Space fluorescence detectors TUS/KLYPVE for study of UHECR .

(Italian-Russian seminar on space detectors)

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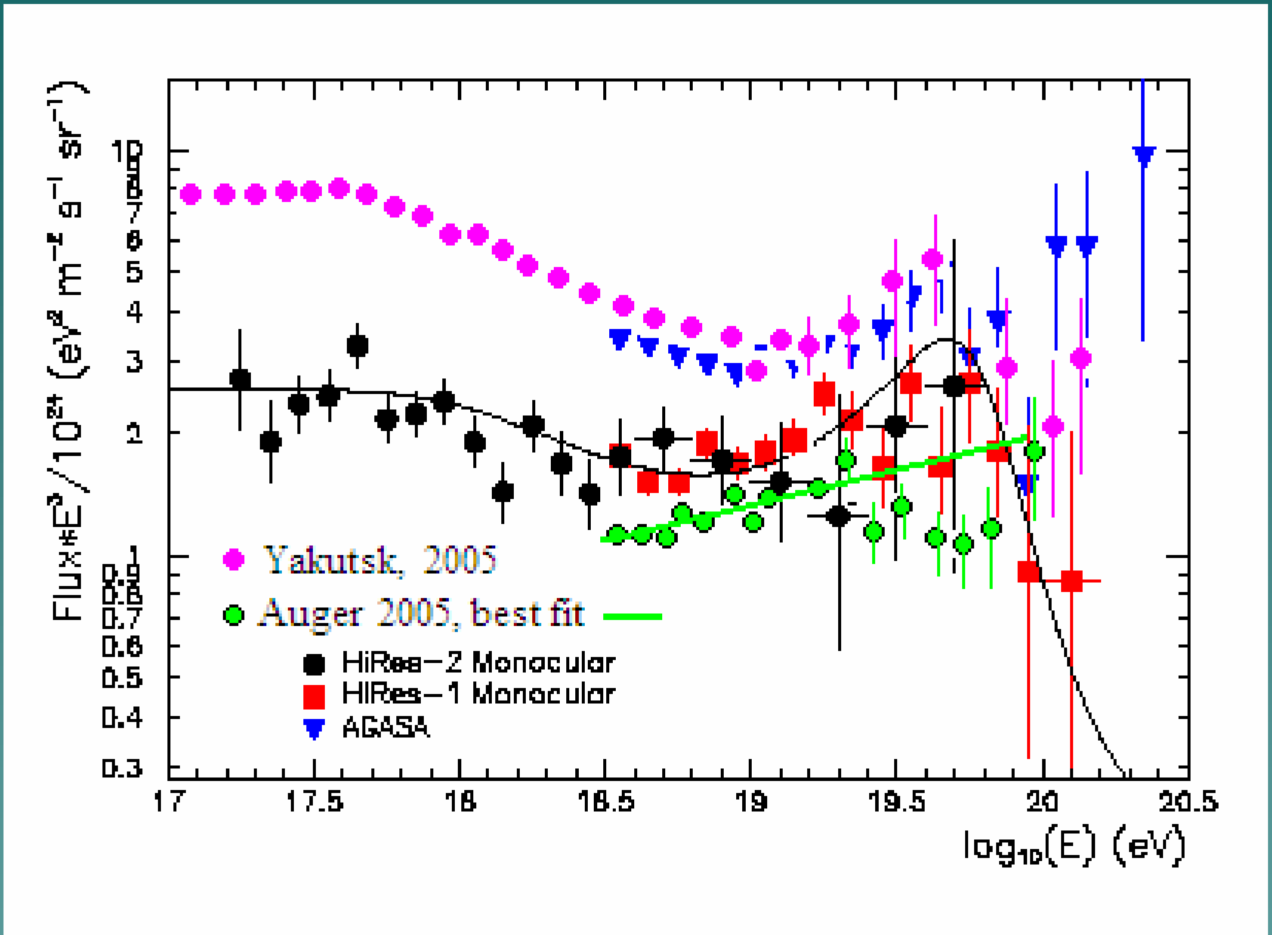
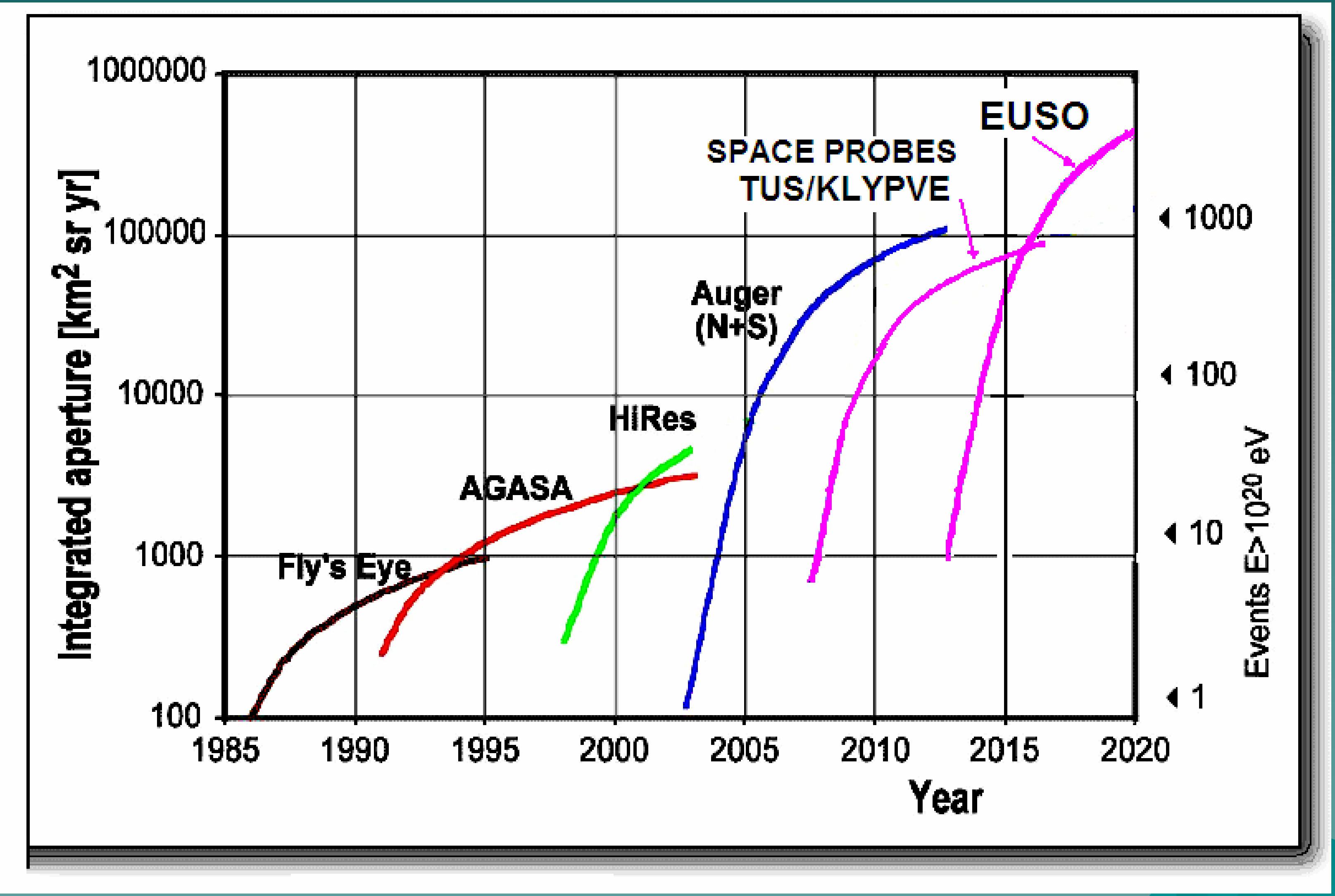
Recent experimental data on the energy spectrum of Ultra High Energy Cosmic Rays (UHECR)



Energy calibration is the main reason of difference in spectra from different experiments. As in case of lower energies the calorimetric data from the atmosphere fluorescence light measurements are decisive.

Reasons for systematic errors in particle detector array is a big ?

What progress in study of EECR we expect in the near future:



In KLYPVE and TUS projects a detector with comparatively narrow FOV is suggested- the “telescope” option of the space detectors:

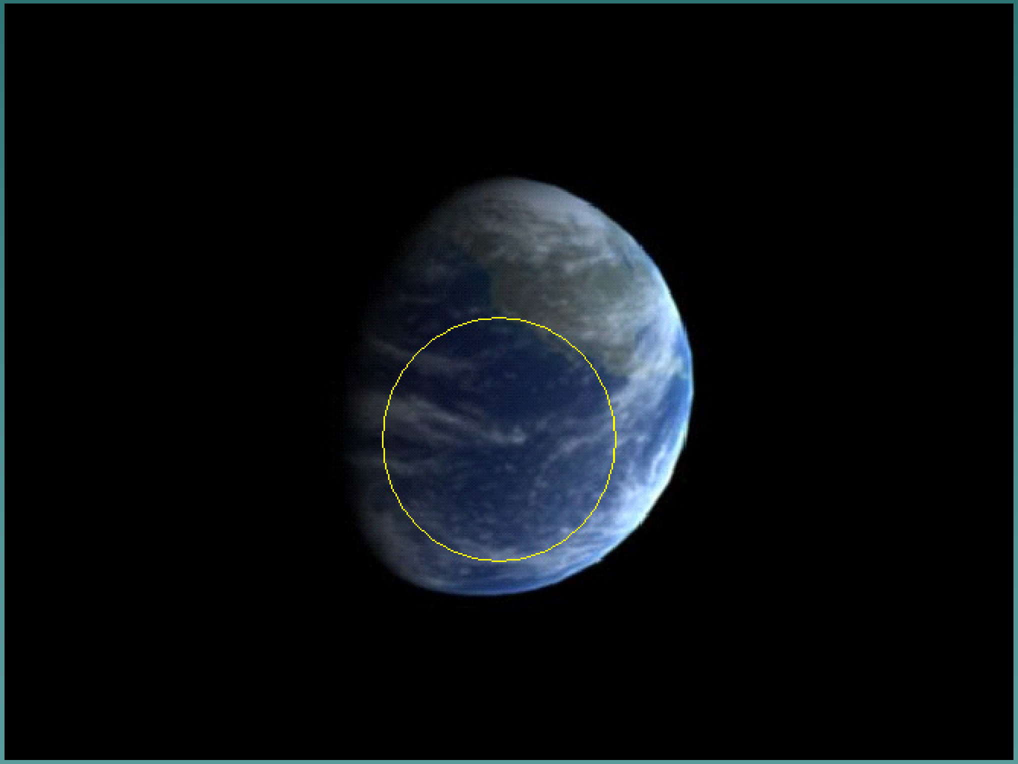
Main goals of this design:

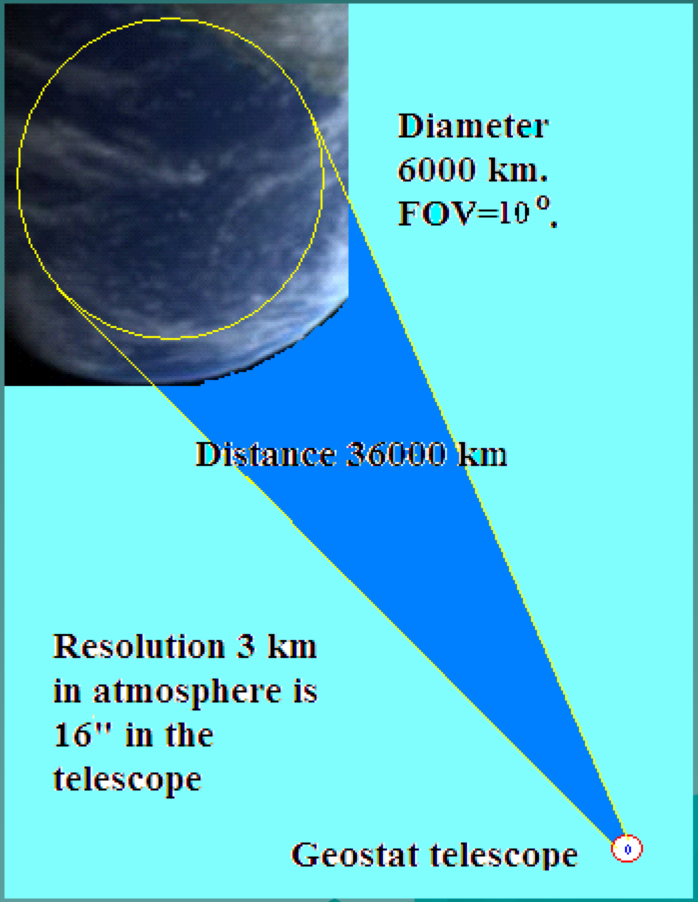
1. Making the energy threshold low ($<\sim 10^{19}$ eV) by applying the mirror area of 10-100 m^2. With this threshold it will be possible to look for cosmological neutrinos- products of the EECR protons interaction with CBMW photons. It means that we will able to look beyond Greisen-Zatsepin-Kuzmin energy limit.

