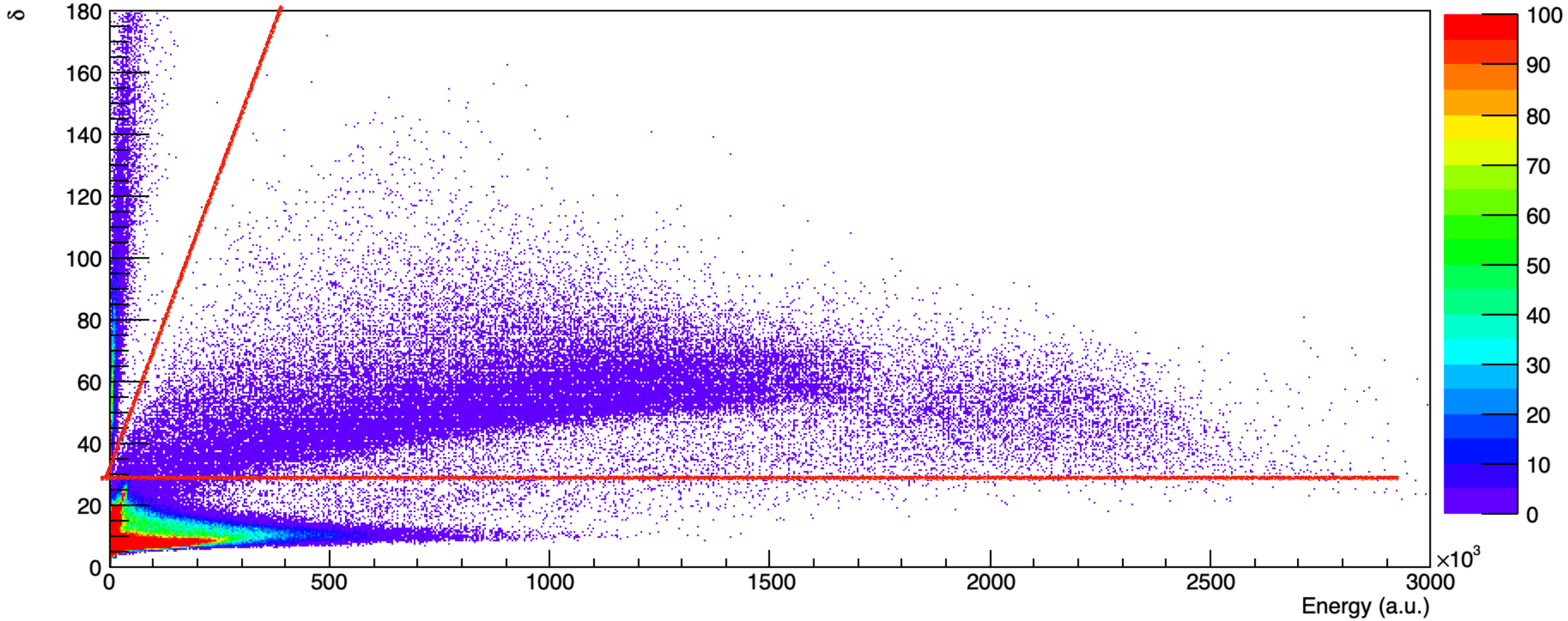
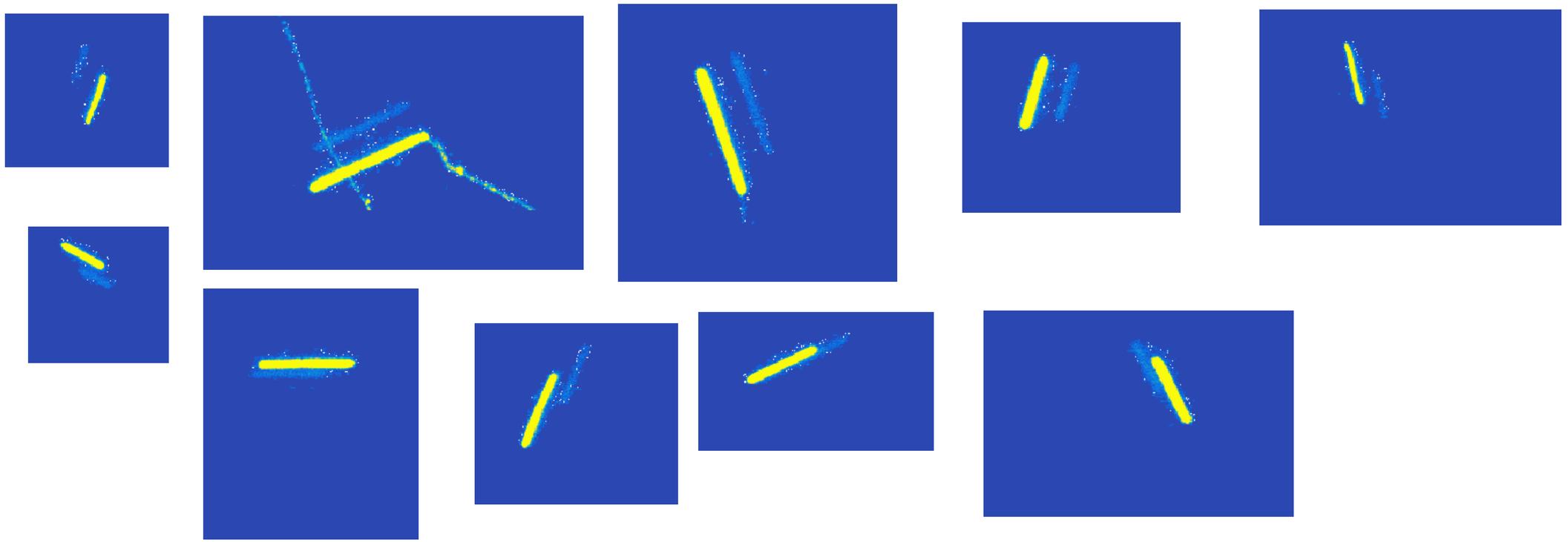
Studies on alphas

The Radon Contamination

- To select alpha we use their large energy density (δ = sc_integral/sc_nhits) > 30;
- nhits>1000;

