# The Terzina Cherenkov telescope onboard the NUSES space mission

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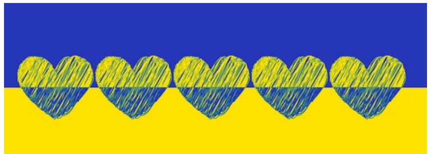
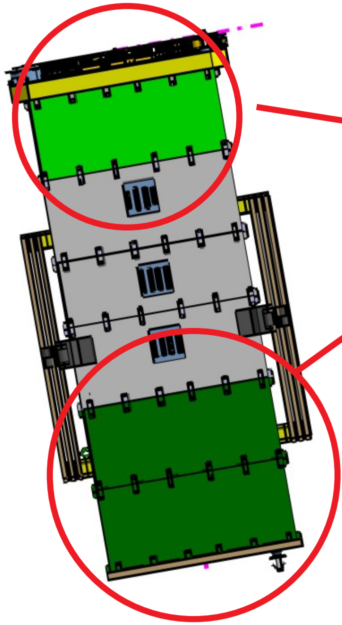
*(on behalf of the NUSES Collaboration)*



# Terzina - is a part of the NUSES space mission.

**NUSES mission**



ZIRE tray

Terzina tray

| | | |
|---|---|---|
| Optics : | Schmidt | 7° full FoV |
| | Primary Mirror | ~40 cm diam. |
| | Corrector Lens | 40 cm diam. |
| | Focal Surface | 12 cm diam. |
| | Pixel size | 3x3mm$^2$ |
| | Pixel FoV | 0.18° |
| | SiPM | 640 |

Dimentions :

**~60 x 60 x 50 cm box**

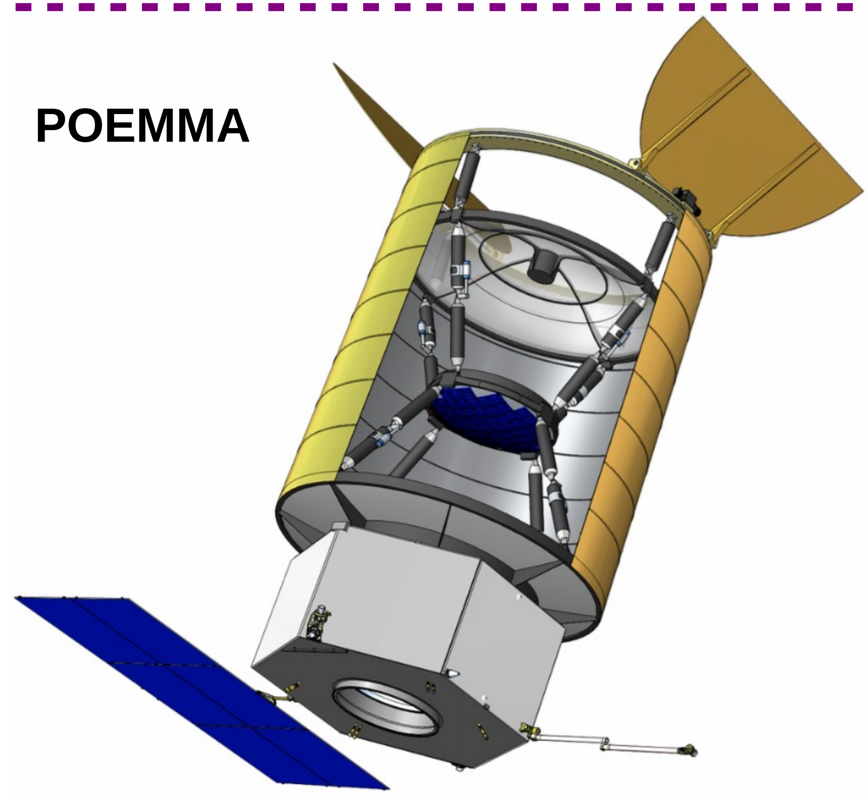
Mass:

~20 kg

Design from Thales Alenia Space

- Height of the orbit : ~ 550 km
- **Sun synchronous orbit**
- **Time duration of the mission 3 years.**
- **Terzina is a precursor for POEMMA experiment.**

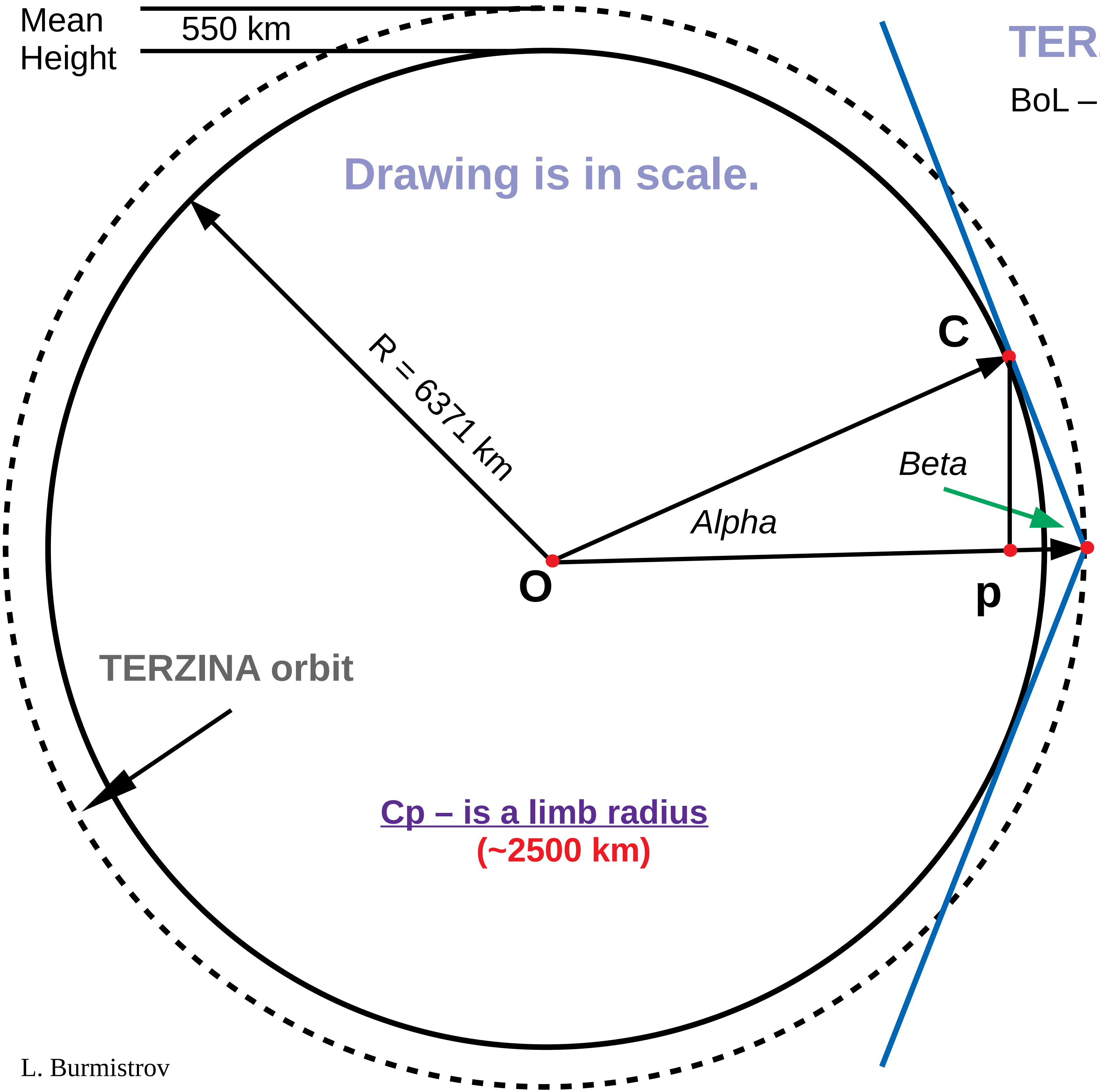
**POEMMA**



| Telescope: | Instrument | |
|---|---|---|
| Optics | Schmidt | 45° full FoV |
| | Primary Mirror | 4 m diam. |
| | Corrector Lens | 3.3 m diam. |
| | Focal Surface | 1.6 m diam. |
| | Pixel Size | $3 \times 3$ mm$^2$ |
| | Pixel FoV | 0.084° |
| PFC | MAPMT (1$\mu s$) | 126,720 pixels |
| PCC | SiPM (20 ns) | 15,360 pixels |

# TERZINA orbit BoL

BoL – beginning of life




Cherenkov light
need to travel abut
~2700 km !!!

*Beta* = *67.0°*

*Alpha* = *23.0°*

Height = 550 km

R = 6371 km

**CT = 2704 km**

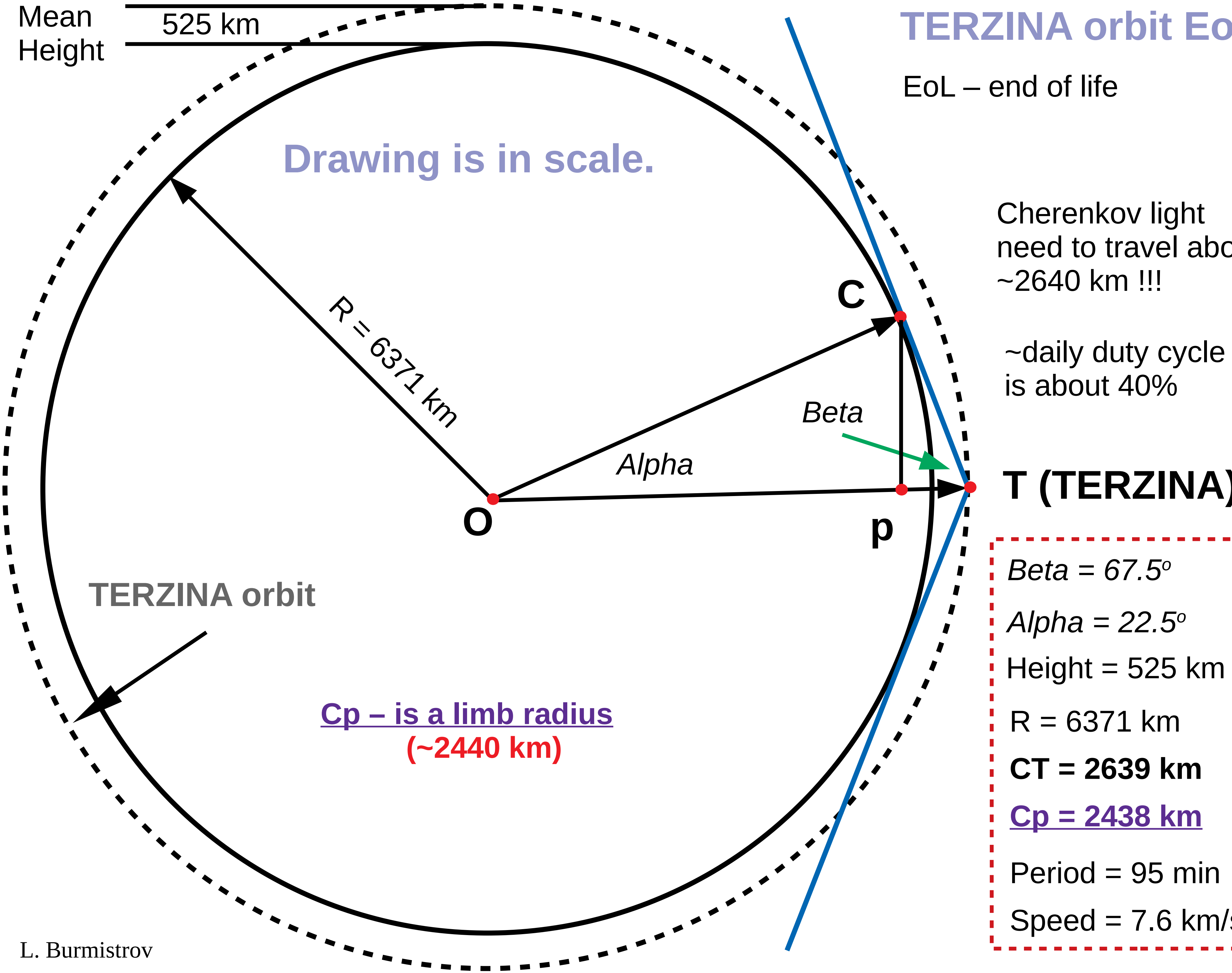
**Cp = 2489 km**

Period = 95.5 min

Speed = 7.59 km/s

# TERZINA orbit EoL

EoL – end of life




Cherenkov light need to travel about ~2640 km !!!

