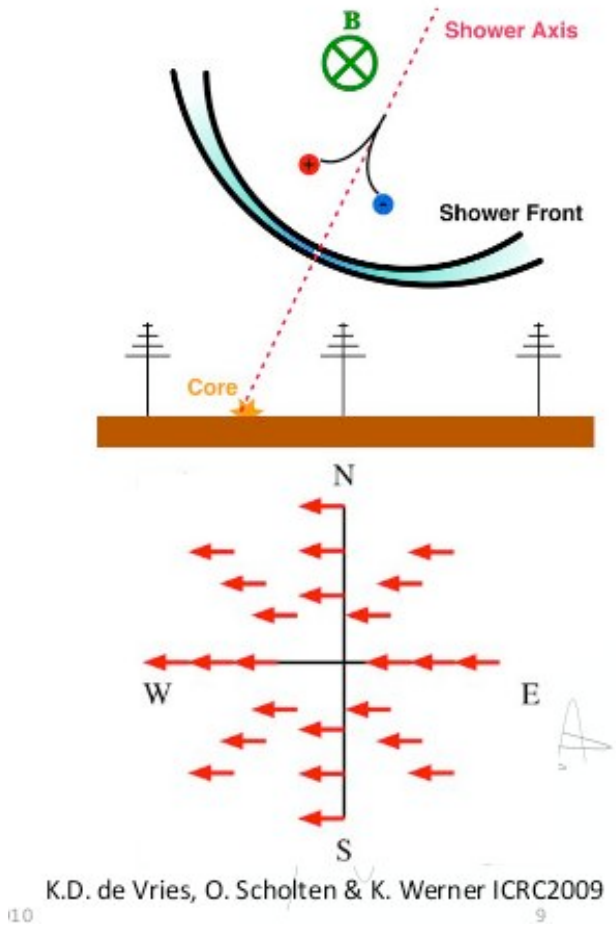
- Small size experiment show the feasibility of the radio technique.
- Main emission mechanism is geomagnetic.
- AERA @ Pierre Auger will provide a 20 km² array with good. measurement of air shower's parameters.
- AERA construction started, first data before the (austral) summer.
- Radio is a growing field. A lot of new projects
- In transition between R&D and physics.

Radio detection of EAS world-wide

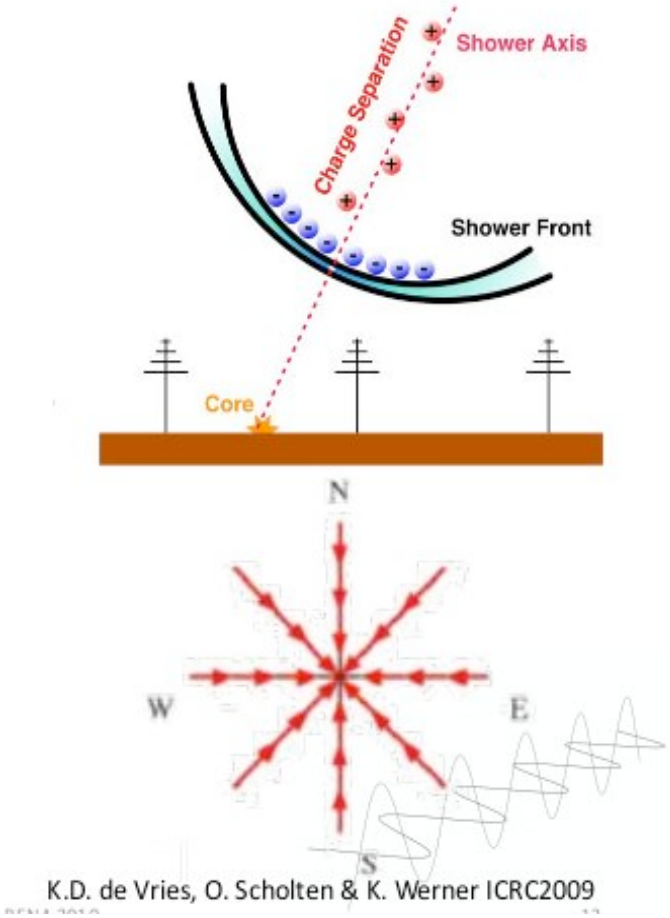


Radio talks at ARENA 10

Can we see contribution from other mechanism ?



