$^{30}Si(n,\gamma)$: Status of the Analysis

Michele Spelta

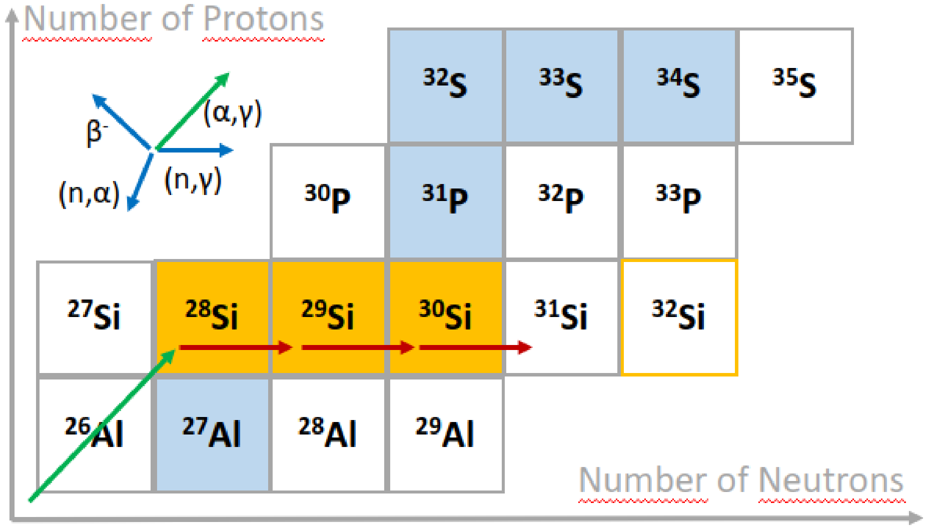
Outline

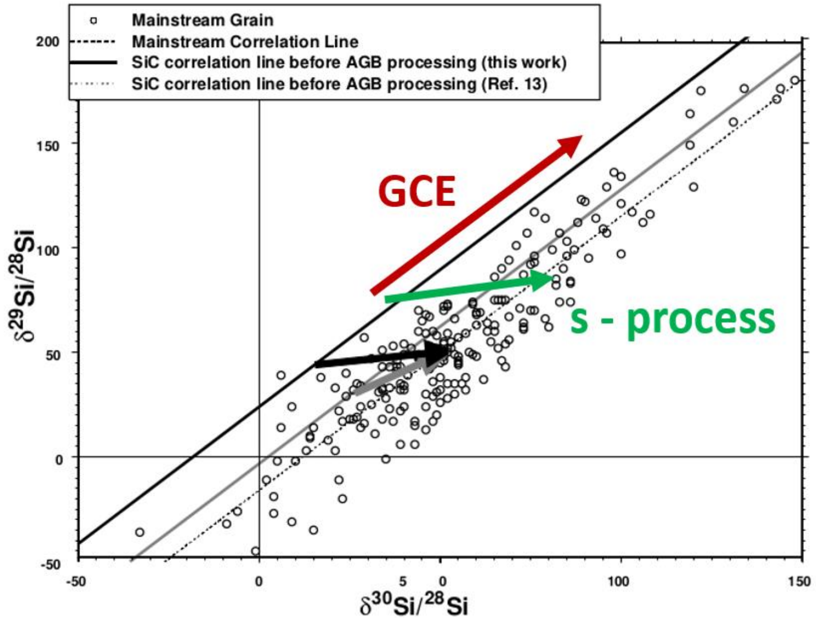
- **0. Recap:** Motivation, setup
- **1. Calibrations**
- **2. Gain Stability**
- **3. Weighting Functions**
- **4. Deposited Energy Thresholds**
- **5. Gold:** Stability, Flight-path determination, Normalization factors
- **6. Consistency Check**
- **7. ^{30}Si:** Background subtraction, Yield
- **Summary and next steps**

Motivations

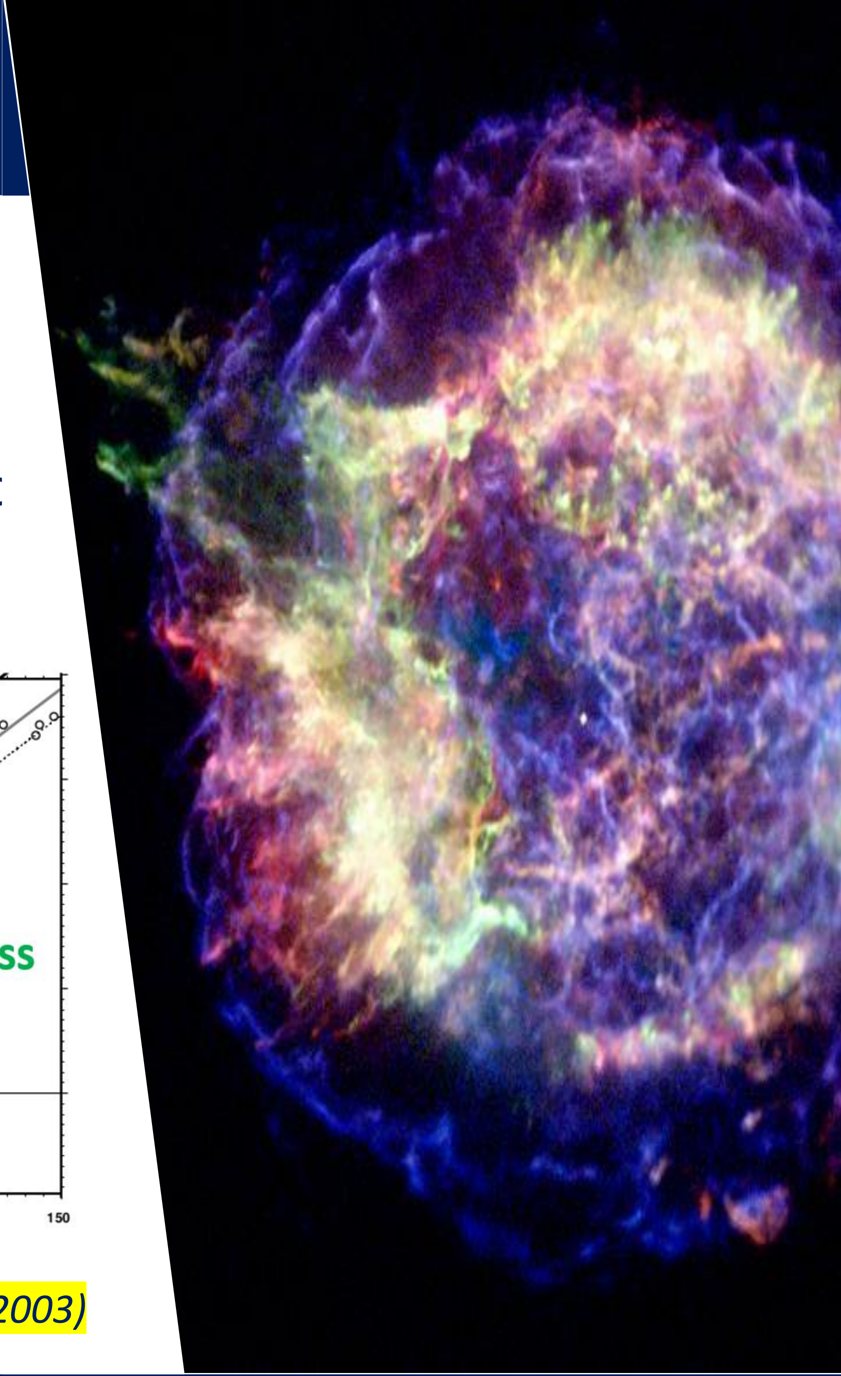
$^{30}Si(n, \gamma)$ cross section is important:

- to predict the abundance of Silicon isotopes produced in the convective carbon shell of **massive stars**
- to disentangle the contributions of **s-process** and **GCE** in the isotopic ratios measured in **mainstream SiC grains**



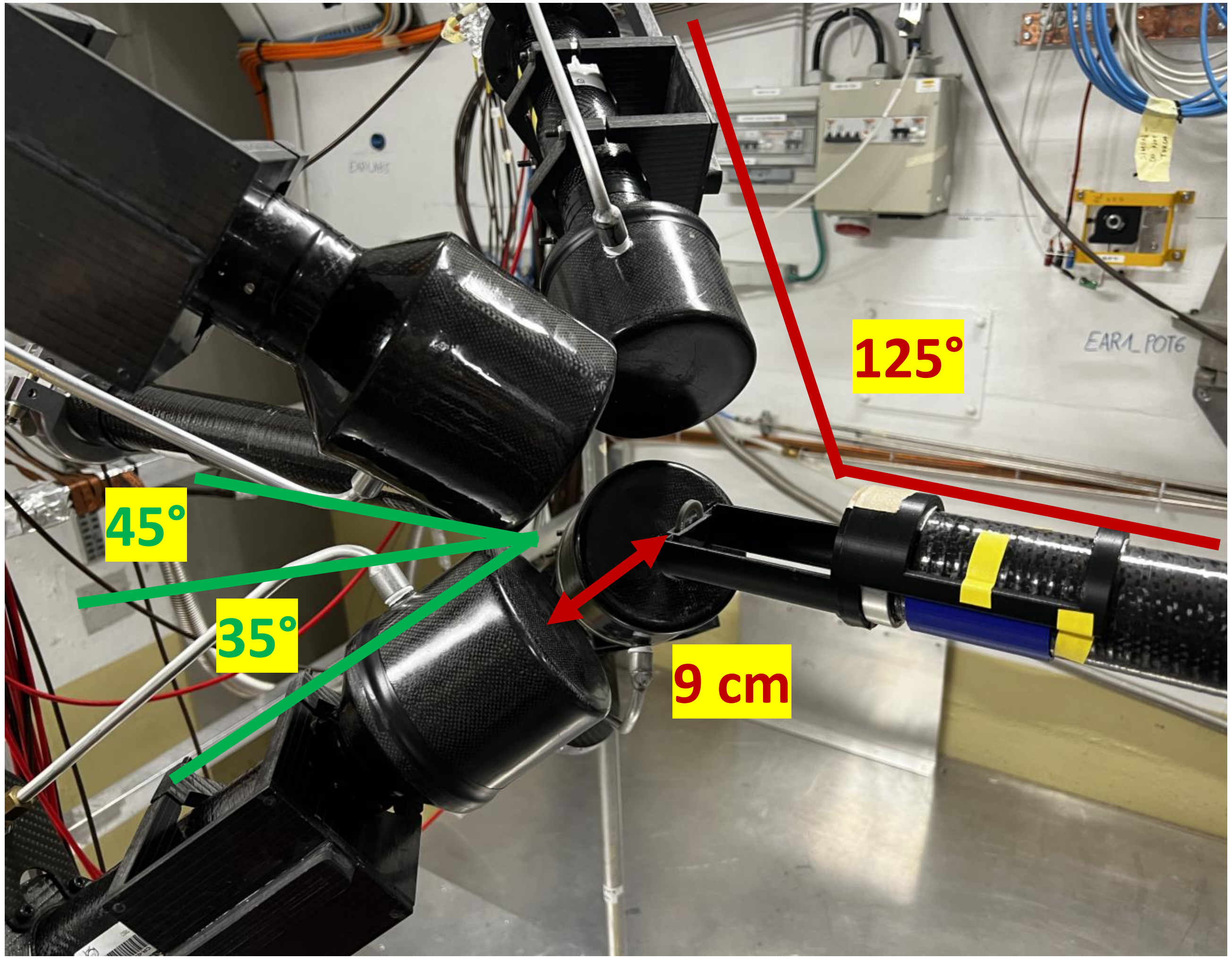


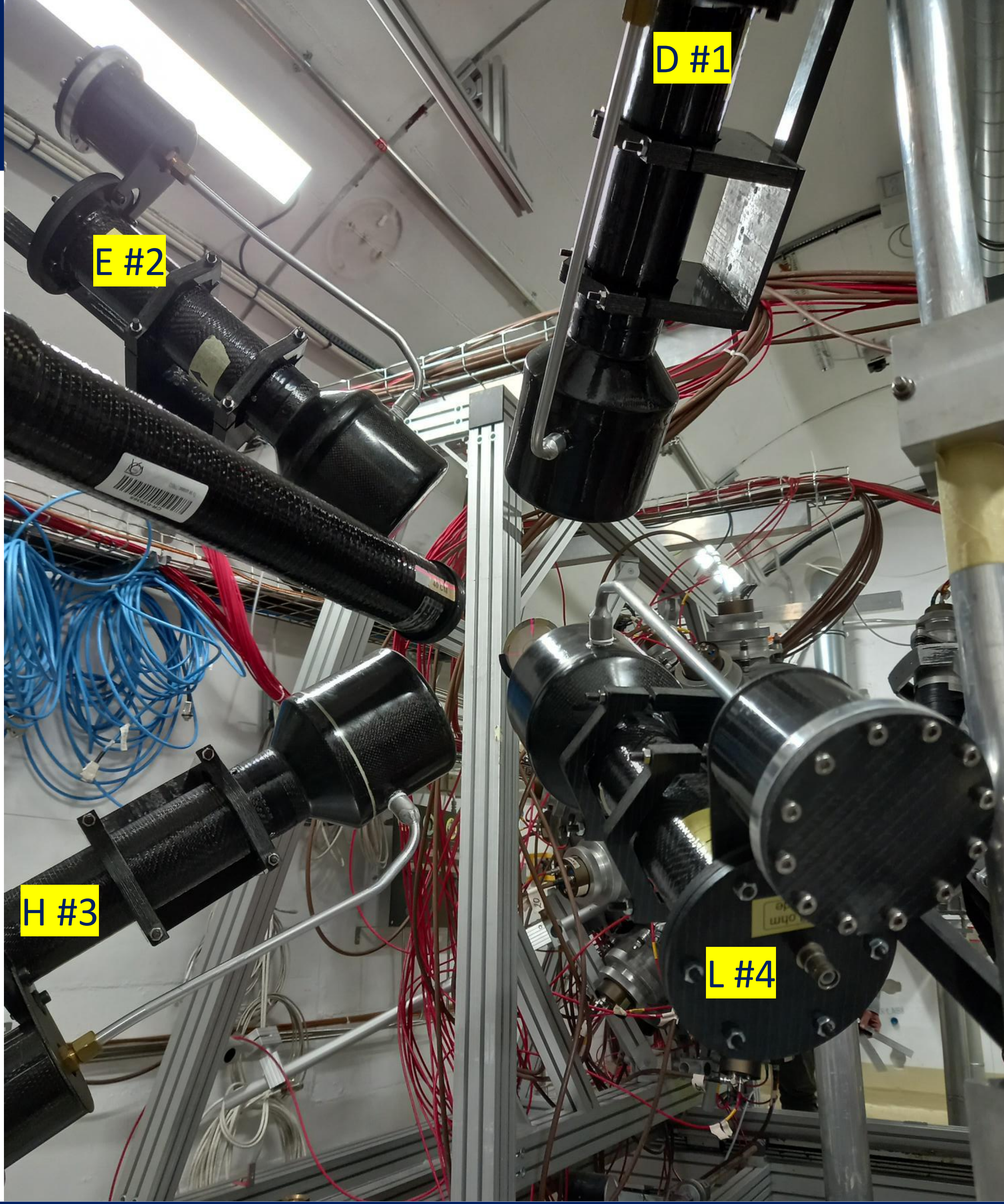
K. Guber et al., *Phys. Rev. C 67, 062802 (2003)*



