PMT Reco integration

CYGNO Analysis Meeting

29-02-2024

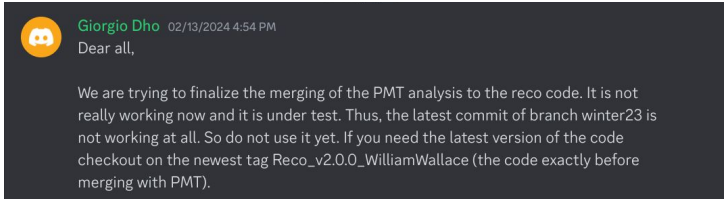
David Marques

& PMT analysis working group

PMT Reco- Full integration

You might have this seen this message from Giorgio.

- There were more complications that we expected.



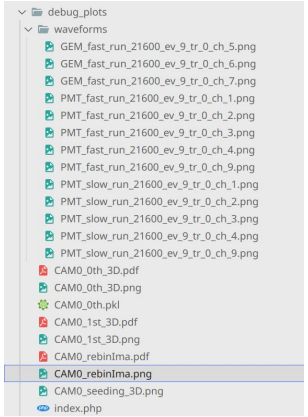
We worked a lot on it and a fully integrated reconstruction should arrive by the end of the week. ⇒ ***Has arrived!***

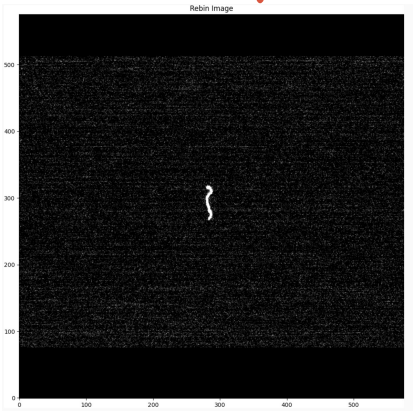
- A lot of change were made, but some of the most crucial are:
  - Reco accepts any number of digitizers (MANGO - 1, LNF/LNGS - 2)
  - MANGO correction tables added
  - Reco accepts any number of PMTs (MANGO - 1; LNF - 2; LNGS - 4)
  - Channels to analyse can be selected now
  - Reco retrieves GEM signals (only available for LNGS)
    - Data is in the output and analysis is up to the GEM interest people

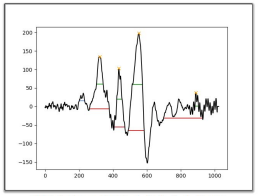
```
### PMT waveform reconstruction
'pmt_mode'              : 1,
'board_pmt_channels'    : [1,2,3,4],    # Board channels used to save PMT.

'threshold'             : 0,
'height_RMS'            : 5,            ## 5 * RMS
'minPeakDistance'       : 1,
'prominence'            : 0.1,
'fixed_prom'            : True,         ## If True, overrides prominence value with optimized one
'width'                 : 5,
'resample'              : 10,           ## Number of samples used for moving average
'pmt_plotpy'            : True,     ## saves ALL waveforms in '{--pdir}./waveforms'. Careful.
'pmt_wf_in_tree'        : False,        ## saves full X and Y arrays in tree branches.
'pmt_verbose'           : 1,            ## Choose from 0 to 3. '0' for no output; '3' for full output.

'include_gem'           : 0,            ## Also performs very basic GEM signal analysis
'board_gem_channels'    : [5,6,7]
}
```

PMT Reco- Some examples

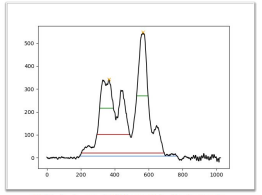
⇒ Now when you run debug mode:



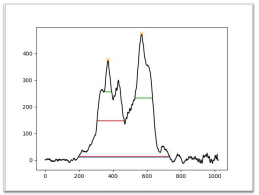




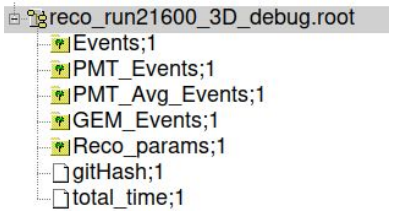
GEM_fast_run_21600_ev_9_tr_0_ch_5.png

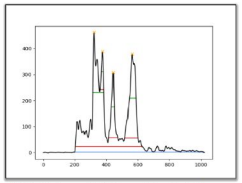


GEM_fast_run_21600_ev_9_tr_0_ch_6.png

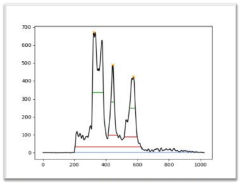


GEM_fast_run_21600_ev_9_tr_0_ch_7.png

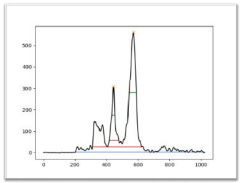




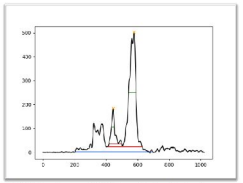
PMT_fast_run_21600_ev_9_tr_0_ch_1.png



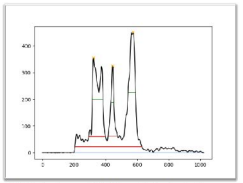
PMT_fast_run_21600_ev_9_tr_0_ch_2.png



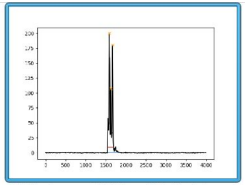
PMT_fast_run_21600_ev_9_tr_0_ch_3.png



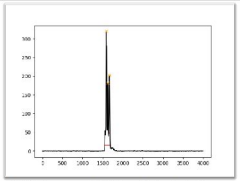
PMT_fast_run_21600_ev_9_tr_0_ch_4.png



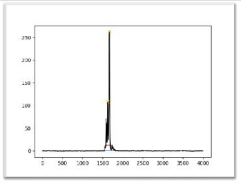
PMT_fast_run_21600_ev_9_tr_0_ch_9.png



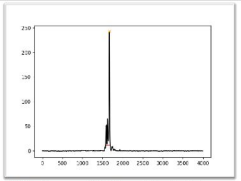
PMT_slow_run_21600_ev_9_tr_0_ch_1.png



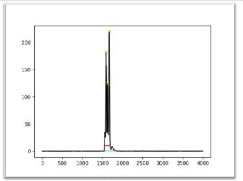
PMT_slow_run_21600_ev_9_tr_0_ch_2.png



PMT_slow_run_21600_ev_9_tr_0_ch_3.png



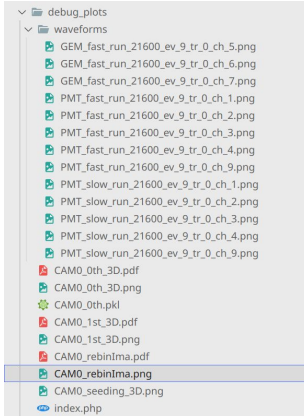
PMT_slow_run_21600_ev_9_tr_0_ch_4.png

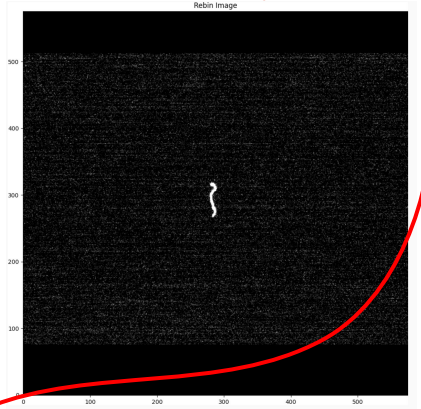


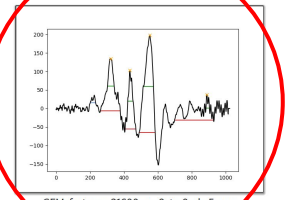
PMT_slow_run_21600_ev_9_tr_0_ch_9.png

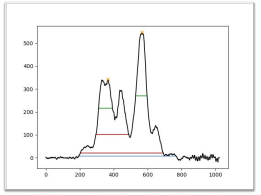
PMT Reco- Some examples

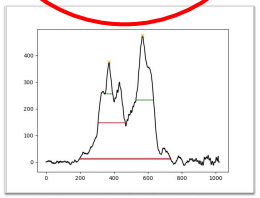
⇒ Now when you run debug mode:

