PMT Reco & Analysis - *Previously*

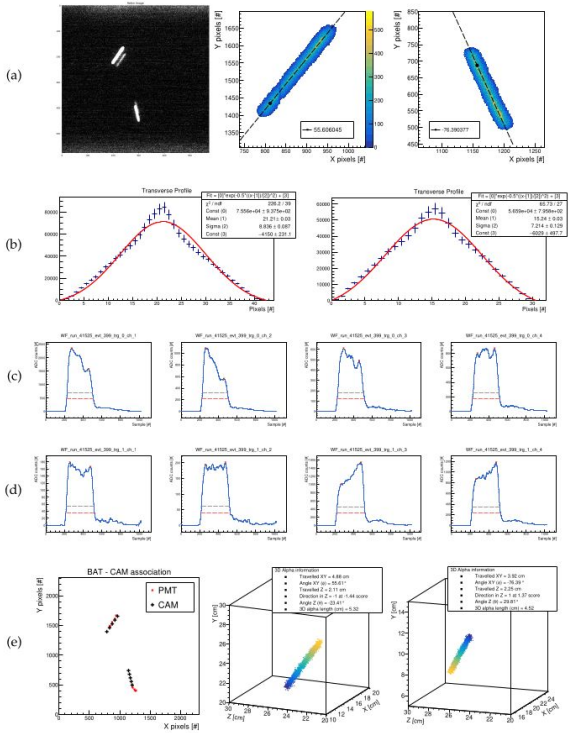


Figure 1.18: Full example of the analysis pipeline for the alpha particles identified in a given picture (run 41525, picture 399): (a) Original picture and sCMOS analysis of both alphas; (b) Light transverse profile of the alpha tracks; (c) and (d) the set of 4 waveforms for each trigger identified as alpha tracks; (e) waveform - cluster association and final 3D projection in the real LIME framework.

Previous episodes:

1. [https://agenda.infn.it/event/41735/]
   Initial look at alpha tracks for directional & head-tail determination
2. [https://agenda.infn.it/event/42030/]
   1 Update on … - 3D reconstructed alpha tracks
3. [https://agenda.infn.it/event/42653/]
   2 Update on … - 3D reconstructed alpha tracks

Full framework retrieves and saves all the relevant information automatically, including plots .

These are *not* cherry-picked events

#3 Update on …

3D alphas - Optimization of parameters

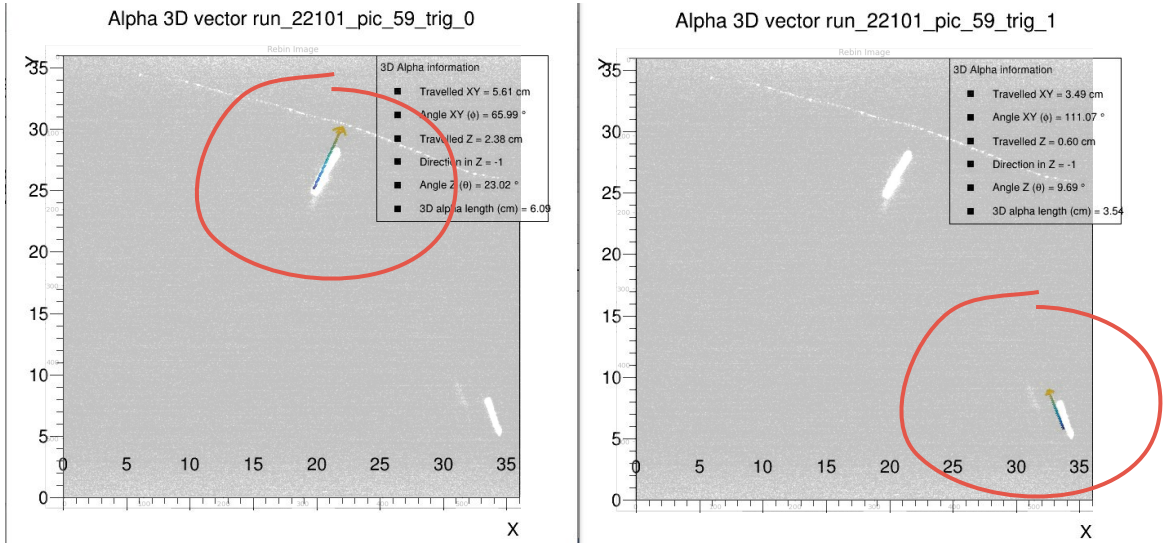
David Marques and PMT Working Group

Technical / Analysis meeting 18-07-2024

Fixing camera coordinates & rotations

PMT 3D reco

… There's still work to be done:



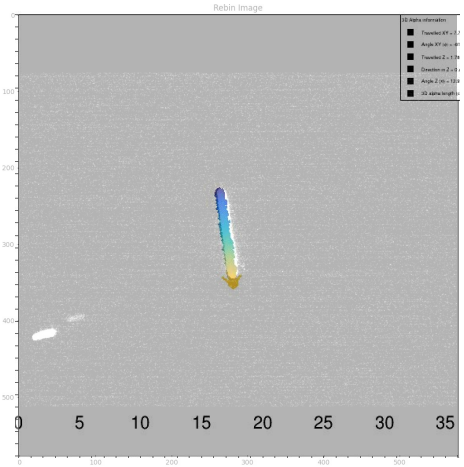
Some incoherence in the 3D projection and CMOS data…

…Maybe there are some coordinate / granularity / centering corrections to do…

PMT 3D reco

Let's analyze the lengths of the tracks

Using **sc_length**



Track start = With *Analyzer::**Edges*** (first())* granularity

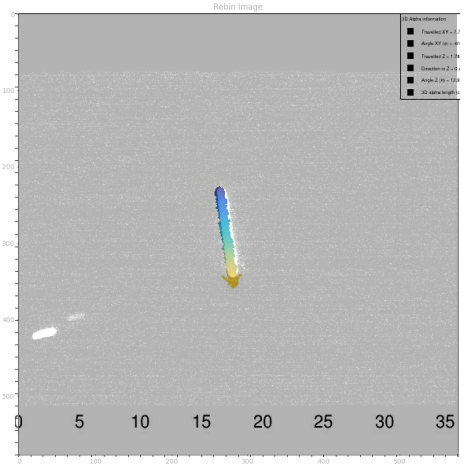
Track end =

- (**sc_length[sc_i]** * granularity * cos(cam.angle_XY * TMath::Pi()/180.));
- (**sc_length[sc_i]** * granularity * sin(cam.angle_XY * TMath::Pi()/180.));

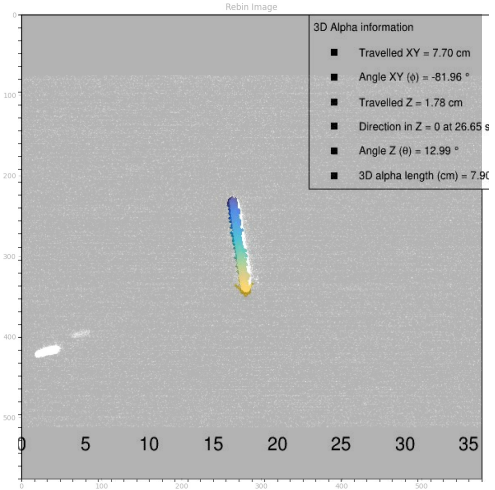
PMT 3D reco

Let's analyze the lengths of the tracks

Using **sc_length**



Using **edges** (from cmos:analyzer class)



Track start = With *Analyzer::**Edges*** (first())* granularity

Track end =

- (**sc_length[sc_i]** * granularity * cos(cam.angle_XY * TMath::Pi()/180.));
- (**sc_length[sc_i]** * granularity * sin(cam.angle_XY * TMath::Pi()/180.));

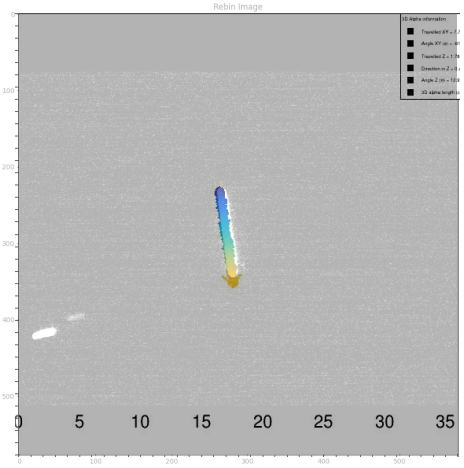
Track start = With *Analyzer::**Edges*** (first())* granularity

Track end = With *Analyzer::**Edges*** (back())* granularity

PMT 3D reco

Let's analyze the lengths of the tracks

Using **sc_length**

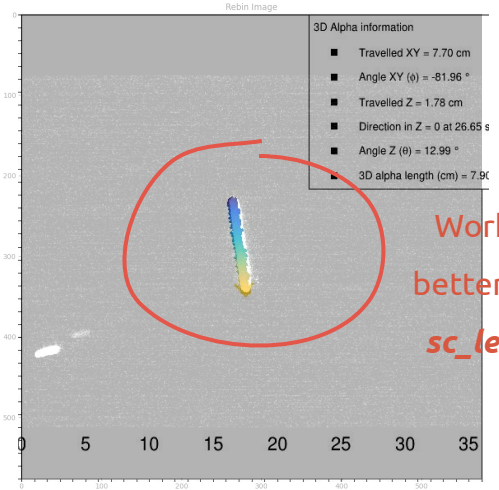


Track start = With *Analyzer::**Edges*** (first())* granularity

Track end =

- (**sc_length[sc_i]** * granularity * cos(cam.angle_XY * TMath::Pi()/180.));
- (**sc_length[sc_i]** * granularity * sin(cam.angle_XY * TMath::Pi()/180.));

Using **edges** (from cmos:analyzer class)



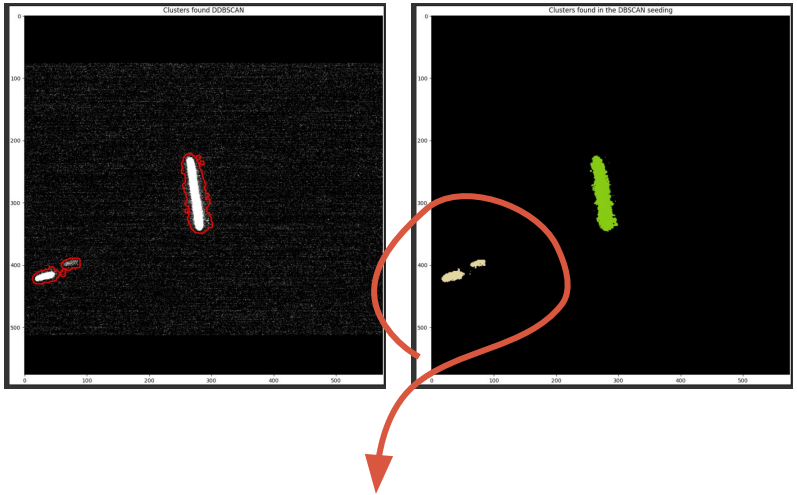
Track start = With *Analyzer::**Edges*** (first())* granularity

Track end = With *Analyzer::**Edges*** (back())* granularity

PMT 3D reco

➔ **It's because of the shadows** ⬅️

- **These get merged into the main cluster**, making some of the variables wrong…



Track and shadow merged in the final code ⇒ **Be careful with reco variables for alphas!**

D. Pinci saw the same issue

PMT 3D reco

➔ **It's because of the shadows** ⬅️

- **These get merged into the main cluster**, making some of the variables wrong…
- With the **CMOS::analyzer** this **doesn't happen** because the "**removeNoise**" function **removes all of this**
  - (NB: If the cluster gets mixed with an alpha with a cosmic, still doesn't work. (CMOS reco could be improved))

