Autonomous radio detection of air showers with TREND

Tianshan Radio Experiment for Neutrinos Detection

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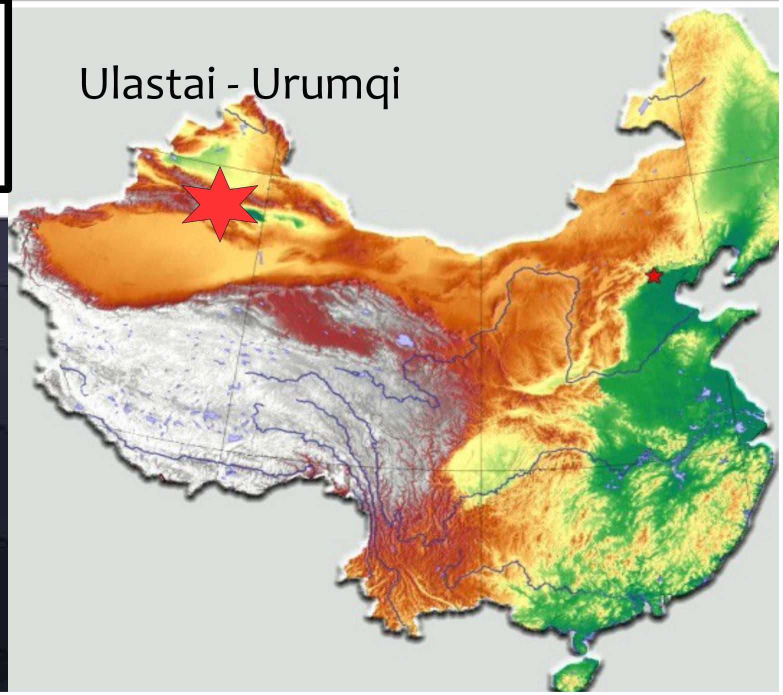
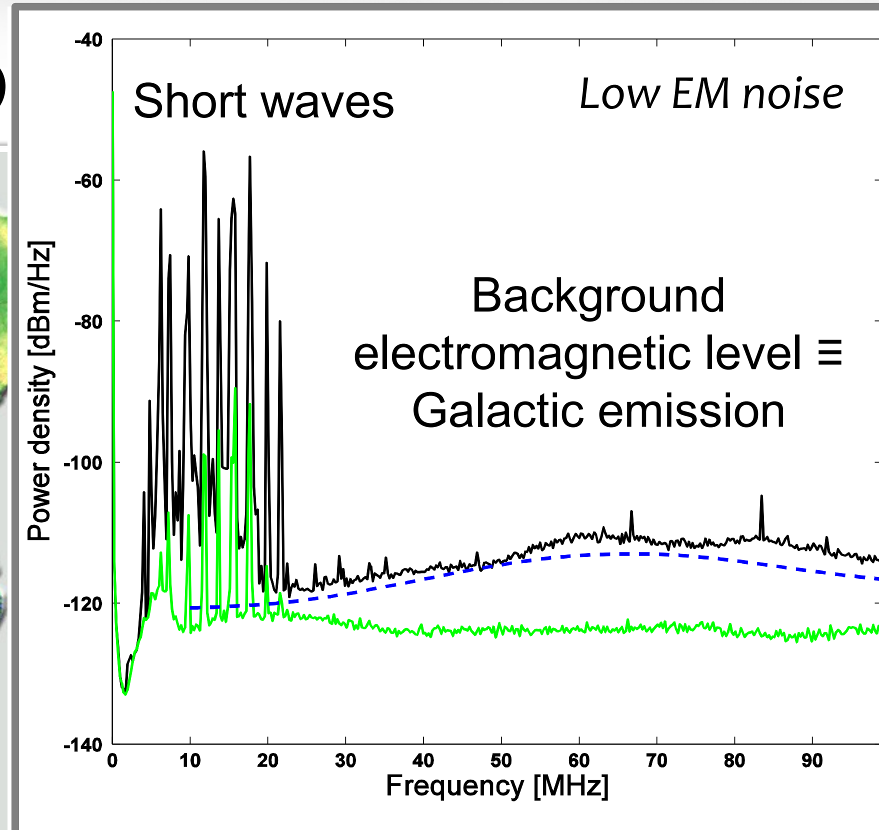
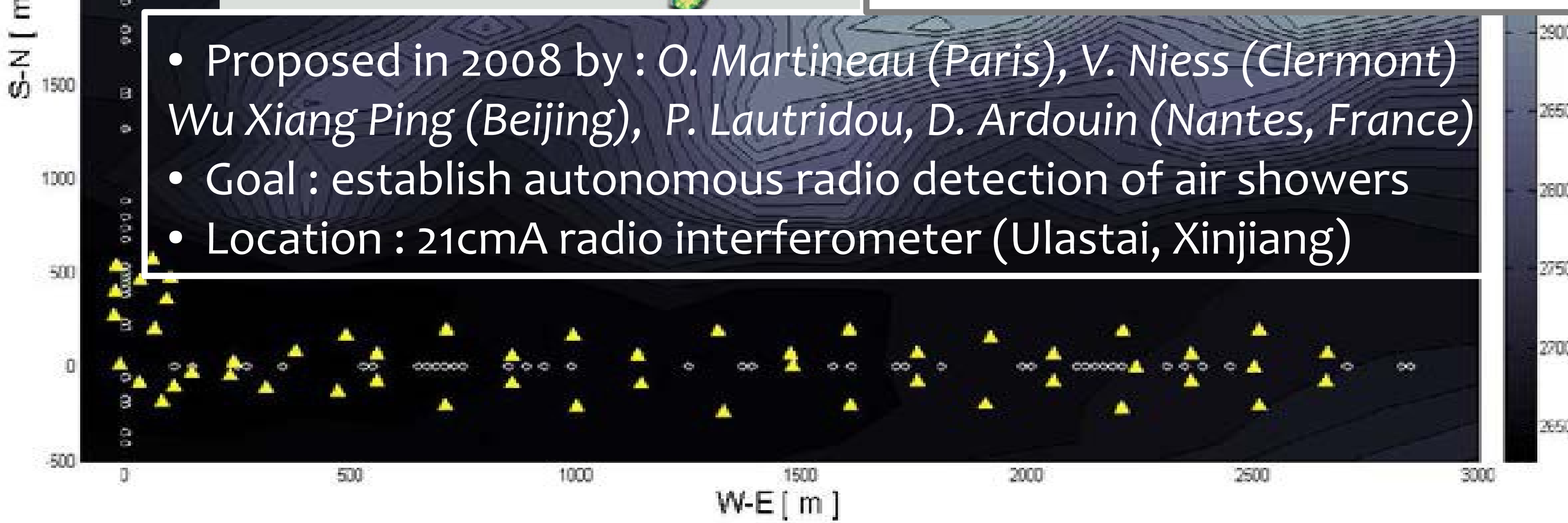
on behalf of the TREND team,
10th FCPPL workshop, March 28th 2017.

