

Cosmic Rays @ 21 CMA

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The Playground

The 21CMA is a currently operated radio array of 10,000- antennas, build by NAOC (Wu Xiang Ping) in Ulastai (Xin Jiang, China) for H reionisation studies.

The pros:

Located in a ~2700 m high altitude isolated valley:

- It benefits from a very clean radio environment in the VHF range (30-300 MHz).
- It is located at a height close to 10^{17-19} eV extensive air showers (EAS) maximum: 13+ EAS events/day expected on a single free antenna.
- It is readily usable 😊.

⇒ Very interesting existing setup for radio observation of air showers

- ~4-5 km high mountains surroundings ⇒ nice neutrinos target / possibility to radio detect ν_τ induced air showers from secondary τ escaping mountains.

The cons:

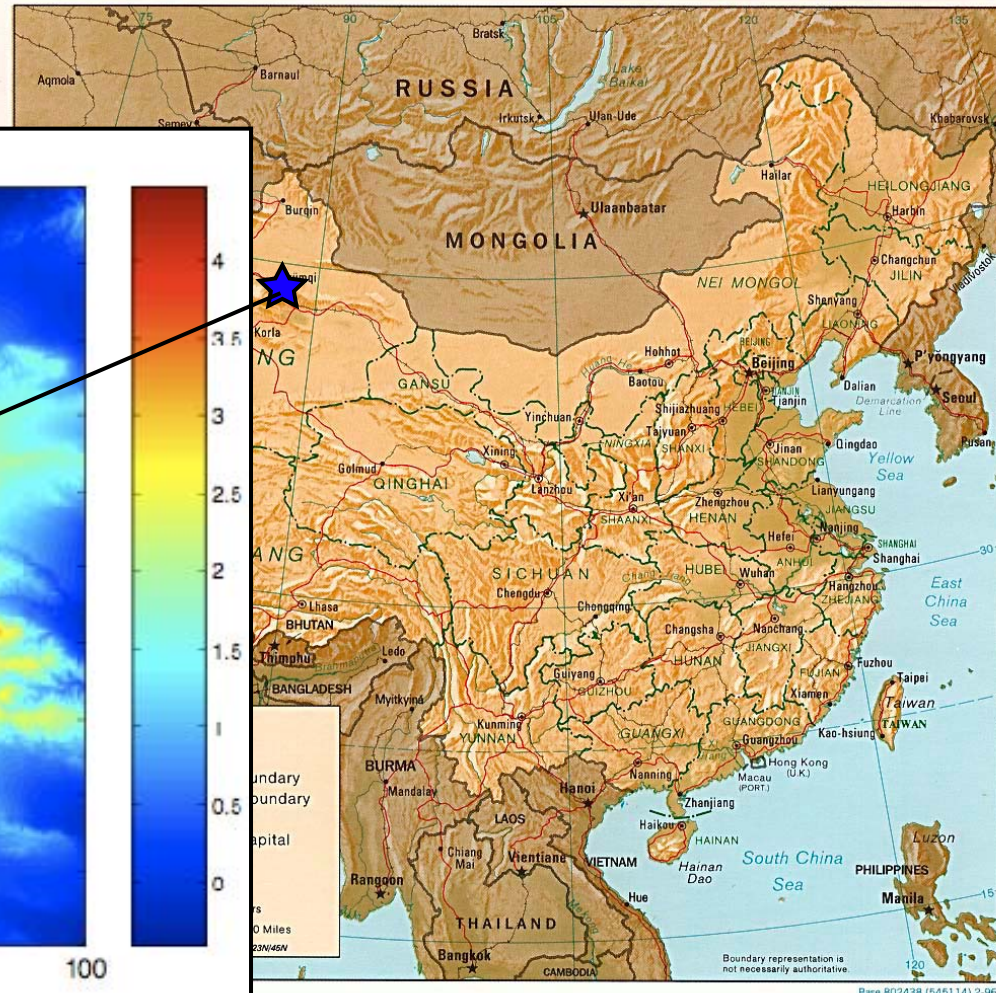
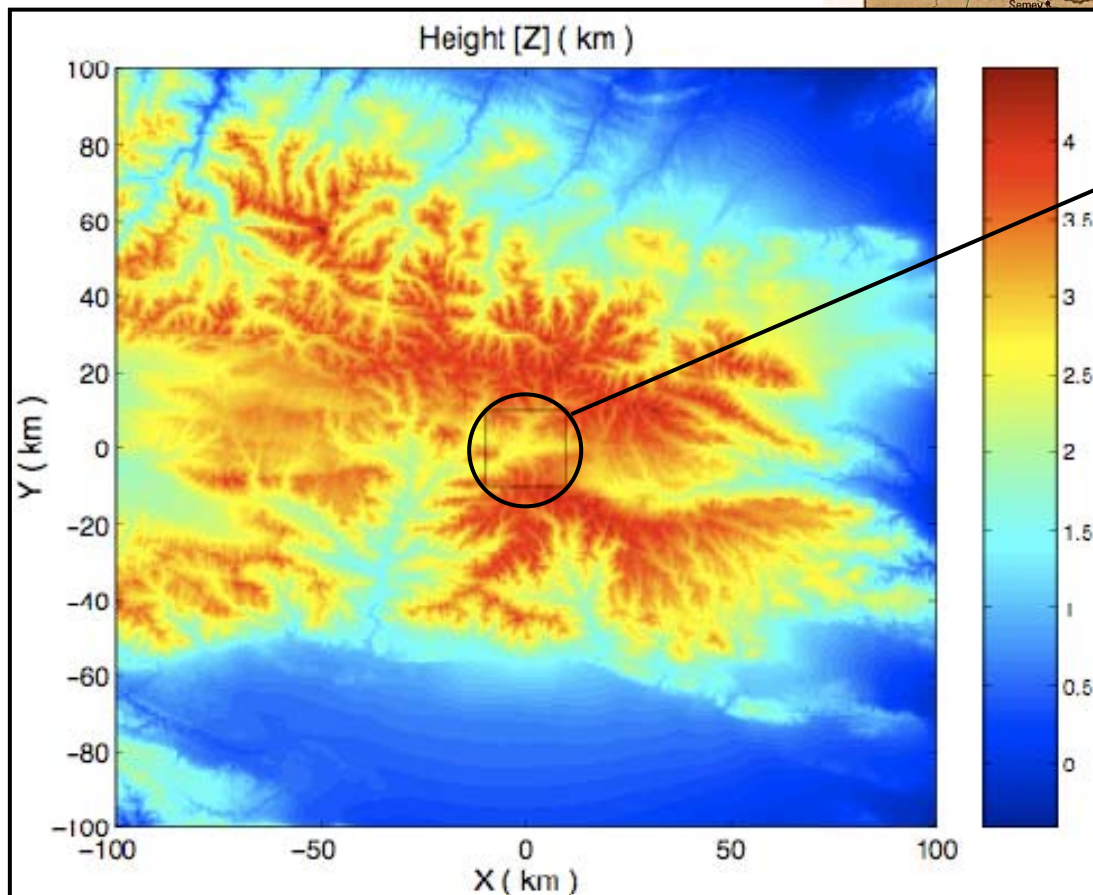
- Radio signal from showers now '*commonly*' observed but not that well characterised theoretically 😞 (😊 for theorists/experimentalists joint research).
- No proof of principle of stand alone/self triggering EAS radio detector sofar ...
Hot R&D topic for the of future of UHE EAS observation.