~daily duty cycle is about 40%

*Beta* = 67.5$^o$

*Alpha* = 22.5$^o$

Height = 525 km

R = 6371 km

**CT = 2639 km**

**Cp = 2438 km**

Period = 95 min

Speed = 7.6 km/s

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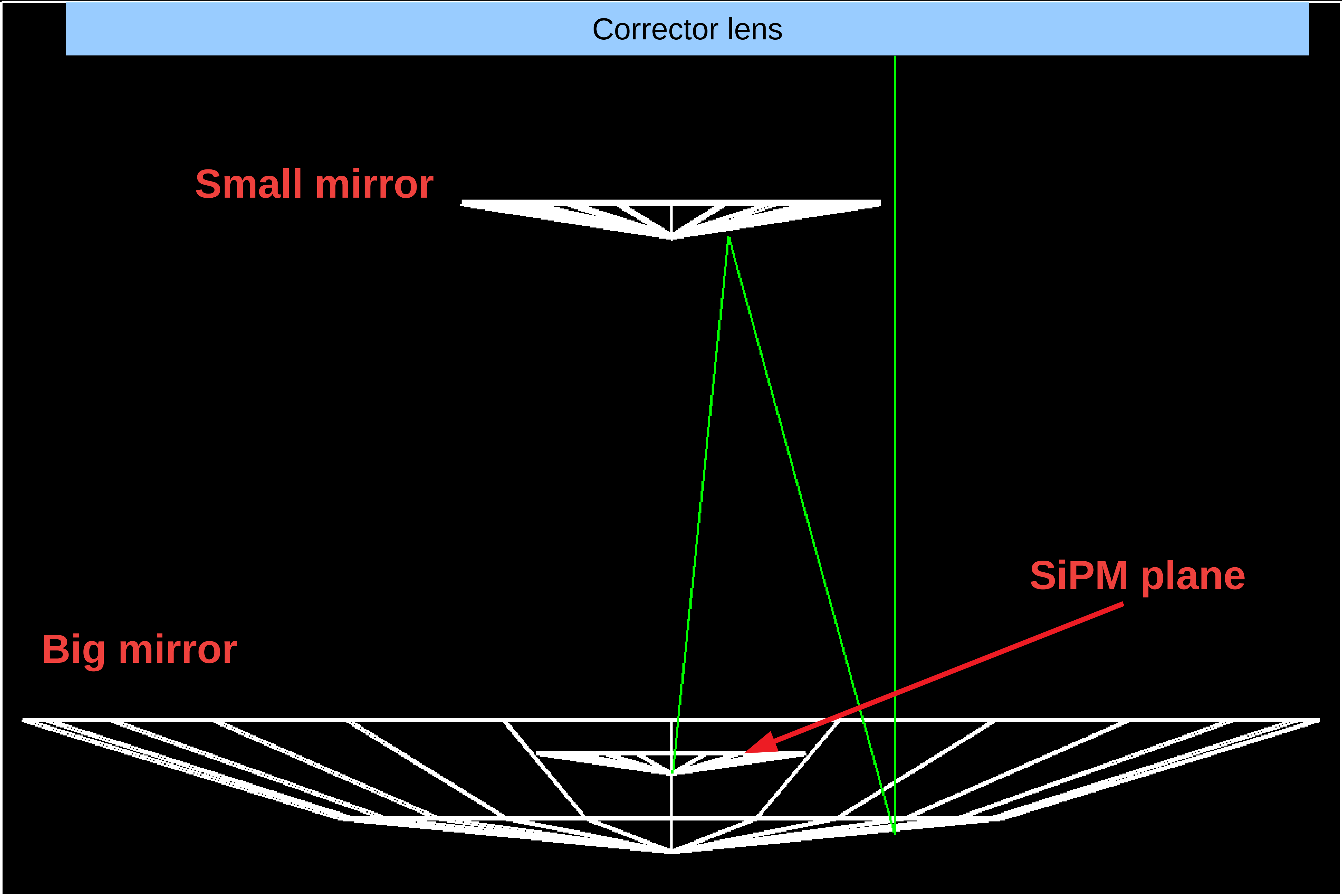
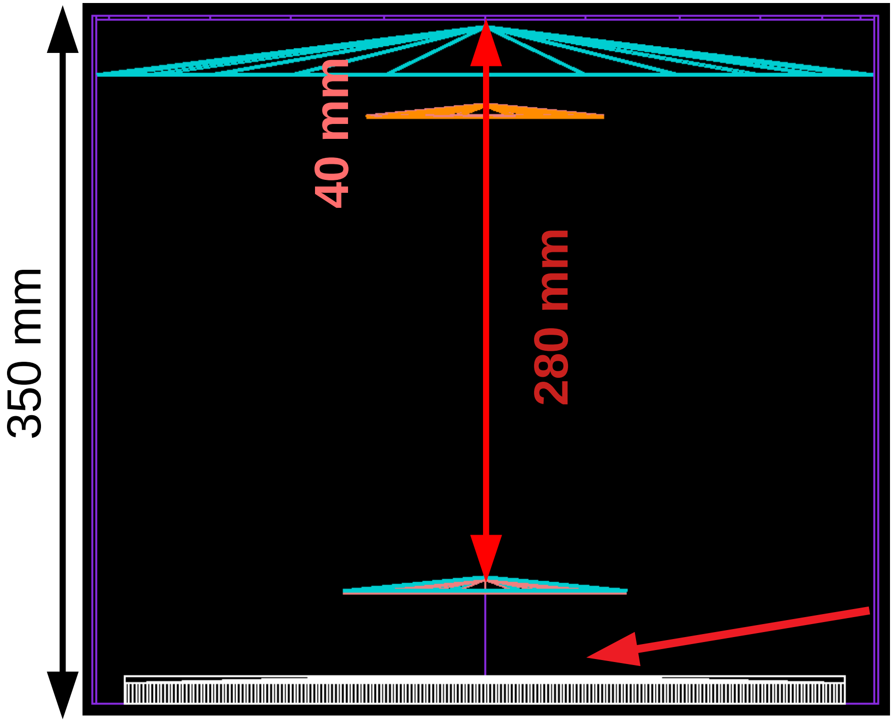
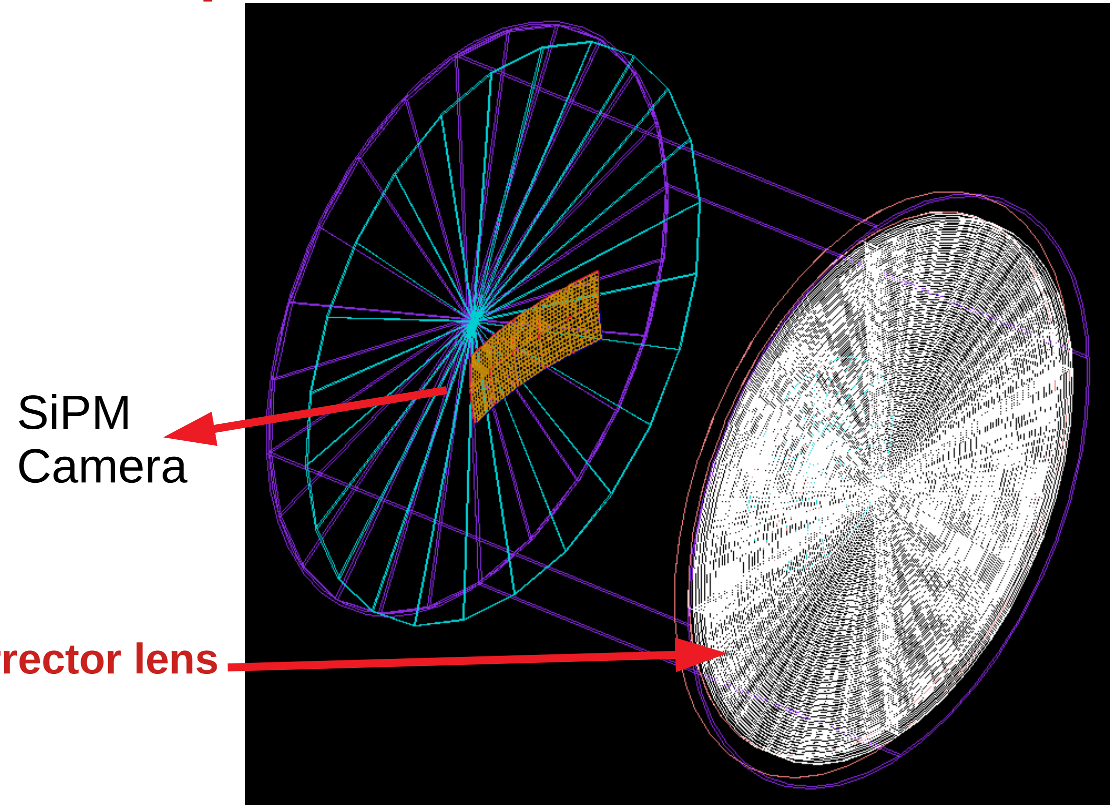
# Photon path in the telescope

