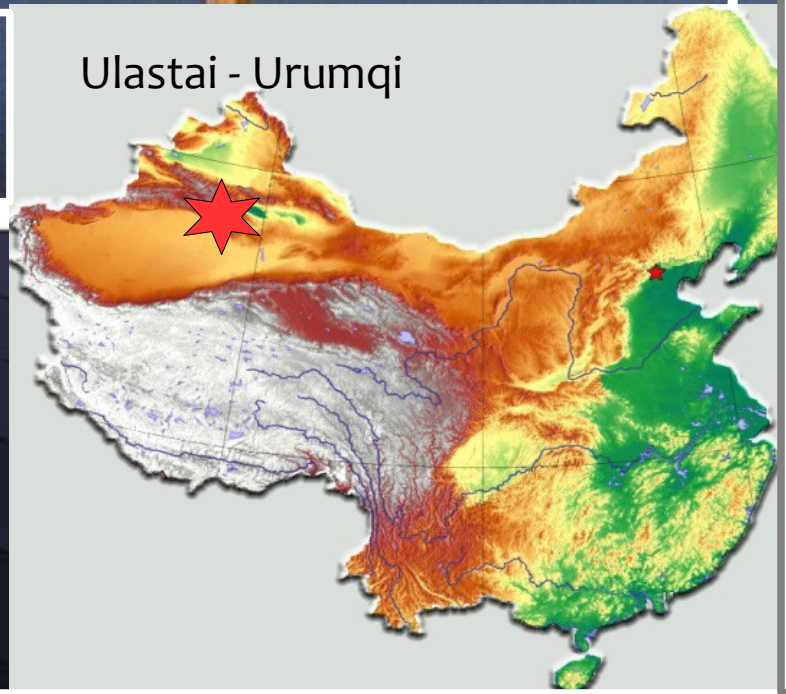
(Nearly) final results of TREND

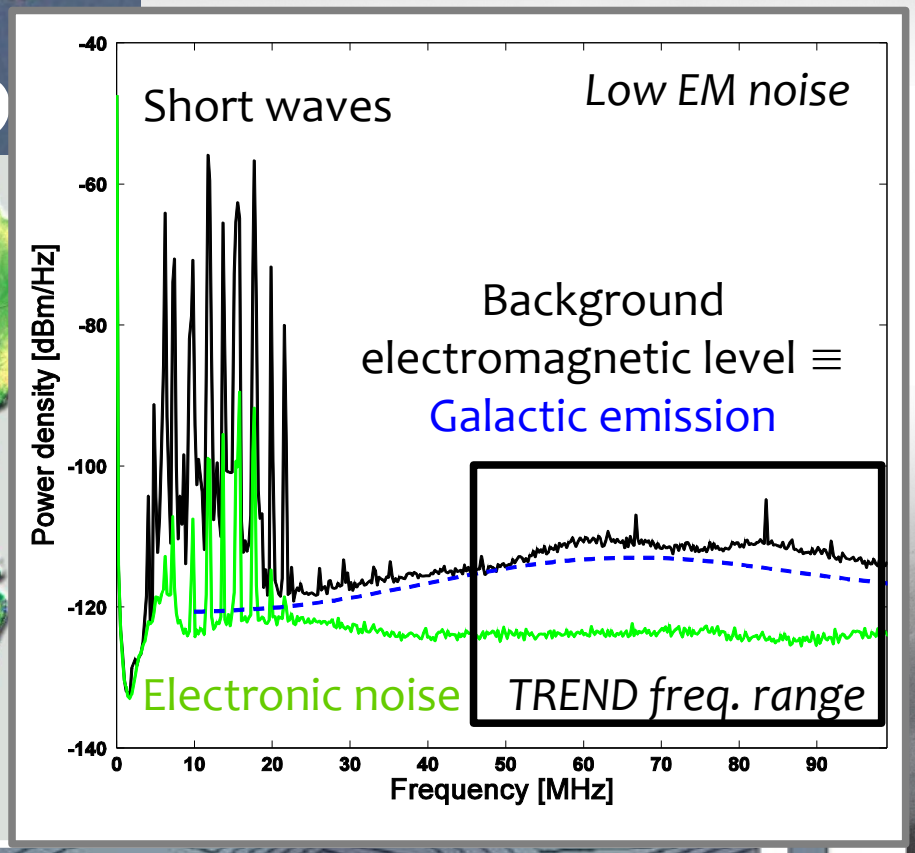
Tianshan Radio Experiment for Neutrinos Detection

Sandra Le Coz, NAOC CAS Beijing,
on behalf of the TREND team,
11th FCPPL workshop, May 25th, 2018, Marseille, France.