TREND setup

~ 1.5 km² 50
150m spacing
antennas







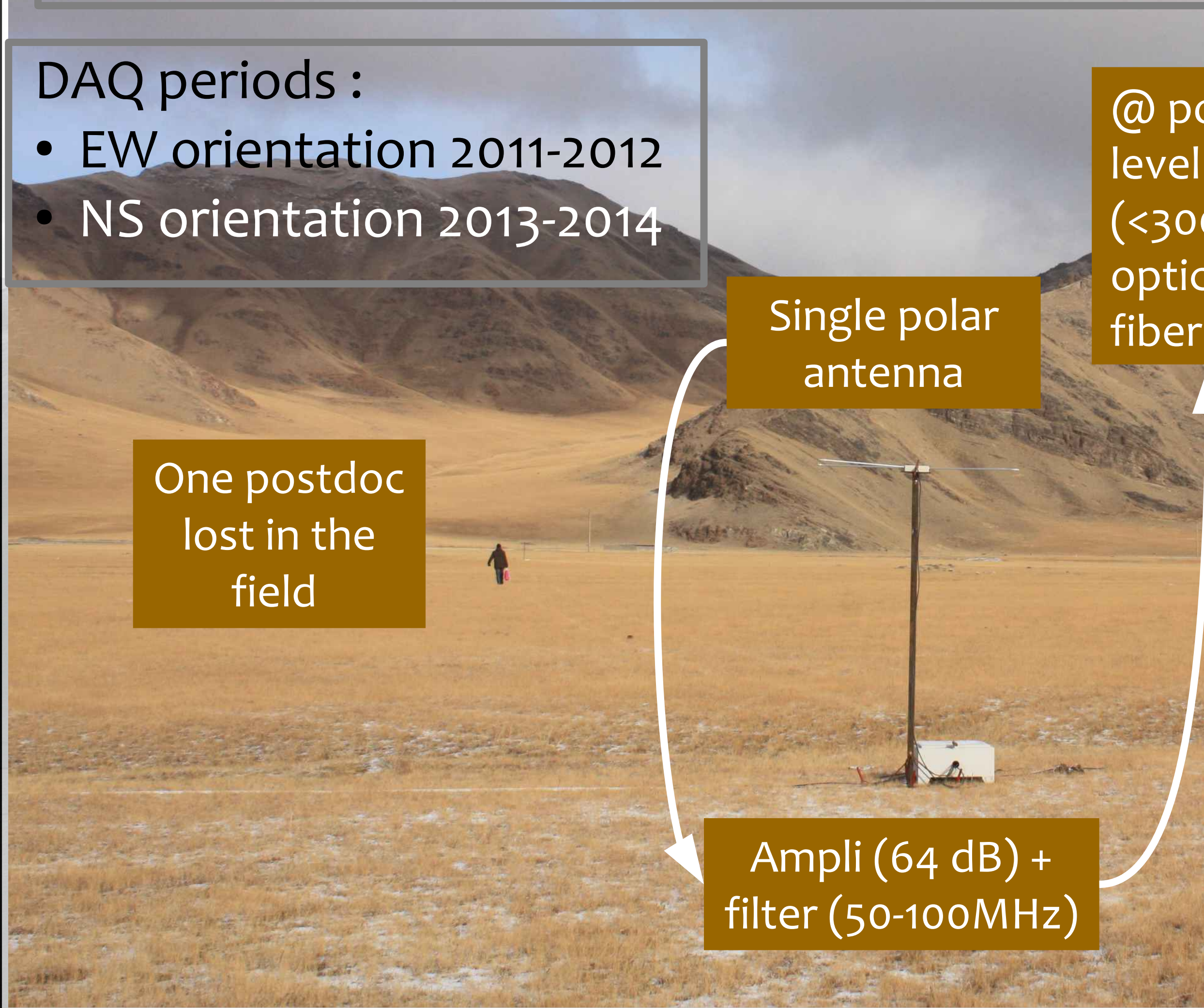
- Proposed in 2008 by : *O. Martineau (Paris), V. Niess (Clermont) Wu Xiang Ping (Beijing), P. Lautridou, D. Ardouin (Nantes, France)*
- Goal : establish autonomous radio detection of air showers
- Location : 21cmA radio interferometer (Ulastai, Xinjiang)

