ALTA/CZELTA – A Sparse Very Large Air Shower Array: overview and recent results

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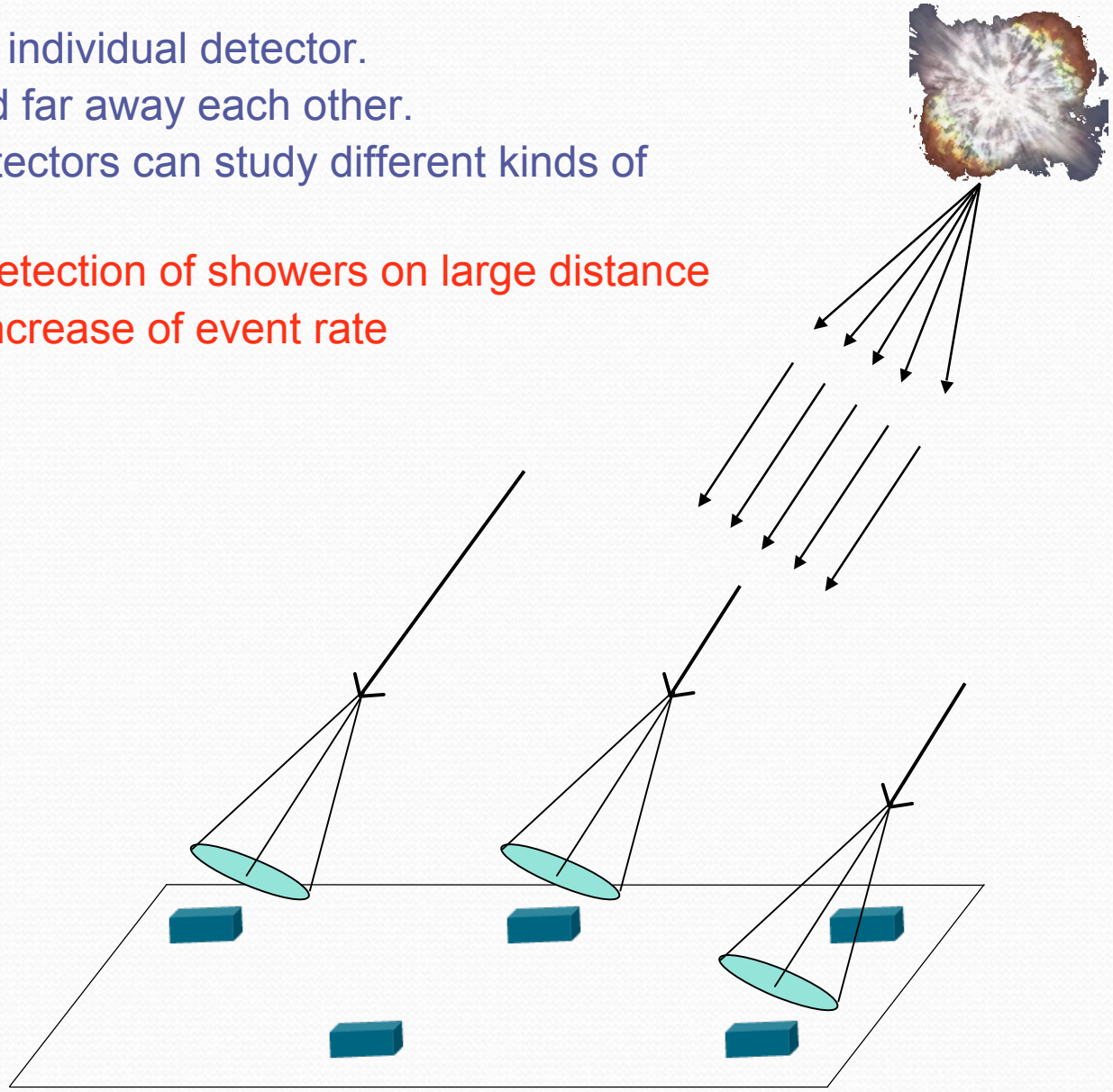
Faculty of Education, University of Turku, 3 - 6 August 2010

Sparse detector arrays

- One shower hits one individual detector.
- Detectors are located far away each other.
- System of distant detectors can study different kinds of phenomena:
  - simultaneous detection of showers on large distance
  - simultaneous increase of event rate



Sparse detector arrays - examples

North America

- ALTA – Alberta, Canada (~16)
- SALTA – Snowmass, USA
- WALTA – Washington, USA
- CHICOS – California, USA (~70)
- CROP – Nebraska, USA (~30)
- .....

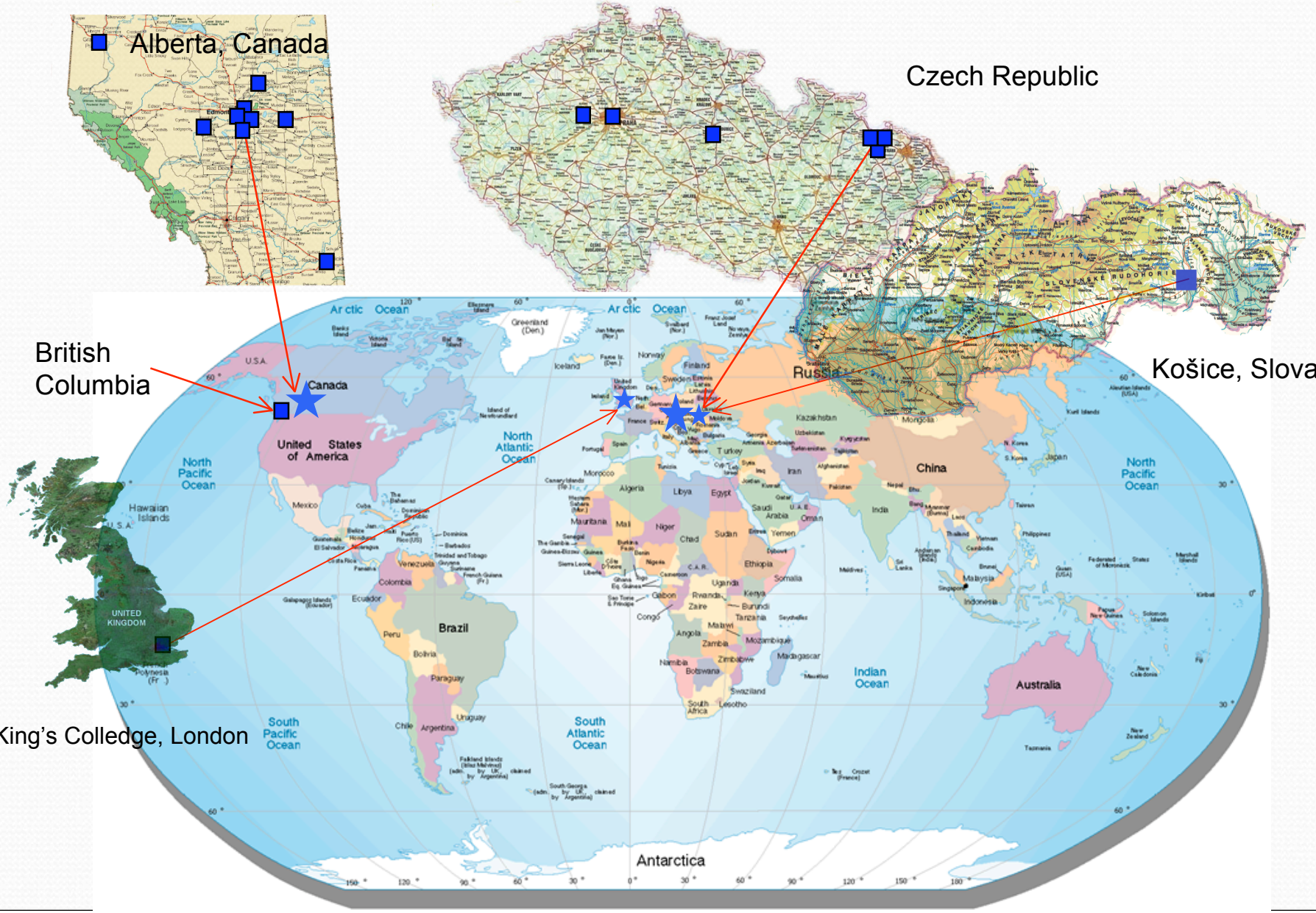
NALTA (North America Large area Time coincidence Arrays)

Europe

- HiSPARC – Netherlands (45)
- OCRE – Belgium (3)
- DUKS – Denmark (2)
- SkyView – Germany
- TRC – Portugal (10)
- CZELTA – Czech Republic (5)
- .....

EuroCosmics

ALTA/CZELTA array



Data

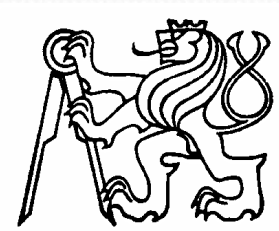
GEOGRAPHICAL LOCATIONS OF DETECTION STATIONS

ID	Name	Latitude	Longitude	τ [day]	λ [s]
1	IEAP CTU	50° 4′ 2″	14° 25′ 22″	387	39.91
2	SU	49° 56′ 16″	17° 53′ 52″	1178	42.26
3	Pardubice	50° 2′ 9″	15° 47′ 22″	731	45.50
4	Opava Mendel	49° 56′ 18″	17° 54′ 26″	660	35.95
5	Kladno	50° 8′ 26″	14° 6′ 3″	426	39.53
6	Alta BC	48° 27′ 43″	-123° 18′ 37″	98	83.87
7	O'Leary	53° 35′ 34″	-113° 28′ 30″	699	25.07
8	O'Brien	53° 32′ 8″	-113° 25′ 37″	998	28.34
9	Trinity	53° 27′ 27″	-113° 26′ 35″	1006	25.79
10	MacDonald	53° 33′ 10″	-113° 34′ 1″	1144	22.64
11	Maddock	53° 13′ 6″	-114° 57′ 50″	719	19.82
12	Thorhild	54° 9′ 11″	-113° 6′ 43″	716	26.78
13	G. Prairie	55° 10′ 56″	-118° 48′ 36″	1133	30.66
14	Norbuck	53° 31′ 41″	-113° 31′ 33″	913	6.19
15	Vegreville	53° 29′ 56″	-112° 4′ 26″	977	27.29
16	Med. Hat	50° 3′ 17″	-110° 41′ 6″	494	26.34
17	Phys. Roofe	53° 31′ 41″	-113° 31′ 34″	284	24.21
18	Laurent	53° 28′ 46″	-113° 31′ 23″	585	24.46
19	Page	53° 27′ 24″	-113° 26′ 46″	345	25.91
20	McNally	53° 32′ 54″	-113° 27′ 32″	455	24.17
21	Beaumont	53° 20′ 56″	-113° 25′ 23″	713	23.99

- The first really global sparse network.
- Almost identical hardware, identical data format.
- Data available from one web-based interface.

