Istituto Nazionale di Fisica Nucleare
LABORATORI NAZIONALI DI LEGNARO

AGATA Week 2025, GSI

Energy drift correction procedure (not just) for AGATA

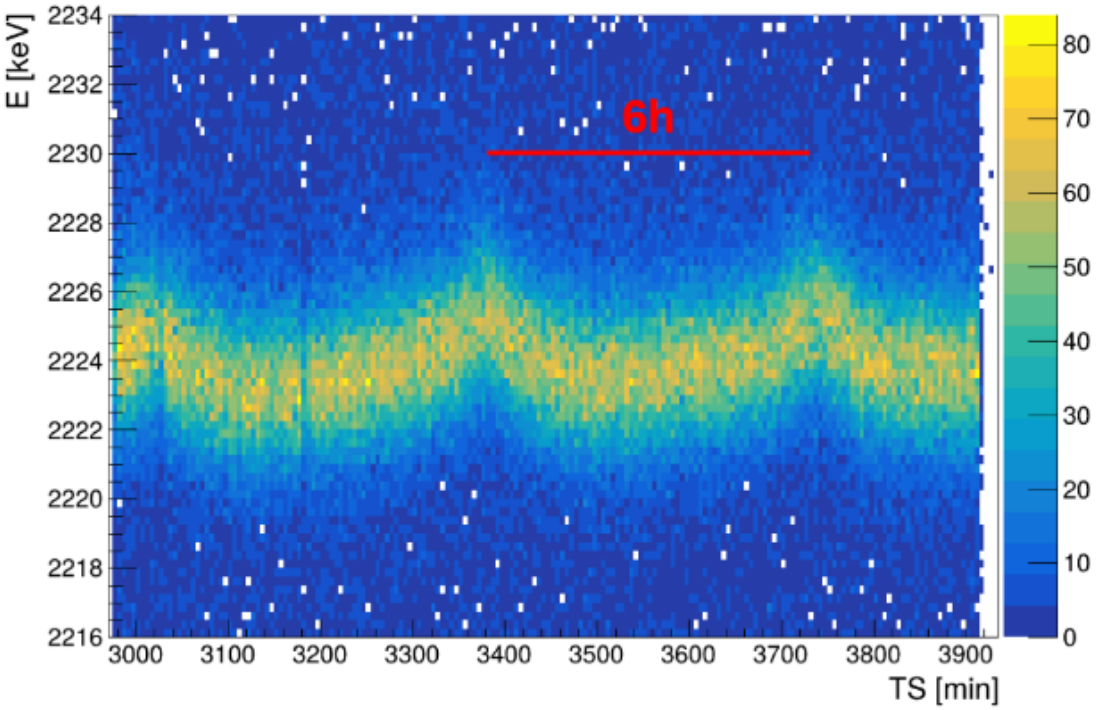
M. Balogh, R.M. Peréz-Vidal

matus.balogh@lnl.infn.it

Motivation - AGATA

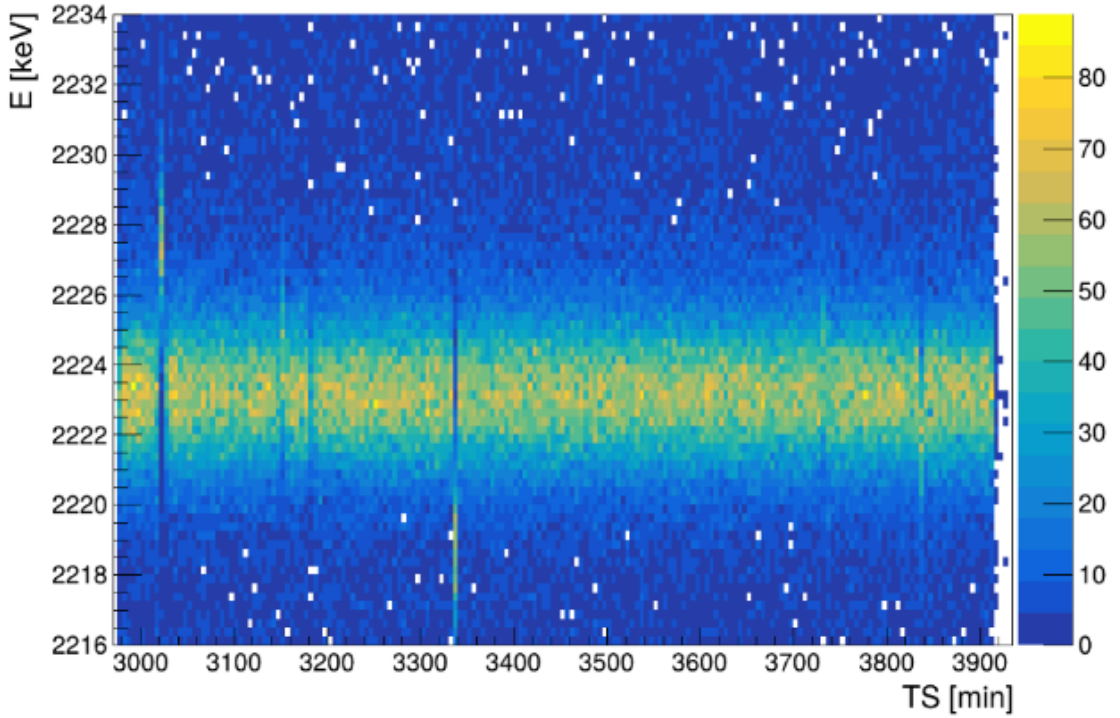
AGATA **low gain** core

Before



FWHM = 3.81 (2) keV @ 2.2 MeV

After

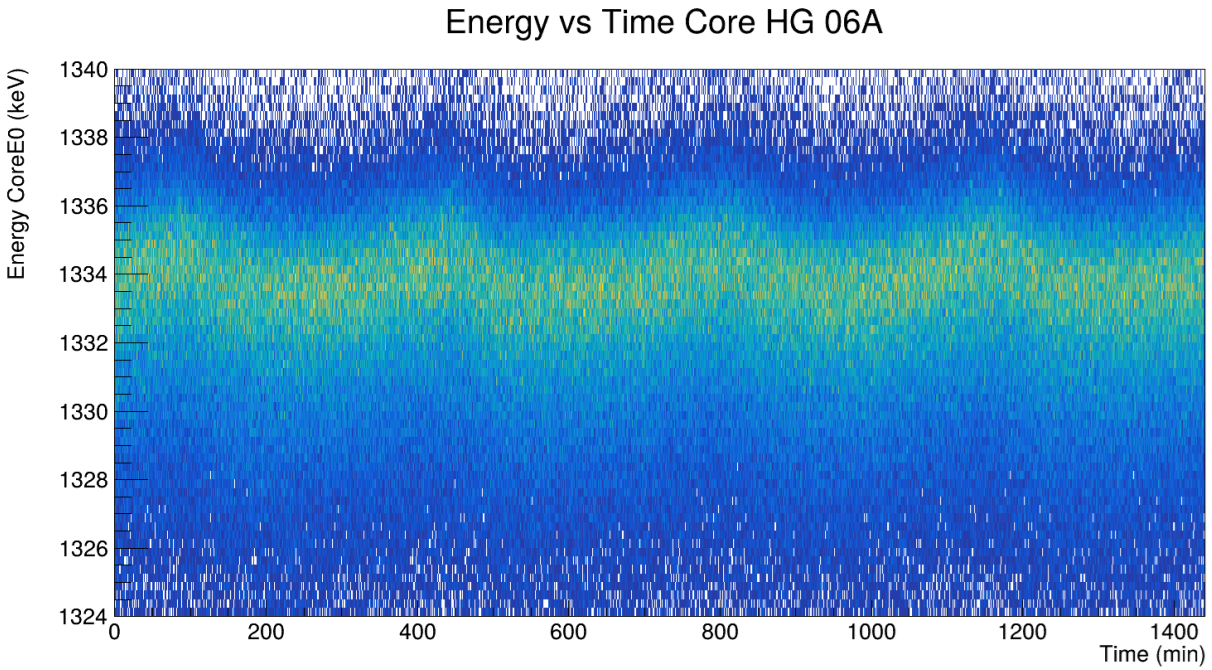


FWHM = 3.53 (2) keV @ 2.2 MeV

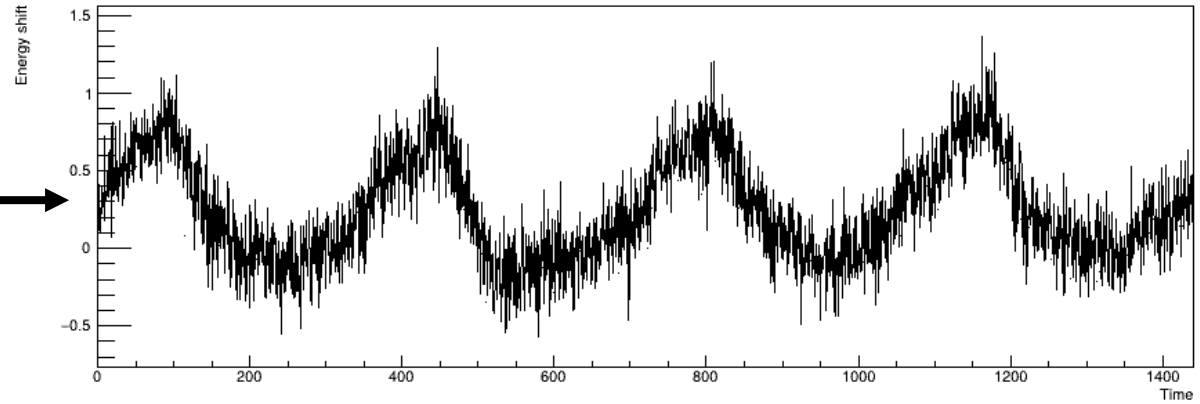
^{15}O experiment, Elia Pilotto

AGATA **high gain** core

24-hour ^{60}Co run

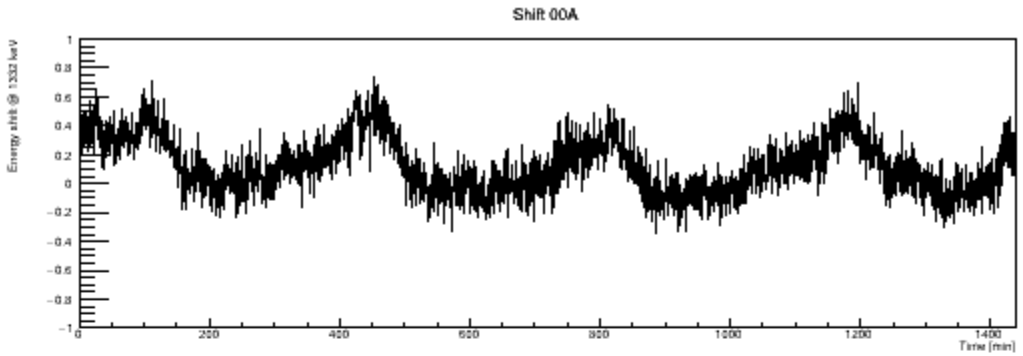


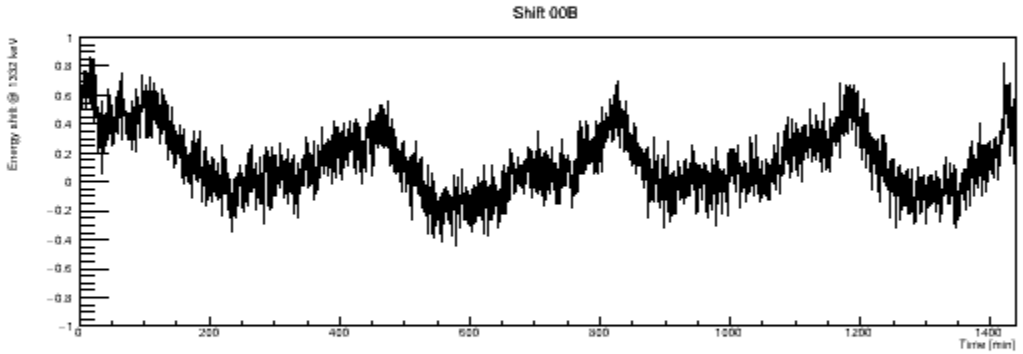
Calculated shifts from nominal position 1332 keV

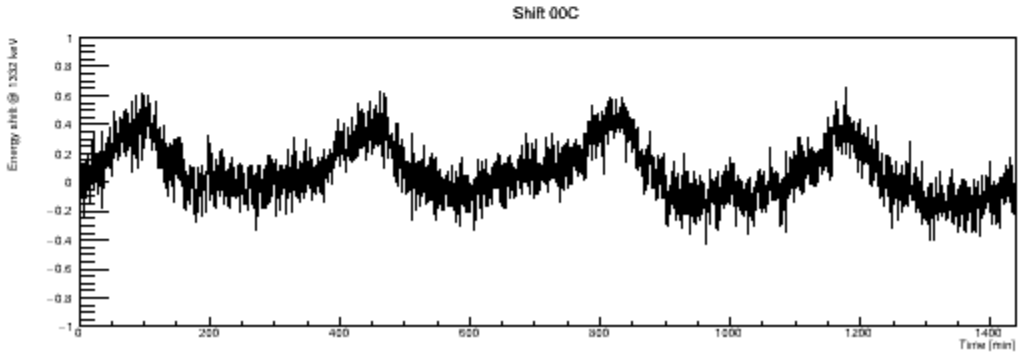


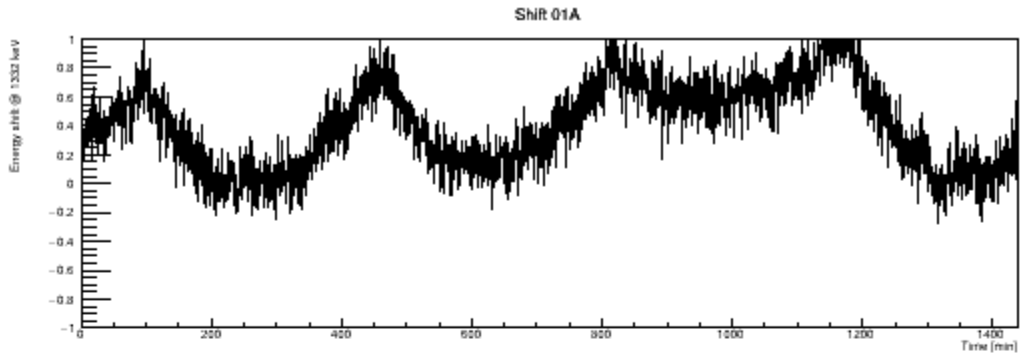
AGATA **high gain** core

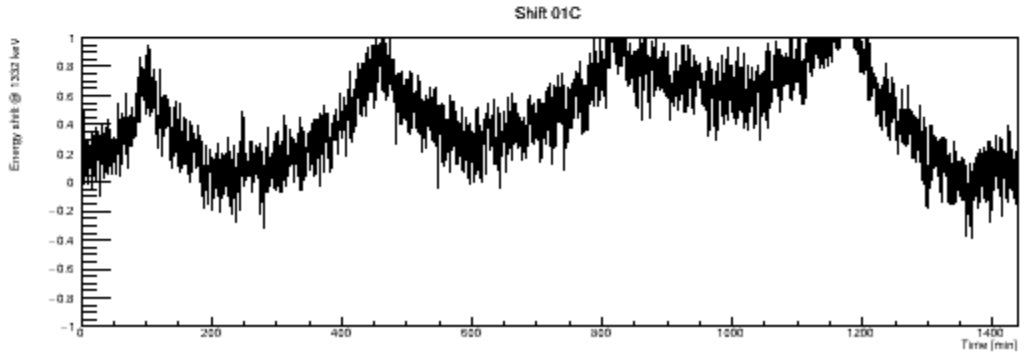
24-hour ^{60}Co run











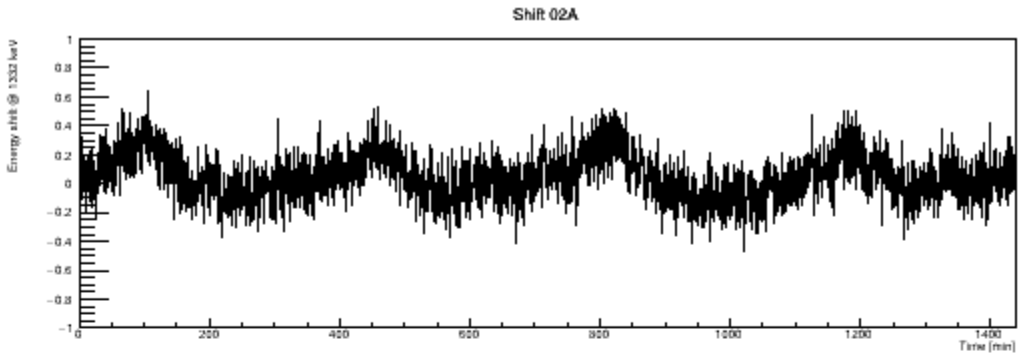
00

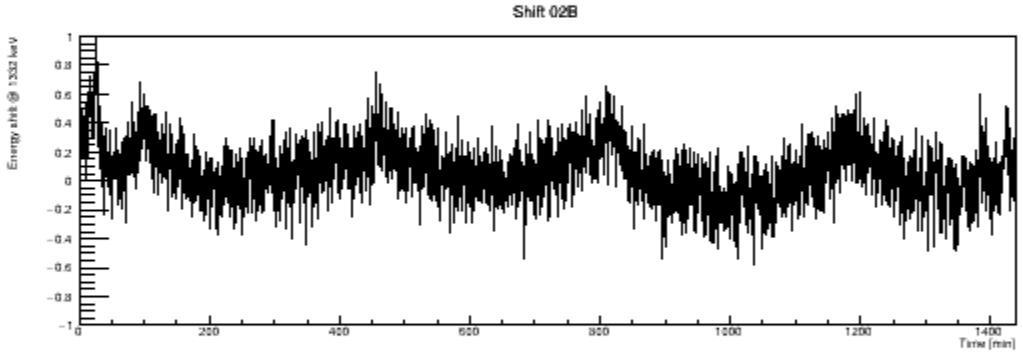
*Y range fixed to (-1,1)