TREND setup

50 antennas
50 m spacing
~ 1.5 km²





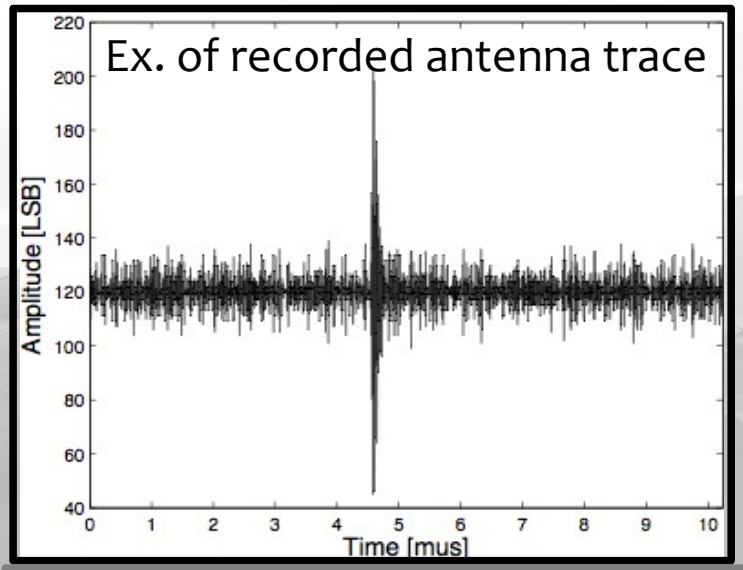
- Proposed in 2008 by : *O. Martineau (Paris), V. Niess (Clermont) Wu Xiang Ping (NAOC Beijing), Hu Hong Bo (IHEP Beijing), P. Lautridou, D. Ardouin (Nantes, France),*
- Goal : **establish autonomous radio detection of air showers**
- Location : 21cmA radio interferometer (Ulastai, Xinjiang)

TREND data analysis

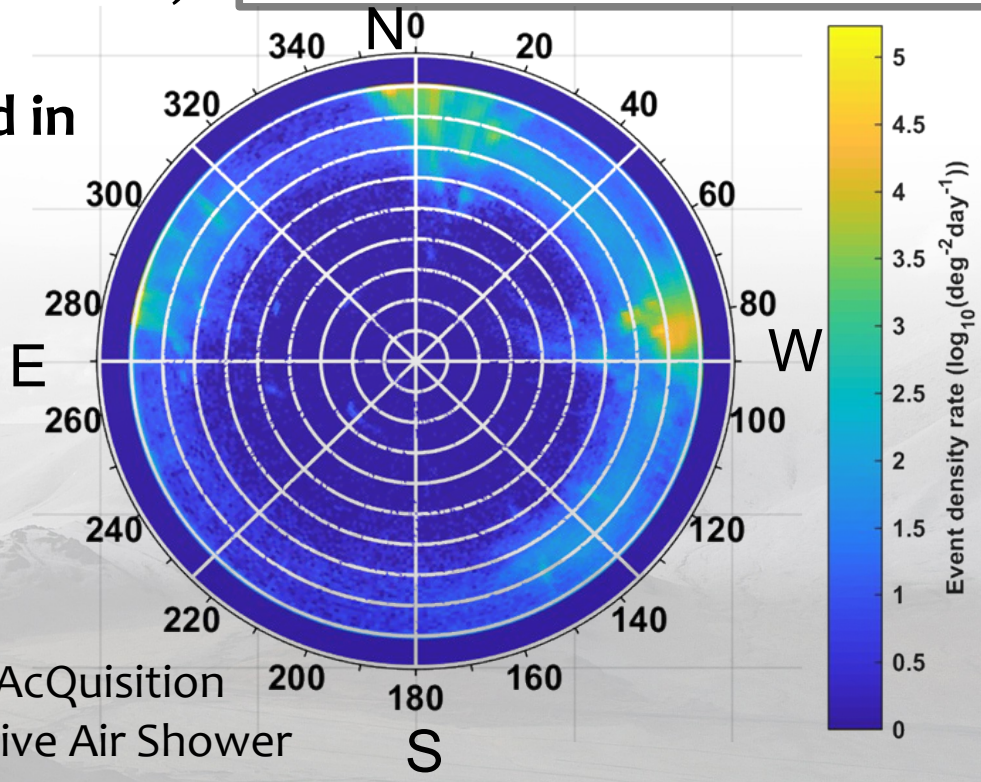
EW antenna orientation DAQ period (2011-2012) :

