Mutual Interaction of Air Showers and Thunderstorms

Astroparticle school in Obertrubach/Bärnfels

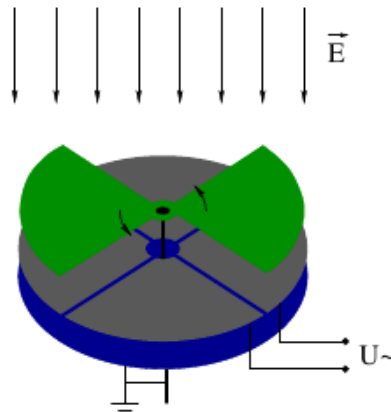**Stefan Braun for the LOPES Collaboration**

LOPES experiment

- Exploration of radio emission of air showers
- 30 Dipole antennas at calibrated air shower Experiment
- Trigger from KASCADE-Grande
- $10^{17} - 10^{18}$ eV
- 40 – 80 MHz
- Update: LOPES 3D

Stefan Braun: Mutual Interaction of Air Showers and Thunderstorms

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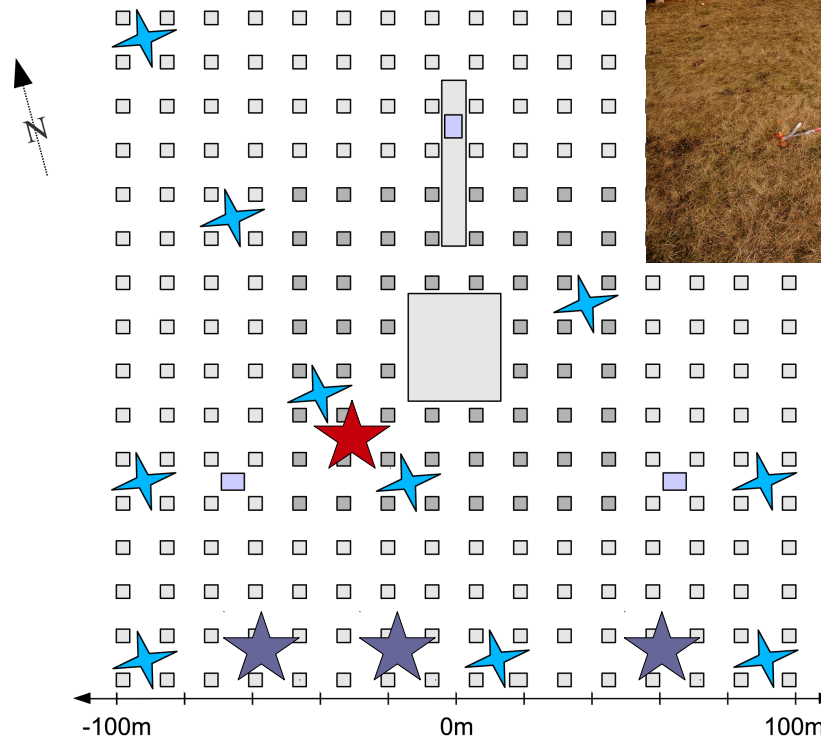
Measuring atmospheric E-field

- E-field mill
  - Measuring static E-field
  - Time resolution: 1 s
  - Installed at LOPES and Auger
- Slow antenna:
  - Measuring dynamic E-field
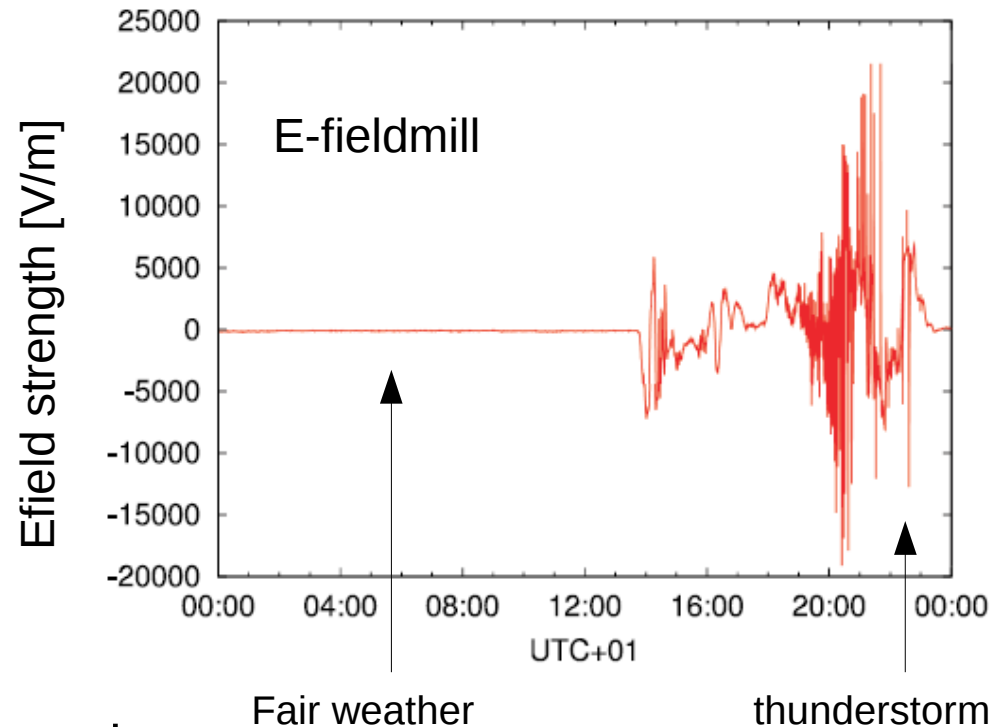 - Time resolution: 0.1 ms
  - Installed at Auger

