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°)

60 km

1660 water Cherenkov stations

Talk by Stephane Coutu at 11:30

Charles Timmermans, Nikhef/Radboud University
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)

Low noise amplifiers

GPS Antenna

Solar Panel

Optical Fiber

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

6/10/11

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• 2 stage amplification and filtering
• Each stage consists of 8\textsuperscript{th} order high- and 9\textsuperscript{th} order low-pass
• High speed amplifiers in 2\textsuperscript{nd} stage for low intermodulation at low power consumption
Characteristics for each module known. All are the same within ~2 dB. Difference between low and high gain outputs is 20 dB.
Digital Electronics
All digitizers have been calibrated.
The responses are identical within 2%
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
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
The setup is sensitive to the Galactic background variation. A 67 MHz man-made interference is clearly visible.
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

Run 3926 Event 7619
time stamp: 588188271 ± 688575436 ns
Trigger: ‘Physics’ Int or L/R trigger, ‘Shower Candidate’
hottest hybrid station: 1764 (TOT), ASP = 112 m
Mie attenuation: model
LIDAR: no data ; CloudCam: no data
in Colhuco mirror 2 3 ( in DAQ: 1 2 3 4 5 6)

\[ E = (1.80 \pm 0.07) \times 10^{19} \text{ eV} \]
\[ X_{\text{max}} = 635 \pm 43 \text{ g/cm}^2 \]
\[ dE/dX_{\text{max}} = 2.75 \pm 0.13 \text{ PeV/(g/cm}^2\text{)} \]
\[ \langle L, X \rangle = (65\pm11,196\pm133) \text{ g/cm}^2 \]
Cherenkov-fraction = 38%, nva=9 deg.
\[ \langle \phi, \theta \rangle = (63.0\pm0.4, 284.2\pm1.5) \text{ deg} \]
\[ \langle x, y \rangle = (-26.19\pm0.04, 14.86\pm0.14) \text{ km} \]
dca to Eye=5.54 ± 0.03 km
First Results – Super Hybrid events

Event 11611756 :-)
Time 986188271 s 688551000 ns
3TOT & 4C1 & FD; 6TS
Candidates: 13 (Acc: 1, Bad: 399)

\[ E = (2.91 \pm 0.31) \times 10^{18} \text{ eV} \]
\[ (\theta, \phi) = (62.6 \pm 0.3, 285.3 \pm 0.2 \text{ deg}) \]

\[ S_{450} = 21.1 \pm 2.4 (\pm 2.3) \text{ VEM} \]

\[ (x, y) = (-26.32 \pm 0.03, 15.28 \pm 0.07) \text{ km} \]

\[ \beta (\text{fixed}) = -1.25 (\pm 0.25) \]

\[ R = 34.29 \pm 7.69 \text{ km} \]

\[ r_{\text{opt}} = 615.95 \text{ m} \]
First Results – Super Hybrid events

Run 2151 Event 1362338
Time: 985188271 ± 698505500 ns
UTC date: 2011/4/30 6:44:18

AERA_A_12 443.2 m/VM
AERA_A_14 936.8 m/VM

x [km]
-27 -26.8 -26.6 -26.4 -26.2 -26 -25.8 -25.6 -25.4

y [km]
16 15.8 15.6 15.4 15.2 15.0 14.8 14.6 14.4

Staben
S-Stabend

Traces Spectrum 3D-Field

0 2000 4000 6000 8000 10000
Signal [pClm]

polarisation East
polarisation North
polarisation Vertical

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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.