Autonomous radio detection of air showers with TREND

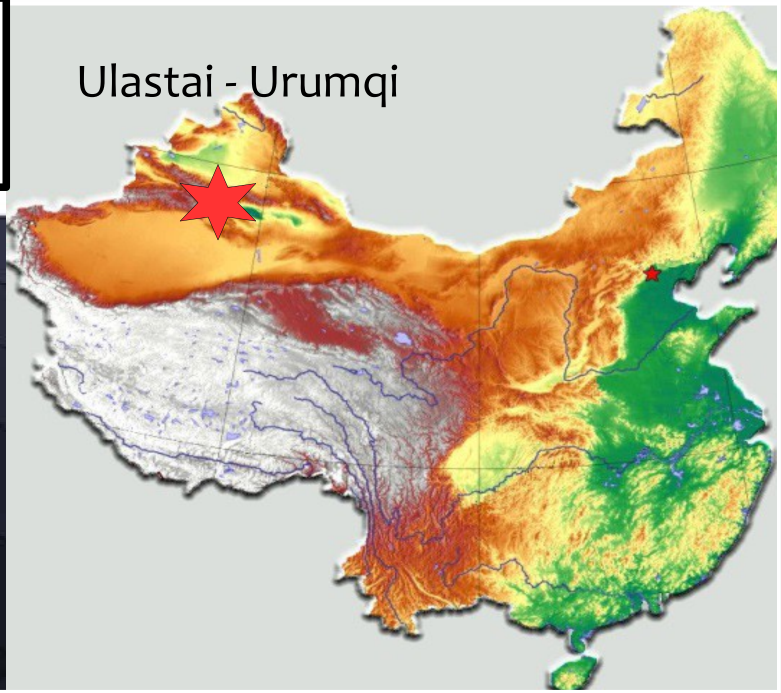
Tianshan Radio Experiment for Neutrinos Detection

