The RF system of the ASTRONEU EAS array

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The group

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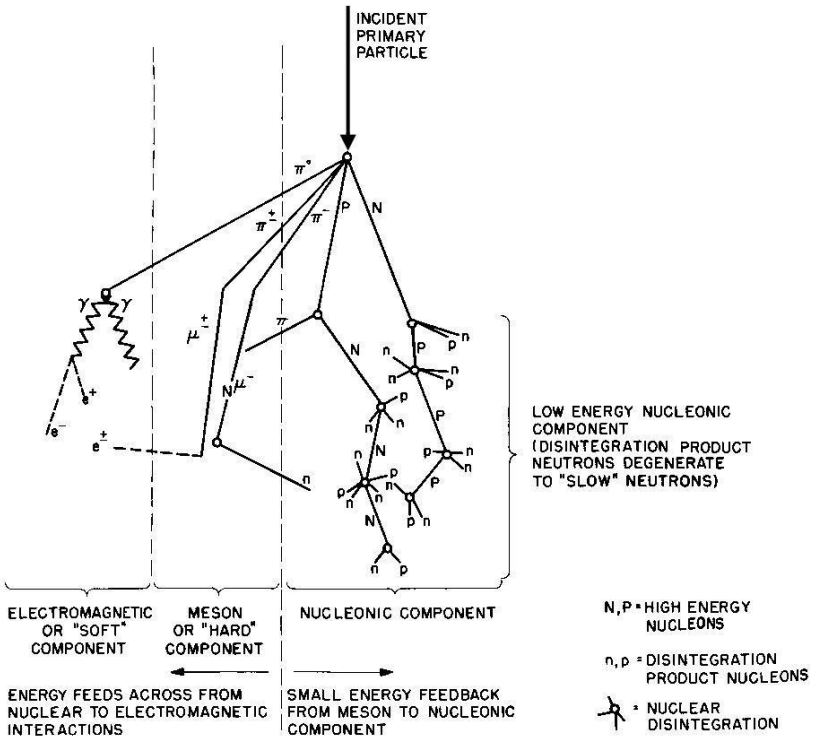
- Dr. G. Bourlis (HOU)
- I. Manthos (UofAeg/HOU)

- Dr. K. Zachariadou (TEI Peir)
- Dr. K. Prekas (TEI Peir)
- Prof. S. Tzamarias (HOU)
- Assoc. prof. K. Papageorgiou (UofAeg)
- G. Georgis (HOU)
- Th. Avgitas (HOU)

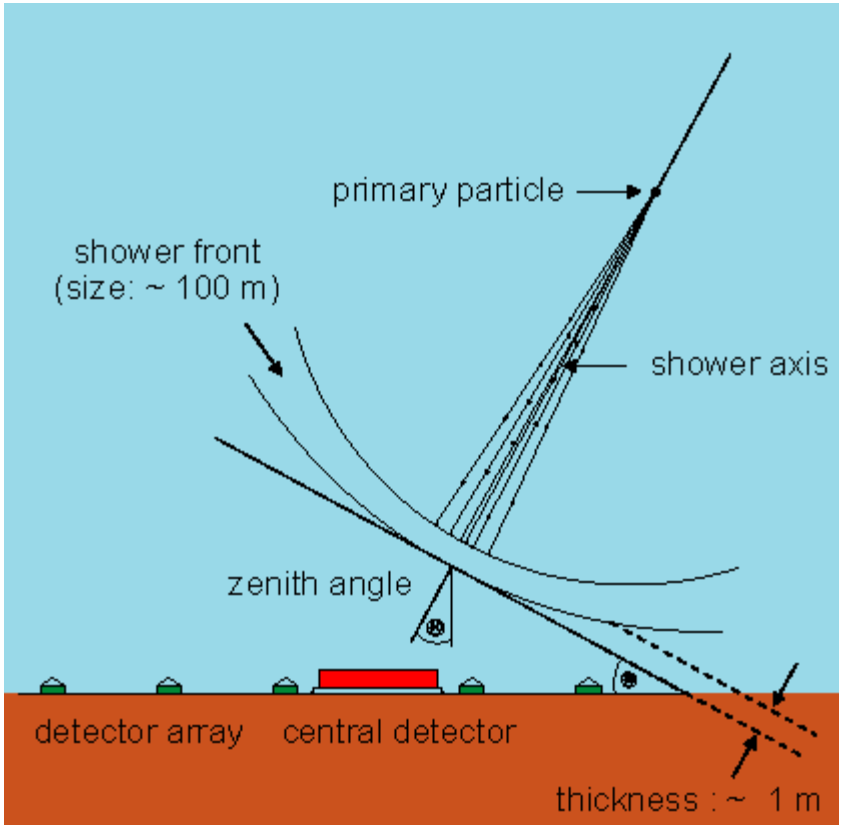
Project History

- INTERREG ELLADA-KYPROS (2005-2010)
- 12 scintillators counters (HELYCON type) and one LOFAR antenna was installed at the U of the Aegean on Chios
- THALIS ASTRONEU (2010-2015)
- 6 CODALEMA antenna systems are to be installed in Patras,
- Add 12 Hellenic Open University HELYCON detectors
- The U of aegean SC and antenna has been transferred to be installed in Patras area

EAS development



Schematic Diagram of Cosmic Ray Shower



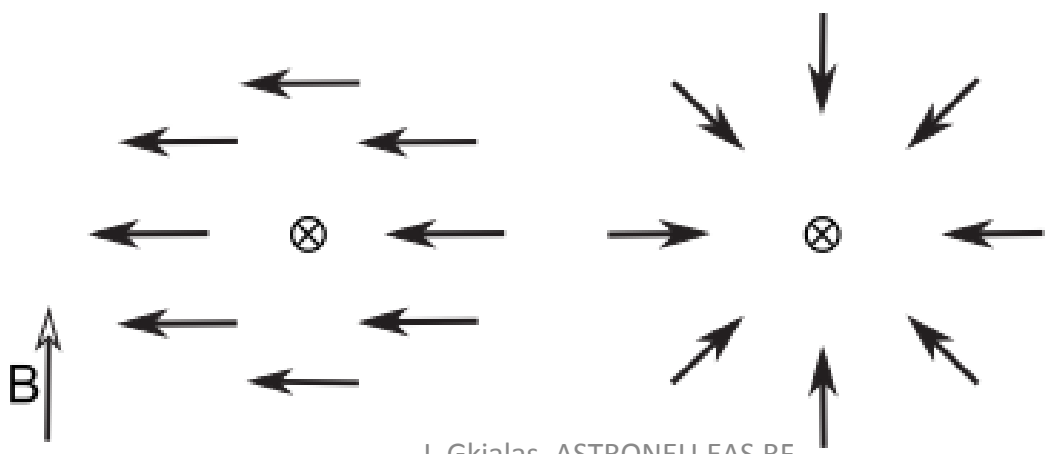
Radiation production mechanisms

- Geomagnetic Effect (Kahn, Lerche, 1966)

Transverse currents in pancake, boosted to ground reference frame

- Charge Excess mechanism (Askaryan, 1962)
- Cerenkov radiation of electron excess in shower development
- Sudden Death mechanism (B. Revenu, V. Marin, 2013)

Radiation from sudden deceleration on impact to ground.



