New method of air shower observations with CROME

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Overview

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   - Calibration
3. Results
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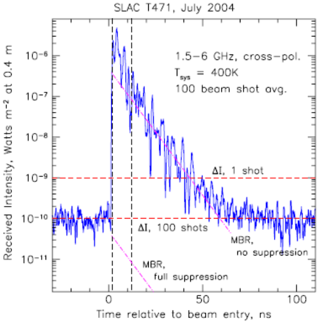
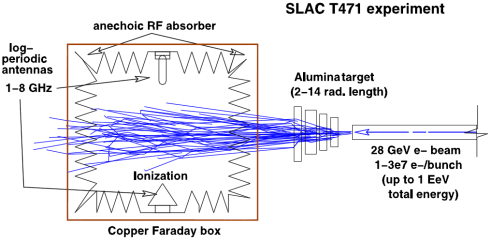
Theory





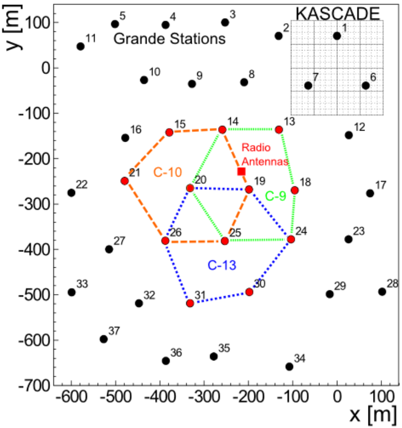
(Gorham et. al, Phys.Rev.D 78, 032007 (2008))

- Electromagnetical radiation, emission in the microwave spectrum
- Theoretical concepts: molecular bremsstrahlung (Gorham), Cherenkov radiation
- Transient: short-lived burst, $\sim$ ns, shape not predictable
- Comparable air shower: $\sim 10^{17} - 10^{18}$ eV
- Experiments (MIDAS, AMBER, CROME, EASIER; AMY, MAYBE) try to verify these results

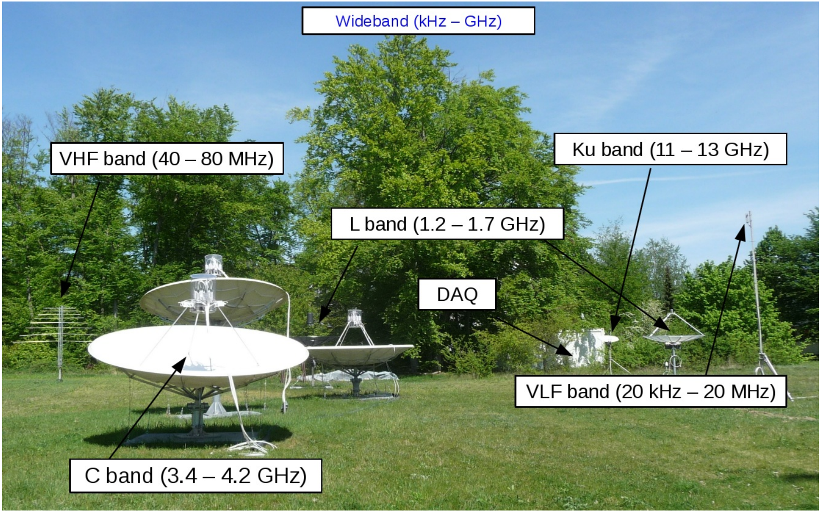
CROME at KASCADE-Grande

- Located in the KASCADE-Grande (KG) array
- Air shower energy: $10^{15.5} - 10^{18}$ eV
- Reconstruction uncertainties:

  arrival direction: 0.8°
  core position: 6 m
  energy: 20 %
- Triggering condition: 12 out of 12 nearby located KG-stations
- EAS-candidate selection via KASCADE-Grande reconstruction
- 800 trigger per day, 3 events per day reconstructed for E$>10^{17}$ eV and $\Theta<40°$.

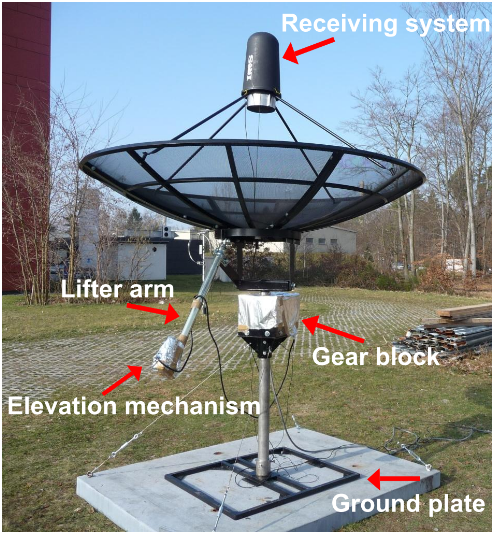


Overview of CROME antennas



L band radio antenna: first version

- Small Radio Telescope parabolic antenna
- D = 230 cm, F = 85.7 cm
- Beam width: 7°
- 360° az. and 90° el. rotatable
- Steering and supervision: Java-based program
    - Functions: 25 point scan, drift scan, tracking
    - Automatical computation of several astronomical objects



