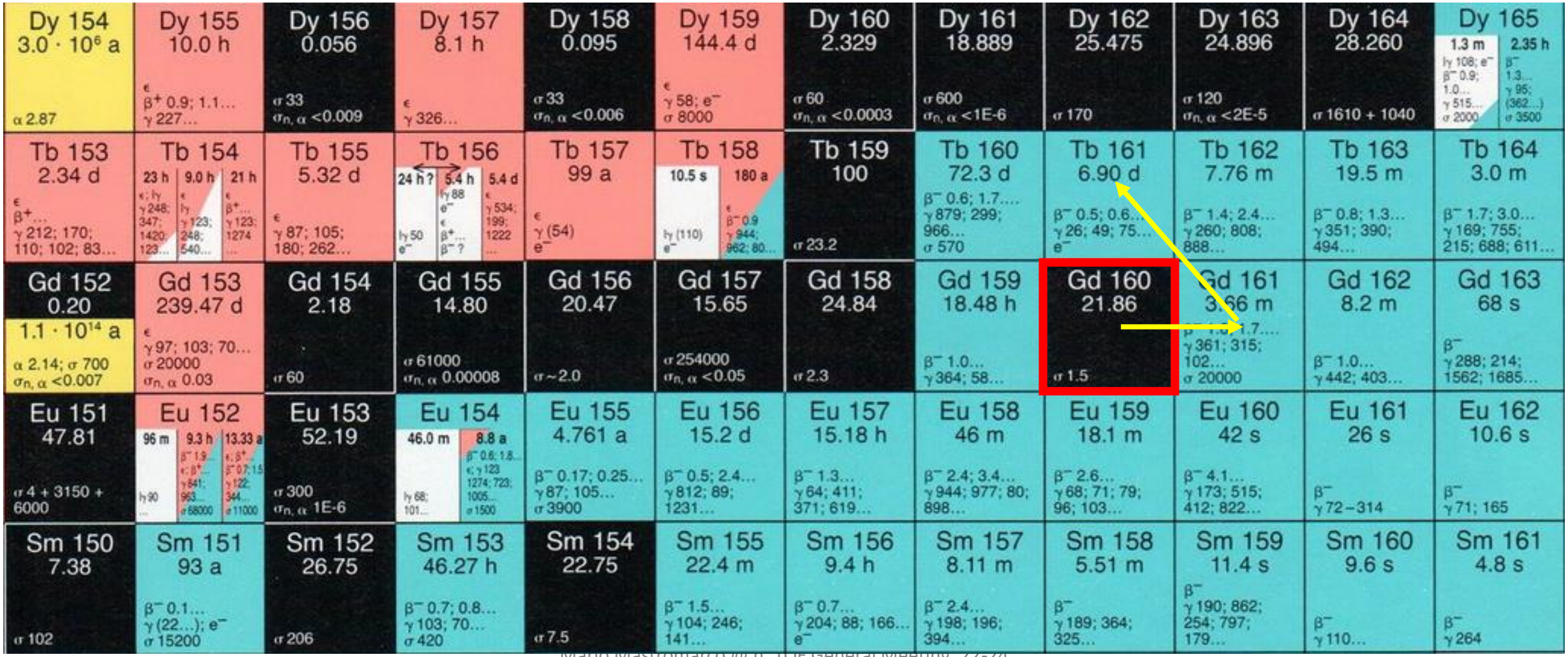
Advances in the Gd-160 capture cross section data analysis

***M. Mastromarco**, A. Mazzone, A. Manna, S. Amaducci, F.G. Infantes, A. Mengoni, S. Cristallo, G. Tagliente, C. Massimi, U. Koester and N. Colonna*

Motivations

^{161}Tb is a clinically interesting isotope for theranostics!!!



(Medical Motivations: terbium-161 production)

- Chemically similar to lutetium-177 (used in theranostic as γ and β^- emitter)

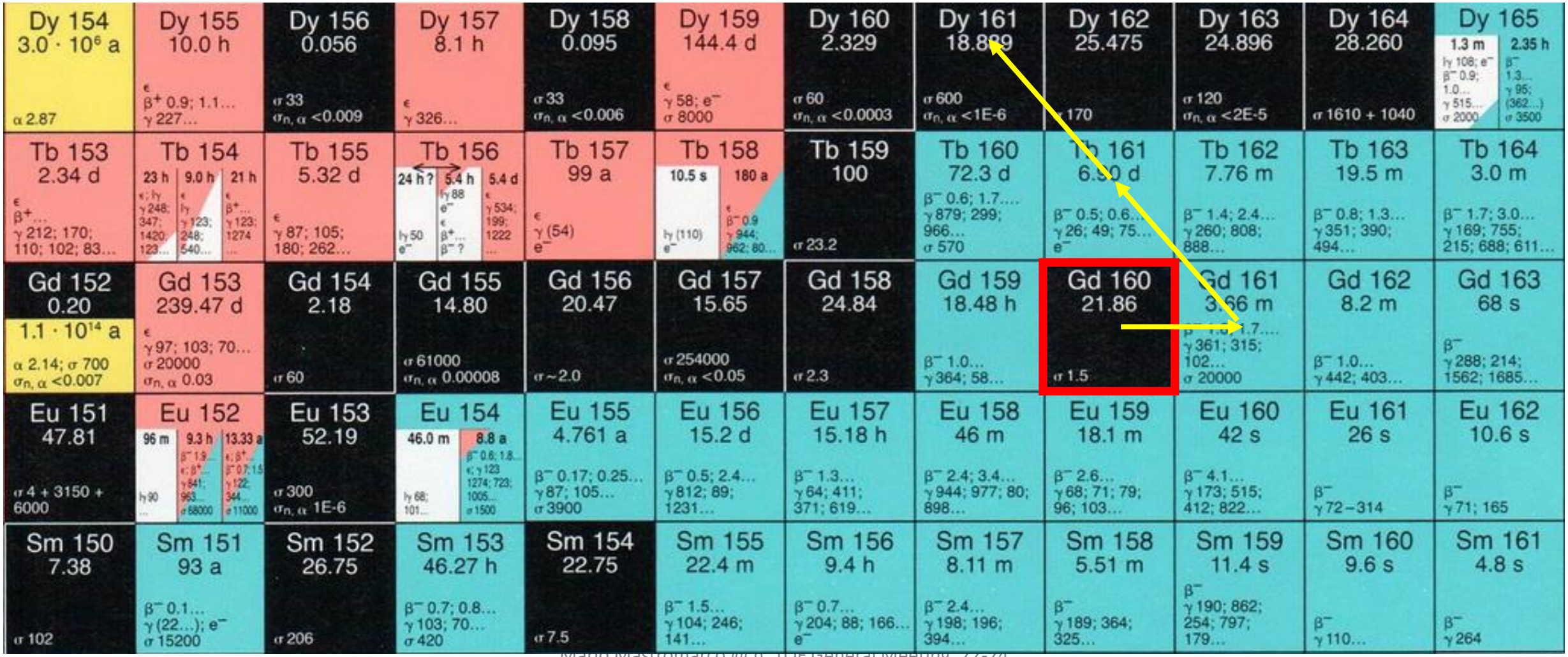
- Similar half-life $T_{1/2}$ = 6.9 d (against 6.7 d of Lu-177)

In addiction to being a γ and β^- emitter (like Lu-177), Tb-161 is also an emitter of Auger and conversion electrons;

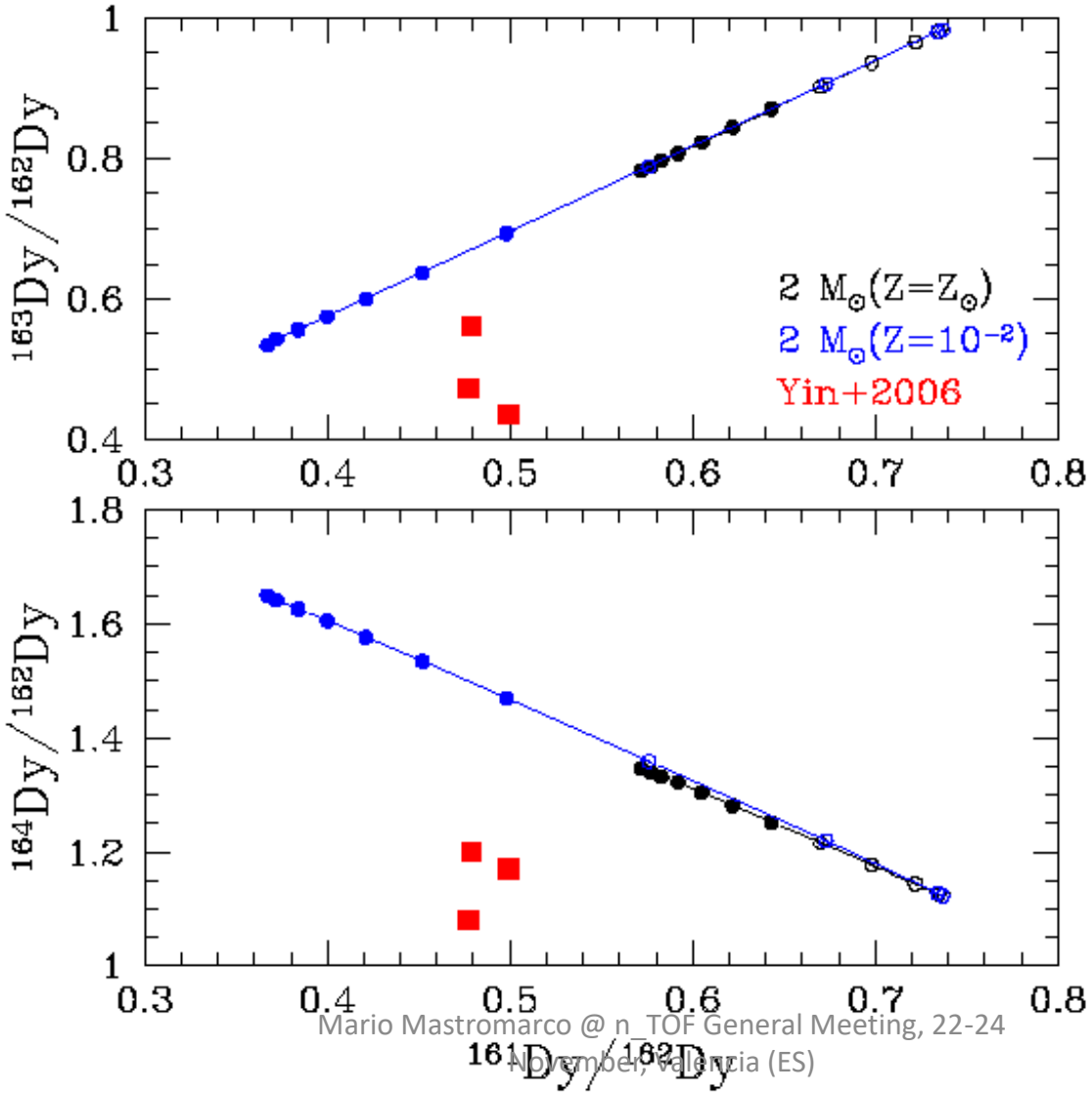
The higher LET (compared to Lu-177) can be effective in reducing the survival probability of tumors cells.

Motivations

…and influences the abundance of Dy in stars!!!

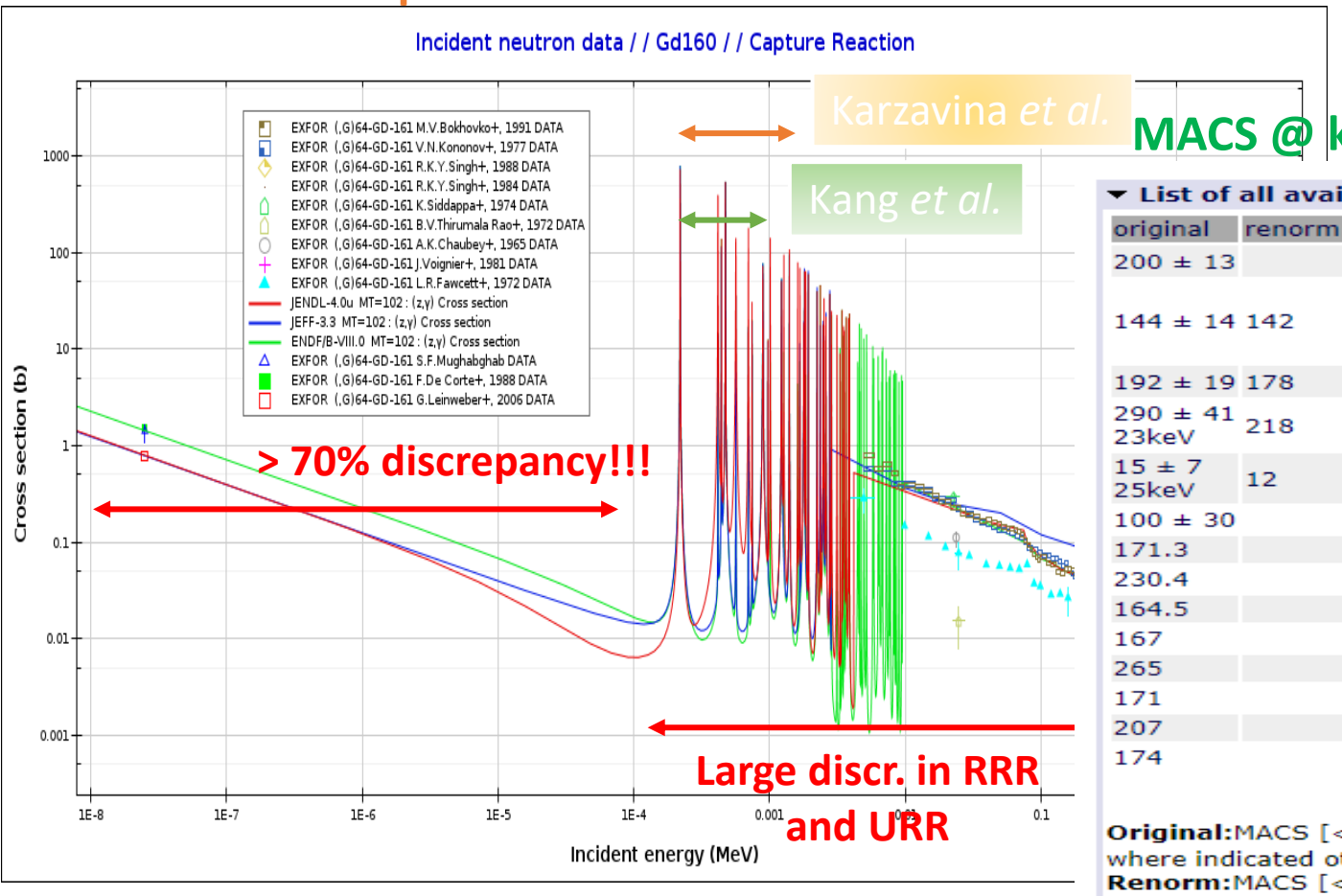


Motivations: Model Calculations against Observations



Motivations: State of the Art

Exp. Data and Main Evaluations



MACS @ kT=30 keV

source: https://exp-astro.de/kadonis1.0/

List of all available values

original	renorm.	year	type	Comment	Ref
200 ± 13		1992	c	VdG, TOF, ^{6}Li, ^{10}B+Au:B-V	BKP92
144 ± 14	142	1984	c	VdG, Act., 1/v(kT), Au:657mb(25keV)^{160}Gd(n,gamma)^{161}Gd beta decay of ^{161}Tb	BKY84
192 ± 19	178	1978	b	VdG, TOF, ^{10}B:Mag75, Au:628mb(kT=30keV)	KYP78
290 ± 41 23keV	218	1973	c	Sb-Be, Act., 1/v(E), ^{127}I:836mb(23keV)	SSR73
15 ± 7 25keV	12	1972	c	Sb-Be, Act., 1/v(E), ^{127}I:832mb(25keV)	TRK72
100 ± 30		1971	e		AGM71
171.3		2006	e		endfb7
230.4		2004	e		jeff31
164.5		2002	e		jendl33
167		2000	t		RaT99
265		1981	t		Har81
171		1976	t		HWF76
207		2002	t	MOST 2002	Gor02
174		2005	t	MOST 2005	Gor05

> 30% discrepancy

Original: MACS [$<\sigma v>/v_T$] (mb) for kT=30 keV, based on the published cross sections except where indicated otherwise.
Renorm: MACS [$<\sigma v>/v_T$] (mb) for kT=30 keV for which the reference or standard cross section was meanwhile improved.
Type: The letters and numbers in the column labelled 'type' give information on how the cross section has been obtained:

c	Directly quoted from the reference itself
b	Calculated from smooth cross sections with model fit: ln(sigma) = a + a1 ln(E) + a2 ln^2(E)
e	Evaluated value taken directly from the reference
t	Theoretical value

Motivations:

Unsatisfactory situation triggered the n_TOF Collaboration to perform a new measurement of the ^{160}Gd(n, γ) reaction from thermal up to 300 keV at n_TOF facility (CERN)

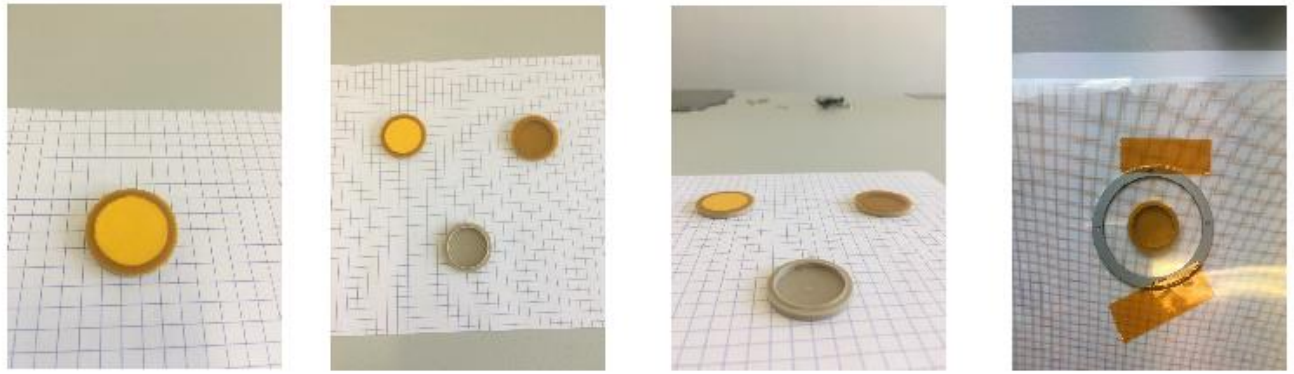
Samples: Gd sample and Dummy

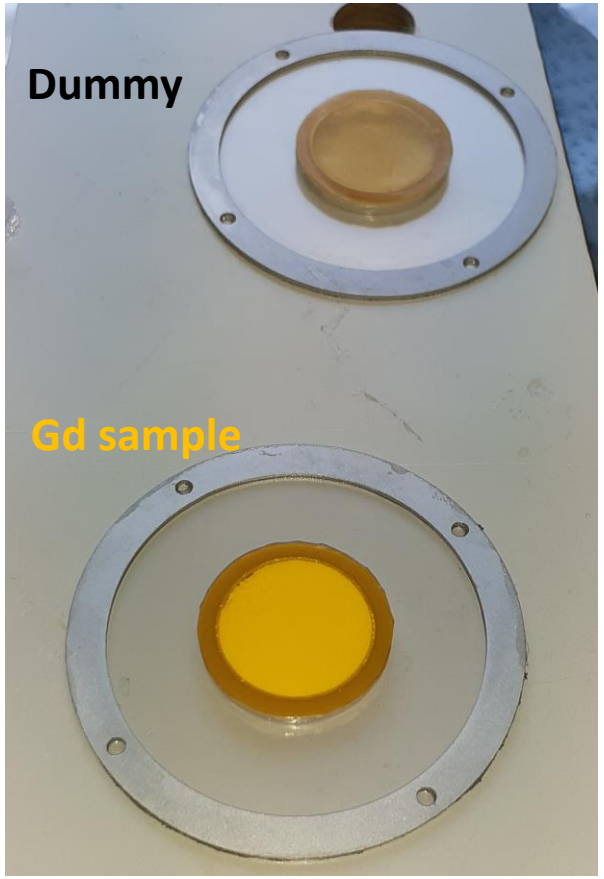
(Sample available in the form of powdred Gd oxide!!!)

Step by step samples preparation…

START

END





Samples: Gd sample and Gd_2O_3 Composition

	mass [mg]
Gd oxide container total mass	1459
Gd oxide container after oxide removal	1141
Gd_2O_3	318
PEEK capsule	795
kapton	17
glue	114
dummy (capsule + glue + kapton)	926
Gd_2O_3	**317**
Gd oxide sample (oxide + PEEK)	**1243**
Gd mass (oxide is Gd_2O_3)	**276**
Gd-160 mass (98.1 % enrichment)	**270**

In the past the **^{160}Gd(n, γ)** measurement was hampered by the natural isotopic presence of **^{155}Gd** and **^{157}Gd**

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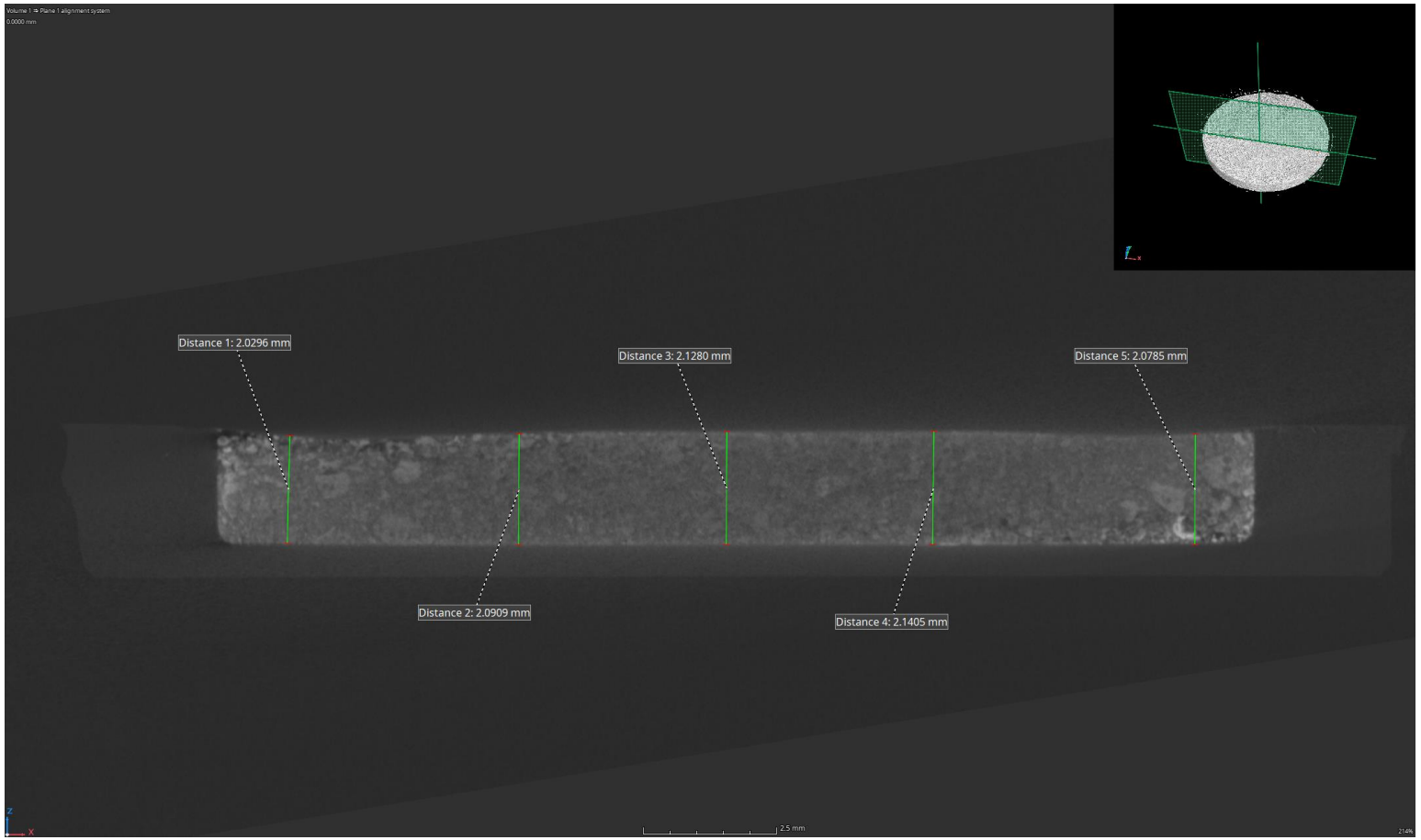
But this time…

Sample irradiated for 55 days at the thermal reactor of ILL: **^{155}Gd and ^{157}Gd burned out!!!**

Gd-160 enrichment:	
Isotope	**[%]**
Gd-152	3.80E-05
Gd-153	3.90E-10
Gd-154	0.02
Gd-155	3.30E-05
Gd-156	0.59
Gd-157	4.20E-06
Gd-158	1.29
Gd-160	**98.1**

Samples: Gd sample, X-ray Spectroscopy



Average thickness ~ **2.10 +/- 0.01 mm**

Experimental Setup @ EAR1 and EAR2

Liquid scintillation detectors with **deutered benzene: (C_6D_6 & sTED)**

- Low neutron sensitivity
- Low γ-ray detection efficiency

EAR1

- Flight Path: **185 m**
- Flux: **10^6/cm^2/Proton Bunch**
- Very High Resolution: **< 10^{-3}**

The **total energy detection principle** by combining the detection system with the so-called **Pulse Height Weighting Technique (PHWT).**

For details see:

P. Schillebeeckx *et al.*, Nucl. Data Sheets **113**, 3054 (2012)

A. Borella, G. Aerts, F. Gunsing *et al.*, Nucl. Instr. Meth. A **577**, 626 (2007)

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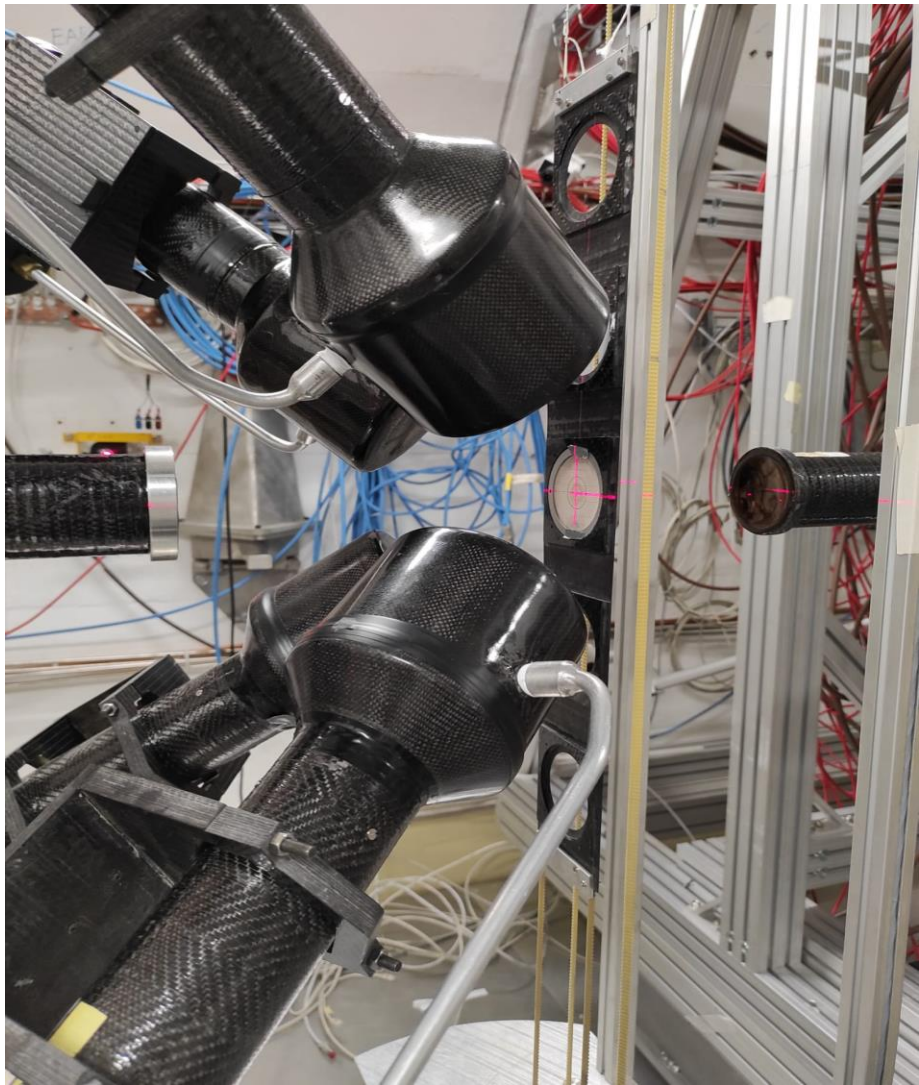
EAR1: 4 C_6D_6



