Determination of the total capture rate in Se76 with ALPACA data

Elisabetta B. - 28.02.2023

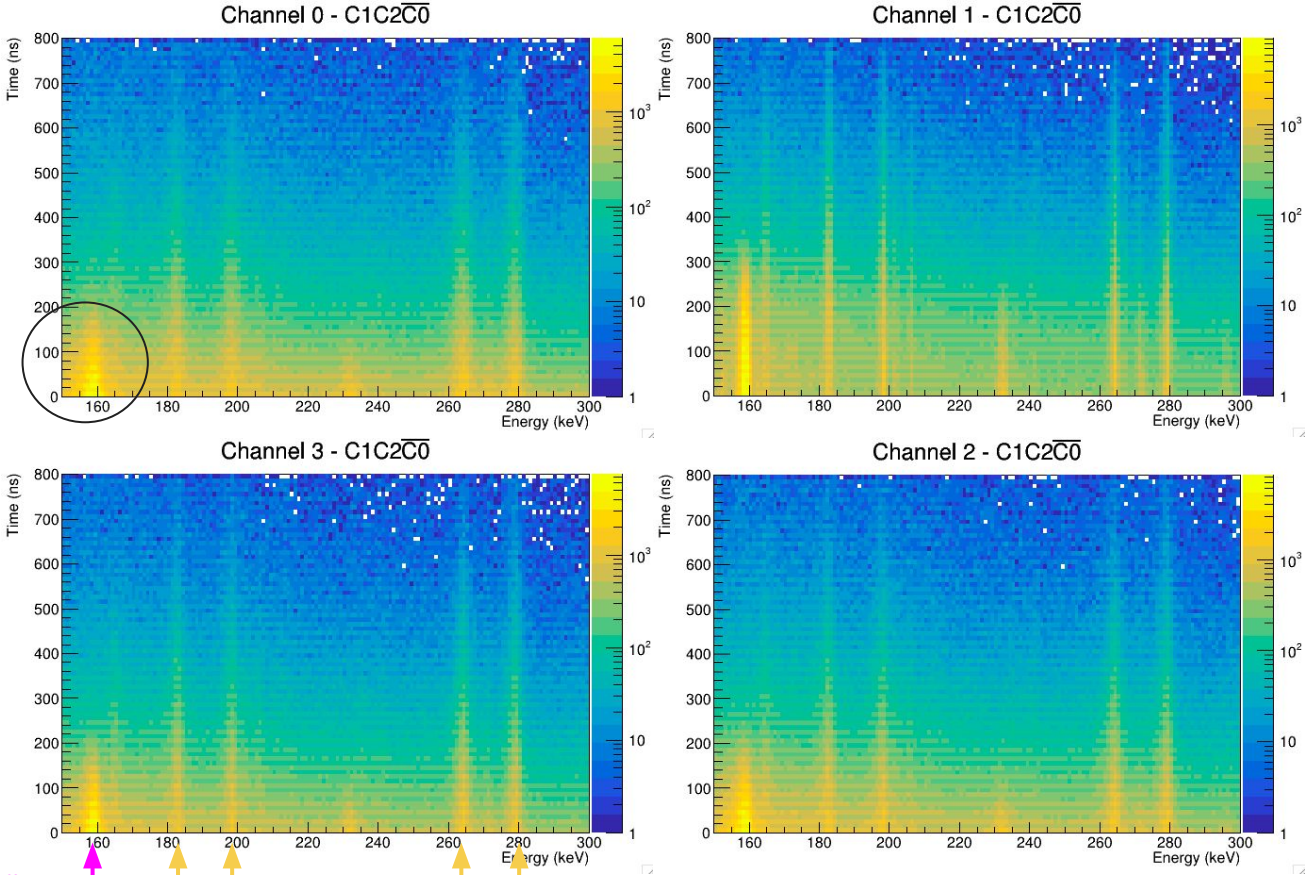
Data Selection

- ALPACA run se76-14: from 2/11 19:20 to 4/11 05:55 (about 34.4 h)
- Muon trigger condition:
  - One trigger in C1 and C2 (-200,800)ns window around ge-trigger
  - Select |deltaT(C1-C2)|<100ns
  - Muon-stop trigger time: $t_{\mu\text{-stop}}=(t_{C1}+t_{C2})/2$
  - Anticoincidence trigger with C0: |deltaT(μ-stop-C0)|<100 ns

