$^{30}Si(n,\gamma)$ & $^{64}Ni(n,\gamma)$: Status of the Analysis

Michele Spelta

^{64}Ni(n,γ): Motivations

RECAP

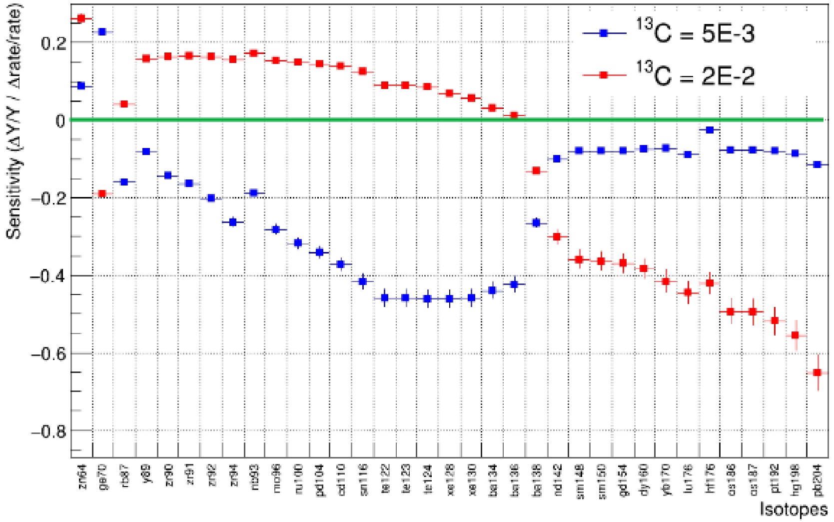
^{64}Ni(n, γ) cross section is important:

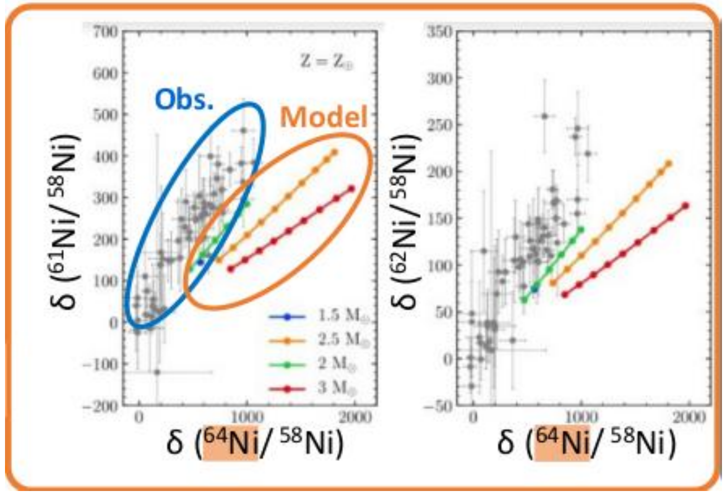
- because, as a **seed of the s-process**, it affects the abundances of many isotopes synthesized in the process

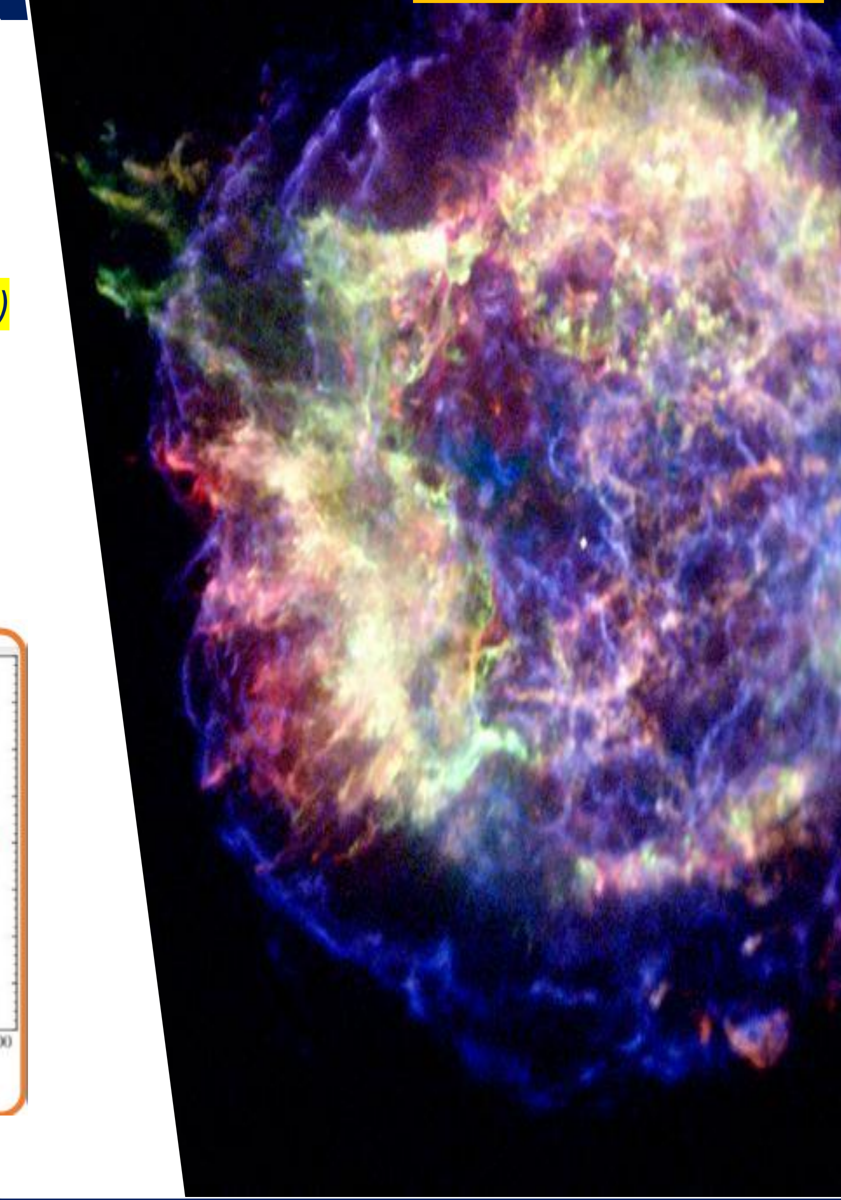
  ***Cescutti et al.**, MNRAS 478, 4101 (2018)*

- to possibly explain the **discrepancy observed in SiC grains** between measured and predicted ^{64}Ni isotopic abundances

  ***Vescovi et al.**, ApJ Lett 897, 25 (2020)*



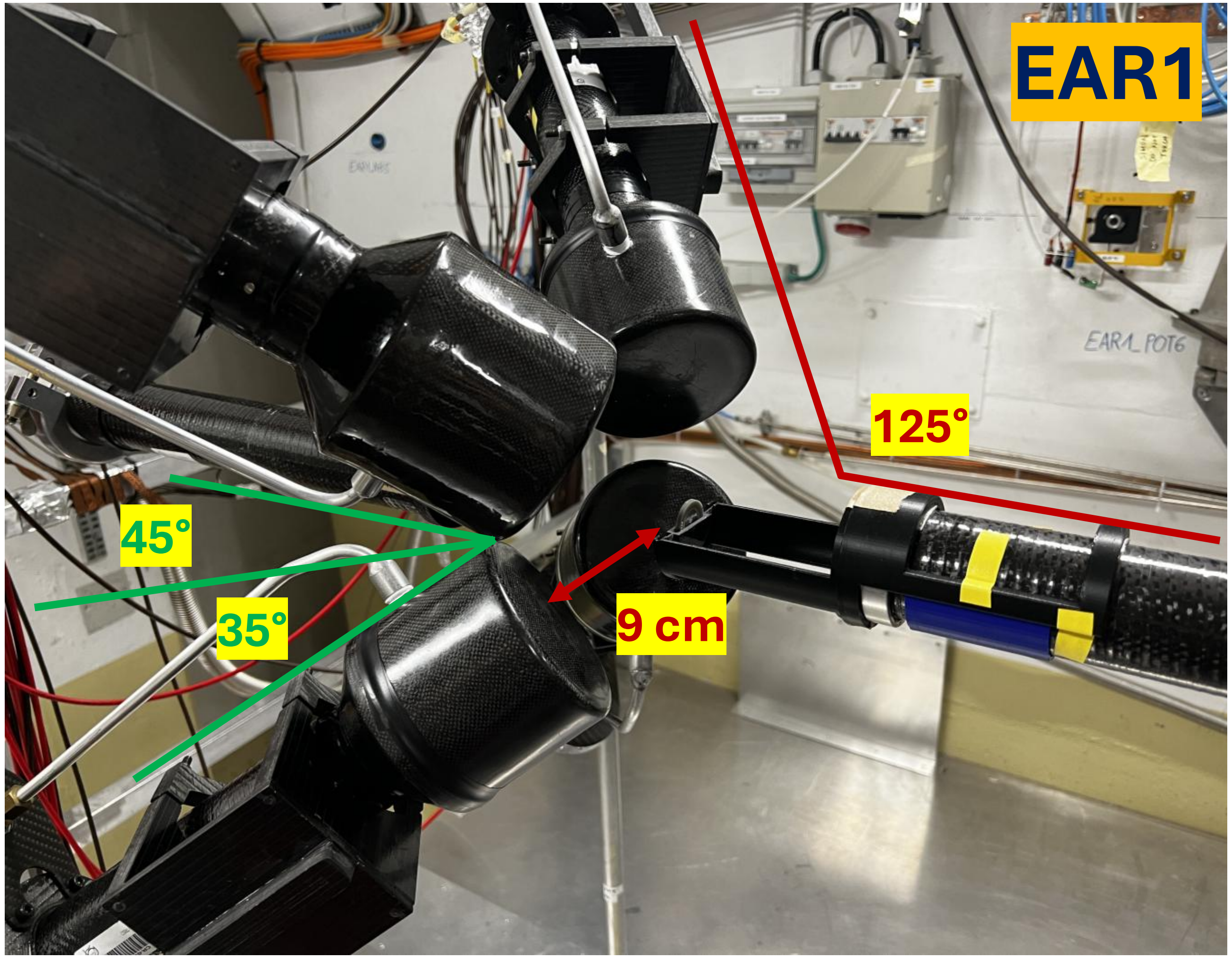


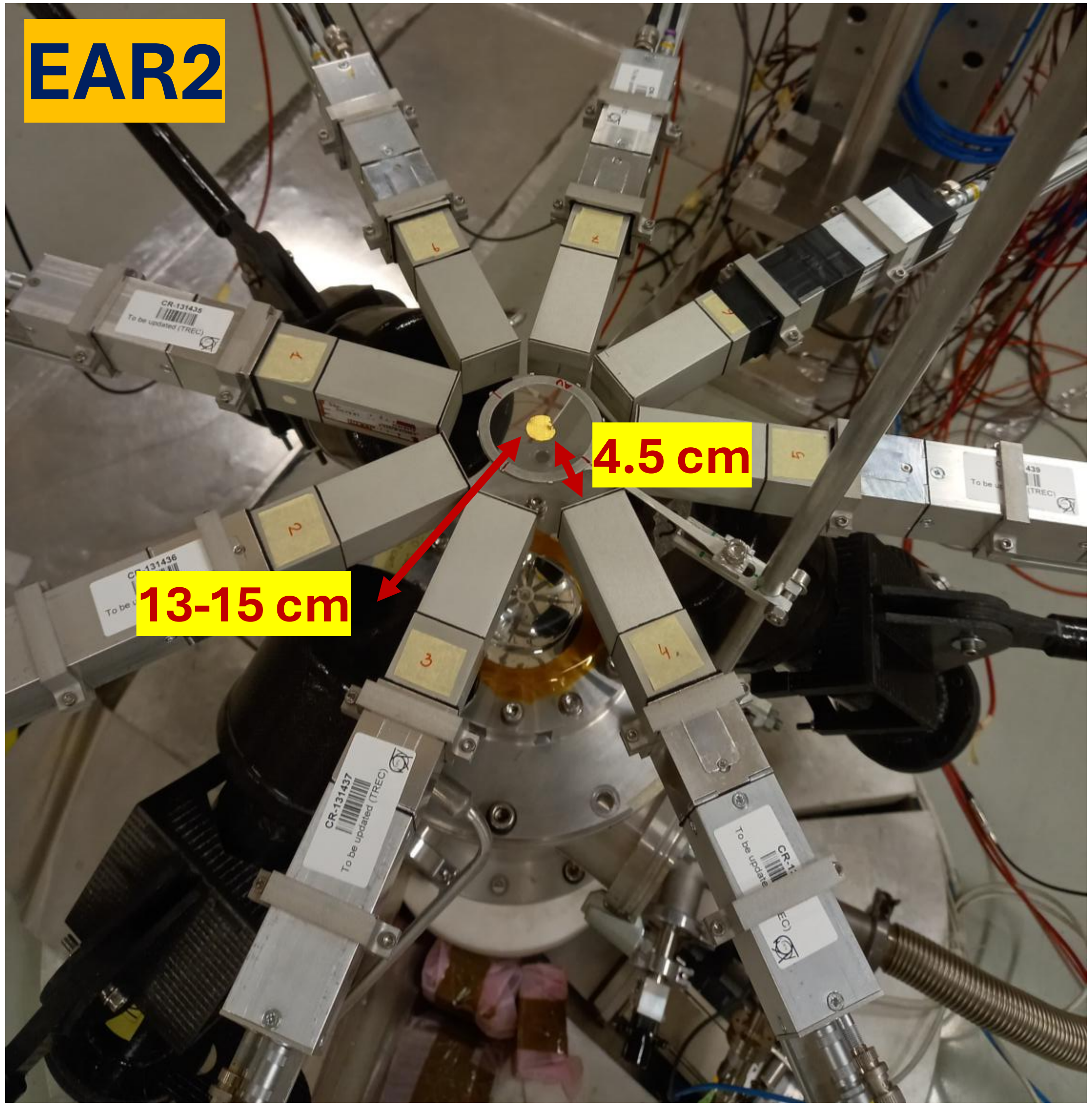


Setup

RECAP

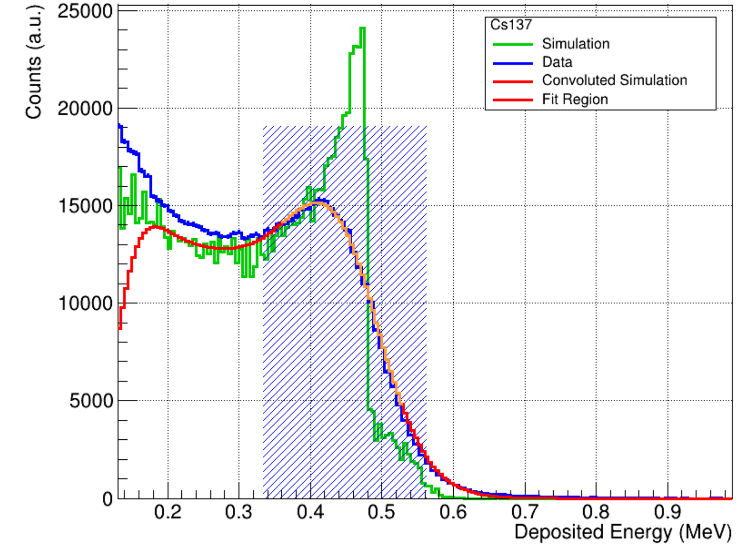
^{30}Si(n, γ): EAR1 + EAR2; ^{64}Ni(n, γ): only EAR2

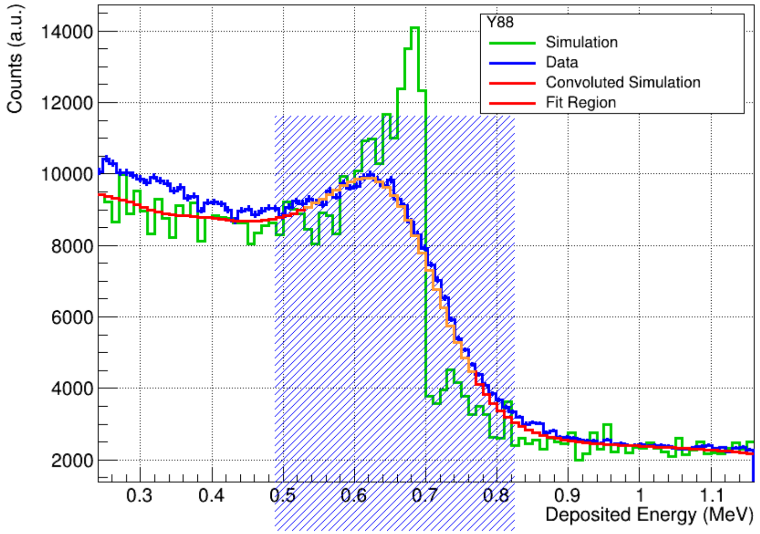




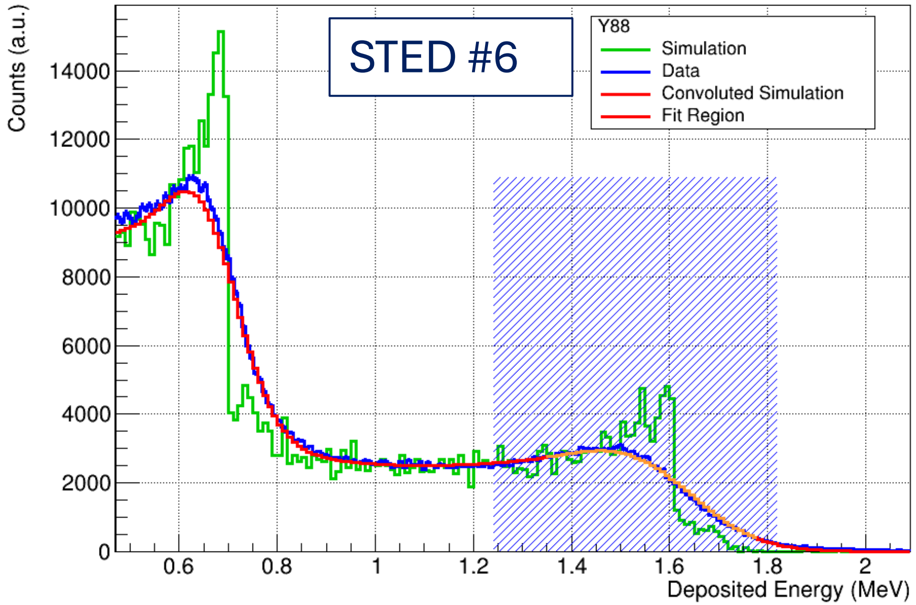
Calibrations STED

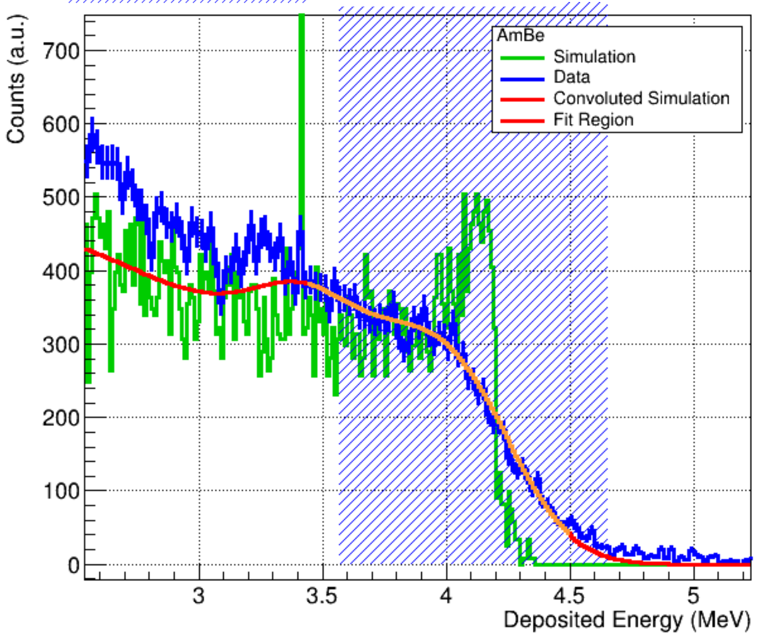
RECAP

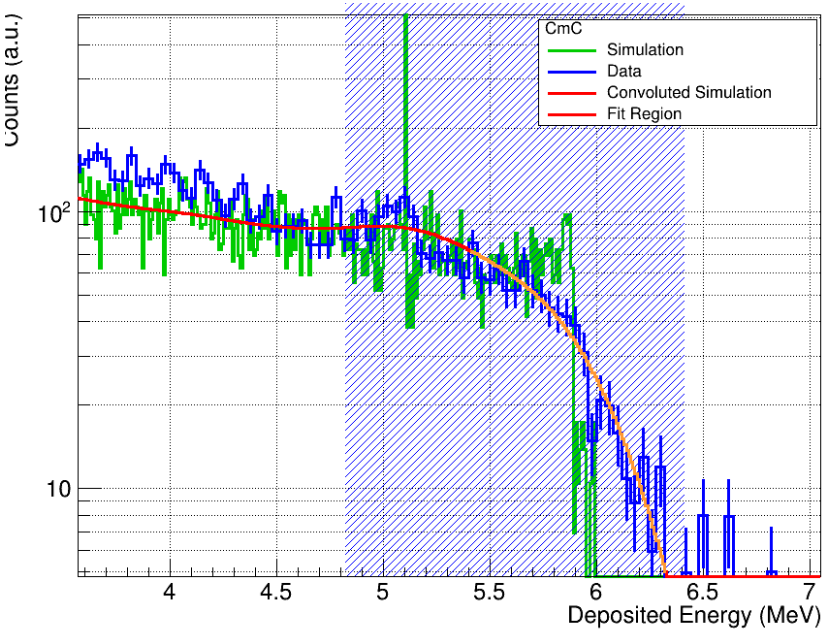




Calibration of the STED has been performed with a **direct comparison** between measured and simulated energy deposited spectra, tuning gain and resolution for each source:



