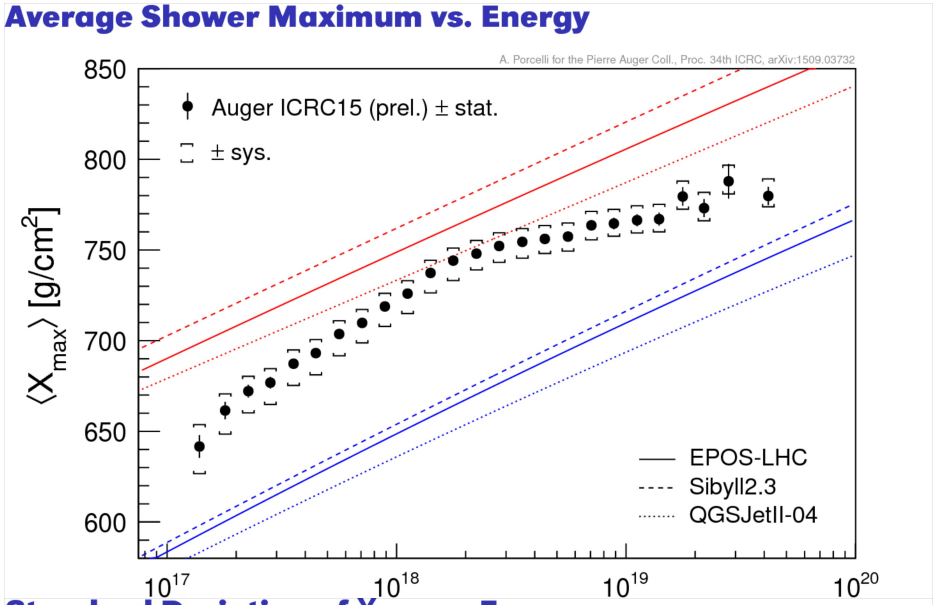
Отчет по эксперименту ТУС

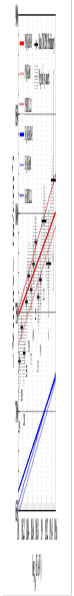
Гринюк А.А.

Launch of the “Lomonosov” satellite on April 28, 2016

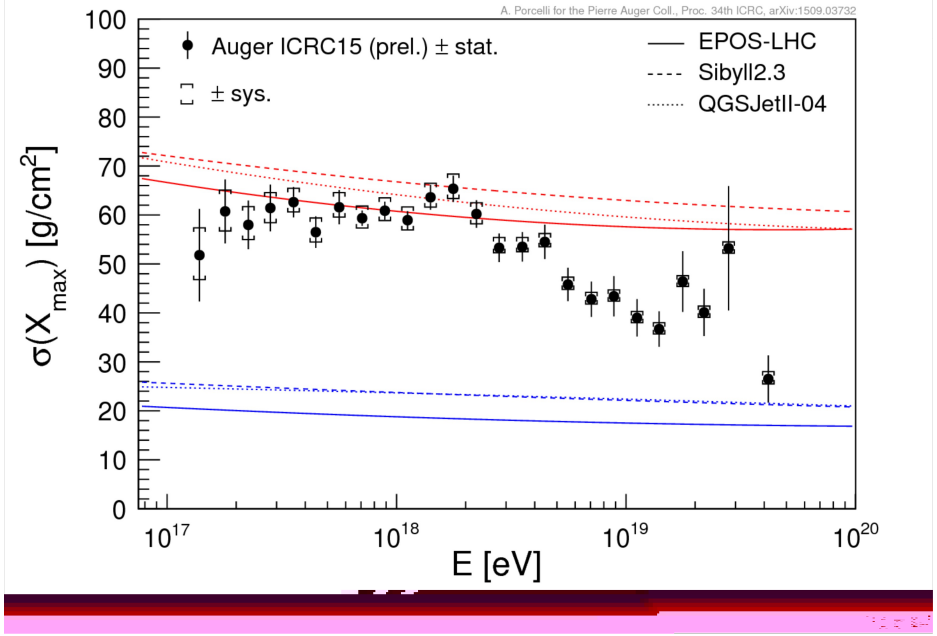
MASS COMPOSITION

Average Shower Maximum vs. Energy





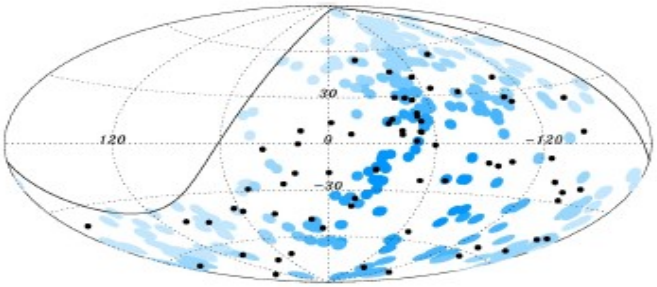
Standard Deviation of X_{max} vs. Energy



UHE Correlation with AGNs within GZK-sphere?

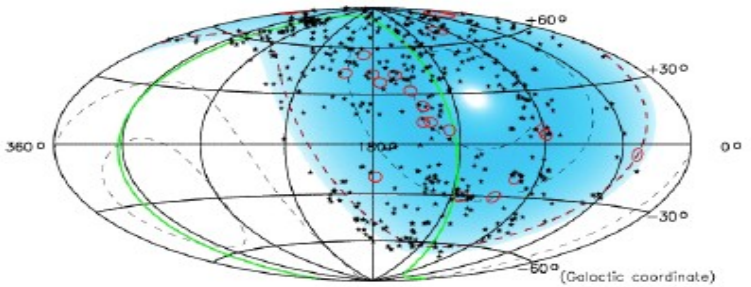
VCV catalogue, E> 57 EeV, z<0.018, distance < 3.1 deg.