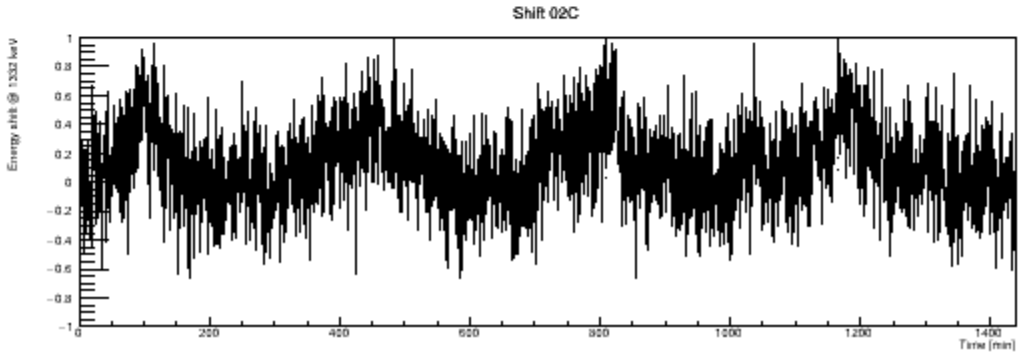
01

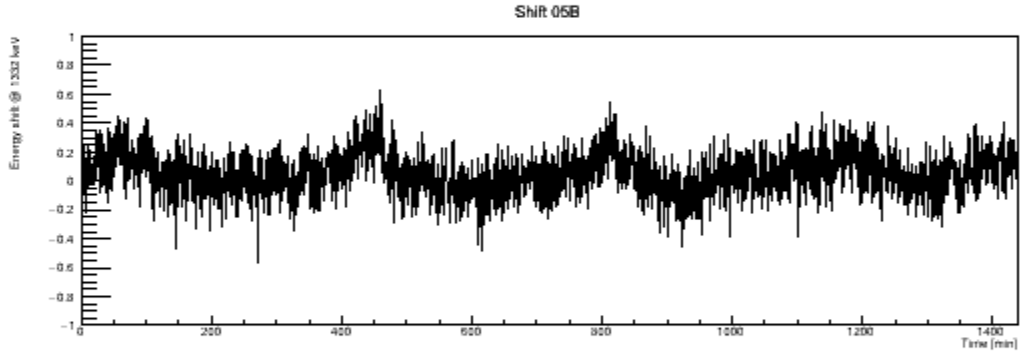
AGATA **high gain** core

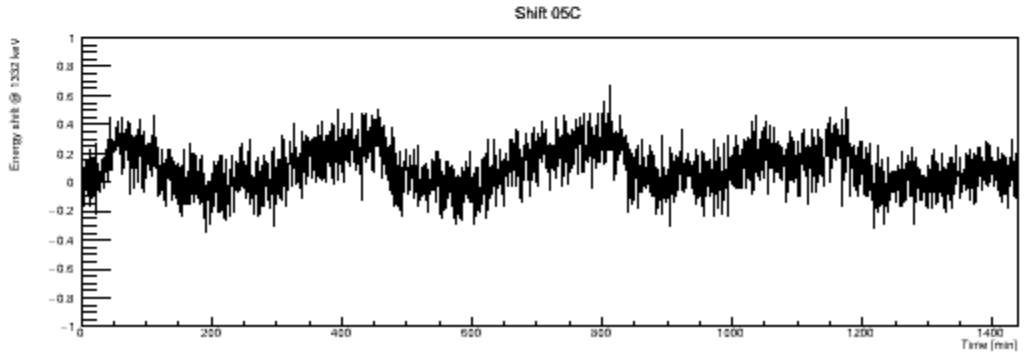
24-hour ^{60}Co run











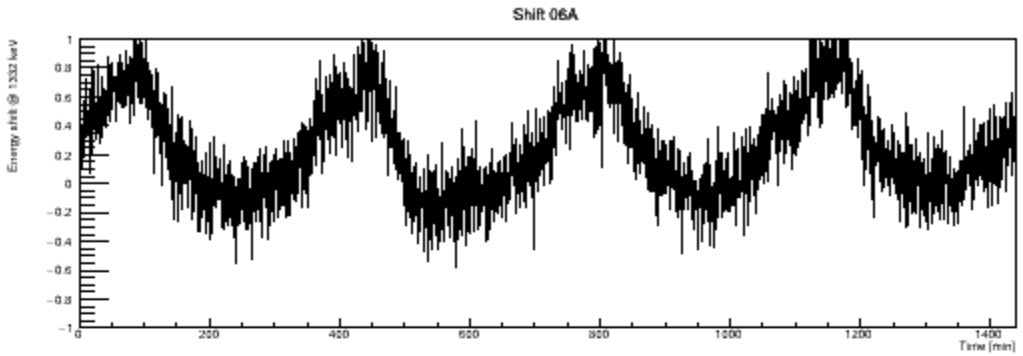
02

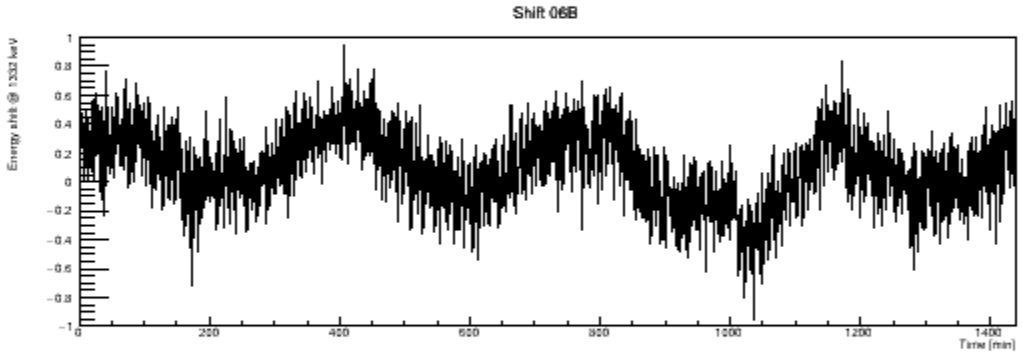
*Y range fixed to (-1,1)

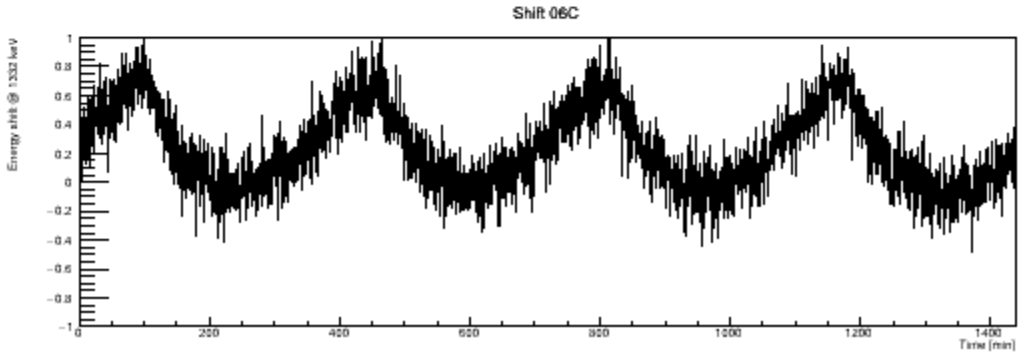
05

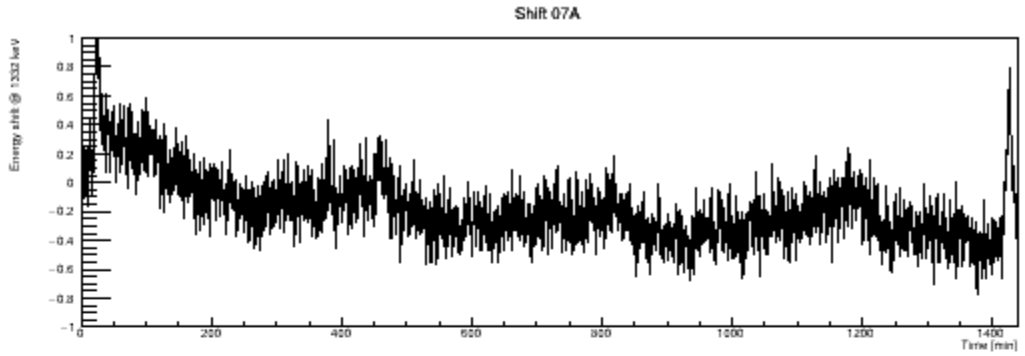
AGATA **high gain** core

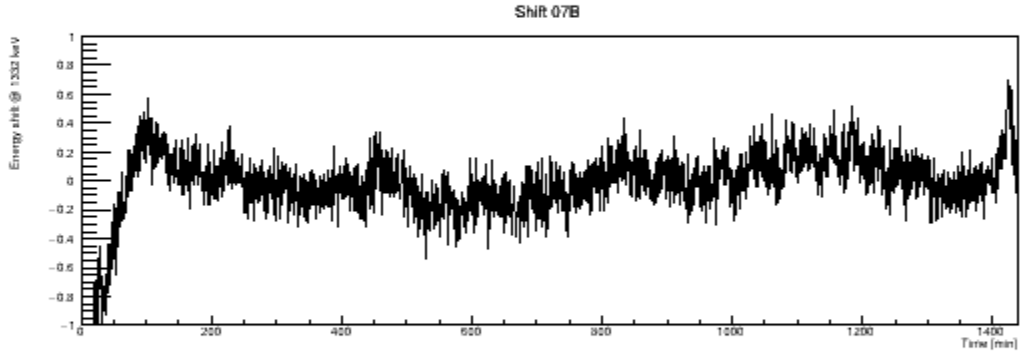
24-hour ^{60}Co run











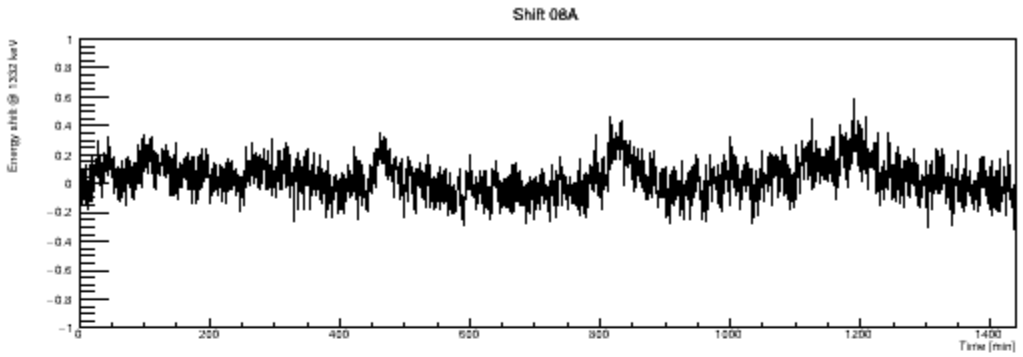
06

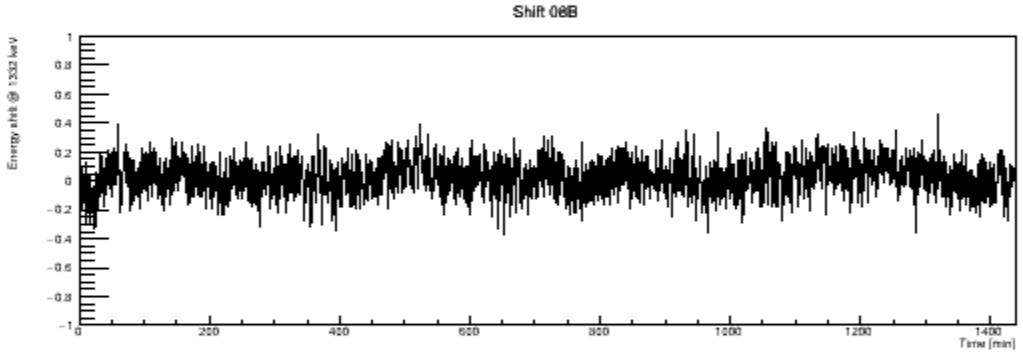
*Y range fixed to (-1,1)

