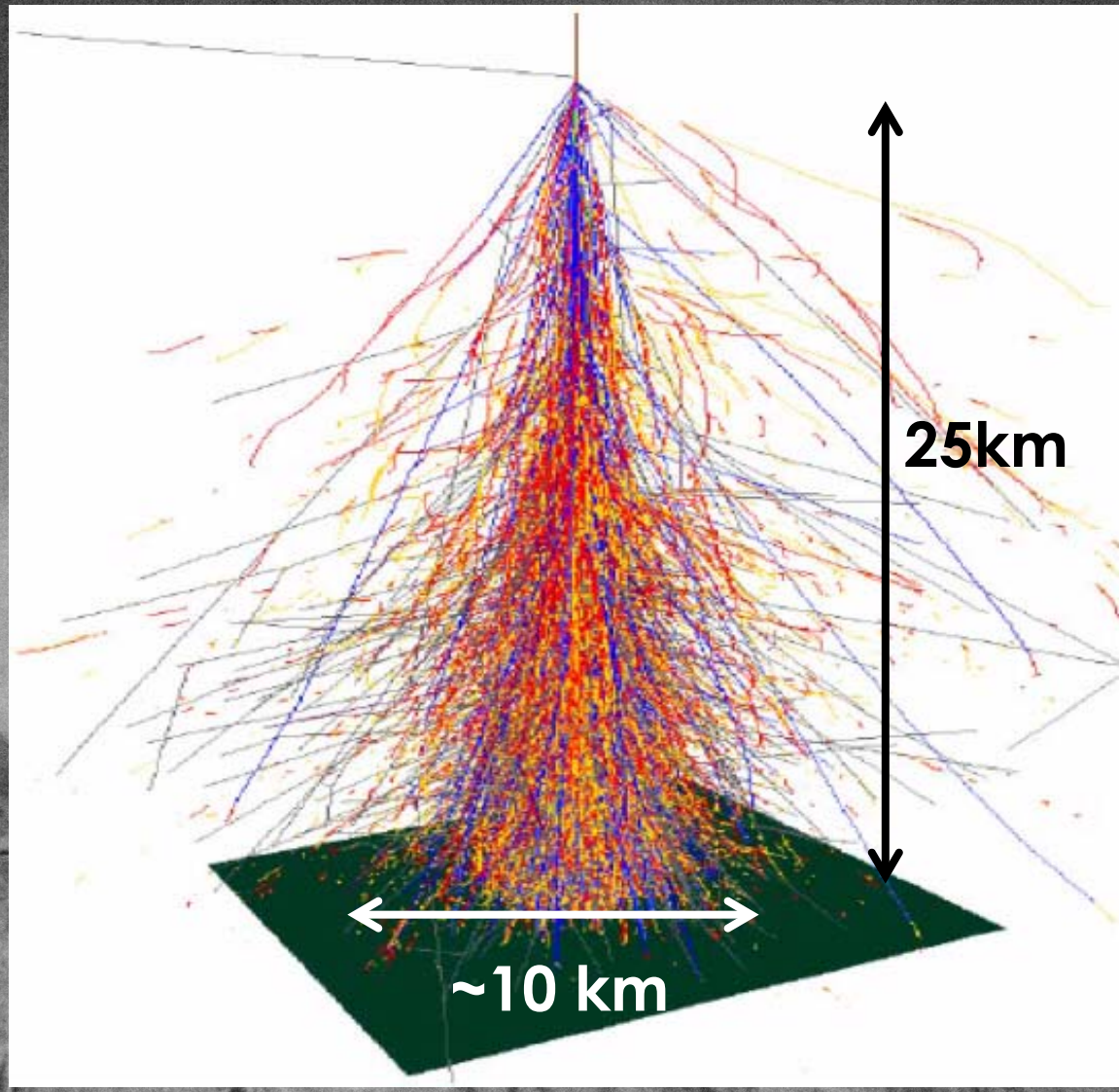

The
Tianshan
Radio
Experiment for
Neutrino
Detection
a Sino-French project for the radio-detection
of ultra high energy cosmic particles.

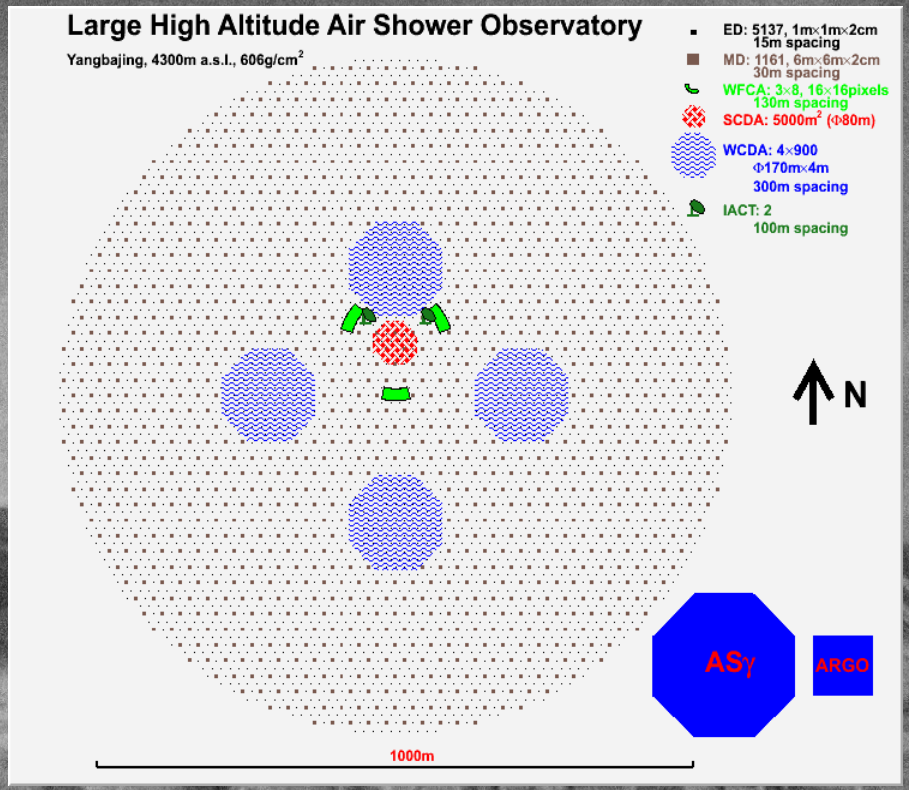
Cosmic particles of Ultra High Energy

- **UHE:**
  energy > 10^{13} eV
- **Topics: violent phenomena in the Universe, UHE particles production & propagation, Cosmology, tests of Theory of Relativity…**
- **A century-old topic… but still a lot to be learned!**
- **Experimental challenge : low flux & indirect measurement.**



UHE particles: messengers of a Violent Universe

- **Gamma rays: field now reaching maturity (H.E.S.S., MAGIC, CTA, LHAASO)**



UHE particles: messengers of a Violent Universe

- **Gamma rays: field now reaching maturity (H.E.S.S., MAGIC, CTA, LHAASO)**
- **Cosmic rays: recent experimental progress (AUGER) but still a lot to figure out… (in particular, what are the sources?)**

AUGER (3000 km²)

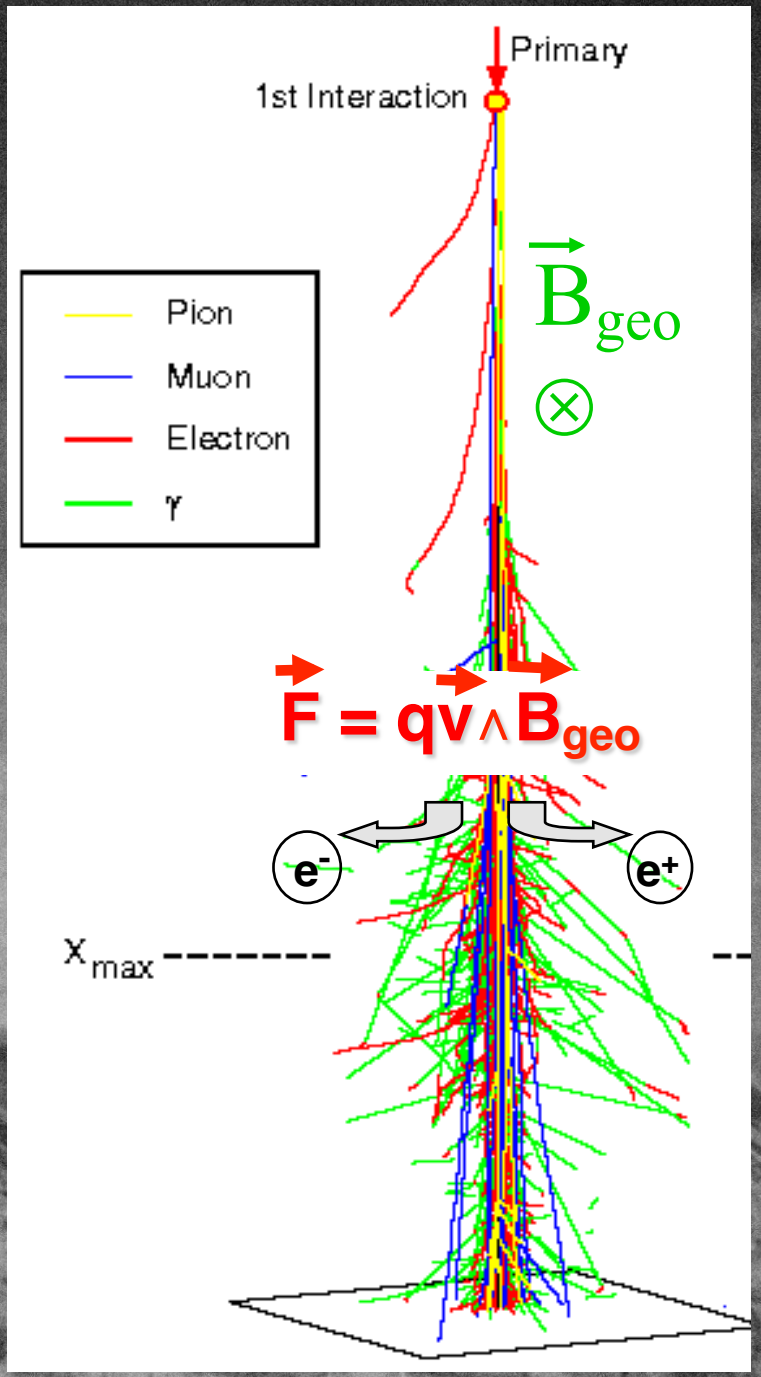
UHE particles: messengers of a Violent Universe

- Gamma rays: field now reaching maturity (H.E.S.S., MAGIC, CTA, LHAASO)
- Cosmic rays: recent experimental progress (AUGER) but still a lot to figure out… (in particular, what are the sources?)
- Neutrinos: very clean messengers (no energy loss & no deflection) but very chalenging detection! No success yet.

Radio detection of UHE cosmic particles

- **UHE cosmic particles generate Extensive Air Showers in the atmosphere.**
- **Lorentz force on charged particles in the EAS by the Earth magnetic field (Kahn & Lerche, 1965): electromagnetic emission (geosynchrotron)**
- **Coherent effect**

➡ **detectable radio emission**



EAS Radio-detection strong points

- **Measurement of EAS direction of origin, energy, nature of primary**
- **Easiness of deployment & cost!**

15k€/unit
3 tons

AUGER

<1k€/unit (?)
<10kg (?)

Radio prototype

Very well adapated to the giant arrays requested for UHE particle detection!

Radio detection of EAS: promising BUT… not mature yet!

- **Only 2 established setups (France & Germany)**
  - **<30 antennas: low stat (1000 showers at most)**
  - **Slave-triggered to standards EAS detectors**

Still a long way ahead!!!

Full understanding of EAS radio signal ?

Self-triggering?

