

ECRS- 2004

Radiodetection of cosmic ray extensive air showers : present status of the CODALEMA experiment

SUBATECH Nantes

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Radio Detection of Cosmic Ray Air Showers by the CODALEMA Experiment



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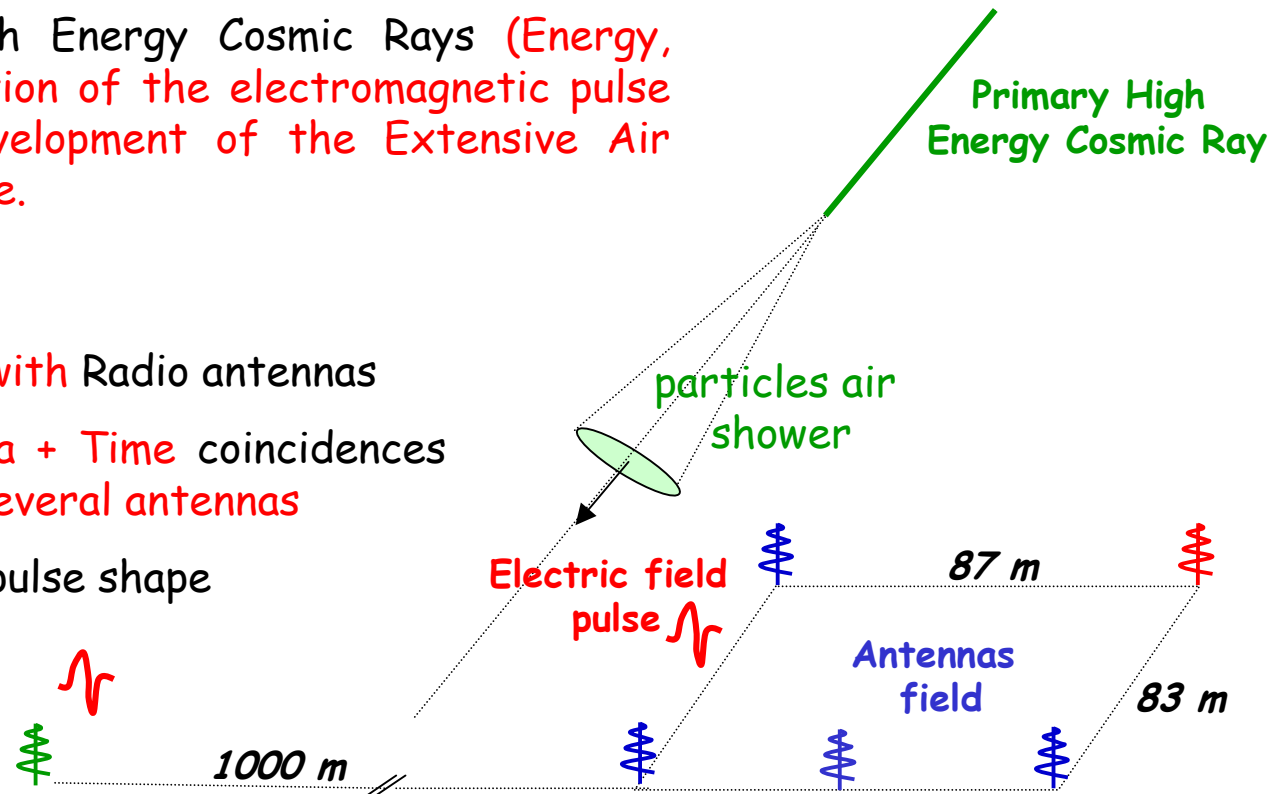
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Objective :

Characterisation of High Energy Cosmic Rays (Energy, Direction) by the detection of the electromagnetic pulse radiated during the development of the Extensive Air Shower in the atmosphere.

Principle:

- Detection of the pulse with Radio antennas
- One Triggering antenna + Time coincidences measurements between several antennas
- Recording the Electric pulse shape



Means :

Demonstrative experiment with 5 broadband antennas (1-200 Mhz) + 1 trigger antenna (35-65 Mhz) (Radio Telescope of Nançay France)

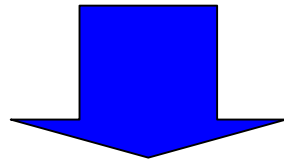
Experimental processes

• **Theory, simulation** : Information is contained in the shape of the signal

- amplitude ($>1\mu\text{V/m}$) \Rightarrow energy
- duration ($\sim 100\text{ ns}$) \Rightarrow impact