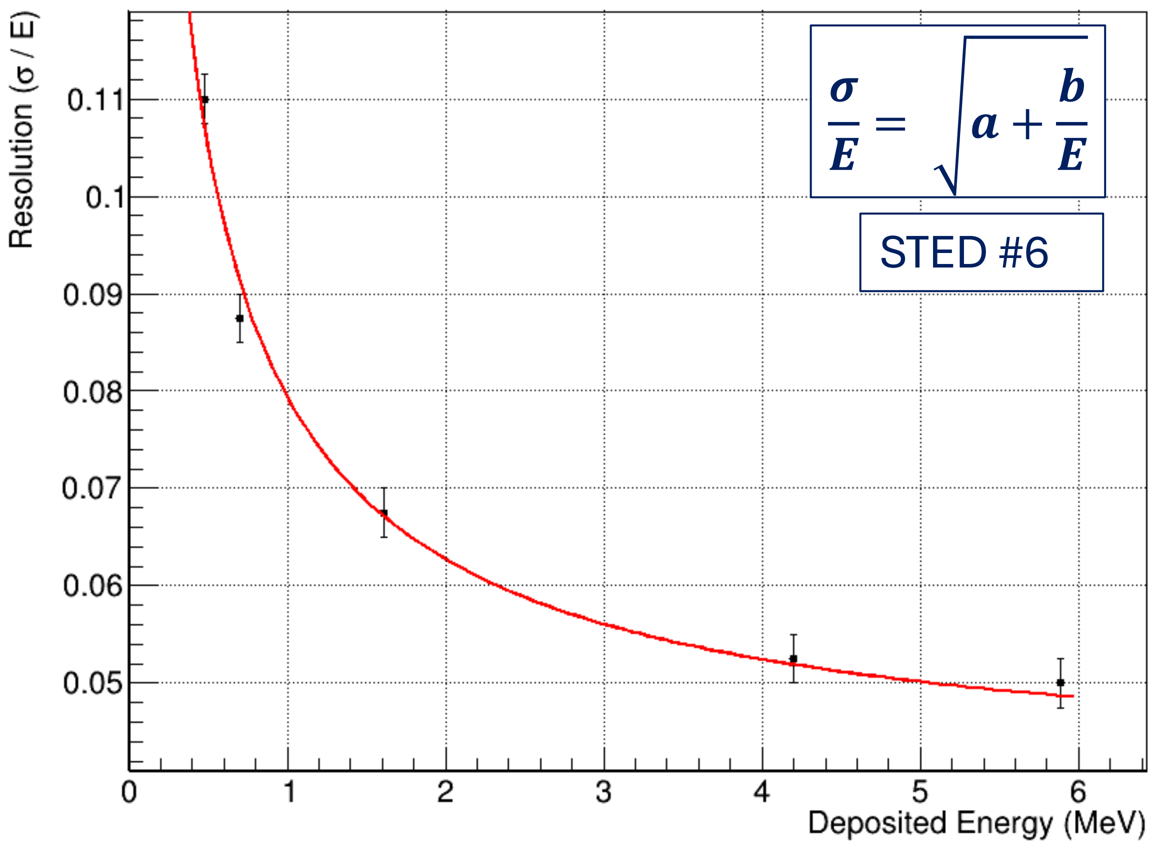


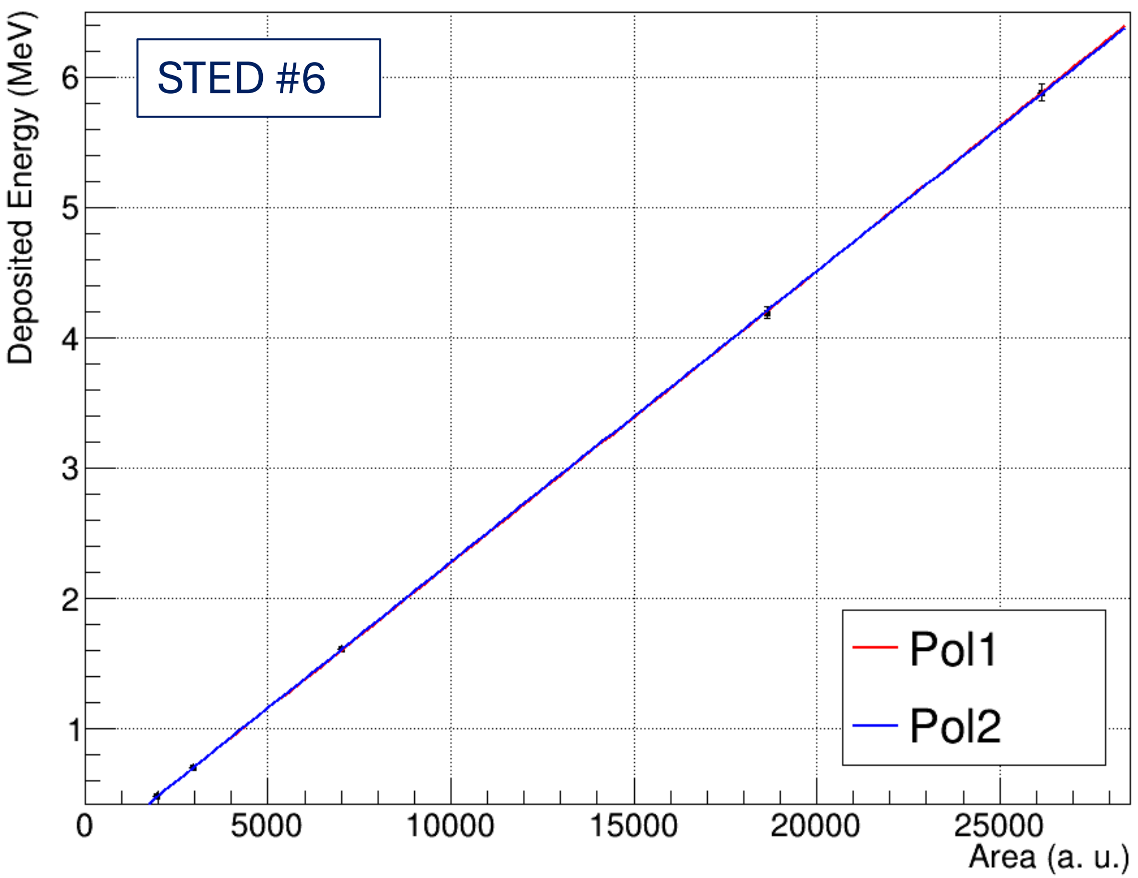


Calibrations STED

RECAP

Calibration and resolution functions have been computed fitting the results from different sources. The calibration of the STEDs are pretty linear.





Calibrations STED

RECAP

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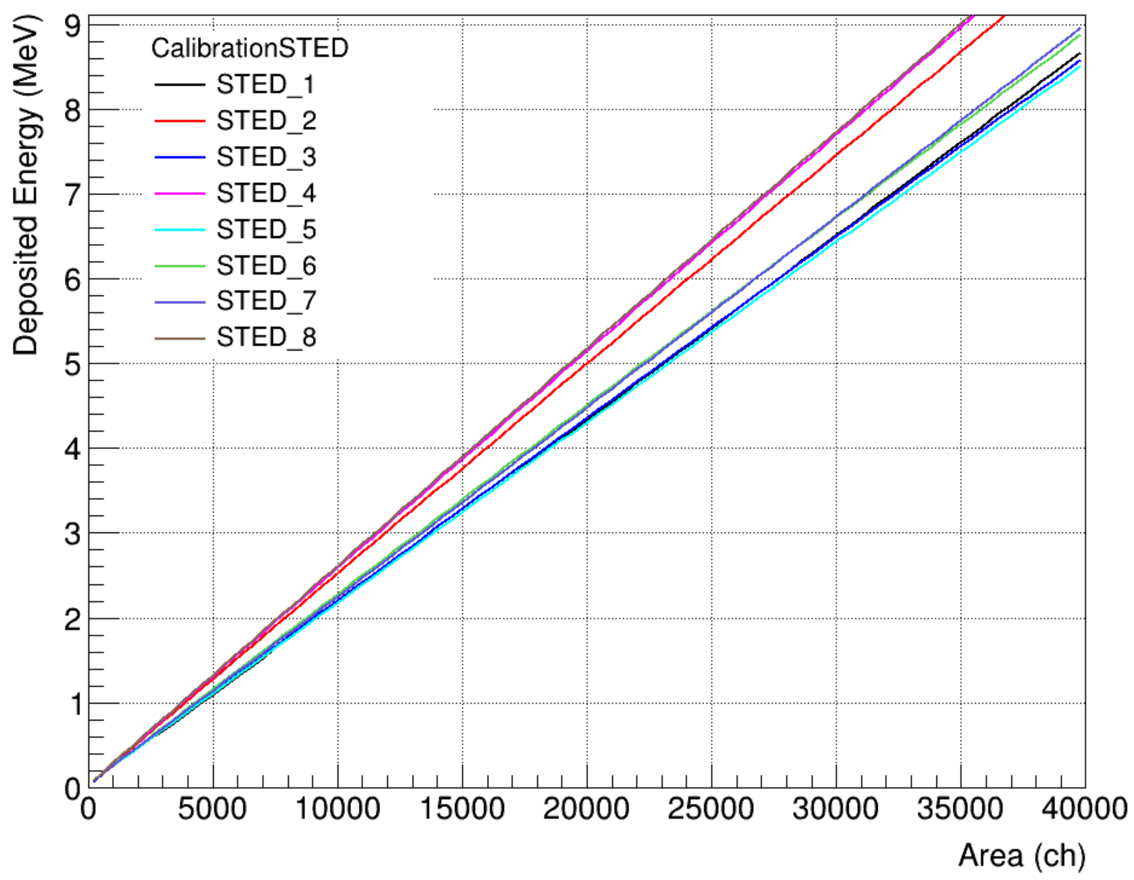
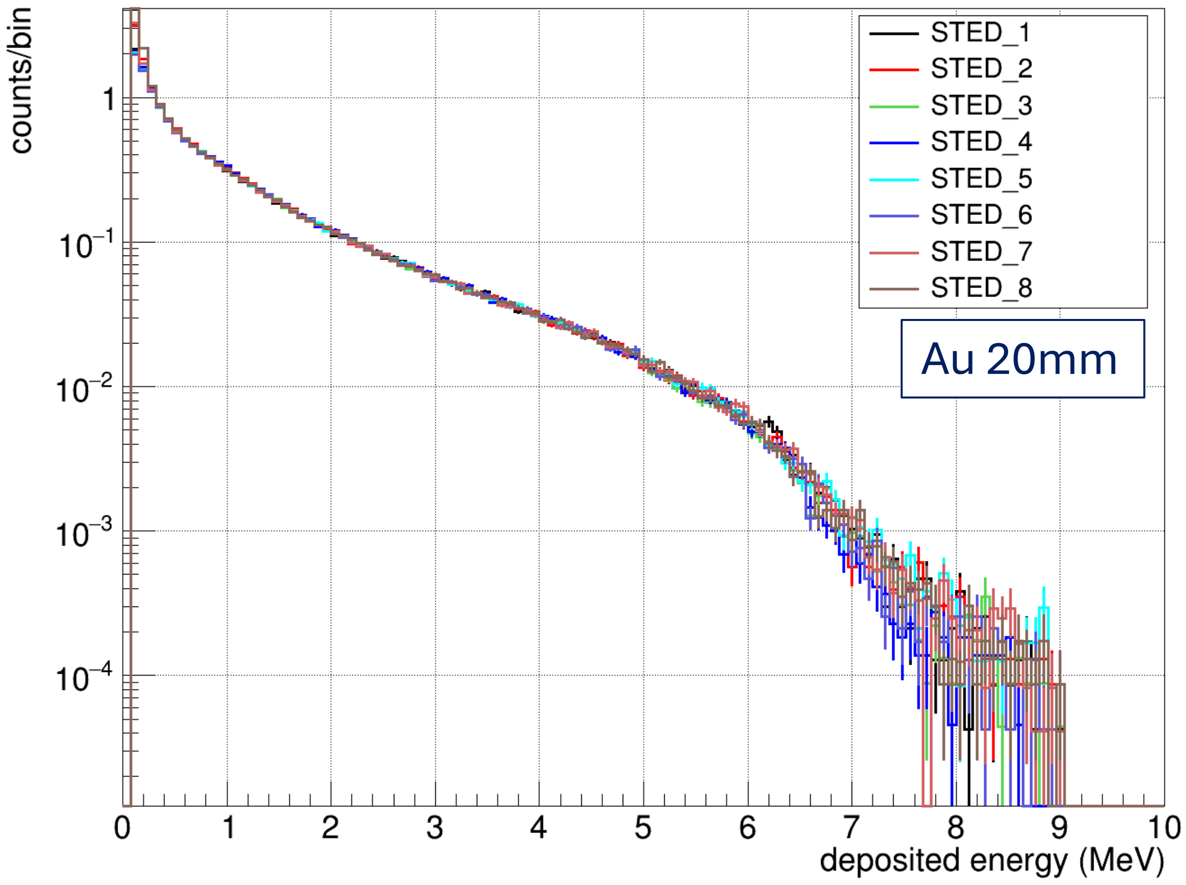
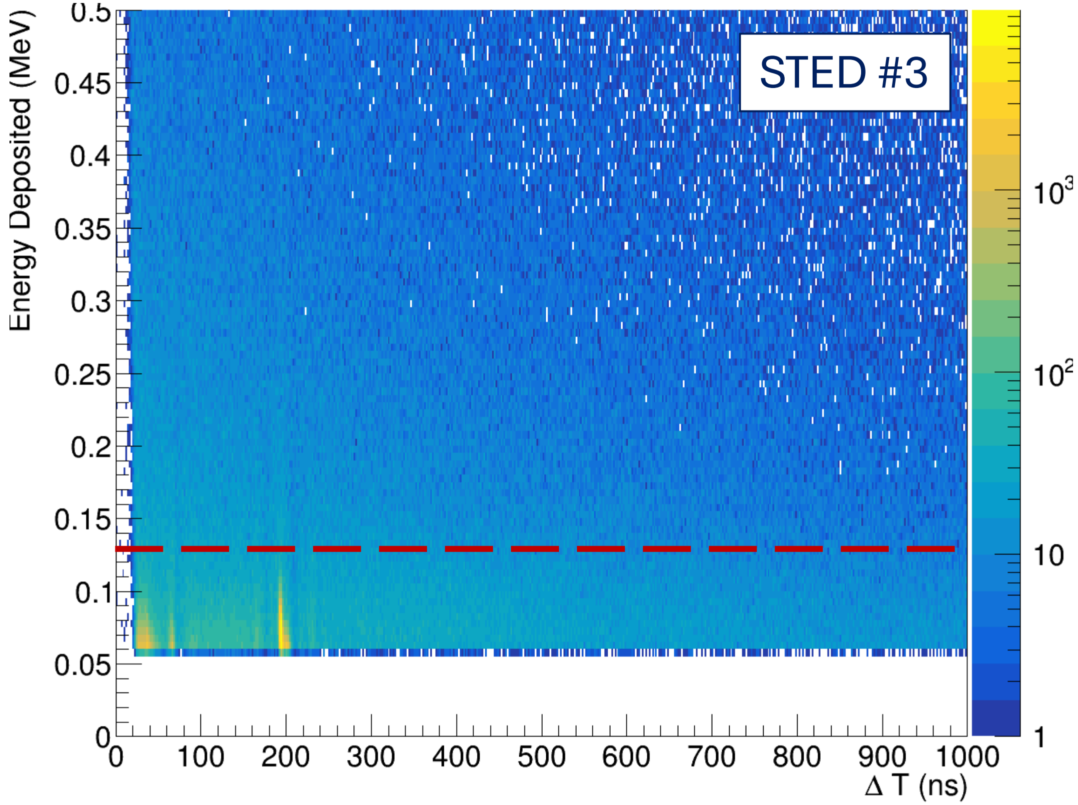


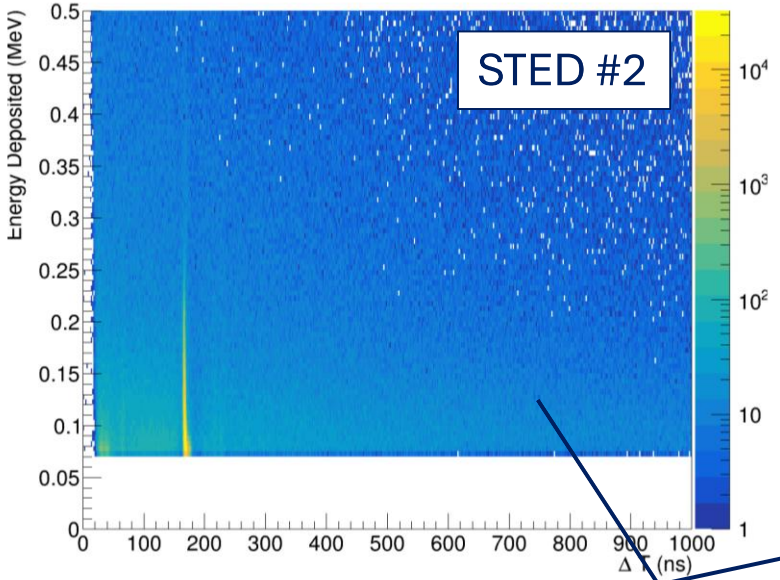


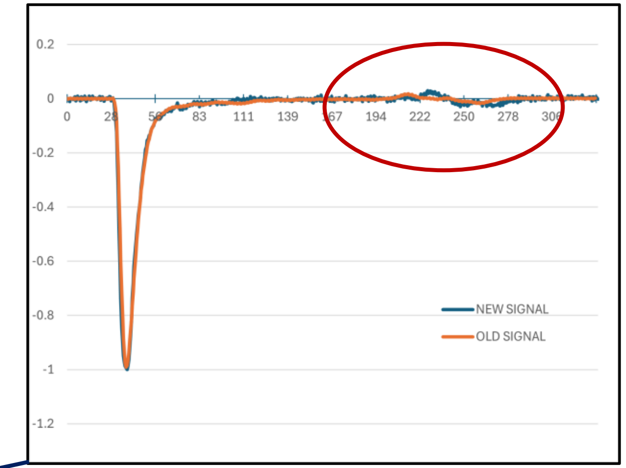
Thresholds STED

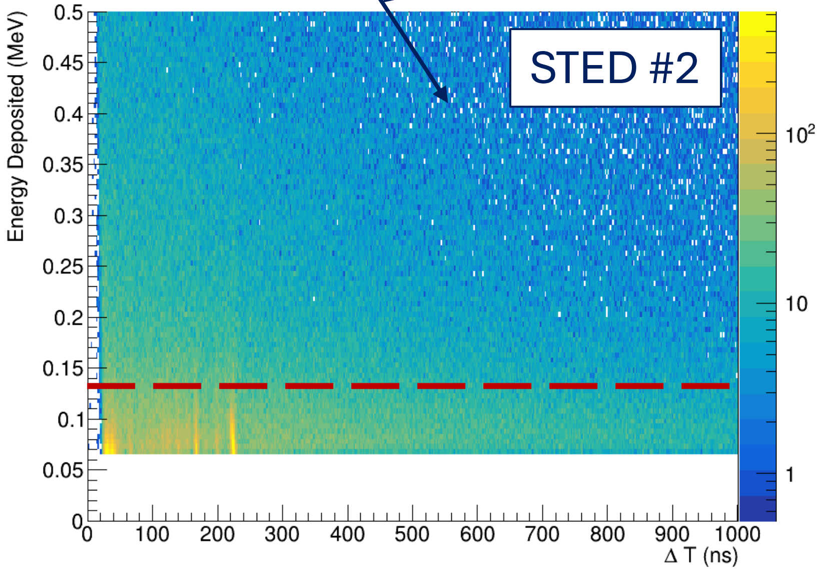
RECAP

STED rebounds have been fixed adjusting the **PSA**. Energy deposited thresholds can be set at **130 keV**.





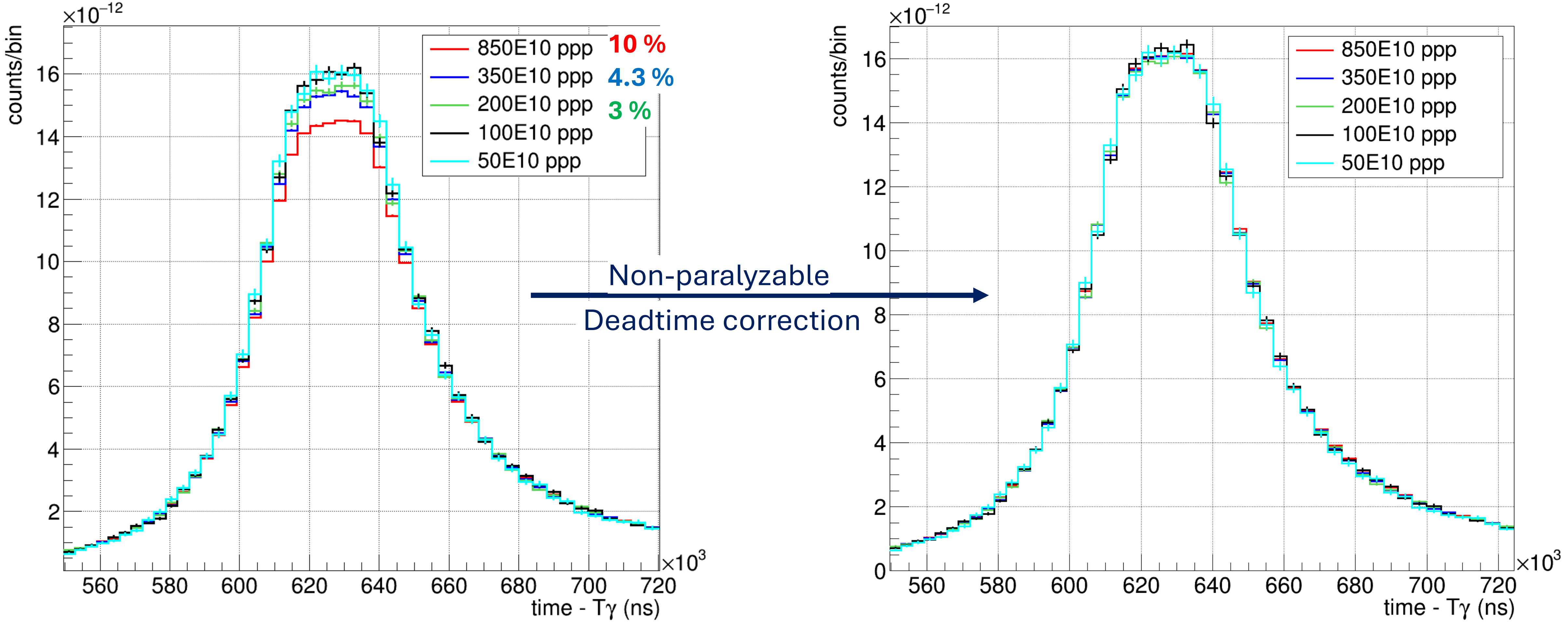




Let's start with **problems**!