I) Setup and Status

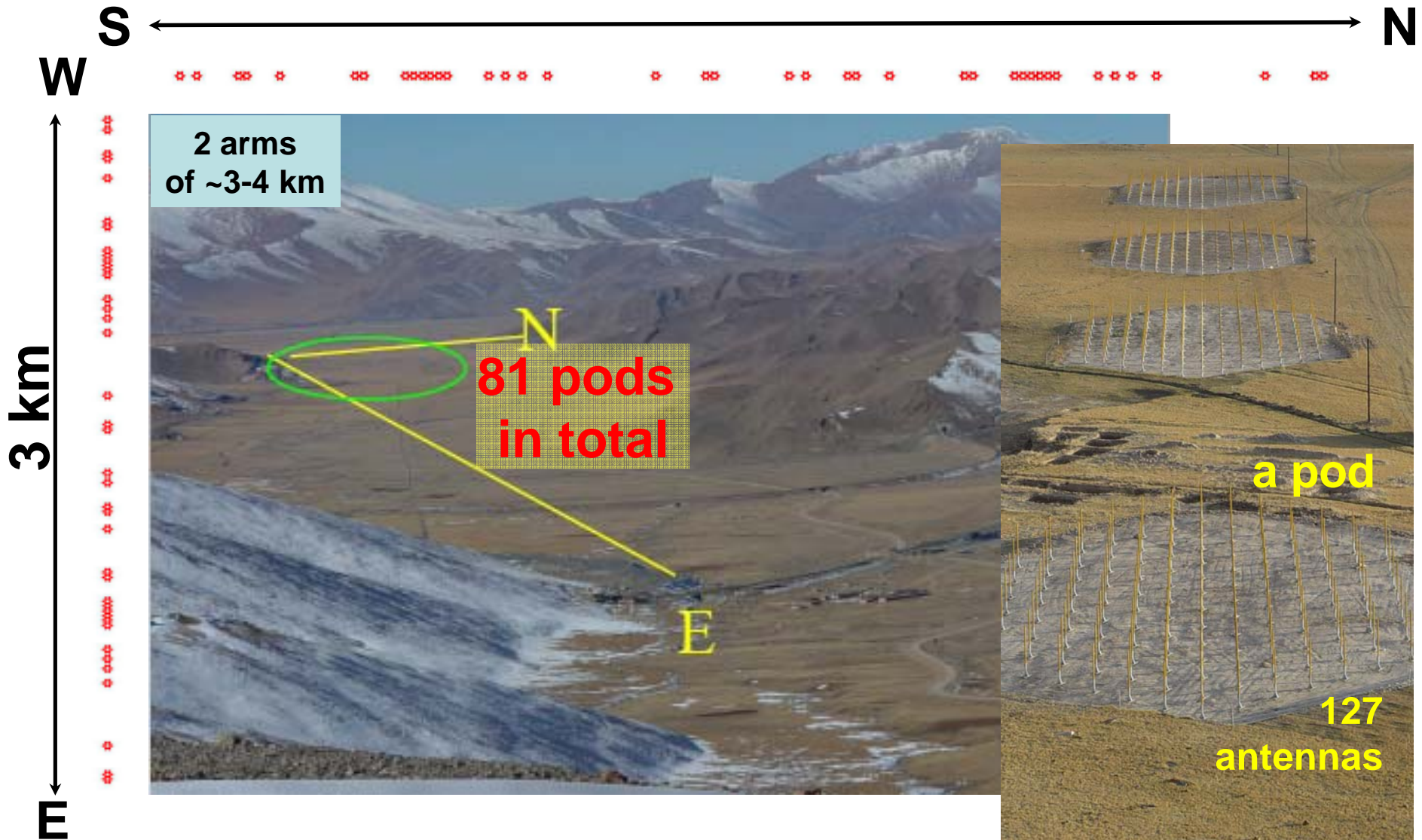
The 21 CMA Location

Array of 10000- antennas, build by NAOC (Wu XiangPing) in Ulastai (Xin Jiang, China) for reionisation studies

Complete area relief from *www* satellite data

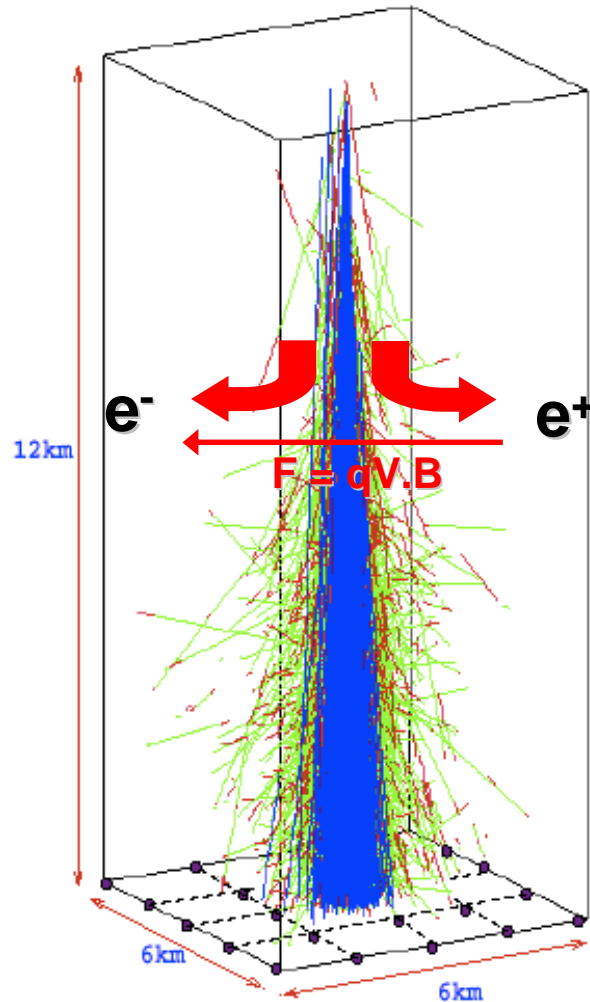


The 21 CMA Installation



Radio Signal from Extensive Air Showers

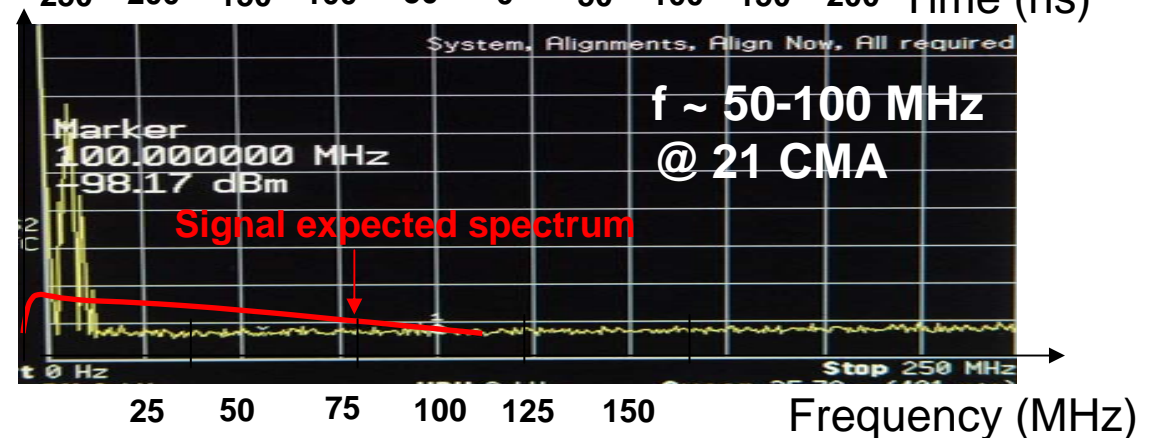
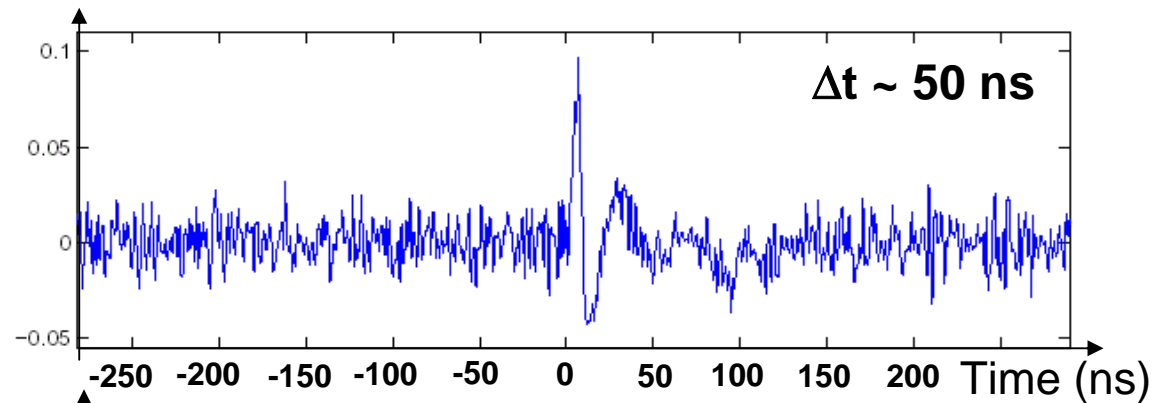
10 EeV EAS



Variety of processes leading to radio signals:

coherent Cherenkov radiation

geo-synchrotron/dipole radiation: dominant for EAS,
sensitive $> 10^{16}$ eV

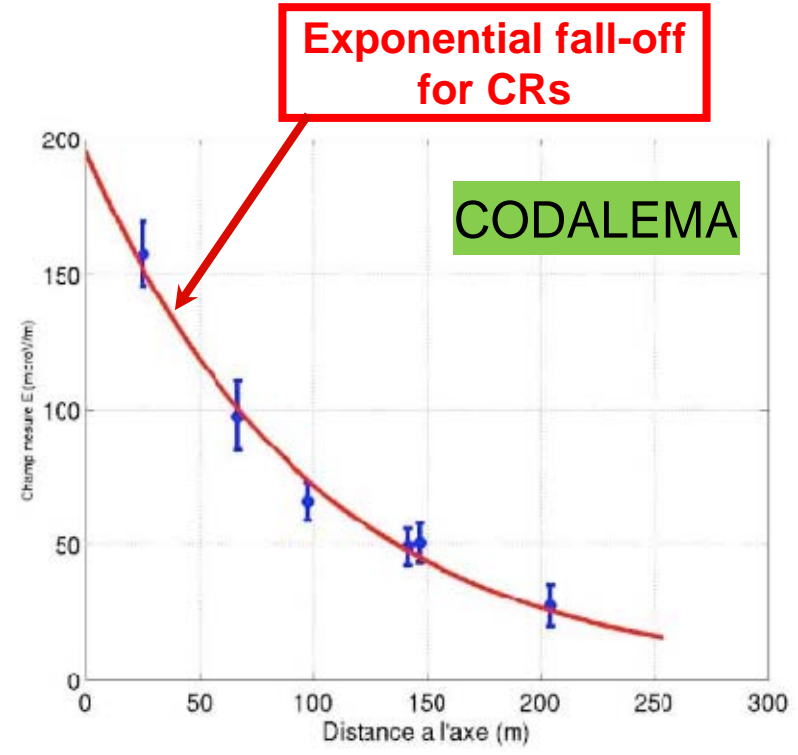
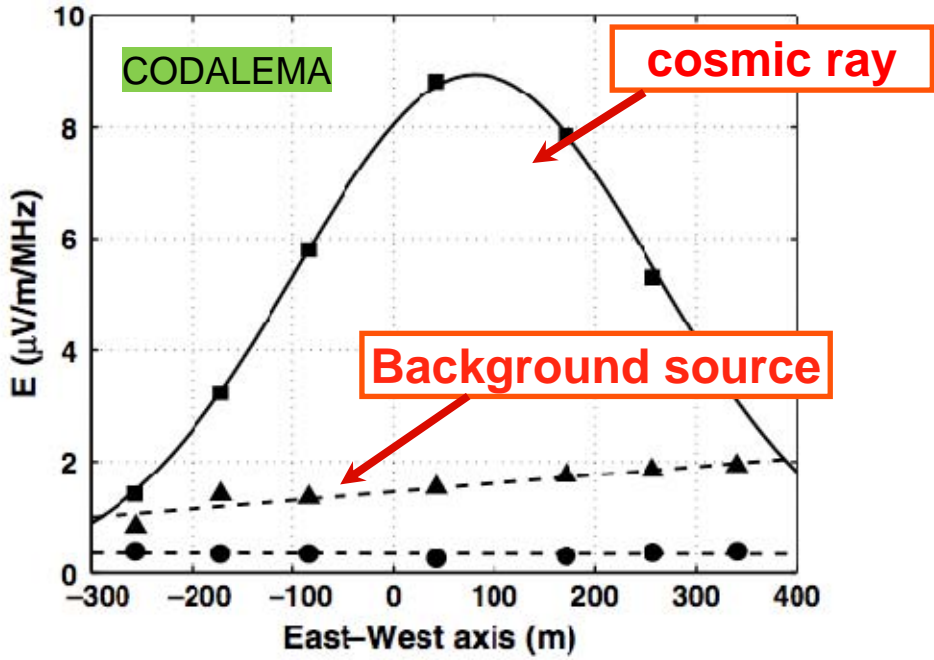


First phase : prototype of 6 antennas

Never done so far!!!

