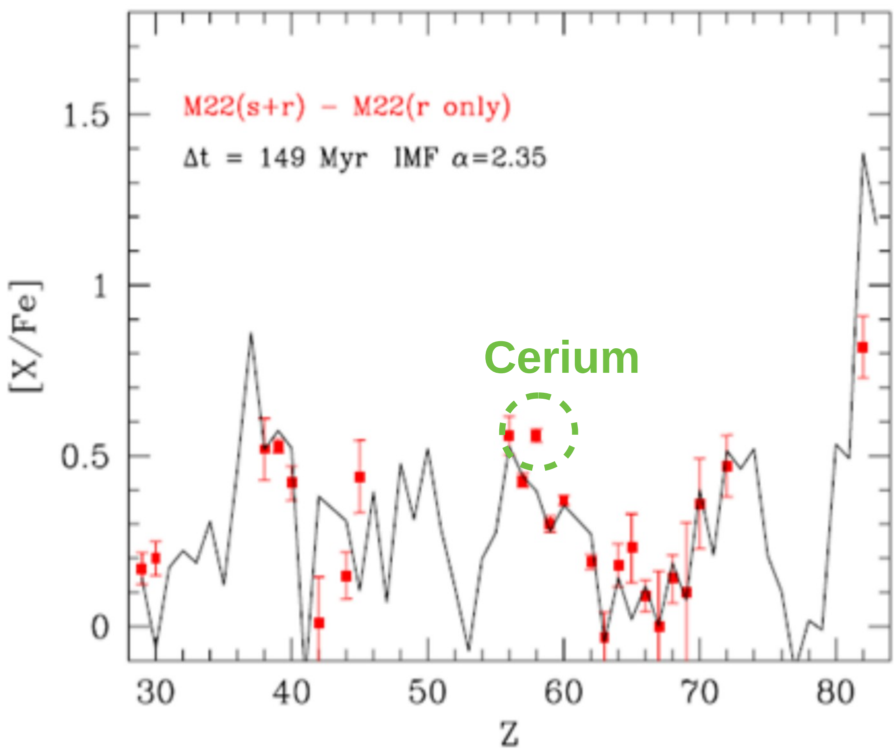
Status of $^{140}Ce(n,\gamma)$

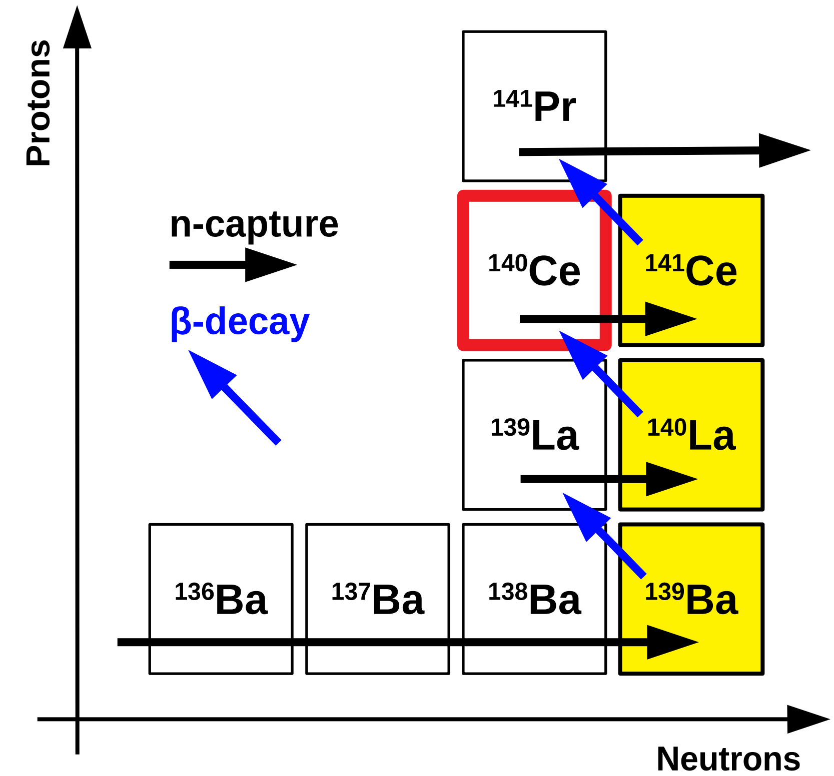
Why Cerium?

Cerium is mostly produced via **s-process**, the final abundance of ^{140}Ce (89% of natural cerium) predicted by stellar models strongly depends on his destruction channel ^{140}Ce(n,γ).

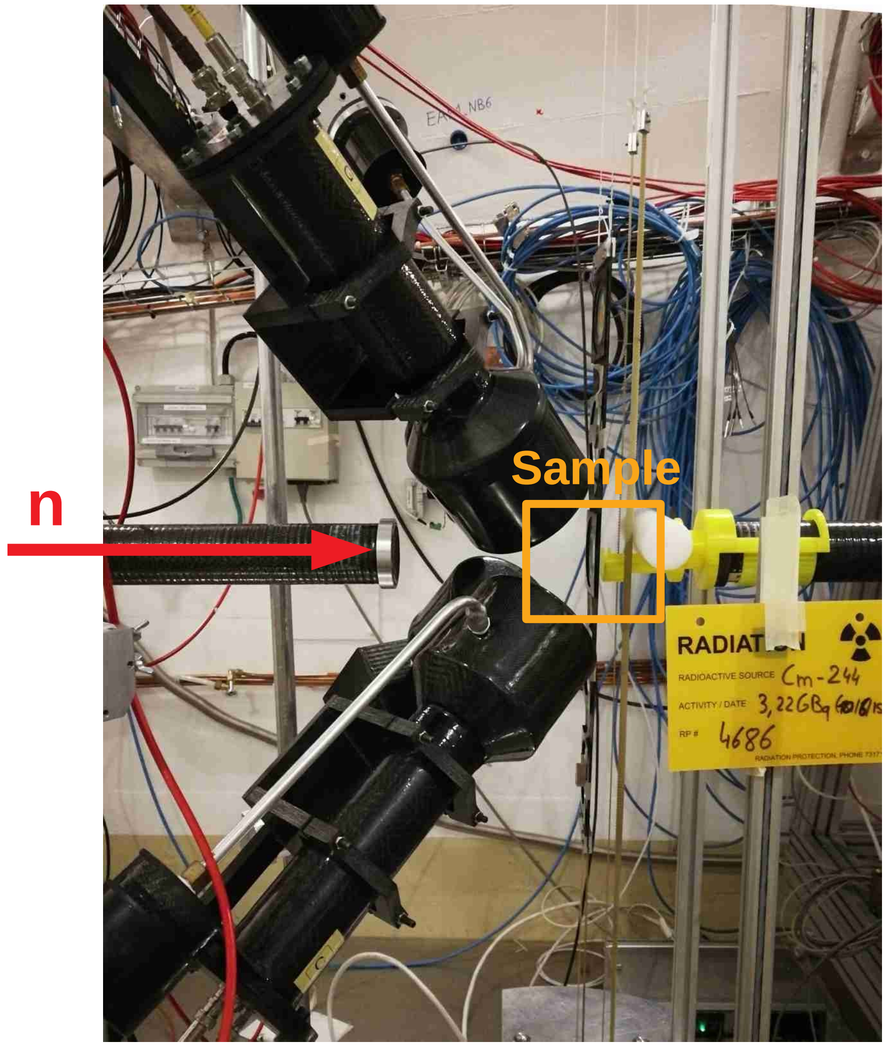
Small cross section (magic number of neutrons), the **MACS (Maxwellian average cross section) is determined by resonances in keV region**.



O. Straniero, S. Cristallo, L. Piersanti APJ **785** (2015) 77



Experimental setup



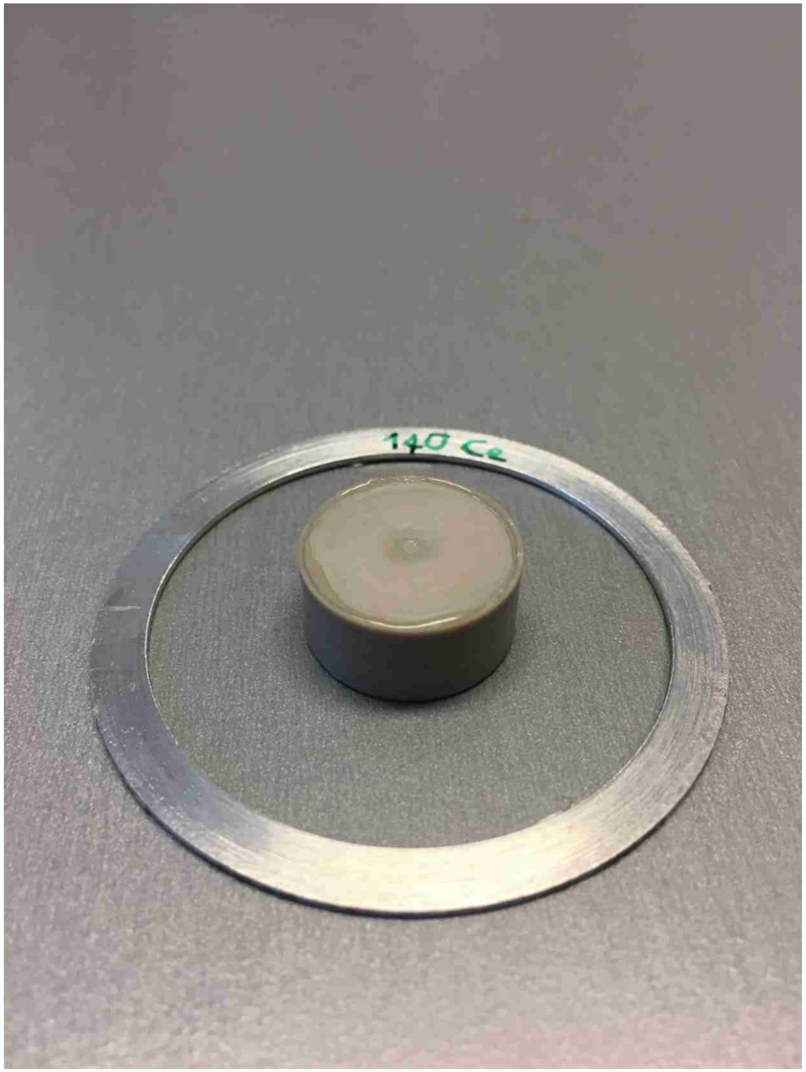
4 Liquid scintillator detectors containing C_6D_6 used to measure **(n,γ)** reaction cross sections.

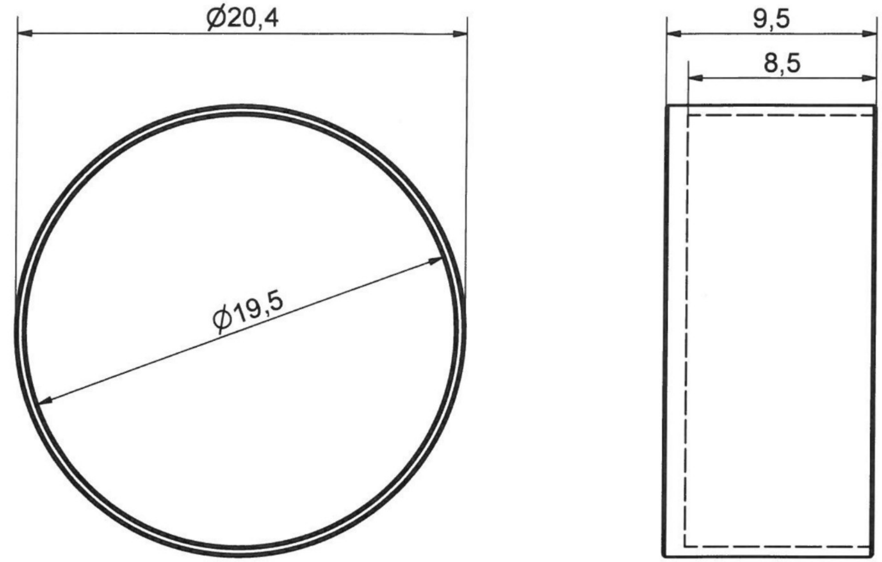
Low neutron sensitivity and background thanks to the carbon fiber structure.

A gold sample is used as reference to normalize the results.

The measurement lasted 3 weeks, including a weekly calibration and the background.