TREND setup

50 1D antenna (1 polarisation) – trigger rate up to ~ 200Hz/antenna – transfert of analogic signal to DAQ room – on-the-fly digitization – trigger if signal>6 or 8σ – record event if 4+ antenna triggers

DAQ periods :

- EW orientation 2011-2012
- NS orientation 2013-2014



One postdoc lost in the field

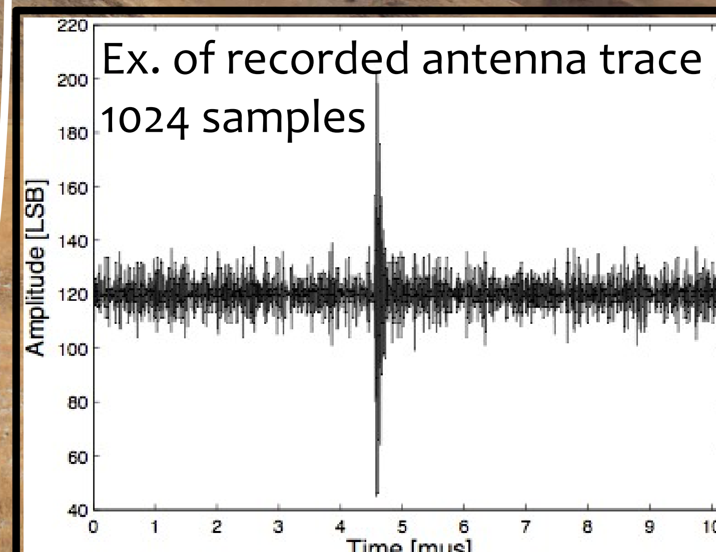
Single polar antenna

Ampli (64 dB) + filter (50-100MHz)