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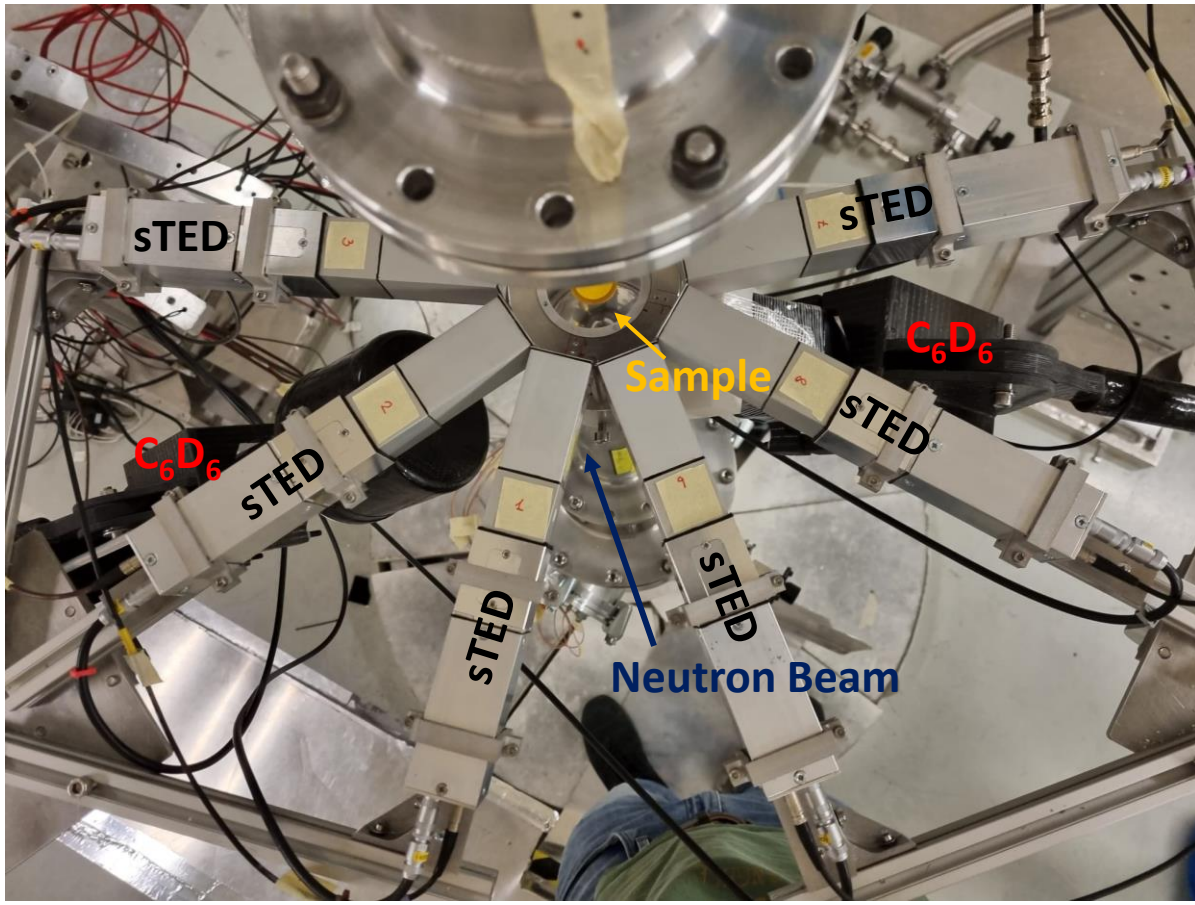
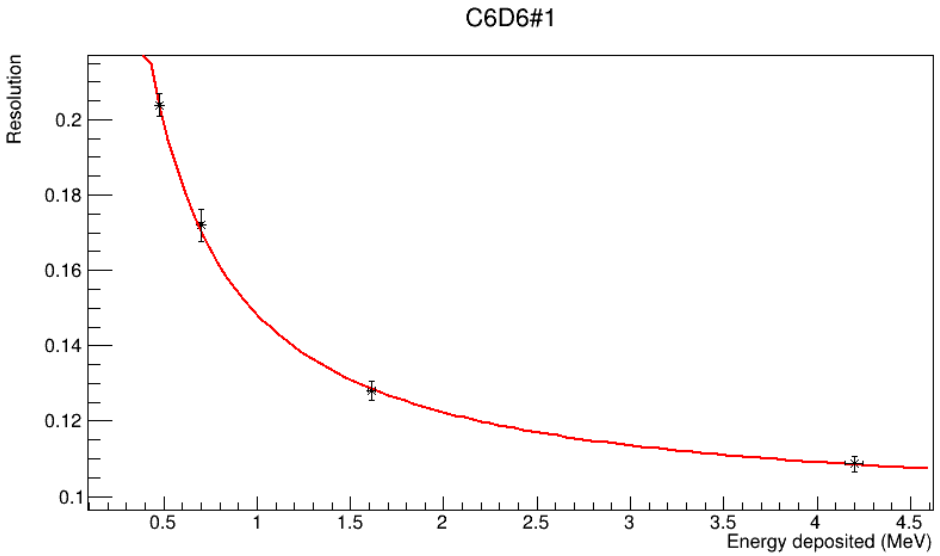
EAR2: 2 C_6D_6 + 9 sTED

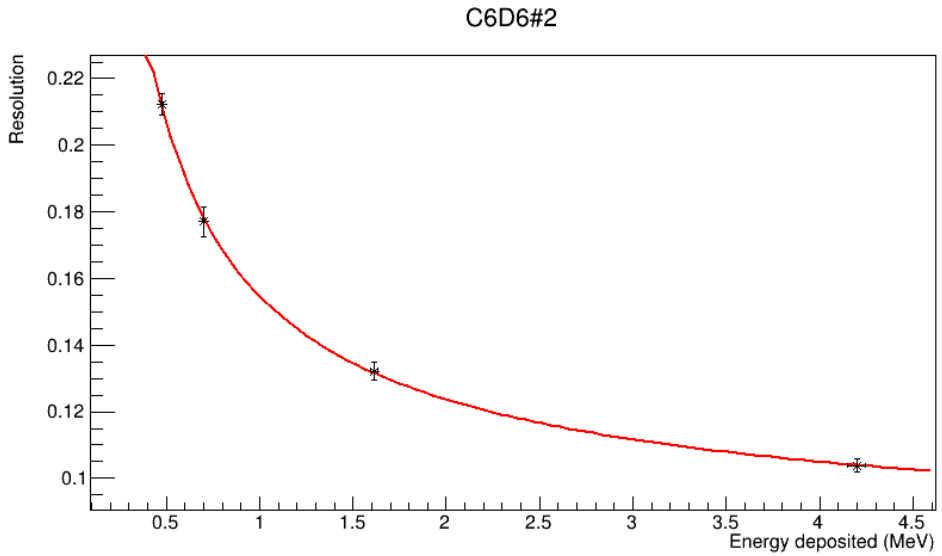


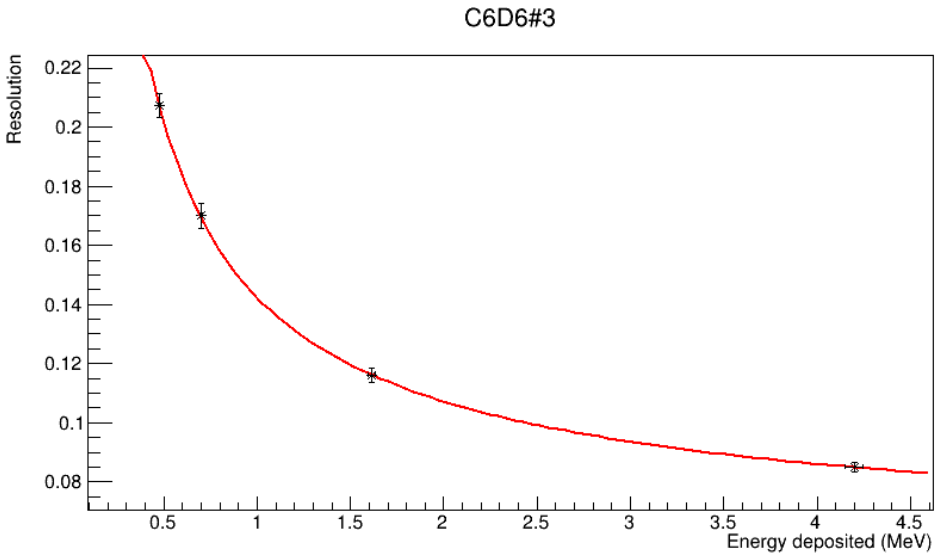
EAR1

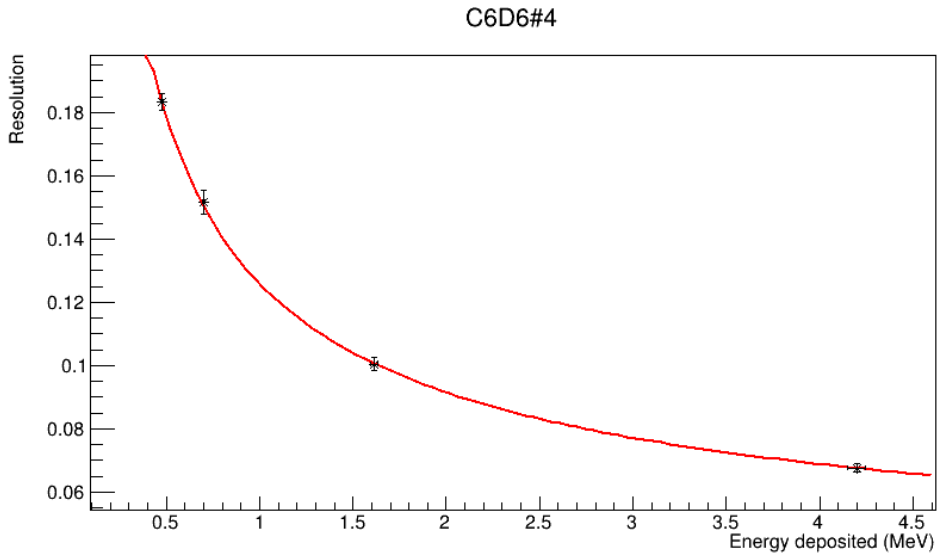
(Resolved and Unresolved Resonances Region)

Resolution, calibration (+ MC)

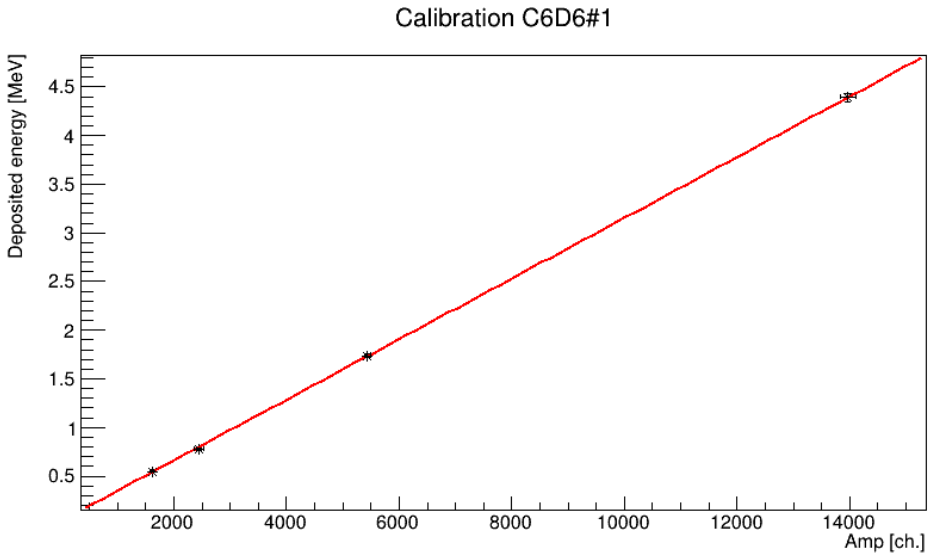


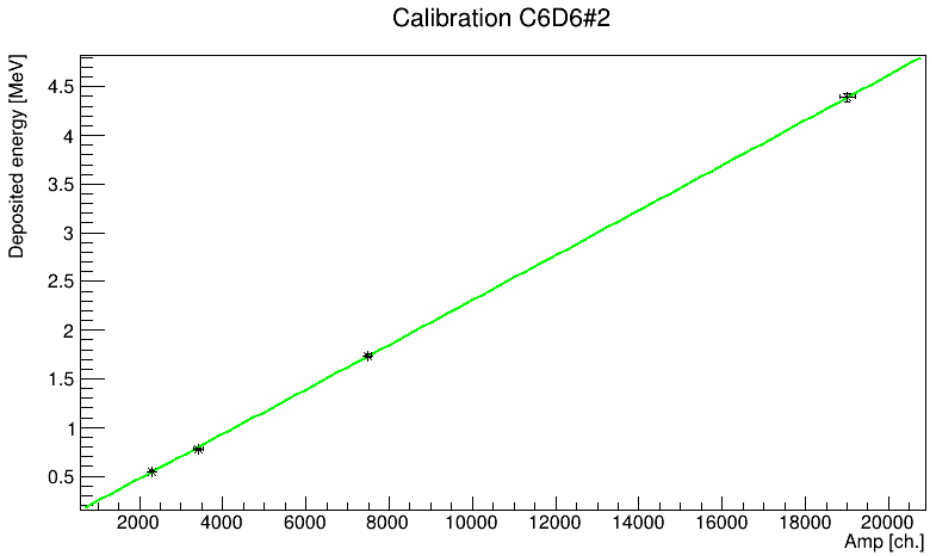


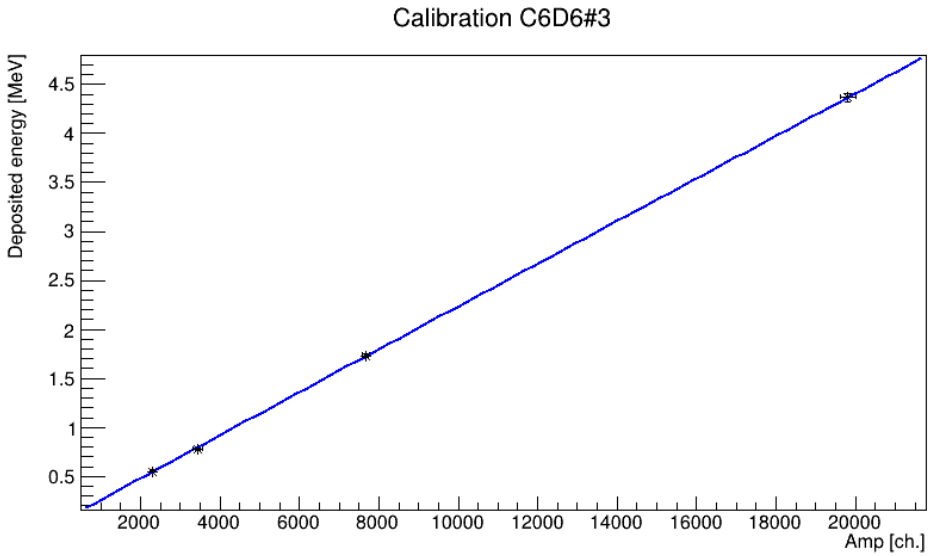


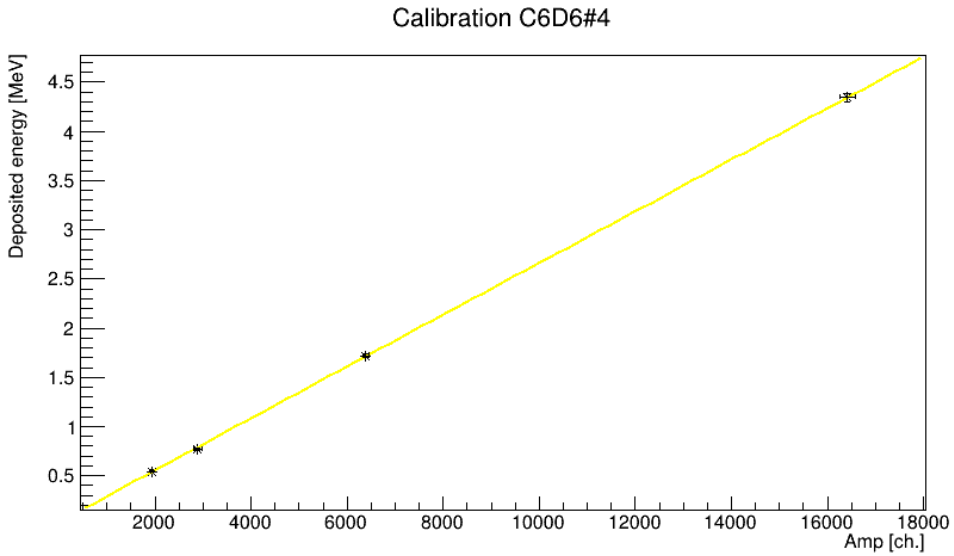


Resolution, calibration (+ MC)









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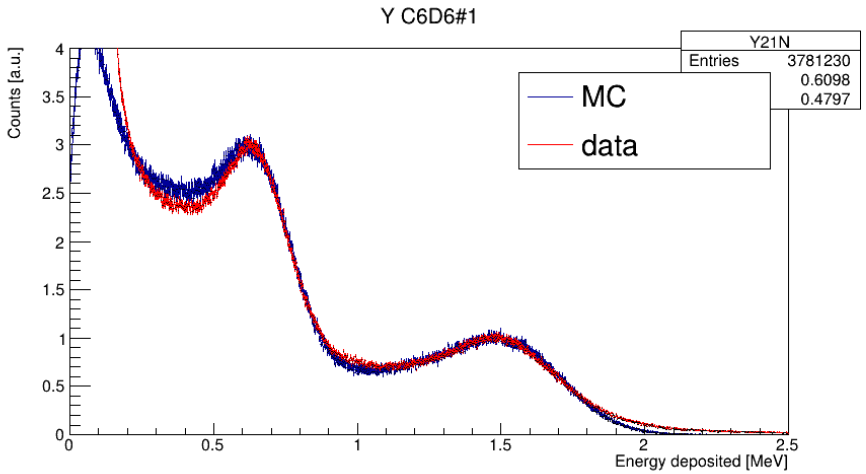
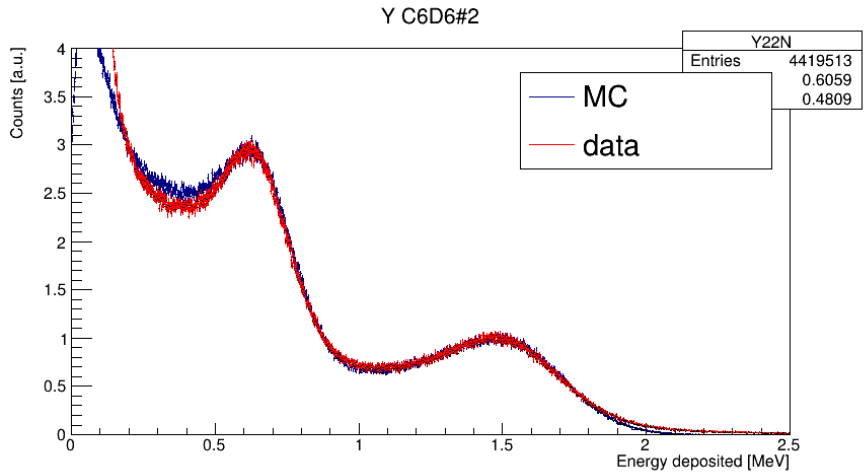
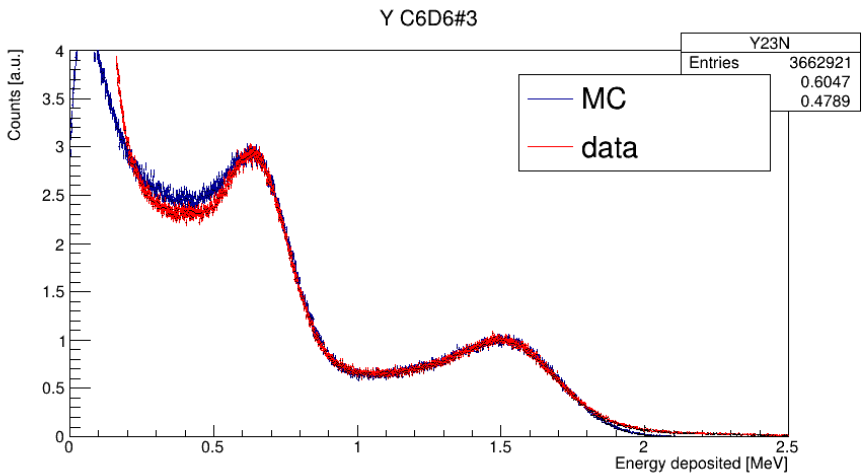
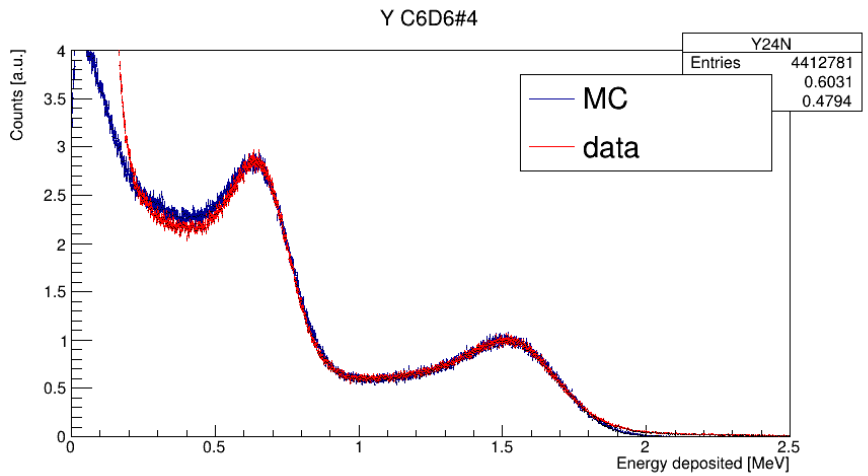
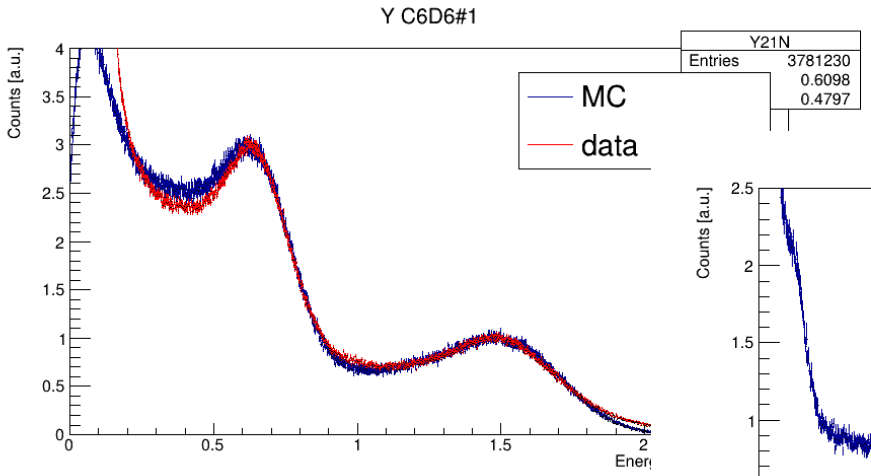


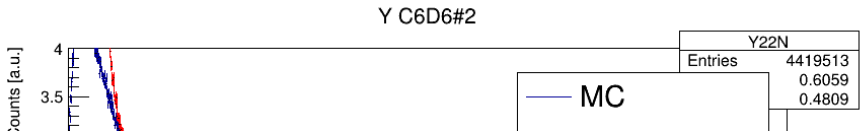


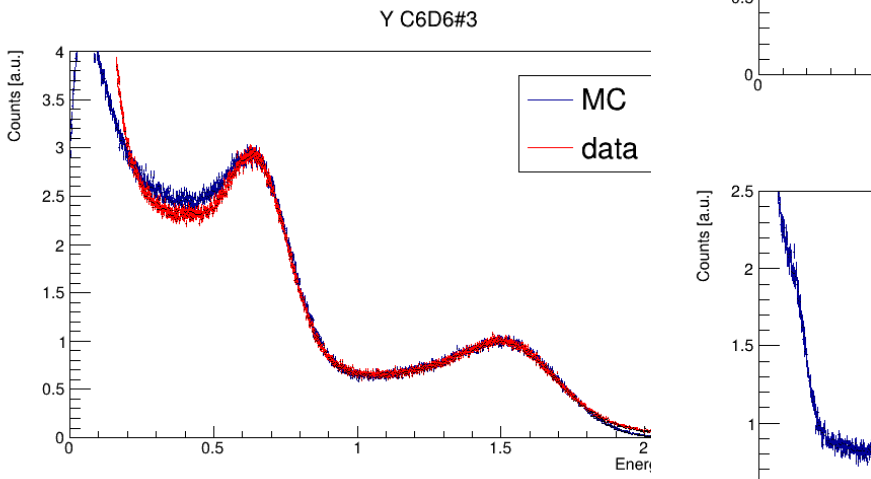


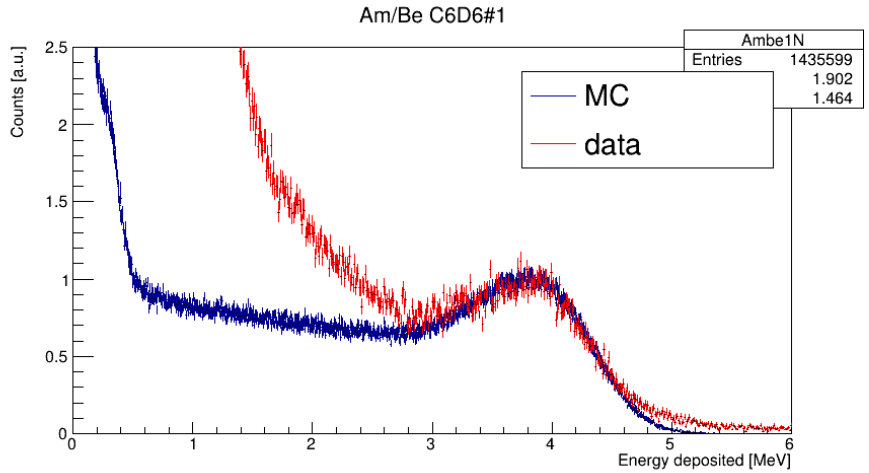


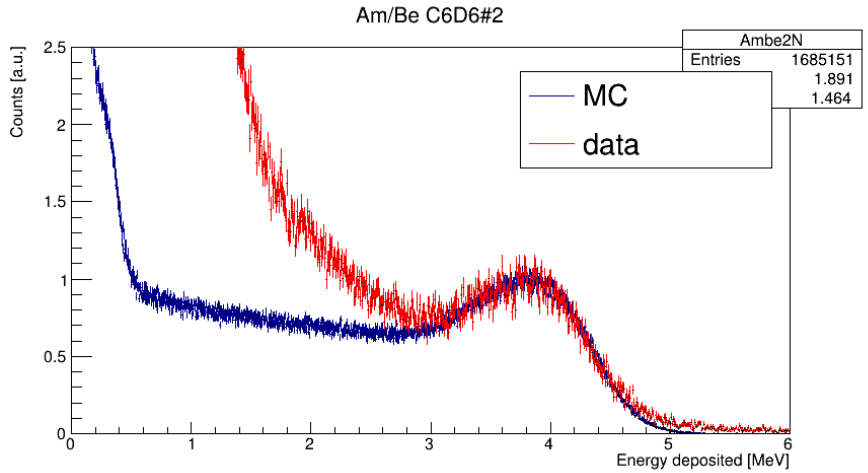
Resolution, calibration (+ MC)