Gold (15 mm*): Pileup & Deadtime

The **saturated resonance** of Gold is affected by a huge pileup effect that can be easily corrected considering **unweighted counts**. **Thermal region is not affected by pileup**.

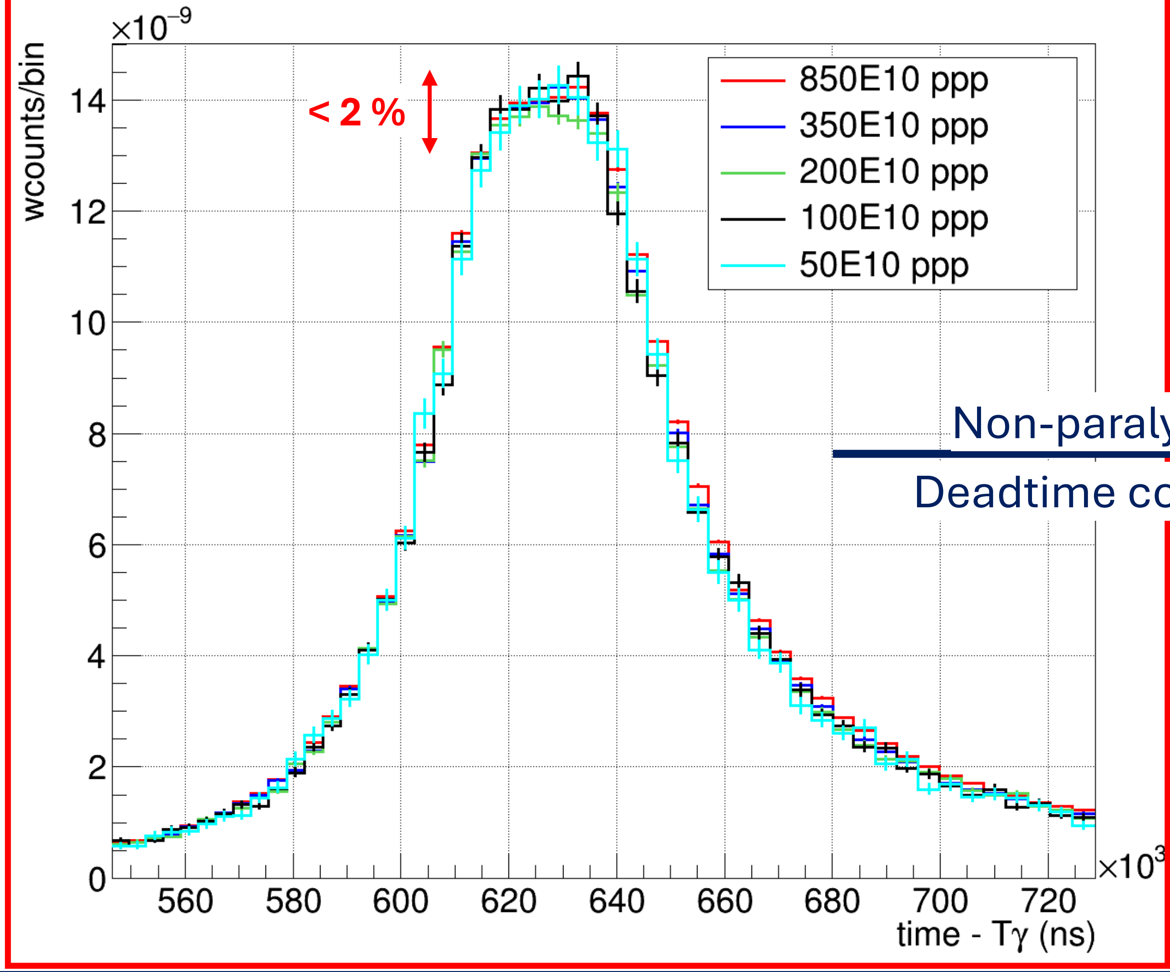


Gold (15 mm*): Pileup & Deadtime

BUT the correction does not work for weighted counts!

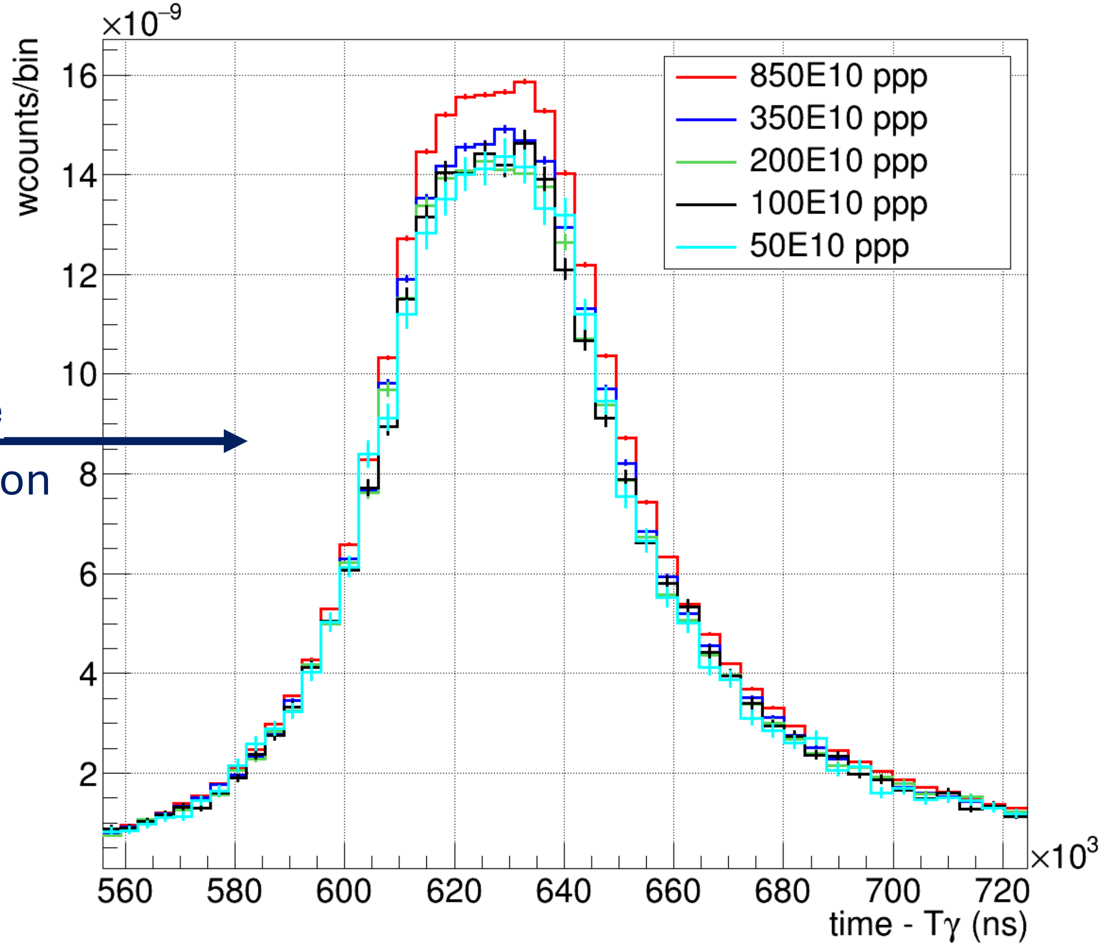
Pileup increases the amplitude of signals, they are weighted more and compensate deadtime correction

Balibrea-Correa et al., https://doi.org/10.1016/j.nima.2024.169385



Non-paralyzable

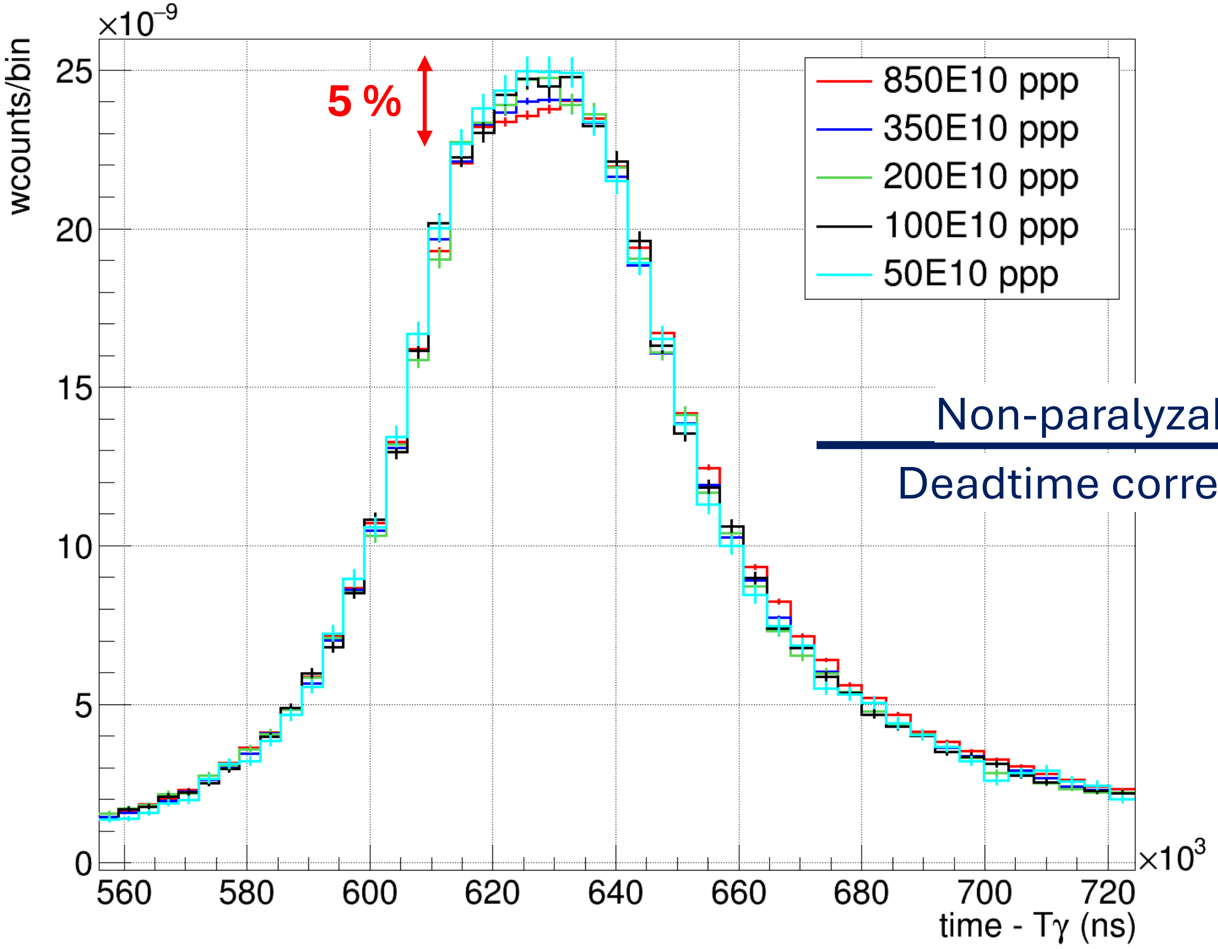
Deadtime correction



Gold (20 mm): Pileup & Deadtime

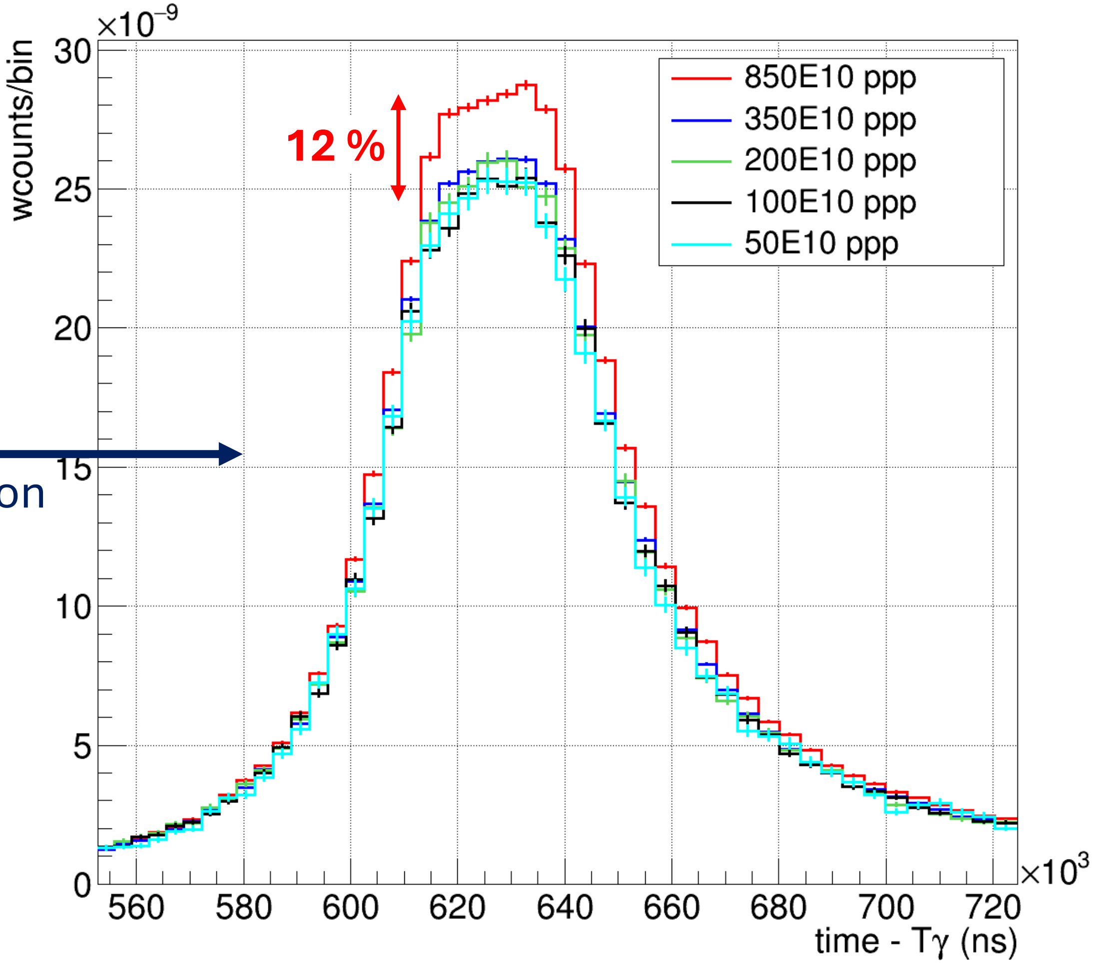
The situation gets **worse increasing the size** of the gold sample (e.g. to 20 mm diameter)

In this case deadtime effect on unweighted count is approx. 20% (850 ppp), 10 % (350 ppp), 4 % (200 ppp)