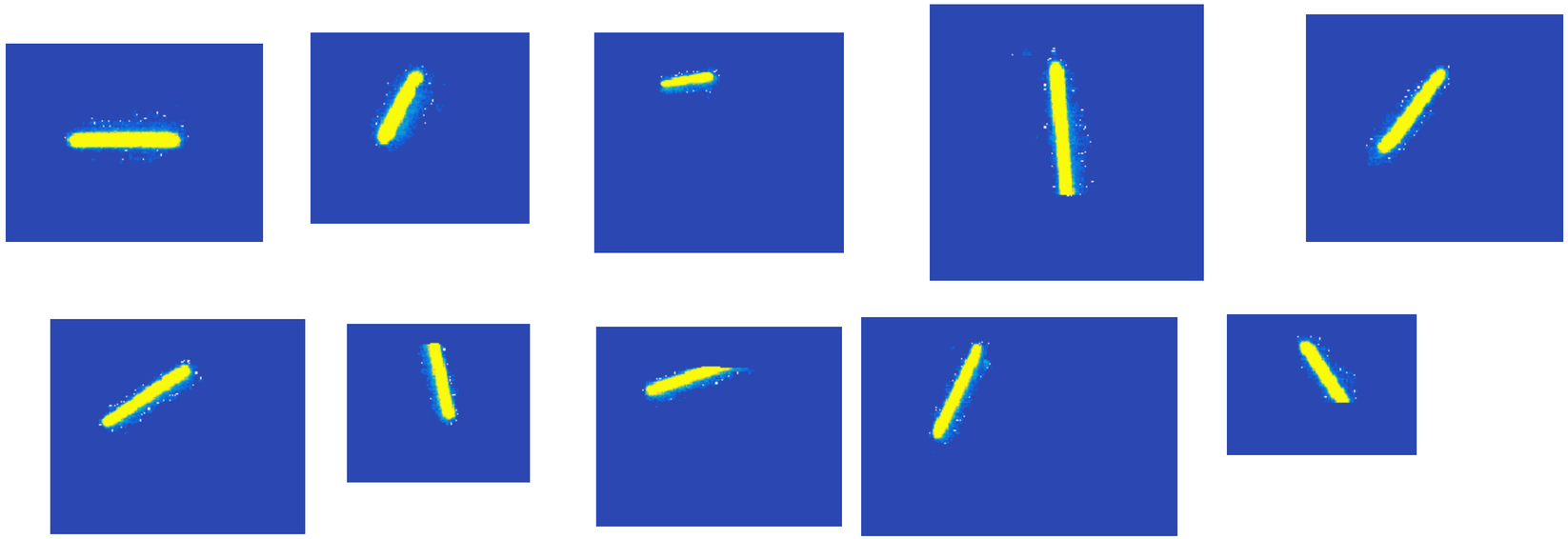


The alpha selection



- These are the first 10 selected events

The alpha selection with occupancy>0.7



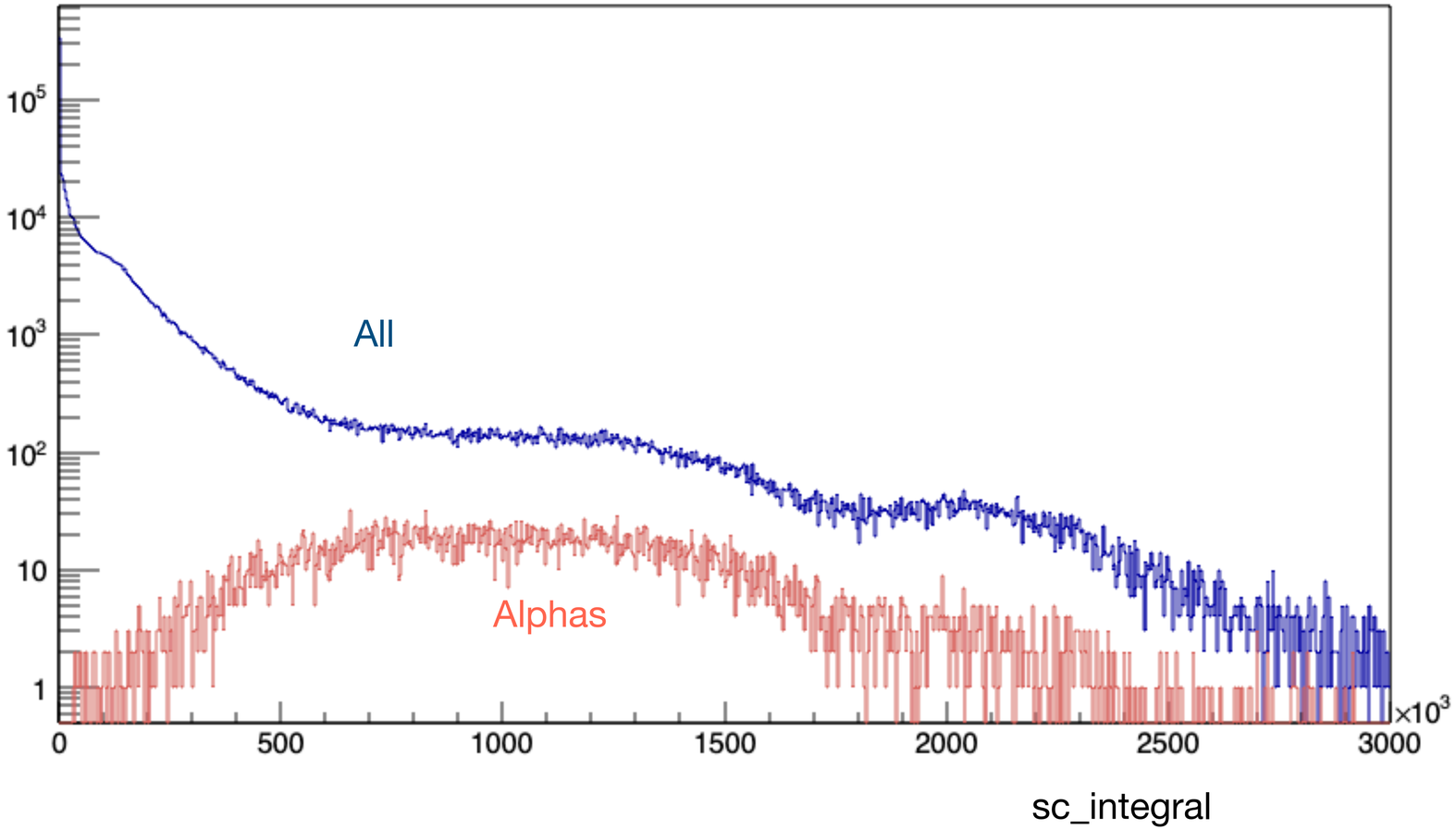
- These are the first 10 selected events

The data sets

- At the beginning of RUN4, we took to very long and stable data-set:
  - Set#1: Runs in the interval 40919-42848 taken 4/14 December 2023 (with a high number of alphas)
  - Set#2: Runs in the interval 43886-46628 taken 15/23 December 2024 (with a lower number of alphas)

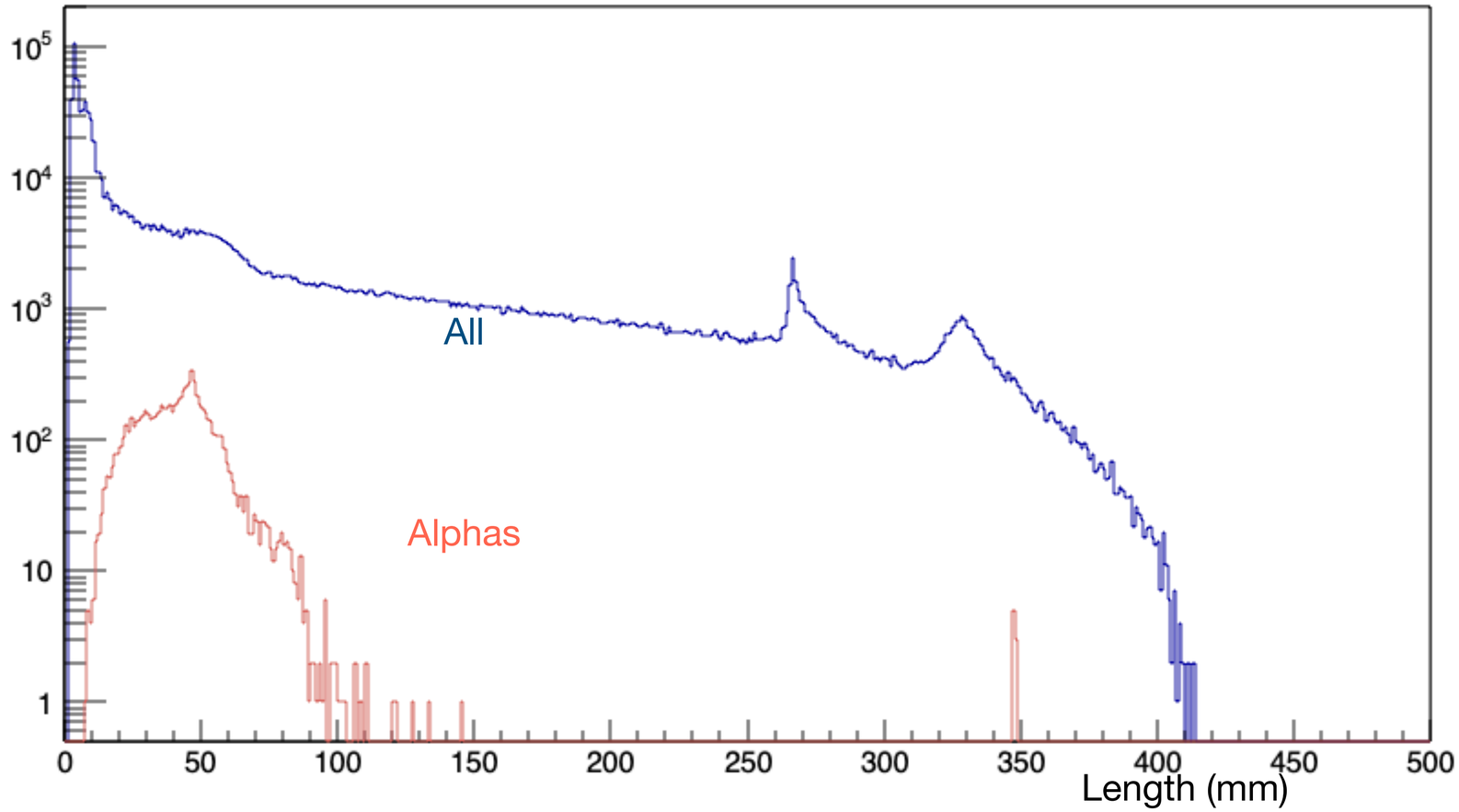
The sc_integral spectrum

- Set#1: Runs in the interval 40919-42848 taken 4/14 December 2023 (with a high number of alphas)



The sc_length spectrum

- Set#1: Runs in the interval 40919-42848 taken 4/14 December 2023 (with a high number of alphas)



The alphas spectra

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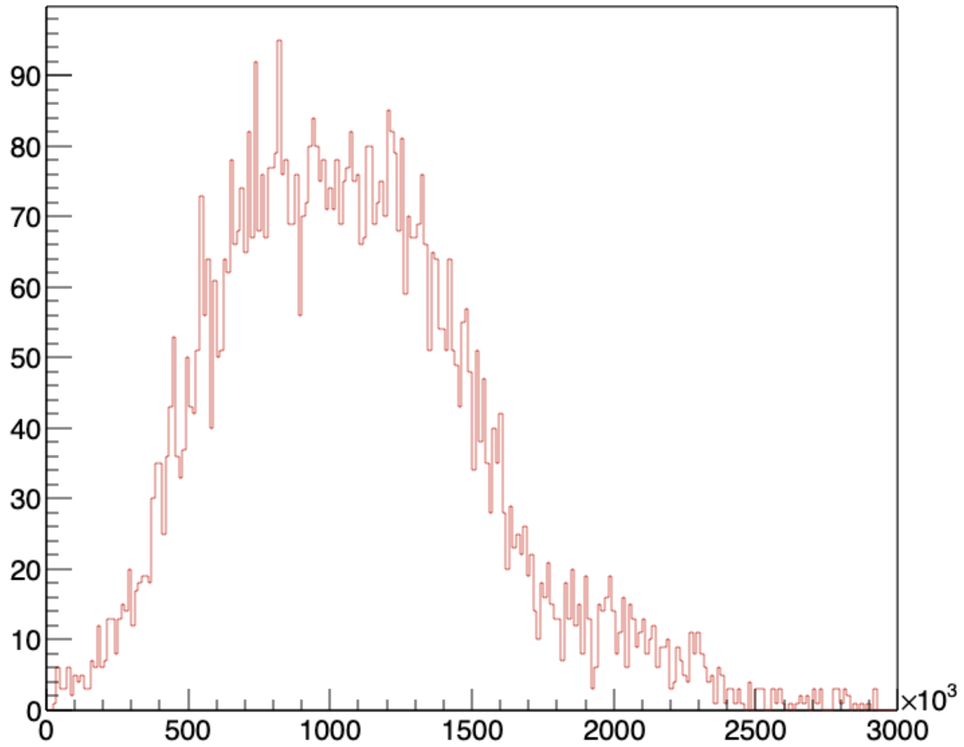
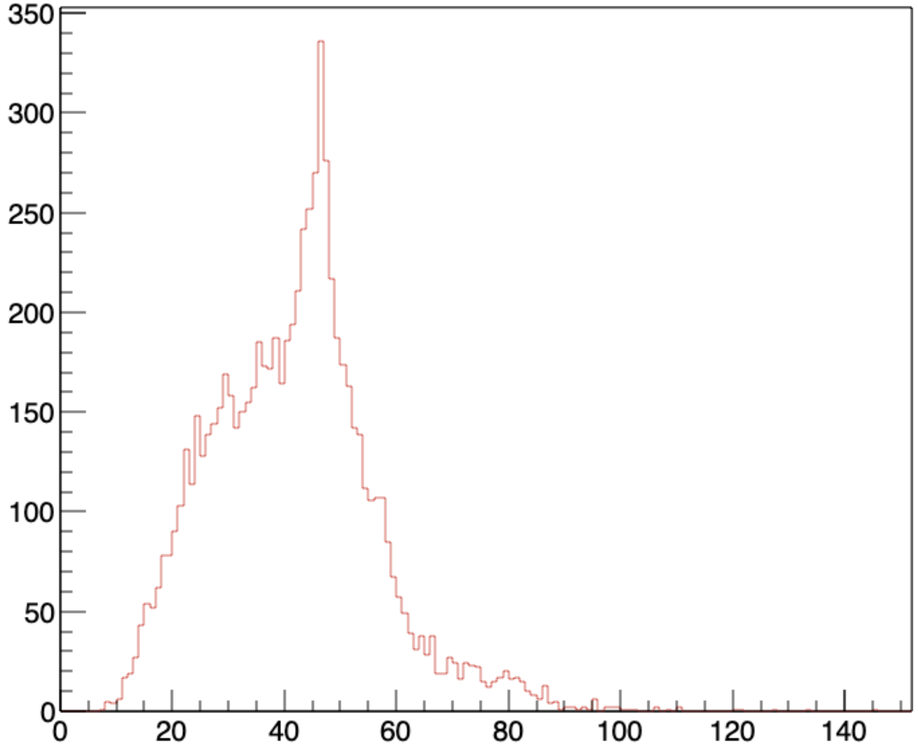