See slides from last meeting for details

2D-HISTOGRAM

Muonic X-ray expected “prompt”, but “bad” time resolution

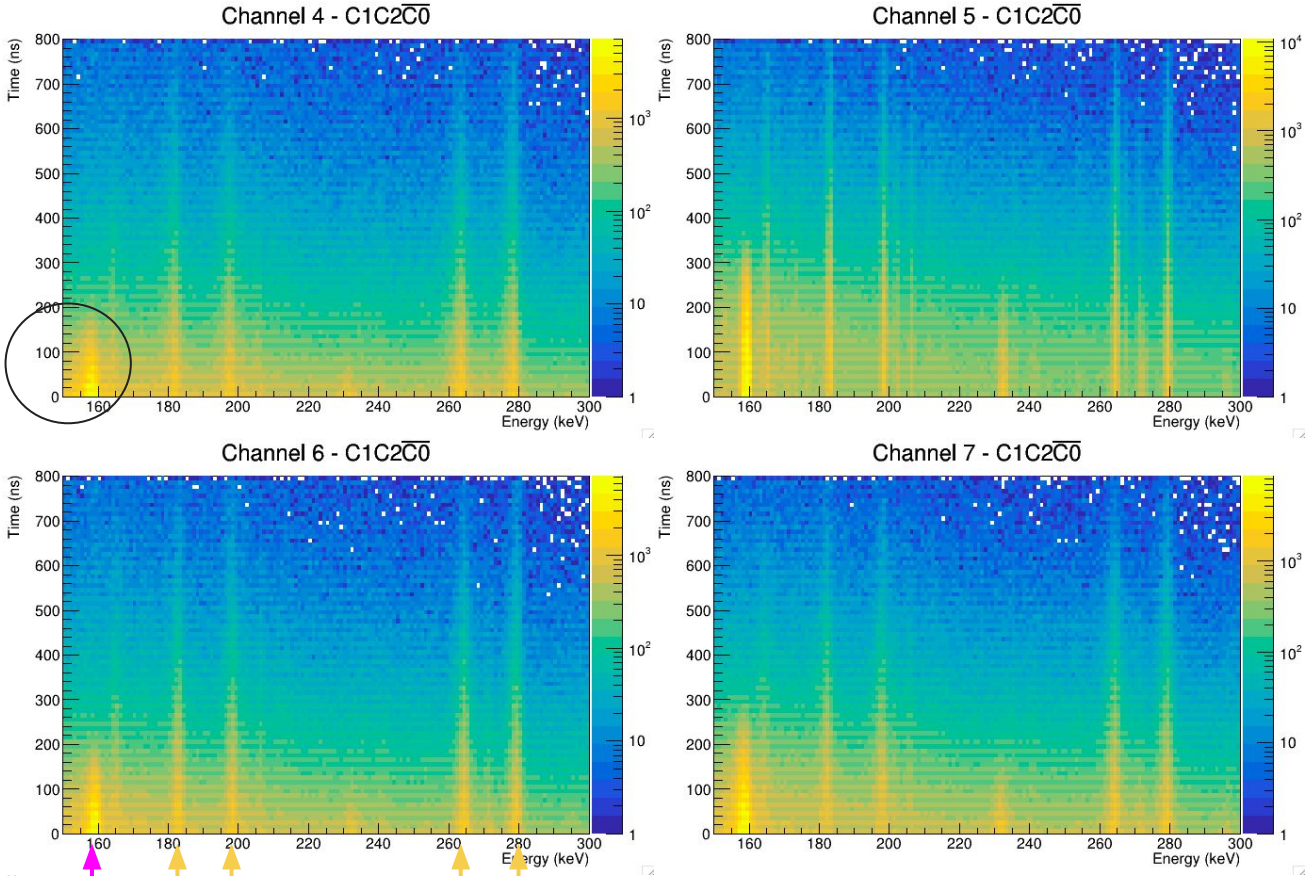


Muonic X-ray from M-series 158.6 keV

Delayed gamma-rays

2D-HISTOGRAM

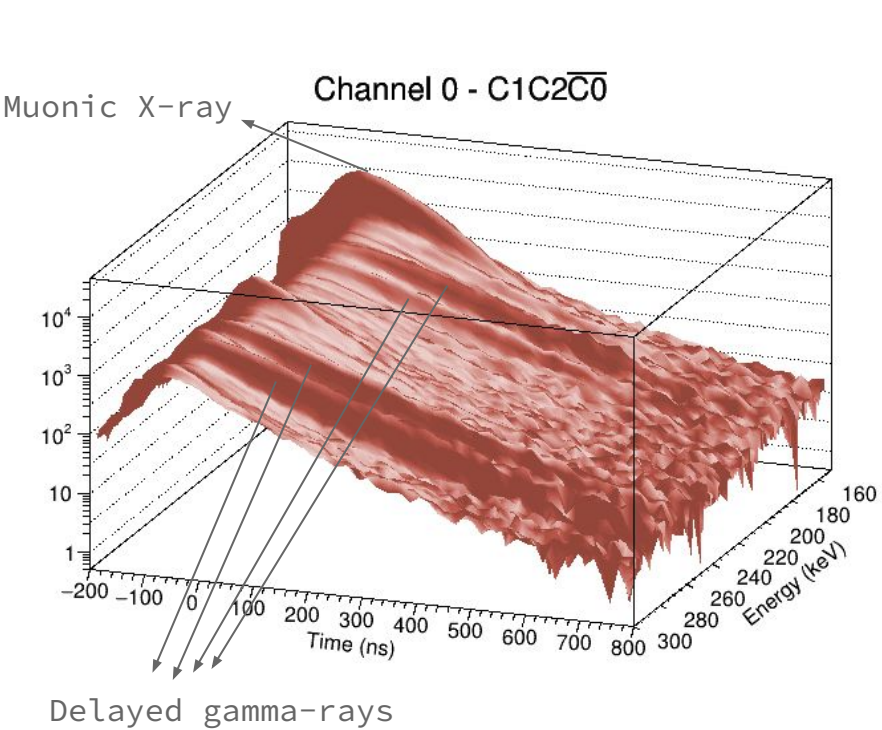
Muonic X-ray expected “prompt”, but “bad” time resolution

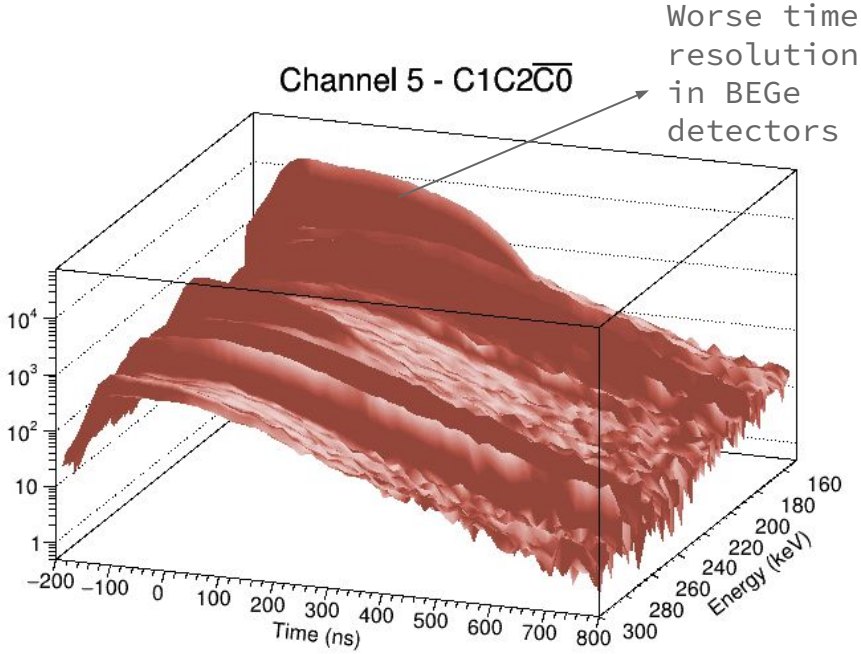


Muonic X-ray from M-series 158.6 keV

Delayed gamma-rays

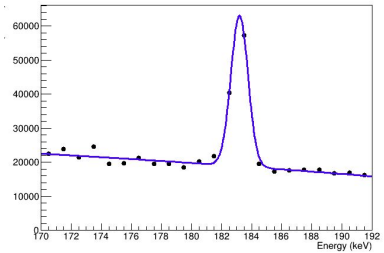
Surface plots (more in backup)



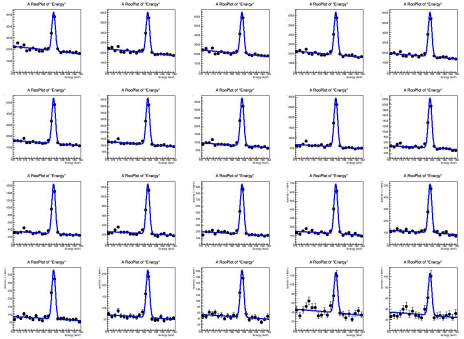


Total Capture rate (τ) determination

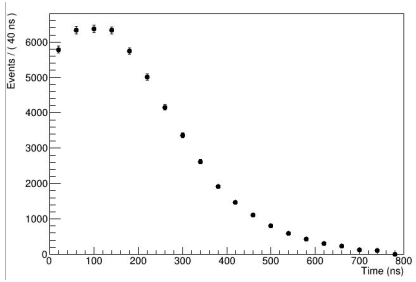
1. Fit total energy spectrum:
gaussian + pol2 background (+ more gaussians if needed)