Goal : prove the principle of CR detection with **self-triggering** array.

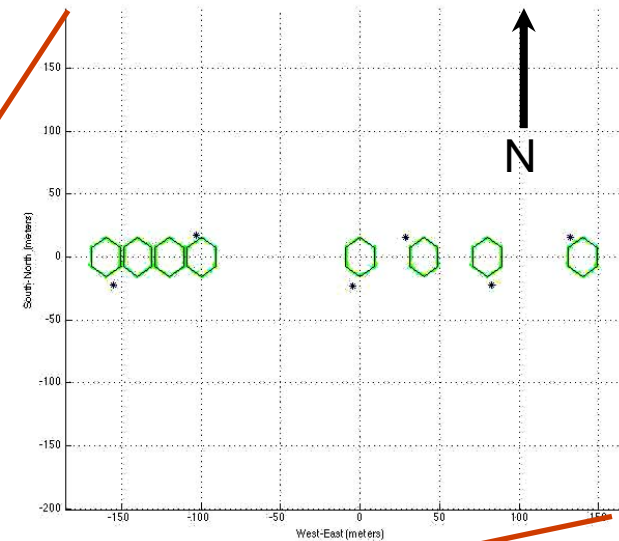
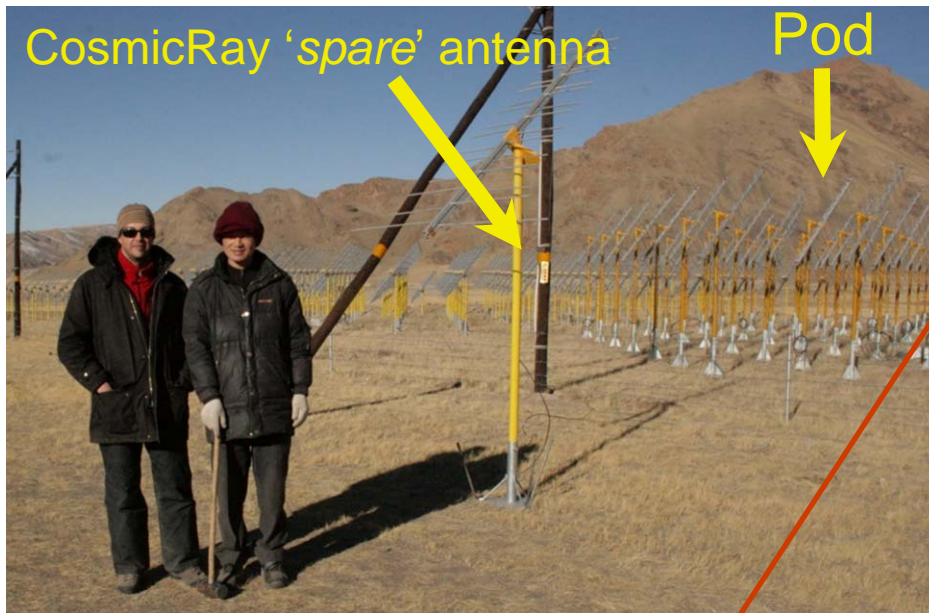
- **Individual antenna triggers** on signals with amplitude $> N \cdot \sigma_{\text{noise}}$ ($N \sim 6$)
- Look for triggers in **coincidence** (causal time window)
- If more than 3 antennas in coincidence: triangulation
 - ➔ **reconstruction of direction of origin** of the wave
- Several background rejection tools
 - signal amplitude variation
 - direction of origin
 - signal duration (< 100 ns)



First phase : prototype of 6 antennas

N

1- Set-up in October 2008



E

S

W

6-antennas prototype

First phase : prototype of 6 antennas

2 - Improvements/calibration/debugging up to January 2009

Check & re-check connections...



Measure time delays...

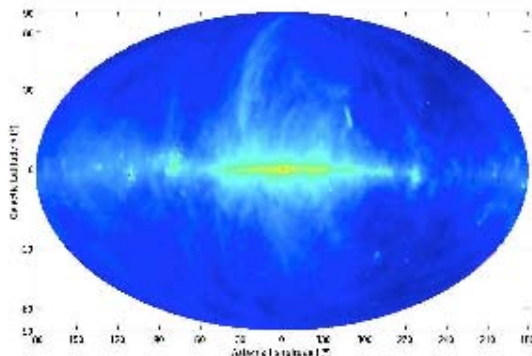
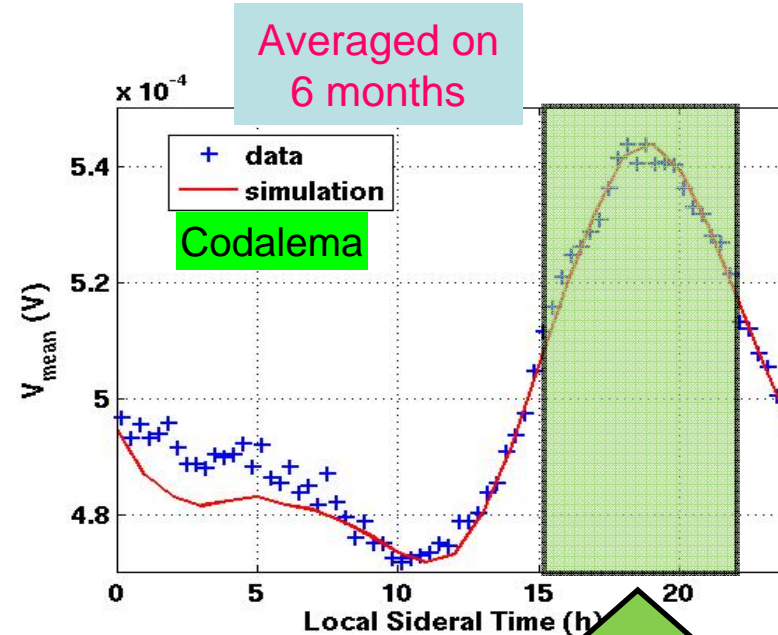
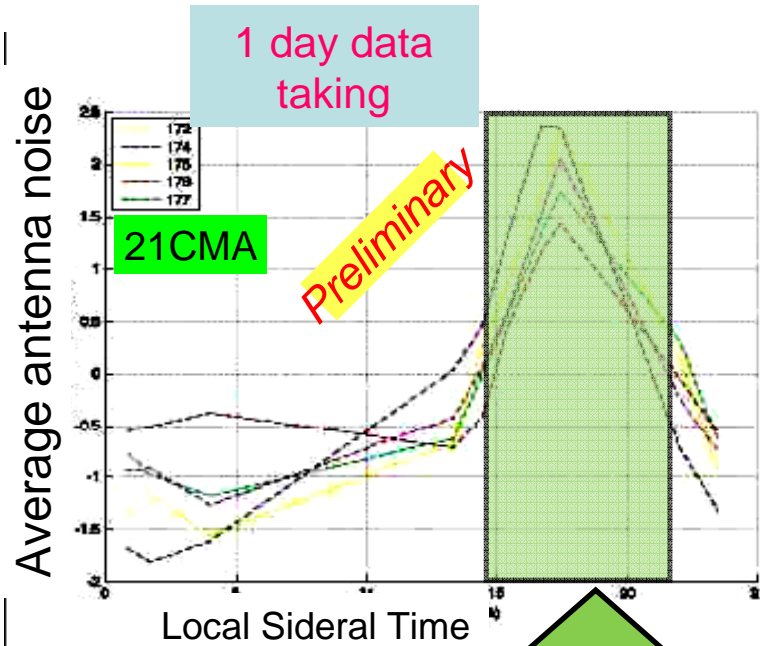


Determine antennas positions...