C band radio antenna

Dish:

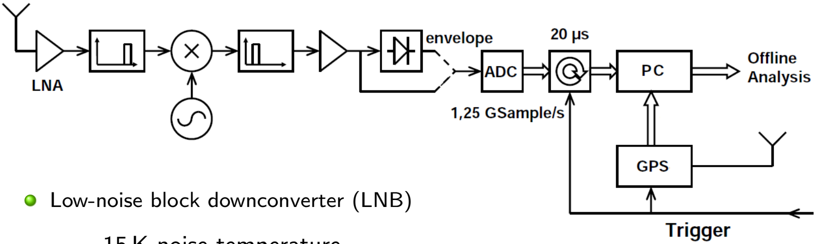
- Commercial available parabolic reflector
- D = 335 cm, F = 119 cm
- Gain: 40 dBi, HPBW = 1.6°
- Currently also used for the L band antenna

Camera:

- 3x9 linearly polarized feedhorns, single and dual
- Current setup:

  35 C band channels
  8 dual polarized receivers
  10 EW only, 9 NS only

Read out chain: C band



- Low-noise block downconverter (LNB)

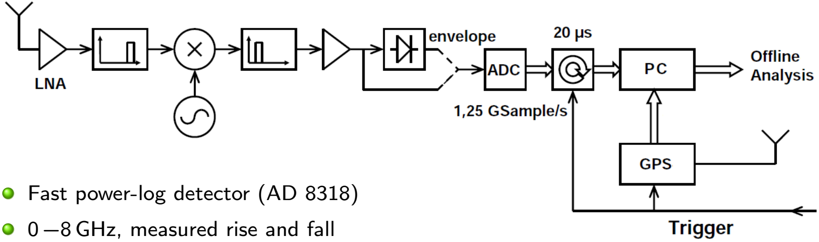
    15 K noise temperature
    64 dB amplification
    input frequency: 3400 MHz-4200 MHz
    output frequency: 950 MHz-1750 MHz

- 6 dB attenuator:

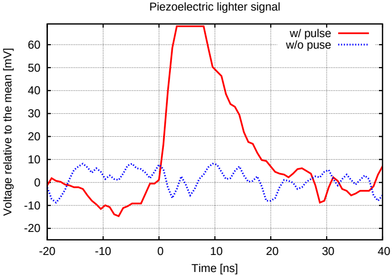
    suppress reflections due to impedance mismatching

- High pass filter 1.2 —1.8 GHz: suppress airplane altimeter radars (4.3 GHz)

Read out chain: C band



- Fast power-log detector (AD 8318)
- 0 —8 GHz, measured rise and fall times: 4 ns (modified)
- Digitizers: 8-bit resolution, 0.8 ns sampling time
- Traces of 10 µs before and after a trigger are stored
- GPS clock for offline merging CROME and KG data



PicoScope and GPS satellite receiver

PicoScope:

- PicoScope 6402 and 6403 USB Oscilloscopes
- 4 channels, 8 bits vertical resolution
- 250 MHz (350 MHz) bandwidth
- Rise time 1.4 ns (1.0 ns)
- 200 ps time resolution
- 5 GS/s real-time sampling (1 channel single shot, 1.25 GS/s when 3 or 4 channel in use)
- Input sensitivity: 10 mV/div
- Integrated function generator and spectrum analyzer

(www.picotech.com)

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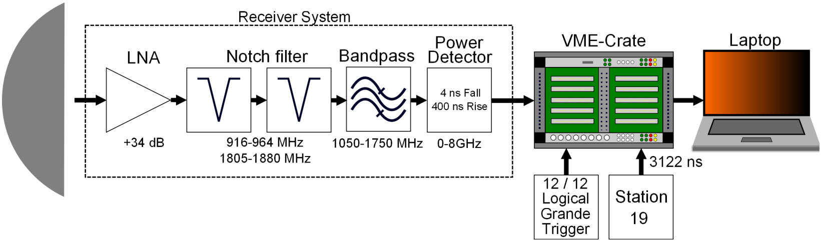
GPS clock:

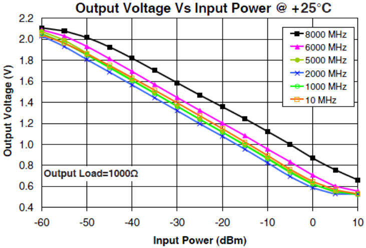
- Meinberg GPS167 Satellite Receiver for high precision timing information
- Buffer for 500 events or continuous stream of asynchronous time events

(www.meinberg.de)

Read out chain: L band



- LNA: 1200 — 1700 MHz, $\sim$ 30 dB
- Notch filter: 916 — 964 MHz, 1805 — 1880 MHz, $\sim$ −50 dB
- Band-pass filter: 1050 — 1750 MHz
- Power-Log detector: 0 — 8 GHz, rise: 4 ns, fall: 4 ns (modified)



Data acquisition L band

- VME Crate with 2 modules, SIS3150 and SIS3320 (SIS3300 also used, extendable up to 7 modules)
- Communication via SIS3150-USB (USB 2.0 possible)
- External hardware trigger: KASCADE-Grande
- Time calibration via digitalisation of KG-Station 19
- C based read out program, fully customizable
- Data amount: roughly 1 GB/day

Struck SIS3320

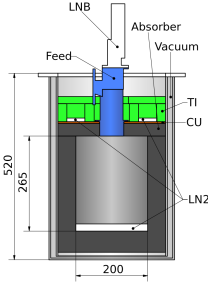
(www.struck.de)

- 8 channel 12 bit FADC VME card
- Sampling rate: 40 MHz-250 MHz per channel
- 32 MSamples/channel memory
- 100 MHz bandwidth
- Offset DACs
- Internal/External clock
- Simultaneous read out and acquisition possible
- In field JTAG and VME firmware upgrade capability

Struck SIS3320 - custom implemented features

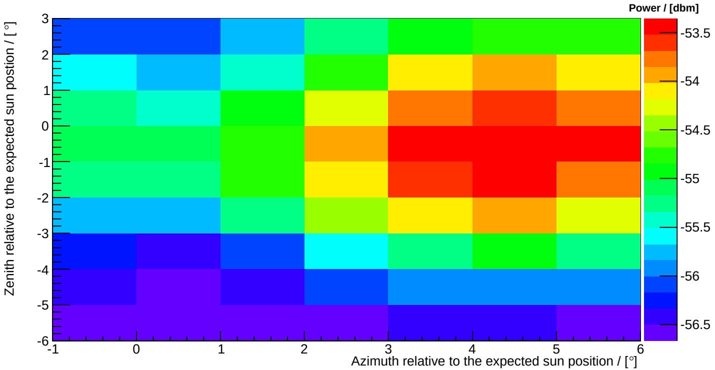
- Multi event mode: memory subdivided in variable number of parts → acquisition of events with a high trigger rate more efficient
- Single event: contiguous memory for more data samples
- Post triggering: trigger time unknown → half of the traces stored before and after the trigger, no data is lost
- Continuously 250 MHz sampling
- 262144 data samples per trace, ~ 1 ms
- Parallel use of additional SIS3300 cards (100 MHz)

C band calibration



- Calibrated microwave emitter (voltage controlled oscillator) with different modes (continuous wave, triggered pulse and triggered sweep)
- Octocopter: electronically stabilised, programmable flight path, radio link to a computer
- Microwave absorbing foam at room 293 K and liquid nitrogen 77 K temperature in a shielded vessel

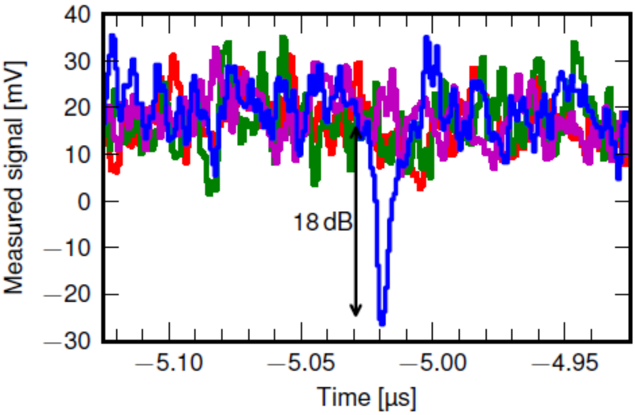
L band: 2D sun scan



- Grid with spacing of 1° around expected sun position
- ∼3.5 dBm enhanced signal level compared to cold sky (∼ -57 dBm)