ALTA/CZELTA

- Alberta Large-area Time coincidence Array
  - Univ. of Alberta, Canada
- CZEch Large-area Time coincidence Array
  - Czech Technical University in Prague
  - Silesian University in Opava, Czech Republic

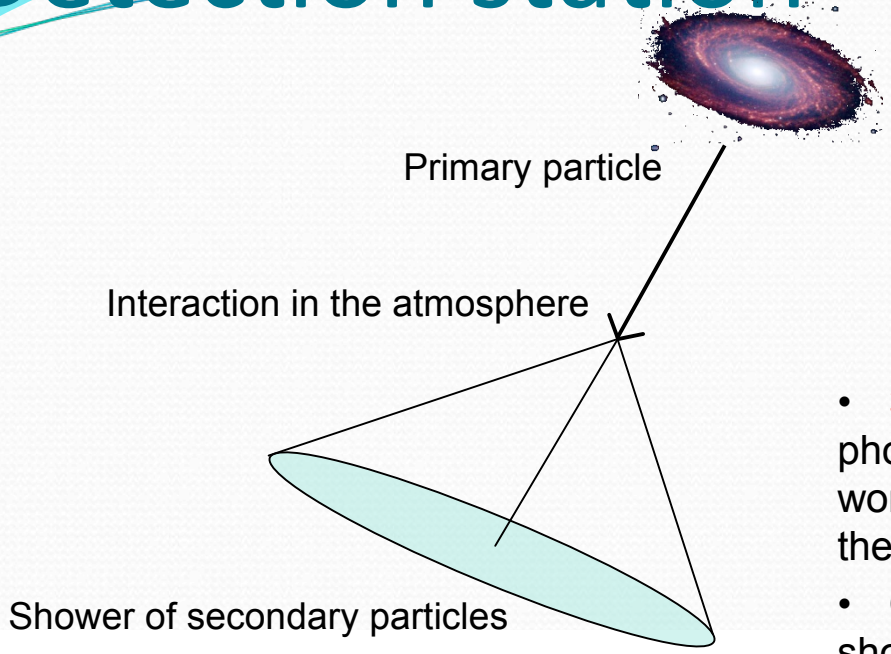


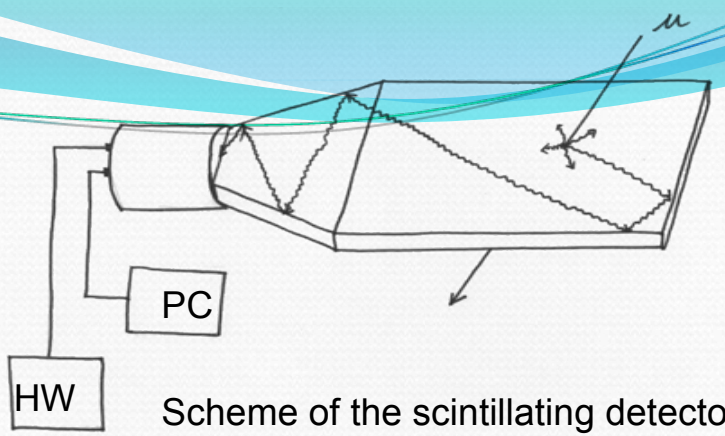
- The sparse network for the detection of high energy cosmic rays (>10^{14} eV).
- Stations are installed at roofs of high schools -> educational impact.
- At present, 21 running detection stations.

- We build the global network of detection stations on the Earth = huge „telescope” for detection of cosmic rays showers.

Detection station

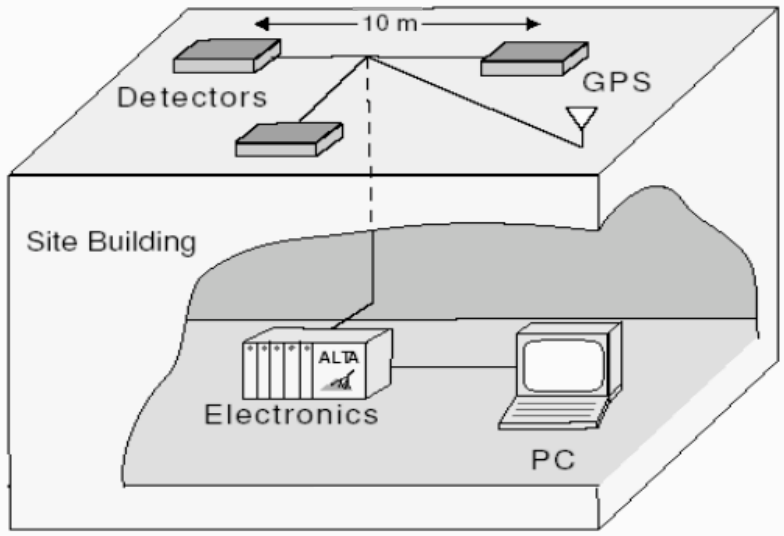
Detection station

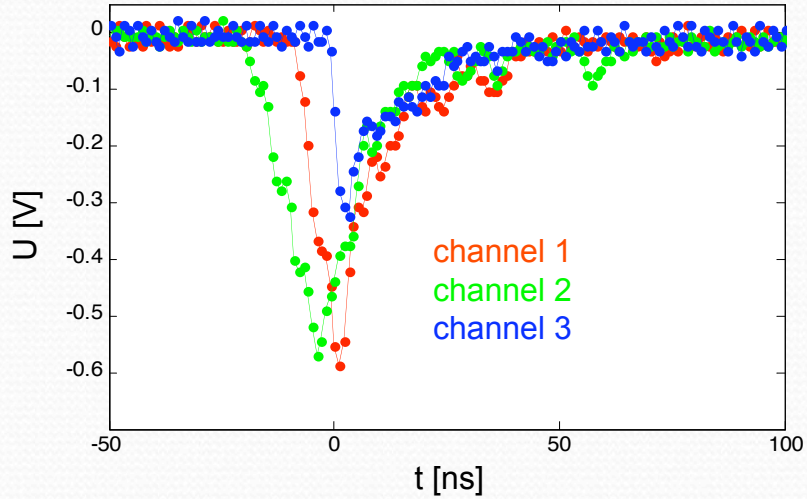




Scheme of the scintillating detector

- 3 scintillators (60 x 60 x 1.5 cm) with photomultipliers in a triangle with a site ~10 m, work in a coincidence => detection of showers with the energy > 10^{14} eV.
- GPS for precise time-labeling of detected showers (precision ~16 ns) => it is possible to study space and time coincidence of the detected showers.

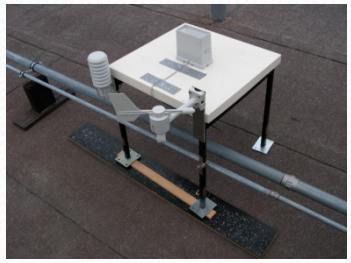




Hardware of the detection station

GPS antenna

Thin metal tube
with cable 230 V

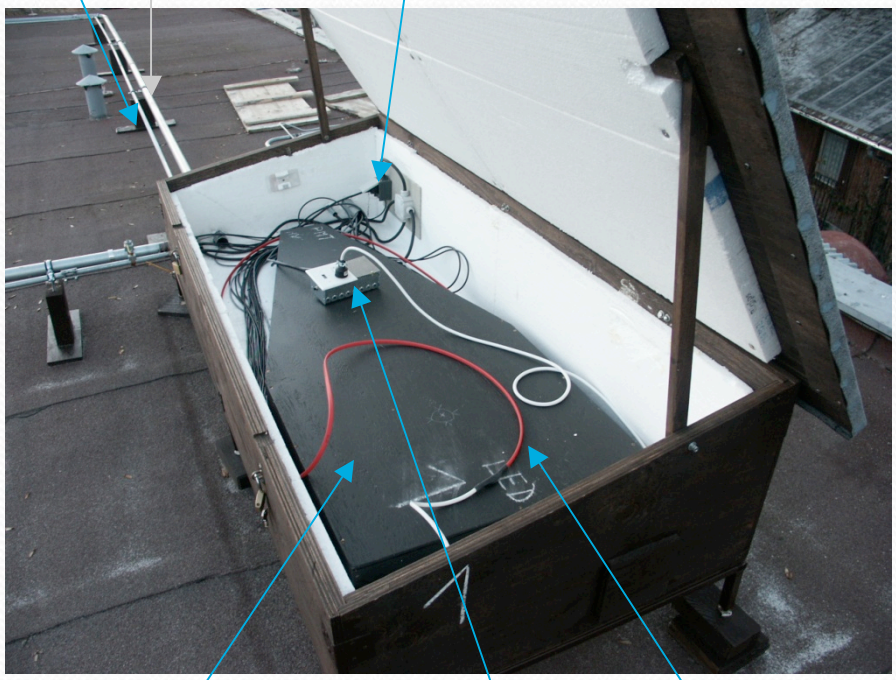


Meteorological station

Metal tube with other cables:
- high voltage for photomultiplier
- signal cables from photomultiplier
- cable to testing LED diode
- cable for controlling of thermostat