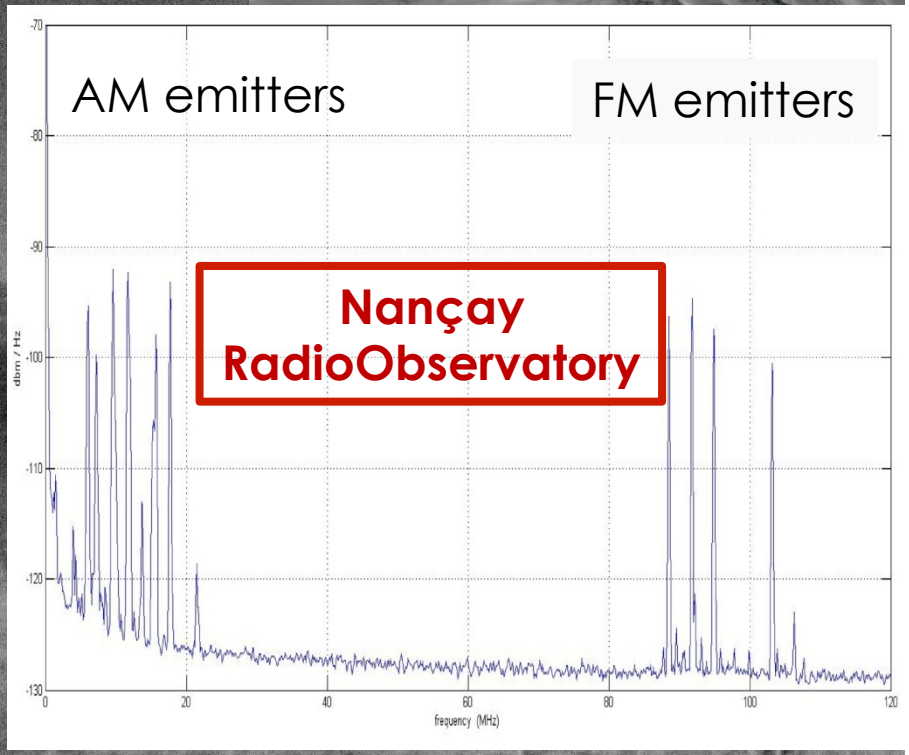
The TREND project aims at providing answers!

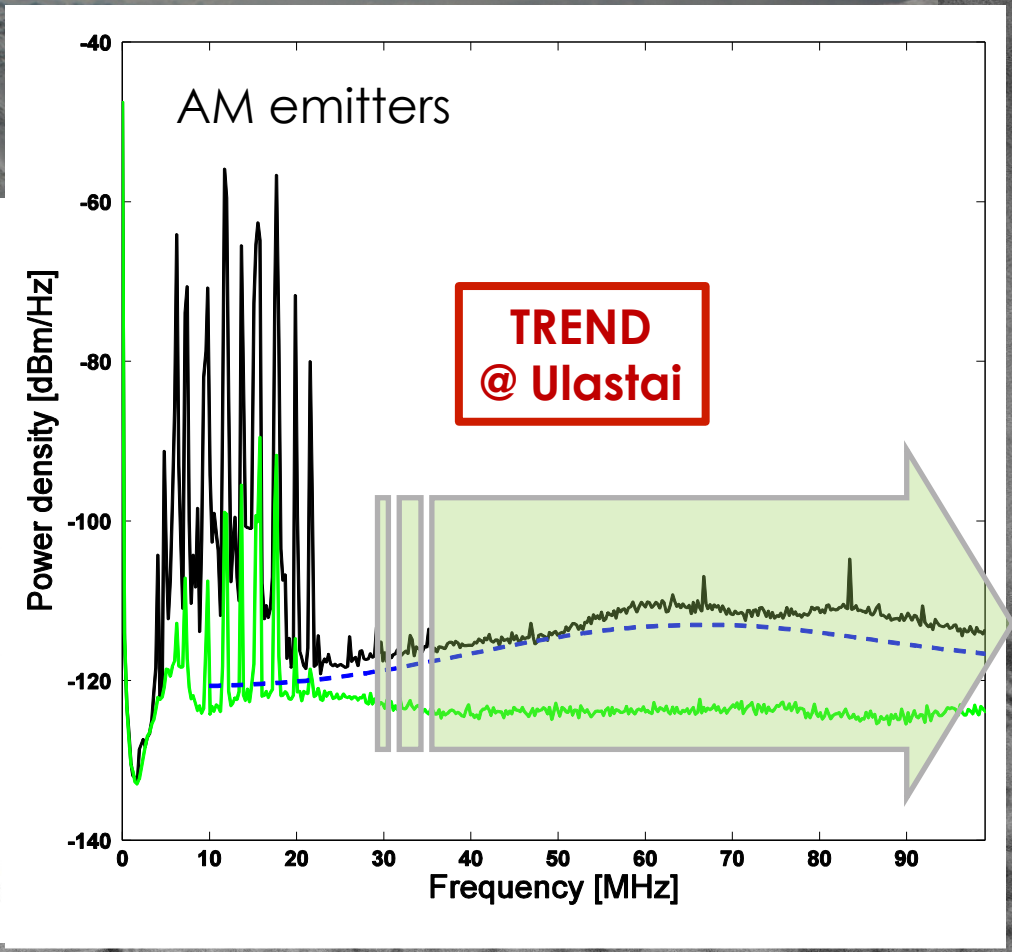
The TREND collaboration

- **China: CAS**
  - **NAOC: Pr. WU XiangPing, Dr. DENG JianRong, Dr. ZHANg Jianli, Dr. GU JunHua, …**
  - **IHEP: Pr. HU HongBo, Pr. LIU Zhen'An, …**
- **France: CNRS-IN2P3**
  - **LPNHE: Dr. Olivier Martineau-Huynh**
  - **SUBATECH: Pr. Pascal Lautridou, Dr. Olivier Ravel, …**
  - **LPC: Dr. Valentin Niess**
  - **Dr Thomas Saugrin (CAS fellow)**

Tianshan Radio Experiment Neutrino Experiment @ Ulastai, XinJiang

Very clean radio environnement above 20MHz.





The 21cm array

a radio-interferometer for the study of the Epoch of Reionization (Wu XiangPing, NAOC)

Ulastai, October 2004

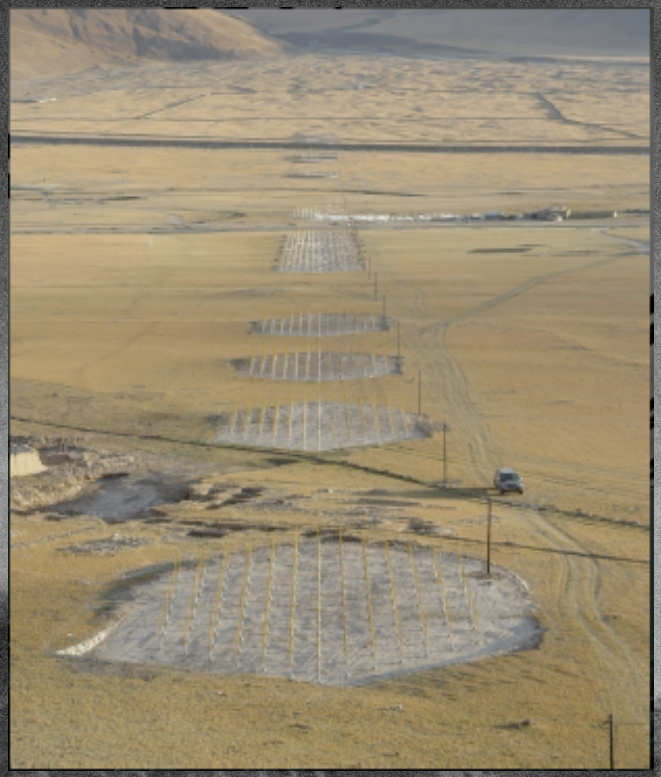
The 21cm array

a radio-interferometer for the study of the Epoch of Reionization (Wu XiangPing, NAOC)