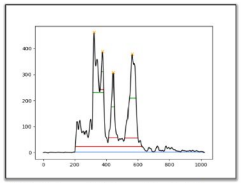


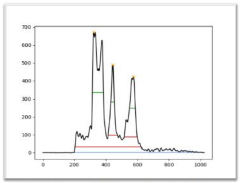


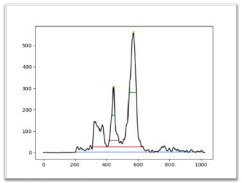


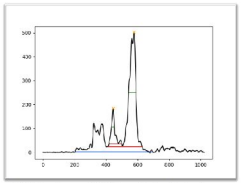


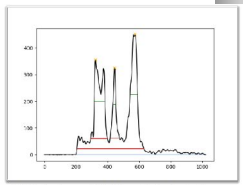


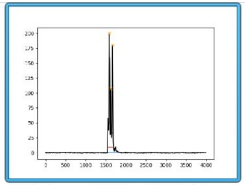


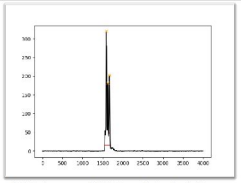


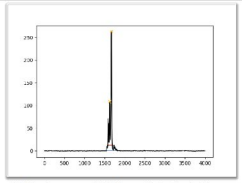


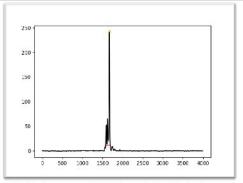


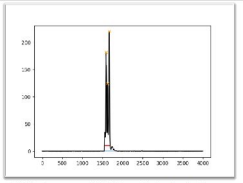












NB:

- GEMs behave very differently from PMTs.
- GEM1, eg., has both positive and negative part.
- I left the structure ready for GEM-specific reco/analysis.

PMT- RecoTTree

➔ **Rundown of the variables [PMT_Events]:**

- pmt_wf_[run/event/trigger/channel/sampling] ⇒ ***Basic*** info of each waveform
- pmt_wf_insideGE ⇒ Checks which triggers are inside the camera's ***Global Exposure***
- pmt_wf_TTT ⇒ Trigger time tag ⇒ Useful to see if event will showup in picture
- pmt_[baseline/RMS] ⇒ Baseline and RMS. Useful to check ***quality of data***
- pmt_tot_[integral/charge] ⇒ Sum and conversion of ***all samples*** of a waveform
- pmt_max_ampl ⇒ Waveform's max amplitude. Used to ***signal selection***
- pmt_nPeaks ⇒ Waveform's number of peaks. Useful to ***easily select*** ^{55}***Fe*** vs. others
- pmt_peak_Number ⇒ Useful for ***peak coincidence*** among PMTs
- *pmt_peak_[Position/Height/HalfWidth/FullWidth]* ⇒ ***Main analysis point. Basic implementation at the moment.***
- pmt_TOT_[time/area] ⇒ Over-threshold variables

➔ **Rundown of the variables [PMT_Avg_Events]:**

- Subsample of above tree. Useful to more accurately find time of threshold of (average) waveform

➔ **Rundown of the variables [GEM_Events]:**

- Same as first tree, but poorly optmized.

PMT- RecoTTree

➔ **Rundown of the variables [PMT_Events]:**

- pmt_wf_[run/event/trigger/channel/sampling] ⇒ ***Basic*** info of each waveform
- pmt_wf_insideGE ⇒ Checks which triggers are inside the camera's ***Global Exposure***
- pmt_wf_TT… …ill showup in picture
- pmt_[base… ***of data***
- pmt_tot_[i… …veform
- pmt_max_a… ***l selection***
- pmt_nPeak… ***sily select*** ^{55}***Fe*** vs. others
- pmt_peak_…
- *pmt_peak_…* ***n at the moment.***
- pmt_TOT_[time/area]… …over threshold variables

If you want to better understand these, tinker with them, or add new functions/calculations, look here: https://github.com/CYGNUS-RD/reconstruction/blob/winter23/waveform.py

➔ **Rundown of the variables [PMT_Avg_Events]:**

- Subsample of above tree. Useful to more accurately find time of threshold of (average) waveform

➔ **Rundown of the variables [GEM_Events]:**

- Same as first tree, but poorly optmized.