E-field mill

Slow antenna

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Thunderstorm mode

- Every three minutes: analysis the last 15 minutes
- Conditions:
  E-field > 500 V/m and jumps
- Trace
  - Fair weather: µs
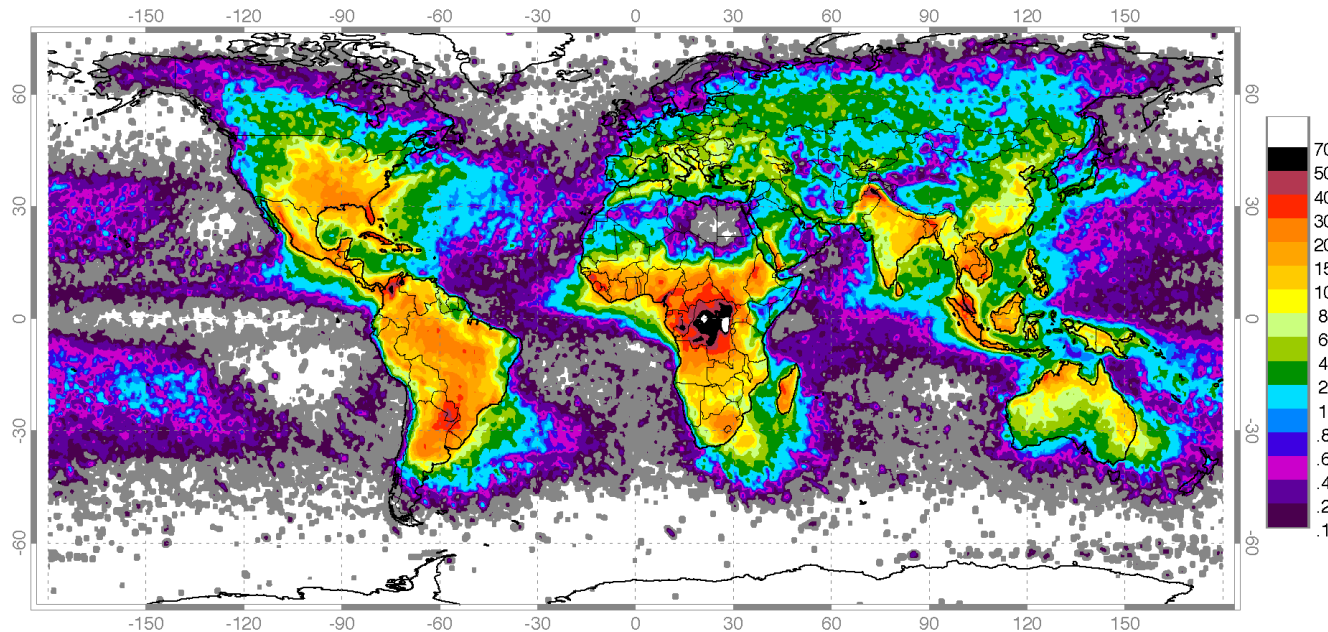 - Thunderstorm mode: ms

E-field:

- Fair weather: between -50 V/m und -200 V/m (small changes)
- Thunderstorm mode: ± 20 kV/m (jumps)

E-fieldmill

Fair weather   thunderstorm

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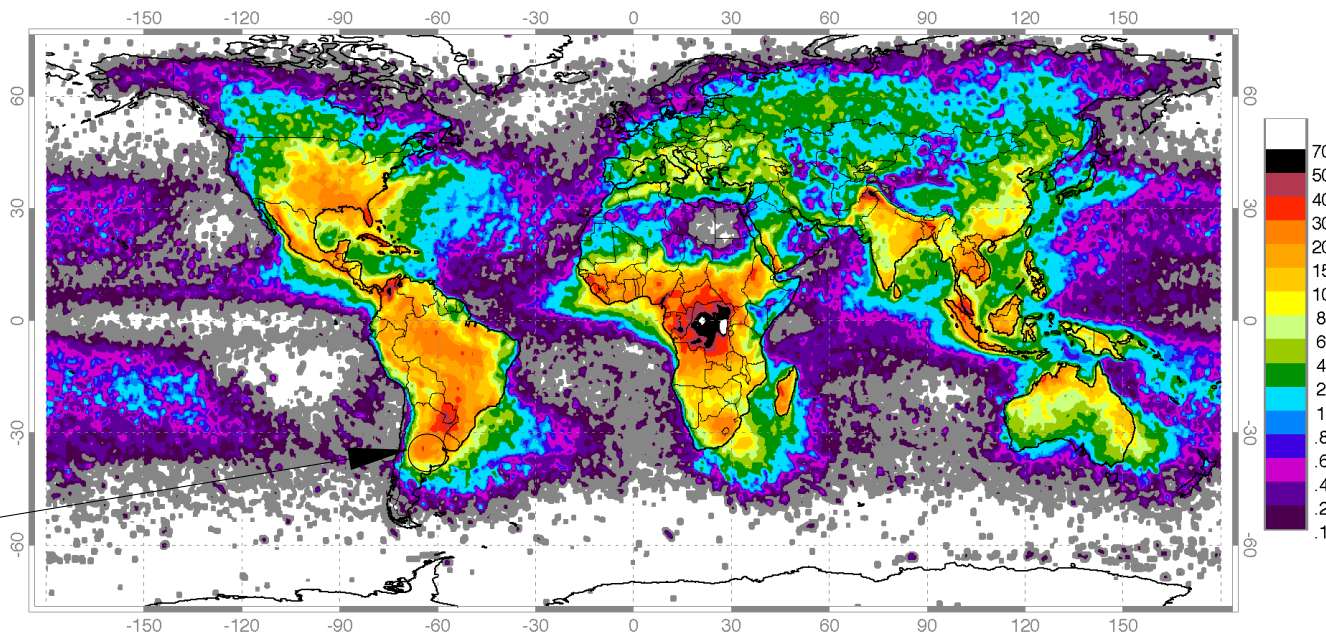# Thunderstorm statistics

- 16 million lightning storms in the world every year
  - World wide at each time 2000-3000 thunderstorms
  - 100 lightnings per second
  - Empire State Building is hit 23 times per year
- More lightning deaths per year than by other weather phenomena
- Commercial aircraft struck once every 5000-10000 hours flight time

http://www.nasa.gov/centers/goddard/news/topstory/2004/0621lightning_prt.htm

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Auger

http://www.nasa.gov/centers/goddard/news/topstory/2004/0621lightning_prt.htm

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Lightnings not well understood