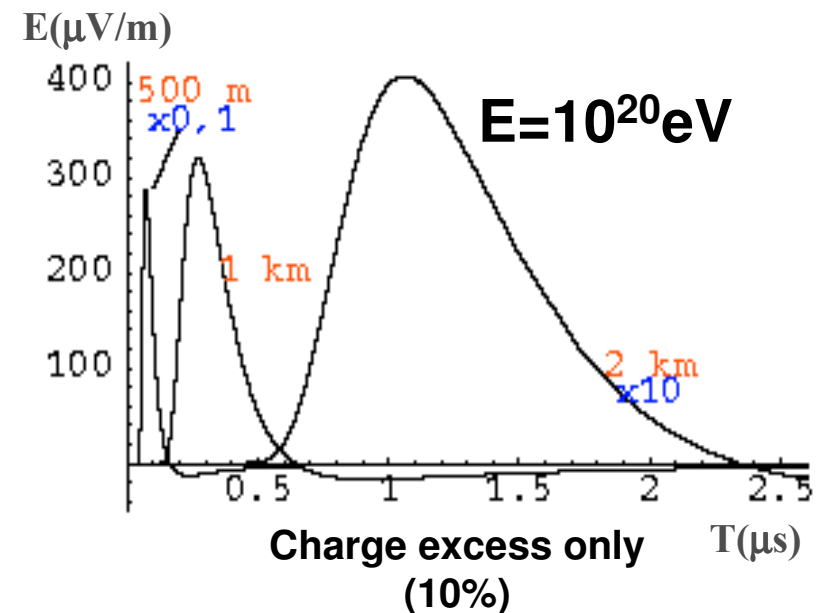
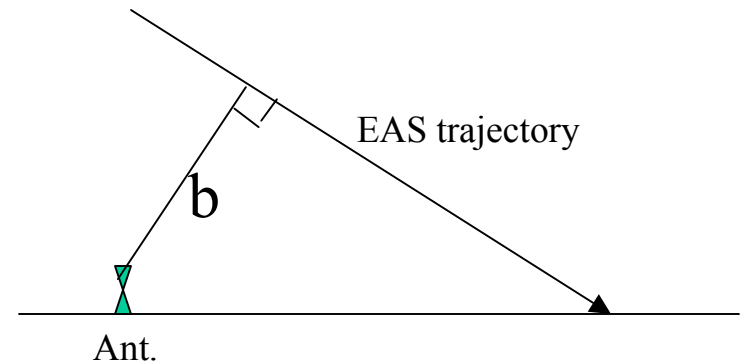
parameter

- shape \Rightarrow nature of particles



• **Measurements** :

- rare events (trigger $\sim 10^{-3}\text{ Hz}$)
- waveform analysis
- time analysis of the signal
- trajectory reconstruction