Sample





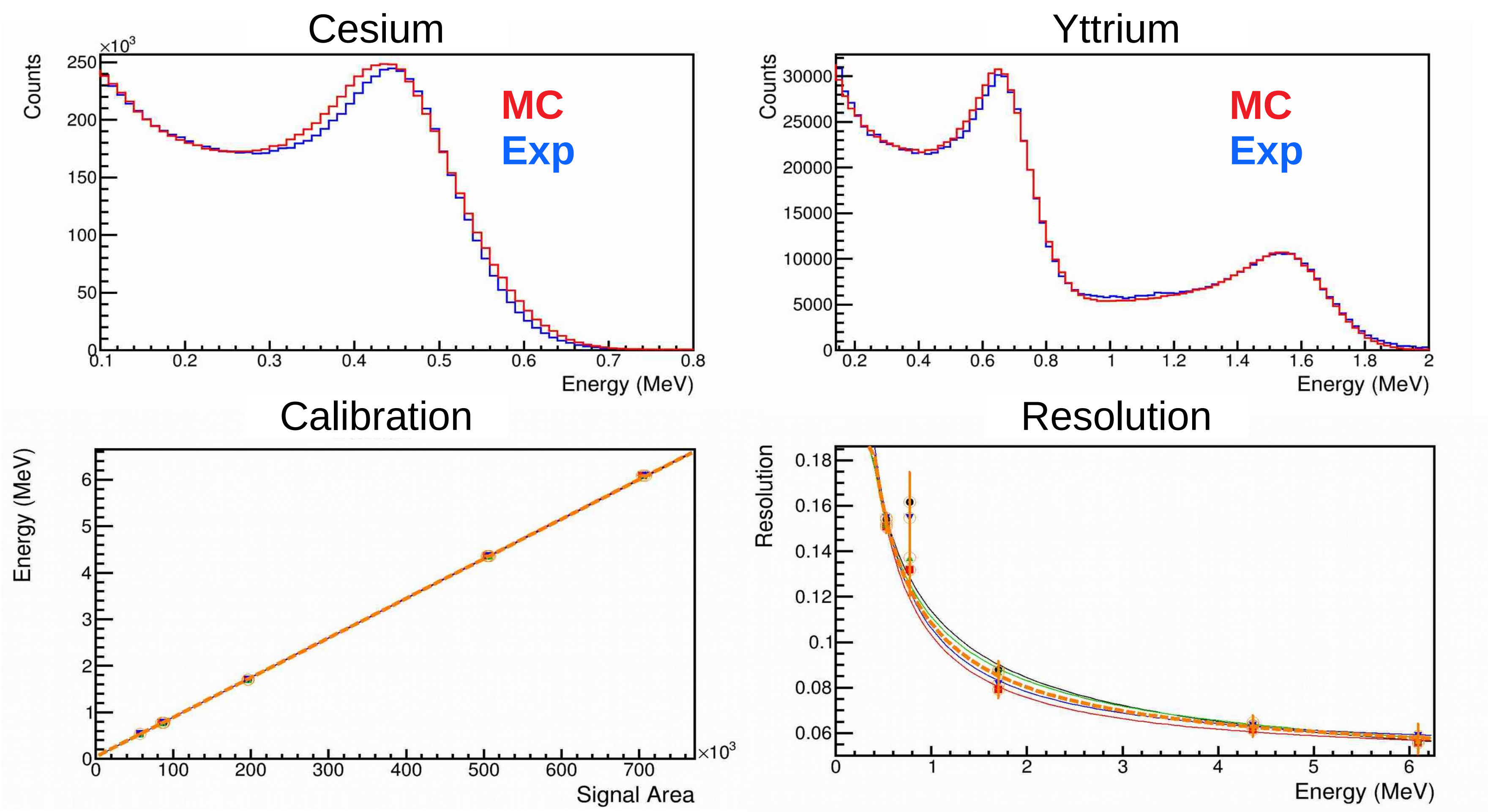
PEEK capsule

ISOTOPIC CONTENT

ISOTOPE	136	138	140	142
CONTENT (%)			99.4	0.6

Calibration & Resolution

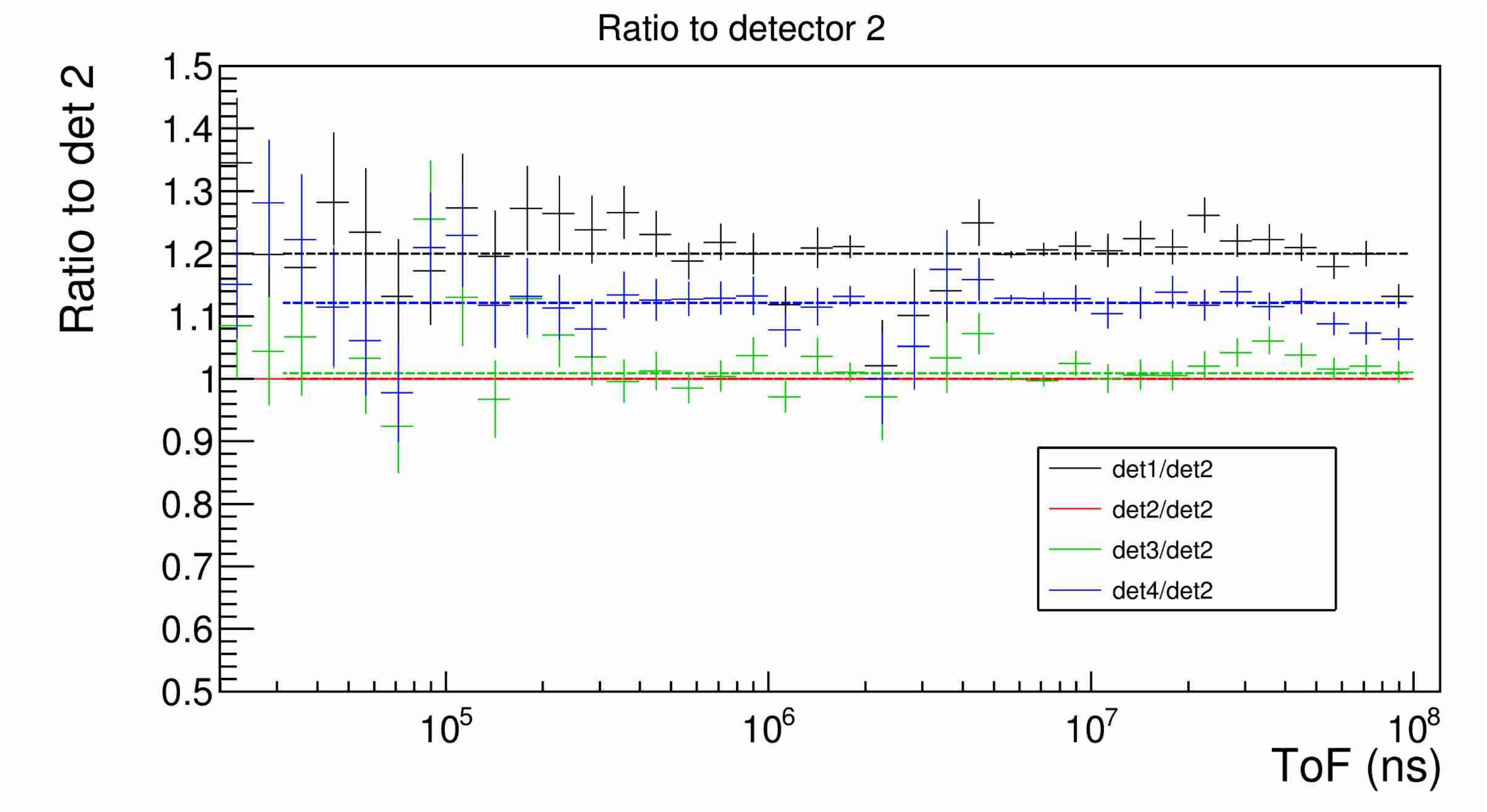
The detectors' calibration lines and resolution have been computed using the data collected with 4 gamma sources (^{137}Cs, ^{88}Y, $^{241}Am^{9}Be$, $^{244}Cm^{13}C$) and a MC simulation (made by Annamaria).



Gold Weighting Functions

Theshold: [0.15,8.0] MeV

Ratio between the tof spectra (weighted) to the detector2 (used as reference), the MC simulation's geometry is modified to reduce the discrepancies.

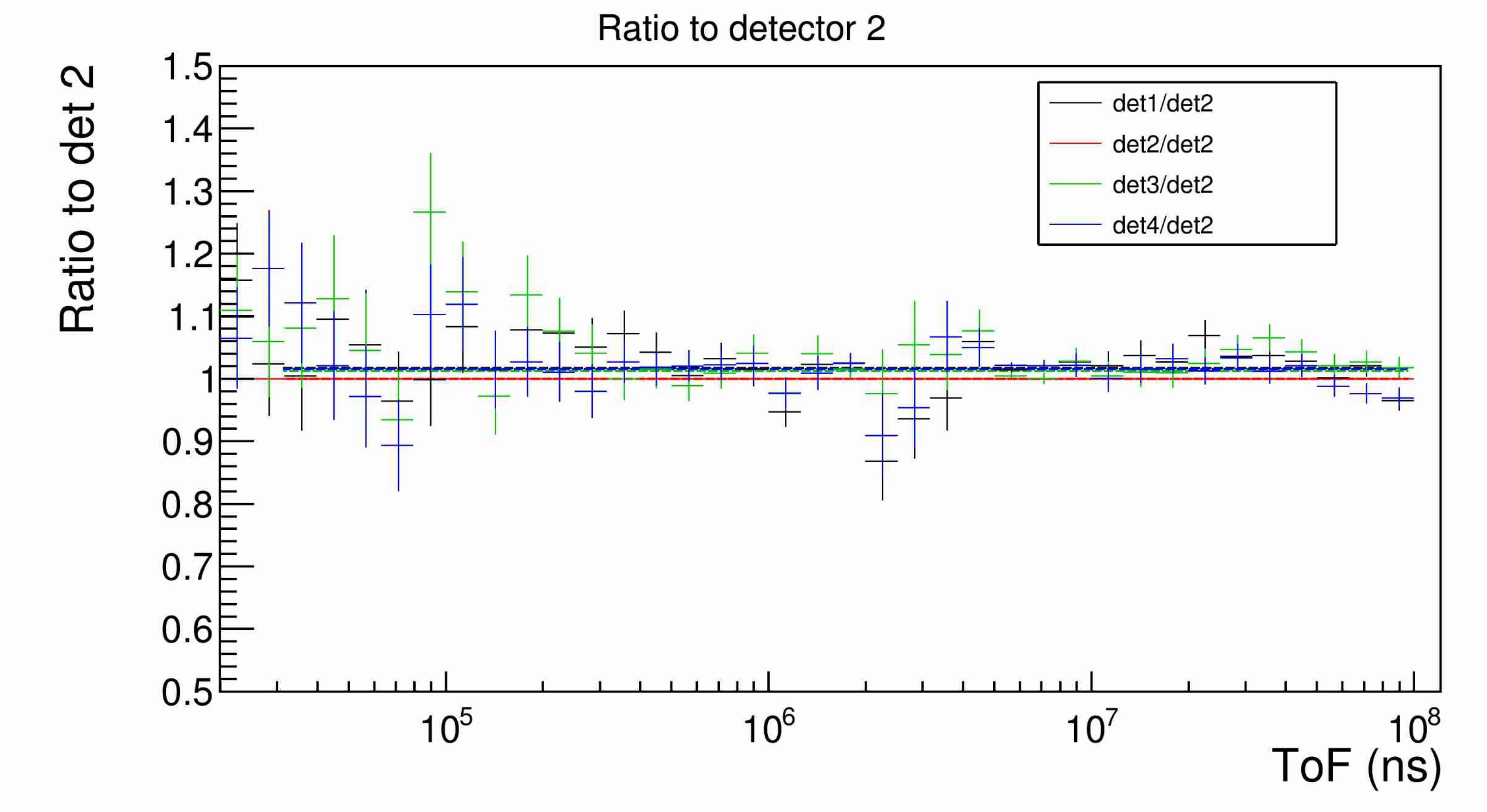


DetN	Distanza
1	**10.0**
2	**10.0**
3	**10.0**
4	**10.0**

Gold Weighting Functions

Theshold: [0.15,8.0] MeV

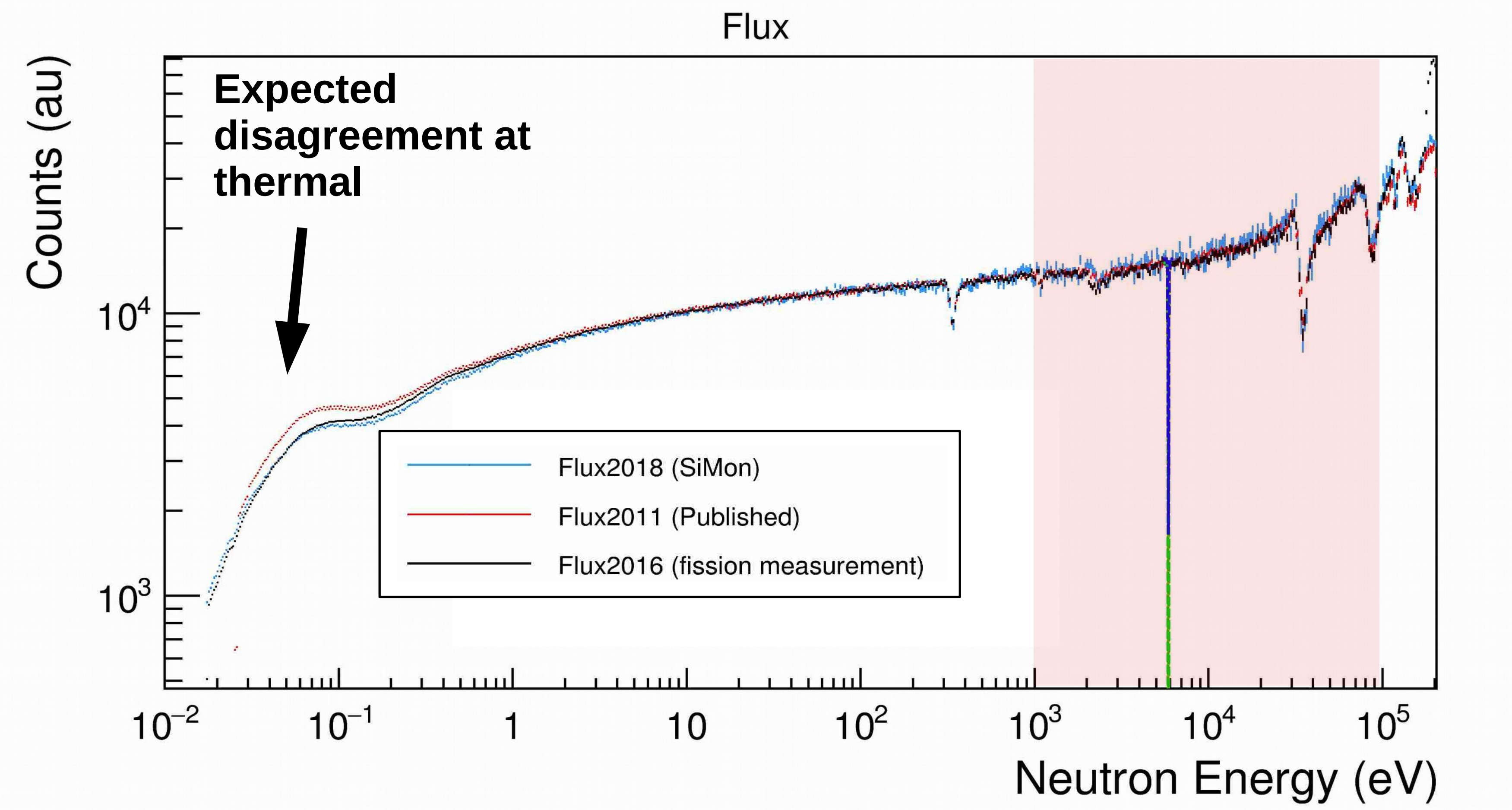
With the final configuration the tof spectra ratio between all the detectors is within the 2%.



DetN	Distanza
1	**9.0**
2	**10.0**
3	**10.0**
4	**9.35**

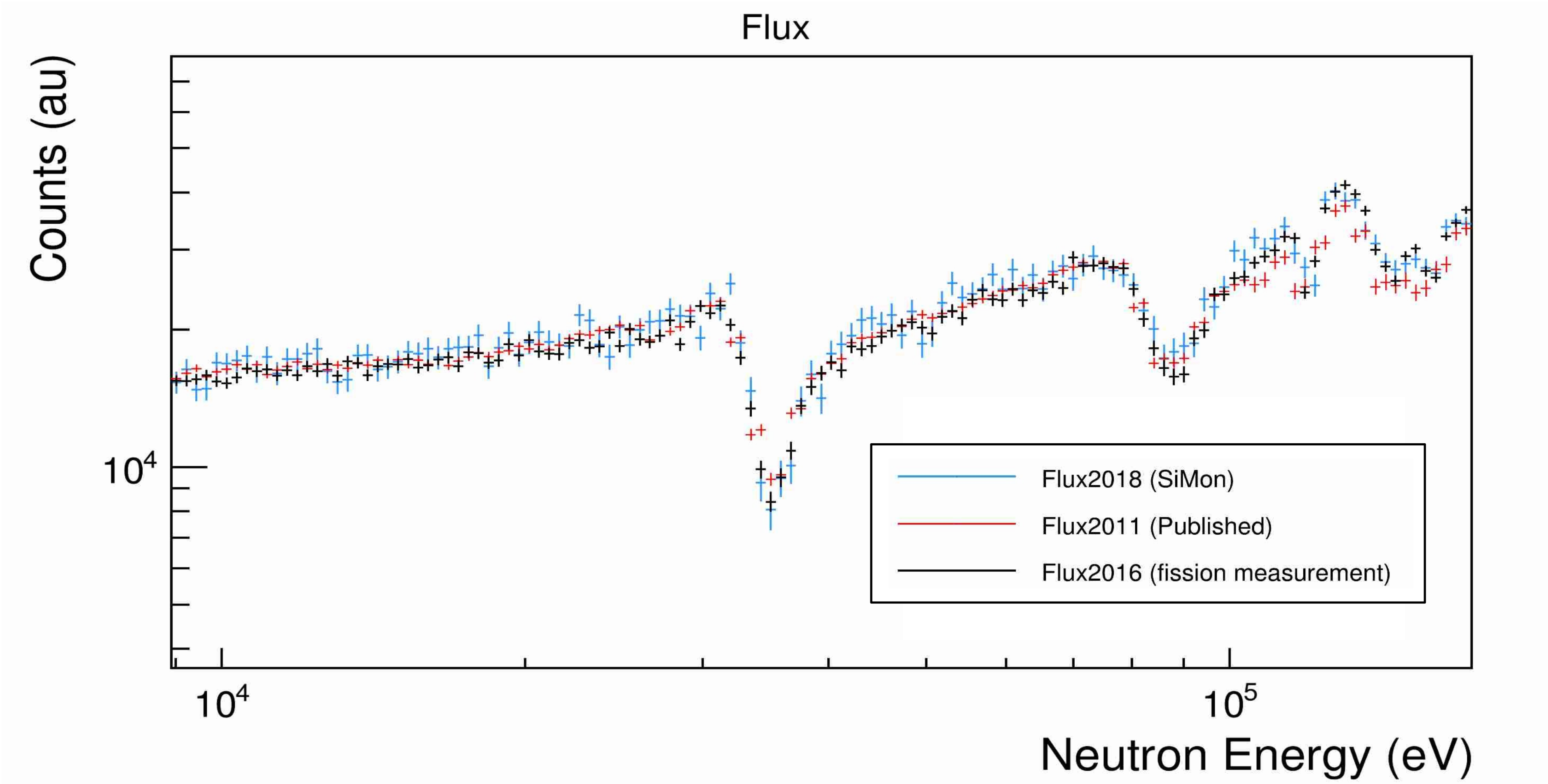
Flux

The flux monitored with SiMon is in good agreement with the official one (2011) and with the flux of the $^{235}U(n,f)$ measurement (2016).



