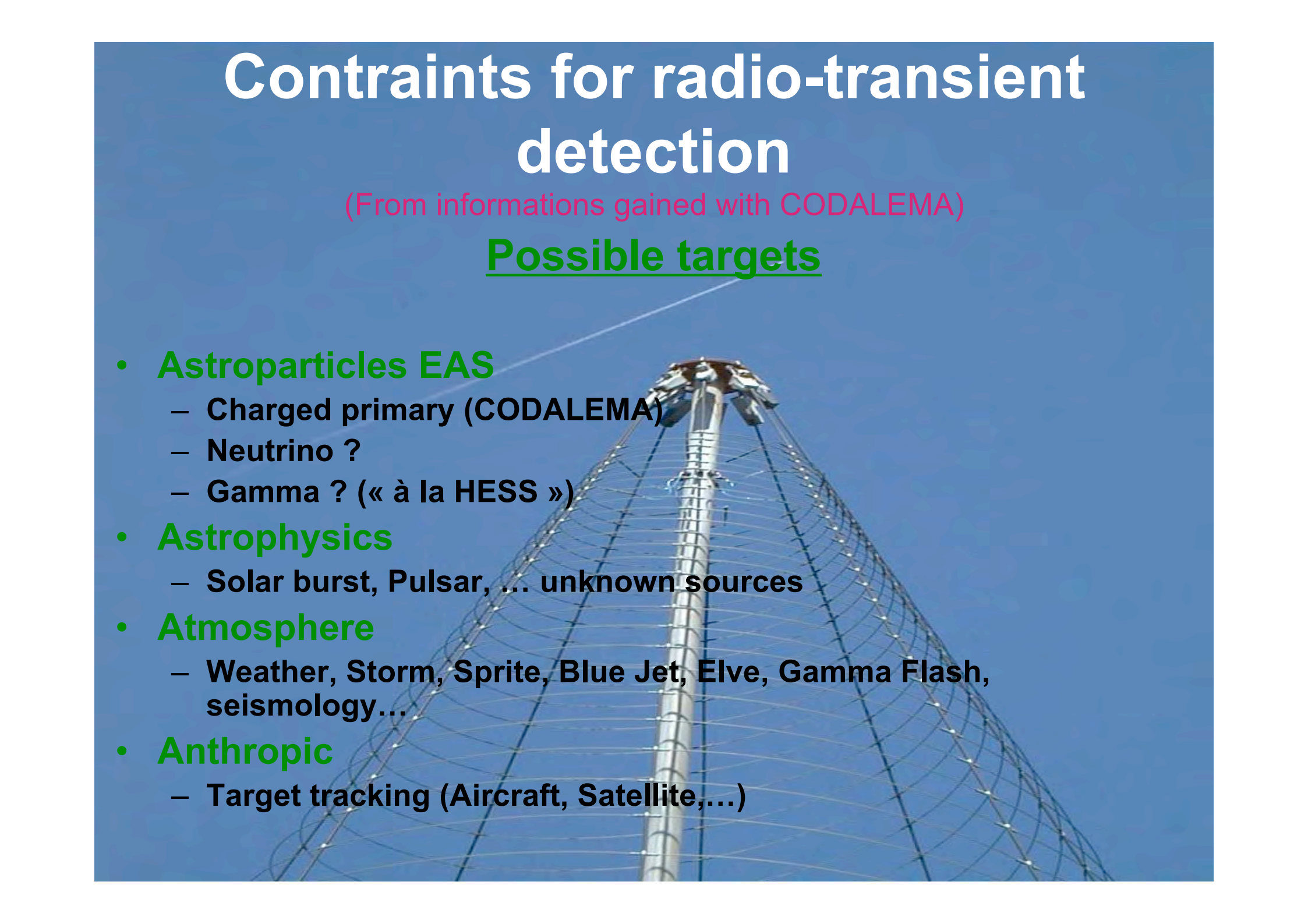
Contraints for radio-transient detection

(From informations gained with CODALEMA)

Possible targets

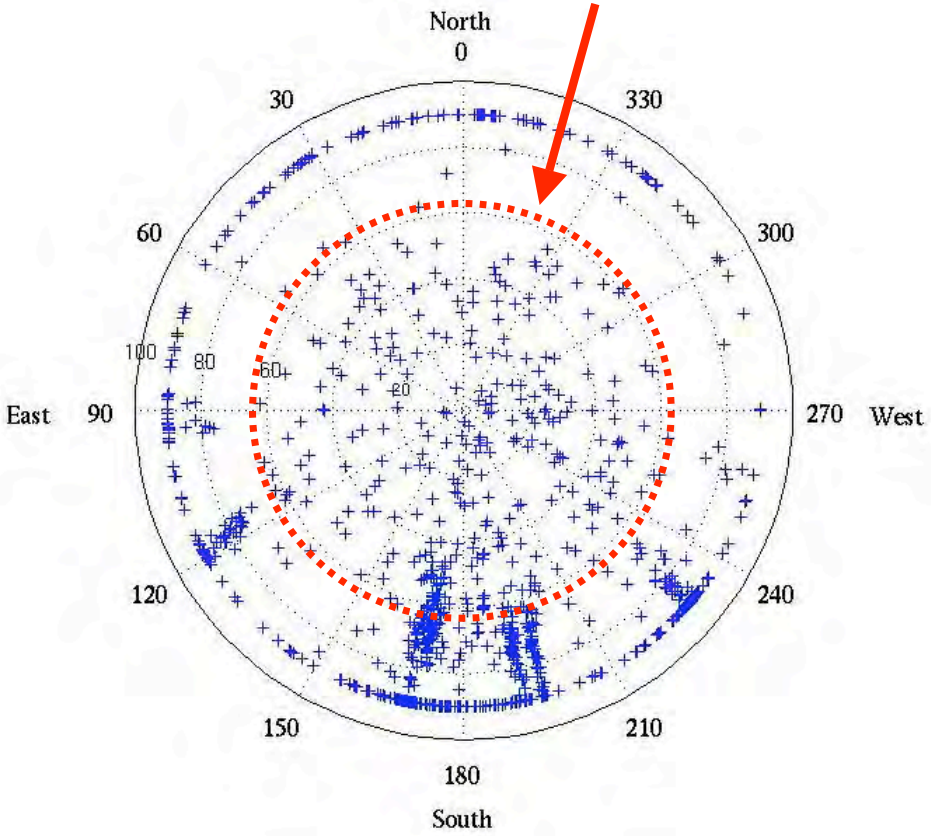


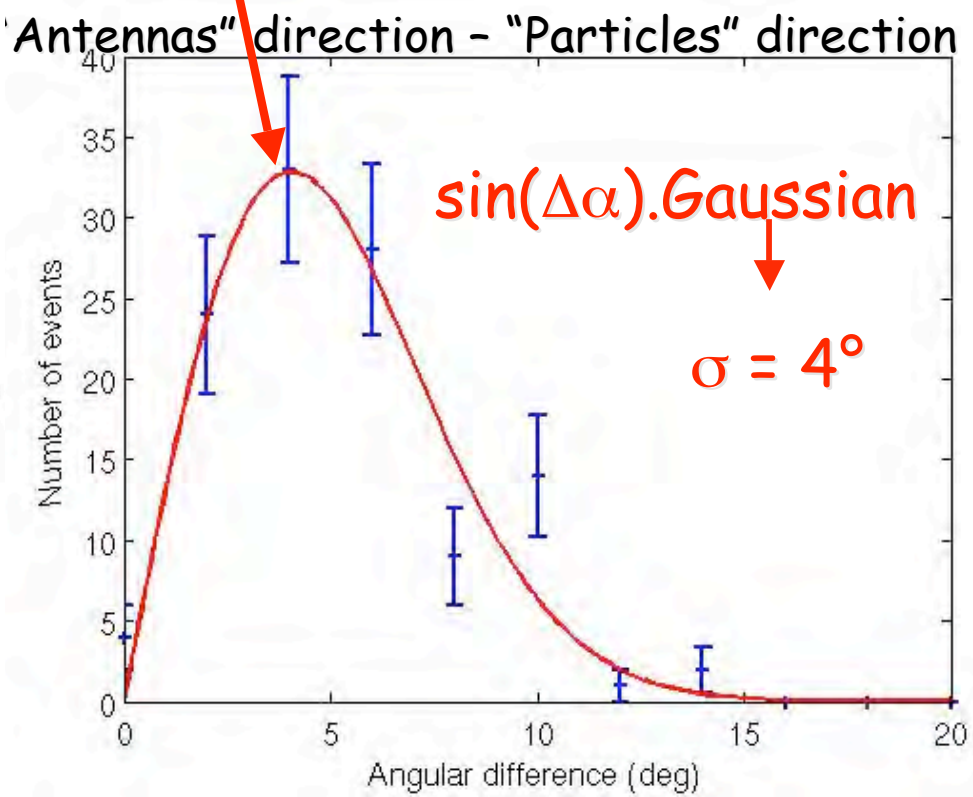
- **Astroparticles EAS**
  - **Charged primary (CODALEMA)**
  - **Neutrino ?**
  - **Gamma ? (« à la HESS »)**
- **Astrophysics**
  - **Solar burst, Pulsar, … unknown sources**
- **Atmosphere**
  - **Weather, Storm, Sprite, Blue Jet, Elve, Gamma Flash, seismology…**
- **Anthropic**
  - **Target tracking (Aircraft, Satellite,…)**

EAS studies (1)

Arrival directions

In time-coincidence with particles





Reconstruction of EAS arrival directions is proved via Radio-Detection

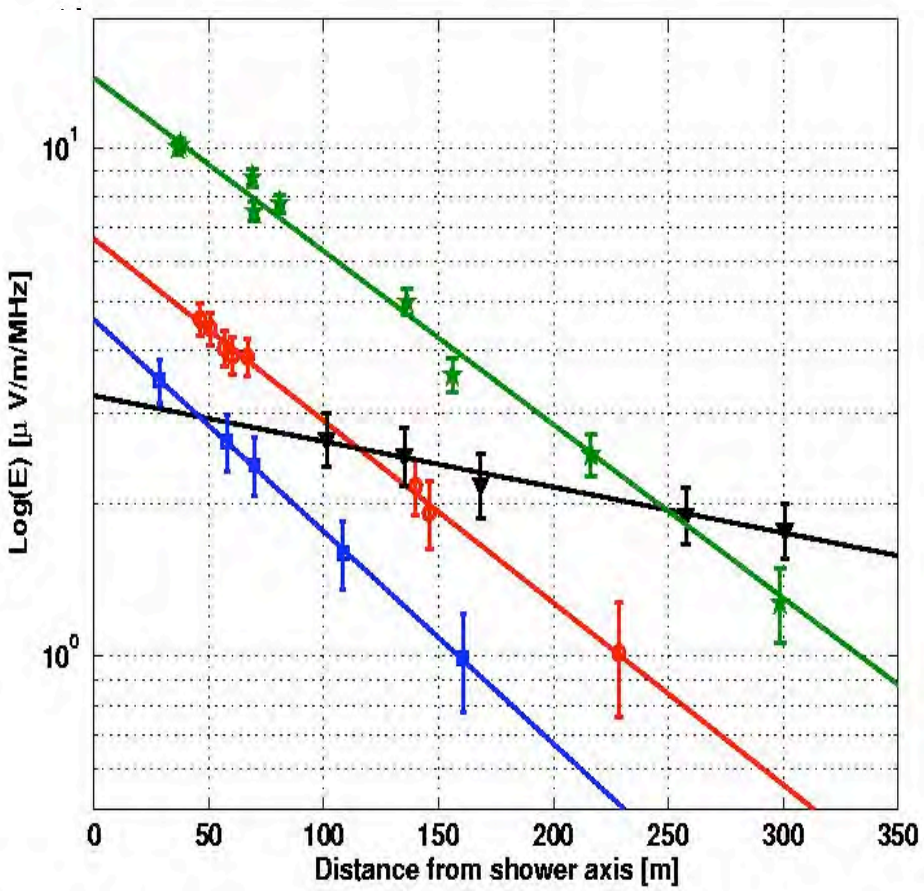
EAS studies (2)