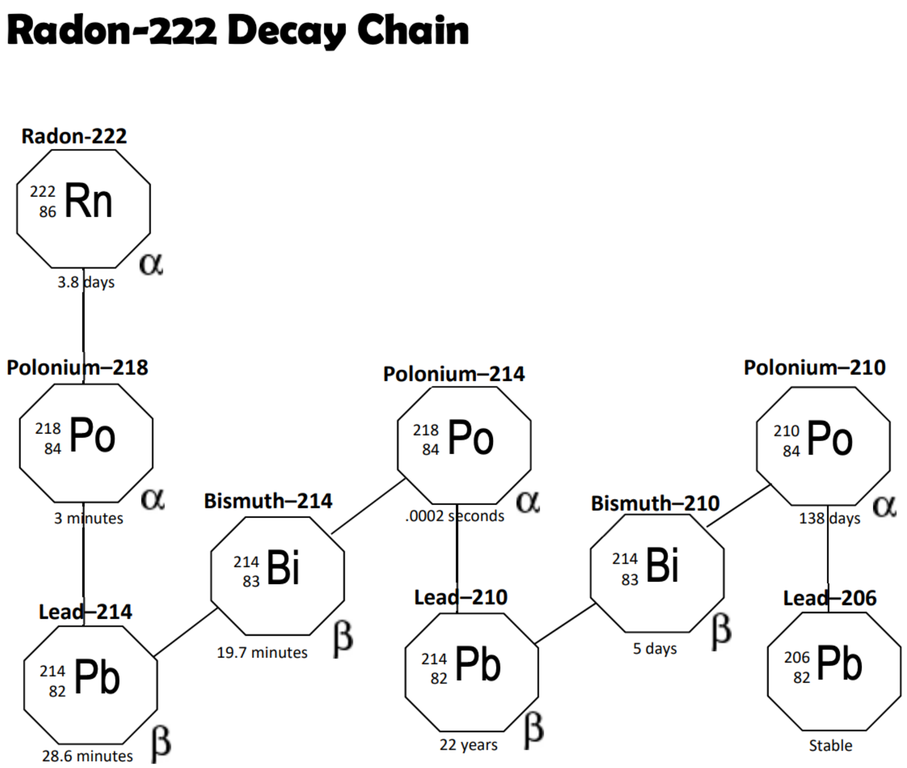
sc_integral

Alphas



Length (mm)

The Radon Contamination



- So, a Rn contamination would produce:
  - 3 alphas:
    - ^{222}Rn -> 5.590 MeV (about 43 mm)
    - ^{218}Po -> 6.115 MeV (about 50 mm)
    - ^{214}Po -> 7.833 MeV (about 73 mm)
  - 2 betas
  - a lot of gammas from 50 keV to 2200 keV

arXiv:1501.07757v1

The Radon Contamination

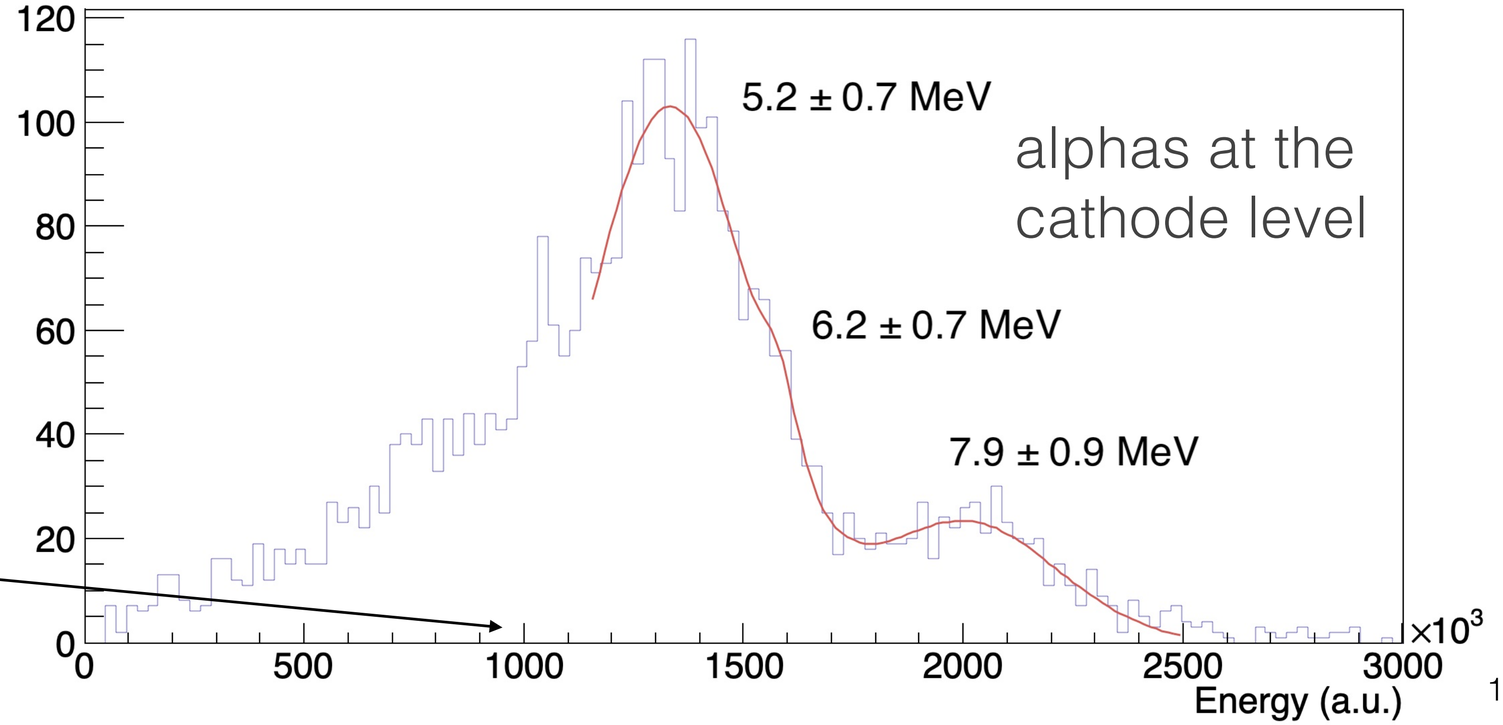
We have shape variables that are a good indicator of the cluster distance from the GEMs

It seems to confirm that the 50 mm component has a large spread in Z while the 80 mm one is concentrated at high Z;

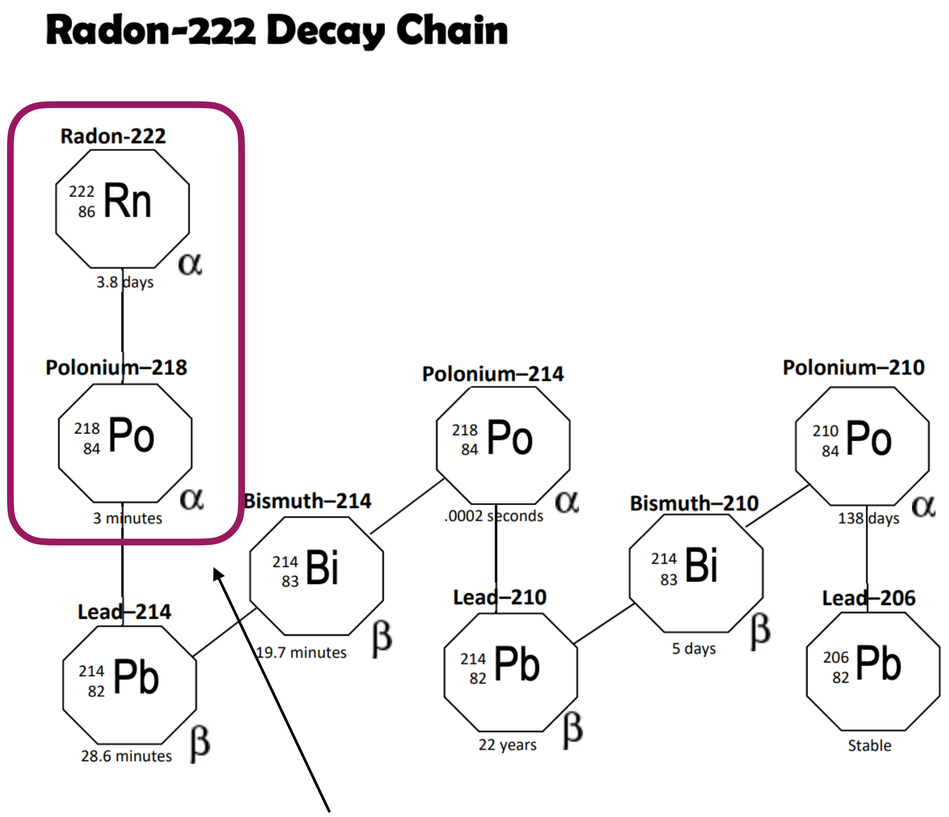
As if it is produced at the cathode level. This is compatible with the production of a positive ion after two beta decays, that do not neutralise and lives enough to reach the cathode