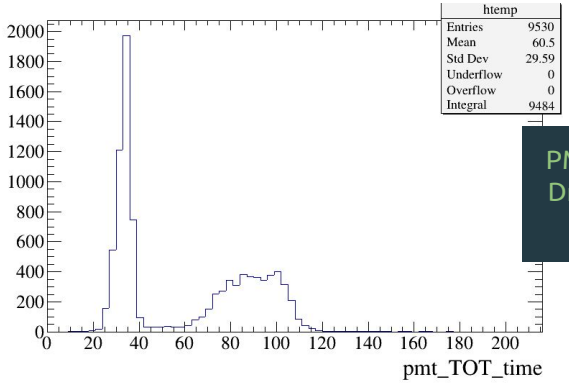
PMT- Reco Parameters

```
### PMT waveform reconstruction
'pmt_mode'              : 1,
'board_pmt_channels'    : [1,2,3,4],    # Board channels used to save PMT.

'threshold'             : 0,
'height_RMS'            : 5,            ## 5 * RMS
'minPeakDistance'       : 1,
'prominence'            : 0.1,
'fixed_prom'            : True,         ## If True, overrides prominence value with optimized one
'width'                 : 5,
'resample'              : 10,           ## Number of samples used for moving average
'pmt_plotpy'            : True,     ## saves ALL waveforms in '{--pdir}./waveforms'. Careful.
'pmt_wf_in_tree'        : False,        ## saves full X and Y arrays in tree branches.
'pmt_verbose'           : 1,            ## Choose from 0 to 3. '0' for no output; '3' for full output.

'include_gem'           : 0,            ## Also performs very basic GEM signal analysis
'board_gem_channels'    : [5,6,7]
}
```

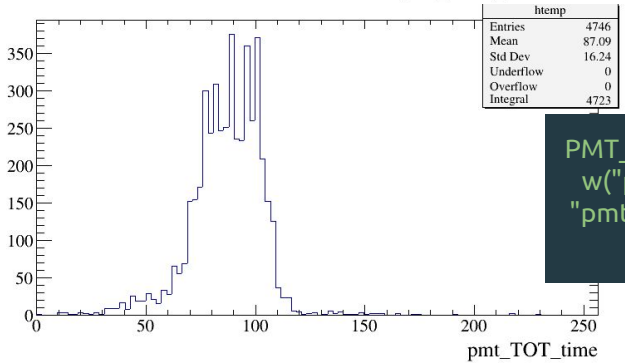
You can find here my preliminary ReadMe file which will soon be merged into the main repo: https://github.com/davidjgmarques/cygno_reco/blob/winter23/PMT_RECO.md

PMT- Playing with the tree - example

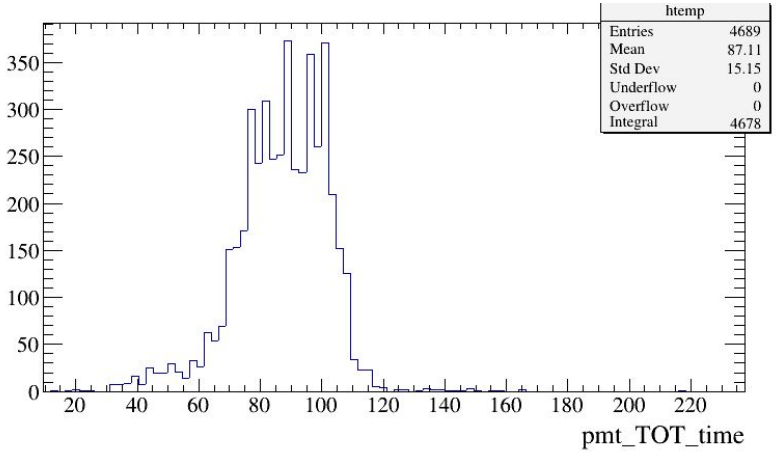
⇒ Let's imagine you want to look at the Iron spots from a calibration run…



PMT_Avg_Events->Draw("pmt_TOT_time", "")



