Study of the calibration method using the stars measured by the EUSO-TA telescope

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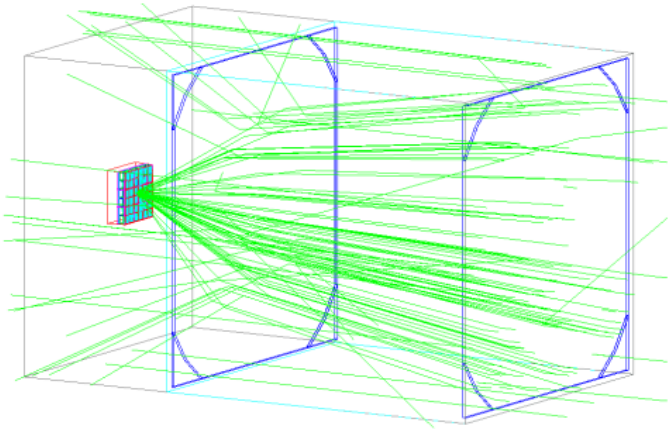
The EUSO-TA fluorescence detector

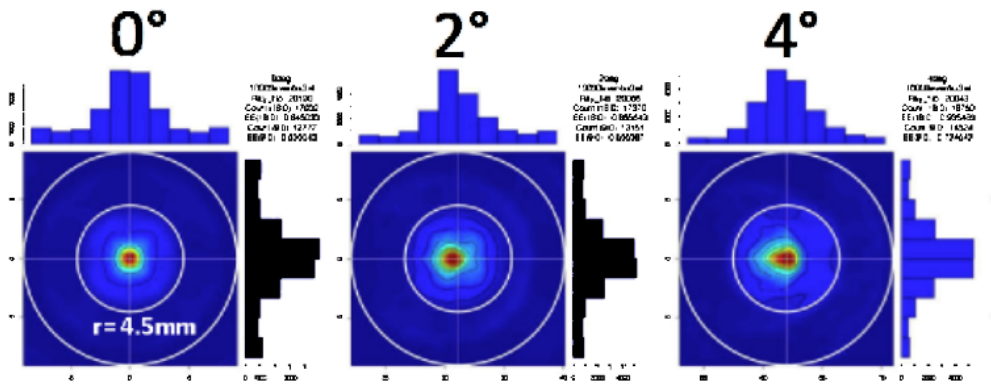
EUSO-TA is a ground-based experiment, placed at Black Rock Mesa of the Telescope Array site as a part of the JEM-EUSO (Joint Experiment Missions for the Extreme Universe Space Observatory) program

Instrument parameters

Detection unit	Photo Detector Module (PDM)
PDM	36 Multi-Anode Photomultiplier Tube (MAPMT)
MAPMT	Hamamatsu R11265-M64
Number of pixels	2304
FOV	10.6° x 10.6°
Optical bandwidth	290nm-450 nm
Optical system	2 Fresnel lenses $1m^2$, PMMA (8mm)
Gate Time Unit	$2.5\mu s$
Dead time	200ns
The average trigger rate for work with TA	2Hz



The visualization of the EUSO-TA ray-tracing simulation performed in the OffLine framework