- Main problem: How lightnings initiated?
  - Classical electrical breakthrough!?
  - Problem: measured E-field in the atmosphere too low for breakthrough
  - Need: 3 MV per meter
- Possible Solution: Relativistic Runaway Breakdown (RRB):
  - Need: only 155 kV per meter
- Can Air shower initiate lightnings!?
  - Provide an high electron density
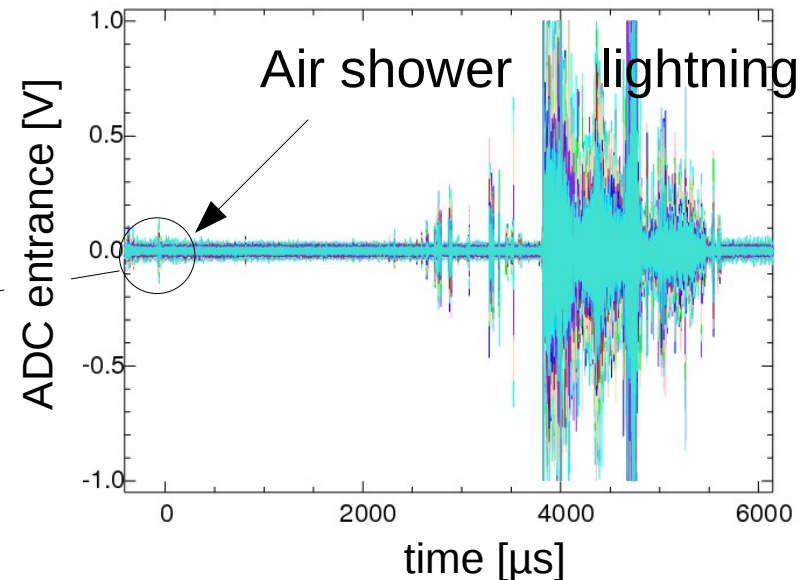- Other Open question:
  - Gamma ray emission from lightnings
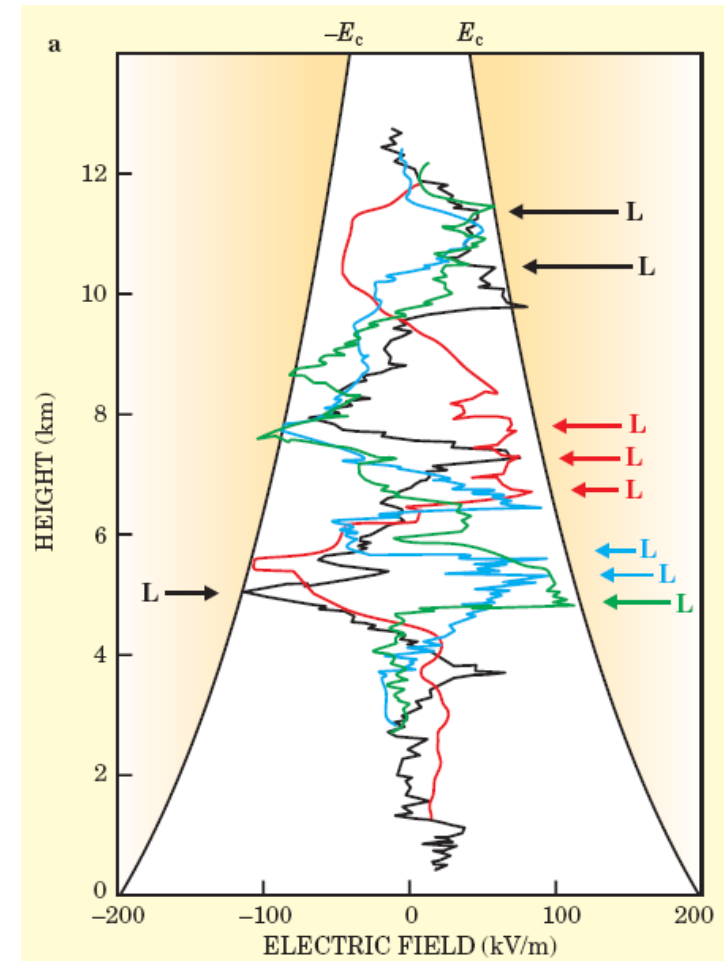
GUREVICH, A.V. Und ZYBIN, K.P.: Physics Today (2005), Bd. 58,5: S.37-43

Correlation between air showers and lightnings

- Time correlation:
  - Time difference: air shower → lightning (tdiff)
  - → kHz antenna
- Direction correlation:
 - Air shower in the same direction as lightning
  - → Skymap

tdiff [s]

bigger

Air shower   lightning

time [µs]
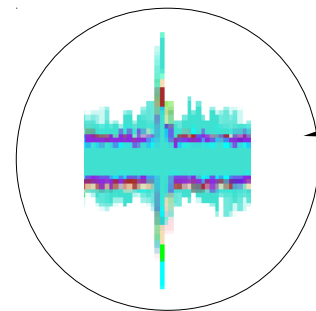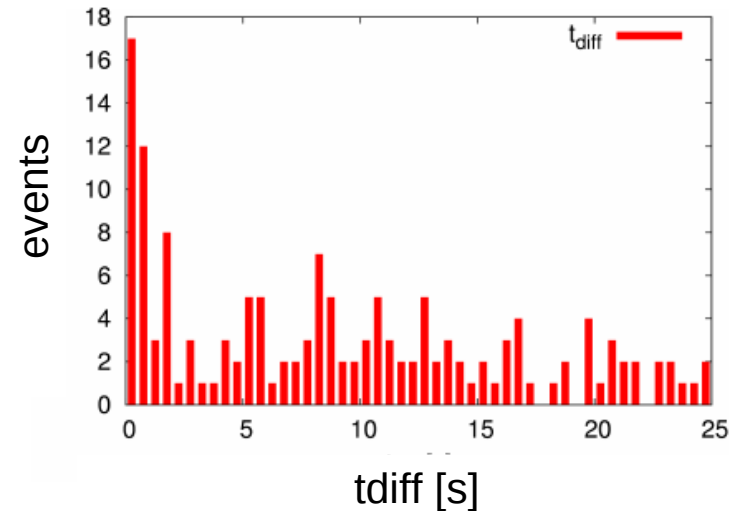
FZKA 7506: Ender, Moses