2. Measuring CR at energies 3-30 EeV with a large exposure factor will allow us to study CR anisotropy with high statistics and reveal the transfer from Galactic to extragalactic origin of CR.

3. In future making the mirror area up to 1000 m^2 will allow us to register EECR (>100 EeV) at very large area of the atmosphere (10^7 km^2) with the help of a telescope at the geostationary orbit.

Telescope on the geostationary orbit. Mirror diameter 30 m, resolution 16’’ (3 km in the atmosphere). Energy threshold 10^{20} eV. Observed area $3x10^7$ km^2 . Future observation of EAS, initiated by UHE neutrinos.

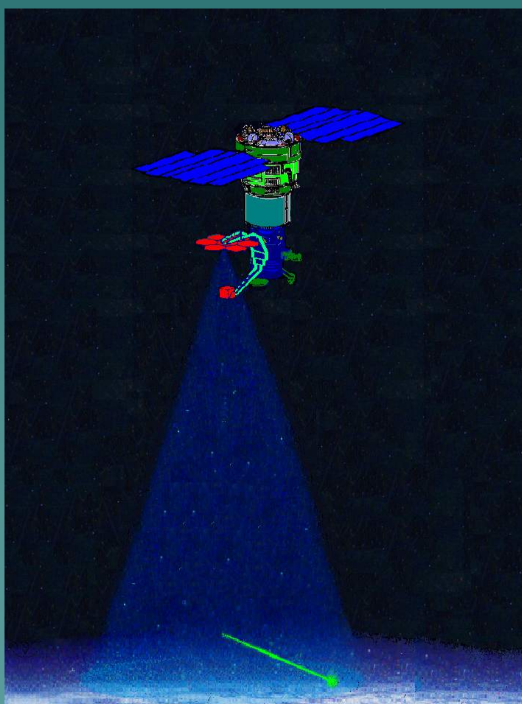




TUS telescope as the first step of the project. Area of the mirror 1.4 m^2 .

1-Resurs DK1 accommodation. 2. Resurs O accommodation.

1



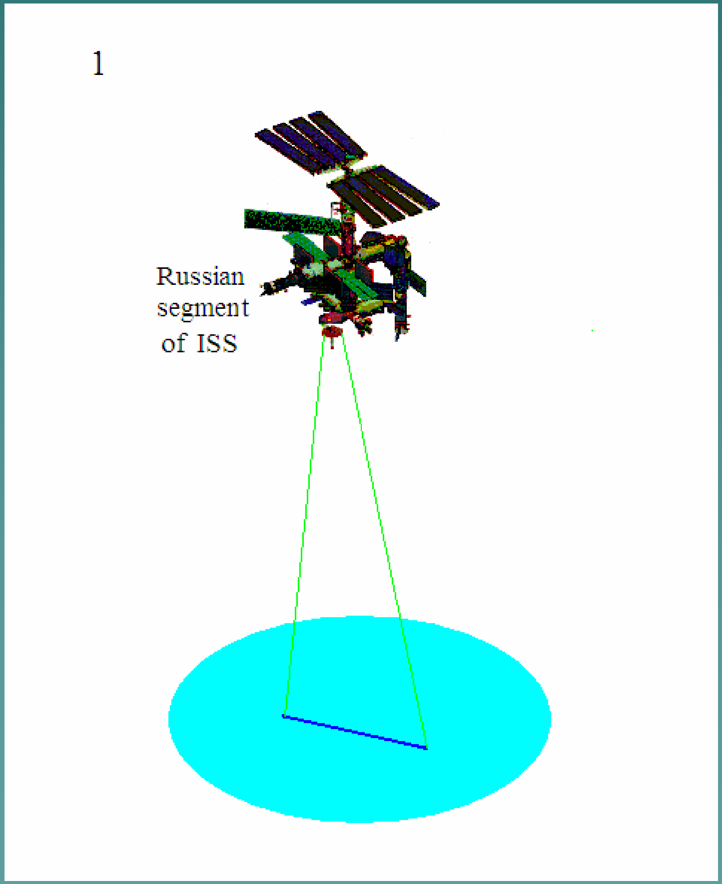
2

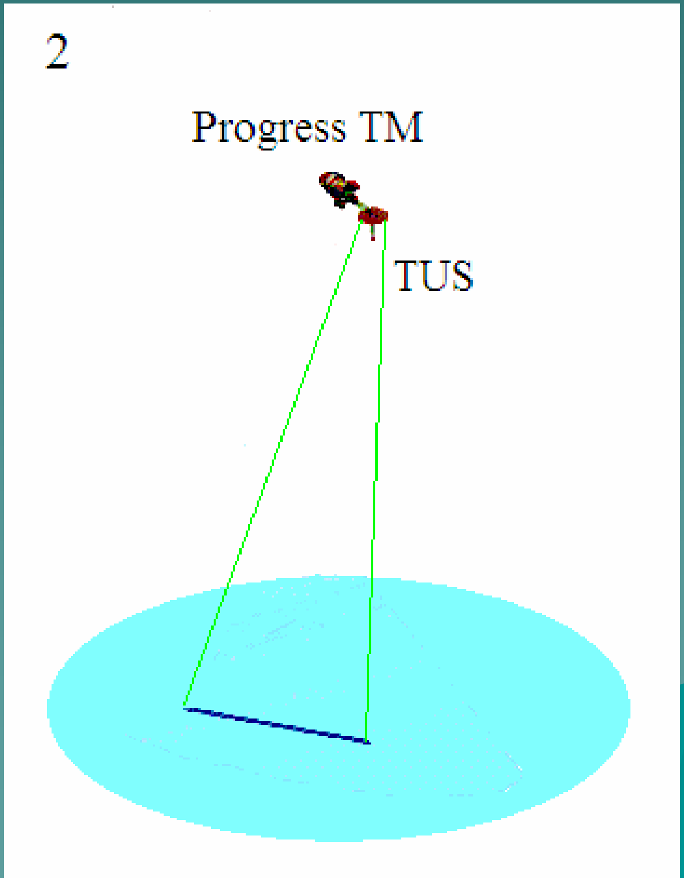
In 2001 Prof. Park joined our project suggesting to make the 2-d TUS detector on the same platform.

In this option (Resurs O) a check of instrumental errors could done in operation.

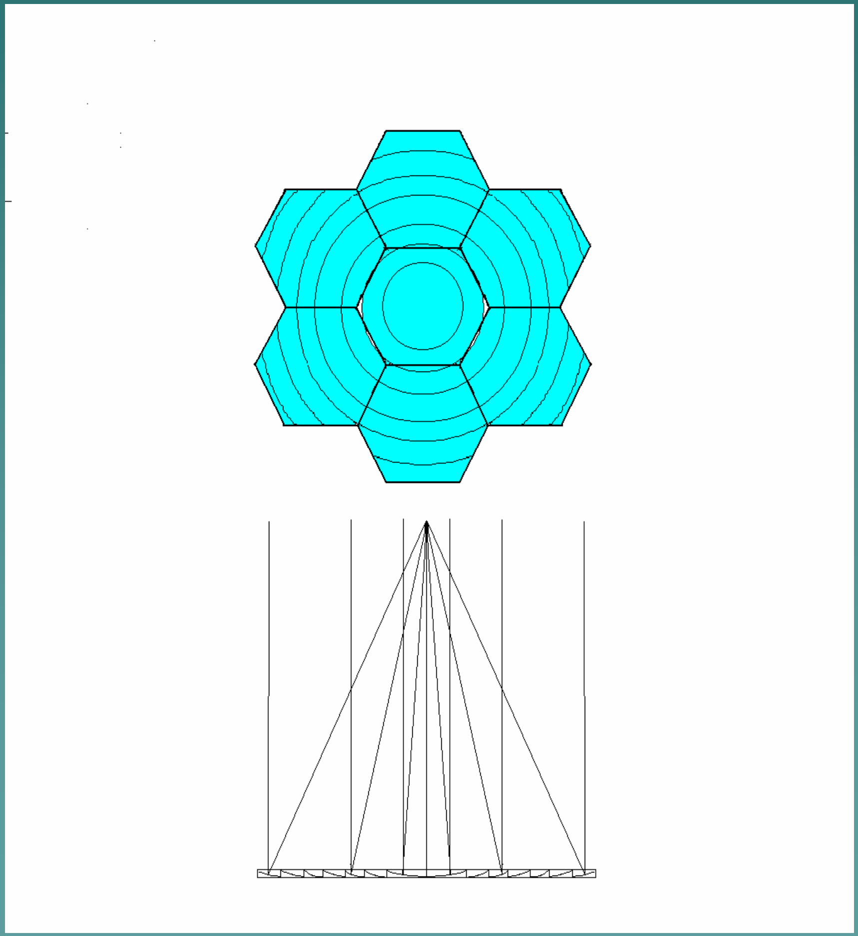
Two more options are under discussion:

1. Detector larger than TUS- mirror area 3-10 m^2 (or 2 detectors, the EUSO type as an optional second detector) is accommodated on the new Russian module of ISS.
2. The same kind of a detector is accommodated on the Progress TM being a "free flyer" after undocking from ISS.



