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Decay heat validation, FISPACT-II & TENDL-2014, JEFF-3.2, ENDF/B-VII.1 and JENDL-4.0 nuclear data libraries

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Executive Summary

The calculation of activation inventories is a key input to virtually all aspects of the operation, safety and environmental assessment of nuclear plants. For the licensing of such devices, regulatory authorities will require proof that the calculations for structural materials and fuel inventories, and calculations to which these quantities are the inputs, are either correct or conservative. An important aspect of activation-transmutation is decay heat power.

In power plants decay power arises after shutdown from the energy released in the decay of the products of neutron interaction by α , γ and β emissions. Computation of the decay power is performed by sophisticated computer codes which solve the large number of coupled differential equations governing the generation and decay chains for the many nuclides involved. They rely on a large volume of nuclear data that includes both neutron activation-transmutation cross sections and radioactive decay data.

Validation of decay power computational predictions by means of direct comparison with integral data and measurement of sample structural materials under high energy relevant neutron spectra generates confidence in the values calculated. It also permits an assessment of the adequacy of the methods and of the nuclear data, and indicates any inaccuracy or omission that may have led to erroneous results.

No experimental data on decay power existed for most fission reactor materials other than reactor fuel, or for materials under high energy irradiation conditions typical of fusion, until a series of experiments were performed using the Fusion Neutron Source FNS facility at the Japan Atomic Energy Agency JAEA. Many elements and some alloy micro-samples were irradiated in a simulated D-T neutron field for times up to 7 hours and the resulting decay power generated was measured for cooling times of up to a year or more. Using the highly sensitive Whole Energy Absorption Spectrometer (WEAS) method, both β and γ emission decay energies were measured at selected cooling times as early as a few tens of seconds after the irradiation ended. The experimental measurements were then compared with simulations by the inventory code FISPACT-II using different nuclear data libraries: TENDL-2014, JEFF-3.2, ENDF/B-VII.1 and JENDL-4.0. This is, to our knowledge, the most detailed comparison of this type that has been undertaken.

Overall the results of this particular validation exercise indicate that the calculational methods and nuclear databases, with some notable exceptions and variability, generally allow predictions, with quantifiable margins, of the decay power of the tested materials against cooling time. This exercise tested the specific production pathways and at the same time the decay data associated with the nuclides that dominate the decay heat. Note that the decay characteristic of the predominant isotopes is independent of the production route: be it fission, fusion or transmutation in general.

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1 Introduction

Safety and Environmental (S&E) impact issues have acquired increasing importance for the development of power plants. As part of future programmes and especially in connection with engineering feasibility studies, S&E and R&D analyses require a sound and reliable database for the neutron-induced primary and secondary responses. The words primary and secondary define two very different types of response: the former relates to neutronic and gamma-ray time independent responses when the plant is in operation, while the latter refers to time dependent responses which are important after shutdown. In power plants, decay heat will arise after shutdown from the energy released in the decay of the products of particle interactions.

The calculation of activation inventories is an important input to virtually all aspects of S&E analysis. For licensing, the regulatory authorities will require proof of either the correctness or conservatism of the calculations of activation-transmutation and of calculations which use activation-transmutation as input. The radioactive inventory and residual decay power generation depend on the specific design of the plant and its components, its geometrical configuration and material choices, as well as the given irradiation conditions: power, operational scenario, and neutron source distribution. It is essential to include in the plant development properly performed activation inventory calculations that are consistent with the overall plant design. An important aspect of activation is residual decay power. The residual decay power, in the event of a postulated accident in which cooling is lost, might induce structural damage in certain plant components. Temperature transients may promote gas-generating chemical reactions and, in plants of high power density, may promote the mobilisation of activation, transmutation or fission products.

There is thus a strong motivation to limit accidental temperature transients and to ensure that the design and material-choices provide for removal of decay heat, preferably by passive means. Safety studies assess the efficiency of the design in this regard using computer models which require, as a starting point, an accurate assessment of the decay heat levels in the plant. Computation of the decay power is performed by sophisticated computer codes which solve the large number of coupled differential equations which govern the generation and decay chains for the many nuclides involved. They rely on a large volume of nuclear data, both neutron activation-transmutation cross sections and radioactive decay data.

Validation of decay power predictions from such codes by means of direct comparison with integral data measurements of sample structural materials under neutron spectra allow confidence to be given to the decay power values calculated. It also permits an assessment of the adequacy of the methods and nuclear data, and indicates any inaccuracy or omission that may have led to erroneous code predictions. Safety authorities world-wide tend to request experimental validation results that can be used to assess the adequacy of the safety features. It is clear that certain safety margins can be derived from such a validation exercise, if relevant to plant operation, materials and

design, and applied as bounding conditions in S&E analyses.

Little experimental data exists for structural material samples irradiated under relevant neutron spectra and even when data does exist the measured quantities are either specific activity and/or γ spectroscopy. In particular, no experimental data on decay power has previously existed for fission plant structural materials and for materials under high energy irradiation conditions (i.e. fusion). It was to fill this gap that a series of experiments were performed using the Fusion Neutron Source (FNS) facility at the Japan Atomic Energy Agency JAEA [1, 2, 3]. Material samples were irradiated in a simulated D-T neutron field and the resulting decay power was measured for cooling times of up to thirteen months. Using the highly sensitive Whole Energy Absorption Spectrometer (WEAS) method, both β and γ emission decay energies were measured at selected cooling times and, quite impressively, as soon as a few tens of seconds after the end of irradiation.

2 EXPERIMENTAL SET-UP

2.1 FNS assembly

14 MeV neutrons are generated by a 2 mA deuteron beam impinging on a stationary tritium-bearing titanium target. The total neutron flux at the sample location, for this experiment, is in the range of 1.0×10^{10} [$n\text{ cm}^{-2}\text{ s}^{-1}$], the same order of magnitude as in the first wall of the Joint European Torus (JET) fusion experiment when operating with D-T plasma. However, the irradiation time at the FNS were of 5 minutes and 7 hours in comparison with the few seconds flat burn achieved during the DTE1 JET fusion campaign. The DTE1 campaign culminated in a single 16MW fusion shot. As a point of reference the total flux in a power plant is typically expected to be in the region of 10^{13} or 10^{15} [$n\text{ cm}^{-2}\text{ s}^{-1}$], three to five orders of magnitude higher than in JET or FNS, and also for much longer irradiation times.

Thin samples, 25x25 mm² in area, and typically 10 μm thick, have been used, either as metallic foil or powder sandwiched between tape. Use of a thin sample minimises the self-absorption of β rays emitted in the sample itself and allows their measurement. A total of 74 different materials have been used across the different phases of the experiment.

The decay energy in each irradiated sample was measured in the Whole Energy Absorption Spectrometer (WEAS), which comprises two large bismuth-germanate BGO scintillators in a geometric arrangement, provides almost 100 % detection efficiency for both β and γ -rays (see Figure 1). Correction factors need to be applied for γ -ray efficiency and for β and electron energy loss in the sample itself (less than 15% generally), and for other effects such as the decay heat due to the plastic tape used for the powder samples. The overall experimental uncertainty totals between 6 to 10% in most cases, although it rises to higher levels at particular cooling time for certain samples. The

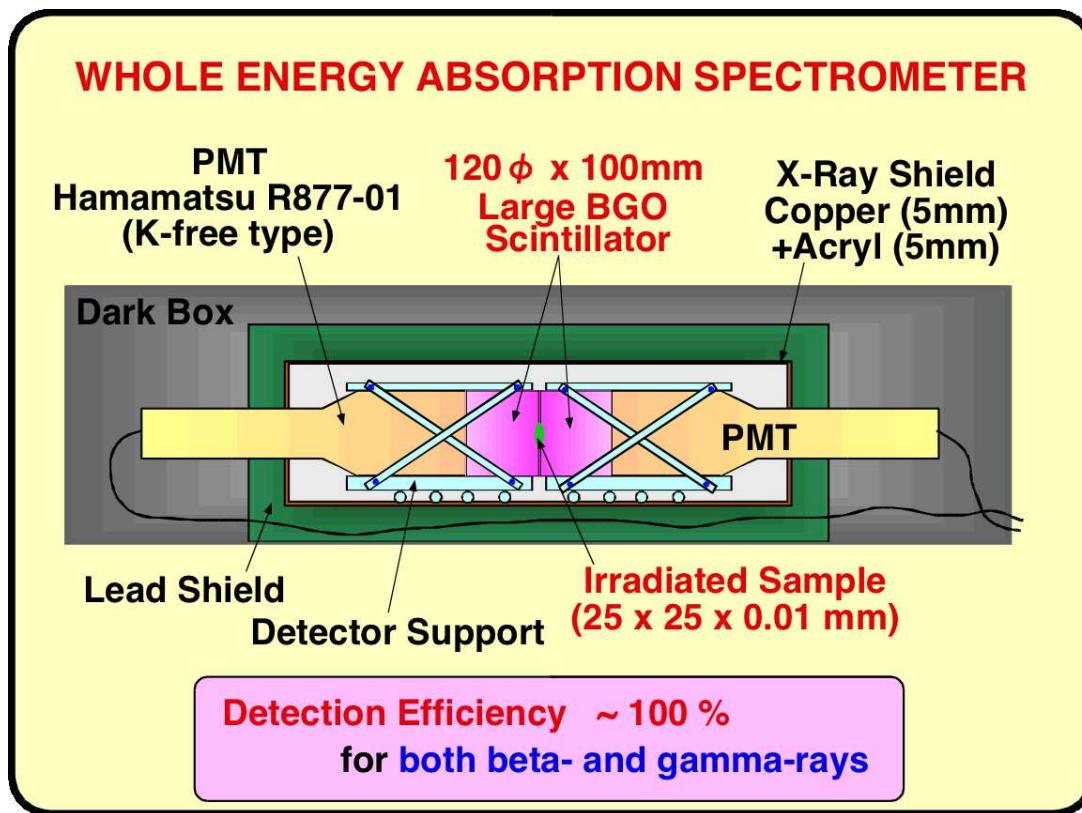


Figure 1: Whole Energy Absorption Spectrometer WEAS set-up

WEAS provides high sensitivity, down to powers less than 1 pW, which is valuable for measurement of some nuclides with long half-lives. It also has a wide dynamic range: measurements of up to a few mW have been achieved in the experiments.

2.2 Irradiation conditions

Three types of irradiation have been performed in order to extract the maximum information possible from such experiments. First, a 5 minute irradiation rapidly followed by a time dependent series of decay power measurements from tens of seconds up to one hour of cooling was used. Such prompt measurements are made possible by the use of a small sample rapidly transported from the irradiation zone to the measurement areas by means of pneumatic tubes. This particular type of measurement allows very short half-life nuclides to be detected and measured. Second, a 7 hour irradiation was performed for some of the samples, followed by a more relaxed time-dependent series of decay power measurements spanning from half a day up to a year of cooling. And third, in order to broaden the scope of the study and enlarge the materials database, the number of studied materials was increased from 32 to 74, covering many more elements of interest, but with published results only on the 5 minute irradiation

experiments.

In the 5 minute irradiation experiments, three different positions were used: positions 1, 2, 3; while only one sample position, 7, was used for the 7 hour irradiations. The experimental set-ups in for each position are depicted in Figure 2. Different neutron spectra, in the 175 Vitamin-J group structure, were calculated using the Monte Carlo code MCNP [3] with a geometrical configuration corresponding to the different assembly positions, and are plotted in Figure 3. Slight spectral differences exist between position 1, 2 and 3; however the neutron flux profiles indicate a marked 14 MeV fusion peak and very few neutrons at energies lower than one MeV. The flux profile corresponding to position 7 is sufficiently shifted from the others to be treated separately. It is clear from Figure 3 and the fact the calculated standard deviation is large (typically greater than 20% [3]) for the energy groups below 100 eV, that few reaction rates can be well characterised at these energies. This means that if the energies below 100 eV are important in the production pathways of a measured radionuclide, no clear conclusion should be drawn from the comparison. Note that a nominal 0.5 to 1% standard deviation convergence criteria for reaction rates in all the neutron energy bins was not achieved in the Monte Carlo simulation, although the standard deviation of the total fluxes was below a few percent. This highlights the fact that in Monte Carlo simulations the total-flux standard deviation is not a good indicator of the quality of the neutron flux spectra, particularly in their low energy tails.

Originally in 1996, 32 relevant materials were irradiated at JAEA/FNS, for 5 minutes and 7 hours, and decay heat values measured over a wide range of cooling times: from a few tens of seconds up to 400 days, and compared to predictions with previous activation databases [4, 5]. These results are referred to as FNS-96 in this report. Additionally in 1998-99, 74 samples - one for each of naturally occurring elements, but excluding very light element and noble gases - were prepared for a new measurement campaign in the same assembly. The experimental results are referred to in this report as FNS-00, having been released officially in 2000.

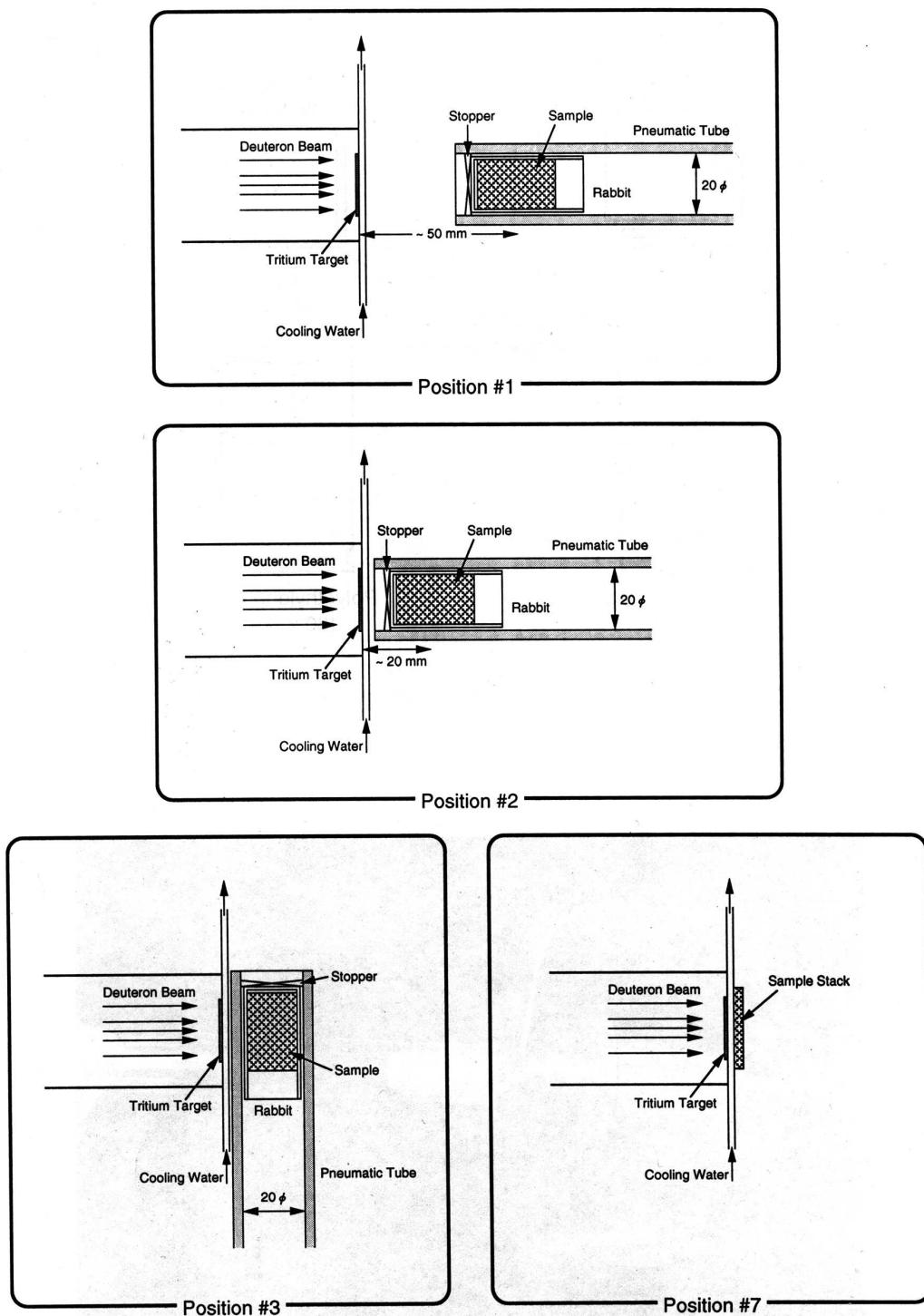


Figure 2: JAEA FNS four set up assemblies

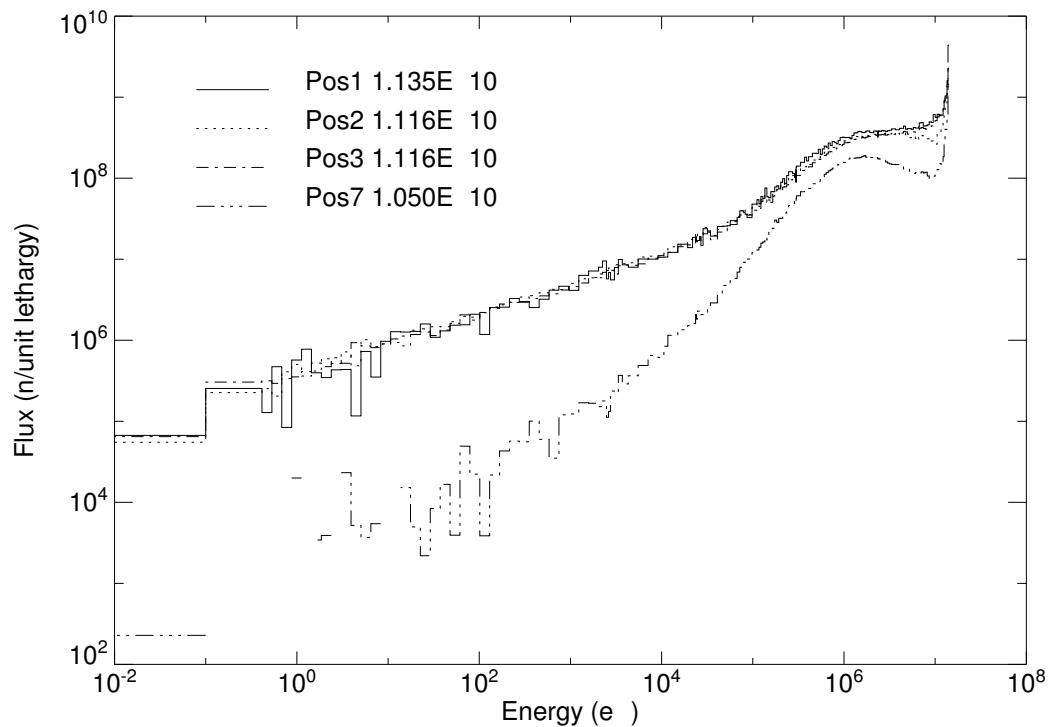


Figure 3: FNS Neutron spectra, neutron fluence monitored by $^{27}\text{Al}(\text{n},\alpha)^{24}\text{Na}$

2.3 Material data

For each of the material samples, the percentage elemental weight has been supplied by JAEA. These tend to correspond to the theoretical weight distribution calculated from the compound or material fractions of the major isotopes. No impurity levels have been given and thus no isotopes other than the major ones have been used in the input data of the calculation scheme. The lack of real chemical analysis of the irradiated samples, although not thought to be important at the preparatory stage of this validation exercise, will be shown to be a drawback for certain materials that seem to have contained a specified (by the manufacturer), but un-quantified, amount of impurities. If those levels of impurities are not known then the code predictions cannot be accurate, and so the comparison will be inconclusive at times when impurities are proven to be important. Table 1 gives a complete list of the irradiated samples and their experimental form.

Z	Element	Form	Z	Element	Form
9	Fluorine	CF ₂	46	Palladium	Metallic Foil
11	Sodium	Na ₂ CO ₃	47	Silver	Metallic Foil
12	Magnesium	MgO	48	Cadmium	Metallic Foil
13	Aluminium	Metallic Foil	49	Indium	Metallic Foil
14	Silicon	Metallic Powder	50	Tin	SnO ₂
15	Phosphorus	P ₃ N ₅	51	Antimony	Metallic Powder
16	Sulphur	Powder	52	Tellurium	TeO ₂
17	Chlorine	C ₂ H ₂ Cl ₂	53	Iodine	IC ₆ H ₄ OH
19	Potassium	K ₂ CO ₃	55	Caesium	Cs ₂ O ₃
20	Calcium	CaO	56	Barium	BaCO ₃
21	Scandium	Sc ₂ O ₃	57	Lanthanum	La ₂ O ₃
22	Titanium	Metallic Foil	58	Cerium	CeO ₂
23	Vanadium	Metallic Foil	59	Praseodymium	Pr ₆ O ₁₁
24	Chromium	Metallic Powder	60	Neodymium	Nd ₂ O ₃
25	Manganese	Metallic Powder	62	Samarium	Sm ₂ O ₃
26	Iron	Metallic Foil	63	Europium	Eu ₂ O ₃
Alloy	SS304	Metallic Foil	64	Gadolinium	Gd ₂ O ₃
Alloy	SS316	Metallic Foil	65	Terbium	Tb ₄ O ₇
27	Cobalt	Metallic Foil	66	Dysprosium	Dy ₂ O ₃
Alloy	Inconel-600	Metallic Foil	67	Holmium	Ho ₂ O ₃
28	Nickel	Metallic Foil	68	Erbium	Er ₂ O ₃
Alloy	Nickel-chrome	Metallic Foil	69	Thulium	Tm ₂ O ₃
29	Copper	Metallic Foil	70	Ytterbium	Yb ₂ O ₃
30	Zinc	Metallic Foil	71	Lutetium	Lu ₂ O ₃
31	Gallium	Ga ₂ O ₃	72	Hafnium	Metallic Powder
32	Germanium	GeO ₂	73	Tantalum	Metallic Foil
33	Arsenic	As ₂ O ₃	74	Tungsten	Metallic Foil
34	Selenium	Metallic Powder	75	Rhenium	Metallic Powder
35	Bromine	BrC ₆ H ₄ COOH	76	Osmium	Metallic Powder
37	Rubidium	Rb ₂ CO ₃	77	Iridium	Metallic Powder
38	Strontium	SrCO ₃	78	Platinum	Metallic Foil
39	Yttrium	Y ₂ O ₃	79	Gold	Metallic Foil
40	Zirconium	Metallic Foil	80	Mercury	HgO
41	Niobium	Metallic Foil	81	Thallium	Tl ₂ O
42	Molybdenum	Metallic Foil	82	Lead	Metallic Foil
44	Ruthenium	Metallic Powder	83	Bismuth	Metallic Powder
45	Rhodium	Metallic Powder			

Table 1: Irradiated sample materials

3 CODE AND LIBRARIES

The European Activation System, EASY-II [6], has been used to perform this validation exercise. Four, quite-different, major cross section databases have been accessed using the FISPACT-II code [7]: TENDL-2014 [8], ENDF/B-VII.1 [9], JEFF-3.2 [10] and JENDL-4.0 [11]. TENDL-2014 is the only one of the libraries that includes a full set of exploitable covariances. In addition to cross-sections the other basic quantities required by an inventory code are information on the decay properties (such as half-life or decay scheme) of all the nuclides considered. These data are available in a handful of evaluated decay data libraries. FISPACT-II is able to read the data directly in ENDF-6 format; it requires no pre-processing to be done. The now well verified and validated eaf_dec_2010 library based primarily on the JEFF-3.1.1 and JEF-2.2 radioactive decay data libraries, with additional data from the latest UK evaluations, UKPADD6.10, contain 2233 nuclides. However, to handle the extension in incident particle type, energy range, and number of targets, many more are needed. A new 3873-nuclide decay library dec_2012 has been assembled from eaf_dec_2010 complemented with all of JEFF-3.1.1 and a handful of ENDF/B-VII.1 decay files. This new decay library was used in all the simulations, see Reference [12] for more details.

In order not to bias the experimental spectral data, the groupwise libraries used in the calculation scheme all correspond to a 709 group structure [7] collapsed using a 1 over E micro flux weighting function.

These calculations required the collapse of the nuclear data libraries for each flux at positions 1, 2, 3 and 7. The well validated FISPACT-II features that allow a determination of the dominant radionuclides, and analysis of the pathways of their formation, have been used and are reflected in the detailed comparison analysis.

Also, and for the fourth time [13, 14, 15], the method used in TENDL libraries to assess the calculation uncertainties from the unique Total Monte Carlo (TMC) method has been related to either the E/C results or the experimental uncertainties. This provides a unique opportunity to assess the adequacy and reliability of the covariance data generated using the Total Monte Carlo TMC method implemented in the TALYS T6 system.

4 COMPARISON OF THE RESULTS

For each material sample and irradiation condition, FISPACT-II, combined with the TENDL-2014, ENDF/B-VII.1, JEFF-3.2 and JENDL-4.0, calculations have been performed. Tabular and graphical comparisons of the results are presented. On the graphs FNS experimental measurements are also plotted and include the uncertainties as vertical lines, while the grey shadow area corresponds to the calculation uncertainty derived from TENDL-2014. The 5 minute irradiation results are presented first followed by those for the 7 hour irradiations. Care needs to be taken when interpreting

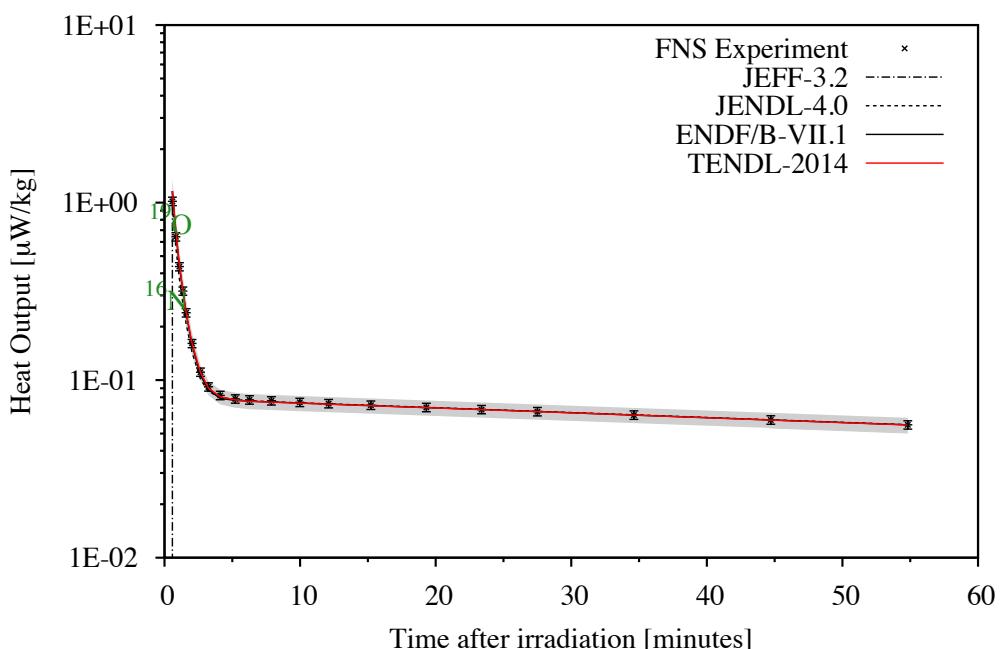
the graphs, particularly in view of the log-linear scales. Such plots allow a direct visual interpretation of nuclide half-life at times when one isotope is clearly dominant. A departure from equivalence in the decay profile between experiment and calculation would indicate a mismatch in terms of half-life in one or more of the important nuclides. Graphs corresponding to the 5-minute irradiations of the year 2000 campaign are given first, followed by the results of the year 1996 experiments, where they exist. A table (for the 2000 5-minute or 1996 7-hour experiments only) give more information, such as the calculation uncertainties, and allows a more precise interpretation of the comparison. This is followed by, for each irradiation experiment, the list of the dominant radionuclides that contribute at a level of more than 0.5% to the total decay power at all cooling times. Their production pathways, calculated by FISPACT-II, are also here, including the percentage contribution of each route, if more than one exists. All these quantities allow a judgement to be made on whether the experimental result is able to validate the calculational method for the production paths and decay data. The judgement is shown in the E/C column. The half-life of each dominant radionuclide, and thus the timescale at which they are predominant, is also presented. Following this, another graph is given (again, only for the 2000 5-minute or 1996 7-hour experiments), showing the calculated decay heat as a function of time with the predominant radionuclides, added on the graphs with their isotopic name at their heat output level at shutdown on the ordinate and half live on the abscissa. Such plotting, on a log-log scale allows one to immediately comprehend the relative contribution of different nuclides to the total heat output as a function of time.

Careful consideration needs to be given when analysing a experimental data such as that produced from FNS. The fact is that the measured quantities may, or may not, be directly related to the pathways of production of a particular radionuclide. There is only a strong possibility, not a certainty, that, firstly the major radionuclides measured are the one predicted by the code, and secondly that their amount has been properly calculated before their respective decay power is derived. Although improbable, one may envisage a 20% under prediction in terms of atomic amount of a nuclide, balanced by a 20% over prediction through the decay data scheme. This would lead to a perfect E/C value. Such possibilities of error compensation, though unlikely, may well exist at a certain level and so make the interpretation of the results more difficult. However, such difficult-to-detect scenarios are made less probable when the experimental results are analysed by different activation codes, cross section and decay data [3], and are used with other comparison methods such as C/E values for the cross sections themselves.

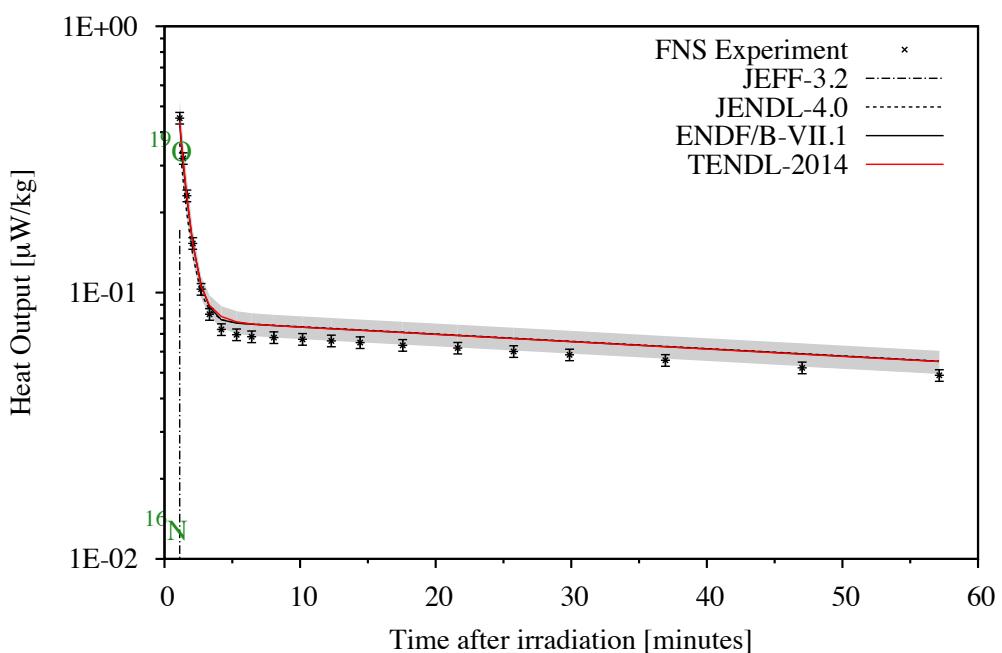
There follows in the rest of the report a presentation, as described above, of the analysis for each of the 74 materials samples that have been irradiated.

To complement the analysis of total heat, an appendix has been included showing the TENDL-2014 differential cross sections against EXFOR [16] for all reactions leading to the production of dominant nuclides. Further details of these plots can be found in [17].

Fluorine
FNS-00 5 Min. Irradiation - CF₂



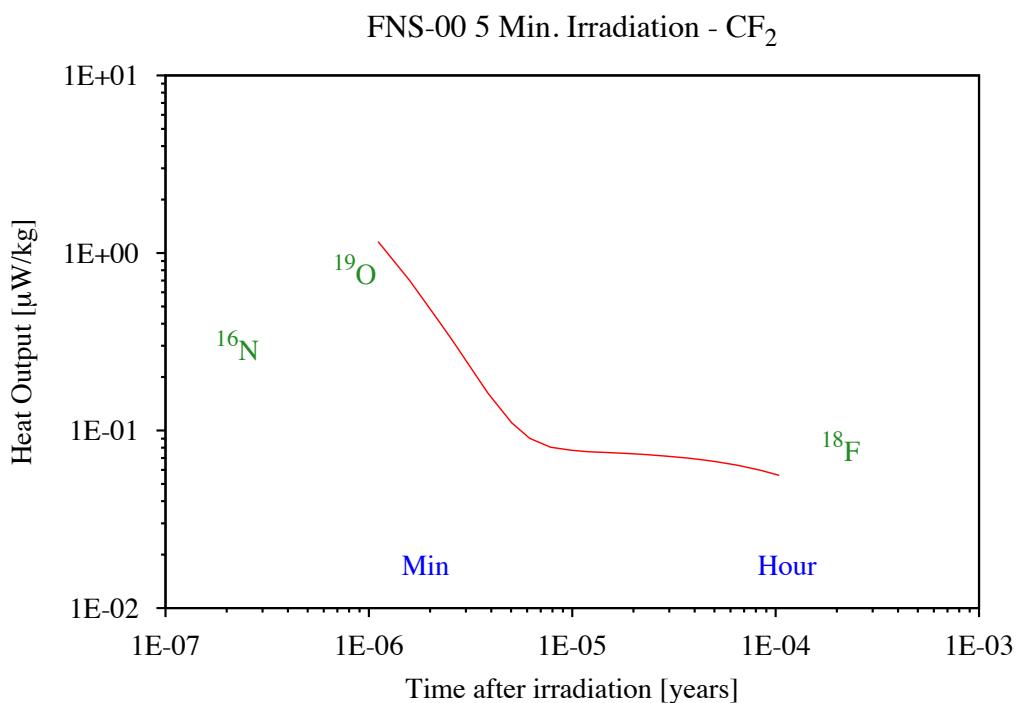
FNS-96 5 Min. Irradiation - CF₂

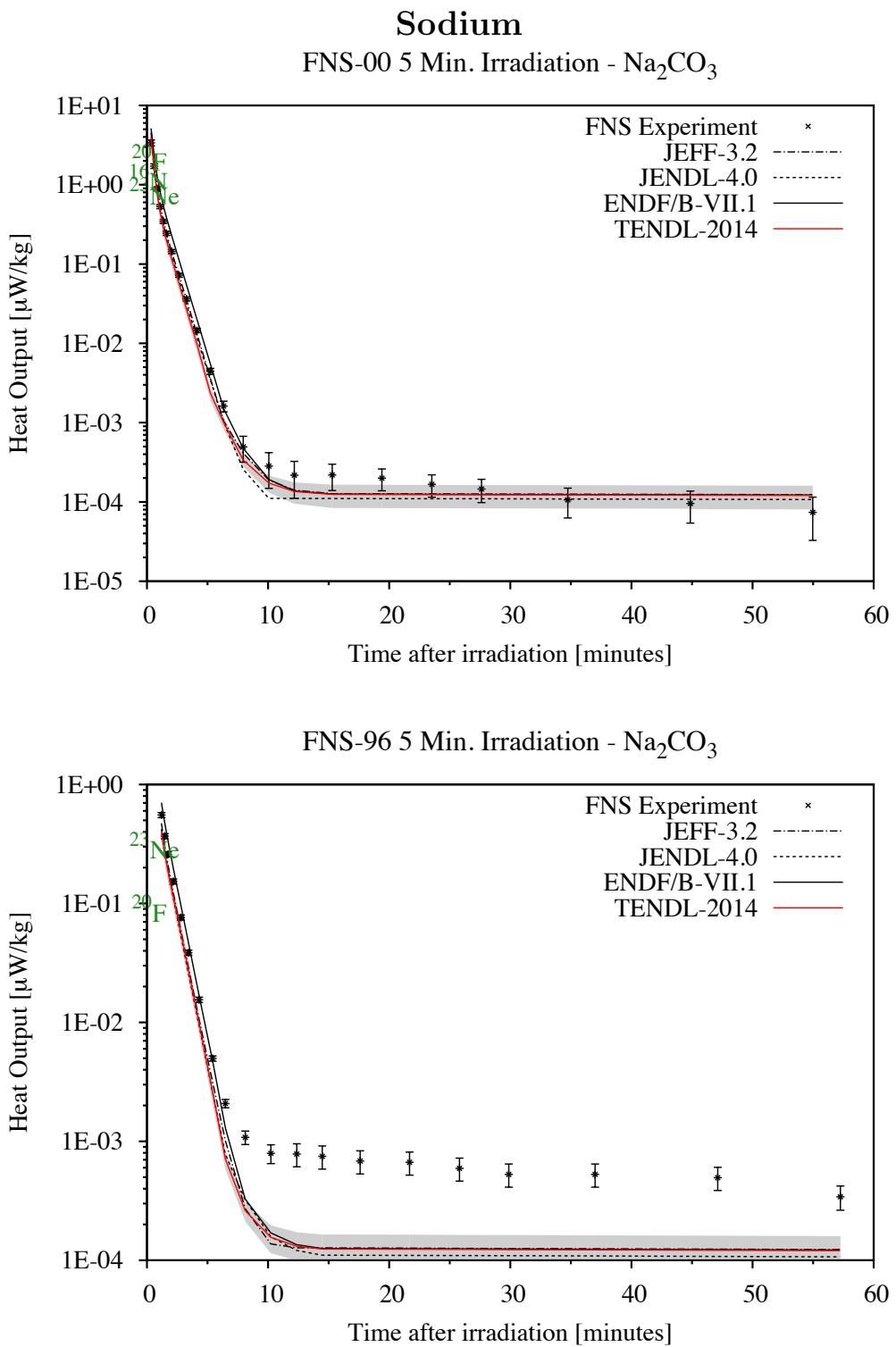


For Fluorine, the agreement looks excellent for both samples and irradiation batches at all times for TENDL-2014, and after 3 minutes cooling for all others libraries except JEFF-3.2. The variation between the two experimental data sets clearly demonstrates that experiments do not always lead to the same measurements, even when carried out in the same assembly set-up. However, the F18 route of production uncertainty of 10% accounts for such experimental fluctuation.

Times	FNS EXP.	5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.		$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.58		$1.02E+00$ +/-5%	$1.16E+00$ +/-18%	0.88	0.88	1.07
0.83		$6.42E-01$ +/-5%	$7.01E-01$ +/-19%	0.92	0.95	1.15
1.10		$4.36E-01$ +/-5%	$4.50E-01$ +/-20%	0.97	0.99	1.17
1.35		$3.17E-01$ +/-5%	$3.23E-01$ +/-19%	0.98	1.00	1.17
1.60		$2.40E-01$ +/-5%	$2.42E-01$ +/-17%	0.99	1.01	1.16
2.03		$1.61E-01$ +/-5%	$1.61E-01$ +/-14%	1.00	1.02	1.12
2.65		$1.11E-01$ +/-5%	$1.10E-01$ +/-10%	1.00	1.04	1.09
3.25		$9.17E-02$ +/-5%	$9.04E-02$ +/-9%	1.01	1.04	1.06
4.12		$8.21E-02$ +/-5%	$8.06E-02$ +/-9%	1.02	1.04	1.02
5.22		$7.84E-02$ +/-5%	$7.74E-02$ +/-10%	1.01	1.02	1.01
6.27		$7.74E-02$ +/-5%	$7.61E-02$ +/-10%	1.02	1.02	1.01
7.88		$7.66E-02$ +/-5%	$7.52E-02$ +/-10%	1.02	1.02	1.01
9.98		$7.50E-02$ +/-5%	$7.42E-02$ +/-10%	1.01	1.01	1.01
12.10		$7.38E-02$ +/-5%	$7.32E-02$ +/-10%	1.01	1.01	1.00
15.22		$7.23E-02$ +/-5%	$7.18E-02$ +/-10%	1.01	1.01	1.00
19.32		$7.02E-02$ +/-5%	$7.00E-02$ +/-10%	1.00	1.00	1.00
23.38		$6.83E-02$ +/-5%	$6.82E-02$ +/-10%	1.00	1.00	1.00
27.50		$6.65E-02$ +/-5%	$6.65E-02$ +/-10%	1.00	1.00	1.00
34.62		$6.36E-02$ +/-5%	$6.35E-02$ +/-10%	1.00	1.00	1.00
44.72		$5.97E-02$ +/-5%	$5.96E-02$ +/-10%	1.00	1.00	1.00
54.82		$5.60E-02$ +/-5%	$5.59E-02$ +/-10%	1.00	1.00	1.00
mean % diff. from E			2	2	96	5

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
O19	F19(n,p)O19	26.9s	99.8	0.88	5%
F18	F19(n,2n)F18	1.82h	100.0	1.00	5%

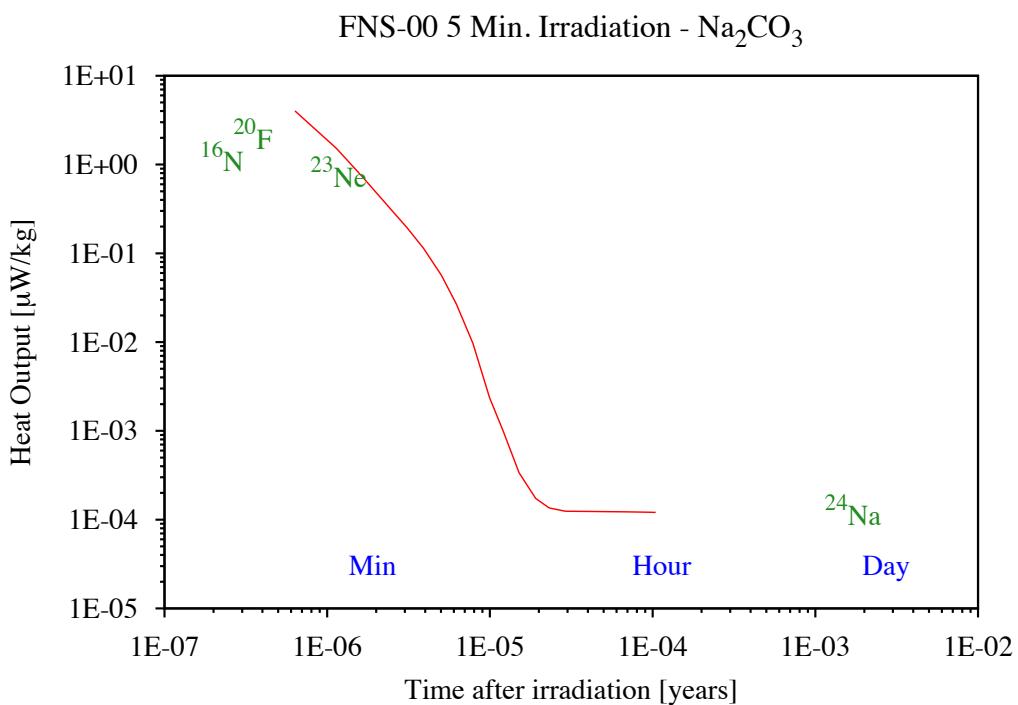


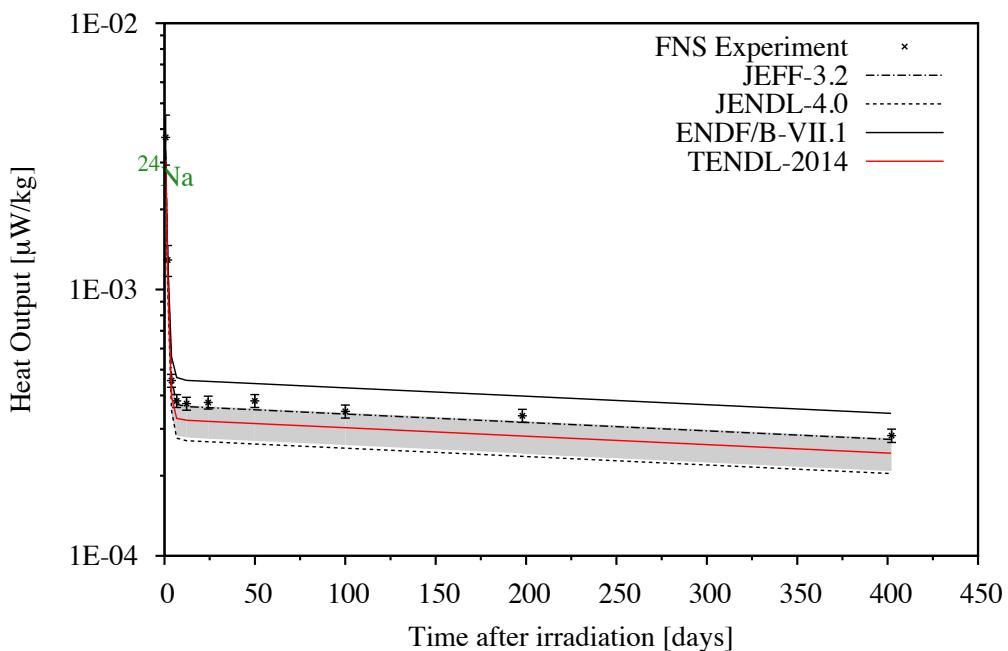


For Sodium, the two experimental measurements do not exhibit the same decay heat level, particularly in the plateau. Many factors could have influenced the experimental set-up and the presence of impurities in the sample is plausible. High experimental uncertainties accompany the latest 2000 experiment but the time dependence shape is definitely there. The TENDL-2014 Na^{23} capture cross section well represents the 2000 experiment and its associated uncertainty.

Times	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.33	$3.38E+00 +/-8\%$	$4.02E+00 +/-11\%$	0.84	0.66	0.74
0.60	$1.72E+00 +/-7\%$	$1.52E+00 +/-12\%$	1.13	0.74	0.91
0.85	$8.86E-01 +/-6\%$	$7.53E-01 +/-14\%$	1.18	0.70	0.95
1.10	$5.30E-01 +/-6\%$	$4.40E-01 +/-16\%$	1.20	0.66	0.96
1.37	$3.45E-01 +/-6\%$	$2.80E-01 +/-18\%$	1.23	0.65	1.00
1.62	$2.44E-01 +/-6\%$	$1.97E-01 +/-19\%$	1.24	0.64	1.00
2.05	$1.44E-01 +/-6\%$	$1.15E-01 +/-20\%$	1.25	0.64	1.03
2.65	$7.22E-02 +/-6\%$	$5.65E-02 +/-20\%$	1.28	0.65	1.00
3.27	$3.63E-02 +/-6\%$	$2.69E-02 +/-20\%$	1.35	0.67	1.03
4.13	$1.45E-02 +/-6\%$	$9.66E-03 +/-20\%$	1.50	0.73	1.11
5.23	$4.44E-03 +/-9\%$	$2.36E-03 +/-19\%$	1.88	0.80	1.23
6.33	$1.61E-03 +/-15\%$	$1.00E-03 +/-18\%$	1.61	1.07	1.55
7.95	$4.94E-04 +/-36\%$	$3.36E-04 +/-18\%$	1.47	1.04	1.20
10.07	$2.83E-04 +/-48\%$	$1.73E-04 +/-24\%$	1.64	1.47	1.50
12.17	$2.18E-04 +/-49\%$	$1.36E-04 +/-30\%$	1.61	1.58	1.55
15.30	$2.19E-04 +/-37\%$	$1.24E-04 +/-33\%$	1.76	1.74	1.72
19.40	$1.99E-04 +/-31\%$	$1.24E-04 +/-33\%$	1.61	1.59	1.57
23.52	$1.67E-04 +/-31\%$	$1.24E-04 +/-33\%$	1.35	1.34	1.32
27.62	$1.46E-04 +/-33\%$	$1.23E-04 +/-33\%$	1.18	1.17	1.16
34.75	$1.06E-04 +/-41\%$	$1.22E-04 +/-33\%$	0.87	0.86	0.85
44.87	$9.55E-05 +/-43\%$	$1.22E-04 +/-33\%$	0.79	0.78	0.77
54.97	$7.39E-05 +/-56\%$	$1.21E-04 +/-33\%$	0.61	0.61	0.60
mean % diff. from E		28	38	20	25

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Ne23	Na23(n,p)Ne23	37.2s	100.0	0.84	8%
Na24	Na23(n, γ)Na24	14.9h	100.0	0.87	41%
	Na23(n, γ)Na24m	0.02s	0.0	0.87	41%

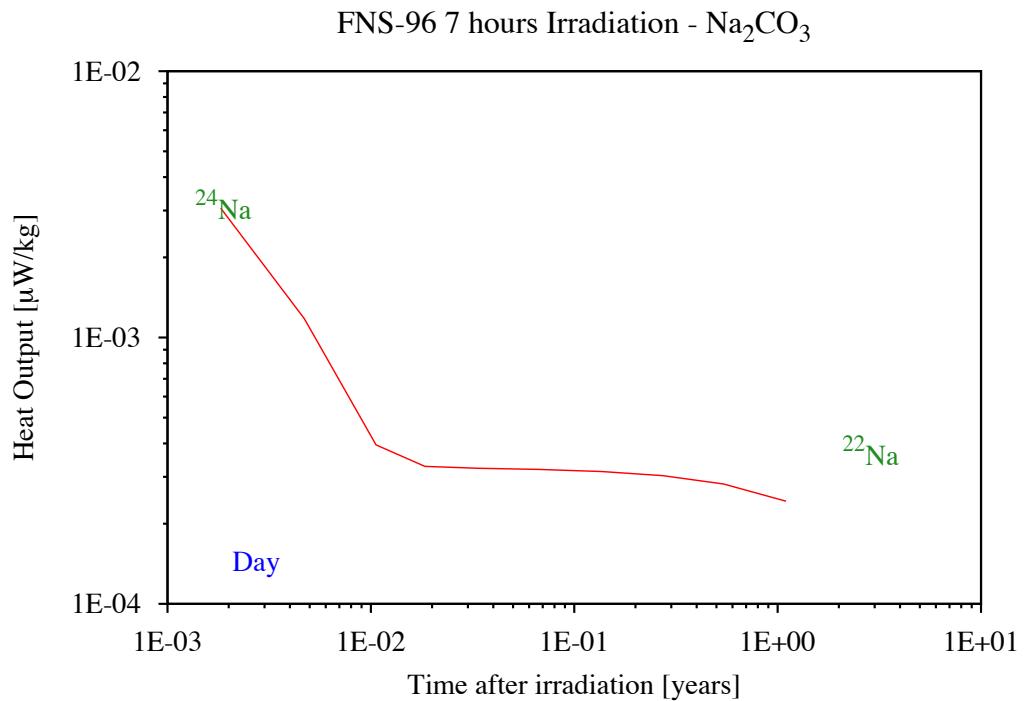


FNS-96 7 hours Irradiation - Na_2CO_3 

In this case the heat arising from Na^{22} seems to be under predicted by around 40% by JENDL-4.0, 15% by TENDL-2014, over-predicted by 20% for ENDF/B-VII.1, but spot on with JEFF-3.2. TENDL-2014 uncertainty bands cover the measurements. Otherwise, there could be a contribution from unknown impurities that have not been taken into account in the simulation.

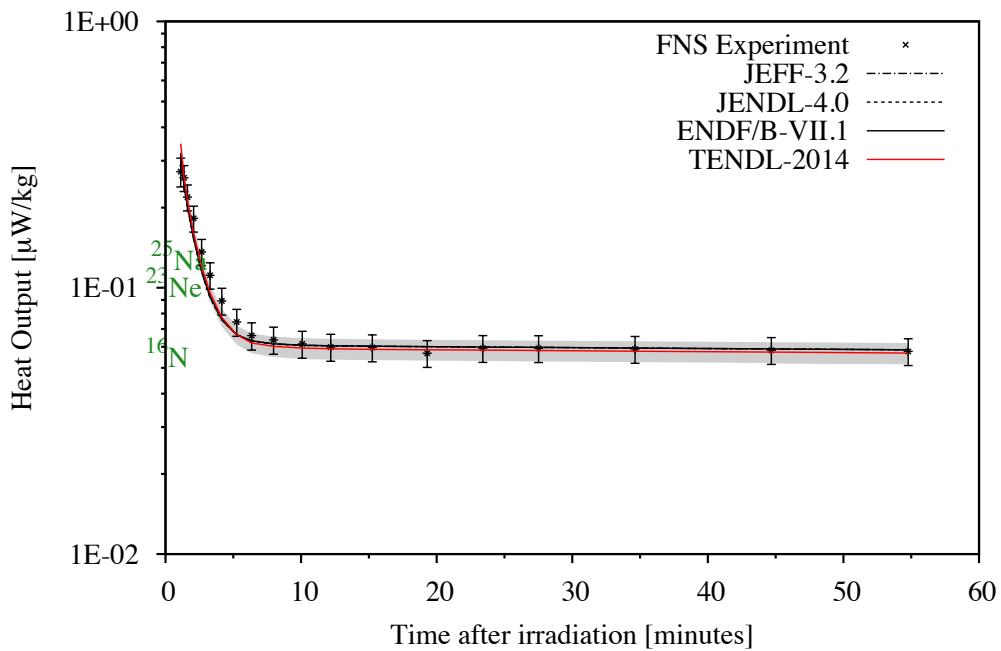
Times Days	FNS EXP. 7 hrs		TENDL-2014		ENDF/B-VII.1		JEFF-3.2	JENDL-4.0
	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C	E/C		
0.67	$3.73E-03$ +/-21%	$3.06E-03$ +/-45%	1.22		1.18		1.12	1.37
1.72	$1.29E-03$ +/-13%	$1.18E-03$ +/-37%	1.10		0.99		0.99	1.23
3.87	$4.55E-04$ +/-6%	$3.95E-04$ +/-15%	1.15		0.81		0.98	1.30
6.74	$3.82E-04$ +/-6%	$3.28E-04$ +/-14%	1.16		0.82		1.03	1.38
12.19	$3.73E-04$ +/-6%	$3.23E-04$ +/-14%	1.15		0.82		1.03	1.38
24.20	$3.77E-04$ +/-6%	$3.20E-04$ +/-14%	1.18		0.83		1.05	1.41
49.95	$3.82E-04$ +/-6%	$3.14E-04$ +/-14%	1.22		0.86		1.08	1.45
100.08	$3.49E-04$ +/-6%	$3.03E-04$ +/-14%	1.15		0.82		1.02	1.37
197.95	$3.36E-04$ +/-6%	$2.82E-04$ +/-14%	1.19		0.84		1.06	1.42
402.16	$2.83E-04$ +/-6%	$2.43E-04$ +/-14%	1.16		0.83		1.03	1.39
mean % diff. from E			14		18		4	27

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Na24	$\text{Na}^{23}(n,\gamma)\text{Na}^{24}$	14.9h	99.9	1.10	13%
Na22	$\text{Na}^{23}(n,2n)\text{Na}^{22}$	2.6y	100.0	1.16	6%



Magnesium

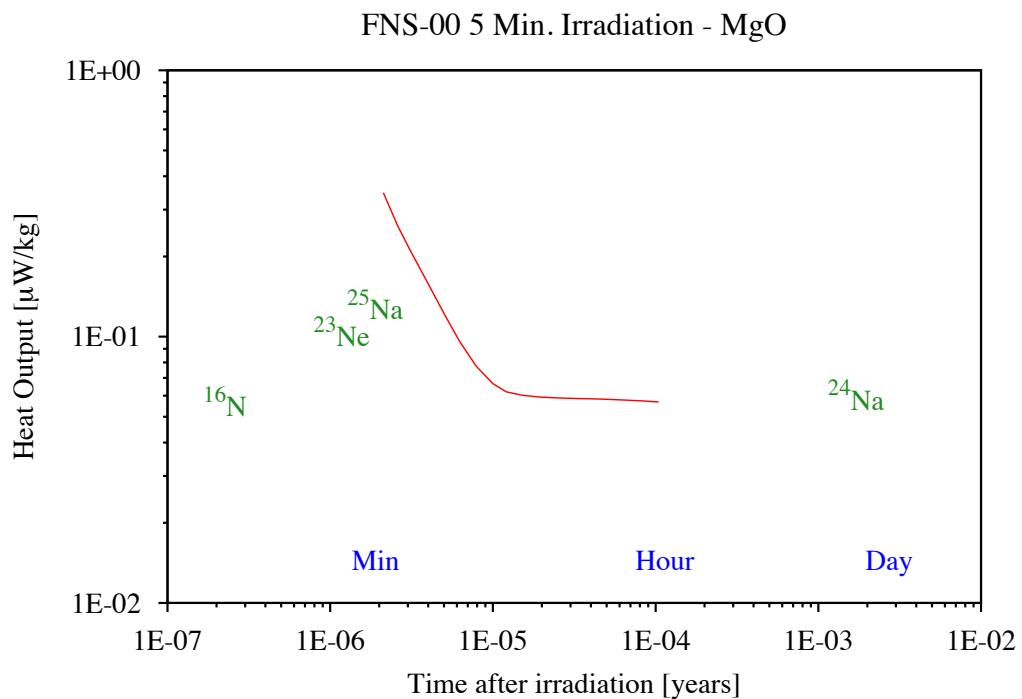
FNS-00 5 Min. Irradiation - MgO



For Magnesium, there is excellent agreement at all cooling times. Na24 production reaction-rates are well predicted, although note that the Na24m 0.02s isomer is not produced in any of the libraries.

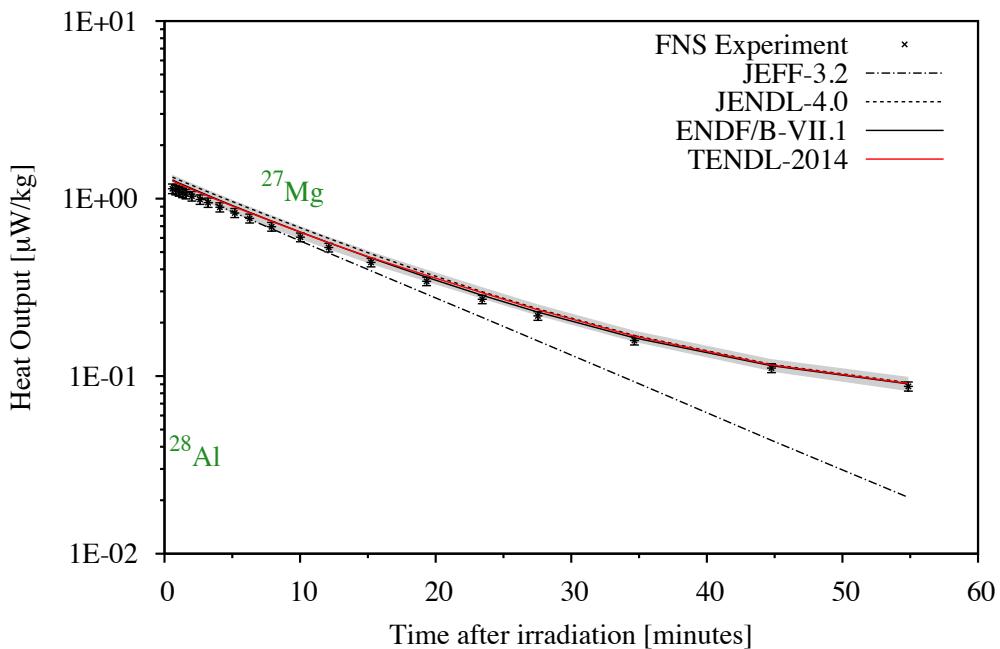
Times Min.	FNS EXP. 5 mins μW/g	TENDL-2014 μW/g	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C
1.12	$2.73E-01$ +/-12%	$3.47E-01$ +/-8%	0.79	0.85	0.85
1.37	$2.59E-01$ +/-11%	$2.61E-01$ +/-8%	0.99	1.07	1.07
1.62	$2.19E-01$ +/-11%	$2.13E-01$ +/-8%	1.03	1.08	1.08
2.07	$1.82E-01$ +/-11%	$1.61E-01$ +/-8%	1.13	1.18	1.18
2.67	$1.36E-01$ +/-11%	$1.20E-01$ +/-8%	1.13	1.18	1.18
3.28	$1.11E-01$ +/-11%	$9.60E-02$ +/-7%	1.16	1.20	1.21
4.15	$8.93E-02$ +/-12%	$7.74E-02$ +/-8%	1.15	1.17	1.18
5.25	$7.43E-02$ +/-12%	$6.66E-02$ +/-8%	1.12	1.12	1.11
6.35	$6.61E-02$ +/-12%	$6.21E-02$ +/-9%	1.06	1.05	1.05
7.97	$6.37E-02$ +/-12%	$6.02E-02$ +/-9%	1.06	1.03	1.03
10.08	$6.15E-02$ +/-12%	$5.93E-02$ +/-9%	1.04	1.01	1.01
12.18	$5.99E-02$ +/-12%	$5.90E-02$ +/-9%	1.02	0.99	0.99
15.25	$5.96E-02$ +/-12%	$5.87E-02$ +/-9%	1.02	0.99	0.99
19.30	$5.67E-02$ +/-12%	$5.85E-02$ +/-9%	0.97	0.94	0.94
23.40	$5.92E-02$ +/-12%	$5.83E-02$ +/-9%	1.02	0.99	0.99
27.52	$5.92E-02$ +/-12%	$5.81E-02$ +/-9%	1.02	0.99	0.99
34.63	$5.88E-02$ +/-12%	$5.78E-02$ +/-9%	1.02	0.99	0.99
44.68	$5.82E-02$ +/-12%	$5.73E-02$ +/-9%	1.02	0.99	0.99
54.78	$5.77E-02$ +/-12%	$5.69E-02$ +/-9%	1.01	0.99	0.99
mean % diff. from E		6	7	7	7

Product	Pathways	T_{1/2}	Path %	E/C	ΔE%
Ne23	Mg26(n,α)Ne23	37.2s	100.0	0.99	11%
Na25	Mg25(n,p)Na25	59.6s	96.9	1.13	11%
	Mg26(n,d+np)Na25		3.3	1.13	11%
Na24	Mg24(n,p)Na24	14.9h	99.0	1.01	12%
	Mg25(n,d+np)Na24		0.0	1.01	12%

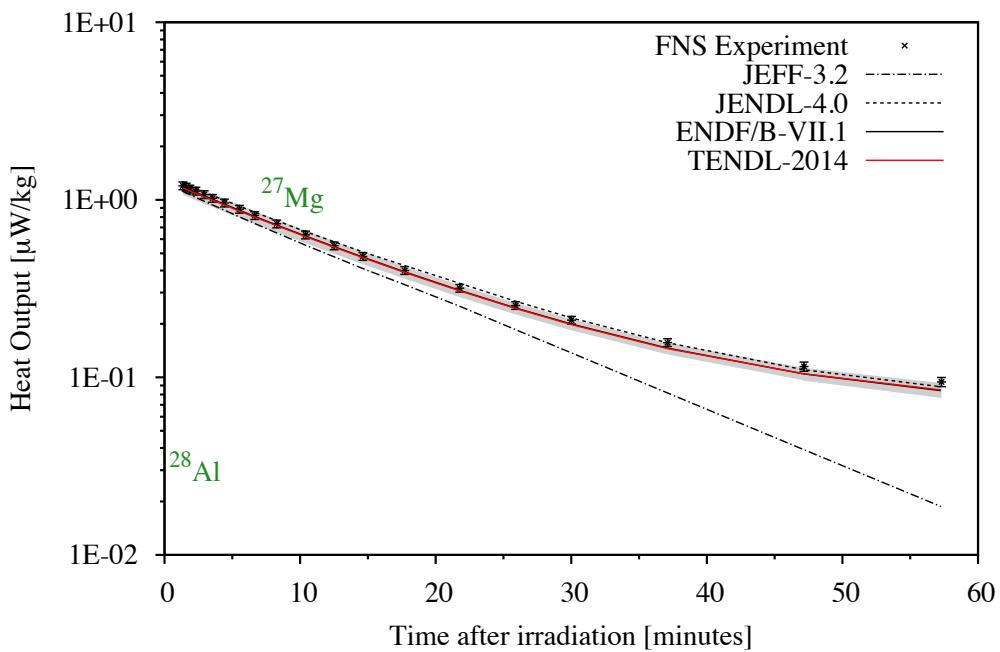


Aluminium

FNS-00 5 Min. Irradiation - Al



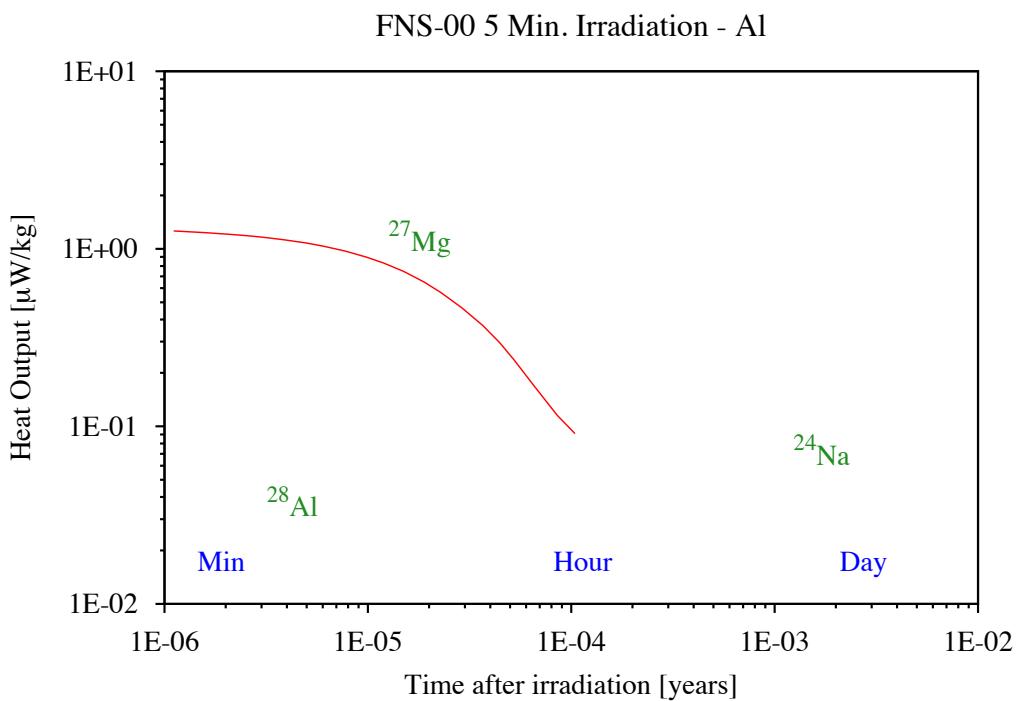
FNS-96 5 Min. Irradiation - Al



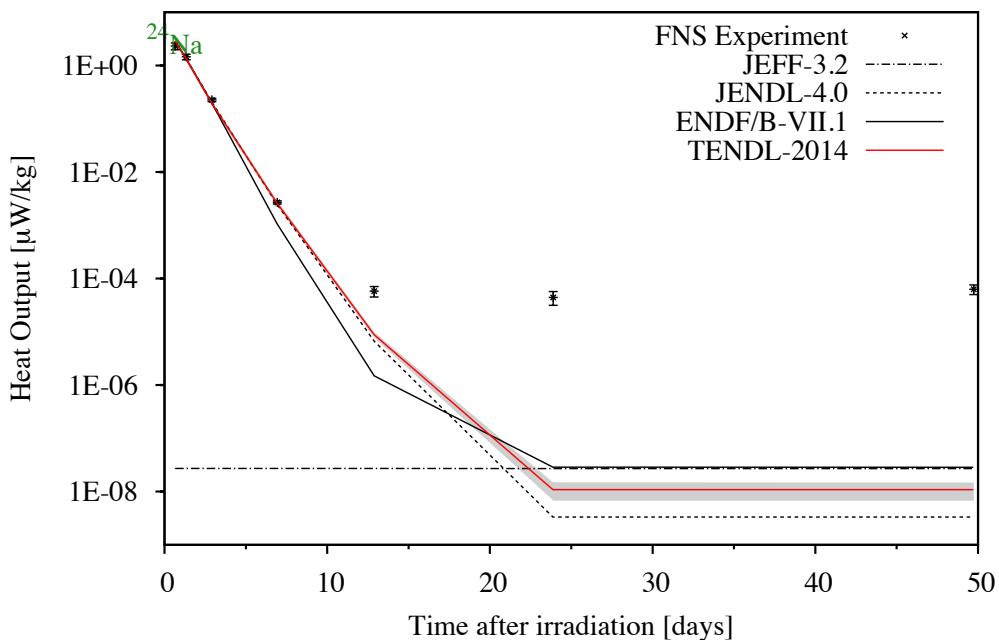
For Aluminium, an excellent agreement can be seen, for both batches, for the production route of the ^{27}Mg radionuclide. TENDL variance reflects well the experimental uncertainty.

Times Min.	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0	
	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C	
0.58	$1.14E+00 +/- 6\%$	$1.26E+00 +/- 8\%$	0.90	0.89	0.95	0.86
0.83	$1.12E+00 +/- 6\%$	$1.23E+00 +/- 9\%$	0.91	0.90	0.95	0.86
1.08	$1.10E+00 +/- 6\%$	$1.21E+00 +/- 9\%$	0.91	0.90	0.95	0.86
1.33	$1.08E+00 +/- 6\%$	$1.18E+00 +/- 9\%$	0.91	0.90	0.96	0.86
1.58	$1.06E+00 +/- 6\%$	$1.16E+00 +/- 9\%$	0.91	0.90	0.96	0.86
2.02	$1.03E+00 +/- 6\%$	$1.13E+00 +/- 9\%$	0.92	0.91	0.97	0.87
2.62	$9.88E-01 +/- 6\%$	$1.08E+00 +/- 9\%$	0.92	0.91	0.97	0.87
3.22	$9.49E-01 +/- 6\%$	$1.03E+00 +/- 9\%$	0.92	0.91	0.98	0.87
4.08	$8.93E-01 +/- 6\%$	$9.70E-01 +/- 9\%$	0.92	0.91	0.99	0.87
5.18	$8.31E-01 +/- 6\%$	$8.98E-01 +/- 8\%$	0.93	0.92	1.00	0.87
6.28	$7.73E-01 +/- 6\%$	$8.32E-01 +/- 8\%$	0.93	0.93	1.01	0.88
7.90	$6.95E-01 +/- 6\%$	$7.45E-01 +/- 8\%$	0.93	0.93	1.03	0.88
10.02	$6.06E-01 +/- 6\%$	$6.47E-01 +/- 8\%$	0.94	0.93	1.05	0.88
12.12	$5.30E-01 +/- 6\%$	$5.64E-01 +/- 8\%$	0.94	0.94	1.07	0.89
15.23	$4.37E-01 +/- 6\%$	$4.66E-01 +/- 8\%$	0.94	0.94	1.11	0.89
19.33	$3.42E-01 +/- 6\%$	$3.69E-01 +/- 8\%$	0.93	0.95	1.18	0.90
23.43	$2.71E-01 +/- 6\%$	$2.95E-01 +/- 8\%$	0.92	0.95	1.26	0.90
27.53	$2.18E-01 +/- 6\%$	$2.37E-01 +/- 7\%$	0.92	0.95	1.38	0.91
34.67	$1.59E-01 +/- 6\%$	$1.68E-01 +/- 7\%$	0.94	0.96	1.70	0.93
44.77	$1.11E-01 +/- 6\%$	$1.16E-01 +/- 8\%$	0.96	0.97	2.55	0.95
54.87	$8.76E-02 +/- 6\%$	$9.10E-02 +/- 9\%$	0.96	0.97	4.21	0.95
mean % diff. from E			8	8	14	13

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Mg27	Al27(n,p)Mg27	9.4m	99.9	0.94	6%



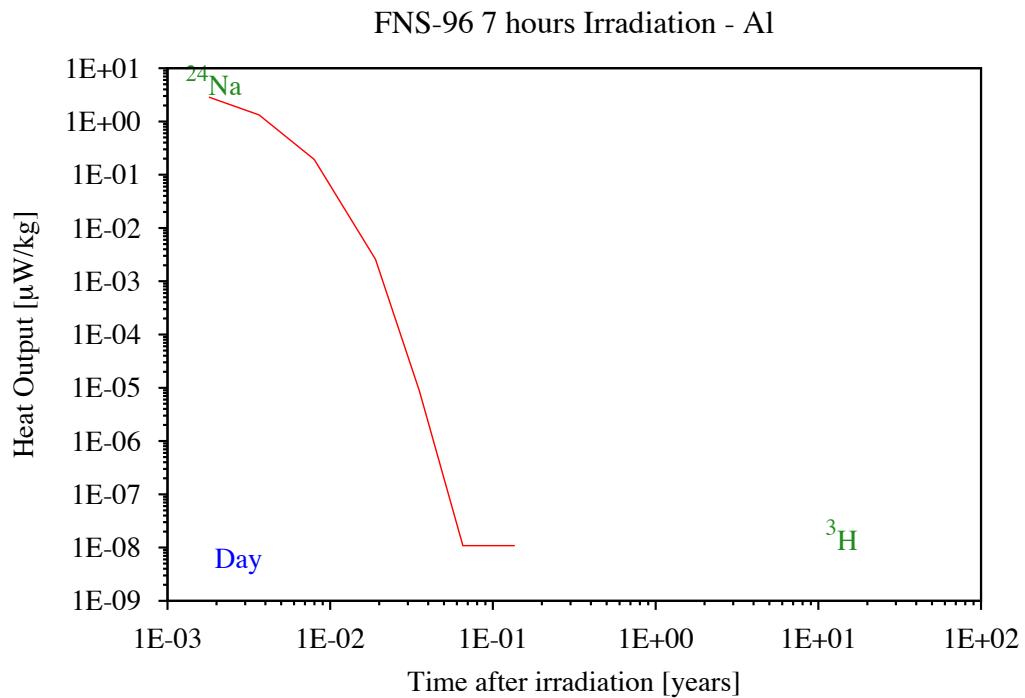
FNS-96 7 hours Irradiation - Al

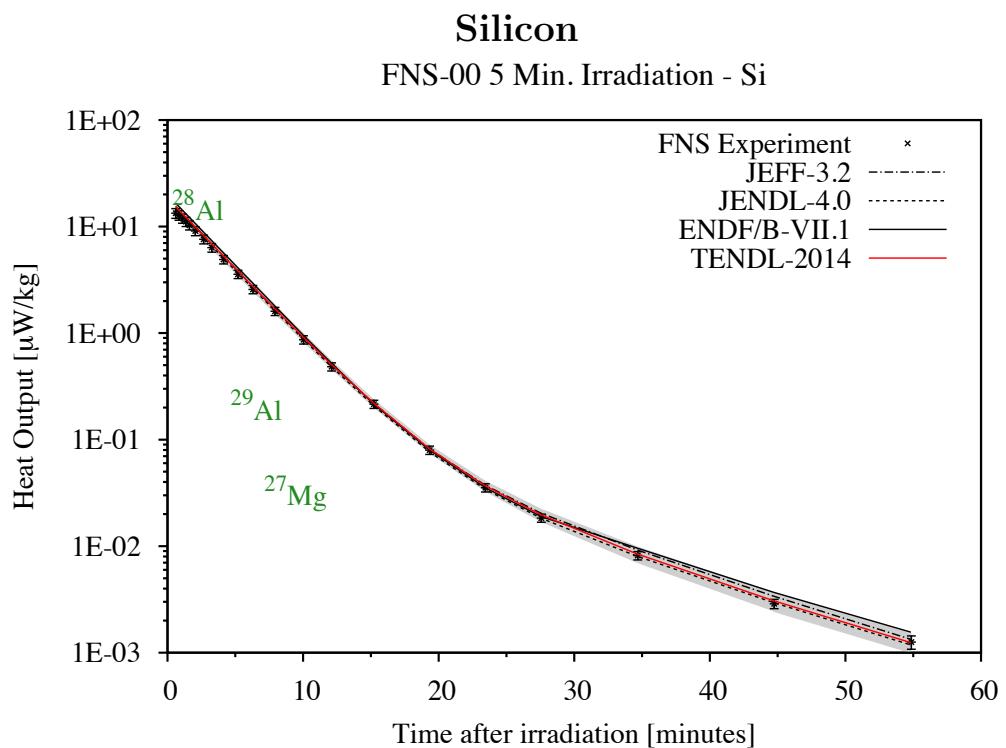


The rather good agreement with all libraries, except JEFF-3.2, up to 7 days of cooling, does not persist at longer times. This may be due to unaccounted levels of impurities in the sample – indeed, thousands of ppm of Mn and Fe are enough to generate such levels of heat. It could also be due to a severe underestimation in the production of H3 or Al26.

Times	FNS EXP. 7 hrs	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Days	μW/g	μW/g	E/C	E/C	E/C
0.66	$2.31E+00 +/- 14\%$	$2.86E+00 +/- 12\%$	0.81	0.81	> 1000
1.34	$1.46E+00 +/- 12\%$	$1.33E+00 +/- 12\%$	1.09	1.10	> 1000
2.92	$2.25E-01 +/- 7\%$	$1.93E-01 +/- 12\%$	1.16	1.15	> 1000
6.93	$2.68E-03 +/- 7\%$	$2.59E-03 +/- 12\%$	1.04	2.53	> 1000
12.89	$5.78E-05 +/- 22\%$	$8.82E-06 +/- 12\%$	6.56	38.91	8.69
23.89	$4.40E-05 +/- 29\%$	$1.09E-08 +/- 36\%$	> 1000	> 1000	> 1000
49.74	$6.28E-05 +/- 20\%$	$1.09E-08 +/- 36\%$	> 1000	> 1000	> 1000
mean % diff. from E		48	58	100	48

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Na24	Al27(n, α)Na24	14.9h	99.9	1.09	12%
	Al27(n, α)Na24m	0.02s	0.0	1.09	12%

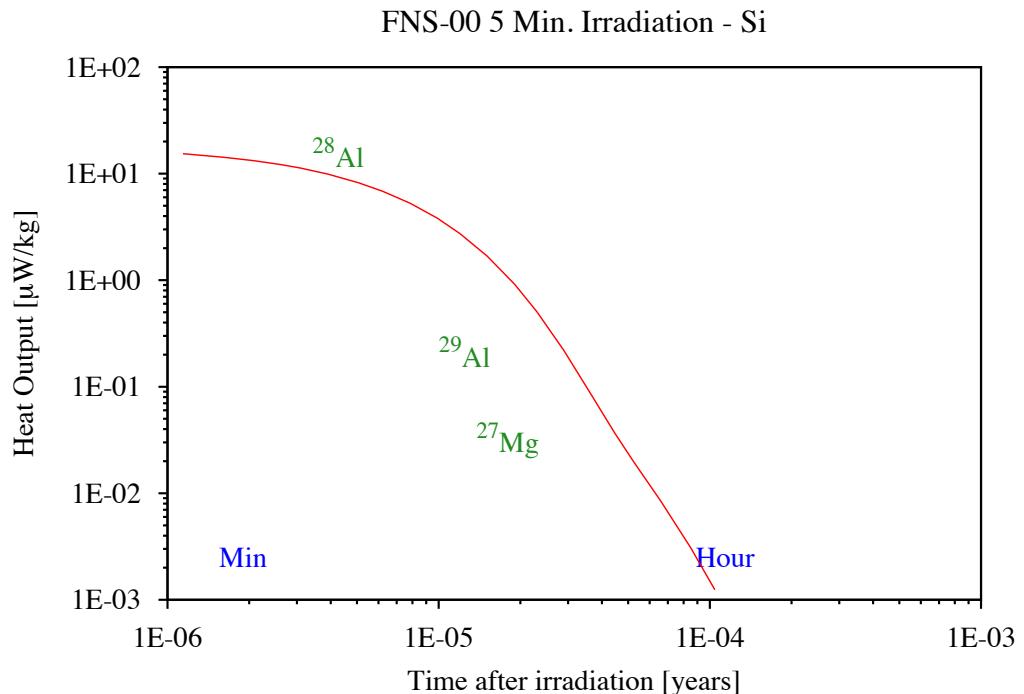




For Silicon, the first irradiated sample in 1996 (results not shown) was made of silicon oxide that certainly did contain some unaccounted level of impurities, causing an under prediction in the simulation. The second experiment contained solely pure silicon as powder and the decay heat is predicted with a much better agreement for all libraries.

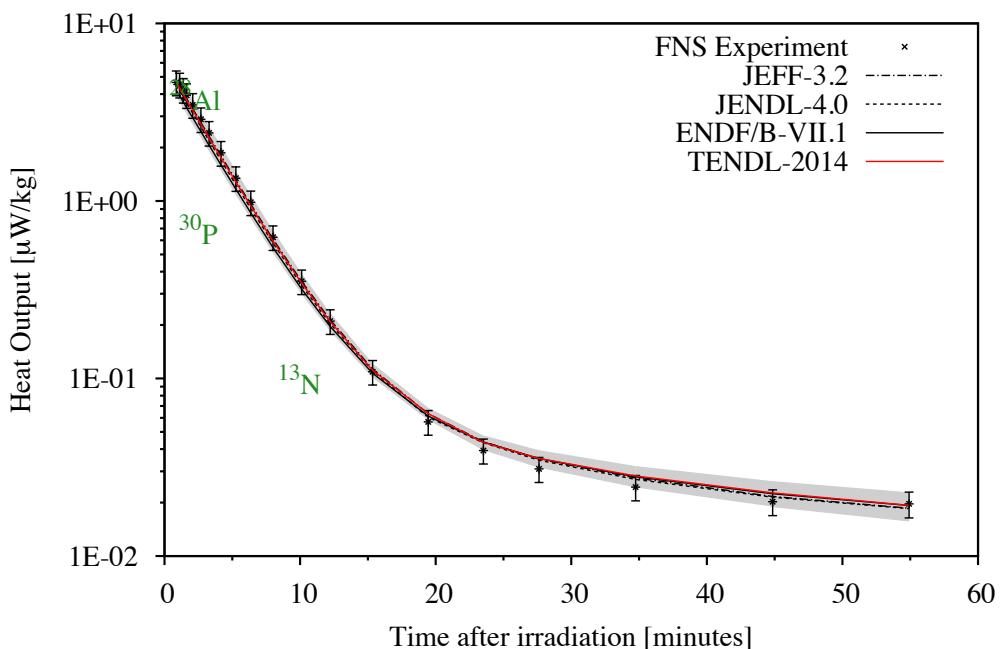
Times	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.60	$1.33E+01$ +/-10%	$1.54E+01$ +/-11%	0.87	0.80	0.86
0.85	$1.28E+01$ +/-10%	$1.43E+01$ +/-11%	0.89	0.83	0.89
1.10	$1.19E+01$ +/-10%	$1.32E+01$ +/-11%	0.90	0.84	0.90
1.37	$1.11E+01$ +/-10%	$1.22E+01$ +/-11%	0.91	0.84	0.91
1.62	$1.03E+01$ +/-10%	$1.13E+01$ +/-11%	0.91	0.84	0.91
2.05	$9.08E+00$ +/-10%	$9.91E+00$ +/-11%	0.92	0.85	0.91
2.67	$7.59E+00$ +/-9%	$8.21E+00$ +/-11%	0.92	0.86	0.92
3.27	$6.34E+00$ +/-9%	$6.84E+00$ +/-11%	0.93	0.86	0.92
4.13	$4.91E+00$ +/-9%	$5.26E+00$ +/-11%	0.93	0.87	0.93
5.20	$3.57E+00$ +/-9%	$3.81E+00$ +/-11%	0.94	0.87	0.94
6.30	$2.57E+00$ +/-9%	$2.74E+00$ +/-11%	0.94	0.88	0.94
7.93	$1.60E+00$ +/-9%	$1.69E+00$ +/-11%	0.95	0.90	0.96
10.03	$8.67E-01$ +/-9%	$9.12E-01$ +/-10%	0.95	0.91	0.96
12.10	$4.83E-01$ +/-9%	$5.07E-01$ +/-10%	0.95	0.92	0.96
15.22	$2.15E-01$ +/-9%	$2.20E-01$ +/-9%	0.98	1.00	0.99
19.33	$7.97E-02$ +/-9%	$8.20E-02$ +/-10%	0.97	1.00	0.98
23.45	$3.53E-02$ +/-9%	$3.69E-02$ +/-12%	0.96	1.00	0.95
27.57	$1.84E-02$ +/-9%	$1.97E-02$ +/-14%	0.93	0.97	0.90
34.68	$8.16E-03$ +/-9%	$8.43E-03$ +/-18%	0.97	0.85	0.89
44.75	$2.88E-03$ +/-10%	$3.07E-03$ +/-21%	0.94	0.78	0.85
54.87	$1.26E-03$ +/-14%	$1.24E-03$ +/-23%	1.01	0.81	0.94
mean % diff. from E		7	14	8	4

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Al28	Si28(n,p)Al28	2.2m	97.8	0.92	10%
Al29	Si29(n,p)Al29	6.5m	98.8	0.95	9%
	Si30(n,d+np)Al29		0.7	0.95	9%
Mg27	Si30(n, α)Mg27	9.4m	99.9	0.95	9%



Phosphorus

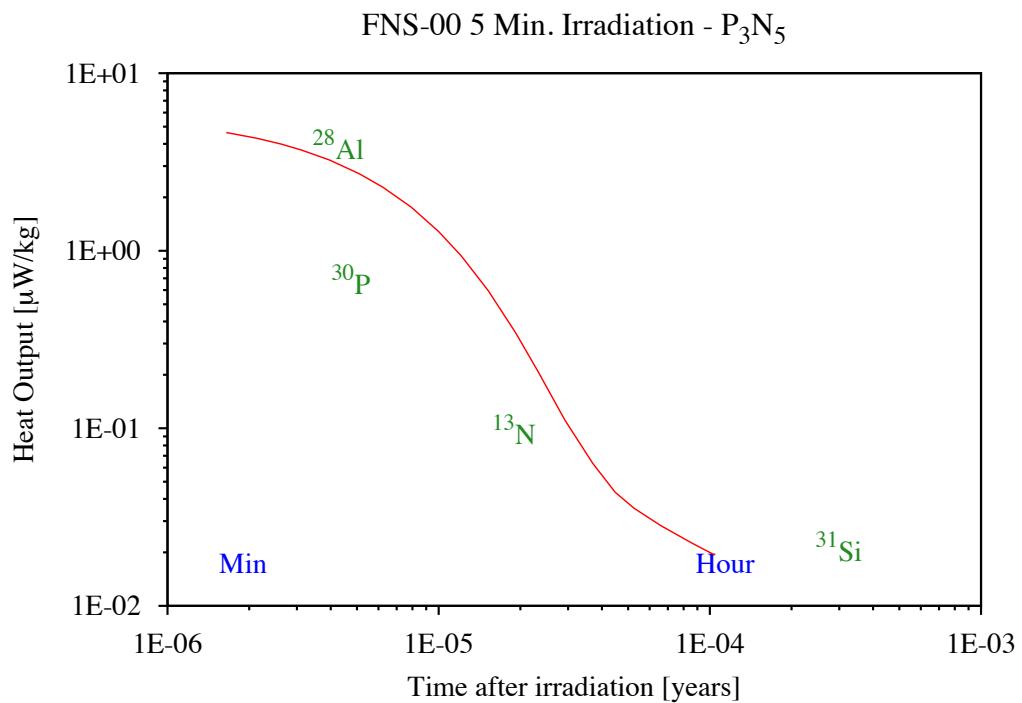
FNS-00 5 Min. Irradiation - P₃N₅



For Phosphorus, there is good agreement with the decay heat predictions for this nitrate sample, with the predictions well within a suspiciously uniform experimental uncertainty of 16%.