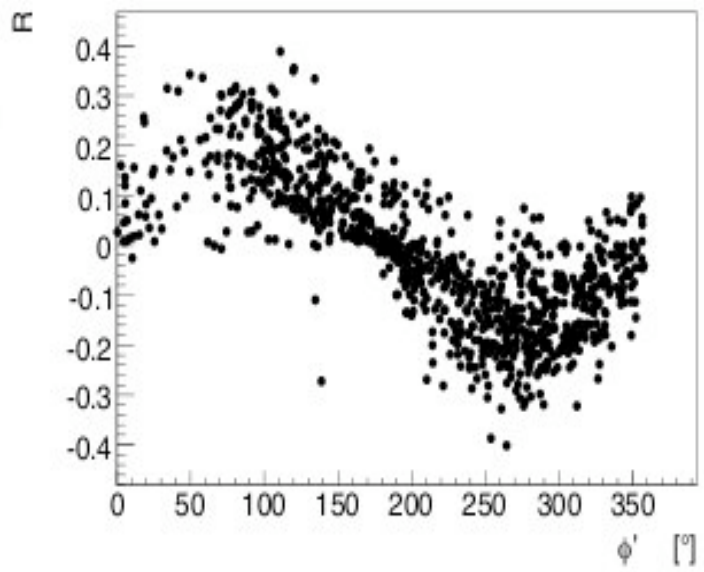
geomagnetic

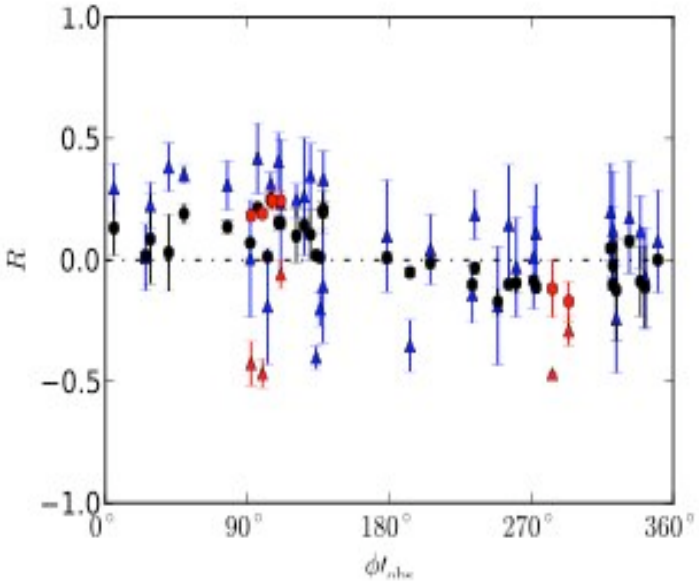


Charge excess

Can we see contribution from other mechanism (2) ?

Polarization after a coordinate changes to suppress the geomagnetic effect





Simulation
Data
bad period

H. Schoorlemmer for AUGER, ARENA 2010

Pulse amplitude parametrization

LOPES Parameterization

$$\varepsilon_{est\text{-}EW} = A \bullet (1 + B \cdot \cos\alpha) \bullet \cos\theta \bullet \exp(-R/R_0) \bullet (E/10^{17}\,eV)^{\gamma}$$

