Last analysis meeting 2024

Update on Rn studies

Alpha energies - Final results

- The final results of the measurement of the alpha energies was carried out using the new absolute Z calculation (with the ***profile RMS***).
- The data was cut in absolute Z and Z angle, to normalize the saturation effect.
- Several cuts were tested, with similar results.
- The length distribution shows three distinct peaks, which we can use to separate each alpha contribution to the final energy spectrum.

properly determine the expected value of Z, we use the approach presented in [1], and later adapted by the CYGNO group in [2]. In these works, the absolute Z is defined as:

$$Z = \frac{\sigma^2 - {\sigma_0}^2}{{\sigma_T}^2} \tag{1.2}$$

where, for LIME (extrapolated from the measurements done with LEMOn [2]), the transverse diffusion coefficient σ_T was measured to be $\sigma_T = 129.7 \pm 3.1\ \mu m/\sqrt{cm}$ and the intercept at zero, i.e., the contribution of the electron avalanche at the amplification stage, to be $\sigma_0 = 292 \pm 12\ \mu m/\sqrt{cm}$.

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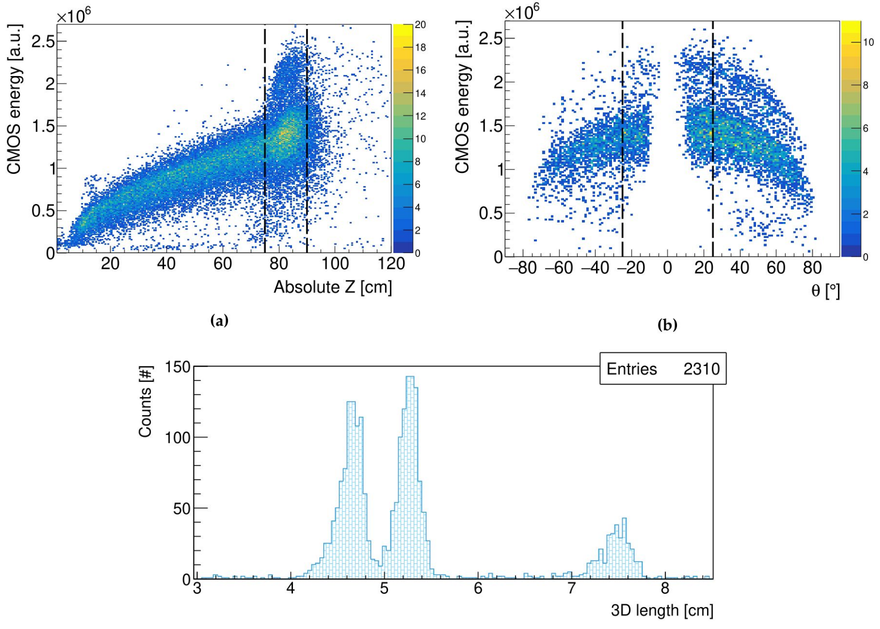
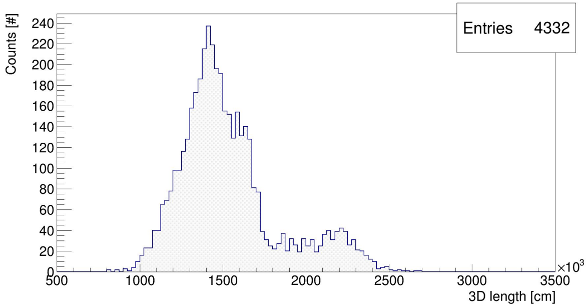


(c)

Figure 1.20: Relations between CMOS measured energy and (a) absolute Z, and (b) θ angle, with the cuts applied in each relation overlaid as black lines. (c) Obtained distribution of alpha 3D lengths using the cuts showed in (a) and (b). >[I have this spectrum also fitted, but I think here is not needed for the discussion.]<

Alpha energies - Final results

- The resulting energy spectrum has been fitted with 3 CrystalBall functions (~ gaussian + exponential tail) since this better represents the saturation effect. This method also better fits the individual contributions obtained by cutting the data using the (very good) length selection.