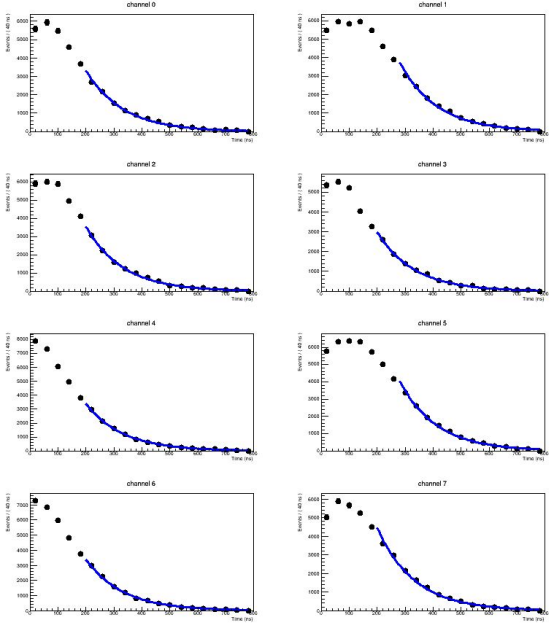
2. Bin data in time (40 ns binning) and fit each slice:
mean, width, background parameters fixed from previously determined model, only amplitudes free



3. Get intensity vs time for each detector

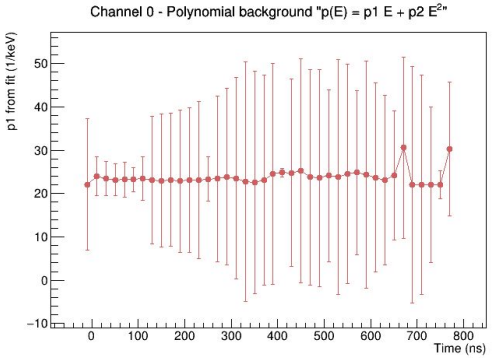


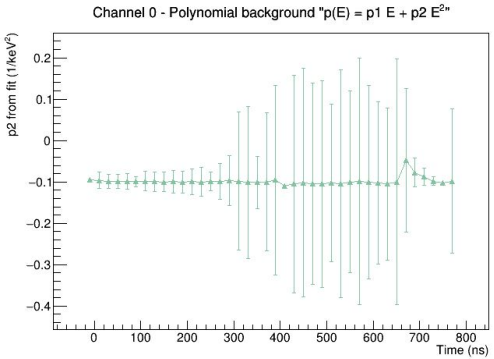
4. Fit simultaneously intensity vs time of all detectors to extract τ

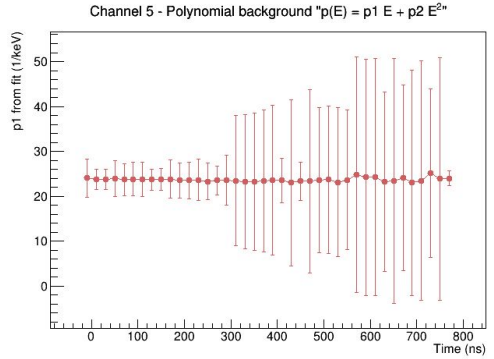


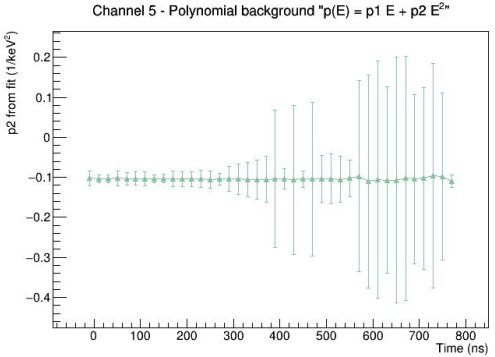
Background-shape VS time

- Check the validity of fixing the coefficients of the polynomial function
- p1 and p2 coefficients very stable in time



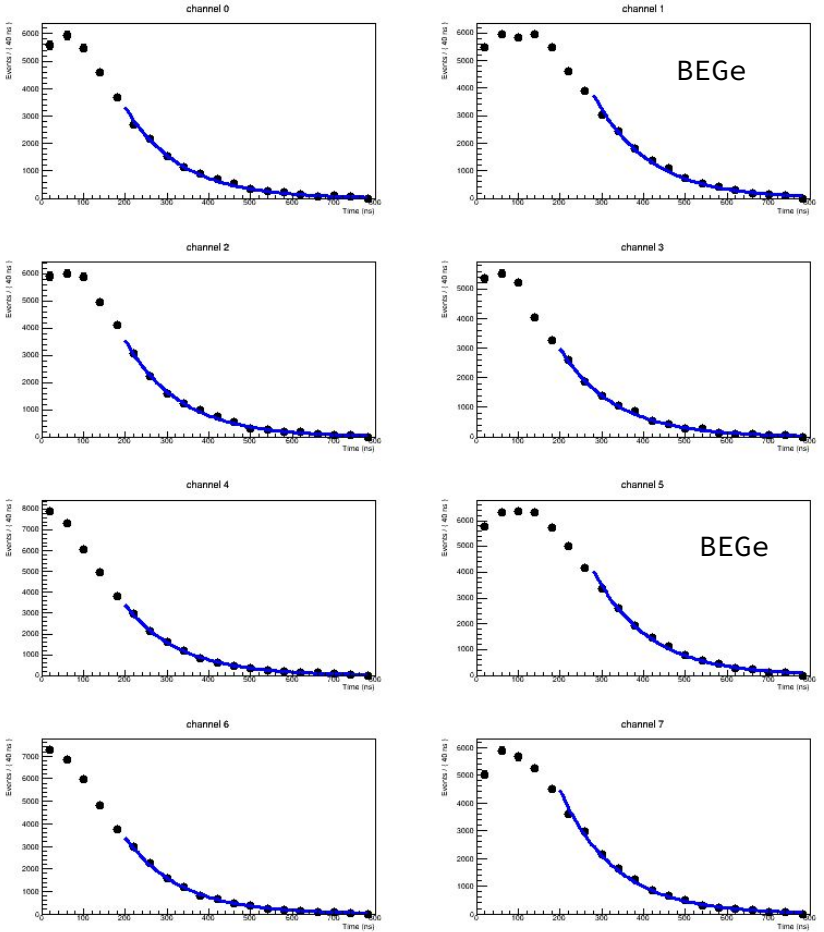






Simultaneous fit

- Exponential function: $A*\exp(-t/\tau)$
- Normalization factor A free for each detector, common fit parameter τ
- Binned likelihood (40 ns binning, integrate PDF over bins)
- Bin weights given by previous fit results
- Fit range: 200-800 ns for all detectors but BEGe's (280-800 ns, worse time resolution)