Setup in EAR1

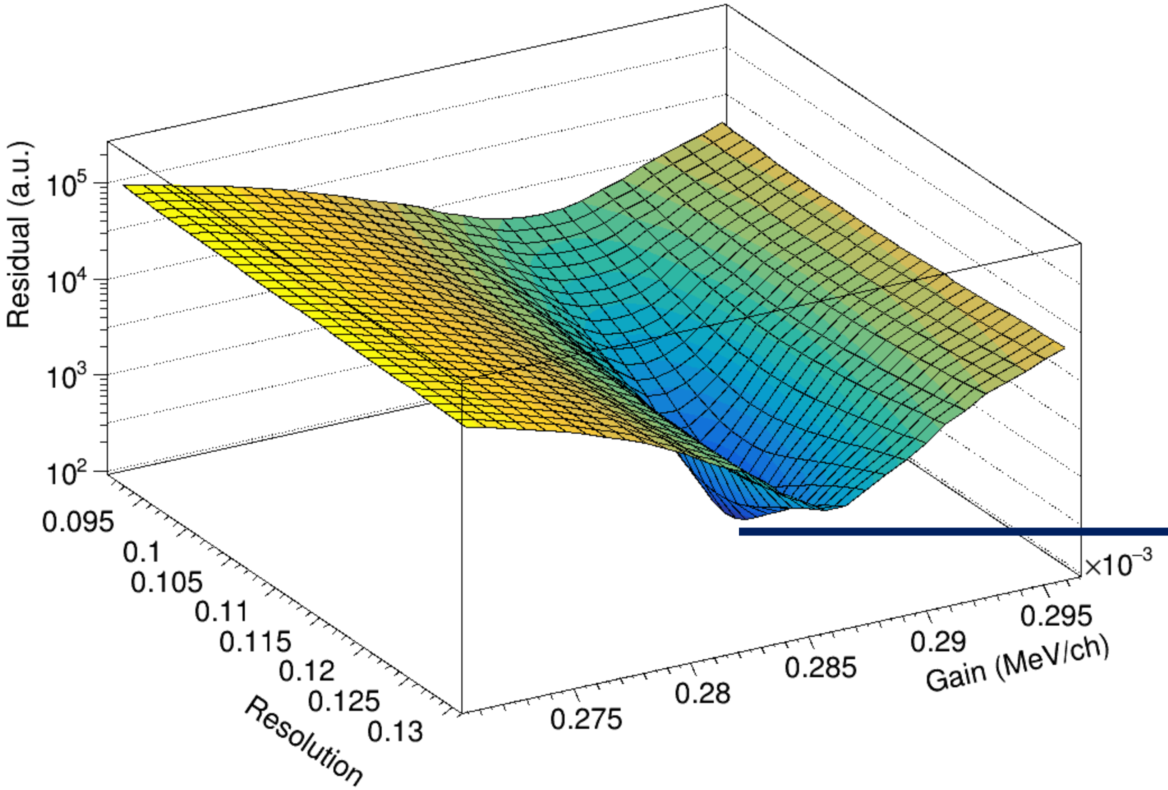
June – July 2023

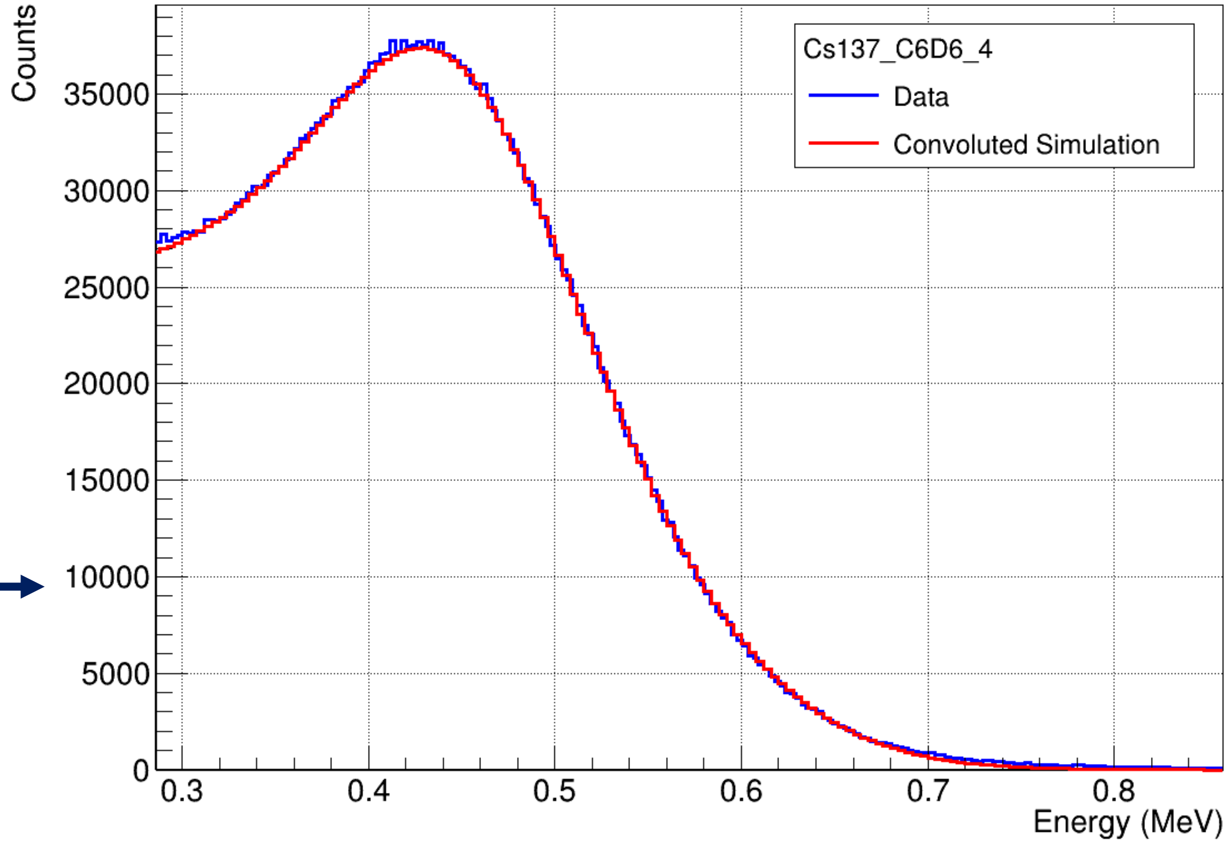




1. Calibration

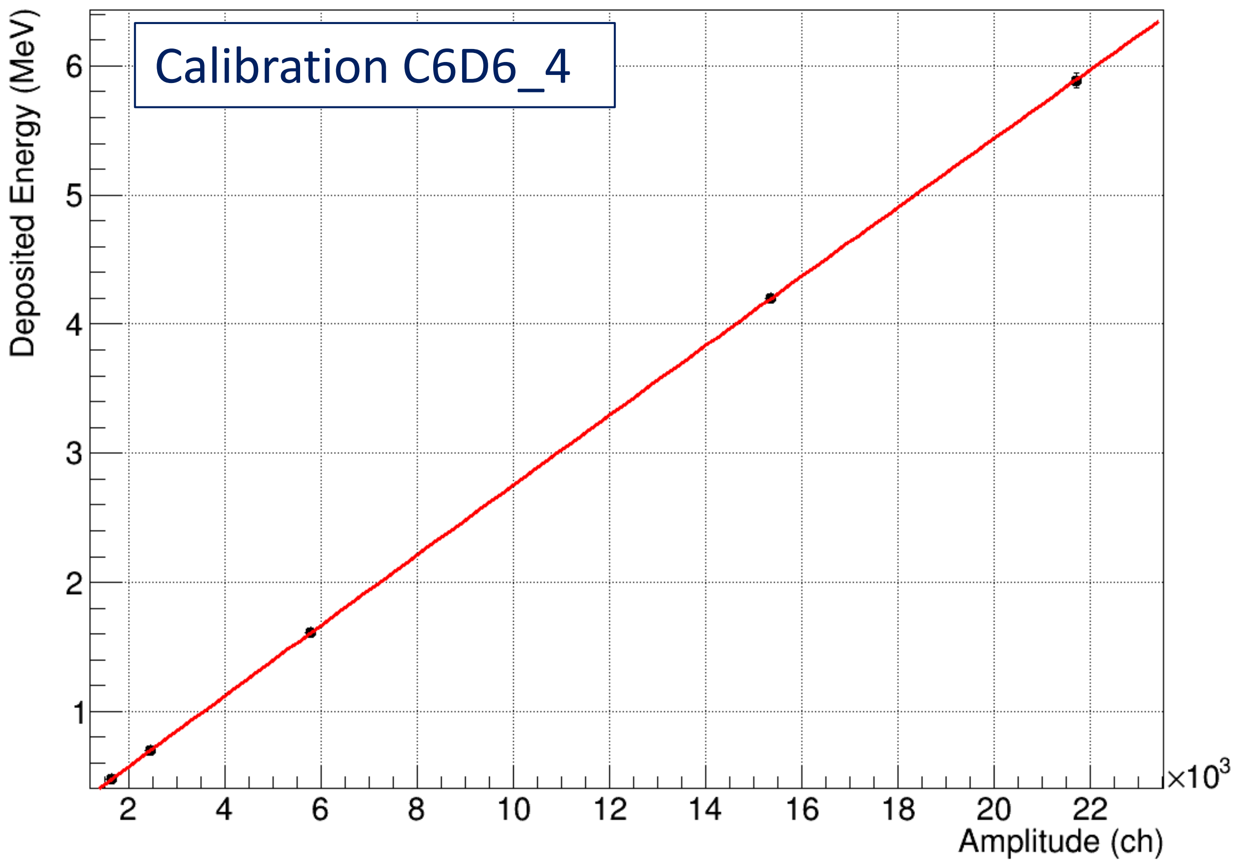
Detector calibration is performed via a **direct comparison of the deposited energy spectra with GEANT4 Simulation** convoluted with the detector resolution.
Gain and resolution are varied at the same time to get the best agreement between data and simulations for each calibration source.

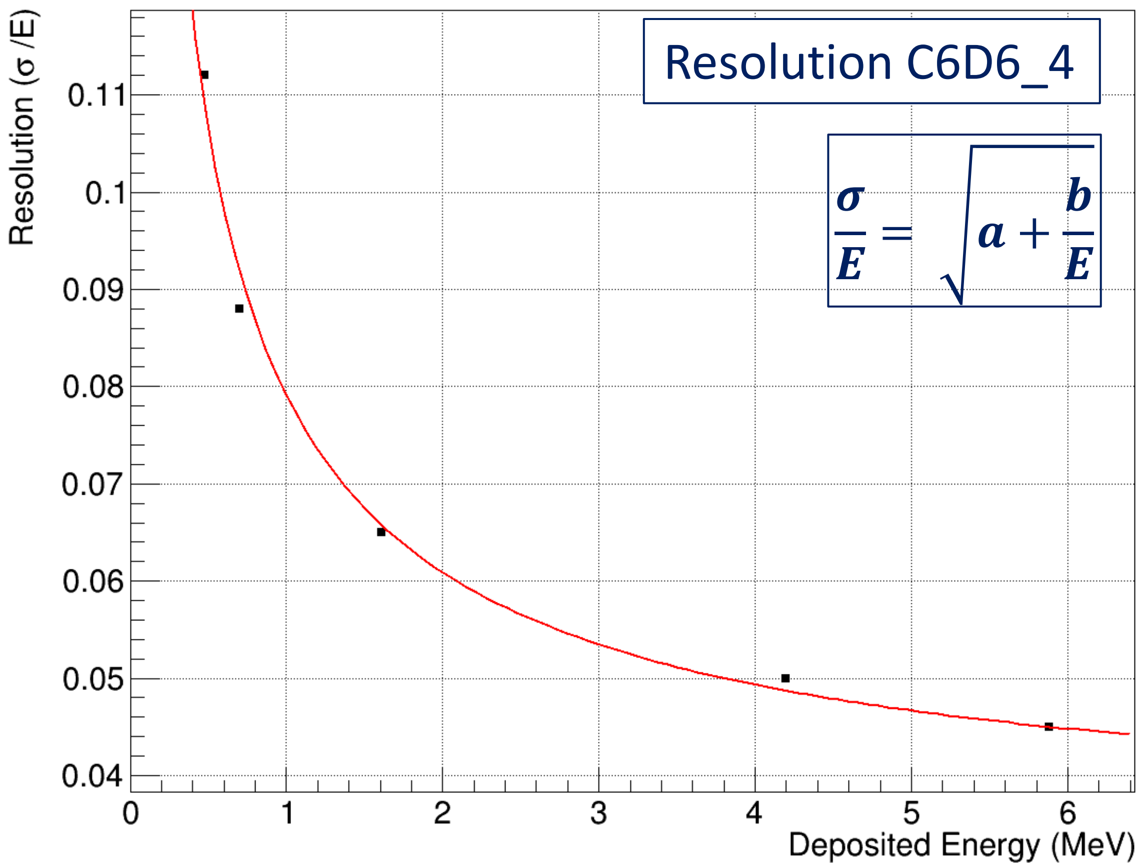




1. Calibration

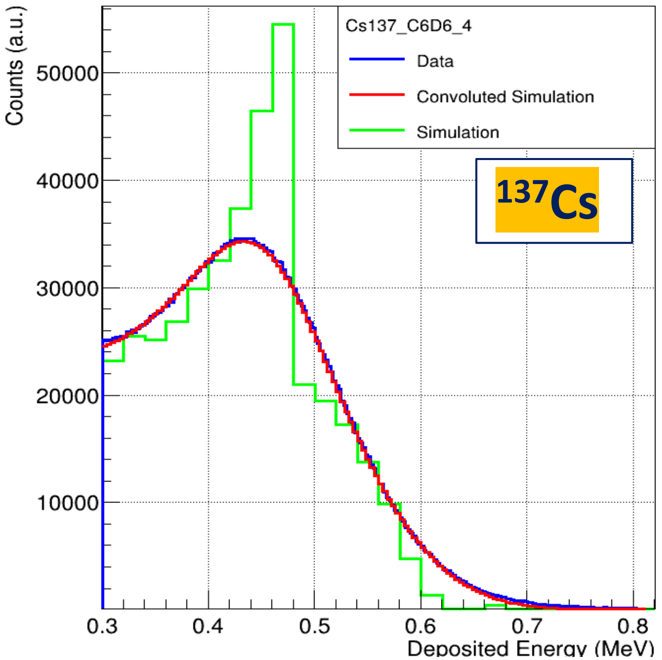
Detector resolution and calibration curves are obtained fitting the results for all the sources (**^{137}Cs, ^{88}Y, AmBe, CmC**)

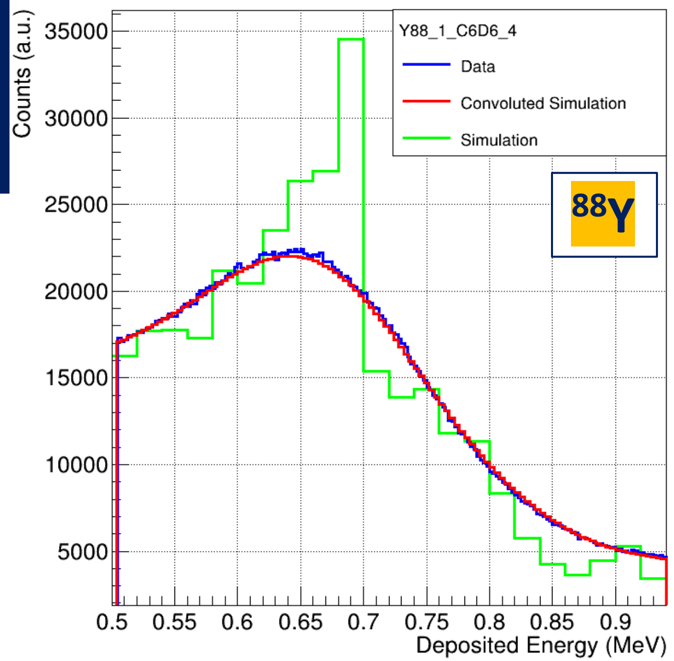


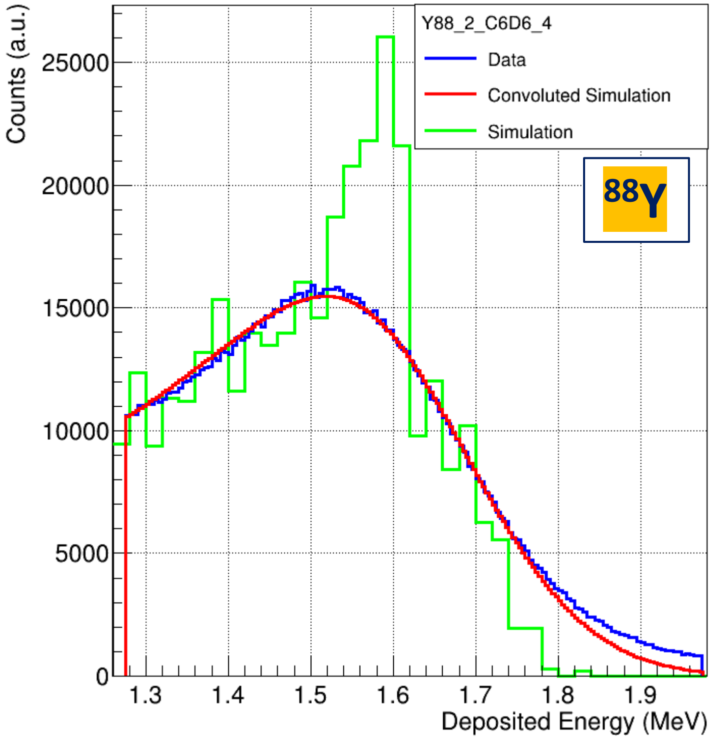


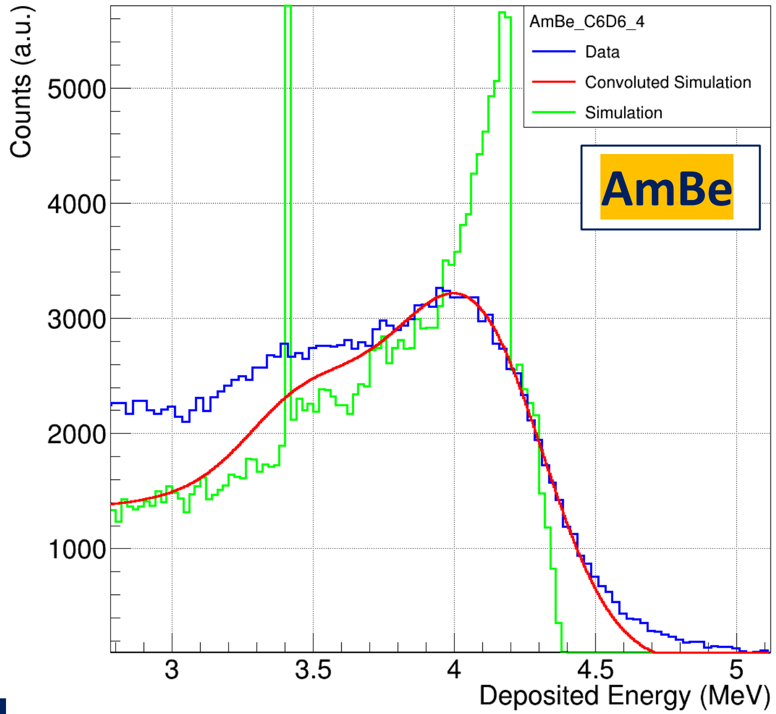
1. Calibration

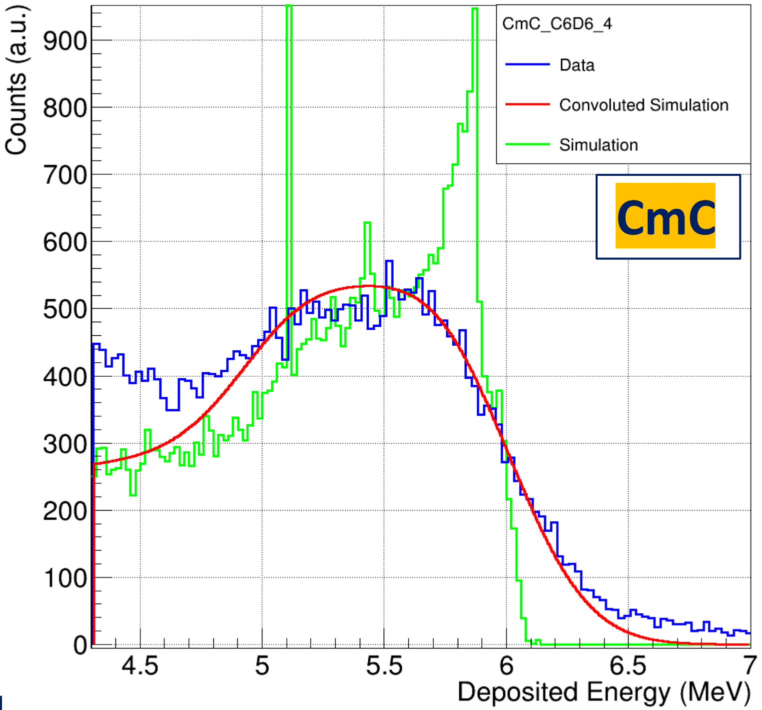
Comparison between data and simiulations after energy and resolution calibration (**C6D6_4**)