North

4 km

South



127 log periodical antennas
x
80 pods
along
2 baselines

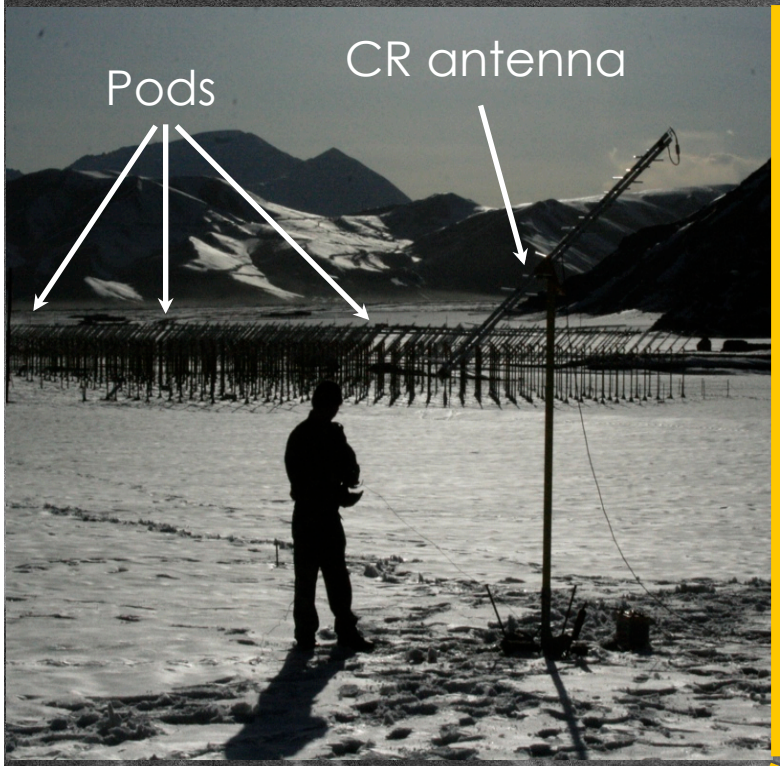
West

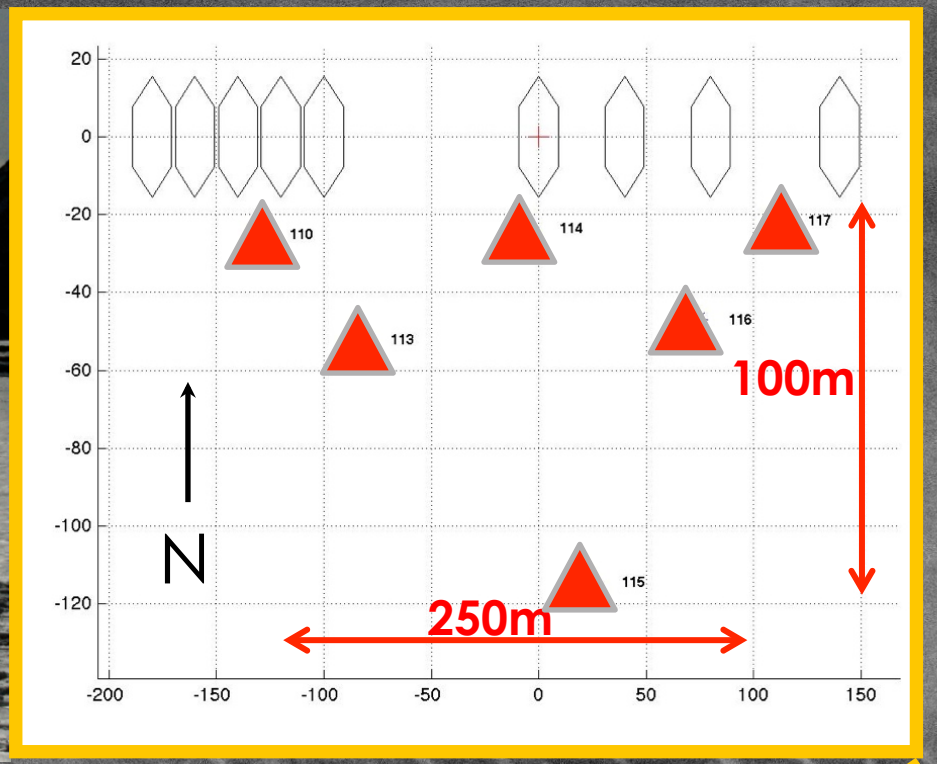
East

DAQ

3 km

2009: 6-antennas prototype





N

W

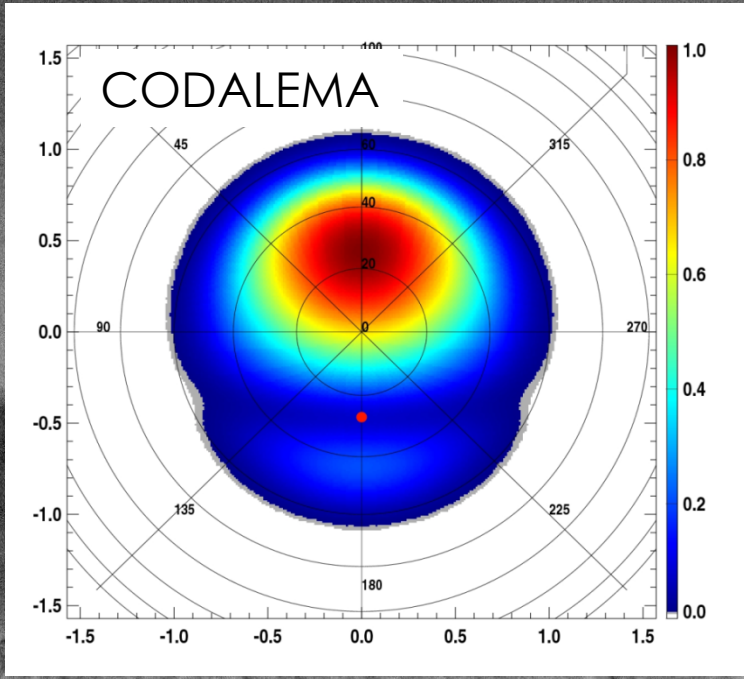
E

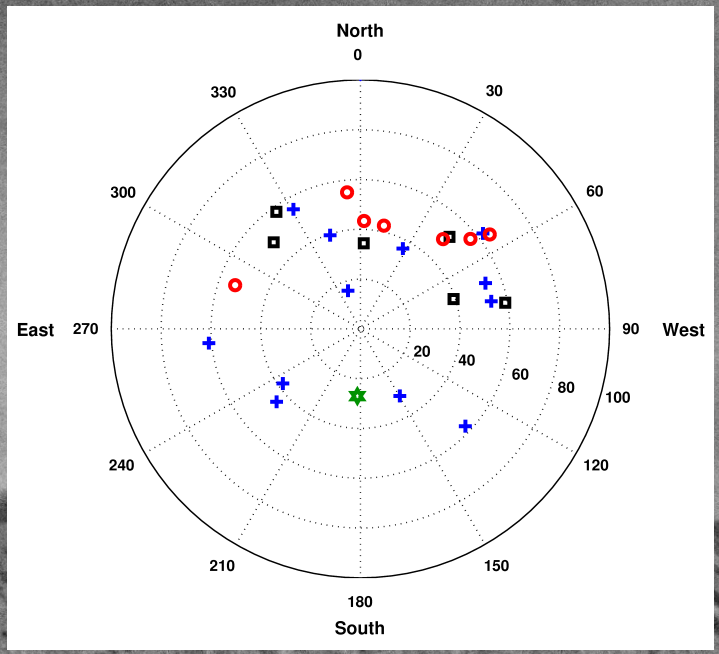
S

DAQ

2009: 6-antenna prototype

- Autonomous trigger
- Algorithm for direction reconstruction & background rejection

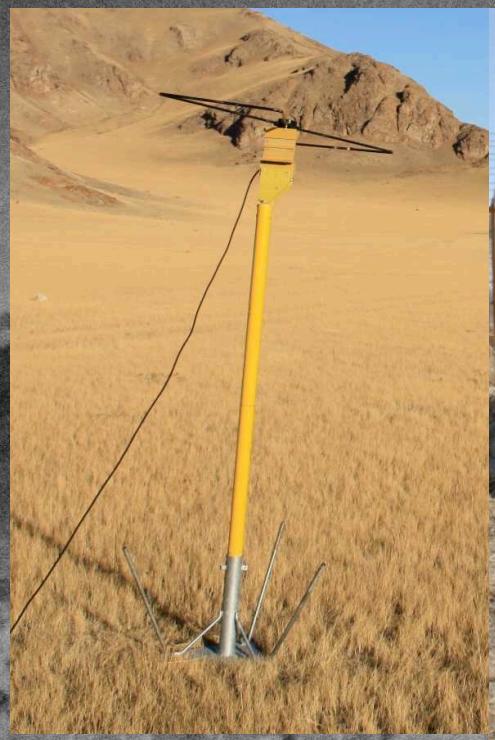


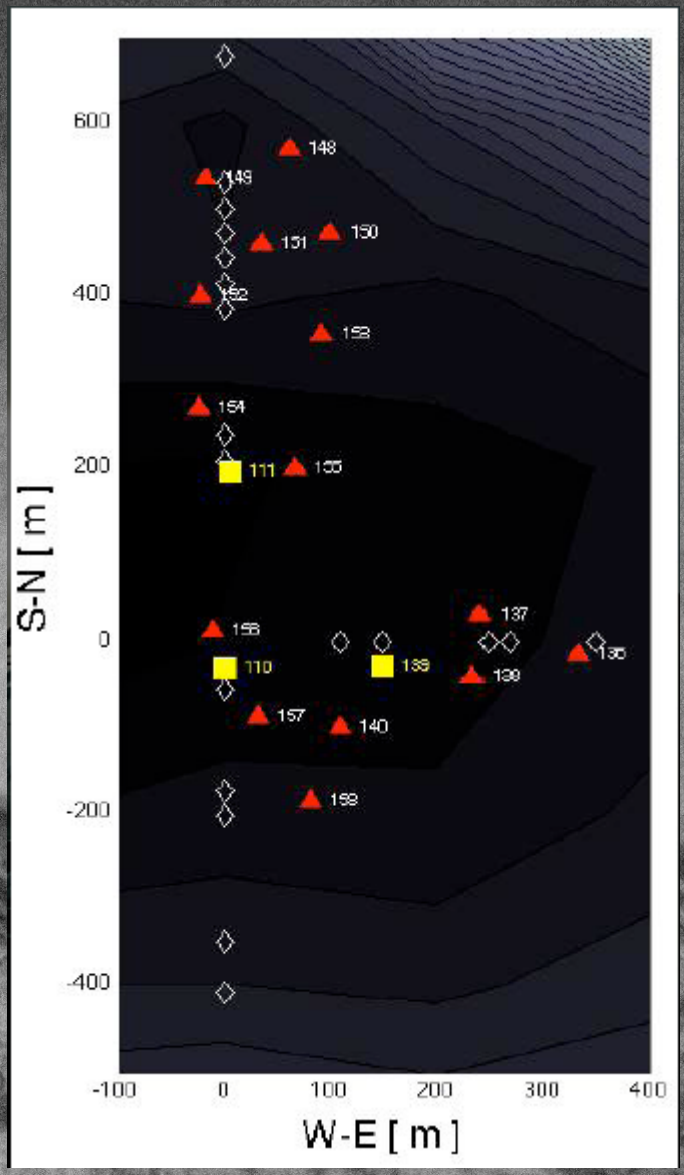


25 EAS candidates isolated in 24-live days of data.
Sky distribution similar to CODALEMA results.

2010: 15-antennas prototype

- **15 antennas (butterfly type)**
- **3 scintillators (EAS detector)**





2010: 15-antennas prototype

- **Independent analysis of radio & scintillator data.**
  - **Antennas: EAS identification through selection algorithm**
  - **Scintillators: 3-fold coincidences are EAS**
- ***A posteriori* comparison: 6 coincident events in 27 live days (+7 with 2 scints), all with consistent reconstruction.**

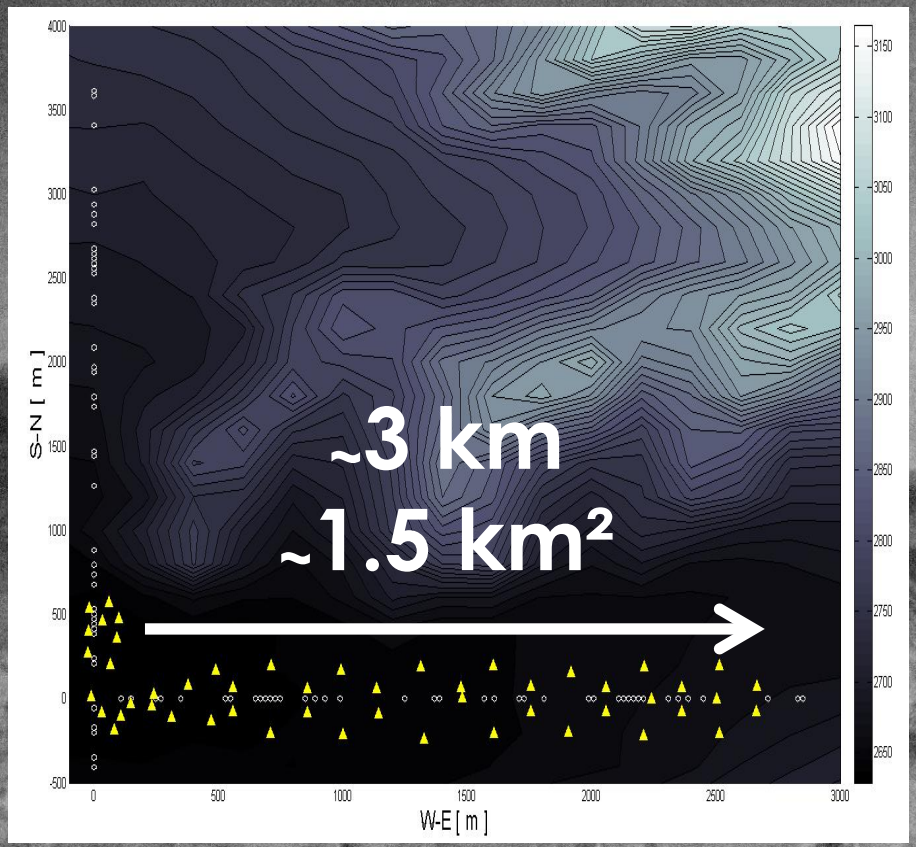
Date	θ_{Rad}	θ_{Scint}	ϕ_{Rad}	ϕ_{Scint}
03/04/10	61±3	67±5	359±2	3±4
19/04/10	55±1	47±3	194±2	188±5
23/08/10	42±1	36±3	56±4	55±5
27/08/10	30±1	19±3	318±3	332±8
01/03/11	45±1	49±3	12±1	10±5
09/03/11	56±2	53±5	323±2	331±3

1st autonomous identification of EAS.