~7.10^8 events recorded in 314 DAQ days

(>5 antennas with signal over threshold in causal coincidence)



The 7.10^8 events angular distribution



DAQ= Data AcQuisition

EAS=Extensive Air Shower

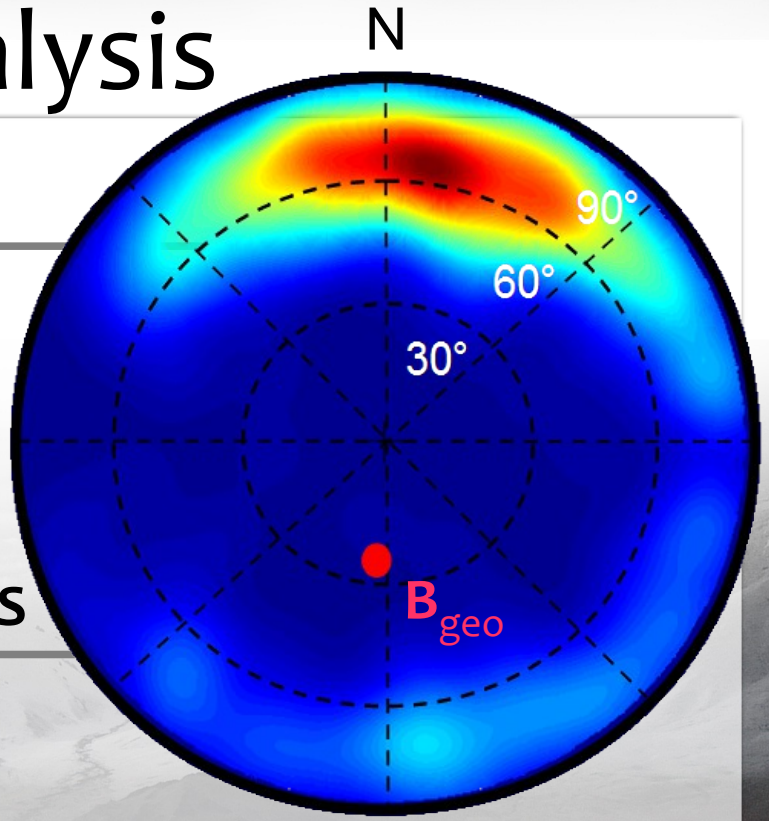
Offline bckg rejection cuts : (based on EAS radio signal expectations)

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

→ **from ~7.10^8 events to 564 EAS candidates**

→ background transient events ultra-dominant even at radio-quiet TREND site

TREND data analysis



The 564 EAS candidates angular distribution : overdensity of events at 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 detected by TREND ?

- How many EAS were actually expected ?

→ efficiency of TREND to detect EAS ?

DAQ= Data AcQuisition

→ Simulate air shower events and propagate them into TREND DAQ + offline analysis (« end-to-end » real time simulation)

TREND end-to-end simulation

- *simulation of EAS (random core & direction) with their radio electric field* using ZHAIRES

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

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

- *analysis of these files with standard TREND offline program*
number of simulated events selected within exp. data → computation of **effective surface** for each EAS θ,ϕ,E, and **aperture** (m^2.sr) as a function of E

