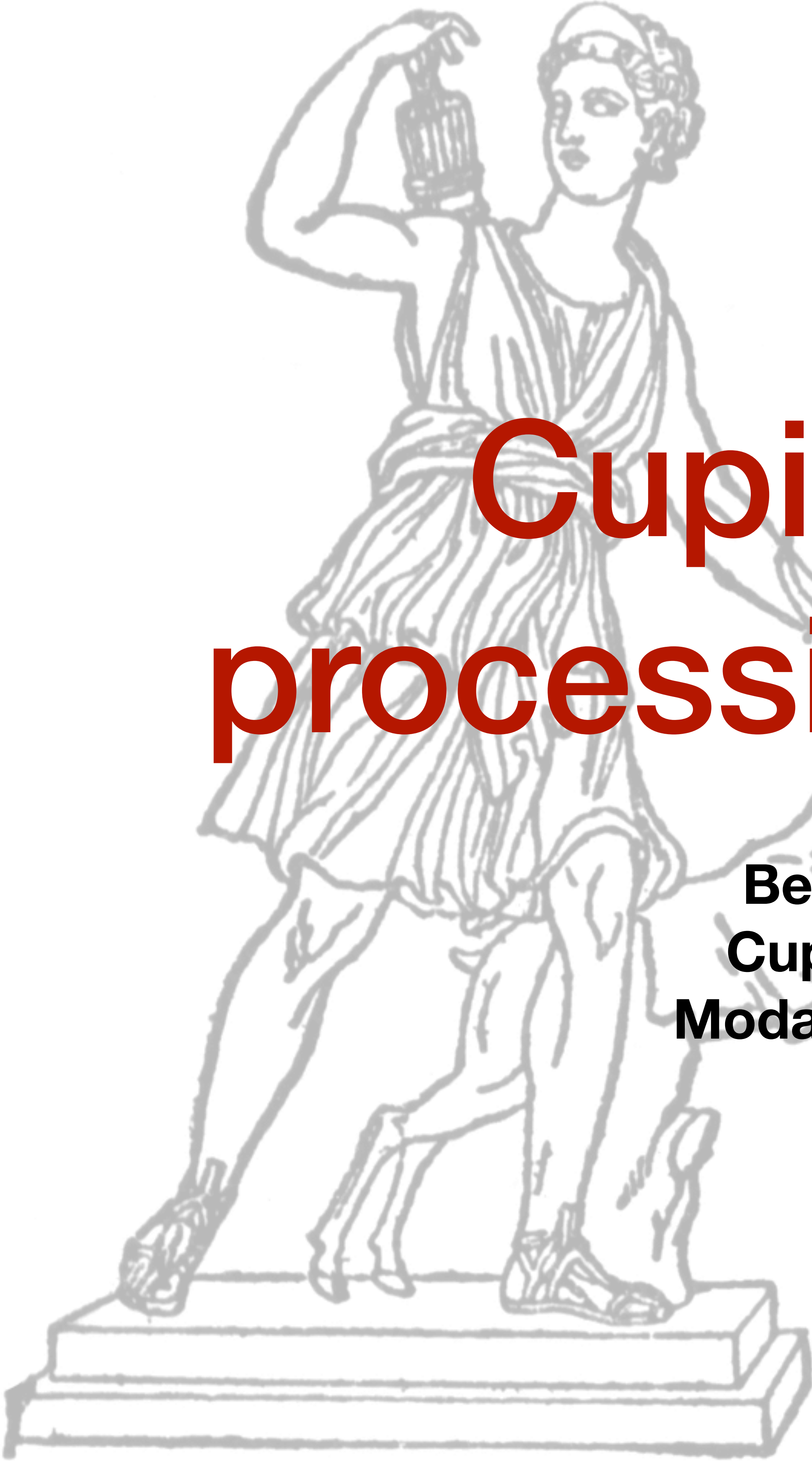
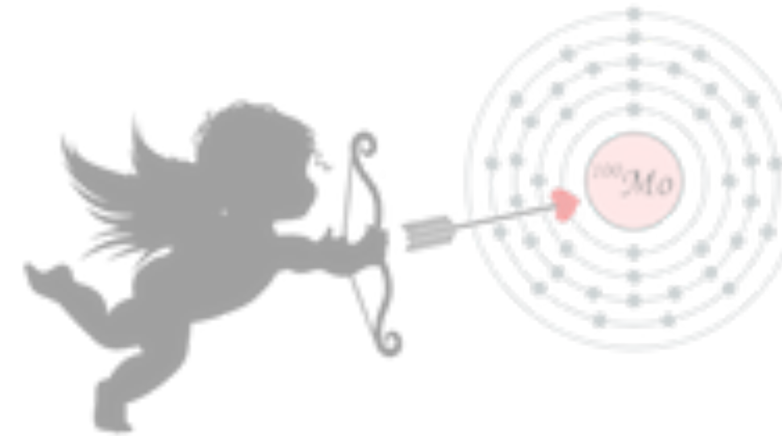




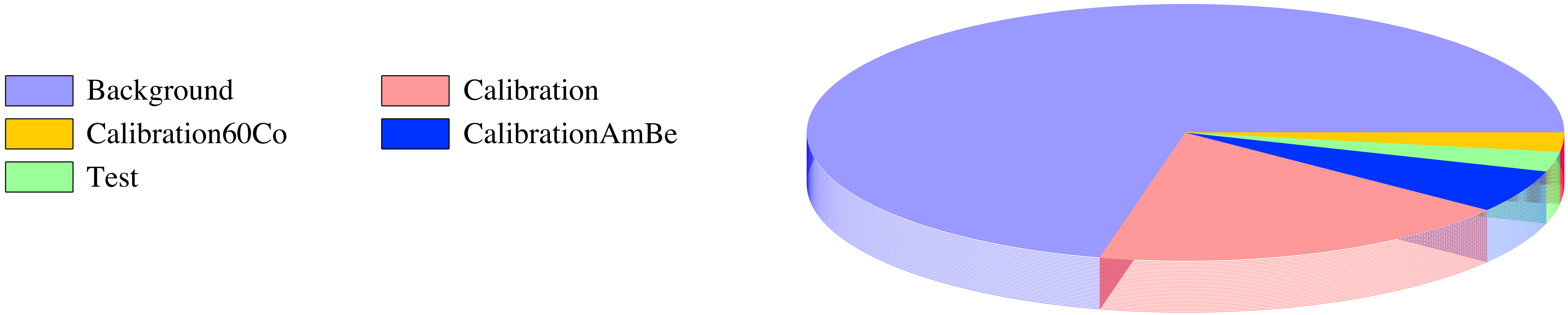
Cupid-Mo data processing with Diana

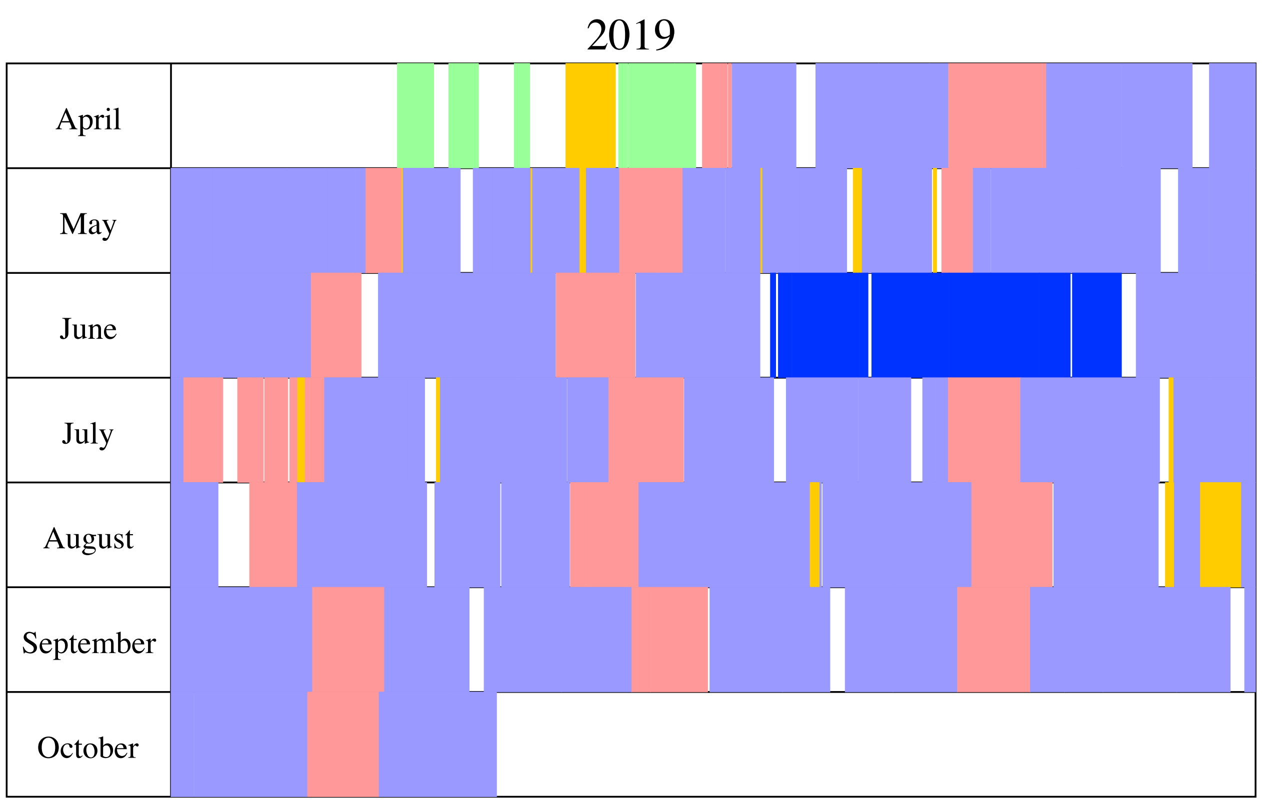
Benjamin S., Laura M.

Cupid-Mo inauguration

Modane 11 December 2019

Data processed after commissioning

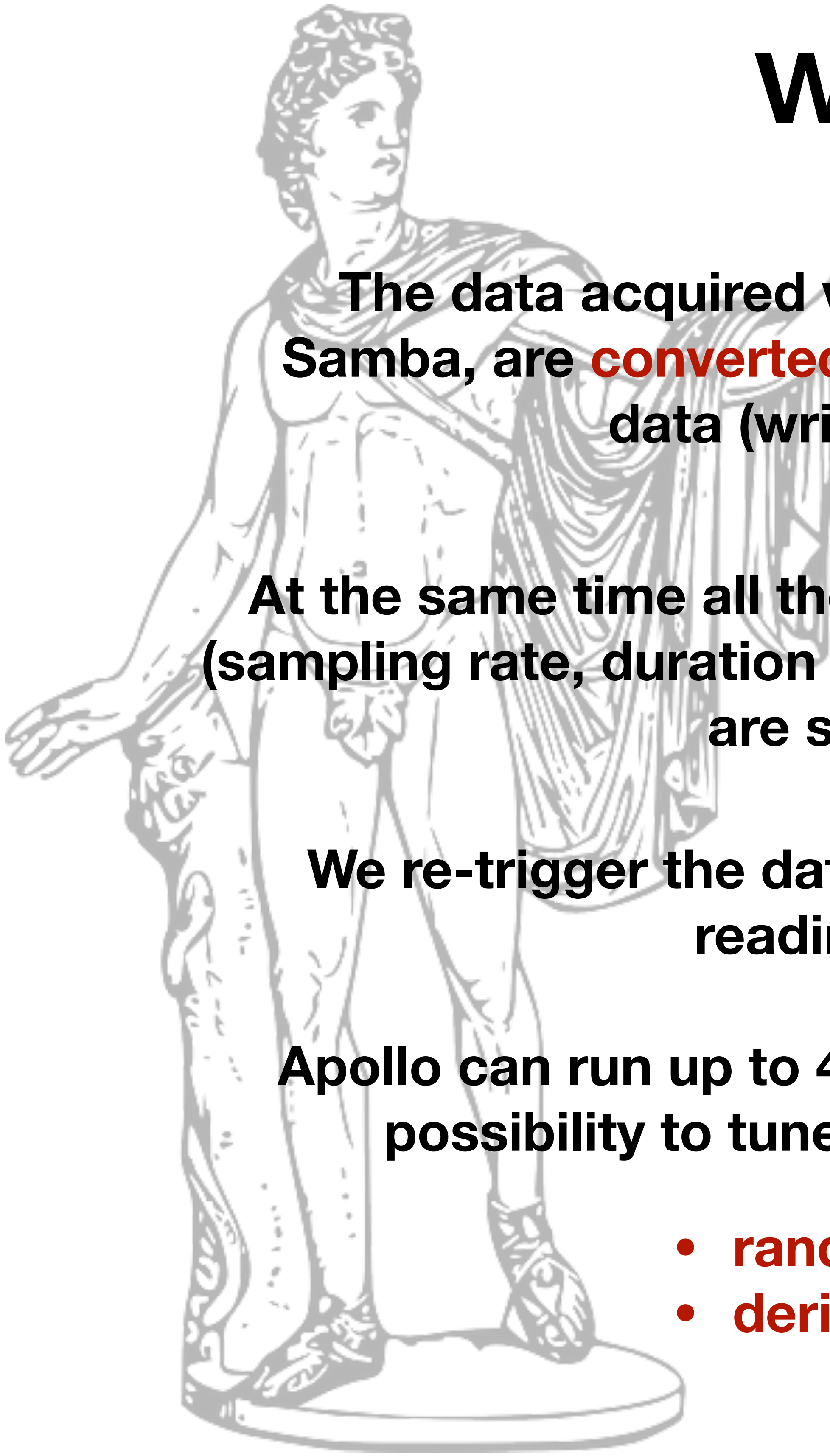




Total exposure	1.4	kg.yr
Total run time	174.8	days
Total live time	(sum over all ch)	7176.25 days
Background run time	124.74	days
Calibration run time	32.01	days

Note: the data from mid-October up to now have not been processed yet

Data conversion and re-triggering with Apollo



The data acquired with the Edelweiss data acquisition system, Samba, are converted to root files with the same format of CUORE data (written by the Apollo DAQ software)