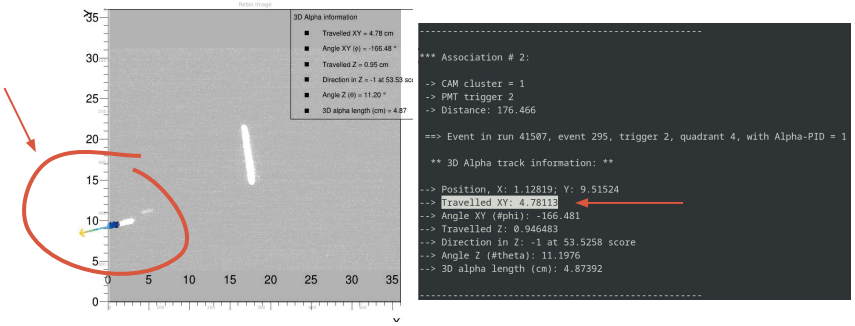
PMT 3D reco

➔ **It's because of the shadows** ⬅️

- **These get merged into the main cluster**, making some of the variables wrong…
- With the **CMOS::analyzer** this **doesn't happen** because the "**removeNoise**" function **removes all of this**
  - (NB: If the cluster gets mixed with an alpha with a cosmic, still doesn't work. (CMOS reco could be improved))

Using **sc_length**

```
XY_length = sc_length[sc_i] * granularity;
track_end_X = begin_X + ( XY_length * cos(cam.angle_XY * Pi()/180.));
track_end_Y = begin_Y + ( XY_length * sin(cam.angle_XY * Pi()/180.));
```



➔ **Track ends up outside the frame?! Length very big ?!**

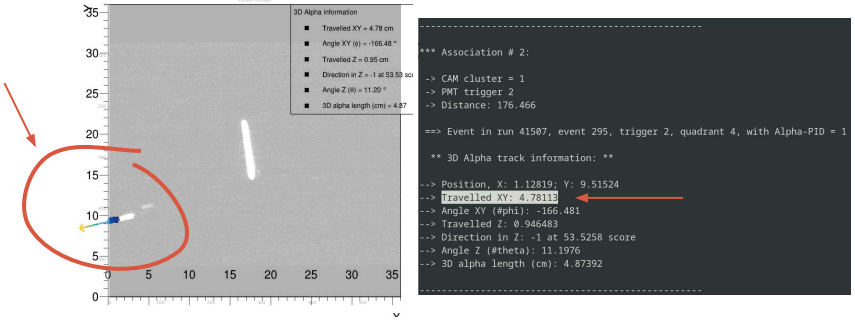
PMT 3D reco

➔ **It's because of the shadows** ⬅️

- **These get merged into the main cluster**, making some of the variables wrong…
- With the **CMOS::analyzer** this **doesn't happen** because the "**removeNoise**" function **removes all of this**
  - (NB: If the cluster gets mixed with an alpha with a cosmic, still doesn't work. (CMOS reco could be improved))

Using **sc_length**

```
XY_length = sc_length[sc_i] * granularity;
track_end_X = begin_X + ( XY_length * cos(cam.angle_XY * Pi()/180.));
track_end_Y = begin_Y + ( XY_length * sin(cam.angle_XY * Pi()/180.));
```

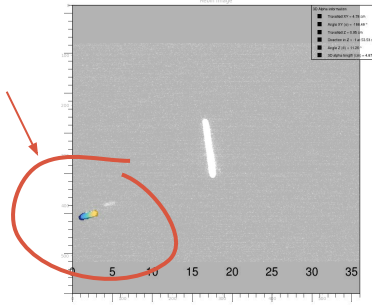



```
*** Association # 2:

 -> CAM cluster = 1
 -> PMT trigger 2
 -> Distance: 176.466

 ==> Event in run 41507, event 295, trigger 2, quadrant 4, with Alpha-PID = 1

  ** 3D Alpha track information: **

--> Position, X: 1.12819; Y: 9.51524
--> Travelled XY: 4.78113
--> Angle XY (#phi): -166.481
--> Travelled Z: 0.946483
--> Direction in Z: -1 at 53.5258 score
--> Angle Z (#theta): 11.1976
--> 3D alpha length (cm): 4.87392
```

➔ **Track ends up outside the frame?! Length very big ?!**

Using **edges** (from cmos:analyzer class)

```
XY_length = sqrt(pow(cam.end_X_cm - begin_X, 2) + pow(cam.end_Y_cm - begin_Y, 2));
track_end_X = cam.end_X_cm;
track_end_Y = cam.end_Y_cm;
```



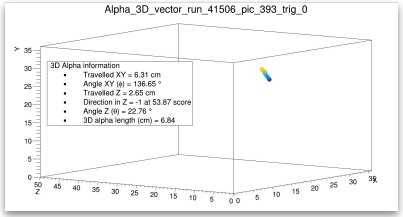
```
*** Association # 2:

 -> CAM cluster = 1
 -> PMT trigger 2
 -> Distance: 174.594

 ==> Event in run 41507, event 295, trigger 2, quadrant 4, with Alpha-PID = 1

  ** 3D Alpha track information: **

--> Position, X: 1.12819; Y: 9.51524
--> Travelled XY: 1.82532
--> Angle XY (#phi): -166.481
--> Travelled Z: 0.946483
--> Direction in Z: -1 at 53.5258 score
--> Angle Z (#theta): 27.4081
--> 3D alpha length (cm): 2.05612
```

➔ Track in **3D fits perfectly image** and **track length makes sense**

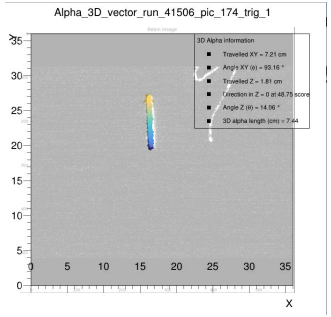
➔ **Also greatly impacts Angle Z and total length!**

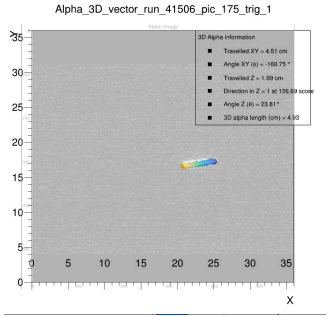
PMT 3D reco

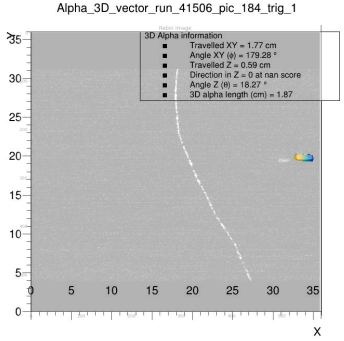
Some more examples to confirm it's working...

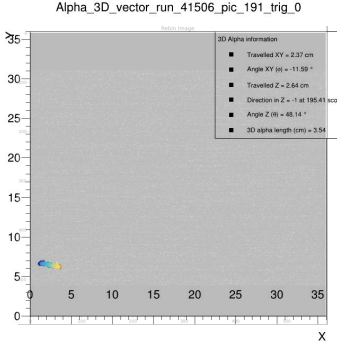


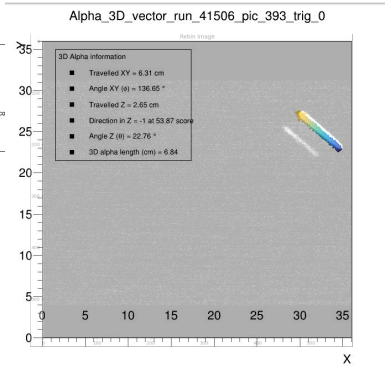
2D projection of the 3D plot overlapped with CMOS picture





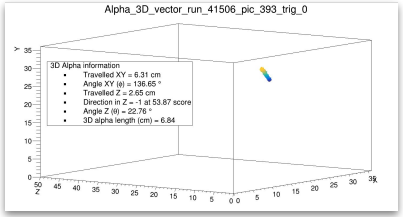




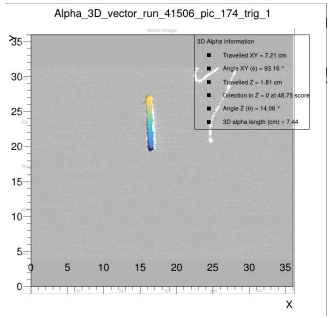


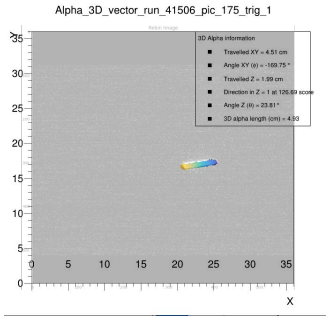
PMT 3D reco

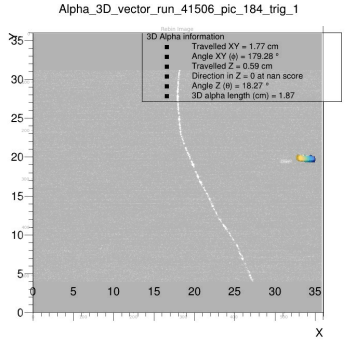
Some more examples to confirm it's working...

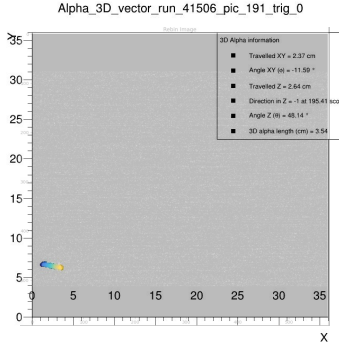


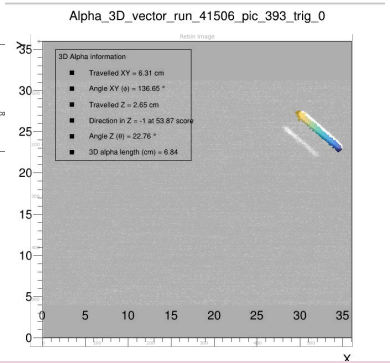
2D projection of the 3D plot overlapped with CMOS picture











- I would say the variables matching are on point! ⇒ **Solved** ✅
- Additionally, if you look at the coordinates, it's not 33x33.
  - This also proves how much the **camera sampling ⇒ 36x36 cm²**.

```
TH3F *axis = new TH3F(name, name,
 1, 0, 36, 1, 0, 50, 1, 0, 36);
```