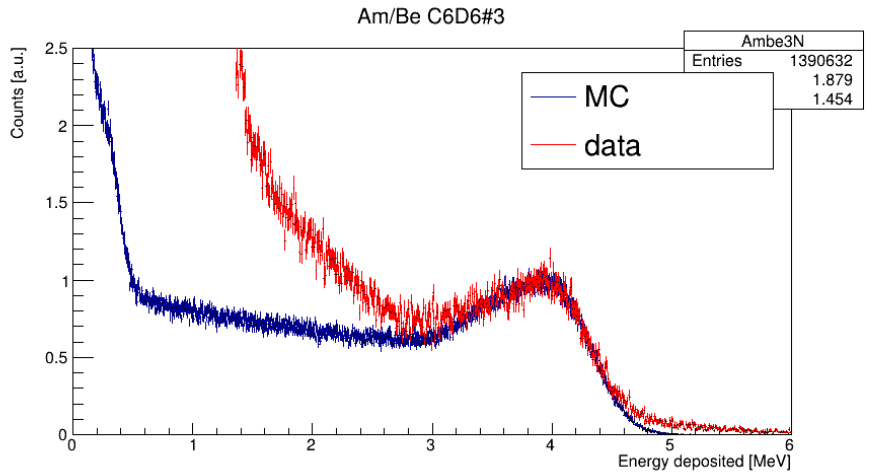


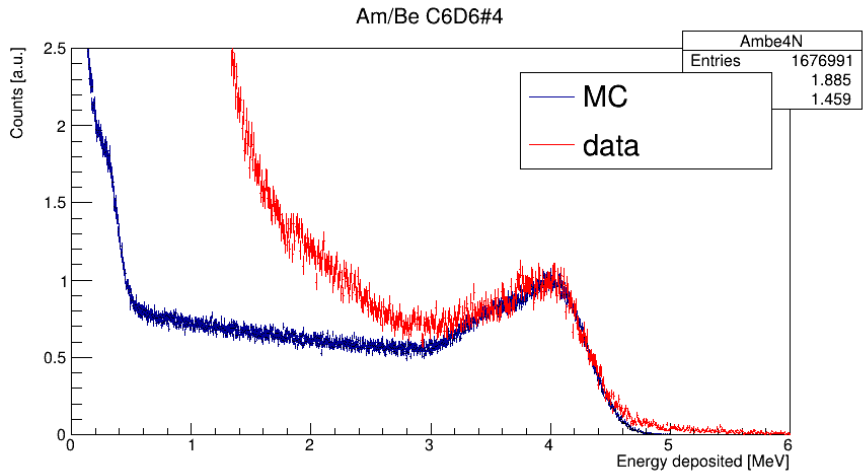




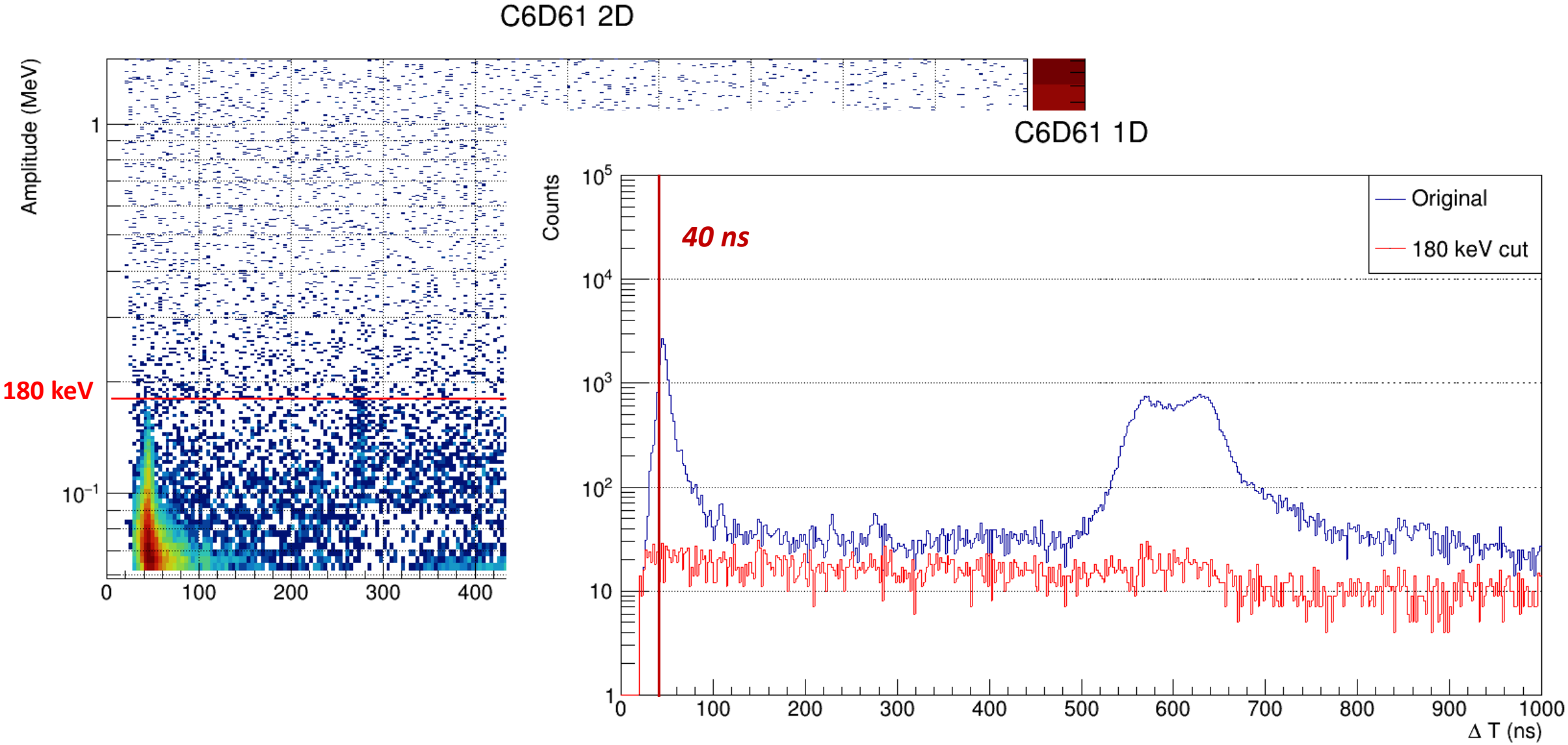




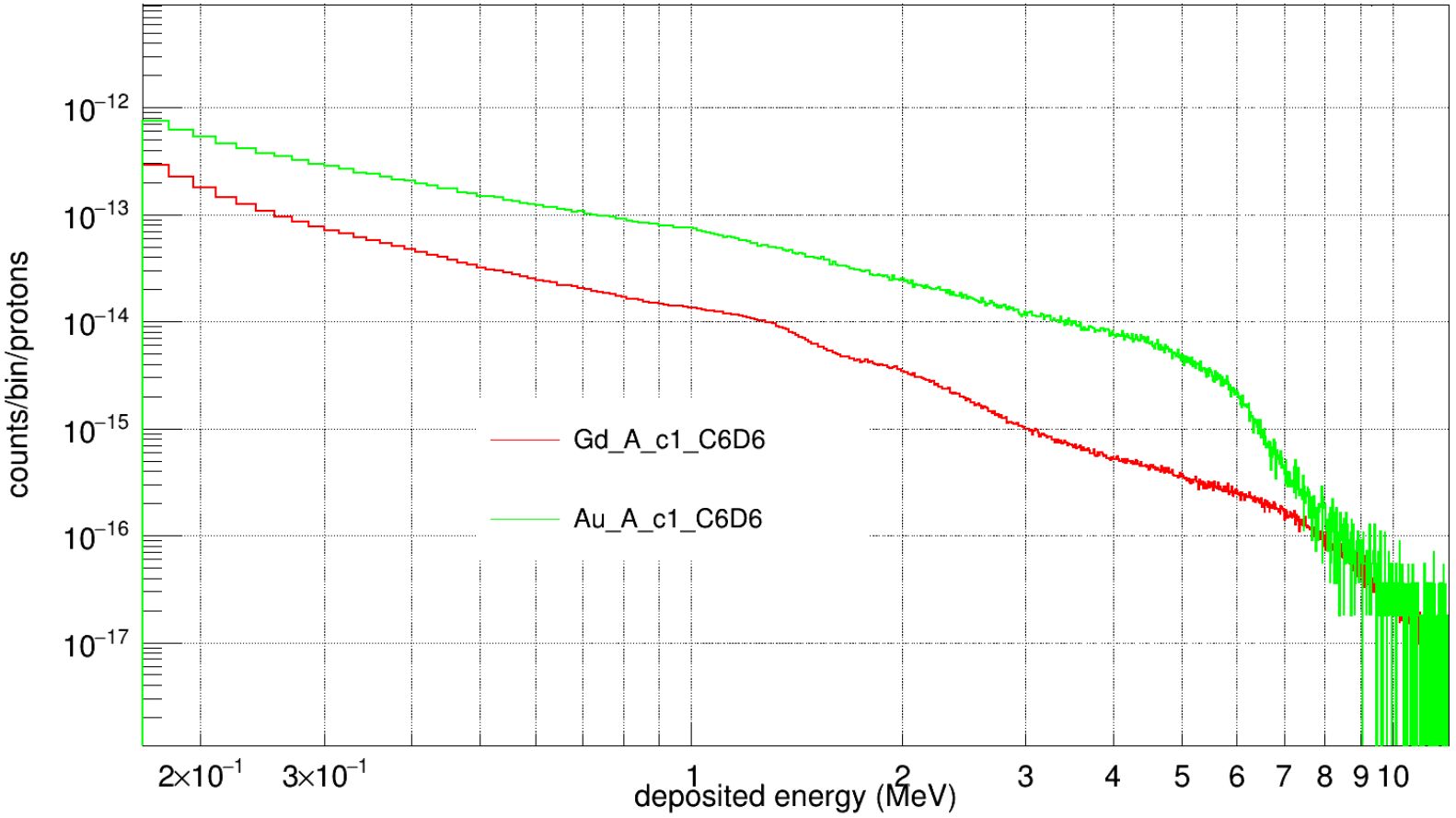




Low Thresholds: after pulse rejection and dead-time



High Thresholds: HE background rejection



Sn_Au = 6.5 MeV

Sn_Gd = 5.6 MeV

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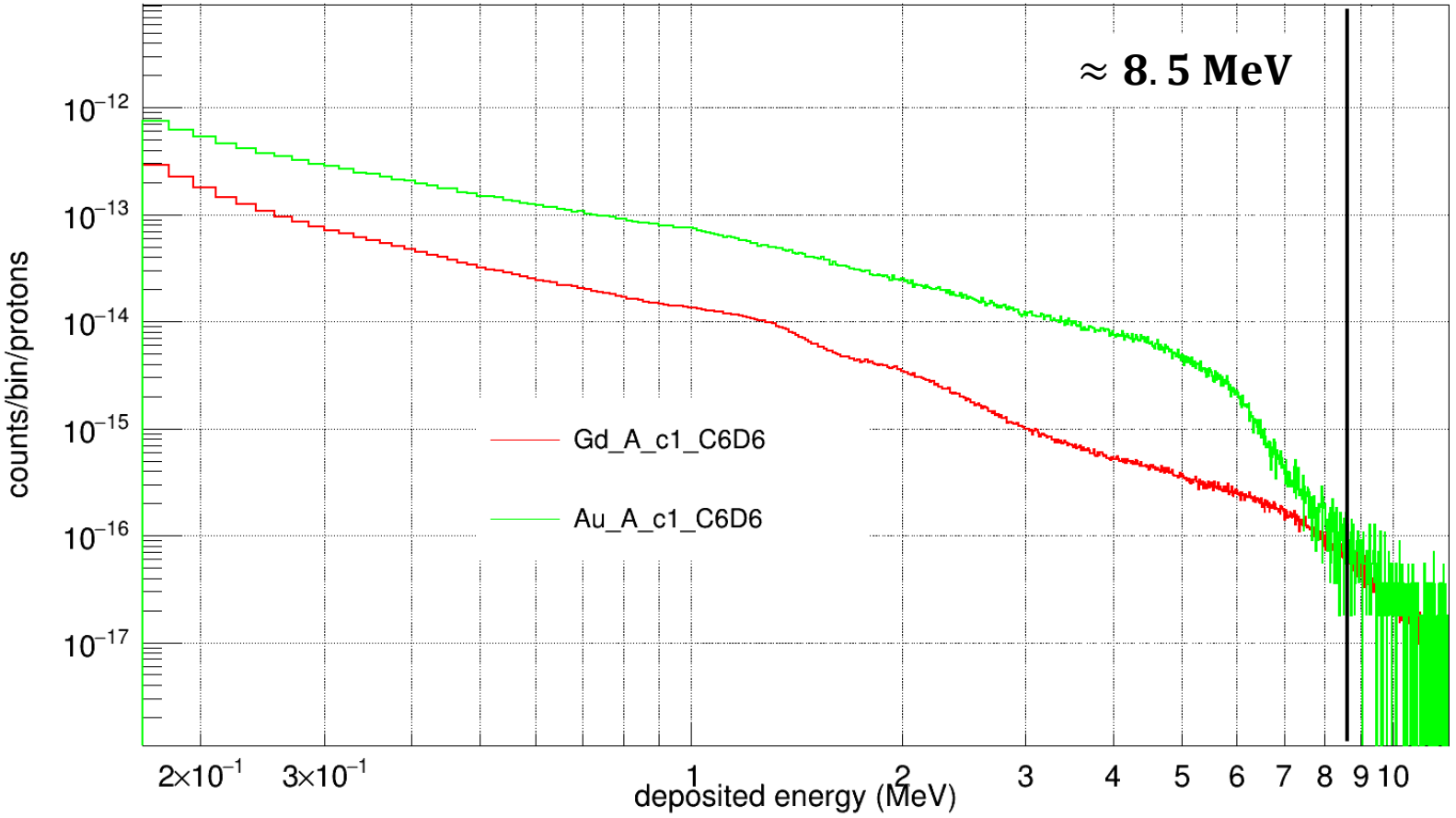

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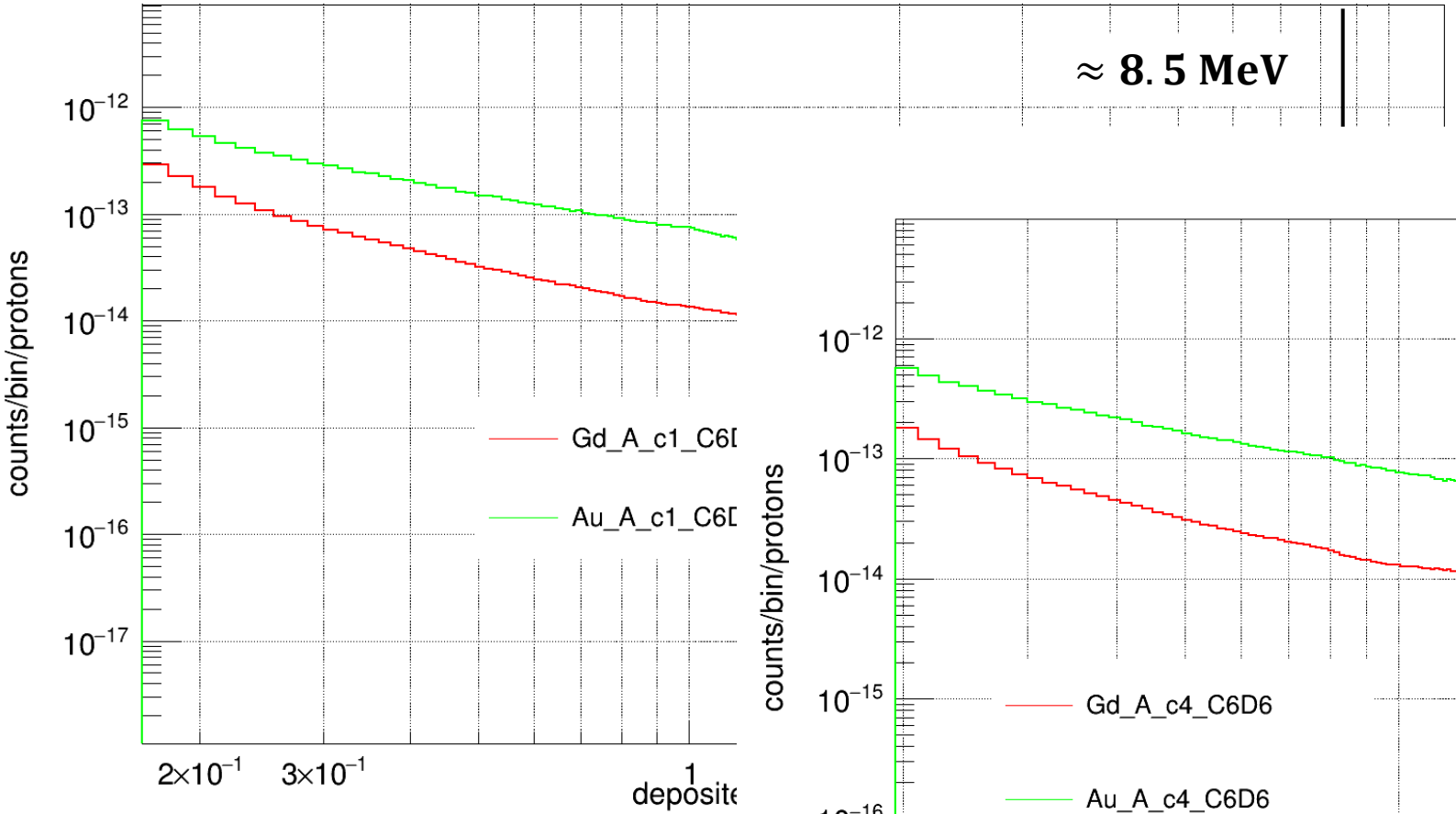