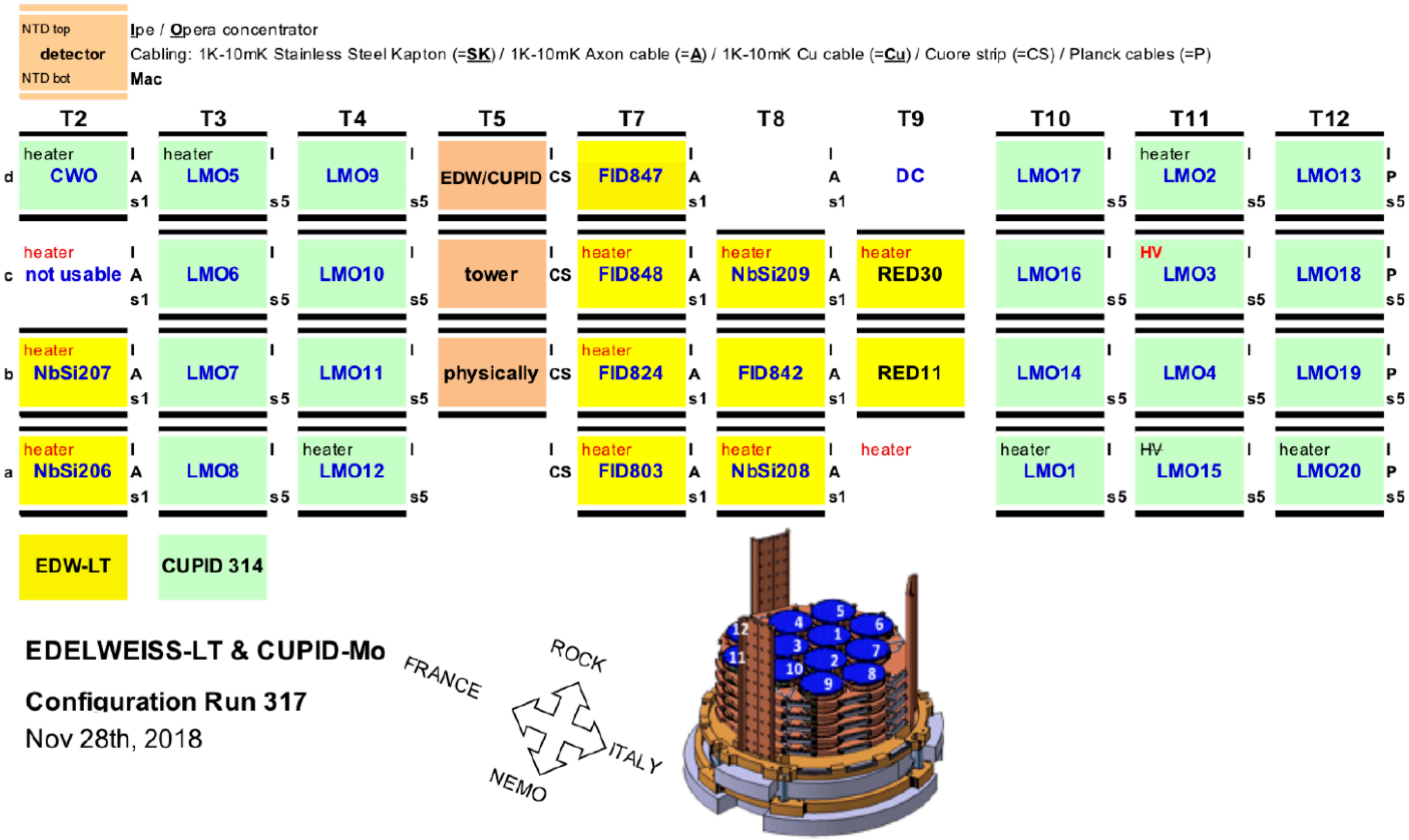
At the same time all the relevant informations for the data processing (sampling rate, duration of the event window, mapping of the channels…) are stored in a Postgres database

We re-trigger the data using Apollo's capability of running offline, reading from continuous data files.

Apollo can run up to 4 trigger algorithms at the same time, with the possibility to tune the trigger parameters for each channel.

- **random trigger for noise events**
- **derivative trigger for signal events**

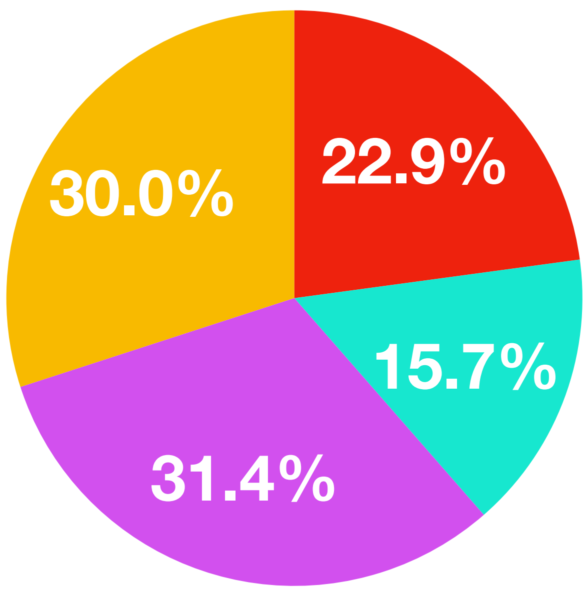
Diana channel notation

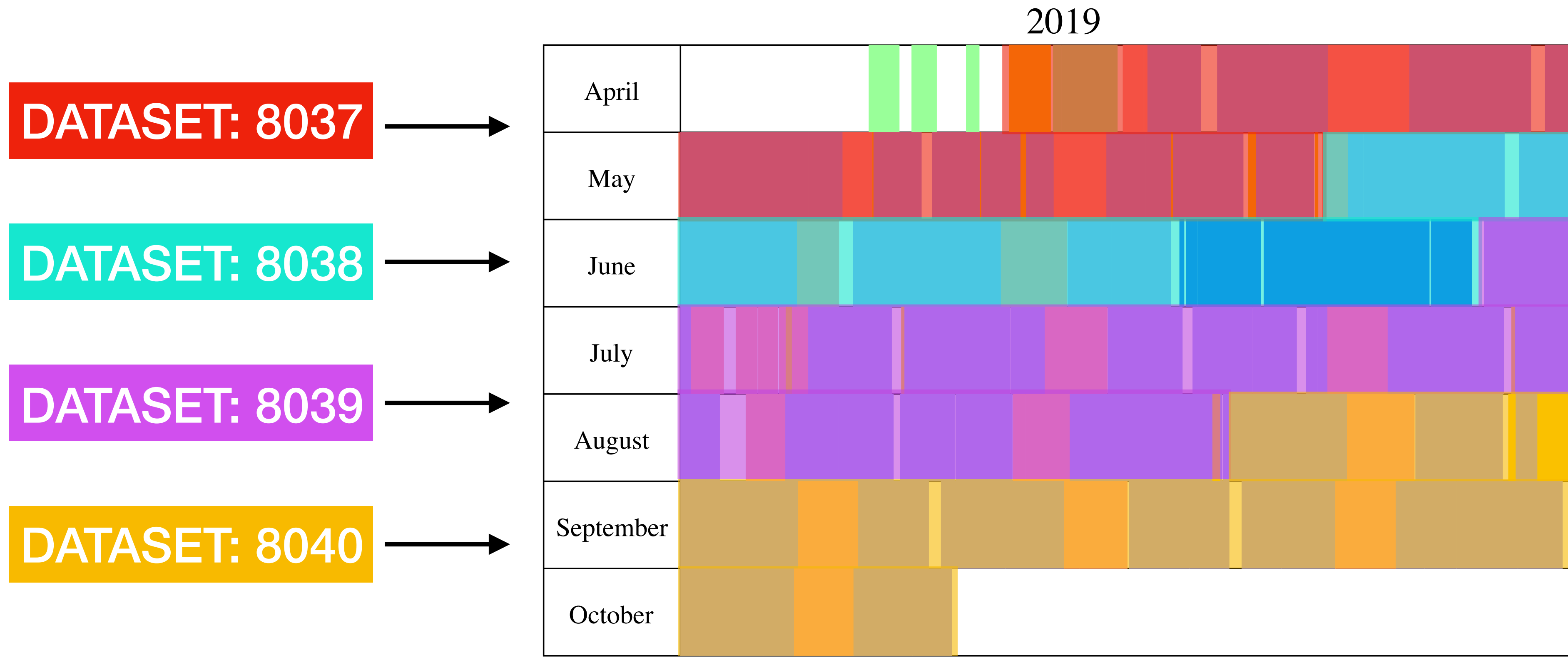


- In Diana we start out by regarding LMO and LD as inidividual channels
- 40 channels (+ 4 Muon Veto channels)
- The conversion from the map (left) to Diana channel number is:
  - Diana Ch i = LMO n * 2 - 1
  - Diana Ch j = LD n*2
- Then we reassociate a LD (either the upper or the lower) one to an LMO channel to compute the LY of events (the mapping is stored on the postgresql DB, and listed on slide 21)

Diana data taking notation

Total exposure:
1.4 kg.yr

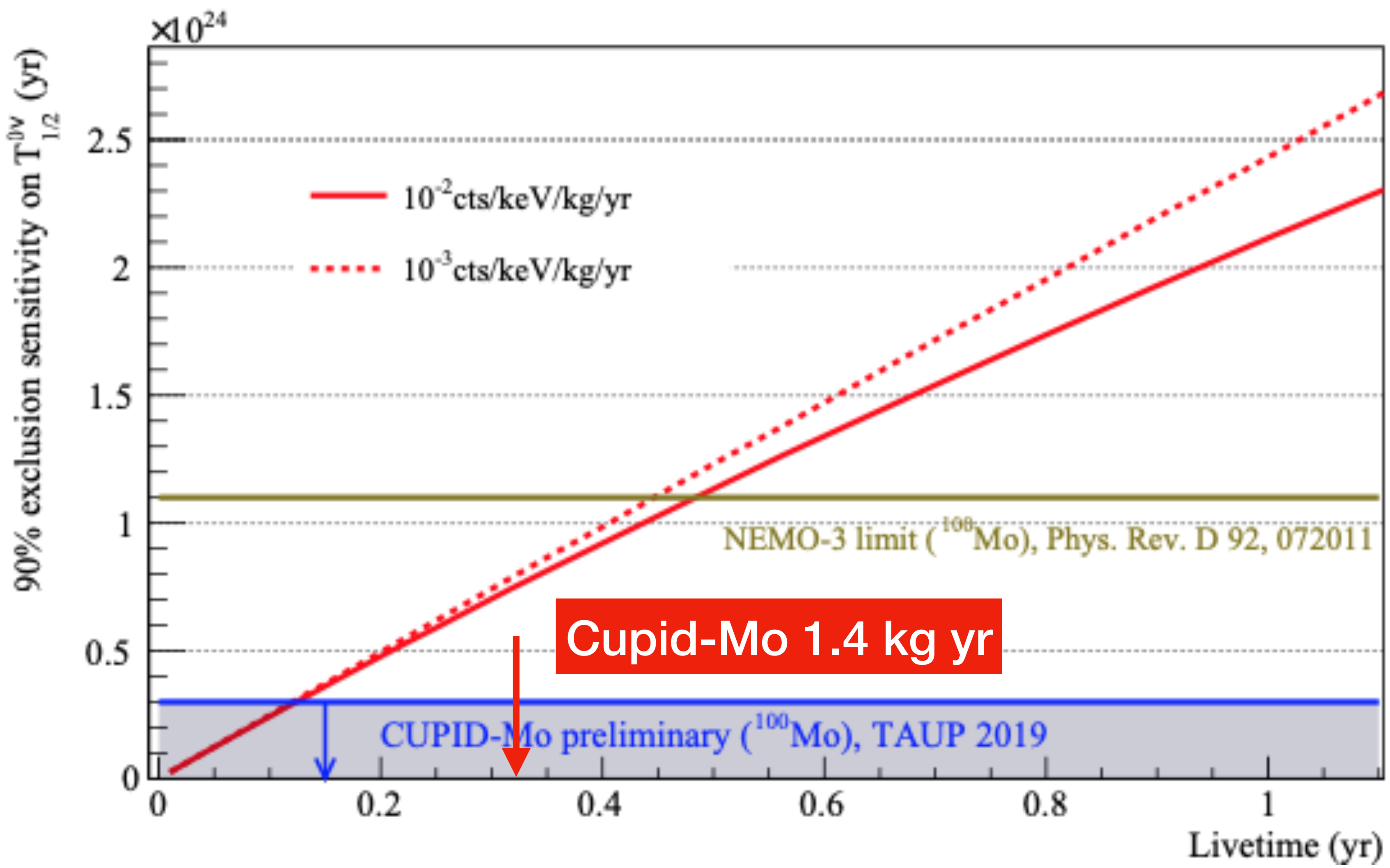




Change in dataset usually happen when there is a major change in the experimental condition, such as the recompensation of a group of channels.

th19b000	60Co	6		**During LHe refill** => consider for DAQ test	yes	DS8039
th19b001	Bkg	1		**After LHe refill.**	yes	DS8039
th19b002	Bkg	54		**Recompensated channels: LMO-2,5,7,12,13**	yes	DS8040

Sensitivity



Data

Computing and software information:
https://wikis.mit.edu/confluence/display/CUPIDMo/CUPID-Mo+Home

Diana (Cupid-Mo version) software is on git:
git@github.mit.edu:CUPID-Mo/cuoresw.git

Processed data is available on CORI (Diana format):
/global/project/projectdirs/cupid-mo/data/processed/

Reduced data (only events that pass basic cuts and only essential variables) are available for datasets 8037, 8038, 8039, 8040. These are in a simple root format. You can find these on CORI here (or write at lmarini@berkeley.edu):

- **/global/project/projectdirs/m3110/scratch/lmarini/official-cupidsw-mo/macros/lineshape/Background_Reduced_Data.root**
- **/global/project/projectdirs/m3110/scratch/lmarini/official-cupidsw-mo/macros/lineshape/Calibration_Reduced_Data.root**

Low level processing

Diana is an event reconstruction software developed in CUORE-0 and later used for CUORE, CUPID-0 and other small setups

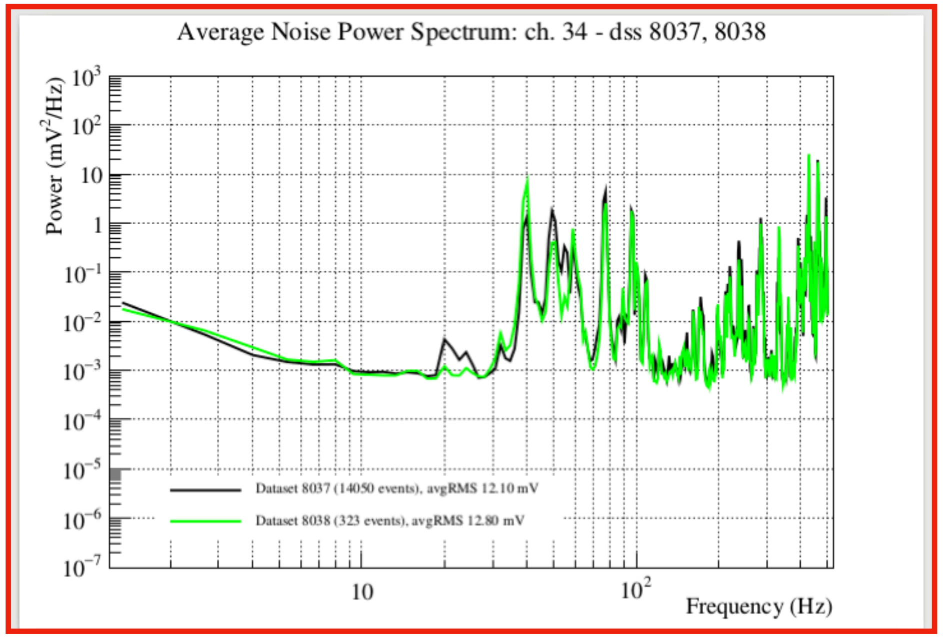
First iteration of the data processing with Diana:

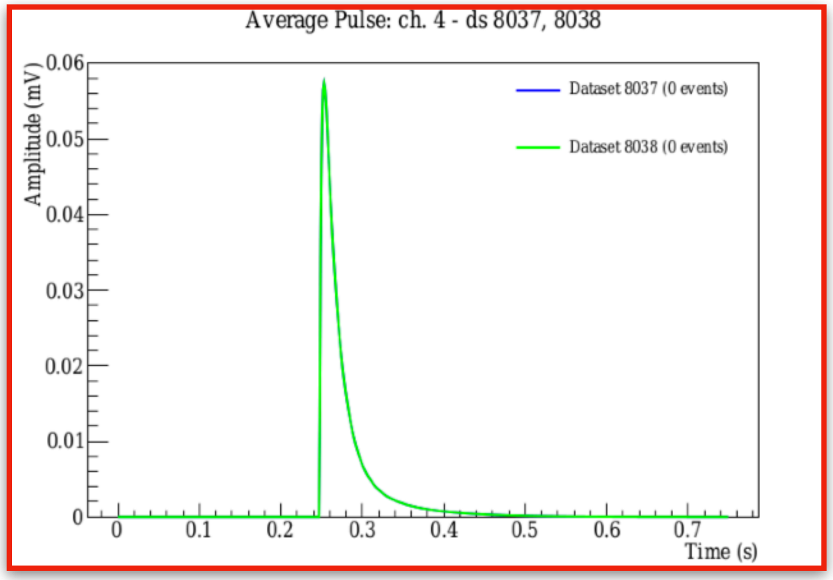
- Applied bad-intervals for all the valid runs of the dataset
    1. visual inspection of the baselines for some of the channels
    2. Identification of bad intervals (noisy or unstable baseline)
    3. Insertion of these periods in the database under the bad-interval table
    4. Sometimes removed data from all channels, sometimes towers sometimes channels

- Preprocessed with Diana software the Background and Th-U Calibration data retriggered with offline Apollo software for both datasets (used derivative trigger)
    1. Retrieve informations from the database including bad-intervals
    2. Compute basic parameters such as baseline and RMS of the pretrigger
    3. Creates side-events on the light channels of the corresponding LMO

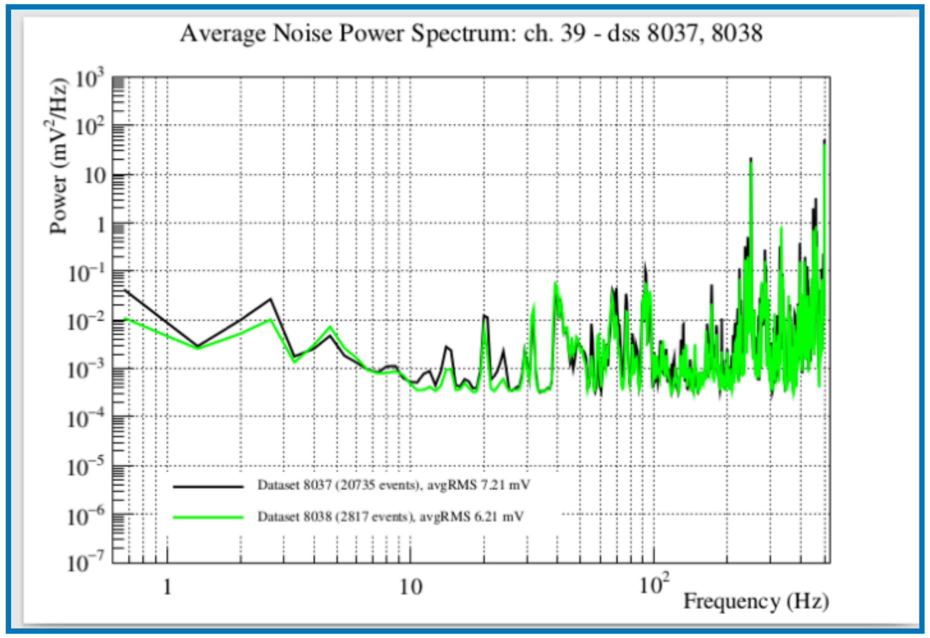
AP and ANPS

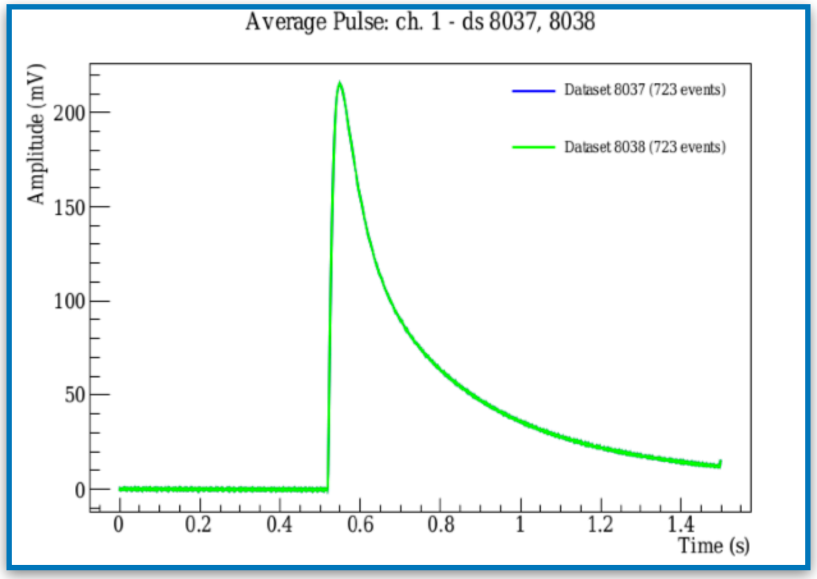
- AP was obtained selected the best AP between all dataset (for the LMO + AP fit for most of the LDs)
- Checked consistency of the pulse shape between one dataset and the other
- ANPS was done independently for each dataset (the noise is more subject to changes)





Example of Light ch





Example of LMO ch

Amplitude and Stabilisation

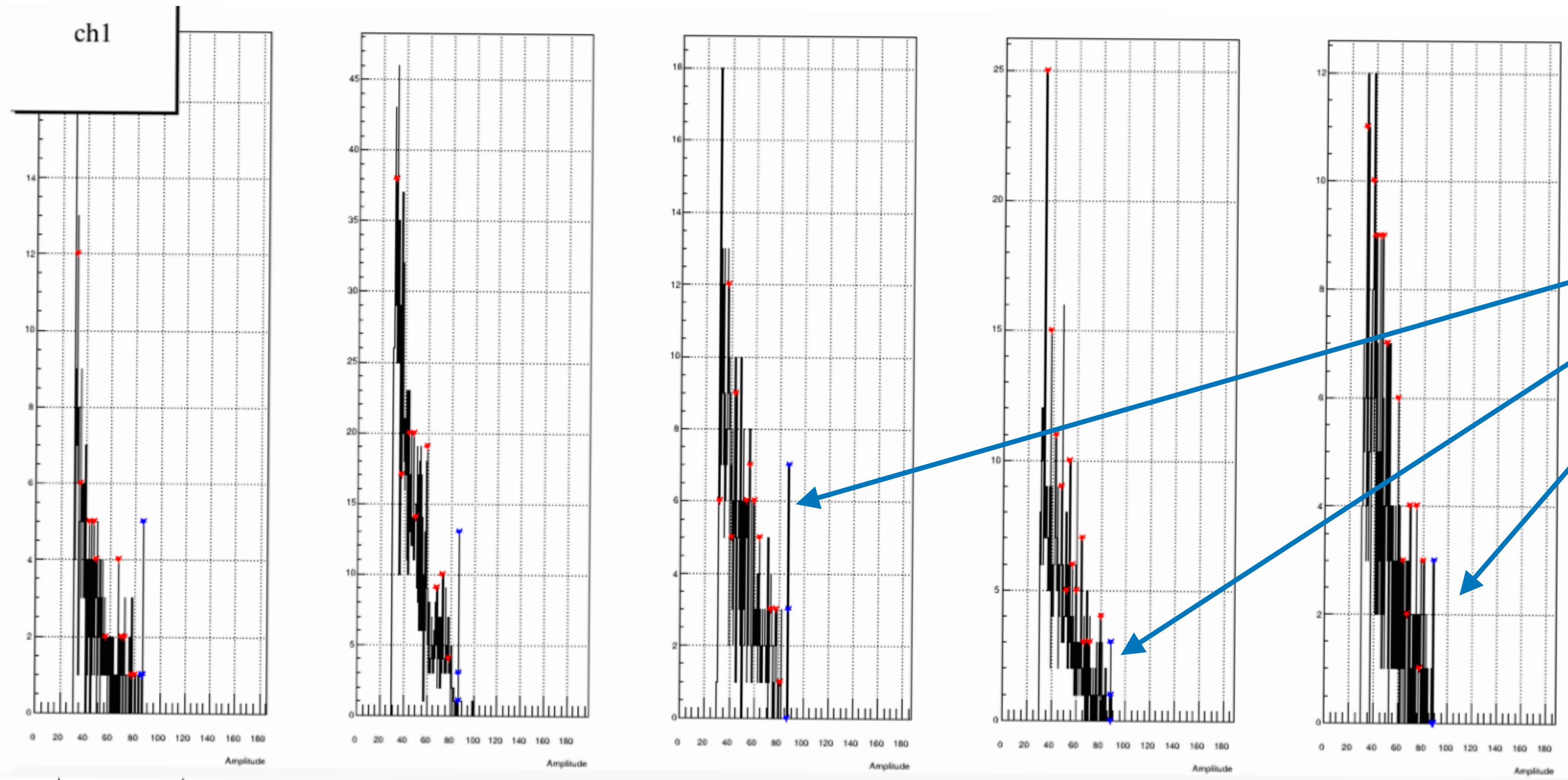
Amplitude is computed using an Optimum Filter algorithm. The transfer function of the filter is

$$H(\omega_k) = h\frac{s^*(\omega_k)}{N(\omega_k)}e^{-j\omega_k i_M}$$

After filtering the pulse presents a symmetric shape with the same height of the original pulse. We can choose different algorithms to find the pulse peak and to compute the amplitude on the filtered waveform.

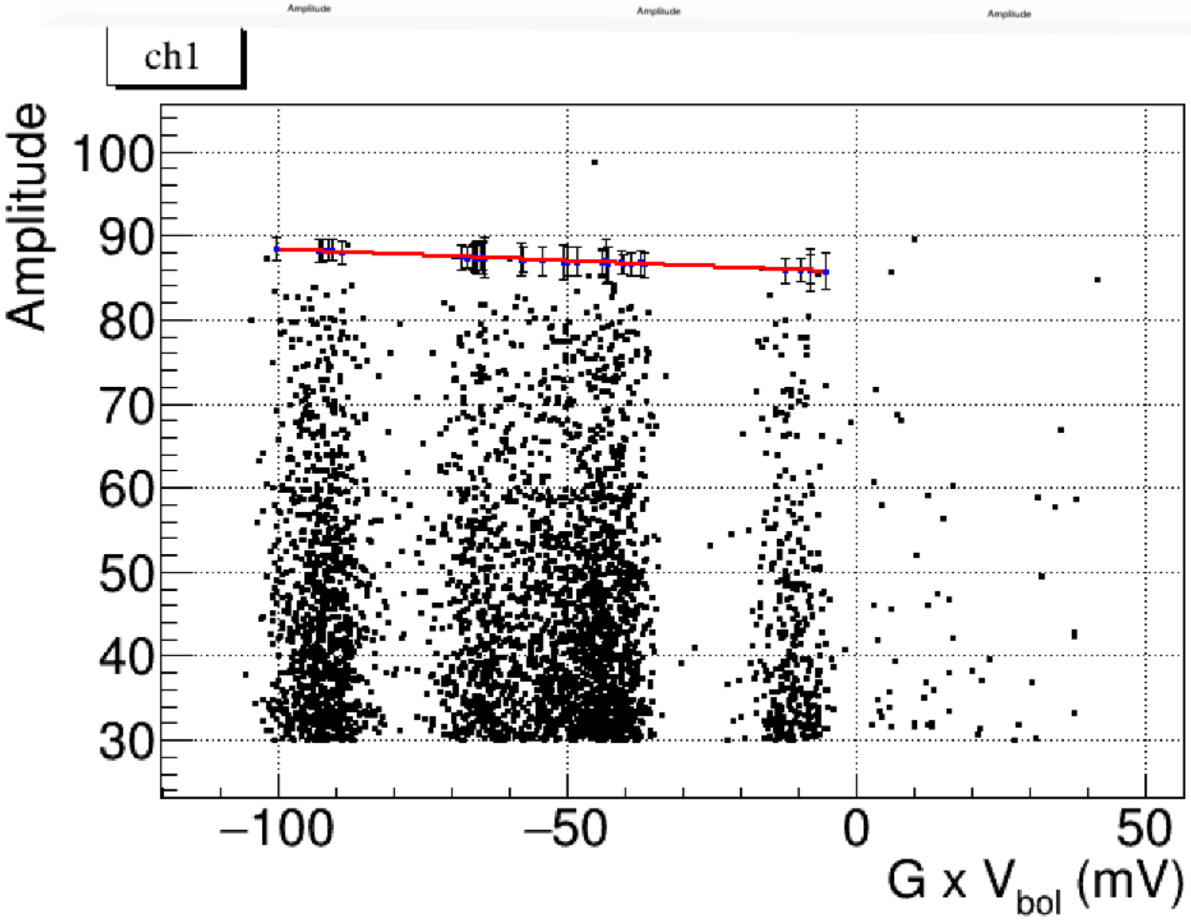
Stabilisation is used to compensate for thermal gain variation due to temperature instabilities (instabilities of the baseline).
Usually the heater pulser is used for this, but since the pulser is not reliable on many channels we decided to proceed for a WoH (Without Heater stabilization).