07

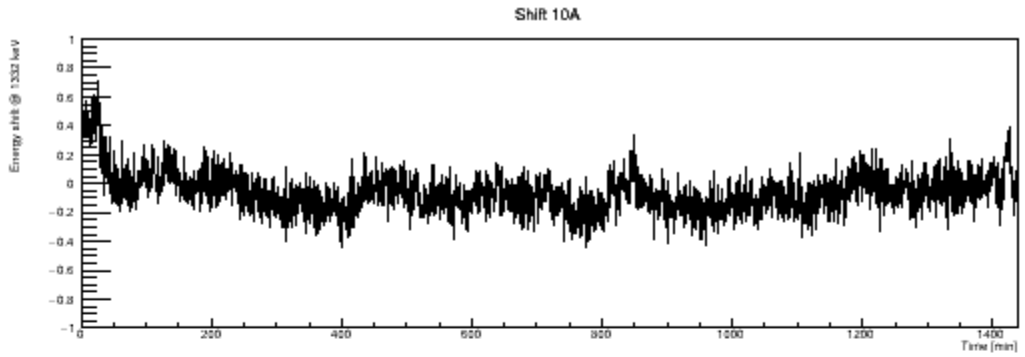
AGATA **high gain** core

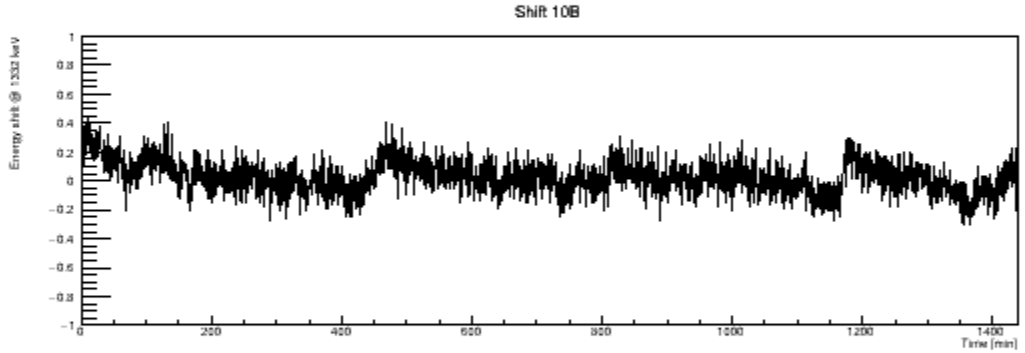
24-hour ^{60}Co run

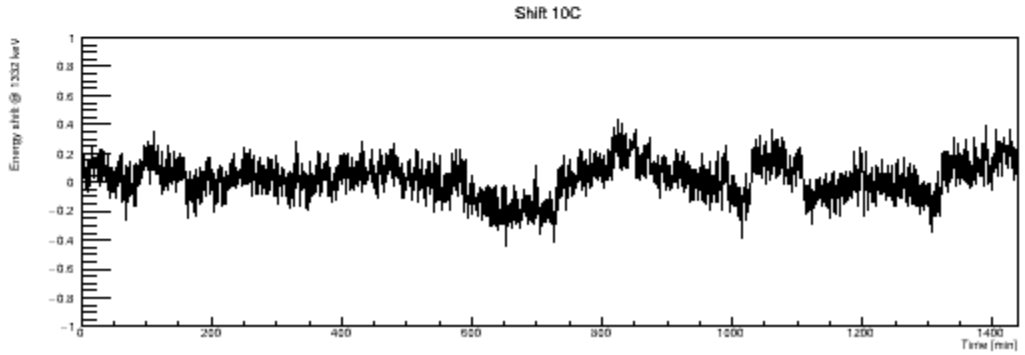




08





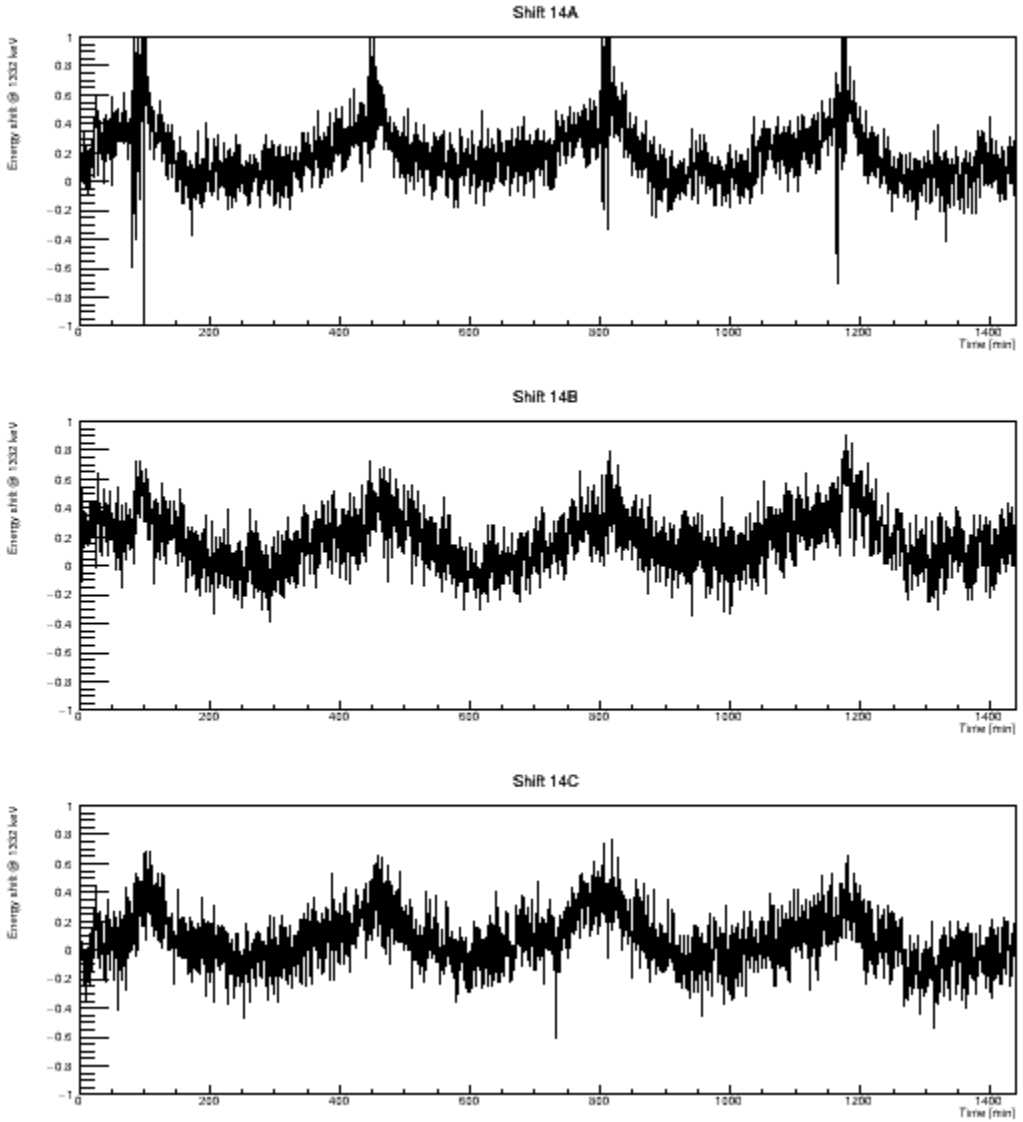


10

*Y range fixed to (-1,1)

AGATA **high gain** core

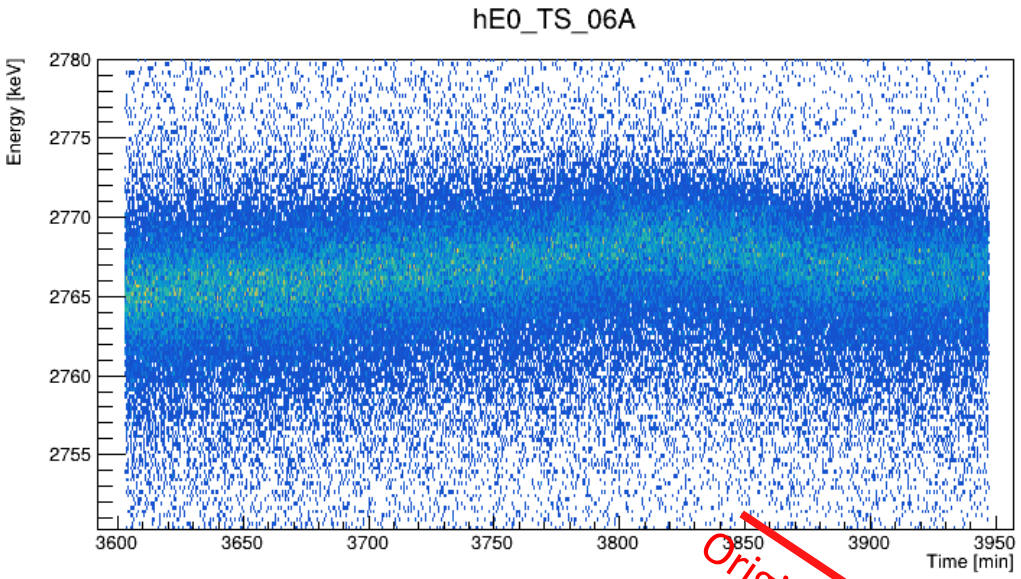
24-hour ^{60}Co run

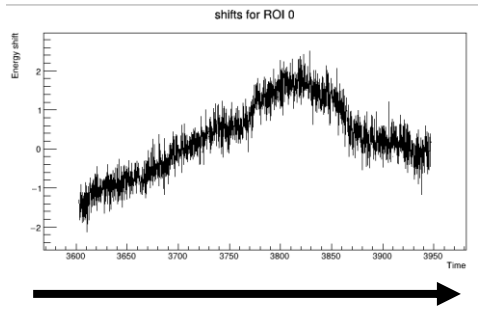


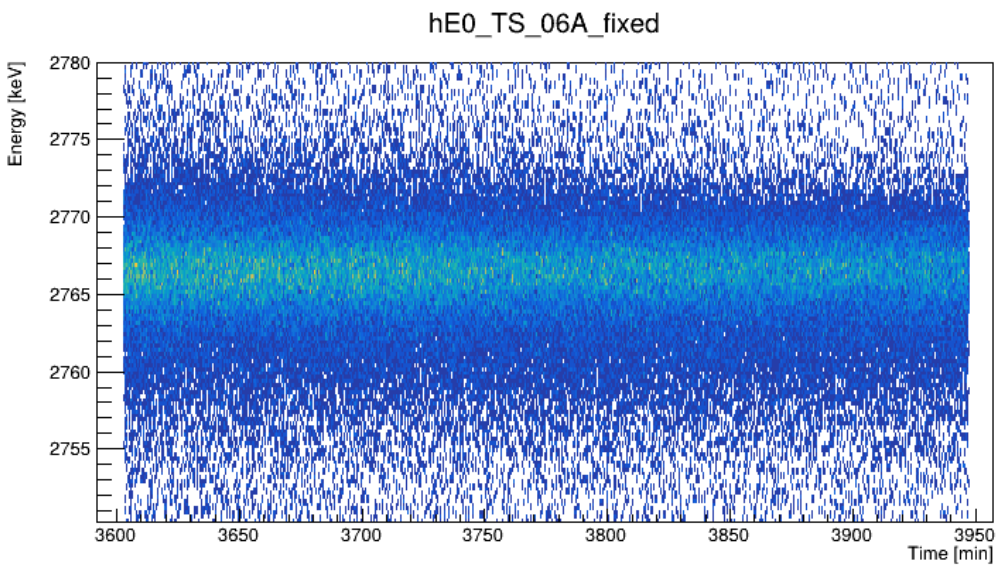
*Y range fixed to (-1,1)

AGATA **high gain** core

^{66}Ga

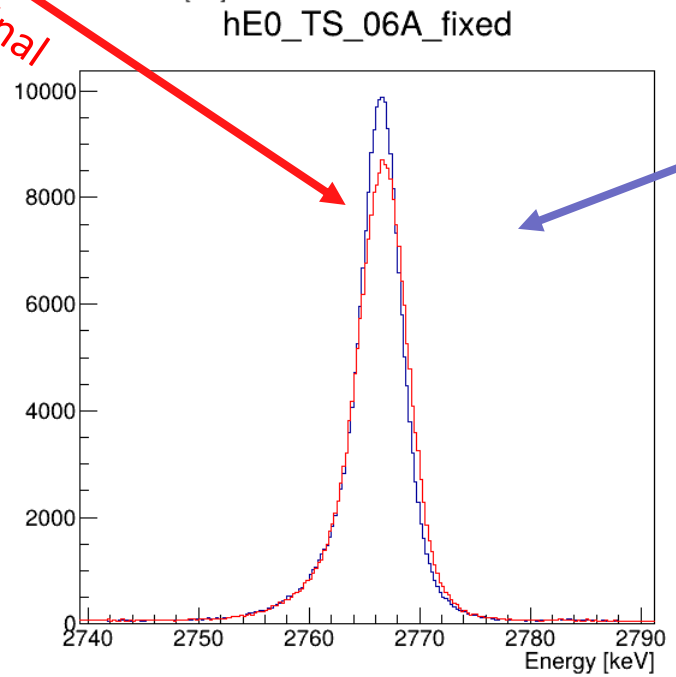






Original

Corrected



@1332 keV	Original	Correction
FWHM	5.15	4.12
Left tail	1.98	1.30
Right tail	3.27	2.02

^{66}Ga – case of 07B

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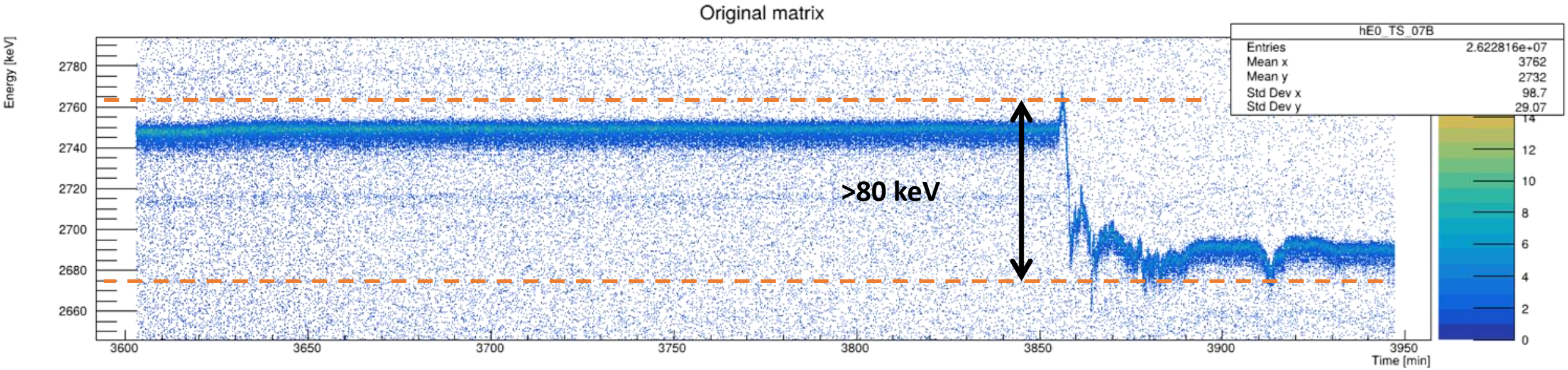
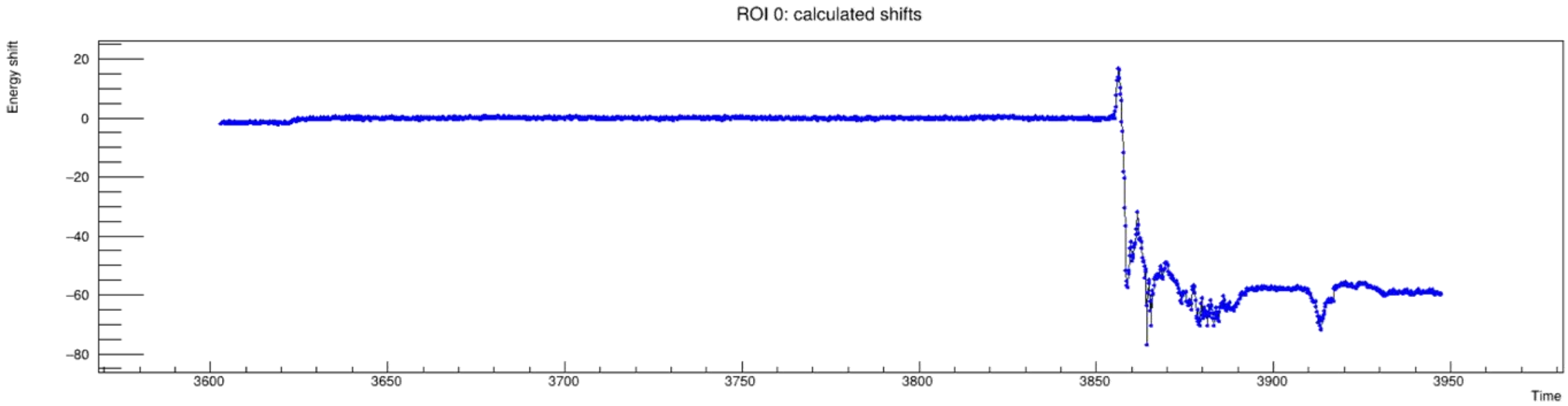
^{66}Ga





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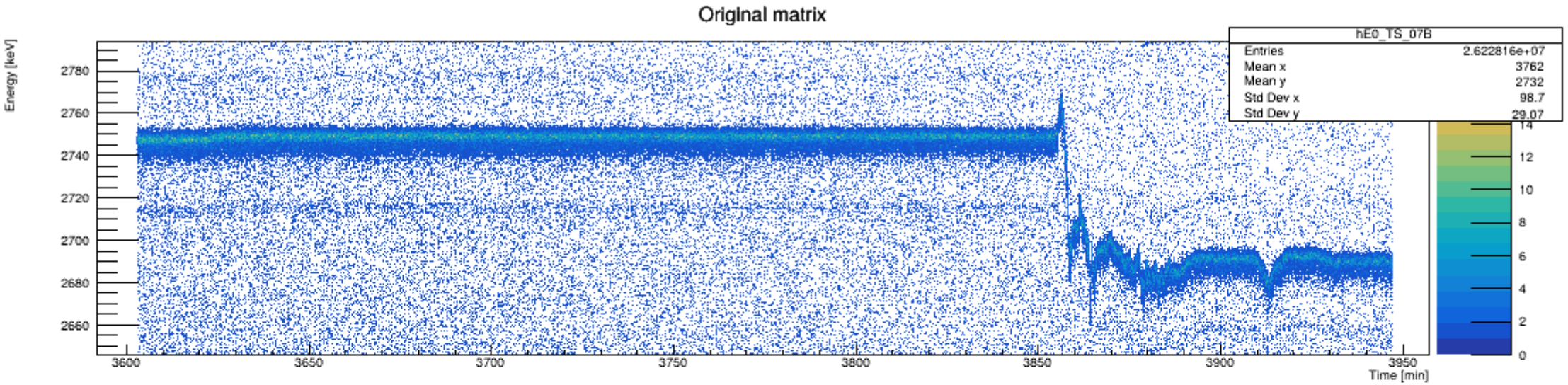
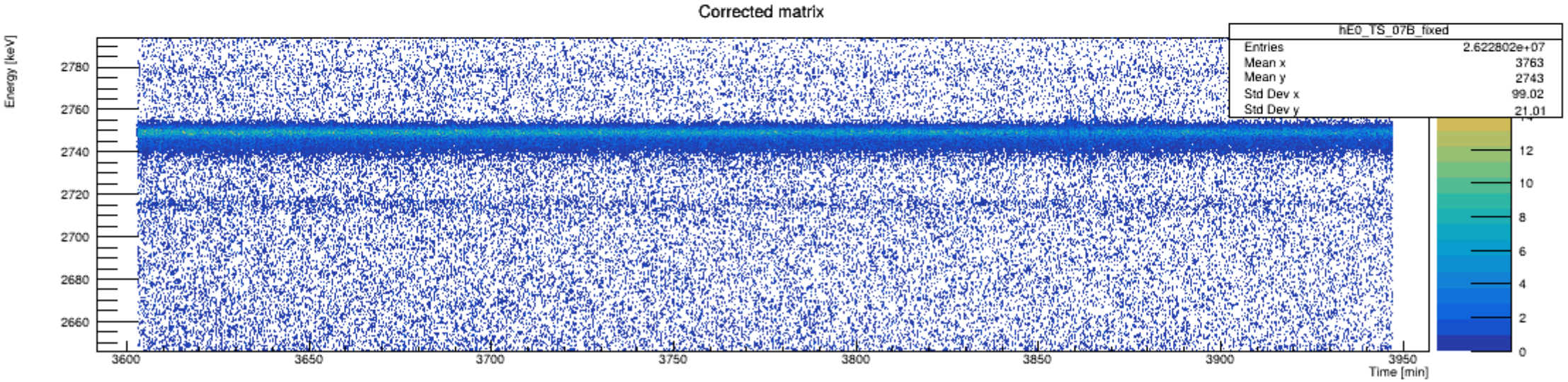
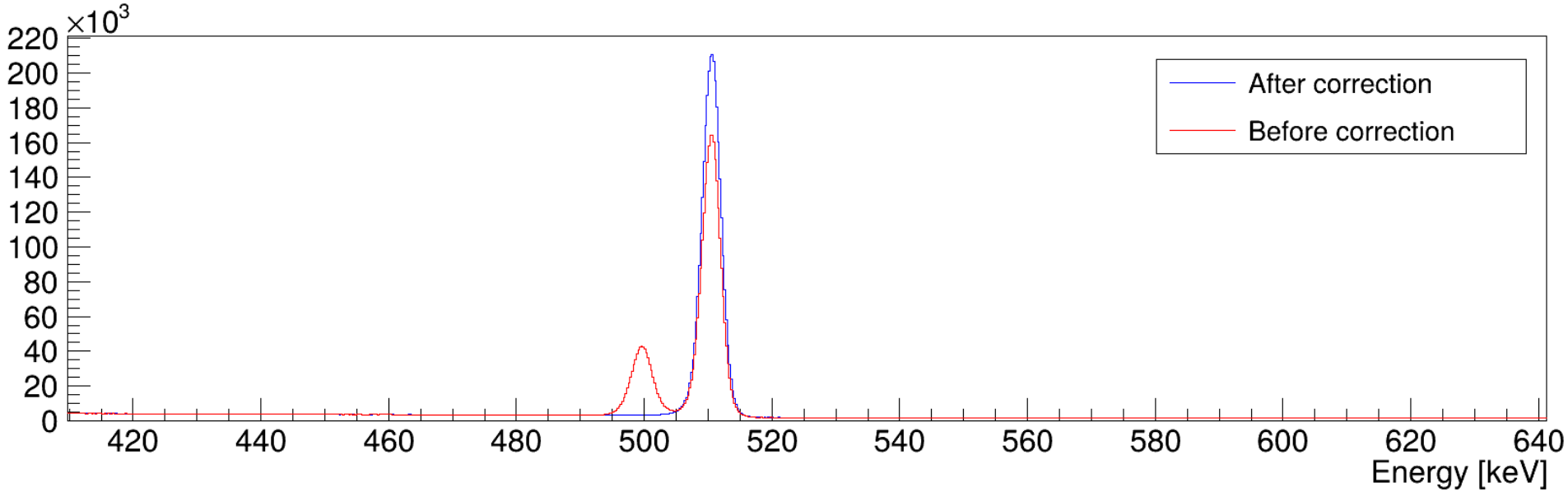
^{66}Ga