For the alphas at the cathode level we can also infer their energies, that are compatible with the expected ones (5.6, 6.2, 7.8 MeV)

Note anyway the the energy scale is arbitrary: here we should have 0.6 MeV in ^{55}Fe scale



The Radon Contamination



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  - 2 betas
  - a lot of gammas from 50 keV to 2200 keV

Since the gas flow is of the order of tens of liters/hours, an atom spends several hours with the gas volume and we should in principle see it decays and these correlated alphas

arXiv:1501.07757v1

The Radon Contamination

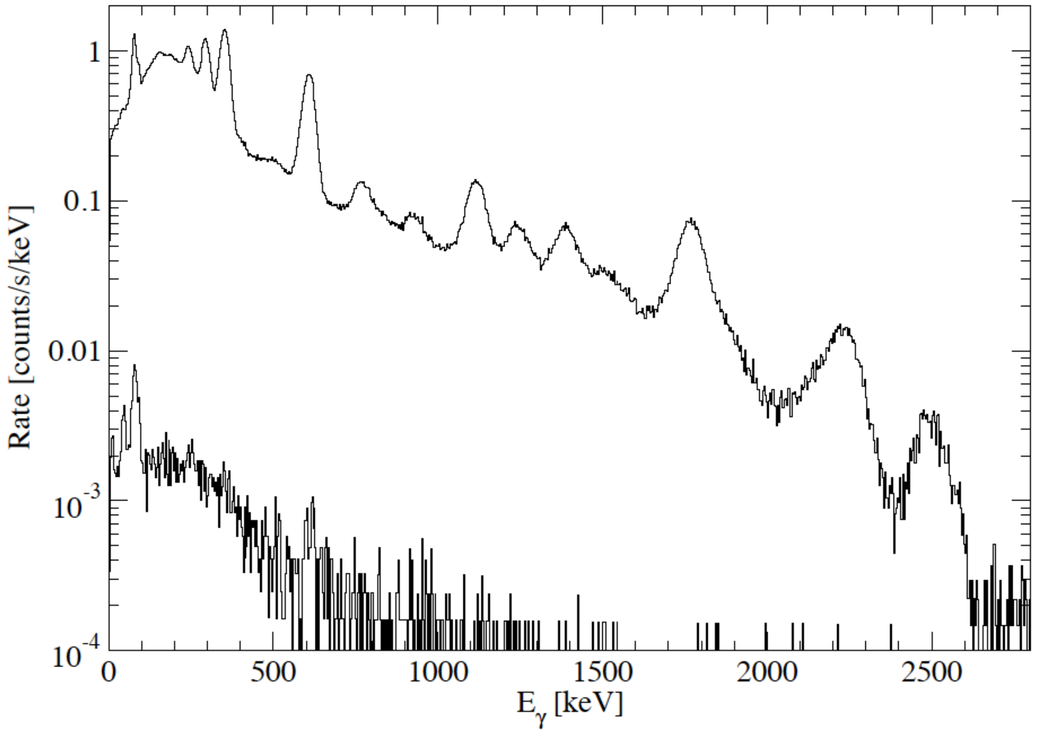


Figure 3: Spectra collected underground before charging the oil with radon (lower graph) and during a radon run (upper graph).

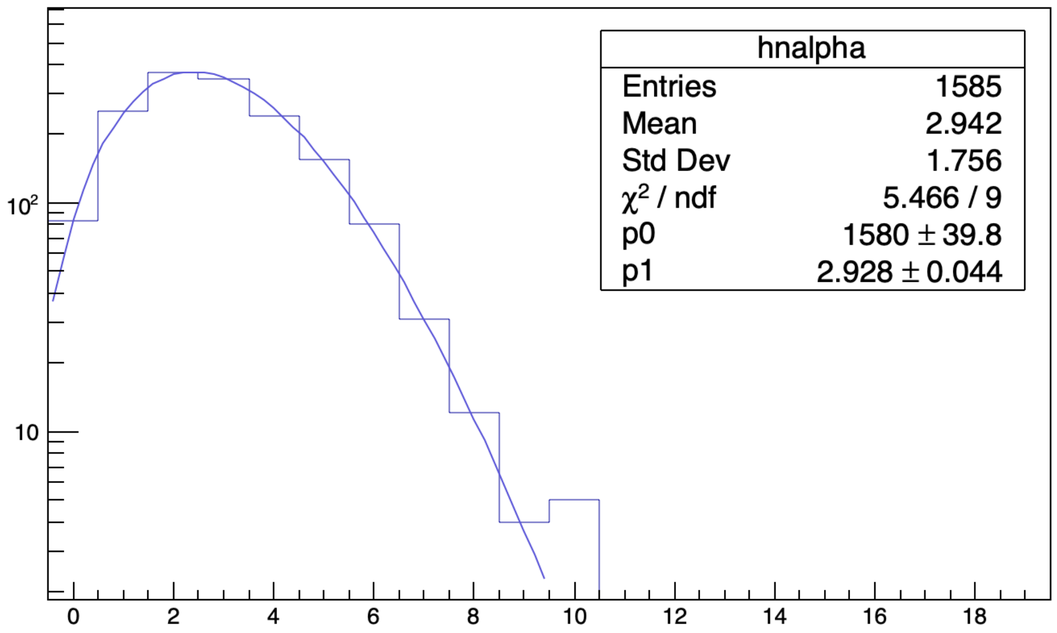
Isotope	Decay type	half-life	Gamma energy [keV]	Relative probability
^{222}Rn	α	3.8 d		
^{218}Po	α	3.1 m		
^{214}Pb	β	26.8 m	242	7%
			295	18%
			352	36%
^{214}Bi	β	19.9 m	609	45%
			768	5%
			934	3%
			1120	15%
			1238	6%
			1378	4%
			1764	15%
			2204	5%
^{214}Po	α	164 μs		
^{210}Pb	β	22.3 y	46.5	4%
^{210}Po	α	138 d		
^{206}Pb				

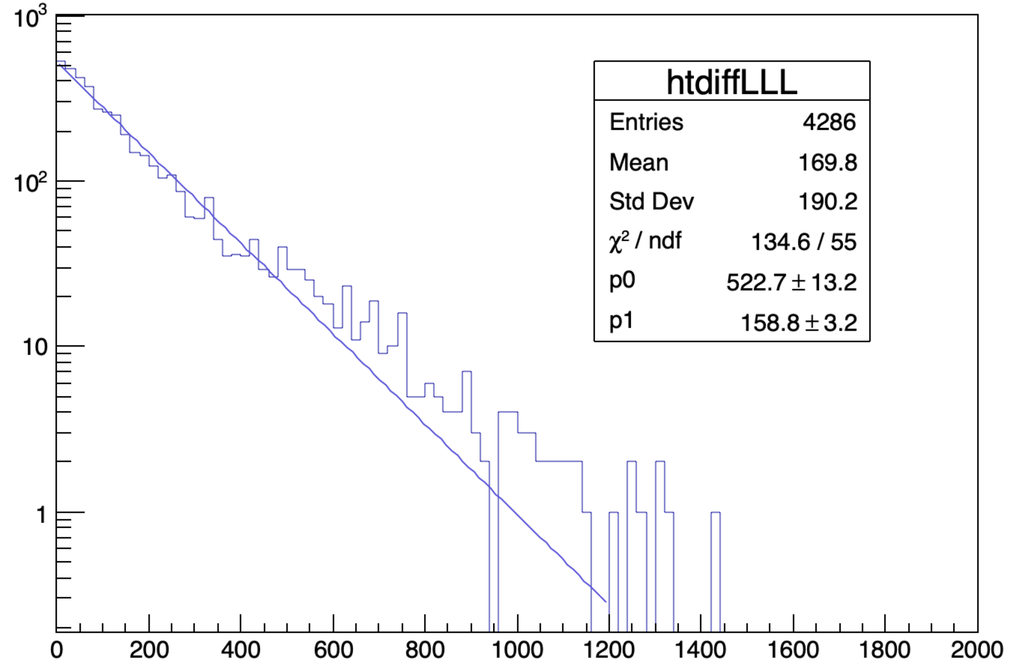
- Therefore we should expect a increase allso of the low energy part of the spectrum

The Rn decay and MC

- In the Rn chain, two alphas of “similar” energies (5.59 MeV and 6.11 MeV) are expected to be produced with a time interval exponentially distributed with a time constant of about 260 sec;
- We cannot easily identify the first (F) and the second (S);
- We can try to study anyway the distribution of the time distance of all possible pairs of successive events: if the average time distance between two F is larger than 260 seconds we can expect it to be dominated by the S production
- I developed a simple toyMC, with F randomly distributed in time producing S with a decay time of 300 units;
- In the MC each bin in time is 10 units;
- In the data, the unit is the interval between 2 images. It changes between the two data sets (1.25 sec in Set#1 and 1.45 sec in Set#2);