Radiation production mechanisms

- Coherent radiation
- $P \propto n^2$
- Dominant mechanism is geomagnetic (LOFAR, CODALEMA)
- Recent results from CODALEMA show superimposed effect of charge excess mechanism (CODALEMA 2011)

Experimental area

- HOU buildings, Perivola, Patras

Station 2 with
3 scintillators and
1 antenna

Instrumentation

Invaluable help from codalema colleagues in installing the antennas

- Lilian Martin,
- Jena-Luc Beney
- Richard Dallier

What do we expect

$$E_\nu = 25 \frac{\mathrm{E}_p}{10^{17} eV} \sin\alpha \sin\theta \exp\left(-\frac{R}{R_0}\right) \quad \left(\frac{\mu V}{mMHz}\right)$$

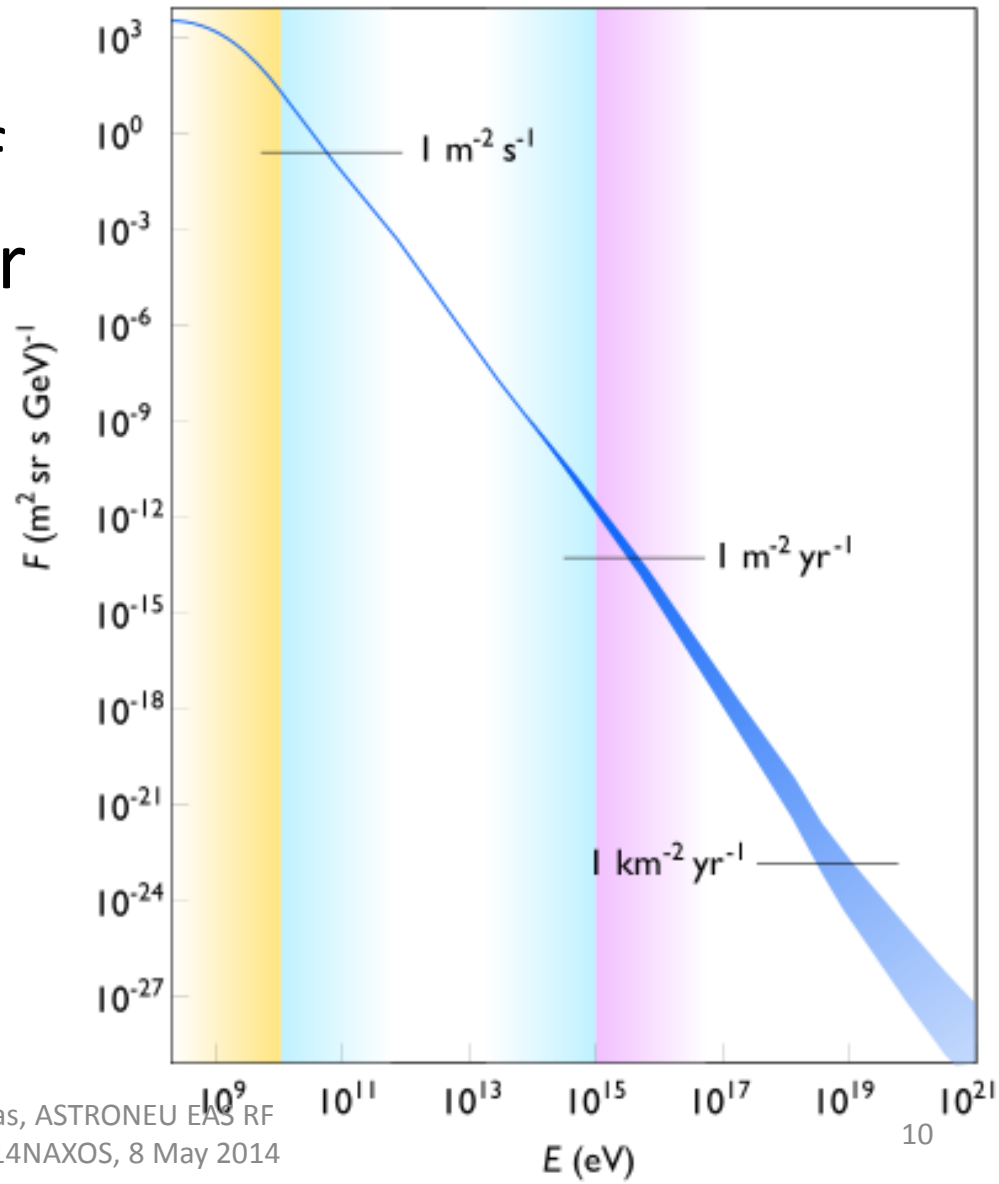
$$\left.\begin{array}{l} \sin\alpha \approx \sin\theta \approx 1 \\ R_0 \approx 100m \\ R \approx 10m \\ \nu \approx 50MHz \\ l = 1m \end{array}\right\} \Rightarrow$$

- At this point we expect to see signal >1 mV,
- so E>10^{17}eV

$$\Delta V = \frac{\mathrm{E}_p}{10^{17} eV} \quad mV$$

Do we expect to see showers?

- So, expected rate of showers about 1 per week



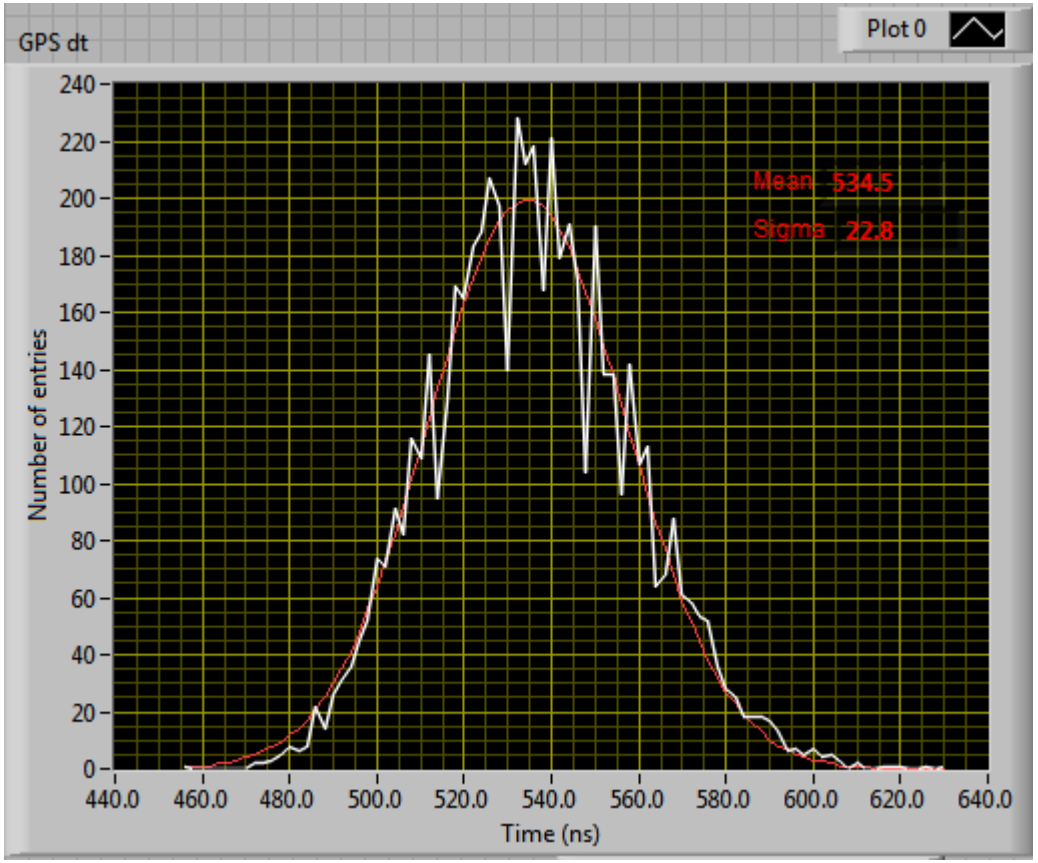
Trigger+Analysis

- Internal clock trigger (1Wire)
- Triple coincidence of scintillator station

- Check understanding of time by quarknet and codalema GPS
- Windowing function
- FFT
- Filter (Remove AM, FM bands)
- Back FFT
- Cut full electronics time range in 10X250 ns bands.
- Calculate cumulative functions and cut on rise times < 30 ns (a la CODALEMA)
- For this report we used 5700 events recorded in the previous days

