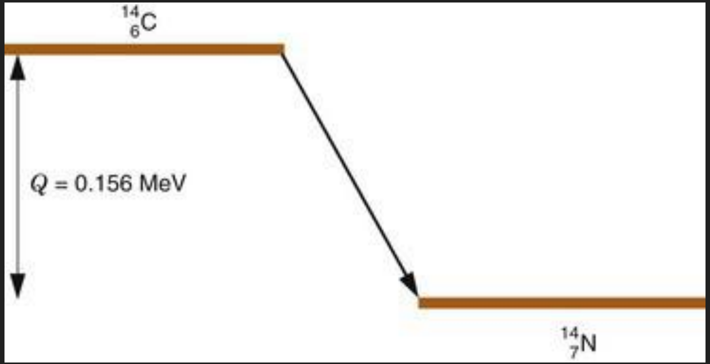
Calibration sources for CYGNO

Flavio Di Clemente
Giulia D'Imperio
Gianluca Cavoto

19 / 12 / 19

He - CF_4

^{12}C ^{13}C ^{14}C

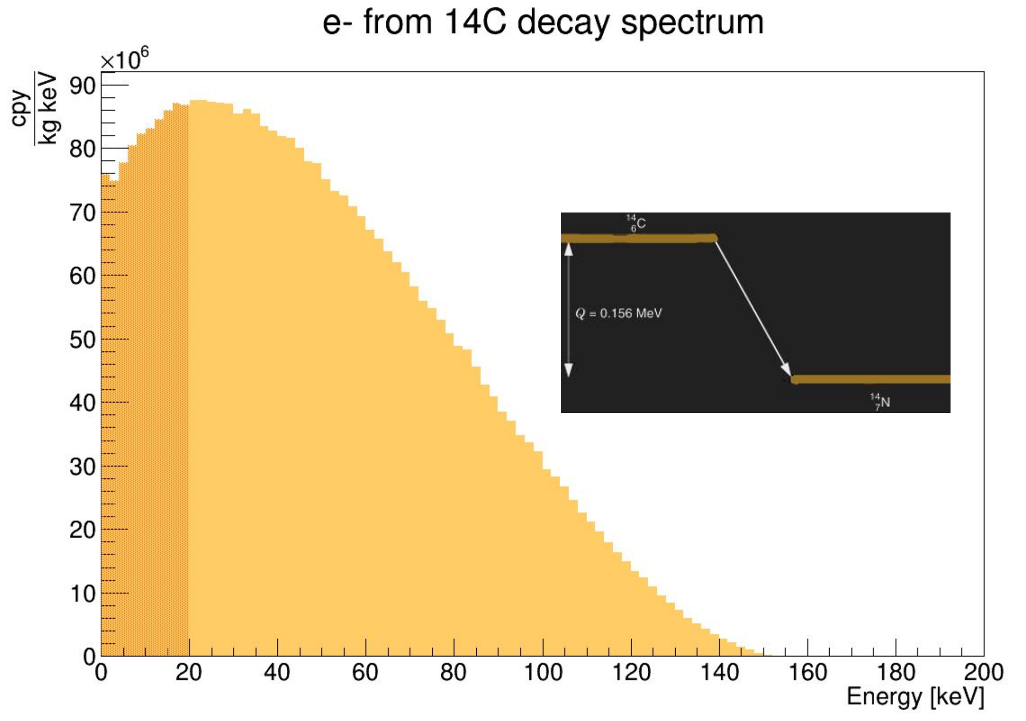


- Is ^{14}C source of background in our detector?
- Is the produced ^{14}N a tagged nuclear recoil?