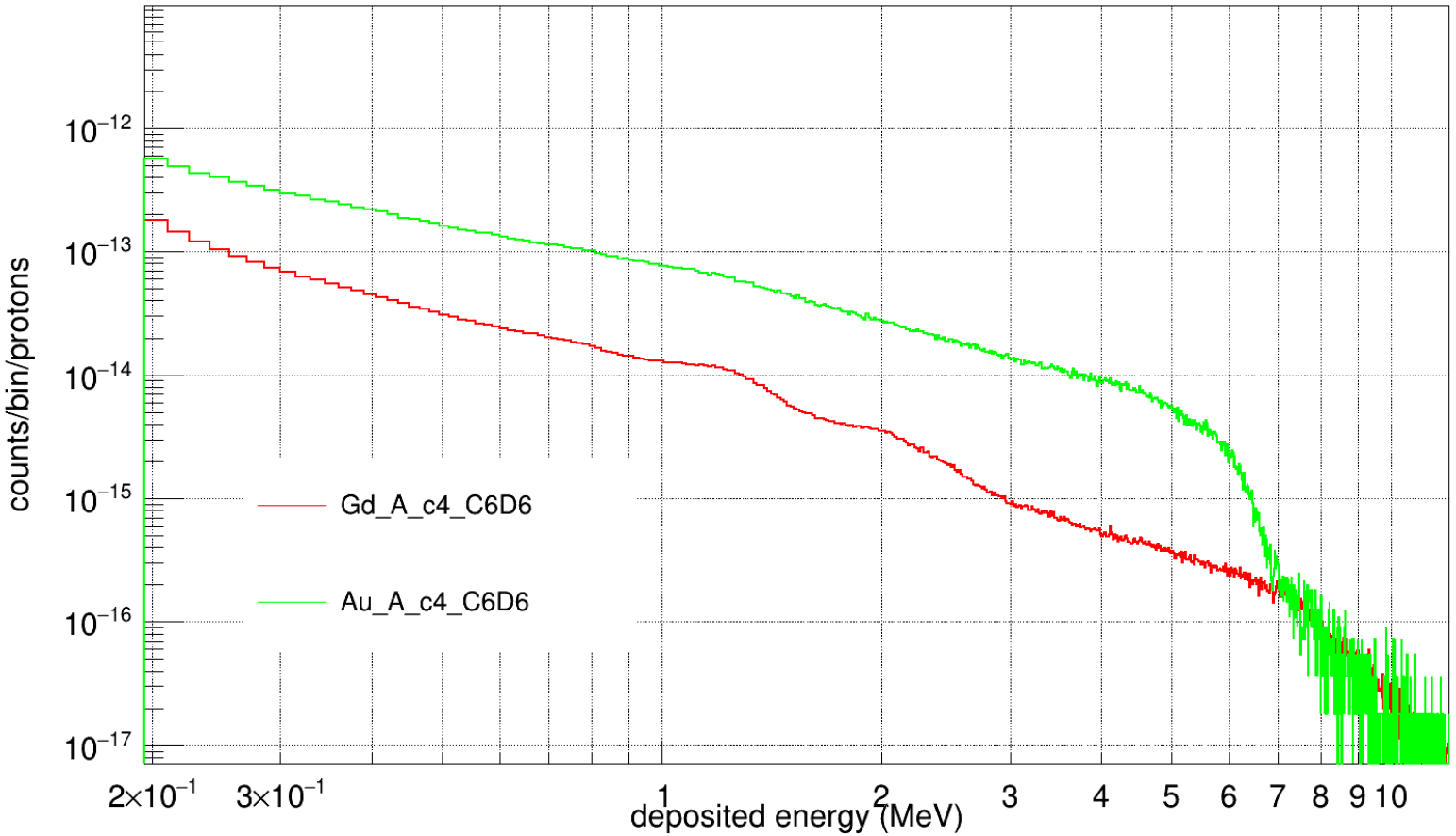

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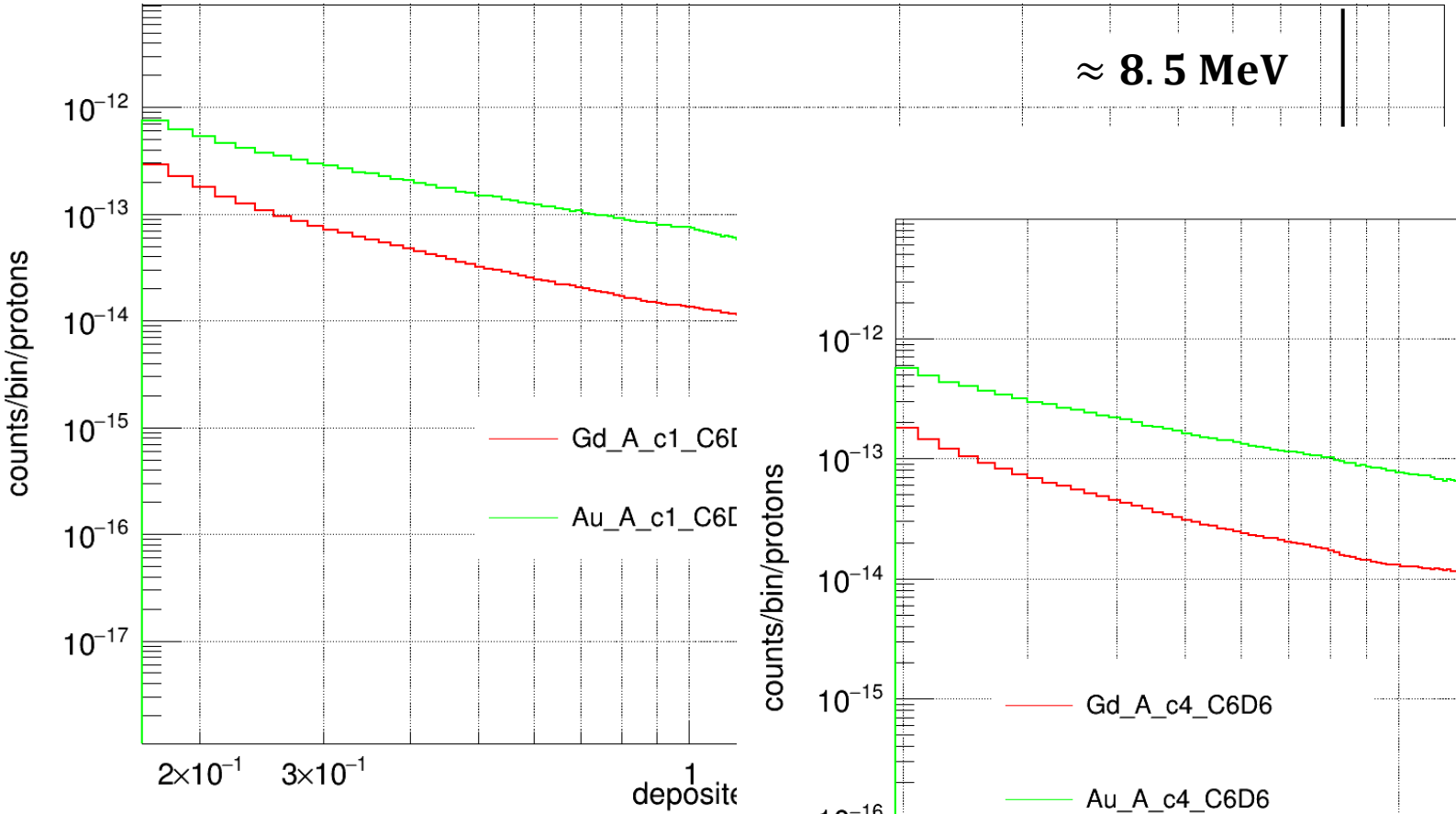
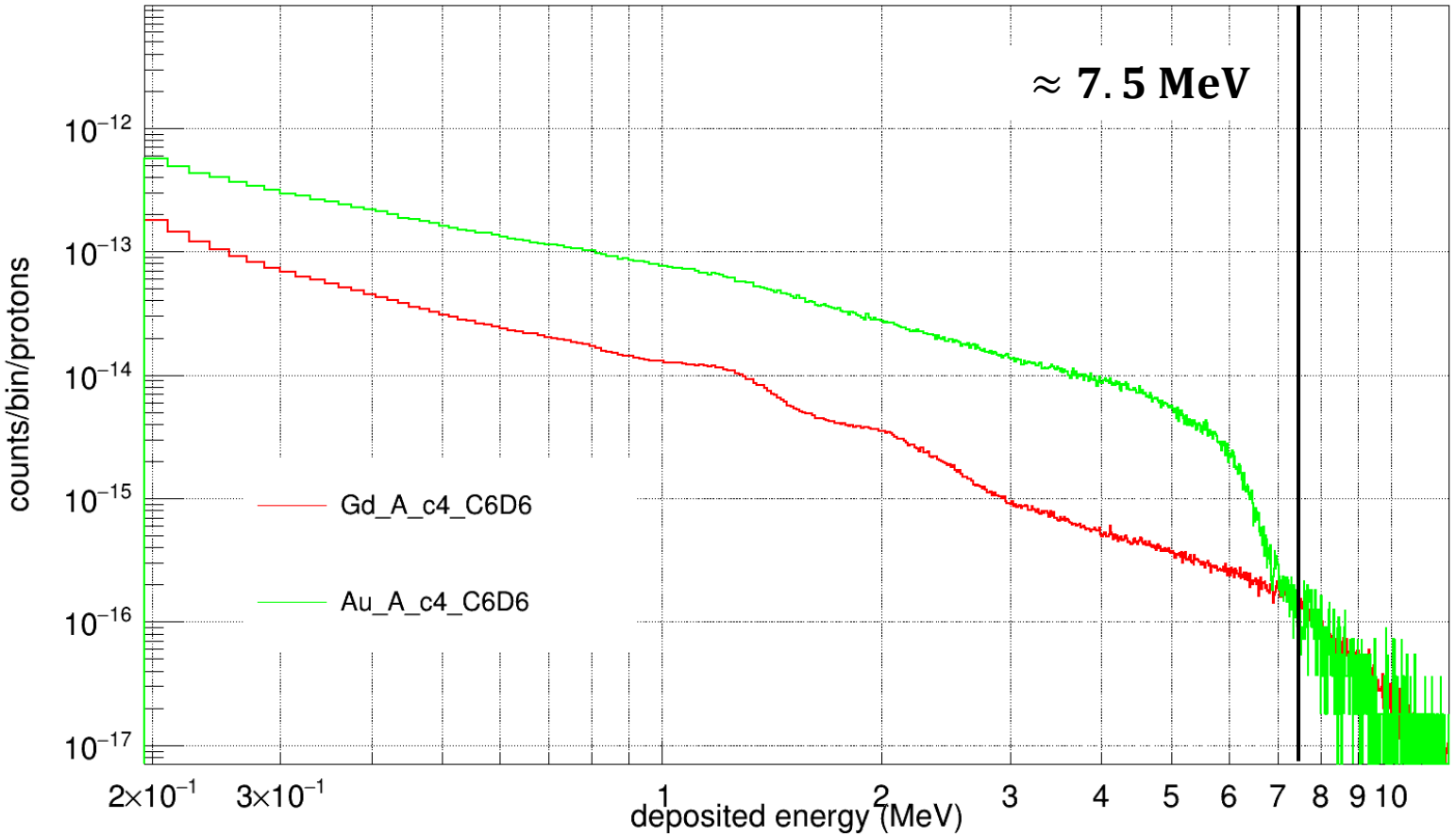
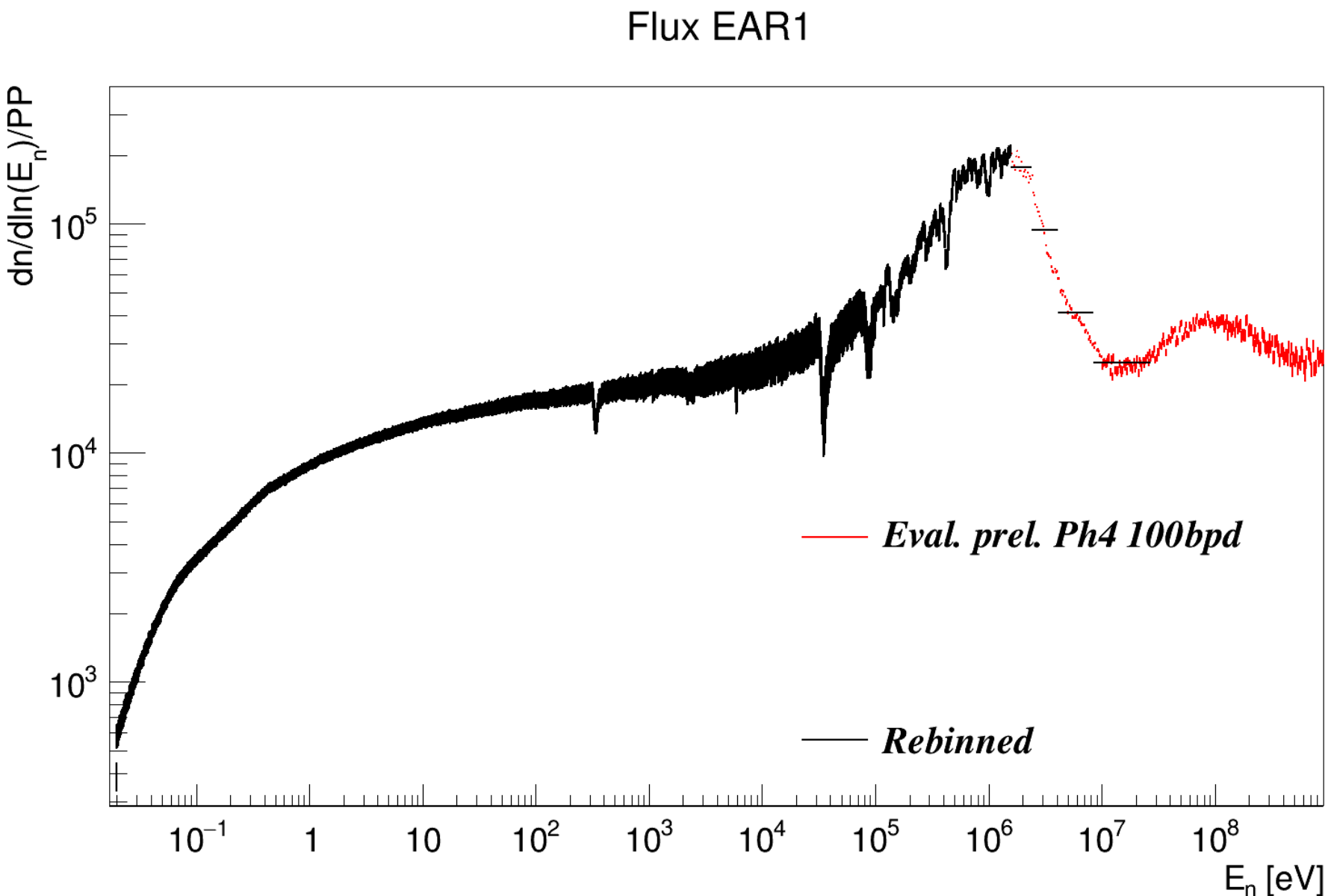
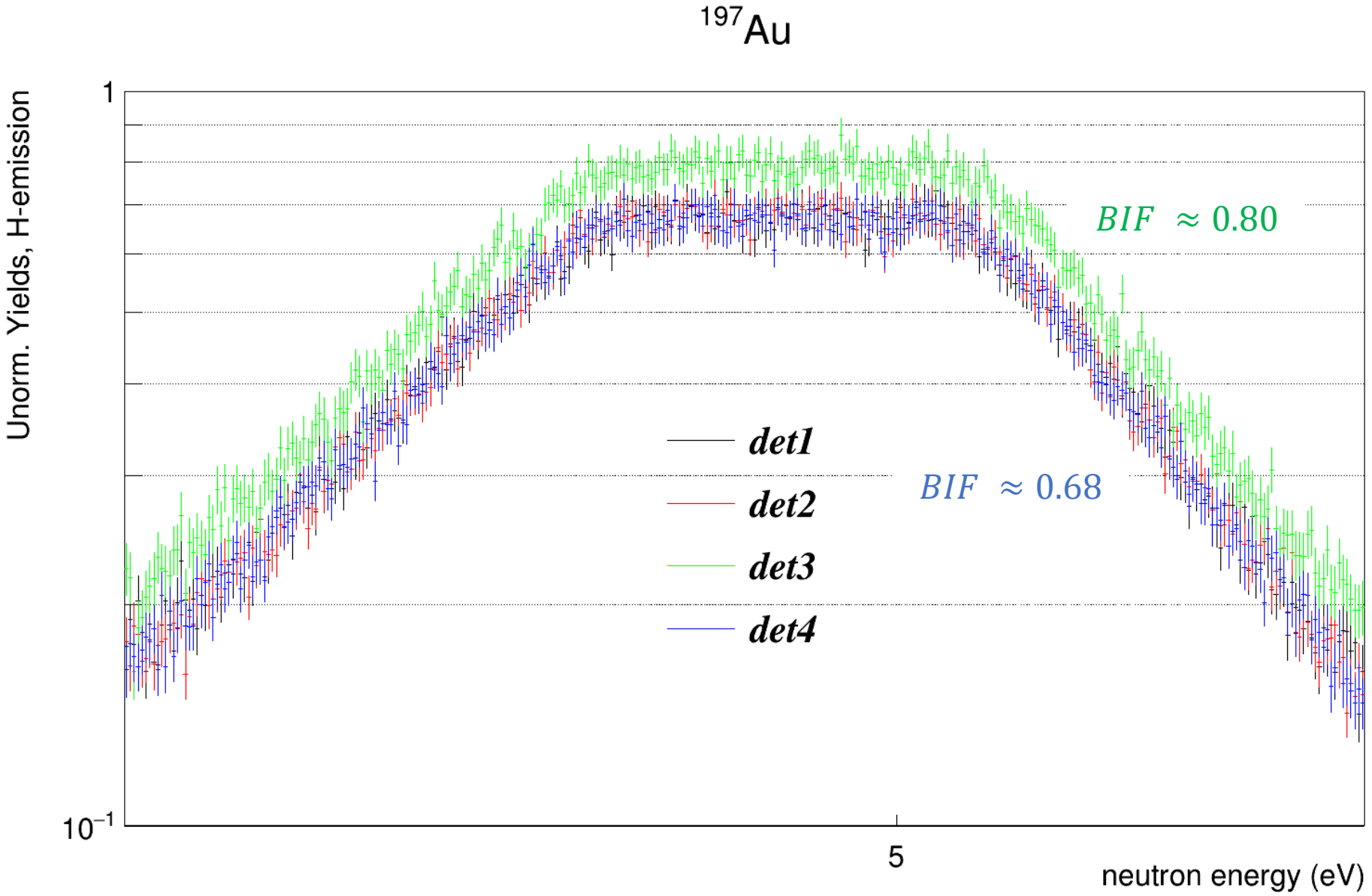




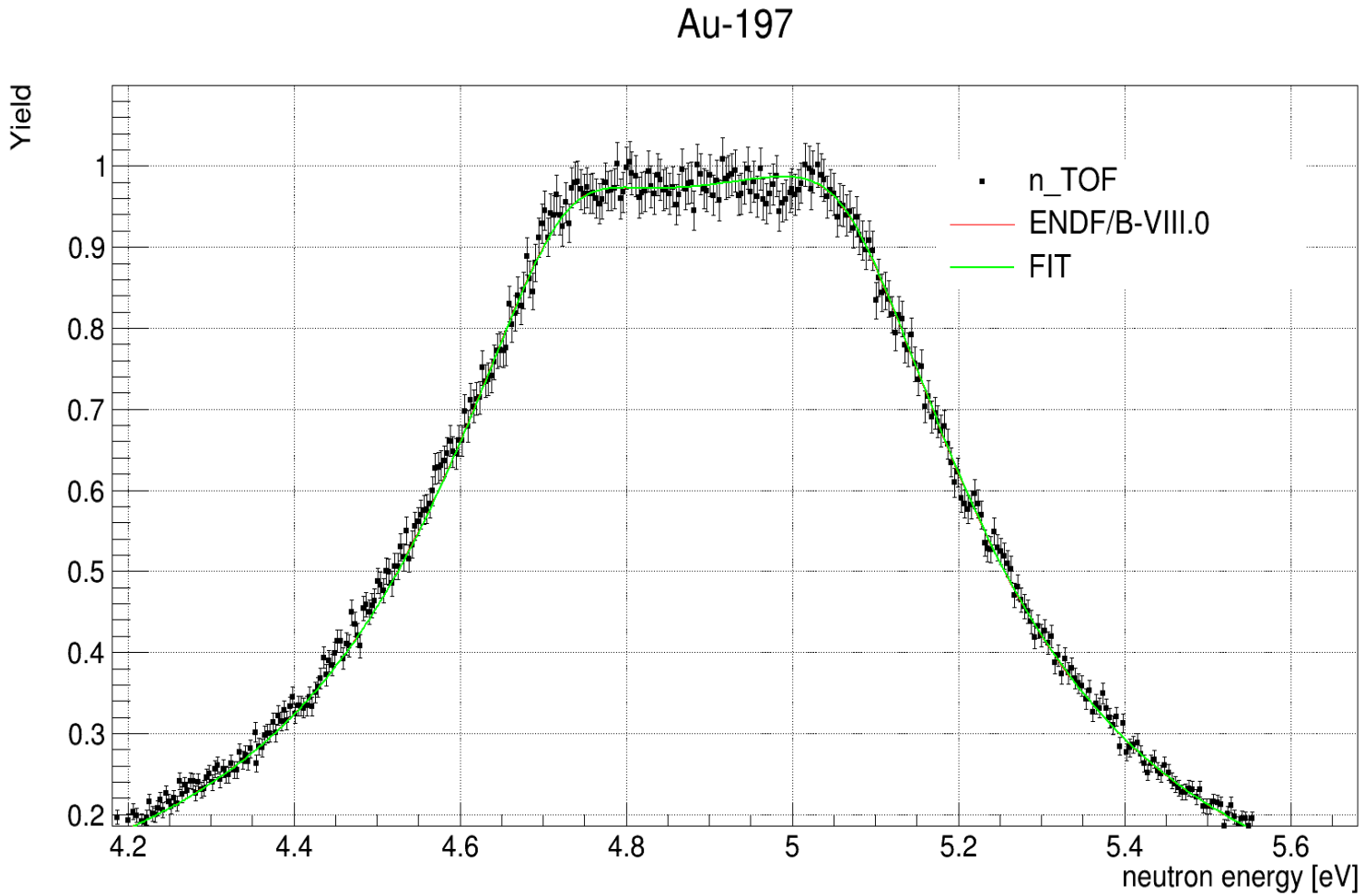
Evaluated Flux



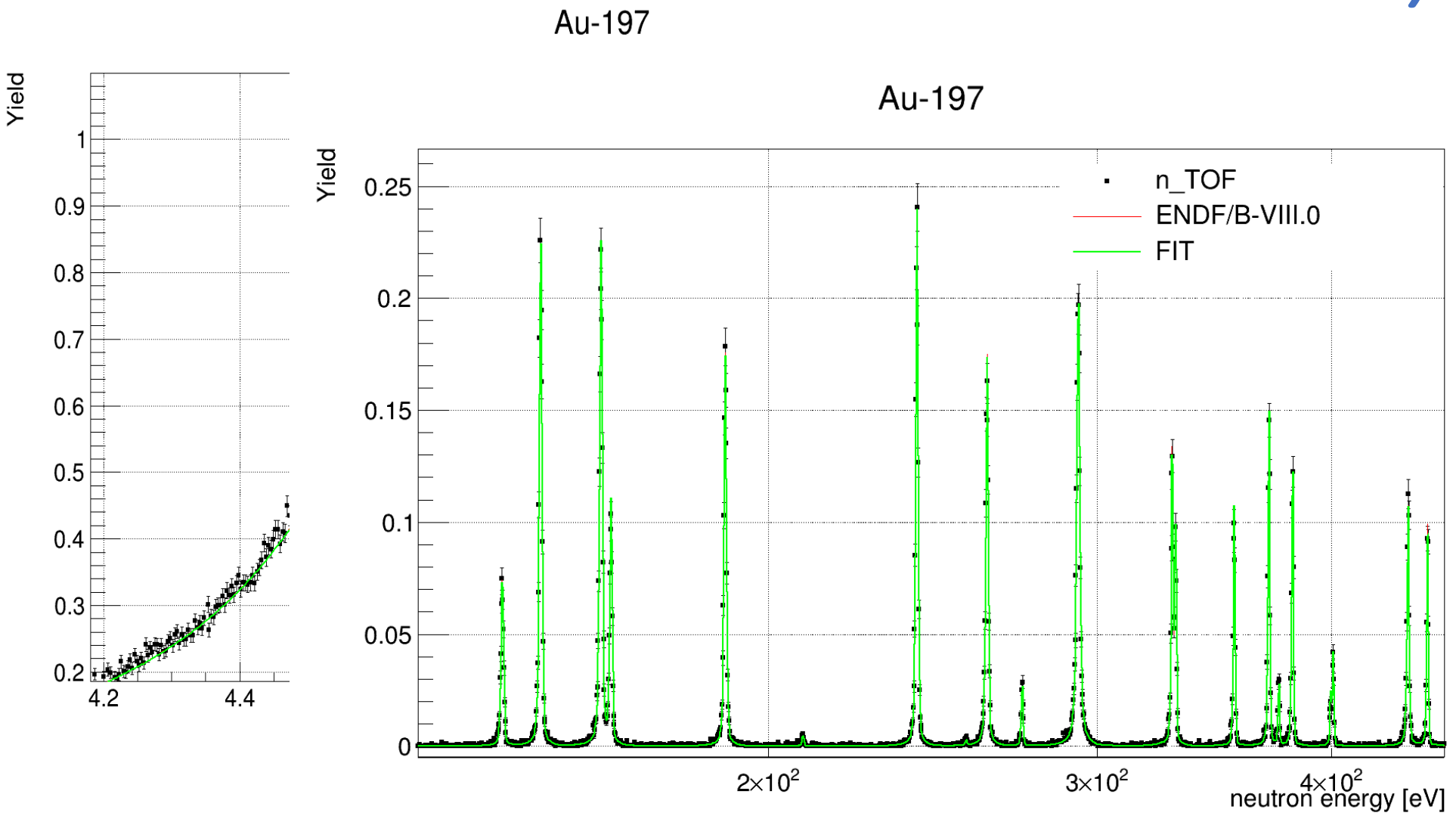
Au-197: normalization factors



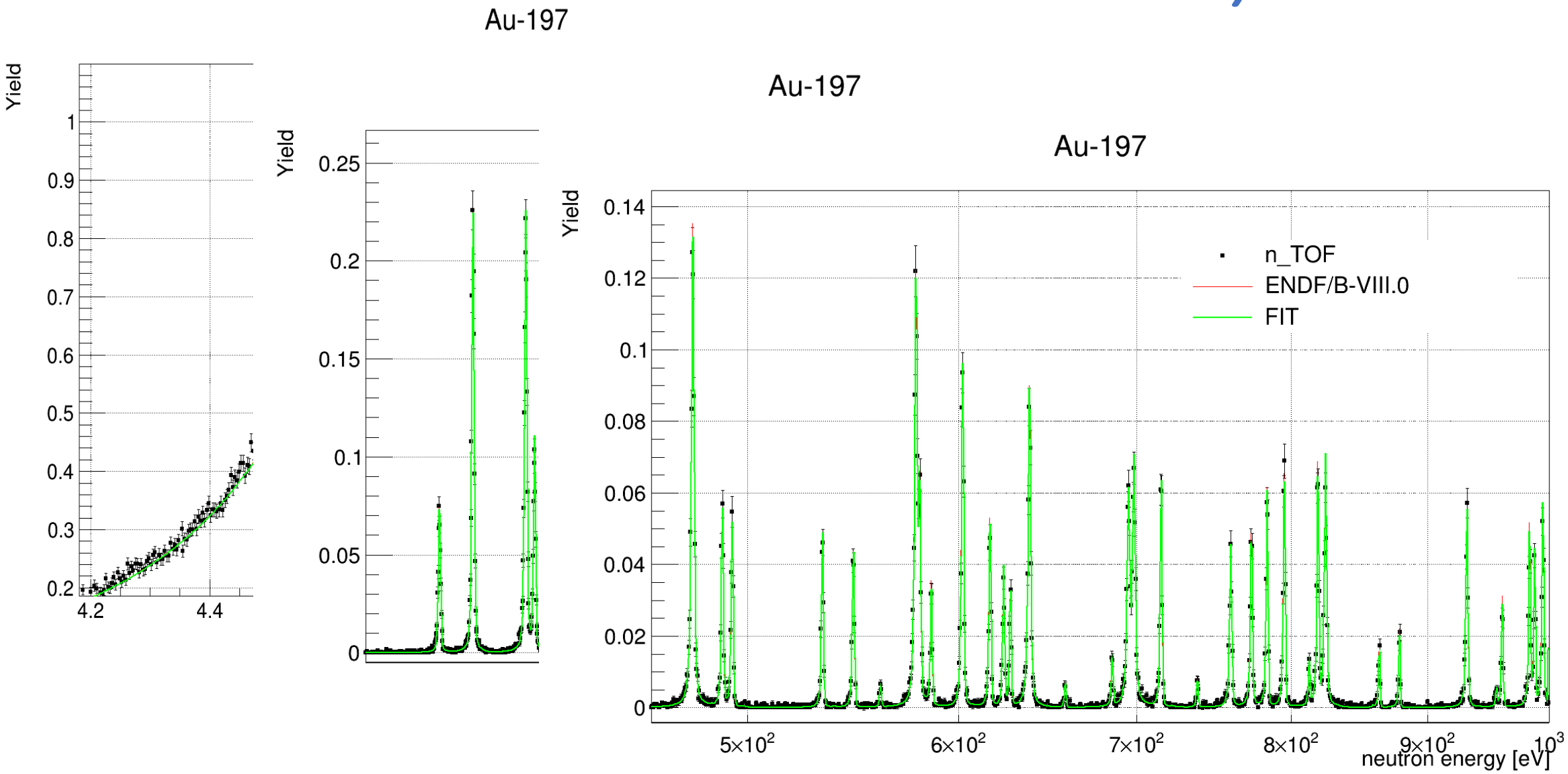
Au-197: TOF – neutron energy check (transport code and SAMMY)



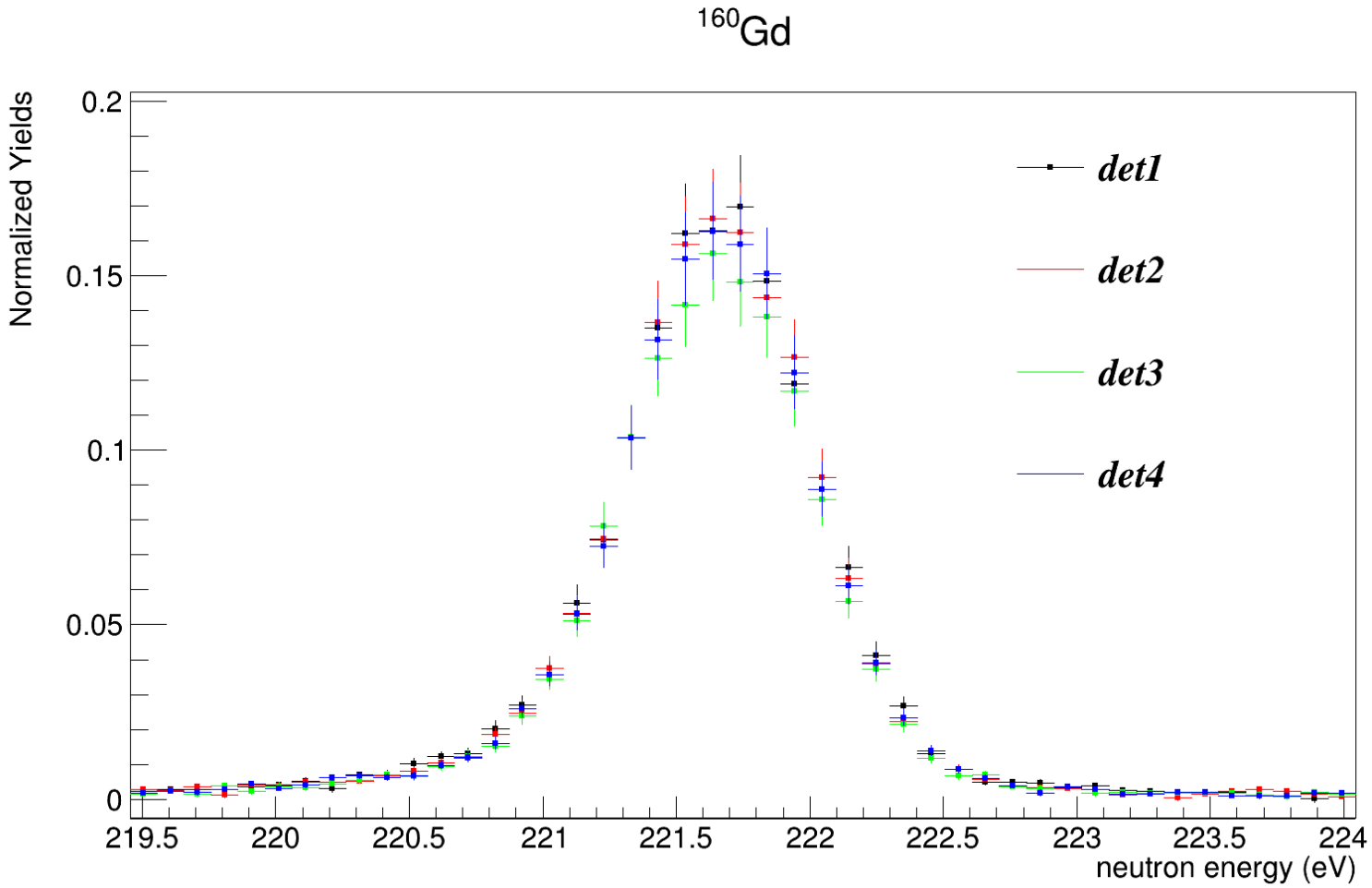
Au-197: TOF – neutron energy check (transport code and SAMMY)



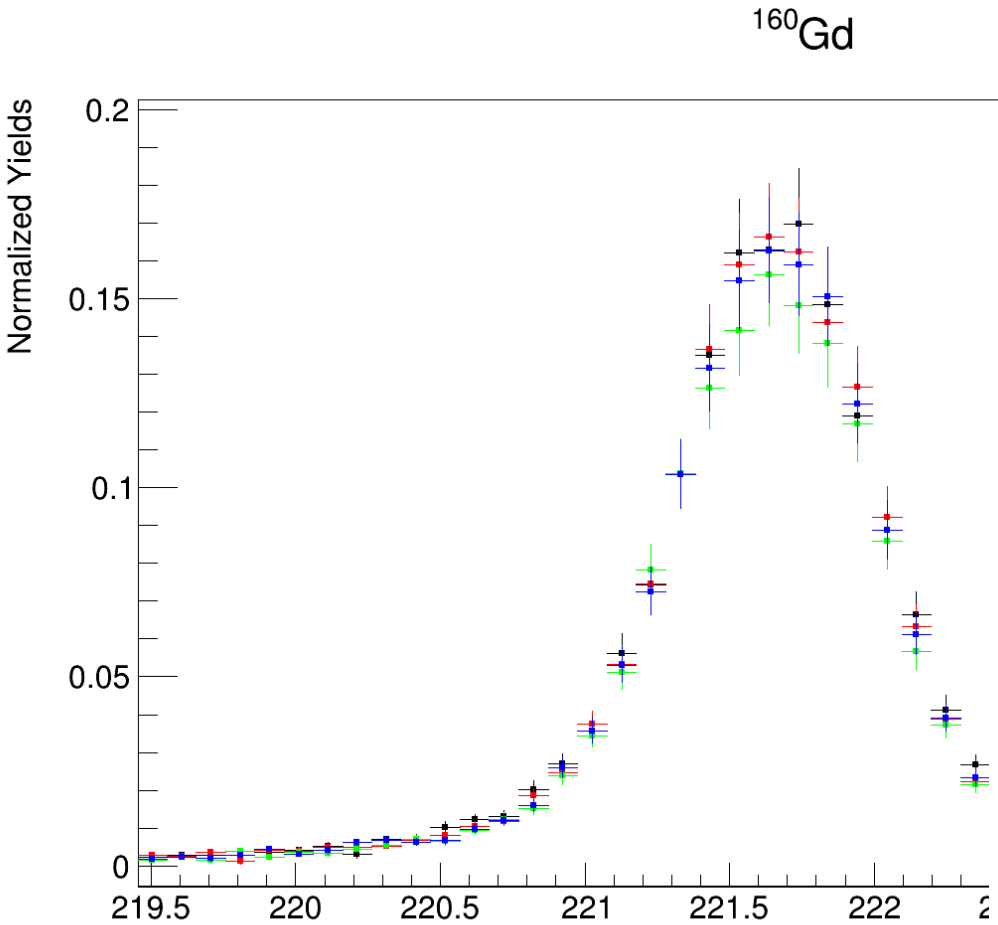
Au-197: TOF – neutron energy check (transport code and SAMMY)