GPS time matching

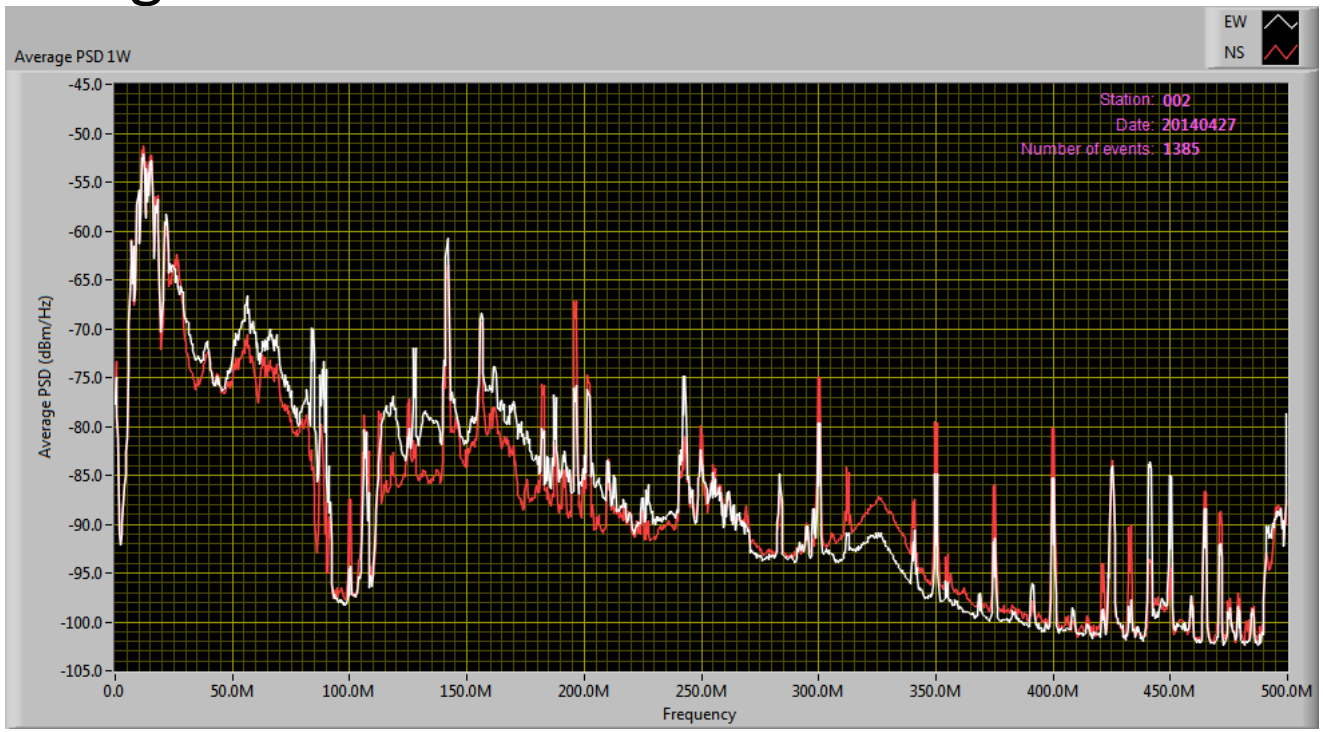
- GPS from counter (Quarknet) electronics boards, 40 ns step
- GPS from CODALEMA electronics, 1ns step



Spectra of clocked triggers (random)

- Station 2
- 1 trigger per min., 1385 triggers
- Full Range

$$P_{(W)} = \frac{1}{1000} 10^{(P(dbm)/10)}$$



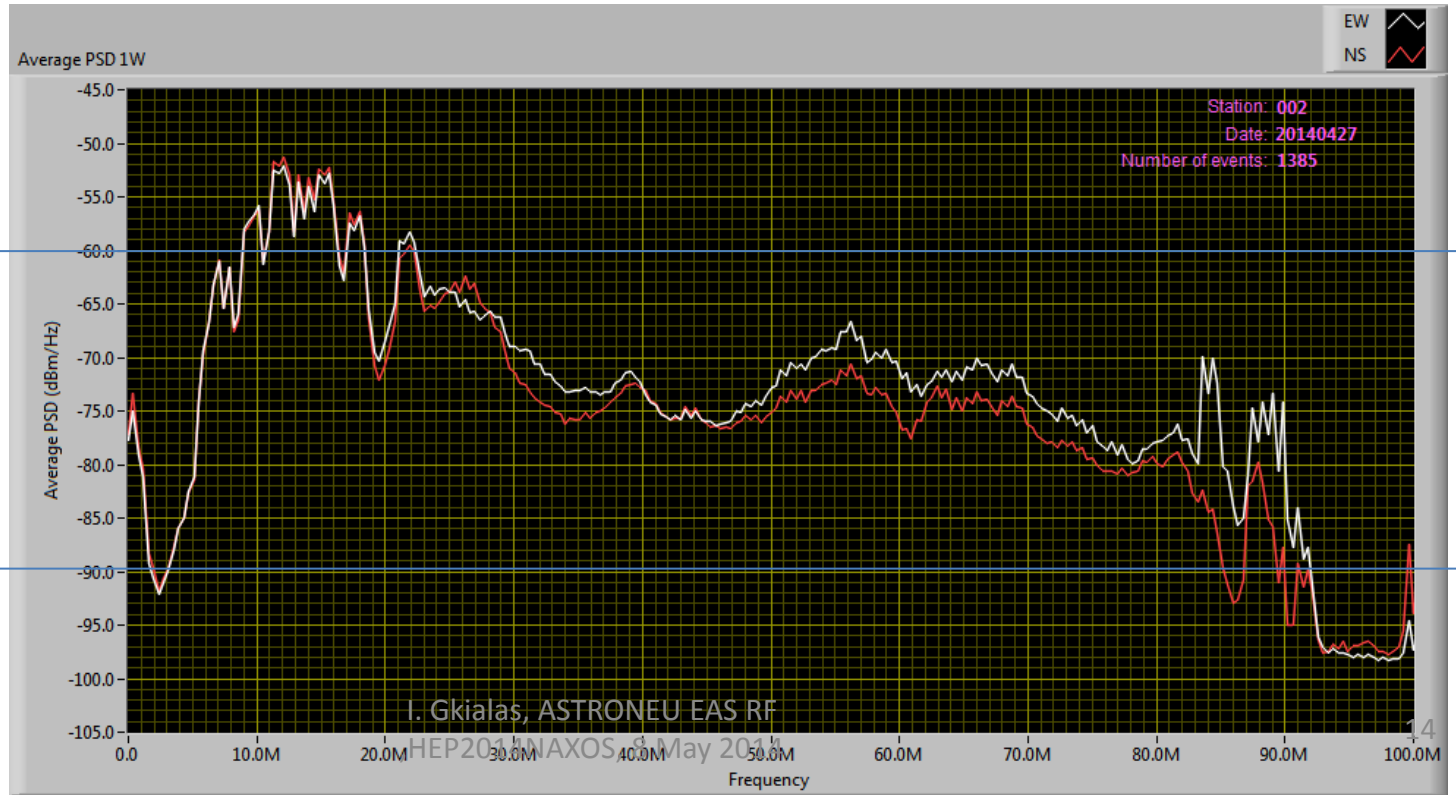
Spectra of clocked triggers (random)