EAS Field topology

From H.R. Allan (1971), Huege & Falcke (2005) : Exponential fit of radial dependence in the shower-based coordinate system

$$E(d) = E_0 \exp\left[\frac{-d}{d_0}\right]$$

d = distance to the shower core



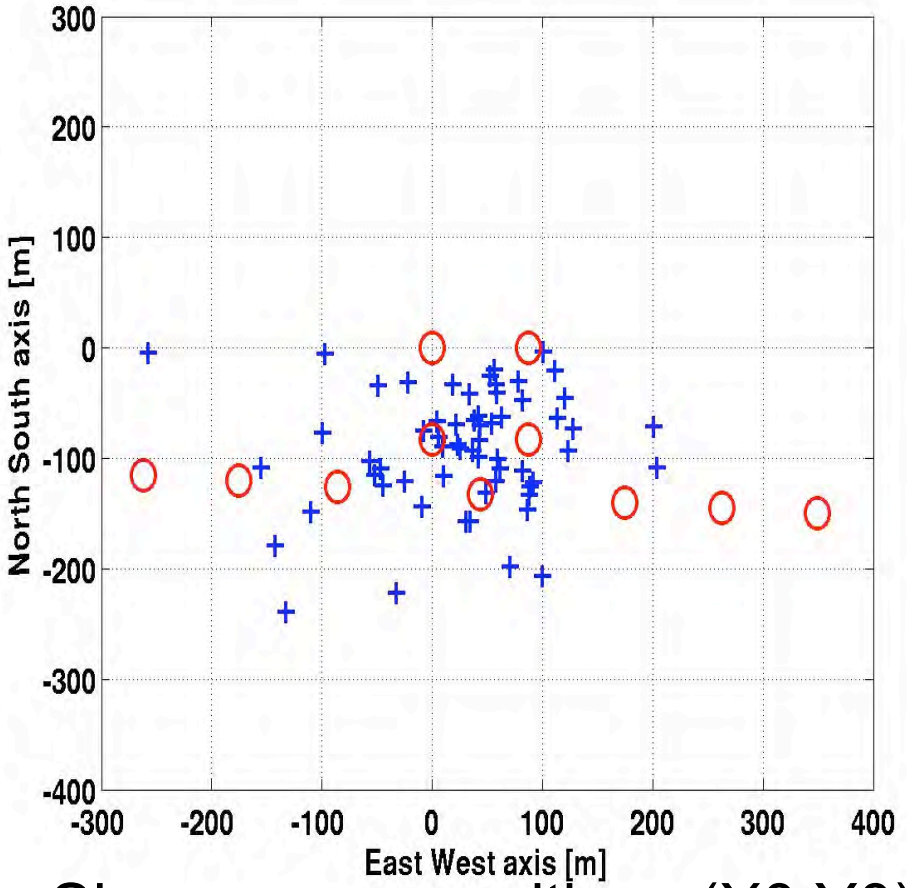
FWHM extension of the field

~ 250 m @ ~ 5.10^{16} eV

Field Measurements

~ 600 m @ ~ 5.10^{16} eV

EAS studies (3)



Shower core positions (X0,Y0)

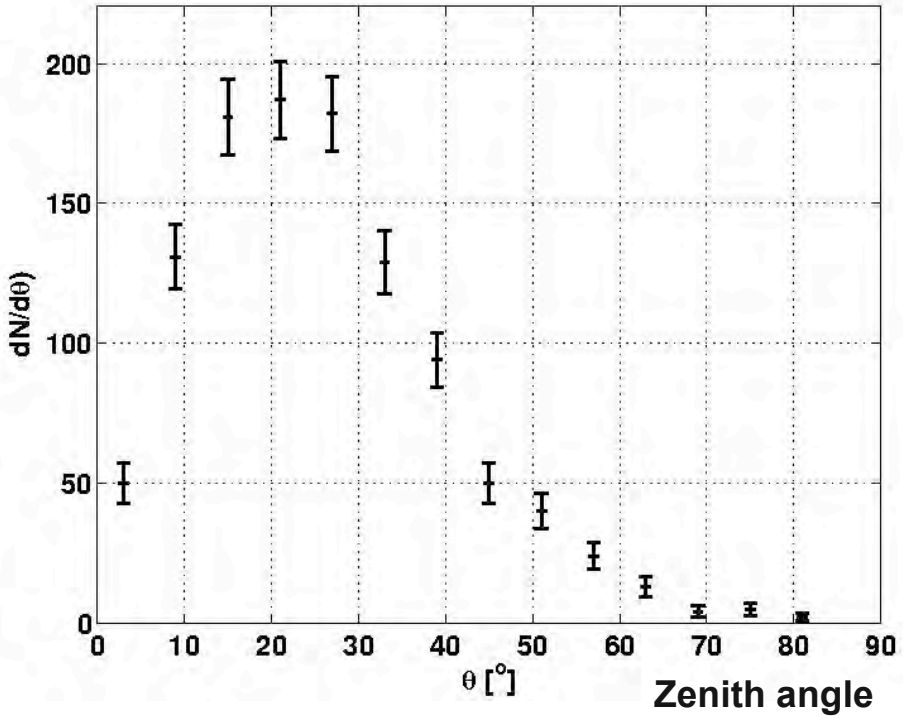
EAS radio-detection technique is in progress

Next Step:

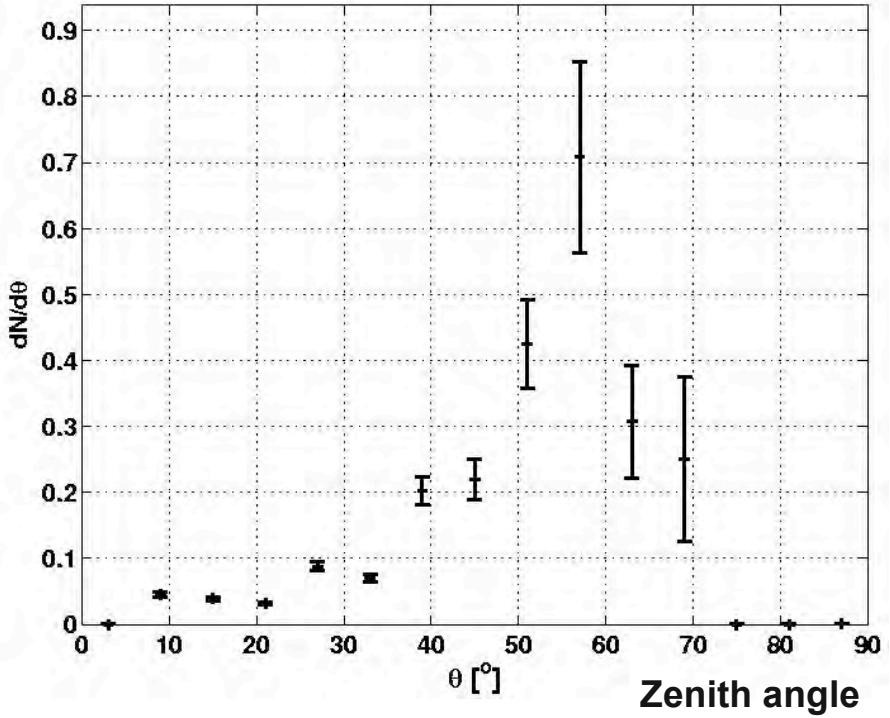
Energy calibration with radio-signal
&
Nature of the EAS

Horizontal EAS (1)

Trigger Counting
(not corrected from solid angles)



Radio / Trigger Acceptance



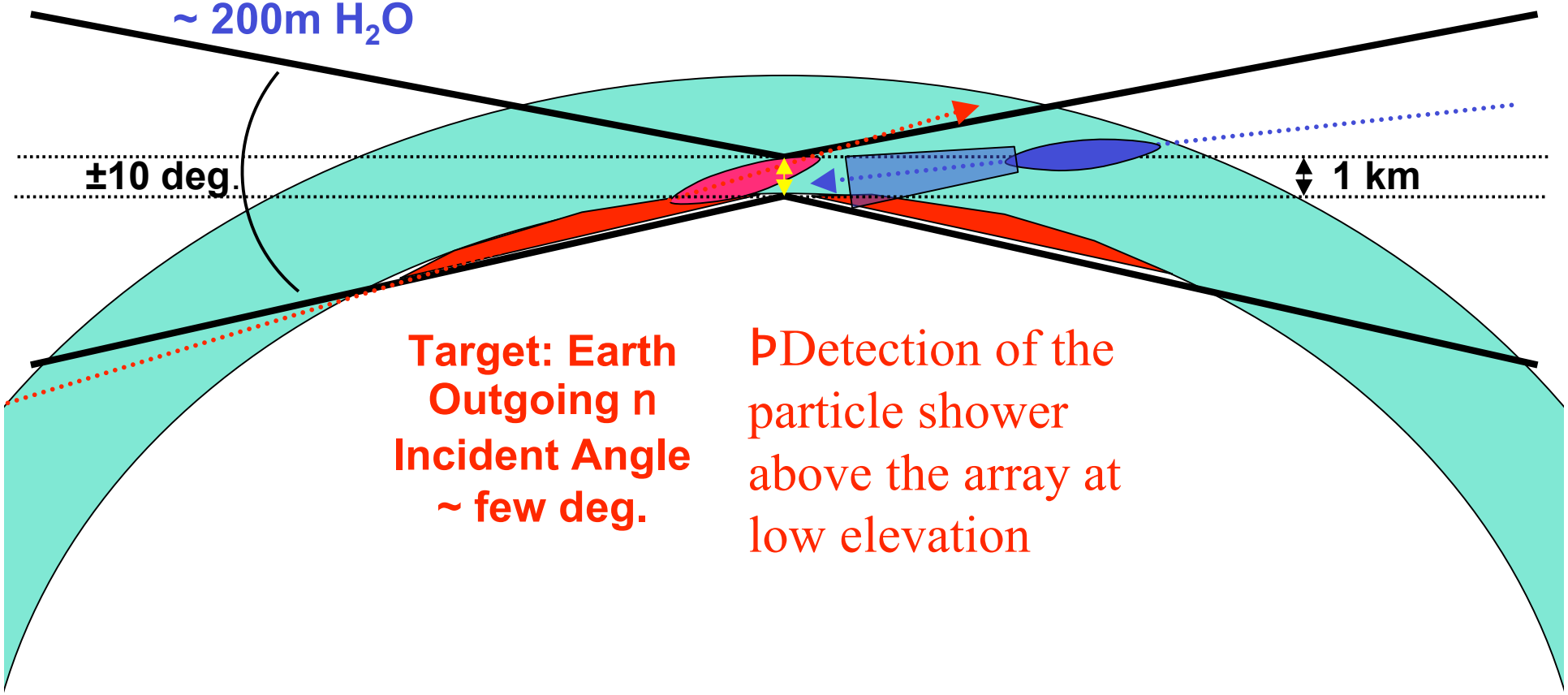
Radio-detection could be in nature adapted to the detection of atmospheric neutrinos ?