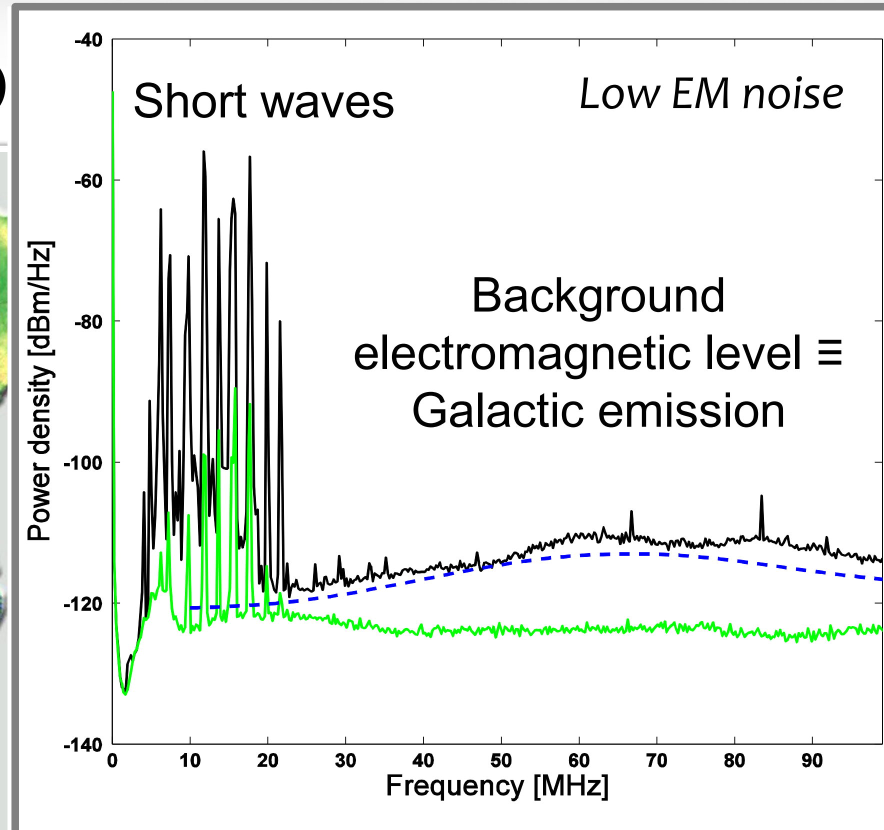
Sandra Le Coz, NAOC Beijing,

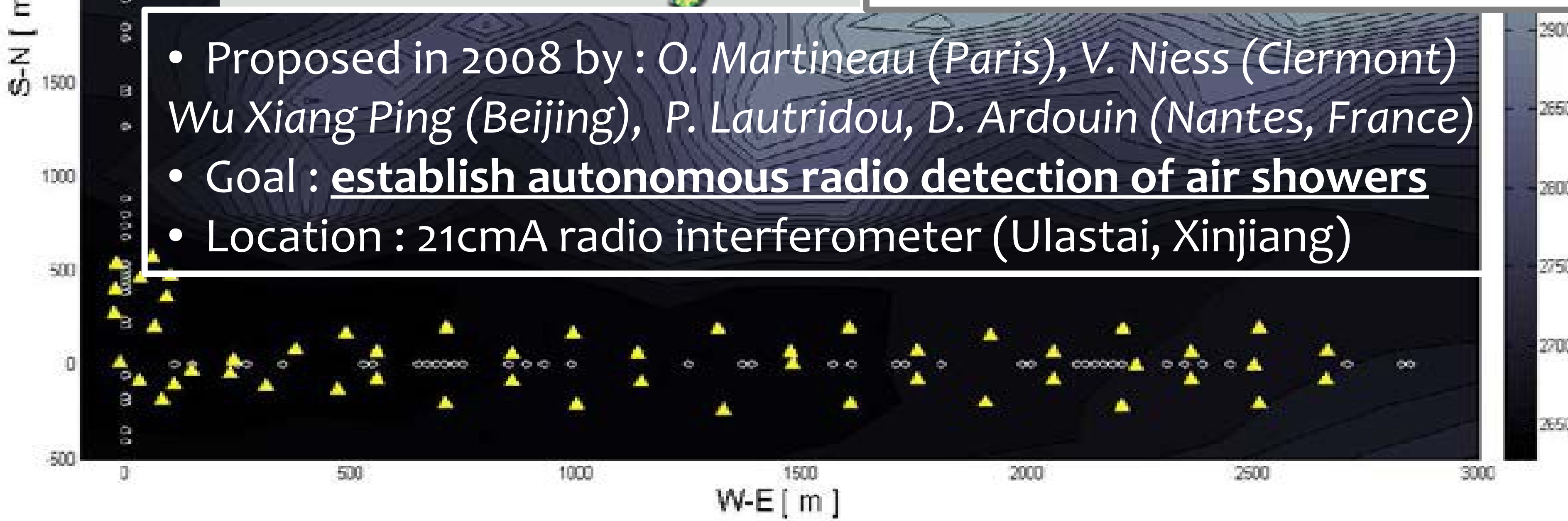
GRAND workshop, May 17th 2017, Paris.

TREND setup

~ 1.5 km² 50
150m spacing
antennas







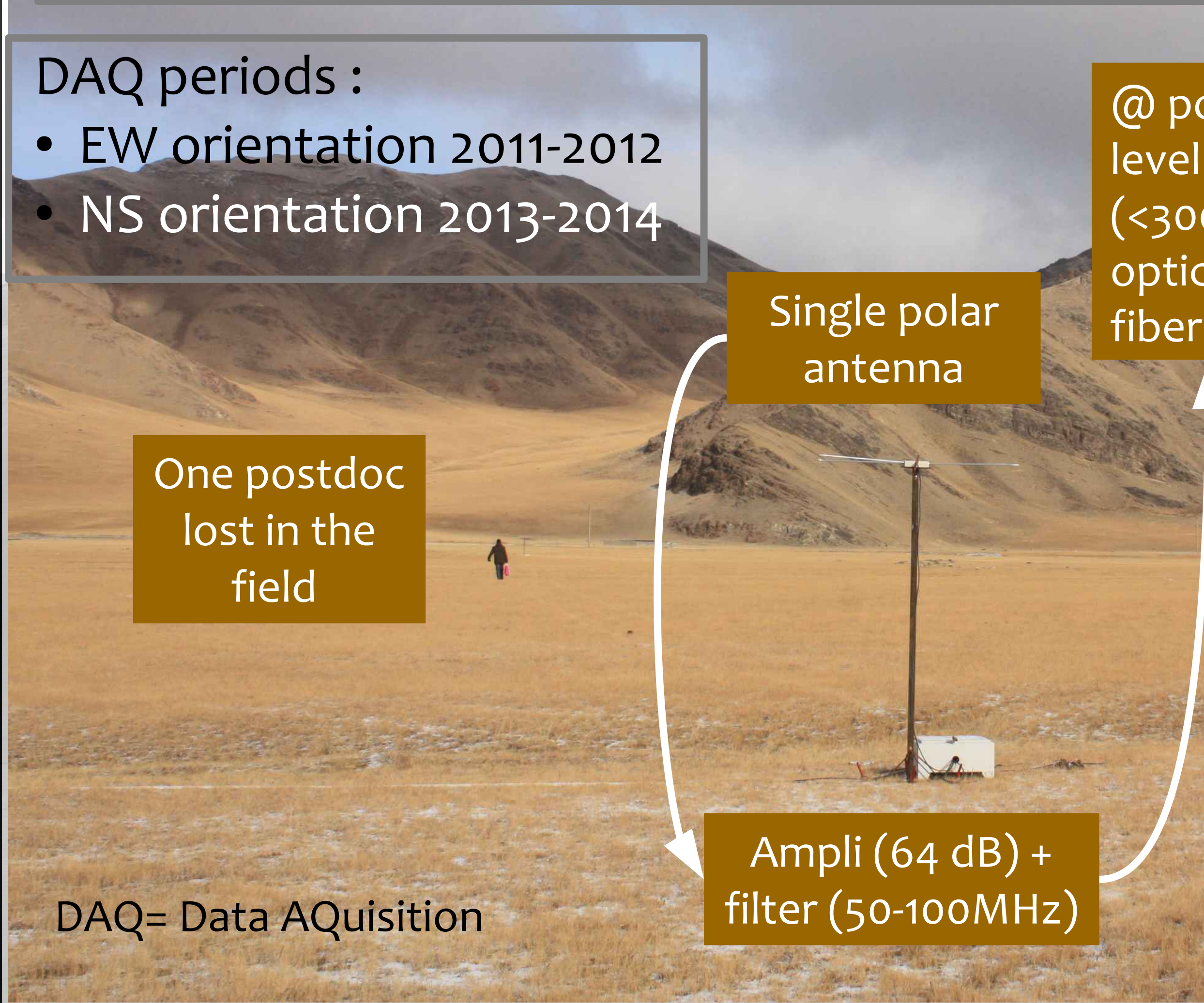
- Proposed in 2008 by : *O. Martineau (Paris), V. Niess (Clermont) Wu Xiang Ping (Beijing), P. Lautridou, D. Ardouin (Nantes, France)*
- Goal : **establish autonomous radio detection of air showers**
- Location : 21cmA radio interferometer (Ulastai, Xinjiang)

