Update CYGNO simulations

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CYGNO meeting 7/11/19

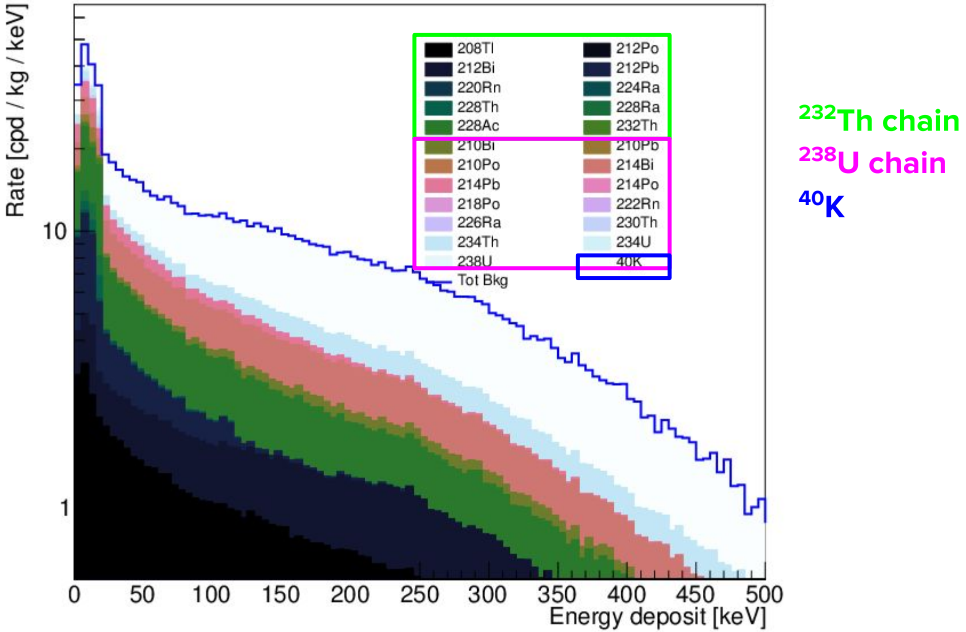
Summary of simulation activities

- **Background simulations** with GEANT4
  - ambient gamma/neutrons and shielding studies(Giulia, Gianluca)
  - internal background, radioactivity of the setup (Flavio, Giulia, Gianluca)
- **Signal simulations**: nuclear recoils with SRIM (Emanuele M., Davide)
- **Signal simulation with Geant4:** nuclear and electron recoils (Flavio, Giulia)
- **Drift and detector effect**: simulation of electron drift and diffusion with Garfield (Emanuele M., Davide, Flavio)
- Study of feasibility of **solar neutrino measurements**, electron range in different gas mixtures (Elisabetta, G. Dho, D. Marques)

Background simulation with GEANT4

Radioactivity background from Acrylic Box

- Energy deposit in CYGNO detector from la **2 cm thick** acrylic box (~200 kg)
- U, Th, K activities from M.Laubenstein measurements @LNGS (upper limits)
- Radiopurity.org numbers for acrylic are upper limits (similar or higher than LNGS values)



	Activity [mBq/kg]	**Rate** [cts/yr]
^{238}U	< 3.5 (^{226}Ra)	
^{232}Th	< 5 (^{228}Ra) < 4.5 (^{212}Pb)	
^{40}K	< 35	

Total rate < 4.57 10^5 cts/yr in (0-20) keV

➔ need more precise measurement of radioactivity

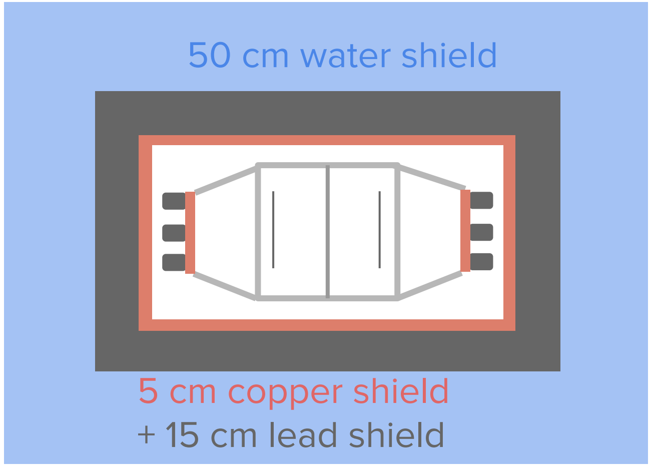
Status background study & to do

- Acrylic background is < 10^5 cts/yr in (0-20) keV
  ➔ more precise activity measurement needed to understand if the background is acceptable (goal is total background < 10^4 cts/yr in 0-20 keV)