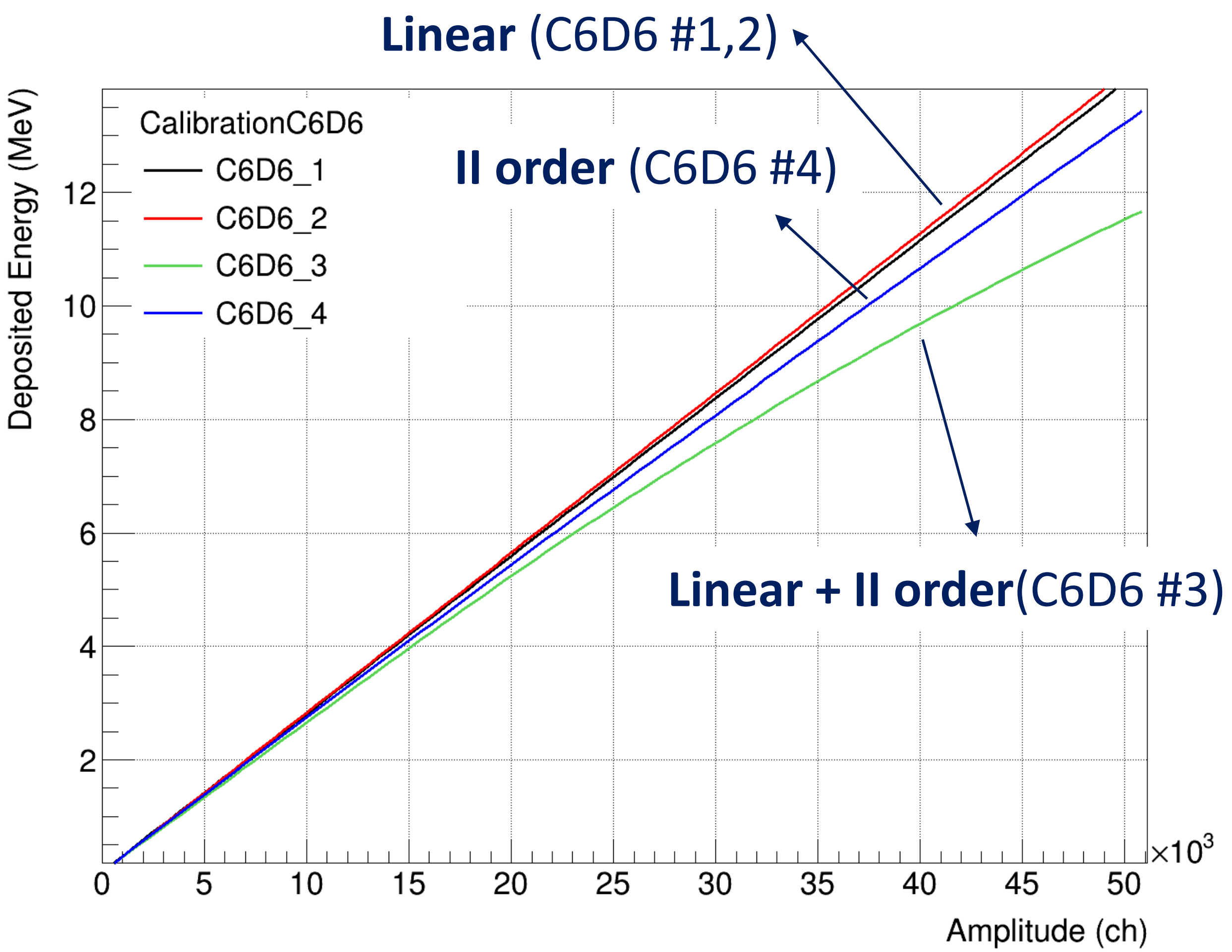


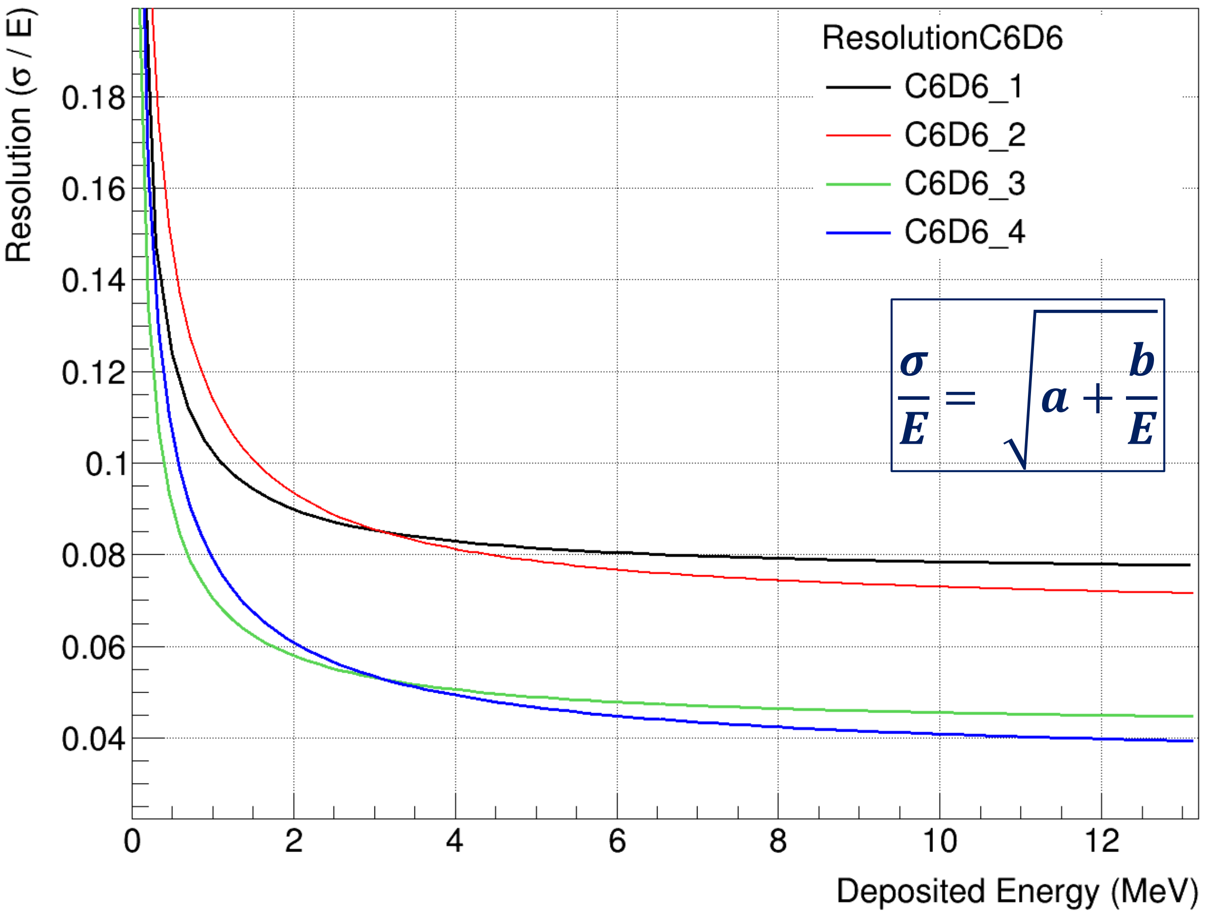




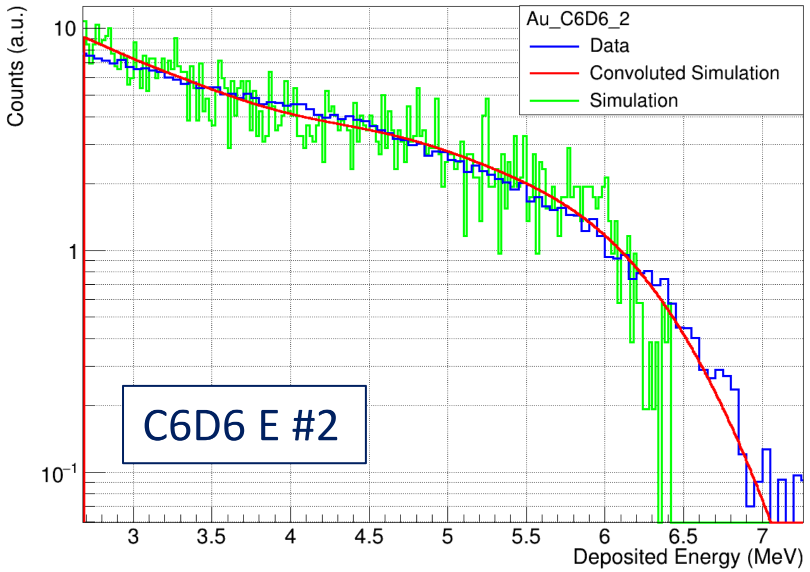
1. Calibration

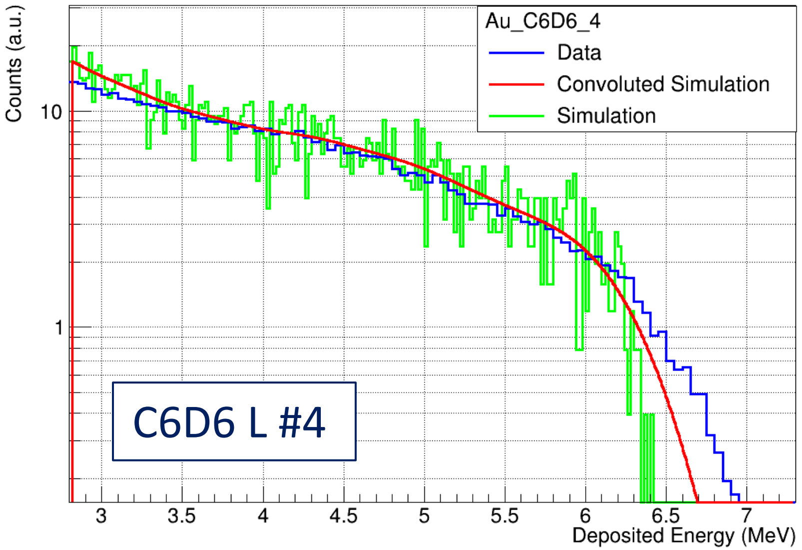
Detector resolution and calibration curves obtained for all the detectors.



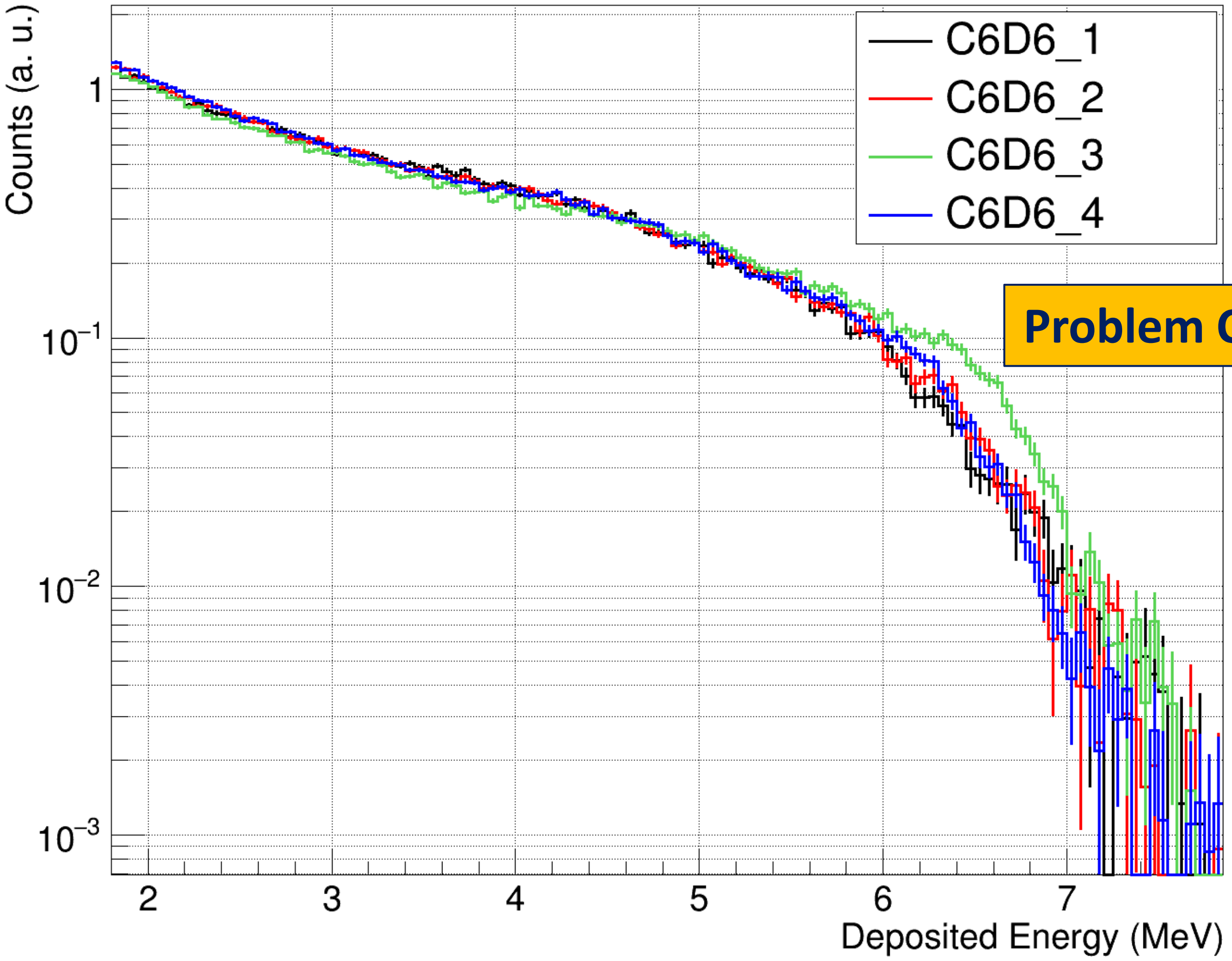


1. Calibration





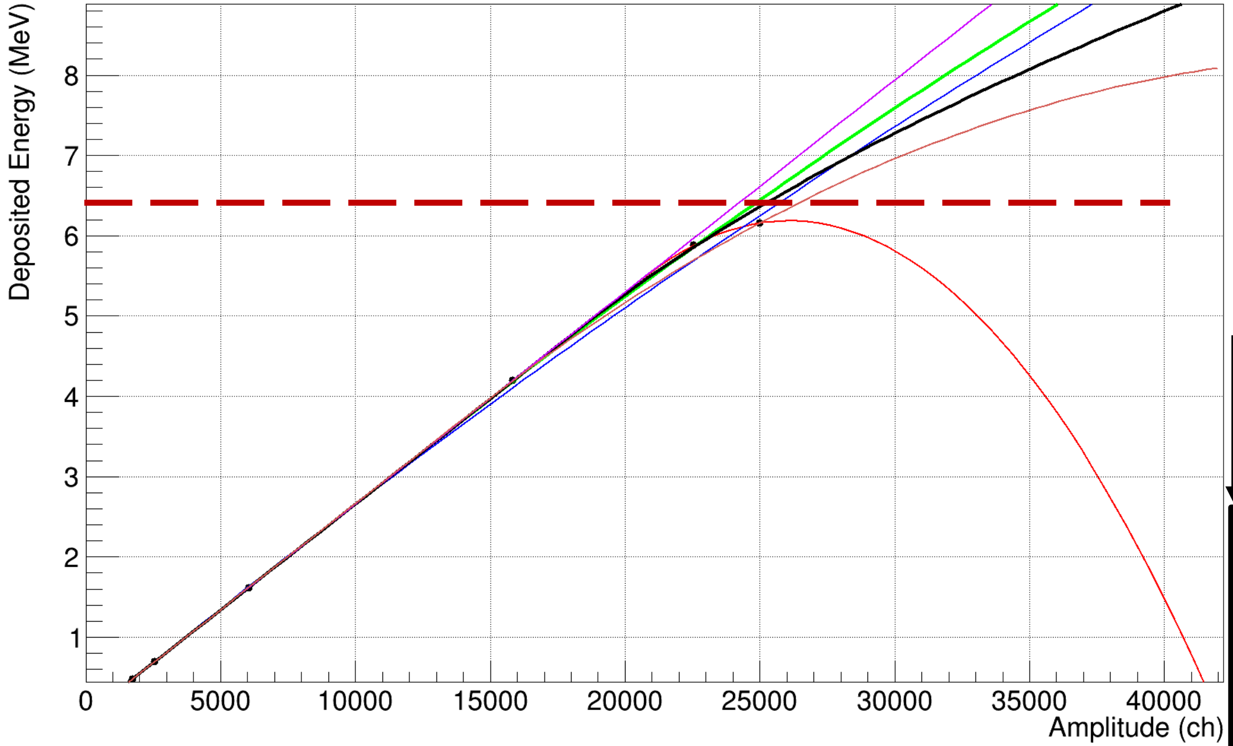
Check of the deposited energy in the **Gold 4.9 eV resonance**



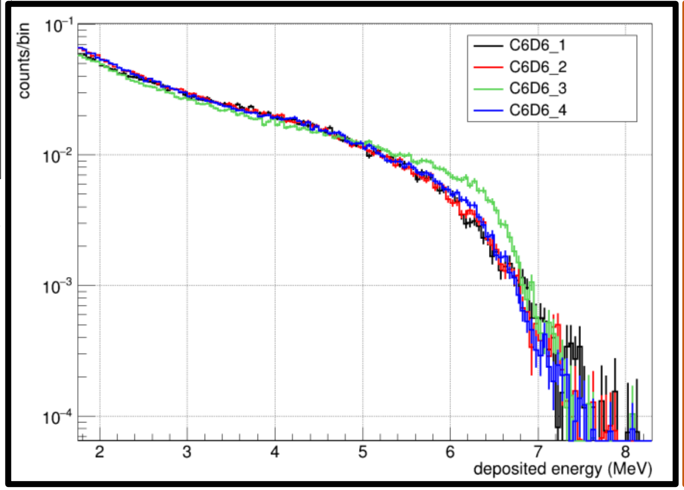
Problem C6D6 #3 ?

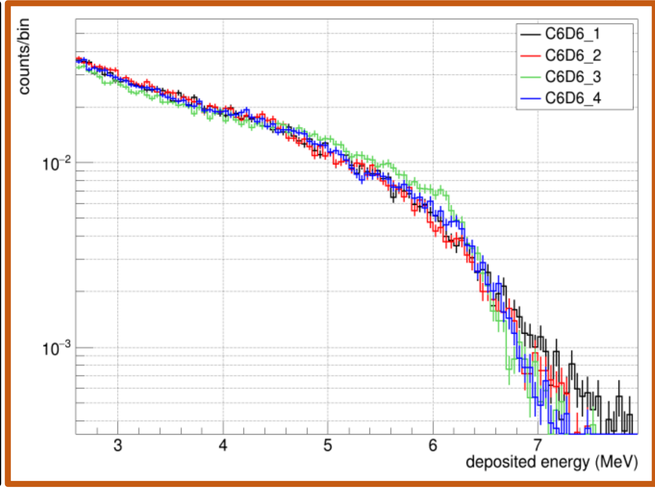
1. Calibration (Problem C6D6 #3)

Need to **"curve"** the calibration curve to reproduce the de-excitation cascade of Gold.



