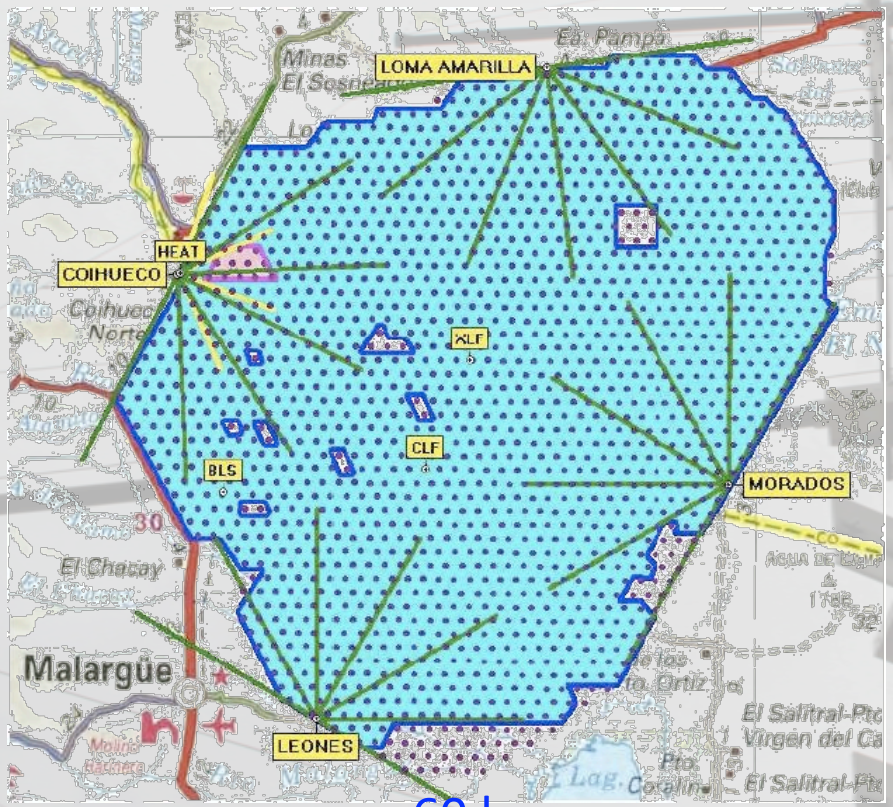
Front-end Electronics and Triggering at the Auger Engineering Radio Array

Charles Timmermans

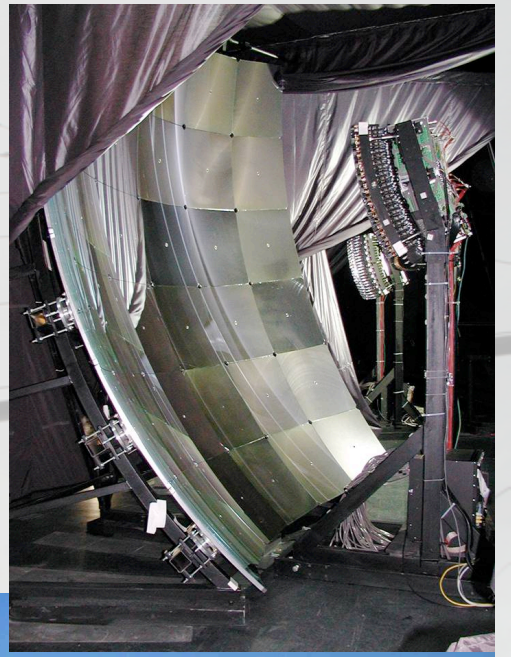
on behalf of

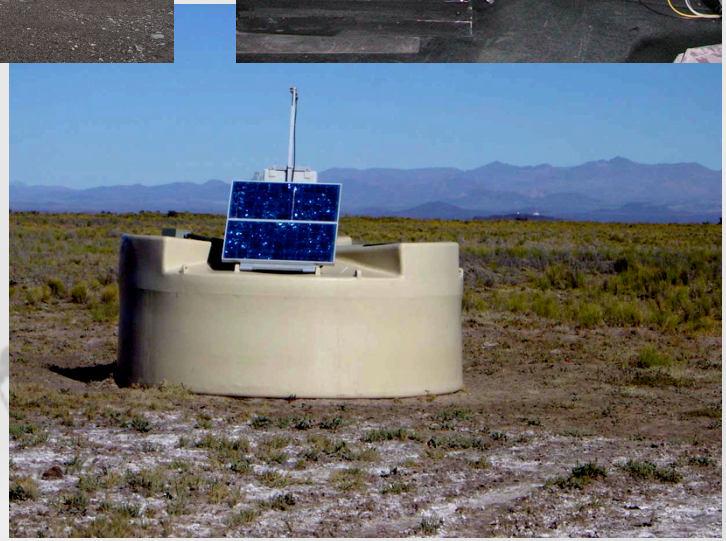
the Pierre Auger Collaboration

The Pierre Auger Observatory



27 fluorescence telescopes (30˚x30˚)



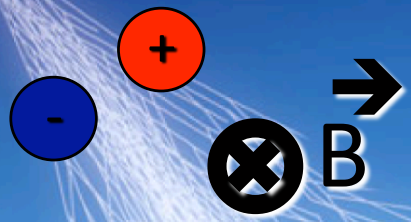


1660 water Cherenkov stations

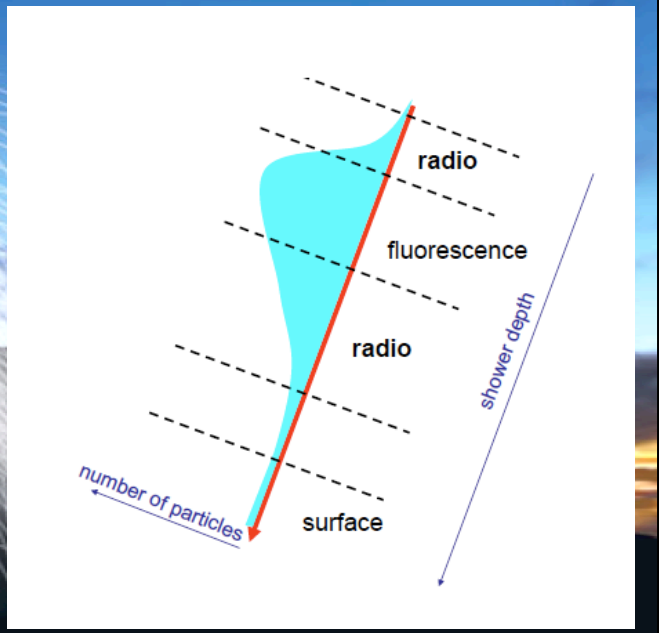
Talk by Stephane Coutu at 11:30

Radio Emission from Air Showers – Macroscopic picture

- Separation, acceleration of e^+, e^- in geomagnetic field
  - secondary: charge excess, moving dipole
- Broadband radio pulse (width ~50 ns)