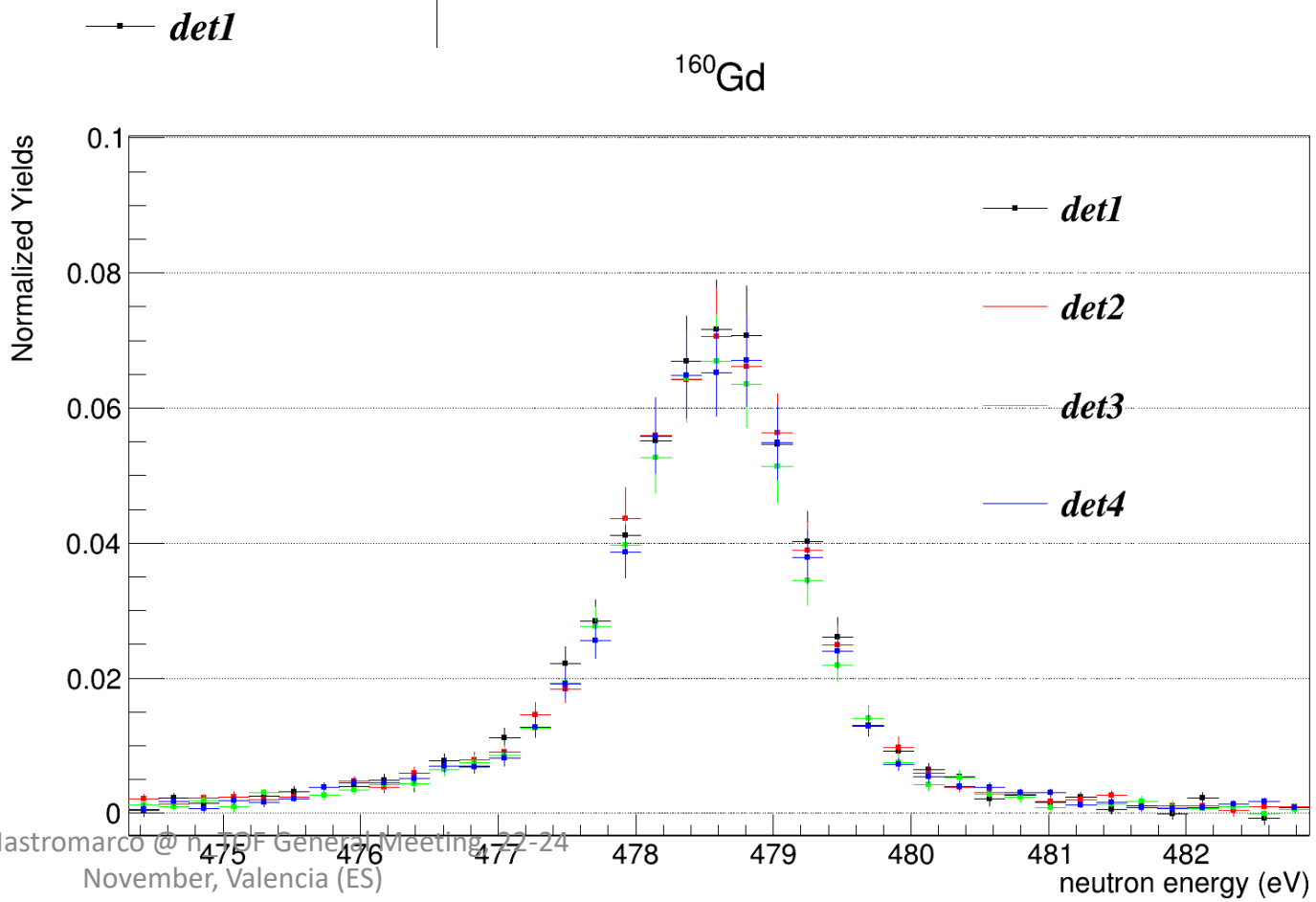


Gd-160: normalization factors

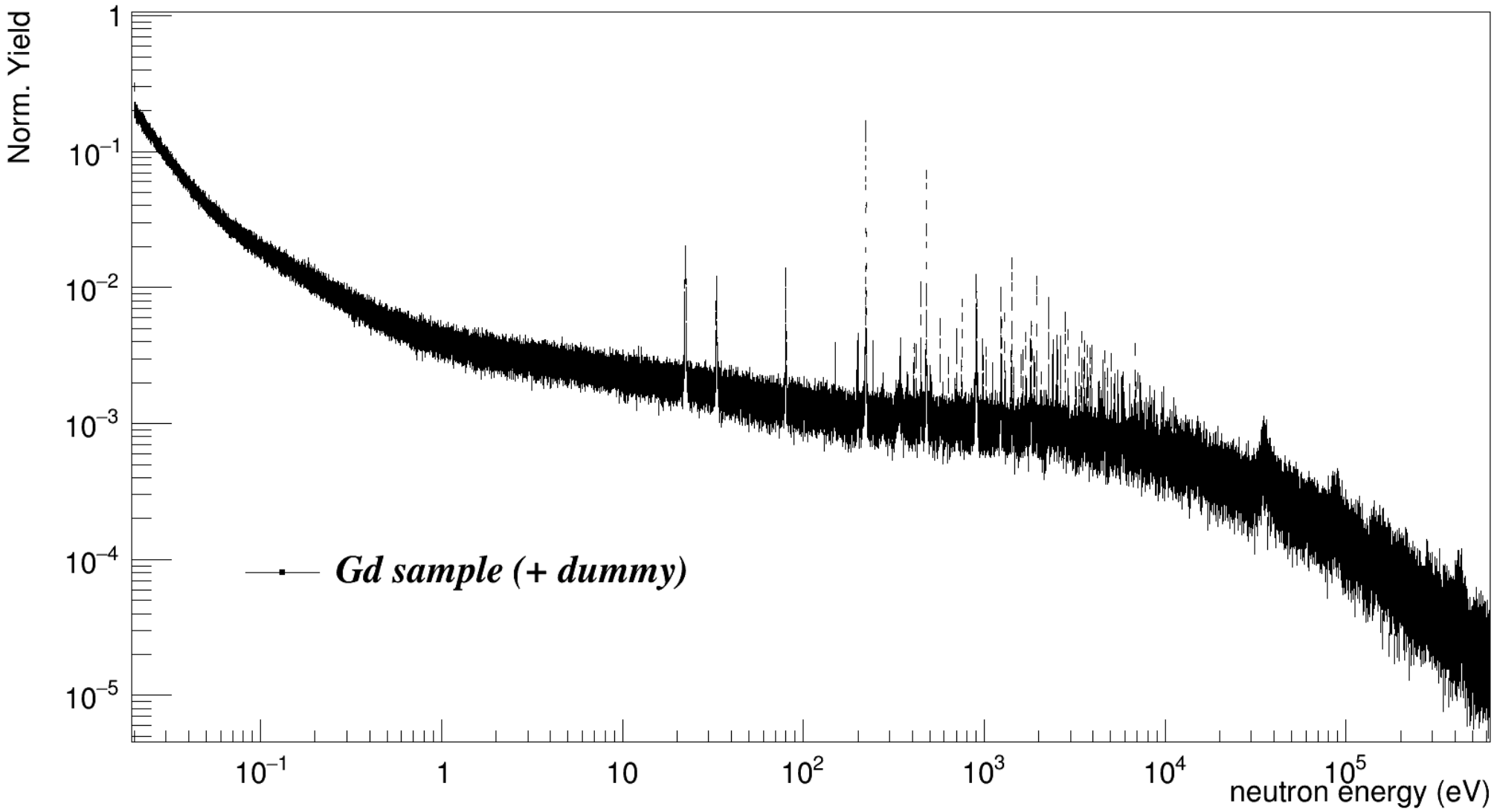


Gd-160: normalization factors

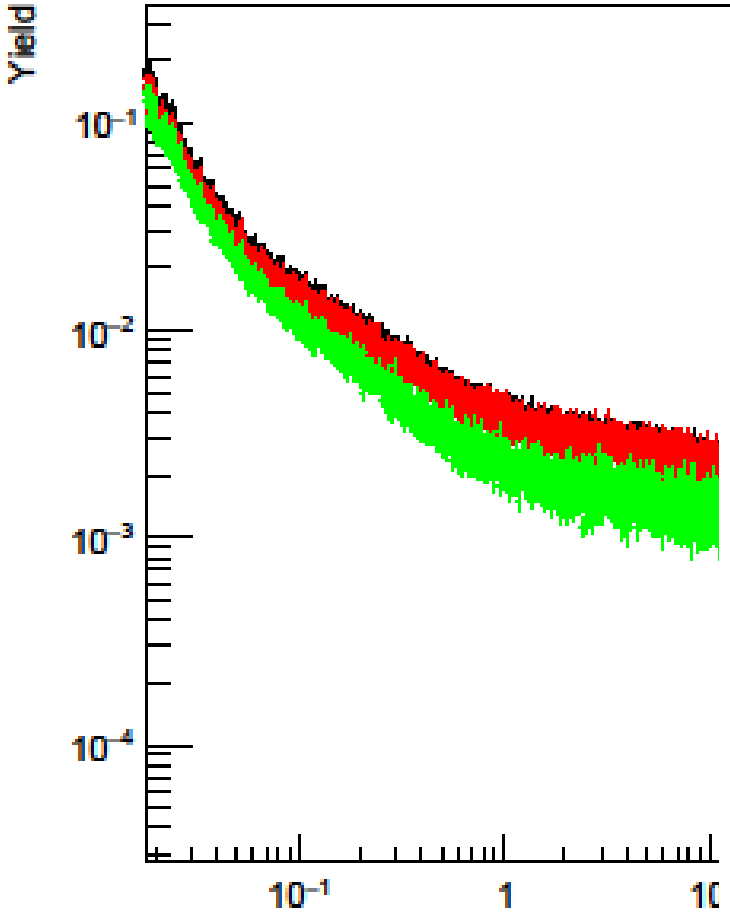


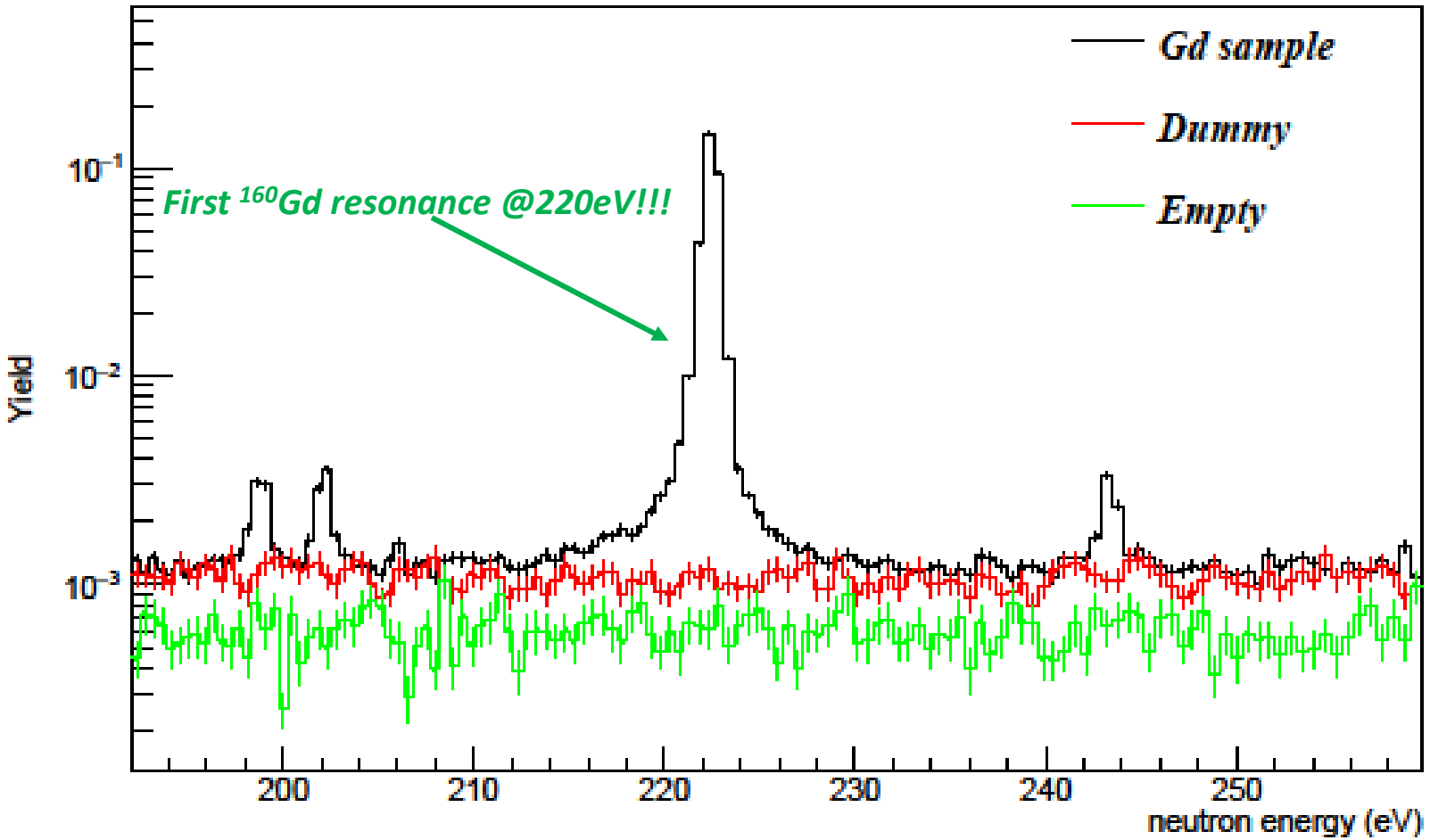


Yields…


Norm. Yield
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
Gd sample (+ dummy)
10^{-1}
1
10
10^{2}
10^{3}
10^{4}
10^{5}
neutron energy (eV)

Yields…


Yield
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-1}
1


Gd sample
Dummy
Empty
First ^{160}Gd resonance @220eV!!!
Yield
10^{-1}
10^{-2}
10^{-3}
200
210
220
230
240
250
neutron energy (eV)

RSA by SAMMY code

```
Gd160 dummy case
Gd 160    151.920066                          5
TWENTY
USE NEW SPIN GROUP FORMAT NUMBER
REICH-MOORE FORMALISM IS WANTED
PRINT ALL INPUT PARAmeters
BROADENING IS WANTED
USE FREE GAS MODEL OF DOPPLER BROADENING
DOUBLE
NORMALIZE AS YIELD Rather than cross section
eV
PUBLISH

294.15      183.9252                          0.007
7.4763380  3.3109e-4                        0.00000
CAPTURE
  1      1    0  0.5       1.0  0.0                          #gd160
    1    1    0    0       0.5
  2      1    0 -0.5       1.0  0.0
    1    1    0    1       0.5
  3      1    0 -1.5       1.0  0.0
    1    1    0    1       0.5
  4      1    0  0.5       1.0  0.0                          #gd158
    1    1    0    0       0.5
  5      1    0 -0.5       1.0  0.0
    1    1    0    1       0.5
  6      1    0 -1.5       1.0  0.0
    1    1    0    1       0.5
  9      1    0  0.5       1.0  0.0                          #gd156
    1    1    0    0       0.5
 10      1    0 -0.5       1.0  0.0
    1    1    0    1       0.5
 11      1    0 -1.5       1.0  0.0
    1    1    0    1       0.5
 14      1    0  0.5       1.0  0.0                          #gd154
    1    1    0    0       0.5

  2.100e-1      1.00       0.0       0.0

USER-DEFINED RESOLUTION FUNCTION
FILE=RF EAR1 v2 CORR.txt
```

```
0.9
RADIUS PARAMETERS FOLLOW
7.4763380  7.4763380 0 0 1
7.4763380  7.4763380 0 0 2 3
7.8000000  7.8000000 0 0 4
7.8000000  7.8000000 0 0 5 6
7.9000000  7.9000000 0 0 7 8
7.9000000  7.9000000 0 0 9
7.9000000  7.9000000 0 01011
7.9000000  7.9000000 0 01213
7.4000000  7.4000000 0 014
8.5000000  8.5000000 0 01516
8.0000000  8.0000000 0 017

NUCLIDE MASSES AND ABUNDANCES FOLLOW
159.926848 .98086900 0.        0 1 2 3
157.923640 1.290E-02 0.        0 4 5 6
156.924053 4.200E-08 0.        0 7 8
155.922449 5.900E-03 0.        0 91011
154.922862 3.300E-07 0.        01213
153.921257 3.3025E-4 0.        014
152.921671 3.900E-12 0.        01516
151.920066 3.800E-07 0.        017

BROADENING PARAMETERS FOLLOW
7.4763800  294.15000 .0003309 0.        0.        0.        0 0 0 0 0 0

MISCEllaneous parameters follow
TZERO 0 0  .00000000 .00000000 .99999999 .00000000 183.9252

NORMAlization and "constant" background follow
1.00000000 1.89773-8 0.        0.        0.        0.        0 1 0 0 0 0
.005000000 1.00000-9 1.00000-8 0.        0.        0.
```

RSA by SAMMY code

```
Gd160 dummy case
Gd 160    151.920066                          5
TWENTY
USE NEW SPIN GROUP FORMAT NUMBER
REICH MOORE FORMALISM IS WANTED
PRINT ALL INPUT PARAmeters
BROADENING IS WANTED
USE FREE GAS MODEL OF DOPPLER BROADENING
DOUBLE
NORMALIZE AS YIELD Rather than cross section
eV
PUBLISH

294.15      183.9252                           0.007
7.4763380  3.3109e-4                         0.00000
CAPTURE
  1      1    0  0.5       1.0  0.0                          #gd160
    1    1    0    0       0.5
  2      1    0 -0.5       1.0  0.0
    1    1    0    1       0.5
  3      1    0 -1.5       1.0  0.0
    1    1    0    1       0.5
  4      1    0  0.5       1.0  0.0                          #gd158
    1    1    0    0       0.5
  5      1    0 -0.5       1.0  0.0
    1    1    0    1       0.5
  6      1    0 -1.5       1.0  0.0
    1    1    0    1       0.5
  9      1    0  0.5       1.0  0.0                          #gd156
    1    1    0    0       0.5
 10      1    0 -0.5       1.0  0.0
    1    1    0    1       0.5
 11      1    0 -1.5       1.0  0.0
    1    1    0    1       0.5
 14      1    0  0.5       1.0  0.0                          #gd154
    1    1    0    0       0.5

  2.100e-1      1.00       0.0       0.0

USER-DEFINED RESOLUTION FUNCTION
FILE=RF EAR1 v2 CORR.txt
```

```
0.9
RADIUS PARAMETERS FOLLOW
7.4763380  7.4763380 0 0 1
7.4763380  7.4763380 0 0 2 3
7.8000000  7.8000000 0 0 4
7.8000000  7.8000000 0 0 5 6
7.9000000  7.9000000 0 0 7 8
7.9000000  7.9000000 0 0 9
7.9000000  7.9000000 0 01011
7.9000000  7.9000000 0 01213
7.4000000  7.4000000 0 014
8.5000000  8.5000000 0 01516
8.0000000  8.0000000 0 017

NUCLIDE MASSES AND ABUNDANCES FOLLOW
159.926848 .98086900 0.        0 1 2 3
157.923640 1.290E-02 0.        0 4 5 6
156.924053 4.200E-08 0.        0 7 8
155.922449 5.900E-03 0.        0 91011
154.922862 3.300E-07 0.        01213
153.921257 3.3025E-4 0.        014
152.921671 3.900E-12 0.        01516
151.920066 3.800E-07 0.        017

BROADENING PARAMETERS FOLLOW
7.4763800  294.15000 .0003309 0.        0.        0.        0 0 0 0 0 0

MISCEllaneous parameters follow
TZERO 0 0  .00000000 .00000000 .99999999 .00000000 183.9252

NORMAlization and "constant" background follow
1.00000000 1.89773-8 0.        0.        0.        0.        0 1 0 0 0 0
.005000000 1.00000-9 1.00000-8 0.        0.        0.
```

RSA by SAMMY code

```
Gd160 dummy case
Gd 160    151.920066                          5
TWENTY
USE NEW SPIN GROUP FORMAT NUMBER
REICH MOORE FORMALISM IS WANTED
PRINT ALL INPUT PARAmeters
BROADENING IS WANTED
USE FREE GAS MODEL OF DOPPLER BROADENING
DOUBLE
NORMALIZE AS YIELD Rather than cross section
eV
PUBLISH

294.15      183.9252                            0.007
7.4763380  3.3109e-4                          0.00000
CAPTURE
  1      1    0  0.5       1.0  0.0                          #gd160
    1    1    0    0       0.5
  2      1    0 -0.5       1.0  0.0
    1    1    0    1       0.5
  3      1    0 -1.5       1.0  0.0
    1    1    0    1       0.5
  4      1    0  0.5       1.0  0.0                          #gd158
    1    1    0    0       0.5
  5      1    0 -0.5       1.0  0.0
    1    1    0    1       0.5
  6      1    0 -1.5       1.0  0.0
    1    1    0    1       0.5
  9      1    0  0.5       1.0  0.0                          #gd156
    1    1    0    0       0.5
 10      1    0 -0.5       1.0  0.0
    1    1    0    1       0.5
 11      1    0 -1.5       1.0  0.0
    1    1    0    1       0.5
 14      1    0  0.5       1.0  0.0                          #gd154
    1    1    0    0       0.5

  2.100e-1      1.00       0.0       0.0

USER-DEFINED RESOLUTION FUNCTION
FILE=RF EAR1 v2 CORR.txt
```

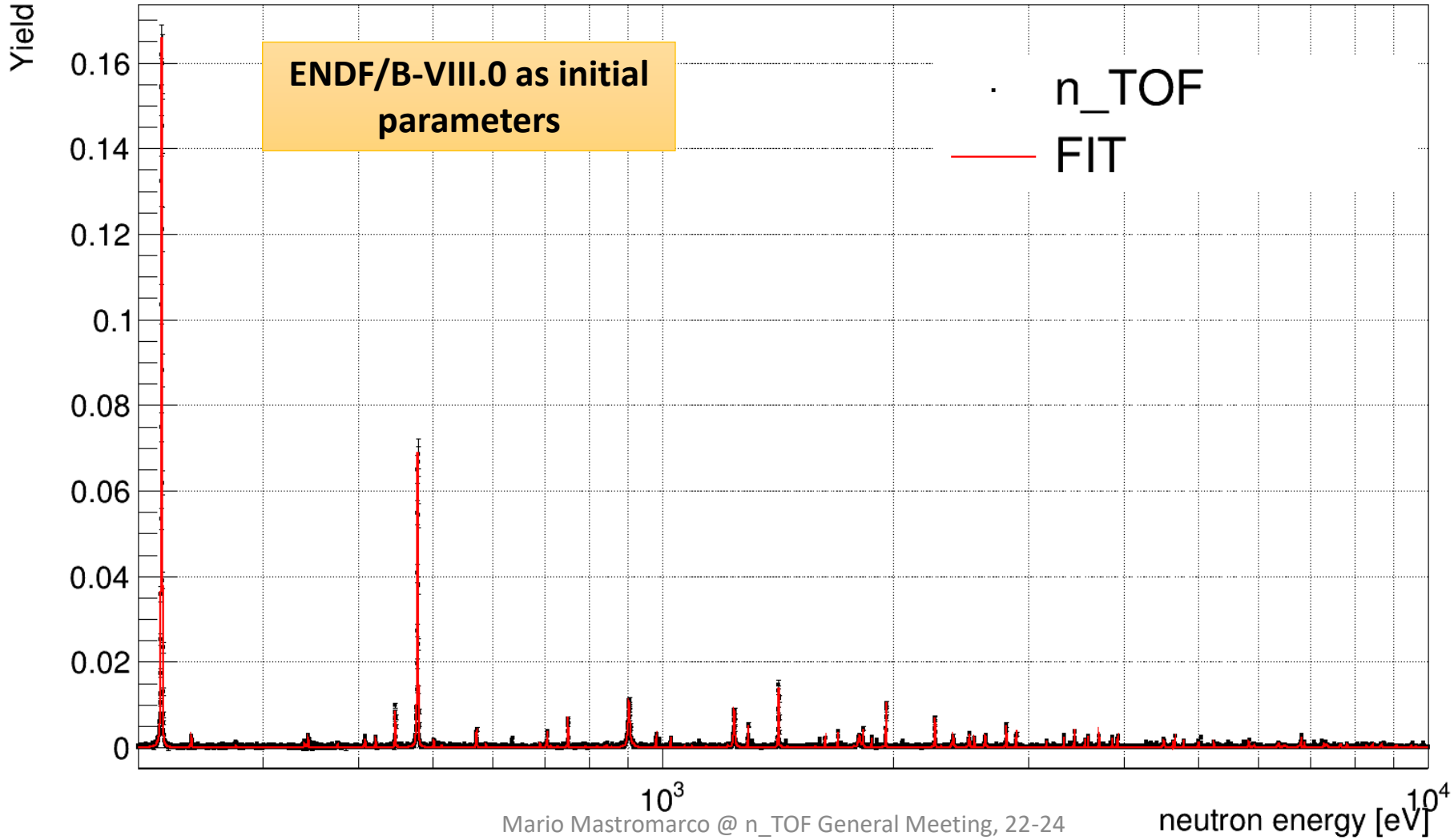
```
0.9
RADIUS PARAMETERS FOLLOW
7.4763380  7.4763380 0 0 1
7.4763380  7.4763380 0 0 2 3
7.8000000  7.8000000 0 0 4
7.8000000  7.8000000 0 0 5 6
7.9000000  7.9000000 0 0 7 8
7.9000000  7.9000000 0 0 9
7.9000000  7.9000000 0 01011
7.9000000  7.9000000 0 01213
7.4000000  7.4000000 0 014
8.5000000  8.5000000 0 01516
8.0000000  8.0000000 0 017

NUCLIDE MASSES AND ABUNDANCES FOLLOW
159.926848 .98086900 0.        0 1 2 3
157.923640 1.290E-02 0.        0 4 5 6
156.924053 4.200E-08 0.        0 7 8
155.922449 5.900E-03 0.        0 91011
154.922862 3.300E-07 0.        01213
153.921257 3.3025E-4 0.        014
152.921671 3.900E-12 0.        01516
151.920066 3.800E-07 0.        017

BROADENING PARAMETERS FOLLOW
7.4763800  294.15000 .0003309 0.        0.        0.        0 0 0 0 0 0

MISCEllaneous parameters follow
TZERO 0 0  .00000000 .00000000 .99999999 .00000000 183.9252

NORMAlization and "constant" background follow
1.00000000 1.89773-8 0.        0.        0.        0.        0 1 0 0 0 0
.005000000 1.00000-9 1.00000-8 0.        0.        0.
```

