



Cosmic-Ray Observation via Microwave Emission (CROME)



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Outline

Talk about the CROME experiment:

Detector

Performance

Calibration

Measurement

Conclusion and outlook

CROME experiment

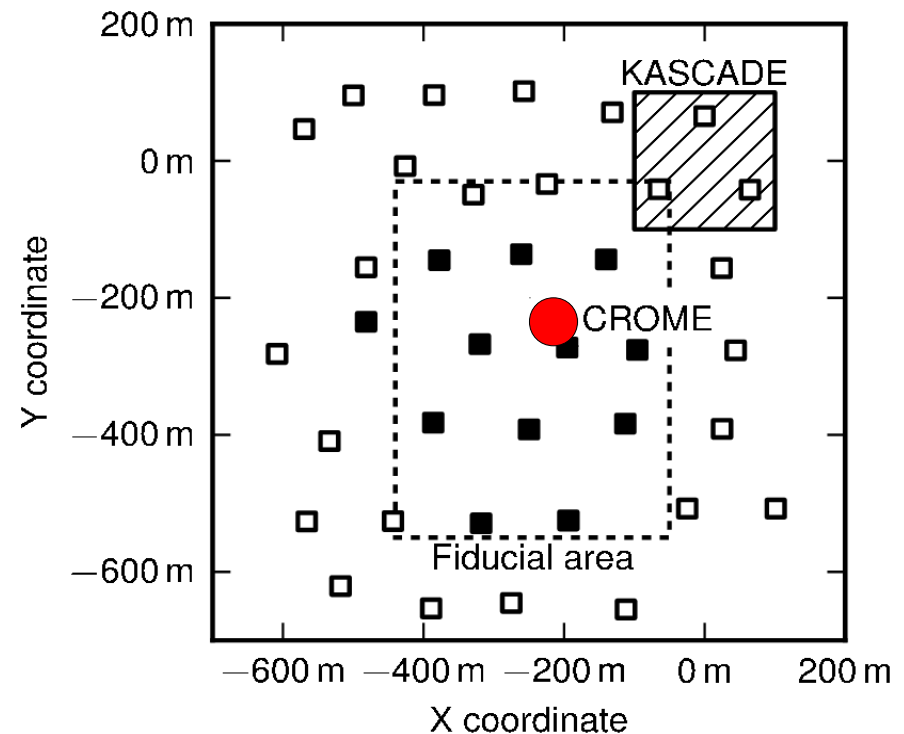
Located in the center of the KASCADE-Grande (KG) array:
*Even if the KG experiment is in the phase,
It still provides a trigger and reconstruction.*

Energy range $10^{15.5} - 10^{18}$ eV

Two air showers reconstructed
above 10^{17} eV and zenith angle
< 40° in a fiducial area per day

12 inner stations provide the trigger

Reconstruction uncertainties:
*0.8° for the arrival direction
6 m for the core position
20% for the energy*



Overview of antennas

Antennas pointed vertically upward:

- 1) to amplify a signal due to time compression
- 2) to minimize distance to the shower maximum

VHF band (40 – 80 MHz)

Ku band (11 – 13 GHz)

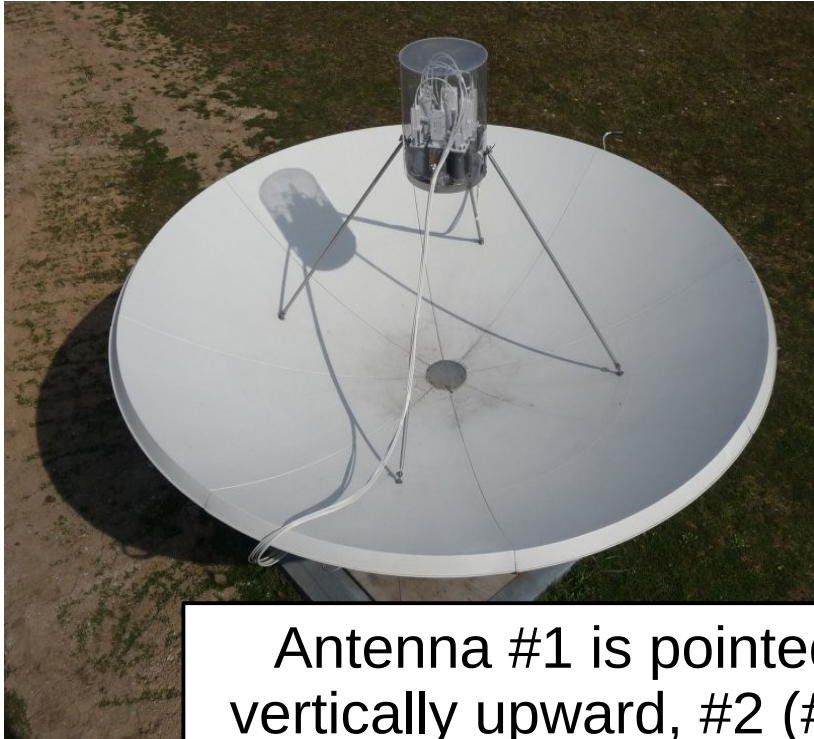
L band (1.2 – 1.7 GHz)

