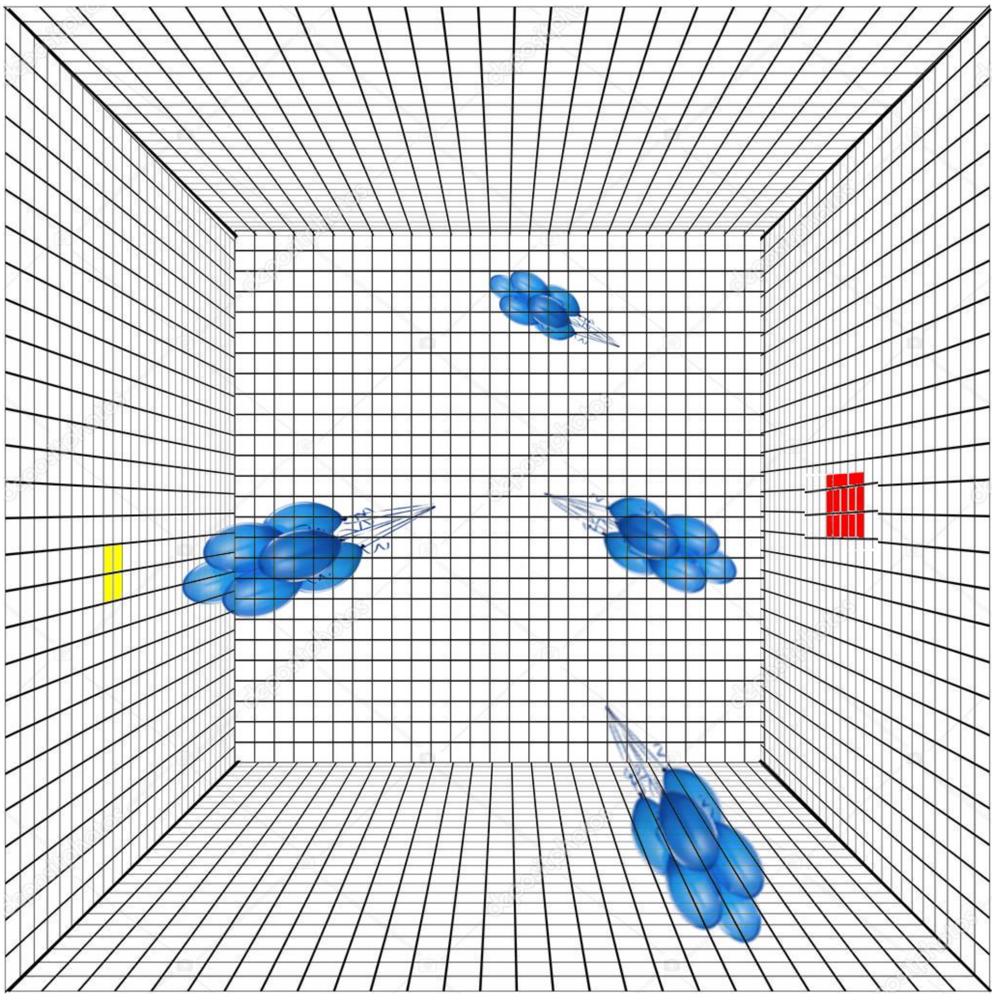
Liceo Scientifico Statale "T.C.Onesti", Fermo, Italy

Team TCO-ASA



A blue light in the darkness

Motivations of the new TEAM

In BL4S 2016 the proposal of our school received the status of highly commended, which really intrigued us. The basic idea is to achieve an authentic detector by using some simple instruments. We wanted to study the Cherenkov's effect that is a radiation emitted when a charged particle passes through a dielectric medium at a speed greater than the phase velocity of light in that medium.
Our senior schoolmates talked us when they tested the box at the BTF section of the INFN in Frascati. They lived an amazing experience even if the beamline was unfortunately available for a very short time and it was impossible to conclude the whole experiment.
Our friends encouraged us to improve our instrument and to try again the CERN competition.

Starting point

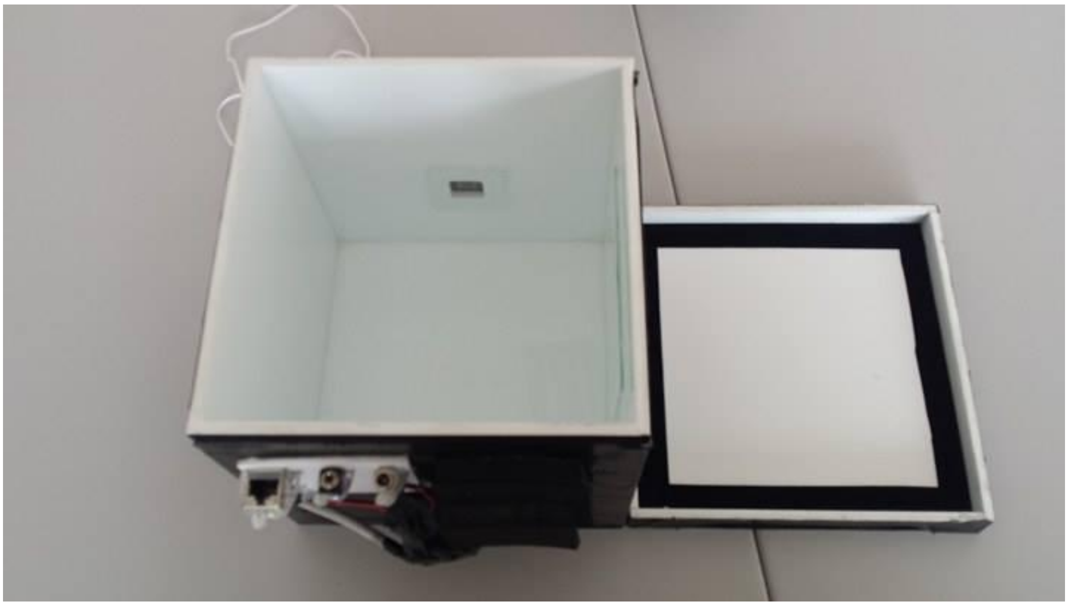
- After some trials based on a Reflex camera, last year, our senior schoolmates made a box with a CMOS sensor on the top: unfortunately only a small part of the particles succeeded to reach the sensor due to the total refraction between the air and water.
- Last year we estimated that the radioactive power of the school (^{226} Ra, 15 μCi), should produce 10^8 photons/sec for the Cherenkov's effect about 100 photons/pixel, very near to the background noise at the ambient temperature.
- The heating of the sensor causes an increasing of the noise which should be opportunely measured.

New Detector

- **Box:**

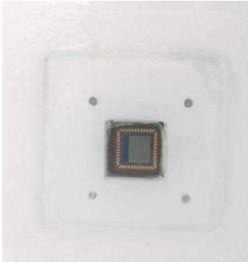
  We made a new box 20 x 20 x 20 cm. Its inside is completely covered by polymethyl methacrylate.

  According to our tutors' suggestions, we decided to make a box with spreading sides instead of covered of mirrors, as in the first experiment, in order to support the uniform distribution of the light. The box is still filled by distilled water. The radioactive source was placed in the center inside a transparent plastic box.