Auger

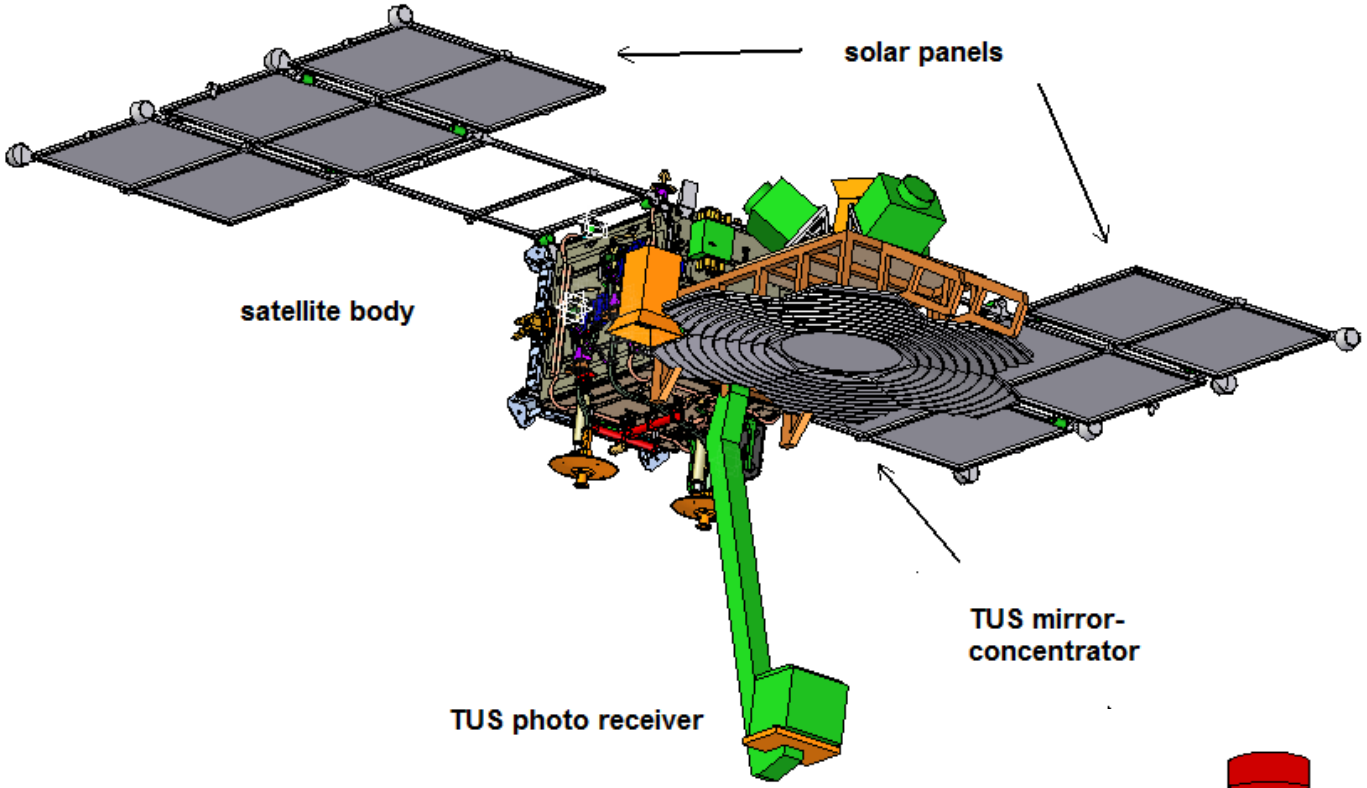


28 out of 84 correlate

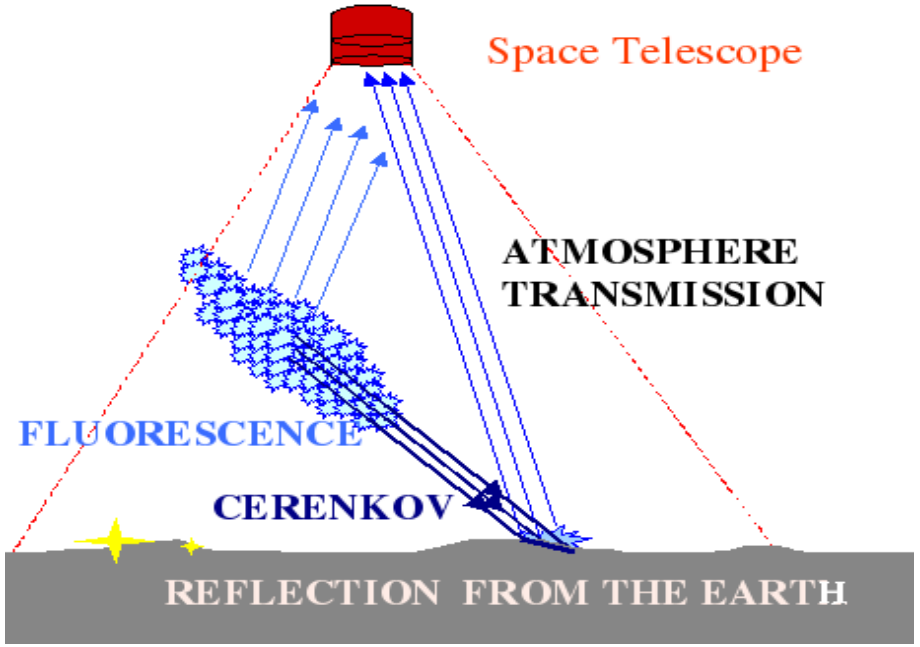
TA



8 out of 20 correlate



The TUS detector on board
on the Lomonosov satellite

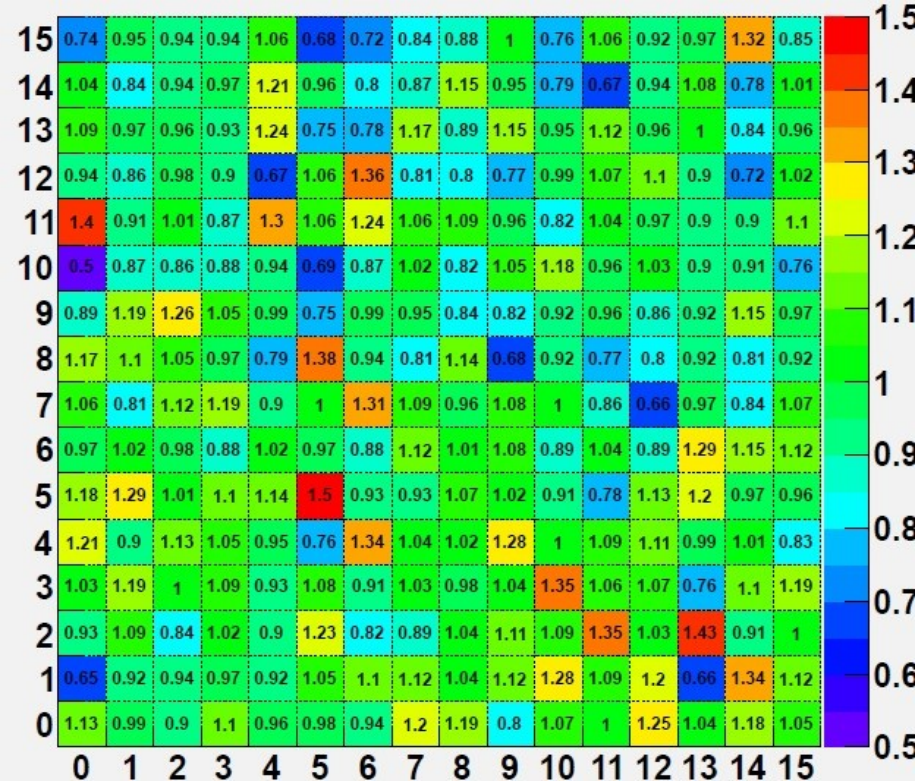


Technical parameters of TUS

Parameter	Value
Mass	< 60 kg
Power (maximum)	65 W
Data (maximum)	200 Mbyte/day
FOV	±4,5 degree
Number of pixels	256 (16 clusters of 16 PMTs)
Pixel size	10 mrad (5.5 × 5.5 km)
Mirror area	2.0 m^2
Focal distance	1.5 m
Duty cycle	30%
Trigger Rate	<1/minute

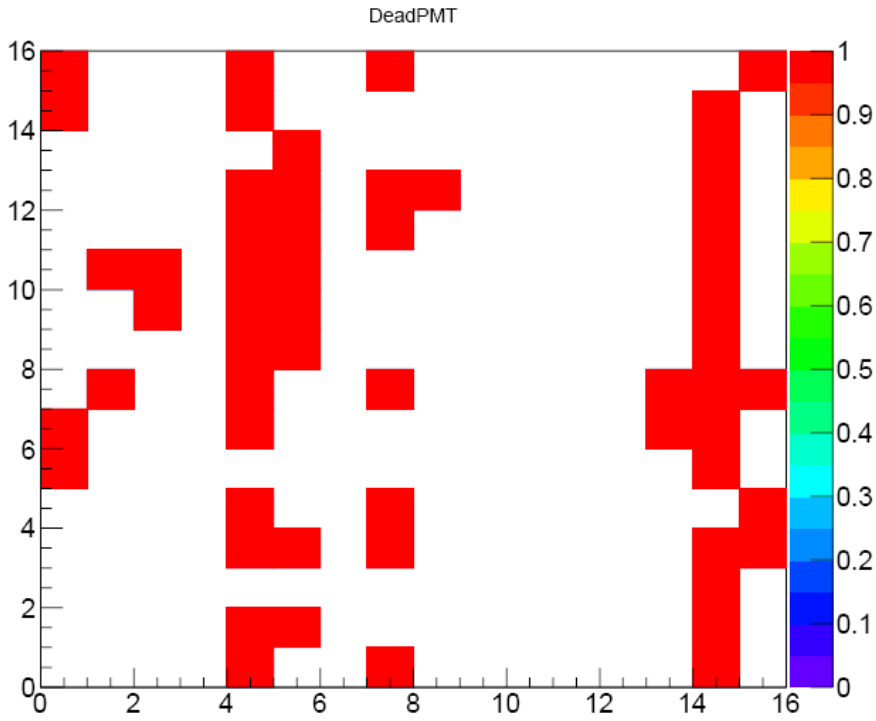
The Lomonosov satellite has a solar-synchronized orbit with an inclination of 97°, a period of ~94 min, and a height of about 470-500 km

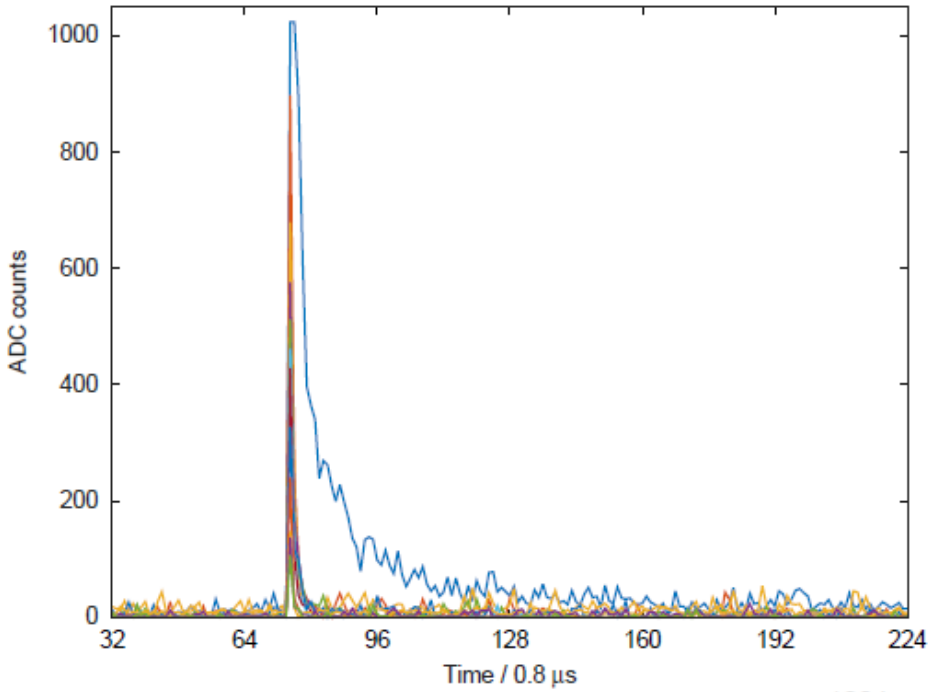
The Fresnel mirror has an area of 2.0 m^2 and a focal distance of 1.5 m. The DAQ electronics forms 256 channels with a time resolution (time step) Δt = 0.8 μs. One pixel FoV is ≈ 0.1 msr, which corresponds to a spatial spot of 5x5 km^2 on the Earth surface for the 500 km orbit height and 80x80 km^2 for the whole detector.