Skymap

- Cross correlation:
    - Interferometric combination of all 30 antennas
    - High cross correlation
        - → signal coherent
    - Low cross correlation
        - → signal incoherent
- Skymap:
    - Cross correlation for all directions
    - → Direction correlation

CC-Beam:
1.0
1.e-2
1.e-4
1.e-6
1.e-8
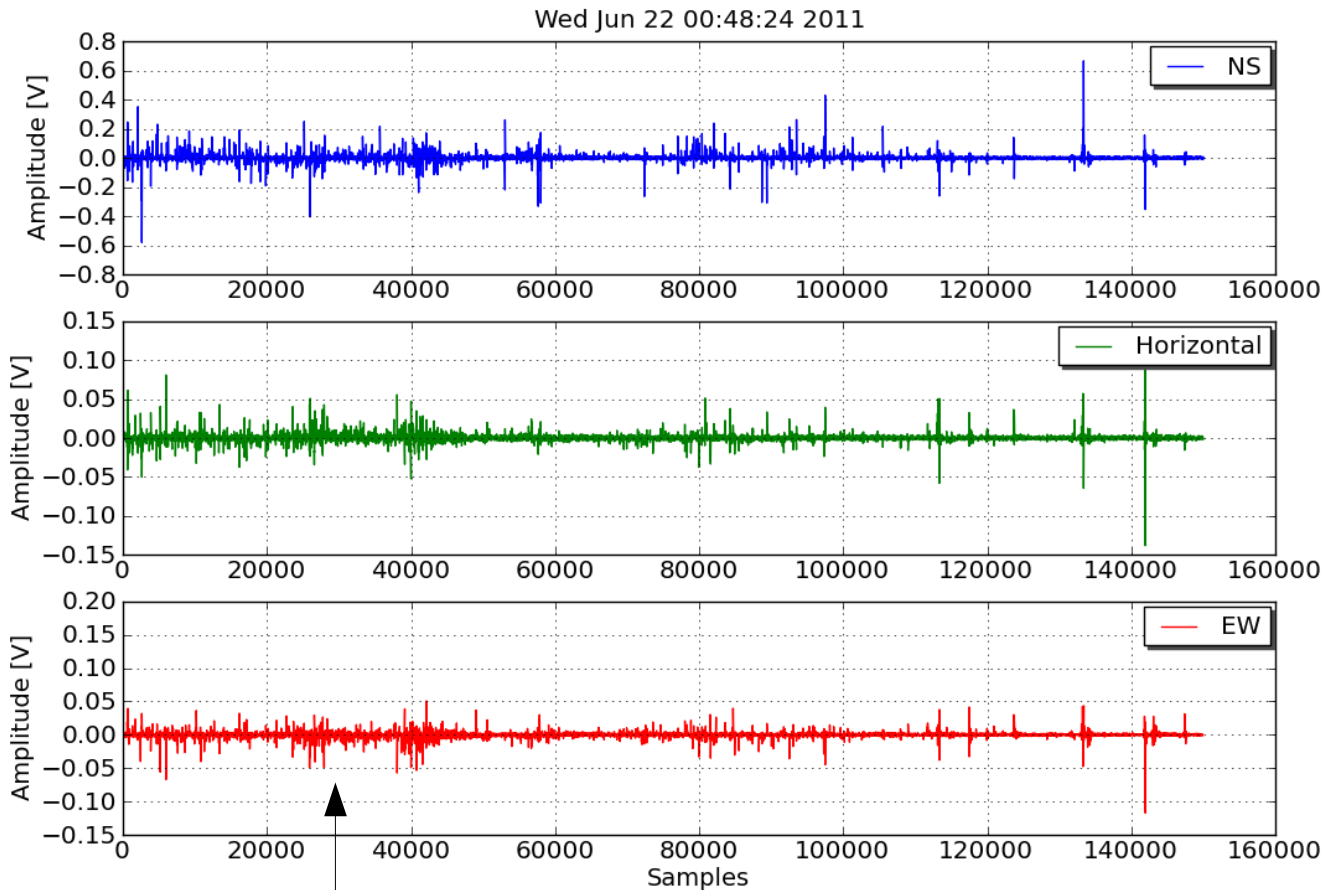0.0
-1.e-8
-1.e-6
-1.e-4
-1.e-2
-1.0
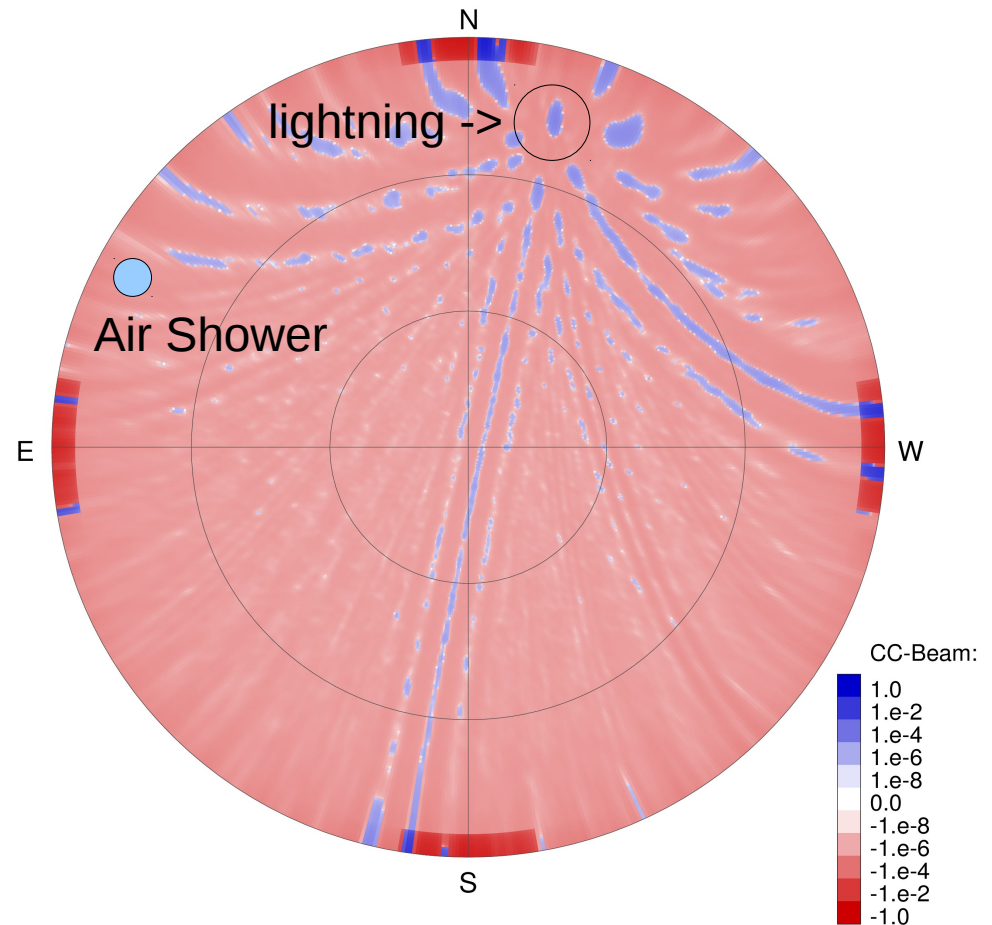
2008.06.02.19:03:49.887.event - frame 351/512 (t=4,083 ms)