- Observed by LOPES, CODALEMA, AERA detectors
  - geomagnetic asymmetry verified

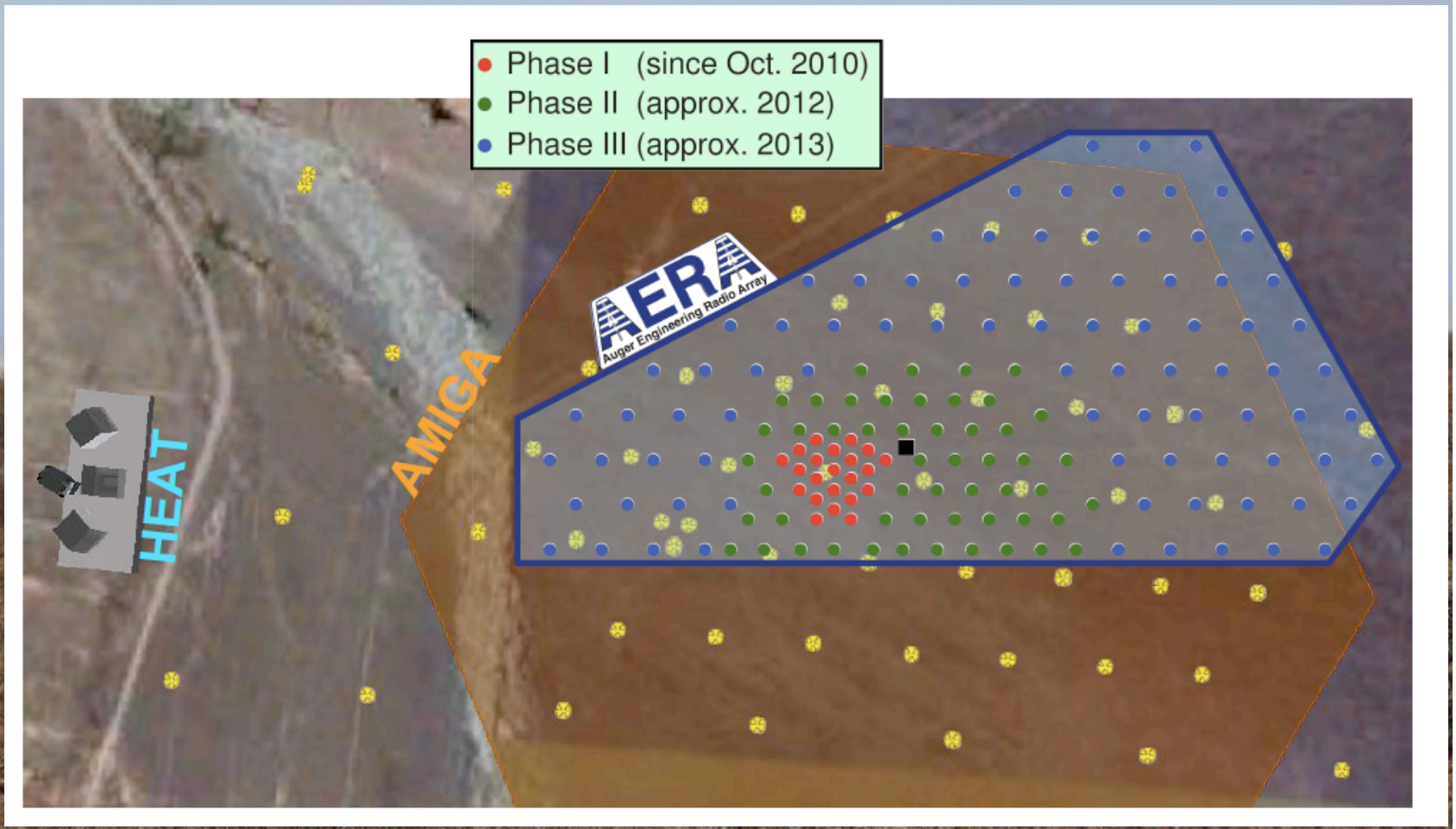


New Window on Shower Development!

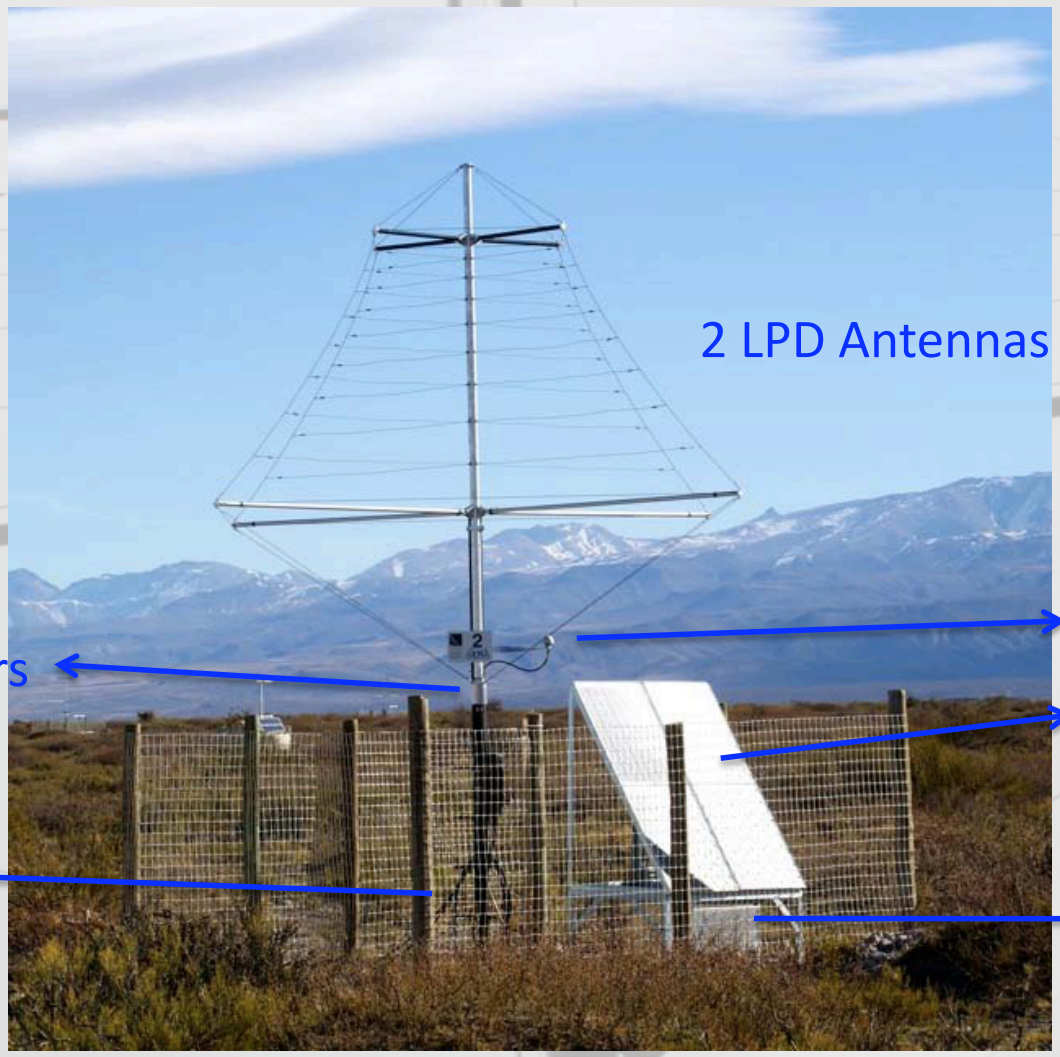
- high duty cycle and access to shower development