- Station 2
- 1 trigger per min., 1385 triggers
- 0-100 MHz

$$P_{(W)} = \frac{1}{1000} 10^{(P(dbm)/10)}$$

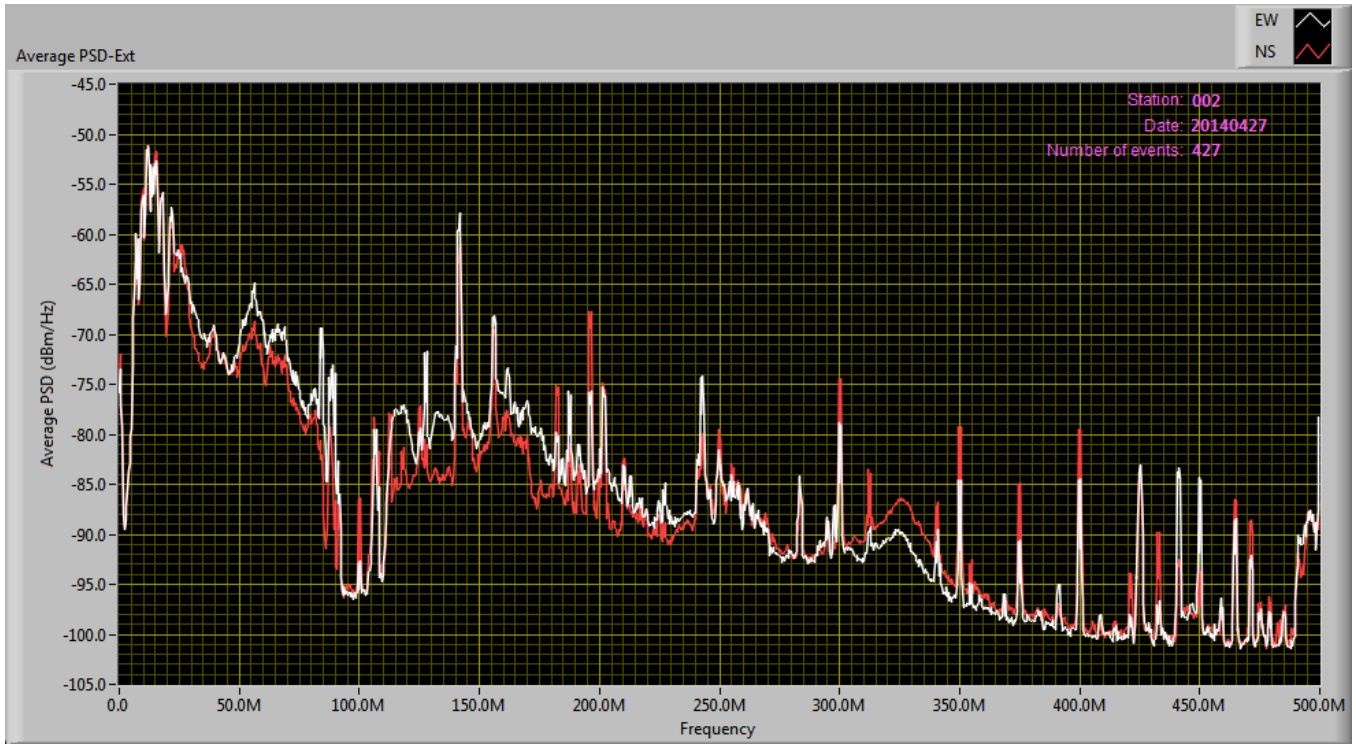
$10^{-9} W / Hz$

$10^{-12} W / Hz$



(Sci Counter) external trigger

- Station 1
- External trigger, 427 events,
- about 1 day of data taking
- Full Range



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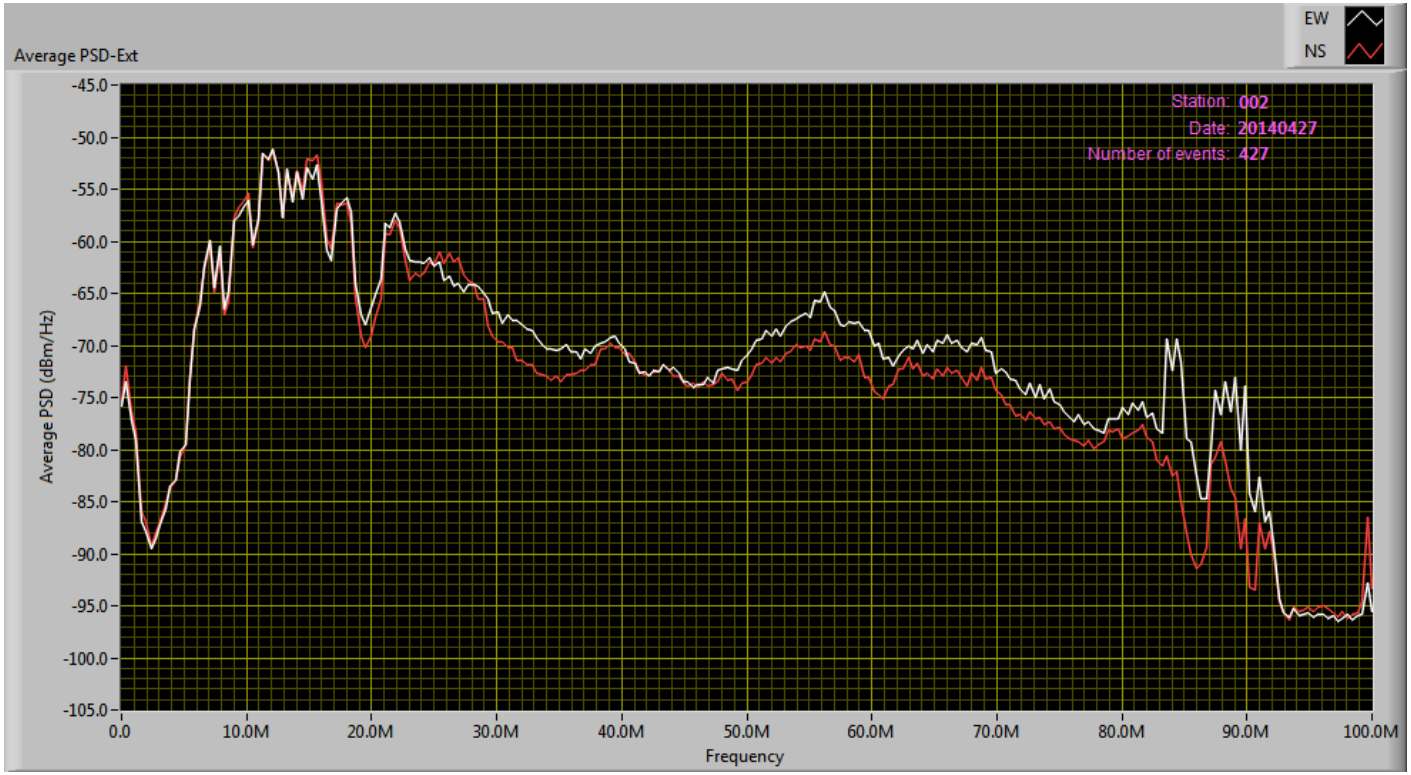
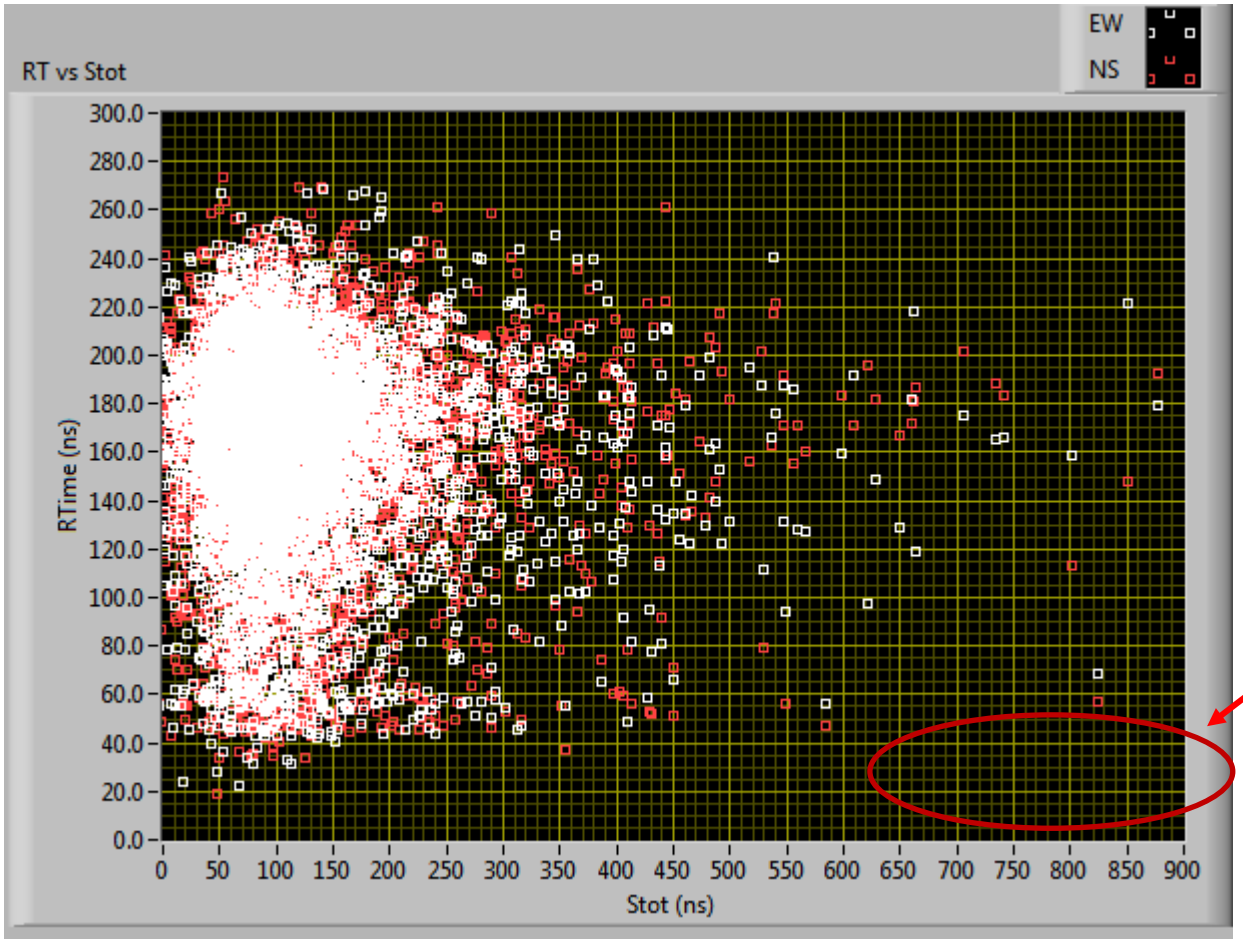


