Measurements with the absolute calibrated L-band radio antenna of CROME for extensive air showers

Philipp Papenbreer

University of Wuppertal

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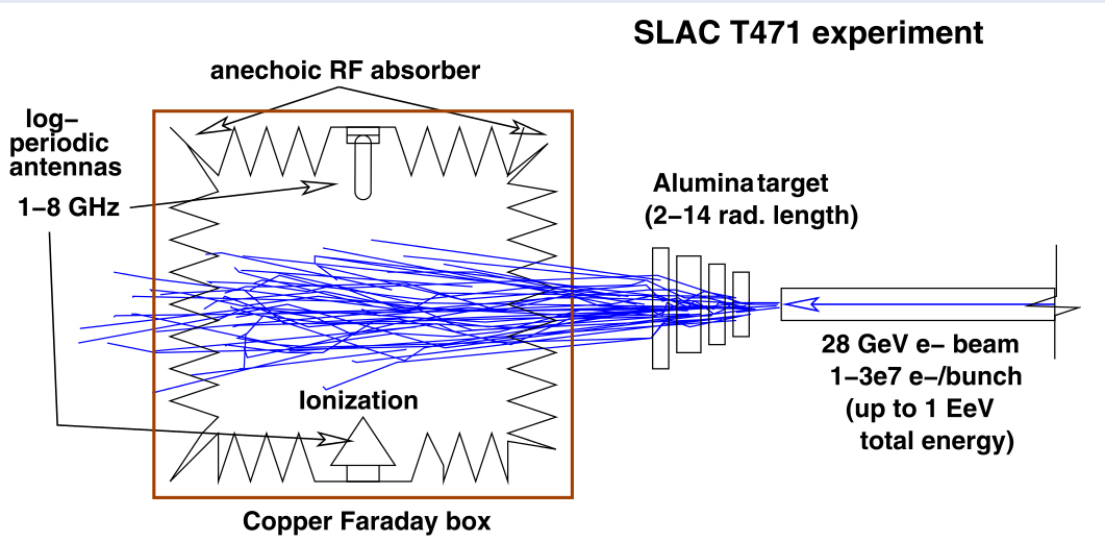
CROME-collaboration

BERGISCHE UNIVERSITÄT WUPPERTAL

Bundesministerium für Bildung und Forschung

Molecular Bremsstrahlung

- 2008: **Gorham et al.** experiment at SLAC
  $\rightarrow$ shower electrons produce **Bremsstrahlung at GHz frequencies**
- Measured power $\propto E_{\text{primary}}$ or $\propto E^2_{\text{primary}}$
- Isotrop und unpolarized signal
- Is this an **additional channel** to measure air showers?



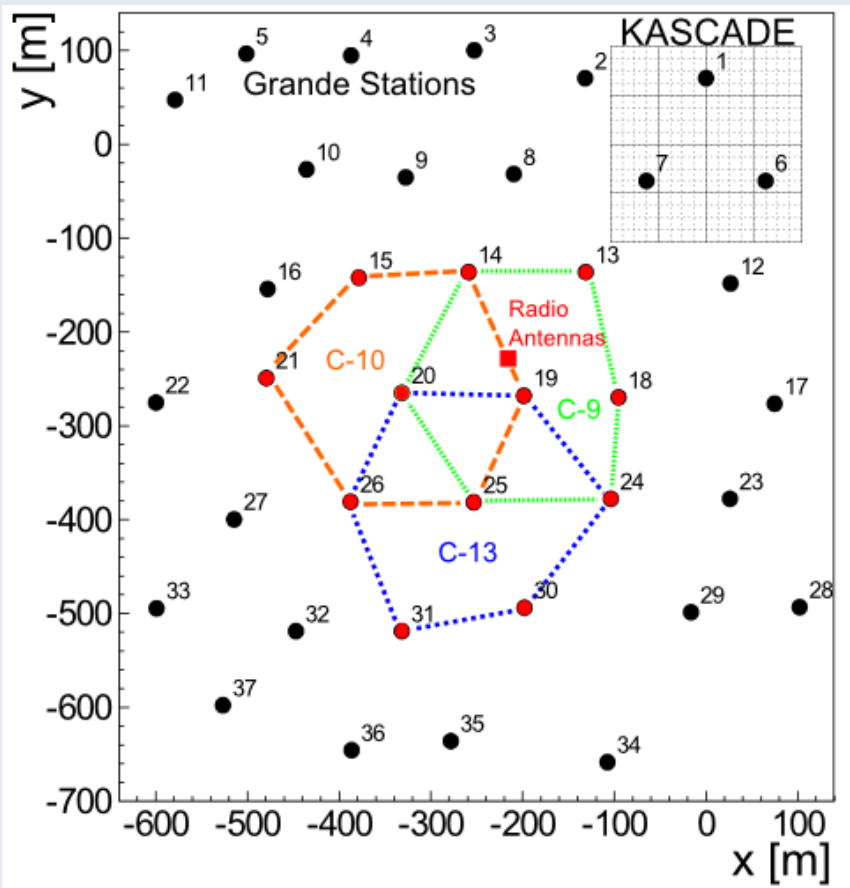
CROME

Cosmic **R**ay **O**bservation via **M**icrowave **E**mission

- Aim: **Measurement of air showers using radio antennas**
- 5 radio antennas (1.1 – 11 GHz)
- Triggered and shower informationen by KASCADE-Grande