AERA in the Pierre Auger Observatory

AERA in the Pierre Auger Observatory



An AERA Station



2 LPD Antennas (NS and EW)

GPS Antenna

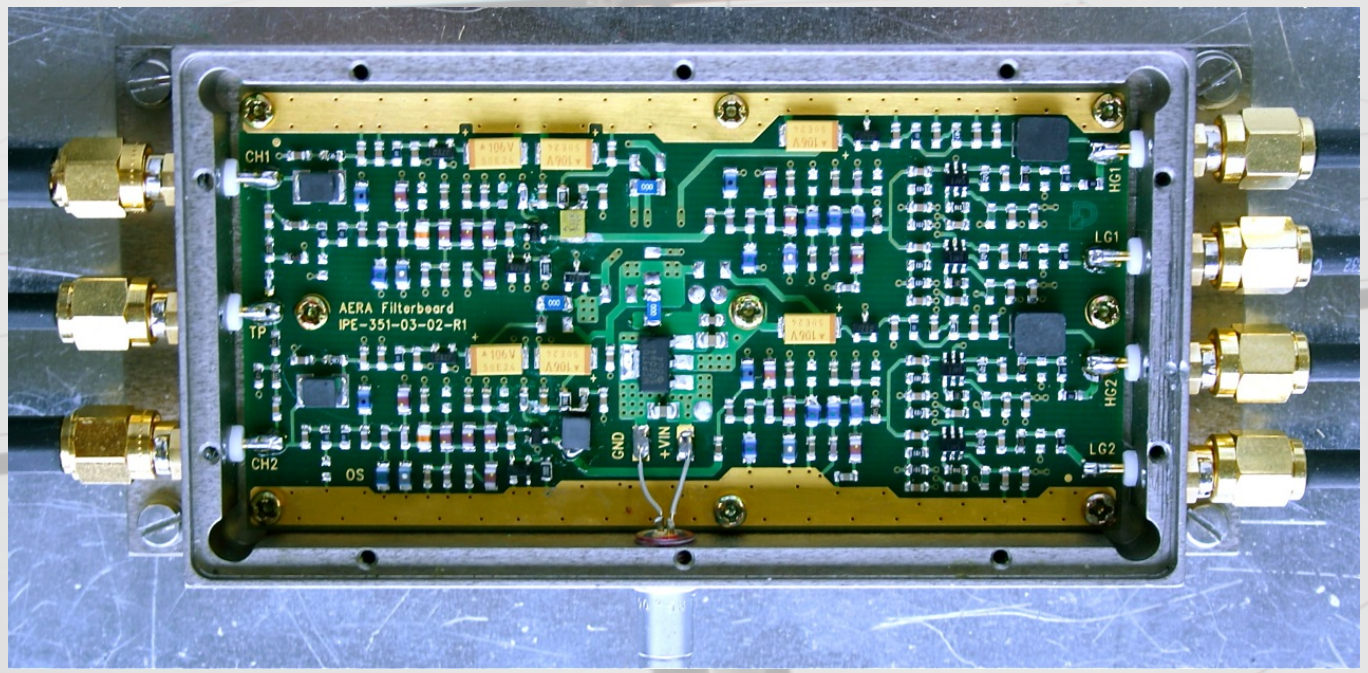
Low noise amplifiers

Solar Panel

Electronics:
- filter-amplifier
- digitizer
- comms
- power control
- batteries

Optical Fiber

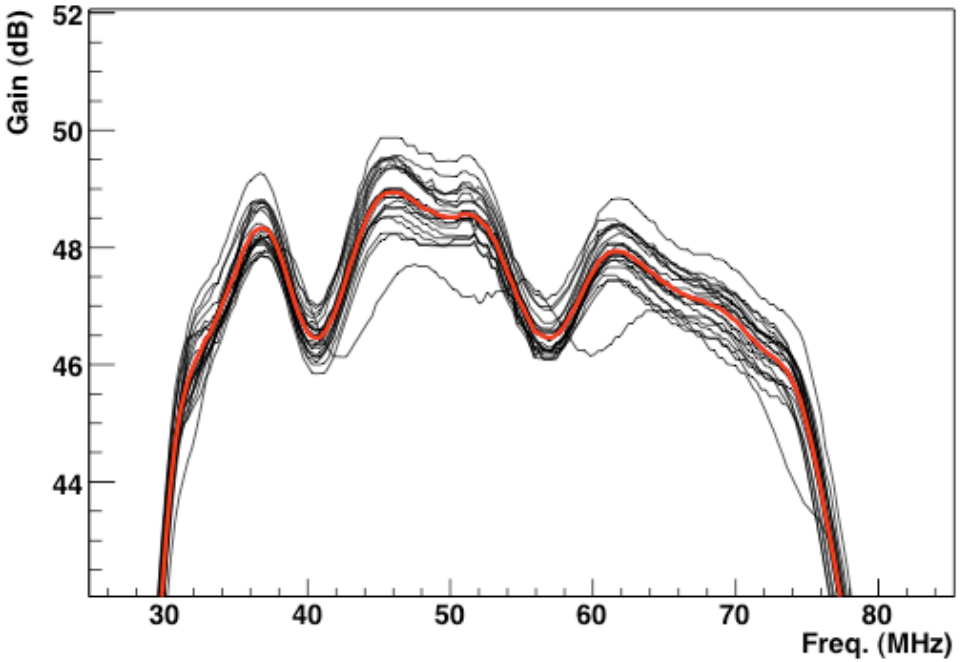
The Analog Chain



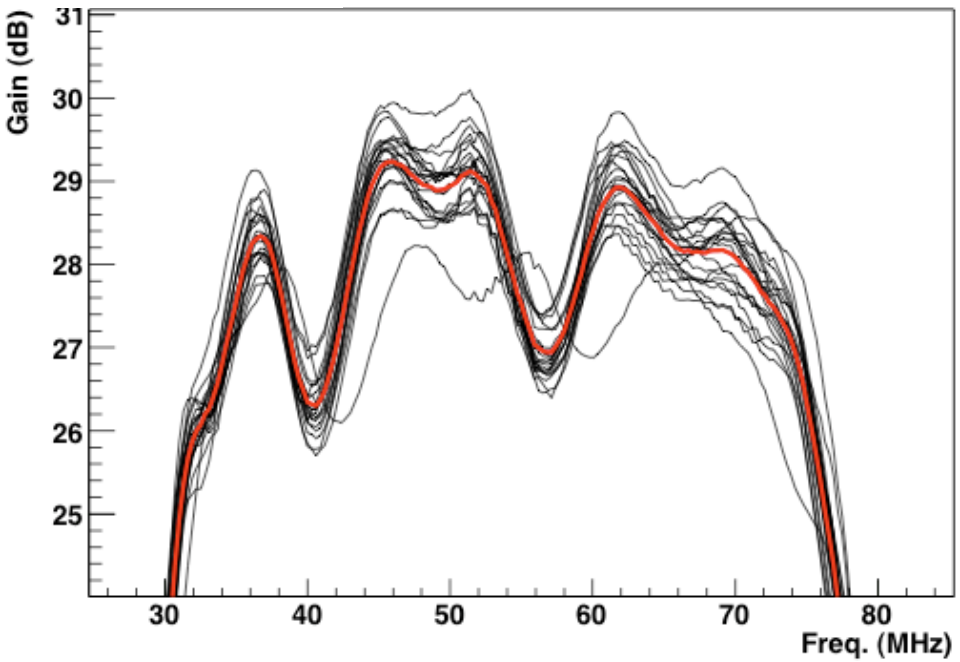
- 2 stage amplification and filtering
- Each stage consists of 8th order high- and 9th order low-pass
- High speed amplifiers in 2nd stage for low intermodulation at low power consumption