Socket of 230 V (heating)

Outer box
with temperature insulation

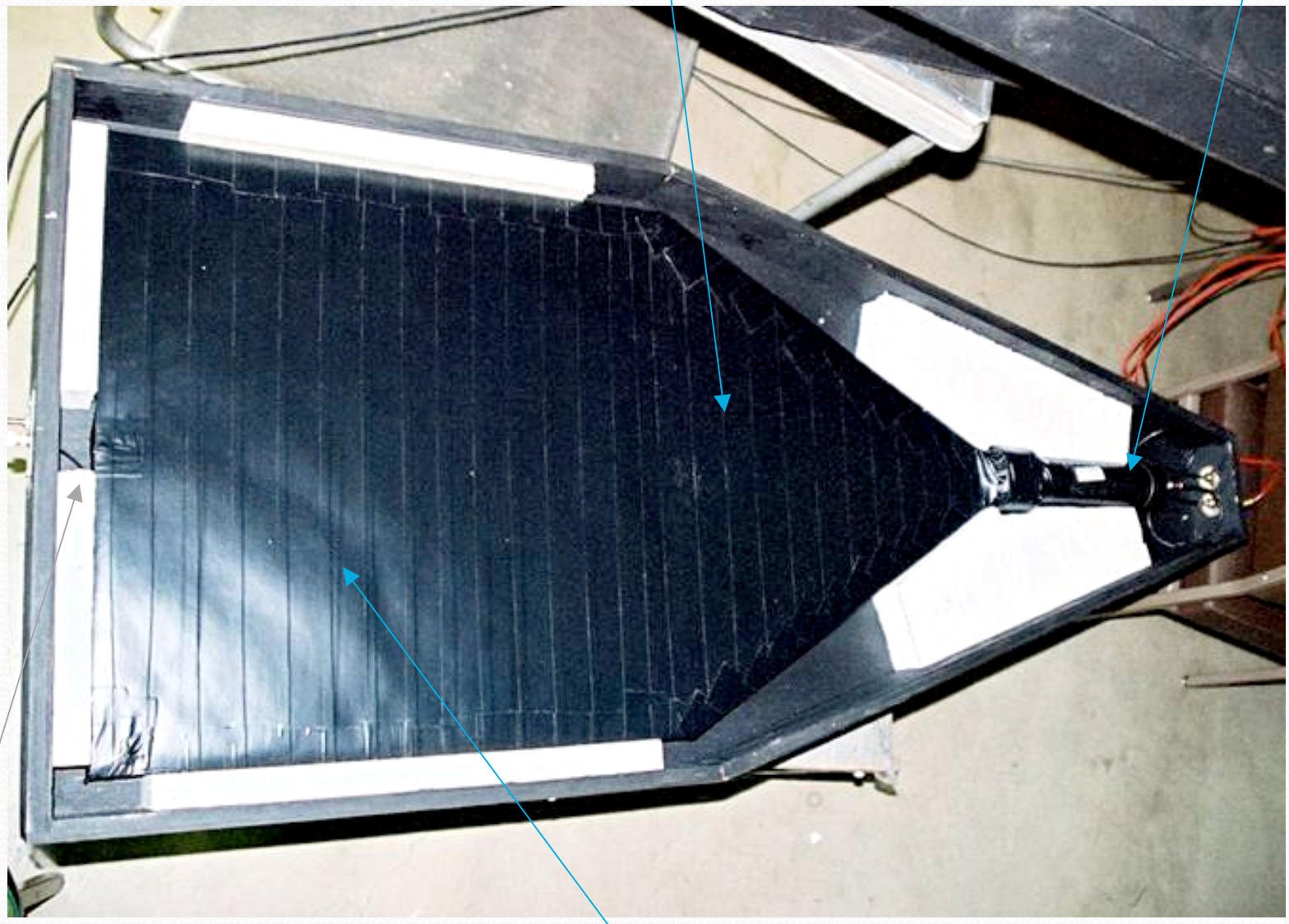


Wooden box
With scintillating detector

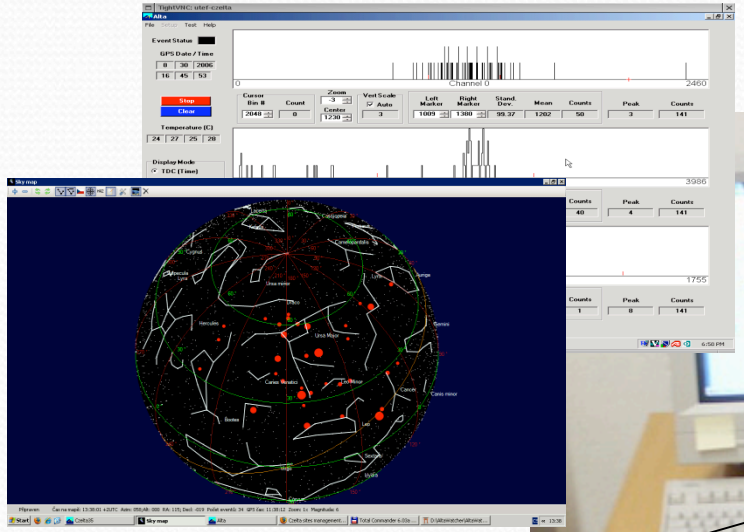
Thermostat

Heating cable

Detector


Light guide
Photomultiplier
Testing LED diode
Scintillator

Electronics

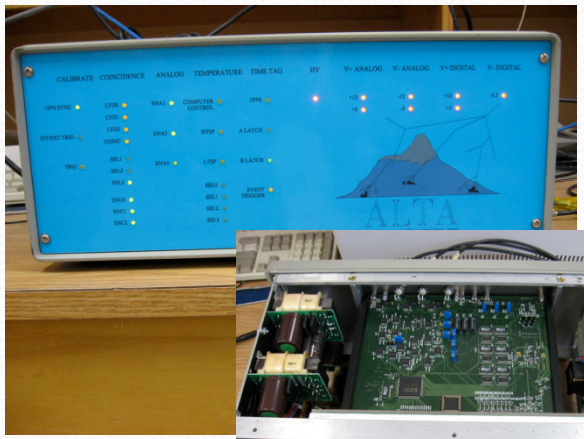


Crates

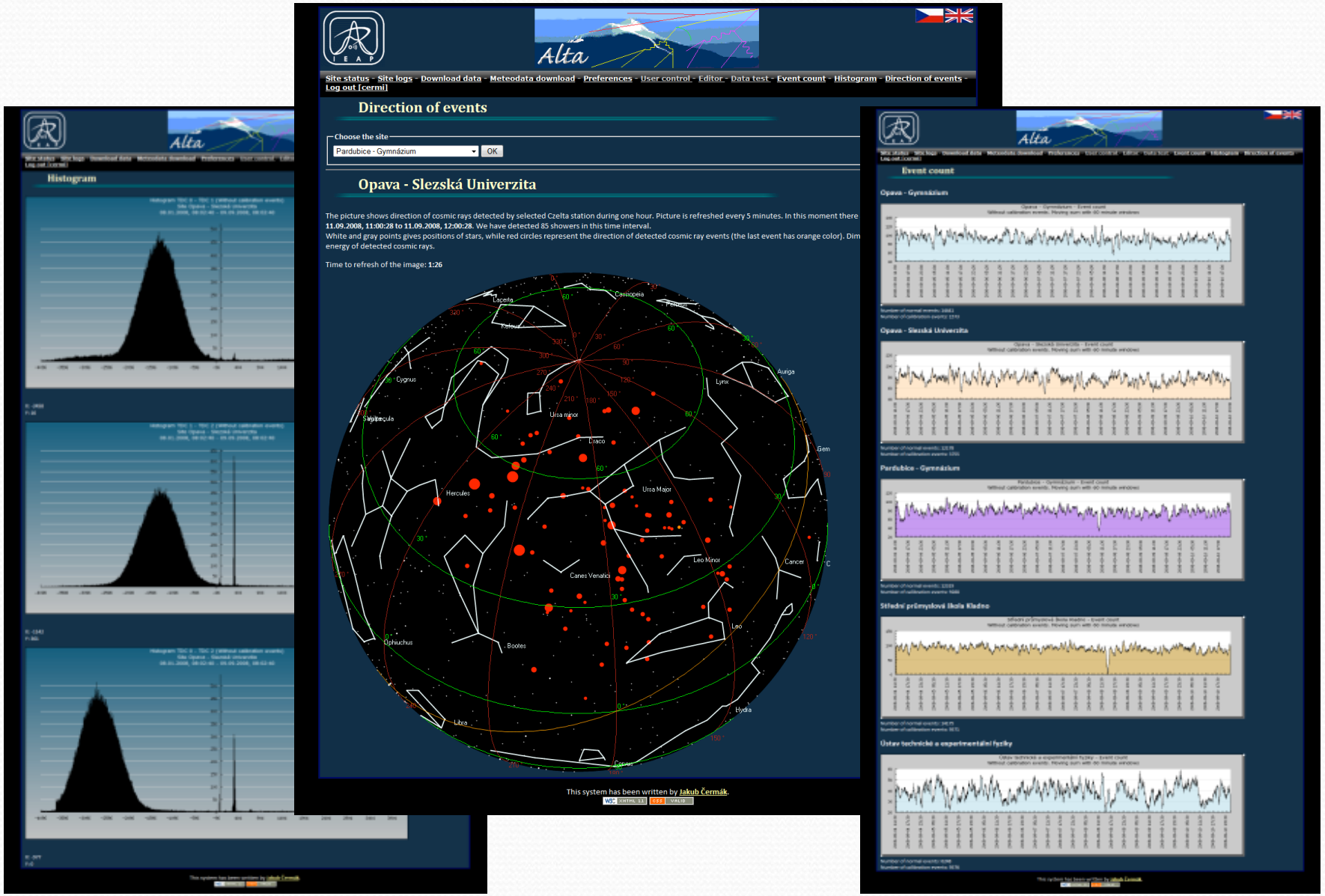
GPS receiver

UPS

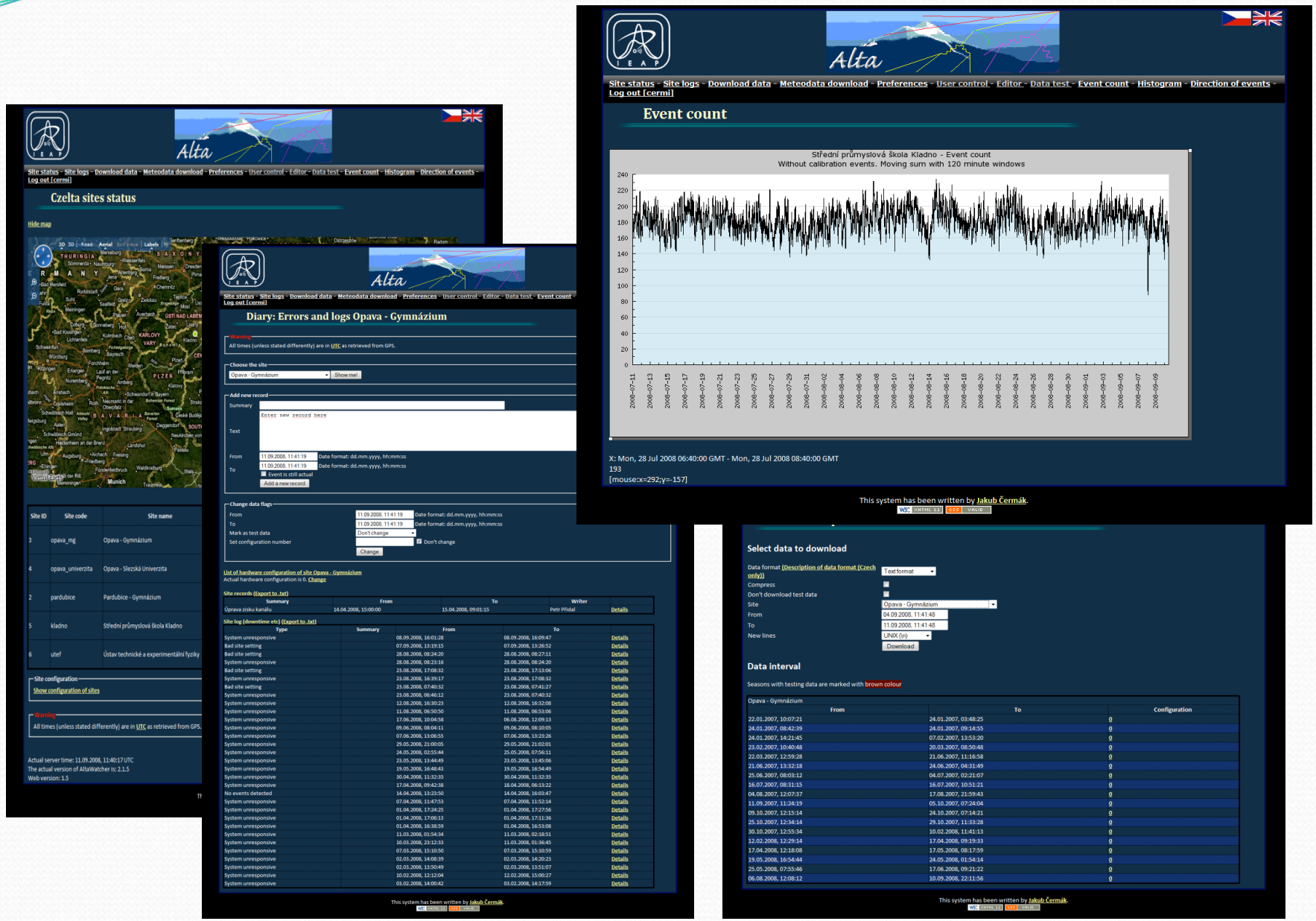
PC



Web-based interface



Web-based interface

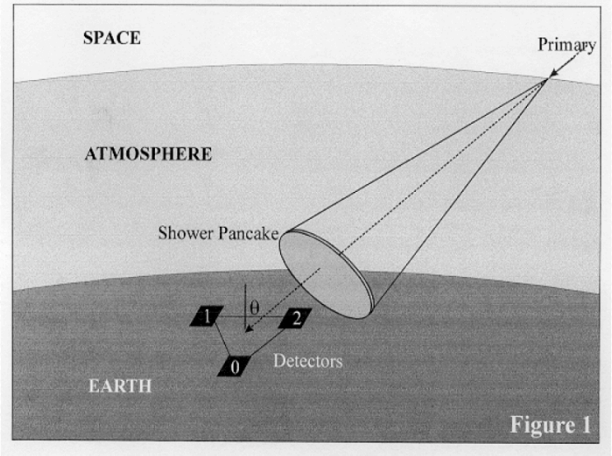


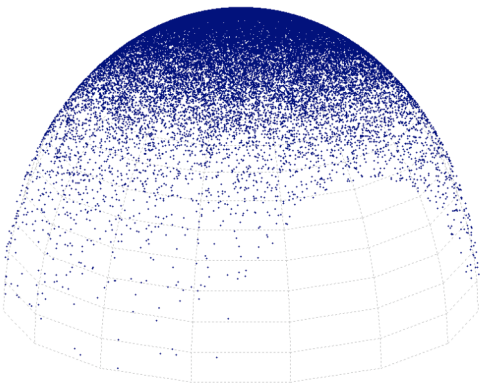
Properties of the station