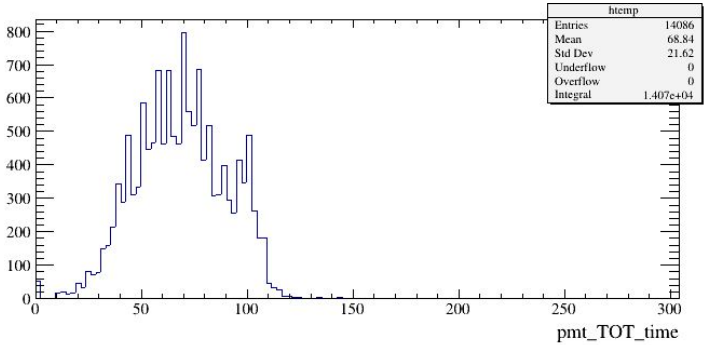
PMT_Avg_Events->Draw("pmt_TOT_time", "pmt_wf_sampling == 1024")



PMT_Avg_Events->Draw("pmt_TOT_time", "pmt_wf_sampling == 1024 && pmt_wf_nPeaks == 1")

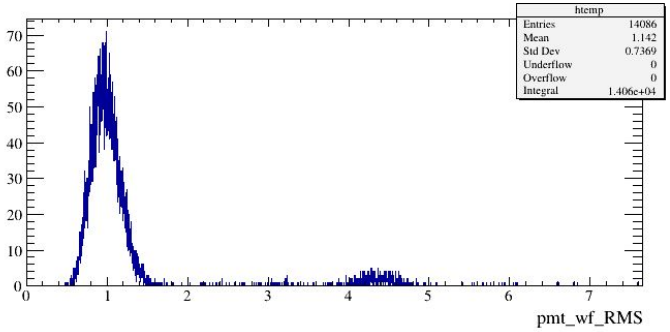
PMT- Playing with the tree - example

⇒ You can also look into the single PMT waveforms…




```
PMT_Events->Draw("pmt_TOT_time", "pmt_wf_sampling == 1024 && pmt_wf_nPeaks == 1")
```

⇒ And make other types of cuts, eg, RMS…




```
PMT_Events->Draw("pmt_wf_RMS")
```

PMT- Conclusions

➔ ***PMT-Integrated-Reco UP and RUNNING***

➔ See this update as the PMT Reco as the initial camera reco 3/4 years ago

- There will unexpected bugs
- Analysis can be greatly improved
  - Optimizations, new variables, new calculations
- ***Questions, testing, and suggestions are more than welcome***

➔ ***Next steps:***

- 1 to 1 association
- 3D reco for tracks with E > ??
- Head-tail (direction)
- PMT Analysis
- ***Combined analysis ⇒ I will now re-run AmBe data and compare with NR cut from Flaminia***