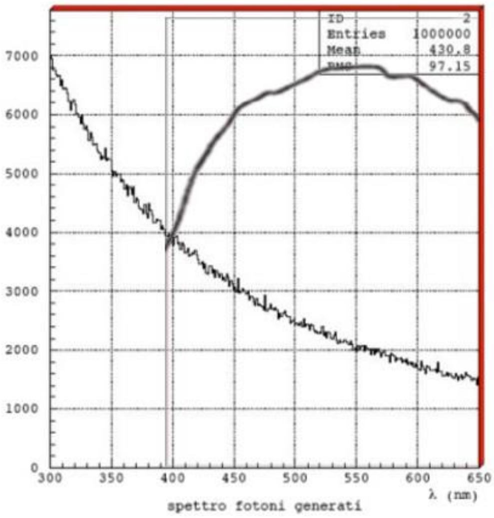


• Sensor n.1: **CMOS**

Camera with a **monochrome** sensor by 1.3 Megapixel resolution (1280 x1024 pixels). It is also provided by thermic sensor. Sensor size 1/2".

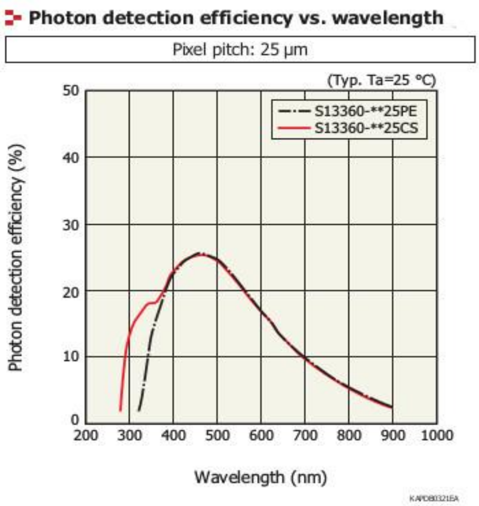


Emission Cherenkov photons and spectrum sensibility of CMOS



• Sensor n.2: **Silicon Photo Multiplier,** Project ArduSIPM – INFN

MPPC for precision measurement, photosensitive area 1.3 x 1.3 mm



In the box every sensor is protected by transparent glass and using polyethylene and silicone oil to improve the optical continuity in the refraction index up to the CMOS sensor.

Radioactive Sources

In our experiment we worked together with a local company producing radionuclides for healthcare. So we can test the equipment both with ^{226}Ra, property of school, and ^{18}F-FDG, property of the company.

Source ^{226}Ra:

Decay: α, β, γ
Activity: $15\ \mu\mathrm{Ci}$

Estimate of the number of photon produced by the Cherenkov effect:

$$\mathrm{N_{photons}} \sim \mathbf{4\ \cdot 10^{8}\ \ photons/s}$$

Source ^{18}F-FDG

Decay: β^{+}
Activity: $15\ \mu\mathrm{Ci} :: 670\ \mu\mathrm{Ci}$

In the dominant mode of ^{18}F-FDG decay, the nucleus emits a high-energy positron with energy of up to 0.635 MeV. They travel **0.5 mm** on average before they annihilate emitting gamma photons.
The evaluated maximum number of photons emitted by our radioactive sources is

$$\mathrm{N_{photons}} = 12.5 \times 670 \times 37 \cdot 10^{3} \sim \mathbf{3\ \cdot 10^{8}\ \ photons/s}$$

Obviously, the real number of photons, which may be detected by the sensors, must be lowered again because all transparent plastic boxes containing the sources, weaken the radiation themselves.

Experimental reaserch

During our tests we realised the pictures taken by the digital camera, depended a lot by the distance between the radioactive source and camera itself. We suppose that Gamma or X rays hit the sensor when this are very near but they don’t reach the camera when this is placed far from the source.

Since our goal was to measure the Cherenkov’s effect, we thought to compare two kinds of pictures: the first were shooted with the shutter darkened by a black film. The second ones were taken with a not-darken shutter. This is beacause we can stop only the optical photons and not the Gamma and X rays. Actually we found a difference in luminosity between the two groups of pictures and the results are shown in appendix. The temperature was the same in both cases.

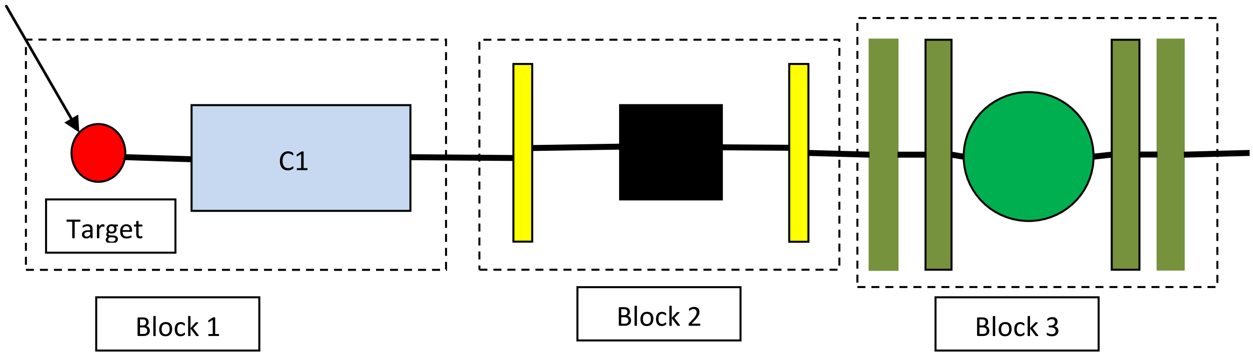
Instead the Sipm sensor seems to be indifferent to the distance with the radioactive source. Even if its operating range is very short, we measured some signals compatible with the activicty of the radioactive source and so they probably are due to the Cherenkov's effects.

New proposal

In the T9 line, we expect a burst with 10^6 particles every 15 seconds and each burst lasts approximately 0.4 s.

The energy of particles is above the Cherenkov threshold and it is from 0.5 GeV up to 10 GeV: they produce Cherenkov photons for the entire length of the radiator. Therefore we expect 10^6x 250 x 60 ~ **10^{10} photons/burst**.

Beamline scheme



Block 1:

Target:The proton beam from the PS hits the production target and generates the secondary particle beam

C1: The secondary beam goes throught the Cherenkov detector to discriminate between electrons (or positrons), pions and muons.

Block 2:

Our detector, coupled with two scintillators in input and output, will act as a trigger for the Sipm sensor. Probably it will not possible to exploit digital impulses as trigger for the camera but we will be able to automatize completely the process of data acquisition.

Block 3:

System to measure the particles momentum: two multi-wire proportional chambers (MWPC), a magnet and two other multi-wire proportional chambers.

Conclusions

This year we made a new box with new sensors and we started the tests on the Cherenkov's effect from the beginning. Our research gave us satisfying results with which we hope to win the BL4S 2017 competition. Our dream is to try our detector in the CERN laboratories with the support of the professional researchers.