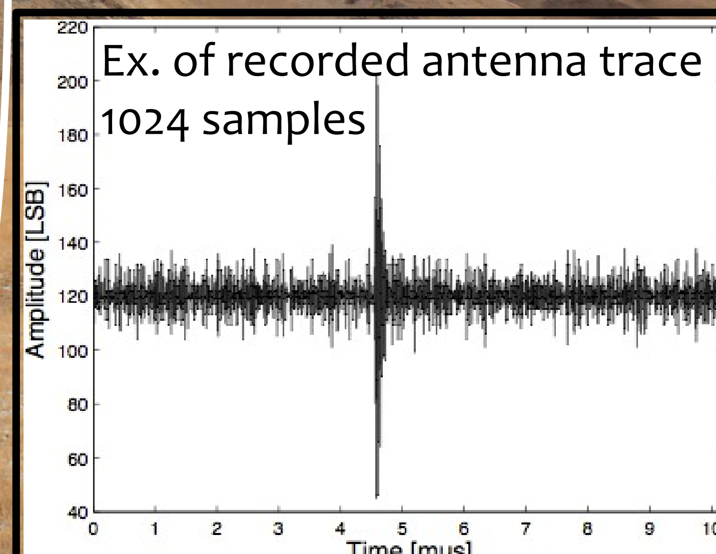
TREND setup

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





DAQ= Data AQuisition

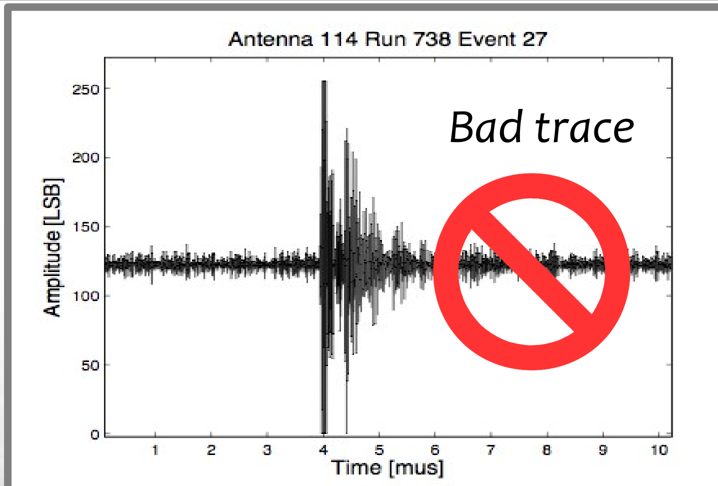
TREND data analysis

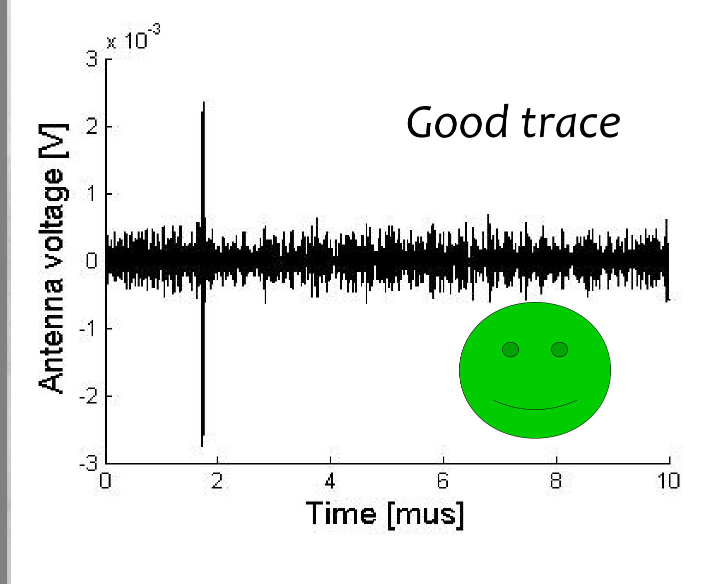
- Offline noise rejection cuts :