Stabilization WoH



The Th-U Calibration runs are arranged into time ordered histograms in order to easily identify the 208Tl peak (last peak in the spectrum)

WoH= Without Heater



Using of U-Th calibration independently for each dataset:

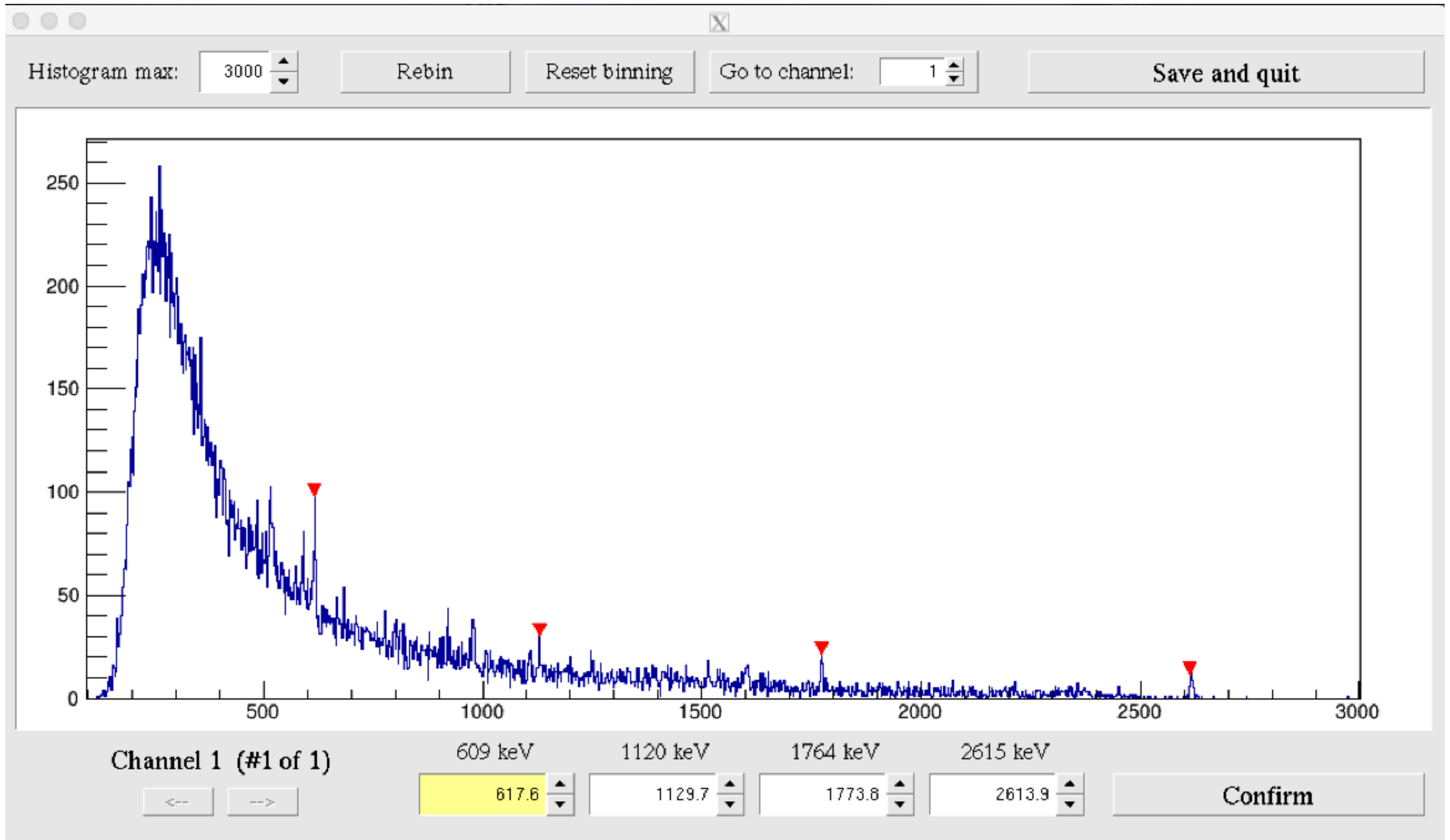
- Merge together runs that have very low statistics (<300 events after cuts)
- Select 208Tl peak using TSpectrum
- Fit Tl events versus Baseline (GxVbol) with a pol1 to get the stabilisation coefficients

Heat Calibration

DS8037 and 8038 where calibrated together while DS8039 and DS8040:

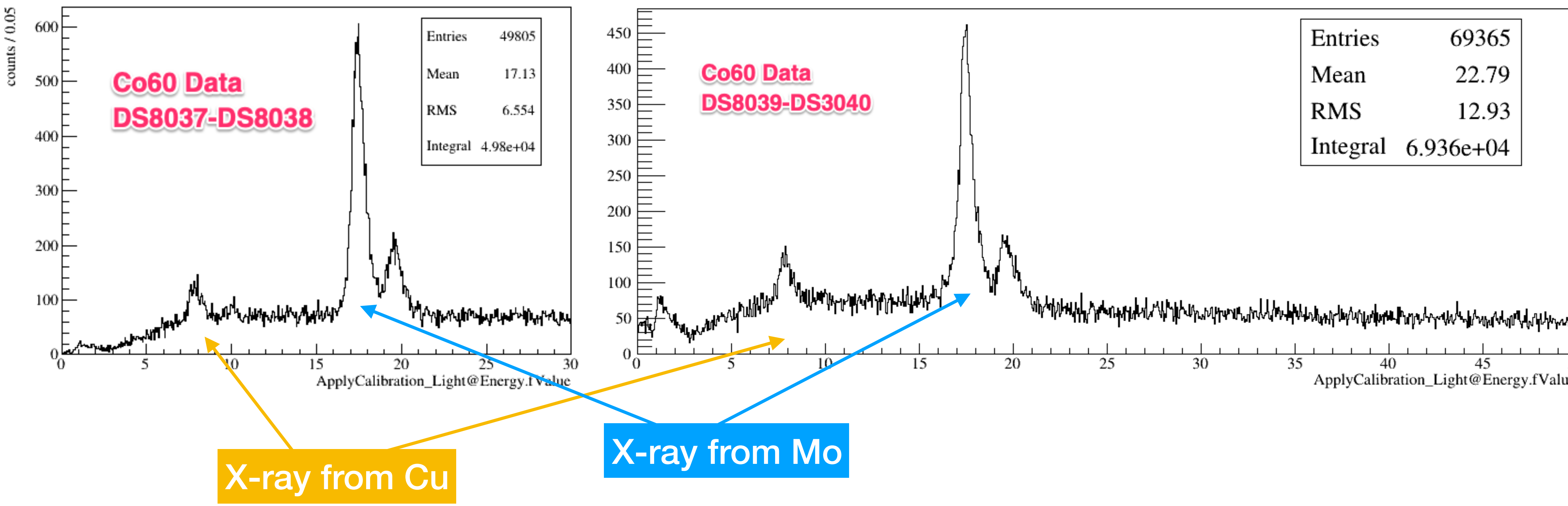
- Use of the Diana calibration module with Th232-U238 source and 4 peaks (609keV, 1120keV, 1764keV from 214Bi and 2615keV from 208Tl)
- Adjusted most of the channels with the manual calibration GUI

- Rerun the calibration module to include the adjusted channels and perform the energy fit
- Energy calibration modelled with a pol2



Light Calibration

Using Co60 calibration runs

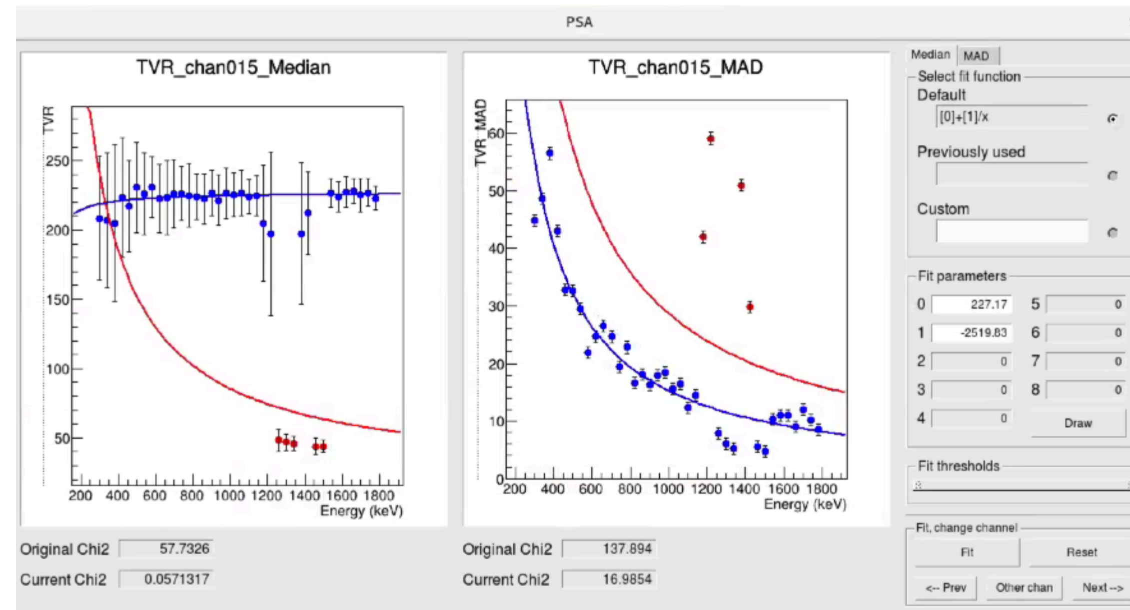


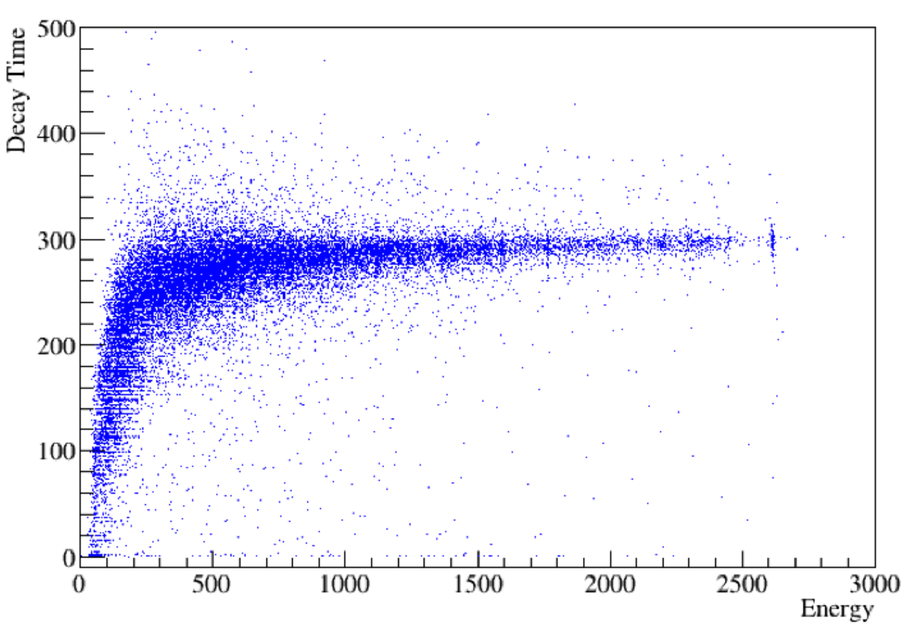
X-ray from Cu is shifted: in order to properly include the LD energy we should investigate this

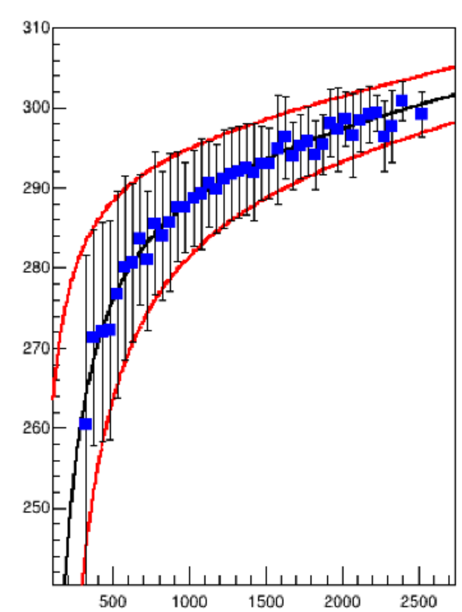
Pulse Shape Analysis

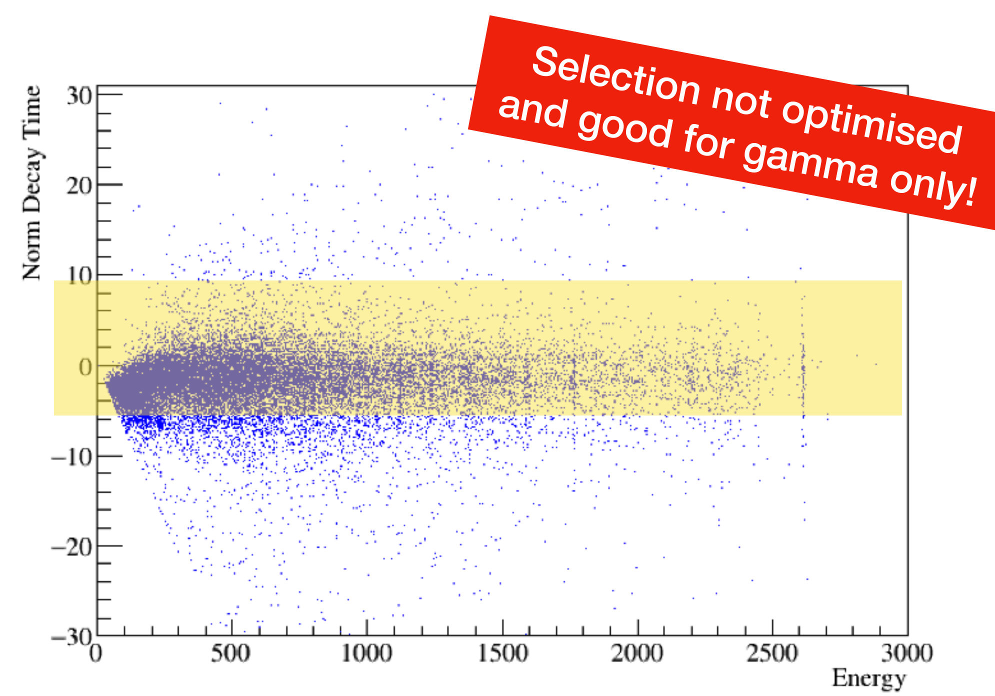
Normalization of PSA variables: used to eliminate pileup and non physical events (spikes - pulser crosstalk)

BaselineSlope: slope of the baseline in the pretrigger
RiseTime: time taken to get from 10% to 90% of the OF-calculated amplitude; calculated by the amplitude sequence.
DecayTime: time taken to get from 90% to 30% of the OF-calculated amplitude, after reaching the peak (amplitude sequence).
Delay: position of the OF filtered pulse maximum in the window (amplitude sequence).
TVL and TVR: Normalized X^2 difference between the OF filtered pulse and OF filtered average pulse on the left and right sides.