Non-paralyzable

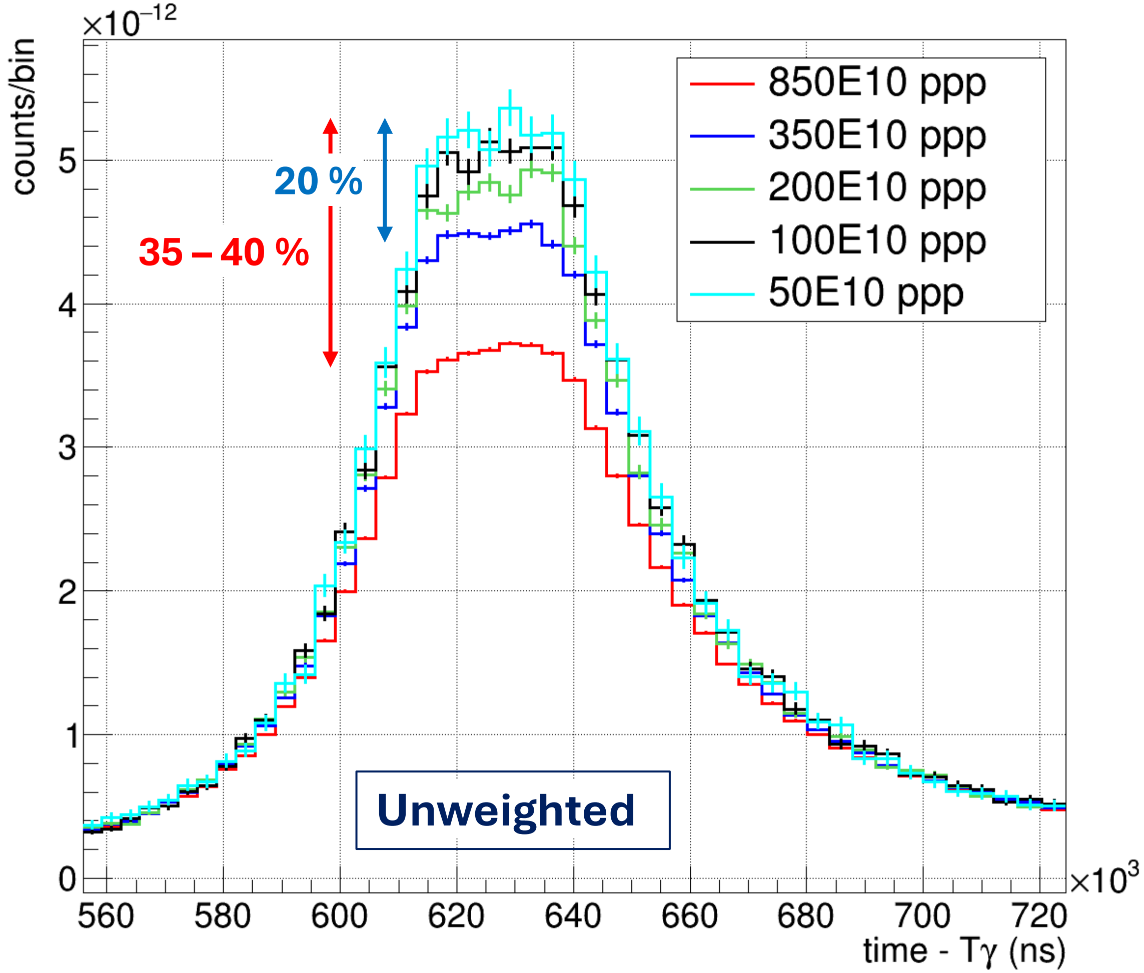
Deadtime correction

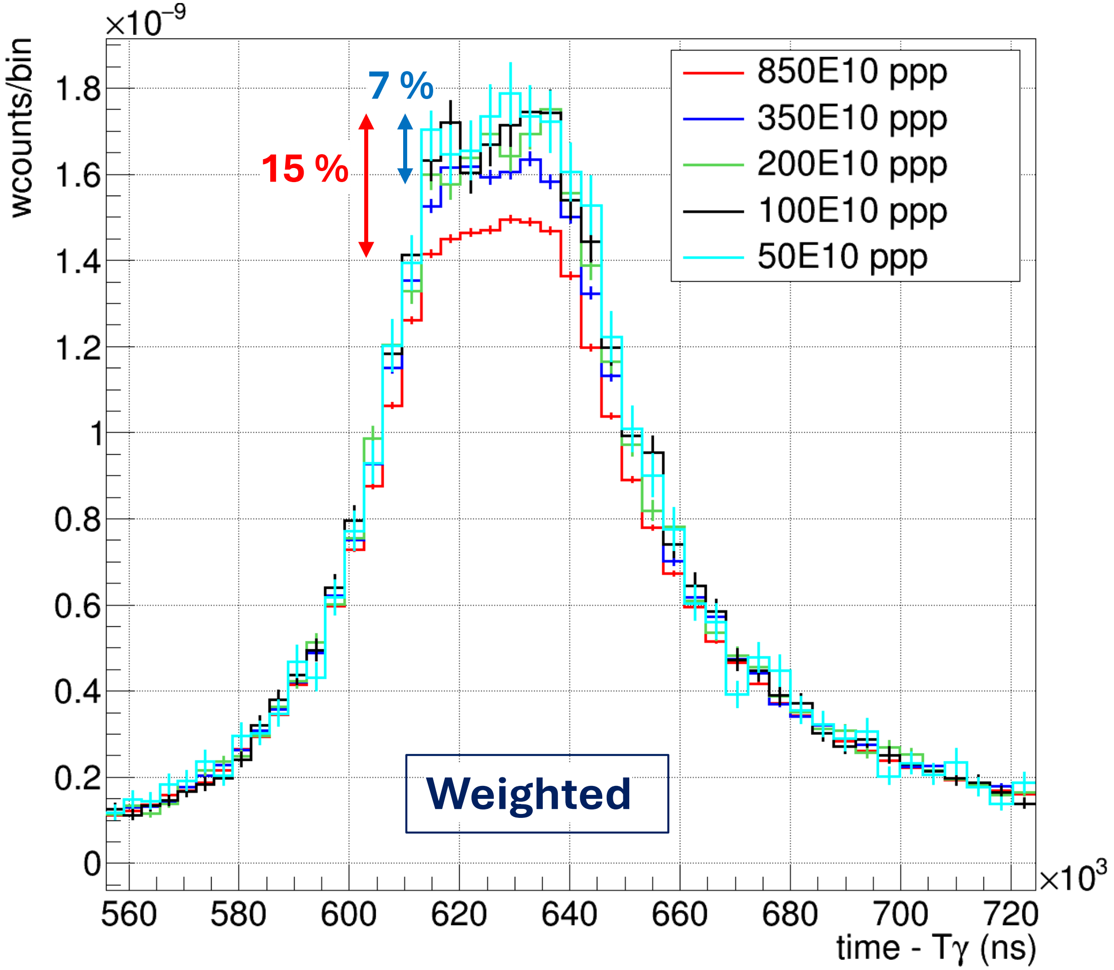


Gold (15 mm*): Pileup & Deadtime

The situation is definitely **worse for C6D6**

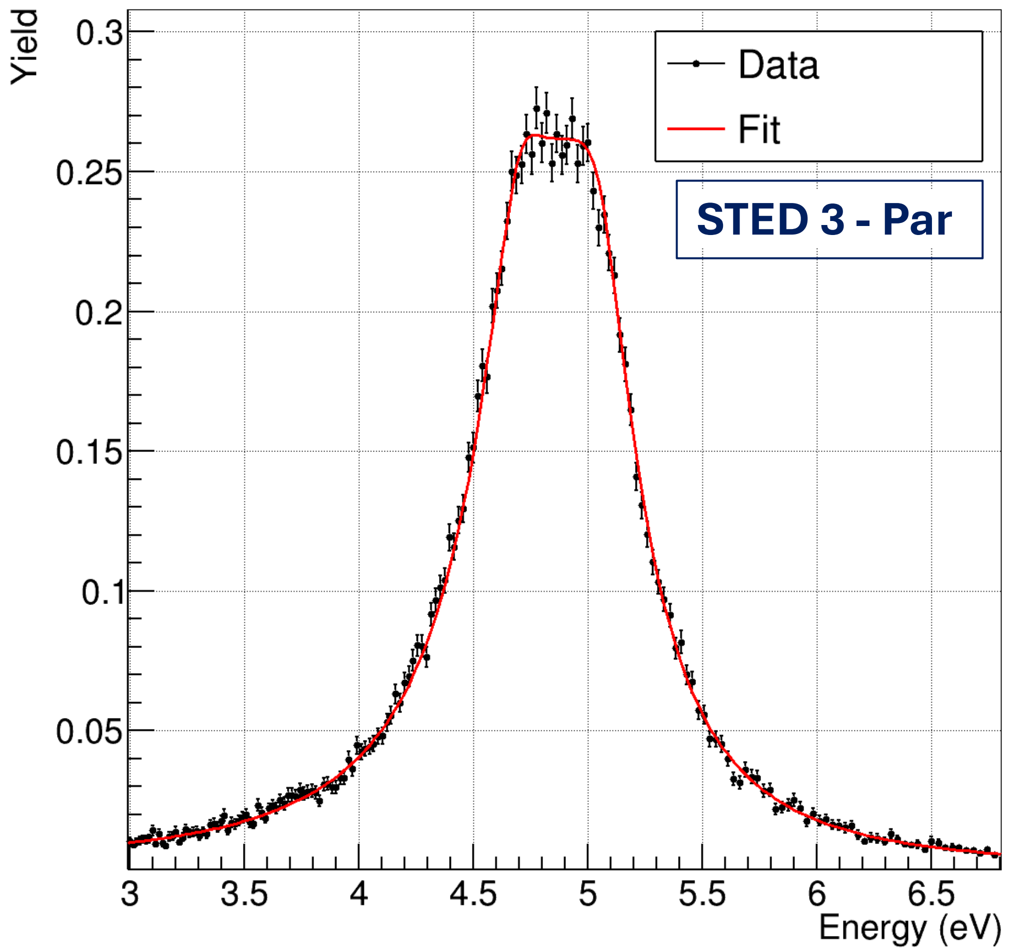
(Higher deadtime and pileup effects, also with 15 mm diameter Au sample)





Gold (15 mm*): Normalization

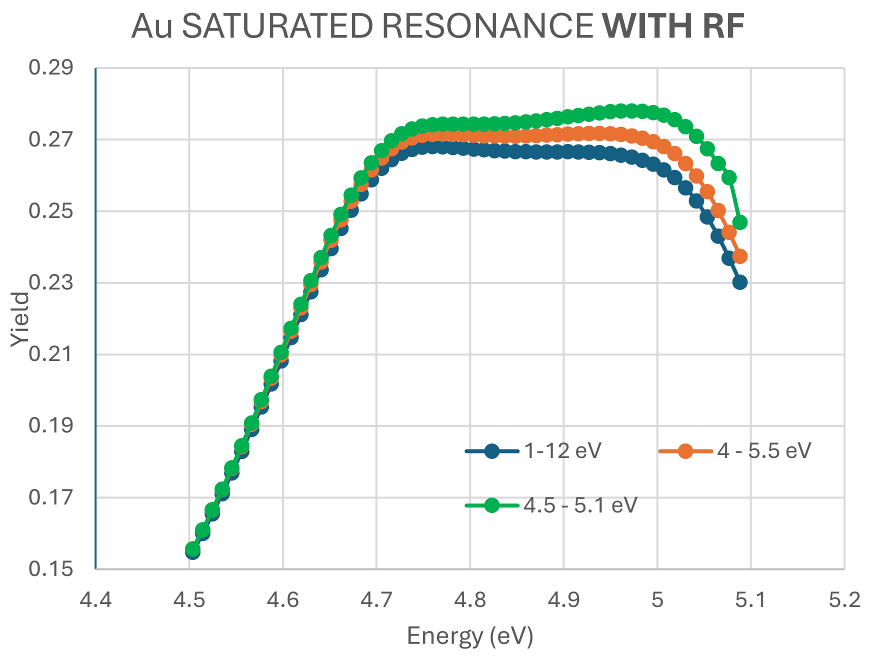
Therefore, **counts have not been corrected for deadtime** and normalized (each detector separately) on the top of the saturated resonance with SAMMY.



- Normalization is on average 0.28 (± 4.5 % for different STEDs)
- Dedicated and parasitic normalizations are within 0.5%
- Flight Path fitted to 19.0976 m (SAMMY)

PS:
Problem fitting with SAMMY!

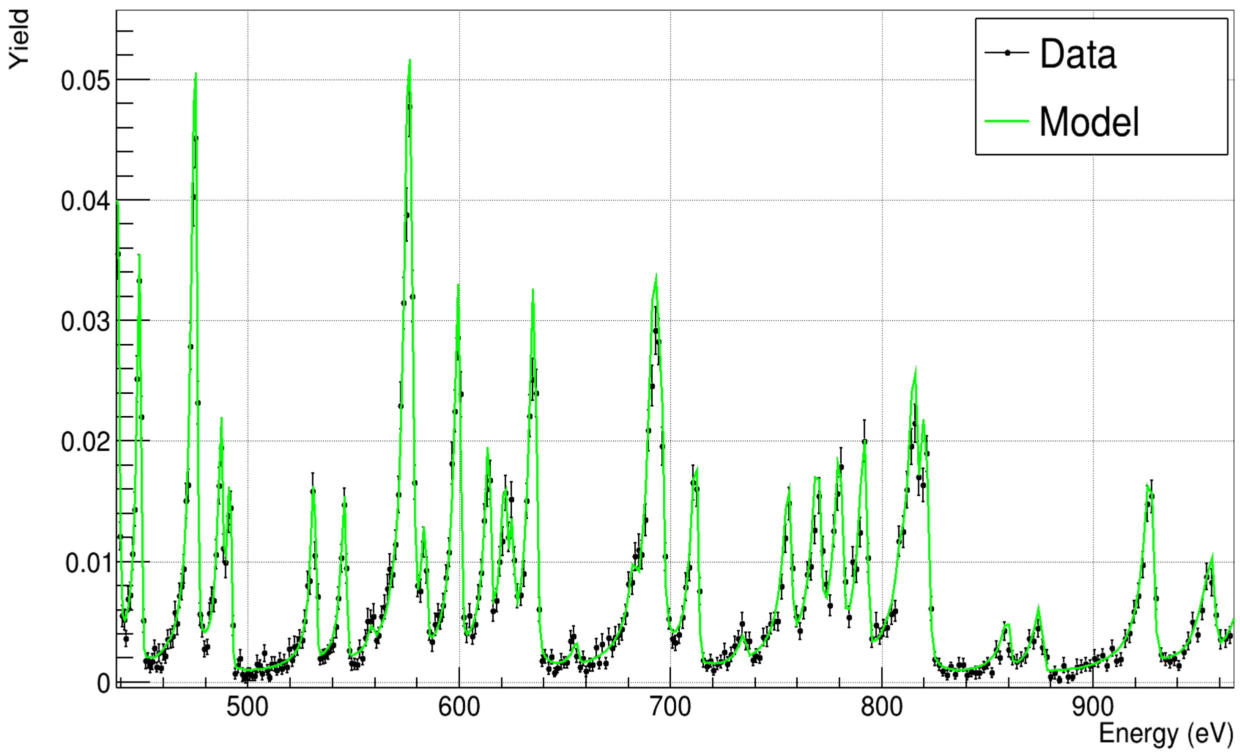
The shape of the "**model**" changes according to the range used (effect of RF, not seen in EAR1)

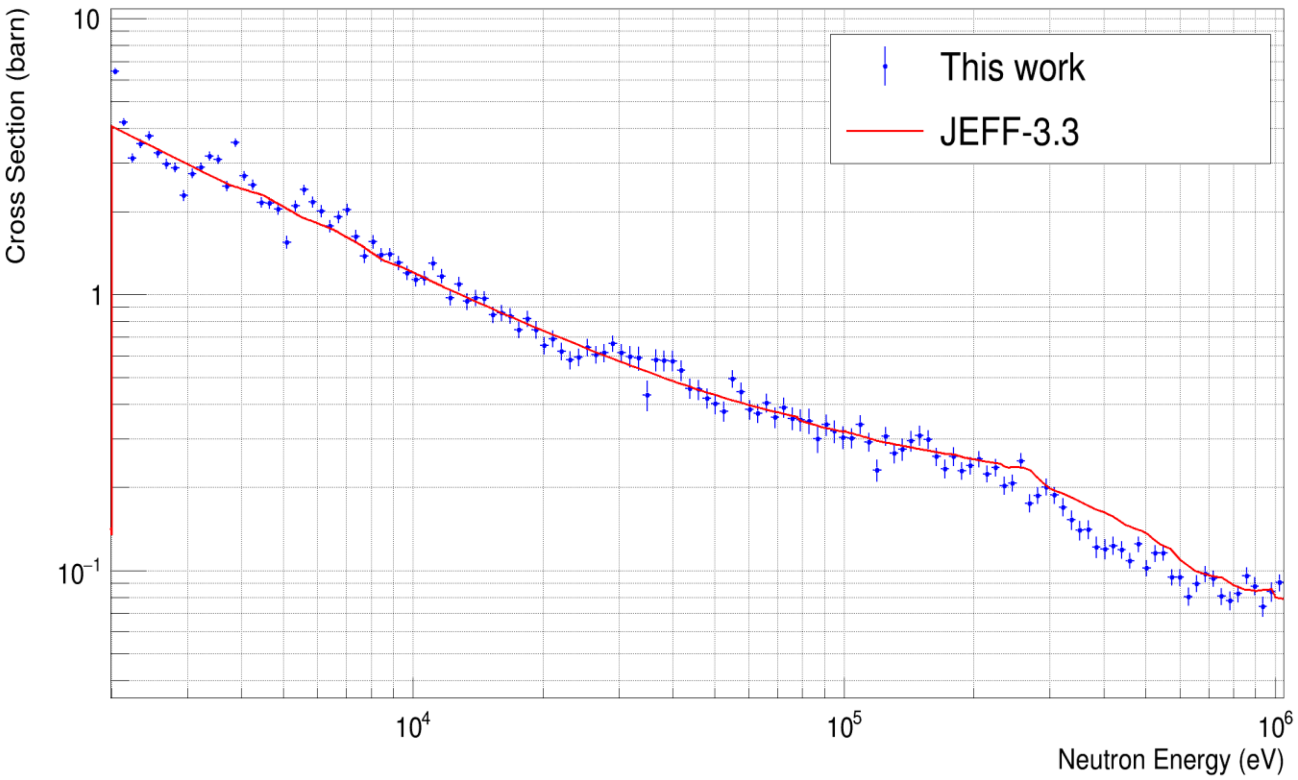


Gold (15 mm*)

The normalization and the flight path fitted well reproduce the Gold capture cross section at **higher neutron energies**

(variation of the BIF has been considered, but the effect is smaller than 3 % in the keV)

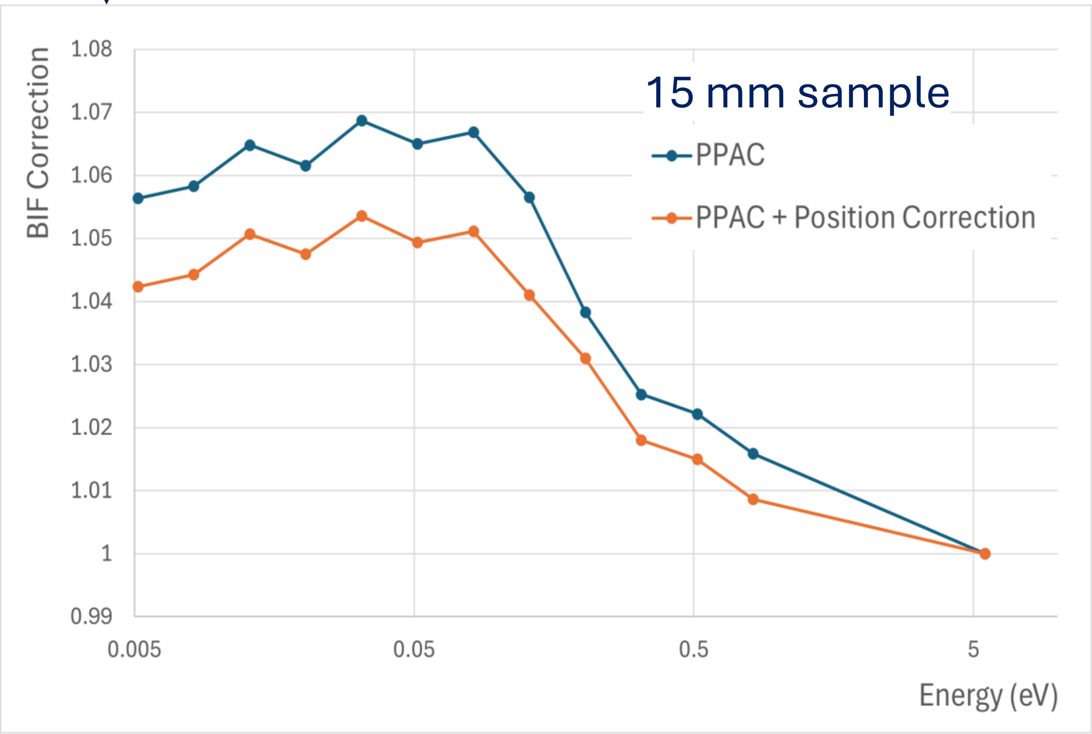


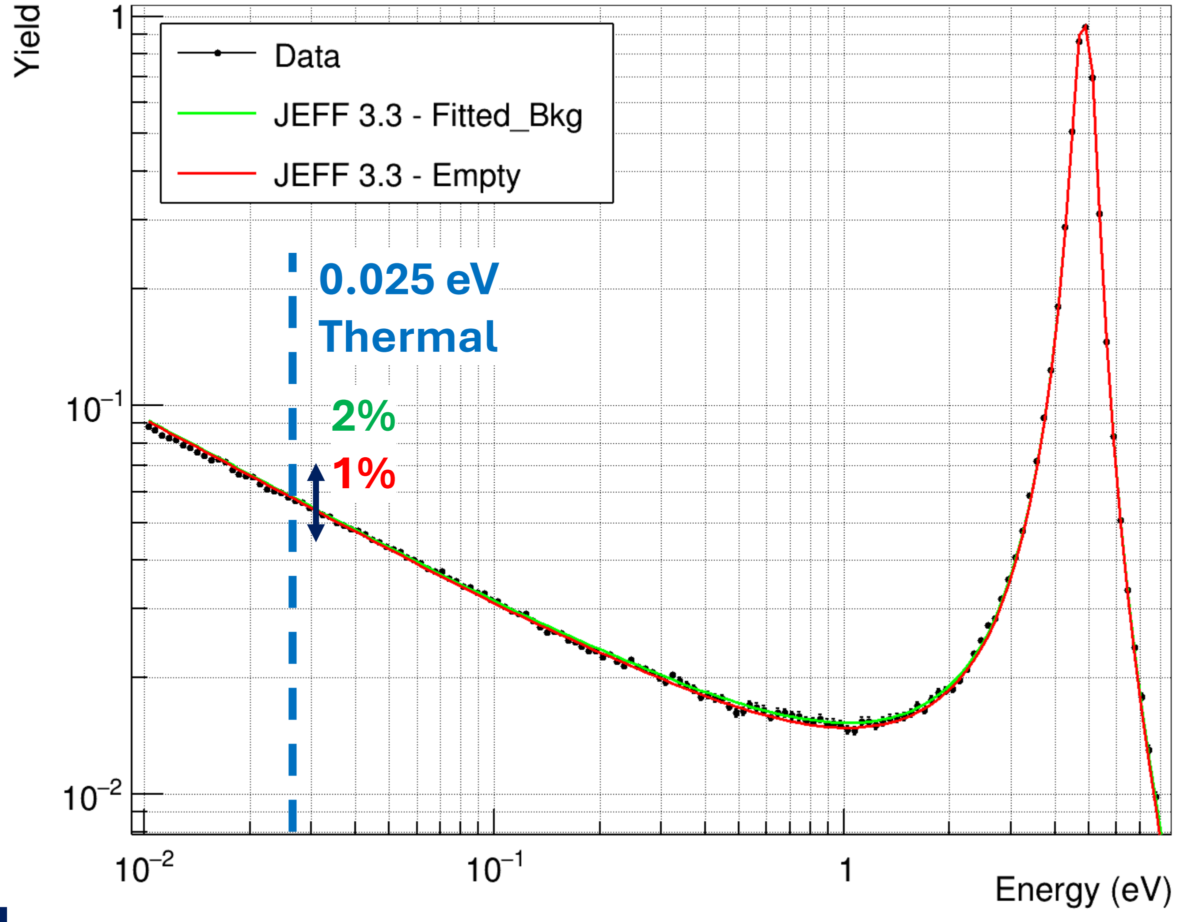


Gold (15 mm*): Thermal region

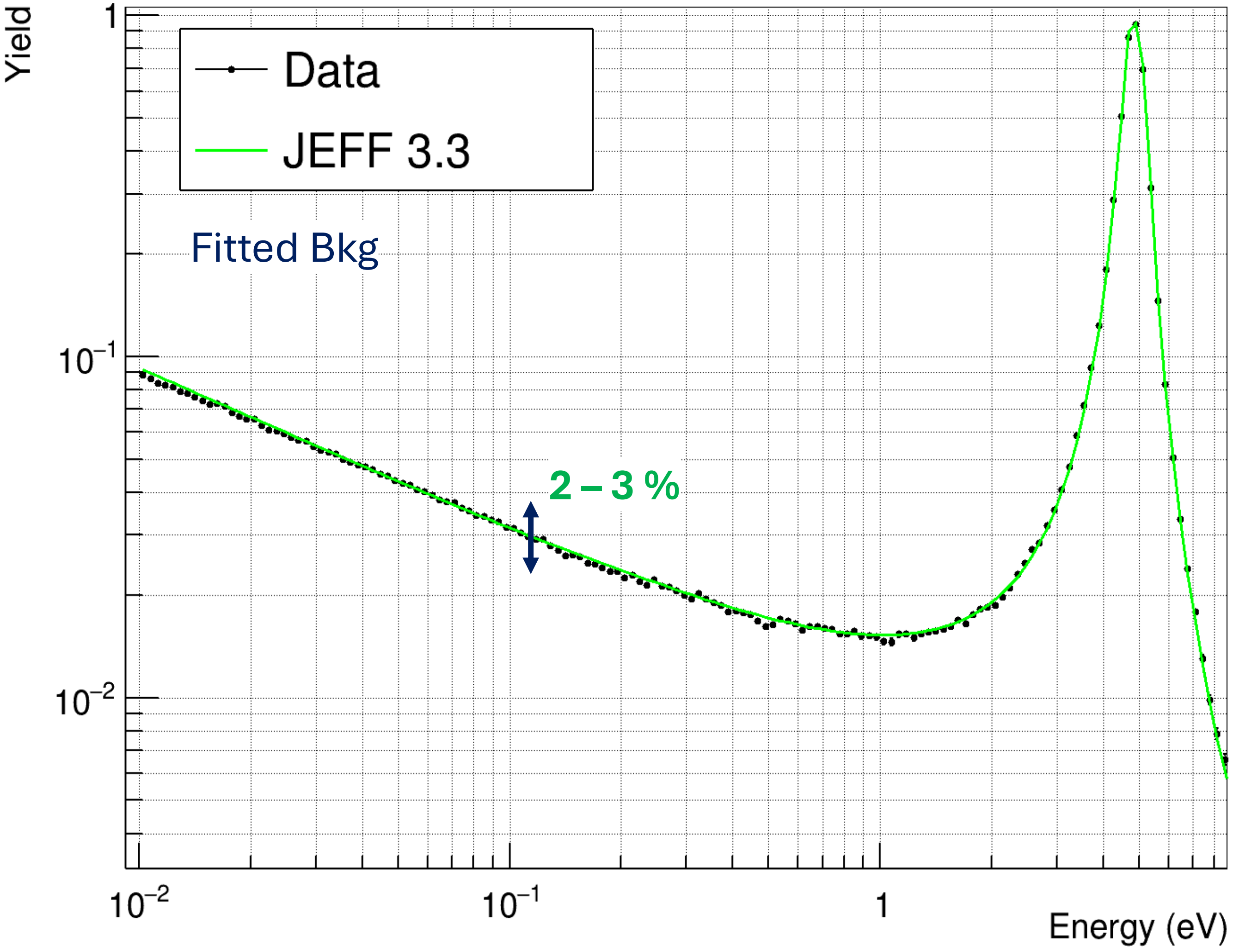
The same value of normalization reproduces the thermal cross section **within ± 2 – 3 %:**