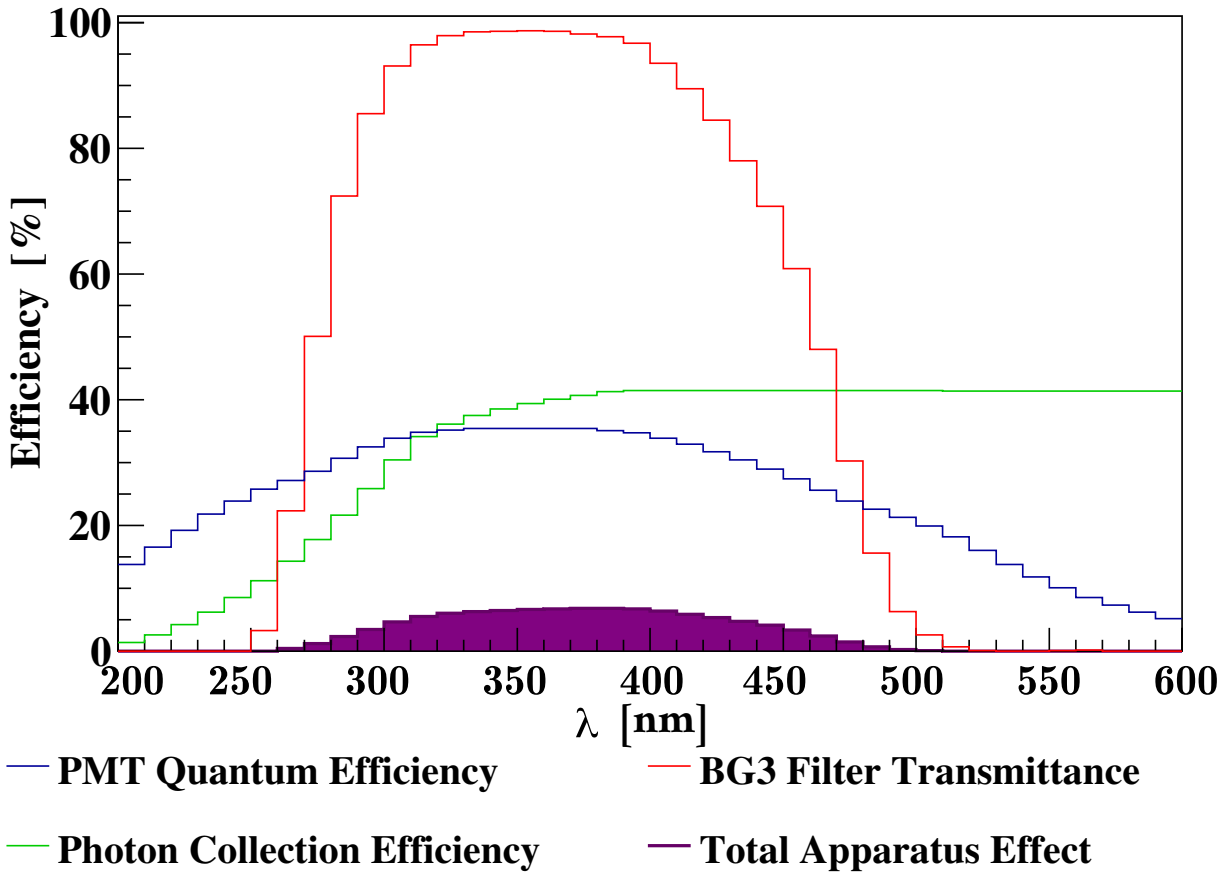


PSF spot diagrams for incident angles

The photometric calibration provides a relationship between the amount of photons arriving at the detector and the measured signal, precise calibration of the instrument is needed to understand registered signal

The EUSO-TA detector parameters

Focal surface containing the matrix of 48x48 pixels consists of the 64-channel MAPMTs with ∼75% collection efficiency and quantum efficiency with maximum reaching 35% at ∼350 nm

