# CROME: Cosmic Ray Observation by Microwave Emission

CROME Collaboration:
H. Blümer, R. Engel, A. Haungs, T. Huege, H. Klages, M. Kleifges,
O. Krömer, M. Roth, F. Salamida, H. Schieler, R. Šmída, M. Unger,
M. Weber, F. Werner, J. Wochele

Karlsruhe Institute of Technology

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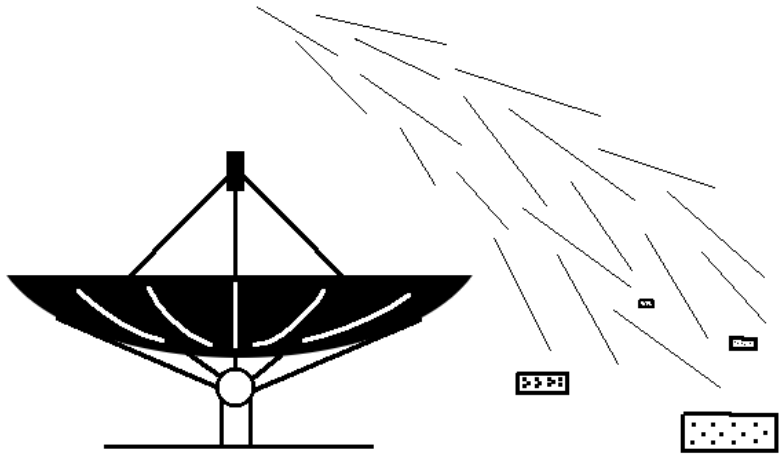
# Outline

- Motivation
- Experimental Setup
- Simulation and expected rate
- Data

# Motivations

- Verify the idea of microwave emission from extensive air showers [Gorham et al., PhysRev D 2008]
- external trigger from KASCADE-Grande
- measurement close to energy in Gorham ($E = 3.4 \times 10^{17}$ eV)
- complementary measurement to other projects (AMBER, MIDAS, EASIER)



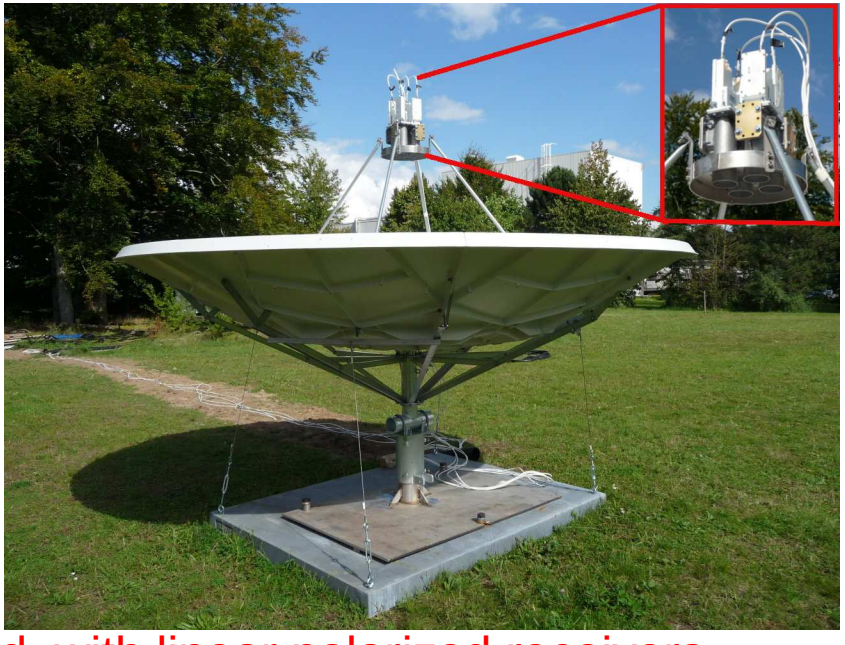
# Detector

## 1st Setup

- 90 and 150 cm offset dishes
- Ku-band (10.7 - 11.7 GHz) and C-band (3.4 - 4.2 GHz)
- 2 months of measurement, still used for tests