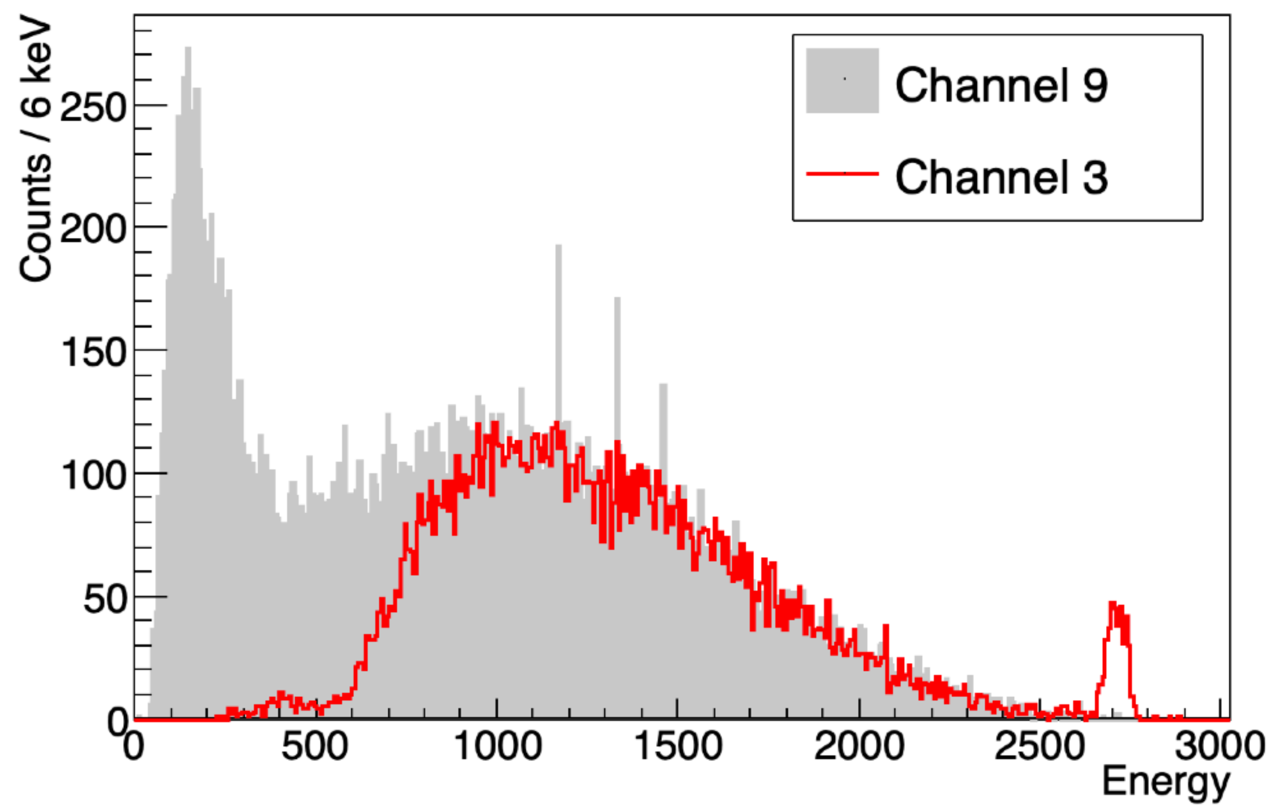






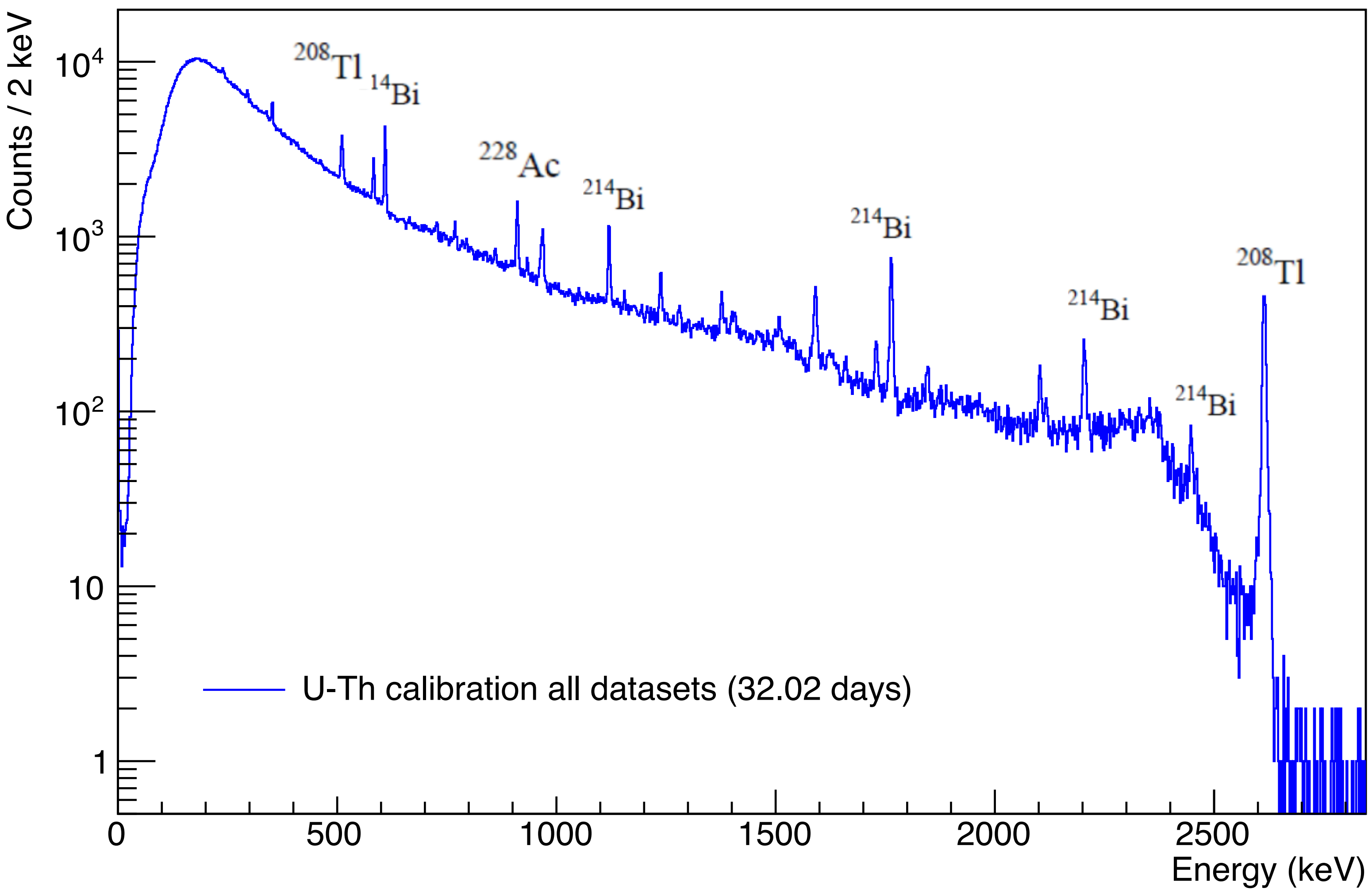
Caveats:

- **Channel 3 (LMO2) has been excluded from this analysis because of its poor resolution and presence of pulsers**

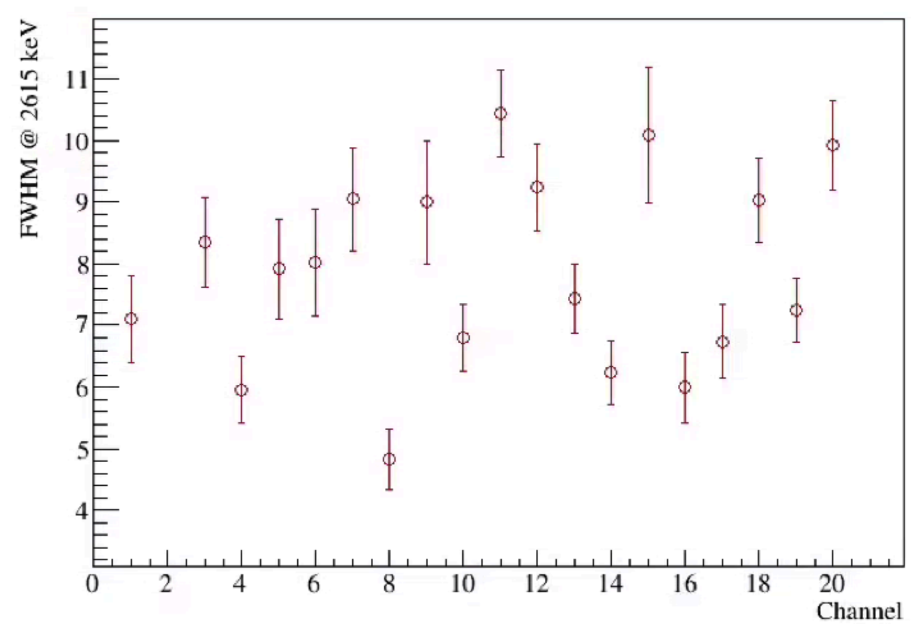


- **Pulse shape analysis has very different efficiency depending on the dataset**
- **Energy thresholds are not optimised (not reliable spectrum below 300keV)**
- **Datasets 8039 and 8040 are from TAUP and have not been reprocessed**

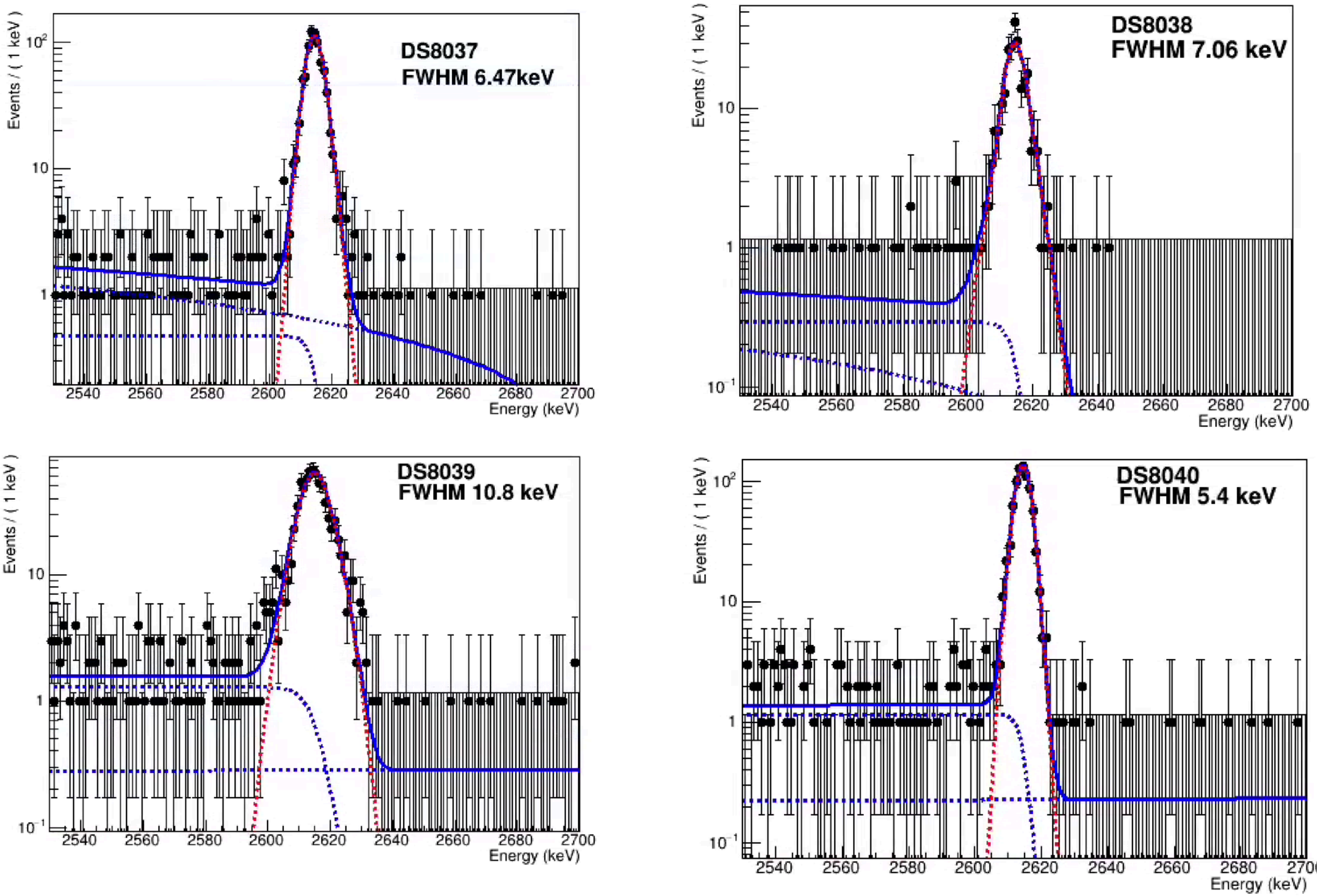
Combined calibration spectrum



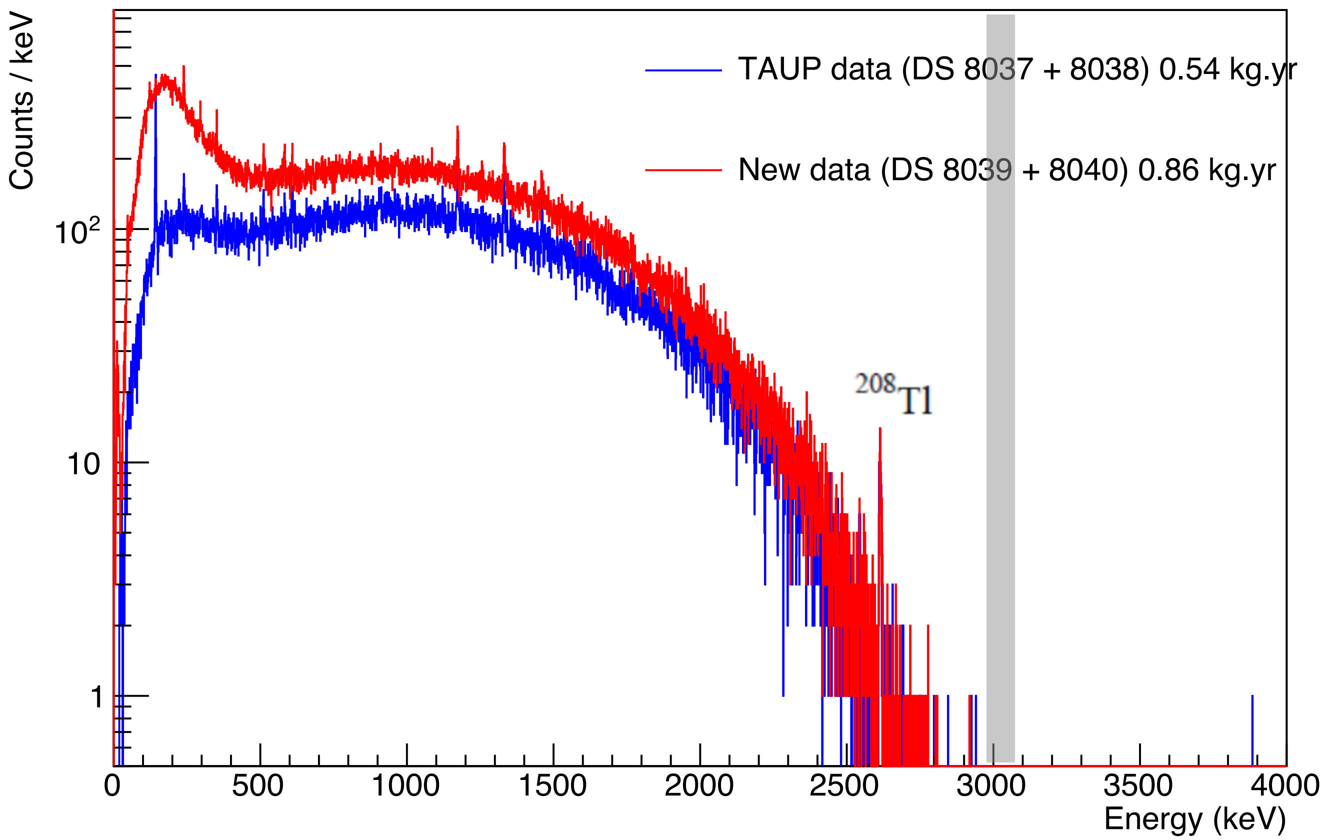
The energy resolution of the crystals varies with the channels in the range [4.5 keV - 10.5 keV]



