#1 Update on …

Initial look at alpha tracks for directional & head-tail determination

David Marques and PMT Working Group

Technical / Analysis meeting 05-06-2024

PMT Signal basic properties – Resume

Let's resume all the information:

1. **Time over threshold** gives me the alpha **ΔZ**
   - Together with camera XY angle ⇒ **theta angle**

2. The **position of the Bragg** peak tells me **angle theta signal in Z**
   - (Towards cathode or GEMs)

3. **Relative amplitudes between PMTs** give me the **quadrant position** in X-Y
   - Useful for **basic association** cluster-waveform

4. **Skewness of Bragg peak** (within the waveform) **difference** between PMTs gives me the **direction** of the particle (head-tail)
   - **Analyser class (directionality)** gives me **Angle in X-Y (phi)** and the **ΔXY**
     - Could be confirmed / tested against PMT Bragg peak skewness method
   - Bragg peak more prominent because the track are small, thus geometrical effect plays a smaller role
   - Also gives a hint of the X-Y angle, but this is easier to get with the camera

PMT Signal basic properties – Resume

Let's resume all the information:

1. **Time over threshold** gives me the alpha **ΔZ**
   - Together with camera XY angle ⇒ **theta angle**

2. The **position of the Bragg** peak tells me **angle theta signal in Z**
   - (Towards cathode or GEMs)

3. **Relative amplitudes between PMTs** give me the **quadrant position** in X-Y
   - Useful for **basic association** cluster-waveform

4. **Skewness of Bragg peak** (within the waveform) **difference** between PMTs gives me the **direction** of the particle (**head-tail**)
   - **Analyser class (directionality)** gives me **Angle in X-Y (phi)** and the **ΔXY**
     - Could be confirmed / tested against PMT Bragg peak skewness method
   - Bragg peak more prominent because the track are small, thus geometrical effect plays a smaller role
   - Also gives a hint of the X-Y angle, but this is easier to get with the camera

Reconstructed info:

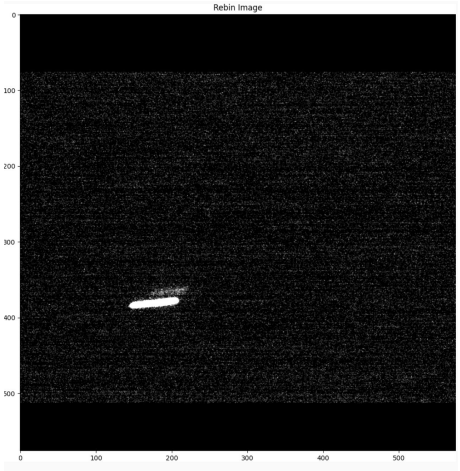
- **ΔZ**
- **Theta angle**
- **ΔXY**
- **Phi angle**
- **Signal of theta + phi == Head-tail**