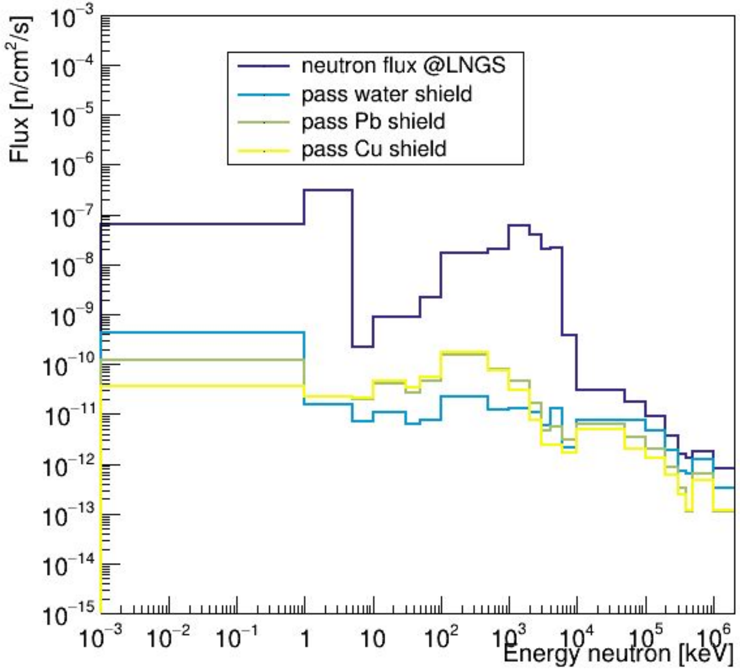
- To do: systematic studies of internal background, starting from the parts close to the sensitive region (GEM, field cage, etc..)

Ambient neutrons option 1

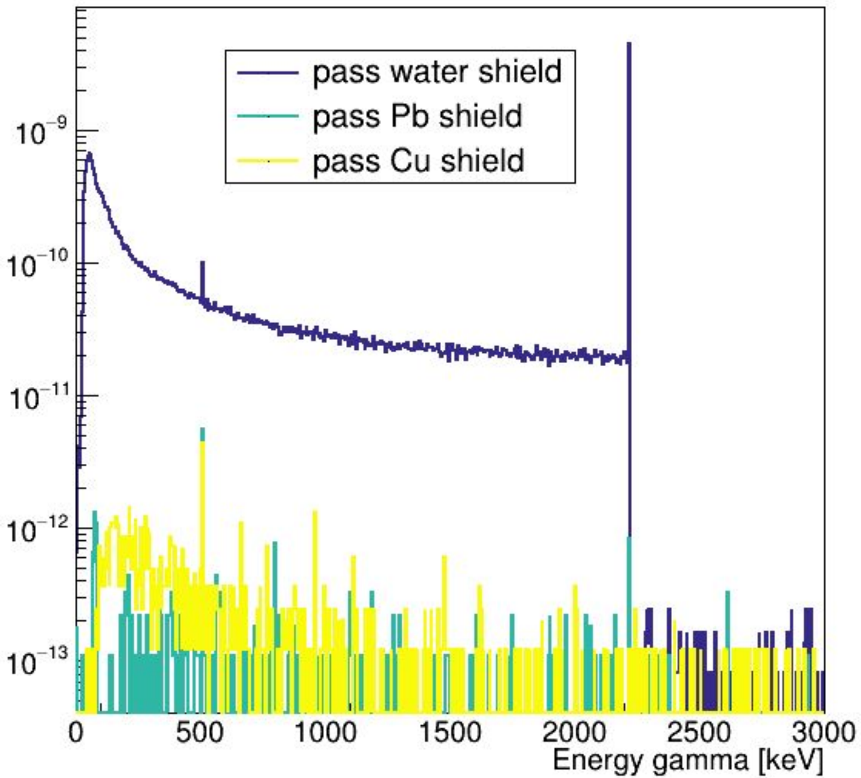
1) 50 cm water + 15 cm Pb + 5 cm Cu



Neutron Flux @LNGS 2.55e-06 cm^-2 s^-1
Neutron Flux after water shield 2.16e-09 cm^-2 s^-1
Neutron Flux after Pb shield 2.31e-09 cm^-2 s^-1
Neutron Flux after Cu shield 1.76e-09 cm^-2 s^-1



