Space fluorescence detectors TUS/KLYPVE for study of UHECR .

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B. A. KHRENOV

for TUS/KLYPVE collaboration of:

Skobeltsyn Institute of Nuclear Physics of MSU,

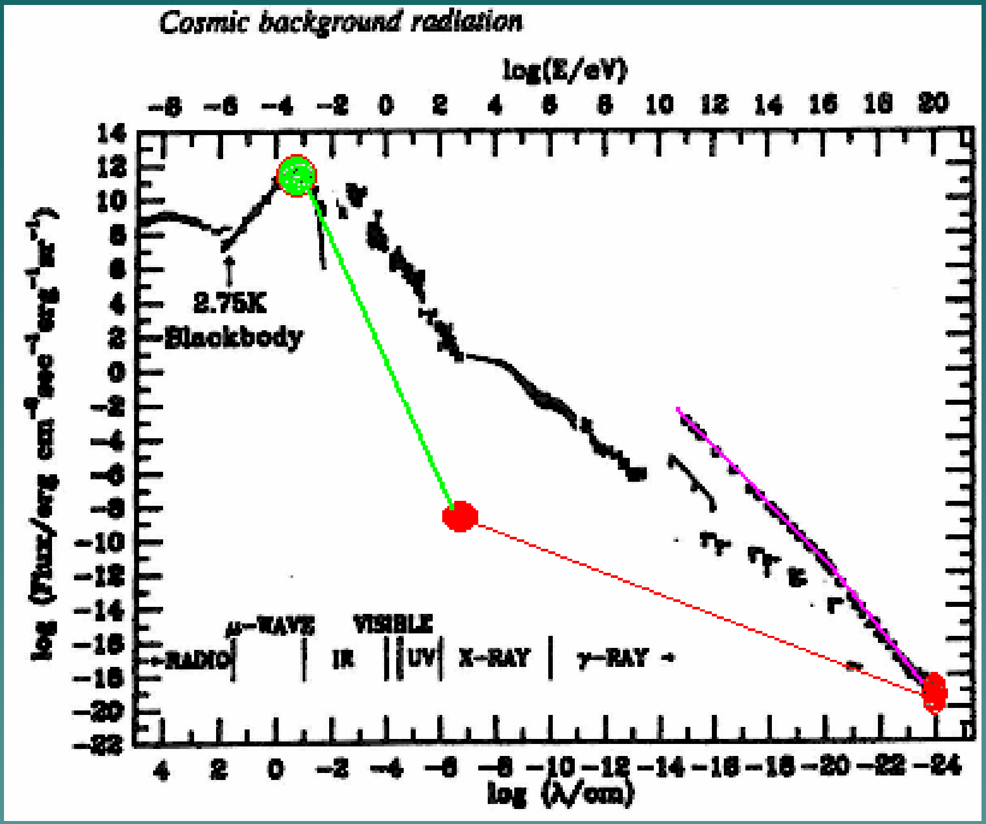
Joint Institute of Nuclear Research, Dubna

EWHA Woman University, Seoul, Korea,

University of Puebla, Mexico,

University of Michiocan, Mexico

Major scientific problem- the CR spectrum cut off.



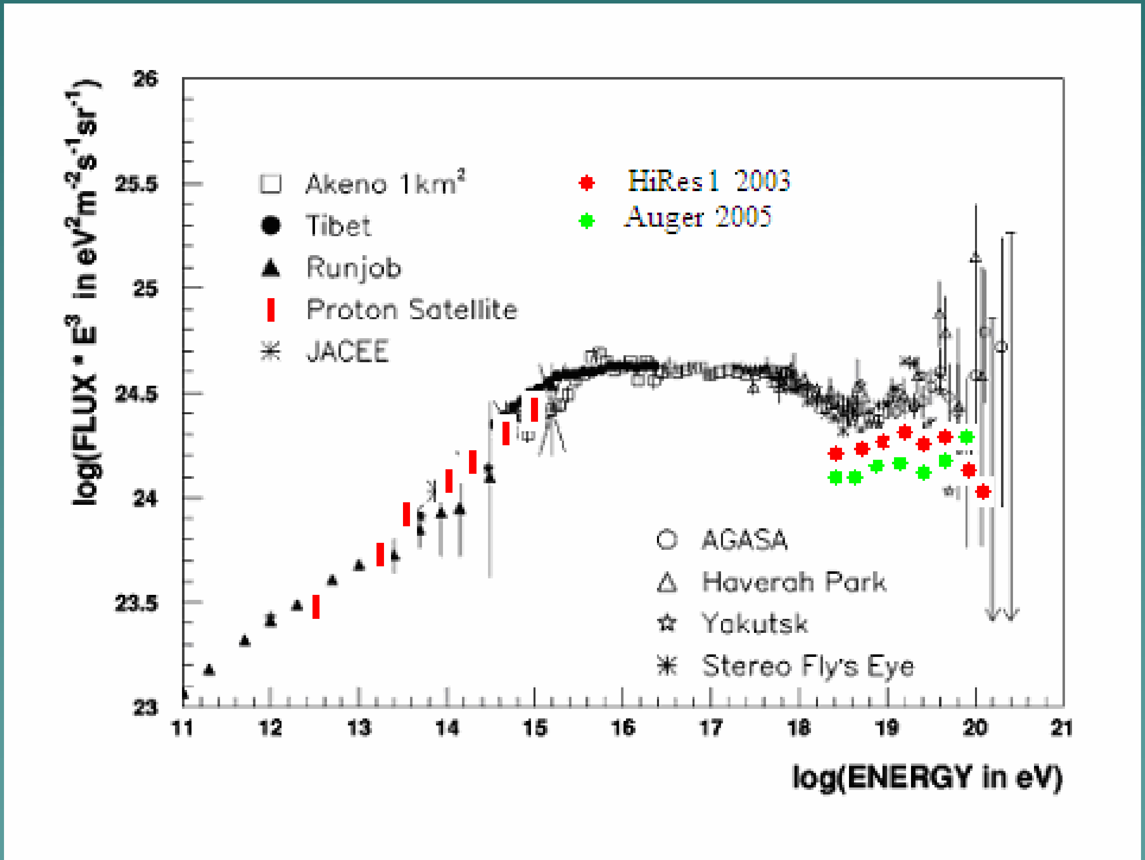
G.T. Zatsepin, 1967

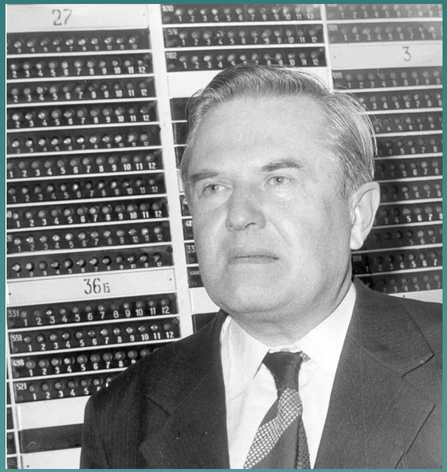
$P+\gamma=P+\text{hadrons}$ $E_\gamma=2E_{ph}E_p/M_p c^2$
$E_{ph}=2.5\ 10^{-4}$ eV (T=2.75K)
In proton rest frame photon energy $E_\gamma>100$ MeV for $E_p>10^{20}$ eV. $\rho_{ph}=500\ cm^{-3}$
Cross-section of interaction is $\sigma=10^{-28}\ cm^2$
Interaction free path $L=1/\sigma\rho_{ph}=70$ Mpc

Greisen-Zatsepin-Kuzmin made the first estimates of the effect and find the energy limit for protons $E_{GZK}=5\times10^{19}$ eV.

Study of Extensive Air Showers has lead to following main results:

1. Discovery of the "knee" in the CR energy spectrum at $3x10^{15}$ eV (G.B. Khristiansen, Moscow EAS array).
1. The "ankle" at the $3\text{-}10x10^{18}$ eV (Yakutsk, Haverah Park, AGASA, Fly's Eye).
2. Problem of CR cut off at $5x10^{19}$ eV.

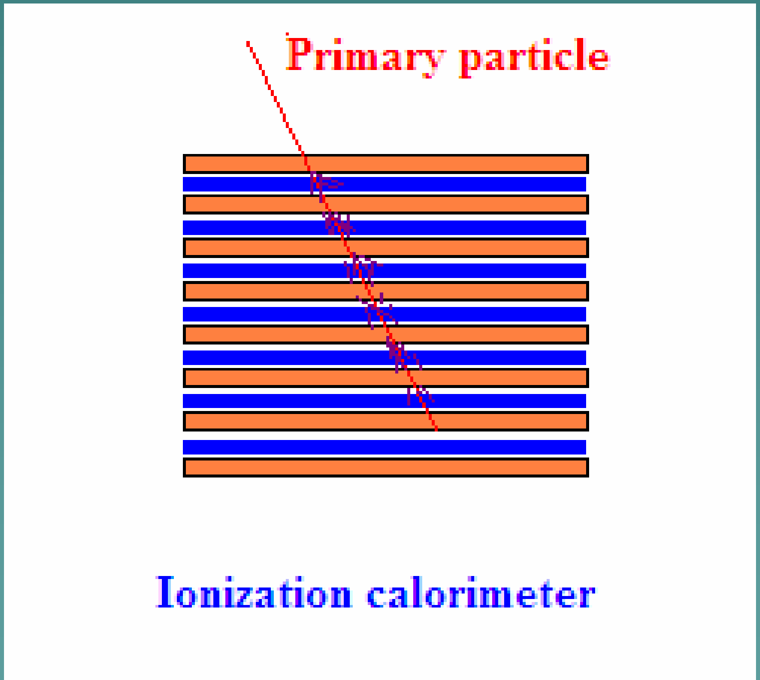


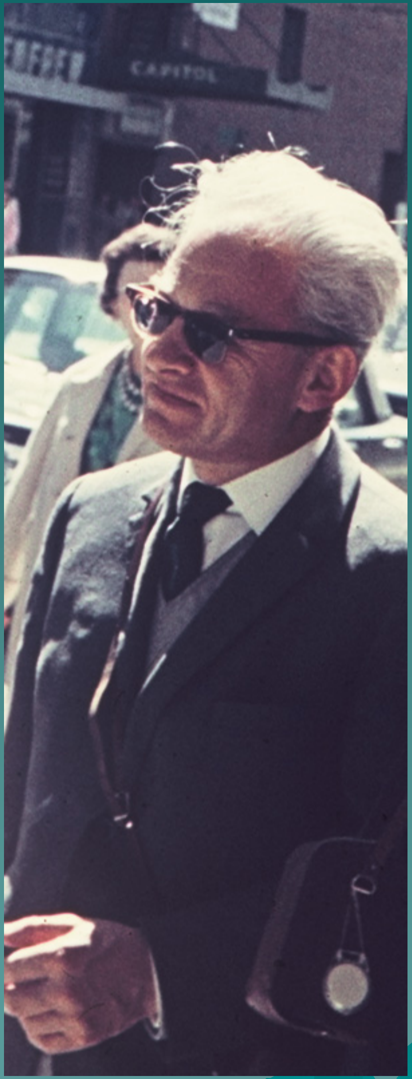


G.B. Khristiansen

Calorimetric measurements of "Proton" satellite gave the reliable intensity at 10^{15} eV.