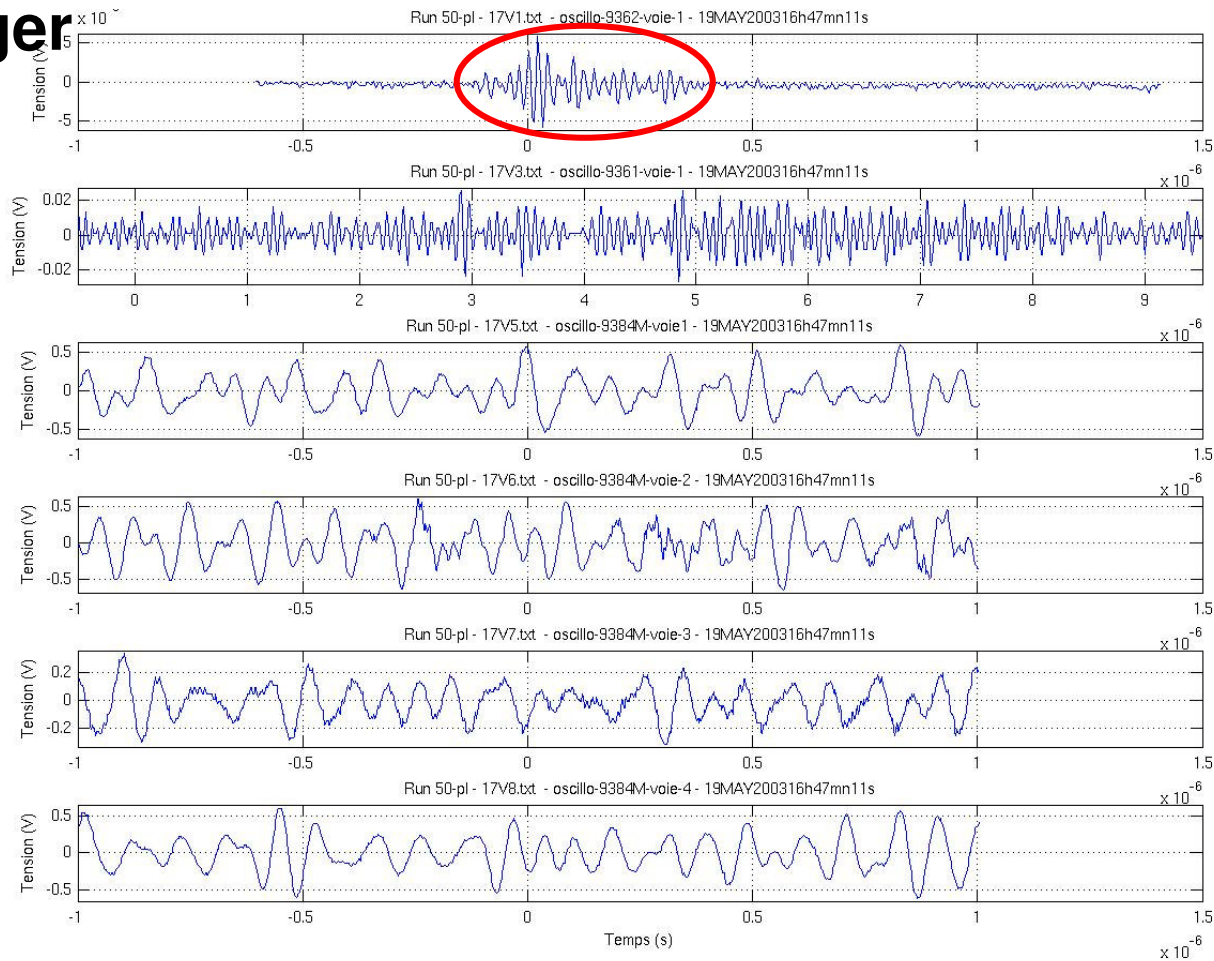


Typical raw event (broadband)

Analog Trigger
(35-65 MHz)