TREND calibration

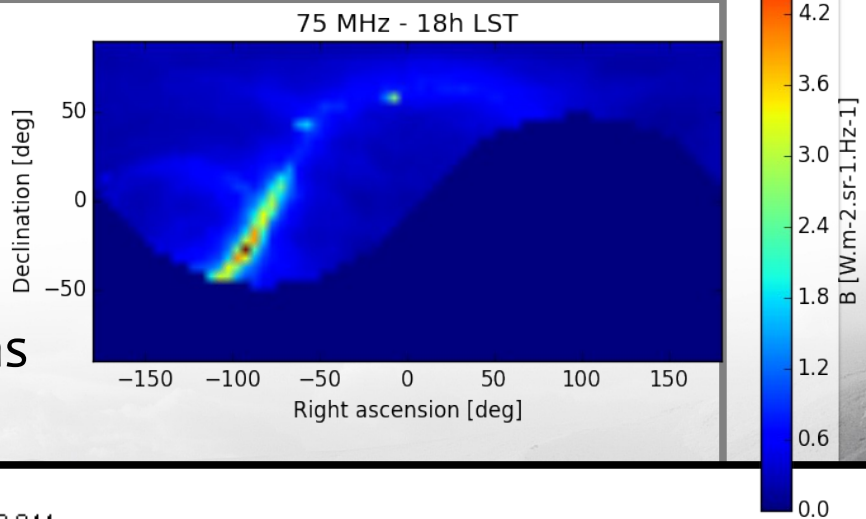
Computation of TREND electronic gain (antennas and time variations)

- **standard candle :** the galatic plane radio emission & ground contribution
- **antenna response** model to radio emissions

→ expected voltage at antenna output

- **recorded voltage** from noise level monitoring, each 20 min

→ elec. gain = recorded voltage / expected voltage at antenna output



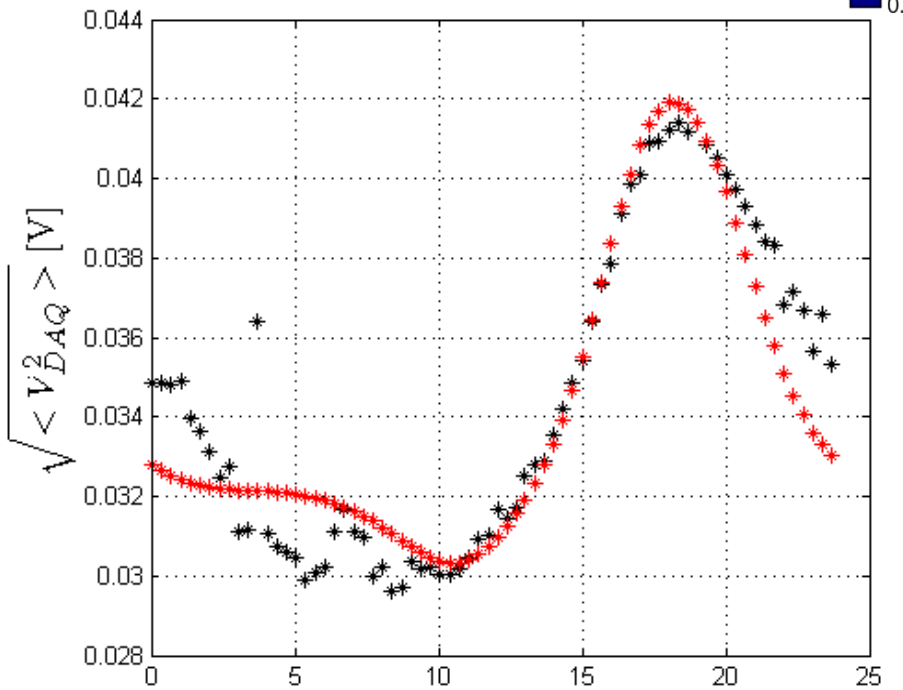
For purpose of illustration only :

1 gain value is adjusted to fit mean recorded voltage on 1 day for 1 ant.

→ peak to peak match &

| **model** - **data** | < 10%

→ model is valid



TREND end-to-end simulation

Exp. data subset (with calilb. available) :

- August 6th 2011 to December 6th 2012
- 251 DAQ days
- Nselected real events = 408

DAQ= Data AcQuisition
EAS=Extensive Air Shower

Simulation set :

- proton and iron EAS
- [5e16, 8e16, 1e17, 2e17, 3e17, 5e17, 7e17, 1e18, 3e18] eV

(up to ~10 K simulated EAS per energy per primary)

- Nselected simulated events leads to effective surface :

$$S_{eff}(\theta,\varphi,E) = S_{draw}(\theta,\varphi,E)\frac{N_{sel}(\theta,\varphi,E)}{N_{draw}(\theta,\varphi,E)}$$