Horizontal EAS (2): n detection

Set-up: large array

Target: Atmosphere
incoming n
Equivalent thickness
~ 200m H_2O

þDetection of the EM wave far from the particle shower

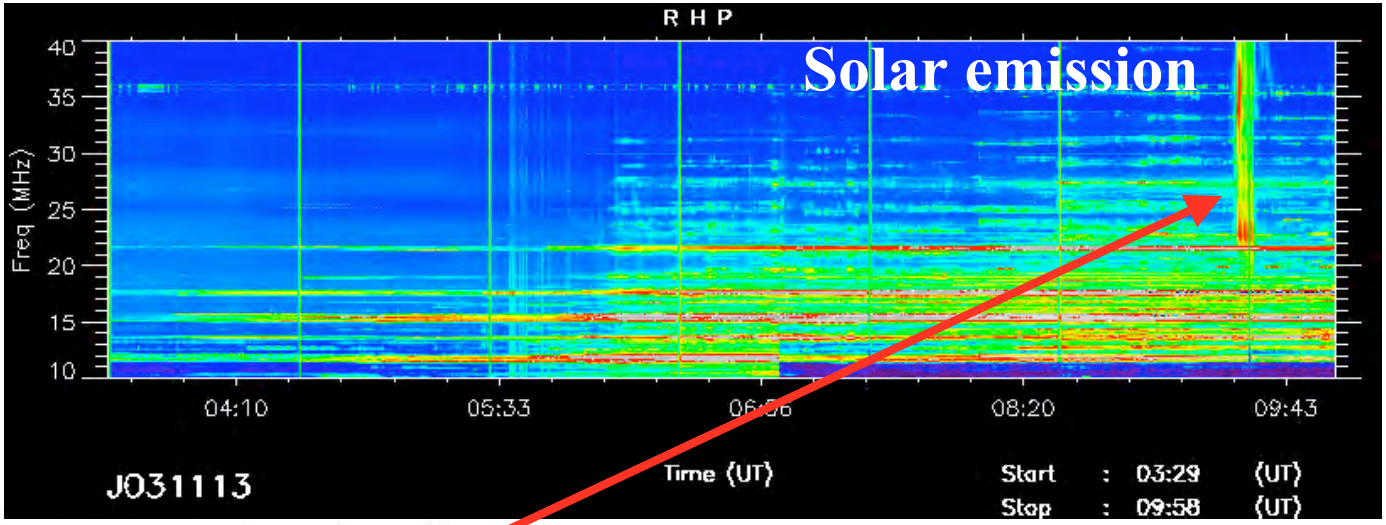


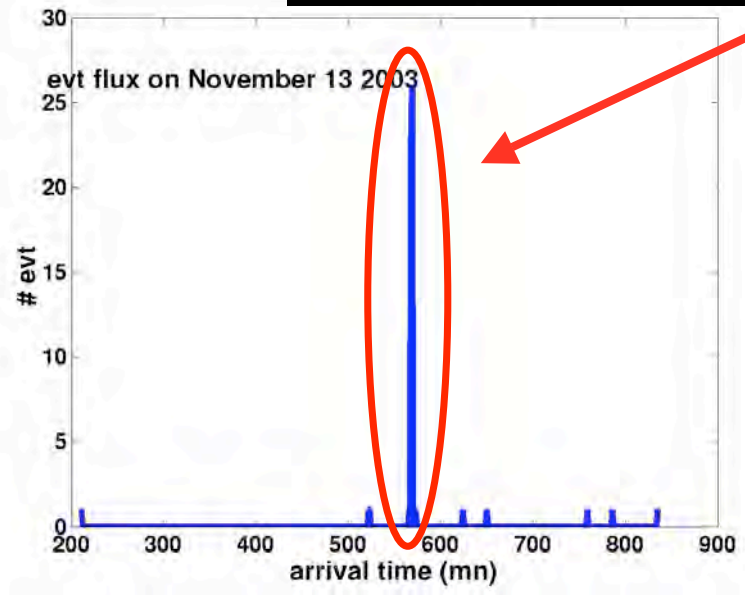
Target: Earth
Outgoing n
Incident Angle
~ few deg.

þDetection of the particle shower above the array at low elevation

Transient Radio-Astronomy (1)

Fast transients (< ms) associated to Solar emission



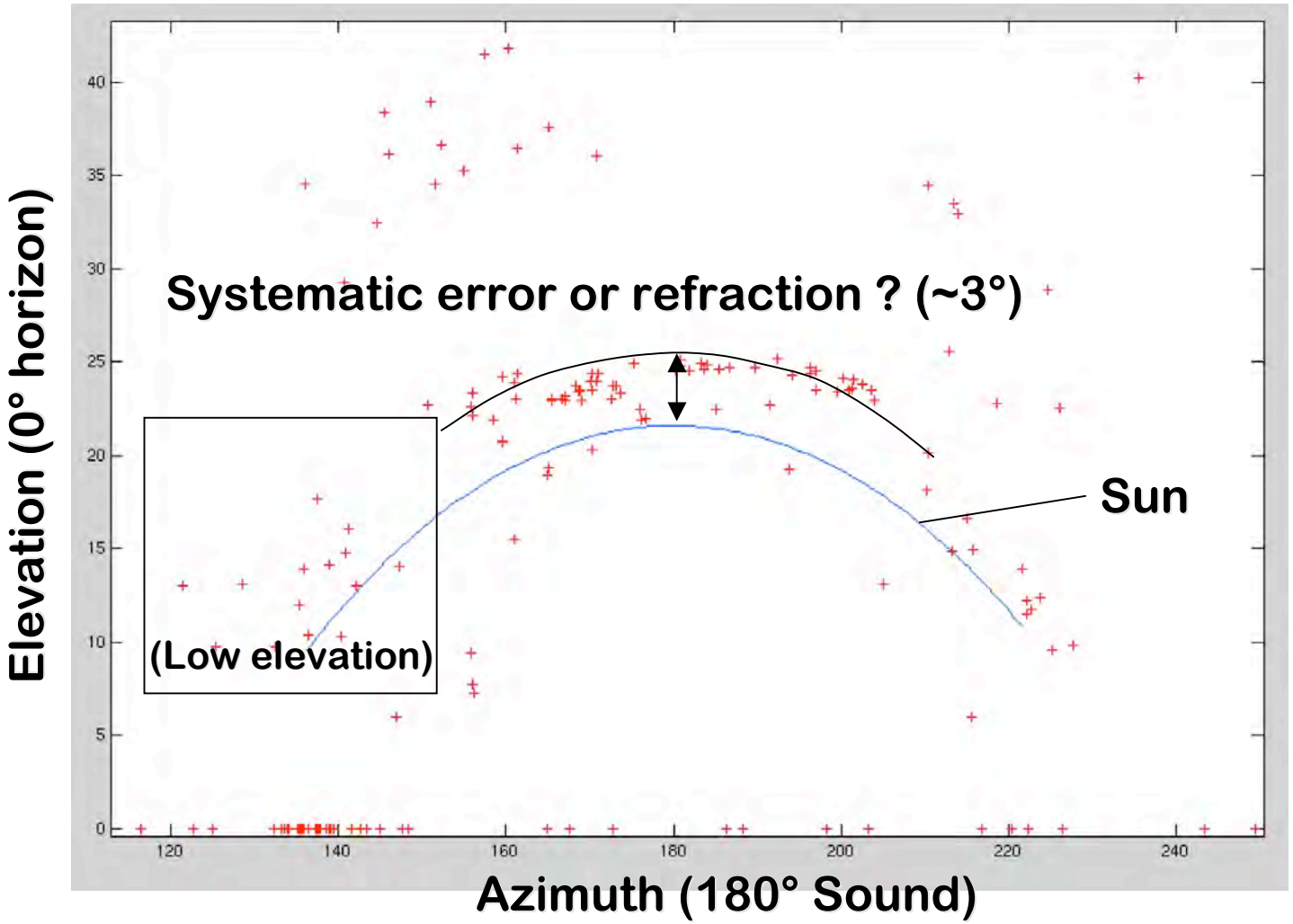


In time-coincidences DAM-CODALEMA

New Radio-Astronomy ?

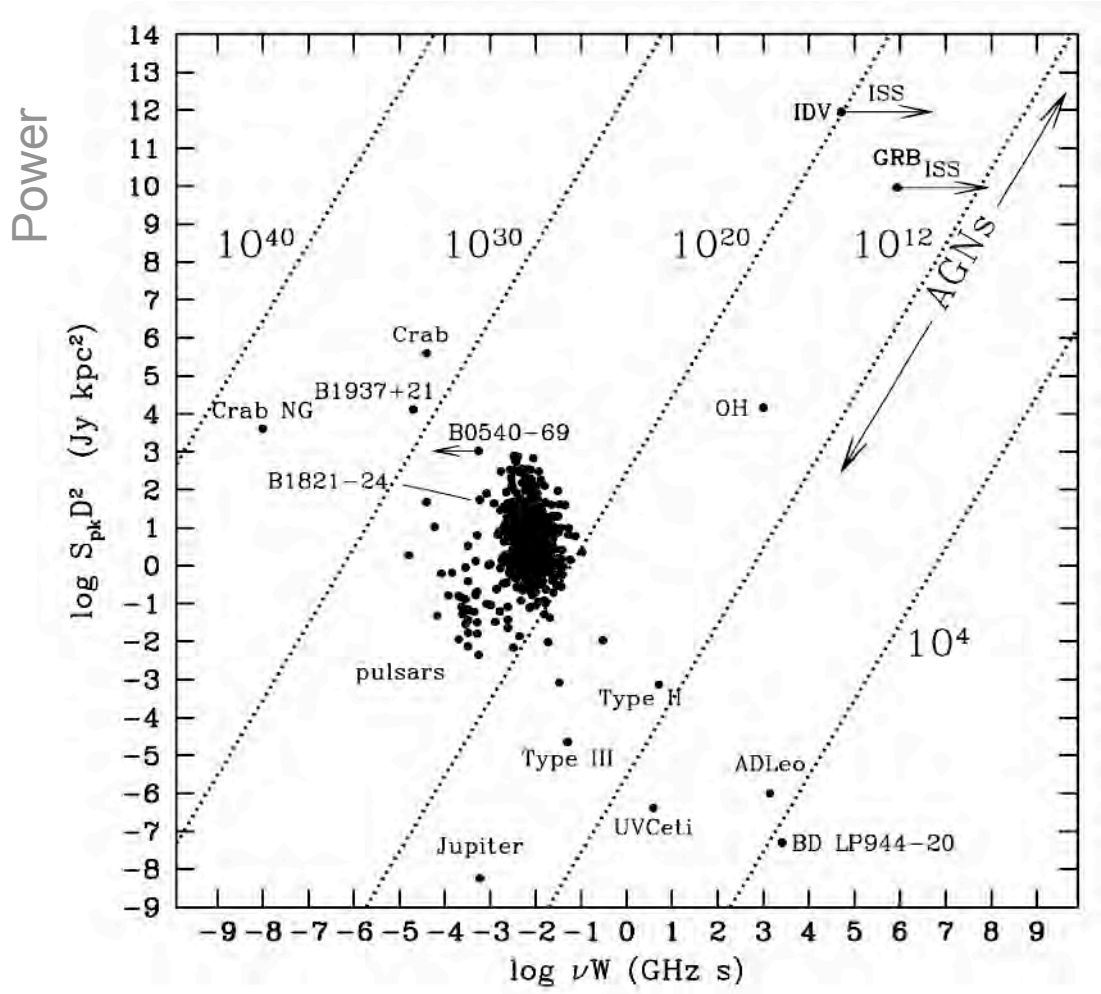
Transient Radio-Astronomy (2)