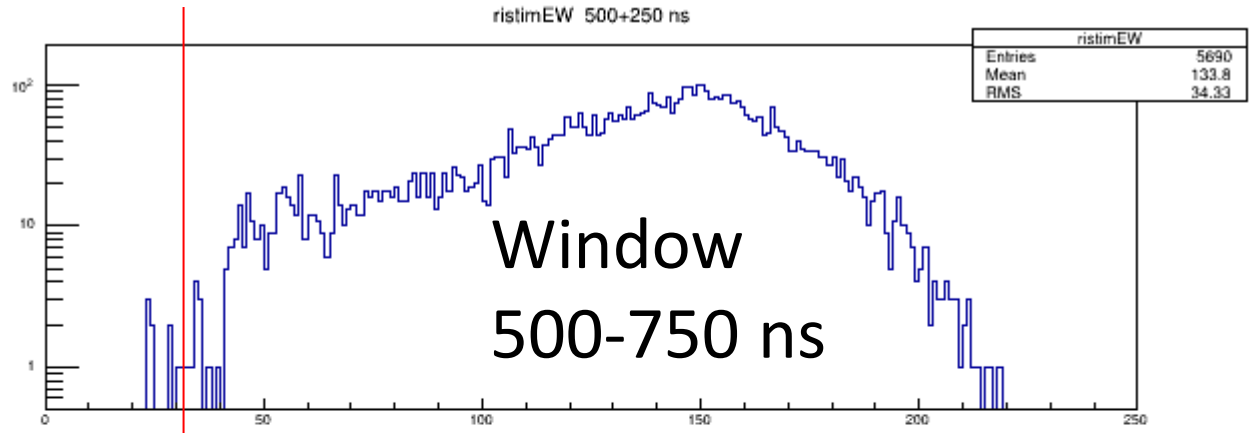
Antenna signal Risetime vs Counter Signal Time Over Threshold

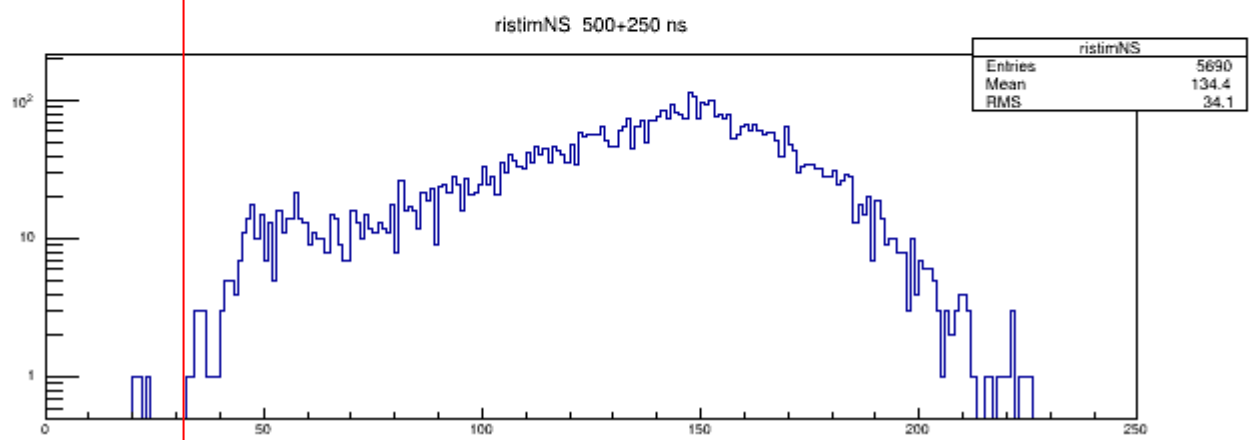


Shower region

Rise time

- Cosmic signals are fast (<100 ns)
- Background signals are slow





$$P_{cum} = \frac{\sum_{i=n10}^{i=n70} s_i^2}{\sum_{i=1}^{n_win} s_i^2}$$

Typical cut 30 ns for 250 ns window. Can depend on frequency

A few antenna events triggered by SC

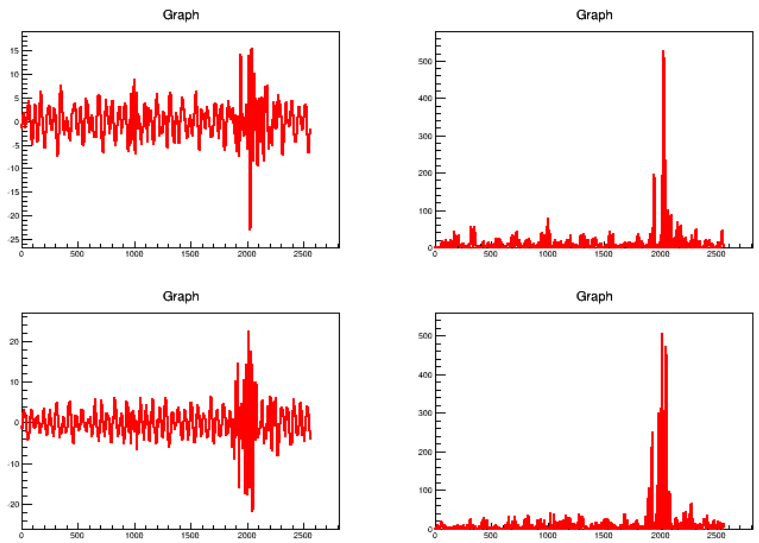
- Background event (3182)
- Clears the 30 ns risetime cut
- Wrong time bin