Performance analog electronics

High gain channel



Low gain channel

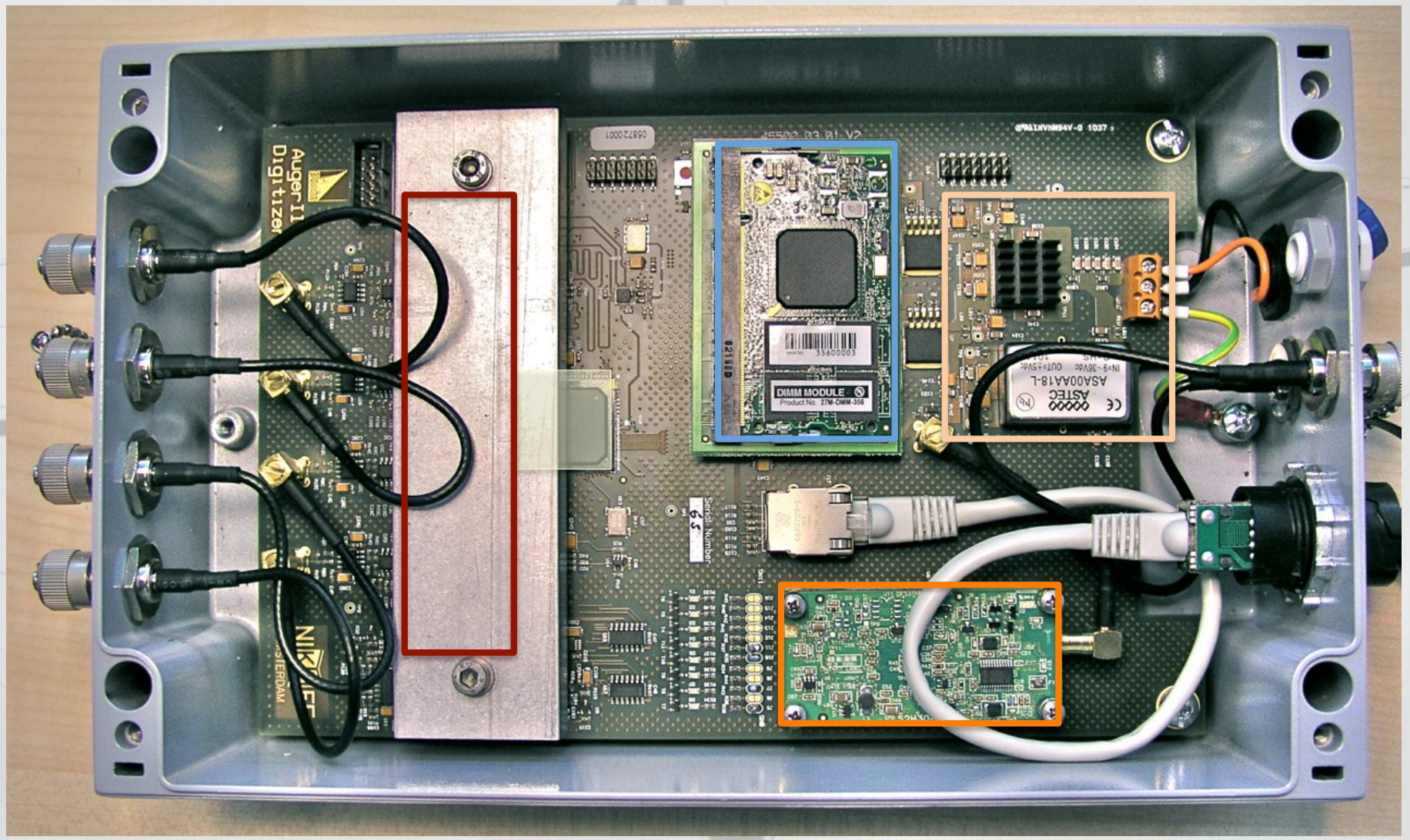


Characteristics for each module known.

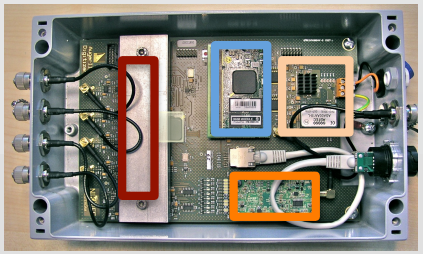
All are the same within ~2 dB

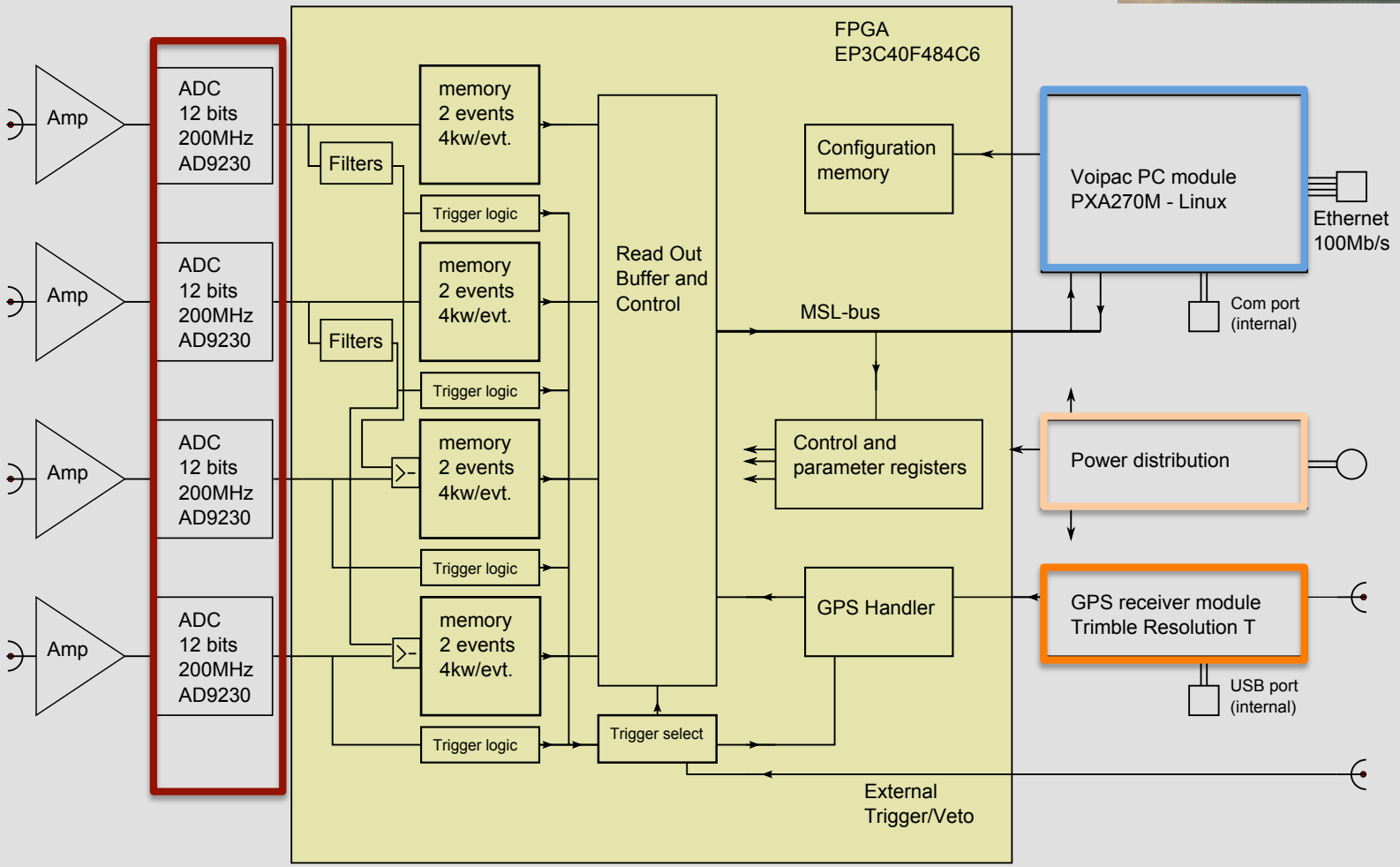
Difference between low and high gain outputs is 20 dB