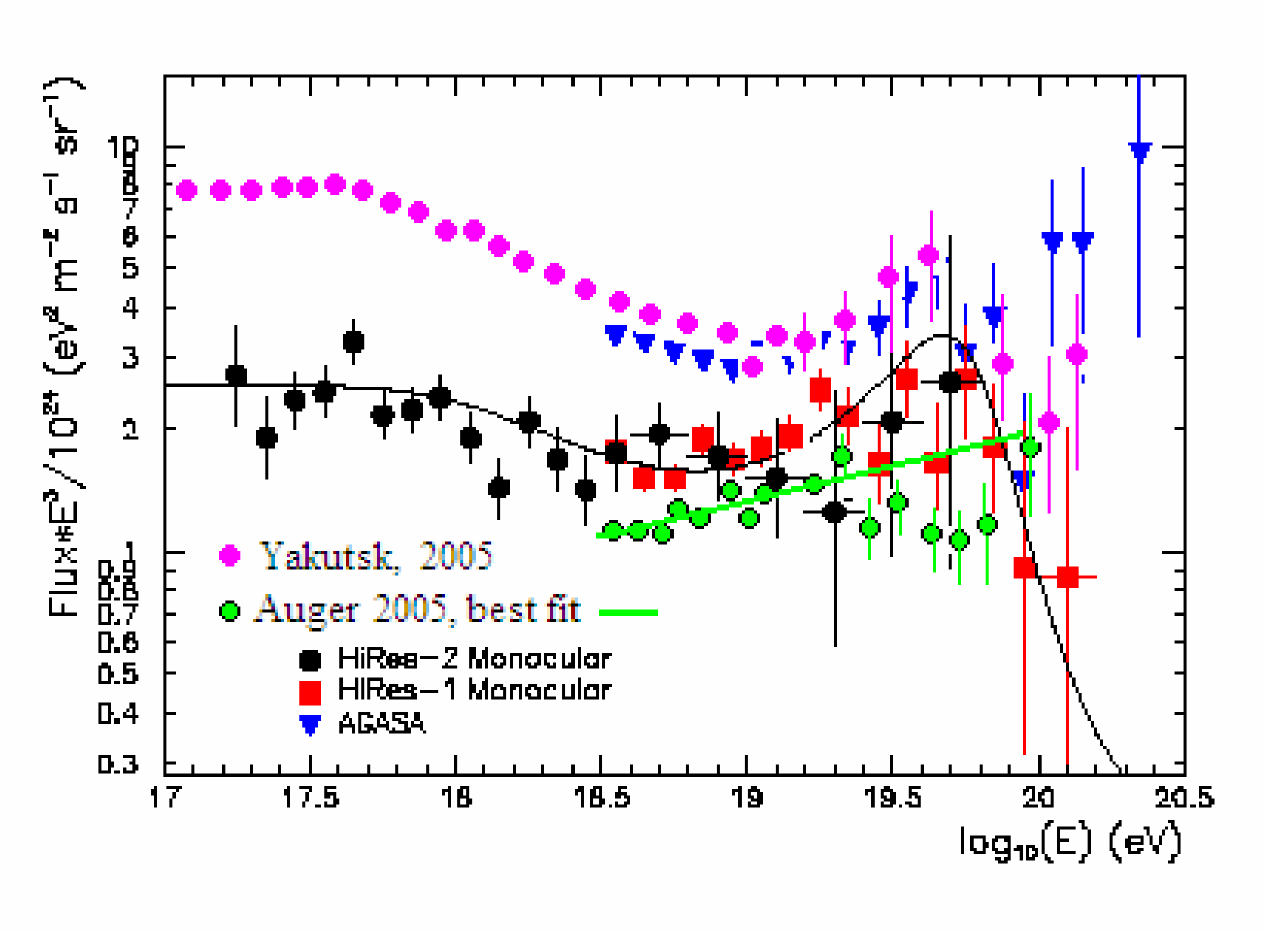
Ionization calorimeter was launched in 1966 by SINP MSU (Grigorov N.L.). The all particle spectrum was measured from 10^{11} eV up to 10^{15} eV , i.e. up to energies measured by the EAS method on the ground.
In 1967 at the Calgary ICRC Prof. Grigorov presented the first satellite results on the High Energy Cosmic Ray spectrum





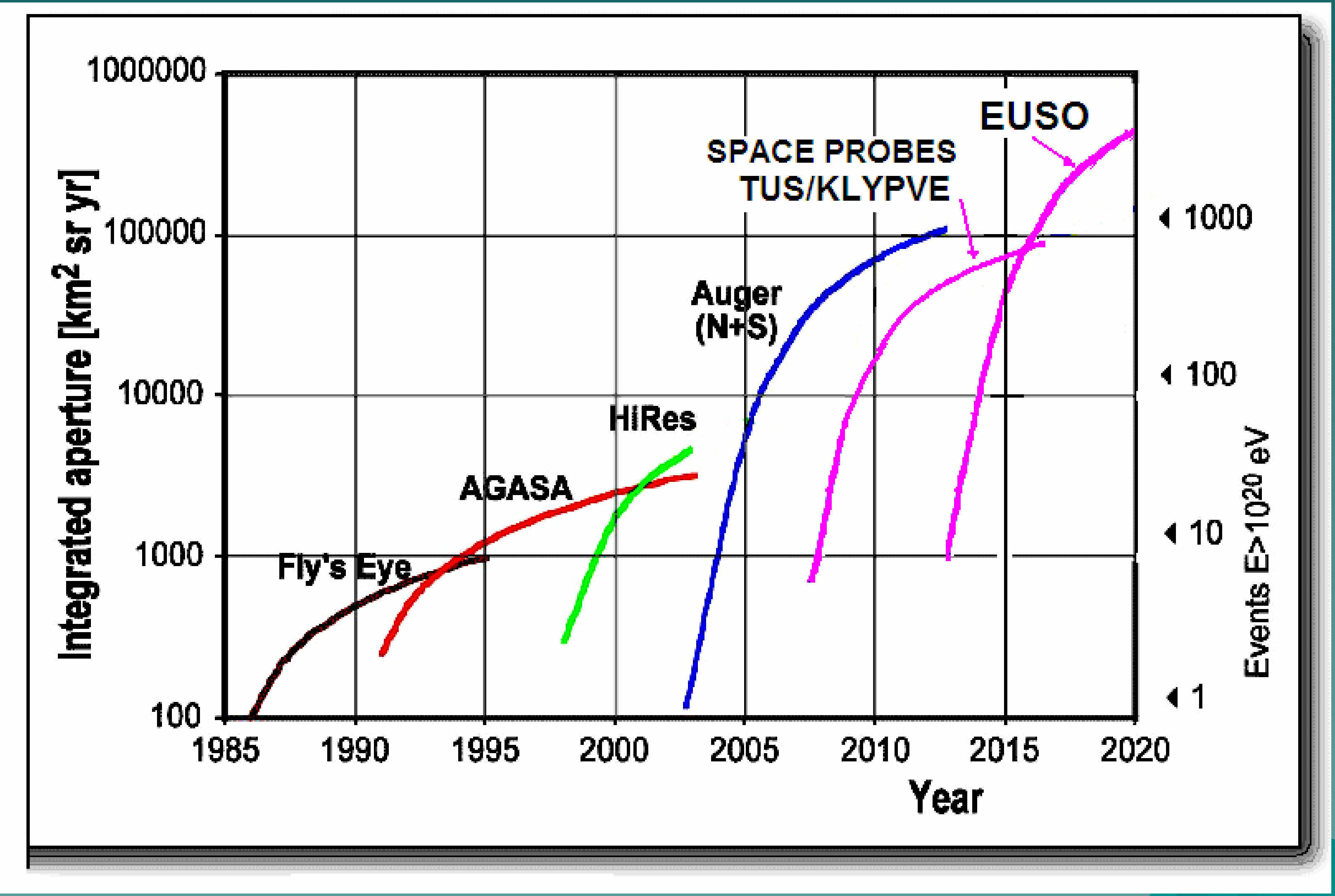
N.L. Grigorov
1967

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 problem now.

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



In 1980 Prof. John Linsley suggested to put the fluorescence detector to space and look down to the Earth atmosphere. He called this experimental concept - "Airwatch".

In Lodz at 2000 European symposium he gave a talk "Beyond the GZK horizon" stressing the point of detection of EAS, generated in the atmosphere by the secondary (cosmological) neutrino with energy threshold of 10 EeV.

John Linsley, 1980

John Linsley, 2000

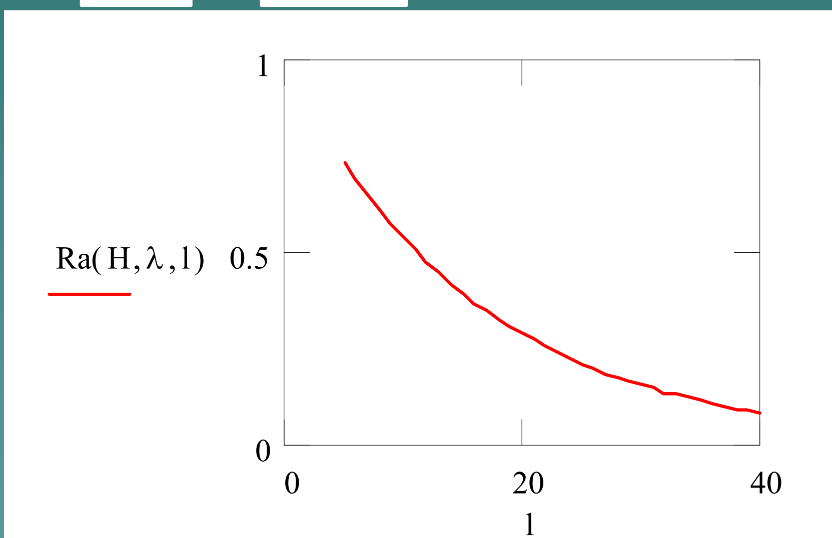
Ground based detector.