VLF band (20 kHz – 20 MHz)

C band (3.4 – 4.2 GHz)

Wideband (kHz – GHz)

C band antennas



Antenna #1 is pointed vertically upward, #2 (#3) tilted by 15° towards N (S)

Linearly polarized feedhorns:
Single and dual
High illumination efficiency
and small spillover

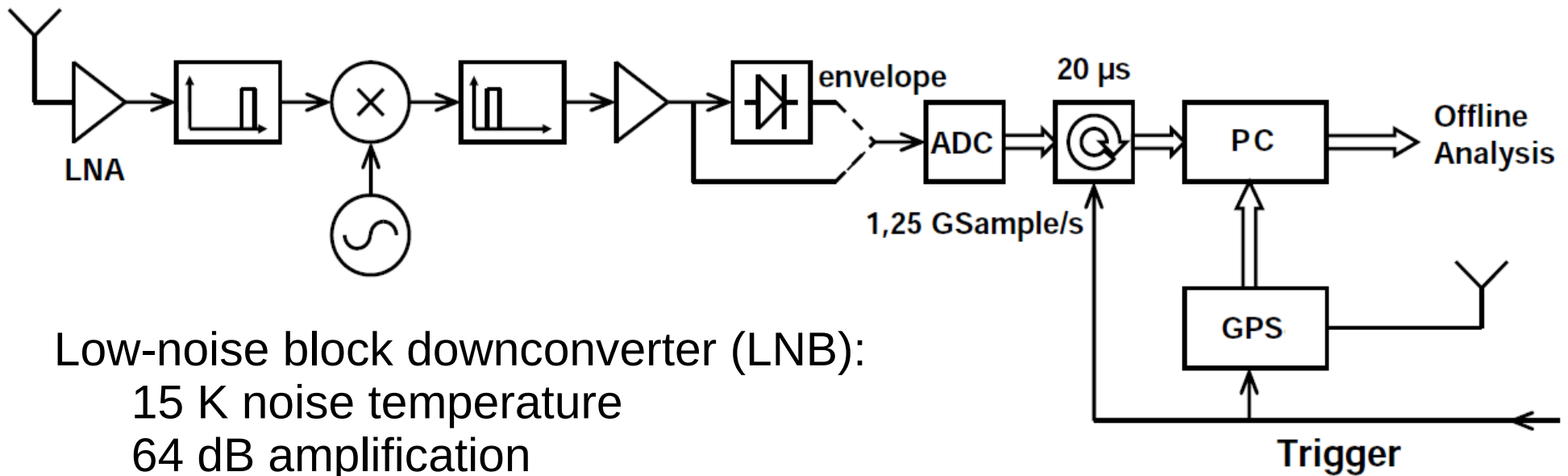
Commercial parabolic reflectors:
C and Ku band
 $D = 335 \text{ cm}$, $F = 119 \text{ cm}$

