Preliminary study on the definition of meteors trigger for JEM-EUSO

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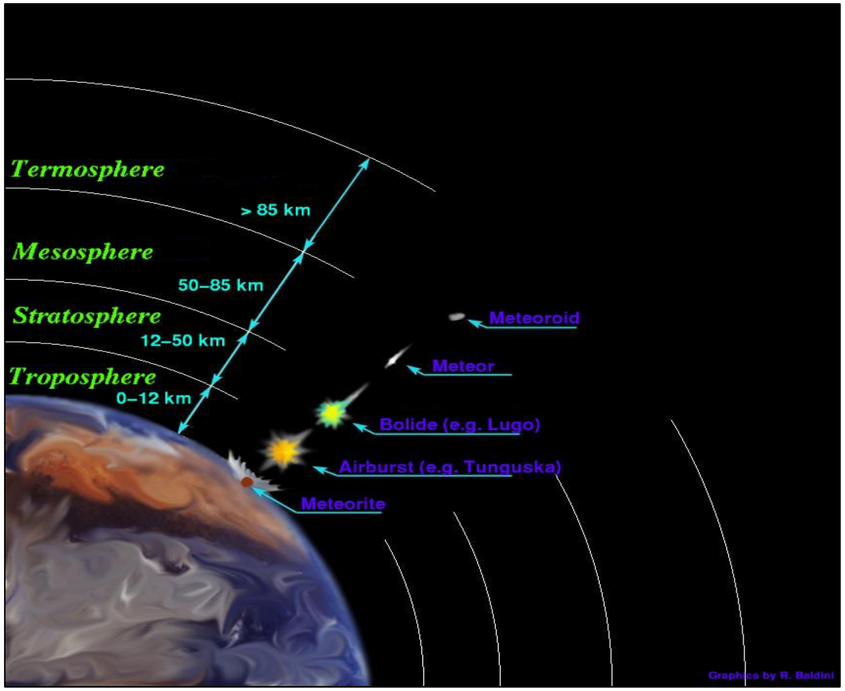
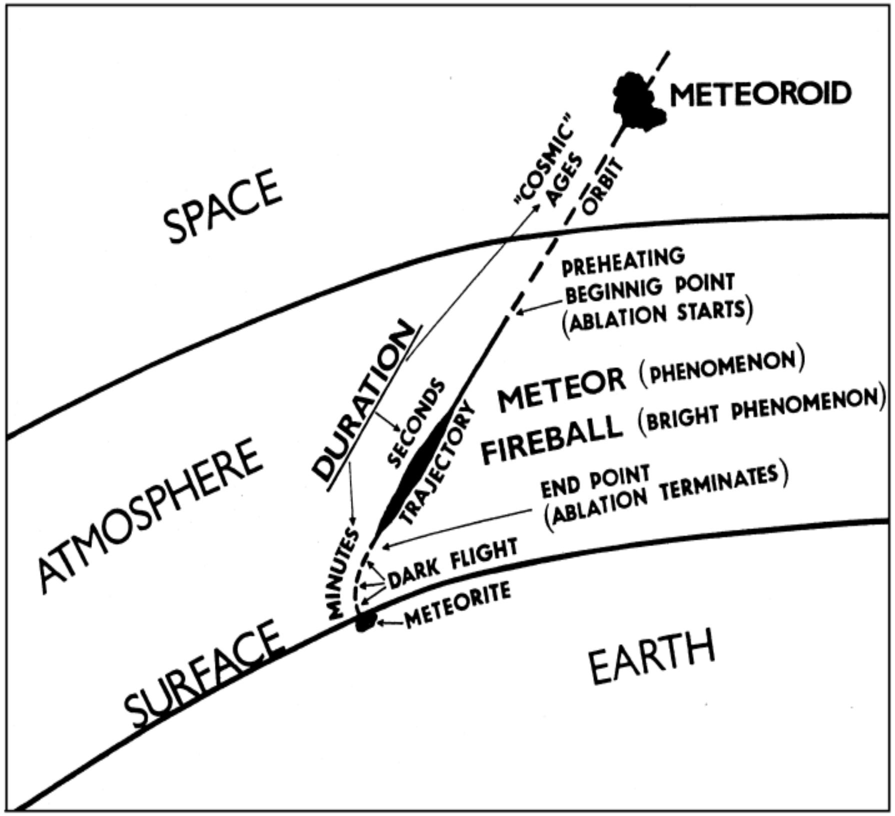
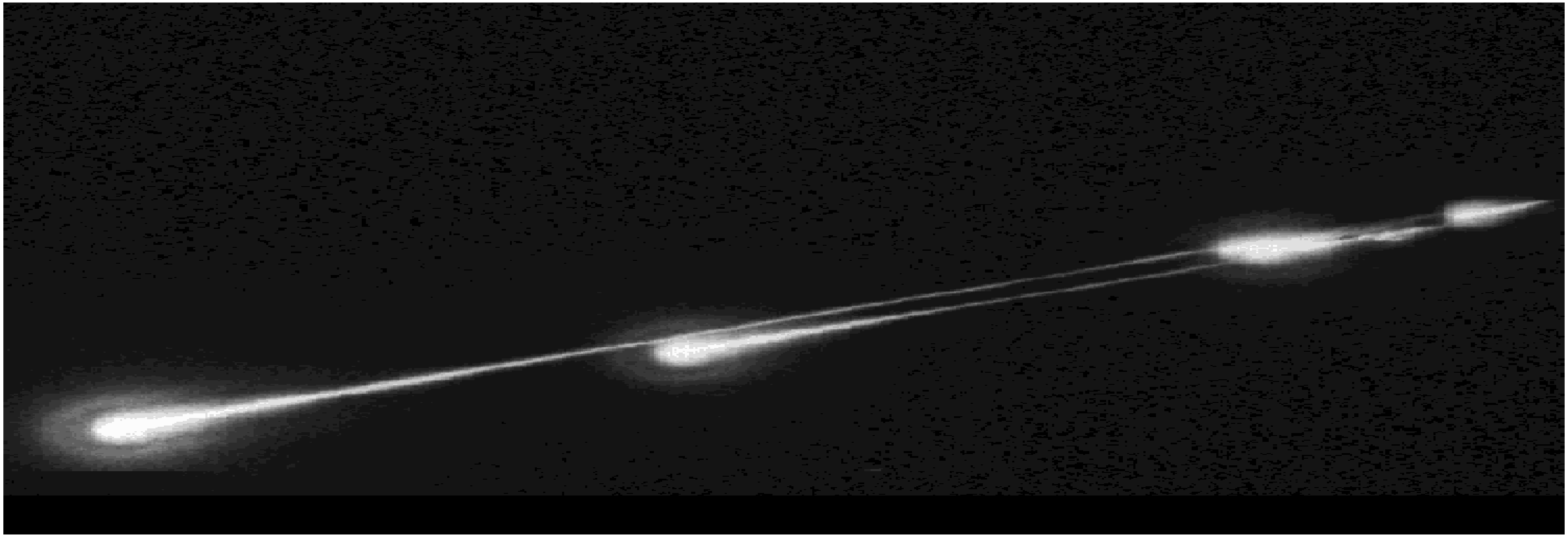




- **Beginning point:** ~ 75 ÷ 120 km
- **End point:** ~ 30 ÷ 70 km
- **Duration:** ~ 0.5 ÷ 3 s
- **Length:** ~ 10 ÷ 20 km
- **Type:** sporadic, showers (~ 25% obs. meteors)
- **Frequency:** ~ 5 ÷ 100 per hour (up to thousands during meteor storms)

Visual meteors → **meteoroids with D > 2 mm**



The Peekskill fireball (Oct. 9, 1992)

m < - 8 bolide or fireball (meteoroid mass 10 ÷ 100 kg)
m < - 17 superbolide (meteoroid mass > 1000 kg)

Fireball precursors, between 10 m and 100 m in size, are the least known population of minor bodies in our Solar system

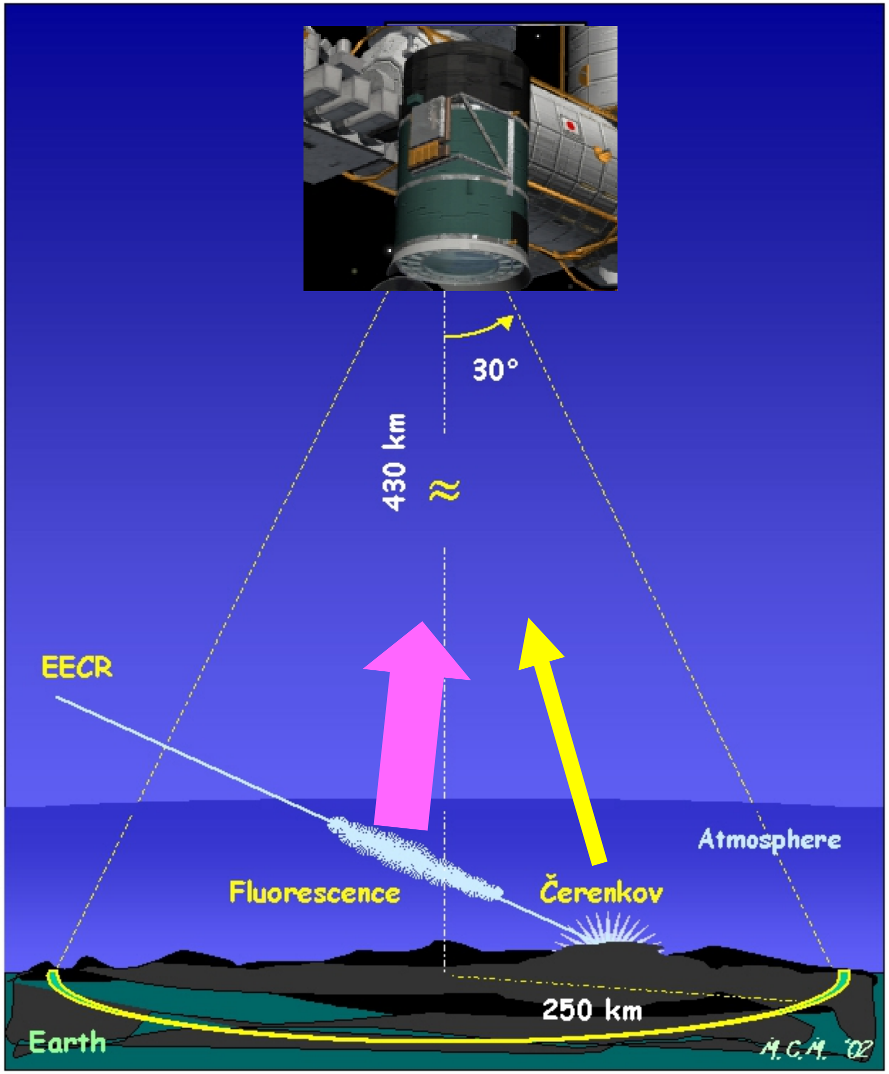
SOURCE: JEM-EUSO Meteor Observation by Watanabe, Ishiguro, Sato (13/06/2009)