#4 Update on …

3D alphas -

Statistical results +

comparison with D. Pinci

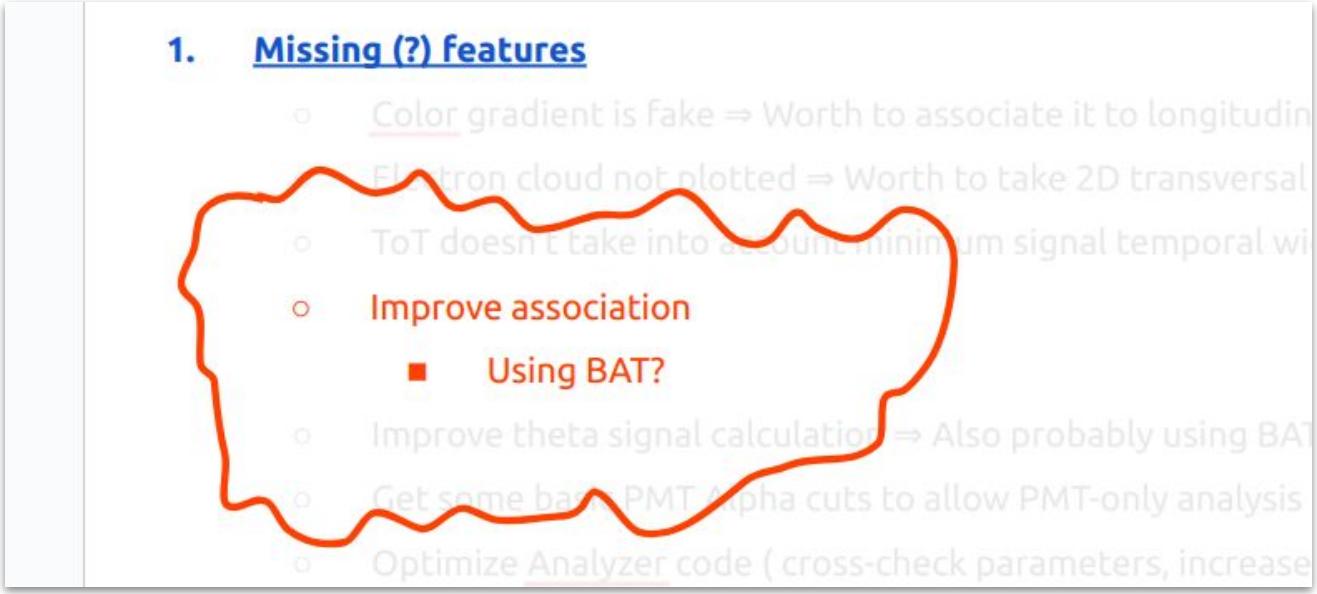
David Marques

Technical / Analysis meeting 18-07-2024

Statistical Analysis

PMT 3D reco – Conclusions

➔ ***But first…***



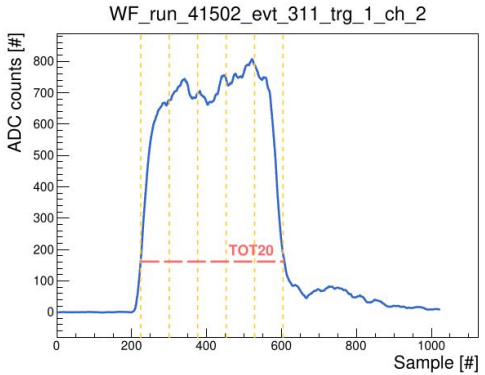
PMT 3D reco – BAT-CAM association

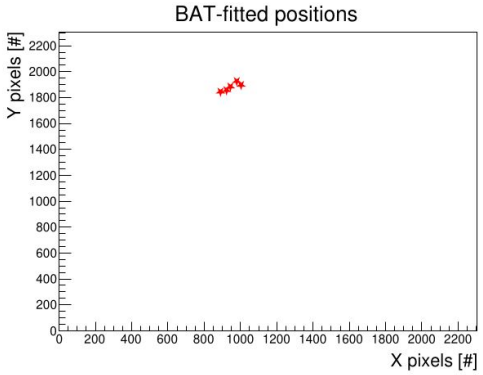
To improve the **cluster-trigger association (1-to-1 association)**, we use the ***BAT-fit to position the PMT signal in the GEM plane:***

PMT 3D reco – BAT-CAM association

To improve the **cluster-trigger association (1-to-1 association)**, we use the ***BAT-fit to position the PMT signal in the GEM plane:***

1. Slice waveform
2. BAT-fit the slice integrated charge ⇒ **(L,X,Y)**
3. Place the point in the GEM plane.





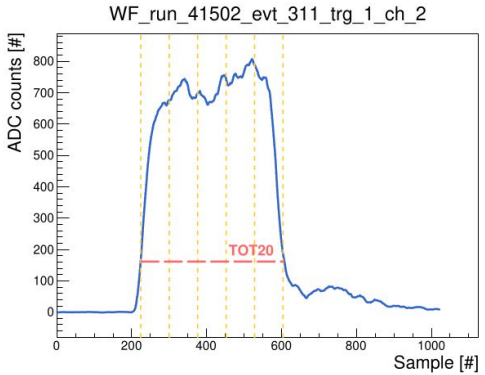
$$V = R * I \Rightarrow V = R * Q/\Delta t \Rightarrow Q = \frac{V * t}{R} \qquad (1.4)$$

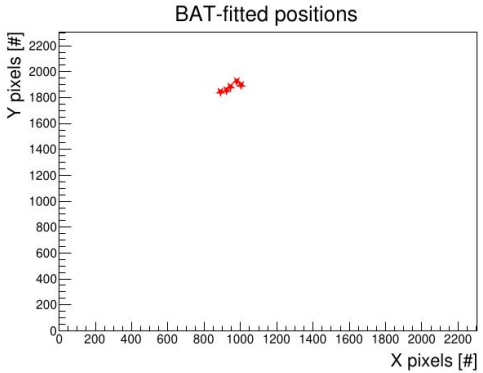
$$\begin{aligned} Q[nC] &= A[ADU] * \frac{\text{DGTZ dynamic range}[V]}{\text{DGTZ resolution}[bits]} * \Delta t \,/\, R \\ &= A[ADU] * \frac{1[V]}{12[bits]} * \frac{1}{\text{DGTZ sampl. freq.}}[ns] \,/\, R[Omega] \\ &= A * \frac{1}{4096} * \frac{4}{3} * \frac{1}{50} \end{aligned} \qquad (1.5)$$

PMT 3D reco – BAT-CAM association

To improve the **cluster-trigger association (1-to-1 association)**, we use the ***BAT-fit to position the PMT signal in the GEM plane:***

1. Slice waveform
2. BAT-fit the slice integrated charge ⇒ **(L,X,Y)**
3. Place the point in the GEM plane.
4. Same for CMOS (using Analyzer::Edges)
5. **Distance between points calculated**
6. **Cluster-trigger association done by smaller distances**



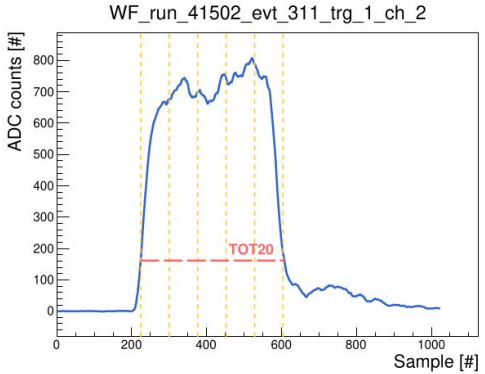


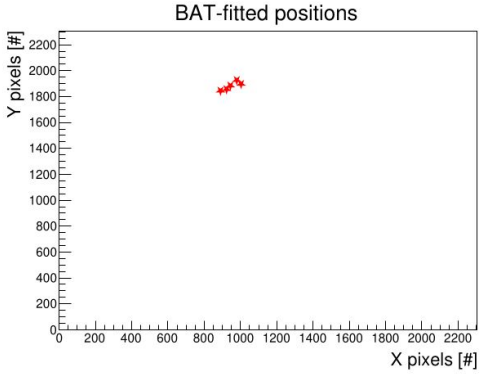
PMT 3D reco – BAT-CAM association

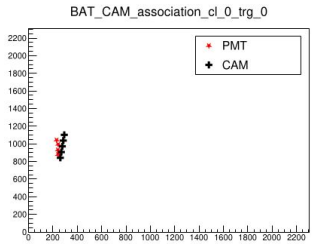
To improve the **cluster-trigger association (1-to-1 association)**, we use the ***BAT-fit to position the PMT signal in the GEM plane:***

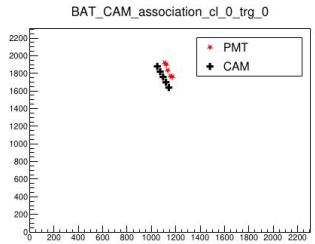
1. Slice waveform
2. BAT-fit the slice integrated charge ⇒ **(L,X,Y)**
3. Place the point in the GEM plane.
4. Same for CMOS (using Analyzer::Edges)
5. **Distance between points calculated**
6. **Cluster-trigger association done by smaller distances**

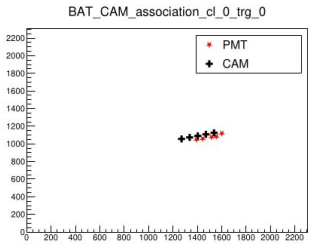
⇒ Works surprisingly well!





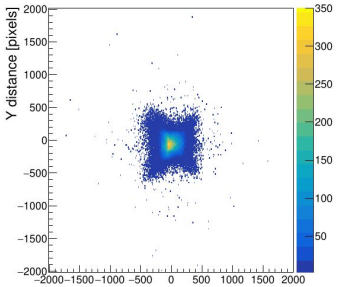


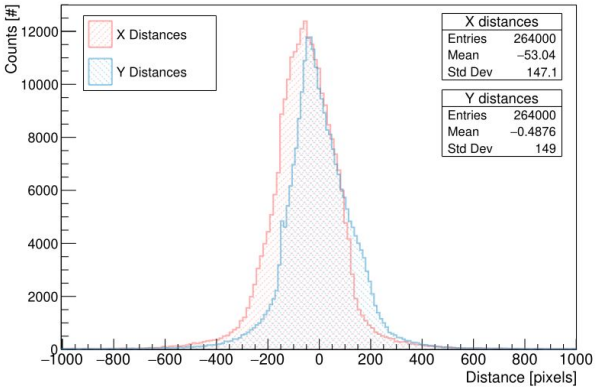




PMT 3D reco – BAT-CAM association

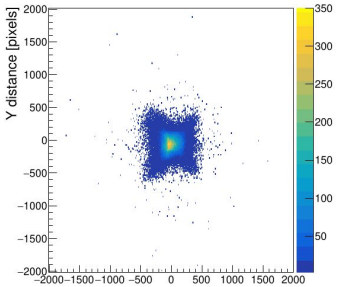
We can study the efficiency of this fit:

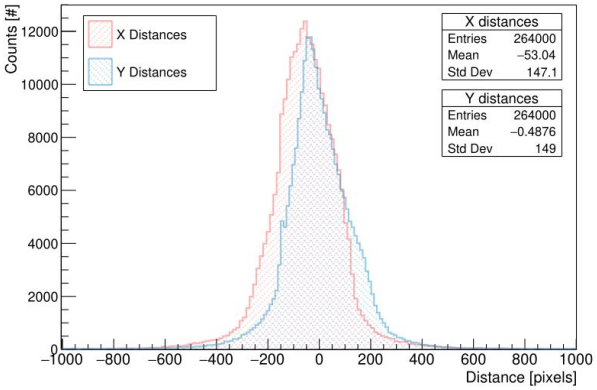




PMT 3D reco – BAT-CAM association

We can study the efficiency of this fit:

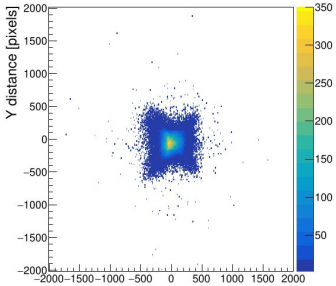


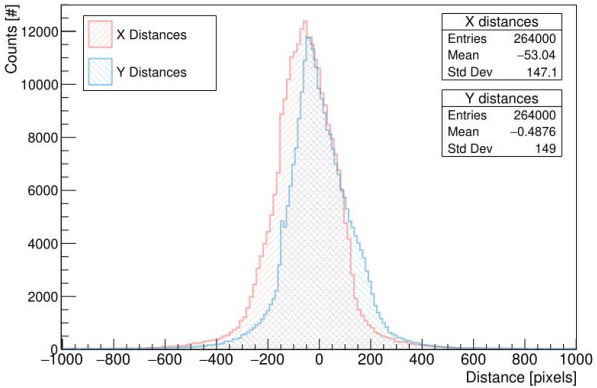


- We get **not very Gaussian distributions** (and it wasn't expected)
  - Standard deviations of **~150 pixels = 2,325 cm**

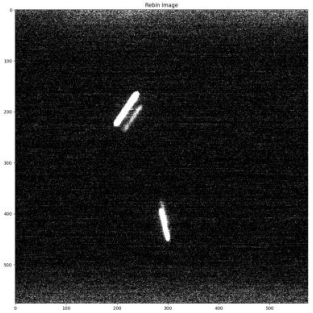
PMT 3D reco – BAT-CAM association

We can study the efficiency of this fit:



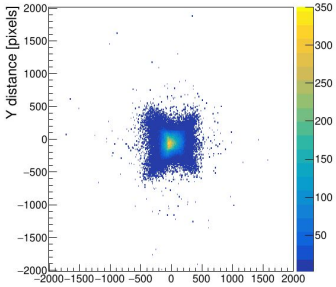


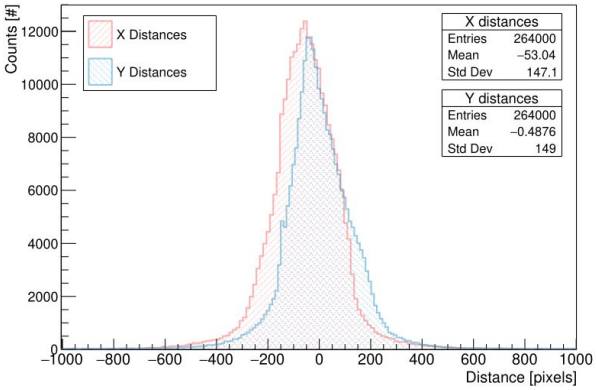
- We get **not very Gaussian distributions** (and it wasn't expected)
  - Standard deviations of **~150 pixels = 2,325 cm**
- At the moment, is only necessary for matching *alpha* tracks.
  - Rarely 2 in one pic.
  - This resolution is more than enough.
    - At closer distances, also the **CMOS reco** starts *failing and merging the tracks*, which renders useless the 3D reco.