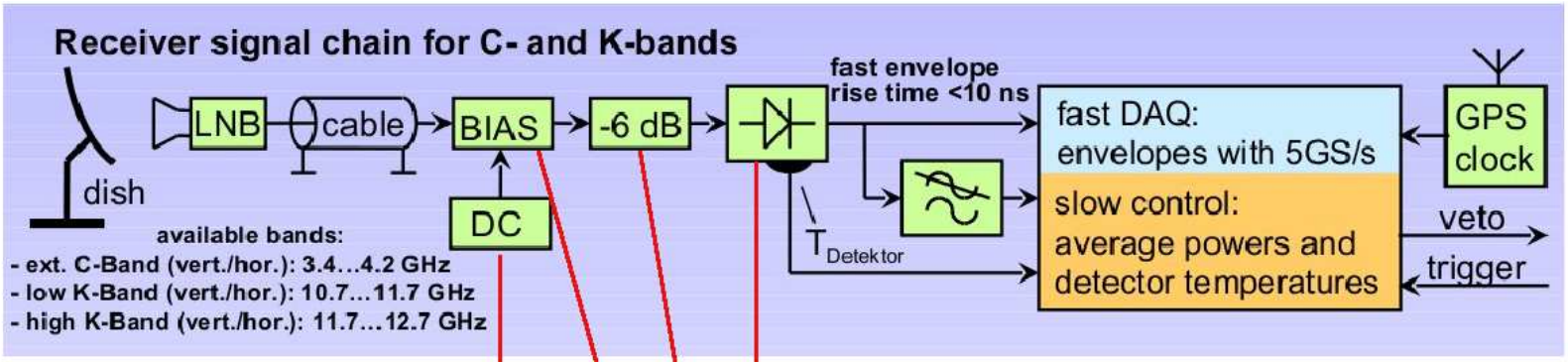
## 2nd Setup

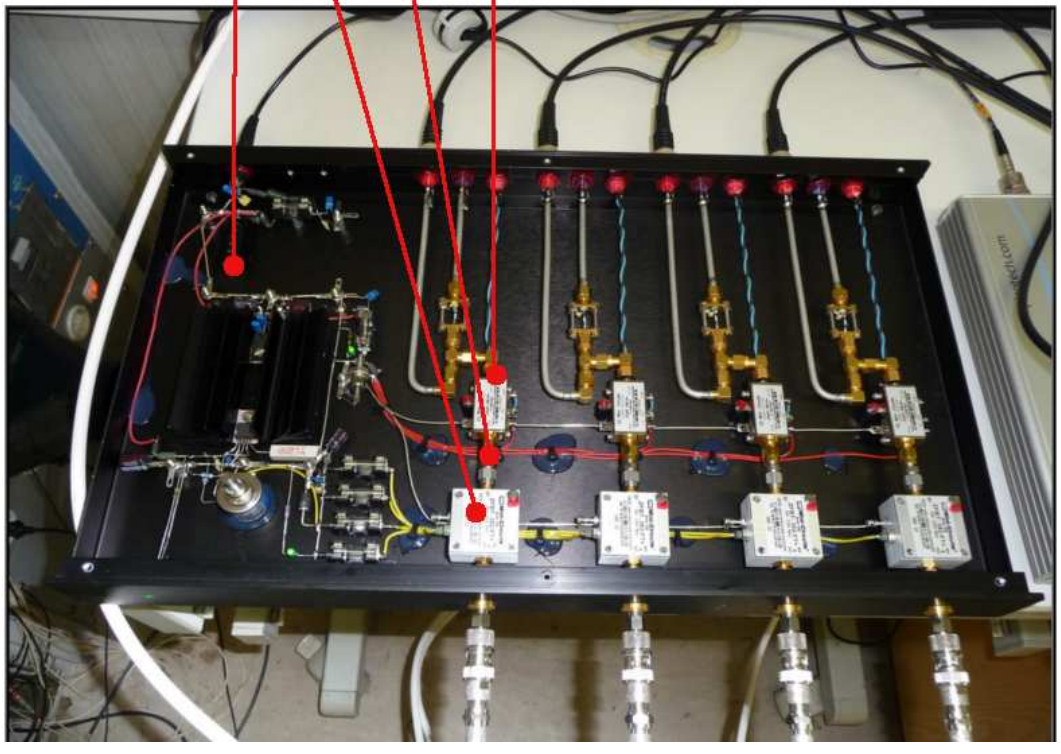
- segmented parabolic dish
- D=335 cm, F=119 cm
- 4 C-band receivers (1.6 deg FOV)
- running since 14th Sept



All antennas vertically oriented, with linear polarized receivers.

# Electronics Chain

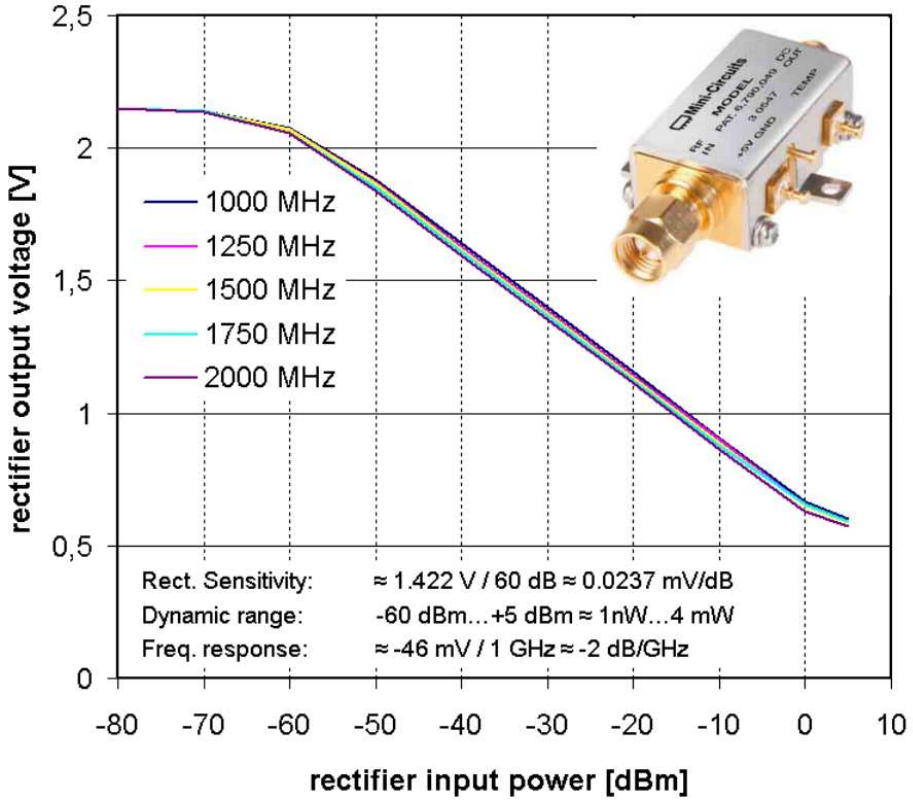


# Signal Processing

## Power Detector:

- Logarithmic power detector Mini-Circuits ZX47-60-S+ (AD8318)
- Response time: 10 ns
- Dynamic range: 60 dB
- Output voltage: 0.5 - 2 V