KASCADE-Grande

KASCADE-Grande detector

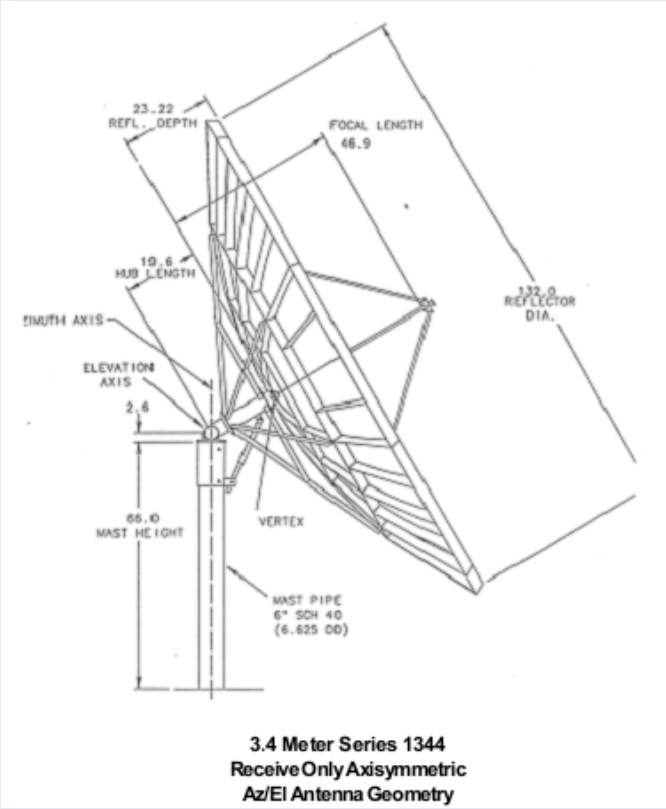


Specifications

- Air shower detector at KIT (Karlsruhe)
- 700×700 m^2 Detector area with 37 detector stations
- Plastic scintillators and photomultiplier
- Energy range up to 10^{18} eV

L-band antenna

Blueprint

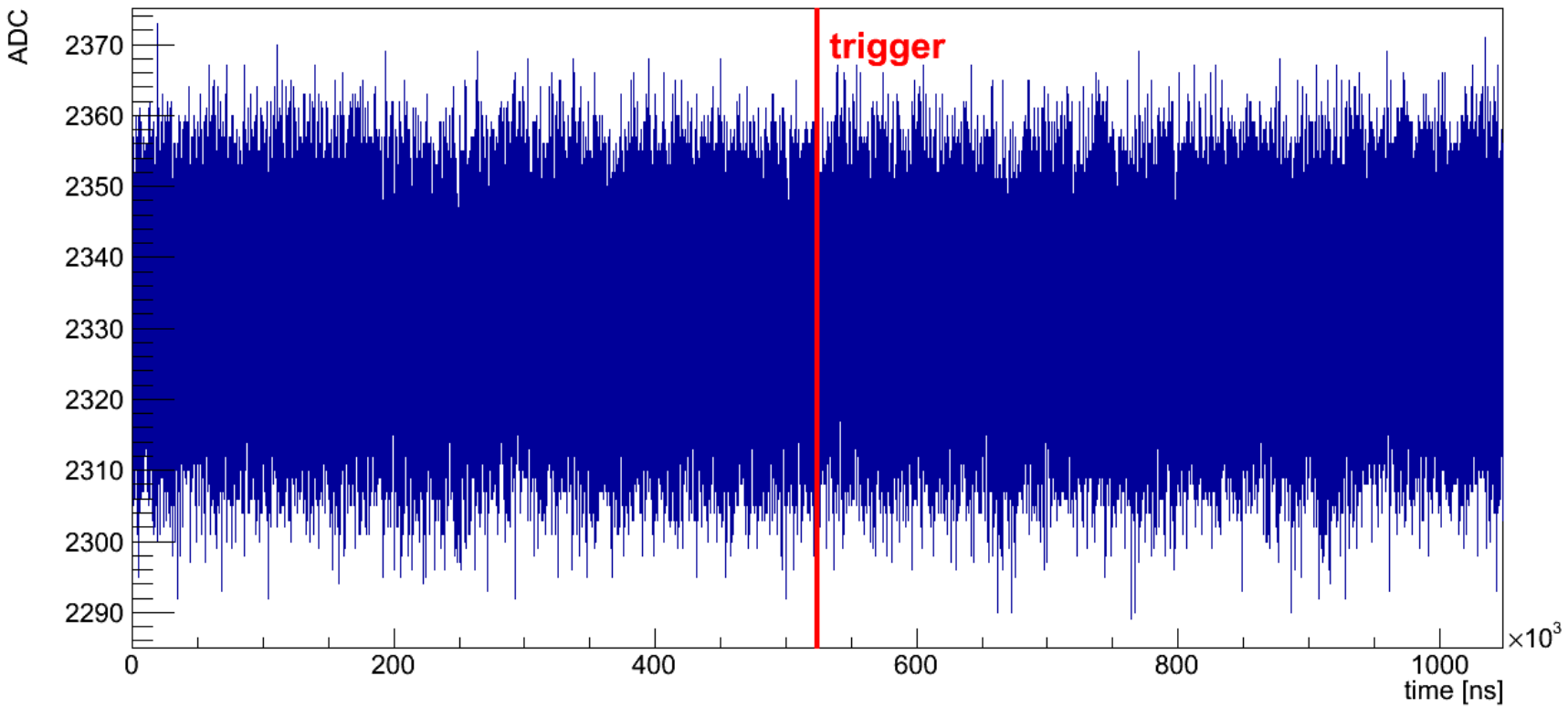


Antenna dish

Specifications

- 1.1 – 1.7 GHz energy range
- Frequency range limited by filters
- Logarithmic power detector (PD)
  - 4 ns-integration time /250 MHz sampling

Data traces



- Data traces of 1 ms length centered around trigger signal
- PD: Signals are **negative peaks** below noise level