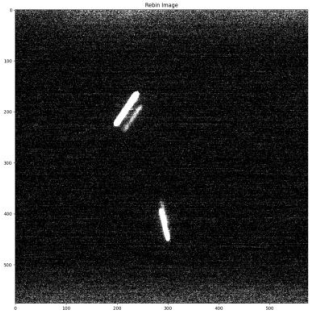
PMT 3D reco – BAT-CAM association

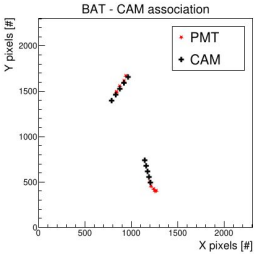
We can study the efficiency of this fit:

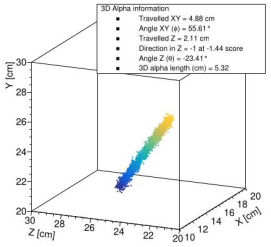


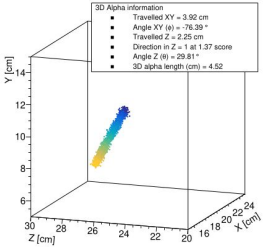


- We get **not very Gaussian distributions** (and it wasn't expected)
  - Standard deviations of **~150 pixels = 2,325 cm**
- At the moment, is only necessary for matching *alpha* tracks.
  - Rarely 2 in one pic.
  - This resolution is more than enough.
    - At closer distances, also the **CMOS reco** starts *failing and merging the tracks*, which renders useless the 3D reco.



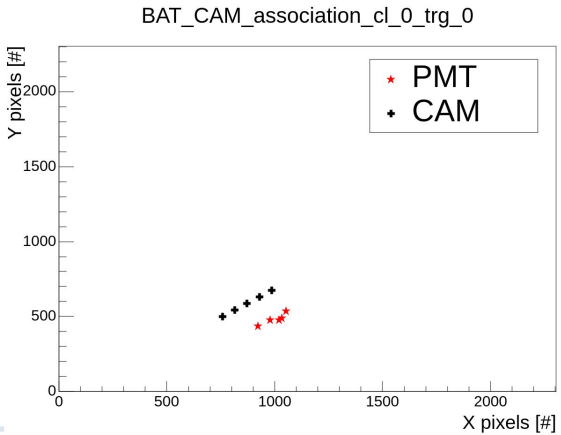


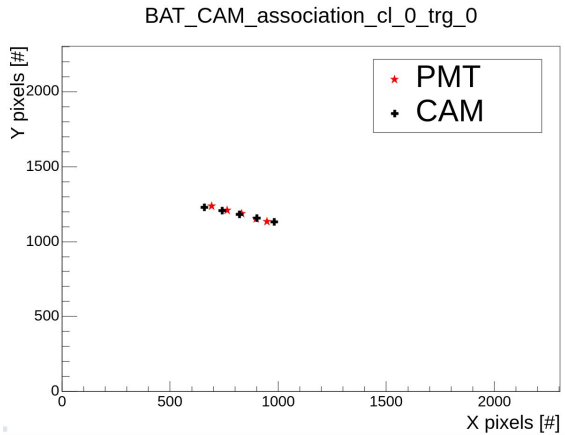




PMT 3D reco – BAT-CAM association

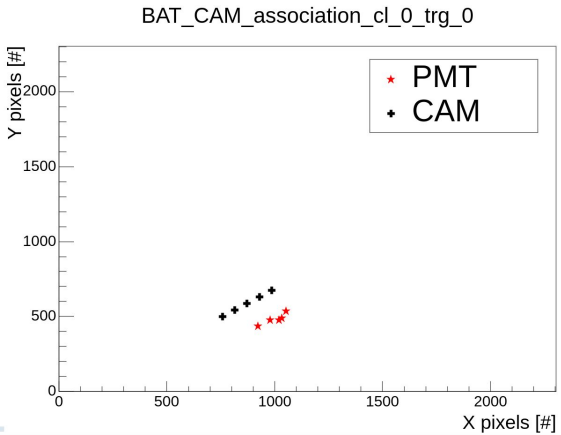
I have many examples, there's a bit of everything...

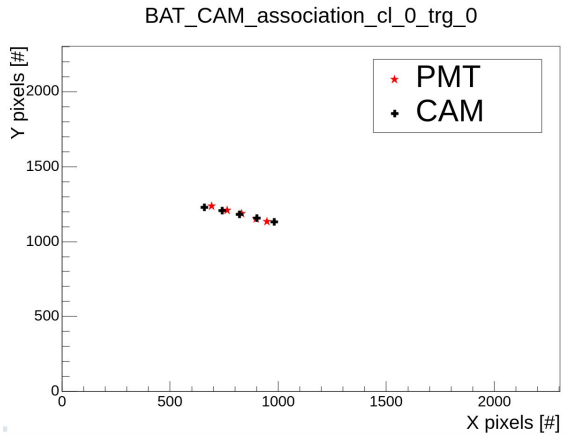




PMT 3D reco – BAT-CAM association

I have many examples, there's a bit of everything…





There are clear reasons to not have a perfect fit:

1. When the **waveforms are saturated** due to high gain, we lose proportionality ⇒ BAT-fit works better in the middle region.
2. Offsets due to **inaccurate gain balance** ⇒ F. Borra recently updated the code to improve this, but I haven't checked.
3. **Barreling effect** from lens towards the sides farther difficulties the fit ⇒ Giorgio working on it

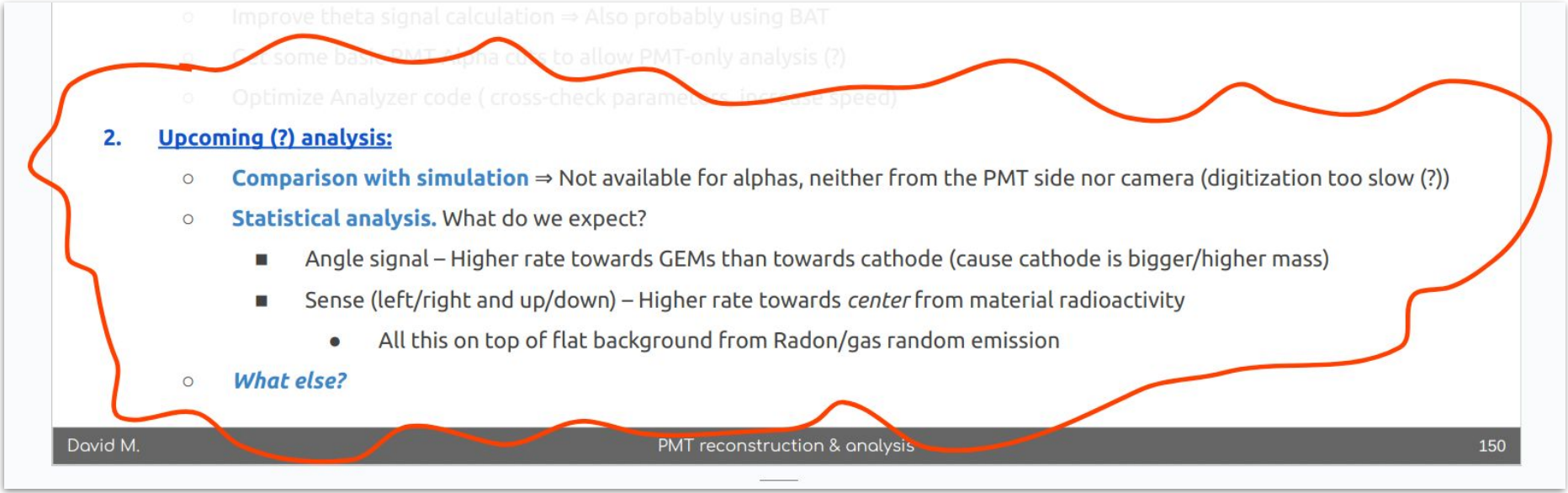
While this is interesting, the **optimization**; test of other **types of particles**; implementation at **front-end level** is *out-of-scope for my work*.

Statistical Results

PMT Reco & Analysis

➔ ***Now we can actually do some statistical analysis on the results***

- *Eventually compare with MC truth from Flaminia's simulations*



- Improve theta signal calculation ⇒ Also probably using BAT
- Cut some basic PMT alpha cuts to allow PMT-only analysis (?)
- Optimize Analyzer code (cross-check parameters, increase speed)

2. **Upcoming (?) analysis:**
   - **Comparison with simulation** ⇒ Not available for alphas, neither from the PMT side nor camera (digitization too slow (?))
   - **Statistical analysis.** What do we expect?
     - Angle signal – Higher rate towards GEMs than towards cathode (cause cathode is bigger/higher mass)
     - Sense (left/right and up/down) – Higher rate towards *center* from material radioactivity
       - All this on top of flat background from Radon/gas random emission
   - ***What else?***

David M. PMT reconstruction & analysis 150

PMT Reco & Analysis

The datasets used were:

1. **Run 3**
   - For optimization only
2. **Run 4**
   - **Most of the long ranges of Bkg + calibs**
3. **Run 5**
   - Different gain:
     - Interesting by will *maybe* require parameter tuning… in the pipeline.

PMT Reco & Analysis

The datasets used were:

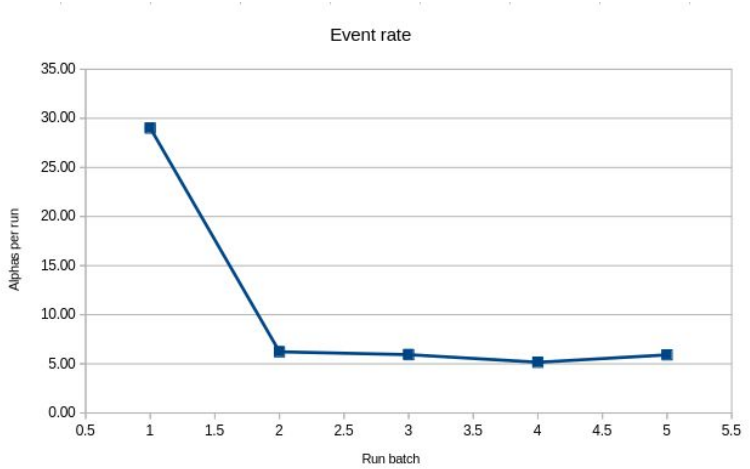
1. **Run 3**
   - For optimization only
2. **Run 4**
   - **Most of the long ranges of Bkg + calibs**
3. **Run 5**
   - Different gain:
     - Interesting by will *maybe* require parameter tuning… in the pipeline.