Digital Electronics

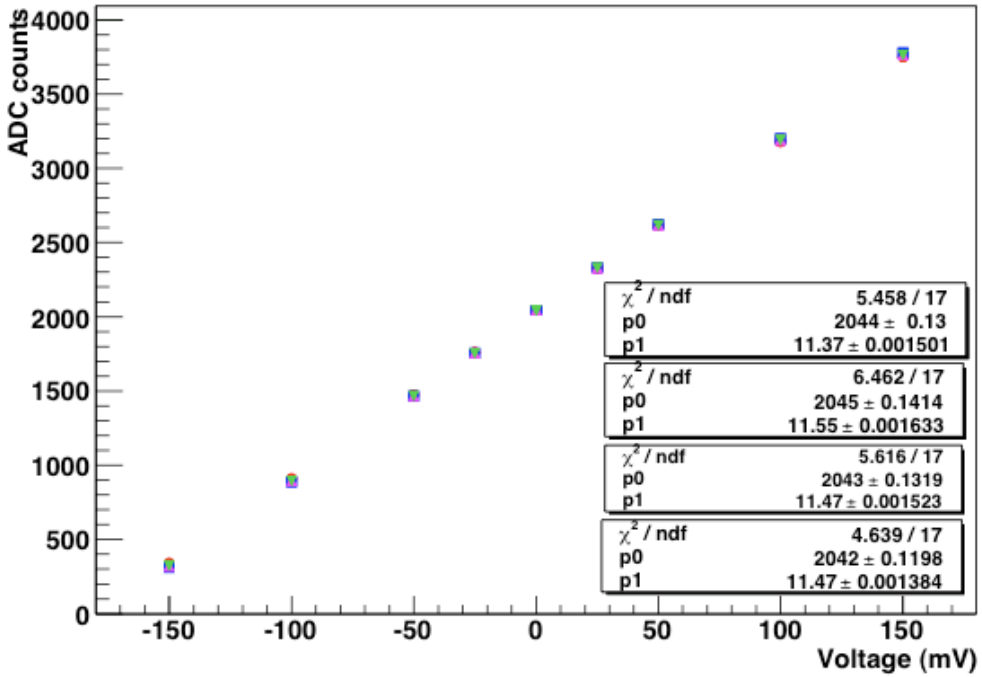


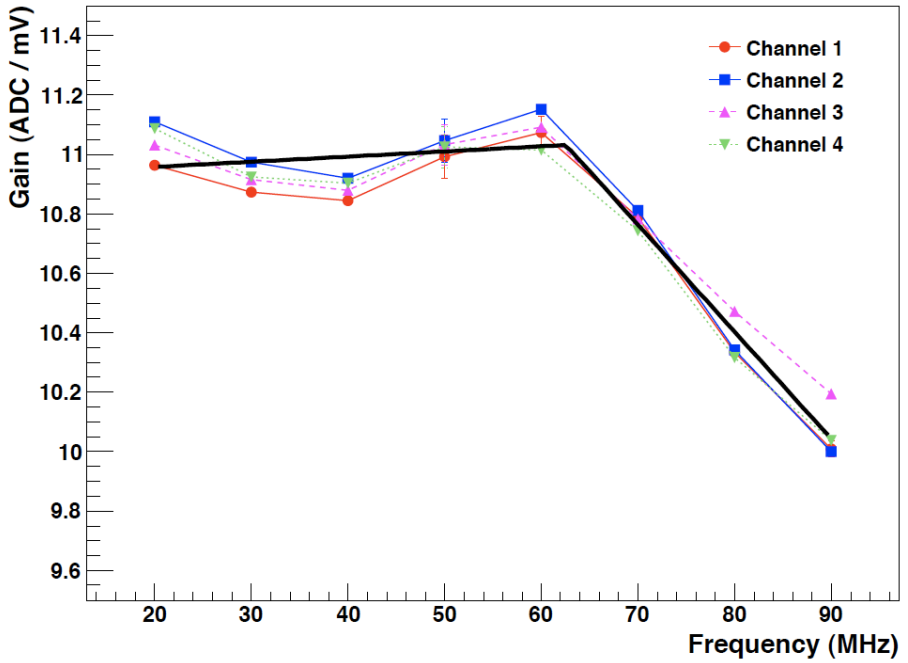
Block Diagram





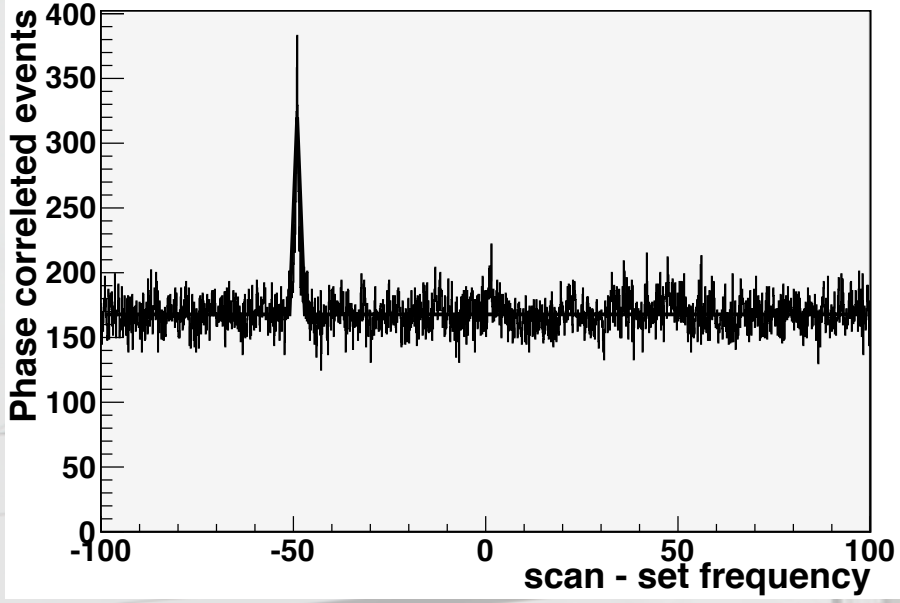
Digitizer Calibration

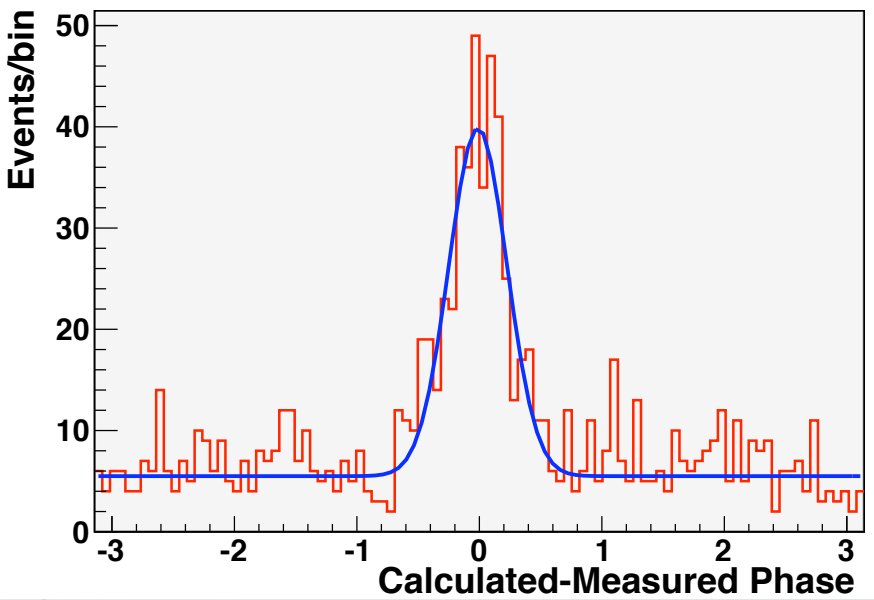




All digitizers have been calibrated.
The responses are identical within 2%

Event Timing Resolution

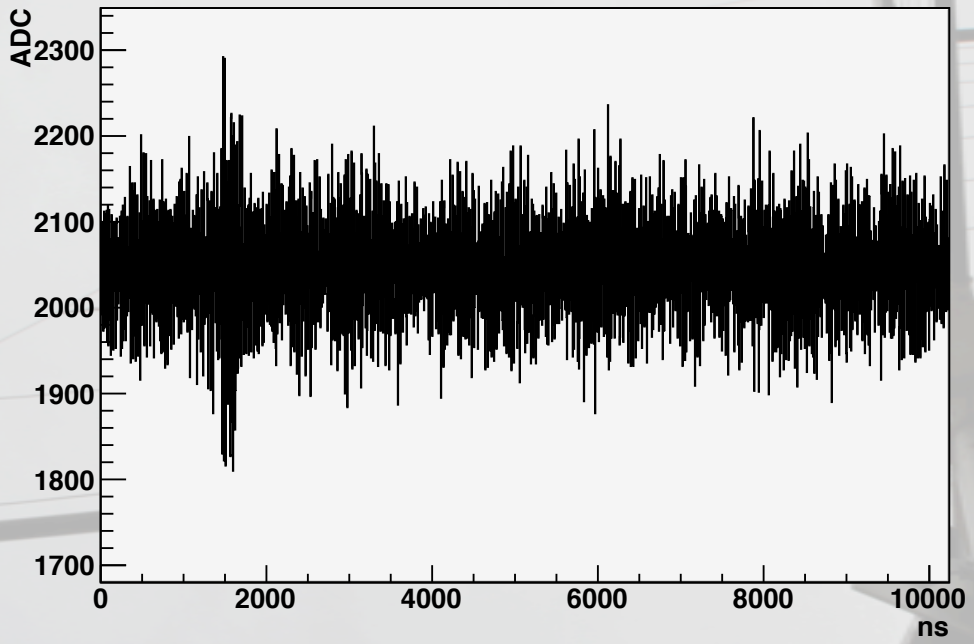


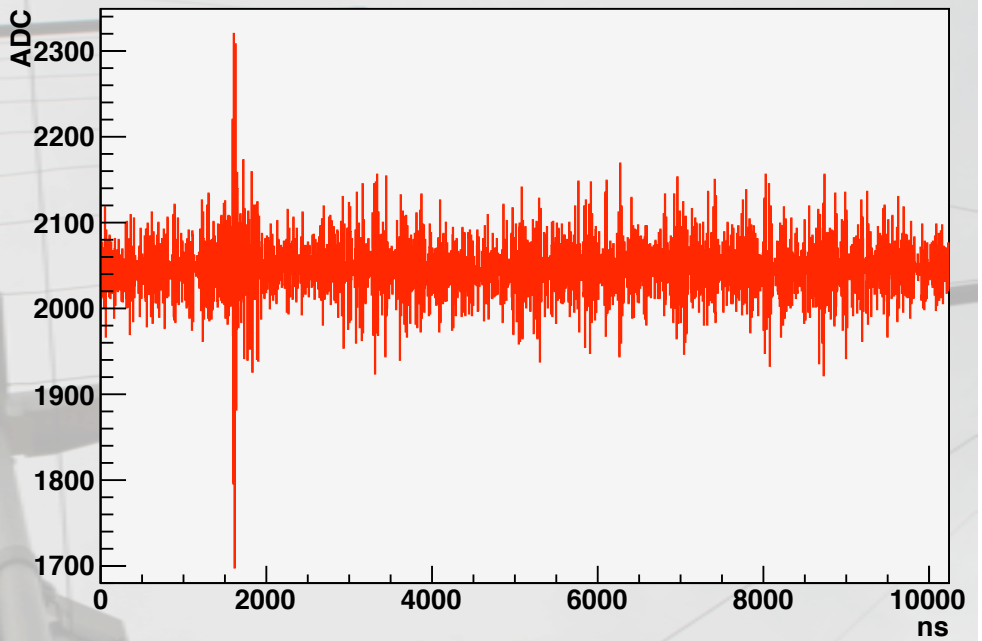


Using a stable 49.6 MHz beacon:

- The exact frequency has been determined using the digitizers
- From event-to-event phase differences at this frequency the station timing precision has been determined