- The timing resolution of the GPS time difference between distant sites: ~16 ns.

We can study time correlations of showers on large area.

- It is possible to reconstruct the direction of the flight of a primary particle.
  - ✓ Uncertainty of reconstructed zenith angle θ of a primary particle:
    $\delta\theta = 4°/\cos(\theta)$
  - ✓ Uncertainty of reconstructed azimuth angle φ of a primary particle: $\delta\varphi = 5°$

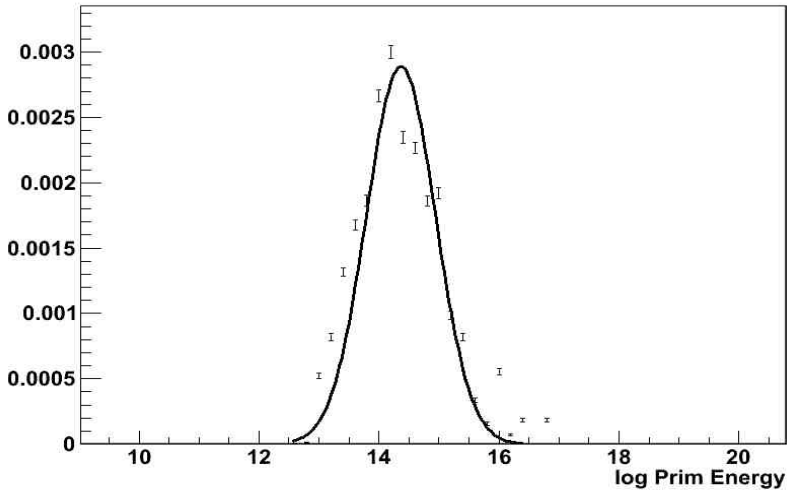




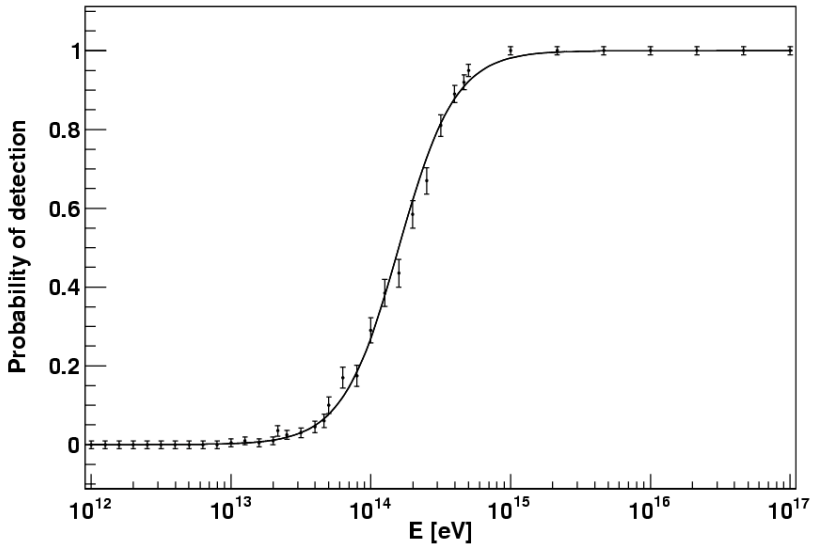
Properties of the station – Corsika simulations

- Mean energy of primary particles producing detectable showers: $2 \cdot 10^{14}$ eV
- Event rate: ~1/30 s^{-1}