Secondary gammas option 1

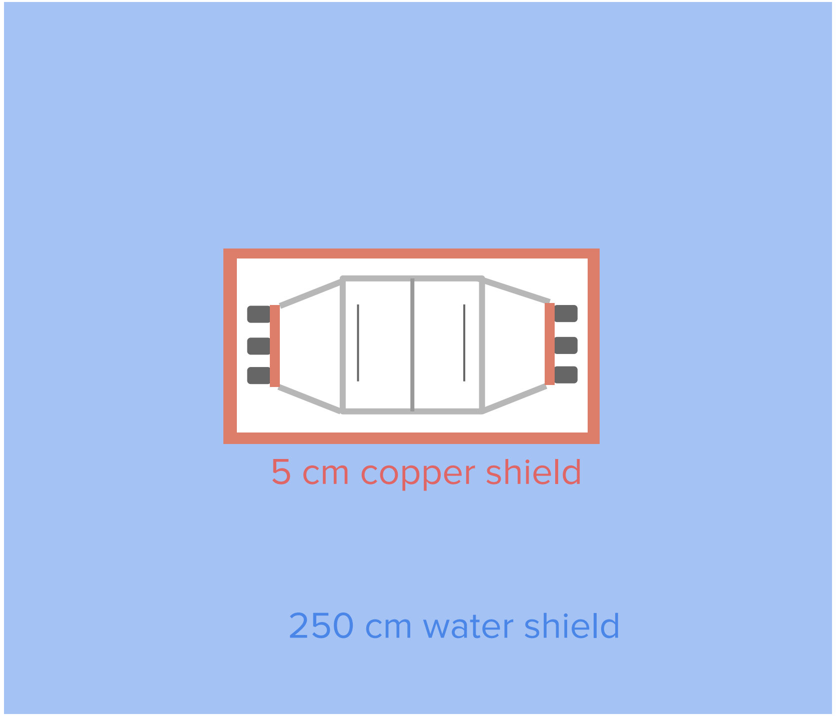


Gamma Flux after water shield 1.45e-07 cm^-2 s^-1
Gamma Flux after Pb shield 1.84e-10 cm^-2 s^-1
Gamma Flux after Cu shield 4.21e-10 cm^-2 s^-1

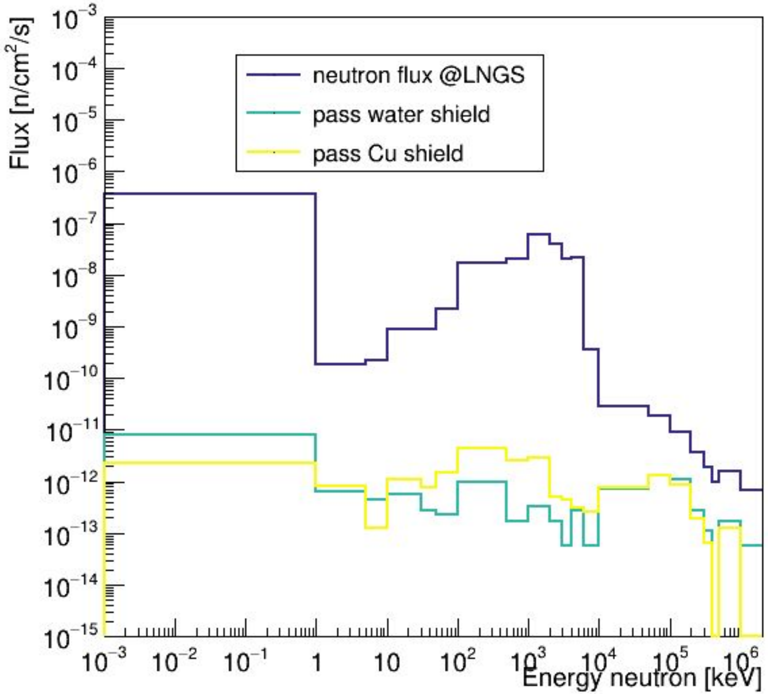
For reference:
Ambient gamma flux entering the full shield option 1 is 4 10^{-7} cm^{-1} s^{-1}