PMT- work overview

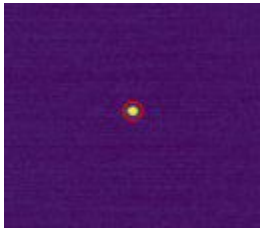
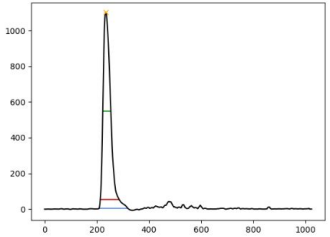
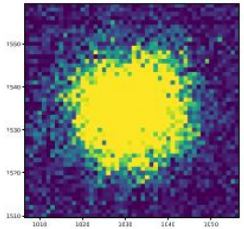
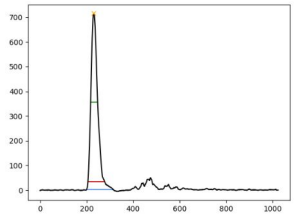
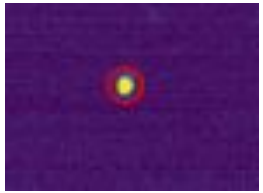
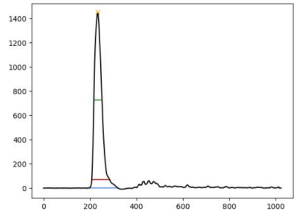
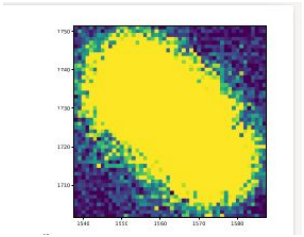
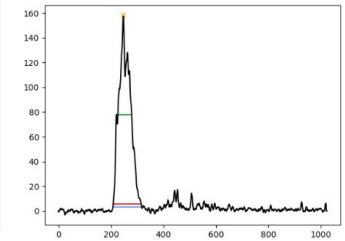
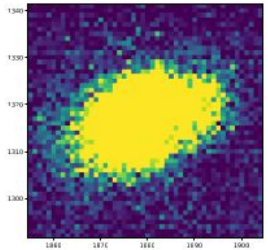
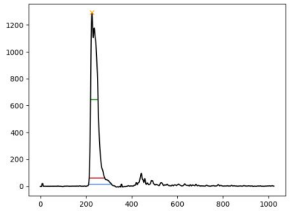
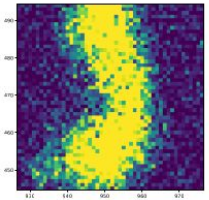
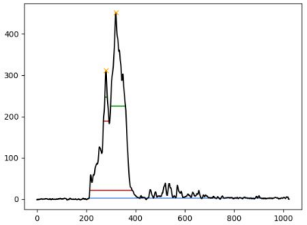
Reco	Simulation	Analysis
Retrieving important parameters	^{55}Fe PMT simulation	Tilted cosmics analysis
Merging with Cygno reco	Analysis of ^{55}Fe PMT simulation with reco	Head-tail / 3D
Association 1-to-1	Other particles/energies PMT simulation	AmBe analysis for ER vs. NR
Single TTree with ionization event information (Giorgio)	Multiple track simulation (for association / resolution purposes)	Longitudinal diffusion ⇒ Confirmation with other sources
PMT Auto-Reco		Am analysis for PID
		PMT intercalibration with multi-source

Legend: Done Undergoing To Do Today

Others...

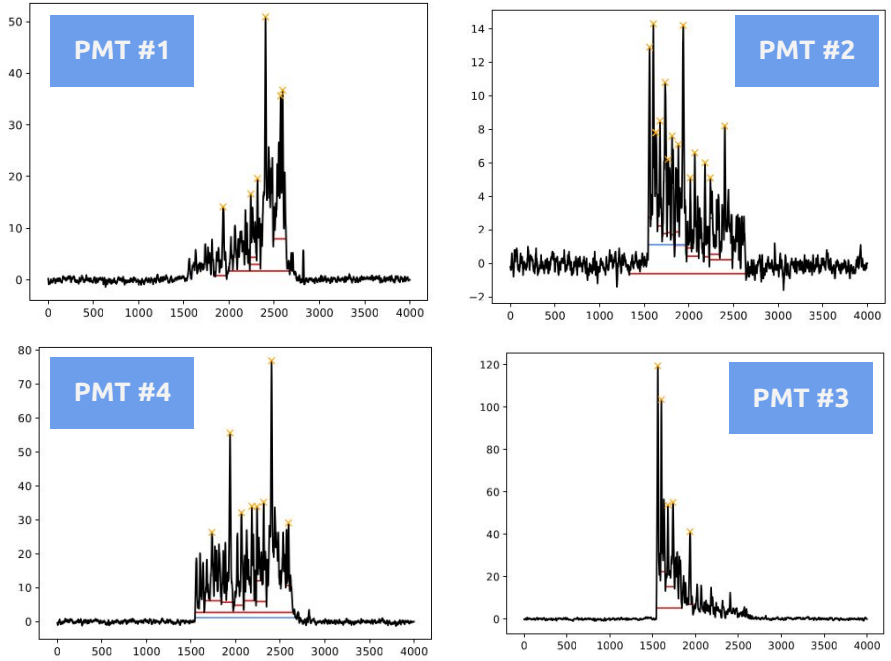
PMT Reco - AmBe

- After technicalities, I started having a look (because now debug mode works perfectly) to the Matteo's handpicked Nuclear Recoils from the AmBe run. Here some quick examples:

PMT Work - 3D and cross-analysis

⇒ Time over threshold (TOT)



➔ Measurement of the **time length** of the signal which is **above a given threshold**.

- Not trivial when each PMT sees a different signal intensity and tracks can have very complicated paths
- I do a ***weighted average based on waveform's SNR*** ⇒ *Only correct for timing purposes*