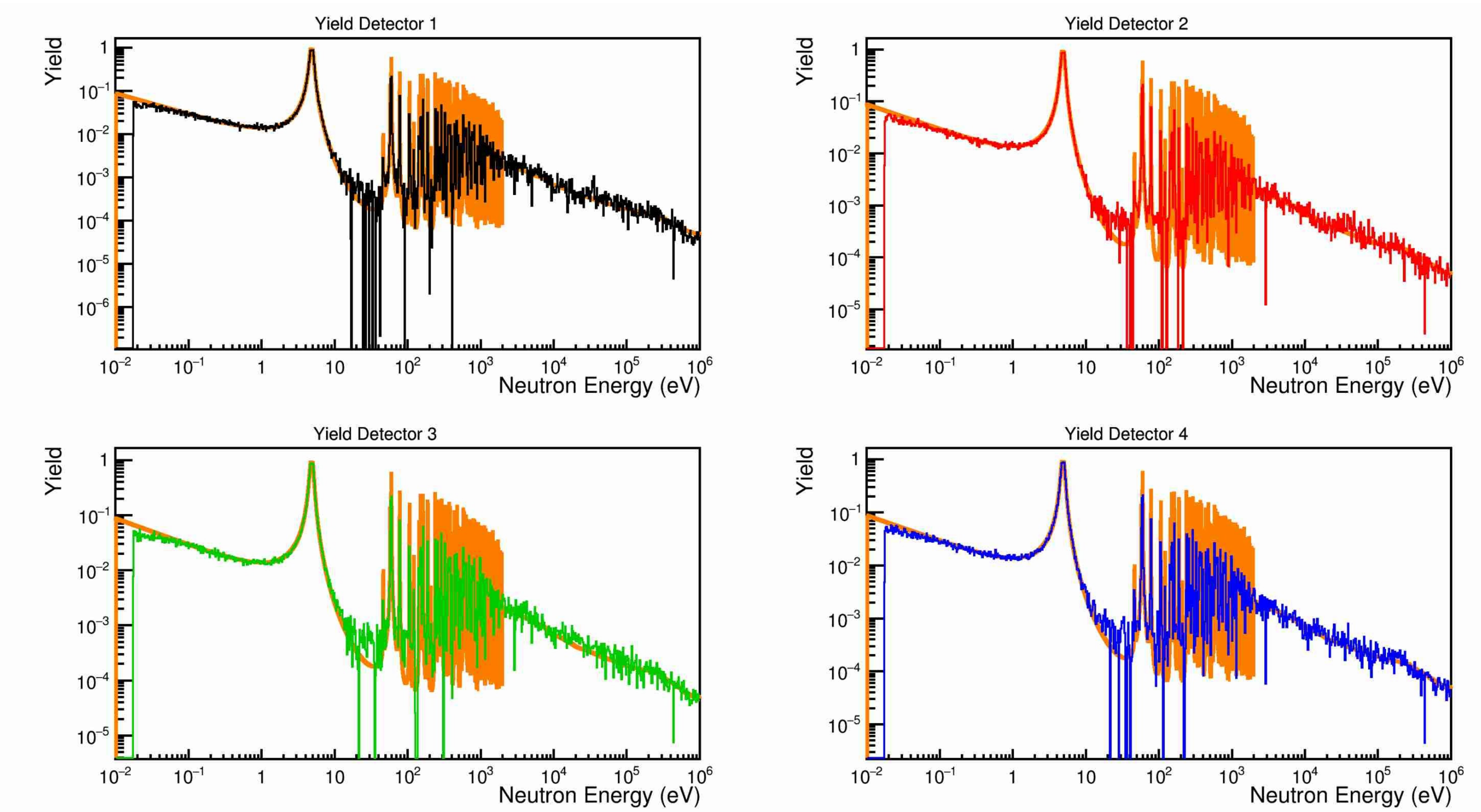
Flux in the keV region

Great agreement in the keV region, where are located cerium resonances and many of aluminum’s absorption depth.



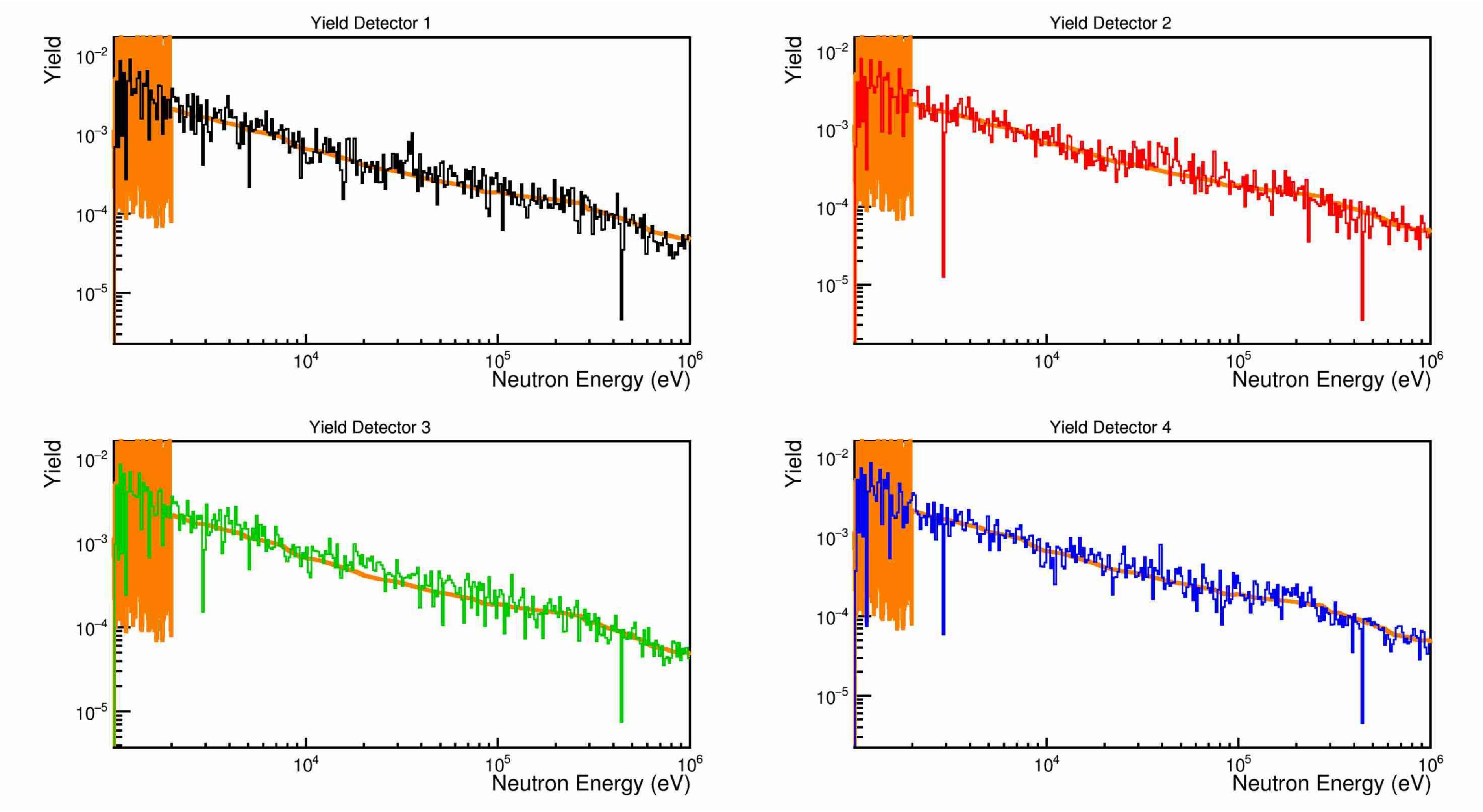
Gold Yield

Yield measured with the four detectors with the gold sample.



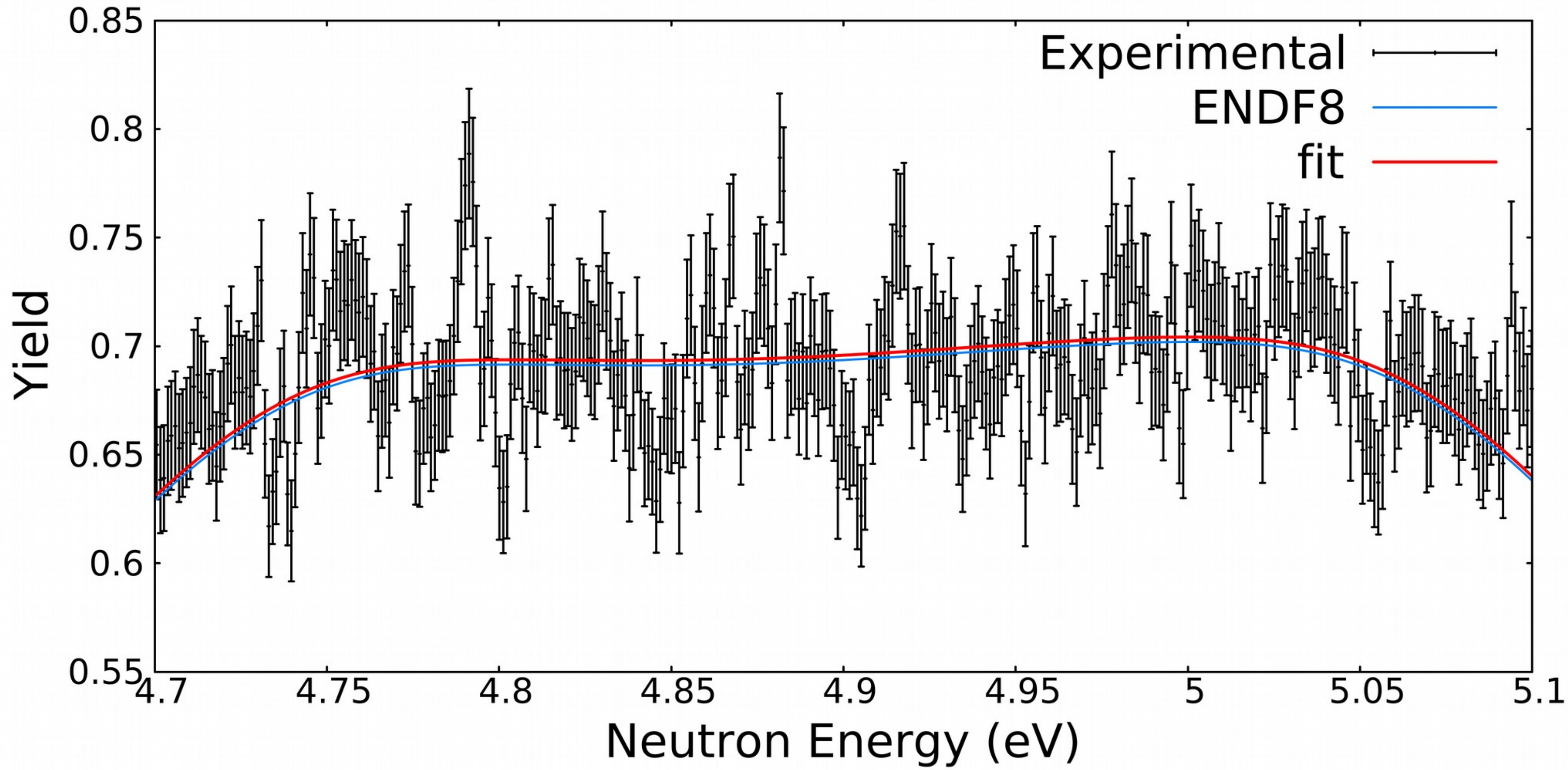
Gold Yield

Good agreement in the keV energy region.



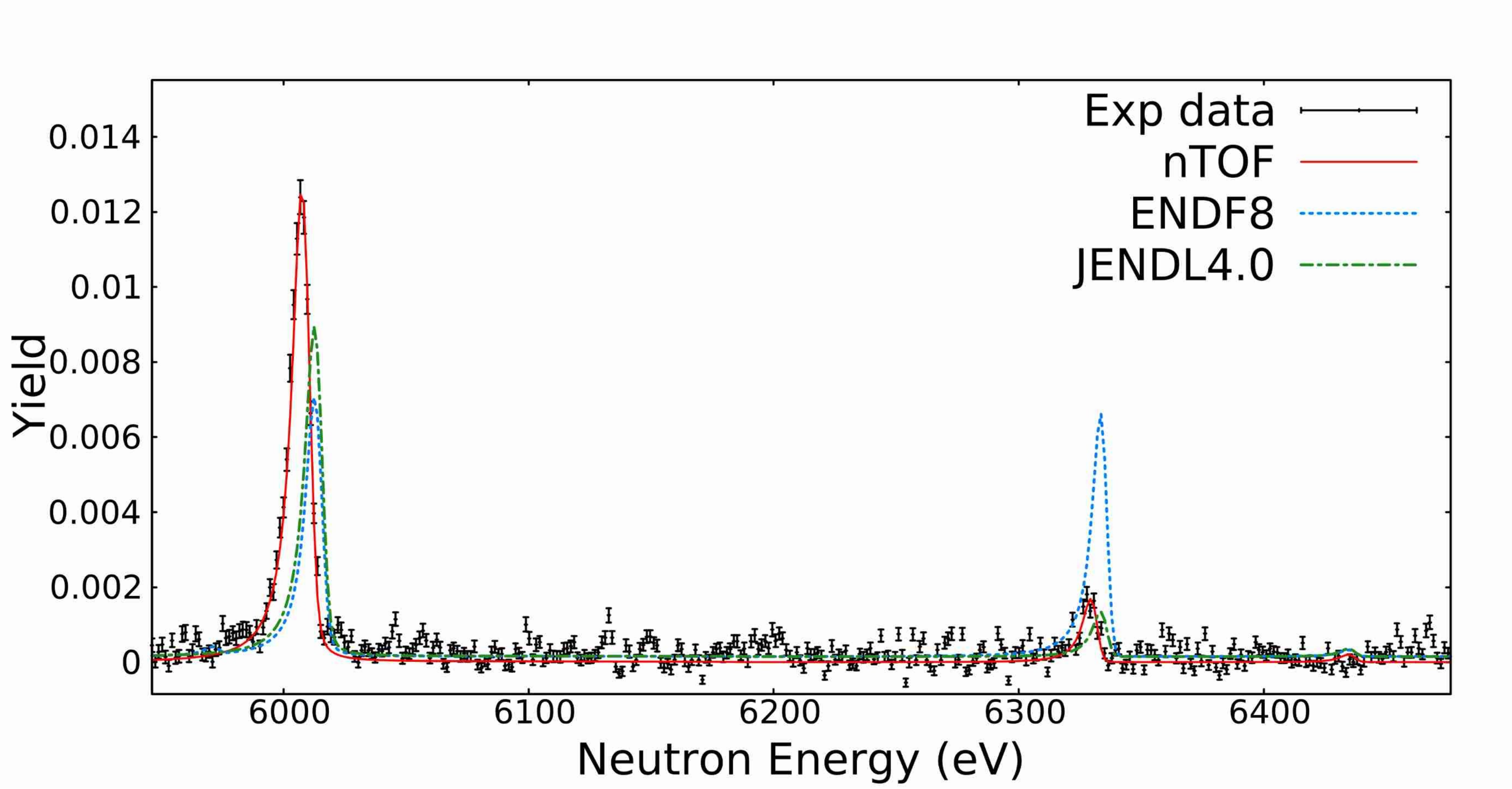
Normalization with Gold

Normalization constant computed fitting the gold yield between 4.7 and 5.1 eV
C = 0.712719020
The value has been corrected for the sample diameter (19.5 mm vs the 20 mm of the gold sample).