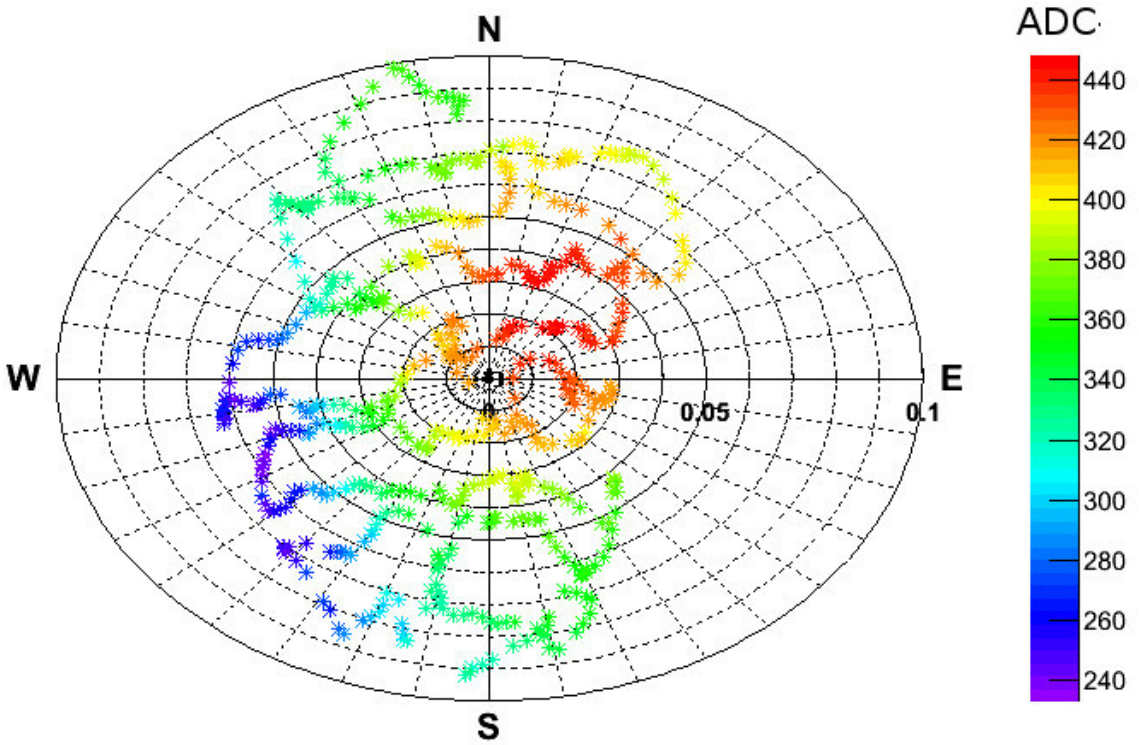
Calibration

Calibration using an octocopter

Measurements in good cooperation with KIT!

- **Aim:** Calculation of measured power/field strength from ADC values
- **Absolute calibration** using an octocopter
  with **GPS-sender** and **sending antenna** mounted

First results



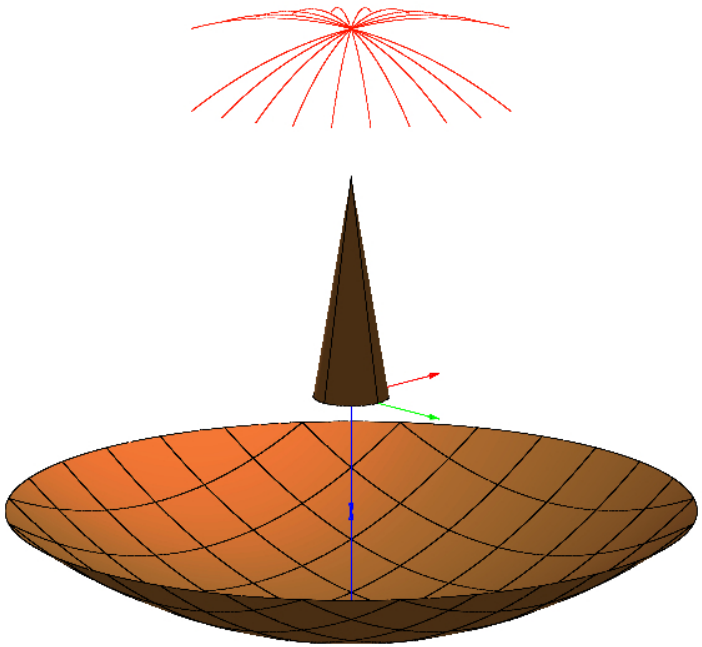
- **First results** already show a directivity with a **distinct mainlobe**!