Specifications:
 40 dBi gain , 1.6° HPBW

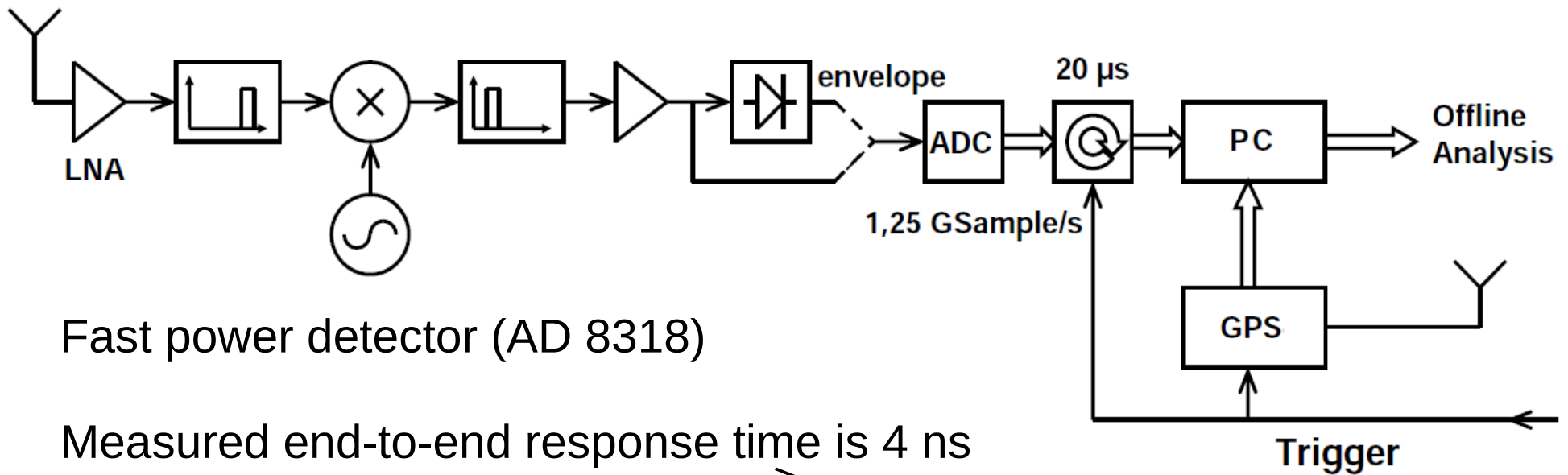


Multi-feed camera

Readout chain I.



Readout chain II.



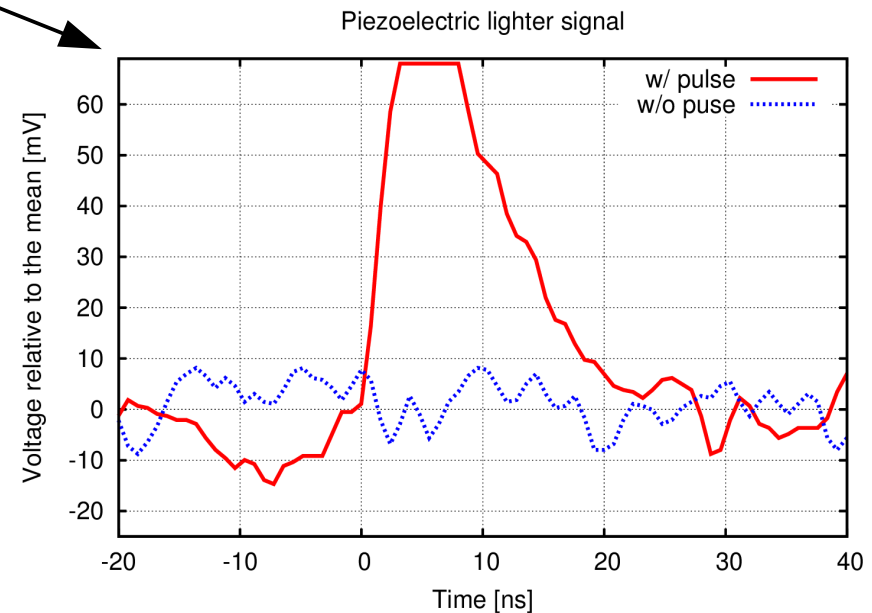
Fast power detector (AD 8318)

Measured end-to-end response time is 4 ns

Digitizers with 8-bit resolution and 0.8 ns sampling time

Traces of 10 μ s before and after a trigger are stored

GPS clock (offline merging CROME and KG data)



Calibration of receivers

Microwave absorbing foam at room (293 K) and liquid nitrogen (77 K) temperature in a shielded vessel