RSA by SAMMY code

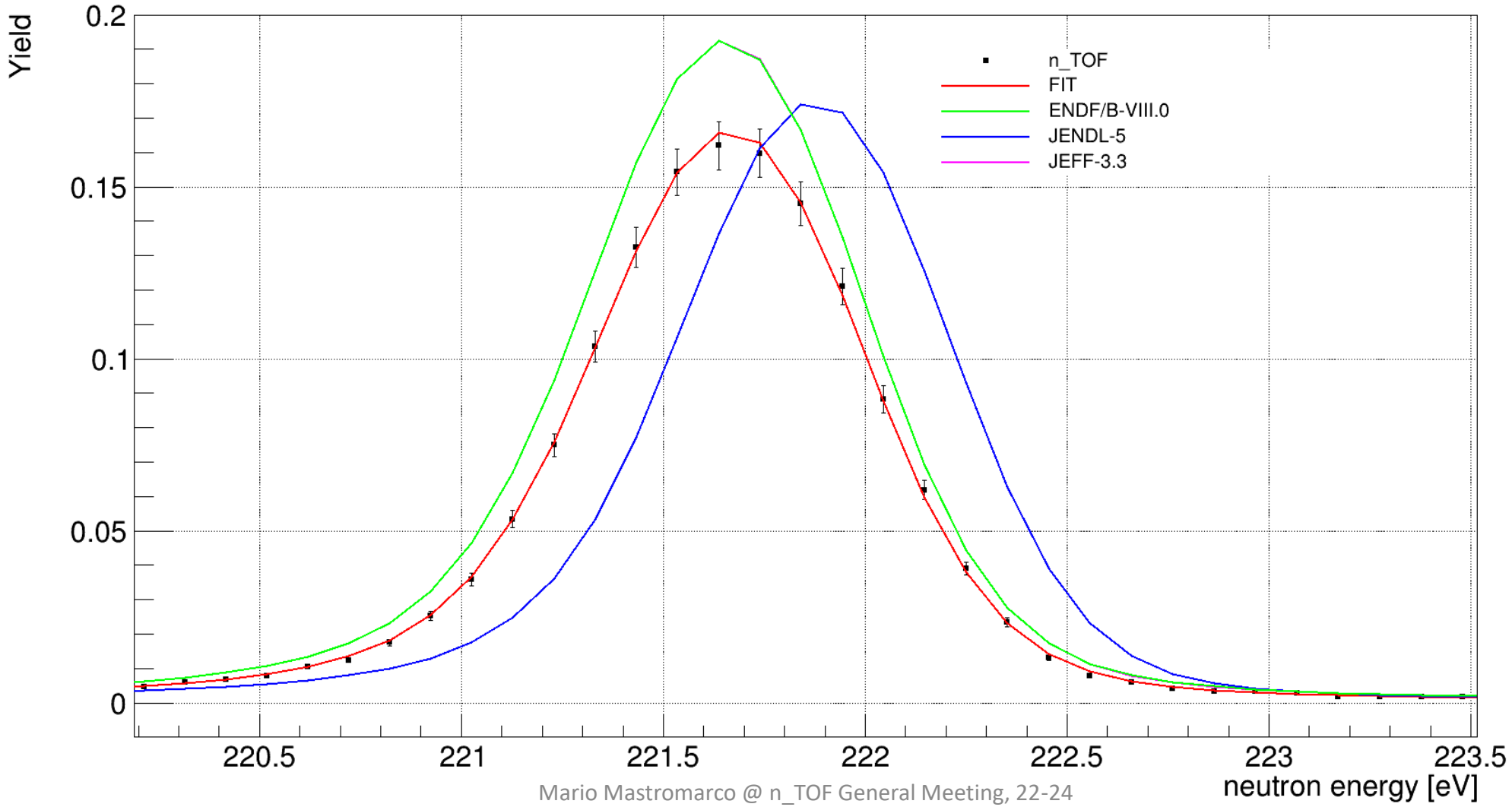
```
Gd160 dummy case
Gd 160    151.920066                          5
TWENTY
USE NEW SPIN GROUP FORMAT NUMBER
REICH MOORE FORMALISM IS WANTED
PRINT ALL INPUT PARAmeters
BROADENING IS WANTED
USE FREE GAS MODEL OF DOPPLER BROADENING
DOUBLE
NORMALIZE AS YIELD Rather than cross section
eV
PUBLISH

294.15      183.9252                            0.007
7.4763380  3.3109e-4                          0.00000
CAPTURE
  1      1    0  0.5       1.0  0.0                          #gd160
    1    1    0    0       0.5
  2      1    0 -0.5       1.0  0.0
    1    1    0    1       0.5
  3      1    0 -1.5       1.0  0.0
    1    1    0    1       0.5
  4      1    0  0.5       1.0  0.0                          #gd158
    1    1    0    0       0.5
  5      1    0 -0.5       1.0  0.0
    1    1    0    1       0.5
  6      1    0 -1.5       1.0  0.0
    1    1    0    1       0.5
  9      1    0  0.5       1.0  0.0                          #gd156
    1    1    0    0       0.5
 10      1    0 -0.5       1.0  0.0
    1    1    0    1       0.5
 11      1    0 -1.5       1.0  0.0
    1    1    0    1       0.5
 14      1    0  0.5       1.0  0.0                          #gd154
    1    1    0    0       0.5

  2.100e-1      1.00       0.0       0.0

USER-DEFINED RESOLUTION FUNCTION
FILE=RF EAR1 v2 CORR.txt
```

```
0.9
RADIUS PARAMETERS FOLLOW
7.4763380  7.4763380 0 0 1
7.4763380  7.4763380 0 0 2 3
7.8000000  7.8000000 0 0 4
7.8000000  7.8000000 0 0 5 6
7.9000000  7.9000000 0 0 7 8
7.9000000  7.9000000 0 0 9
7.9000000  7.9000000 0 01011
7.9000000  7.9000000 0 01213
7.4000000  7.4000000 0 014
8.5000000  8.5000000 0 01516
8.0000000  8.0000000 0 017

NUCLIDE MASSES AND ABUNDANCES FOLLOW
159.926848 .98086900 0.        0 1 2 3
157.923640 1.290E-02 0.        0 4 5 6
156.924053 4.200E-08 0.        0 7 8
155.922449 5.900E-03 0.        0 91011
154.922862 3.300E-07 0.        01213
153.921257 3.3025E-4 0.        014
152.921671 3.900E-12 0.        01516
151.920066 3.800E-07 0.        017

BROADENING PARAMETERS FOLLOW
7.4763800  294.15000 .0003309 0.        0.        0.        0 0 0 0 0 0

MISCEllaneous parameters follow
TZERO 0 0  .00000000 .00000000 .99999999 .00000000 183.9252

NORMAlization and "constant" background follow
1.00000000 1.89773-8 0.        0.        0.        0.        0 1 0 0 0 0
.005000000 1.00000-9 1.00000-8 0.        0.        0.
```

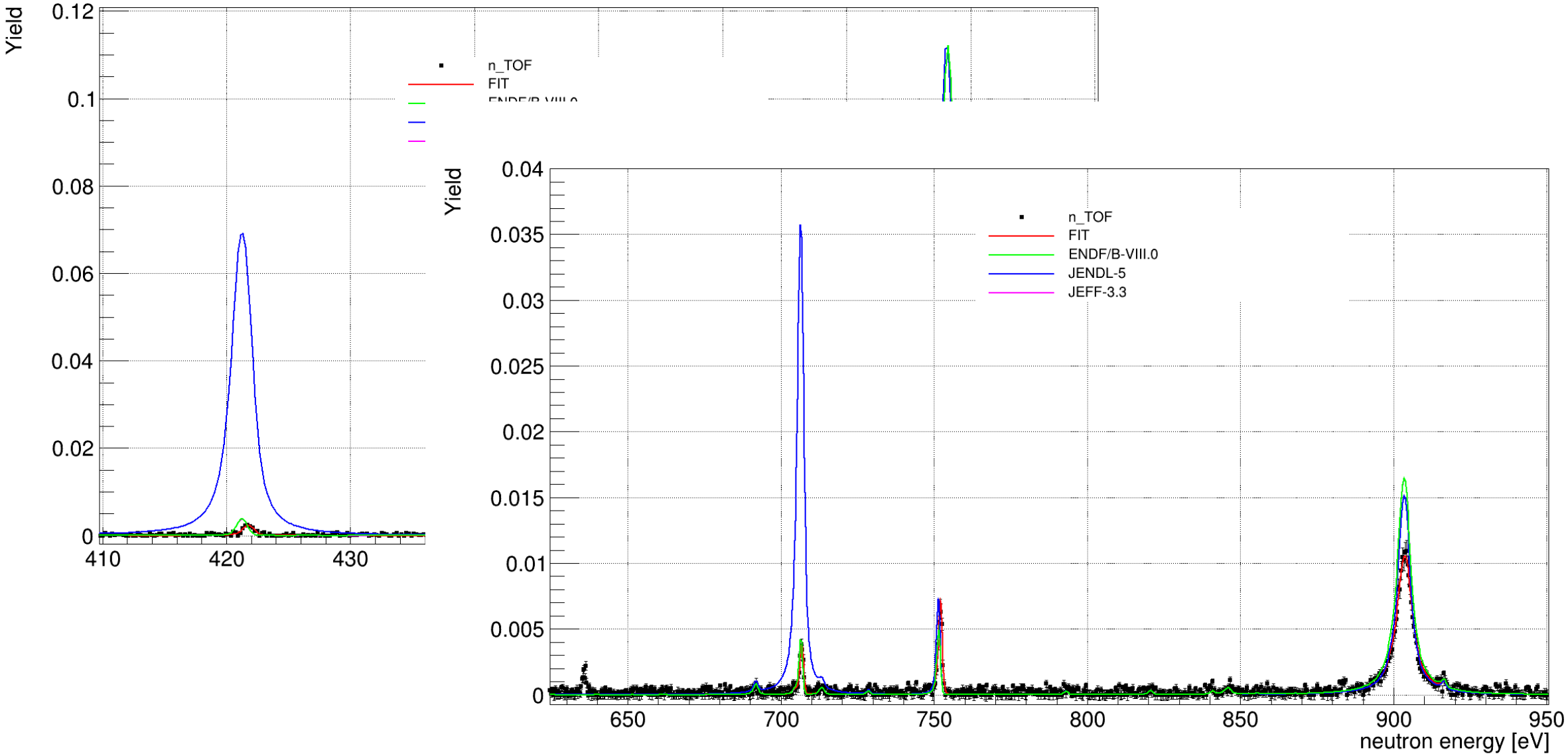
RSA up to 10 keV



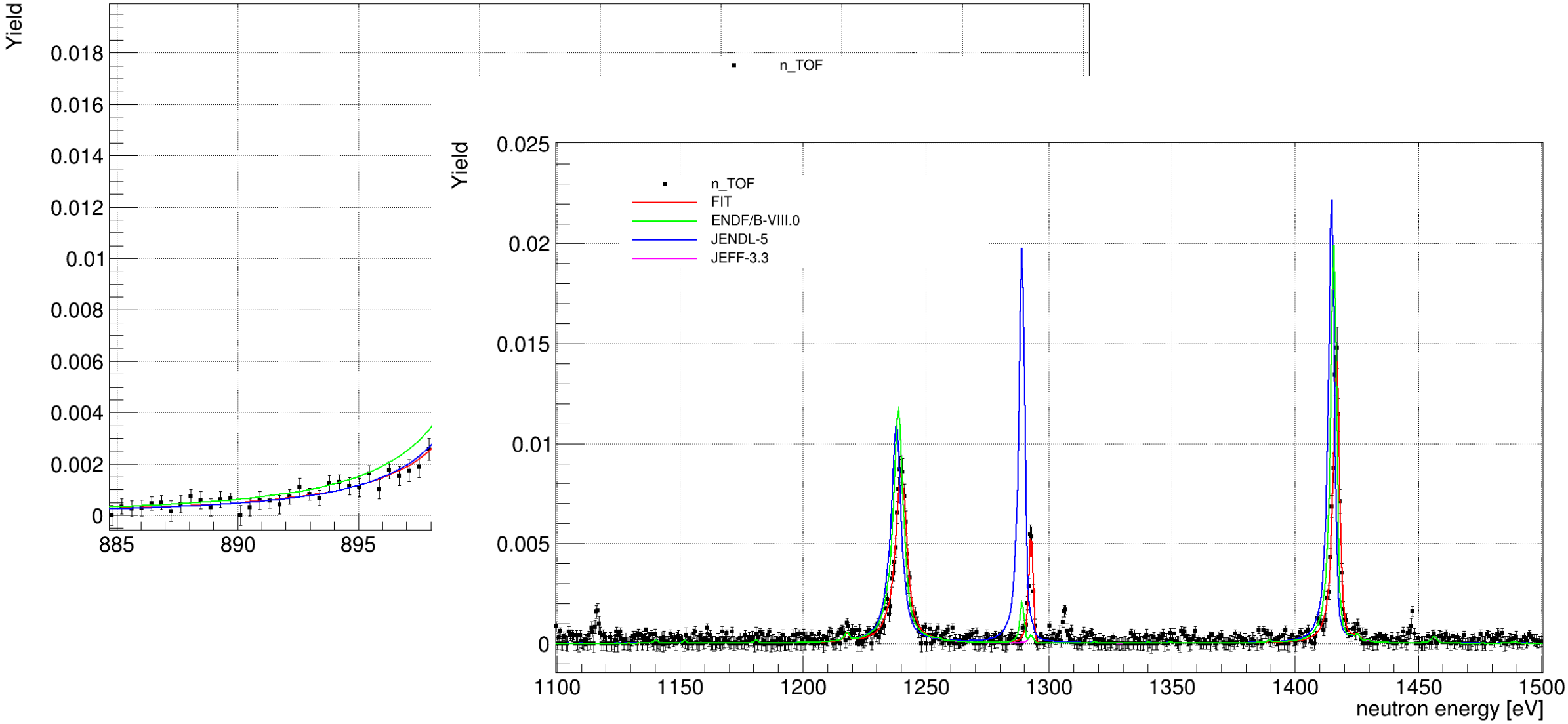
Main ^{160}Gd capture resonance



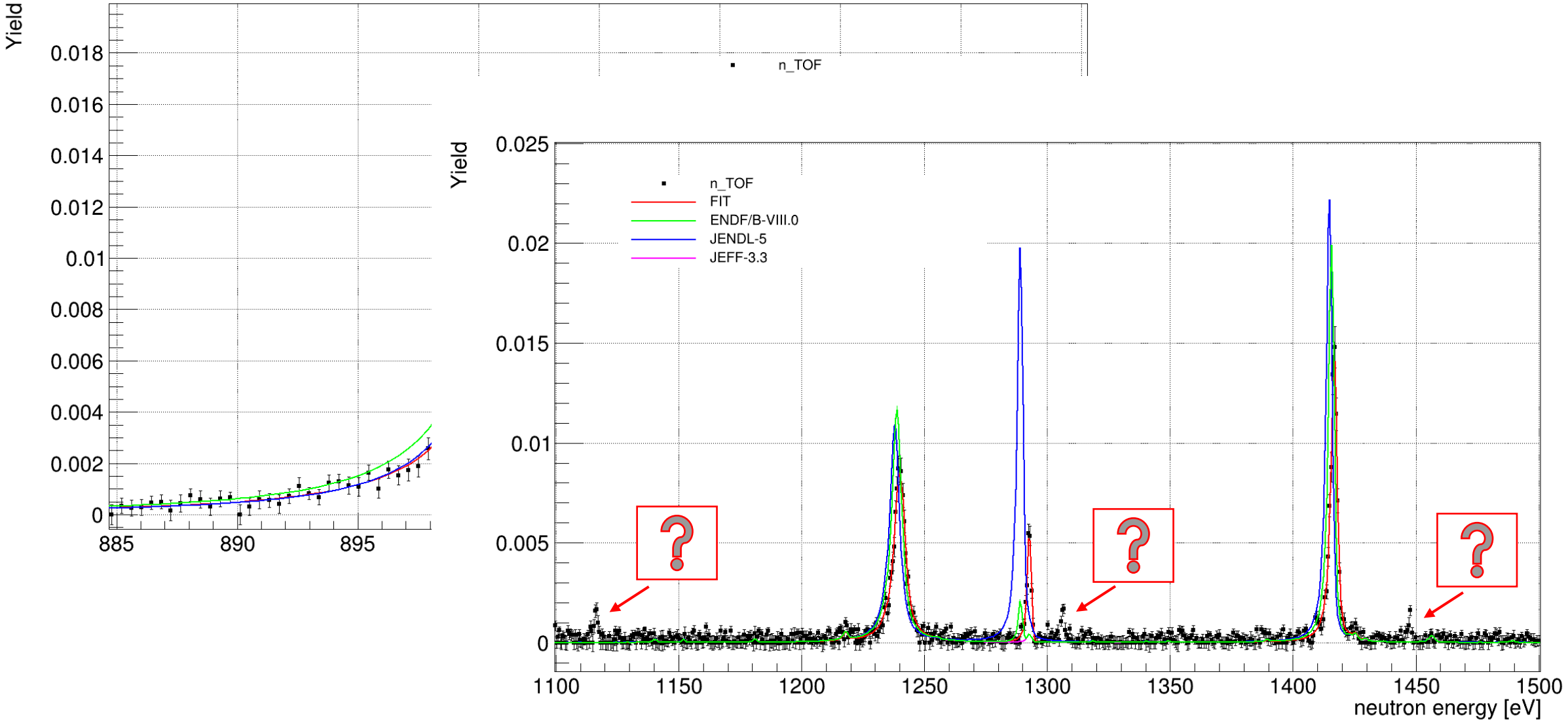
RSA...


Yield
0.12
0.1
0.08
0.06
0.04
0.02
0
410
420
430
n_TOF
FIT
Yield
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
650
700
750
800
850
900
950
neutron energy [eV]
n_TOF
FIT
ENDF/B-VIII.0
JENDL-5
JEFF-3.3

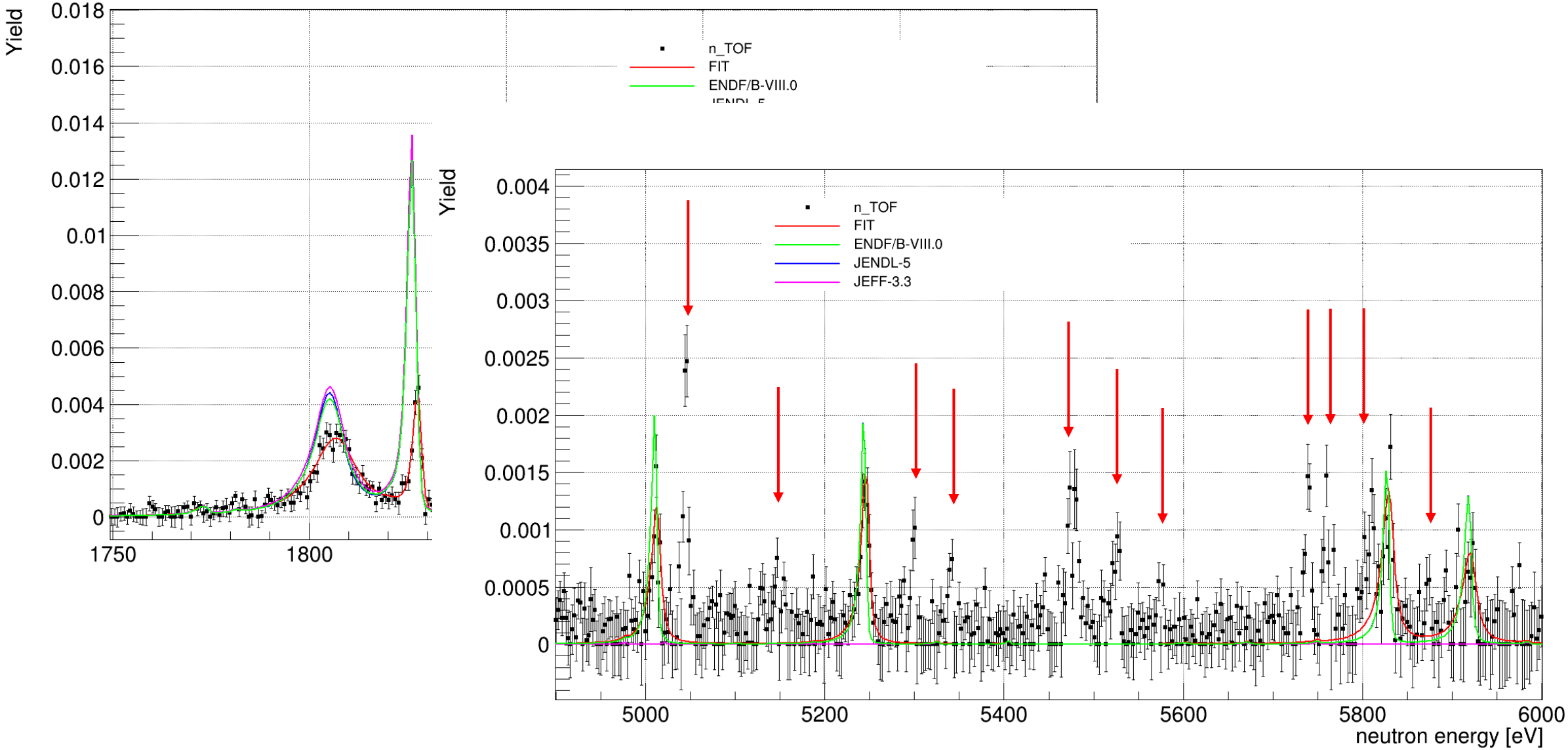
RSA...