TREND expected events

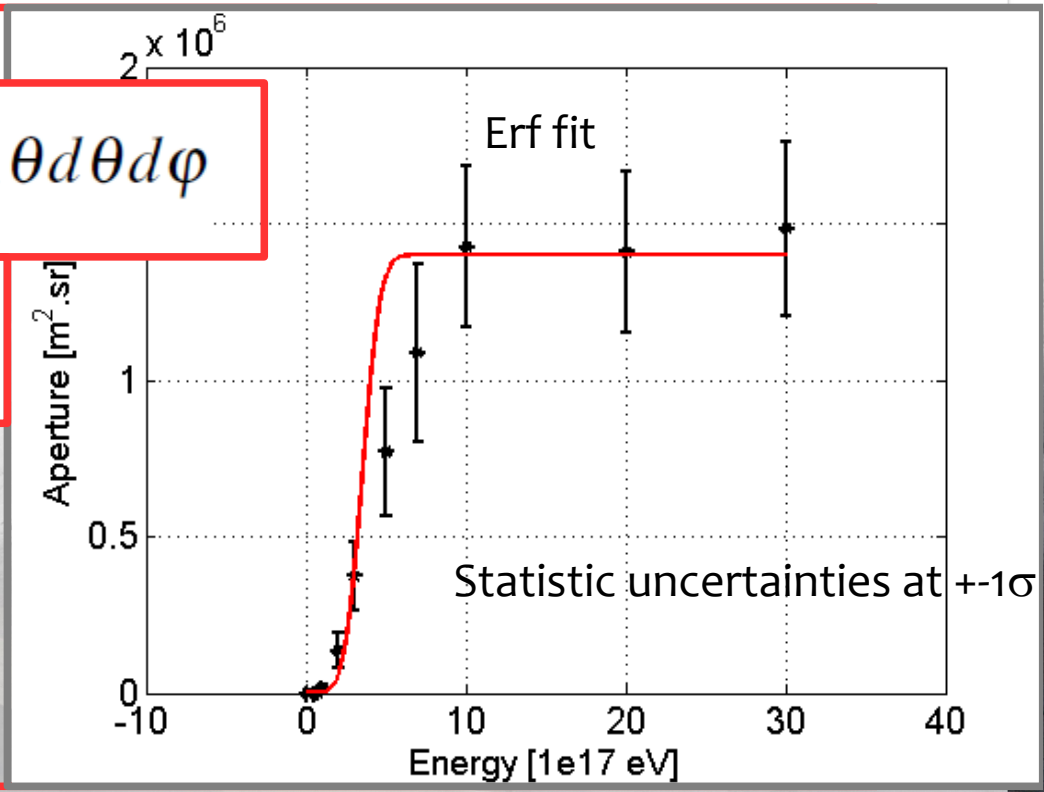
Aperture of TREND :

$$Ap(E) = \int_{2\pi} S_{eff}(\theta, \varphi, E) \cos\theta \sin\theta d\theta d\varphi$$

$$N_{expected} = \int_{\Delta E} Ap(E) F(E) dE \Delta t$$

F(E) = cosmic ray flux [/GeV/m²/sr/s]