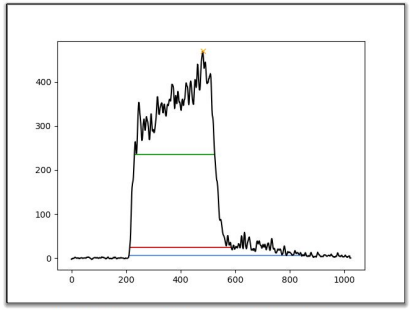
⇓

3D reconstruction

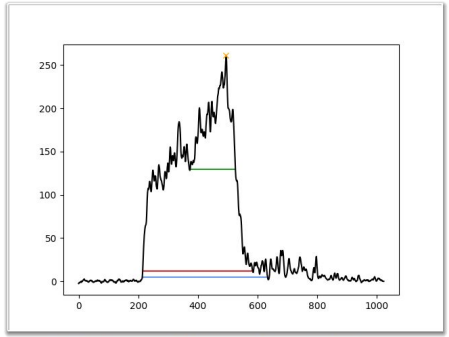
PMT Signal – Examples

- Run 22100, ev 40

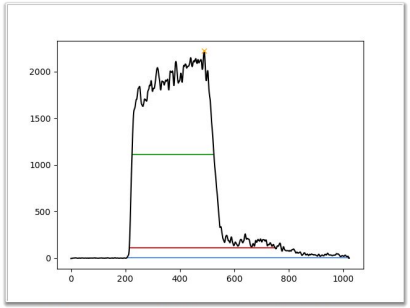




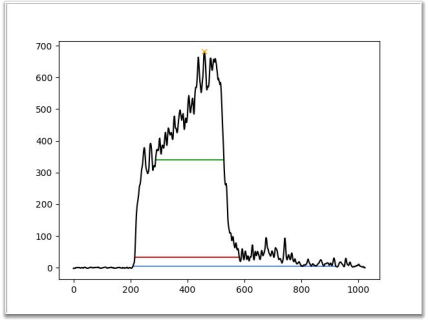
PMT_fast_run_22100_ev_40_tr_0_ch_1.png



PMT_fast_run_22100_ev_40_tr_0_ch_2.png



PMT_fast_run_22100_ev_40_tr_0_ch_4.png



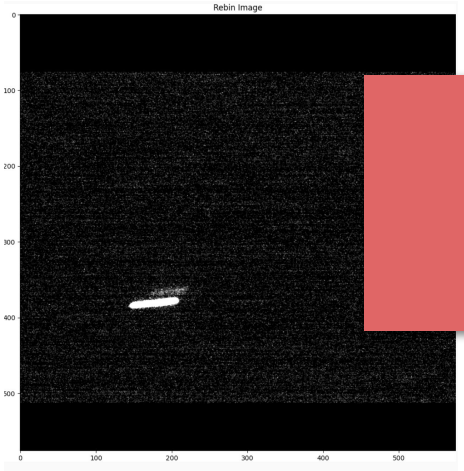
PMT_fast_run_22100_ev_40_tr_0_ch_3.png

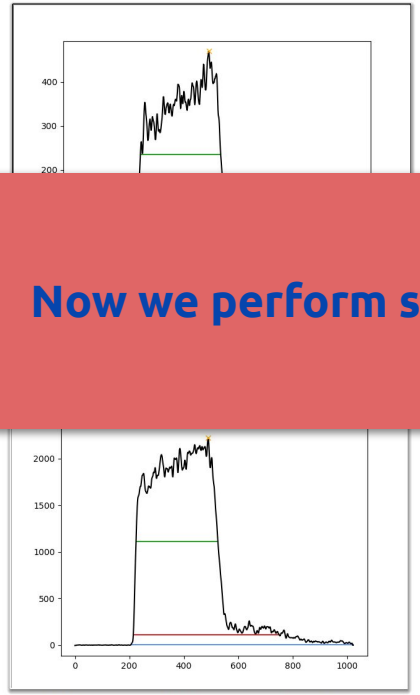
- Bragg peak on the right ⇒ moving **towards cathode**.
- Leftwards or rightwards? ⇒ Skewness higher for PMTs 2 and 3, moving **rightwards**

<<<<<< Last time example >>>>>>

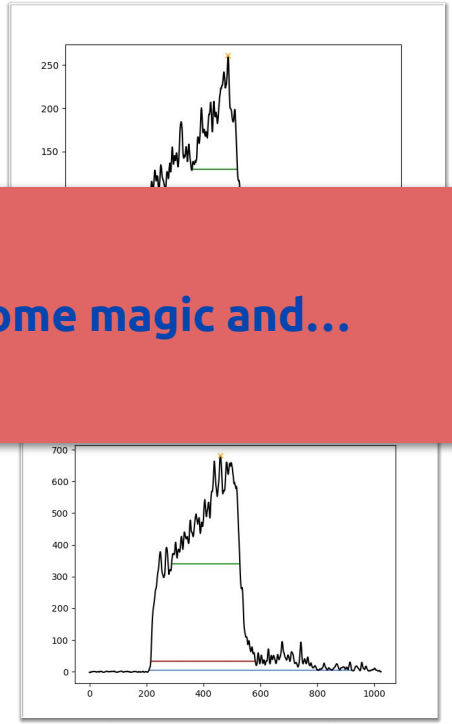
PMT Signal – Examples

- Run 22100, ev 40





PMT_fast_run_22100_ev_40_tr_0_ch_4.png



PMT_fast_run_22100_ev_40_tr_0_ch_3.png

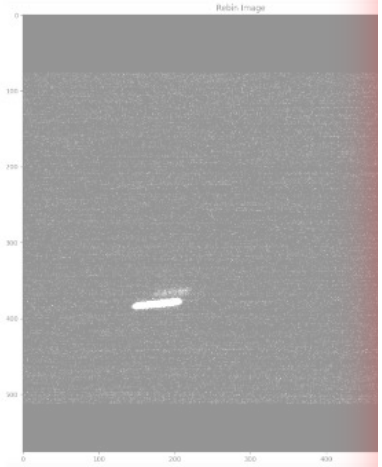
Now we perform some magic and…

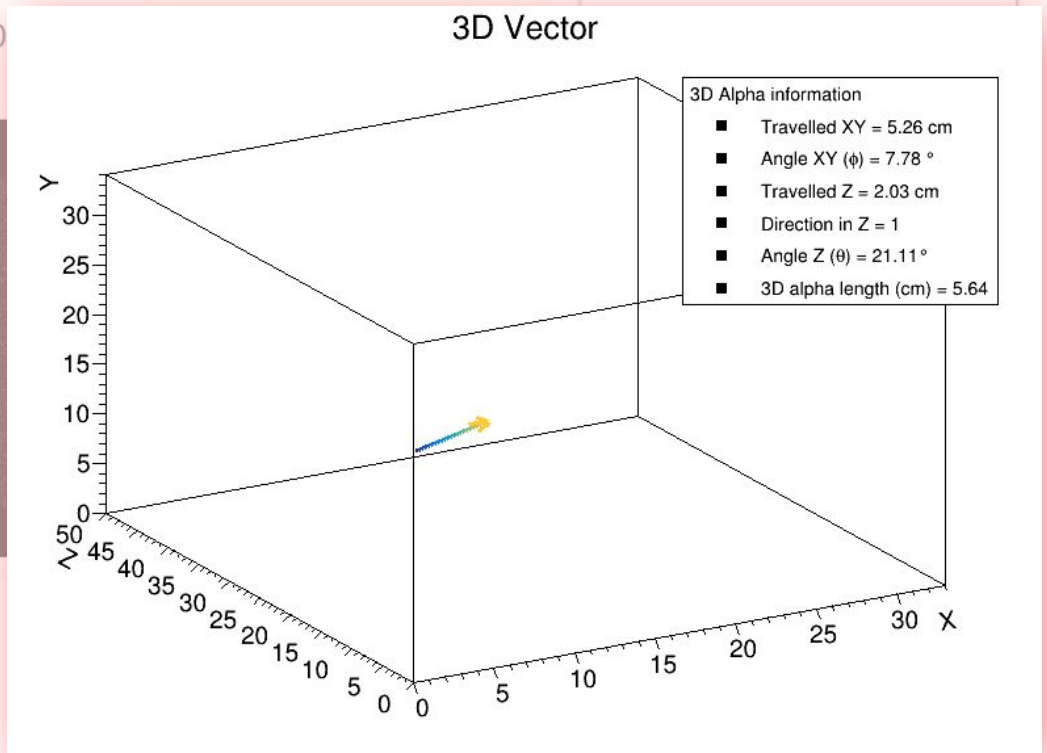
Bragg peak on the right ⇒ moving **towards cathode**. Leftwards or rightwards? ⇒ Skewness higher for PMTs 2 and 3, moving **rightwards**