Ambient neutrons option 2

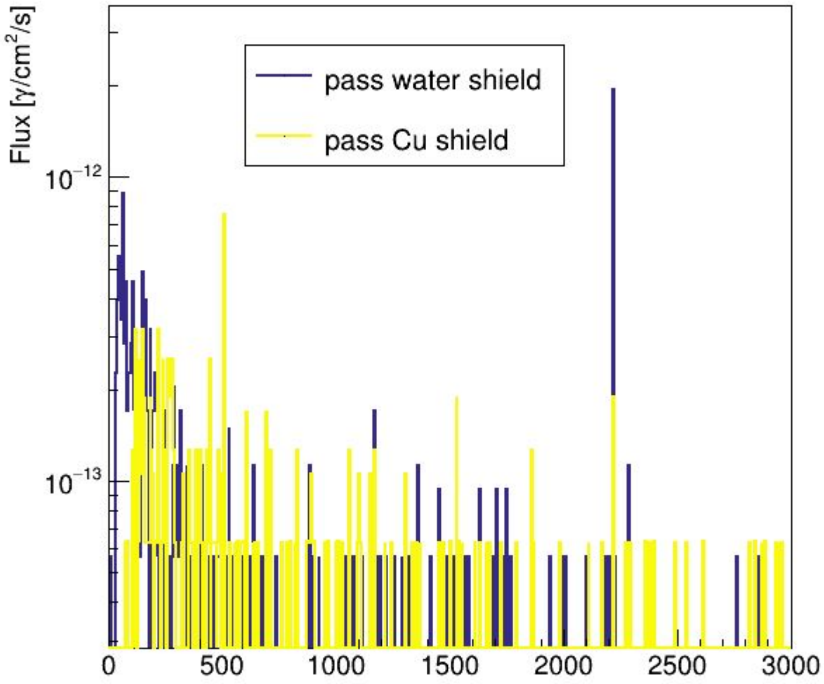
2) 250 cm water + 5 cm Cu



Neutron Flux @LNGS 2.55e-06 cm^-2 s^-1
Neutron Flux after water shield 1.41e-10 cm^-2 s^-1
Neutron Flux after Cu shield 6.31e-11 cm^-2 s^-1



Secondary gammas option 2



Gamma Flux after water shield 9.89e-11 cm^-2 s^-1
Gamma Flux after Cu shield 6.97e-11 cm^-2 s^-1

For reference:
Ambient gamma flux entering the full shield option 1 is 4 10^{-7} cm^{-1} s^{-1}

Status shielding & to do

- First results for neutron background + secondary gammas
  ➜ work in progress, need more statistics, but seems that neutron background is not worrisome for both options 1 and 2

- Option 2 looks better to shield neutrons and also better with respect to secondary gammas

Neutron simulation

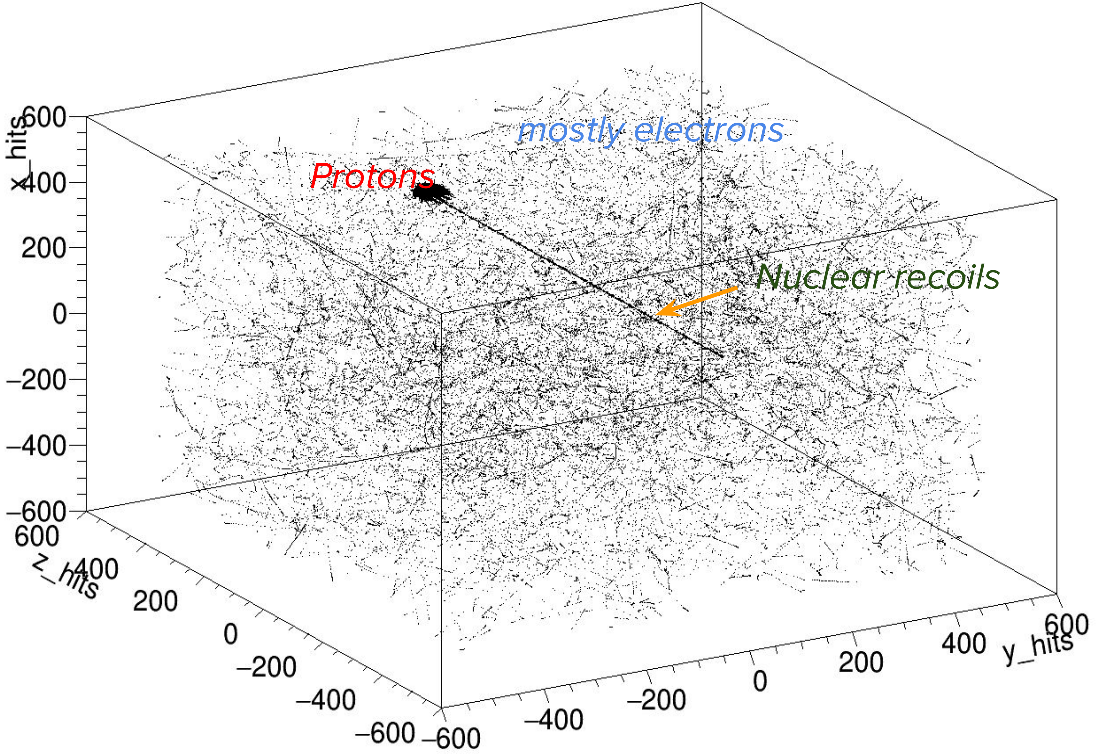
Neutrons for calibration

- Simulate 2.5 MeV (FNG) neutrons

- Correlate the nuclear recoil (NR) with neutron direction
  - Understand the effect of **plastic** box (can act as a **moderator**!)
  - Understand the observed **rate** of NR at FNG
    - moderator decreases *n* energy, lower energy means larger cross section
    - neutron are bouncing around (on the shields, losing energy, increasing their probability to interact)
  - Understand the effect of diffuse **gamma** ray background in data
  - Can we really use a neutron beam for **calibration** ?