- Linear → *Just reference*
- Linear + II order (using both) → *Not physical*
- II order (using both) → *Average, AmBe not ok*
- Linear + II order (using Au) → *Too much curved ?*
- **Linear + sqroot (using CmC)** → *Curving towards Au*
- **Linear + II order (using CmC)** → ***Currently used***

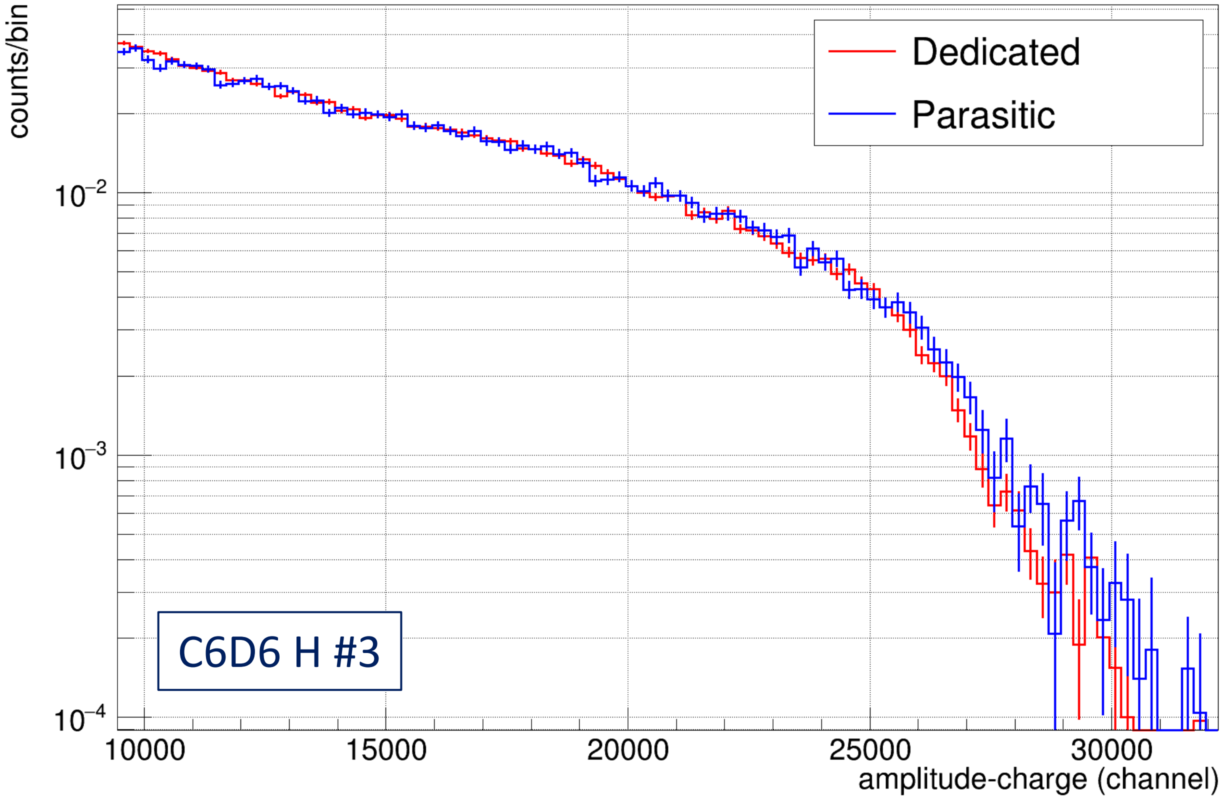


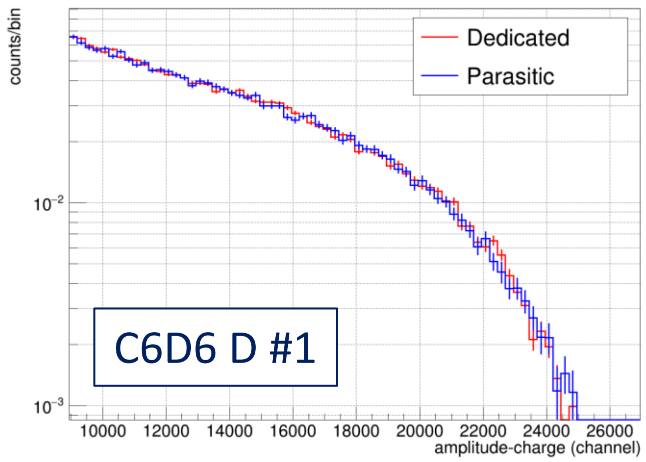


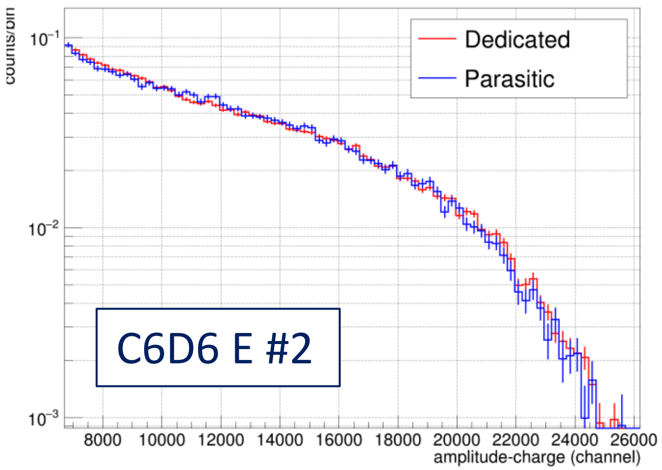
No differences observed on Au & Si30 yields (*"linear" up to 6.5 MeV*)

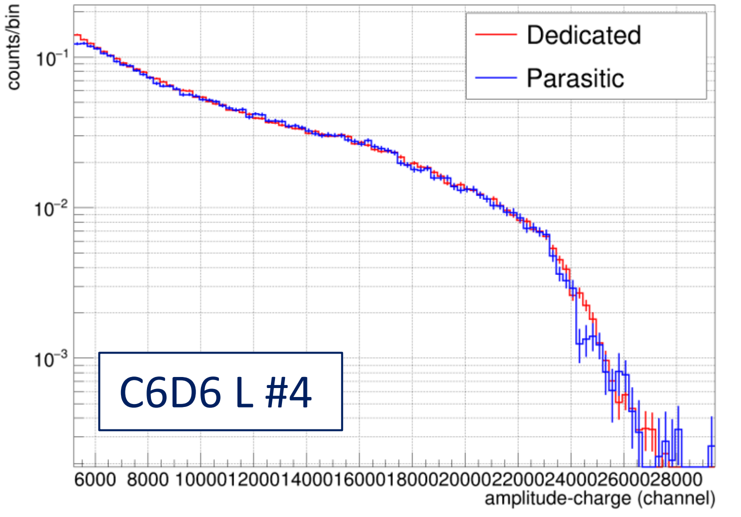
1. Calibration (Problem C6D6 #3)

No important effect due to the counting rate (checking the deposited energy in 4.9 eV Gold resoanance for **parasitic** and **dedicated** bunches).



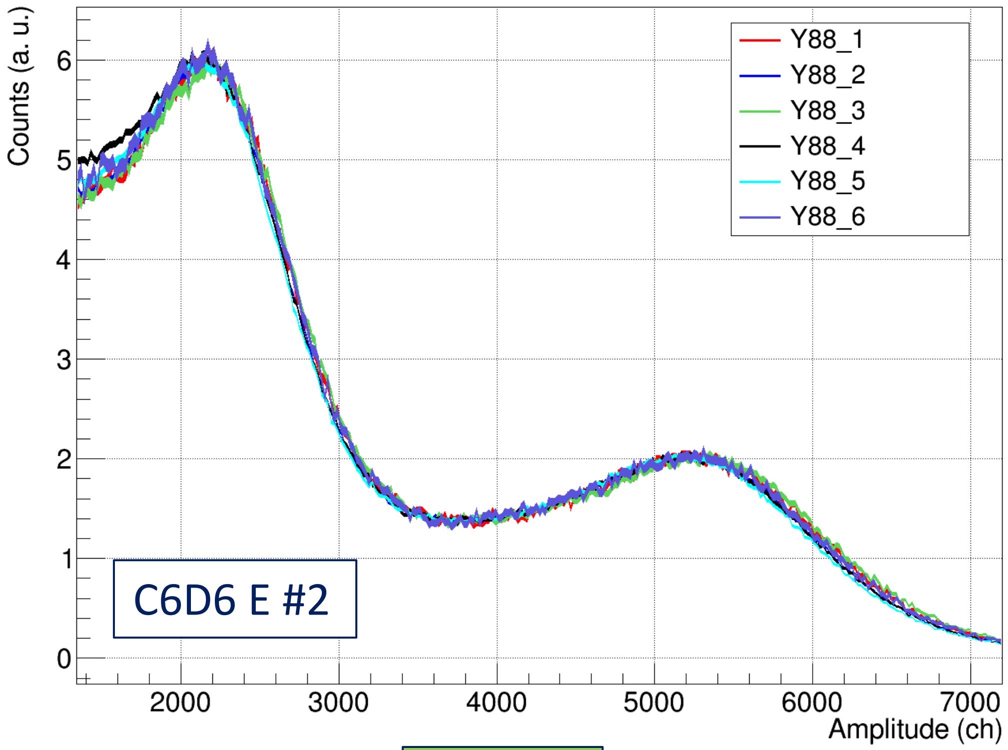






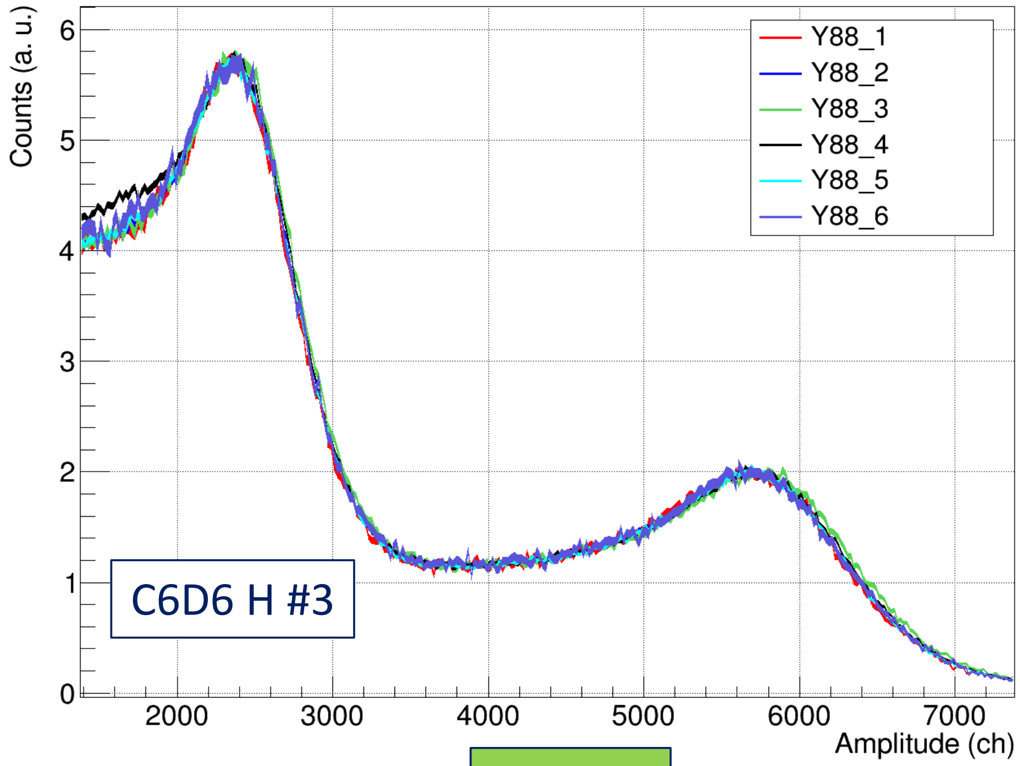
2. Gain Stability

Possible gain shift Gain stability is assessed comparing the ^{88}Y amplitude spectra of different calibration run



Stable

Max. 0.8 %

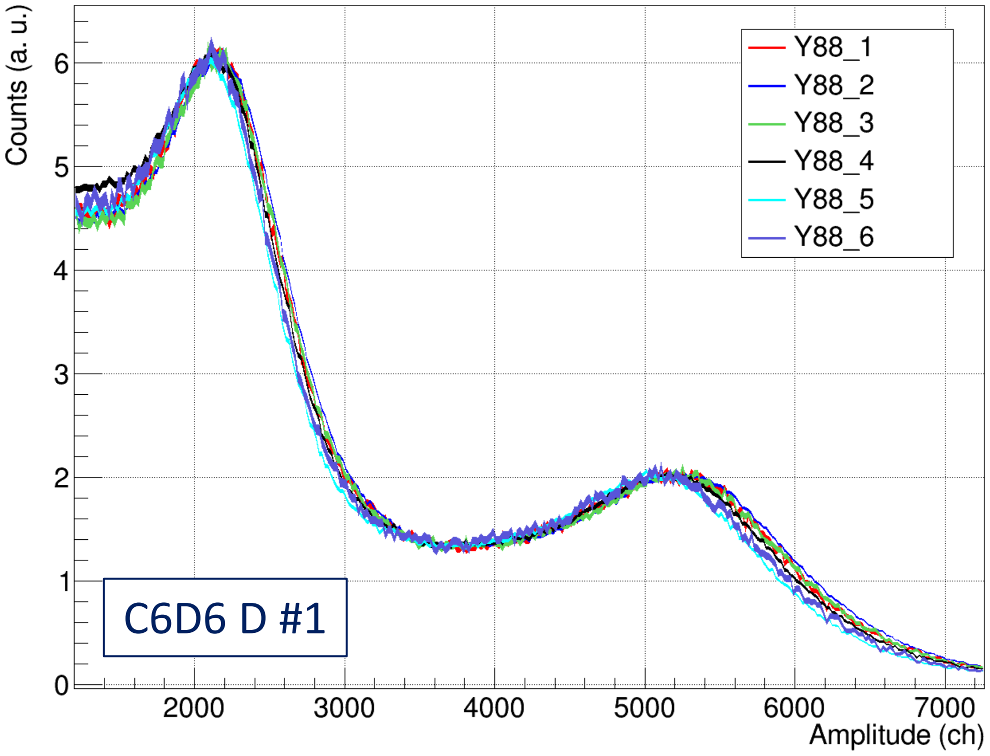


Stable

Max. 1 %

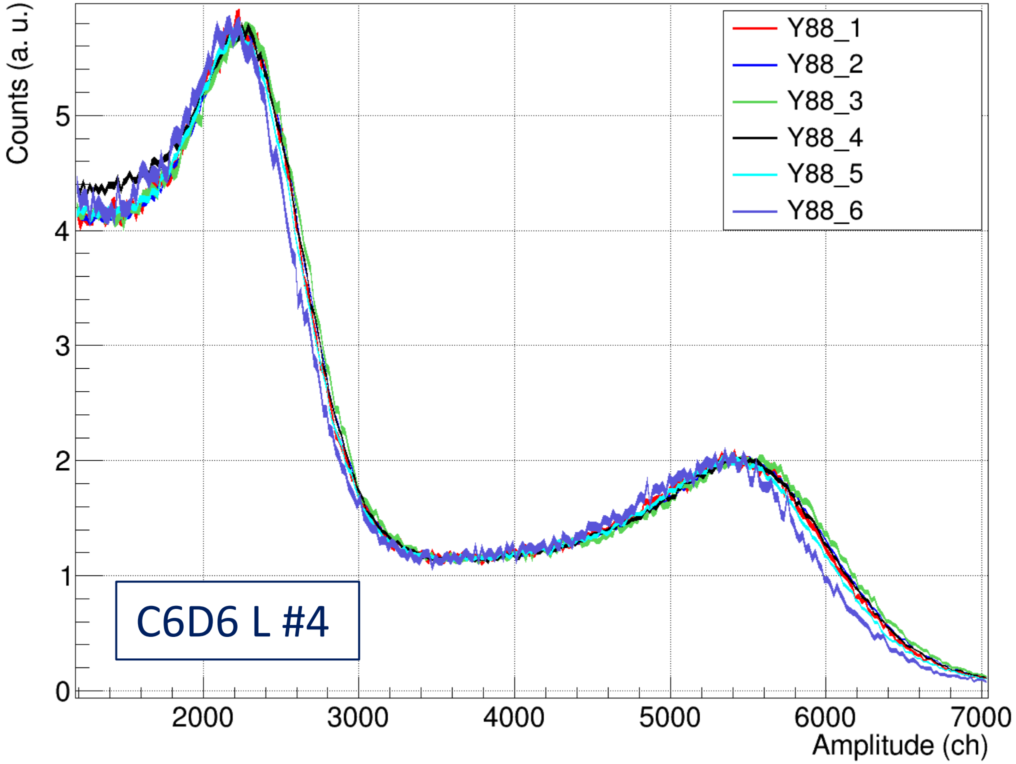
2. Gain Stability

Possible gain shift Gain stability is assessed comparing the ^{88}Y amplitude spectra of different calibration run



Fluctuating

Fluctuating within 1.7 % in first 4 run, > 3% in last 2 run
(*Si30 & Au22 enclosed within the stable time interval*)



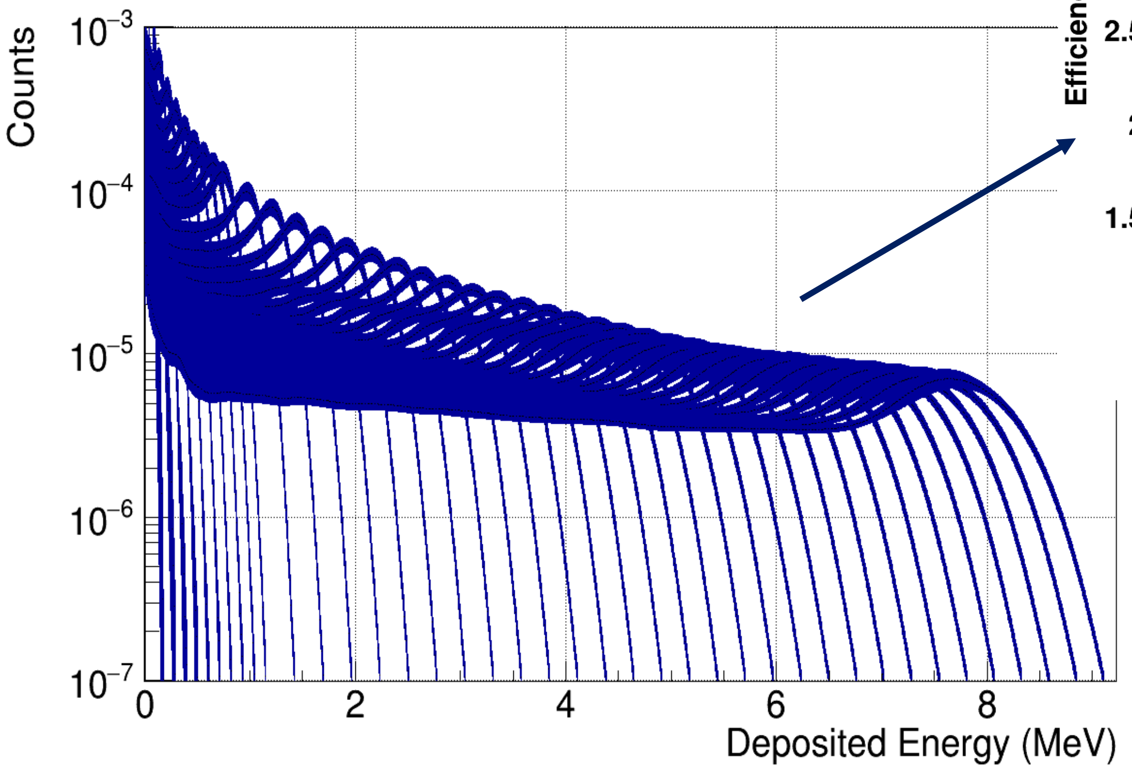
Stable before last calibration

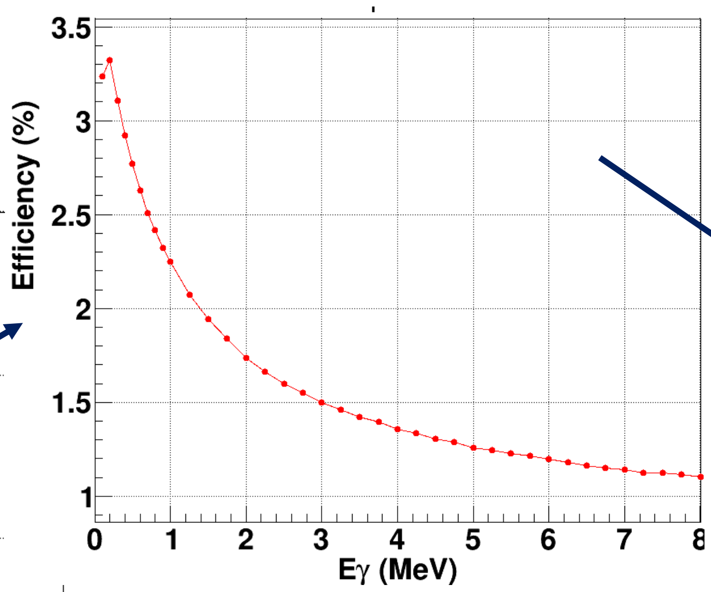
Max. 1.2 %, last calibration 2.5 %

3. Weighting Functions

Polynomial WF calculated using GEANT4 simulations of ɣ of different energy emitted from the sample to account for the **detector efficiency**.