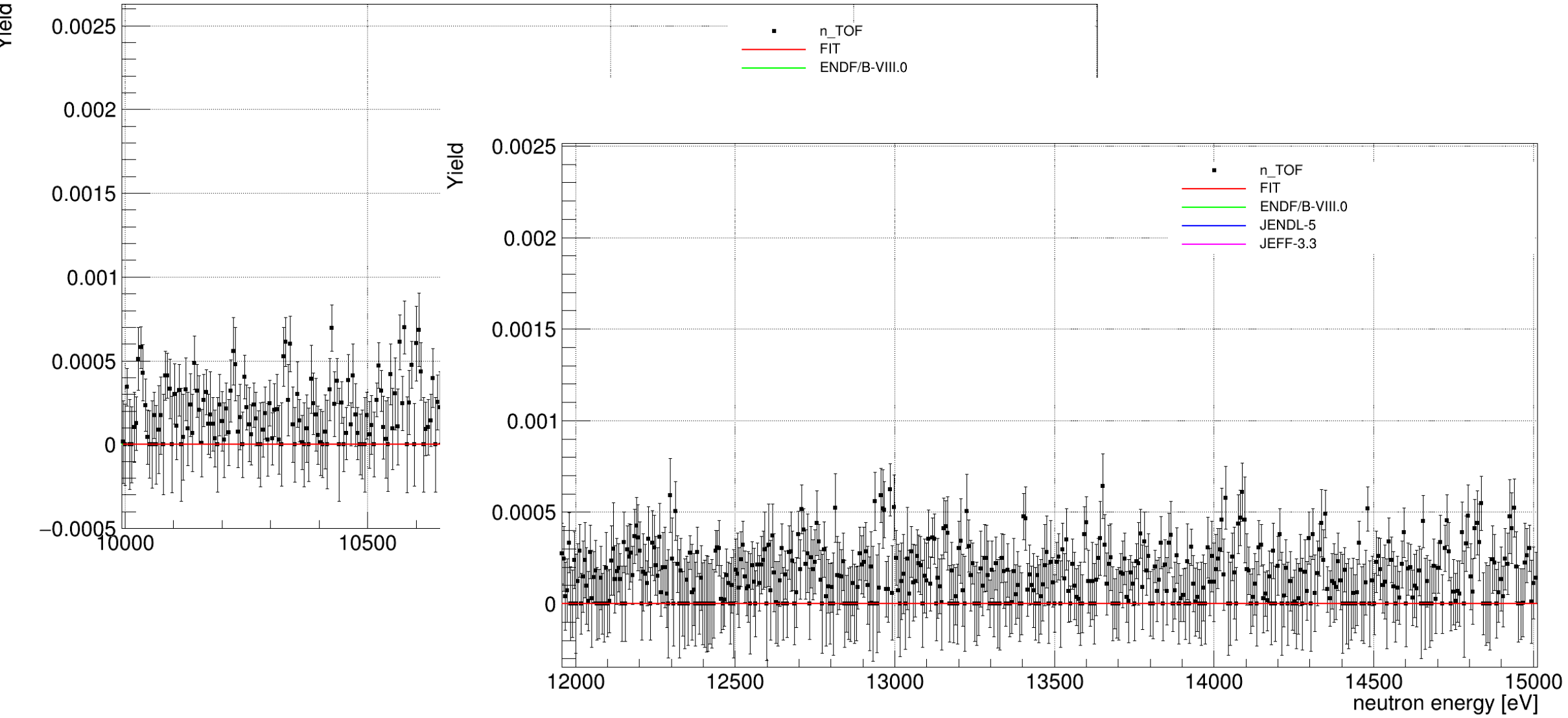
RSA… unricognized structures



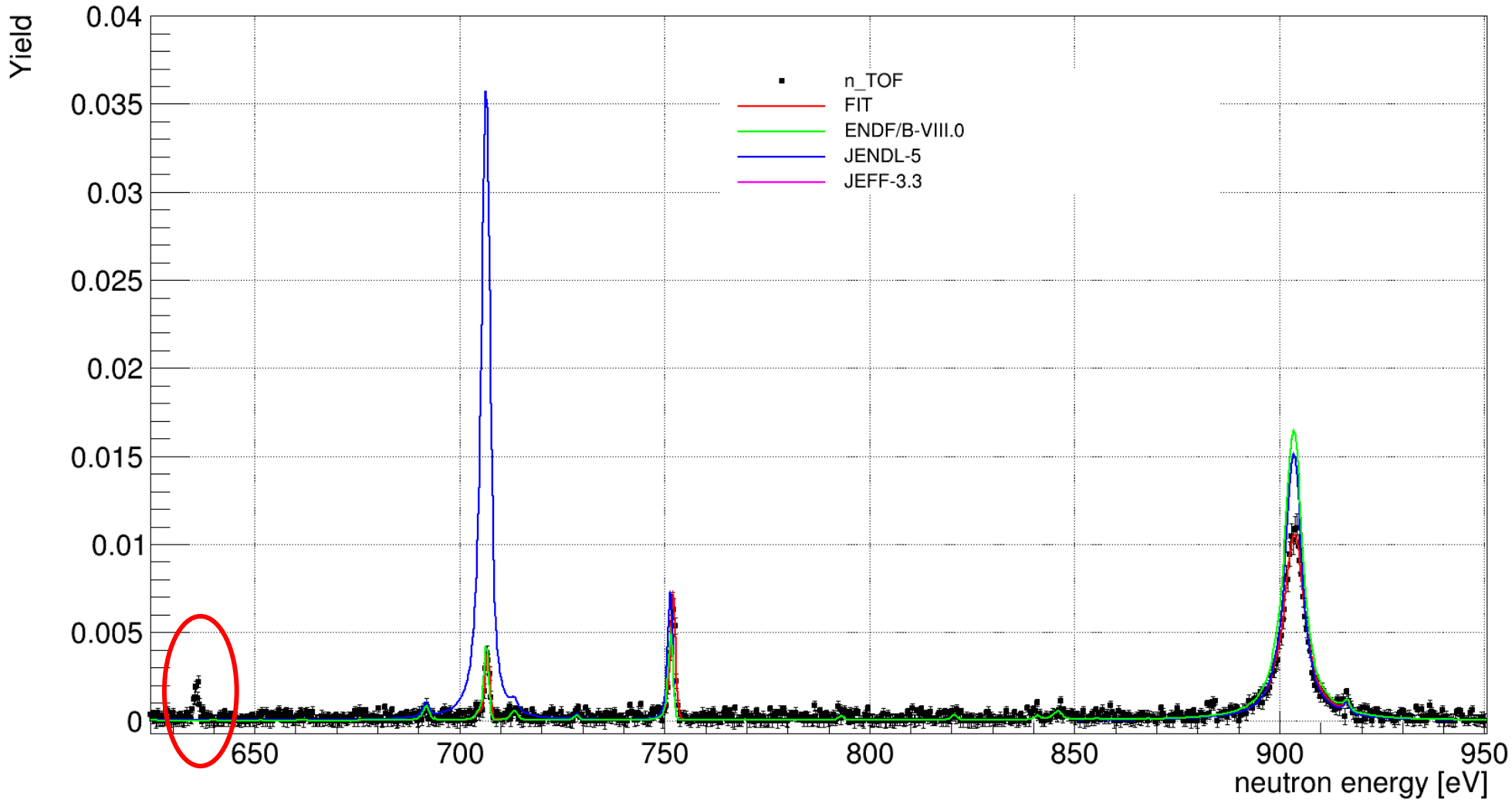
RSA… unricognized structures



Unsigned structures above 10 keV



structure @ 635 eV

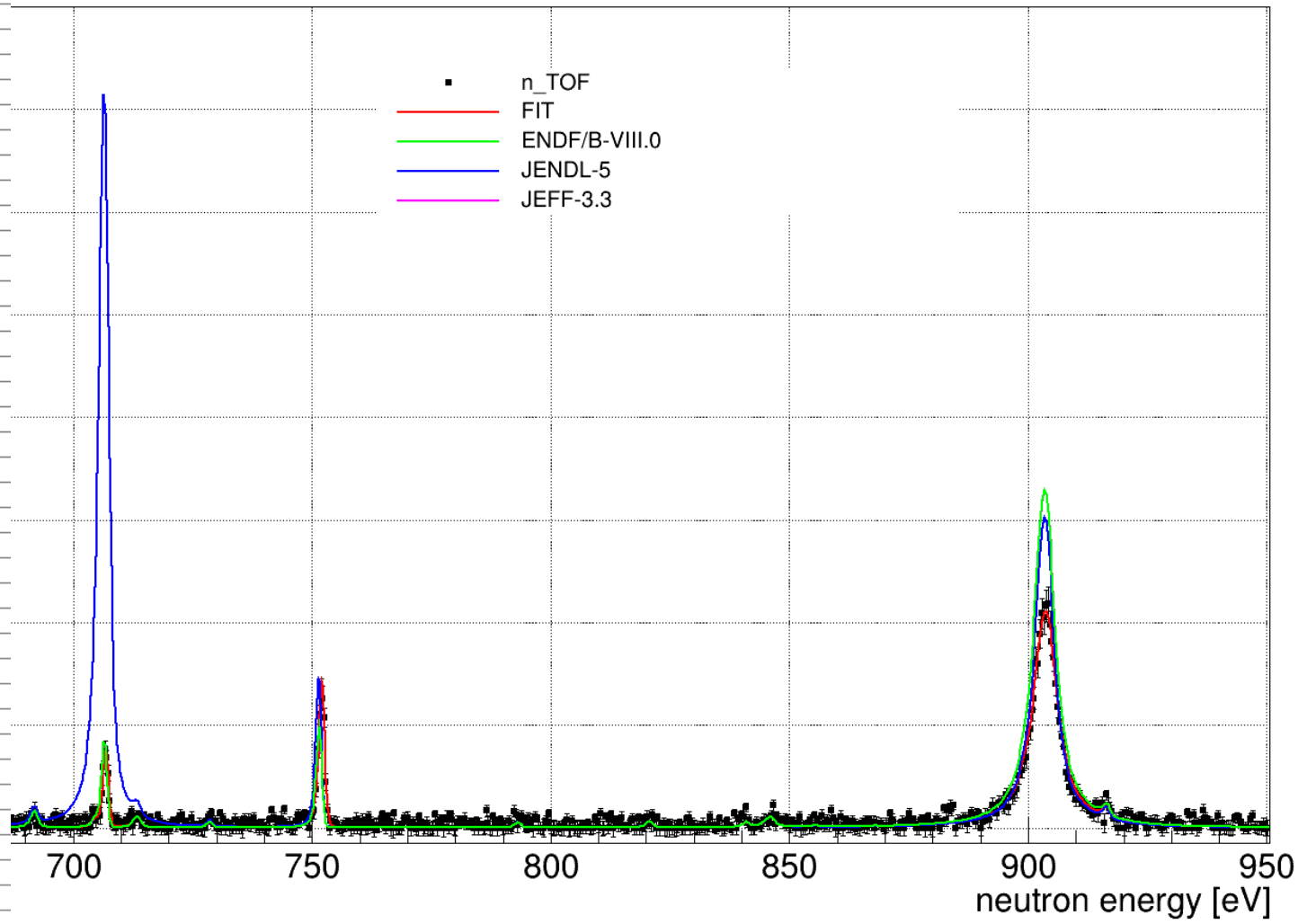


48 rows

JEFF

Search	Incident particle	Evaluation	Material	E
NEA	Incident neutron data	JEFF-3.3	As72	635.0613
NEA	Incident neutron data	JEFF-3.3	As74	637.2687
NEA	Incident neutron data	JEFF-3.3	As74	637.3422
NEA	Incident neutron data	JEFF-3.3	Sr84	635
NEA	Incident neutron data	JEFF-3.3	Sr89	636.8112
NEA	Incident neutron data	JEFF-3.3	Ru99	636.2
NEA	Incident neutron data	JEFF-3.3	Pd108	636.2
NEA	Incident neutron data	JEFF-3.3	Pd110	636.5
NEA	Incident neutron data	JEFF-3.3	Ag108	635.36
NEA	Incident neutron data	JEFF-3.3	Ag109	634.5
NEA	Incident neutron data	JEFF-3.3	Ag110	637.1204
NEA	Incident neutron data	JEFF-3.3	Ag110	637.4988
NEA	Incident neutron data	JEFF-3.3	Cd106	635.087
NEA	Incident neutron data	JEFF-3.3	In114	634.3417
NEA	Incident neutron data	JEFF-3.3	In114	637.0182
NEA	Incident neutron data	JEFF-3.3	Sb126	634.5823
NEA	Incident neutron data	JEFF-3.3	Te121	635.9277
NEA	Incident neutron data	JEFF-3.3	I127	635.75
NEA	Incident neutron data	JEFF-3.3	Xe127	637.111
NEA	Incident neutron data	JEFF-3.3	Xe129	636.8
NEA	Incident neutron data	JEFF-3.3	Ba131	634.9718
NEA	Incident neutron data	JEFF-3.3	Ba131	635.5911
NEA	Incident neutron data	JEFF-3.3	La138	635.7065
NEA	Incident neutron data	JEFF-3.3	Ce137	636.527
NEA	Incident neutron data	JEFF-3.3	Ce143	636.832
NEA	Incident neutron data	JEFF-3.3	Pr141	635.8
NEA	Incident neutron data	JEFF-3.3	Nd142	636.4
NEA	Incident neutron data	JEFF-3.3	Gd149	635.845
NEA	Incident neutron data	JEFF-3.3	Tb159	637.6
NEA	Incident neutron data	JEFF-3.3	Dy161	635.3
NEA	Incident neutron data	JEFF-3.3	Dy163	637.17
NEA	Incident neutron data	JEFF-3.3	Ho165	634.8
NEA	Incident neutron data	JEFF-3.3	Er167	636.9
NEA	Incident neutron data	JEFF-3.3	Tm170	635.7607
NEA	Incident neutron data	JEFF-3.3	Yb168	636.2426
NEA	Incident neutron data	JEFF-3.3	Hf177	634.32
NEA	Incident neutron data	JEFF-3.3	Ta181	636.29
NEA	Incident neutron data	JEFF-3.3	Re187	636
NEA	Incident neutron data	JEFF-3.3	Re188	635.007
NEA	Incident neutron data	JEFF-3.3	Re188	637.4905
NEA	Incident neutron data	JEFF-3.3	Os187	636.5
NEA	Incident neutron data	JEFF-3.3	U234	637
NEA	Incident neutron data	JEFF-3.3	U235	635.3746
NEA	Incident neutron data	JEFF-3.3	U235	635.9864
NEA	Incident neutron data	JEFF-3.3	U235	636.5639
NEA	Incident neutron data	JEFF-3.3	U238	636.5637
NEA	Incident neutron data	JEFF-3.3	Pu239	637.2519
NEA	Incident neutron data	JEFF-3.3	Pu240	637.56

635 eV



635 eV

48 rows

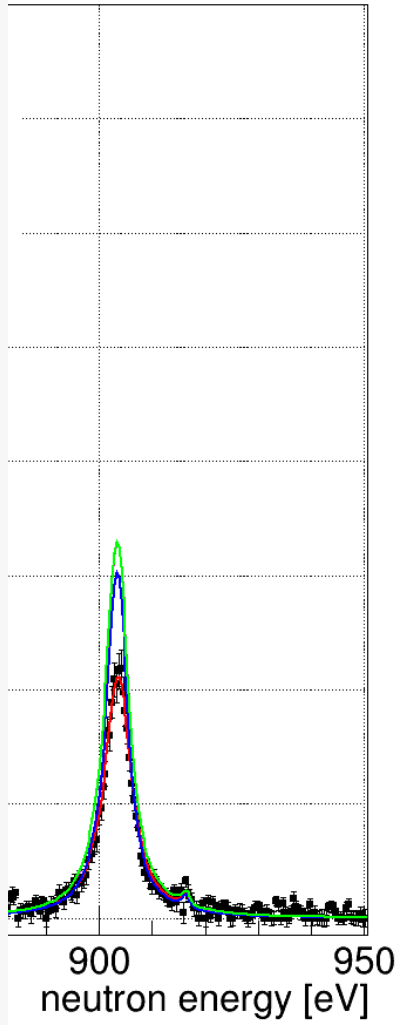
JEFF

Search	Incident particle	Evaluation	Material	E
NEA	Incident neutron data	JEFF-3.3	As72	635.0613
NEA	Incident neutron data	JEFF-3.3	As74	637.2687
NEA	Incident neutron data	JEFF-3.3	As74	637.3422
NEA	Incident neutron data	JEFF-3.3	Sr84	635
NEA	Incident neutron data	JEFF-3.3	Sr89	636.8112
NEA	Incident neutron data	JEFF-3.3	Ru99	636.2
NEA	Incident neutron data	JEFF-3.3	Pd108	636.2
NEA	Incident neutron data	JEFF-3.3	Pd110	636.5
NEA	Incident neutron data	JEFF-3.3	Ag108	635.36
NEA	Incident neutron data	JEFF-3.3	Ag109	634.5
NEA	Incident neutron data	JEFF-3.3	Ag110	637.1204
NEA	Incident neutron data	JEFF-3.3	Ag110	637.4988
NEA	Incident neutron data	JEFF-3.3	Cd106	635.087
NEA	Incident neutron data	JEFF-3.3	In114	634.3417
NEA	Incident neutron data	JEFF-3.3	In114	637.0182
NEA	Incident neutron data	JEFF-3.3	Sb126	634.5823
NEA	Incident neutron data	JEFF-3.3	Te121	635.9277
NEA	Incident neutron data	JEFF-3.3	I127	635.75
NEA	Incident neutron data	JEFF-3.3	Xe127	637.111
NEA	Incident neutron data	JEFF-3.3	Xe129	636.8
NEA	Incident neutron data	JEFF-3.3	Ba131	634.9718
NEA	Incident neutron data	JEFF-3.3	Ba131	635.5911
NEA	Incident neutron data	JEFF-3.3	La138	635.7065
NEA	Incident neutron data	JEFF-3.3	Ce137	636.527
NEA	Incident neutron data	JEFF-3.3	Ce143	636.832
NEA	Incident neutron data	JEFF-3.3	Pr141	635.8
NEA	Incident neutron data	JEFF-3.3	Nd142	636.4
NEA	Incident neutron data	JEFF-3.3	Gd149	635.845
NEA	Incident neutron data	JEFF-3.3	Tb159	637.6
NEA	Incident neutron data	JEFF-3.3	Dy161	635.3
NEA	Incident neutron data	JEFF-3.3	Dy163	637.17
NEA	Incident neutron data	JEFF-3.3	Ho165	634.8
NEA	Incident neutron data	JEFF-3.3	Er167	636.9
NEA	Incident neutron data	JEFF-3.3	Tm170	635.7607
NEA	Incident neutron data	JEFF-3.3	Yb168	636.2426
NEA	Incident neutron data	JEFF-3.3	Hf177	634.32
NEA	Incident neutron data	JEFF-3.3	Ta181	636.29
NEA	Incident neutron data	JEFF-3.3	Re187	636
NEA	Incident neutron data	JEFF-3.3	Re188	635.007
NEA	Incident neutron data	JEFF-3.3	Re188	637.4905
NEA	Incident neutron data	JEFF-3.3	Os187	636.5
NEA	Incident neutron data	JEFF-3.3	U234	637
NEA	Incident neutron data	JEFF-3.3	U235	635.3746
NEA	Incident neutron data	JEFF-3.3	U235	635.9864
NEA	Incident neutron data	JEFF-3.3	U235	636.5639
NEA	Incident neutron data	JEFF-3.3	U238	636.5637
NEA	Incident neutron data	JEFF-3.3	Pu239	637.2519
NEA	Incident neutron data	JEFF-3.3	Pu240	637.56

27 rows

ENDF

Search	Incident particle	Evaluation	Material	E
NEA	Incident neutron data	ENDF/B-VIII.0	As73	637.6
NEA	Incident neutron data	ENDF/B-VIII.0	Rb86	636
NEA	Incident neutron data	ENDF/B-VIII.0	Sr84	635
NEA	Incident neutron data	ENDF/B-VIII.0	Ru99	636.2
NEA	Incident neutron data	ENDF/B-VIII.0	Pd108	636.2
NEA	Incident neutron data	ENDF/B-VIII.0	Pd110	636.5
NEA	Incident neutron data	ENDF/B-VIII.0	Ag111	634.5
NEA	Incident neutron data	ENDF/B-VIII.0	Cd106	635.087
NEA	Incident neutron data	ENDF/B-VIII.0	Xe129	636.8
NEA	Incident neutron data	ENDF/B-VIII.0	Pr141	635.8
NEA	Incident neutron data	ENDF/B-VIII.0	Nd142	636.4
NEA	Incident neutron data	ENDF/B-VIII.0	Pm145	634.7093
NEA	Incident neutron data	ENDF/B-VIII.0	Dy161	635.3
NEA	Incident neutron data	ENDF/B-VIII.0	Dy163	637.17
NEA	Incident neutron data	ENDF/B-VIII.0	Ho165	634.8
NEA	Incident neutron data	ENDF/B-VIII.0	Er167	636.9
NEA	Incident neutron data	ENDF/B-VIII.0	Re187	636
NEA	Incident neutron data	ENDF/B-VIII.0	Os186	634.7
NEA	Incident neutron data	ENDF/B-VIII.0	Os187	636.5
NEA	Incident neutron data	ENDF/B-VIII.0	Ir194m	634.3605
NEA	Incident neutron data	ENDF/B-VIII.0	U234	637
NEA	Incident neutron data	ENDF/B-VIII.0	U235	635.3727
NEA	Incident neutron data	ENDF/B-VIII.0	U235	635.9863
NEA	Incident neutron data	ENDF/B-VIII.0	U235	636.5657
NEA	Incident neutron data	ENDF/B-VIII.0	U238	636.5637
NEA	Incident neutron data	ENDF/B-VIII.0	Pu239	637.2534
NEA	Incident neutron data	ENDF/B-VIII.0	Pu240	637.4241



635 eV

48 rows

JEFF

Search	Incident particle	Evaluation	Material	E
NEA	Incident neutron data	JEFF-3.3	As72	635.0613
NEA	Incident neutron data	JEFF-3.3	As74	637.2687
NEA	Incident neutron data	JEFF-3.3	As74	637.3422
NEA	Incident neutron data	JEFF-3.3	Sr84	635
NEA	Incident neutron data	JEFF-3.3	Sr89	636.8112
NEA	Incident neutron data	JEFF-3.3	Ru99	636.2
NEA	Incident neutron data	JEFF-3.3	Pd108	636.2
NEA	Incident neutron data	JEFF-3.3	Pd110	636.5
NEA	Incident neutron data	JEFF-3.3	Ag108	635.36
NEA	Incident neutron data	JEFF-3.3	Ag109	634.5
NEA	Incident neutron data	JEFF-3.3	Ag110	637.1204
NEA	Incident neutron data	JEFF-3.3	Ag110	637.4988
NEA	Incident neutron data	JEFF-3.3	Cd106	635.087
NEA	Incident neutron data	JEFF-3.3	In114	634.3417
NEA	Incident neutron data	JEFF-3.3	In114	637.0182
NEA	Incident neutron data	JEFF-3.3	Sb126	634.5823
NEA	Incident neutron data	JEFF-3.3	Te121	635.9277
NEA	Incident neutron data	JEFF-3.3	I127	635.75
NEA	Incident neutron data	JEFF-3.3	Xe127	637.111
NEA	Incident neutron data	JEFF-3.3	Xe129	636.8
NEA	Incident neutron data	JEFF-3.3	Ba131	634.9718
NEA	Incident neutron data	JEFF-3.3	Ba131	635.5911
NEA	Incident neutron data	JEFF-3.3	La138	635.7065
NEA	Incident neutron data	JEFF-3.3	Ce137	636.527
NEA	Incident neutron data	JEFF-3.3	Ce143	636.832
NEA	Incident neutron data	JEFF-3.3	Pr141	635.8
NEA	Incident neutron data	JEFF-3.3	Nd142	636.4
NEA	Incident neutron data	JEFF-3.3	Gd149	635.845
NEA	Incident neutron data	JEFF-3.3	Tb159	637.6
NEA	Incident neutron data	JEFF-3.3	Dy161	635.3
NEA	Incident neutron data	JEFF-3.3	Dy163	637.17
NEA	Incident neutron data	JEFF-3.3	Ho165	634.8
NEA	Incident neutron data	JEFF-3.3	Er167	636.9
NEA	Incident neutron data	JEFF-3.3	Tm170	635.7607
NEA	Incident neutron data	JEFF-3.3	Yb168	636.2426
NEA	Incident neutron data	JEFF-3.3	Hf177	634.32
NEA	Incident neutron data	JEFF-3.3	Ta181	636.29
NEA	Incident neutron data	JEFF-3.3	Re187	636
NEA	Incident neutron data	JEFF-3.3	Re188	635.007
NEA	Incident neutron data	JEFF-3.3	Re188	637.4905
NEA	Incident neutron data	JEFF-3.3	Os187	636.5
NEA	Incident neutron data	JEFF-3.3	U234	637
NEA	Incident neutron data	JEFF-3.3	U235	635.3746
NEA	Incident neutron data	JEFF-3.3	U235	635.9864
NEA	Incident neutron data	JEFF-3.3	U235	636.5639
NEA	Incident neutron data	JEFF-3.3	U238	636.5637
NEA	Incident neutron data	JEFF-3.3	Pu239	637.2519
NEA	Incident neutron data	JEFF-3.3	Pu240	637.56

27 rows

ENDF

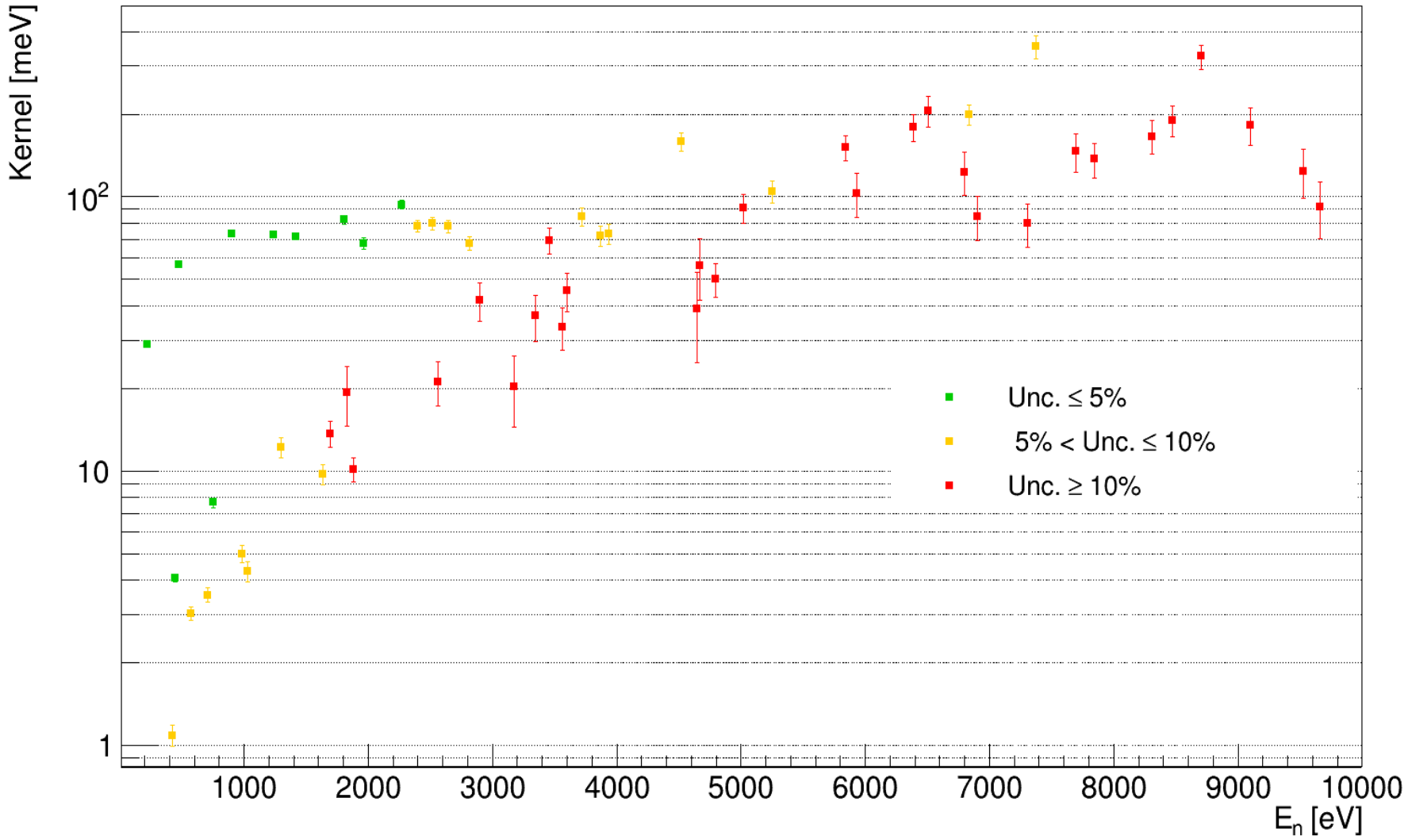
Search	Incident particle	Evaluation	Material	E
NEA	Incident neutron data	ENDF/B-VIII.0	As73	637.6
NEA	Incident neutron data	ENDF/B-VIII.0	Rb86	636
NEA	Incident neutron data	ENDF/B-VIII.0	Sr84	635
NEA	Incident neutron data	ENDF/B-VIII.0	Ru99	636.2
NEA	Incident neutron data	ENDF/B-VIII.0	Pd108	636.2
NEA	Incident neutron data	ENDF/B-VIII.0	Pd110	636.5
NEA	Incident neutron data	ENDF/B-VIII.0	Ag111	634.5
NEA	Incident neutron data	ENDF/B-VIII.0	Cd106	635.087
NEA	Incident neutron data	ENDF/B-VIII.0	Xe129	636.8
NEA	Incident neutron data	ENDF/B-VIII.0	Pr141	635.8
NEA	Incident neutron data	ENDF/B-VIII.0	Nd142	636.4
NEA	Incident neutron data	ENDF/B-VIII.0	Pm145	634.7093
NEA	Incident neutron data	ENDF/B-VIII.0	Dy161	635.3
NEA	Incident neutron data	ENDF/B-VIII.0	Dy163	637.17
NEA	Incident neutron data	ENDF/B-VIII.0	Ho165	634.8
NEA	Incident neutron data	ENDF/B-VIII.0	Er167	636.9
NEA	Incident neutron data	ENDF/B-VIII.0	Re187	636
NEA	Incident neutron data	ENDF/B-VIII.0	Os186	634.7
NEA	Incident neutron data	ENDF/B-VIII.0	Os187	636.5
NEA	Incident neutron data	ENDF/B-VIII.0	Ir194m	634.3605
NEA	Incident neutron data	ENDF/B-VIII.0	U234	637
NEA	Incident neutron data	ENDF/B-VIII.0	U235	635.3727
NEA	Incident neutron data	ENDF/B-VIII.0	U235	635.9863
NEA	Incident neutron data	ENDF/B-VIII.0	U235	636.5657
NEA	Incident neutron data	ENDF/B-VIII.0	U238	636.5637
NEA	Incident neutron data	ENDF/B-VIII.0	Pu239	637.2534
NEA	Incident neutron data	ENDF/B-VIII.0	Pu240	637.4241

117 rows

TENDL

Search	Incident particle	Evaluation	Material	E
NEA	Incident neutron data	TENDL-2019	Mn50m	634.465
NEA	Incident neutron data	TENDL-2019	Co62	634.6249
NEA	Incident neutron data	TENDL-2019	Cu76m	634.6431
NEA	Incident neutron data	TENDL-2019	Ga65	637.5577
NEA	Incident neutron data	TENDL-2019	As73	637.4963
NEA	Incident neutron data	TENDL-2019	Br79m	636.5836
NEA	Incident neutron data	TENDL-2019	Rb86	635.5952
NEA	Incident neutron data	TENDL-2019	Sr84	635
NEA	Incident neutron data	TENDL-2019	Nb102m	637.2151
NEA	Incident neutron data	TENDL-2019	Nb106	635.9606
NEA	Incident neutron data	TENDL-2019	Nb94	635.6213
NEA	Incident neutron data	TENDL-2019	Nb95	636.027
NEA	Incident neutron data	TENDL-2019	Nb98	637.4332
NEA	Incident neutron data	TENDL-2019	Nb98m	635.5377
NEA	Incident neutron data	TENDL-2019	Mo103	635.8959
NEA	Incident neutron data	TENDL-2019	Tc95	637.2974
NEA	Incident neutron data	TENDL-2019	Tc95m	637.5628
NEA	Incident neutron data	TENDL-2019	Ru99	635.7896
NEA	Incident neutron data	TENDL-2019	Ru99	636.2
NEA	Incident neutron data	TENDL-2019	Rh101	634.4981
NEA	Incident neutron data	TENDL-2019	Rh101	635.4865
NEA	Incident neutron data	TENDL-2019	Rh111	635.7004
NEA	Incident neutron data	TENDL-2019	Rh98m	636.0915
NEA	Incident neutron data	TENDL-2019	Rh99	636.2984
NEA	Incident neutron data	TENDL-2019	Pd108	636.2
NEA	Incident neutron data	TENDL-2019	Pd110	636.5
NEA	Incident neutron data	TENDL-2019	Ag105	634.7806
NEA	Incident neutron data	TENDL-2019	Ag105	635.3285
NEA	Incident neutron data	TENDL-2019	Ag116	634.3221
NEA	Incident neutron data	TENDL-2019	Cd99	635.2761
NEA	Incident neutron data	TENDL-2019	Cd99	637.3324
NEA	Incident neutron data	TENDL-2019	In122	636.9546
NEA	Incident neutron data	TENDL-2019	In122	637.2724
NEA	Incident neutron data	TENDL-2019	In124	637.0118
NEA	Incident neutron data	TENDL-2019	In124m	635.2783
NEA	Incident neutron data	TENDL-2019	In124m	636.6797
NEA	Incident neutron data	TENDL-2019	Sn110	636.6528
NEA	Incident neutron data	TENDL-2019	Sn113	637.2378
NEA	Incident neutron data	TENDL-2019	I127	635.75
NEA	Incident neutron data	TENDL-2019	Xe124	637.1186
NEA	Incident neutron data	TENDL-2019	Xe129	636.8
NEA	Incident neutron data	TENDL-2019	Cs135	636.1415
NEA	Incident neutron data	TENDL-2019	La146	637.5143
NEA	Incident neutron data	TENDL-2019	Ce138	635.8478
NEA	Incident neutron data	TENDL-2019	Ce141	635.3785
NEA	Incident neutron data	TENDL-2019	Ce141	636.4137
NEA	Incident neutron data	TENDL-2019	Pr141	635.8
NEA	Incident neutron data	TENDL-2019	Pr143	635.162
NEA	Incident neutron data	TENDL-2019	Pr147	636.7186
NEA	Incident neutron data	TENDL-2019	Pr154	635.4293