STATUS	present in SSD?	Start	Stop	Numbers		Description	Data runs	Data pics	Gas Flow	Filter Line 1	Filter Line2	
		2023-12-01 15:08	2023-12-04 9:39	40784 -	40917	Stability	133	53200	5	Blu	Not in use	
DONE	YES	2023-12-04 10:23	2023-12-14 16:40	40919 -	42848	Bkg + Daily Calibrations	1929	771600	5	Blu	Not in use	Th
		2023-12-14 18:07:07	2023-12-16 10:17:27	42863 -	43185	Bkg + Daily Calibrations Low GAIN	322	128800	5	Blu	Not in use	the
		2023-12-15 11:54:46	2023-12-15 14:44:20	42985	43050	VGEM1 scan	65	26000	5	Blu	Not in use	
		2023-12-16 23:50:59	2023-12-17 21:53:14	43186 -	43231	Stability + Daily Calibrations- LOW Gas Flow : 2 l/h	45	18000	2	Blu	Not in use	
		2023-12-17 22:45:16	2023-12-22 16:18:47	43232 -	43308	Stability + Daily Calibrations- LOW Gas Flow : 1 l/h	76	30400	1	Blu	Not in use	
		2023-12-17 22:45:16	2023-12-22 16:18:47	43316 -	43486	Stability + Daily Calibrations- LOW Gas Flow : 1 l/h	170	68000	1	Blu + Rosso	Not in use	
		2023-12-31		43502 -	43508	Daily Calibration			1	Blu + Rosso	Not in use	
				43509 -	43515	Daily Calibration			1	Blu + Rosso	Not in use	
		2024-01-04		43517 -	43522	Daily Calibration			1	Blu + Rosso	Not in use	
		2024-01-06		43524 -	43529	Daily Calibration			1	Blu + Rosso	Not in use	
		2024-01-08		43531 -	43536	Daily Calibration			2	Blu + Rosso	Not in use	
		2024-01-10		43636 -	43641	Daily Calibration			2	Blu + Rosso	Not in use	
		2024-01-12		43732 -	43738	Daily Calibration			5	Blu + Rosso	Not in use	Flo
		2024-01-14		43849 -	43855	Daily Calibration			5	Blu + Rosso	Not in use	
		2024-01-16		44047 -	44053	Daily Calibration			5	Blu + Rosso	Not in use	
		2024-01-17		44203 -	44209	Daily Calibration			5	Blu + Rosso	Not in use	
		2024-01-18		44367 -	44372	Daily Calibration			5	Blu + Rosso	Not in use	
		2024-01-19		44553 -	44559	Daily Calibration			5	Blu + Rosso	Not in use	
		2024-01-08 12:00:15	2024-01-08 18:38:15	43537 -	43701	Stability + Daily Calibrations- LOW Gas Flow : 2 l/h	164	65600	2	Blu + Rosso	Not in use	
		2024-01-08 18:38:15	2024-01-15 9:00:00	43702 -	43885	Stability + Daily Calibrations- Gas Flow : 5 l/h	183	73200	5	Blu + Rosso	Not in use	
NO		2024-01-15 9:11:14	2024-01-23 12:31	43886 -	45213	Bkg + Daily Calibrations	1327	530800	5	Blu + Rosso	Not in use	
		2024-01-23 15:44:30	2024-01-24 9:53:11	45214 -	45251	Stability + Daily Calibrations- Gas Flow : 5 l/h	37	14800	5	Blu + Rosso	Not in use	
DONE	YES	2024-01-24 10:27:00	2024-02-02 9:42	45259 -	46628	Bkg + Daily Calibrations	1369	547600	5	Blu + Rosso	Not in use	
		2024-02-02 9:47:28	2024-02-04 11:21:19	46636 -	46740	Stability + Daily Calibrations- Gas Flow : 4 l/h	104	41600	5	Blu + Rosso	Not in use	
		2024-02-04 11:21:19	2024-02-05 14:03:49	46741 -	46802	Stability + Daily Calibrations- Gas Flow : 5 l/h	61	24400	5	Blu + Rosso	Not in use	
		2024-02-05 14:13:49	2024-02-06 23:50	46803 -	47023	Bkg + Daily Calibrations	220	88000	5	Blu + Rosso	Not in use	
		2024-02-06 23:59:42	2024-02-07 10:03:47	47024 -	47051	Stability + Daily Calibrations- LOW Gas Flow : 1 l/h	27	10800	1	Blu + Rosso	Not in use	
		2024-02-07 10:03:47		47052 -	47108	Stability + Daily Calibrations- LOW Gas Flow : 0 l/h	56	22400	1	Blu + Rosso	Not in use	
				47982 -	47985	DT test: trigger rate 36 Hz, PMT 590 V	4	1600	1	Blu + Rosso	Not in use	
				47986 -	47989	DT test: trigger rate 26 Hz, PMT 580 V	4	1600	1	Blu + Rosso	Not in use	
				47990 -	48014	DT test: trigger rate 4 Hz, PMT 560 V	25	10000	1	Blu + Rosso	Not in use	
				48015 -	48054	DT test: trigger rate 2 Hz, PMT 555 V	40	16000	1	Blu + Rosso	Not in use	
		2024-02-10 14:55:57	2024-02-15 13:07:13	47209 -	47981	Bkg + Daily Calibrations	772	308800	5	Blu + Rosso	Not in use	
Igor sentinel		2024-02-15 15:35:22	2024-03-05 9:33	48055 -	50891	Bkg + Daily Calibrations	2836	1134400	5	Blu + Rosso	Not in use	
		2024-03-17 16:20:14	2024-03-18 15:14	52664 -	52808	Bkg + Daily Calibrations	144	57600	5	Blu + Rosso	Not in use	
		2024-03-18 15:42:55	2024-03-19 15:19:04	52816 -	52874	Stability + Daily Calibrations- LOW Gas Flow : 1 l/h	58	23200	1	Blu + Rosso	Not in use	
		2024-03-19 16:46:18		52882 -		Stability + Daily Calibrations- Gas Flow : 5 l/h	121	48400	5	Blu + Rosso	Not in use	Air
					53003	Stability + Daily Calibrations- Gas Flow : 5 l/h			5	Blu + Rosso	Not in use	Air
		2024-03-21 17:51:00		53004 -	53109	Stability + Daily Calibrations- LOW Gas Flow : 1 l/h	105	42000	1	Blu + Rosso	Not in use	Air
DONE	YES	2024-03-23 18:20:34	2024-03-26 9:41:19	53110 -	53502	Bkg + Daily Calibrations	392	156800	5+20	Blu + Rosso	Not in use	Air
DONE	YES	2024-03-29 10:01:40	2024-04-02 10:02:22	53707 -	54403	Bkg + Daily Calibrations	696	278400	5+20	Blu + Rosso + RADON	Not in use	Air
		2024-04-02 10:42:22		54411 -	54502	Stability + Daily Calibrations- HIGH recirculation 40 l/h	91	36400	5+40	Blu + Rosso + RADON	Not in use	Air
DONE	YES	2024-04-04 8:31:50	2024-04-08 8:26:06	54503 -	55093	Bkg + Daily Calibrations	590	236000	5+40	Blu + Rosso + RADON	Not in use	Air
NO		2024-04-08 13:00:06		55101 -	56883	Bkg + Daily Calibrations - Low Gain - Low Drift	1782	712800	5+40	Blu + Rosso + RADON	Not in use	Air

PMT Reco & Analysis

1. **Alpha frequency** in each batch

Batch	Runs	N runs	N matched alphas	N alphas per run
1	40919-42848	1820	52800	29.01
2	45259-46628	1370	8529	6.23
3	53110-53502	390	2315	5.94
4	54503-55093	591	3050	5.16
5	53707-54403	531		
(6)	48055-50891	-	-	-

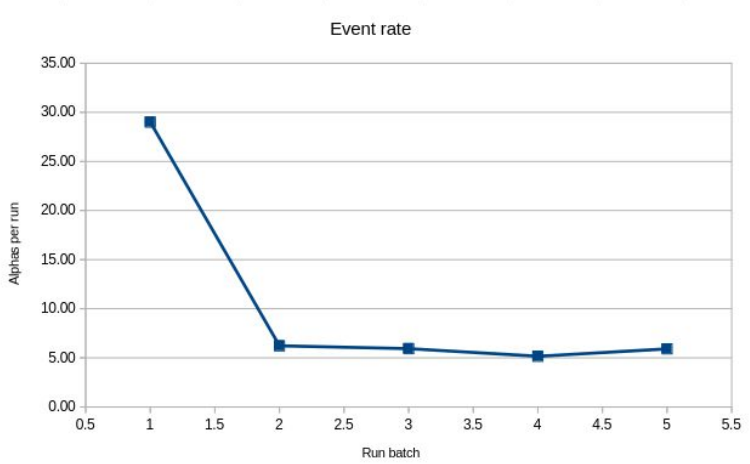


High number of alphas in December, before oxygen and humidity filters were installed (correct?)

PMT Reco & Analysis

1. **Alpha frequency** in each batch

Batch	Runs	N runs	N matched alphas	N alphas per run
1	40919-42848	1820	52800	29.01
2	45259-46628	1370	8529	6.23
3	53110-53502	390	2315	5.94
4	54503-55093	591	3050	5.16
5	53707-54403	531		
(6)	48055-50891	-	-	-



High number of alphas in December, before oxygen and humidity filters were installed (correct?)

For all analysis, I don't have many cuts as I only saved *matched and alpha-PID* signals. ⇒ You can assume near-perfect selection.

Given the statistics, I'll group the data as *before (batch 1) and after Christmas (batch 2-5)*.

PMT Reco & Analysis

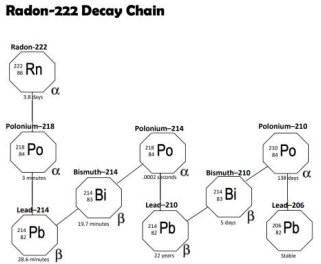
2. **3D lengths distributions**

PMT Reco & Analysis

2. **3D lengths distributions**

…comparing with Pinci's slides (2D alpha lengths)

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

@Pinci, do we know the precision and source of these numbers.

Flaminia has slightly higher values for these alphas.

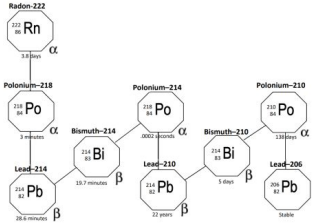
PMT Reco & Analysis

2. **3D lengths distributions**

…comparing with Pinci's slides (2D alpha lengths)

The Radon Contamination

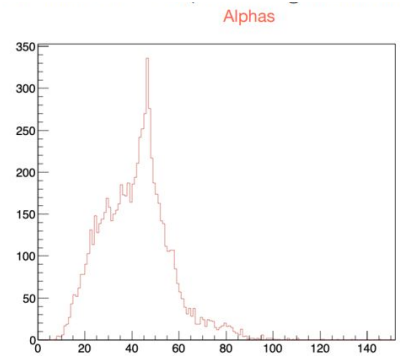
Radon-222 Decay Chain



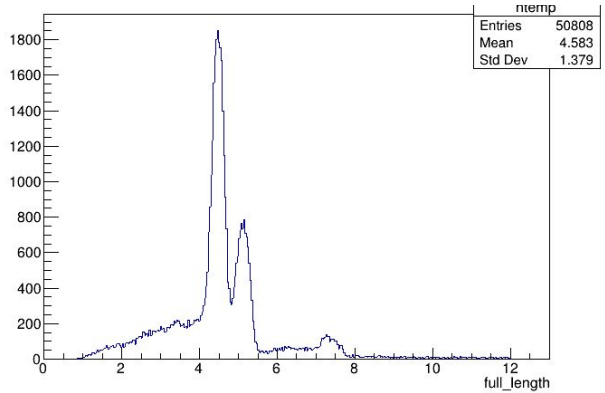
- So, a Rn contamination would produce:
  - 3 alphas:
    - ^{222}Rn -> 5.590 MeV (about 43 mm)
    - ^{218}Po -> 6.115 MeV (about 50 mm)
    - ^{214}Po -> 7.833 MeV (about 73 mm)
  - 2 betas
  - a lot of gammas from 50 keV to 2200 keV

@Pinci, do we know the precision and source of these numbers.

Flaminia has slightly higher values for these alphas.