Using Correlation produces & Delays between antennas ⇒ plane wave fit ⇒ wave direction



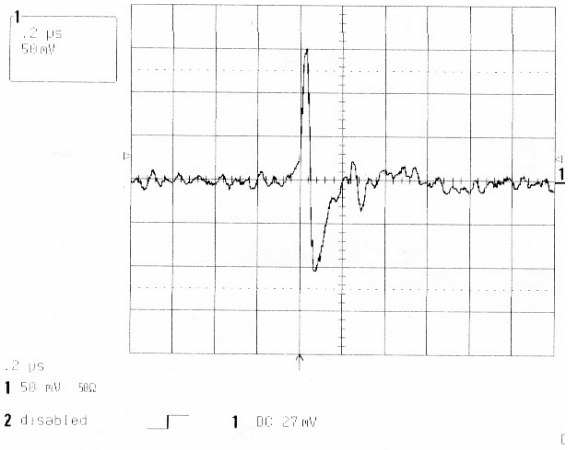
Obtained in random coincidence with a particle trigger

Fast radio transients
Cordes & McLaughlin, ApJ 596, 2003



Atmospheric signals (1)

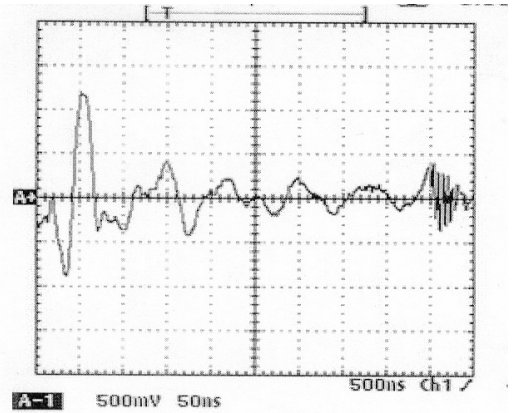
A big Bestiary…

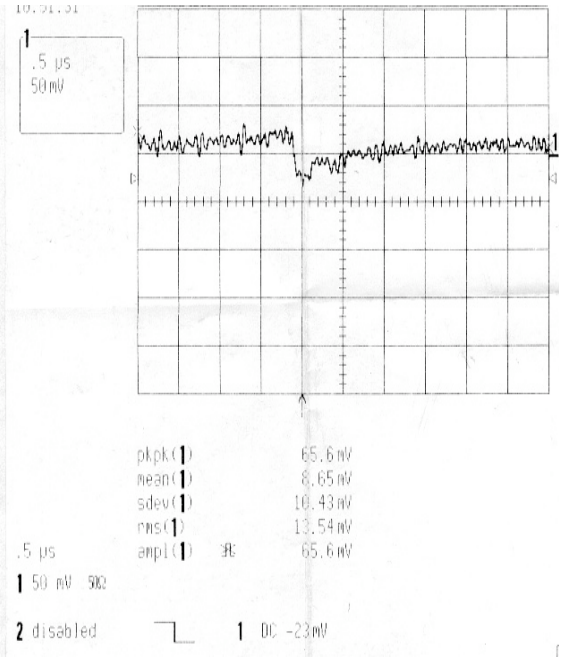


Out of stormy weather

<= log-spiral ant.

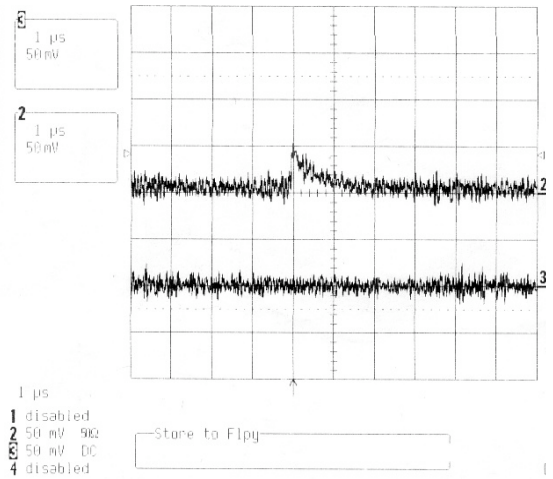
Monopolar ant. =>



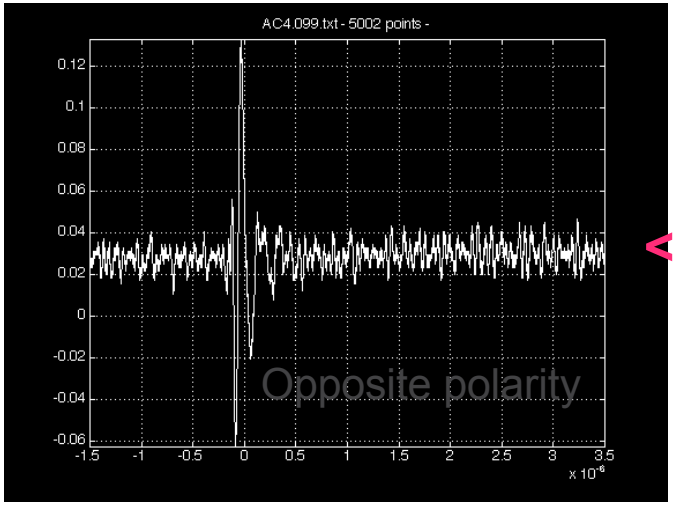


Unipolar signals

<= log-spiral ant.=>



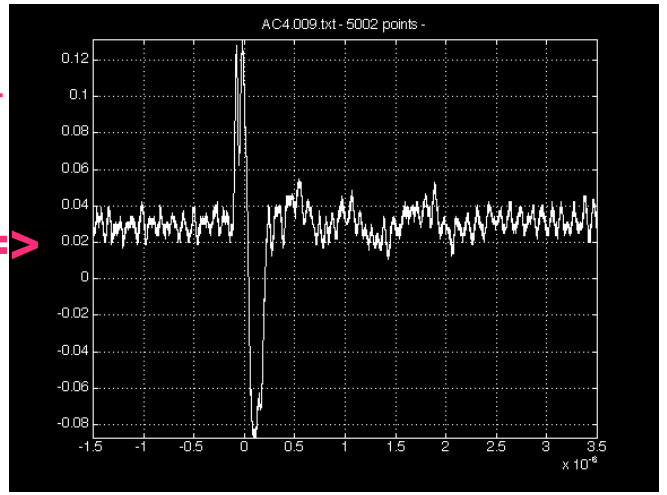
Atmospheric signals (2)



During storms

<= Ant. log-spiral =>

1-100MHz

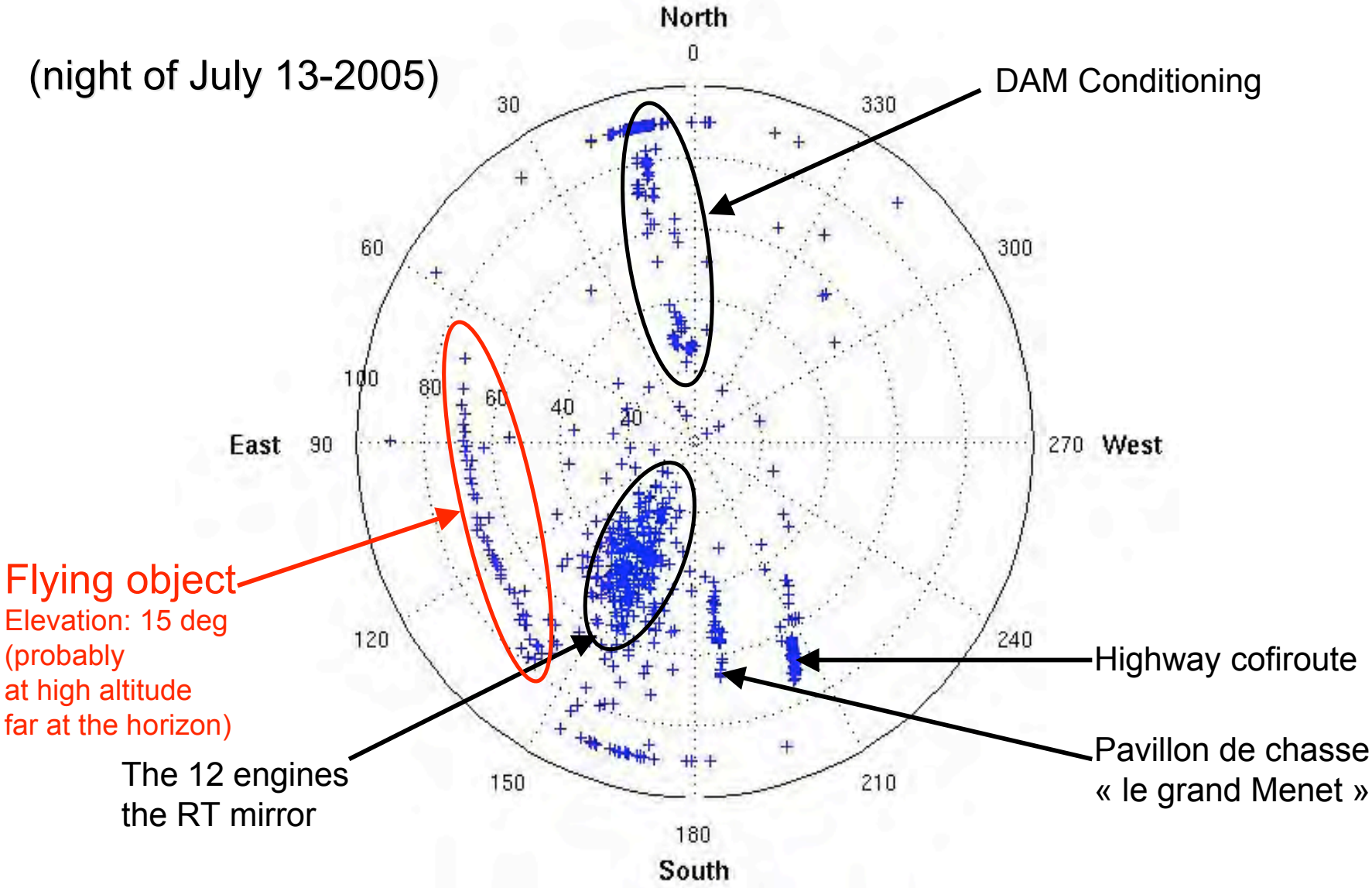


For Dt ~ 50 ns => with v_e=c => spark length ~ 15 m !
Very different from lightnings
Looks more like “precursors”