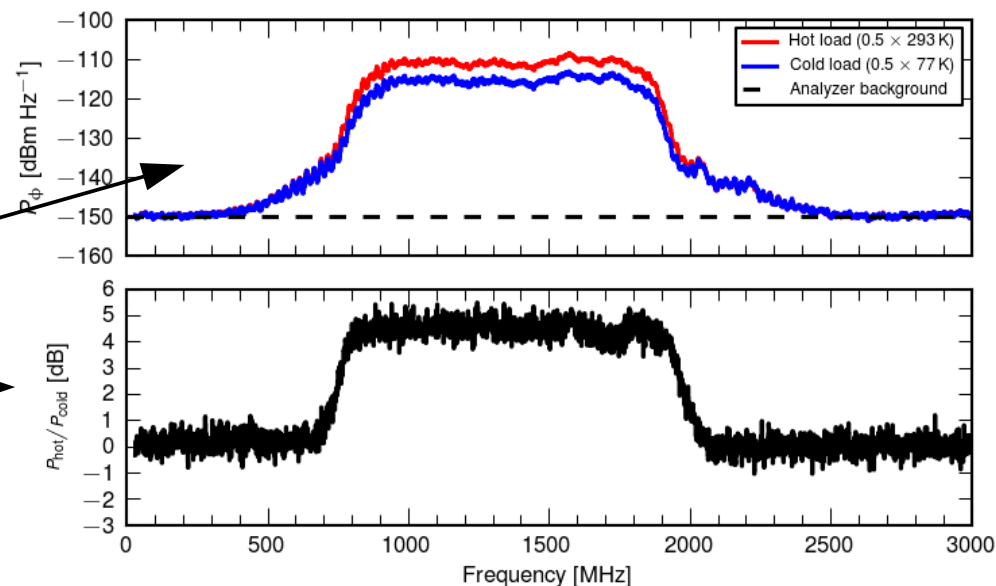
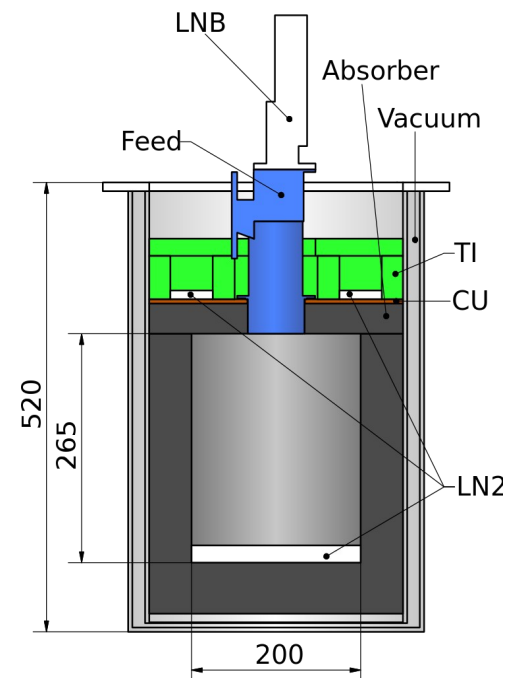
Same electronics as in the experiment or with a spectrum analyzer

LNBS were measured before their installation

Also LNBS used in other experiments were tested.

Noise temperature (24 ± 2) K

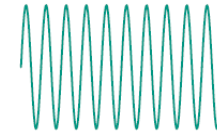
Flat frequency response



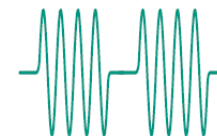
End-to-end calibration



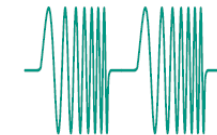
Calibrated microwave emitter
(voltage controlled oscillator)
Up to 8 dBm (6 mW)
Different modes
2.97 – 3.95 GHz



Continuous wave
• selectable frequency

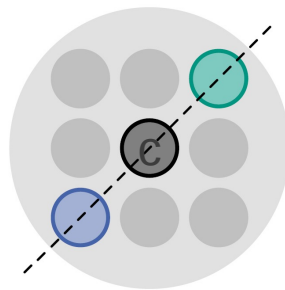


Triggered pulse
• 60 μ s–180 ms length
• rate up to 10 kHz



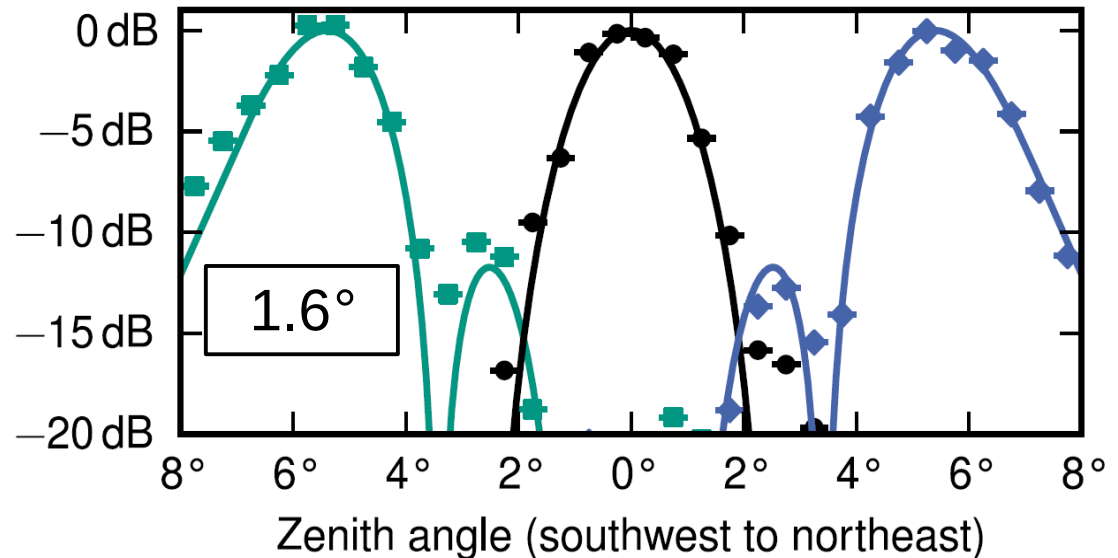
Triggered sweep
• frequency sweep
over full range

