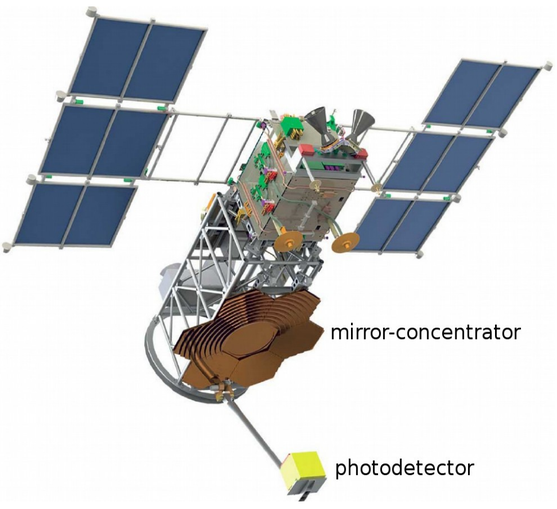
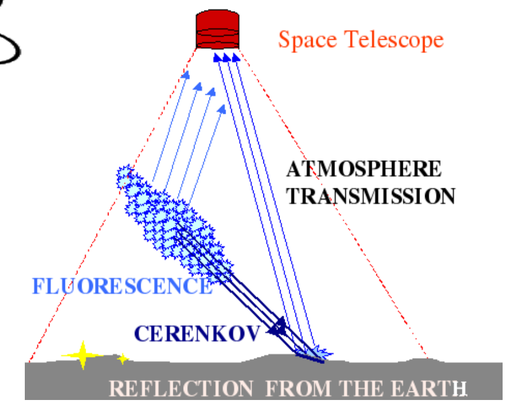


Moscow International School of Physics

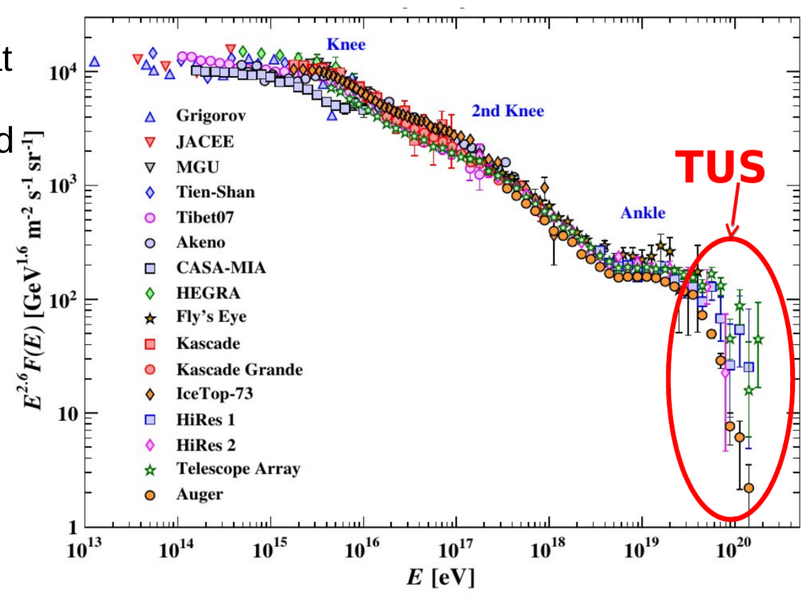
Search and study of extensive air shower events in the TUS detector data

M. Lavrova on behalf of the Lomonosov-UHECR/TLE Collaboration



Mass	< 60 kg.
Power	65 W.
Data rate	200 Mbytes/day
Number of pixels	16x16 PMTs
FOV	±4,5 degree.
Duty cycle	30%
Altitude	500 km
Pixel:	10 mrad(5x5 km)
Mirror area	1,8 m².
Focal distance	1,5 m
Period	94 min

The TUS space experiment is aimed to study the energy spectrum and arrival direction of Ultra High Energy Cosmic Rays (UHECR) at E ~ 10^{20} eV by measuring the fluorescence yield of the Extensive Atmospheric Shower (EAS) in the atmosphere. The fluorescent and Cherenkov radiation of the EAS generated by UHECR particles should be detected in the Earth's atmosphere on the night side of the space orbit at altitudes 400–500 km. The multifunctional "Lomonosov" satellite, with the TUS detector on board, was launched from the newly built Cosmodrome Vostochny on April 28, 2016. The satellite has a solar-synchronized orbit with an inclination of 97˚, a period of ~94 min, and a height of about 470-500 km. The TUS detector consists of two main parts: a modular Fresnel mirror-concentrator and a photo-receiver matrix. A PMT quantum efficiency is ~20% for the wavelength of 350 nm.