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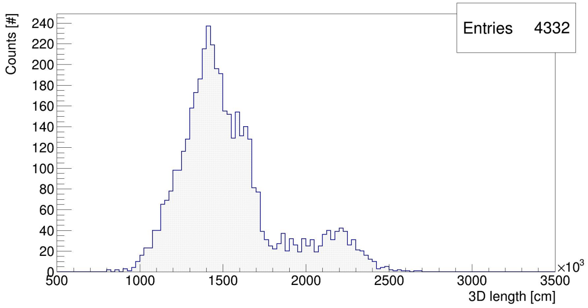


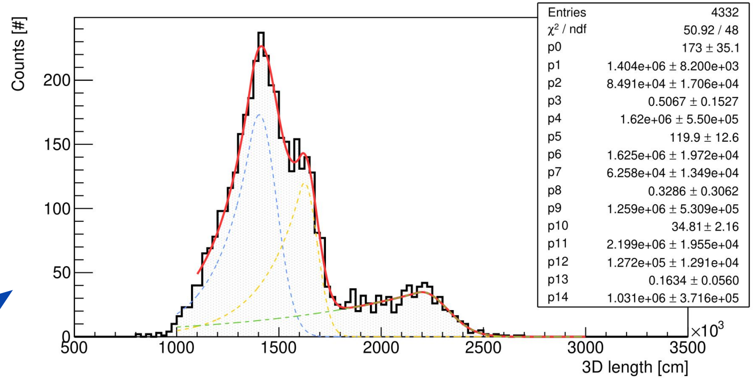


Figure 1.21: Distribution of measured CMOS energy using the data cuts mentioned in figure 1.20. The data was fitted with 3 Crystalball functions. Each of these fits is also showed in colored dashed lines.

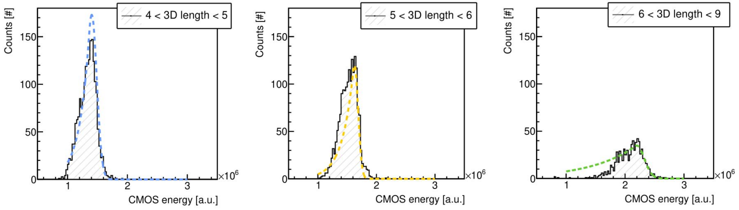
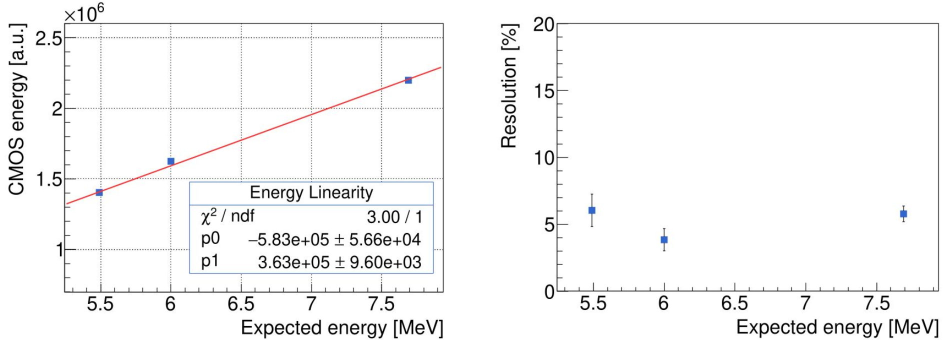


Figure 1.22: Individual Crystalball fits used to fit the CMOS measured energy in figure 1.21. Each fit is overlaid with the CMOS distribution obtained by cutting the data using the 3D length of the alphas. From left to right, using "l" as 3D length in cm, the cuts are: $4 < l < 5$; $5 < l < 6$; and $6 < l < 9$.

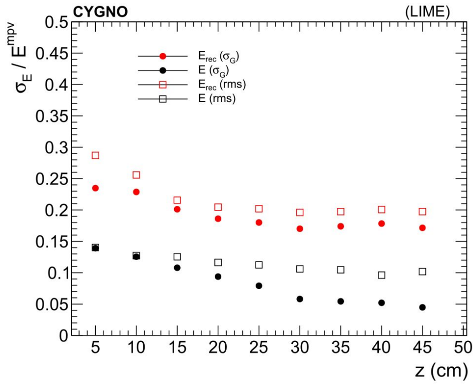
Alpha energies - Final results

- The (limited) linearity and resolution can be calculated by fitting the means of each crystalball, and by dividing the sigma by the means, respectively.
  a. The points decently align, assuming a free 0-cross.
  b. The results are compatible with the resolution of 55Fe, although a strong selection was applied (only 7% of total events used), so the direct comparison is rather hard.