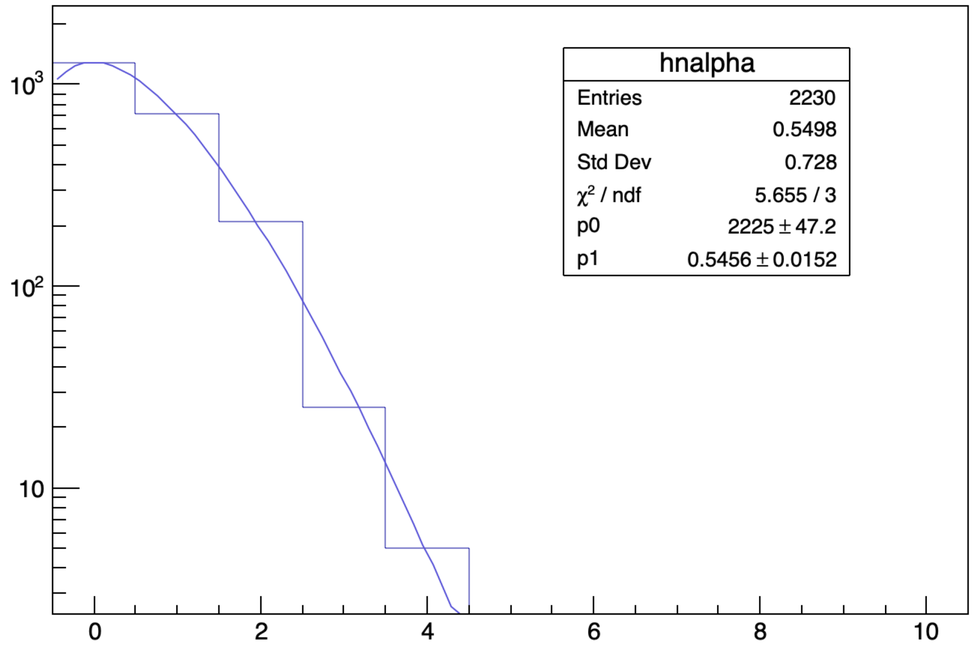
Set #1

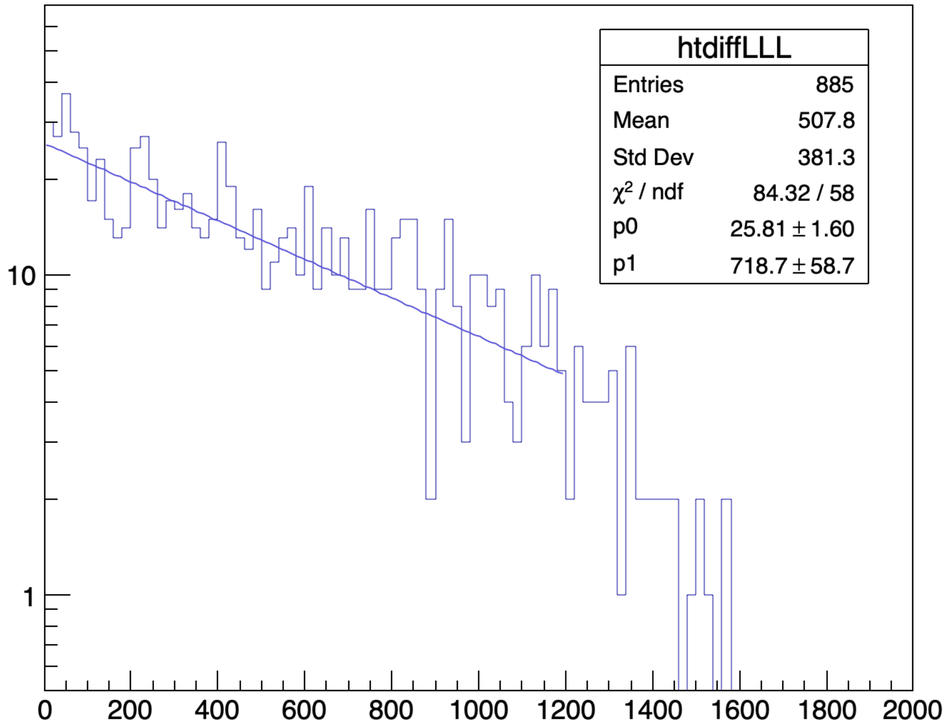




- In total we found 4313 alphas in 1589 runs (635615 images);
- if randomly distributed, 147 img in average between two consecutive alphas in good agreement with the exponential fit;
- from the Poissonian fit with could expect 400/2.9 = 137 images

Set #2

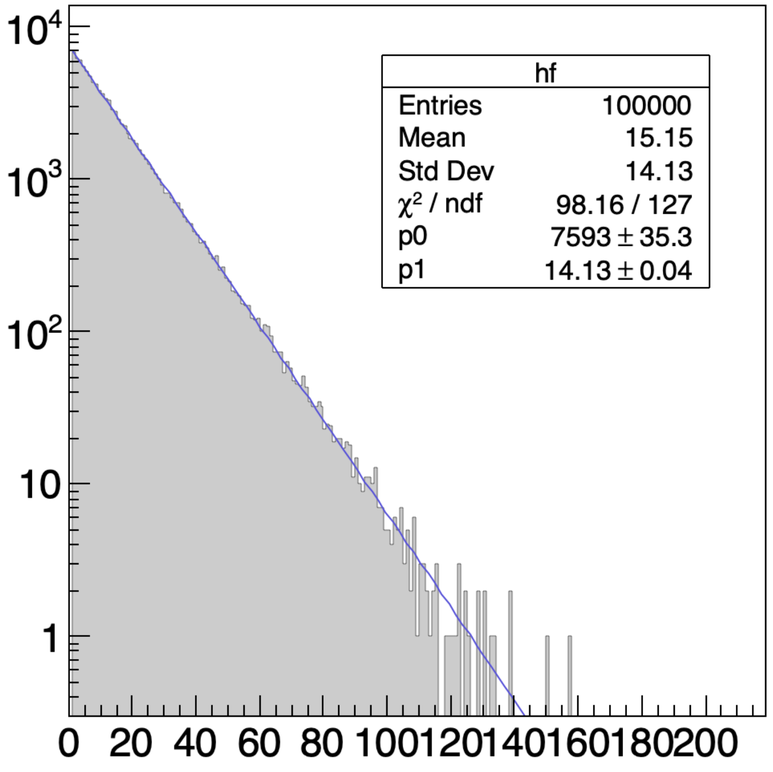


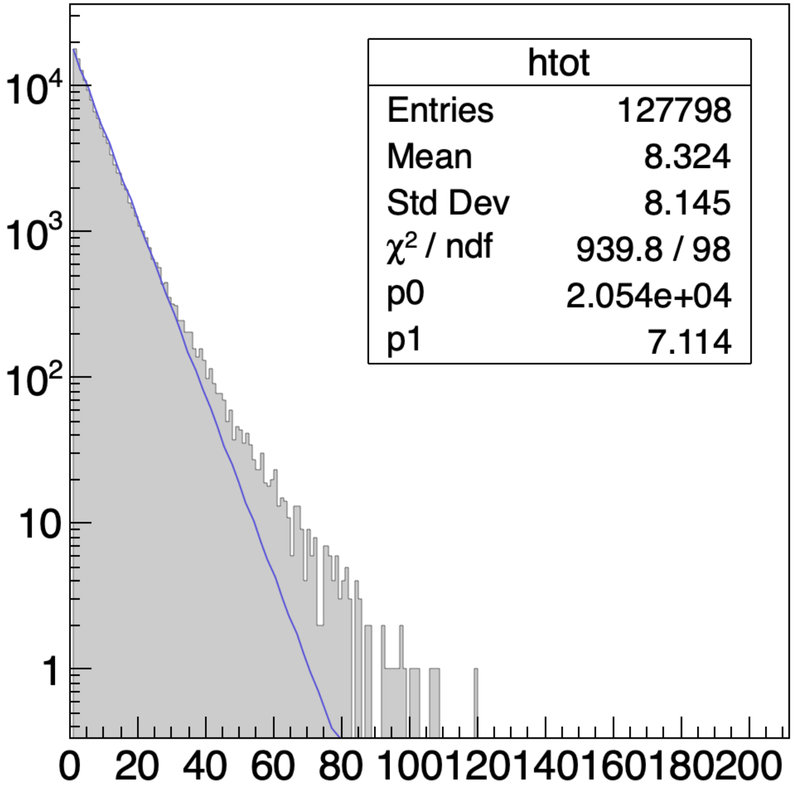


- In total we found 1146 alphas in 2135 runs (854217 images);
- if randomly distributed, 788 img in average between two consecutive alphas in good agreement with the exponential fit;
- from the Poissonian fit with could expect 400/0.54 = 727 images

MC-Set #1

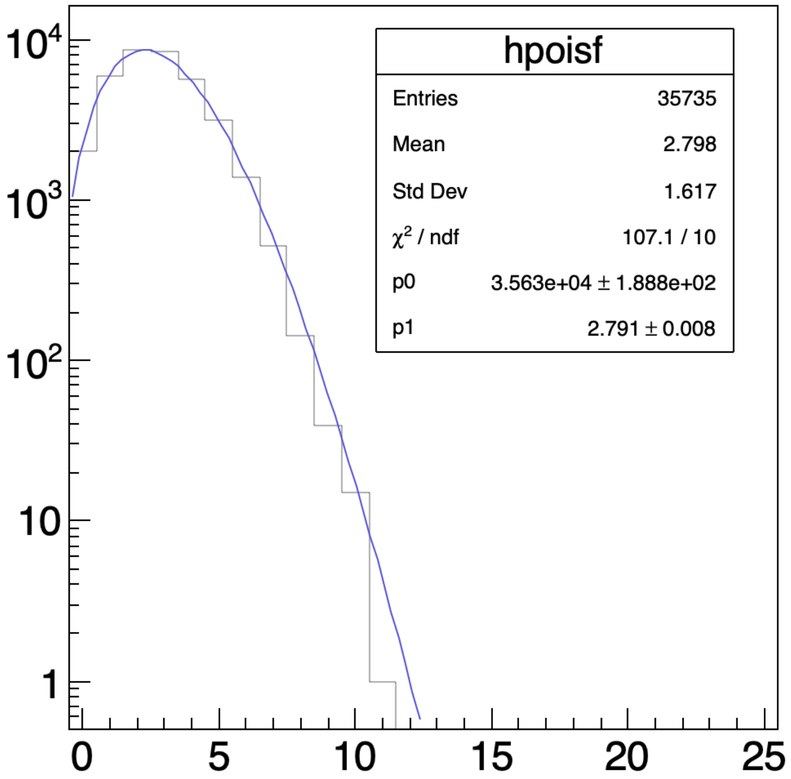
- Simulated F with a probability of 1/15 per time unit. Very good exponential