ABSOLUTE MAGNITUDE	FLUX (phe/GTU) [1 GTU = 2.5 μs]	MASS (g)	COLLISIONS IN THE FIELD OF VIEW OF JEM-EUSO
+7	11	0.002	1/s
+5	68	0.01	6/min
0	6750	1	0.27/orbit
-5	675000	100	6.3/year (duty cycle 0.2)

ph = photons

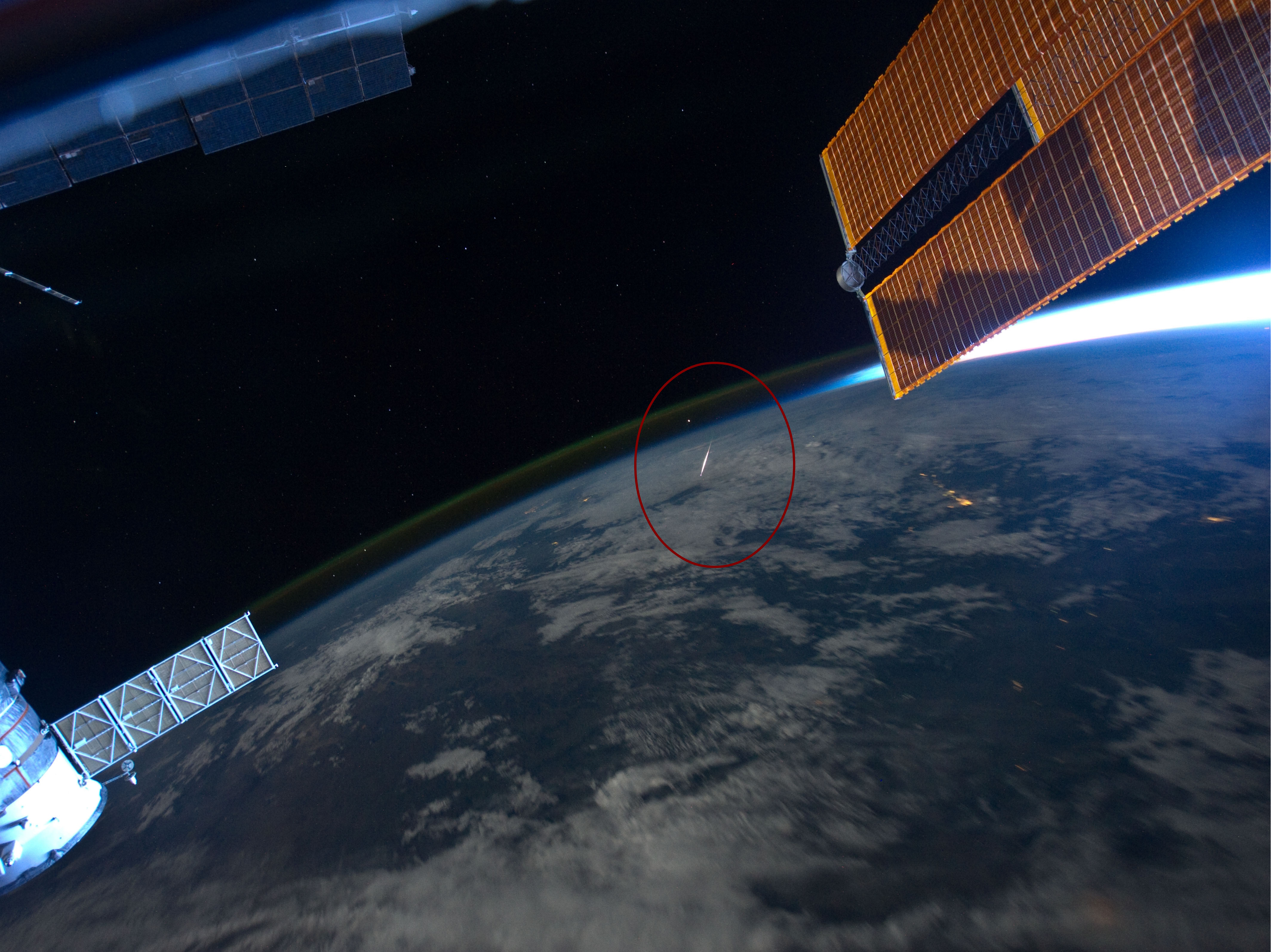
phe = photoelectrons

The JEM-EUSO experiment



JEM-EUSO main goal is to detect the Fluorescence and the Cherenkov light from the EECR...

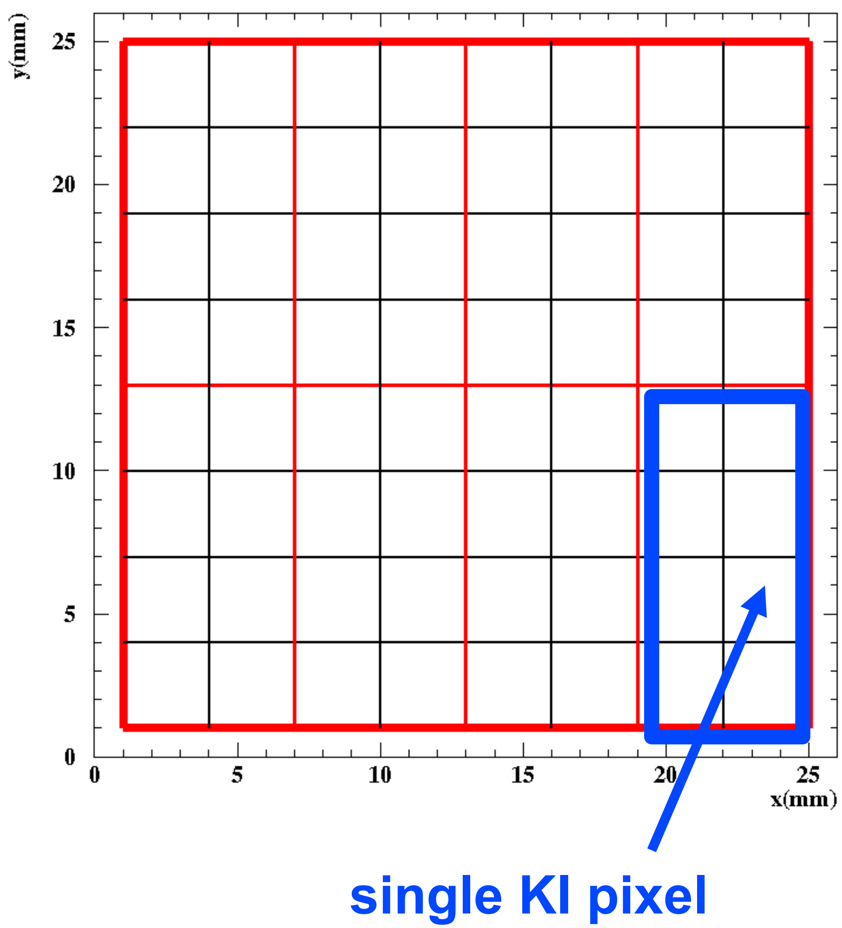
But we can use it to investigate other atmospheric phenomena like meteors!



Objectives

- Definition of the thresholds for the first level trigger
- Simulation of the first level trigger algorithm
- Reconstruction of the events that had passed the first level trigger from the raw data.
- Adapt the second level trigger algorithm conceived for the EECR for the meteors.

Some definitions - KI



- JEM-EUSO works in single-photon counting mode for the EECR detection
- Meteors are brighter then EECR so we need to switch to analog mode for the meteor detection. In this way we can avoid the photons pile-up.
- JEM-EUSO primary analog unit is the KI, a front-end integrator. The KI sums the charge of a 2x4 pixels rectangle.

EECR GTU and memory usage for PDM

- EECR travels at luminal speed and the typical duration of the event can range from 50 μs to 200 μs. JEM-EUSO acquires the data every 2,5 μs for 128 GTU (Gate Time Unit) that means 320 μs.
- Suppose we use a single byte for every pixel.

ECCR ⟶ 128 GTU X 2304 Pixels ~ 300 KB

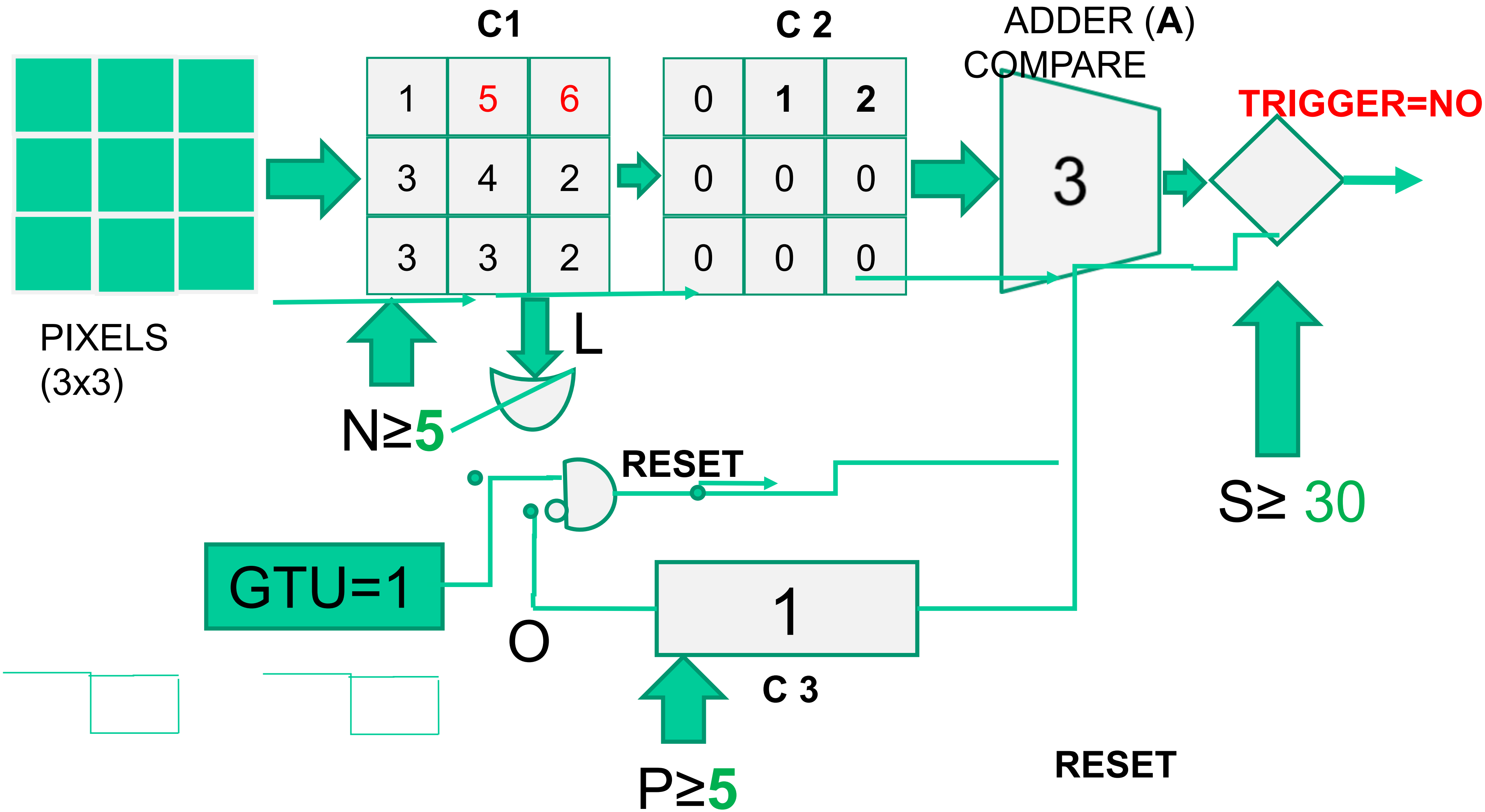
Meteors GTU and memory usage for PDM

- Meteors have a velocity that can range between 11 km/s and 72 km/s. The rate at which we collect data can therefore decrease.
- The simplest solution would be to acquire a GTU of 2,5 μs every 1024 GTU. So we would be acquiring a data every 2,56 ms
- For the meteors we need more GTU to follow the entire event, we can take 1024 GTU (one every 1024!) so we can follow an event for 2,62 s.