<<<<<< Last time example >>>>>>

PMT Signal – Examples

- Run 22100, ev 40





- Bragg peak on the right ⇒ moving **towards cathode**.
- Leftwards or rightwards? ⇒ Skewness higher for PMTs 2 and 3, moving **rightwards**

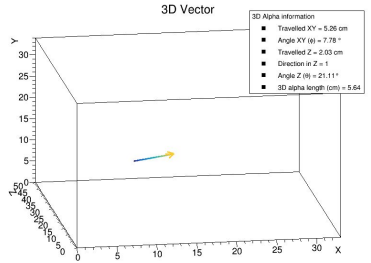
<<<<<< Last time example >>>>>>

PMT - 3D Deconstruction

1. Read reco-files directly after official reconstruction (we start with camera since it's more likely to *not* see the signal)

```
CAM Reco data file openend: reco_run22100_3D.root
PMT Reco data file openend: reco_run22100_3D_pmt.root
```

- Run 22100, ev 40



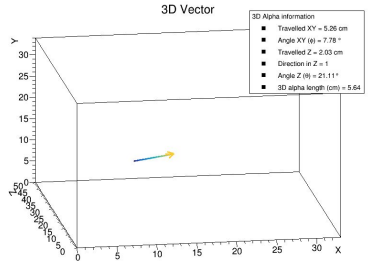
PMT - 3D Deconstruction

1. Read reco-files directly after official reconstruction (we start with camera since it's more likely to *not* see the signal)

```
CAM Reco data file openend: reco_run22100_3D.root
PMT Reco data file openend: reco_run22100_3D_pmt.root
```

2. Apply some basic cuts
    - `if ( sc_integral[sc_i]/sc_nhits[sc_i] > 25 && sc_length[sc_i] > 100 && sc_width[sc_i] > 50 ) {  //Alpha cut from Giorgio`

- Run 22100, ev 40



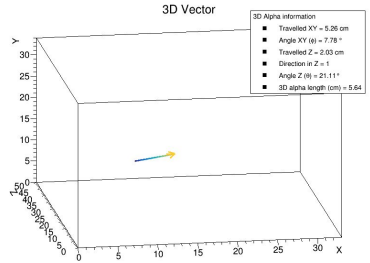
PMT - 3D Deconstruction

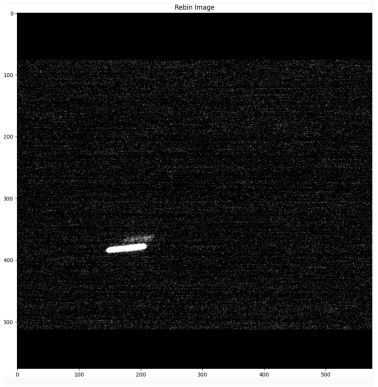
1. Read reco-files directly after official reconstruction (we start with camera since it's more likely to *not* see the signal)

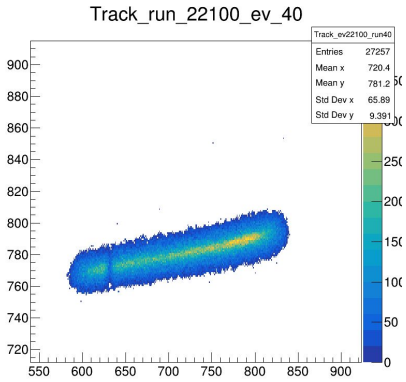
```
CAM Reco data file openend: reco_run22100_3D.root
PMT Reco data file openend: reco_run22100_3D_pmt.root
```

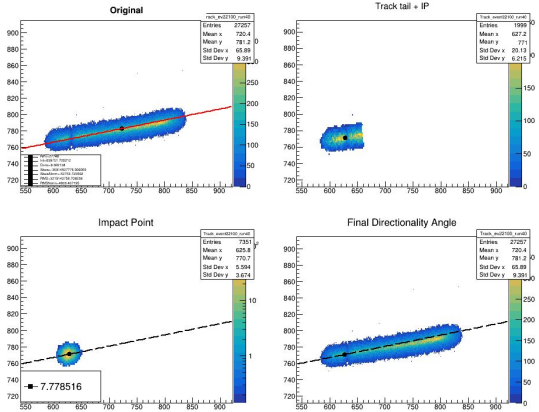
2. Apply some basic cuts
   - `if ( sc_integral[sc_i]/sc_nhits[sc_i] > 25 && sc_length[sc_i] > 100 && sc_width[sc_i] > 50 ) {  //Alpha cut from Giorgio`
3. Run analyser class (Flaminia base, Samuele directionality, Atul's ML, Davide comments …)