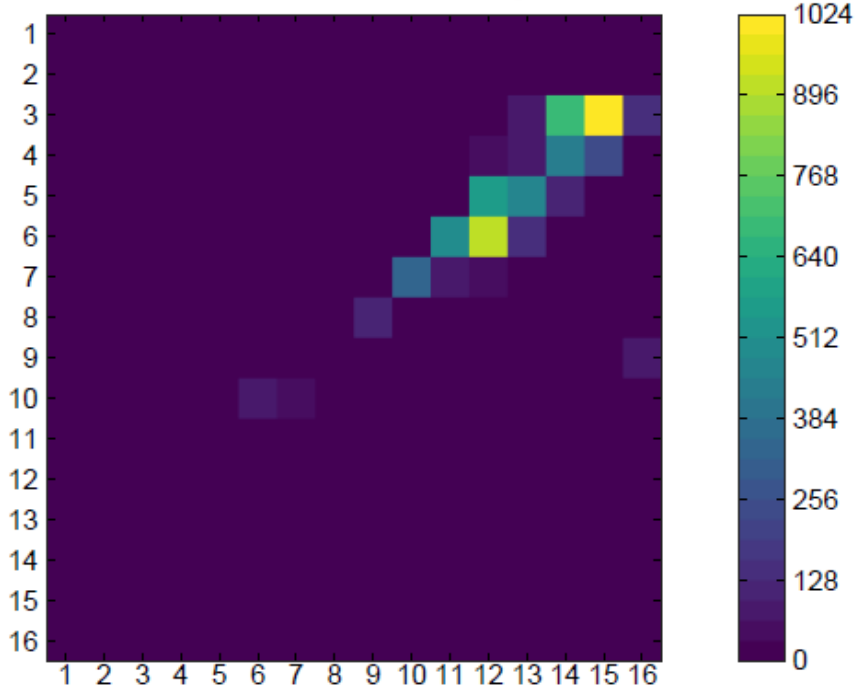


Before:
Map of the TUS pixel gains after preliminary PMT grouping and adjustment

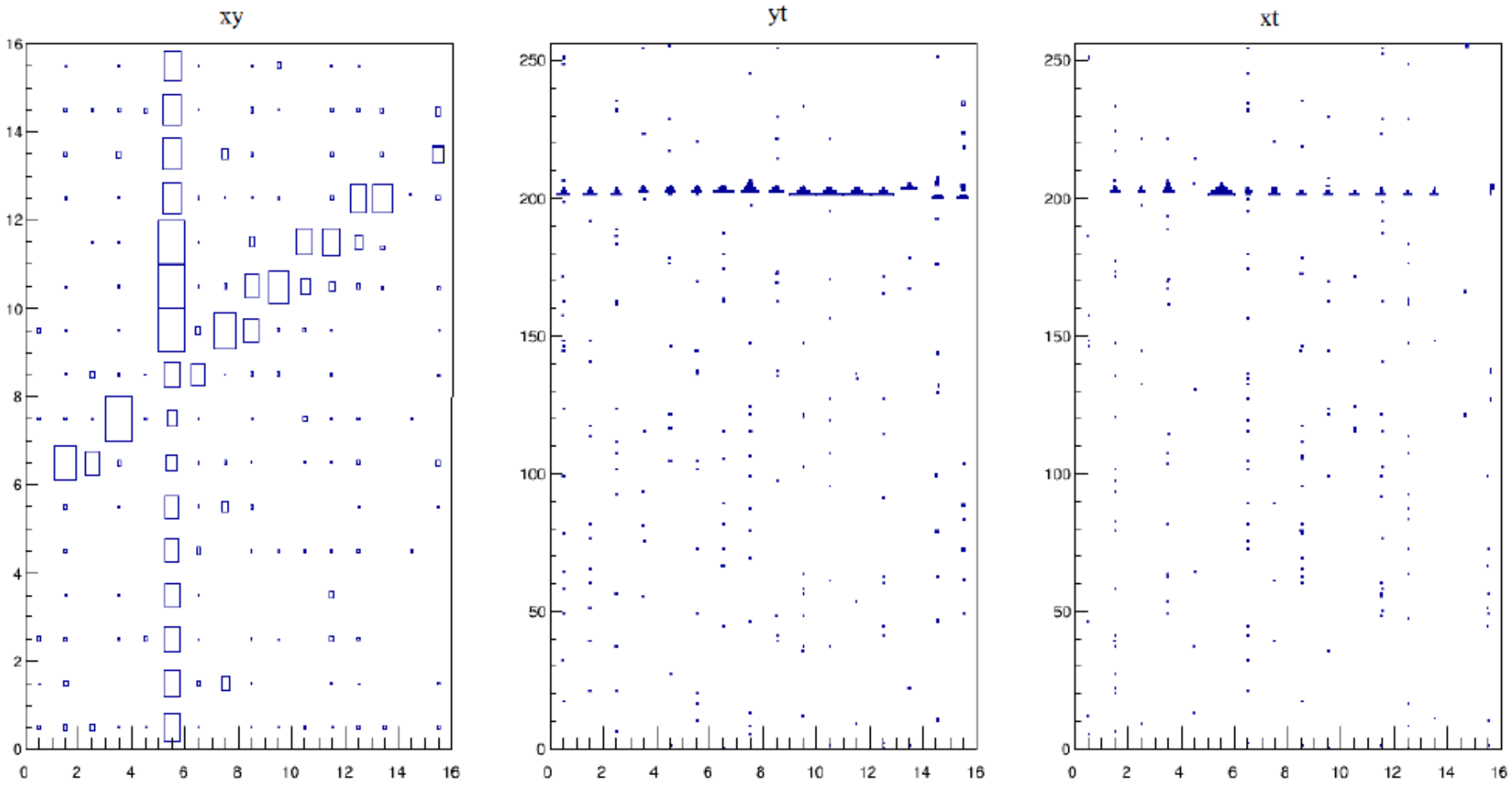
After:
Dead PMTs map



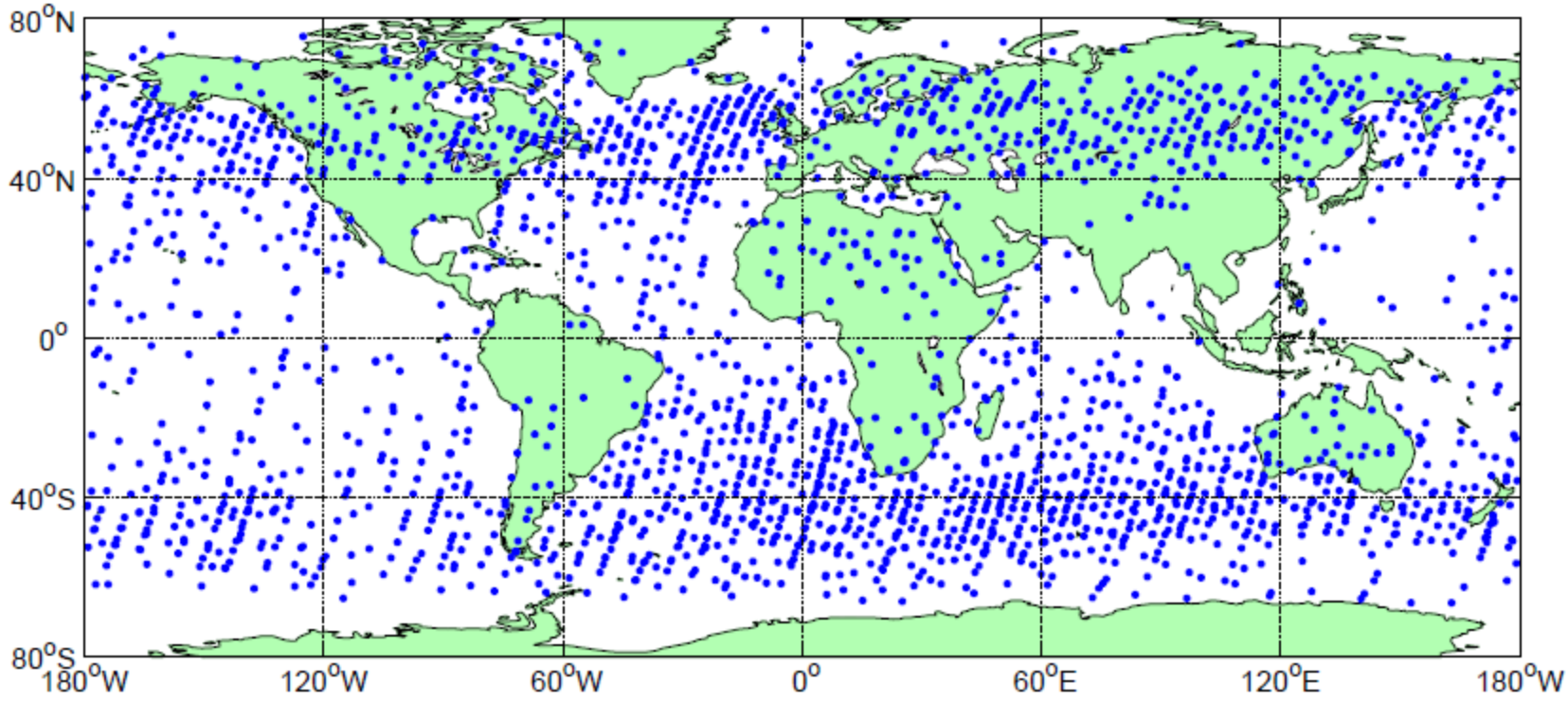




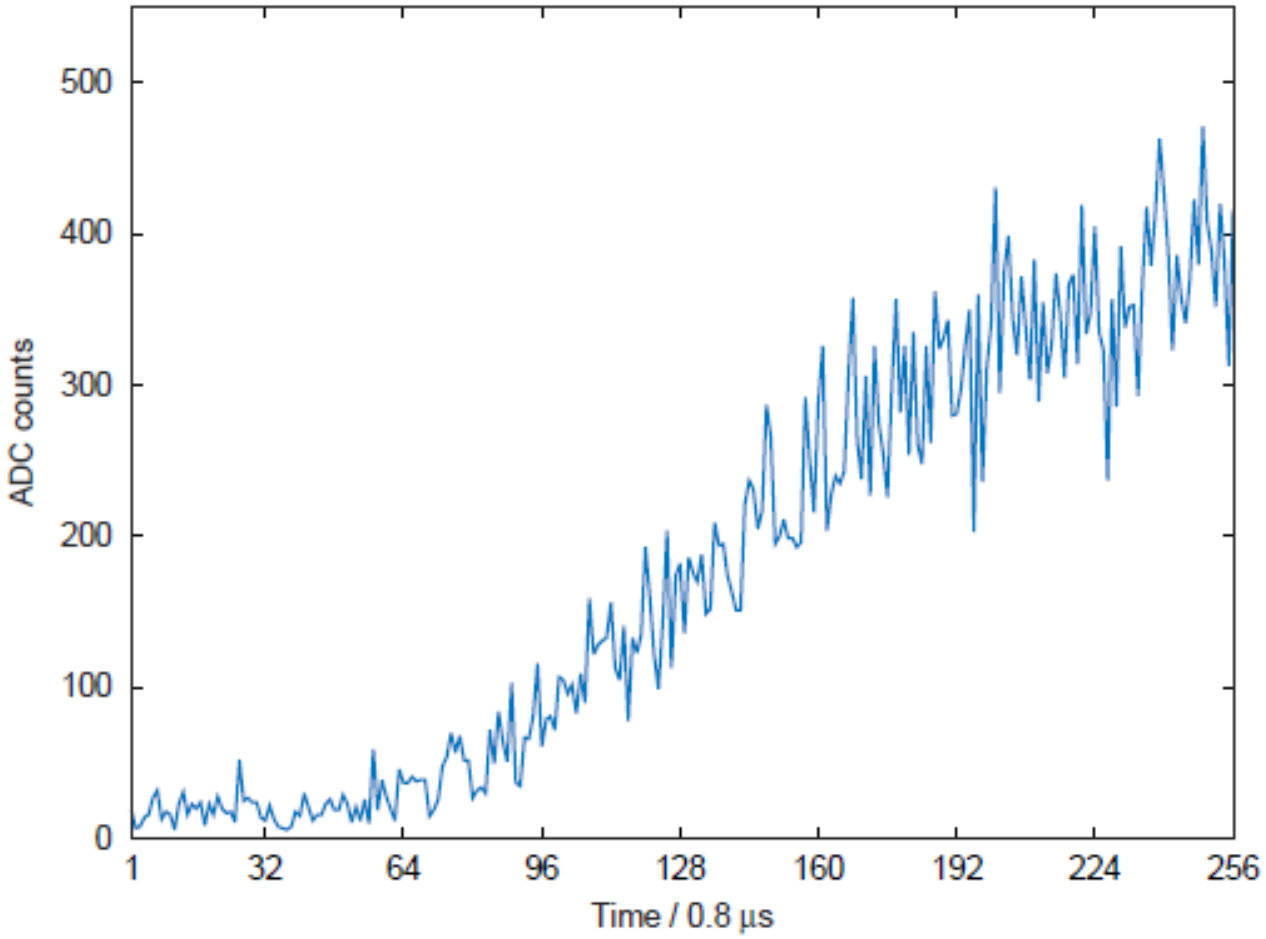
Track-like event registered on October 25, 2016.
Top:
waveforms of ten PMTs that demonstrated the biggest ADC counts.
Colors denote different pixels.
Bottom:
snapshot of the focal plane at the moment of maximum ADC counts.