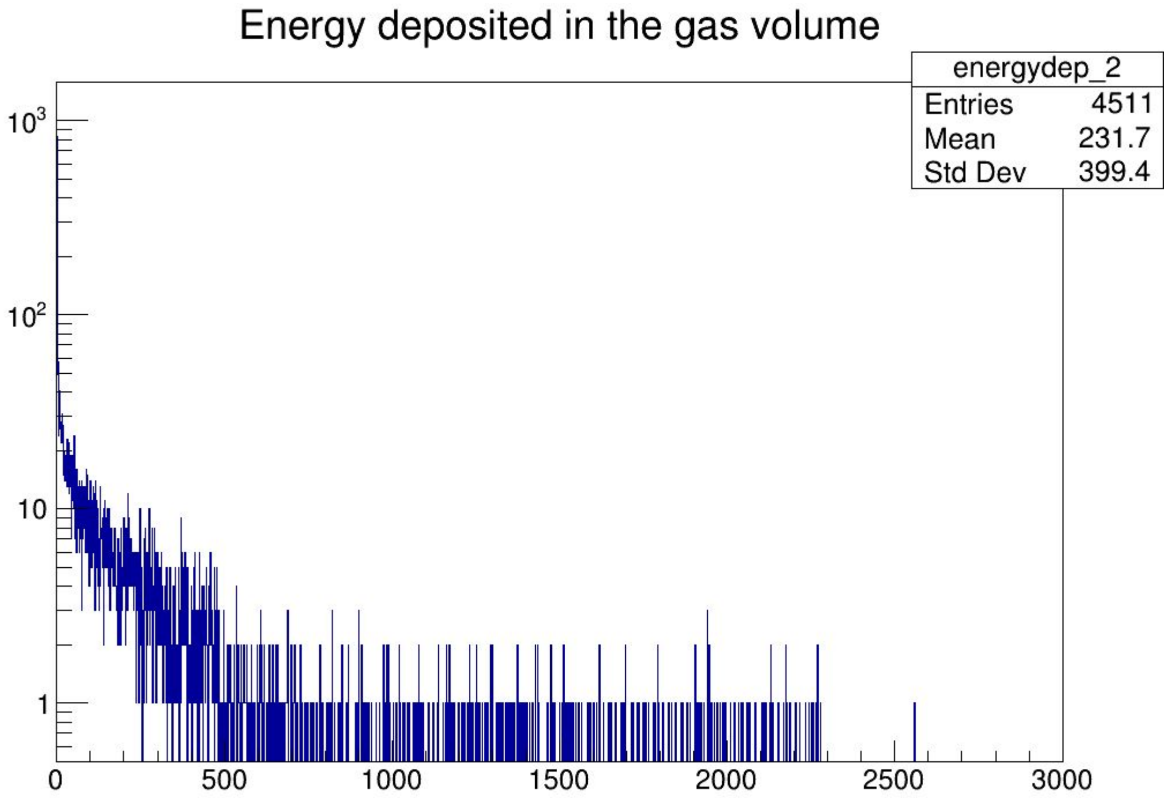
CYGNO 1m3 with 2.5 MeV neutrons

- First attempt
- Full CYGNO geometry with shields (water)
  - 100k neutrons shot from (x_0,y_0,z_0) = (250,0.0,655) mm (just outside acrylic vessel)
  -
  - all directed along negative *z*
- Plotting all the G4hits (350k) in the gas volume



Energy spectrum

- 100k generated events
- 4511 events with energy deposit >0
- ~2300 events from NR