kHz antennas

- Hardware:
  - 3 magnetic loop antennas (3 polarisations)
  - 50 – 500 kHz
  - Trigger from KASCADE-Grande (as LOPES)
- Motivation
  - Detailed look in lightning signals from LOPES
  - Lightnings emit the most power in kHz range
- New update:
  - Trace : 150 ms
  - Dynamic range higher
  - Protection against lawn mowers

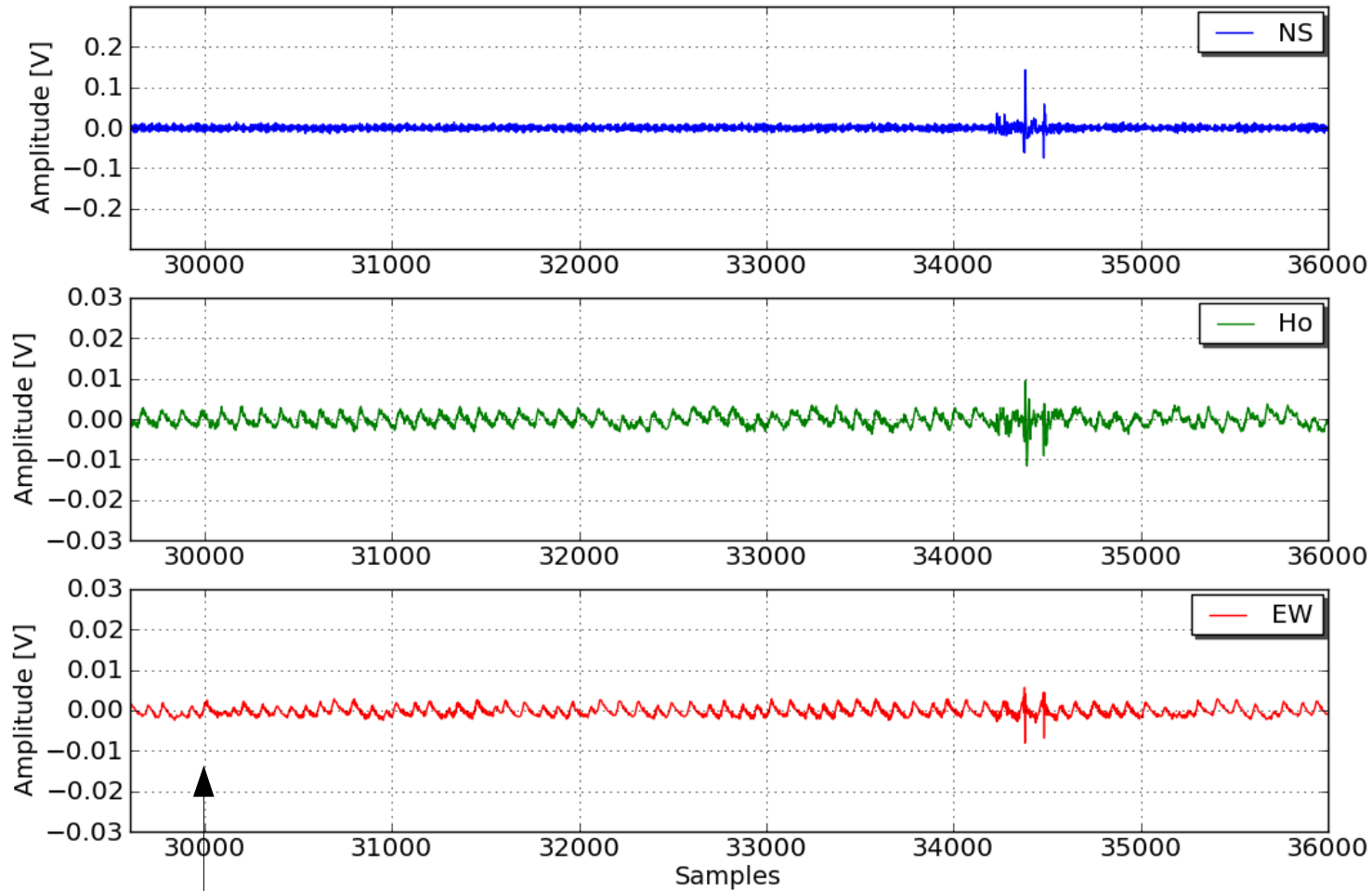Stefan Braun: Mutual Interaction of Air Showers and Thunderstorms