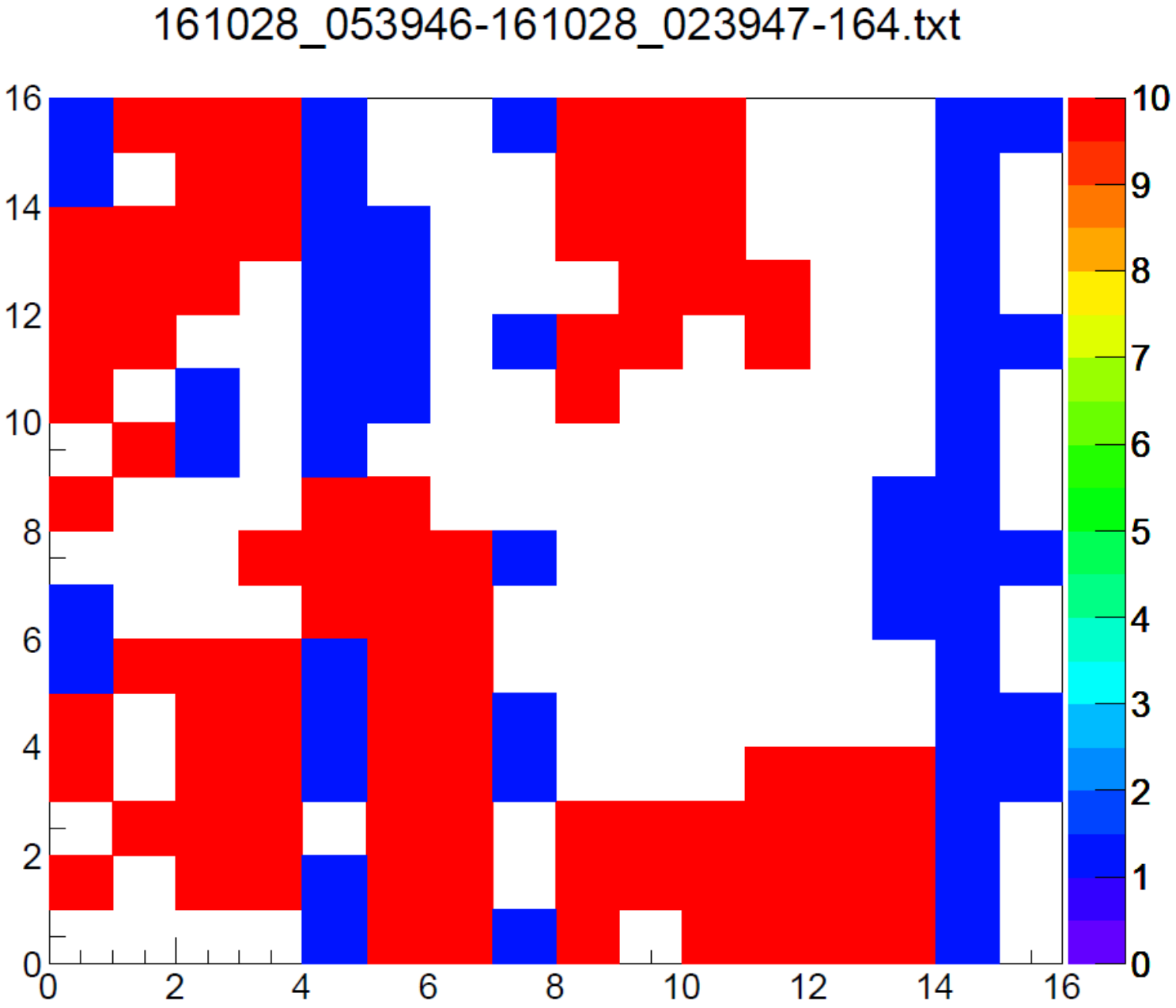
The track-like event in UV filter as it presented by Event Display program



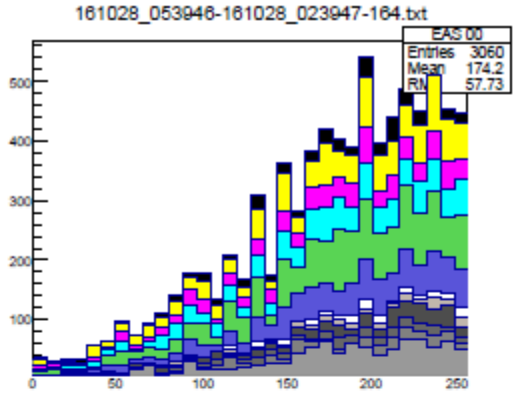
Geographic distribution of 2394 track-like events over Earth

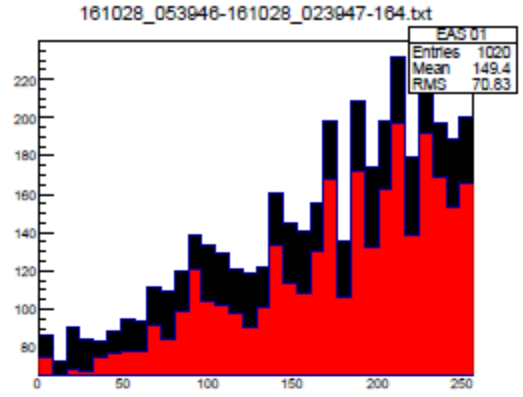


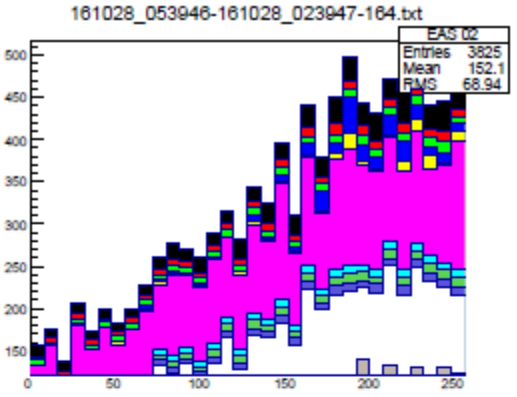
Example of a waveform of one channel of a slow flash