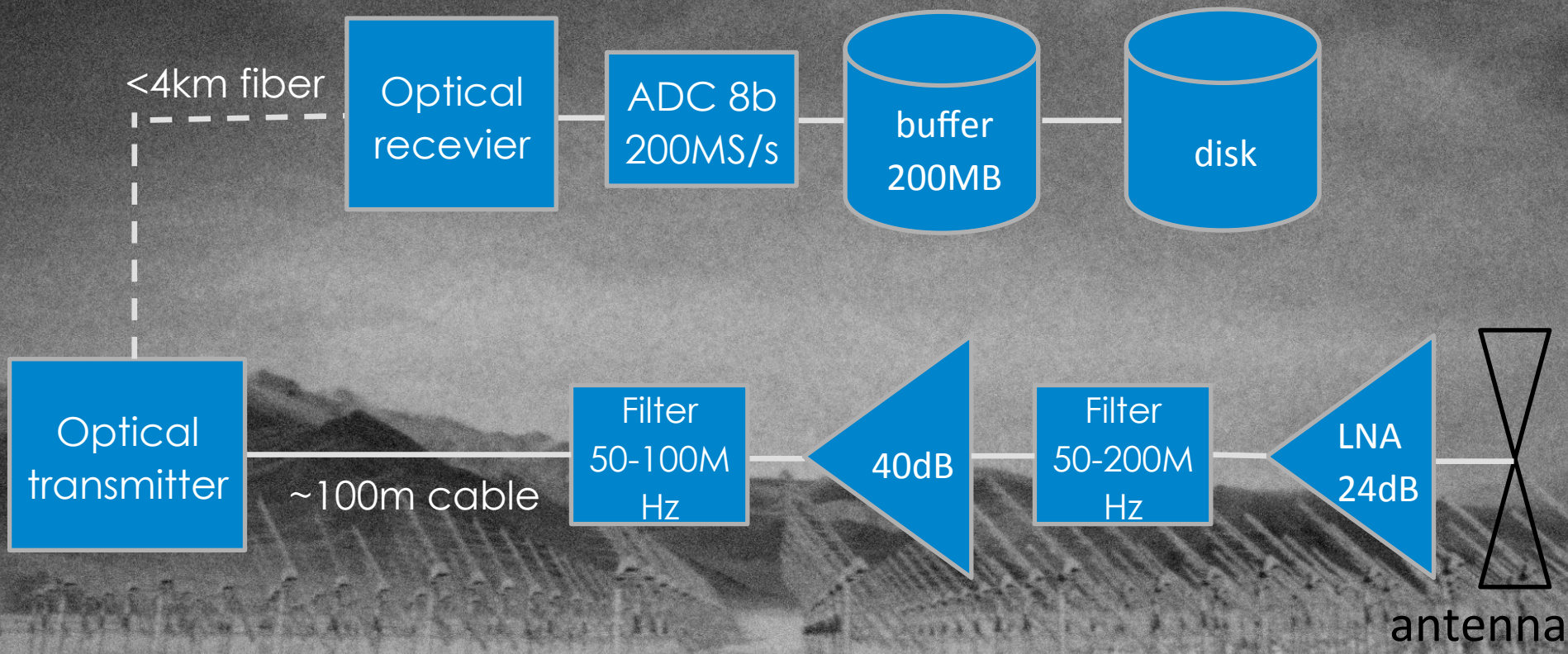
D. Ardouin et al., Astropart. Phys 24 (2011), arXiv:1007.4359

The TREND setup

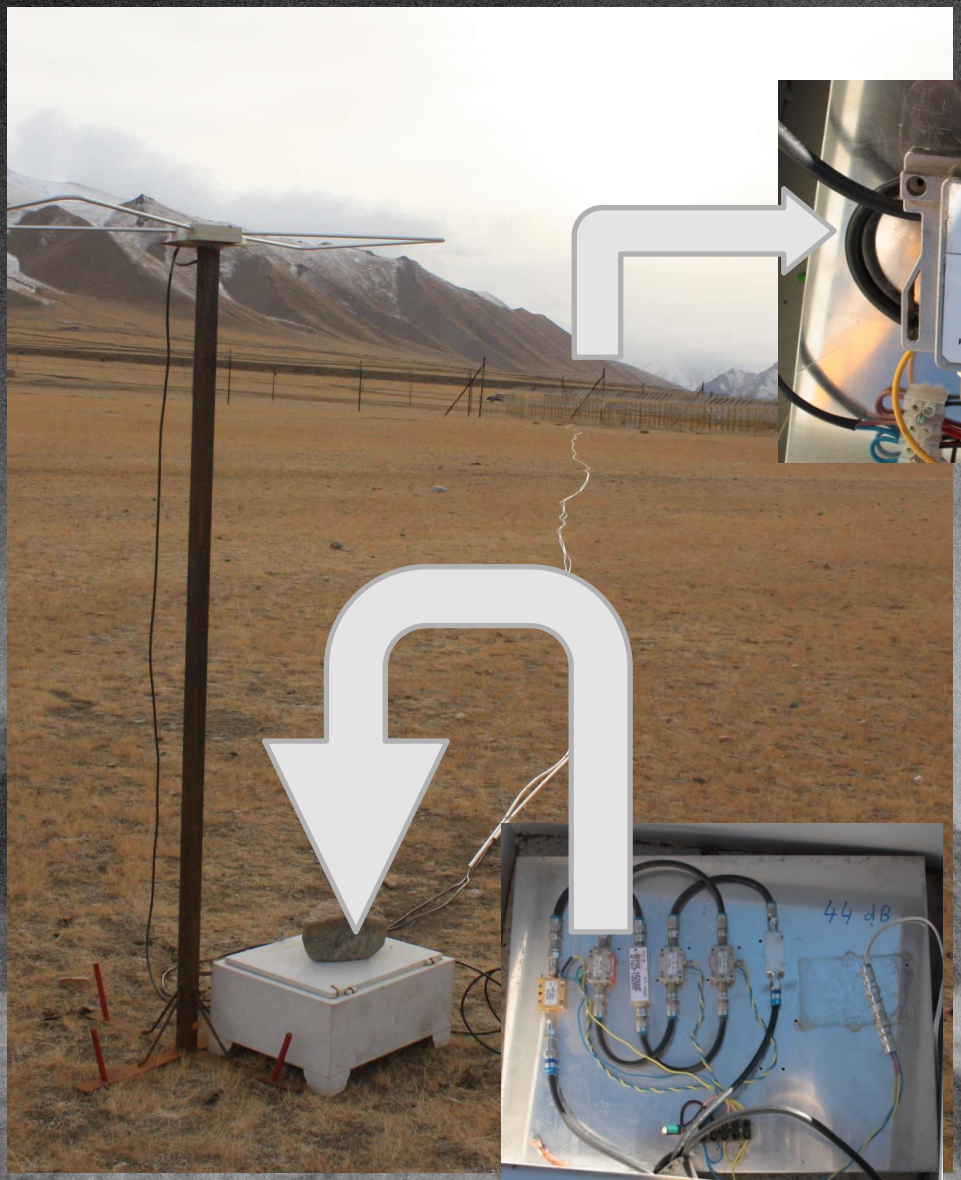
- **50 antennas deployed in summer+autumn 2010, stable operation since March 2011.**
- **Largest EAS radio-array in the world.**



TREND acquisition chain



TREND acquisition chain



fiber to the DAQ room (<4km)

TREND EAS search

- **Discrimination of EAS from RF background**

CR signals

- ~ short/symmetrical/isolated pulses
- ~ random time & direction of arrivals
- ~ ~plane wave front from sky
- ~ exponential decrease for lateral amplitude profile

Background signals

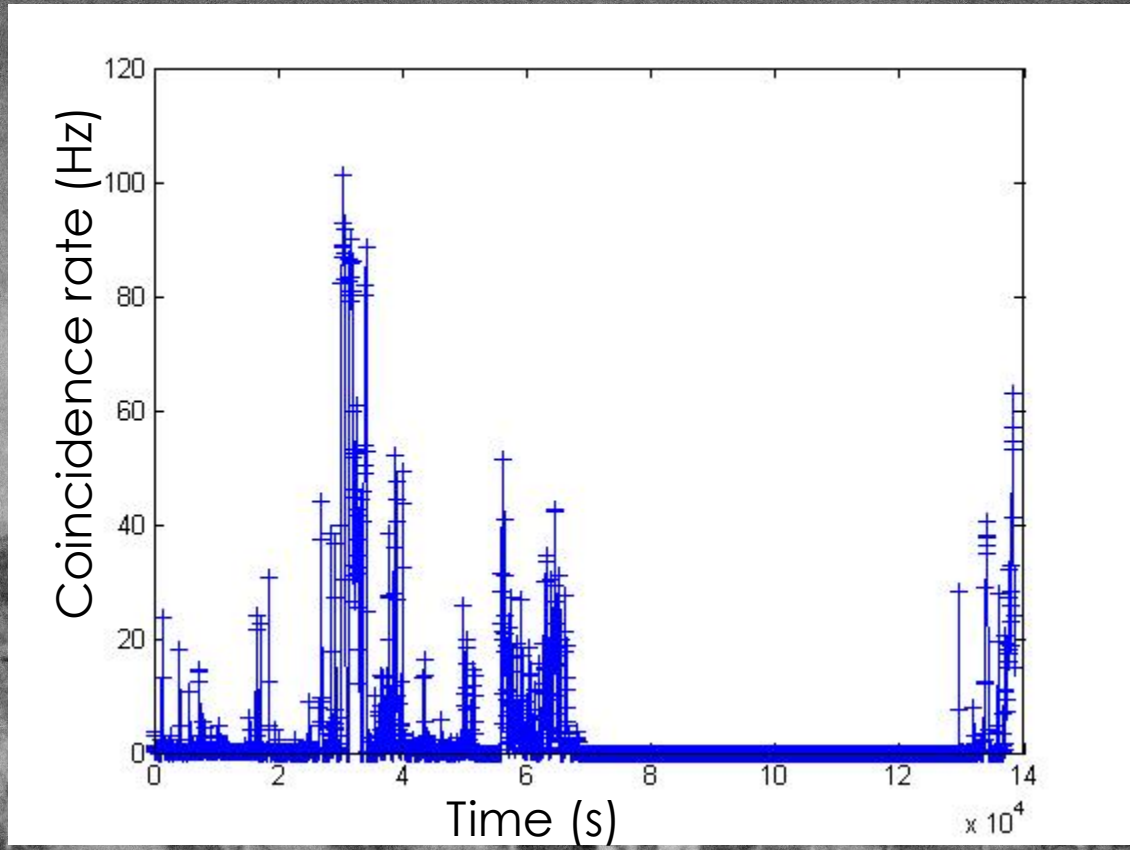
- ~ in general, longer & repetitive pulses
- ~ in general, localized sources or tracks
- ~ spherical wave front from ground
- ~ 1/distance decrease for lateral amplitude profile

DATA PRE PROCESSING : STAGE 1

- Informations on run set-up (antennas, positions, delays….)
- **Rejection of « empty » events** (bug DAQ, corrected 02/2012).
- Identification of coincidences between antennas.