Transparency of the atmosphere R_a is poor in the detector view.

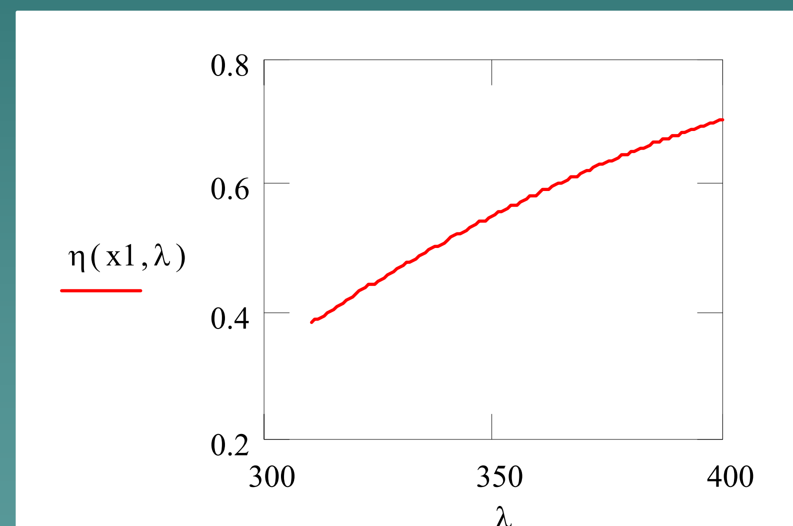
Space based detector.

Transparency of the atmosphere in the vertical view is high.

$H := 0$ $\lambda := 360$



$x1 := 1030$ $\lambda := 310, 311 .. 400$



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

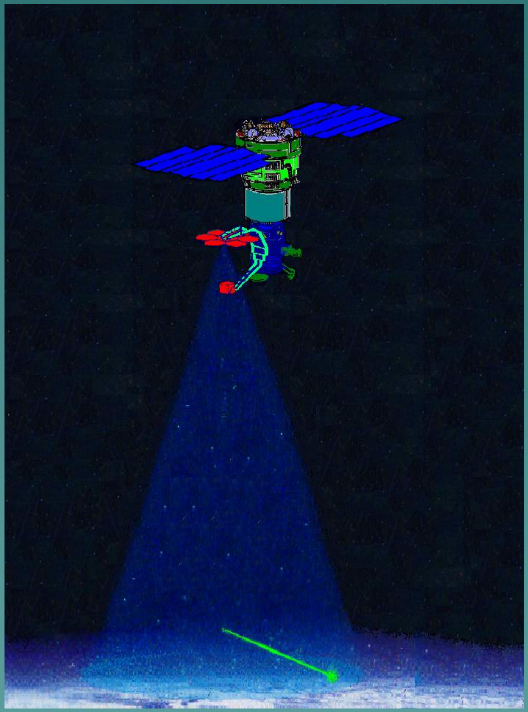
Main goals of this design:

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 interacting 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.

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.

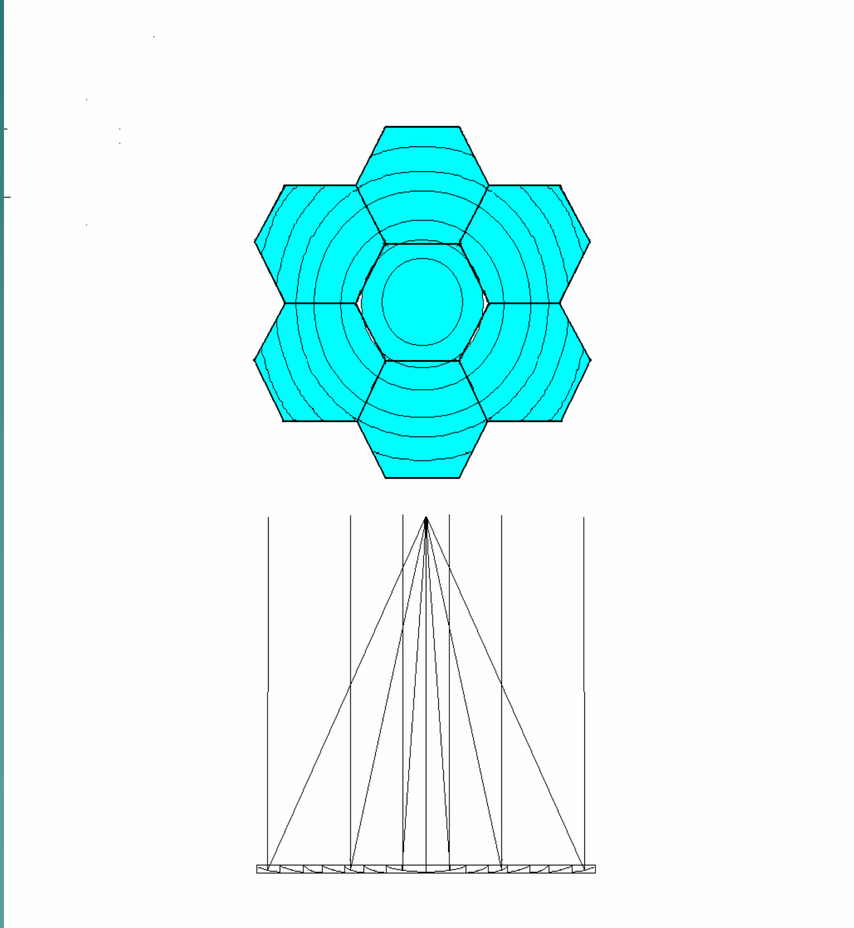
1



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.

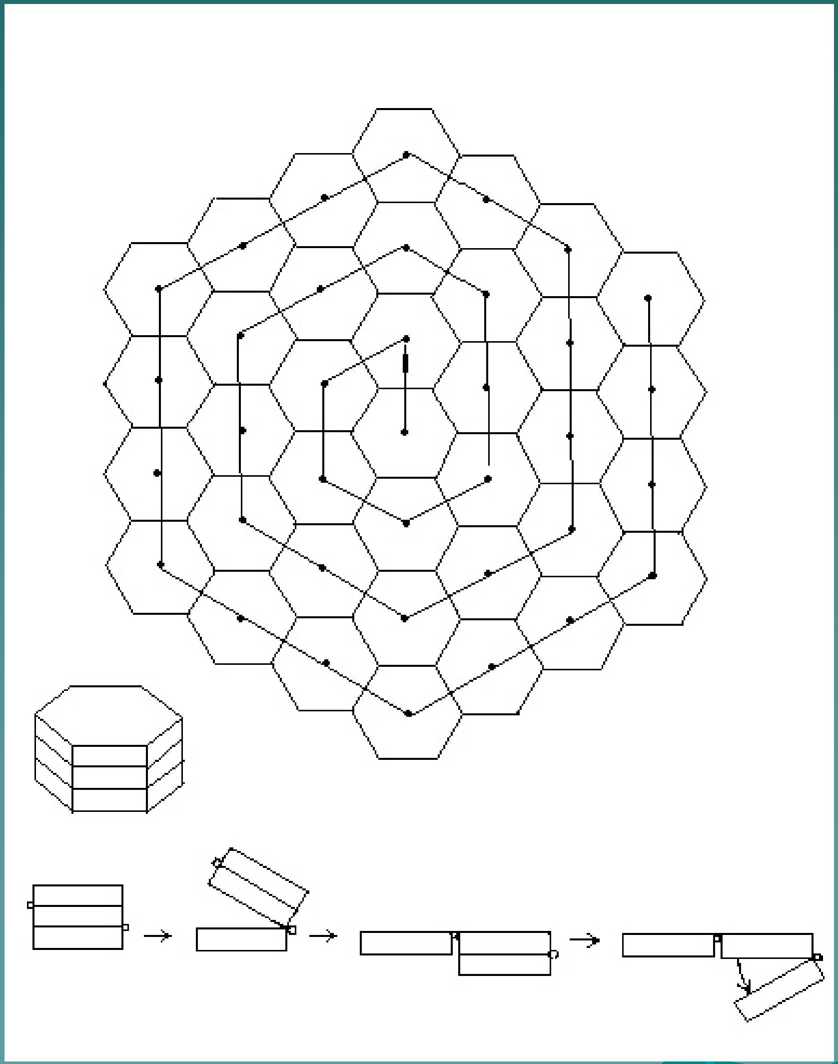
Limited area under a rocket cover dictates the segmented mirror- concentrator design In the TUS telescope it consisted of 6 Fresnel type mirror segments.



- 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.

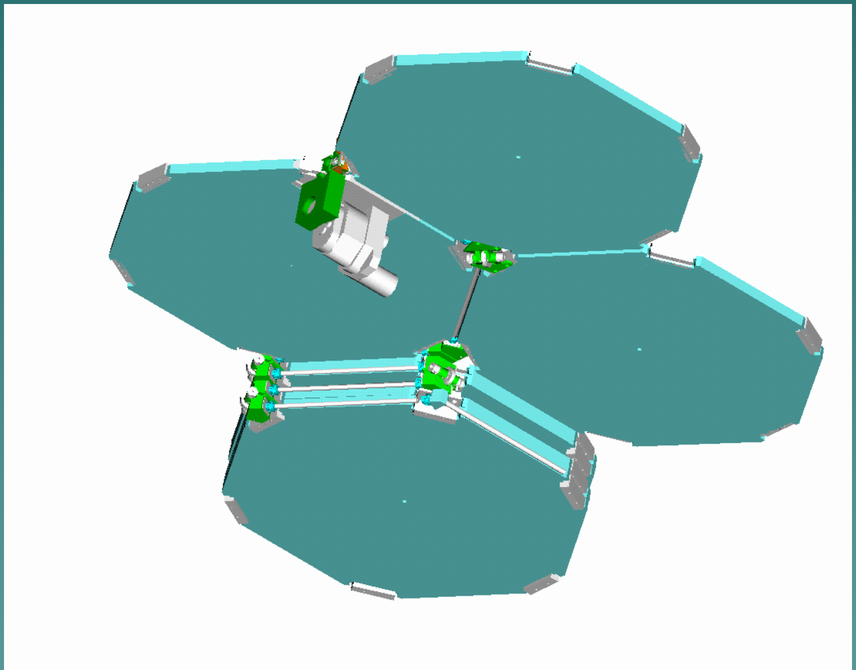
Segmented mirror- concentrator of the KLYPVE project.