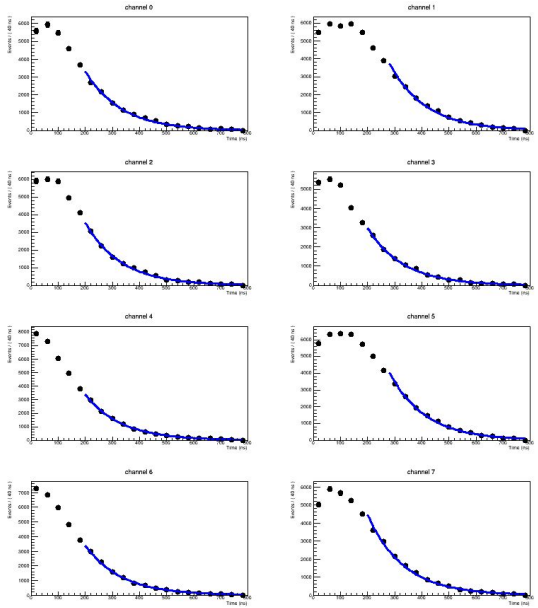


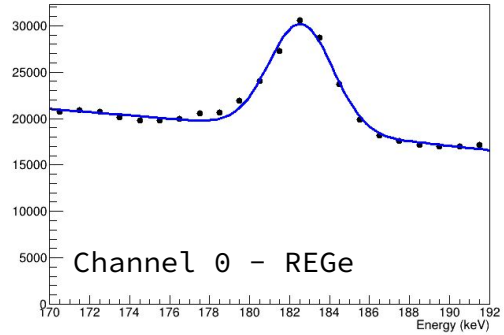
Results: 182.9 keV line

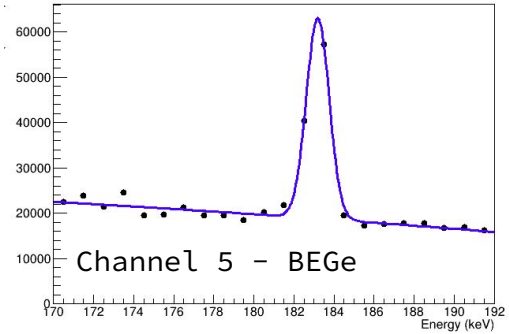
*Need to fix fit model to include tails

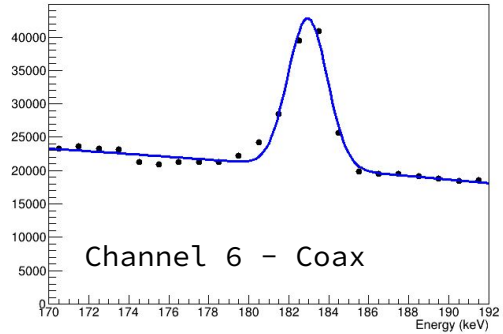
- Energy fit range 170-192 keV
- Fit model*: gaussian peak ~183 keV + pol2 background

τ = (133.8 ± 0.8) ns





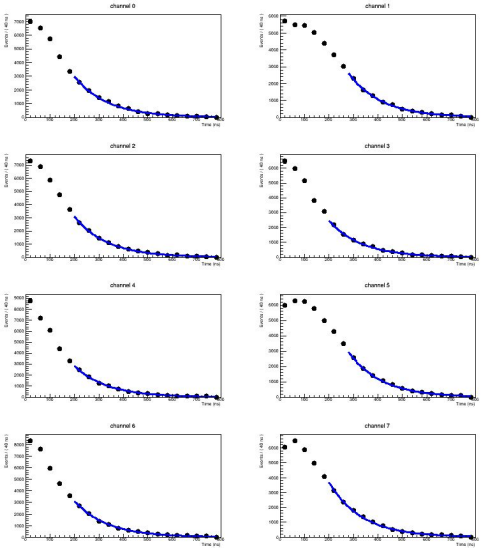


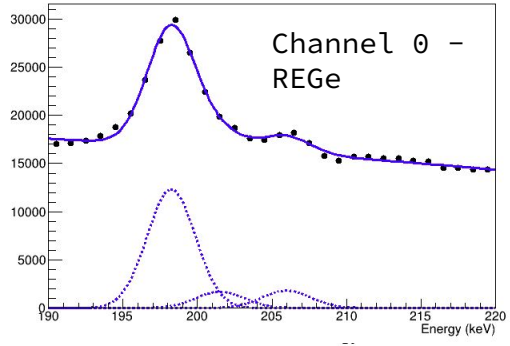


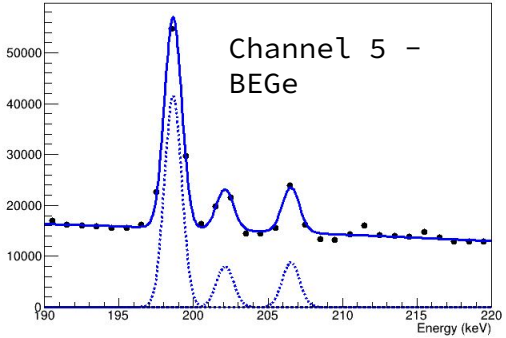
Results: 198.6 keV line

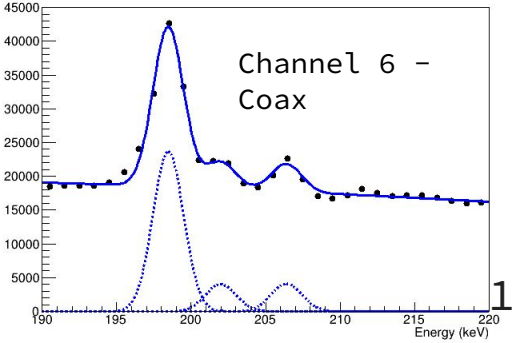
- Energy fit range 190-220 keV
- Fit model: gaussian peak ~199 keV + pol2 background + 2 background peaks ~202 keV and ~206 keV

τ = (135.7 ± 0.9) ns



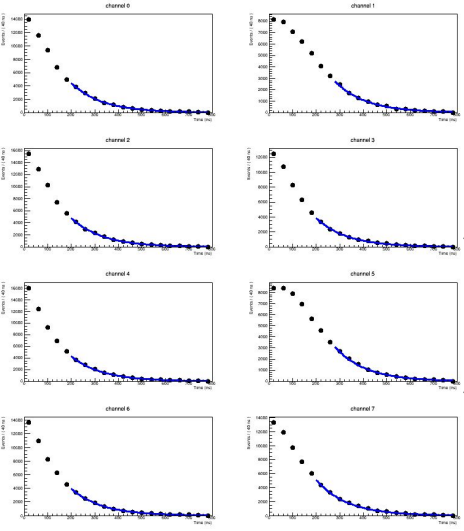






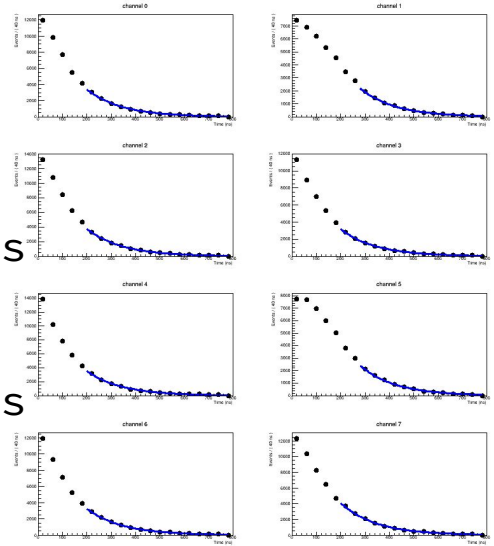
Results: 264.7 keV & 279.5 keV lines

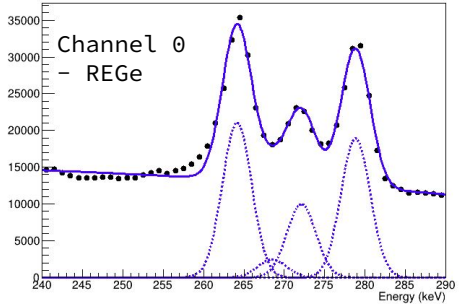
- Energy fit range 240-290 keV
- Fit model: gaussian peak ~265 keV & 279 keV + pol2 background + 2 background peaks ~267 keV and ~272 keV