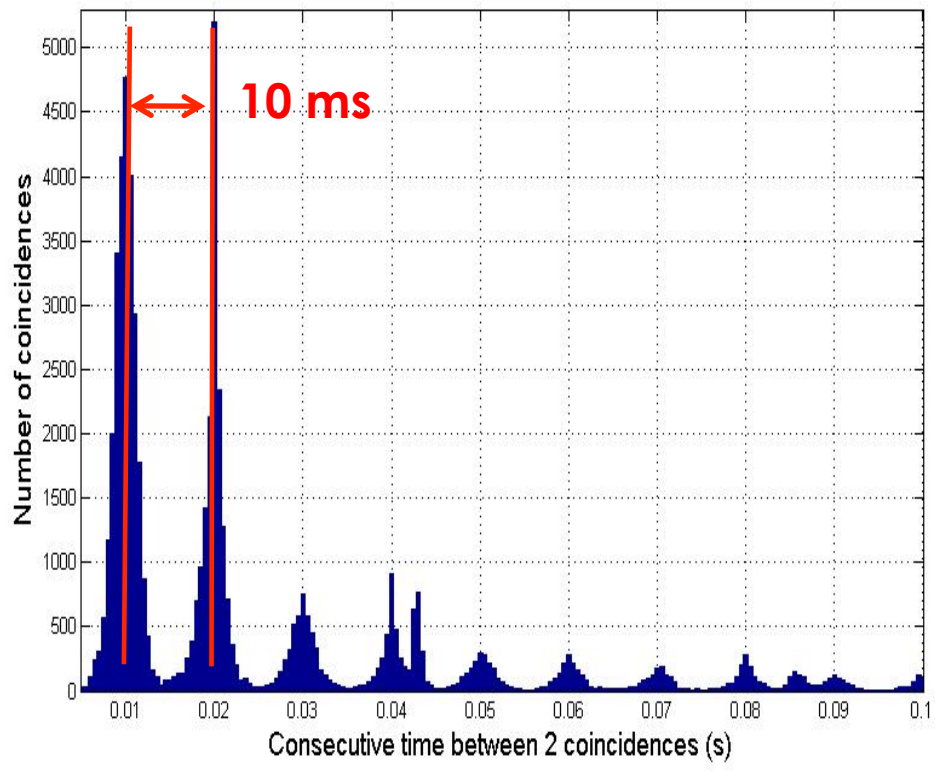
Example of run 3577

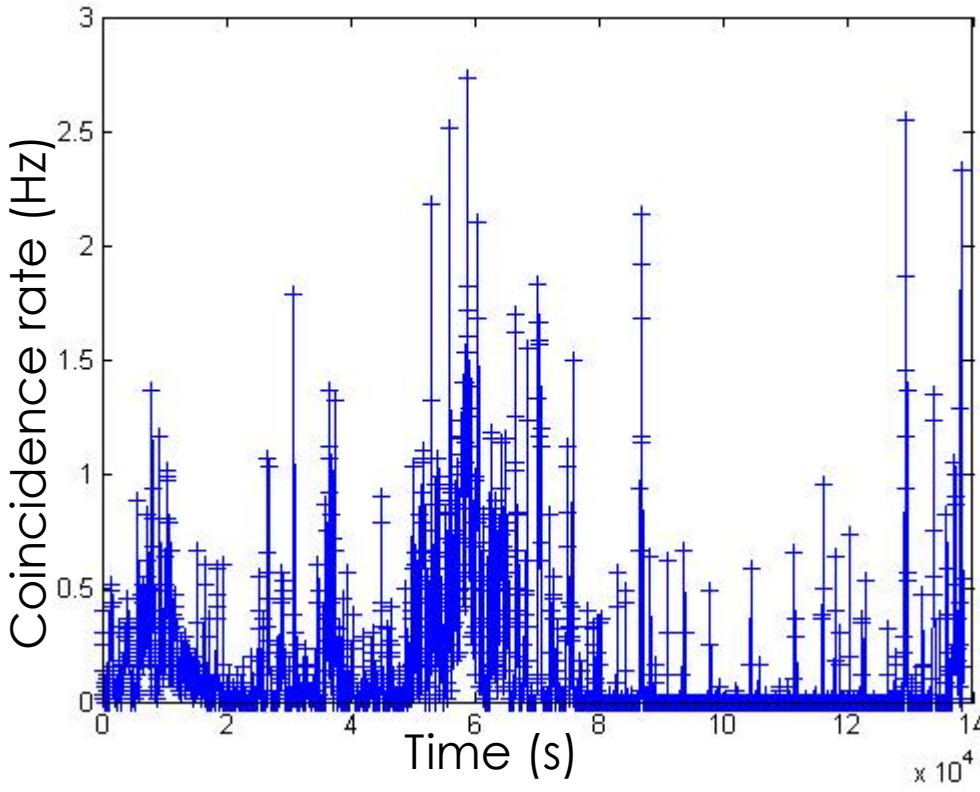
- 49 antennas
- Total duration: ~38h30
- Number of events: 4.452.938
- Number of coincs: 633.918



DATA PRE PROCESSING : STAGE 2

- **Rejection of events with Δt consecutive = n.10 ms**
- Main source of pollution: **power line**
- On run 3577: 67.406 coincidences remaining (**89% rejection**)
- Influence on acceptance?
  (mainly cross-point events, estimated dead-time ~10%)





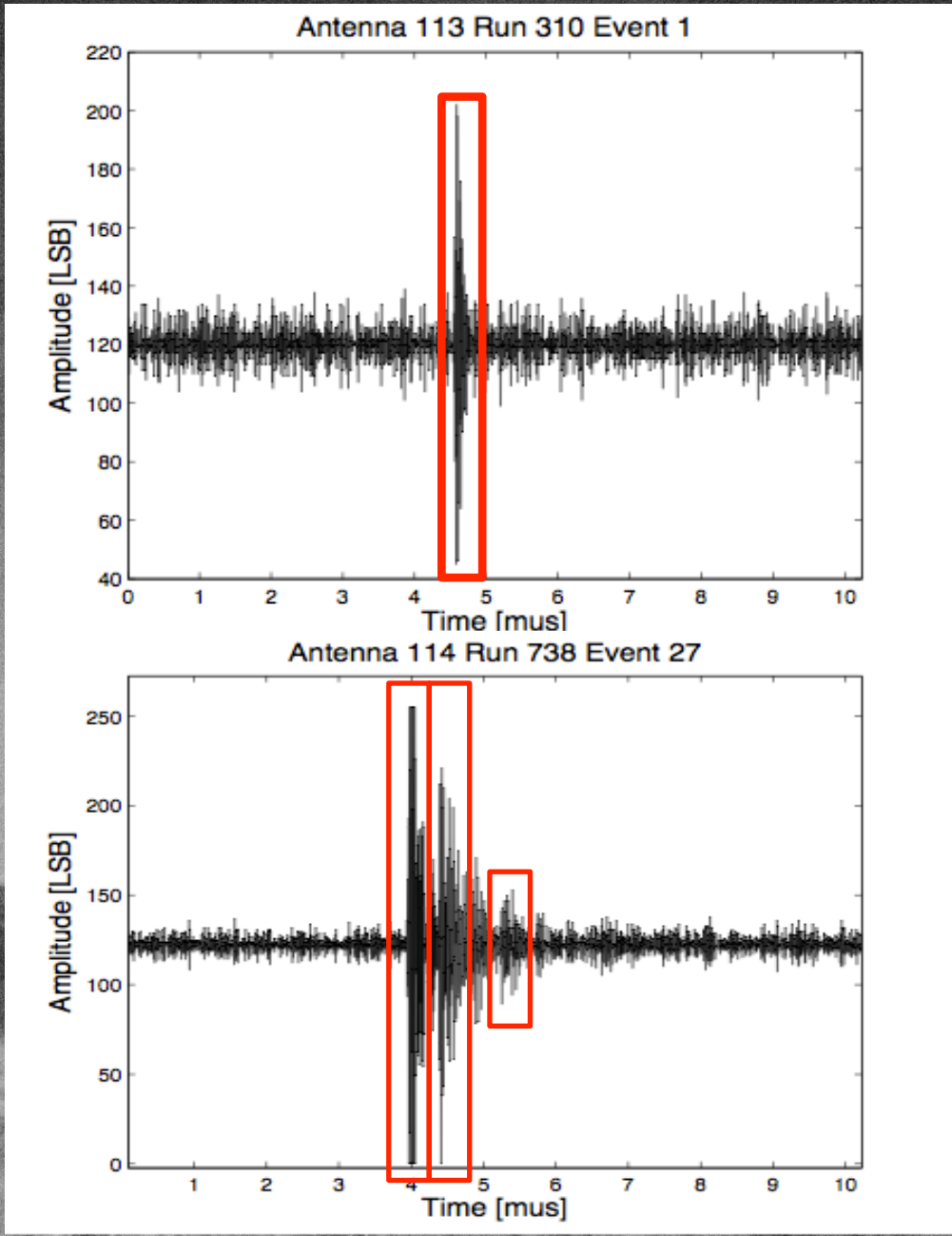
DATA PRE PROCESSING : STAGE 2

- Signal waveform analysis:

Create « **boxes** » around parts of the signal over the threshold

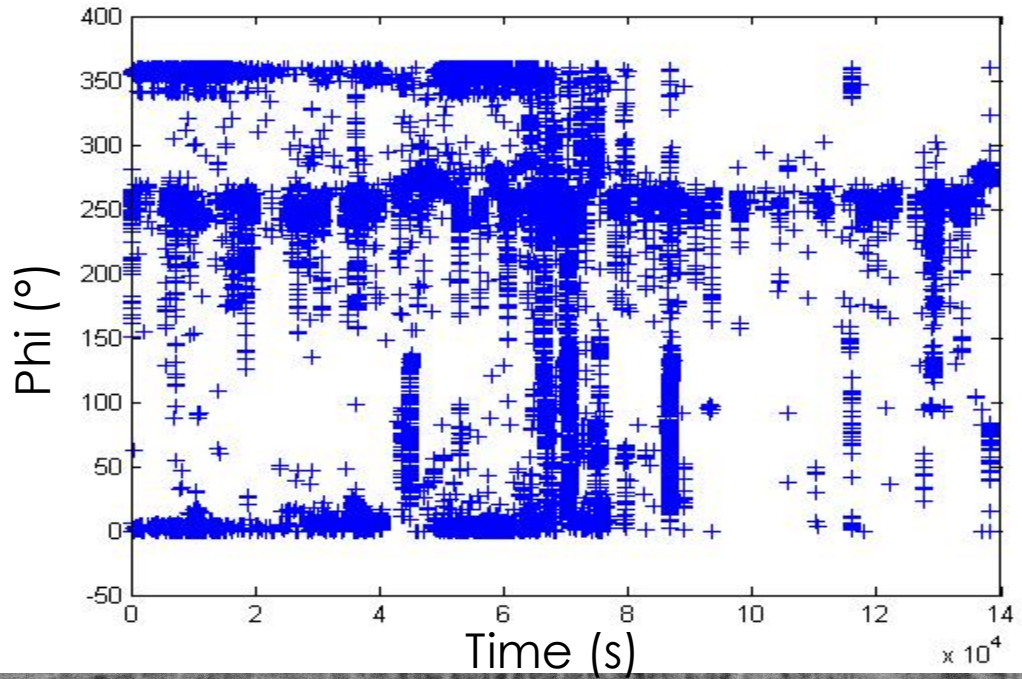
- Total ToT
- Number of boxes
- Boxes ToT
- Pre-trigger ToT
- Central box (at expected trigger time)
- …

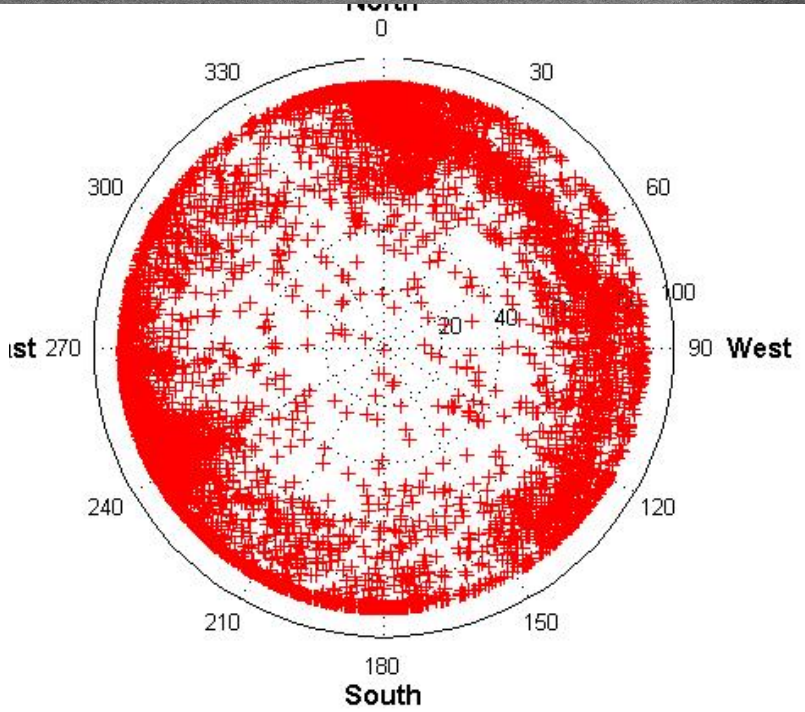
Informations available for signal rejection in stage 3



DATA PRE PROCESSING : STAGE 3

- **Rejection of « bad » signals** -> coincidences with mult<4 also rejected
- For run 3577, 22.244 remaining coincidences (**66% rejection**)
- For all remaining coincidences, reconstruction of arrival direction
- + For «shower candidates » (for now, events with θ <65°), shower profile reconstruction