- Run 22100, ev 40





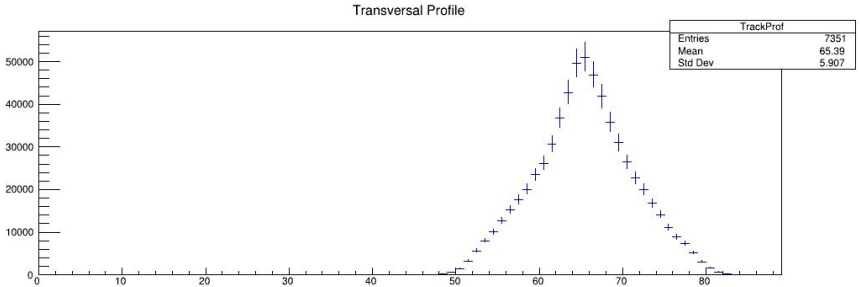


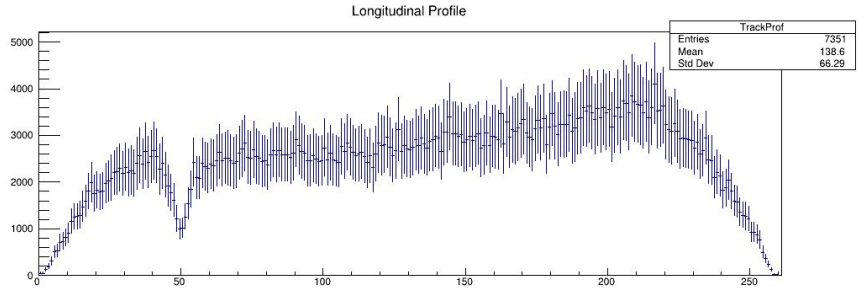



```
        Track information:

--> Position barycenter: x: 722.224; y: 782.877
--> Quadrant: 4
--> Angle: 7.77852 degrees.
--> Length (cm): 5.26497
```

PMT - 3D Deconstruction

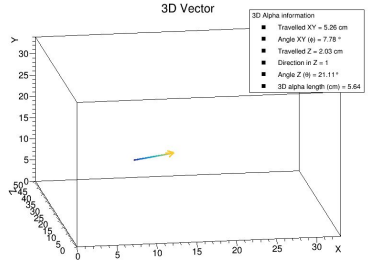
4. (Optional) Save the track's profiles





5. Save all the ***camera*** information

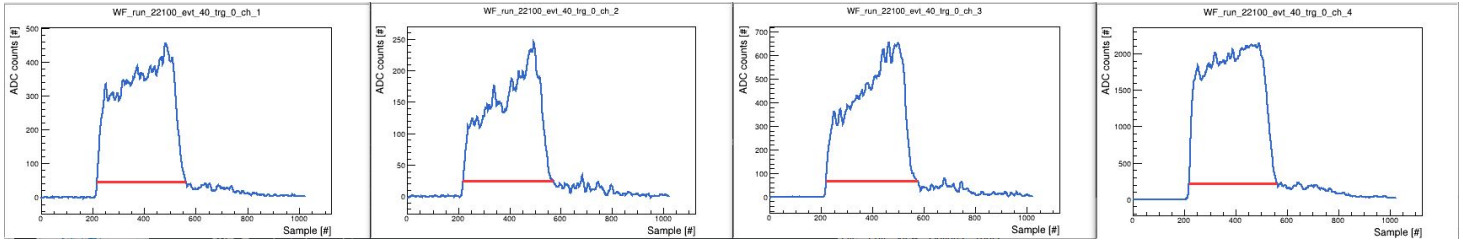
- Run 22100, ev 40



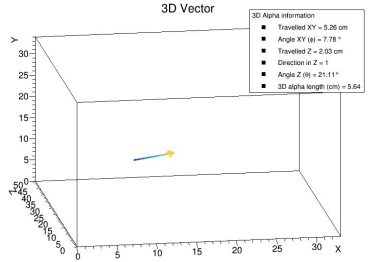

```
//----------- Collect all the relevant info for posterior analysis  ---

CAM_alphas.push_back({
    .run = cam_run,
    .pic  = cam_event,

    .angle_XY = angle_cam,
    .trv_XY = sc_length[sc_i] * granularity,

    .quad = quadrant_cam,

        .IP_X_cm = x_impact,
        .IP_Y_cm = y_impact
});
```

PMT - 3D Deconstruction

6. Look at waveforms



- Run 22100, ev 40



6.1. Retrieve:

6.1.1. ToT (*different from the one of reco) ⇒ average travelled Z

6.1.2. Calculate integral in first and second half ⇒ Majority gives me theta signal

6.1.3. Get alpha quadrant in XY ⇒ Retrieved by checking with PMT sees the stronger signal

6.2 Save all the information

```
       PMT Track information:

--> Skewness signs: 1 1 1 0   -> skewness sign average is: 0.75
--> This track is moving towards the cathode.
--> The average travelled Z (cm) is: 2.0329
--> The track is in the quadrant: 4
```

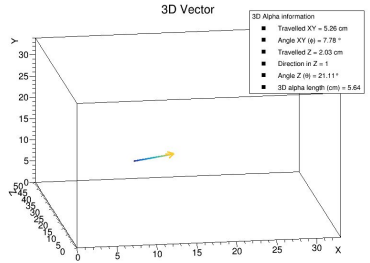
PMT - 3D Deconstruction

7. Combined analysis

   7.1. Only for 1-to-1 matched tracks (tested for multi-trigger events)

```
# Matched alpha in quadrant: 4; in trigger: 0
```

- Run 22100, ev 40



PMT - 3D Deconstruction

7. Combined analysis

   7.1. Only for 1-to-1 matched tracks (tested for multi-trigger events)

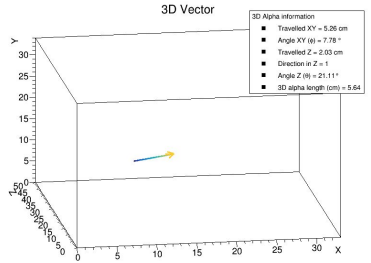
```
# Matched alpha in quadrant: 4; in trigger: 0
```