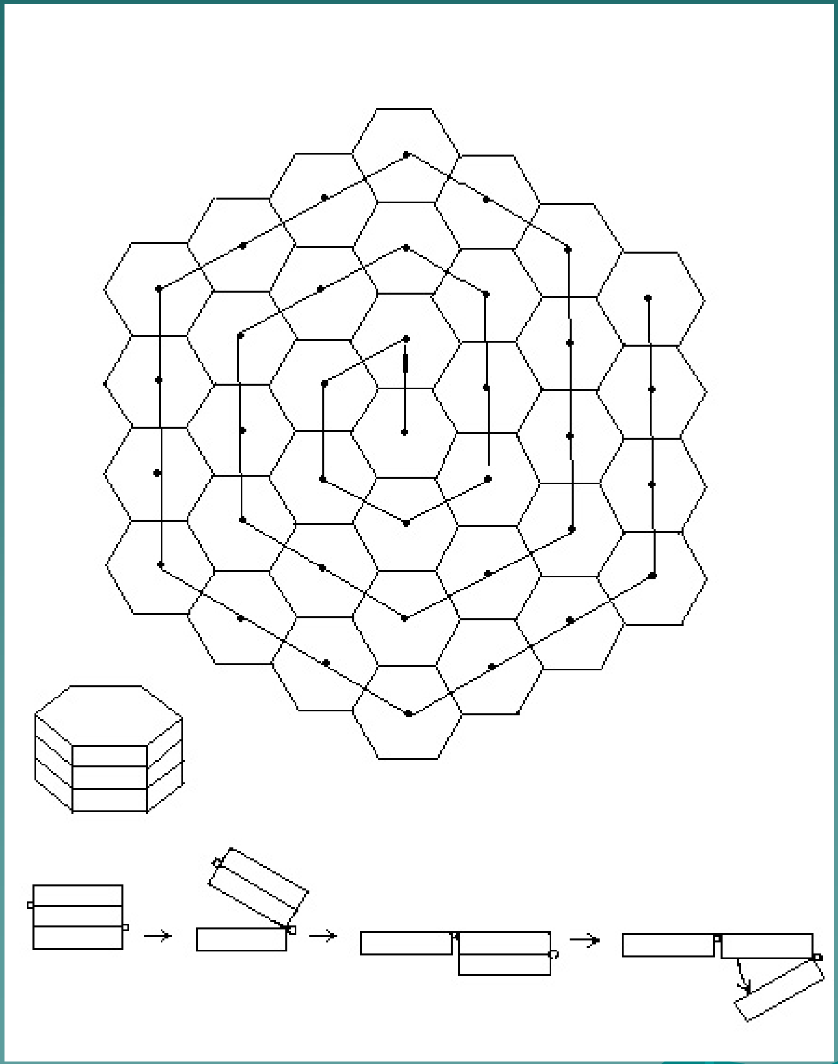


Limited area under a rocket cover dictates the segmented mirror- concentrator design.
In the TUS telescope it consisted of 6 Fresnel type mirror segments.



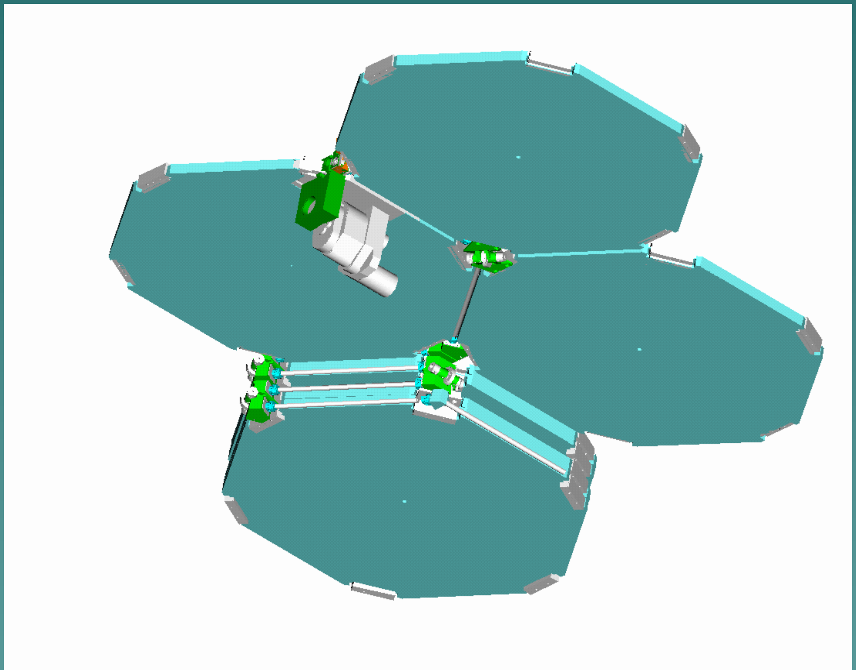
- The mirror- concentrator mass is less than 20 kg for the mirror area 1.4 m^2.
- Accuracy in mirror ring profiles ± 0.01 mm.
- Stability of the mirror construction in the temperature range from – 80^o to + 60^o C.
- The mirror development mechanism makes the mirror plane with the angular accuracy less than 1 mrad.

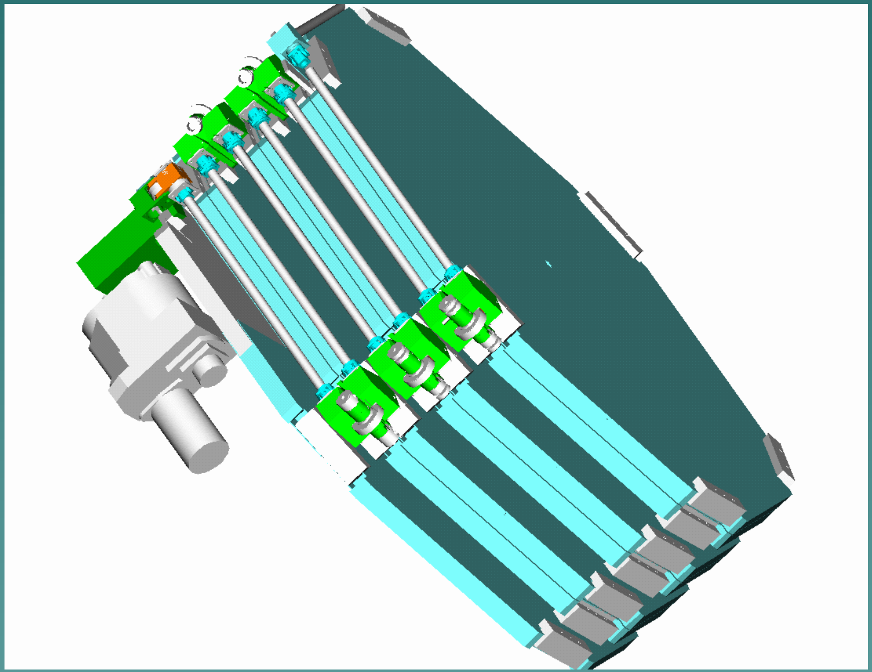
In larger than the TUS detector (KLYPVE project) diameter of the mirror and focal distance is 3 m. Mirror area is 10 m^2 .



Number of Segments is 37.

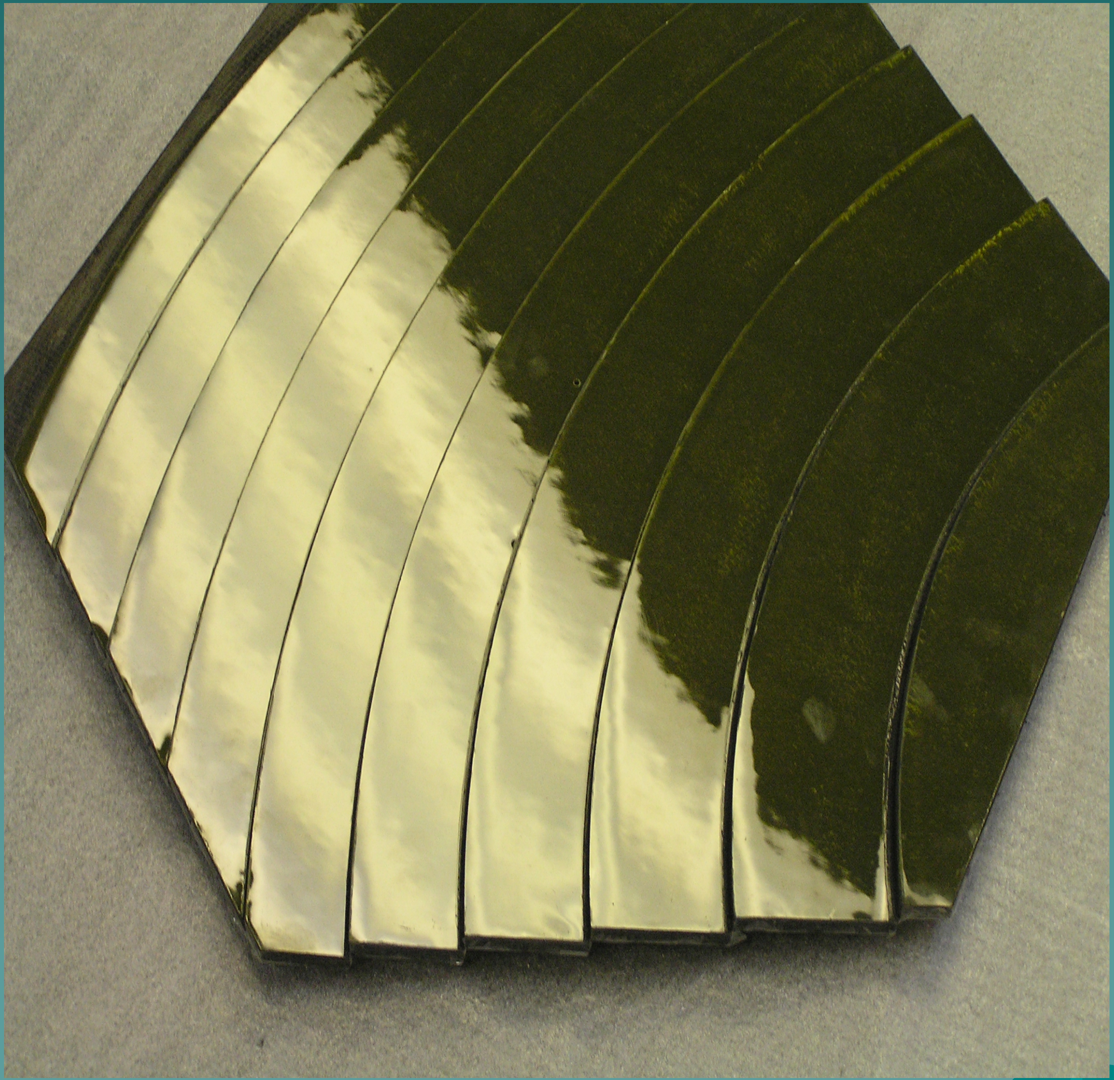
The mechanism of mirror development is designed (Consortium Space Regatta)





In this mechanism one electric motor moves the segments via axles and cardan joints.

A sample of the mirror segment.



TUS Photo Receiver , comprising 256 PM tubes.