(a) Linearity **(b)** Resolution

Figure 1.23: Energy (a) linearity and (b) resolution obtained using the fit parameters showed in figure 1.21.



Alpha energies - Final results

- We can measure the energy of alphas (~NR) with a linear response
  - Driven by the different lengths with same dE/dx
- Using the new absolute Z (calculated with the ***profile RMS***), we can also evaluate how the saturation goes with the Z for very high charge densities and compare with the MC expectations.
  - Regarding the absolute Z, I believe the systematic error (peaks at ~85cm) it's mostly a fixed systematic from using wrong values in the equation (Z = (sigma^2 - sigma_0^2) / sigma_L^2). It could just be normalized a posteriori since we actually the length of LIME.
- Eventually, having a moving alpha source in CYGNO could teach more about saturation and optimize the calculation of the absolute Z, likely crucial for NRs and DM searches…

GEM alpha peak - Final results

- ➔ During the CM meeting, we noticed there is indeed a should in the main alpha peak, with a specific direction (towards GEMs), and very narrow. This is also visible in the length plots, although less pronounced
  - Very narrow means with a similar diffusion ~ similar Z

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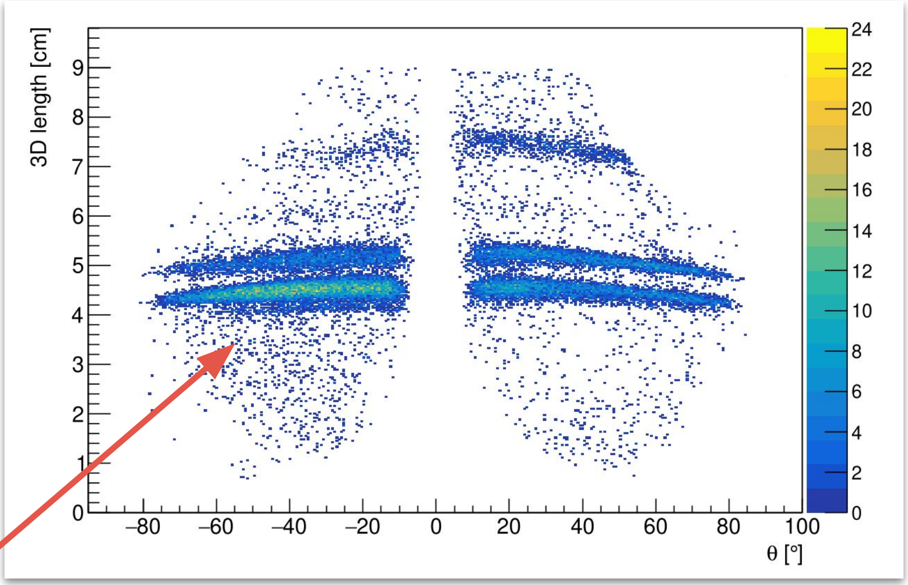

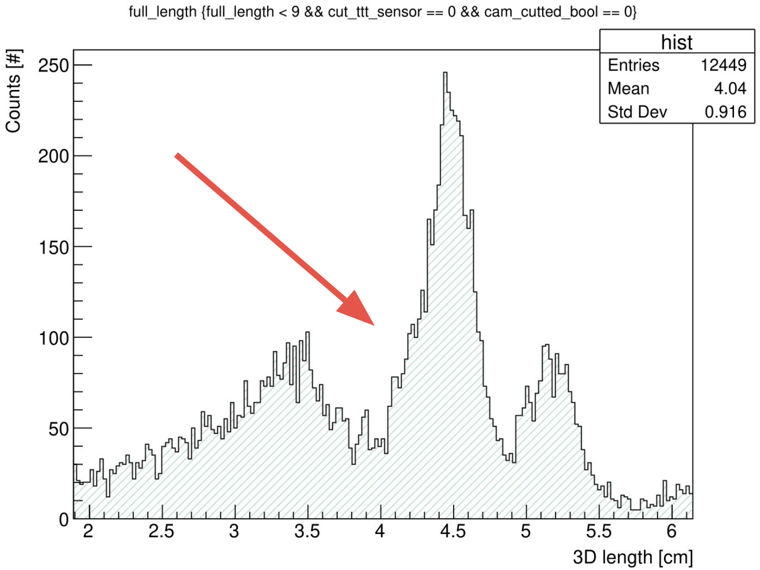

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➔ So I fitted this shoulder in the length distribution:

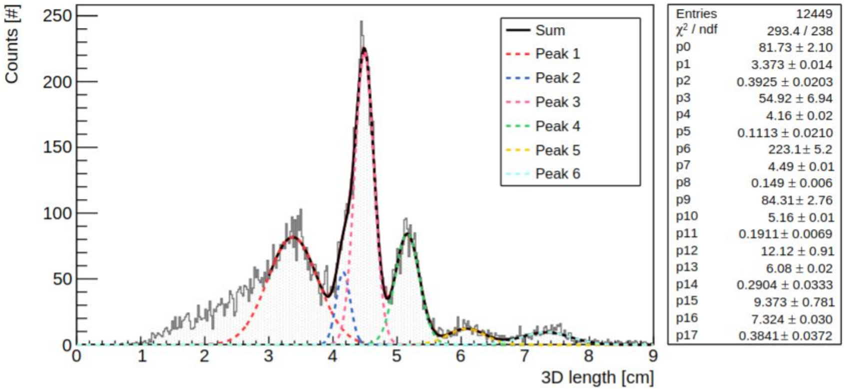

Figure 1.17: Distribution of 3D lengths of alphas measured in LIME, batch 6 (see table 1.2). The distribution was fitted with the sum of 6 Gaussian curves associated to each of the expected peaks. Each Gaussian fit is also individually plotted for better visualization. The fit parameters of each Gaussian is shown on the side.

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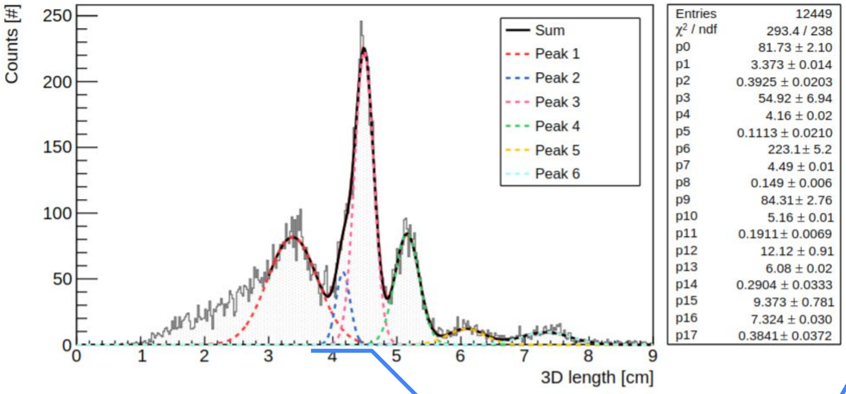

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Table 1.5: Summary of the alpha energies estimated through their range, for the non-^{222}Rn peaks showed in figure 1.17, and the candidate decay associated to each of these energies.

Measured values				Candidate decay	
Peak #	3D length [mm]	3D length - 3D min length [mm]	Estimated energy [MeV]	Isotope	α energy [MeV]
1	33.73 ± 3.93 (1σ)	25.34 ± 3.93 ± 1.04	$4.175^{+0.580}_{-0.635}$	^{238}U	4.151 / 4.198
2	41.60 ± 1.11 (1σ)	33.21 ± 1.11 ± 1.04	$5.070^{+0.225}_{-0.235}$	^{210}Po	5.304
5	60.80 ± 2.90 (1σ)	52.41 ± 2.9 ± 1.04	$6.890^{+0.330}_{-0.340}$	^{216}Po	6.778

➔ **It's estimated energy is very close to *Po-210*, another typical background source. Also DRIFT saw it.**

GEM alpha peak - Final results

➔ Looking at the absolute Zs, we see a "blob" at ~4cm, slightly below the main band, *only* at low Z, and *only* with negative theta

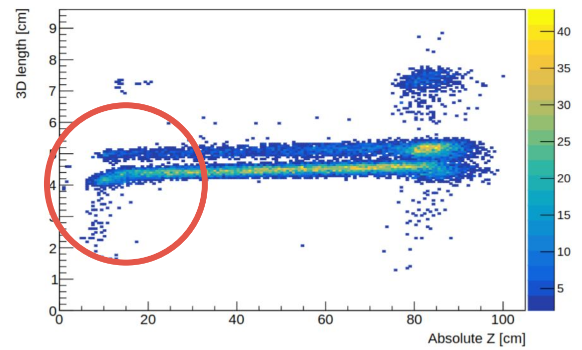

Figure 1.16: Relation between 3D length and absolute Z of alpha particles in LIME.To improve visualization, a minimum of 2 counts was required in each bin.