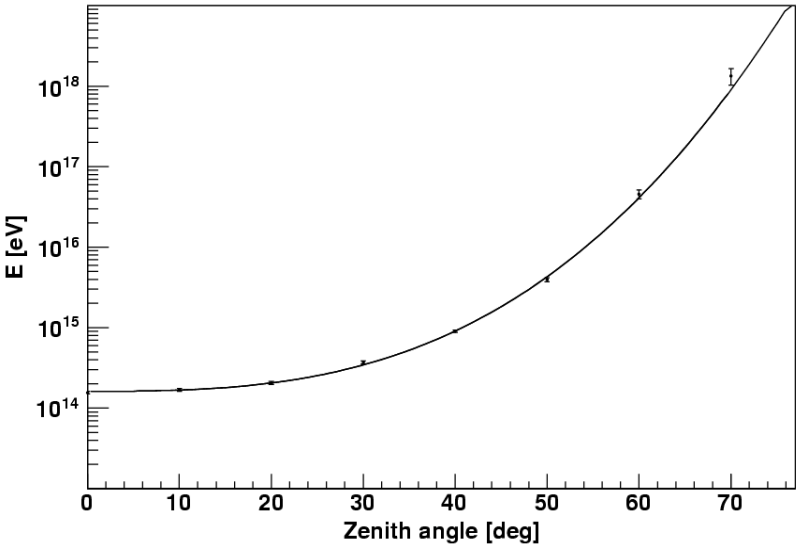
Spectrum of detected showers



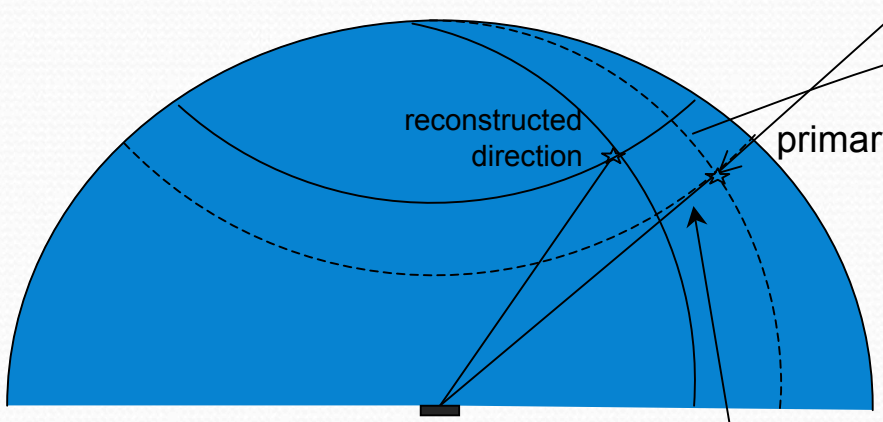
Probability of detection
(perpendicular showers aimed to the center of the triangle)



Minimal energy of primary particle
(showers aimed to the center of the triangle)

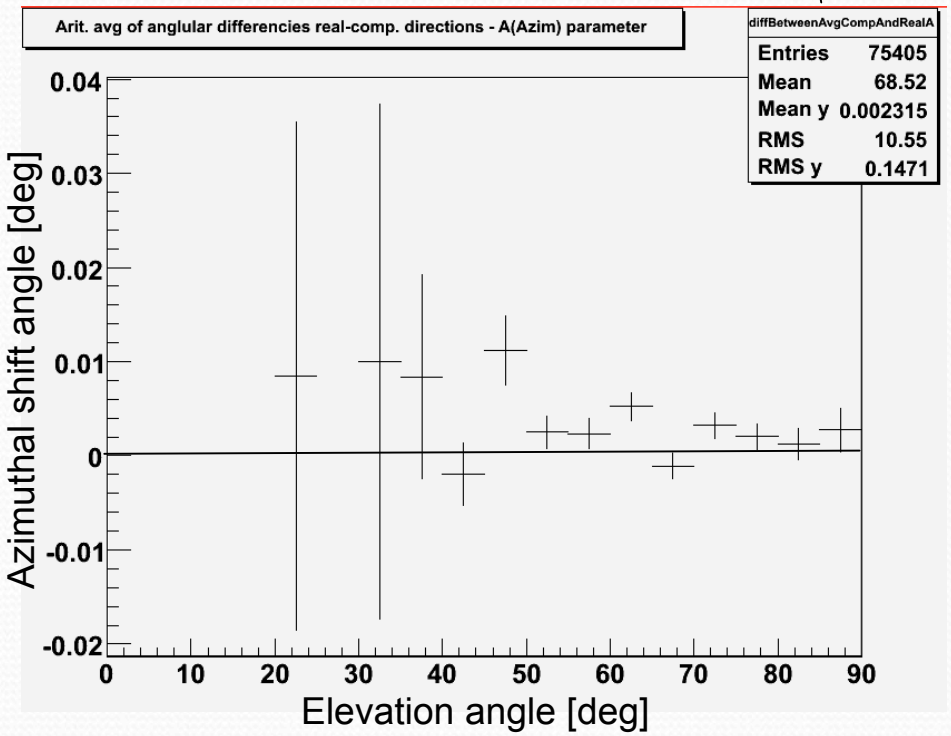


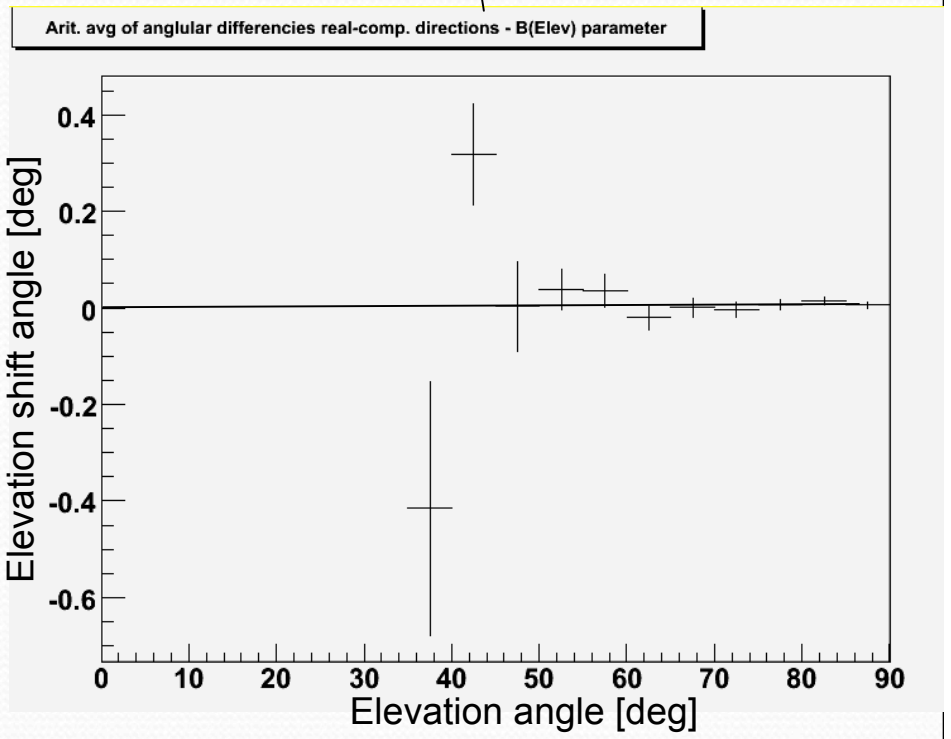
Simulations – error of direction



No shift

Estimation of error of TDC caused
by electronics: ~1.5 ns





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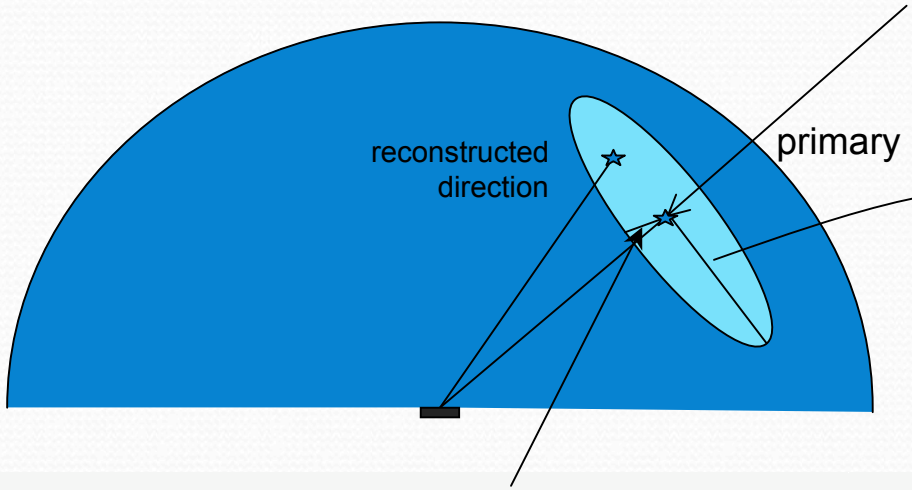
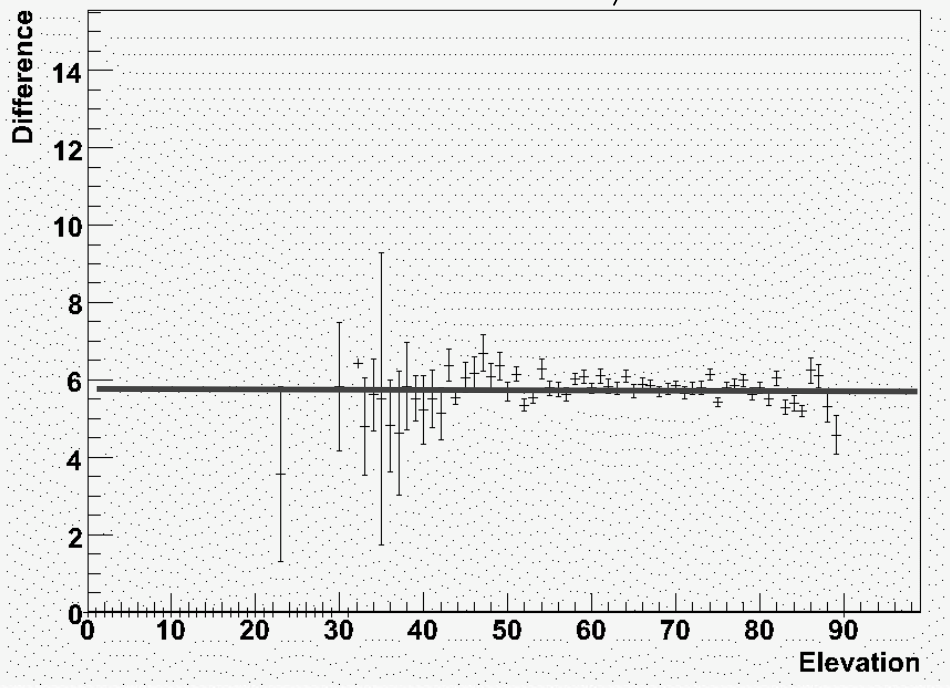
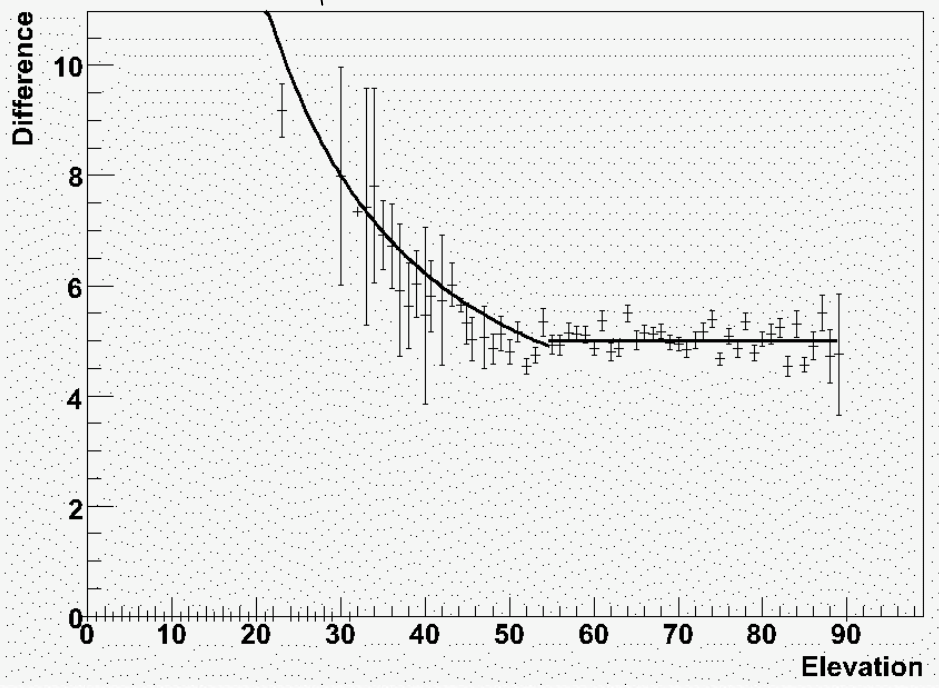