Raw signal in 2560 ns window

Amplitude Power

East-West

North-South

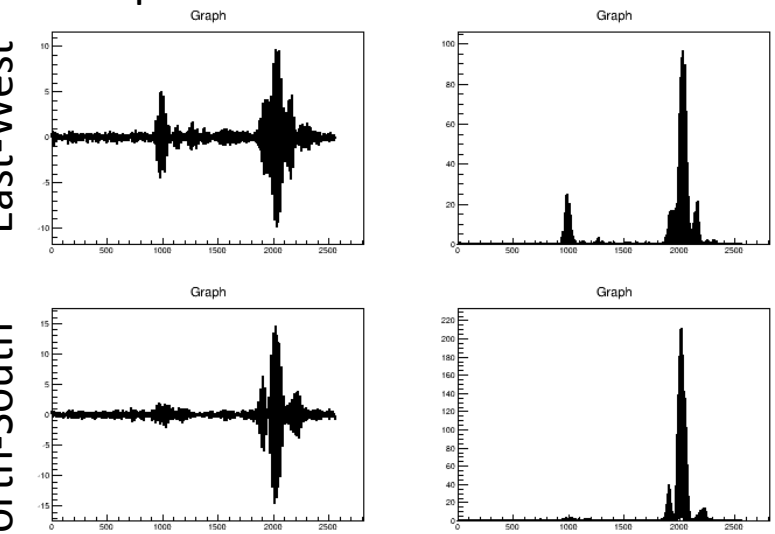


Filtered in 2560 ns window

Amplitude Power

East-West

North-South



East-West

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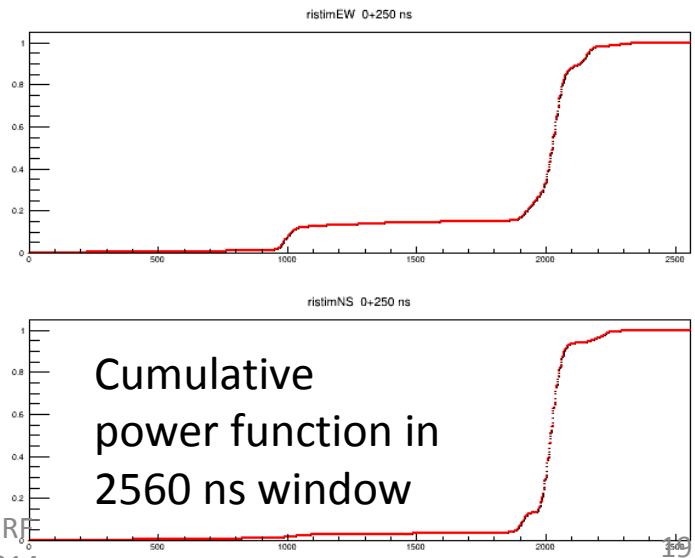


Cumulative power function in 2560 ns window

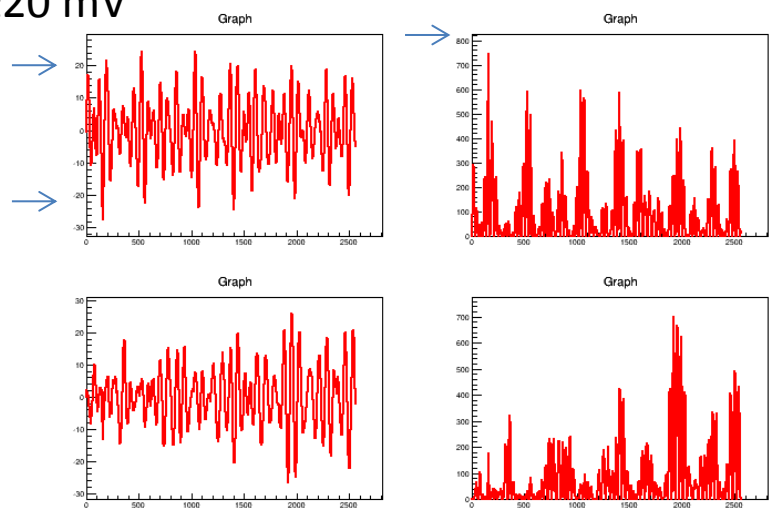
Constant background Event

- Event 3546

Raw signal in 2560 ns window

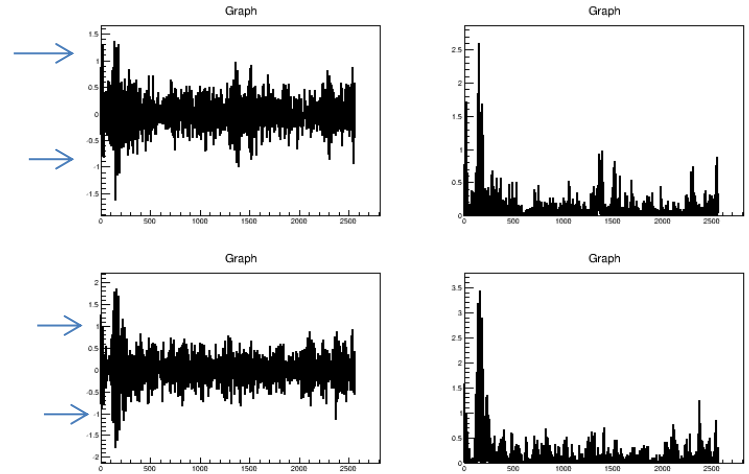
Amplitude Power

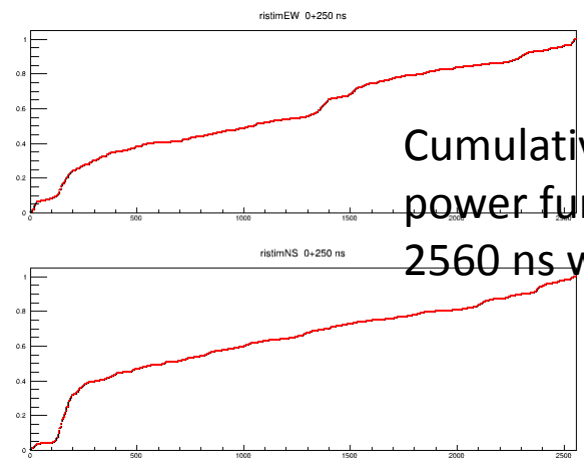
±20 mV



Filtered in 2560 ns window

±1 mV Amplitude Power





Cumulative power function in 2560 ns window

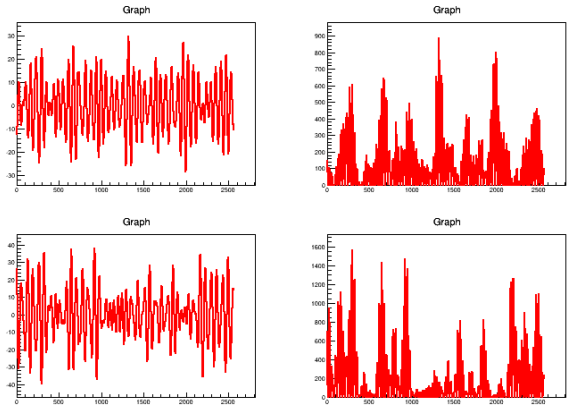
Cosmic candidate event (?)