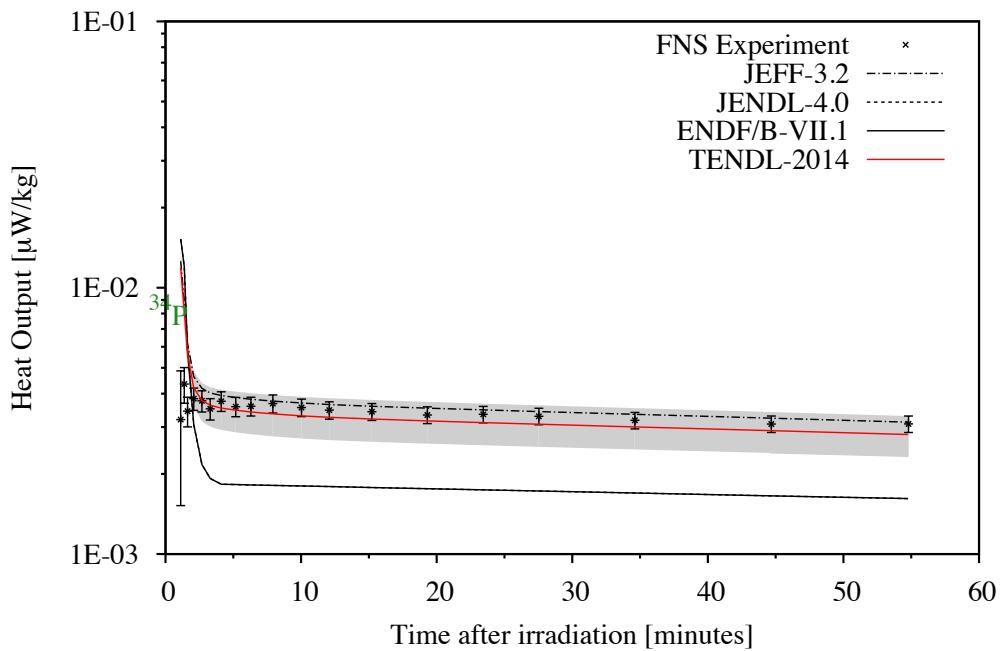
Times Min.	FNS EXP. 5 mins μW/g	TENDL-2014 μW/g	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.87	$4.65E+00$ +/-16%	$4.63E+00$ +/-17%	1.00	1.11	0.99	1.04
1.12	$4.52E+00$ +/-16%	$4.31E+00$ +/-17%	1.05	1.16	1.03	1.09
1.38	$4.22E+00$ +/-16%	$3.99E+00$ +/-17%	1.06	1.17	1.04	1.10
1.63	$3.94E+00$ +/-16%	$3.70E+00$ +/-17%	1.06	1.18	1.05	1.11
2.08	$3.47E+00$ +/-16%	$3.24E+00$ +/-17%	1.07	1.18	1.05	1.11
2.68	$2.88E+00$ +/-16%	$2.71E+00$ +/-16%	1.06	1.17	1.04	1.10
3.28	$2.42E+00$ +/-16%	$2.27E+00$ +/-16%	1.06	1.17	1.04	1.10
4.17	$1.87E+00$ +/-16%	$1.76E+00$ +/-16%	1.06	1.17	1.04	1.10
5.27	$1.34E+00$ +/-16%	$1.28E+00$ +/-16%	1.05	1.15	1.03	1.09
6.37	$9.82E-01$ +/-16%	$9.37E-01$ +/-15%	1.05	1.15	1.03	1.08
8.00	$6.25E-01$ +/-16%	$5.98E-01$ +/-15%	1.05	1.14	1.02	1.08
10.12	$3.53E-01$ +/-16%	$3.45E-01$ +/-13%	1.02	1.10	1.00	1.05
12.22	$2.10E-01$ +/-16%	$2.10E-01$ +/-12%	1.00	1.07	0.98	1.03
15.35	$1.09E-01$ +/-16%	$1.12E-01$ +/-9%	0.98	1.02	0.96	0.98
19.45	$5.70E-02$ +/-16%	$6.34E-02$ +/-8%	0.90	0.93	0.90	0.94
23.52	$3.93E-02$ +/-16%	$4.37E-02$ +/-10%	0.90	0.89	0.89	0.90
27.62	$3.10E-02$ +/-16%	$3.55E-02$ +/-11%	0.87	0.87	0.88	0.89
34.75	$2.45E-02$ +/-16%	$2.82E-02$ +/-14%	0.87	0.87	0.89	0.90
44.85	$2.02E-02$ +/-17%	$2.27E-02$ +/-16%	0.89	0.90	0.93	0.94
54.92	$1.97E-02$ +/-17%	$1.93E-02$ +/-18%	1.02	1.02	1.06	
mean % diff. from E			6	11	5	8

Product	Pathways	T _{1/2}	Path %	E/C	ΔE%
Al28	P31(n,α)Al28	2.2m	100.0	1.06	16%
N13	N14(n,2n)N13	9.9m	100.0	1.02	16%

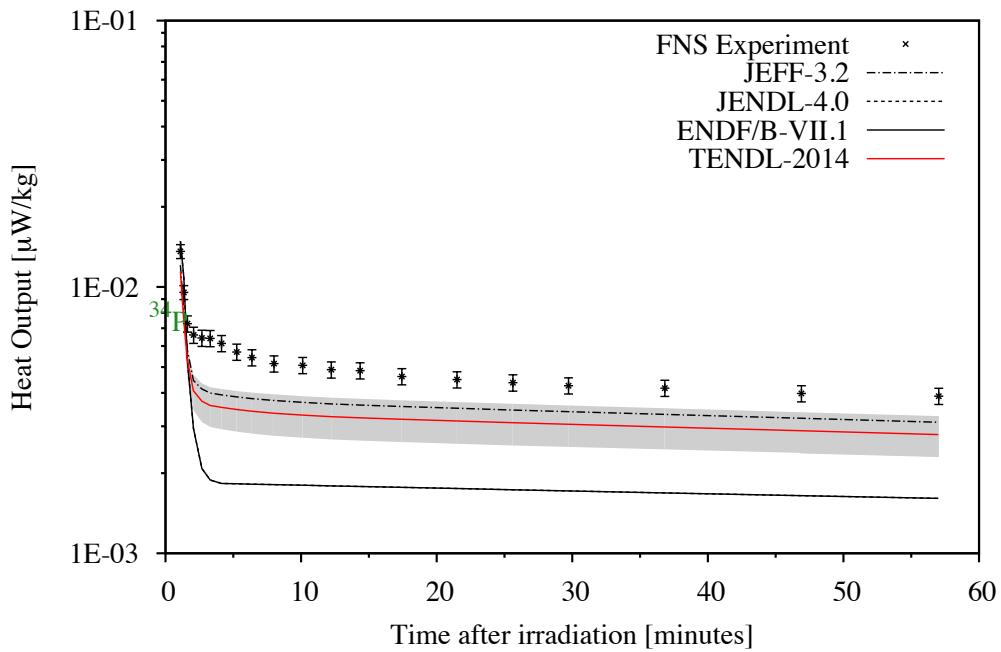


Sulphur

FNS-00 5 Min. Irradiation - S



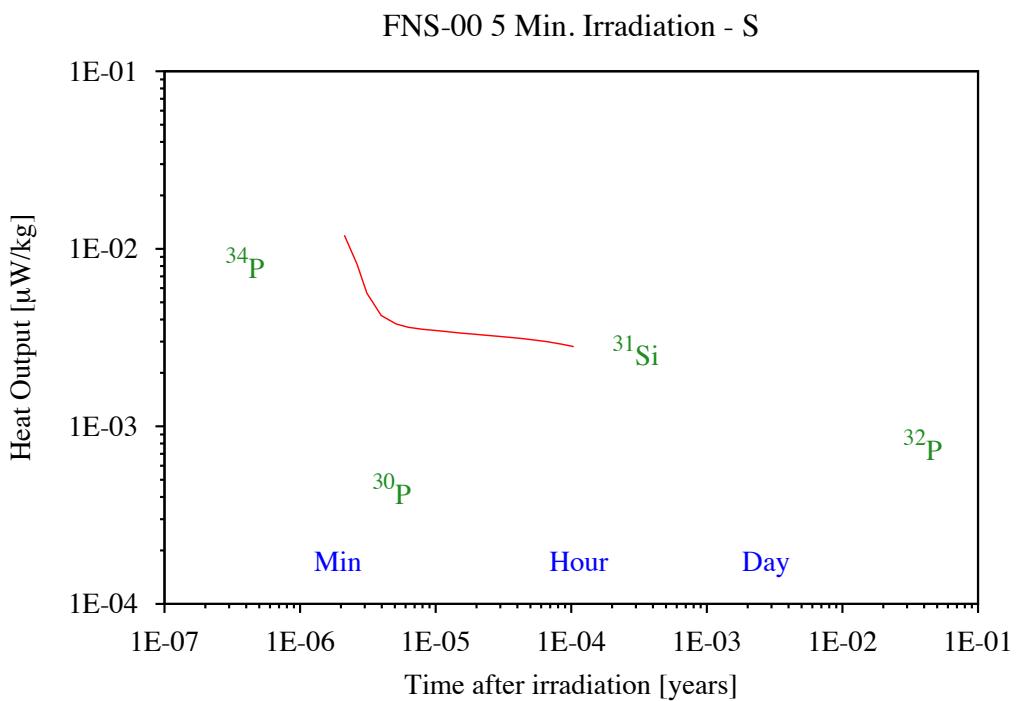
FNS-96 5 Min. Irradiation - S

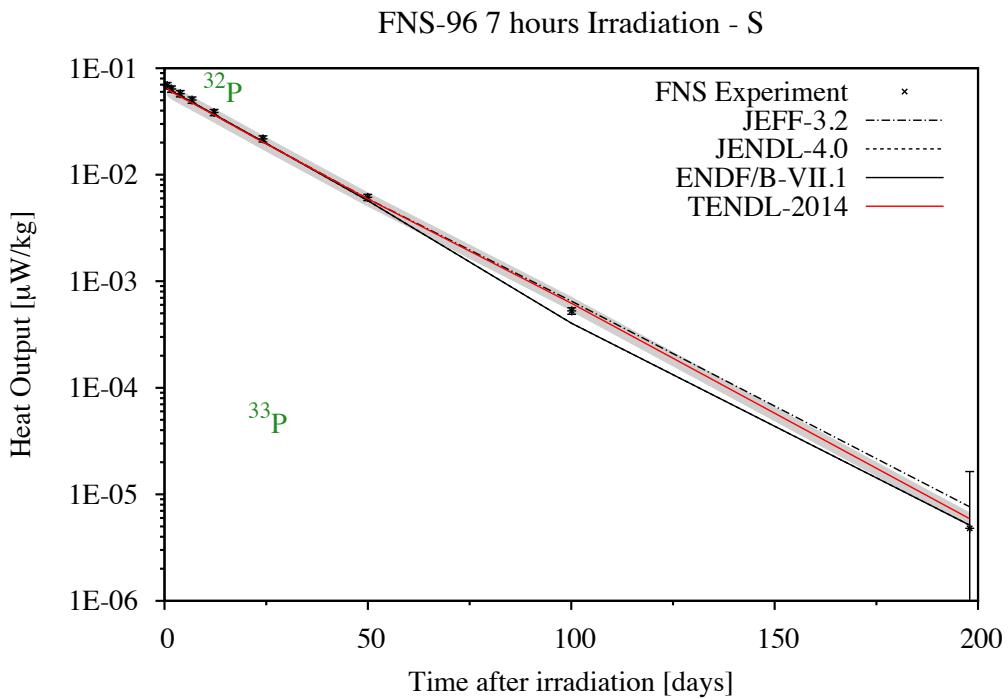


For Sulphur, it is clear that the two sets of experimental measurements do not agree, despite the fact that they should have been performed on identical sample materials. TENDL-2014 and JEFF-3.2 agree well on the most recent one. Nothing further can be extracted from such discrepant experimental results, other than an identification of the predominant isotopes.

Times Min.	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
1.12	$3.20E-03 +/- 52\%$	$1.19E-02 +/- 16\%$	0.27	0.21	0.25
1.38	$4.35E-03 +/- 15\%$	$8.21E-03 +/- 14\%$	0.53	0.36	0.49
1.63	$3.44E-03 +/- 13\%$	$5.63E-03 +/- 13\%$	0.61	0.59	0.56
2.08	$3.83E-03 +/- 10\%$	$4.21E-03 +/- 15\%$	0.91	1.25	0.83
2.68	$3.76E-03 +/- 9\%$	$3.77E-03 +/- 16\%$	1.00	1.73	0.90
3.30	$3.51E-03 +/- 9\%$	$3.62E-03 +/- 17\%$	0.97	1.83	0.87
4.12	$3.75E-03 +/- 8\%$	$3.53E-03 +/- 17\%$	1.06	2.05	0.95
5.18	$3.58E-03 +/- 8\%$	$3.47E-03 +/- 17\%$	1.03	1.96	0.92
6.30	$3.59E-03 +/- 8\%$	$3.42E-03 +/- 18\%$	1.05	1.97	0.94
7.92	$3.67E-03 +/- 8\%$	$3.36E-03 +/- 18\%$	1.09	2.03	0.98
10.03	$3.55E-03 +/- 8\%$	$3.30E-03 +/- 18\%$	1.07	1.97	0.96
12.08	$3.47E-03 +/- 7\%$	$3.26E-03 +/- 18\%$	1.06	1.94	0.95
15.22	$3.43E-03 +/- 7\%$	$3.21E-03 +/- 18\%$	1.07	1.93	0.95
19.32	$3.33E-03 +/- 7\%$	$3.16E-03 +/- 18\%$	1.05	1.89	0.94
23.43	$3.35E-03 +/- 7\%$	$3.12E-03 +/- 18\%$	1.07	1.92	0.96
27.53	$3.29E-03 +/- 7\%$	$3.07E-03 +/- 18\%$	1.07	1.91	0.96
34.62	$3.18E-03 +/- 7\%$	$3.00E-03 +/- 18\%$	1.06	1.87	0.95
44.68	$3.08E-03 +/- 7\%$	$2.91E-03 +/- 17\%$	1.06	1.86	0.95
54.80	$3.08E-03 +/- 7\%$	$2.81E-03 +/- 17\%$	1.10	1.91	0.98
mean % diff. from E			27	72	31
					72

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
P34	S34(n,p)P34	12.4s	100.0	0.27	52%
Si31	S32(n,2p)Si31	2.62h	20.6	1.06	7%
	S34(n, α)Si31		70.5	1.06	7%

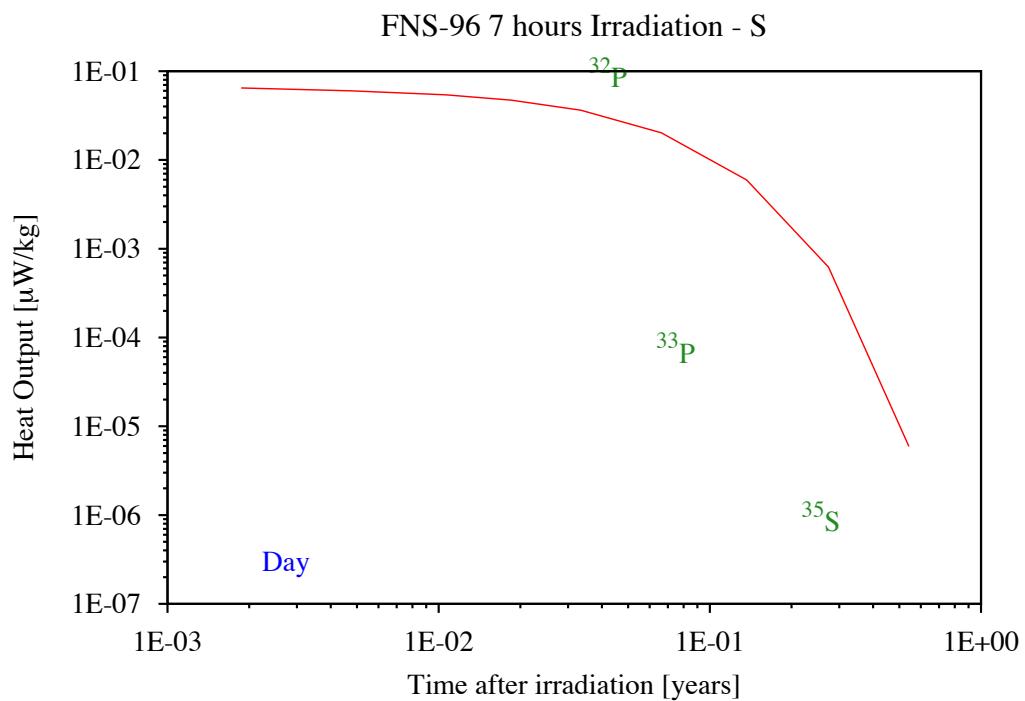


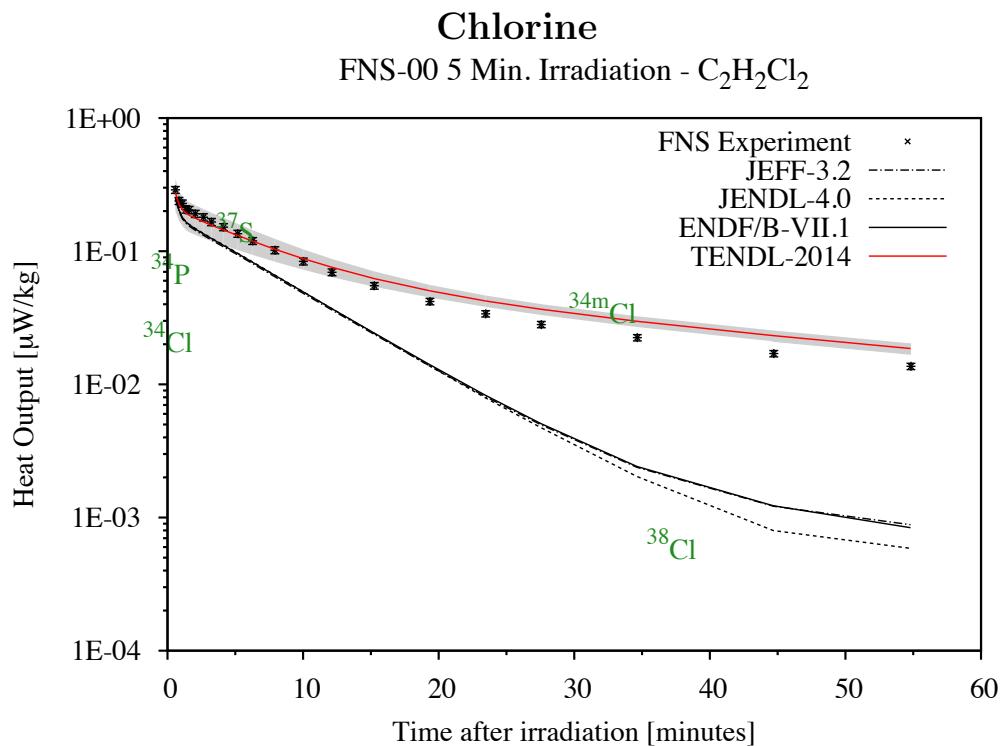


Good agreement with TENDL-2014 for this unambiguous, text-book case. None of the others libraries contains covariance for this channel.

Times	FNS EXP. 7 hrs	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Days	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.68	$6.87E-02 +/-7\%$	$6.48E-02 +/-15\%$	1.06	1.06	1.05
1.74	$6.38E-02 +/-7\%$	$6.01E-02 +/-15\%$	1.06	1.05	1.06
3.89	$5.77E-02 +/-7\%$	$5.41E-02 +/-15\%$	1.07	1.05	1.06
6.76	$5.02E-02 +/-7\%$	$4.73E-02 +/-15\%$	1.06	1.05	1.06
12.20	$3.84E-02 +/-7\%$	$3.64E-02 +/-15\%$	1.06	1.04	1.05
24.21	$2.17E-02 +/-7\%$	$2.02E-02 +/-15\%$	1.07	1.06	1.07
49.96	$6.13E-03 +/-7\%$	$5.94E-03 +/-15\%$	1.03	1.07	1.07
100.09	$5.27E-04 +/-7\%$	$6.21E-04 +/-15\%$	0.85	1.31	0.81
197.94	$4.79E-06 +/-242\%$	$5.93E-06 +/-15\%$	0.81	0.93	0.93
mean % diff. from E		9	8	13	8

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
P32	S32(n,p)P32	14.2d	99.5	1.06	7%
	S33(n,d+np)P32		0.0	1.06	7%

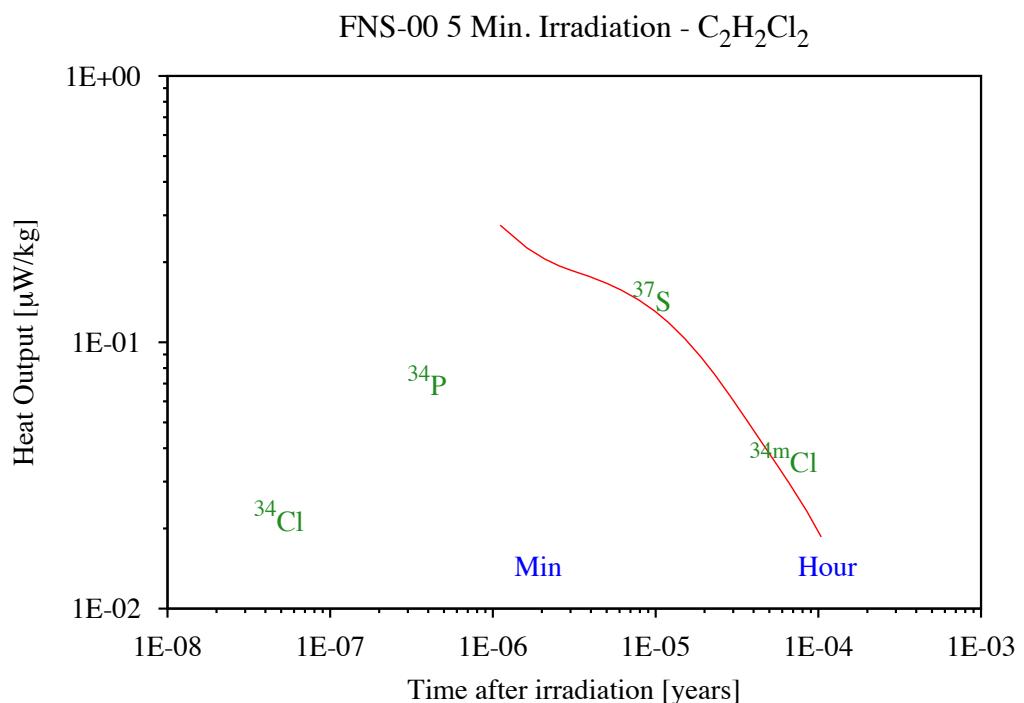


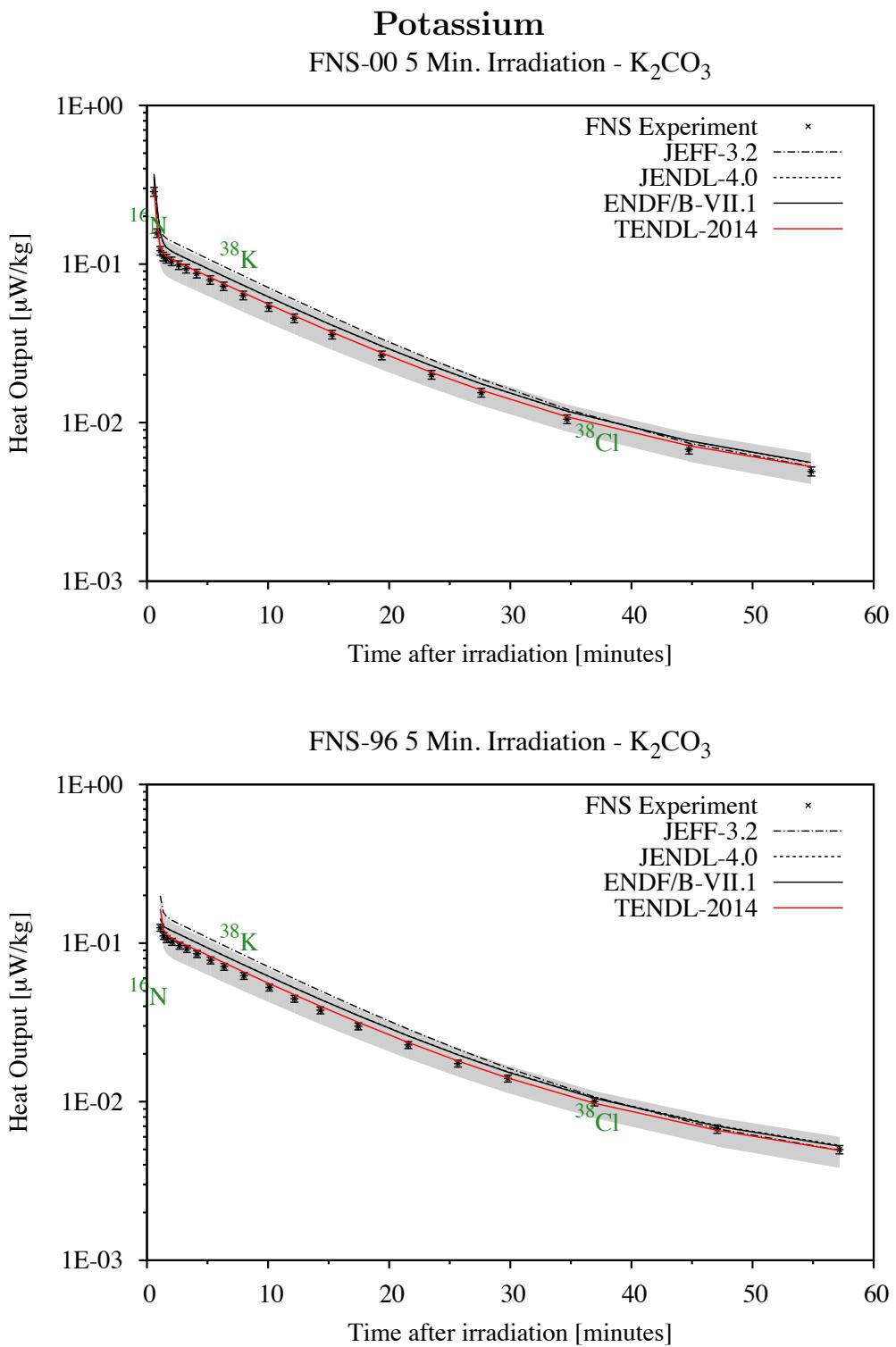


For Chlorine, a good agreement can be seen up to the point when Cl34m becomes predominant when TENDL-2014 is used. The discrepancy beyond this may be due to an incorrect branching ratio or decay heat level allocated to this short-lived metastable. None of the other libraries produce this predominant metastable.

Times	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.58	$2.89E-01$ +/-6%	$2.75E-01$ +/-27%	1.05	1.14	1.16
0.85	$2.39E-01$ +/-6%	$2.26E-01$ +/-25%	1.06	1.17	1.19
1.10	$2.28E-01$ +/-6%	$2.05E-01$ +/-25%	1.11	1.27	1.30
1.35	$2.06E-01$ +/-6%	$1.93E-01$ +/-25%	1.07	1.24	1.27
1.60	$2.04E-01$ +/-6%	$1.86E-01$ +/-25%	1.10	1.29	1.32
2.05	$1.91E-01$ +/-6%	$1.77E-01$ +/-25%	1.08	1.30	1.33
2.65	$1.80E-01$ +/-6%	$1.66E-01$ +/-25%	1.08	1.33	1.37
3.25	$1.66E-01$ +/-6%	$1.57E-01$ +/-24%	1.06	1.33	1.37
4.13	$1.52E-01$ +/-6%	$1.44E-01$ +/-23%	1.05	1.37	1.41
5.18	$1.35E-01$ +/-6%	$1.31E-01$ +/-22%	1.03	1.41	1.45
6.28	$1.19E-01$ +/-6%	$1.19E-01$ +/-21%	1.00	1.45	1.48
7.92	$1.02E-01$ +/-6%	$1.04E-01$ +/-20%	0.98	1.54	1.58
10.02	$8.38E-02$ +/-6%	$8.79E-02$ +/-17%	0.95	1.70	1.74
12.13	$6.95E-02$ +/-6%	$7.57E-02$ +/-16%	0.92	1.88	1.92
15.25	$5.50E-02$ +/-6%	$6.23E-02$ +/-13%	0.88	2.26	2.32
19.35	$4.19E-02$ +/-6%	$5.04E-02$ +/-11%	0.83	2.98	3.04
23.47	$3.39E-02$ +/-6%	$4.23E-02$ +/-10%	0.80	4.09	4.18
27.57	$2.81E-02$ +/-5%	$3.66E-02$ +/-9%	0.77	5.55	5.66
34.65	$2.24E-02$ +/-5%	$2.97E-02$ +/-9%	0.75	9.28	9.42
44.72	$1.70E-02$ +/-5%	$2.32E-02$ +/-9%	0.73	13.90	13.99
54.83	$1.37E-02$ +/-5%	$1.86E-02$ +/-9%	0.74	16.28	15.45
mean	% diff. from E	13	44	45	45

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
P34	$\text{Cl}^{37}(\text{n},\alpha)\text{P}^{34}$	12.4s	99.9	1.06	6%
S37	$\text{Cl}^{37}(\text{n},\text{p})\text{S}^{37}$	4.9m	100.0	1.03	6%
Cl^{34}m	$\text{Cl}^{35}(\text{n},2\text{n})\text{Cl}^{34}\text{m}$	32.1m	100.0	0.75	5%

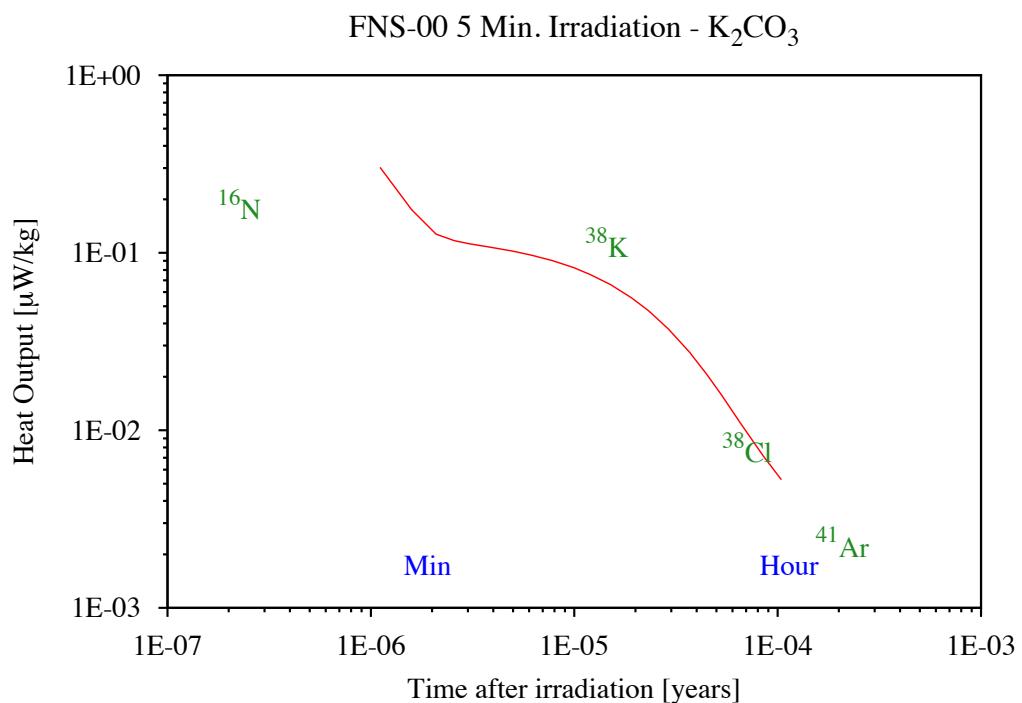


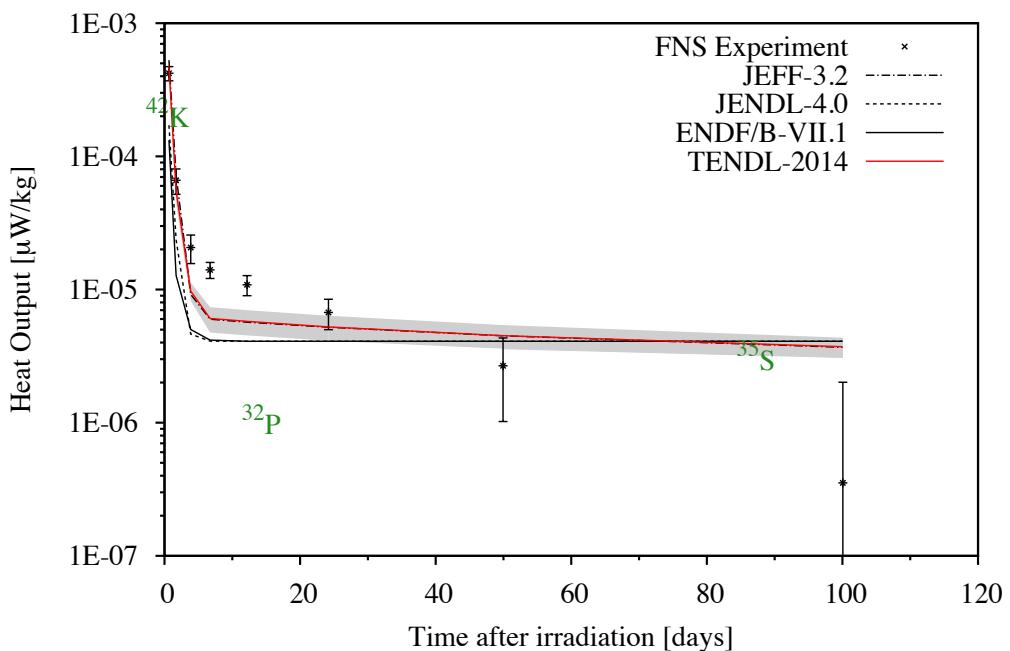


For Potassium, the extremely rapid measurements made barely 34 seconds after irradiation allow a glimpse of the N16 isotope heat, prior to the appearance of K38, and then Cl38, both of which are over-predicted by all libraries except TENDL-2014

Times	FNS	EXP.	5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.				E/C	E/C	E/C	E/C
0.58				$2.85E-01$ +/-7% $3.03E-01$ +/-10% 0.94	0.77	0.83	0.80
0.83				$1.57E-01$ +/-6% $1.75E-01$ +/-17% 0.90	0.67	0.78	0.70
1.10				$1.21E-01$ +/-6% $1.27E-01$ +/-23% 0.95	0.77	0.75	0.78
1.35				$1.12E-01$ +/-6% $1.17E-01$ +/-25% 0.96	0.82	0.74	0.82
1.60				$1.08E-01$ +/-6% $1.12E-01$ +/-25% 0.96	0.85	0.74	0.85
2.03				$1.04E-01$ +/-6% $1.07E-01$ +/-25% 0.97	0.87	0.75	0.86
2.63				$9.86E-02$ +/-6% $1.02E-01$ +/-25% 0.97	0.86	0.74	0.86
3.25				$9.36E-02$ +/-6% $9.69E-02$ +/-25% 0.97	0.86	0.74	0.86
4.12				$8.72E-02$ +/-6% $9.03E-02$ +/-25% 0.97	0.86	0.75	0.87
5.22				$7.94E-02$ +/-6% $8.25E-02$ +/-25% 0.96	0.86	0.75	0.86
6.33				$7.25E-02$ +/-6% $7.53E-02$ +/-25% 0.96	0.86	0.75	0.86
7.95				$6.35E-02$ +/-6% $6.60E-02$ +/-24% 0.96	0.86	0.75	0.86
10.05				$5.37E-02$ +/-6% $5.58E-02$ +/-24% 0.96	0.87	0.76	0.87
12.17				$4.55E-02$ +/-6% $4.72E-02$ +/-23% 0.96	0.87	0.76	0.87
15.28				$3.59E-02$ +/-6% $3.72E-02$ +/-23% 0.97	0.87	0.77	0.87
19.38				$2.66E-02$ +/-6% $2.76E-02$ +/-22% 0.96	0.87	0.79	0.88
23.50				$2.01E-02$ +/-6% $2.07E-02$ +/-21% 0.97	0.88	0.80	0.88
27.60				$1.55E-02$ +/-6% $1.60E-02$ +/-20% 0.96	0.88	0.82	0.88
34.68				$1.05E-02$ +/-6% $1.09E-02$ +/-19% 0.97	0.89	0.86	0.89
44.75				$6.77E-03$ +/-6% $7.15E-03$ +/-20% 0.95	0.88	0.91	0.88
54.85				$4.93E-03$ +/-6% $5.27E-03$ +/-22% 0.94	0.88	0.93	0.88
mean % diff. from E				4	18	28	18

Product	Pathways	T _{1/2}	Path %	E/C	ΔE%
N16	O16(n,p)N16	7.1s	100.0	0.94	7%
K38	K39(n,2n)K38	7.6m	100.0	0.96	6%
Cl38	K39(n,2p)Cl38	37.2m	1.7	0.97	6%
	K41(n,α)Cl38		73.9	0.97	6%
	K39(n,2p)Cl38m	0.7s	0.7	0.97	6%
	K41(n,α)Cl38m		24.3	0.97	6%

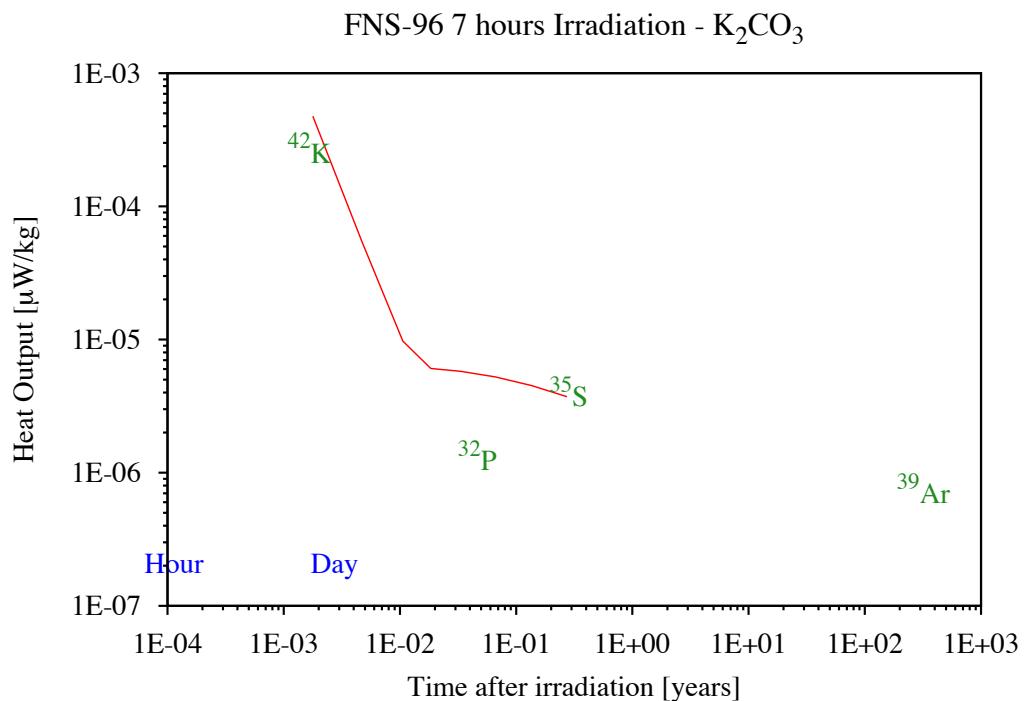


FNS-96 7 hours Irradiation - K_2CO_3 

The rather high uncertainty bands on the experimental results do not allow an in-depth analysis to be undertaken. However, the decay heat profile is properly shaped.

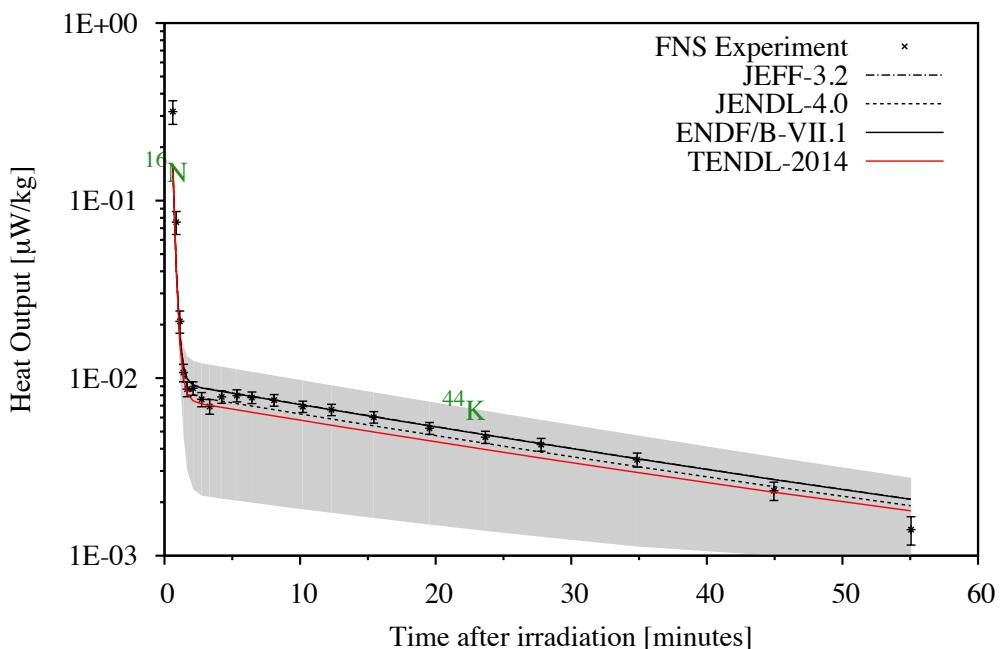
Times Days	FNS EXP. 7 hrs $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.65	$4.21E-04$ +/-12%	$4.75E-04$ +/-13%	0.89	3.18	0.80	2.46
1.71	$6.62E-05$ +/-22%	$5.49E-05$ +/-19%	1.20	5.19	0.91	2.80
3.87	$2.07E-05$ +/-24%	$9.74E-06$ +/-16%	2.12	4.13	2.25	4.47
6.73	$1.40E-05$ +/-14%	$6.06E-06$ +/-22%	2.32	3.37	2.34	3.42
12.18	$1.09E-05$ +/-17%	$5.76E-06$ +/-22%	1.88	2.66	1.91	2.66
24.19	$6.72E-06$ +/-26%	$5.24E-06$ +/-21%	1.28	1.65	1.29	1.65
49.94	$2.68E-06$ +/-62%	$4.50E-06$ +/-20%	0.59	0.66	0.60	0.66
100.07	$3.53E-07$ +/-469%	$3.72E-06$ +/-17%	0.10	0.09	0.10	0.09
mean % diff. from E			154	188	154	185

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
K42	$\text{K}41(\text{n},\gamma)\text{K}42$	12.3h	99.9	0.89	12%
S35	$\text{K}39(\text{n},\text{p}\alpha)\text{S}35$	87.3d	100.0	0.59	62%

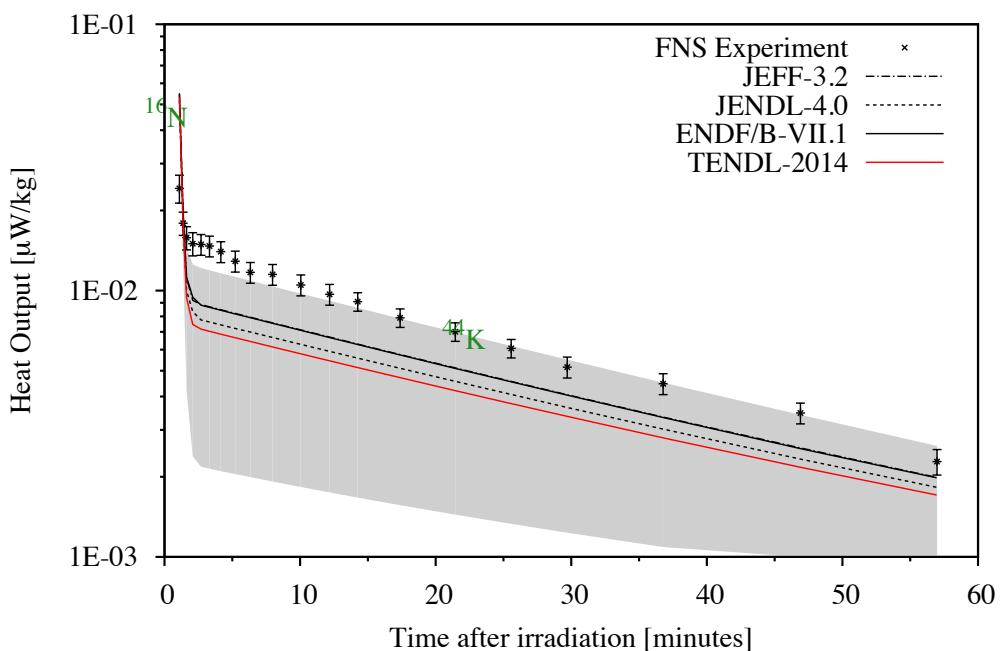


Calcium

FNS-00 5 Min. Irradiation - CaO



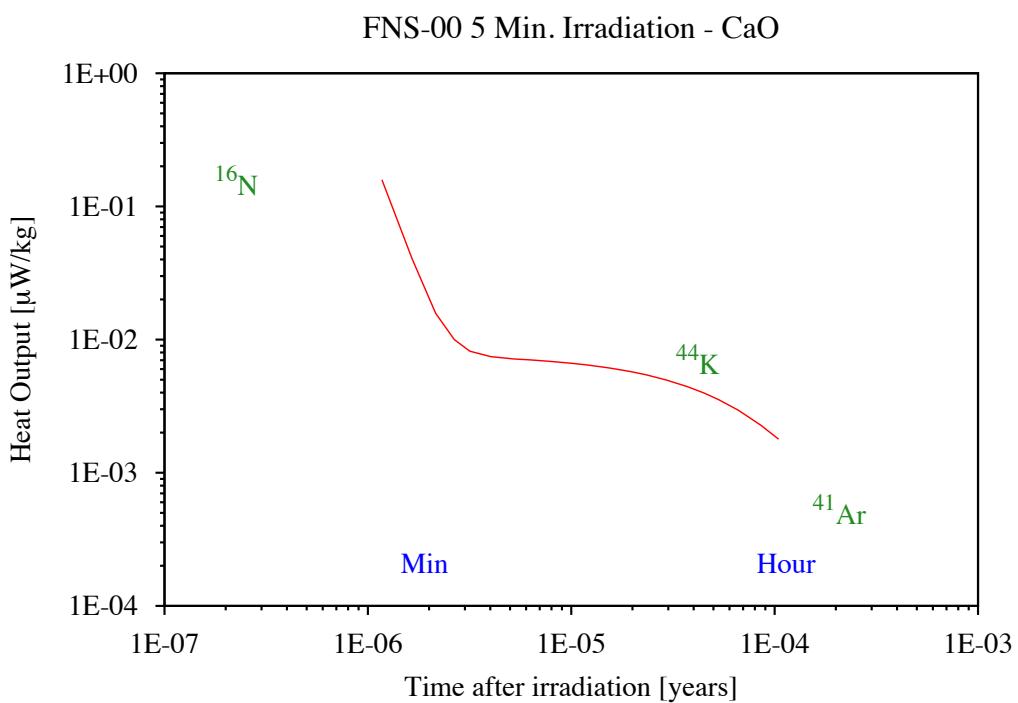
FNS-96 5 Min. Irradiation - CaO

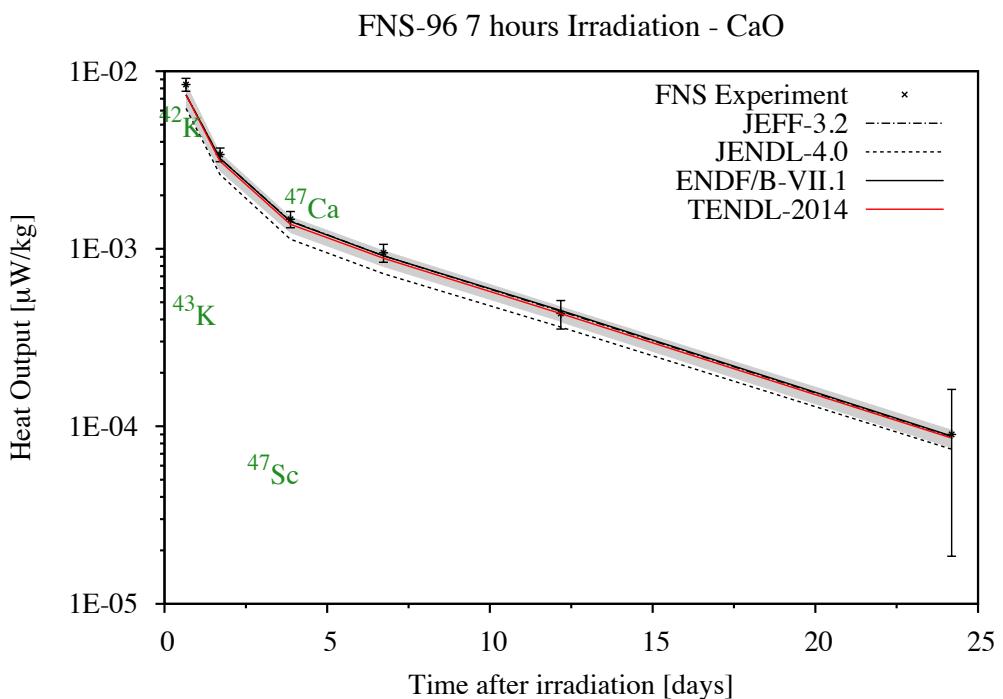


For Calcium, the latest experiment, when analysed with all libraries, seems to lead to a much better agreement than for the earlier experiment, even at rather short cooling times for TENDL-2014. Discrepancies seem to exist between this and the original experiment. One explanation for this is that the CaO powder, being extremely fine, was used in extremely small amounts. Because the sample was sandwiched in-between plastic tape, its contribution needed to be subtracted from the raw measured data. In other words, the signal-to-noise ratio was high. Such a situation should have been better reflected in the otherwise low experimental uncertainties. This situation also occurs for the SrCO₃, Y₂O₃, and SnO₂ samples.

Times Min.	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0	
	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C	
0.62	$3.17E-01$ +/-15%	$1.59E-01$ +/-3%	2.00	1.99	1.98	2.09
0.87	$7.56E-02$ +/-15%	$4.05E-02$ +/-13%	1.86	1.80	1.79	1.90
1.13	$2.09E-02$ +/-14%	$1.57E-02$ +/-33%	1.33	1.24	1.19	1.19
1.40	$1.07E-02$ +/-11%	$1.00E-02$ +/-52%	1.07	0.92	0.91	0.96
1.67	$8.67E-03$ +/-9%	$8.19E-03$ +/-63%	1.06	0.87	0.87	0.96
2.12	$8.77E-03$ +/-9%	$7.44E-03$ +/-68%	1.18	0.96	0.96	1.08
2.73	$7.60E-03$ +/-9%	$7.16E-03$ +/-70%	1.06	0.86	0.86	0.98
3.33	$6.92E-03$ +/-9%	$7.03E-03$ +/-69%	0.98	0.80	0.80	0.91
4.22	$7.85E-03$ +/-8%	$6.85E-03$ +/-69%	1.15	0.93	0.93	1.06
5.33	$7.97E-03$ +/-8%	$6.63E-03$ +/-69%	1.20	0.98	0.97	1.11
6.45	$7.77E-03$ +/-8%	$6.42E-03$ +/-69%	1.21	0.99	0.98	1.12
8.08	$7.51E-03$ +/-7%	$6.13E-03$ +/-69%	1.23	1.00	1.00	1.13
10.20	$6.91E-03$ +/-7%	$5.77E-03$ +/-68%	1.20	0.98	0.97	1.11
12.32	$6.64E-03$ +/-7%	$5.43E-03$ +/-68%	1.22	1.00	1.00	1.13
15.43	$6.02E-03$ +/-7%	$4.98E-03$ +/-67%	1.21	0.99	0.99	1.12
19.55	$5.22E-03$ +/-8%	$4.44E-03$ +/-66%	1.18	0.97	0.96	1.09
23.67	$4.65E-03$ +/-8%	$3.97E-03$ +/-65%	1.17	0.97	0.97	1.08
27.78	$4.22E-03$ +/-8%	$3.55E-03$ +/-64%	1.19	0.99	0.98	1.10
34.87	$3.47E-03$ +/-9%	$2.94E-03$ +/-62%	1.18	0.99	0.98	1.09
44.95	$2.32E-03$ +/-12%	$2.28E-03$ +/-58%	1.02	0.86	0.86	0.95
55.07	$1.40E-03$ +/-18%	$1.79E-03$ +/-54%	0.78	0.68	0.67	0.73
mean % diff. from E			17	13	13	14

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
K44	Ca44(n,p)K44	22.1m	100.0	1.17	8%

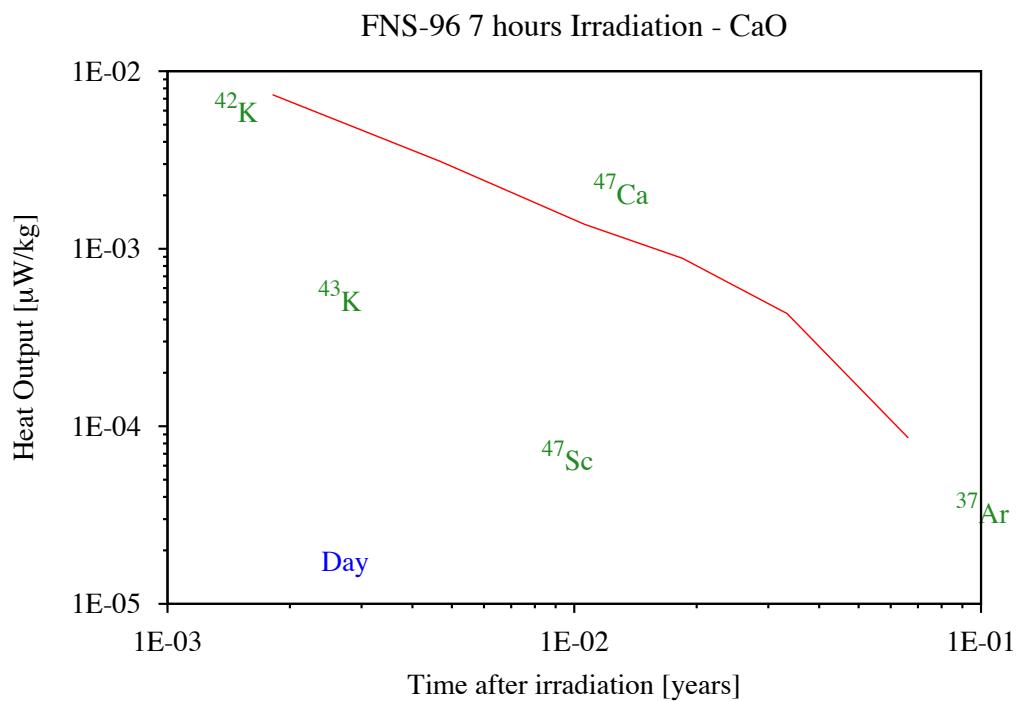


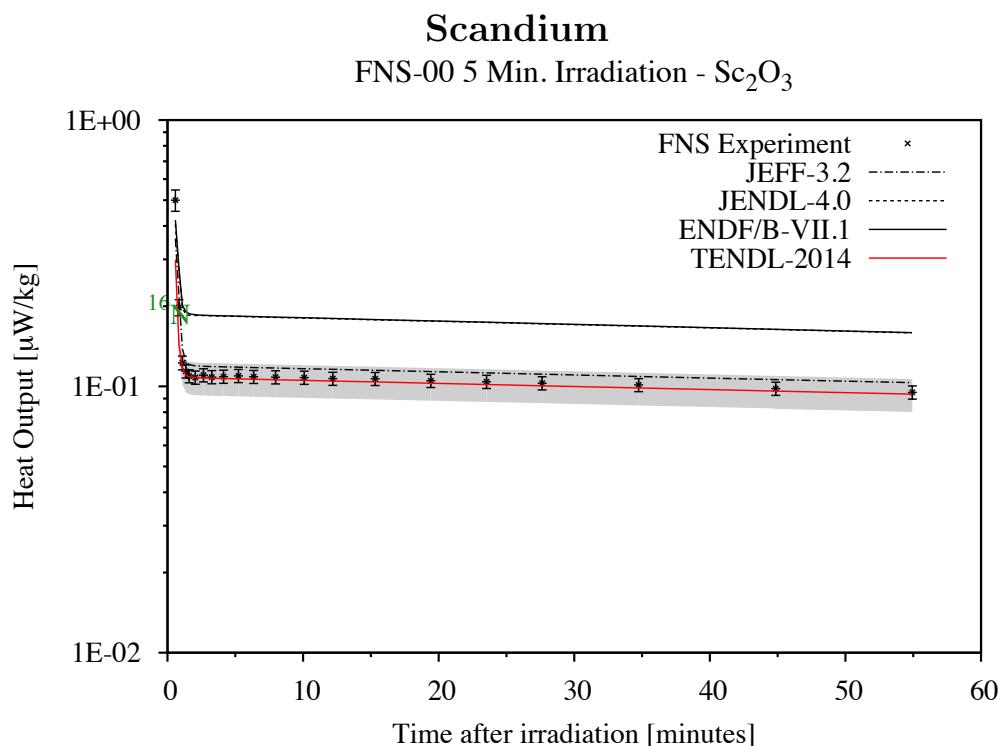


A rather good agreement exists for this element with multiple production pathways in all libraries.

Times	FNS EXP. 7 hrs	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Days	μW/g	μW/g	E/C	E/C	E/C
0.66	$8.41E-03 \pm/-8\%$	$7.37E-03 \pm/-16\%$	1.14	1.14	1.14
1.71	$3.40E-03 \pm/-9\%$	$3.11E-03 \pm/-12\%$	1.09	1.05	1.05
3.87	$1.47E-03 \pm/-10\%$	$1.37E-03 \pm/-11\%$	1.07	1.03	1.02
6.73	$9.49E-04 \pm/-12\%$	$8.84E-04 \pm/-11\%$	1.07	1.04	1.04
12.18	$4.32E-04 \pm/-18\%$	$4.31E-04 \pm/-10\%$	1.00	0.96	0.97
24.19	$9.00E-05 \pm/-79\%$	$8.60E-05 \pm/-12\%$	1.05	1.02	1.03
mean % diff. from E			6	5	22

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
K42	Ca42(n,p)K42	12.3h	97.9	1.14	8%
	Ca43(n,d+np)K42		1.6	1.14	8%
Ca47	Ca48(n,2n)Ca47	4.5d	100.0	1.07	10%



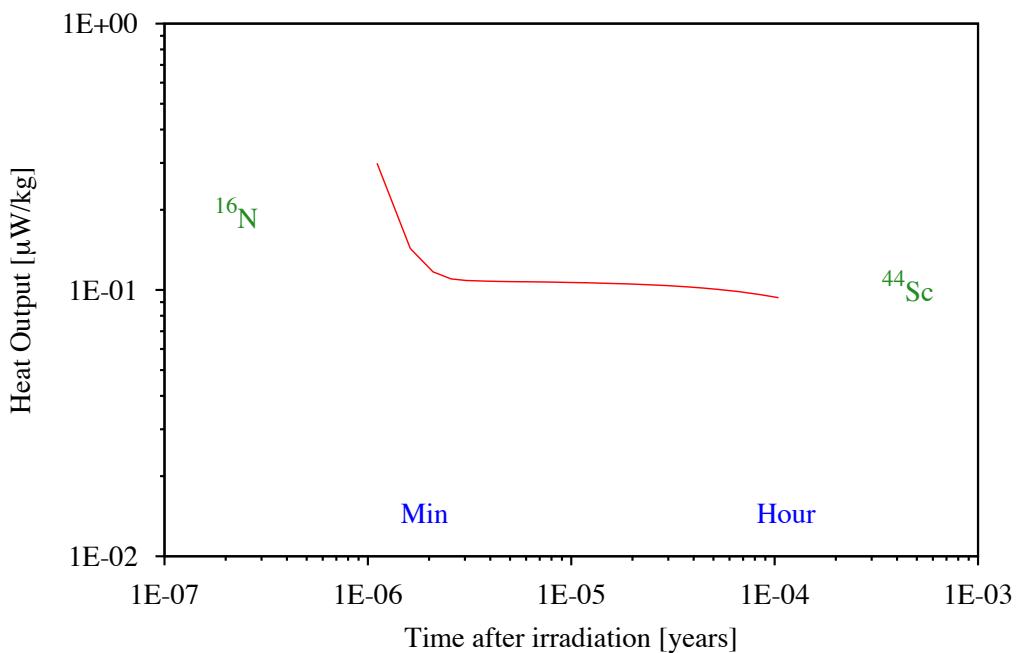


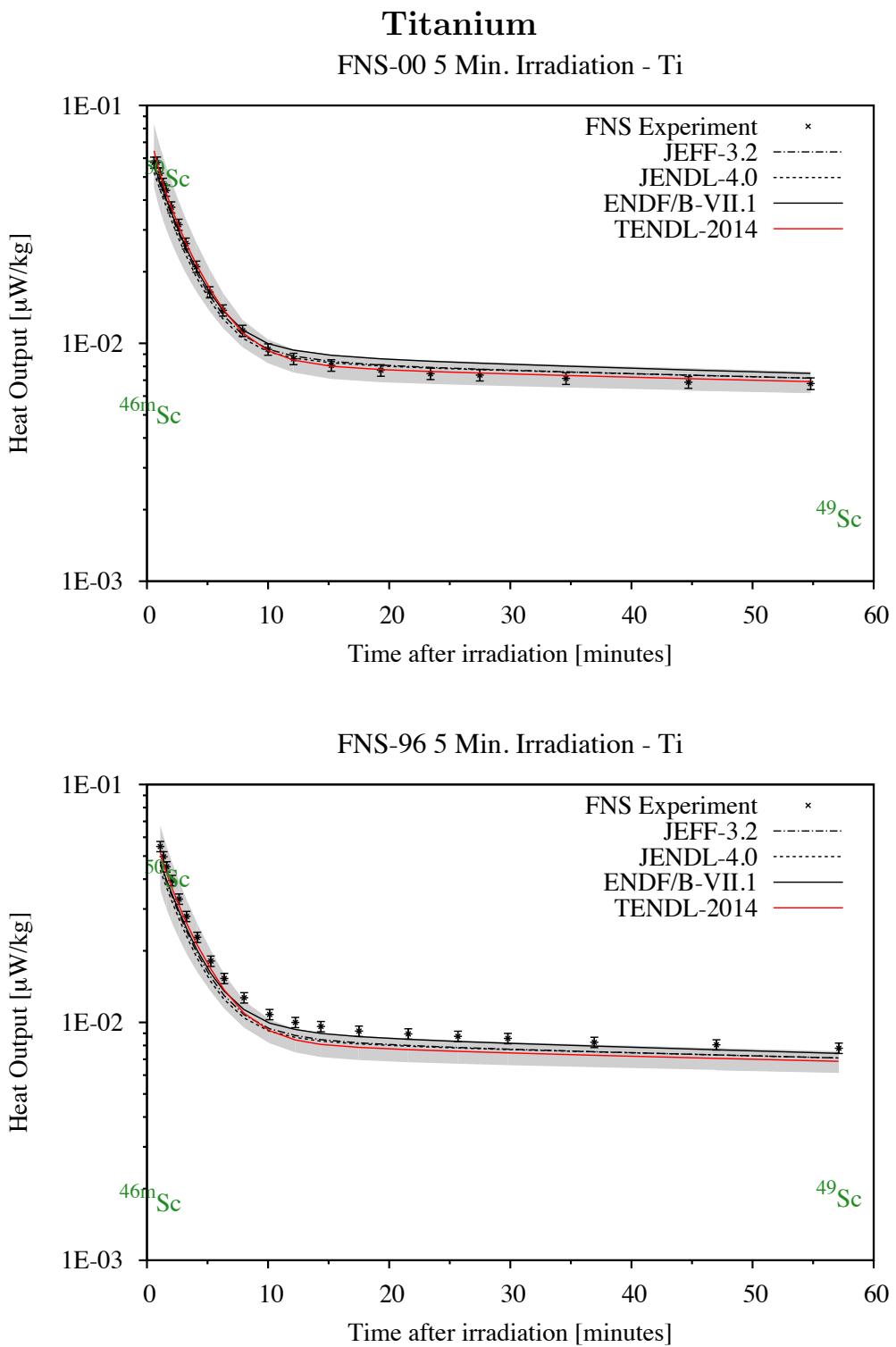
For Scandium, the above plot demonstrates an excellent agreement for the production of Sc44, where the TENDL results are always within the experimental uncertainty. TENDL-2014 variance could be reduced to reflect this experiment. ENDF/B-VII.1 and JENDL-4.0 over-predict by a factor of two.

Times Min.	FNS EXP. 5 mins $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.58	$5.00E-01$ +/-9%	$2.99E-01$ +/-5%	1.67	1.19	1.39	1.23
0.85	$1.98E-01$ +/-7%	$1.43E-01$ +/-11%	1.38	0.71	0.90	0.73
1.10	$1.23E-01$ +/-6%	$1.17E-01$ +/-13%	1.05	0.61	0.89	0.62
1.35	$1.14E-01$ +/-6%	$1.10E-01$ +/-14%	1.03	0.60	0.92	0.62
1.60	$1.09E-01$ +/-6%	$1.09E-01$ +/-14%	1.01	0.58	0.91	0.59
2.05	$1.08E-01$ +/-6%	$1.08E-01$ +/-14%	1.00	0.58	0.90	0.58
2.65	$1.10E-01$ +/-6%	$1.07E-01$ +/-14%	1.03	0.60	0.93	0.60
3.27	$1.08E-01$ +/-6%	$1.07E-01$ +/-14%	1.01	0.59	0.91	0.59
4.13	$1.09E-01$ +/-6%	$1.07E-01$ +/-14%	1.02	0.59	0.92	0.59
5.23	$1.10E-01$ +/-6%	$1.07E-01$ +/-14%	1.03	0.60	0.93	0.60
6.35	$1.09E-01$ +/-6%	$1.06E-01$ +/-14%	1.02	0.59	0.92	0.60
7.97	$1.08E-01$ +/-6%	$1.06E-01$ +/-14%	1.02	0.59	0.92	0.60
10.08	$1.08E-01$ +/-6%	$1.05E-01$ +/-14%	1.02	0.60	0.93	0.60
12.18	$1.07E-01$ +/-6%	$1.05E-01$ +/-14%	1.02	0.59	0.92	0.60
15.32	$1.07E-01$ +/-6%	$1.04E-01$ +/-14%	1.03	0.60	0.93	0.60
19.42	$1.05E-01$ +/-6%	$1.03E-01$ +/-14%	1.02	0.60	0.92	0.60
23.53	$1.04E-01$ +/-6%	$1.02E-01$ +/-14%	1.02	0.60	0.93	0.60
27.63	$1.03E-01$ +/-6%	$1.01E-01$ +/-14%	1.02	0.60	0.93	0.60
34.75	$1.01E-01$ +/-6%	$9.86E-02$ +/-14%	1.03	0.60	0.93	0.60
44.87	$9.81E-02$ +/-6%	$9.60E-02$ +/-14%	1.02	0.60	0.92	0.60
54.93	$9.50E-02$ +/-6%	$9.35E-02$ +/-14%	1.02	0.60	0.92	0.60
mean % diff. from E			5	64	10	63

Product	Pathways	T _{1/2}	Path %	E/C	ΔE%
Sc44	Sc45(n,2n)Sc44	3.9h	100.0	1.02	6%

FNS-00 5 Min. Irradiation - Sc₂O₃

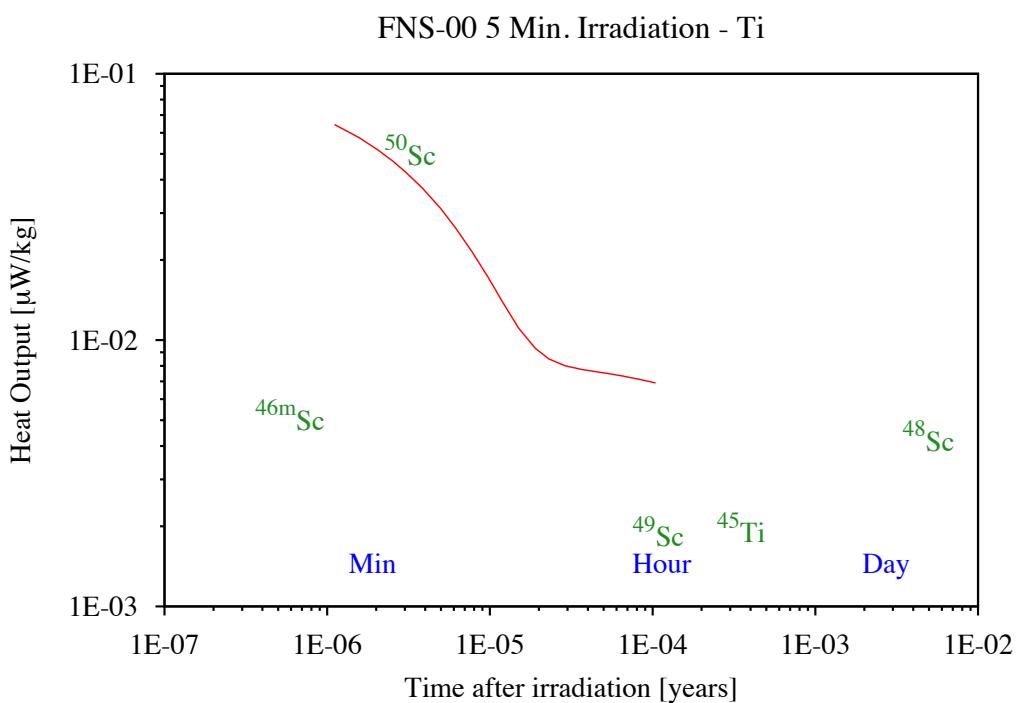




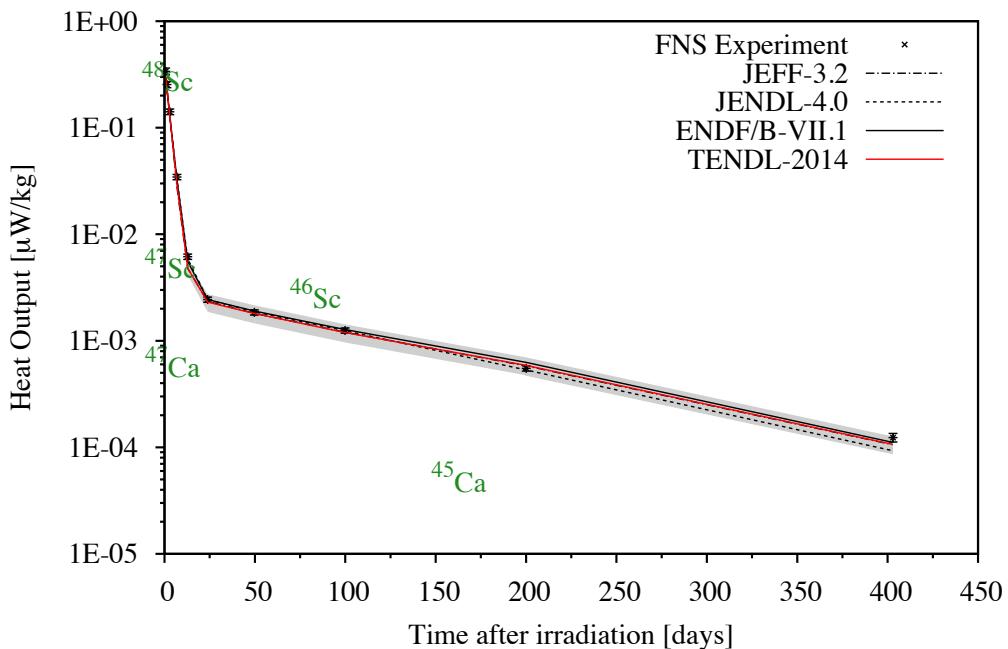
For titanium, the two 5-minute graphs exhibit some unexplained differences between the two experimental batches. The routes of production of the many isotopes involved are complex and prohibit further in-depth analyses.

Times	FNS EXP.	5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.		$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.58		$5.75E-02$ +/-5%	$6.45E-02$ +/-30%	0.89	1.02	1.04
0.83		$5.76E-02$ +/-5%	$5.74E-02$ +/-30%	1.00	1.12	1.14
1.08		$5.19E-02$ +/-5%	$5.17E-02$ +/-30%	1.00	1.09	1.11
1.33		$4.69E-02$ +/-5%	$4.69E-02$ +/-30%	1.00	1.07	1.09
1.58		$4.39E-02$ +/-5%	$4.29E-02$ +/-30%	1.02	1.08	1.11
2.02		$3.73E-02$ +/-5%	$3.73E-02$ +/-29%	1.00	1.05	1.08
2.62		$3.15E-02$ +/-5%	$3.12E-02$ +/-27%	1.01	1.06	1.09
3.22		$2.63E-02$ +/-5%	$2.65E-02$ +/-26%	0.99	1.04	1.07
4.08		$2.10E-02$ +/-5%	$2.15E-02$ +/-23%	0.98	1.02	1.06
5.18		$1.64E-02$ +/-5%	$1.70E-02$ +/-20%	0.96	1.00	1.04
6.28		$1.38E-02$ +/-5%	$1.39E-02$ +/-17%	0.99	1.00	1.04
7.90		$1.13E-02$ +/-5%	$1.11E-02$ +/-13%	1.02	0.99	1.04
10.00		$9.43E-03$ +/-5%	$9.31E-03$ +/-11%	1.01	0.95	1.00
12.10		$8.60E-03$ +/-6%	$8.50E-03$ +/-11%	1.01	0.92	0.97
15.22		$8.08E-03$ +/-6%	$8.01E-03$ +/-11%	1.01	0.91	0.96
19.32		$7.71E-03$ +/-6%	$7.76E-03$ +/-11%	0.99	0.90	0.95
23.42		$7.45E-03$ +/-6%	$7.62E-03$ +/-11%	0.98	0.89	0.94
27.48		$7.36E-03$ +/-6%	$7.50E-03$ +/-11%	0.98	0.89	0.94
34.60		$7.12E-03$ +/-6%	$7.33E-03$ +/-11%	0.97	0.89	0.94
44.70		$6.86E-03$ +/-6%	$7.11E-03$ +/-11%	0.96	0.89	0.93
54.80		$6.77E-03$ +/-6%	$6.91E-03$ +/-10%	0.98	0.91	0.95
mean % diff. from E			2	7	6	8

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Sc50	Ti50(n,p)Sc50	1.7m	56.8	1.02	5%
	Ti50(n,p)Sc50m	0.3s	42.3	1.02	5%
Sc48	Ti48(n,p)Sc48	1.8d	99.4	0.98	6%
	Ti49(n,d+np)Sc48		0.0	0.98	6%



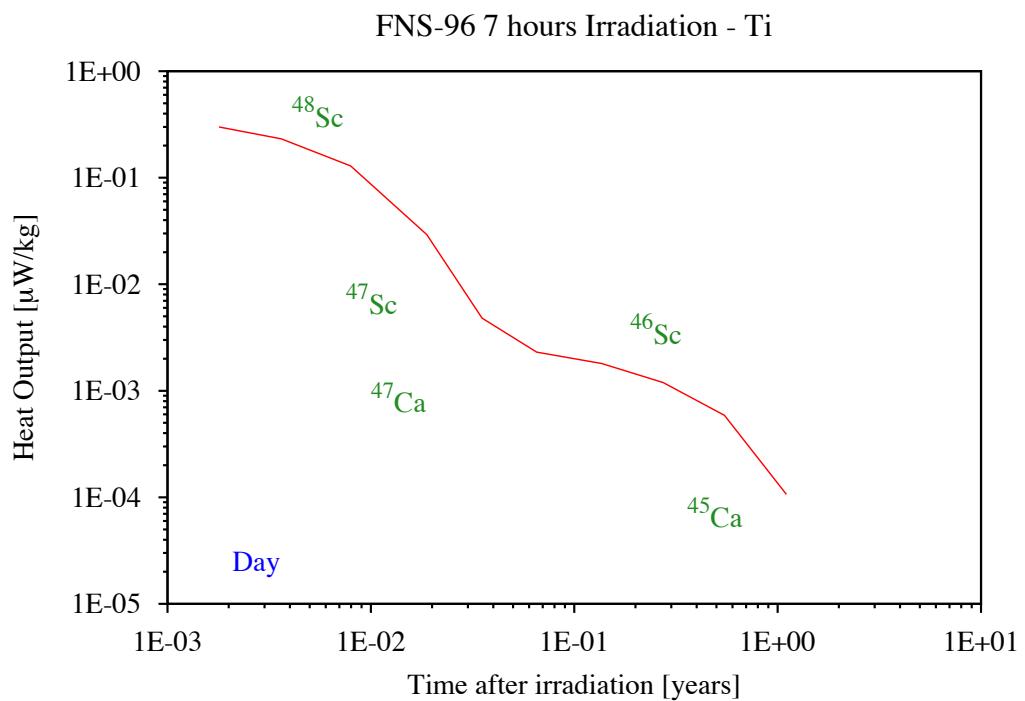
FNS-96 7 hours Irradiation - Ti



An excellent agreement exists at all cooling times, even with such complex production routes, for all libraries. TENDL-2013 [13] under-predicted the Sc46 production routes by about a factor 2.

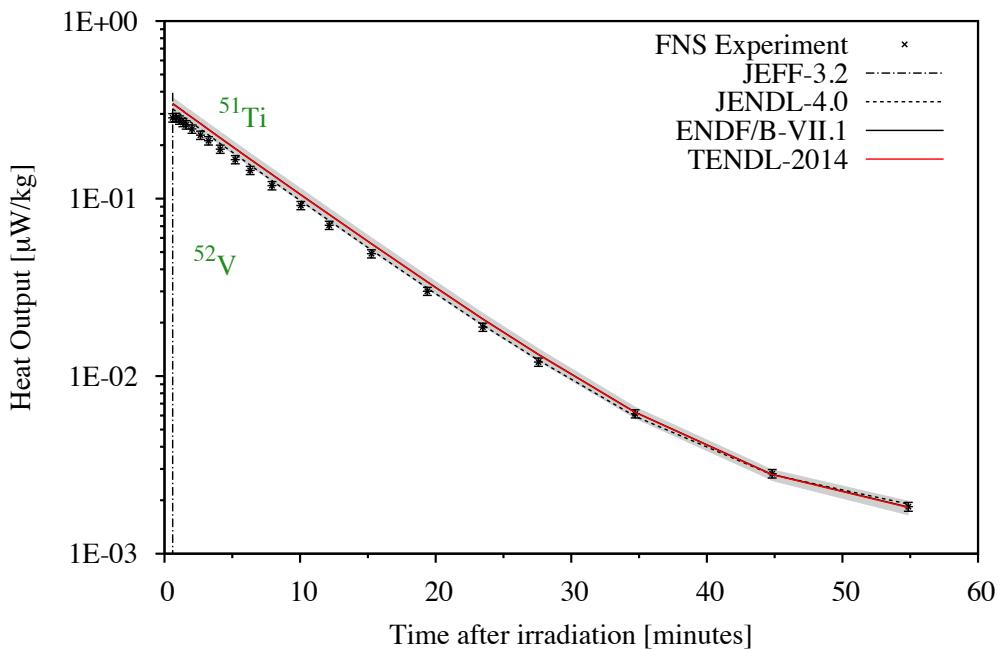
Times	FNS EXP. 7 hrs	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0	
Days	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C	
0.65	$3.38E-01 +/- 7\%$	$2.99E-01 +/- 6\%$	1.13	1.15	1.12	1.12
1.32	$2.54E-01 +/- 6\%$	$2.32E-01 +/- 6\%$	1.10	1.11	1.09	1.09
2.90	$1.41E-01 +/- 6\%$	$1.29E-01 +/- 7\%$	1.09	1.11	1.08	1.09
6.87	$3.45E-02 +/- 6\%$	$2.92E-02 +/- 8\%$	1.18	1.06	1.24	1.06
12.87	$6.16E-03 +/- 6\%$	$4.80E-03 +/- 14\%$	1.28	1.11	1.29	1.05
23.86	$2.43E-03 +/- 6\%$	$2.30E-03 +/- 19\%$	1.06	1.00	1.04	1.00
49.71	$1.85E-03 +/- 6\%$	$1.81E-03 +/- 19\%$	1.02	0.97	1.02	0.99
99.90	$1.25E-03 +/- 6\%$	$1.20E-03 +/- 19\%$	1.04	0.98	1.04	1.00
200.12	$5.51E-04 +/- 6\%$	$5.87E-04 +/- 19\%$	0.94	0.88	0.95	1.03
402.96	$1.23E-04 +/- 9\%$	$1.07E-04 +/- 18\%$	1.16	1.11	1.17	1.33
mean % diff. from E		10	8	10	7	

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Sc48	Ti48(n,p)Sc48	1.8d	99.6	1.10	6%
Sc46	Ti46(n,p)Sc46	83.7d	61.0	1.04	6%
	Ti47(n,d)Sc46		1.2	1.04	6%
	Ti47(n,np)Sc46		13.9	1.04	6%
	Ti46(n,p)Sc46m	18.7s	21.7	1.04	6%
	Ti47(n,d+np)Sc46m		2.0	1.04	6%

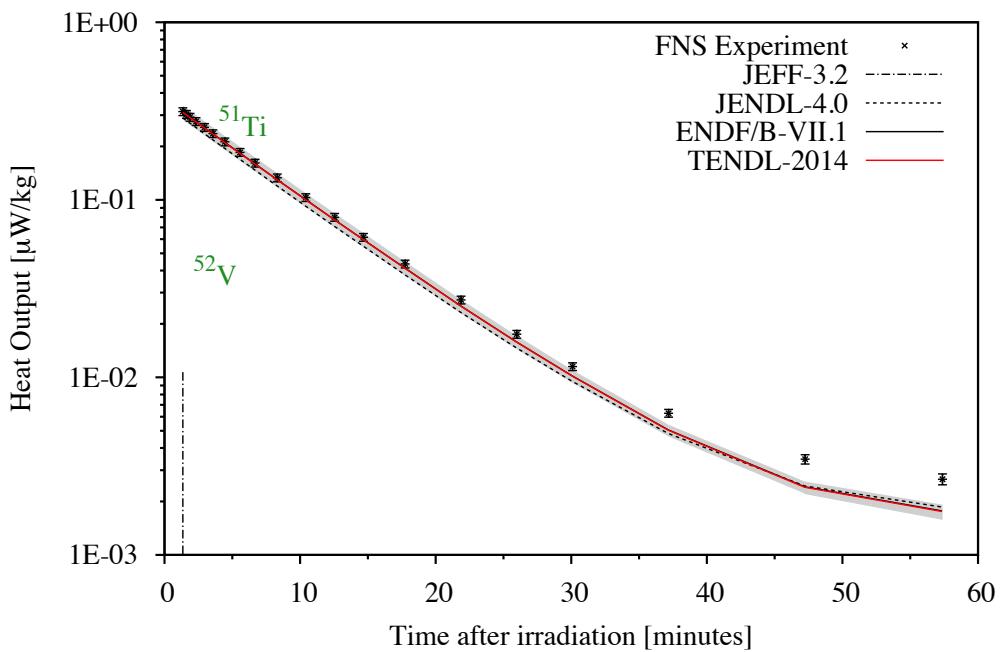


Vanadium

FNS-00 5 Min. Irradiation - V



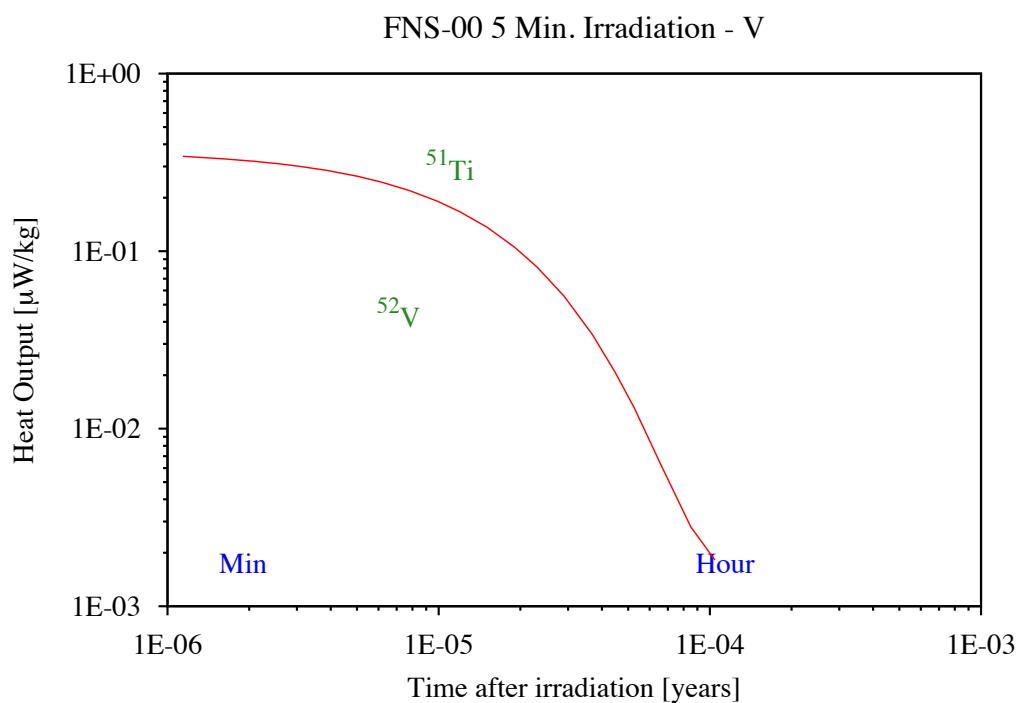
FNS-96 5 Min. Irradiation - V

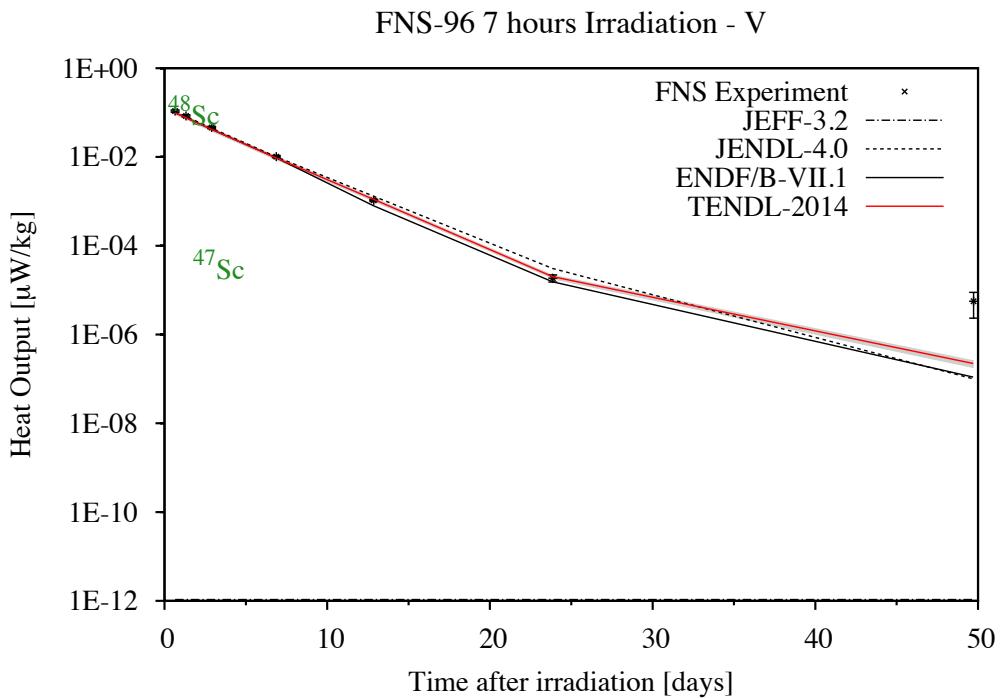


For Vanadium, the clear underestimation after 30 minutes cooling in the 1996 sample does not seem to persist in the results of the second batch. The two measured data-sets do not corroborate one another. However, TENDL-2014 shows good agreement with the experiment while JEFF-3.2 simply fails to deliver.

Times Min.	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0	
	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C	
0.60	$2.85E-01$ +/-5%	$3.42E-01$ +/-9%	0.83	0.83	0.72	0.89
0.85	$2.87E-01$ +/-5%	$3.31E-01$ +/-9%	0.87	0.86	0.00	0.92
1.10	$2.77E-01$ +/-5%	$3.21E-01$ +/-9%	0.86	0.86	0.00	0.92
1.35	$2.69E-01$ +/-5%	$3.11E-01$ +/-9%	0.86	0.86	0.00	0.92
1.60	$2.61E-01$ +/-5%	$3.01E-01$ +/-9%	0.87	0.86	0.00	0.93
2.03	$2.47E-01$ +/-5%	$2.85E-01$ +/-9%	0.87	0.86	0.00	0.93
2.65	$2.28E-01$ +/-5%	$2.64E-01$ +/-9%	0.86	0.86	0.00	0.93
3.25	$2.12E-01$ +/-5%	$2.44E-01$ +/-9%	0.87	0.86	0.00	0.93
4.12	$1.90E-01$ +/-5%	$2.19E-01$ +/-9%	0.87	0.86	0.00	0.93
5.22	$1.66E-01$ +/-5%	$1.91E-01$ +/-9%	0.87	0.87	0.00	0.93
6.32	$1.44E-01$ +/-5%	$1.66E-01$ +/-9%	0.87	0.86	0.00	0.93
7.93	$1.18E-01$ +/-5%	$1.36E-01$ +/-9%	0.87	0.87	0.00	0.94
10.05	$9.15E-02$ +/-5%	$1.05E-01$ +/-9%	0.87	0.87	0.00	0.94
12.15	$7.07E-02$ +/-5%	$8.12E-02$ +/-9%	0.87	0.87	0.00	0.94
15.27	$4.89E-02$ +/-5%	$5.56E-02$ +/-9%	0.88	0.88	0.00	0.95
19.38	$3.01E-02$ +/-5%	$3.39E-02$ +/-9%	0.89	0.88	0.00	0.96
23.48	$1.89E-02$ +/-5%	$2.09E-02$ +/-9%	0.90	0.90	0.00	0.97
27.58	$1.20E-02$ +/-5%	$1.32E-02$ +/-9%	0.91	0.90	0.00	0.97
34.72	$6.14E-03$ +/-5%	$6.25E-03$ +/-8%	0.98	0.98	0.00	1.03
44.82	$2.82E-03$ +/-6%	$2.79E-03$ +/-7%	1.01	1.01	0.00	1.01
54.87	$1.84E-03$ +/-6%	$1.82E-03$ +/-9%	1.01	1.00	0.00	0.97
mean % diff. from E		13	13	97	6	

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Ti51	V51(n,p)Ti51	5.8m	99.9	0.87	5%
V52	V51(n, γ)V52	3.7m	99.9	0.87	5%
Sc48	V51(n, α)Sc48	1.8d	100.0	1.01	6%

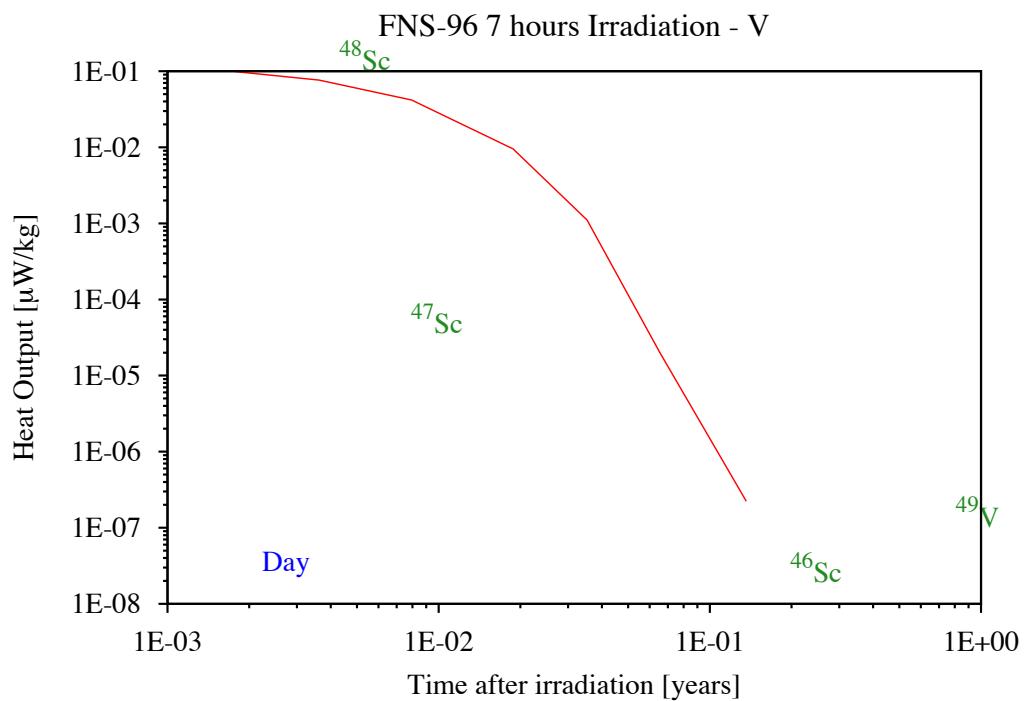




An excellent agreement can be seen, except for JEFF-3.2, at all but the last 50-day cooling step, where the experimental uncertainty is quoted as 58%.