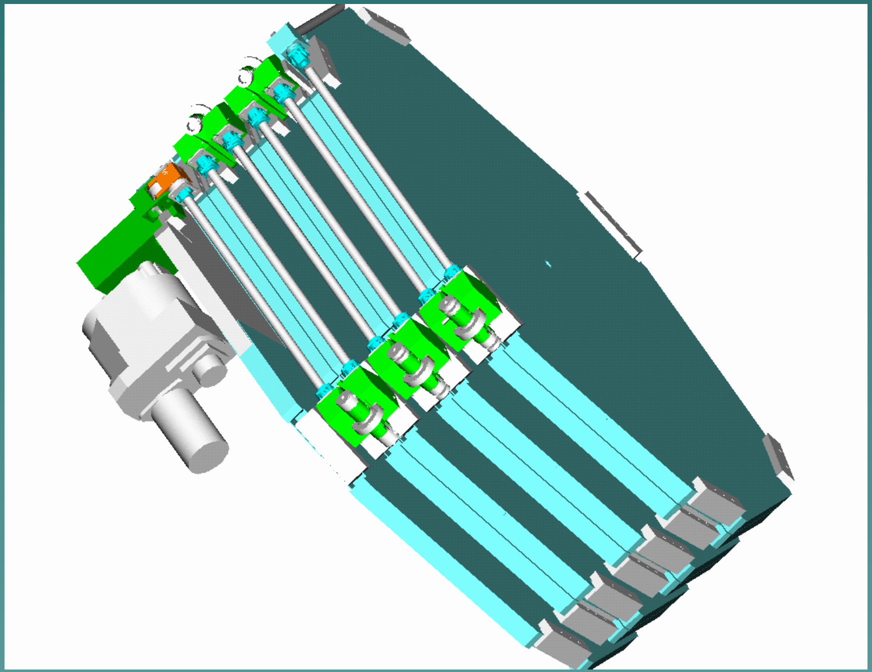
Diameter of the mirror and focal distance 3 m. Full area is 10 m^2 .



Number of Segments is 37.

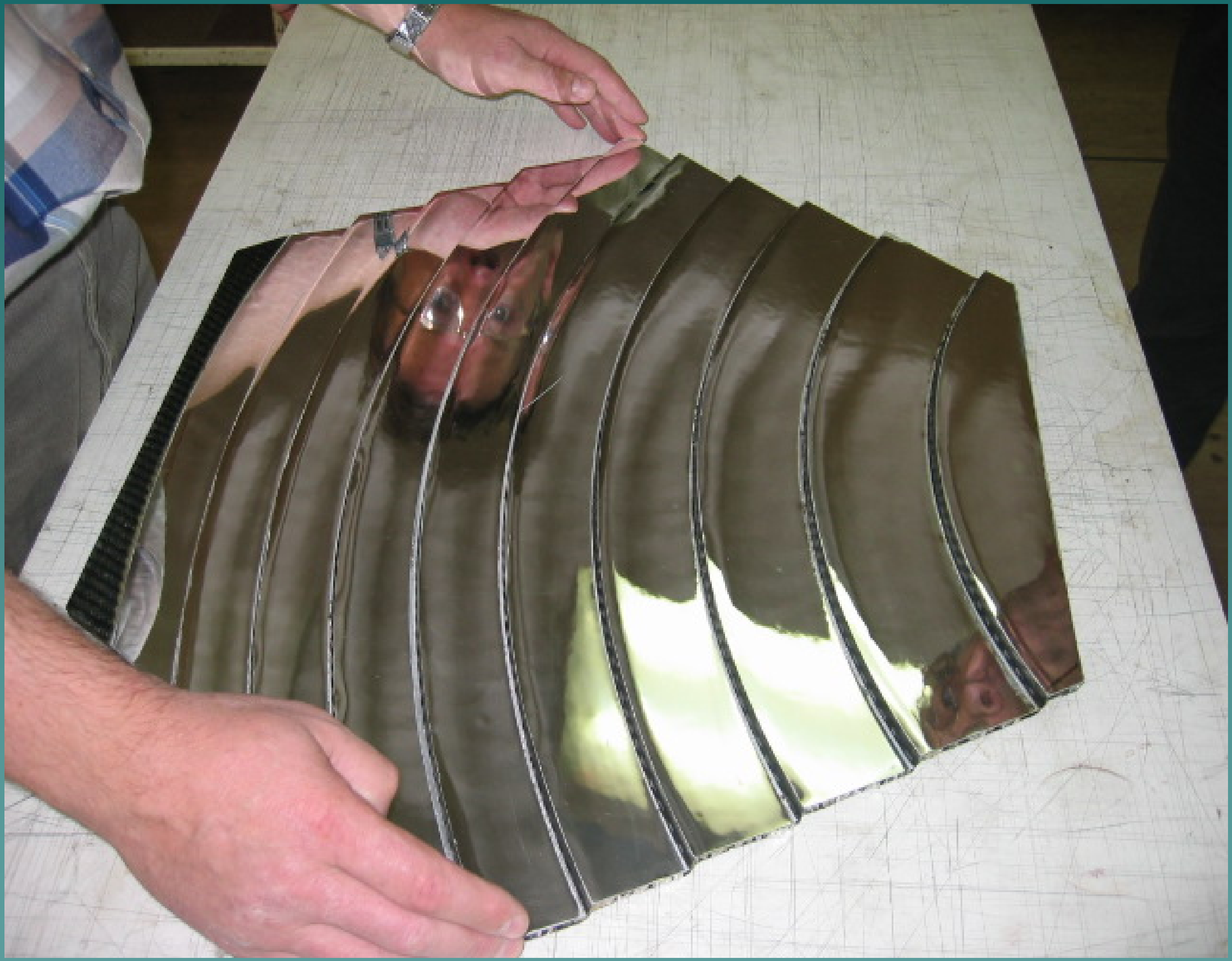
The mechanism of mirror development is designed (Consortium Space Regatta)



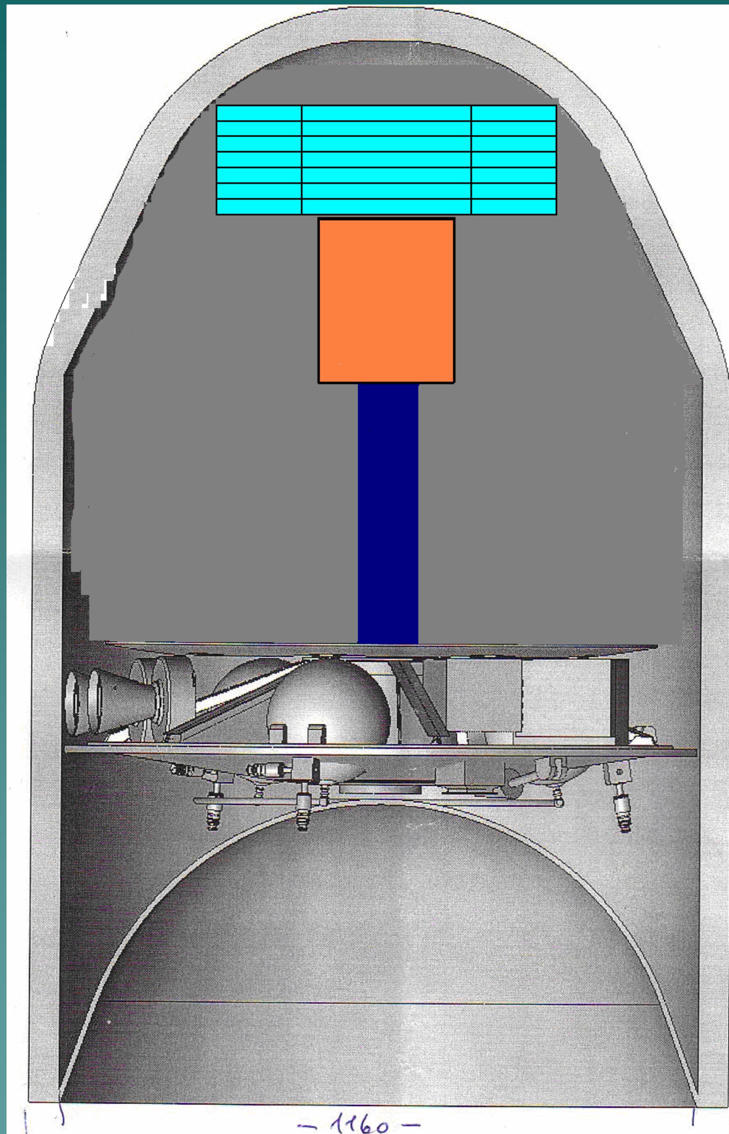


In this mechanism one electric motor moves the segments via axles and cardan joints.