We attend the third class and we do not know which choice of university we are going to do but we doing this work we realized that scientific research is curiosity, passion and beauty. As our comrades of last year's team, we will continue to publish our results and (hopefully) our trips to Geneva on **www.tco-beamline.com, to share them with the rest of the TCO students.**

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Davide Cartuccia
Luca Ciucci
Simone Giano
Letizia Manardi
Simone Pierantozzi
Marco Ricci
Alessandro Rongoni

Acknowledgement

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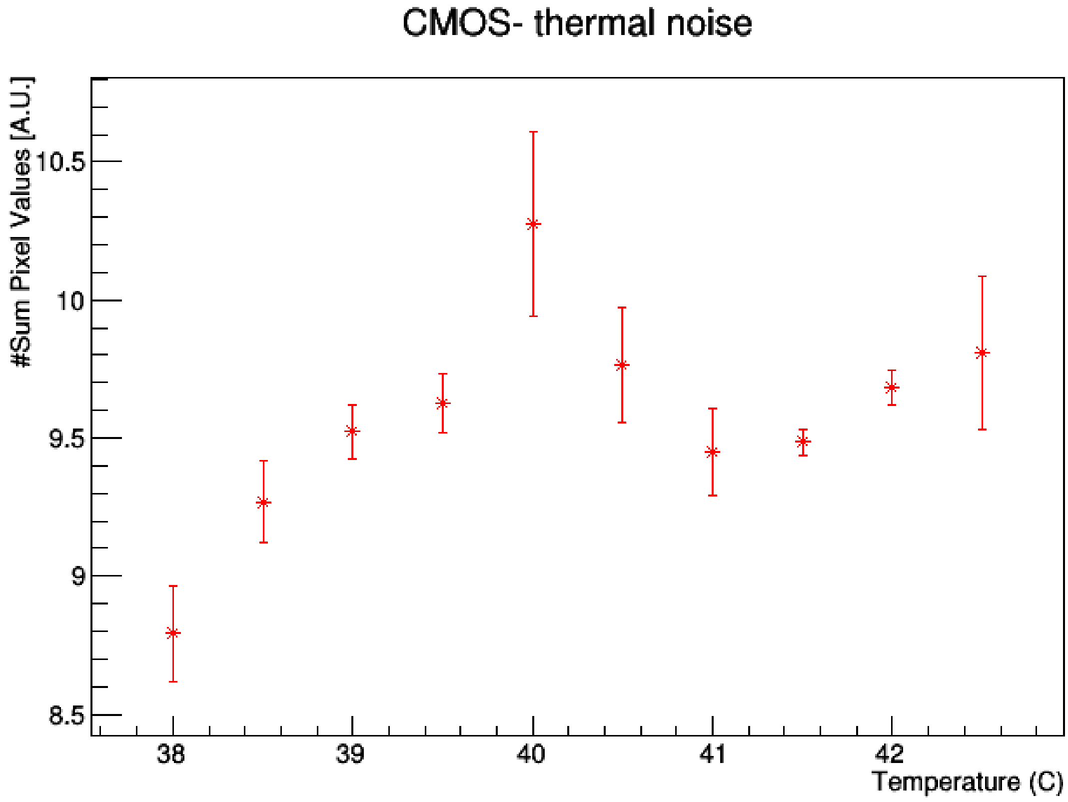
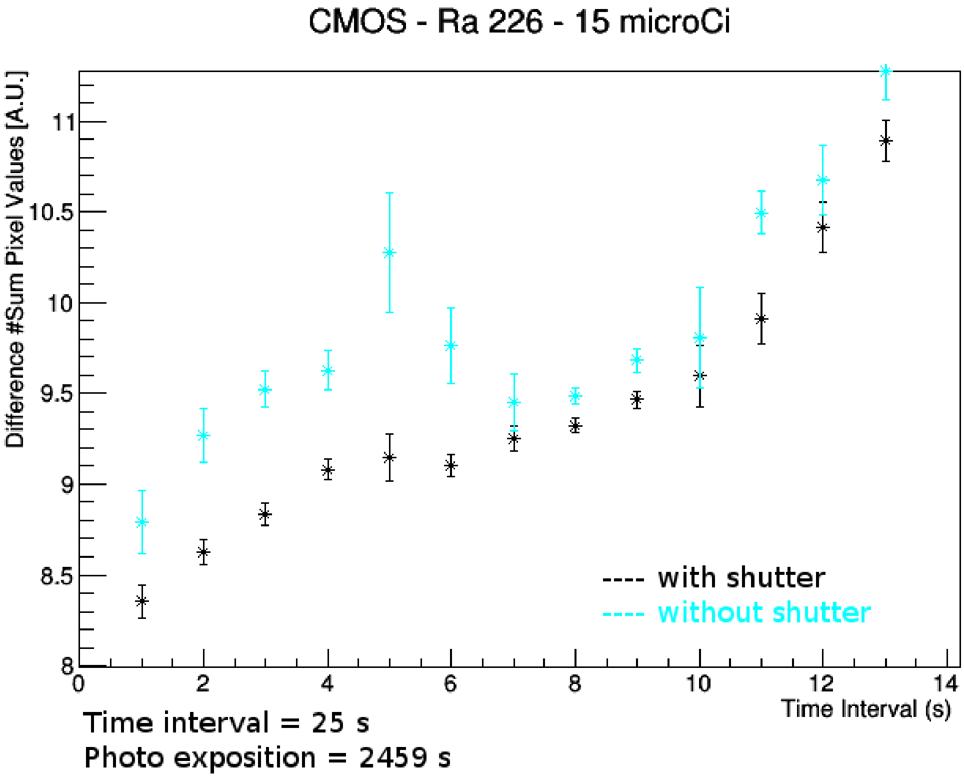
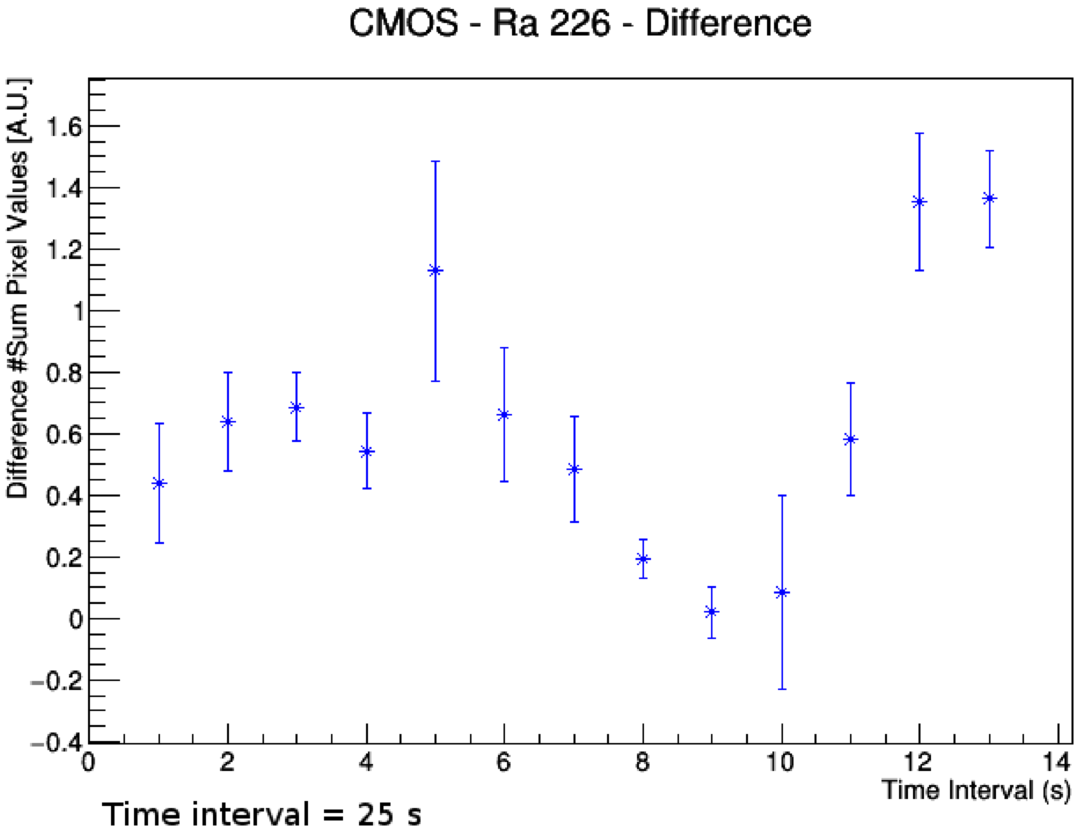
Appendix

