Radio Emission in Atmospheric Air Showers Measured by LOPES in Coincidence with KASCADE-Grande Observations

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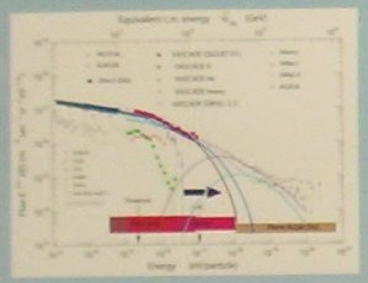
KASCADE-Grande

Das Energiespektrum der Primärteilchen



Motivation:

Gibt es ein Eisen-Knie?
Übergang von galaktischen zu extragalaktischen Teilchen?

Hauptziele:

Energiespektrum 10-1000 PeV
Elementzusammensetzung
Hadronische Wechselwirkungen

Realisation:

Erweiterung von KASCADE mit zusätzlichen Detektorstationen:
==> KASCADE-Grande

Kombination von Grande mit KASCADE durch gemeinsamen schnellen Trigger:
==> KASCADE-Piccolo

Erste Ergebnisse:

Flash-ADC System

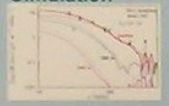
LOPES

Antennenfeld zur Detektion hochenergetischer Luftschauer

Geosynchrotron Mechanismus

Simulation

LOPES Elektronik



LOPES Aufbau in KASCADE-Grande

Rekonstruktion generierten Ra

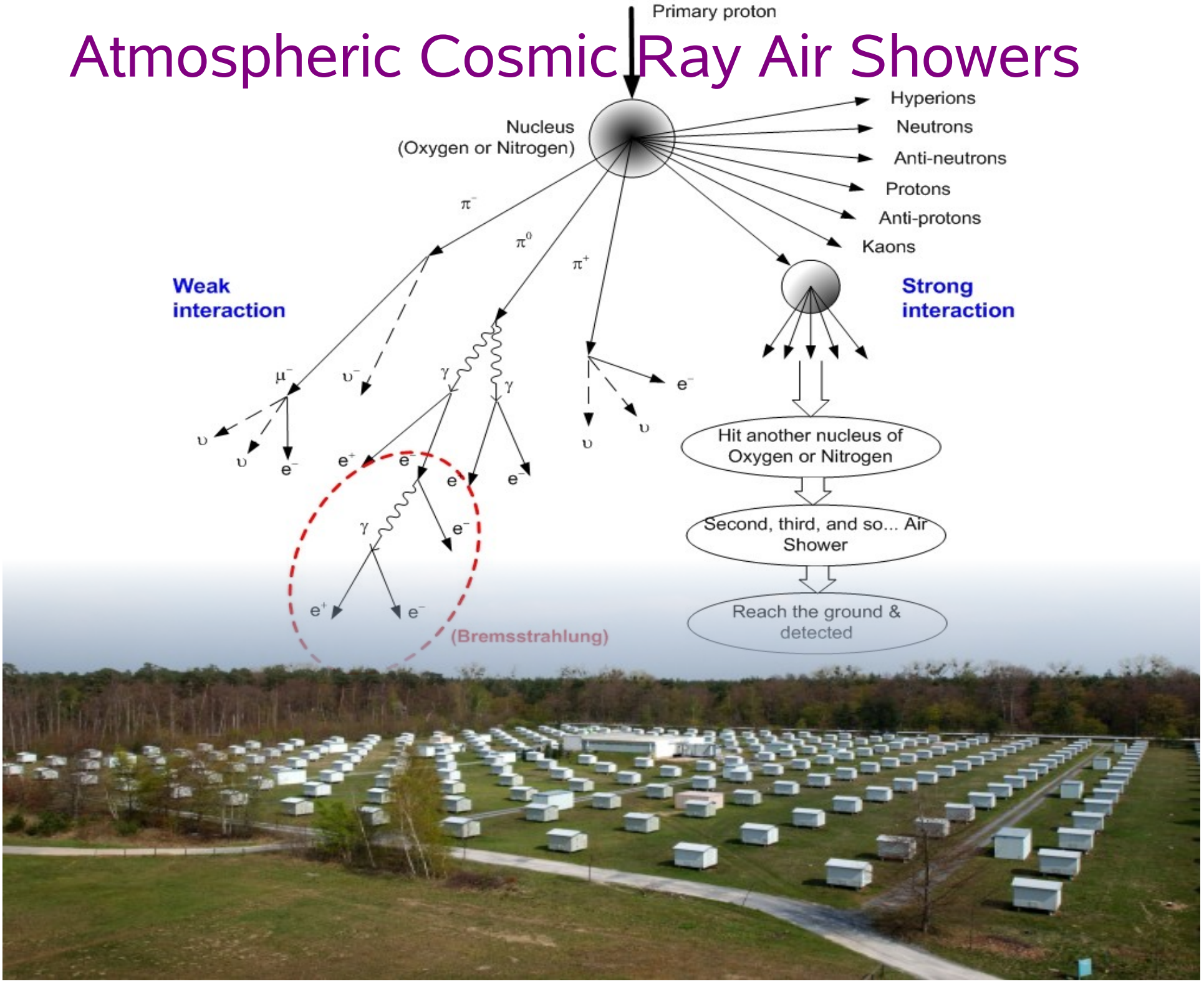
Erste Ergebnisse mit LOPES-10 - Kalib

Korrelation zwischen Radiopulsstärke und Myonzahl

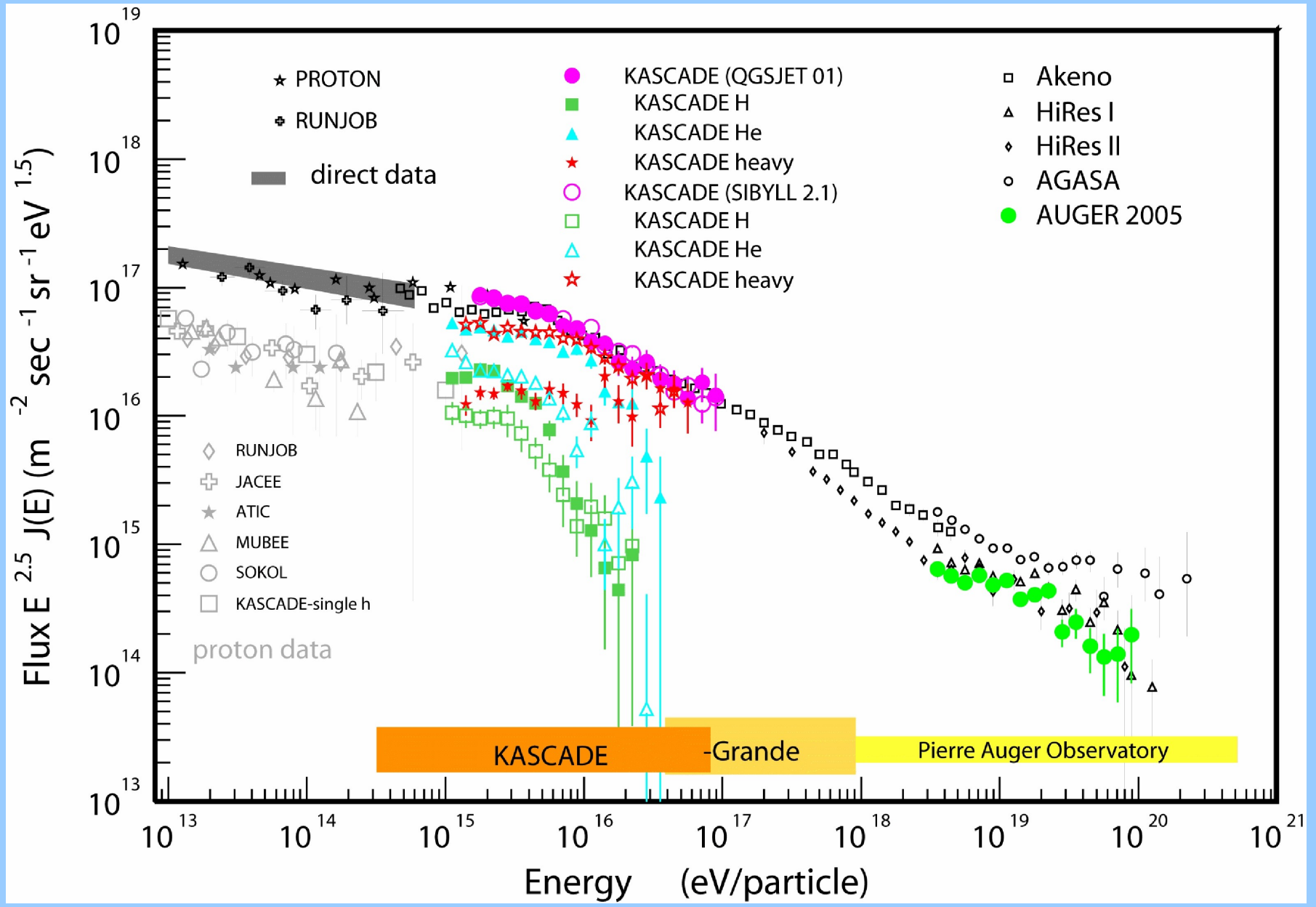
LOPES at the KSACADE-Grande Array

Forschungszentrum Karlsruhe, Germany

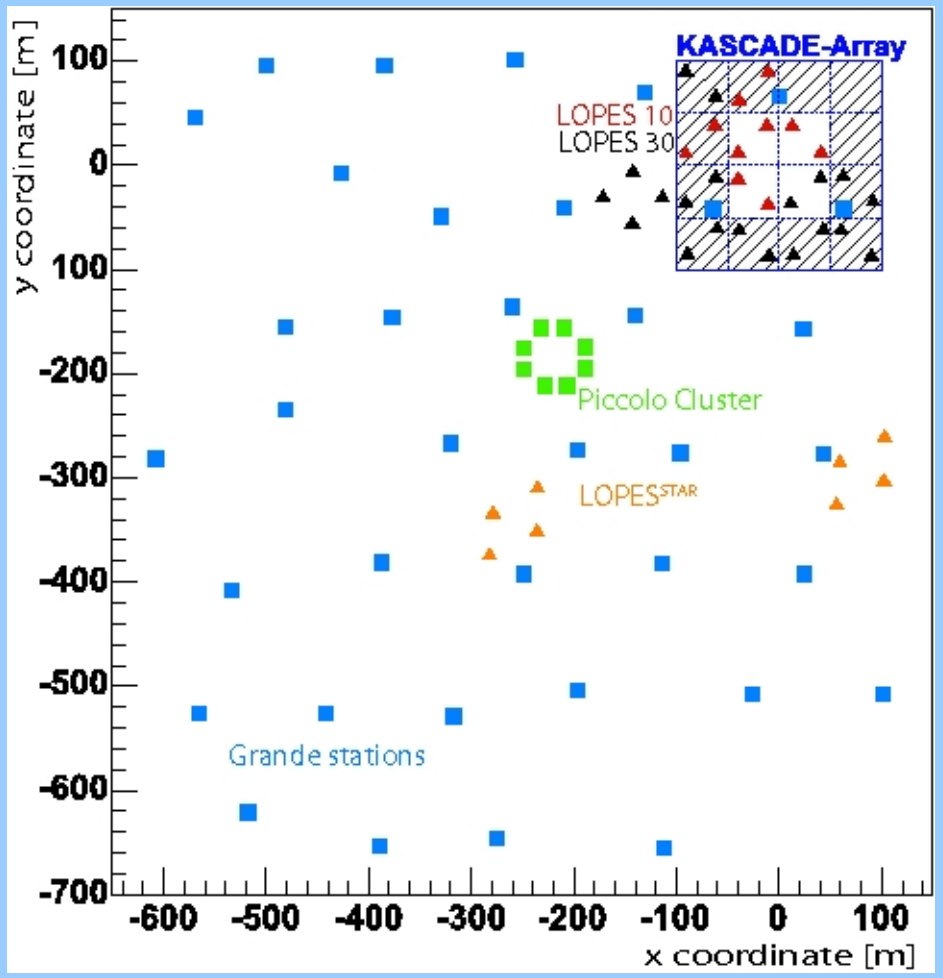
Atmospheric Cosmic Ray Air Showers

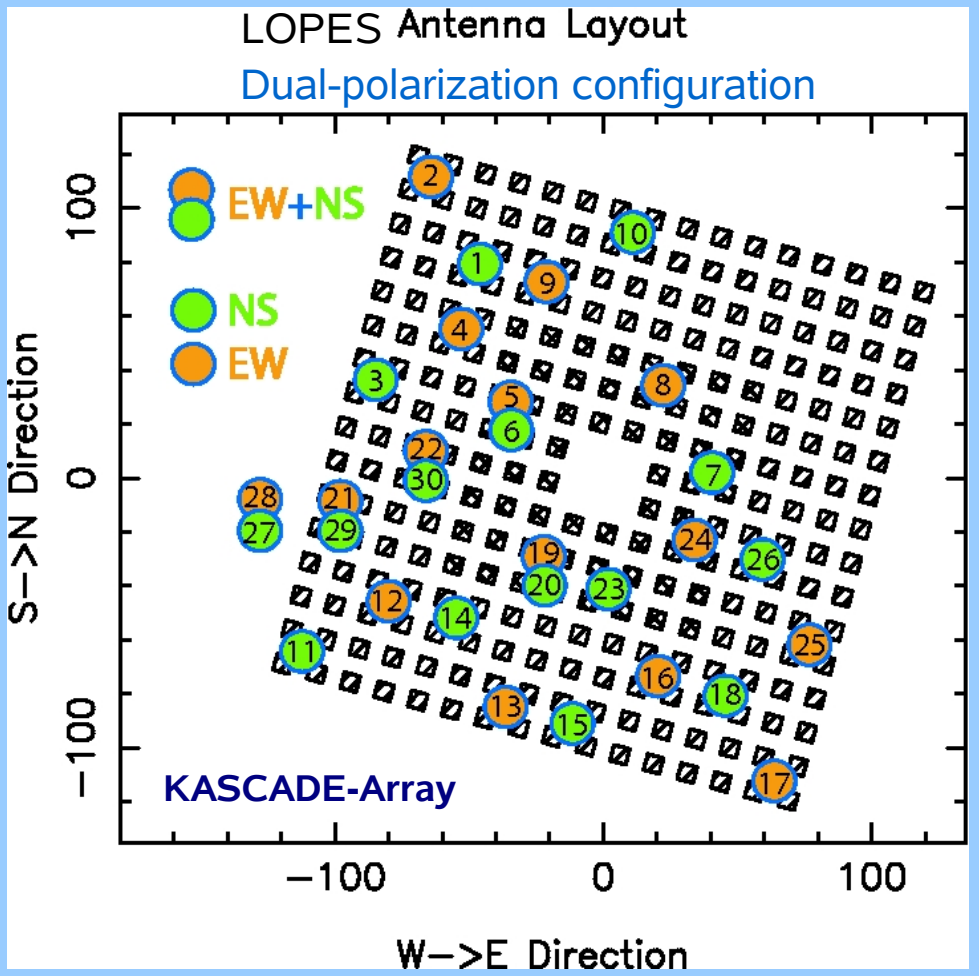


Cosmic Ray Spectrum



LOPES Experiment -- Status Operation





Location: most antennas inside the original KASCADE array.

Configuration:

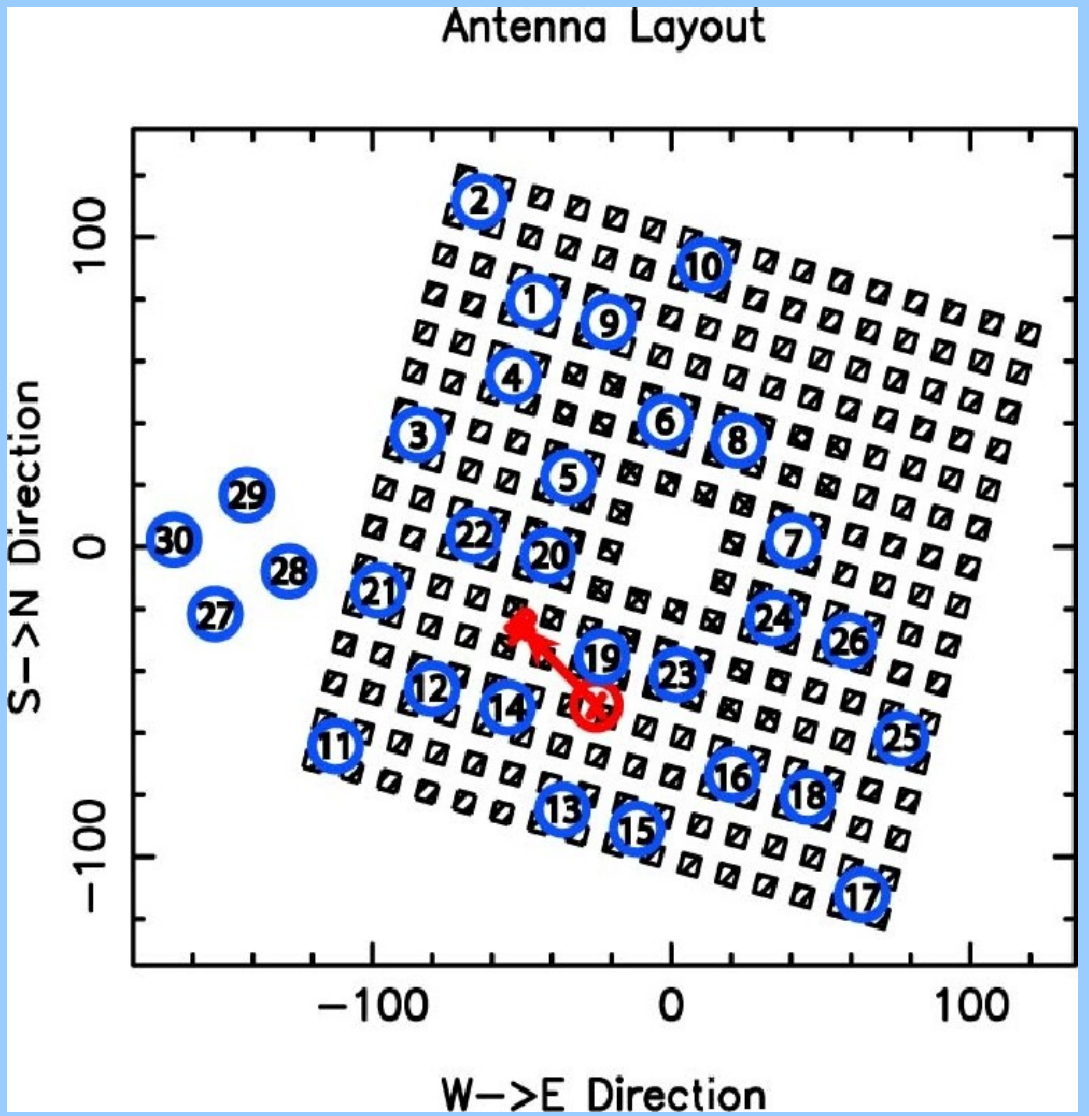
5 dual EW+NS antennas
10 single NS antennas
10 single EW antennas