Event 4684
Correct time
One transient survives filtering
Large Stot from the counters
BUT…
Rise time about 100 ns in a 500 ns window

Probably not!

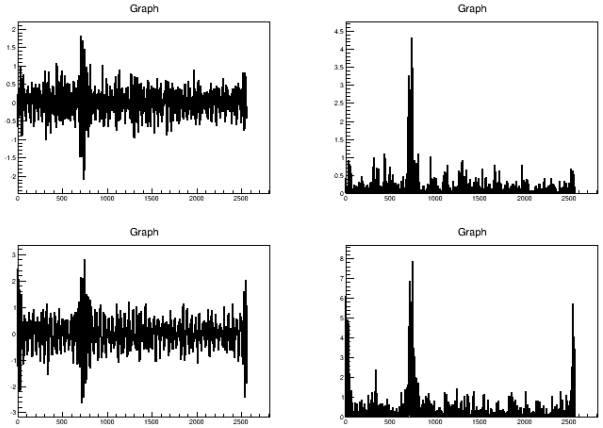
Raw signal in 2560 ns window

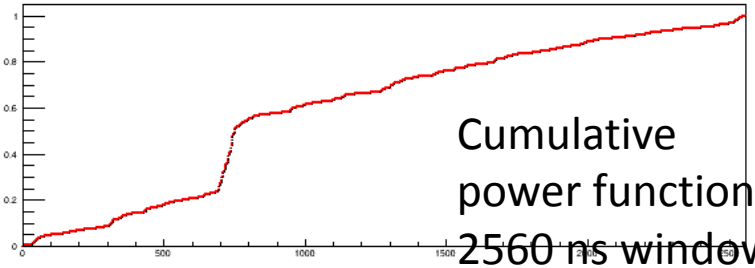
Amplitude Power



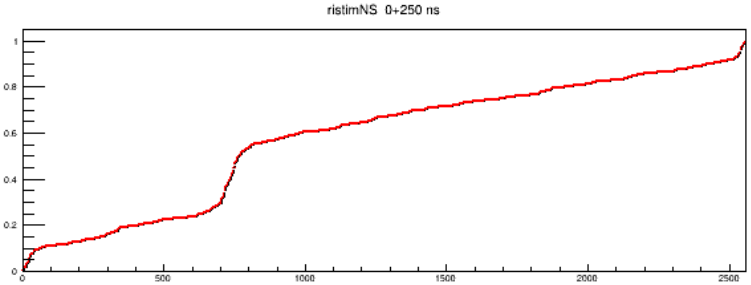
Filtered in 2560 ns window

Amplitude Power

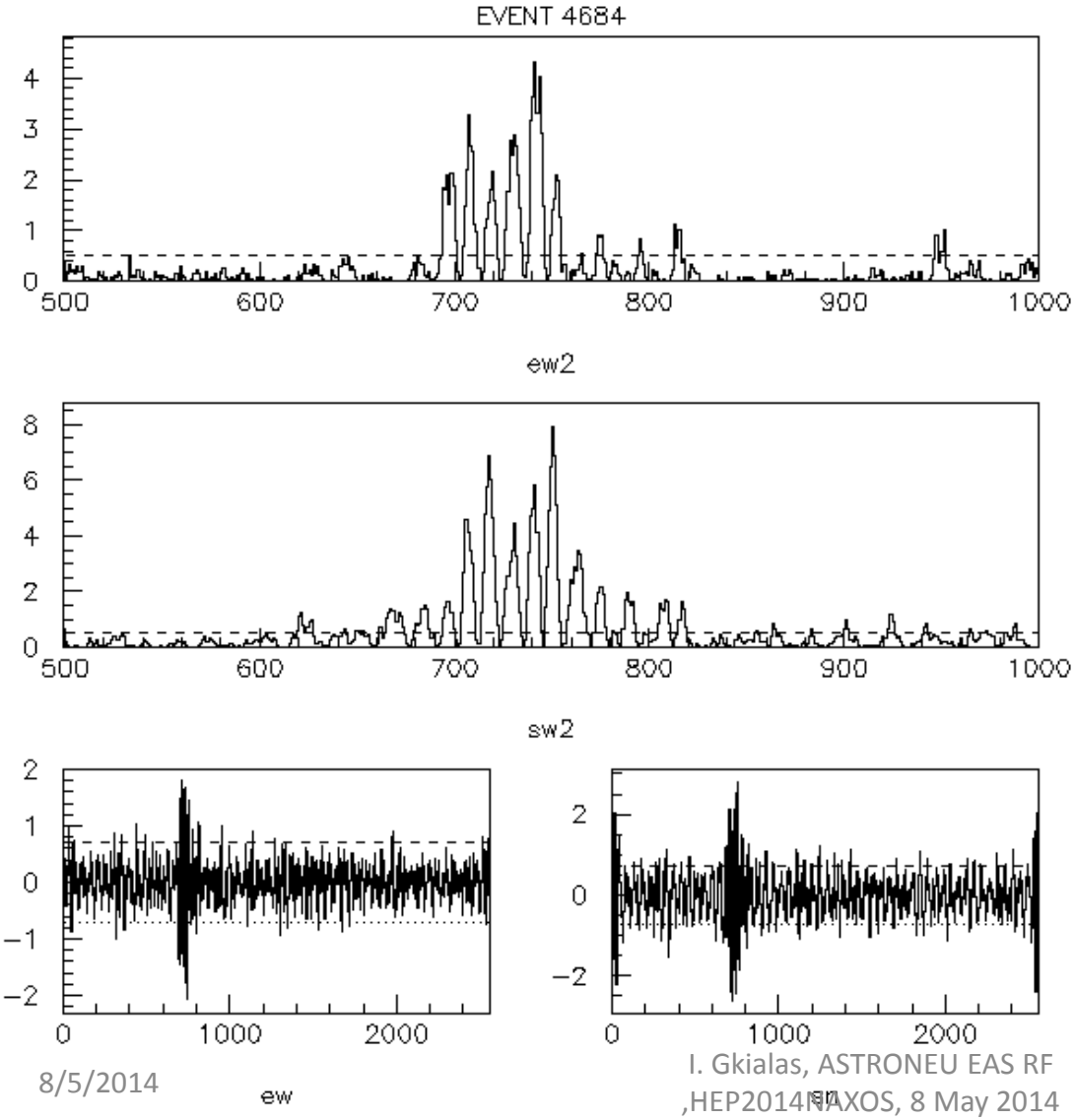




Cumulative power function in 2560 ns window



Cosmic candidate event (?)