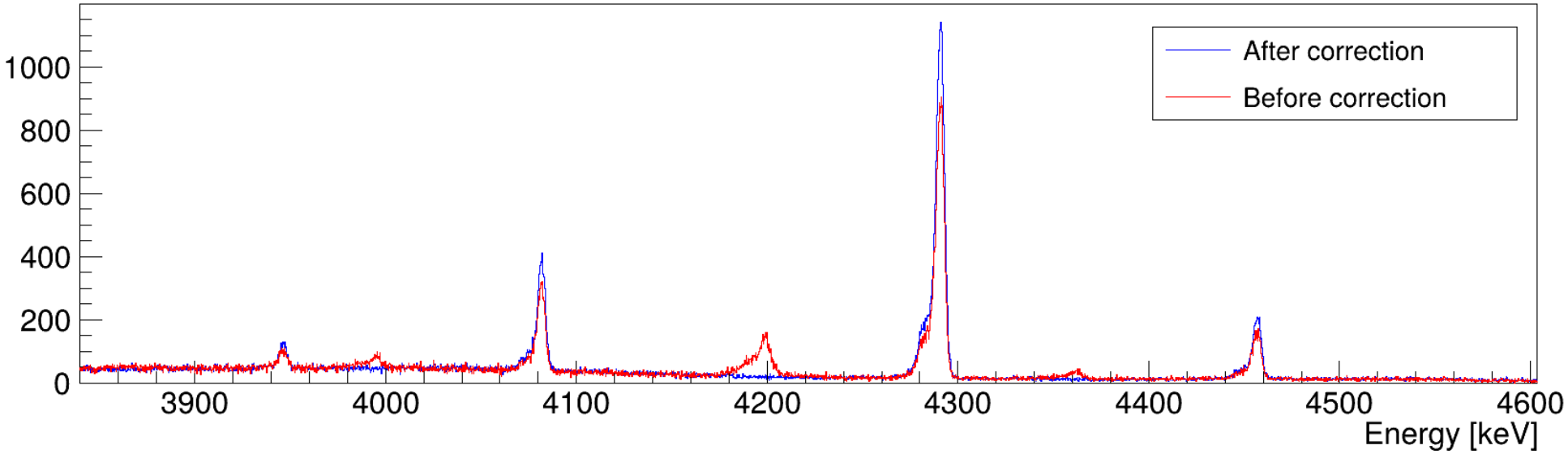




AGATA **high gain** core

^{66}Ga

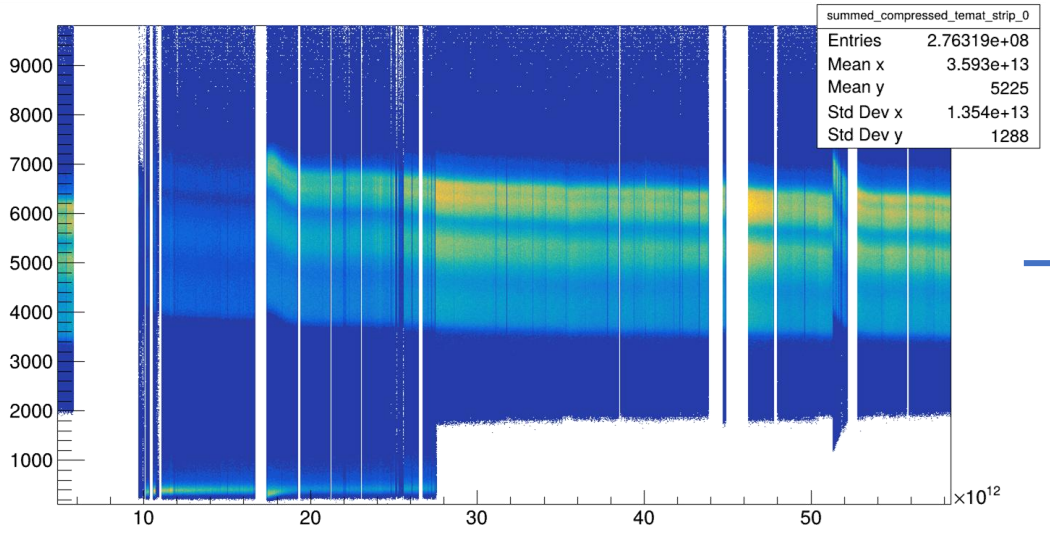


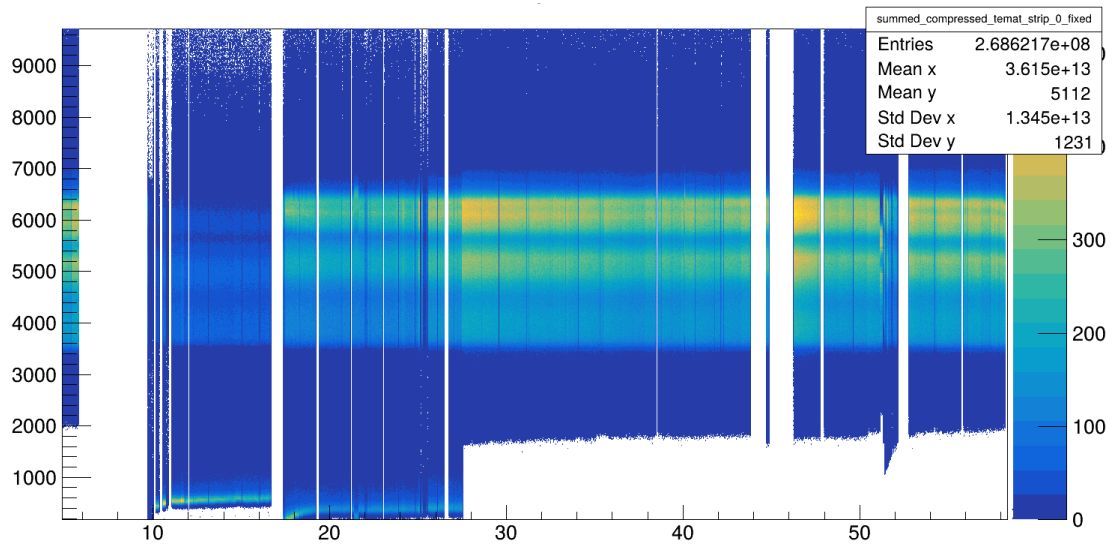


Motivation – Particle detectors

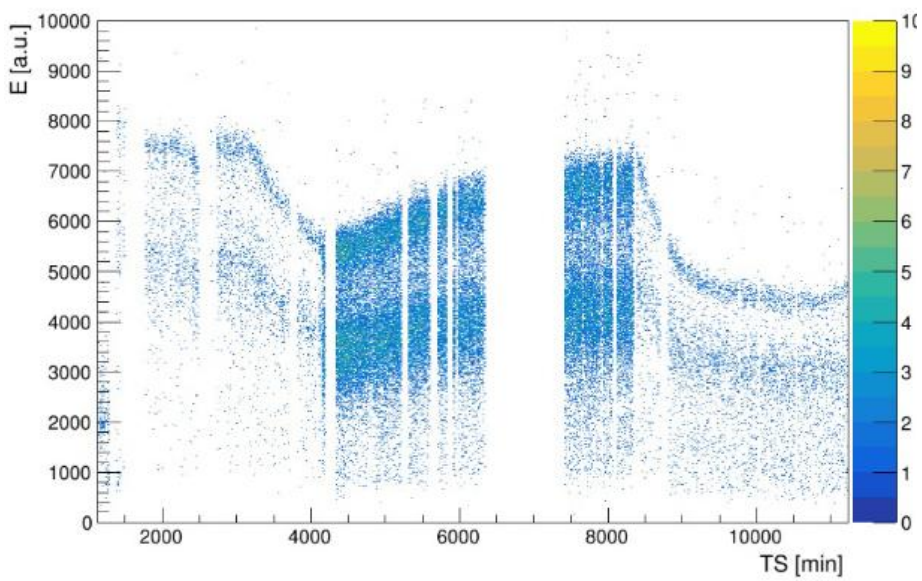
Silicon detectors

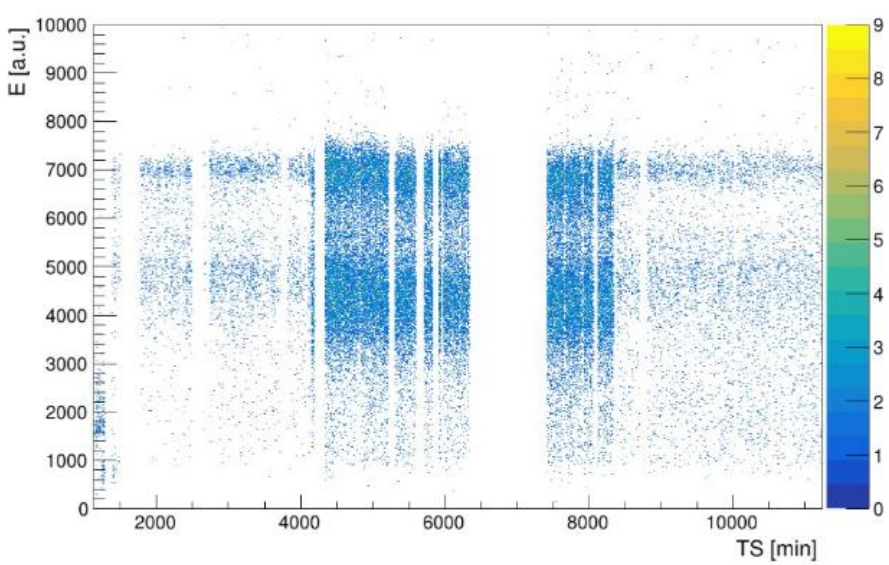
OSCAR



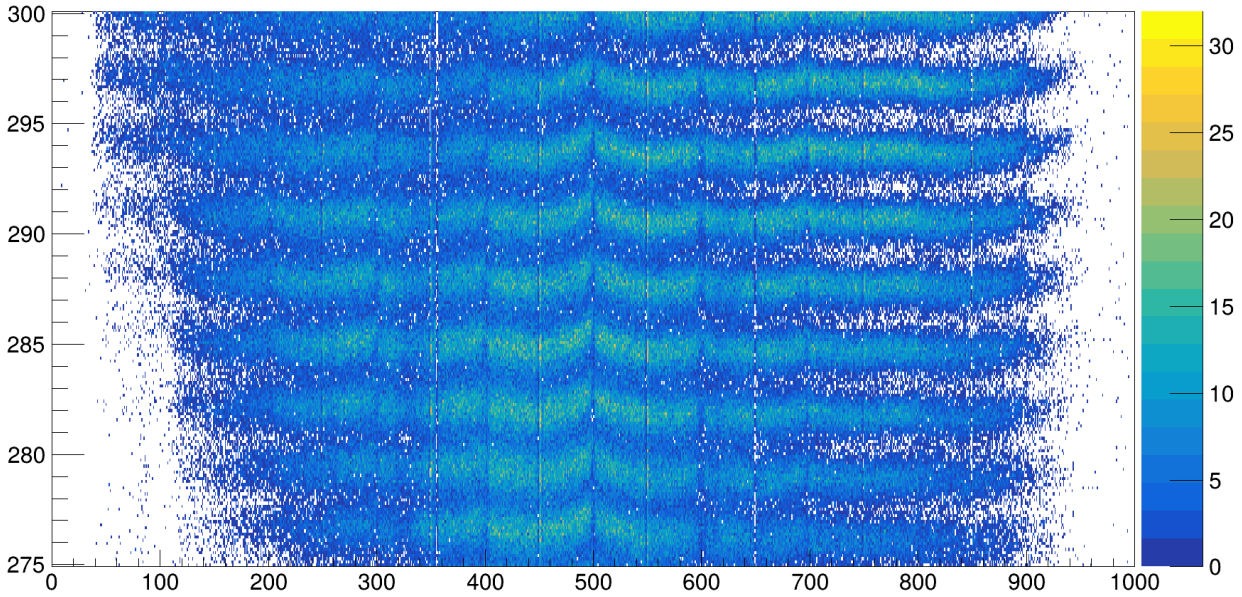


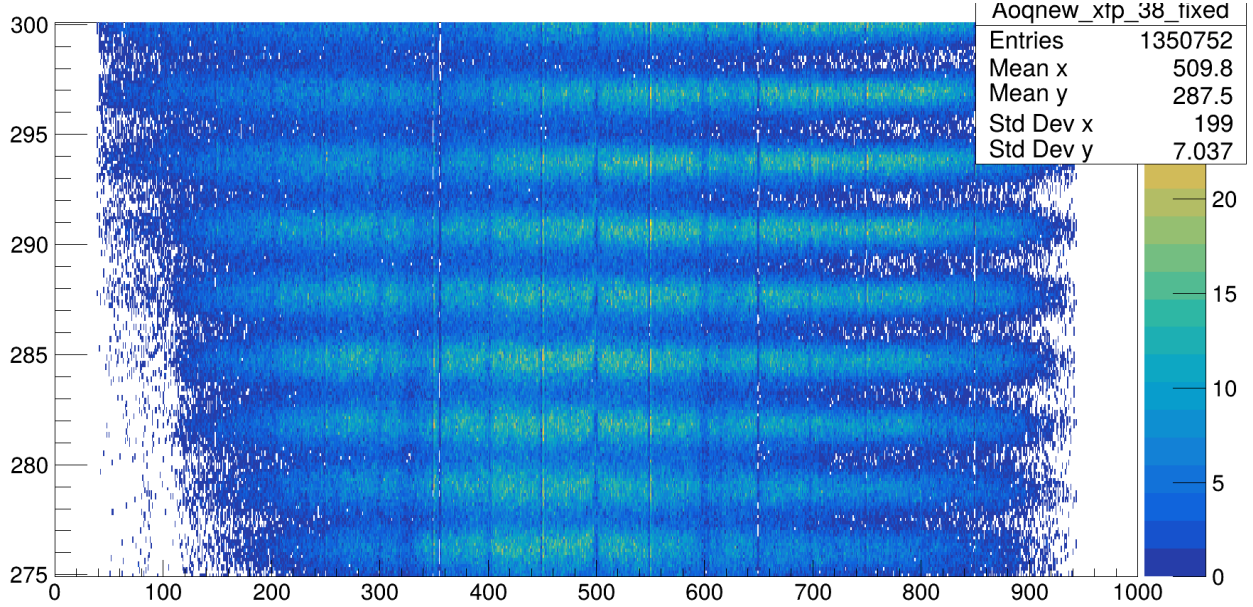
SAURON





PRISMA abberation correction



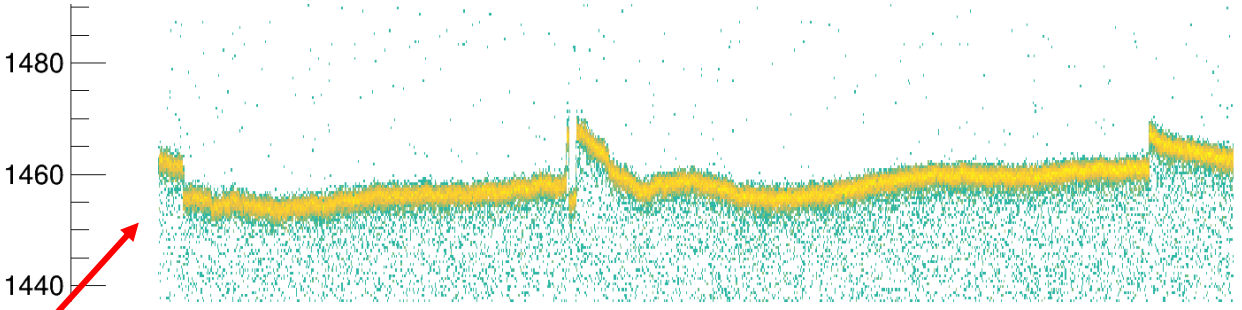


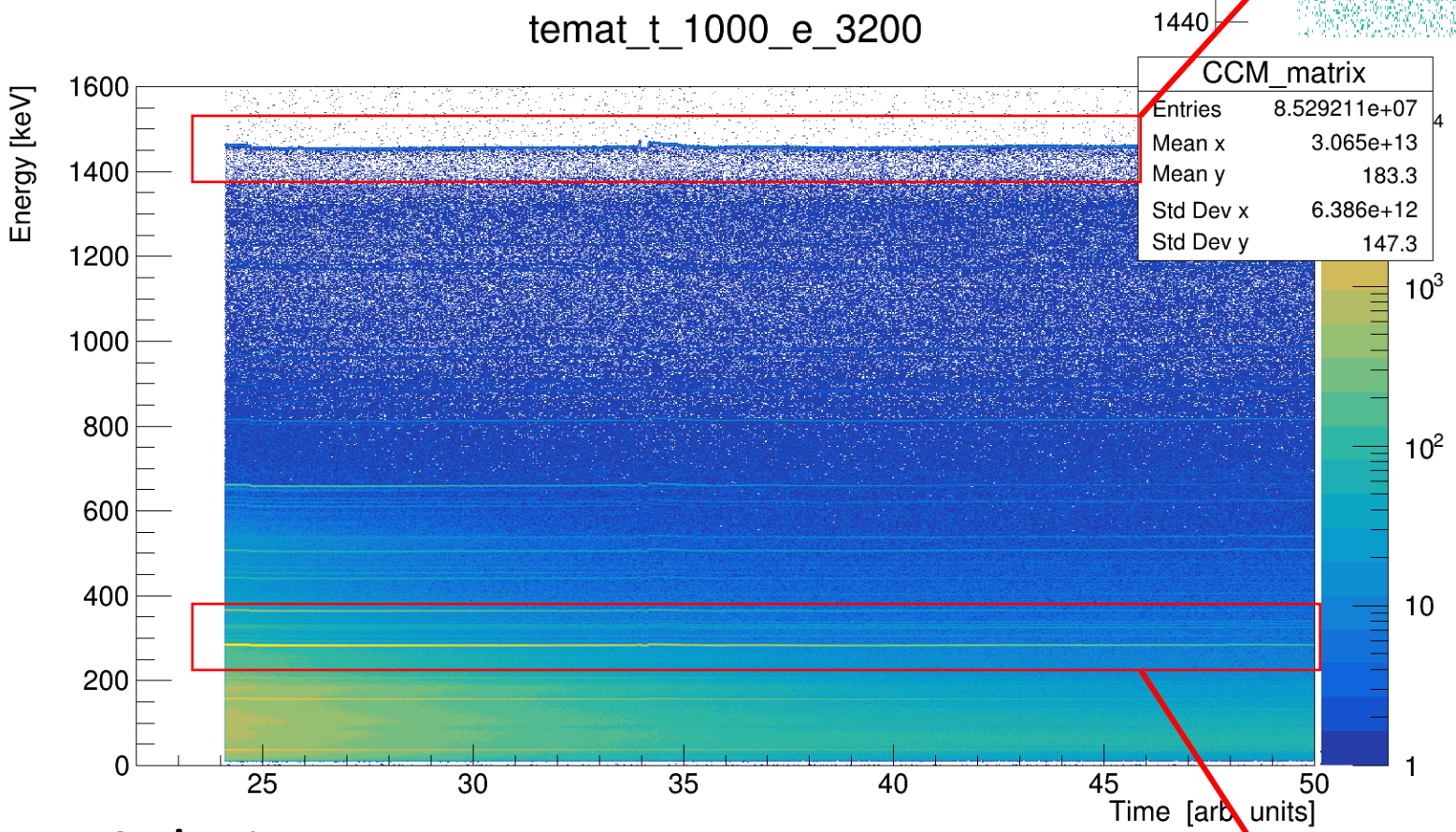
General algorithm

(not just AGATA)

Problem

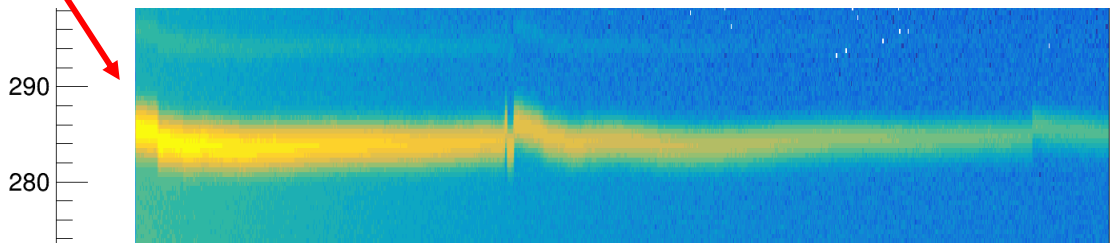
- apparent change in energy calibration over time
- suspected temperature effects on preamps





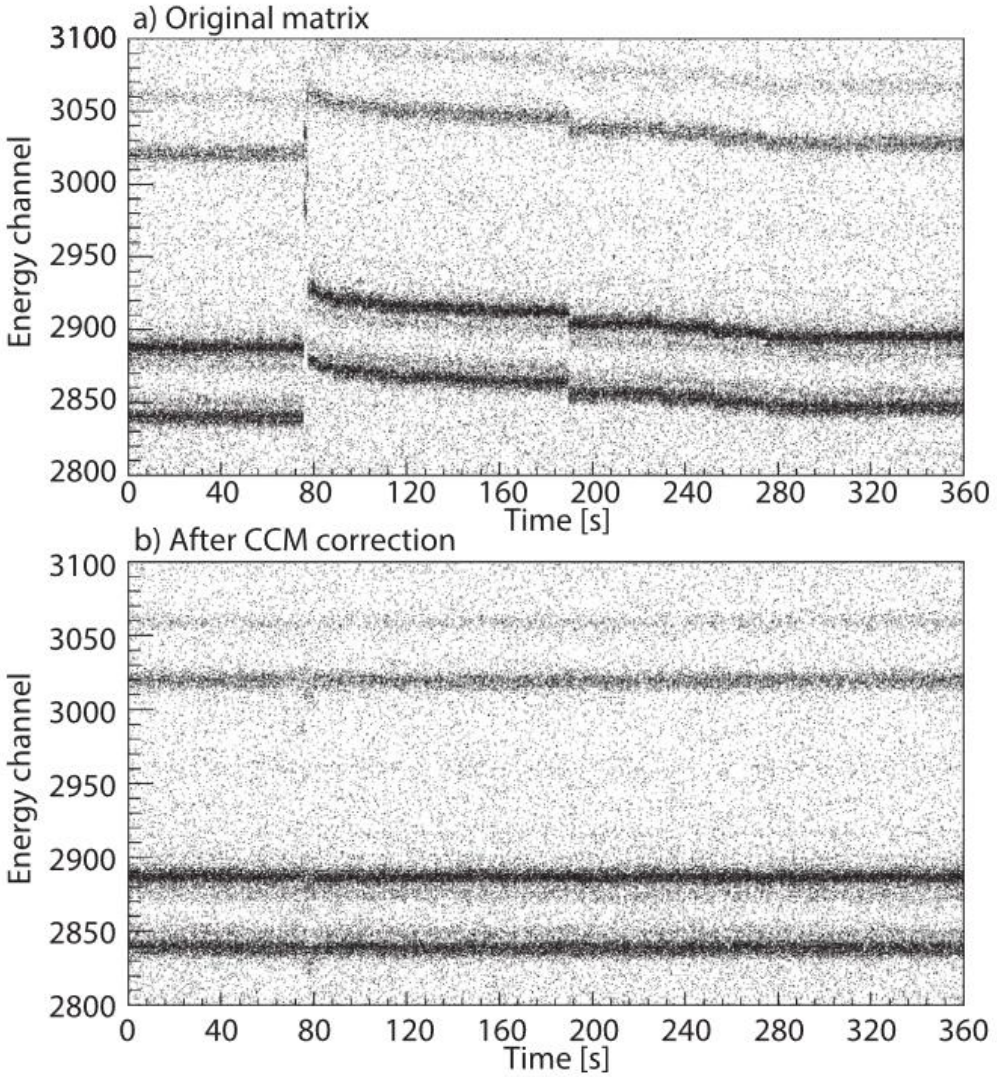
Solution

- divide data in time and recalibrate individually each set
- represented by Time vs Energy MATrix (TEMAT)