1 km

4 corners



⇒ **Transient signal is hidden by broadcasting stations**

Time coincidences detection

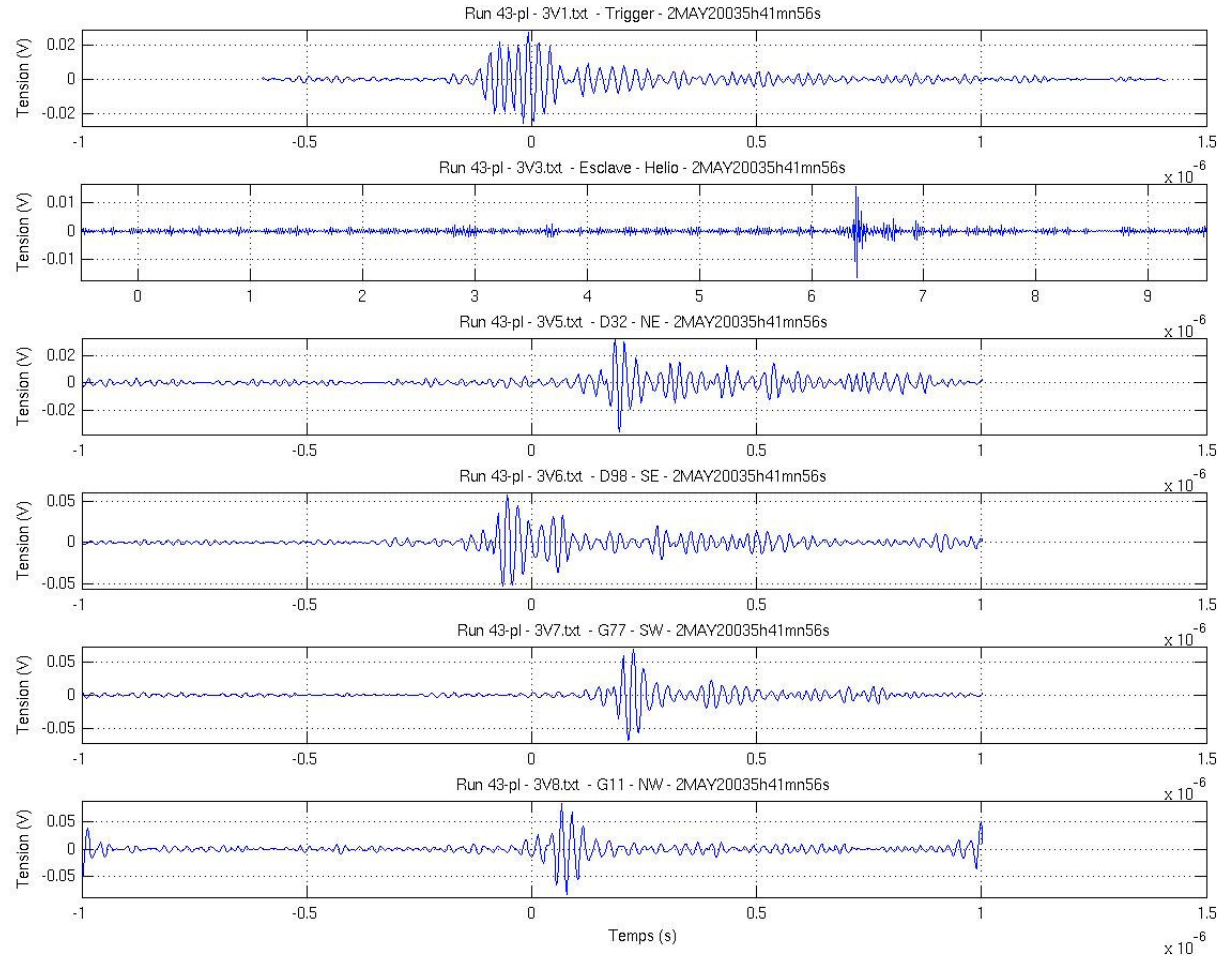
**Analog trigger
(35-65 Mhz)**

Antenna at
1km

**Numerical filtering
33-65 MHz band**

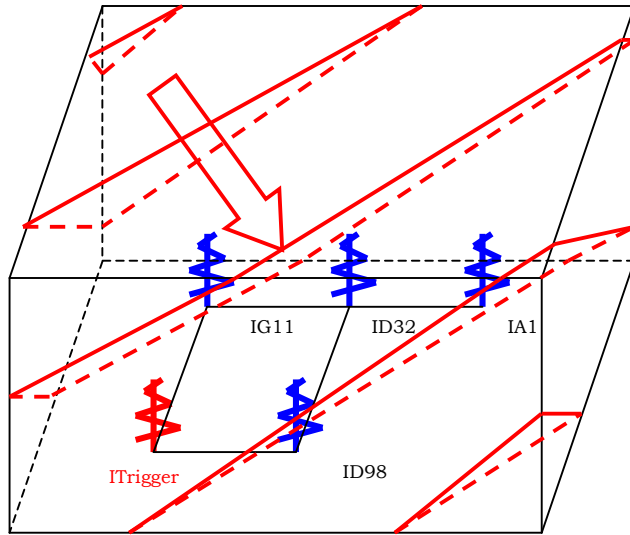
central area antennas
with numerical filtering

- **Time limited signals**
- **Arrival time consistent with wave propagation**
- **Transients observed over large distances (1 km)**

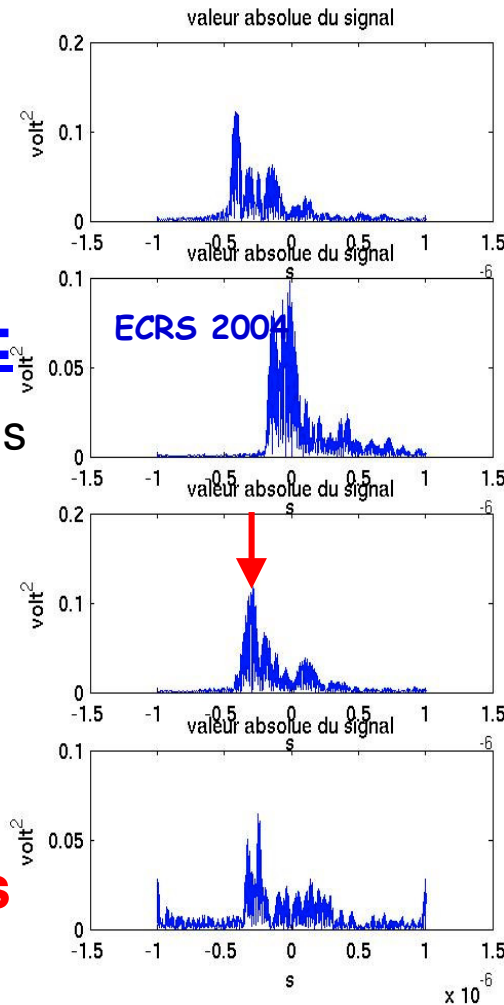


Time (μ s)