The simulation is performed as if all the carbon atoms were unstable isotopes (^{14}C)

Integrating the signal region ([0-20]keV) we get $1{,}64 \times 10^9$ cpy

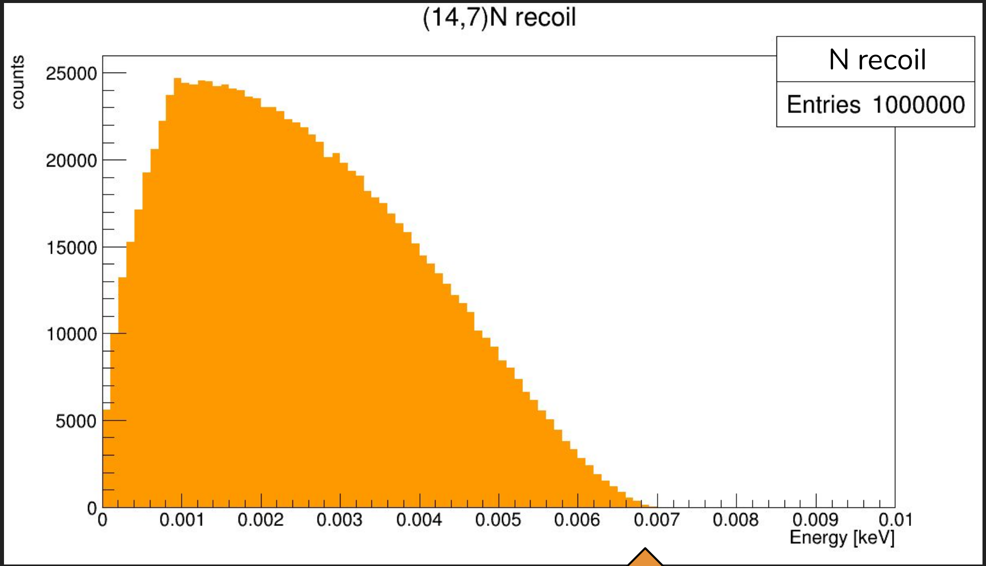
This means we need the ^{14}C fraction to be $< \sim 10^{-5}$ of the total carbon, having set the usual 10^4 cpy threshold



Since the natural abundance of the ^{14}C is about 1 part per trillion ($\sim 10^{-12}$), we can conclude this is a negligible internal background

From the simulation we get the spectrum of the (14,7)N recoil after the 14C decay

Using it as a calibration source of nuclear recoil is not possible due to the low energies involved