Mikrokopter flying platform:
Electronically stabilised
Programmable flight path
Radio link to a computer

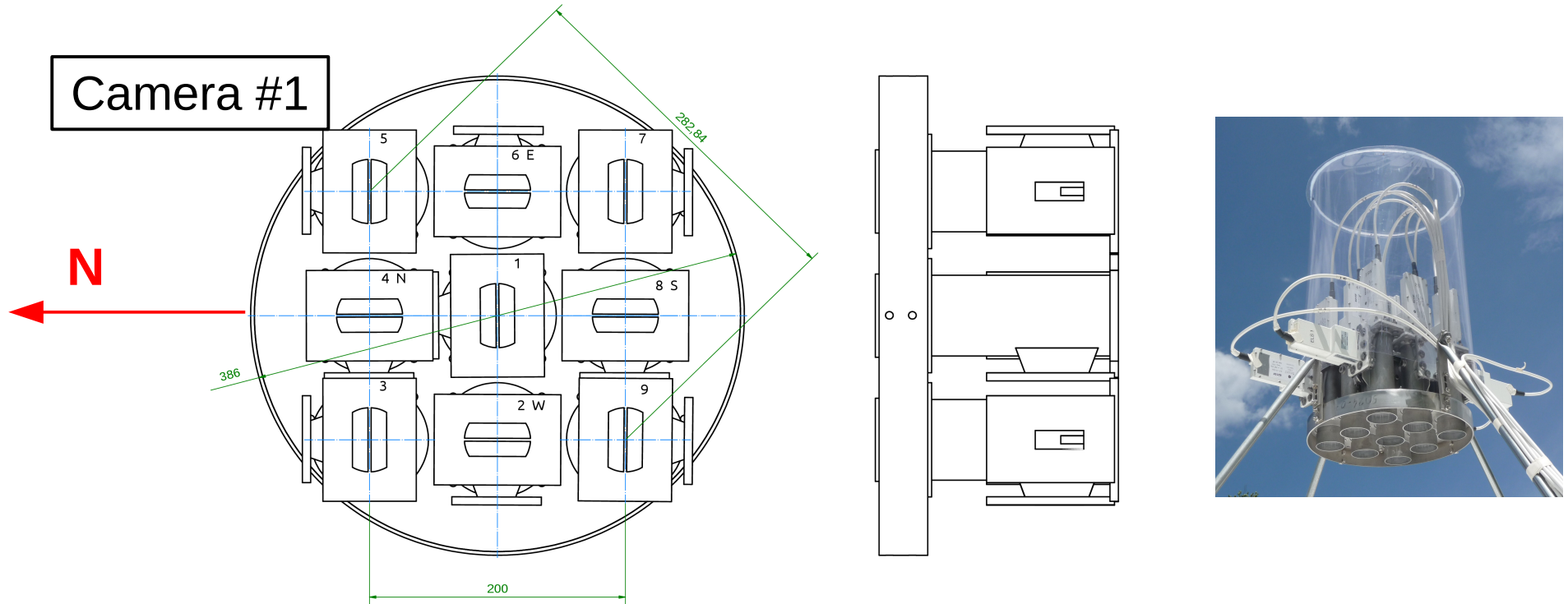


$$T_{\text{sys}} = 50 \text{ K}$$

Analysis isn't finished yet.



Polarization



Current setup:

- 35 C band channels in total

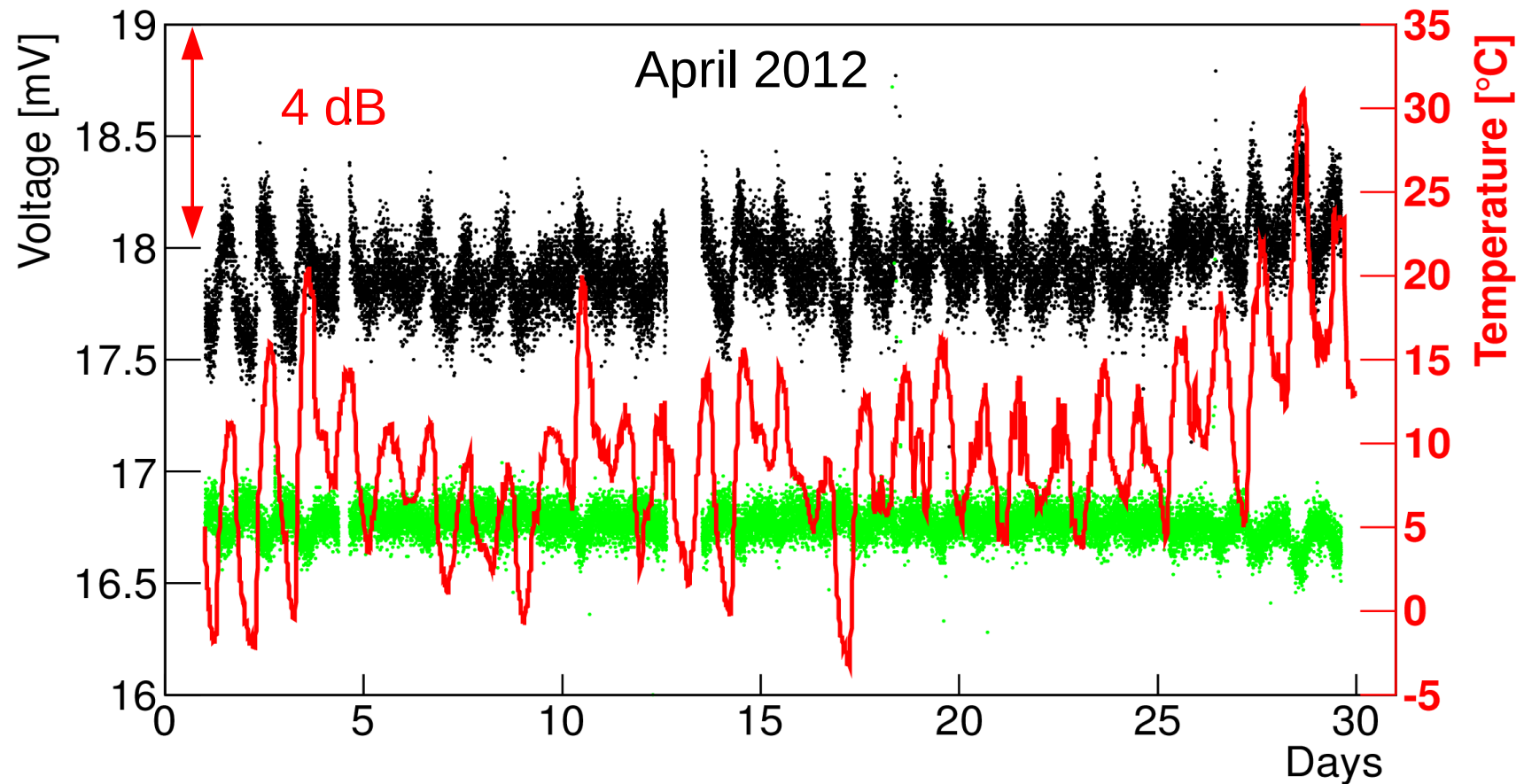
- 8 are dual polarized receivers (i.e. with 2 LNBS)

- 18 LNBS with EW

- 17 LNBS with NS

First 2 cameras were rotated by 20° and 9° relatively to the NS projection of the local geomagnetic field before Jun, 2012.

Temperature stability



Average voltage in a trace

Voltage RMS in a trace + 11 mV

Temperature at 2 m above the ground

Integrated exposure

Period:

May 4, 2011 – installation of fast electronics

May 21, 2012 – available data analysis

In total **383 days** (9200 h)

Dead time:

510 h – KG: quality cuts and hw failures

150 h – CROME: test measurements, upgrades, failures

It gives **72%** uptime in total.

Receivers:

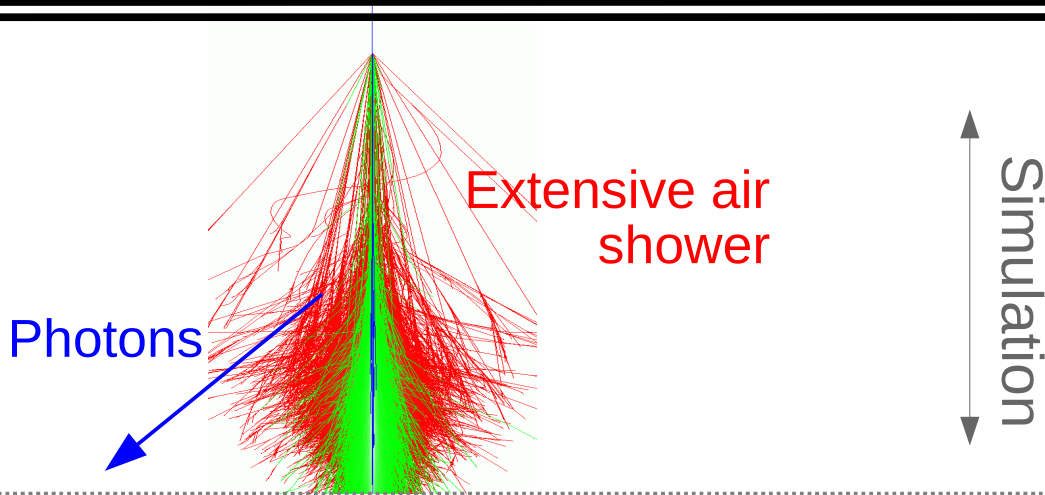
18 between May 4, 2011 and April 4, 2012

27 between April 4, 2012 and May 21, 2012

HPBW = 1.6°

Integrated exposure: **50.2 deg² yr**

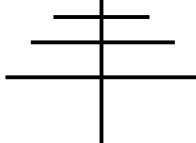
Propagation time



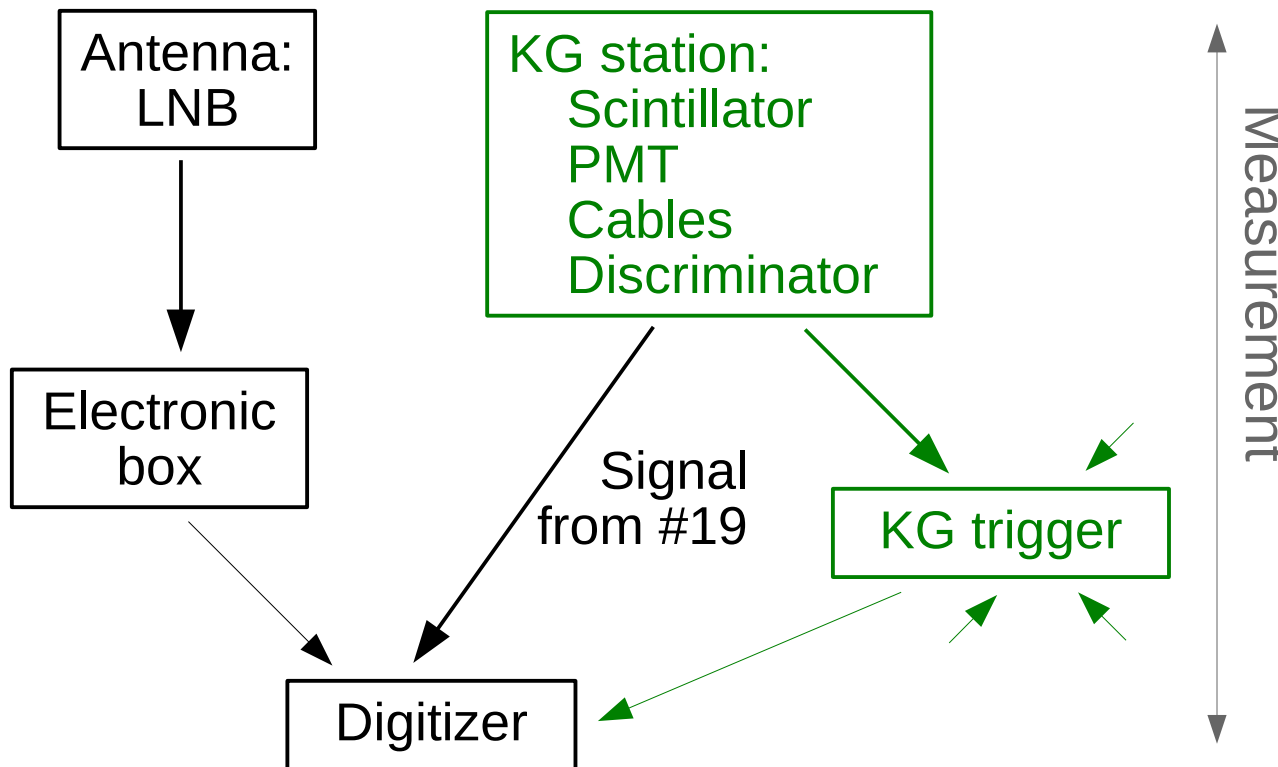
10 ns pulse is expected for a vertical shower.

Trace of 10 μ s before the trigger.

Precise timing is very Important!