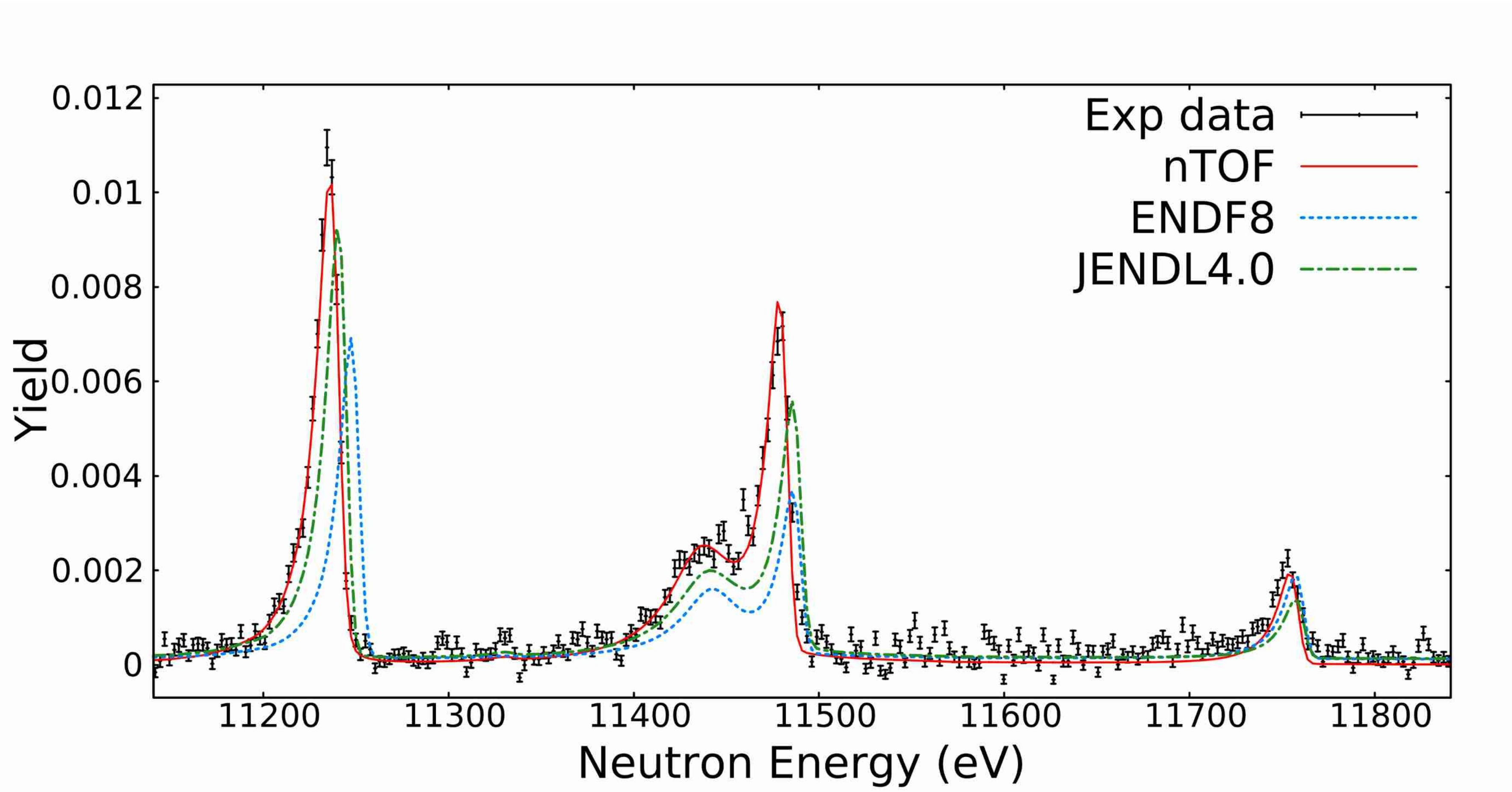
Resonance analysis

The resonance analysis has been performed with SAMMY (R-Matrix code), using JENDL4.0 as reference library. The two reaction witdh (capture and scattering) are fitted at the same time, together with the resonance energy.



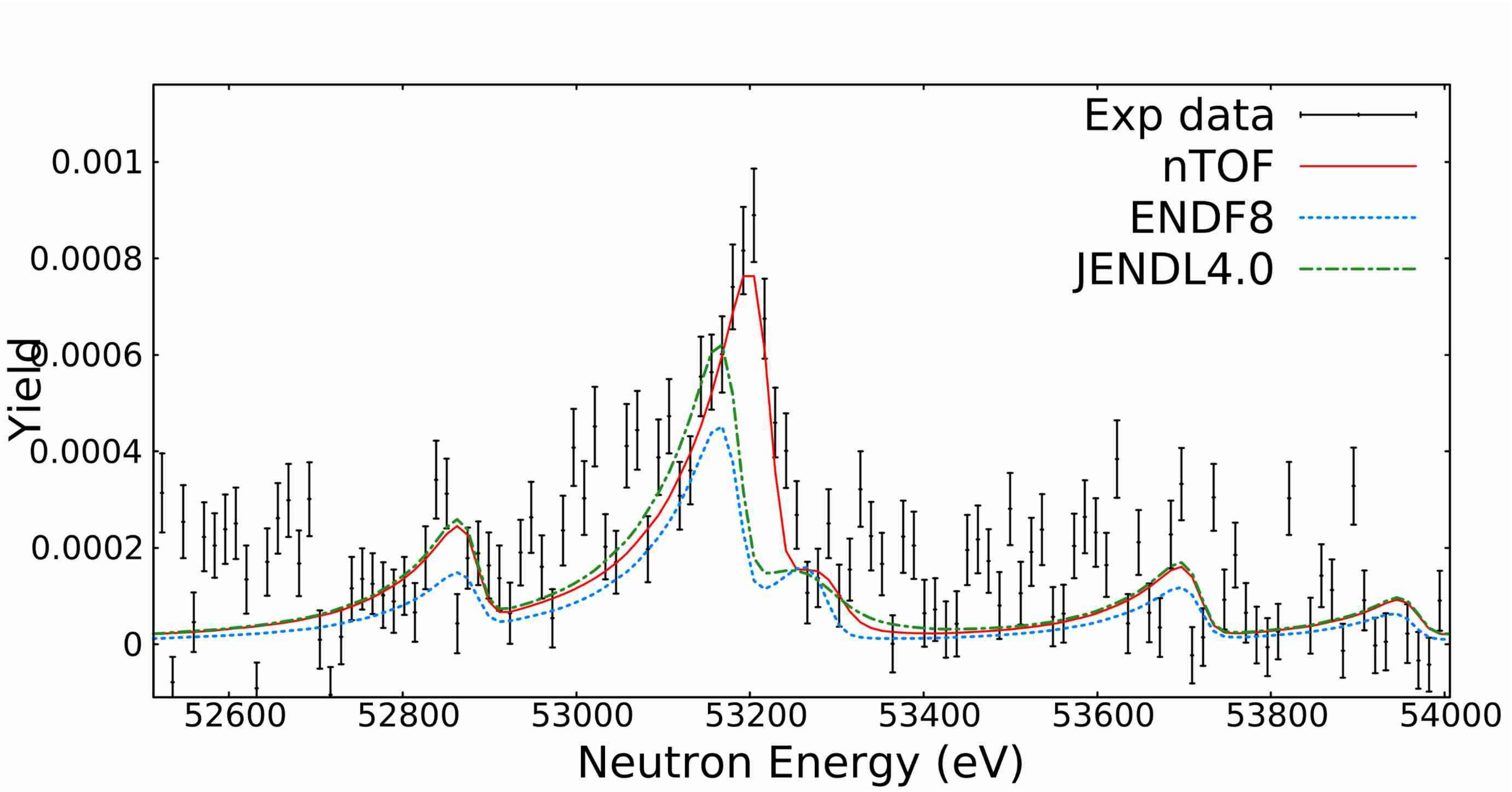
Resonance analysis

In general our data are in better agreement with JENDL4.0 parameters than ENDF8.



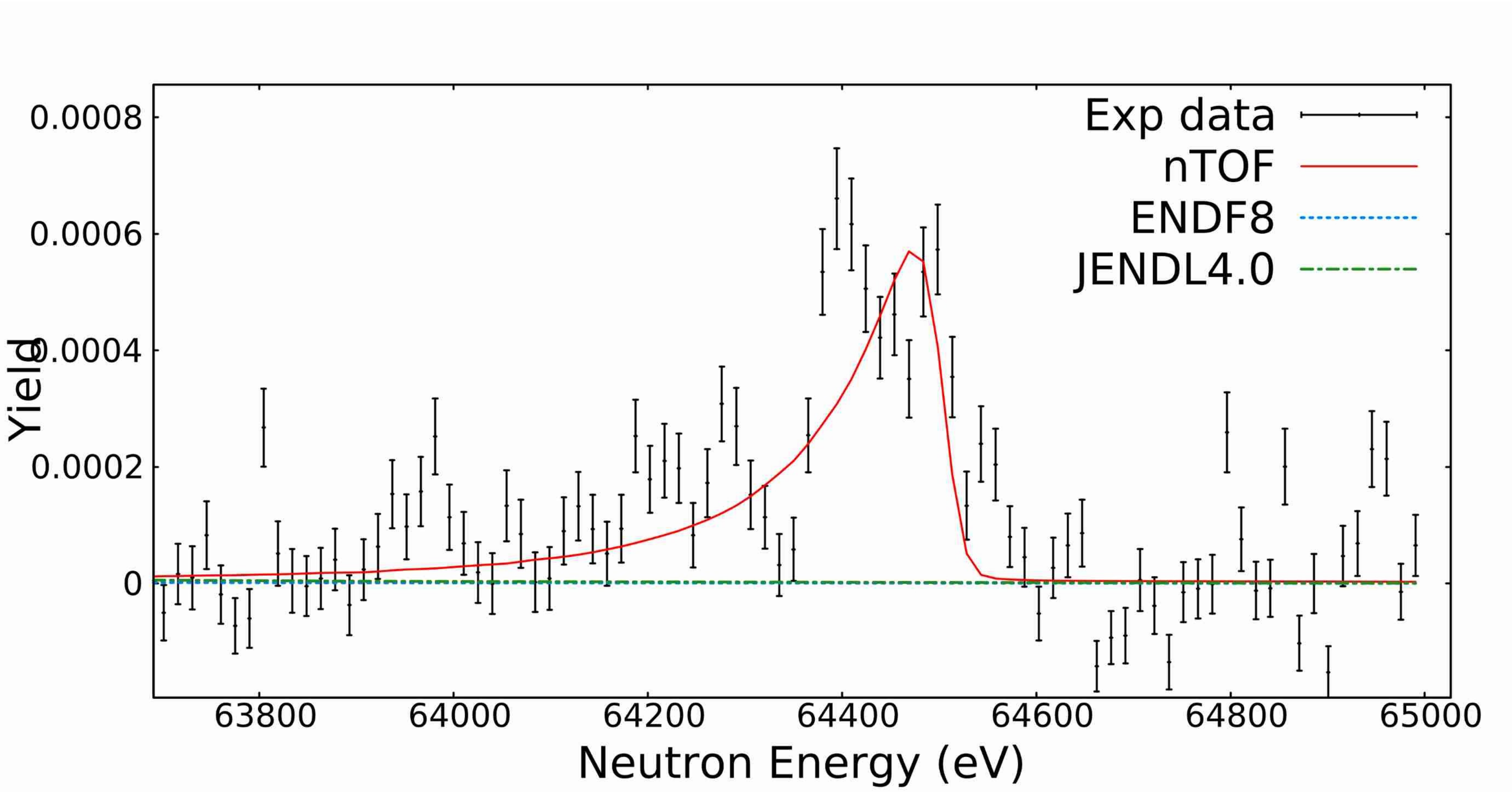
Resonance analysis

In the range 40 to 60 keV some resonance are too small to perform a reliable fit, in the below plot only the larger one is fitted.



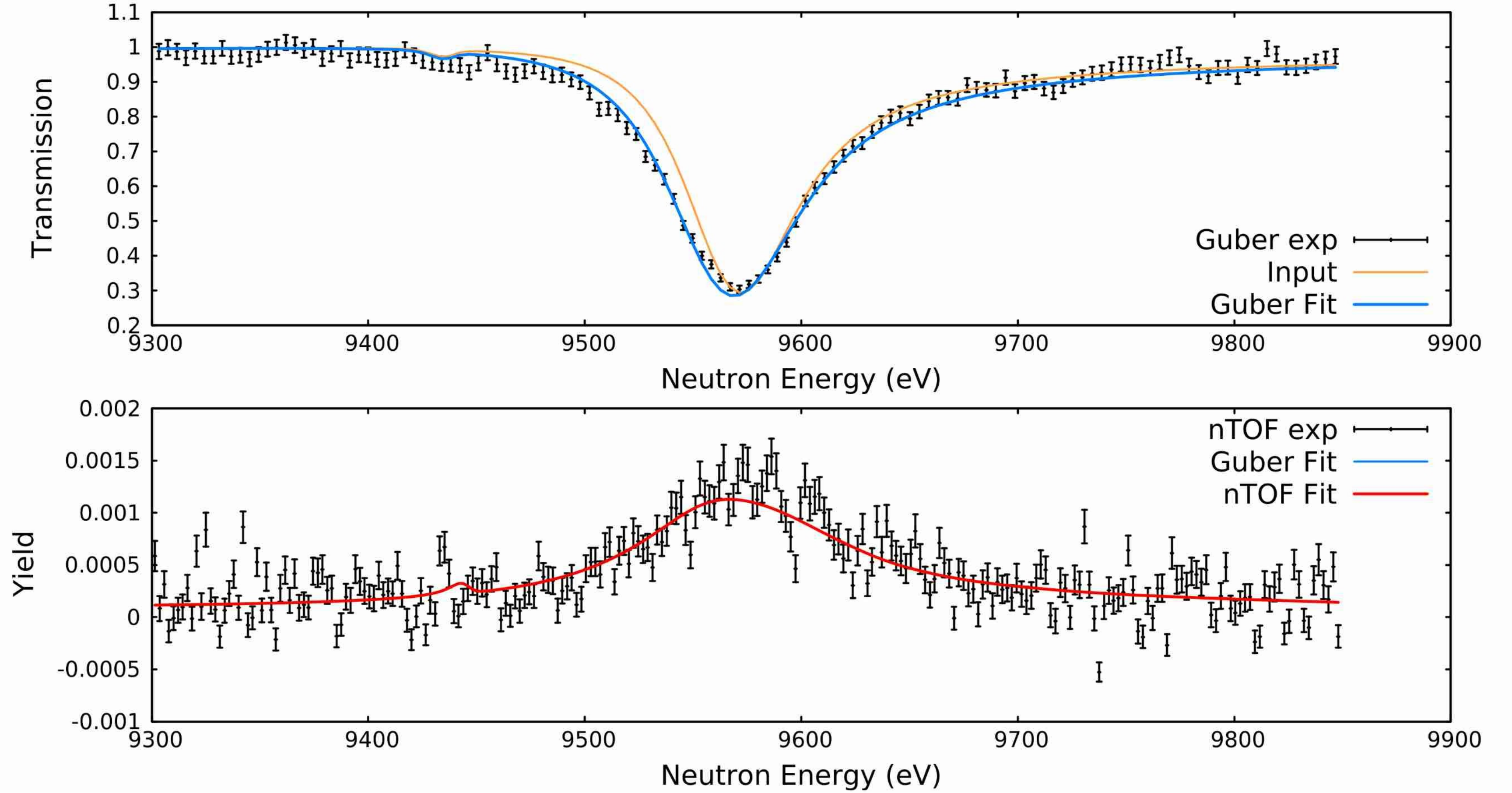
Resonance analysis

A new resonance has been found at 64.4 keV.