Antennas sensitivity

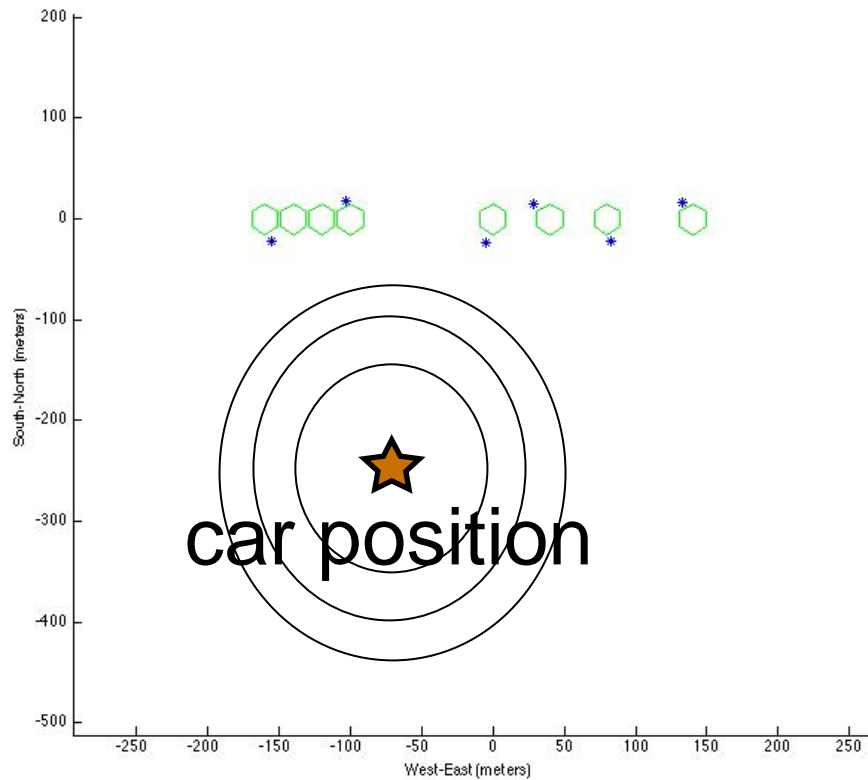
Galactic radio noise (Thermal emission, diffuse continuum)



Galactic plane (strong radio emission) is in the antennas field of view at this position

Reconstruction algorithm

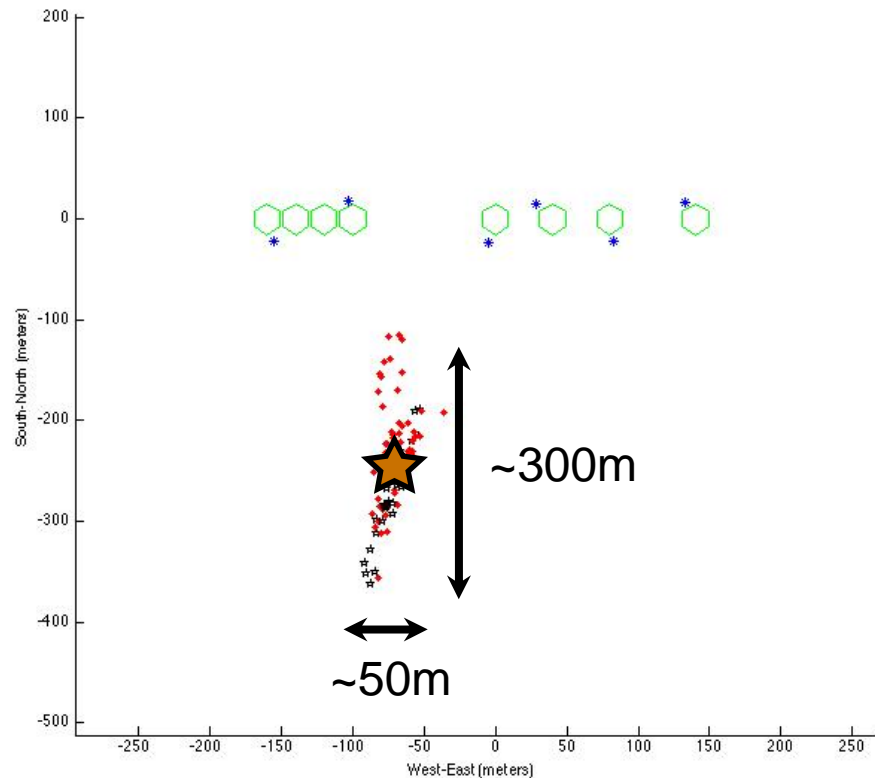
Validation with a known source: the car



Calibration run with
fixed source position

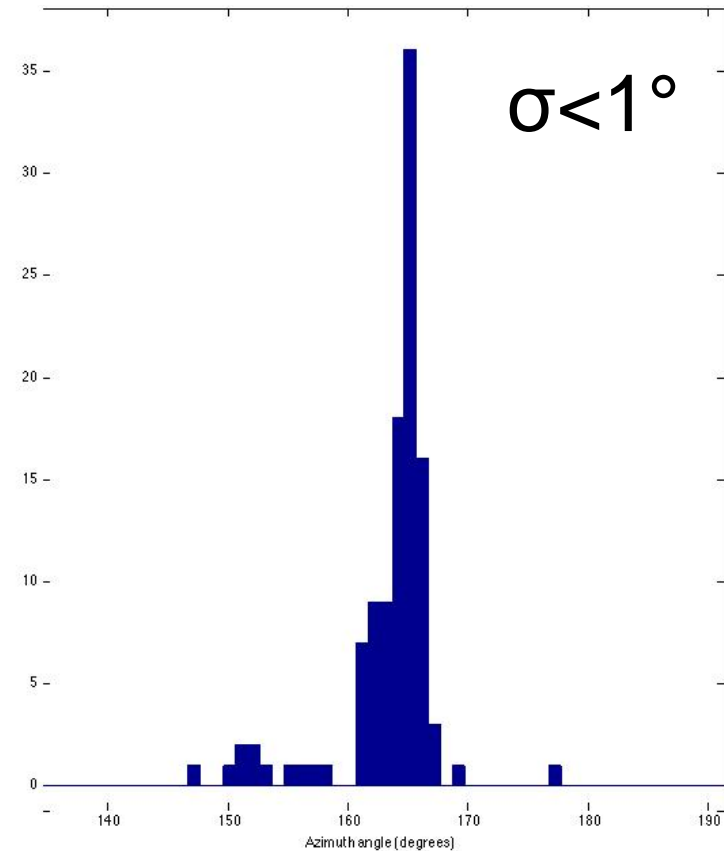
Reconstruction algorithm

Source position reconstruction



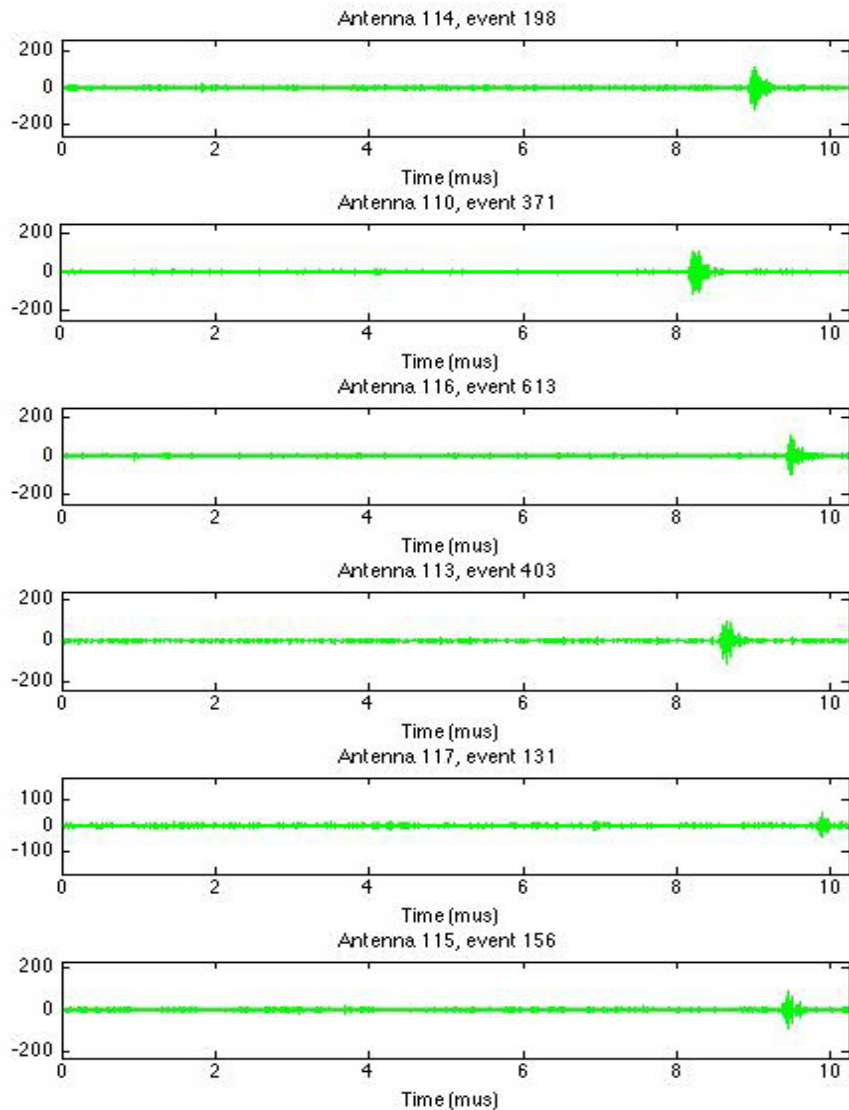
Poor resolution along N-S axis due to set-up geometry...