Trigger sources:

KASCADE and KASCADE - Grande

LOPES30 Analysis

Dec, 2005
Core in KASCADE
Zenith angle=15°
Geomagnetic Angle: 36,4°
$\log(N_e)= 7.4$, $\log(N_\mu)= 6.03$
$E_p(\text{estimate})= 1.6 \times 10^{17}$ eV



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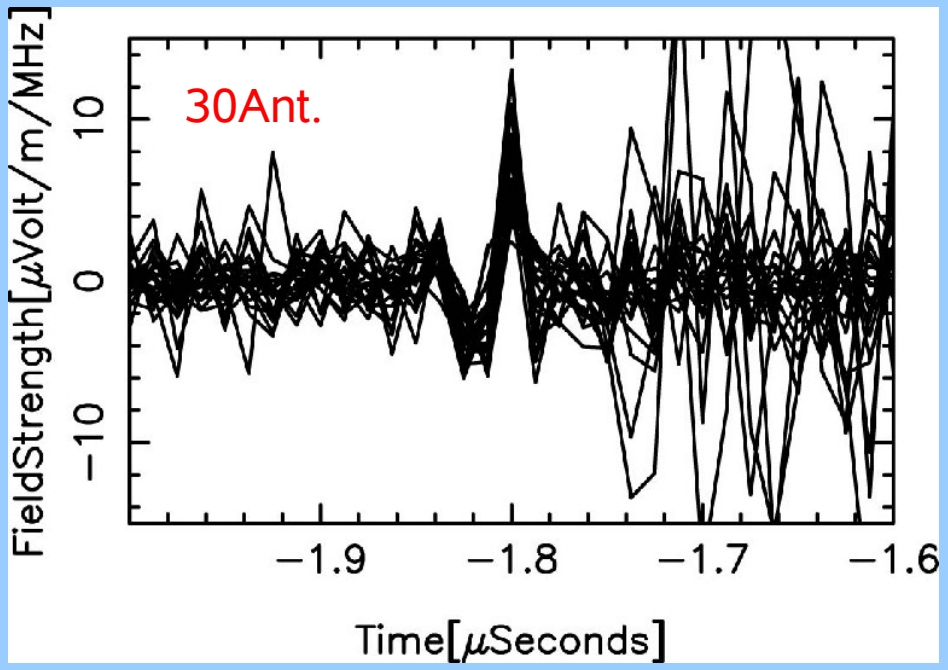
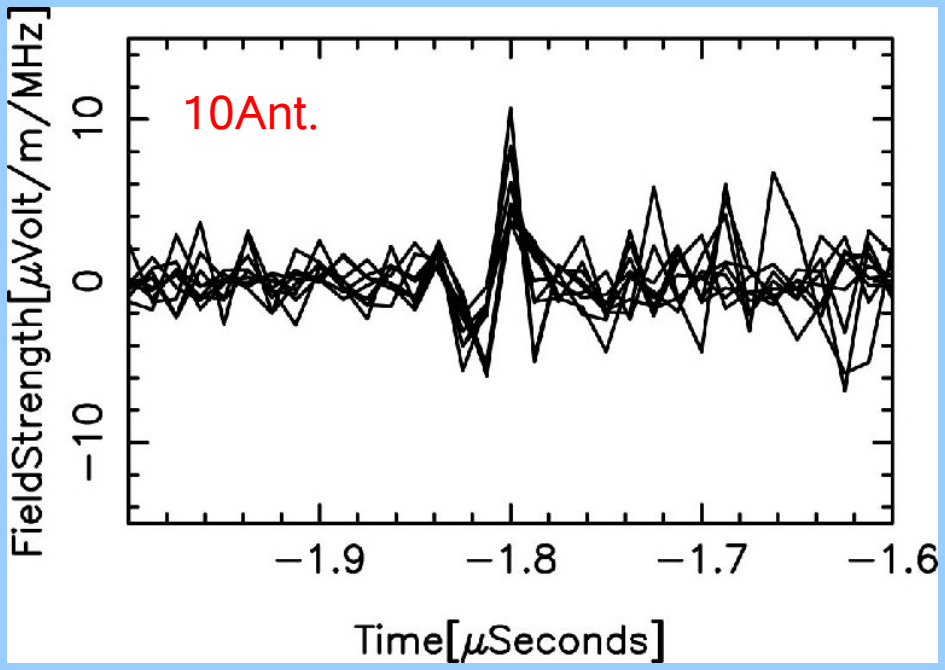
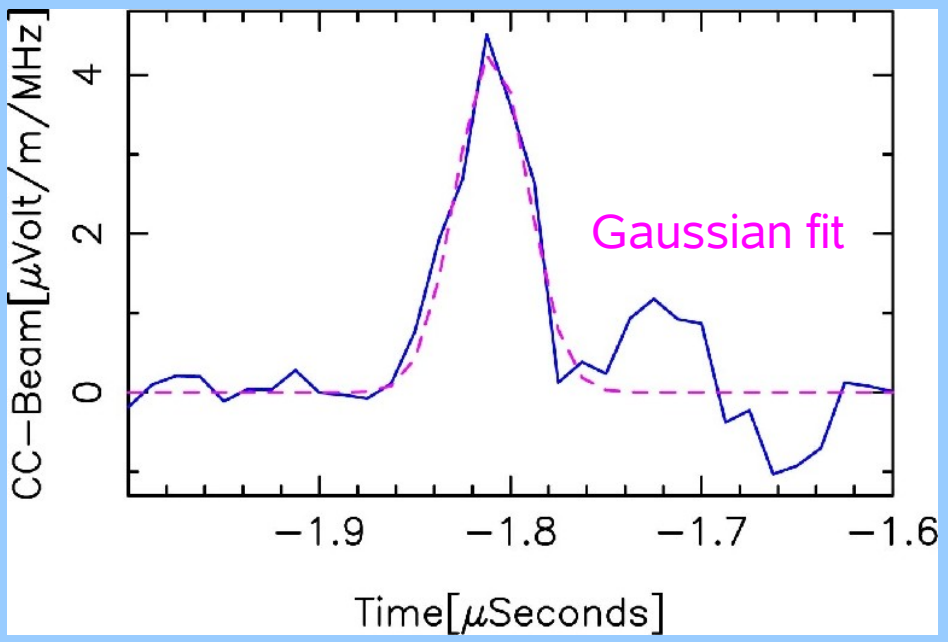
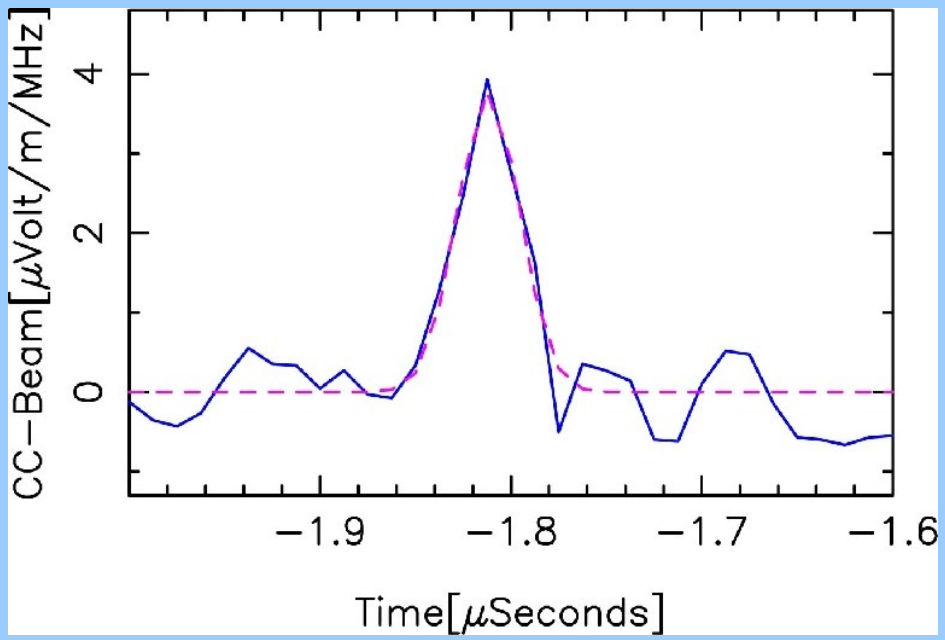
http://arxiv.org/abs/astro-ph/0610554]