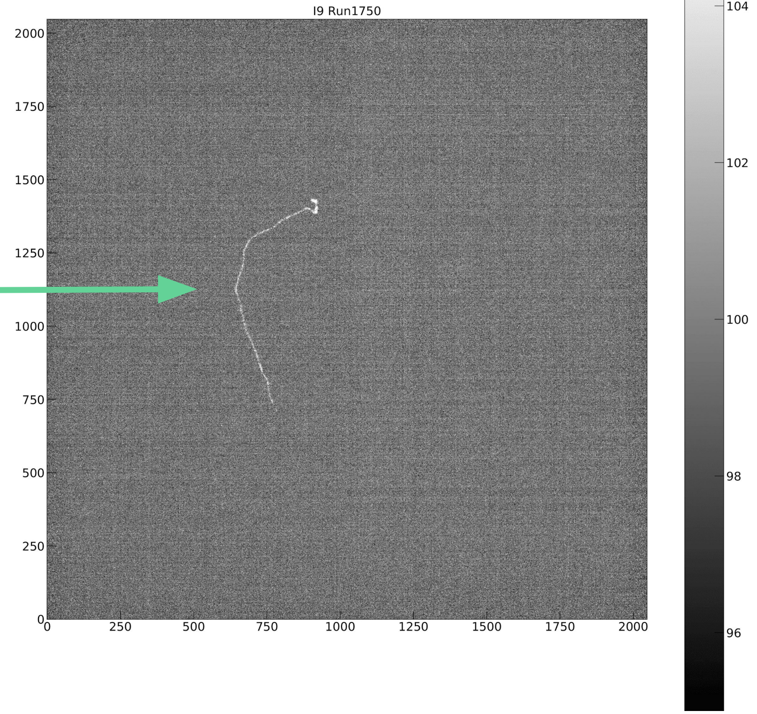


Signal simulation

Task: generate a MC simulated image which matches experimental data

We want to reproduce the track given by a ~100keV electron like this one

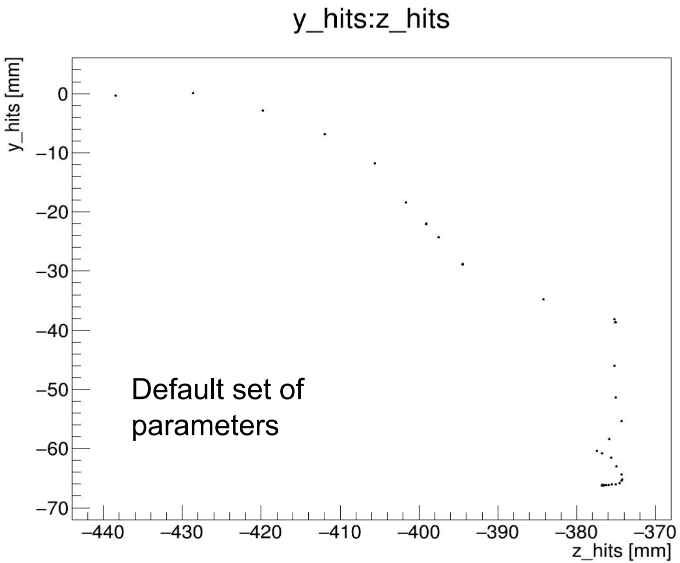
LEMON data sample

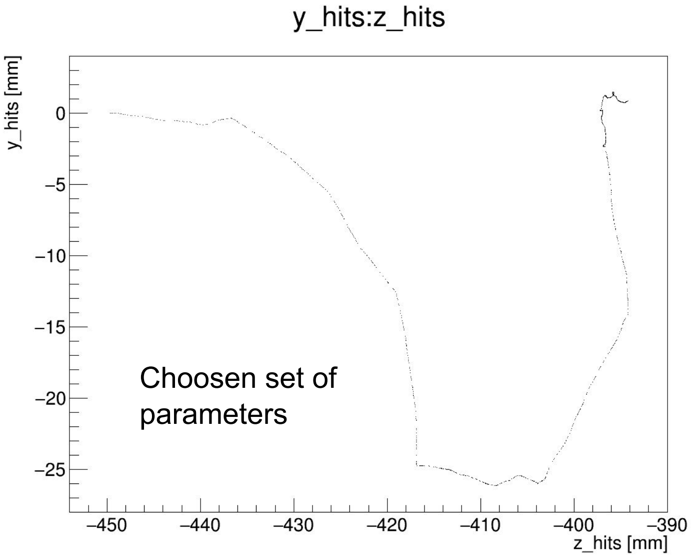


First of all, we noticed that the track density was strongly dependent on some simulation parameters concerning the step length as a function of the energy loss.