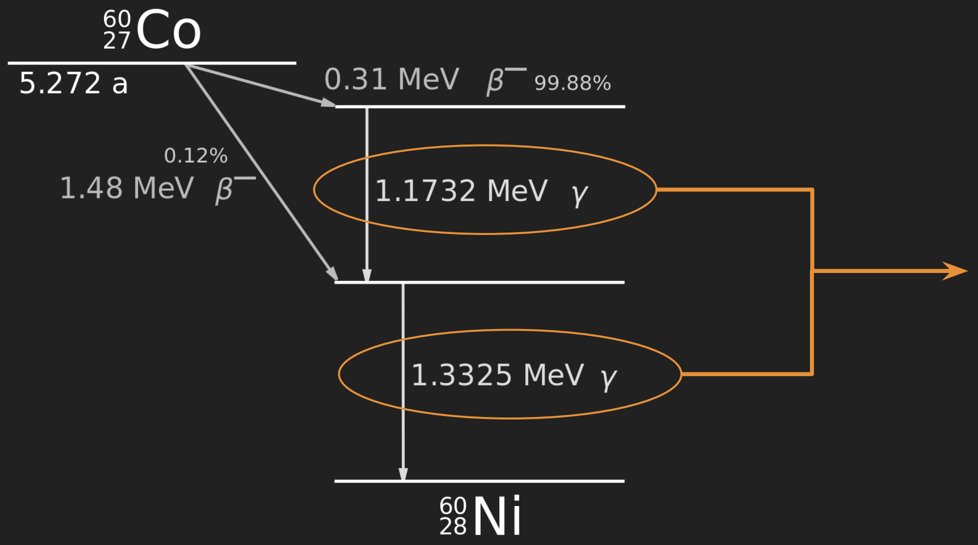


The maximum N recoil energy is lower than the ionization threshold

Table 1: Physical Properties of gases at 20◦C and 760 Torr

Gas	Z	A	Density 10^{-3} (g/cm^3)	E_x (eV)	E_i (eV)	w_i (eV)	$[dE/dx]_{mip}$ ($keV\ cm^{-1}$)	n_p (cm^{-1}) N.T.P	n_t (cm^{-1}) N.T.P.	Radiation Length (m)
He	2	2	0.178	19.8	24.5	41	0.32	4.2	8	745
Ar	18	39.9	1.782	11.6	15.7	26	2.44	23	94	110
Ne	10	20.2	0.90	16.67	21.56	36.3	1.56	12	43	345
Xe	54	131.3	5.86	8.4	12.1	22	6.76	44	307	15
CF_4	42	88	3.93	12.5	15.9	54	7	51	100	92.4
DME	26	46	2.2	6.4	10.0	23.9	3.9	55	160	222
CO_2	22	44	1.98	5.2	13.7	33	3.01	35.5	91	183
CH_4	10	16	0.71	9.8	15.2	28	1.48	25	53	646
C_2H_6	18	30	1.34	8.7	11.7	27	1.15	41	111	340
i-C_4H_{10}	34	58	2.59	6.5	10.6	23	5.93	84	195	169

60Co calibration source



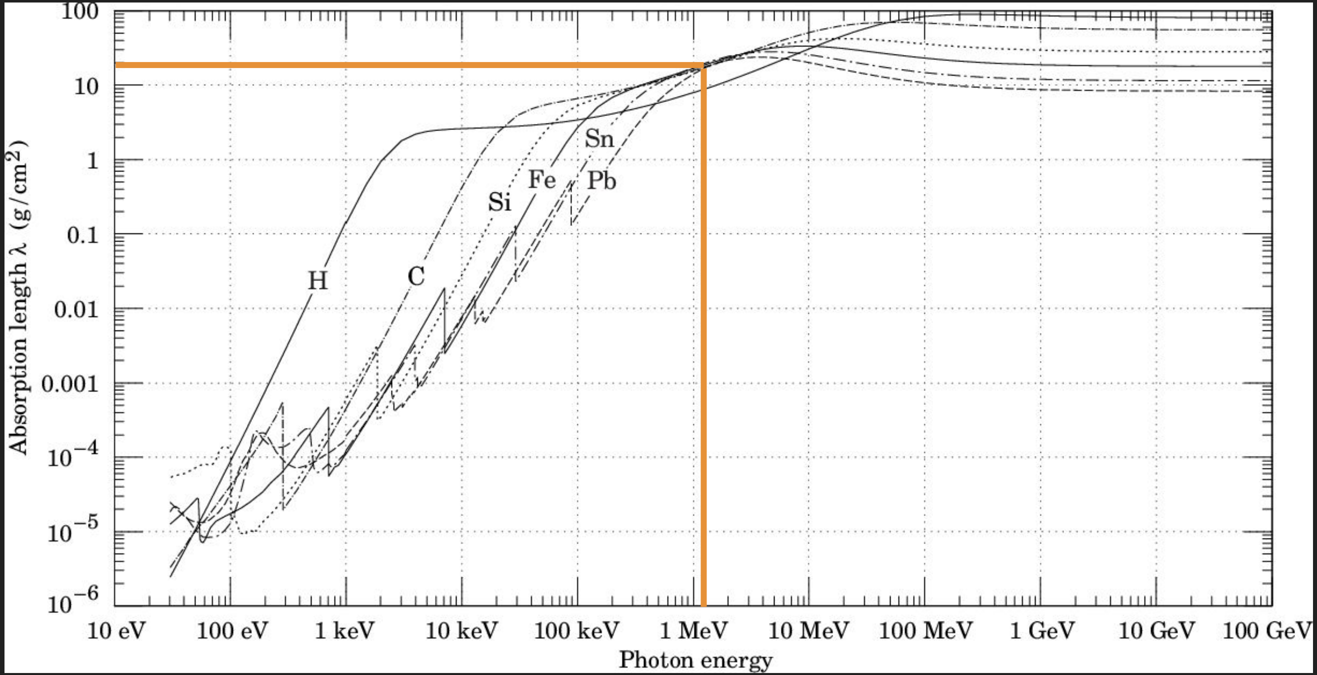
Can we use them as a calibration source during data taking?