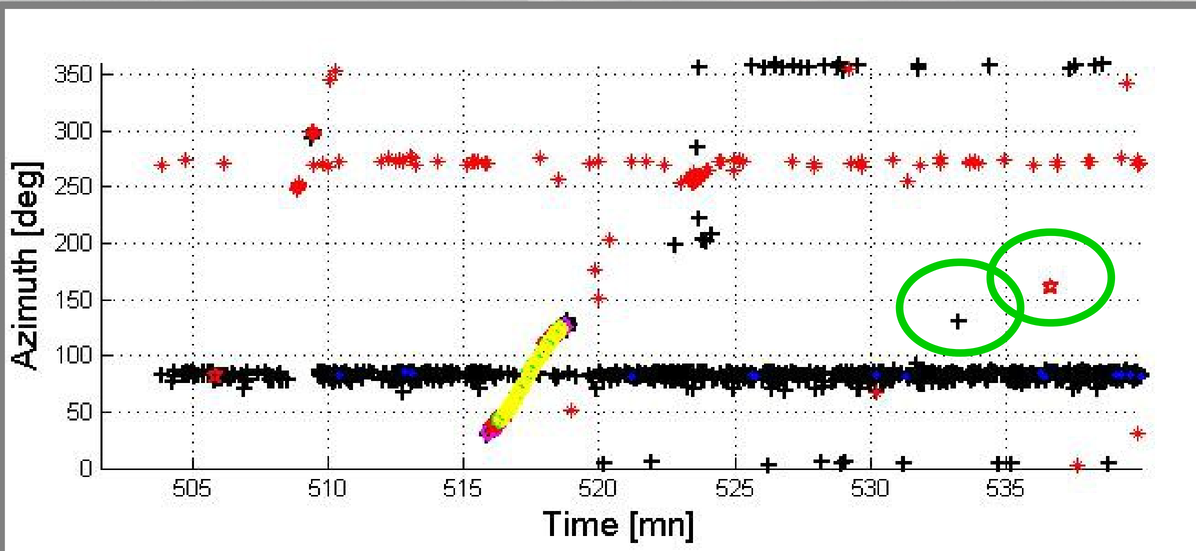
(based on EAS radio signal expectations)

pulse duration, multiplicity, trigger pattern at ground, valid direction reconstruction, wavefront, direction & time correlation between events

→ from 2e8 events to 526 EAS candidates in 317 DAQ days (background domination)





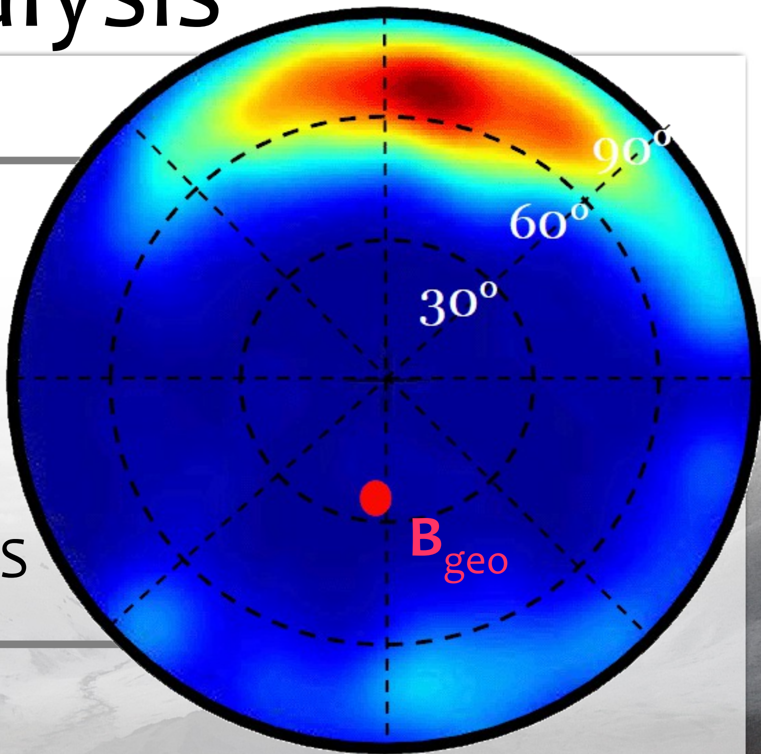


DAQ= Data AQuisition

EAS=Extensive Air Shower

TREND data analysis

- The 526 EAS candidates angle distribution : overdensity of events with θ>60° coming from North, as expected for EAS (radio signal ↑ if EAS ⊥ $\mathbf{B}_{geo}$)
→ indicating candidates are likely to be real EAS



EAS=Extensive Air Shower

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

DAQ= Data AQuisition

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

TREND events simulation

For energies between 5e16 and 3e18 eV :

- *simulation of random location proton EAS with their radio electric field*
using ZHAIRES (number of simulated EAS up to ~10 K per energy)

- *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:

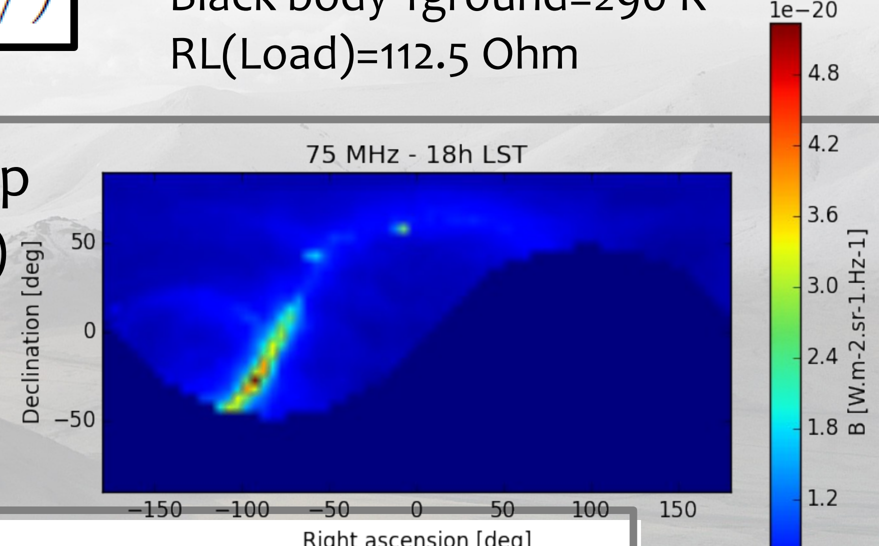
$$\left\langle V_{ant}^2 \right\rangle = G^2 \left(\left\langle V_{sky}^2 \right\rangle + \left\langle V_{ground}^2 \right\rangle \right)$$