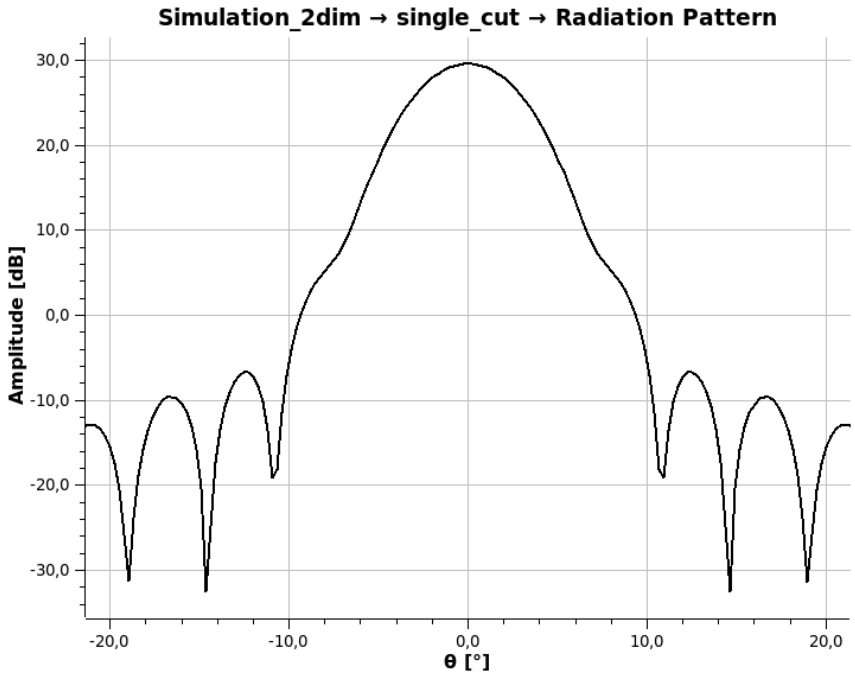
Friis-Equation

- **Friis-Equation** describes measured signal strength
  $P_R = P_T + G_T + 20 \cdot \log_{10}\left(\frac{\lambda}{4\pi d}\right) + G_R$
  depending from
  - oscillator power and gain of sending antenna (calibration measurement is known)
  - free-space path loss
  - Directional gain of receiver system **(wanted!)**

Antenna simulation

- **Modeling** for directivity of receiver system:
  → **Simulation** using GRASP

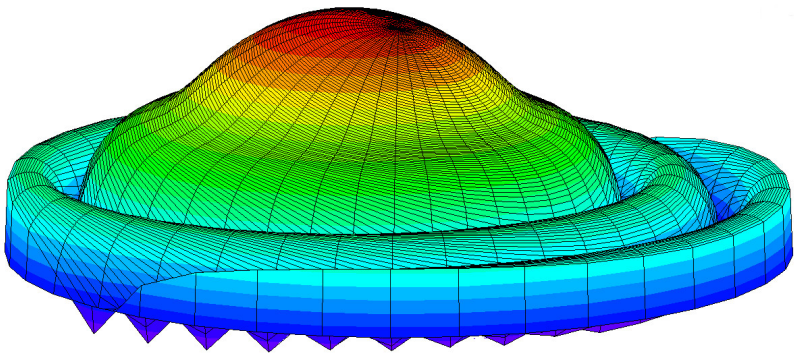


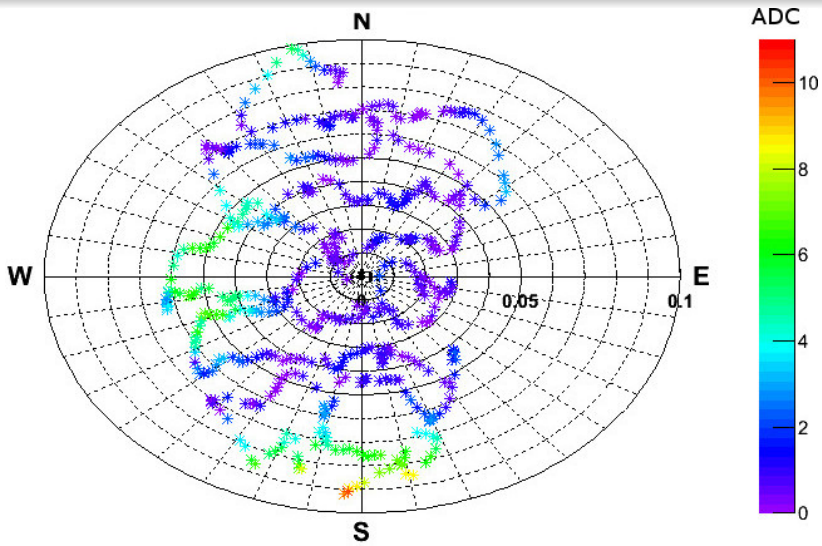


Fitting of results

1. Create **three-dimensional characteristic**
2. **Find parameters**, that describe measurement $\left(\frac{\chi^2}{\text{ndf}}\text{-fit}\right)$

directivity simulation of the receiver system





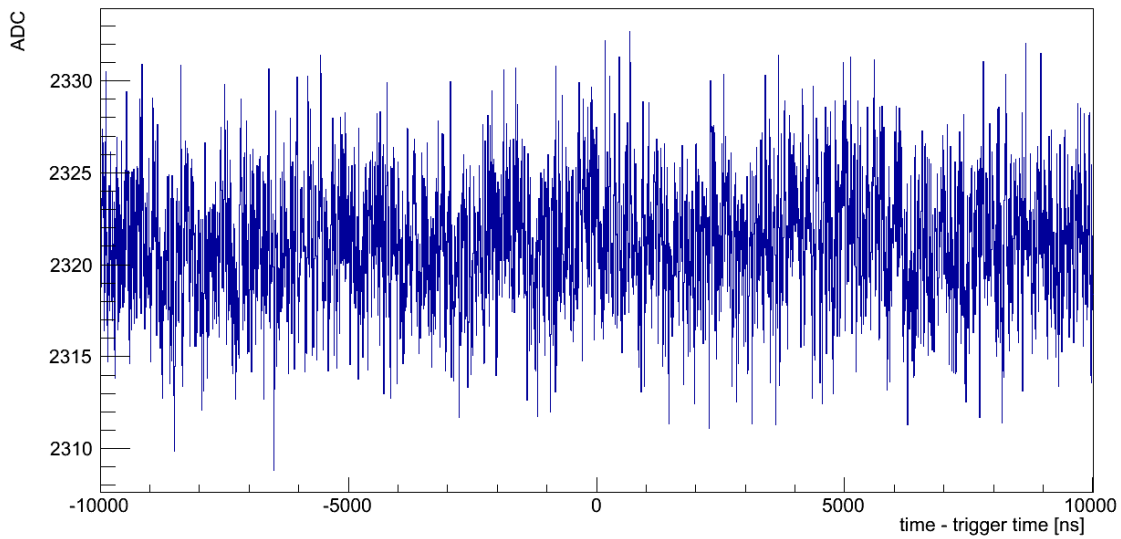
- **Main lobe azimuth** $= 34{,}34^\circ \pm 0{,}51^\circ_{\text{stat}}$, **zenith** $= 1{,}95^\circ \pm 0{,}02^\circ_{\text{stat}}$[a]
- **Gain** $= (26{,}45 \pm 0{,}03_{\text{stat}} \pm 3{,}79_{\text{syst}})$ dB
- Result of gain **matches** measurement of gain (≈ 27.5 dB) from electronics