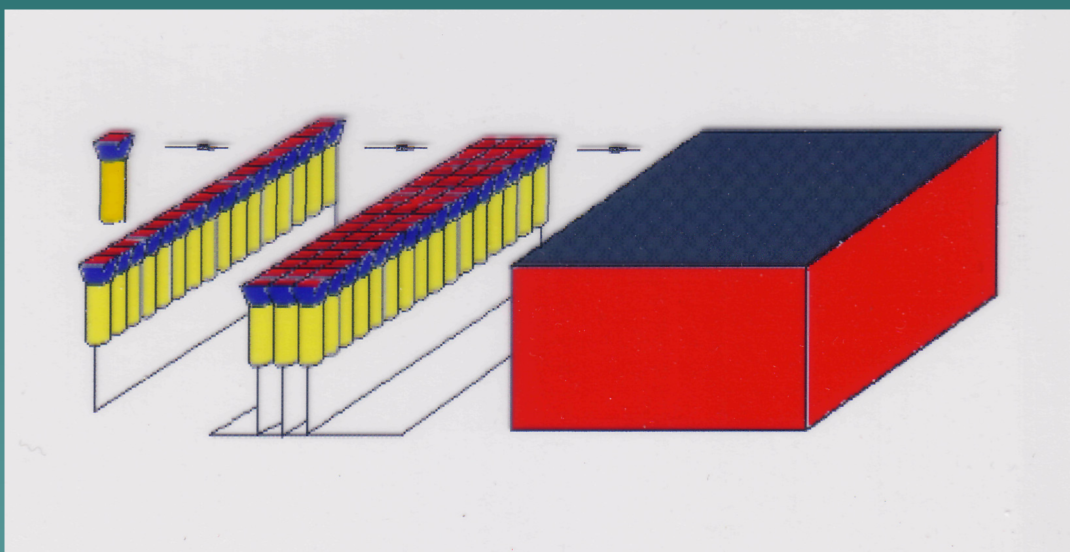
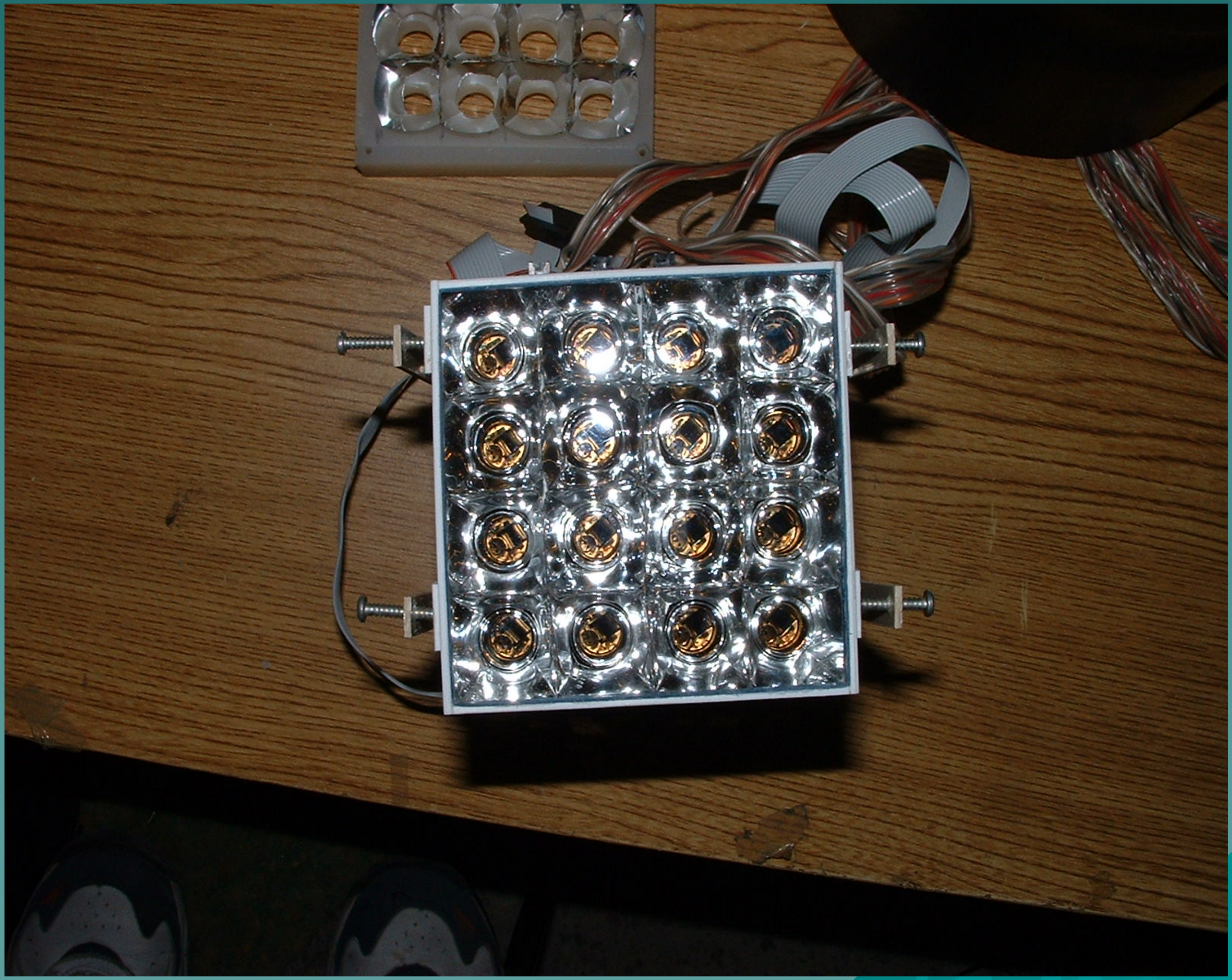


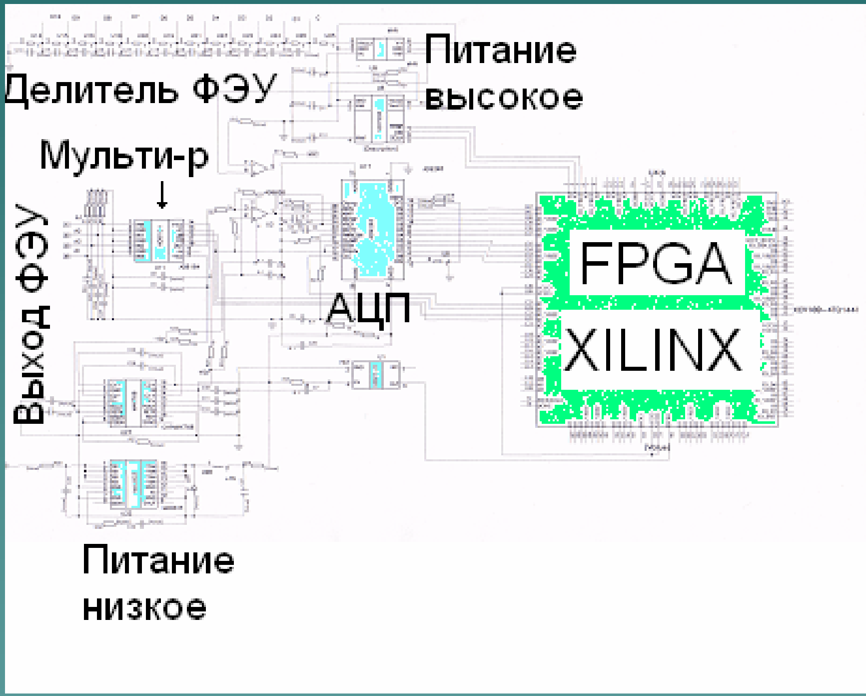
Photo receiver is consisted of 16 pixel rows and columns. Every pixel is a PM tube (Hamamatsu R1463, 13 mm diameter multialcali cathode) with a square window mirror light guide. 16 PM tubes (a row) has a common voltage supply and are controlled by one data acquisition unit. UV filter cover all pixel windows.

The TUS photo receiver prototype: 4x4=16 PM tubes. It was tested in the Puebla University (Mexico). Now one pixel is operating in space- as the UV detector of the “Universitetsky- Tatiana” satellite.



Registration Electronics.

256 photo receiver pixels are grouped in 16 clusters. In every cluster the PM tube analog signal is transmitted to one ADC with the help of multiplexer (40-20 MHz frequency). Every 400 (800) nsec the digital tube signal is recorded in the FPGA memory. The digital information is also coming to the trigger system. The first stage trigger signal is worked out in the cluster FPGA. The final trigger is worked out in the TUS FPGA where the map of triggered pixels is analyzed. Energy consumption per a channel is 10 mWt. The TUS energy consumption is less than 40 Wt.

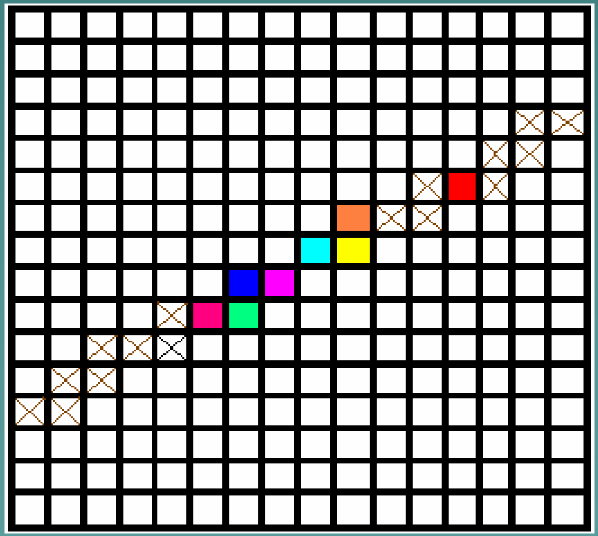


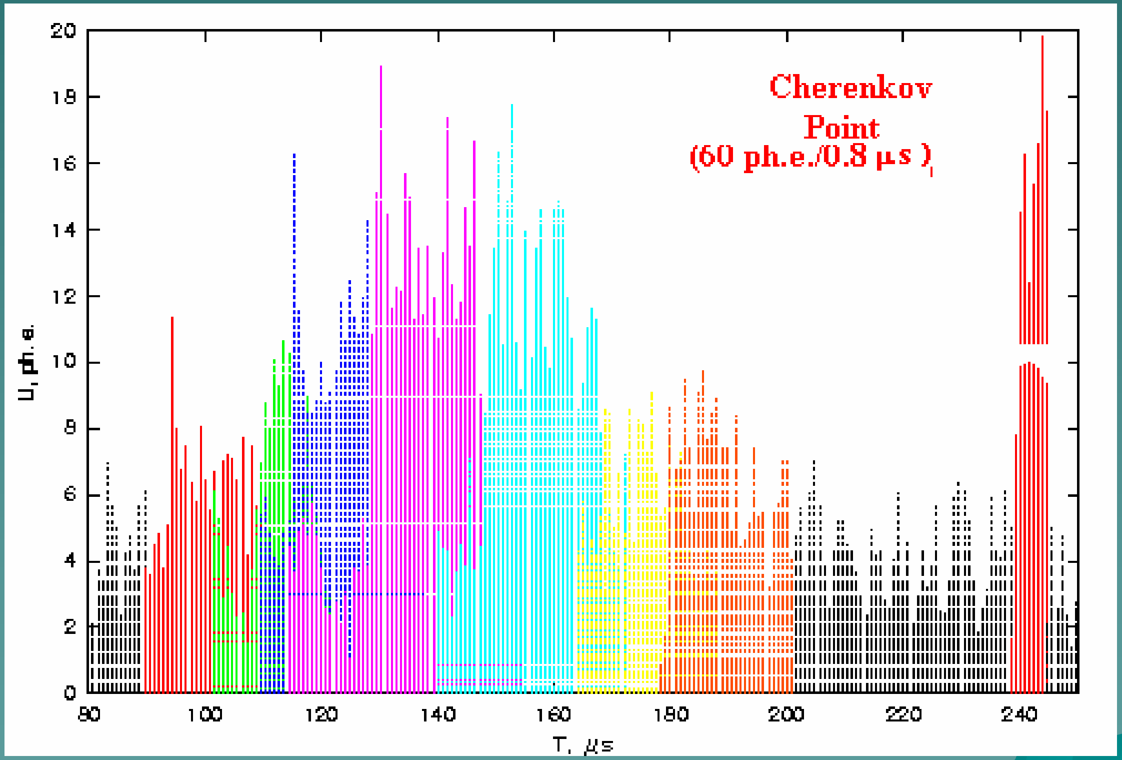
The TUS electronics design could be used for larger number of pixels in the next detectors.

Simulation of UHECR registration

Example of the EAS, “registered” by the KLYPVE detector

E_0=100 EeV, θ_0=75°, φ_0=25°,
Moonless night; $\sigma E_0/E_0 \sim 10$ %,
$\sigma\theta_0 \sim 1.5°$, $\sigma\varphi_0 \sim 1°$.