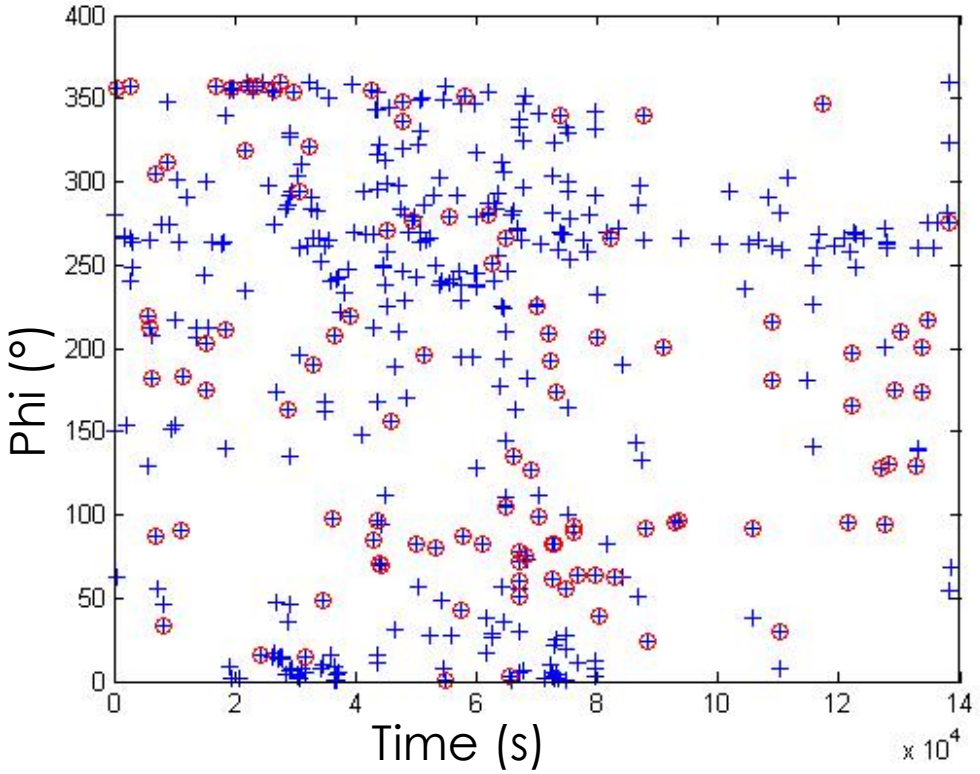


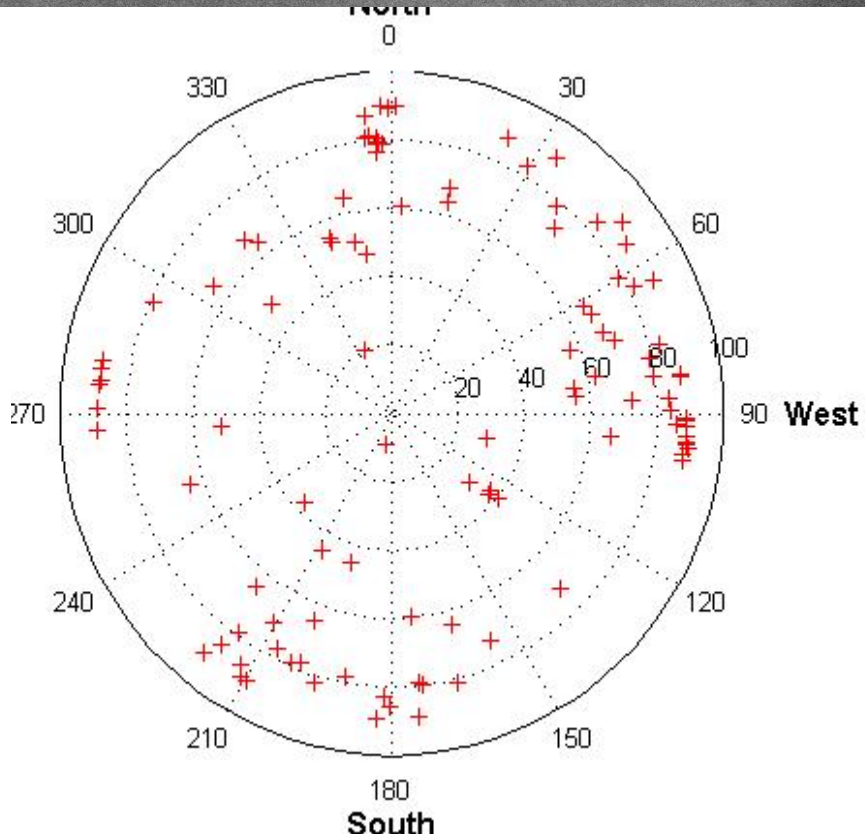


DATA ANALYSIS

- Rejection of coincidences with **inconsistent ground pattern**
- Rejection of coincidences with **bad direction reconstruction**
- **Track** identification ($\Delta\theta / \Delta\phi < 10°$, $\Delta t < 1m$) and rejection
- For run 3577, 432 remaining coincidences (**98% rejection**)
- Rejection on **plane wavefront criteria**

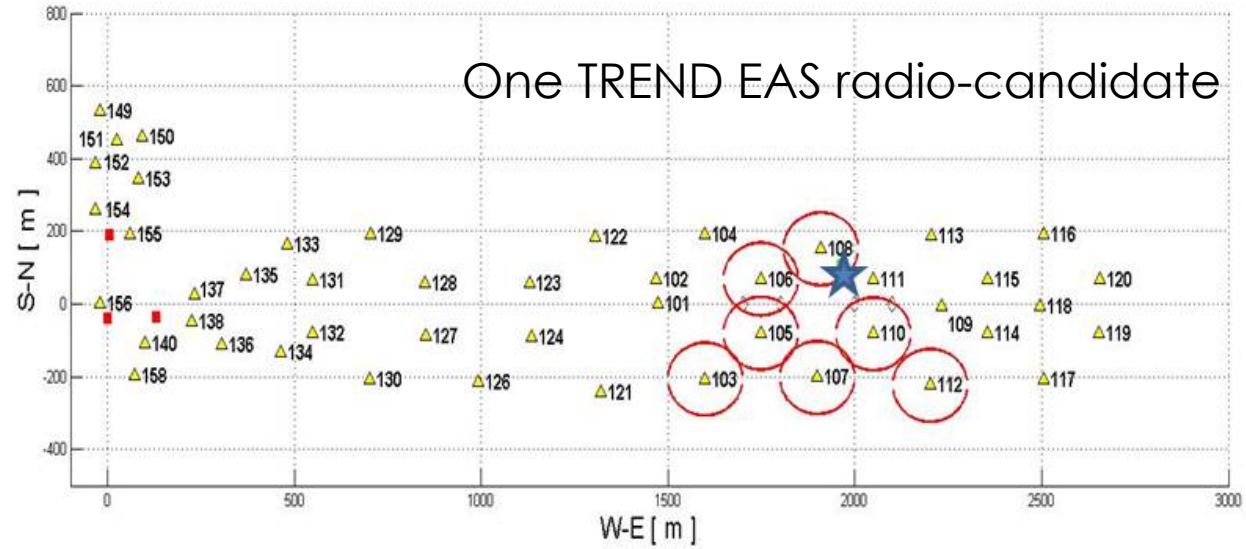
105 coincidences remaining, 3 with mult>4 and θ <65°