[a] Direction of main lobe: additional systematic uncertainty of $0{,}83^\circ$ due to octocopter position

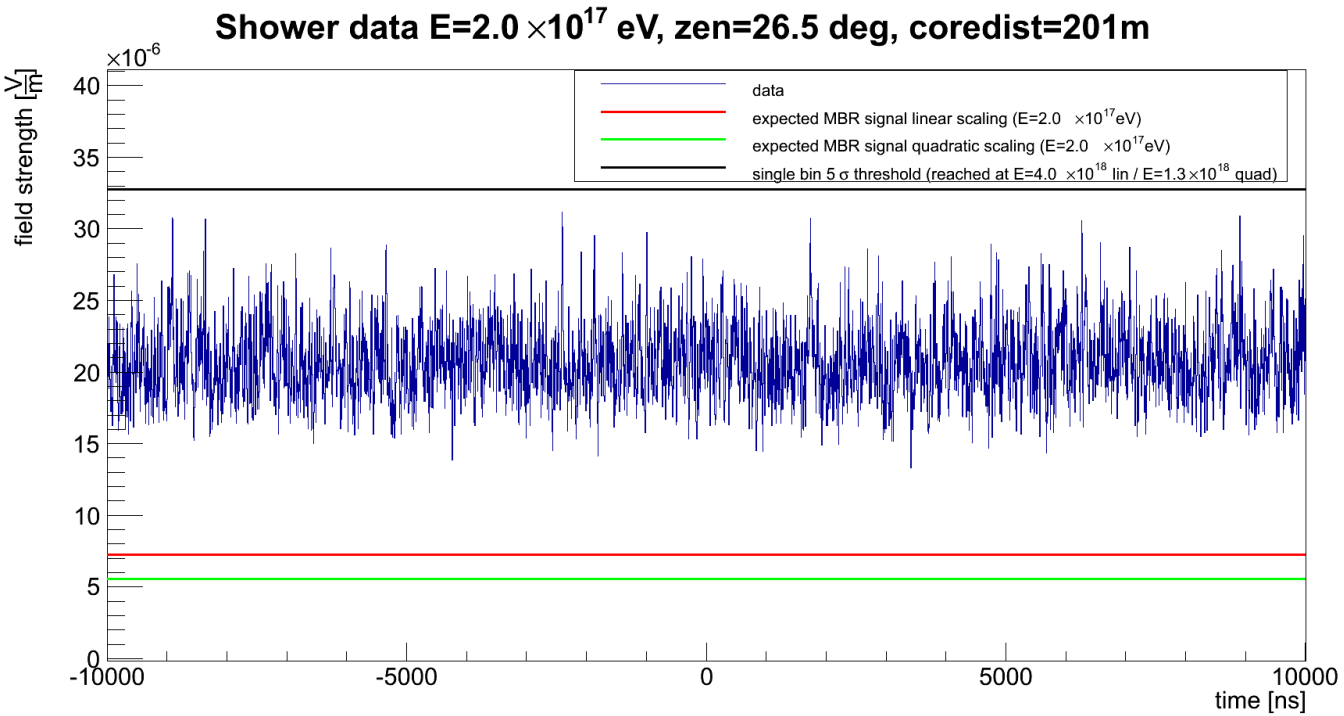
Signal search and comparison with expectations

Approach

- Select **showers**
- **Reconstruction** (clean traces & calibration)
- Read-out **time information** from trigger signals
- **Time synchronization** to shower arrival time (**No candidate found**)
- **Stacked analysis** by overlaying traces with appropriate delay (again: **no significant detection**)