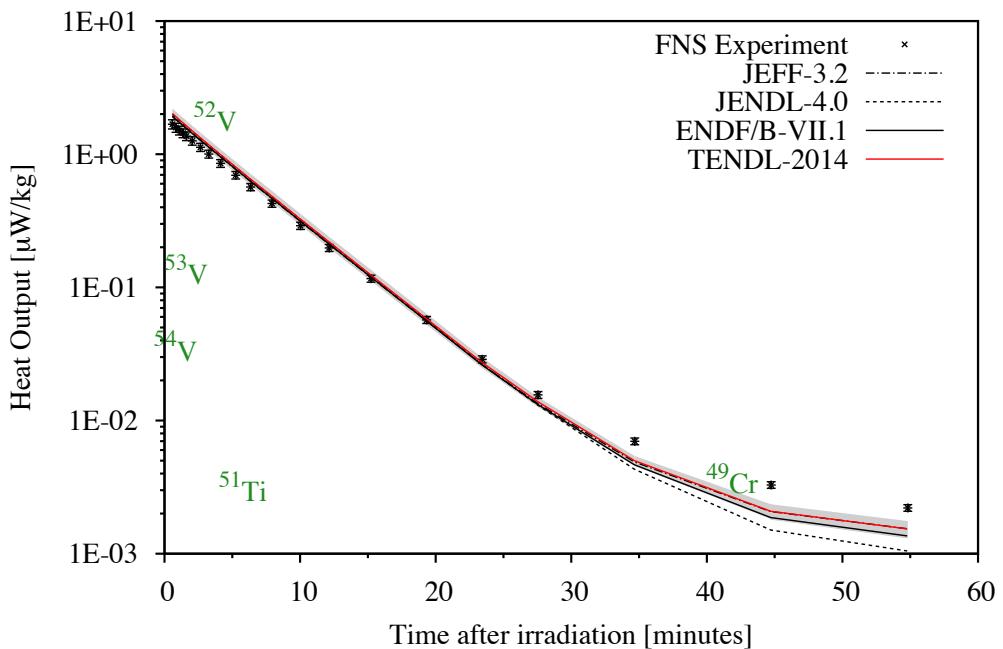
Times	FNS EXP. 7 hrs	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Days	μW/g	μW/g	E/C	E/C	E/C
0.65	$1.08E-01$ +/-6%	$9.85E-02$ +/-11%	1.10	1.09	> 1000
1.32	$8.42E-02$ +/-6%	$7.65E-02$ +/-11%	1.10	1.10	> 1000
2.90	$4.61E-02$ +/-6%	$4.18E-02$ +/-11%	1.10	1.10	> 1000
6.87	$1.02E-02$ +/-6%	$9.51E-03$ +/-11%	1.07	1.07	> 1000
12.86	$1.06E-03$ +/-6%	$1.11E-03$ +/-11%	0.95	1.33	> 1000
23.86	$1.86E-05$ +/-18%	$2.02E-05$ +/-11%	0.92	1.21	0.60
49.73	$5.62E-06$ +/-58%	$2.23E-07$ +/-19%	25.21	51.32	> 1000
mean % diff. from E			21	25	100
					28

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Sc48	V51(n, α)Sc48	1.8d	100.0	1.02	6%

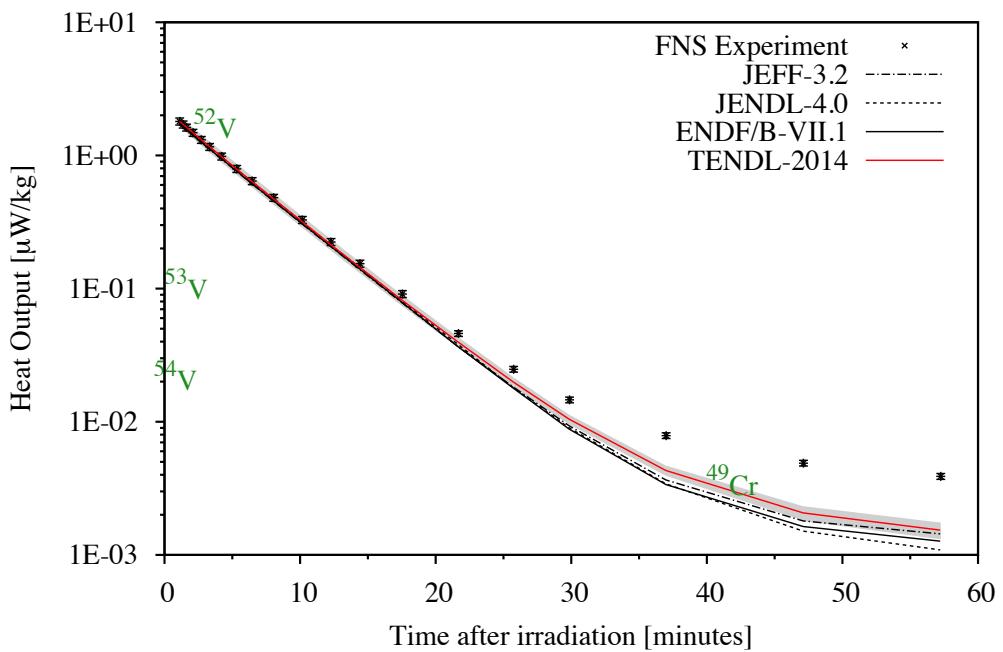


Chromium

FNS-00 5 Min. Irradiation - Cr



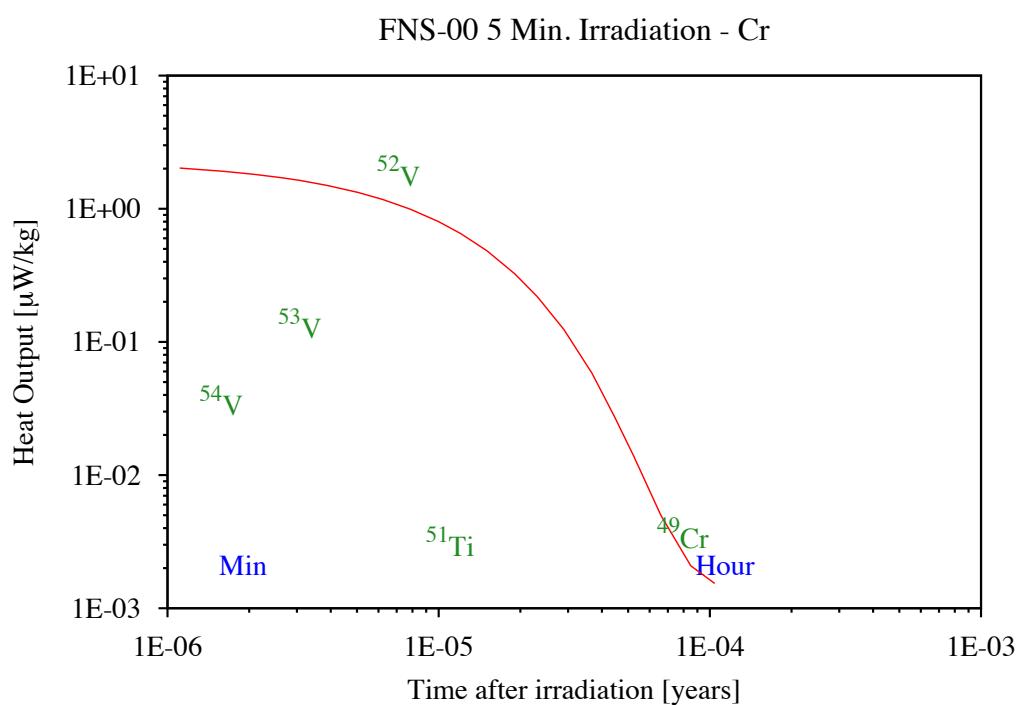
FNS-96 5 Min. Irradiation - Cr

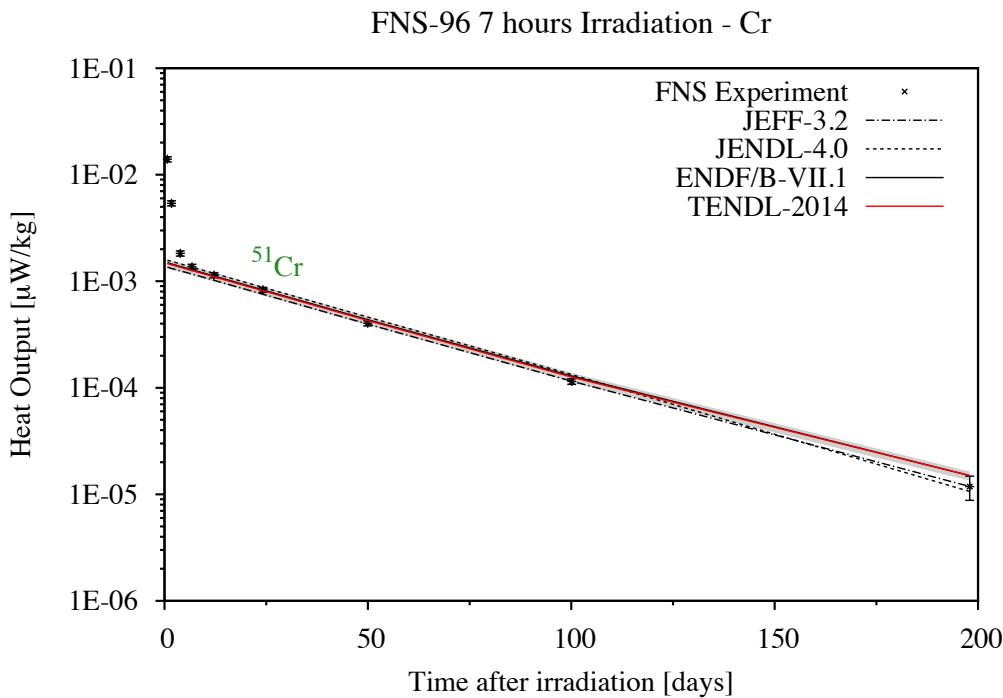


For Chromium, there is a good agreement if one allows for the fact that Al and Fe impurities could have been present in the sample at levels up to 2000 and 6000 ppm, respectively. Such levels of impurities have been measured in similar samples.

Times	FNS EXP.	5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.		$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.58		$1.68E+00$ +/-8%	$2.02E+00$ +/-9%	0.83	0.87	0.87
0.85		$1.58E+00$ +/-8%	$1.91E+00$ +/-9%	0.83	0.87	0.87
1.10		$1.51E+00$ +/-8%	$1.81E+00$ +/-9%	0.83	0.87	0.87
1.37		$1.44E+00$ +/-8%	$1.72E+00$ +/-9%	0.84	0.88	0.88
1.62		$1.37E+00$ +/-7%	$1.63E+00$ +/-9%	0.84	0.87	0.87
2.05		$1.26E+00$ +/-7%	$1.50E+00$ +/-9%	0.84	0.88	0.88
2.65		$1.13E+00$ +/-7%	$1.33E+00$ +/-9%	0.85	0.88	0.89
3.27		$1.00E+00$ +/-7%	$1.18E+00$ +/-10%	0.85	0.89	0.89
4.13		$8.53E-01$ +/-7%	$9.93E-01$ +/-10%	0.86	0.89	0.89
5.25		$6.95E-01$ +/-6%	$8.01E-01$ +/-10%	0.87	0.90	0.90
6.35		$5.67E-01$ +/-6%	$6.50E-01$ +/-10%	0.87	0.90	0.91
7.93		$4.26E-01$ +/-6%	$4.82E-01$ +/-10%	0.88	0.92	0.92
10.03		$2.90E-01$ +/-6%	$3.25E-01$ +/-10%	0.89	0.93	0.93
12.15		$1.98E-01$ +/-6%	$2.19E-01$ +/-10%	0.90	0.94	0.94
15.23		$1.16E-01$ +/-6%	$1.24E-01$ +/-10%	0.94	0.97	0.98
19.33		$5.70E-02$ +/-6%	$5.81E-02$ +/-9%	0.98	1.02	1.02
23.43		$2.88E-02$ +/-6%	$2.73E-02$ +/-9%	1.06	1.10	1.09
27.55		$1.56E-02$ +/-6%	$1.39E-02$ +/-9%	1.12	1.18	1.16
34.68		$6.98E-03$ +/-6%	$5.00E-03$ +/-9%	1.40	1.50	1.43
44.75		$3.28E-03$ +/-6%	$2.08E-03$ +/-13%	1.57	1.76	1.58
54.82		$2.21E-03$ +/-6%	$1.54E-03$ +/-14%	1.44	1.62	1.44
mean % diff. from E			17	15	14	19

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
V52	Cr52(n,p)V52	3.7m	98.1	0.86	7%
	Cr53(n,d+np)V52		1.7	0.86	7%
Cr49	Cr50(n,2n)Cr49	41.9m	100.0	1.57	6%

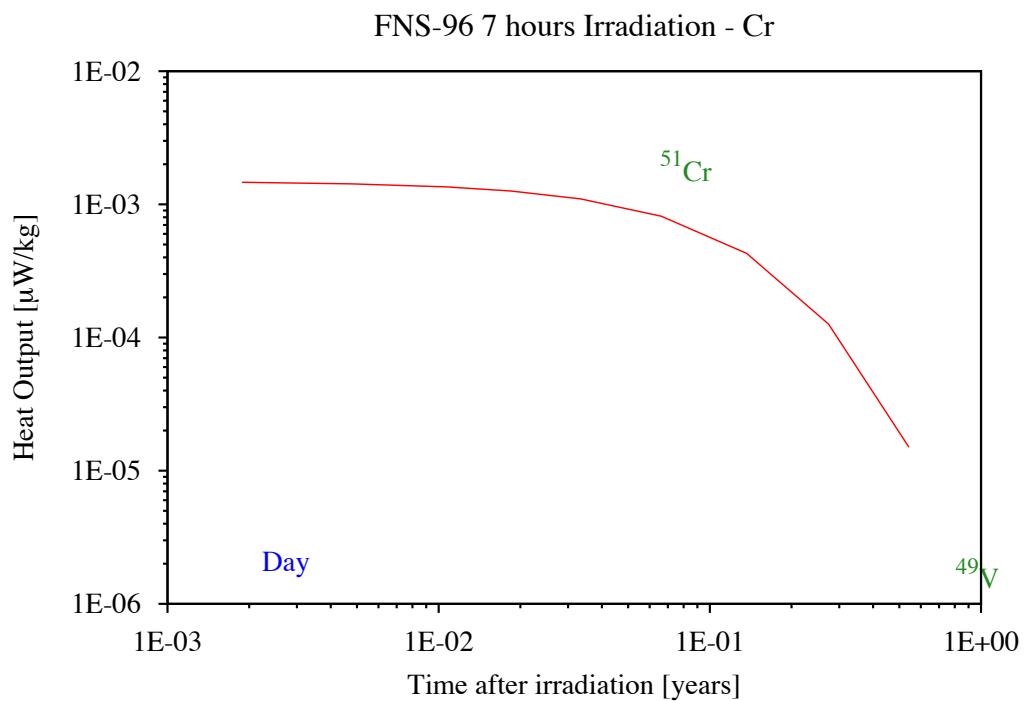




Some short-lived isotopes seem to be missing in all the simulations, almost certainly produced from impurities within the sample, but the overall agreement remains excellent.

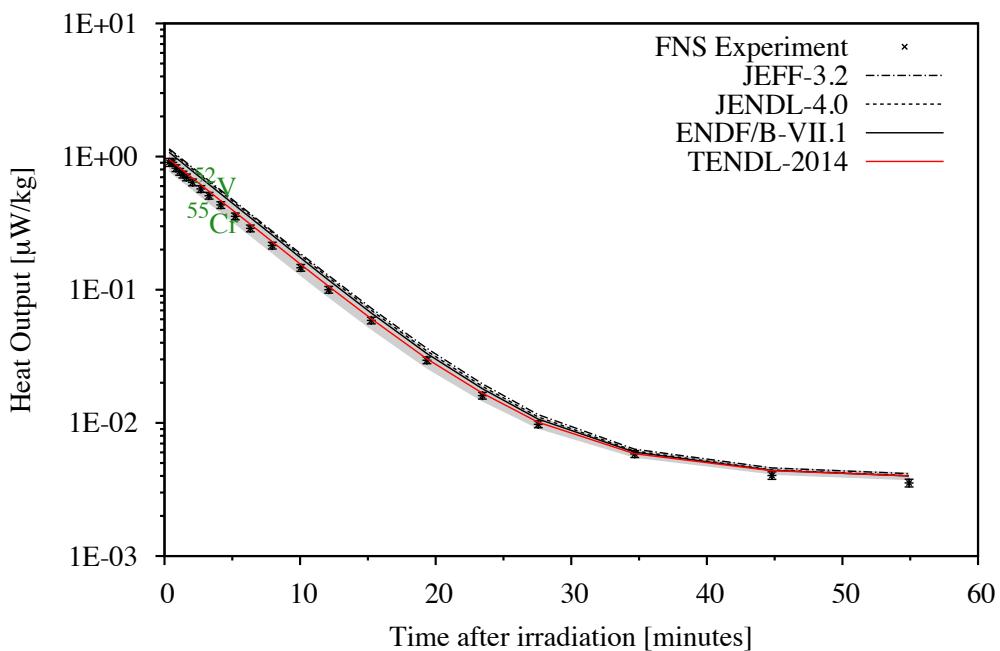
Times	FNS EXP. 7 hrs	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Days	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.69	$1.40E-02 +/- 6\%$	$1.46E-03 +/- 10\%$	9.54	9.36	10.30
1.74	$5.39E-03 +/- 6\%$	$1.43E-03 +/- 10\%$	3.78	3.71	4.08
3.89	$1.83E-03 +/- 6\%$	$1.35E-03 +/- 10\%$	1.35	1.32	1.46
6.75	$1.37E-03 +/- 6\%$	$1.26E-03 +/- 10\%$	1.08	1.06	1.17
12.20	$1.14E-03 +/- 6\%$	$1.10E-03 +/- 10\%$	1.04	1.02	1.12
24.21	$8.31E-04 +/- 6\%$	$8.14E-04 +/- 10\%$	1.02	1.00	1.10
49.96	$4.03E-04 +/- 6\%$	$4.29E-04 +/- 10\%$	0.94	0.92	1.02
100.09	$1.15E-04 +/- 6\%$	$1.26E-04 +/- 10\%$	0.91	0.89	0.99
197.96	$1.18E-05 +/- 26\%$	$1.50E-05 +/- 9\%$	0.79	0.78	0.99
mean % diff. from E			27	27	26

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Cr51	Cr52(n,2n)Cr51	27.7d	100.0	1.00	6%

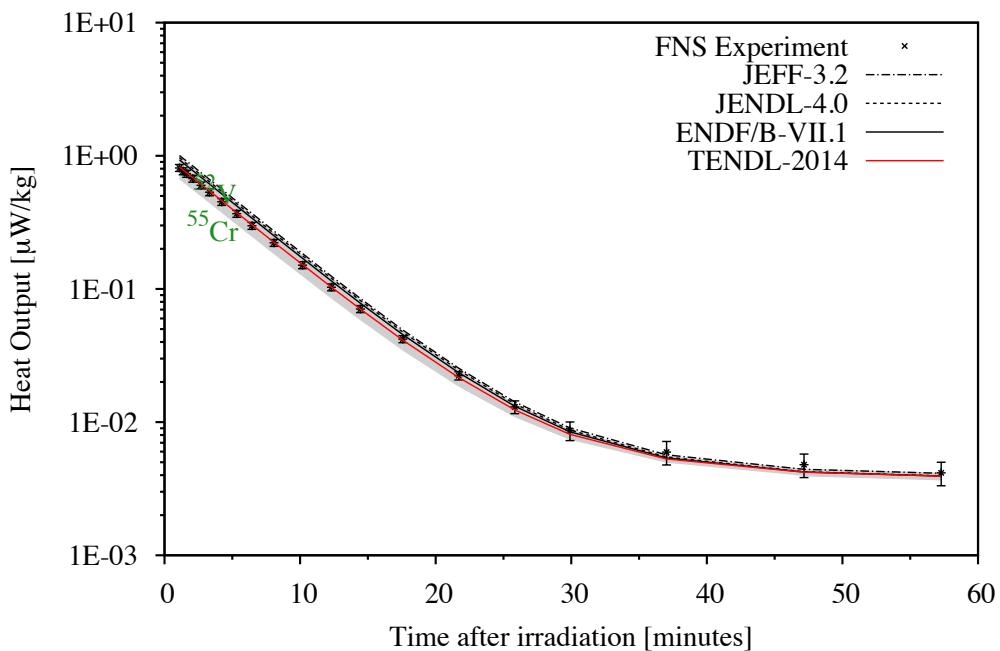


Manganese

FNS-00 5 Min. Irradiation - Mn



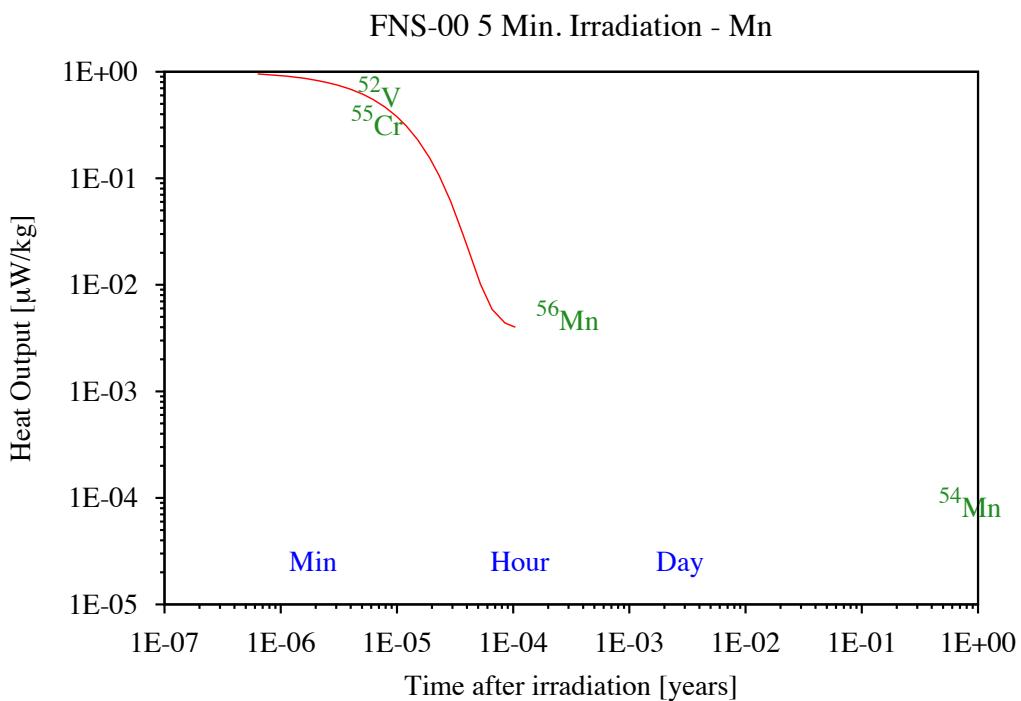
FNS-96 5 Min. Irradiation - Mn

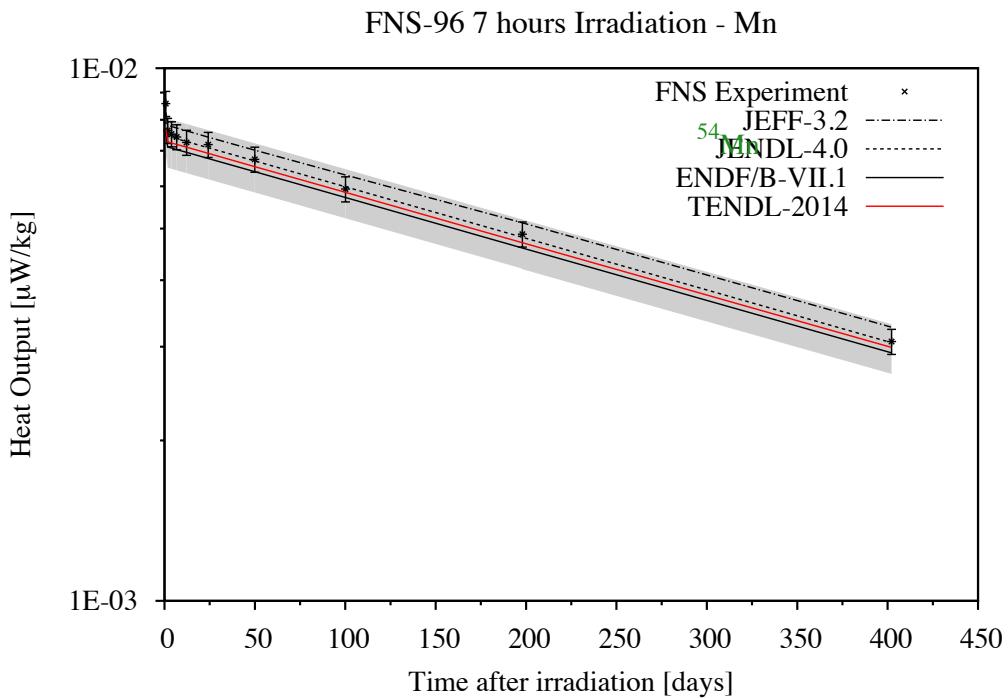


For Manganese, there is a good agreement at short cooling times for both batches with all libraries. All those libraries accurately reproduce the most recent IRDFF International Reference Dosimetry File.

Times	FNS EXP.	5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.		$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.33		$9.06E-01$ +/-7%	$9.54E-01$ +/-19%	0.95	0.84	0.79
0.60		$9.06E-01$ +/-6%	$9.08E-01$ +/-19%	1.00	0.88	0.83
0.85		$8.18E-01$ +/-6%	$8.66E-01$ +/-19%	0.94	0.84	0.79
1.12		$7.70E-01$ +/-6%	$8.24E-01$ +/-19%	0.93	0.83	0.78
1.37		$7.34E-01$ +/-6%	$7.86E-01$ +/-19%	0.93	0.83	0.78
1.63		$6.98E-01$ +/-6%	$7.48E-01$ +/-19%	0.93	0.83	0.78
2.07		$6.41E-01$ +/-6%	$6.89E-01$ +/-19%	0.93	0.82	0.77
2.68		$5.71E-01$ +/-6%	$6.14E-01$ +/-19%	0.93	0.83	0.77
3.28		$5.09E-01$ +/-6%	$5.49E-01$ +/-19%	0.93	0.82	0.77
4.15		$4.33E-01$ +/-6%	$4.66E-01$ +/-19%	0.93	0.83	0.77
5.22		$3.56E-01$ +/-6%	$3.82E-01$ +/-19%	0.93	0.83	0.78
6.33		$2.89E-01$ +/-6%	$3.10E-01$ +/-19%	0.93	0.83	0.78
7.95		$2.15E-01$ +/-6%	$2.29E-01$ +/-19%	0.94	0.84	0.78
10.05		$1.46E-01$ +/-6%	$1.55E-01$ +/-18%	0.94	0.84	0.78
12.12		$1.00E-01$ +/-6%	$1.06E-01$ +/-18%	0.94	0.85	0.78
15.25		$5.88E-02$ +/-6%	$6.05E-02$ +/-17%	0.97	0.88	0.81
19.35		$2.95E-02$ +/-6%	$3.04E-02$ +/-16%	0.97	0.89	0.81
23.45		$1.60E-02$ +/-6%	$1.68E-02$ +/-14%	0.96	0.89	0.81
27.57		$9.76E-03$ +/-6%	$1.01E-02$ +/-11%	0.97	0.91	0.85
34.68		$5.85E-03$ +/-6%	$5.87E-03$ +/-7%	1.00	0.97	0.92
44.80		$4.02E-03$ +/-7%	$4.38E-03$ +/-6%	0.92	0.91	0.88
54.92		$3.54E-03$ +/-7%	$4.00E-03$ +/-6%	0.89	0.88	0.85
mean % diff. from E			6	17	25	21

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
V52	Mn55(n, α)V52	3.7m	100.0	0.93	6%
Cr55	Mn55(n,p)Cr55	3.5m	100.0	0.93	6%
Mn56	Mn55(n, γ)Mn56	2.5h	100.0	0.89	7%

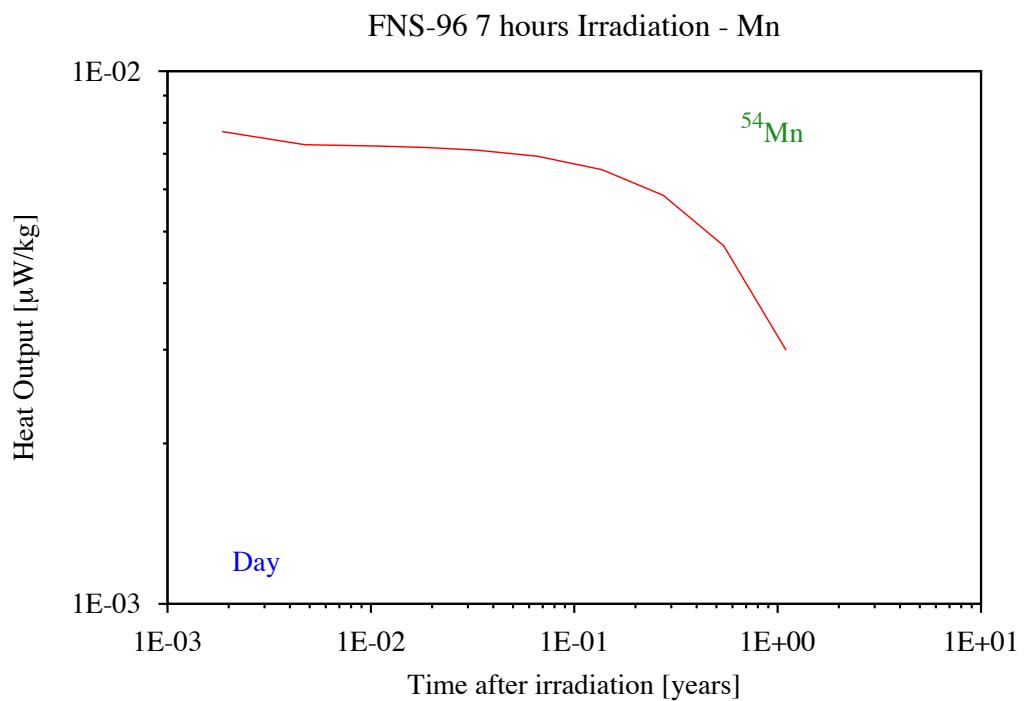




The calculated production of Mn54 seems to agree well with measurement. The calculation uncertainty derived from TENDL-2014 covariance well reflects the dispersion.

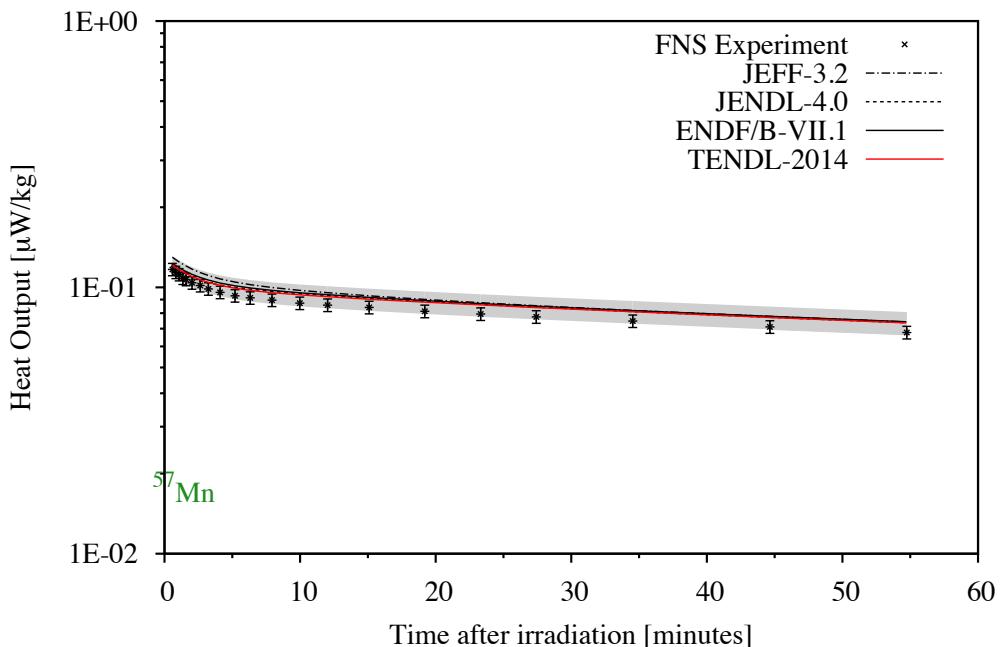
Times	FNS EXP. 7 hrs	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0	
Days	μW/g	μW/g	E/C	E/C	E/C	
0.68	$8.58E-03$ +/-5%	$7.70E-03$ +/-10%	1.11	1.14	1.04	1.08
1.73	$7.64E-03$ +/-5%	$7.28E-03$ +/-11%	1.05	1.07	0.98	1.02
3.89	$7.52E-03$ +/-5%	$7.24E-03$ +/-11%	1.04	1.06	0.97	1.01
6.75	$7.43E-03$ +/-5%	$7.19E-03$ +/-11%	1.03	1.06	0.96	1.01
12.20	$7.25E-03$ +/-5%	$7.11E-03$ +/-11%	1.02	1.04	0.95	1.00
24.21	$7.19E-03$ +/-5%	$6.92E-03$ +/-11%	1.04	1.06	0.97	1.01
49.96	$6.74E-03$ +/-5%	$6.53E-03$ +/-11%	1.03	1.06	0.96	1.01
100.10	$5.93E-03$ +/-5%	$5.85E-03$ +/-11%	1.01	1.04	0.94	0.99
197.97	$4.88E-03$ +/-5%	$4.70E-03$ +/-11%	1.04	1.06	0.95	1.01
402.18	$3.07E-03$ +/-5%	$2.99E-03$ +/-11%	1.03	1.05	0.94	1.00
mean % diff. from E		4	6	4	2	

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Mn54	Mn55(n,2n)Mn54	312d	100.0	1.03	5%

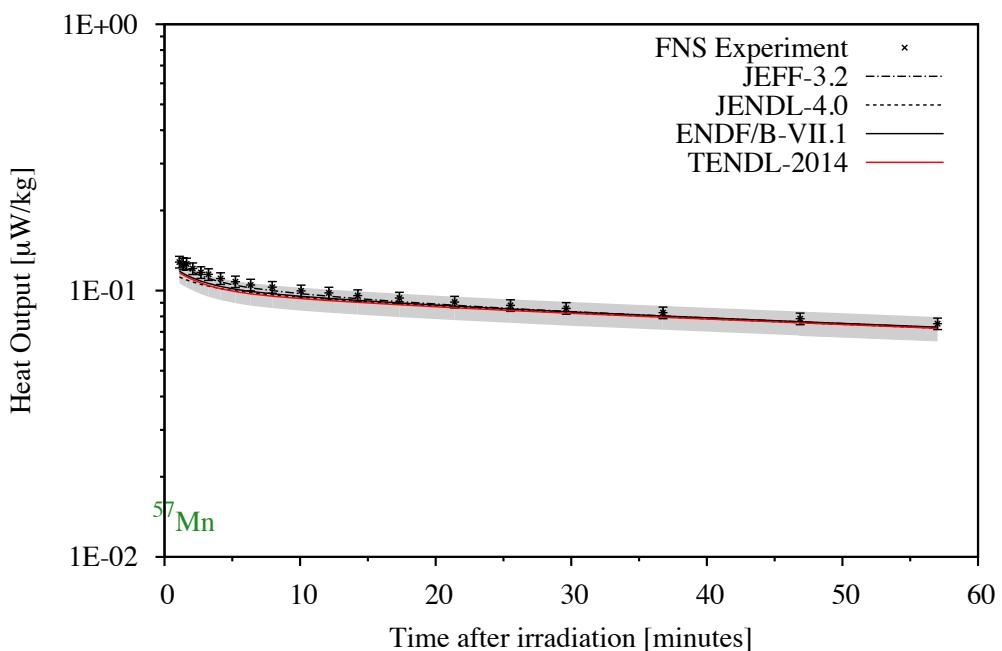


Iron

FNS-00 5 Min. Irradiation - Fe



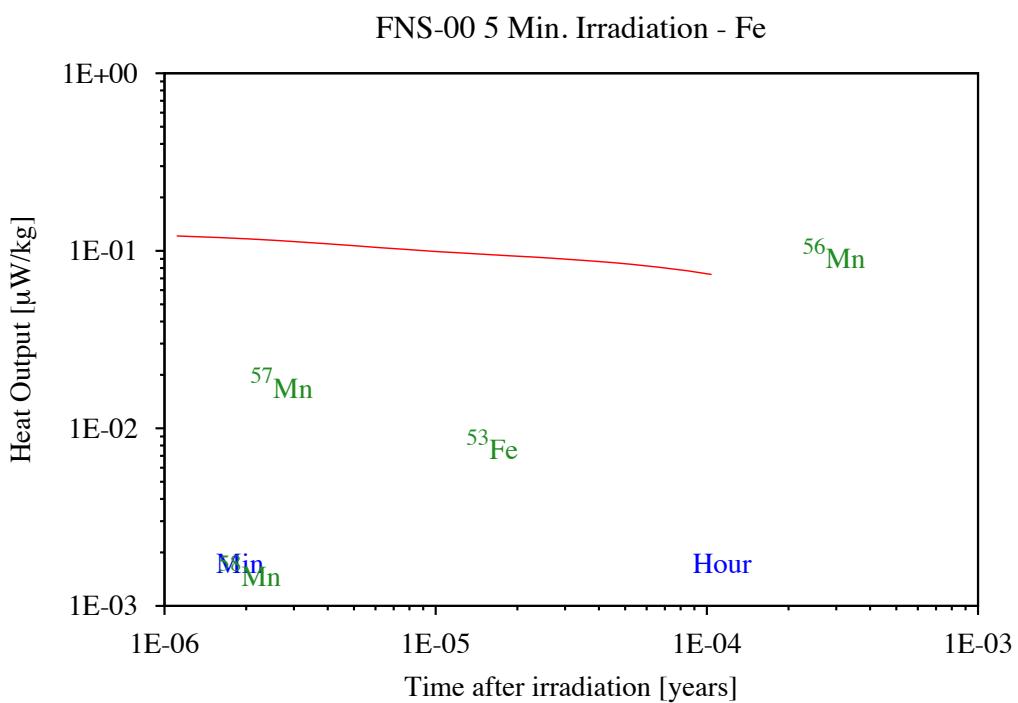
FNS-96 5 Min. Irradiation - Fe



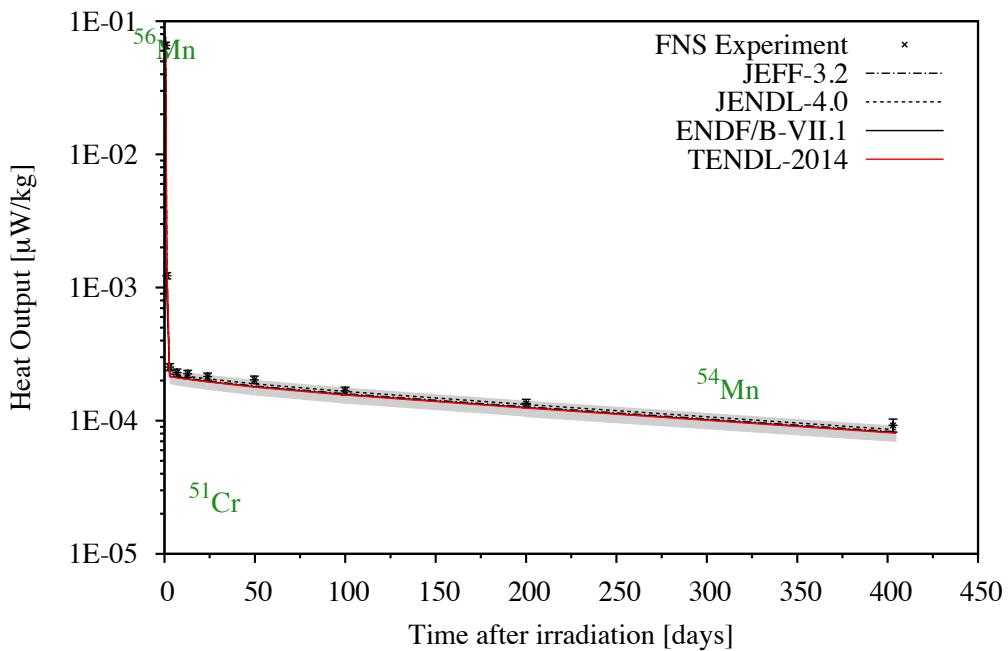
For Iron, the experimental decay results differ in the two batches and are positioned just above and below the code predictions that remain unchanged in all but the distribution of cooling time steps. However, the experimental errors are given as a range of one standard deviation, not a limit of the error. TENDL-2014 variance encompasses the experimental uncertainty.

Times	FNS EXP.	5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.		$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.58		$1.17E-01$ +/-5%	$1.21E-01$ +/-8%	0.96	0.95	0.90
0.83		$1.14E-01$ +/-5%	$1.19E-01$ +/-8%	0.96	0.94	0.90
1.08		$1.12E-01$ +/-5%	$1.17E-01$ +/-8%	0.96	0.94	0.90
1.35		$1.08E-01$ +/-5%	$1.14E-01$ +/-8%	0.95	0.93	0.89
1.60		$1.07E-01$ +/-5%	$1.13E-01$ +/-8%	0.95	0.93	0.89
2.03		$1.04E-01$ +/-5%	$1.10E-01$ +/-9%	0.95	0.93	0.89
2.63		$1.02E-01$ +/-5%	$1.07E-01$ +/-9%	0.95	0.93	0.89
3.23		$9.87E-02$ +/-5%	$1.04E-01$ +/-9%	0.95	0.93	0.89
4.10		$9.58E-02$ +/-5%	$1.02E-01$ +/-9%	0.94	0.92	0.89
5.20		$9.30E-02$ +/-5%	$9.93E-02$ +/-9%	0.94	0.92	0.89
6.32		$9.13E-02$ +/-5%	$9.75E-02$ +/-9%	0.94	0.92	0.89
7.93		$8.96E-02$ +/-5%	$9.55E-02$ +/-9%	0.94	0.92	0.90
9.98		$8.73E-02$ +/-5%	$9.37E-02$ +/-9%	0.93	0.91	0.90
12.03		$8.58E-02$ +/-5%	$9.22E-02$ +/-10%	0.93	0.91	0.90
15.10		$8.41E-02$ +/-5%	$9.03E-02$ +/-10%	0.93	0.92	0.90
19.20		$8.13E-02$ +/-5%	$8.80E-02$ +/-10%	0.92	0.91	0.90
23.32		$7.94E-02$ +/-5%	$8.59E-02$ +/-10%	0.92	0.91	0.91
27.42		$7.75E-02$ +/-5%	$8.40E-02$ +/-10%	0.92	0.91	0.91
34.53		$7.47E-02$ +/-5%	$8.10E-02$ +/-10%	0.92	0.91	0.91
44.65		$7.10E-02$ +/-5%	$7.71E-02$ +/-10%	0.92	0.91	0.91
54.75		$6.77E-02$ +/-5%	$7.36E-02$ +/-10%	0.92	0.91	0.91
mean % diff. from E			7	8	11	6

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Mn56	Fe56(n,p)Mn56	2.5h	99.7	0.92	5%



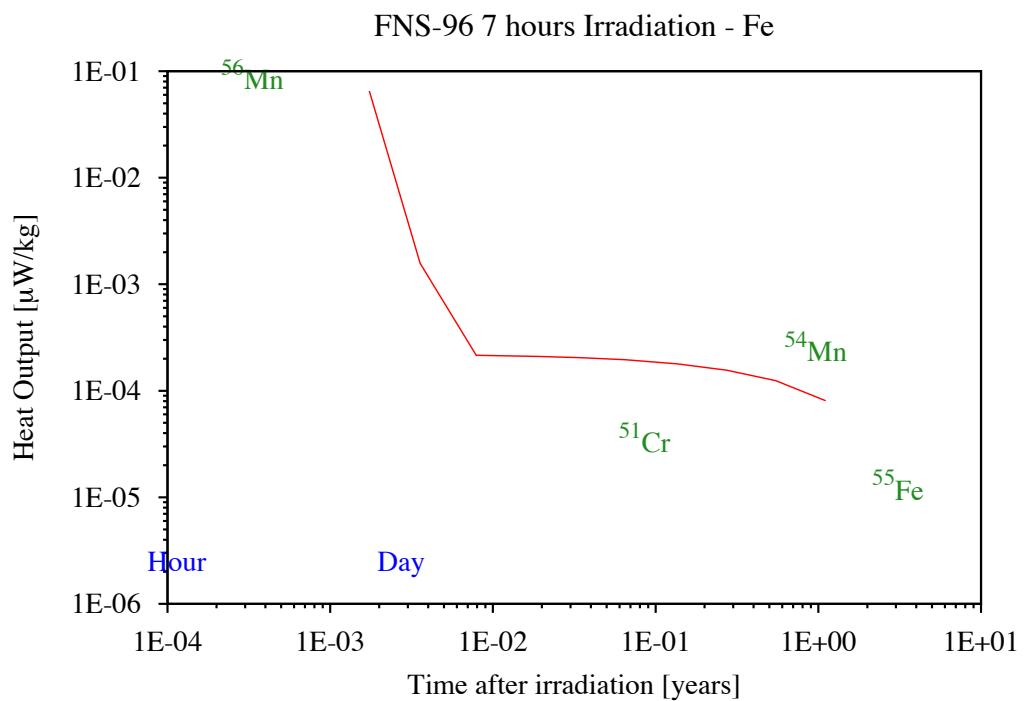
FNS-96 7 hours Irradiation - Fe



The above picture shows excellent agreements, well within the experimental uncertainty bands.

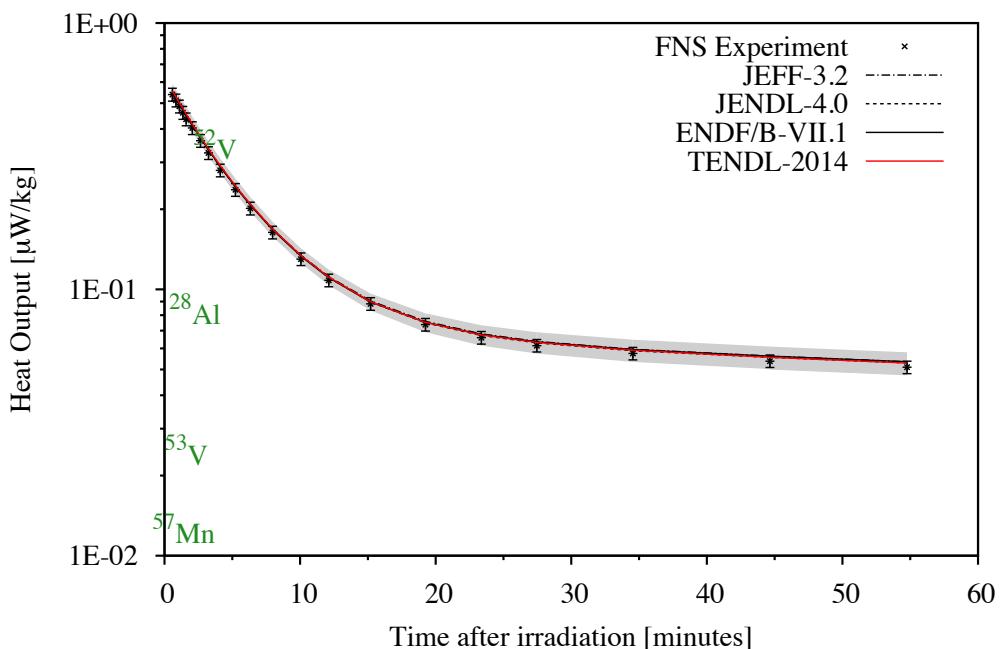
Times	FNS EXP. 7 hrs	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0	
Days	μW/g	μW/g	E/C	E/C	E/C	
0.63	$6.58E-02$ +/-5%	$6.52E-02$ +/-7%	1.01	1.64	0.86	1.12
1.30	$1.23E-03$ +/-5%	$1.57E-03$ +/-6%	0.78	1.34	0.78	0.93
2.88	$2.53E-04$ +/-6%	$2.16E-04$ +/-12%	1.17	1.18	1.17	1.12
6.89	$2.30E-04$ +/-6%	$2.10E-04$ +/-13%	1.09	1.09	1.08	1.04
12.88	$2.25E-04$ +/-6%	$2.05E-04$ +/-13%	1.10	1.10	1.08	1.04
23.89	$2.14E-04$ +/-6%	$1.96E-04$ +/-13%	1.10	1.09	1.08	1.04
49.72	$2.03E-04$ +/-6%	$1.79E-04$ +/-13%	1.13	1.13	1.11	1.07
99.91	$1.67E-04$ +/-7%	$1.56E-04$ +/-14%	1.07	1.07	1.05	1.01
200.13	$1.35E-04$ +/-7%	$1.24E-04$ +/-14%	1.08	1.08	1.06	1.02
402.95	$9.24E-05$ +/-11%	$8.07E-05$ +/-14%	1.15	1.14	1.12	1.08
mean % diff. from E		11	14	11	6	

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Mn56	Fe56(n,p)Mn56	2.5d	98.3	1.17	5%
Mn54	Fe54(n,p)Mn54	312d	100.0	1.15	11%

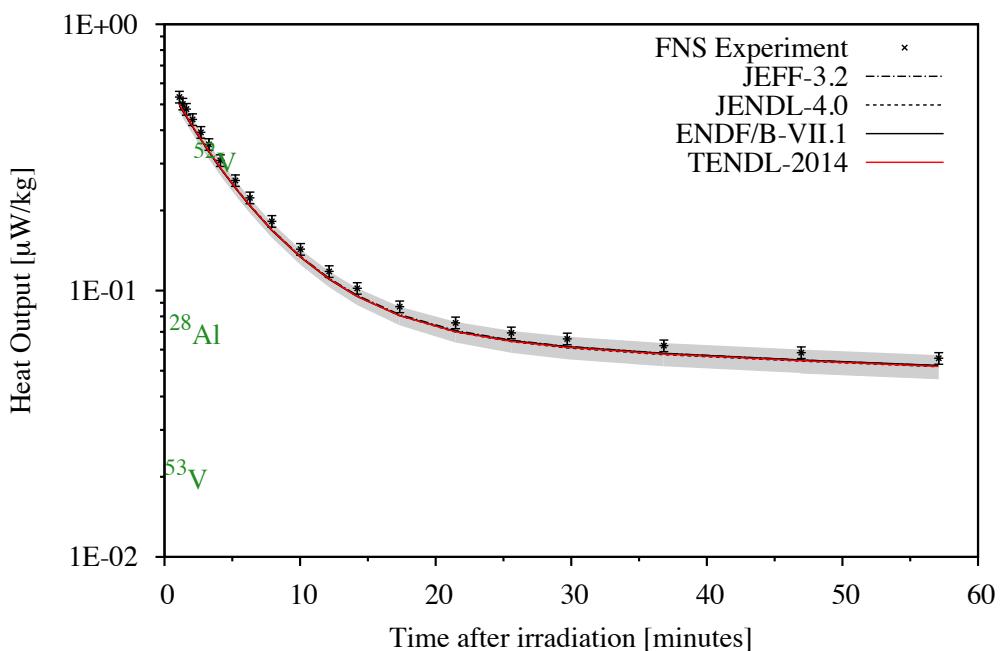


SS304

FNS-00 5 Min. Irradiation - SS304



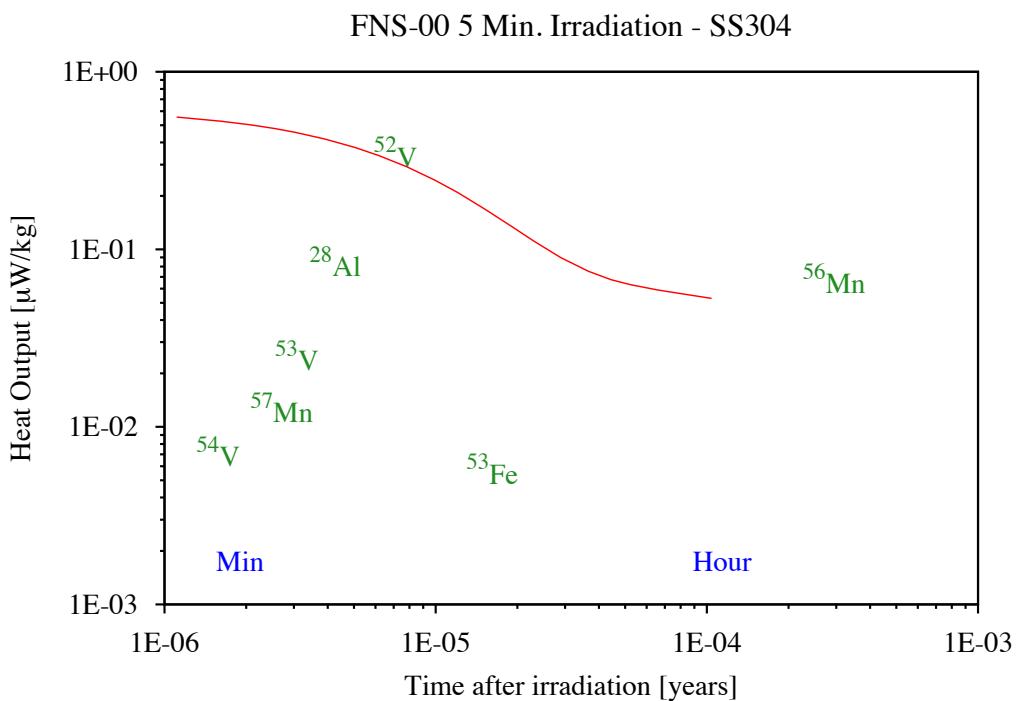
FNS-96 5 Min. Irradiation - SS304



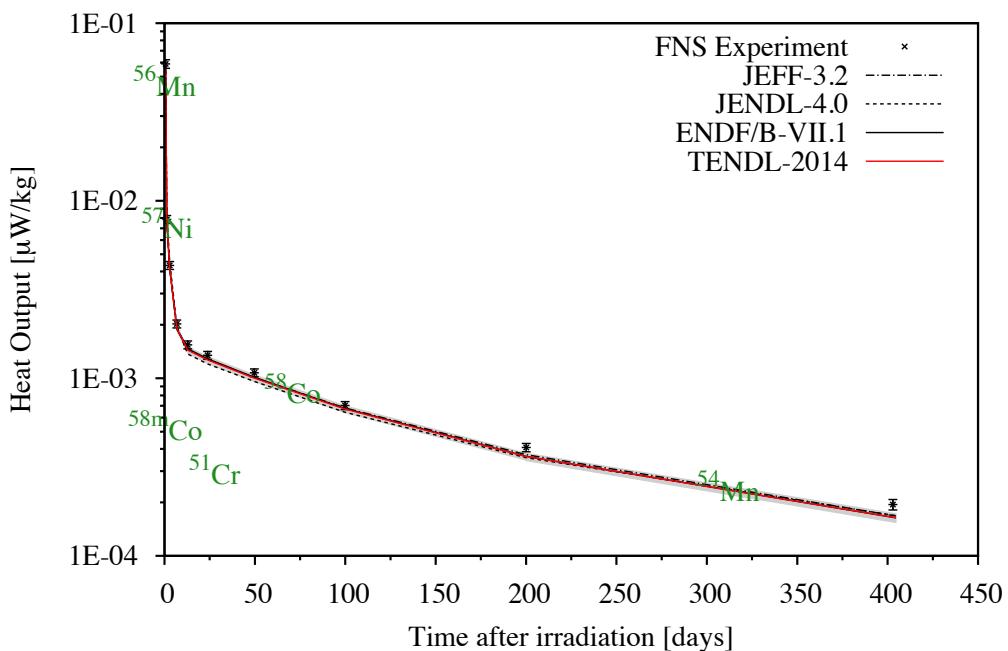
For SS-304, remarkable agreements between experiment and predictions exist for this steel for cooling times up to 1 hour.

Times	FNS EXP.	5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.		$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.58		$5.39E-01$ +/-6%	$5.56E-01$ +/-6%	0.97	0.98	0.98
0.85		$5.12E-01$ +/-6%	$5.27E-01$ +/-6%	0.97	0.98	0.99
1.10		$4.86E-01$ +/-6%	$5.02E-01$ +/-6%	0.97	0.98	0.98
1.35		$4.60E-01$ +/-6%	$4.78E-01$ +/-6%	0.96	0.97	0.98
1.60		$4.35E-01$ +/-6%	$4.55E-01$ +/-6%	0.96	0.97	0.97
2.05		$4.04E-01$ +/-6%	$4.18E-01$ +/-7%	0.97	0.98	0.98
2.65		$3.61E-01$ +/-6%	$3.74E-01$ +/-7%	0.96	0.97	0.97
3.25		$3.25E-01$ +/-6%	$3.37E-01$ +/-7%	0.97	0.97	0.97
4.12		$2.80E-01$ +/-6%	$2.91E-01$ +/-6%	0.96	0.97	0.97
5.23		$2.37E-01$ +/-5%	$2.45E-01$ +/-6%	0.97	0.98	0.97
6.33		$2.01E-01$ +/-5%	$2.09E-01$ +/-6%	0.96	0.97	0.97
7.97		$1.64E-01$ +/-5%	$1.69E-01$ +/-6%	0.97	0.98	0.97
10.07		$1.30E-01$ +/-5%	$1.34E-01$ +/-6%	0.97	0.98	0.97
12.12		$1.08E-01$ +/-5%	$1.11E-01$ +/-7%	0.97	0.98	0.97
15.20		$8.82E-02$ +/-5%	$8.99E-02$ +/-7%	0.98	0.98	0.97
19.25		$7.37E-02$ +/-5%	$7.52E-02$ +/-8%	0.98	0.98	0.98
23.37		$6.59E-02$ +/-5%	$6.74E-02$ +/-9%	0.98	0.97	0.98
27.47		$6.15E-02$ +/-5%	$6.32E-02$ +/-9%	0.97	0.97	0.98
34.55		$5.74E-02$ +/-5%	$5.91E-02$ +/-10%	0.97	0.97	0.96
44.65		$5.38E-02$ +/-5%	$5.56E-02$ +/-10%	0.97	0.96	0.97
54.77		$5.10E-02$ +/-5%	$5.29E-02$ +/-10%	0.96	0.95	0.96
mean % diff. from E			3	3	3	3

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
V52	Cr52(n,p)V52	3.7m	95.6	0.97	6%
	Cr53(n,d+np)V52		1.6	0.97	6%
	Mn55(n, α)V52		2.5	0.97	6%
Mn56	Fe56(n,p)Mn56	2.5h	99.6	0.96	5%



FNS-96 7 hours Irradiation - SS304

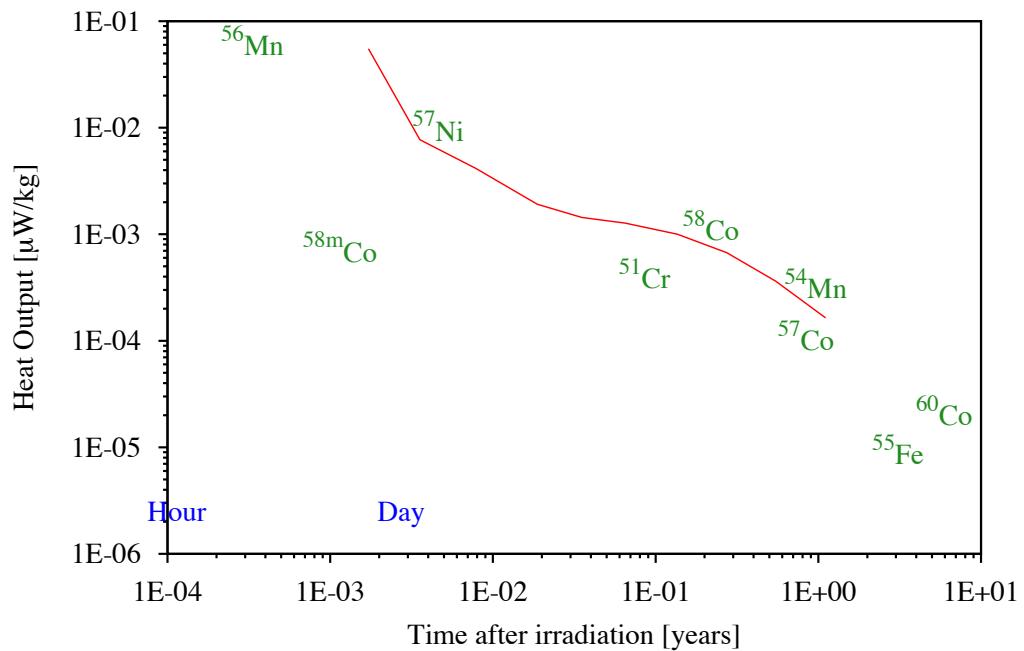


From the above graph one sees a very clean and well defined agreement.

Times Days	FNS EXP. 7 hrs μW/g	TENDL-2014 μW/g	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C
0.63	$5.90E-02$ +/-6%	$5.51E-02$ +/-6%	1.07	1.03	1.03
1.30	$7.85E-03$ +/-5%	$7.72E-03$ +/-7%	1.02	1.03	1.04
2.88	$4.32E-03$ +/-5%	$4.14E-03$ +/-7%	1.04	1.02	1.04
6.85	$2.02E-03$ +/-5%	$1.91E-03$ +/-5%	1.06	1.07	1.06
12.84	$1.54E-03$ +/-5%	$1.44E-03$ +/-5%	1.07	1.05	1.06
23.84	$1.35E-03$ +/-5%	$1.27E-03$ +/-5%	1.06	1.05	1.06
49.69	$1.07E-03$ +/-5%	$1.00E-03$ +/-5%	1.07	1.06	1.06
99.88	$7.03E-04$ +/-5%	$6.70E-04$ +/-5%	1.05	1.04	1.03
200.10	$4.08E-04$ +/-5%	$3.63E-04$ +/-5%	1.12	1.12	1.10
402.93	$1.94E-04$ +/-7%	$1.64E-04$ +/-6%	1.19	1.19	1.16
mean % diff. from E			7	6	9

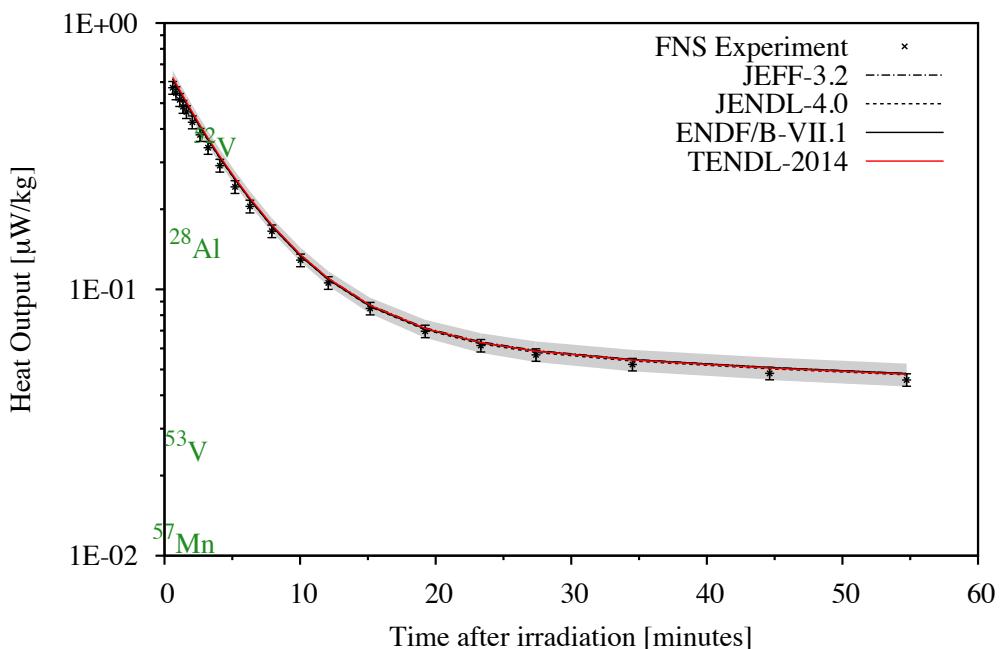
Product	Pathways	T _{1/2}	Path %	E/C	ΔE%
Ni57	Ni58(n,2n)Ni57	1.4d	100.0	1.02	5%
Co58	Ni58(n,p)Co58	70.8d	79.7	1.05	5%
	Ni58(n,p)Co58m	9.0h	20.4	1.05	5%
Mn54	Mn55(n,2n)Mn54	312d	46.2	1.19	7%
	Fe54(n,p)Mn54		54.7	1.19	7%

FNS-96 7 hours Irradiation - SS304

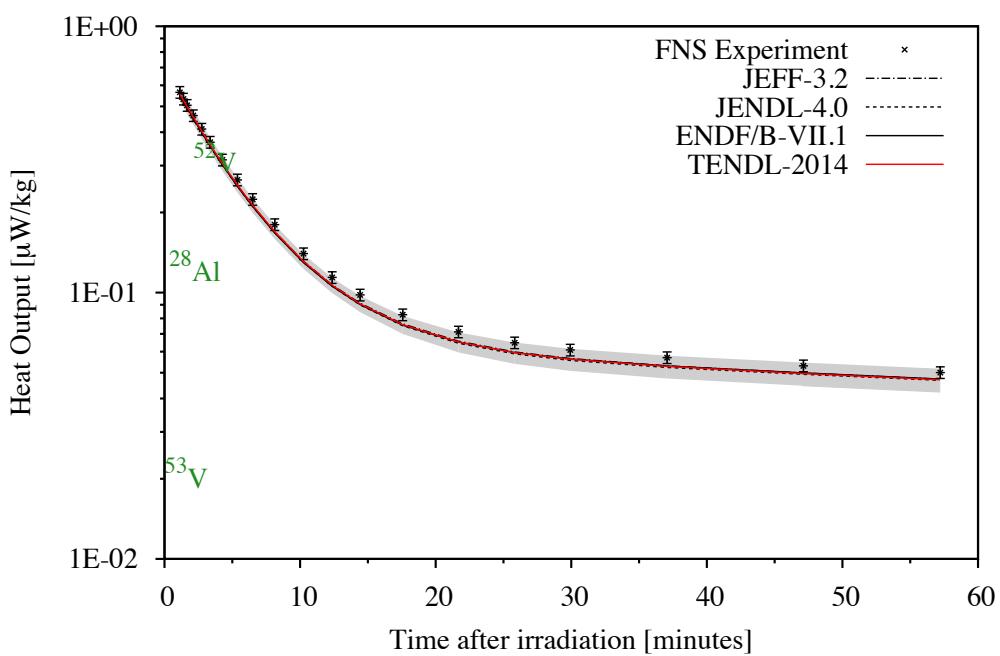


SS316

FNS-00 5 Min. Irradiation - SS316



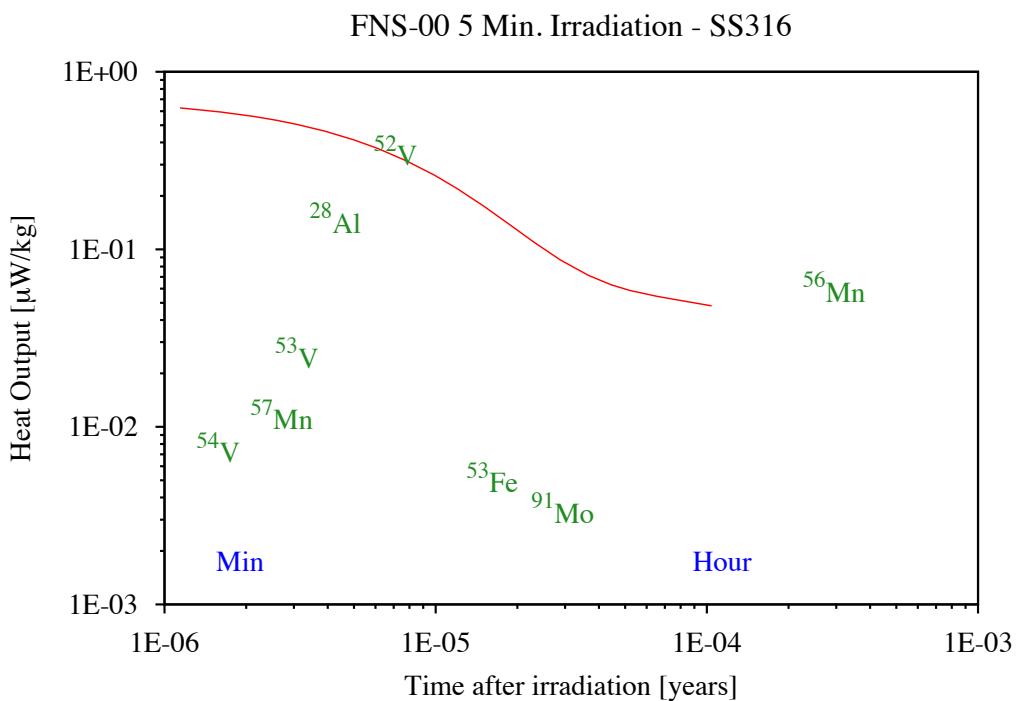
FNS-96 5 Min. Irradiation - SS316



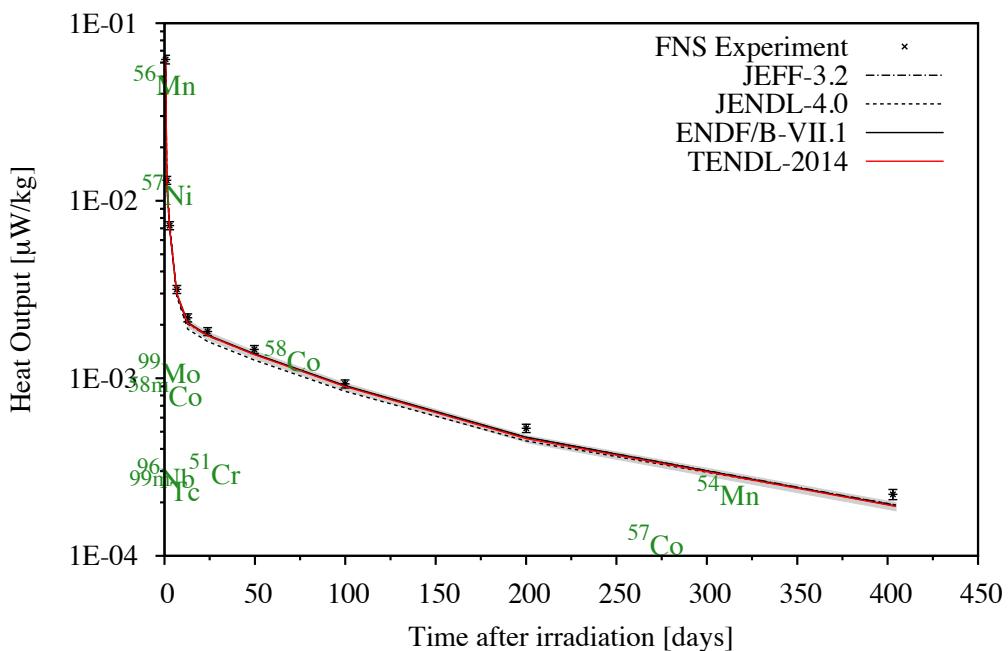
For SS-316, remarkable agreements between experiment and predictions exist for this type of stainless steel for cooling times up to 1 hour.

Times	FNS	EXP.	5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.				$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C
0.60				$5.72E-01$ +/-6%	$6.26E-01$ +/-6%	0.91	0.93
0.85				$5.46E-01$ +/-6%	$5.94E-01$ +/-6%	0.92	0.93
1.12				$5.15E-01$ +/-6%	$5.61E-01$ +/-6%	0.92	0.93
1.37				$4.85E-01$ +/-6%	$5.33E-01$ +/-6%	0.91	0.92
1.62				$4.64E-01$ +/-6%	$5.06E-01$ +/-6%	0.92	0.93
2.05				$4.24E-01$ +/-6%	$4.63E-01$ +/-6%	0.92	0.93
2.62				$3.80E-01$ +/-6%	$4.14E-01$ +/-6%	0.92	0.93
3.22				$3.40E-01$ +/-6%	$3.70E-01$ +/-6%	0.92	0.93
4.08				$2.91E-01$ +/-6%	$3.16E-01$ +/-6%	0.92	0.93
5.20				$2.43E-01$ +/-5%	$2.62E-01$ +/-6%	0.93	0.94
6.30				$2.05E-01$ +/-5%	$2.20E-01$ +/-6%	0.93	0.94
7.92				$1.65E-01$ +/-5%	$1.75E-01$ +/-6%	0.95	0.96
10.03				$1.29E-01$ +/-5%	$1.35E-01$ +/-6%	0.95	0.96
12.08				$1.06E-01$ +/-5%	$1.10E-01$ +/-6%	0.96	0.96
15.17				$8.48E-02$ +/-5%	$8.71E-02$ +/-7%	0.97	0.97
19.23				$6.96E-02$ +/-5%	$7.13E-02$ +/-8%	0.98	0.98
23.33				$6.15E-02$ +/-5%	$6.31E-02$ +/-8%	0.97	0.97
27.40				$5.68E-02$ +/-5%	$5.86E-02$ +/-9%	0.97	0.96
34.52				$5.22E-02$ +/-5%	$5.43E-02$ +/-9%	0.96	0.96
44.63				$4.84E-02$ +/-5%	$5.07E-02$ +/-10%	0.95	0.95
54.73				$4.57E-02$ +/-5%	$4.80E-02$ +/-10%	0.95	0.95
mean % diff. from E				6	6	6	5

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
V52	Cr52(n,p)V52	3.7m	95.0	0.92	6%
	Cr53(n,d)V52		1.6	0.92	6%
	Mn55(n, α)V52		2.4	0.92	6%
Mn56	Fe56(n,p)Mn56	2.5h	99.6	0.95	5%



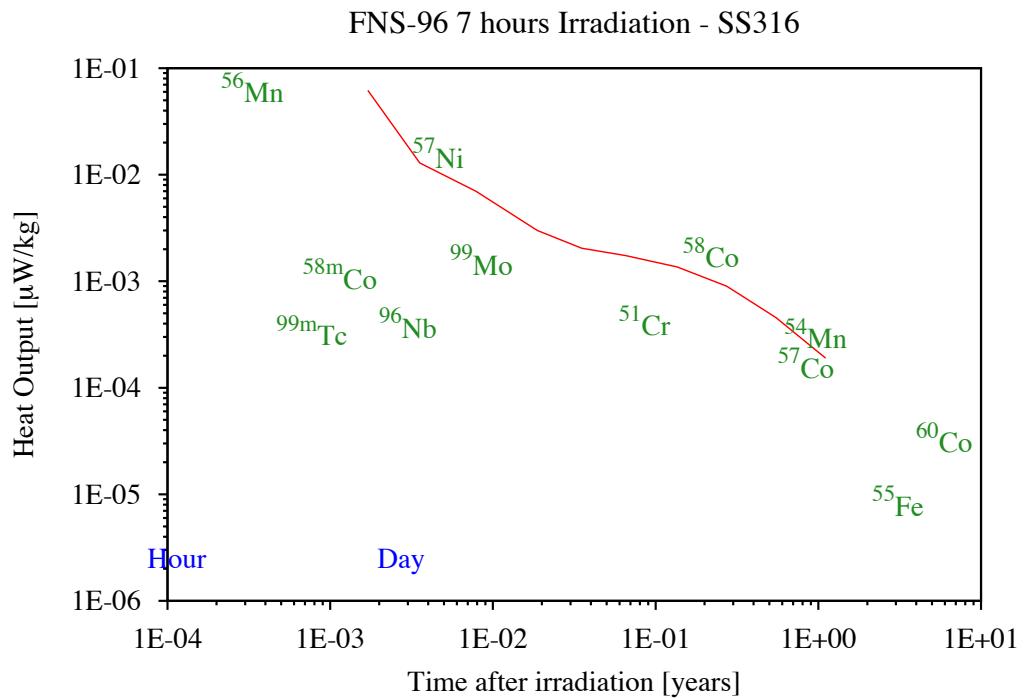
FNS-96 7 hours Irradiation - SS316

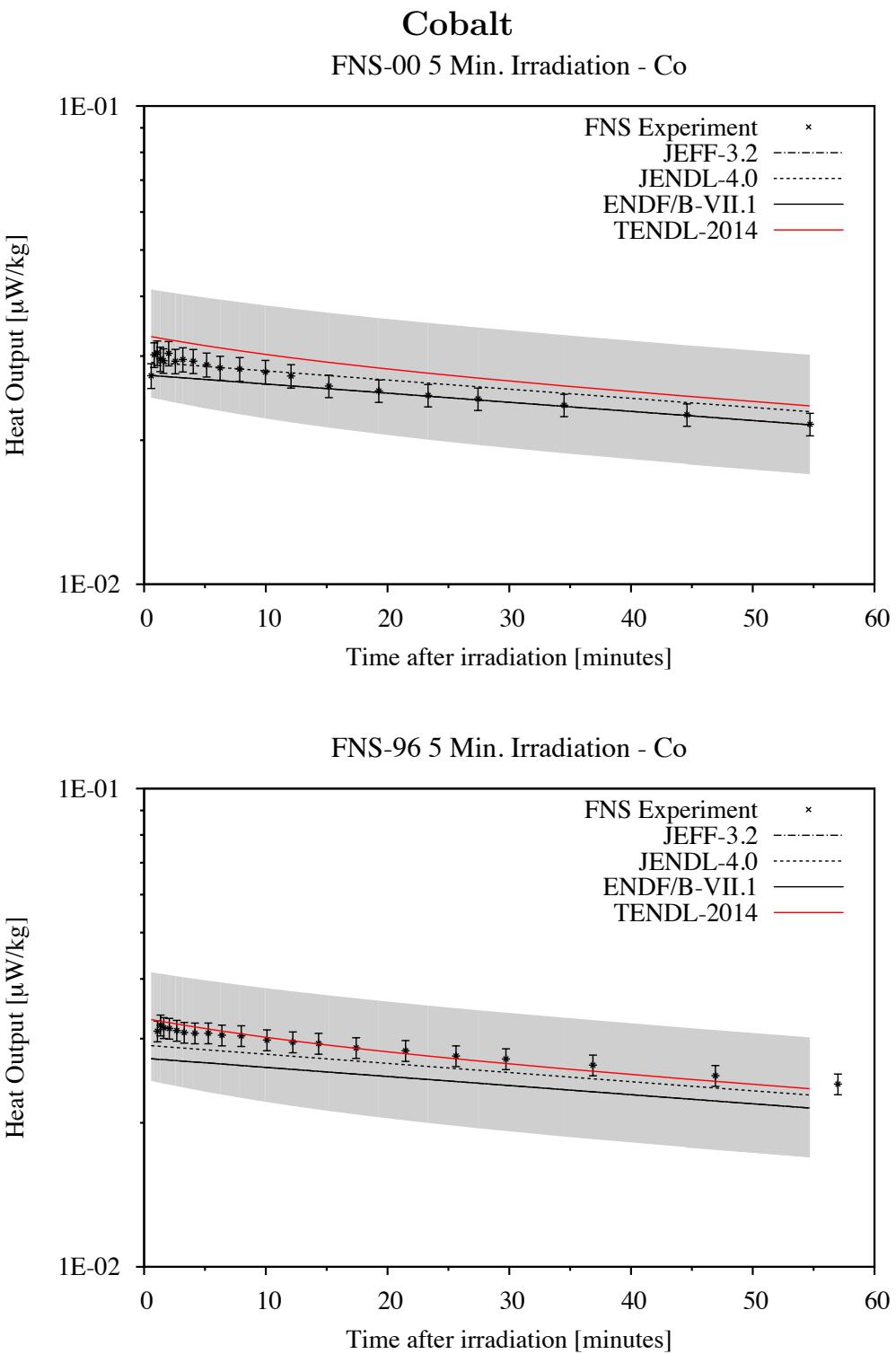


Although numerous radionuclides are present, a well characterised agreement exists, nearly within the uncertainties, up to an amazing 400 days cooling.

Times	FNS EXP. 7 hrs	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0	
Days	μW/g	μW/g	E/C	E/C	E/C	
0.62	$6.24E-02$ +/-6%	$6.19E-02$ +/-5%	1.01	1.01	1.13	1.17
1.30	$1.30E-02$ +/-5%	$1.29E-02$ +/-7%	1.01	1.03	1.08	0.95
2.88	$7.24E-03$ +/-5%	$6.98E-03$ +/-6%	1.04	1.04	1.05	0.96
6.85	$3.17E-03$ +/-5%	$3.00E-03$ +/-4%	1.06	1.06	1.07	1.10
12.84	$2.19E-03$ +/-5%	$2.04E-03$ +/-5%	1.07	1.06	1.08	1.16
23.83	$1.84E-03$ +/-5%	$1.74E-03$ +/-6%	1.05	1.05	1.06	1.14
49.69	$1.45E-03$ +/-5%	$1.36E-03$ +/-6%	1.07	1.06	1.06	1.15
99.88	$9.31E-04$ +/-5%	$8.98E-04$ +/-5%	1.04	1.02	1.03	1.10
200.10	$5.23E-04$ +/-5%	$4.57E-04$ +/-5%	1.14	1.12	1.13	1.18
402.93	$2.22E-04$ +/-7%	$1.90E-04$ +/-6%	1.17	1.16	1.15	1.15
mean % diff. from E		6	6	8	11	

Product	Pathways	T _{1/2}	Path %	E/C	ΔE%
Ni57	Ni58(n,2n)Ni57	1.4d	100.0	1.01	5%
Co58	Ni58(n,p)Co58	70.8d	79.7	1.04	5%
	Ni58(n,p)Co58m	9.0h	20.4	1.04	5%
Mn54	Mn55(n,2n)Mn54	312d	48.9	1.17	7%
	Fe54(n,p)Mn54		50.9	1.17	7%

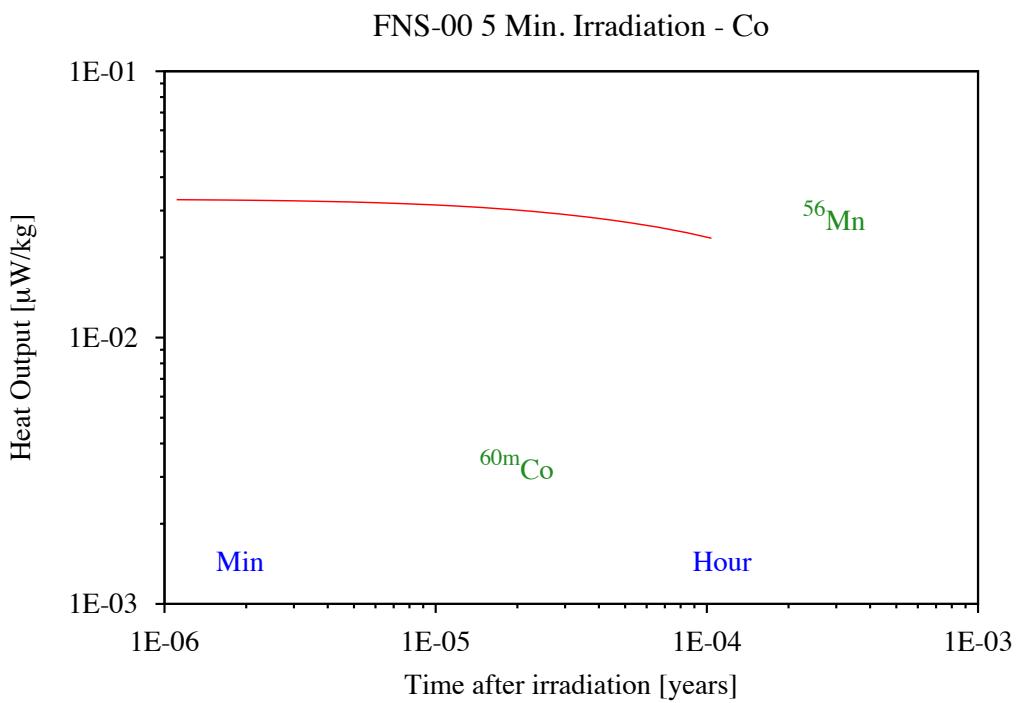


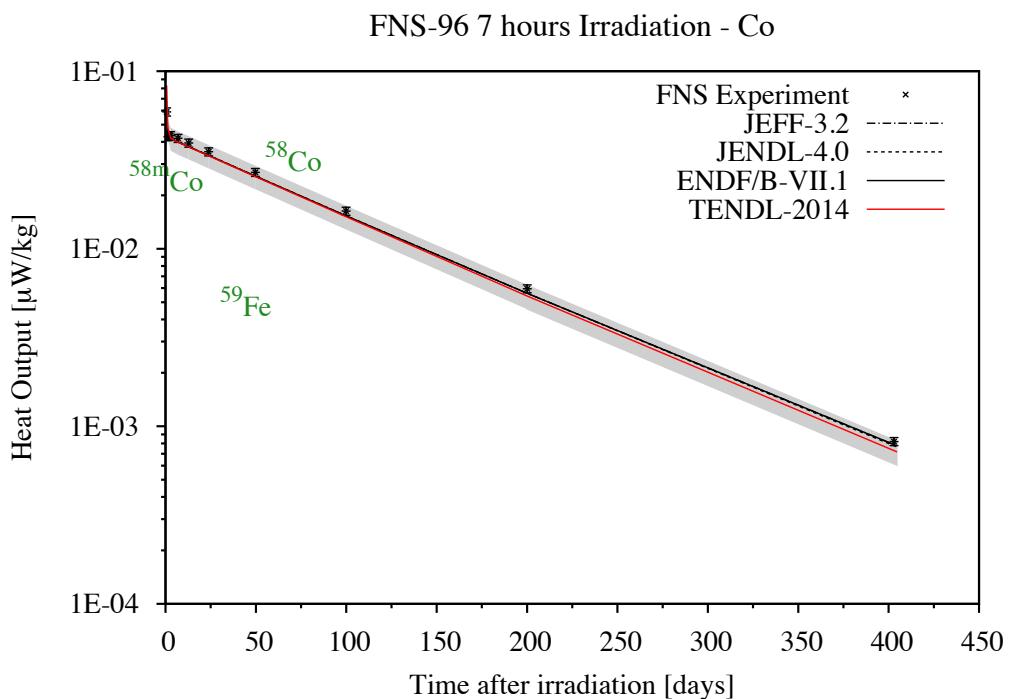


For Cobalt, the two batches of measured experimental data sets are different. The differences lie outside of the quoted experimental uncertainty. However, the code predictions stay, for both batches, within the large quoted calculational uncertainties. TENDL-2014 variance could be halved to 20%.