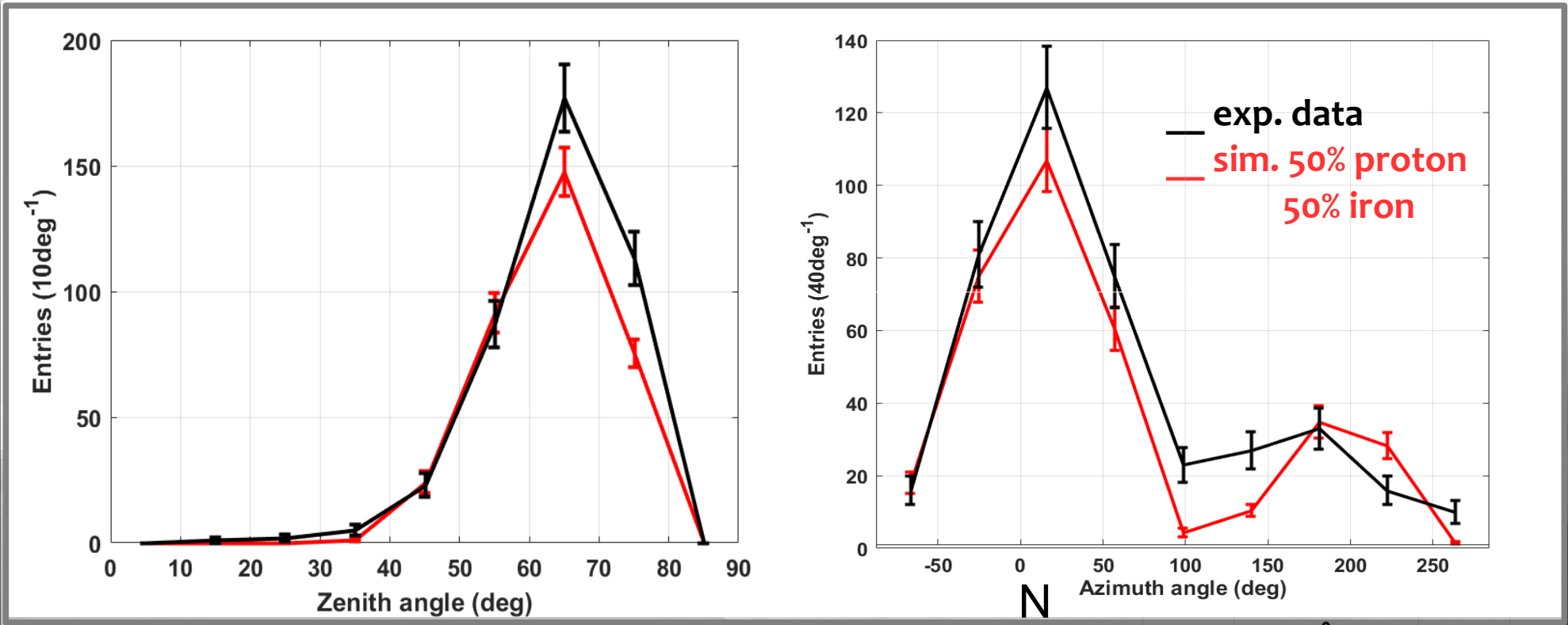
Expected number of events for
251 DAQ days = 340



Effective number of events in the 251 DAQ days exp. data subset = 408

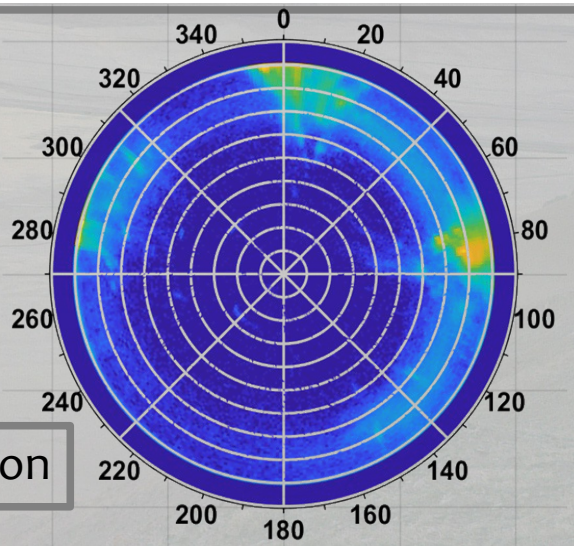
340 and 408 compatible (Δ=20%)
→ satisfying modelisation of EAS radio emission + TREND response

TREND expected events



Angles distributions for selected events

- Partial agreement between **exp. data** and **simulation** distributions shows that TREND has indeed detected air shower events
- Excess in **exp. data** indicates noise contamination of ~20%



exp. data before selection

TREND efficiency

(for protons EAS)