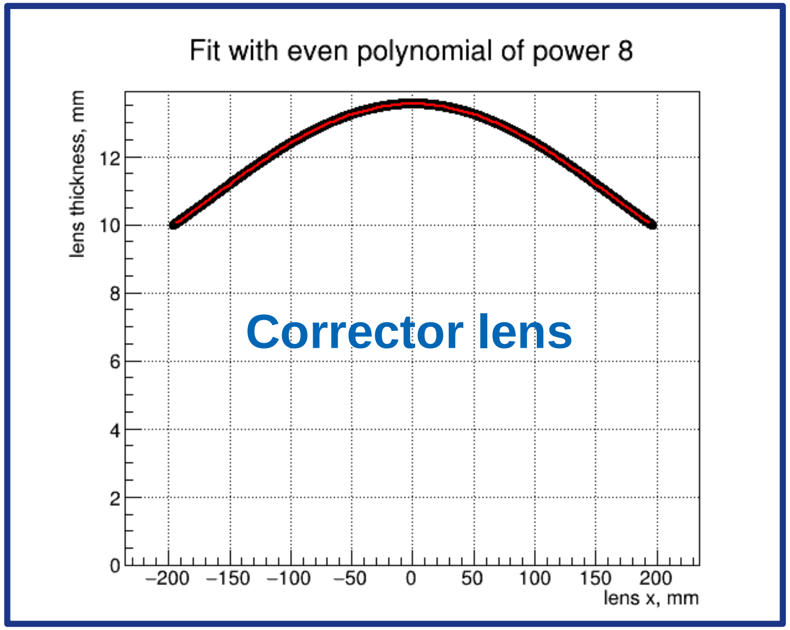


# The telescope

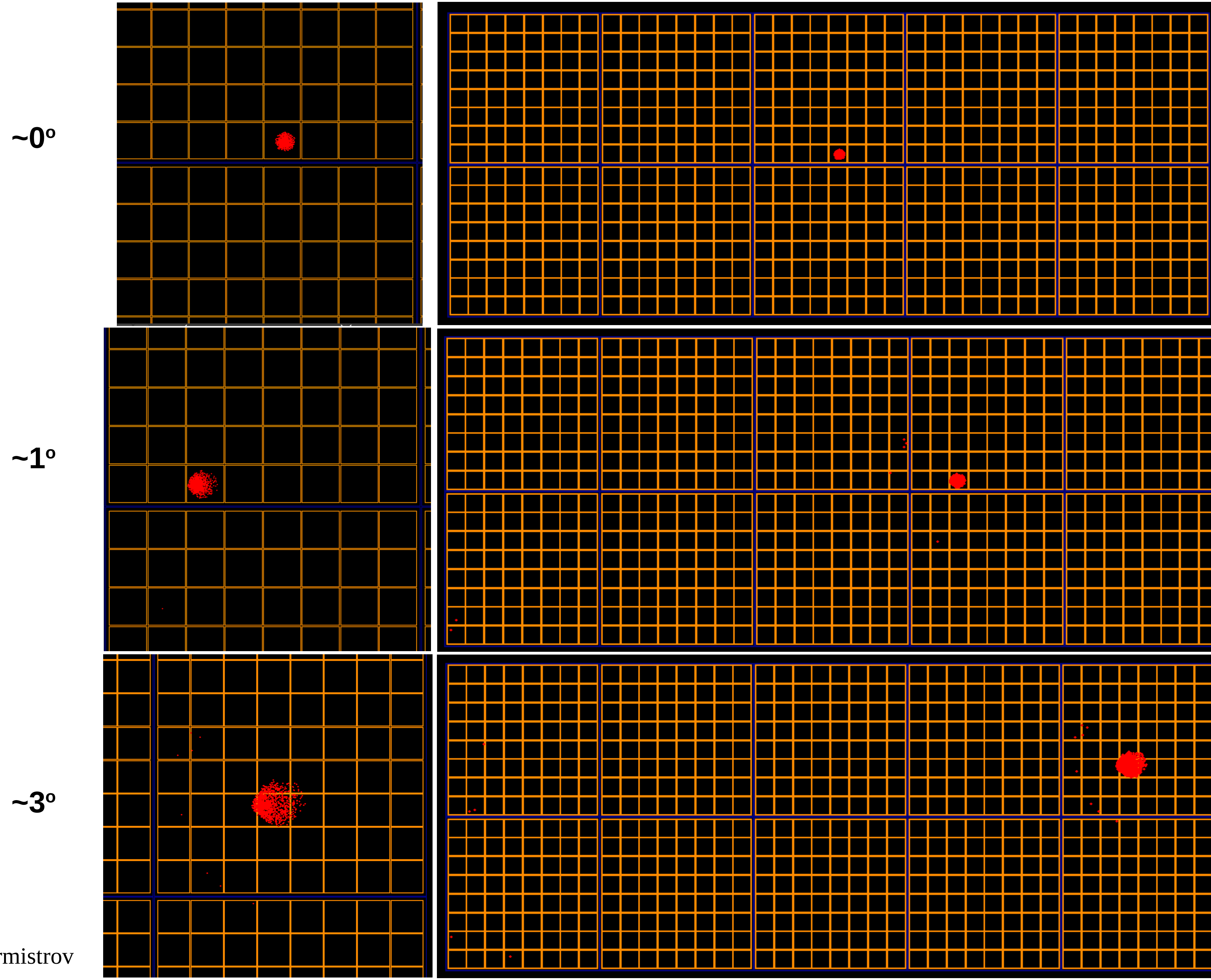



| | RoC, m (Radius of Curvature) | Distance to big mirror,mm | Diameter, mm |
|---|---|---|---|
| Big mirror | 0.8 | 0 | 394 |
| Small mirror | 0.36 | 280 | **144** |
| Projection Plane | 0.3 | 40 | **121** |
| Corrector lens | Variable | 350 | 362 |



# Point spread function vs theta

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## Upside-down image

## Left to right flip

## What can we see from Terzina

**LUNA in Geneva**

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# SiPM (FBK) camera plane

SiPM arrays of : **8 x 8 channels**

Pixel : **3 x 3 mm$^2$**

Pixel pitch : **3.1 mm**

Dead area from the ages of a single SiPM array : **0.3 mm**

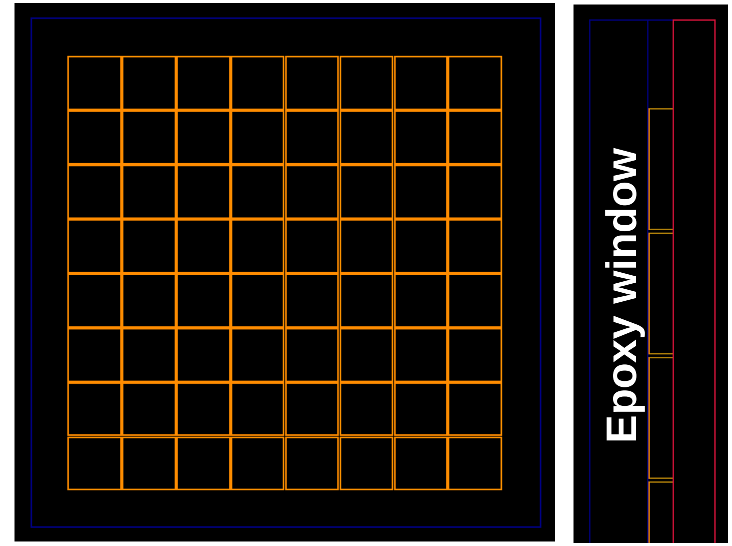
Distance between two arrays : **0.2 mm**

**We have 5 x 2 = 10 SiPM arrays In total**

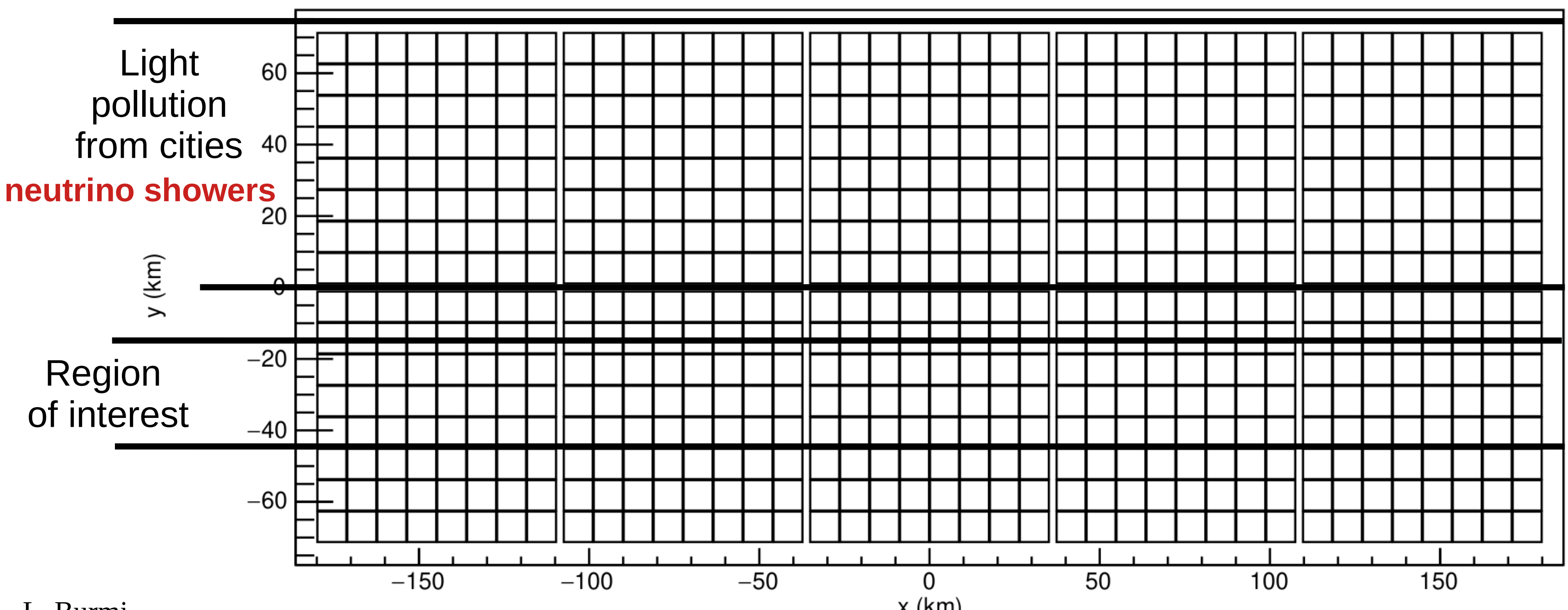
**We have 40 x 16 = 640 SiPM**

**Array dim. : 25.3 x 25.3 mm$^2$**

**Array Eff. area : 24 x 24 mm$^2$**

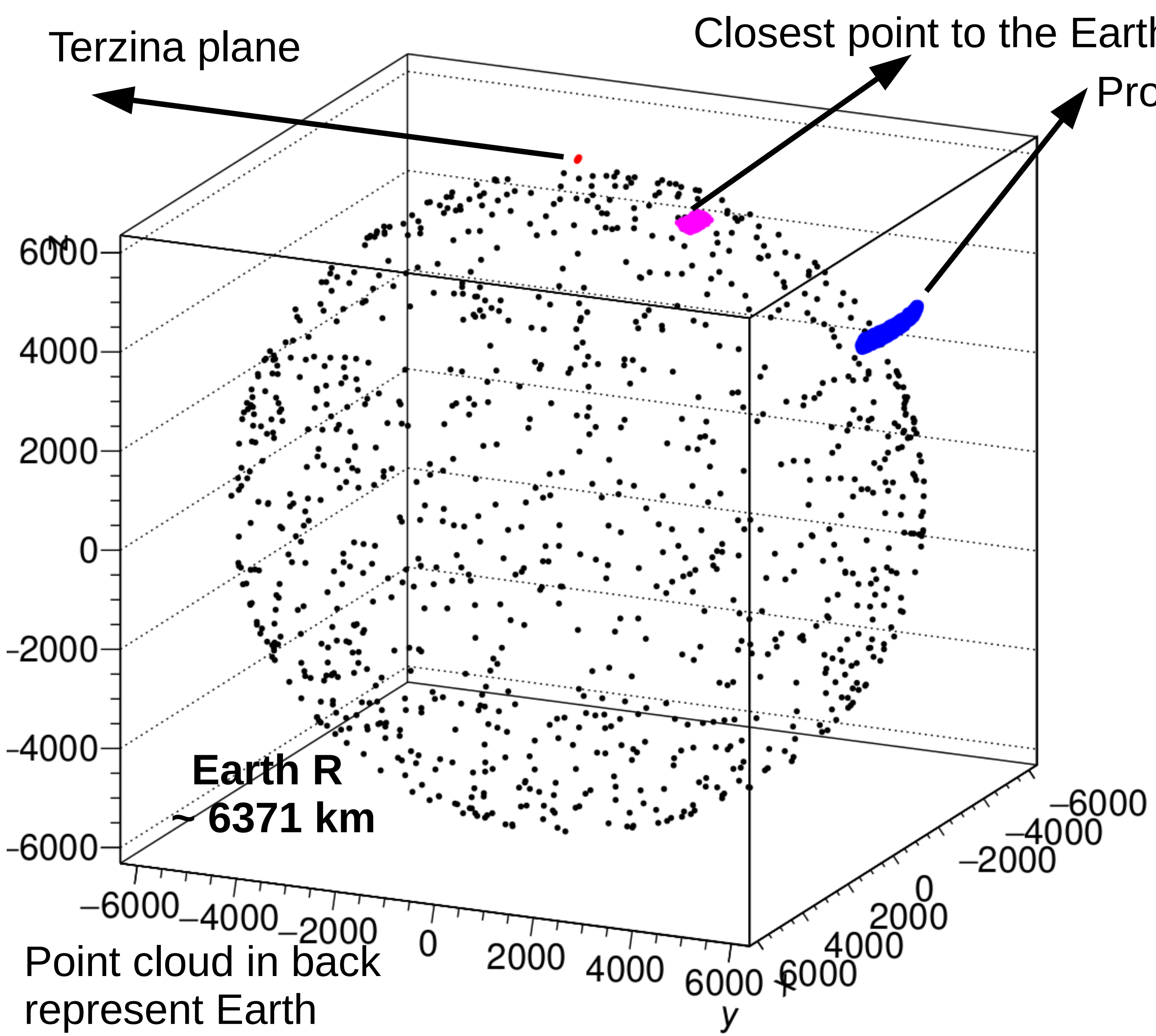



## Camera plane : what can we see from Terzina (projection on the earth)



# Simulation pipeline. Track fast sim.

| Track fast sim | Easchersim | Geant4 photon Propagation | Digitization | Analysis |
|---|---|---|---|---|
| 100/100 | 100/100 | 90/100 | 50/100 | 0/100 |




We generate a proton with spherical symmetry around Terzina Telescope.