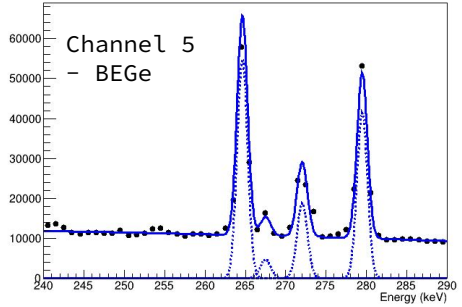


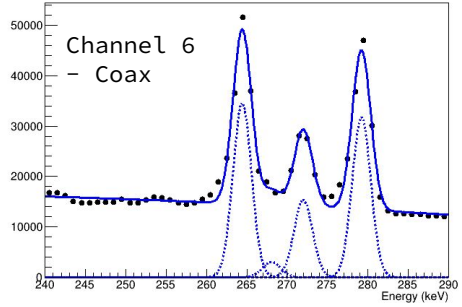
264.7 keV
τ = (132.2 ± 0.6) ns

279.5 keV
τ = (145.9 ± 0.8) ns









Summary of Preliminary results

- Only statistical uncertainty, need to evaluate systematics

Line Energy (keV)	τ (ns)
182.9	133.8 ± 0.8
198.6	135.7 ± 0.9
264.7	132.2 ± 0.6
279.5	145.9 ± 0.8

MIDAS results from 2022 Progress Report

Table 2: Estimations of the muon lifetime in ^{76}Se obtained with different γ lines, different detectors, and different time binning. The weighted average is also shown, including statistical and systematic uncertainties. (See the text for more explanation)

Processed γ line, keV	Detector	Total muon capture rate, λ, ns					
		Bin width 25.34 ns		Bin width 49.64 ns		Bin width 12.81 ns	
		Value	Error	Value	Error	Value	Error
182.9	Ge1	135.6	1.1	132.5	1	137.1	1.1
	Ge3	136.9	0.8	133.4	0.7	138.1	0.8
	Ge4	136	0.8	133.7	0.8	140.3	0.8
	Ge5	133.5	0.7	130.8	0.7	135.1	0.7
	Ge7	135.7	0.8	132.3	0.7	137.1	0.8
198.6	Ge1	136.9	1.2	135.2	1.1	139.1	1.3
	Ge3	137.1	0.9	133.8	0.8	138.5	0.9
	Ge4	136.7	1	134.3	0.9	138.5	1
	Ge5	135.9	0.9	132.9	0.9	132.8	0.8
	Ge7	139	1	136.6	0.9	141.1	1
	Ge8	141.3	0.7	138.7	0.6	142.4	0.7
264.7	Ge1	132.6	0.8	130.2	0.7	134.2	0.8
	Ge3	133.7	0.6	131.5	0.6	135.1	0.6
	Ge4	133.8	0.7	131	0.6	135.3	0.7
	Ge5	133.6	0.6	131.2	0.5	135.1	0.6
	Ge7	134	0.6	131.2	0.6	135.5	0.6
	Ge8	134.3	0.5	131.5	0.4	135.8	0.5
279.5	Ge1	132.1	1.9	130	1.8	133.9	1.8
	Ge3	133.5	1.1	131.3	1	143.6	1.1
	Ge4	142.8	1.1	129	0.9	136.9	1
	Ge5	142	1.2	135	1.1	134.6	1.1
	Ge7	135.3	1	131.9	0.9	134.3	0.9
	Ge8	134.2	0.7	131.4	0.7	133.3	0.7
By bin widths		**135,9**	**2,9**	**132,6**	**2,3**	**136,9**	**2,9**
Final result (CL=68%):		**135.9 ± 2.9 (stat) ± 3.5 (sys) = 135.9 ± 4.5**					

Fit Uncertainty

- In the fit of the “intensity vs time” the uncertainty of each bin is informed by the previous fit-> each bin comes with a weight
- In the presence of weights, the inverse second derivative of the negative logarithmic likelihood is not representative anymore of the error matrix (see Ref)
- Asymptotically correct approach to estimate errors in the presence of weights available in RooFit -> arxiv:1911.01303

Line Energy (keV)	τ (ns)
182.9	133.8 ± 5.2 (0.8)
198.6	135.7 ± 6.1 (0.9)
264.7	132.2 ± 7.0 (0.6)
279.5	145.9 ± 8.3 (0.8)