Calibration resolution



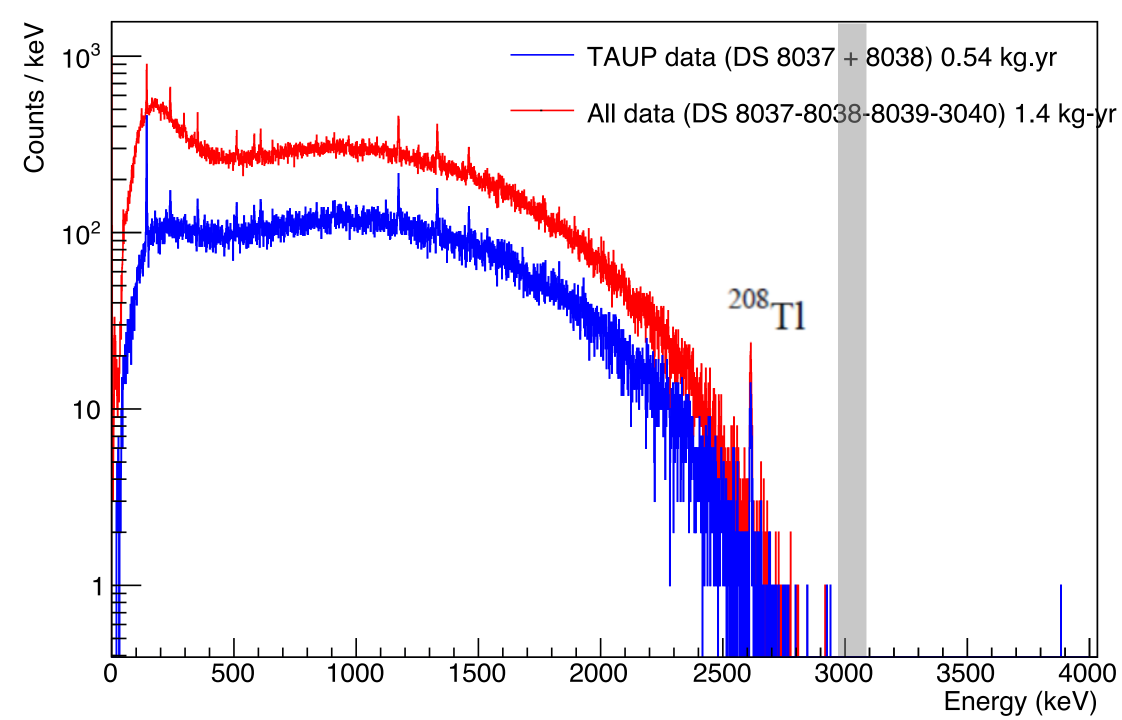
Background Spectrum



The blinded region is 100keV around the Q-value
[2984.4 - 3084.4] keV

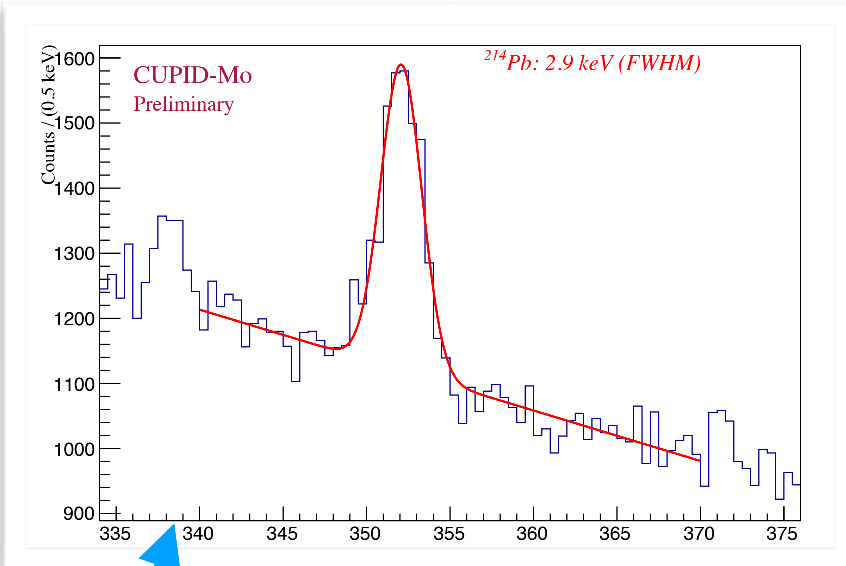
All events present in the blinded region have been removed from the Reduced-Data (data used for high level analysis)

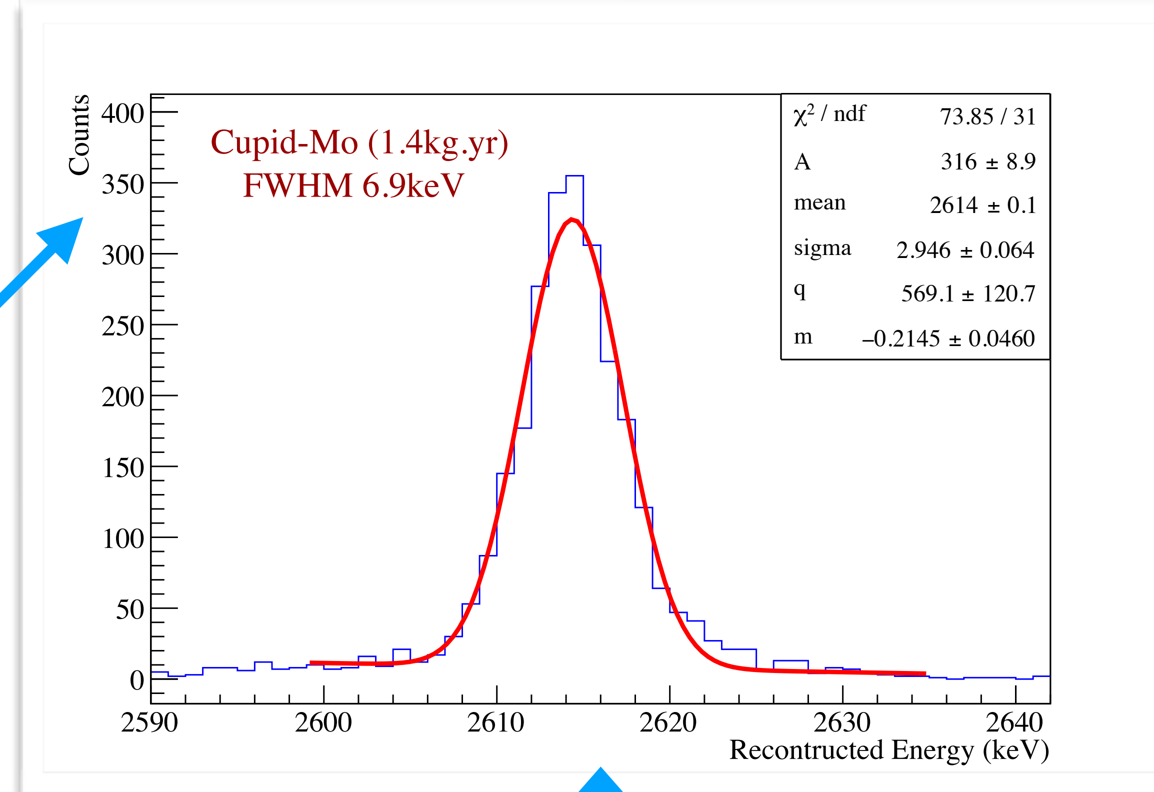
The difference in spectral shape is due to a change in the PSA efficiency (TAUP data has not been reprocessed)

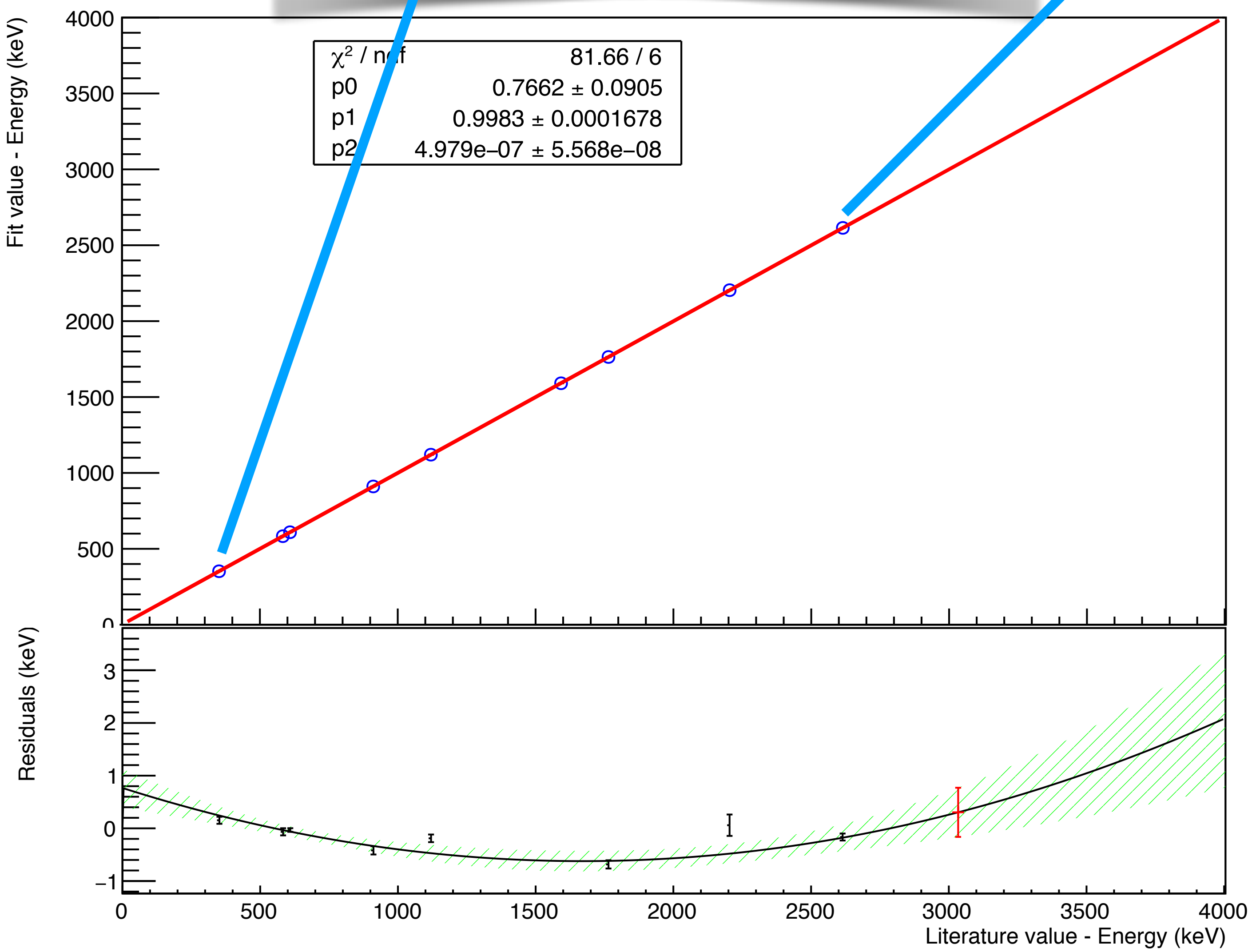


If we evaluate the background index in the region [3084-3200] keV
BI<1.4 10^{-2} counts/keV/kg/yr