Times Min.	FNS EXP. $\mu\text{W/g}$	5 mins $\mu\text{W/g}$	TENDL-2014 E/C	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C
0.58	$2.73E-02$ +/-6%	$3.29E-02$ +/-25%	0.83	1.00	1.00	0.94
0.83	$3.02E-02$ +/-6%	$3.29E-02$ +/-25%	0.92	1.11	1.11	1.04
1.08	$3.05E-02$ +/-6%	$3.28E-02$ +/-26%	0.93	1.12	1.12	1.05
1.33	$2.96E-02$ +/-6%	$3.27E-02$ +/-26%	0.90	1.09	1.09	1.02
1.58	$2.93E-02$ +/-6%	$3.26E-02$ +/-26%	0.90	1.08	1.08	1.01
2.02	$3.04E-02$ +/-6%	$3.25E-02$ +/-26%	0.94	1.12	1.12	1.05
2.57	$2.93E-02$ +/-6%	$3.23E-02$ +/-26%	0.91	1.08	1.08	1.01
3.18	$2.95E-02$ +/-6%	$3.21E-02$ +/-26%	0.92	1.09	1.09	1.03
4.03	$2.93E-02$ +/-6%	$3.18E-02$ +/-26%	0.92	1.09	1.09	1.02
5.13	$2.88E-02$ +/-6%	$3.15E-02$ +/-26%	0.91	1.07	1.07	1.01
6.25	$2.83E-02$ +/-6%	$3.12E-02$ +/-26%	0.91	1.06	1.06	1.00
7.85	$2.82E-02$ +/-6%	$3.08E-02$ +/-26%	0.92	1.06	1.06	1.00
9.97	$2.78E-02$ +/-6%	$3.03E-02$ +/-27%	0.92	1.06	1.06	0.99
12.07	$2.72E-02$ +/-6%	$2.98E-02$ +/-27%	0.92	1.05	1.05	0.98
15.18	$2.60E-02$ +/-5%	$2.91E-02$ +/-27%	0.89	1.01	1.01	0.95
19.28	$2.54E-02$ +/-5%	$2.83E-02$ +/-27%	0.90	1.01	1.01	0.95
23.33	$2.48E-02$ +/-5%	$2.76E-02$ +/-27%	0.90	1.00	1.00	0.94
27.43	$2.44E-02$ +/-5%	$2.70E-02$ +/-28%	0.90	1.00	1.00	0.94
34.50	$2.37E-02$ +/-5%	$2.60E-02$ +/-28%	0.91	1.01	1.01	0.94
44.60	$2.26E-02$ +/-5%	$2.47E-02$ +/-28%	0.91	1.00	1.00	0.94
54.70	$2.16E-02$ +/-5%	$2.36E-02$ +/-28%	0.91	1.00	1.00	0.94
mean % diff. from E			10	5	5	3

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Mn56	Co59(n,α)Mn56	2.5h	100.0	0.91	5%

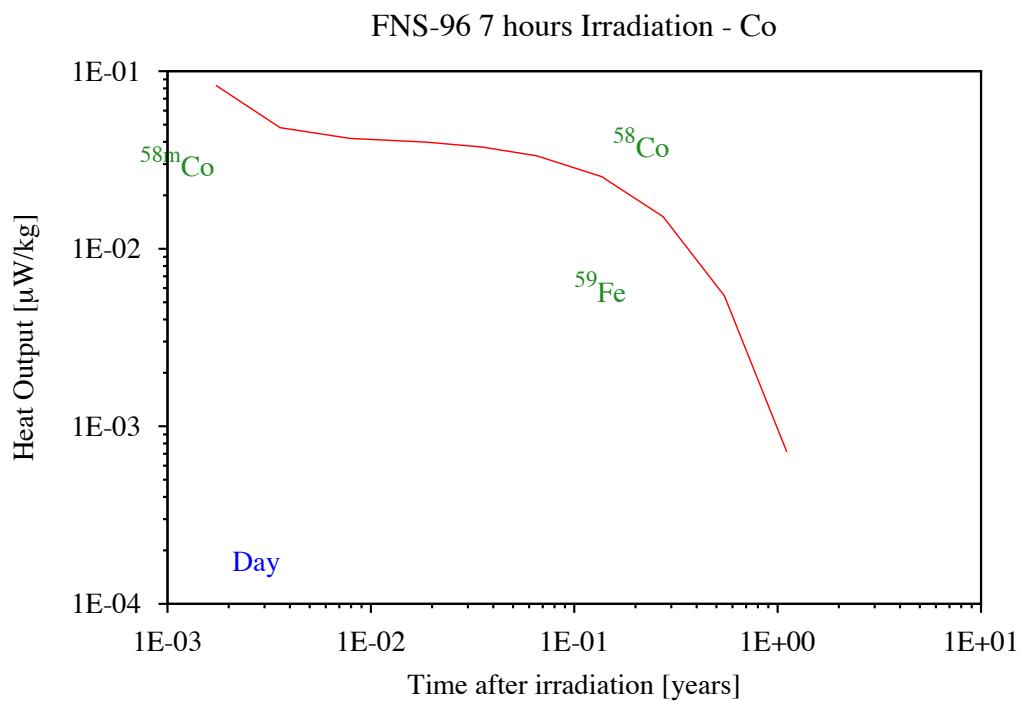




Good agreement, within the experimental uncertainty bands.

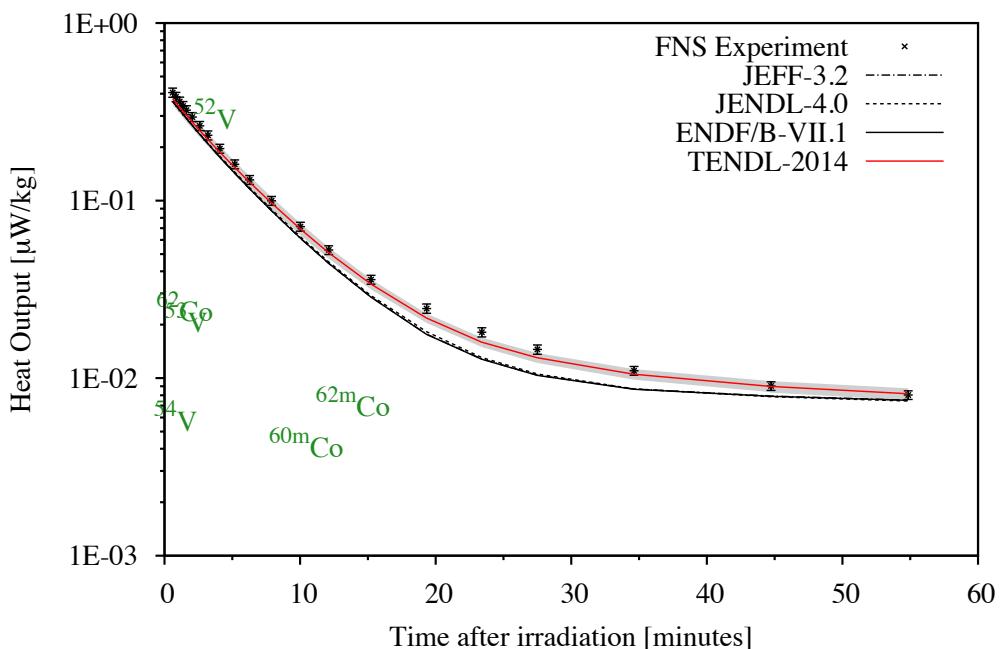
Times Days	FNS EXP. 7 hrs $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C
0.63	$5.90E-02 +/- 5\%$	$8.31E-02 +/- 11\%$	0.71	0.97	0.97
1.31	$4.28E-02 +/- 5\%$	$4.81E-02 +/- 13\%$	0.89	1.00	1.00
2.89	$4.33E-02 +/- 5\%$	$4.18E-02 +/- 15\%$	1.04	1.04	1.04
6.86	$4.19E-02 +/- 5\%$	$3.98E-02 +/- 15\%$	1.05	1.05	1.05
12.85	$3.94E-02 +/- 5\%$	$3.74E-02 +/- 15\%$	1.05	1.05	1.05
23.84	$3.52E-02 +/- 5\%$	$3.34E-02 +/- 15\%$	1.05	1.05	1.05
49.70	$2.69E-02 +/- 5\%$	$2.55E-02 +/- 15\%$	1.06	1.05	1.05
99.89	$1.63E-02 +/- 5\%$	$1.52E-02 +/- 15\%$	1.07	1.06	1.06
200.11	$5.95E-03 +/- 5\%$	$5.42E-03 +/- 16\%$	1.10	1.06	1.06
402.95	$8.21E-04 +/- 5\%$	$7.17E-04 +/- 16\%$	1.15	1.06	1.07
mean % diff. from E			11	4	4
					5

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Co58m	Co59(n,2n)Co58m	8.9h	99.8	0.71	5%
Co58	Co59(n,2n)Co58	70.8d	71.0	1.07	5%
	Co59(n,2n)Co58m	8.9h	29.0	1.07	5%

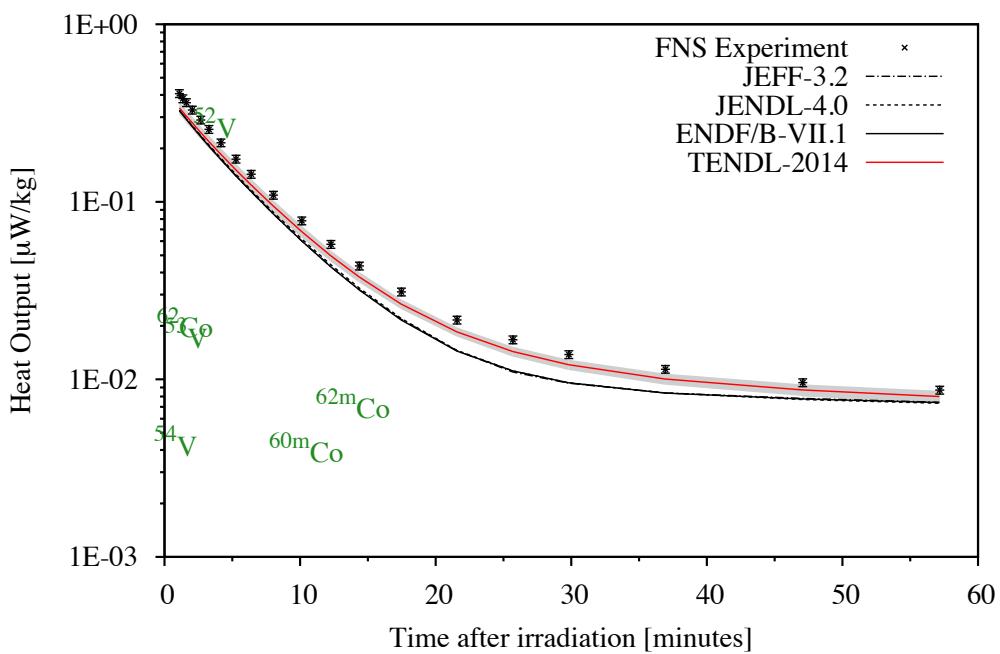


Inconel-600

FNS-00 5 Min. Irradiation - Inc600



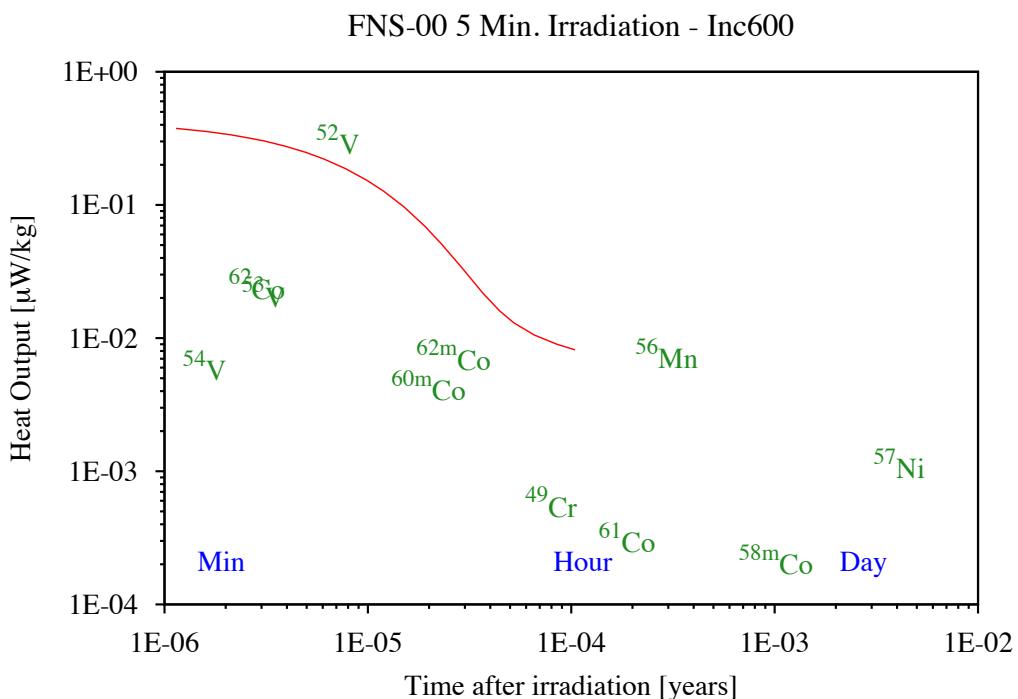
FNS-96 5 Min. Irradiation - Inc600



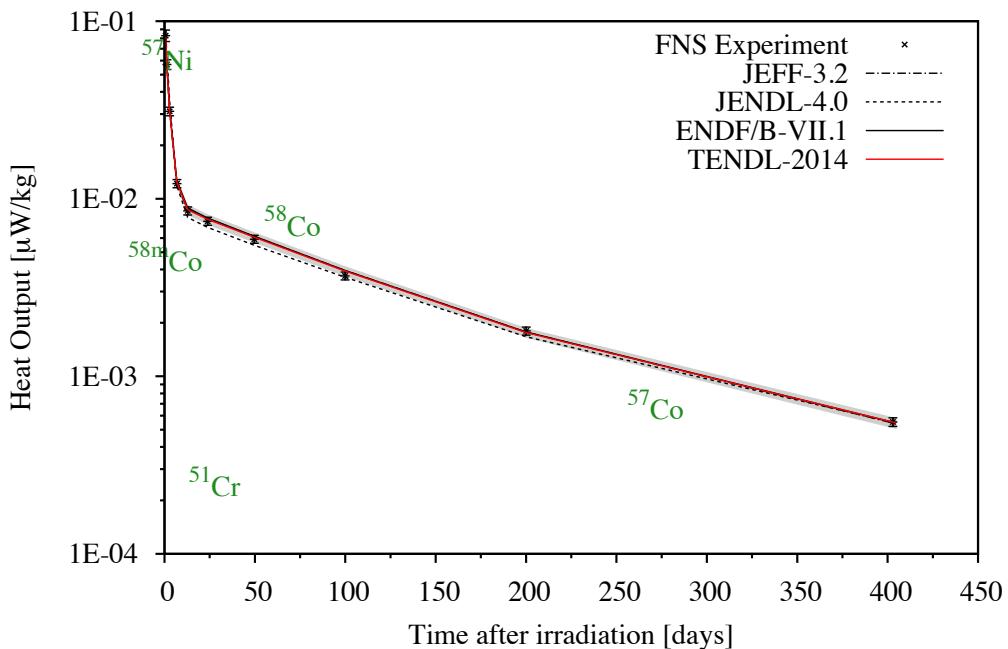
For Inconel, an interesting parallel can be drawn there when V-52 is dominant up to 30 minutes cooling time. It is produced through multiple channels from Cr-52, Cr-53 and Mn-55 and is well predicted by TENDL-2014. This trend is corroborated in the pathways arising from pure Cr isotopes.

Times	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.60	$4.06E-01$ +/-6%	$3.75E-01$ +/-8%	1.08	1.12	1.12
0.85	$3.84E-01$ +/-6%	$3.56E-01$ +/-8%	1.08	1.12	1.12
1.12	$3.61E-01$ +/-6%	$3.36E-01$ +/-8%	1.08	1.12	1.11
1.37	$3.41E-01$ +/-6%	$3.19E-01$ +/-8%	1.07	1.11	1.11
1.62	$3.23E-01$ +/-6%	$3.02E-01$ +/-8%	1.07	1.11	1.11
2.05	$2.95E-01$ +/-6%	$2.77E-01$ +/-8%	1.07	1.12	1.11
2.60	$2.64E-01$ +/-6%	$2.48E-01$ +/-8%	1.06	1.12	1.11
3.20	$2.33E-01$ +/-6%	$2.21E-01$ +/-8%	1.05	1.12	1.10
4.08	$1.96E-01$ +/-6%	$1.87E-01$ +/-8%	1.05	1.12	1.10
5.18	$1.60E-01$ +/-6%	$1.54E-01$ +/-8%	1.04	1.12	1.11
6.28	$1.31E-01$ +/-6%	$1.27E-01$ +/-8%	1.03	1.12	1.11
7.90	$9.98E-02$ +/-6%	$9.68E-02$ +/-8%	1.03	1.14	1.12
10.02	$7.14E-02$ +/-6%	$6.93E-02$ +/-8%	1.03	1.16	1.14
12.12	$5.27E-02$ +/-6%	$5.09E-02$ +/-7%	1.04	1.19	1.16
15.23	$3.59E-02$ +/-6%	$3.38E-02$ +/-7%	1.06	1.26	1.25
19.33	$2.47E-02$ +/-6%	$2.18E-02$ +/-6%	1.13	1.40	1.39
23.40	$1.81E-02$ +/-6%	$1.60E-02$ +/-6%	1.14	1.42	1.41
27.50	$1.45E-02$ +/-6%	$1.30E-02$ +/-6%	1.11	1.40	1.39
34.63	$1.10E-02$ +/-6%	$1.05E-02$ +/-7%	1.05	1.27	1.27
44.73	$9.03E-03$ +/-6%	$8.98E-03$ +/-7%	1.00	1.14	1.15
54.85	$8.03E-03$ +/-6%	$8.17E-03$ +/-7%	0.98	1.07	1.08
mean % diff. from E		6	15	14	14

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
V52	Cr52(n,p)V52	3.7m	97.3	1.05	6%
	Cr53(n,d+np)V52		1.6	1.05	6%
	Mn55(n, α)V52		2.4	1.05	6%
Mn56	Fe56(n,p)Mn56	2.5h	99.4	0.98	6%



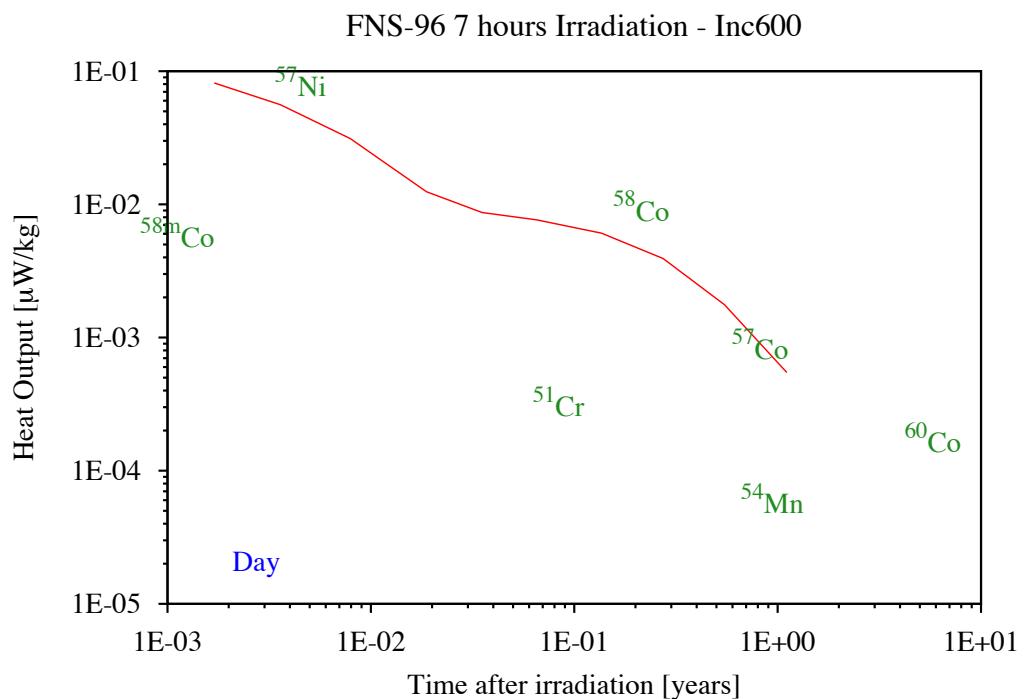
FNS-96 7 hours Irradiation - Inc600



For this Inconel 600 alloy, one sees clean agreements between measurement and simulations.

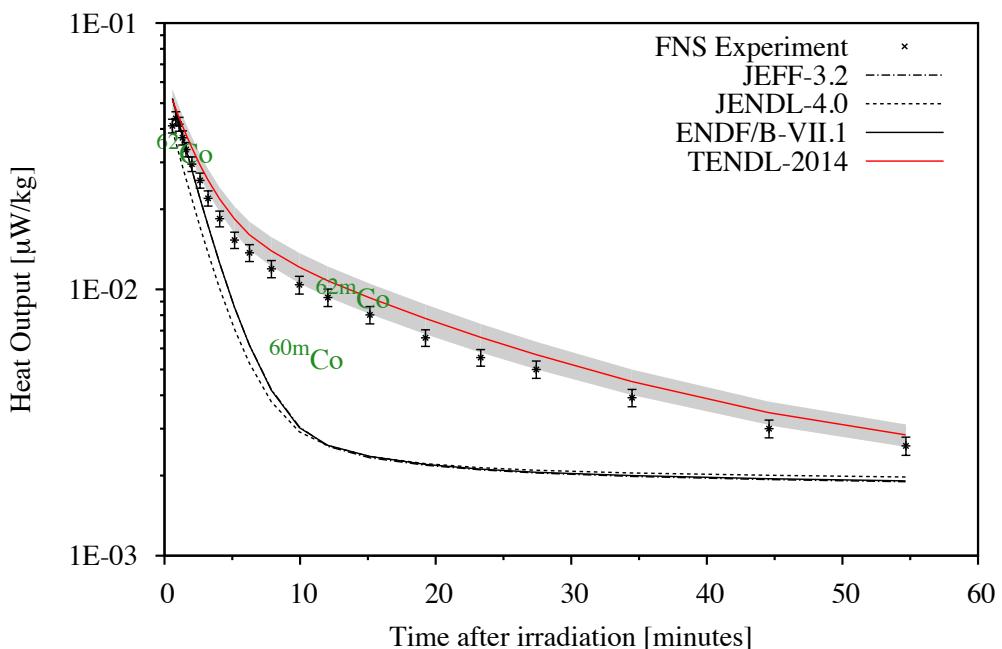
Times	FNS EXP. 7 hrs	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Days	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.62	$8.29E-02 +/- 7\%$	$8.16E-02 +/- 8\%$	1.02	1.05	1.06
1.31	$5.70E-02 +/- 6\%$	$5.60E-02 +/- 9\%$	1.02	1.02	1.03
2.89	$3.11E-02 +/- 6\%$	$3.12E-02 +/- 8\%$	1.00	0.98	0.99
6.86	$1.22E-02 +/- 5\%$	$1.24E-02 +/- 6\%$	0.98	0.96	1.02
12.86	$8.55E-03 +/- 5\%$	$8.67E-03 +/- 7\%$	0.99	0.96	0.98
23.84	$7.47E-03 +/- 5\%$	$7.66E-03 +/- 7\%$	0.98	0.96	0.97
49.69	$5.92E-03 +/- 5\%$	$6.07E-03 +/- 7\%$	0.97	0.96	0.97
99.88	$3.68E-03 +/- 5\%$	$3.92E-03 +/- 7\%$	0.94	0.93	0.93
200.11	$1.80E-03 +/- 5\%$	$1.77E-03 +/- 6\%$	1.02	1.01	1.02
402.94	$5.53E-04 +/- 6\%$	$5.46E-04 +/- 7\%$	1.01	1.01	1.01
mean % diff. from E		2	3	3	7

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Ni57	$\text{Ni}58(\text{n},2\text{n})\text{Ni}57$	1.4d	100.0	1.02	6%
Co58	$\text{Ni}58(\text{n},\text{p})\text{Co}58$	70.8d	79.7	0.94	5%
	$\text{Ni}58(\text{n},\text{p})\text{Co}58\text{m}$	9.0h	20.4	0.94	5%
Co57	$\text{Ni}58(\text{n},\text{np})\text{Co}57$	271d	97.5	1.01	5%
	$\text{Ni}58(\text{n},\text{d})\text{Co}57$	271d	2.2	1.01	5%

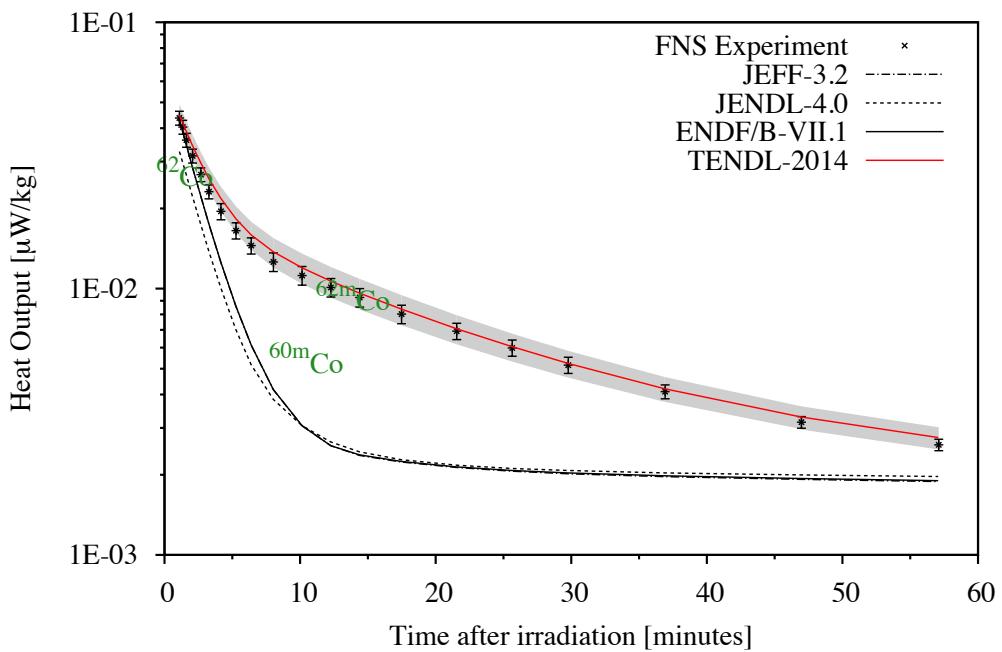


Nickel

FNS-00 5 Min. Irradiation - Ni



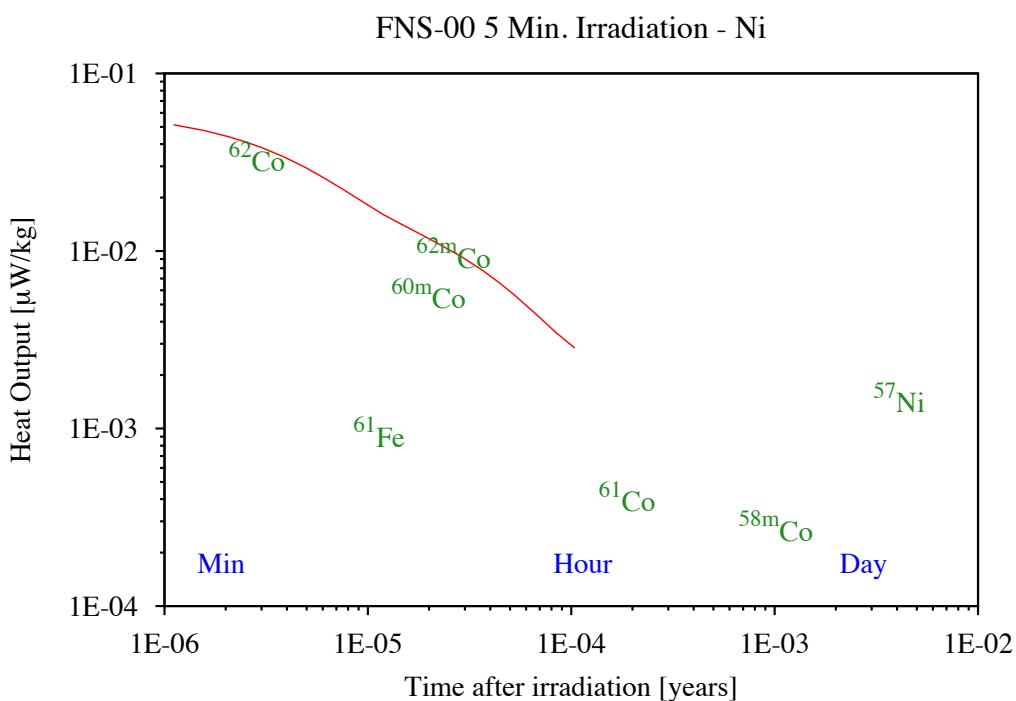
FNS-96 5 Min. Irradiation - Ni



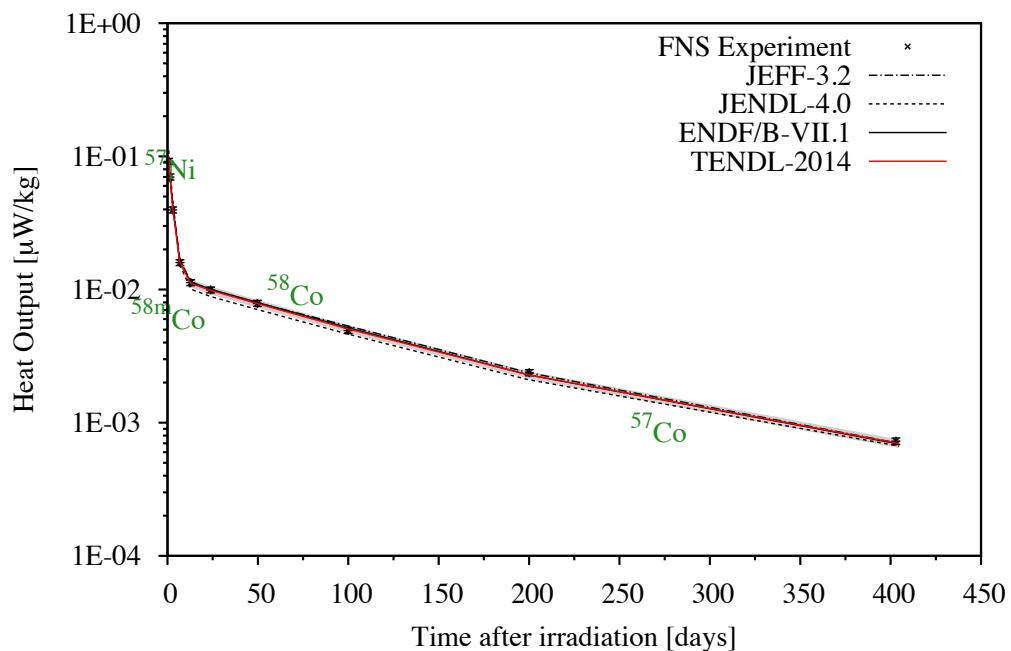
For Nickel, the two sets of experimental measurements differ. However, the code predictions stay within 15% of the measurements at all cooling times for TENDL-2014. All the others libraries lack isomer production pathways.

Times	FNS EXP.	5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.		$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.58		$4.11E-02$ +/-6%	$5.14E-02$ +/-10%	0.80	0.79	0.79
0.83		$4.38E-02$ +/-6%	$4.76E-02$ +/-10%	0.92	0.94	0.94
1.08		$4.18E-02$ +/-6%	$4.41E-02$ +/-10%	0.95	1.00	1.00
1.33		$3.71E-02$ +/-6%	$4.10E-02$ +/-10%	0.91	0.99	0.99
1.58		$3.35E-02$ +/-6%	$3.82E-02$ +/-10%	0.88	0.99	0.99
2.02		$2.95E-02$ +/-6%	$3.40E-02$ +/-10%	0.87	1.05	1.05
2.62		$2.56E-02$ +/-6%	$2.94E-02$ +/-10%	0.87	1.17	1.17
3.22		$2.20E-02$ +/-7%	$2.57E-02$ +/-10%	0.85	1.27	1.27
4.07		$1.84E-02$ +/-7%	$2.19E-02$ +/-11%	0.84	1.46	1.46
5.17		$1.53E-02$ +/-7%	$1.84E-02$ +/-11%	0.83	1.79	1.79
6.27		$1.37E-02$ +/-7%	$1.60E-02$ +/-12%	0.86	2.22	2.22
7.88		$1.19E-02$ +/-7%	$1.40E-02$ +/-13%	0.86	2.85	2.84
9.95		$1.04E-02$ +/-8%	$1.21E-02$ +/-13%	0.86	3.44	3.42
12.05		$9.32E-03$ +/-8%	$1.08E-02$ +/-13%	0.87	3.59	3.62
15.15		$8.02E-03$ +/-7%	$9.30E-03$ +/-13%	0.86	3.40	3.44
19.25		$6.58E-03$ +/-7%	$7.78E-03$ +/-13%	0.85	2.99	3.01
23.32		$5.54E-03$ +/-7%	$6.61E-03$ +/-12%	0.84	2.62	2.64
27.42		$5.00E-03$ +/-7%	$5.69E-03$ +/-12%	0.88	2.43	2.45
34.48		$3.92E-03$ +/-8%	$4.51E-03$ +/-11%	0.87	1.96	1.97
44.58		$3.00E-03$ +/-8%	$3.45E-03$ +/-10%	0.87	1.54	1.55
54.68		$2.58E-03$ +/-8%	$2.84E-03$ +/-9%	0.91	1.35	1.36
mean % diff. from E			15	37	37	44

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Co62	Ni62(n,p)Co62	1.5m	98.7	0.88	6%
Co62m	Ni62(n,p)Co62m	13.9m	100.0	0.86	7%



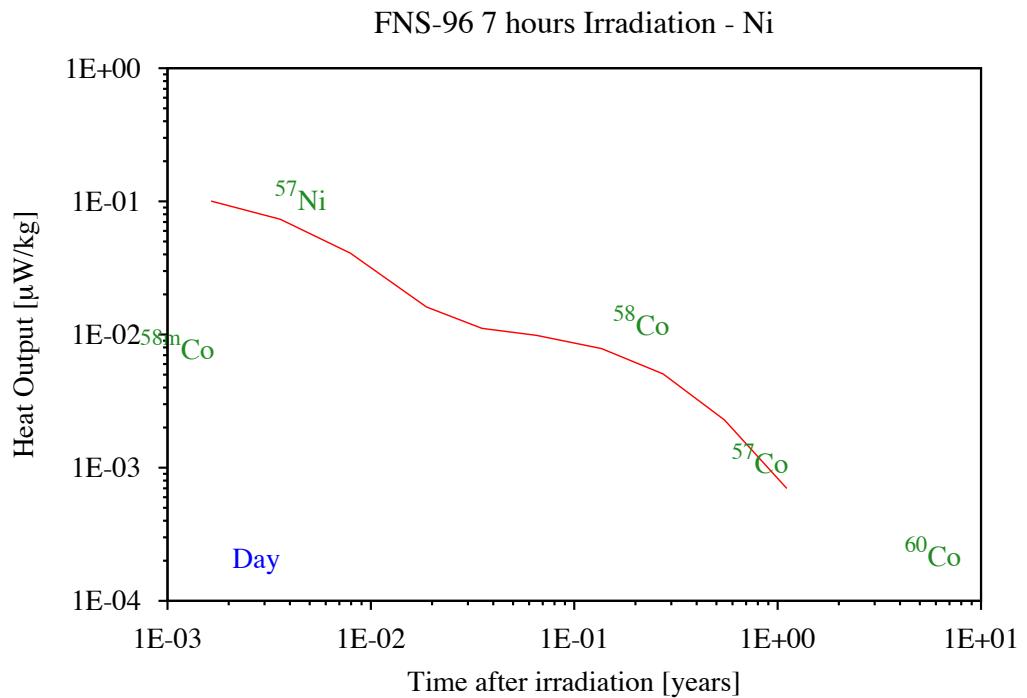
FNS-96 7 hours Irradiation - Ni



An excellent agreement exists with all databases.

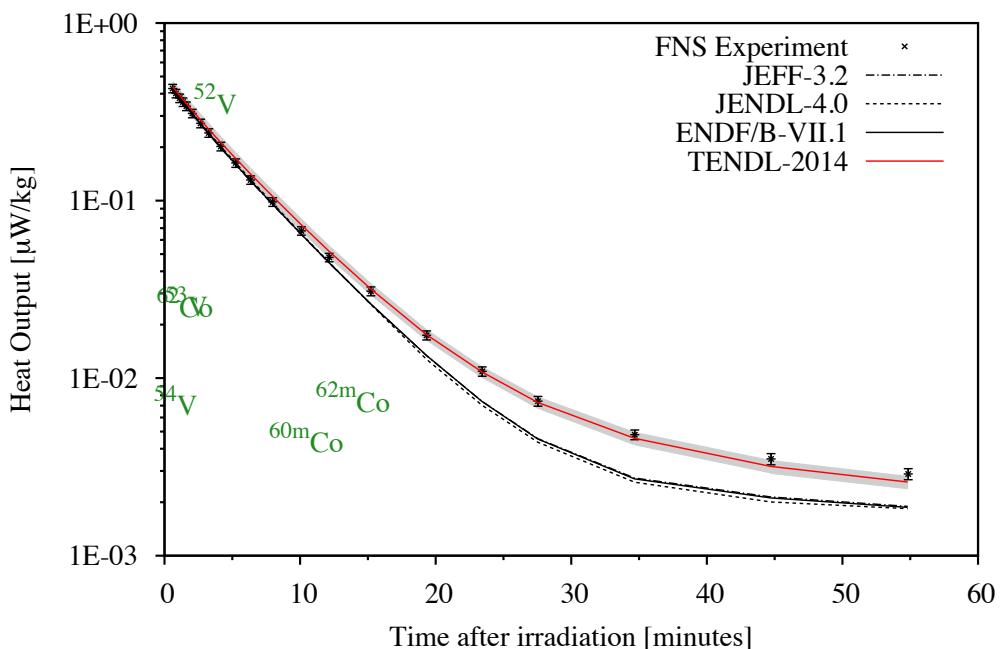
Times Days	FNS EXP. 7 hrs $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C
0.60	$9.17E-02$ +/-5% $1.01E-01$ +/-9%	0.91	0.95	0.95	0.83
1.31	$7.01E-02$ +/-5% $7.34E-02$ +/-9%	0.95	0.96	0.97	0.85
2.89	$3.96E-02$ +/-5% $4.09E-02$ +/-8%	0.97	0.90	0.91	0.83
6.86	$1.59E-02$ +/-5% $1.61E-02$ +/-6%	0.99	1.00	0.93	1.04
12.85	$1.13E-02$ +/-5% $1.11E-02$ +/-7%	1.01	0.99	0.99	1.12
23.85	$9.92E-03$ +/-5% $9.85E-03$ +/-7%	1.01	0.99	1.00	1.12
49.70	$7.87E-03$ +/-5% $7.85E-03$ +/-7%	1.00	0.98	0.99	1.11
99.89	$4.92E-03$ +/-5% $5.06E-03$ +/-7%	0.97	0.95	0.92	1.07
200.11	$2.37E-03$ +/-5% $2.28E-03$ +/-6%	1.04	1.04	1.00	1.13
402.94	$7.27E-04$ +/-6% $6.99E-04$ +/-7%	1.04	1.05	1.04	1.09
mean % diff. from E		3	4	4	12

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Ni57	Ni58(n,2n)Ni57	1.4d	100.0	0.95	5%
Co58	Ni58(n,p)Co58	70.8d	79.6	0.97	5%
	Ni58(n,p)Co58m	8.9h	20.3	0.97	5%
Co57	Ni58(n,np)Co57	271d	97.5	1.04	5%
	Ni58(n,d)Co57	271d	2.2	1.04	5%

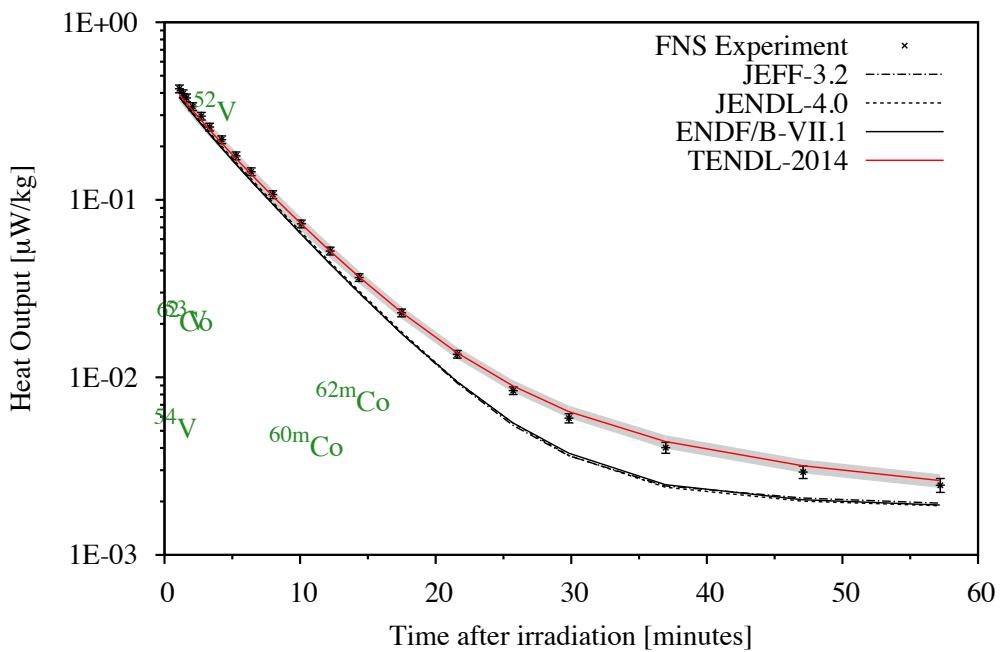


Nickel-chrome

FNS-00 5 Min. Irradiation - NiCr



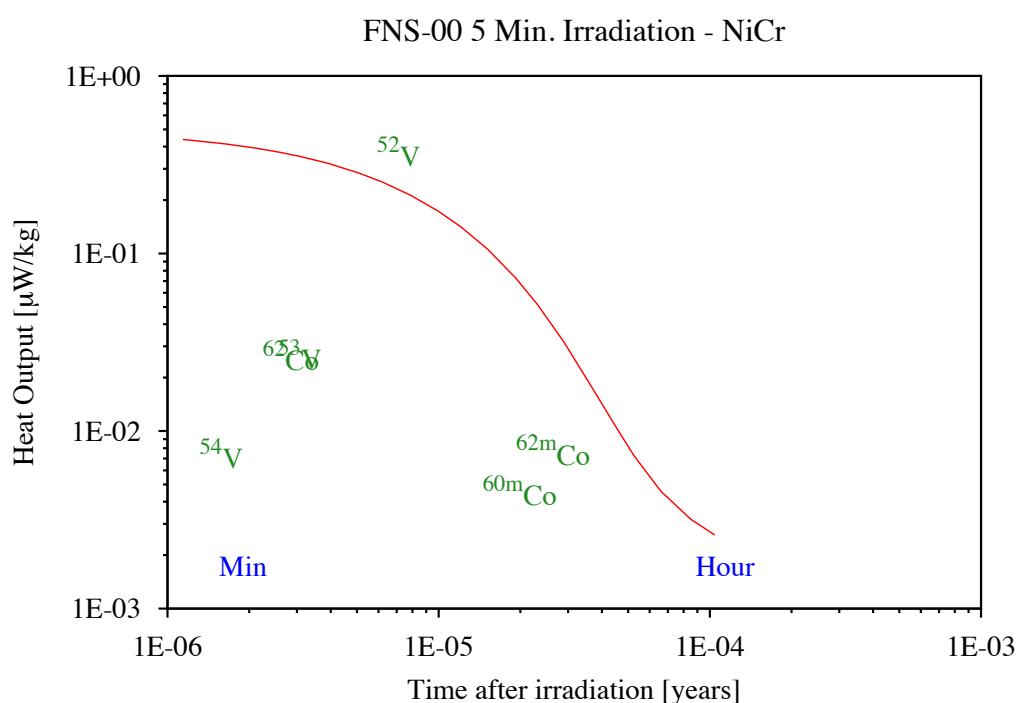
FNS-96 5 Min. Irradiation - NiCr

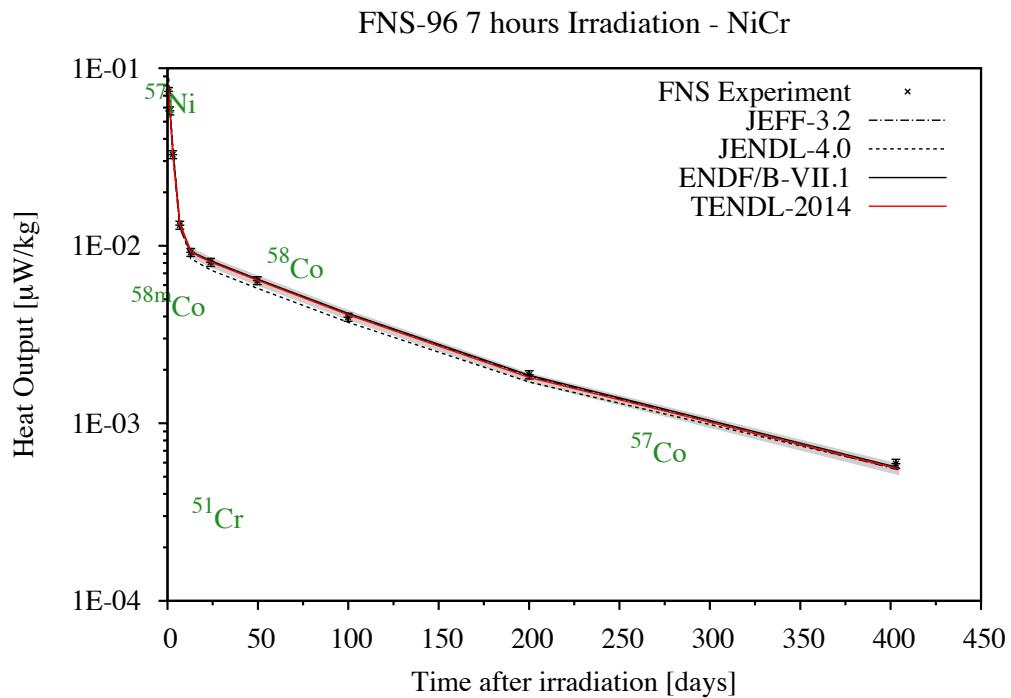


For Ni-Cr, the first 15 minutes of cooling time are dominated by the Cr isotope produced V-52 and the trend is the same as seen in the Cr alloys. Here again the lack of isomeric states production pathways lead the other libraries to under-predict.

Times Min.	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.60	$4.27E-01$ +/-5%	$4.39E-01$ +/-8%	0.97	1.01	1.01
0.85	$4.01E-01$ +/-5%	$4.15E-01$ +/-8%	0.97	1.00	1.00
1.12	$3.77E-01$ +/-5%	$3.92E-01$ +/-8%	0.96	1.00	1.00
1.37	$3.59E-01$ +/-5%	$3.72E-01$ +/-9%	0.97	1.01	1.00
1.62	$3.40E-01$ +/-5%	$3.52E-01$ +/-9%	0.96	1.01	1.00
2.05	$3.10E-01$ +/-5%	$3.22E-01$ +/-9%	0.96	1.01	1.00
2.67	$2.72E-01$ +/-5%	$2.84E-01$ +/-9%	0.96	1.01	1.00
3.27	$2.40E-01$ +/-5%	$2.52E-01$ +/-9%	0.95	1.01	1.00
4.15	$2.02E-01$ +/-5%	$2.13E-01$ +/-9%	0.95	1.01	1.02
5.25	$1.63E-01$ +/-5%	$1.73E-01$ +/-9%	0.94	1.02	1.00
6.35	$1.31E-01$ +/-5%	$1.41E-01$ +/-9%	0.92	1.01	0.99
7.98	$9.83E-02$ +/-5%	$1.05E-01$ +/-9%	0.93	1.03	1.02
10.10	$6.75E-02$ +/-5%	$7.30E-02$ +/-9%	0.92	1.05	1.04
12.15	$4.78E-02$ +/-5%	$5.17E-02$ +/-8%	0.92	1.07	1.08
15.22	$3.08E-02$ +/-6%	$3.18E-02$ +/-8%	0.97	1.18	1.18
19.33	$1.74E-02$ +/-6%	$1.76E-02$ +/-8%	0.99	1.30	1.30
23.43	$1.09E-02$ +/-6%	$1.08E-02$ +/-8%	1.01	1.48	1.47
27.55	$7.42E-03$ +/-6%	$7.30E-03$ +/-8%	1.02	1.63	1.62
34.68	$4.80E-03$ +/-6%	$4.59E-03$ +/-9%	1.05	1.77	1.75
44.73	$3.50E-03$ +/-7%	$3.18E-03$ +/-9%	1.10	1.66	1.64
54.85	$2.88E-03$ +/-7%	$2.60E-03$ +/-8%	1.11	1.54	1.52
mean % diff. from E		5	12	12	12

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
V52	Cr52(n,p)V52	3.7m	98.1	0.95	5%
	Cr53(n,d+np)V52		1.7	0.95	5%
Co60m	Ni60(n,p)Co60m	10.4m	98.9	0.92	5%
	Ni61(n,d)Co60m		1.1	0.90	5%
Co62m	Ni62(n,p)Co62m	13.9m	100.0	0.97	6%

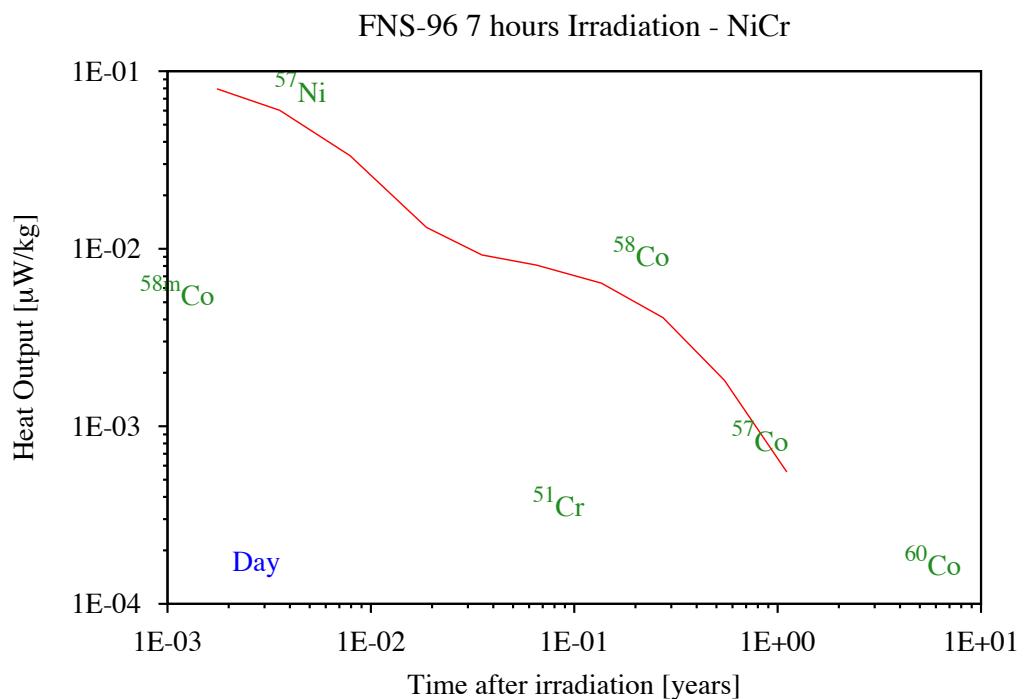




Here also clean agreements exist between measurements and predictions.

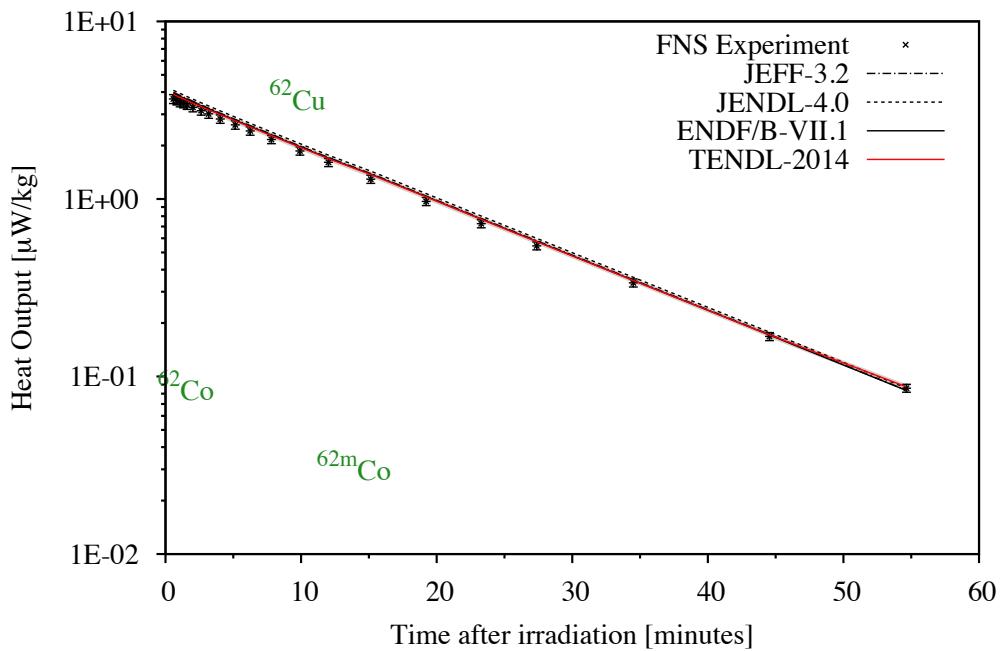
Times	FNS EXP. 7 hrs	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Days	μW/g	μW/g	E/C	E/C	E/C
0.64	$7.40E-02 +/- 5\%$	$7.96E-02 +/- 9\%$	0.93	0.96	0.97
1.30	$5.75E-02 +/- 5\%$	$6.02E-02 +/- 9\%$	0.96	0.97	0.98
2.88	$3.26E-02 +/- 5\%$	$3.35E-02 +/- 8\%$	0.97	0.91	0.98
6.85	$1.31E-02 +/- 5\%$	$1.32E-02 +/- 6\%$	0.99	0.98	1.04
12.85	$9.18E-03 +/- 5\%$	$9.23E-03 +/- 7\%$	0.99	0.99	1.00
23.85	$8.07E-03 +/- 5\%$	$8.08E-03 +/- 7\%$	1.00	0.98	0.99
49.70	$6.36E-03 +/- 5\%$	$6.39E-03 +/- 7\%$	1.00	0.98	1.11
99.89	$3.96E-03 +/- 5\%$	$4.09E-03 +/- 7\%$	0.97	0.95	0.96
200.12	$1.88E-03 +/- 5\%$	$1.81E-03 +/- 6\%$	1.03	1.01	1.02
402.94	$5.92E-04 +/- 6\%$	$5.53E-04 +/- 7\%$	1.07	1.06	1.08
mean % diff. from E		3	4	3	10

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Ni57	Ni58(n,2n)Ni57	1.4d	100.0	0.96	5%
Co58	Ni58(n,p)Co58	70.8d	79.7	0.97	5%
	Ni58(n,p)Co58m	9.0h	20.4	0.97	5%
Co57	Ni58(n,np)Co57	271d	97.5	1.07	6%
	Ni58(n,d)Co57	271d	2.2	1.07	6%

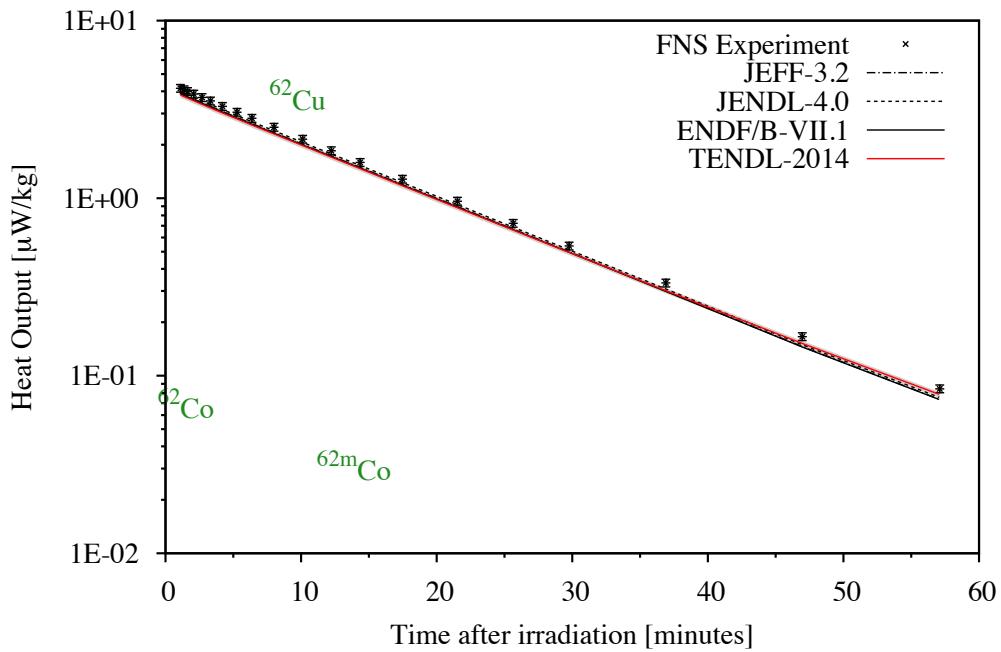


Copper

FNS-00 5 Min. Irradiation - Cu



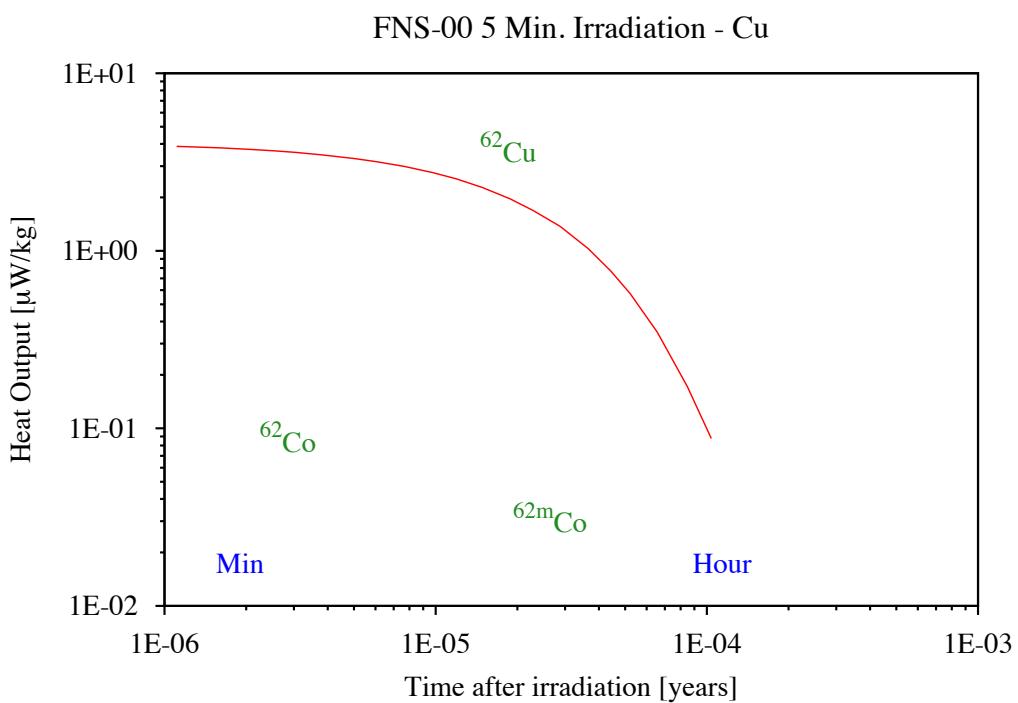
FNS-96 5 Min. Irradiation - Cu

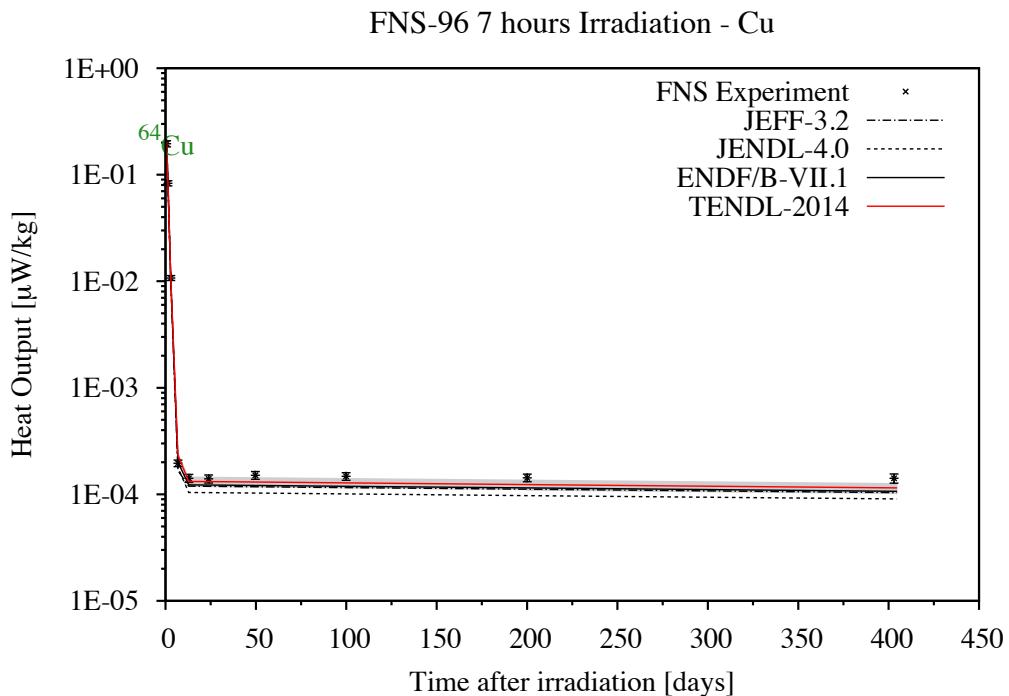


For Copper, a good agreement can be seen for both sample runs. However, the rather uniform measurements could be used to question the quoted 6% experimental uncertainty in face of the fact that the two batches seem to differ by more than this 6% value.

Times Min.	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.58	$3.66E+00 +/- 6\%$	$3.88E+00 +/- 4\%$	0.94	0.93	0.92
0.83	$3.59E+00 +/- 6\%$	$3.80E+00 +/- 4\%$	0.95	0.93	0.92
1.08	$3.50E+00 +/- 6\%$	$3.73E+00 +/- 4\%$	0.94	0.93	0.91
1.33	$3.45E+00 +/- 6\%$	$3.66E+00 +/- 4\%$	0.94	0.93	0.92
1.60	$3.38E+00 +/- 6\%$	$3.58E+00 +/- 4\%$	0.95	0.93	0.92
2.02	$3.28E+00 +/- 6\%$	$3.47E+00 +/- 4\%$	0.95	0.93	0.92
2.63	$3.14E+00 +/- 6\%$	$3.31E+00 +/- 4\%$	0.95	0.94	0.93
3.18	$3.01E+00 +/- 6\%$	$3.18E+00 +/- 3\%$	0.95	0.94	0.93
4.03	$2.82E+00 +/- 6\%$	$2.99E+00 +/- 3\%$	0.95	0.94	0.93
5.15	$2.61E+00 +/- 5\%$	$2.75E+00 +/- 3\%$	0.95	0.94	0.93
6.25	$2.42E+00 +/- 5\%$	$2.54E+00 +/- 3\%$	0.95	0.94	0.93
7.82	$2.16E+00 +/- 5\%$	$2.27E+00 +/- 3\%$	0.95	0.94	0.94
9.92	$1.86E+00 +/- 5\%$	$1.96E+00 +/- 3\%$	0.95	0.95	0.94
12.02	$1.61E+00 +/- 5\%$	$1.69E+00 +/- 3\%$	0.95	0.95	0.94
15.13	$1.29E+00 +/- 5\%$	$1.37E+00 +/- 3\%$	0.94	0.94	0.93
19.23	$9.68E-01 +/- 5\%$	$1.03E+00 +/- 3\%$	0.94	0.94	0.93
23.28	$7.26E-01 +/- 5\%$	$7.69E-01 +/- 3\%$	0.94	0.94	0.93
27.38	$5.44E-01 +/- 5\%$	$5.76E-01 +/- 3\%$	0.95	0.94	0.94
34.50	$3.37E-01 +/- 5\%$	$3.49E-01 +/- 3\%$	0.97	0.96	0.96
44.55	$1.68E-01 +/- 5\%$	$1.72E-01 +/- 3\%$	0.98	0.98	0.97
54.65	$8.60E-02 +/- 5\%$	$8.76E-02 +/- 3\%$	0.98	1.03	1.02
mean % diff. from E		5	6	7	10

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Cu62	Cu63(n,2n)Cu62	9.7m	100.0	0.95	5%

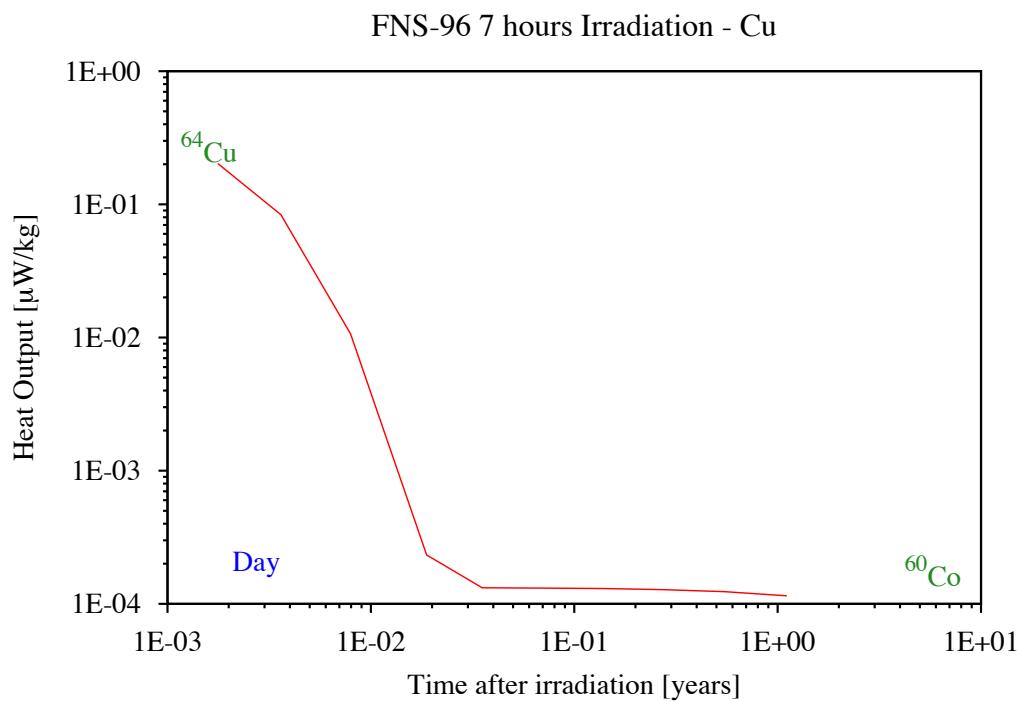


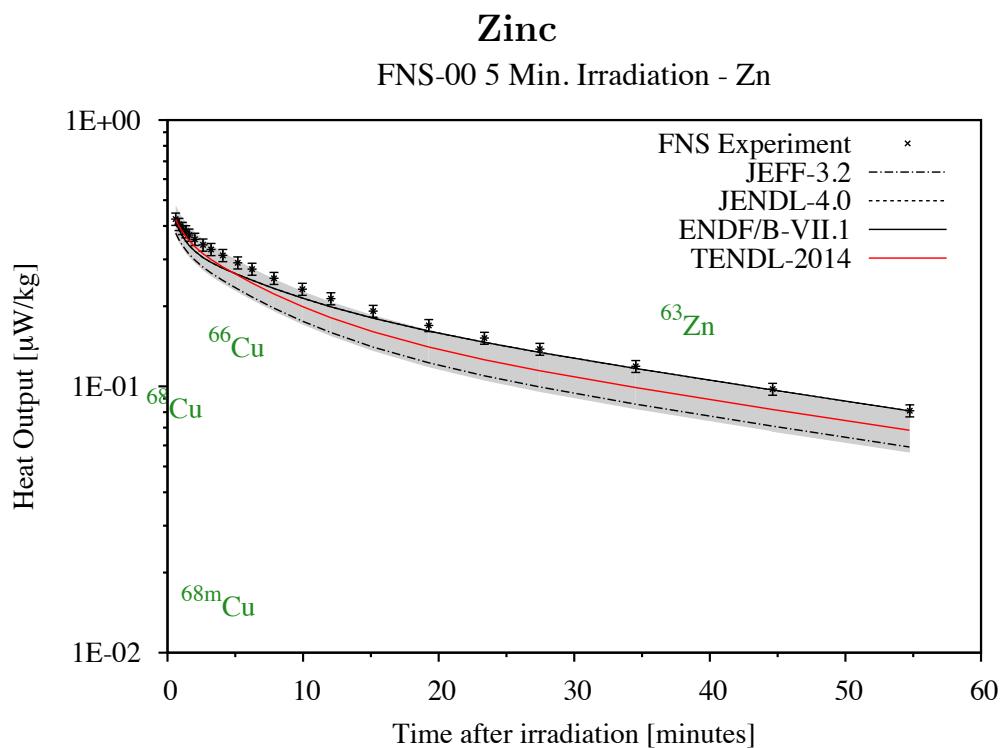


The above graph shows a good agreement, often within the experimental uncertainty.

Times	FNS EXP. 7 hrs	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Days	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.65	$1.95E-01 +/-7\%$	$2.03E-01 +/-5\%$	0.96	0.94	0.95
1.32	$8.31E-02 +/-6\%$	$8.37E-02 +/-5\%$	0.99	0.97	0.98
2.90	$1.07E-02 +/-5\%$	$1.07E-02 +/-5\%$	1.00	1.06	1.09
6.87	$1.96E-04 +/-7\%$	$2.33E-04 +/-7\%$	0.84	0.98	1.17
12.89	$1.42E-04 +/-9\%$	$1.32E-04 +/-11\%$	1.07	1.15	1.19
23.90	$1.40E-04 +/-9\%$	$1.31E-04 +/-11\%$	1.06	1.14	1.18
49.72	$1.51E-04 +/-8\%$	$1.30E-04 +/-11\%$	1.16	1.25	1.28
99.92	$1.48E-04 +/-8\%$	$1.28E-04 +/-11\%$	1.15	1.24	1.27
200.14	$1.43E-04 +/-8\%$	$1.23E-04 +/-11\%$	1.16	1.25	1.28
402.97	$1.41E-04 +/-10\%$	$1.15E-04 +/-11\%$	1.23	1.33	1.36
mean % diff. from E			10	13	15
					20

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Cu64	Cu65(n,2n)Cu64	12.7h	99.8	0.96	7%
	Cu63(n,g)Cu64		0.0	0.96	7%
Co60	Cu63(n, α)Co60m	10.4m	52.5	1.23	10%
	Cu63(n, α)Co60	5.2y	47.5	1.23	10%

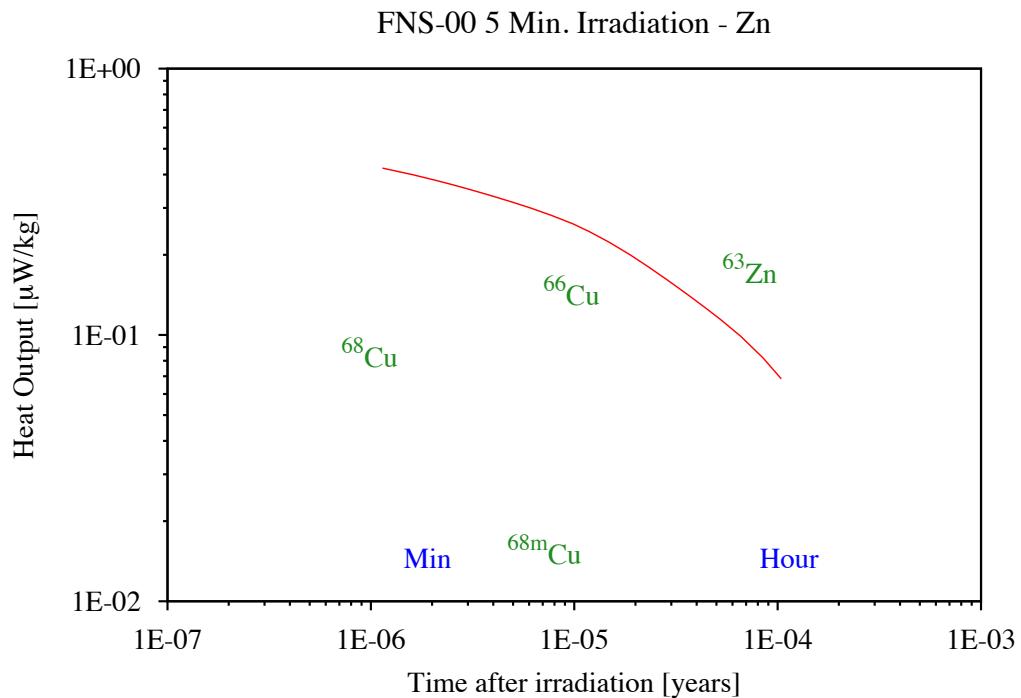


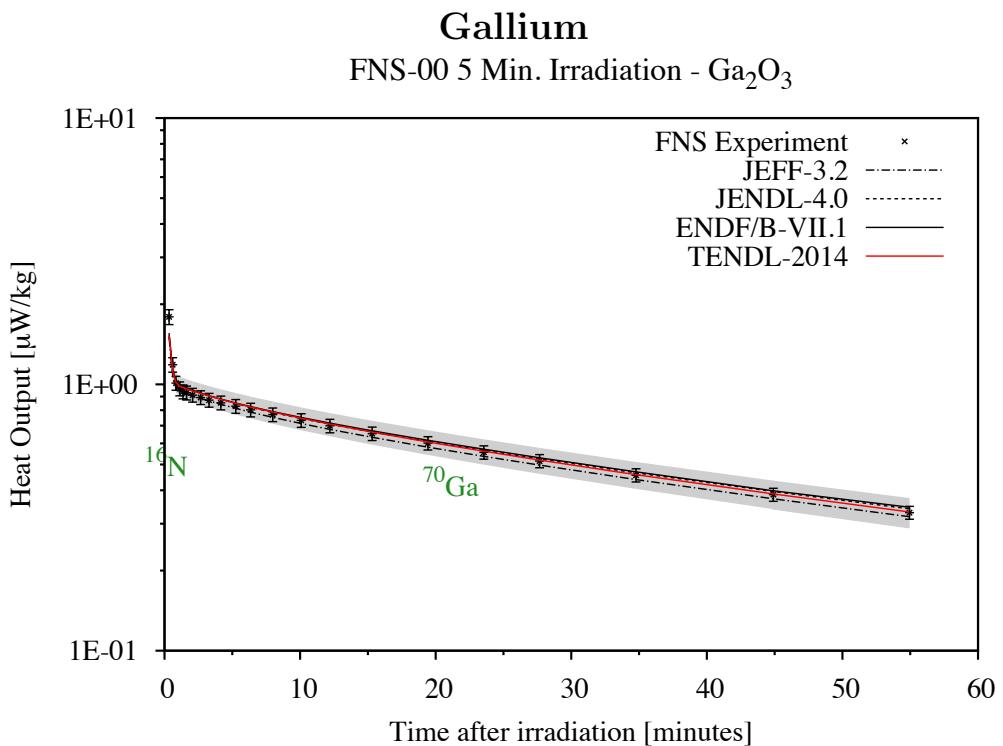


For Zinc, in the above graph a remarkable agreement can be seen with ENDF/B-VII.1 and JENDL-4.0 for cooling times above 20 minutes where Zn63 dominates, while with TENDL-2014 there is good agreement at short cooling times of less than 5 minutes where several short-lived radionuclides contribute. up to 5 minutes cooling.

Times	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0	
Min.	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C	
0.60	$4.25E-01 +/- 5\%$	$4.23E-01 +/- 13\%$	1.00	1.02	1.13	1.02
0.85	$4.06E-01 +/- 5\%$	$3.99E-01 +/- 13\%$	1.02	1.05	1.14	1.05
1.10	$3.92E-01 +/- 5\%$	$3.80E-01 +/- 13\%$	1.03	1.07	1.16	1.07
1.35	$3.81E-01 +/- 5\%$	$3.65E-01 +/- 13\%$	1.04	1.09	1.17	1.09
1.60	$3.70E-01 +/- 5\%$	$3.52E-01 +/- 13\%$	1.05	1.09	1.18	1.09
2.02	$3.57E-01 +/- 5\%$	$3.35E-01 +/- 13\%$	1.07	1.11	1.20	1.11
2.62	$3.40E-01 +/- 5\%$	$3.15E-01 +/- 13\%$	1.08	1.11	1.21	1.11
3.22	$3.27E-01 +/- 5\%$	$2.99E-01 +/- 13\%$	1.09	1.12	1.23	1.12
4.08	$3.10E-01 +/- 5\%$	$2.81E-01 +/- 14\%$	1.10	1.12	1.24	1.12
5.18	$2.91E-01 +/- 5\%$	$2.61E-01 +/- 14\%$	1.11	1.11	1.25	1.11
6.23	$2.76E-01 +/- 5\%$	$2.45E-01 +/- 14\%$	1.13	1.10	1.27	1.10
7.85	$2.55E-01 +/- 5\%$	$2.22E-01 +/- 14\%$	1.14	1.09	1.29	1.09
9.95	$2.32E-01 +/- 5\%$	$1.99E-01 +/- 14\%$	1.16	1.08	1.32	1.08
12.05	$2.13E-01 +/- 5\%$	$1.81E-01 +/- 15\%$	1.18	1.07	1.34	1.07
15.17	$1.92E-01 +/- 5\%$	$1.60E-01 +/- 15\%$	1.19	1.06	1.36	1.06
19.27	$1.69E-01 +/- 5\%$	$1.41E-01 +/- 16\%$	1.21	1.05	1.38	1.05
23.37	$1.52E-01 +/- 5\%$	$1.26E-01 +/- 16\%$	1.21	1.04	1.38	1.04
27.47	$1.38E-01 +/- 5\%$	$1.14E-01 +/- 17\%$	1.21	1.03	1.39	1.03
34.53	$1.19E-01 +/- 5\%$	$9.90E-02 +/- 17\%$	1.20	1.02	1.39	1.02
44.63	$9.77E-02 +/- 5\%$	$8.19E-02 +/- 17\%$	1.19	1.01	1.38	1.01
54.75	$8.10E-02 +/- 5\%$	$6.84E-02 +/- 17\%$	1.18	1.00	1.37	1.00
mean % diff. from E		11	6	21	6	

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Zn63	Zn64(n,2n)Zn63	38.4m	100.0	1.20	5%

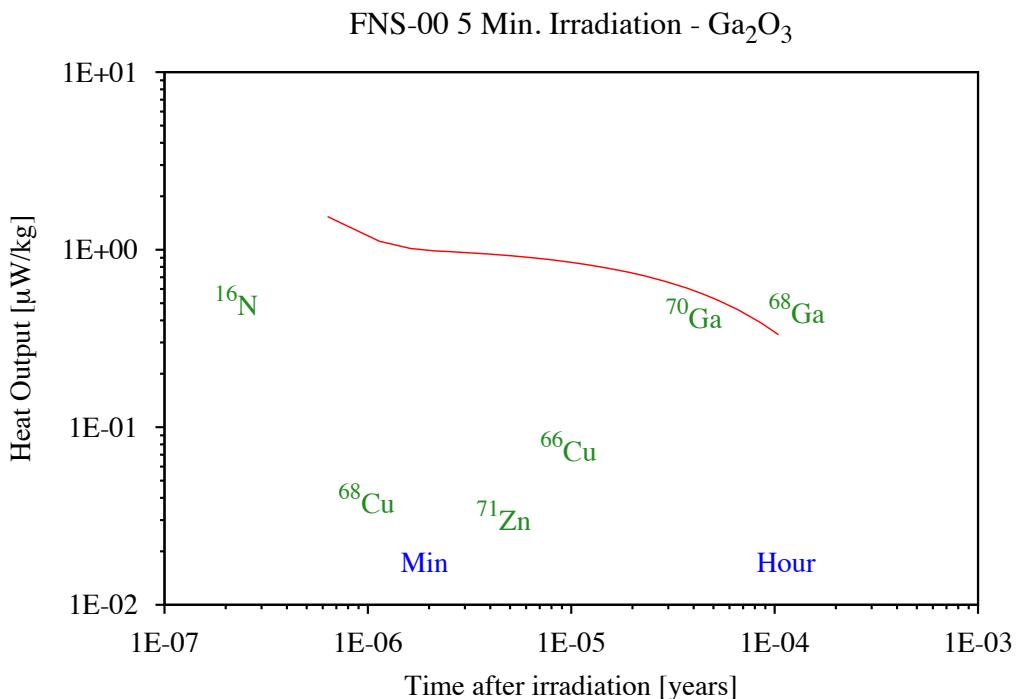


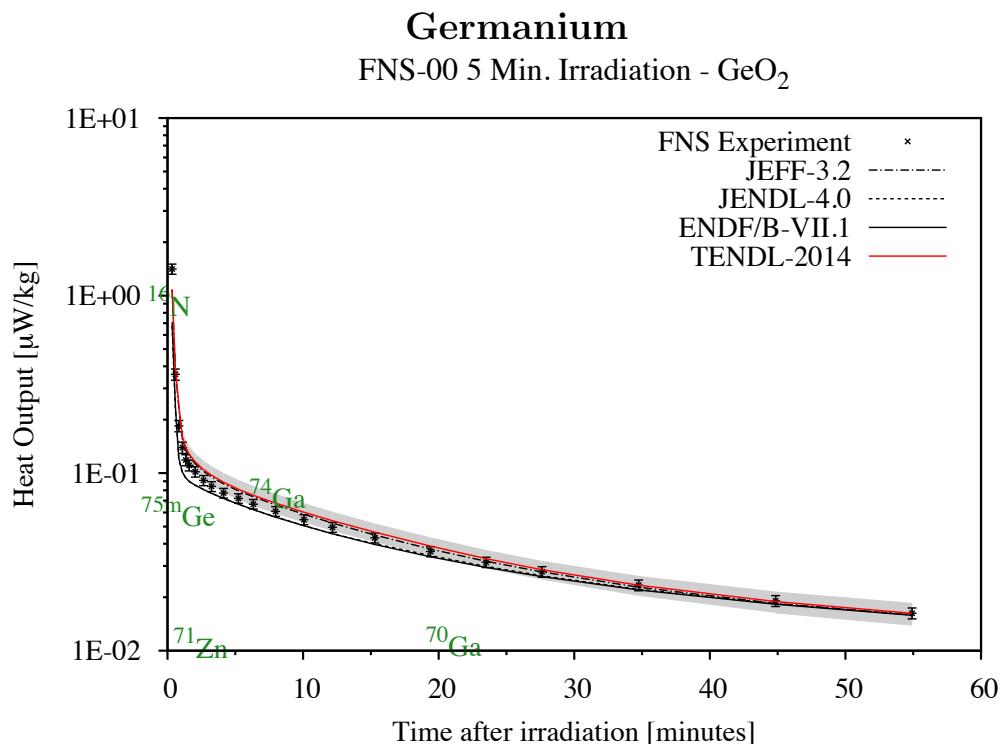


For Gallium, a remarkable agreement can be seen with all libraries.

Times Min.	FNS EXP. 5 mins $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.33	$1.79E+00$ +/-6%	$1.53E+00$ +/-6%	1.17	1.15	1.20	1.18
0.60	$1.19E+00$ +/-6%	$1.11E+00$ +/-8%	1.06	1.05	1.10	1.05
0.85	$1.01E+00$ +/-6%	$1.02E+00$ +/-8%	0.99	0.98	1.03	0.98
1.12	$9.63E-01$ +/-6%	$9.85E-01$ +/-9%	0.98	0.97	1.02	0.97
1.37	$9.39E-01$ +/-6%	$9.73E-01$ +/-9%	0.96	0.96	1.00	0.95
1.63	$9.29E-01$ +/-6%	$9.61E-01$ +/-9%	0.97	0.96	1.01	0.96
2.07	$9.12E-01$ +/-6%	$9.44E-01$ +/-9%	0.97	0.96	1.01	0.96
2.67	$8.92E-01$ +/-6%	$9.24E-01$ +/-9%	0.97	0.96	1.01	0.96
3.28	$8.73E-01$ +/-6%	$9.04E-01$ +/-9%	0.97	0.96	1.01	0.96
4.15	$8.53E-01$ +/-6%	$8.79E-01$ +/-9%	0.97	0.97	1.01	0.97
5.25	$8.28E-01$ +/-6%	$8.49E-01$ +/-9%	0.97	0.97	1.02	0.98
6.35	$8.02E-01$ +/-6%	$8.23E-01$ +/-9%	0.98	0.97	1.02	0.98
7.98	$7.70E-01$ +/-6%	$7.87E-01$ +/-10%	0.98	0.97	1.02	0.98
10.08	$7.33E-01$ +/-6%	$7.46E-01$ +/-10%	0.98	0.98	1.03	0.98
12.20	$6.99E-01$ +/-6%	$7.10E-01$ +/-10%	0.98	0.98	1.03	0.99
15.32	$6.53E-01$ +/-6%	$6.62E-01$ +/-10%	0.99	0.98	1.03	0.98
19.43	$6.02E-01$ +/-6%	$6.08E-01$ +/-11%	0.99	0.98	1.04	0.98
23.55	$5.56E-01$ +/-6%	$5.61E-01$ +/-11%	0.99	0.97	1.04	0.98
27.67	$5.15E-01$ +/-6%	$5.20E-01$ +/-11%	0.99	0.97	1.04	0.98
34.78	$4.56E-01$ +/-6%	$4.58E-01$ +/-12%	0.99	0.97	1.04	0.98
44.90	$3.85E-01$ +/-6%	$3.88E-01$ +/-12%	0.99	0.97	1.04	0.97
54.95	$3.30E-01$ +/-6%	$3.32E-01$ +/-13%	0.99	0.95	1.03	0.97
mean % diff. from E			3	4	3	

Product	Pathways	T_{1/2}	Path %	E/C	ΔE%
N16	O16(n,p)N16	7.1s	100.0	1.17	6%
Ga70	Ga69(n, γ)Ga70	21.1m	1.0	0.99	6%
	Ga71(n,2n)Ga70		99.0	0.99	6%
Ga68	Ga69(n,2n)Ga68	1.1h	100.0	0.99	6%

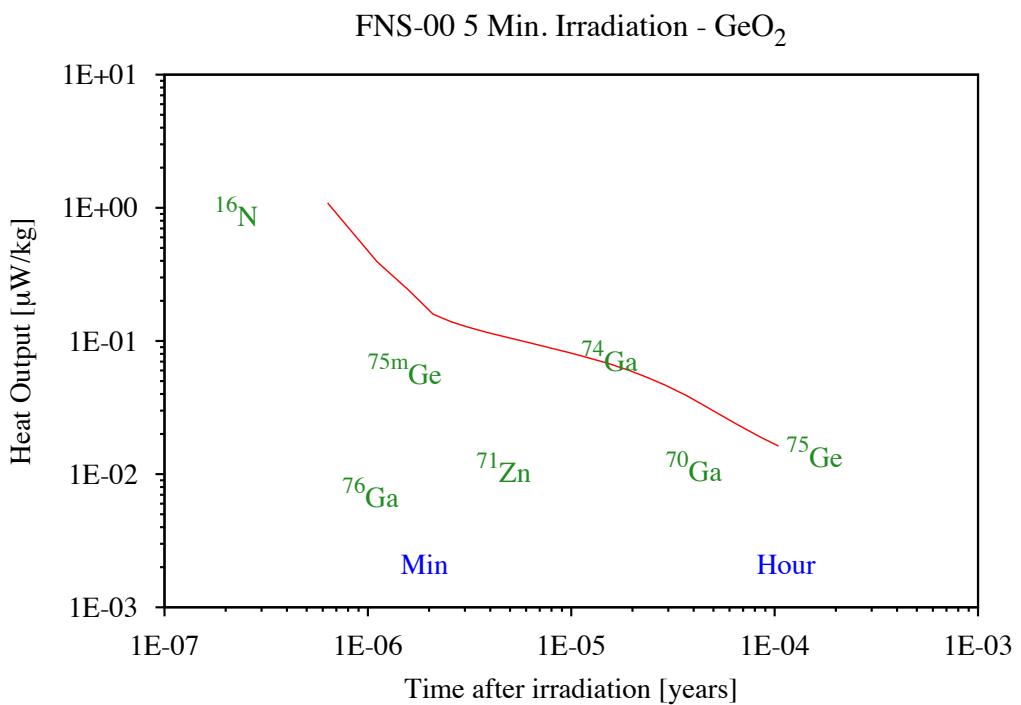


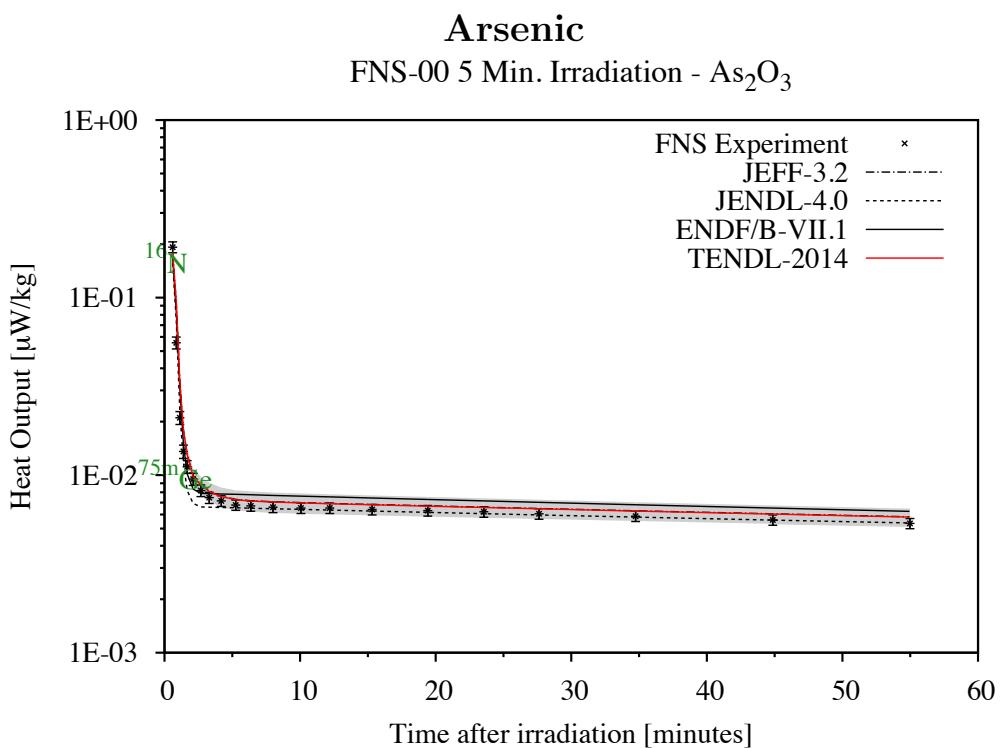


For Germanium, it is clear that the changes made in the TENDL-2014 data on the complex routes of production of the Ge75 and Ga74 isotopes have improved the predictions compared to earlier version of TENDL [14].