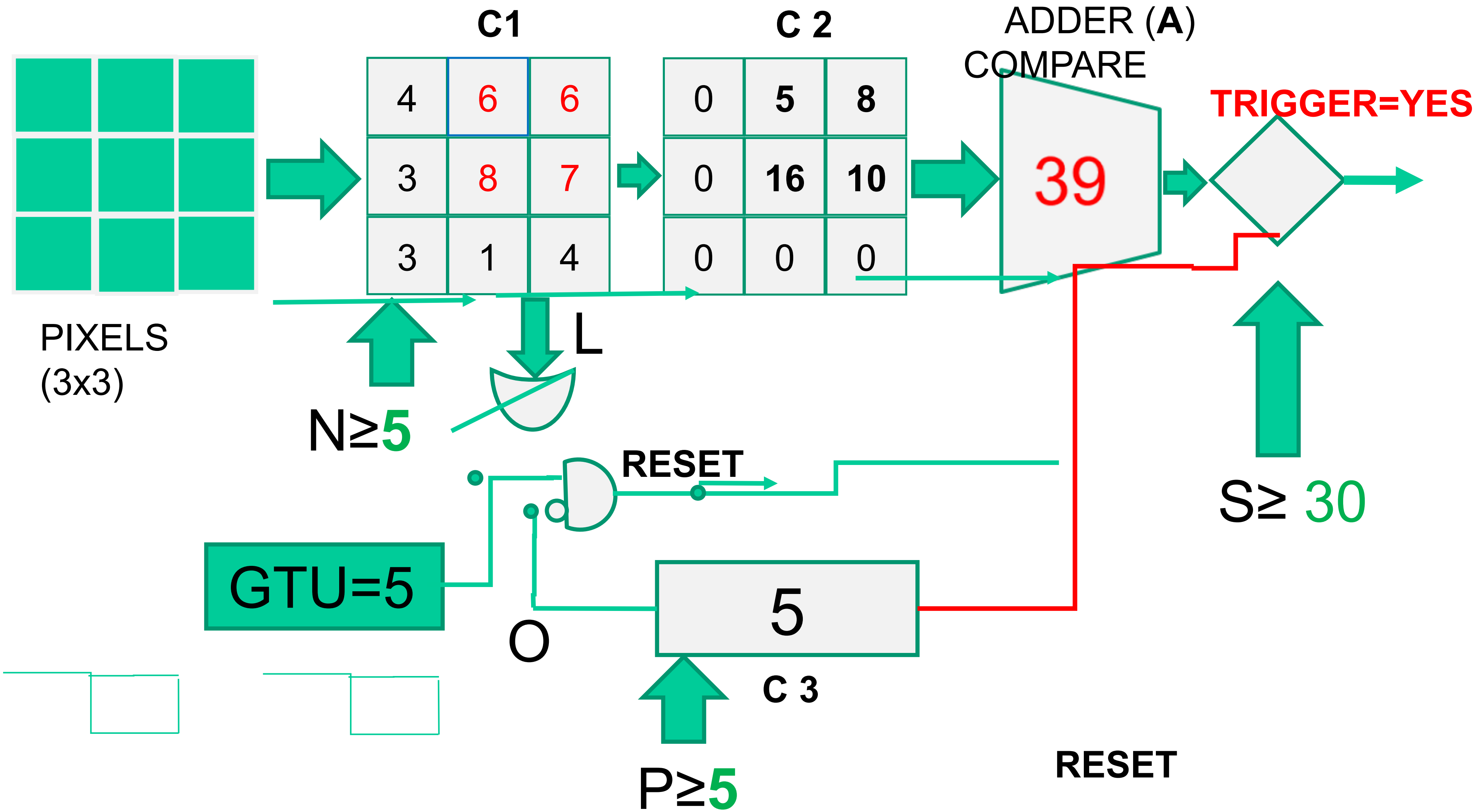
Meteor ⟶ 1024 GTU X 288 KI ~ 300 KB

PROGRESSIVE TRACK TRIGGER – PTT (1st LEVEL TRIGGER)

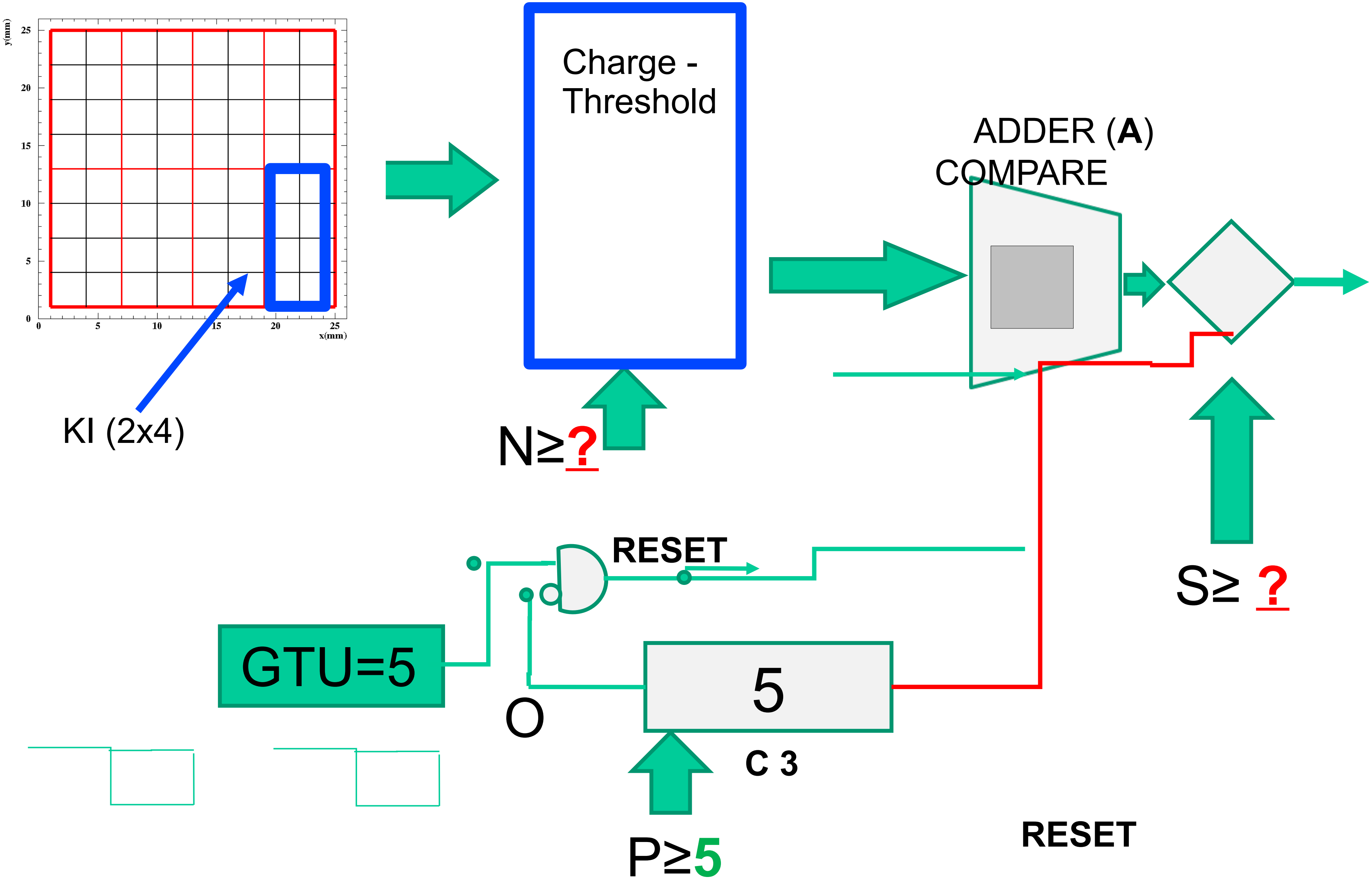
EXAMPLE: TRIGGER



PROGRESSIVE TRACK TRIGGER – PTT (1st LEVEL TRIGGER)