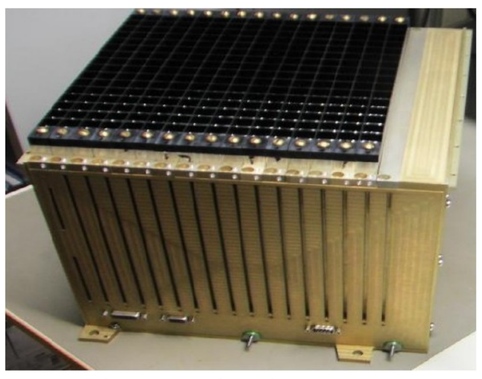
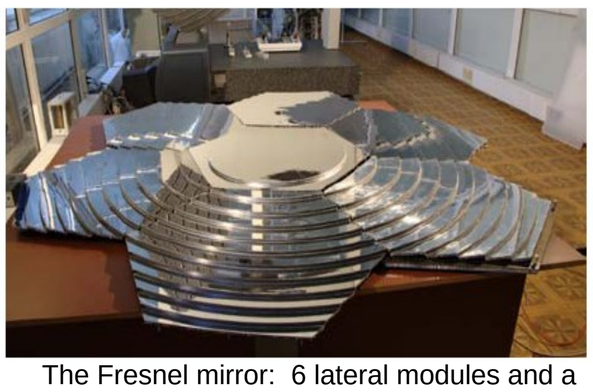


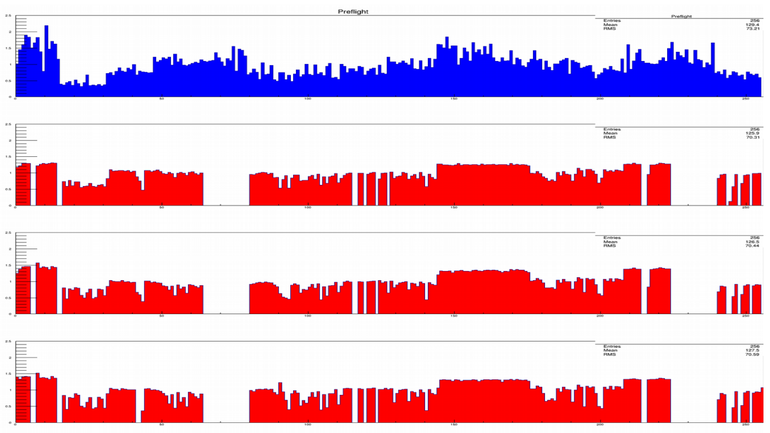
Photo receiver box.


Launch of the "Lomonosov" satellite on April 28, 2016.

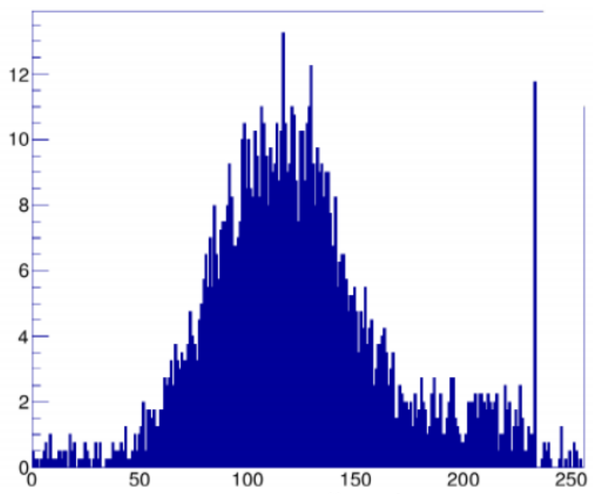

The Fresnel mirror: 6 lateral modules and a central one.

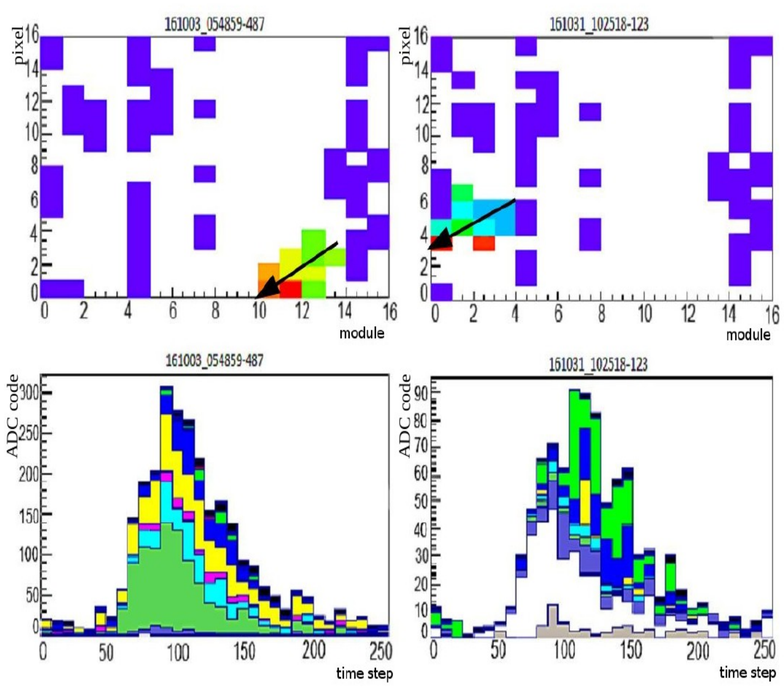
TUS has a two-level trigger. The first-level trigger is a threshold trigger: the photodetector modules board calculates a moving sum of PMT signals during 16 time steps in each channel and looks for an moving sum value above a threshold level. The second-level trigger is a pixel-mapping trigger. This procedure selects cases of sequential triggering of spatially contiguous active pixels that are also adjacent in time, allowing for the selection of events with a special spatial-temporal pattern.