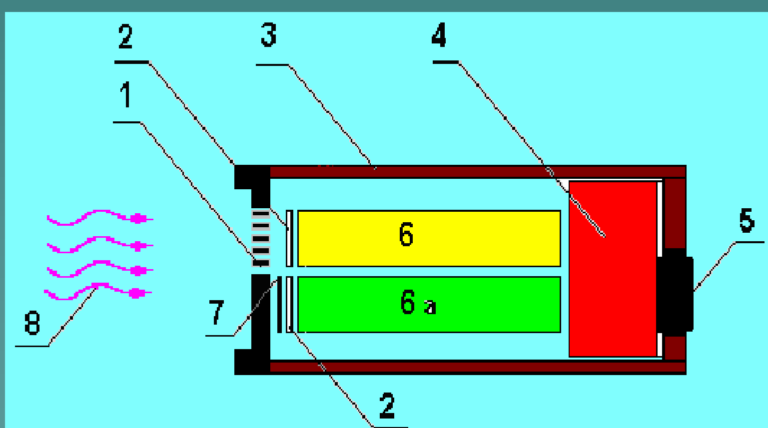


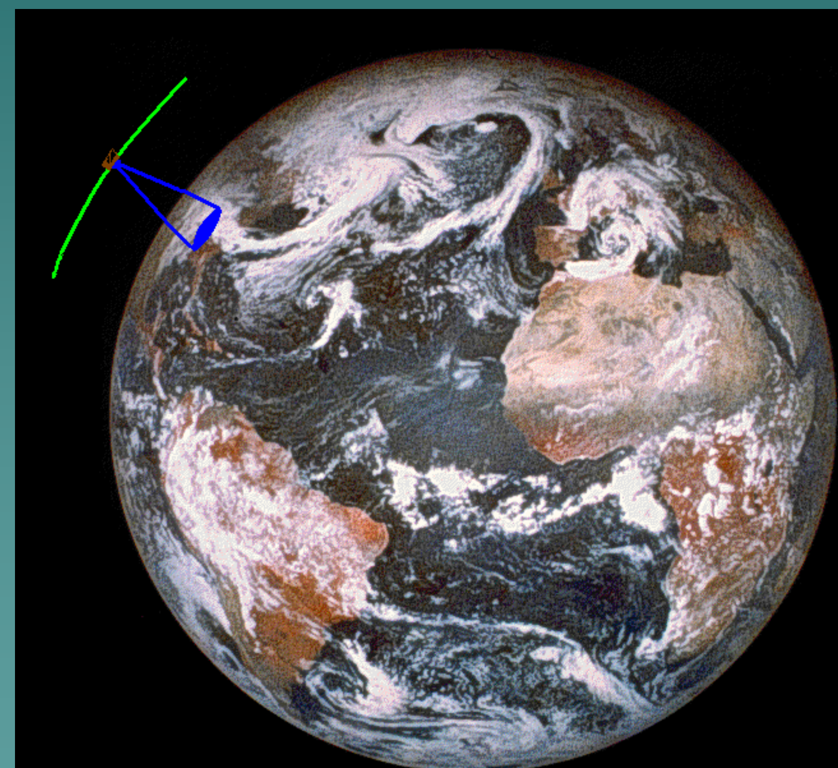


In the “horizontal” tracks the scattered Cherenkov light from the atmosphere is negligible to compare with fluorescence. The Cherenkov scattered from the clouds or ground is a strong signal.

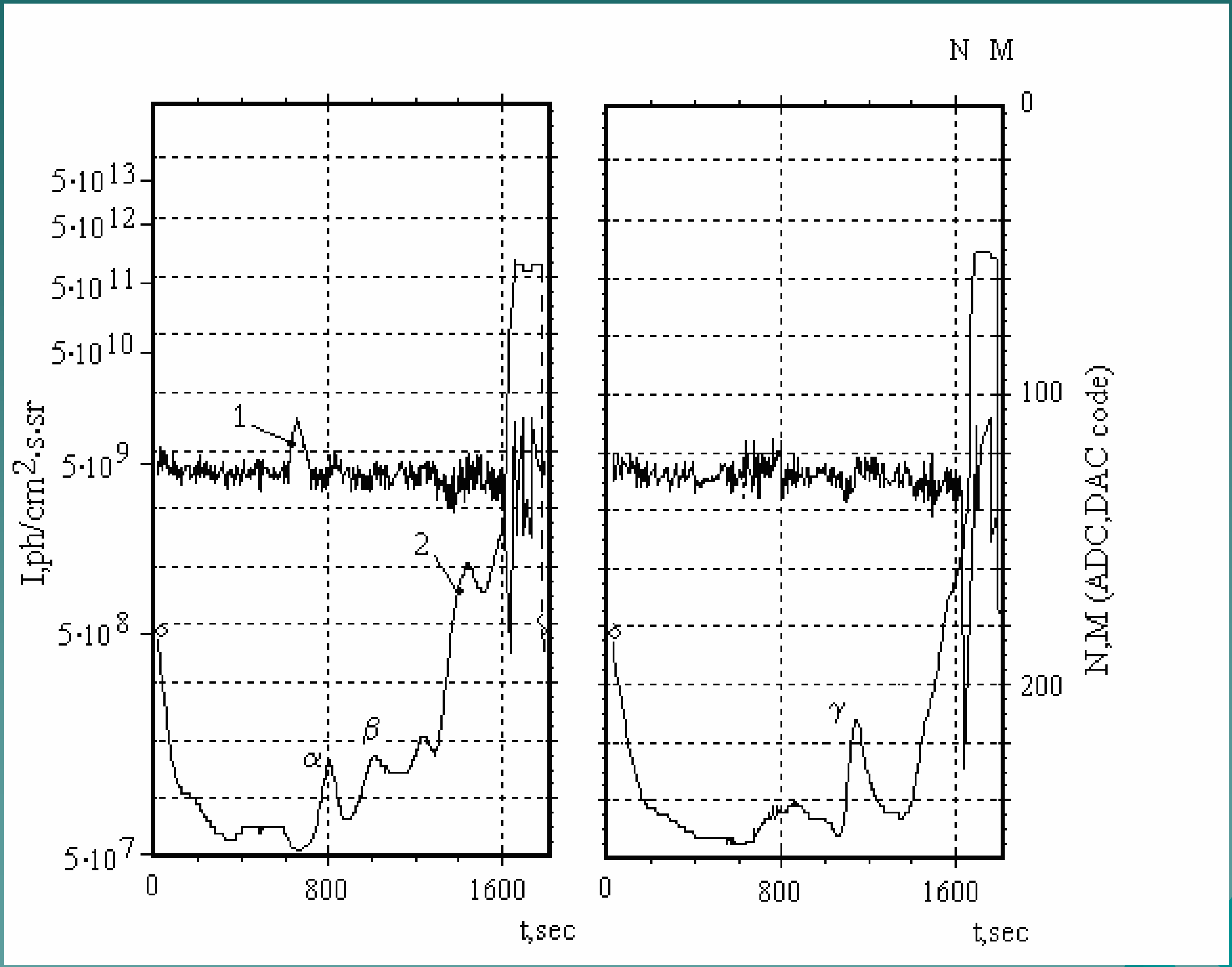
UV detector based on the pixel design of the TUS telescope is measuring UV from the atmosphere on board of the “Universitetsky-Tatiana” satellite. Orbit height-950 km.

The first results are published in JETP Lett., 82 (2005), 204 and subnitted to Astroparticle Physics.