Azimuth angle reconstruction

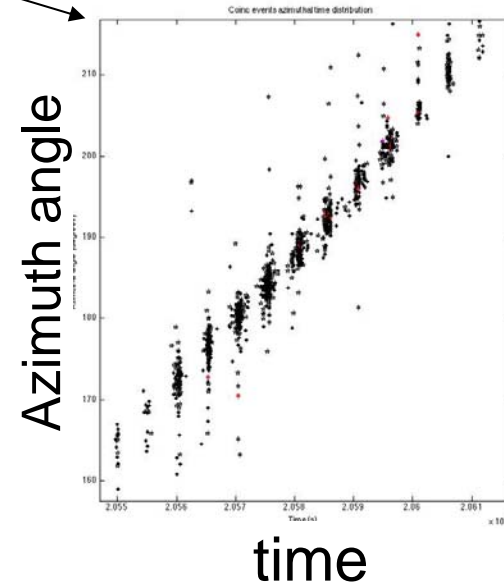


3 - "Cosmic rays" data taking (~200h in February 2009)

6-antennas coincident events seen 

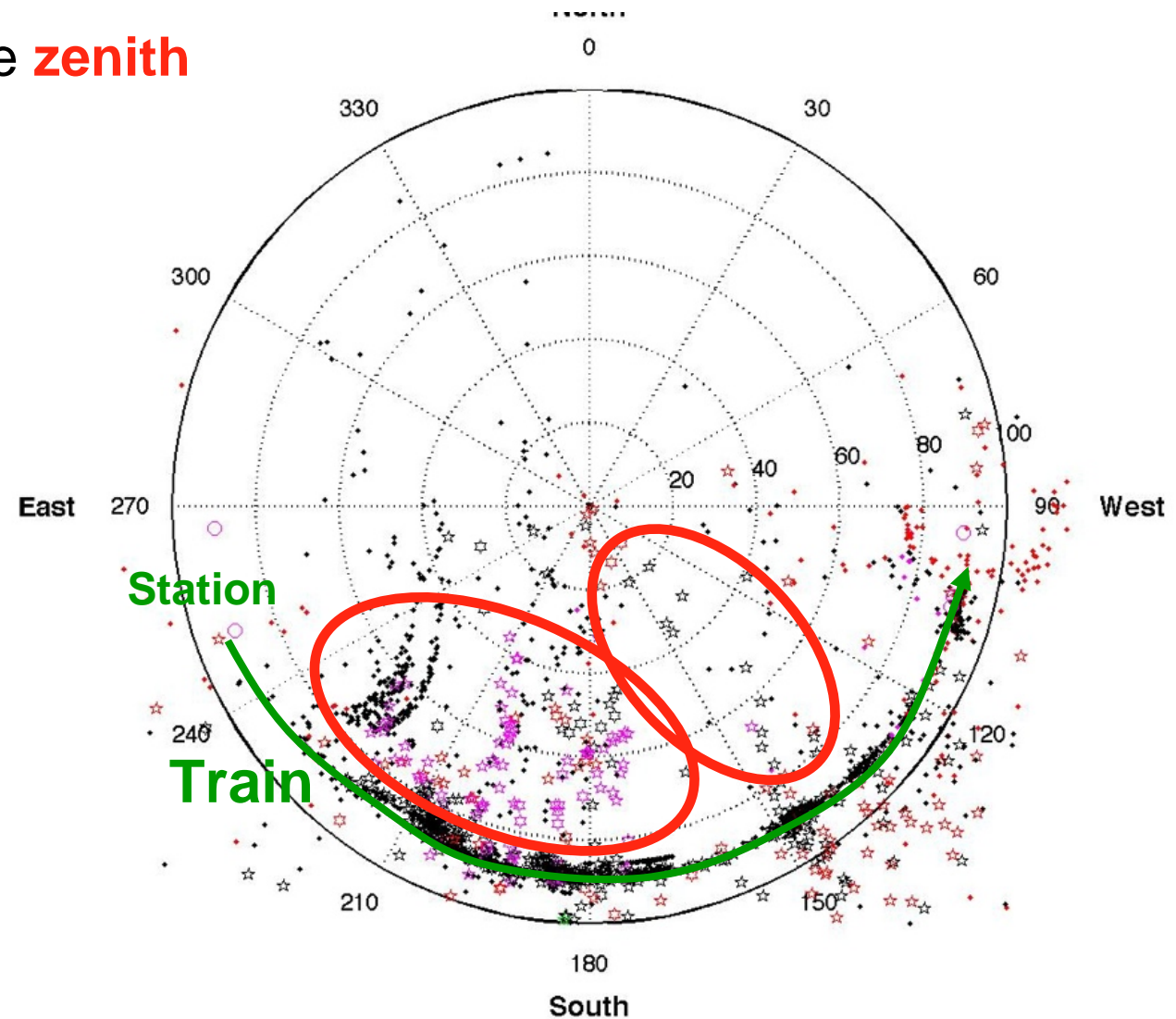


Anthropic sources seen:
trains, electrical transformer, planes,...



But...

Obviously poor reconstruction of the **zenith angle**



Well reproduced in simulations

Randomly generated sources in the sky



Compute times of arrival on antennas



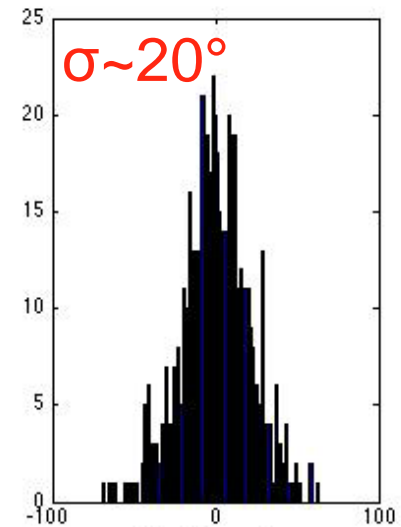
Apply reconstruction algorithm



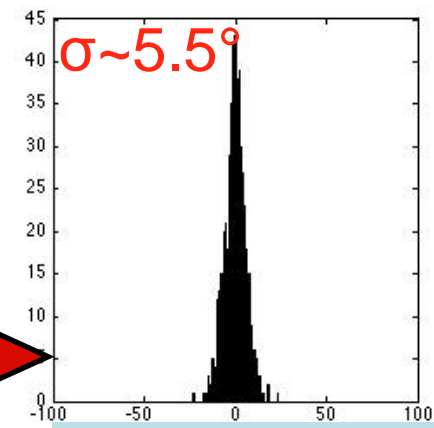
Compare reconstructed direction to true one

Important factor: array geometry:

With 1 antenna 6 m above ground



Error on zenith (deg)



Error on zenith (deg)

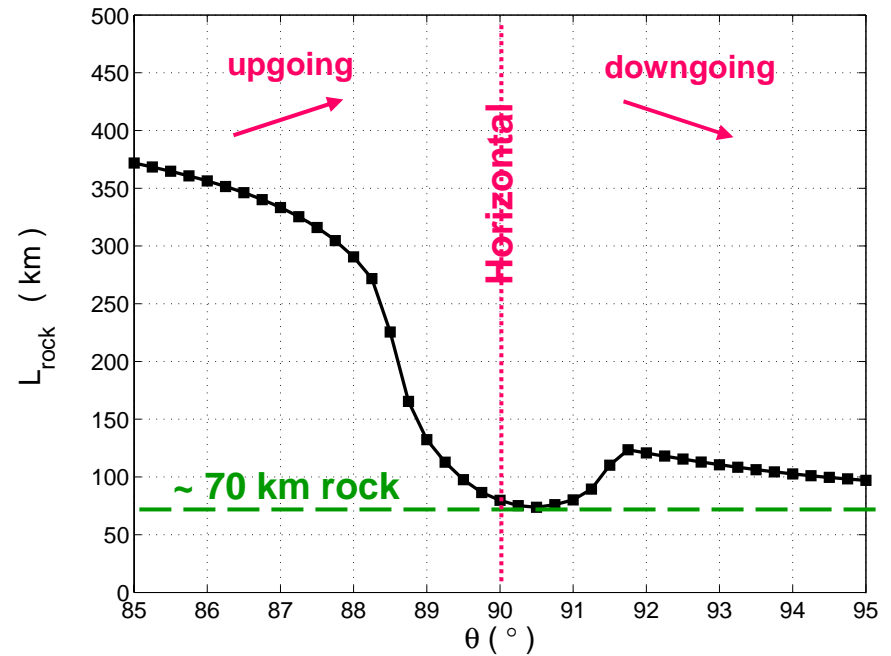
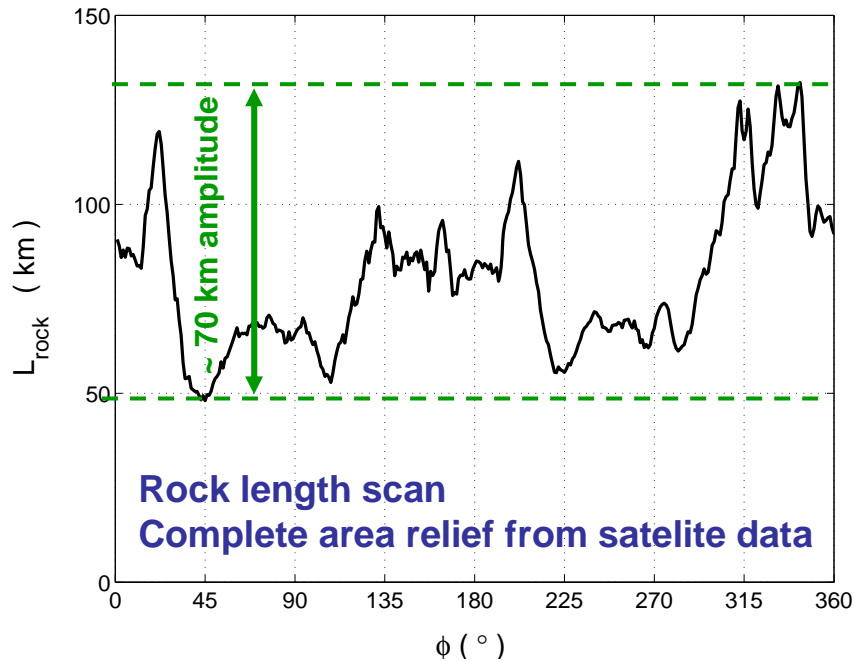
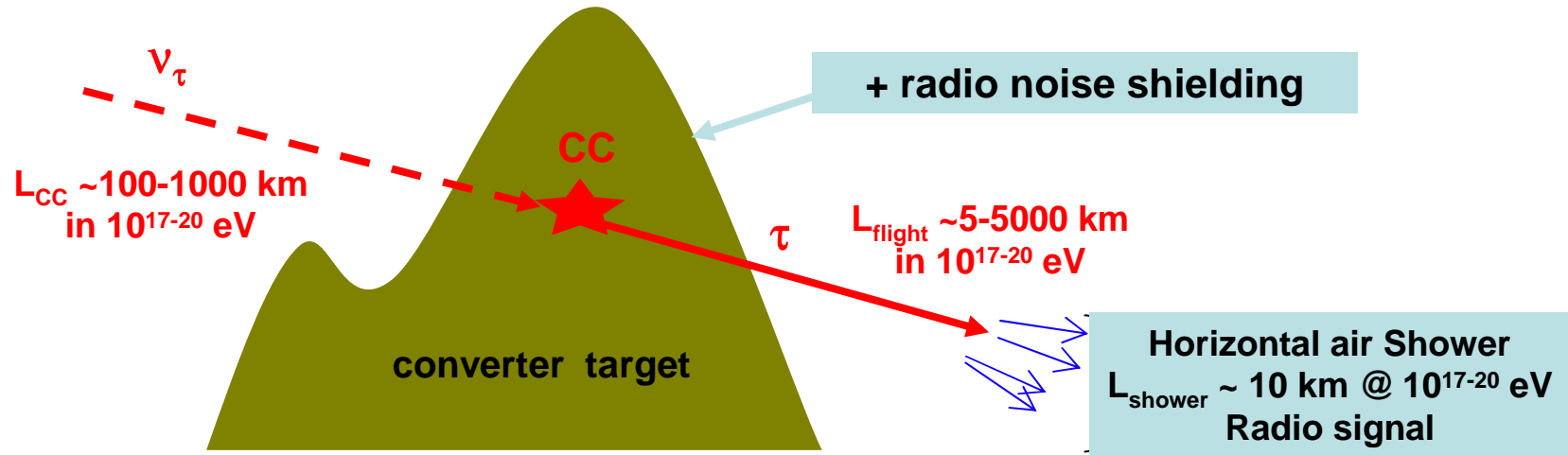
Future tests (right after this workshop):