- From station-to-station phase differences, the relative timing between stations has been determined.
- Time resolution is about 1.5 ns

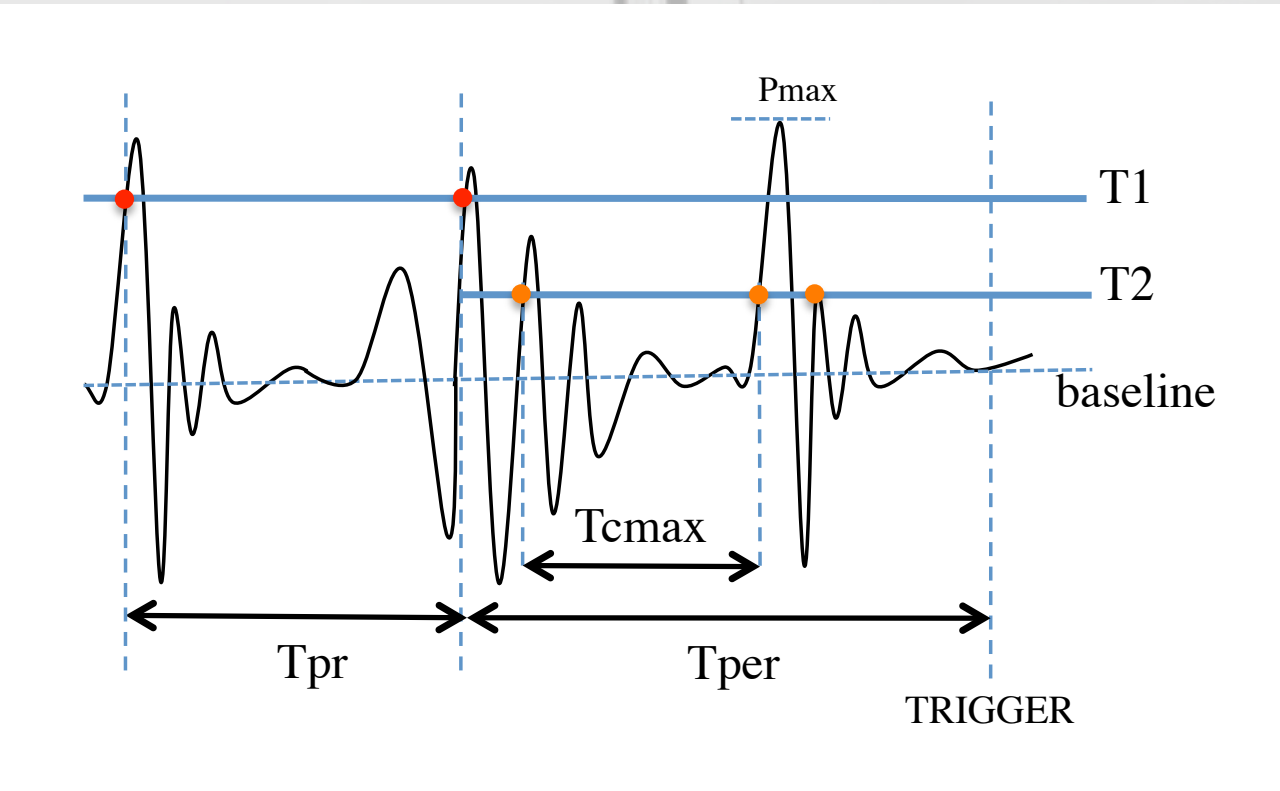
Implemented digital filter





3 infinite impulse response filters are implemented in the FPGA before the digital trigger algorithm is applied to the data in order to remove narrow band transmitters and reduce the noise-level.

Implemented trigger algorithm

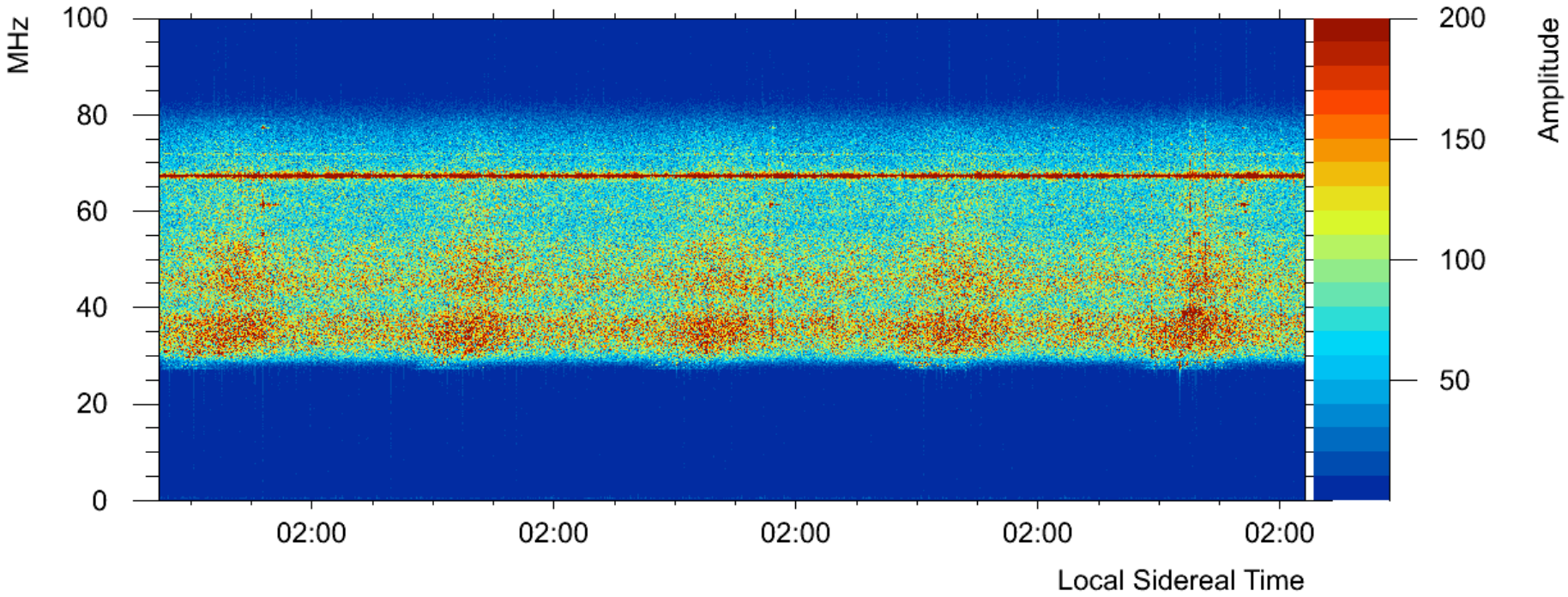


- Algorithm starts with a signal over threshold
- No pulse during some time before the current pulse
- No pulse train (of possibly lower amplitude) during a long period after the current pulse