We tuned them in order to reproduce:

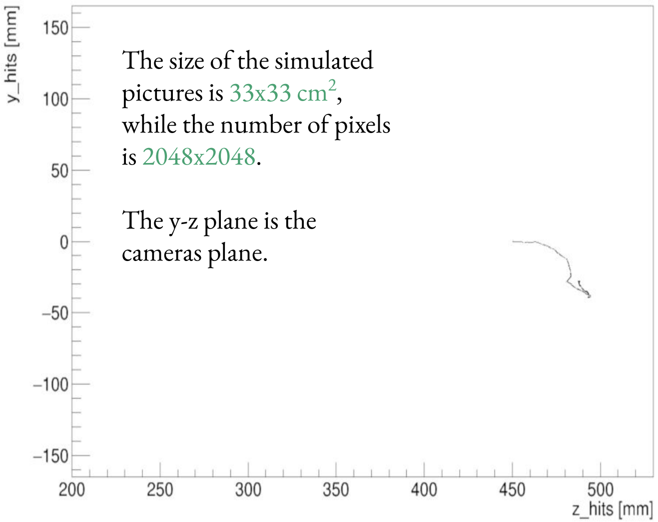
- The energy loss along the tracks (i.e. the gas stopping power)
- The single-hit deposited energy (GARFIELD)





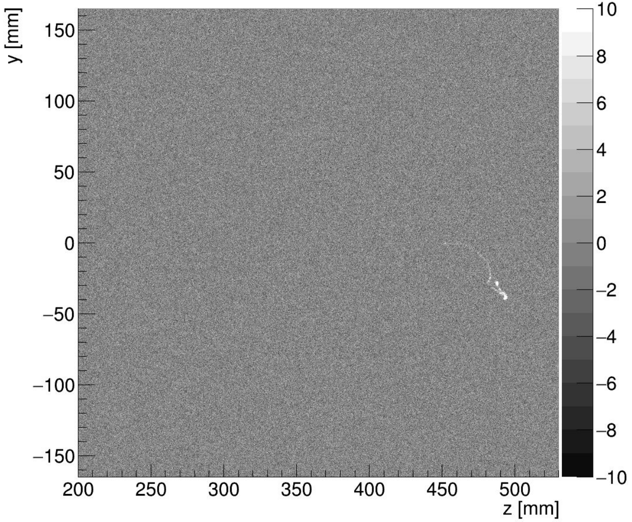
From GEANT4 output to simulated image

We applied to the MC track both the smearing from diffusion and the background from camera noise, using the typical **LEMON parameters**.
The diffusion parameter was extracted from the GARFIELD simulations, while the noise was computed from experimental data.

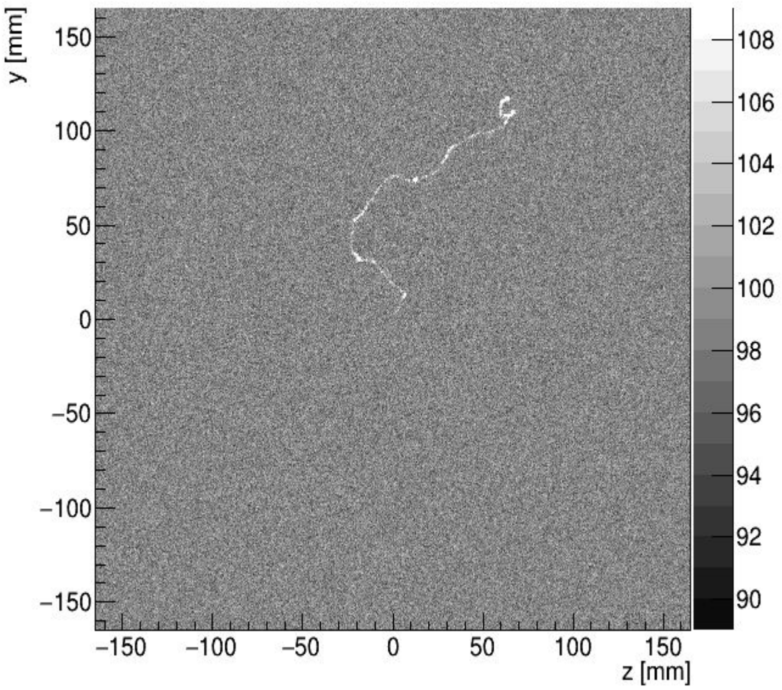


Diffusion parameter, which is the sigma of the gaussian distribution of the diffused photoelectrons, is 0.5mm