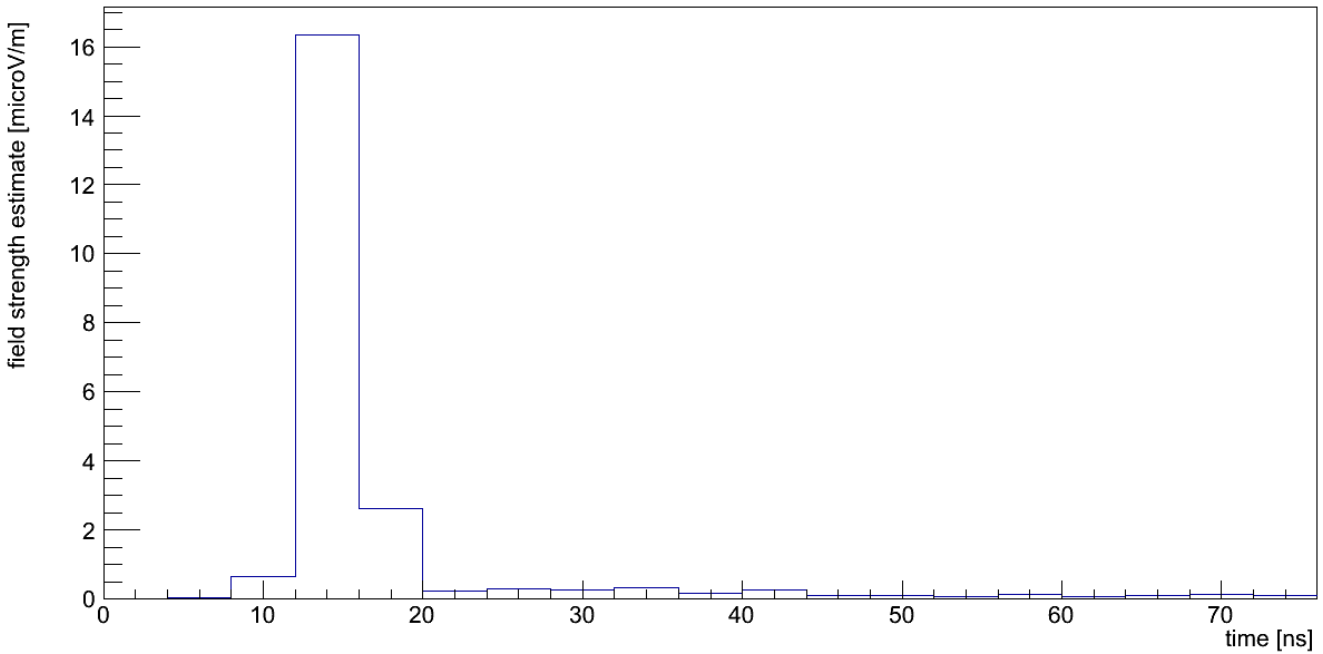


Comparison with MBR



- MBR predicts flux density $I_{\mathrm{f,exp,Gorham}} = 2.77 \cdot 10^{-24} \frac{W}{\mathrm{m}^2 \mathrm{Hz}}$ for a shower with $E = 3.36 \cdot 10^{17}$ eV of
- **Scaled to** the **energies and distances** of measured air showers
- Energy scaling could be linear or quadratical
- Results are **compared to** measured **noise level**

Comparison with CoREAS simulations



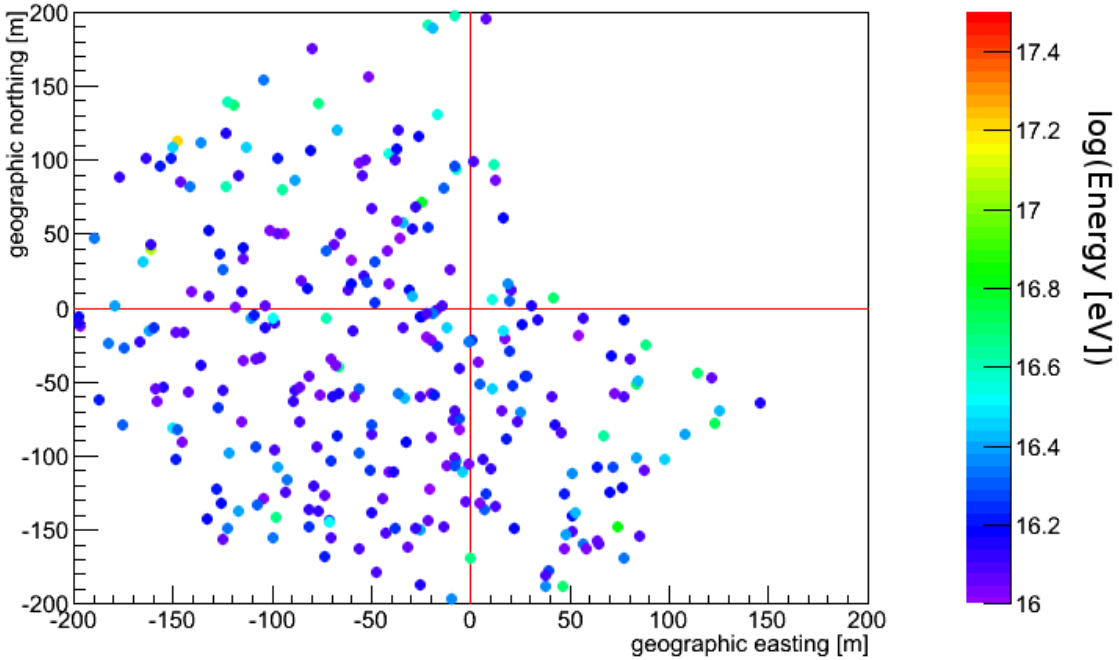
Approach

- Simulation of radio signals from measured air showers
- Get full bandwidth trace from CoREAS with a sampling of 10 GHz
- Multiply window function on FFT to limit frequency range to L-Band
- Apply a peak search on traces

Data Sample

Approach

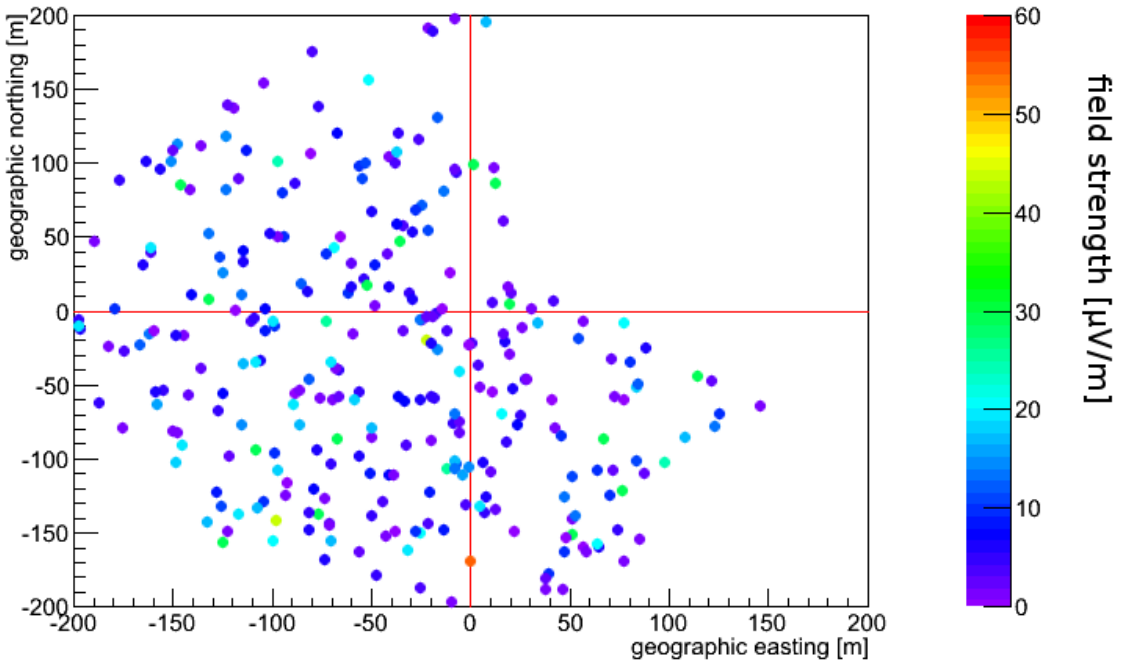
- Use showers with calibrated antenna setup,
  $E \geq 7.3$ EeV, core distance ≤ 200 m and use Kascade-Grande quality cuts
- Strong signals for showers propagating to south