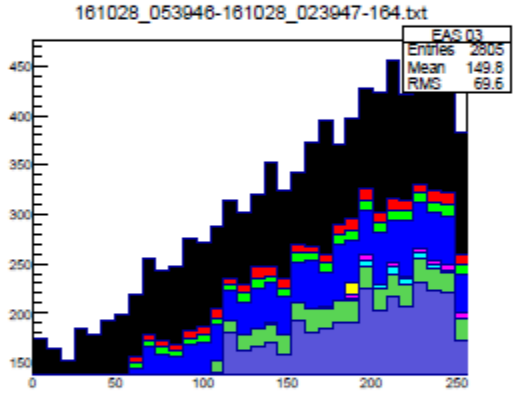


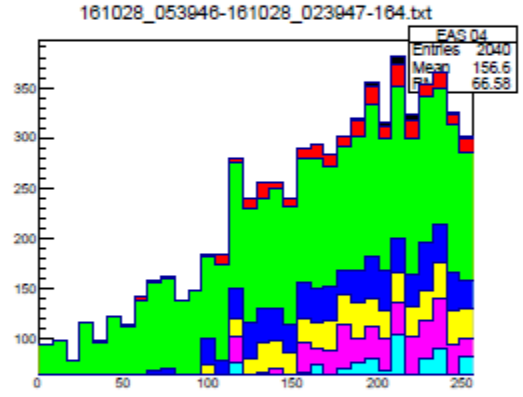
Red – hit pixels, blue – dead PMT

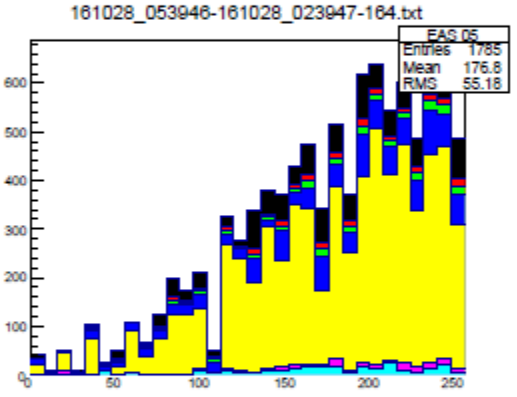

161028_053946-161028_023947-164.txt
EAS 00
Entries 3060
Mean 174.2
RMS 57.73

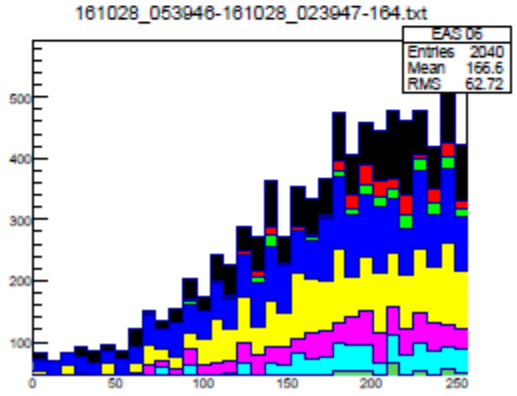

161028_053946-161028_023947-164.txt
EAS 01
Entries 1020
Mean 149.4
RMS 70.83


161028_053946-161028_023947-164.txt
EAS 02
Entries 3825
Mean 152.1
RMS 68.94


161028_053946-161028_023947-164.txt
EAS 03
Entries 2805
Mean 149.8
RMS 69.6


161028_053946-161028_023947-164.txt
EAS 04
Entries 2040
Mean 156.6
RMS 66.58


161028_053946-161028_023947-164.txt
EAS 05
Entries 1785
Mean 176.8
RMS 55.18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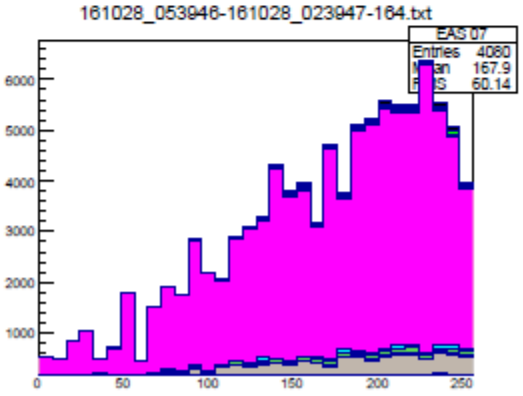
EAS 06
Entries 2040
Mean 166.6
RMS 62.72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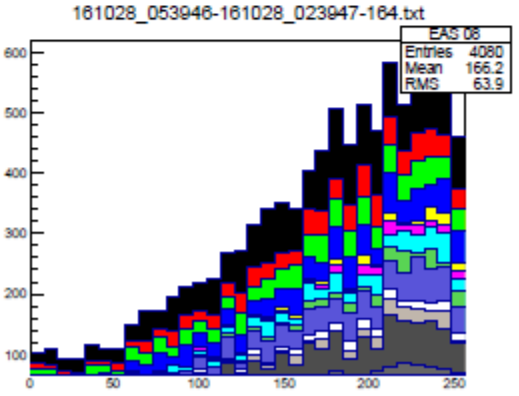
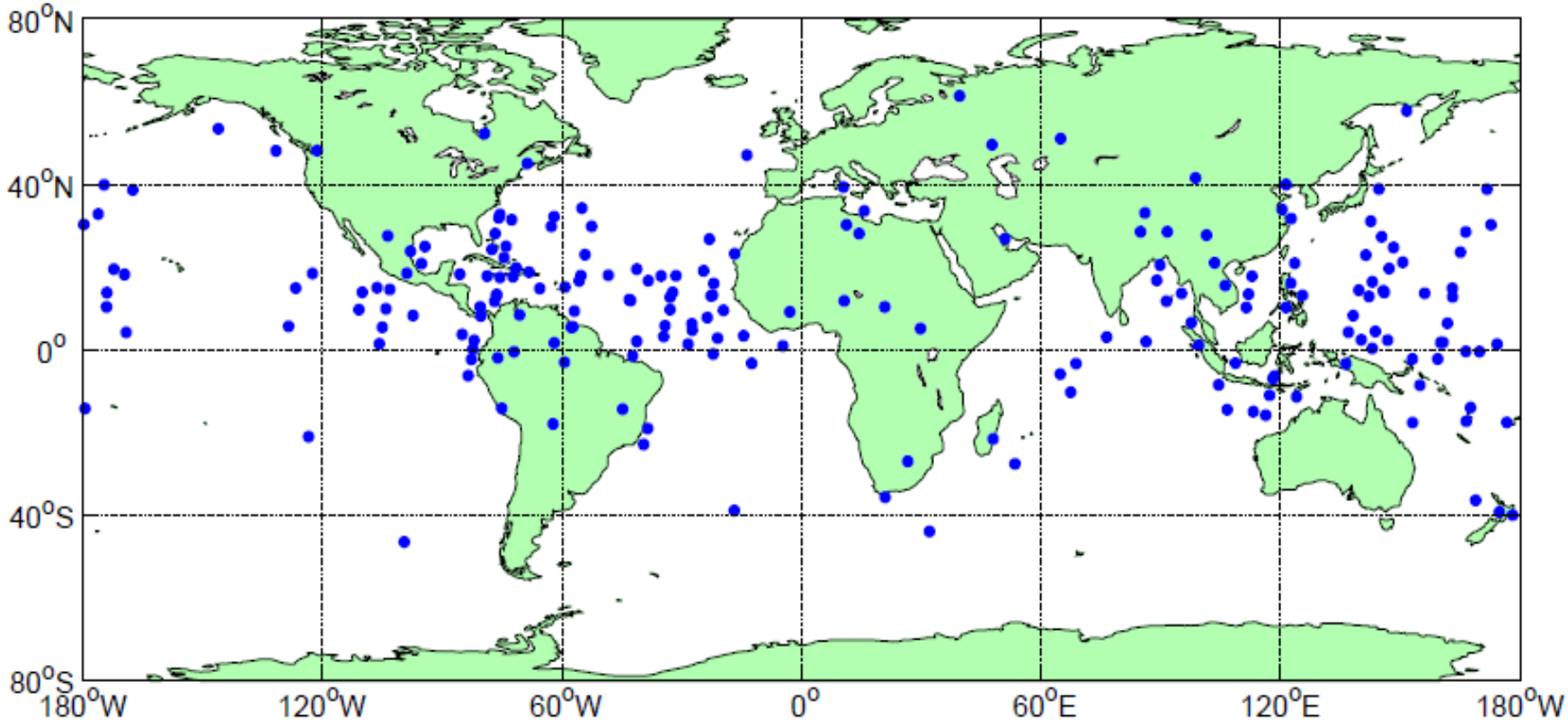
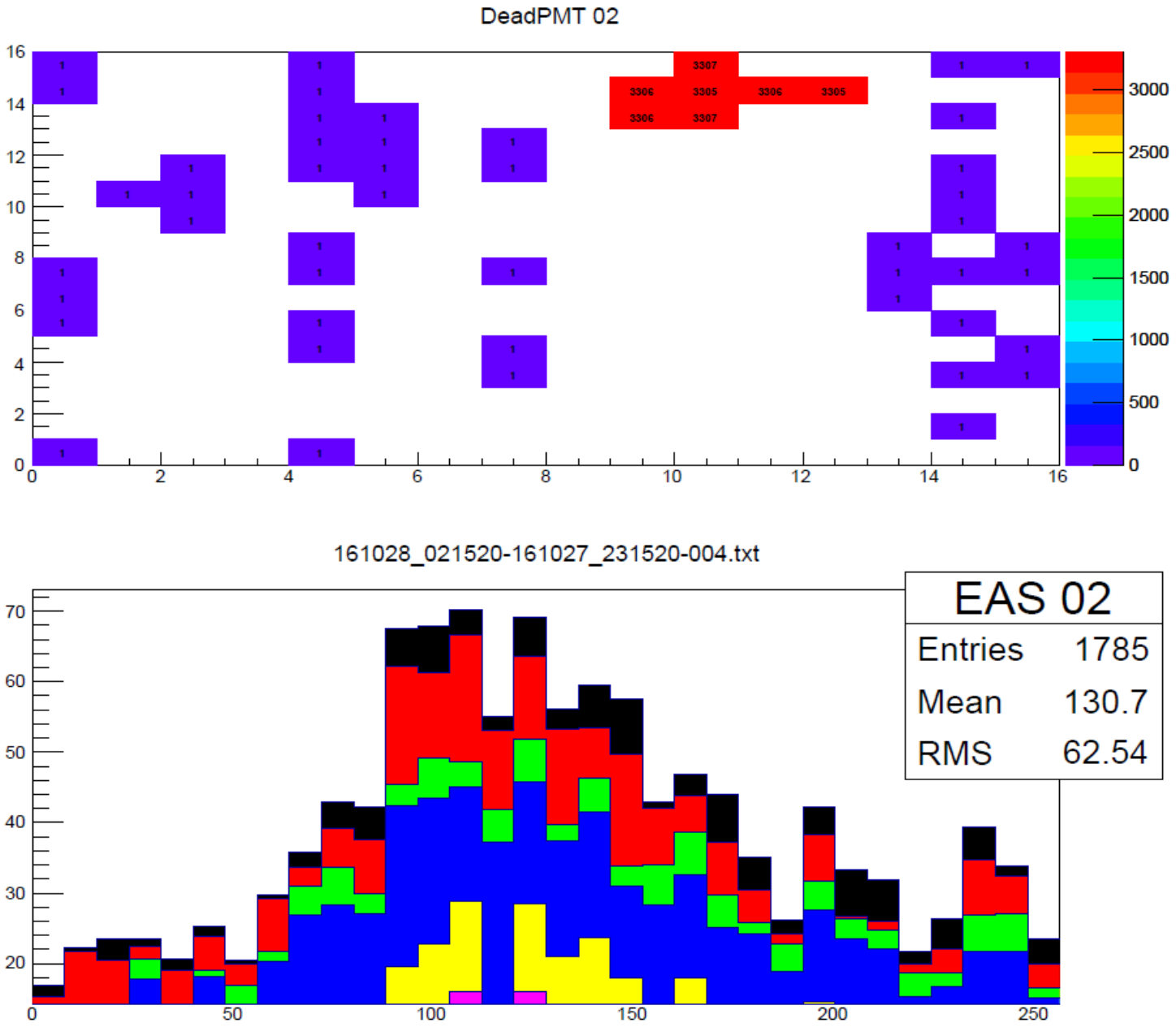
EAS 07
Entries 4080
Mean 167.9
RMS 60.14

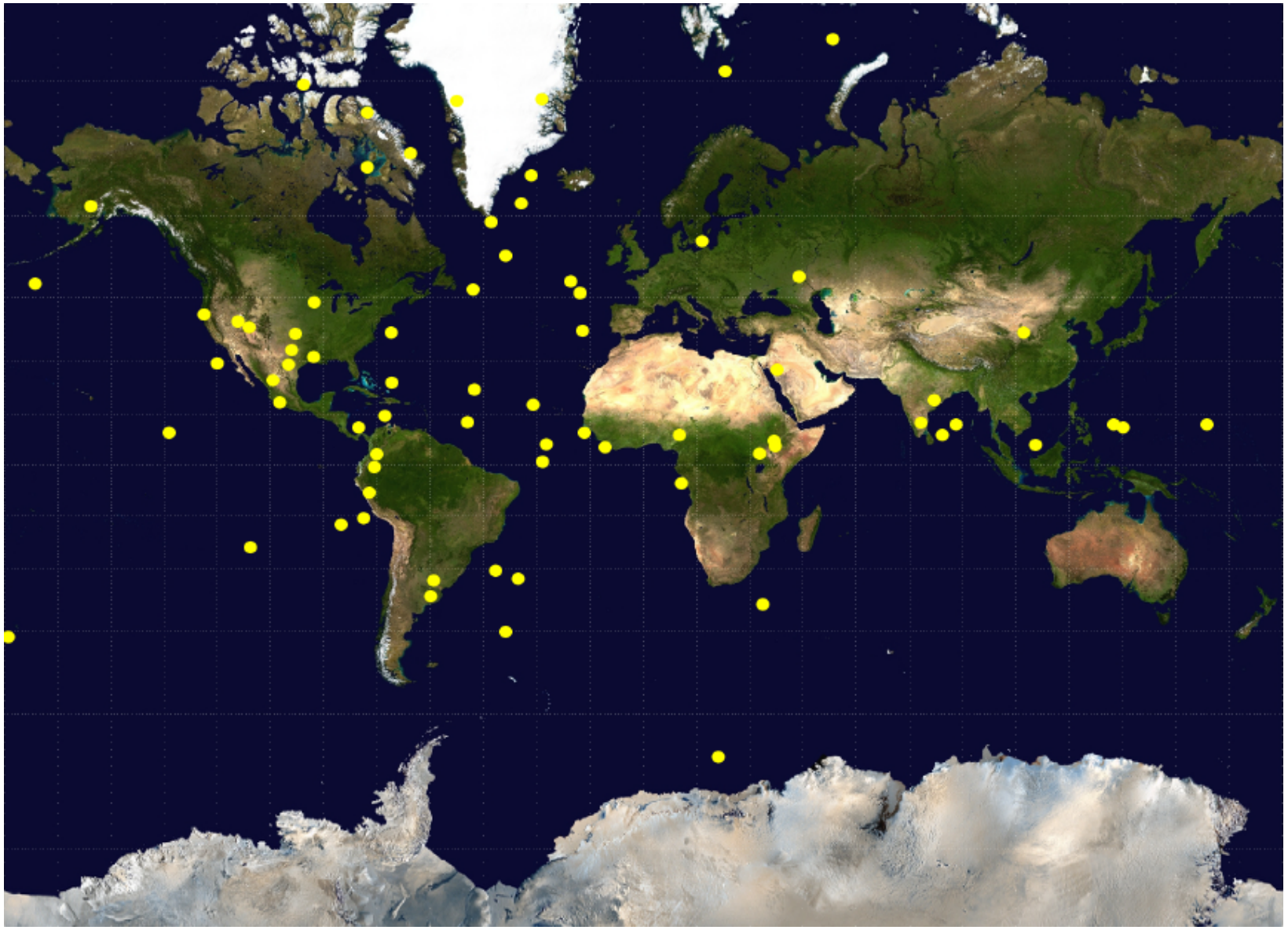

161028_053946-161028_023947-164.txt
EAS 08
Entries 4080
Mean 166.2
RMS 63.9



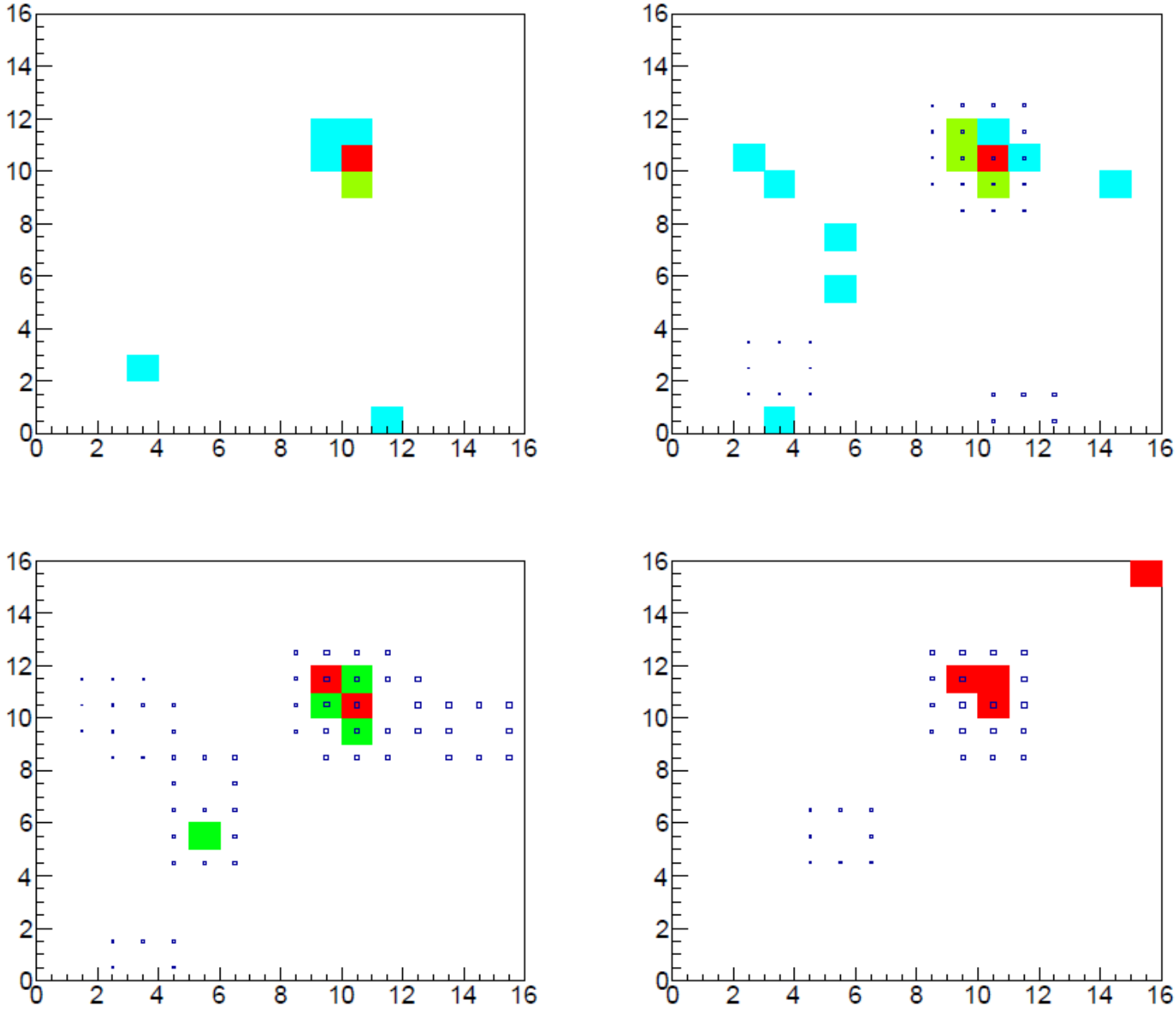
Geographic distribution of 207 slow flashes