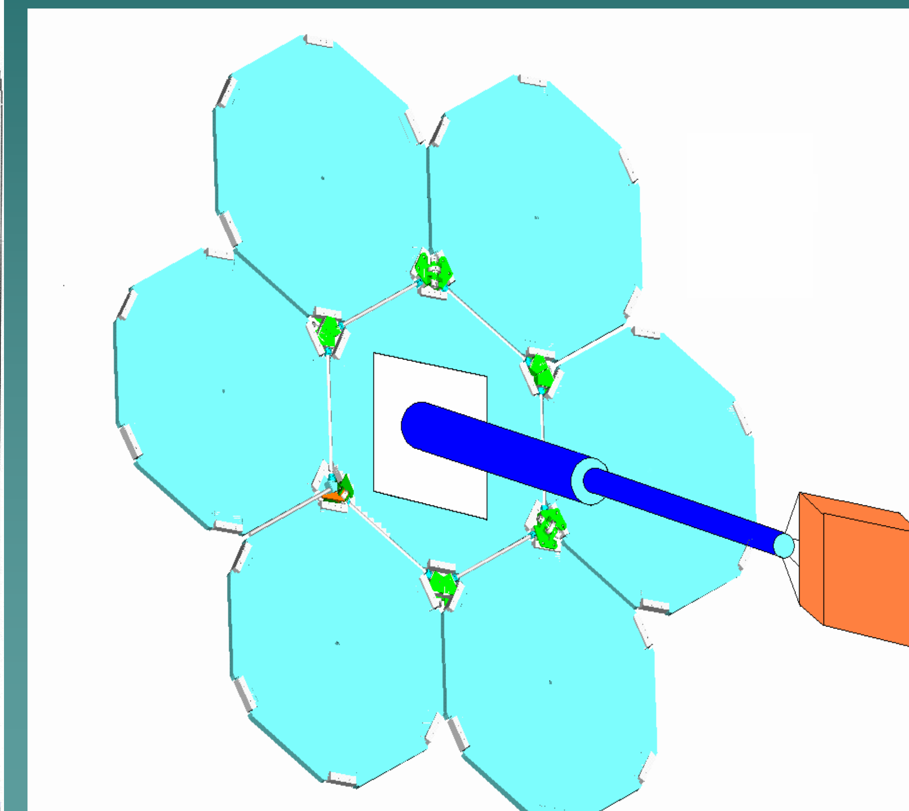
The first mirror segment sample made as a carbon plastic replica of the mold.



Other variant of the TUS accommodation: on the Makeev rocket.

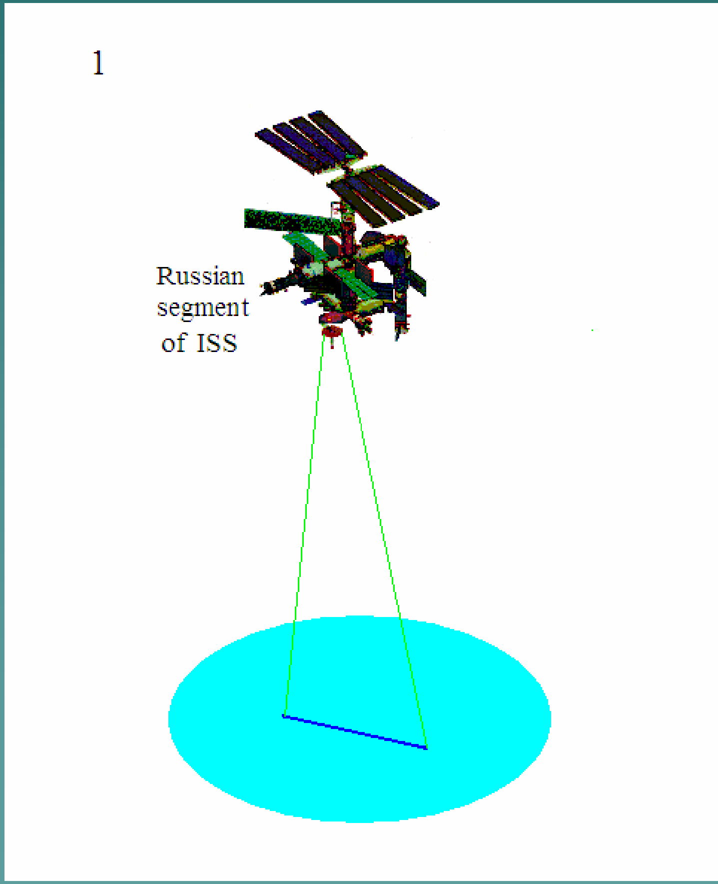


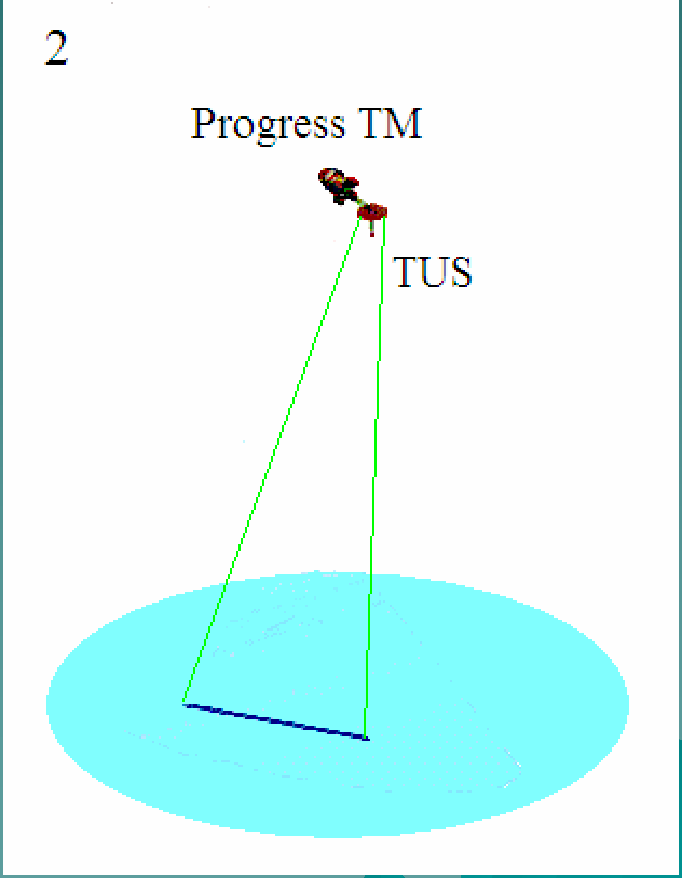
Note that the photo receiver is moved away from the mirror by the telescopic arm



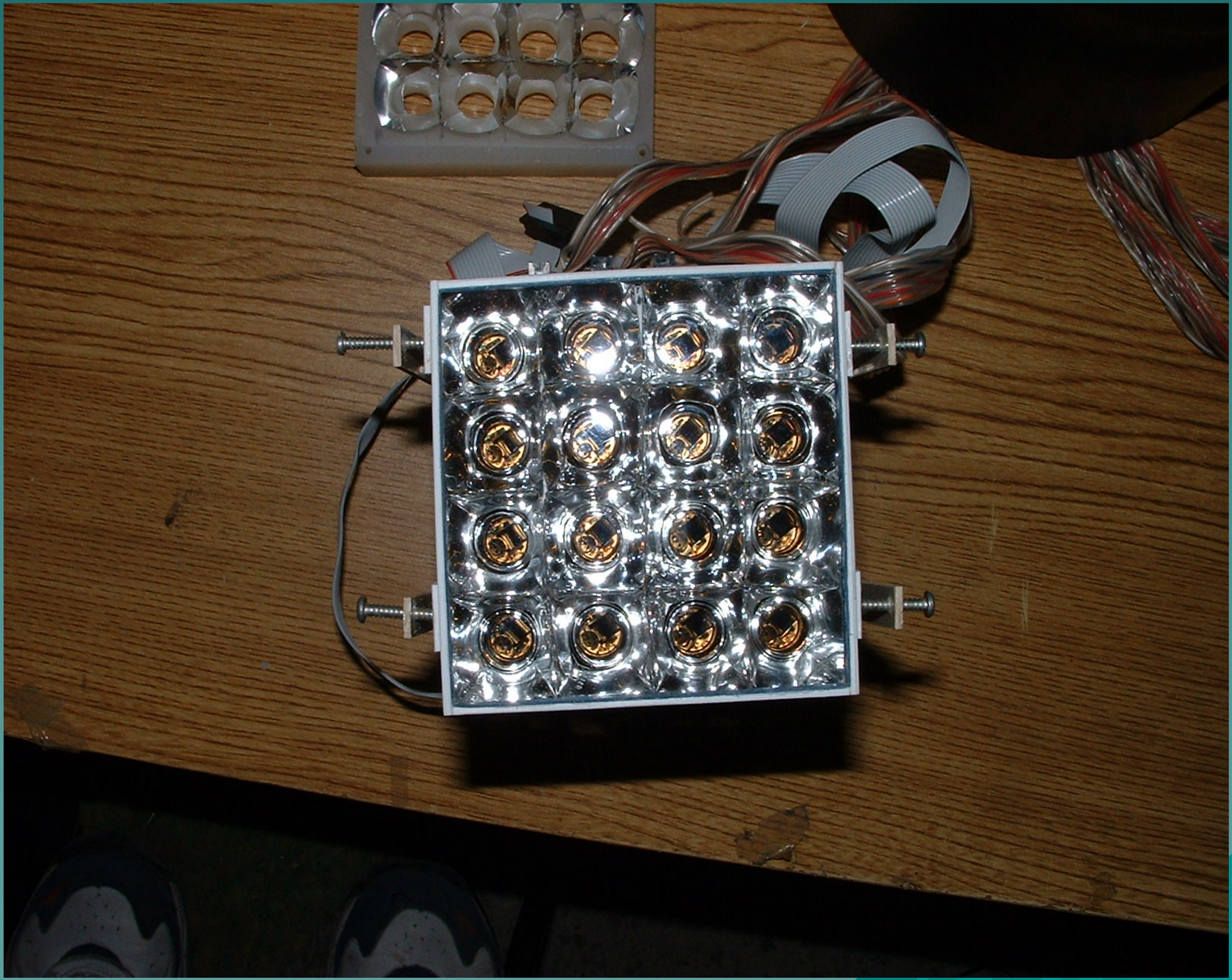
Two more options are under discussion:

1. a detector (or 2 detectors, the EUSO type as an optional second detector) is accommodated on the new Russian module of ISS.
2. The TUS detector has to be launched with the Progress TM being a "free flyer" after undocking from ISS.





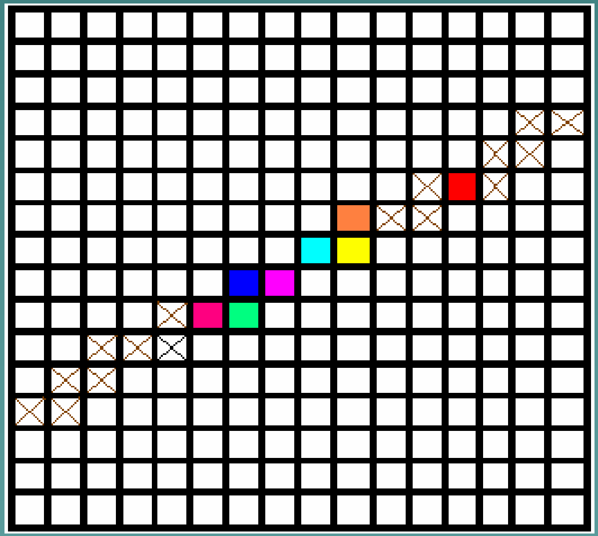
The TUS photo receiver prototype: 4x4=16 PM tubes. It was tested in the Puebla University (Mexico). Now one pixel is operating in space- as the UV detector of the “Universitetsky- Tatiana” satellite.