@ pod level (<300m): optical fiber

@ DAQ room(<2km): digitization (200MS/s+8bits) +trigger +reccord if 4+ant

Ex. of recorded antenna trace 1024 samples

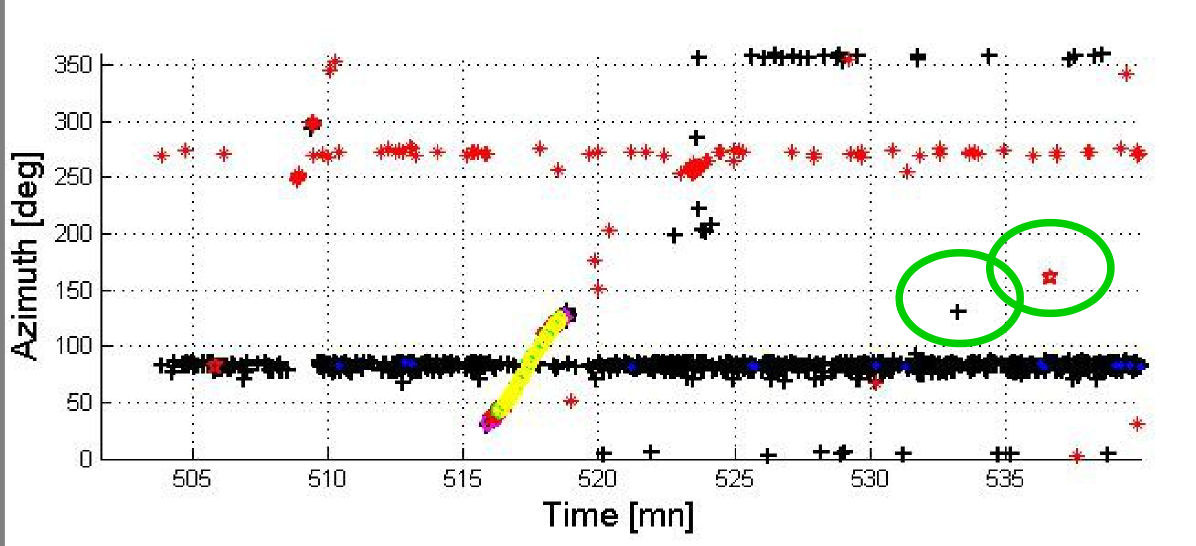


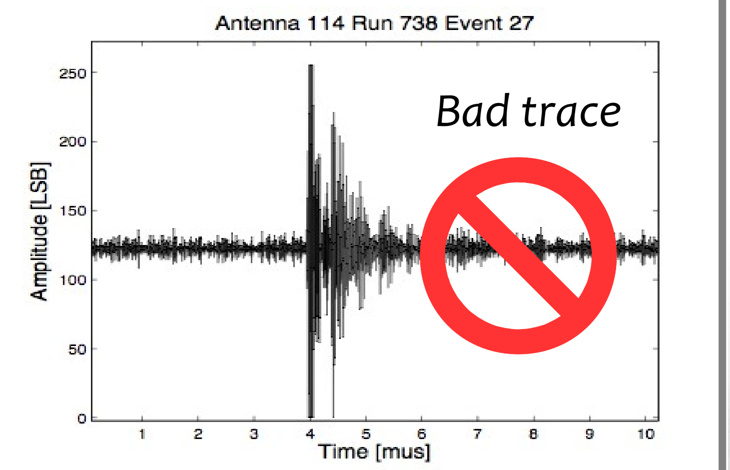
TREND data analysis

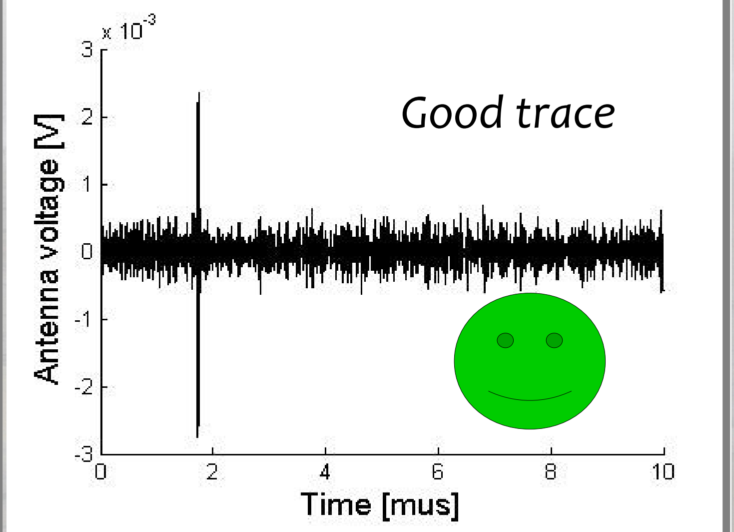
- Offline noise rejection cuts :

(based on EAS radio signal expectations)
pulse duration, multiplicity, trigger pattern at ground, valid direction reconstruction, wavefront, direction & time correlation between events

→ from 2e8 to 465 EAS candidates
in 317 DAQ days (background domination)



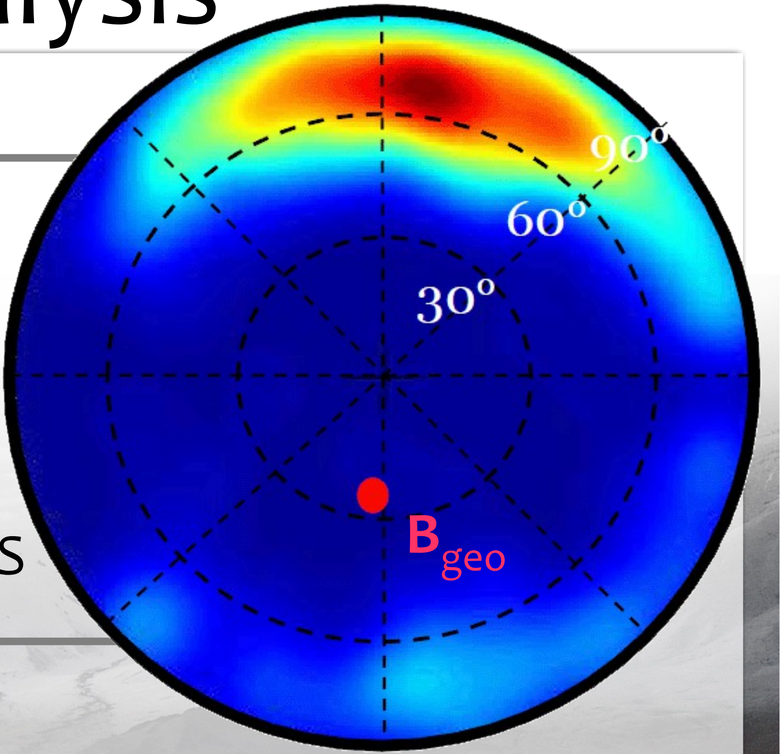




DAQ= Data AQuisition
EAS=Extensive Air Shower

TREND data analysis

- The 465 EAS candidates angle distribution : overdensity of events with $\theta>60°$ coming from North, as expected for EAS (radio signal ↑ if EAS ⊥ $\mathbf{B}_{geo}$)
→ indicating candidates are likely to be real EAS