$$[\,\mu V / m\ MHz\,]$$

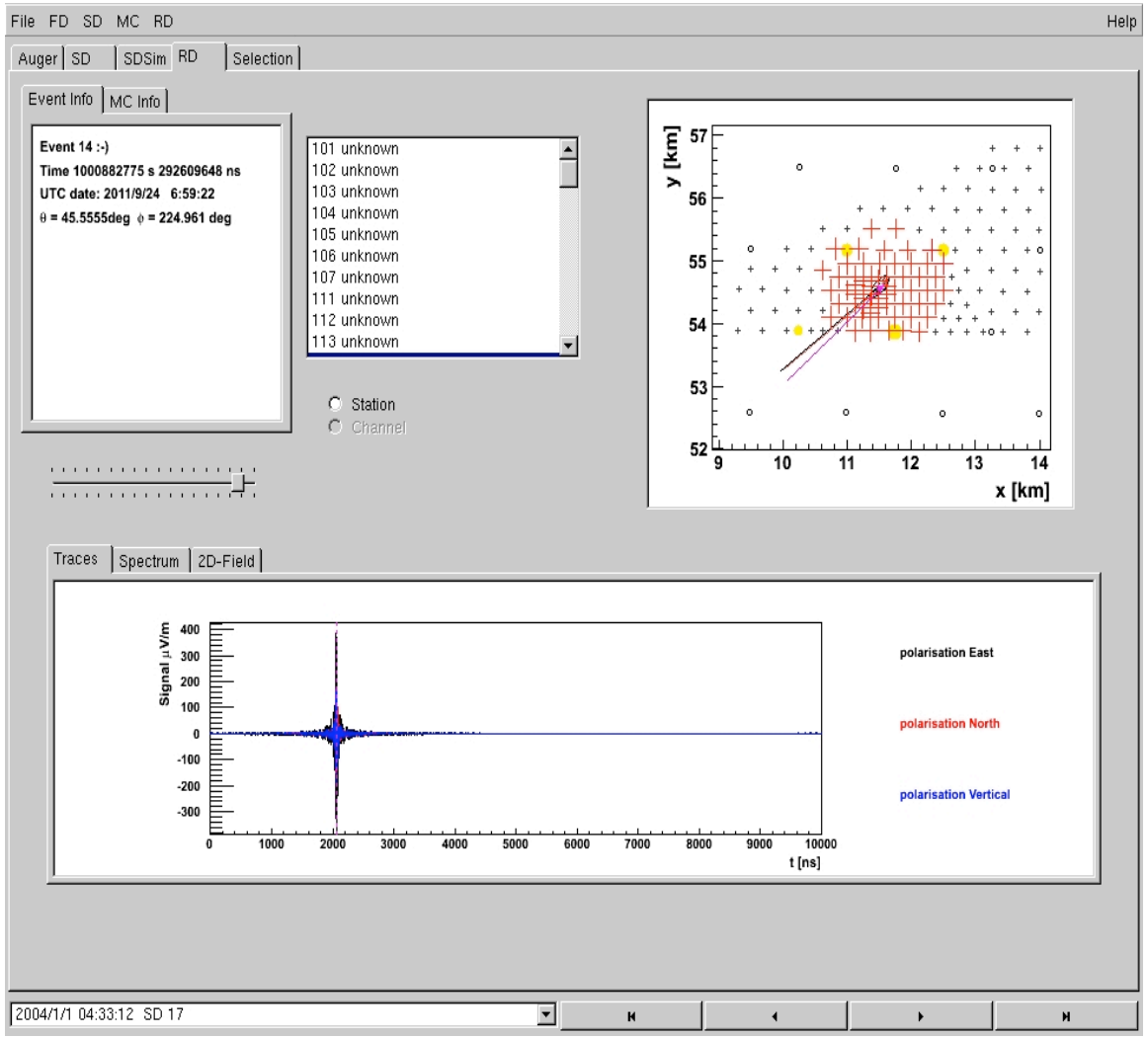
$A = 10.9 \pm 1.1$
$B = 1.16 \pm 0.02$
$R_o = 202 \pm 64$ m
$\gamma = 0.94 \pm 0.03$

CODALEMA Parameterization

$$E_0 = \frac{v}{B} 10^{b} E^{a} \exp\left(d/d_0\right)$$

a=1.05
b=-15.93

Toward a super hybrid detector @ AUGER



- Simulated radio event with Surface detector reconstruction.
- AERA is on the same energy range as the infill array.