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

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)

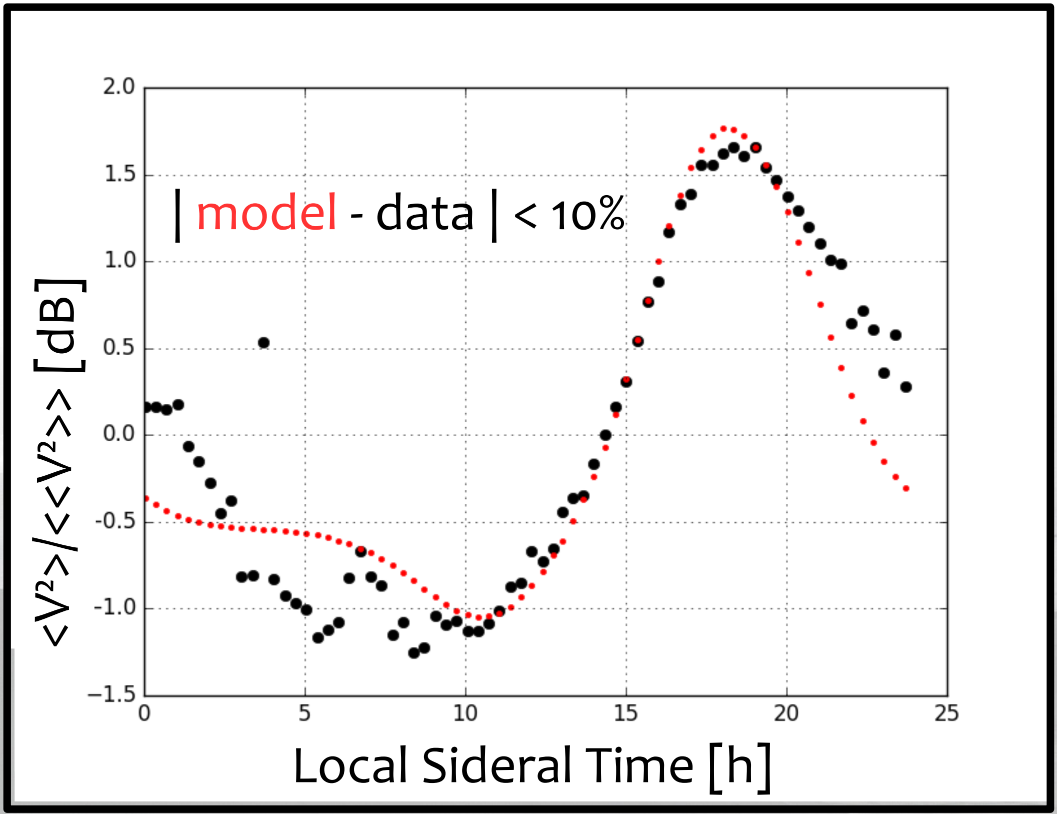
computation with NEC2
(taking ground effet into account)