Adding 3rd coordinate



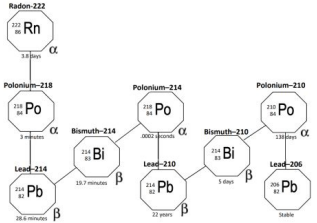
PMT Reco & Analysis

2. **3D lengths distributions**

…comparing with Pinci's slides (2D alpha lengths)

The Radon Contamination

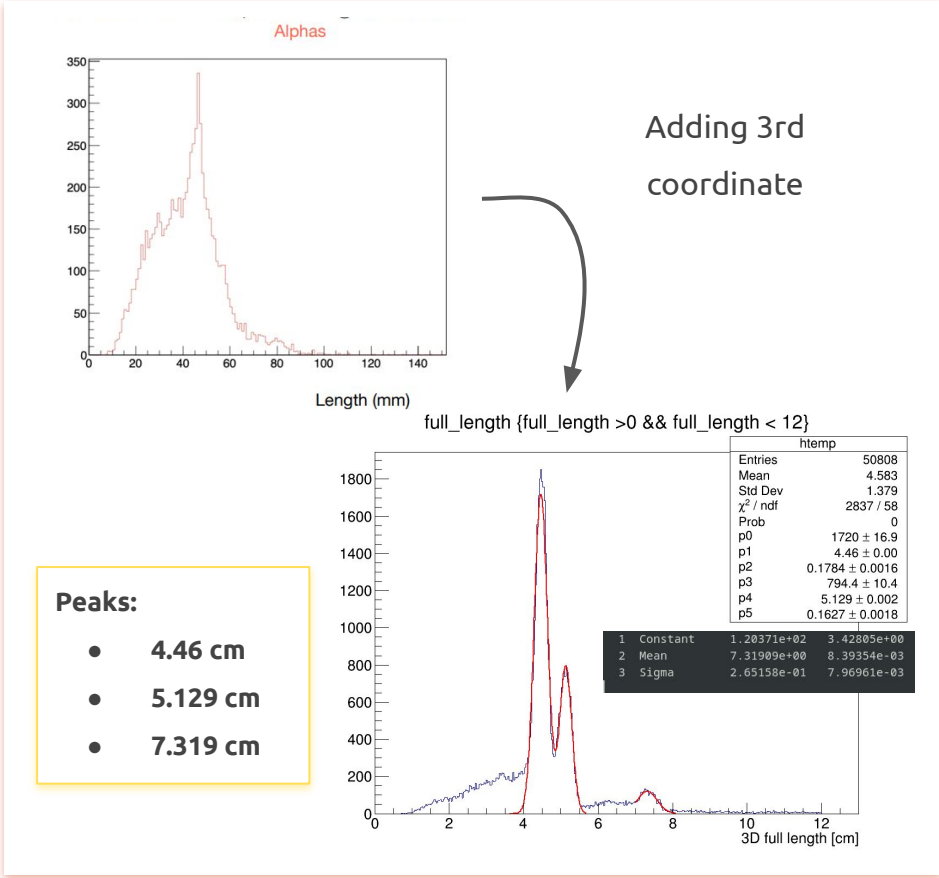
Radon-222 Decay Chain



- 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

@Pinci, do we know the precision and source of these numbers.

Flaminia has slightly higher values for these alphas.



Peaks:

- **4.46 cm**
- **5.129 cm**
- **7.319 cm**

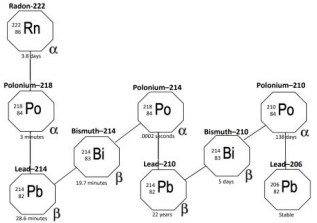
PMT Reco & Analysis

2. **3D lengths distributions**

…comparing with Pinci's slides (2D alpha lengths)

The Radon Contamination

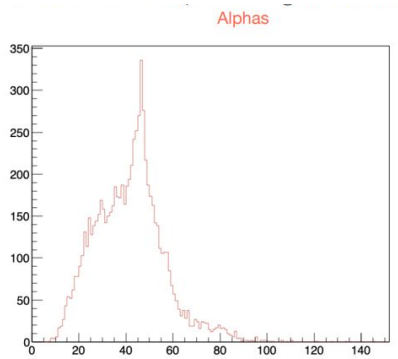
Radon-222 Decay Chain



- 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

@Pinci, do we know the precision and source of these numbers.

Flaminia has slightly higher values for these alphas.

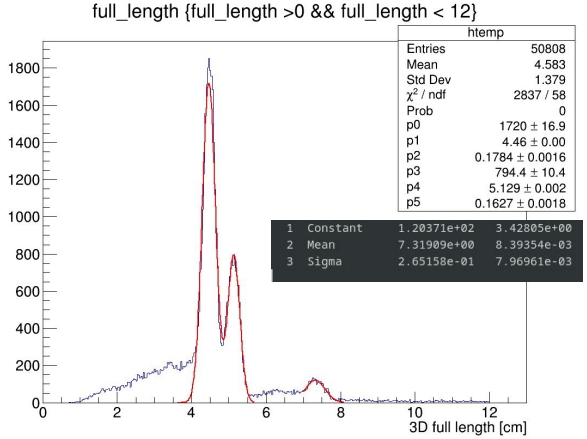


Adding 3rd coordinate

Very similar!

Peaks:

- **4.46 cm**
- **5.129 cm**
- **7.319 cm**

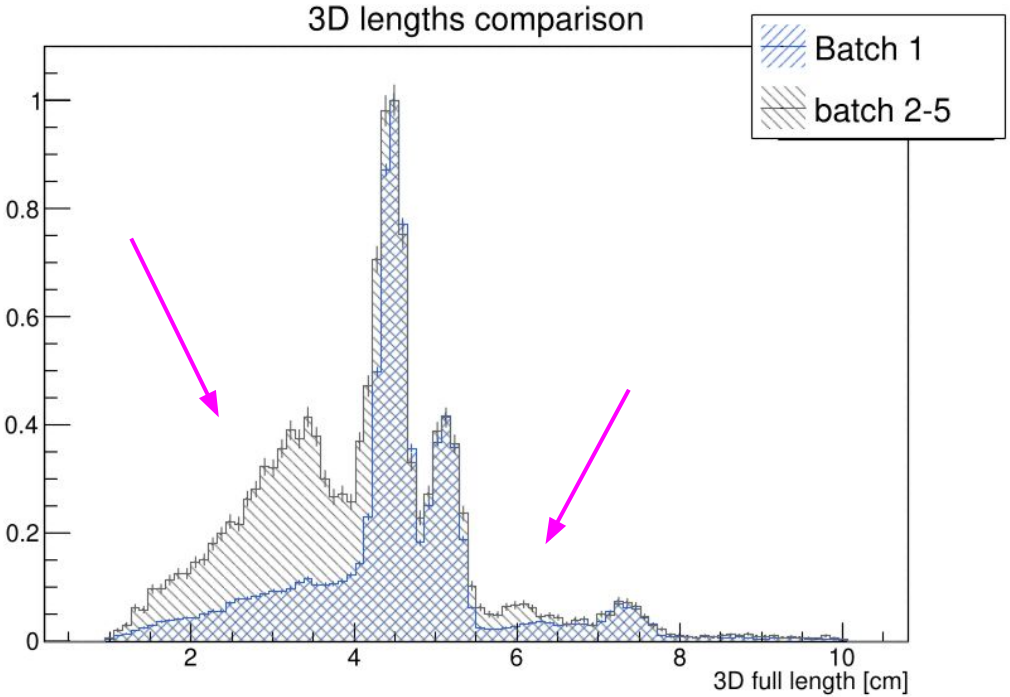


PMT Reco & Analysis

2. **3D lengths distributions**

… Comparing batches:

- ***before (1)*** *vs after (2-5) Rn filters*
- *Normalized to 1*
- *Statistics: 40k vs 10k samples*

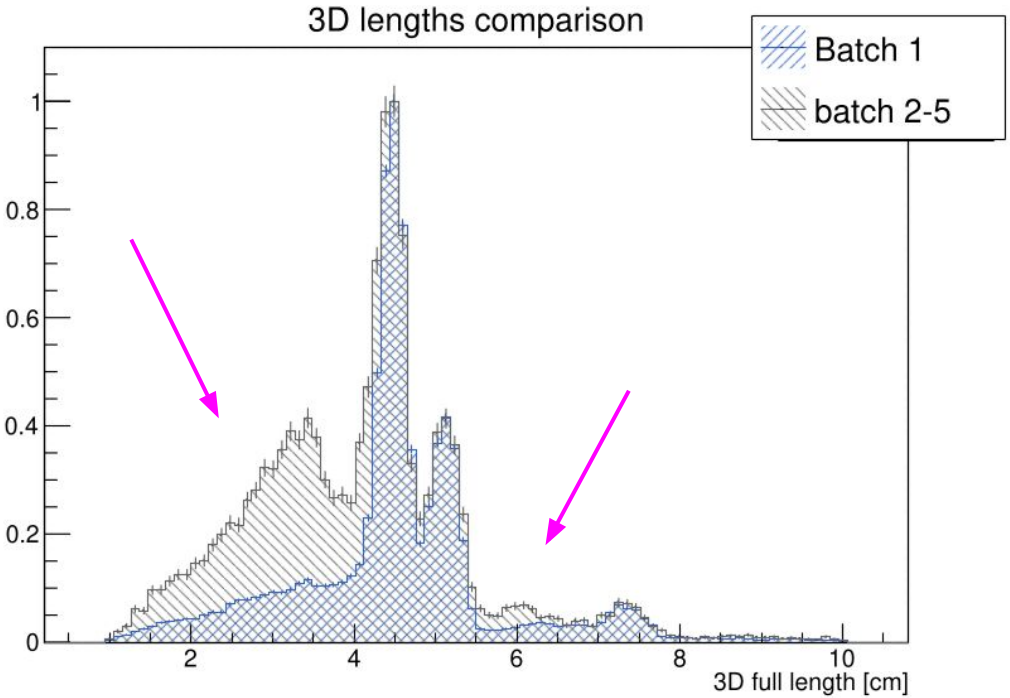


PMT Reco & Analysis

2. **3D lengths distributions**

… Comparing batches:

- ***before (1)** vs after (2-5) Rn filters*
- *Normalized to 1*
- *Statistics: 40k vs 10k samples*



➔ The **Rn peaks** are in the same positions
  - ◆ Good consistency ✅

➔ The relative quantity of Rn alphas in batch 2-5 reduced, highlighting other peaks.
  - ◆ Another **proof of presence of Rn** and posterior effectiveness of filters ✅

PMT Reco & Analysis

2. **3D lengths distributions**

… Caveats:

➔ Actually, there is some discrepancy in my numbers and Pinci's ⇒ mine are systematically bigger.

PMT Reco & Analysis

2. **3D lengths distributions**

… Caveats:

➔ Actually, there is some discrepancy in my numbers and Pinci's ⇒ mine are systematically bigger.

- Likely due to the fact that I'm not subtracting the **"minimum temporal signal"** from the measured ToTs.

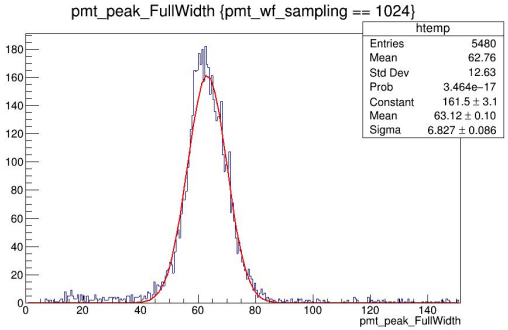
PMT Reco & Analysis

2. 3D lengths distributions

… Caveats:

➔ Actually, there is some discrepancy in my numbers and Pinci's ⇒ mine are systematically bigger.

- Likely due to the fact that I'm not subtracting the **"minimum temporal signal"** from the measured ToTs.
  - If I were to remove the ^{55}Fe length (= 63 samples = 4.6mm)...



➔ **FullWidth distribution of ^{55}Fe in calib runs in the same data set**

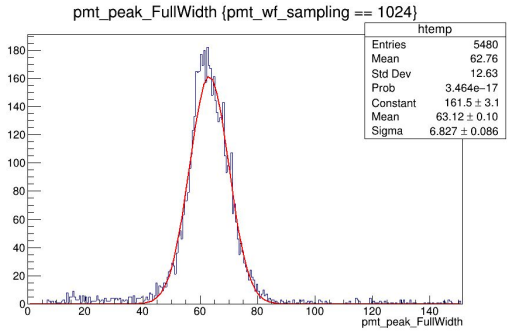
2. 3D lengths distributions

*** NB:** This correction was also applied in the tilted cosmic (flux) studies (https://agenda.infn.it/event/38654/contributions/217319/)

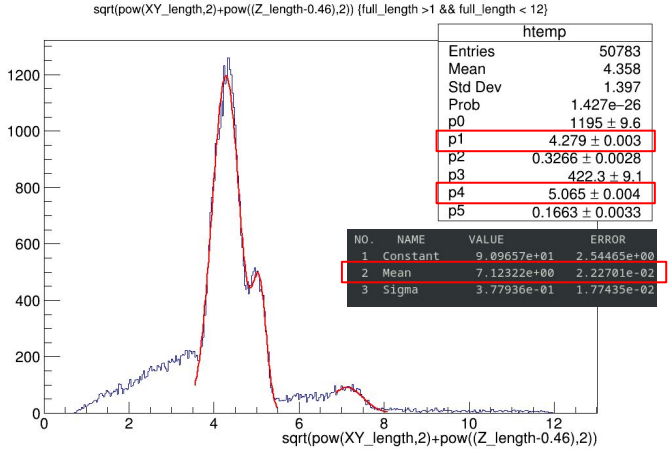
… Caveats:

➔ Actually, there is some discrepancy in my numbers and Pinci's ⇒ mine are systematically bigger.