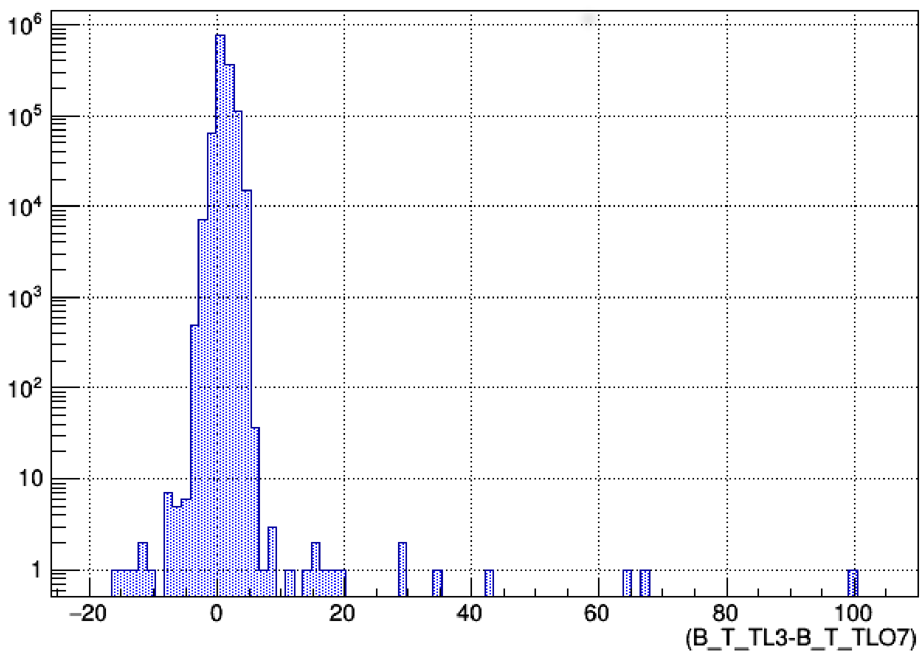

CMOS- thermal noise
#Sum Pixel Values [A.U.]
Temperature (C)

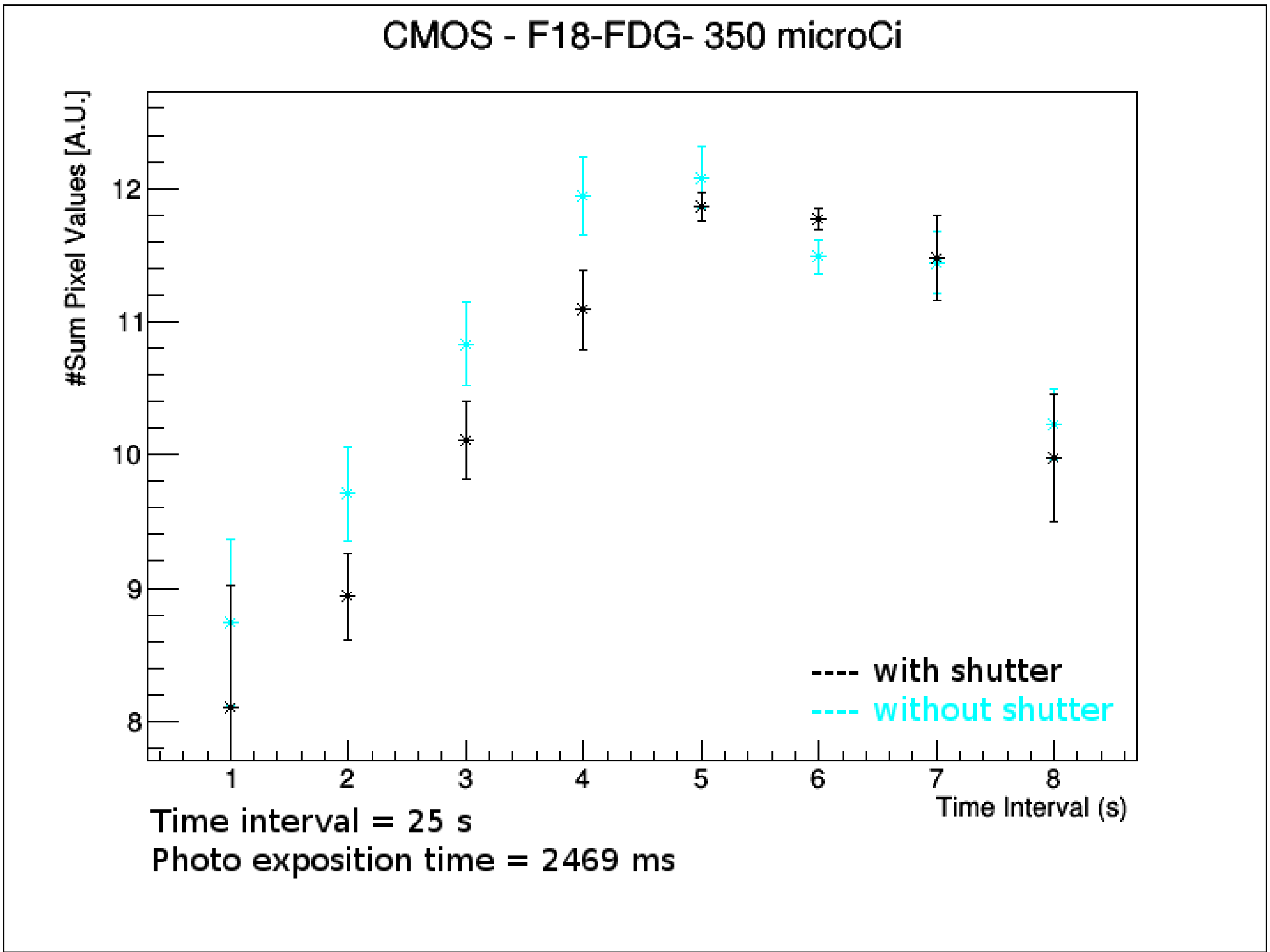

CMOS - Ra 226 - 15 microCi
Difference #Sum Pixel Values [A.U.]
Time Interval (s)
---- with shutter
---- without shutter
Time interval = 25 s
Photo exposition = 2459 s