- **BIF** considered using PPAC data (Alice & Roberto) corrected for the different flight path (Transport Code)
  - **Background**: empty subtracted, additional background fitted in the resonance valley

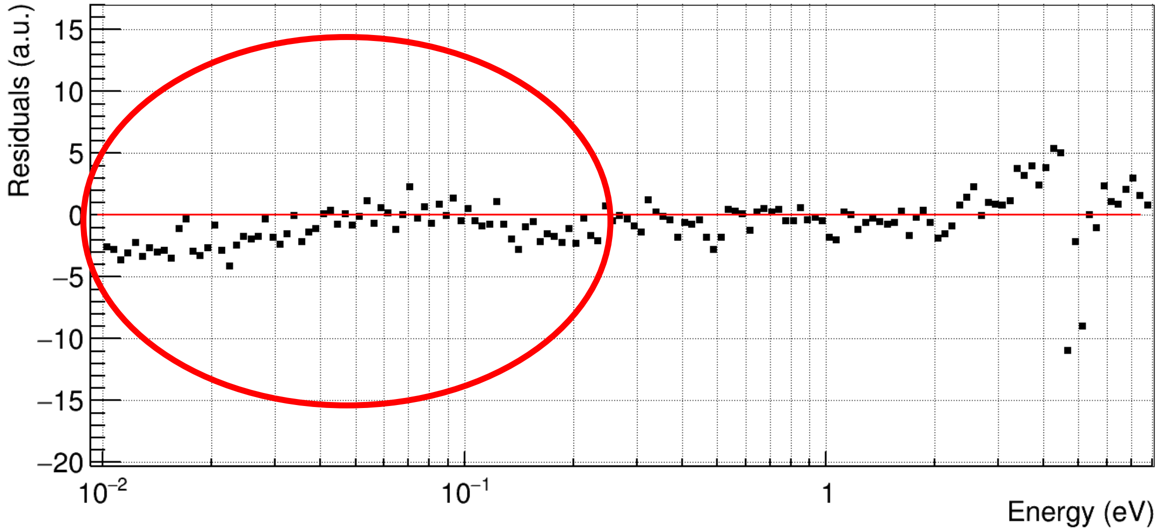




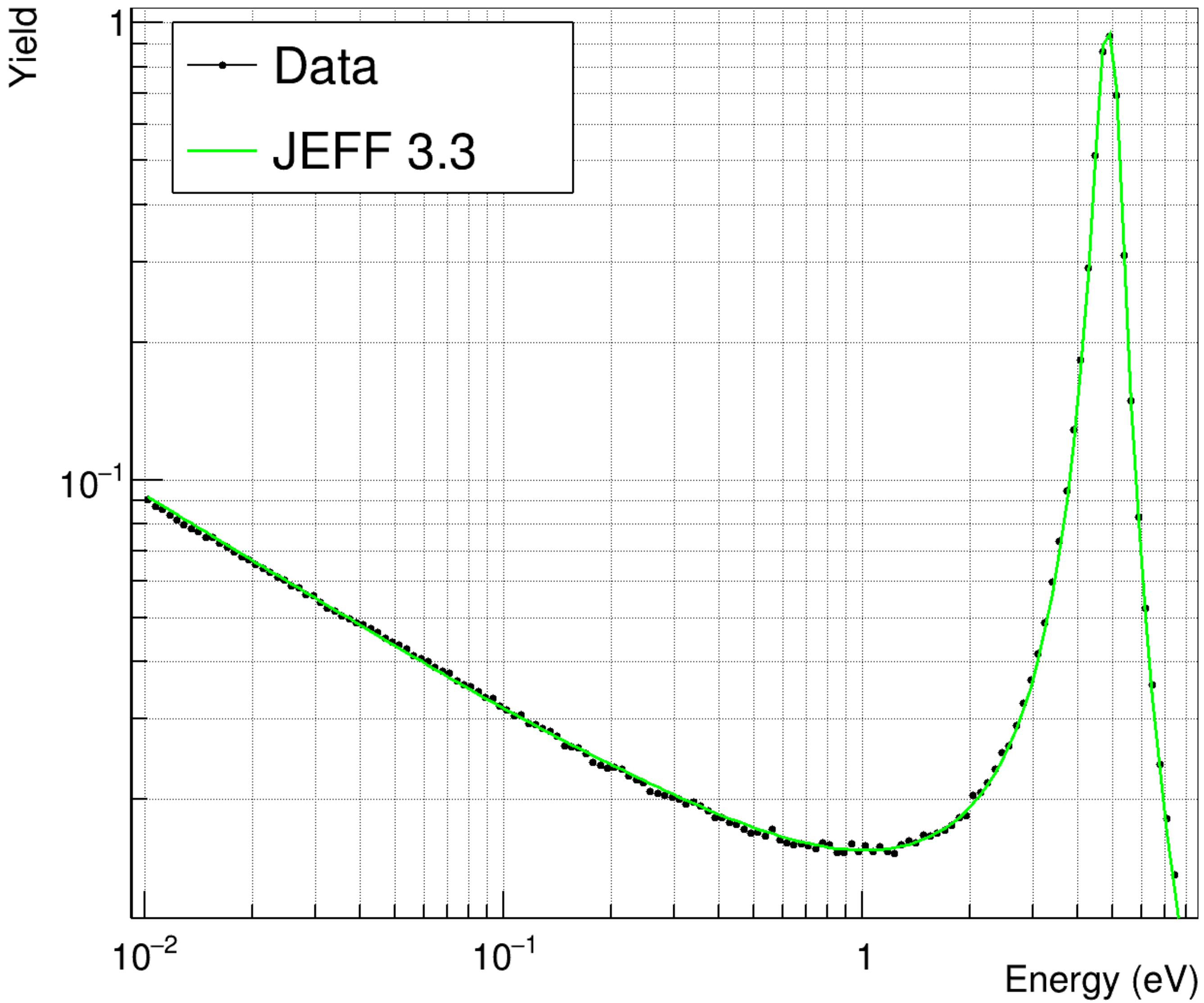
Gold (15 mm*): Thermal region



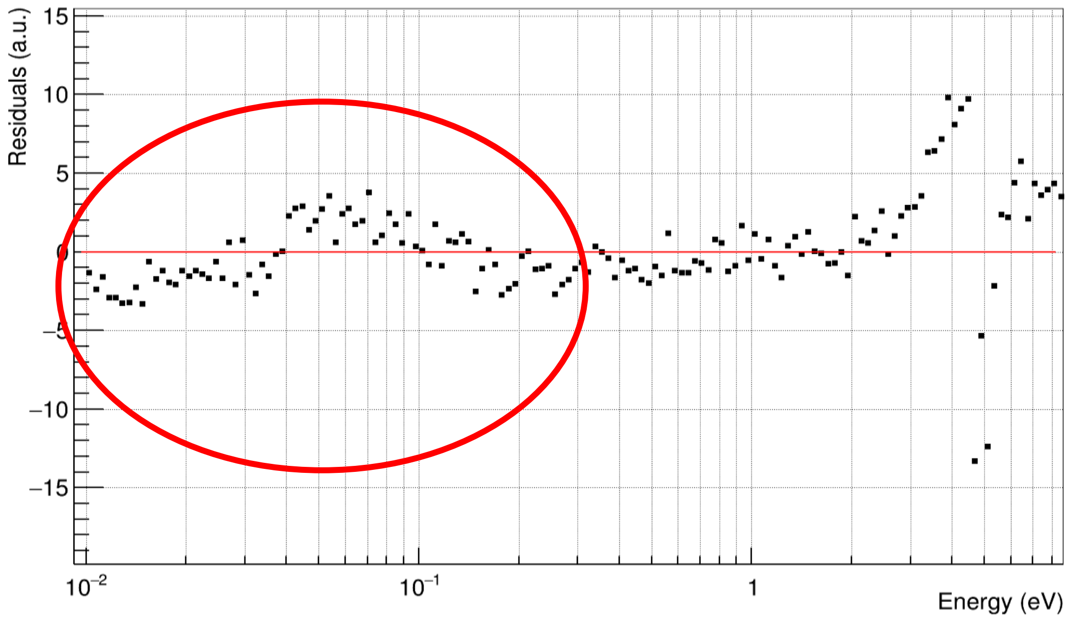
But still there seems to be a **structure in the shape** that is not understood (even if the values are in agreement within 2 – 3 % if fitted background is subtracted)



Gold (20 mm): Thermal region

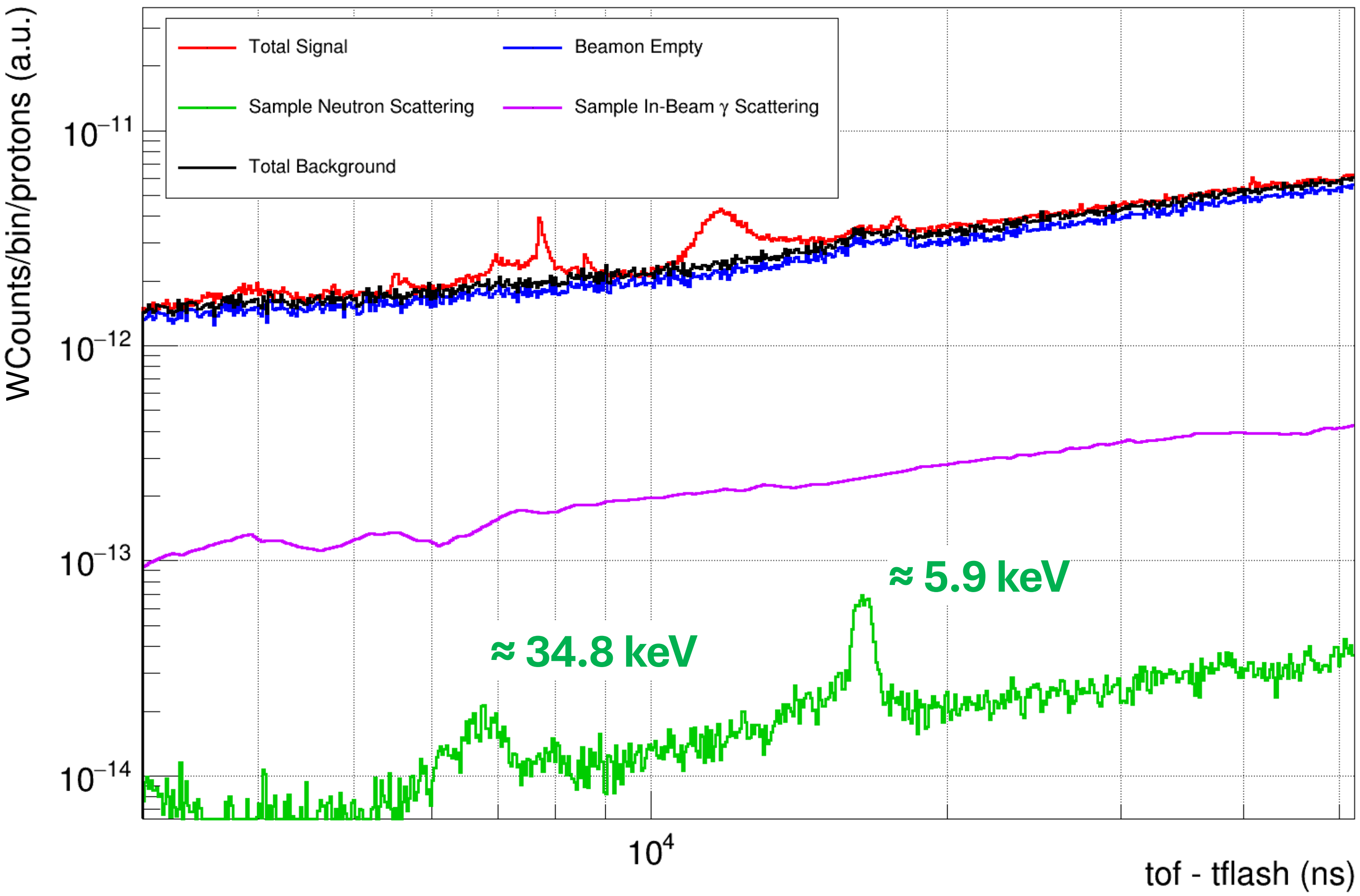


The **same structure** (even more evident) is also in the 20mm sample
(even if data are still in agreement with the predicted yield within 2 – 3 %)
Already reported by Riccardo

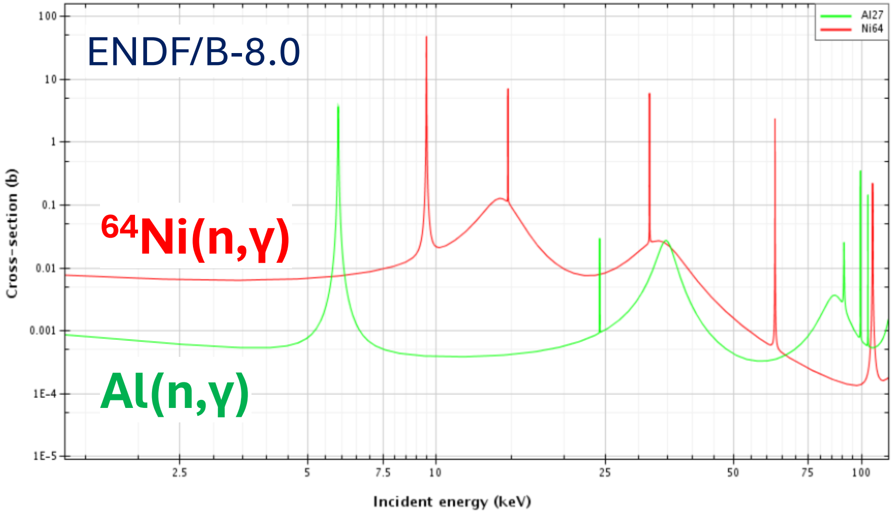


Background subtraction: Carbon

The subtraction of the **sample neutron scattering** (***Carbon***) is problematic:

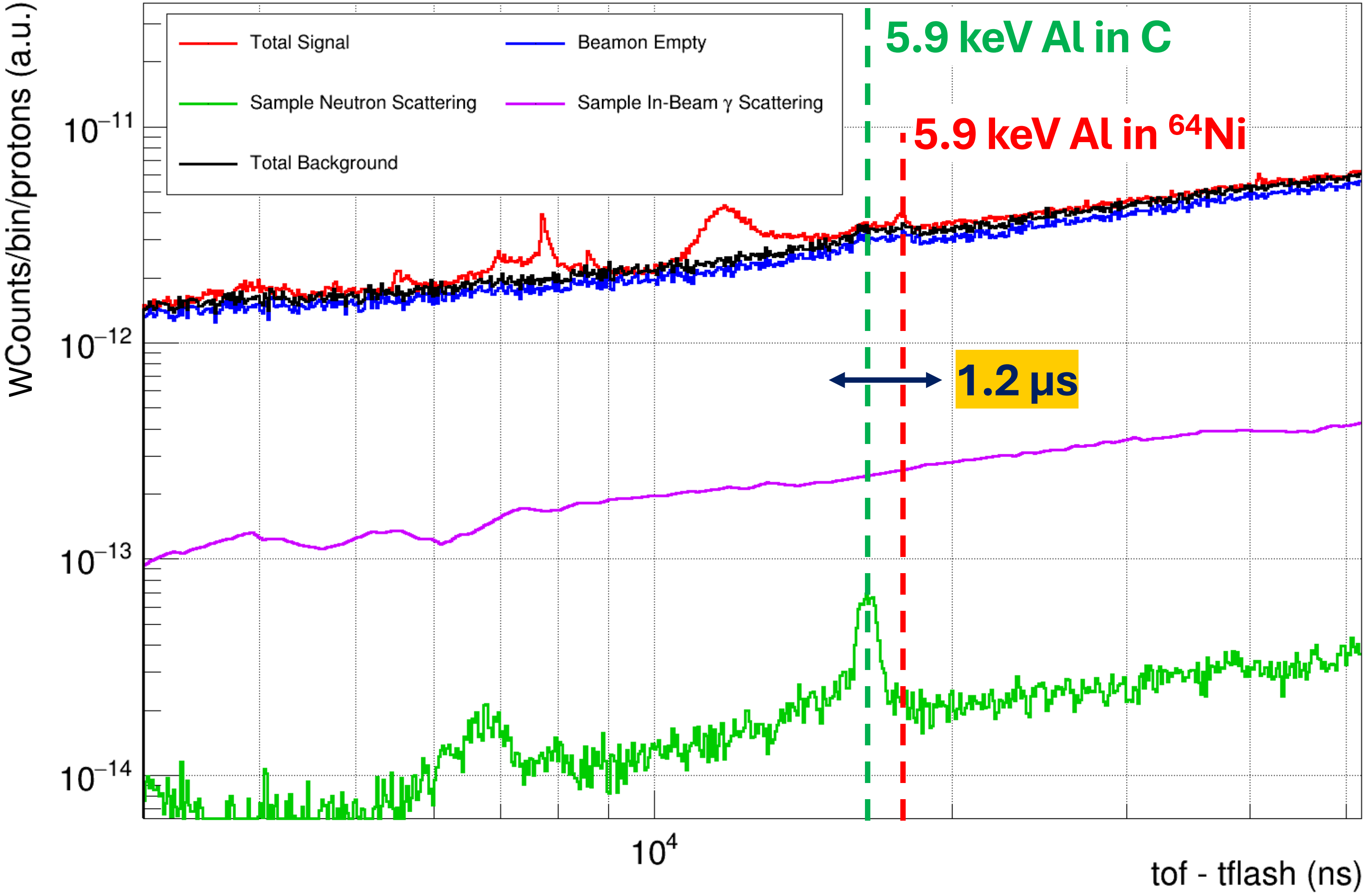


- **Al capture resonances** are clearly observed (in Carbon and Ni64)
- Around 30 keV, Al resonance is exactly **superimposed to Ni64 resonance**

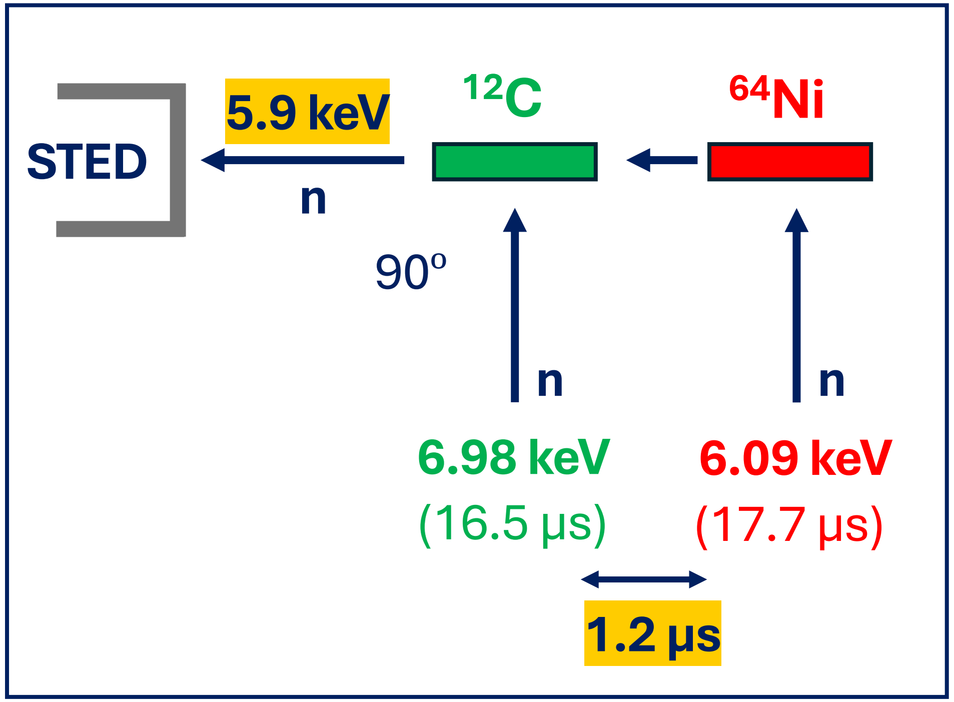


Background subtraction: Carbon

Problem 1: the 5.9 keV Al resonance **appears shifted in tof** between Carbon and Ni64.