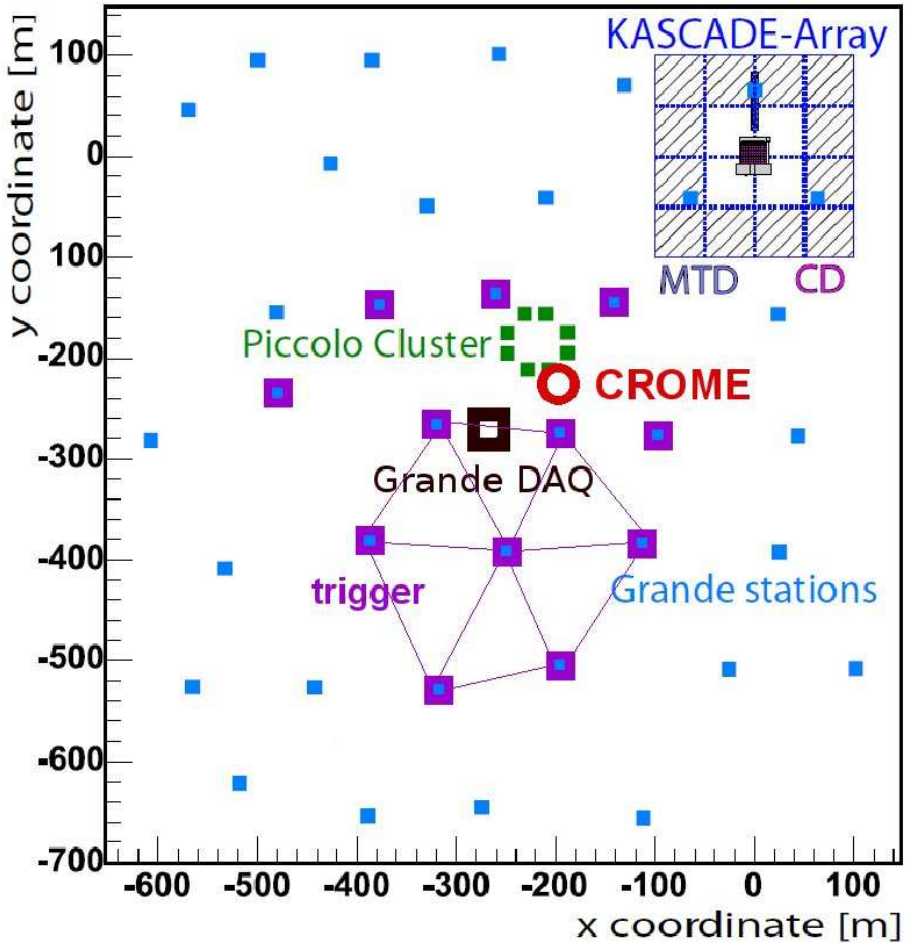



## Digitizer Picoscope 6403:

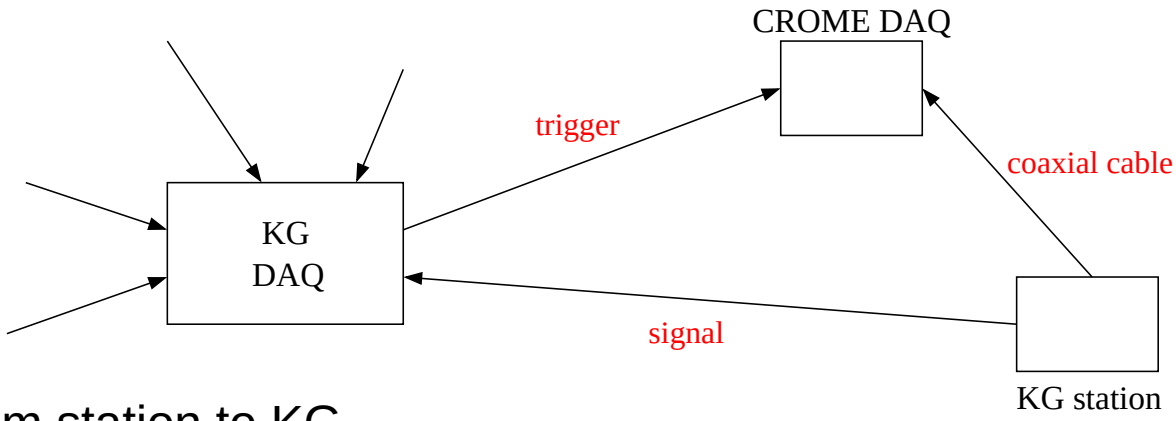
- 4 channels
- 350 MHz analog bandwidth
- Sampling rate up to 5 GS/s
- Vertical resolution is 8 bits

# Location

- Almost at the center of KASCADE-Grande array (37 scintillator detectors)
- Energy range: $10^{16}$ - $10^{18}$ eV
- trigger for CROME requires 3 inner hexagons in KG
- Trigger rate 1 event each 5 minutes



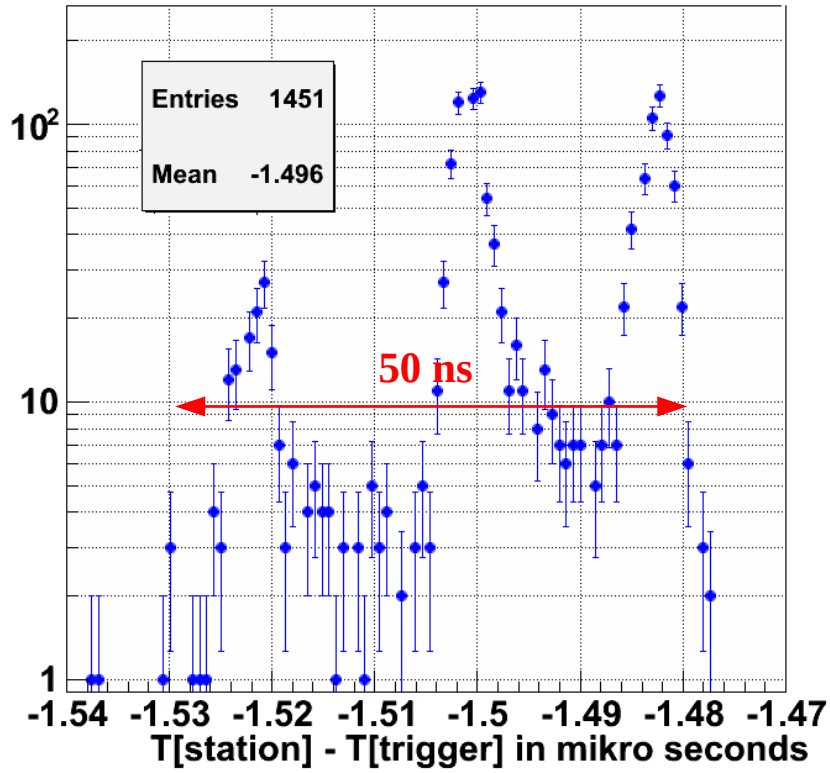
# Time Offset




- signal from station to KG DAQ: 2.8 $\mu$s (same for all stations)
- trigger from KG DAQ to CROME: 1.5 $\mu$s
- coaxial cable from station to CROME (same as normal signal)

Shower to trigger:

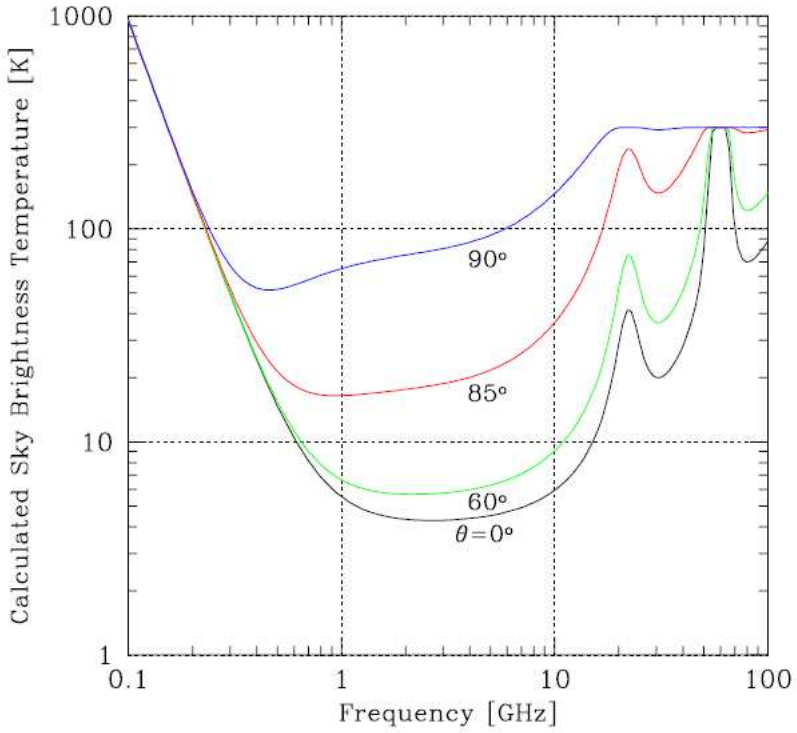
4.3 $\mu$s $\pm$ 25 ns



# Background Noise

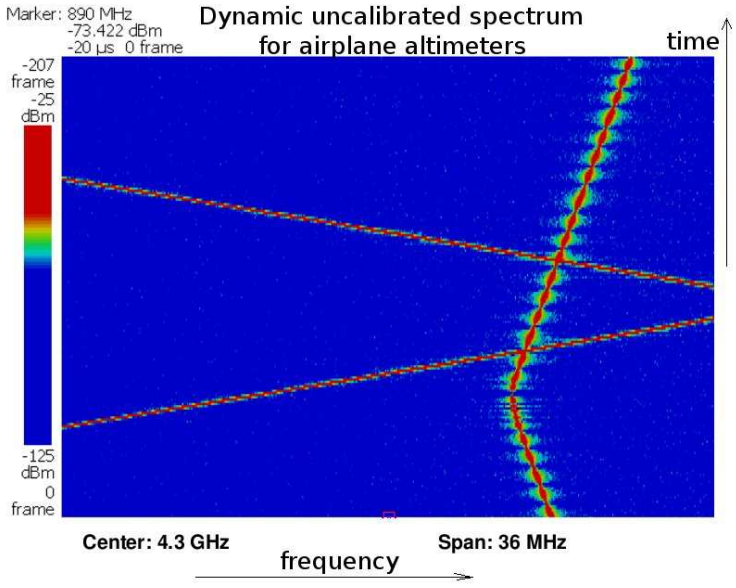
## Thermal Noise

- Caused by thermal movement, external and internal sources
- elevation dependent
- *white* spectrum
- measured system temperature is ∼80 K for clear sky




## Radio Frequency Interference

- Airplane altimeter radars at 4.3 GHz (Band Pass filter tested thanks to P.Privitera ☺)
- Synchrotron ANKA (2.5 GeV) during injection period, visible in both C and Ku band



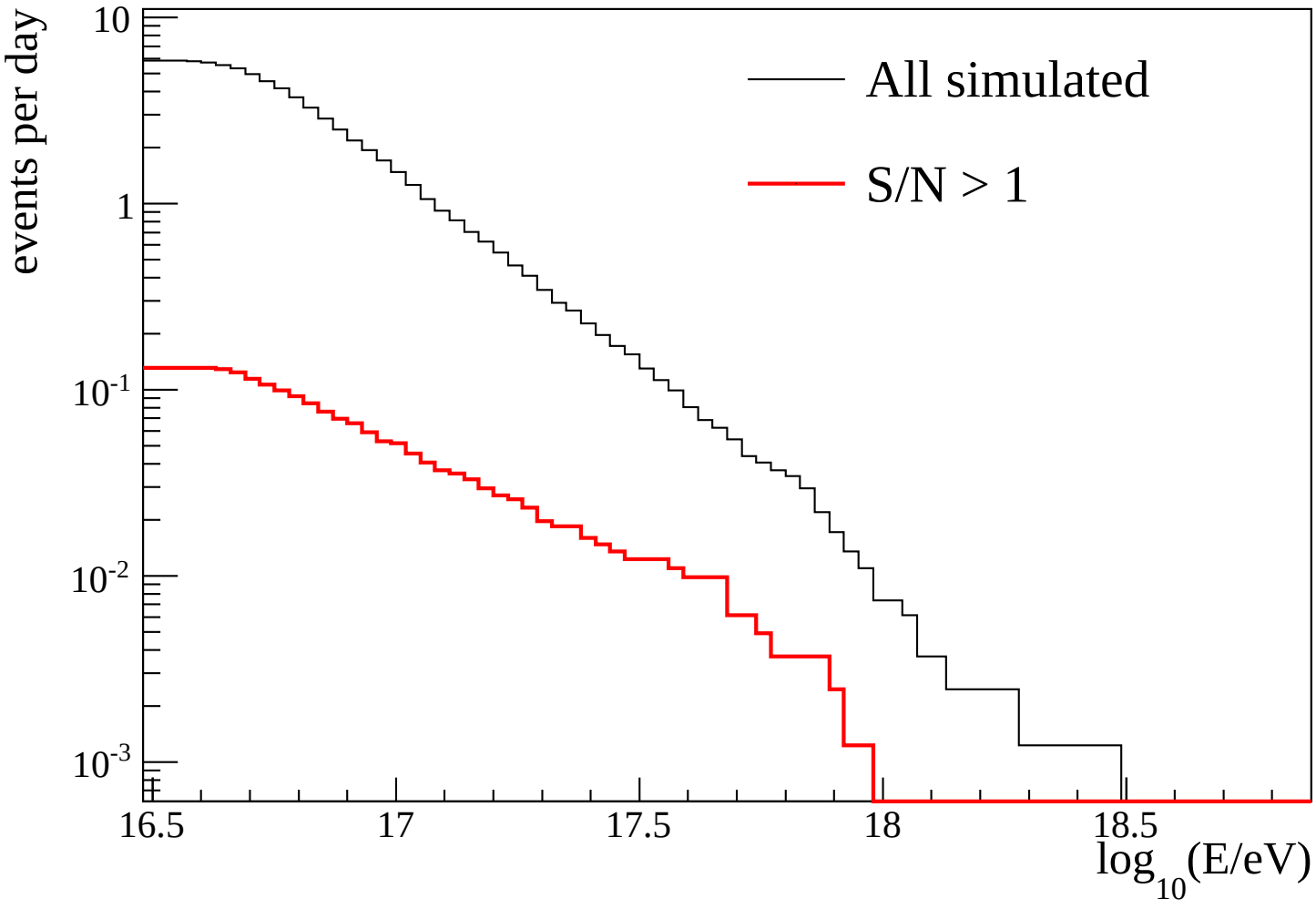
# EAS Simulation

- Gaisser-Hillas profiles (iron or protons) GAP-2005-087
- $E_{dep}$ is converted in microwave signal:

$$MW_{sign} \propto E_{dep}\ Y_{MW}$$

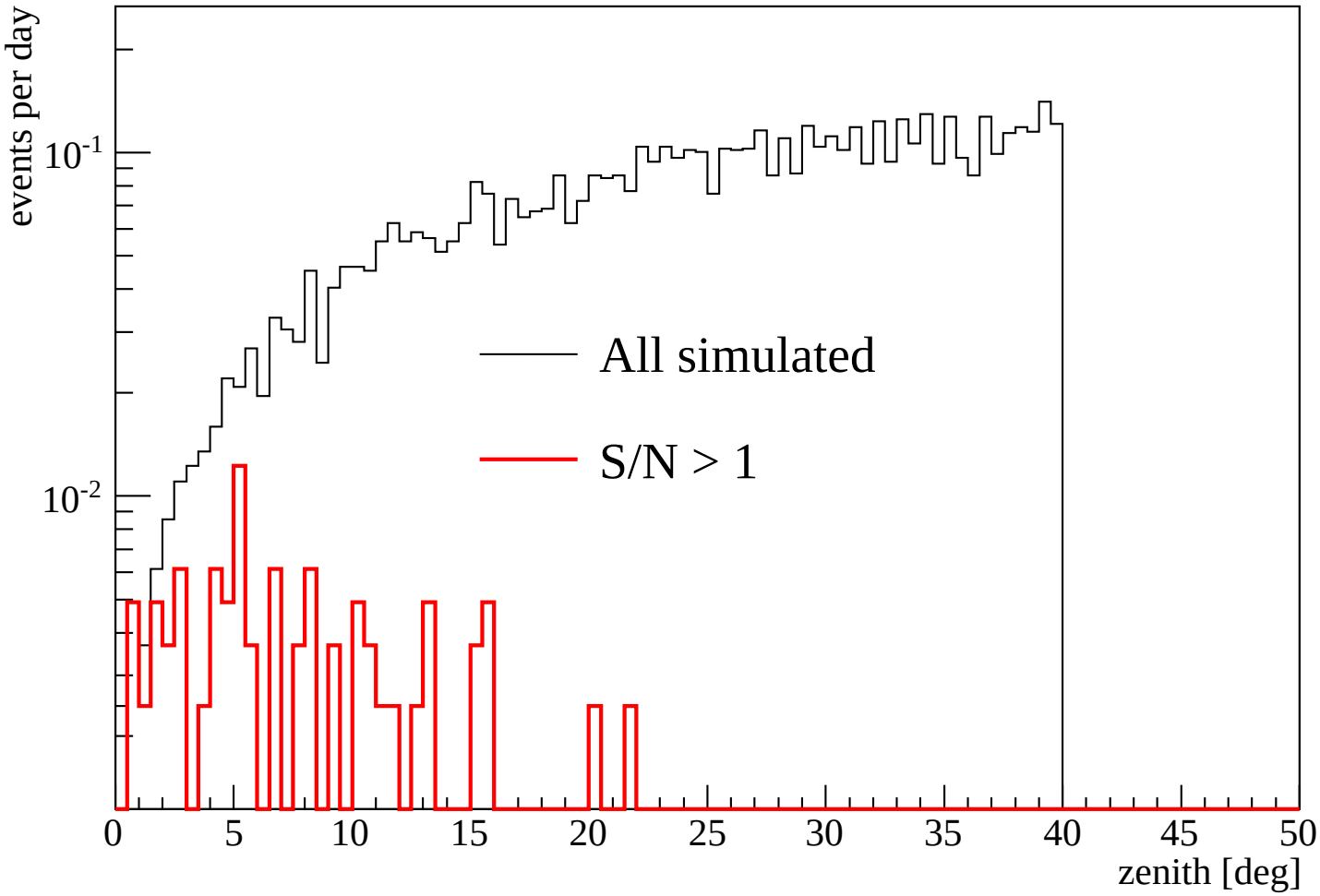
- $Y_{MW}$ is calculated in order to match Gorham predicted flux for $3.4 \times 10^{17}$ eV shower at 10 km
- 3D simulation of the shower (Gora LDF function)
- detector geometry (FOV) taken into account
- NO attenuation of the signal due to atmosphere (lower than 0.01 dB/km below 10 GHz)
- Simulation for CROME setup (D=335 cm, 4 receivers, $T_{sys}$=80 K)
- Minimum detectable flux is $\frac{K_B T_{sys}}{A_{eff}\sqrt{\Delta t\ \Delta\nu}}$ ($\sim 1\sigma$ to be confirmed)