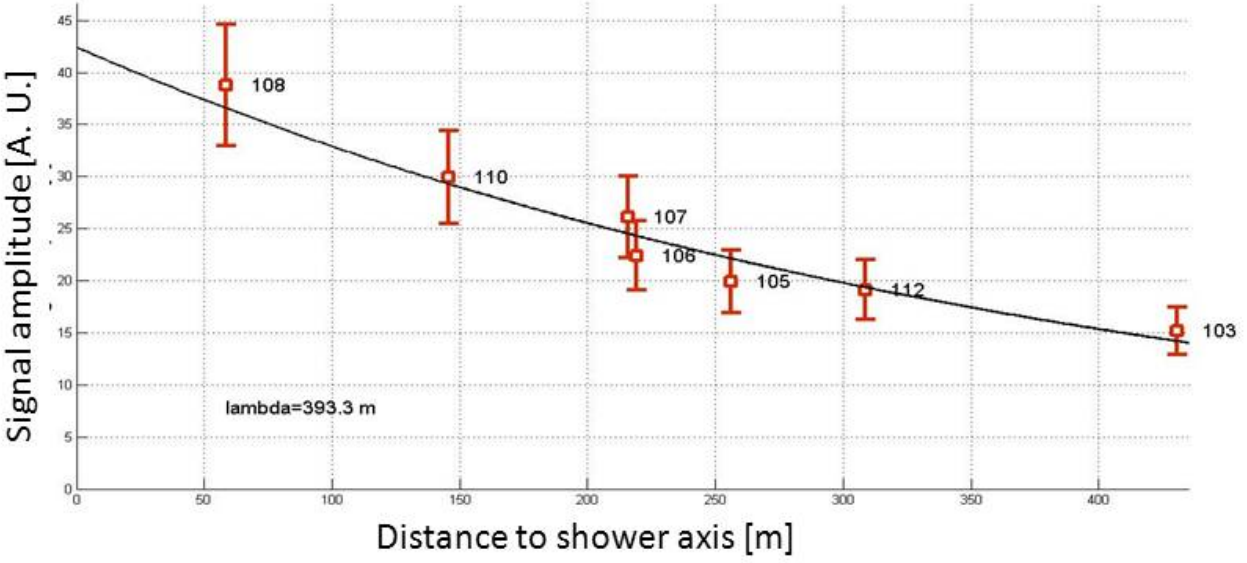




TREND achievements

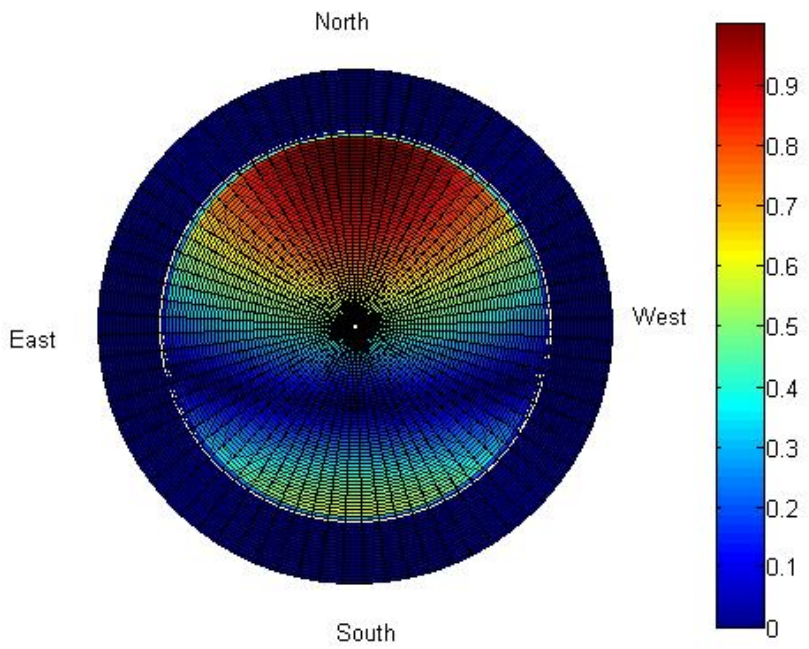
One TREND EAS radio-candidate

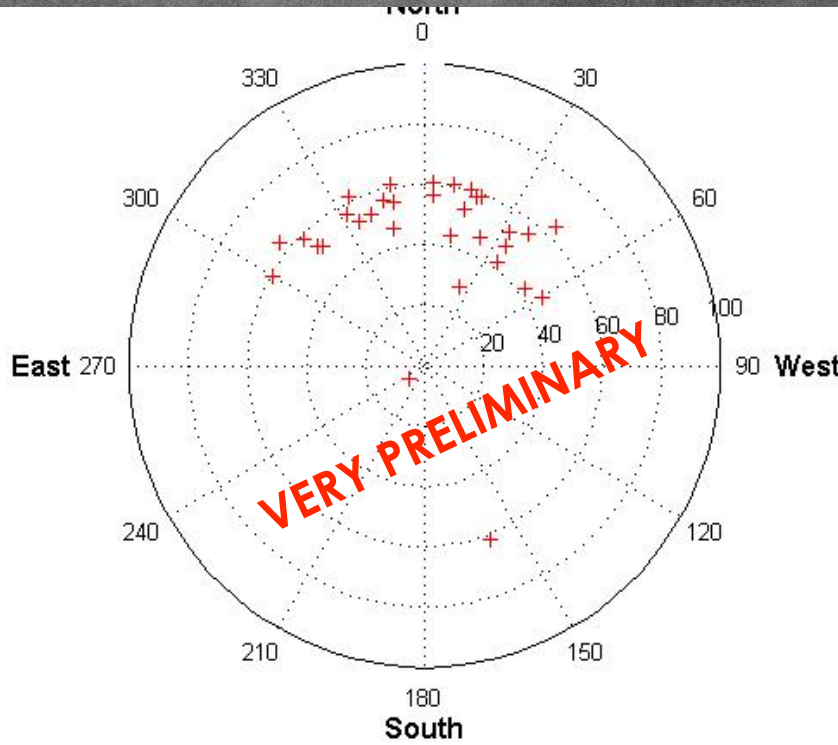




2012: preliminary results with 50-antennas array

- **104 days analysed so far: 33 EAS candidates.**





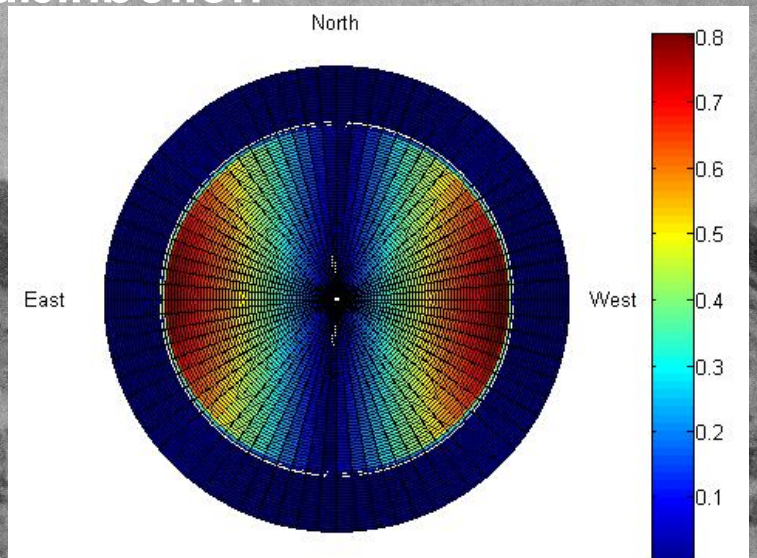
$E_{EW} = q\,|\,\mathbf{v}\hat{}\mathbf{B}\,|\,.\,\mathbf{x}$

(to be corrected by EAS effects & antenna lobe)

50-antennas array: to do

- **Complete/refine analysis**
  -> larger stat (100-200 candidates)
  - **Confirm expected radio-EAS distribution**
  - **Perform statistical analysis of radio properties**
    (lateral profile with E and θ, sky distribution with E, …)
  - **Perform analysis at large angles.**
- **Rotate antennas by 90° (September 2012)**
  - **Confirm expected EAS distribution**

N-S polarization



TREND future plan

- **Present phase validates principle of autonomous radio detection.**
- **On-going MC simulation + detector R&D to study the TREND potential for**

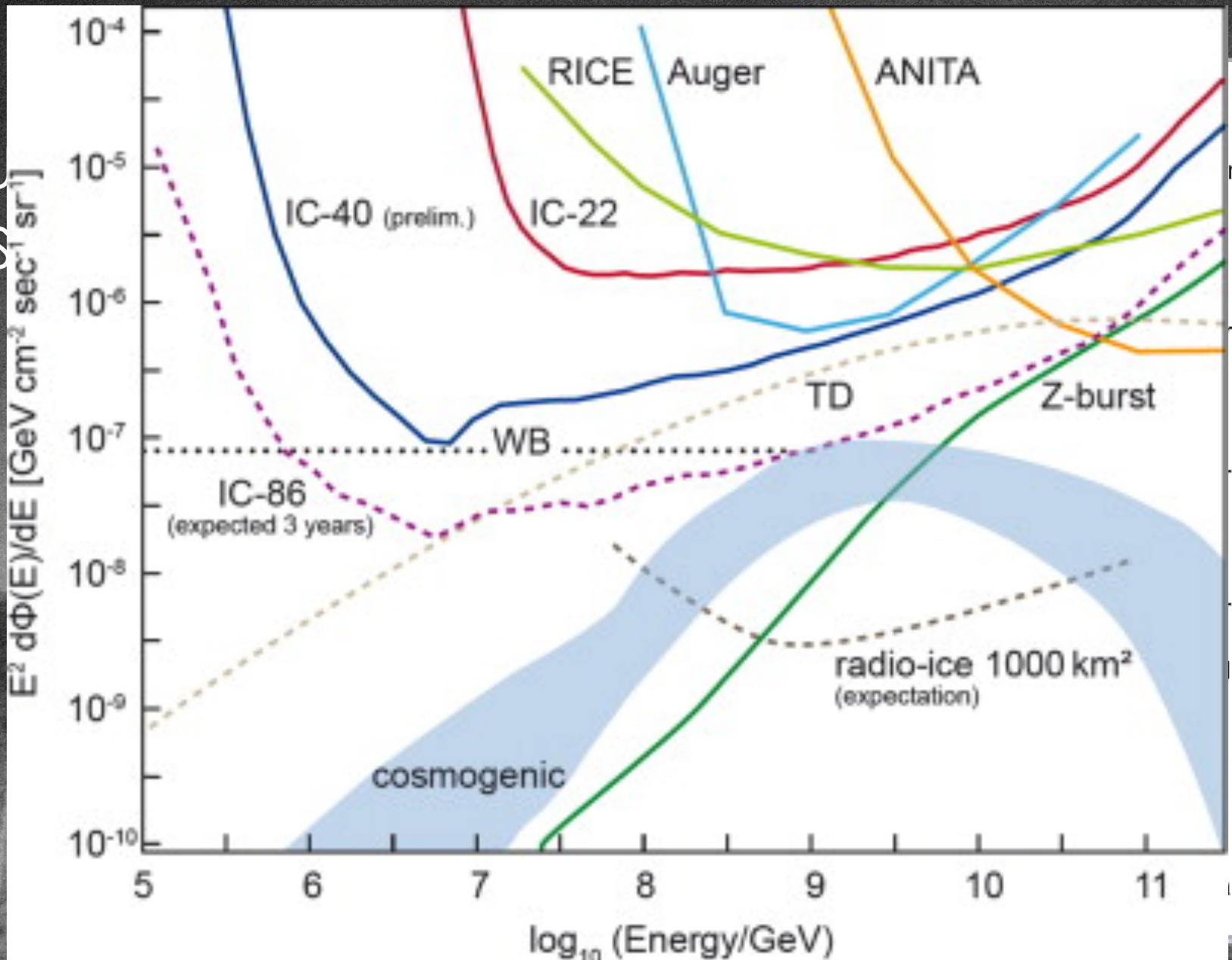
a GIANT RADIO ARRAY FOR THE DETECTION OF UHE NEUTRINOS & COSMIC RAYS.

Why cosmic neutrinos?

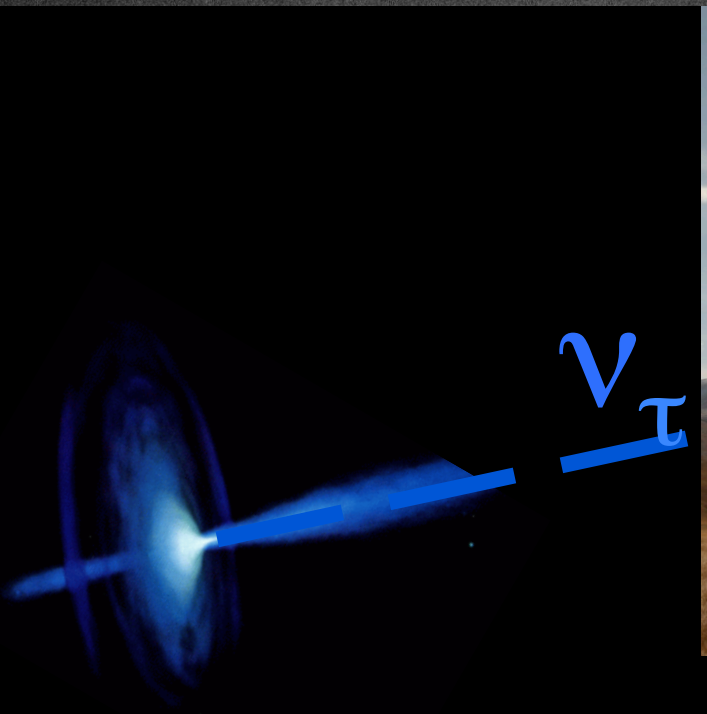
- Universe studied through its messengers reaching Earth (or satellites)
  - Electromagnetic radiation: optical, radio (21CMA), CMB, X rays, gamma rays (YBJ)
  - Cosmic rays (i.e. nuclei) (YBJ)
  - Neutrinos
    - Very clean messengers
    - Rich info on sources & cosmology
    - «3rd window on the Universe» not opened yet!

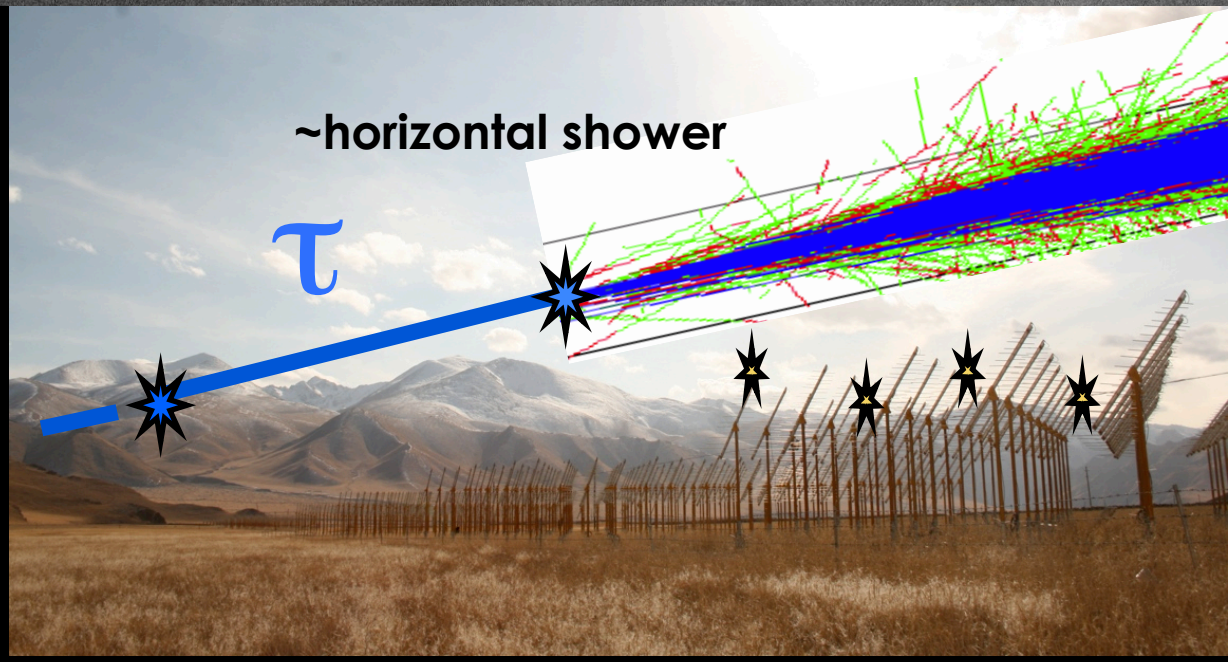
Search for cosmic neutrinos

- AU
- @S



UHE neutrino detection





Chalenges:

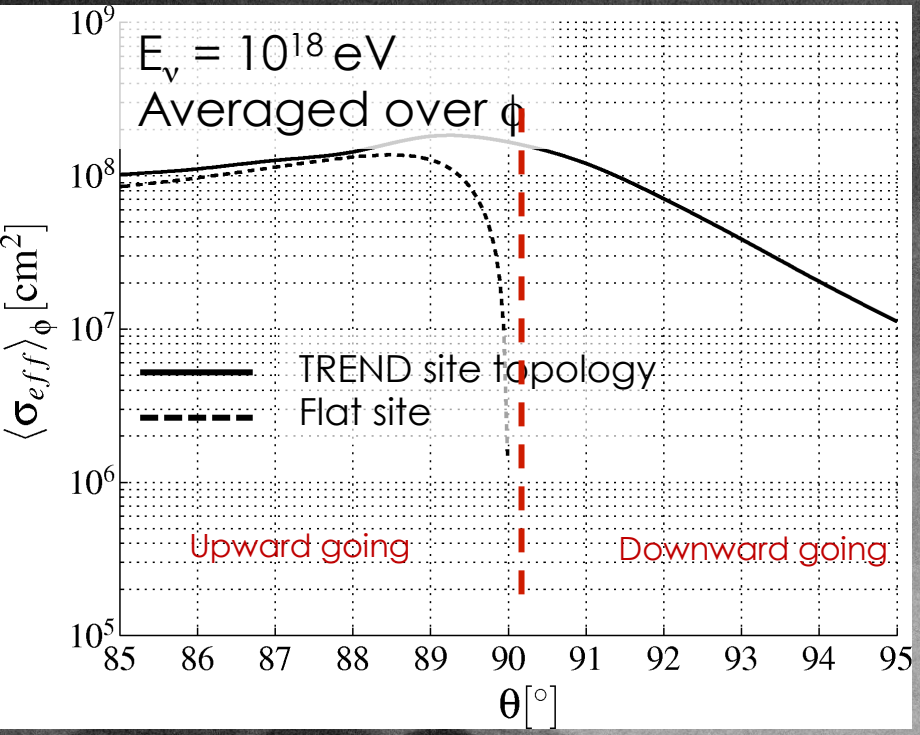
- rate of neutrino showers (**~ few per year)** **-> compute it for TREND!**
- background rejection (~**few per second)** **-> prototype study!**

Answers expected on these topics in the coming year!

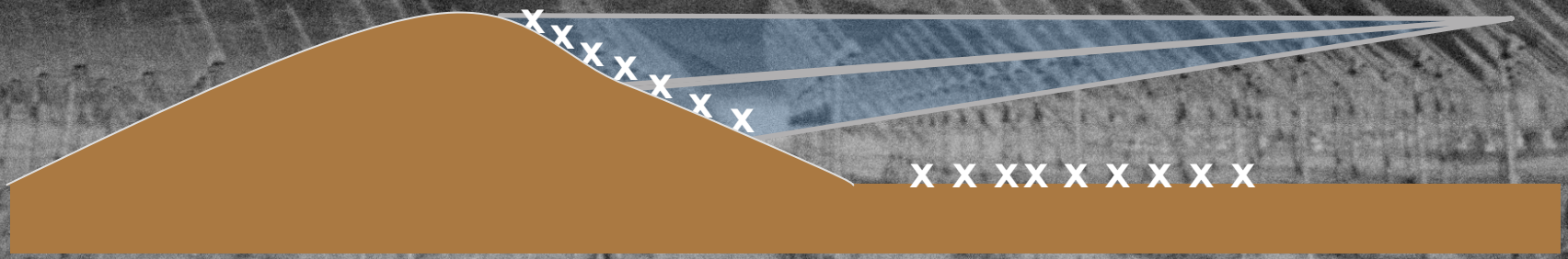
Neutrino sensitivity simulation

- ν DIS:
  - Integrated cross sections (NC+CC) from Gandhi *et al.* (CTEQ4-DIS)
  - Inelasticity randomised with Pythia + CTEQ5d pdf.
- τ propagation in rocks (energy loss + lifetime):
  - τ photonuclear interactions coded in GEANT4 following Dutta *et al.* (dominant energy loss process for UHE τ's)
  - Detailed simulations of the τ energy loss in rocks with GEANT4 for various τ initial energies $\Rightarrow$ parametrization of the τ energy loss and of the proper time spectra according to the distance d (0-60 km) and the initial energy, E_0.
  - Hybrid Monte-Carlo scheme for the τ propagation in rocks (energy loss, decay) according to the parametrization derived from GEANT4.
- τ Decays
  - Use Pythia + TAUOLA… or CORSIKA?
- **Simulation for radio detection in progress (cross checks with REAS & MGMR**

TREND: role of mountains

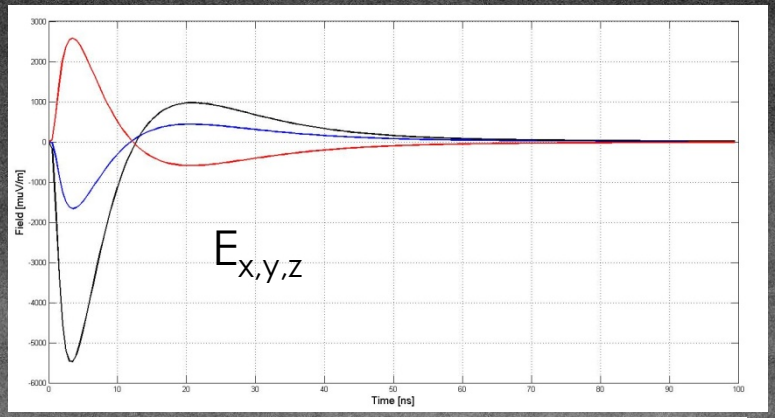


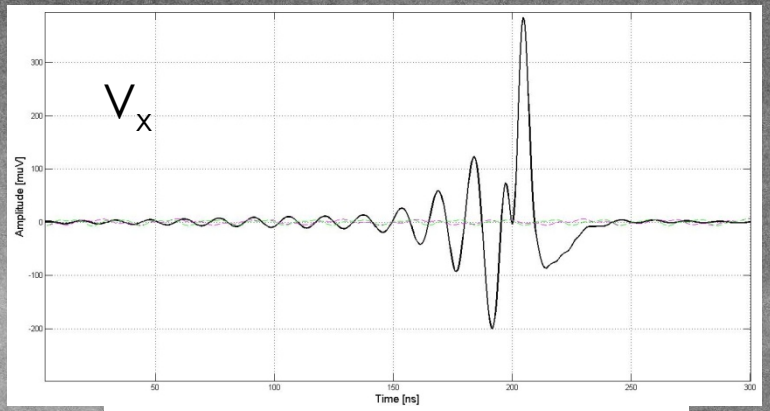
- Significantly increase event flux (x2)
- Screen for « standard » CRs
- Very attractive sites for detection
  - Increased efficency
  - Better geometry

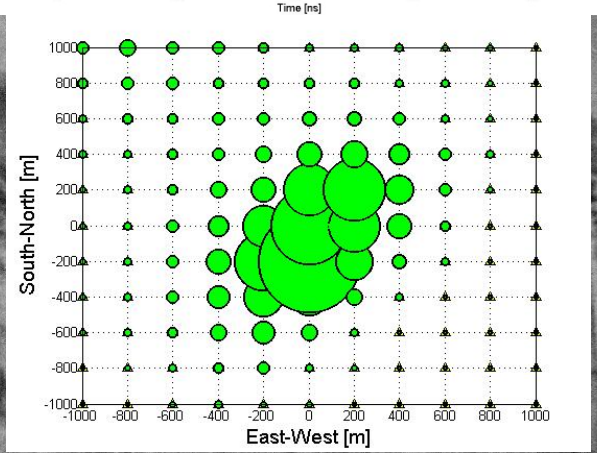


Background rejection… polarization measurement?

- **EAS radio signal is polarized (at 1st order E ⊥ v & E ⊥ B_{geo})**
- **$E_{x,y,z}$ can be simulated very precisely knowing EAS geometry & energy.**
- **Knowing antenna response, $V_{x,y,z}$ can then be computed.**
- **Therefore possible to determine expected $P_{EAS} = V_z / V_x$ for each antenna of the array and each EAS candidate -> polarization map.**
- **Comparison of expected and measured polarization maps should be a very strong discimination tool!**

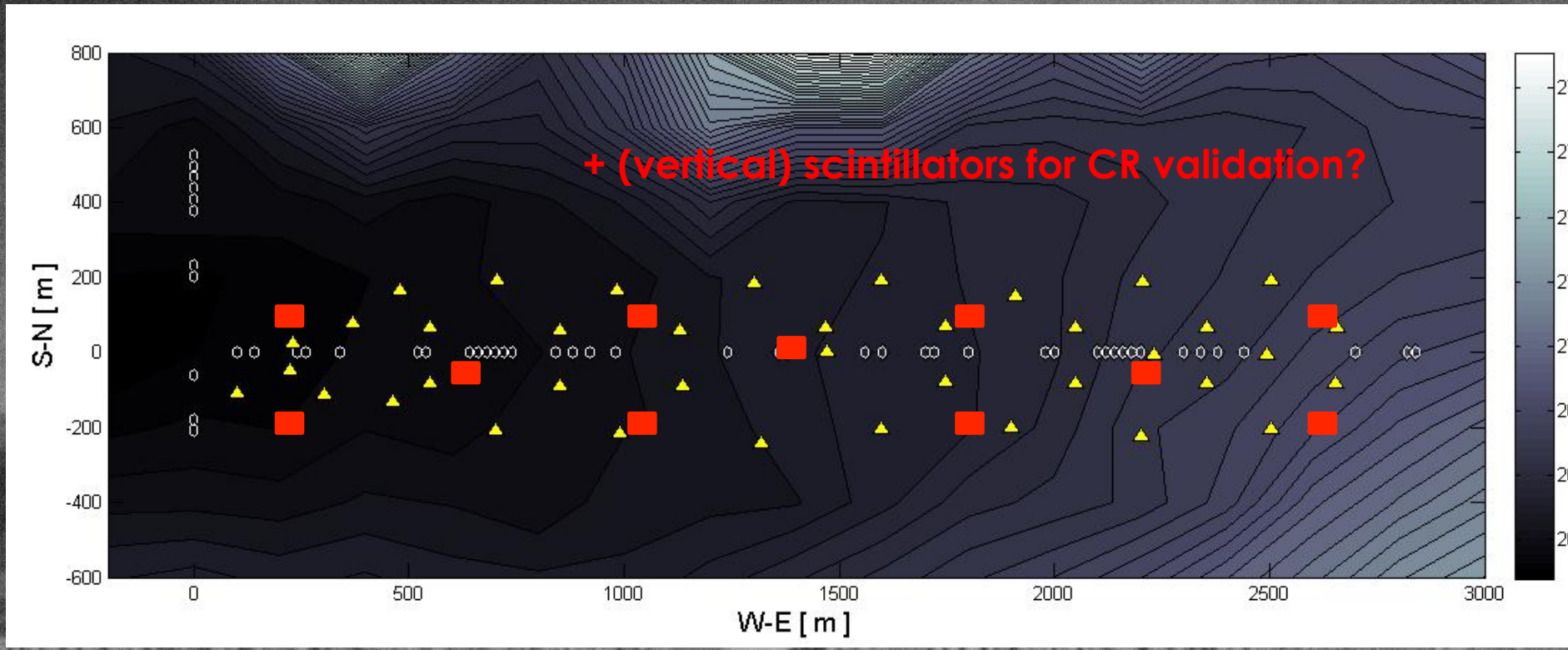






Prototype test

- To be installed at Ulastai asap (2013) and tested on inclined showers. Requires funding.
- Possible setup:



- Prototype could then be used as a testbench for the definition of the TREND detection unit final design.

Tianshan: 25 000 km² of lowly populated mountains are within reach…
+ 21CMA infrastructure & technical support.

Tibet (Ali plateau) : could be a very attractive option as well: remoteness + mountains + benefit from YBJ infrastructure & technical support (?)…