Digitizer Performance

- 4 channel digital scope at 200Msps
- FPGA buffers 2 events of 24 kb each
- More than 500 Hz of triggered events can be sent from FPGA to CPU
- CPU is able to perform second-level triggering
- Timestamps of triggered events are sent to central DAQ
- A third-level trigger compares timestamps of individual stations
- CPU buffers several 1000 events waiting to be requested from the central DAQ
- Total power consumption: 6 Watt

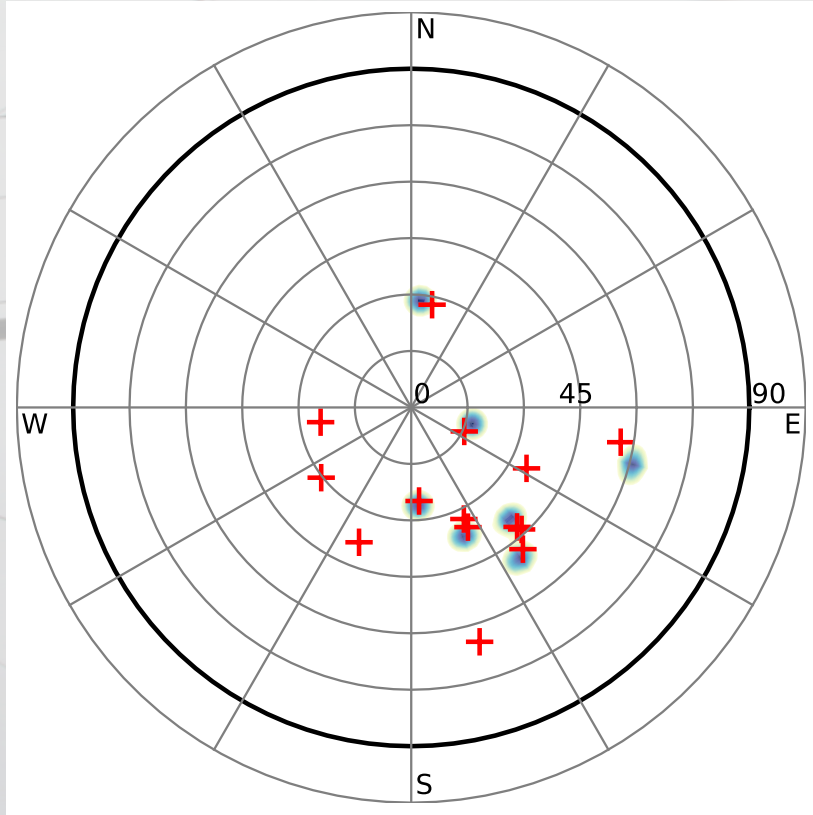
First Results – Background Levels



The setup is sensitive to the Galactic background variation

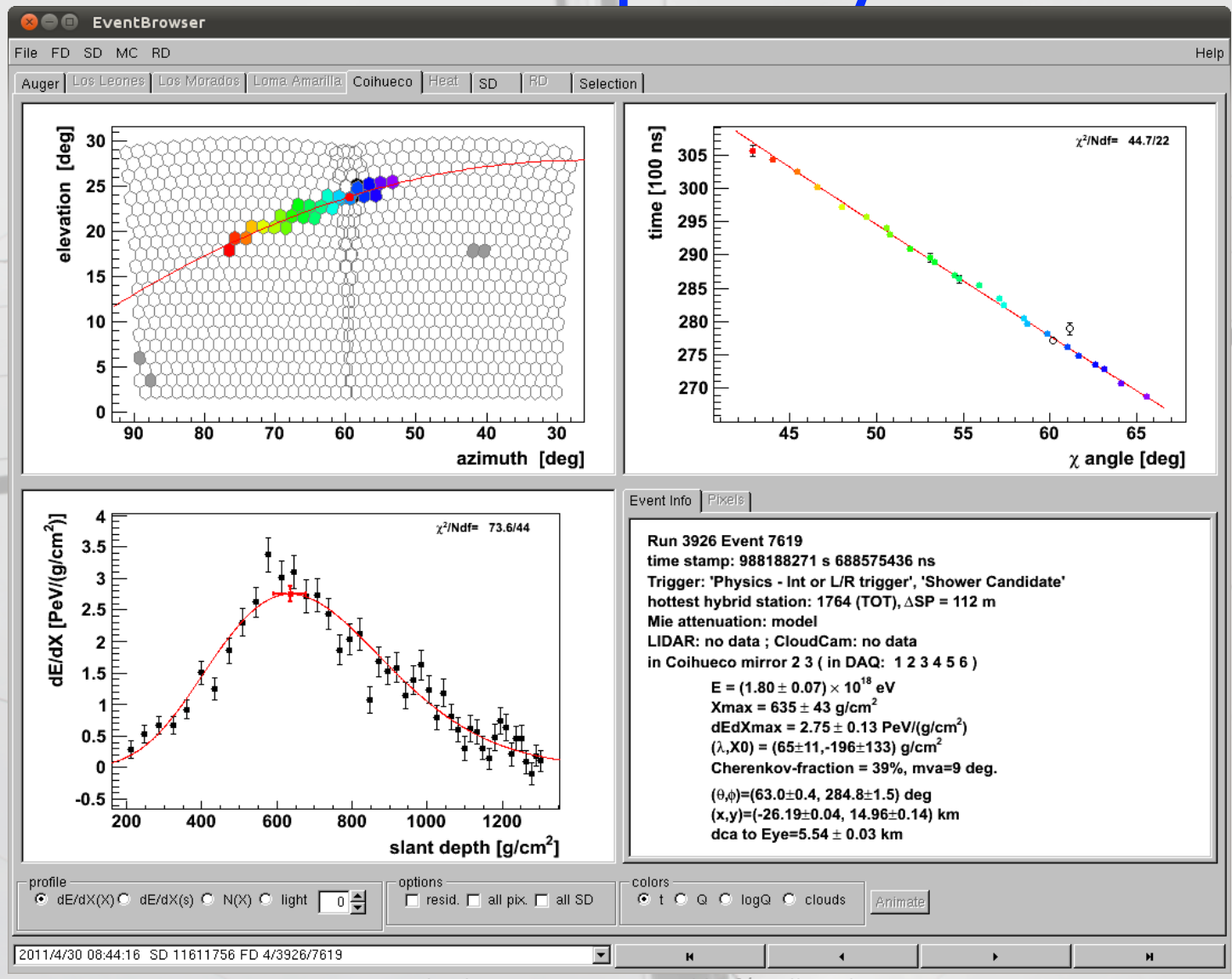
A 67 MHz man-made interference is clearly visible

First Results – Coincidences with the Surface detector



Self-triggered events are in coincidence with the Surface Detector for recorded energies above 0.1 EeV, mostly originating from the south.
This is in agreement with a dominant geomagnetic origin of the signal.