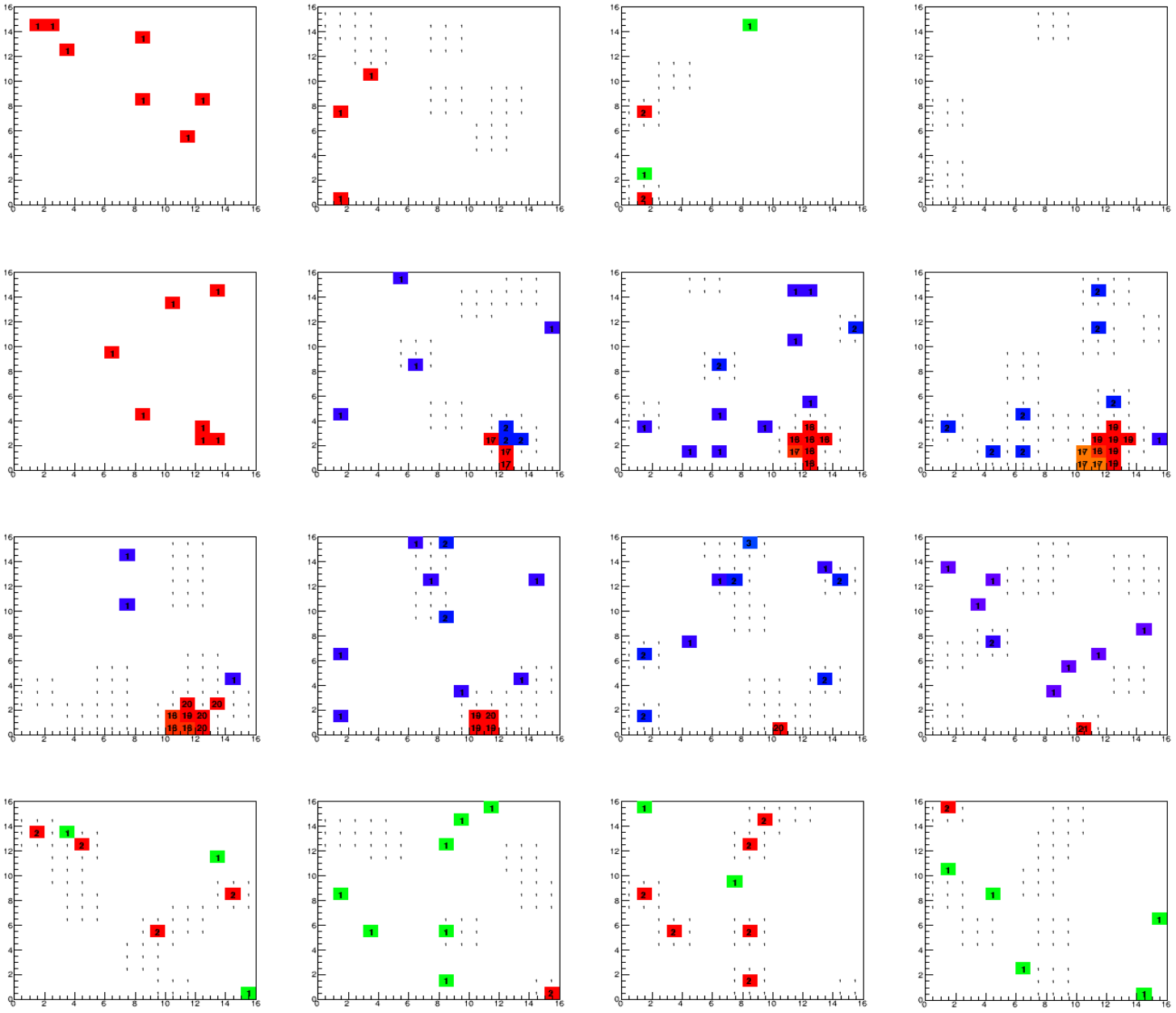
An example of the time profile for the fake EAS event



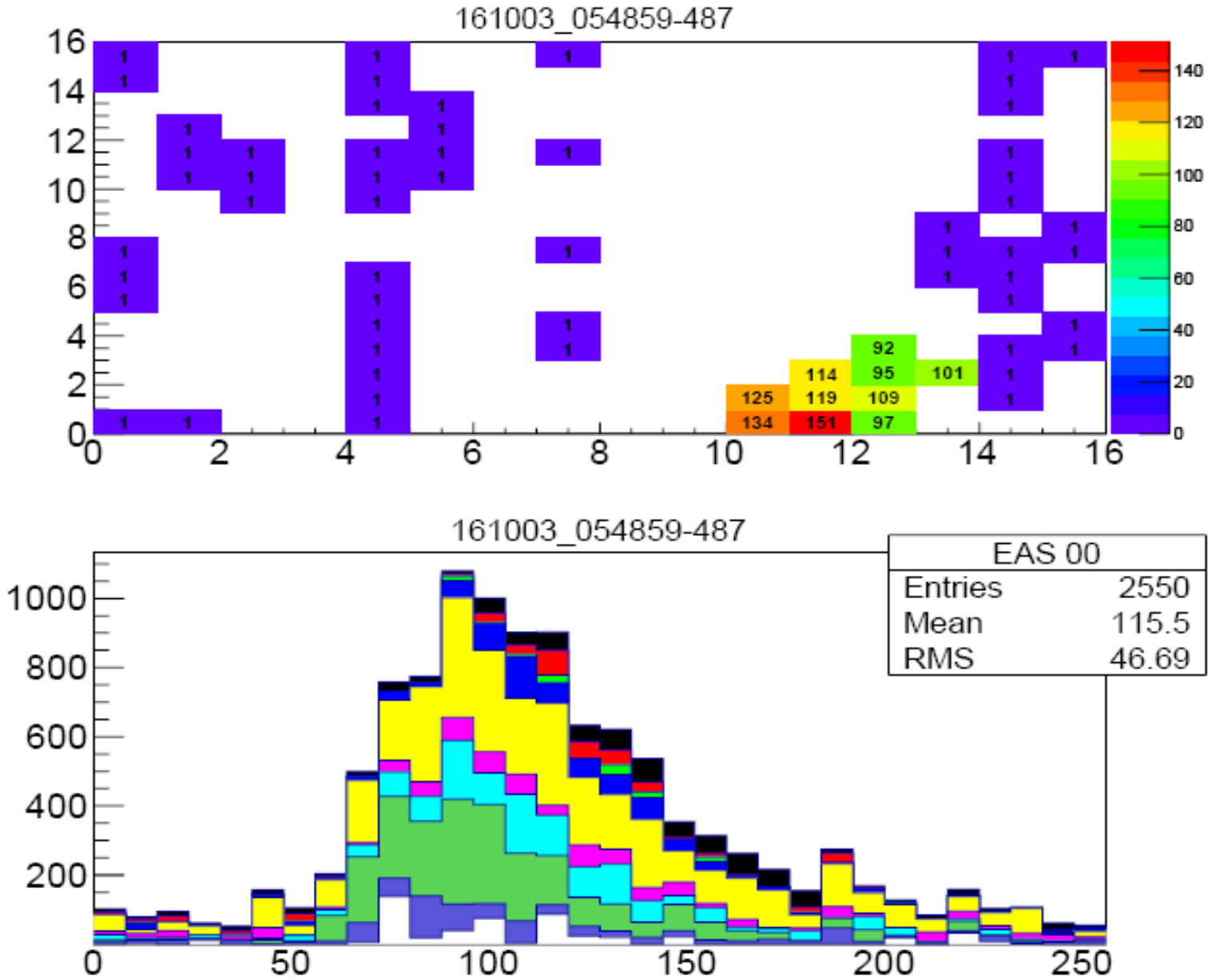
Distribution of the 88 pseudo EAS events