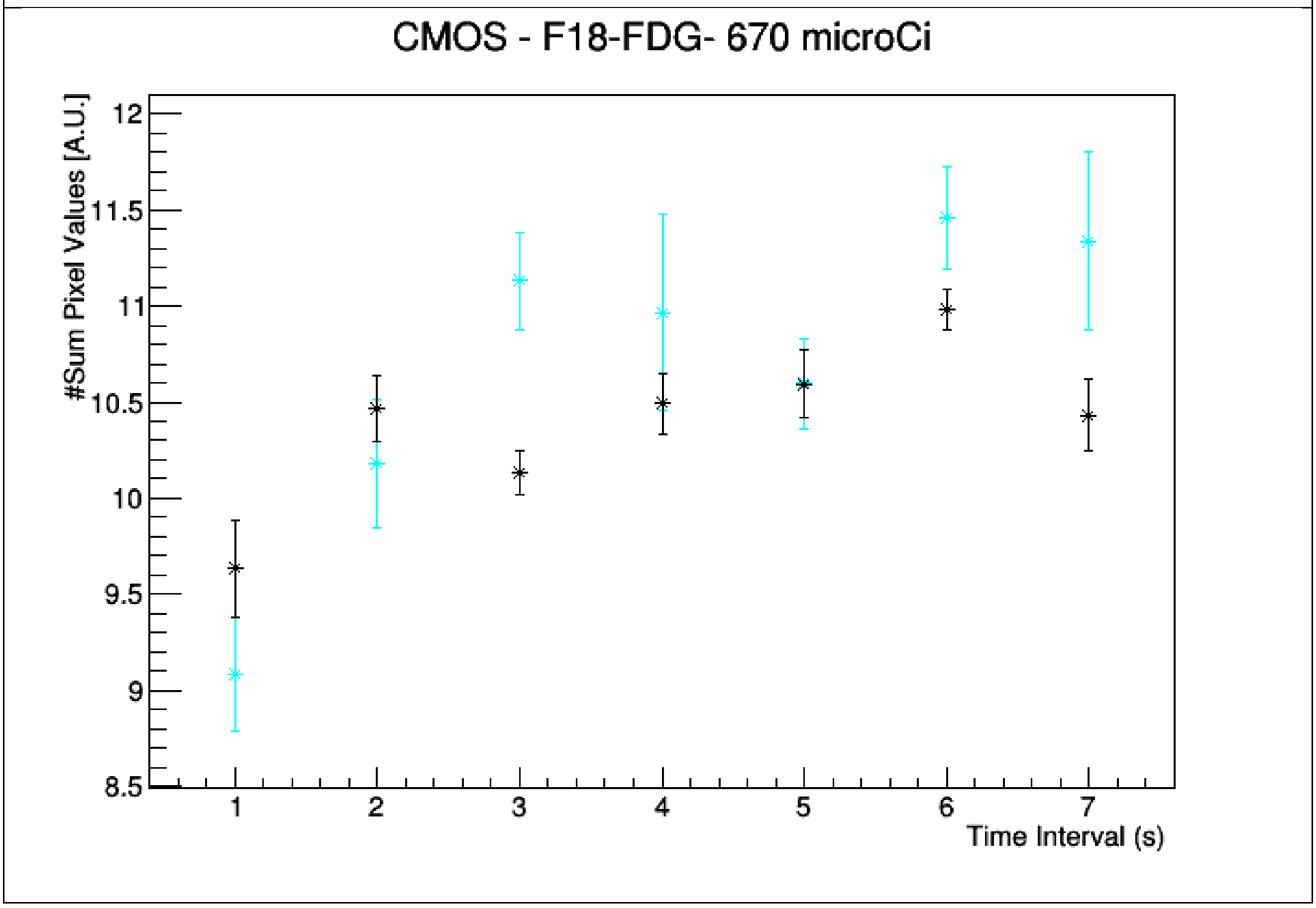


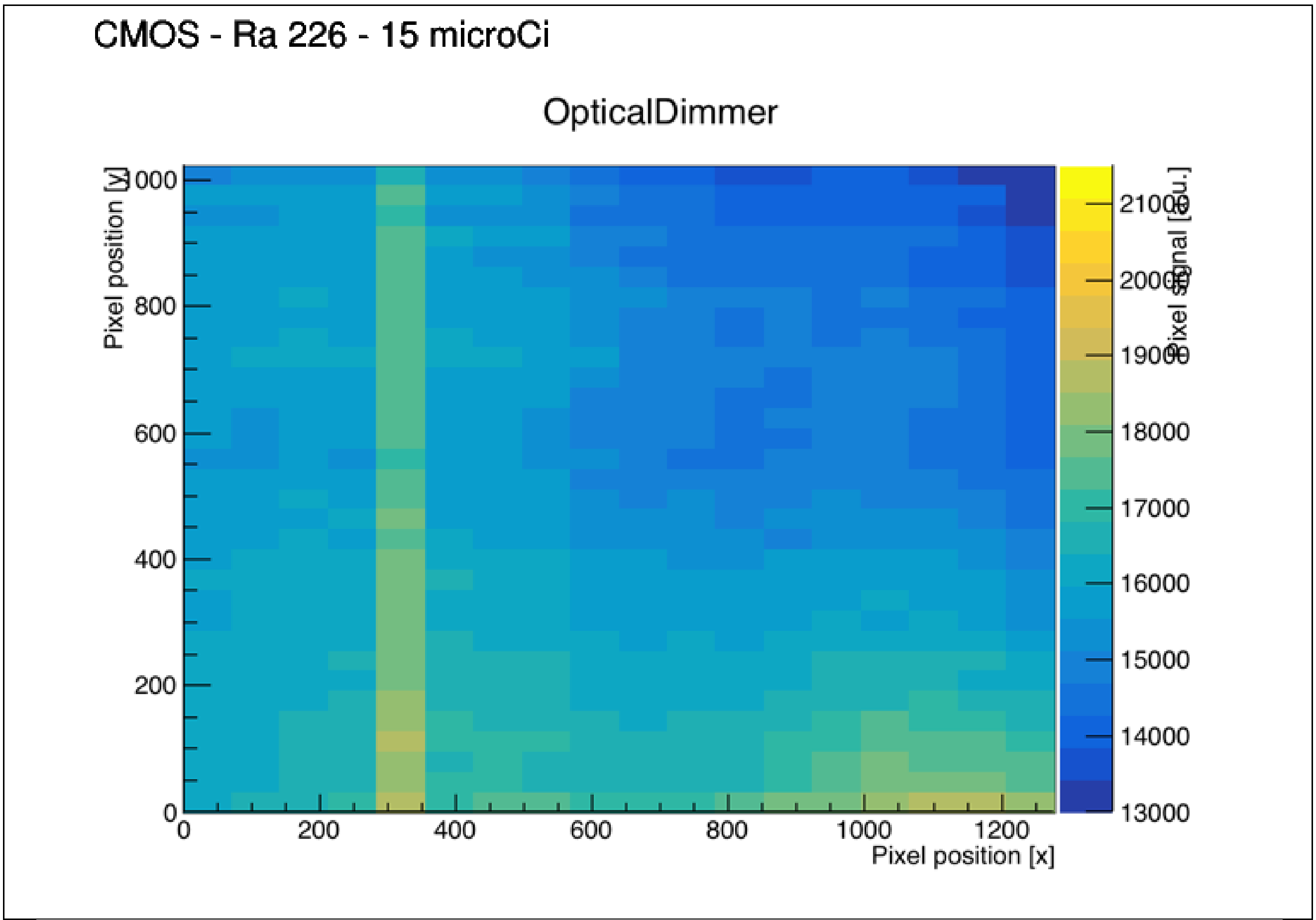
Time interval = 25 s
Photo exposition time = 2469 ms