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

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

Gain calibration of TREND electronic

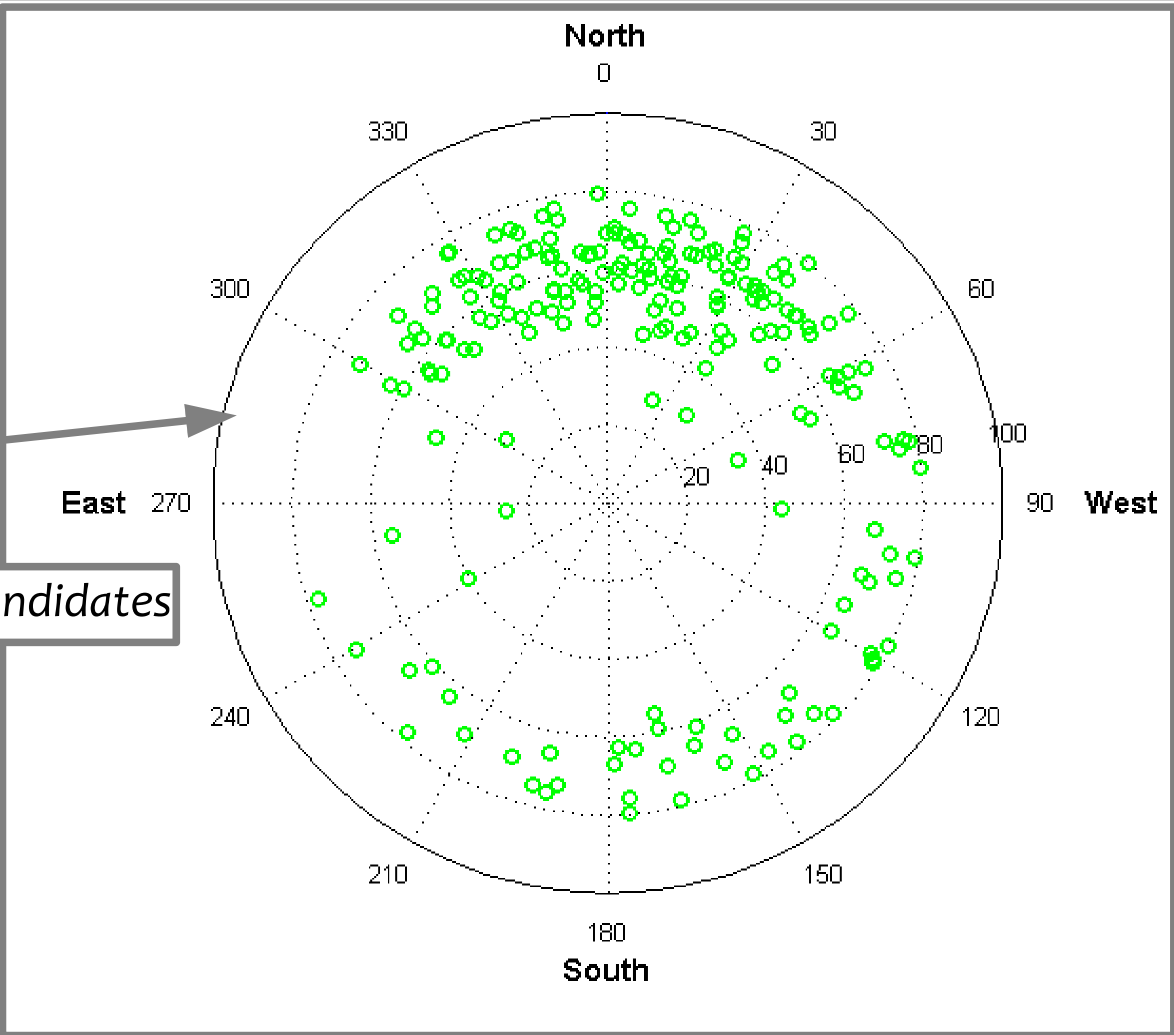


→ regular antenna gain computation from noise level monitoring

TREND efficiency results

Data set :

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



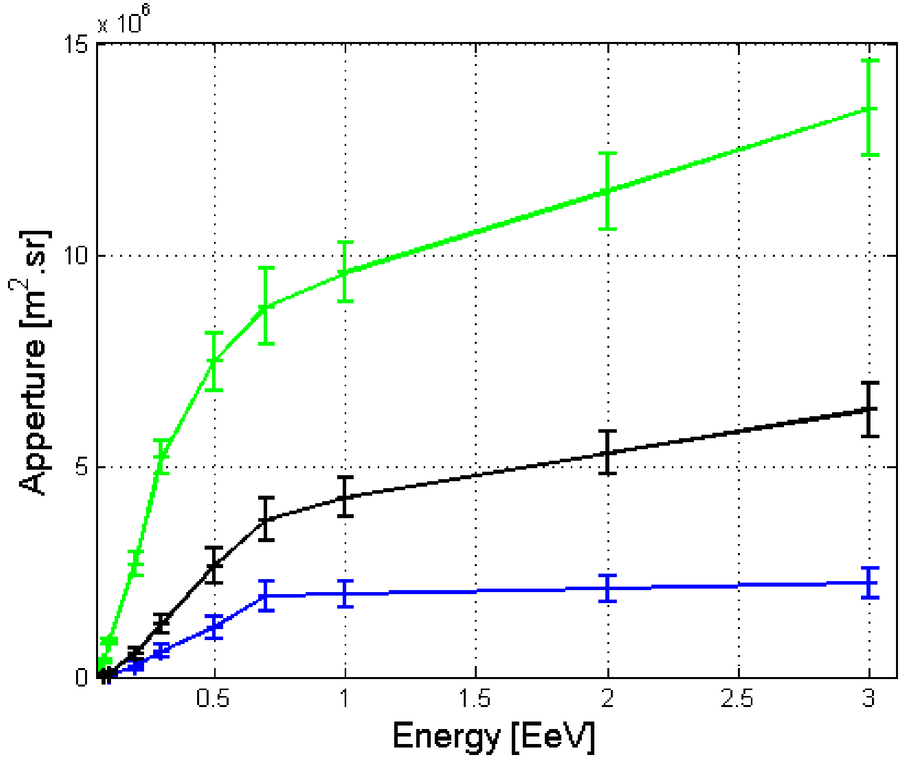
Angle distribution of the 204 EAS candidates