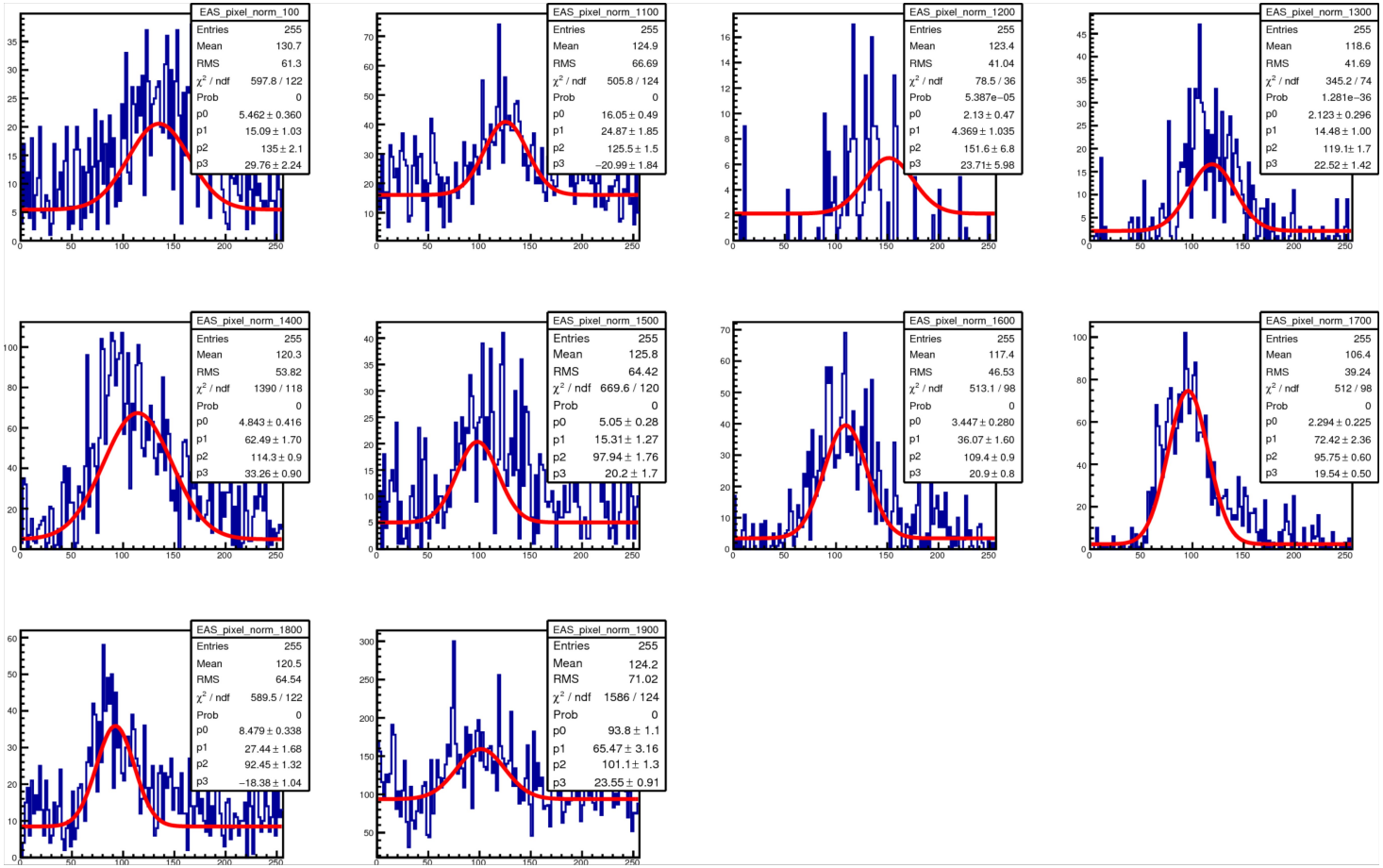
Simulation of successive 16-time bin images used for level 2 trigger



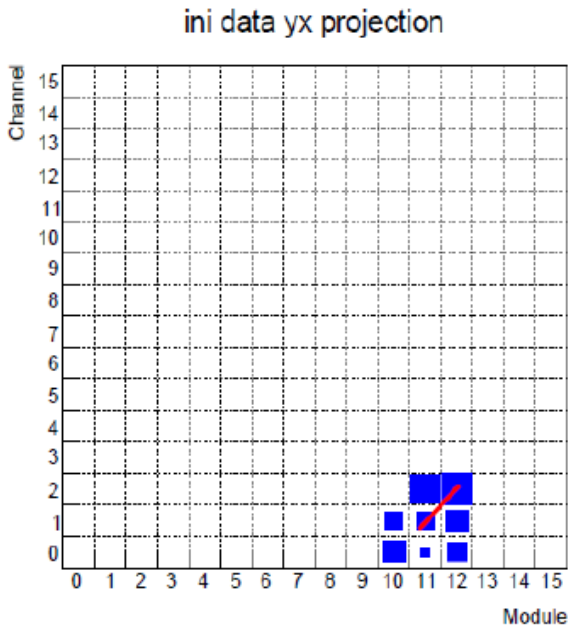
Event-map plot of the 16 frames with the 16 time of the 0.8 µsec steps each

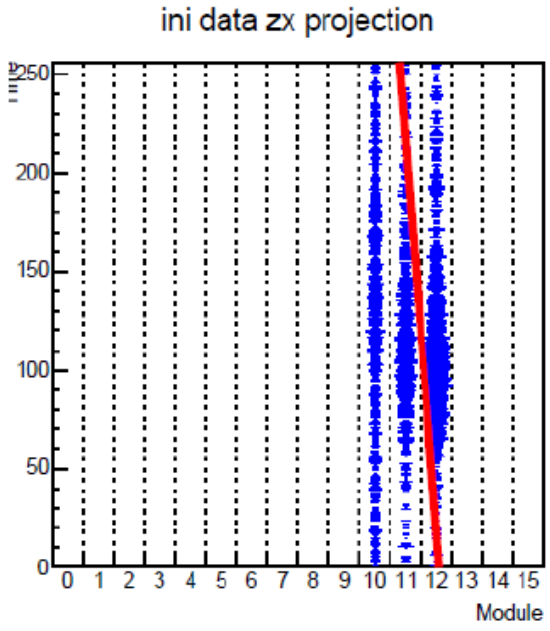


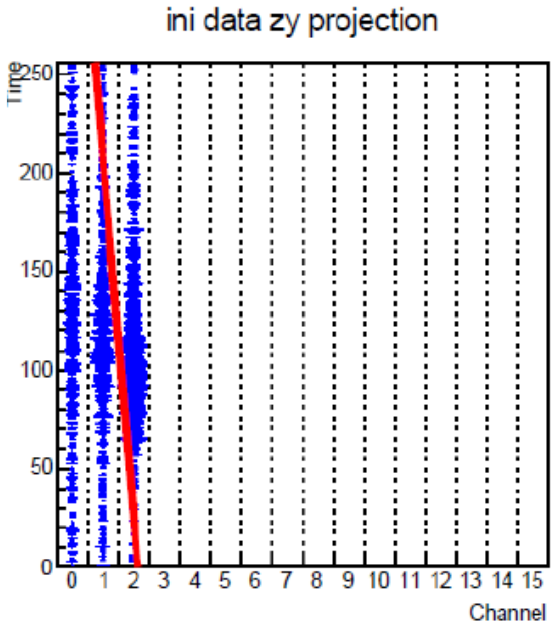
Selected EAS candidate. Upper plot – image of event with hit (red) and dead (blue) pixels. Bottom plot – the amplitude variation of time for selected hit pixels



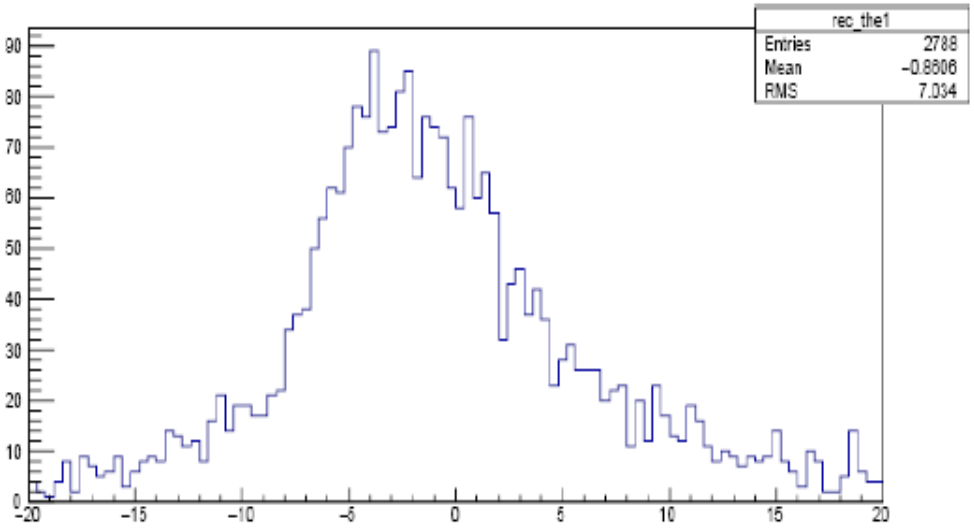
Amplitude dependence on time for the hit PMTs for the event