Primary position of the proton located on the sphere with r = $r_{earth}$.

Direction of a proton have uniform (spherical) distribution.

We apply selection cuts on potentially interesting events.

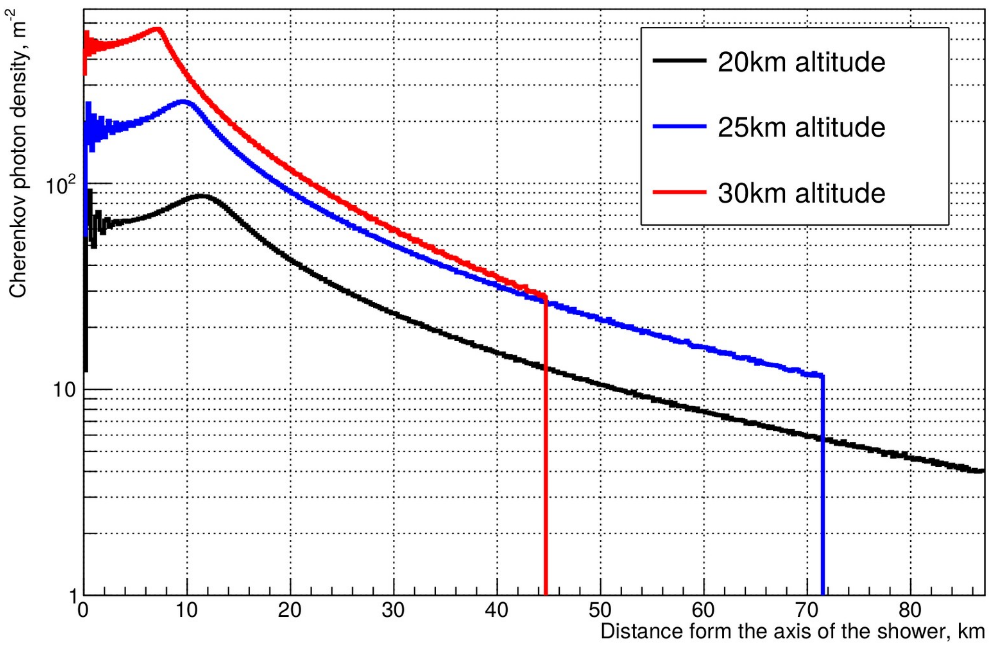
This give us acceptance of Terzina telescope :

$$\frac{108950}{2 \times 10^{13}} = 5.45 \times 10^{-9}$$

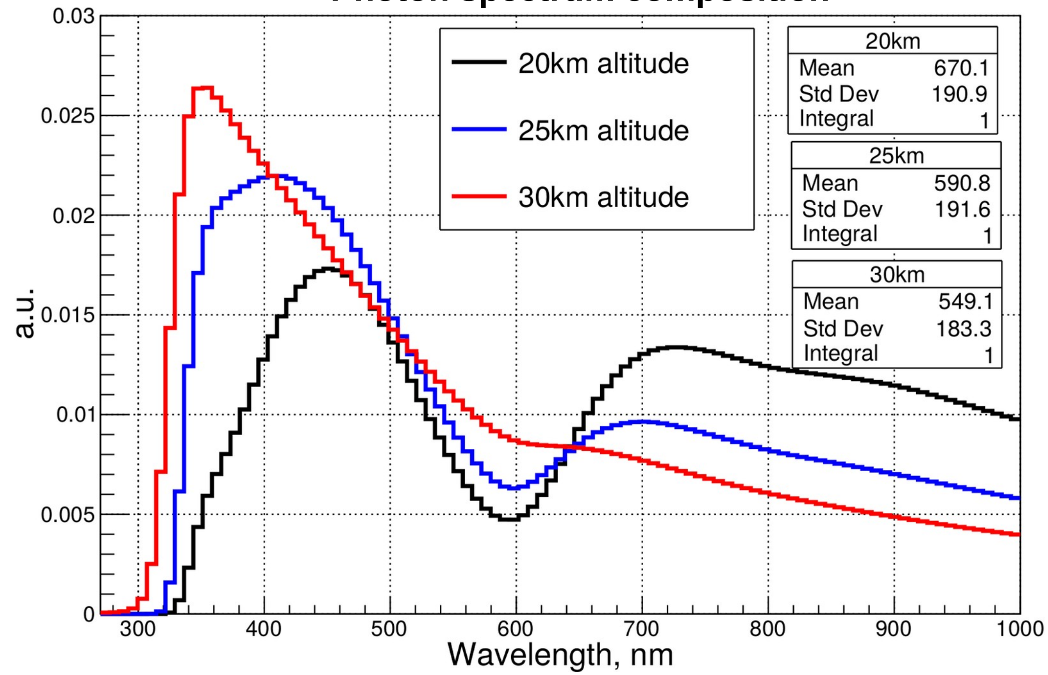
# Shower simulation with EASCherSim (100 PeV proton)

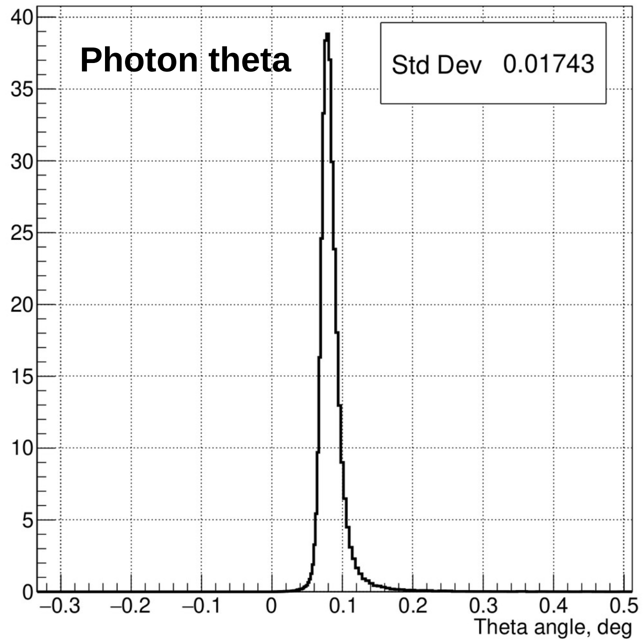
**EASCherSim** - Simulation of the Cherenkov light emission for extensive airshowers with trajectories below and above the limb as a full Monte Carlo simulation.0