First Results – Super Hybrid events



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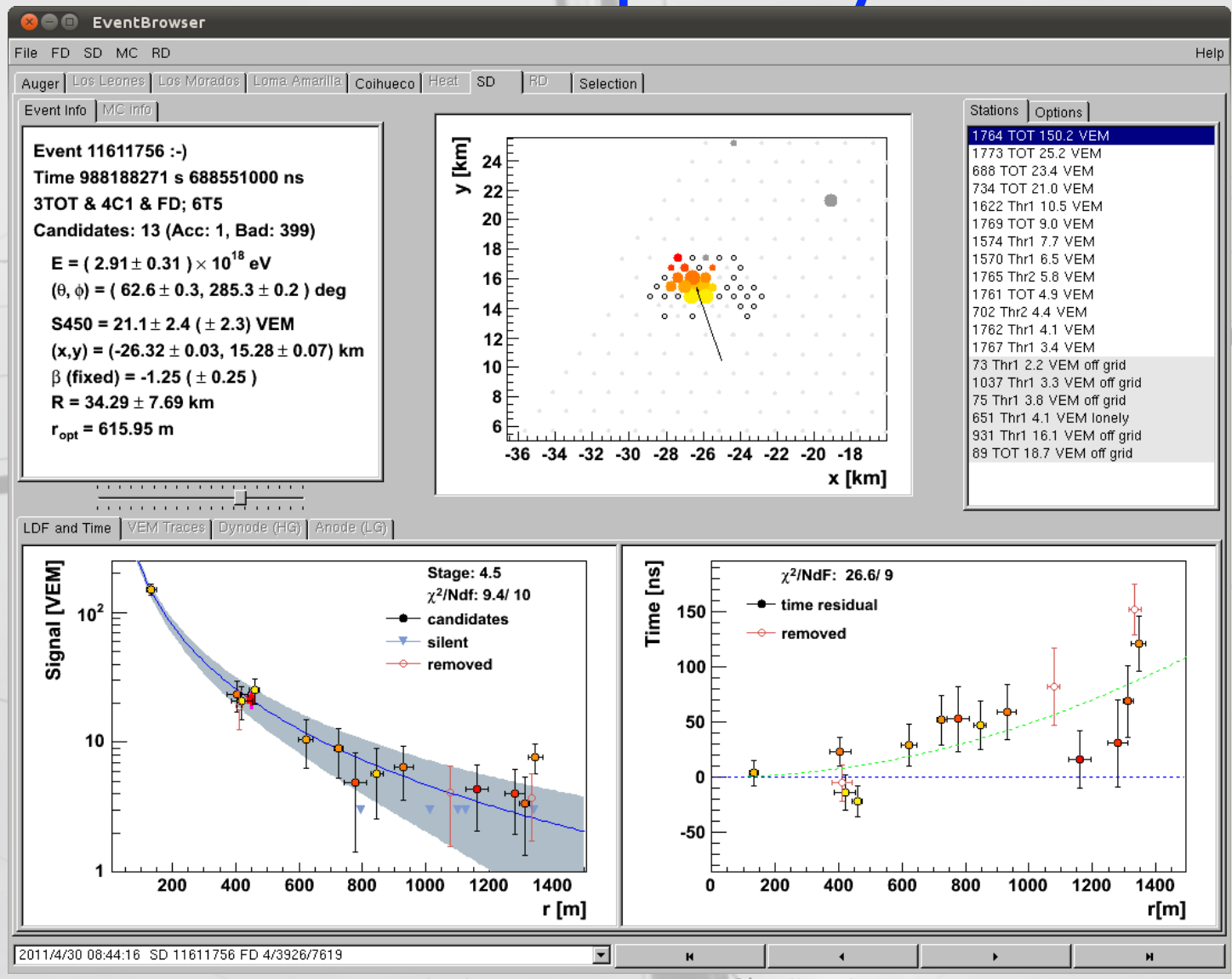
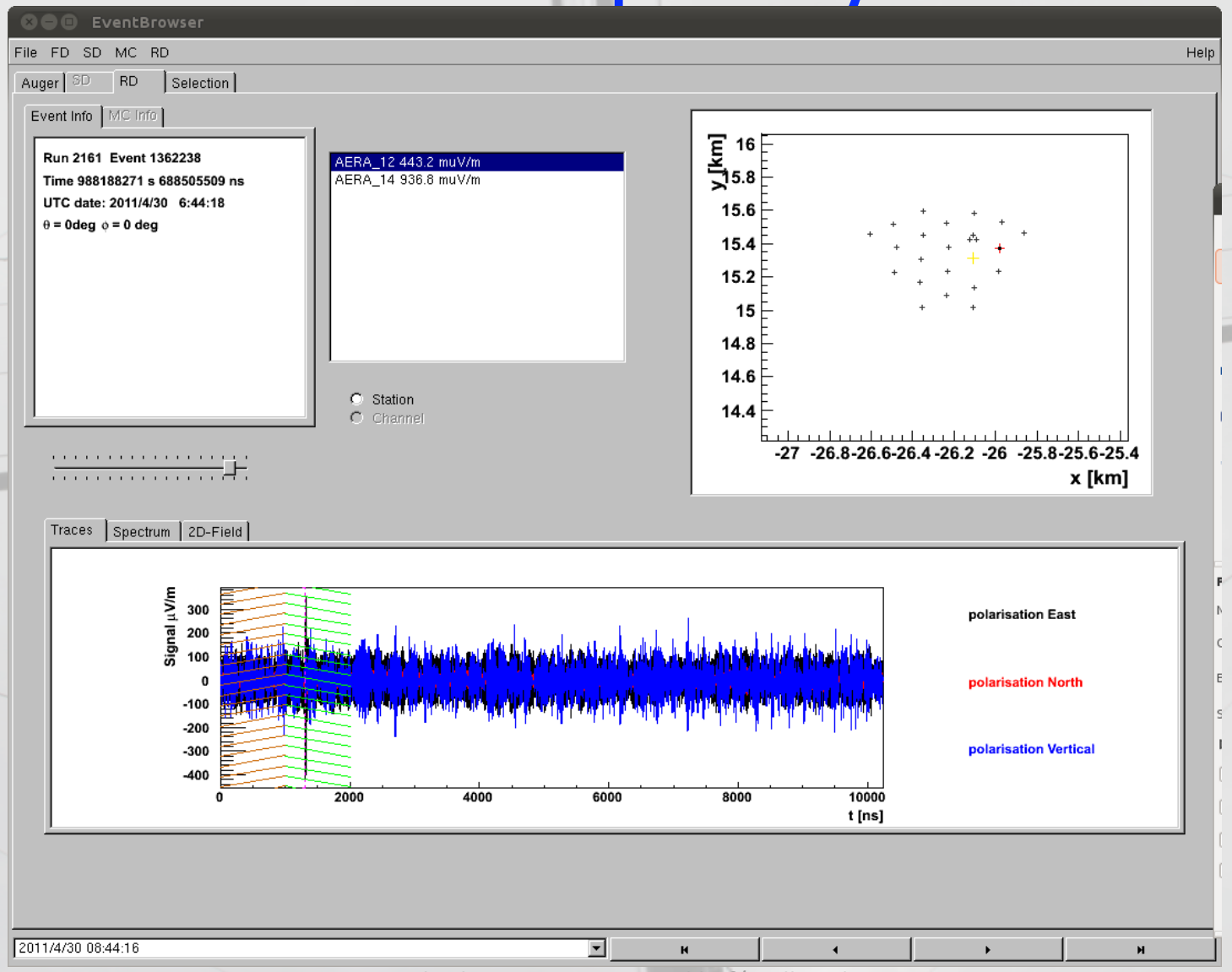


First Results – Super Hybrid events



Conclusion and outlook

- Almost 50 years after the first radio measurements, AERA Phase I is running as an independent CR detector.
- The available digital techniques allow self triggering of the individual AERA detectors.
- Time coincidences with other Auger sub-detectors allow to find true CR induced air showers.
- Phase I will provide more insight in the radio emission mechanisms.
- Knowledge obtained in phase I will be used in design improvements for phase II.