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kHz signals

Wed Jun 22 00:48:24 2011

Trigger from KASCADE   1Sample is 1μs

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                                                                                                                                      IEKP

Events in kHz and MHz

Signal 4ms after Trigger

Sun May 15 12:30:57 2011

Trigger

1Sample is 1μs

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Events in kHz and MHz

GT 1305466256 - 30 Antennas

Signal also 4ms after Trigger

Trigger

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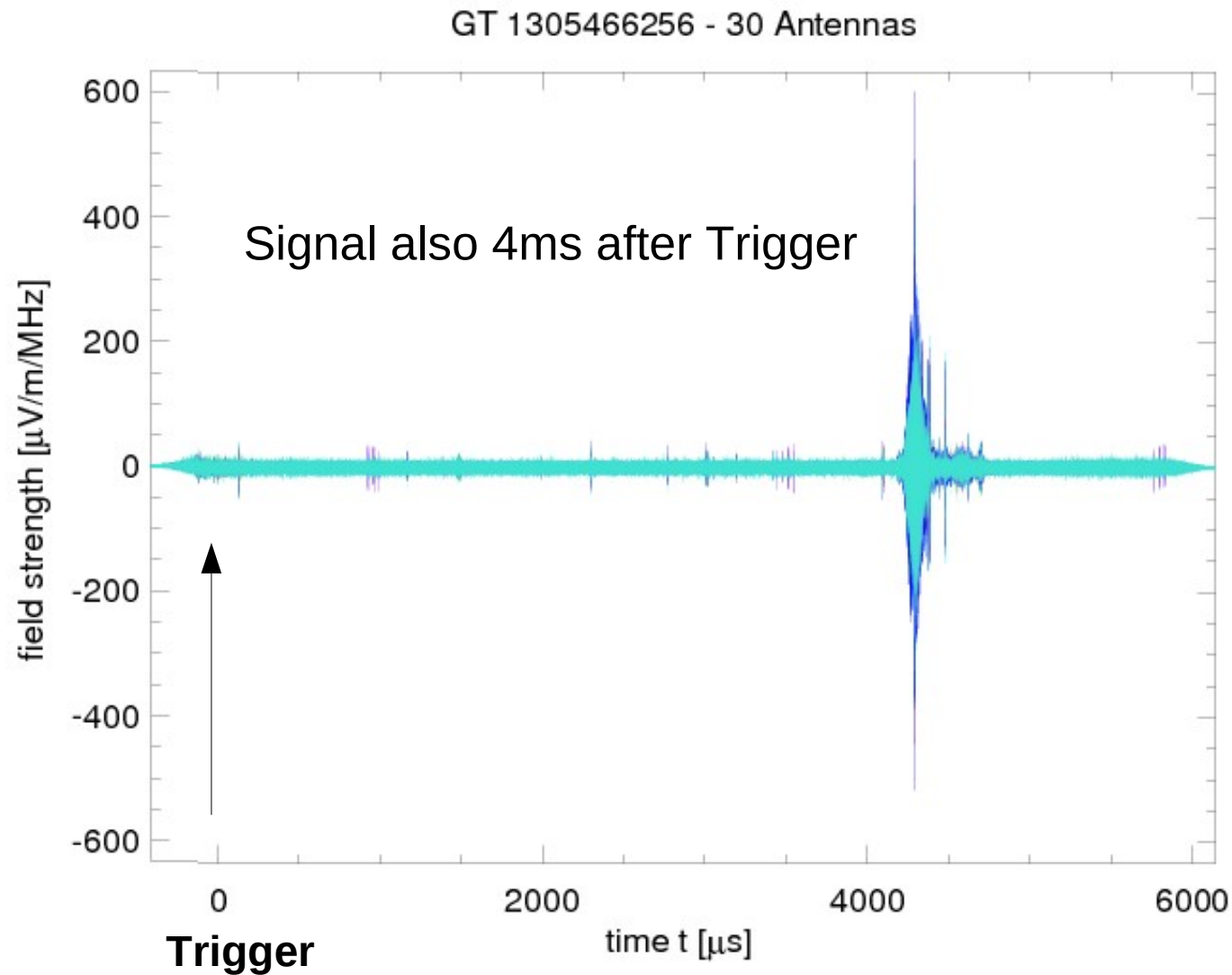
KHz + E-fieldmill