$$I = I_0 e^{-\frac{x}{\mu}} \quad \text{with} \quad \mu = \rho\lambda^{-1}$$

Compton

Photoelectric effect

Pair production



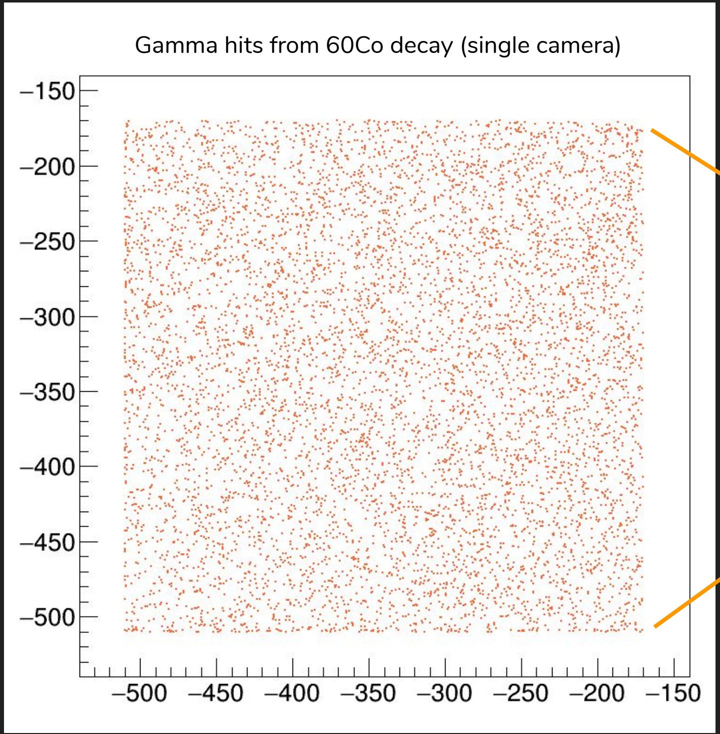
λ = 20 g/cm^2
ρ = 0.00153 g/cm^3
μ = ~70m

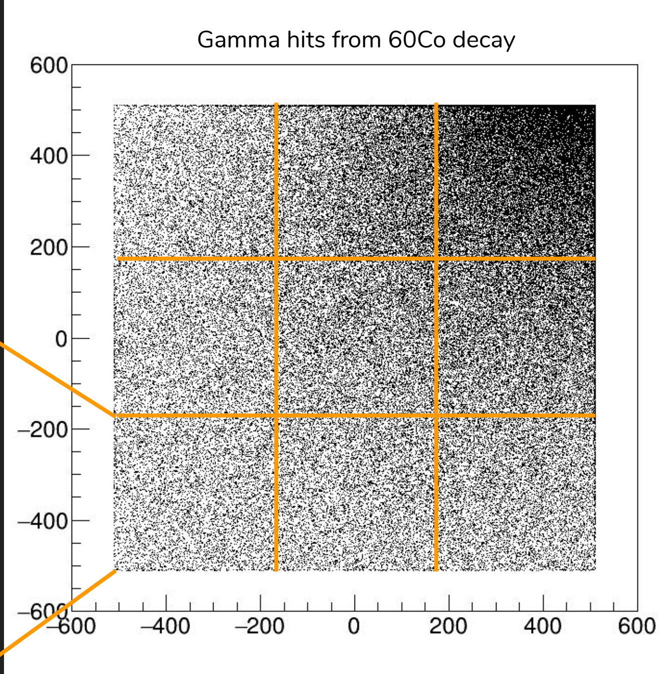
The interaction probability, given a thickness of 1m, is ~2.5%

The simulation took into account $3x10^7$ 60Co decays. Each of them emitted 2 gammas.