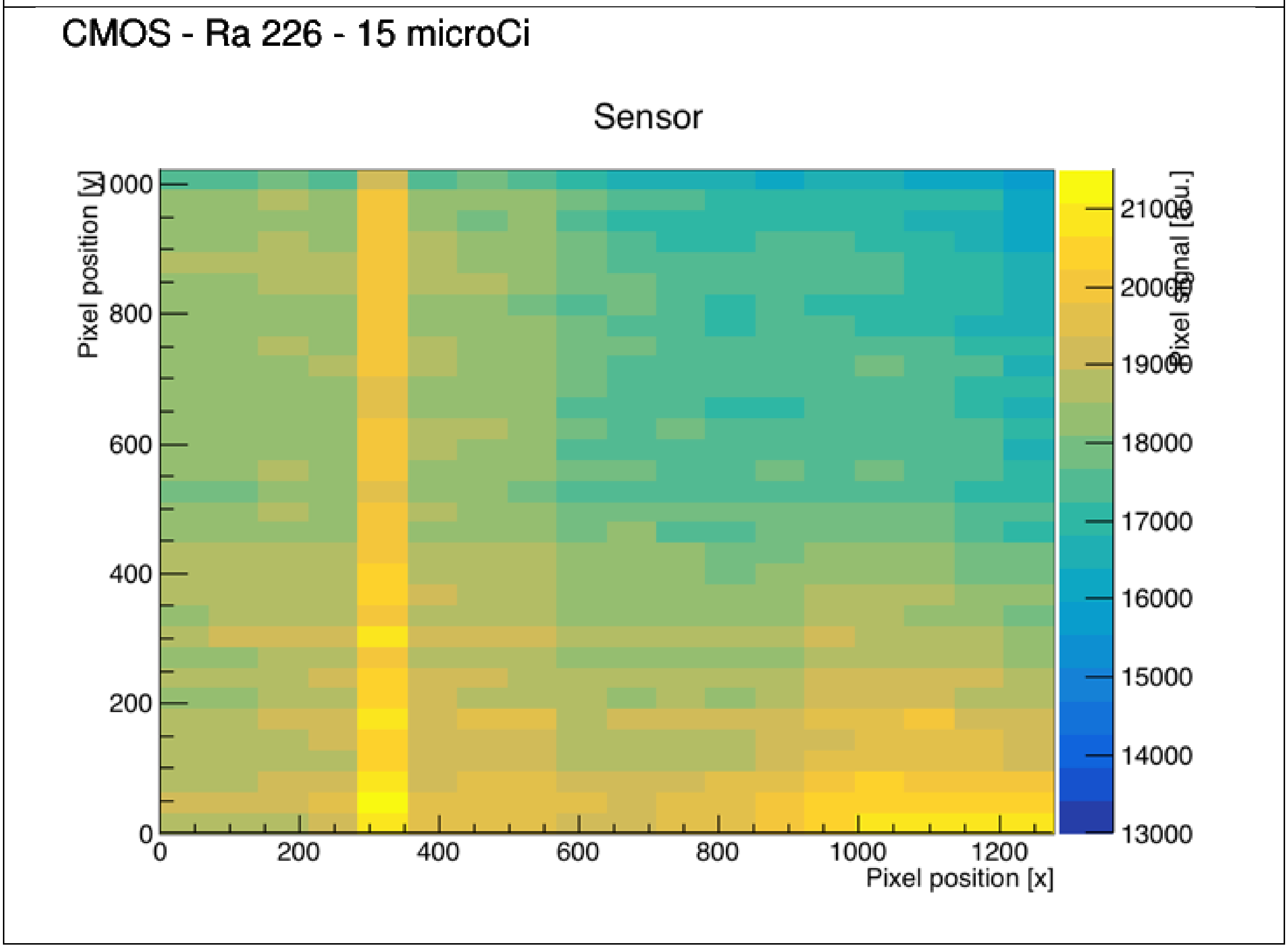
CMOS- Ra 226
Difference photo without shutter/with shutter