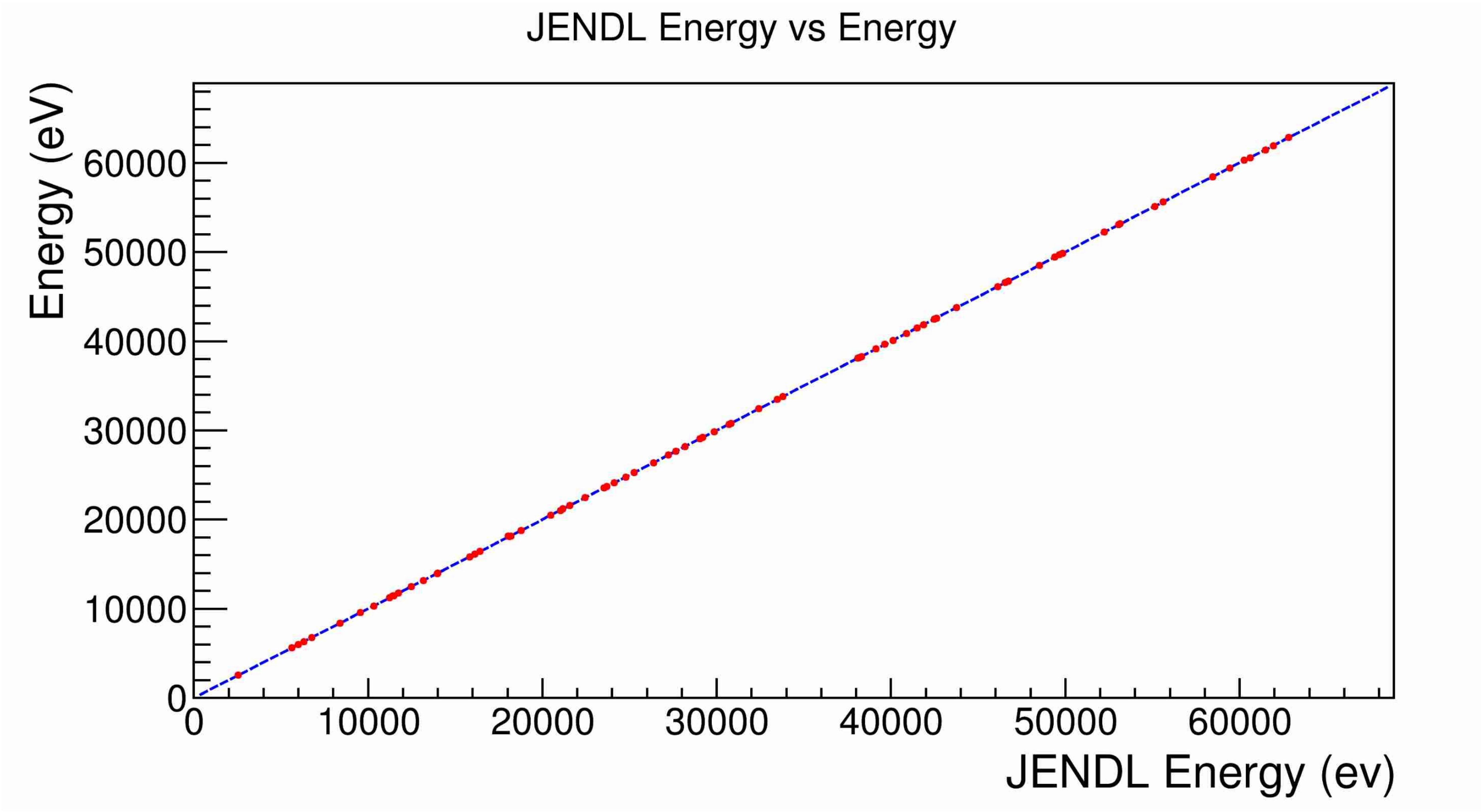
Resonance analysis

We included in the analysis a transmission measurement performed at GELINA in 2016 by Guber et al. with a natural sample (89% of 140Ce). The combined fit provided a better estimation for the Γ_n of s-waves.



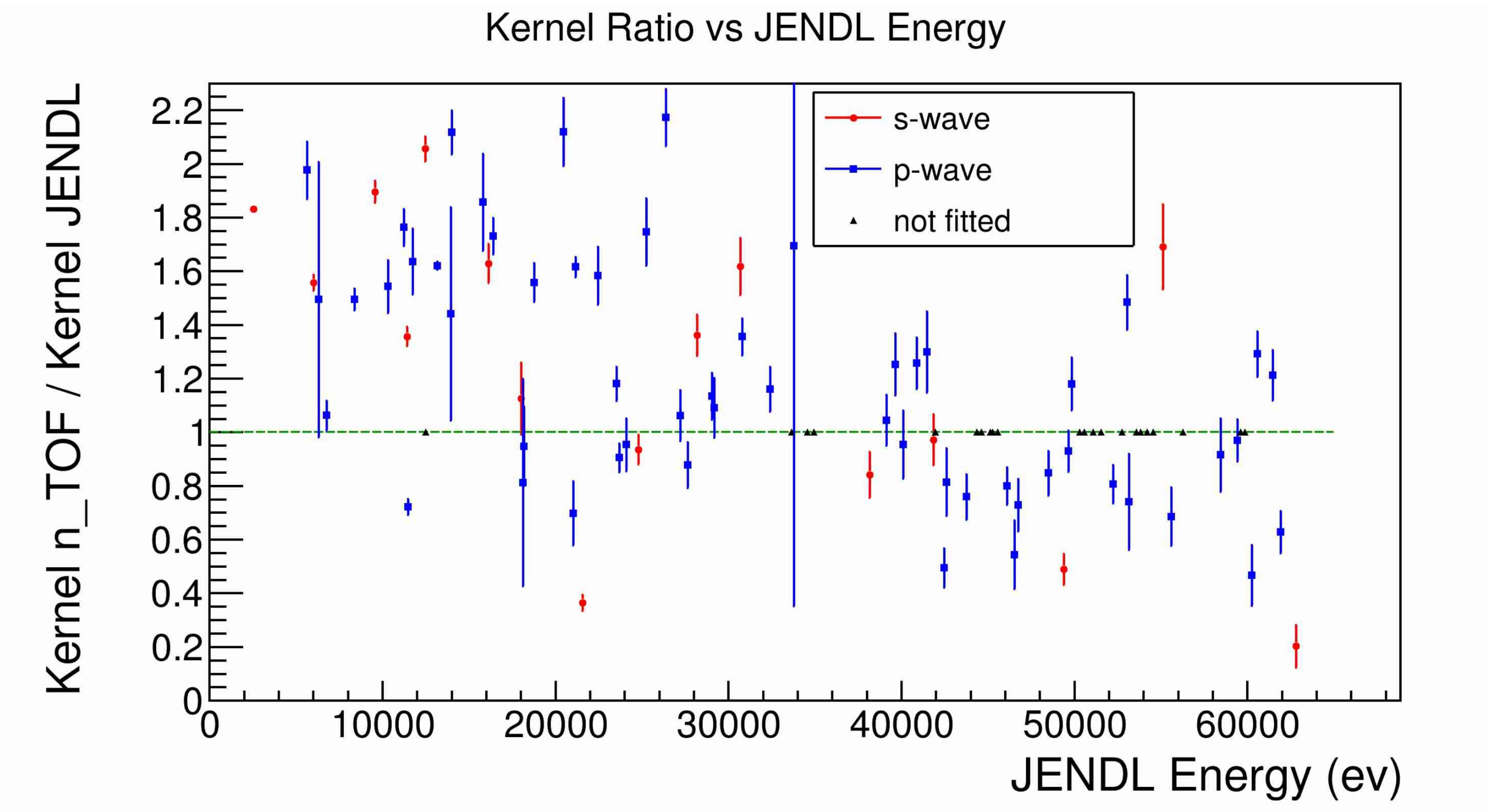
Energy vs JENDL Energy

No significant changes in the energy.

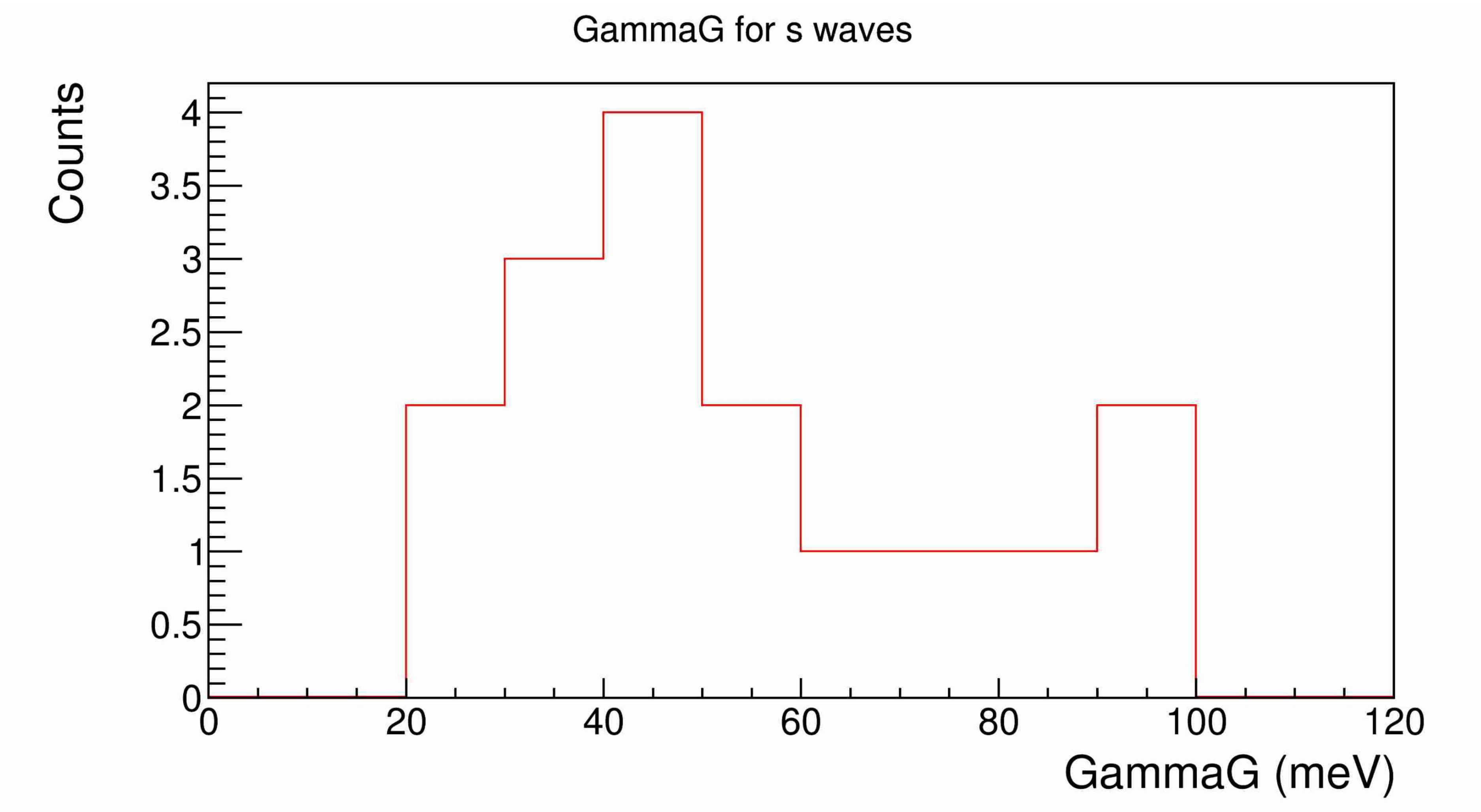


Kernel ratio vs JENDL Energy

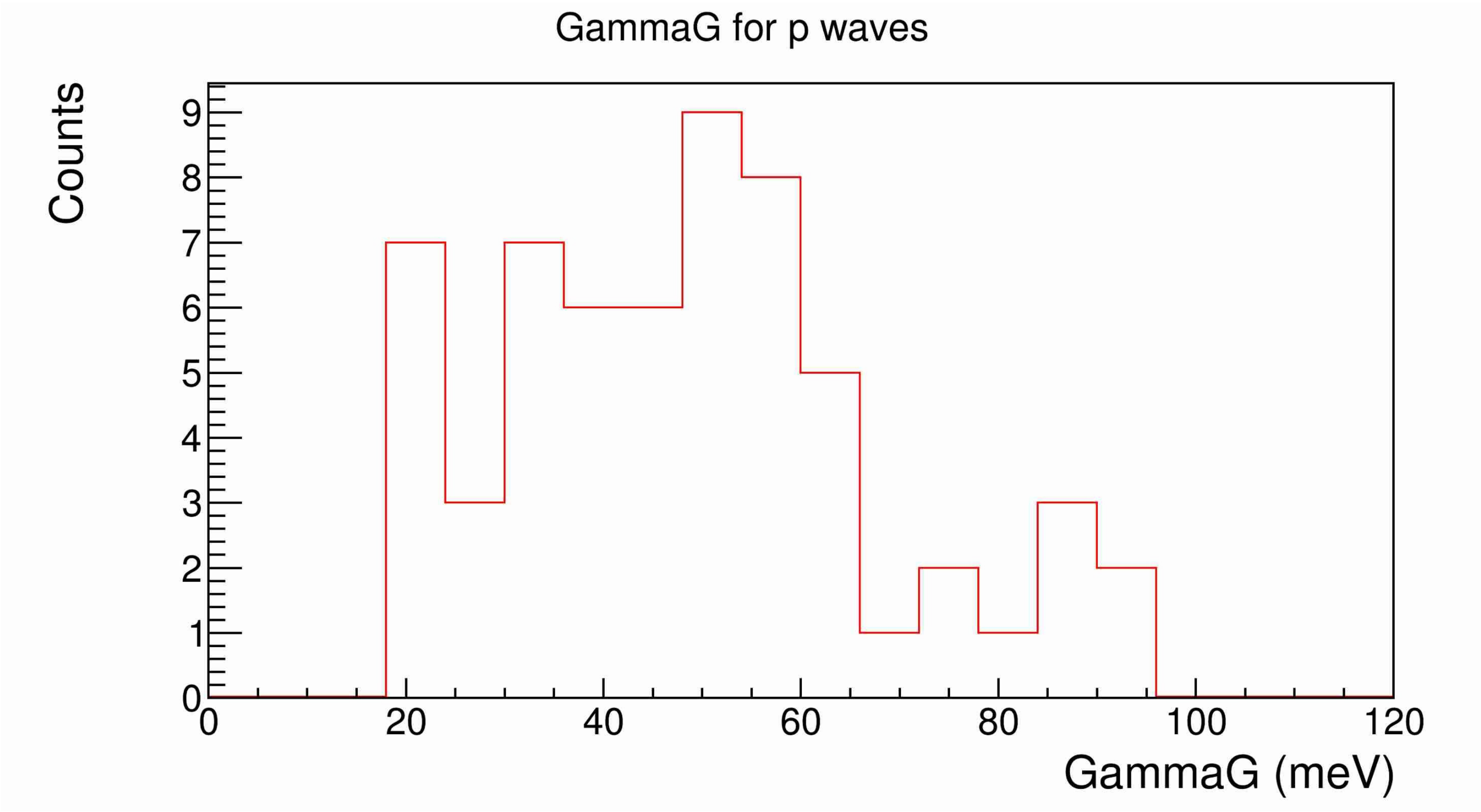
The kernel ratio n_TOF/JENDL in general greater than 1, especially at lower energies.