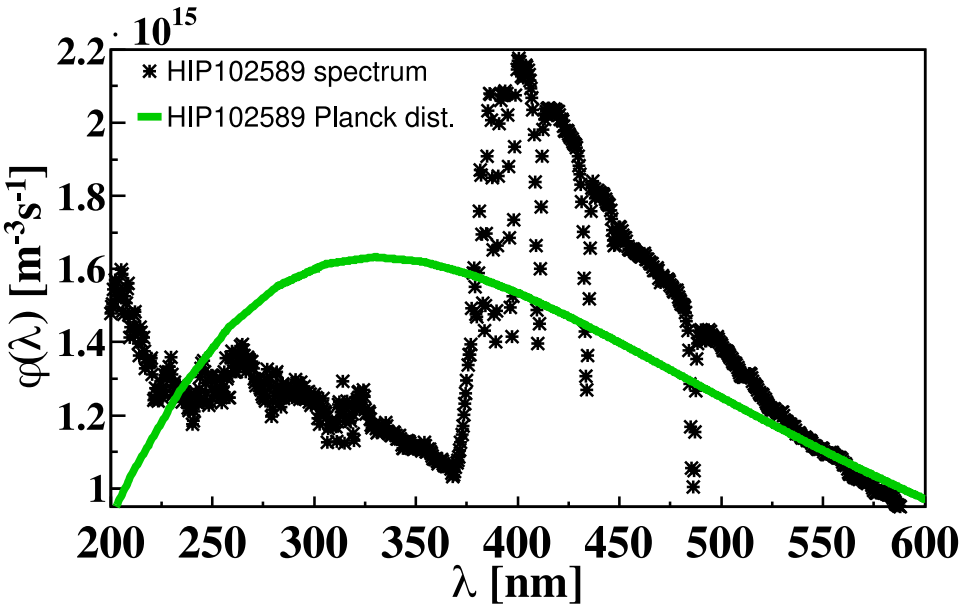


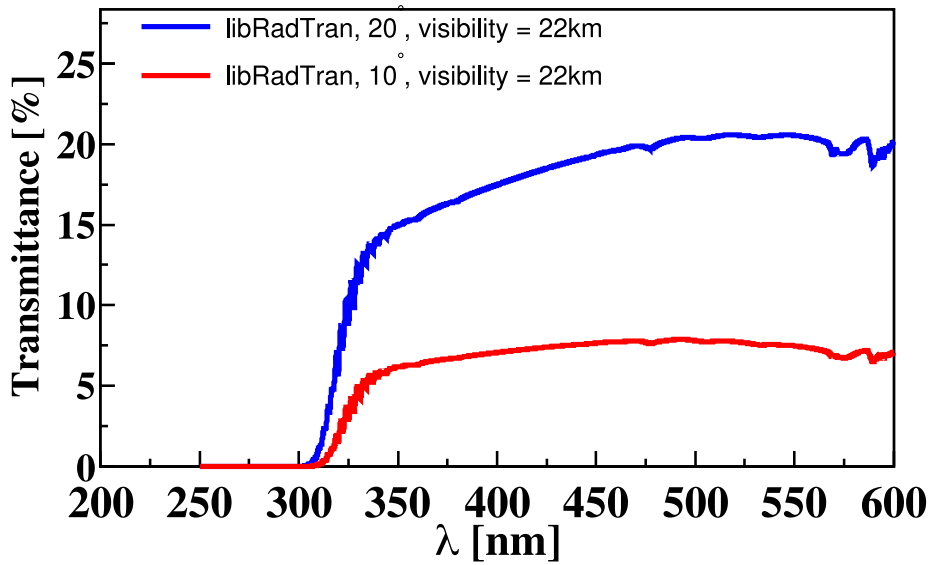
Atmospheric attenuation and predicted star signal

Expected signal N_{exp} for fixed observation angle can be simply described by following formula:

$$N_{exp} = C_{abs} \int_0^\infty T_{atm}(\lambda)\Phi_{top}(\lambda)P_{det}(\lambda)d\lambda$$

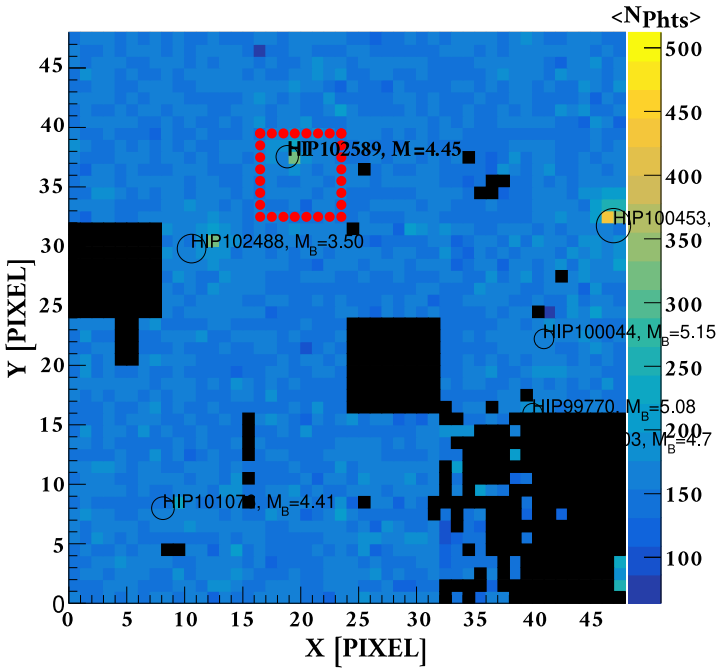
where: $\Phi_{top}(\lambda)$ - star light flux at the top of the atmosphere
$T_{atm}(\lambda)$ - atmospheric transmittance
$P_{det}(\lambda)$ - known detector parameters
C_{abs} - wavelength independent absolute calibration constant