- Likely due to the fact that I'm not subtracting the **"minimum temporal signal"** from the measured ToTs.
  - If I were to remove the ^{55}Fe length (= 63 samples = 4.6mm)…
    - ***The results would be even closer.***



➔ **FullWidth distribution of ^{55}Fe in calib runs in the same data set**



- 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. 3D lengths distributions - conclusion

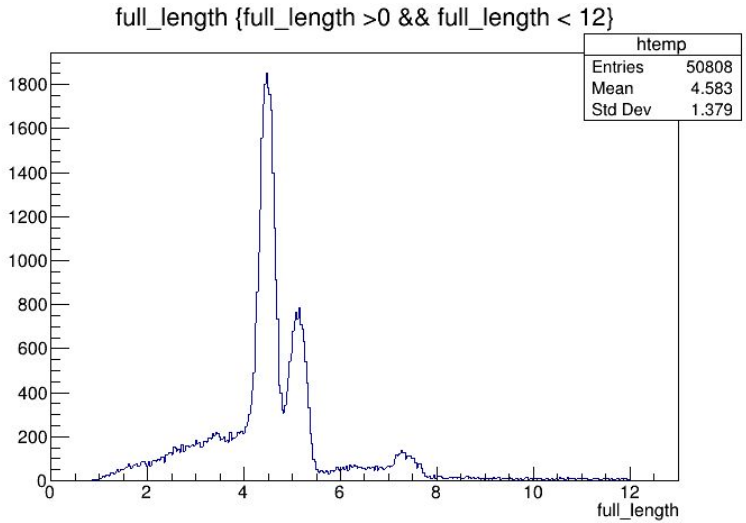
… Conclusions:

PMT Reco & Analysis

2. 3D lengths distributions - conclusion

… Conclusions:

- Results are very interesting because, ***unlike the energy that saturates*** and spoils the spectrum, **the length of the tracks can be quite precise**, and indeed we can see, also with a **good resolution**!



➔ We are **clearly in the presence of Rn** as we see the 3 contributions.

➔ A **simulation + digitization** would help my analysis, mostly on the accuracy of the CMOS:analyzer class, since it was initially optimized only for ERs.

➔ **PMT simulation** would be even better to test full 3D analysis!

PMT Reco & Analysis

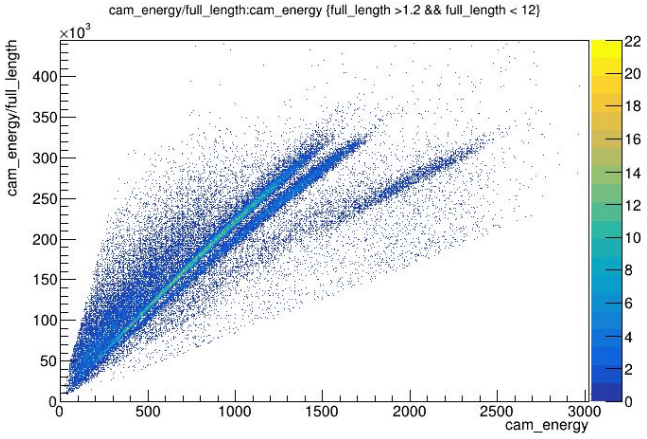
3. **dE/dx vs energy and vs length**

… a quick look:

PMT Reco & Analysis

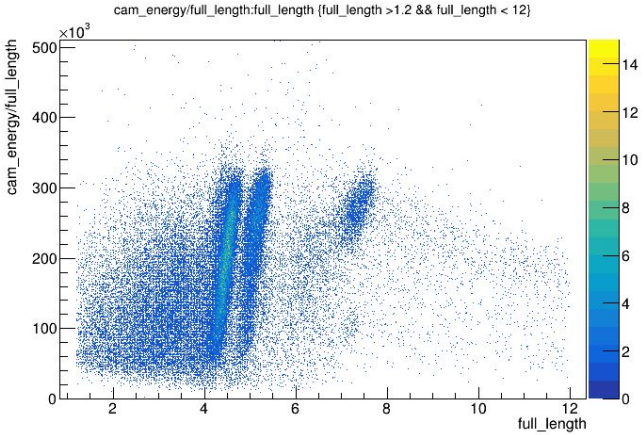
3. **dE/dx vs energy and vs length**

… a quick look:



➔ Lines likely correspond to the **3 alphas observed**.

- They are not points because of saturation!
  - Could saturation be studied from here?

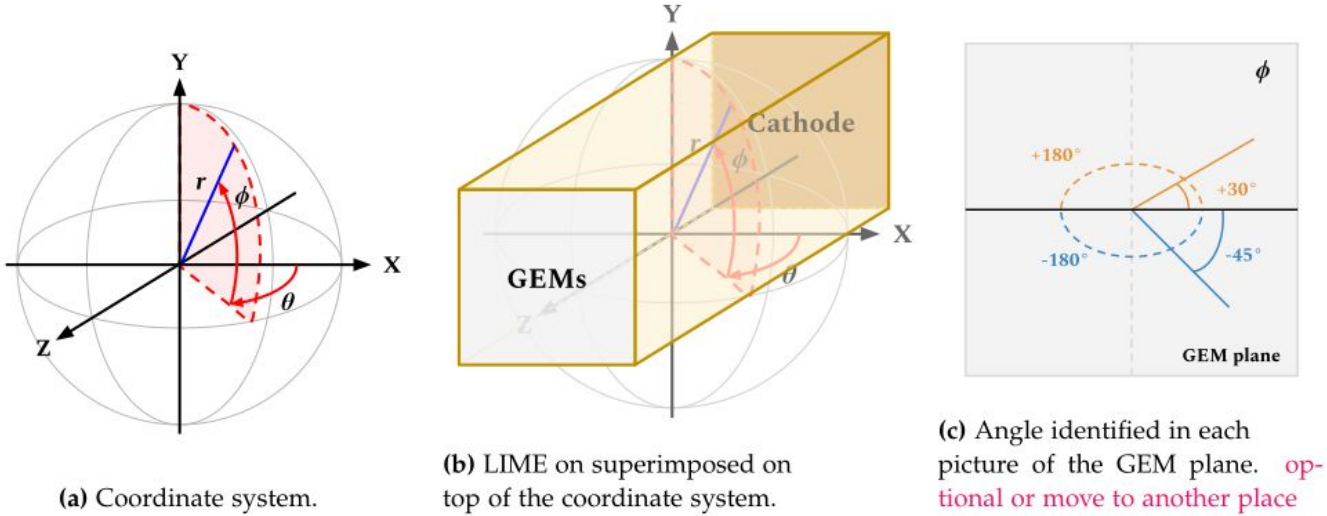


PMT Reco & Analysis

4. **Angles**

4. **Angles**

➔ Reference frame



(a) Coordinate system.

(b) LIME on superimposed on top of the coordinate system.

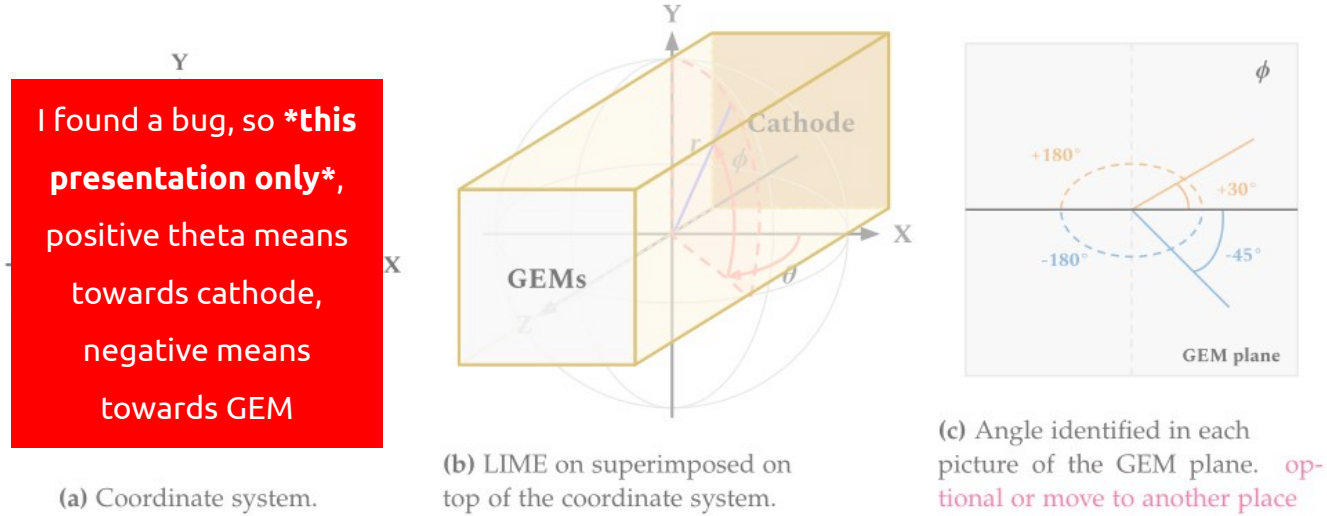
(c) Angle identified in each picture of the GEM plane. optional or move to another place

Figure 1.5: System of coordinates and angles used in the analysis of LIME data.

PMT Reco & Analysis

4. **Angles**

➔ Reference frame



(a) Coordinate system.

(b) LIME on superimposed on top of the coordinate system.

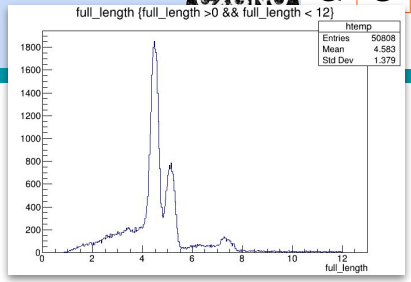
(c) Angle identified in each picture of the GEM plane. optional or move to another place

Figure 1.5: System of coordinates and angles used in the analysis of LIME data.

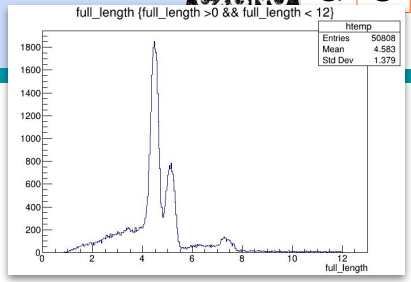
PMT Reco & Analysis

4. **Angles** ➔ Cuts based on the alpha 3D lengths:

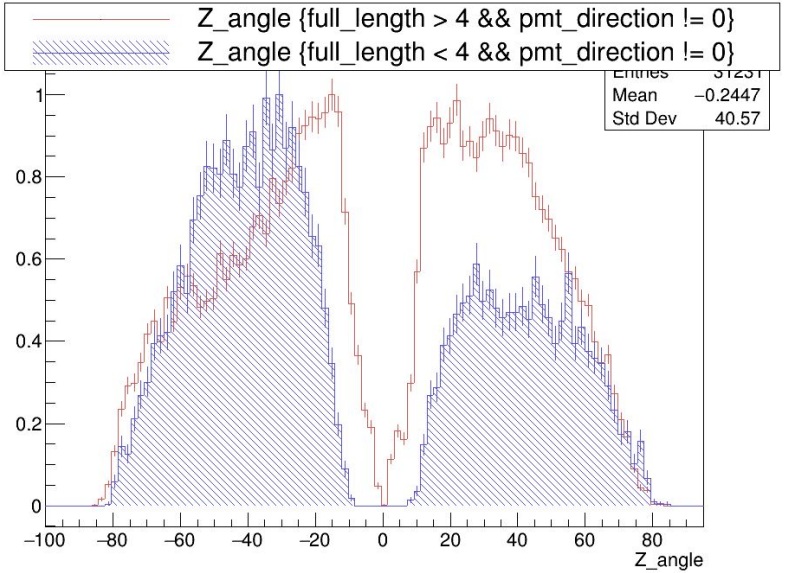
- 🔷 > 4 cm: Rn alphas
- 🔷 < 4 cm: Everything else