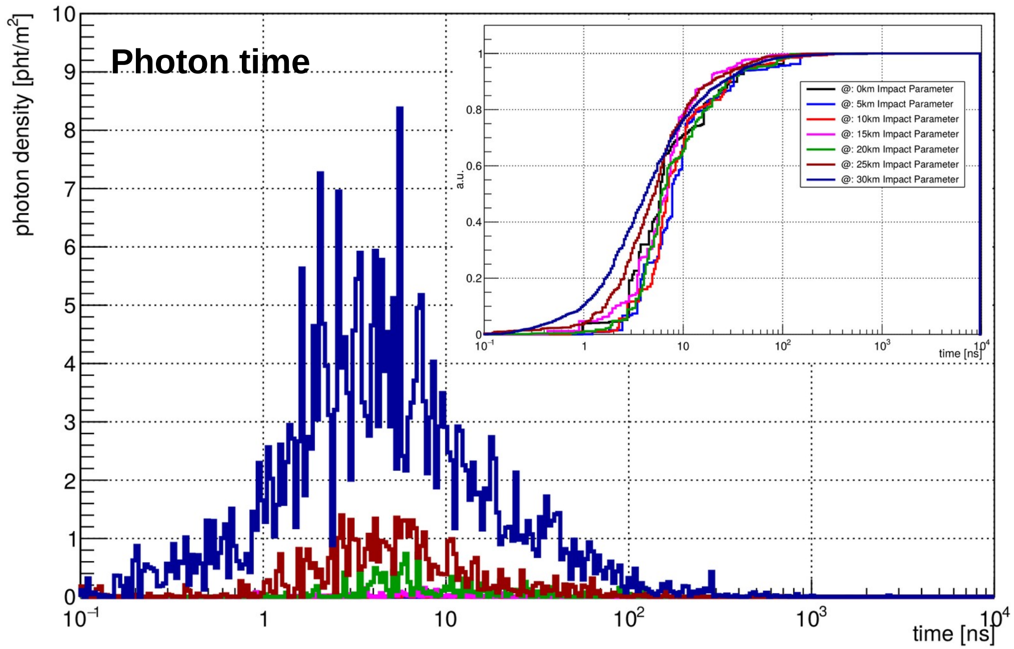
**Photon density**




**Photon spectrum composition**

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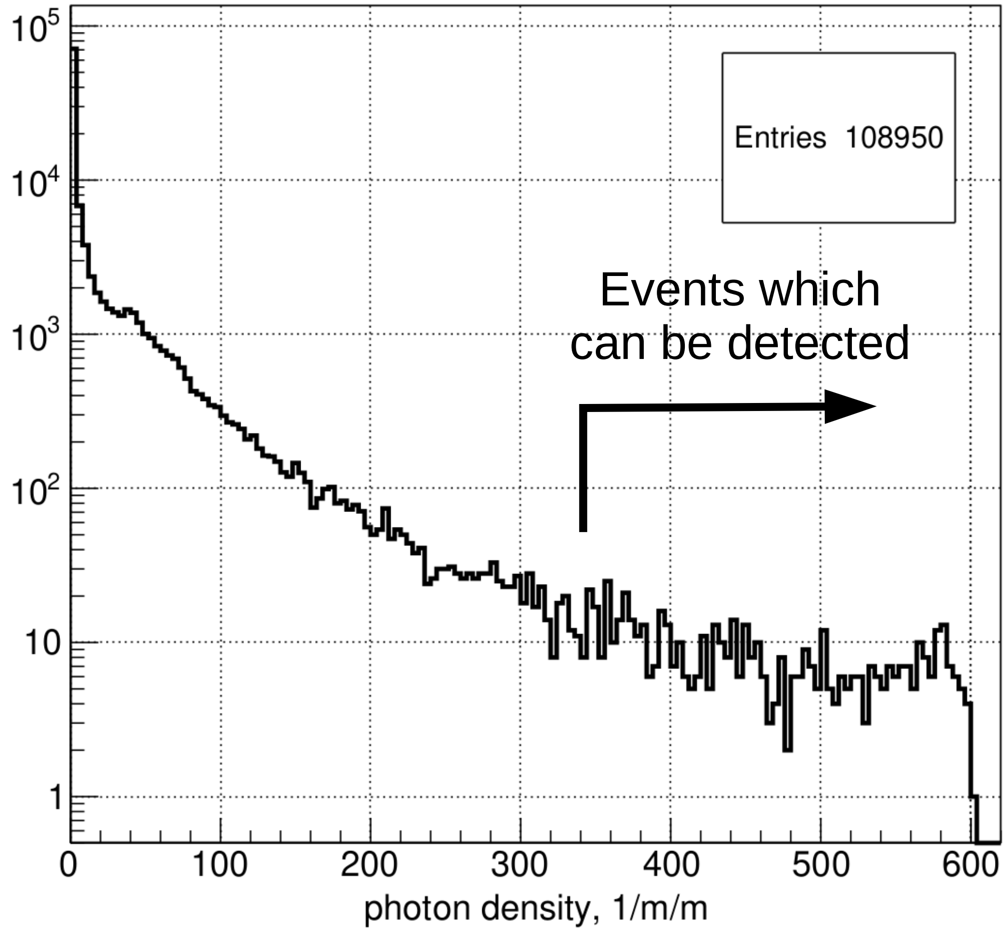
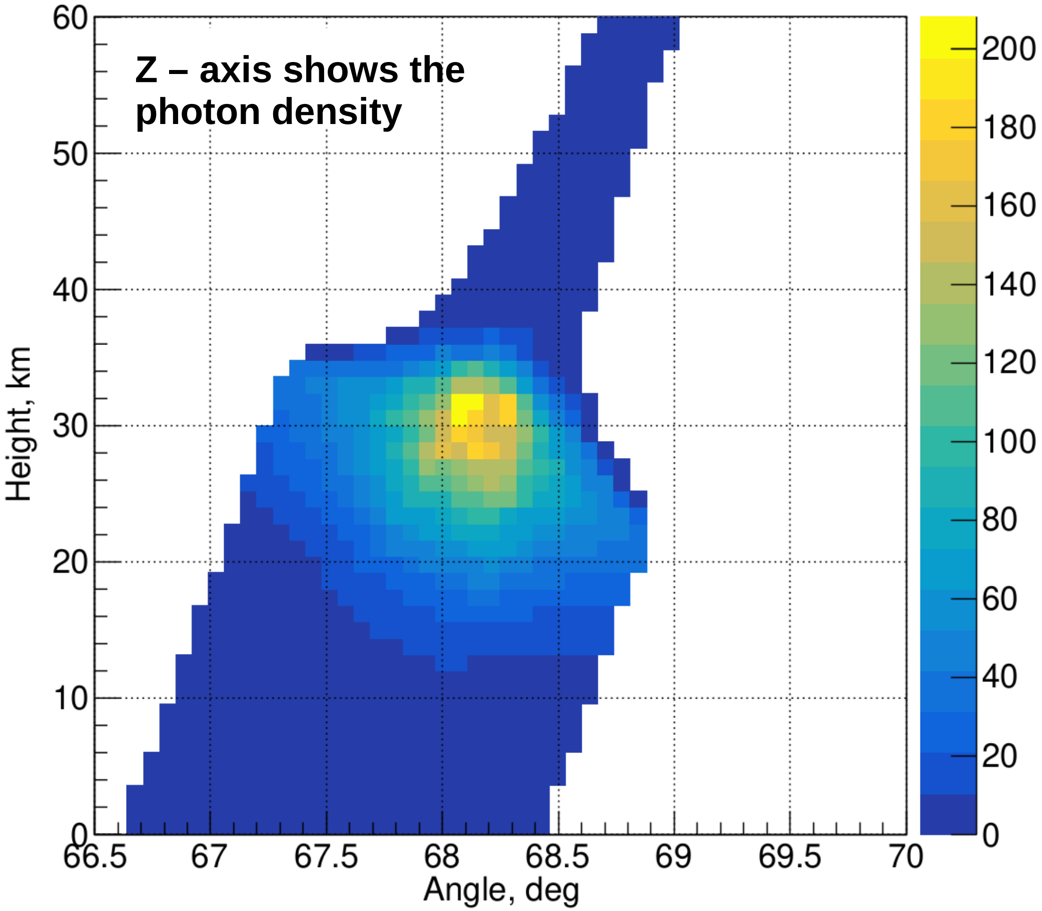
# Lets choose a good event (with good enough photon density).



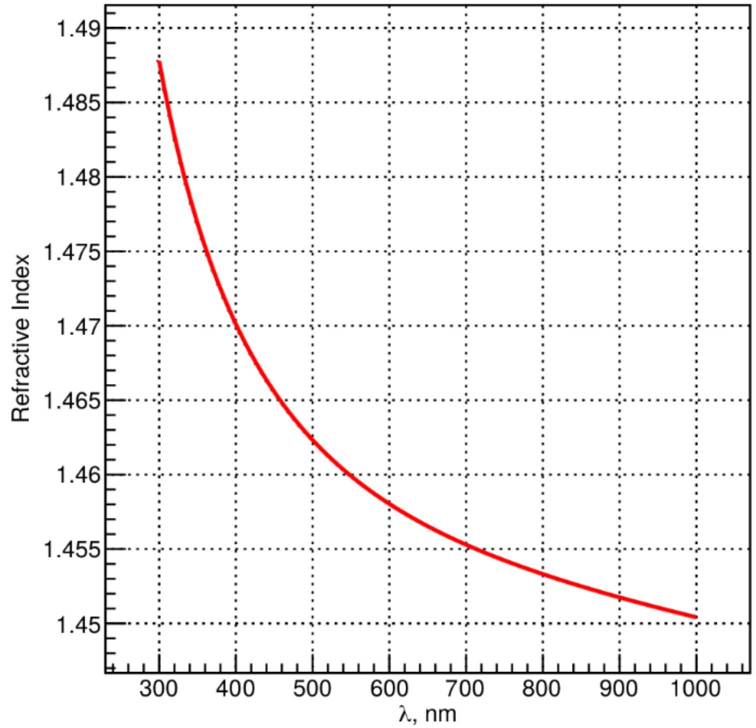

As one can see that even tracks which are chosen to be good ones – produce very little amount of light … Only some of them can be detected.

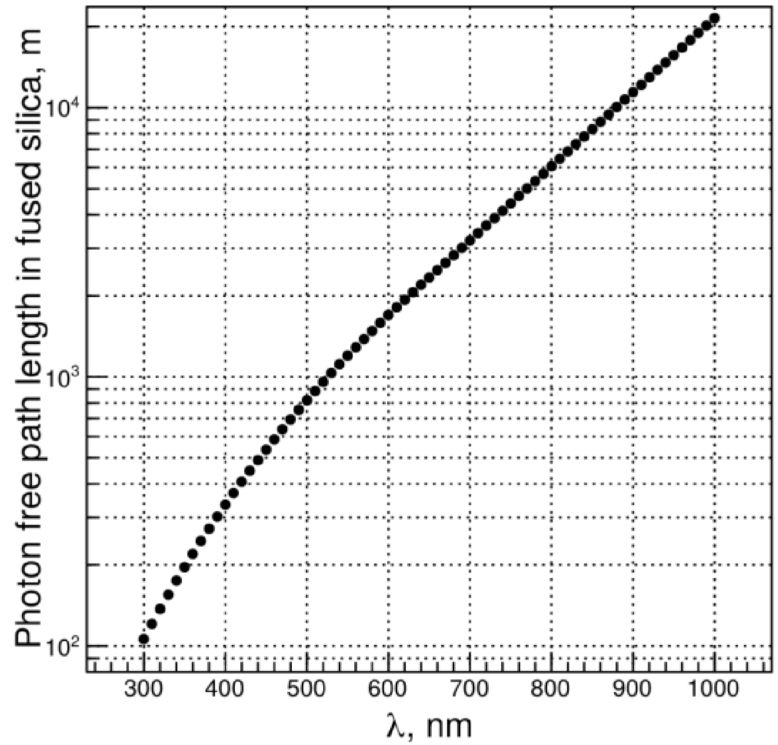
One can see the region of interests.

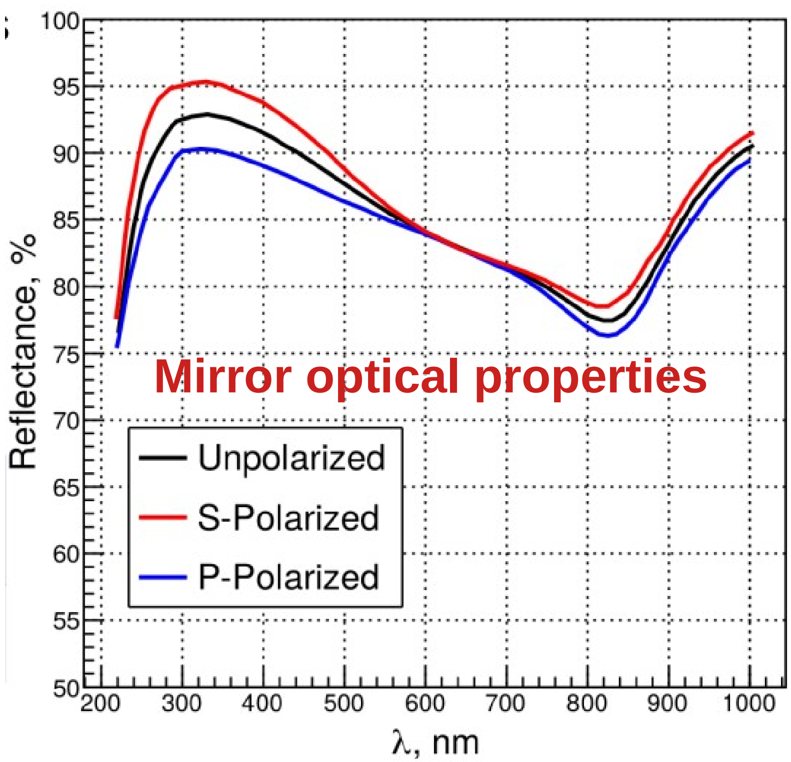
The tracks at a height about 30 km and “looking” into Terzina optical axis.

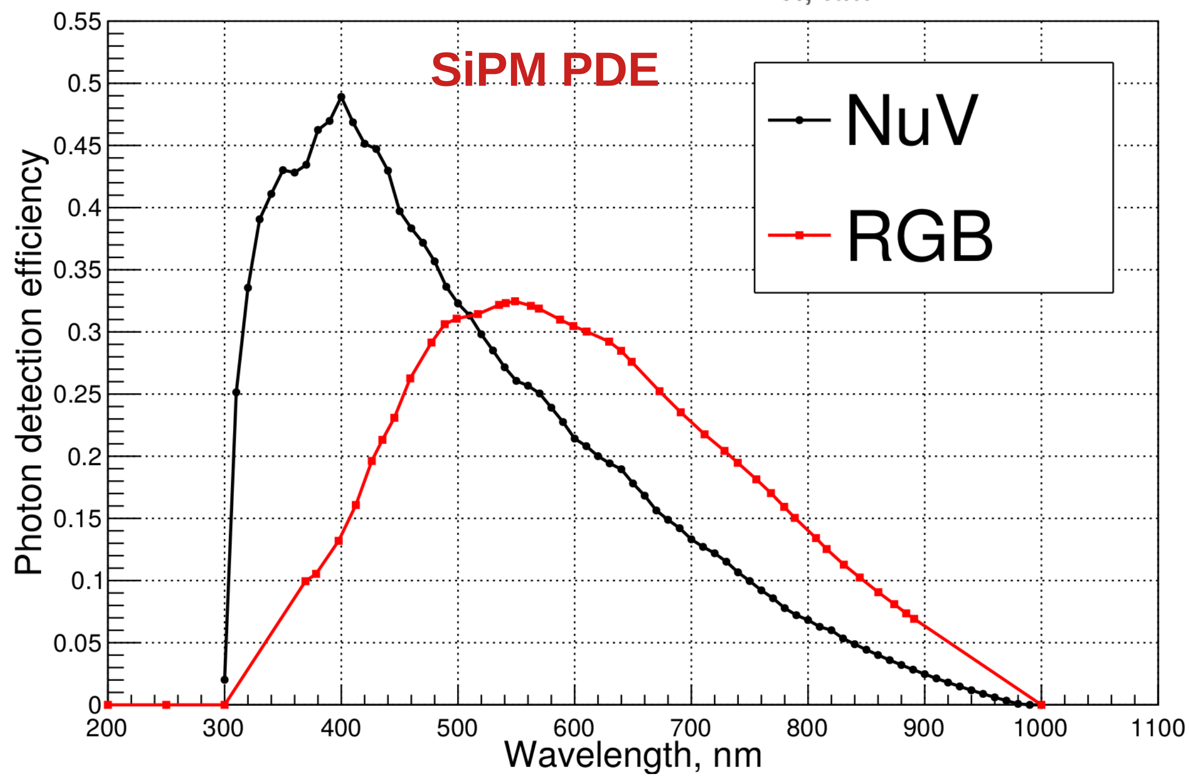
# Corrector lens optical properties.