Fit of calibration lines



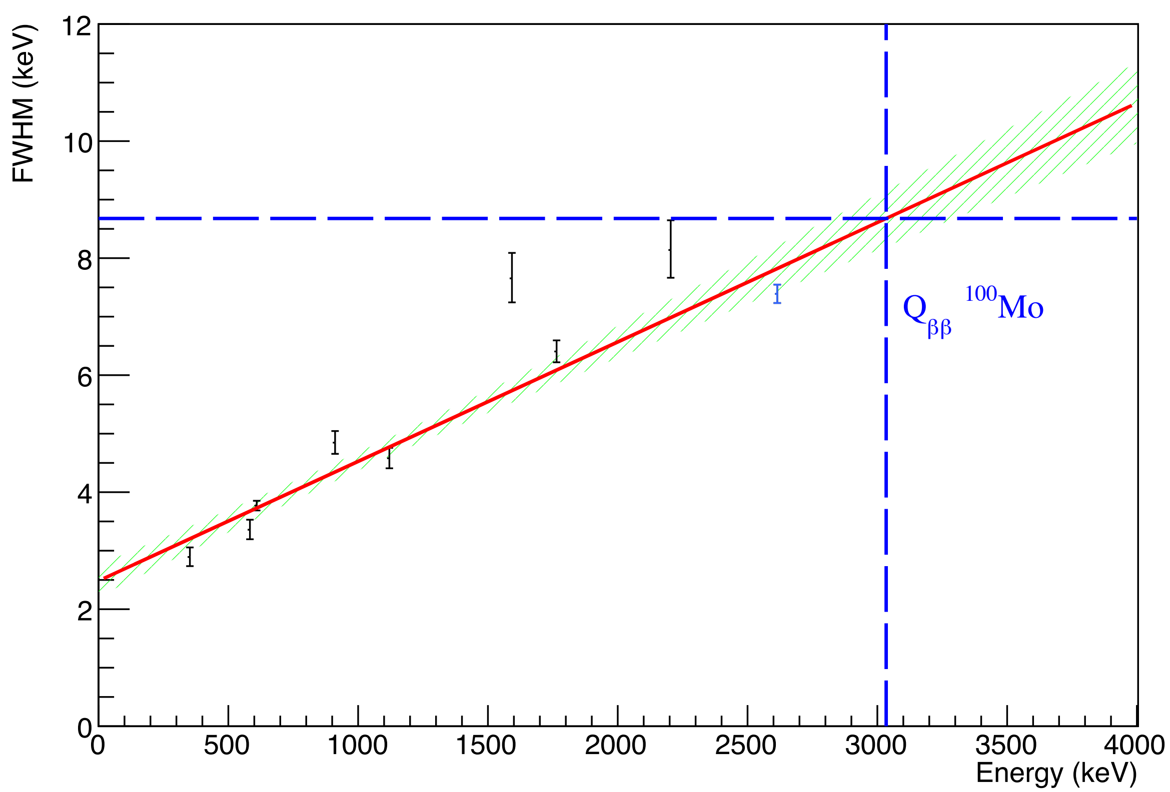


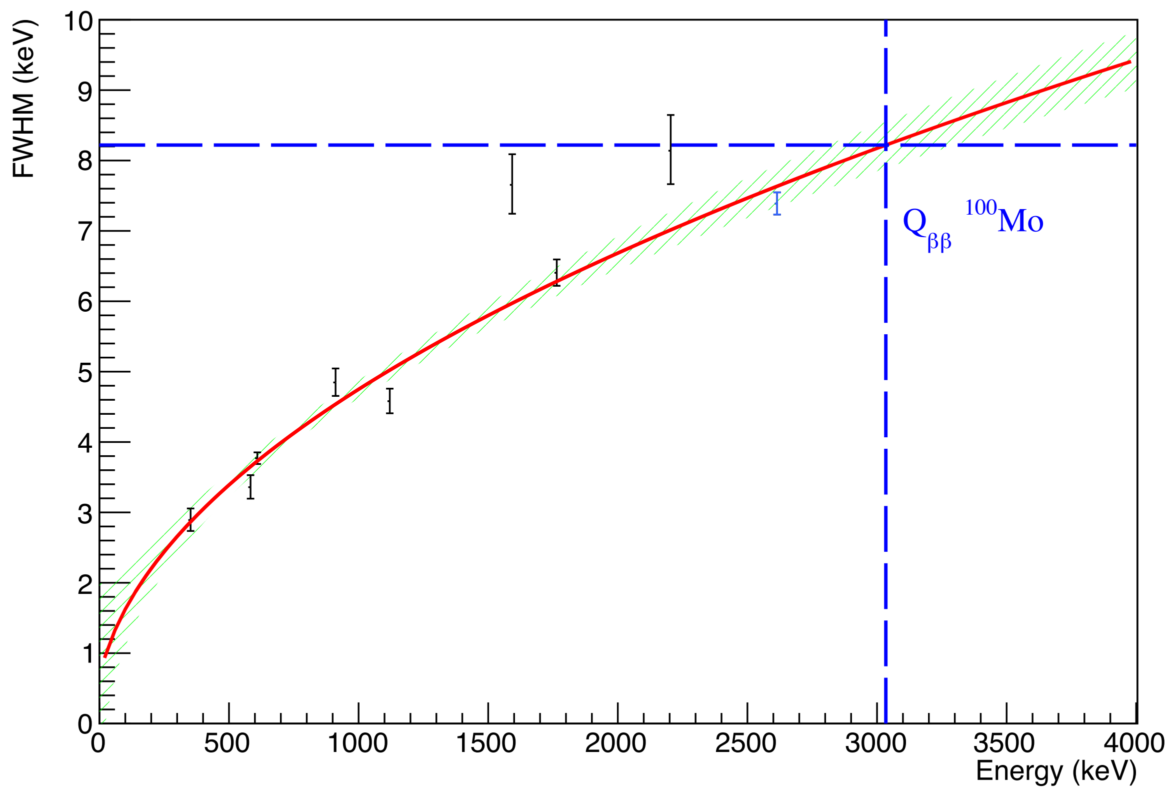


Energy resolution @ ^{208}Tl line is consistent with previous results

Energy non-linearity consistent with zero at Q_{BB}

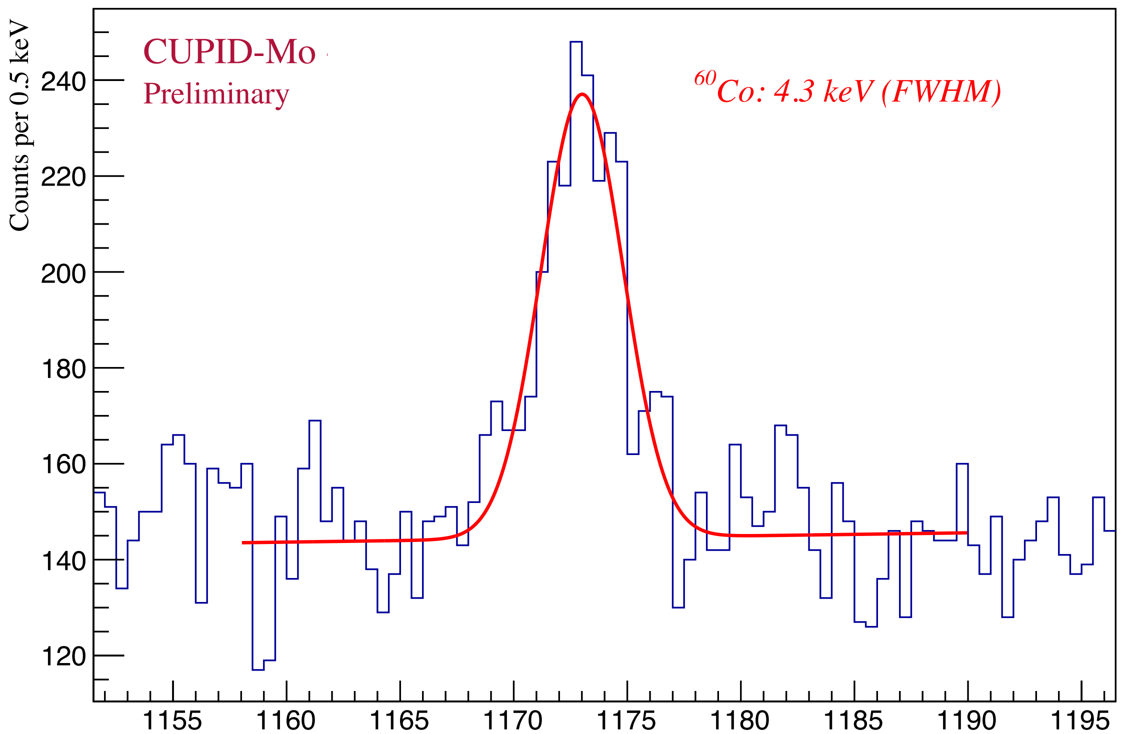
Extrapolation at Q_{BB}





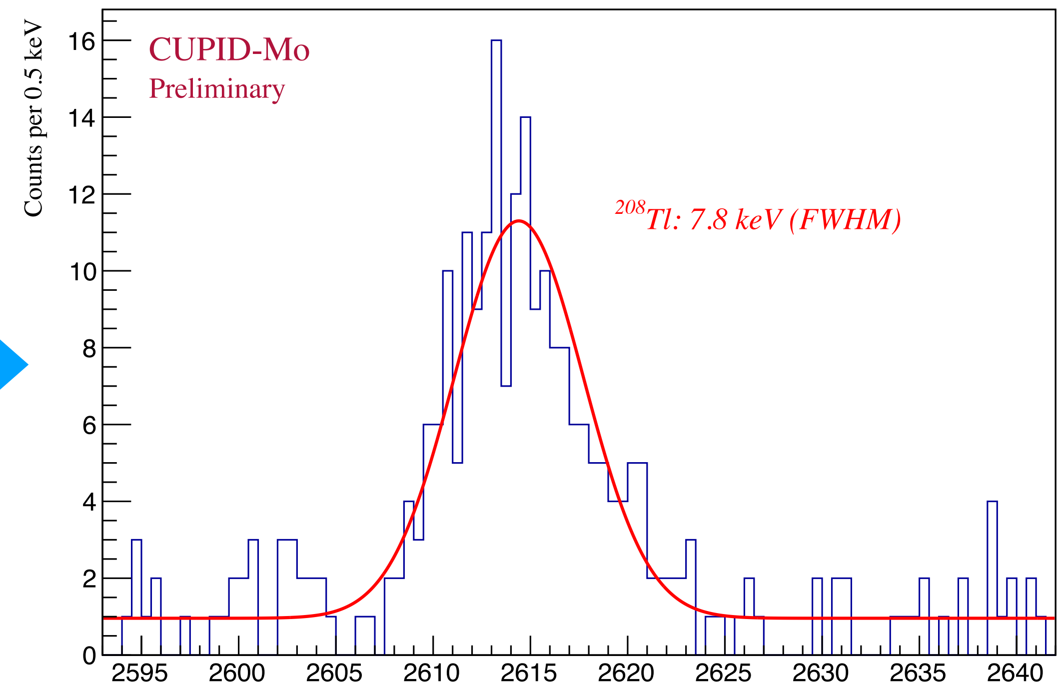
The FWHM extrapolated at the Q-value (3034.4 keV) for U-Th calibration data is 8.22 ± 0.32 keV

Fit of Background lines

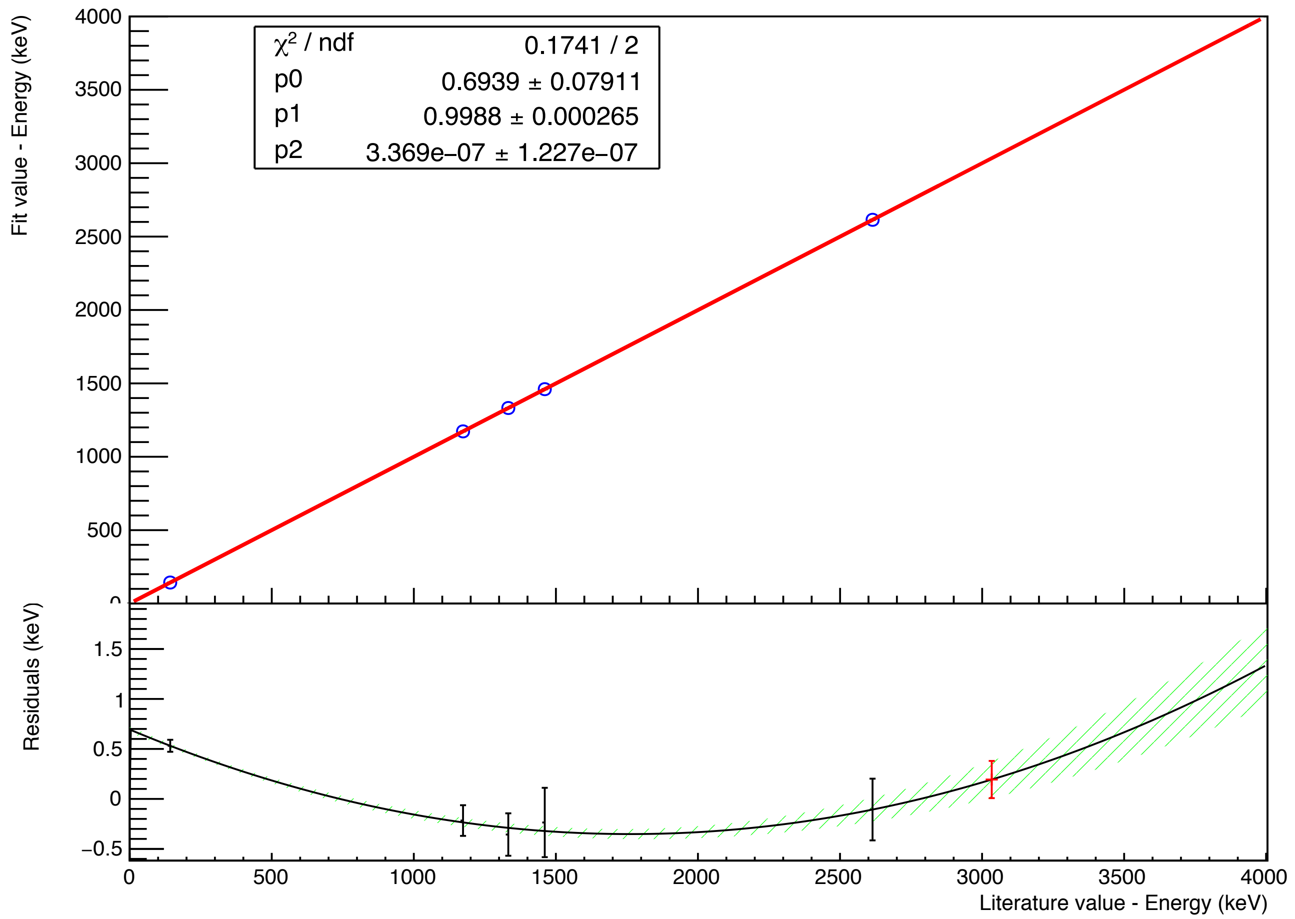


We fit the most prominent background lines with a simple gaussian + linear background

The position and width of these peaks are used to study the energy bias and the energy dependence of the FWHM