Times FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0	
Min.	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.33	$1.41E+00$ +/-7%	$1.09E+00$ +/-1%	1.30	1.99	1.31
0.58	$3.60E-01$ +/-7%	$3.93E-01$ +/-4%	0.91	1.52	0.94
0.83	$1.84E-01$ +/-7%	$2.41E-01$ +/-6%	0.77	1.52	0.79
1.10	$1.39E-01$ +/-7%	$1.59E-01$ +/-9%	0.88	1.38	0.90
1.35	$1.18E-01$ +/-7%	$1.39E-01$ +/-10%	0.85	1.26	0.88
1.60	$1.11E-01$ +/-7%	$1.28E-01$ +/-11%	0.86	1.23	0.89
2.05	$1.02E-01$ +/-7%	$1.15E-01$ +/-12%	0.88	1.19	0.90
2.65	$9.09E-02$ +/-7%	$1.05E-01$ +/-12%	0.87	1.12	0.89
3.25	$8.42E-02$ +/-6%	$9.73E-02$ +/-13%	0.87	1.09	0.88
4.13	$7.73E-02$ +/-6%	$8.89E-02$ +/-13%	0.87	1.07	0.89
5.23	$7.21E-02$ +/-6%	$8.11E-02$ +/-13%	0.89	1.08	0.91
6.33	$6.69E-02$ +/-6%	$7.51E-02$ +/-13%	0.89	1.07	0.91
7.97	$6.09E-02$ +/-6%	$6.79E-02$ +/-13%	0.90	1.08	0.92
10.07	$5.47E-02$ +/-6%	$6.03E-02$ +/-13%	0.91	1.08	0.93
12.17	$4.96E-02$ +/-6%	$5.40E-02$ +/-12%	0.92	1.09	0.95
15.30	$4.32E-02$ +/-7%	$4.65E-02$ +/-12%	0.93	1.09	0.96
19.40	$3.62E-02$ +/-7%	$3.89E-02$ +/-12%	0.93	1.07	0.97
23.50	$3.15E-02$ +/-7%	$3.30E-02$ +/-12%	0.96	1.07	0.99
27.62	$2.78E-02$ +/-7%	$2.86E-02$ +/-12%	0.97	1.06	1.00
34.75	$2.34E-02$ +/-7%	$2.34E-02$ +/-13%	1.00	1.06	1.03
44.85	$1.91E-02$ +/-7%	$1.89E-02$ +/-14%	1.01	1.04	1.03
54.92	$1.63E-02$ +/-7%	$1.62E-02$ +/-14%	1.00	1.03	1.02
mean % diff. from E		11	14	9	14

Product	Pathways	T_{1/2}	Path %	E/C	ΔE%
Ge75m	Ge76(n,2n)Ge75m	47.7s	98.5	0.77	7%
	Ge76(n,g)Ge75m		0.0	0.77	7%
Ga74	Ge74(n,p)Ga74	8.1m	80.8	0.90	6%
	Ge74(n,p)Ga74m	9.5s	19.1	0.90	6%
Ge75	Ge76(n,2n)Ge75	1.3h	40.0	1.00	7%
	Ge76(n,2n)Ge75m	47.7s	59.6	1.00	7%
	Ge76(n,g)Ge75		0.6	1.00	7%

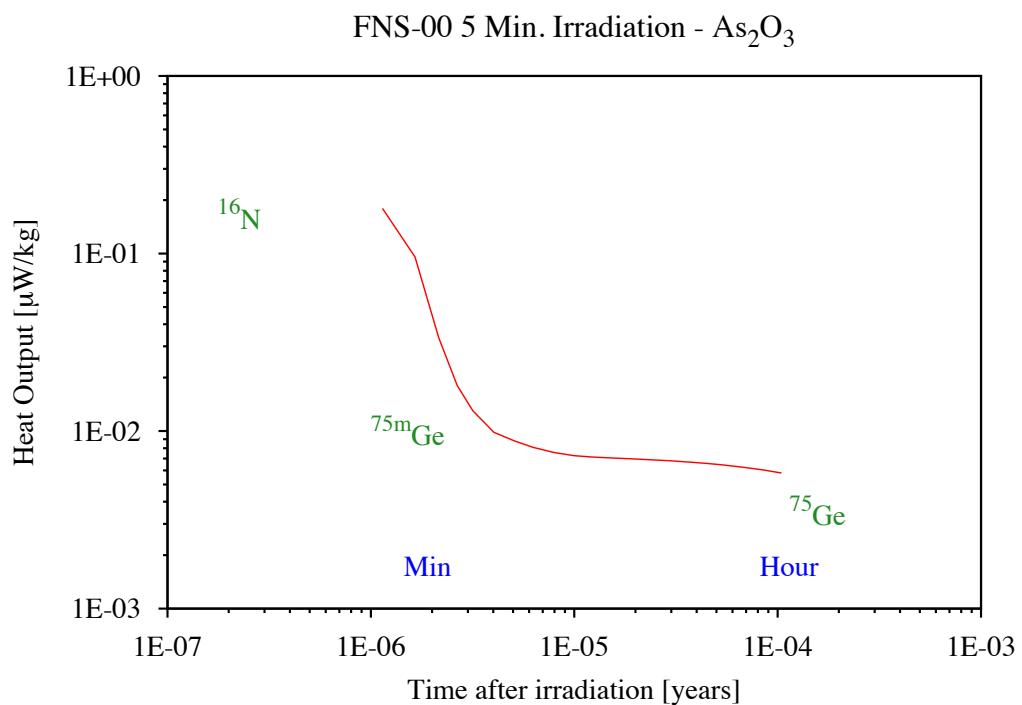




For Arsenic, the same isotope as for the germanium decay heat, Ge75, dominates, but this time produced through different paths.

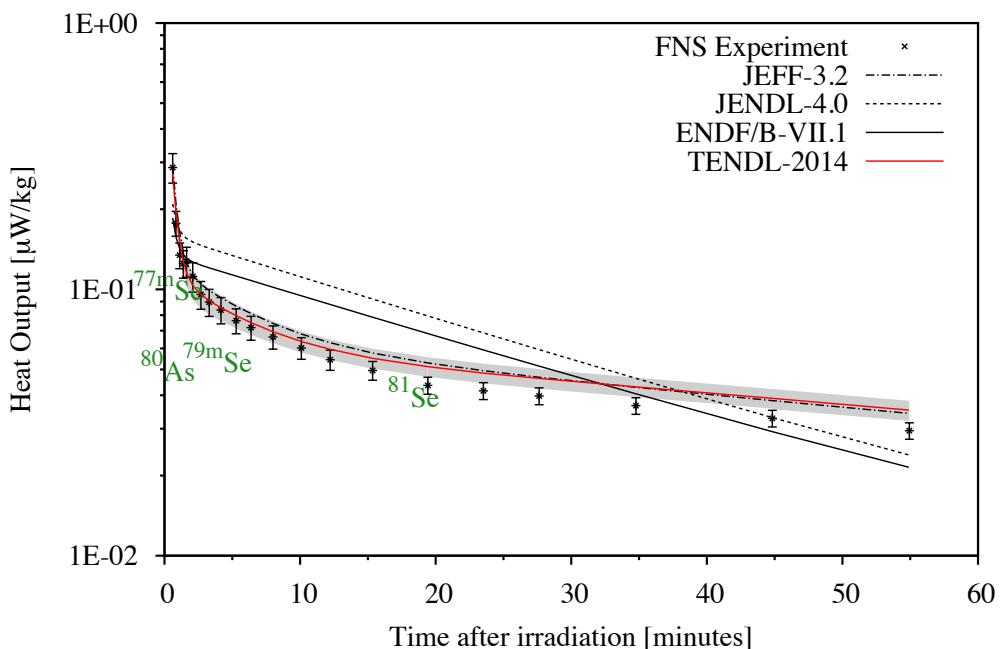
Times Min.	FNS EXP. 5 mins $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.60	$1.92E-01$ +/-7%	$1.79E-01$ +/-1%	1.07	1.15	1.08	1.23
0.87	$5.56E-02$ +/-8%	$9.55E-02$ +/-2%	0.58	0.67	0.59	0.74
1.13	$2.11E-02$ +/-8%	$3.36E-02$ +/-4%	0.63	0.68	0.63	0.92
1.40	$1.36E-02$ +/-9%	$1.80E-02$ +/-7%	0.76	0.91	0.76	1.15
1.67	$1.12E-02$ +/-8%	$1.30E-02$ +/-9%	0.86	1.10	0.85	1.36
2.12	$9.50E-03$ +/-8%	$9.83E-03$ +/-11%	0.97	1.14	0.96	1.37
2.68	$8.19E-03$ +/-8%	$8.78E-03$ +/-11%	0.93	1.04	0.92	1.24
3.30	$7.47E-03$ +/-7%	$8.10E-03$ +/-12%	0.92	0.95	0.92	1.13
4.18	$7.16E-03$ +/-7%	$7.57E-03$ +/-13%	0.95	0.91	0.94	1.09
5.25	$6.79E-03$ +/-7%	$7.27E-03$ +/-13%	0.93	0.87	0.93	1.04
6.37	$6.71E-03$ +/-7%	$7.15E-03$ +/-13%	0.94	0.87	0.94	1.03
8.00	$6.60E-03$ +/-7%	$7.05E-03$ +/-13%	0.94	0.86	0.93	1.02
10.07	$6.53E-03$ +/-7%	$6.97E-03$ +/-13%	0.94	0.86	0.93	1.02
12.18	$6.52E-03$ +/-7%	$6.90E-03$ +/-13%	0.94	0.87	0.94	1.03
15.32	$6.40E-03$ +/-7%	$6.81E-03$ +/-13%	0.94	0.86	0.94	1.02
19.42	$6.31E-03$ +/-7%	$6.69E-03$ +/-13%	0.94	0.87	0.94	1.02
23.55	$6.21E-03$ +/-7%	$6.57E-03$ +/-13%	0.95	0.87	0.94	1.02
27.62	$6.06E-03$ +/-7%	$6.46E-03$ +/-12%	0.94	0.86	0.93	1.02
34.75	$5.87E-03$ +/-7%	$6.28E-03$ +/-12%	0.94	0.86	0.93	1.01
44.87	$5.60E-03$ +/-7%	$6.03E-03$ +/-12%	0.93	0.86	0.92	1.00
54.98	$5.34E-03$ +/-7%	$5.81E-03$ +/-11%	0.92	0.85	0.92	0.99
mean % diff. from E			14	17	14	9

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Ge75m	As75(n,p)Ge75m	47.7s	99.3	0.92	8%
Ge75	As75(n,p)Ge75	1.3h	47.8	0.92	6%
	As75(n,p)Ge75m	47.7s	52.2	0.92	6%



Selenium

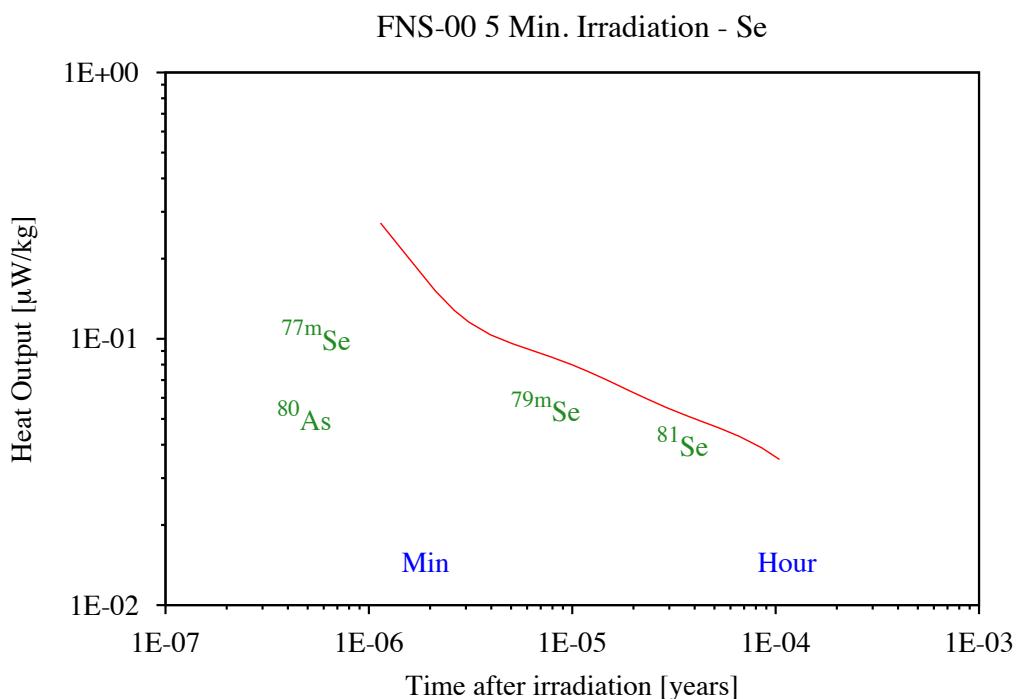
FNS-00 5 Min. Irradiation - Se

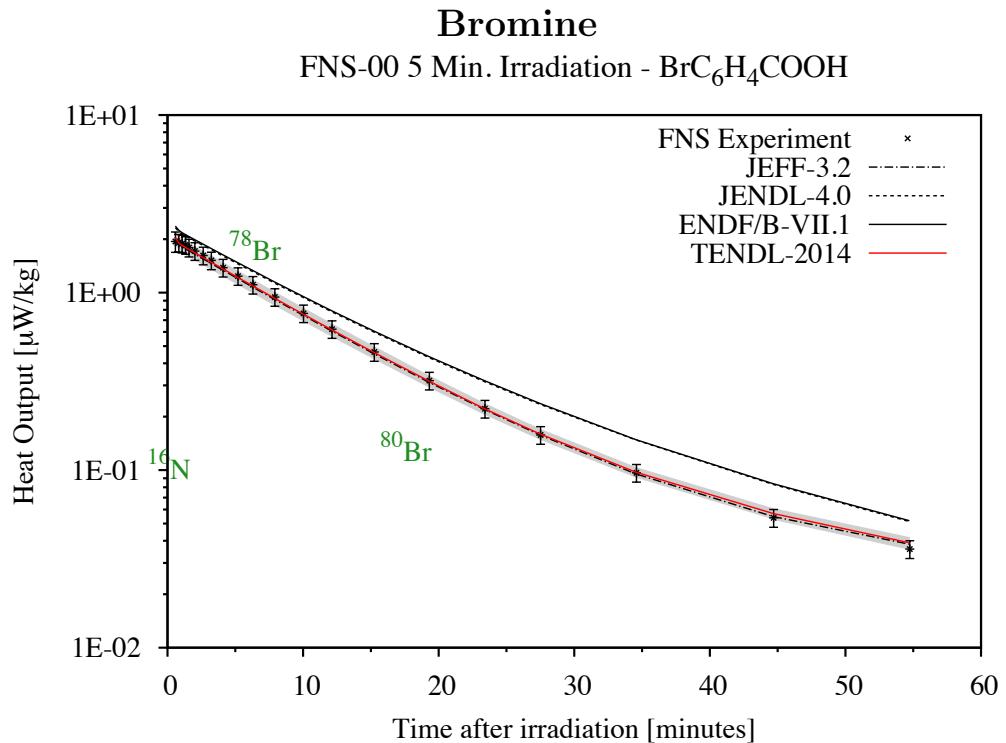


For Selenium, a complex set of pathways influence the decay heat arising from this element. The code predictions are just outside the quoted experimental uncertainties for JEFF-3.2 and TENDL-2014. Metastable isomers dominate at short cooling times.

Times Min.	FNS EXP. 5 mins μW/g	TENDL-2014 μW/g	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.60	$2.87E-01$ +/-13%	$2.72E-01$ +/-11%	1.05	1.55	0.98	1.37
0.85	$1.77E-01$ +/-11%	$1.96E-01$ +/-10%	0.91	1.13	0.84	0.98
1.12	$1.34E-01$ +/-11%	$1.51E-01$ +/-10%	0.89	0.94	0.82	0.81
1.38	$1.25E-01$ +/-12%	$1.28E-01$ +/-11%	0.98	0.93	0.90	0.78
1.63	$1.28E-01$ +/-13%	$1.16E-01$ +/-11%	1.10	0.98	1.01	0.82
2.08	$1.12E-01$ +/-13%	$1.04E-01$ +/-12%	1.08	0.88	0.99	0.74
2.68	$9.56E-02$ +/-12%	$9.57E-02$ +/-12%	1.00	0.77	0.91	0.65
3.30	$8.95E-02$ +/-12%	$9.07E-02$ +/-12%	0.99	0.74	0.90	0.63
4.17	$8.37E-02$ +/-11%	$8.54E-02$ +/-11%	0.98	0.72	0.90	0.61
5.28	$7.63E-02$ +/-11%	$7.97E-02$ +/-11%	0.96	0.68	0.88	0.57
6.38	$7.18E-02$ +/-10%	$7.50E-02$ +/-10%	0.96	0.67	0.88	0.56
8.00	$6.63E-02$ +/-10%	$6.94E-02$ +/-10%	0.96	0.65	0.89	0.55
10.10	$6.03E-02$ +/-9%	$6.37E-02$ +/-9%	0.95	0.64	0.89	0.54
12.22	$5.44E-02$ +/-9%	$5.95E-02$ +/-9%	0.91	0.62	0.86	0.53
15.35	$4.96E-02$ +/-8%	$5.51E-02$ +/-9%	0.90	0.63	0.86	0.54
19.42	$4.36E-02$ +/-7%	$5.13E-02$ +/-8%	0.85	0.64	0.82	0.55
23.52	$4.16E-02$ +/-7%	$4.85E-02$ +/-8%	0.86	0.70	0.84	0.61
27.63	$3.98E-02$ +/-7%	$4.63E-02$ +/-8%	0.86	0.77	0.85	0.67
34.77	$3.66E-02$ +/-7%	$4.30E-02$ +/-8%	0.85	0.90	0.85	0.79
44.83	$3.28E-02$ +/-7%	$3.90E-02$ +/-8%	0.84	1.12	0.86	0.99
54.93	$2.95E-02$ +/-7%	$3.52E-02$ +/-8%	0.84	1.37	0.86	1.23
mean % diff. from E		9	33	13	50	

Product	Pathways	T_{1/2}	Path %	E/C	ΔE%
Se77m	Se77(n,n')Se77m	17.3s	12.5	1.05	13%
	Se78(n,2n)Se77m		87.2	1.05	13%
	Se78(n,g)Se77m		0.0	1.05	13%
Se81	Se80(n,γ)Se81	18.45m	2.3	0.85	7%
	Se82(n,2n)Se81		89.7	0.85	7%
	Se82(n,2n)Se81m		7.9	0.85	7%



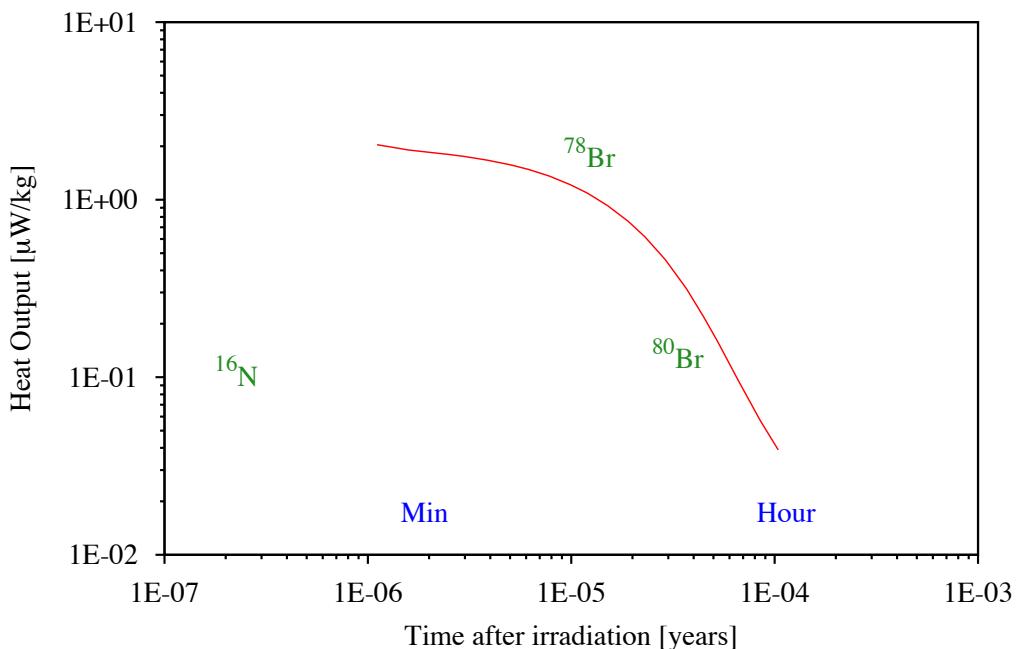


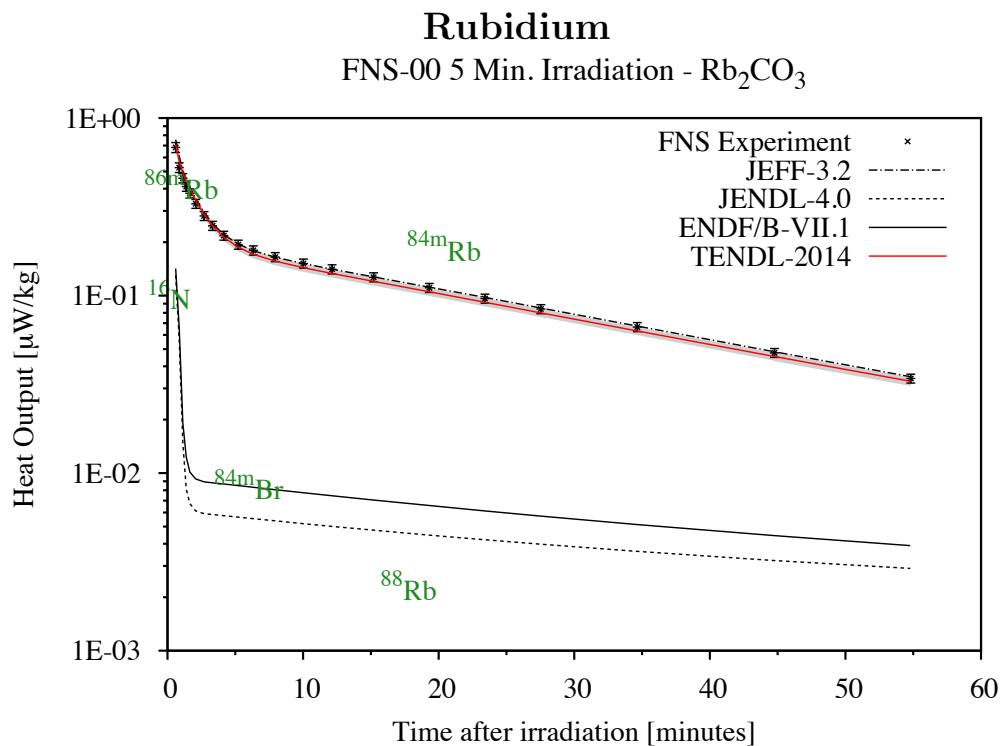
For Bromine, the above picture not only shows a near perfect match in term of experimental and calculated values for JEFF-3.2 and TENDL-2014 but also good agreement between the experimental and calculational uncertainties, even at cooling times as small as 30 seconds.

Times Min.	FNS EXP. 5 mins $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.58	$1.94E+00 +/- 13\%$	$2.04E+00 +/- 9\%$	0.95	0.82	0.97	0.84
0.83	$1.91E+00 +/- 11\%$	$1.90E+00 +/- 9\%$	1.00	0.85	1.01	0.87
1.08	$1.89E+00 +/- 11\%$	$1.84E+00 +/- 9\%$	1.02	0.87	1.04	0.88
1.33	$1.85E+00 +/- 11\%$	$1.79E+00 +/- 9\%$	1.03	0.88	1.05	0.89
1.58	$1.79E+00 +/- 11\%$	$1.75E+00 +/- 9\%$	1.02	0.87	1.04	0.88
2.02	$1.71E+00 +/- 11\%$	$1.67E+00 +/- 9\%$	1.02	0.86	1.04	0.88
2.63	$1.62E+00 +/- 11\%$	$1.57E+00 +/- 9\%$	1.03	0.86	1.05	0.88
3.23	$1.52E+00 +/- 11\%$	$1.48E+00 +/- 9\%$	1.02	0.86	1.04	0.87
4.10	$1.38E+00 +/- 11\%$	$1.36E+00 +/- 9\%$	1.02	0.85	1.03	0.86
5.20	$1.24E+00 +/- 11\%$	$1.22E+00 +/- 9\%$	1.02	0.84	1.04	0.85
6.30	$1.11E+00 +/- 11\%$	$1.09E+00 +/- 9\%$	1.01	0.83	1.03	0.84
7.92	$9.44E-01 +/- 11\%$	$9.29E-01 +/- 9\%$	1.02	0.82	1.03	0.83
10.03	$7.64E-01 +/- 11\%$	$7.55E-01 +/- 9\%$	1.01	0.80	1.03	0.82
12.13	$6.23E-01 +/- 11\%$	$6.16E-01 +/- 9\%$	1.01	0.79	1.03	0.80
15.25	$4.63E-01 +/- 11\%$	$4.59E-01 +/- 8\%$	1.01	0.76	1.02	0.77
19.32	$3.19E-01 +/- 11\%$	$3.17E-01 +/- 8\%$	1.01	0.73	1.02	0.74
23.42	$2.22E-01 +/- 11\%$	$2.21E-01 +/- 8\%$	1.00	0.70	1.01	0.70
27.52	$1.58E-01 +/- 11\%$	$1.60E-01 +/- 7\%$	0.99	0.66	1.00	0.67
34.58	$9.66E-02 +/- 11\%$	$9.73E-02 +/- 7\%$	0.99	0.65	1.02	0.65
44.70	$5.39E-02 +/- 11\%$	$5.70E-02 +/- 7\%$	0.95	0.64	0.98	0.65
54.75	$3.59E-02 +/- 11\%$	$3.90E-02 +/- 8\%$	0.92	0.69	0.94	0.70
mean % diff. from E		2	28	3	26	

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Br78	Br79(n,2n)Br78	6.46m	99.9	1.01	11%
Br80	Br79(n, γ)Br80	17.6m	6.7	1.01	11%
	Br81(n,2n)Br80		92.2	1.01	11%
	Br81(n,2n)Br80m		1.1	1.01	11%

FNS-00 5 Min. Irradiation - $\text{BrC}_6\text{H}_4\text{COOH}$

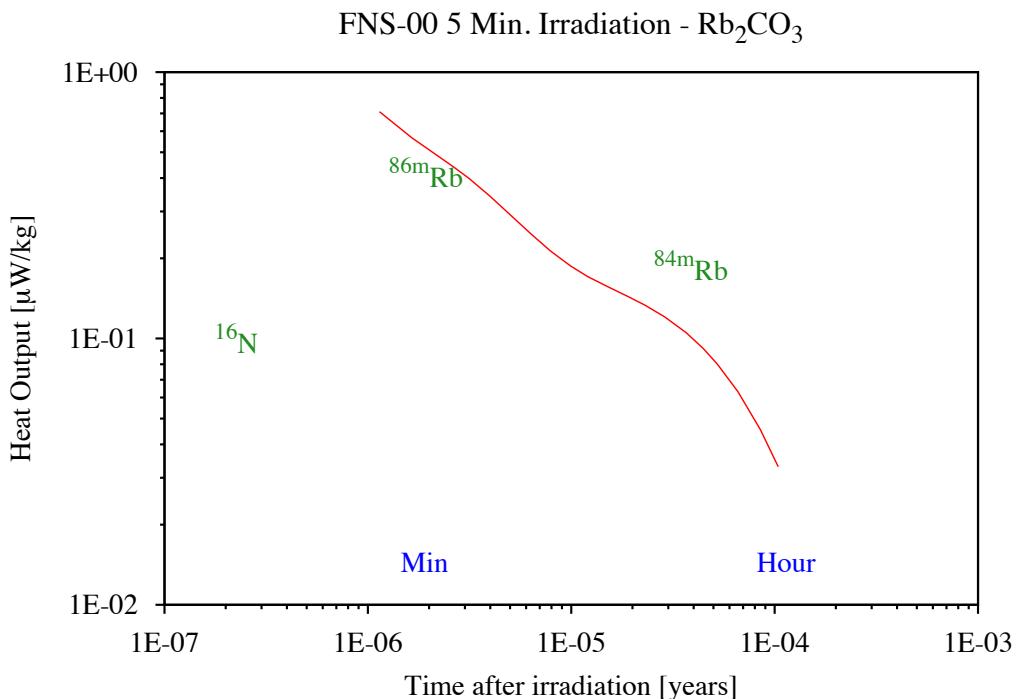


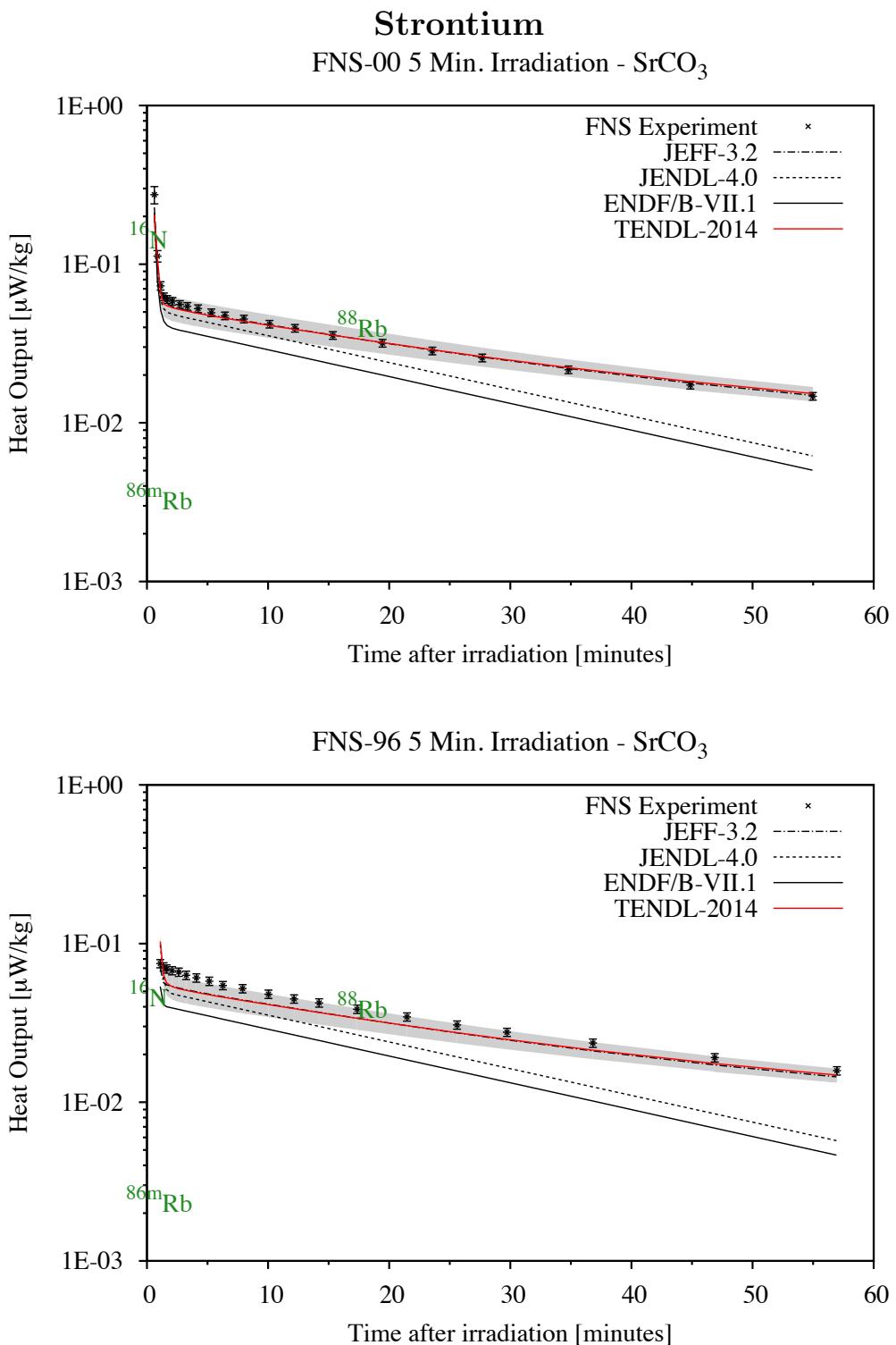


Rubidium: EAF-2010 and TENDL-2012 performed better than TENDL-2013 [14]. TENDL-2014 and JEFF-3.2 generates the best agreement. The graph also shows a clean validation of the two paths leading to metastable isomers.

Times Min.	FNS EXP. 5 mins $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1			
			JEFF-3.2 E/C	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C
0.60	$6.83E-01$ +/-7%	$7.10E-01$ +/-5%	0.96	4.81	0.91	5.24
0.87	$5.26E-01$ +/-6%	$5.66E-01$ +/-6%	0.93	8.09	0.86	9.40
1.13	$4.58E-01$ +/-6%	$4.91E-01$ +/-6%	0.93	23.94	0.91	30.95
1.38	$4.11E-01$ +/-6%	$4.41E-01$ +/-5%	0.93	33.40	0.91	50.57
1.65	$3.77E-01$ +/-6%	$3.99E-01$ +/-5%	0.94	37.18	0.93	55.99
2.08	$3.29E-01$ +/-6%	$3.44E-01$ +/-5%	0.96	35.51	0.94	53.68
2.70	$2.81E-01$ +/-6%	$2.86E-01$ +/-5%	0.98	31.44	0.96	47.48
3.32	$2.47E-01$ +/-6%	$2.48E-01$ +/-5%	1.00	28.02	0.97	42.28
4.15	$2.18E-01$ +/-6%	$2.13E-01$ +/-5%	1.02	25.08	0.99	37.81
5.22	$1.94E-01$ +/-6%	$1.87E-01$ +/-5%	1.03	22.79	0.99	34.29
6.33	$1.80E-01$ +/-6%	$1.71E-01$ +/-5%	1.05	21.62	1.01	32.48
7.95	$1.65E-01$ +/-6%	$1.56E-01$ +/-5%	1.05	20.44	1.00	30.63
10.02	$1.52E-01$ +/-6%	$1.44E-01$ +/-5%	1.06	19.54	1.00	29.18
12.13	$1.41E-01$ +/-6%	$1.33E-01$ +/-5%	1.06	18.86	1.00	28.06
15.20	$1.27E-01$ +/-6%	$1.20E-01$ +/-5%	1.05	17.96	0.99	26.58
19.32	$1.11E-01$ +/-6%	$1.05E-01$ +/-5%	1.05	16.84	0.99	24.71
23.42	$9.62E-02$ +/-6%	$9.18E-02$ +/-5%	1.05	15.70	0.99	22.84
27.53	$8.40E-02$ +/-6%	$8.00E-02$ +/-5%	1.05	14.66	0.99	21.12
34.65	$6.65E-02$ +/-6%	$6.32E-02$ +/-5%	1.05	12.95	0.99	18.36
44.77	$4.76E-02$ +/-6%	$4.54E-02$ +/-5%	1.05	10.70	0.98	14.78
54.82	$3.41E-02$ +/-6%	$3.30E-02$ +/-5%	1.03	8.73	0.98	11.74
mean % diff. from E		5	94	4	95	

Product	Pathways	T_{1/2}	Path %	E/C	ΔE%
Rb86m	Rb85(n, γ)Rb86m	1.0m	0.6	0.93	6%
	Rb87(n,2n)Rb86m		99.7	0.93	6%
Rb84	Rb85(n,2n)Rb84	33.1d	94.8	1.05	6%
	Rb85(n,2n)Rb84m	20.4m	5.2	1.05	6%

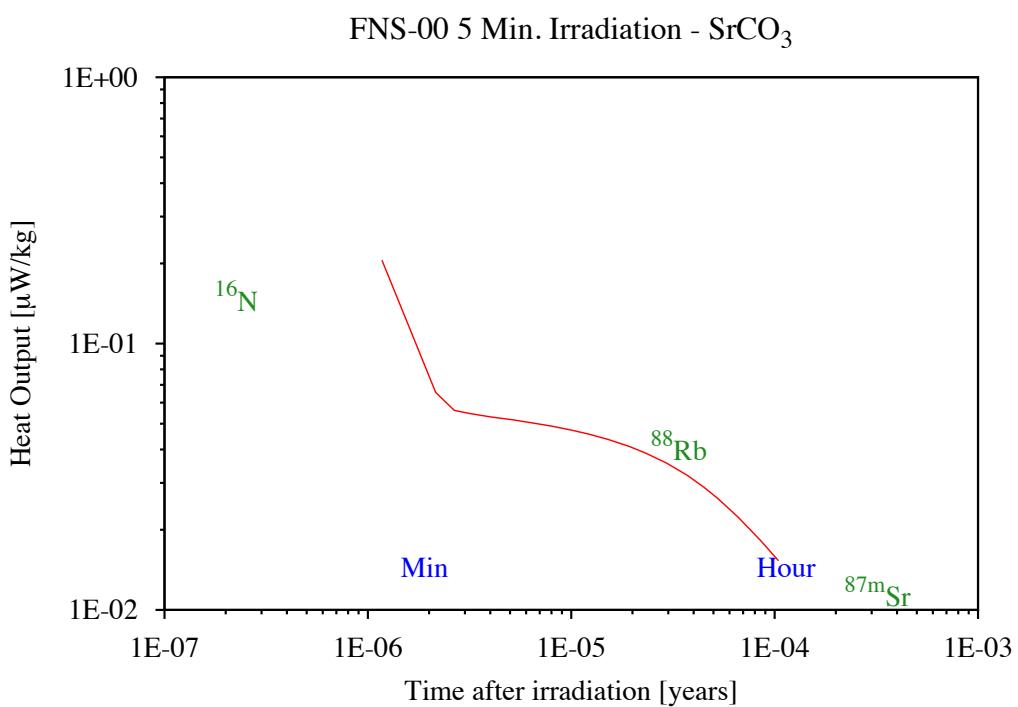


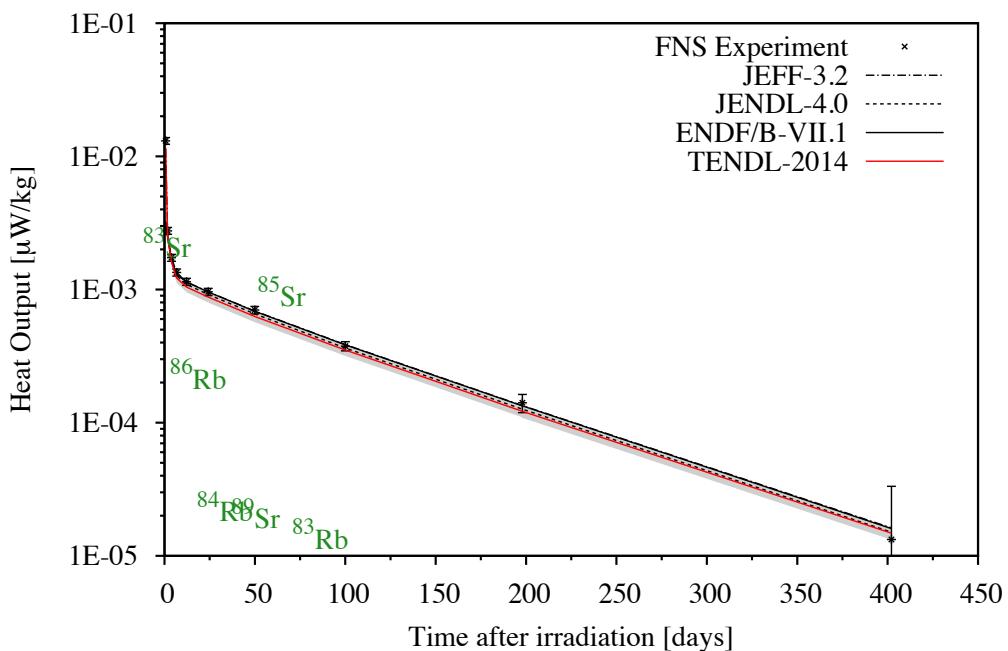


For Strontium, the two experimental measurement sets differ significantly, although both JEFF-3.2 and TENDL-2014 data libraries exhibit remarkable agreement with both measurement sets.

Times Min.	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.62	$2.74E-01$ +/-13%	$2.06E-01$ +/-5%	1.33	1.31	1.20
0.87	$1.12E-01$ +/-8%	$1.09E-01$ +/-9%	1.04	1.44	1.19
1.13	$7.30E-02$ +/-6%	$6.55E-02$ +/-15%	1.11	1.43	1.06
1.40	$6.23E-02$ +/-6%	$5.61E-02$ +/-17%	1.11	1.43	1.04
1.67	$6.00E-02$ +/-6%	$5.46E-02$ +/-17%	1.10	1.46	1.07
2.10	$5.85E-02$ +/-6%	$5.31E-02$ +/-17%	1.10	1.48	1.08
2.72	$5.58E-02$ +/-6%	$5.17E-02$ +/-17%	1.08	1.46	1.07
3.33	$5.42E-02$ +/-6%	$5.05E-02$ +/-17%	1.07	1.45	1.06
4.22	$5.25E-02$ +/-6%	$4.90E-02$ +/-17%	1.07	1.45	1.06
5.32	$4.94E-02$ +/-6%	$4.73E-02$ +/-17%	1.05	1.43	1.04
6.43	$4.73E-02$ +/-6%	$4.57E-02$ +/-17%	1.03	1.42	1.03
8.00	$4.51E-02$ +/-5%	$4.37E-02$ +/-17%	1.03	1.45	1.03
10.12	$4.19E-02$ +/-5%	$4.11E-02$ +/-17%	1.02	1.46	1.01
12.22	$3.94E-02$ +/-5%	$3.88E-02$ +/-16%	1.02	1.49	1.01
15.35	$3.56E-02$ +/-5%	$3.57E-02$ +/-16%	1.00	1.52	1.00
19.45	$3.18E-02$ +/-5%	$3.21E-02$ +/-15%	0.99	1.59	0.99
23.57	$2.84E-02$ +/-5%	$2.89E-02$ +/-14%	0.98	1.67	0.99
27.68	$2.57E-02$ +/-5%	$2.62E-02$ +/-14%	0.98	1.77	0.99
34.80	$2.16E-02$ +/-5%	$2.23E-02$ +/-13%	0.97	1.96	0.98
44.87	$1.73E-02$ +/-5%	$1.82E-02$ +/-11%	0.95	2.32	0.97
54.98	$1.47E-02$ +/-5%	$1.53E-02$ +/-10%	0.96	2.92	0.99
mean % diff. from E		6	36	4	23

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Rb88	Sr88(n,p)Rb88	17.8m	100.0	0.99	5%

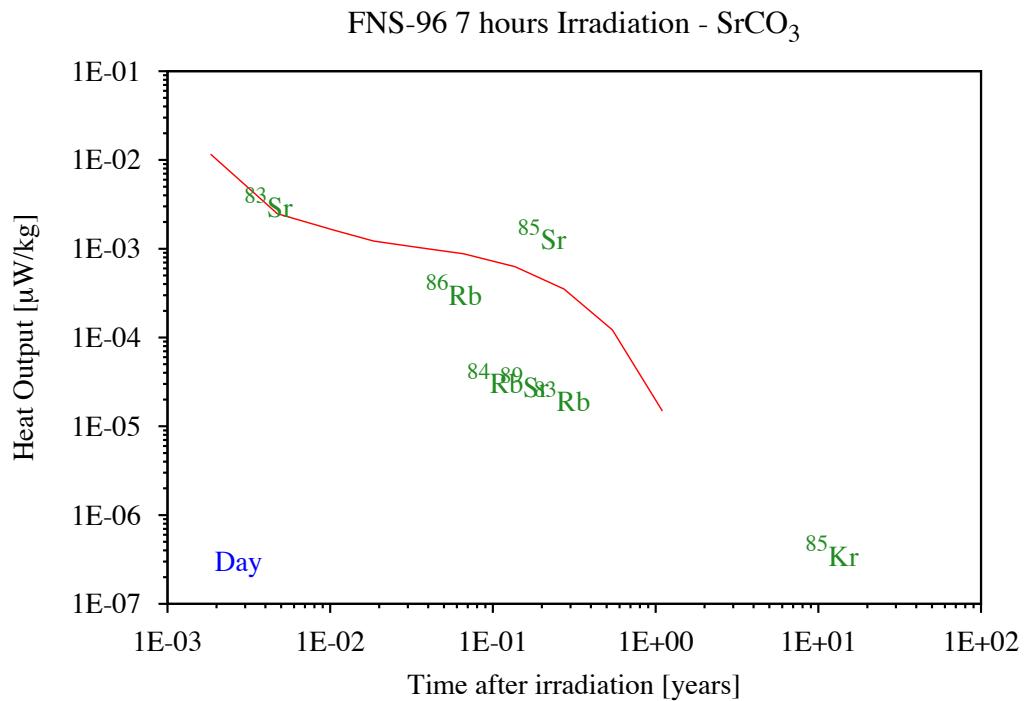


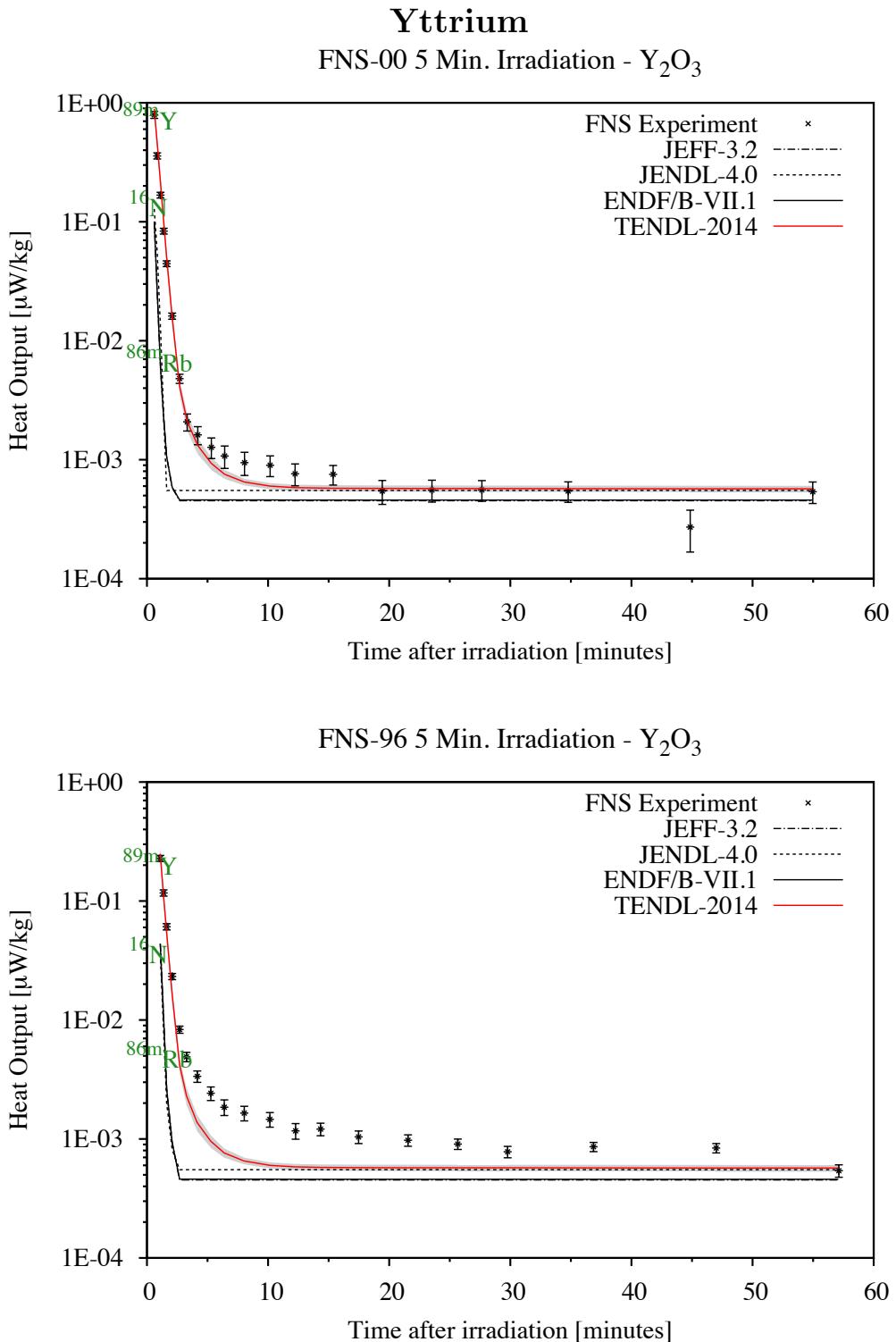
FNS-96 7 hours Irradiation - SrCO₃

The above picture shows an unequivocal, near perfect agreement, in all cases on the heat arising from complex pathways.

Times Days	FNS EXP. 7 hrs $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.67	$1.31E-02 +/- 6\%$	$1.16E-02 +/- 8\%$	1.12	4.09	1.15	3.99
1.73	$2.76E-03 +/- 6\%$	$2.48E-03 +/- 7\%$	1.11	1.12	1.07	1.10
3.88	$1.73E-03 +/- 6\%$	$1.61E-03 +/- 7\%$	1.07	1.06	1.00	1.06
6.75	$1.34E-03 +/- 6\%$	$1.22E-03 +/- 8\%$	1.10	1.03	1.01	1.06
12.19	$1.14E-03 +/- 6\%$	$1.04E-03 +/- 9\%$	1.10	1.01	1.00	1.05
24.20	$9.61E-04 +/- 6\%$	$8.77E-04 +/- 9\%$	1.10	1.00	1.00	1.05
49.95	$7.01E-04 +/- 6\%$	$6.27E-04 +/- 9\%$	1.12	1.02	1.02	1.07
100.08	$3.76E-04 +/- 8\%$	$3.51E-04 +/- 10\%$	1.07	0.98	0.97	1.03
197.95	$1.41E-04 +/- 16\%$	$1.22E-04 +/- 10\%$	1.16	1.05	1.05	1.11
402.15	$1.33E-05 +/- 151\%$	$1.48E-05 +/- 10\%$	0.89	0.82	0.82	0.88
mean % diff. from E		10	13	5	14	

Product	Pathways	T _{1/2}	Path %	E/C	ΔE%
Sr87m	Sr88(n,2n)Sr87m	2.8h	96.1	1.12	8%
	Sr87(n,n')		3.4	1.12	8%
Sr83	Sr84(n,2n)Sr83	1.3d	82.4	1.11	6%
	Sr84(n,2n)Sr83m		17.6	1.11	6%
Sr85	Sr86(n,2n)Sr85	64.8d	80.6	1.07	8%
	Sr86(n,2n)Sr85m		19.4	1.07	8%

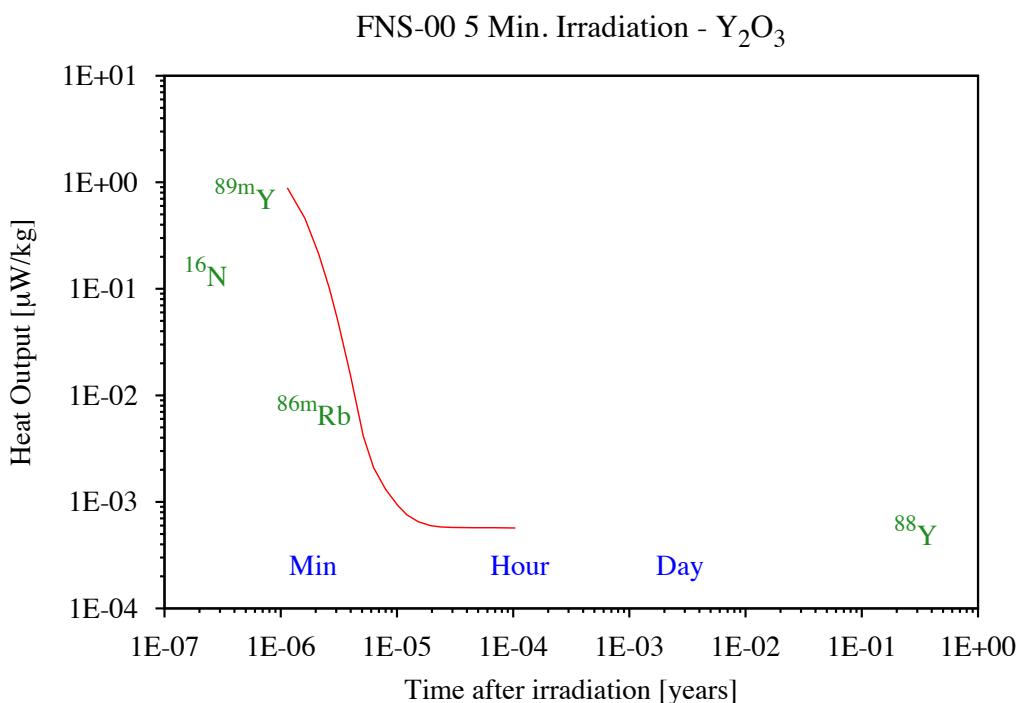


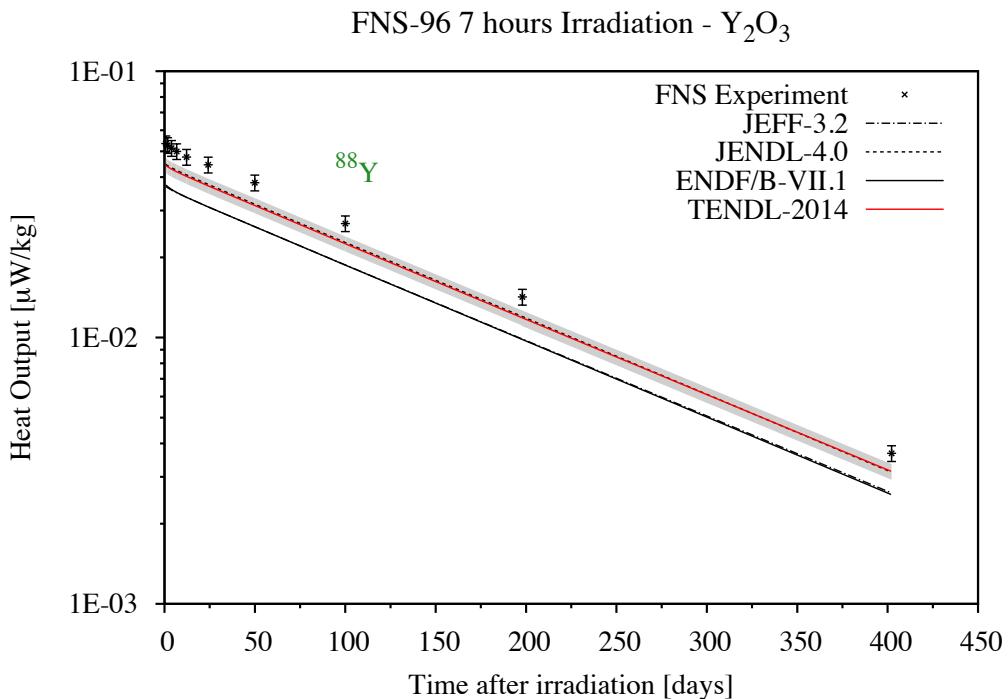


For Yttrium, here again the two experimental data sets differ significantly and the more recent one is accompanied by some rather high uncertainty levels. However, only TENDL-2014 properly predict the short lived predominant isotopes.

Times	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.60	$7.92E-01$ +/-7%	$8.87E-01$ +/-14%	0.89	7.88	7.88
0.85	$3.58E-01$ +/-6%	$4.58E-01$ +/-14%	0.78	13.96	13.96
1.12	$1.68E-01$ +/-6%	$2.12E-01$ +/-15%	0.79	28.39	28.34
1.38	$8.35E-02$ +/-6%	$1.00E-01$ +/-16%	0.83	37.81	37.85
1.63	$4.44E-02$ +/-6%	$4.97E-02$ +/-15%	0.89	41.98	42.19
2.08	$1.61E-02$ +/-6%	$1.58E-02$ +/-14%	1.02	27.39	27.68
2.70	$4.80E-03$ +/-9%	$4.15E-03$ +/-15%	1.16	10.46	10.61
3.32	$2.08E-03$ +/-16%	$2.10E-03$ +/-17%	0.99	4.54	4.61
4.20	$1.62E-03$ +/-17%	$1.32E-03$ +/-16%	1.23	3.53	3.58
5.32	$1.27E-03$ +/-20%	$9.30E-04$ +/-12%	1.37	2.78	2.81
6.42	$1.07E-03$ +/-21%	$7.54E-04$ +/-9%	1.42	2.34	2.37
8.05	$9.46E-04$ +/-22%	$6.50E-04$ +/-6%	1.46	2.06	2.09
10.17	$8.98E-04$ +/-20%	$5.99E-04$ +/-6%	1.50	1.96	1.99
12.23	$7.62E-04$ +/-21%	$5.83E-04$ +/-6%	1.31	1.66	1.69
15.37	$7.54E-04$ +/-19%	$5.76E-04$ +/-6%	1.31	1.64	1.67
19.43	$5.45E-04$ +/-23%	$5.73E-04$ +/-6%	0.95	1.19	1.21
23.53	$5.56E-04$ +/-21%	$5.73E-04$ +/-6%	0.97	1.21	1.23
27.65	$5.57E-04$ +/-20%	$5.72E-04$ +/-6%	0.97	1.22	1.23
34.78	$5.45E-04$ +/-20%	$5.71E-04$ +/-6%	0.95	1.19	1.21
44.85	$2.72E-04$ +/-38%	$5.70E-04$ +/-6%	0.48	0.59	0.60
54.97	$5.39E-04$ +/-20%	$5.69E-04$ +/-6%	0.95	1.18	1.19
mean % diff. from E		21	60	60	54

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
N16	O16(n,p)N16	7.1s	100.0	0.89	7%
Y89m	Y89(n,n')Y89m	15.6s	100.0	0.89	6%
Rb86m	Y89(n, α)Rb86m	1.0m	100.0	0.79	6%
Y88	Y89(n,2n)Y88	106.6d	100.0	0.95	20%

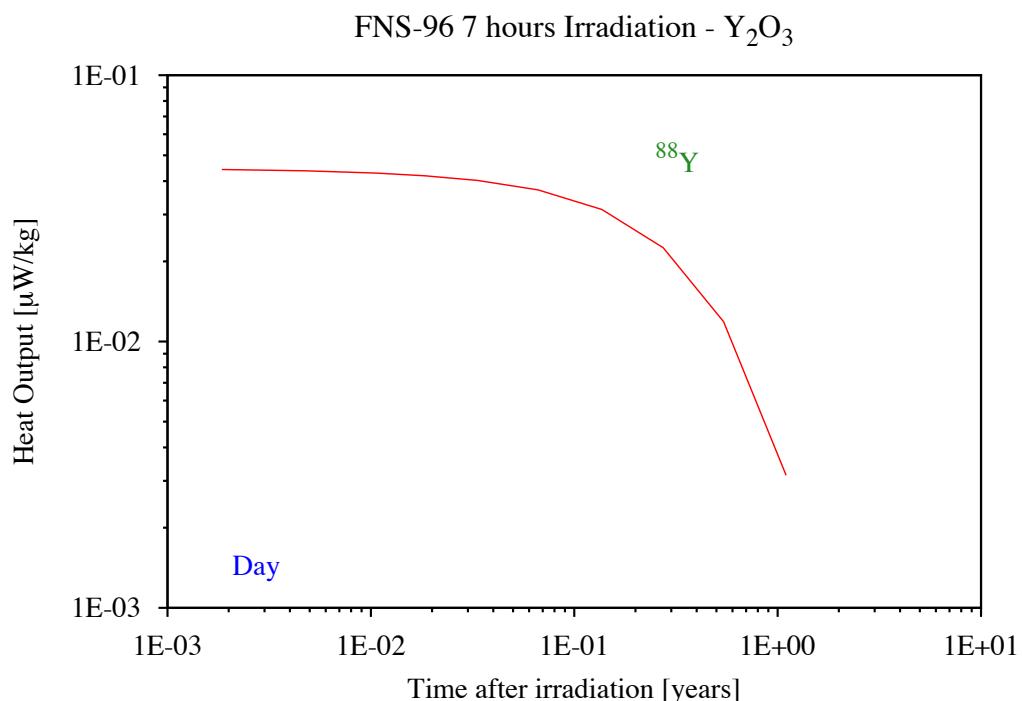




The code predictions underestimate the decay heat by around 20%, rather evenly and up to 400 days cooling for TENDL-2014 and JENDL-4.0. This unique ($n,2n$) pathway seems a perfect case to act on, although the question remains as to whether the change should be made to the cross section or decay file.

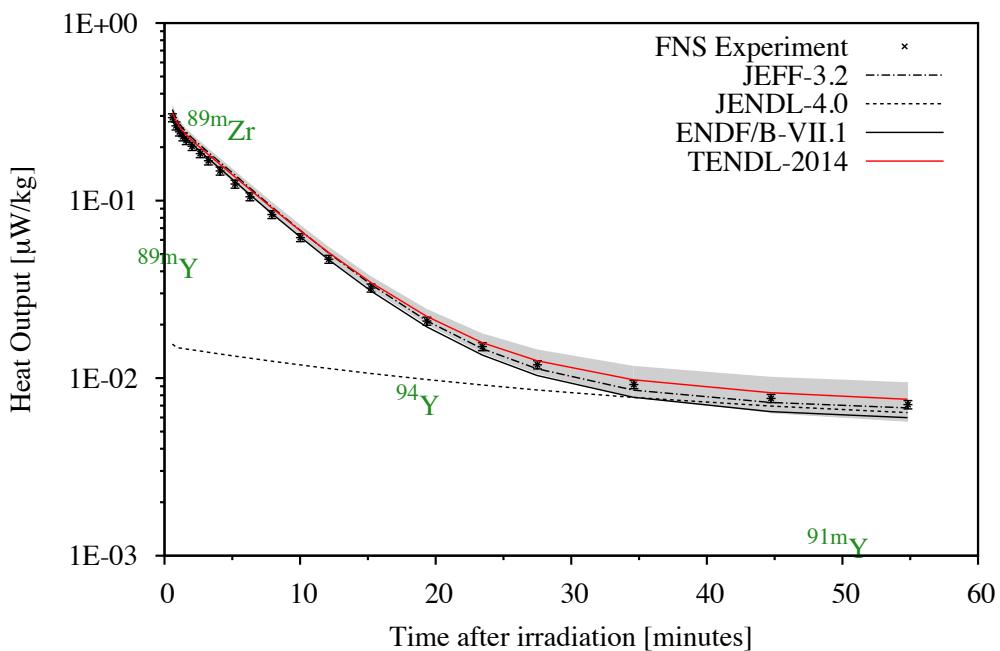
Times Days	FNS EXP. 7 hrs $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.68	$5.35E-02 +/- 7\%$	$4.43E-02 +/- 6\%$	1.21	1.43	1.45	1.20
1.73	$5.27E-02 +/- 7\%$	$4.38E-02 +/- 6\%$	1.20	1.43	1.44	1.19
3.89	$5.14E-02 +/- 7\%$	$4.29E-02 +/- 6\%$	1.20	1.43	1.44	1.18
6.76	$5.00E-02 +/- 7\%$	$4.19E-02 +/- 6\%$	1.19	1.43	1.43	1.18
12.20	$4.76E-02 +/- 7\%$	$4.03E-02 +/- 6\%$	1.18	1.42	1.42	1.17
24.21	$4.45E-02 +/- 7\%$	$3.71E-02 +/- 6\%$	1.20	1.44	1.44	1.18
49.96	$3.81E-02 +/- 7\%$	$3.13E-02 +/- 6\%$	1.22	1.46	1.46	1.20
100.09	$2.68E-02 +/- 7\%$	$2.25E-02 +/- 6\%$	1.19	1.43	1.43	1.18
197.96	$1.42E-02 +/- 7\%$	$1.19E-02 +/- 7\%$	1.20	1.44	1.44	1.18
402.17	$3.67E-03 +/- 7\%$	$3.15E-03 +/- 7\%$	1.17	1.43	1.41	1.17
mean % diff. from E		16	30	30	16	

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Y88	Y89($n,2n$)Y88	106d	100.0	1.19	7%

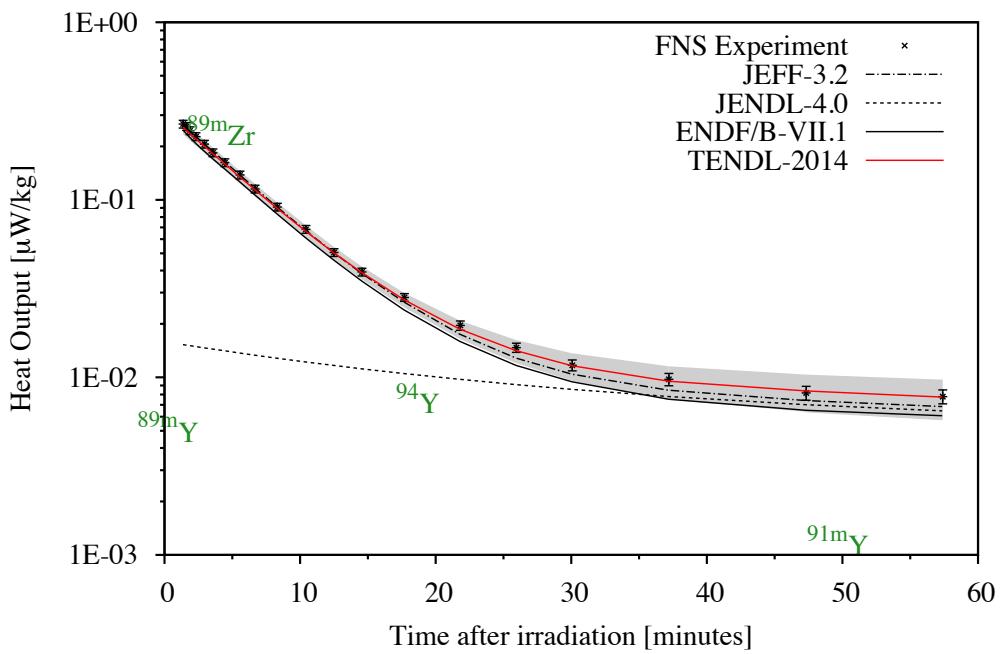


Zirconium

FNS-00 5 Min. Irradiation - Zr



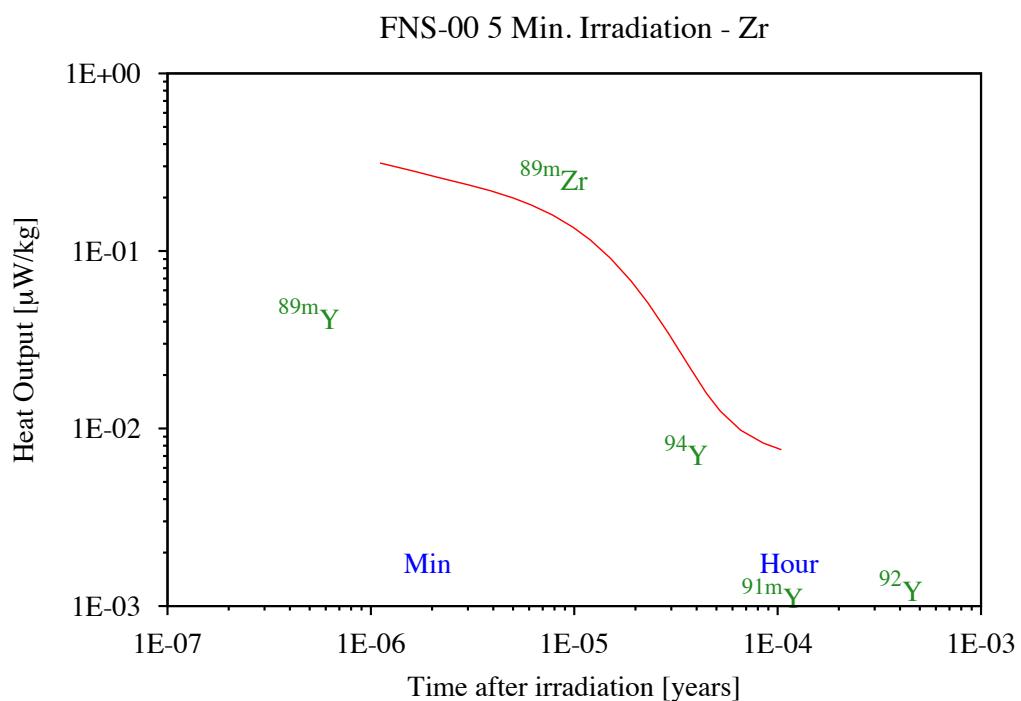
FNS-96 5 Min. Irradiation - Zr



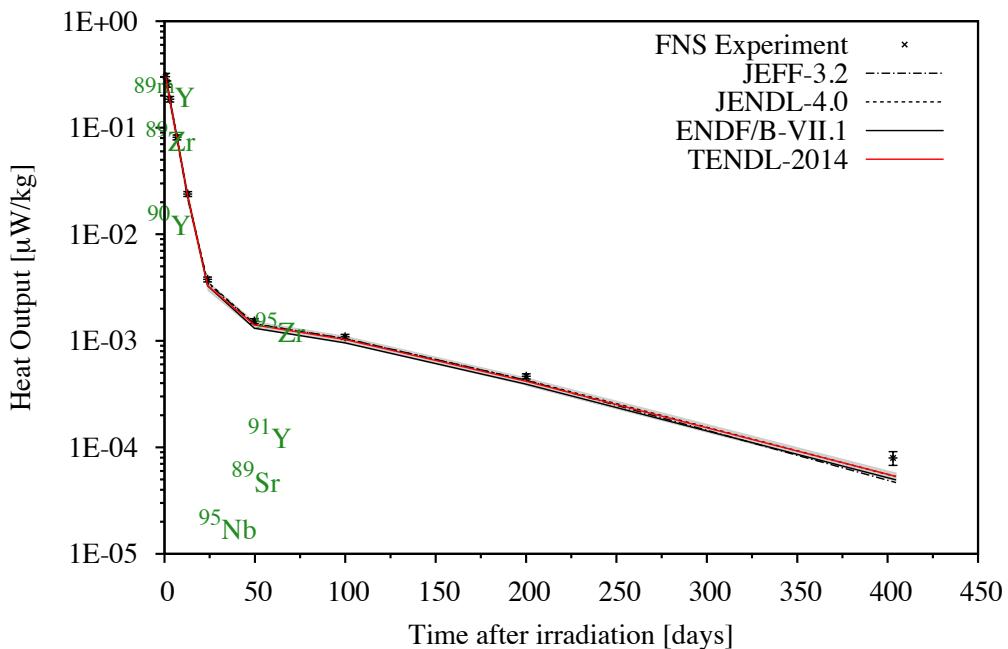
For Zirconium, a good agreement at all cooling times may be seen, when TENDL-2014, ENDF/B-VII.1 or JEFF-3.2 are used. JENDL-4.0 does not produce Zr^{89m} .

Times	FNS EXP.	5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.		$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.58		$2.93E-01$ +/-5%	$3.13E-01$ +/-12%	0.94	1.01	0.90
0.85		$2.64E-01$ +/-5%	$2.82E-01$ +/-10%	0.94	1.00	0.91
1.10		$2.44E-01$ +/-5%	$2.62E-01$ +/-9%	0.93	0.98	0.90
1.35		$2.29E-01$ +/-5%	$2.47E-01$ +/-9%	0.93	0.97	0.90
1.60		$2.18E-01$ +/-5%	$2.35E-01$ +/-9%	0.93	0.97	0.90
2.03		$2.02E-01$ +/-5%	$2.19E-01$ +/-8%	0.92	0.97	0.90
2.63		$1.84E-01$ +/-5%	$1.99E-01$ +/-8%	0.93	0.97	0.90
3.23		$1.68E-01$ +/-5%	$1.81E-01$ +/-8%	0.92	0.97	0.90
4.10		$1.47E-01$ +/-5%	$1.60E-01$ +/-8%	0.92	0.97	0.89
5.20		$1.24E-01$ +/-5%	$1.36E-01$ +/-8%	0.91	0.97	0.89
6.30		$1.05E-01$ +/-5%	$1.16E-01$ +/-8%	0.91	0.97	0.89
7.92		$8.35E-02$ +/-5%	$9.11E-02$ +/-8%	0.92	0.98	0.90
10.02		$6.19E-02$ +/-5%	$6.77E-02$ +/-8%	0.91	0.99	0.91
12.12		$4.67E-02$ +/-5%	$5.10E-02$ +/-8%	0.92	1.01	0.92
15.23		$3.22E-02$ +/-5%	$3.46E-02$ +/-8%	0.93	1.04	0.95
19.35		$2.10E-02$ +/-5%	$2.23E-02$ +/-10%	0.94	1.08	1.00
23.45		$1.51E-02$ +/-5%	$1.58E-02$ +/-13%	0.95	1.12	1.03
27.50		$1.19E-02$ +/-5%	$1.25E-02$ +/-16%	0.95	1.15	1.05
34.62		$9.20E-03$ +/-5%	$9.78E-03$ +/-20%	0.94	1.18	1.08
44.73		$7.69E-03$ +/-5%	$8.28E-03$ +/-23%	0.93	1.19	1.05
54.83		$7.09E-03$ +/-5%	$7.60E-03$ +/-25%	0.93	1.18	1.04
mean % diff. from E			8	5	9	70

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Zr89m	Zr90(n,2n)Zr89m	4.1m	100.0	0.92	5%
Y94	Zr94(n,p)Y94	18.7m	100.0	0.94	5%



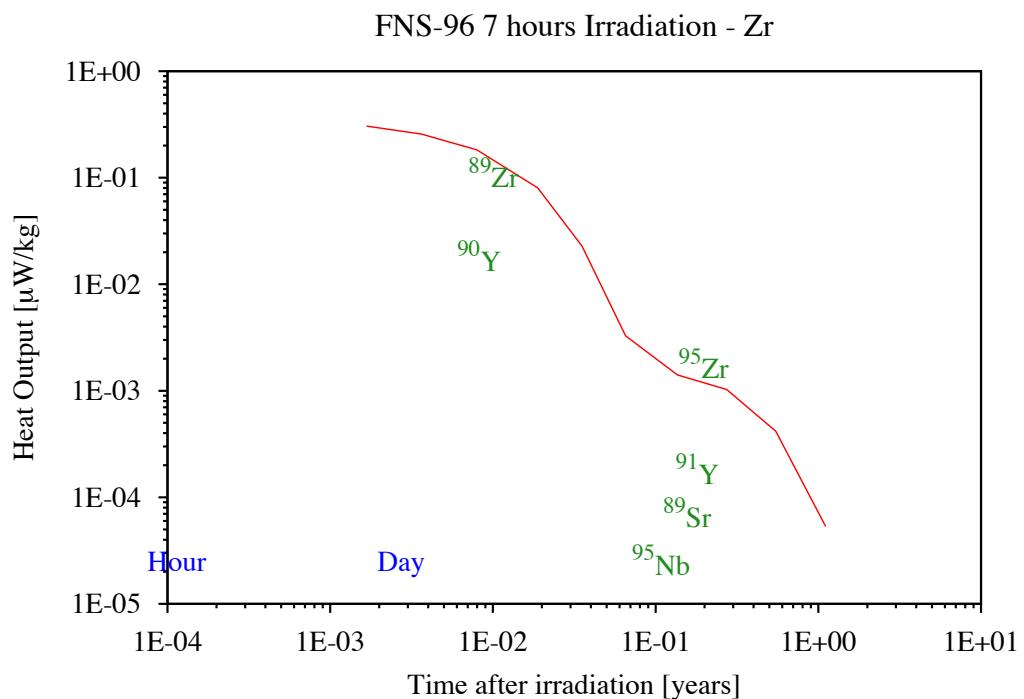
FNS-96 7 hours Irradiation - Zr



Although numerous radionuclides are present excellent agreements exist, within the experimental uncertainty, up to a year of cooling.

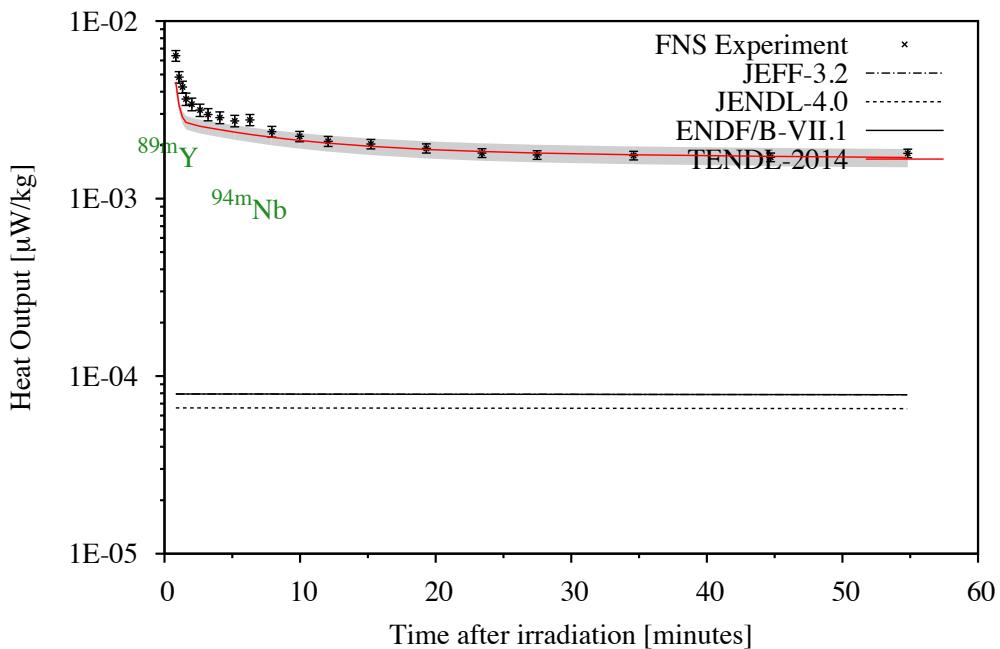
Times	FNS EXP. 7 hrs	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Days	μW/g	μW/g	E/C	E/C	E/C
0.61	3.02E-01 +/-7%	3.06E-01 +/-17%	0.99	0.98	0.98
1.33	2.57E-01 +/-7%	2.57E-01 +/-18%	1.00	0.99	1.00
2.91	1.85E-01 +/-6%	1.83E-01 +/-18%	1.01	1.00	1.01
6.88	8.12E-02 +/-5%	8.03E-02 +/-18%	1.01	1.00	1.02
12.88	2.39E-02 +/-5%	2.28E-02 +/-17%	1.04	1.04	1.09
23.85	3.77E-03 +/-5%	3.28E-03 +/-11%	1.15	1.15	1.08
49.71	1.53E-03 +/-5%	1.41E-03 +/-9%	1.09	1.17	1.06
99.90	1.09E-03 +/-5%	1.03E-03 +/-9%	1.06	1.14	1.04
200.12	4.64E-04 +/-6%	4.17E-04 +/-9%	1.11	1.18	1.09
402.96	7.94E-05 +/-15%	5.32E-05 +/-9%	1.49	1.60	1.49
mean % diff. from E		8	10	8	7

Product	Pathways	T _{1/2}	Path %	E/C	ΔE%
Zr89	Zr90(n,2n)Zr89	3.2d	84.3	1.01	6%
	Zr90(n,2n)Zr89m	4.18m	15.8	1.01	6%
Zr95	Zr96(n,2n)Zr95	64.0d	99.4	1.06	5%
	Zr94(n,γ)Zr95	64.0d	0.6	1.06	5%

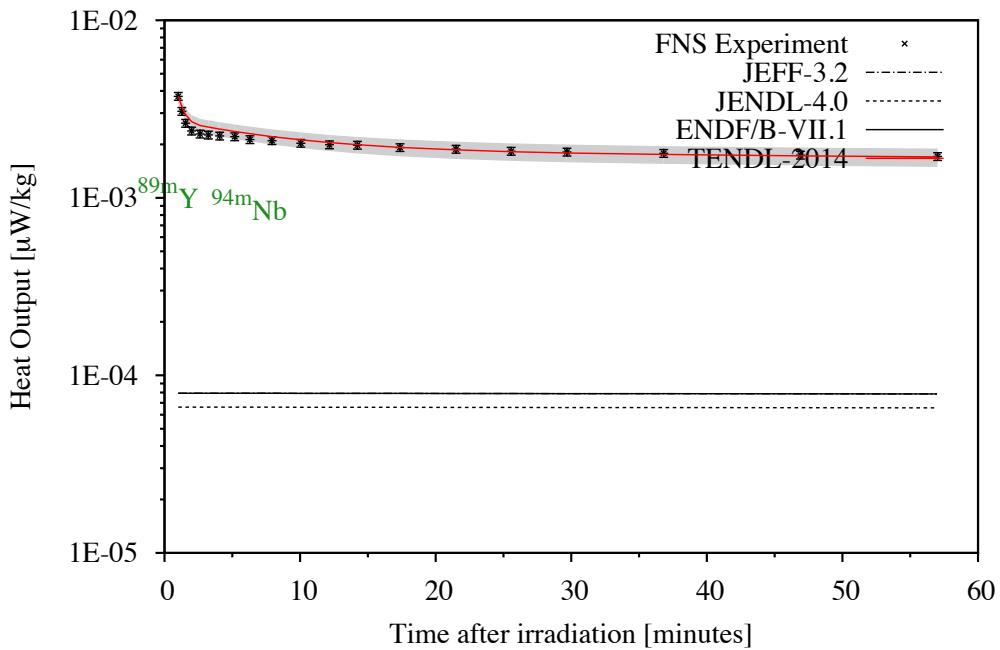


Niobium

FNS-00 5 Min. Irradiation - Nb



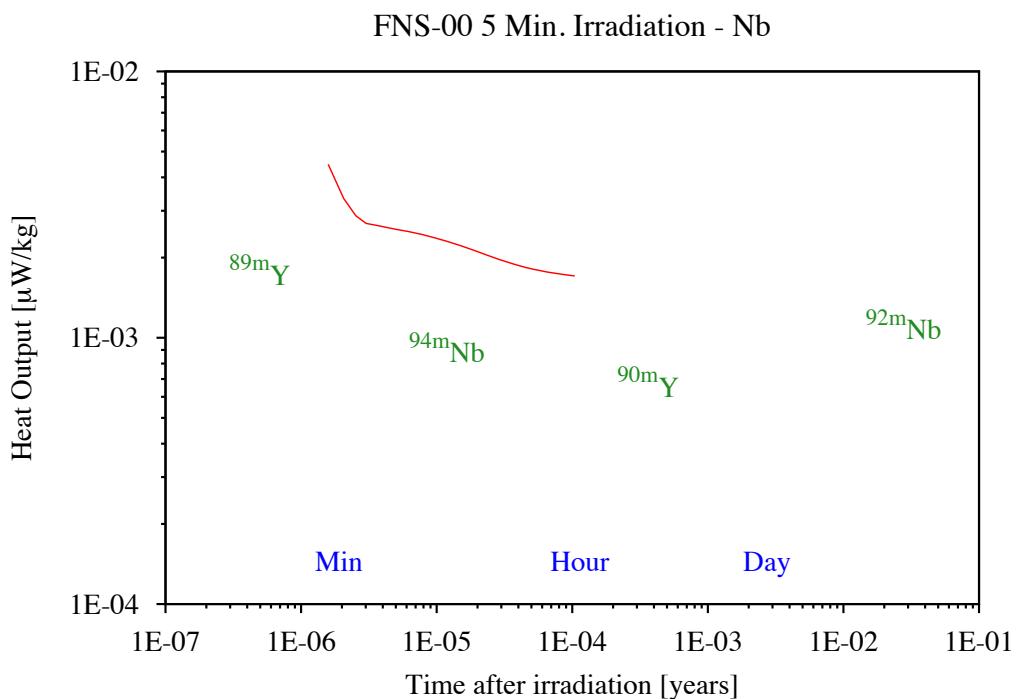
FNS-96 5 Min. Irradiation - Nb

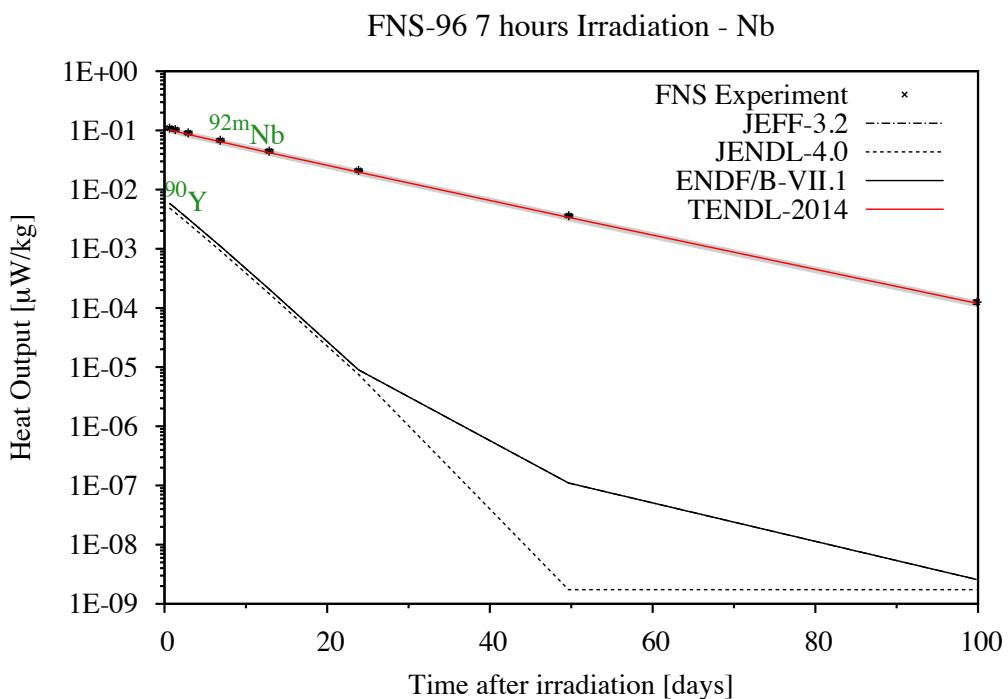


For Niobium, the difficulties in predicting its decay heat derive from the determination of the energy dependant isomeric branching ratios of the three isomers that dominate the response function. Obviously none of the major libraries, ENDF/B-VII.1, JEFF-3.2 or JENDL-4.0 contains such crucial branching informations.