Total number of gamma hits: 148653

Gamma hits in a single camera: 7732





How high should the source activity be?

Distances are given in mm

A calibration during the data acquisition is needed. Then the 60Co decay should produce a number of event equal to

1 event for each camera each 20ms

Using the sample from the previous slides we can see that the camera with the lowest occupancy gets

1 event each 3.9×10^3 decays

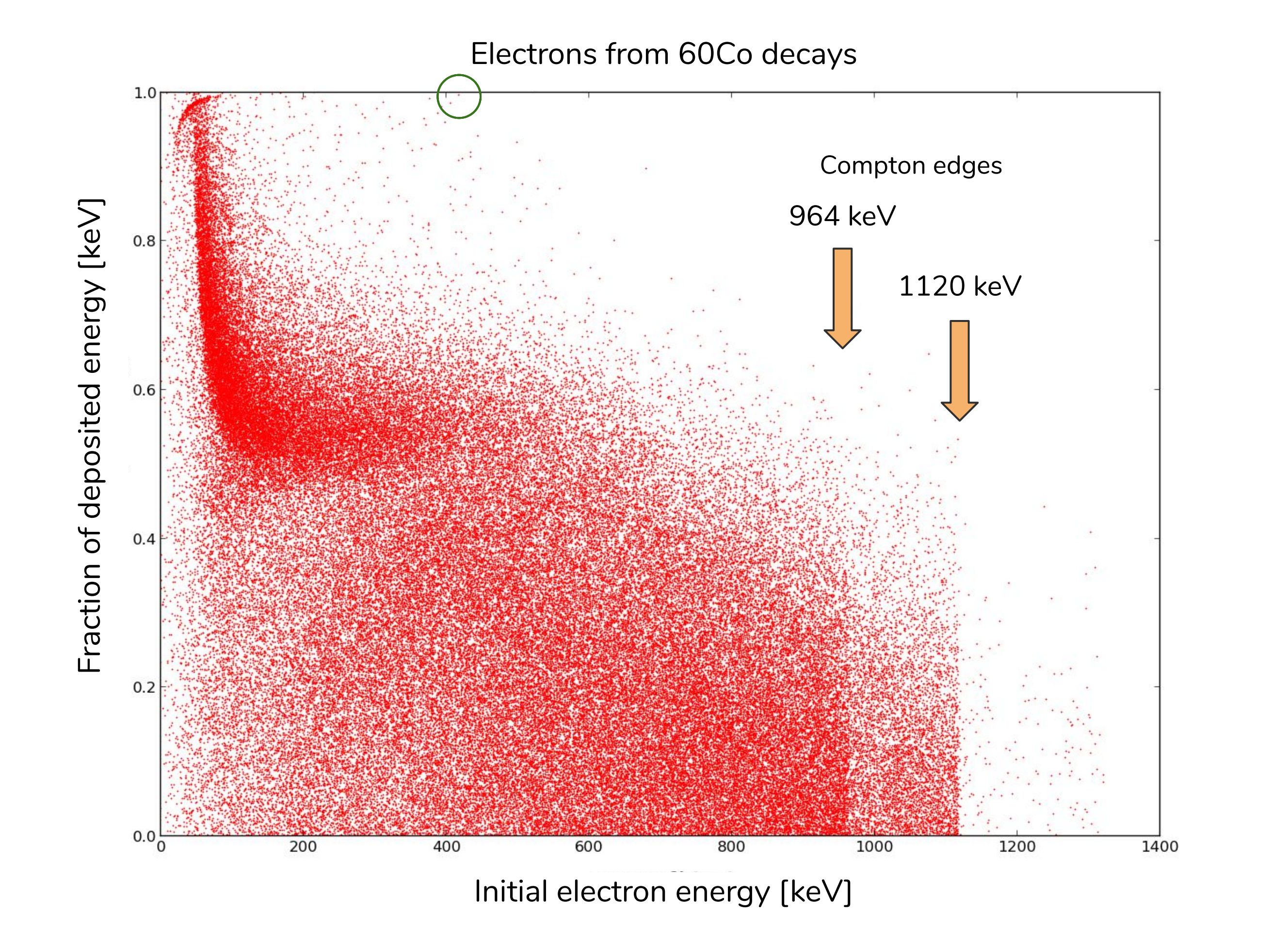
Then the needed activity is 3.9×10^3 decays / 2.0×10^{-2} s = 2×10^5 Bq