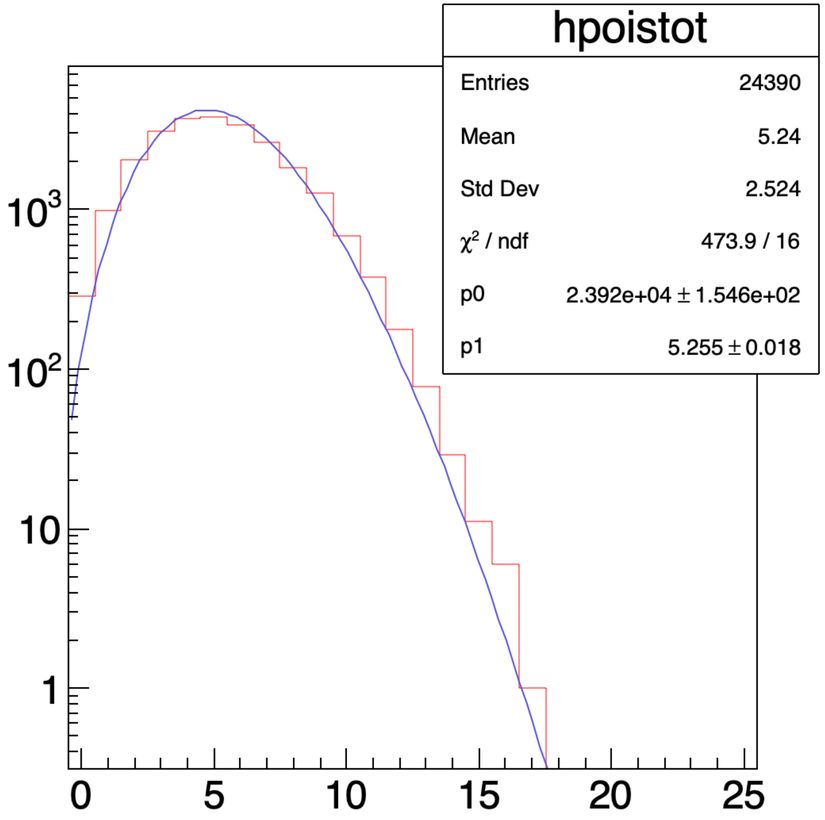


- By turning On the decays with a tau of 30 units, the spectrum shrinks and is less exponential

MC-Set #1



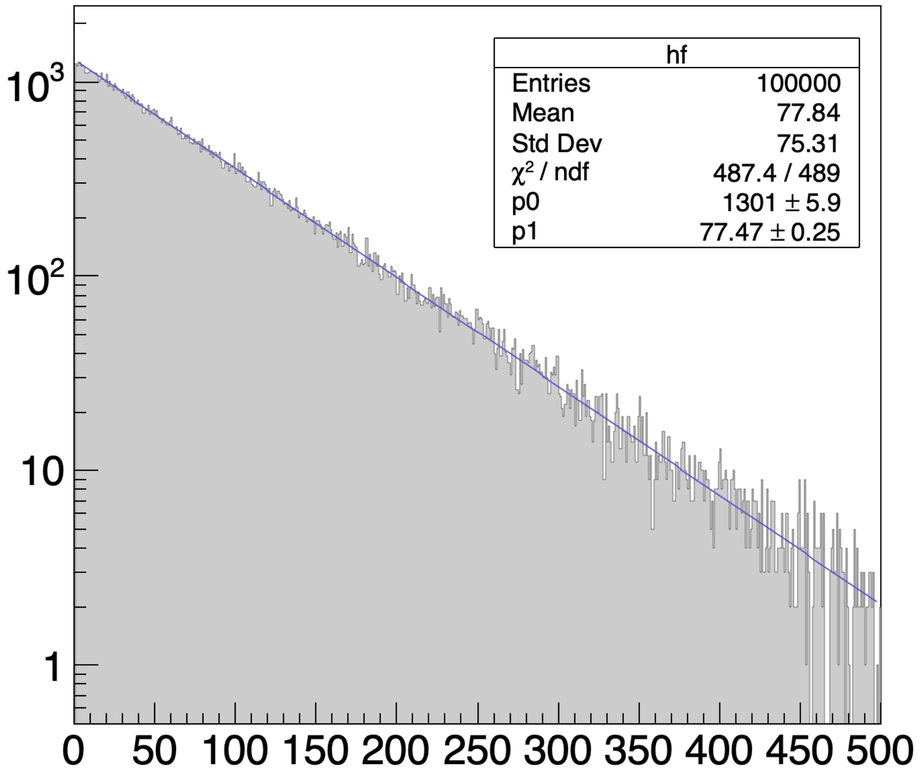
The number of alphas per run spectra are different for the only F randomly distributed and the F and S because of the correlation between them

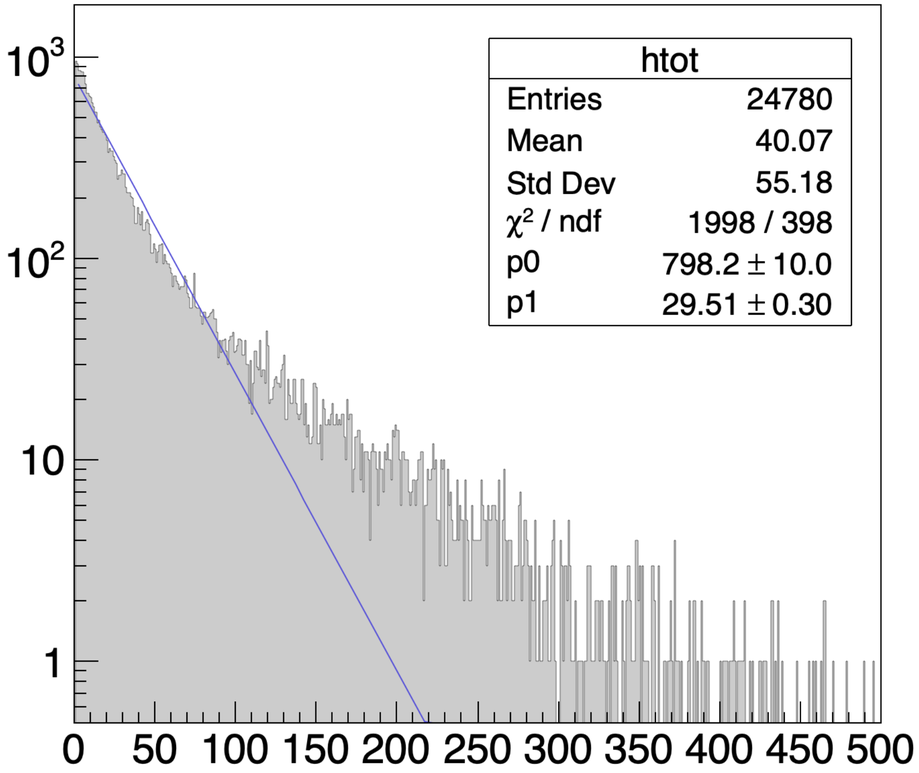


- Both of them are poissonian

MC-Set #2

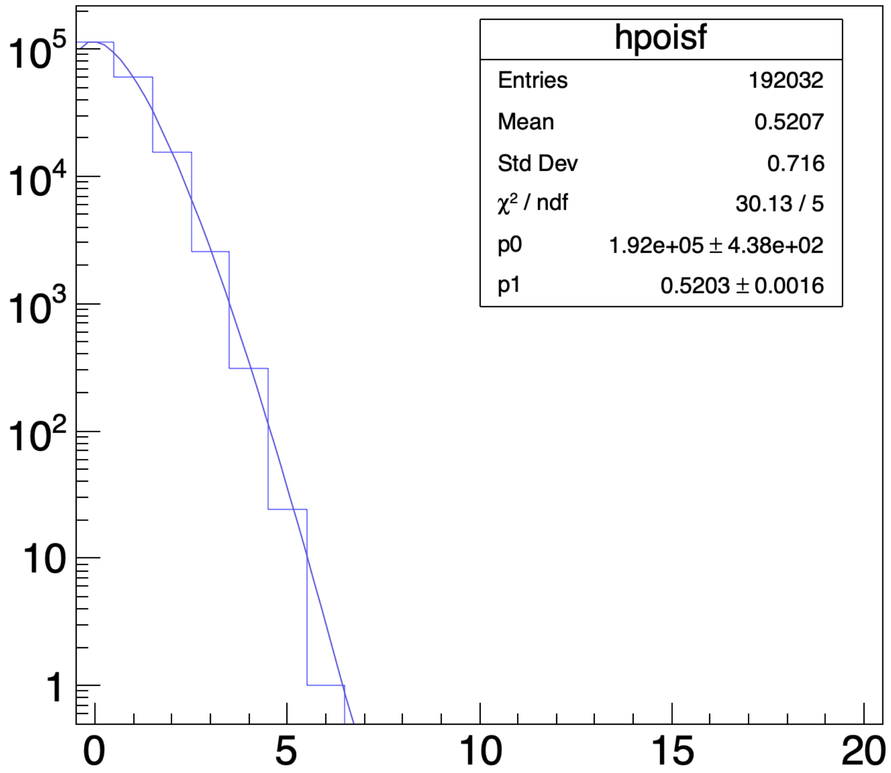
- Simulated F with a probability of 1/79 per time unit. Very good exponential