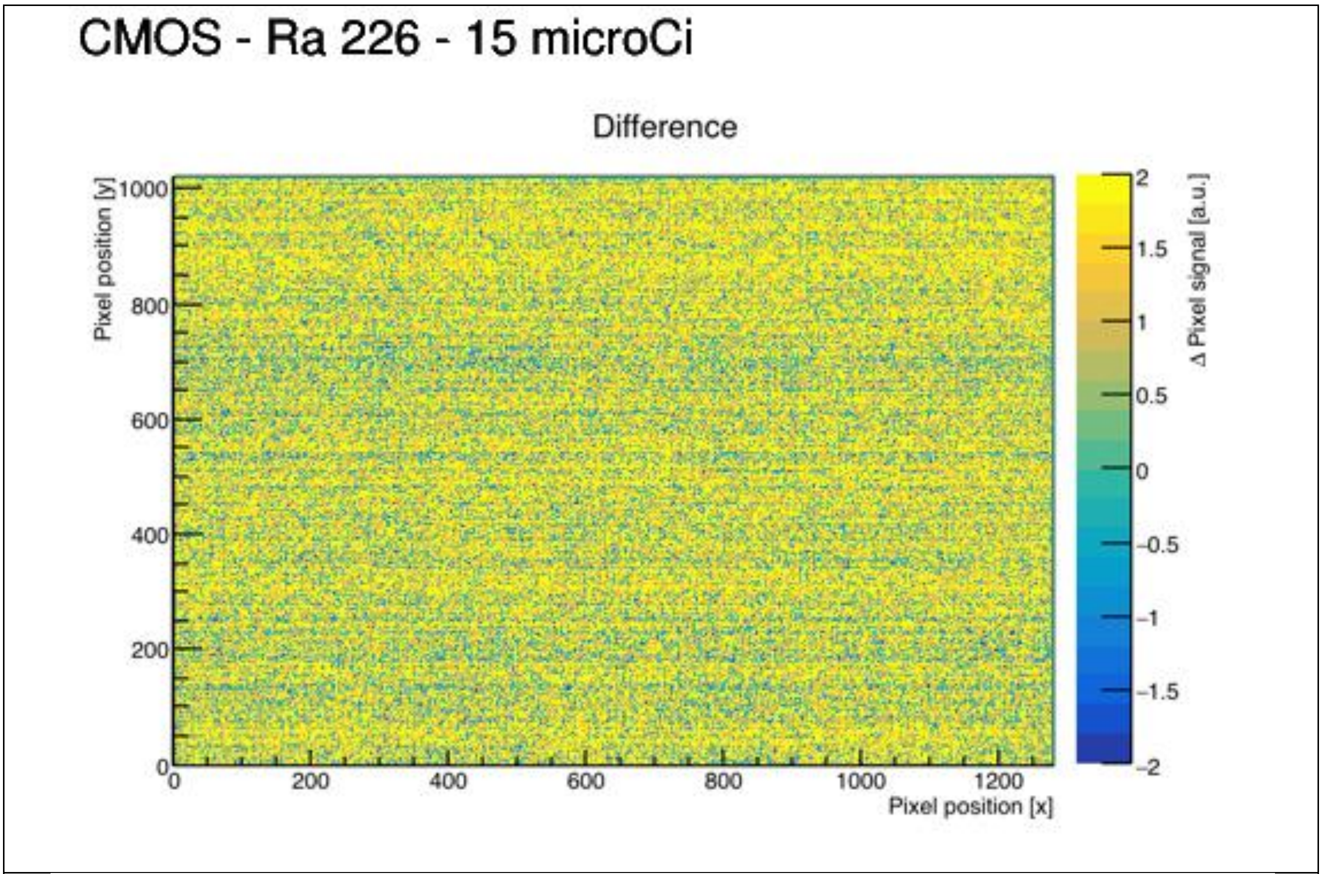


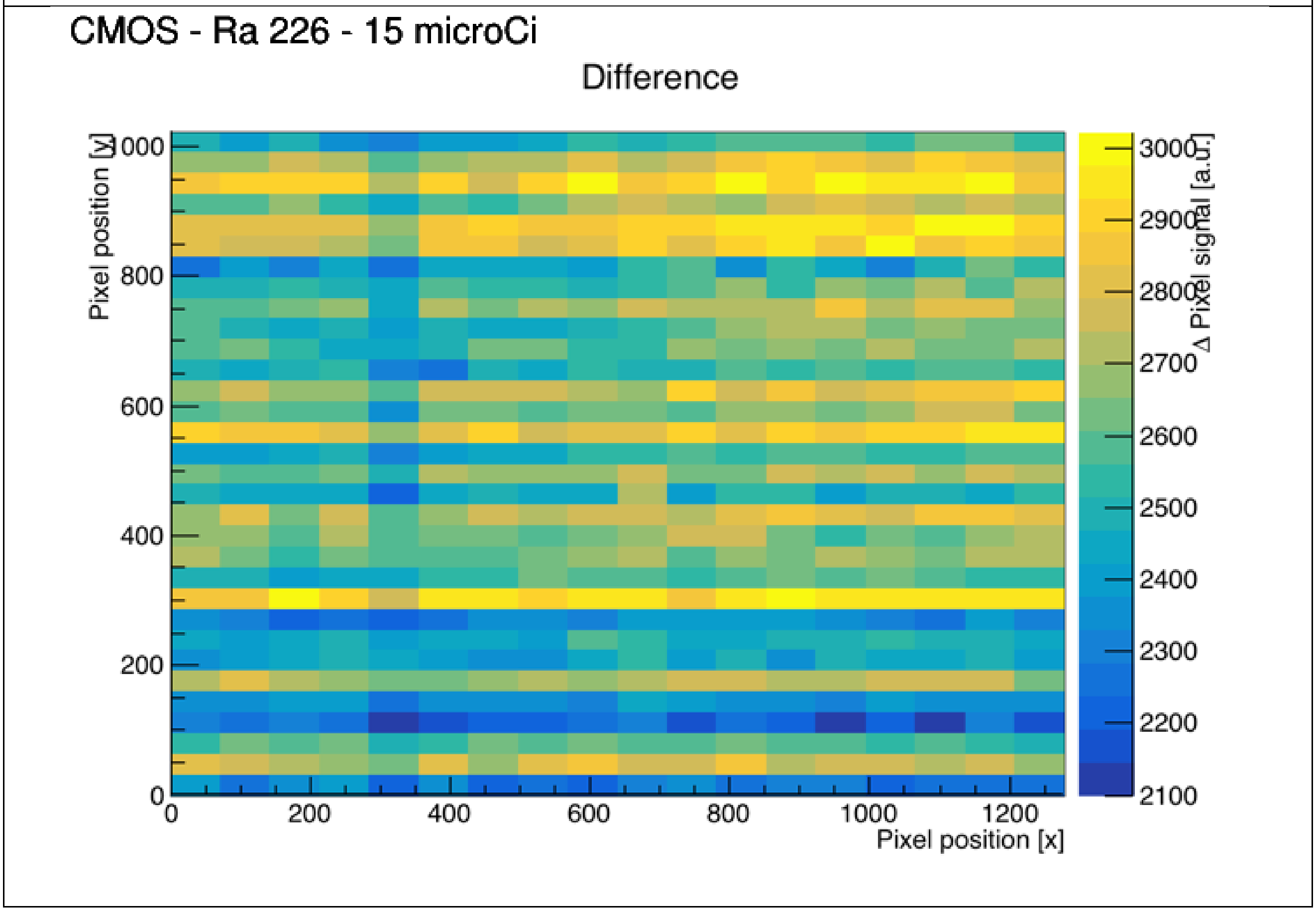

CMOS - F18-FDG- 350 microCi
#Sum Pixel Values [A.U.]
8
9
10
11
12
1
2
3
4
5
6
7
8
Time Interval (s)
---- with shutter
---- without shutter
Time interval = 25 s
Photo exposition time = 2469 ms