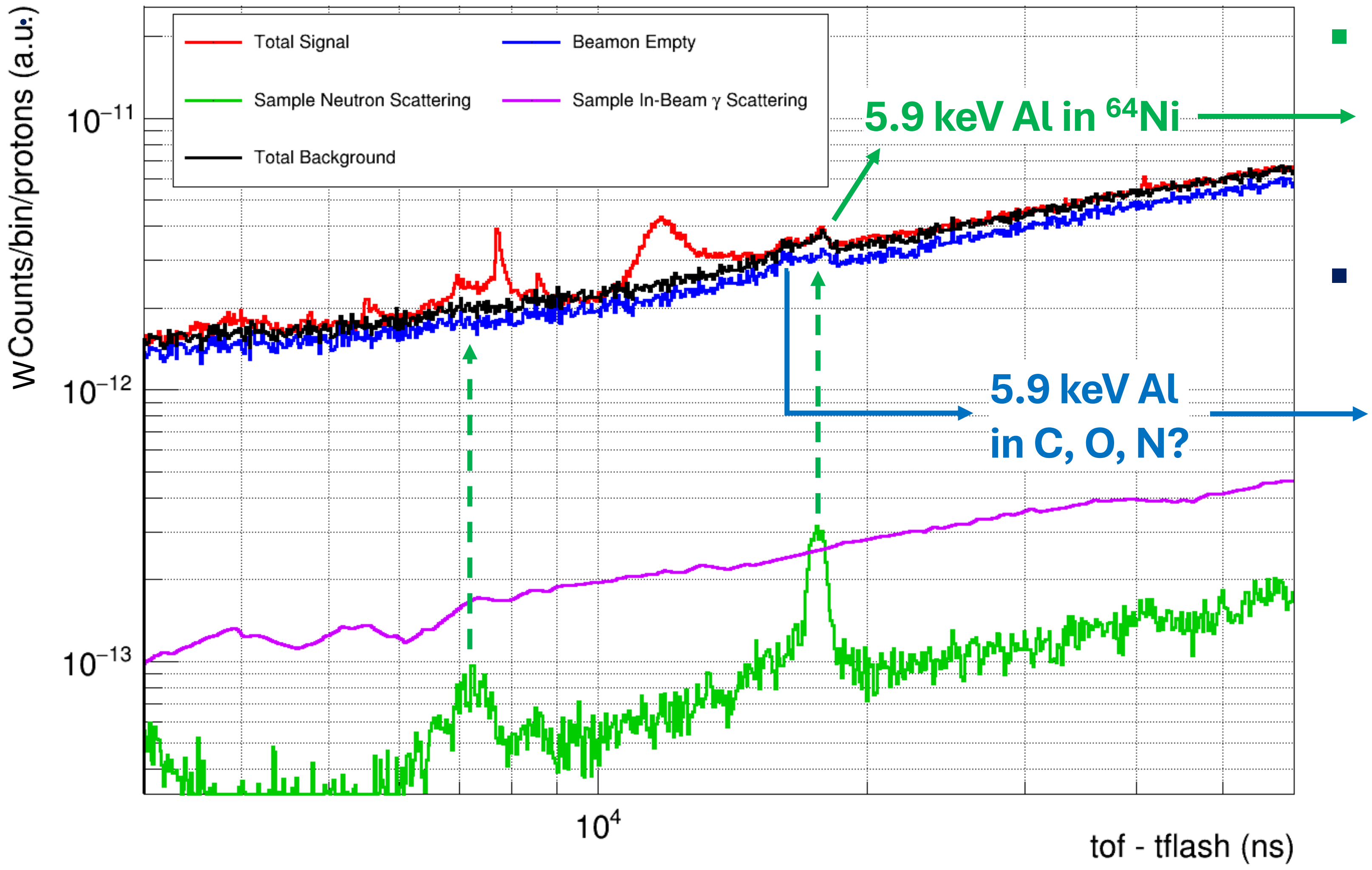


It is just the **dynamic of scattering**:



Background subtraction: Carbon

Problem 1: **Carbon has to be not only scaled, but also shifted!**

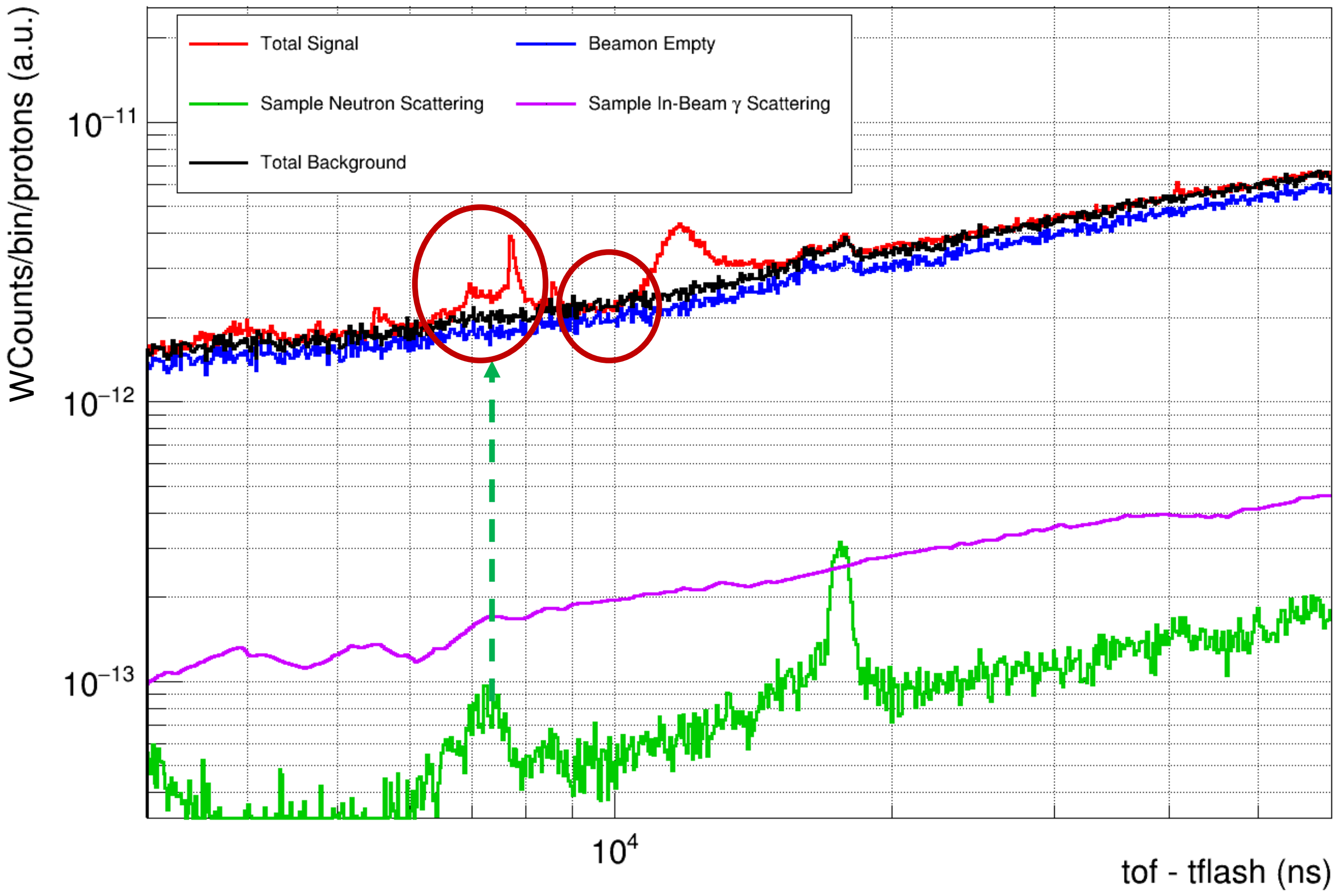


- Shifted and scaled **Carbon** reproduces Ni64 neutron scattering background around the 5.9 keV Al resonance.
- **Additional neutron scattering** component due to scattering on **light material** observed in **empty** (Mylar, **air** ?)

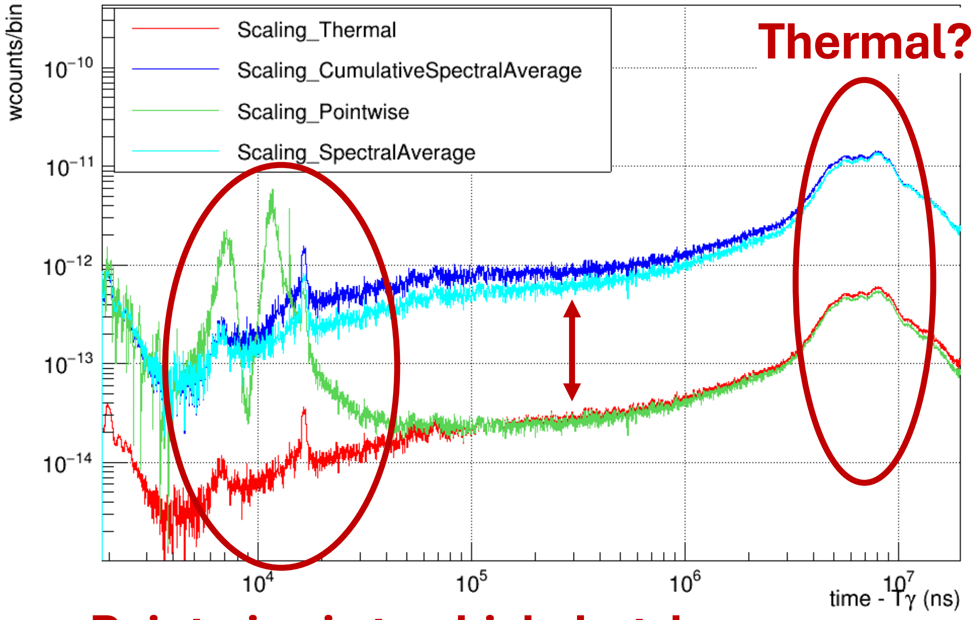
Background subtraction: Carbon

Problem 2: **Backround is not well reproduced** around 30 keV and in the resonance

Problem 3: How to estimate **Neutron Sensitivity ?** (n scattered in Ni resonances and immediately captured)



How to properly scale Carbon?



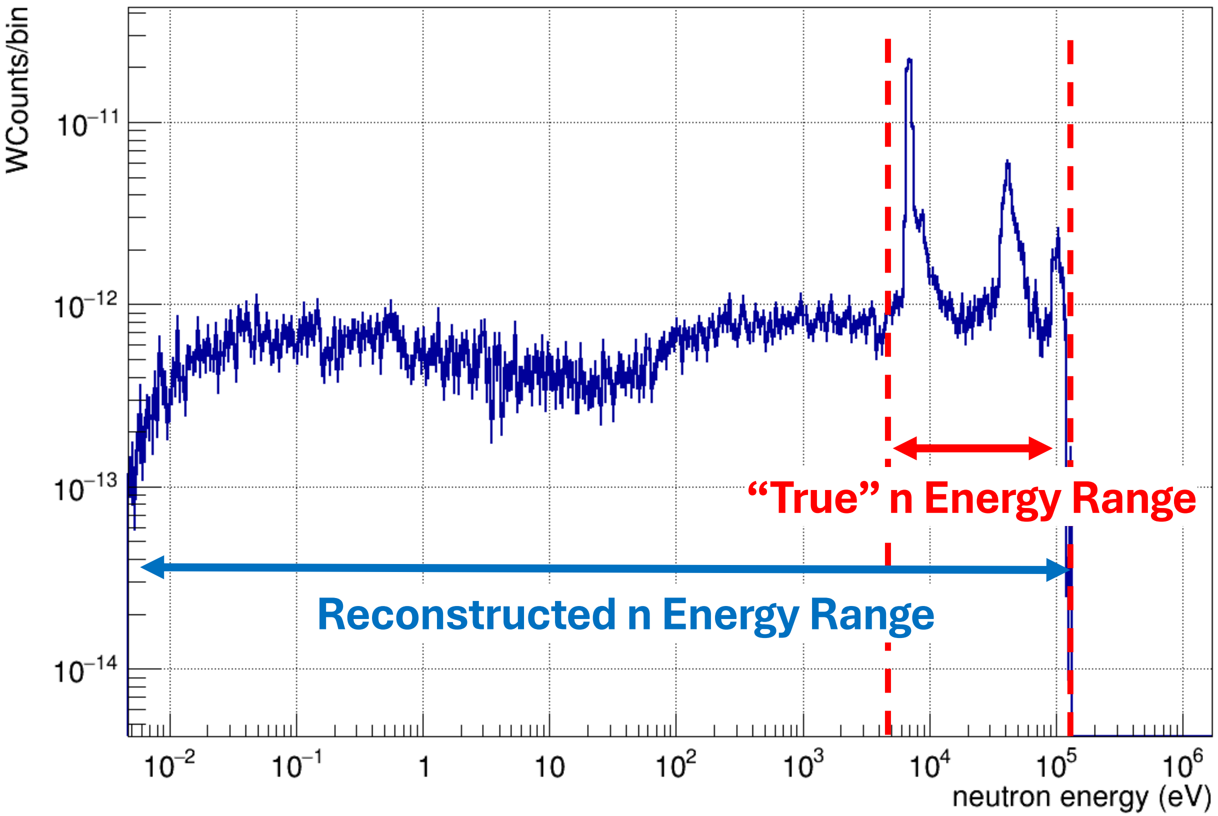
Pointwise is too high, but how else neutron sensitivity?

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

Background subtraction: Simulations

GEANT4 simulations of the neutron scattered from the sample may be a solution.

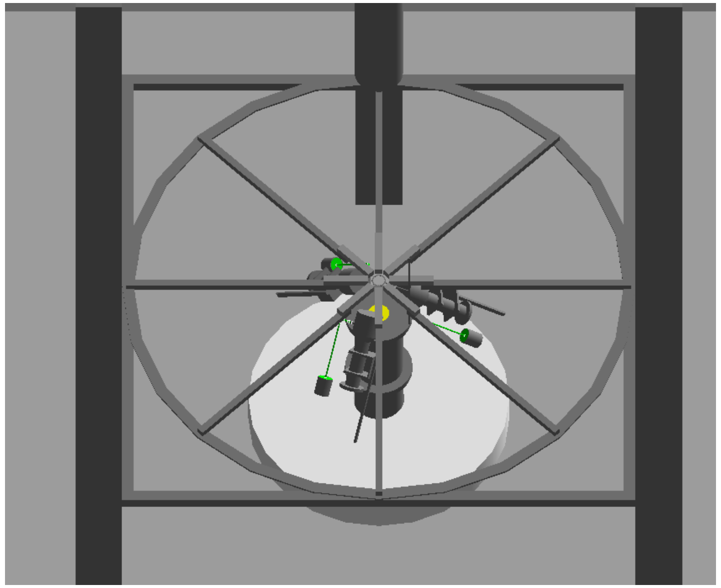
EAR1: ***P. Zugec et al.,*** *NIM A 826 (2016) 80–89*

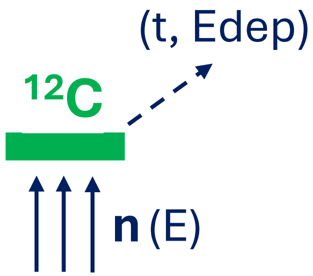


Need to perform simulation of neutrons in the full energy range (GeV – meV)

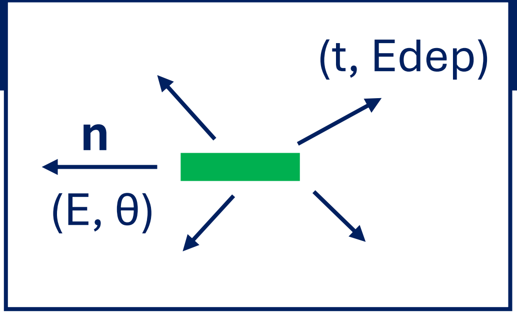
IDEA FOR FUTURE:

- Reproduce Carbon TOF spectrum with GEANT4
- If works, use G4 Simulation for Ni64 neutron scattering bkg and neutron sensitivity



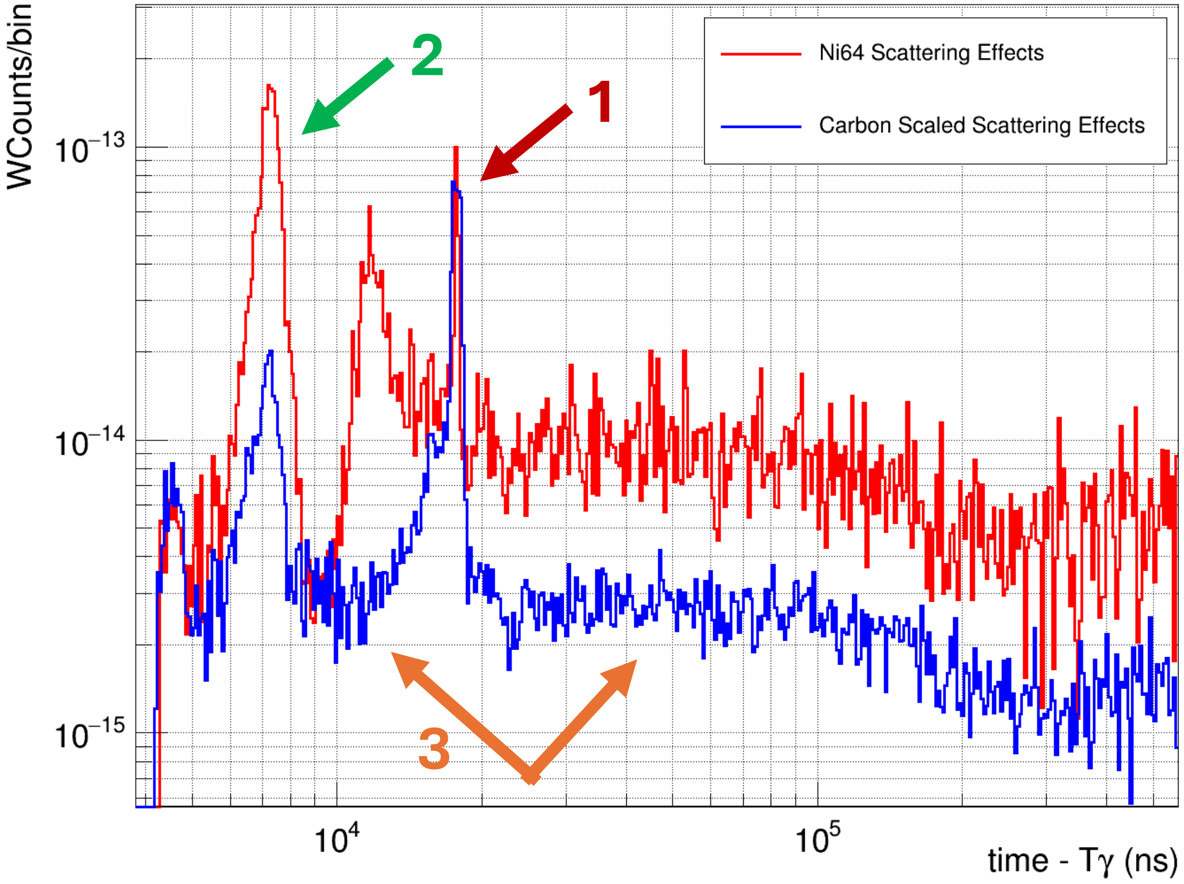


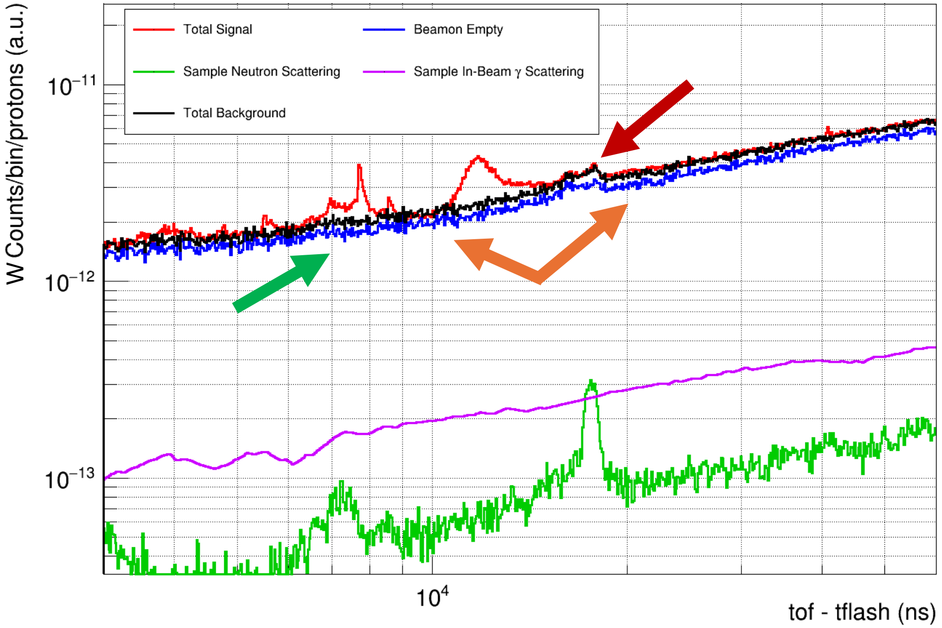
Background subtraction : Simulations



FOR THE MOMENT:

- **Scattered neutrons** simulated only in the energy range of interest **(4 – 100 keV)**
  (Comparison with data is not possible)