Event example: C band trace

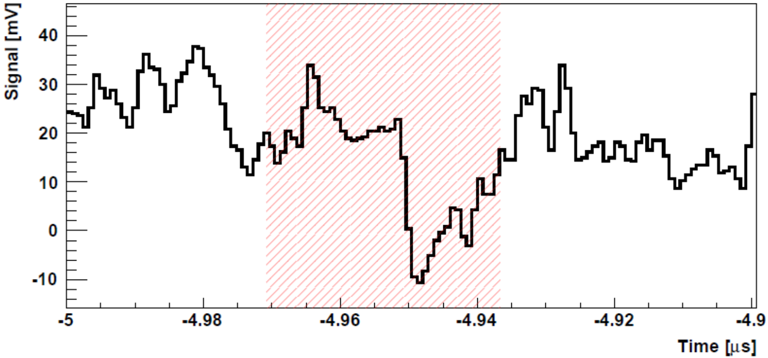
$E_0=2\times10^{17}$ eV, $R_C=120$ m, $\Theta=7°$



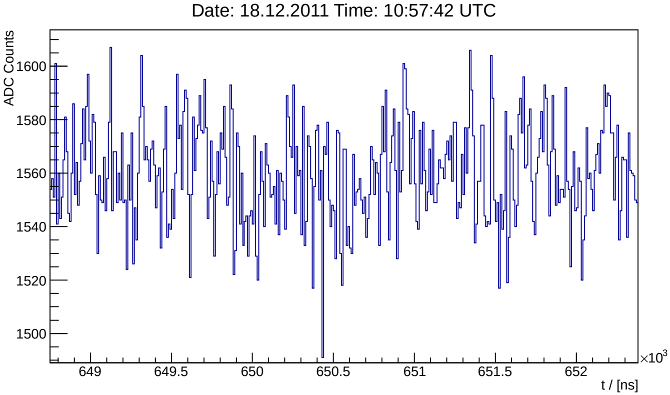
- Short pulse with 10 ns order of magnitude visible in the C band

Event example: 18.12.2011 - C band trace

$E_0=5\times10^{17}$ eV, $R_C=98$ m, $\Theta=5°$

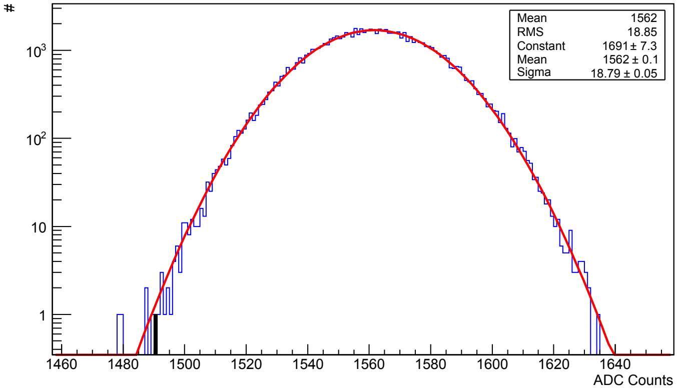


Event example: 18.12.2011 - L band trace



- Expected signal: t $\sim$650 460 ns
- Signal above the noise level also seen in L band

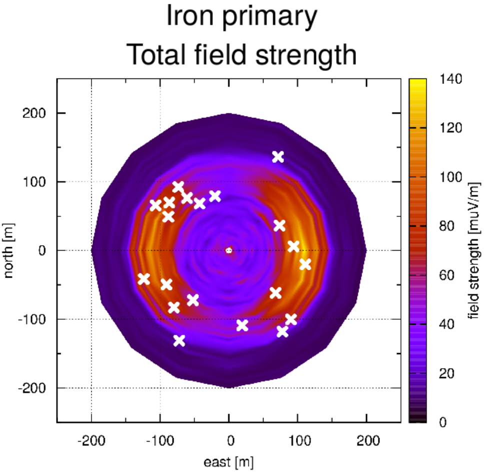
Event example: 18.12.2011 - L band amplitude distribution



- 80000 entries, only 5 with higher signal
- Peak value is 3.78 σ off the mean value (single bin probability)

CoREAS

- MC Simulation of radio emission from MHz up to GHz frequencies
- Implemented the endpoint formalism directly in CORSIKA, no histogramming needed anymore
- Broken ring structure on ground
- 20 measured events with core distances between 80 m and 150 m
- Ring structure → Cherenkov cone?



(F. Werner, ARENA2012)

Summary and Outlook

- Presentation of the CROME experiment
- Description of the signal chain and the DAQ of the L and C band antennas
- Calibration methods to estimate system temperatures
- CROME has measured 20 events (C band) within 356 days since May 2011 but the analysis is still ongoing
- First event candidate with a visible signal above the noise level coincident measured in the L band

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- KASCADE-Grande has been shut down on Nov. 5, 2012, no new data at the moment
- Absolute calibration of the receiving system and estimation of the expected sensitivity level with octocopter flights (L band)
- Polarisation studies (C band)

Thanks for your attention!