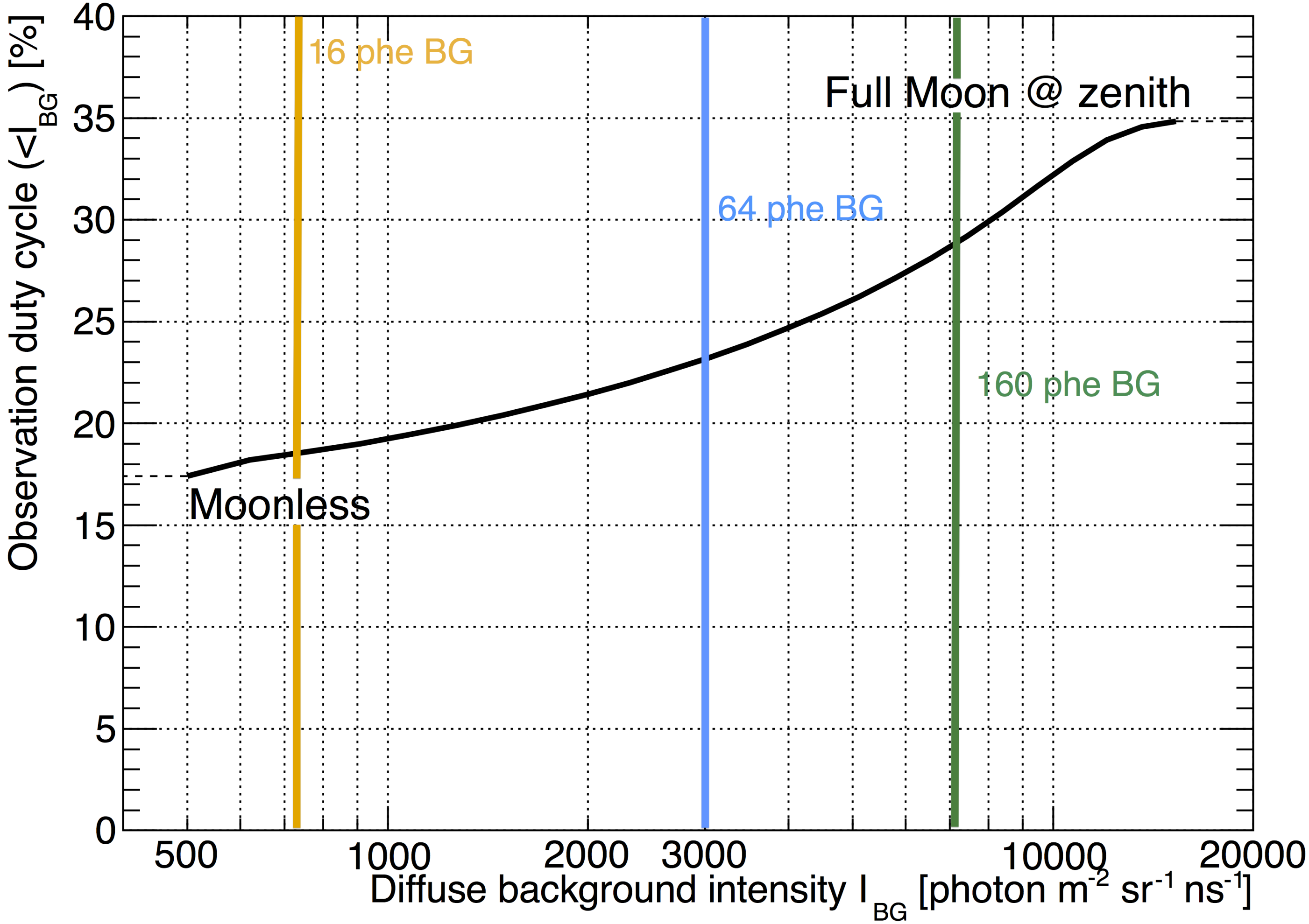


Meteors first level trigger

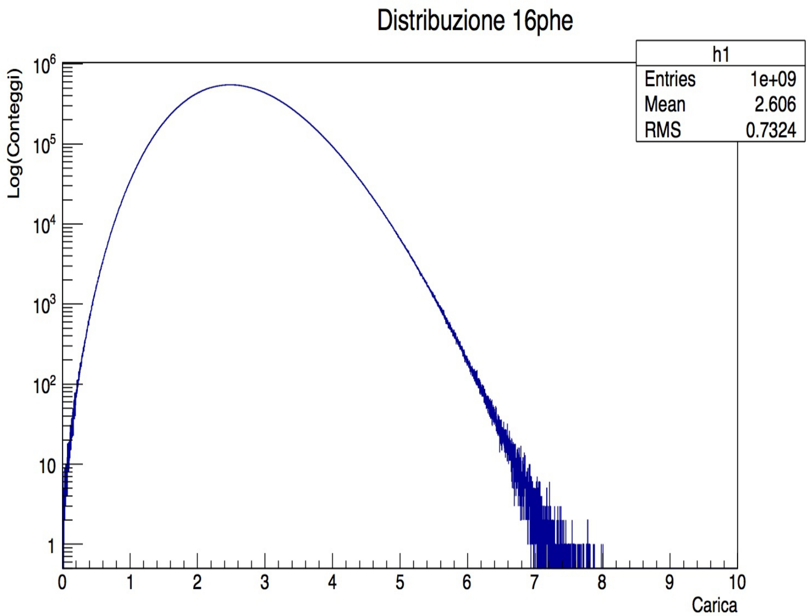


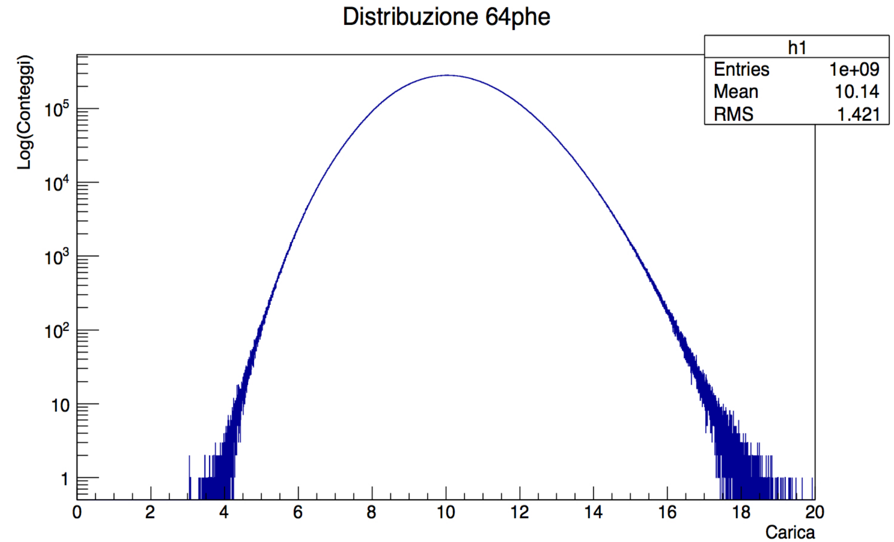
Duty cycle/Background for KI

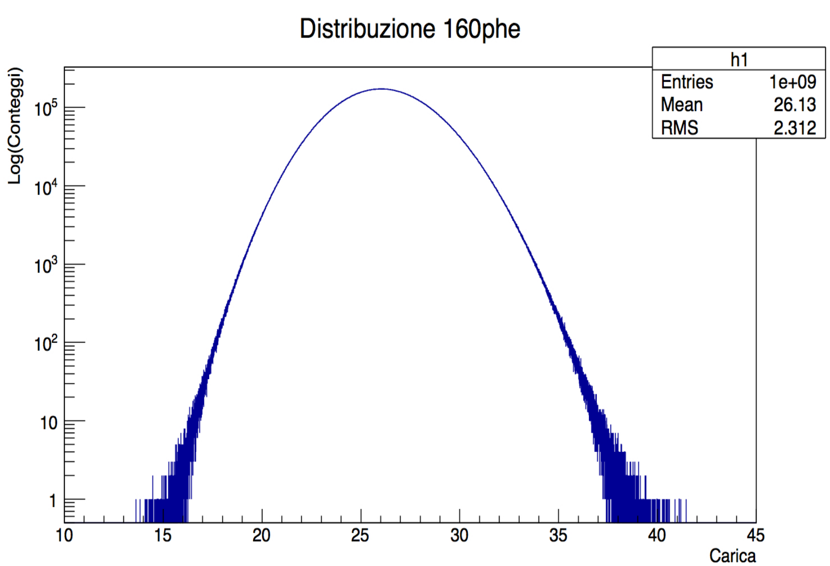
We have assumed a Background standard (on the ocean in a new moon night) of 16 phe for KI



N: KI Threshold







We have simulated 10^9 GTU that correspond to:

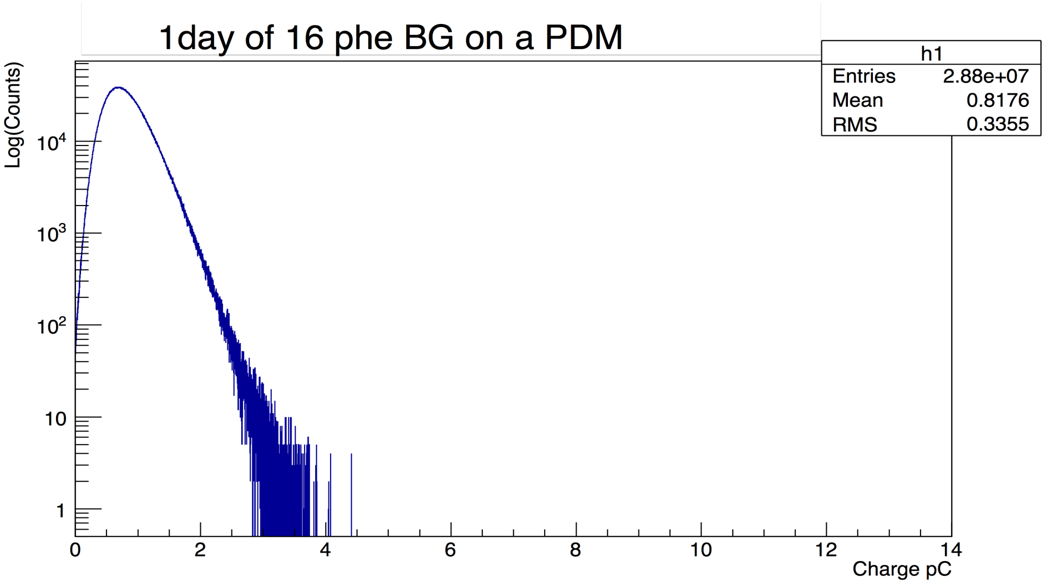
- 2,56x10^6 s (~ 30 days) on a single pixel
- 8888 s on a PDM
- 65 s on the entire focal surface

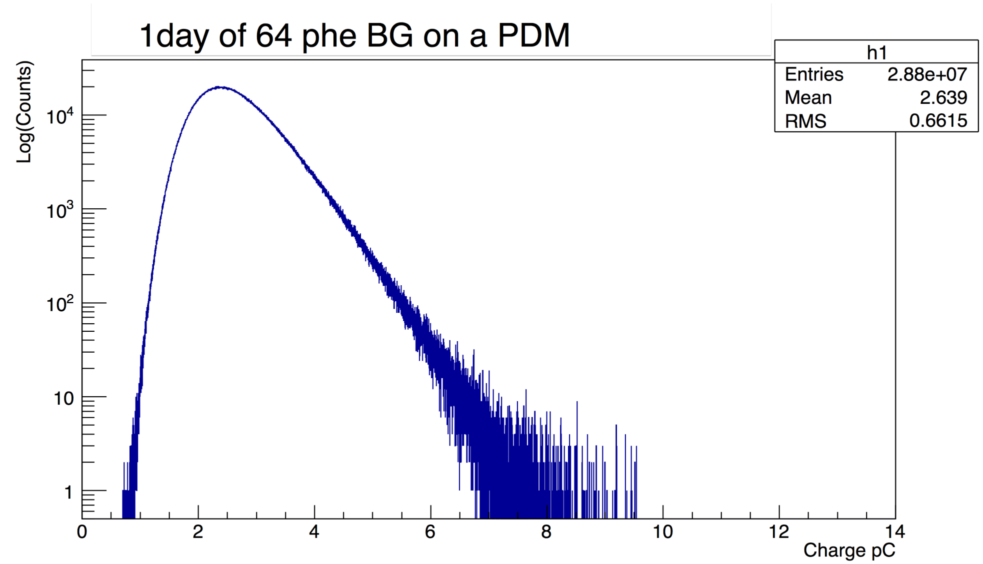
we have chose as threshold the value for which we had 99% of GTU in the left tail.

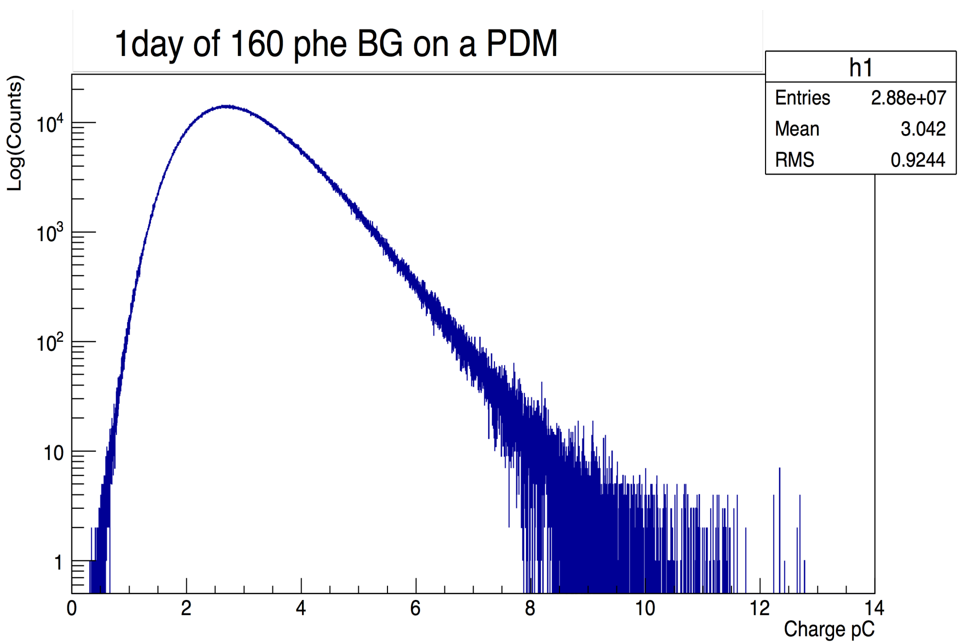
Threshold for different background:

- 16 phe → 4.48 pC
- 64 phe → 13.61 pC
- 160 phe → 31.67 pC

S: Adder Threshold





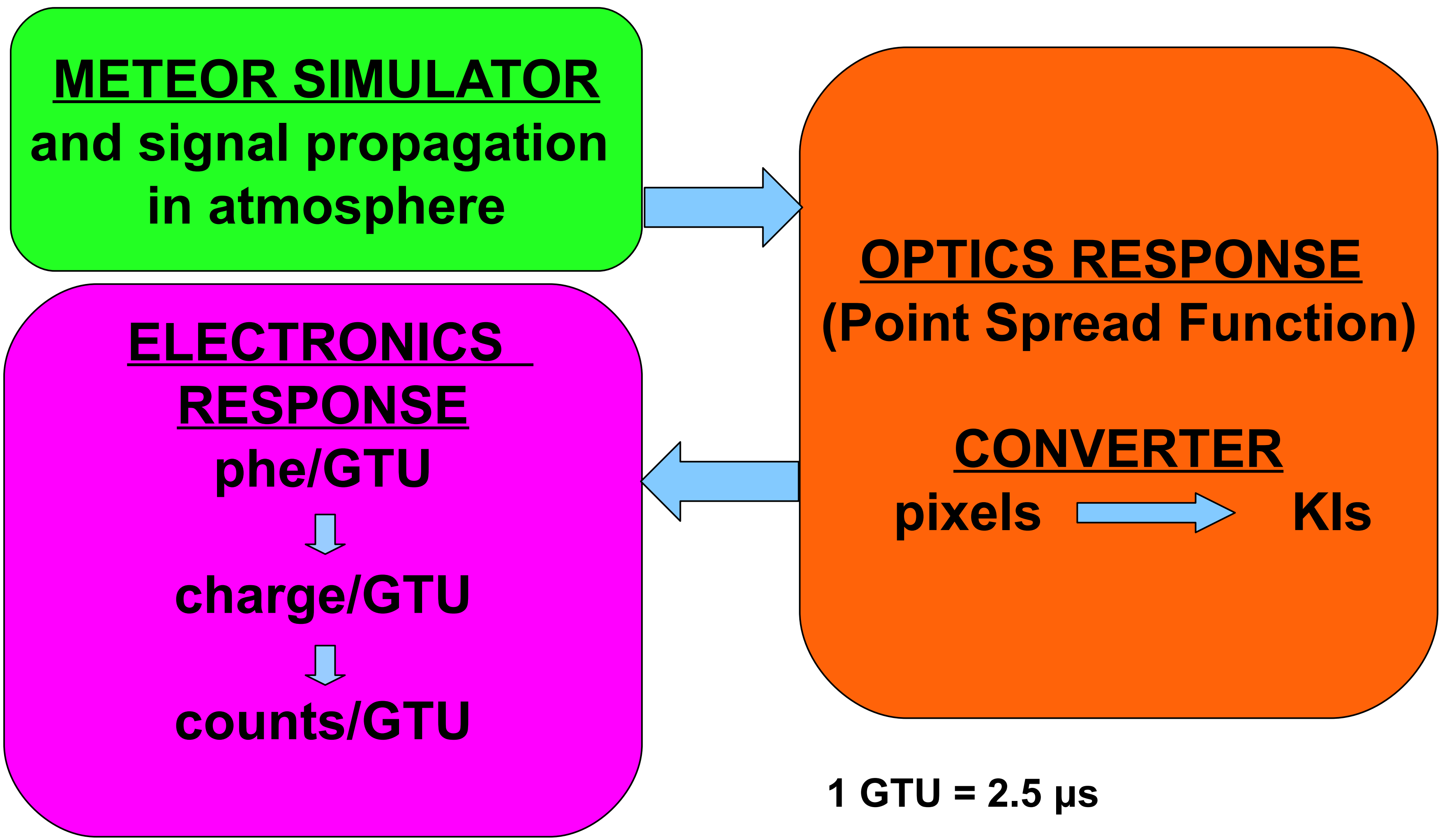


We have simulated a day of background and on that we have ran the first level trigger algorithm. For every sum of 5 GTU we have took the KI on which the signal was stronger. In this way we have a distribution and we can decide how many fake events we want to take