Times	FNS EXP.	5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.		$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.83		$6.37E-03 +/-7\%$	$4.48E-03 +/-12\%$	1.42	80.31	80.31
1.08		$4.83E-03 +/-7\%$	$3.34E-03 +/-9\%$	1.45	60.88	60.88
1.33		$4.25E-03 +/-8\%$	$2.87E-03 +/-8\%$	1.48	53.57	53.57
1.58		$3.64E-03 +/-8\%$	$2.69E-03 +/-9\%$	1.35	45.83	45.83
2.02		$3.40E-03 +/-8\%$	$2.63E-03 +/-9\%$	1.30	42.88	42.88
2.62		$3.15E-03 +/-8\%$	$2.56E-03 +/-9\%$	1.23	39.72	39.72
3.22		$2.98E-03 +/-8\%$	$2.51E-03 +/-9\%$	1.19	37.52	37.52
4.08		$2.86E-03 +/-8\%$	$2.44E-03 +/-9\%$	1.17	36.05	36.05
5.18		$2.74E-03 +/-7\%$	$2.37E-03 +/-9\%$	1.16	34.54	34.54
6.30		$2.78E-03 +/-7\%$	$2.30E-03 +/-10\%$	1.21	35.00	35.00
7.92		$2.38E-03 +/-7\%$	$2.21E-03 +/-10\%$	1.08	30.07	30.07
9.97		$2.24E-03 +/-7\%$	$2.13E-03 +/-10\%$	1.05	28.30	28.30
12.07		$2.10E-03 +/-6\%$	$2.05E-03 +/-10\%$	1.02	26.54	26.54
15.22		$2.03E-03 +/-6\%$	$1.97E-03 +/-11\%$	1.03	25.62	25.62
19.32		$1.92E-03 +/-6\%$	$1.89E-03 +/-11\%$	1.01	24.28	24.28
23.42		$1.81E-03 +/-6\%$	$1.84E-03 +/-11\%$	0.98	22.85	22.85
27.48		$1.76E-03 +/-6\%$	$1.81E-03 +/-11\%$	0.98	22.31	22.31
34.60		$1.75E-03 +/-6\%$	$1.76E-03 +/-11\%$	0.99	22.16	22.16
44.70		$1.71E-03 +/-6\%$	$1.73E-03 +/-11\%$	0.99	21.72	21.72
54.82		$1.80E-03 +/-6\%$	$1.71E-03 +/-11\%$	1.05	22.87	22.87
mean % diff. from E			13	97	97	97

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Y89m	$\text{Nb}^{93}(n,\text{n}\alpha)\text{Y}^{89m}$	15.6s	100.0	1.42	7%
Nb94m	$\text{Nb}^{93}(n,\gamma)\text{Nb}^{94m}$	6.2m	99.7	1.21	7%
Y90m	$\text{Nb}^{93}(n,\alpha)\text{Y}^{90m}$	3.1h	100.0	1.05	6%

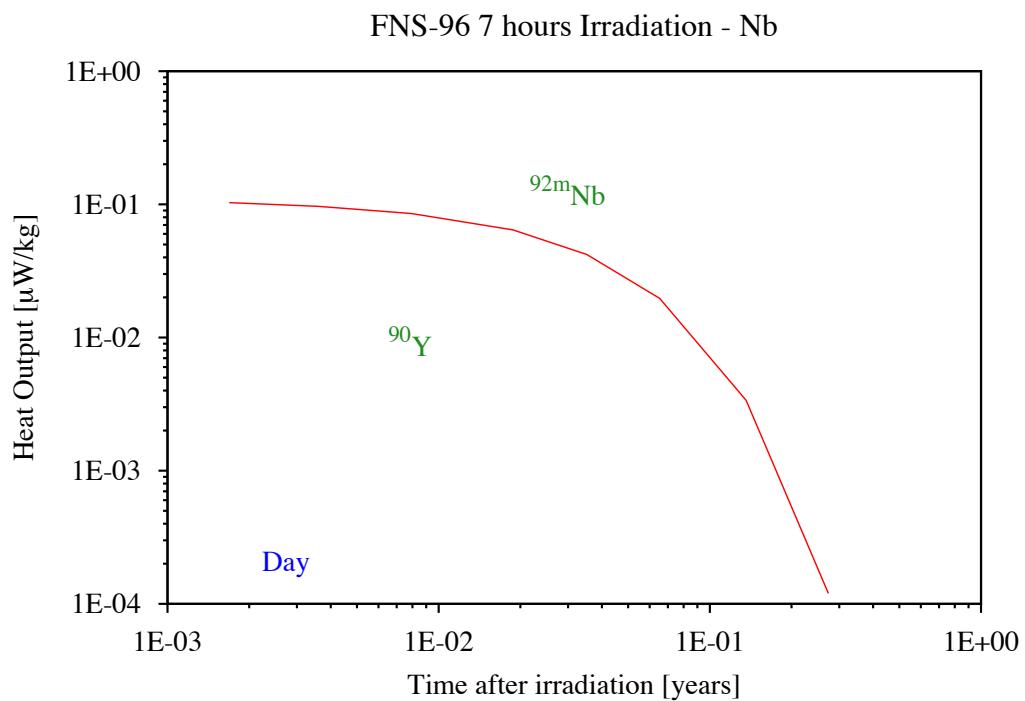




A superb agreement occurs on the route of production and decay data for the metastable isotope Nb92m, up to 100 days of cooling. However, no such production path exists in ENDF/B-VII.1, JEFF-3.2 or JENDL-4.0.

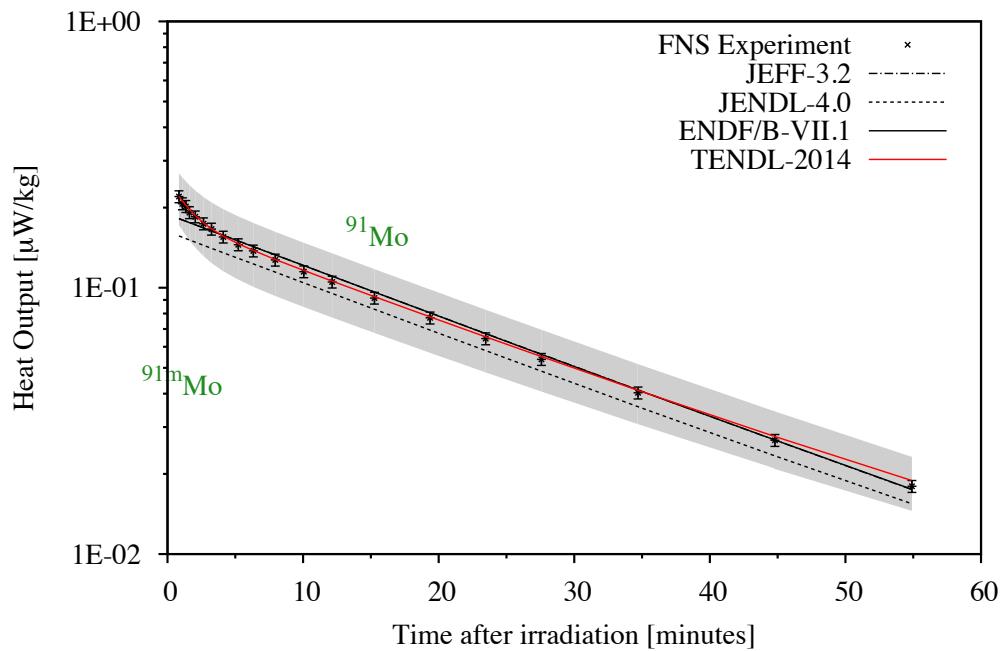
Times Days	FNS EXP. 7 hrs μW/g	TENDL-2014 μW/g	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C
0.62	$1.09E-01$ +/-6%	$1.03E-01$ +/-12%	1.06	18.67	18.67
1.32	$1.03E-01$ +/-6%	$9.66E-02$ +/-12%	1.07	21.12	21.12
2.90	$9.08E-02$ +/-6%	$8.54E-02$ +/-12%	1.06	28.22	28.22
6.86	$6.81E-02$ +/-6%	$6.43E-02$ +/-12%	1.06	61.19	61.19
12.86	$4.48E-02$ +/-5%	$4.20E-02$ +/-13%	1.07	214.08	214.08
23.85	$2.10E-02$ +/-5%	$1.97E-02$ +/-13%	1.07	> 1000	> 1000
49.70	$3.62E-03$ +/-5%	$3.38E-03$ +/-13%	1.07	> 1000	> 1000
99.89	$1.25E-04$ +/-8%	$1.20E-04$ +/-13%	1.05	> 1000	> 1000
mean % diff. from E			6	98	98

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Nb92m	Nb93(n,2n)Nb92m	10.1d	100.0	1.07	5%

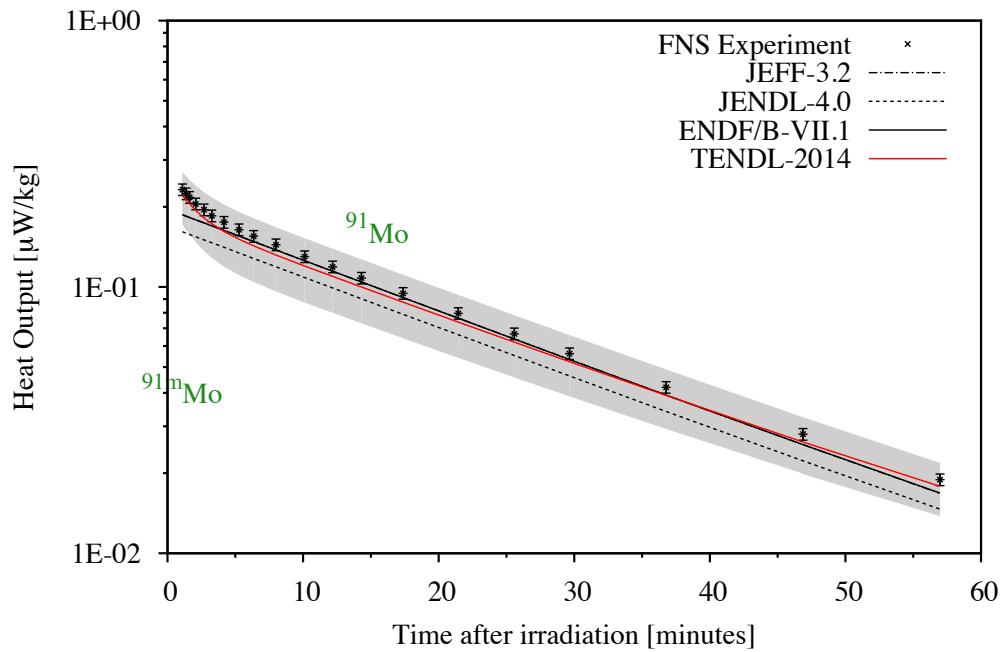


Molybdenum

FNS-00 5 Min. Irradiation - Mo



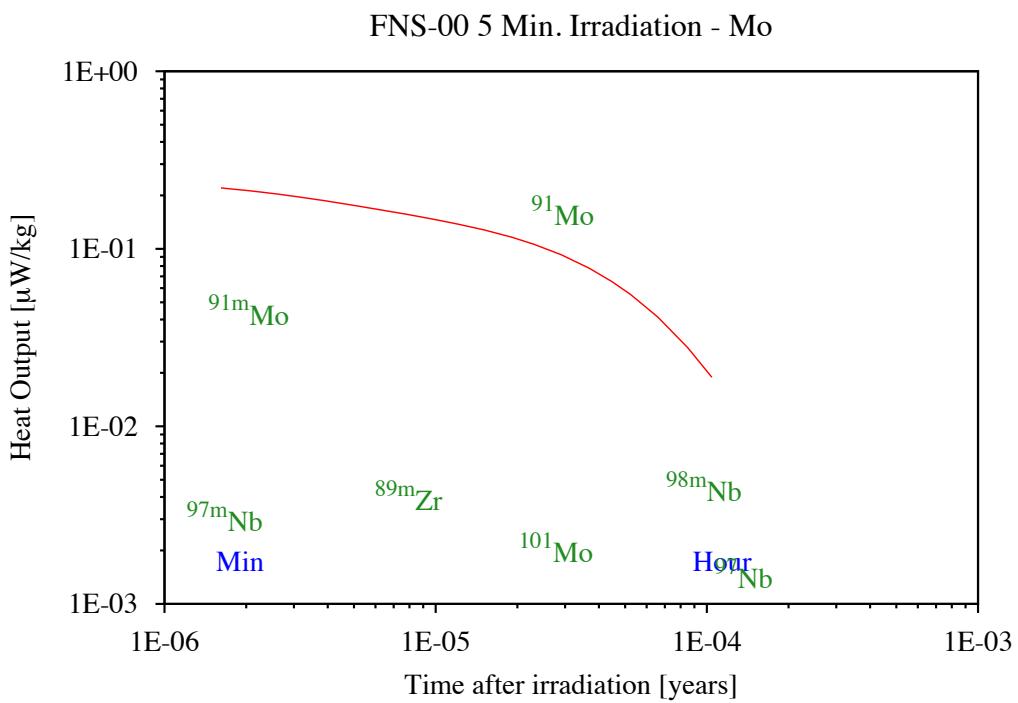
FNS-96 5 Min. Irradiation - Mo

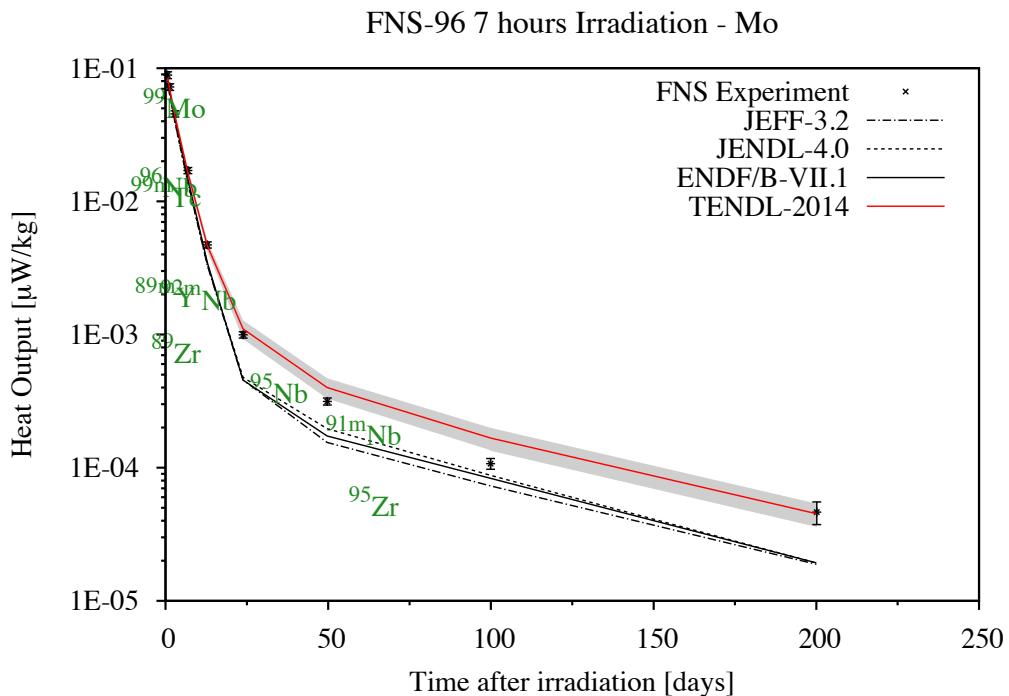


For Molybdenum, a good agreement with the experimental results was already seen when the TENDL-2011 data library [15] was used to predict the experiment. However, the two experimental batches differ somewhat, but both comfortably within the boundaries given by the TENDL-2014 uncertainty.

Times	FNS EXP.	5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.		$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.85		$2.20E-01$ +/-5%	$2.20E-01$ +/-22%	1.00	1.21	1.21
1.10		$2.07E-01$ +/-5%	$2.12E-01$ +/-22%	0.98	1.15	1.15
1.35		$2.02E-01$ +/-5%	$2.04E-01$ +/-23%	0.99	1.14	1.14
1.62		$1.92E-01$ +/-5%	$1.97E-01$ +/-23%	0.97	1.09	1.09
2.05		$1.85E-01$ +/-5%	$1.87E-01$ +/-24%	0.99	1.07	1.07
2.65		$1.74E-01$ +/-5%	$1.75E-01$ +/-25%	0.99	1.04	1.04
3.25		$1.66E-01$ +/-5%	$1.66E-01$ +/-26%	1.00	1.02	1.02
4.12		$1.55E-01$ +/-5%	$1.56E-01$ +/-26%	0.99	0.99	0.99
5.22		$1.45E-01$ +/-5%	$1.46E-01$ +/-27%	0.99	0.97	0.97
6.33		$1.38E-01$ +/-5%	$1.38E-01$ +/-27%	1.00	0.96	0.96
7.95		$1.27E-01$ +/-5%	$1.28E-01$ +/-27%	1.00	0.96	0.96
10.05		$1.15E-01$ +/-5%	$1.16E-01$ +/-27%	0.99	0.95	0.95
12.15		$1.05E-01$ +/-5%	$1.06E-01$ +/-27%	0.99	0.95	0.95
15.27		$9.15E-02$ +/-5%	$9.26E-02$ +/-27%	0.99	0.95	0.95
19.37		$7.70E-02$ +/-5%	$7.77E-02$ +/-27%	0.99	0.96	0.96
23.47		$6.44E-02$ +/-5%	$6.54E-02$ +/-26%	0.98	0.96	0.96
27.58		$5.38E-02$ +/-5%	$5.52E-02$ +/-26%	0.98	0.96	0.96
34.70		$4.03E-02$ +/-5%	$4.12E-02$ +/-25%	0.98	0.98	0.97
44.80		$2.67E-02$ +/-5%	$2.77E-02$ +/-24%	0.97	1.00	1.00
54.90		$1.80E-02$ +/-5%	$1.89E-02$ +/-23%	0.95	1.02	1.03
mean % diff. from E				1	5	6
					15	

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Mo91	Mo92(n,2n)Mo91	15.49m	95.9	0.99	5%
	Mo92(n,2n)Mo91m	1.0m	4.2	0.99	5%

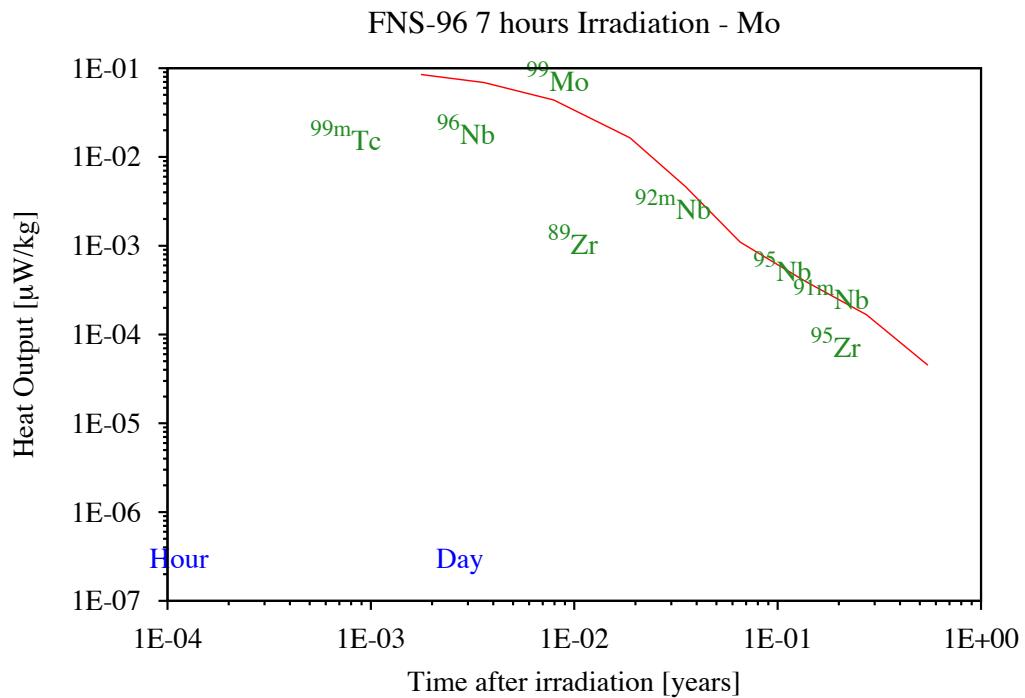


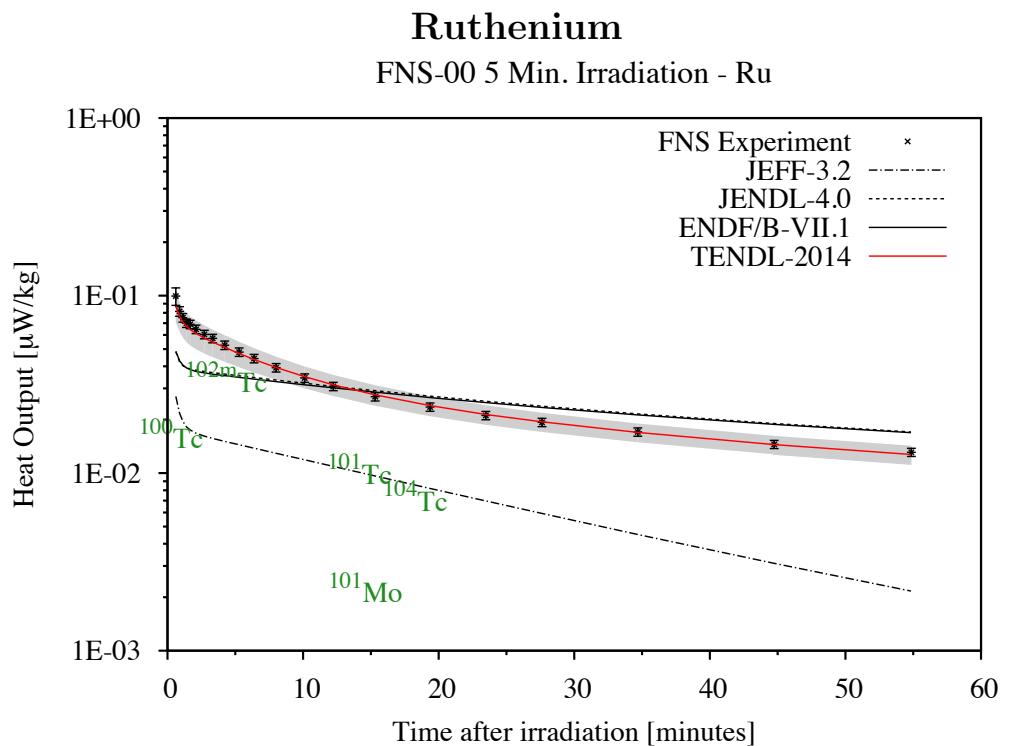


The complex time dependence of the decay heat arising from Mo is well shaped by the predicted results up to 200 days of cooling when the TENDL-2014 library is used.

Times	FNS EXP. 7 hrs	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Days	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.64	$8.87E-02$ +/-6%	$8.48E-02$ +/-9%	1.05	1.10	1.14
1.31	$7.23E-02$ +/-6%	$6.89E-02$ +/-8%	1.05	1.08	1.14
2.90	$4.54E-02$ +/-5%	$4.38E-02$ +/-8%	1.04	1.08	1.15
6.86	$1.70E-02$ +/-5%	$1.64E-02$ +/-8%	1.04	1.16	1.22
12.86	$4.71E-03$ +/-5%	$4.64E-03$ +/-9%	1.01	1.36	1.43
23.86	$9.95E-04$ +/-5%	$1.10E-03$ +/-16%	0.90	2.19	2.18
49.71	$3.14E-04$ +/-6%	$4.00E-04$ +/-17%	0.79	1.82	2.03
99.90	$1.07E-04$ +/-9%	$1.67E-04$ +/-19%	0.64	1.29	1.47
200.14	$4.64E-05$ +/-19%	$4.51E-05$ +/-19%	1.03	2.40	2.46
mean % diff. from E			13	27	31
					29

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Mo99	Mo100(n,2n)Mo99	2.7d	99.6	1.04	5%
Nb92m	Mo92(n,p)Nb92m	10.1d	100.0	1.01	5%
Nb95	Mo95(n,p)Nb95	34.9d	86.5	0.90	6%
	Mo96(n,np)Nb95		5.7	0.90	6%
	Mo96(n,d)Nb95		7.0	0.90	6%
	Mo95(n,p)Nb95m	3.6d	0.6	0.90	6%
Nb91m	Mo92(n,np)Nb91m	60.9d	93.8	0.79	9%
	Mo92(n,d)Nb91m		2.4	0.79	9%
	Mo92(n,2n)Mo91m(β^+)	64.6s	3.8	0.79	9%
Zr95	Mo98(n, α)Zr95	64.0d	100.0	1.03	19%

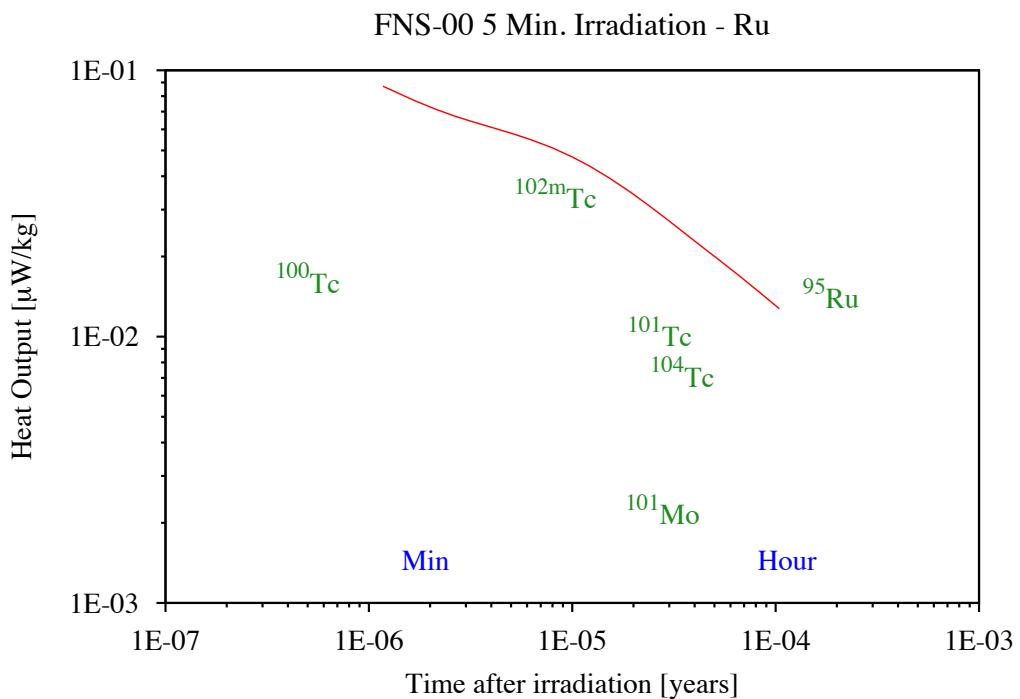


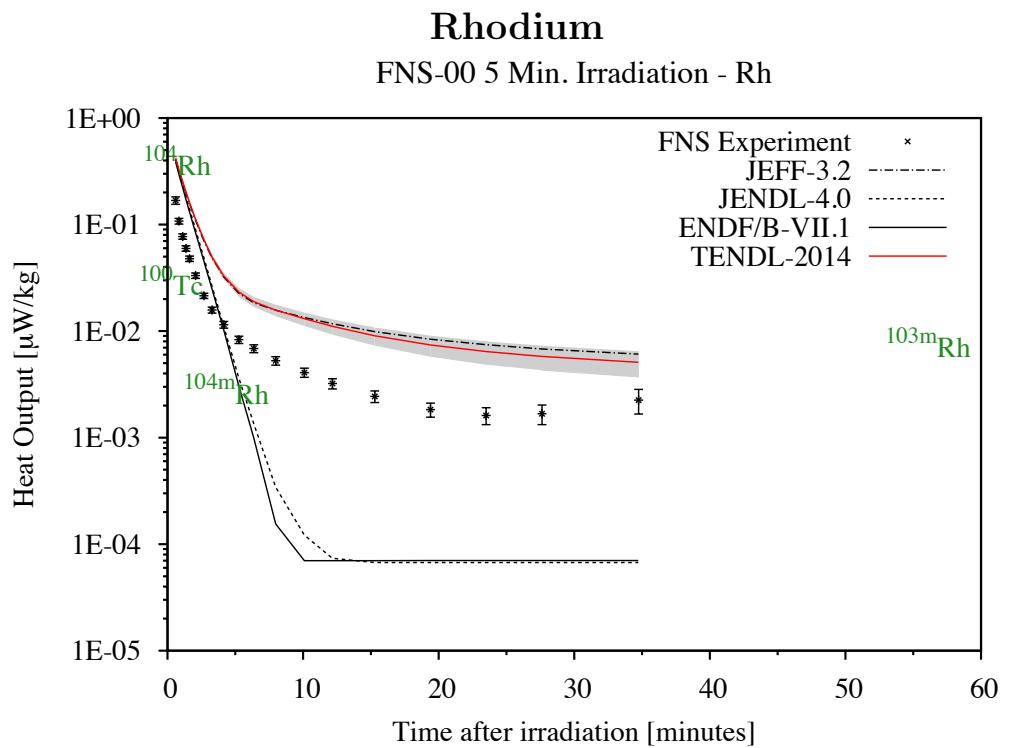


For Ruthenium, a superb fit can be seen in the short term prediction of the decay heat of this element when the TENDL-2014 database is used. The short-lived $\text{Tc}^{102\text{m}}$ isomer was missing in TENDL-2012, causing the under prediction [14]. JEFF-3.2 predicts poorly.

Times Min.	FNS EXP. 5 mins $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.62	$9.93E-02$ +/-11%	$8.71E-02$ +/-19%	1.14	2.04	3.67	2.06
0.88	$8.15E-02$ +/-6%	$7.69E-02$ +/-18%	1.06	1.90	3.74	1.92
1.13	$7.50E-02$ +/-6%	$7.12E-02$ +/-18%	1.05	1.84	3.83	1.86
1.40	$7.00E-02$ +/-5%	$6.72E-02$ +/-19%	1.04	1.79	3.83	1.79
1.67	$6.89E-02$ +/-5%	$6.44E-02$ +/-19%	1.07	1.80	3.94	1.78
2.10	$6.46E-02$ +/-5%	$6.12E-02$ +/-18%	1.06	1.73	3.85	1.70
2.72	$6.04E-02$ +/-5%	$5.76E-02$ +/-18%	1.05	1.65	3.74	1.62
3.33	$5.74E-02$ +/-5%	$5.47E-02$ +/-18%	1.05	1.59	3.66	1.56
4.22	$5.25E-02$ +/-5%	$5.11E-02$ +/-17%	1.03	1.48	3.48	1.45
5.28	$4.81E-02$ +/-5%	$4.72E-02$ +/-16%	1.02	1.39	3.32	1.36
6.38	$4.42E-02$ +/-5%	$4.37E-02$ +/-16%	1.01	1.31	3.20	1.28
8.02	$3.93E-02$ +/-5%	$3.94E-02$ +/-15%	1.00	1.20	3.03	1.17
10.12	$3.43E-02$ +/-5%	$3.50E-02$ +/-14%	0.98	1.09	2.89	1.07
12.23	$3.08E-02$ +/-5%	$3.15E-02$ +/-14%	0.98	1.02	2.82	1.00
15.32	$2.69E-02$ +/-5%	$2.76E-02$ +/-13%	0.97	0.94	2.79	0.92
19.37	$2.36E-02$ +/-5%	$2.40E-02$ +/-13%	0.98	0.88	2.87	0.87
23.48	$2.11E-02$ +/-5%	$2.14E-02$ +/-13%	0.99	0.85	3.03	0.83
27.62	$1.93E-02$ +/-5%	$1.95E-02$ +/-12%	0.99	0.82	3.26	0.81
34.68	$1.70E-02$ +/-5%	$1.70E-02$ +/-12%	1.00	0.80	3.77	0.79
44.75	$1.45E-02$ +/-5%	$1.45E-02$ +/-12%	1.00	0.77	4.68	0.76
54.87	$1.31E-02$ +/-5%	$1.27E-02$ +/-12%	1.03	0.77	6.05	0.77
mean % diff. from E		3	29	71	29	

Product	Pathways	T_{1/2}	Path %	E/C	ΔE%
Tc100	Ru100(n,p)Tc100	15.8s	76.0	1.14	11%
	Ru101(n,np)Tc100		18.3	1.14	11%
	Ru101(n,d)Tc100		5.7	1.14	11%
Tc102m	Ru102(n,p)Tc102m	4.3m	100.0	1.03	5%
Ru95	Ru96(n,2n)Ru95	1.6h	100.0	1.03	5%

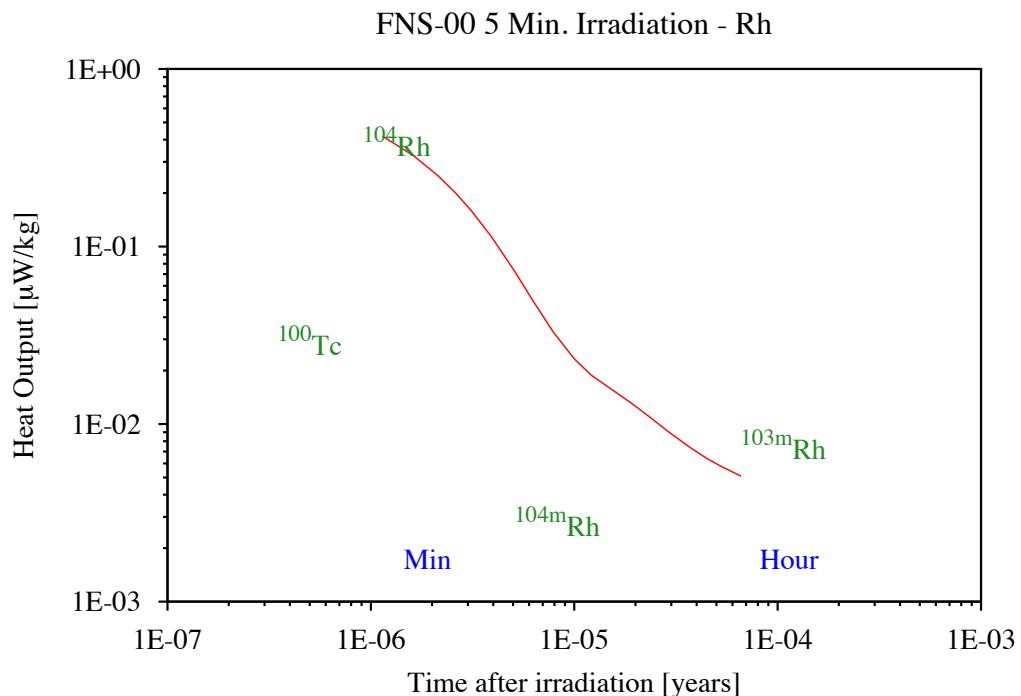




For Rhodium, the fit is poor with all libraries for this important element. The two predominant isotopes routes of production involve a branched capture channel, which cannot be well characterised in such neutron spectra, and a super-inelastic reaction that leads to the Rh103m isomer.

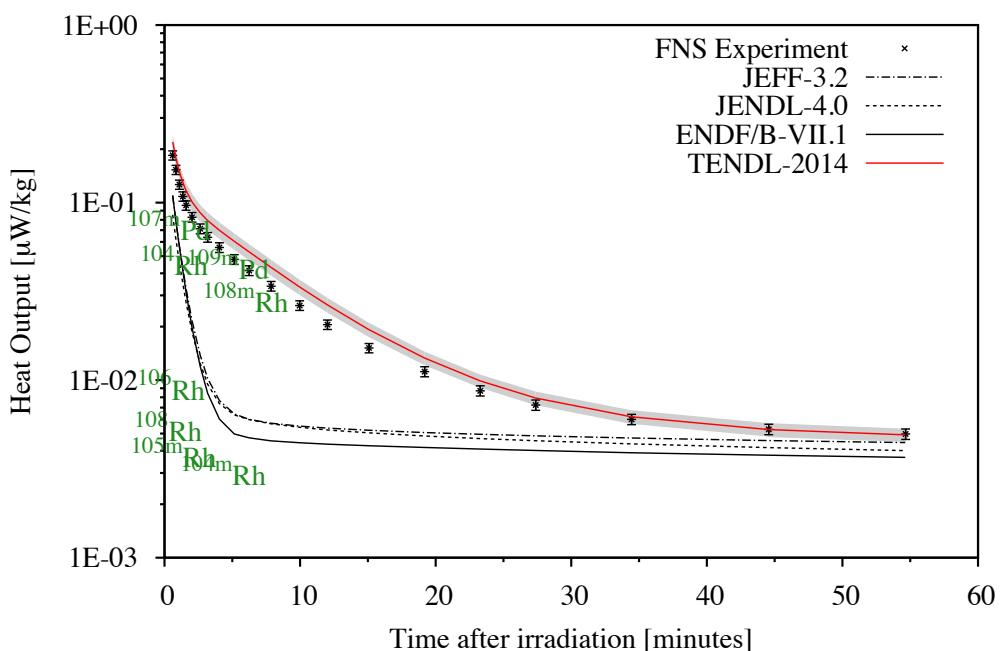
Times Min.	FNS EXP. 5 mins $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C
0.60	$1.69E-01$ +/-8%	$4.18E-01$ +/-8%	0.40	0.44	0.41
0.85	$1.08E-01$ +/-6%	$3.25E-01$ +/-7%	0.33	0.37	0.34
1.12	$7.72E-02$ +/-6%	$2.52E-01$ +/-6%	0.31	0.35	0.31
1.37	$5.97E-02$ +/-6%	$2.01E-01$ +/-5%	0.30	0.35	0.30
1.63	$4.78E-02$ +/-6%	$1.60E-01$ +/-5%	0.30	0.37	0.30
2.07	$3.32E-02$ +/-6%	$1.13E-01$ +/-5%	0.29	0.39	0.30
2.68	$2.15E-02$ +/-6%	$7.23E-02$ +/-6%	0.30	0.47	0.30
3.28	$1.58E-02$ +/-6%	$4.98E-02$ +/-6%	0.32	0.63	0.32
4.15	$1.15E-02$ +/-7%	$3.30E-02$ +/-7%	0.35	1.12	0.36
5.27	$8.31E-03$ +/-8%	$2.33E-02$ +/-9%	0.36	2.72	0.37
6.37	$6.85E-03$ +/-8%	$1.89E-02$ +/-11%	0.36	6.90	0.37
7.98	$5.27E-03$ +/-9%	$1.58E-02$ +/-12%	0.33	34.03	0.34
10.10	$4.08E-03$ +/-10%	$1.31E-02$ +/-14%	0.31	58.27	0.30
12.17	$3.22E-03$ +/-11%	$1.11E-02$ +/-17%	0.29	45.96	0.27
15.28	$2.44E-03$ +/-13%	$9.05E-03$ +/-19%	0.27	34.81	0.25
19.40	$1.83E-03$ +/-15%	$7.41E-03$ +/-22%	0.25	26.15	0.22
23.50	$1.61E-03$ +/-18%	$6.42E-03$ +/-25%	0.25	23.03	0.22
27.62	$1.68E-03$ +/-21%	$5.79E-03$ +/-26%	0.29	23.90	0.25
34.75	$2.25E-03$ +/-26%	$5.09E-03$ +/-27%	0.44	32.10	0.37
mean % diff. from E		221	111	232	117

Product	Pathways	T_{1/2}	Path %	E/C	ΔE%
Rh104	Rh103(n, γ)Rh104	42.3s	96.3	0.40	8%
	Rh103(n, γ)Rh104m	4.3m	2.9	0.40	7%
Rh103m	Rh103(n,n')Rh103m	56.1m	100.0	0.44	26%



Palladium

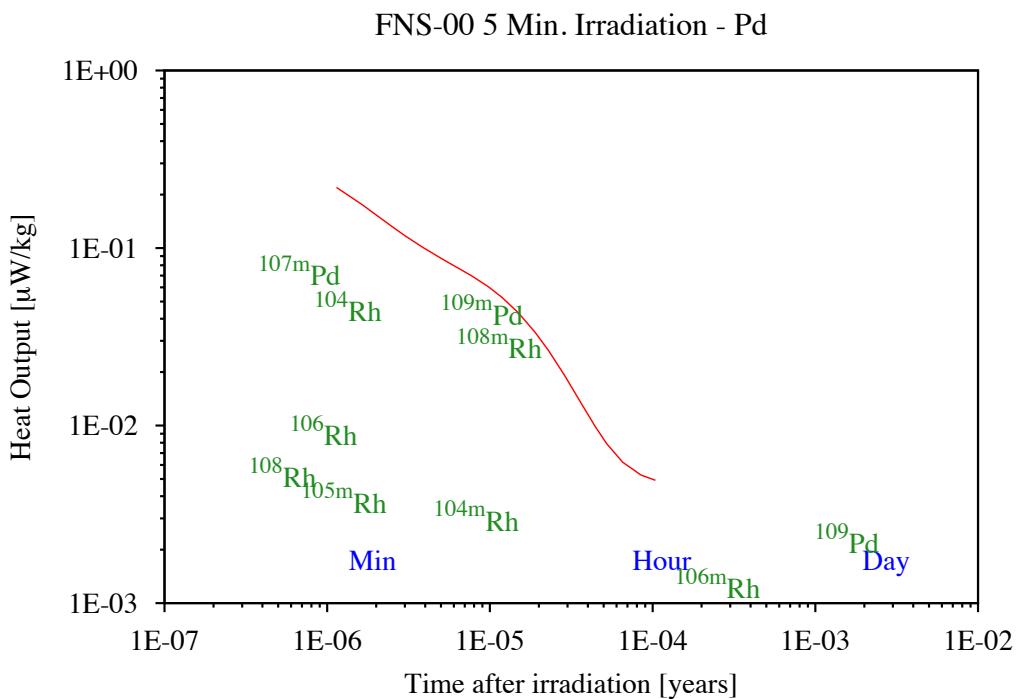
FNS-00 5 Min. Irradiation - Pd

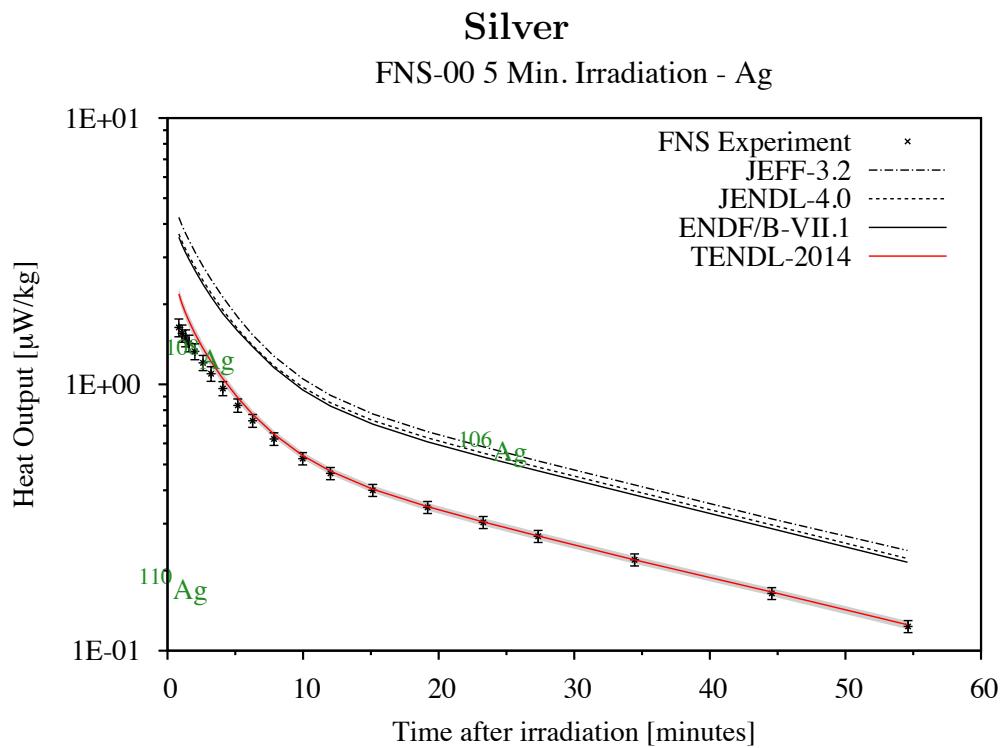


For Palladium, TENDL-2014 slightly over predict the decay heat up to 30 min but perfectly fits the experimental data thereafter. Short cooling times are dominated by metastable isomers. This proves once again the strength of the TALYS modelling processes and a truly general purpose library.

Times	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0	
Min.	μW/g	μW/g	E/C	E/C	E/C	
0.60	$1.84E-01$ +/-6%	$2.20E-01$ +/-9%	0.84	1.68	1.69	2.16
0.85	$1.53E-01$ +/-6%	$1.77E-01$ +/-10%	0.86	1.97	1.96	2.48
1.10	$1.26E-01$ +/-6%	$1.49E-01$ +/-10%	0.85	2.25	2.21	2.76
1.35	$1.08E-01$ +/-6%	$1.30E-01$ +/-11%	0.83	2.62	2.54	3.10
1.60	$9.64E-02$ +/-6%	$1.16E-01$ +/-11%	0.83	3.11	2.95	3.54
2.03	$8.27E-02$ +/-6%	$1.01E-01$ +/-11%	0.82	4.18	3.82	4.42
2.63	$7.13E-02$ +/-6%	$8.75E-02$ +/-11%	0.81	5.96	5.16	5.74
3.18	$6.38E-02$ +/-6%	$7.92E-02$ +/-11%	0.80	7.56	6.23	6.72
4.05	$5.58E-02$ +/-6%	$6.98E-02$ +/-11%	0.80	9.26	7.27	7.57
5.15	$4.79E-02$ +/-6%	$6.05E-02$ +/-11%	0.79	9.63	7.42	7.52
6.25	$4.14E-02$ +/-6%	$5.28E-02$ +/-10%	0.79	8.76	6.89	6.92
7.87	$3.38E-02$ +/-6%	$4.32E-02$ +/-10%	0.78	7.44	5.92	5.96
9.97	$2.63E-02$ +/-6%	$3.35E-02$ +/-10%	0.79	5.93	4.78	4.85
12.02	$2.06E-02$ +/-6%	$2.65E-02$ +/-10%	0.77	4.72	3.83	3.92
15.08	$1.52E-02$ +/-6%	$1.93E-02$ +/-9%	0.79	3.55	2.91	3.01
19.18	$1.12E-02$ +/-6%	$1.33E-02$ +/-9%	0.84	2.68	2.20	2.30
23.28	$8.71E-03$ +/-7%	$9.91E-03$ +/-9%	0.88	2.13	1.76	1.86
27.38	$7.24E-03$ +/-7%	$7.92E-03$ +/-9%	0.91	1.80	1.49	1.59
34.45	$6.02E-03$ +/-7%	$6.22E-03$ +/-9%	0.97	1.54	1.27	1.38
44.57	$5.28E-03$ +/-7%	$5.27E-03$ +/-9%	1.00	1.40	1.16	1.27
54.67	$4.97E-03$ +/-7%	$4.92E-03$ +/-8%	1.01	1.35	1.12	1.24
mean % diff. from E		19	65	59	63	

Product	Pathways	T_{1/2}	Path %	E/C	ΔE%
Pd107m	Pd108(n,2n)Pd107m	21.3s	99.6	0.84	5%
Pd109m	Pd110(n,2n)Pd109m	4.6m	99.1	0.80	6%
	Pd110(n, γ)Pd109m	4.6m	0.7	0.80	6%
Pd109	Pd108(n, γ)Pd109	13.7h	5.7	1.01	6%
	Pd110(n,2n)Pd109		84.5	1.01	6%
	Pd110(n,2n)Pd109m	4.6m	9.7	1.01	6%

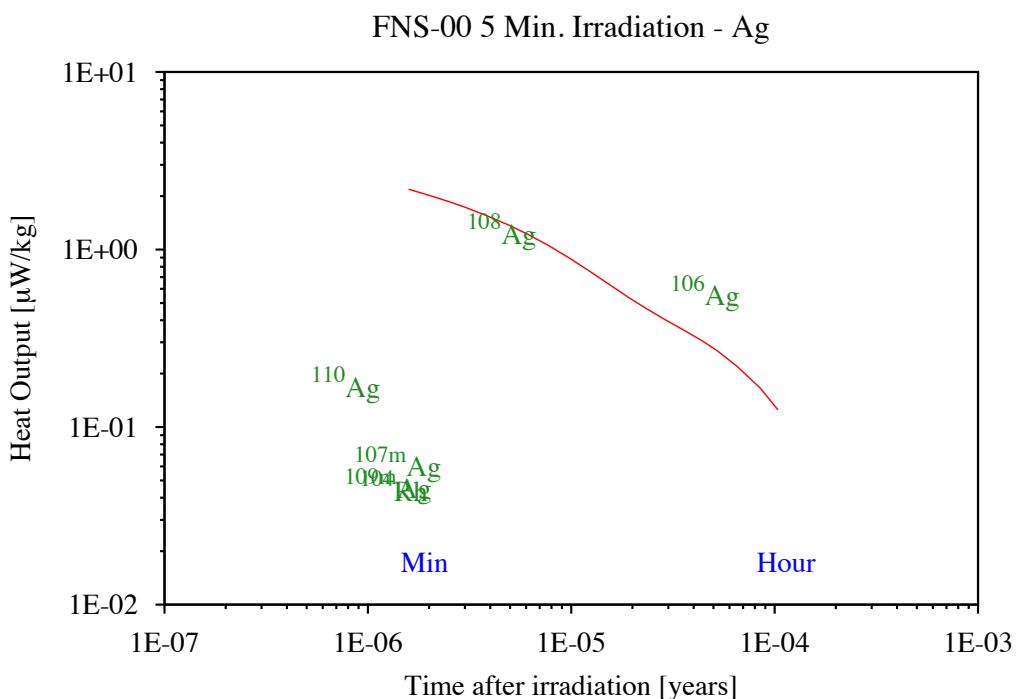


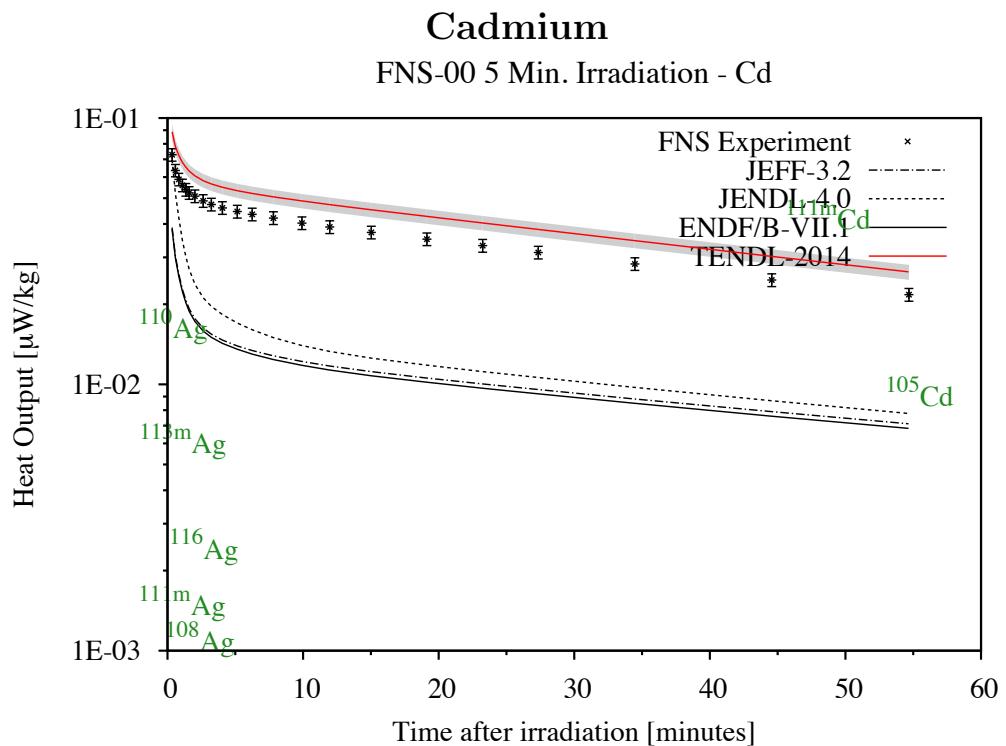


For Silver and TENDL-2014 there is a slight over-prediction up to 5 minutes cooling, followed by a marginal under prediction at longer cooling times – in both cases dominated by different ($n,2n$) channels. The short time decay heat arising from silver can be considered as rather well predicted. All the other simulations over-predict by a factor of 2.

Times Min.	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0	
	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C	
0.83	$1.64E+00 +/- 8\%$	$2.19E+00 +/- 5\%$	0.75	0.46	0.39	0.44
1.08	$1.55E+00 +/- 7\%$	$2.00E+00 +/- 5\%$	0.78	0.47	0.39	0.45
1.33	$1.49E+00 +/- 7\%$	$1.85E+00 +/- 5\%$	0.81	0.48	0.40	0.46
1.58	$1.43E+00 +/- 7\%$	$1.73E+00 +/- 5\%$	0.83	0.48	0.41	0.47
2.02	$1.33E+00 +/- 7\%$	$1.55E+00 +/- 5\%$	0.86	0.50	0.42	0.48
2.62	$1.21E+00 +/- 7\%$	$1.37E+00 +/- 5\%$	0.88	0.51	0.43	0.49
3.22	$1.10E+00 +/- 6\%$	$1.22E+00 +/- 5\%$	0.90	0.51	0.44	0.50
4.08	$9.65E-01 +/- 6\%$	$1.05E+00 +/- 4\%$	0.92	0.52	0.45	0.51
5.18	$8.33E-01 +/- 6\%$	$8.91E-01 +/- 4\%$	0.93	0.53	0.47	0.52
6.28	$7.30E-01 +/- 6\%$	$7.72E-01 +/- 4\%$	0.95	0.53	0.48	0.52
7.85	$6.24E-01 +/- 5\%$	$6.50E-01 +/- 3\%$	0.96	0.54	0.49	0.53
9.97	$5.26E-01 +/- 5\%$	$5.41E-01 +/- 3\%$	0.97	0.55	0.50	0.54
12.02	$4.63E-01 +/- 5\%$	$4.73E-01 +/- 3\%$	0.98	0.56	0.51	0.54
15.13	$4.00E-01 +/- 5\%$	$4.04E-01 +/- 3\%$	0.99	0.56	0.52	0.55
19.18	$3.45E-01 +/- 5\%$	$3.47E-01 +/- 3\%$	0.99	0.57	0.52	0.55
23.28	$3.03E-01 +/- 5\%$	$3.05E-01 +/- 3\%$	1.00	0.57	0.52	0.55
27.33	$2.69E-01 +/- 5\%$	$2.70E-01 +/- 3\%$	1.00	0.57	0.52	0.55
34.45	$2.19E-01 +/- 5\%$	$2.19E-01 +/- 3\%$	1.00	0.57	0.52	0.55
44.57	$1.64E-01 +/- 5\%$	$1.66E-01 +/- 3\%$	0.99	0.57	0.52	0.55
54.62	$1.23E-01 +/- 5\%$	$1.25E-01 +/- 3\%$	0.99	0.57	0.52	0.56
mean	% diff. from E	9	89	114	95	

Product	Pathways	T_{1/2}	Path %	E/C	ΔE%
Ag108	Ag107(n,γ)Ag108	2.4m	3.7	0.88	7%
	Ag109($n,2n$)Ag108		95.9	0.88	7%
Ag106	Ag107($n,2n$)Ag106	24.0m	100.0	1.00	5%

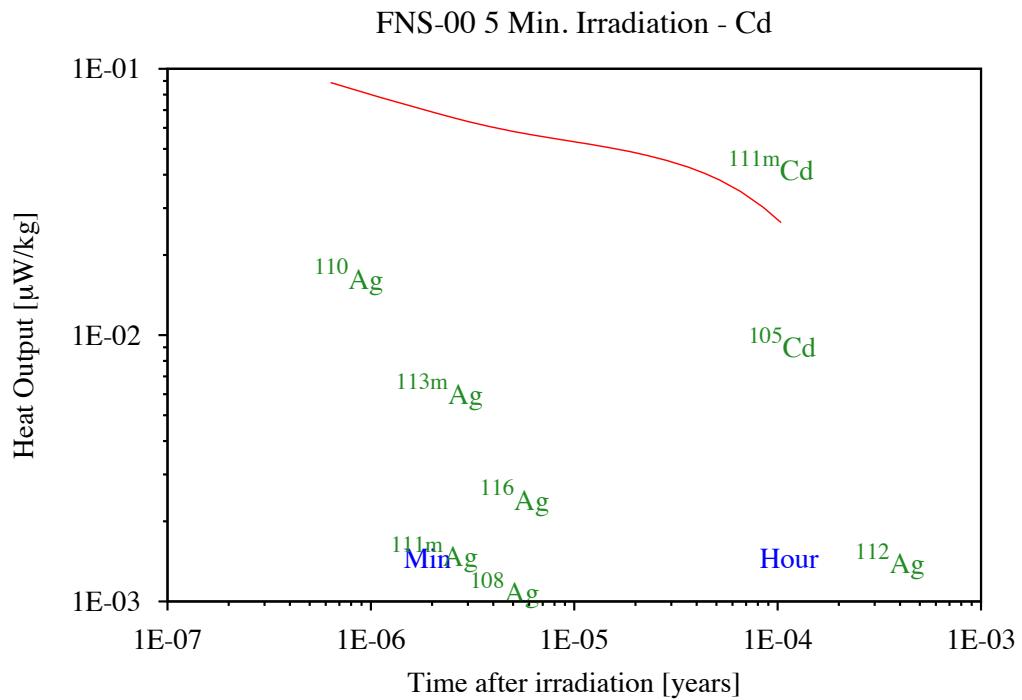


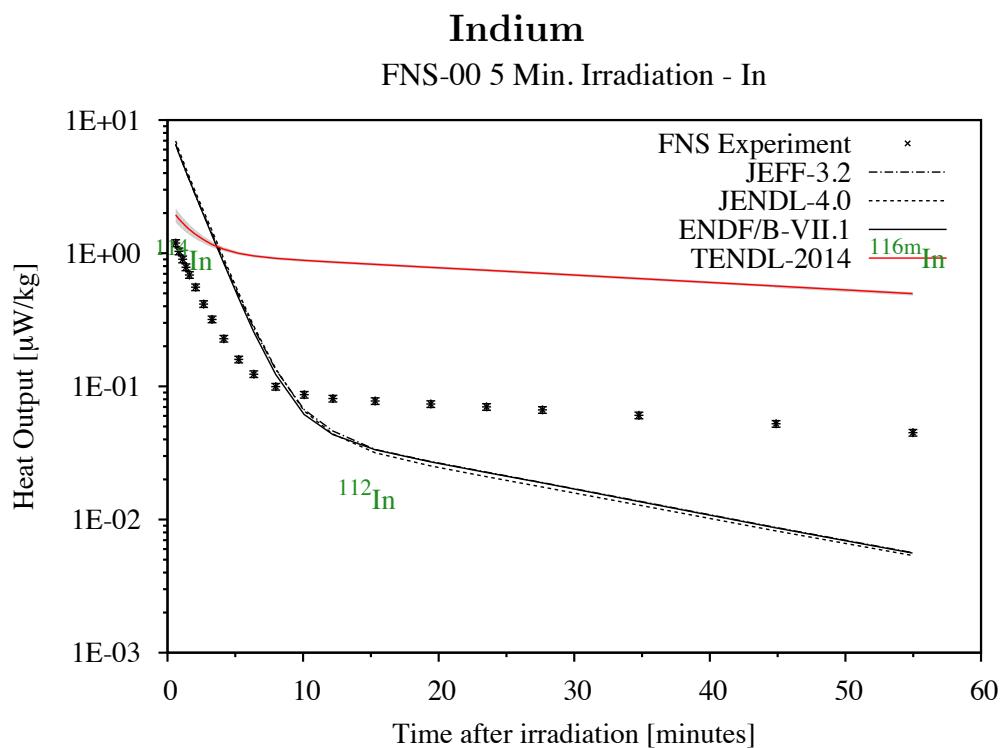


For Cadmium, there was a good time dependant agreement for EAF-2010 [14], within the quoted calculational uncertainty. TENDL-2014 libraries over-predict by 20%, but still out-perform the other libraries.

Times	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.33	$7.28E-02$ +/-5%	$8.88E-02$ +/-7%	0.82	1.90	1.88
0.58	$6.36E-02$ +/-5%	$7.81E-02$ +/-6%	0.81	2.13	2.10
0.83	$5.88E-02$ +/-5%	$7.24E-02$ +/-6%	0.81	2.31	2.27
1.10	$5.59E-02$ +/-5%	$6.82E-02$ +/-6%	0.82	2.51	2.46
1.35	$5.38E-02$ +/-5%	$6.53E-02$ +/-6%	0.82	2.66	2.60
1.60	$5.24E-02$ +/-5%	$6.32E-02$ +/-6%	0.83	2.78	2.72
2.02	$5.09E-02$ +/-5%	$6.07E-02$ +/-6%	0.84	2.95	2.88
2.63	$4.89E-02$ +/-5%	$5.82E-02$ +/-6%	0.84	3.08	3.00
3.23	$4.74E-02$ +/-5%	$5.66E-02$ +/-6%	0.84	3.16	3.07
4.05	$4.60E-02$ +/-5%	$5.49E-02$ +/-6%	0.84	3.23	3.14
5.15	$4.45E-02$ +/-5%	$5.34E-02$ +/-6%	0.83	3.29	3.19
6.25	$4.35E-02$ +/-5%	$5.21E-02$ +/-6%	0.83	3.35	3.25
7.82	$4.21E-02$ +/-5%	$5.06E-02$ +/-6%	0.83	3.40	3.29
9.92	$4.03E-02$ +/-5%	$4.88E-02$ +/-6%	0.83	3.42	3.31
11.97	$3.90E-02$ +/-5%	$4.73E-02$ +/-6%	0.82	3.44	3.33
15.03	$3.72E-02$ +/-5%	$4.53E-02$ +/-6%	0.82	3.45	3.33
19.13	$3.51E-02$ +/-5%	$4.27E-02$ +/-6%	0.82	3.45	3.32
23.25	$3.32E-02$ +/-5%	$4.04E-02$ +/-6%	0.82	3.43	3.30
27.35	$3.13E-02$ +/-5%	$3.82E-02$ +/-6%	0.82	3.40	3.27
34.47	$2.83E-02$ +/-5%	$3.46E-02$ +/-6%	0.82	3.34	3.21
44.57	$2.46E-02$ +/-5%	$3.03E-02$ +/-6%	0.81	3.24	3.12
54.68	$2.17E-02$ +/-5%	$2.64E-02$ +/-6%	0.82	3.18	3.05
mean % diff. from E		21	66	65	54

Product	Pathways	T_{1/2}	Path %	E/C	ΔE%
Cd111m	Cd111(n,n')Cd111m	48.5m	15.5	0.81	5%
	Cd112(n,2n)Cd111m		84.4	0.81	5%

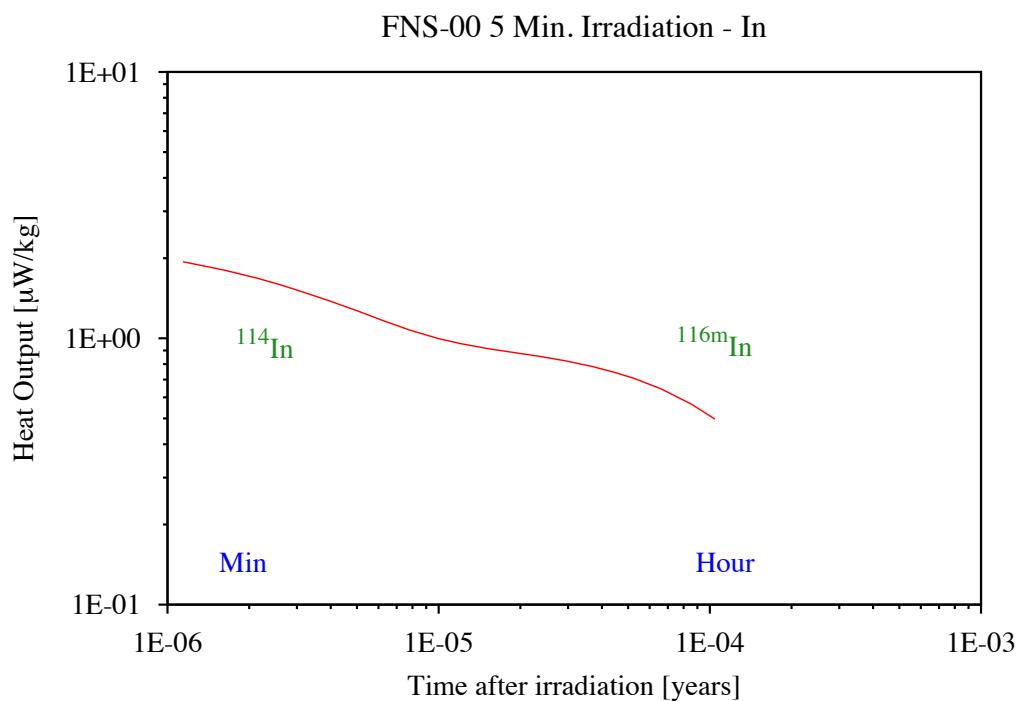


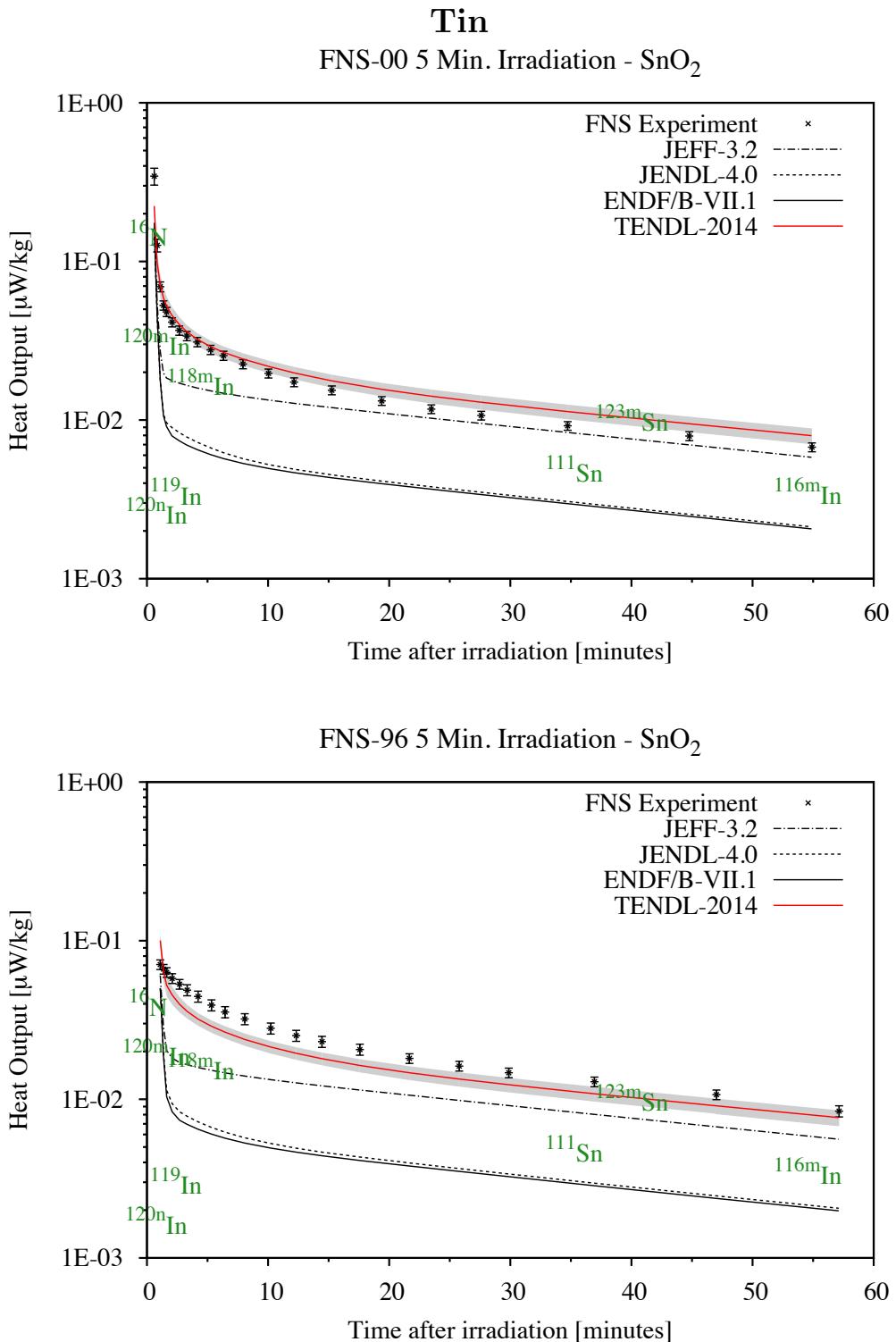


For Indium, a large over-prediction can be seen for this element at all cooling times when TENDL-2014 is used. The others libraries seem to better shape, if not follow, the decay heat profile. The poor characterisation of the thermal profile of the neutron spectrum may have an influence on the predicted results for this neutron absorber, although this tendency is not seen for all neutron absorbers.

Times Min.	FNS EXP. 5 mins		TENDL-2014		ENDF/B-VII.1		JEFF-3.2	JENDL-4.0
	$\mu\text{W/g}$	% diff. from E	$\mu\text{W/g}$	E/C	$\mu\text{W/g}$	E/C	$\mu\text{W/g}$	E/C
0.60	$1.19E+00$	+/-6%	$1.94E+00$	+/-12%	0.61		0.18	0.18
0.85	$1.03E+00$	+/-6%	$1.80E+00$	+/-11%	0.57		0.19	0.18
1.12	$9.00E-01$	+/-6%	$1.69E+00$	+/-11%	0.53		0.19	0.19
1.37	$7.85E-01$	+/-6%	$1.59E+00$	+/-10%	0.49		0.19	0.18
1.62	$6.87E-01$	+/-6%	$1.51E+00$	+/-9%	0.46		0.19	0.18
2.07	$5.56E-01$	+/-6%	$1.39E+00$	+/-8%	0.40		0.20	0.20
2.67	$4.15E-01$	+/-6%	$1.26E+00$	+/-6%	0.33		0.21	0.21
3.28	$3.19E-01$	+/-6%	$1.16E+00$	+/-5%	0.27		0.23	0.23
4.15	$2.28E-01$	+/-6%	$1.07E+00$	+/-4%	0.21		0.27	0.26
5.25	$1.59E-01$	+/-6%	$9.98E-01$	+/-3%	0.16		0.35	0.33
6.37	$1.24E-01$	+/-6%	$9.54E-01$	+/-3%	0.13		0.48	0.45
7.98	$9.95E-02$	+/-6%	$9.15E-01$	+/-2%	0.11		0.81	0.75
10.08	$8.65E-02$	+/-6%	$8.83E-01$	+/-2%	0.10		1.41	1.29
12.20	$8.10E-02$	+/-6%	$8.57E-01$	+/-2%	0.09		1.86	1.75
15.32	$7.76E-02$	+/-6%	$8.24E-01$	+/-2%	0.09		2.32	2.31
19.42	$7.37E-02$	+/-6%	$7.83E-01$	+/-2%	0.09		2.72	2.70
23.53	$7.01E-02$	+/-6%	$7.44E-01$	+/-2%	0.09		3.11	3.09
27.65	$6.66E-02$	+/-6%	$7.07E-01$	+/-2%	0.09		3.53	3.51
34.77	$6.05E-02$	+/-6%	$6.45E-01$	+/-2%	0.09		4.43	4.40
44.88	$5.23E-02$	+/-6%	$5.66E-01$	+/-2%	0.09		6.04	6.00
54.98	$4.49E-02$	+/-6%	$4.97E-01$	+/-2%	0.09		8.01	7.96
mean % diff. from E			578		210		213	227

Product	Pathways	T_{1/2}	Path %	E/C	ΔE%
In114	In115(n,2n)In114	1.1m	99.0	0.53	5%
In116m	In115(n, γ)In116m	54.6m	95.5	0.09	5%
	In115(n, γ)In116n	2.1s	4.6	0.09	5%

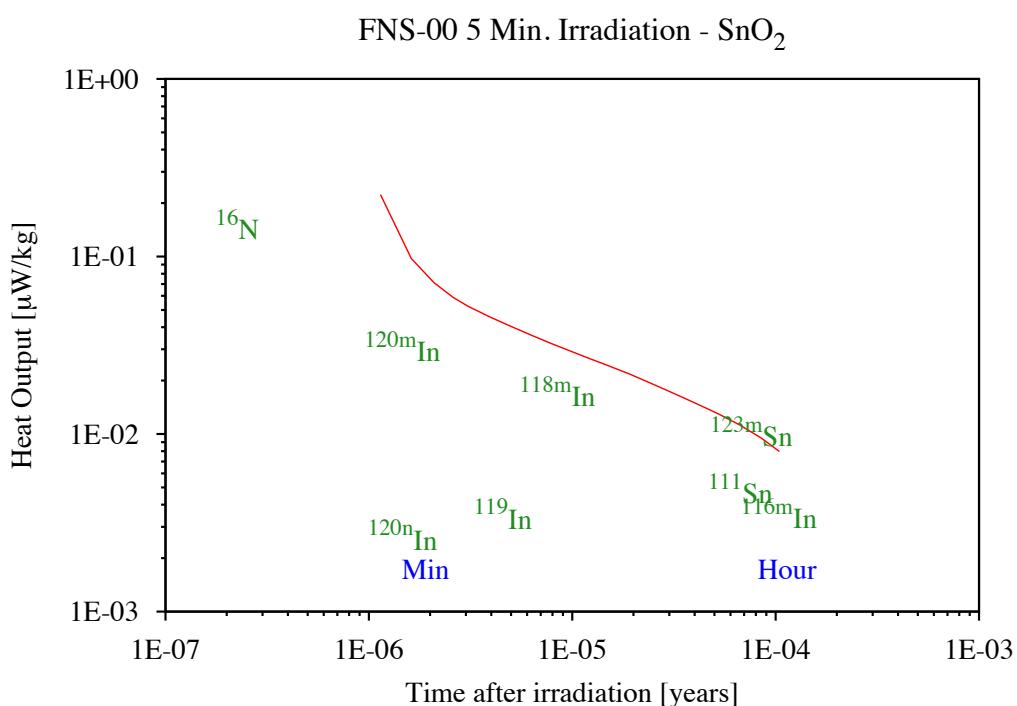


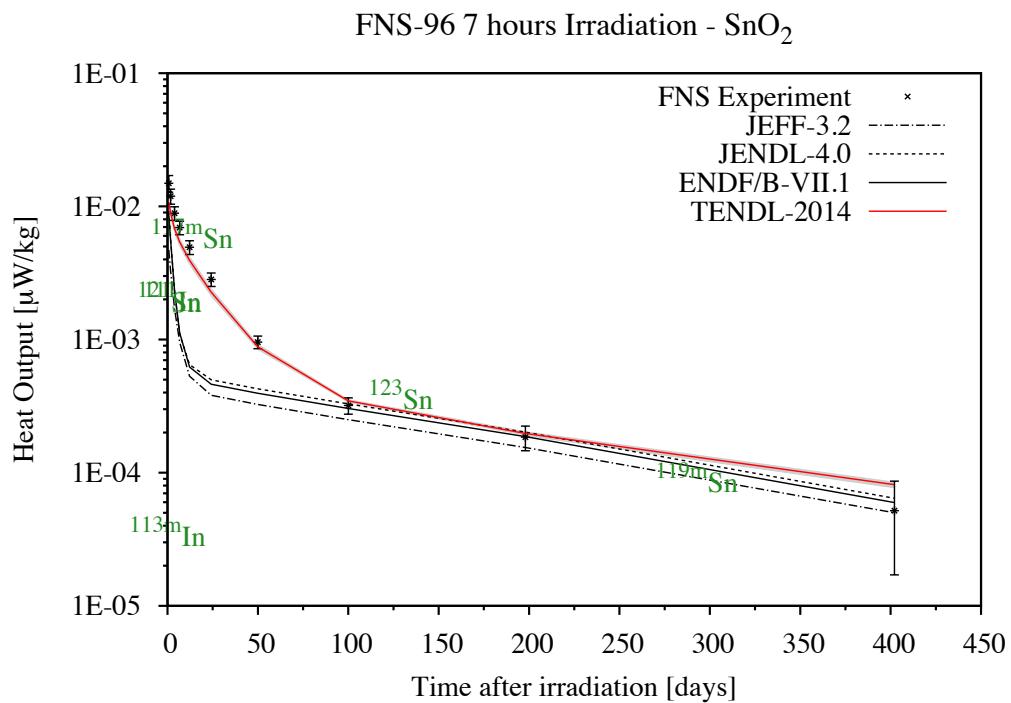


For Tin, the two experimental result sets differ, although the simulation produces much better agreement with the most recent one, particularly at very short cooling times, but only with TENDL-2014.

Times Min.	FNS EXP. 5 mins	TENDL-2014		ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C	E/C
0.60	$3.45E-01$ +/-12%	$2.23E-01$ +/-8%	1.55	2.09	1.97	2.19
0.85	$1.26E-01$ +/-9%	$9.73E-02$ +/-14%	1.30	2.82	2.32	2.90
1.10	$6.93E-02$ +/-7%	$7.11E-02$ +/-16%	0.97	3.91	2.56	3.89
1.37	$5.28E-02$ +/-7%	$5.88E-02$ +/-16%	0.90	4.95	2.67	4.85
1.62	$4.81E-02$ +/-7%	$5.24E-02$ +/-15%	0.92	5.29	2.61	5.00
2.07	$4.14E-02$ +/-7%	$4.57E-02$ +/-13%	0.90	5.21	2.33	4.61
2.67	$3.67E-02$ +/-7%	$4.01E-02$ +/-11%	0.92	4.96	2.15	4.40
3.28	$3.39E-02$ +/-7%	$3.61E-02$ +/-10%	0.94	4.87	2.05	4.33
4.15	$3.10E-02$ +/-7%	$3.24E-02$ +/-9%	0.96	4.77	1.95	4.28
5.25	$2.77E-02$ +/-7%	$2.91E-02$ +/-9%	0.95	4.58	1.81	4.15
6.32	$2.55E-02$ +/-7%	$2.68E-02$ +/-9%	0.95	4.46	1.73	4.09
7.93	$2.25E-02$ +/-7%	$2.42E-02$ +/-9%	0.93	4.23	1.60	3.94
10.03	$1.97E-02$ +/-6%	$2.18E-02$ +/-9%	0.90	3.97	1.47	3.75
12.15	$1.73E-02$ +/-6%	$1.98E-02$ +/-9%	0.87	3.72	1.36	3.54
15.27	$1.54E-02$ +/-6%	$1.77E-02$ +/-9%	0.87	3.56	1.29	3.41
19.38	$1.32E-02$ +/-6%	$1.56E-02$ +/-10%	0.84	3.33	1.19	3.20
23.48	$1.17E-02$ +/-6%	$1.42E-02$ +/-10%	0.83	3.19	1.14	3.09
27.60	$1.07E-02$ +/-6%	$1.30E-02$ +/-10%	0.82	3.15	1.12	3.04
34.73	$9.20E-03$ +/-6%	$1.13E-02$ +/-11%	0.81	3.10	1.10	3.00
44.78	$7.92E-03$ +/-6%	$9.48E-03$ +/-11%	0.84	3.21	1.14	3.11
54.90	$6.74E-03$ +/-6%	$7.98E-03$ +/-11%	0.84	3.27	1.16	3.17
mean % diff. from E		14	73	37	72	

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
In120m	Sn120(n,p)In120m	46.2s	98.7	1.55	12%
In118m	Sn118(n,p)In118m	4.4m	88.0	0.96	7%
	Sn118(n,p)In118n	8.5s	10.6	0.96	7%
	Sn119(n,d+np)In118m		0.6	0.96	7%
Sn123m	Sn124(n,2n)Sn123m	40.0m	99.9	0.84	6%

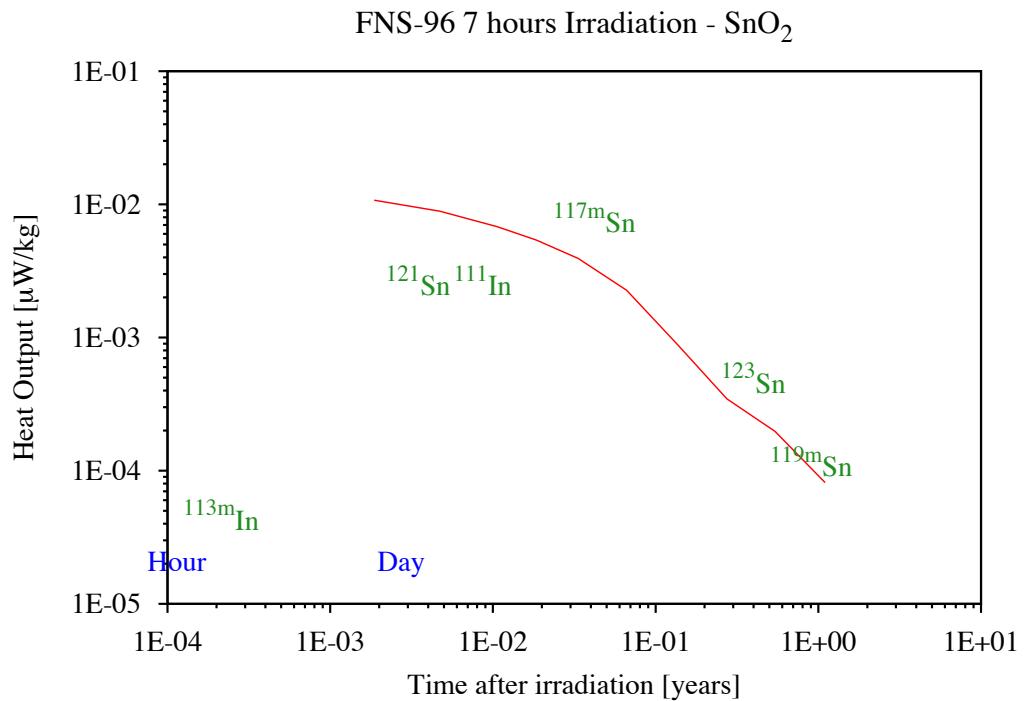




The above graph shows a relatively good agreement across all cooling times when TENDL-2014 is used. It also shows the limit of the experimental measurement technique, with the large uncertainty after 13 months of cooling reflecting the fact that the heat output is approaching the pico-watt limit of sensitivity.

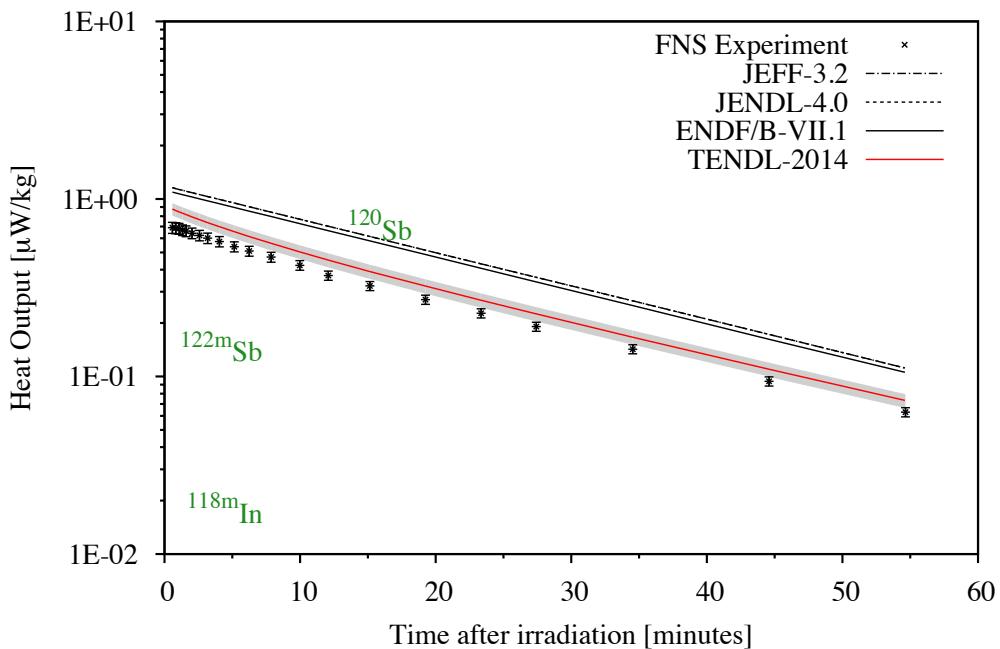
Times	FNS EXP. 7 hrs	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0	
Days	μW/g	μW/g	E/C	E/C	E/C	
0.68	$1.49E-02 +/- 14\%$	$1.07E-02 +/- 10\%$	1.39	1.71	3.17	1.62
1.73	$1.19E-02 +/- 13\%$	$8.88E-03 +/- 9\%$	1.34	2.17	3.68	2.11
3.88	$8.88E-03 +/- 12\%$	$6.80E-03 +/- 9\%$	1.31	3.79	5.20	3.85
6.75	$6.93E-03 +/- 12\%$	$5.40E-03 +/- 8\%$	1.28	6.18	7.28	6.30
12.20	$4.94E-03 +/- 12\%$	$3.93E-03 +/- 8\%$	1.25	7.94	9.31	7.62
24.20	$2.83E-03 +/- 12\%$	$2.27E-03 +/- 8\%$	1.25	6.13	7.42	5.68
49.95	$9.57E-04 +/- 11\%$	$8.82E-04 +/- 5\%$	1.08	2.43	2.94	2.24
100.08	$3.20E-04 +/- 14\%$	$3.46E-04 +/- 3\%$	0.92	1.05	1.28	0.97
197.93	$1.85E-04 +/- 21\%$	$1.97E-04 +/- 4\%$	0.94	0.99	1.20	0.92
402.13	$5.18E-05 +/- 67\%$	$8.14E-05 +/- 5\%$	0.64	0.87	1.04	0.80
mean % diff. from E		22	50	59	51	

Product	Pathways	T _{1/2}	Path %	E/C	ΔE%
Sn117m	Sn118(n,2n)Sn117m	13.6d	94.4	1.25	12%
	Sn117(n,n')Sn117m		5.5	1.25	12%
Sn123	Sn124(n,2n)Sn123	129d	99.9	0.92	14%
Sn119m	Sn120(n,2n)Sn119m	293d	93.9	0.80	67%
	Sn119(n,n')Sn119m		6.0	0.80	67%



Antimony

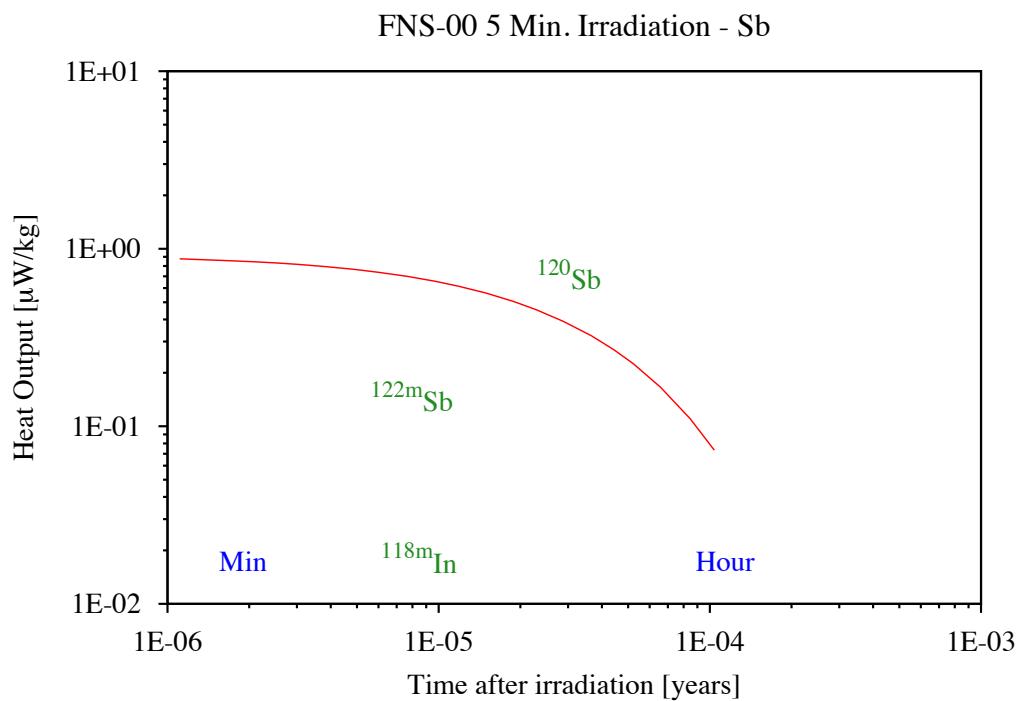
FNS-00 5 Min. Irradiation - Sb

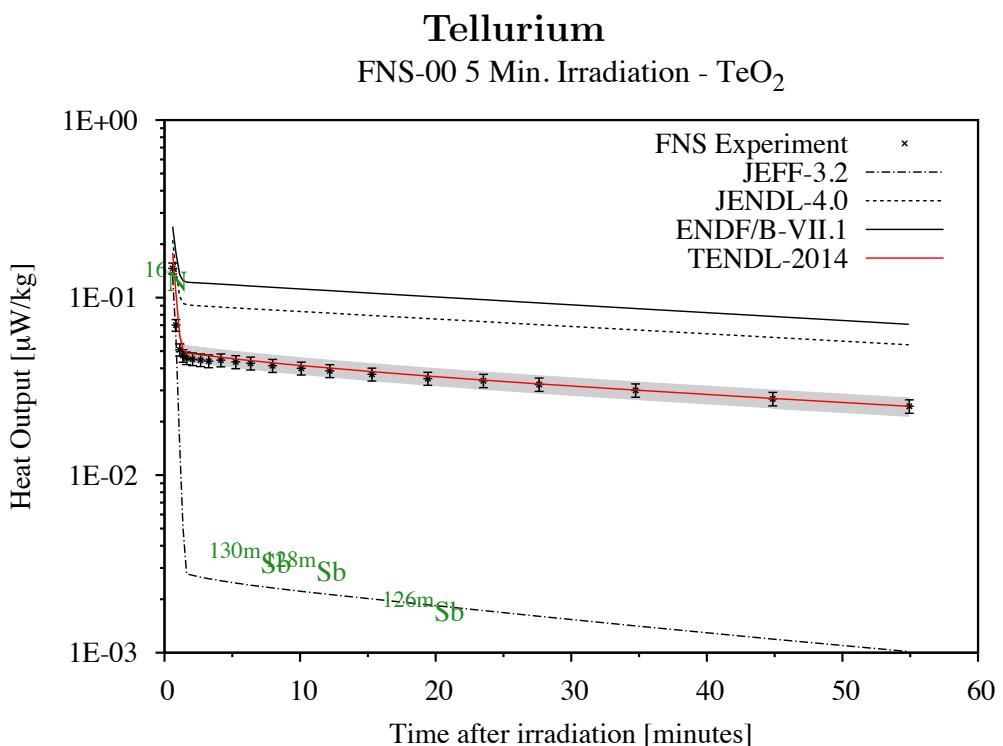


For Antimony, TENDL-2014 results are very similar to EAF-2010 ones [14], but still over-predict by circa 20% at all cooling times.