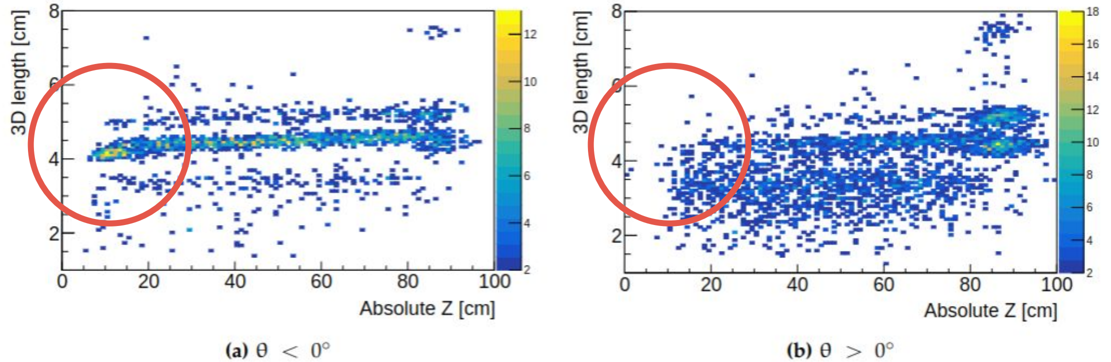

Figure 1.19: Relation between 3D lengths and absolute Z of the alpha particles with emission angle (a) $\theta < 0°$ and (b) $\theta > 0°$.

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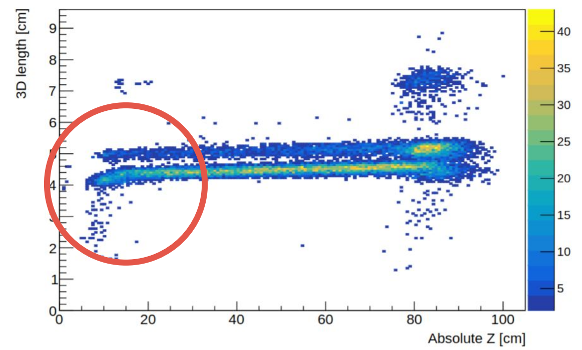

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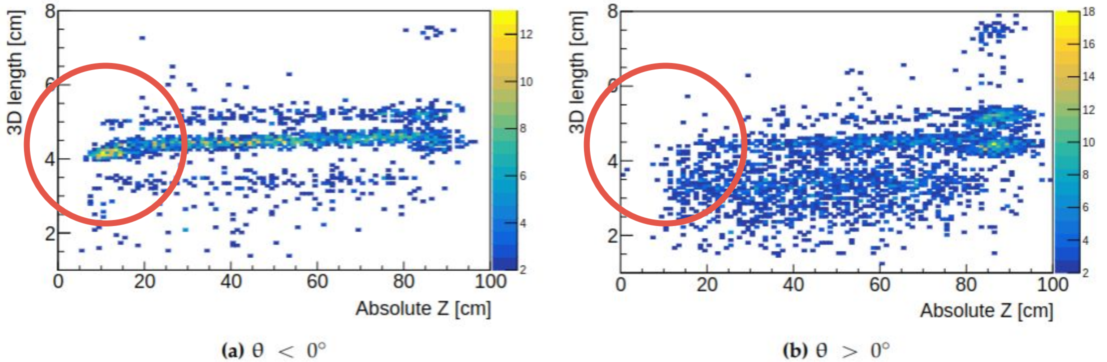

Figure 1.19: Relation between 3D lengths and absolute Z of the alpha particles with emission angle (a) θ < 0° and (b) θ > 0°.

➔ **This emission is likely from Po-210, and very likely *coming from the GEMs***

Thank you - Buon Natale