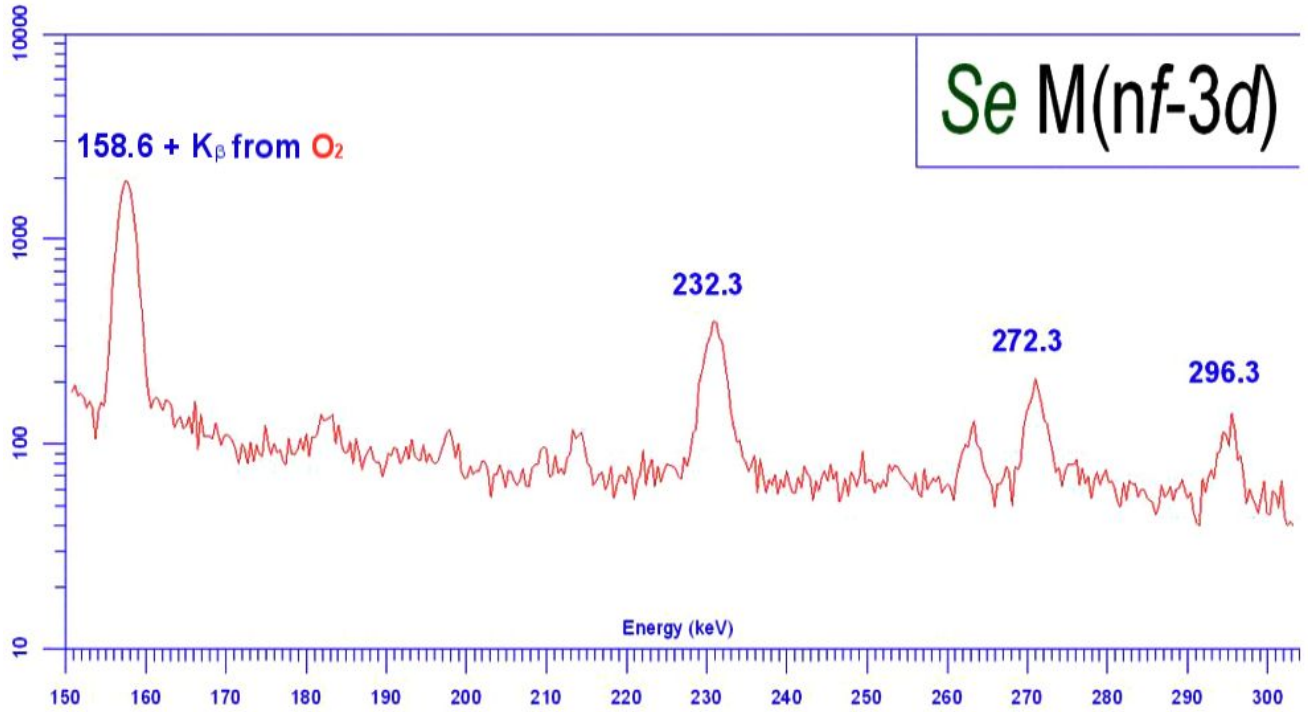
Conclusions & next steps

- ***First preliminary results*** on the total capture rate of Se76 with ALPACA data -> agree with MIDAS results

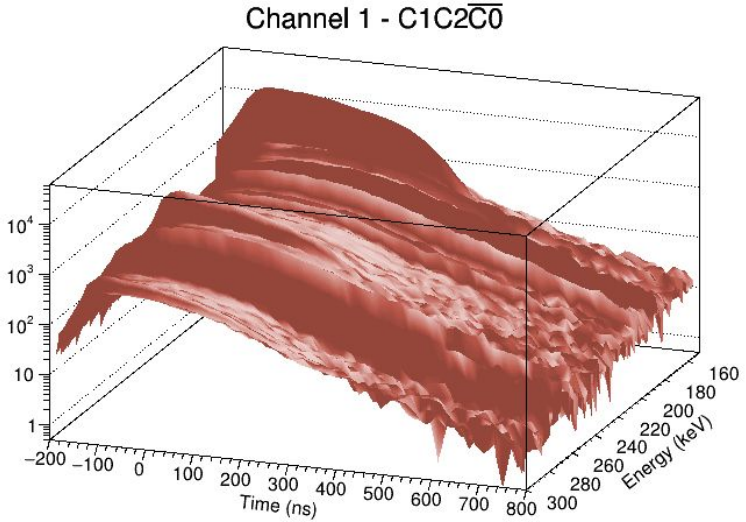
- Need to improve the **fit model** (tails of Gaussian peaks)
- Add **all se76 runs** into the analysis (need to check energy stability)
- Need to evaluate **systematic uncertainties** (e.g. fit range for exponential fit, time binning, …)