Γ_g distribution for s-waves

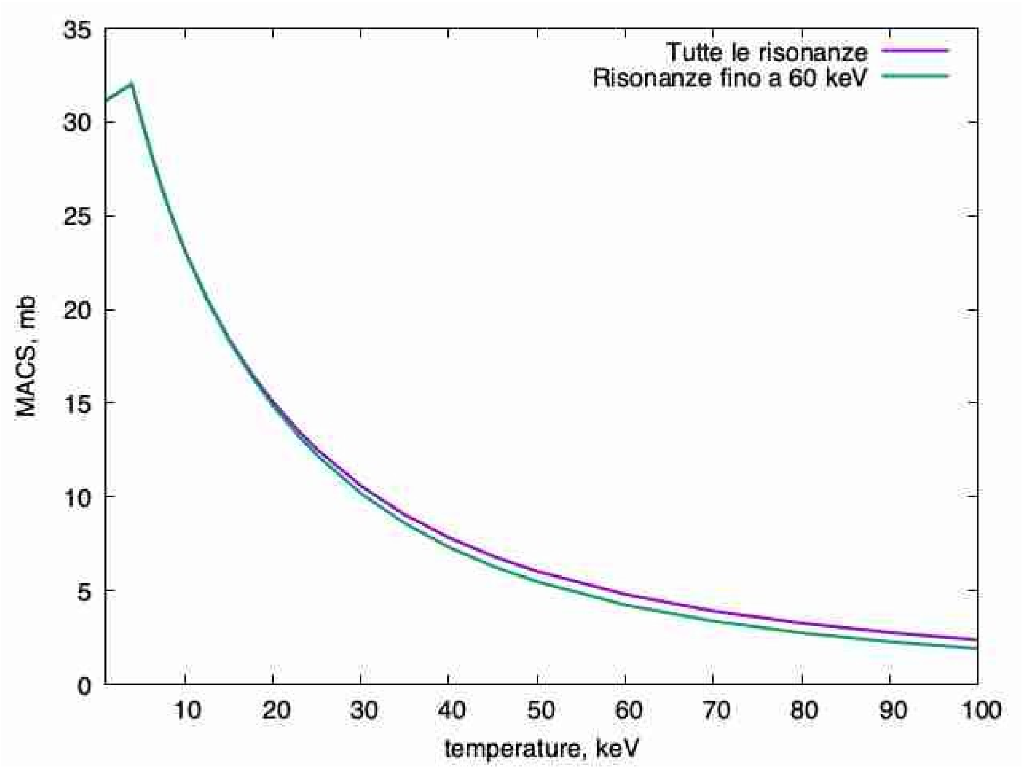


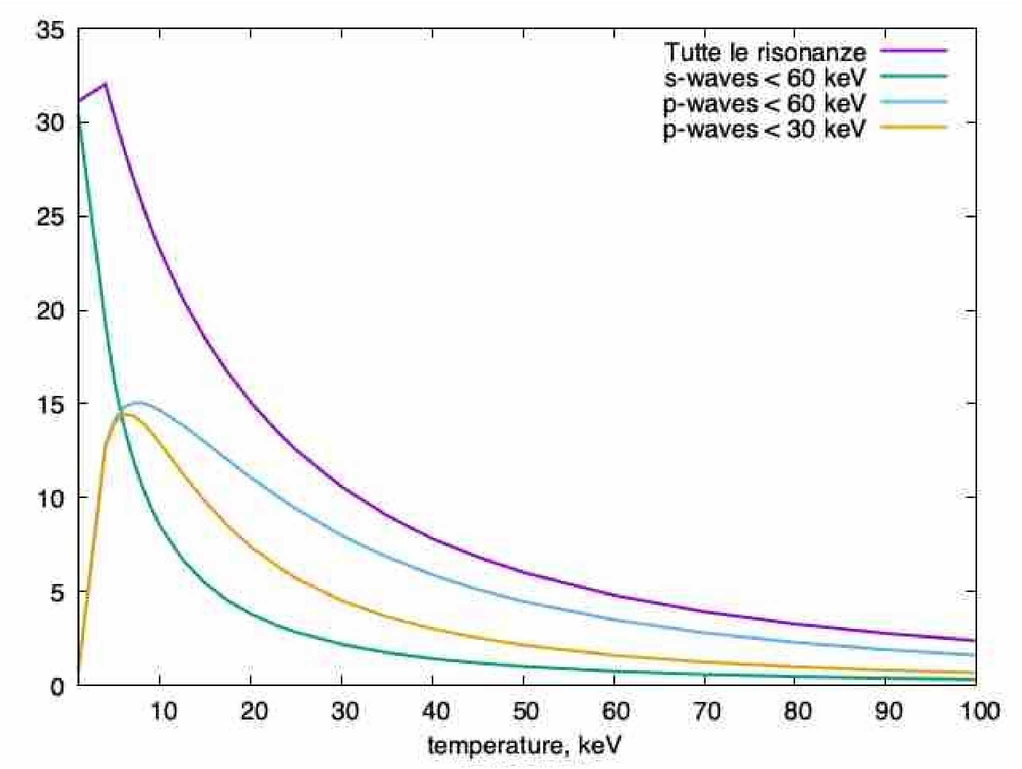
Γ_g distribution for p-waves



Contributes to MACS

The main contribute to the MACS come from the resonances below 60 keV (left panel), between them the p-waves contribute is significant, especially for T > 10 keV (right panel).





Conclusions and perspectives

A measurement of $^{140}Ce(n,\gamma)$ cross section has been successfully performed at n_TOF, the resonance analysis has been carried out up to 65 keV and the parameters of s and p waves has been estimated.

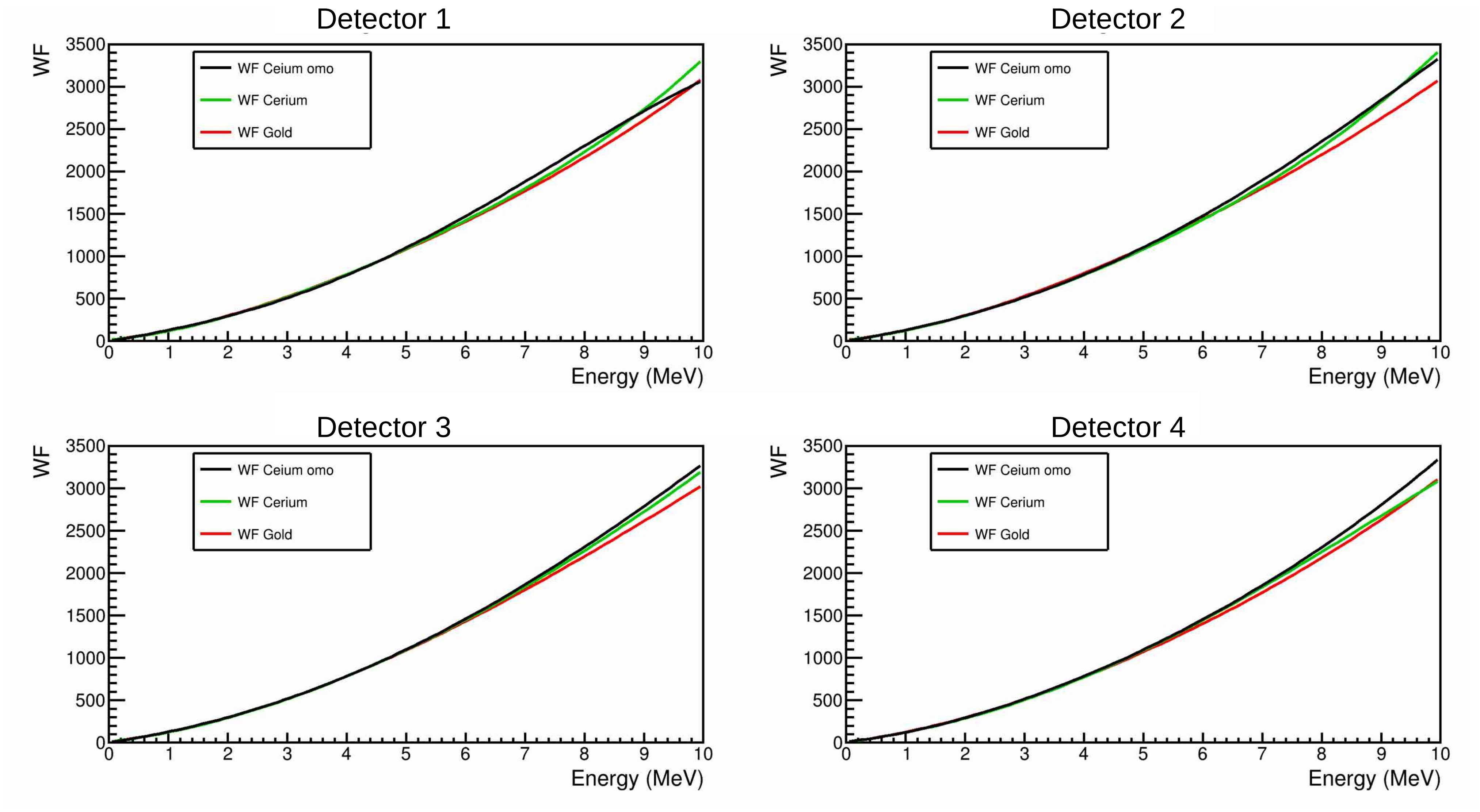
Next steps will be:

1) Extract the resonance average parameters and spacing.

2) Compute the MACS.

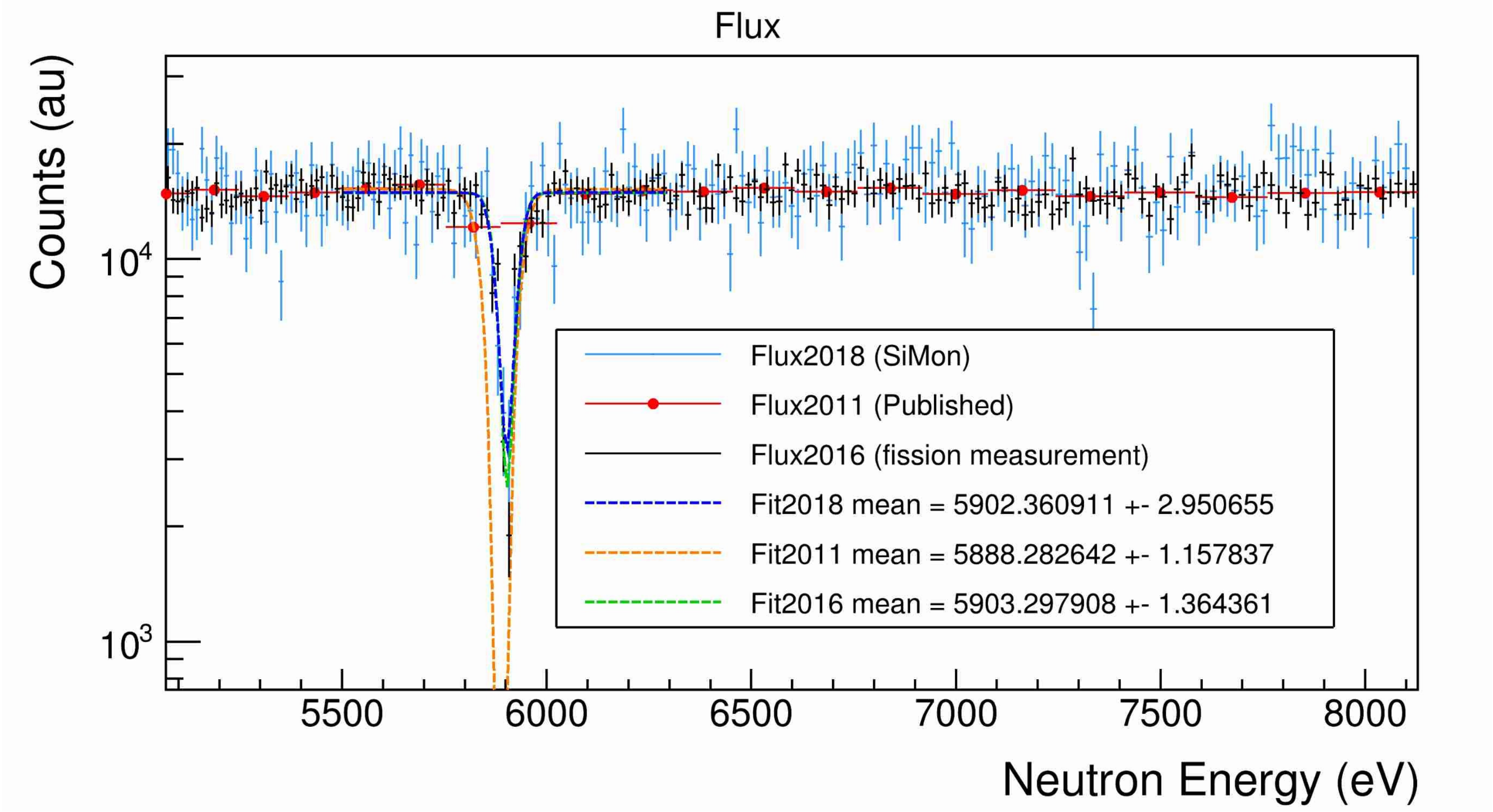
3) Include the new MACS in the stellar model and evaluate the impact.

Backup – All WF

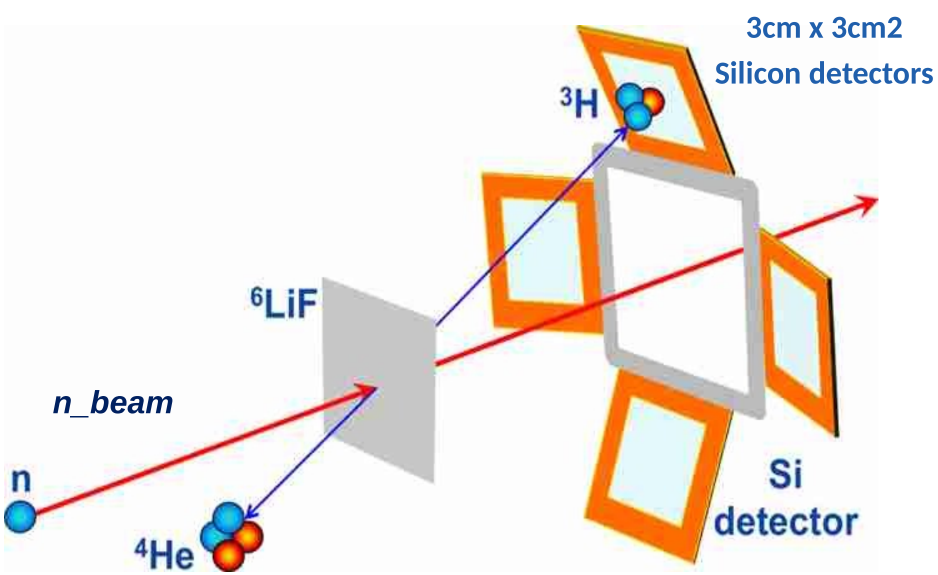


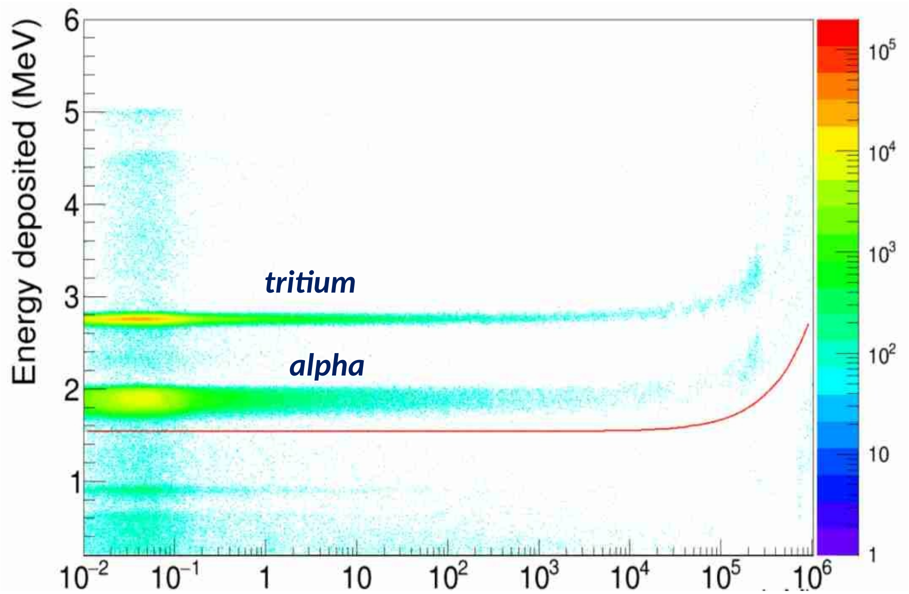
Aluminum absorption

Fit of the aluminum's depth at 5903 eV to test the time-to-energy calibration, the peak value is within the error for the 2018 data (and 2016). The lage binning of 2011 prevents to perform a reliable fit.