Trigger: 30.000 samples

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KHz + E-fieldmill

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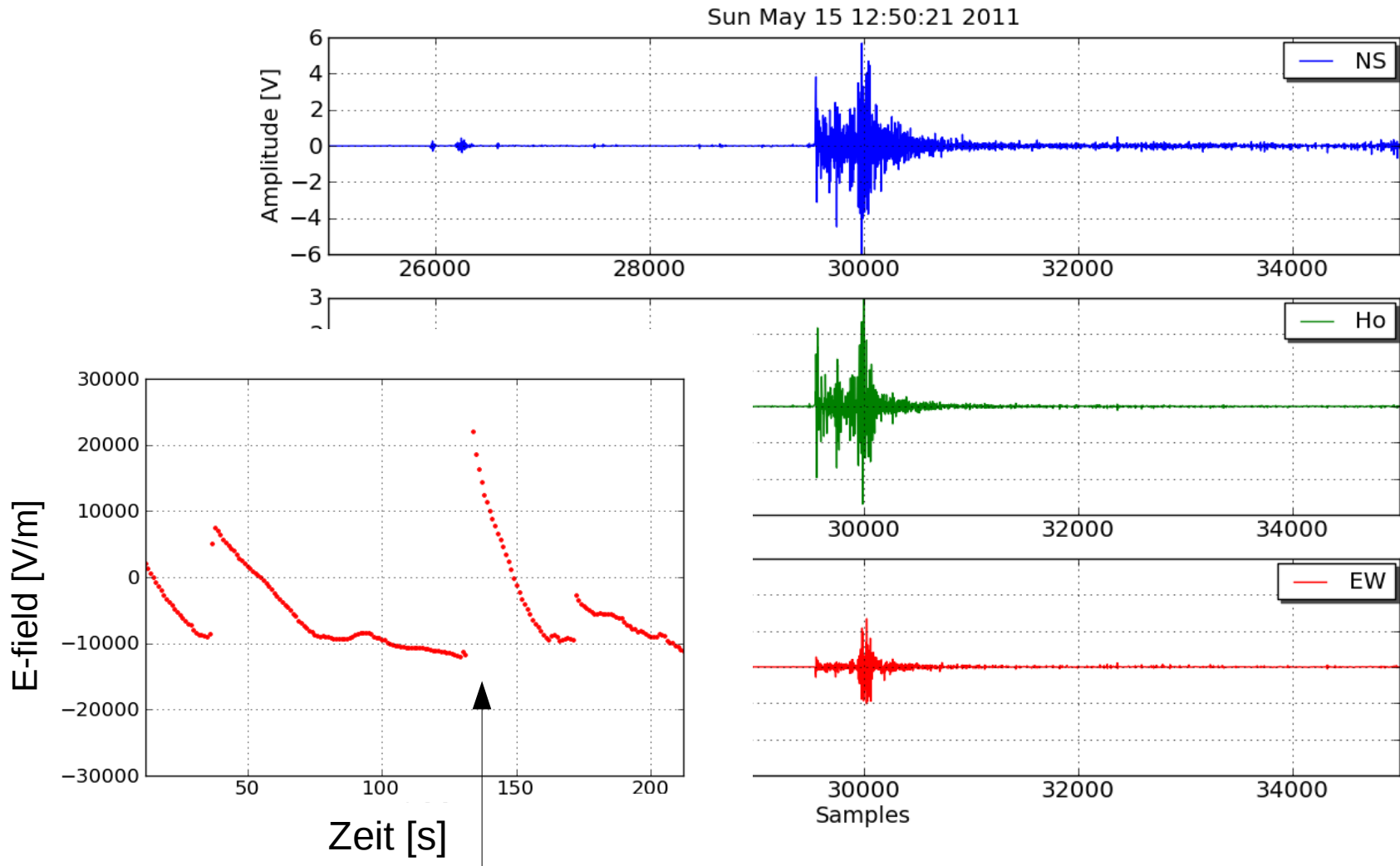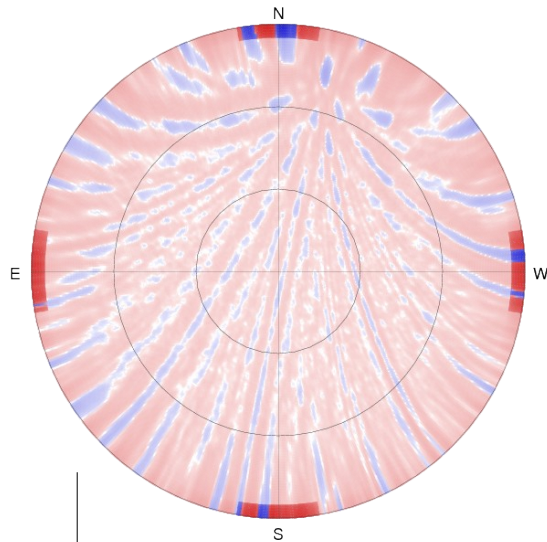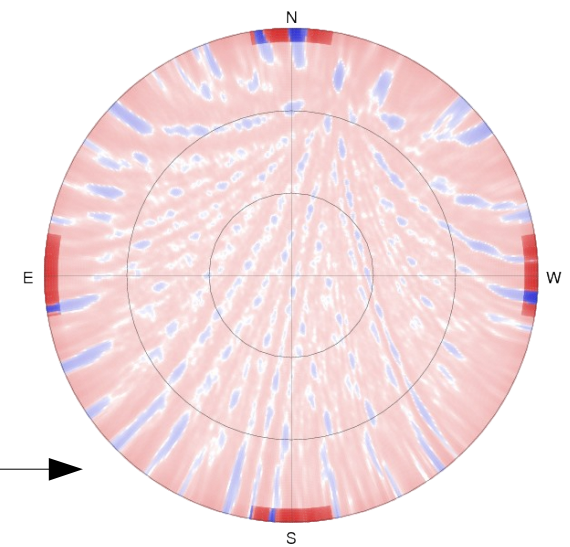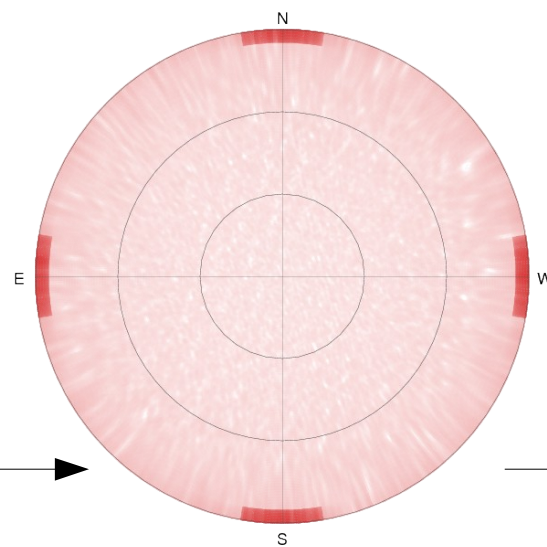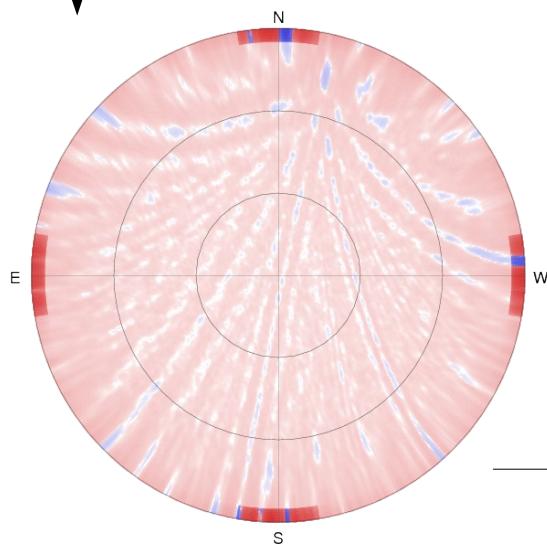
Conclusion