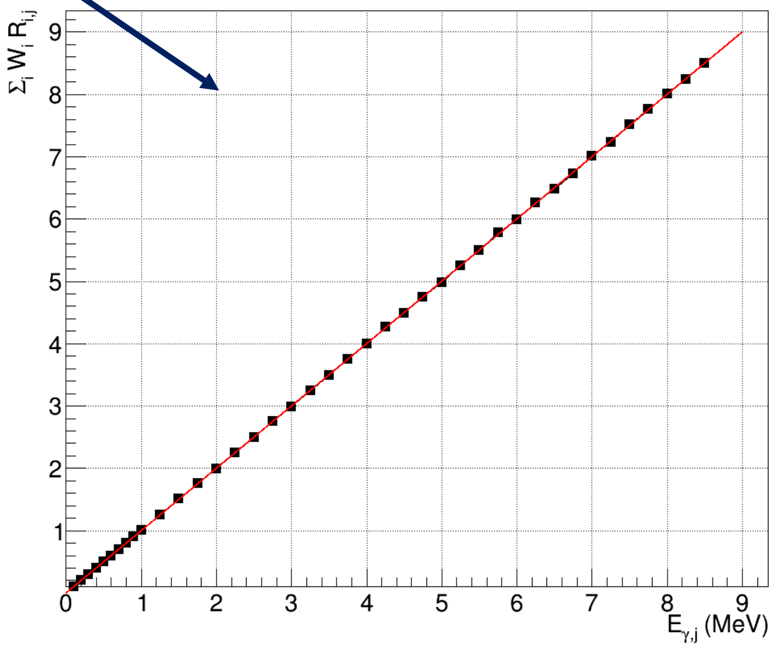
GEANT4 simulations of ɣ convoluted with Detector resolution



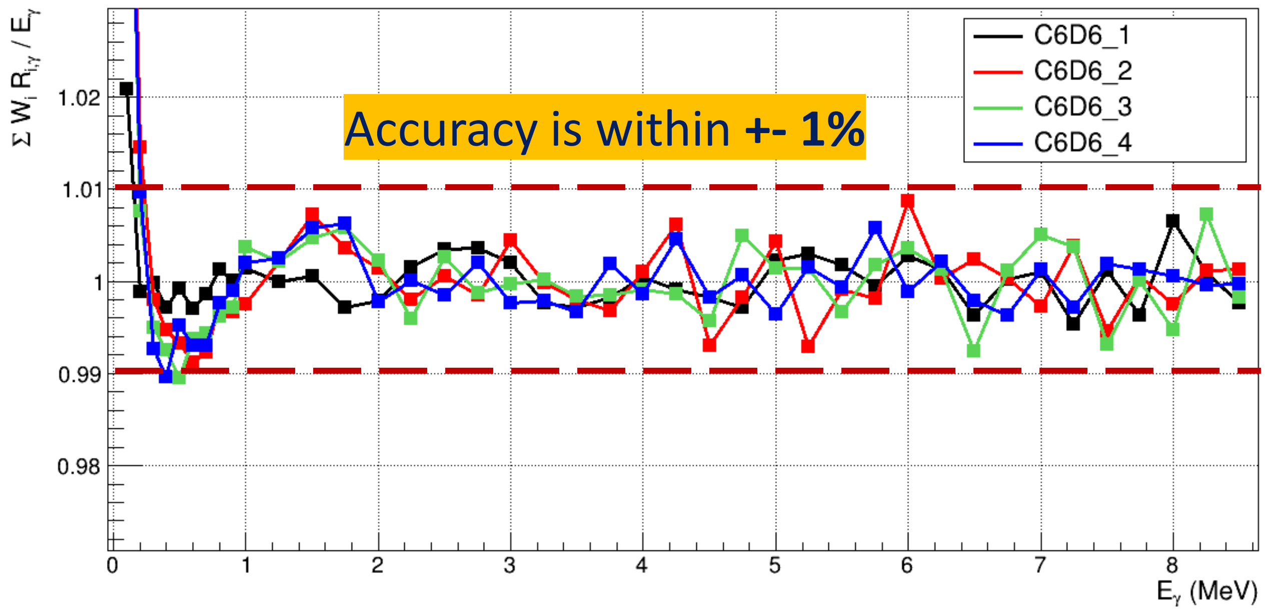


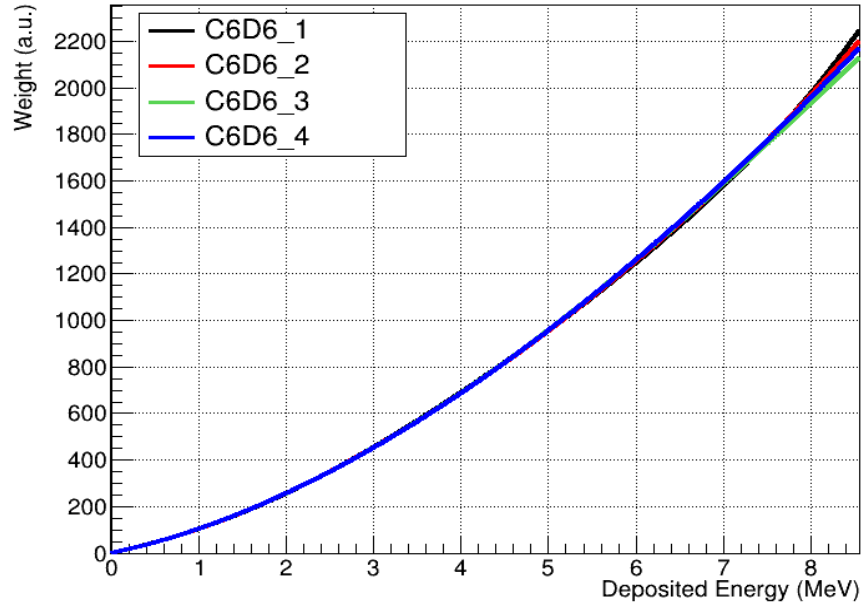
Detector efficiency for of ɣ

Weighted efficiency for of ɣ



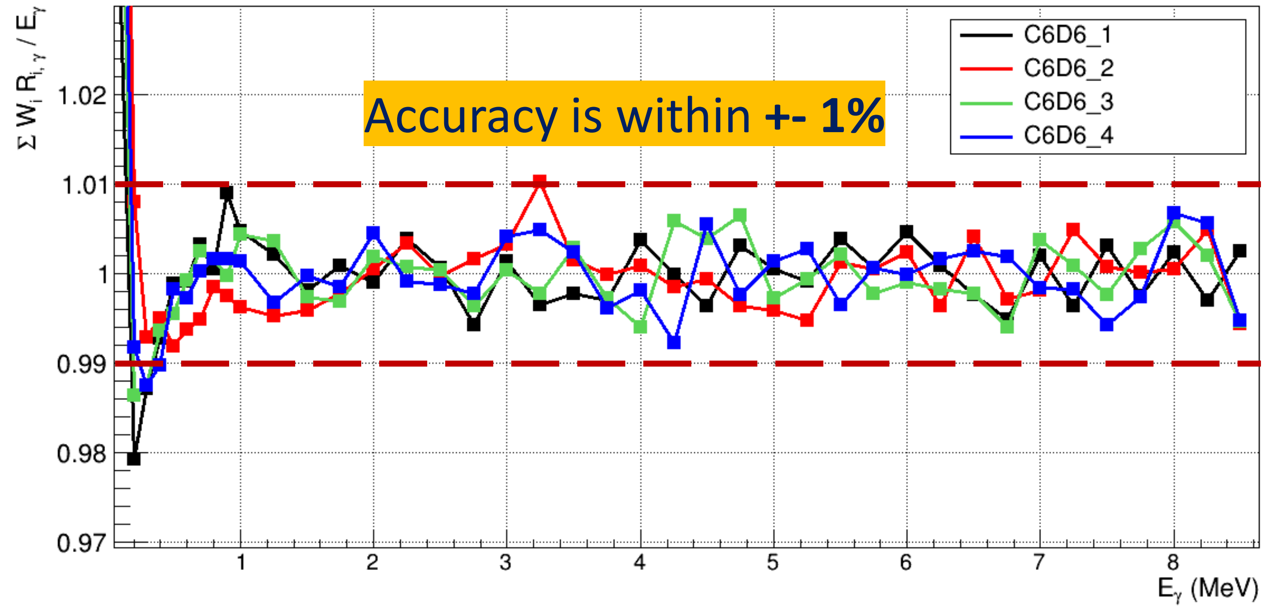
3. Weighting Functions

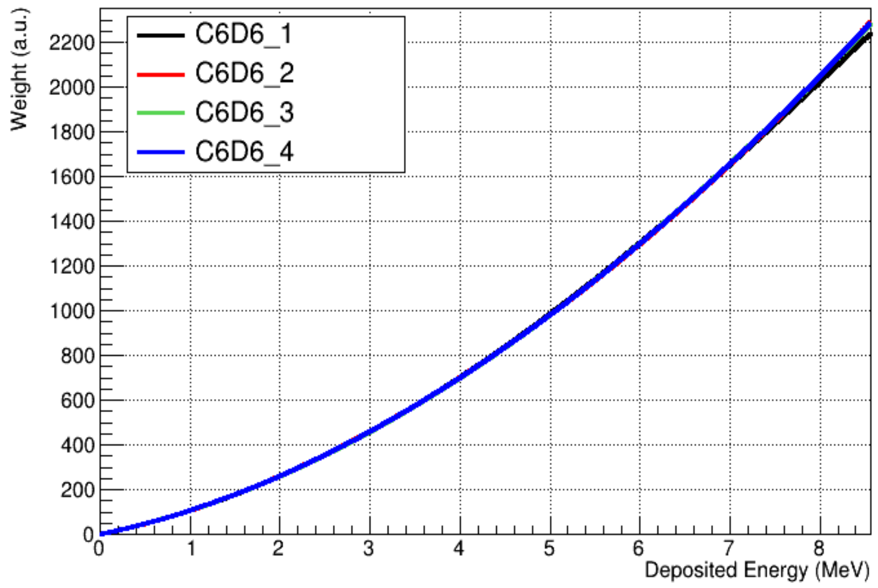




WF Au 22mm

(5^{th} order polynomial)





WF Si30

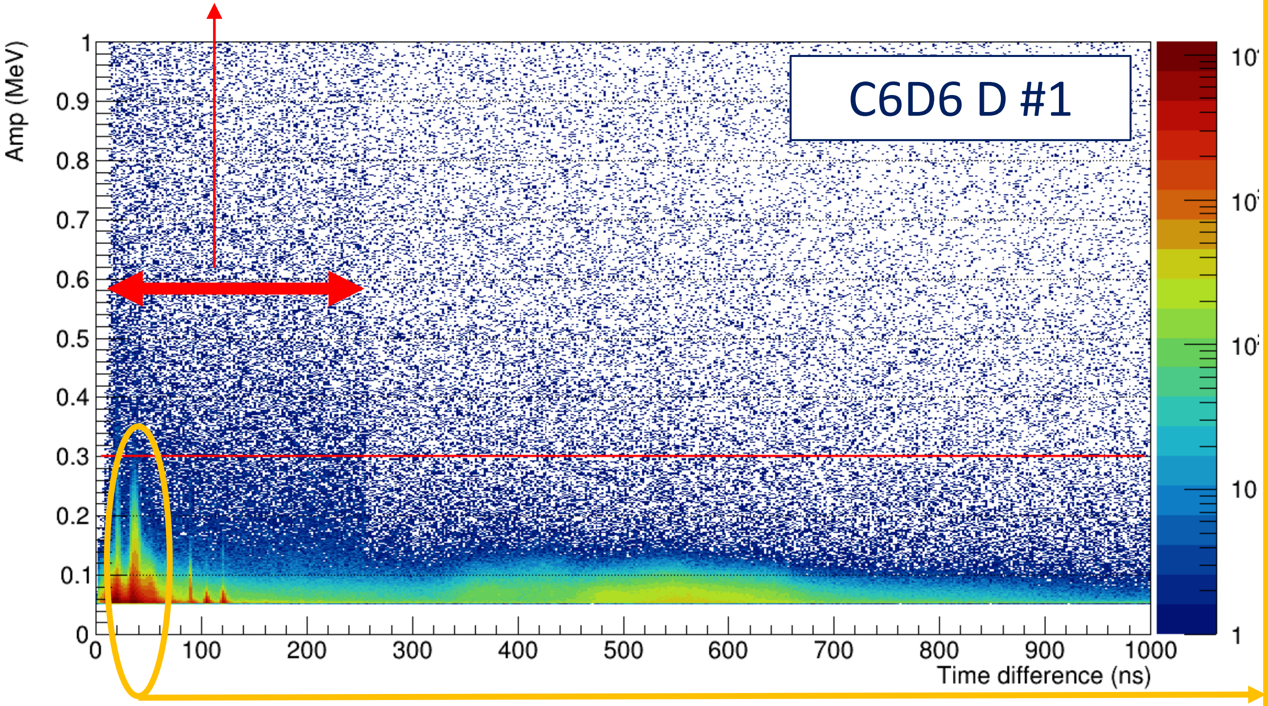
(4^{th} order polynomial)

4. Deposited Energy Thresholds

The **amplitude spectra of subsequent signals as a function of their delay** is studied in order to identify **rebounds/afterpulses** and set a suitable energy deposited threshold.

Situation with the initial (default) parameter for signal identification:

Noise in the «presample» window (256 ns)

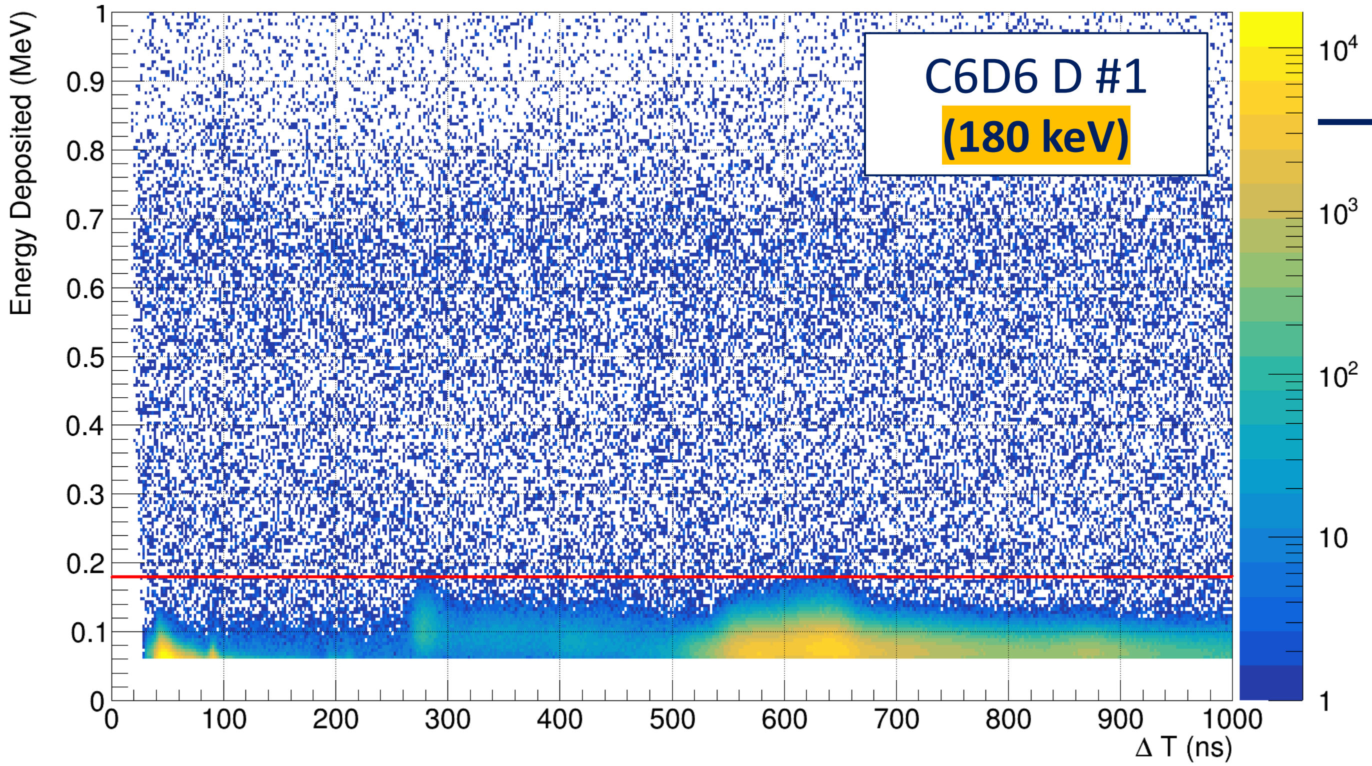


20-30 ns electronic rebounds

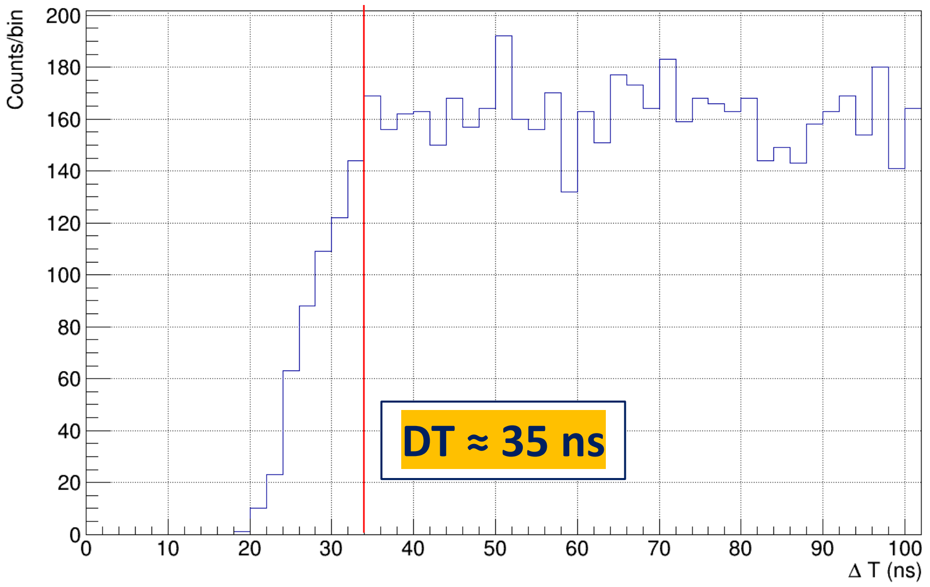
4. Deposited Energy Thresholds

The situation with new PSA parameters allows for more reasonable energy deposited thresholds :