- How to check quantitatively if these candidates are EAS ?
→ expected angle distribution for EAS ?
- How many EAS were expected with this array ?
→ efficiency of TREND to detect EAS ?

EAS=Extensive Air Shower

→ Simulate air shower events and propagate them into TREND DAQ + offline analysis

TREND events simulation

For energies between 5e16 and 3e18 eV :

EAS=Extensive Air Shower

- *simulation of EAS with their radio electric field at each antenna location* using ZHAIRES (simulated EAS number to reach ~10 K)

- *simulation of voltage at each antenna output from each electric field* using NEC2

- *insertion of simulated events in real data files*
randomisation of insertion time ;
propagate events through DAQ electronic chain : frequency filter, gain, ?
digitization, noise addition (from real data), trigger

- *data analysis of these files with standard TREND algorithm*
number of simulated events selected within real data → computation of effective area for each θ,ϕ , and aperture ($m^2.sr$) of TREND

Gain calibration of TREND electronic

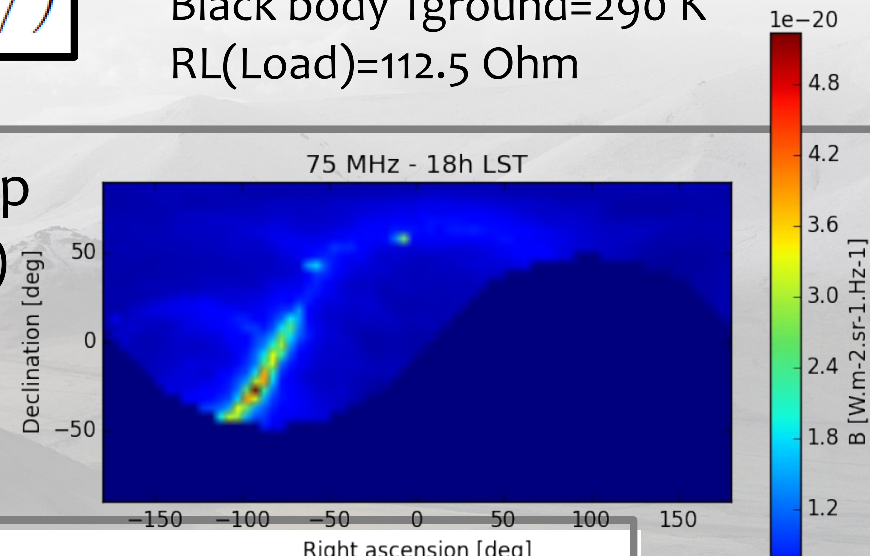
Need to calibrate TREND gain (antennas and time variations)
→ can be drag from the recorded antenna voltage **<Vant²>**, with **<Vsky²>** and **<Vground²>** expectations:

$$\left\langle V_{ant}^2 \right\rangle = G^2\left(\left\langle V_{sky}^2 \right\rangle + \left\langle V_{ground}^2 \right\rangle\right)$$

$$\left\langle V_{ground}^2 \right\rangle = \frac{1}{2} k_B T_{ground} \Delta\nu R_L$$