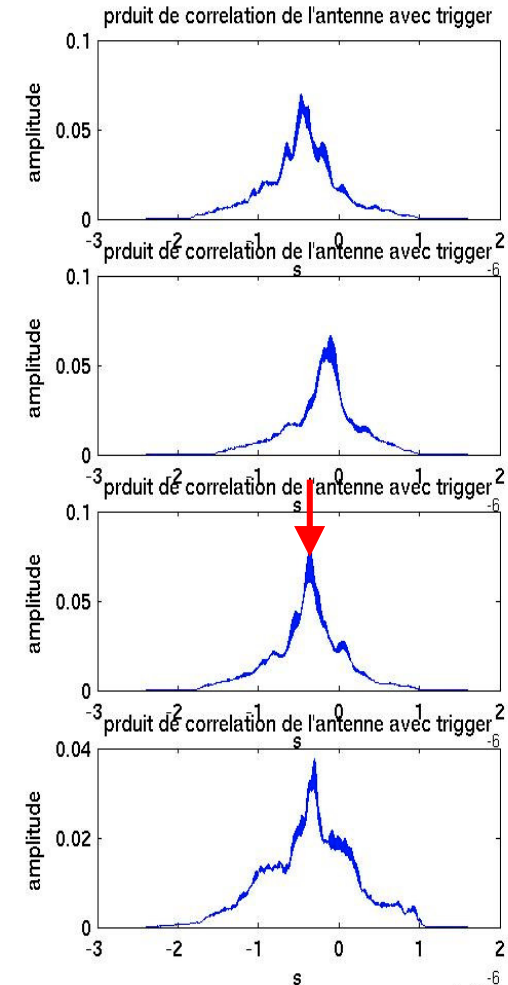
Time analysis



Maximum of $V^2(t)$



Trigger-Antenna correlation function



Expected time resolution:

- Intrinsicly: 500 Ms/s $\Rightarrow \Delta t \sim 2\text{ns}$

But

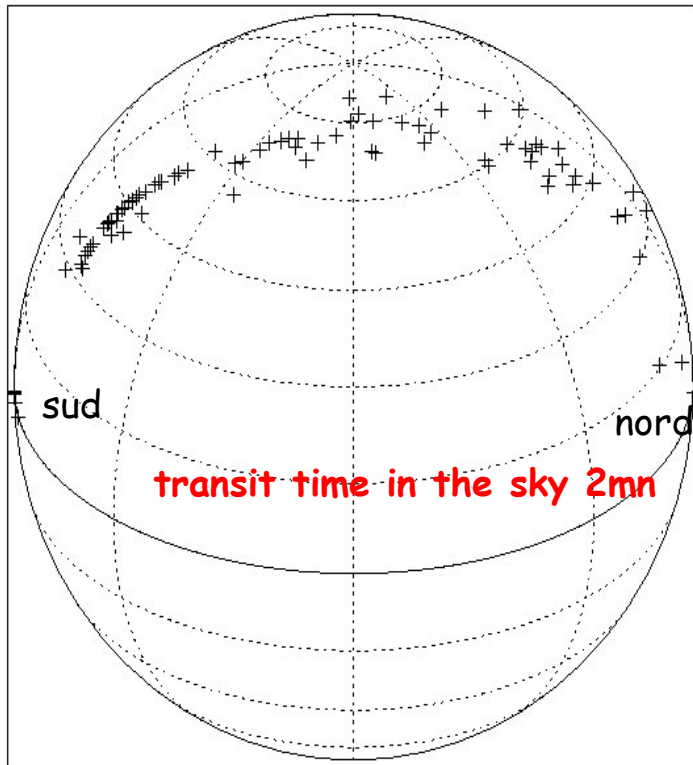
- Filter low cut-off: 33 MHz $\Rightarrow V^2(t) \sim 66\text{ MHz}$



$\Delta t \sim 15\text{ ns} \sim 3\text{ light meters}$

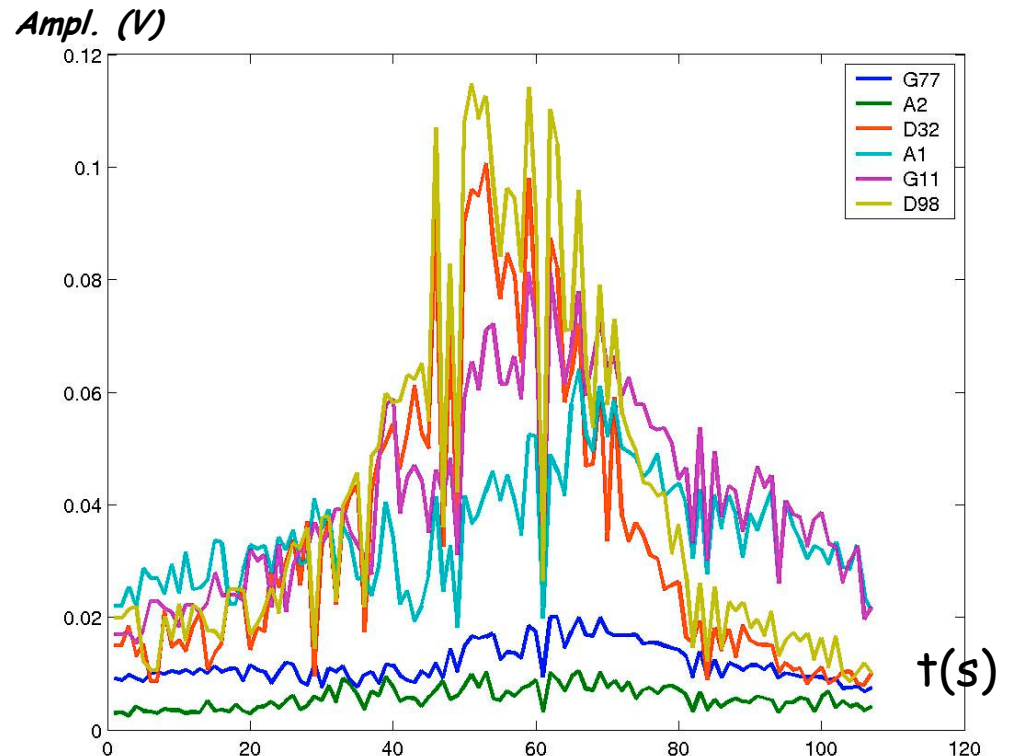
Triangulation tests using identified sources