Backup – SiMon

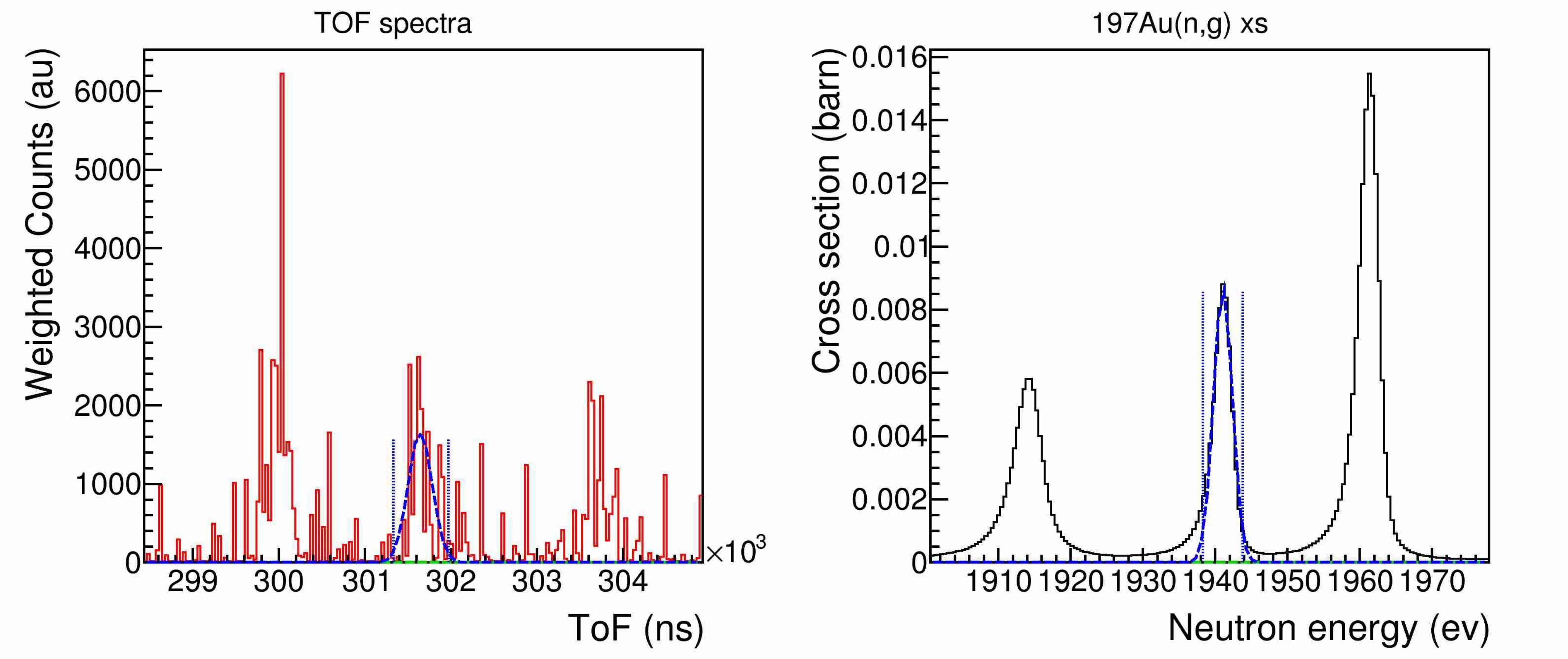




Time-to-Energy

Step1: intervals corresponding to the resonances are identified manually on the ToF spectra and Au(n,γ) cross section

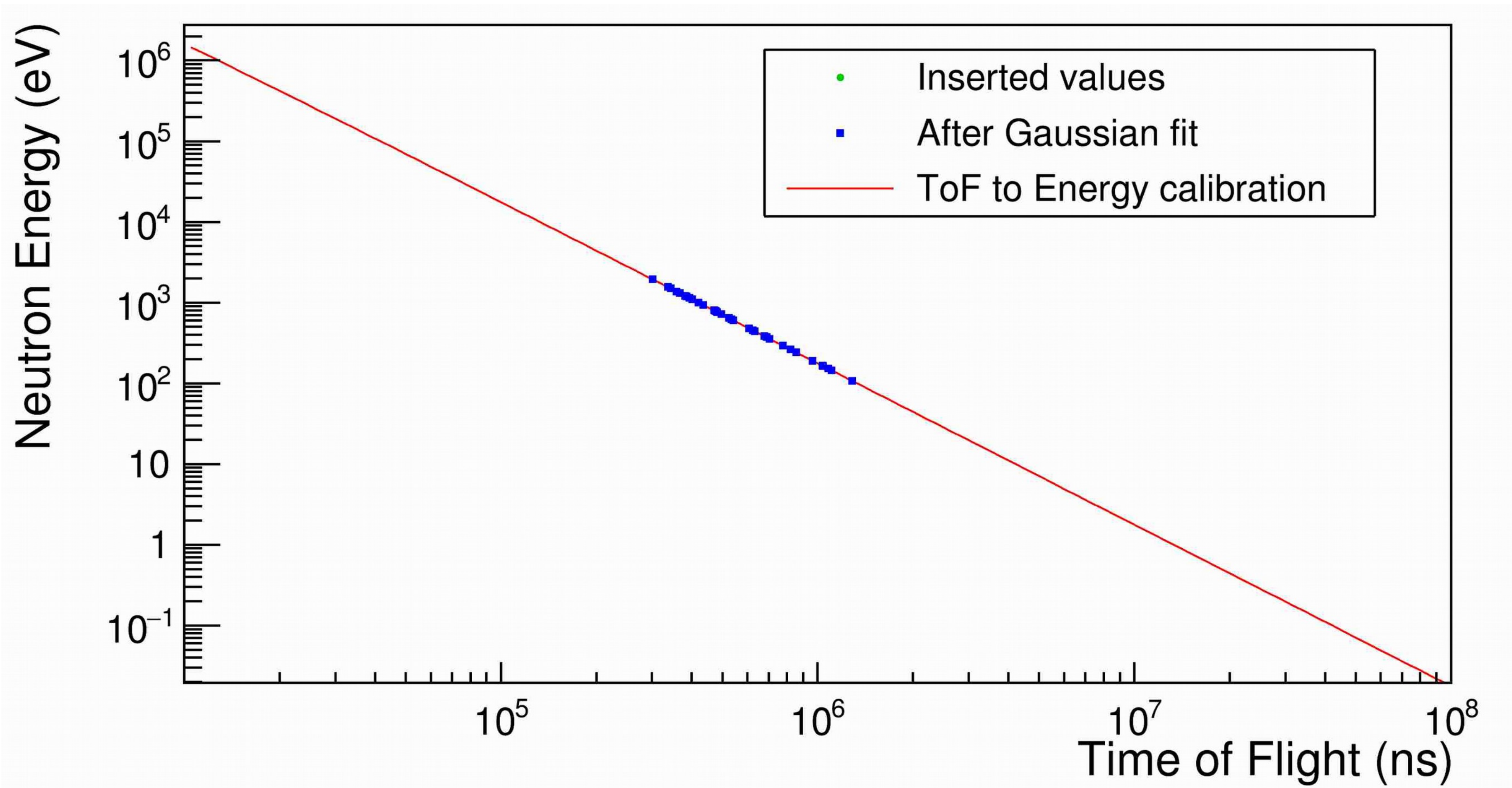
Step2: with a Gaussian the center of the resonance is well located



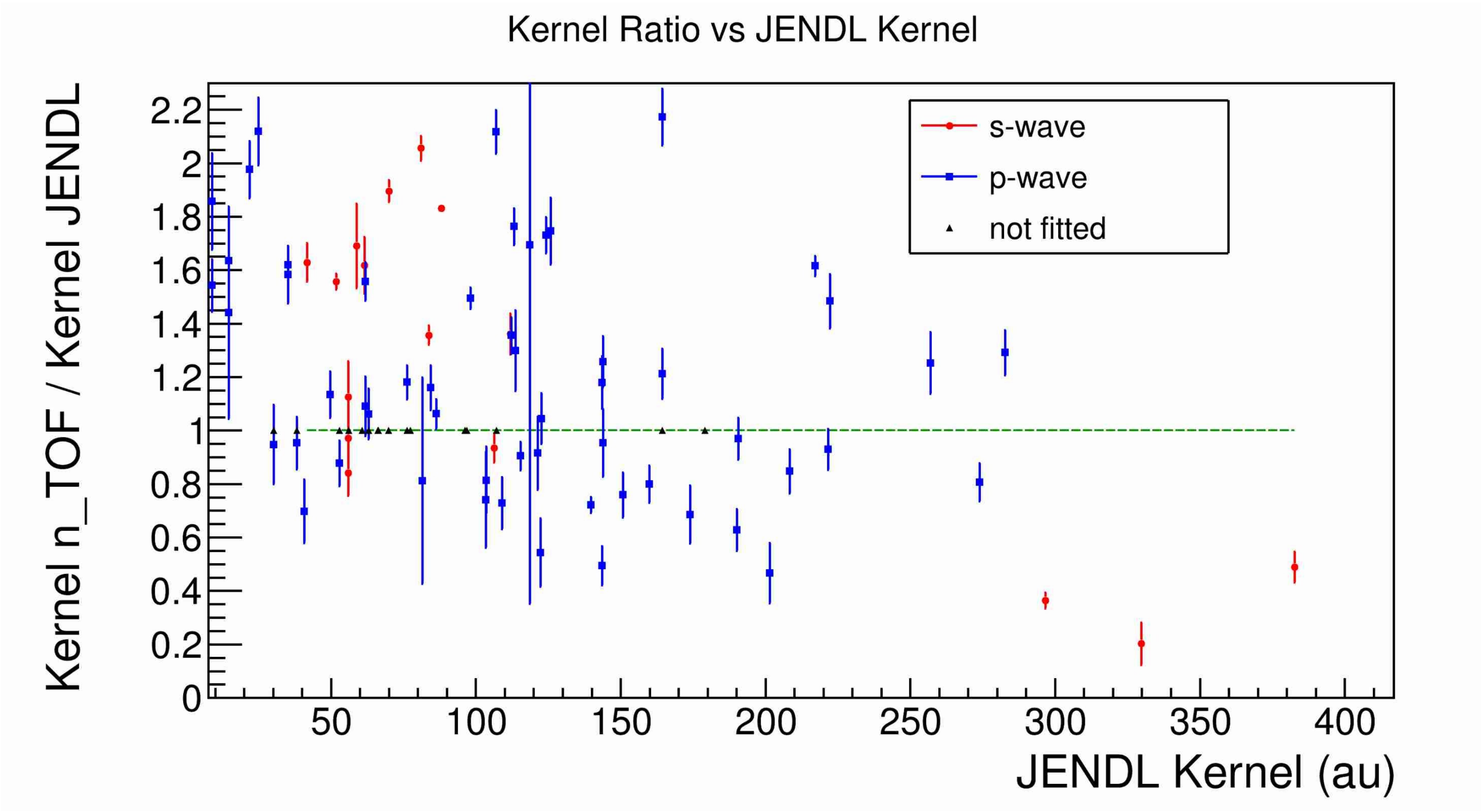
Time-to-Energy

Step3: time-to-energy formula with Lorusso correction is used to fit the flight path.

```
939.e6*((1./sqrt(1.-(pow([0]+0.01*[1]*sqrt(939.e6*((1./sqrt(1.-(pow([0],2)/((9.e16)*(pow(x+610.,2)*1.e-18)))))-1)),2)/((9.e16)*(pow(x+610.,2)*1.e-18)))))-1)
```