30Ant.
FieldStrength[μVolt/m/MHz]
10
0
−10
−1.9
−1.8
−1.7
−1.6
Time[μSeconds]


10Ant.
FieldStrength[μVolt/m/MHz]
10
0
−10
−1.9
−1.8
−1.7
−1.6
Time[μSeconds]


Gaussian fit
CC−Beam[μVolt/m/MHz]
4
2
0
−1.9
−1.8
−1.7
−1.6
Time[μSeconds]


CC−Beam[μVolt/m/MHz]
4
2
0
−1.9
−1.8
−1.7
−1.6
Time[μSeconds]

Dual-Polarization measurements

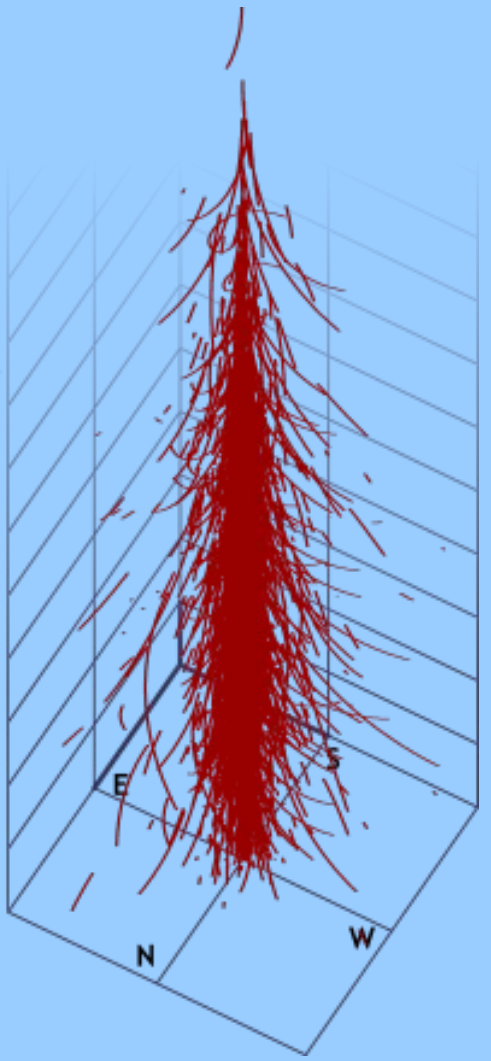
Why dual-polarization measurements?

- Initially, all 30 antennas of the LOPES experiment were aligned to measure the East-West polarization direction of the air shower pulse only.
- Recently, for recording the full radio signal, LOPES-30 has been reconfigured to perform dual-polarization measurements.
- Dual-polarization measurements provide the 'tool' that can verify the geosynchrotron mechanism of the radio emission in air showers.

Theoretical predictions

What simulations tell us:

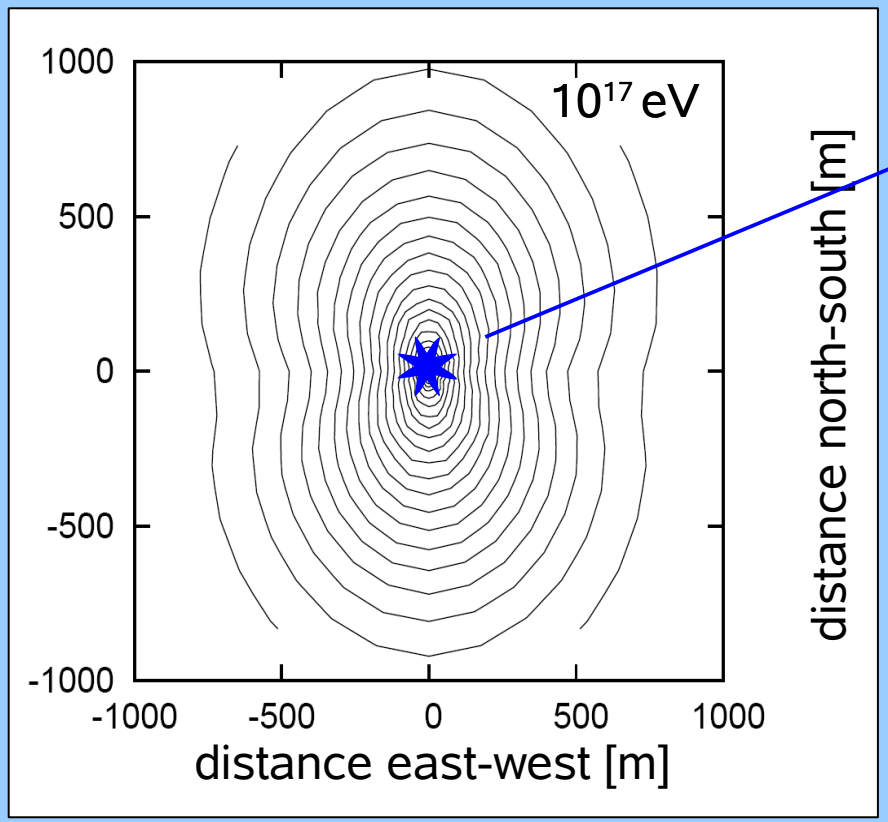
- highly linearly polarized radio emission
- signal usually present in both polarization components: East-West AND North-South
- polarization directly related with the shower azimuth (ϕ) for a given zenith (θ) angle
- dependence of the signal on the position of the observer relative to the shower

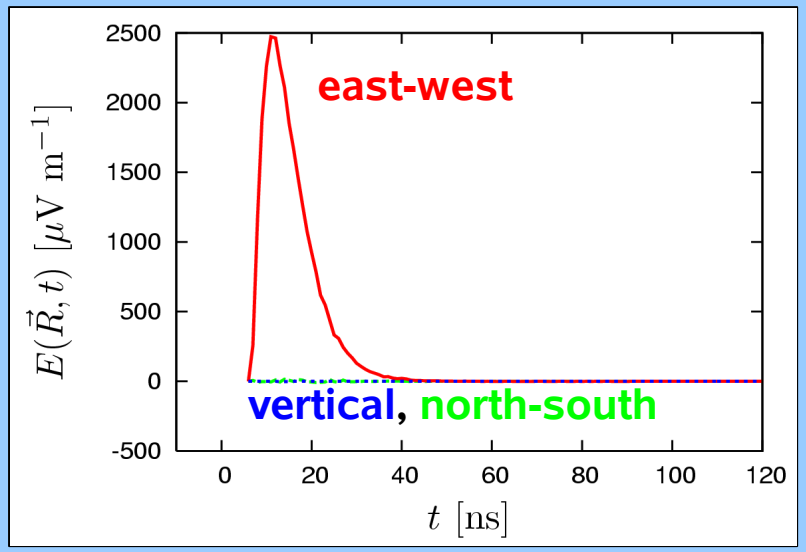


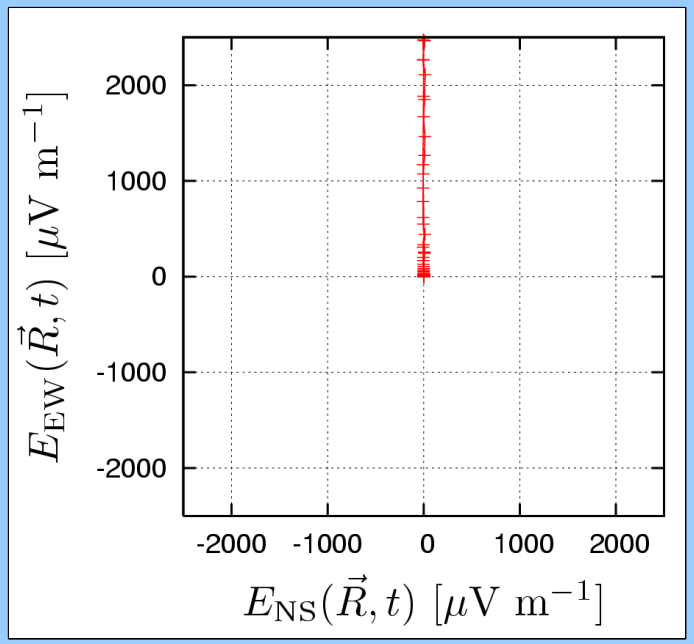
Simulated trajectories of e^+ and e^- in the air shower.
T.Huege