Reconstructed trajectory of airplanes



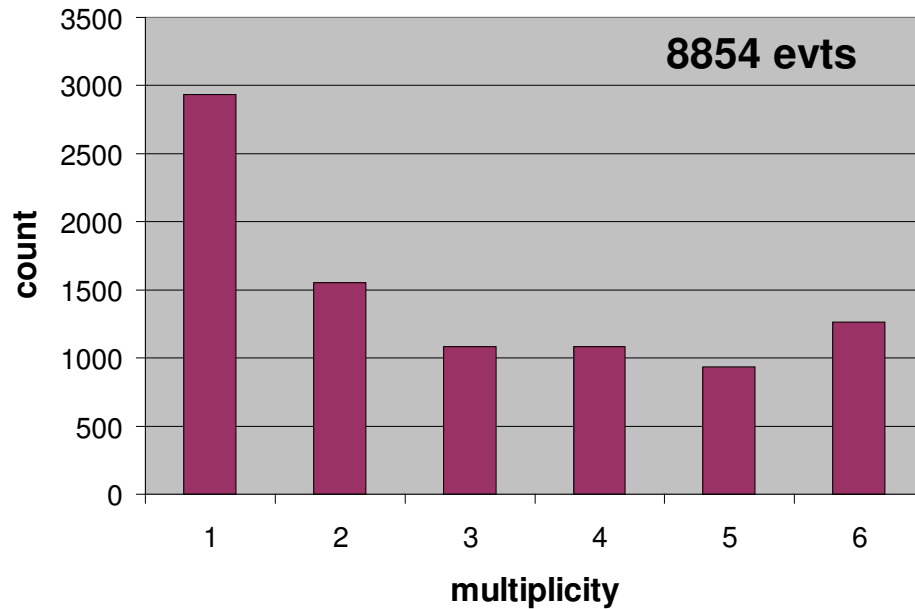
- Time tagging is demonstrated
- Triangulation algorithm is working