   7.2. Calculate all the remaining variables through geometry

```
//----------- Creating 3D alpha track information  ----------//

x0 = cam.IP_X_cm;
y0 = cam.IP_Y_cm;
z0 = 25.0;                          // Absolute Z fixed.

x1 = x0 + ( cam.trv_XY * cos(cam.angle_XY * TMath::Pi()/180.));
y1 = y0 + ( cam.trv_XY * sin(cam.angle_XY * TMath::Pi()/180.));
z1 = z0 + ( pmt.trv_Z  * pmt.dir);

double theta_angle = atan(pmt.trv_Z/cam.trv_XY) * 180. / TMath::Pi();

// double length = TMath::Sqrt(pow(x1-x0,2) + pow(y1-y0,2) + pow(z1-z0,2));
double length = TMath::Sqrt(pow(cam.trv_XY,2) + pow(pmt.trv_Z,2));
```

```
        ** 3D Alpha track information: **

--> Travelled XY: 5.26497
--> Angle XY (#phi): 7.77852
--> Travelled Z: 2.0329
--> Direction in Z: 1
--> Angle Z (#theta): 21.1125
--> 3D alpha length (cm): 5.64381
```

- Run 22100, ev 40



PMT - 3D Deconstruction

7. Combined analysis

7.1. Only for 1-to-1 matched tracks (tested for multi-trigger events)

```
# Matched alpha in quadrant: 4; in trigger: 0
```

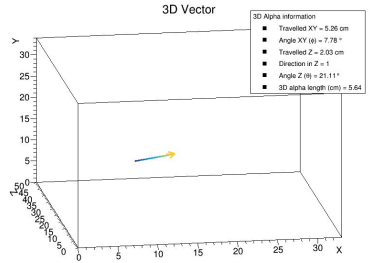
7.2. Calculate all the remaining variables through geometry

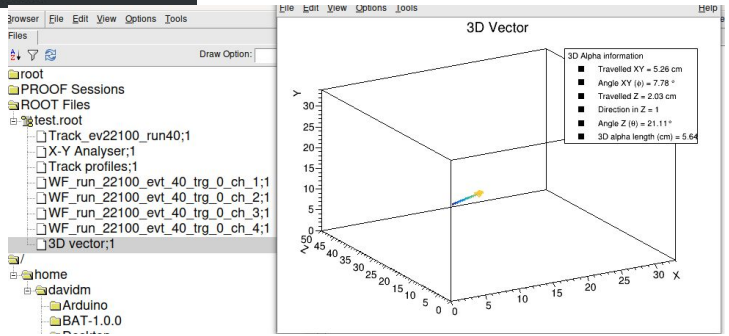
```
//----------- Creating 3D alpha track information  ----------//

x0 = cam.IP_X_cm;
y0 = cam.IP_Y_cm;
z0 = 25.0;                          // Absolute Z fixed.

x1 = x0 + ( cam.trv_XY * cos(cam.angle_XY * TMath::Pi()/180.));
y1 = y0 + ( cam.trv_XY * sin(cam.angle_XY * TMath::Pi()/180.));
z1 = z0 + ( pmt.trv_Z  * pmt.dir);

double theta_angle = atan(pmt.trv_Z/cam.trv_XY) * 180. / TMath::Pi();

// double length = TMath::Sqrt(pow(x1-x0,2) + pow(y1-y0,2) + pow(z1-z0,2));
double length = TMath::Sqrt(pow(cam.trv_XY,2) + pow(pmt.trv_Z,2));
```

```
        ** 3D Alpha track information: **

--> Travelled XY: 5.26497
--> Angle XY (#phi): 7.77852
--> Travelled Z: 2.0329
--> Direction in Z: 1
--> Angle Z (#theta): 21.1125
--> 3D alpha length (cm): 5.64381
```