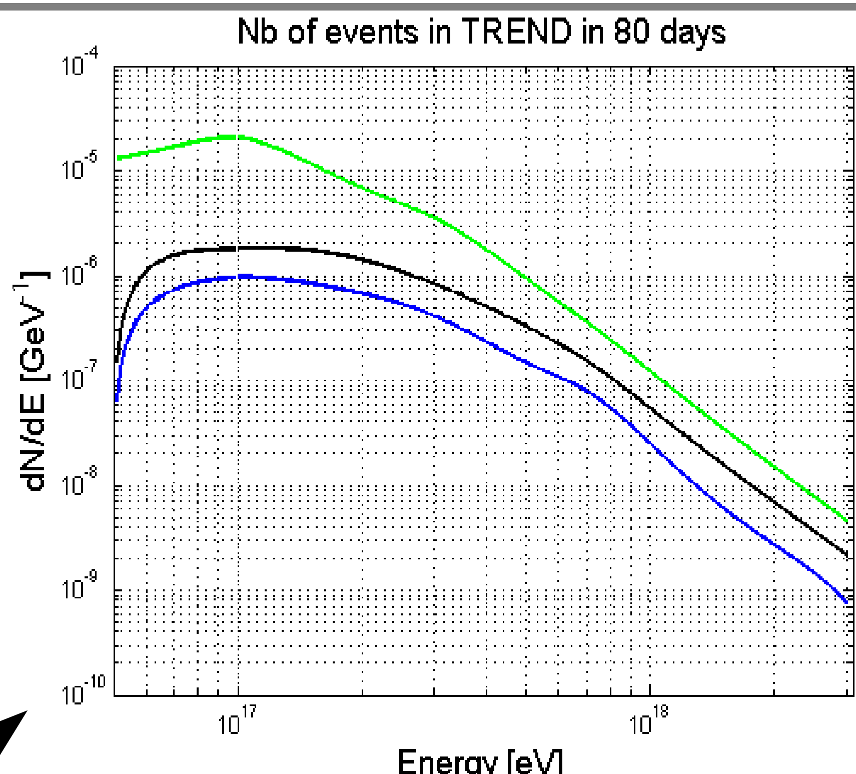
EAS=Extensive Air Shower
DAQ= Data AQuisition

Simulation set :

[5e16, 8e16, 1e17, 2e17, 3e17, 5e17, 7e17, 1e18, 3e18] eV
Nselected (with DAQ state + offline analysis) / Nsimulated =
[0/10K 9/10K 20/10K 38/4K 74/3K 87/3K 105/2K 169/3K 166/3K]

TREND efficiency results





aperture (m^2.sr) * flux ($GeV^{-1}.m^{-2}.sr^{-1}.s^{-1}$) * 80 jours

« ideal » behavior TREND detector

real TREND DAQ state

real TREND DAQ state + offline analysis

TREND efficiency results

- **Expected** number of events in the data set (80 days)

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

= 266 (+- 74)

- **Effective** number of events in the data set = 204

→ satisfying modelisation of EAS radio emission + TREND response

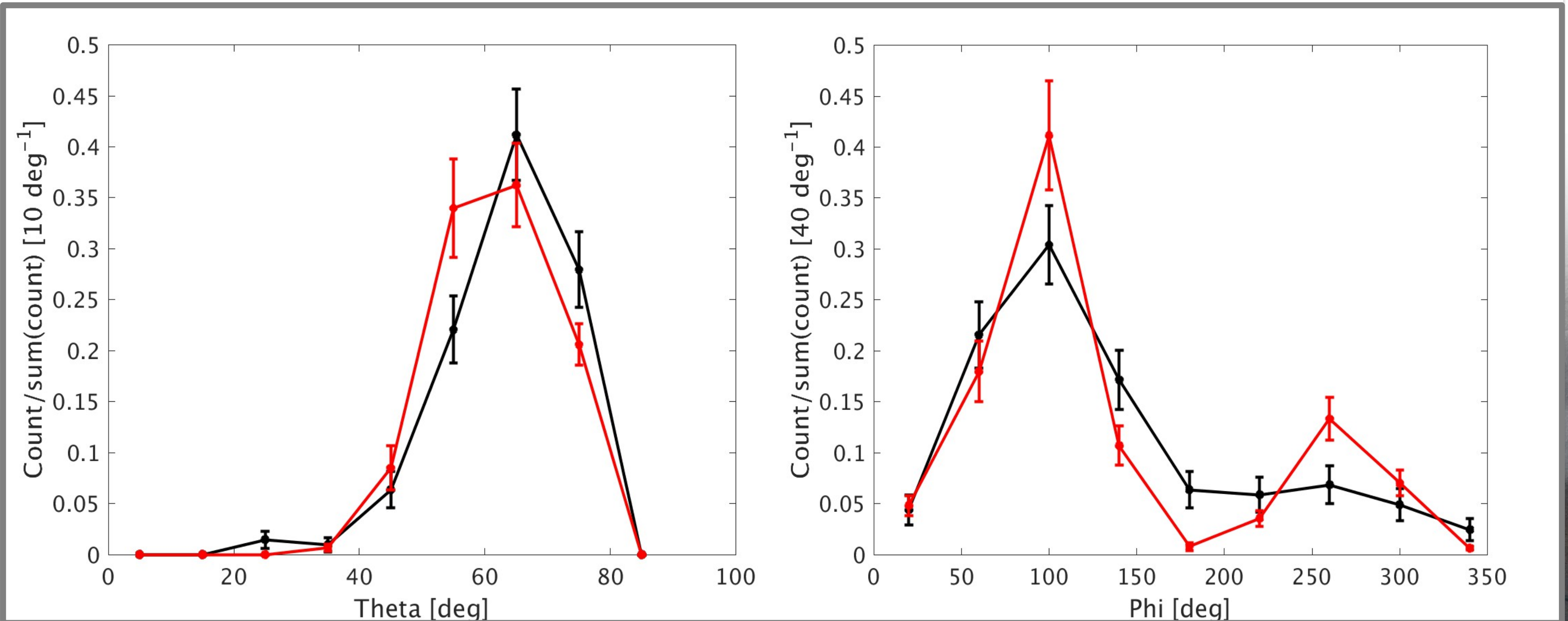
Number of events expected :