C6D6 D #1	C6D6 E #2	C6D6 H #3	C6D6 L #4
180 keV	200 keV	170 keV	220 keV

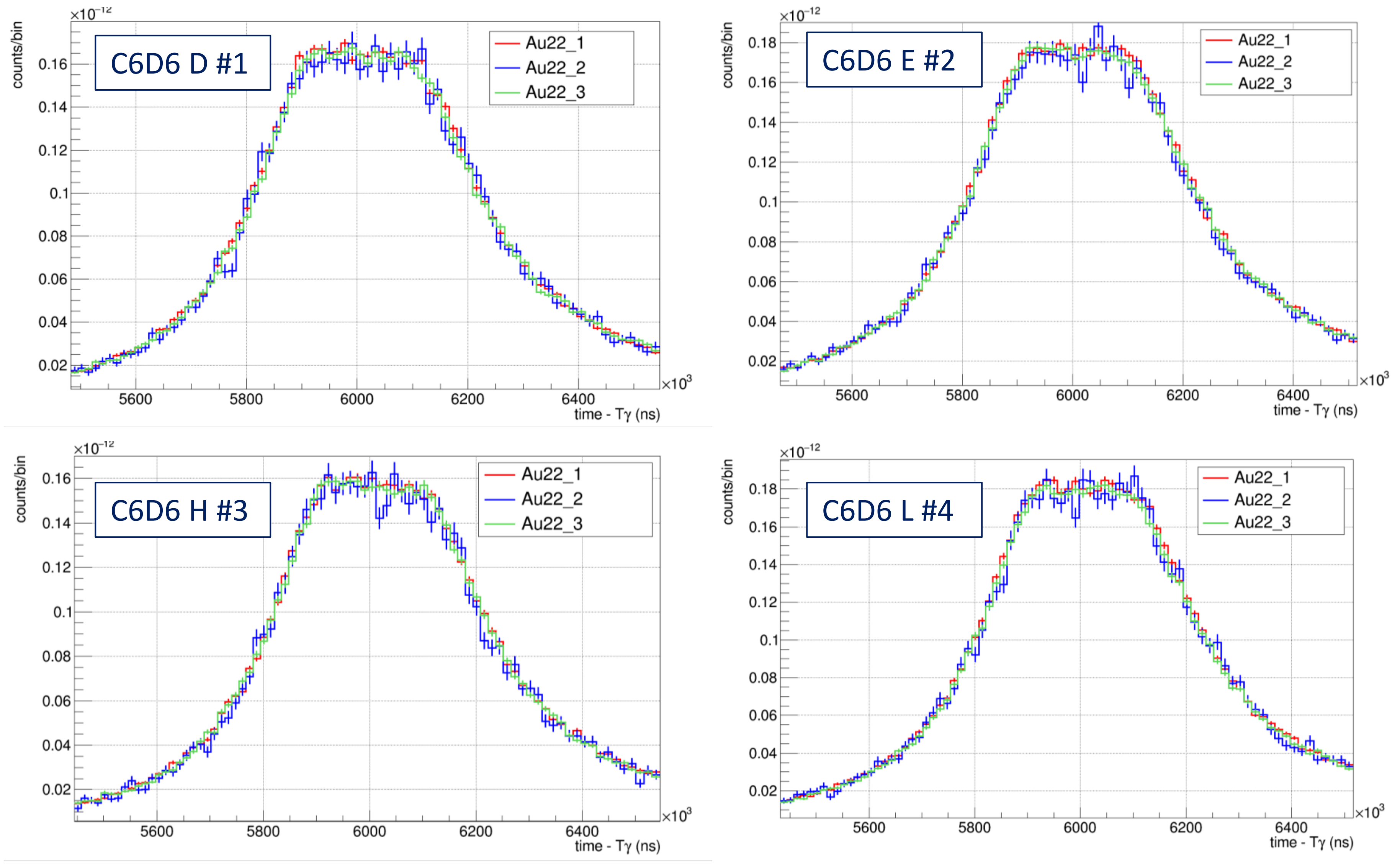


Projecting the histogram after the threshold application leads to the estimation of **deadtime**

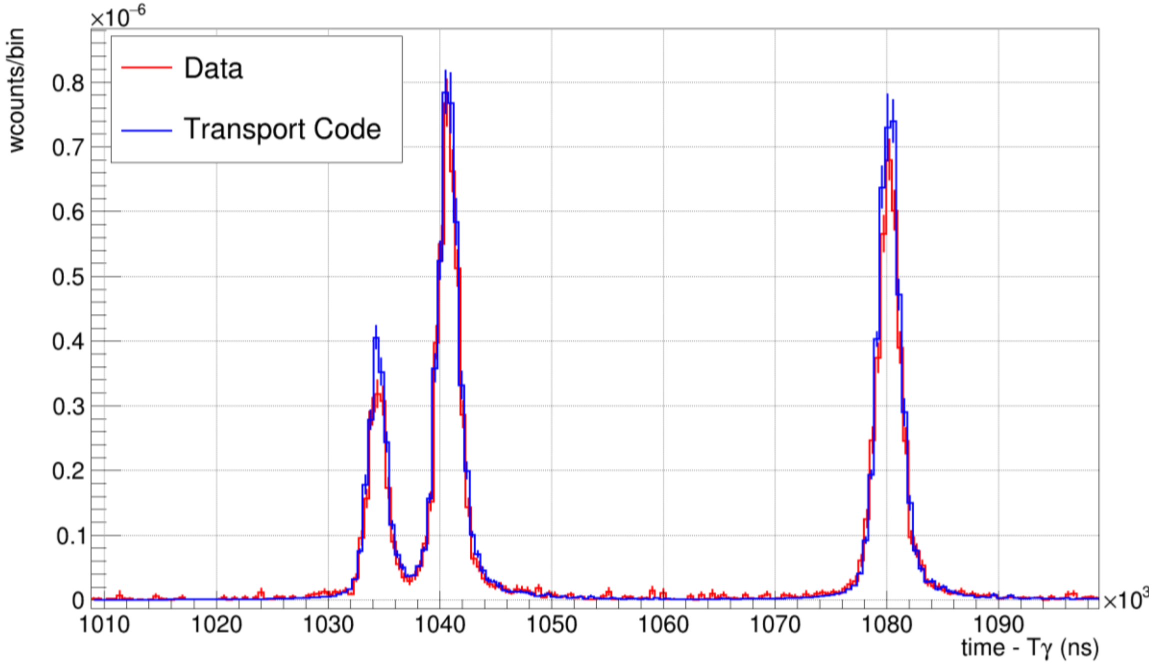


5. Gold Stability

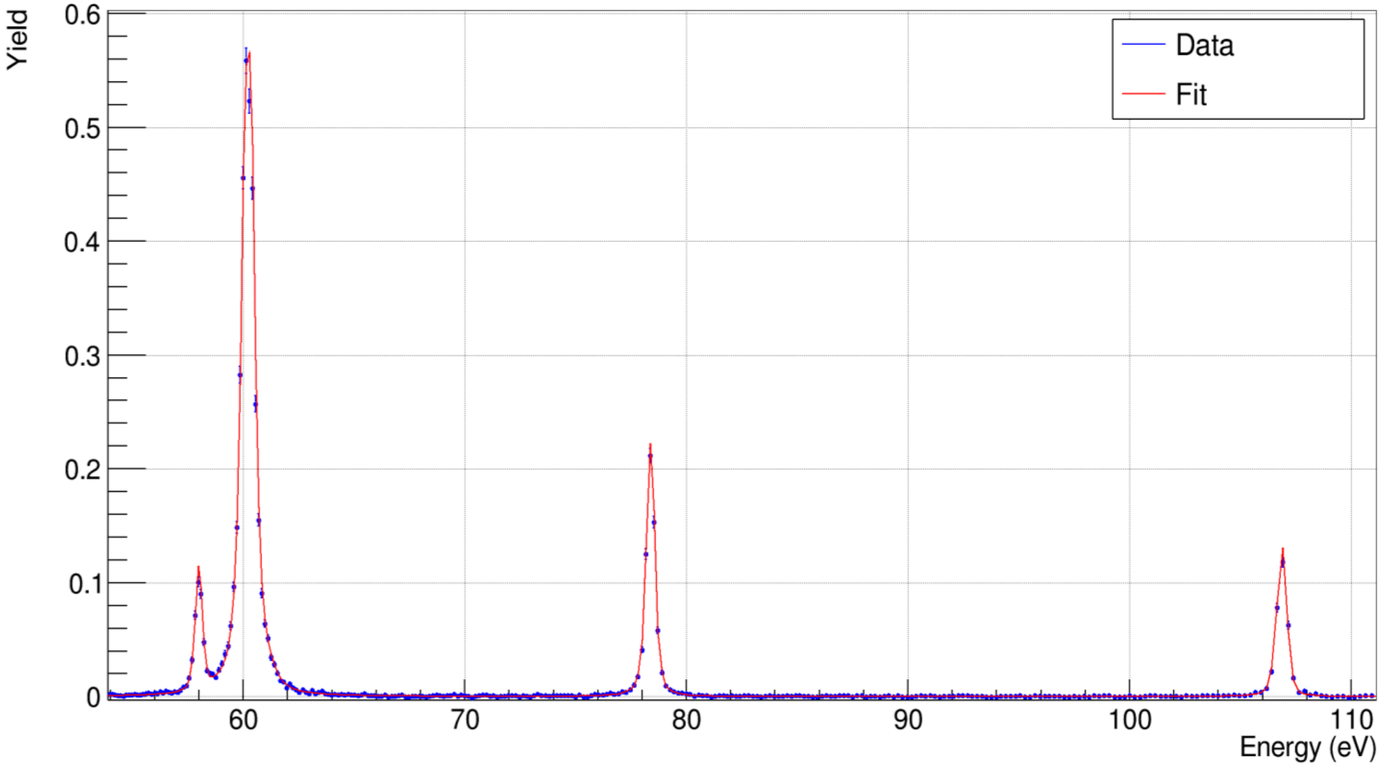
The **saturated 4.9 eV resonance of Gold** is monitored along the campaign to check the stability of the experimental setup.
All the detectors show a stable behaviour (**within 1.5 %**).



5. Gold Flight-path



A first guess of the flight-path is obtained aligning the tof spectra from data and from the **transport code**. (L ≈ 183.79 + 0.41 m)

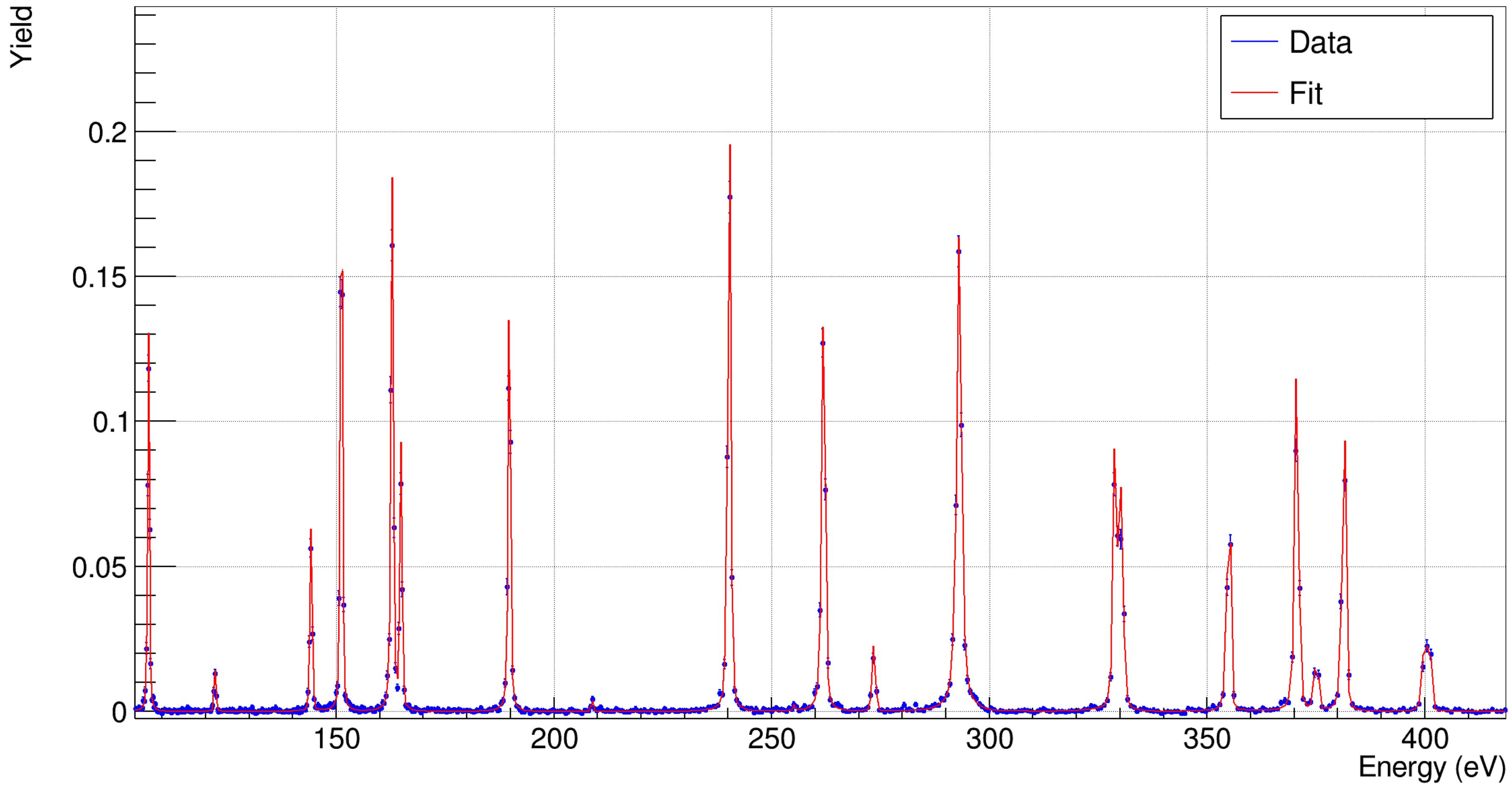


The flight-path is then refined via an **iterative procedure**, fitting the data from the first gold resonances with **Sammy**.

L = 183.794 m

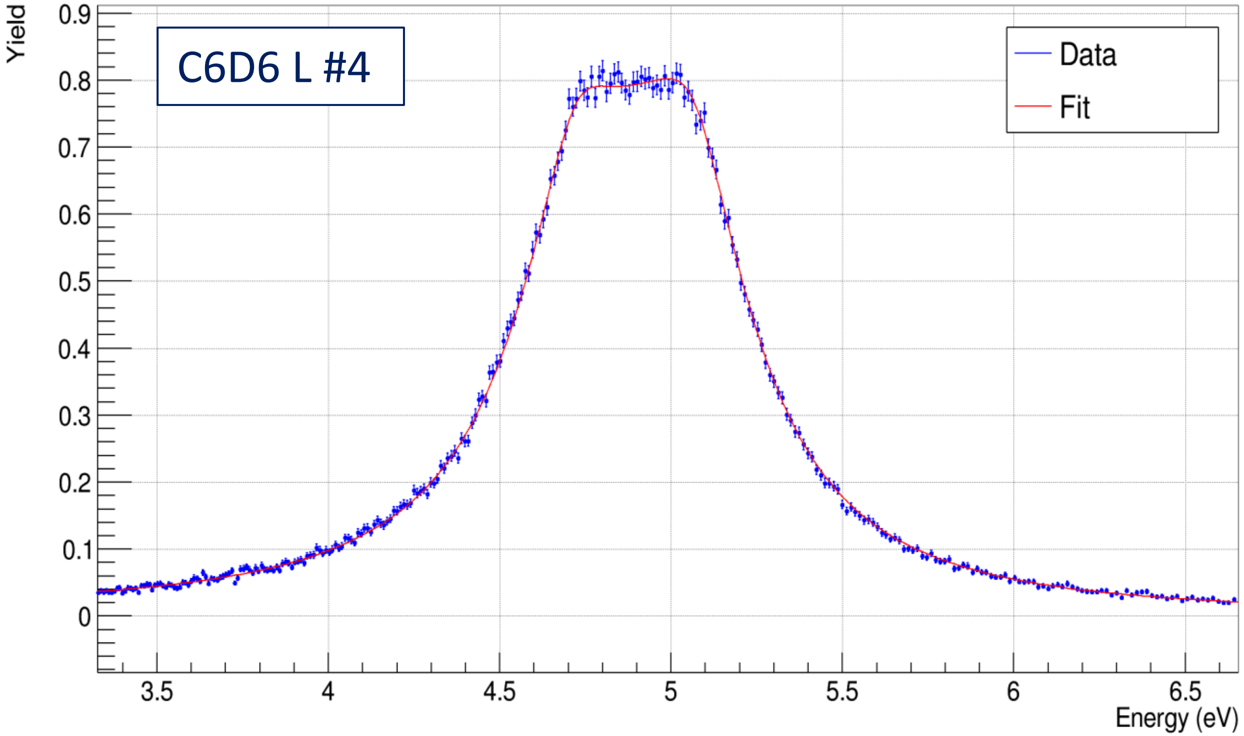
5. Gold Flight-path

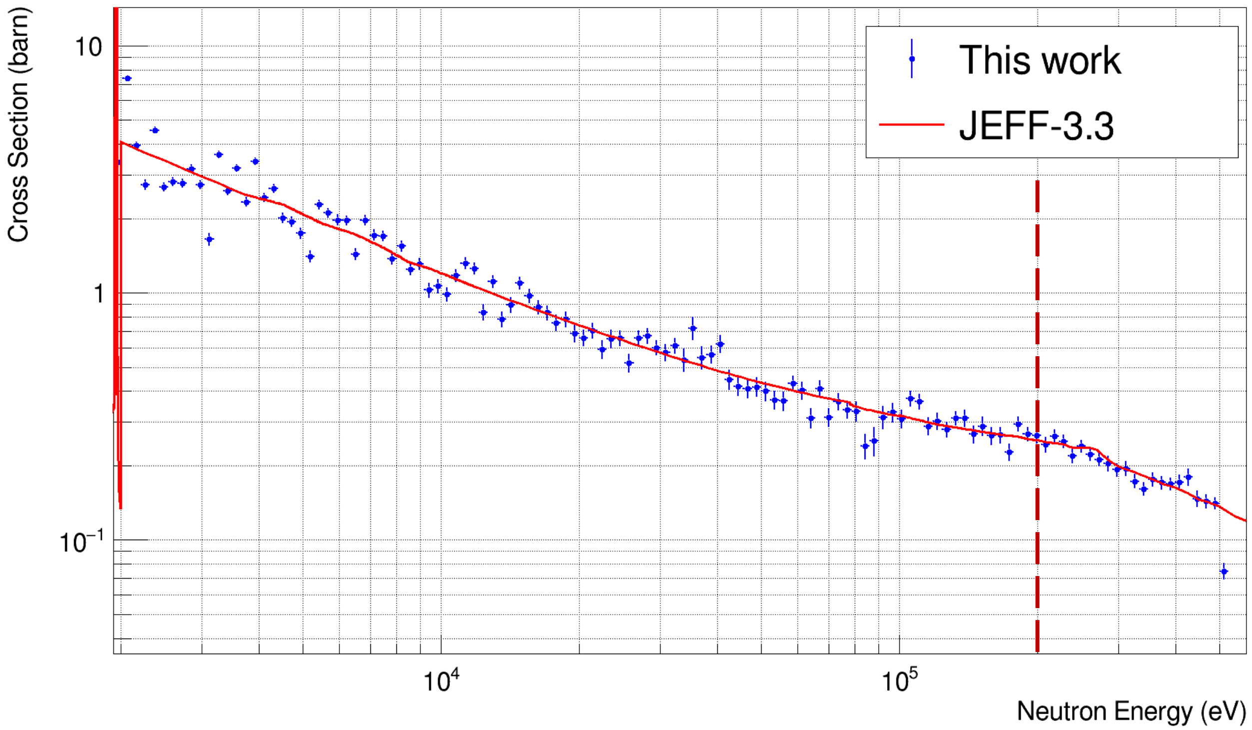
The flight-path is eventually checked to work well even for the resonances at higher energies.



5. Gold Normalization

The **saturated 4.9 eV Gold resonance** is fitted for each detector to get the normalization factor.
This normalization factor is tested at higher energy and **it reproduces the Au(n,ɣ) cross section in the continuum region** (*Au(n,γ) standard above 200 keV*).