Estimation of error of TDC caused by electronics: ~1.5 ns

The direction of most of showers is measured with the precision of 5-6°.

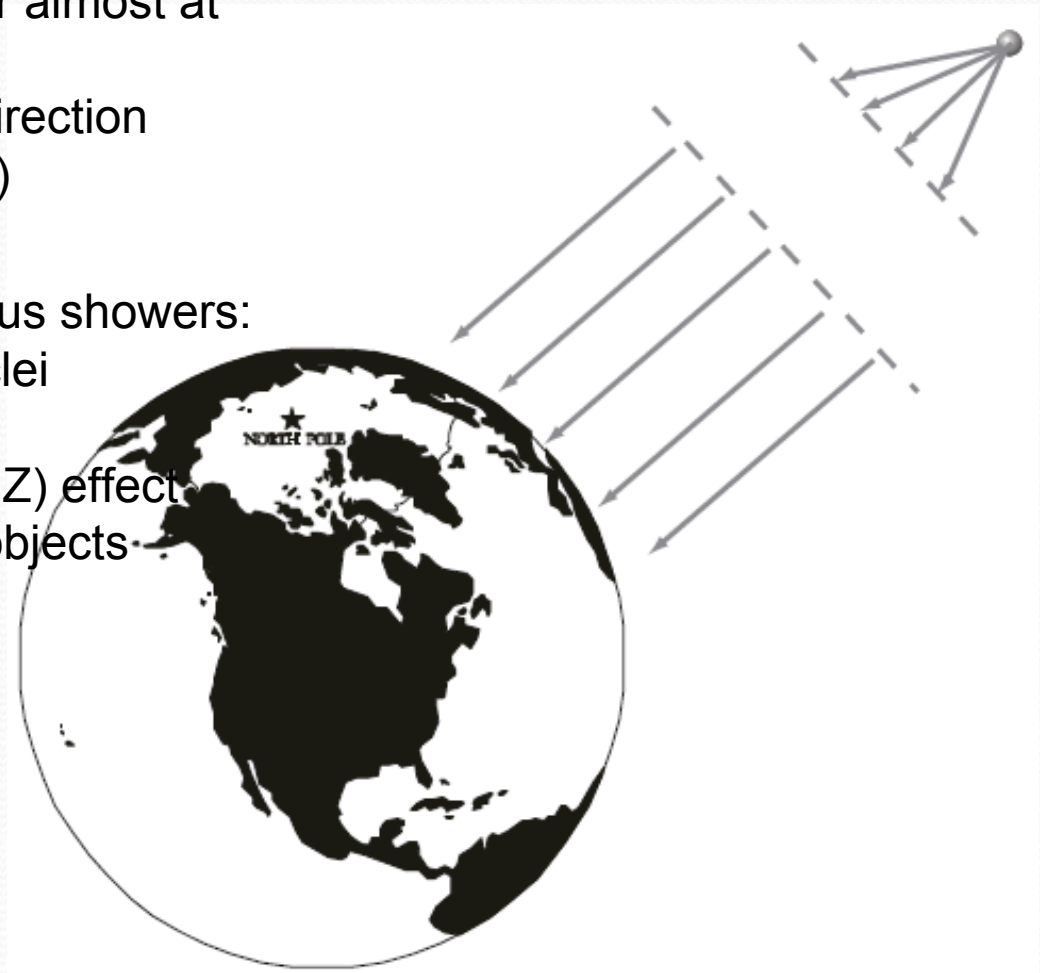




Correlated Showers

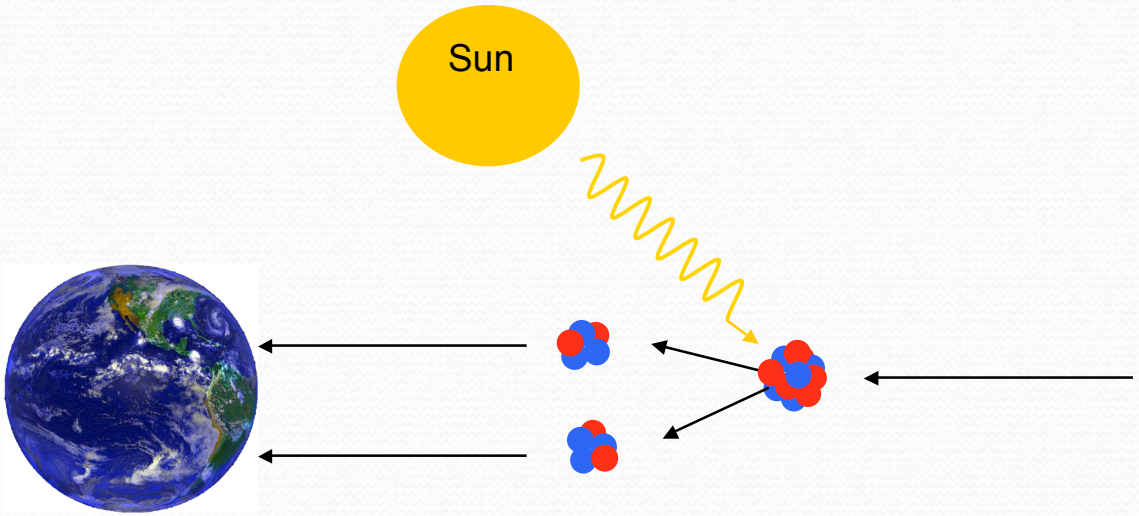
- Correlated showers are:
  - simultaneous – they apper almost at the same time
  - allign – they have same direction (within measurement error)

- Potential sources of simultaneous showers:
  - Photodisintegration of nuclei in the Solar system - Gerazimova-Zatsepin (GZ) effect
  - Decay of massive exotic objects
  - ???