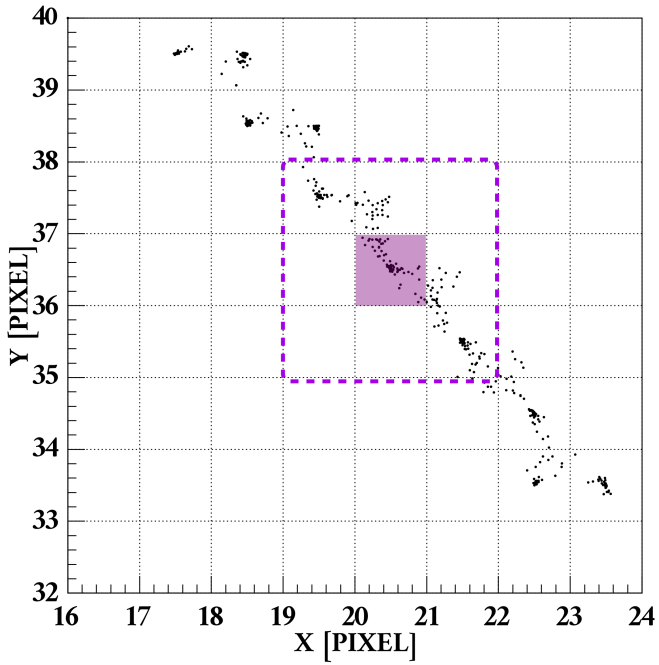
Comparison of photons spectrum for HIP102589 star (based on the Pickles stellar spectral flux library) with related Planck distribution at the top of the atmosphere (left) and atmospheric transmittance for observations at 10° and 20° of elevation. For radiative transfer calculations has been used libRadTran package applying atmospheric parameters corresponding to the desert conditions where EUSO-TA detector is placed