- automatization needed



CCM – cross-correlation correction method

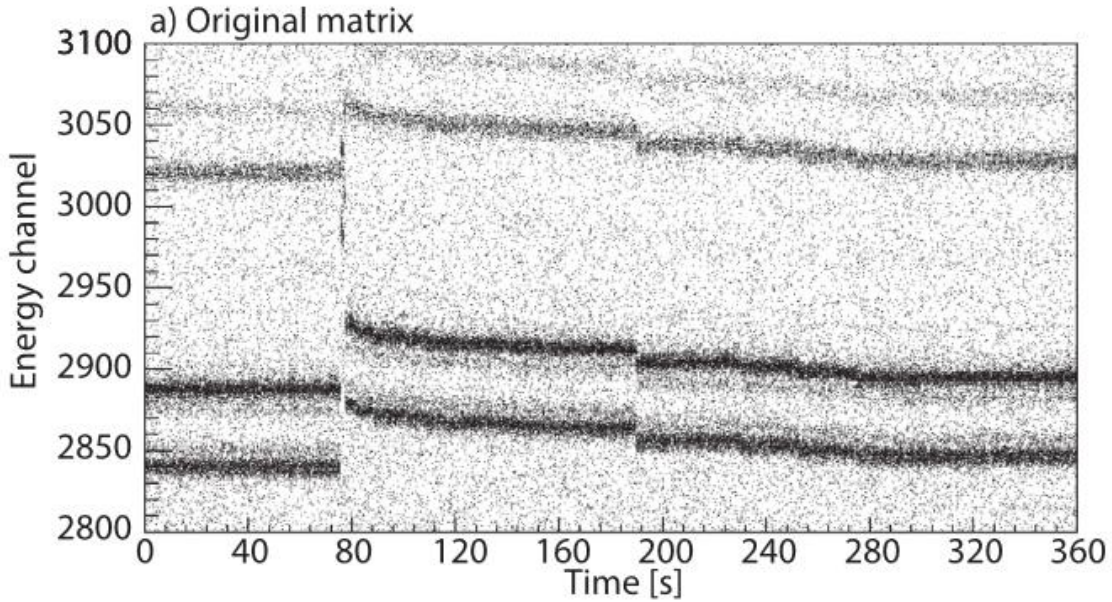
- simple, fast and reliable
- does not require well defined (e.i. fitable) spectral feature, such as Gaussian, Lorenzian etc. *
- works also on time-evolving spectrum, such as beta decays**



*require fitable peaks https://www.sciencedirect.com/science/article/pii/S0168900204005339?via%3Dihub
**require stable spectra https://www.sciencedirect.com/science/article/pii/S0168900296007565?via%3Dihub

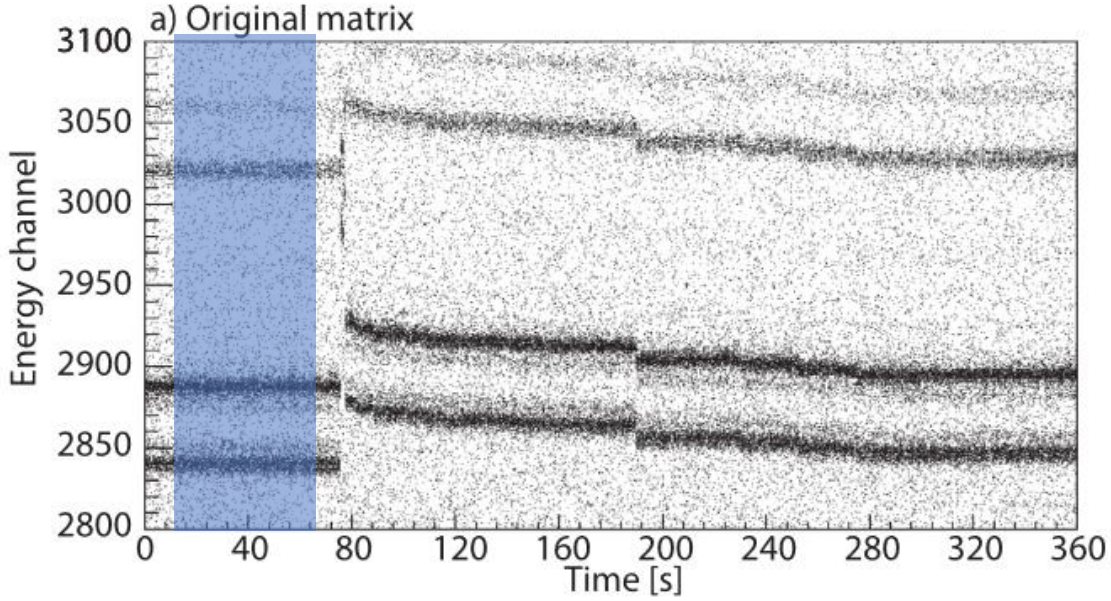
Recipe part 1

1. Create TEMAT
    - binning matters!



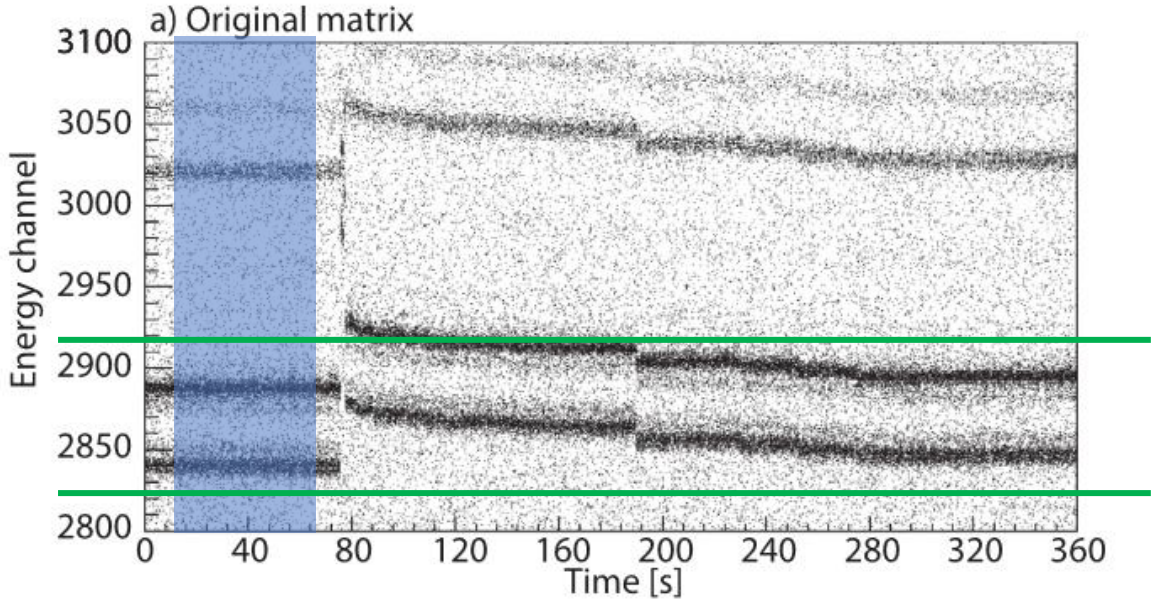
Recipe part 1

1. Create TEMAT
   - binning matters!
2. Define reference time
   - time interval during which no change in energy is observed
   - should be as wide as possible!