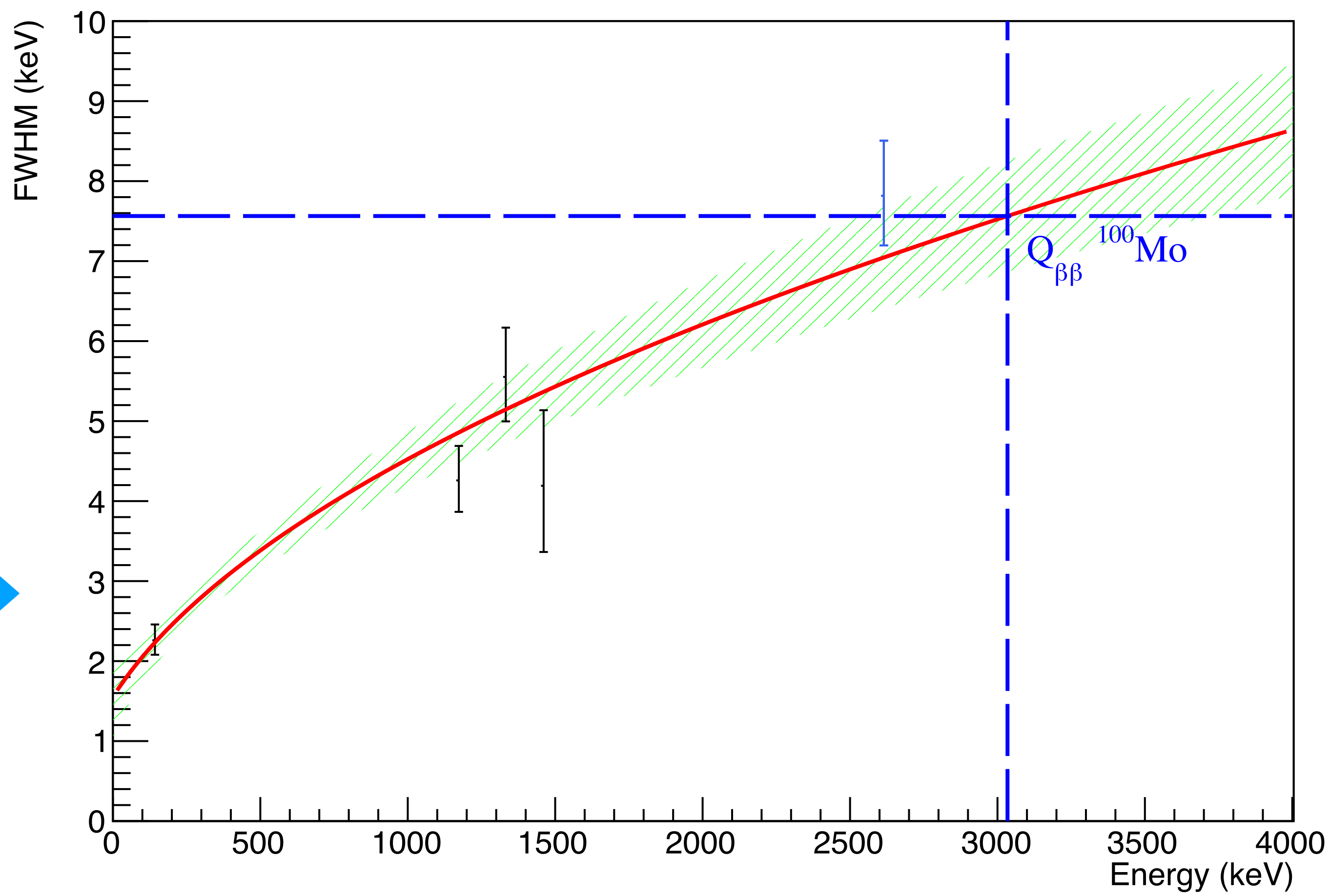


Extrapolations at QBB

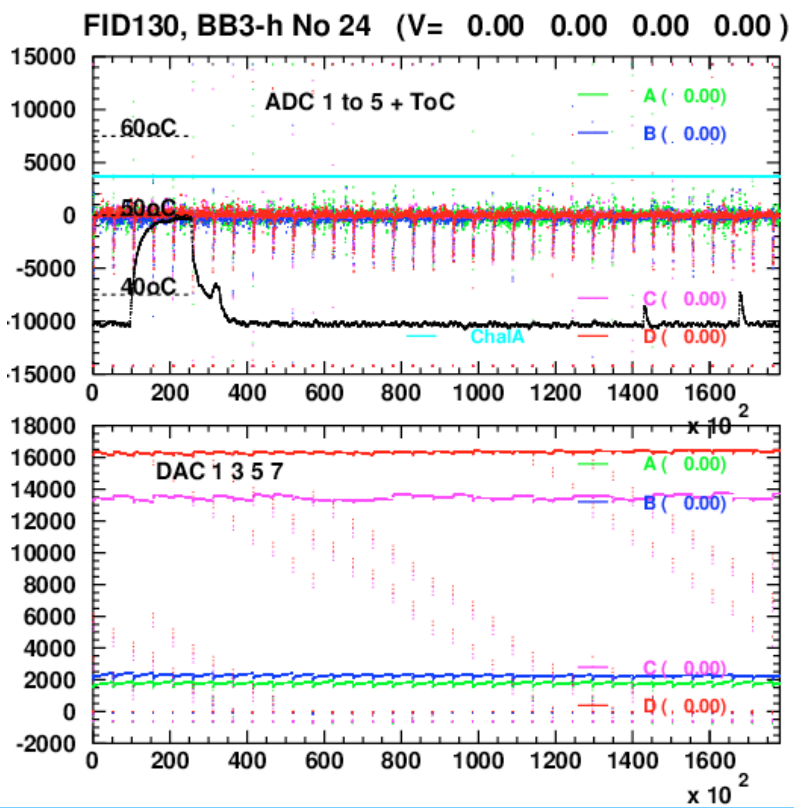


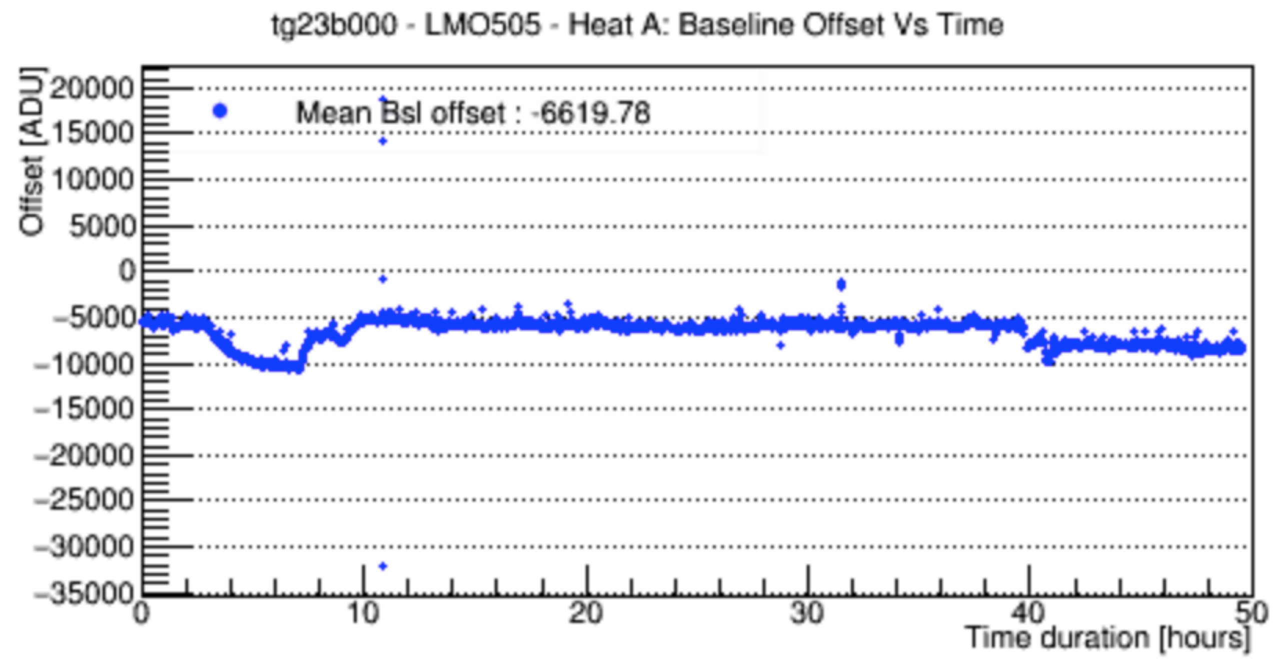
Energy non-linearity
0.19±0.18 keV @ 3034.4keV

Energy resolution
7.56±0.69 keV @ 3034.4keV



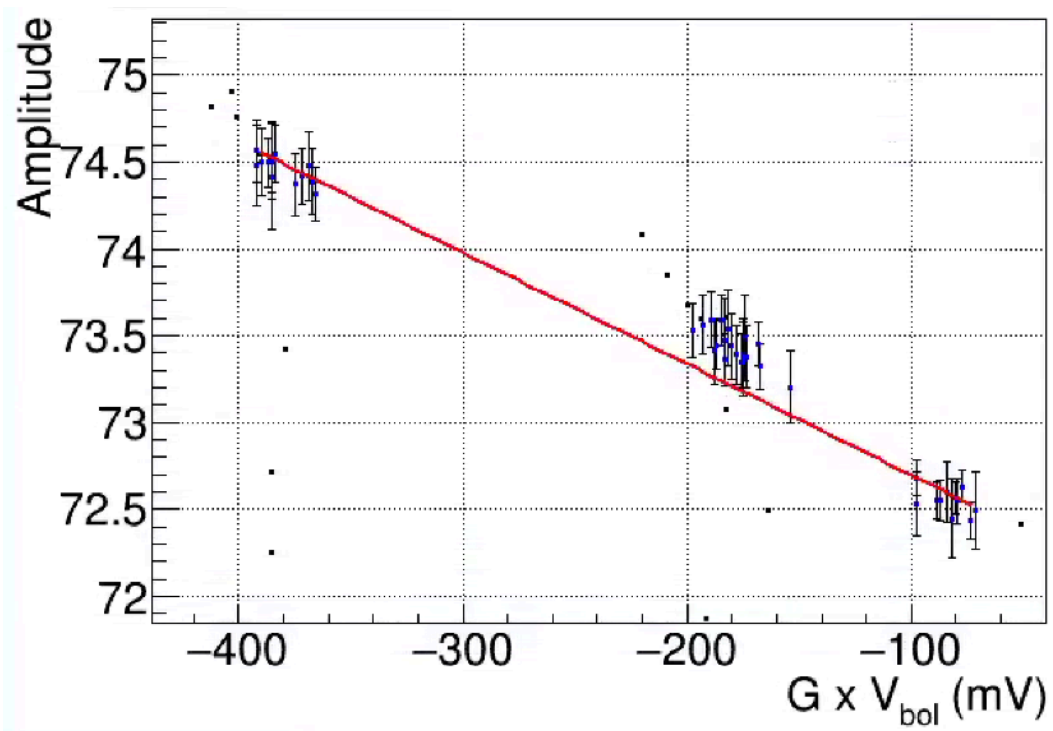
Instabilities of water cooling during DS 8039

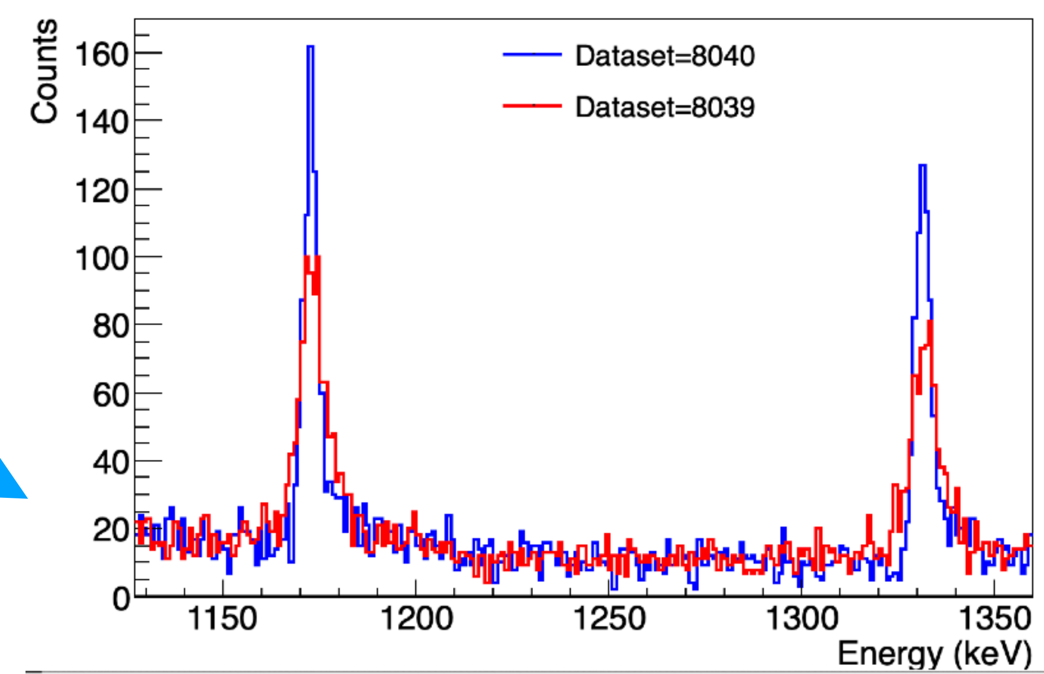




Instabilities of the baseline (not thermal?)

Instabilities of the bolo-boxes temp.

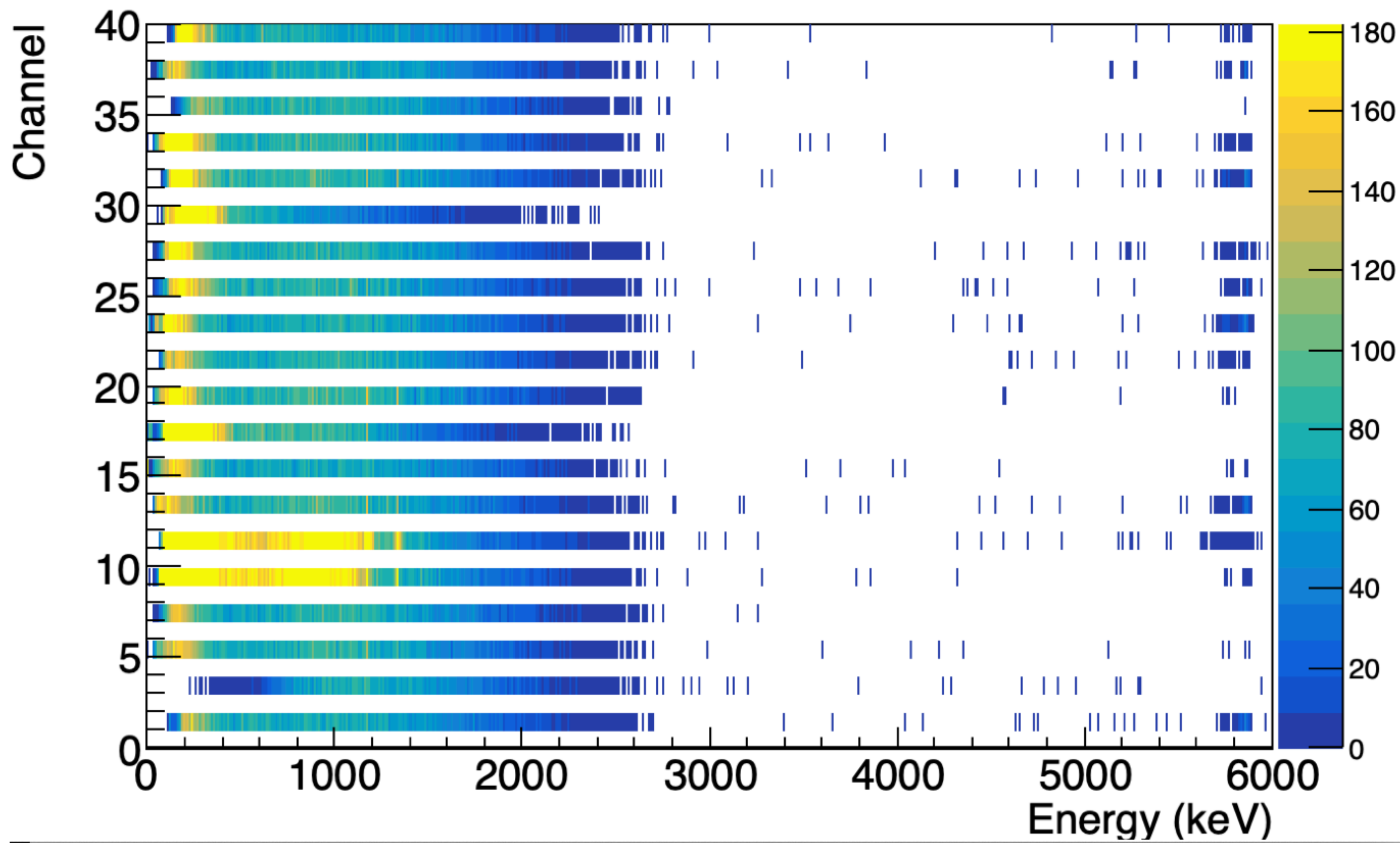




Worst energy resolution

Co60 in Background data

- Channel 9 and 11 (LMO5 & LMO6) have a ^{60}Co excess in M1 and M2 data
- LMO5 & LMO6: ~ 20 evts/day in 1173 and 1332 keV peaks before LY cut, ~ 4 evts/day wo bg subtraction after LY cut
- Avg of the others: ~ 3.9 evts/day before LY cut, 3.6 evts/day after LY cut (note some minor pulser contamination possible before LY cut)



Co60 in Background data