Times Min.	FNS EXP. 5 mins μW/g	TENDL-2014 μW/g	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.58	$6.89E-01$ +/-7%	$8.77E-01$ +/-8%	0.79	0.63	0.60	0.60
0.83	$6.86E-01$ +/-7%	$8.60E-01$ +/-8%	0.80	0.63	0.60	0.60
1.08	$6.81E-01$ +/-7%	$8.45E-01$ +/-8%	0.81	0.64	0.60	0.60
1.33	$6.68E-01$ +/-7%	$8.31E-01$ +/-8%	0.80	0.63	0.60	0.60
1.60	$6.59E-01$ +/-7%	$8.16E-01$ +/-8%	0.81	0.63	0.60	0.60
2.03	$6.41E-01$ +/-7%	$7.92E-01$ +/-8%	0.81	0.63	0.59	0.59
2.58	$6.23E-01$ +/-7%	$7.64E-01$ +/-8%	0.82	0.62	0.59	0.59
3.18	$6.02E-01$ +/-7%	$7.36E-01$ +/-8%	0.82	0.62	0.58	0.58
4.05	$5.75E-01$ +/-7%	$6.98E-01$ +/-8%	0.82	0.61	0.58	0.58
5.15	$5.38E-01$ +/-7%	$6.54E-01$ +/-9%	0.82	0.60	0.57	0.57
6.25	$5.09E-01$ +/-6%	$6.14E-01$ +/-9%	0.83	0.60	0.56	0.56
7.87	$4.70E-01$ +/-6%	$5.62E-01$ +/-9%	0.84	0.59	0.56	0.56
9.98	$4.23E-01$ +/-6%	$5.03E-01$ +/-9%	0.84	0.58	0.55	0.55
12.08	$3.70E-01$ +/-6%	$4.53E-01$ +/-9%	0.82	0.56	0.53	0.53
15.15	$3.24E-01$ +/-6%	$3.90E-01$ +/-9%	0.83	0.56	0.53	0.53
19.25	$2.71E-01$ +/-6%	$3.23E-01$ +/-9%	0.84	0.56	0.53	0.53
23.35	$2.27E-01$ +/-6%	$2.69E-01$ +/-9%	0.84	0.56	0.53	0.53
27.42	$1.91E-01$ +/-6%	$2.25E-01$ +/-9%	0.85	0.56	0.53	0.53
34.53	$1.42E-01$ +/-6%	$1.66E-01$ +/-9%	0.86	0.57	0.53	0.53
44.58	$9.39E-02$ +/-6%	$1.10E-01$ +/-9%	0.85	0.58	0.54	0.54
54.65	$6.30E-02$ +/-6%	$7.33E-02$ +/-9%	0.86	0.60	0.56	0.56
mean % diff. from E		21	68	78	78	

Product	Pathways	T _{1/2}	Path %	E/C	ΔE%
Sb120	Sb121(n,2n)Sb120	15.9m	100.0	0.83	6%

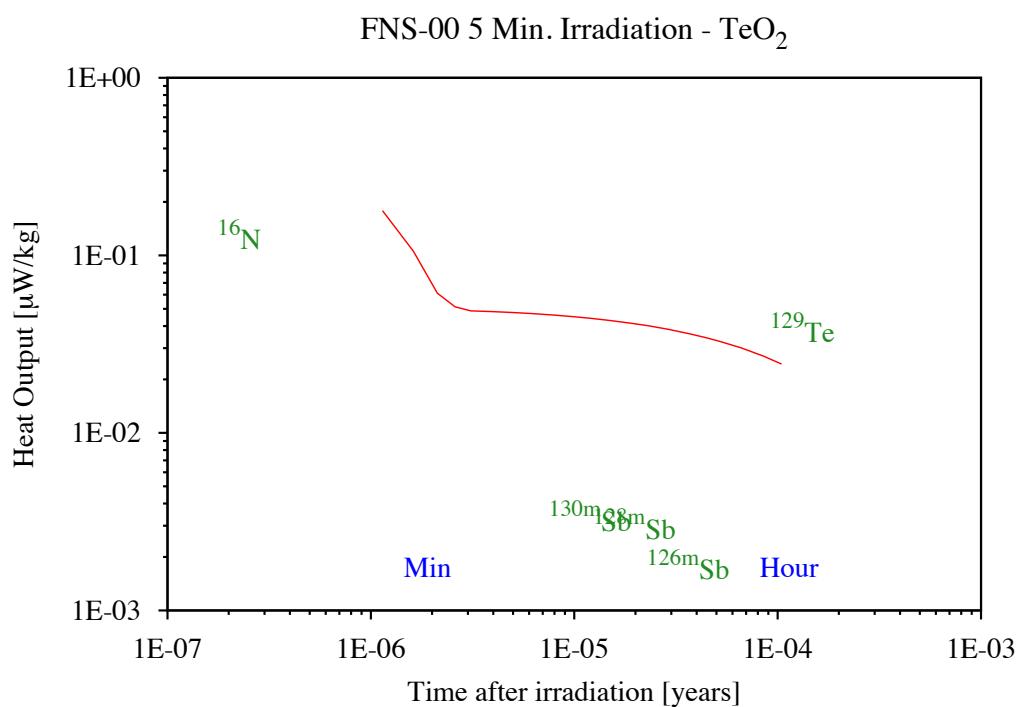


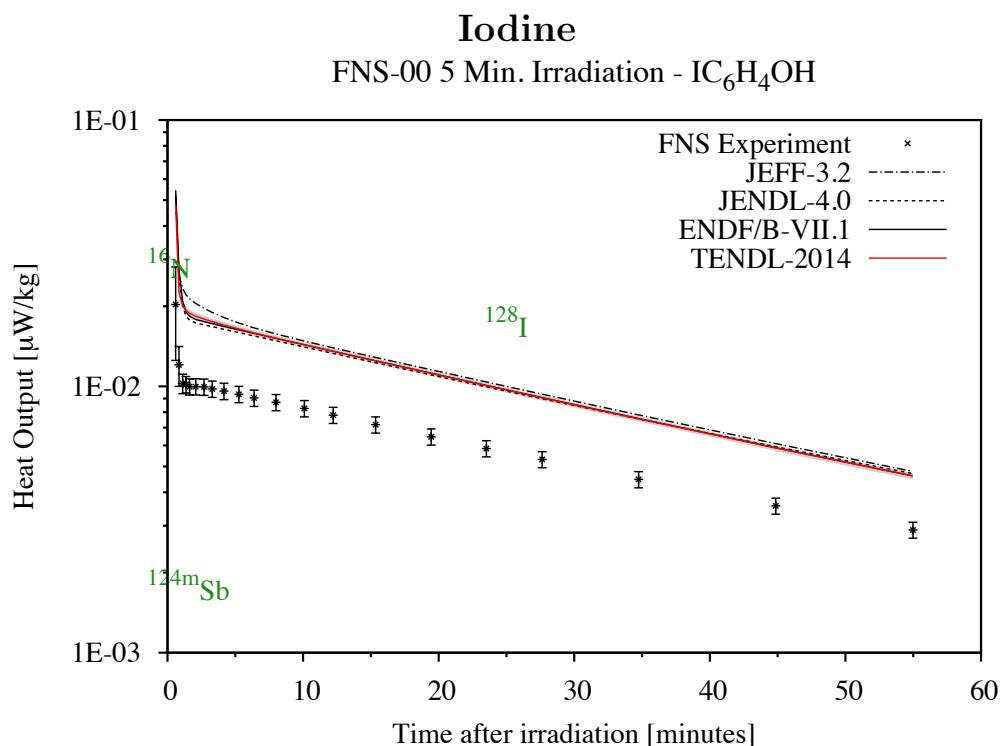


For Tellurium, and TENDL-2014, an excellent agreement can be seen, at all cooling times, within the uncertainty of the experiment, which even allows for the decay of the short-lived N16 to be observed. All the others libraries predict poorly.

Times FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0		
Min.	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C	
0.60	$1.46E-01$ +/-7%	$1.78E-01$ +/-3%	0.82	0.58	1.11	0.69
0.85	$6.99E-02$ +/-7%	$1.06E-01$ +/-5%	0.66	0.39	1.19	0.49
1.12	$5.08E-02$ +/-8%	$6.12E-02$ +/-9%	0.83	0.38	3.45	0.50
1.37	$4.71E-02$ +/-8%	$5.13E-02$ +/-10%	0.92	0.38	9.31	0.51
1.63	$4.56E-02$ +/-8%	$4.87E-02$ +/-11%	0.94	0.37	16.42	0.50
2.07	$4.51E-02$ +/-8%	$4.82E-02$ +/-11%	0.93	0.37	16.52	0.50
2.67	$4.45E-02$ +/-8%	$4.76E-02$ +/-11%	0.94	0.37	16.71	0.50
3.27	$4.39E-02$ +/-8%	$4.70E-02$ +/-11%	0.93	0.37	16.81	0.49
4.15	$4.44E-02$ +/-8%	$4.61E-02$ +/-11%	0.96	0.37	17.48	0.50
5.25	$4.34E-02$ +/-8%	$4.51E-02$ +/-11%	0.96	0.37	17.61	0.50
6.35	$4.27E-02$ +/-8%	$4.42E-02$ +/-11%	0.97	0.37	17.77	0.49
7.97	$4.13E-02$ +/-8%	$4.29E-02$ +/-11%	0.96	0.36	17.86	0.49
10.08	$4.00E-02$ +/-8%	$4.14E-02$ +/-11%	0.96	0.36	18.02	0.48
12.18	$3.86E-02$ +/-8%	$4.01E-02$ +/-11%	0.96	0.35	18.16	0.47
15.30	$3.70E-02$ +/-8%	$3.83E-02$ +/-12%	0.97	0.35	18.43	0.47
19.42	$3.50E-02$ +/-8%	$3.62E-02$ +/-12%	0.97	0.34	18.79	0.46
23.52	$3.40E-02$ +/-9%	$3.43E-02$ +/-12%	0.99	0.35	19.70	0.46
27.63	$3.24E-02$ +/-9%	$3.27E-02$ +/-12%	0.99	0.35	20.20	0.46
34.75	$3.00E-02$ +/-9%	$3.01E-02$ +/-12%	1.00	0.35	21.22	0.46
44.87	$2.69E-02$ +/-9%	$2.71E-02$ +/-12%	0.99	0.34	22.55	0.45
54.93	$2.44E-02$ +/-9%	$2.44E-02$ +/-12%	1.00	0.35	24.10	0.45
mean % diff. from E		8	172	85	105	

Product	Pathways	T_{1/2}	Path %	E/C	ΔE%
N16	O16(n,p)N16	7.1s	100.0	0.82	7%
Te129	Te130(n,2n)Te129	1.1h	99.6	1.00	8%

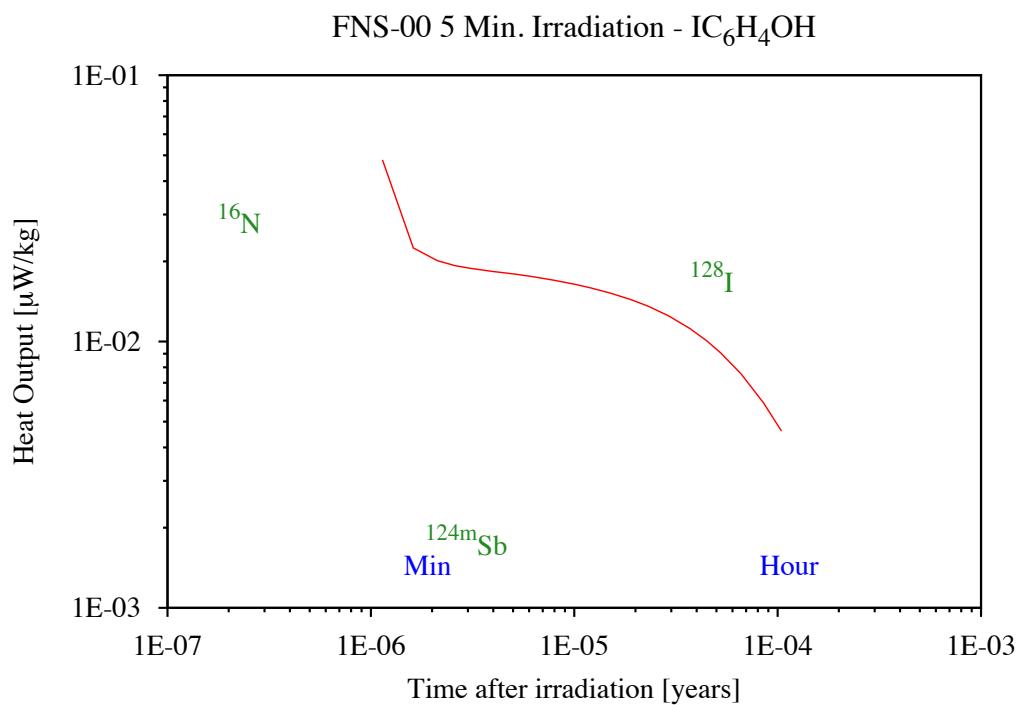


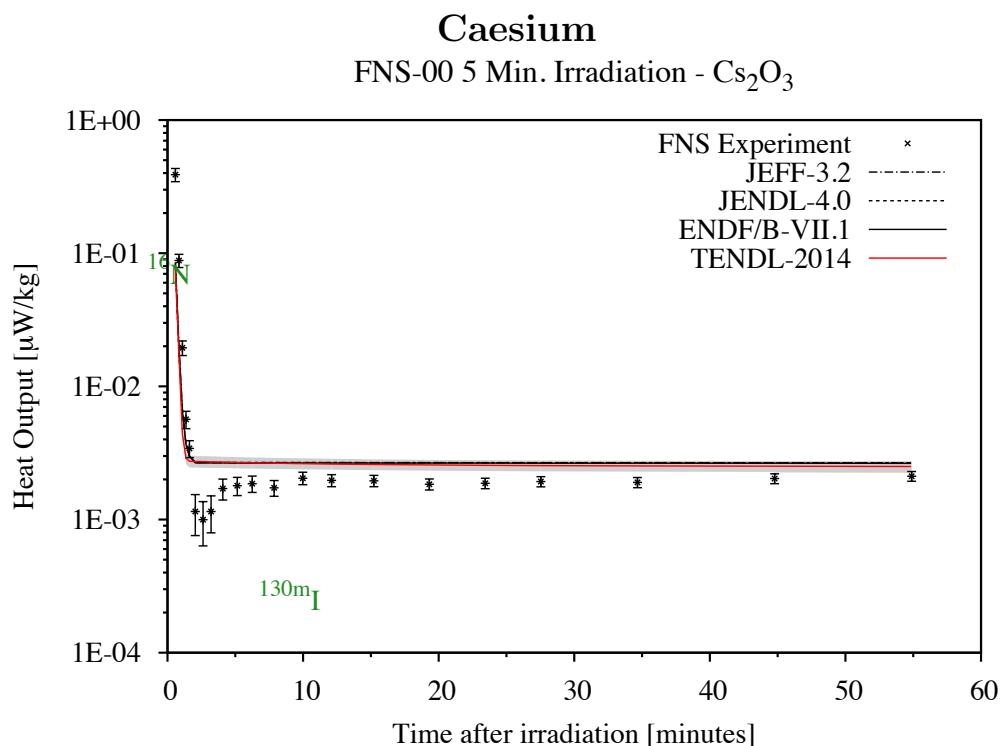


For Iodine, a rather systematic over-prediction is observed for the sample compound, and here again the major channel involved is a capture for which the thermal part has not been accurately predicted.

Times	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.60	$2.03E-02$ +/-38%	$4.81E-02$ +/-2%	0.42	0.37	0.39
0.85	$1.20E-02$ +/-17%	$2.25E-02$ +/-3%	0.54	0.44	0.46
1.12	$1.03E-02$ +/-8%	$2.01E-02$ +/-3%	0.51	0.49	0.44
1.37	$1.02E-02$ +/-7%	$1.93E-02$ +/-3%	0.53	0.53	0.46
1.63	$9.97E-03$ +/-7%	$1.88E-02$ +/-3%	0.53	0.54	0.47
2.08	$9.98E-03$ +/-7%	$1.83E-02$ +/-3%	0.54	0.56	0.49
2.70	$9.95E-03$ +/-7%	$1.79E-02$ +/-3%	0.56	0.57	0.51
3.30	$9.78E-03$ +/-7%	$1.75E-02$ +/-3%	0.56	0.57	0.52
4.17	$9.59E-03$ +/-7%	$1.70E-02$ +/-3%	0.56	0.57	0.53
5.27	$9.34E-03$ +/-7%	$1.64E-02$ +/-2%	0.57	0.57	0.54
6.38	$9.04E-03$ +/-7%	$1.59E-02$ +/-2%	0.57	0.57	0.55
8.00	$8.71E-03$ +/-7%	$1.52E-02$ +/-2%	0.57	0.58	0.59
10.10	$8.26E-03$ +/-7%	$1.43E-02$ +/-2%	0.58	0.58	0.56
12.22	$7.80E-03$ +/-7%	$1.35E-02$ +/-2%	0.58	0.58	0.56
15.35	$7.18E-03$ +/-7%	$1.25E-02$ +/-2%	0.58	0.58	0.59
19.45	$6.47E-03$ +/-7%	$1.12E-02$ +/-2%	0.58	0.58	0.56
23.52	$5.84E-03$ +/-7%	$1.01E-02$ +/-2%	0.58	0.58	0.59
27.63	$5.31E-03$ +/-7%	$9.06E-03$ +/-2%	0.59	0.59	0.57
34.75	$4.47E-03$ +/-7%	$7.56E-03$ +/-2%	0.59	0.59	0.59
44.87	$3.56E-03$ +/-7%	$5.87E-03$ +/-2%	0.61	0.60	0.58
54.98	$2.89E-03$ +/-7%	$4.61E-03$ +/-2%	0.63	0.63	0.60
mean % diff. from E		80	82	93	78

Product	Pathways	T _{1/2}	Path %	E/C	ΔE%
I128	I127(n,γ)I128	24.9m	100.0	0.58	6%



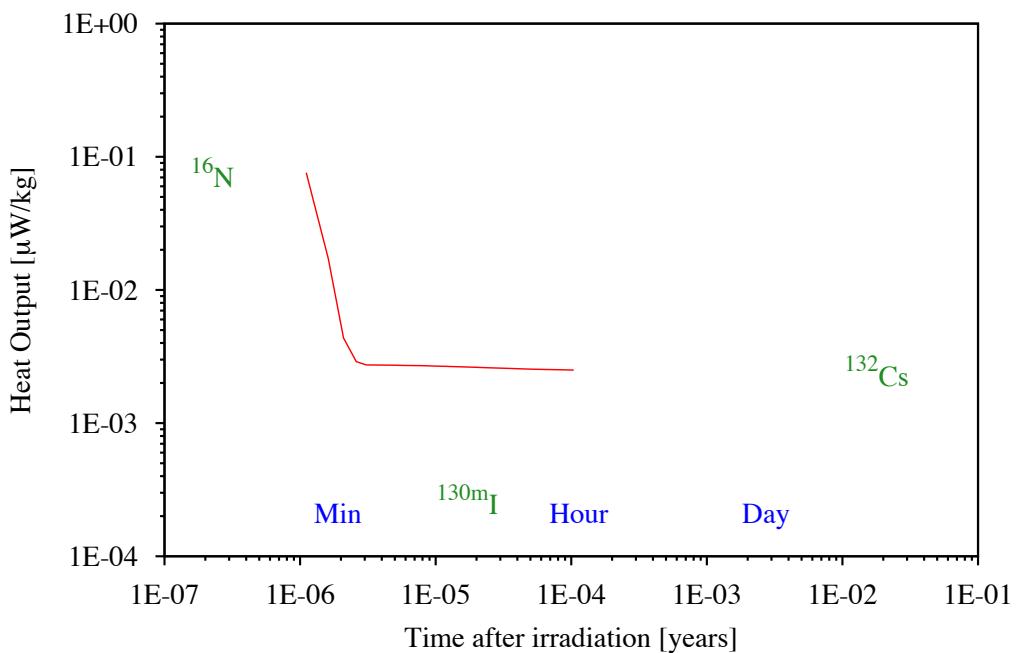


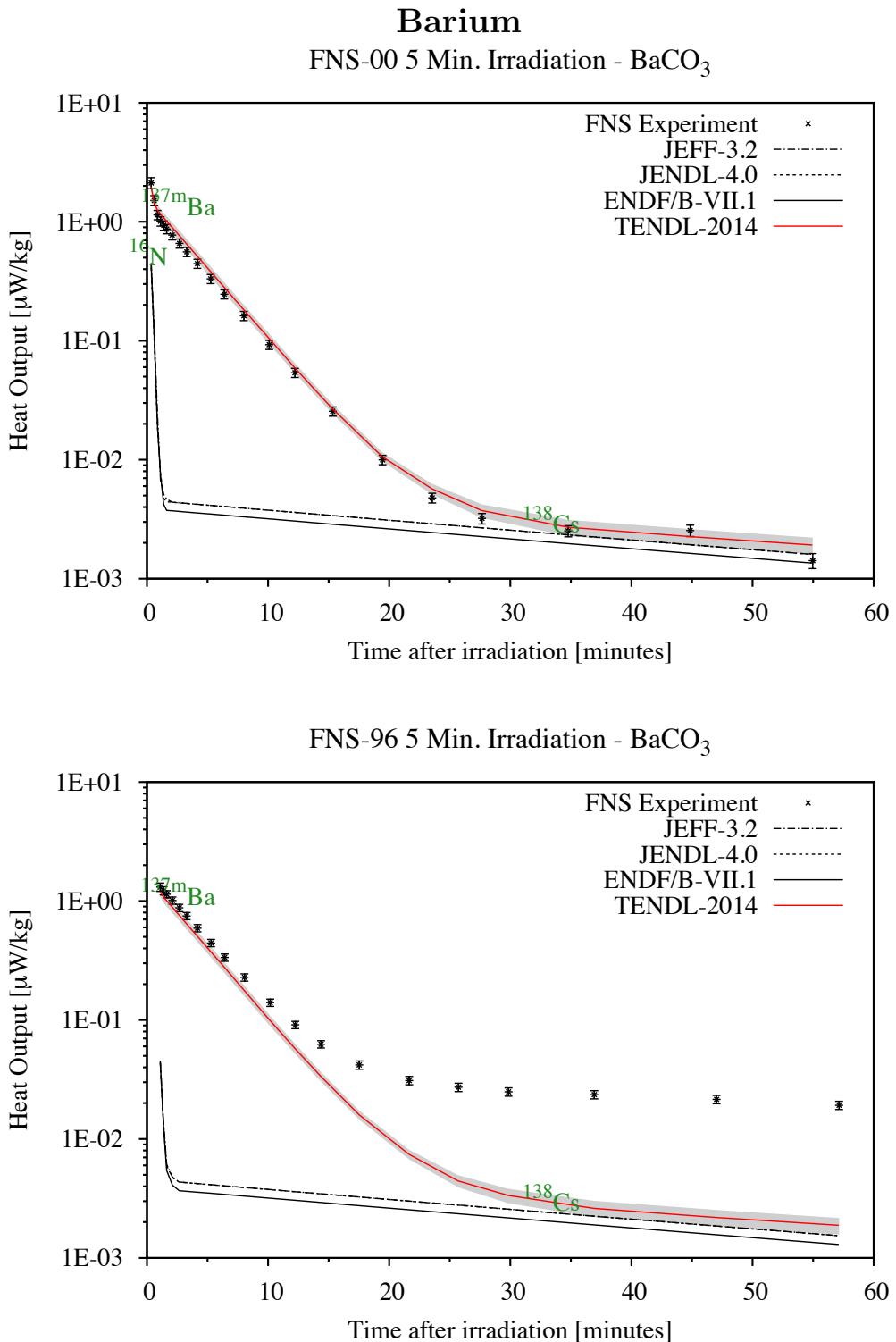
For Caesium, a surprising, but not un-physical upward short-term trend in the experimental heat measurements is observed, that may be caused by isomeric states that are unidentified in the calculational scheme, or by a larger than expected subtraction of the tape contribution.

Times	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.58	$3.89E-01 +/-11\%$	$7.60E-02 +/-0\%$	5.12	4.60	4.54
0.85	$8.81E-02 +/-11\%$	$1.72E-02 +/-2\%$	5.14	4.62	4.39
1.10	$1.95E-02 +/-13\%$	$4.36E-03 +/-6\%$	4.47	2.97	2.88
1.37	$5.66E-03 +/-15\%$	$2.90E-03 +/-10\%$	1.96	1.54	1.54
1.62	$3.42E-03 +/-15\%$	$2.74E-03 +/-10\%$	1.25	1.14	1.13
2.05	$1.15E-03 +/-34\%$	$2.73E-03 +/-10\%$	0.42	0.43	0.43
2.62	$9.98E-04 +/-37\%$	$2.72E-03 +/-10\%$	0.37	0.38	0.37
3.22	$1.15E-03 +/-31\%$	$2.71E-03 +/-10\%$	0.42	0.43	0.43
4.08	$1.71E-03 +/-18\%$	$2.70E-03 +/-10\%$	0.63	0.64	0.64
5.15	$1.79E-03 +/-16\%$	$2.68E-03 +/-10\%$	0.67	0.67	0.67
6.25	$1.86E-03 +/-14\%$	$2.67E-03 +/-10\%$	0.70	0.70	0.69
7.87	$1.73E-03 +/-14\%$	$2.65E-03 +/-10\%$	0.65	0.65	0.65
9.98	$2.04E-03 +/-11\%$	$2.63E-03 +/-9\%$	0.78	0.77	0.76
12.10	$1.97E-03 +/-10\%$	$2.61E-03 +/-9\%$	0.75	0.74	0.74
15.22	$1.95E-03 +/-10\%$	$2.59E-03 +/-9\%$	0.75	0.74	0.73
19.32	$1.84E-03 +/-9\%$	$2.57E-03 +/-9\%$	0.72	0.69	0.69
23.43	$1.87E-03 +/-9\%$	$2.55E-03 +/-9\%$	0.73	0.71	0.70
27.53	$1.93E-03 +/-9\%$	$2.54E-03 +/-9\%$	0.76	0.73	0.72
34.67	$1.90E-03 +/-9\%$	$2.52E-03 +/-9\%$	0.75	0.72	0.71
44.78	$2.03E-03 +/-9\%$	$2.51E-03 +/-9\%$	0.81	0.77	0.76
54.88	$2.12E-03 +/-8\%$	$2.50E-03 +/-9\%$	0.84	0.80	0.79
mean % diff. from E		59	58	59	59

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Cs132	Cs133(n,2n)Cs132	6.5d	100.0	0.84	8%

FNS-00 5 Min. Irradiation - Cs_2O_3

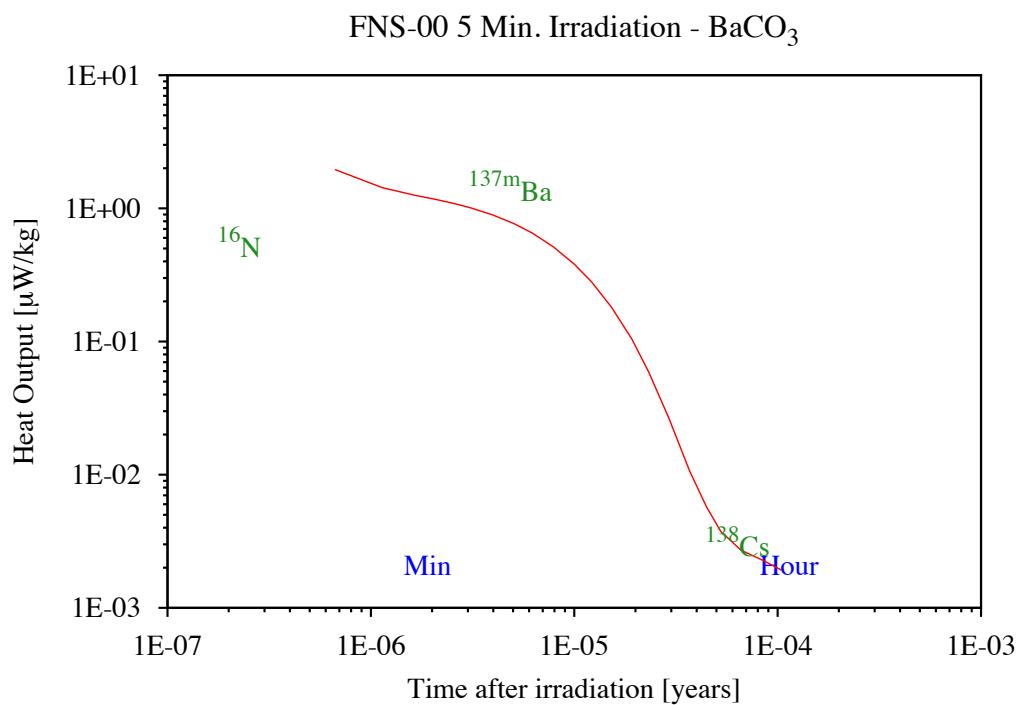


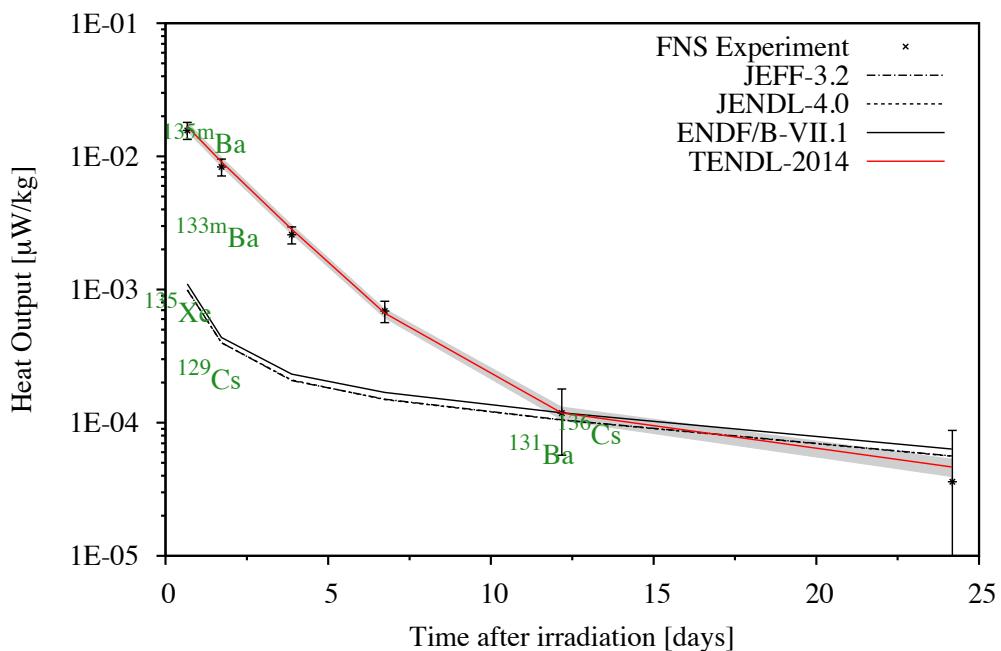


For Barium, once again the two sets of experimental measurements differ. The 1996 sample may have contained some unidentified impurities, possibly Fluorine. However, only TENDL-2014 E/C are reasonable below 30 min cooling.

Times Min.	FNS EXP. 5 mins	TENDL-2014		ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C	E/C
0.35	$2.12E+00$ +/-11%	$1.96E+00$ +/-8%	1.08	4.87	4.71	5.14
0.60	$1.51E+00$ +/-10%	$1.43E+00$ +/-10%	1.06	14.37	13.02	15.12
0.87	$1.14E+00$ +/-9%	$1.25E+00$ +/-10%	0.91	58.45	47.65	60.39
1.12	$1.01E+00$ +/-9%	$1.16E+00$ +/-10%	0.87	137.83	150.74	132.74
1.38	$9.32E-01$ +/-9%	$1.08E+00$ +/-10%	0.86	221.85	182.63	196.91
1.63	$8.69E-01$ +/-9%	$1.01E+00$ +/-10%	0.86	231.65	185.82	196.29
2.08	$7.72E-01$ +/-9%	$8.96E-01$ +/-10%	0.86	207.62	175.63	175.92
2.68	$6.58E-01$ +/-9%	$7.64E-01$ +/-10%	0.86	179.05	151.46	151.71
3.28	$5.59E-01$ +/-9%	$6.49E-01$ +/-10%	0.86	153.91	130.19	130.40
4.17	$4.45E-01$ +/-9%	$5.12E-01$ +/-10%	0.87	124.65	105.44	105.61
5.27	$3.31E-01$ +/-9%	$3.81E-01$ +/-10%	0.87	94.74	80.12	80.27
6.38	$2.46E-01$ +/-9%	$2.82E-01$ +/-10%	0.87	71.97	60.86	60.97
8.00	$1.62E-01$ +/-9%	$1.82E-01$ +/-10%	0.89	48.92	41.36	41.44
10.10	$9.27E-02$ +/-9%	$1.04E-01$ +/-10%	0.89	29.16	24.66	24.70
12.22	$5.38E-02$ +/-9%	$5.92E-02$ +/-10%	0.91	17.64	14.91	14.94
15.33	$2.55E-02$ +/-9%	$2.67E-02$ +/-9%	0.95	8.88	7.51	7.52
19.45	$9.97E-03$ +/-9%	$1.06E-02$ +/-9%	0.94	3.76	3.18	3.18
23.55	$4.78E-03$ +/-9%	$5.69E-03$ +/-10%	0.84	1.95	1.65	1.65
27.67	$3.21E-03$ +/-10%	$3.73E-03$ +/-13%	0.86	1.42	1.20	1.20
34.78	$2.52E-03$ +/-11%	$2.71E-03$ +/-16%	0.93	1.28	1.08	1.08
44.85	$2.54E-03$ +/-11%	$2.26E-03$ +/-16%	1.12	1.56	1.31	1.32
54.97	$1.42E-03$ +/-14%	$1.92E-03$ +/-15%	0.74	1.05	0.89	0.89
mean % diff. from E		14	80	77	78	

Product	Pathways	T _{1/2}	Path %	E/C	$\Delta E\%$
N16	O16(n,p)N16	7.1s	100.0	1.08	10%
Ba137m	Ba137(n,n')Ba137m	2.5m	3.9	0.86	8%
	Ba138(n,2n)Ba137m		95.2	0.86	8%
Cs138	Ba138(n,p)Cs138	33.4m	86.5	0.93	10%
	Ba138(n,p)Cs138m	2.9m	13.7	0.93	10%



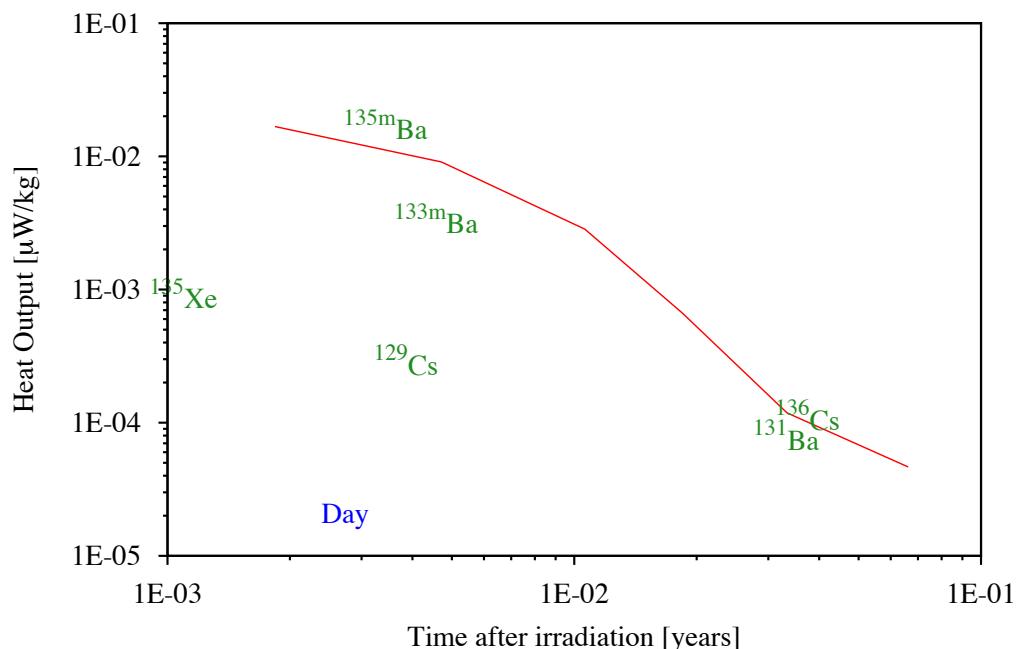
FNS-96 7 hours Irradiation - BaCO₃

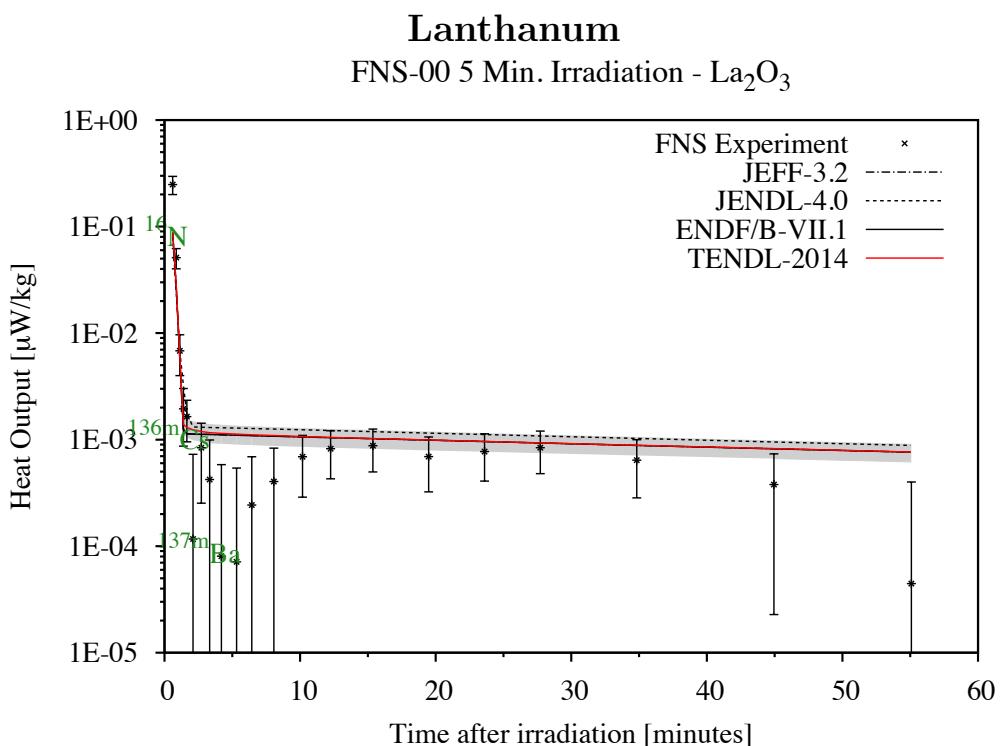
A relatively good agreement is seen between experiment and TENDL-2014 simulation for cooling times from one day up nearly a month.

Times Days	FNS EXP. 7 hrs $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.67	$1.57E-02$ +/-15%	$1.67E-02$ +/-9%	0.94	14.23	15.84	15.76
1.72	$8.33E-03$ +/-14%	$9.09E-03$ +/-9%	0.92	19.10	20.87	20.97
3.88	$2.58E-03$ +/-15%	$2.84E-03$ +/-9%	0.91	11.11	12.42	12.29
6.74	$6.90E-04$ +/-18%	$6.64E-04$ +/-9%	1.04	4.09	4.60	4.63
12.18	$1.18E-04$ +/-52%	$1.18E-04$ +/-12%	1.00	0.99	1.12	1.13
24.18	$3.60E-05$ +/-143%	$4.65E-05$ +/-15%	0.77	0.57	0.64	0.64
mean % diff. from E			10	72	71	71

Product	Pathways	T _{1/2}	Path %	E/C	ΔE%
Ba135m	Ba136(n,2n)Ba135m	1.1d	89.3	0.94	15%
	Ba135(n,n')Ba135m		10.7	0.94	15%
Ba133m	Ba134(n,2n)Ba133m	1.5d	100.0	0.92	14%
Cs136	Ba136(n,p)Cs136	13d	82.1	1.00	52%
	Ba136(n,p)Cs136m	19s	8.5	1.00	52%
	Ba137(n,np)Cs136		3.0	1.00	52%
	Ba137(n,d)Cs136		6.0	1.00	52%

FNS-96 7 hours Irradiation - BaCO₃

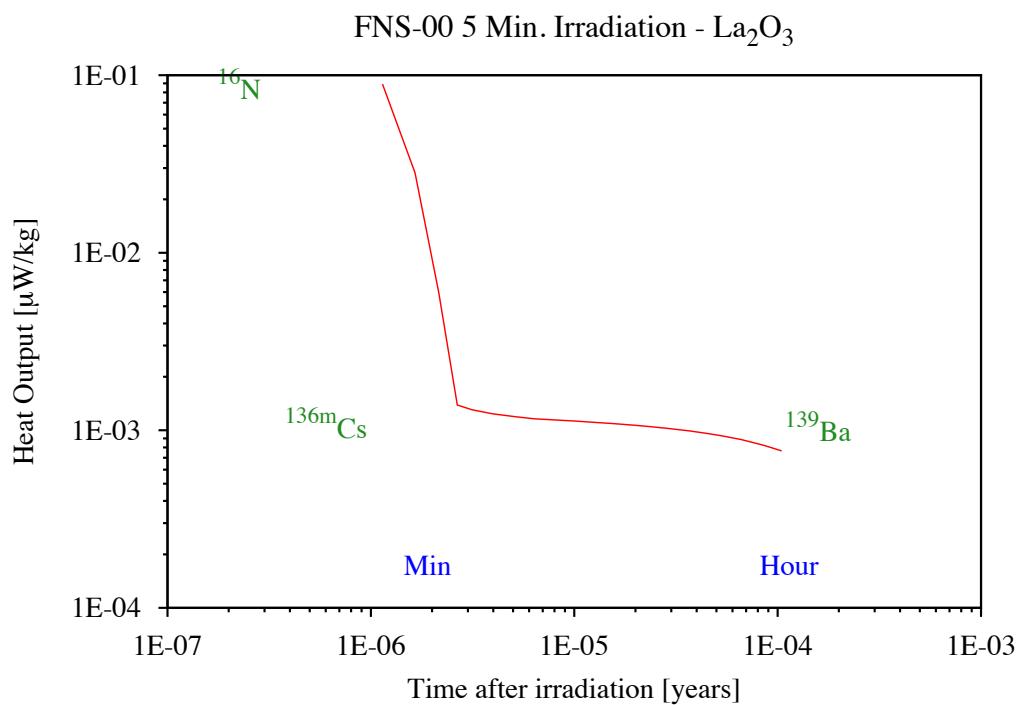


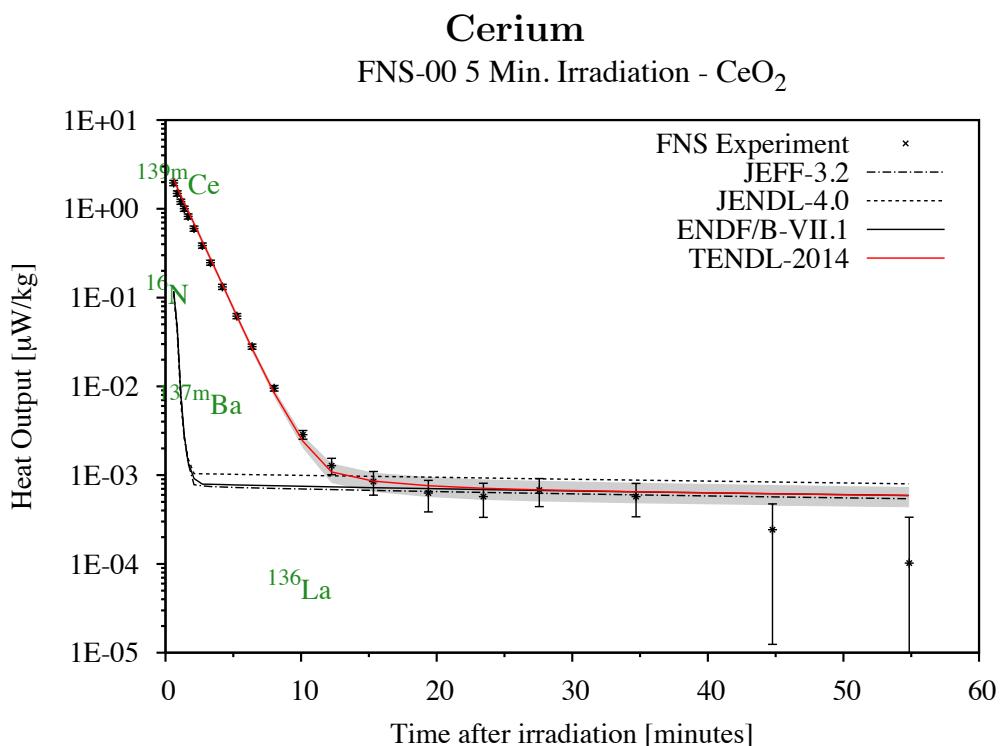


For Lanthanum, the rather large and honest experimental uncertainties do not permit an in-depth investigation, although the overall trend seems to be present in the simulations.

Times Min.	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.60	$2.48E-01$ +/-19%	$8.91E-02$ +/-1%	2.78	2.85	2.82
0.87	$5.11E-02$ +/-22%	$2.82E-02$ +/-1%	1.81	1.90	1.86
1.13	$6.81E-03$ +/-41%	$6.01E-03$ +/-5%	1.13	1.22	1.22
1.40	$1.94E-03$ +/-55%	$1.39E-03$ +/-19%	1.40	1.55	1.71
1.65	$1.65E-03$ +/-42%	$1.30E-03$ +/-20%	1.26	1.46	1.45
2.10	$1.17E-04$ +/-524%	$1.24E-03$ +/-20%	0.09	0.10	0.10
2.72	$8.40E-04$ +/-70%	$1.19E-03$ +/-20%	0.70	0.75	0.75
3.33	$4.22E-04$ +/-135%	$1.16E-03$ +/-20%	0.36	0.38	0.38
4.20	$8.05E-05$ +/-623%	$1.14E-03$ +/-20%	0.07	0.07	0.07
5.32	$7.13E-05$ +/-659%	$1.13E-03$ +/-20%	0.06	0.06	0.06
6.43	$2.43E-04$ +/-184%	$1.11E-03$ +/-20%	0.22	0.22	0.22
8.07	$4.05E-04$ +/-106%	$1.09E-03$ +/-20%	0.37	0.38	0.38
10.18	$6.91E-04$ +/-58%	$1.07E-03$ +/-20%	0.65	0.65	0.65
12.25	$8.20E-04$ +/-48%	$1.05E-03$ +/-20%	0.78	0.79	0.79
15.37	$8.76E-04$ +/-43%	$1.02E-03$ +/-20%	0.86	0.86	0.86
19.48	$6.92E-04$ +/-53%	$9.91E-04$ +/-20%	0.70	0.70	0.60
23.60	$7.72E-04$ +/-47%	$9.61E-04$ +/-20%	0.80	0.80	0.69
27.72	$8.40E-04$ +/-43%	$9.33E-04$ +/-20%	0.90	0.90	0.78
34.83	$6.42E-04$ +/-56%	$8.86E-04$ +/-20%	0.72	0.73	0.63
44.95	$3.78E-04$ +/-94%	$8.24E-04$ +/-20%	0.46	0.46	0.40
55.08	$4.45E-05$ +/-799%	$7.66E-04$ +/-19%	0.06	0.06	0.05
mean % diff. from E		316	306	307	368

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Ba139	La139(n,p)Ba139	1.3h	100.0	0.90	43%

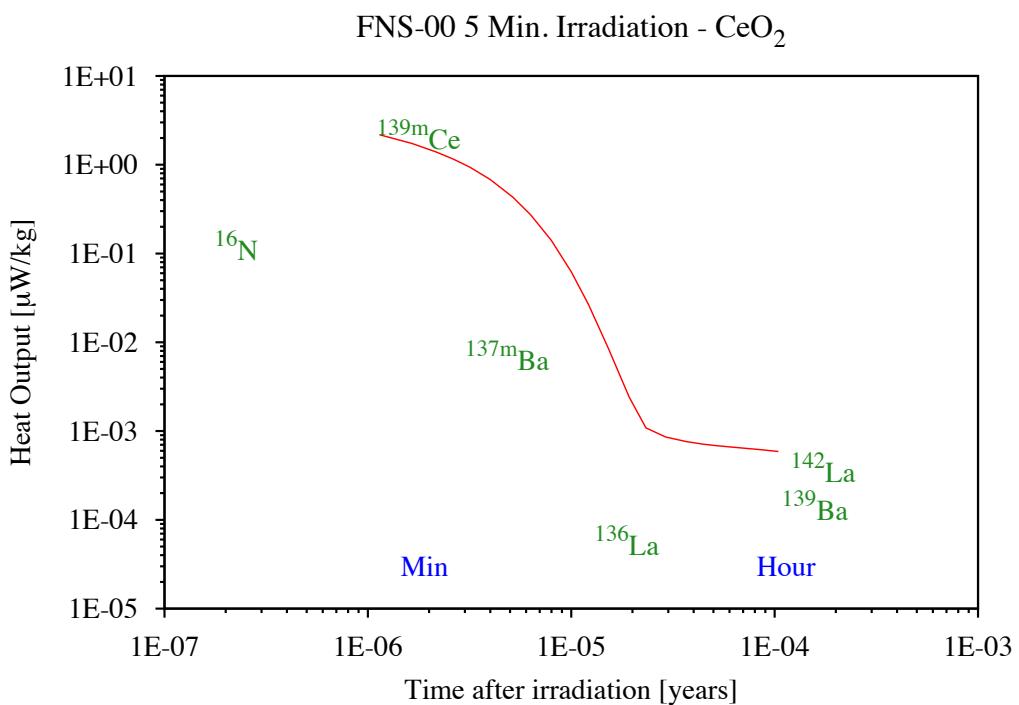




For Cerium and TENDL-2014, a good agreement exists up to 30 minutes cooling, and beyond this the large experimental uncertainties might explain the significant disagreement.

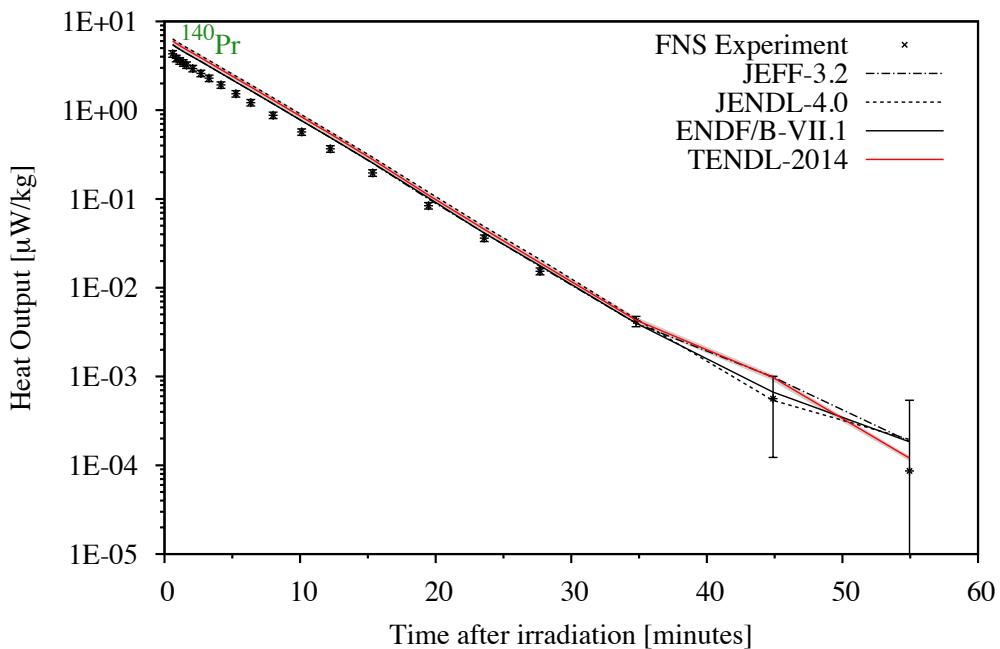
Times Min.	FNS EXP. 5 mins μW/g	TENDL-2014 μW/g	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.60	$1.96E+00$ +/-7%	$2.18E+00$ +/-8%	0.90	16.73	16.52	17.83
0.87	$1.49E+00$ +/-7%	$1.74E+00$ +/-8%	0.86	33.09	32.11	36.88
1.13	$1.21E+00$ +/-7%	$1.40E+00$ +/-8%	0.86	152.14	142.94	189.28
1.38	$1.00E+00$ +/-7%	$1.16E+00$ +/-8%	0.87	359.04	377.15	384.15
1.67	$8.21E-01$ +/-7%	$9.41E-01$ +/-8%	0.87	591.34	602.66	536.24
2.10	$5.99E-01$ +/-7%	$6.82E-01$ +/-8%	0.88	654.89	767.25	577.46
2.72	$3.86E-01$ +/-7%	$4.31E-01$ +/-8%	0.90	486.78	509.72	373.14
3.32	$2.47E-01$ +/-7%	$2.74E-01$ +/-8%	0.90	313.62	331.93	239.94
4.20	$1.32E-01$ +/-7%	$1.41E-01$ +/-8%	0.94	168.89	180.08	128.86
5.27	$6.19E-02$ +/-7%	$6.17E-02$ +/-8%	1.00	79.76	85.30	60.67
6.38	$2.80E-02$ +/-7%	$2.68E-02$ +/-8%	1.05	36.46	39.01	27.65
8.02	$9.53E-03$ +/-7%	$8.47E-03$ +/-10%	1.12	12.54	13.42	9.47
10.13	$2.86E-03$ +/-11%	$2.42E-03$ +/-16%	1.18	3.82	4.10	2.88
12.25	$1.28E-03$ +/-21%	$1.09E-03$ +/-25%	1.18	1.74	1.86	1.30
15.33	$8.47E-04$ +/-30%	$8.57E-04$ +/-25%	0.99	1.17	1.26	0.87
19.38	$6.29E-04$ +/-39%	$7.60E-04$ +/-25%	0.83	0.89	0.96	0.66
23.45	$5.73E-04$ +/-42%	$7.12E-04$ +/-26%	0.80	0.83	0.90	0.62
27.57	$6.79E-04$ +/-35%	$6.84E-04$ +/-26%	0.99	1.01	1.09	0.75
34.70	$5.73E-04$ +/-41%	$6.52E-04$ +/-26%	0.88	0.88	0.96	0.65
44.77	$2.43E-04$ +/-95%	$6.17E-04$ +/-26%	0.39	0.39	0.43	0.29
54.85	$1.02E-04$ +/-229%	$5.88E-04$ +/-25%	0.17	0.17	0.19	0.13
mean % diff. from E		41	95	91	114	

Product	Pathways	T _{1/2}	Path %	E/C	ΔE%
Ce139m	Ce140(n,2n)Ce139m	56.1s	98.7	0.90	7%
Ba137m	Ce140(n,α)Ba137m	2.5m	99.3	0.90	7%
La142	Ce142(n,p)La142	1.5h	100.0	0.88	41%



Praseodymium

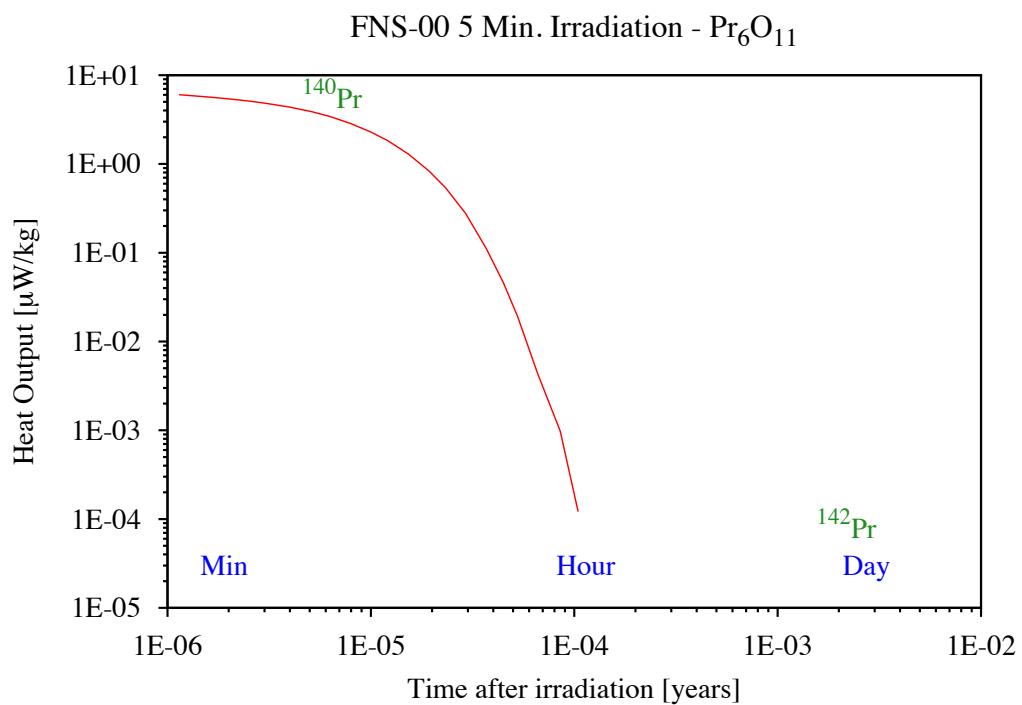
FNS-00 5 Min. Irradiation - Pr_6O_{11}



For Praseodymium, a systematic 30% over-prediction exists in the TENDL-2014 simulation, which may indicate that a cross section and/or decay data correction is foreseeable.

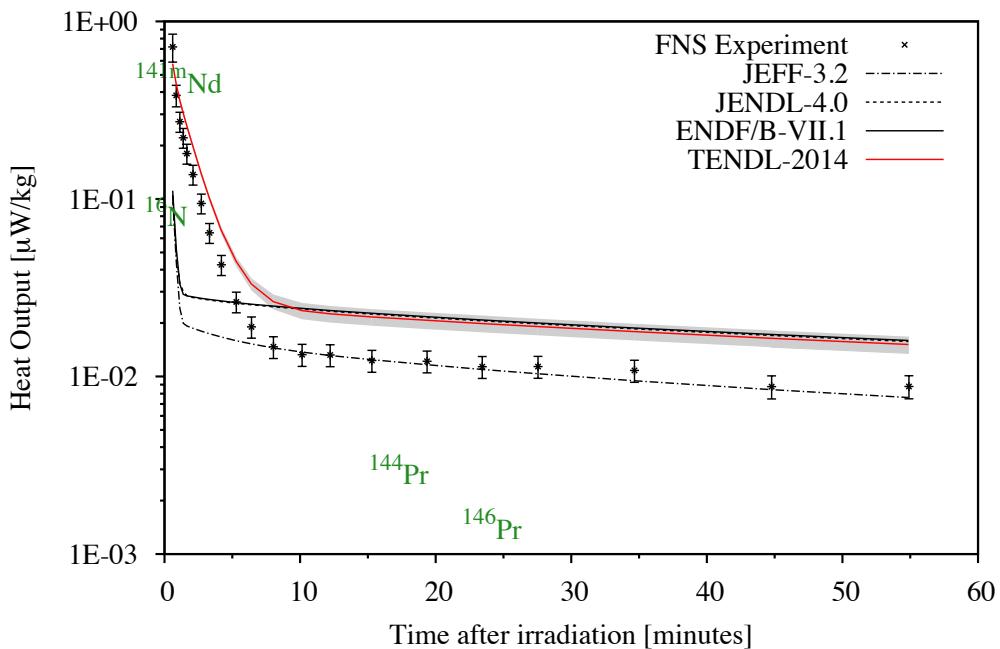
Times Min.	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0	
	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C	
0.60	$4.31E+00 +/- 9\%$	$6.03E+00 +/- 9\%$	0.72	0.79	0.79	0.68
0.87	$3.83E+00 +/- 8\%$	$5.64E+00 +/- 9\%$	0.68	0.75	0.75	0.64
1.12	$3.60E+00 +/- 8\%$	$5.33E+00 +/- 9\%$	0.68	0.74	0.74	0.64
1.38	$3.42E+00 +/- 8\%$	$5.04E+00 +/- 9\%$	0.68	0.75	0.75	0.64
1.63	$3.22E+00 +/- 8\%$	$4.79E+00 +/- 9\%$	0.67	0.74	0.74	0.64
2.08	$2.95E+00 +/- 8\%$	$4.38E+00 +/- 9\%$	0.67	0.74	0.74	0.64
2.68	$2.60E+00 +/- 8\%$	$3.89E+00 +/- 9\%$	0.67	0.74	0.74	0.63
3.28	$2.29E+00 +/- 8\%$	$3.44E+00 +/- 9\%$	0.67	0.73	0.73	0.63
4.17	$1.92E+00 +/- 8\%$	$2.87E+00 +/- 9\%$	0.67	0.74	0.74	0.63
5.27	$1.53E+00 +/- 8\%$	$2.29E+00 +/- 9\%$	0.67	0.74	0.74	0.63
6.37	$1.22E+00 +/- 8\%$	$1.83E+00 +/- 9\%$	0.67	0.73	0.73	0.63
8.02	$8.77E-01 +/- 8\%$	$1.30E+00 +/- 9\%$	0.67	0.74	0.74	0.64
10.12	$5.68E-01 +/- 8\%$	$8.40E-01 +/- 9\%$	0.68	0.75	0.75	0.64
12.23	$3.67E-01 +/- 8\%$	$5.42E-01 +/- 9\%$	0.68	0.75	0.75	0.64
15.35	$1.96E-01 +/- 8\%$	$2.79E-01 +/- 9\%$	0.71	0.77	0.78	0.66
19.47	$8.40E-02 +/- 8\%$	$1.11E-01 +/- 9\%$	0.76	0.81	0.84	0.70
23.58	$3.62E-02 +/- 8\%$	$4.57E-02 +/- 9\%$	0.79	0.87	0.87	0.74
27.70	$1.53E-02 +/- 9\%$	$1.91E-02 +/- 9\%$	0.80	0.86	0.88	0.74
34.78	$4.20E-03 +/- 13\%$	$4.34E-03 +/- 9\%$	0.97	1.05	1.05	0.94
44.88	$5.63E-04 +/- 78\%$	$9.79E-04 +/- 8\%$	0.58	0.84	0.57	1.04
54.95	$8.63E-05 +/- 526\%$	$1.21E-04 +/- 6\%$	0.71	0.47	0.46	0.44
mean % diff. from E		44	33	36	52	

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Pr140	Pr141(n,2n)Pr140	3.3m	99.6	0.67	8%



Neodymium

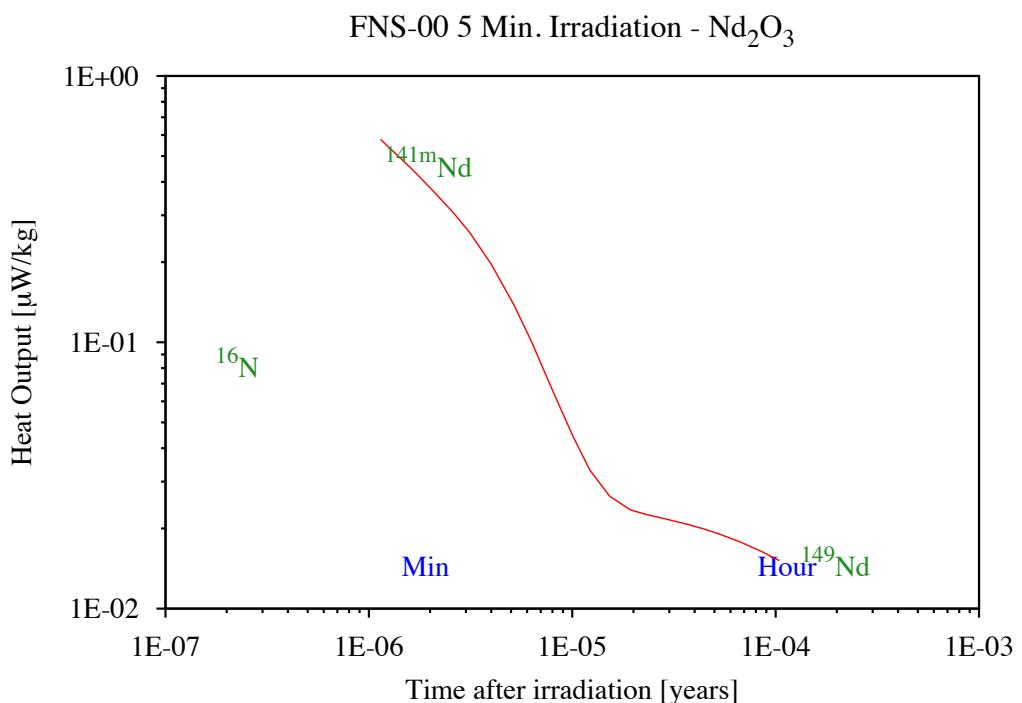
FNS-00 5 Min. Irradiation - Nd₂O₃

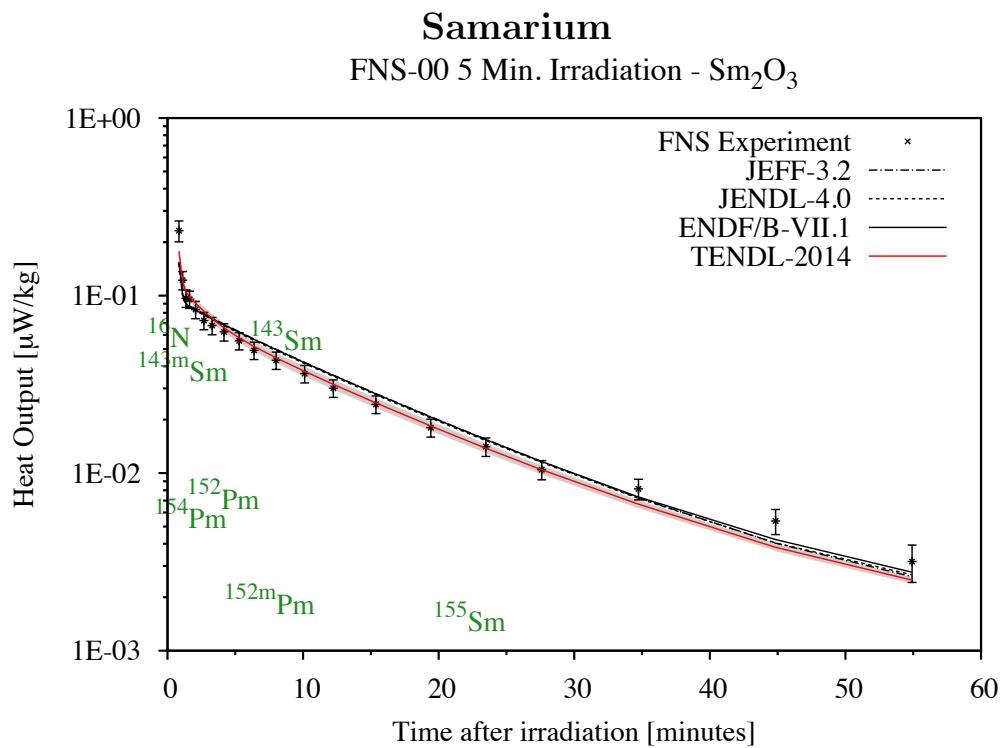


For Neodymium, the rather uniform and significant 50% over-prediction appearing after a few minutes of cooling for TENDL-2014 may need to be acted upon. The Nd141m isomer half life seems to be well predicted although its level may also be on the high side. JEFF-3.2 Nd149 production pathway better agree with the experiment but only after 8 min cooling.

Times Min.	FNS EXP. 5 mins μW/g	TENDL-2014 μW/g	ENDF/B-VII.1		JEFF-3.2 E/C	JENDL-4.0 E/C
			E/C	E/C		
0.60	$7.19E-01$ +/-18%	$5.78E-01$ +/-3%	1.24	6.45	6.97	6.83
0.87	$3.83E-01$ +/-14%	$4.43E-01$ +/-3%	0.87	7.27	8.62	7.77
1.13	$2.72E-01$ +/-13%	$3.58E-01$ +/-4%	0.76	8.22	11.23	8.11
1.38	$2.21E-01$ +/-13%	$3.04E-01$ +/-4%	0.73	7.62	11.09	7.32
1.65	$1.80E-01$ +/-13%	$2.58E-01$ +/-4%	0.70	6.33	9.35	6.30
2.10	$1.37E-01$ +/-13%	$1.97E-01$ +/-4%	0.70	4.89	7.34	4.93
2.72	$9.44E-02$ +/-13%	$1.38E-01$ +/-4%	0.68	3.42	5.24	3.45
3.32	$6.44E-02$ +/-13%	$1.00E-01$ +/-4%	0.64	2.37	3.70	2.39
4.20	$4.25E-02$ +/-13%	$6.63E-02$ +/-5%	0.64	1.60	2.55	1.61
5.30	$2.63E-02$ +/-13%	$4.43E-02$ +/-6%	0.59	1.01	1.66	1.02
6.42	$1.90E-02$ +/-14%	$3.31E-02$ +/-8%	0.57	0.75	1.25	0.75
8.03	$1.47E-02$ +/-14%	$2.64E-02$ +/-10%	0.56	0.59	1.01	0.59
10.15	$1.33E-02$ +/-14%	$2.35E-02$ +/-10%	0.57	0.55	0.97	0.55
12.22	$1.32E-02$ +/-14%	$2.25E-02$ +/-11%	0.59	0.56	1.01	0.57
15.30	$1.23E-02$ +/-14%	$2.17E-02$ +/-11%	0.57	0.54	0.99	0.55
19.37	$1.22E-02$ +/-14%	$2.07E-02$ +/-11%	0.59	0.56	1.05	0.57
23.43	$1.14E-02$ +/-14%	$1.99E-02$ +/-11%	0.57	0.54	1.03	0.55
27.55	$1.14E-02$ +/-14%	$1.91E-02$ +/-11%	0.60	0.57	1.10	0.58
34.67	$1.08E-02$ +/-14%	$1.79E-02$ +/-11%	0.60	0.58	1.14	0.58
44.78	$8.78E-03$ +/-15%	$1.64E-02$ +/-11%	0.54	0.51	1.04	0.52
54.90	$8.79E-03$ +/-15%	$1.51E-02$ +/-11%	0.58	0.55	1.15	0.56
mean % diff. from E			59	72	41	71

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Nd141m	Nd142(n,2n)Nd141m	1.0m	98.6	0.76	13%
Nd149	Nd148(n, γ)Nd149	1.7h	0.5	0.58	15%
	Nd150(n,2n)Nd149		99.5	0.58	15%

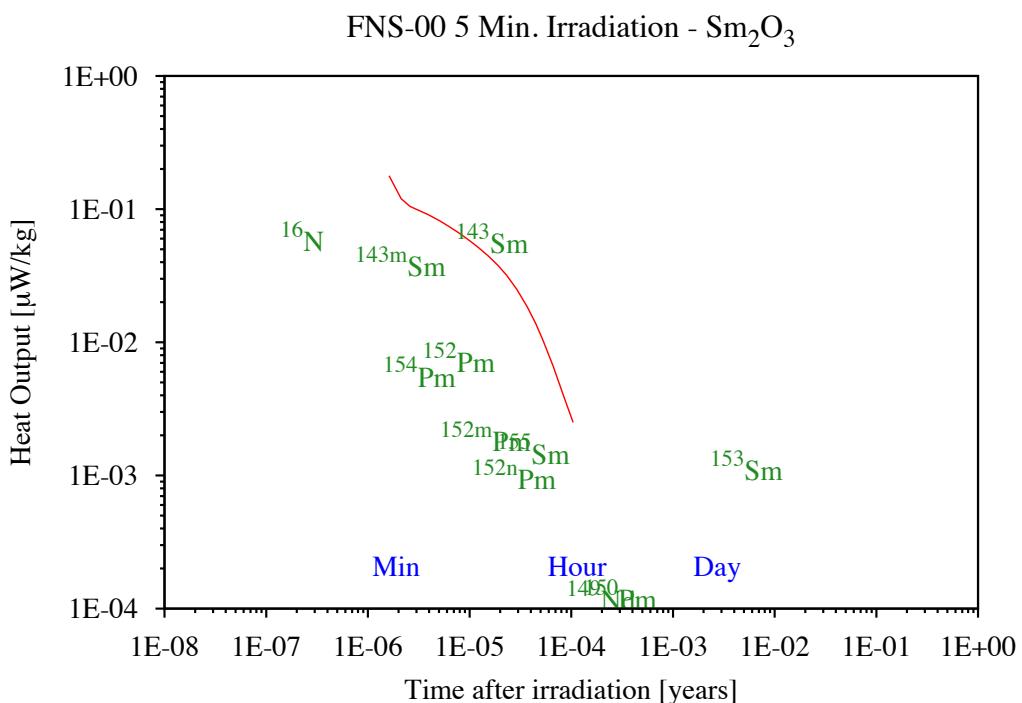




For Samarium, a good agreement exists, fully endorsed by both the quoted experimental and calculational uncertainties. This provides, once again, proof of the well founded processes that allow the build-up of the European Activation and TENDL covariance data files.

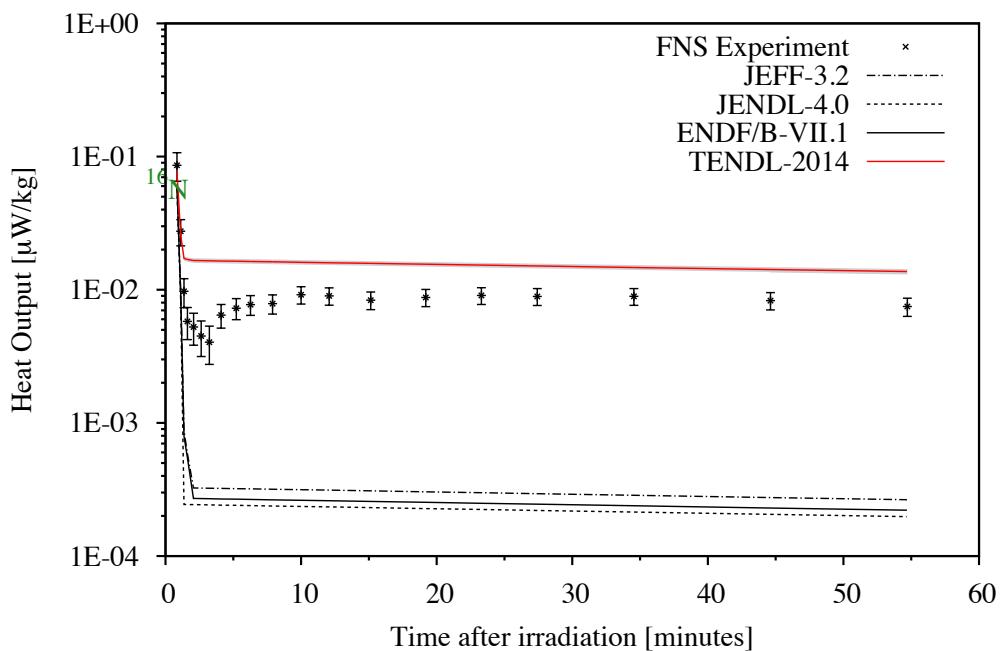
Times Min.	FNS EXP. 5 mins $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.85	$2.32E-01 +/-14\%$	$1.78E-01 +/-4\%$	1.30	1.51	1.50	1.54
1.12	$1.22E-01 +/-12\%$	$1.20E-01 +/-5\%$	1.02	1.22	1.21	1.24
1.37	$9.67E-02 +/-11\%$	$1.05E-01 +/-5\%$	0.92	1.08	1.07	1.10
1.63	$9.53E-02 +/-11\%$	$9.86E-02 +/-5\%$	0.97	1.10	1.09	1.11
2.07	$8.34E-02 +/-11\%$	$9.08E-02 +/-6\%$	0.92	1.01	1.00	1.01
2.68	$7.23E-02 +/-11\%$	$8.17E-02 +/-6\%$	0.89	0.92	0.91	0.93
3.28	$6.78E-02 +/-11\%$	$7.43E-02 +/-6\%$	0.91	0.91	0.91	0.92
4.17	$6.24E-02 +/-11\%$	$6.59E-02 +/-6\%$	0.95	0.91	0.90	0.92
5.28	$5.57E-02 +/-11\%$	$5.79E-02 +/-6\%$	0.96	0.90	0.89	0.91
6.38	$4.91E-02 +/-11\%$	$5.18E-02 +/-6\%$	0.95	0.87	0.86	0.88
8.02	$4.32E-02 +/-11\%$	$4.46E-02 +/-6\%$	0.97	0.87	0.87	0.88
10.12	$3.63E-02 +/-11\%$	$3.75E-02 +/-6\%$	0.97	0.87	0.86	0.88
12.23	$3.01E-02 +/-11\%$	$3.17E-02 +/-6\%$	0.95	0.85	0.84	0.86
15.37	$2.44E-02 +/-11\%$	$2.49E-02 +/-6\%$	0.98	0.87	0.87	0.88
19.42	$1.80E-02 +/-12\%$	$1.85E-02 +/-6\%$	0.98	0.87	0.87	0.88
23.48	$1.41E-02 +/-12\%$	$1.38E-02 +/-6\%$	1.02	0.91	0.91	0.92
27.60	$1.05E-02 +/-12\%$	$1.05E-02 +/-6\%$	1.00	0.90	0.90	0.91
34.73	$8.15E-03 +/-13\%$	$6.69E-03 +/-5\%$	1.22	1.11	1.12	1.13
44.85	$5.37E-03 +/-16\%$	$3.83E-03 +/-4\%$	1.40	1.27	1.33	1.33
54.92	$3.18E-03 +/-24\%$	$2.50E-03 +/-4\%$	1.27	1.15	1.22	1.19
mean % diff. from E		8	13	14	13	

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Sm143m	Sm144(n,2n)Sm143m	1.1m	98.5	1.02	12%
Sm143	Sm144(n,2n)Sm143	8.7m	63.3	0.97	11%
	Sm144(n,2n)Sm143m	1.1m	36.9	0.97	11%



Europium

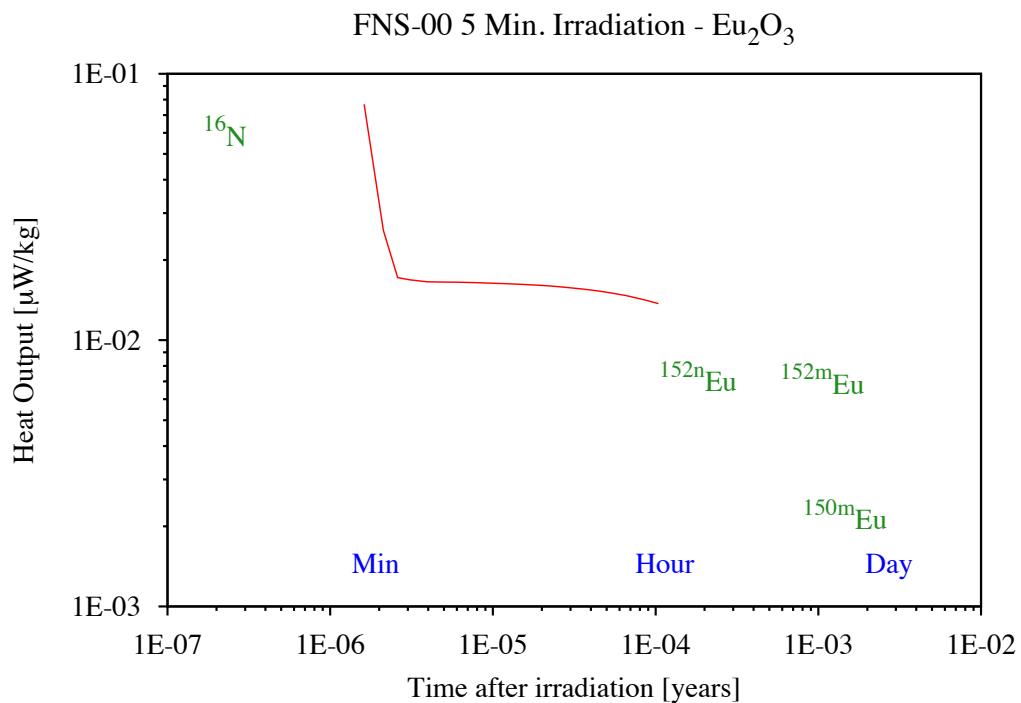
FNS-00 5 Min. Irradiation - Eu₂O₃

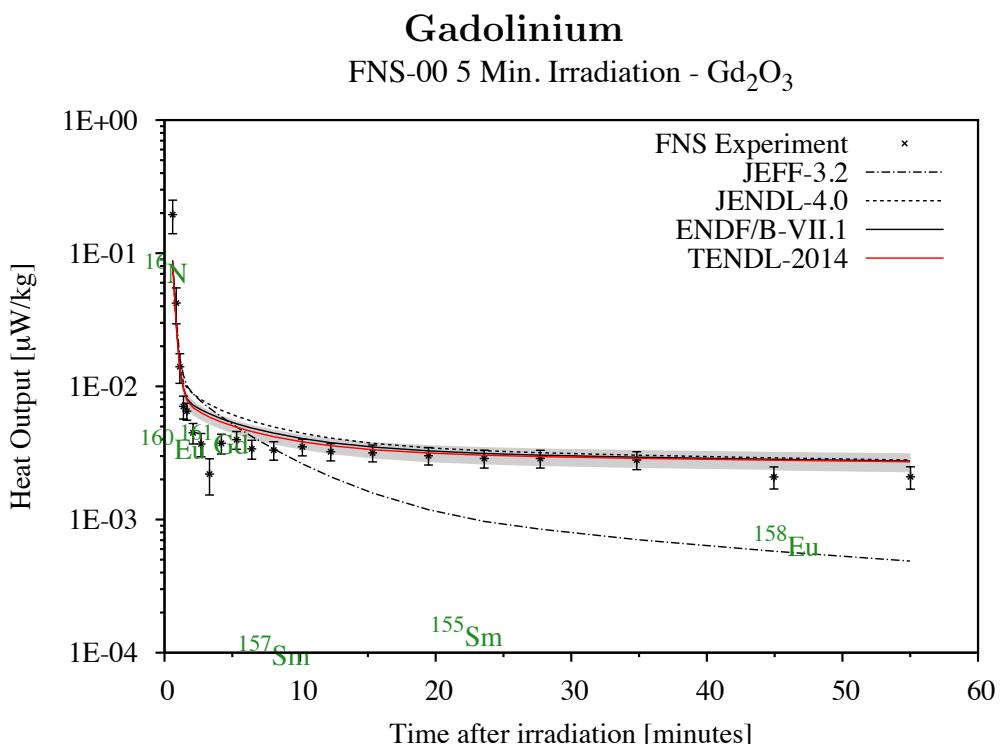


For Europium and TENDL-2014, as with Caesium, an upward trend can be seen at short cooling times, with the possibility of still missing isomeric states in the databases. It is clearly the reason behind the poor agreement seen in the other libraries

Times Min.	FNS EXP. 5 mins μW/g	TENDL-2014 μW/g	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.85	$8.60E-02$ +/-24%	$7.68E-02$ +/-1%	1.12	1.43	1.42	1.48
1.12	$2.75E-02$ +/-22%	$2.58E-02$ +/-3%	1.06	2.92	2.88	3.32
1.37	$9.72E-03$ +/-25%	$1.72E-02$ +/-4%	0.57	12.22	11.14	39.87
1.62	$5.79E-03$ +/-27%	$1.69E-02$ +/-4%	0.34	10.60	9.87	23.75
2.07	$5.25E-03$ +/-27%	$1.66E-02$ +/-4%	0.32	19.41	16.17	21.59
2.63	$4.49E-03$ +/-30%	$1.65E-02$ +/-4%	0.27	16.62	13.84	18.49
3.23	$4.04E-03$ +/-32%	$1.65E-02$ +/-4%	0.24	14.99	12.49	16.68
4.10	$6.45E-03$ +/-20%	$1.64E-02$ +/-4%	0.39	24.02	20.01	26.73
5.22	$7.27E-03$ +/-18%	$1.64E-02$ +/-4%	0.44	27.18	22.65	30.25
6.27	$7.72E-03$ +/-17%	$1.63E-02$ +/-4%	0.47	29.02	24.17	32.29
7.90	$7.85E-03$ +/-16%	$1.62E-02$ +/-4%	0.48	29.69	24.74	33.05
10.00	$9.18E-03$ +/-15%	$1.61E-02$ +/-4%	0.57	34.97	29.14	38.93
12.07	$8.99E-03$ +/-15%	$1.59E-02$ +/-4%	0.56	34.53	28.77	38.44
15.13	$8.34E-03$ +/-15%	$1.58E-02$ +/-4%	0.53	32.44	27.03	36.12
19.20	$8.76E-03$ +/-15%	$1.55E-02$ +/-4%	0.56	34.58	28.82	38.52
23.30	$9.05E-03$ +/-14%	$1.53E-02$ +/-4%	0.59	36.32	30.27	40.47
27.42	$8.90E-03$ +/-15%	$1.51E-02$ +/-4%	0.59	36.29	30.25	40.45
34.55	$8.91E-03$ +/-14%	$1.47E-02$ +/-4%	0.61	37.35	31.15	41.66
44.62	$8.29E-03$ +/-15%	$1.42E-02$ +/-4%	0.58	36.10	30.12	40.29
54.72	$7.47E-03$ +/-16%	$1.37E-02$ +/-4%	0.55	33.83	28.23	37.79
mean % diff. from E		113	91	90	92	

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Eu152m	Eu151(n, γ)Eu152m	9.2h	64.6	0.58	15%
	Eu153(n,2n)Eu152m		35.6	0.58	15%

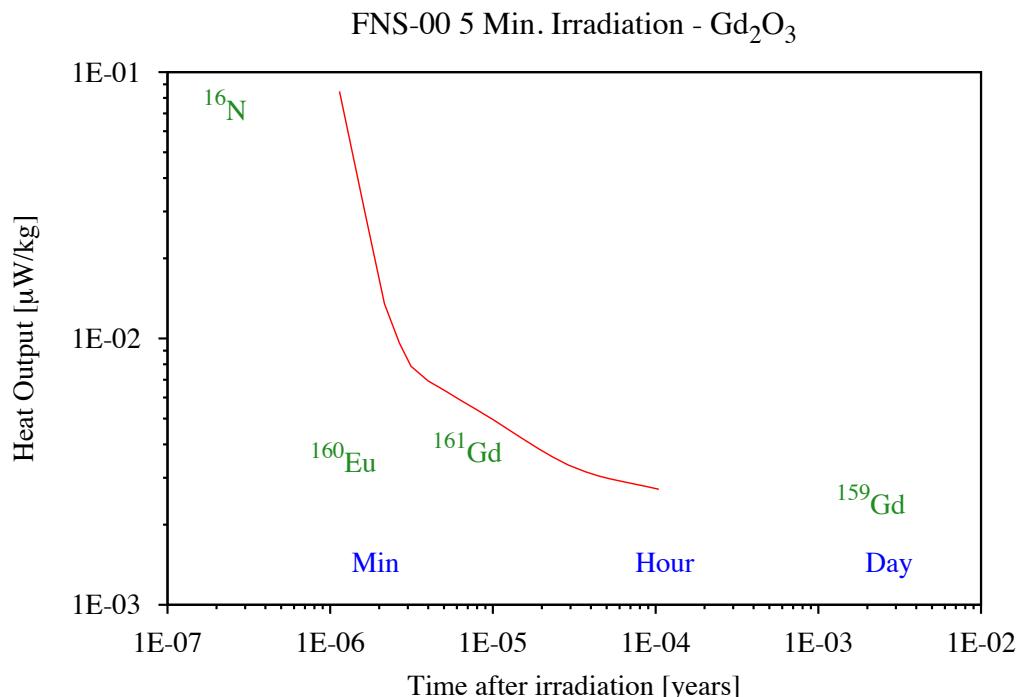


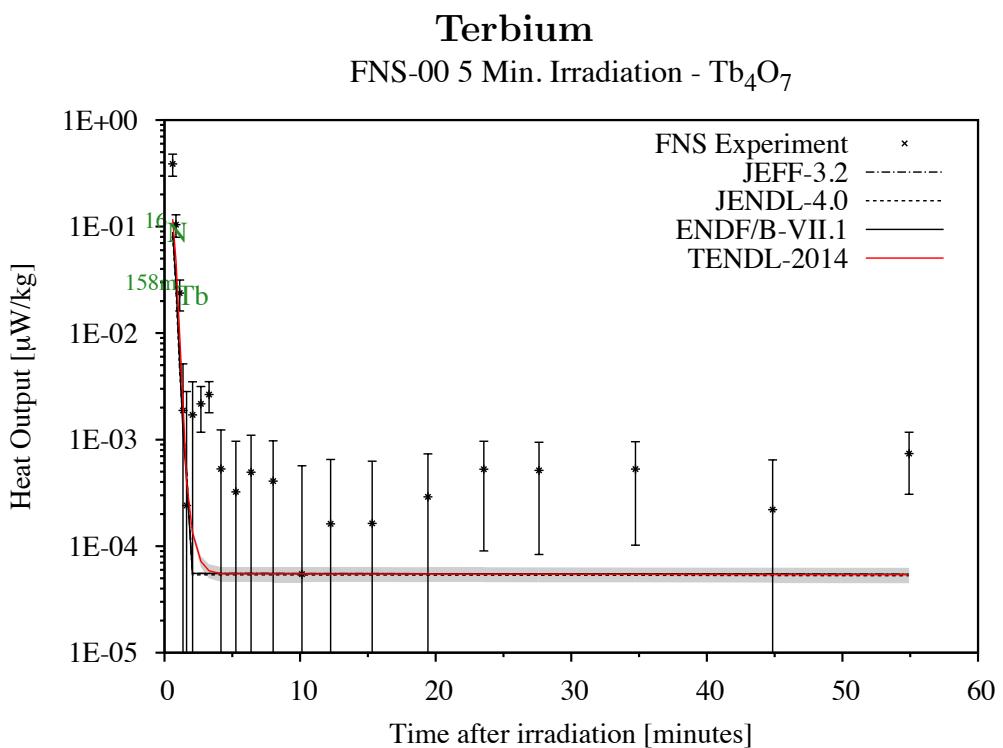


For Gadolinium, the fluctuation with time of the measured decay heat, as well as the large number of contributing isotopes and their complex production routes, leads to difficulties in the interpretation.