# CROME Expected Rate

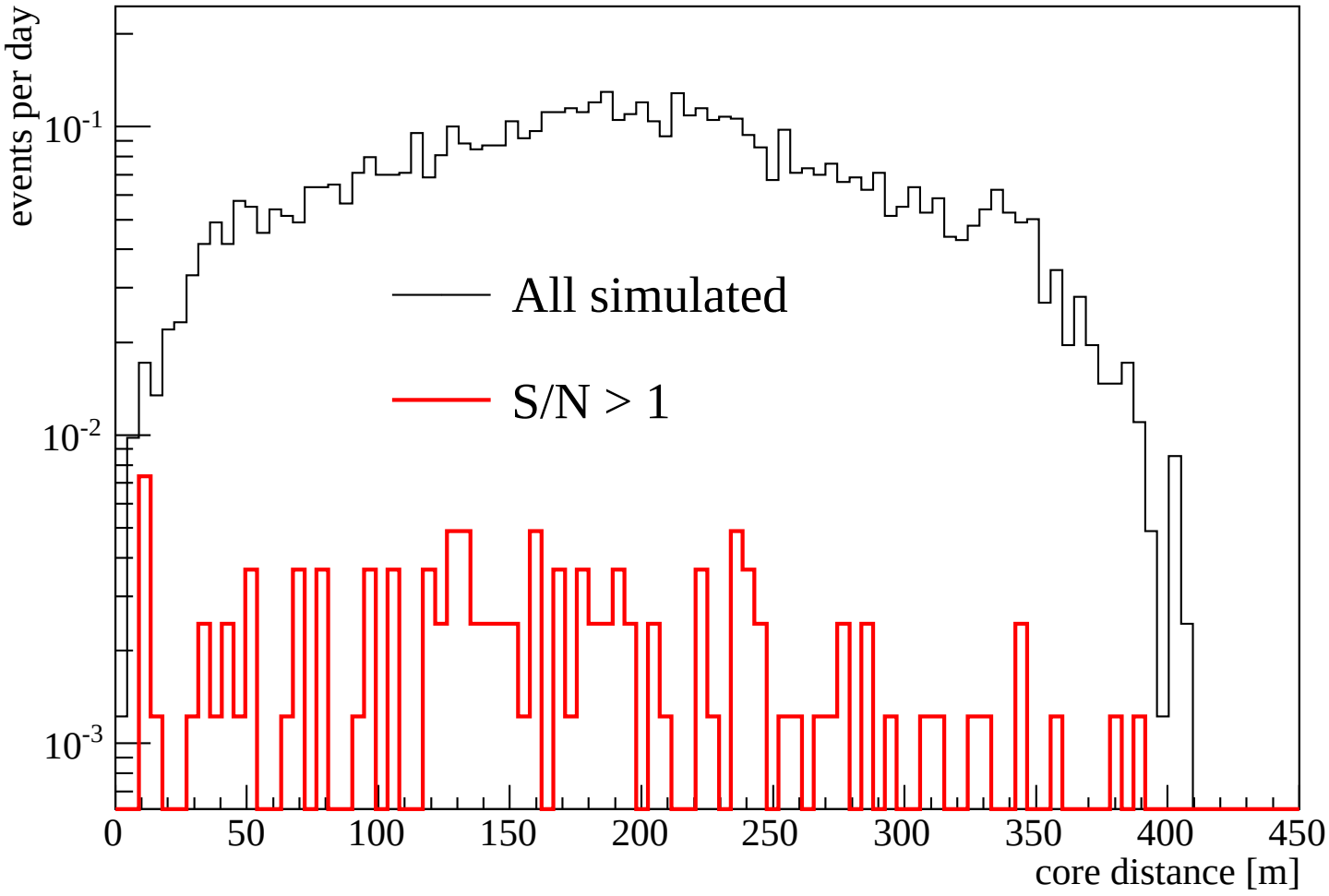



0.13 events per day ($\sim$ 4 events per month)

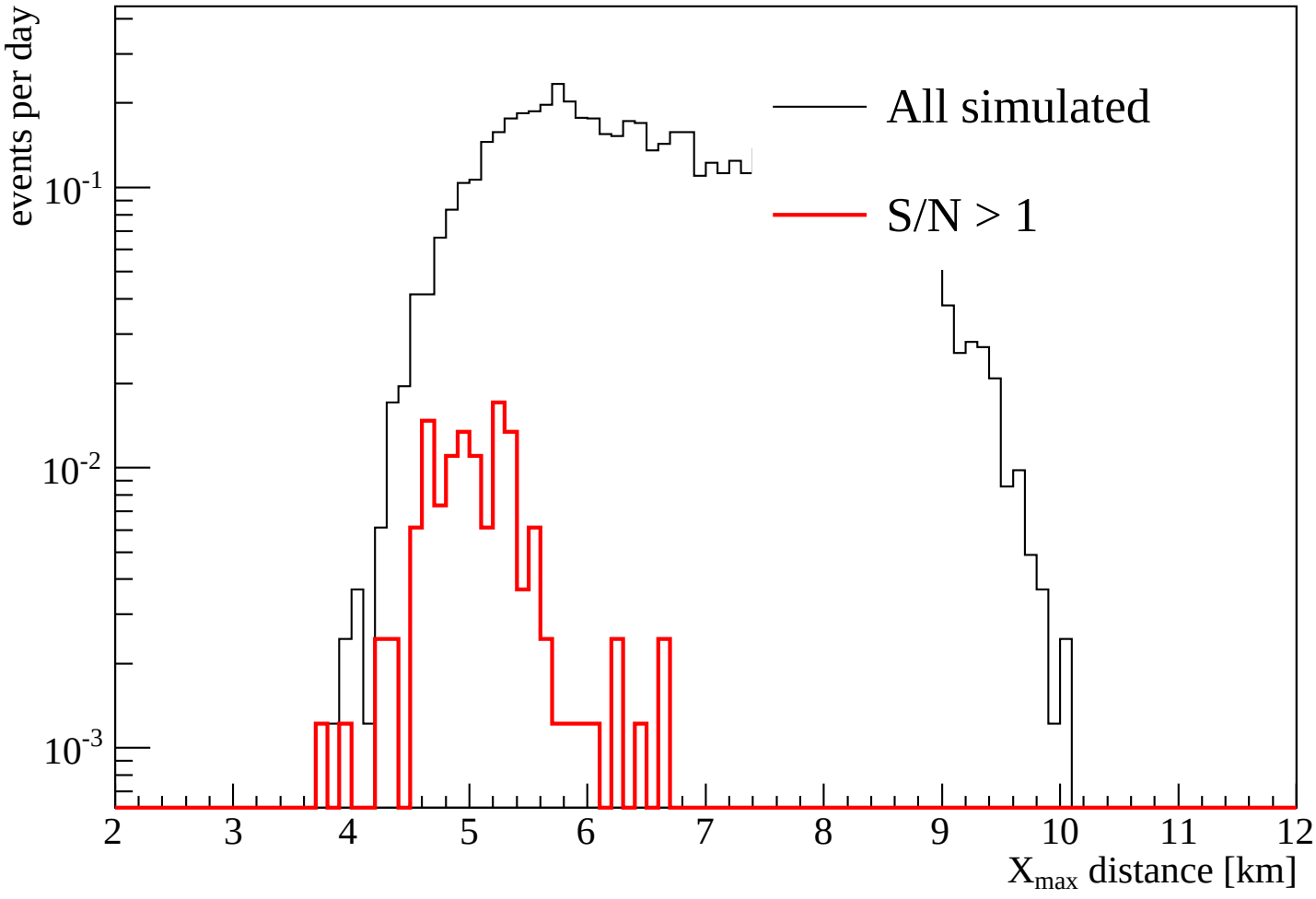
# Zenith


events per day
$10^{-1}$
$10^{-2}$
All simulated
S/N > 1
0
5
10
15
20
25
30
35
40
45
50
zenith [deg]