Simulated Pulse

45° inclined air shower, total field strength at 10MHZ







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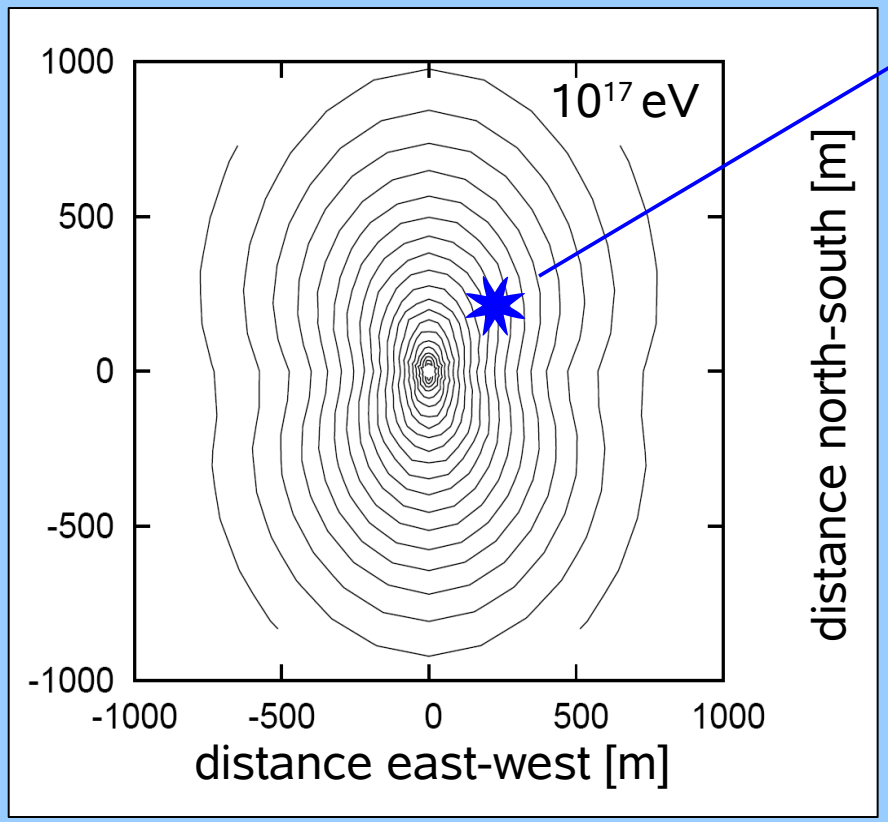
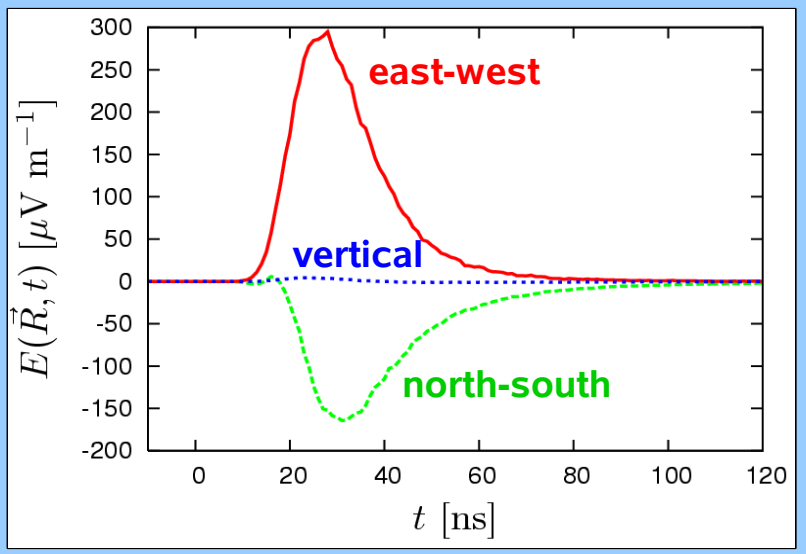
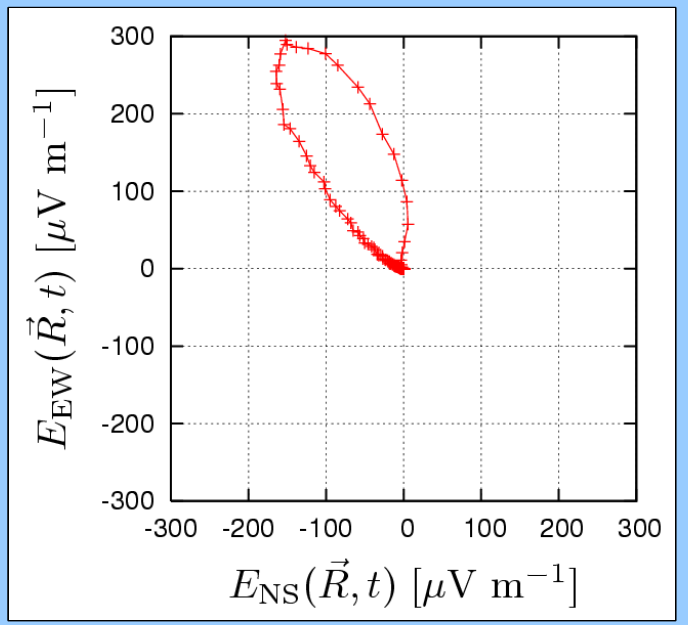
Simulated Pulse

45° inclined air shower, total field strength at 10MHZ







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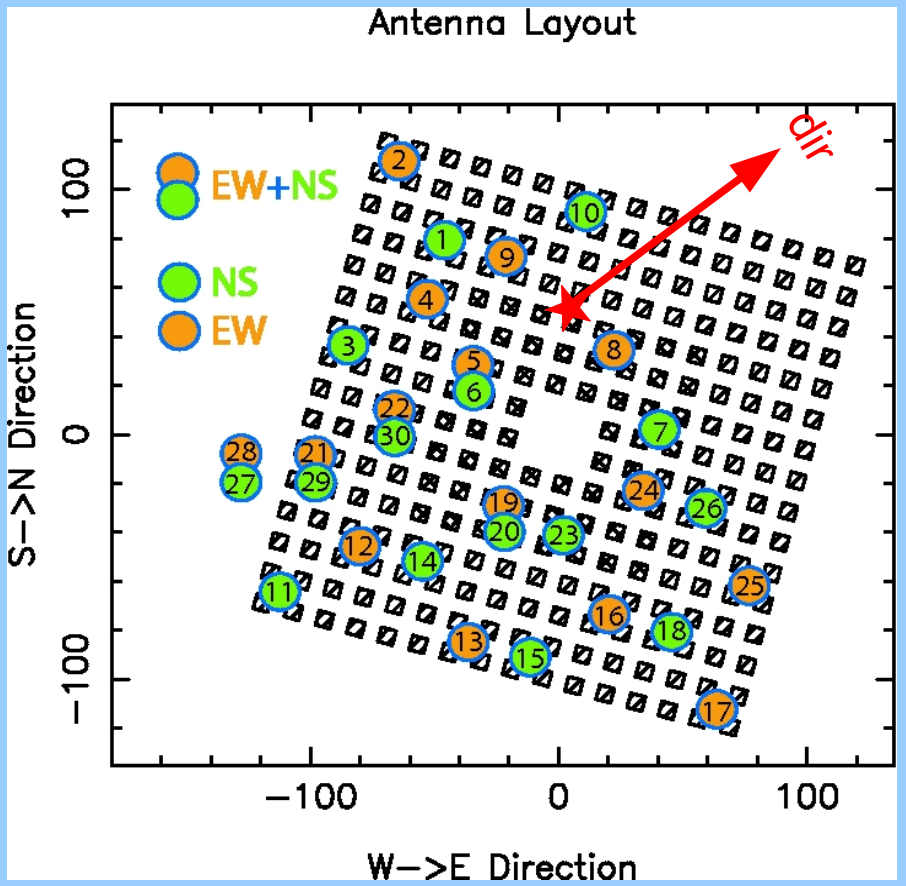
Polarization Measurements

Preliminary Analysis: Event example I

Dec 21, 2006
Core in KASCADE
ϕ=51.18°, θ=66.44°
Geomagnetic Angle: 83°
$\log(N_e)$= 5.3, $\log(N_\mu)$= 5.4
$E_{p(\text{estimate})}$= 1.8 x 10^{18} eV