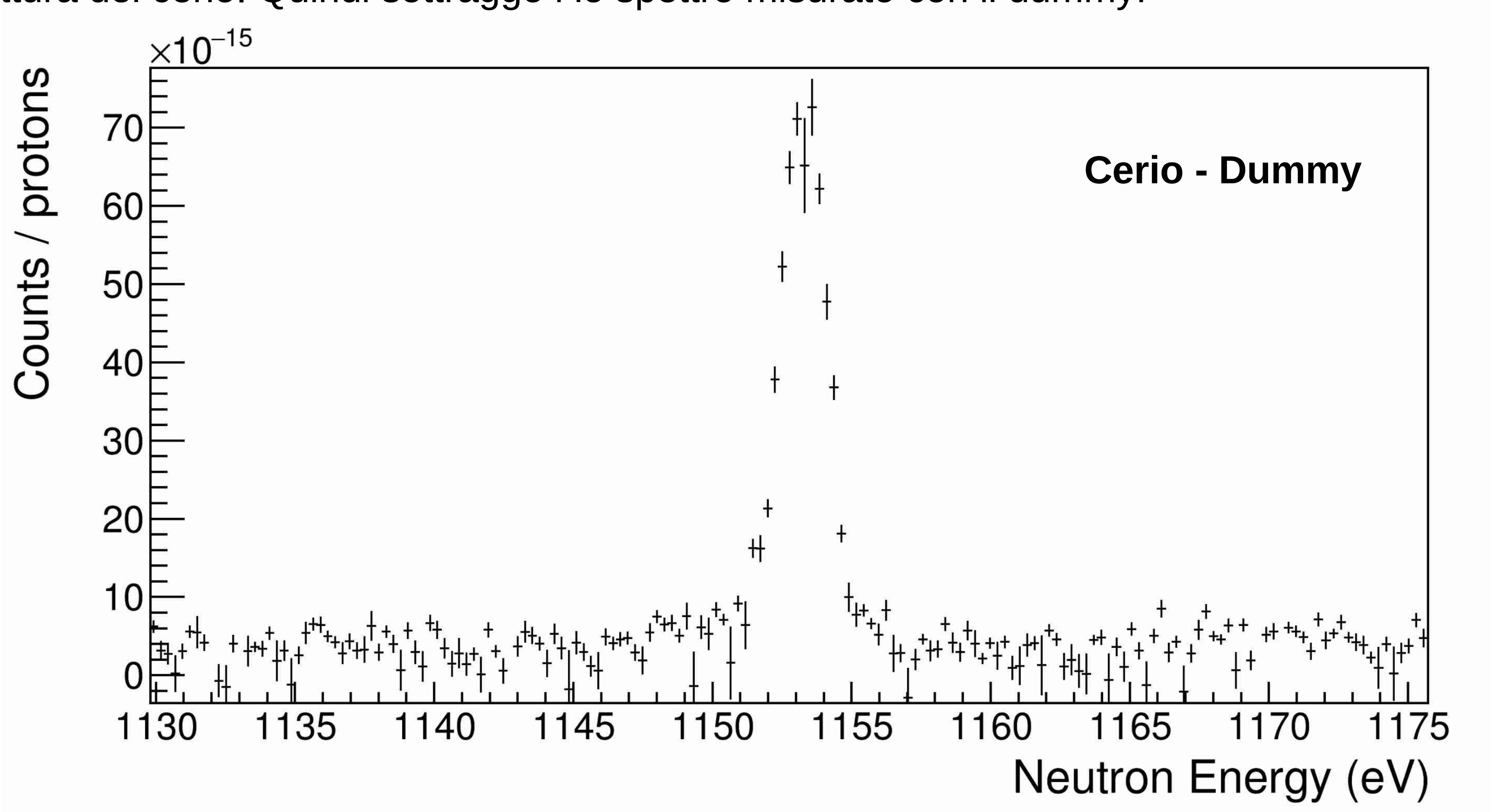


Kernel ratio vs JENDL Kernel



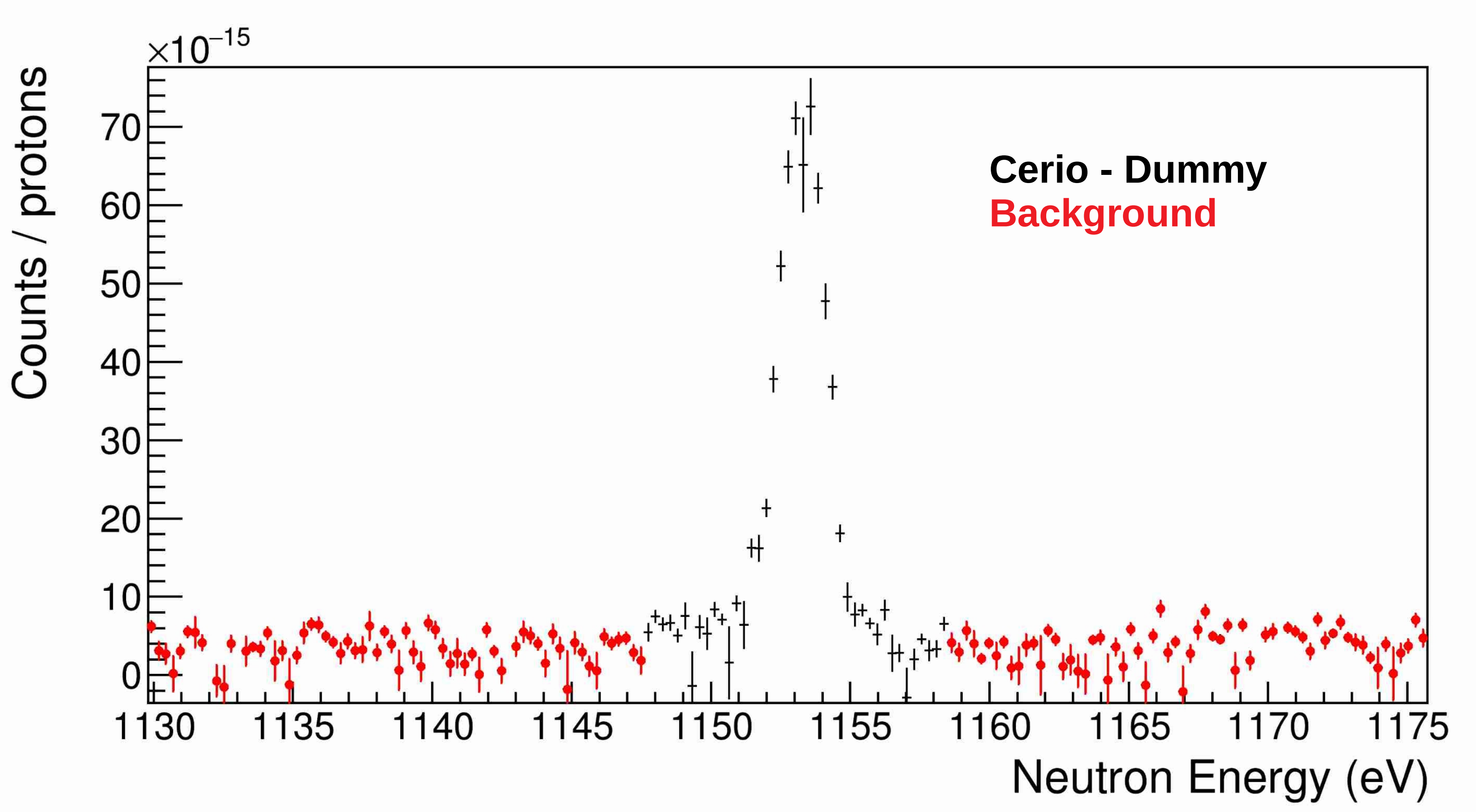
Background

Il background che osserviamo è temporalmente non correlato, ha un andamento ragionevolmente smooth ed è molto maggiore dei segnali, eccetto che nelle risonanze di cattura del cerio. Quindi sottraggo i lo spettro misurato con il dummy:



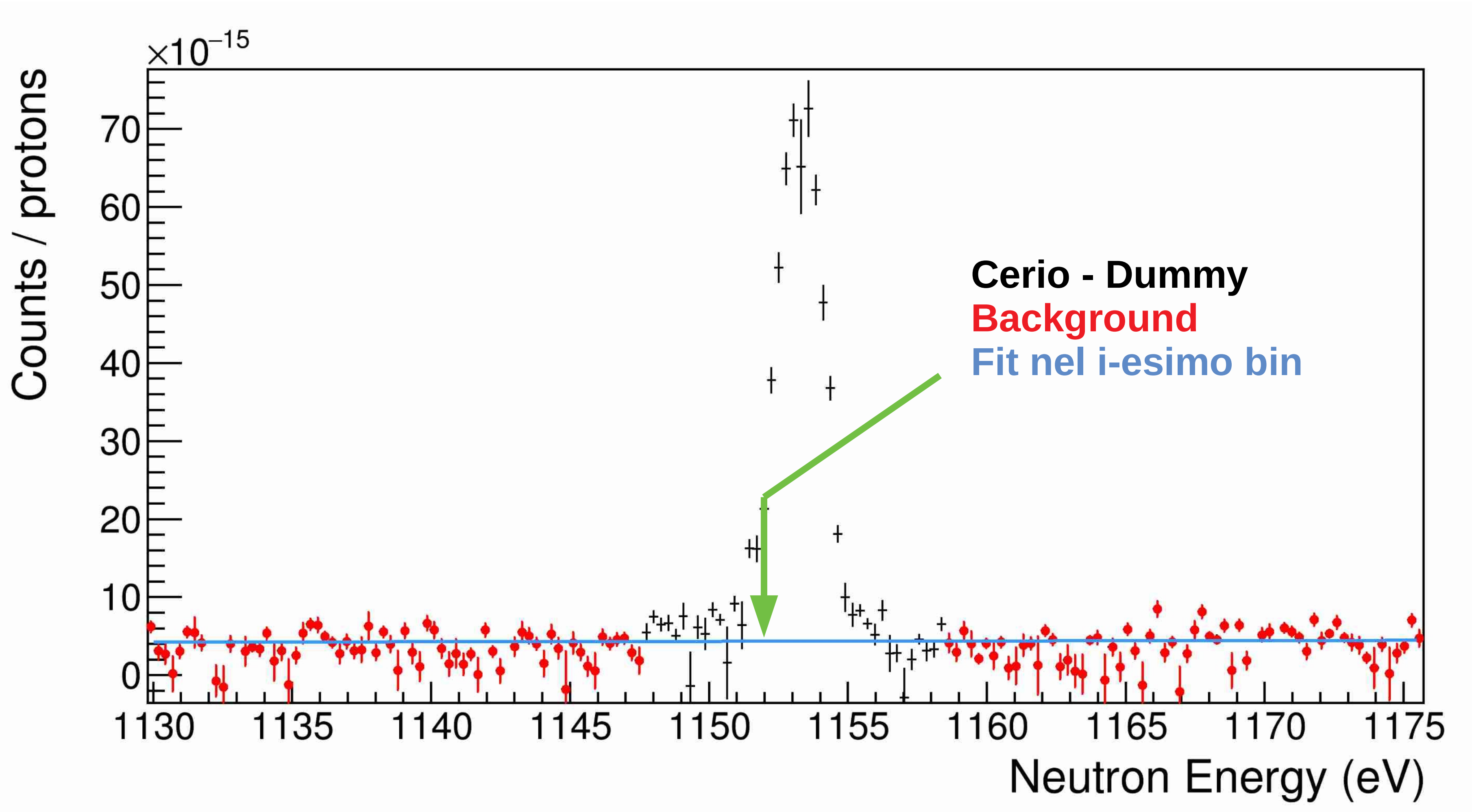
Background

Creo uno **scatter plot**, sovrapposto al **Cerio-Dummy** ma in cui elimino le risonanze e il loro intorno:



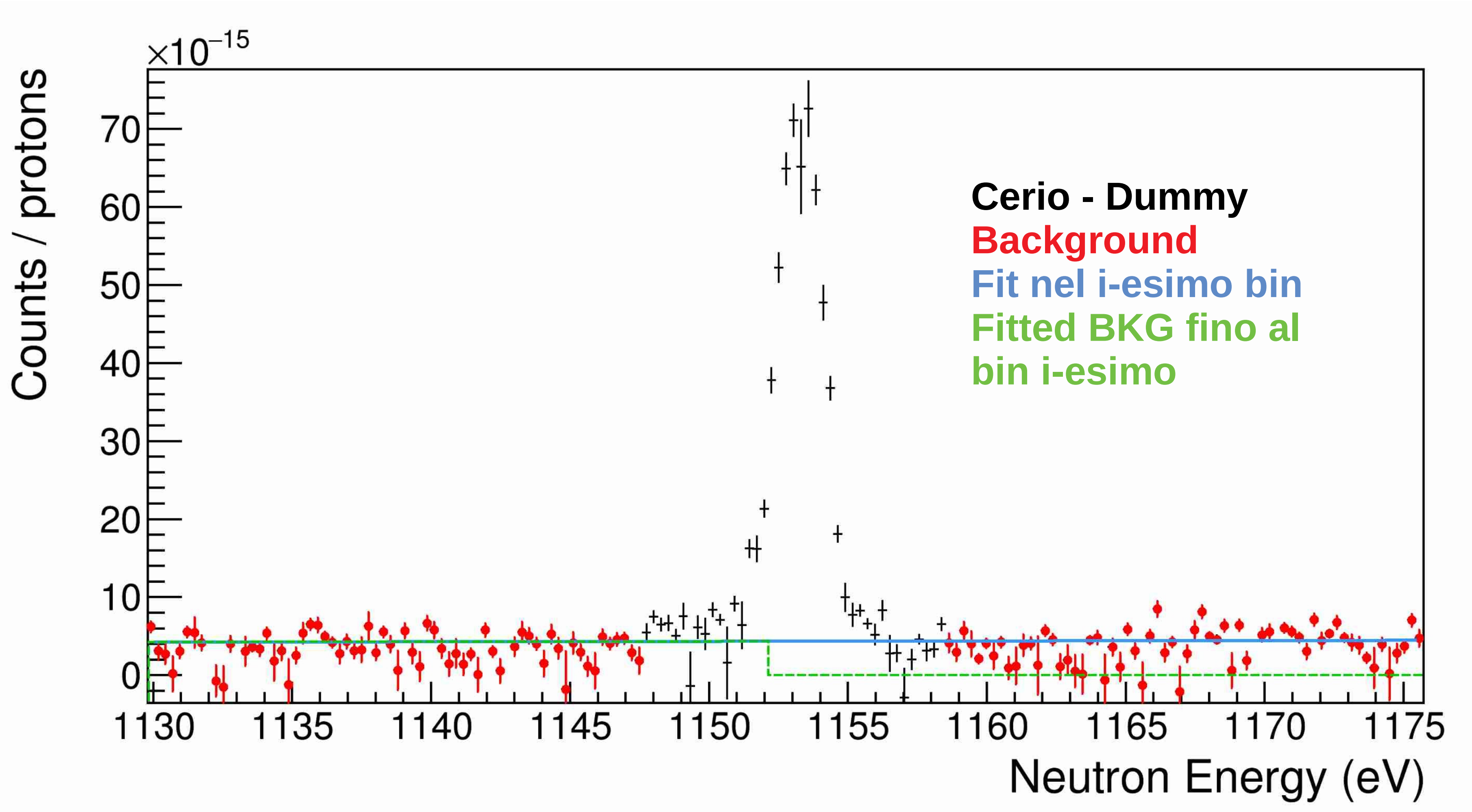
Background

Per ogni bin effettuo un fit lineare del **background**, per valutarlo nella regione della risonanza, sotto l'ipotesi di un andamento smooth.

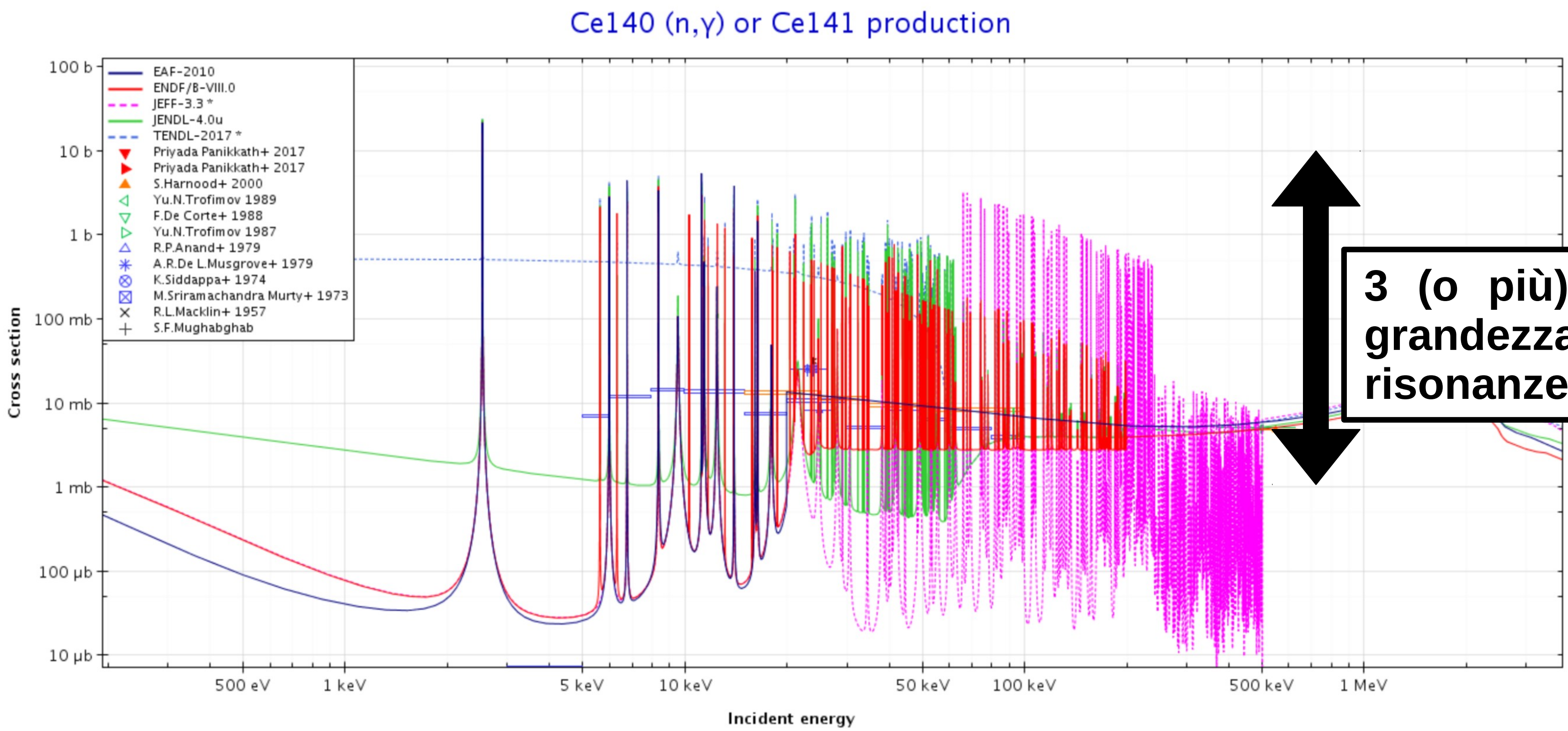


Background

Ottengo l'istogramma del background fittando lo **scatter plot** iniziale in un intervallo più largo di una risonanza, quindi valutando il background fittato nel centro del bin i-esimo.



Contributo cerio



3 (o più) ordini di grandezza fra le risonanze e le valli

Experimental setup