Automated CAST Analysis

From recorded signal to calibrated spectrum

Convert the signals into tracks

↓

Plot the observables

↓

Find the relation between ADC and keV

↓

Compute raw background spectrum

→ `Run_Analysis.py`

↓

Cut selection

→ `Run_Cut_Selection.py`

↓

Compute the calibrated background spectrum applying desired cuts

→ `Run_Apply_Cut_Selection.py`

Dataset

As first step, a list of CAST data runs must be provided (see example below).

CAVEATS:
- The calibration run related to a background run must be specified right after it.
- The first part of the file name must be in the format RunNUmber_RunType_ObsTime (ex: R10418_Background_23h...).
- In case of multiple subruns they must be mergend in a single file named as mentioned in the previous point.

Example:

Runs: 10418 – 10455 (38 runs)

17th January 2020 – 3rd February 2020

Argon

Background: 357 h

Calibration: 4 h

Script to run the analysis:

`Run_Analysis.py`

REST version:

2.3.5

-

```
R10418_Background_23hr_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10419_Calibration_15min_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10420_Background_23hr_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10421_Calibration_15min_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10422_Background_23hr_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10423_Calibration_15min_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10424_Background_23hr_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10425_Calibration_15min_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10426_Background_21hr_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10427_Calibration_15min_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10428_Background_23hr_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10429_Calibration_15min_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10430_Background_24hr_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10431_Calibration_15min_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10432_Background_25hr_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10433_Calibration_15min_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10434_Background_23hr_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10435_Calibration_15min_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10436_Background_23hr_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10437_Calibration_15min_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10438_Background_24hr_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10439_Calibration_15min_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10444_Background_17hr_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10445_Calibration_15min_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10446_Background_22hr_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10447_Calibration_15min_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10448_Background_22hr_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10449_Calibration_15min_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10450_Background_19hr_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10453_Calibration_15min_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10454_Background_22hr_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
R10455_Calibration_15min_Vm_340_Vd_113_Pr_1.4_Gain_0x1_Shape_0xD_Clock_0x02-000.aqs
```

REST Analysis

REST processes

The following REST processes are applied to the data:

- TrestRawMultiFEMINOSToSignalProcess
- TrestRawSignalChannelActivityProcess
- TrestRawVetoAnalysisProcess
- TrestRawSignalAnalysisProcess
- TrestRawZeroSuppresionProcess

→ Specified in **`rawToSignal.rml`** configuration file.

- TrestDetectorSignalToHitsProcess
- TRestDetectorHitsAnalysisProcess
- TrestDetectorHitsToTrackProcess
- TRestTrackAnalysisProcess

→ Specified in **`signalToTrack.rml`** configuration file.

Both these rml files load other three rml files containing global variables and common definitions for the analysis:

`globals.rml`
`run.rml`
`Processes.rml`

In order to modify the processes you want to run for your analysis and their related parameters, you need to modify these rml files.

REST Analysis

REST processes

- TrestRawMultiFEMINOSToSignalProcess
- TrestRawSignalChannelActivityProcess
- TrestRawVetoAnalysisProcess
- TrestRawSignalAnalysisProcess
- TrestRawZeroSuppresionProcess
- TrestDetectorSignalToHitsProcess
- TRestDetectorHitsAnalysisProcess
- TrestDetectorHitsToTrackProcess
- TRestTrackAnalysisProcess

If you want to run manually the REST analysis, for each run you should run the commands:

restManager --c rawToSignal.rml --f <datarun.aqs>

that gives as output a root file (output_rawToSignal.root)

restManager --c signalToTrack.rml --f <output_rawToSignal.root>

that gives as output a root file (output_signalToTrack.root)

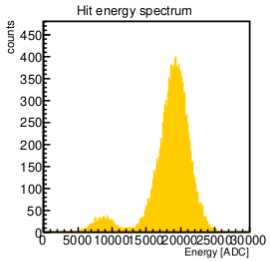
In the automated procedure these commands are executed for each run by the scripts
Run_rawToSignal.sh
Run_signalToTrack.sh

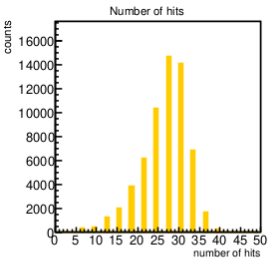
Plots

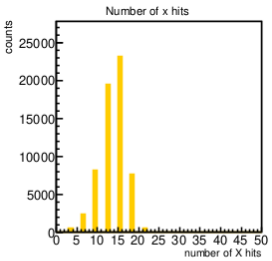
Analysis | Cut selection | Apply cuts

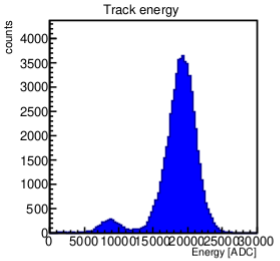
Observable plots

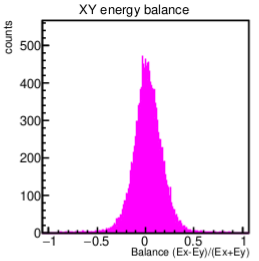
For each analyzed run, observable plots (by selecting only 1 track events, that will be used for the cut selection) are created:

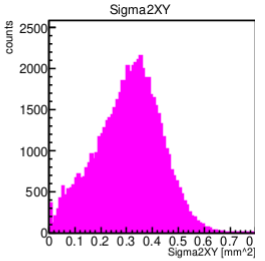


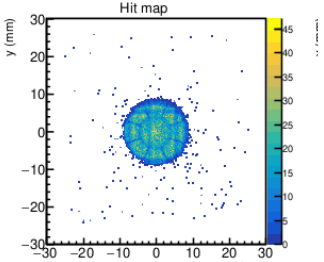


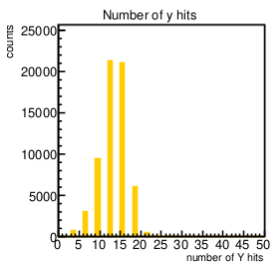


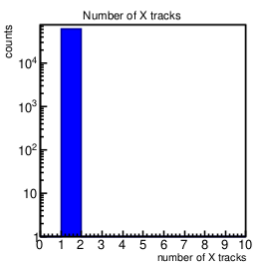


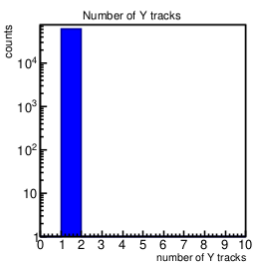


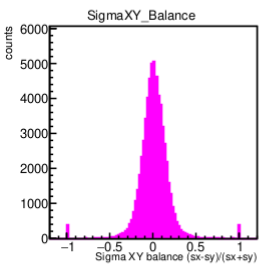


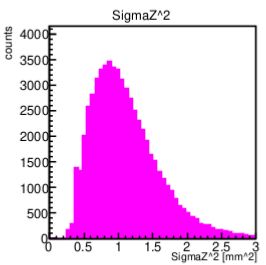


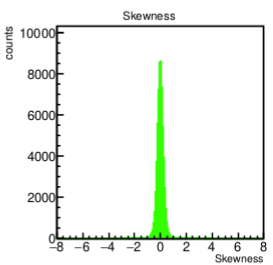


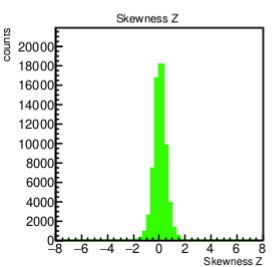


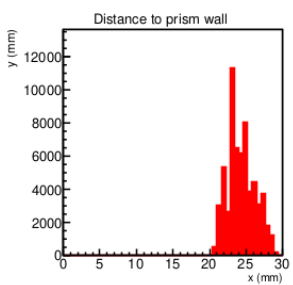












Observable plots obtained for calibration run R10419.

Plots

Observable plots

Number of triggered strips and energy spectrum of the hits.

Number of tracks and energy spectrum of the tracks (hits form tracks if closer than 3.5 mm).

Topology of the energy deposit: balance between the energy collected by the x and y strips; $\sigma^2_{x,y}$ (2D extension of energy deposit); balance between σ_x and σ_y (balance between the size in x and y direction); σ^2_z (temporal duration of the event).

Skewness γ_{xy} and γ_z: geometrical asymmetry of the event.

Distance–to–wall, d_w (distance of the closest hit of the hit event to the fiducial prism).

The observable lists of each REST process are available at:

Observables computed by TrestRawSignalAnalysisProcess here.
Observables computed by TRestDetectorHitsAnalysisProcess here.
Observables computed by TRestTrackAnalysisProcess here.

Plots

Observable plots

In order to change the observables you want to plot (or the applied cuts, for example the number of tracks), you need to modify the script **Observable_plots_ONE_Track.rml**

If you want to generate manually the observable plots, for each run you should run the command:

restManager --c Observable_plots_ONE_Track.rml --f <output_signalToTrack.root>

In the automated procedure these commands are executed for each run by the script **Run_Observable_Plots.sh**

Calibration

ADC — keV conversion

- Generate the root histograms for calibration runs.