CC-Beam_{EW} = 47 μVolt/m/MHz
CC-Beam_{NS} = 33 μVolt/m/MHz



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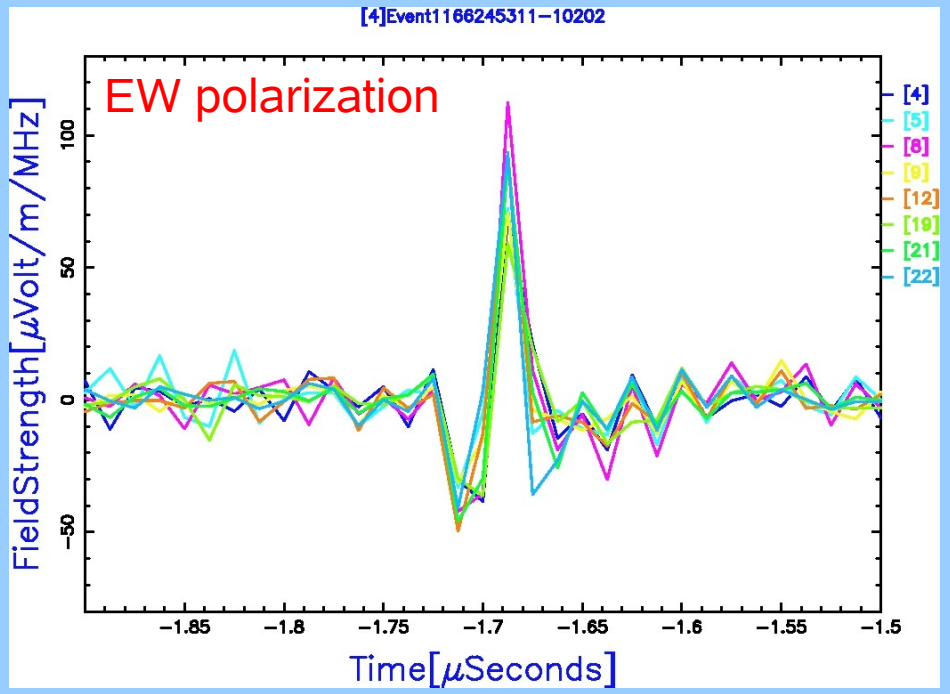
[4]Event1166245311−10202
EW polarization
FieldStrength[μVolt/m/MHz]
Time[μSeconds]
[4]
[5]
[8]
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[12]
[19]
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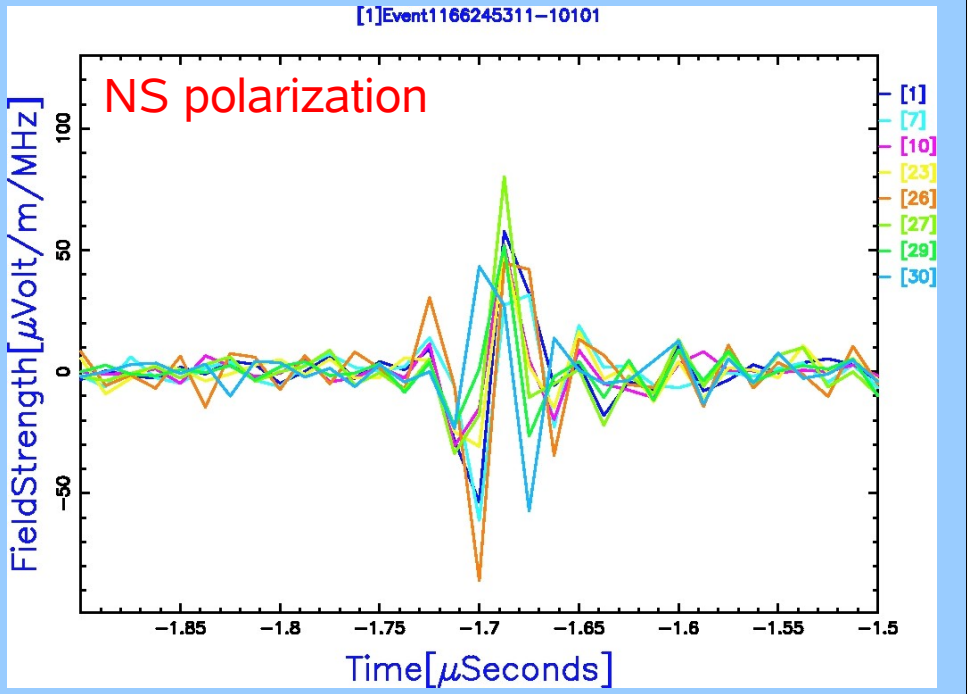
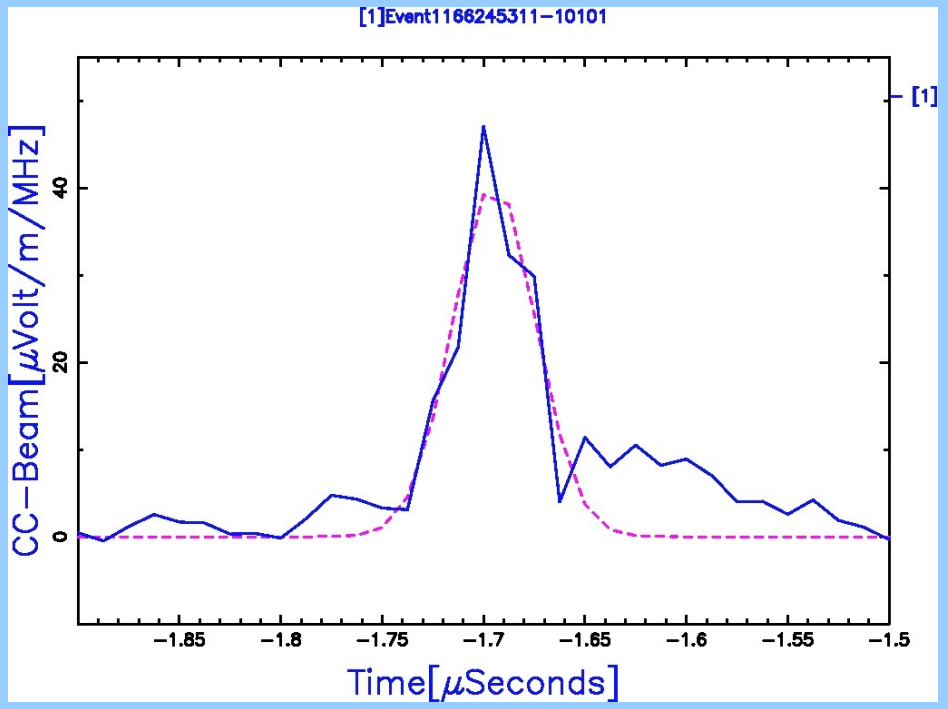
[22]


[1]Event1166245311−10101
NS polarization
FieldStrength[μVolt/m/MHz]
Time[μSeconds]
[1]
[7]
[10]
[23]
[26]
[27]
[29]
[30]


[1]Event1166245311−10101
CC−Beam[μVolt/m/MHz]
Time[μSeconds]
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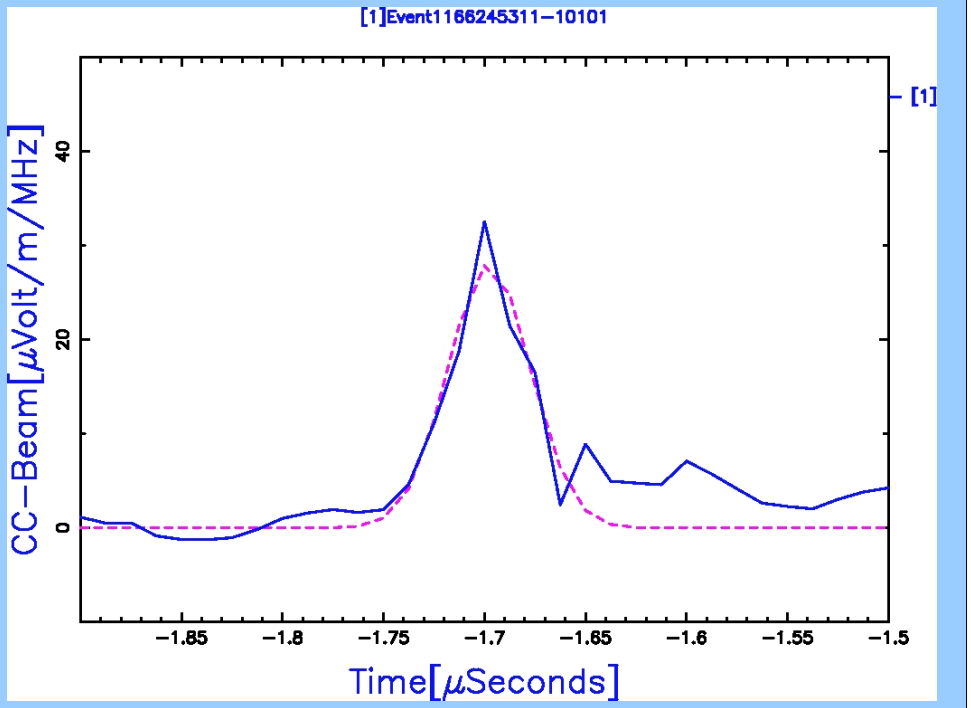
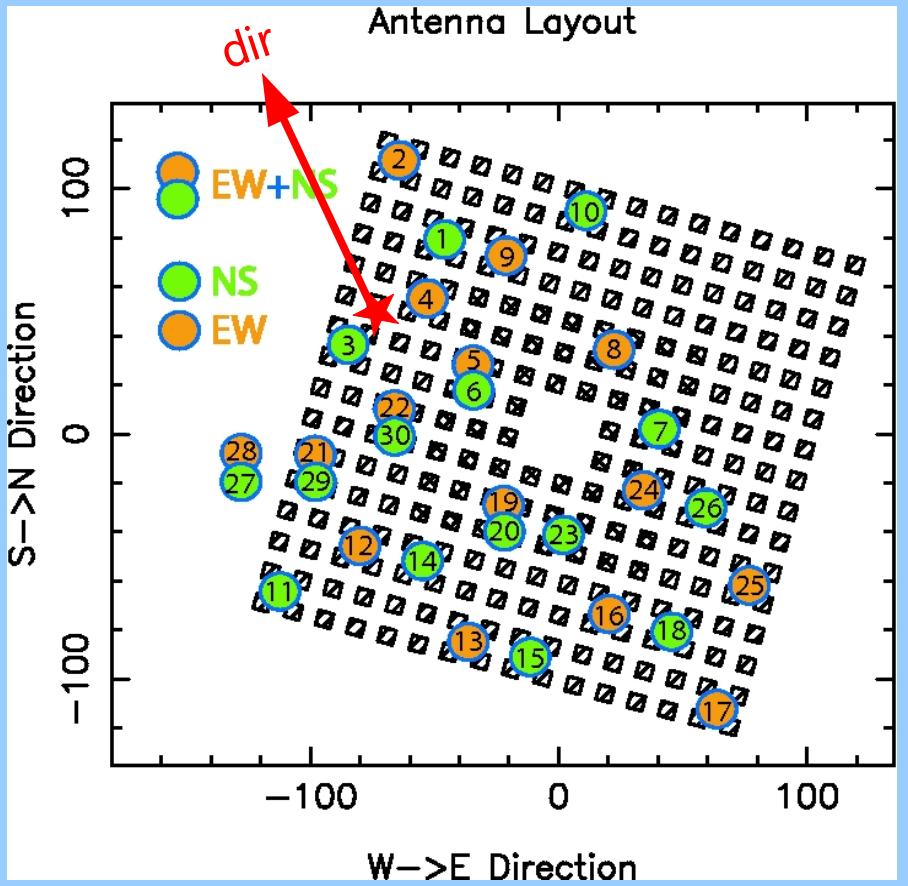