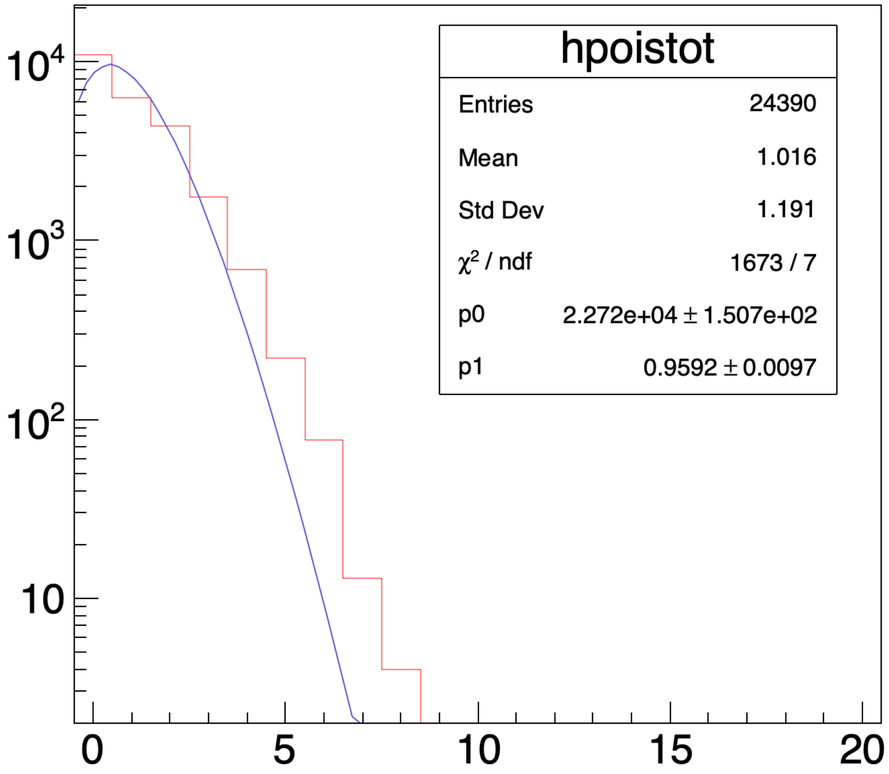


- By turning On the decays with a tau of 30 units, the spectrum shrinks and no longer exponential and on the first part the tau = 30 appears;

MC-Set #2

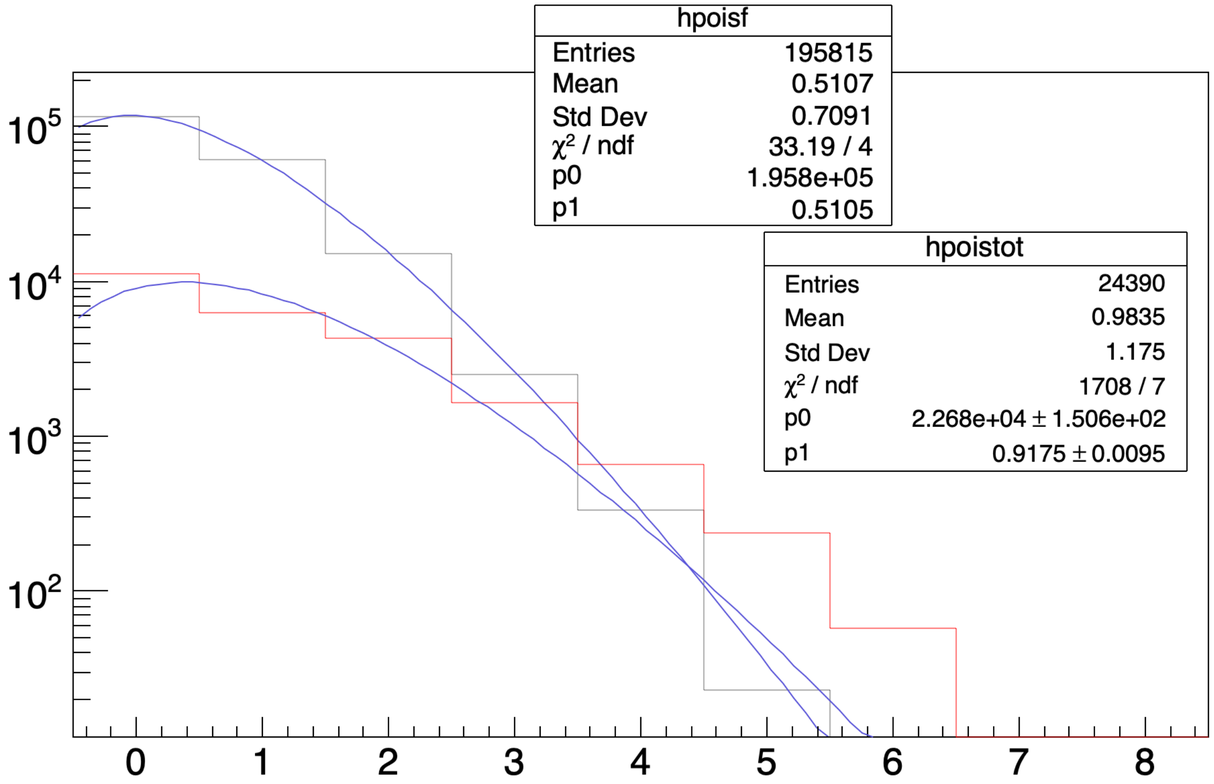


The number of alphas per run spectra are different for the only F randomly distributed and the F and S because of the correlation between them



- In particular, the number of alphas per run is expected to be “not-poissonian” if alphas are mixed F and S

MC-Set #2

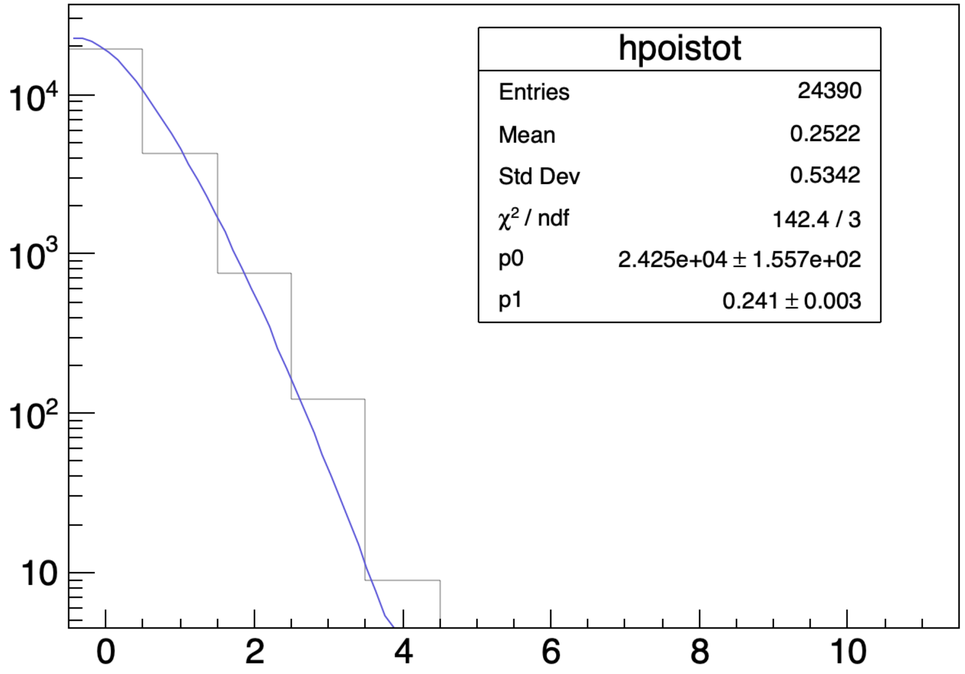


- The number of alphas per run spectra are different for the only F randomly distributed and the F and S because of the correlation between them

- In particular, the number of alphas per run is expected to be “not-poissonian” if alphas are mixed F and S

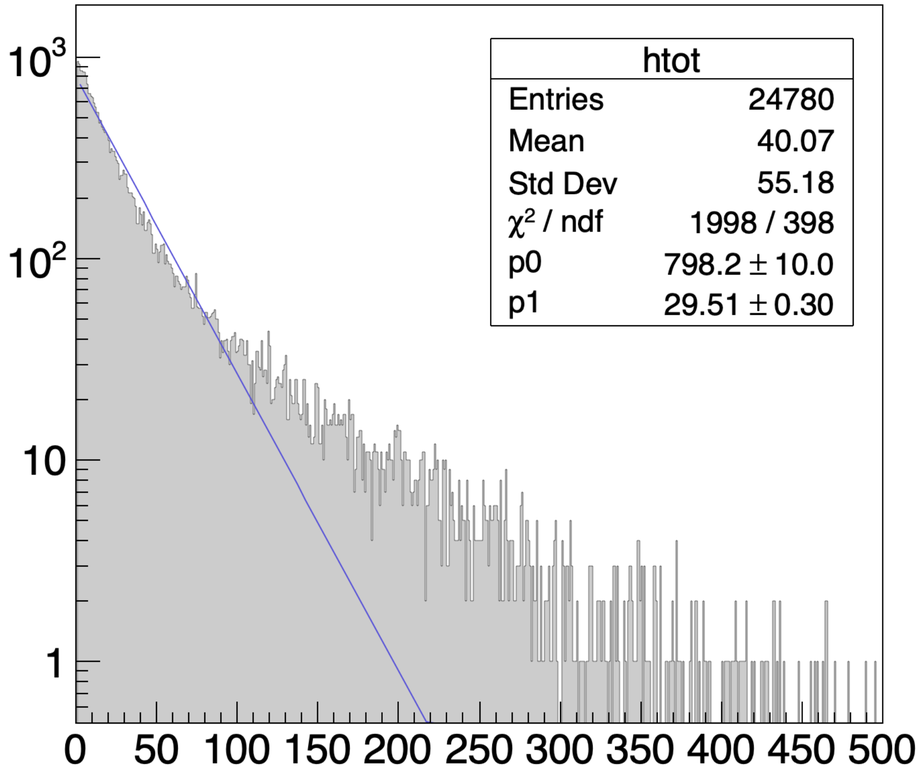
Why are experimental data poissonian

- Why can’t we see any evident correlation between the pairs of alphas?
- A possible explanation was suggested by Stefano and Giorgio: if “geometrical” efficiency is low (i.e. atom can diffuse in regions of the gas volume that are not acquired), it is very likely to miss the F or the S some pair and to then loose the correlation;
- Adding a geometrical efficiency of 30% produces a poissonian distribution similar to the experimental on