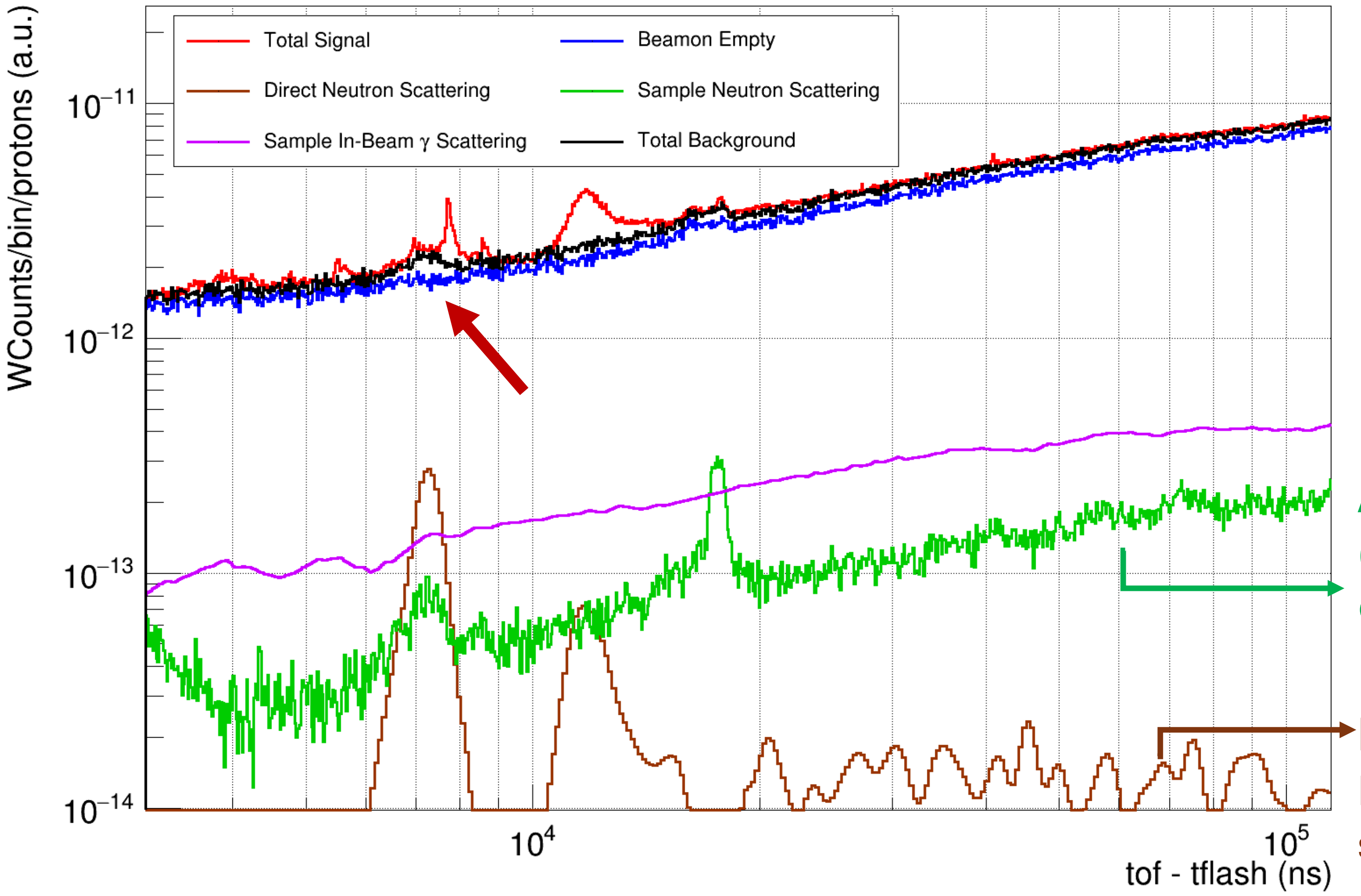




- Simulated Carbon spectrum is scaled as data and subtracted from Ni64 spectrum to **only keep the effect of scattering in Ni64 selected resonances.**

Background subtraction : Simulations

FOR THE MOMENT: PRELIMINARY BACKGROUND SUBTRACTION

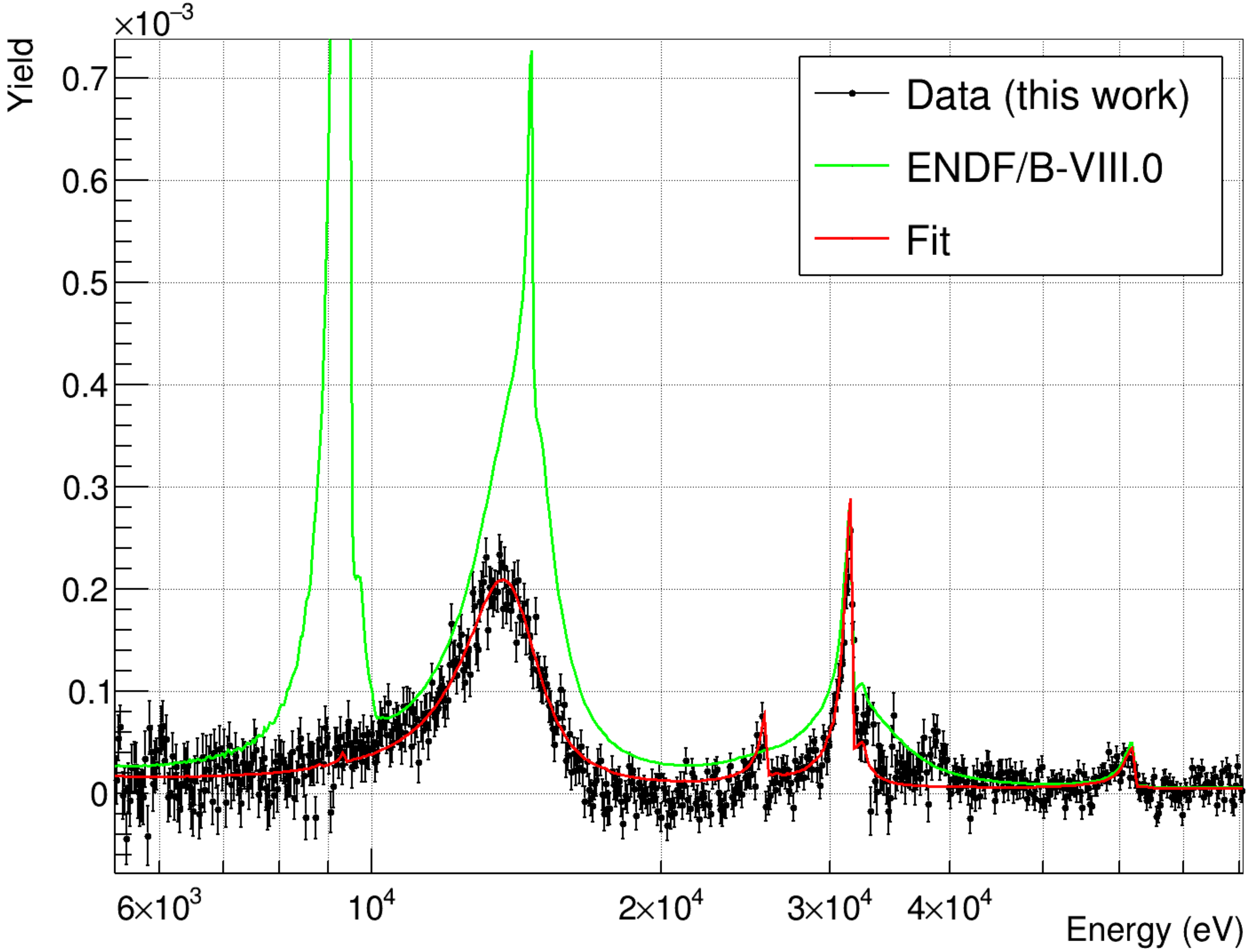


- **«Prompt» (Direct) Neutron Sensitivity** is not bad in the 12 keV resonance, but it is better considered at 30 keV (even if still not enough)
- The improvement in the resonance valley is also not enough

Average neutron scattering bkg (Carbon scaled by **spectral scattering σ,** high energy also)

Neutron Sensitivity: Effect of scattering in the **selected resonances from simulations** *(not possible using pointwise σ scaling)*

If you are impatient: Yield

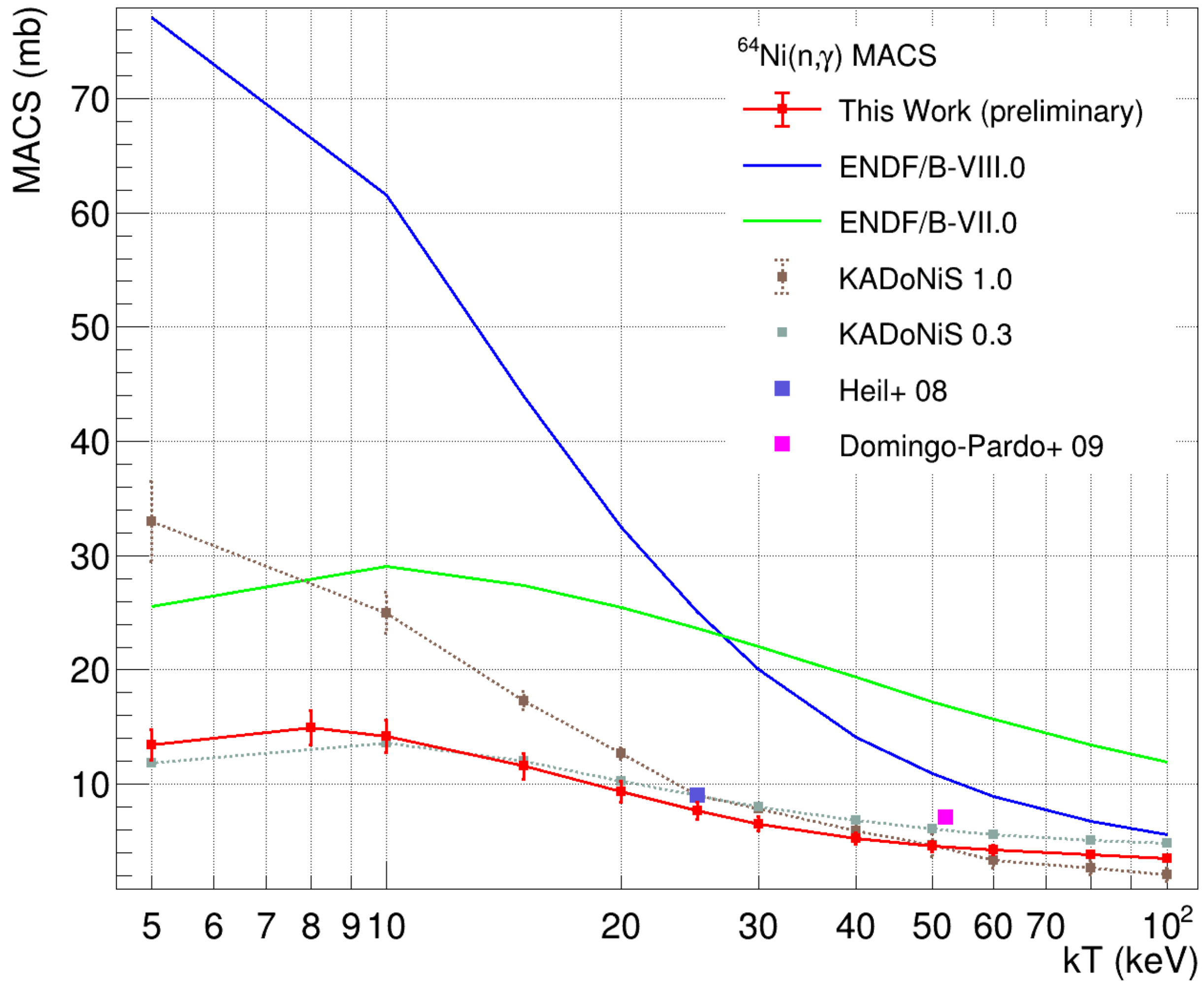


- **No resonance at 9.52 keV**
- **No p-wave at 14.8 keV**
- **Reduced kernel for s-wave at 13.7 keV**
  This work: 1.00 ± 0.02 eV **(PRELIM)**
  Wisshak et al: 1.01 ± 0.07 eV
  Beer et al: 1.9 ± 0.4 eV (ENDF/B-8.0)
- **New p-wave at 25.95 keV ?**
- p-wave at 62.8 keV confirmed (fit is tricky)

- **Fit around 30 keV is not reliable at all**:
  - 33.9 keV s-wave cannot be fitted (Al)
  - 31.9 keV p-wave is fitted, but kernel depends on the underlying s-wave

If you are impatient: MACS

A **preliminary MACS** has been computed using the preliminary resonance fits

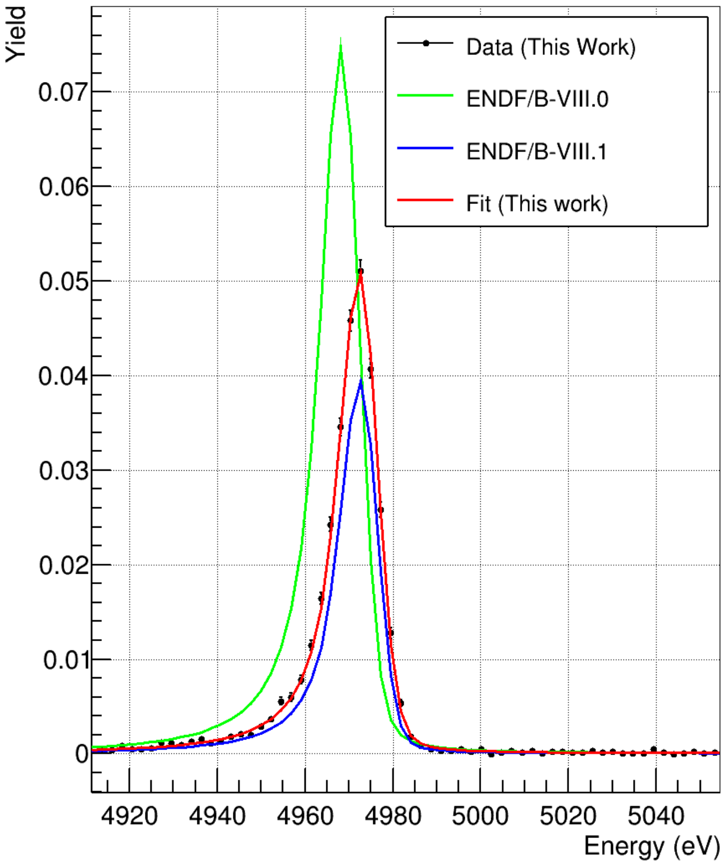


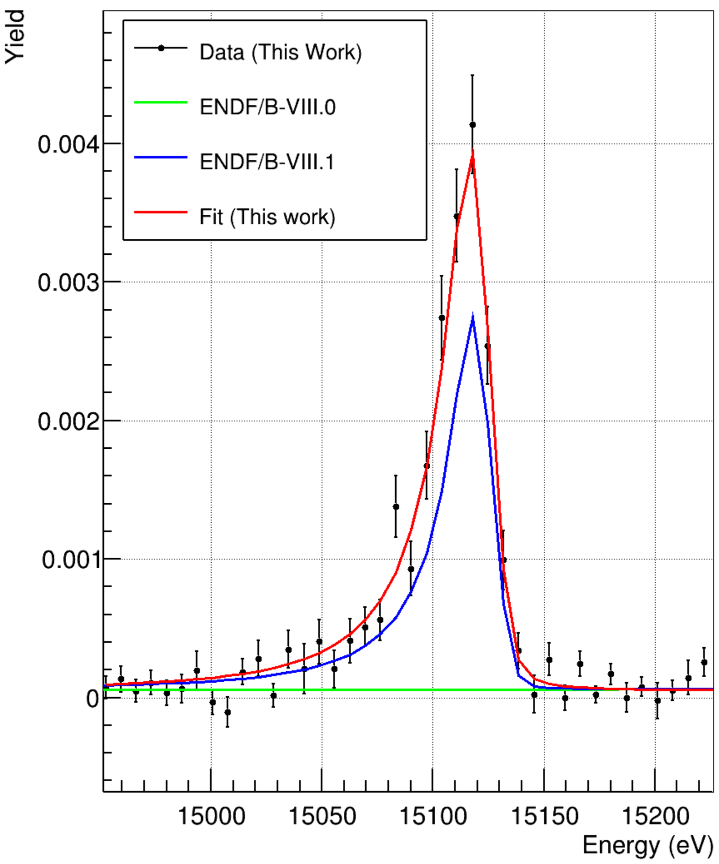
- MACS from this work **is closer to activation measurements** (**Heil+ 2008**) wrt nuclear data libraries
- Energy extrapolation is similar to **KADoNiS0.3** (based on ENDF/B-VII.0, no resonance at 9.52 keV)

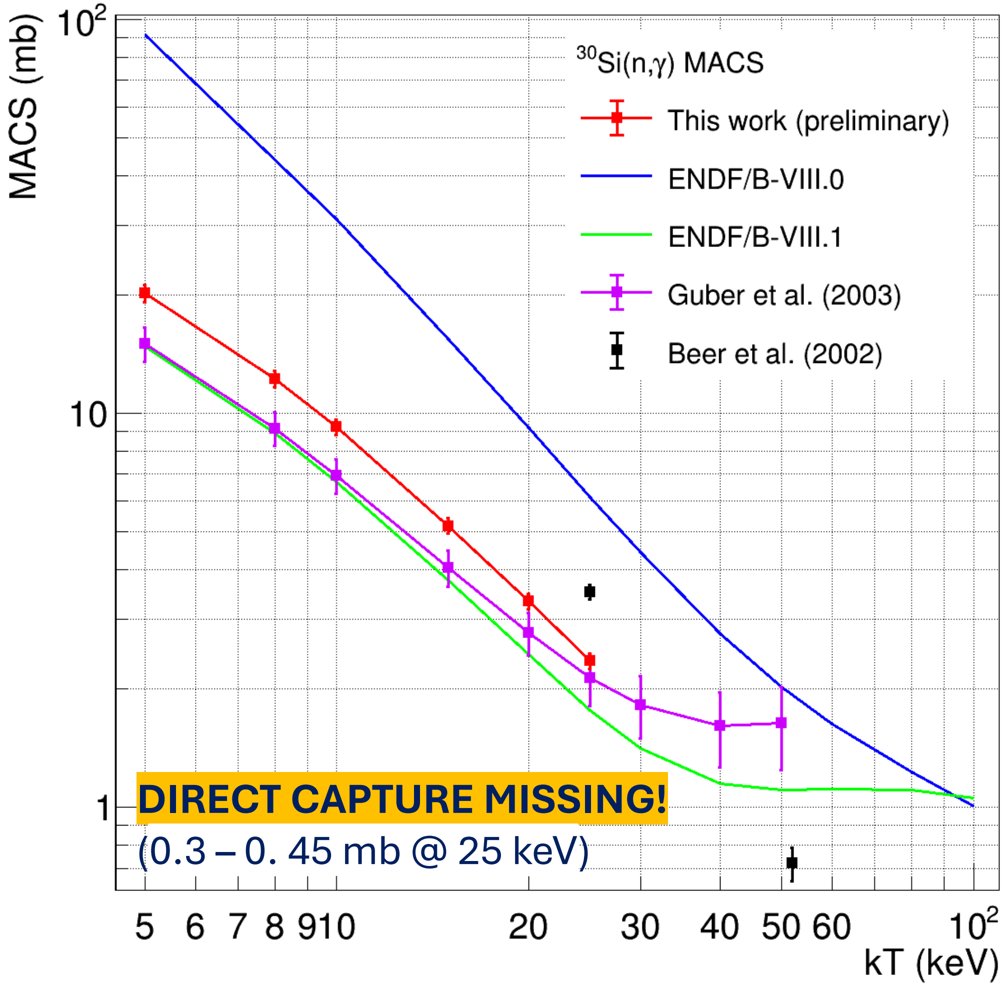
- **Direct capture** (thermal cross section) has to be fitted, yet.
- **MACS around 30 keV is probably underestimated** because of the problems in resonance fitting in this energy region

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

Results of **$^{30}Si(n,\gamma)$ measurement in EAR1** (still missing direct capture from thermal in EAR2):







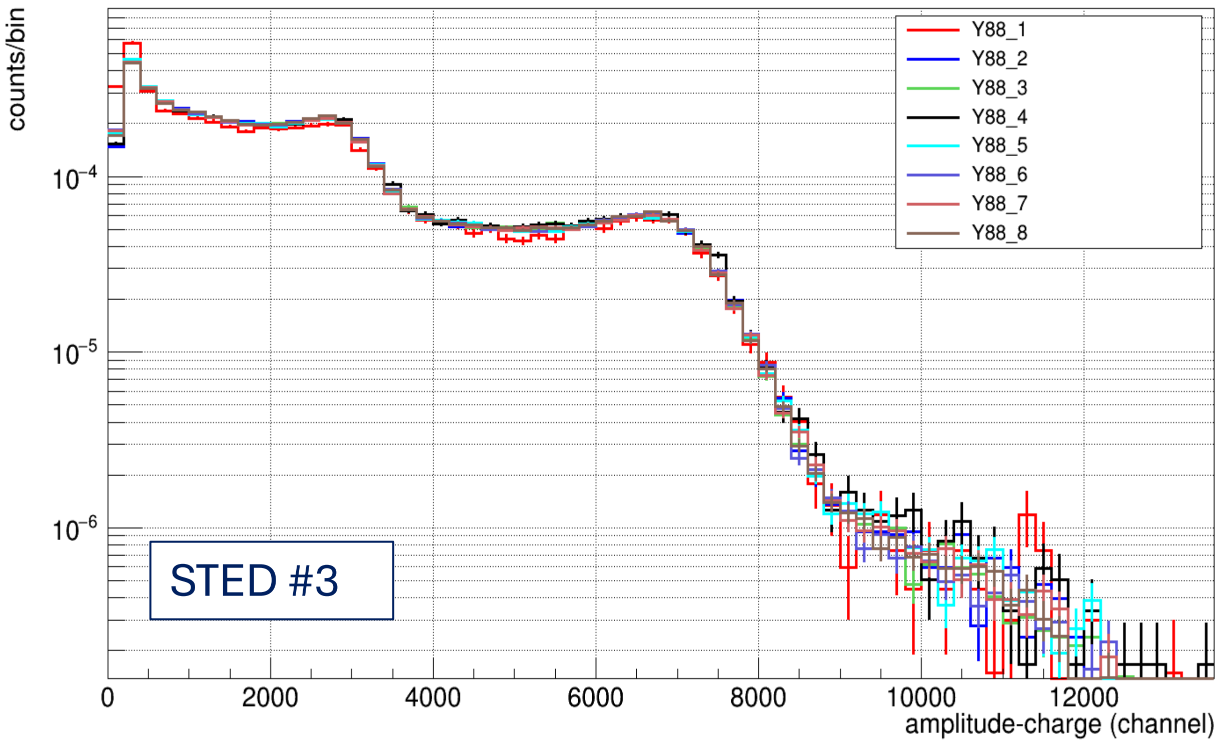
^{30}Si(n,γ) & ^{64}Ni(n,γ): Status of the Analysis