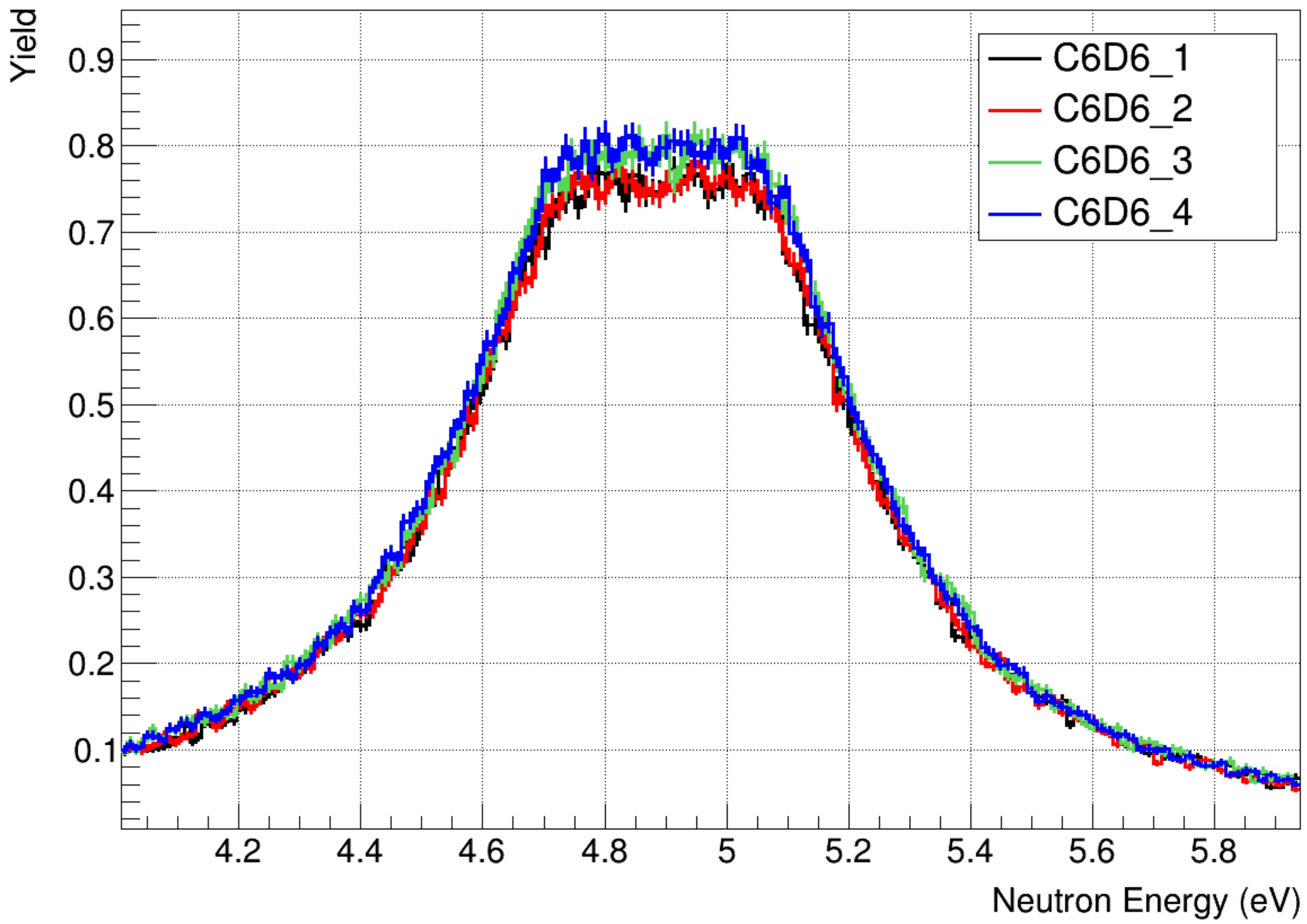


5. Gold Normalization

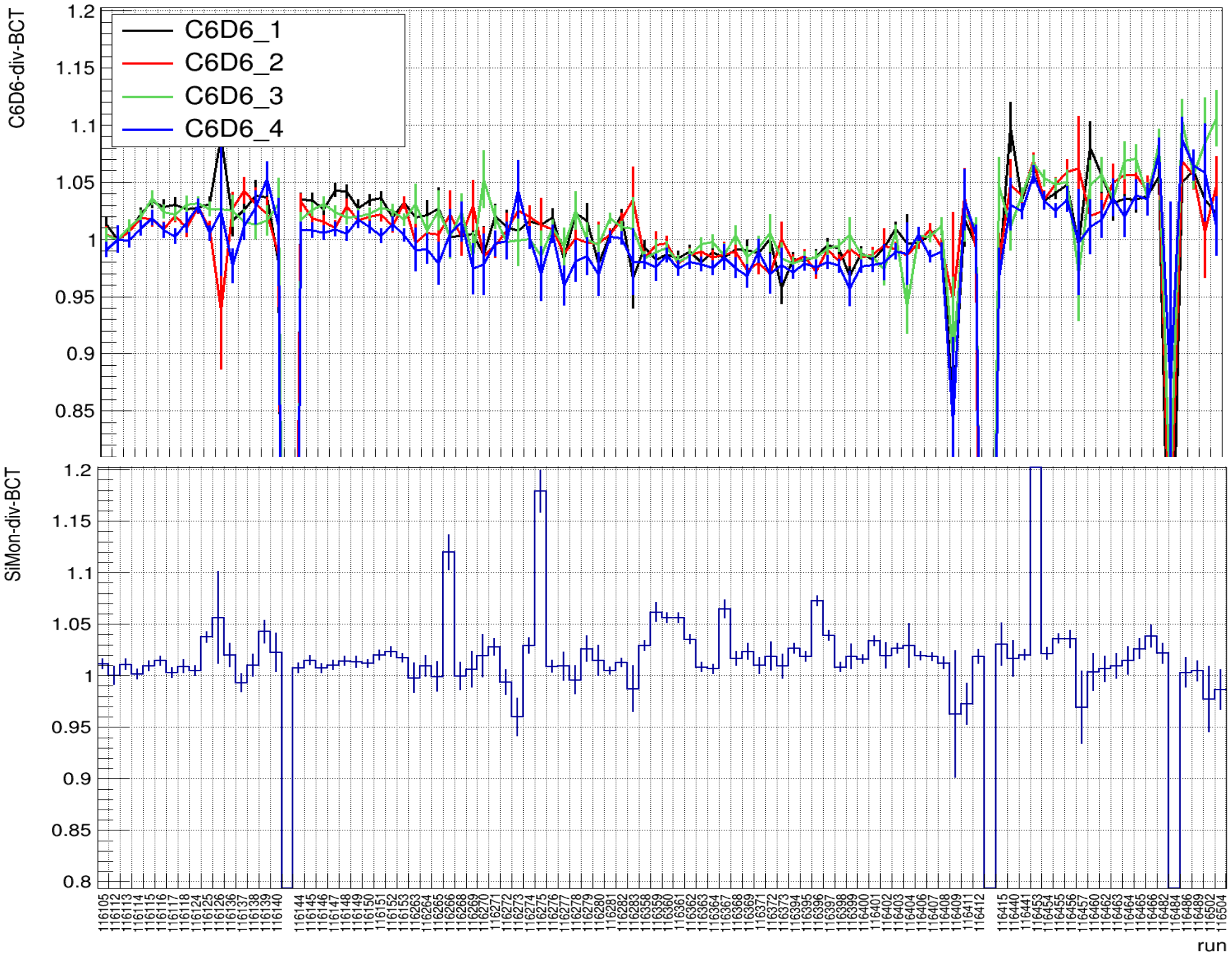
Normalization factors for different detectors have a **maximum discrepancy of 5 %.**

	Au 22 mm	Au 20 mm
C6D6 D #1	0.773036	0.686456
C6D6 E #2	0.773155	0.694770
C6D6 H #3	0.807478	0.712807
C6D6 L #4	0.812832	0.720205

BIF difference between 20 and 22 mm diameter sample is 8.89 %



6. Consistency Checks

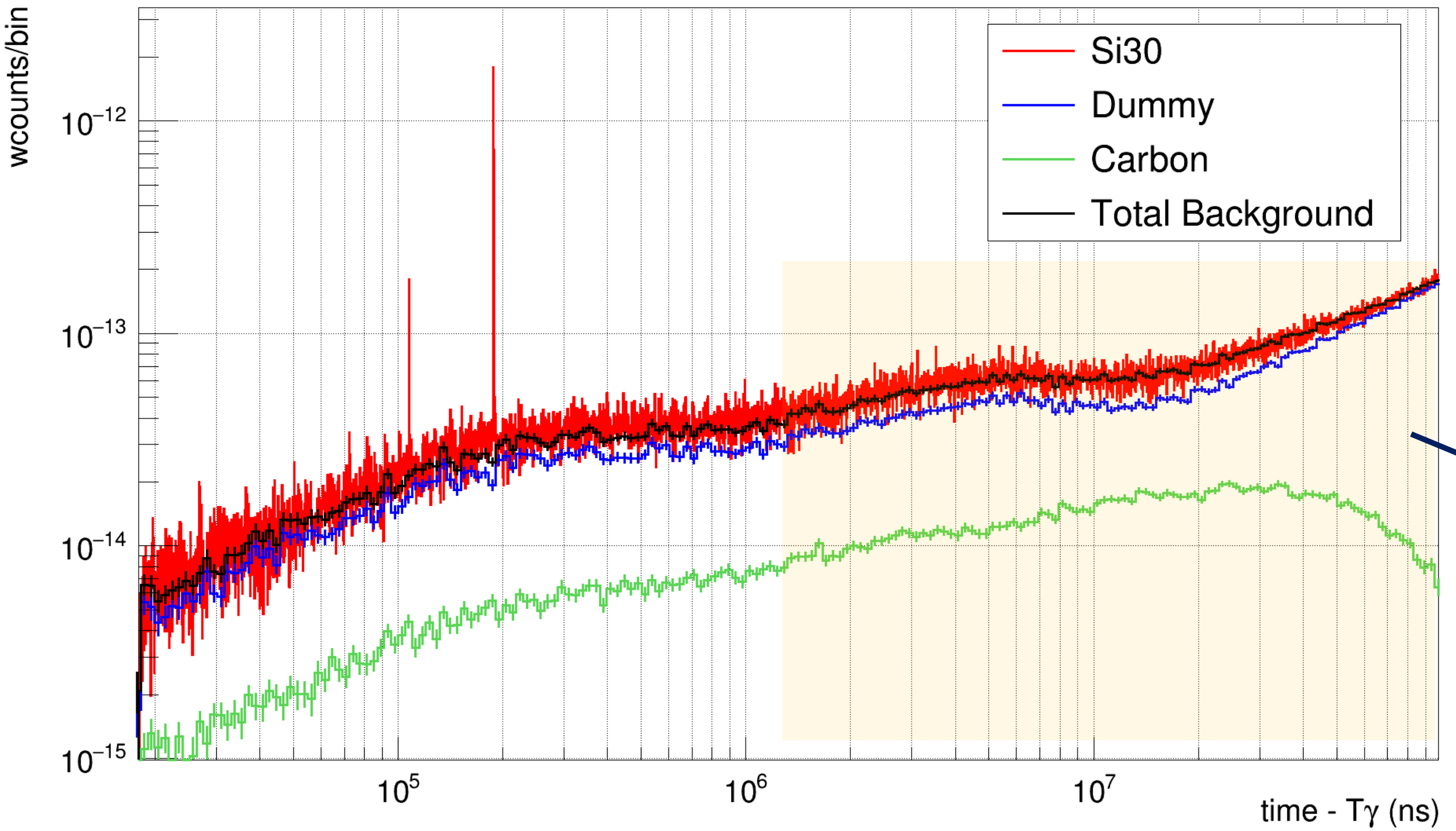


C6D6/BCT gives information on the stability of the C6D6

SiMon/BCT gives information on the stability of the beam (and SiMon itself)

7. ^{30}Si Background subtraction

^{30}Si counts have to be subtracted by the **sample-independent background** (**Dummy**) and by the **neutron scattering background** component (estimated **rescaling Carbon** counts).



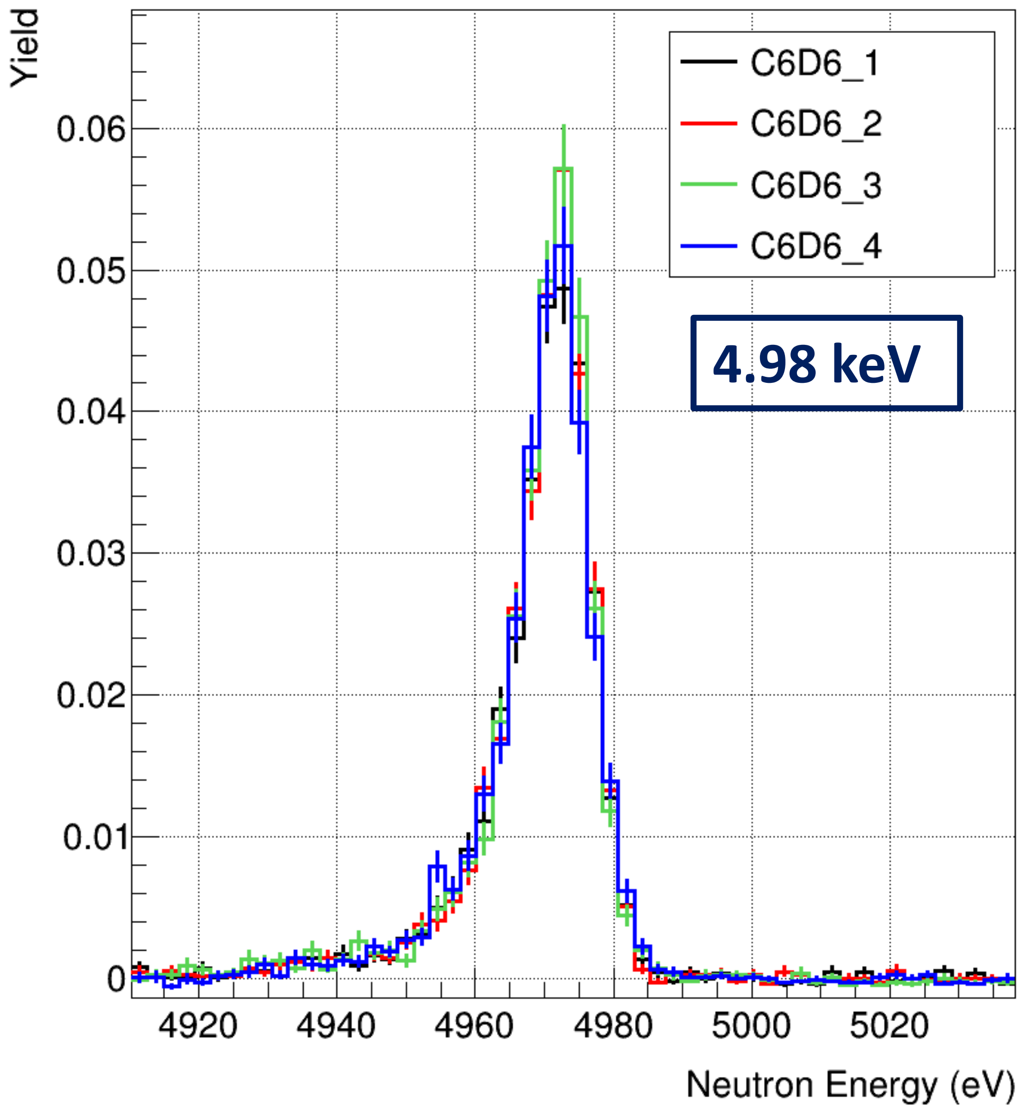
Neutron sensitivity in the resonances is still missing!

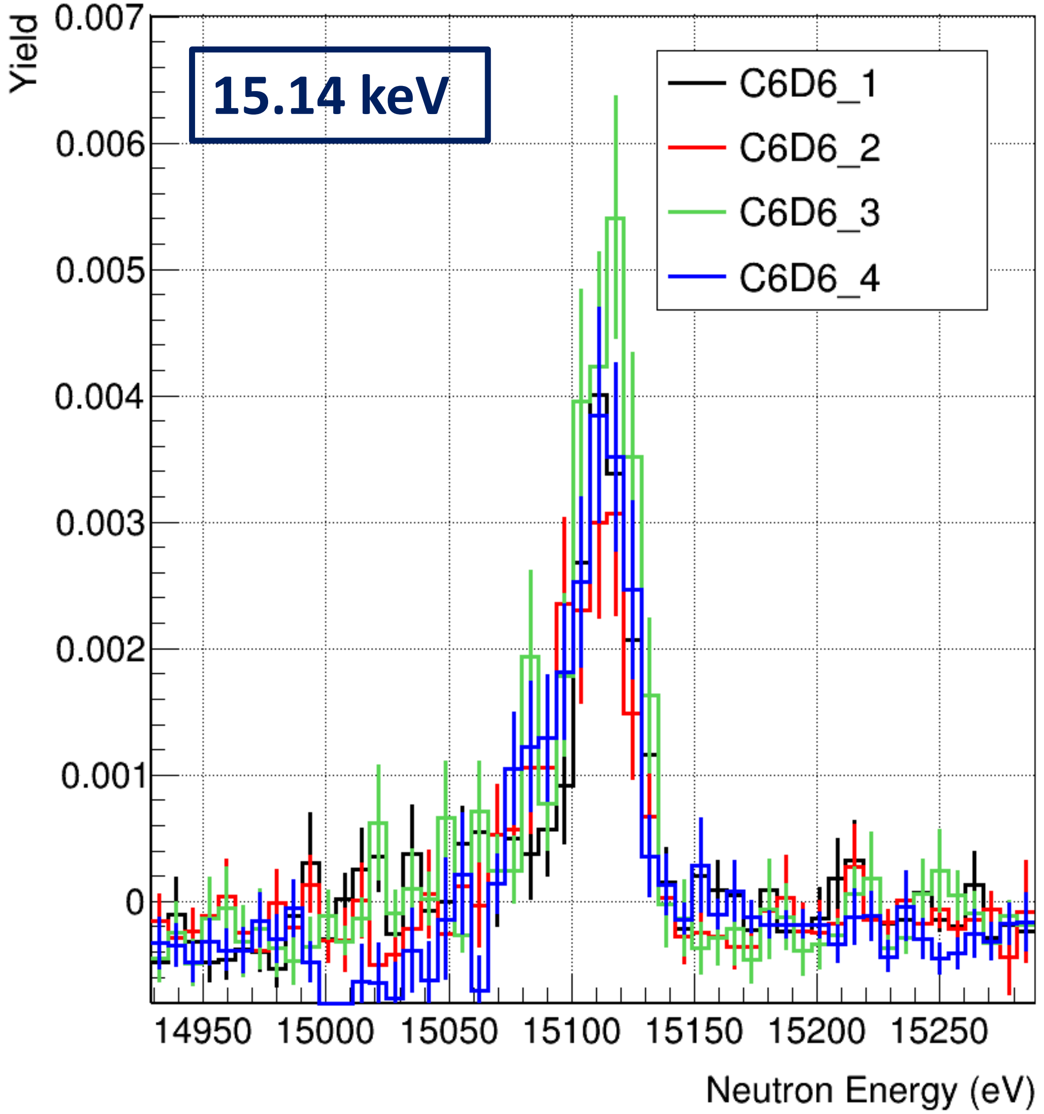
Estimated background larger than ^{30}Si counts: **is Carbon reliable?**