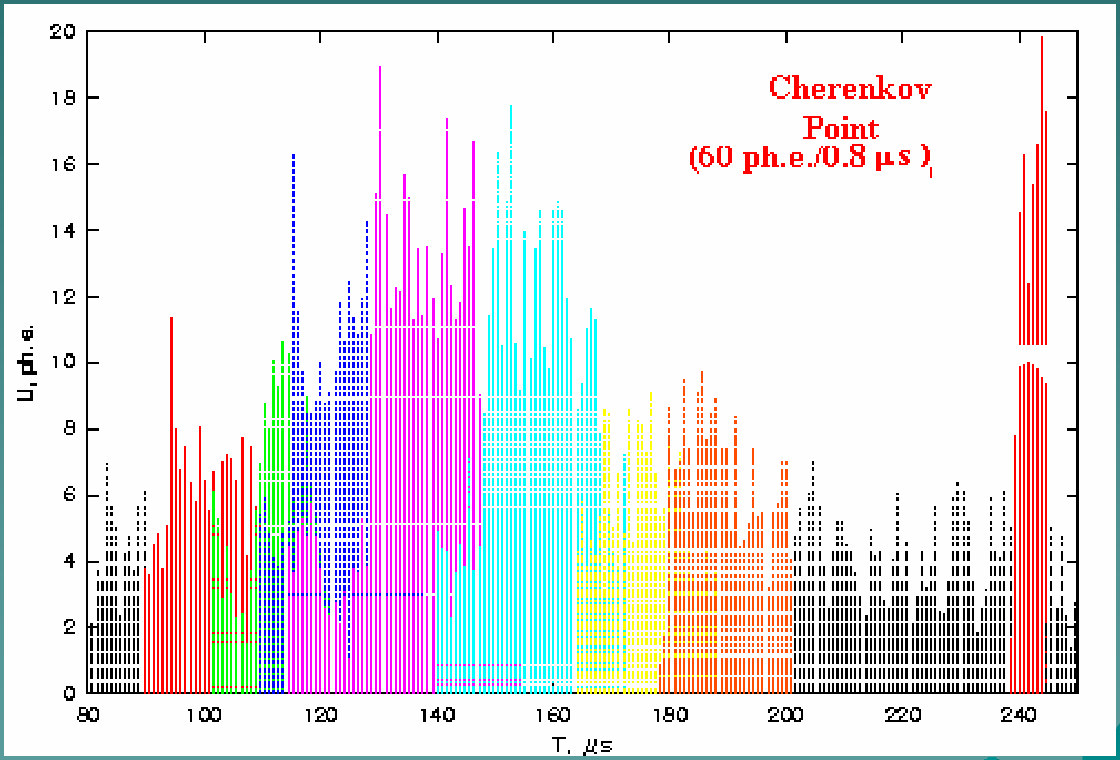


Simulation of UHECR registration

Example of the EAS, "registered" by the KLYPVE detector

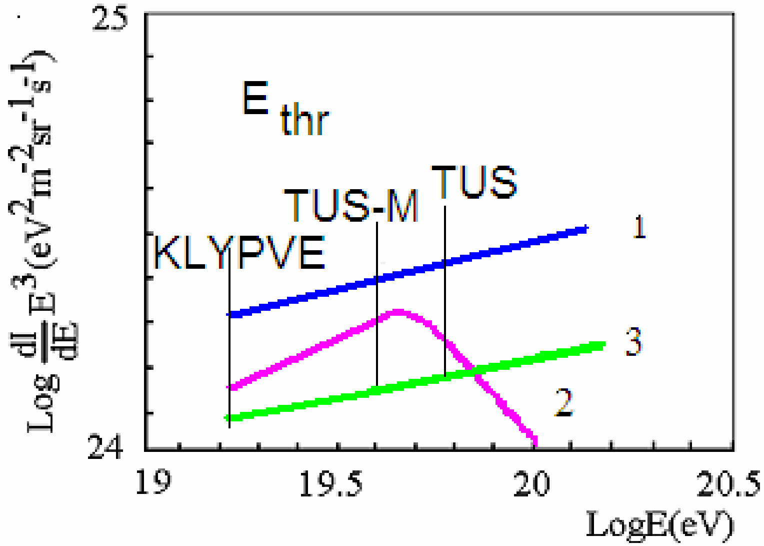
E_0=100 EeV, θ_0=75°, φ_0=25°,
Moonless night; $\sigma E_0 / E_0 \sim 10$ %,
$\sigma\theta_0 \sim 1.5°$, $\sigma\varphi_0 \sim 1°$.





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

Energy spectrum of EECR events expected in TUS and KLYPVE telescopes due to ground arrays data.



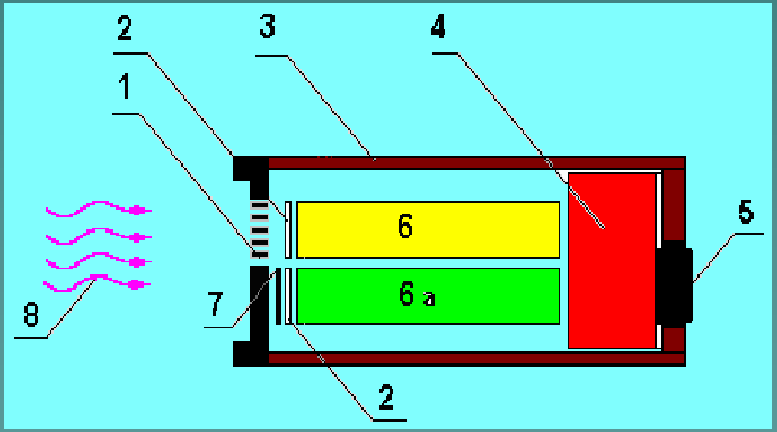
1-expected due to AGASA data,
2- .... to HiRes data,
3- .... to Auger data

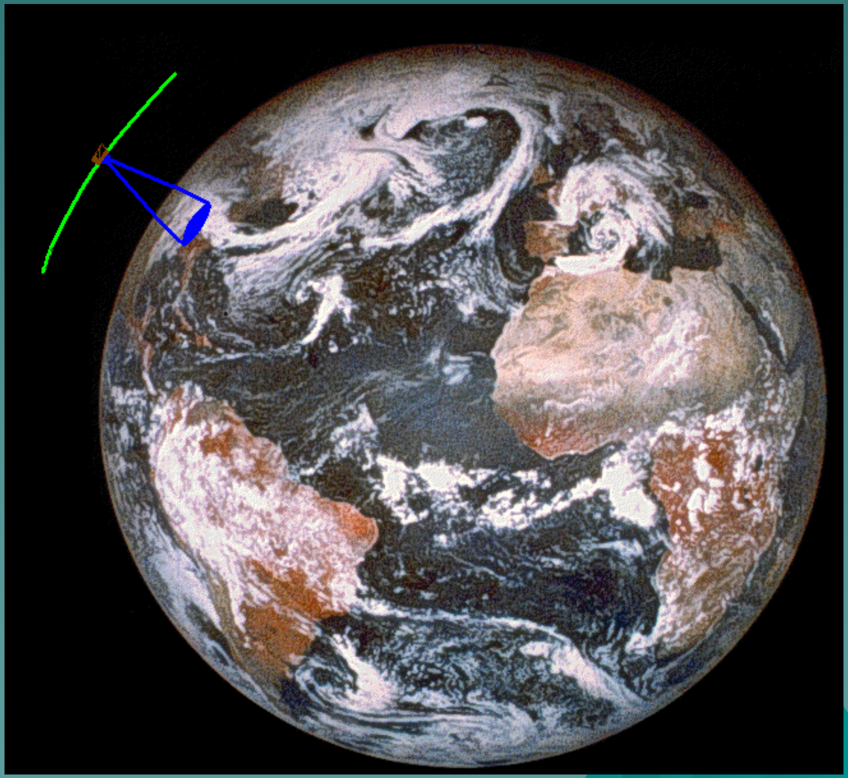
Rate of inclined EAS, zenith angle >60° for E_{thr}=100 EeV per year due to Auger data