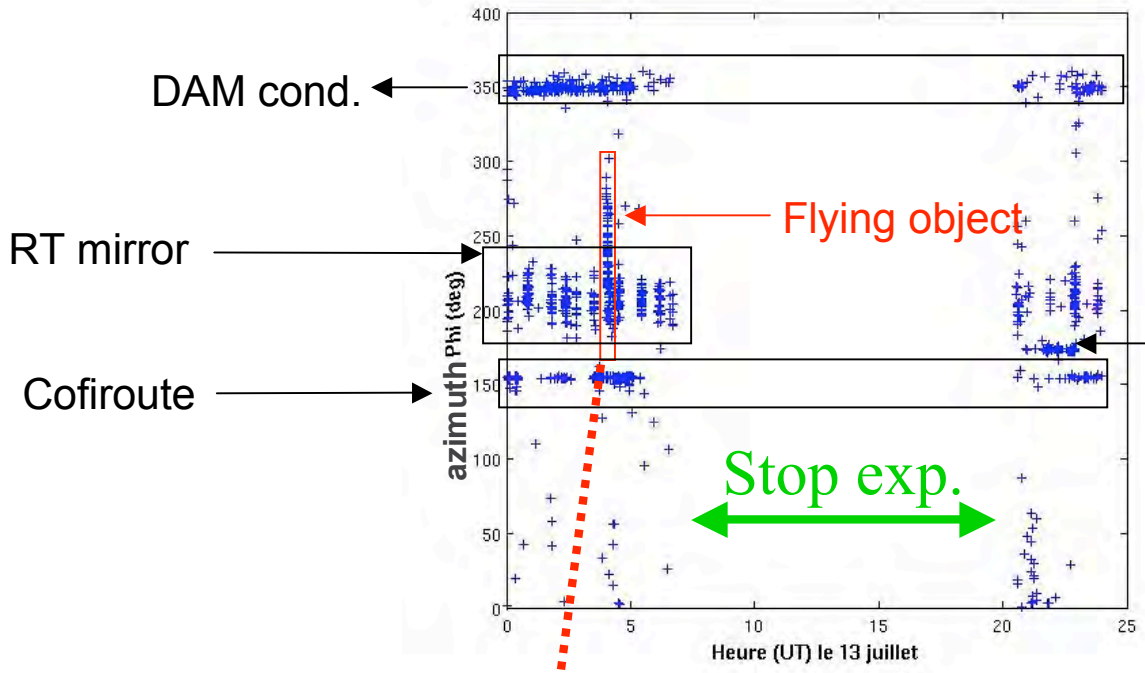
Far detection: ~ few 1000 km showing fast signals
Near detection: needs high dynamics

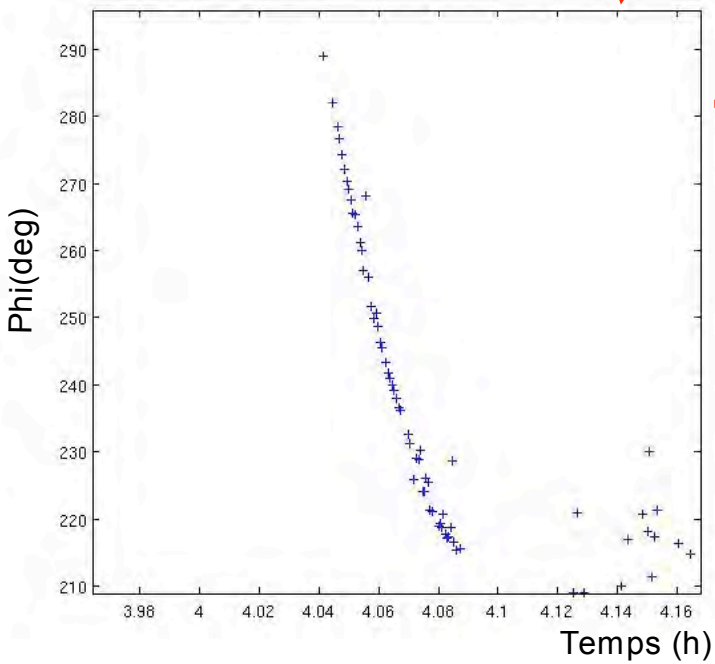
Anthropic signals (1)

(night of July 13-2005)



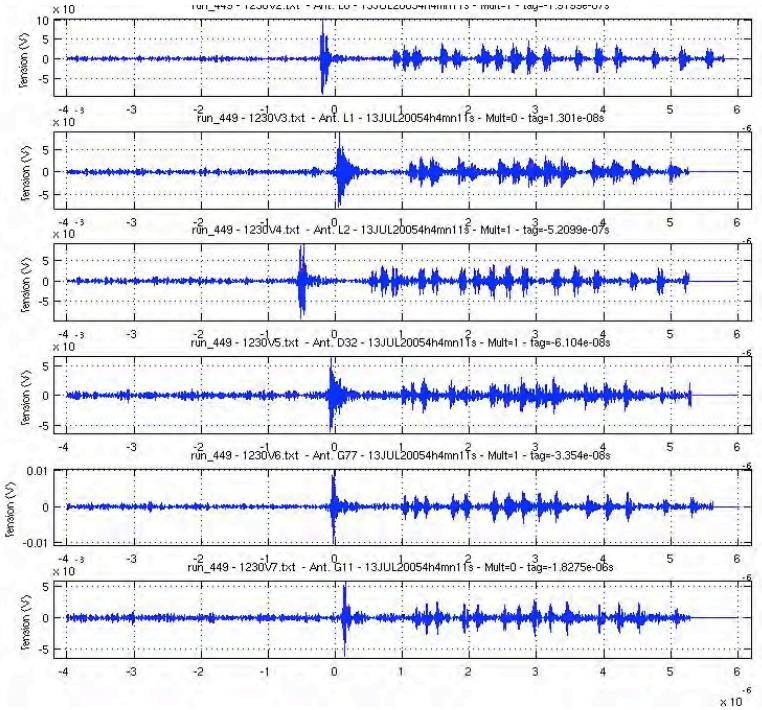
Anthropic signals (2)





Time of fly:
3 mn
from one
horizon to
another

In 33-65 MHz



Detector concept

Broad band antennas

Band: 0.1-100 MHz

Sensitivity: 1 mV/m/MHz

FOV: 2p str

Waveform: 12-14 bits, 10 ms, 250MS/s

Time tagging < 10 ns

Arrival direction < 1 deg.

Polarization ?

Trigger capability

•Low rate physics:

1 evt /km^2/century @ 10^{20} eV

Select candidates

Decrease data flux

•Trigger specifications:

<100 Hz

Thresholds in several frequency bands

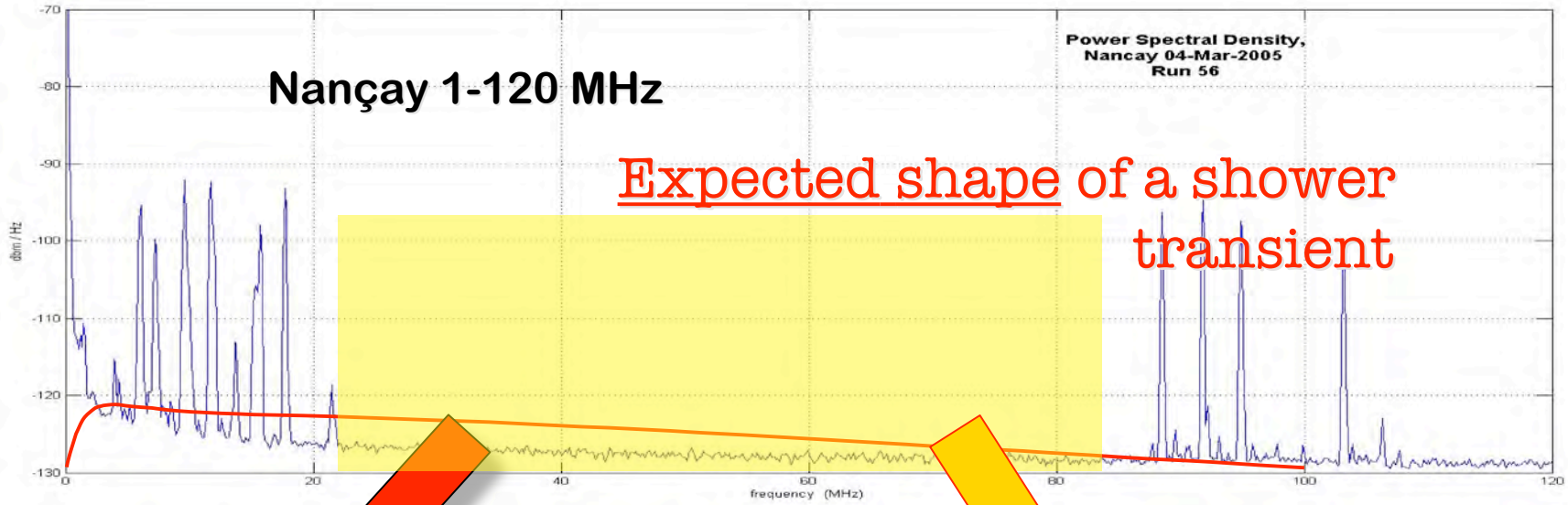
Large array

Topology of the electric field

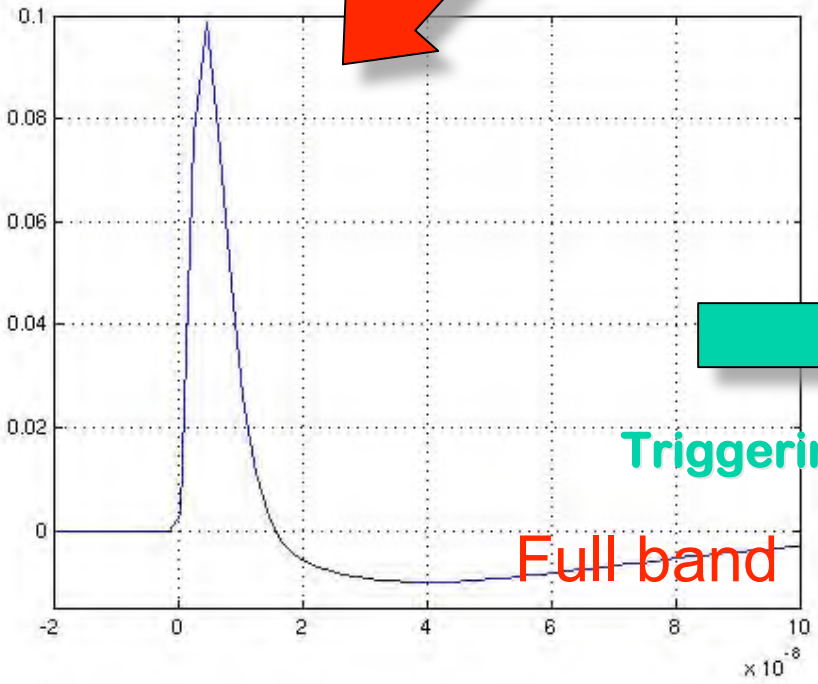
SOMEWHAT DIFFERENT FROM LOFAR DESIGN

(hard trigger & snapshot waveform)