~5 % losses per edge interface.

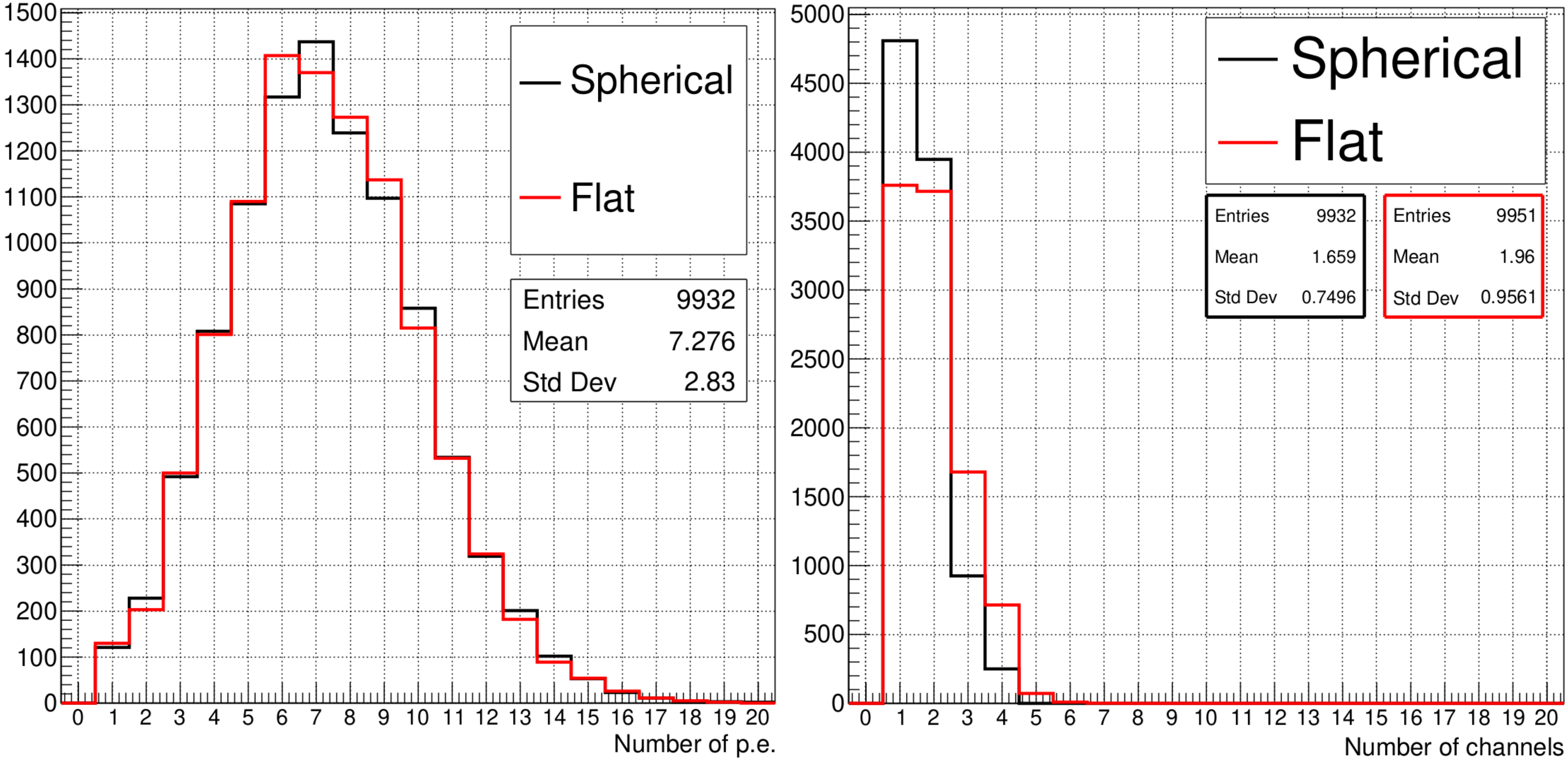


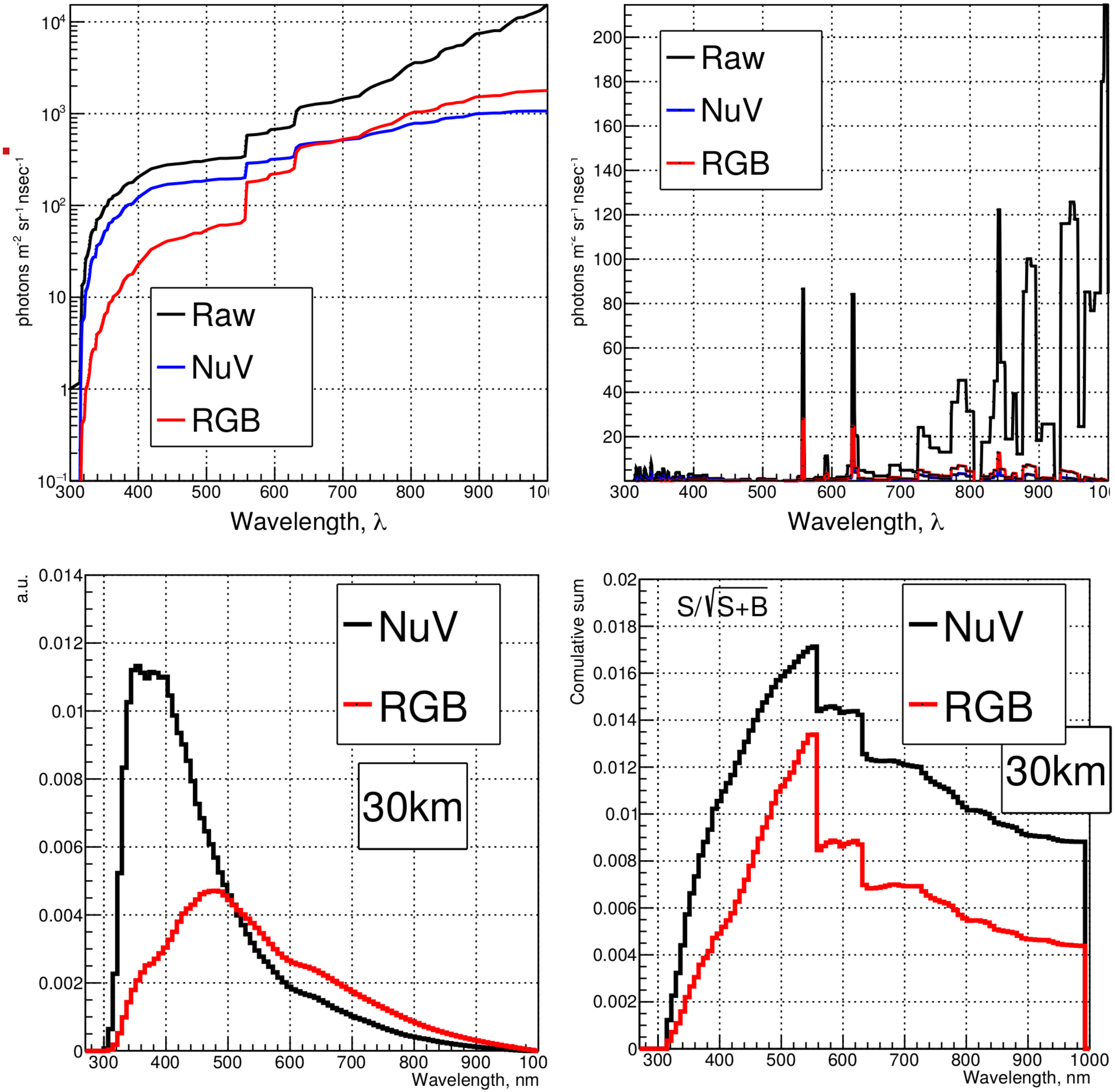
# Terzina - estimation of number of the pixels per event.
# We chose a “good” 100 PeV proton.




Threshold = 0.9 p.e. (we exclude all 0 p.e.) events.

~ 7 p.e. per “good” proton with energy about 100 PeV
These 7 p.e. will be spread over two channels.

# Background study – signal to noise ration.

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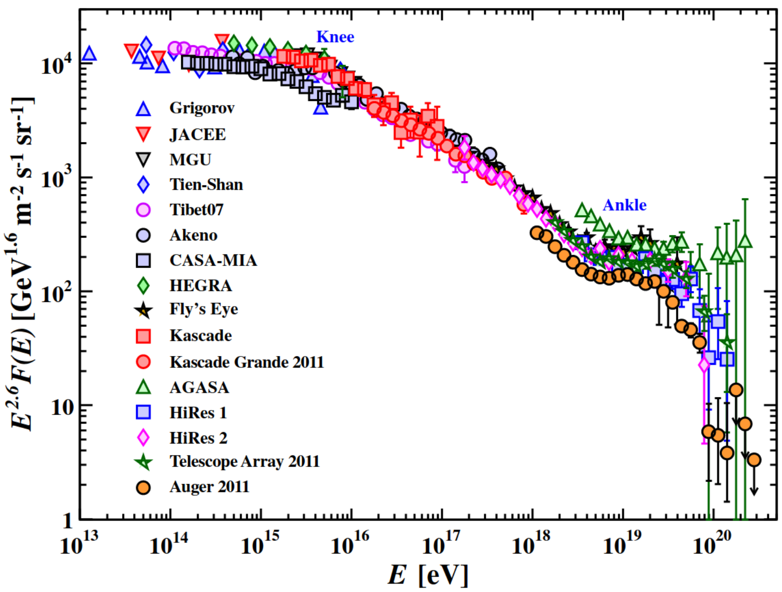
# Lets have an estimation signal event rate

The all-particle spectrum as a function of E (energy-per-nucleus)

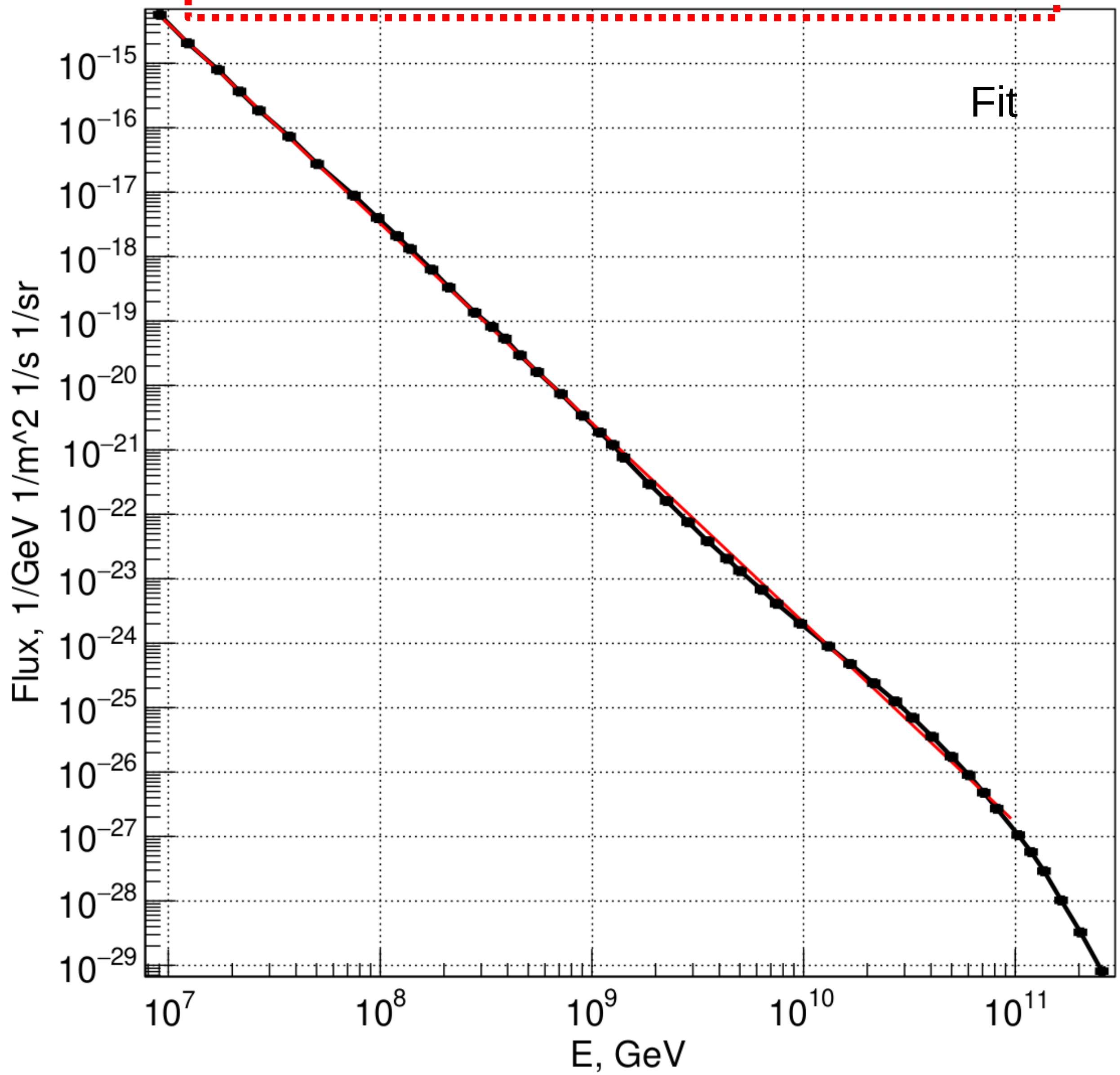



Please note
The function is choose only for rough values estimation within 10-20% precision.