Time evolution of the amplitude recorded for an airplanes trajectory

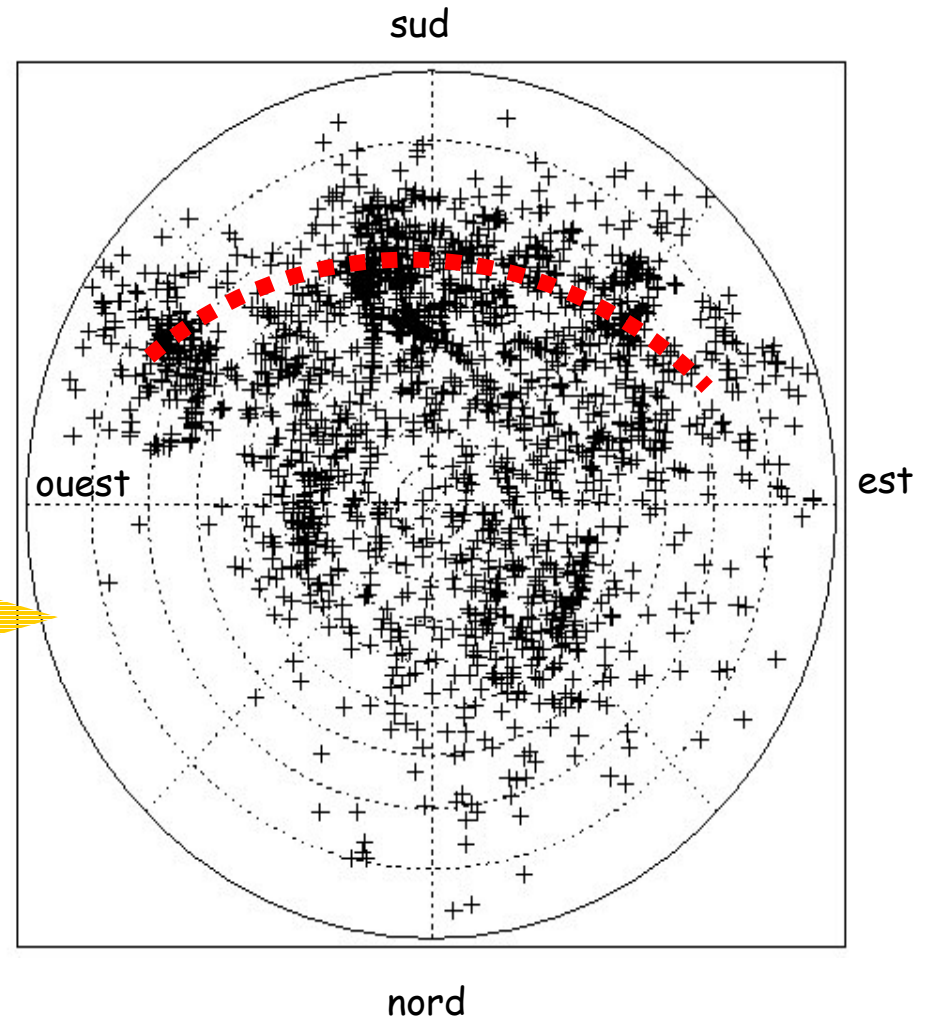


- Antenna responses are coherent
- Amplitudes evolve as expected with the distance

Collected Data (6 month)



Event distribution

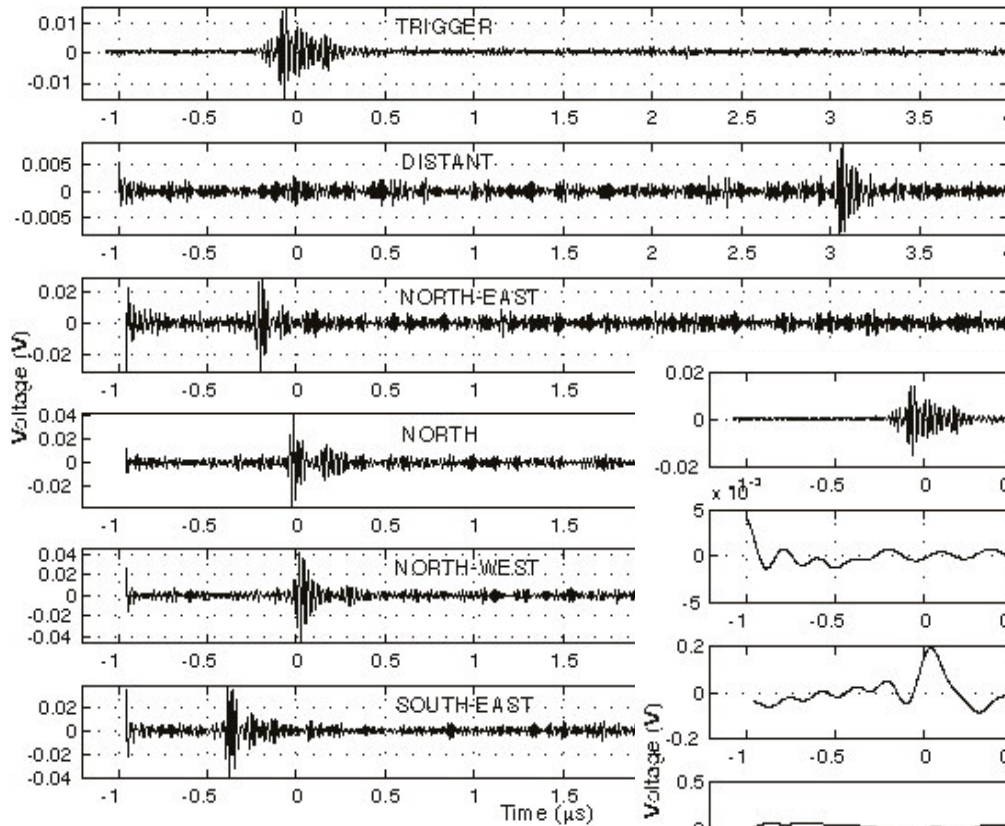


1200 events with multiplicity 6

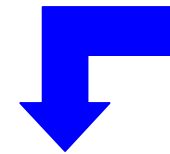
point source located far from our antennas

(flat plane wave assumption)