7.3 Feed all the information to a 100 line script to create a 3D vector in ROOT and put everything in a file.

- Run 22100, ev 40



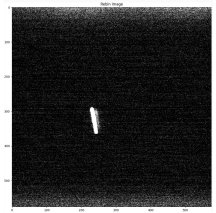


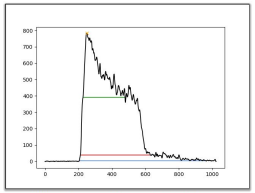
PMT Alpha 3D reco – Examples

Some other examples

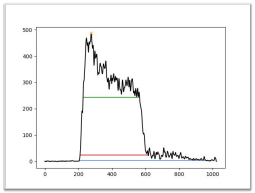
PMT Alpha 3D reco – Examples

- Run 22101, ev 33

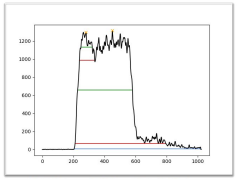




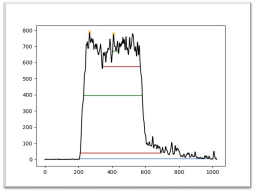
PMT_fast_run_22101_ev_33_tr_0_ch_1.png



PMT_fast_run_22101_ev_33_tr_0_ch_2.png



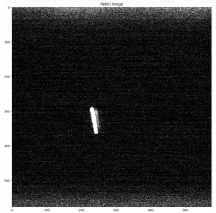
PMT_fast_run_22101_ev_33_tr_0_ch_4.png

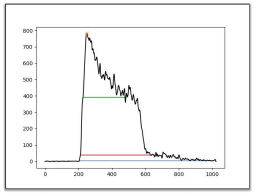


PMT_fast_run_22101_ev_33_tr_0_ch_3.png

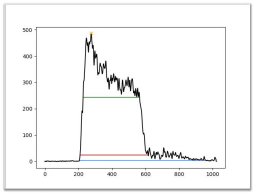
PMT Alpha 3D reco – Examples

- Run 22101, ev 33

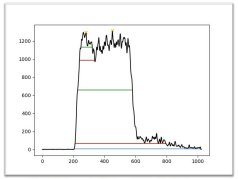




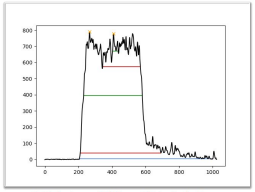
PMT_fast_run_22101_ev_33_tr_0_ch_1.png



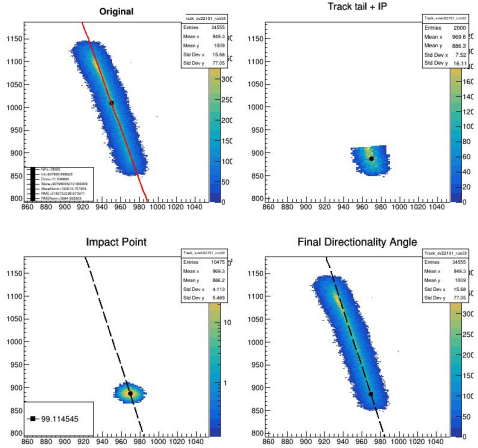
PMT_fast_run_22101_ev_33_tr_0_ch_2.png

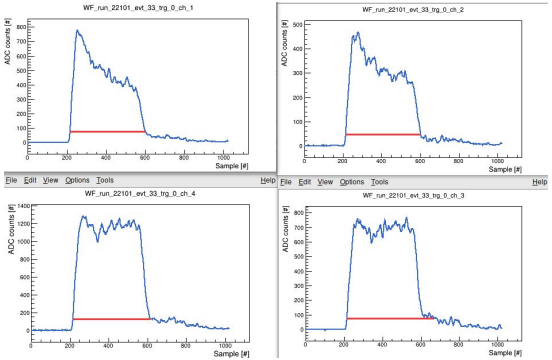


PMT_fast_run_22101_ev_33_tr_0_ch_4.png



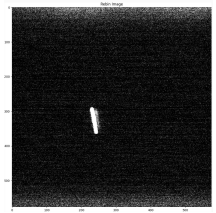
PMT_fast_run_22101_ev_33_tr_0_ch_3.png

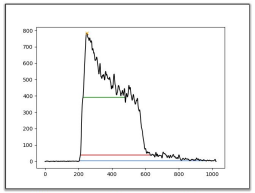




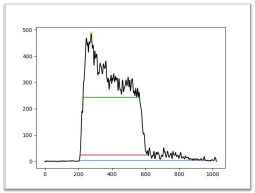
PMT Alpha 3D reco – Examples

- Run 22101, ev 33

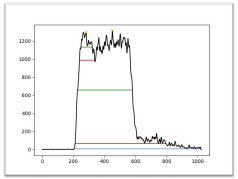




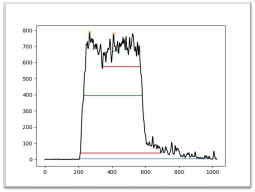
PMT_fast_run_22101_ev_33_tr_0_ch_1.png



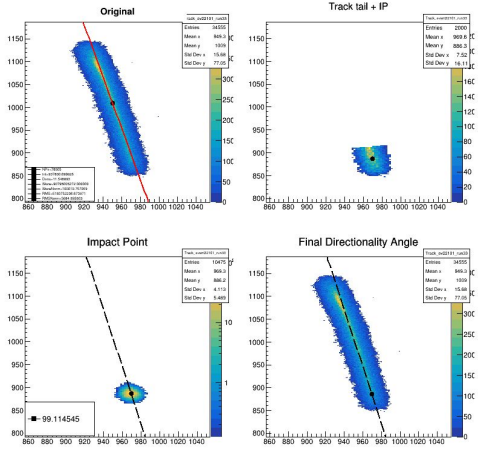
PMT_fast_run_22101_ev_33_tr_0_ch_2.png