Tot1 110
Tot2 137
Tot.3 175 ns
Σtot 422 ns

EW rising 99.ns
NS rising 100.ns

CUT at 0.5 of EW power
and 1. of NS power
EW rising 43 ns
NS rising 69 ns

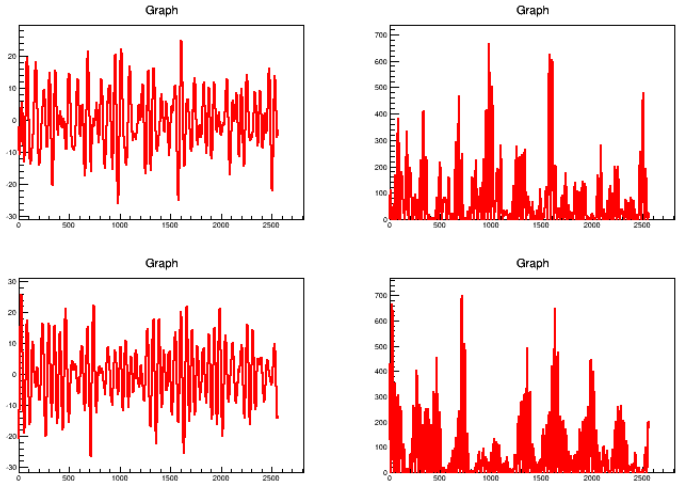
A cosmic candidate (?)

Event 4652
Correct time
One transient survives filtering
Large Stot from the counters
Rise time about 37 ns in a 500 ns window

Just maybe!

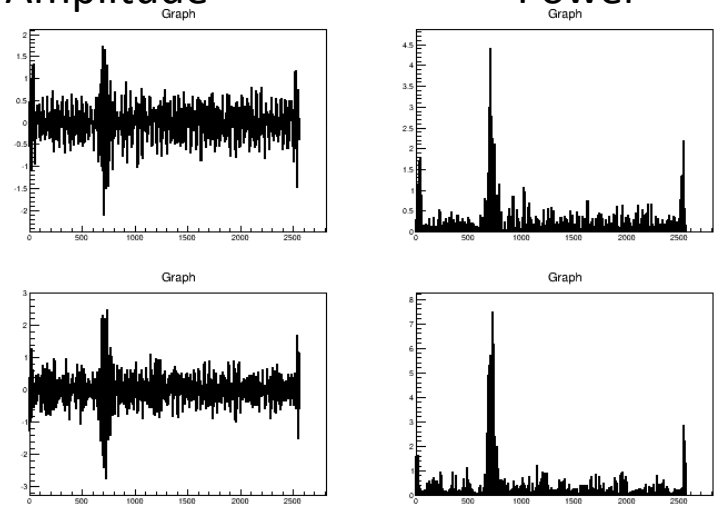
Raw signal in 2560 ns window

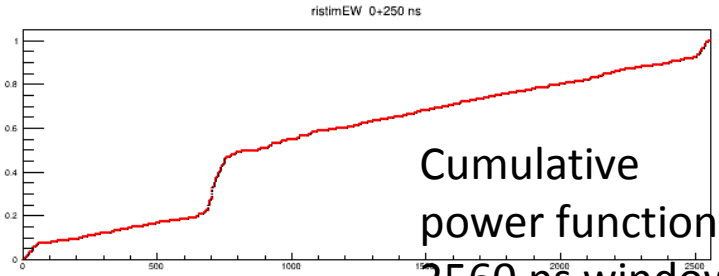
Amplitude Power



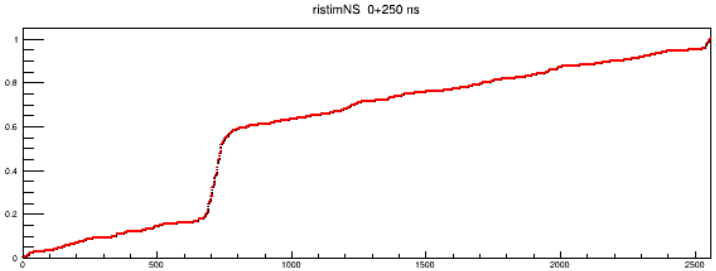
Filtered in 2560 ns window

Amplitude Power

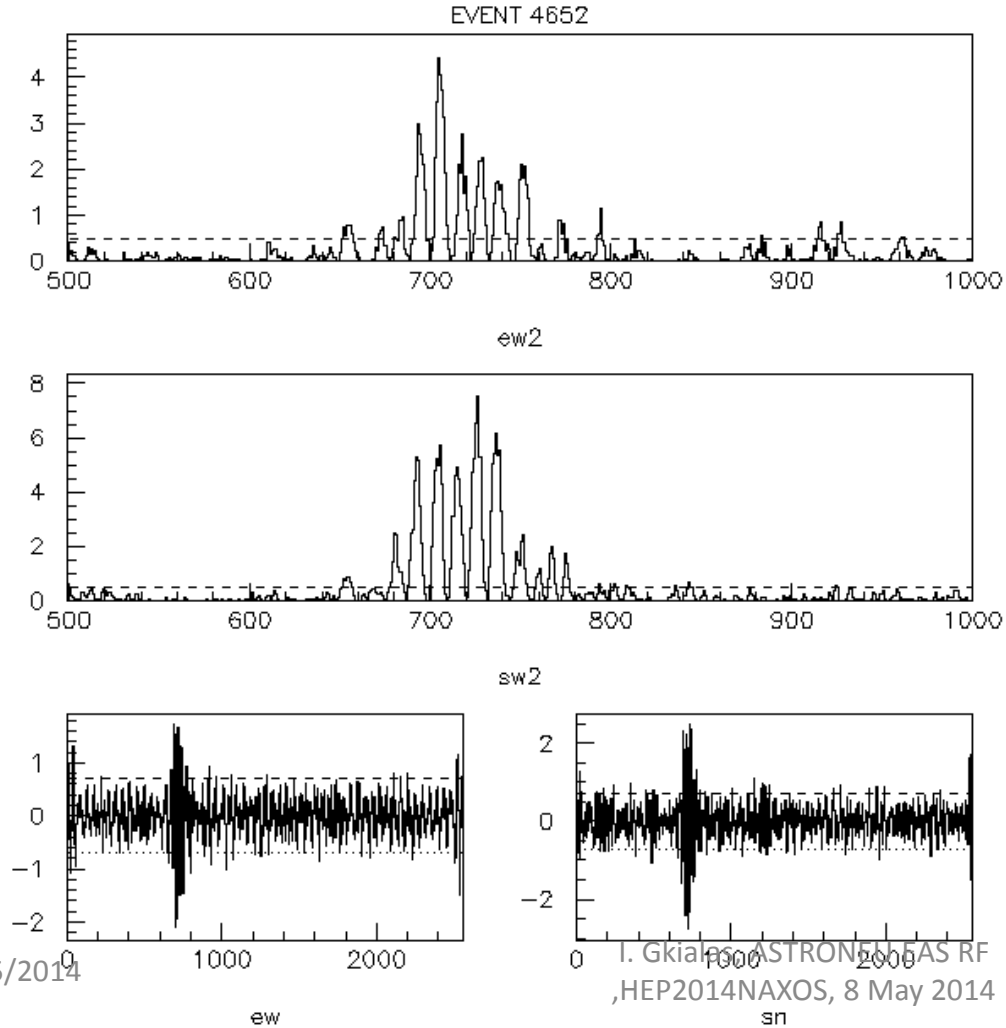




Cumulative power function in 2560 ns window



A cosmic candidate (?)



Tot1 107.5
Tot2 383.75
Tot.3 92.5 ns
Σtot 583.75 ns

EW rising 90.ns
NS rising 155.ns

CUT at 0.5 of EW power
and 0.7. of NS power
EW rising 37 ns
NS rising 43 ns

Learnt Lessons and Next steps

Present

- We learn how to operate the antennas
- Readout antennas with trigger from HELYCON counters
- Event analysis in progress

Immediate future:

- Understand data and identify cosmic ray signals

Medium future

- Add the rest of the stations and operate them as a single system
- Add a fast micromegas chamber as trigger of the antenna array