Simulated events

Random (θ,φ)
Random core position
Random t

5+ antenna triggers

«ideal» detector: Antenna+DAQ live time = 100%

Expected nb of events: 12106

DAQ time: 251 days

Instantaneous antenna + DAQ status

ε_{det} ~ 10%

ε_{tot} ~ 3%

«ideal» selection: 100% EAS pass cuts

Expected nb of events: 1182

Offline EAS selection

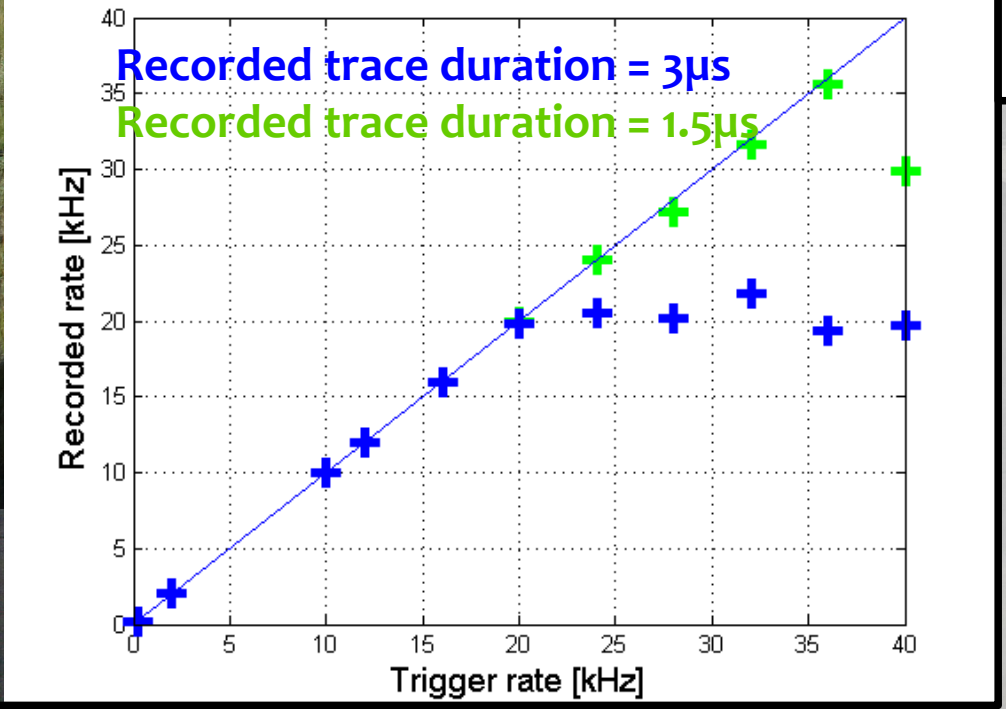
ε_{sel} ~ 30%

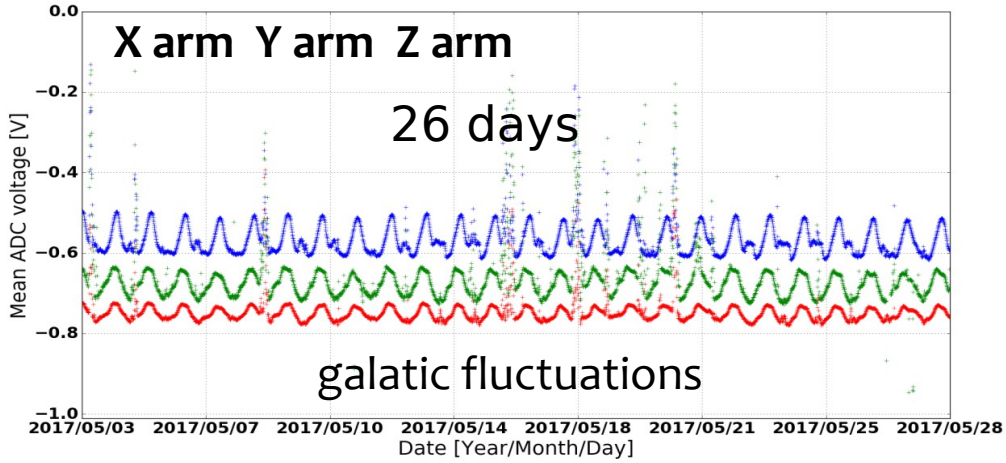
TREND EAS selection

Expected nb of events: 355

GRANDproto35

35 antennas 24 scintillators





Improved antenna :

- 3 arms for better bckg rejection

Improved DAQ unit : (prod. at LPNHE thanks to contract with NAOC CAS)

- trigger rate up to 20kHz per antenna
- stable baseline

Scintillators for EAS selection crosscheck

IHEP lead

Conclusion and 'to do'

Conclusion

- TREND system well understood
- Autonomous radio detection of EAS goal reached
- Detector efficiency 10% and selection efficiency 30%
- Noise contamination ~20%
- Promising for future neutrinos experiments such as GRAND
- GRANDproto35 is in TREND continuation and a GRAND pathfinder

To do

- Submit a publication on the TREND analysis results
- Considering relocation for GRANDproto35

Keep smiling

Stuck at the police station near Ulastaï in XinJiang