Recipe part 1

1. Create TEMAT
   - binning matters!
2. Define reference time
   - time interval during which no change in energy is observed
   - should be as wide as possible!
3. Define energy Region Of Interest (ROI)
   - in the reference time, it needs to contain a “feature” that is unique in the close vicinity
   - higher energies are preferred (changes are more pronounced)
   - energy of the feature – “desired energy” needs to be specified



Recipe part 1

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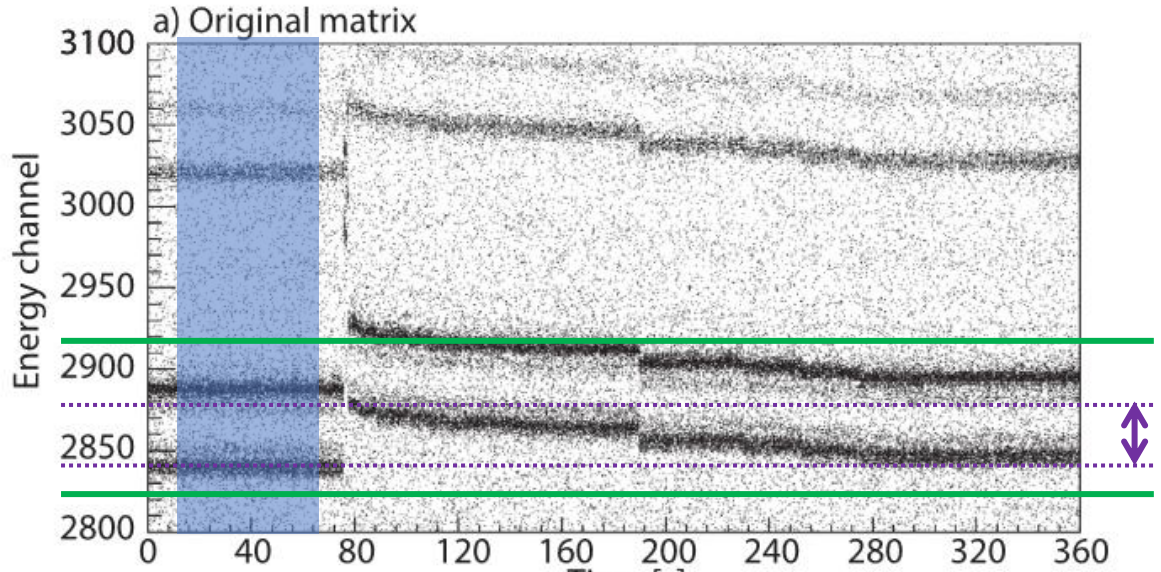
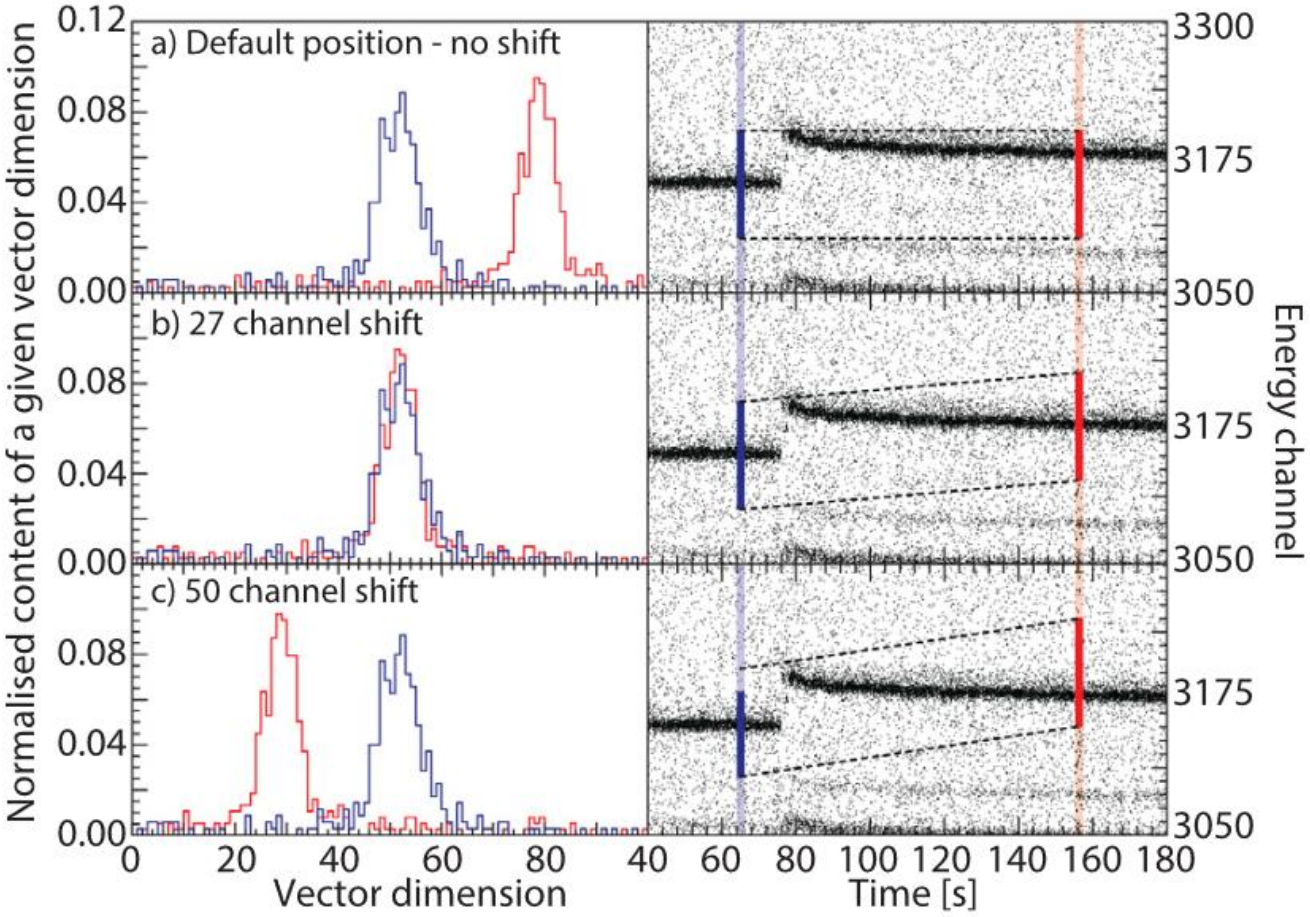
   - in the reference time, it needs to contain a “feature” that is unique in the close vicinity
   - higher energies are preferred (changes are more pronounced)
   - energy of the feature – “desired energy” needs to be specified
4. Define “shift range”
   - minimum and maximum energy difference between the “feature” in the reference spectrum and all other (shifted) ones
   - a rough numbers, should be actually slightly larger to surely encapsule all offsets



range roughly 30 ch, can be set to 50

CCM – calculating offset

- ROI energy range is treated as N-dimensional vector
- reference vector is constructed and normalized
- a N-dimensional test vectors are constructed by offsetting the ROI range one energy bin at a time within the “shift range”, vectors are normalized. One set of test vectors per time bin is produced.



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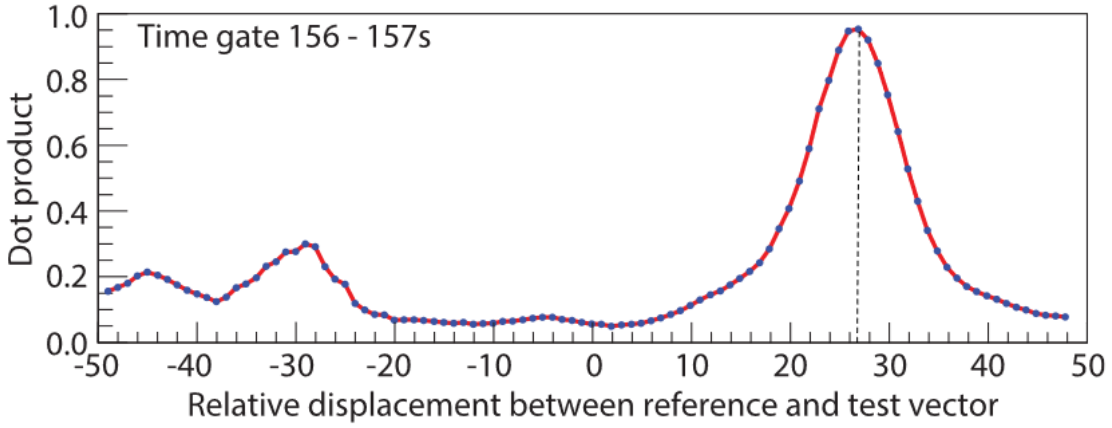
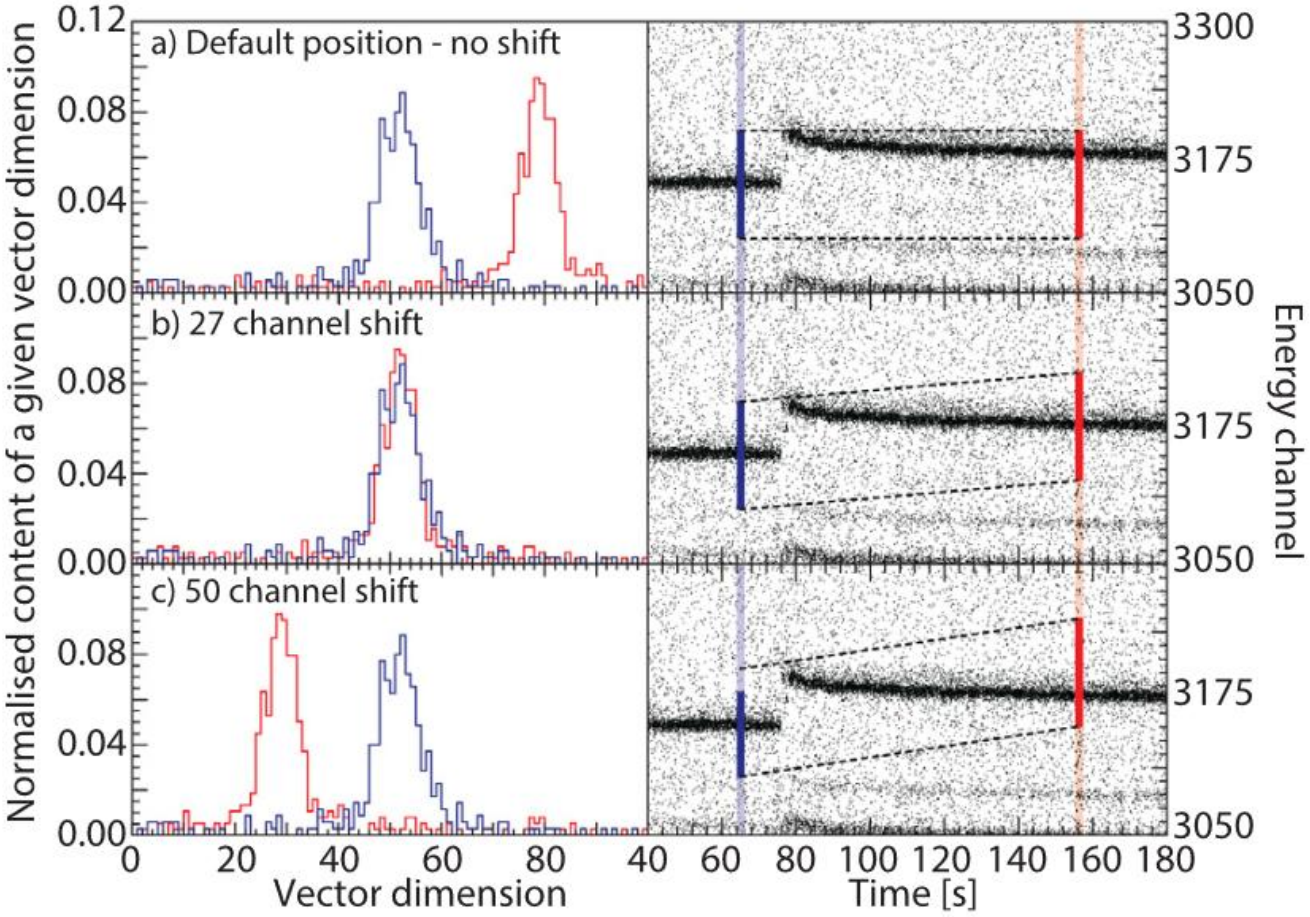
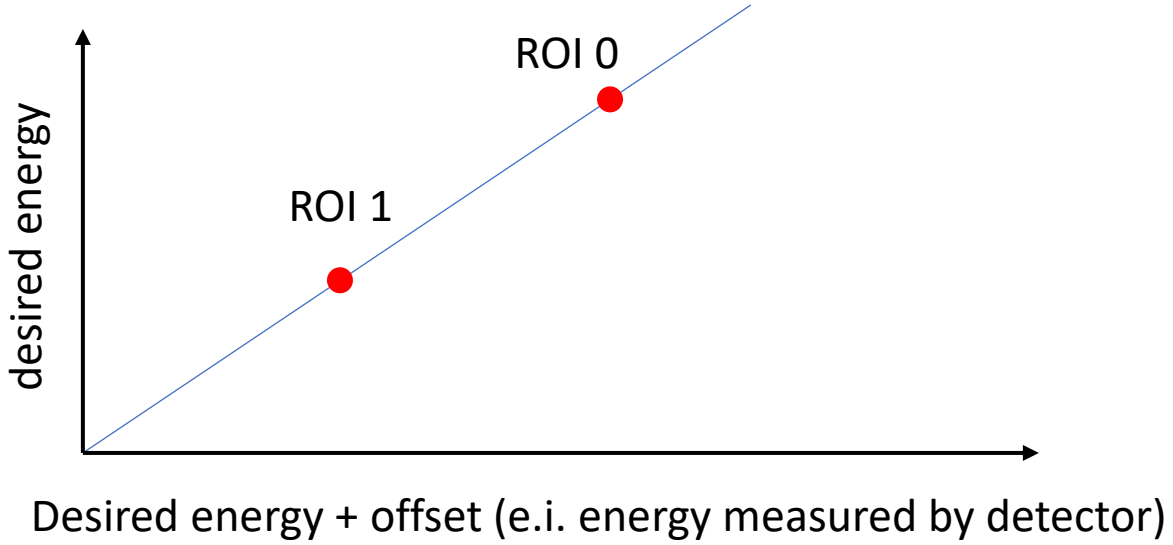
- dot product between test vectors and reference vector is calculated
- **maximum dot product -> offset**