Transient detection and datation

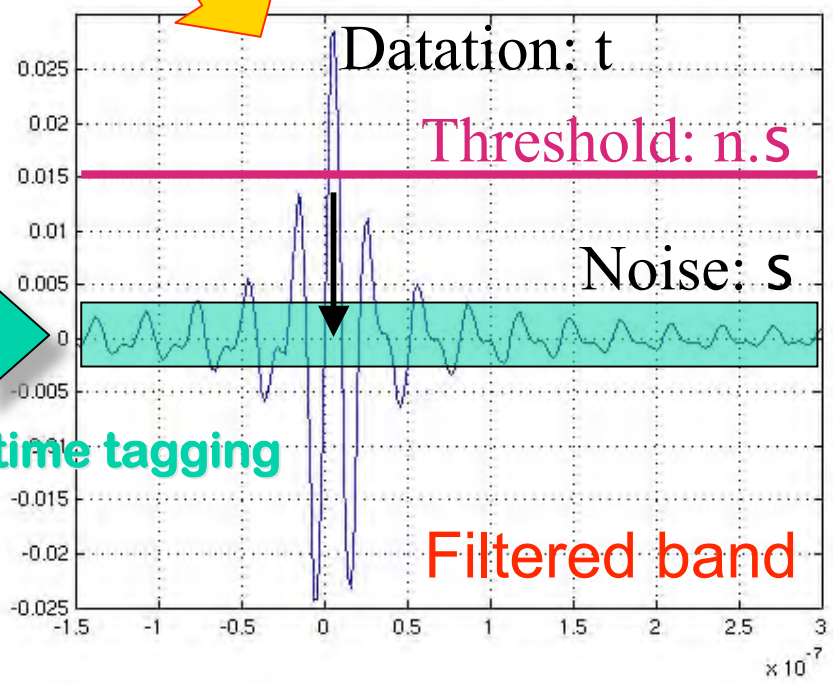


Expected shape of a shower transient



Full band

Triggering & time tagging

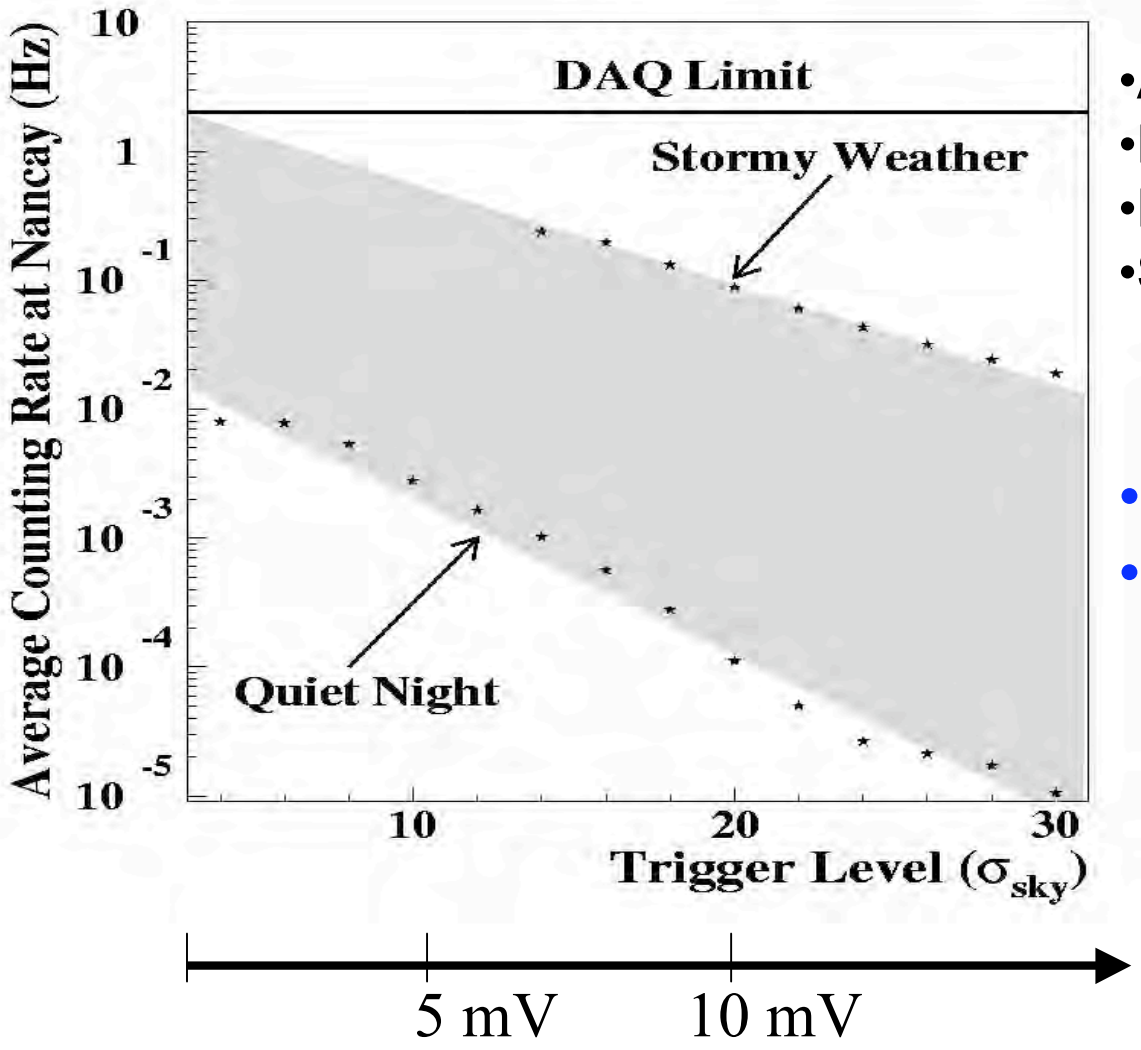


Filtered band

Trigger rate

(in 33-65 band with 1 antenna)

Knowledge of the transient radio background



- **Atmosphéric conditions**
- **Day-Night modulations**
- **Human activities**
- **Solar activities**

- **Low rate < 1 Hz**
- **100 % duty cycle**

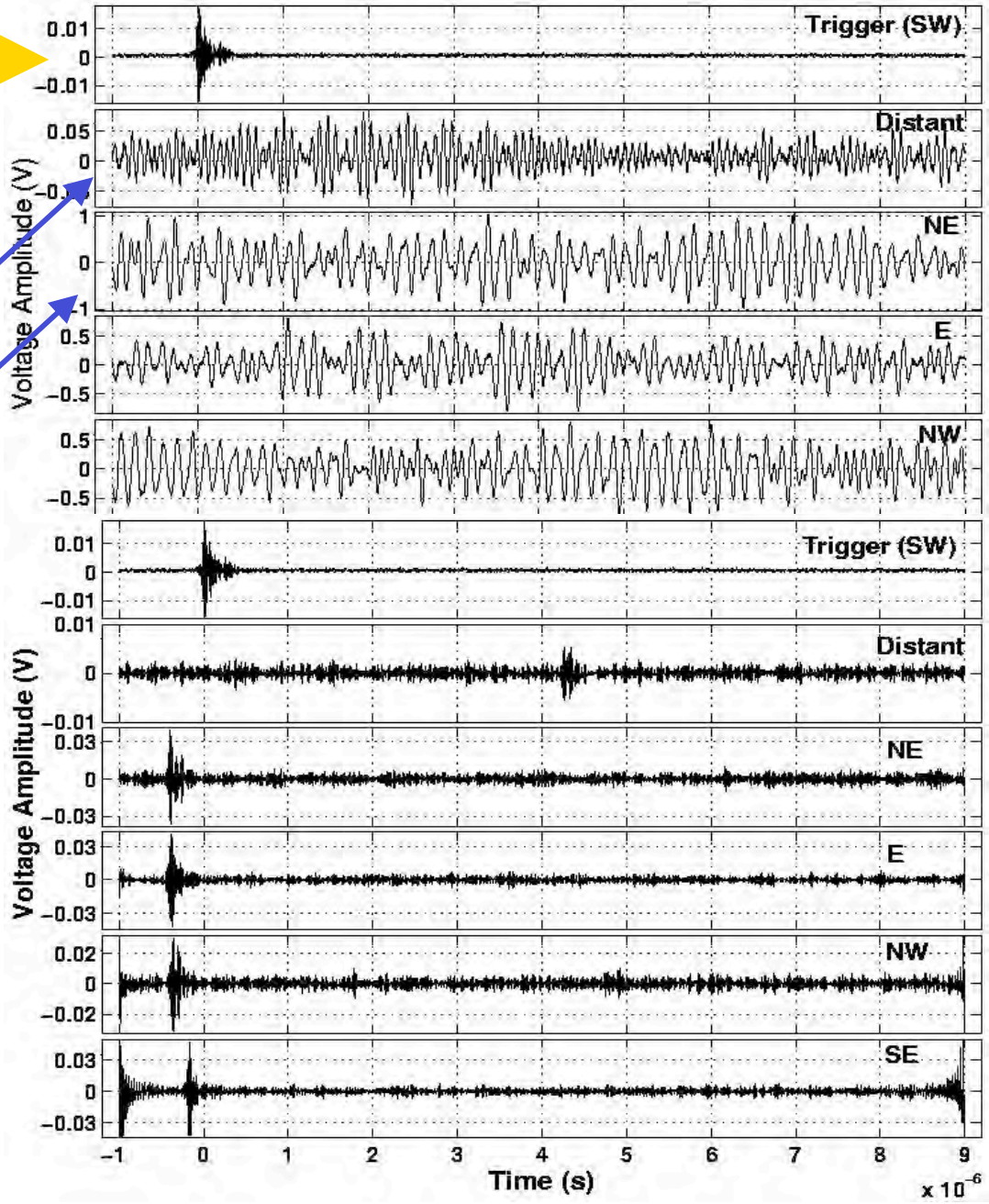
Trigger with antenna is possible in stand alone mode

Transient analysis (1)

Trigger = antenna filtered signal (33-65 MHz) + voltage threshold

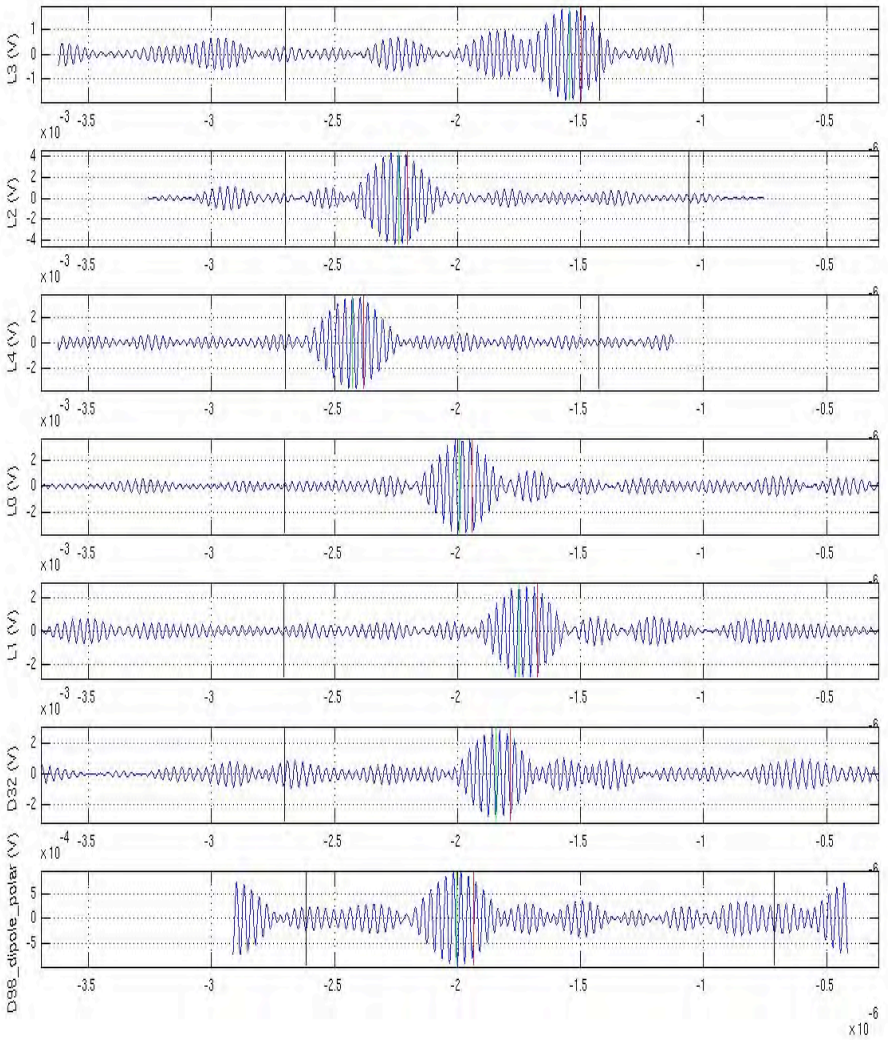
1 restricted band antenna (1 km, 10-100 MHz)
5 broad band antennas (1-100 MHz)