1 gram of pure 60Co has an activity of 44 TBq

Problem: track containment

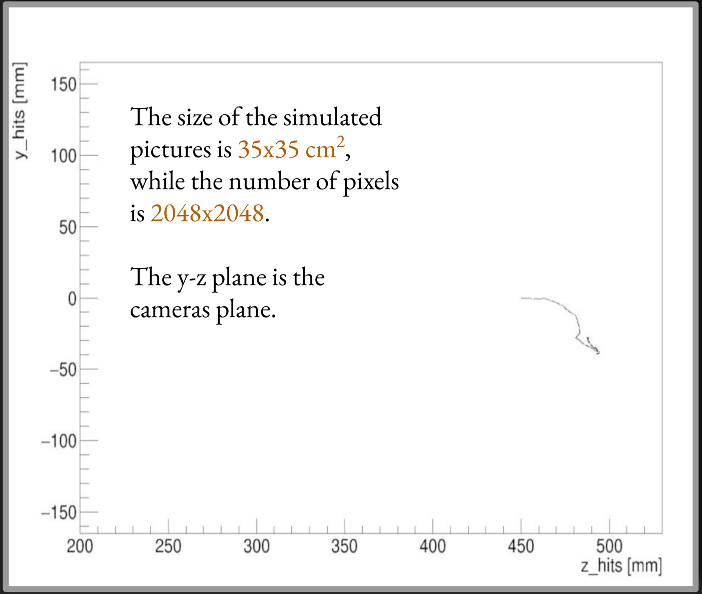
In general, only a fraction of the total energy carried by the particle is deposited inside the sensitive region

The maximum registered energy contained inside a $0.5m^3$ region (between cathode and readout) is ~420keV



From GEANT4 output to simulated image

We applied to the MC track both the smearing from diffusion and the background from camera noise, using the typical LEMON/LIME parameters.
The diffusion parameter was extracted from the GARFIELD simulations, while the noise was computed from experimental data, in runs where the objective of the camera was obscured (work in progress too).