During the first days of operation ≈20% PMTs were broken due to HV tuning system failure.For the same reason, the properties of the remaining PMTs are changed.
Calibration of PMT gains was done based on analyzing background data itself.



Relative PMT gain coefficients for all 256 channels according to pre-flight measurements (top) and reconstructed from background data for first 3 half-years of operation.


ESAF MC event. E = 10^{20} эВ, θ = 60°



The EAS candidates. Upper plots – image of event with hit pixels and not-working (blue) ones.
Bottom plots – the amplitude variation of time for selected hit pixels.

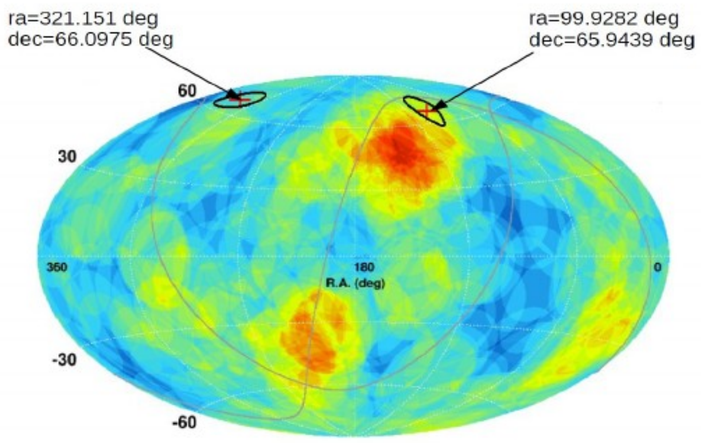
The simulations employed ESAF (EUSO Simulation and Analysis Framework) for the fluorescent radiation of EAS and the TUSSIM program for the Fresnel mirror optical parameters, the light guide of the photo detector, the front end and trigger electronics.
These simulations allow to study the EAS signal temporal structure and expected amplitude and to develop the criteria for the EAS search in the TUS detector data.
Based on the simulation, a reconstruction program was created.

-The TUS electronics can operate in four modes intended for detecting various fast optical phenomena in the atmosphere on different time scales (1 time step): 0.8μs, 25.6 μs, 0.4 ms, 6.6 ms

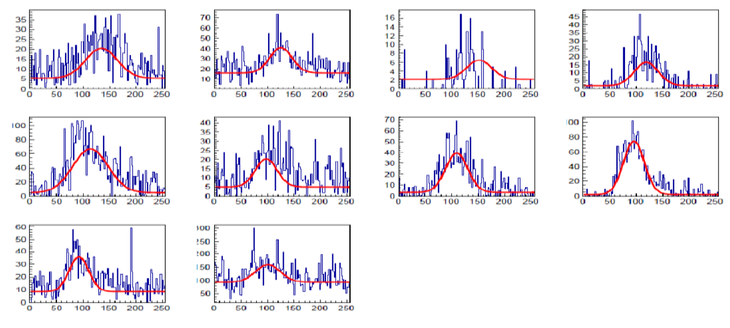
-During two years of operation, the TUS detector has measured about 200000 events in EAS mode.

- More than 80% of events registered by TUS have noise-like waveforms.

-The TUS detector has measured numerous UV transient flashes in the EAS mode with different temporal dynamics and spatial structure.



Location of the EAS candidates in the equatorial coordinate system on top of the Auger+ TA data. Crosses show EAS in TUS events taking into account errors in measuring angles.



Time distributions of the EAS signals in the hit PMT pixels of the EAS candidate event №487.

Conclusion:

-The TUS detector is operating on board the "Lomonosov" satellite. TUS proved the possibility of registration of UHECR from the space orbit.
-During the search for an UHECR EAS a large number of events of various origins that take place in the atmosphere of the Earth were observed. These events may contain some genuine EAS events.
-A multi-level algorithm for the search of EAS-like events was developed and applied to the TUS data set analysis.
-As a result, at least two EAS candidates were selected and preliminary have been analyzed.
-A more detailed analysis of this and other EAS candidate events, which were found in the TUS detector data, is in progress.