Data Sample

Approach

- Searched traces of highest expected field strengths
- → No signal candidates found



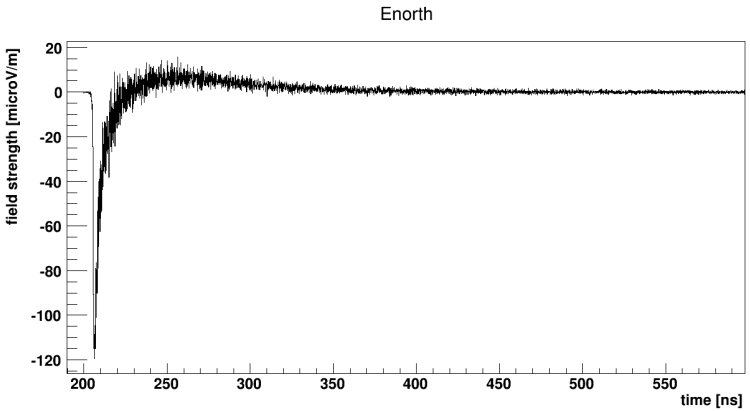
Summary

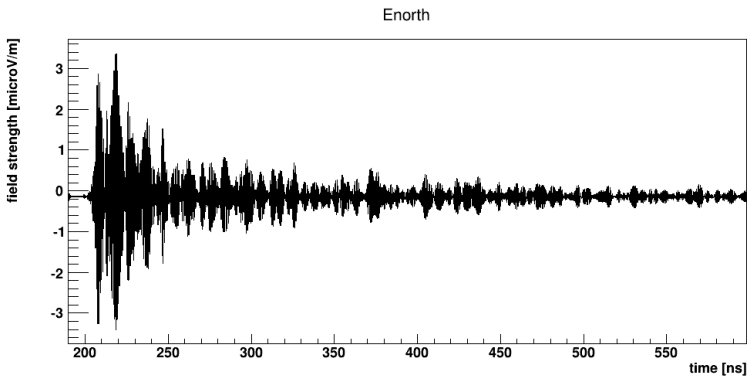
- **Receiver system** to measure air showers using a radio signal in the GHz range
- **Absolute calibration** of receiver system
- **Search for signals**
- **Comparison with MBR and CoREAS** expectations
  - $\rightarrow$ more amplification/measurement time needed

Thanks for your attention!

Backup

Comparison with CoREAS simulation

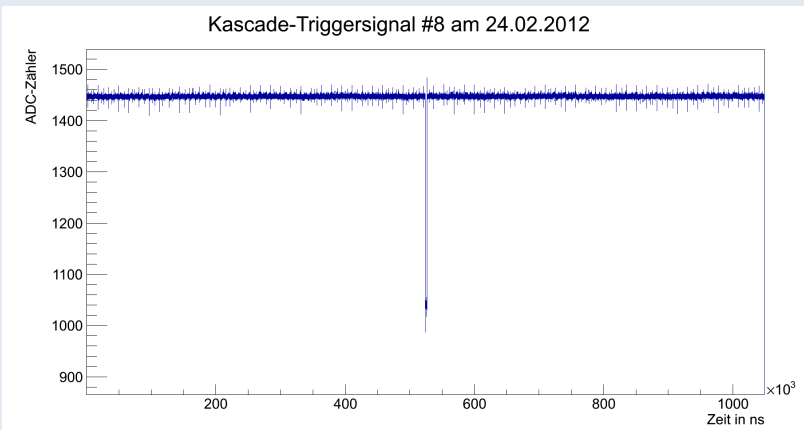




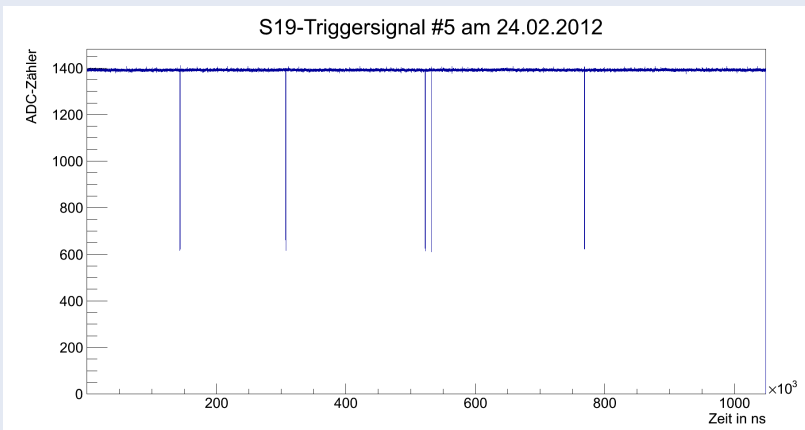
- Simulate measured air showers using CoREAS and small integration steps (0.1 ns)
- Calculate FFT and limit frequency range to L-Band using Hanning-window
- Get L-band signal with backwards transformation
- Comparison of results with data are in progress

A sample of traces..