$$F(E) = \frac{A}{E^B} + C$$

Table 8: Parameters

| Parameter name | Parameter value |
|---|---|
| A | 1.86767e+07 |
| B | 3.09484e+00 |
| C | -5.07028e-29 |

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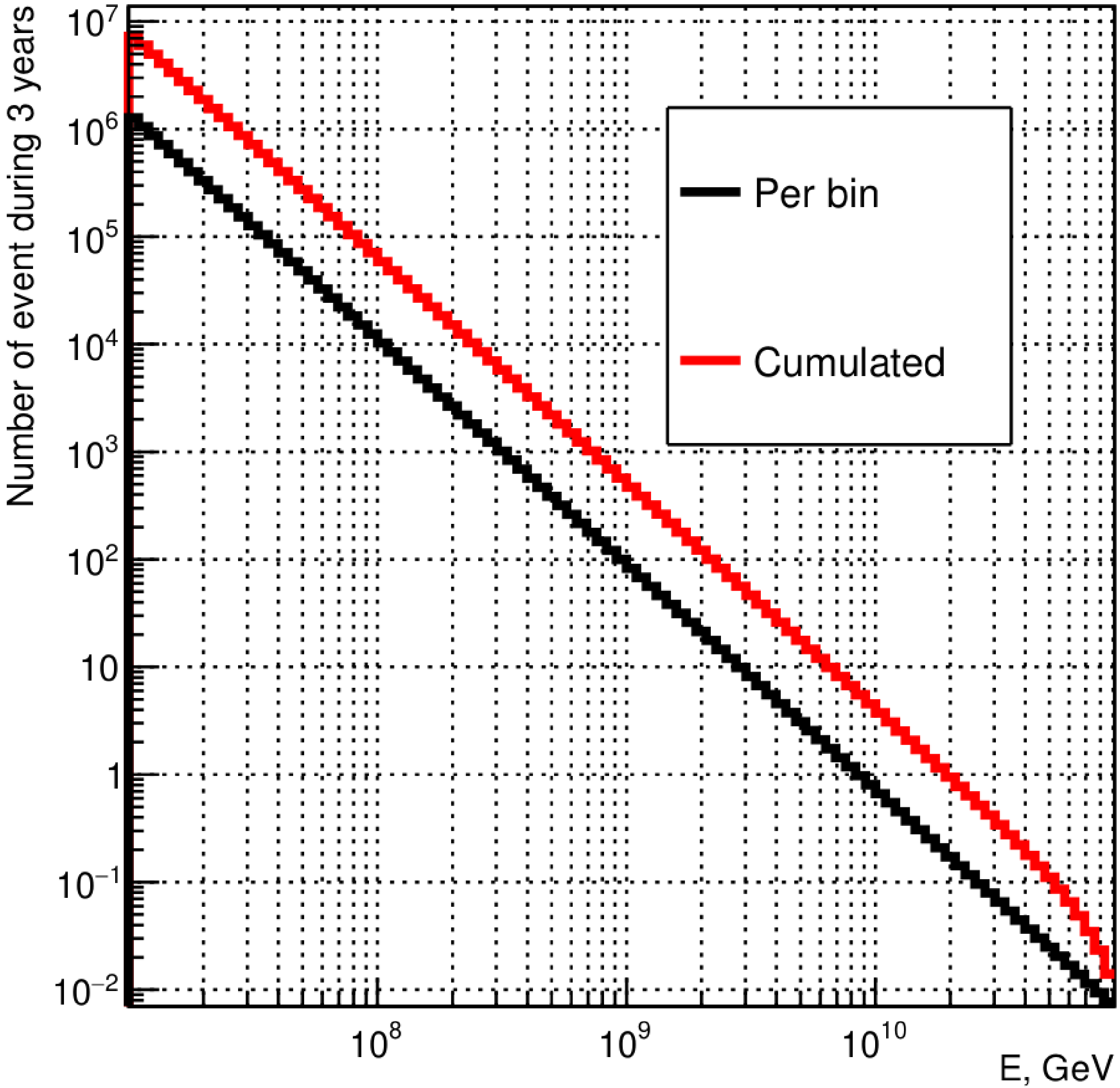
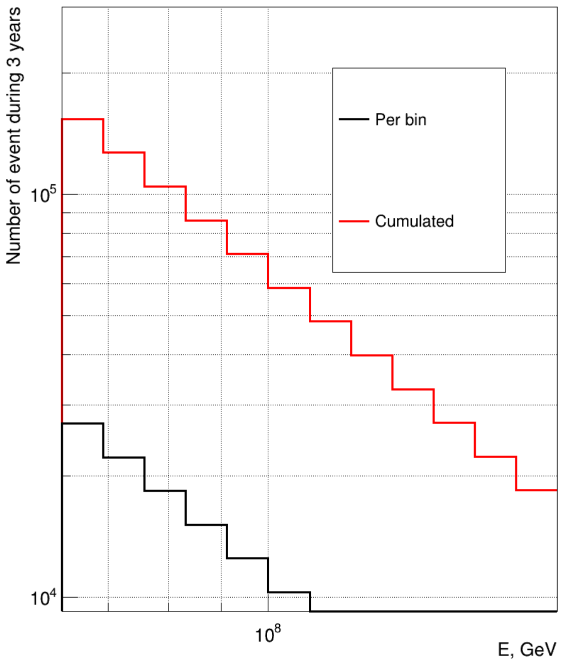
https://pdg.lbl.gov/2011/reviews/rpp2011-rev-cosmic-rays.pdf

# Number of events during 3 years mission.

Event rates takes into account only the geometrical orientation of Cherenkov light from UHECR showers. The efficiency of the optical system, of the SIPMs and the NSB is ignored.




With particles with P > 100 PeV
**6.0e+4** in three years.

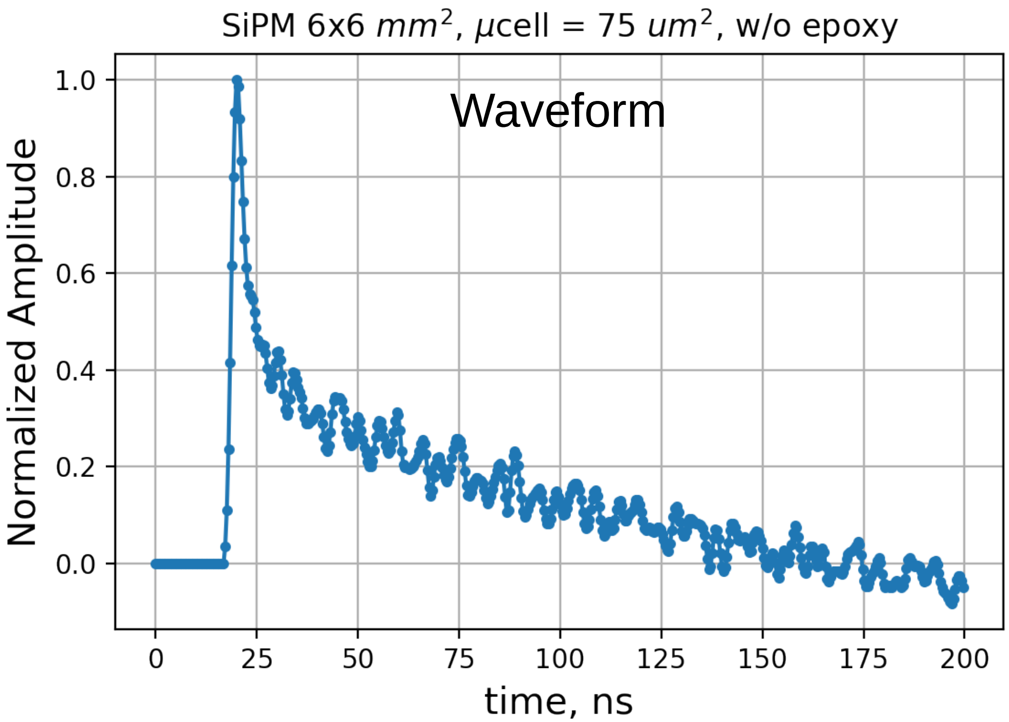
2.3 event per hour

If we include Terzina efficiency

One event per week

(very preliminary)