TUS	16
KLYPVE	30

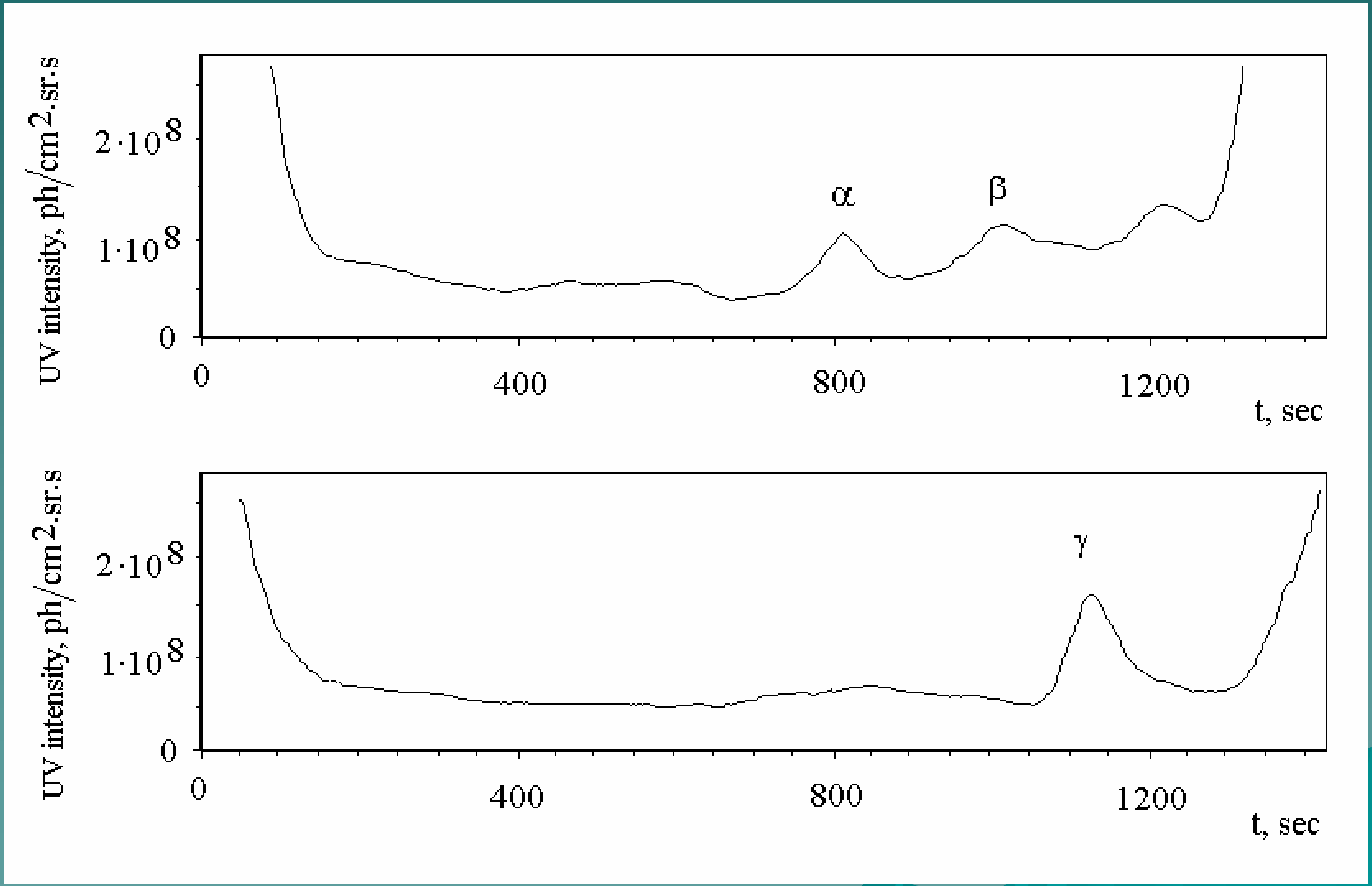
Due to new data on the atmosphere UV background the energy threshold of TUS has to be lower.
Larger mirror is planned for the TUS-M option.

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.

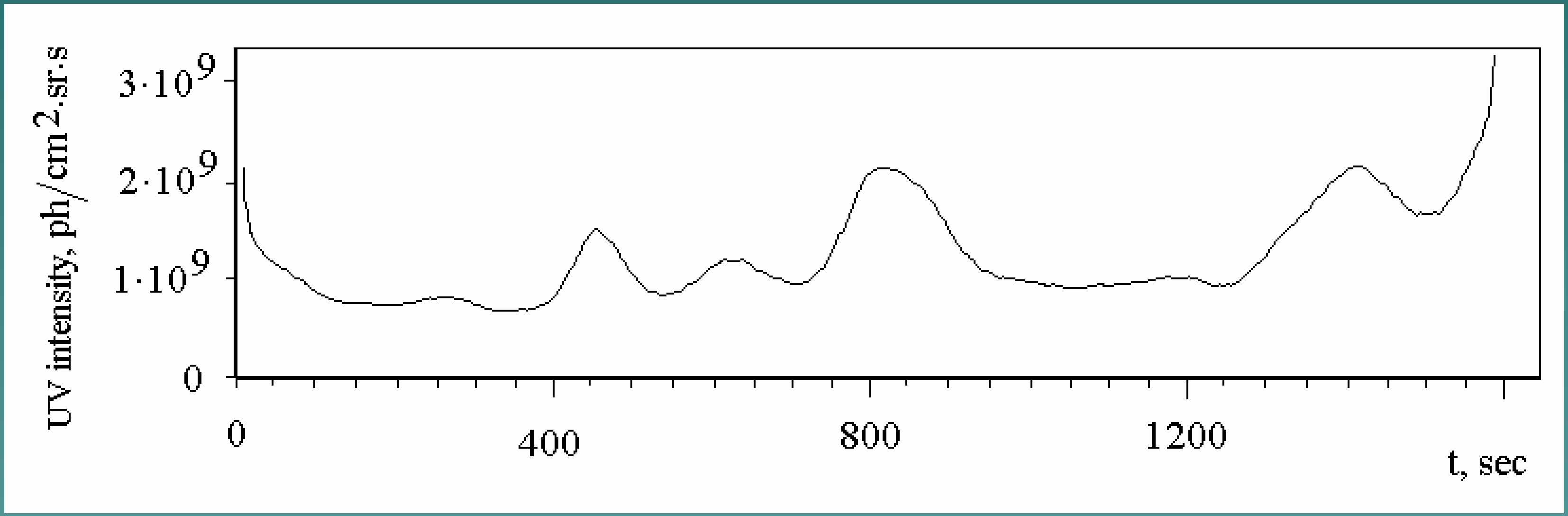




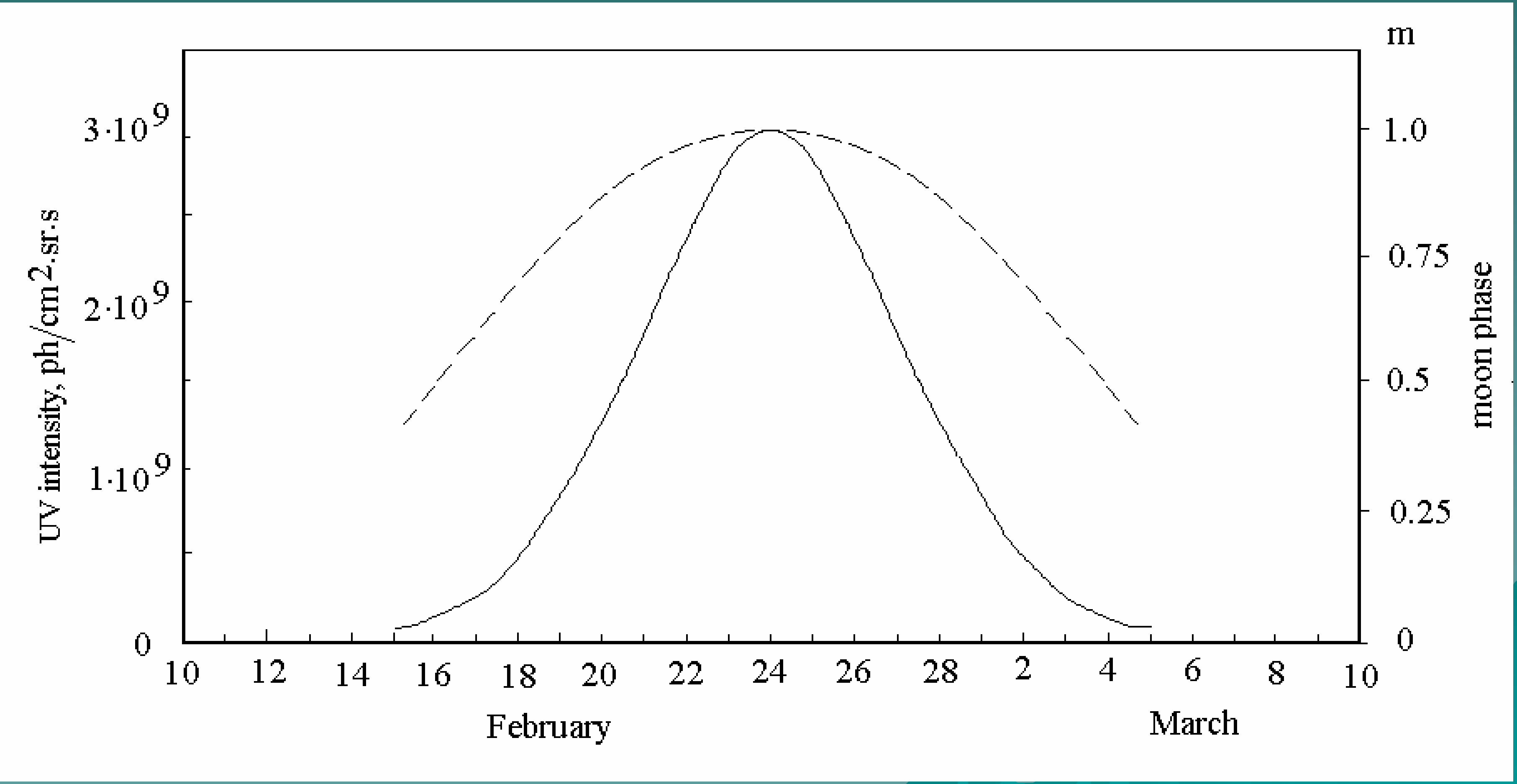
UV light intensity, measured by the “Tatiana” detector- moonless night side of the Earth. Peaks are from the large city lights.