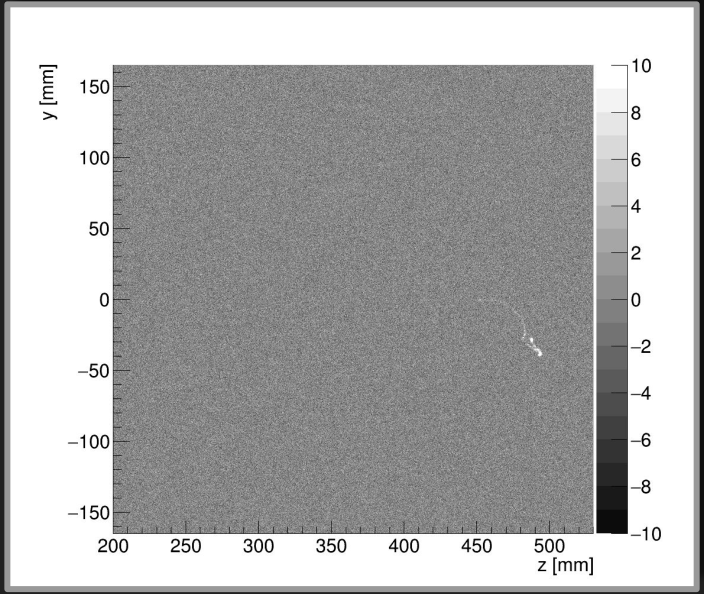


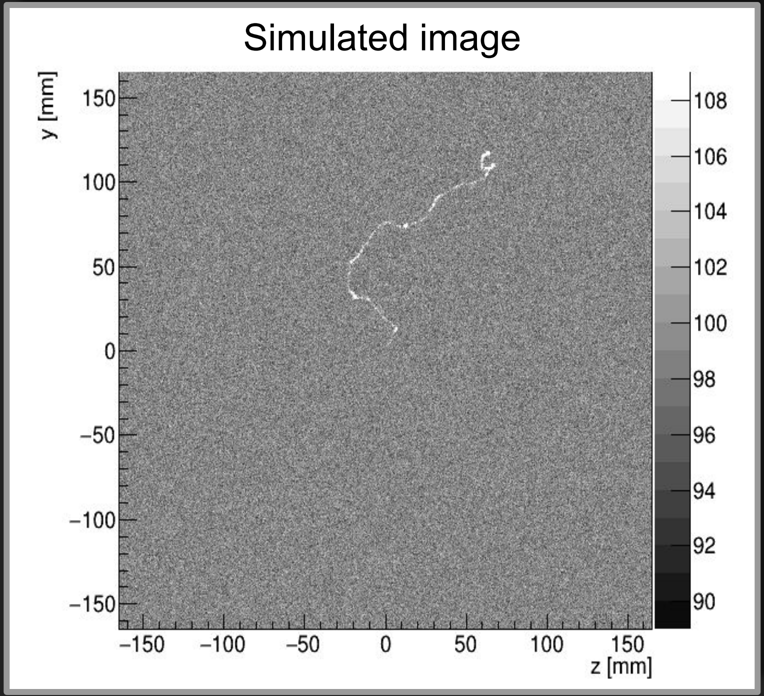
The size of the simulated pictures is 35x35 cm^2, while the number of pixels is 2048x2048.

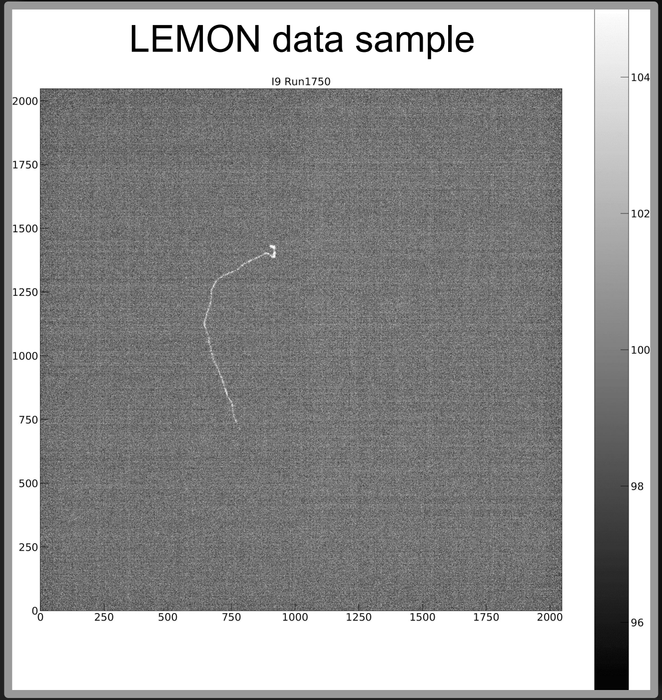
The y-z plane is the cameras plane.

Diffusion parameter, which is the sigma of the gaussian distribution of the diffused photoelectrons, is 0.8