Black body Tground=290 K
RL(Load)=112.5 Ohm

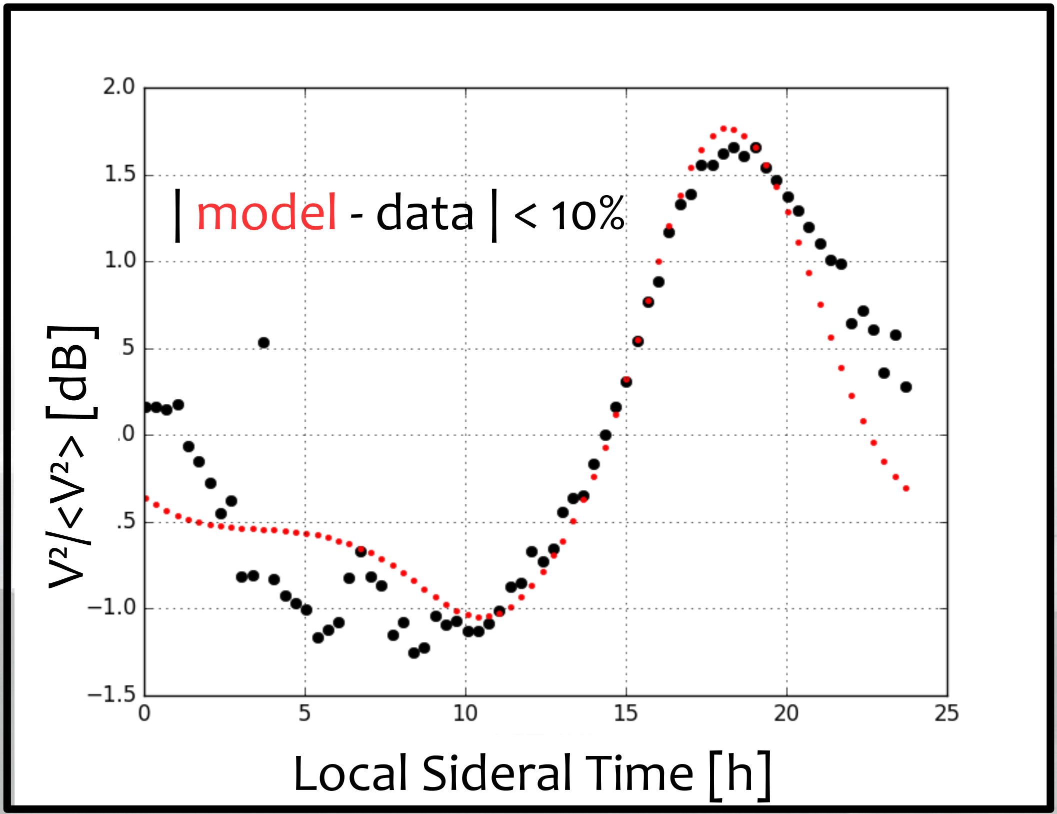
- sky brightness B(θ,ϕ,ν) using LFMap
- antenna effective area Aeff(θ',ϕ',ν) computation with NEC2 (taking ground effet into account)



$$\left\langle V_{sky}^2 \right\rangle = \frac{R_L}{2}\int_{\Delta\nu}\int_{4\pi} B_\nu(\theta,\varphi) A_{eff}(\theta',\varphi') \sin\theta d\theta d\varphi d\nu$$

→ **<Vsky²>** received by antenna as a function of antenna instantaneous field of view (Local Sideral Time)

Gain calibration of TREND electronic



→ regular antenna gain computation from noise level monitoring

TREND efficiency results

Data set :

- Period 6 of DAQ
- Runs 3562 to 3733
- Feb. 23th to June 19th 2012
- 80 DAQ days
- Nselected events = 204

EAS=Extensive Air Shower

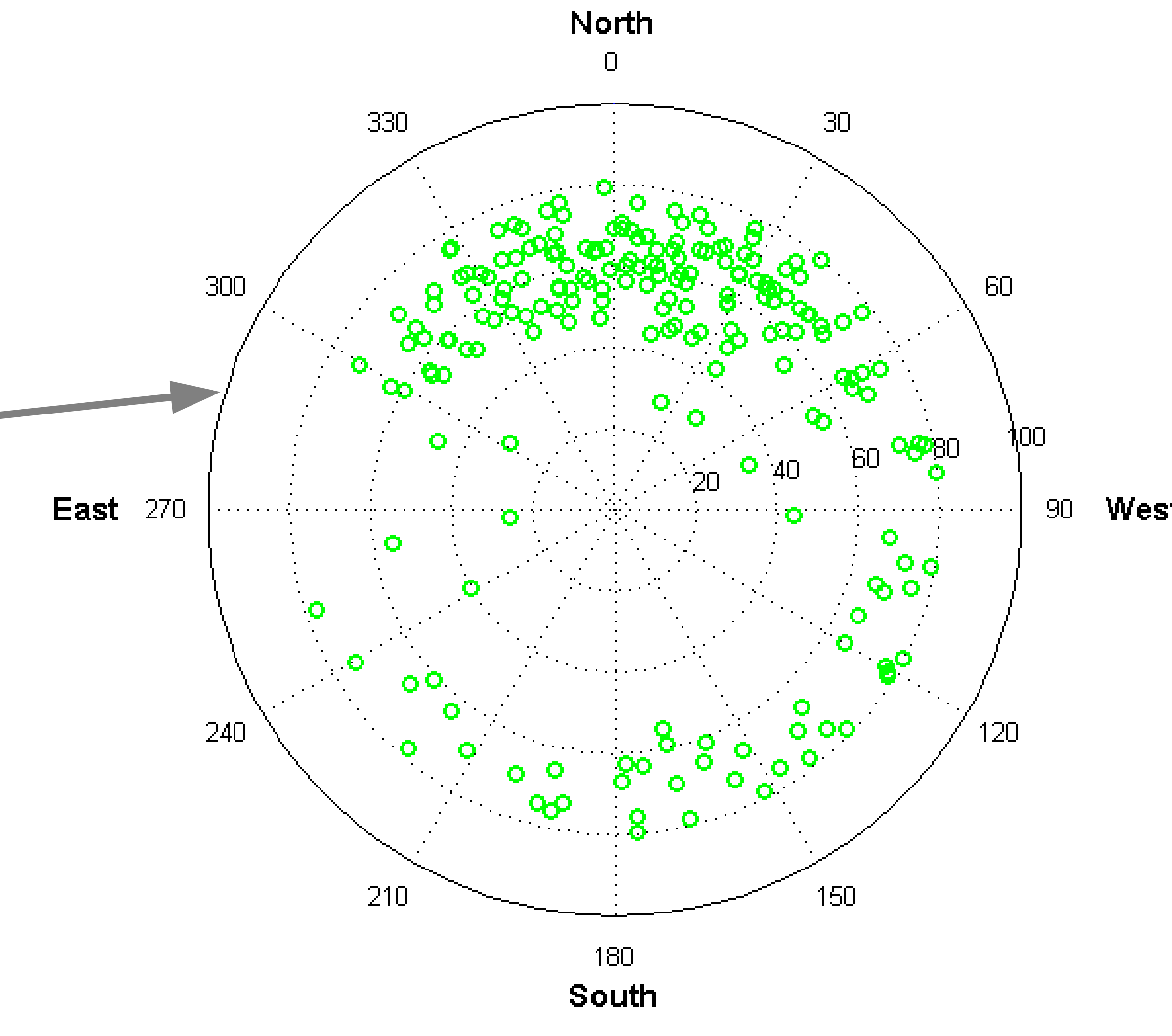
Simulation set :