We've choose:

- 16 phe → 5 pC
- 64 phe → 9 pC
- 160 phe → 12 pC

From meteor simulation to the recorded signal

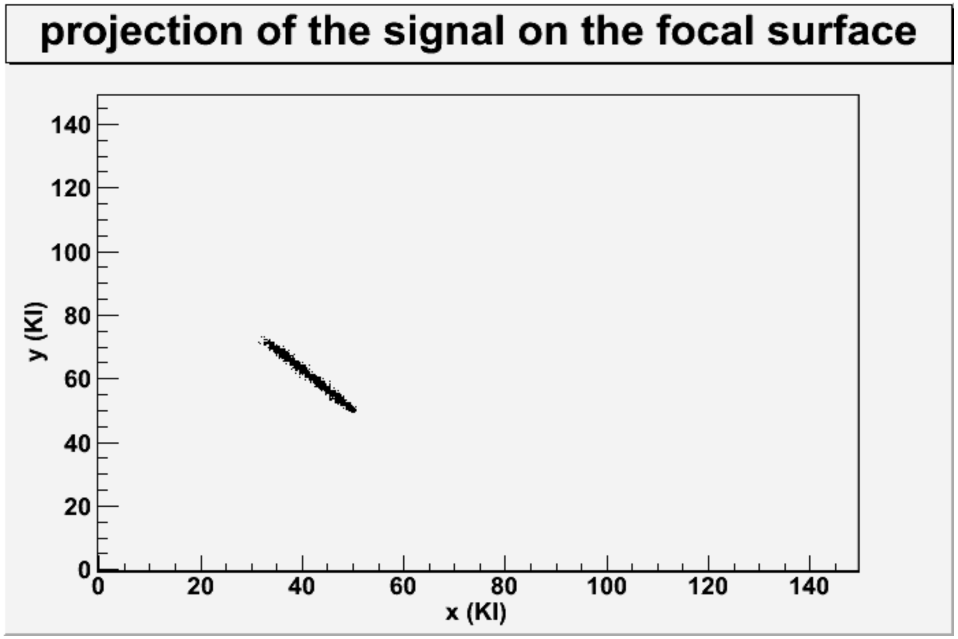


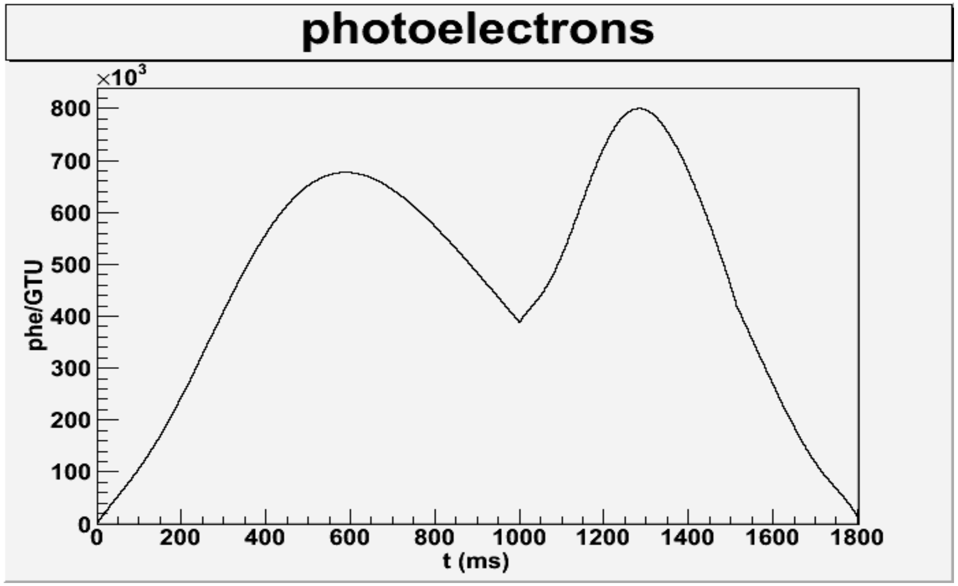
COMPLETE METEOR PROFILE

$v_x = v_z = 0$ km/s

$v_y = 20$ km/s

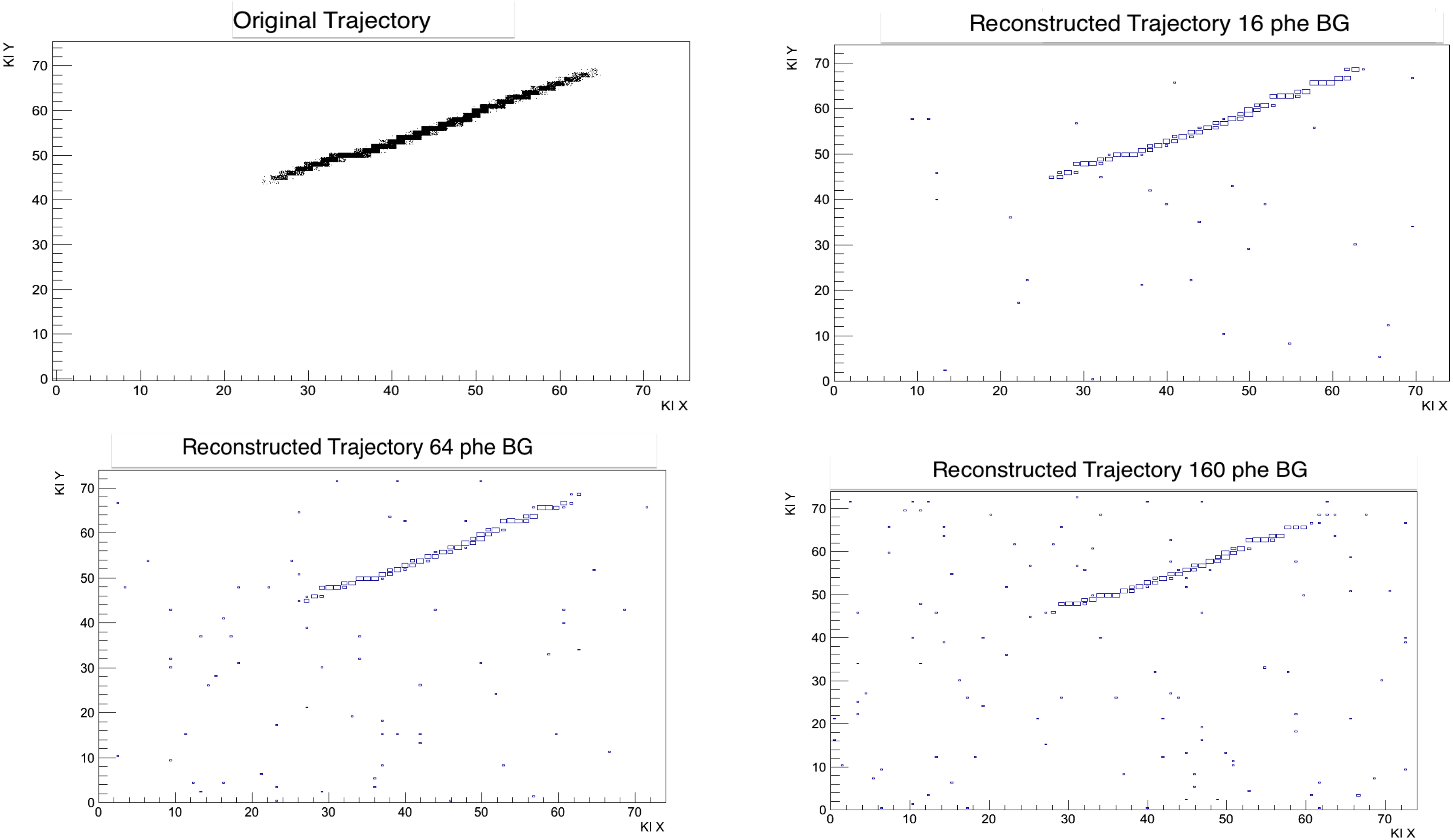
M = -5



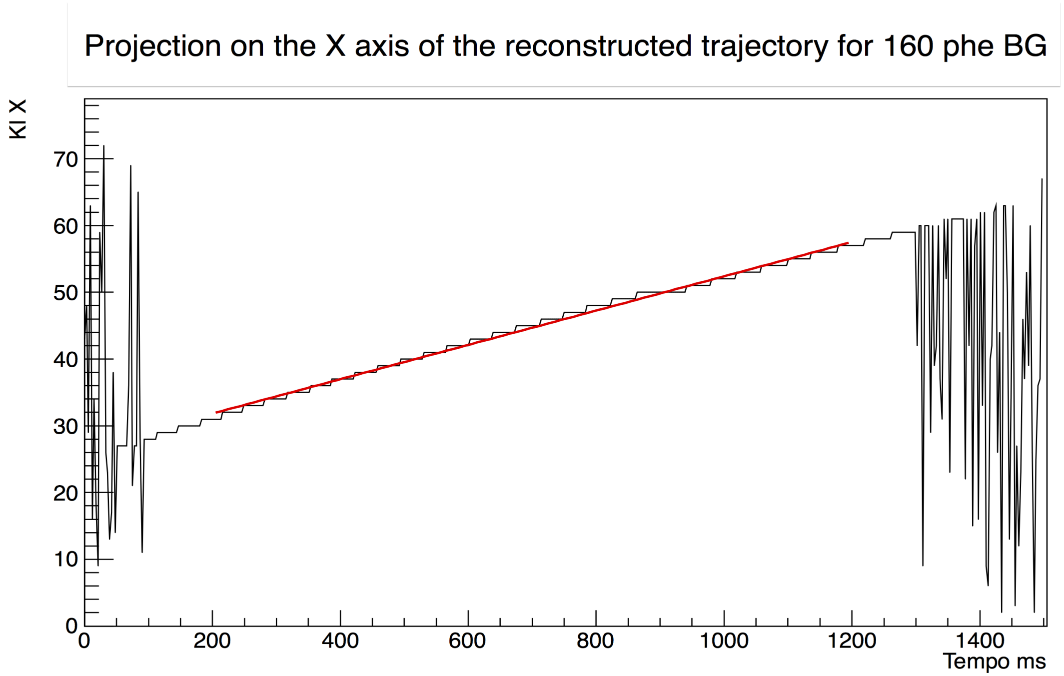


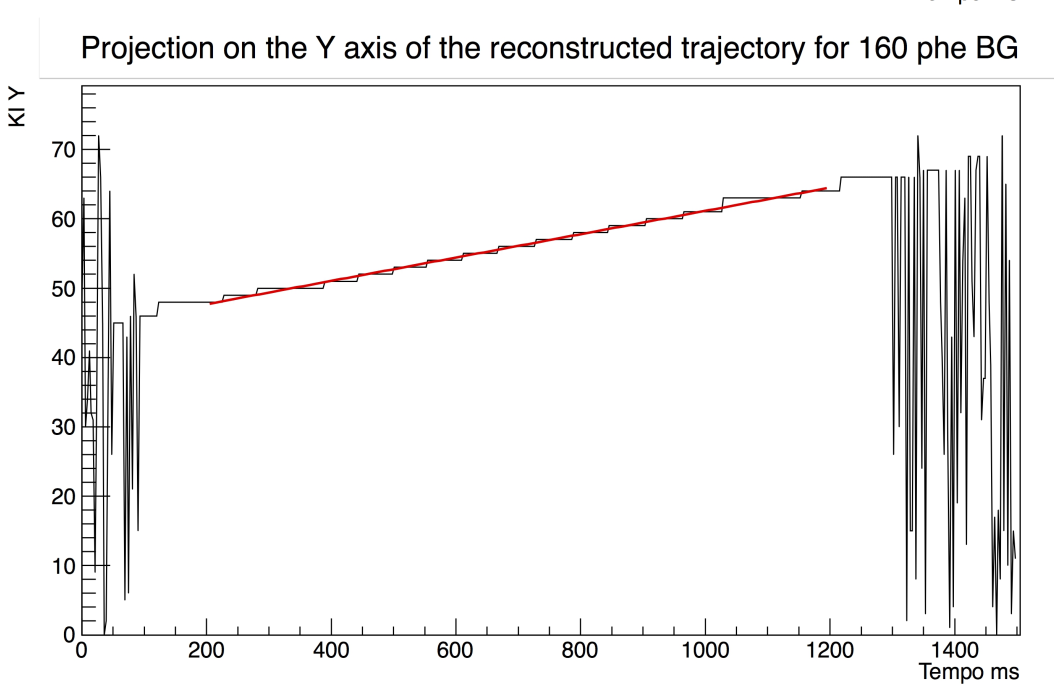
1 GTU = 2.5 μs

Reconstruction from the data
M=3 - Trajectory



Reconstruction of the light profile

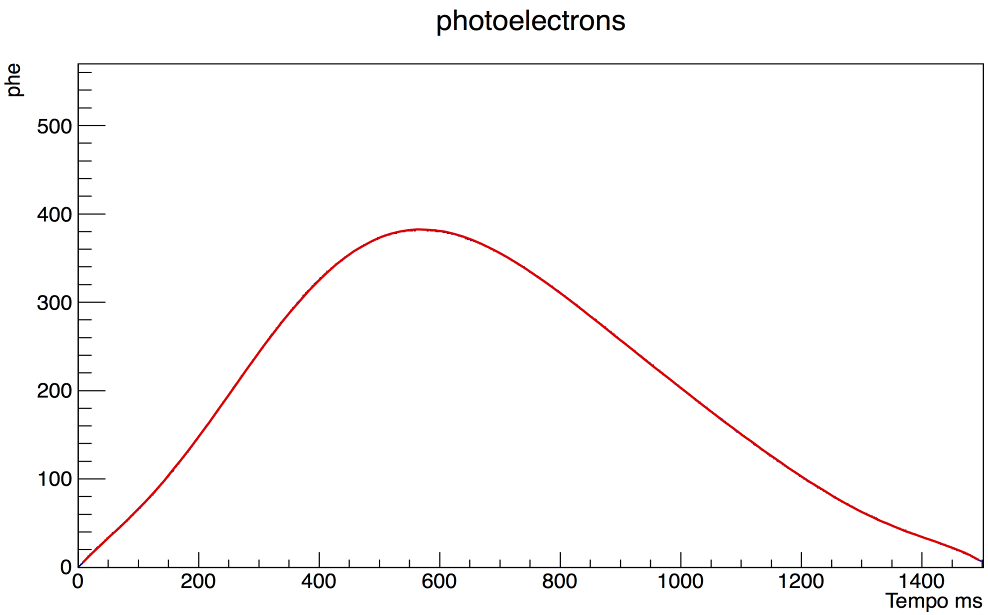