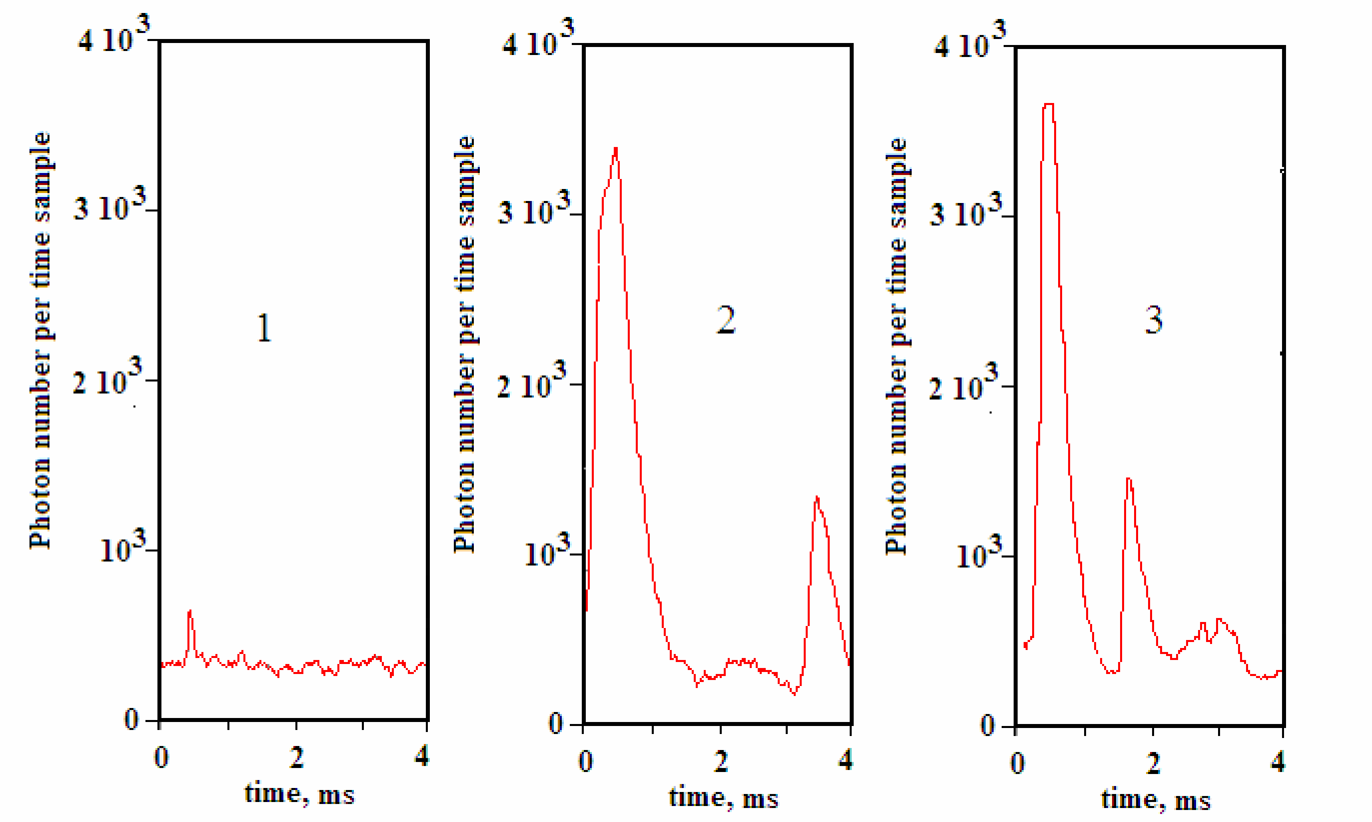
UV intensity on the night side of the Earth at full moon.



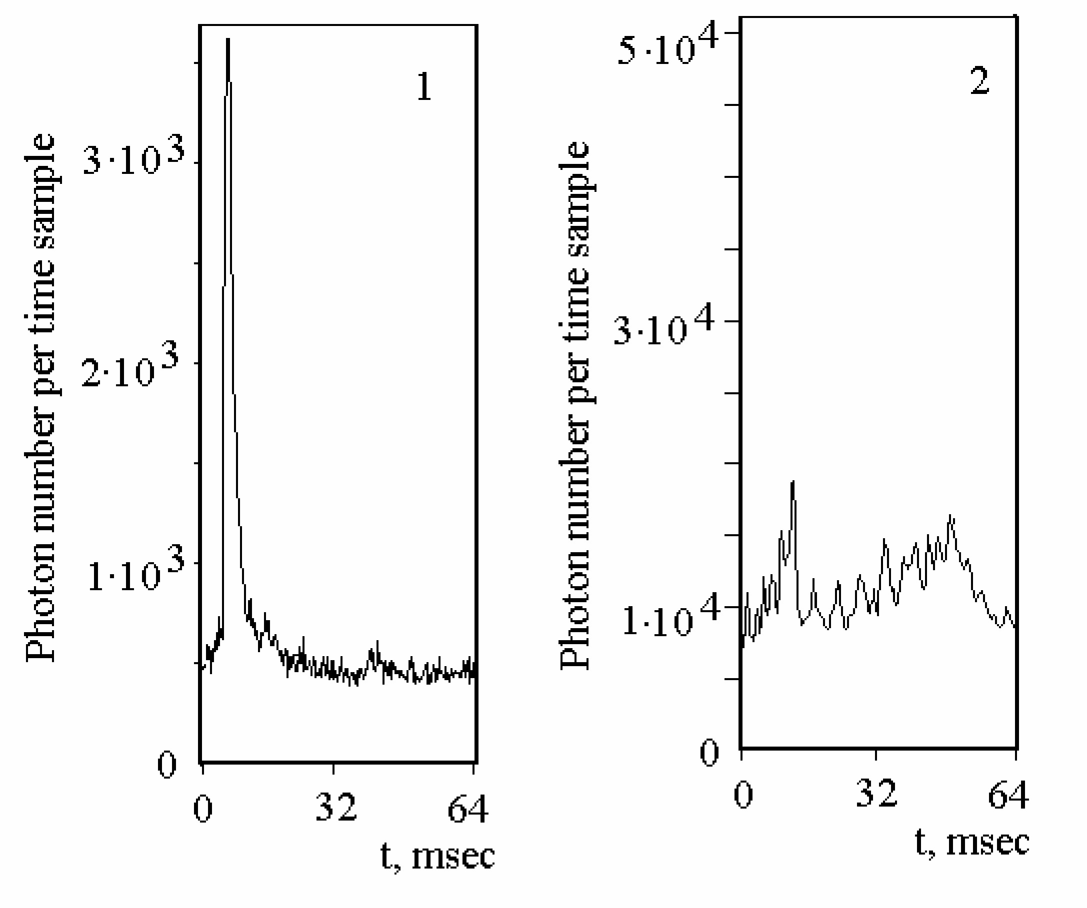
Average UV intensity per circulation (at the night side) during one moon month. Dashed line is the moon phase.
In 8 days of the moon month the average UV intensity is more than 10 times higher than at moonless night.



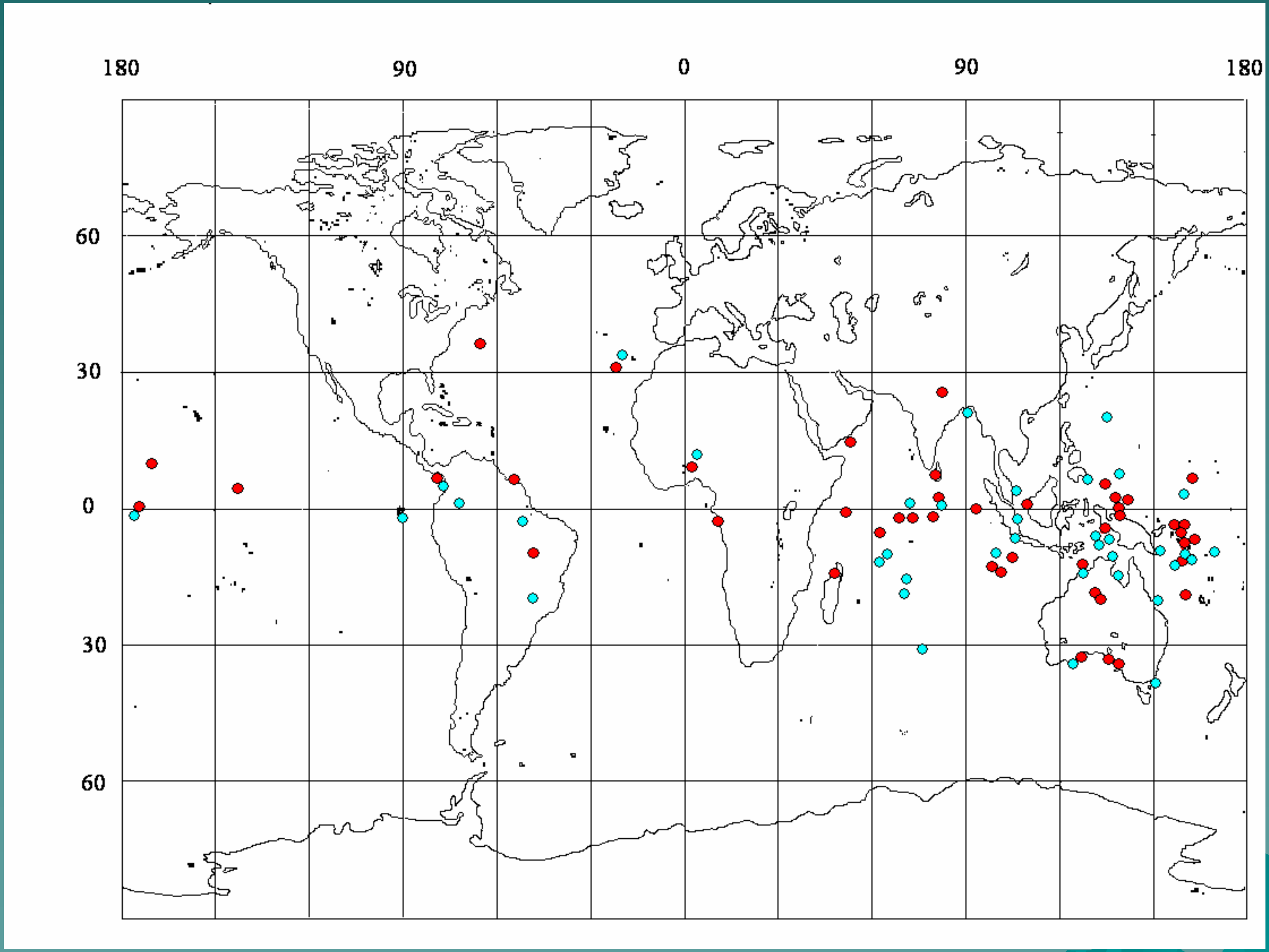
UV flashes registered by the "Tatiana" detector.
Oscilloscope trace 4 ms. UV energy in the atmosphere 10-100 kJ.



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.



Conclusion

1. Space experiment on measuring UHECR particles is promising in getting large geometrical factor (exposure).

2. It will give an independent evidence for UHECR particle energies as an absorption in the atmosphere is much less than in the ground experiments.

3. The new data on the UV light noise (including short flashes) have to be taken into account. The TUS mirror has to be enlarged.

4. We incline to develop the technology of the space experiment in the step-by-step manner- to avoid serious mishaps and to make experiments on other phenomena of fluorescence light in the atmosphere (origin of TLE, sub-relativistic dust grains – I need more time for this topic).

We invite Italian colleagues to participate in

launching space UHECR probe detectors before

EUSO becomes operating.

For more detailed discussion please come to SINP MSU at Wednesday 3 PM. Our place is near Lebedev Institute- ask me for guiding to MSU.