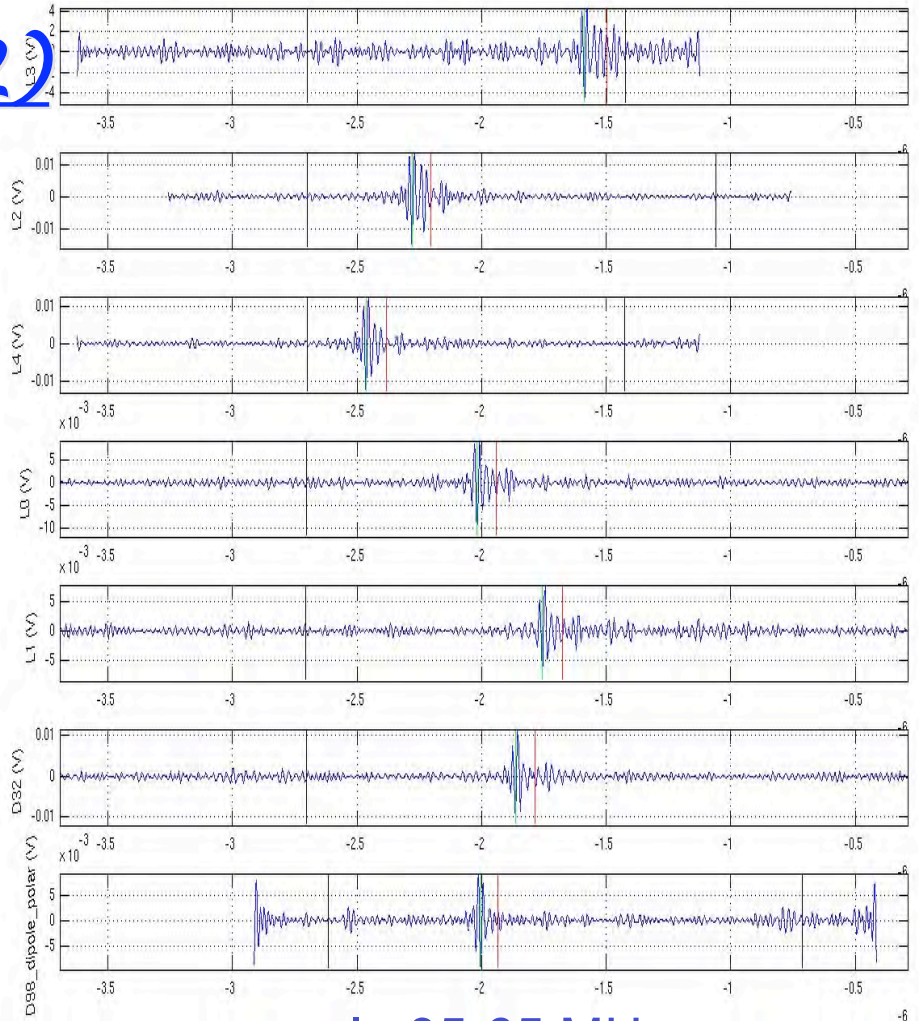
After 33-65 MHz off-line numerical filtering



Transient analysis (2)

In 30-35 MHz



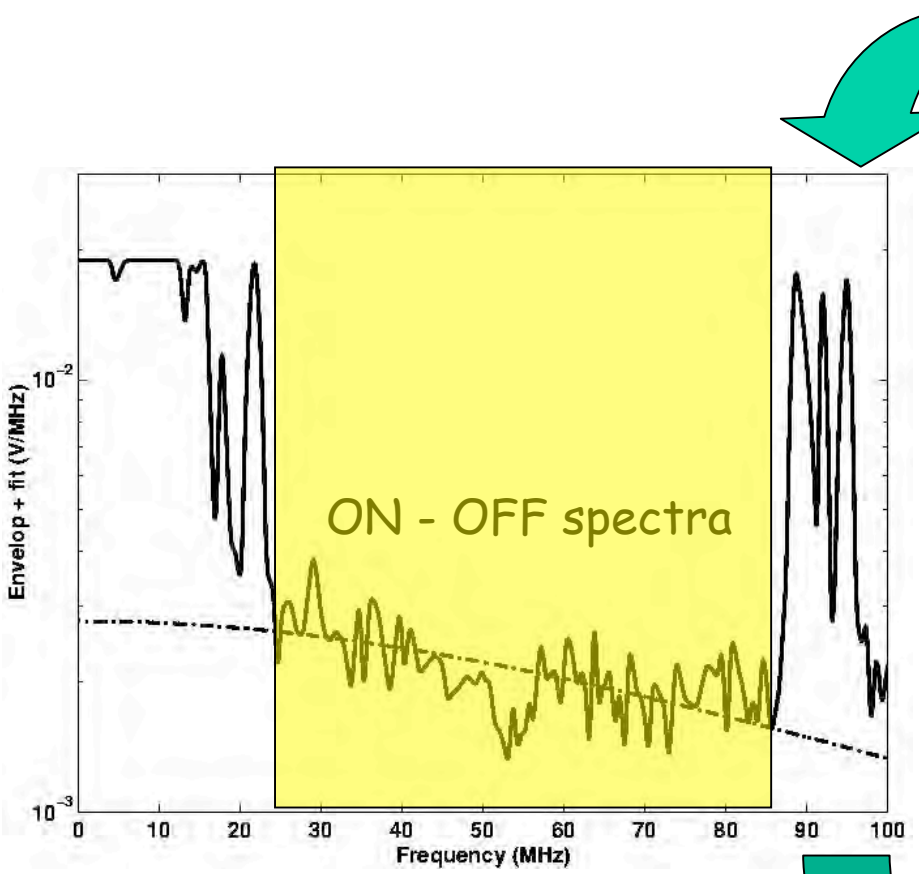


In 35-65 MHz

- Frequency analysis
- Shape of the signal

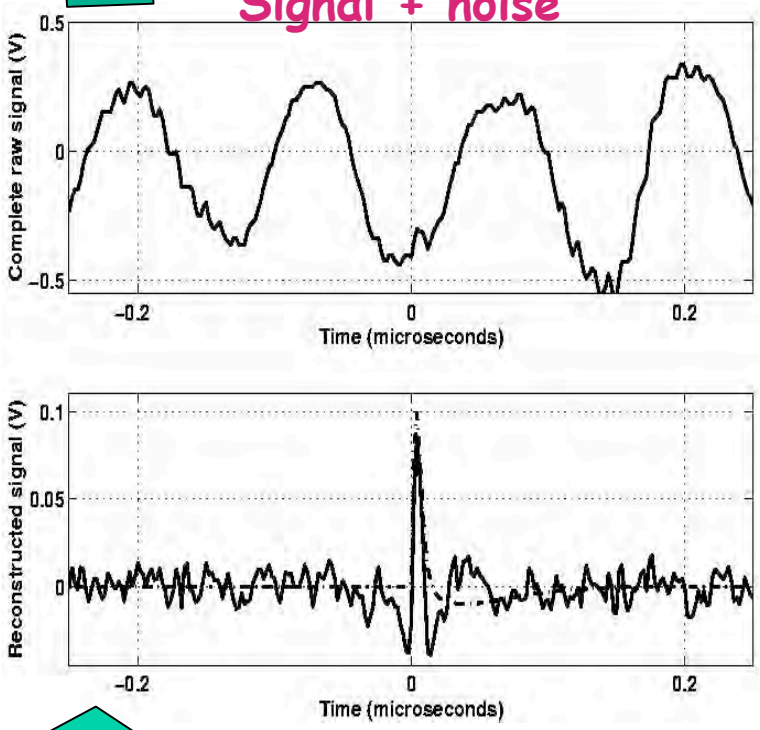
Transient analysis (3)

via Waveform Recovery with FFT



Fit in the frequency Space

Signal + noise



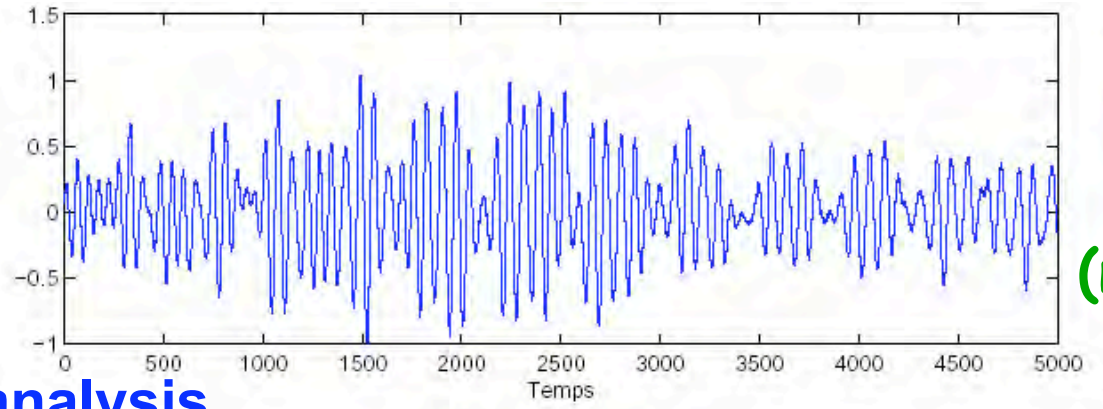
After reconstruction (full band)

Model of signal => Shape parameters

Full Band Recovery

via un filtre LPC

Adaptative optimal filtering & Wavelet Analysis

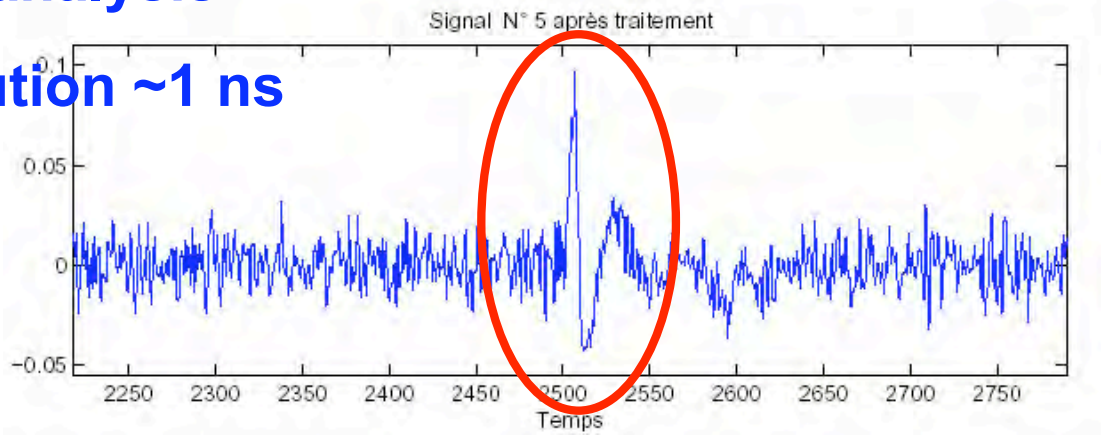


Signal

(noise+pulse)