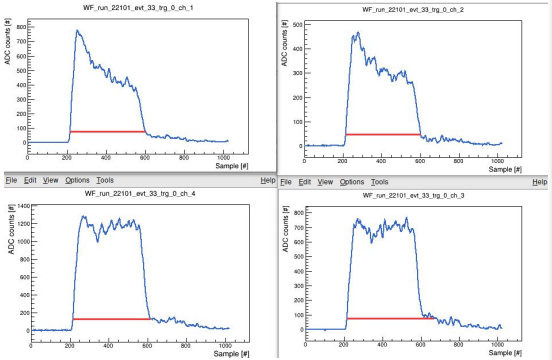


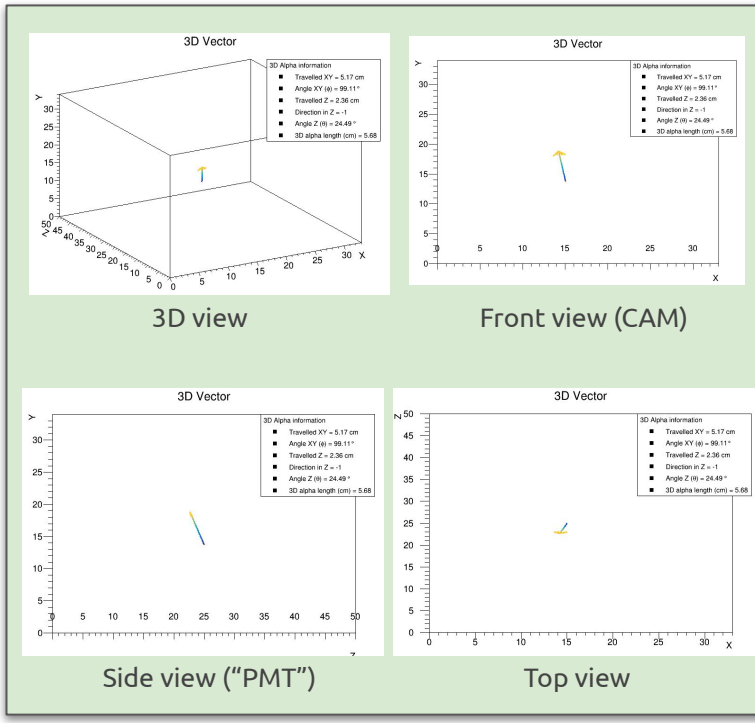
PMT_fast_run_22101_ev_33_tr_0_ch_4.png



PMT_fast_run_22101_ev_33_tr_0_ch_3.png

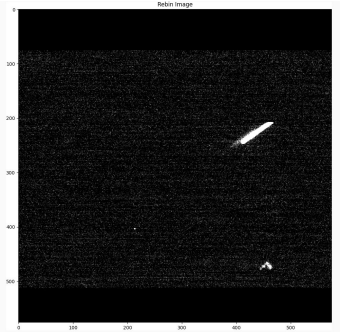


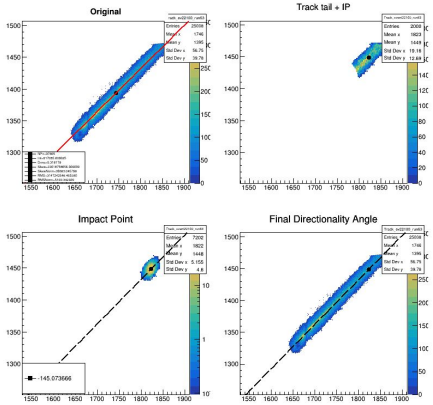


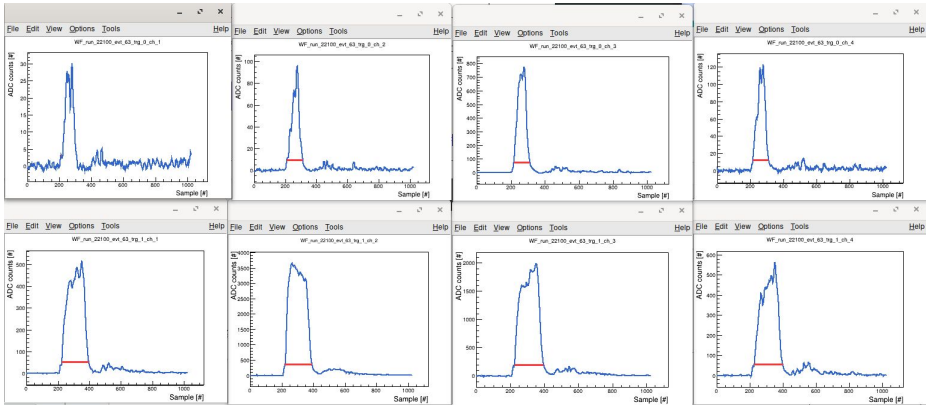


PMT Alpha 3D reco – Examples

- Run 22101, ev 63 - multi-trigger

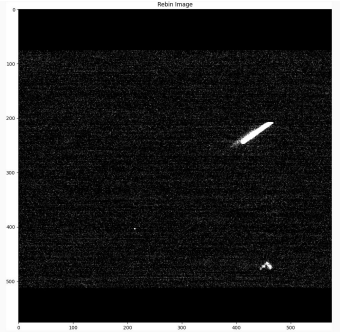


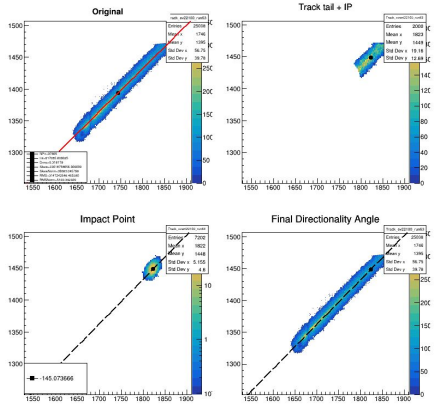


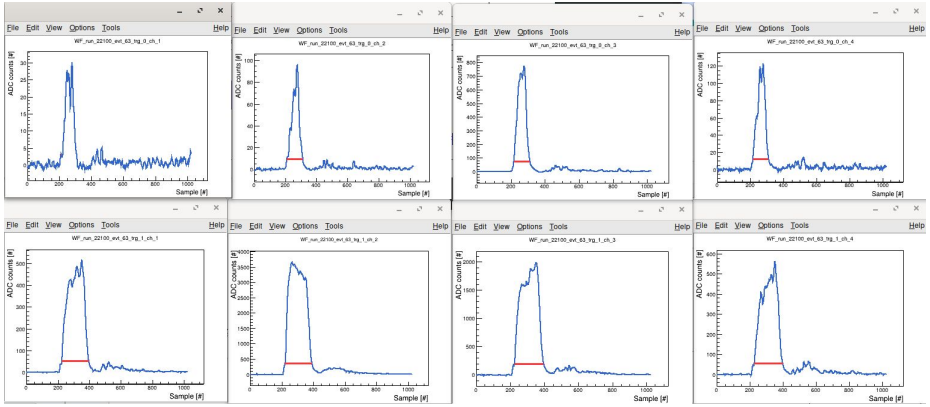


PMT Alpha 3D reco – Examples

- Run 22101, ev 63 - multi-trigger







```
Cam run: 22100; event(pic): 63; nSc: 3

Cluster ID: 0
Warning in <TFile::Append>: Replacing existing TH1: Track_event2210

        Track information:

--> Position barycenter: x: 1743.04; y: 1393.8
--> Quadrant: 2
--> Angle: -145.074 degrees.
--> Length (cm): 5.75051
Warning in <TFile::Append>: Replacing existing TH1: TrackProf (Pote

Cluster ID: 1

Cluster ID: 2
PMT run: 22100; event: 63; trigger: 0; channel: 1; sampling: 1024
PMT run: 22100; event: 63; trigger: 0; channel: 2; sampling: 1024
PMT run: 22100; event: 63; trigger: 0; channel: 3; sampling: 1024
PMT run: 22100; event: 63; trigger: 0; channel: 4; sampling: 1024

        PMT Track information:

--> Skewness signs: 1 0 1   -> skewness sign average is: 0.666667
--> This track is moving towards the cathode.
--> The average travelled Z (cm) is: 0.42775
--> The track is in the quadrant: 3
PMT run: 22100; event: 63; trigger: 1; channel: 1; sampling: 1024
PMT run: 22100; event: 63; trigger: 1; channel: 2; sampling: 1024