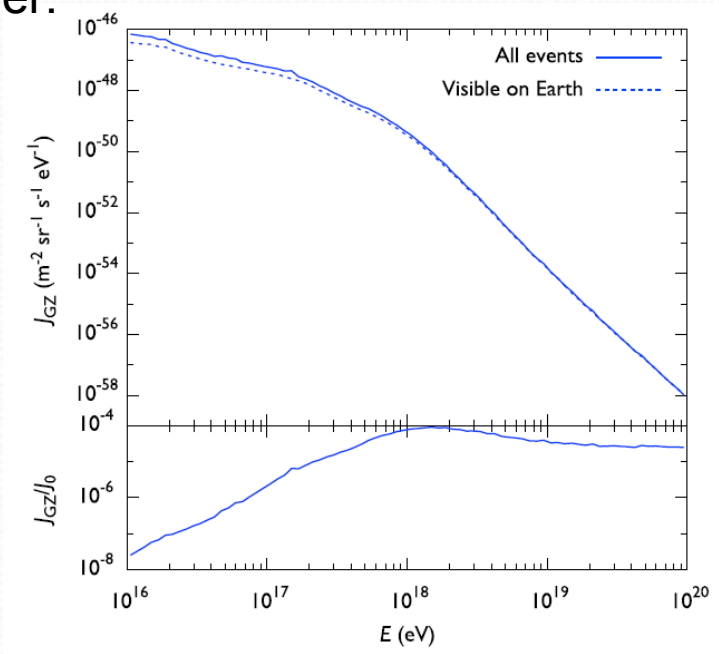
Gerasimova-Zatsepin effect

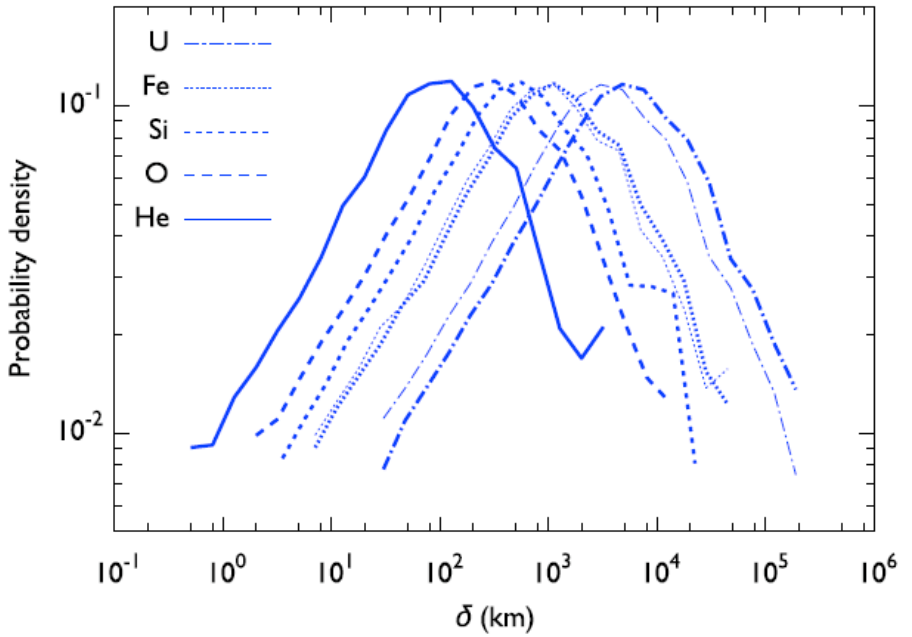
- GZ effect - good “non-exotic” candidate of sources of correlated events
  - ➢ The solar radiation field may break ultra-high-energy cosmic nuclei apart, after which both remnants will be deflected in the interplanetary magnetic field in different ways.
  - ➢ We could observe correlated air showers at large distance (hundreds or thousands of km)



Gerasimova-Zatsepin effect

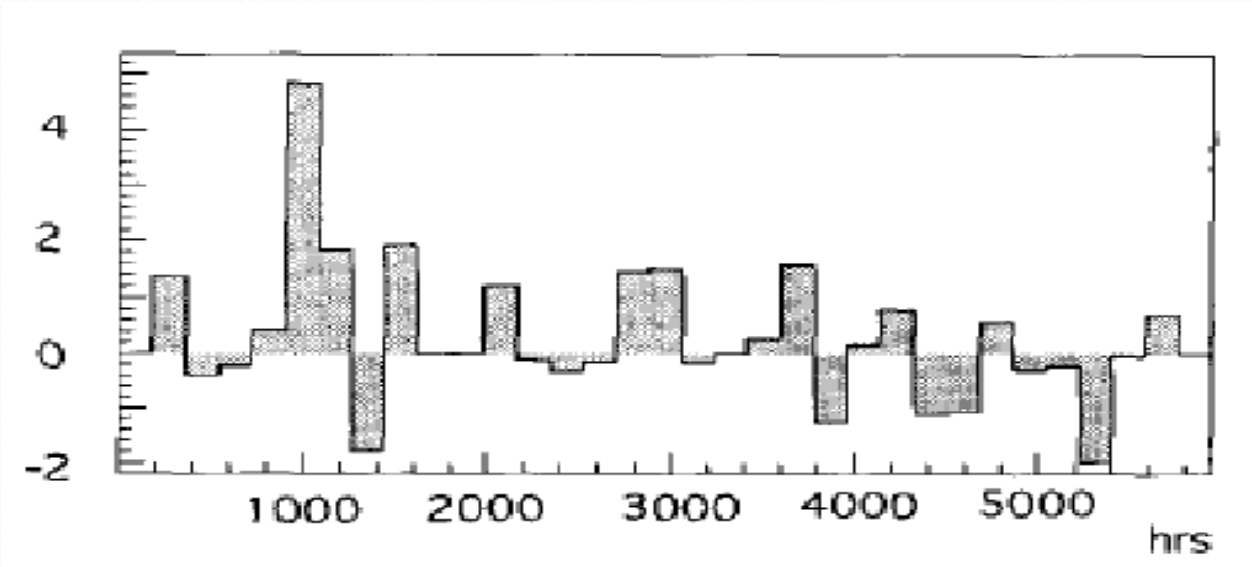
- S. Lafebre et al., Astronomy & Astrophysics (2008) – estimated correlated event rate for various primaries with $E > 10^{16}$ eV.
  - ➢ The fraction of GZ events is found to be of the order 10^{-5} of the c. ray flux.
  - ➢ Correlated event rate of around 0.07 km^{-2} sr^{-1} yr^{-1}.
  - ➢ Separation of showers depends on the energy and kind of the primary particle (number of nucleons in the nucleus) – can vary from hundreds of meters to thousands of km.
- For lower energies, the probability of the detection of correlated events could be higher.





Reported events

- D. J. Fegan et al., Phys. Rev. Lett. V51, No 25 (1983) p. 2341.
  - ➢ simultaneous increase of shower rate measured with two stations separated by 250 km.
- O. Carrel and M. Martin, Phys. Lett. B325 (1994) p. 526.
  - ➢ 4 detectors across Switzerland.
  - ➢ Reported simultaneous detection of showers.
- N. Ochi et al., J. Phys. G, 29 (2003) p. 1169.
  - ➢ LAAS (Large Area Air Shower) – 8 compact detection arrays across Japan.
  - ➢ Reported 3 almost simultaneous showers with similar directions.



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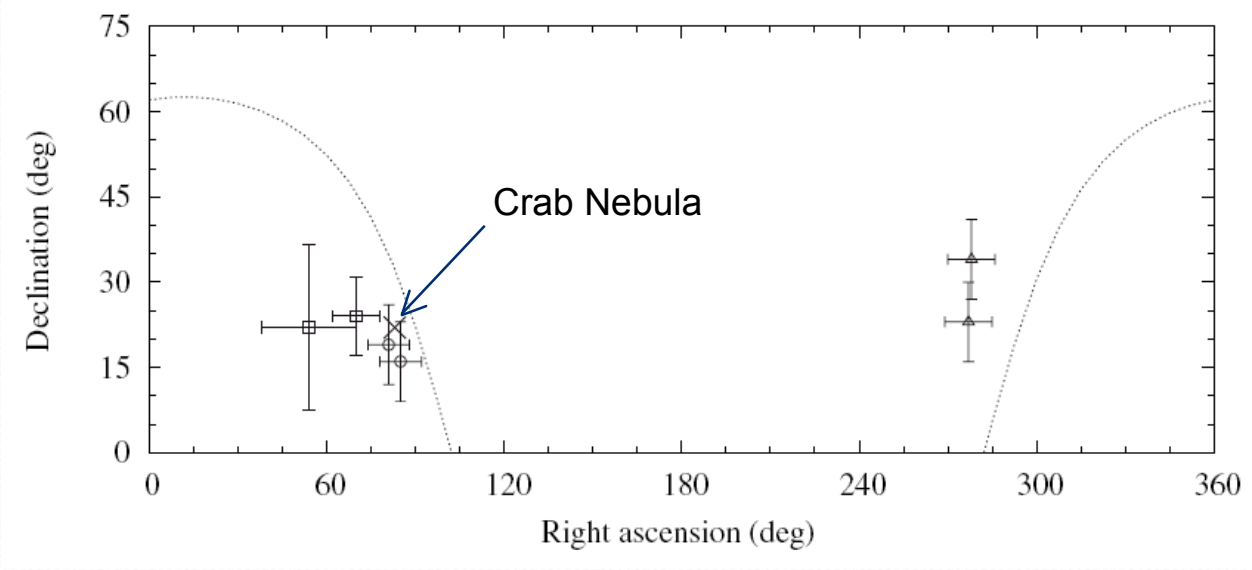
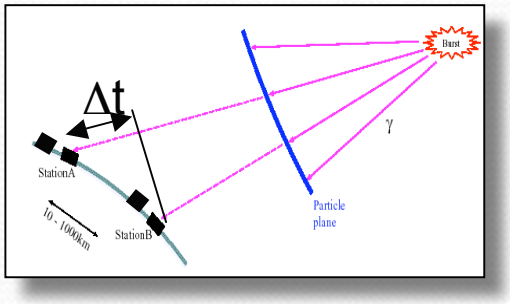


Search for correlated showers

• We search for pairs of showers from different stations coming in a short time window. No information of direction of showers was used.



• Data from 21 stations (ALTA+CZELTA) analysed.

• Double-coincidences on large distances

➢ No significant excess of coincidences.

➢ Bayes estimation of the event rate of the non-background coincidencies using data from all pairs of stations:

$f < 2.6\ yr^{-1}$ (c.l. 95%)

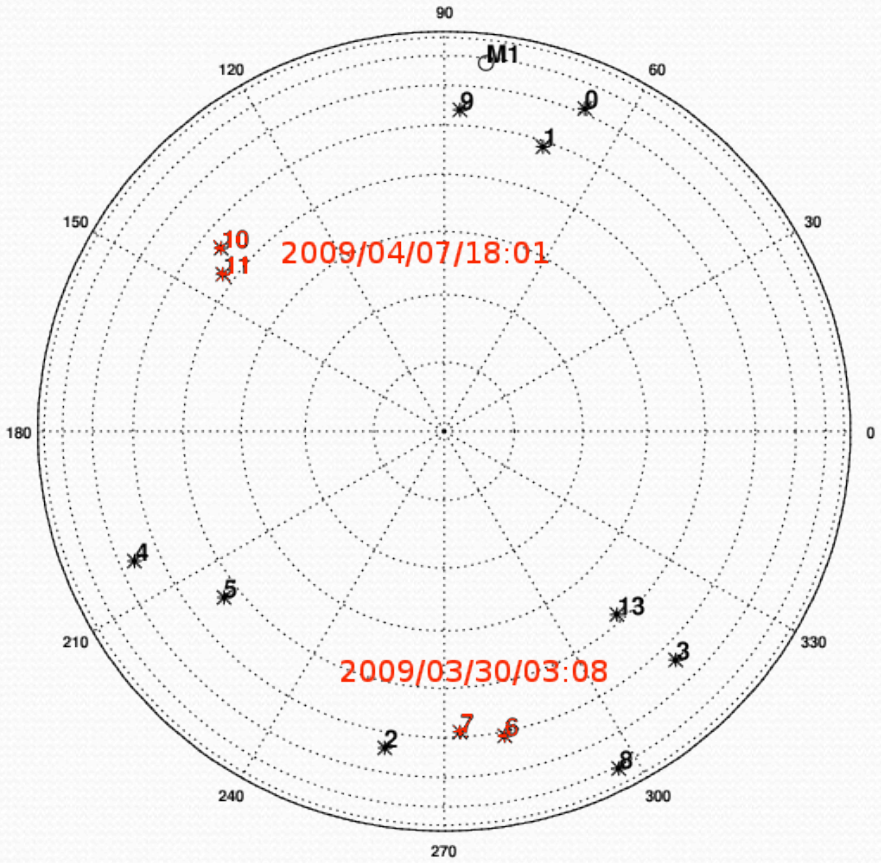
• Tripple-coincidences on large distances