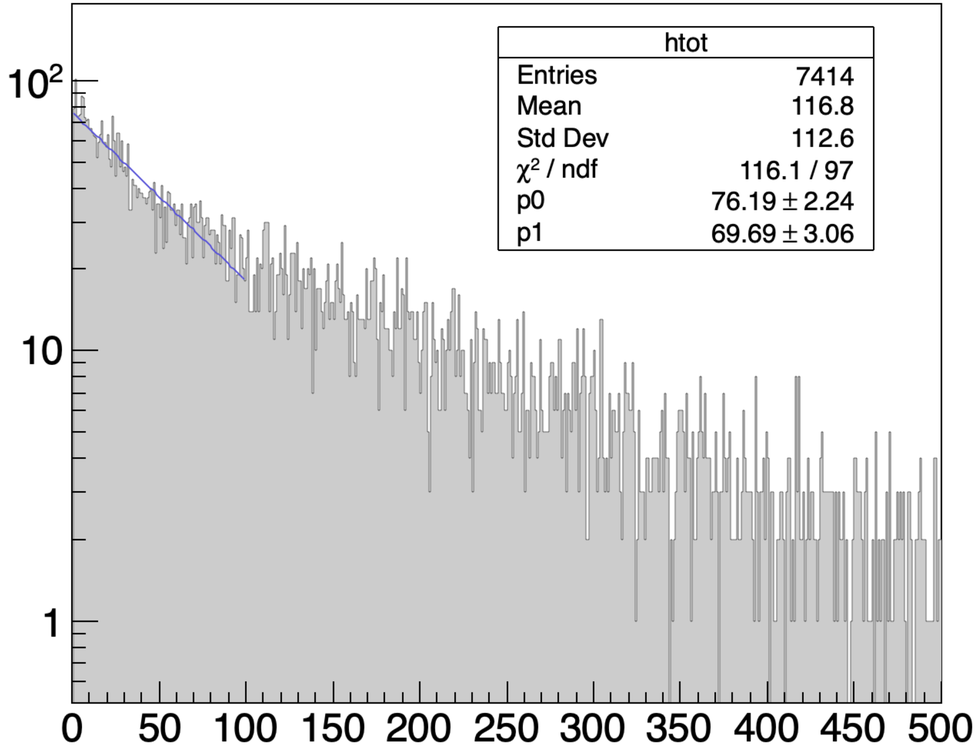


MC-Set #2

geometrical efficiency of 100%



geometrical efficiency of 30%

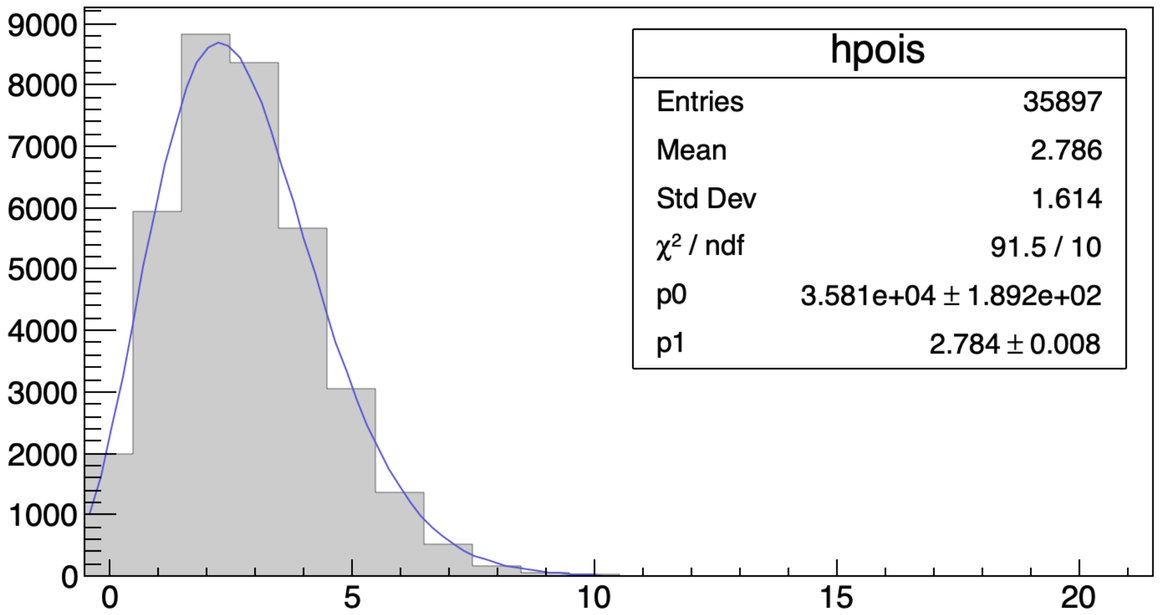


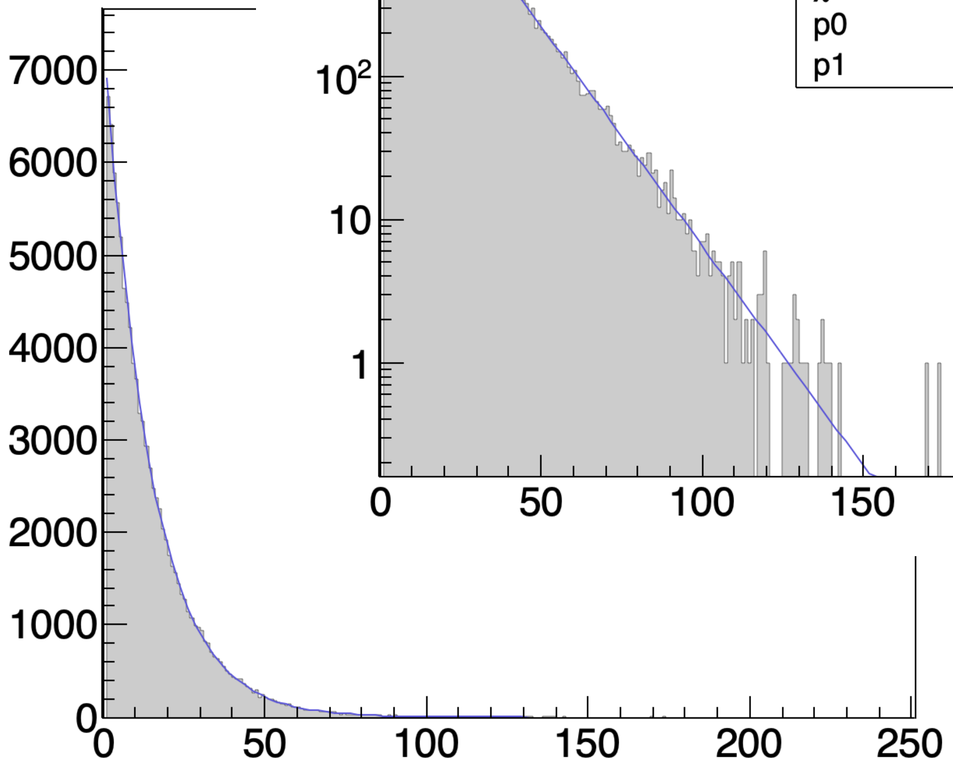
- An also in the time difference distribution, the right time constant is lost

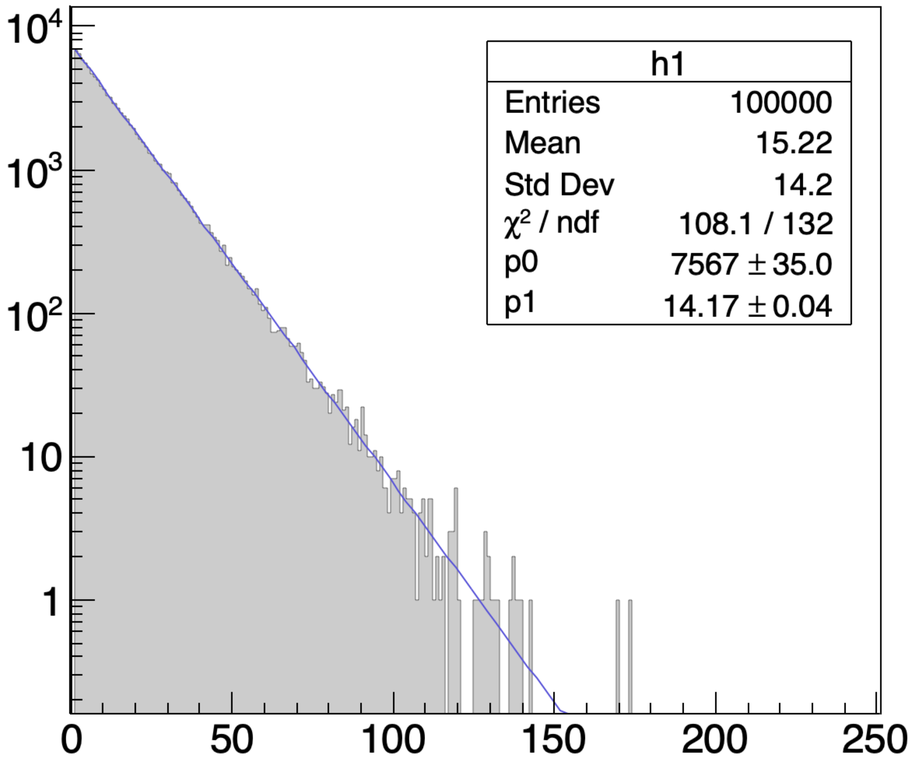
Conclusion

- Identify the presence of Radon in LIME it's crucial to understand its behaviour, to explain the differences data/MC, to have indication about possible interventions to upgrade the detector performance and radioactivity background;
- Lifetime would have been a very strong signature, but seems not feasible;
- Energy resolution is not that bad, but we should have experimental (if possible) and simulation reliable indications about the absolute scale.
- The AmBe data are one possibility to evaluate the "saturation" order of magnitude at the MeV scale;
- The new and fast digitisation (once the saturation parameters are checked and certified) will also help to simulate 5-8 MeV alpha signals;
- What about old data of ^{241}Am in Mango? Do we have long drift paths?
- Can we think to some test on GIN with ^{241}Am?

The alpha/run spectrum







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