Þ **Full shape analysis**

Þ **Time resolution ~1 ns**

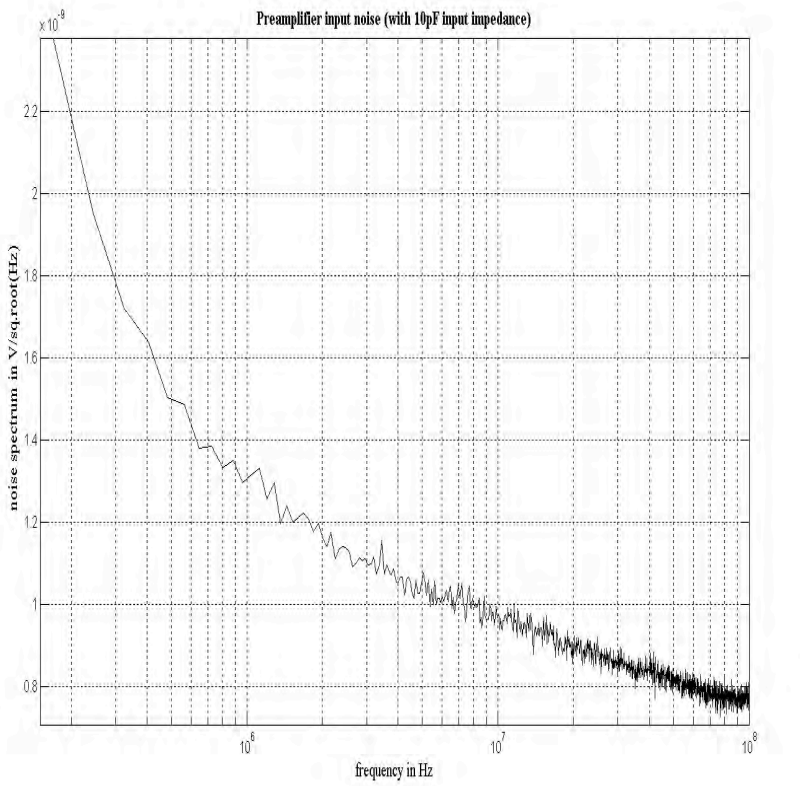


Remaining

signal

=> Need detector frequency band as large as possible

CODALEMA short active dipole (1)



ASIC

Gain: V_{out}/V_{in} = 200/4=50 (34dB)

Band (-3dB): >200MHz

Input dynamic : $\pm 15mV_{peak}$

Output dynamic : $\pm 750mV_{peak}/50\Omega$

Dynamic [1M-100MHz]: 61dB

Input Impedance: Zin=10pF

Consumption: 54mA sous [9V-15V]

Input noise: 0.78nV/√Hz @100MHz

COST

Mechanic : 10 €

Electronic: 15 €

CODALEMA Short active Dipole (2)

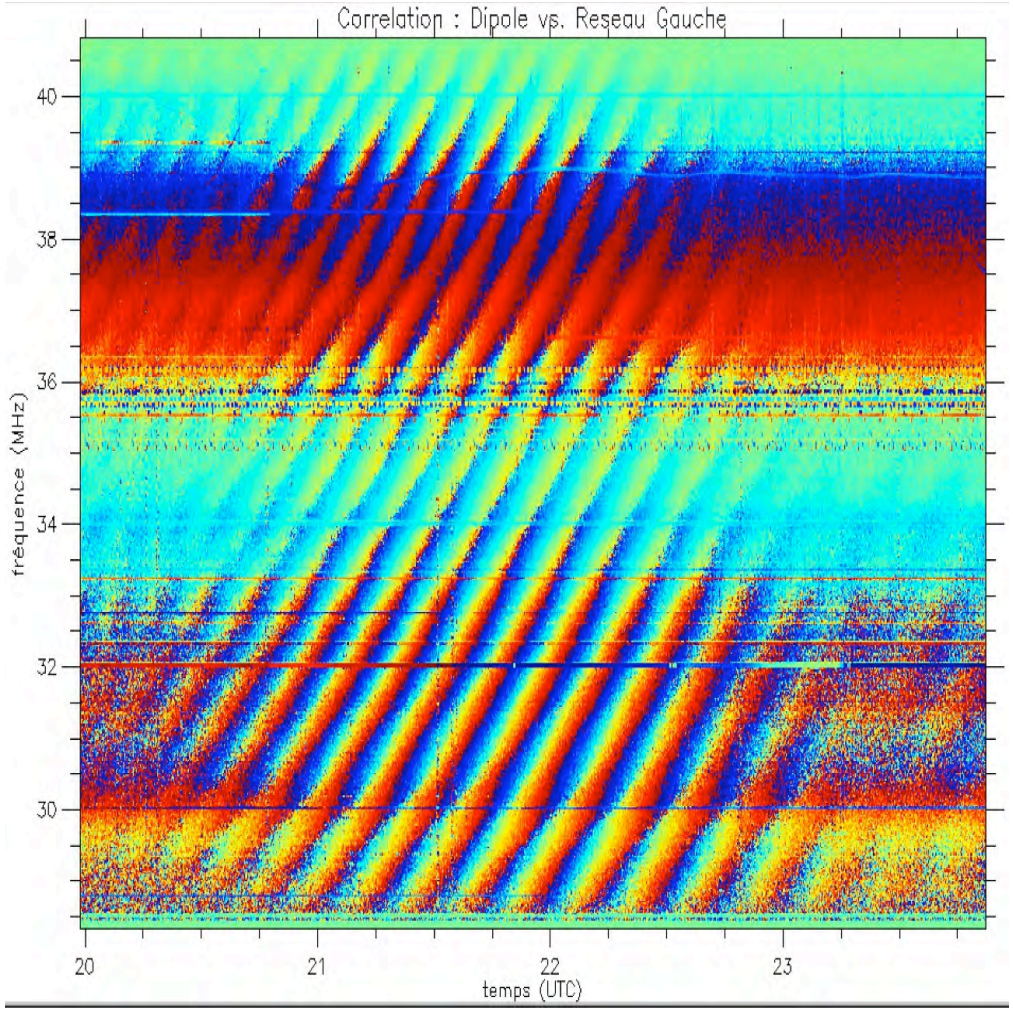
Interférométry Dipole-DAM
CasA

Ref

ADC+AMP.+Dip.

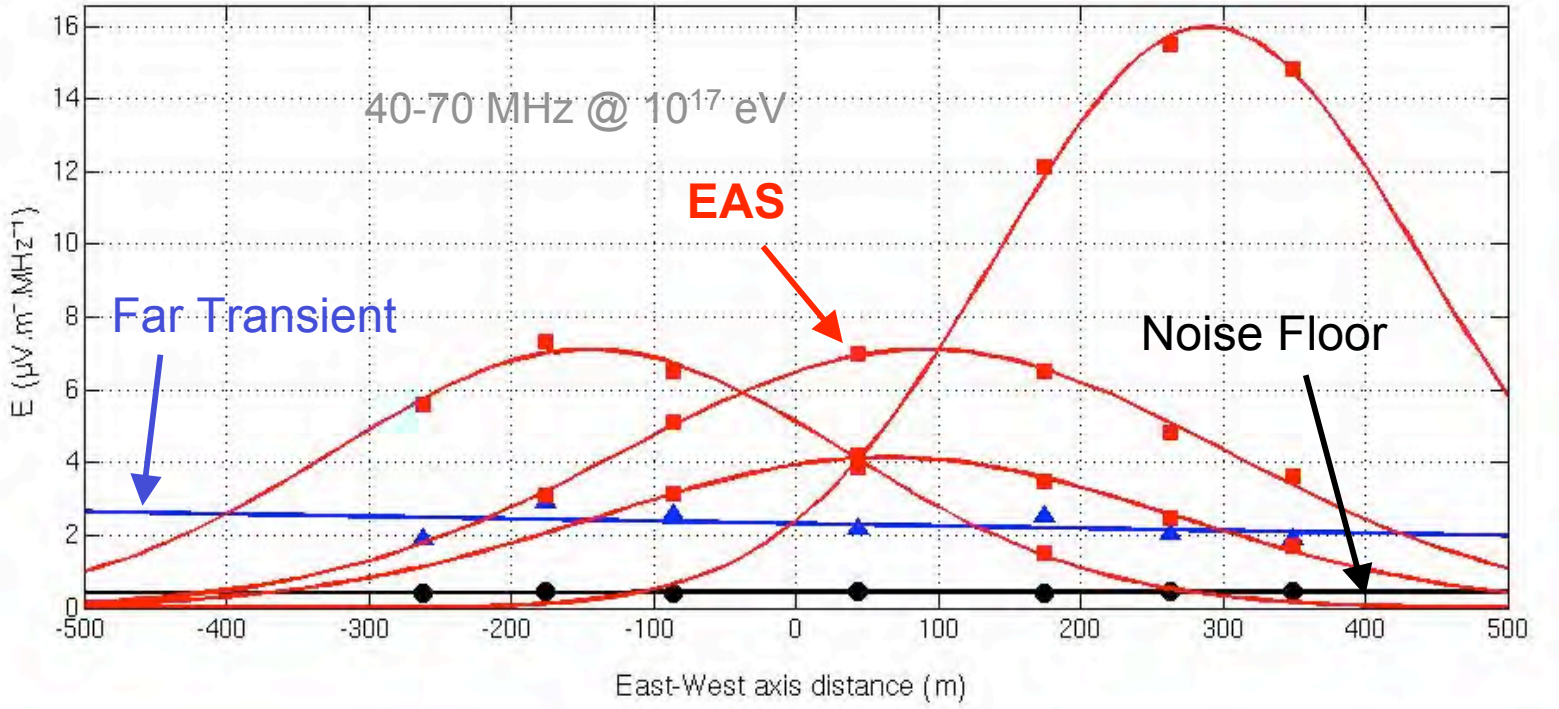
ADC+AMP.

ADC



Electric Field topology

Field topology is a decisive criterion of selection Enables the stand alone mode for the antennas



=> Recognition of a limited electric spot = Large array of antennas

Possible set-up

Scaled surface & pitch

- **Eye array (like the DAM of Nançay)**
  - E ~ 10^{16} eV & Rate ~100 evt/day
  - ~ 200 X 200 m & Antenna pitch ~ 10-20 m => ~200 Antennas
  - Centralized trigger for the eye (cables)
- **Intermediate array**
  - E ~ 10^{17} eV & Rate ~100 evt/day
  - ~ 1000 X 1000 m & Antenna pitch ~ 50-100 m => ~200 Antennas
  - Stand alone antenna with its own trigger capability
- **Outer array**
  - E ~ 10^{18} eV & Rate ~100 evt/day
  - ~ 10 X 10 km & Antenna pitch ~ 0.5-1 km => ~200 Antennas
  - Stand alone antenna with its own trigger capability

- **… For E ~ 10^{20} eV => 100 X 100 km ….**

NOT FAR FROM THE LOFAR DESIGN
(but with an squared mesh)