KG trigger

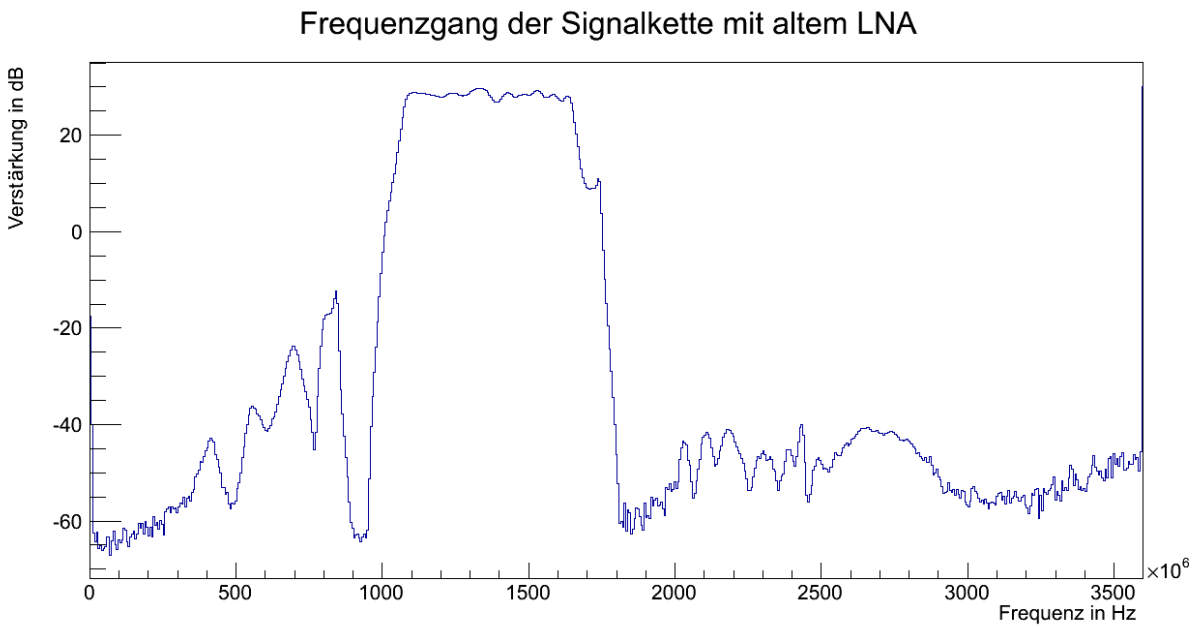


S19 trigger



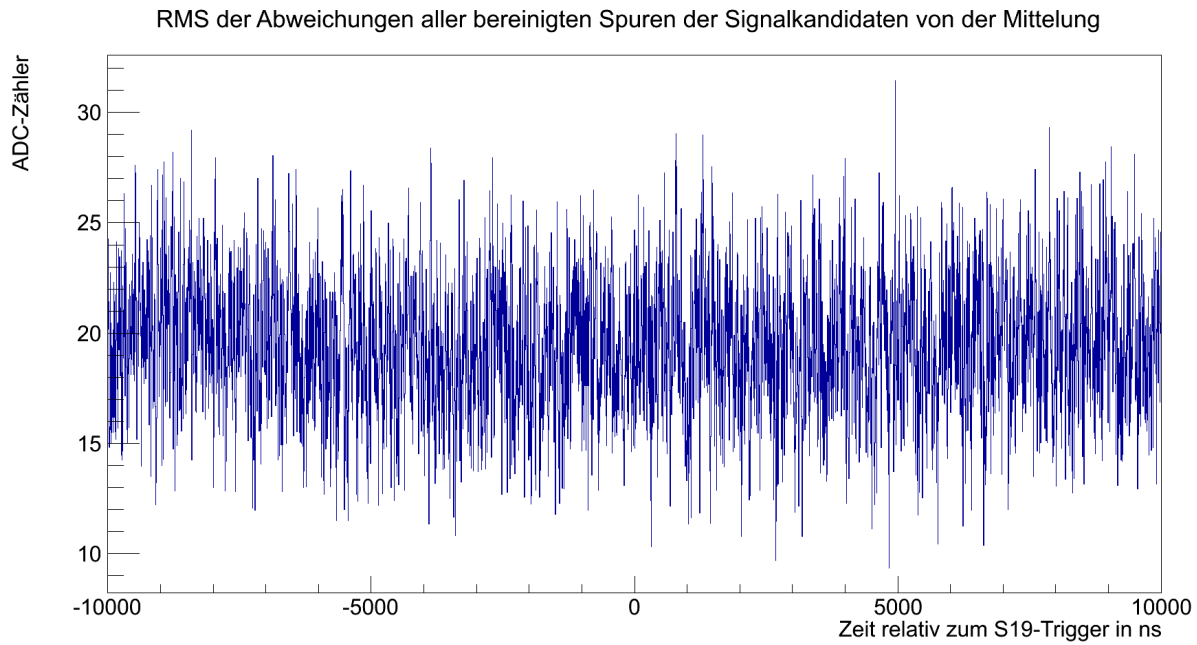
Comparison of calibration results to expectations

- calibration result:
  gain $= (26{,}45 \pm 0{,}03_{\text{stat}} \pm 3{,}79_{\text{syst}})$ dB
- **comparison to frequency response characteristic of data chain** possible



signal search using RMS

running RMS of candidate traces



calibration of power detector