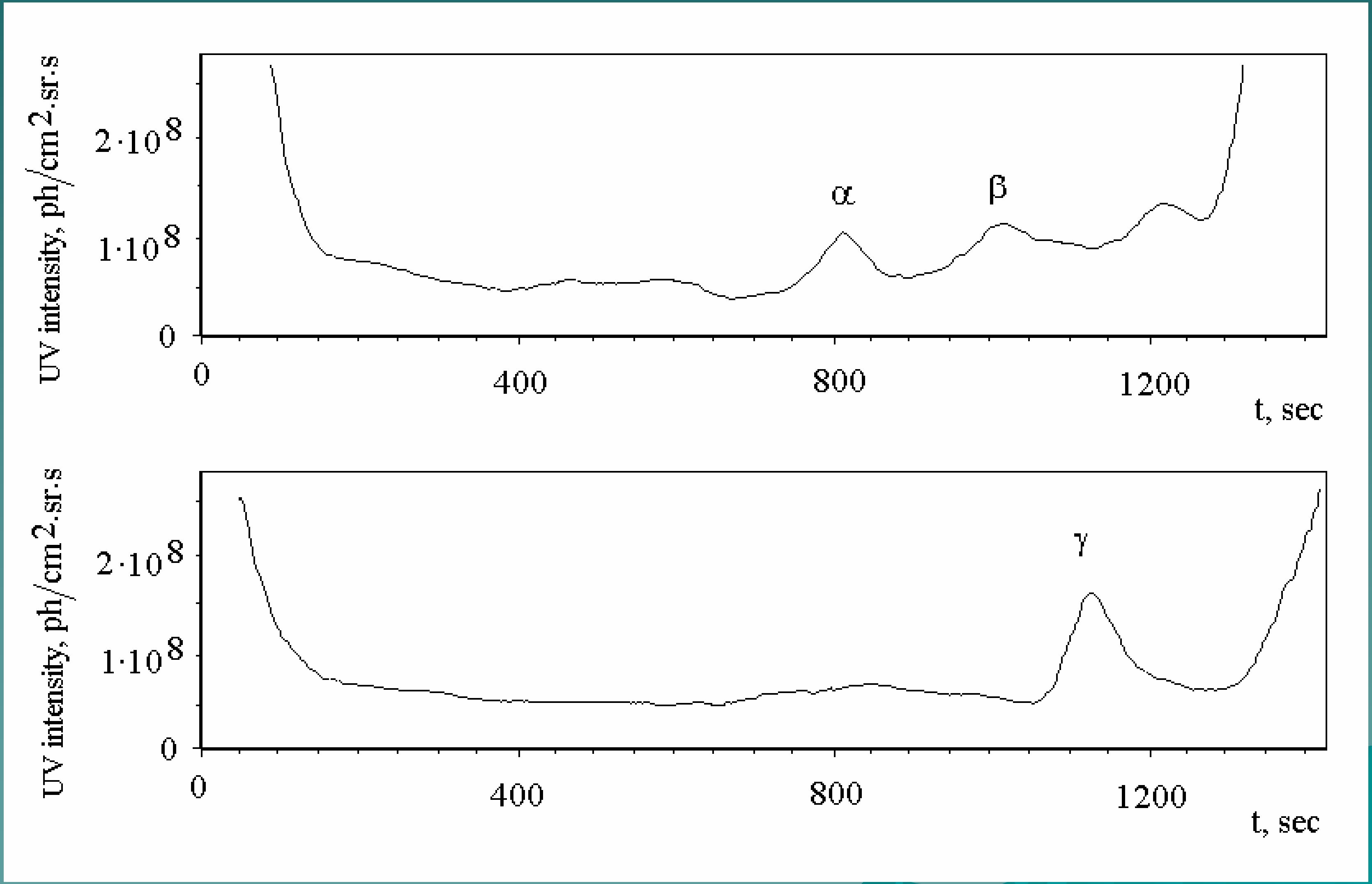




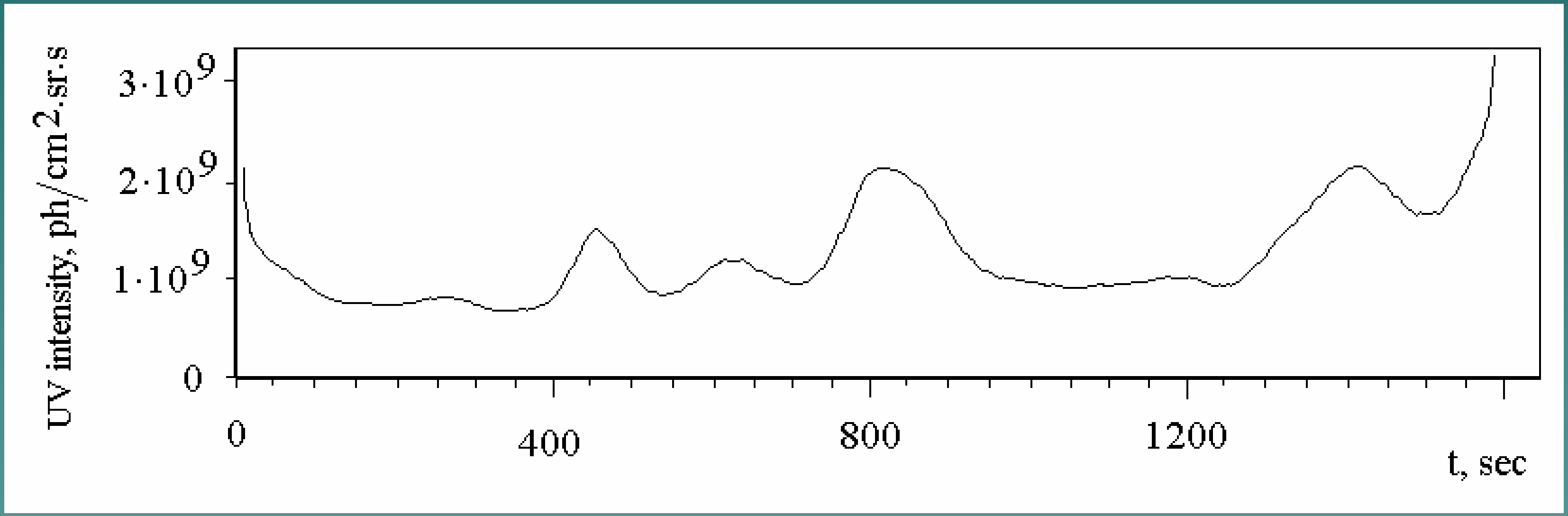
Data from UV detector in codes of ADC and DAC.



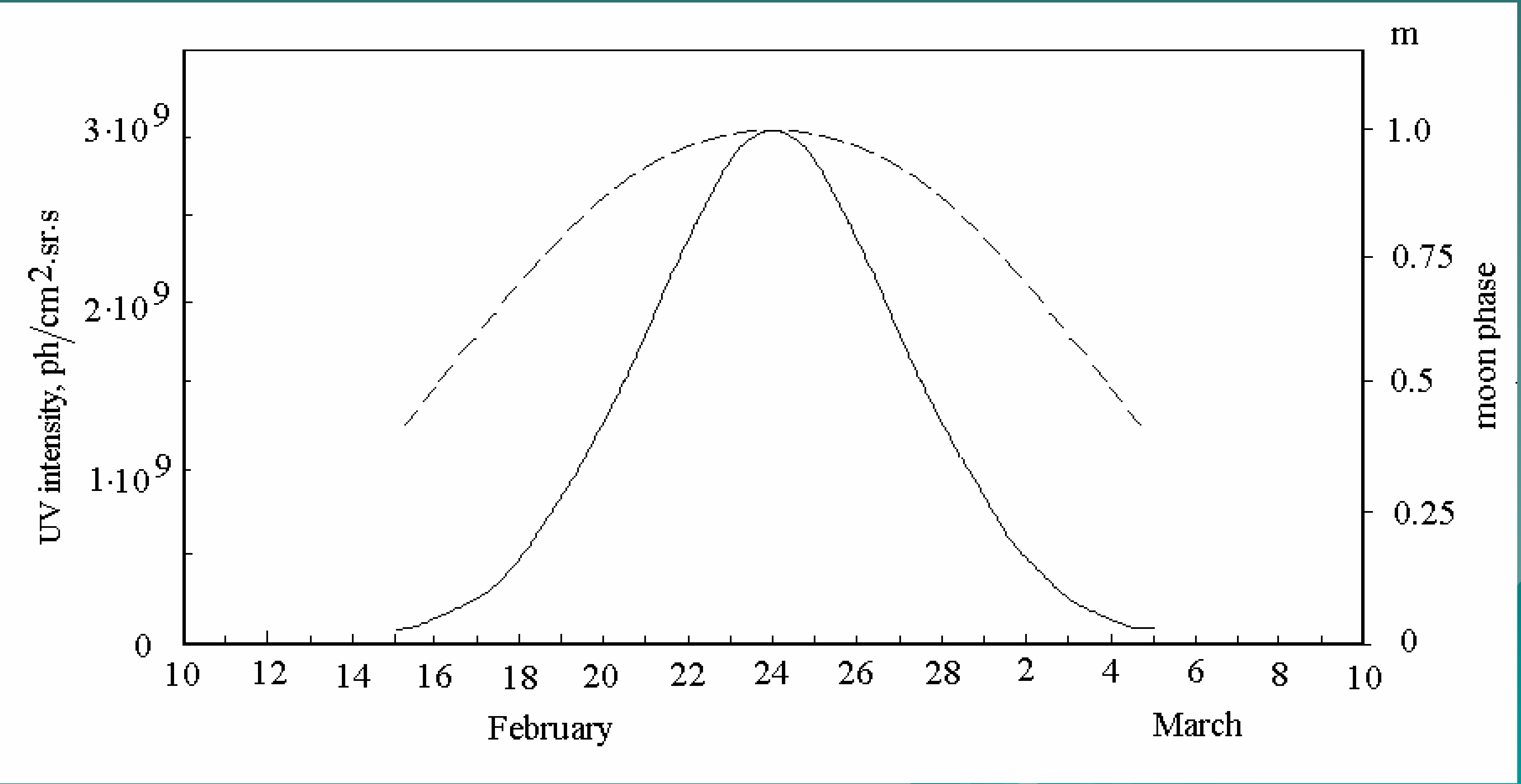
UV light intensity, measured by the “Tatiana” detector- moonless night side of the Earth. Peaks are from the large city lights.



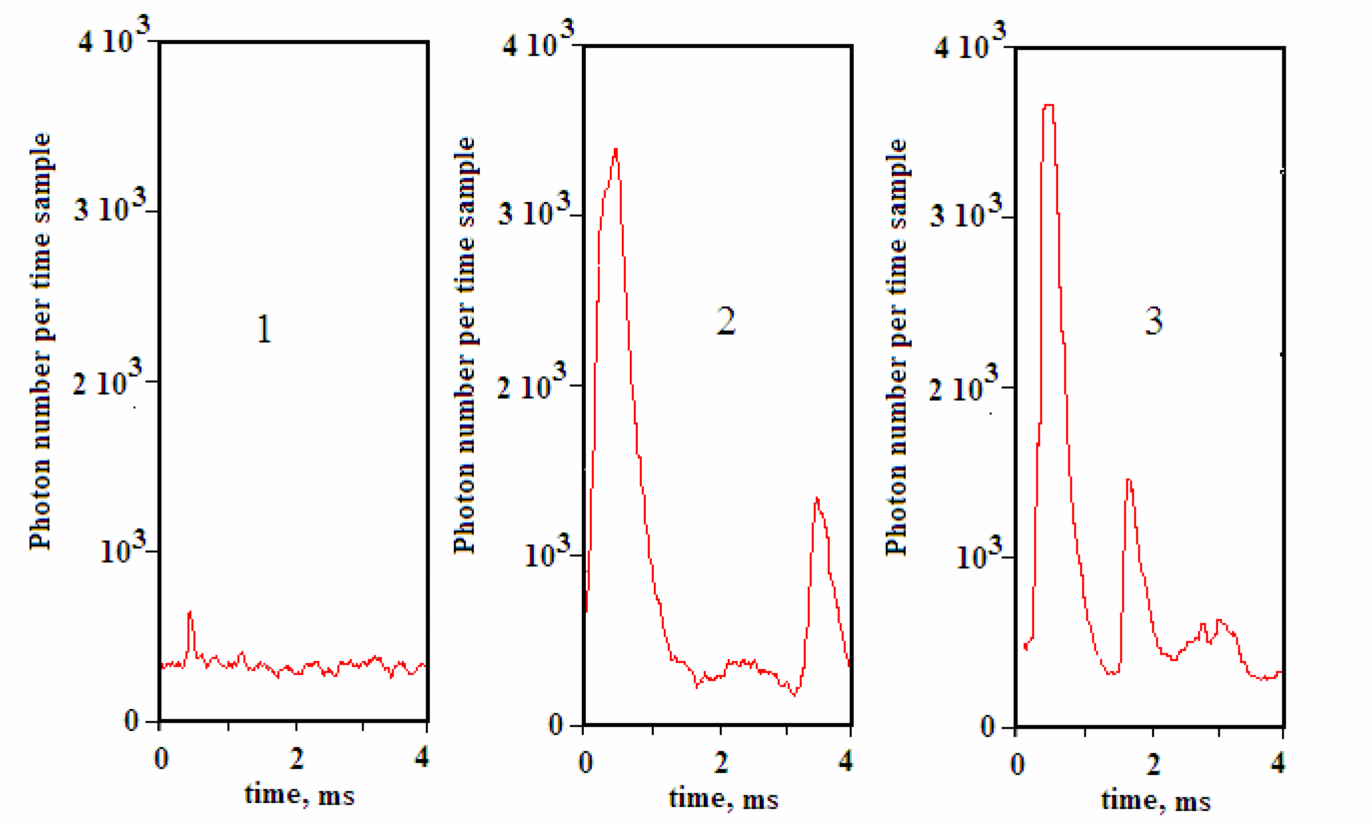
UV intensity on the night side of the Earth at full moon.



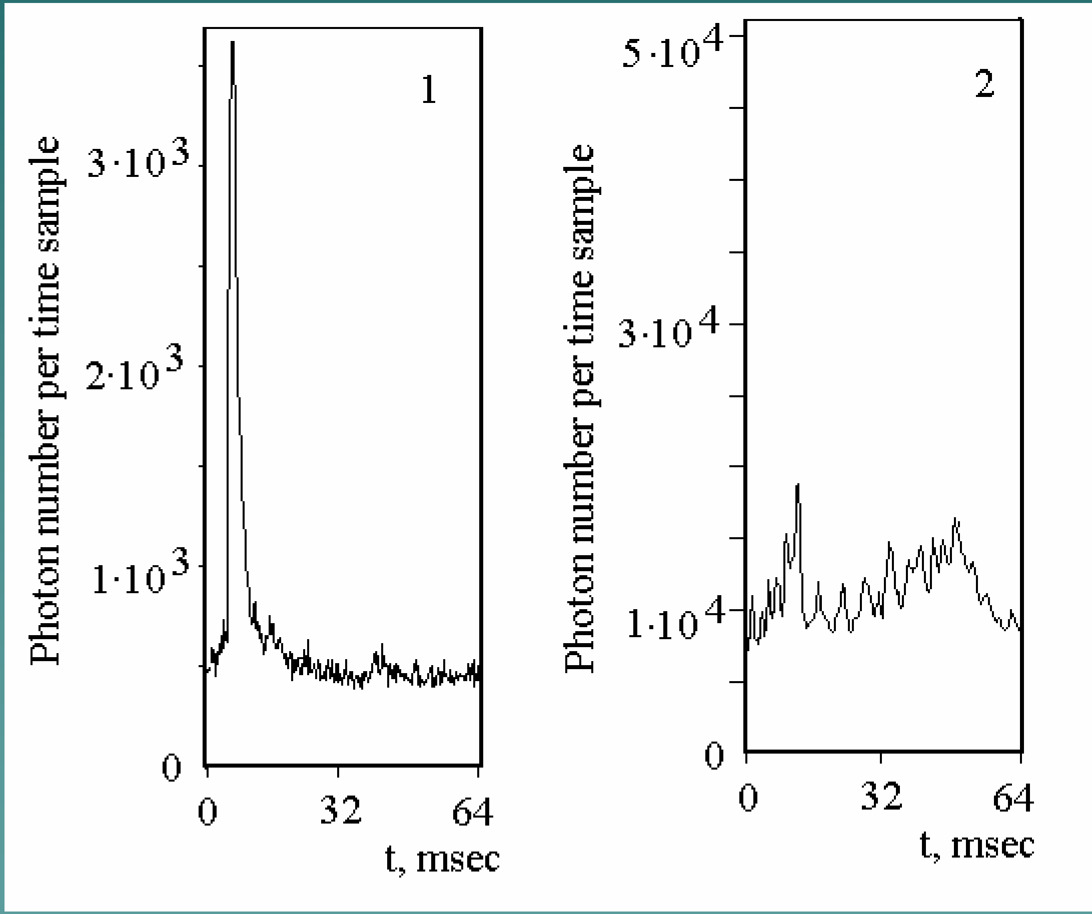
Average UV intensity per circulation (at the night side) during one moon month. Dashed line is the moon phase.
In 8 days of the moon month the average UV intensity is more than 10 times higher than at moonless night.