~ 500 EAS per E= [1e17,3e17,5e17,1e18,3e18]

Nselected events = [1 10 21 28 37]

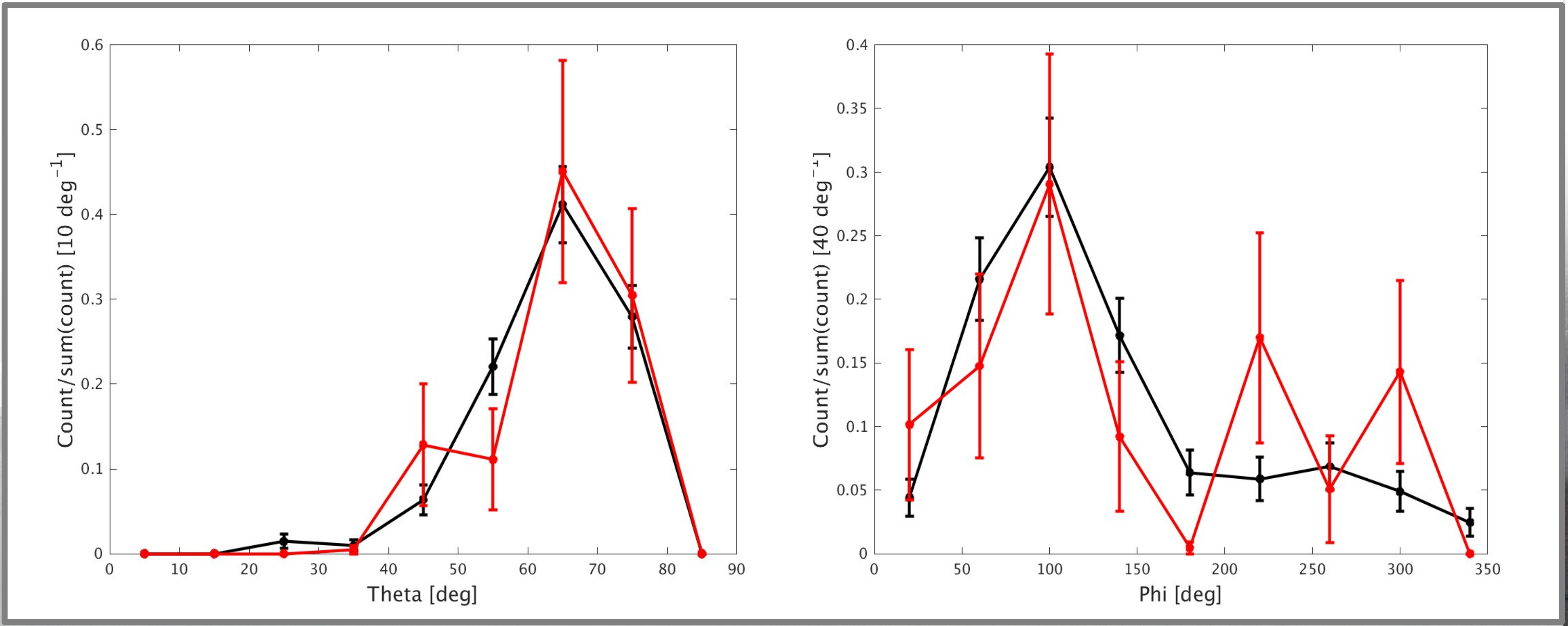
→ low Nselected events

→ stat. limited results



Angle distribution of the 204 EAS candidates of period 6

TREND efficiency results



- Good agreement between **data** and simulation for angle distribution of selected events (given very low statistics for simulation)
- Clearly show that experimental radio candidates ARE indead air shower events