P. Zugec et al., *NIM A 826 (2016) 80–89*

7. ^{30}Si Yield

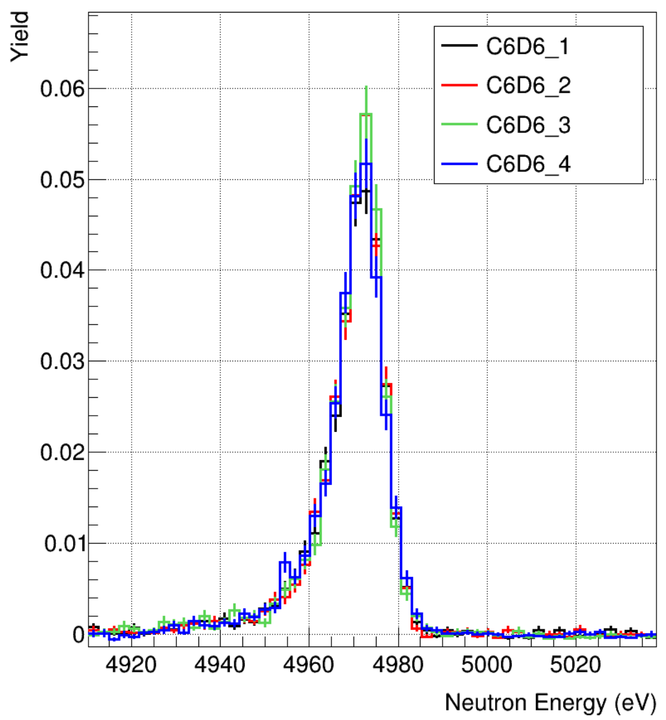
5000 bpd
Already normalized to Gold

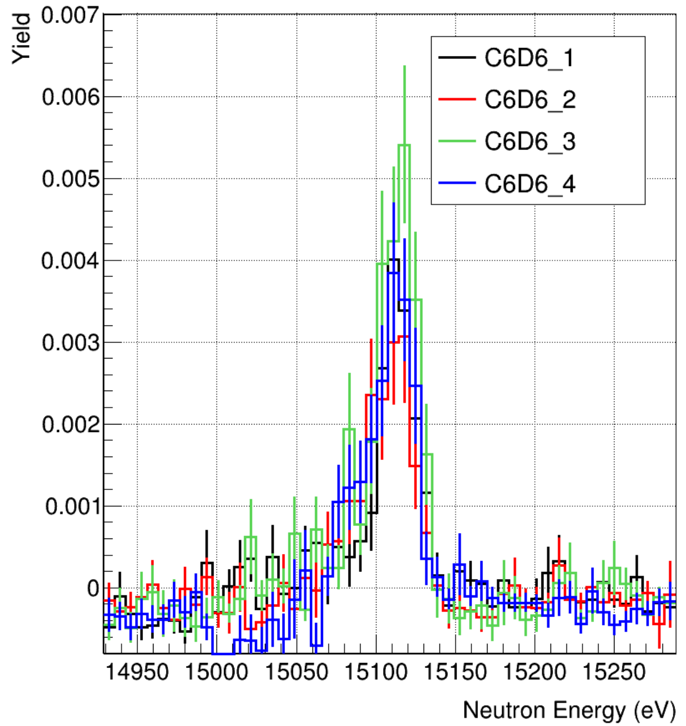


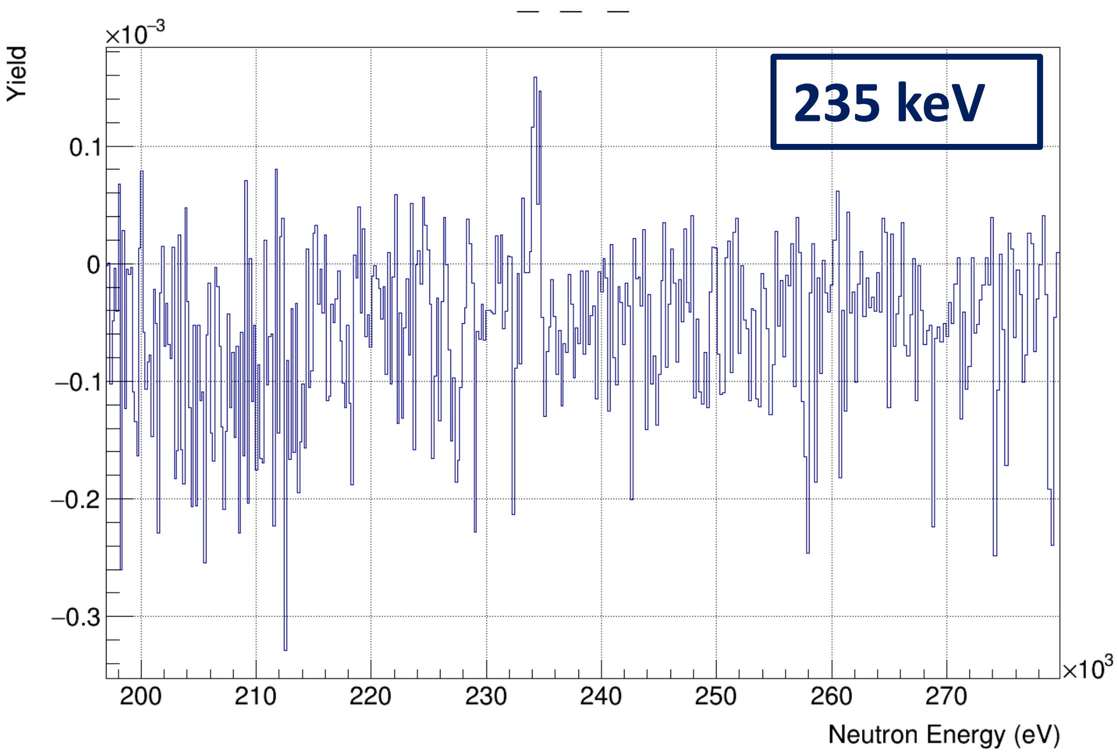


7. ^{30}Si Next Steps

- **Check background higher than signal** (region of negative yield)
- **Check if the differences between the detectors are within the statistical uncertainty** (resonance integral, Sammy)
- **Second-order correction to the yield**: neutron sensitivity, counts below threshold, …
- **Resonance fitting with Sammy**







Summary

$^{64}Ni(n,\gamma)$

- Measurement EAR2
- Preliminary results
- Detector calibrations
- WF
- Yield
- Resonance Fitting

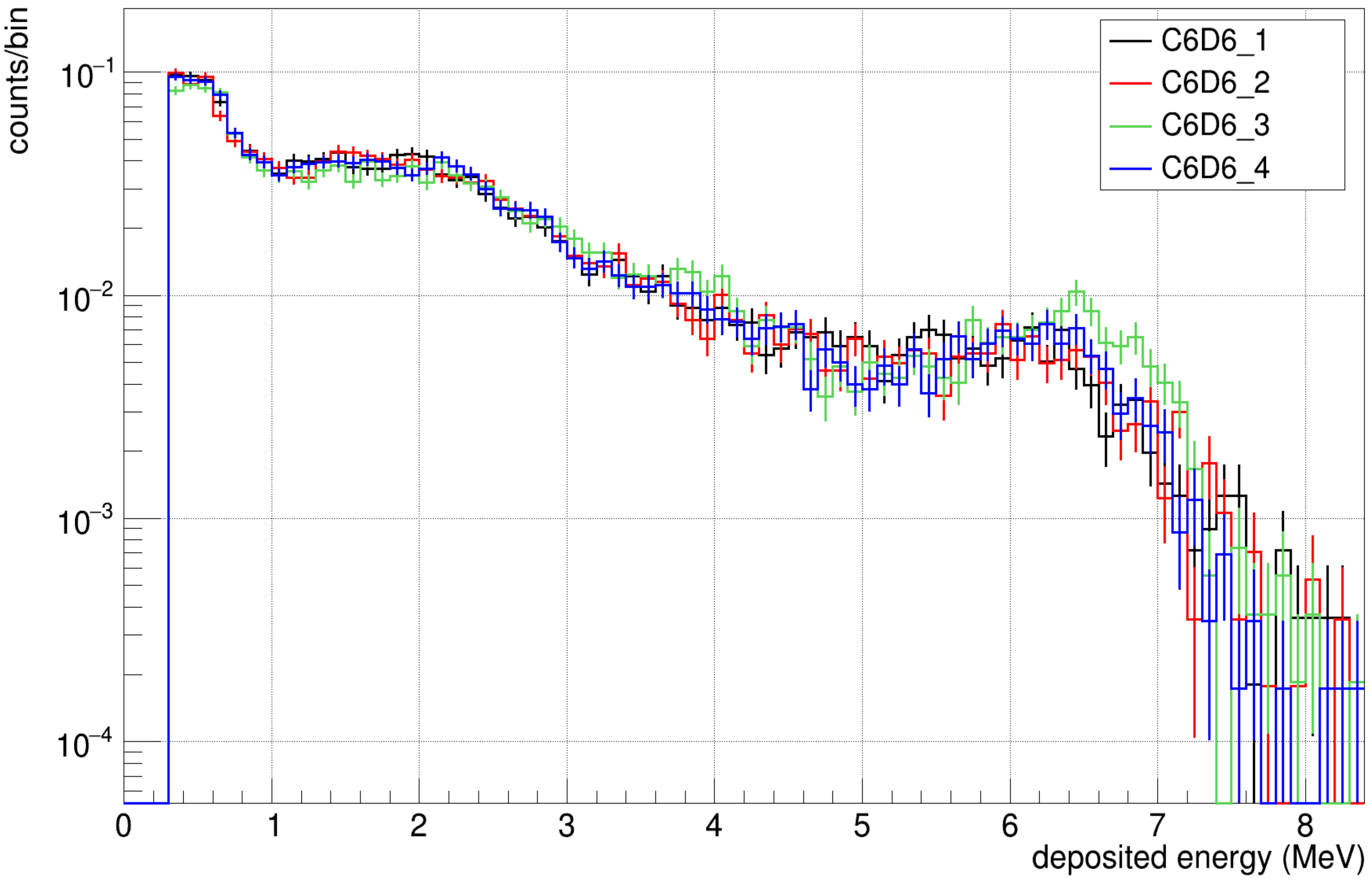
$^{30}Si(n,\gamma)$

- Measurement EAR1 & EAR2
- Preliminary results EAR1
- Detector calibrations EAR1
- WF EAR1
- Measurement ^{28}Si,$^{29}Si(n,\gamma)$
- Yield EAR1
- Resonance Fitting EAR1
- Analysis EAR2 (thermal)

$^{30}Si(n,\gamma)$: Status of the Analysis

Michele Spelta

7. ^{30}Si De-excitation spectrum



$^{30}Si(n,\gamma)$: State of the art

Only **a few discrepant measurements available** in literature, leading to discrepant MACS

▼ **Recommended MACS30** (Maxwellian Averaged Cross Section @ 30keV)

$$^{30}Si\,(n,\gamma)^{31}Si$$

Total MACS at 30keV: 1.82 ± 0.33 mb

Cross sections do not include stellar enhancement factors!

▸ History

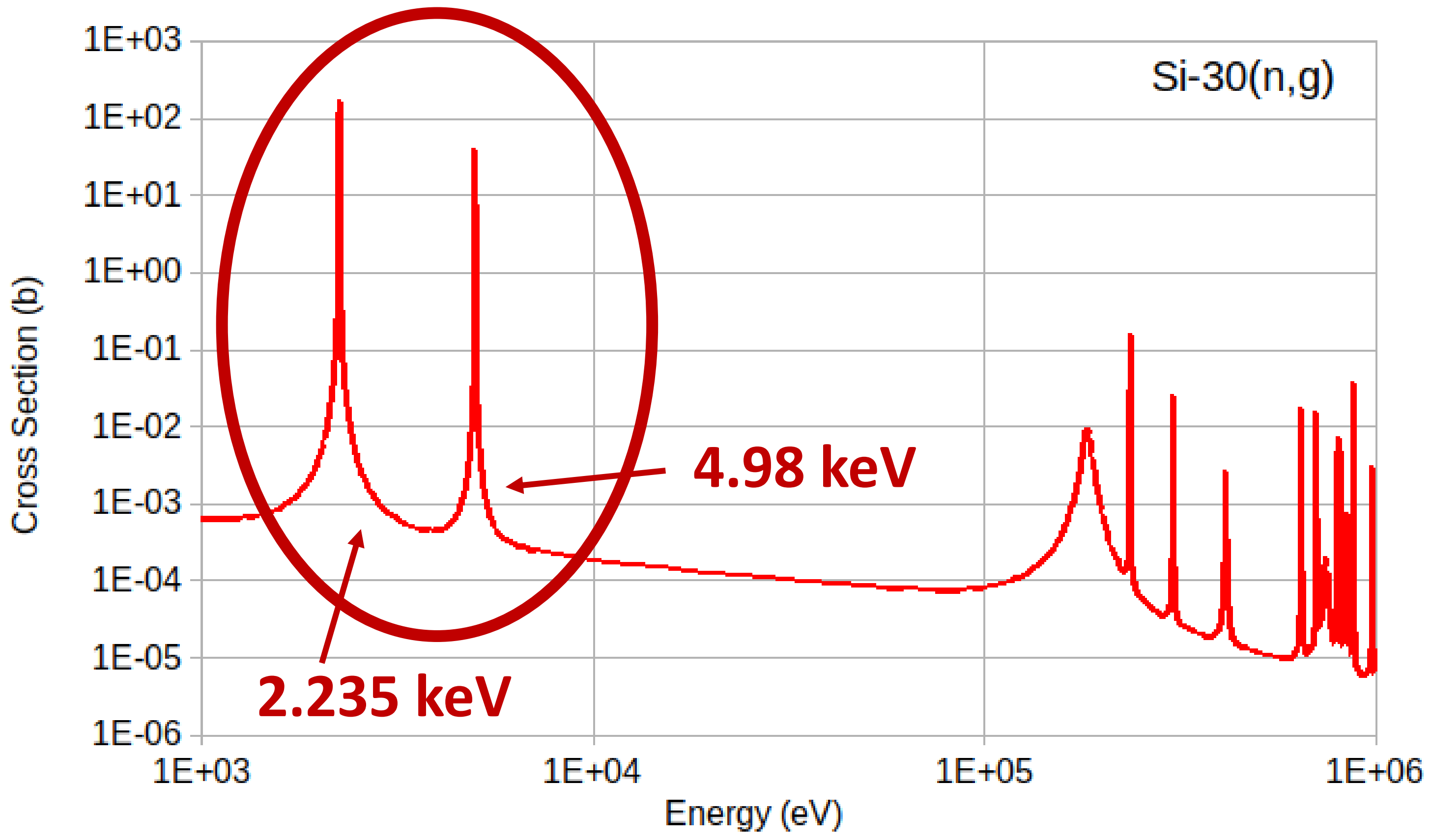
***H. Beer et al.**, Nucl. Phys. A 453, 062802 (2002)*

▸ Comment

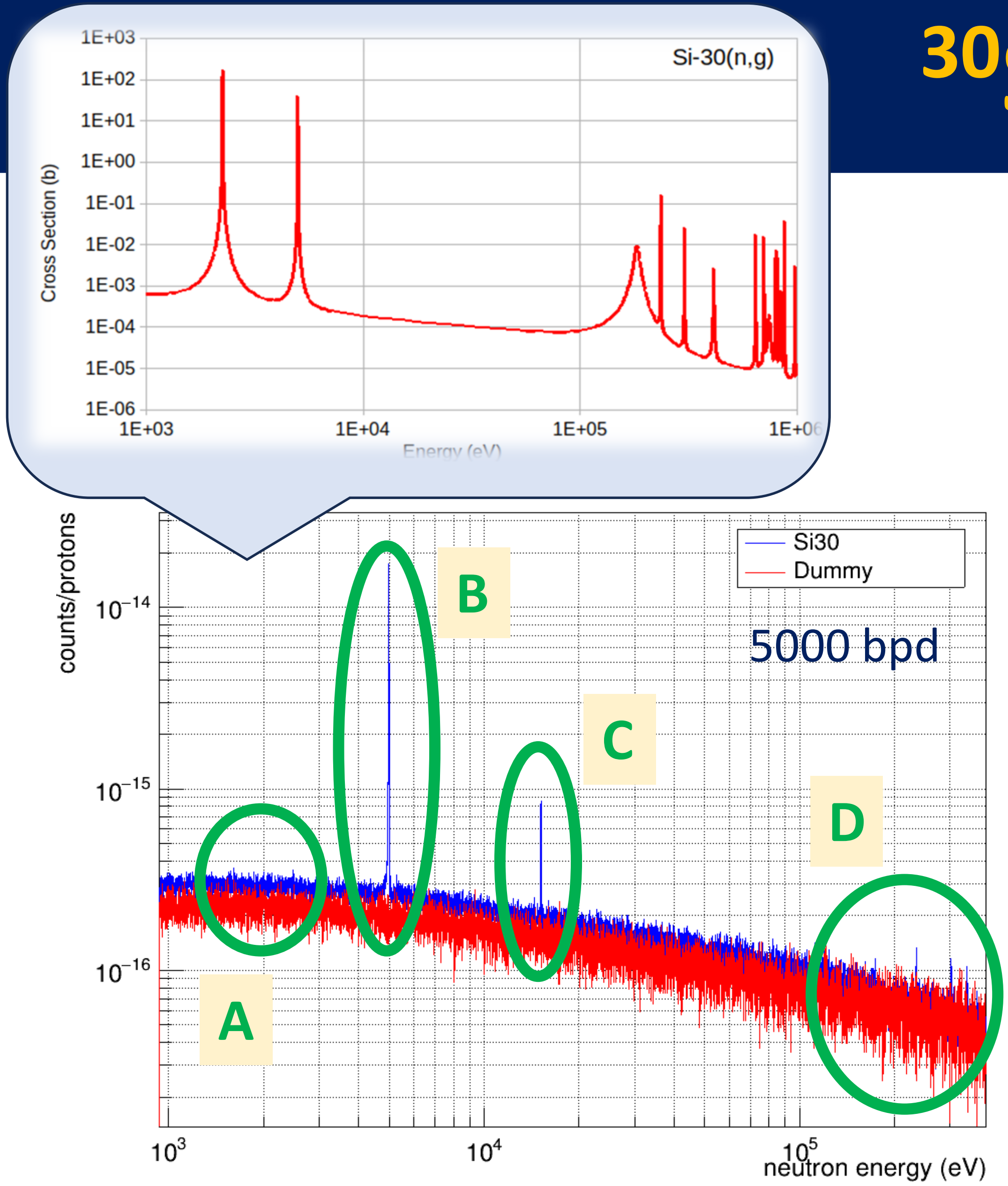
***K. Guber et al.**, Phys. Rev. C 67, 062802 (2003)*

▼ List of all available values

original	renorm.	year	type	Comment
1.82 ± 0.33		2003	[illegible]	Linac, TOF, Au: Sat.; DC component is 0.48 (30) mb; no res. at
3.51 ± 0.15 kT= 25 keV	3.24 ± 0.14	2002,2015	[illegible]	VdG, Act., Au:RaK88 corrected by 632 mb/586 mb= 1.0785; D(
0.72 ± 0.07 kT= 52 keV		2002	c	VdG, Act., Au:RaK88
6.5 ± 0.6		1975	r	Linac, TOF, ^{6}Li, Au:Sat. Recalcul. including data of MDH81



$^{30}Si(n,\gamma)$: Preliminary Results



C. Resonance at 15.14 keV

J. Boldeman et al.,
Nucl. Phys. A252, 62 (1975)