Michele Spelta

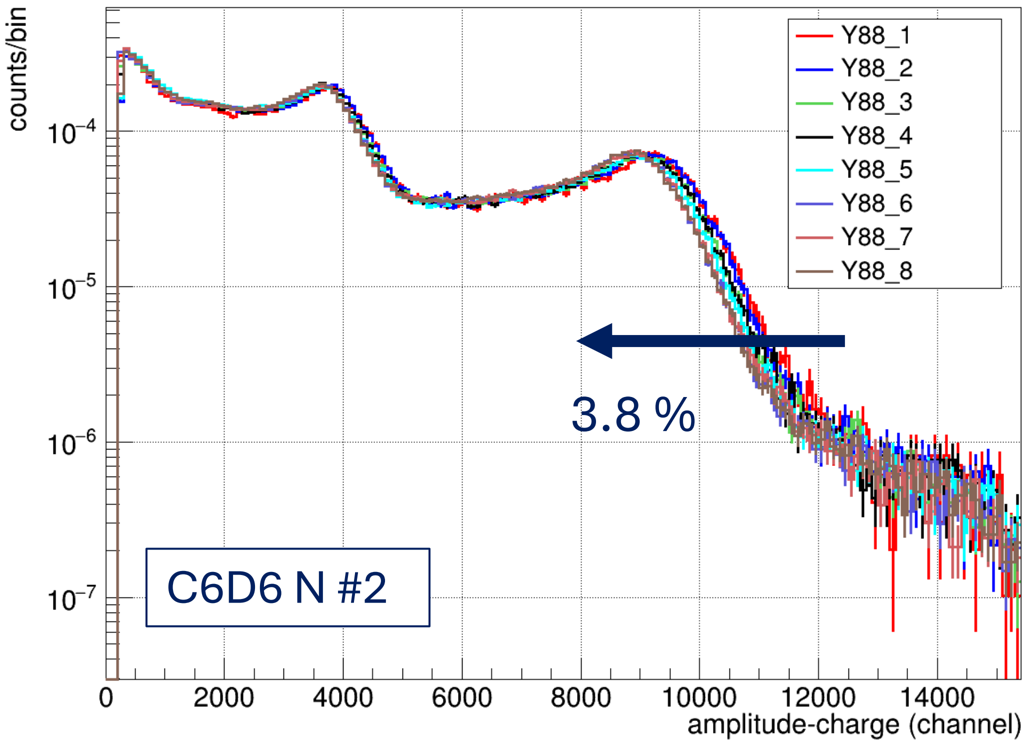
EAR2: Calibrations

Gain shift has been comparing different Y88 and Au runs:

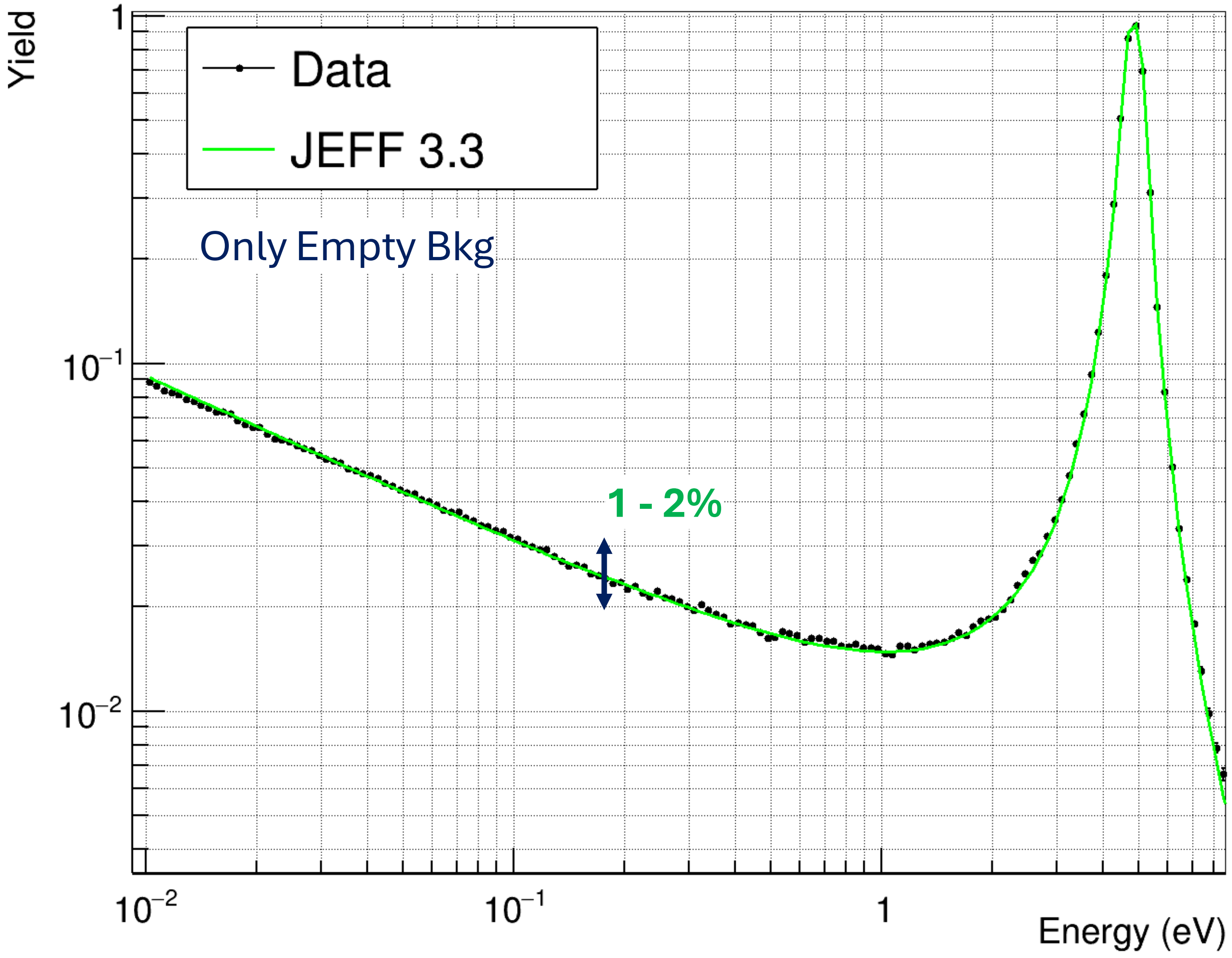
STED: Stable



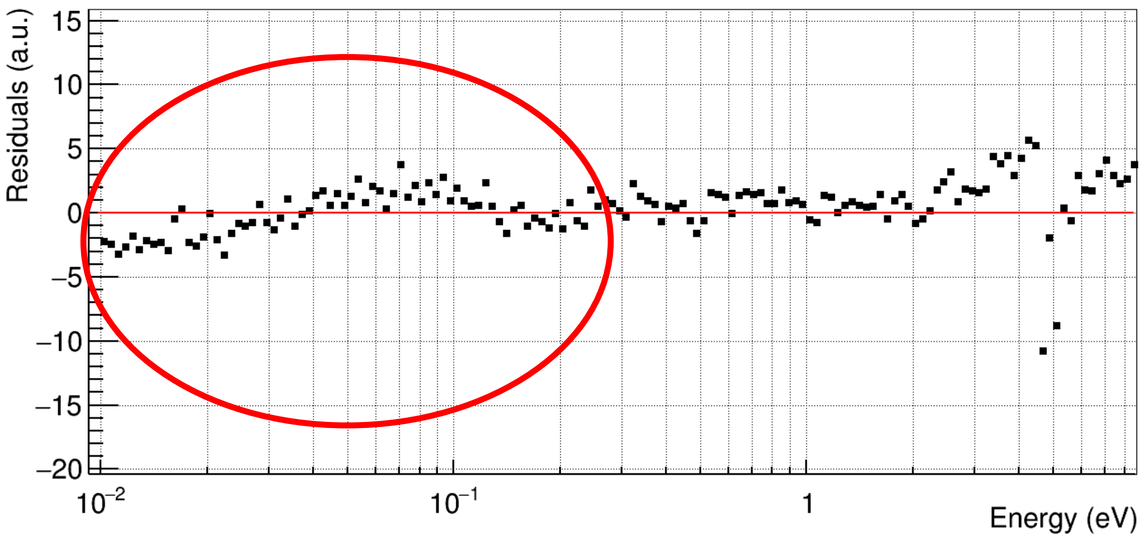
C6D6: Gain Shift



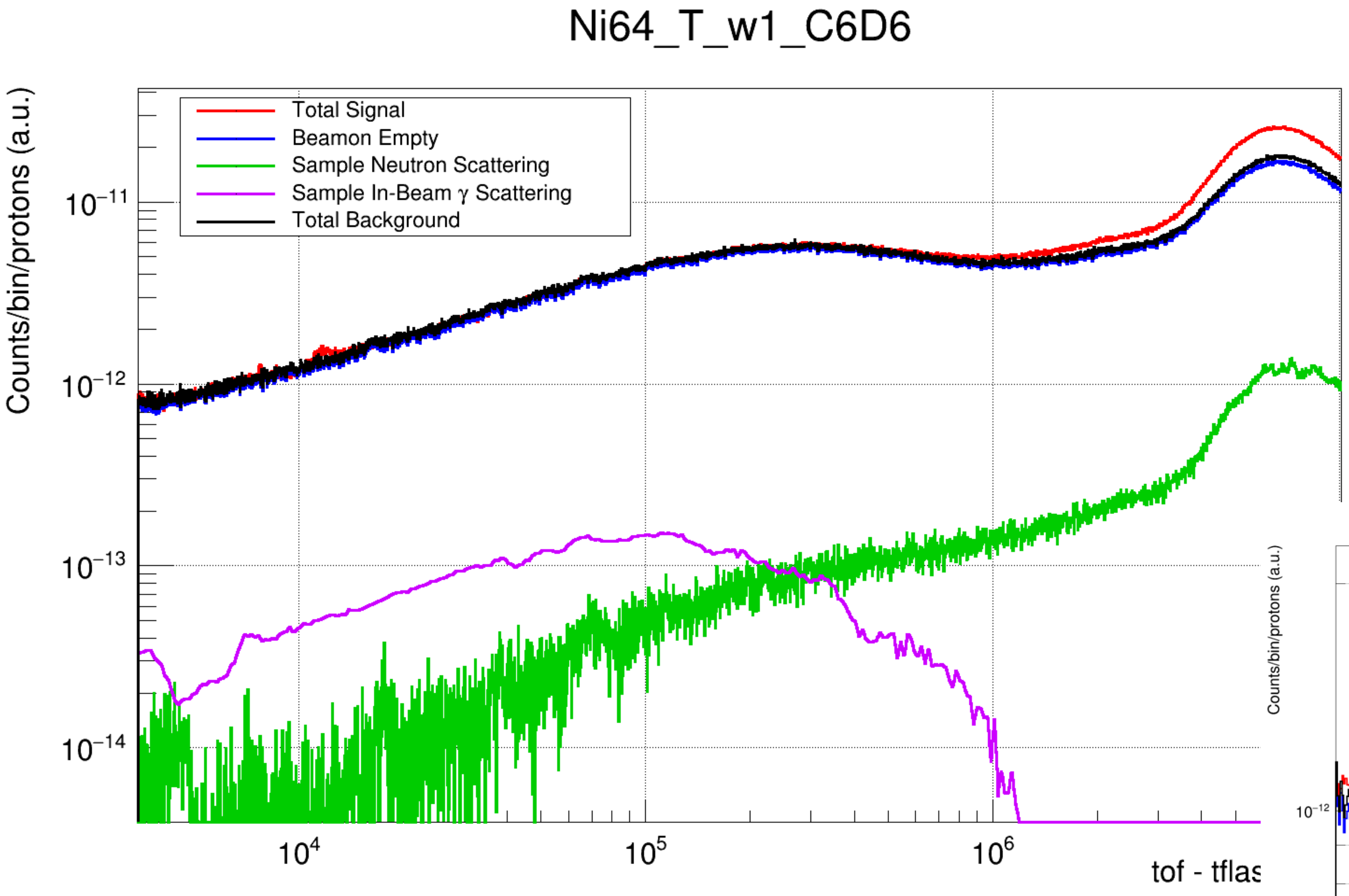
Gold (15 mm*): Thermal region



- But still there seems to be a **structure in the shape** that is not understood (even if the values are in agreement within 1 – 2 % if only empty subtracted)

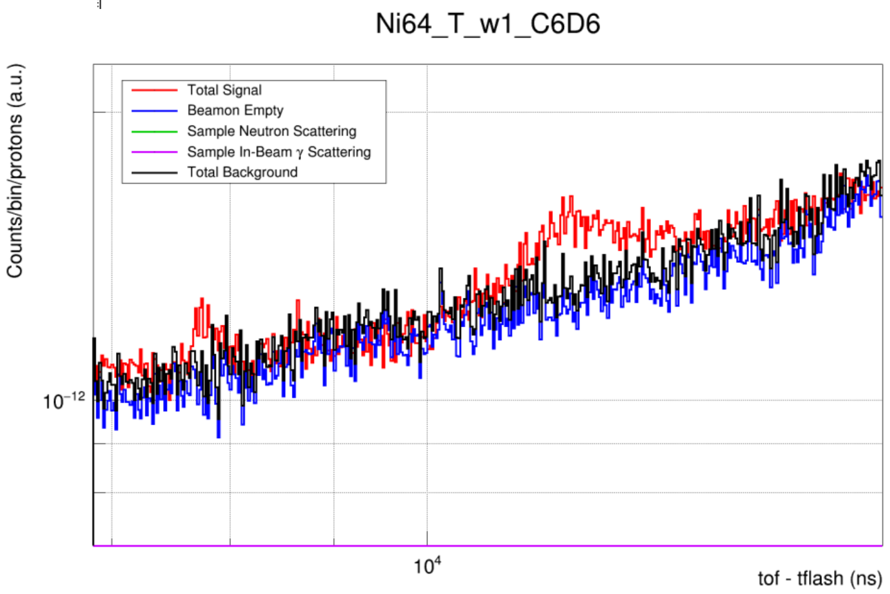


PROBLEMS IN BACKGROUND ESTIMATION FOR NEUTRON SCATTERING (CARBON)

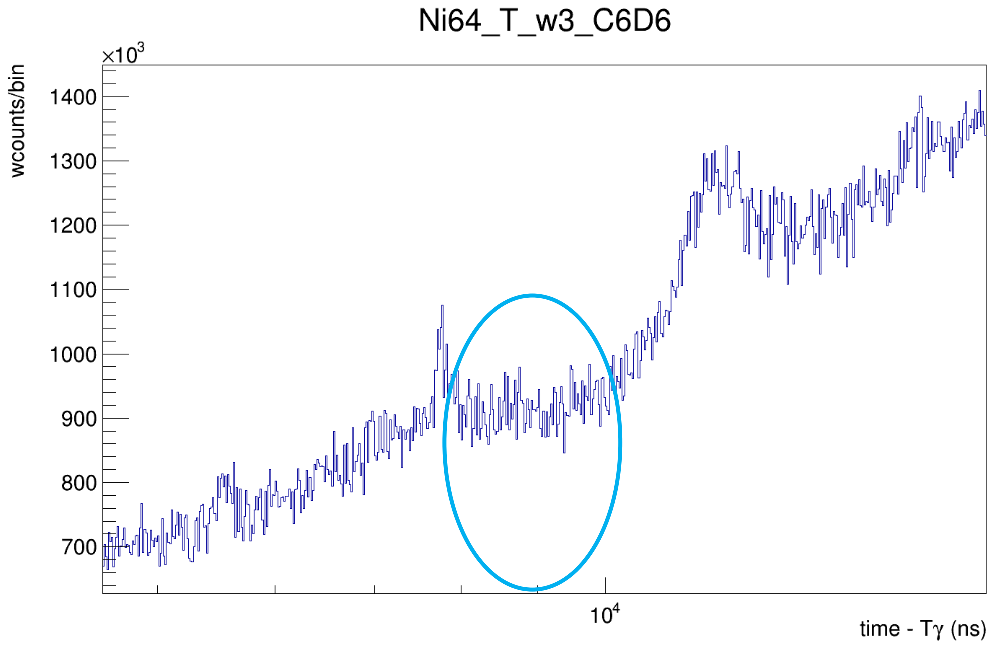


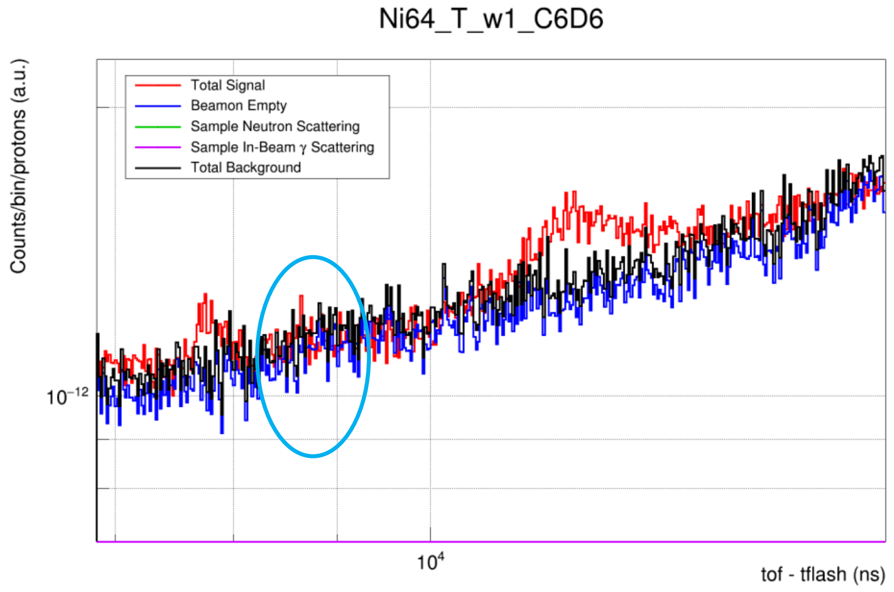
C6D6 do not have Aluminum, **BUT**:

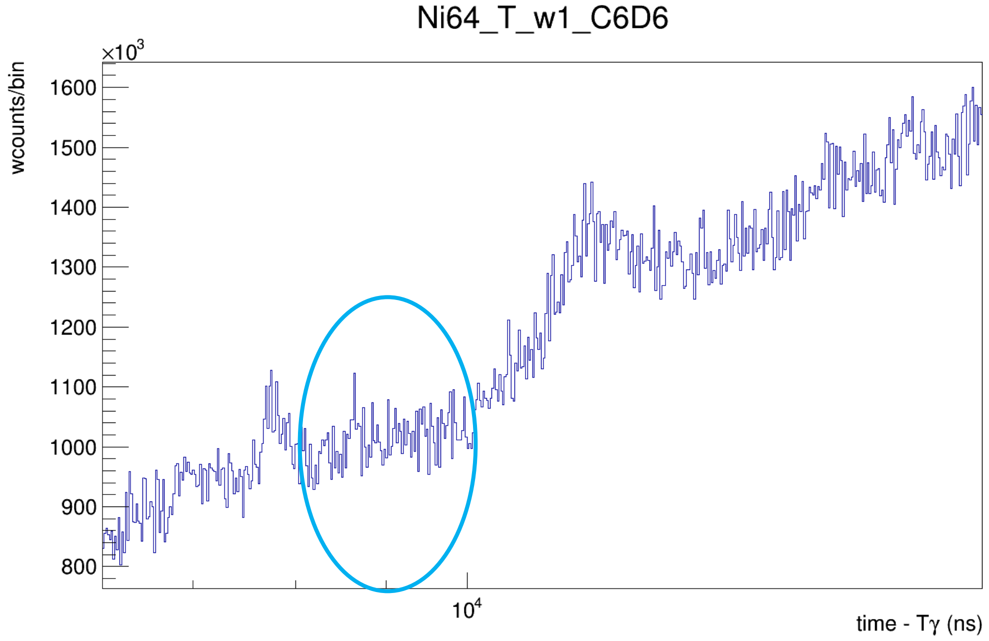
- Signal/Bkg ratio is worse
- No way to accurately normalize (idea can be to normalize to first Ni resonance, but need to fit it well with STED or normalize gold at thermal)

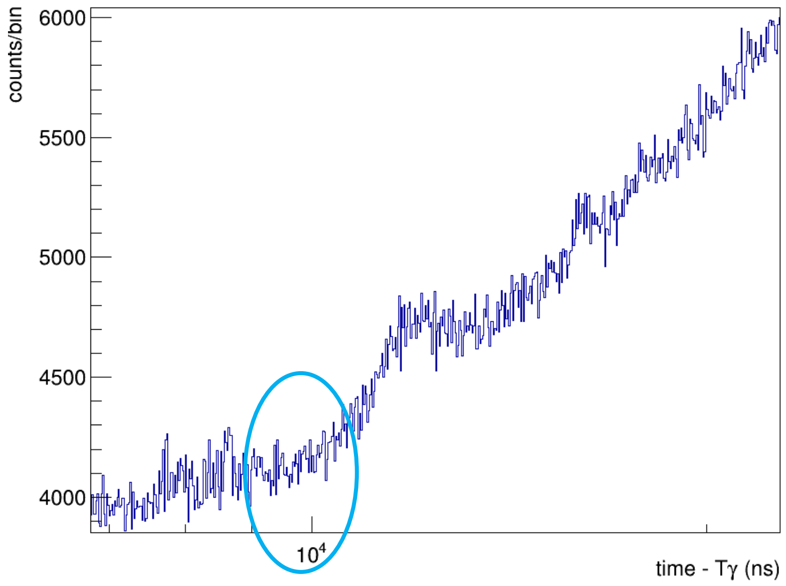


PROBLEMS IN BACKGROUND ESTIMATION FOR NEUTRON SCATTERING (CARBON)









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