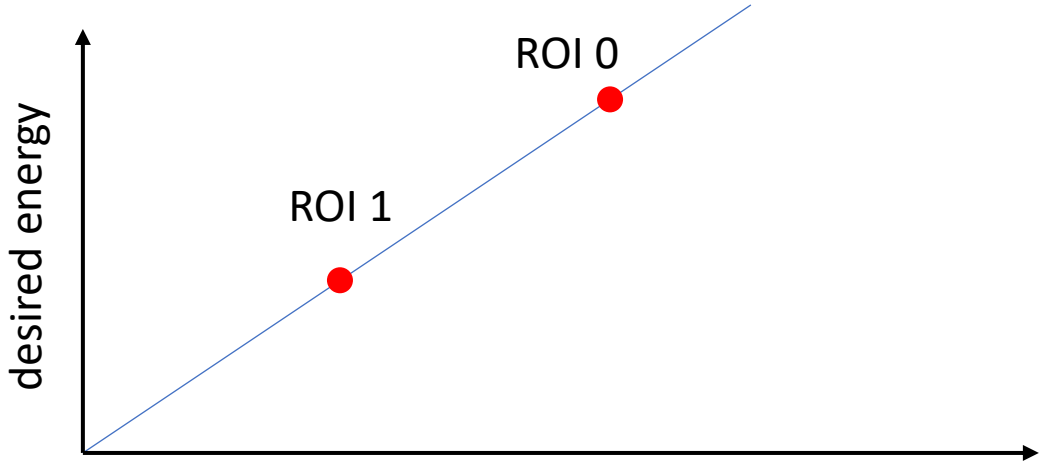
Recipe part 2

1. Supply “**correction function**”
    - calculated for each time slice

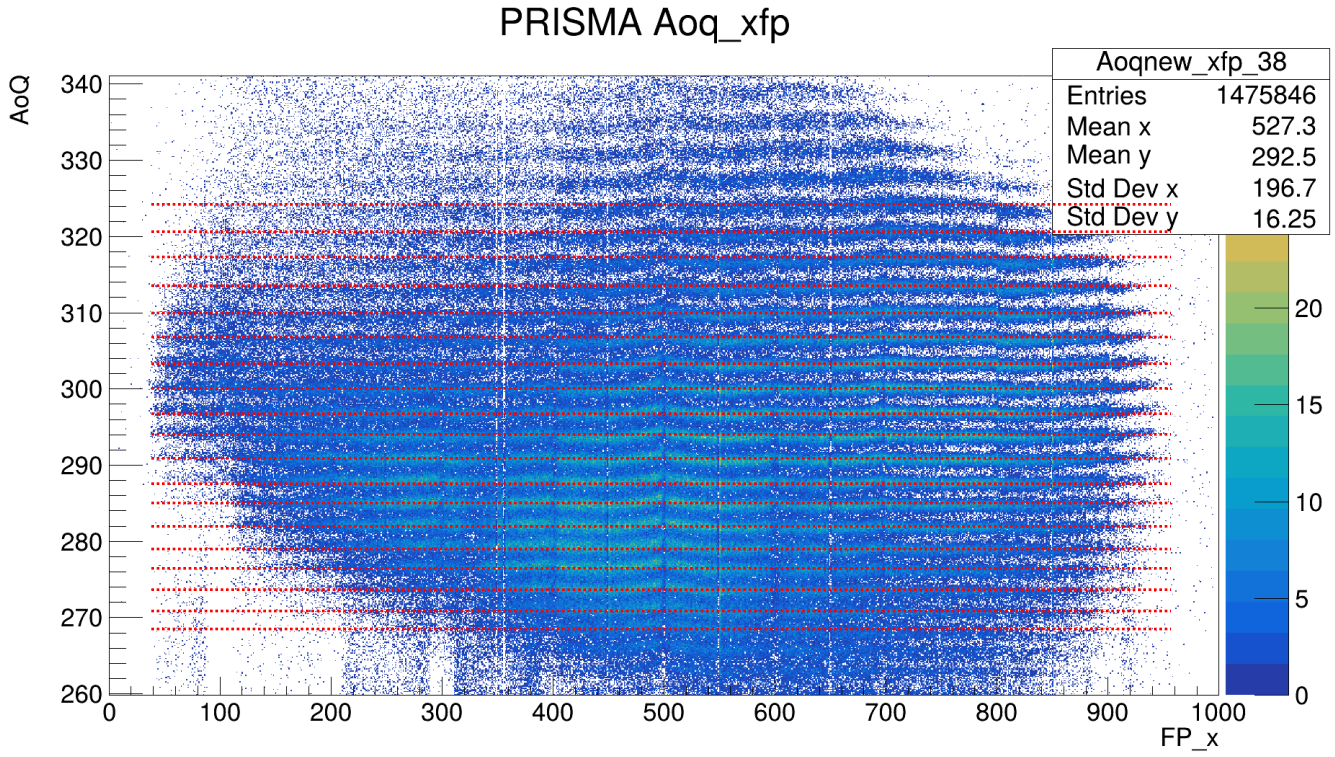


Recipe part 2

1. Supply “**correction function**”
   - calculated for each time slice
2. Multiple ROIs can be defined
   - detection of “bad” ROIs



Desired energy + offset (e.i. energy measured by detector)

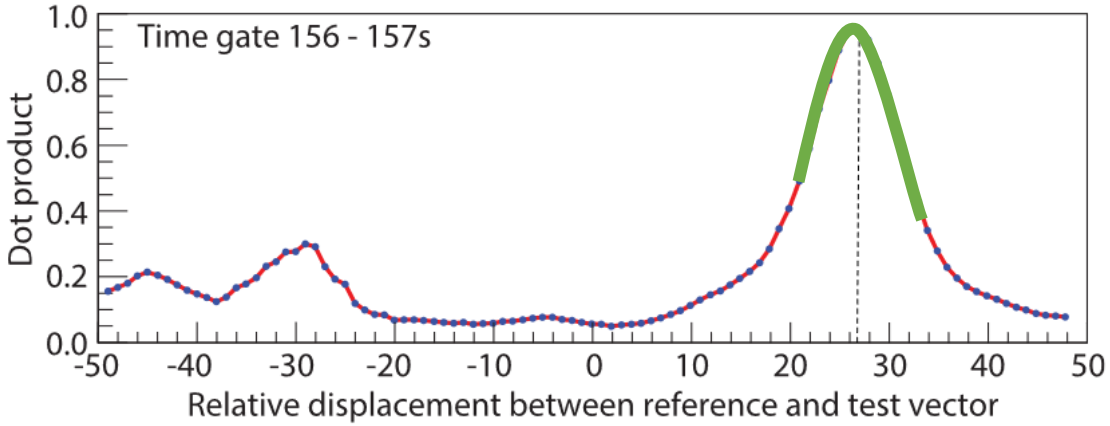


19 ROIs, some are not valid at certain X

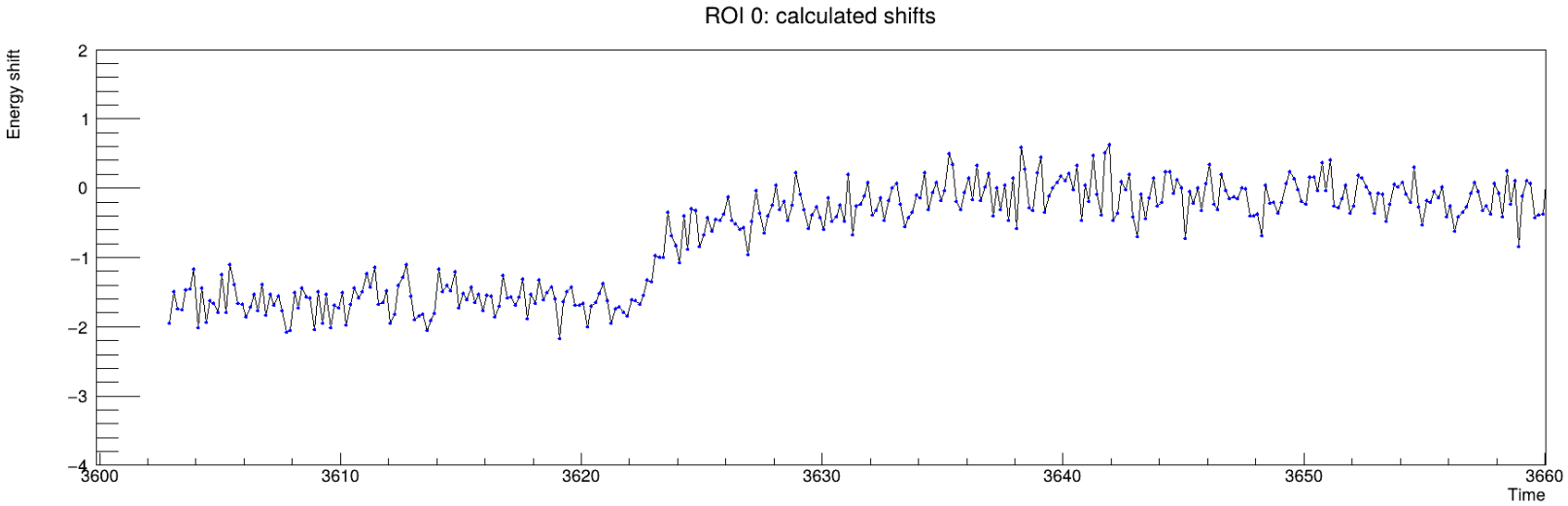
Improvements/Optimization

Improvements – offset precision

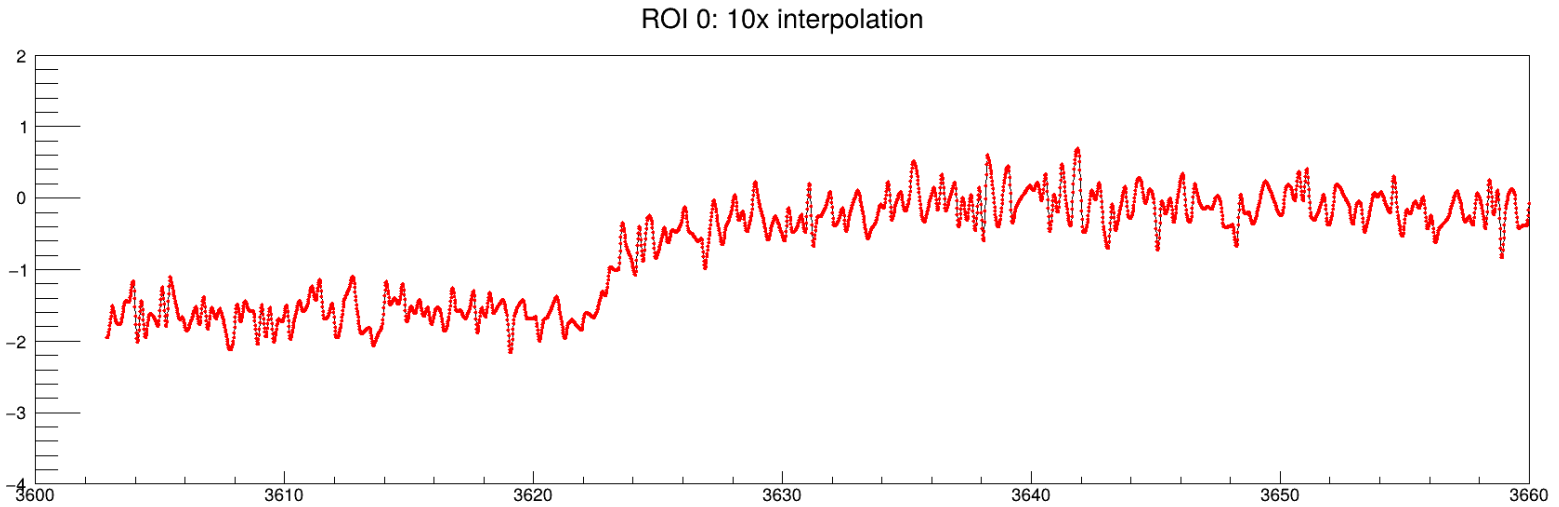
- By default, the offset is an integer (due to energy binning). Floating point precision can be achieved by fitting the region around the maximum dot product: **pol2** or **gauss**



Improvements – offset interpolation

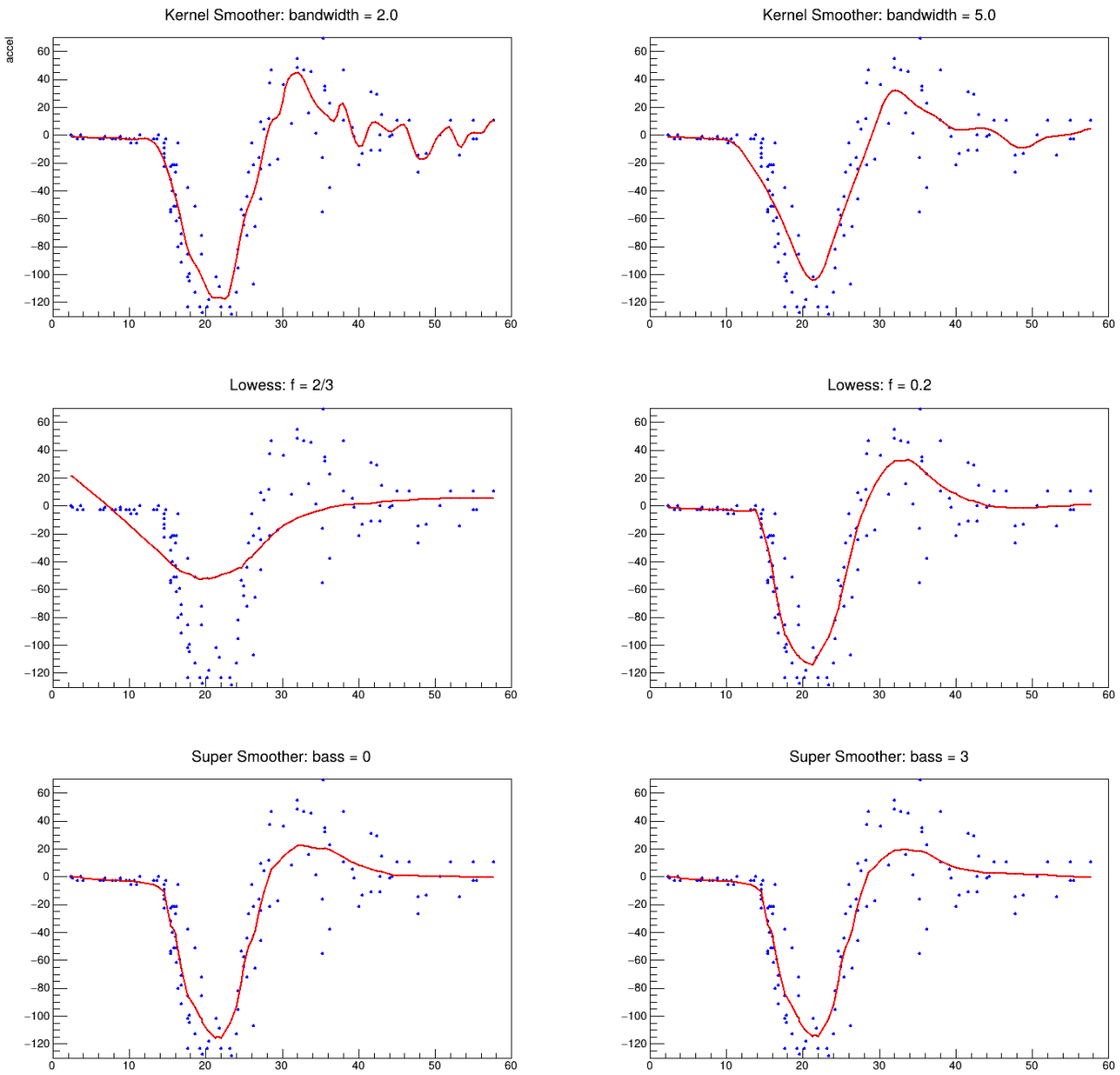


x10 interpolation



- Improving performance for low statistic matrices
- ROOT's interpolators:
  - **linear**
  - **polynomial**
  - **cspline**
  - **cspline_periodic**
  - **akima** (default)
  - **akima_periodic**

Improvements – smoothing

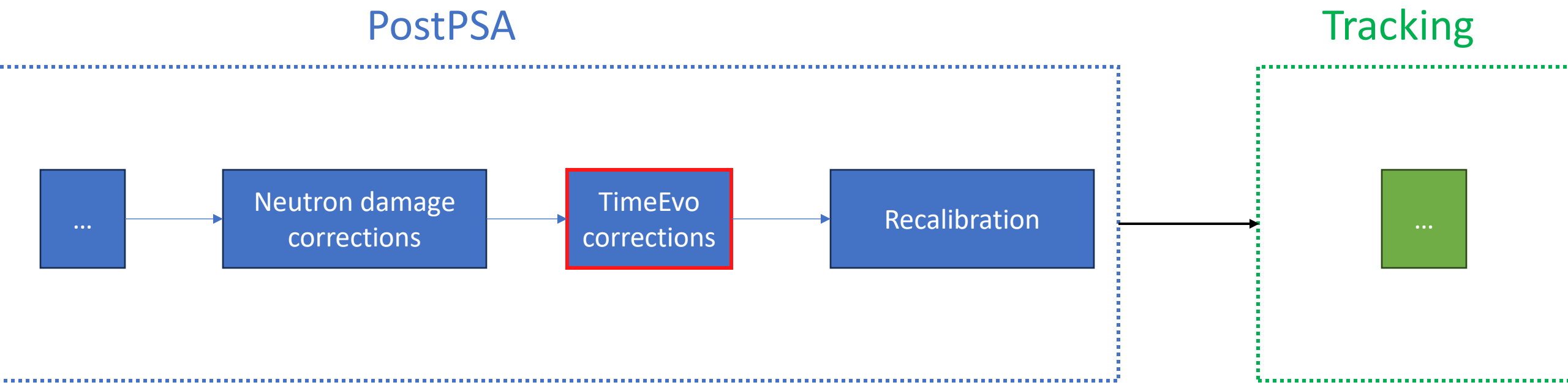


example from $ROOTSYS/tutorial/graphs/motorcycle.C

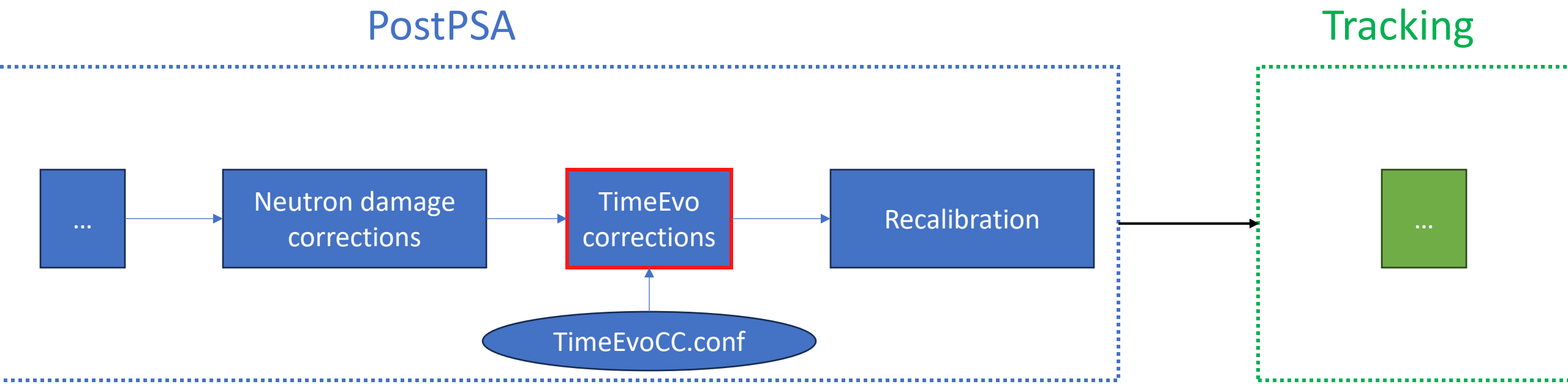
- Improving performance for low statistic matrices, but requires setting up 1 extra parameter related to the smoother
- ROOT's smoothers:
  - **kernel**
  - **lowess**
  - **super smoother**