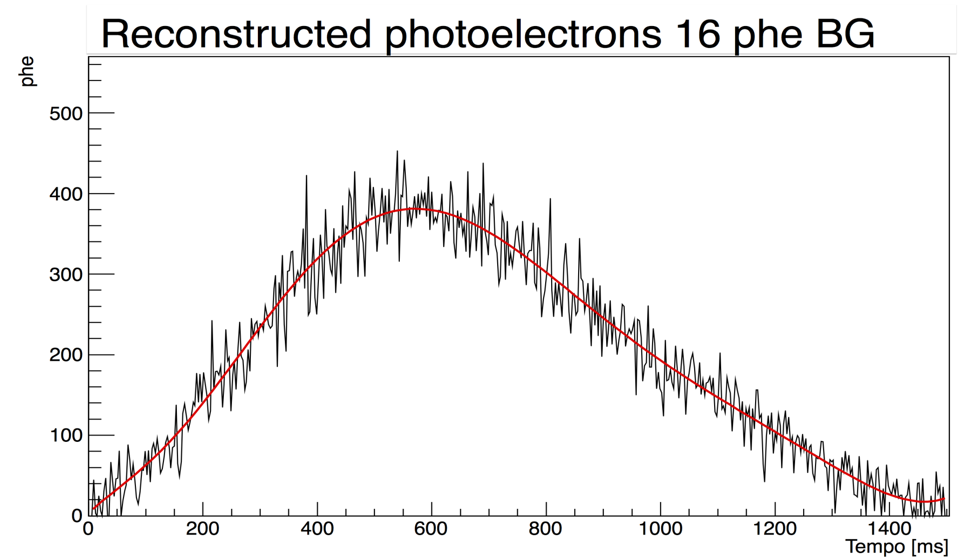


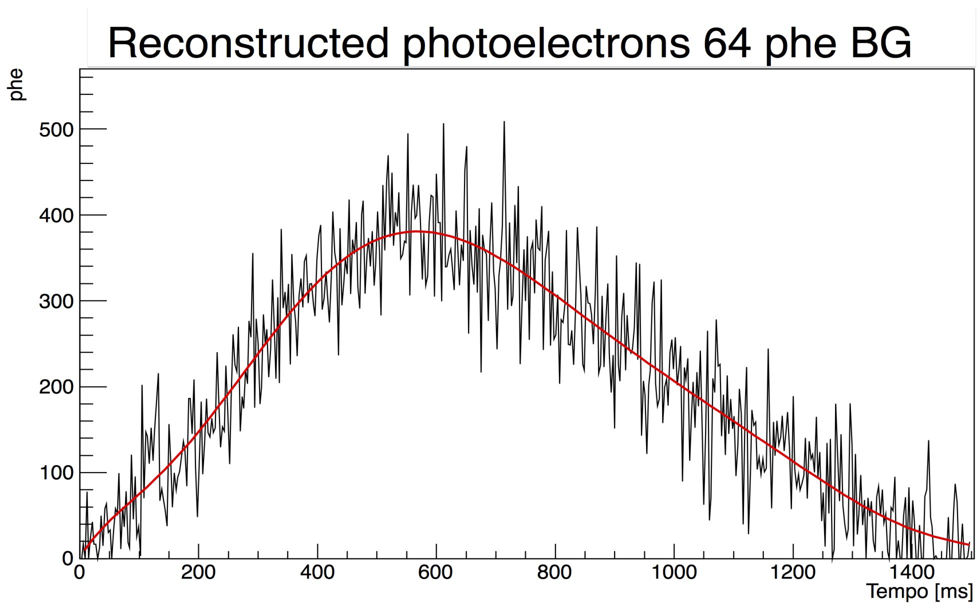
We have decomposed the meteor reconstructed trajectory in two graph representing x(t) and y(t). In the zone of the graphs in which we could recognize a linear shape we've done a linear fit and we've obtained a $f_x(t)$ and a $f_y(t)$. Then we have found for the entire duration of the event the points $(x,y)=(f_x(t),f_y(t))$.

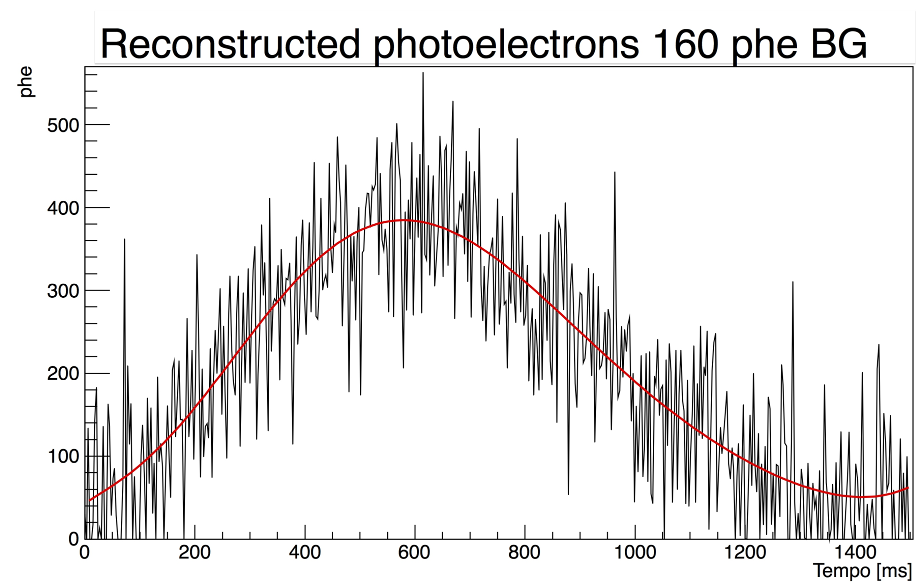
We have centered a box of 5x5 KI in this points and we have summed the charge in it for every GTU.