- move antennas appart from the pods
- try to place one antenna atop a post

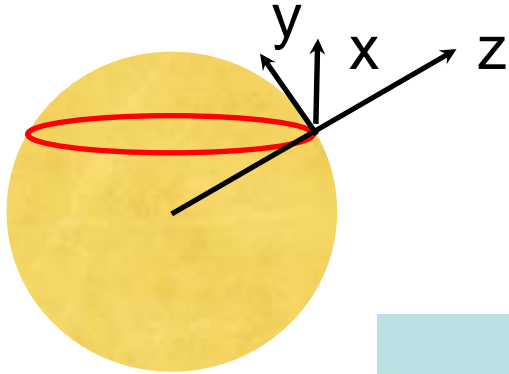


II) Detailed simulation for ν_τ detection

Detection Principle



Simulation Scheme

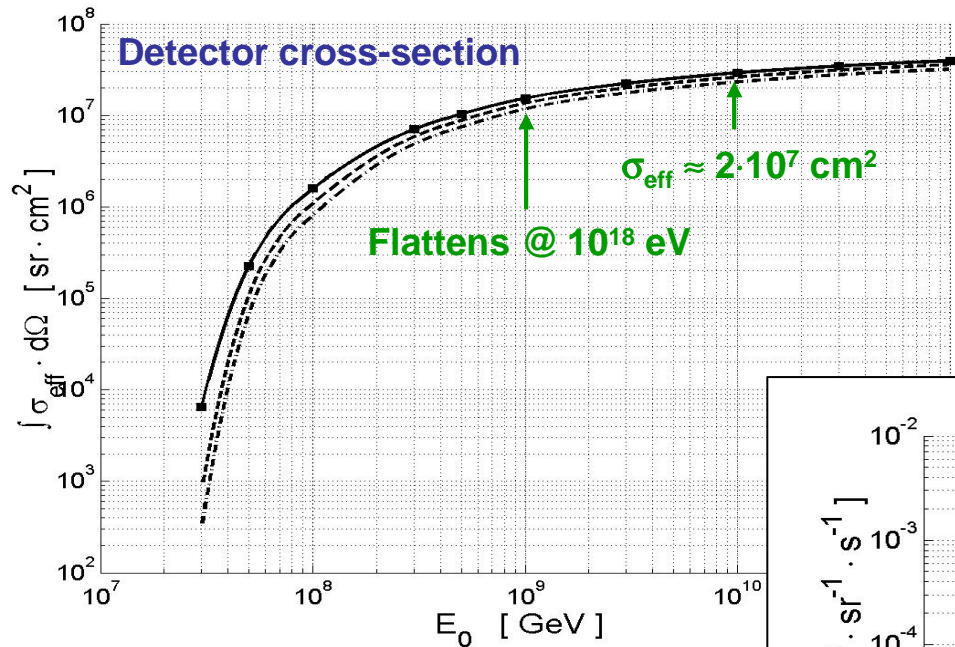


Diffuse ν_τ flux

- generate interaction within the rock (Pythia 6.4.14)
- keep if $CC > \tau$ generation (CTEQ5D (DIS))
- propagate the tau (Continuous losses approx of model III, Dutta et al, Phys. Rev. D72, 013005 (2005))
- tau decay (TAUOLA)

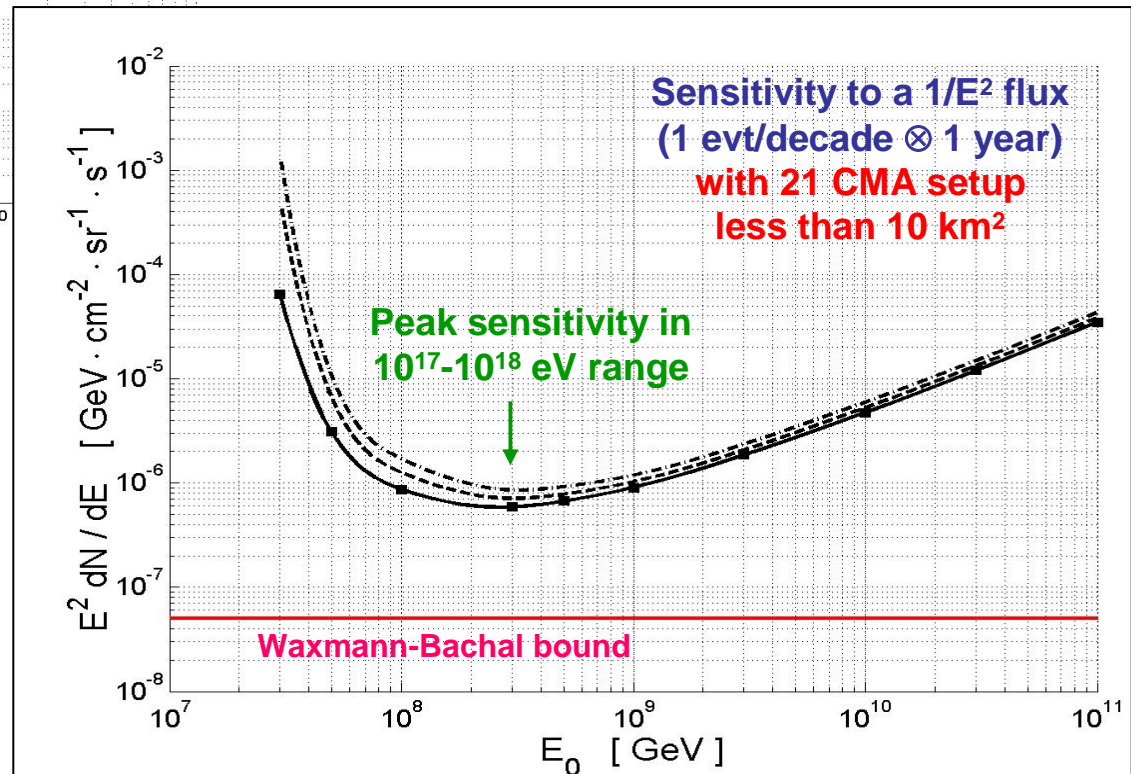
- Modelisation of the radio signal according to: A. Horneffer et al., proceedings ICRC Mexico (2007) + scaling with shower age.
 - ⇒ Exponential fall of radio signal amplitude with distance
- Standard noise level: $\varepsilon \sim 50 \mu\text{V/m}$ in the [50;100 MHz] band.
- Detection threshold fixed at $6 \sigma_{\text{noise}}$
- Variable nb of hit antennas in coincidence (1, 3, 4)

21 CMA Sensitivity to ν_τ



Cross section increases only logarithmically with energy in the UHE range 10^{18+} eV / due to exponential fall of radio signal amplitude with range

Peak sensitivity $\sim 10^{17-18}$ eV
Complementary with other detectors (ν telescopes, AUGER)