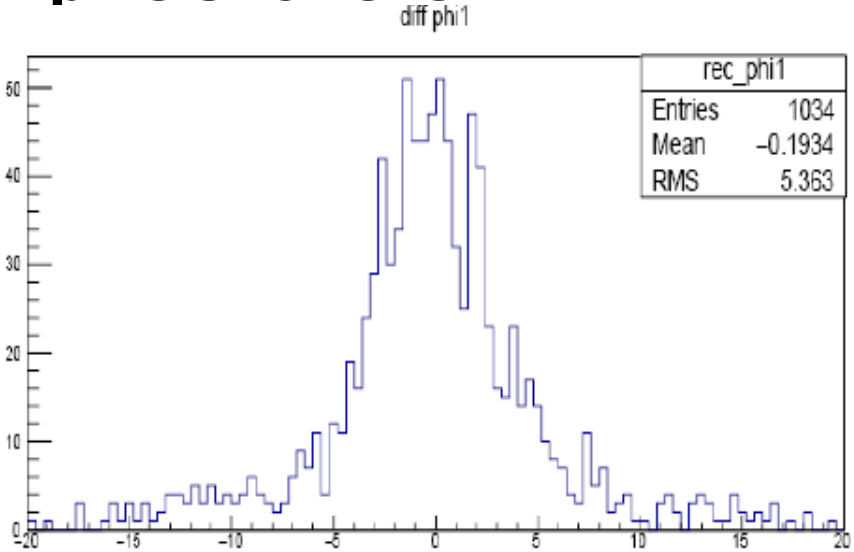




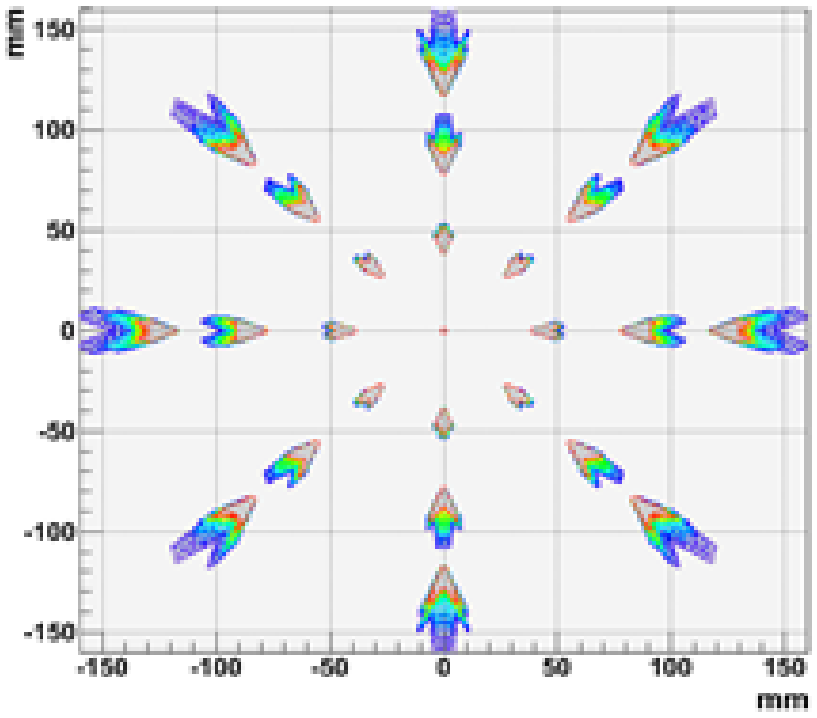


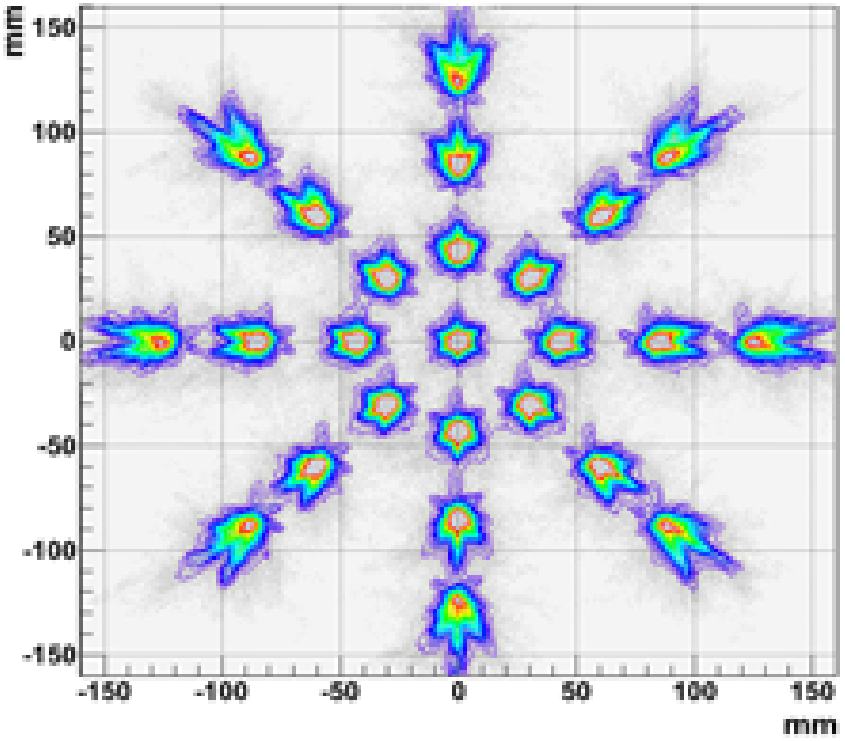
Linear 3D fit of hit pixels for event



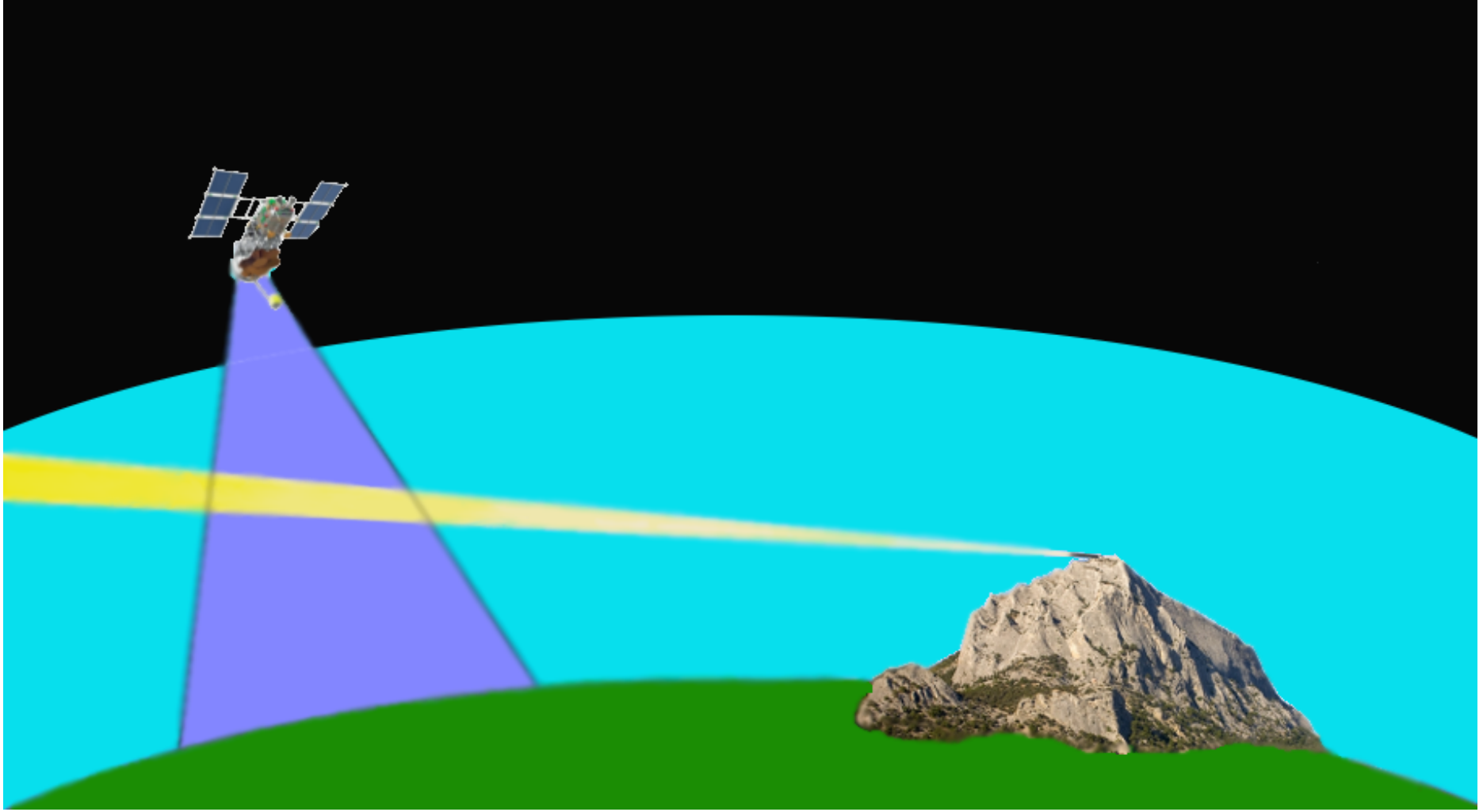


Difference between simulated and reconstructed zenith θ and azimuthal φ angles





PSF for different azimuthal and polar angles.
Left panel: an “ideal” mirror, right panel: the real mirror.



Schematic of PMT calibration with an inclined laser beam

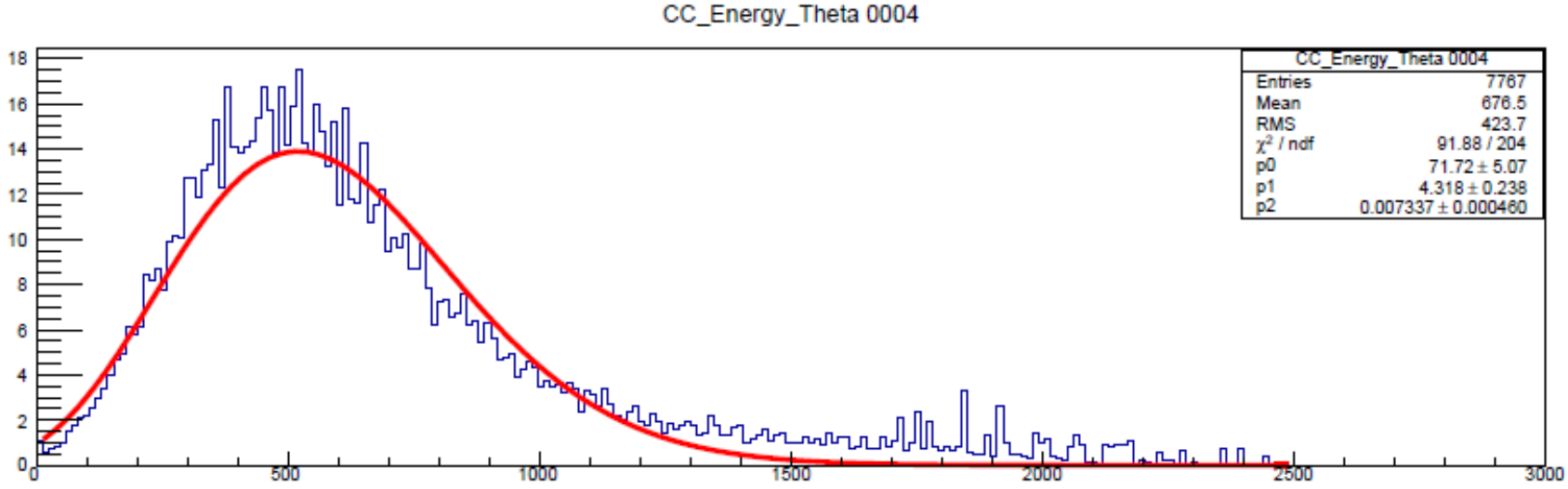
Simeiz-1873

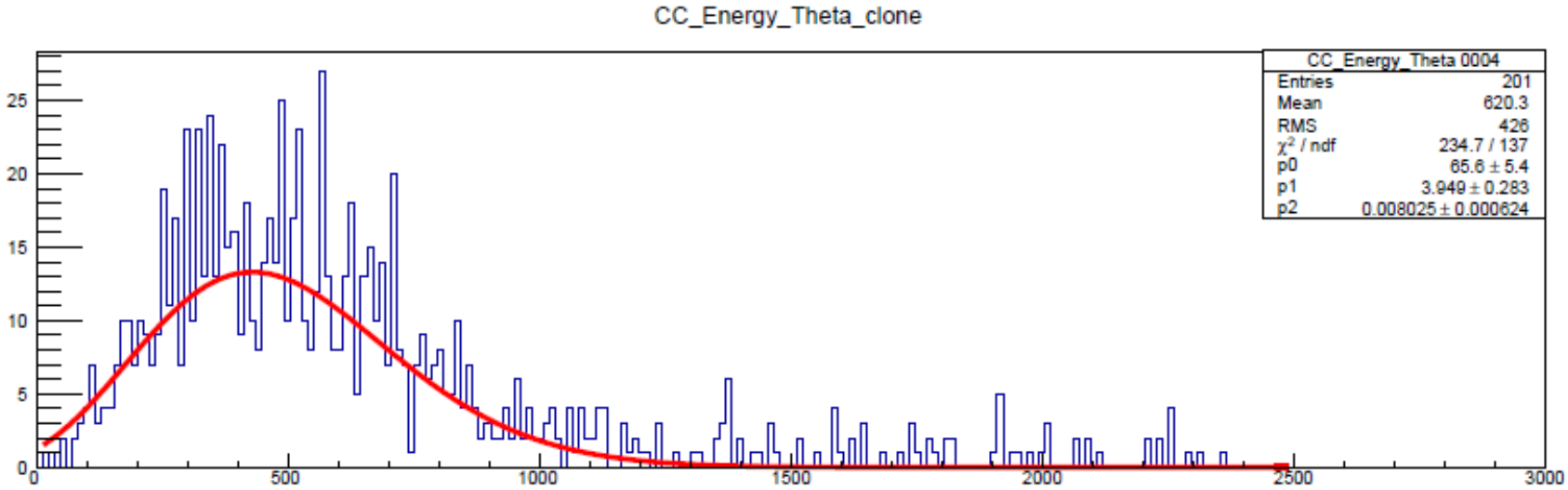
Laser rangefinder of Crimean Astrophysical Observatory

Conclusion

1. The TUS mission aboard the dedicated Lomonosov satellite is the first mission to use an orbital UV telescope for the study of EASs produced by UHECR. The multifunctional "Lomonosov" satellite was launched on April 28, 2016. The satellite now is in the 500 km solar-synchronized orbit, operates and takes data, including the TUS measurements of EAS.
2. The ground-based calibration methods based on the use of high-power LEDs and laser beams are currently under development.

Backup slides





Top plot – cascade curve distribution of the MC EASs in the selected ΔE, Δθ range. Bottom plot – cascade curve distribution of the random MC EAS with E and θ in the interval