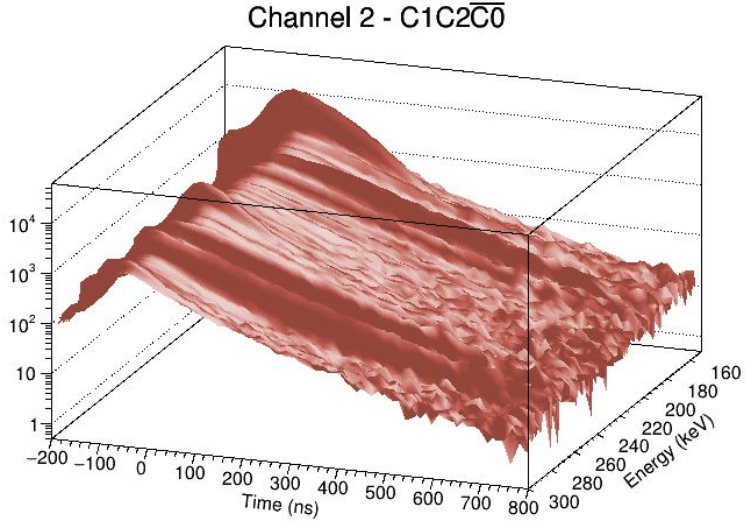
BACKUP SLIDES

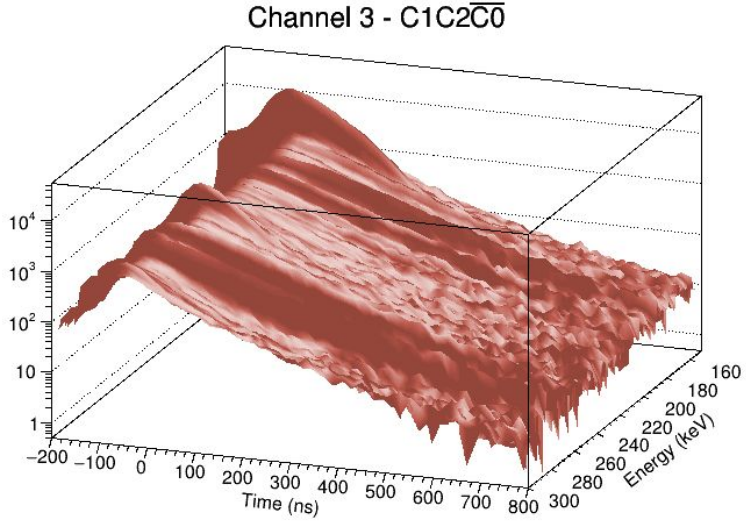
Muonic X-rays M-series



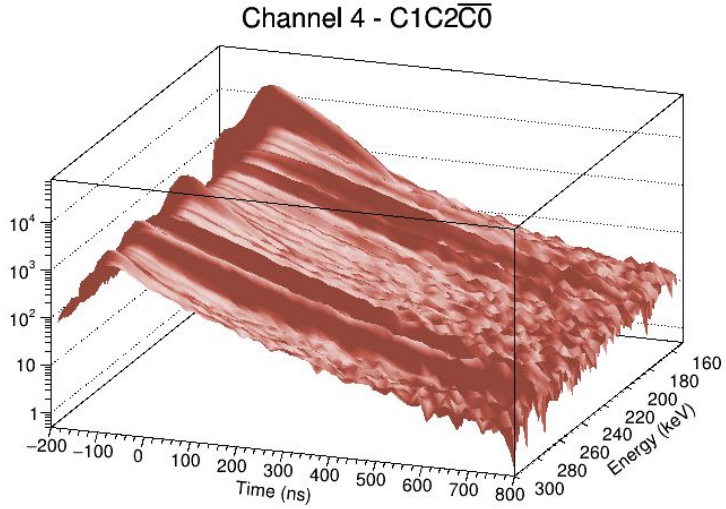
More surface plots

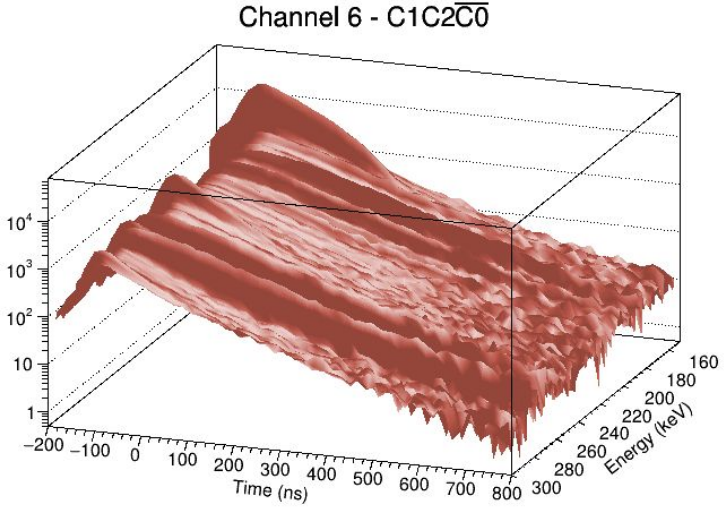


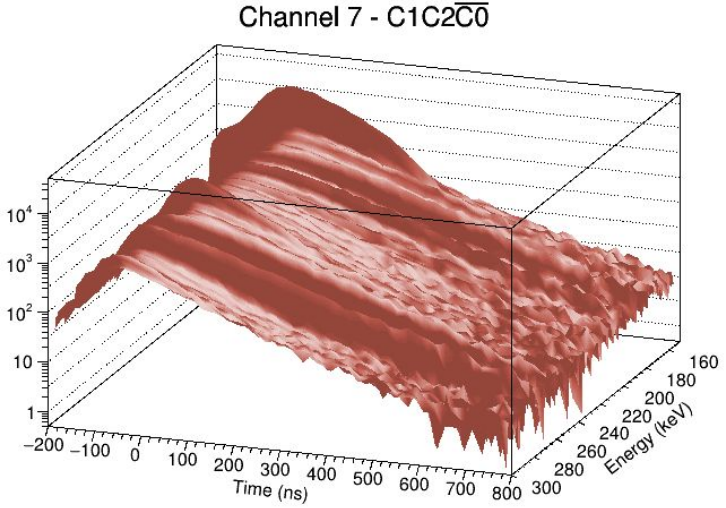




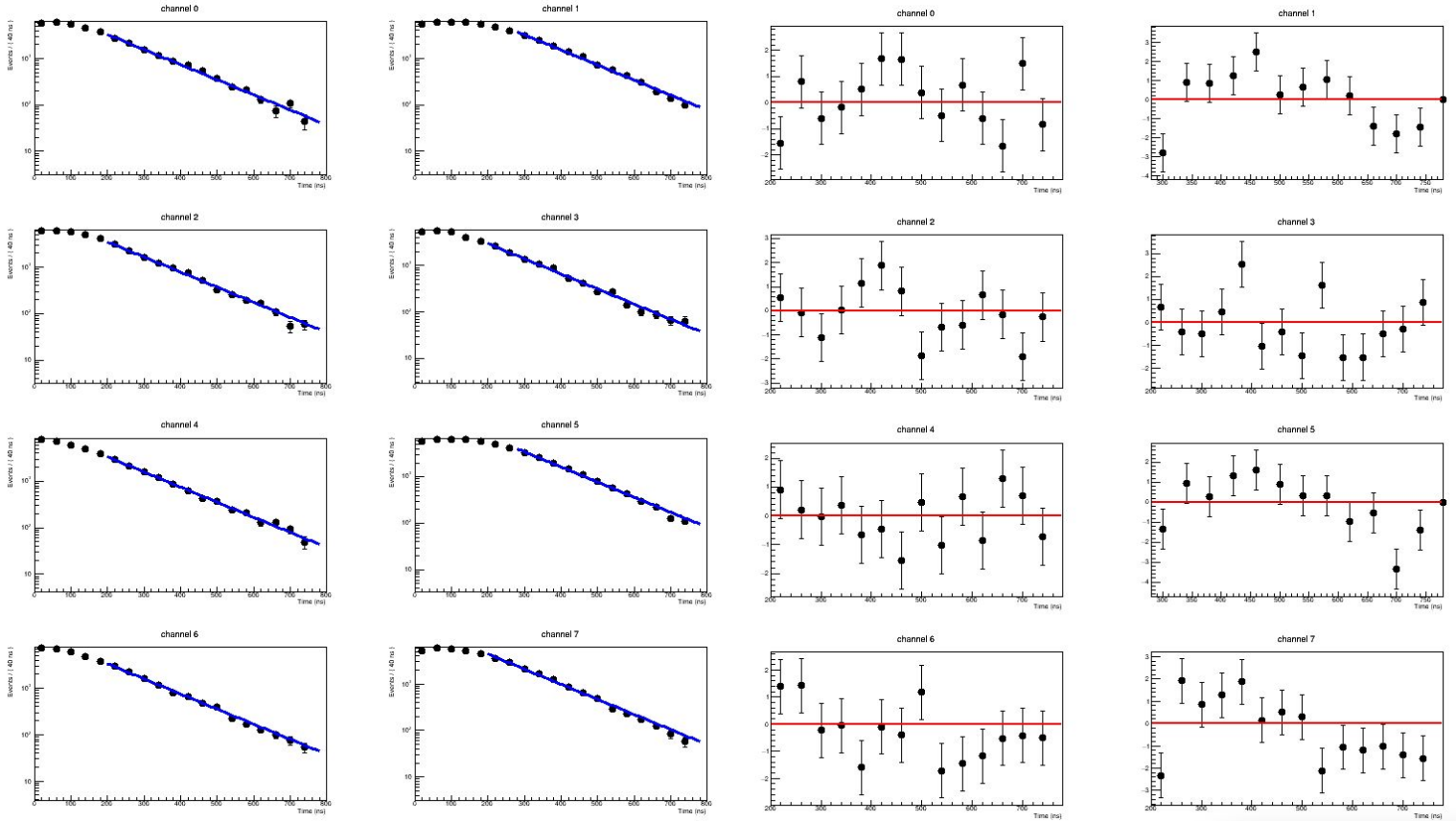