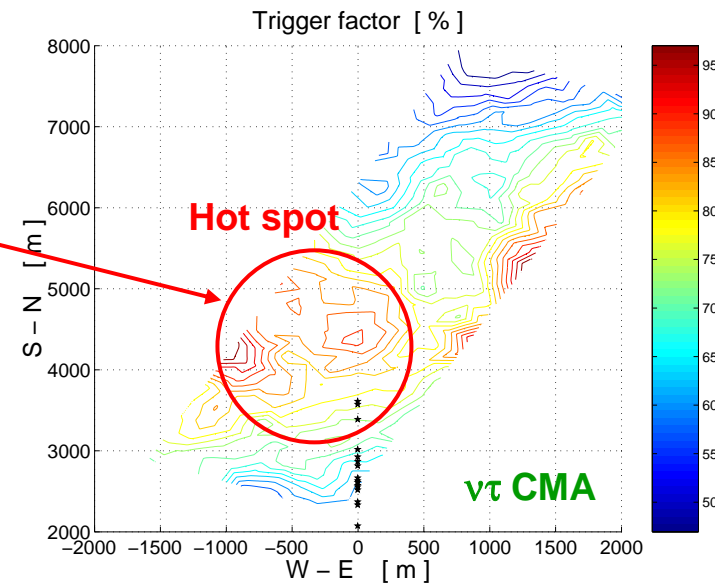
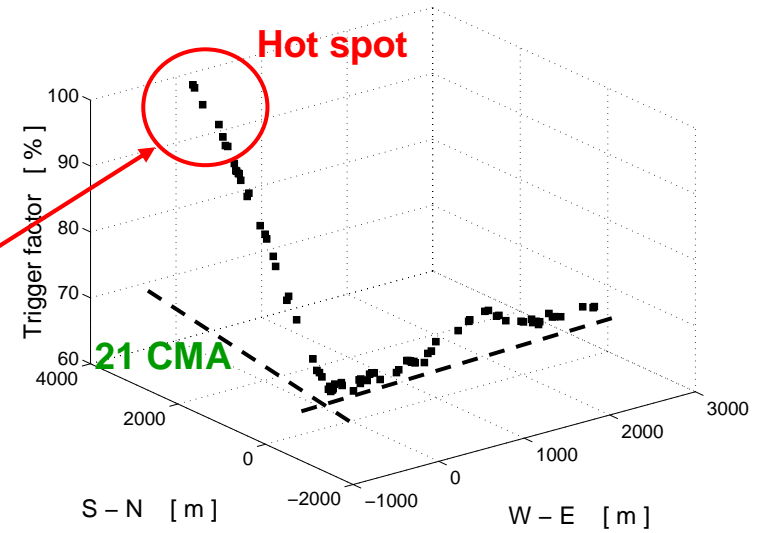
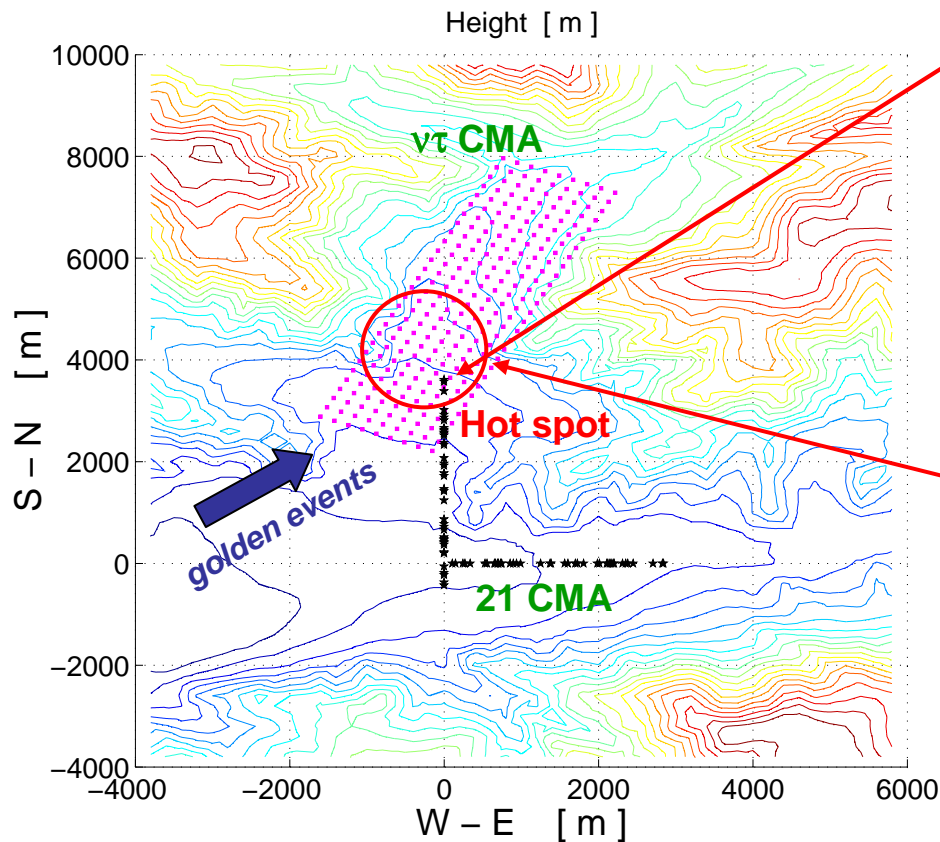


Trigger Factors

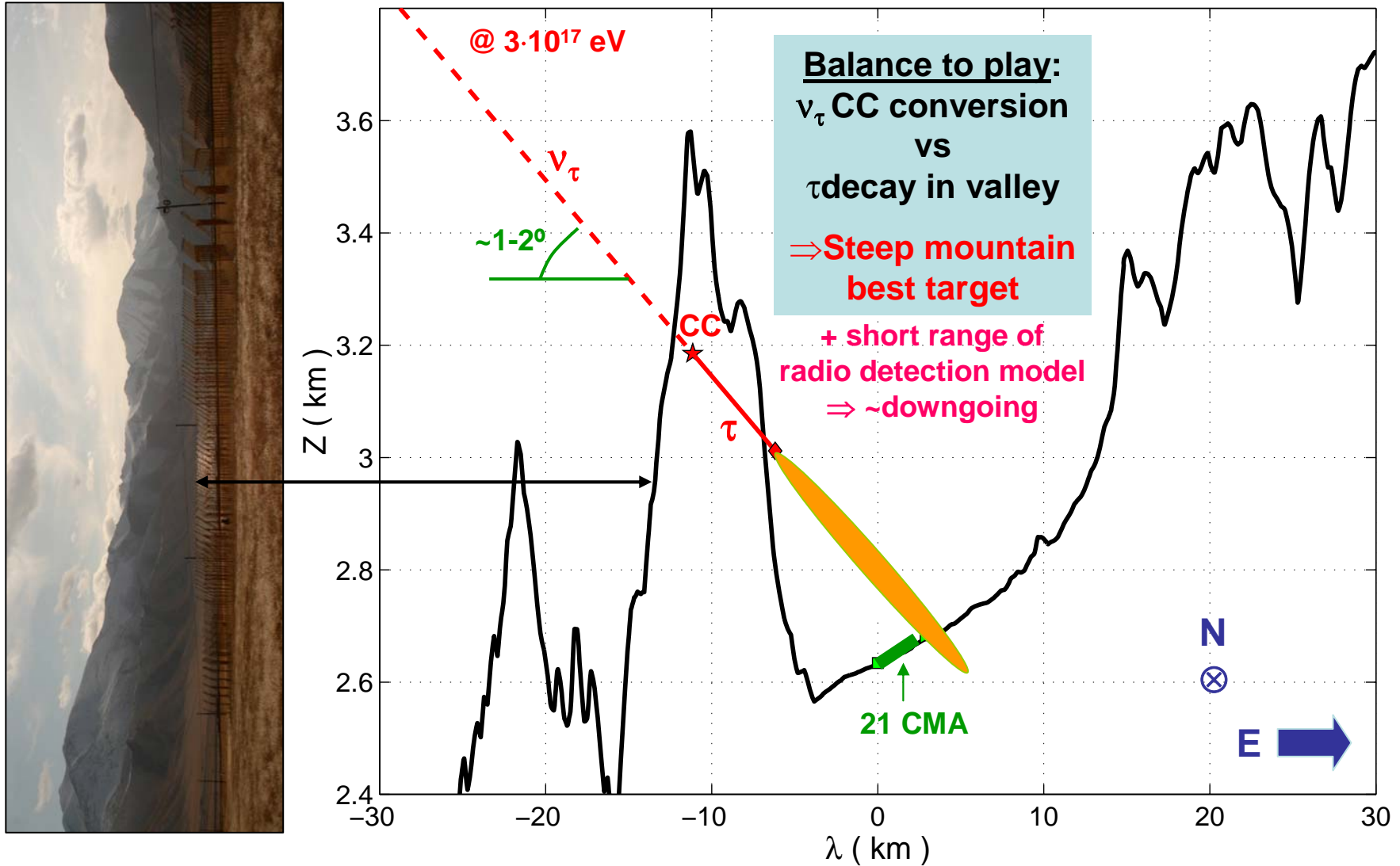
$$\text{Trigger factor} = \# \text{triggers on antenna} / \max(\# \text{triggers})$$