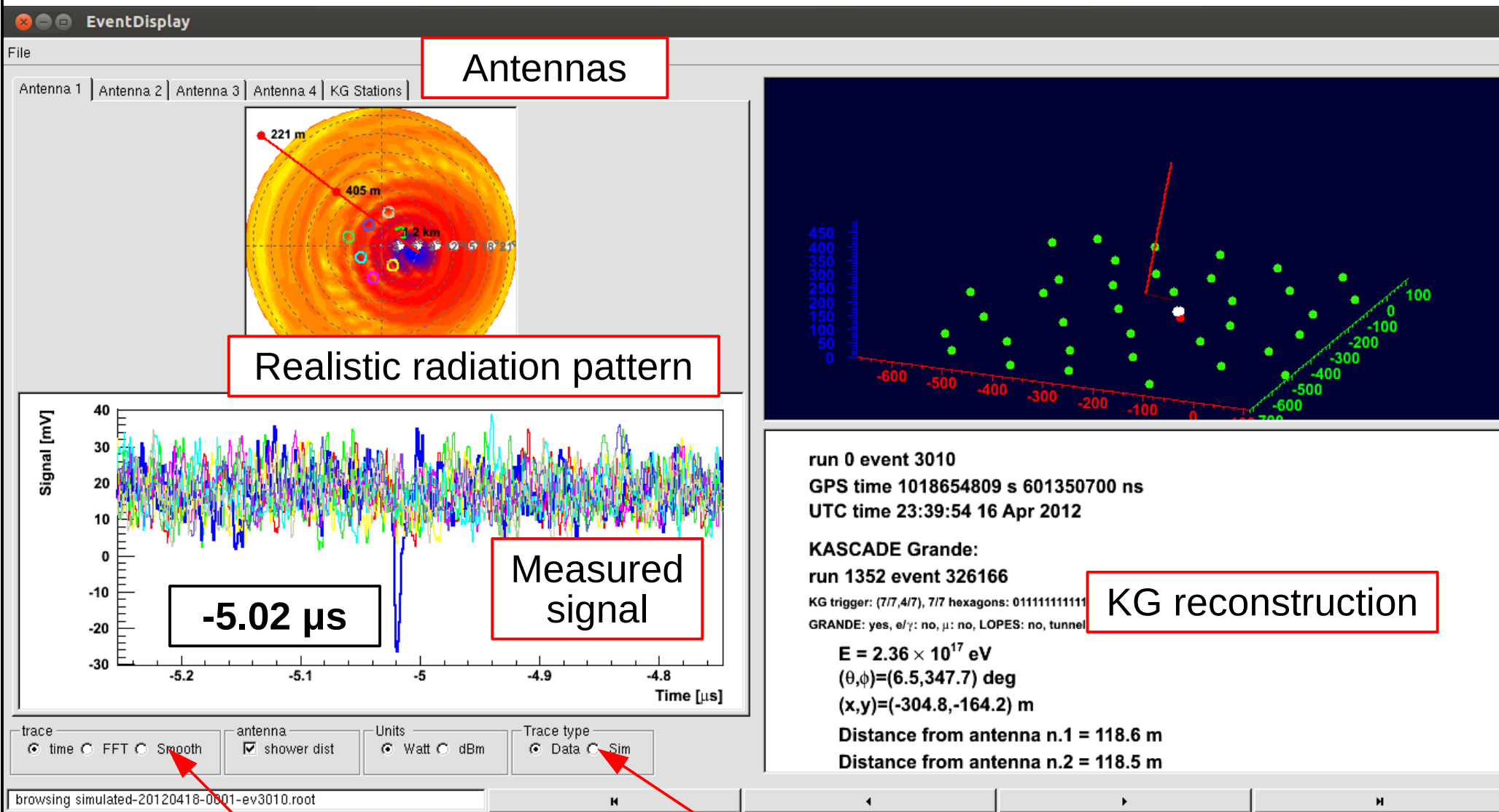


Measurement of arrival time of radio signal with LOPES* antennas.



Microwave signal is expected **$(5.0 \pm 0.1) \mu$ s** before the trigger.

Event display



Response of electronics to a simulated isotropic signal

Conclusion and outlook

At conference UHECR 2012 (CERN, Feb 2012) two experiments, EASIER (Auger) and CROME announced the first measurements of microwave signal from air showers in the C band (3.4—4.2 GHz).

CROME has measured **20 events** within 356 days since May 2011.

New upgrades are under way:

- Dual polarized receivers

- Progress on L band antennas

- Wideband monitoring of radio background

We're working on an absolute calibration.

Running mode with an external trigger is limited by the lifetime of KASCADE-Grande during dismantling.

Measured events are extensively studied and Felix Werner will discuss about it in the next talk.

Thank you



CROME group



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