# Conclusions : one slide on SiPM wf. simulation.




Signal shape: → 6x6 mm² with 75x75 um², w/o epoxy

Pxt = 10%

Light pulse of 3 photons

DCR = 3x3 mm² x 2e⁵ Hz/mm = 1.8 MHz per SiPM

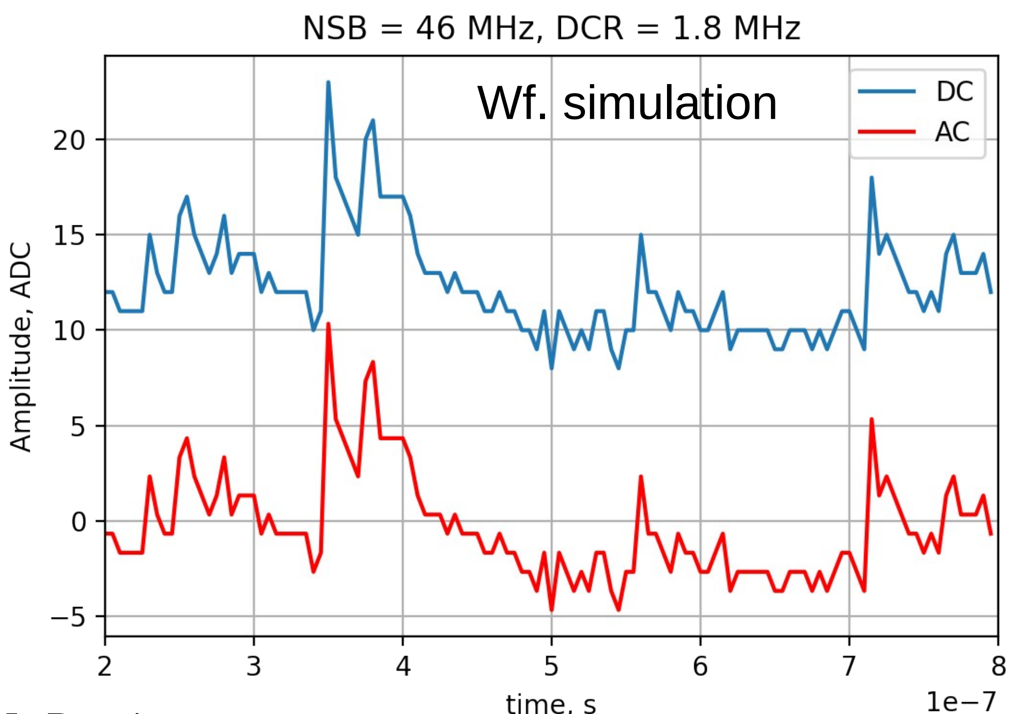
NSB = 0 HZ

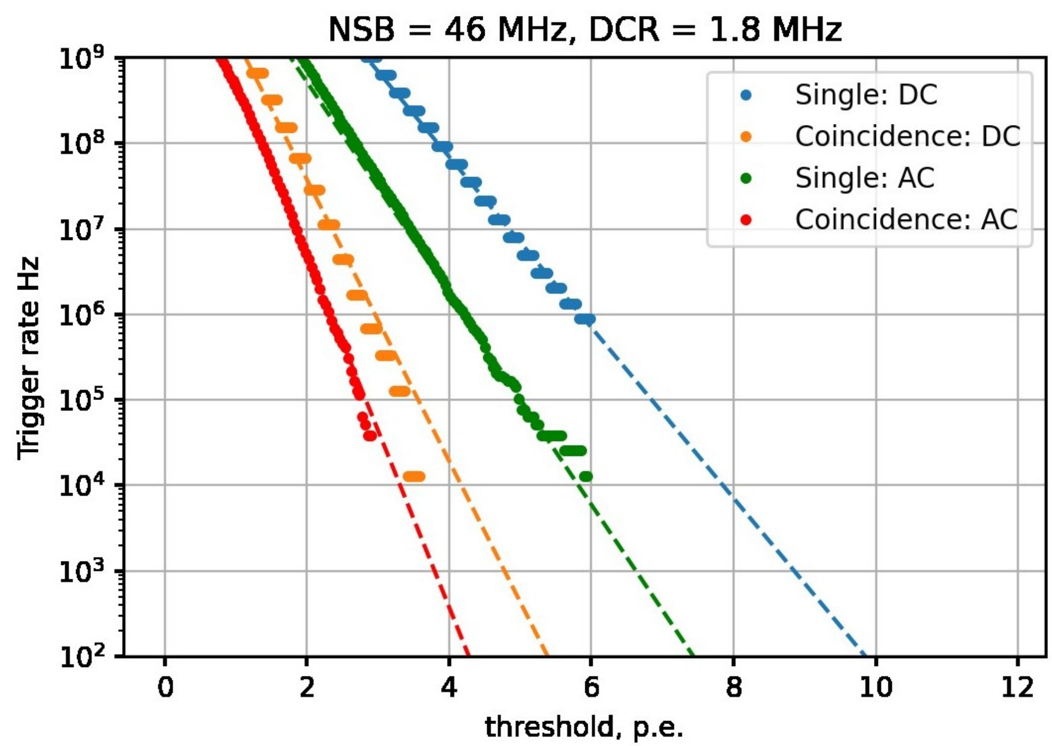
1 p.e amplitude = 5, 4, 3, 2 ADC

Electronics noise STD = 10% 1p.e. ampl.

Electronics baseline = 10 ADC

Sampling = 5ns

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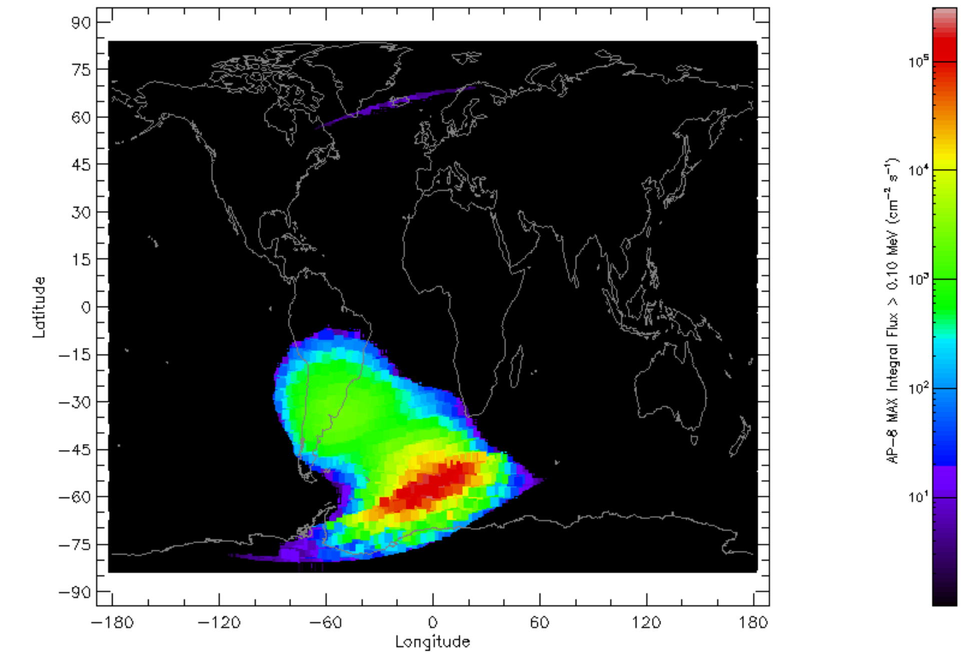
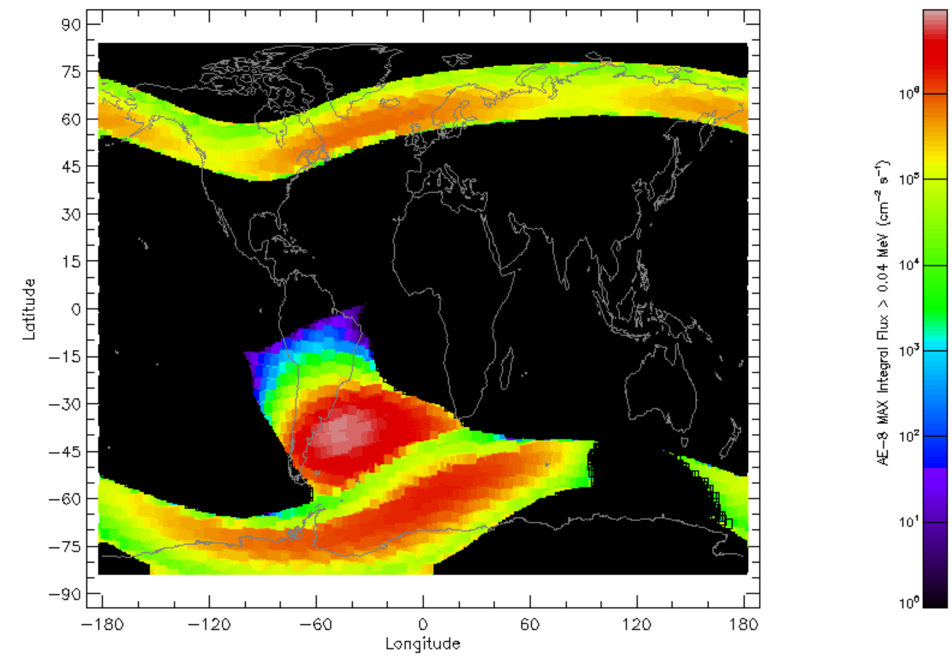
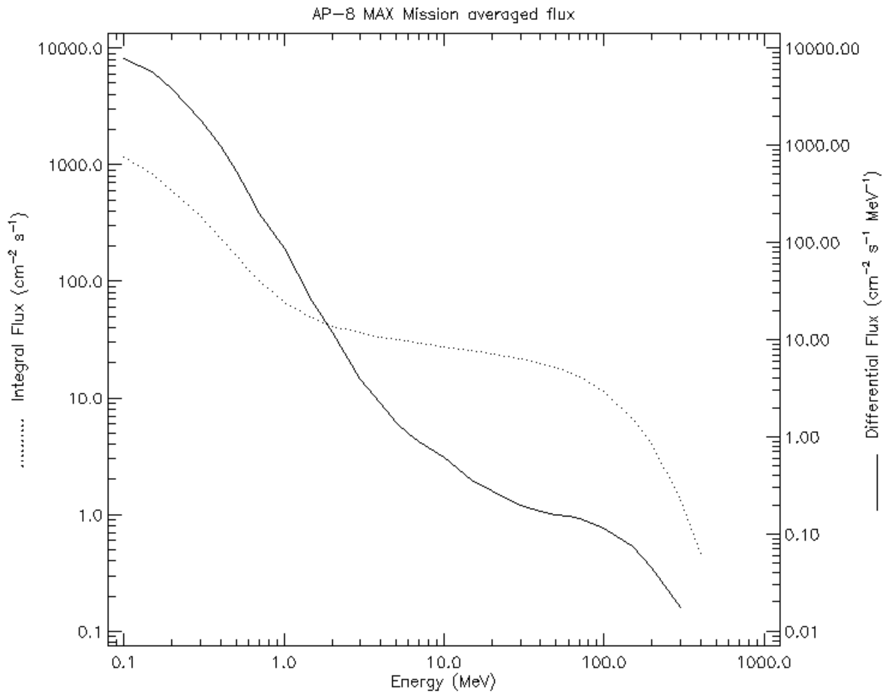
# Conclusions : one slide on SiPM rad. dose :-)

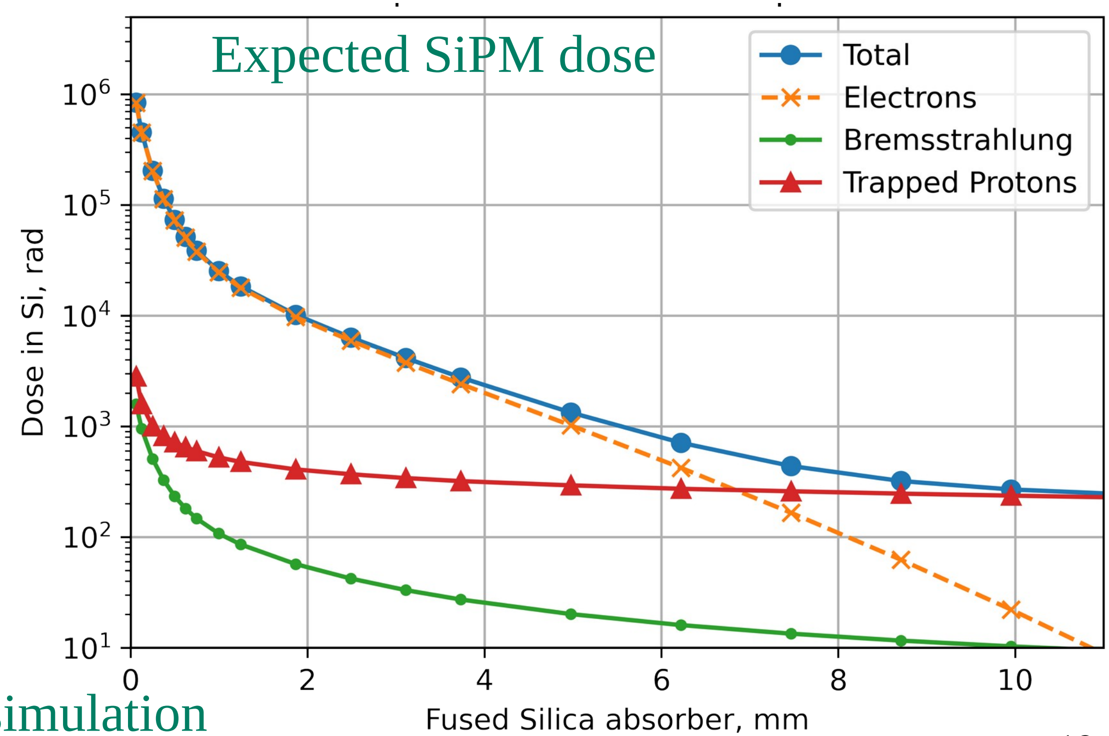
Trapped proton Flux




Trapped electron Flux




SPENVIS simulation