TREND efficiency results

- **Effective** number of events = 204 in 80 days
- **Expected** number of events

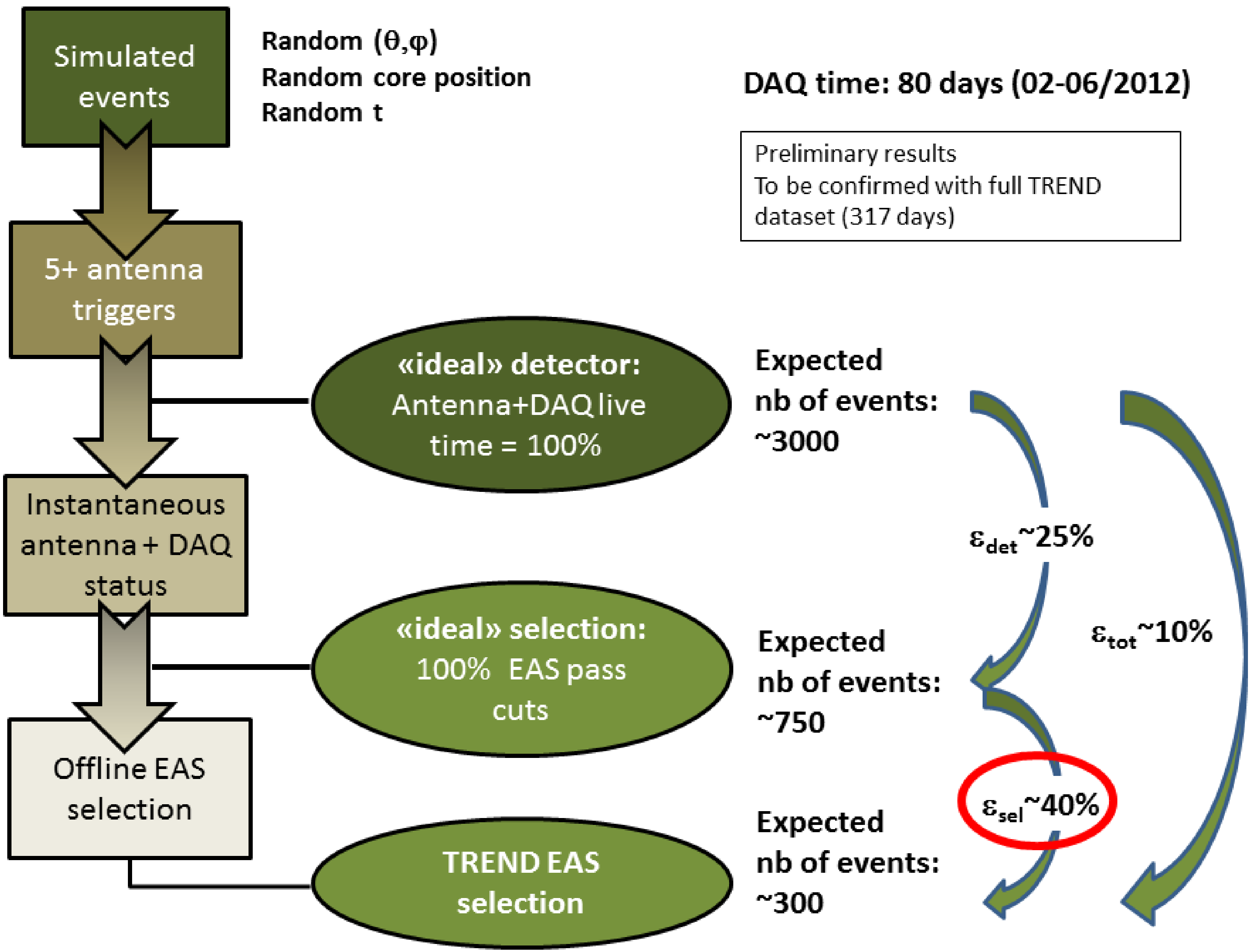
= Σ aperture ($m^2.sr$) * $dN/dEdtd\Omega$ ($GeV^{-1}.m^{-2}.sr^{-1}.s^{-1}$) * ΔE * Δt

= ~ 300

→ satisfying modelisation of EAS radio emission + TREND response

What number of events should we expect for an « ideal » behavior TREND detector ?

TREND efficiency results



Conclusion and to do

Conclusion

- TREND system well understood
- Autonomous radio detection EAS goal reached first time ever
- Detector efficiency 25% and EAS selection efficiency 40%
- Both to be improved with GRANDproto, see Olivier's talk

To do

- Increase the number of simulations to have more statistics
- Quantify the errors
- Do the same work for all the other DAQ periods
- Submit a publication on the results & present them at ICRC 2017