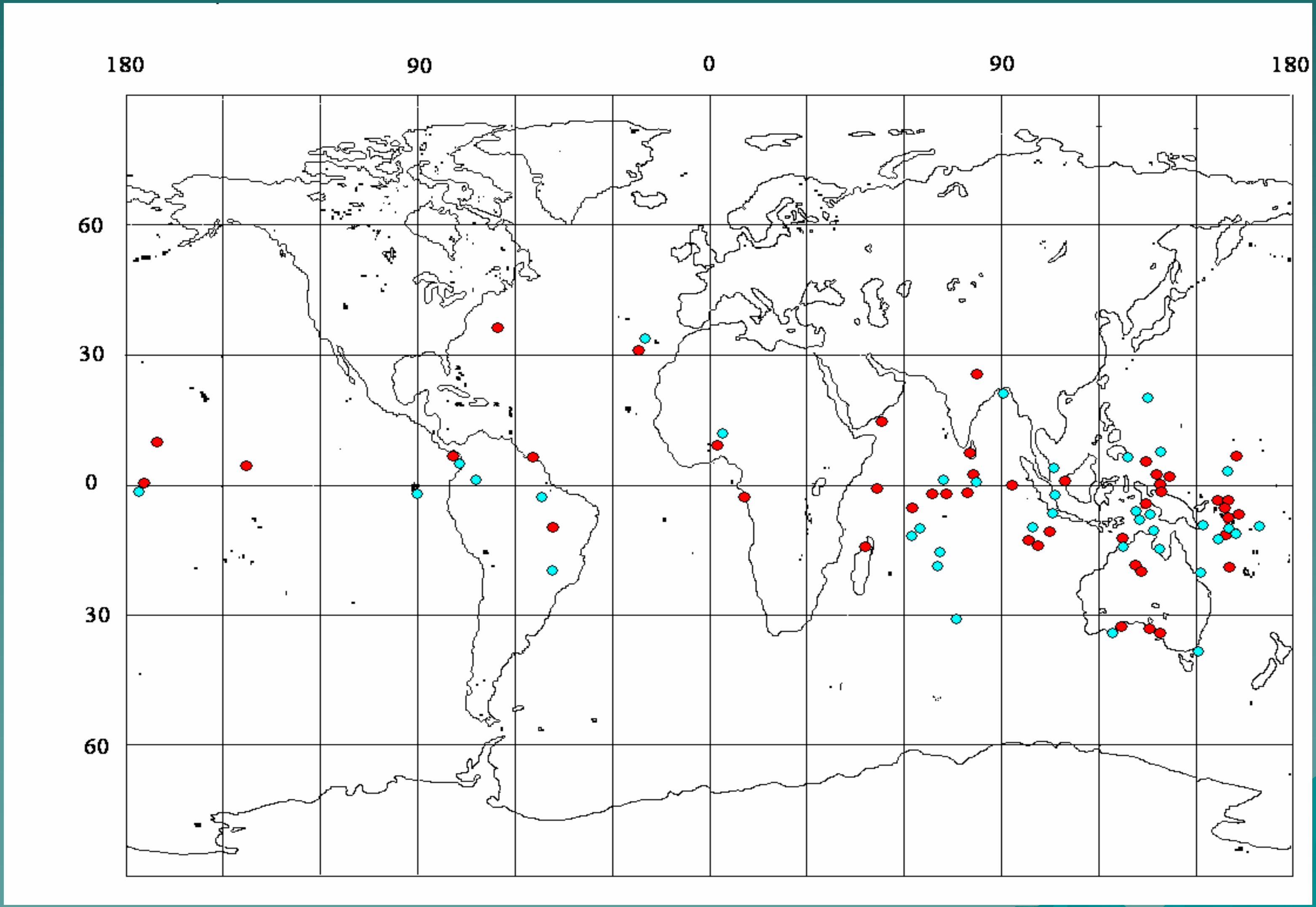
UV flashes registered by the "Tatiana" detector.
Oscilloscope trace 4 ms. UV energy in the atmosphere 10-100 kJ.



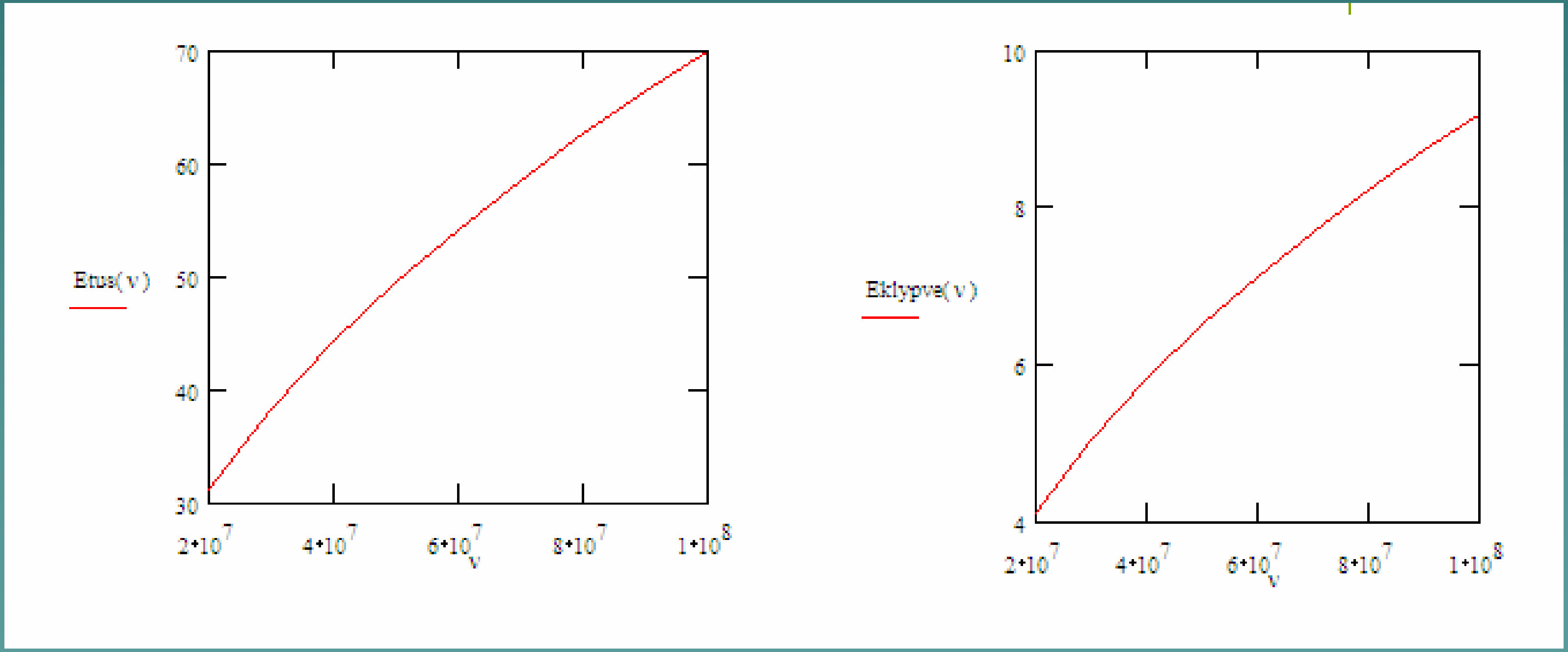
UV flashes registered by the "Tatiana" detector.
Oscilloscope trace- 64 ms. UV energy in the atmosphere 0.1-1MJ.



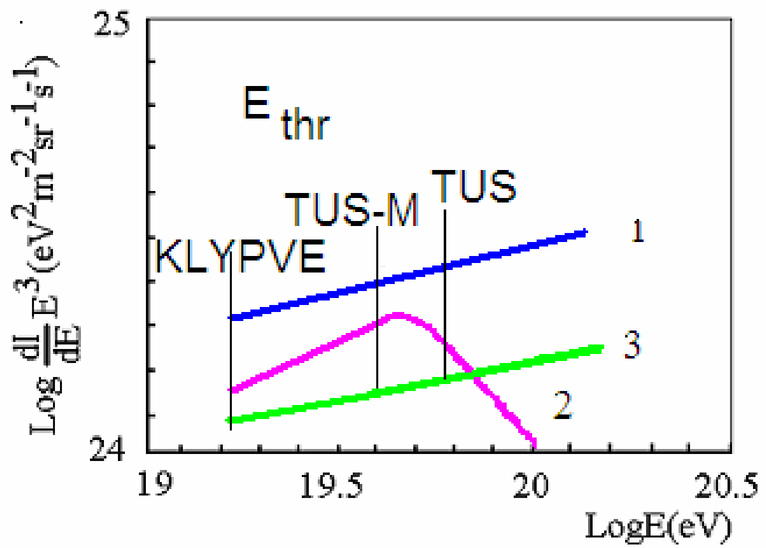
UV flash distribution over the world map. 50 of 83 registered flashes are in the equatorial belt 10º N- 10º S.



Energy threshold for TUS and KLYPVE detectors as function of background UV intensity. In EAS of E_{thr} the signal in the shower maximum is equal to 5sigma of the background .



Energy spectrum of EECR events expected in the TUS telescope from the ground arrays data.