Trigger rates can vary by a factor of ~ 2 depending on the antenna location

The N edge of the N-S arm is a hot spot

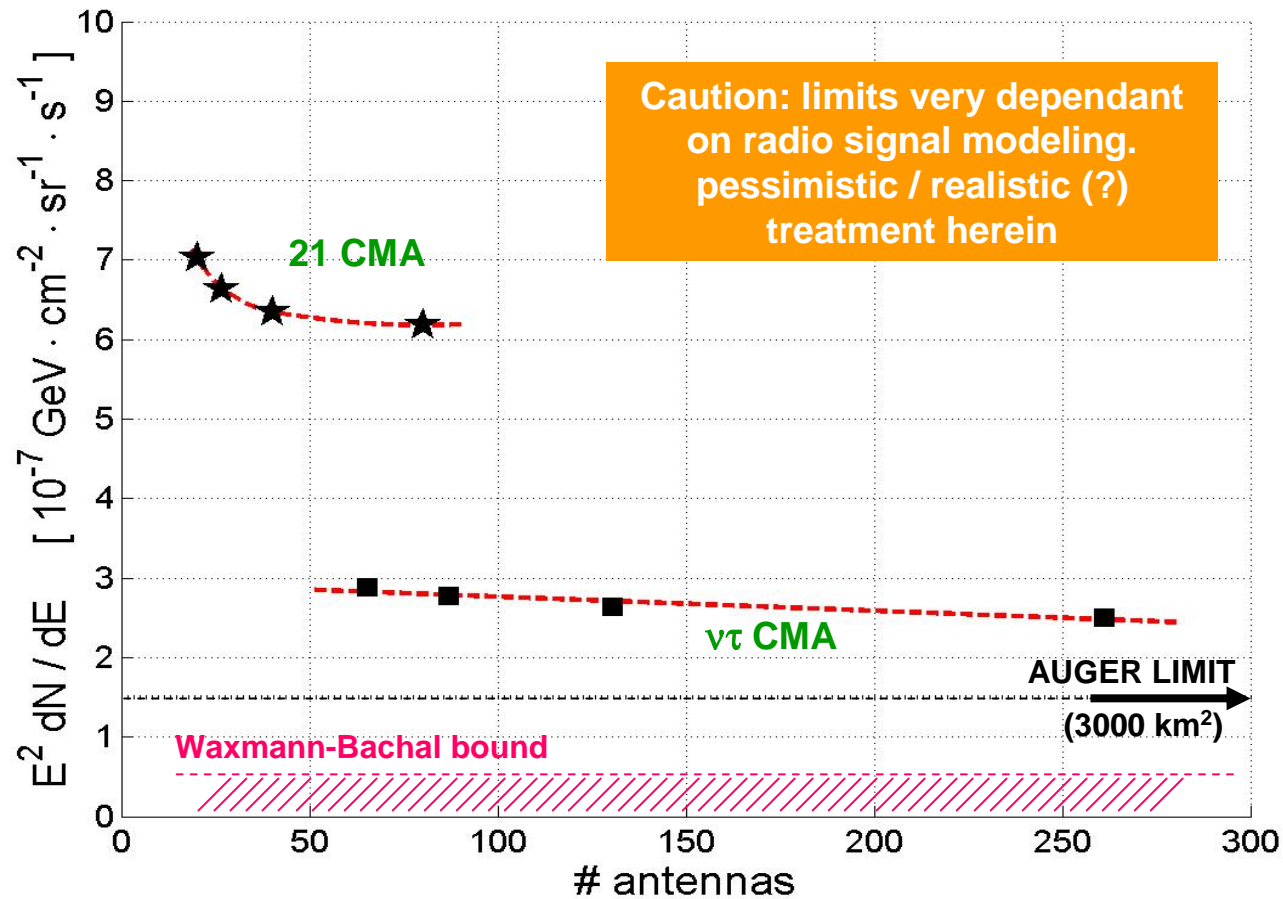


Golden Event



1/E² Flux Limits Estimates

90% CL exclusion limit on a 1/E² flux (F&C for 0 candidates and 0 background)
~3.7 year exposure to compare to AUGER limit: $1.5 \cdot 10^{-7} \cdot \text{GeV} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1} \cdot \text{s}^{-1}$



Conclusion and Outlooks

Present status and plans:

- Started October 2008 from scratch / very encouraging results.
- Sensitive antennas in low radio noise conditions: galactic plane 'out of the box'
- Complete calibration ongoing: optimising the antennas layout should improve reconstruction.

⇒ Clear radio **air showers** signals should follow soon: **expected before this summer**

⇒ Then move to **full 80 antennas** layout during **summer 09**

- French master student @ Subatech, Nantes / Stay in China (1.5 month)
- Many travels to Ulaanbaatar foreseen in the following months: calibration, 1st self triggered radio cosmics, array extension ... but ...

Funding issues on French side ... support from FCPPL eagerly required !!!

Cosmic neutrinos sensitivity:

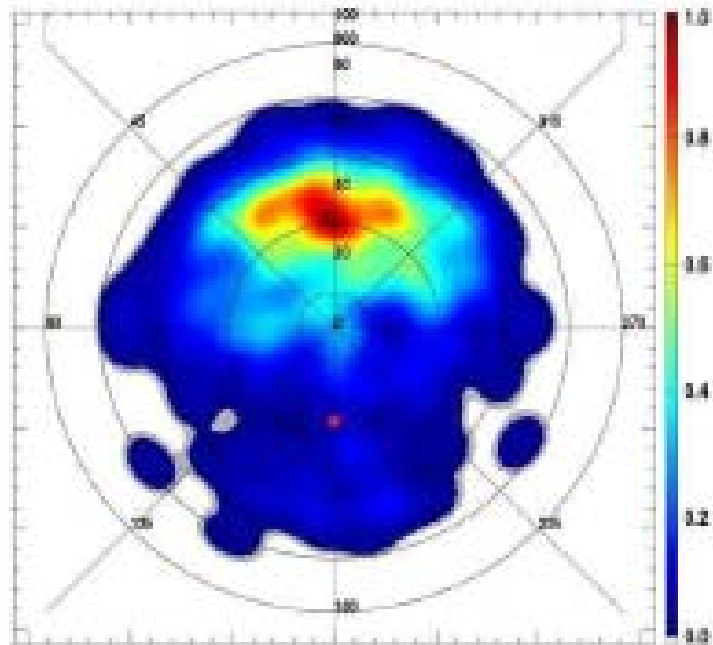
- Simulation studies show that the 21CMA location is **very efficient** for 10^{16} - 10^{19} eV ν_τ cosmic flux observations, though some **scaling** would be required to become **absolutely competitive**

No neutrinos so far but ...

Thank you for
your attention
谢谢



Clear evidence for cosmic ray detection: excess in Northern part of the sky



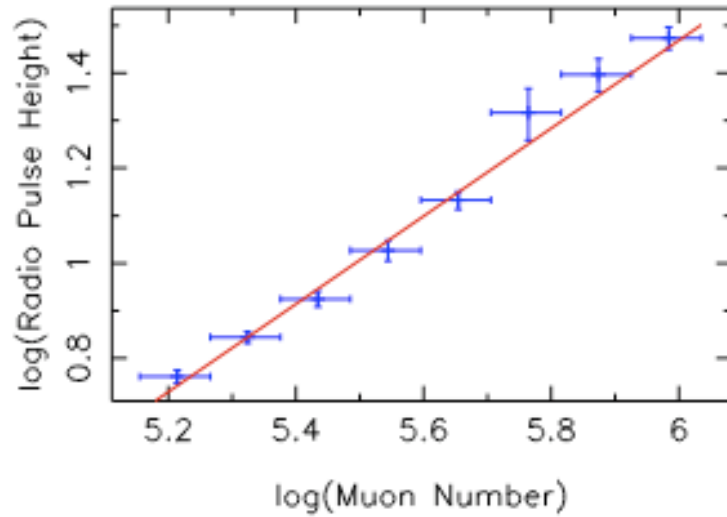
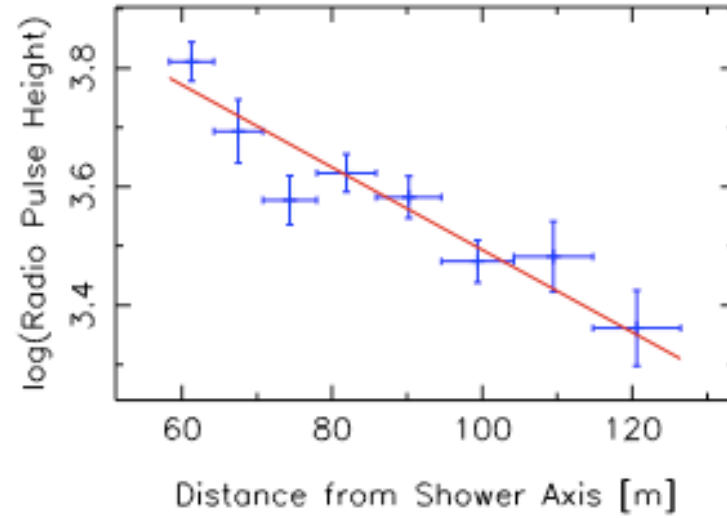
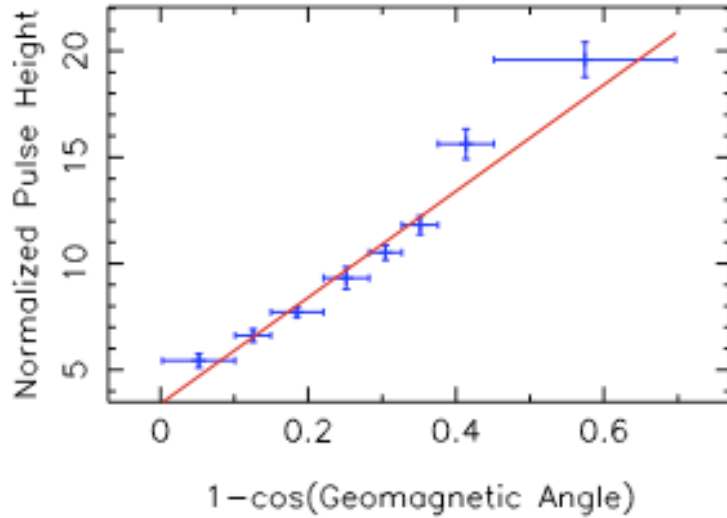
Magnetic field from South
Geomagnetic effect is the source
for radio emission (CODALMEA,
LOPES)

➔ Excess of events from
North.

Skyplot CODALEMA

If observed in 21CMA dataset, excess from North would prove that CRs are indeed observed.

The LOPES/KASCADE Parameterisation



or