- Lightning mechanism is not completely understood
    - Runaway Breakdown with air shower!?
- E-field measurements
    - Efieldmill at LOPES and at Auger
    - Slow antenna installed at Auger
- Correlation Air shower with Lightning
    - Time correlation
    - Direction correlation
- kHz antennas:
    - Included in thunderstorm measurement
    - Many signals during thunderstorm
    - Lightnings measured in kHz and E-fieldmill
    - Waiting for more lightnings
- Thunderstorm season in Karlsruhe started

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Skymap

2008.06.02.19:03:49.887.event - 30 Antennen
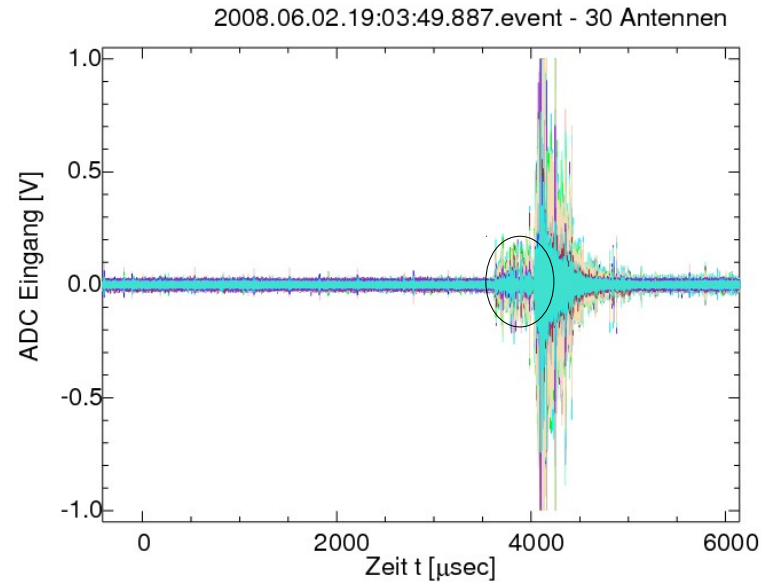
One skymap:
2µs of the trace

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Typical activity of CG-

- Preliminary Breakdown

- Stepped Leader
- Return Stroke

- Dart Leader
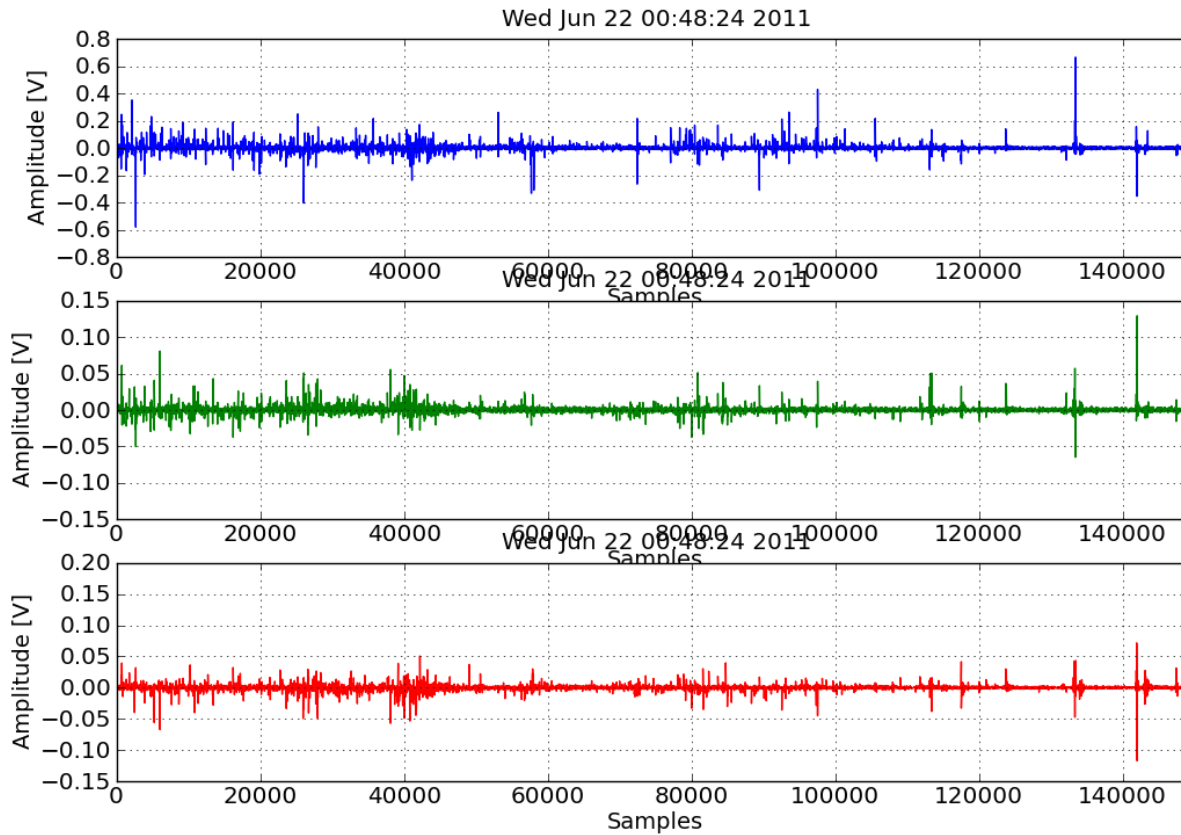- Return Stroke

- Dart Leader
- Return Stroke

....

Stepped Leader

Return Stroke

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KHz antennas

New update:
- Trace : 150 ms
- Entrance signal higher
- Protection against lawn mowers

KHz signals

■ Many signals during thunderstorms!

■ NS

■ Horizontal

■ EW

1 Sample: 1μs

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