[1]Event1166245311−10101
CC−Beam[μVolt/m/MHz]
Time[μSeconds]
[1]

Polarization Measurements

Preliminary Analysis: Event example II

Dec 16, 2006
Core in KASCADE
$\phi = 332.67^{\circ}$, $\theta = 54.24^{\circ}$
Geomagnetic Angle: 77°
$\log(N_e) = 5.8$, $\log(N_\mu) = 5.4$
$E_p(\text{estimate}) = 2.9 \times 10^{17}$ eV

$\text{CC-Beam}_{EW} = 50\ \mu\text{Volt/m/MHz}$
$\text{CC-Beam}_{NS} < 10\ \mu\text{Volt/m/MHz}$



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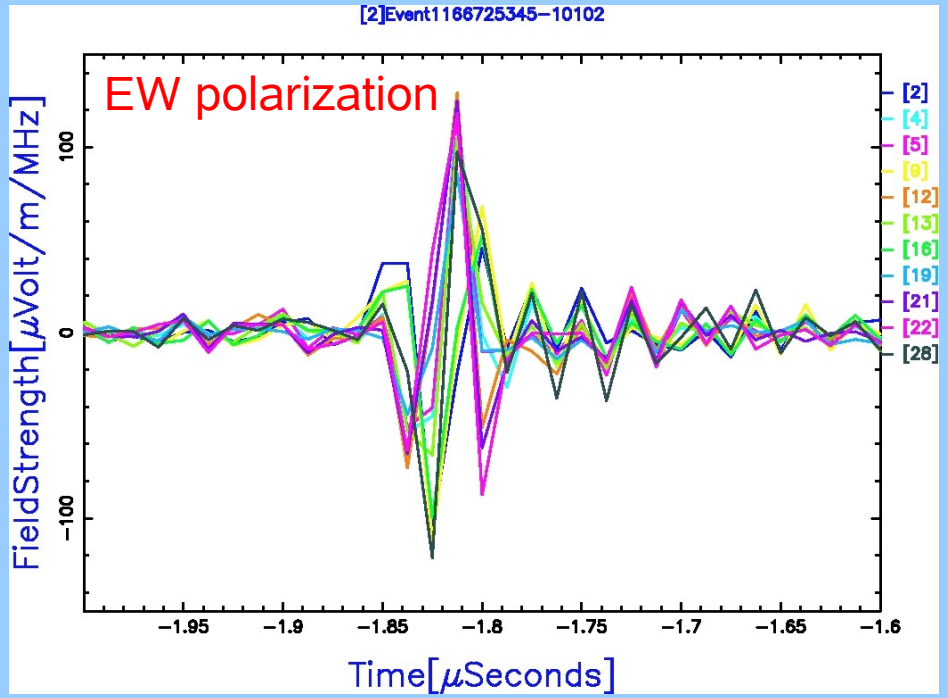
[2]Event1166725345–10102
EW polarization
FieldStrength[μVolt/m/MHz]
Time[μSeconds]
[2]
[4]
[5]
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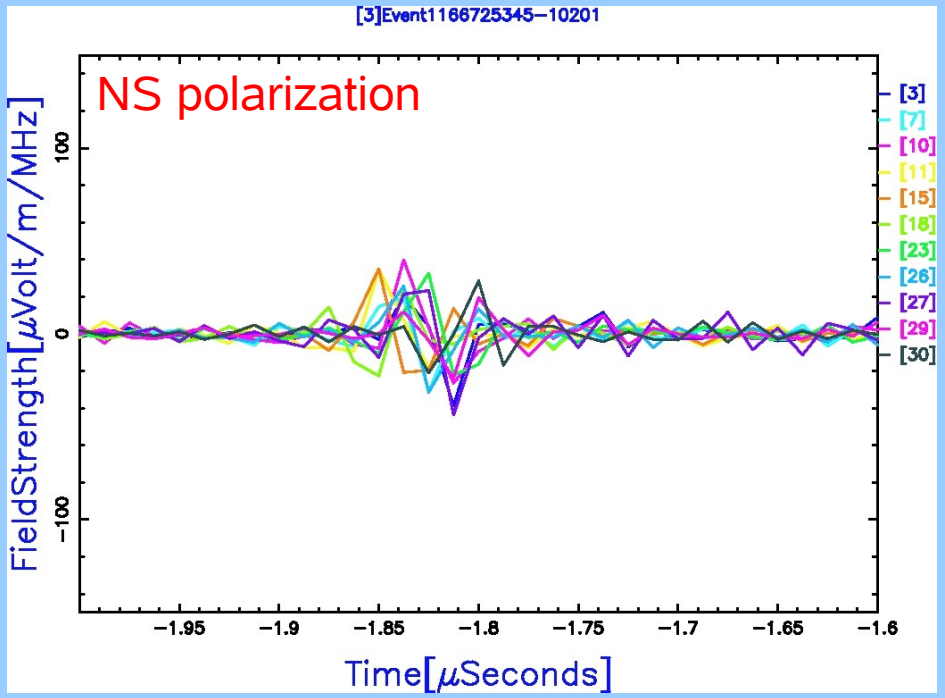
[3]Event1166725345–10201
NS polarization
FieldStrength[μVolt/m/MHz]
Time[μSeconds]
[3]
[7]
[10]
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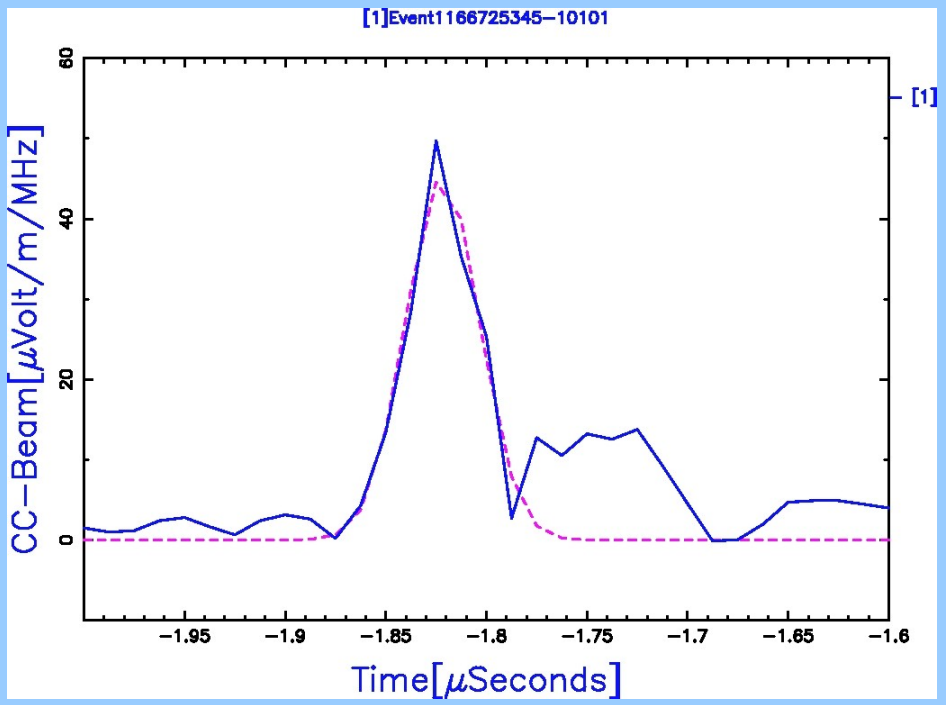
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CC–Beam[μVolt/m/MHz]
Time[μSeconds]
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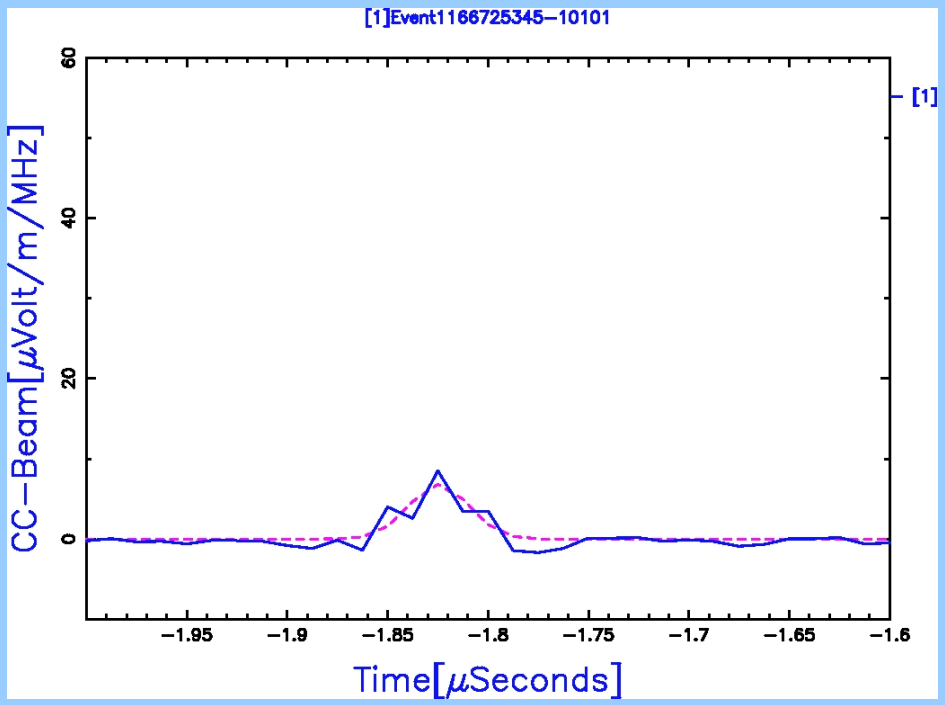
[1]Event1166725345–10101
CC–Beam[μVolt/m/MHz]
Time[μSeconds]