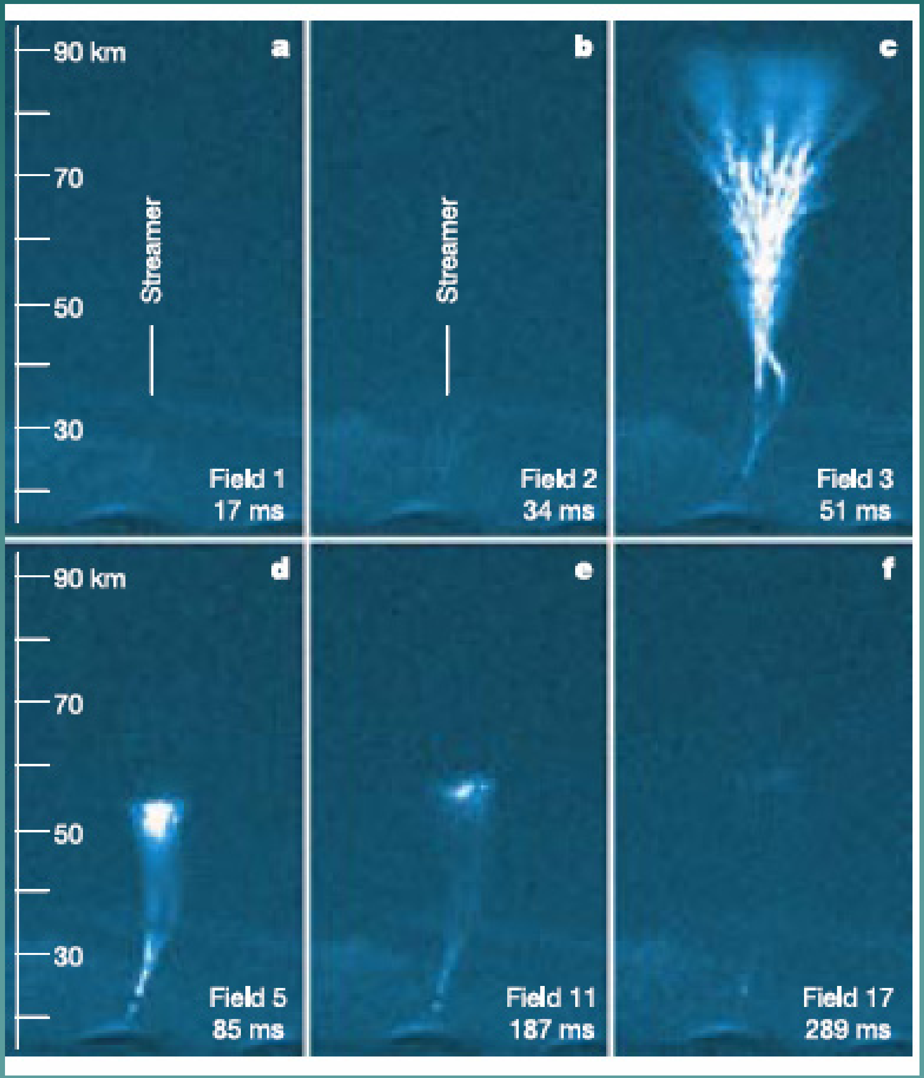


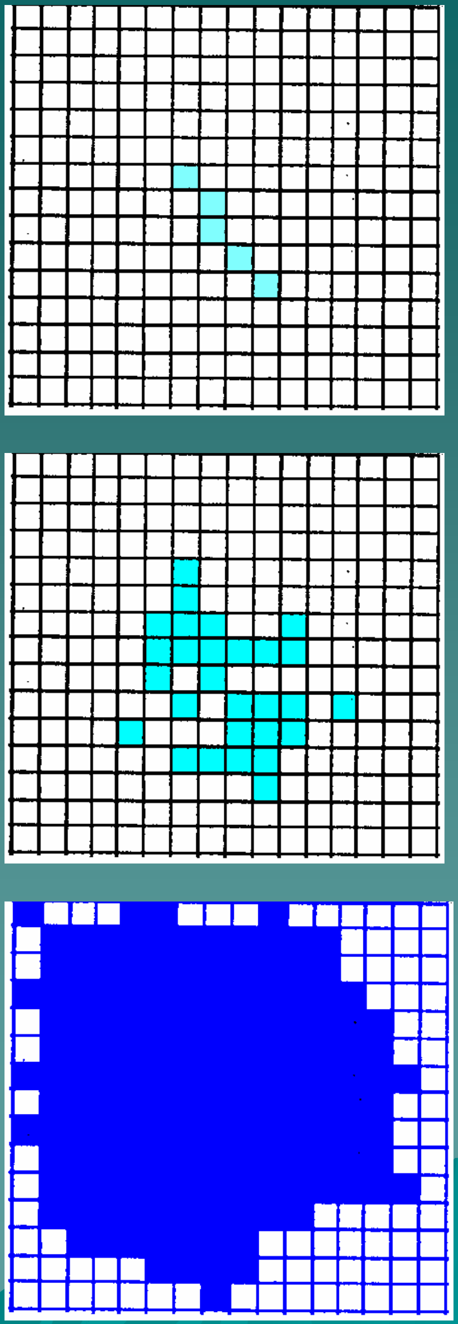
1-expected due to AGASA data,
2- .... to HiRes data,
3- .... to Auger data

Rate of inclined EAS, zenith angle >60°, for E_{thr}=100 EeV per year due to Auger data

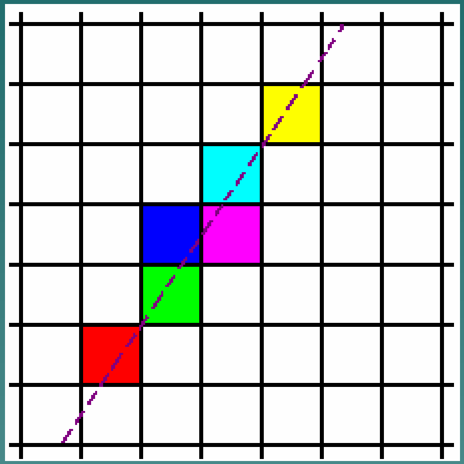
TUS	16
KLYPVE	30

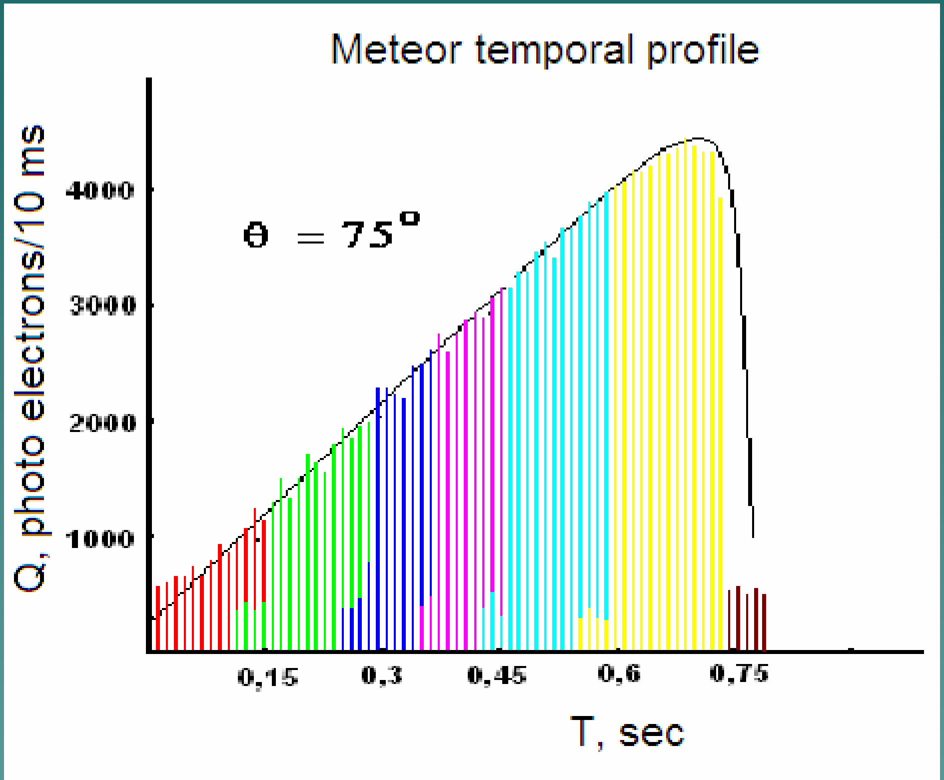
Development of TLE in video (left) and in TUS pixels (expected).





Simulation of the meteor registration by TUS

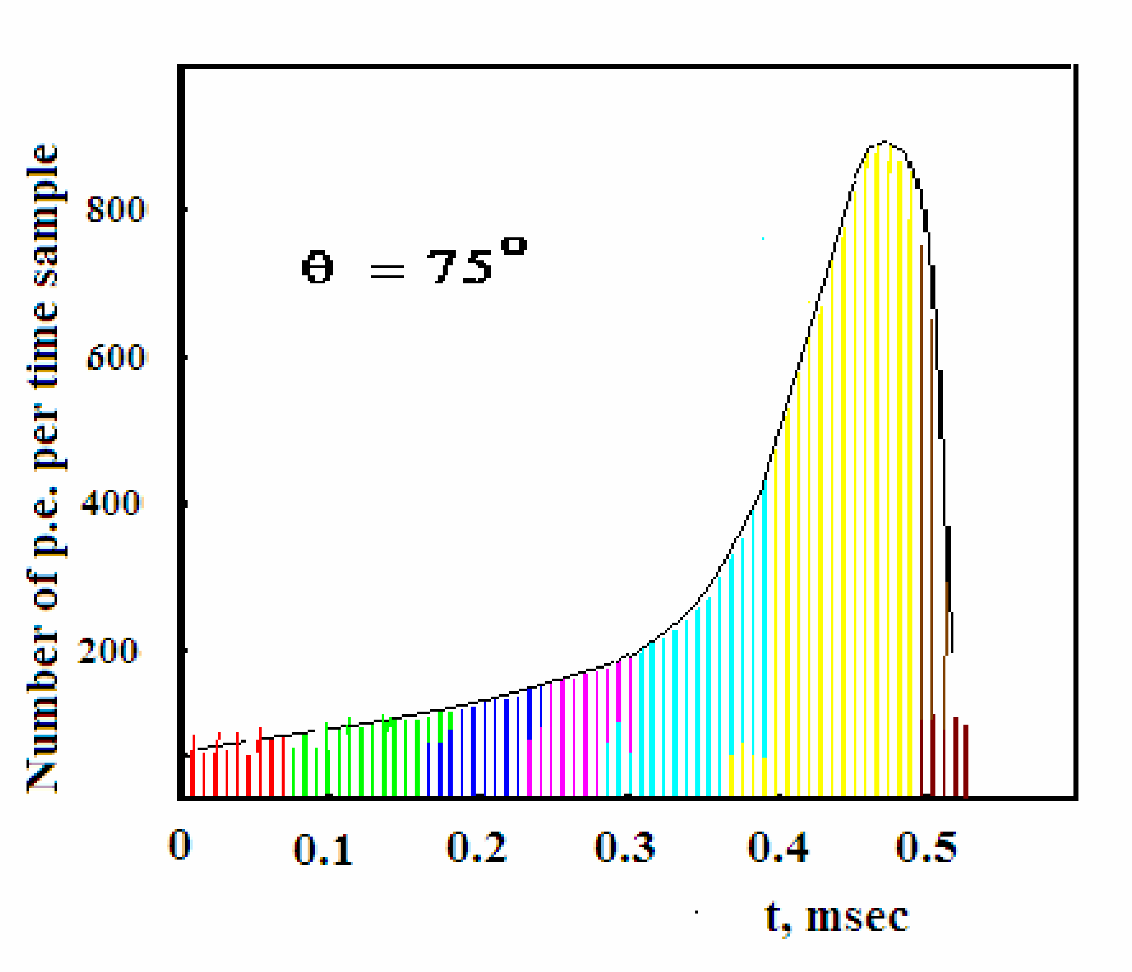




For more information see the poster by Khrenov and Stulov.

The meteor threshold kinetic energy – 100J. Expected rate- 100 per day.

Expected signal profile from the sub-relativistic (velocity 10^{10} cm/s) dust grain. Energy 20J.



Conclusion

1. Space experiments will give an independent evidence for true UHECR particle energy as an absorption in the atmosphere is much less than in ground experiments.

3. The new data on the UV light noise (including short flashes) from the atmosphere has to be taken into account when the space experiment is planned.

4. We incline to develop the technology of the space experiment in the step-by-step manner- to avoid serious mishaps.

5. Other phenomena of fluorescence light in the atmosphere (origin of TLE, sub-relativistic dust grains, small meteors) could be studied by TUS/KLYPVE detectors. Cycling memory should be larger than in the EAS experiment but nowadays it is affordable.