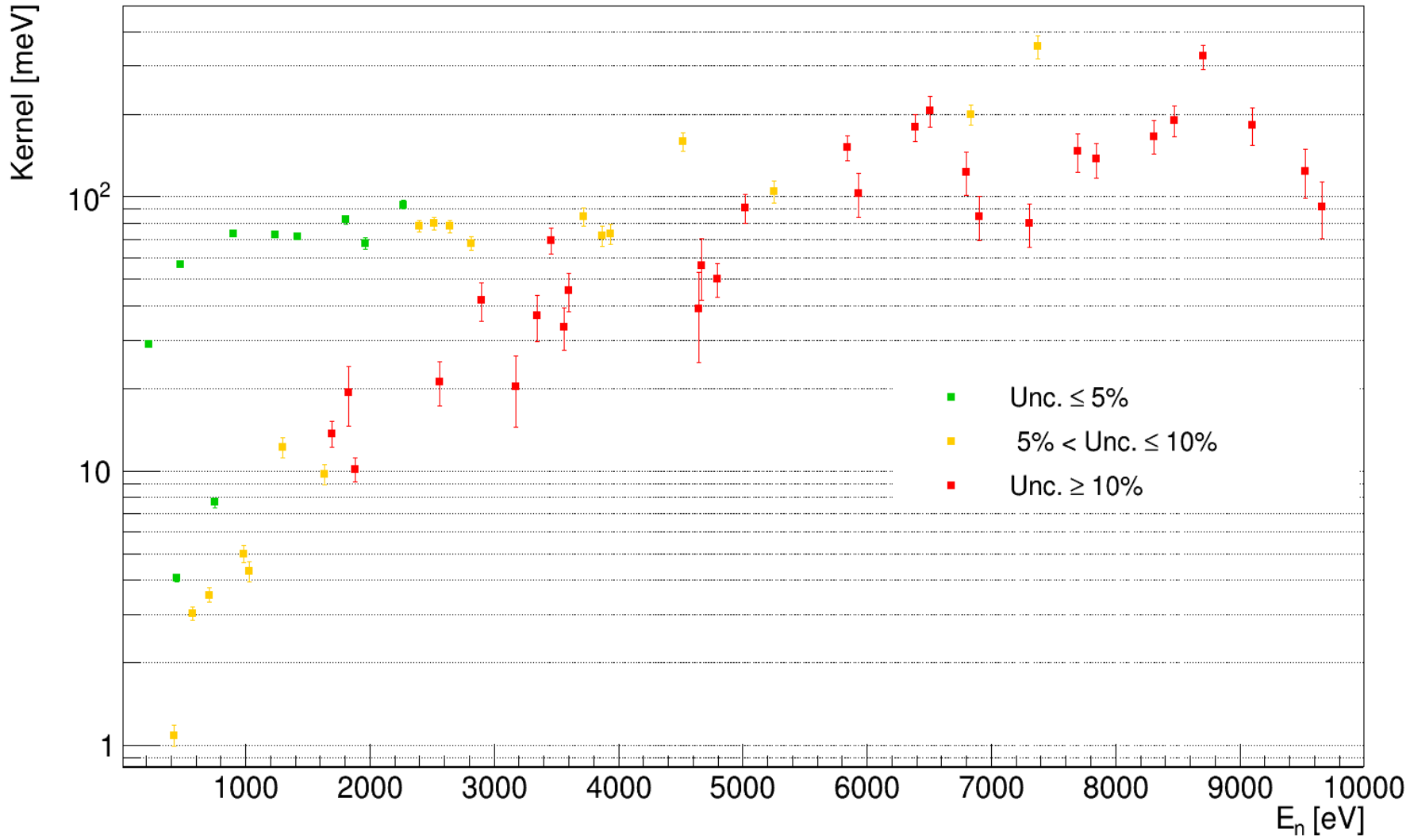
Extracted kernels



Extracted kernels

$$\Gamma_{\gamma 0} = 74.99 \pm 0.62\ meV$$

$$\Gamma_{n0} = 4.73 \pm 0.12\ meV$$



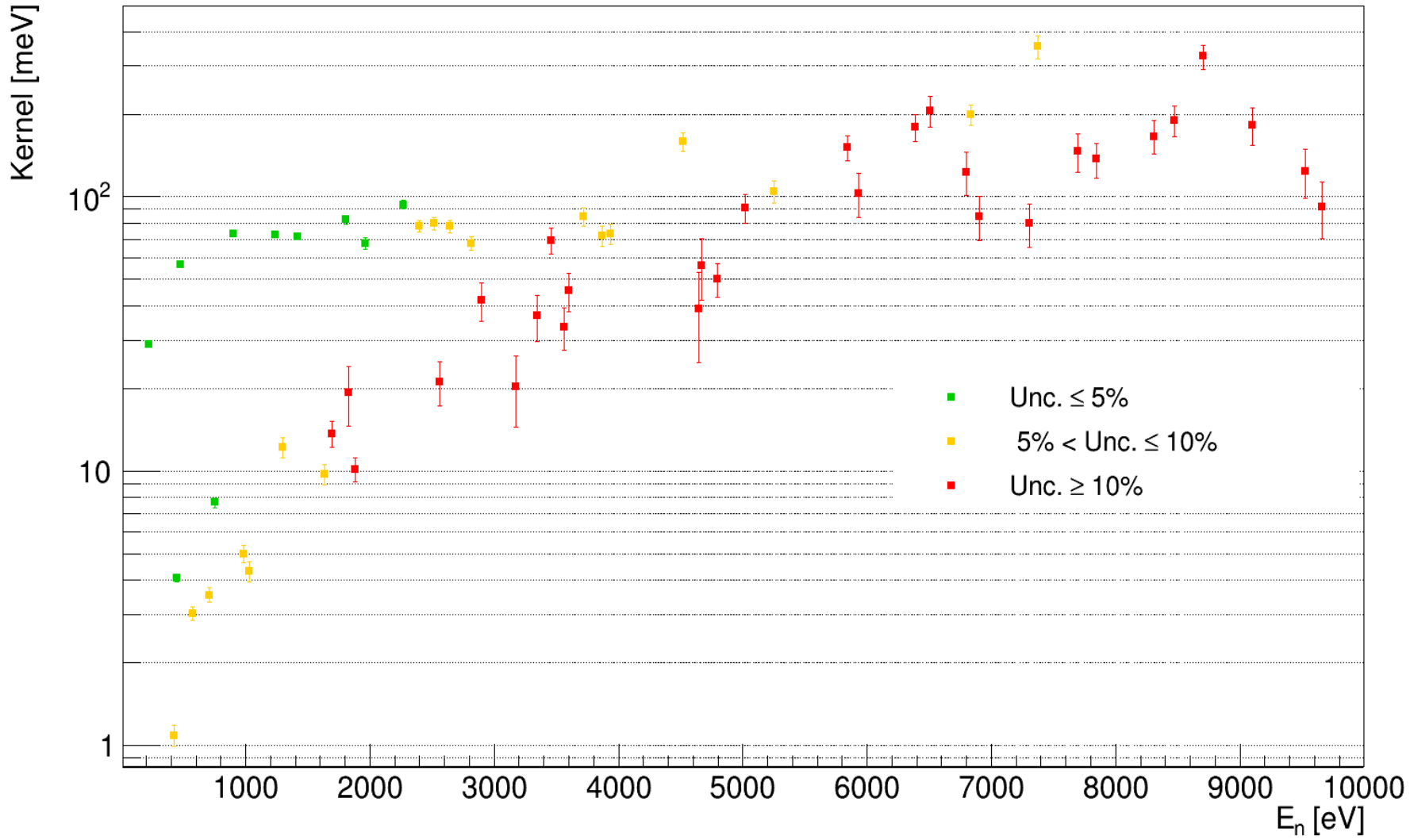
Extracted kernels

$\Gamma_{\gamma 0} = 74.99 \pm 0.62\ meV$

$\Gamma_{n0} = 4.73 \pm 0.12\ meV$

$\Gamma_{\gamma 1} = 84.16 \pm 5.72\ meV$

$\Gamma_{n1} = 5.72 \pm 0.03\ meV$

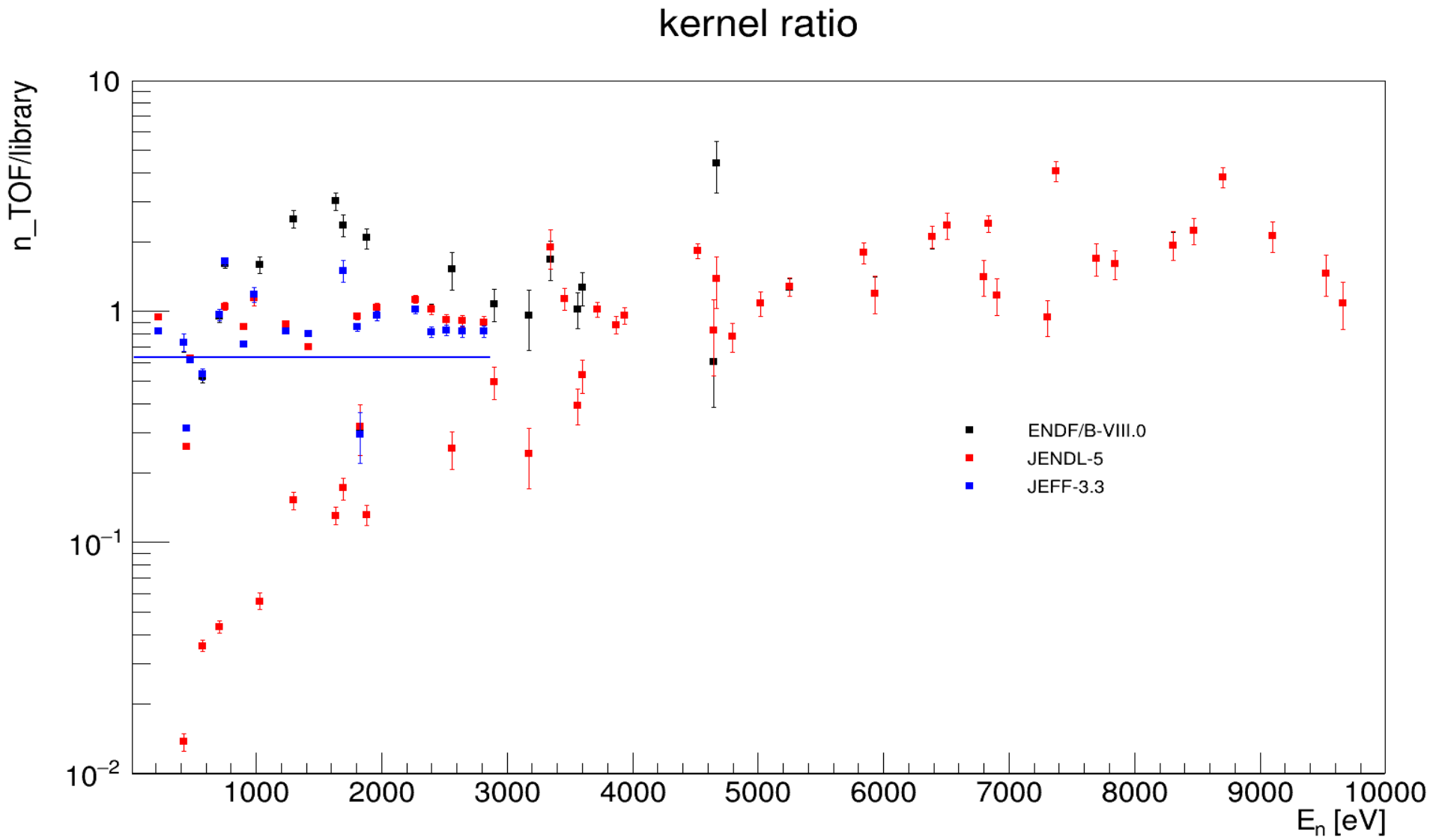


Kernels comparison

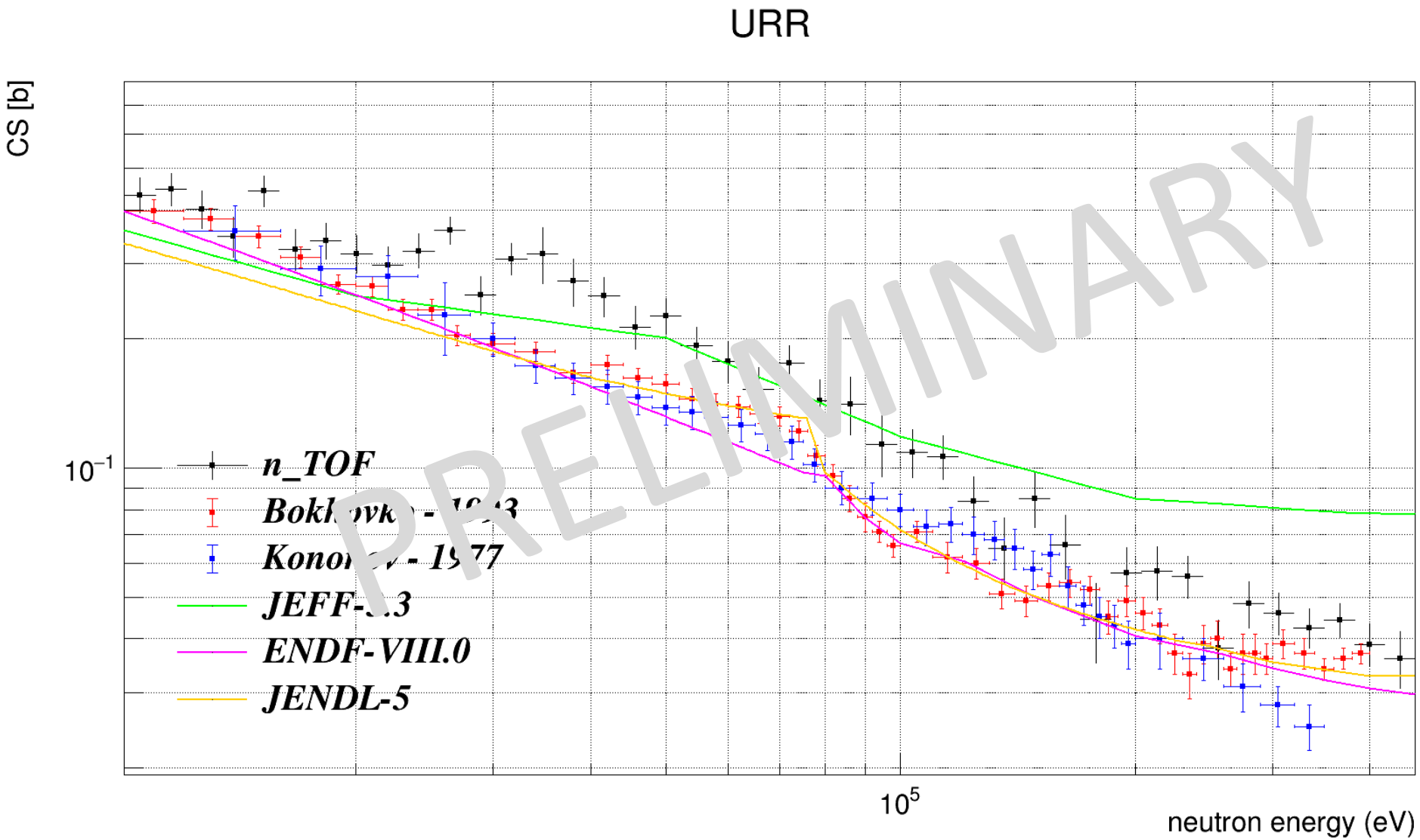
n_TOF/ENDF ≈ 0.61

n_TOF/JENDL ≈ 0.05

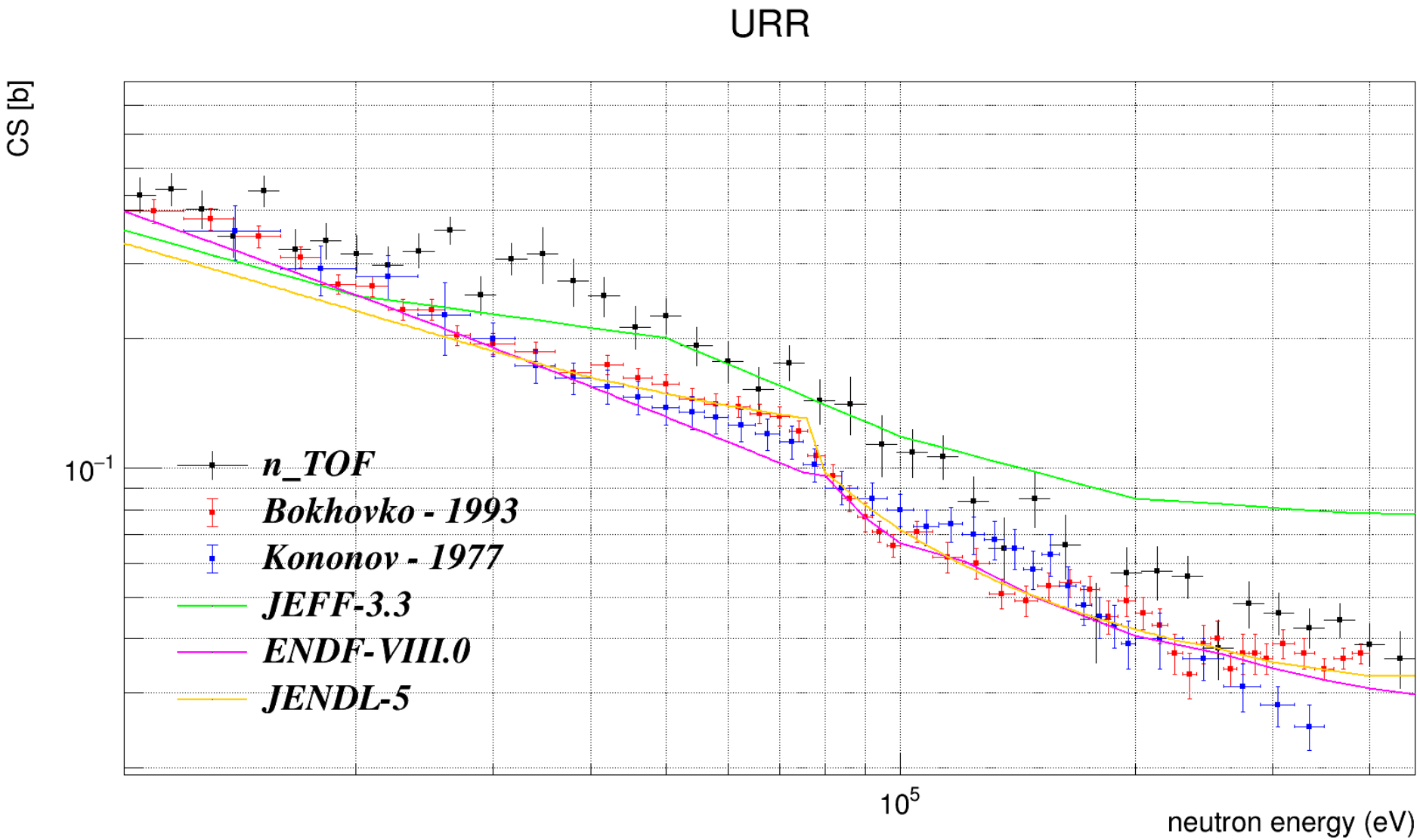
n_TOF/JEFF ≈ 0.63



URR


URR
CS [b]
10^{-1}
10^5
neutron energy (eV)
n_TOF
Bokl'ovk' - 19?3
Konon'v - 19?7
JEFF-?.3
ENDF-VIII.0
JENDL-5
PRELIMINARY

URR

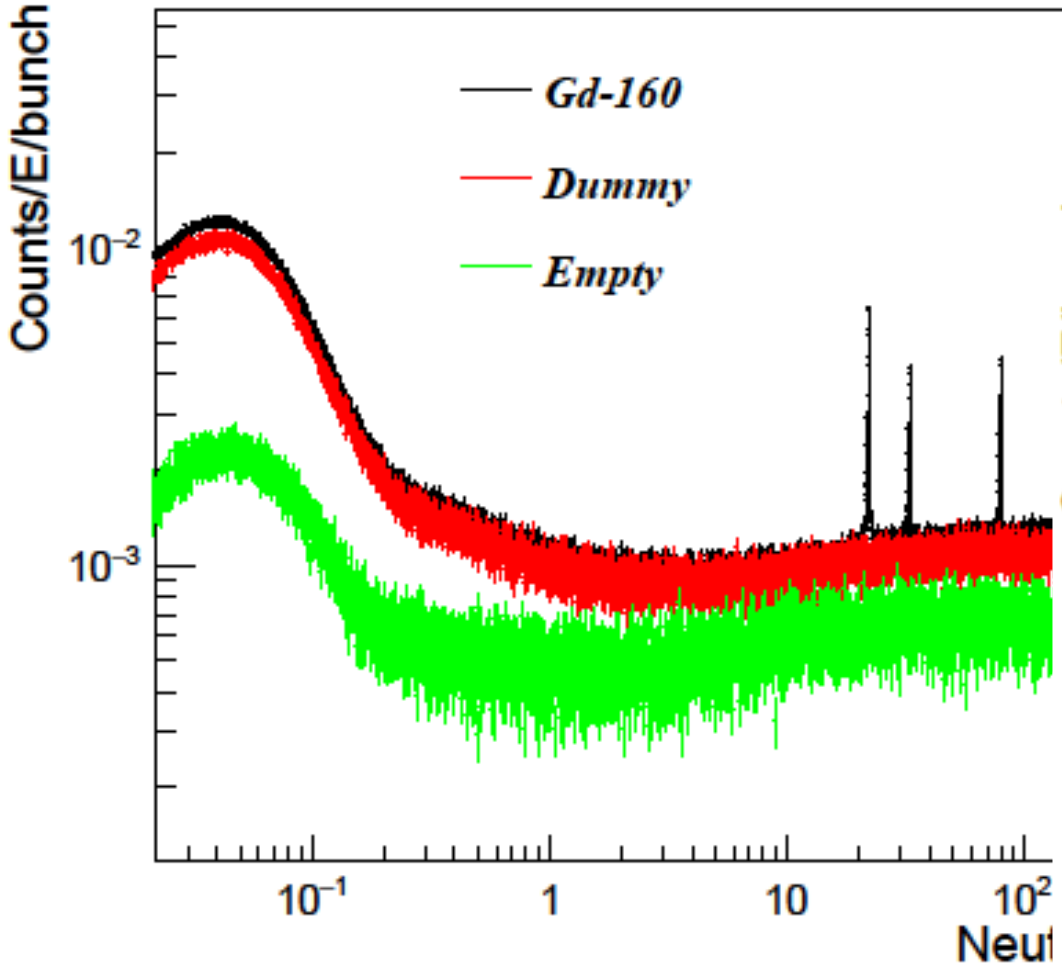

URR
CS [b]
10^{-1}
10^{5}
neutron energy (eV)
n_TOF
Bokhovko - 1993
Kononov - 1977
JEFF-3.3
ENDF-VIII.0
JENDL-5

EAR2

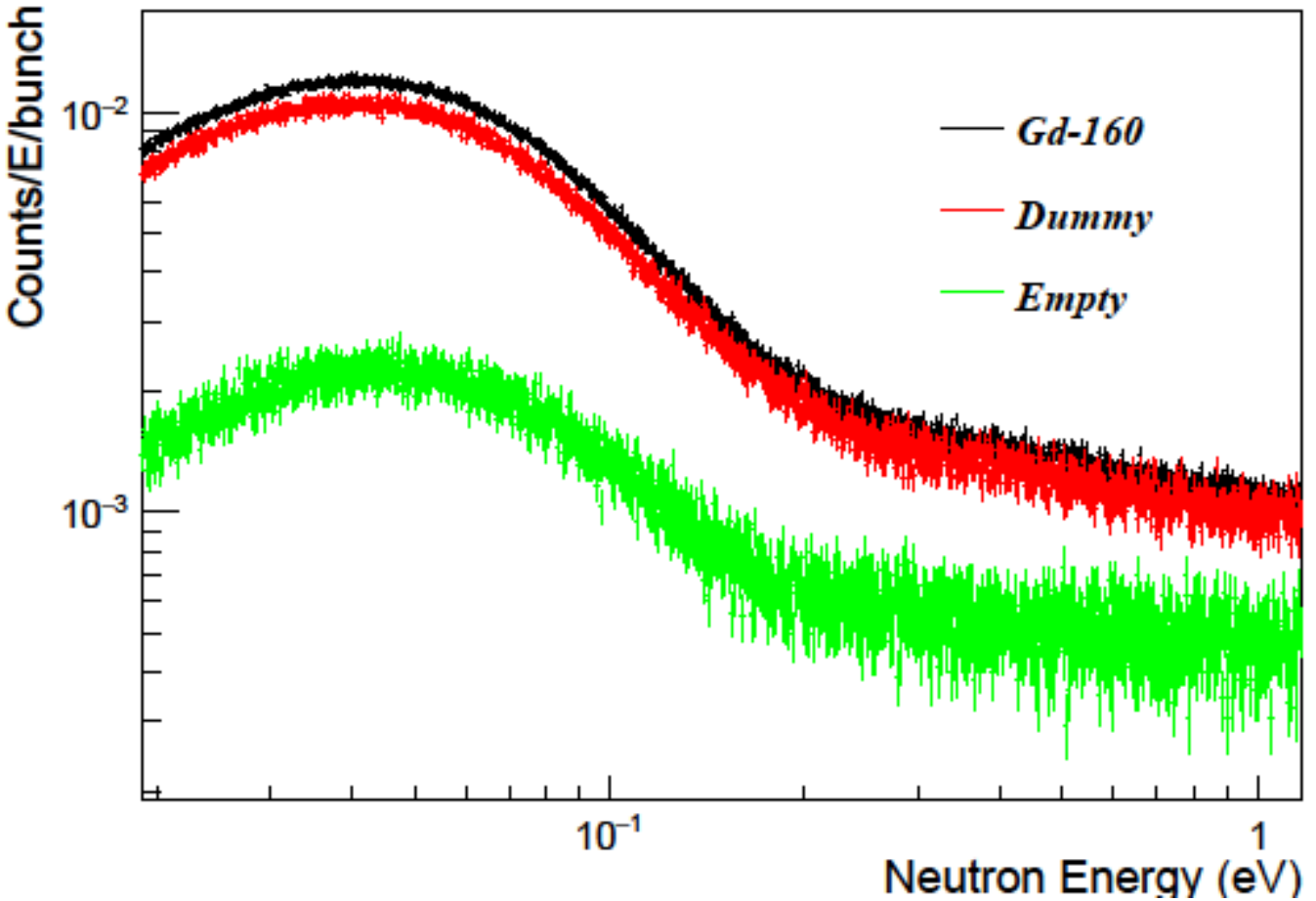
(Thermal and Resolved Resonances Region)

sTED scintillators

Whole Energy Range



Thermal Region



Conclusions

STEPS DONE & TO DO (EAR1)

- *Kernel average uncertainty ≤ 12.0 %*
- *Dummy background subtracted + in beam γ-rays*
- *RRR analized by R-matrix SAMMY Code + unsigned structures + URR*

TO DO (EAR2)

- *Implementation of the Setup geometry and energy loss (MC code) to get the WF for the PHWT*
- *Extract the Yield from Weighted Counts and normalize at @4.9 eV of Au*
- *Study of the reaction at low neutron energies and the RRR*

Thank You

Conclusions (EAR2)

- *The ^{160}Gd(n,γ) has been measured from thermal to a few hundreds of keV in both n_TOF experimental area*
- *The preliminary results have a good S/B ratio in the thermal and in RRR*

TO DO

- *Implementation of the Setup geometry and energy loss (MC code) to get the WF for the PHWT*
- *Extract the Yield from Weighted Counts and normalize at @4.9 eV of Au*
- *Study of the reaction at low neutron energies and the RRR*