`Calibration_spectrum.rml`
called for each run by
`Run_Calibration_Spectra.sh`

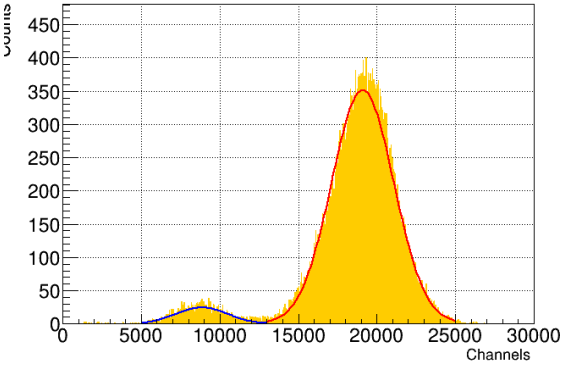
- Fit the 3 and 6 peak (independent Gaussian fit).
- Perform a linear fit to find the relation to convert ADC into keV.
- Extrapolate the ADC for some energies of interest (example 3.8, 12 keV).
- Write data in a file (fitted_peaks.dat).
- Plot the peaks position as a function of runs (calibration_peaks.png).

`Fit_the_peaks.C`
called for each run by
`Run_FitPeaks_RootMacro.sh`

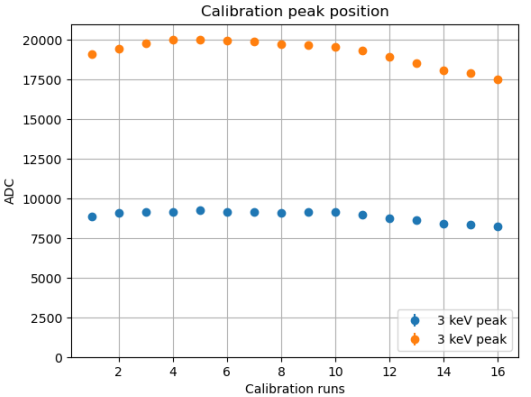
Calibration

Analysis | Cut selection | Apply cuts

ADC — keV conversion



3 and 6 keV peak fit for R10419.



Peak positions as a function of runs.

# Cal_run	3keV peak	3kev_peak_err	6keV peak	6kev_peak_err	slope	coeff	ADC(3.8 keV)	ADC(10 keV)	ADC(12 keV)
R10419	8868.068484	31.077373	19117.615556	8.402846	3534.326577	-1734.911246	11695.529746	33608.354521	40677.007674
R10421	9079.724654	33.315213	19458.390010	8.580996	3578.850123	-1656.825714	11942.804752	34131.675513	41289.375759
R10423	9140.101155	33.472554	19781.761761	8.779191	3669.538140	-1868.513265	12075.731667	34826.868134	42165.944414
R10425	9151.359385	32.339675	20026.038864	8.958060	3749.889476	-2098.309042	12151.270965	35400.585714	42900.364665
R10427	9268.724608	32.091647	20031.863382	8.998531	3711.427164	-1865.556884	12237.866339	35248.714754	42671.569081
R10429	9165.385063	32.534473	19957.584488	8.885026	3721.448078	-1998.959169	12142.543525	35215.521607	42658.417762
R10431	9154.464435	34.569059	19879.147354	8.859821	3698.166524	-1940.035136	12112.997654	35041.630101	42437.963148
R10433	9084.602551	31.853537	19725.317417	8.720522	3669.212023	-1923.033516	12019.972169	34769.086709	42107.510755
R10435	9186.861229	32.938471	19694.620067	8.711629	3623.365117	-1683.234122	12085.553322	34550.417047	41797.147280
R10437	9139.803981	32.965628	19553.395922	8.764699	3590.893773	-1632.877338	12012.518999	34276.060391	41457.847936
R10439	9010.762720	32.412230	19339.871149	8.607644	3561.761527	-1674.521862	11860.171942	33943.093411	41066.616466
R10445	8775.521701	29.952559	18938.368877	8.443982	3504.430061	-1737.768481	11579.065749	33306.532126	40315.392247
R10447	8621.557607	33.117437	18525.404673	8.340236	3415.119678	-1623.801426	11353.653350	32527.395351	39357.634707
R10449	8423.037049	33.504367	18105.647746	8.403200	3338.831275	-1593.456775	11094.102069	31794.855972	38472.518522
R10453	8378.464924	32.859264	17901.602224	8.301925	3283.840448	-1473.056421	11005.537283	31365.348063	37933.028960
R10455	8245.214041	37.609495	17487.262337	8.243995	3186.913205	-1315.525575	10794.744606	30553.606479	36927.432890

Output file (fitted_peaks.dat)

Raw BG spectra

The raw background spectrum (without cuts) is computed for both the full area and the 10 mm inner circle.

- Generate the root histograms for the 3 and 6 keV energy ranges.