More surface plots



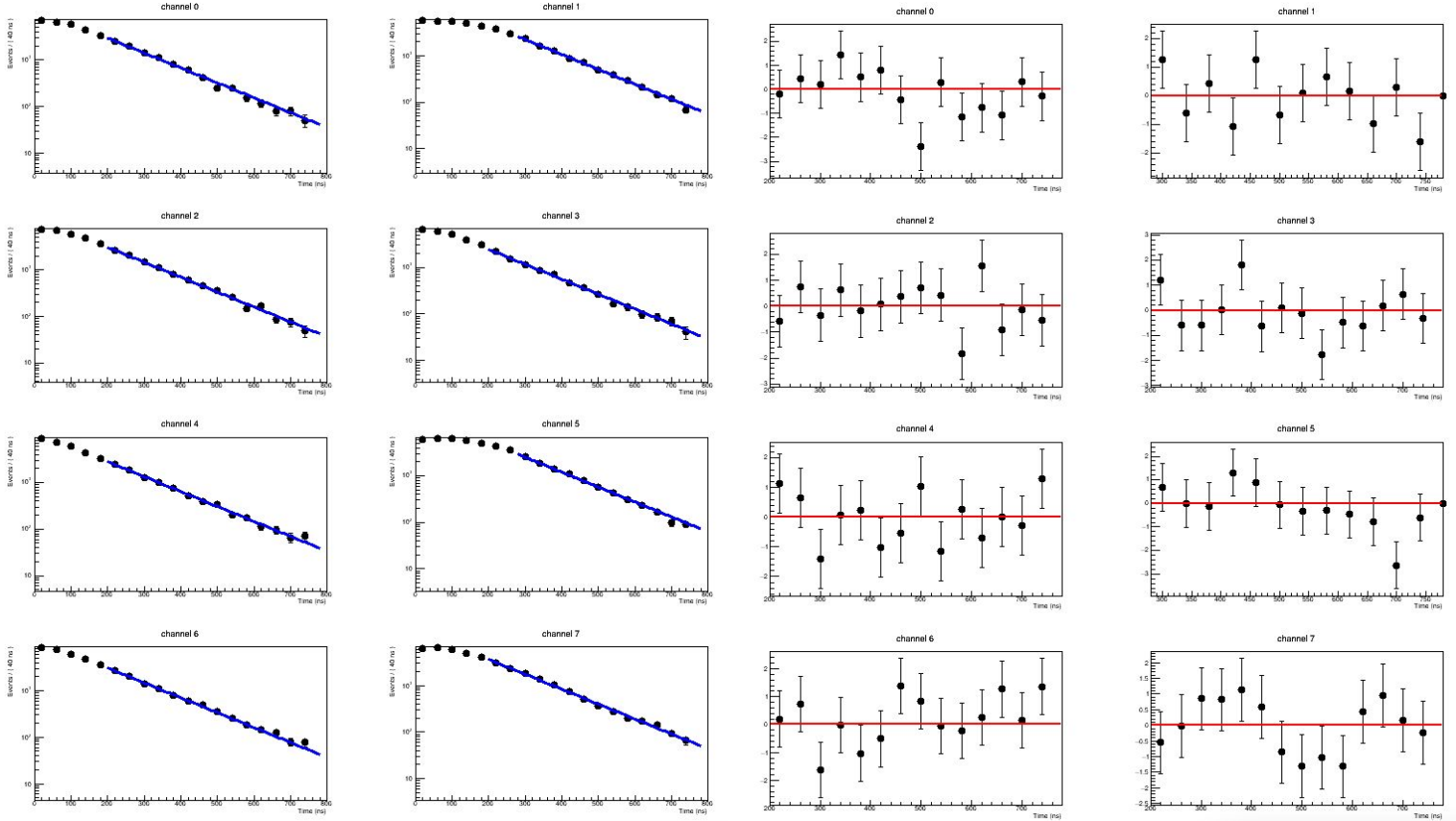




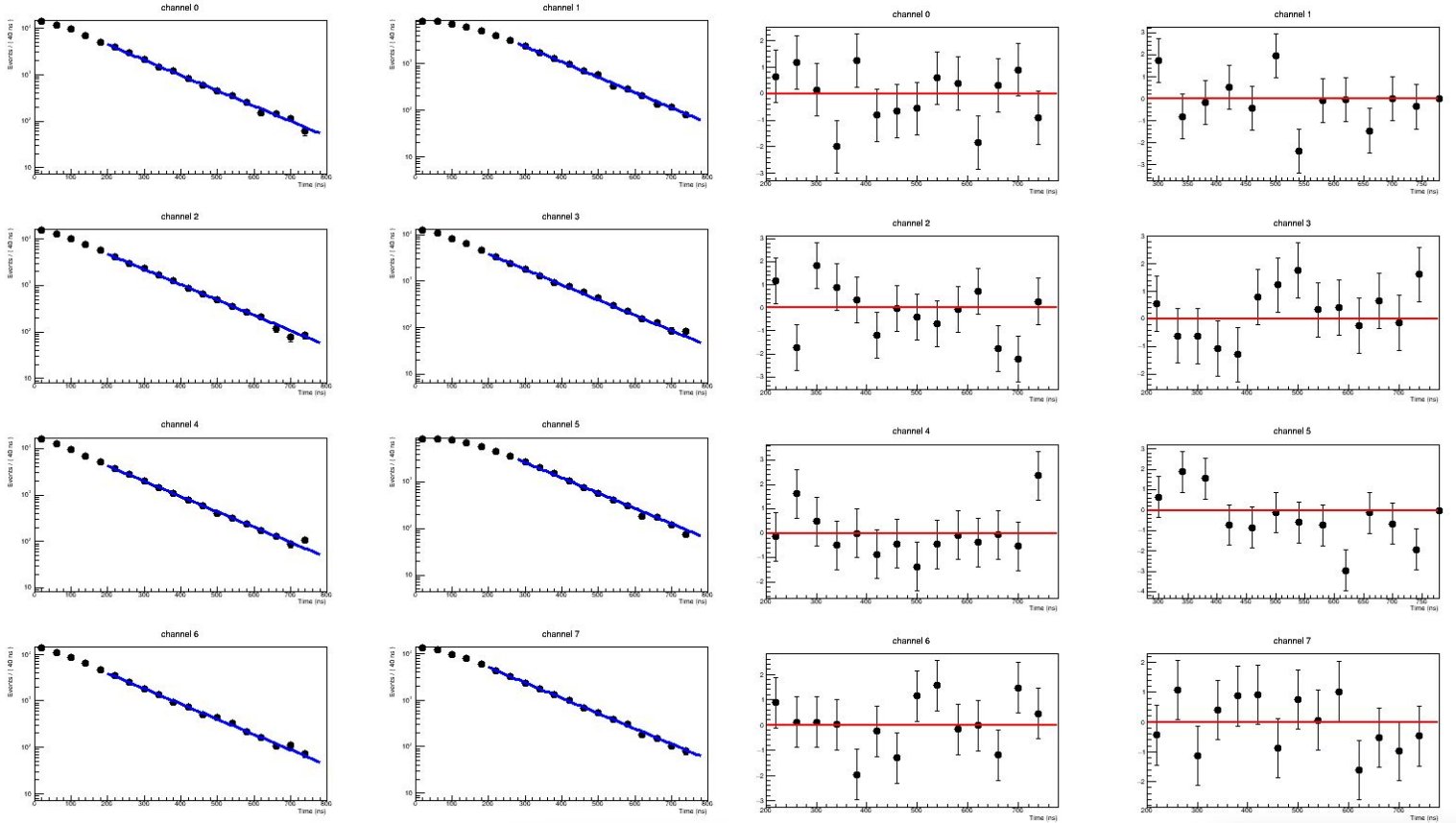
182.9 keV line, log-scale data and residuals



198.6 keV line, log-scale data and residuals



264.7 keV line, log-scale data and residuals



279.5 keV line, log-scale data and residuals