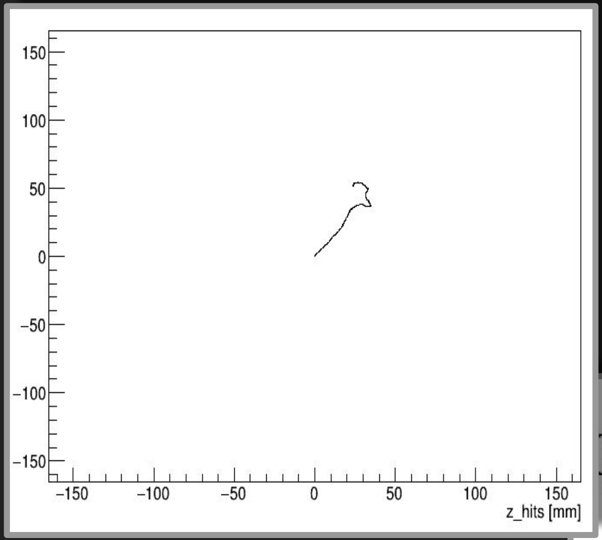
Noise is a gaussian centered on the pedestal with a sigma of 2 photoelectrons per pixel




Simulated image
y [mm]
z [mm]
150
100
50
0
−50
−100
−150
108
106
104
102
100
98
96
94
92
90

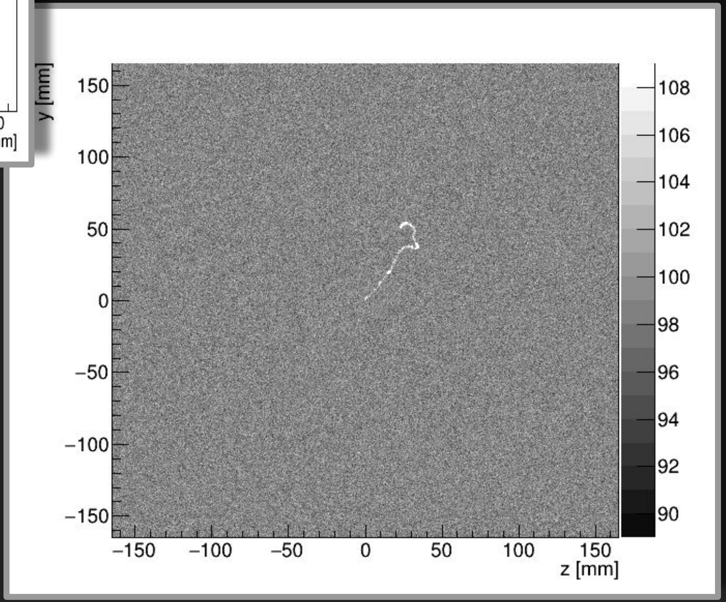

LEMON data sample
I9 Run1750
2000
1750
1500
1250
1000
750
500
250
0
104
102
100
98
96

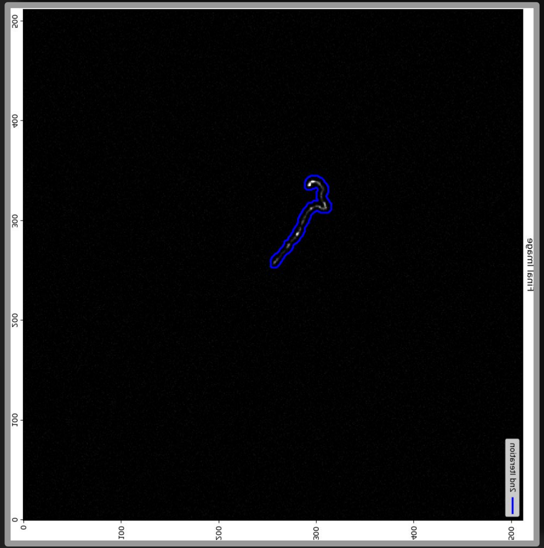
IDBSCAN2 can run on MC data samples



GEANT4 output

Initial energy: 100keV





IDBSCAN2 output

Reconstructed energy: 96 keV

Conclusions

- ^{14}C in our gas is a negligible source of background. Unfortunately, it can't be used as a source of tagged nuclear recoils due to low energies involved.

- 60Co seems not to be an optimal source since it delivers very penetrating gammas. Those particles have a small interaction probability and they produce tracks which are generally not fully contained within the sensitive region.

- Digitization is running in the proper way for electron tracks. Nuclear recoil study is still in progress, and it needs some further works to produce realistic tracks.