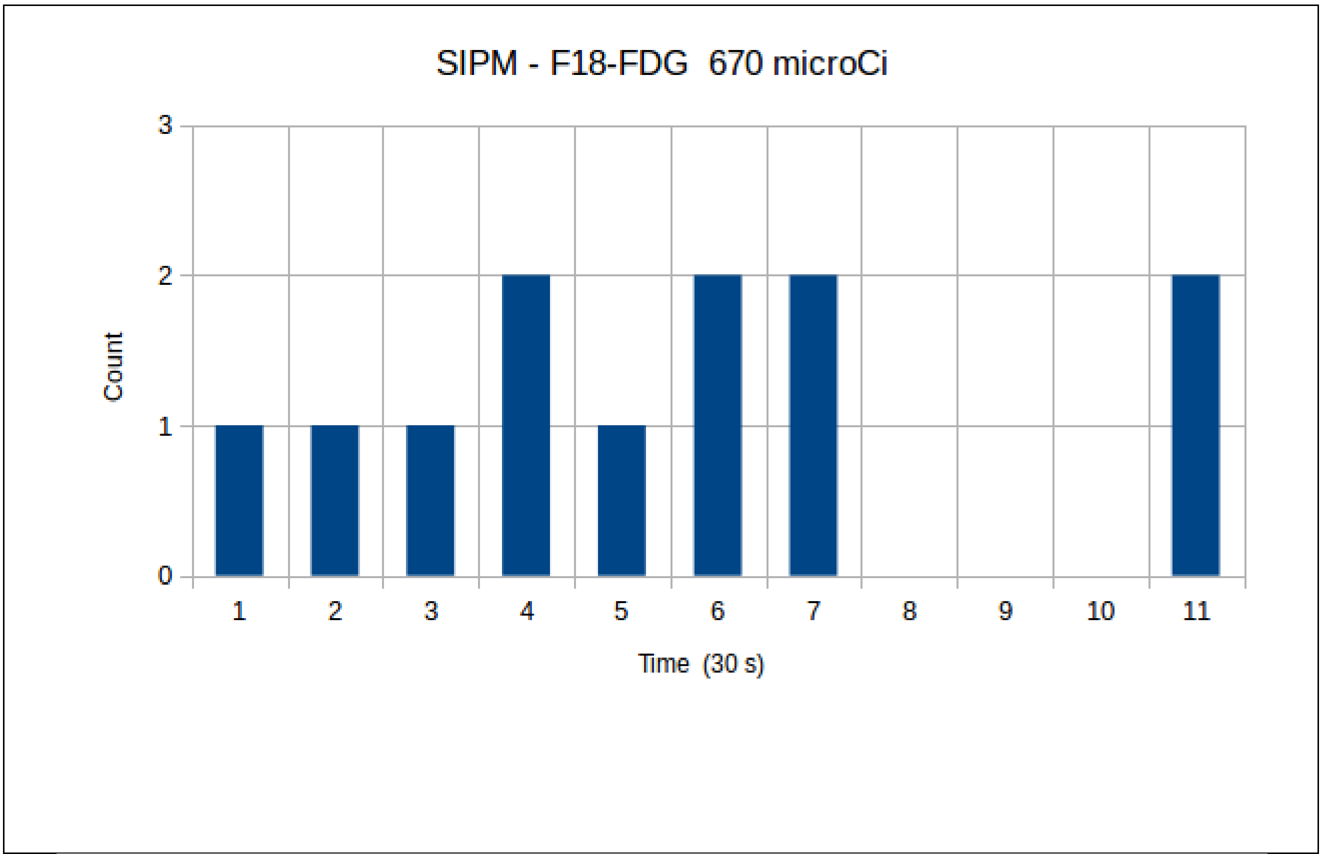

CMOS - F18-FDG- 670 microCi
#Sum Pixel Values [A.U.]
8.5
9
9.5
10
10.5
11
11.5
12
1
2
3
4
5
6
7
Time Interval (s)

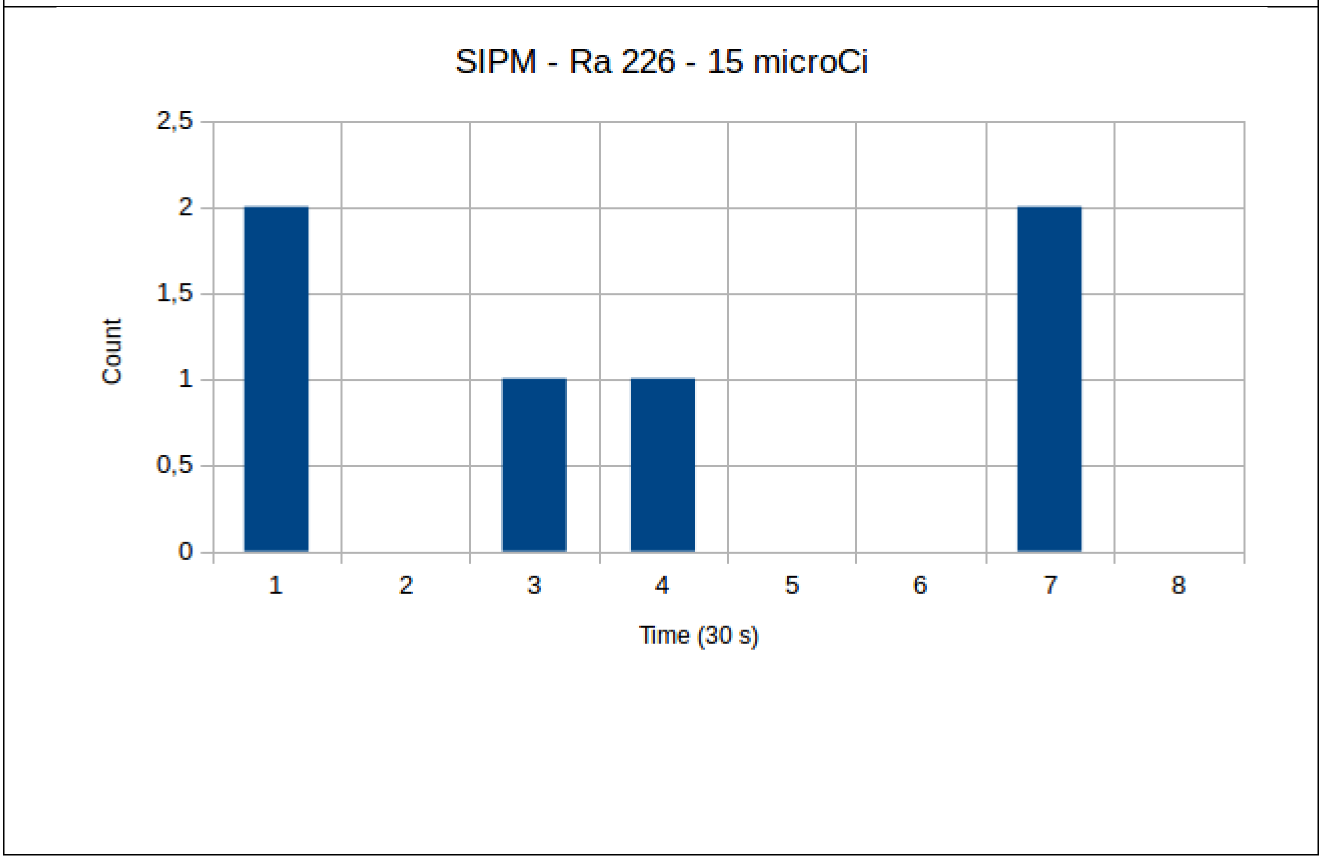

CMOS - Ra 226 - 15 microCi
OpticalDimmer
Pixel position [y]
Pixel position [x]
Pixel signal [a.u.]
0
200
400
600
800
1000
1200
13000
14000
15000
16000
17000
18000
19000
20000
21000


CMOS - Ra 226 - 15 microCi
Sensor
Pixel position [y]
Pixel position [x]
Pixel signal [a.u.]
0
200
400
600
800
1000
1200
13000
14000
15000
16000
17000
18000
19000
20000
21000


CMOS - Ra 226 - 15 microCi
Difference
Pixel position [y]
Pixel position [x]
Δ Pixel signal [a.u.]


CMOS - Ra 226 - 15 microCi
Difference
Pixel position [y]
Pixel position [x]
Δ Pixel signal [a.u.]


SIPM - F18-FDG 670 microCi
Count
0
1
2
3
1
2
3
4
5
6
7
8
9
10
11
Time (30 s)


SIPM - Ra 226 - 15 microCi
Count
0
0,5
1
1,5
2
2,5
1
2
3
4
5
6
7
8
Time (30 s)

Gamma rays' effect