# Core Distance



# $X_{max}$ distance



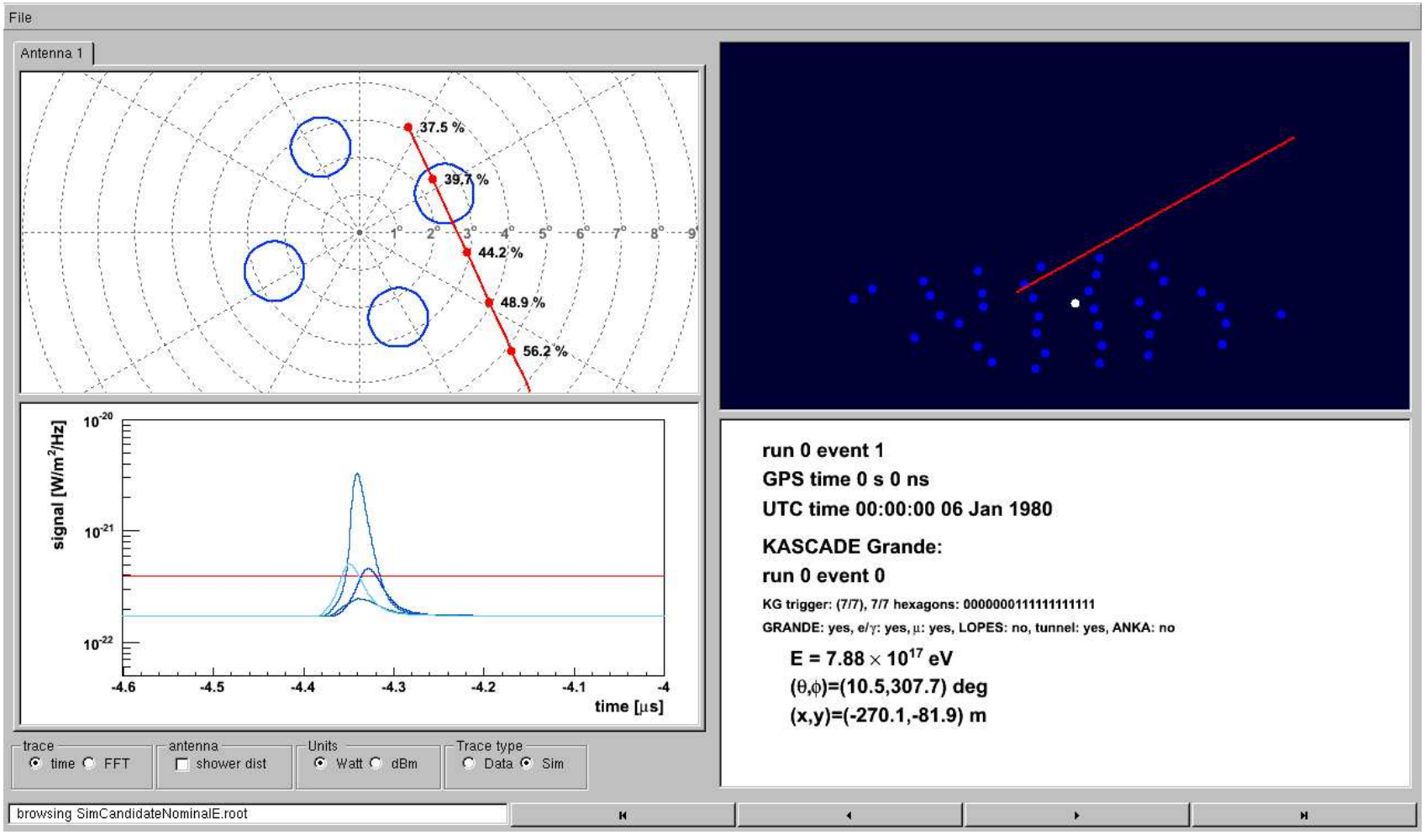
# Detector Performance

- Stable operation since September $\sim$280 KG triggers per day
- 2.6 showers above $10^{16.5}$ eV per day
- off-line merging with KG reconstructed data
- few showers inside field of view

## Event Candidate

- $E = 7.9 \times 10^{17}$ eV
- very close to antenna ($\sim$ 100 m)
- energy uncertainty $\pm$20%
- compatible with iron (Thanks to M. Bertaina)

# Simulation of Candidate



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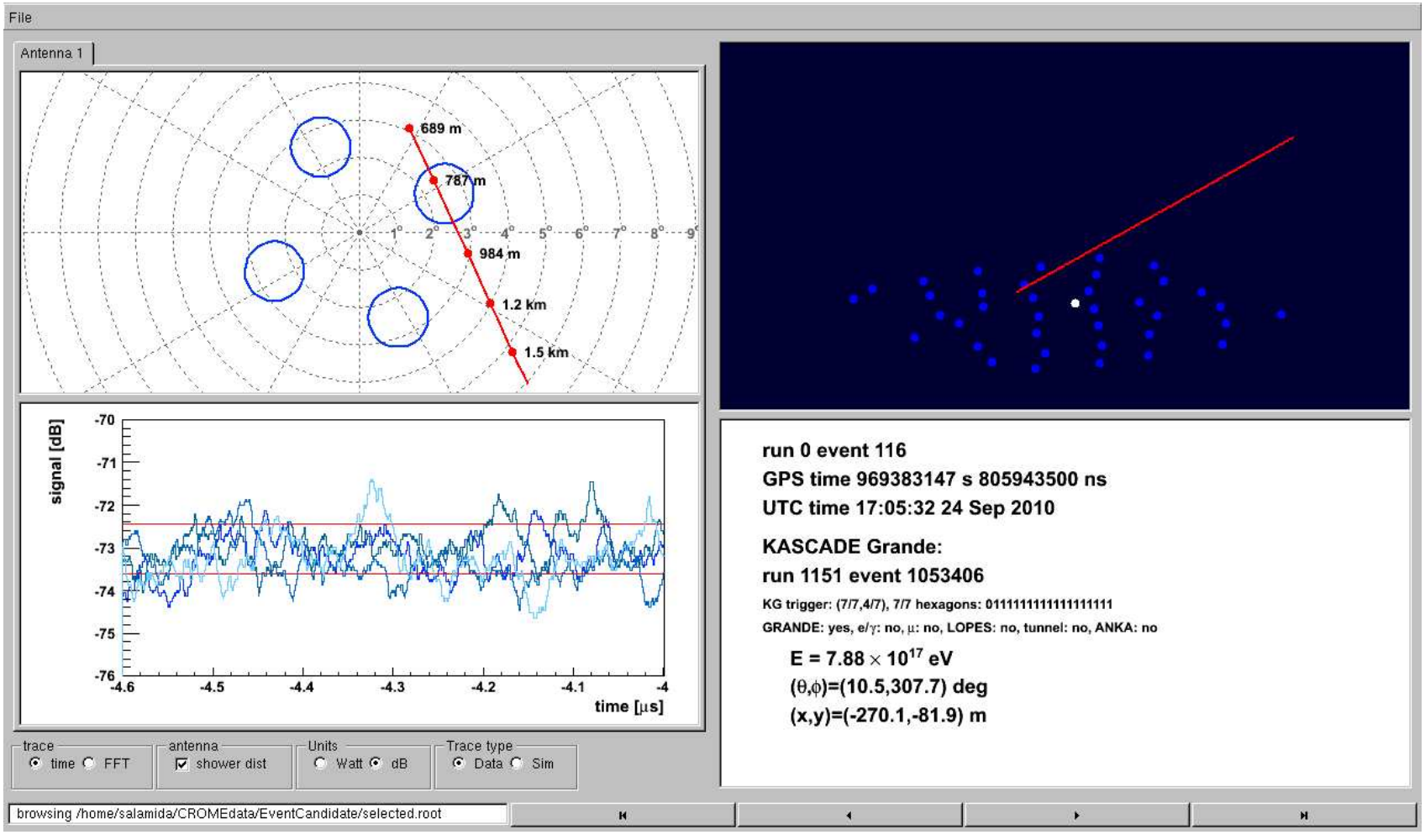