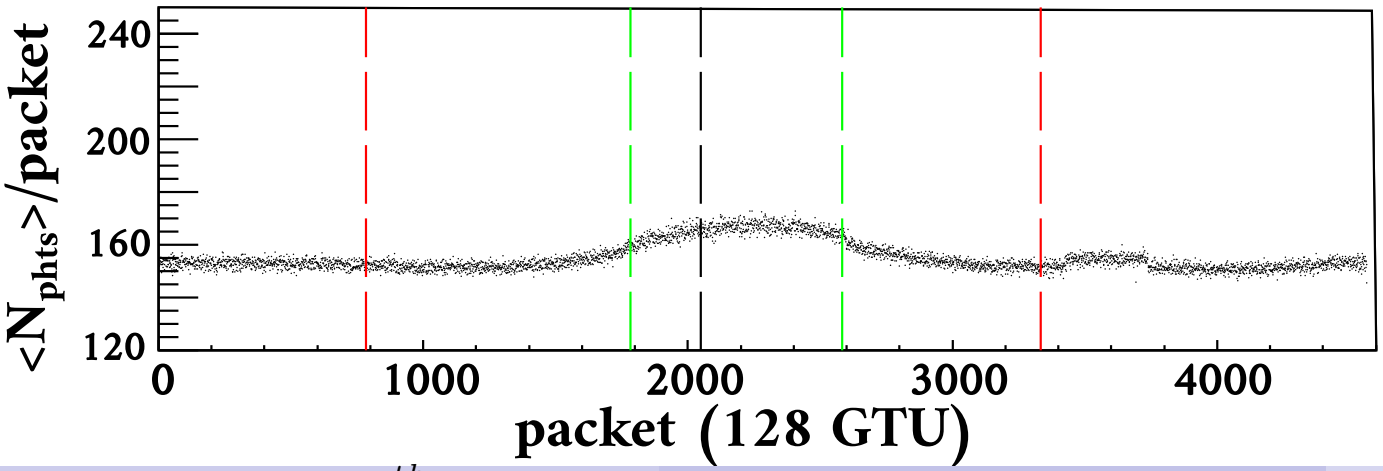
The EUSO-TA data analysis



Positions of few stars are displayed on the left plot

To identify stars in the detector's field of view we use the HIPPARCOS catalogue

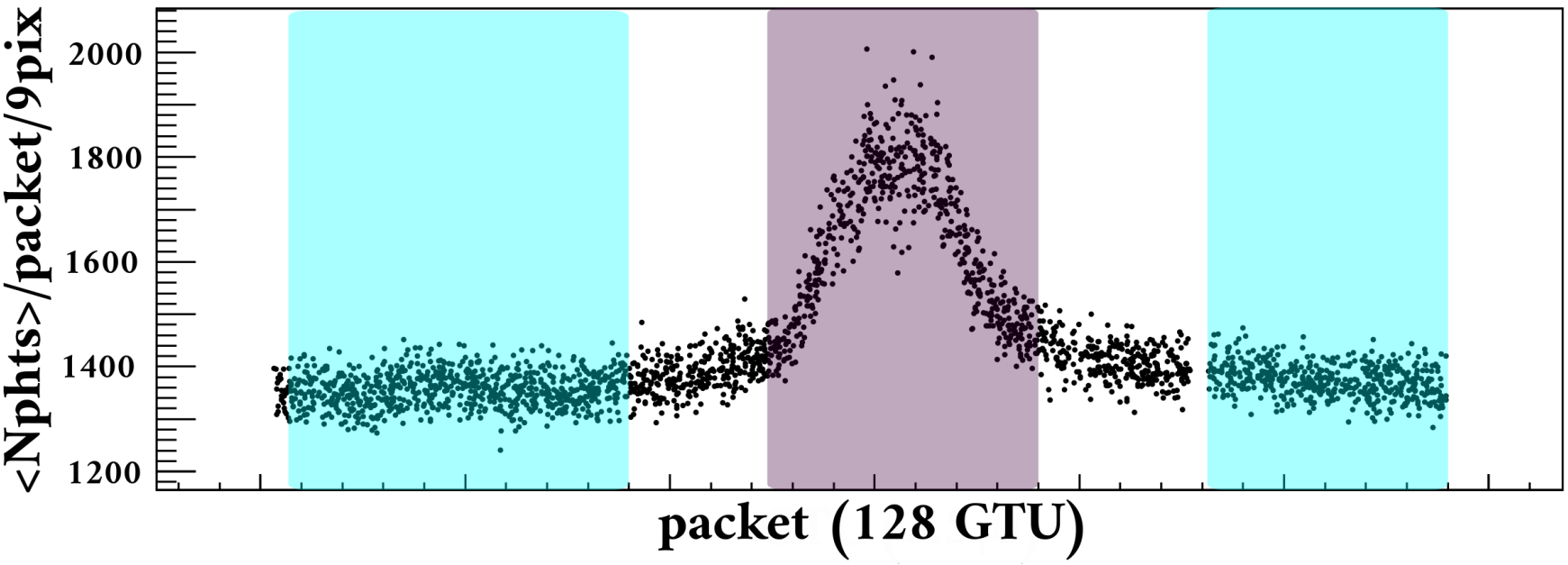




The light-curve representing the counts in entire PMT

The EUSO-TA data analysis

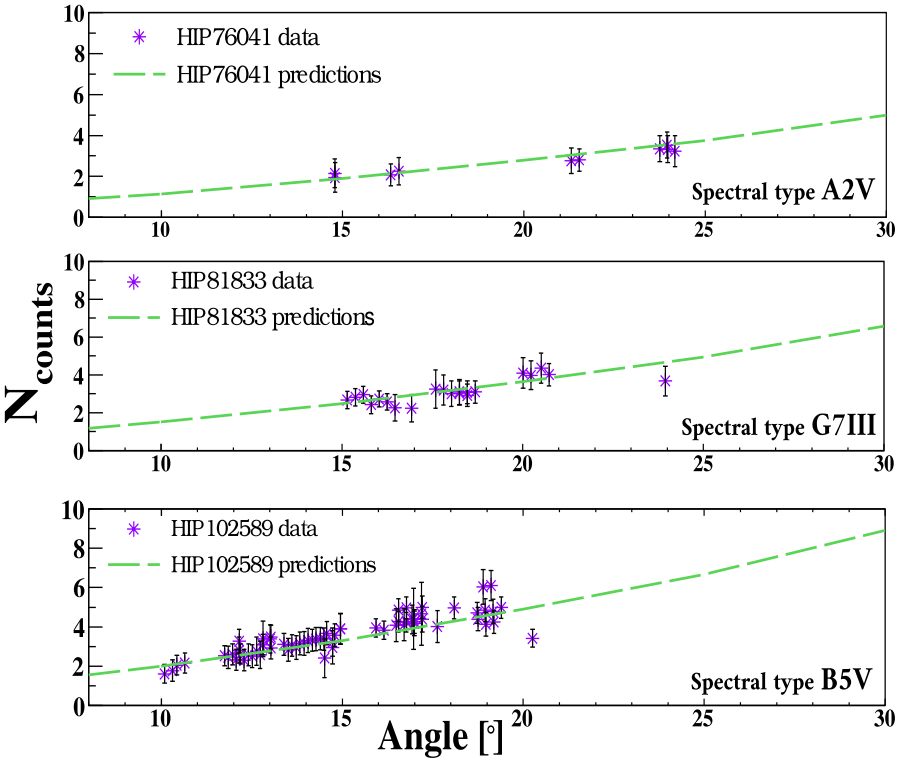
The analysis of lightcurve for 3x3 pixels area around the pixel which star is going through



Background: 10.63, **Background+Signal:** 13.78, **Signal:**3.13+/- 0.65

Following the described procedure we have analyzed signals from about 100 stars in the data taken by EUSO-TA in the years 2015 and 2016

Results comparison for several measured stars with various spectral types



Comparison of measured and expected signals for three selected stars in wide range of elevation angle

An agreement at various angles confirms that atmospheric extinction model has been used correctly

All results obtained with the calibration constant $C_{abs} = 0.86$