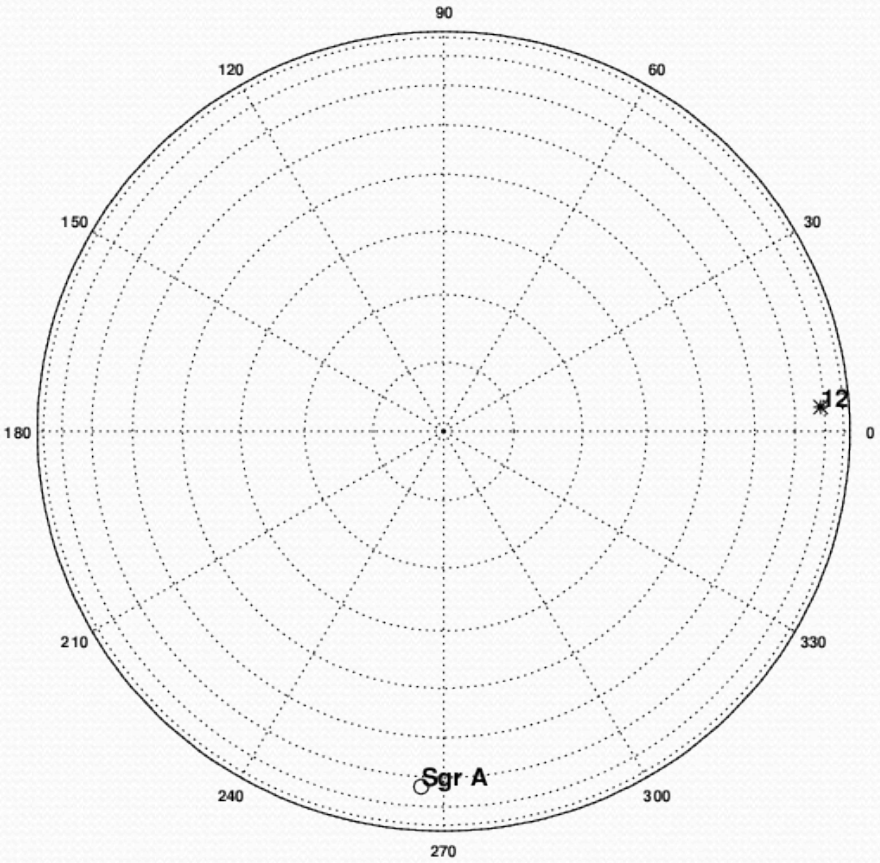
ID_1 & ID_2 & ID_3	$Dist_{12}$ / $Dist_{13}$ / $Dist_{23}$ [km]	Time	τ [day]	t_{12}^{obs} / t_{13}^{obs} / t_{23}^{obs} [ms]	n_{exp}	p-value
1 & 9 & 15	7110 / 7050 / 90	2005/01/08/02:23:34	171	15.7 / 15.5 / 0.2	0.17	0.16
11 & 14 & 16	90 / 450 / 420	2004/06/05/03:48:08	366	0.1 / 0.4 / 0.3	0.0028	0.0028

➢ No significant excess

Search for correlated showers

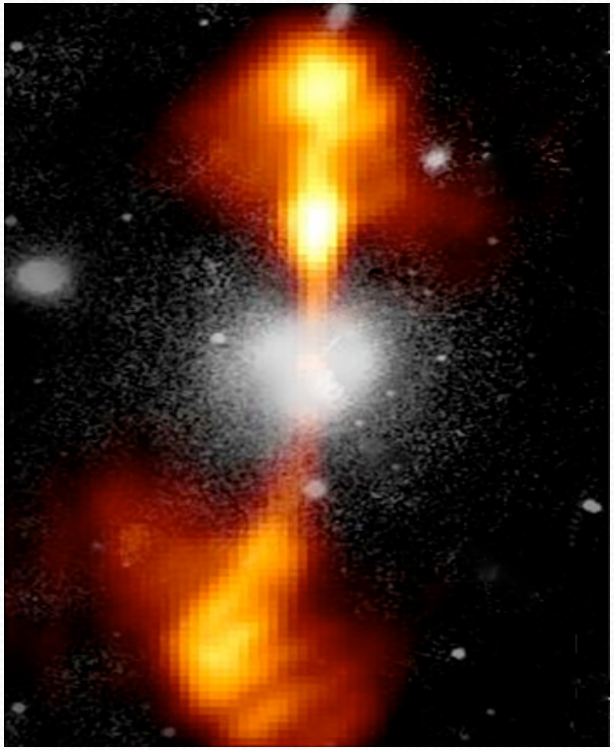
- We analysed time-correlated pairs also for angular correlation. We used cuts for maximal angular deviation ranging from 5 to 10 degrees.
- Following results are only for CZELTA stations.
- We found two interesting events correlated over 300 km.





Other interesting events

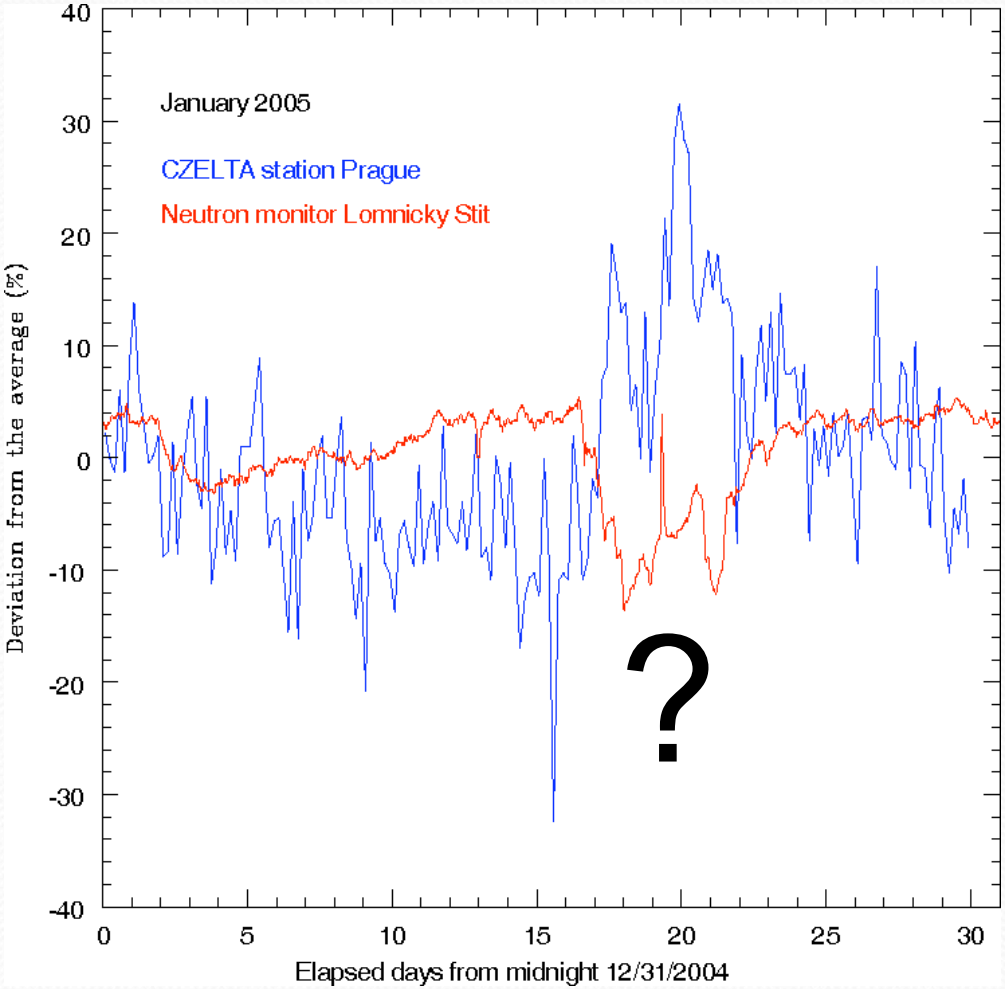
- 14.7. 2007 in 4:59:29 UTC gamma burst GRB 070714A was observed.
- The same day at 5:00:03 UTC we detected a shower, whose position on the sky was 6° far from GRB. The statistical probability of the random event in this short time interval and with this distance from the exact position of the GRB is 0.5%.
- Nice example of work of students from high school.



?

Other interesting events

• Interesting anticorrelation between the flux of high energy showers measured by the station in Prague and the flux of neutrons in the low energetical component of the cosmic rays measured by the neutron monitor at Lomnický Štít in Slovakia.



• Interesting cluster of events

20.1.2005 - 20:32:25

20.1.2005 - 21:10:54

- the rate was increased 1.5x from average!

Conclusion

- ALTA/CZELTA is the first really global network for detection of high energy cosmic rays (all sub-networks use the same hardware, all data are available on-line from one web-page).
- Precise measurement of time => the project is designed for study of correlations of showers on very large distances.
- Secondary purpose of the project is to attract young students from high schools to physics, mathematics and computer sciences.

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Thank you for your attention!