Two-band analysis



**33-65 Mhz
numerical
filtering**

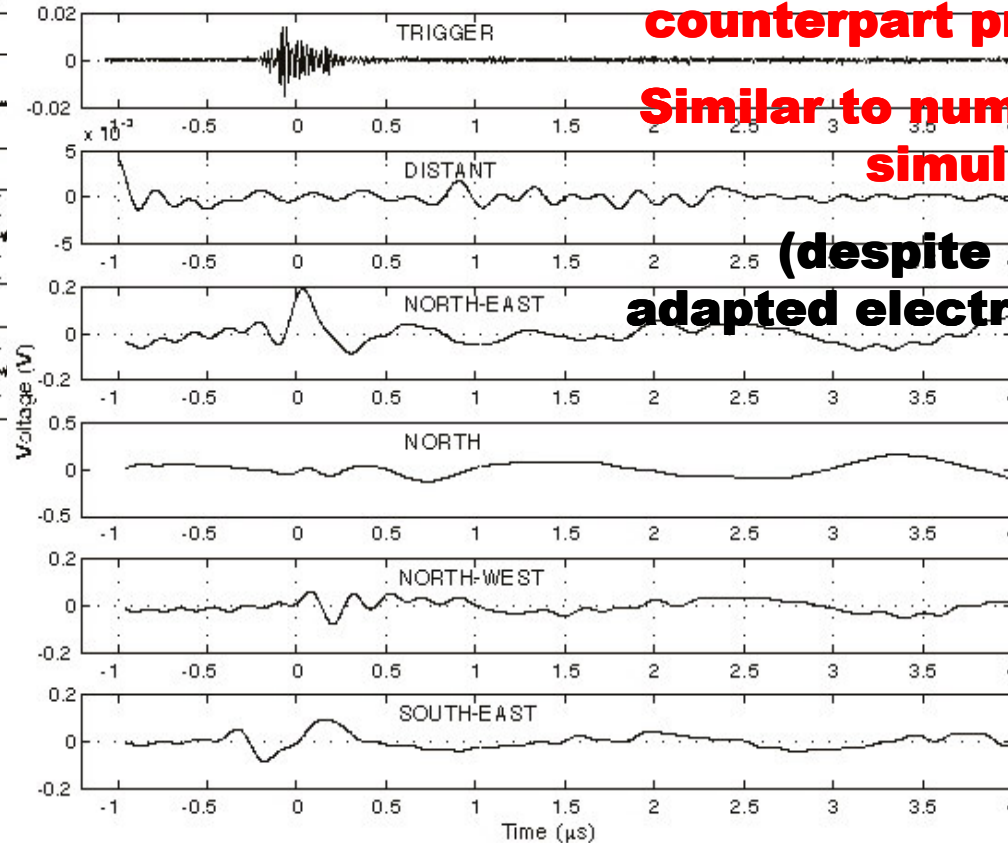


**0.5-9 Mhz
numerical
filtering**

**Transient LF
counterpart present**

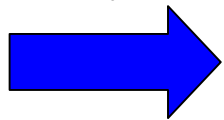
**Similar to numerical
simulations**

**(despite poorly
adapted electronics)**

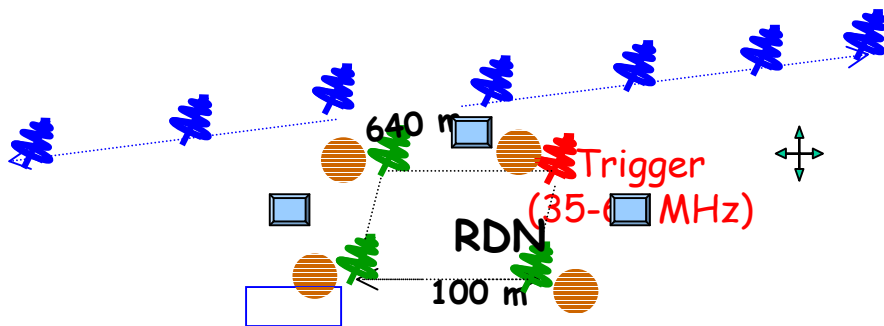


What do we learn with CODALEMA ?

- Trigger off on radiopulse : **OK**
- Detection sensibility : **4σ** above the sky noise at Nancay (2mV threshold)
- Coincidence transients : **observed**
- Source localization and identification: **OK using triangulation**



- Experimental apparatus under control (fully understood)
- New tools devoted to transient analysis available and ready to use



CODALEMA Phase 2 :

- Study of the **ELECTRIC FIELD TOPOLOGY** (Cerenkov vs far field)
=> Line of 7 antennas (in installation)
- Increase of our sensibility (to achieve the significant bit at the level of sky noise)
- particles - radio pulse coincidences => **4 scintillation units** ($1.5 \times 1.5 \text{ m}^2$) (new set-up working)