AGATA codes

Processing chain



Processing chain



Add line to gen_conf's PostPSAFilter:

"TimeEvoCCFile TimeEvoCC.conf", # file with the energy-drift correction coefficients

matTimeEvo_cores

- construct time vs energy matrices from ROOT files **after NDC** and **before recalibration**
- matrices stored in Out/timeEvo/

```
mbalogh@agataanalysis-5:/agata07_data4/mbalogh/EXP_035/Replay/mb$ matTimeEvo_cores --help
To use the code, you should be in the directory where you ran replays

Usage: program [OPTIONS]
Options:
  --help                    Display this help message
  --run <integer>           Specify the run number (required)
  --crys <3-letter strings> Specify crystals (can be multiple 3-character strings)
  --maxentries <integer>    Set the maximum number of entries (optional)
  --allcrys                 Run for all crystals of EXP_035
  --Tbinning <integer>      Set number of seconds per bin (default 30)
  --Ebinning <1> <2> <3>    Set energy binning as:
                                <1> number of bins (default 32 000)
                                <2> min energy (default 0)
                                <3> max energy (default 8 000)
  --outdir <string>       Specify output directory (default: TimeEvo/)
  --replaydir <string>    Specify replay directory that contain ROOT trees, default is run_XXXX/Out/Analysis
```

TODO:

- cleanup folder structure
- option to create matrices using sliding window

detectTimeEvo

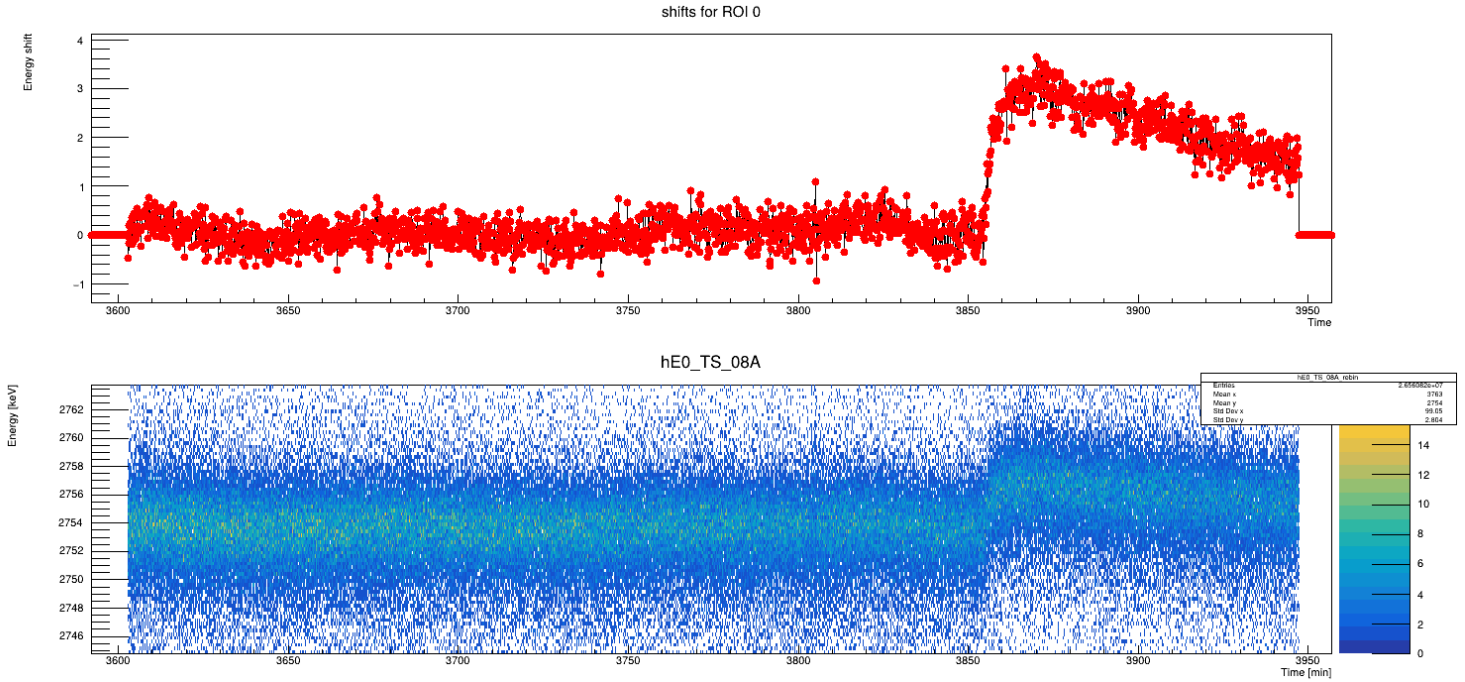
- checks if timeEvo occurred during the run by running barebone CCM with hardcoded parameters
- spectrum is reported if an offset above pre-set threshold is found

```
mbalogh@agataanalysis-5:/agata07_data4/mbalogh/EXP_035/Replay/mb$ detectTimeEvo --help
This code uses some assumptions and hardcoded values to run CCM - namely it uses a reference time in around 1/3 of the matrix that is 2x in energy and 2x in time
If a shift larger than set threshold (default 0.5) is detected, a TimeEvo is reported.
Two reports are made: one while code is running showing also some statistics, and one at the end sorted by run number.
You can use --draw option to draw matrices with calculated shifts while the code is running.

Usage: detectTimeEvo_AGATA [options]
Options:
  --help, -h                 Show this help message
  --crystal <1> <...>        Specify the crystal(s) name
  --allcrys                  Run for all crystals of EXP_035
  --run <1> <...>            Specify the run number
  --shift_threshold <1>      Energy threshold, if energy shift value threshold is found the timeEvo is reported (default 0.5)
  --draw                     Use this flag to enable drawing the matrices that are over the set threshold
  --ROI <1> <2> <3> <4> <5>  Specify the Region of Interest (ROI) as:
                                <1> - desired energy of the ROI
                                <2> - left edge of ROI n
                                <3> - right edge of ROI
                                <4> - shift ROI by maximum of <4> to the LEFT (neg value!)
                                <5> - shift ROI by maximum of <5> to the RIGHT
  --ROIsource <1>            Define ROI for calibration sources. Currently recognized are: 60Co, 66Ga, 133Ba, 226Ra
  --dir <1>                  Set directory in which to search for matrices
```

detectTimeEvo

```
mbalogh@Agrippa:~/CCM/build$ ./detectTimeEvo --draw --ROIsource 66Ga --dir /home/mbalogh/perf/timeEvo/ --allcrys --run 6
Parameters used are:
Run number(s):    6
Crystals:         00A 00B 00C 01A 01C 02A 02B 02C 04A 04B 04C 05B 05C 06A 06B 06C 07A 07B 08A 08B 09A 09B 09C 10A 10B 10C 11A 11B 11C 14A 14B 14C
Data directory:         /home/mbalogh/perf/timeEvo/
Energy shift threshold: 0.5
ROI:              2751.83 2720 2780 -90 50
-----------------------------------------------------------
TimeEvolution detected!
  Run 6 crys 00A: above thr: 326 mean: 0.76 stdev: 0.20 rms: 0.79 max_abs: 1.44 median: 0.71
  Run 6 crys 00B: above thr: 504 mean: 0.78 stdev: 0.20 rms: 0.81 max_abs: 1.45 median: 0.75
  Run 6 crys 00C: above thr: 61 mean: 1.34 stdev: 5.60 rms: 5.76 max_abs: 44.72 median: 0.60
Killed
```



solveTimeEvo

- calculates gain corrections for selected/all crystals of given run

```
mbalogh@agataanalysis-5:/agata07_data4/mbalogh/EXP_035/Replay/mb$ solveTimeEvo --help
Usage: program [OPTIONS]

Options:
  --help                      Display this help message and exit.
  --crystal <1>               Specify the crystal name (e.g. 00A).
  --run <1>                   Specify the run number
  --ROI <1> <2> <3> <4> <5>   Specify the Region of Interest (ROI) as:
                                 <1> - desired energy of the ROI
                                 <2> - left edge of ROI n
                                 <3> - right edge of ROI
                                 <4> - shift ROI by maximum of <4> to the LEFT (neg value!)
                                 <5> - shift ROI by maximum of <5> to the RIGHT
  --ROIsource <1>             Define ROI for calibration sources. Currently recognized are: 60Co, 66Ga, 133Ba, 226Ra
  --ref_time <1> <2>          Specify the reference time interval
  --fit_peak <1> <2> <3>      If running in minimization mode, specify peak used
                                 which FWFM is used to find the optimal parameters
                                 <1> peak center
                                 <2> left fit region
                                 <3> right fit region
                              Specify the peak used to find optimal parameters
                              Note that this should be different peak than one contained in ROI, otherwise you are risking overfitting
  --dir <1>                   Set directory in which to search for matrices and where TimeEvoCC.conf files will be saved
  --rootfile <1>              Specify the root file name
  --matrix <1>                Specify the matrix name
  --super_settings            Run corrections with hardcoded parameters
  --chain_runs <1> [...]      Specify the runs that are going to use the same reference vector as defined for --run
```

- runs through a set of parameters and uses a FoM (--fit_peak) to identify the best set for given run and given crystal

solveTimeEvo

- runs through a set of parameters and looks for ones that minimizes FoM (FWFM of selected peak) – individually for each run & crystal
- FoM is calculated by fast correction of the input matrix – it is normal to see small difference when compared to replayed data with corrections

```
mbalogh@agataanalysis-5:/agata07_data4/mbalogh/EXP_035/Replay/mb$ solveTimeEvo  --run 6 --ref_time 3700 3710 --ROI 2751.835 2720 2780 -90 30 --fit_peak 4295.187 4220 4360 --crystal 07B
Parsed Input Parameters:
  Crystal: 07B
  Run: 6
  Root File: timeEvo/temat_0006_07B.root
  Matrix Name: hE0_TS_07B
  ROI: 2751.83 2720 2780 -90 30
  Reference Run: -1
  Reference Time: 3700 3710
  Fit Peak: 4295.19 4220 4360
  Use Super Settings: false
Output configuration file will be saved to: timeEvo/run_0006/Conf/07B/TimeEvoCC.conf
Adjusted ROI energy to: 2749.26
Adjusted cost peak energy to: 4291.38

Testing following settings:
      Cost    RebX    RebY    Gaussian     Valid          InterpType   Smoothing   SmootherType   SmoothPar
   8.69385       1       1        true      true               akima       false           NONE          -1
   9.69432       1       1        true      true               akima        true          SUPER           1
   9.69432       1       1        true      true               akima        true          SUPER           2
   9.69431       1       1        true      true               akima        true          SUPER           5
   8.68675       1       1       false      true               akima       false           NONE          -1
   9.68719       1       1       false      true               akima        true          SUPER           1
   9.68719       1       1       false      true               akima        true          SUPER           2
   9.68718       1       1       false      true               akima        true          SUPER           5
Duration: 28603 ms
      Cost    RebX    RebY    Gaussian     Valid          InterpType   Smoothing   SmootherType   SmoothPar
   8.68675       1       1       false      true               akima       false           NONE          -1
   8.69385       1       1        true      true               akima       false           NONE          -1
   9.68718       1       1       false      true               akima        true          SUPER           5
   9.68719       1       1       false      true               akima        true          SUPER           2
   9.68719       1       1       false      true               akima        true          SUPER           1
   9.69431       1       1        true      true               akima        true          SUPER           5
   9.69432       1       1        true      true               akima        true          SUPER           2
   9.69432       1       1        true      true               akima        true          SUPER           1
Running final corrections for run 6 with super settings...
      Cost    RebX    RebY    Gaussian     Valid          InterpType   Smoothing   SmootherType   SmoothPar
   8.68675       1       1       false      true               akima       false           NONE          -1
Corrections for postPSAfilter are being written to: timeEvo/run_0006/Conf/07B/TimeEvoCC.conf
mbalogh@agataanalysis-5:/agata07_data4/mbalogh/EXP_035/Replay/mb$
```

- **--super_settings** option to skip the “minimization” and use some default parameters

solveTimeEvo

- runs through a set of parameters and looks for ones that minimizes FoM (FWFM of selected peak) – individually for each run & crystal
- FoM is calculated by fast correction of the input matrix – it is normal to see small difference when compared to replayed data with corrections

```
mbalogh@agataanalysis-5:/agata07_data4/mbalogh/EXP_035/Replay/mb$ solveTimeEvo  --run 6 --ref_time 3700 3710 --ROI 2751.835 2720 2780 -90 30 --fit_peak 4295.187 4220 4360 --crystal 07B
Parsed Input Parameters:
  Crystal: 07B
  Run: 6
  Root File: timeEvo/temat_0006_07B.root
  Matrix Name: hE0_TS_07B
  ROI: 2751.83 2720 2780 -90 30
  Reference Run: -1
  Reference Time: 3700 3710
  Fit Peak: 4295.19 4220 4360
  Use Super Settings: false
Output configuration file will be saved to: timeEvo/run_0006/Conf/07B/TimeEvoCC.conf
Adjusted ROI energy to: 2749.26
Adjusted cost peak energy to: 4291.38

Testing following settings:
      Cost    RebX    RebY    Gaussian     Valid          InterpType   Smoothing   SmootherType   SmoothPar
   8.69385       1       1        true      true               akima       false           NONE          -1
   9.69432       1       1        true      true               akima        true          SUPER           1
   9.69432       1       1        true      true               akima        true          SUPER           2
   9.69431       1       1        true      true               akima        true          SUPER           5
   8.68675       1       1       false      true               akima       false           NONE          -1
   9.68719       1       1       false      true               akima        true          SUPER           1
   9.68719       1       1       false      true               akima        true          SUPER           2
   9.68718       1       1       false      true               akima        true          SUPER           5
Duration: 28603 ms
      Cost    RebX    RebY    Gaussian     Valid          InterpType   Smoothing   SmootherType   SmoothPar
   8.68675       1       1       false      true               akima       false           NONE          -1
   8.69385       1       1        true      true               akima       false           NONE          -1
   9.68718       1       1       false      true               akima        true          SUPER           5
   9.68719       1       1       false      true               akima        true          SUPER           2
   9.68719       1       1       false      true               akima        true          SUPER           1
   9.69431       1       1        true      true               akima        true          SUPER           5
   9.69432       1       1        true      true               akima        true          SUPER           2
   9.69432       1       1        true      true               akima        true          SUPER           1
Running final corrections for run 6 with super settings...
      Cost    RebX    RebY    Gaussian     Valid          InterpType   Smoothing   SmootherType   SmoothPar
   8.68675       1       1       false      true               akima       false           NONE          -1
Corrections for postPSAfilter are being written to: timeEvo/run_0006/Conf/07B/TimeEvoCC.conf
mbalogh@agataanalysis-5:/agata07_data4/mbalogh/EXP_035/Replay/mb$
```

FoM is calculated from corrections estimated by fast-correction of input matrix!

- **--super_settings** option to skip the “minimization” and use some default parameters

Code access

Library repository https://github.com/matLogh/CCM/tree/master
Repository contain CCM library and s**olution** subdirectory for:

- ***AGATA***
- *OSCAR*
- *PRISMA*
- *simple_example* (starting point for own solutions)

Repository contain example data sets

- *AGATA* (extreme case of 07B)
- *PRISMA*
- *simple_example* (simulated beta decay measurement)

Let me know if you need a help!

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Volume 1004, 11 July 2021, 165368

Automated method for offline correction of spectrometry data affected by time instability

M. Balogh [a], A. Herzáň [a], V. Matoušek [a], M. Sedlák [a], M. Beňo [b], J. Dobrovodský [b], G. Kantay [a], P. Konopka [a], P. Noga [b], A. Repko [a], A. Špaček [a], D. Vaňa [b], M. Venhart [a], S. Vielhauer [a]

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GitHub code: https://github.com/matLogh/CCM

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GitHub code: https://github.com/matLogh/CCM

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