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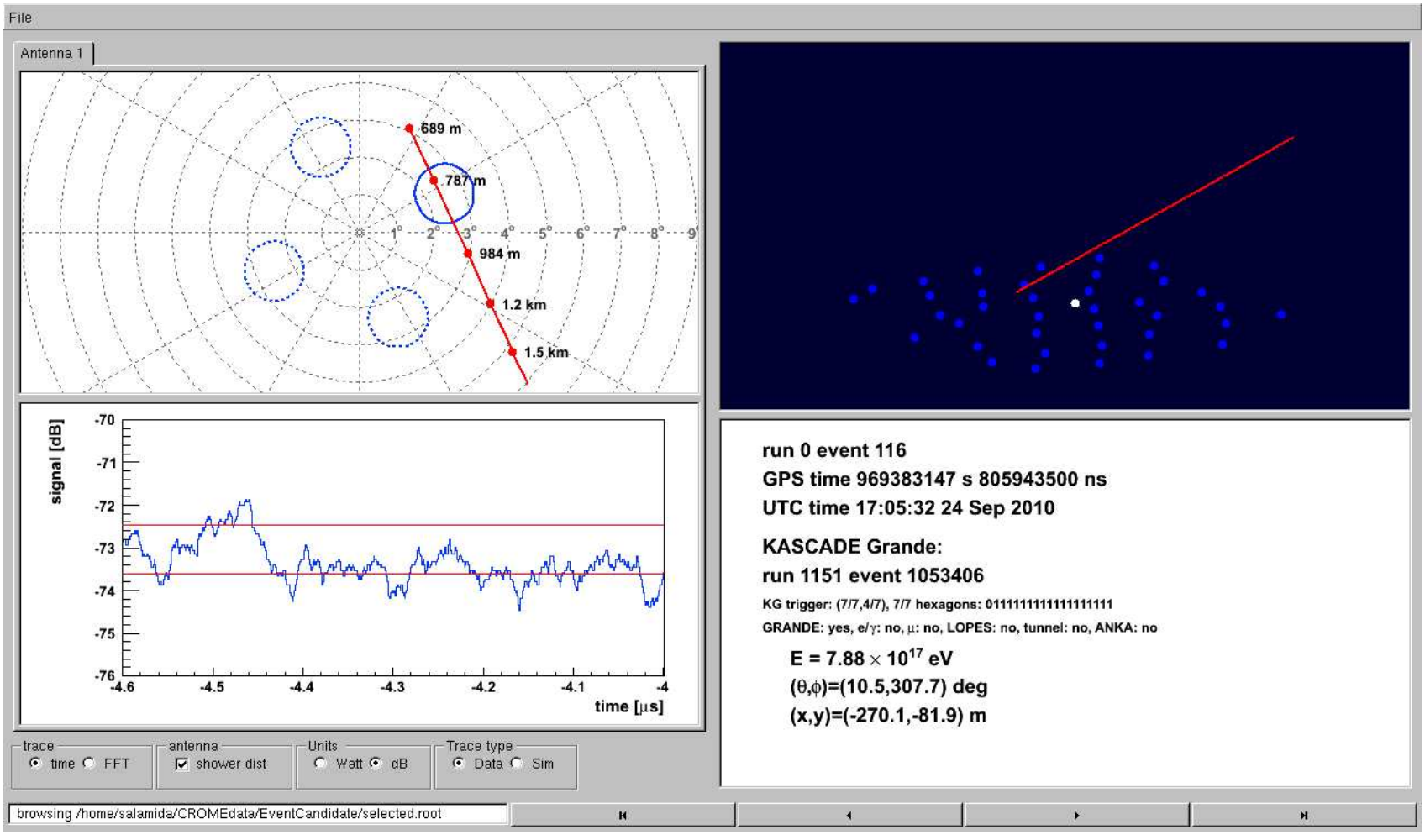
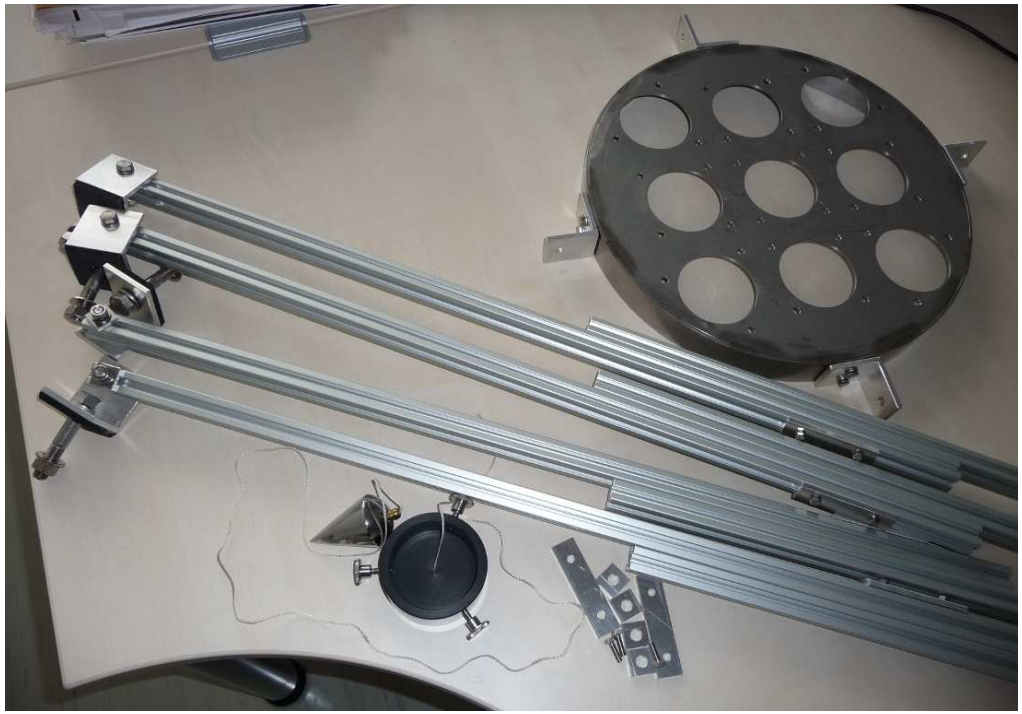


# Future plans

## Short term

- Increase number of receivers to 8
- notch filter for airplane altimeter radars
- background and calibration measurements (sun & calibrated source);
- effect of shower geometry on time offset



## Medium term

- Two new dishes to increase statistics:
  - Wuppertal
  - ASPERA