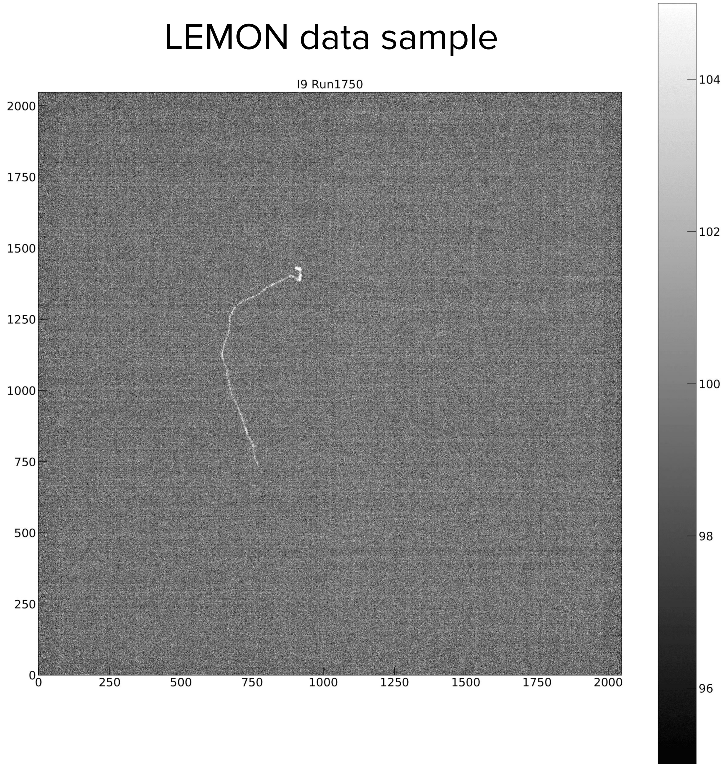
Noise is a gaussian centered on the pedestal with a sigma of 2 photoelectrons per pixel



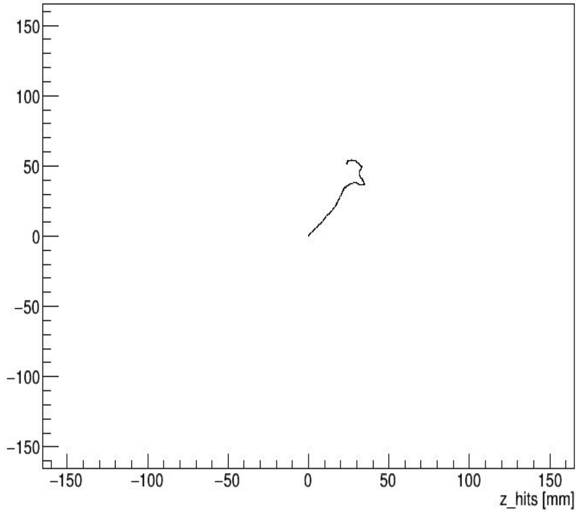
Simulated image



LEMON data sample

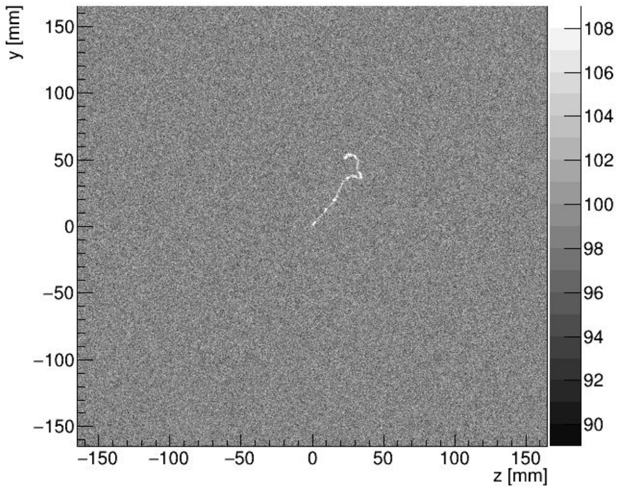


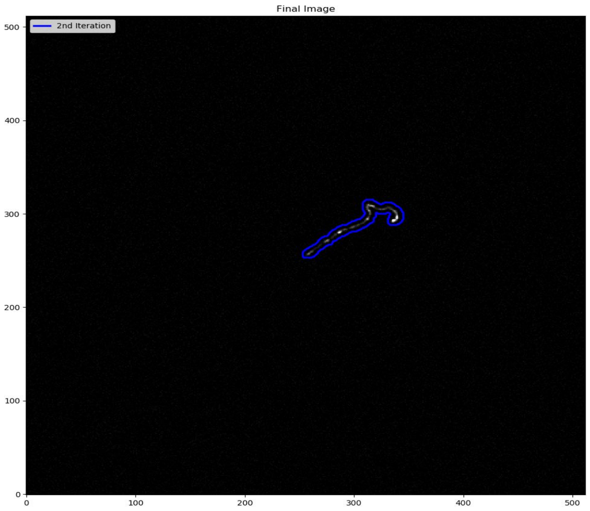
From now on, MC data are available for IDBSCAN2



GEANT4 output

Initial energy: 100keV





IDBSCAN2 output

Reconstructed energy: 96 keV