PMT Reco & Analysis



4. **Angles** ➔ Cuts based on the alpha 3D lengths:
   - 🔷 > 4 cm: Rn alphas
   - 🔷 < 4 cm: Everything else



➔ Before Christmas/Rn filters

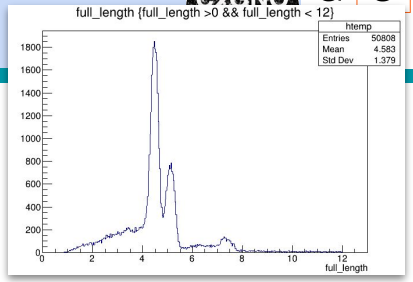
➔ Rn alphas have symmetric distribution of angles.
- ◆ Makes sense since emission is random

➔ Non-Rn alphas have preferential direction towards GEM
- ◆ Perhaps coming from cathode? ⇒ To investigate with absolute Z

PMT Reco & Analysis

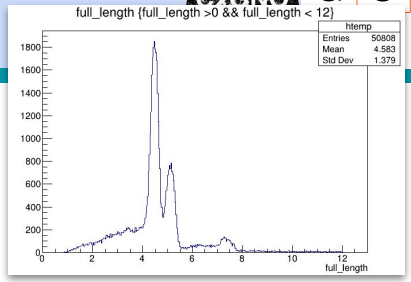
4. **Angles** ➔ Cuts based on the alpha 3D lengths:

- 🔷 > 4 cm: Rn alphas
- 🔷 < 4 cm: Everything else



… Comparing before and after Rn filters:

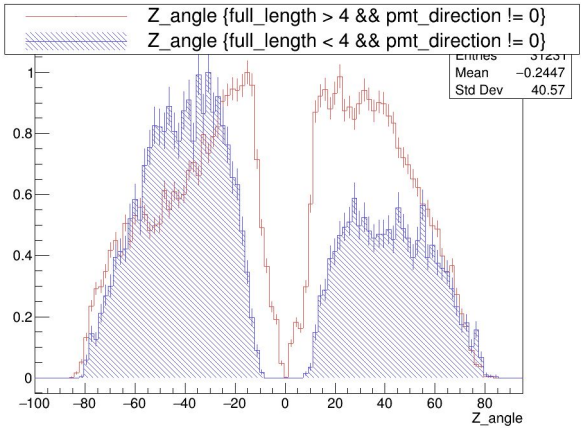
PMT Reco & Analysis

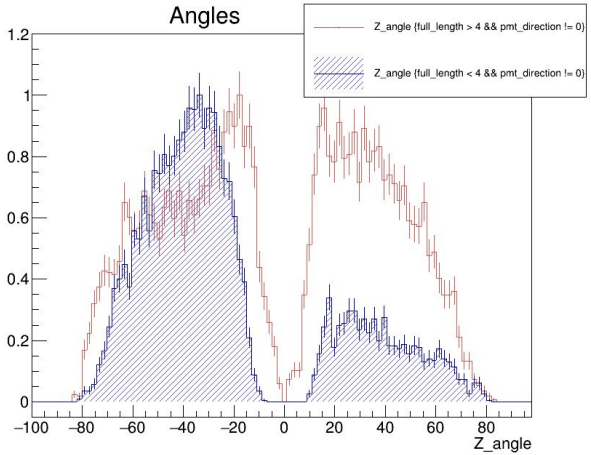


4. **Angles** ➔ Cuts based on the alpha 3D lengths:

- 🔷 > 4 cm: Rn alphas
- 🔷 < 4 cm: Everything else

… Comparing before and after Rn filters:





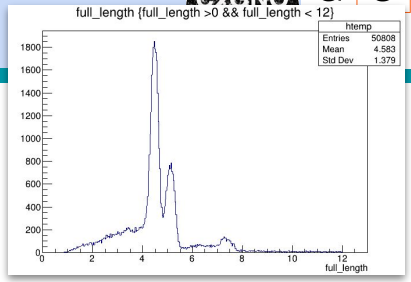
➔ Before Christmas

➔ After Christmas

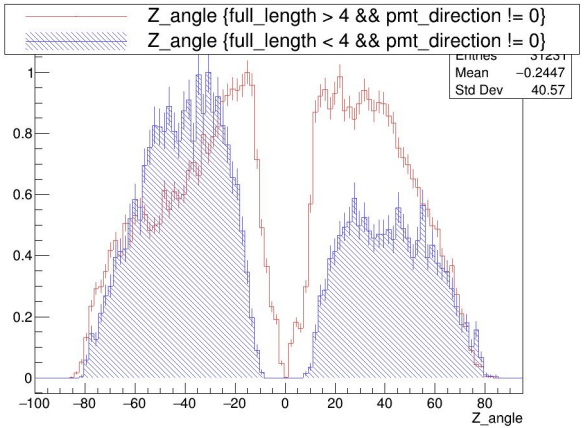
PMT Reco & Analysis

4. **Angles** ➔ Cuts based on the alpha 3D lengths:

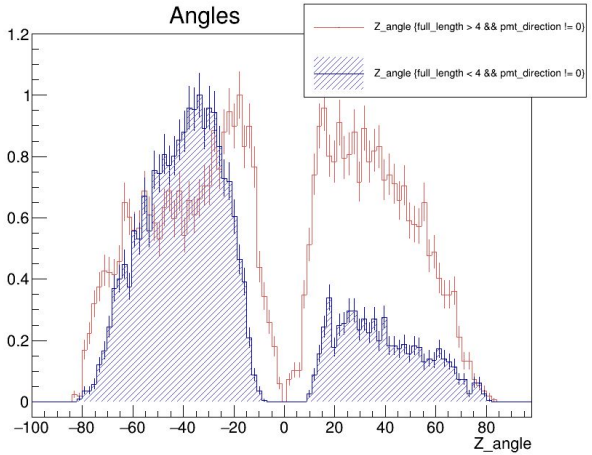
- 🔷 > 4 cm: Rn alphas
- 🔷 < 4 cm: Everything else



… Comparing before and after Rn filters:



➔ Before Christmas



➔ After Christmas

➔ Proportion of non-Rn alphas travelling towards GEMs increased.

- ◆ To study correlation from specific materials…

PMT Reco & Analysis

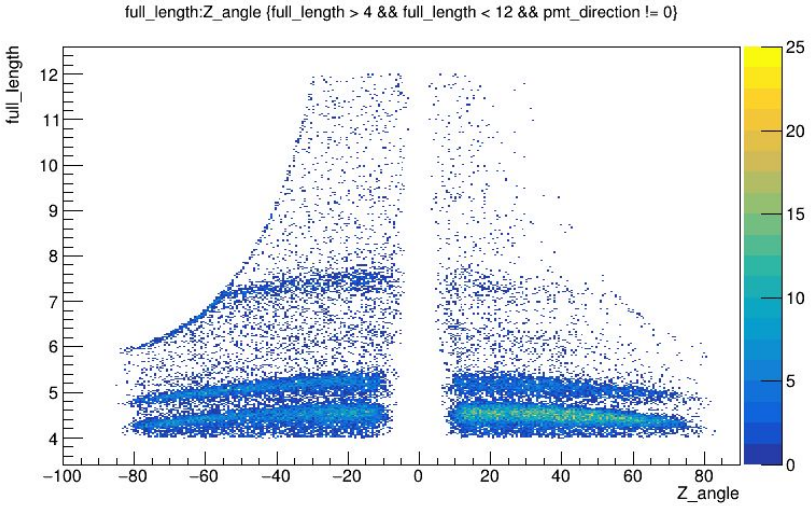
4. **Angles**

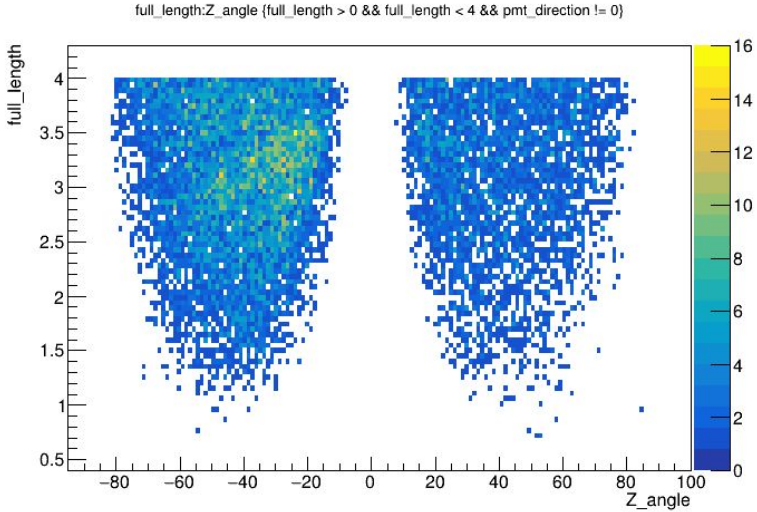
…We can also look at the distribution of angles

PMT Reco & Analysis

4. **Angles**

…We can also look at the distribution of angles





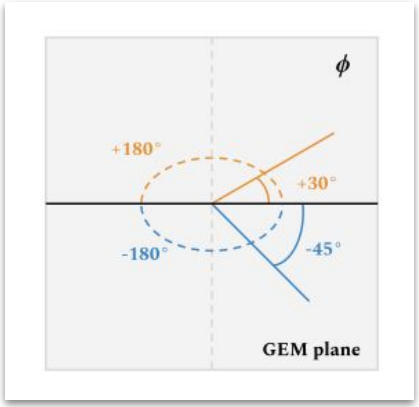
➔ Alphas at 7 cm more towards GEMs. Po charged daughters that drift towards cathode?

PMT Reco & Analysis

4. **Angles**

..We can also look at XY angle, meaning <u>CMOS-only analysis*</u>

**Xenon nT style*

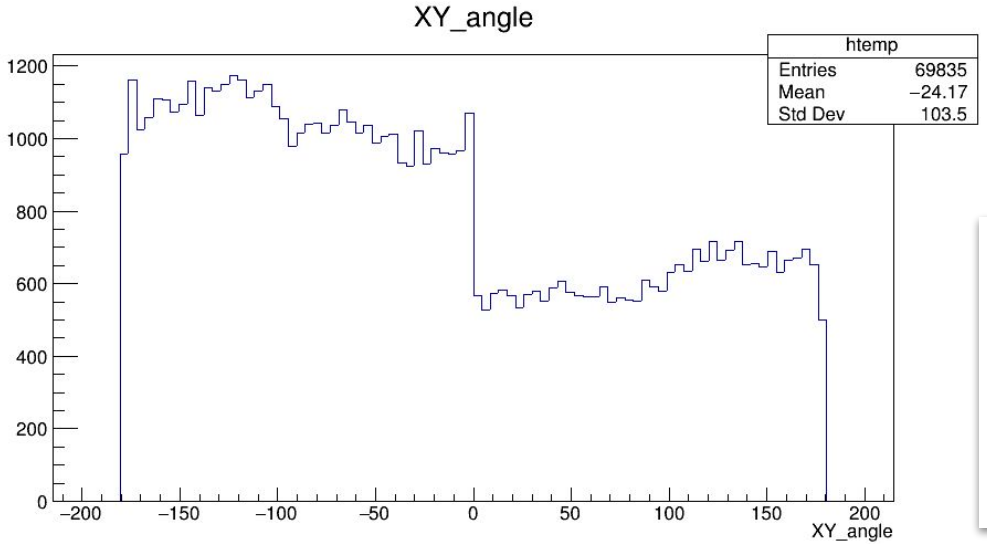


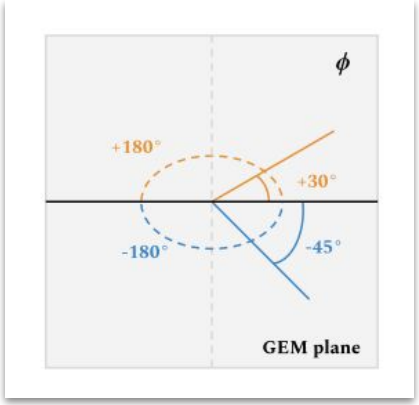
PMT Reco & Analysis

4. **Angles**

..We can also look at XY angle, meaning <u>CMOS-only analysis*</u>

**Xenon nT style*





➔ This shows a much greater amount of track going downwards, which could be from the resistors?

- To be confirmed with position dependent cuts…