PMT run: 22100; event: 63; trigger: 1; channel: 3; sampling: 1024
PMT run: 22100; event: 63; trigger: 1; channel: 4; sampling: 1024

        PMT Track information:

--> Skewness signs: 1 0 1 1   -> skewness sign average is: 0.75
--> This track is moving towards the cathode.
--> The average travelled Z (cm) is: 0.9947
--> The track is in the quadrant: 2

# Matched alpha in quadrant: 2; in trigger: 1

        ** 3D Alpha track information: **

--> Travelled XY: 5.75051
--> Angle XY (#phi): -145.074
--> Travelled Z: 0.9947
--> Direction in Z: 1
--> Angle Z (#theta): 9.81369
--> 3D alpha length (cm): 5.8359
**Finished**
```

CAM

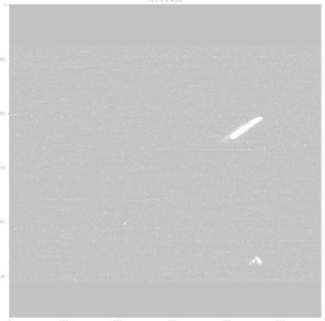
PMT

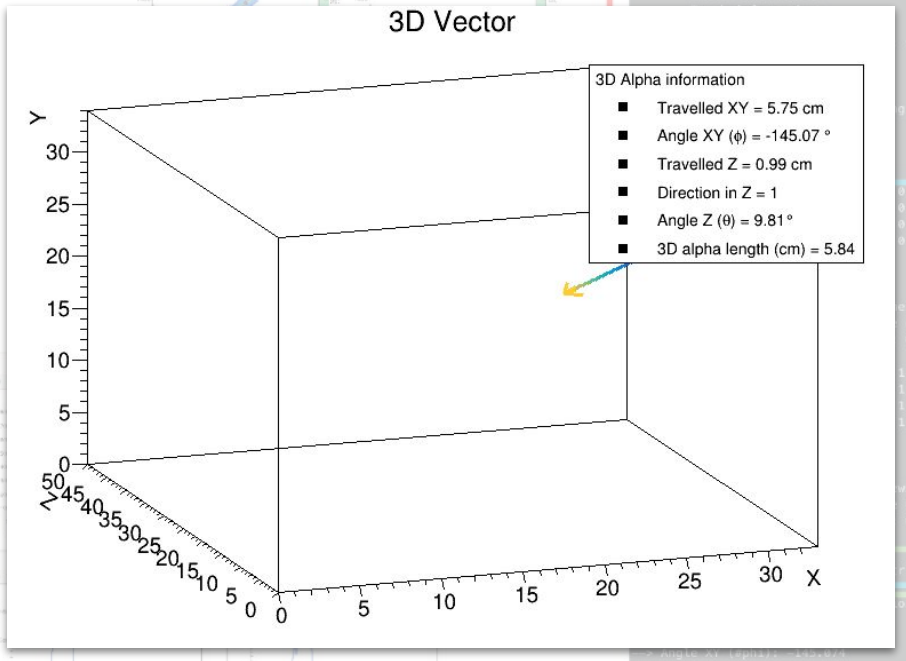
Association

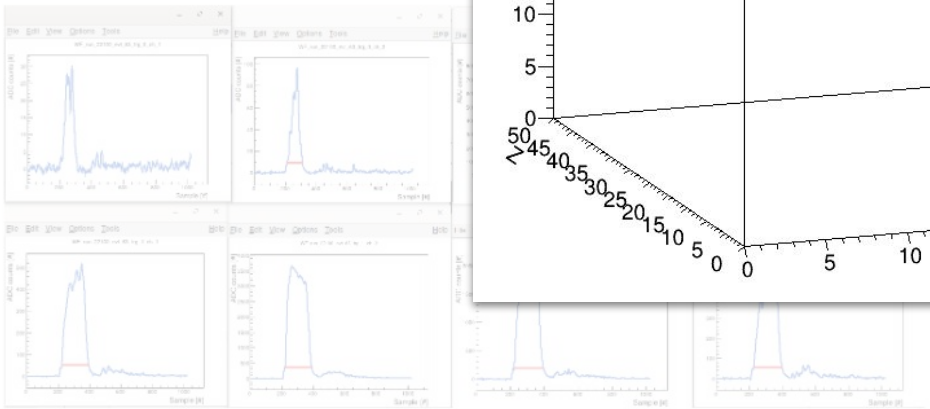
(will be improved with other PMT selection / Bayes)

PMT Alpha 3D reco – Examples

- Run 22101, ev 63 - multi-trigger







CAM

PMT

Association (will be improved with other PMT selection / Bayes)

PMT 3D reco – Conclusions

1. **Missing (?) features**
   - Color gradient is fake ⇒ Worth to associate it to longitudinal ionization profile?
   - Electron cloud not plotted ⇒ Worth to take 2D transversal profile and create a 3D cylinder around main vector?
   - ToT doesn't take into account minimum signal temporal width -> travelled Z slightly overestimated
   - Improve association ⇒ Using BAT?
   - Improve theta signal calculation ⇒ Also probably using BAT
   - Get 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?***