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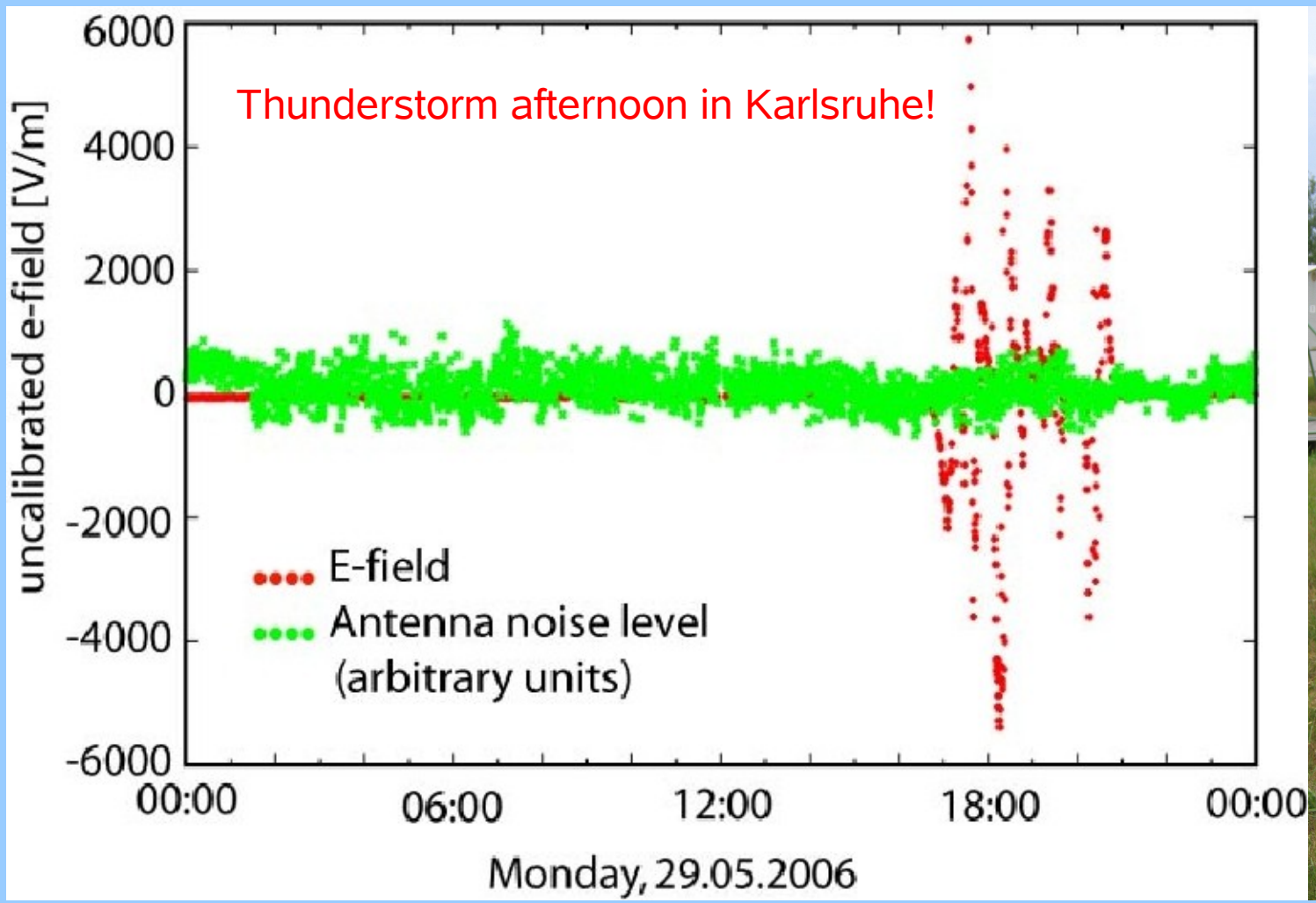
Environmental Monitoring



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Conclusions

- **One of the main goals of the LOPES project is to pave the way for an application of this "re-discovered" detection technique to large UHECR experiments (e.g. LOFAR (Low Frequency Array) and the Pierre Auger Observatory).**

- **In its current configuration, the LOPES experiment is performing dual polarized measurements and allows a much more detailed analysis of the radio events than with only E-W polarized measurements.**

- **Measuring at the same time, both the E-W and N-S polarization components of the radio emission, the geosynchrotron effect as the dominant emission mechanism in air showers can be verified.**

- **Monitoring the atmospheric E-Field and further environmental conditions allow to investigate the influence of thunderstorms to the measurements.**

LOPES Collaboration

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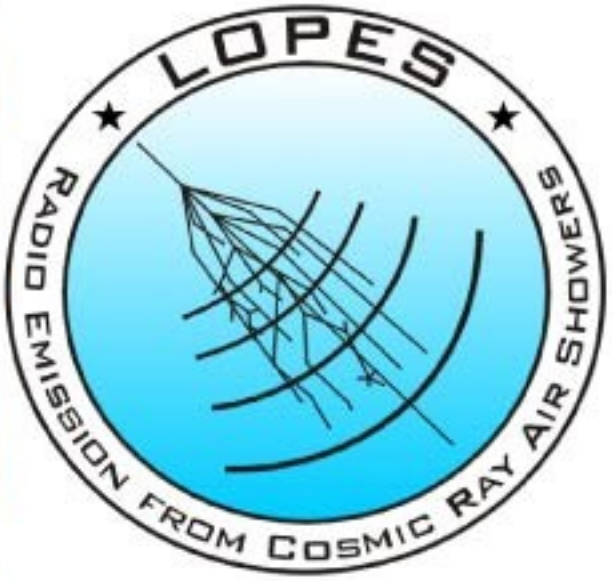

THANK YOU!

Master Advisors: Prof. M.V. Rusu & P.L. Biermann