Reconstruction from the data
M=3 – Light Profile

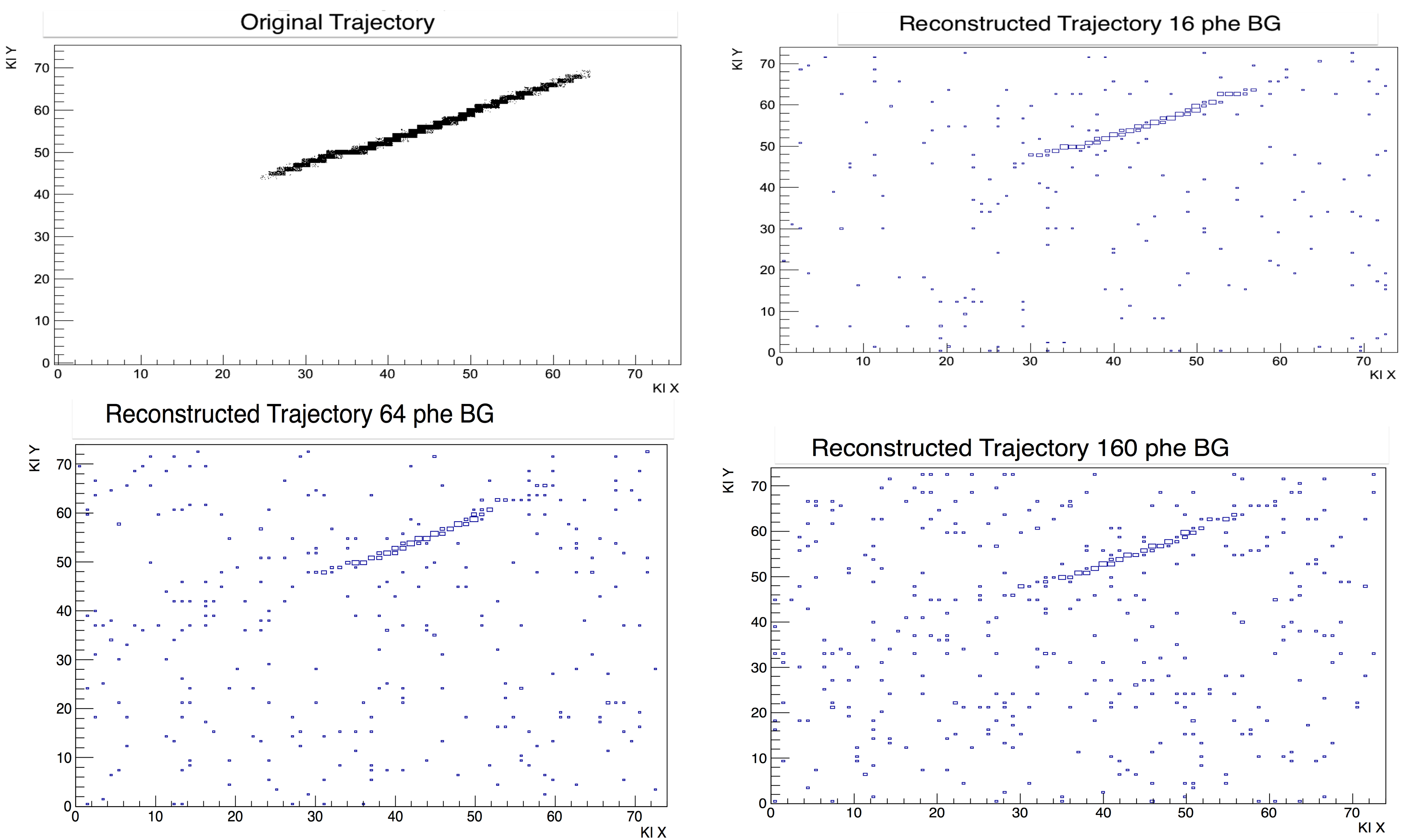




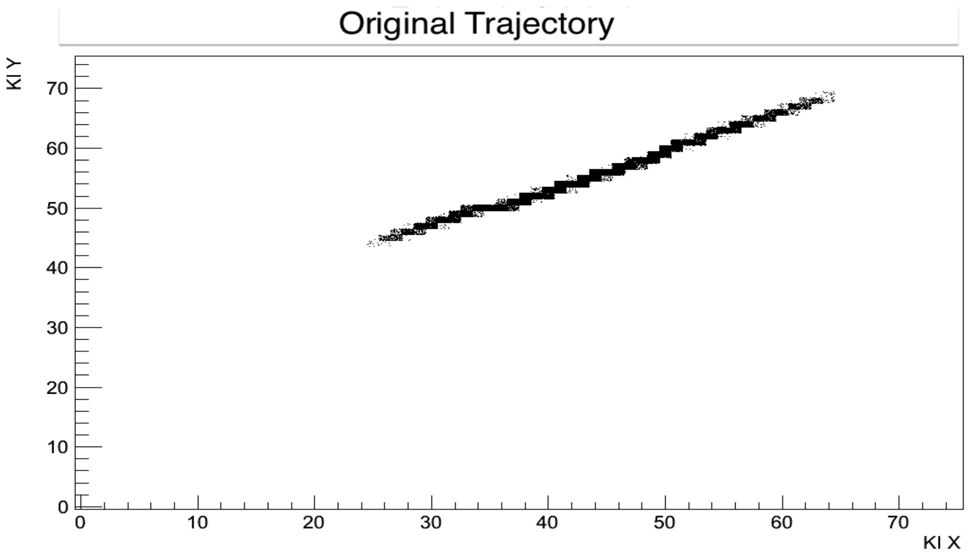


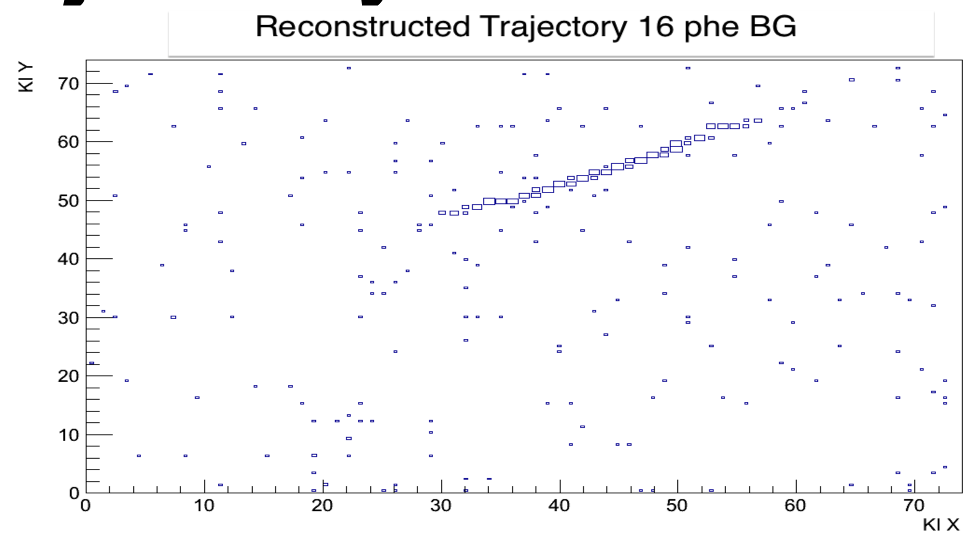


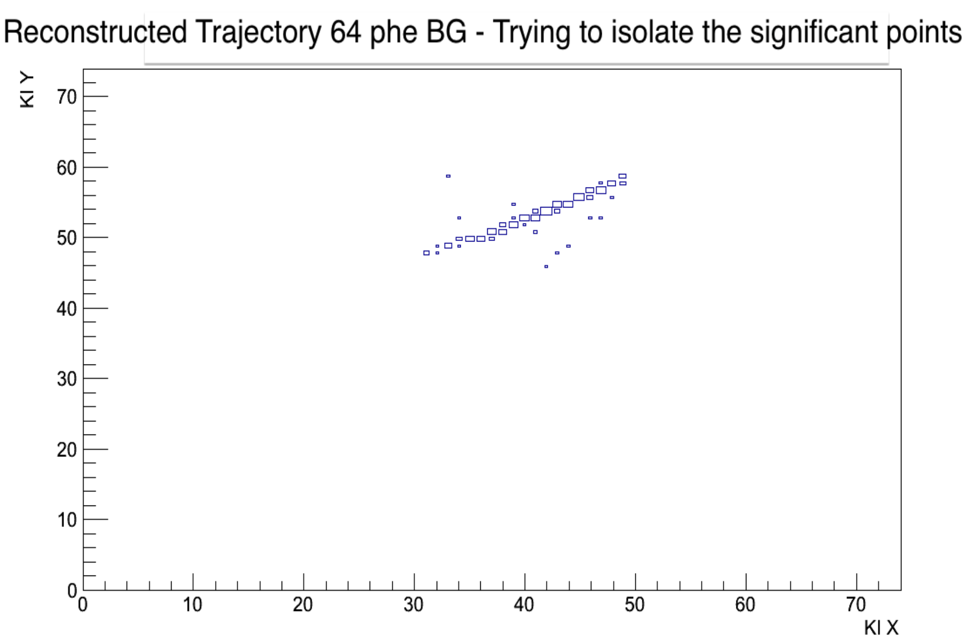
Reconstruction from the data
M=5 - Trajectory

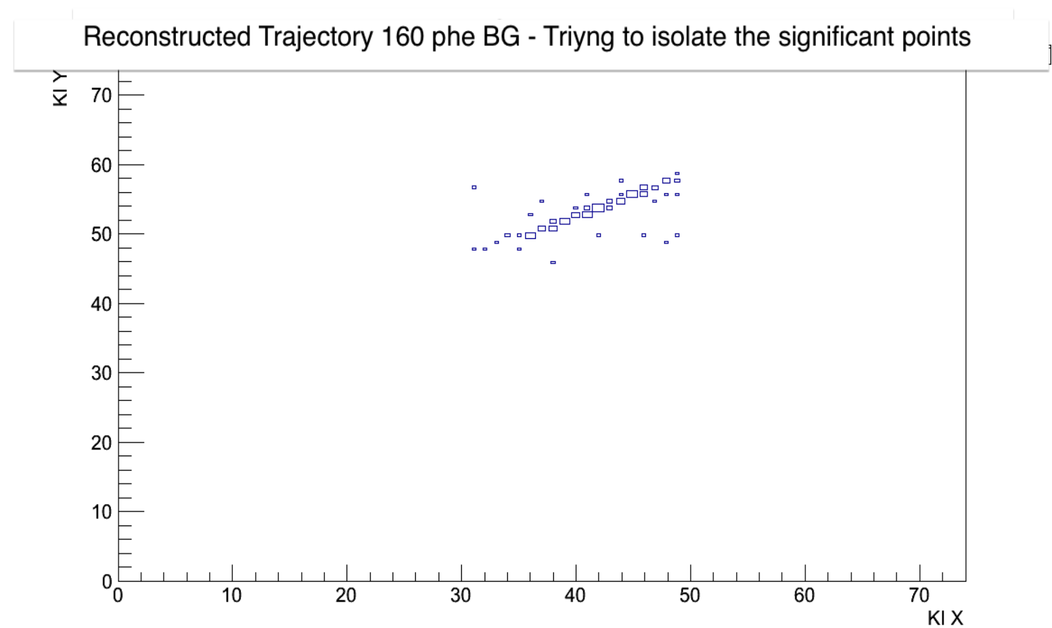


Reconstruction from the data
M=5 - Trajectory

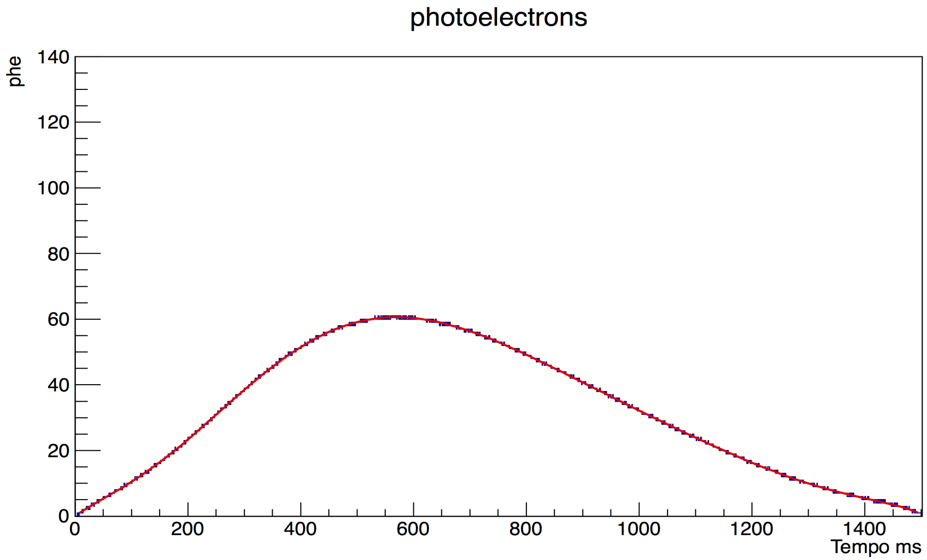


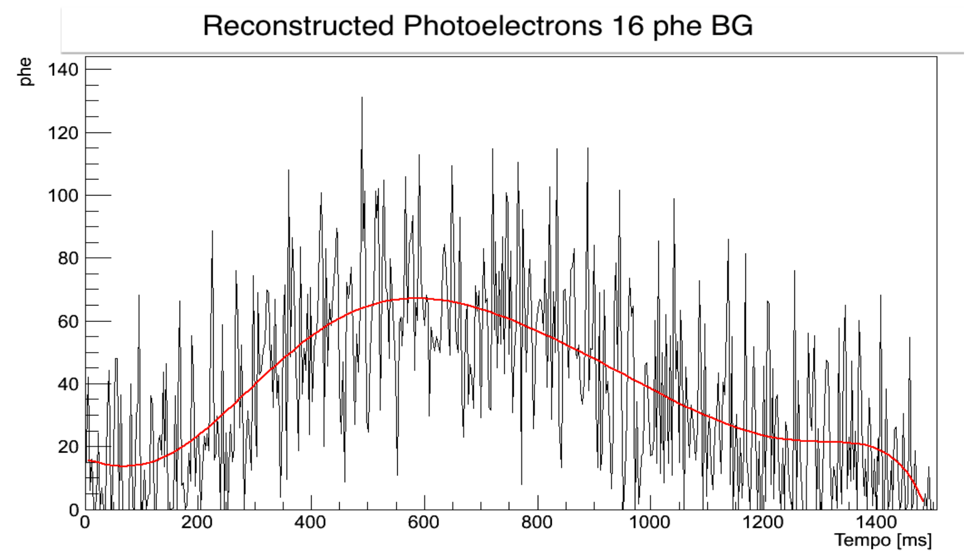


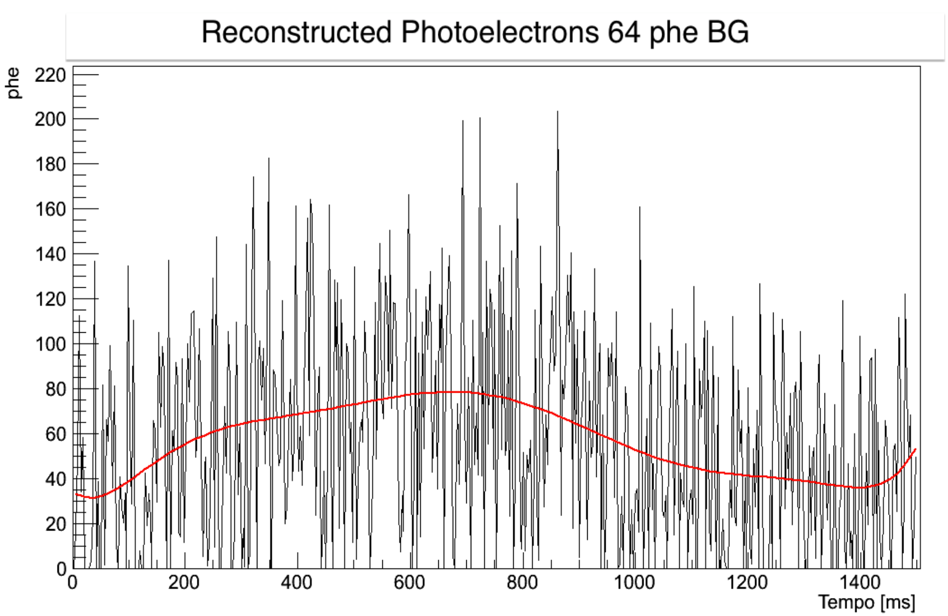


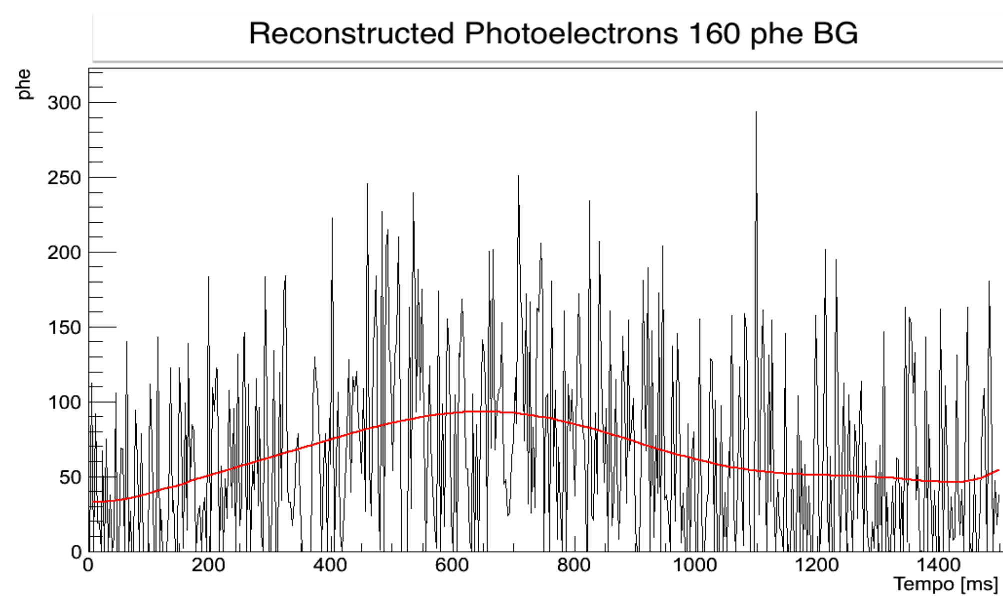


Reconstruction from the data M=5 – Light Profile









Reconstruction

To evaluate the quality of our reconstructions we have calculated:

- The percentual delta between the integral of the original light curve and the reconstructed one as:

$$\Delta I = \frac{(ReconstructedIntegral - OriginalIntegral)}{OriginalIntegral} * 100$$

- The percentual delta between the maximum of the original light curve and the reconstructed one as:

$$\Delta M = \frac{(ReconstructedMaximum - OriginalMaximum)}{OriginalMaximum} * 100$$

Background	Magnitude	Delta % integral	Delta % maximum
16 phe BG	0	-0,20	-0,01
16 phe BG	1	-0,13	-0,39
16 phe BG	2	-1,61	-1,14
16 phe BG	3	-5,72	-3,47
16 phe BG	4	-0,12	-2,19
16 phe BG	5	19,54	10,72
16 phe BG	6	-0,32	-13,61
64 phe BG	0	0,73	0,33
64 phe BG	1	-0,20	-0,39
64 phe BG	2	3,91	1,70
64 phe BG	3	0,73	-0,45
64 phe BG	4	11,35	4,99
64 phe BG	5	-9,75	-34,08
160 phe BG	0	-1,06	-0,81
160 phe BG	1	-7,46	-3,89
160 phe BG	2	5,76	3,21
160 phe BG	3	1,94	0,54
160 phe BG	4	116,52	56,54
160 phe BG	5	99,72	53,93

Second level trigger

- The second level trigger checks if the signal movement is a straight line on the focal surface and determines in which direction the signal is moving.
- For EECR we know the velocity vector magnitude, so set a zenith and azimuth angle we can retrieve all the velocity vector components.

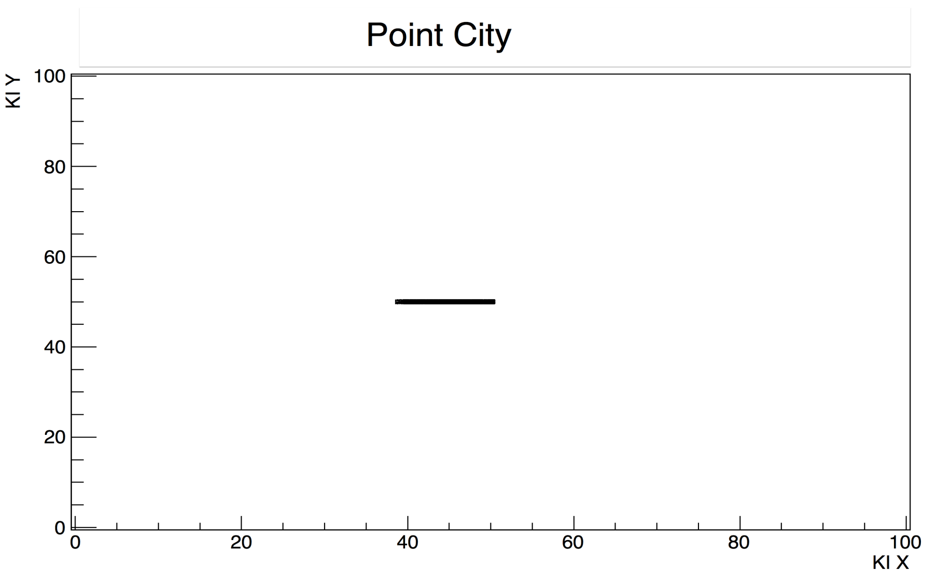
Second level trigger

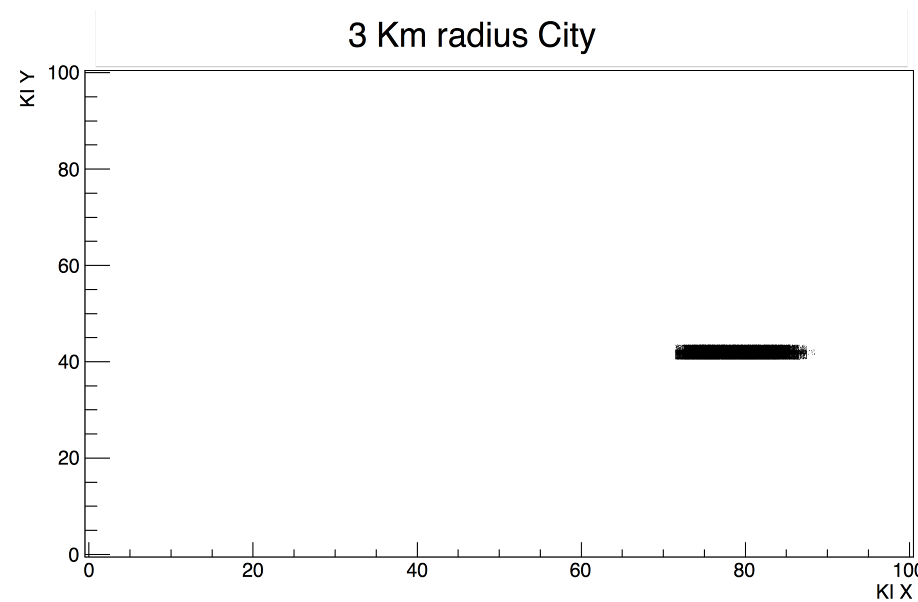
- For meteors we don't know the velocity vector magnitude, so meteor with different speed and different zenith angle may appear the same on the focal surface.
- This will be a issue in the reconstruction of the event.
- For the moment we're only interest in finding a way to discriminate meteors from cities.

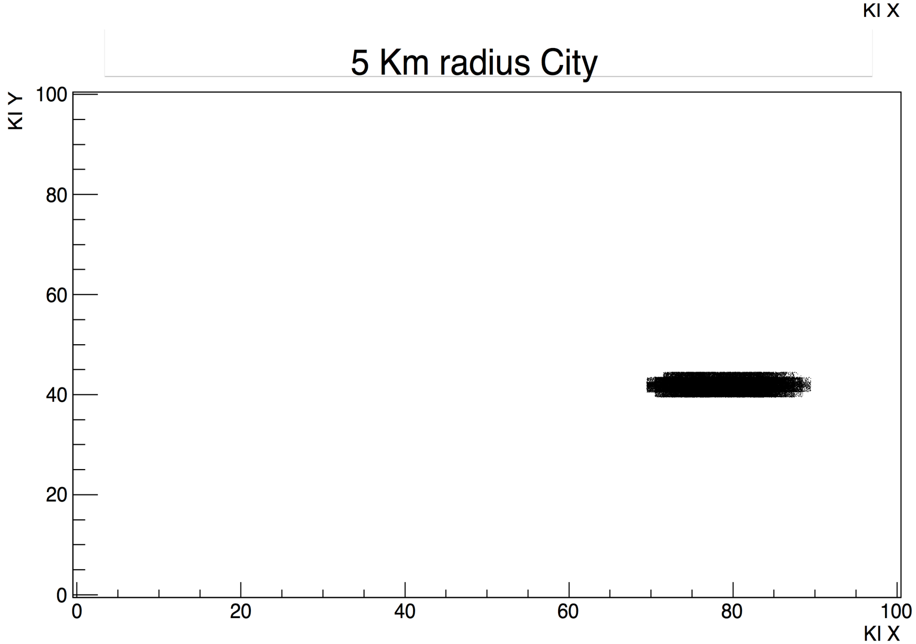
Meteor (M = 3) and the response of the second level trigger

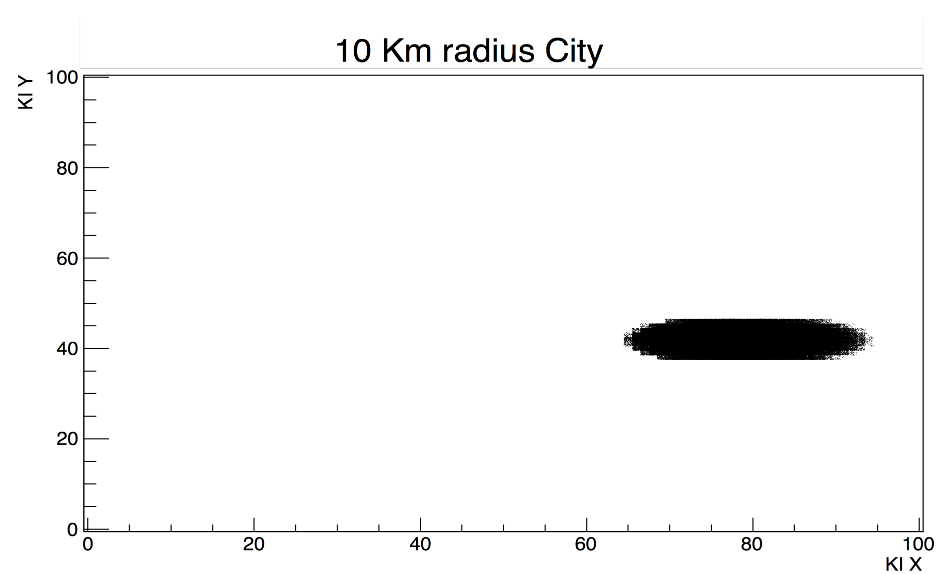
Velocity [Km/s]	V on focal surface [Km/s]	V on FS detected [Km/s]	Azimuth angle [Degree]	Azimuth angle detected [d]
10	2	4	0	245
10	14	18	120	135
10	14	19	240	215
20	13	16	20	35
20	26	30	140	145
20	21	22	260	245
30	24	34	40	55
30	37	45	160	175
30	29	34	280	265
40	36	43	60	75
40	48	62	180	185
40	36	50	300	285
50	49	66	80	85
50	57	70	200	205
50	44	52	320	315
60	61	-	100	-
60	66	69	220	225
60	53	54	340	345

Cities on the focal surface









Magnitude	Radius [Km]	V on FS Detected [Km/s]	Azimuth angle detected [d]
3.5	0	7	145
3.5	3	7	145
3.5	5	8	195
3.5	10	12	215
4	0	9	205
4	3	8	195
4	5	6	125
4	10	8	235
4.5	0	6	175
4.5	3	5	175
4.5	5	9	205
4.5	10	3	315
5	0	7	175
5	3	9	155
5	5	9	195
5	10	5	175

ASSUMPTIONS (INPUT PARAMETERS)

CITY = METEOR with:

- Beginning height = 0 km
- Constant light curve
- Circular shape
- $v_x = v_y = v_z = 0$ km/s

We can see that we obtain a magnitude for the velocity vector <13

- We can therefore put a threshold in velocity and take only the event with, for exemple, $|v|>15$

Conclusions

- We can adapt the first level trigger to meteors detection using KI and changing the rate at which we acquire data
- We can detect and reconstruct event up to:
  - *M = 3 for a 160 phe background*
  - *M = 4 for a 64 phe background*
  - *M = 5 for a 16 phe background*
- We have found a way to discriminate cities from meteors.

Photo: ESA