Run_3-6KeV_histo.sh
For each run the energy ranges are defined based on the results in fitted_peaks.dat (see slide 9).

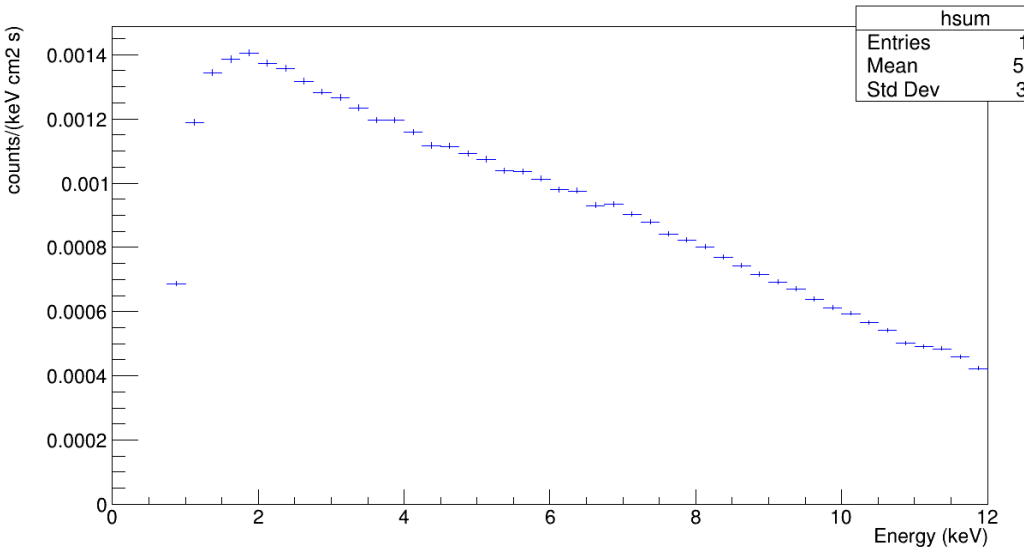
- Compute the calibrated background spectrum (sum the histograms in the two energy ranges and normalize it. The main quantities taken into account are those computed in the ADC–keV conversion, the detector area, the observation time).
- Save plots in root and png files.
- Write results in a file (results_raw_bg.dat).

histoSumCal.C
that needs a configuration file for each spectrum you want to compute (ex. **config_RawBG_10mm_NOCuts.txt**)

Raw BG spectra

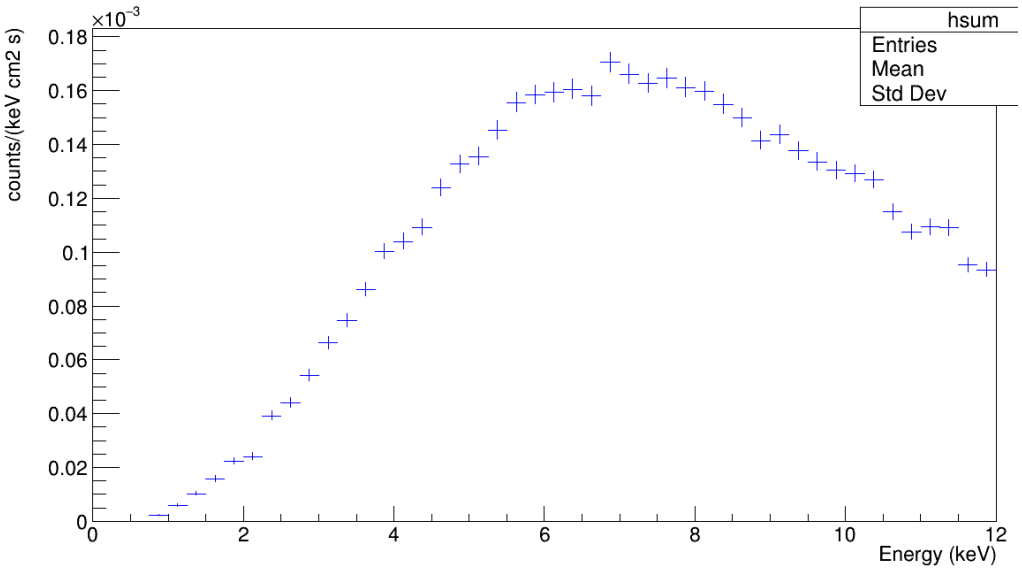
Raw background spectrum (without cuts) obtained for the full detector area and for the 10 mm inner circle.

No cuts, full area.



Bg level [0.4–10 keV] = 9.83 + −0.01 e−04

No cuts, 10 mm circle.



Bg level [0.4–10 keV] = 1.058 + − 0.005 e−04