- without the offline analysis cuts : 551 (+- 121)
- without the offline cuts and DAQ state (« ideal » detector) : 3206 (+- 351)

N expected with **uncertainty on gain calibration of 10%** :

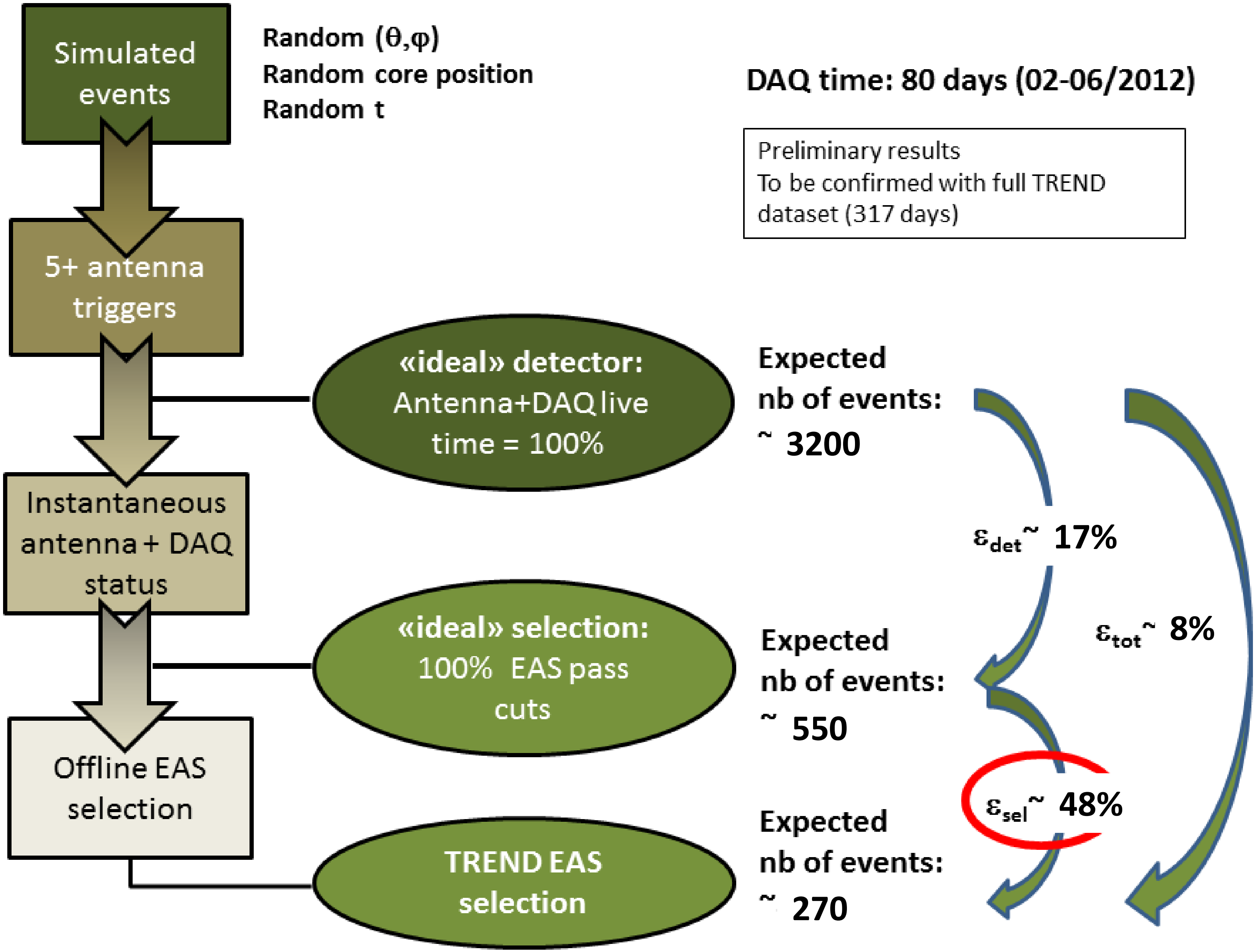
- in the data set : 266→ 209 to 329
- without the offline analysis cuts : 551→ 432 to 680
- without the offline cuts and DAQ state : 3206→ 2590 to 3873

TREND efficiency results



Good agreement between **data** and simulation for angle distribution of selected events
→ clearly show that experimental radio candidates are indeed mainly air shower events

TREND efficiency summary



Conclusion and to do

Conclusion

- TREND system well understood
- Autonomous radio detection EAS goal reached first time ever
- Detector efficiency ~17% and EAS selection efficiency ~48%
- Both to be improved with GRANDproto, see Olivier's talk

To do

- What if we use iron EAS instead of proton EAS ?
  use EVA instead of ZHAIRES ?
- Do the same work for all the other DAQ periods
- Submit a publication on the results & present them at ICRC 2017