HIP	M_B	Spectral Type	Angle	Measured N_{ph}/GTU	Expected N_{ph}/GTU
102488	2.44	K0III	12.31	5.93±0.99	6.06
102589	4.54	B5V	14.73	2.96±0.85	3.21
100453	2.23	F8I	14.55	11.40±1.58	11.89
50801	3.05	M0III	23.00	2.91±0.57	3.13
93194	3.25	B9III	11.71	8.20±1.40	7.97
81833	3.50	G7III	15.37	2.82±0.46	2.52
93903	5.25	B6IV	15.93	1.57±0.37	1.67
109410	4.29	F5III	13.51	2.26±0.63	2.42
76041	4.98	A2V	14.79	2.15±0.70	1.82
4436	3.87	A6V	16.33	5.02±0.84	4.86

preliminary results

Summary of the analysis

Absolute calibration of EUSO detectors is an important step necessary to understand registered signal

Calibration constant C_{abs} = 0.86

Assuming that obtained calibration constant should be taken into account as a detector parameter, we calculated the total detector efficiency for registration of point-like signal in 3x3 pixels area as:

- @300nm - 3.48%
- @365nm - 5.81%
- @400nm - 5.60%

Based on EUSO-TA data we have developed the procedure dedicated for data analysis of point-like sources resulting absolute calibration of EUSO detector