Times Min.	FNS EXP. 5 mins $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.60	$1.95E-01$ +/-28%	$8.47E-02$ +/-3%	2.30	2.32	2.20	2.38
0.87	$4.22E-02$ +/-30%	$2.91E-02$ +/-6%	1.45	1.47	1.30	1.47
1.13	$1.41E-02$ +/-25%	$1.35E-02$ +/-11%	1.04	1.05	0.86	0.97
1.40	$7.06E-03$ +/-20%	$9.61E-03$ +/-13%	0.73	0.73	0.58	0.66
1.65	$6.51E-03$ +/-15%	$7.86E-03$ +/-14%	0.83	0.81	0.64	0.66
2.10	$4.48E-03$ +/-17%	$6.93E-03$ +/-13%	0.65	0.62	0.51	0.51
2.70	$3.69E-03$ +/-20%	$6.34E-03$ +/-12%	0.58	0.55	0.48	0.46
3.32	$2.19E-03$ +/-30%	$5.87E-03$ +/-12%	0.37	0.35	0.32	0.30
4.20	$3.74E-03$ +/-17%	$5.39E-03$ +/-12%	0.69	0.65	0.63	0.56
5.32	$3.97E-03$ +/-15%	$4.94E-03$ +/-12%	0.80	0.76	0.80	0.67
6.43	$3.39E-03$ +/-16%	$4.58E-03$ +/-12%	0.74	0.70	0.81	0.62
8.05	$3.32E-03$ +/-16%	$4.19E-03$ +/-13%	0.79	0.74	0.98	0.67
10.17	$3.51E-03$ +/-14%	$3.84E-03$ +/-13%	0.92	0.87	1.34	0.79
12.27	$3.23E-03$ +/-15%	$3.59E-03$ +/-13%	0.90	0.86	1.54	0.79
15.35	$3.17E-03$ +/-15%	$3.35E-03$ +/-14%	0.95	0.90	2.00	0.85
19.47	$3.01E-03$ +/-15%	$3.16E-03$ +/-15%	0.95	0.92	2.54	0.87
23.58	$2.88E-03$ +/-15%	$3.04E-03$ +/-15%	0.94	0.92	2.97	0.88
27.72	$2.87E-03$ +/-15%	$2.97E-03$ +/-15%	0.97	0.94	3.39	0.91
34.83	$2.80E-03$ +/-15%	$2.88E-03$ +/-15%	0.97	0.95	3.96	0.92
44.95	$2.09E-03$ +/-19%	$2.79E-03$ +/-16%	0.75	0.74	3.61	0.72
55.02	$2.09E-03$ +/-19%	$2.71E-03$ +/-16%	0.77	0.76	4.29	0.75
mean % diff. from E		32	37	61	51	

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Eu160	Gd160(n,p)Eu160	38.0s	98.5	1.04	25%
Gd161	Gd160(n, γ)Gd161	3.6m	99.4	0.69	17%
Gd159	Gd158(n, γ)Gd159	18.4h	1.1	0.77	19%
	Gd160(n,2n)Gd159		98.9	0.77	19%

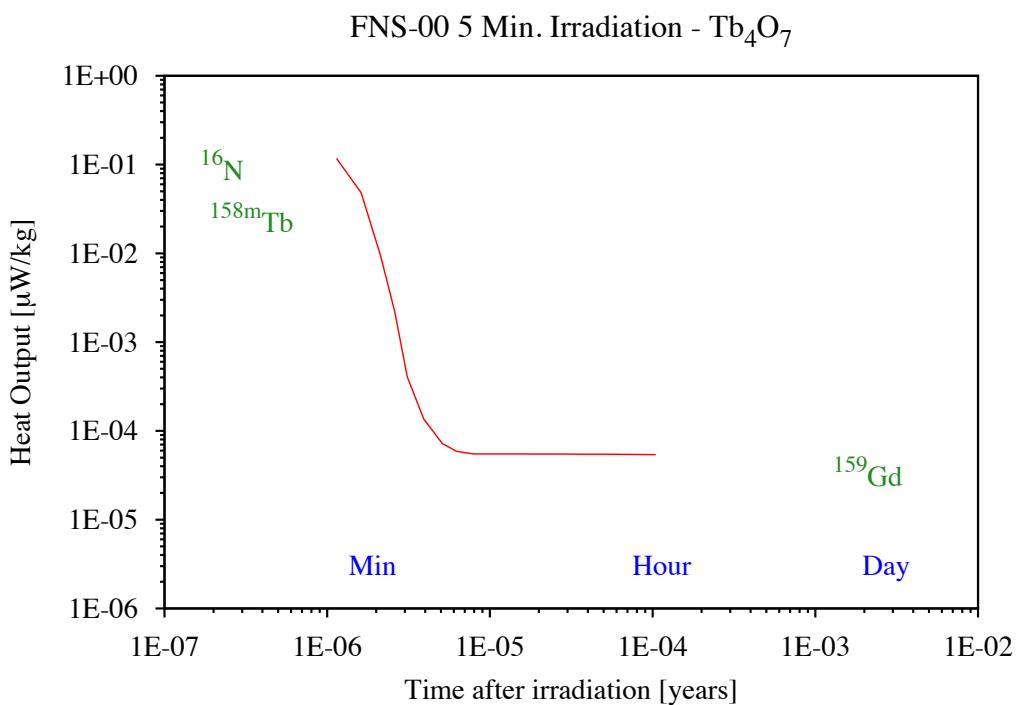




For Terbium, the short lived Tb^{158m} isomer seems to be predicted with some accuracy. At longer cooling times the measurements need to be viewed with caution due to the large, uneven uncertainties.

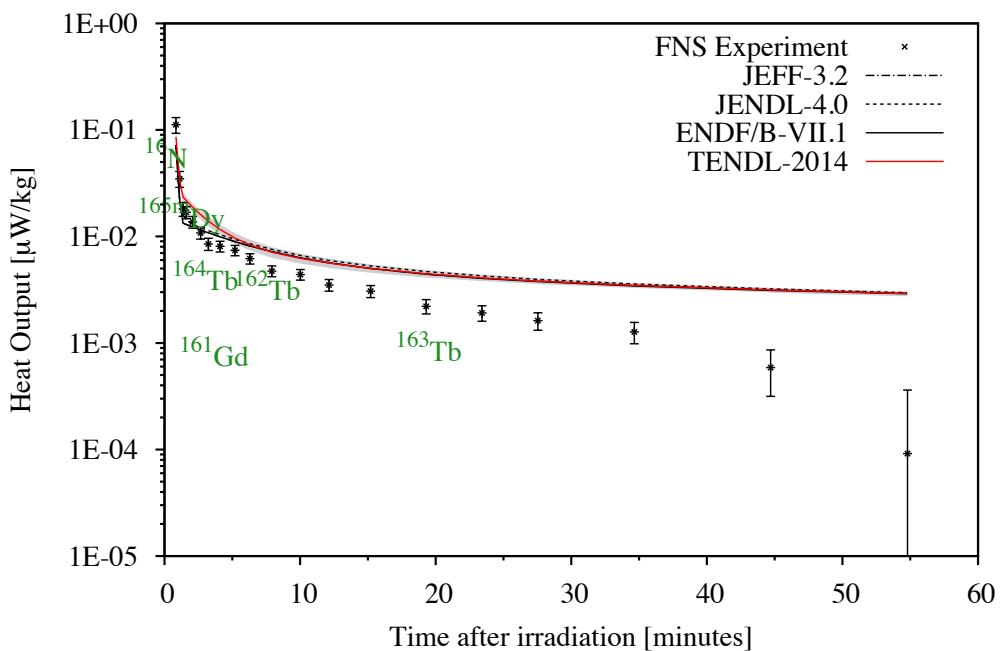
Times Min.	FNS EXP. 5 mins $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.60	$3.88E-01 +/- 23\%$	$1.18E-01 +/- 1\%$	3.30	4.40	4.36	4.76
0.85	$1.04E-01 +/- 24\%$	$4.82E-02 +/- 1\%$	2.16	3.50	3.42	4.05
1.12	$2.38E-02 +/- 32\%$	$9.60E-03 +/- 2\%$	2.48	4.50	4.23	5.60
1.37	$1.88E-03 +/- 174\%$	$2.21E-03 +/- 3\%$	0.85	1.57	1.34	1.29
1.63	$2.41E-04 +/- 1077\%$	$4.05E-04 +/- 5\%$	0.59	0.56	0.47	0.47
2.07	$1.70E-03 +/- 105\%$	$1.35E-04 +/- 7\%$	12.63	30.71	30.71	31.67
2.68	$2.16E-03 +/- 46\%$	$7.20E-05 +/- 12\%$	30.06	38.99	38.99	40.21
3.28	$2.65E-03 +/- 32\%$	$5.88E-05 +/- 15\%$	45.09	47.74	47.74	49.23
4.17	$5.31E-04 +/- 132\%$	$5.50E-05 +/- 16\%$	9.64	9.56	9.56	9.86
5.27	$3.23E-04 +/- 199\%$	$5.50E-05 +/- 16\%$	5.87	5.82	5.82	6.01
6.38	$4.94E-04 +/- 122\%$	$5.50E-05 +/- 16\%$	8.99	8.92	8.92	9.20
8.02	$4.08E-04 +/- 139\%$	$5.49E-05 +/- 16\%$	7.43	7.37	7.37	7.60
10.13	$5.46E-05 +/- 942\%$	$5.49E-05 +/- 16\%$	0.99	0.99	0.99	1.02
12.25	$1.62E-04 +/- 302\%$	$5.49E-05 +/- 16\%$	2.96	2.93	2.93	3.02
15.32	$1.64E-04 +/- 283\%$	$5.48E-05 +/- 16\%$	2.99	2.96	2.96	3.06
19.43	$2.90E-04 +/- 154\%$	$5.47E-05 +/- 16\%$	5.30	5.25	5.25	5.42
23.55	$5.27E-04 +/- 83\%$	$5.46E-05 +/- 16\%$	9.65	9.56	9.56	9.86
27.62	$5.14E-04 +/- 84\%$	$5.45E-05 +/- 16\%$	9.43	9.35	9.35	9.64
34.73	$5.29E-04 +/- 81\%$	$5.44E-05 +/- 16\%$	9.73	9.64	9.64	9.95
44.85	$2.20E-04 +/- 193\%$	$5.42E-05 +/- 16\%$	4.07	4.03	4.03	4.15
54.92	$7.40E-04 +/- 59\%$	$5.40E-05 +/- 16\%$	13.70	13.56	13.56	13.99
mean % diff. from E			74	78	79	80

Product	Pathways	T_{1/2}	Path %	E/C	ΔE%
Tb158m	Tb159(n,2n)Tb158m	10.8s	100.0	0.85	174%
Gd159	Tb159(n,p)Gd159	18.4h	100.0	4.07	193%



Dysprosium

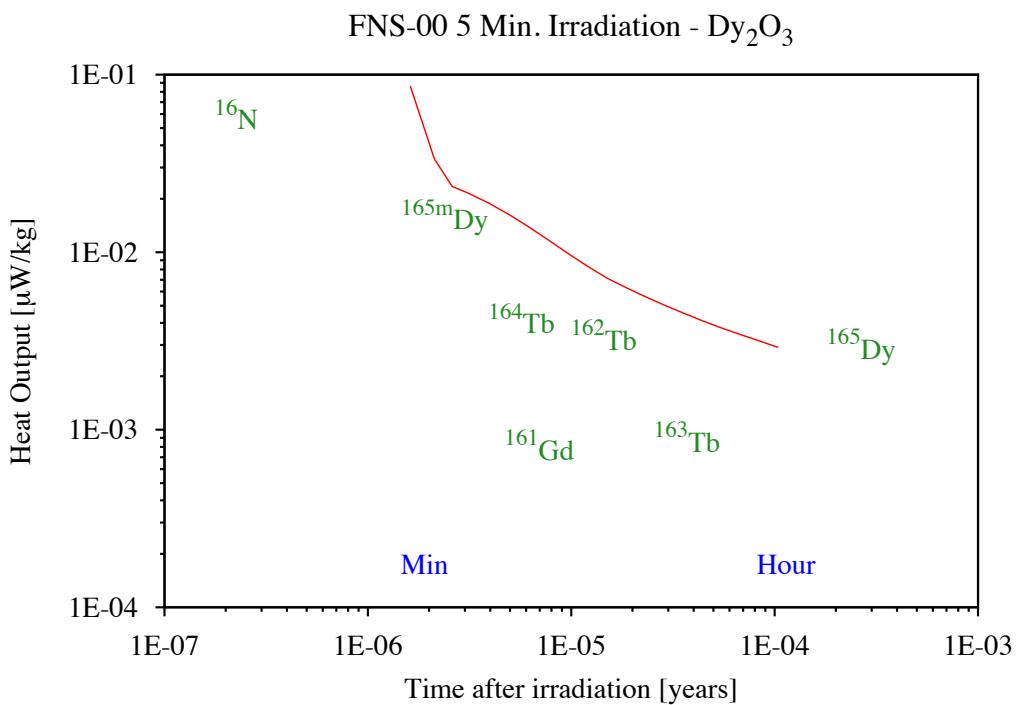
FNS-00 5 Min. Irradiation - Dy₂O₃

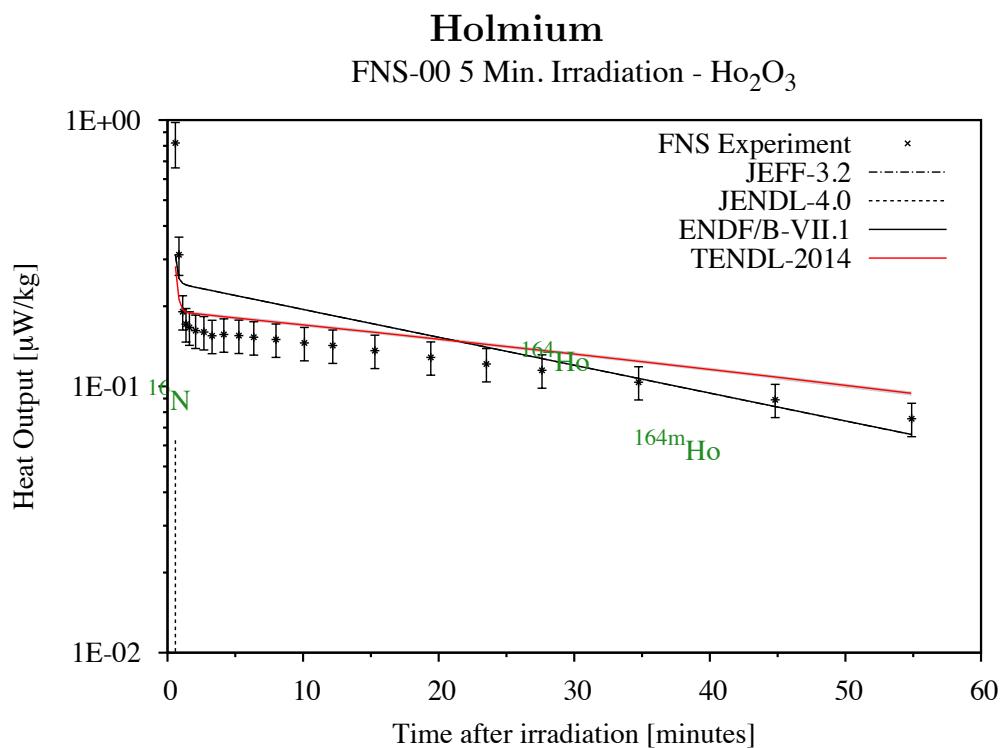


For Dysprosium, the complex routes of production and the presence of many contributing isotopes, make interpretation of the results extremely difficult. However, the production pathways from all libraries need to be carefully examined.

Times Min.	FNS EXP. 5 mins μW/g	TENDL-2014 μW/g	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.85	$1.12E-01$ +/-17%	$8.62E-02$ +/-3%	1.30	1.55	1.54	1.58
1.12	$3.48E-02$ +/-17%	$3.35E-02$ +/-6%	1.04	1.60	1.60	1.62
1.37	$1.81E-02$ +/-15%	$2.34E-02$ +/-8%	0.77	1.36	1.36	1.13
1.62	$1.69E-02$ +/-13%	$2.17E-02$ +/-9%	0.78	1.30	1.30	1.18
2.07	$1.37E-02$ +/-13%	$1.89E-02$ +/-9%	0.73	1.12	1.12	1.06
2.67	$1.08E-02$ +/-13%	$1.60E-02$ +/-10%	0.67	0.94	0.94	0.90
3.23	$8.50E-03$ +/-13%	$1.39E-02$ +/-10%	0.61	0.79	0.79	0.75
4.10	$8.08E-03$ +/-12%	$1.16E-02$ +/-11%	0.70	0.82	0.82	0.78
5.20	$7.42E-03$ +/-11%	$9.64E-03$ +/-12%	0.77	0.83	0.83	0.79
6.30	$6.20E-03$ +/-11%	$8.36E-03$ +/-12%	0.74	0.76	0.76	0.72
7.92	$4.74E-03$ +/-12%	$7.12E-03$ +/-11%	0.66	0.66	0.66	0.62
10.02	$4.39E-03$ +/-11%	$6.23E-03$ +/-11%	0.71	0.70	0.70	0.66
12.13	$3.50E-03$ +/-12%	$5.63E-03$ +/-10%	0.62	0.62	0.62	0.59
15.20	$3.07E-03$ +/-13%	$5.01E-03$ +/-9%	0.61	0.61	0.61	0.58
19.30	$2.21E-03$ +/-15%	$4.47E-03$ +/-8%	0.49	0.50	0.50	0.47
23.42	$1.92E-03$ +/-17%	$4.09E-03$ +/-7%	0.47	0.47	0.47	0.45
27.53	$1.62E-03$ +/-19%	$3.81E-03$ +/-6%	0.42	0.43	0.43	0.41
34.65	$1.27E-03$ +/-23%	$3.47E-03$ +/-6%	0.37	0.37	0.37	0.35
44.70	$5.88E-04$ +/-46%	$3.15E-03$ +/-5%	0.19	0.19	0.19	0.18
54.80	$9.15E-05$ +/-296%	$2.91E-03$ +/-5%	0.03	0.03	0.03	0.03
mean % diff. from E		230	224	226	232	

Product	Pathways	T_{1/2}	Path %	E/C	ΔE%
Dy165m	Dy164(n, γ)Dy165m	1.2m	98.3	0.77	15%
Tb164	Dy164(n,p)Tb164	3.0m	99.2	0.61	13%
Tb162	Dy162(n,p)Tb162	7.6m	93.2	0.66	12%
	Dy163(n,np)Tb162		1.9	0.66	12%
	Dy163(n,d)Tb162		4.7	0.66	12%
Dy165	Dy164(n, γ)Dy165	2.3h	40.2	0.19	23%
	Dy164(n, γ)Dy165m	1.2m	60.3	0.19	23%

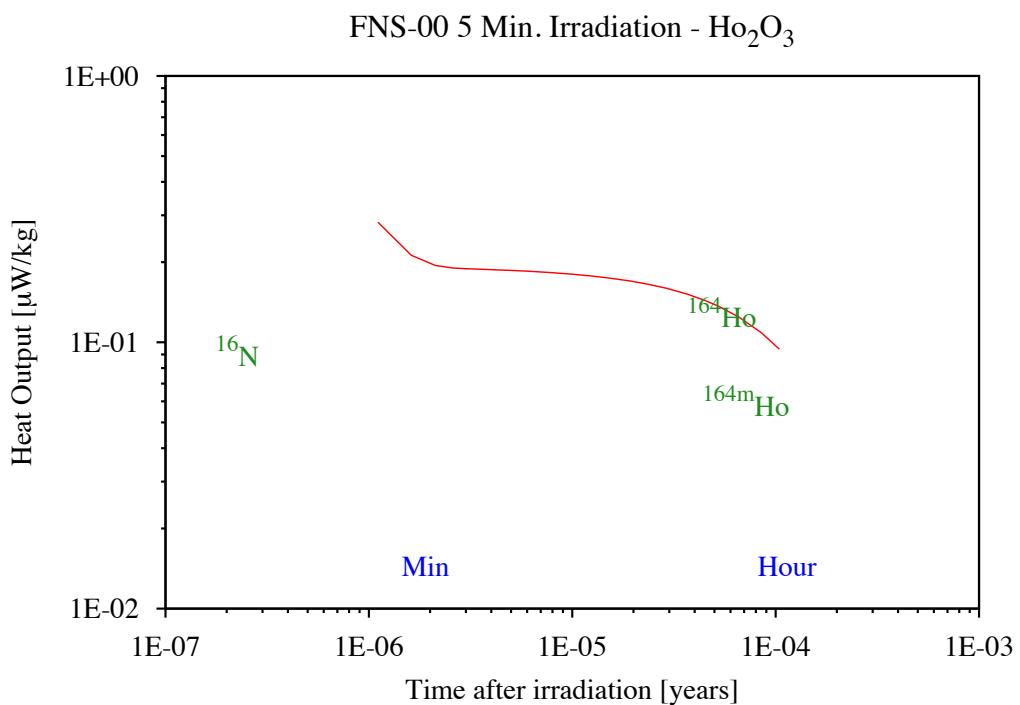


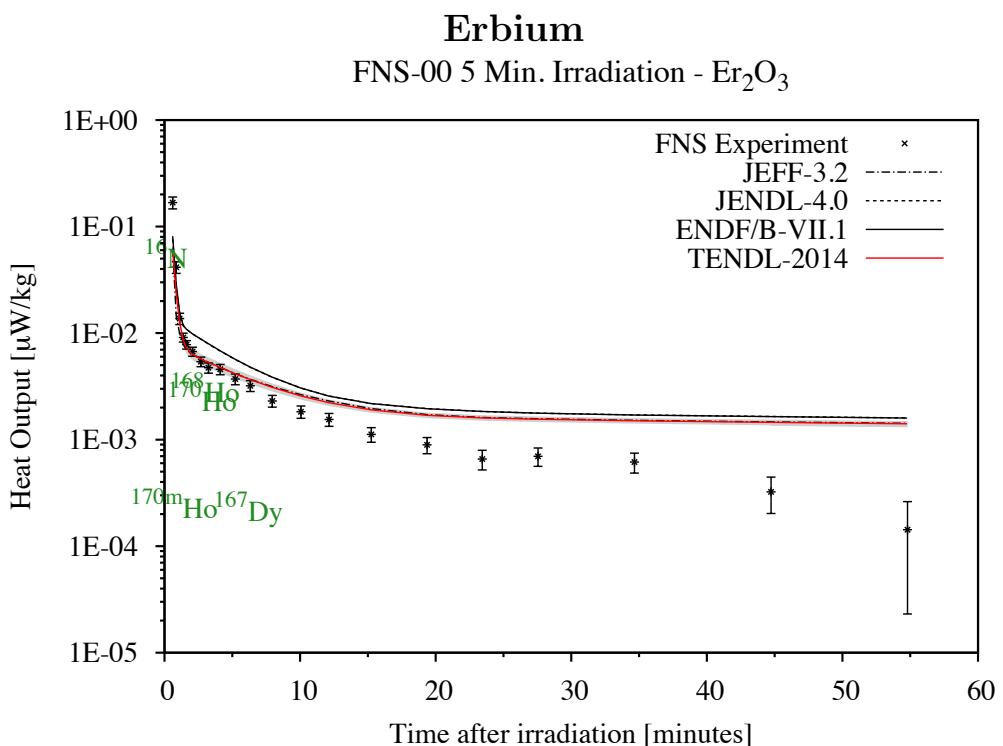


For the lanthanide Holmium, the interpretation is not too bad (except with JENDL-4.0), and the experiment gives a rare insight into possible half life and/or branching ratio corrections. As a reminder, the decay data was the only reason behind the factor two over-prediction in the previous generation of libraries [14].

Times Min.	FNS EXP. 5 mins $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C
0.58	$8.20E-01$ +/-19%	$2.82E-01$ +/-1%	2.91	2.63	2.63
0.85	$3.12E-01$ +/-16%	$2.12E-01$ +/-1%	1.47	1.23	1.23
1.12	$1.91E-01$ +/-15%	$1.94E-01$ +/-1%	0.98	0.78	0.78
1.37	$1.71E-01$ +/-14%	$1.90E-01$ +/-2%	0.90	0.71	0.71
1.62	$1.67E-01$ +/-14%	$1.89E-01$ +/-2%	0.88	0.70	0.70
2.07	$1.62E-01$ +/-14%	$1.88E-01$ +/-2%	0.86	0.69	0.69
2.68	$1.60E-01$ +/-14%	$1.86E-01$ +/-2%	0.86	0.69	0.69
3.28	$1.55E-01$ +/-14%	$1.85E-01$ +/-2%	0.84	0.68	0.68
4.15	$1.57E-01$ +/-14%	$1.83E-01$ +/-2%	0.86	0.70	0.70
5.27	$1.55E-01$ +/-14%	$1.80E-01$ +/-2%	0.86	0.71	0.71
6.37	$1.53E-01$ +/-14%	$1.78E-01$ +/-2%	0.86	0.72	0.72
8.00	$1.50E-01$ +/-14%	$1.74E-01$ +/-2%	0.86	0.73	0.73
10.10	$1.45E-01$ +/-14%	$1.70E-01$ +/-2%	0.86	0.75	0.75
12.18	$1.42E-01$ +/-14%	$1.66E-01$ +/-2%	0.86	0.77	0.77
15.30	$1.36E-01$ +/-14%	$1.59E-01$ +/-2%	0.85	0.80	0.80
19.42	$1.29E-01$ +/-14%	$1.52E-01$ +/-2%	0.85	0.83	0.83
23.52	$1.21E-01$ +/-14%	$1.44E-01$ +/-2%	0.84	0.86	0.86
27.62	$1.15E-01$ +/-14%	$1.36E-01$ +/-2%	0.84	0.90	0.90
34.75	$1.04E-01$ +/-14%	$1.24E-01$ +/-2%	0.83	0.97	0.97
44.82	$8.90E-02$ +/-14%	$1.08E-01$ +/-2%	0.82	1.06	1.06
54.88	$7.56E-02$ +/-14%	$9.42E-02$ +/-2%	0.80	1.14	1.15
mean % diff. from E		20	31	31	100

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Ho164	Ho165(n,2n)Ho164	28.6m	95.8	0.84	14%
	Ho165(n,2n)Ho164m	37.6m	4.2	0.83	14%
Ho164m	Ho165(n,2n)Ho164m	37.6m	100.0	0.83	14%

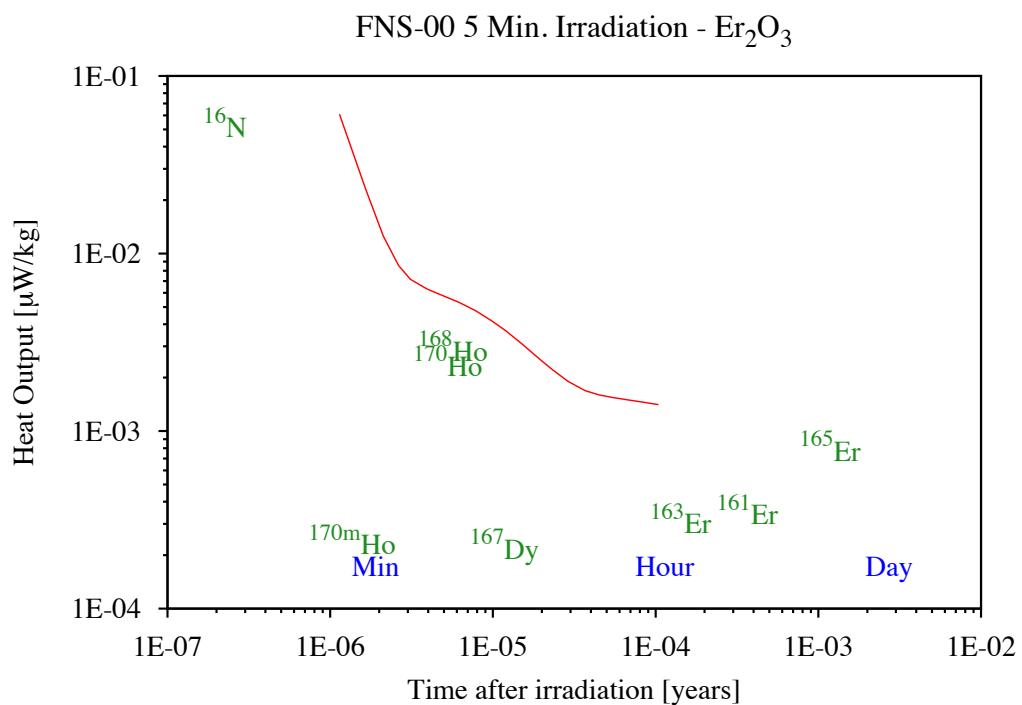


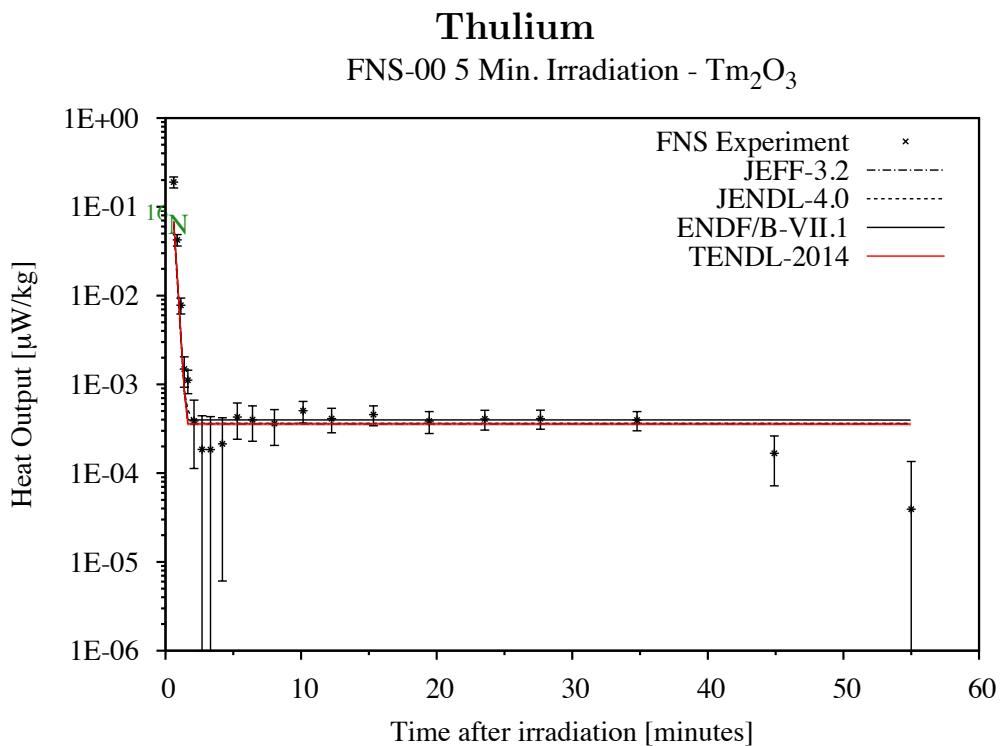


For Erbium, here again a rare insight of what may be a half life problem, shadowing the response of the isotopes that shape the decay heat underneath.

Times Min.	FNS EXP. 5 mins		TENDL-2014		ENDF/B-VII.1		JEFF-3.2	JENDL-4.0
	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C	E/C		
0.60	$1.68E-01$ +/-13%	$6.09E-02$ +/-2%	2.76	2.07	2.69	2.20		
0.87	$4.15E-02$ +/-12%	$2.32E-02$ +/-4%	1.79	1.44	2.89	1.57		
1.12	$1.37E-02$ +/-12%	$1.25E-02$ +/-7%	1.09	0.89	1.39	0.91		
1.38	$9.10E-03$ +/-10%	$8.56E-03$ +/-10%	1.06	0.77	1.16	0.77		
1.63	$7.79E-03$ +/-9%	$7.16E-03$ +/-11%	1.09	0.72	1.11	0.72		
2.07	$6.71E-03$ +/-10%	$6.31E-03$ +/-12%	1.06	0.68	1.07	0.68		
2.68	$5.39E-03$ +/-10%	$5.71E-03$ +/-12%	0.94	0.61	0.94	0.62		
3.25	$4.73E-03$ +/-11%	$5.31E-03$ +/-11%	0.89	0.60	0.89	0.60		
4.12	$4.57E-03$ +/-11%	$4.76E-03$ +/-11%	0.96	0.67	0.96	0.67		
5.22	$3.70E-03$ +/-11%	$4.16E-03$ +/-10%	0.89	0.65	0.89	0.65		
6.33	$3.20E-03$ +/-12%	$3.66E-03$ +/-10%	0.87	0.67	0.87	0.67		
7.95	$2.31E-03$ +/-13%	$3.09E-03$ +/-9%	0.75	0.60	0.74	0.60		
10.07	$1.83E-03$ +/-13%	$2.57E-03$ +/-8%	0.71	0.60	0.69	0.60		
12.13	$1.54E-03$ +/-14%	$2.22E-03$ +/-7%	0.69	0.60	0.67	0.60		
15.25	$1.12E-03$ +/-16%	$1.90E-03$ +/-6%	0.59	0.51	0.57	0.51		
19.37	$8.93E-04$ +/-17%	$1.69E-03$ +/-6%	0.53	0.46	0.52	0.46		
23.43	$6.57E-04$ +/-21%	$1.60E-03$ +/-6%	0.41	0.36	0.41	0.36		
27.55	$6.98E-04$ +/-20%	$1.55E-03$ +/-6%	0.45	0.39	0.44	0.39		
34.67	$6.16E-04$ +/-21%	$1.50E-03$ +/-6%	0.41	0.36	0.41	0.36		
44.73	$3.24E-04$ +/-37%	$1.45E-03$ +/-6%	0.22	0.20	0.22	0.20		
54.80	$1.42E-04$ +/-84%	$1.41E-03$ +/-6%	0.10	0.09	0.10	0.09		
mean % diff. from E				100	135	105	136	

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Ho168	Er168(n,p)Ho168	2.9m	66.4	0.94	10%
	Er168(n,p)Ho168m	2.2m	34.3	0.94	10%
Er165	Er166(n,2n)Er165	10.3h	99.6	0.20	37%

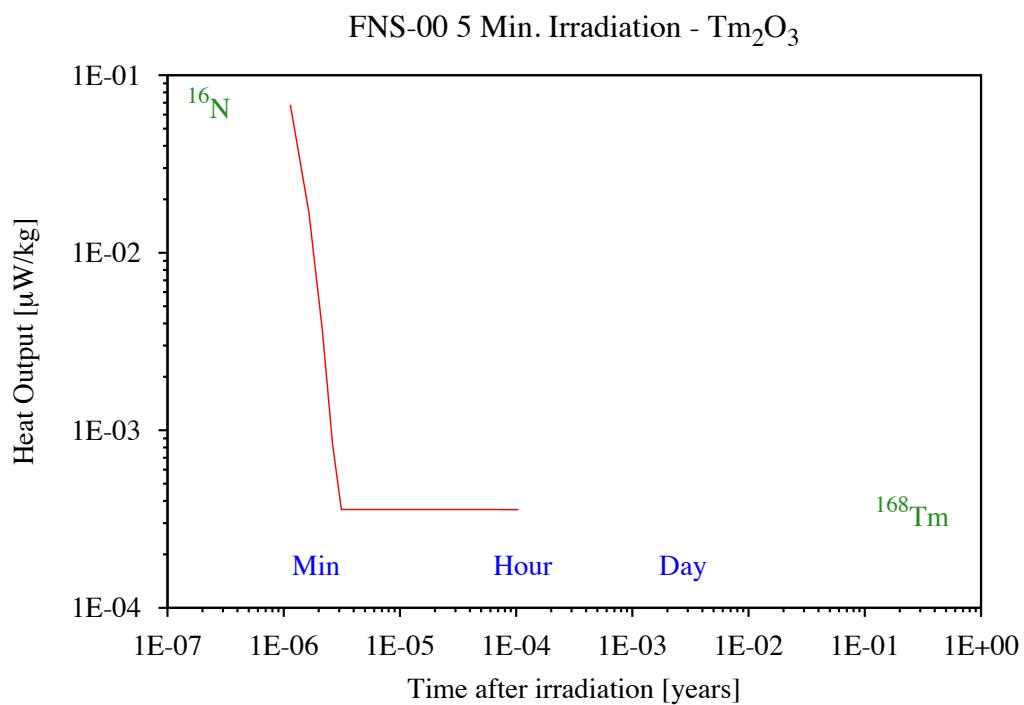


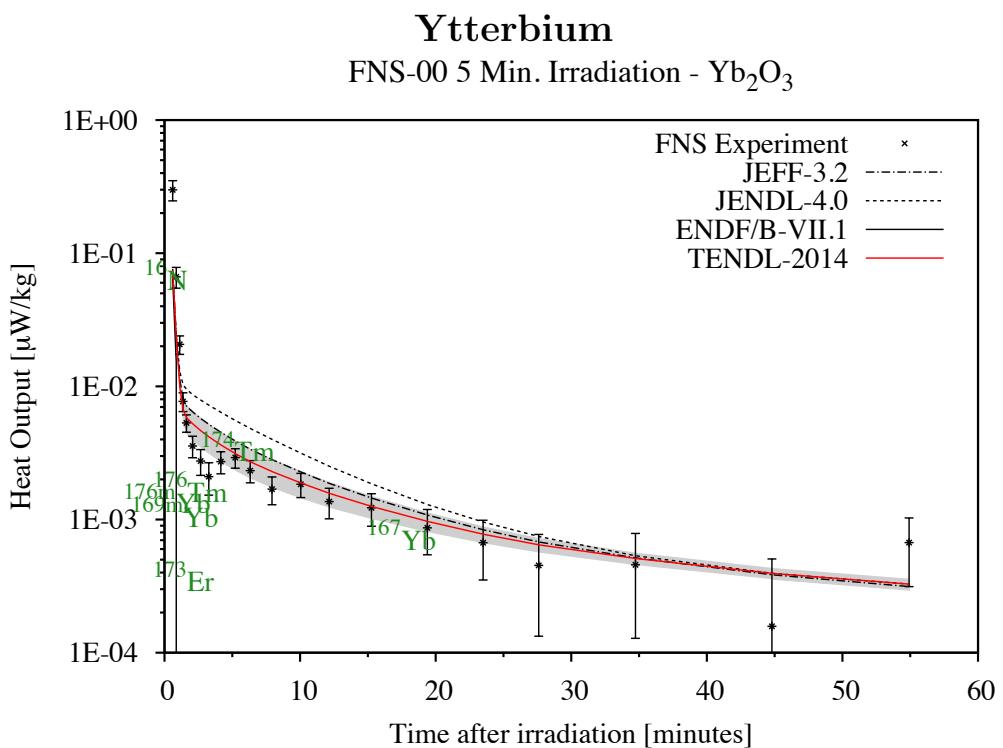


For the lanthanide Thulium, the representation of the experimental data is not too bad, allowing for the large experimental uncertainties at short and long cooling times, and the possibility of some missing isomers in the calculational paths.

Times Min.	FNS EXP. 5 mins $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C
0.60	$1.90E-01$ +/-14%	$6.82E-02$ +/-0%	2.78	2.79	2.79
0.87	$4.24E-02$ +/-15%	$1.68E-02$ +/-0%	2.53	2.57	2.53
1.13	$7.78E-03$ +/-20%	$3.62E-03$ +/-0%	2.15	2.15	2.15
1.38	$1.49E-03$ +/-38%	$8.45E-04$ +/-2%	1.76	1.69	1.76
1.65	$1.12E-03$ +/-30%	$3.58E-04$ +/-4%	3.12	2.80	3.11
2.10	$3.88E-04$ +/-71%	$3.58E-04$ +/-4%	1.08	0.97	1.08
2.70	$1.85E-04$ +/-140%	$3.58E-04$ +/-4%	0.52	0.46	0.51
3.32	$1.84E-04$ +/-136%	$3.58E-04$ +/-4%	0.51	0.46	0.51
4.20	$2.14E-04$ +/-97%	$3.58E-04$ +/-4%	0.60	0.54	0.59
5.30	$4.29E-04$ +/-44%	$3.58E-04$ +/-4%	1.20	1.08	1.19
6.42	$4.01E-04$ +/-43%	$3.58E-04$ +/-4%	1.12	1.01	1.12
8.03	$3.62E-04$ +/-43%	$3.58E-04$ +/-4%	1.01	0.91	1.01
10.15	$5.04E-04$ +/-27%	$3.58E-04$ +/-4%	1.41	1.27	1.40
12.25	$4.11E-04$ +/-31%	$3.58E-04$ +/-4%	1.15	1.03	1.15
15.33	$4.57E-04$ +/-25%	$3.58E-04$ +/-4%	1.28	1.15	1.27
19.45	$3.87E-04$ +/-28%	$3.58E-04$ +/-4%	1.08	0.97	1.08
23.55	$4.07E-04$ +/-25%	$3.58E-04$ +/-4%	1.14	1.02	1.14
27.65	$4.12E-04$ +/-24%	$3.58E-04$ +/-4%	1.15	1.04	1.15
34.78	$3.97E-04$ +/-25%	$3.58E-04$ +/-4%	1.11	1.00	1.11
44.90	$1.67E-04$ +/-57%	$3.58E-04$ +/-4%	0.47	0.42	0.47
55.00	$3.92E-05$ +/-245%	$3.58E-04$ +/-4%	0.11	0.10	0.11
mean % diff. from E		77	82	77	77

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Tm168	Tm169(n,2n)Tm168	93.1d	100.0	1.11	25%

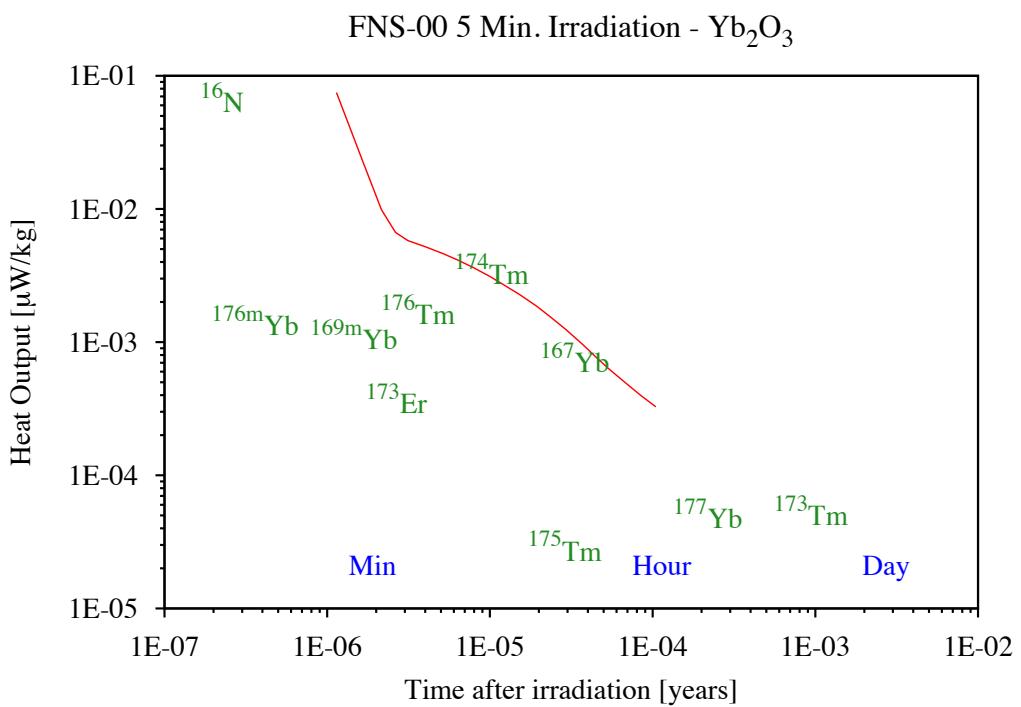


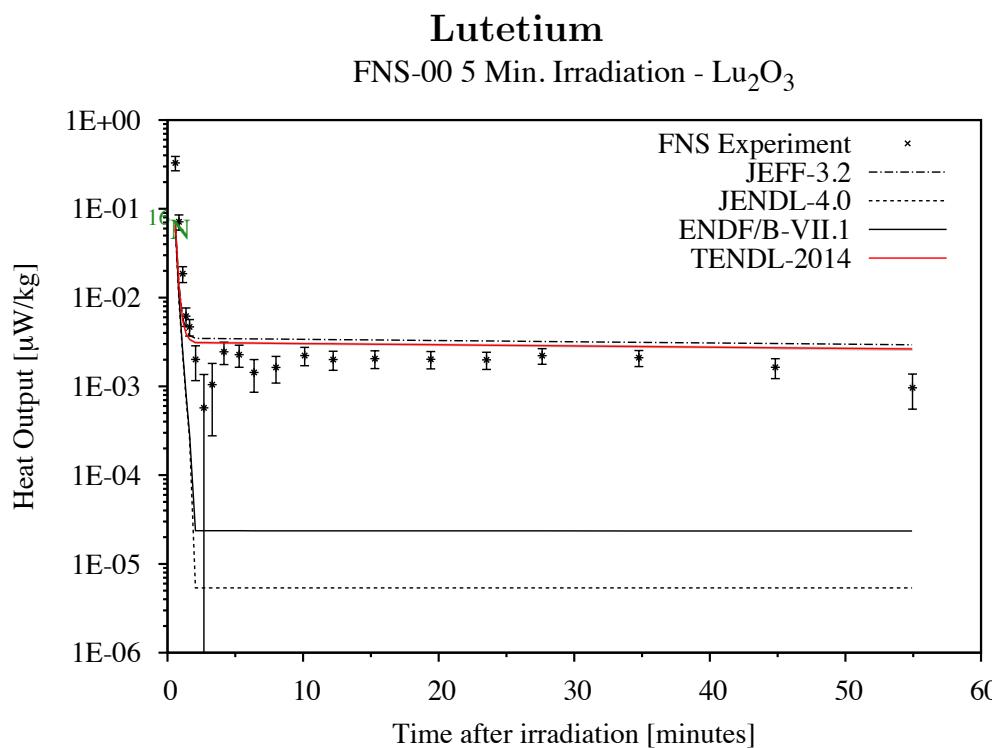


For Ytterbium, one can see a reasonable agreement for this element except with ENDF/B-VII.1, even allowing for the high experimental uncertainties and the many isotopes underlying the decay heat response function.

Times Min.	FNS EXP. 5 mins $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.60	$2.99E-01$ +/-17%	$7.48E-02$ +/-2%	3.99	4.56	3.92	4.17
0.87	$6.64E-02$ +/-18%	$2.31E-02$ +/-7%	2.88	4.39	2.72	2.83
1.12	$2.07E-02$ +/-16%	$9.85E-03$ +/-16%	2.10	0.00	1.85	1.61
1.37	$7.71E-03$ +/-16%	$6.67E-03$ +/-23%	1.16	0.00	0.97	0.76
1.62	$5.31E-03$ +/-15%	$5.78E-03$ +/-25%	0.92	0.00	0.75	0.56
2.07	$3.57E-03$ +/-18%	$5.21E-03$ +/-25%	0.68	0.00	0.56	0.41
2.67	$2.75E-03$ +/-22%	$4.63E-03$ +/-26%	0.59	0.00	0.48	0.35
3.27	$2.10E-03$ +/-27%	$4.15E-03$ +/-26%	0.51	0.00	0.41	0.29
4.15	$2.72E-03$ +/-19%	$3.61E-03$ +/-26%	0.75	0.00	0.61	0.43
5.22	$2.92E-03$ +/-17%	$3.09E-03$ +/-26%	0.94	0.00	0.76	0.53
6.32	$2.33E-03$ +/-19%	$2.69E-03$ +/-25%	0.86	0.00	0.70	0.49
7.93	$1.69E-03$ +/-24%	$2.27E-03$ +/-25%	0.75	0.00	0.61	0.43
10.05	$1.84E-03$ +/-21%	$1.87E-03$ +/-23%	0.99	0.00	0.82	0.59
12.15	$1.36E-03$ +/-26%	$1.56E-03$ +/-22%	0.87	0.00	0.74	0.55
15.27	$1.23E-03$ +/-27%	$1.25E-03$ +/-20%	0.98	0.00	0.85	0.67
19.38	$8.66E-04$ +/-37%	$9.66E-04$ +/-17%	0.90	0.00	0.80	0.67
23.50	$6.69E-04$ +/-48%	$7.75E-04$ +/-14%	0.86	0.00	0.80	0.70
27.60	$4.53E-04$ +/-71%	$6.45E-04$ +/-13%	0.70	0.00	0.67	0.61
34.73	$4.57E-04$ +/-72%	$5.09E-04$ +/-11%	0.90	0.00	0.89	0.86
44.80	$1.58E-04$ +/-221%	$3.94E-04$ +/-10%	0.40	0.00	0.41	0.40
54.92	$6.70E-04$ +/-53%	$3.27E-04$ +/-10%	2.05	0.00	2.14	2.05
mean % diff. from E		39	98	54	90	

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Tm174	Yb174(n,p)Tm174	5.4m	99.6	0.94	17%
Yb167	Yb168(n,2n)Yb167	17.5m	100.0	0.90	37%

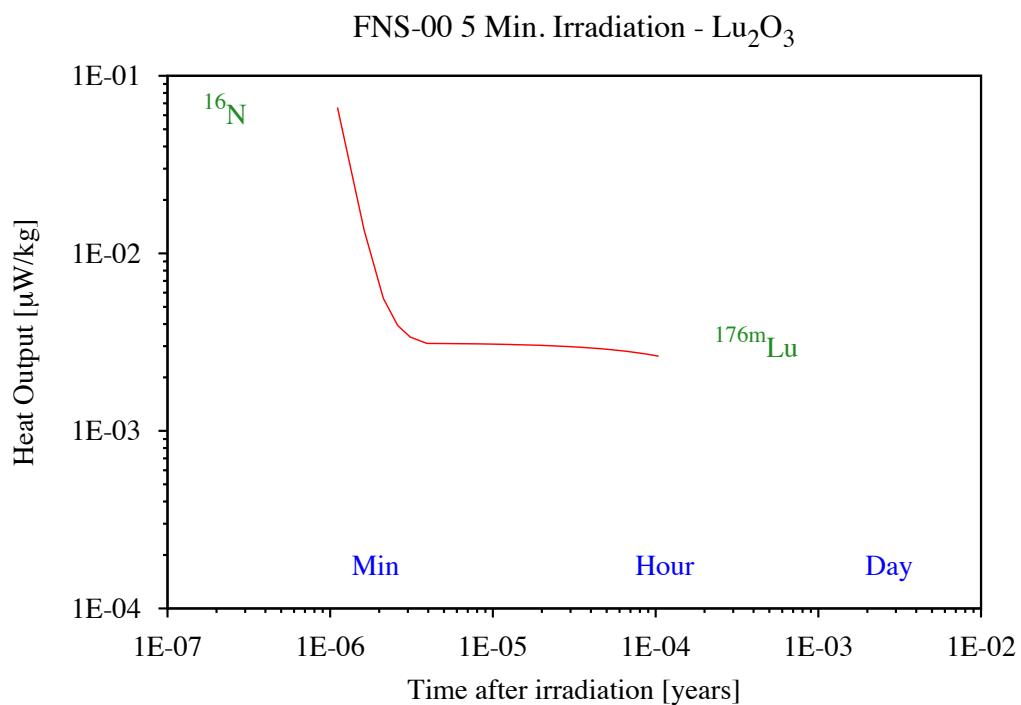


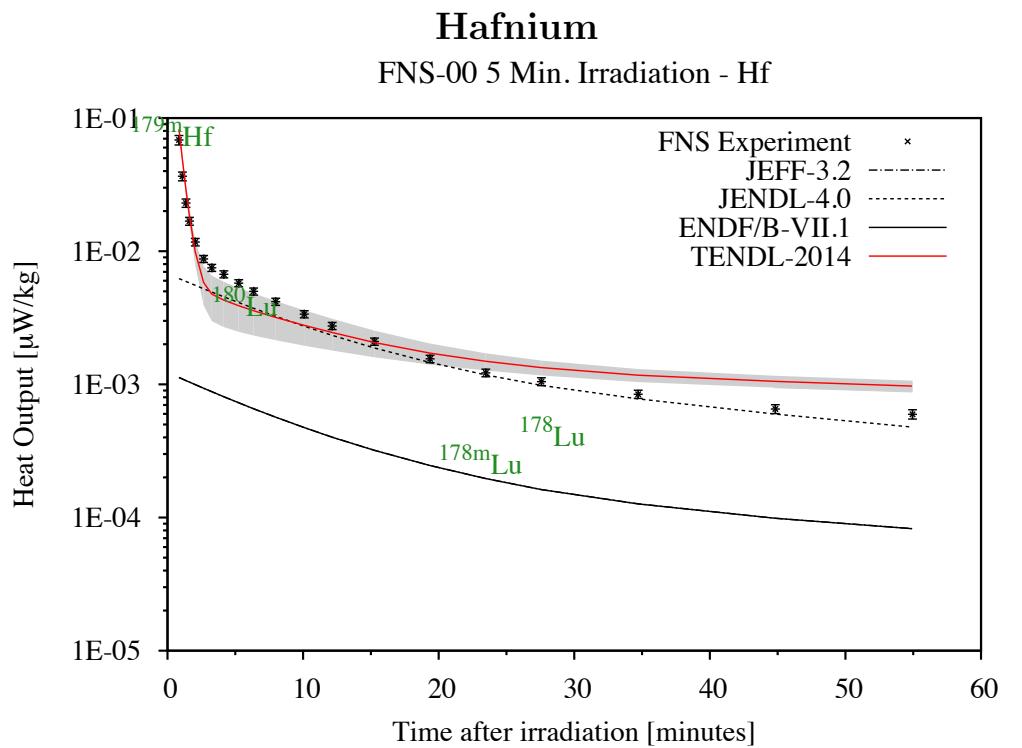


For Lutetium, once again the experimental results in the minute ranges show some structures missing in the simulations, possibly underlying a lack of isomeric state and associated decay data, or an incorrect level of the subtracted tape contribution in the experiment. ENDF/B.VII.1, JEFF-3.2 and JENDL-4.0 lack the Lu176m isomeric production pathways.

Times Min.	FNS EXP. 5 mins $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1		JEFF-3.2 E/C	JENDL-4.0 E/C
			E/C	E/C		
0.58	$3.29E-01$ +/-18%	$6.64E-02$ +/-0%	4.96	5.20	4.93	5.58
0.85	$7.14E-02$ +/-19%	$1.35E-02$ +/-1%	5.29	6.93	5.15	7.86
1.12	$1.86E-02$ +/-20%	$5.57E-03$ +/-2%	3.33	7.52	3.12	8.19
1.37	$6.19E-03$ +/-24%	$3.92E-03$ +/-3%	1.58	7.42	1.44	8.37
1.63	$4.67E-03$ +/-21%	$3.38E-03$ +/-3%	1.38	16.20	1.25	18.11
2.07	$2.01E-03$ +/-42%	$3.11E-03$ +/-4%	0.65	85.18	0.58	375.06
2.68	$5.73E-04$ +/-137%	$3.10E-03$ +/-4%	0.18	24.26	0.17	106.84
3.30	$1.05E-03$ +/-74%	$3.10E-03$ +/-4%	0.34	44.27	0.30	194.89
4.17	$2.45E-03$ +/-28%	$3.09E-03$ +/-4%	0.79	103.74	0.71	456.67
5.28	$2.27E-03$ +/-28%	$3.08E-03$ +/-4%	0.74	96.18	0.66	423.32
6.38	$1.43E-03$ +/-40%	$3.07E-03$ +/-4%	0.47	60.63	0.42	266.81
8.00	$1.63E-03$ +/-33%	$3.05E-03$ +/-4%	0.54	69.20	0.48	304.45
10.12	$2.23E-03$ +/-23%	$3.03E-03$ +/-4%	0.73	94.39	0.66	415.12
12.22	$2.00E-03$ +/-24%	$3.01E-03$ +/-4%	0.66	84.79	0.60	372.83
15.30	$2.05E-03$ +/-23%	$2.98E-03$ +/-4%	0.69	86.83	0.62	381.59
19.42	$2.02E-03$ +/-22%	$2.95E-03$ +/-4%	0.69	85.77	0.62	376.74
23.53	$1.99E-03$ +/-22%	$2.91E-03$ +/-4%	0.68	84.43	0.61	370.59
27.63	$2.21E-03$ +/-20%	$2.87E-03$ +/-4%	0.77	94.07	0.69	412.70
34.77	$2.10E-03$ +/-21%	$2.81E-03$ +/-4%	0.75	89.28	0.67	391.27
44.83	$1.64E-03$ +/-25%	$2.72E-03$ +/-4%	0.60	69.74	0.54	305.19
54.95	$9.65E-04$ +/-43%	$2.64E-03$ +/-4%	0.37	41.15	0.33	179.82
mean % diff. from E			85	96	101	97

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Lu176m	Lu175(n, γ)Lu176m	3.6h	90.1	0.75	21%
	Lu176(n,n')Lu176m		9.9	0.75	21%

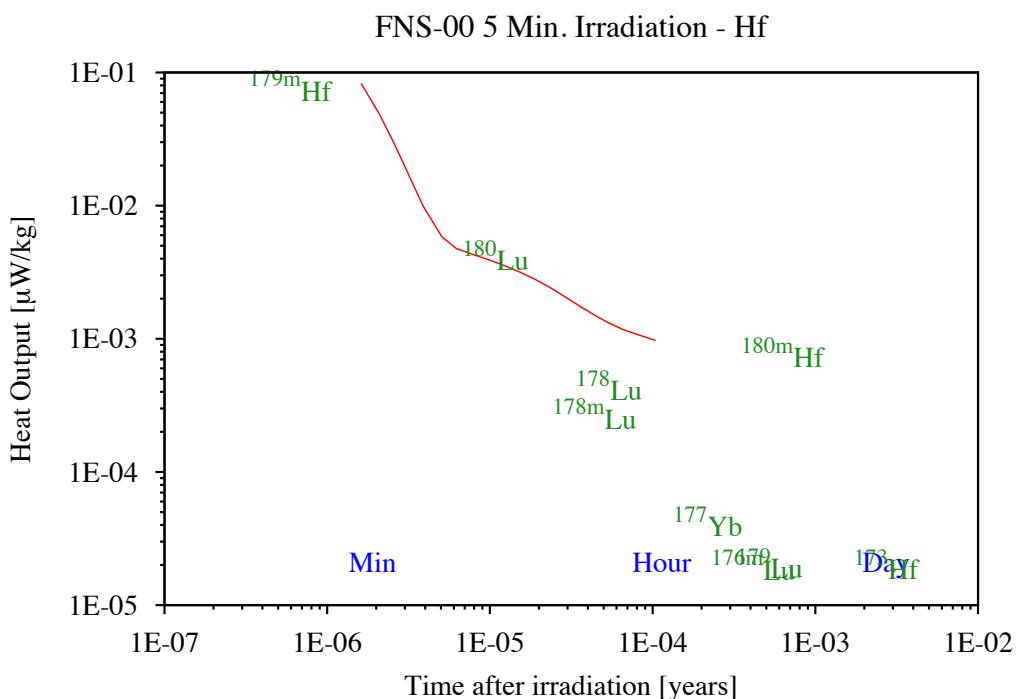




For Hafnium, the analysis of this element with anterior databases was extremely poorly interpreted because of a gross overestimation of the $\text{Hf}^{177}(\text{n},\text{n}')$ channel. With this overshadowing effect now taken out one can still observe half life and/or branching ratio inconsistencies, but TENDL's libraries shows a significant improvement over the earlier databases, with JENDL-4.0 performing better after 20 mn cooling.

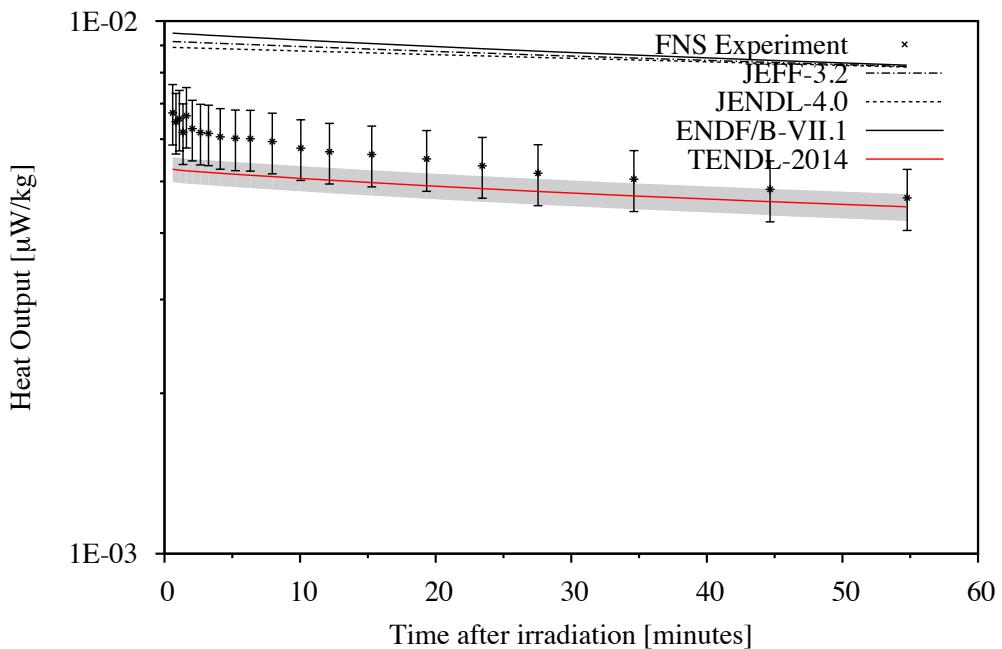
Times	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.85	$6.84E-02$ +/-8%	$8.25E-02$ +/-5%	0.83	60.71	60.70
1.10	$3.65E-02$ +/-8%	$4.88E-02$ +/-6%	0.75	33.30	33.30
1.37	$2.30E-02$ +/-7%	$2.88E-02$ +/-9%	0.80	21.54	21.53
1.62	$1.68E-02$ +/-7%	$1.84E-02$ +/-12%	0.91	16.17	16.16
2.05	$1.17E-02$ +/-6%	$9.86E-03$ +/-21%	1.19	11.76	11.76
2.67	$8.75E-03$ +/-6%	$5.83E-03$ +/-33%	1.50	9.36	9.36
3.27	$7.51E-03$ +/-6%	$4.76E-03$ +/-37%	1.58	8.52	8.52
4.15	$6.71E-03$ +/-6%	$4.30E-03$ +/-37%	1.56	8.31	8.30
5.25	$5.76E-03$ +/-6%	$3.90E-03$ +/-36%	1.48	7.92	7.91
6.35	$4.99E-03$ +/-6%	$3.58E-03$ +/-35%	1.39	7.61	7.60
7.98	$4.18E-03$ +/-6%	$3.18E-03$ +/-33%	1.31	7.36	7.36
10.08	$3.37E-03$ +/-6%	$2.78E-03$ +/-30%	1.21	7.10	7.10
12.15	$2.75E-03$ +/-6%	$2.45E-03$ +/-27%	1.12	6.84	6.84
15.27	$2.10E-03$ +/-6%	$2.06E-03$ +/-23%	1.02	6.56	6.56
19.37	$1.55E-03$ +/-6%	$1.72E-03$ +/-18%	0.91	6.32	6.32
23.48	$1.22E-03$ +/-7%	$1.49E-03$ +/-15%	0.82	6.22	6.22
27.58	$1.05E-03$ +/-7%	$1.34E-03$ +/-13%	0.78	6.47	6.47
34.72	$8.44E-04$ +/-7%	$1.17E-03$ +/-11%	0.72	6.66	6.65
44.83	$6.53E-04$ +/-8%	$1.05E-03$ +/-10%	0.62	6.62	6.61
54.95	$5.96E-04$ +/-8%	$9.72E-04$ +/-10%	0.61	7.24	7.23
mean	% diff. from E	27	88	88	32

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Hf179m	Hf178(n, γ)Hf179m	18.6s	14.1	0.83	8%
	Hf179(n,n')Hf179m		3.6	0.83	8%
	Hf180(n,2n)Hf179m		82.4	0.83	8%
Lu180	Hf180(n,p)Lu180	5.7m	100.0	1.48	6%
	Hf180(n,n')	5.5h	98.0	0.61	8%
	Hf179(n, γ)		2.0	0.61	8%

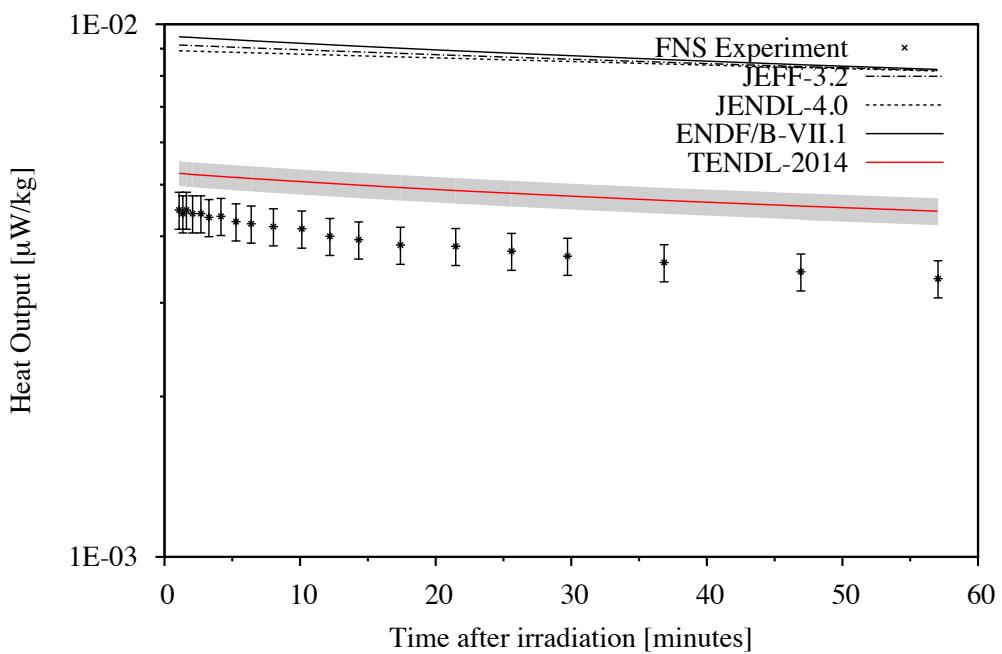


Tantalum

FNS-00 5 Min. Irradiation - Ta



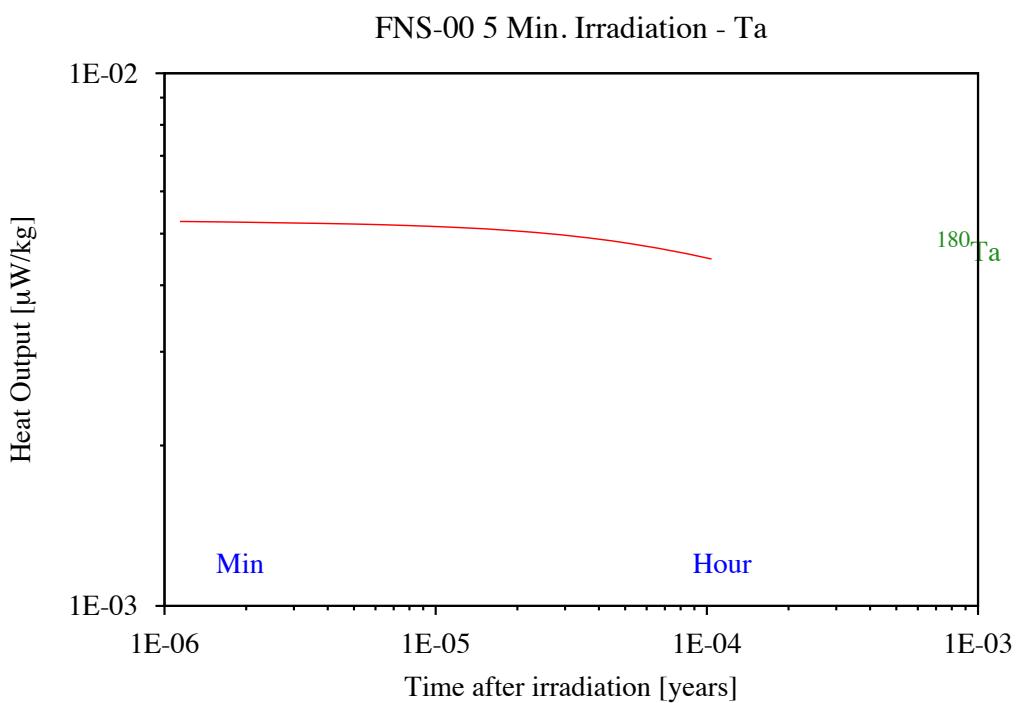
FNS-96 5 Min. Irradiation - Ta

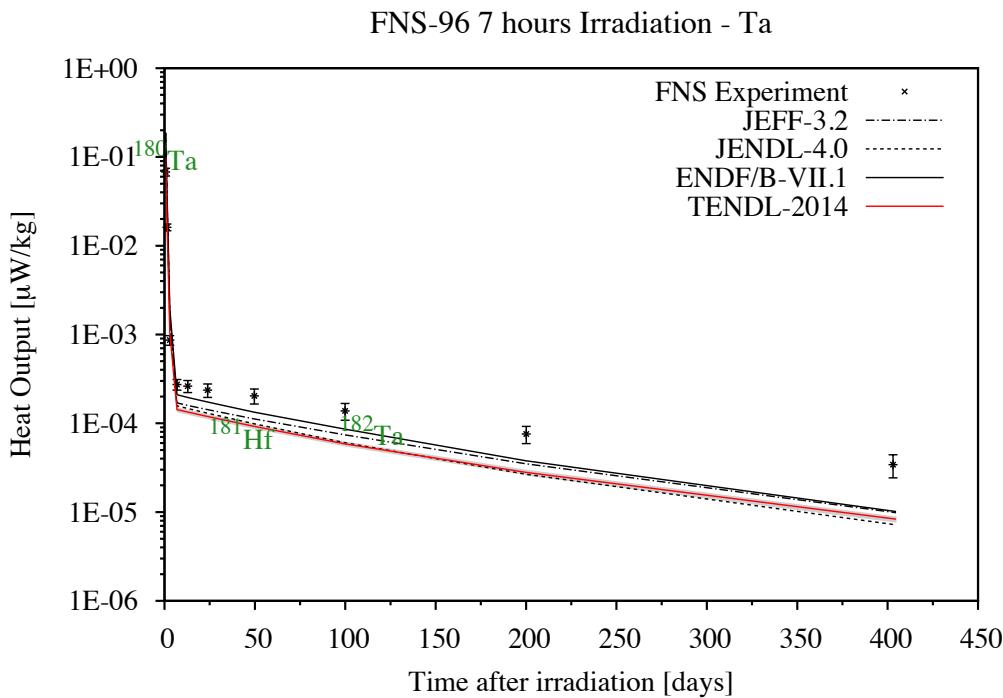


For Tantalum, once again there are some noticeable differences between the two experiments, but a within the experimental uncertainty band agreement exists for the latest, 2000, experiment when TENDL-2014 is used.

Times Min.	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0	
	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C	
0.60	$6.72E-03$ +/-13%	$5.27E-03$ +/-5%	1.28	0.71	0.73	0.75
0.85	$6.47E-03$ +/-13%	$5.26E-03$ +/-5%	1.23	0.68	0.71	0.73
1.10	$6.56E-03$ +/-13%	$5.25E-03$ +/-5%	1.25	0.69	0.72	0.74
1.37	$6.18E-03$ +/-13%	$5.24E-03$ +/-5%	1.18	0.65	0.68	0.69
1.62	$6.64E-03$ +/-13%	$5.23E-03$ +/-5%	1.27	0.70	0.73	0.75
2.05	$6.28E-03$ +/-13%	$5.22E-03$ +/-5%	1.20	0.67	0.69	0.71
2.65	$6.17E-03$ +/-13%	$5.21E-03$ +/-5%	1.18	0.65	0.68	0.69
3.25	$6.15E-03$ +/-13%	$5.20E-03$ +/-5%	1.18	0.65	0.68	0.69
4.12	$6.06E-03$ +/-13%	$5.18E-03$ +/-5%	1.17	0.65	0.67	0.68
5.23	$6.02E-03$ +/-13%	$5.16E-03$ +/-5%	1.17	0.64	0.67	0.68
6.33	$6.01E-03$ +/-13%	$5.14E-03$ +/-5%	1.17	0.65	0.67	0.68
7.95	$5.94E-03$ +/-13%	$5.10E-03$ +/-5%	1.16	0.64	0.66	0.67
10.05	$5.77E-03$ +/-13%	$5.06E-03$ +/-5%	1.14	0.63	0.64	0.66
12.17	$5.68E-03$ +/-13%	$5.03E-03$ +/-5%	1.13	0.62	0.64	0.65
15.28	$5.62E-03$ +/-13%	$4.97E-03$ +/-5%	1.13	0.62	0.63	0.64
19.33	$5.51E-03$ +/-13%	$4.91E-03$ +/-6%	1.12	0.61	0.63	0.64
23.43	$5.35E-03$ +/-13%	$4.85E-03$ +/-6%	1.10	0.60	0.61	0.62
27.55	$5.18E-03$ +/-13%	$4.79E-03$ +/-6%	1.08	0.59	0.60	0.61
34.62	$5.05E-03$ +/-13%	$4.70E-03$ +/-6%	1.08	0.58	0.59	0.60
44.67	$4.83E-03$ +/-13%	$4.58E-03$ +/-6%	1.05	0.57	0.58	0.58
54.78	$4.66E-03$ +/-13%	$4.48E-03$ +/-6%	1.04	0.56	0.57	0.57
mean % diff. from E		13	58	53	51	

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Ta180	Ta181(n,2n)Ta180	8.0h	100.0	1.04	13%

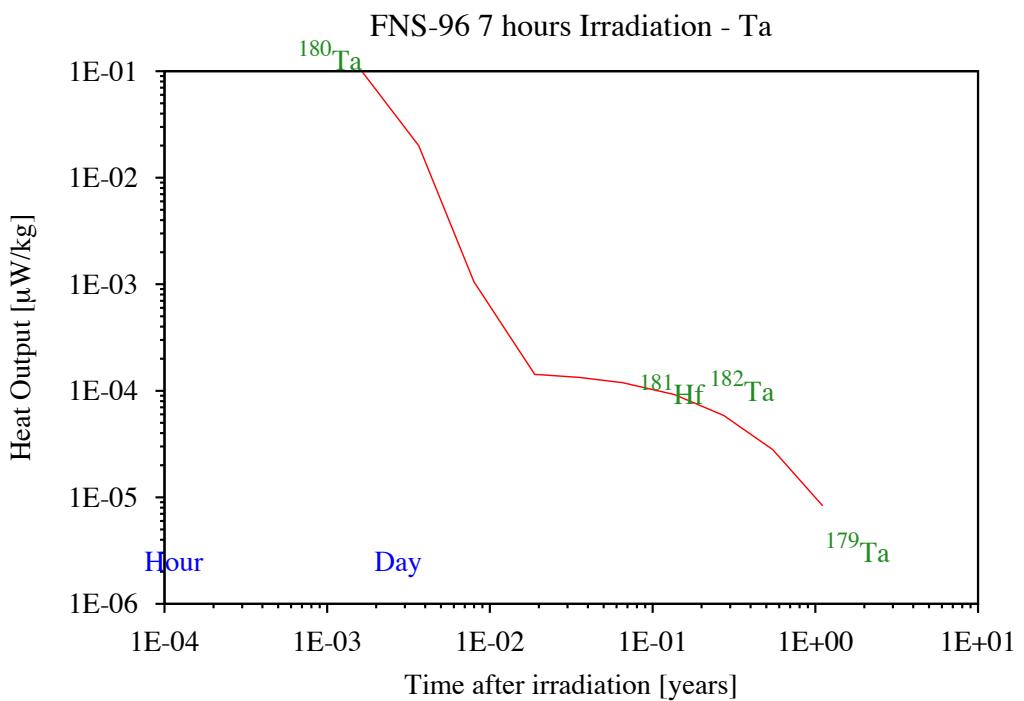




The presence of capture pathways and multiple isomeric states, do not allow for a definite interpretation to be made in this complex case.

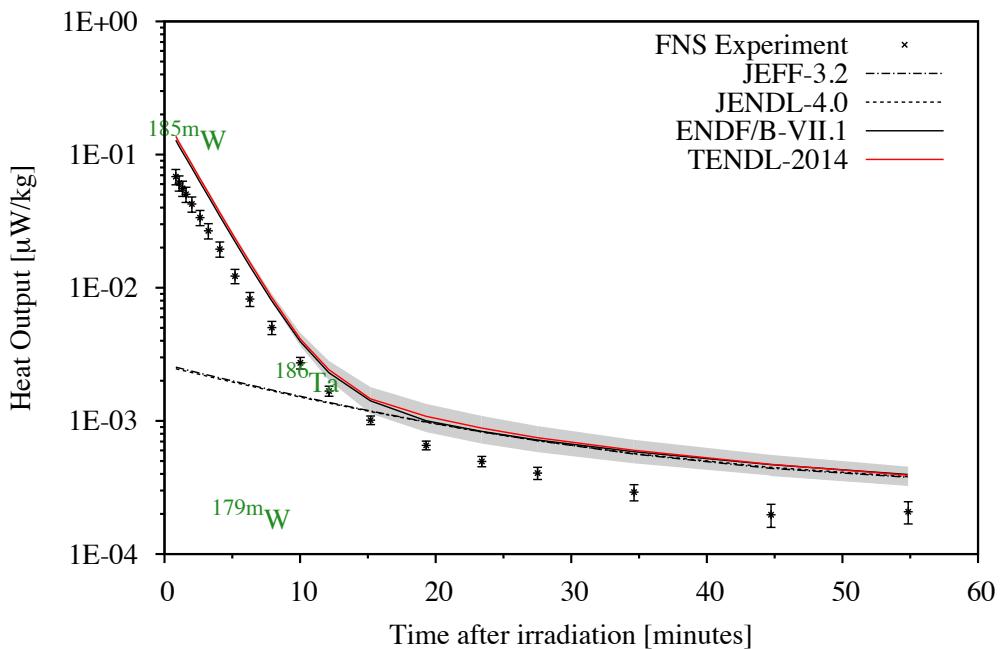
Times	FNS EXP. 7 hrs	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0	
Days	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C	
0.60	$6.79E-02$ +/-10%	$9.78E-02$ +/-6%	0.69	0.37	0.36	0.36
1.33	$1.62E-02$ +/-9%	$2.00E-02$ +/-6%	0.81	0.38	0.45	0.45
2.91	$8.64E-04$ +/-12%	$1.05E-03$ +/-5%	0.82	0.44	0.60	0.51
6.88	$2.73E-04$ +/-14%	$1.43E-04$ +/-7%	1.92	1.30	1.61	1.74
12.88	$2.63E-04$ +/-15%	$1.34E-04$ +/-7%	1.97	1.34	1.65	1.79
23.88	$2.36E-04$ +/-17%	$1.19E-04$ +/-7%	1.98	1.36	1.66	1.81
49.72	$2.04E-04$ +/-19%	$9.22E-05$ +/-6%	2.21	1.53	1.82	2.07
99.91	$1.38E-04$ +/-21%	$5.86E-05$ +/-7%	2.35	1.60	1.86	2.28
200.13	$7.57E-05$ +/-22%	$2.80E-05$ +/-7%	2.70	2.00	2.17	2.84
402.97	$3.42E-05$ +/-29%	$8.32E-06$ +/-7%	4.12	3.37	3.48	4.78
mean % diff. from E		49	73	70	78	

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Ta180	Ta181(n,2n)Ta180	8.0h	99.7	0.69	10%
Hf181	Ta181(n,p)Hf181	42.3d	100.0	2.21	19%
Ta182	Ta181(n, γ)Ta182	114d	61.8	2.35	22%
	Ta181(n, γ)Ta182m	0.3s	37.8	2.35	22%
	Ta181(n, γ)Ta182n	15.8m	0.0	2.35	22%

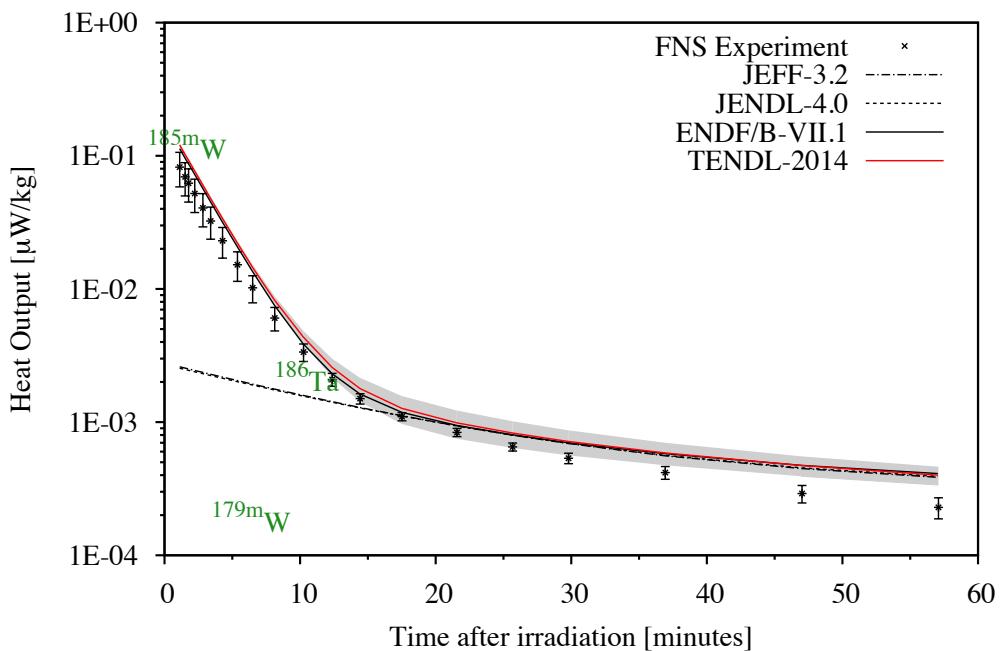


Tungsten

FNS-00 5 Min. Irradiation - W



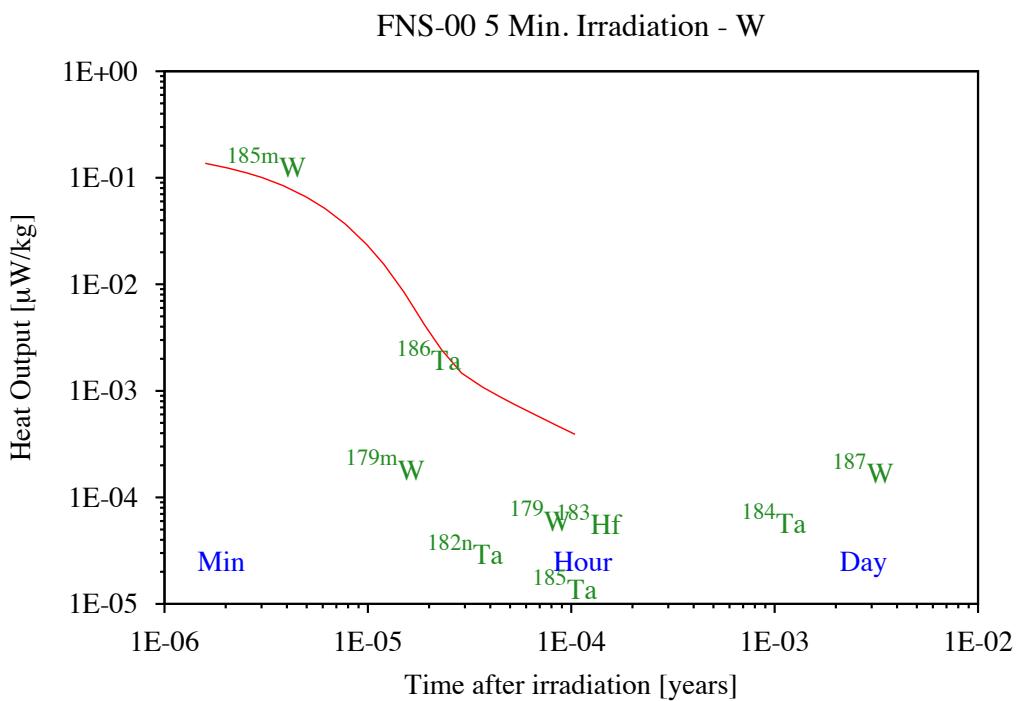
FNS-96 5 Min. Irradiation - W

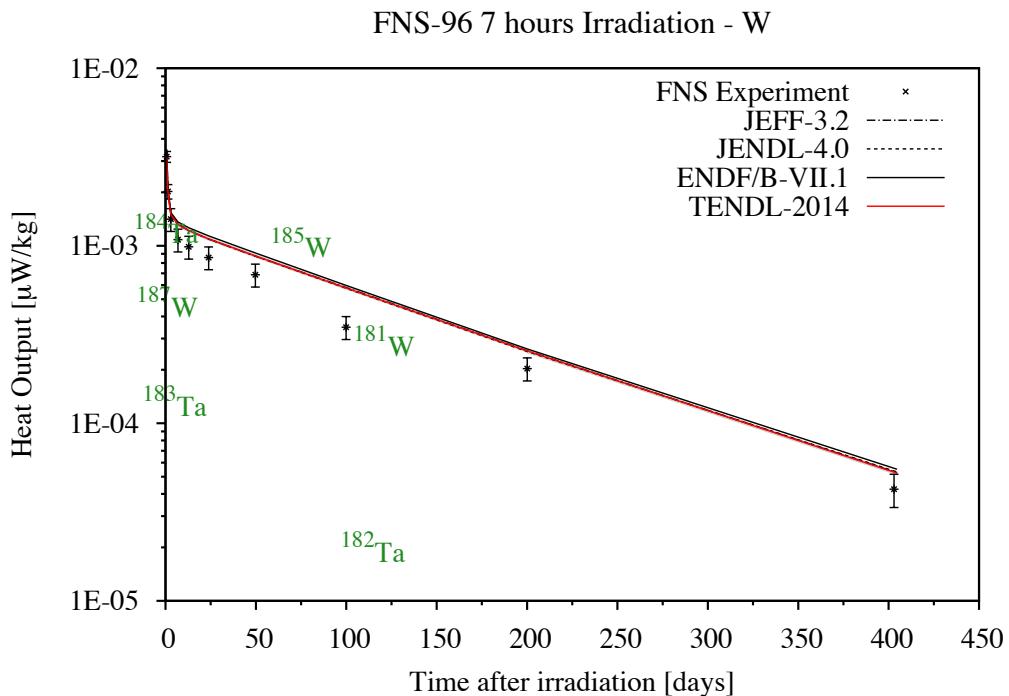


For Tungsten, a better than expected level of agreement is observed for this particularly troublesome, in nuclear data terms, element even at short cooling time for ENDF/B-VII.1 and TENDL-2014. The systematic code over-prediction on both batches (although by more in the 2000 case) may need to be addressed via an in-depth analysis of the two production routes involved.

Times Min.	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.83	$6.83E-02$ +/-13%	$1.37E-01$ +/-4%	0.50	0.53	26.98
1.08	$6.11E-02$ +/-13%	$1.23E-01$ +/-4%	0.50	0.53	24.51
1.33	$5.57E-02$ +/-13%	$1.11E-01$ +/-4%	0.50	0.54	22.67
1.58	$5.03E-02$ +/-13%	$1.01E-01$ +/-4%	0.50	0.53	20.75
2.02	$4.25E-02$ +/-13%	$8.44E-02$ +/-4%	0.50	0.54	17.98
2.62	$3.36E-02$ +/-13%	$6.61E-02$ +/-4%	0.51	0.54	14.72
3.23	$2.67E-02$ +/-13%	$5.16E-02$ +/-4%	0.52	0.55	12.12
4.08	$1.95E-02$ +/-13%	$3.67E-02$ +/-4%	0.53	0.57	9.26
5.20	$1.22E-02$ +/-12%	$2.35E-02$ +/-4%	0.52	0.55	6.18
6.30	$8.22E-03$ +/-12%	$1.55E-02$ +/-5%	0.53	0.57	4.41
7.92	$5.02E-03$ +/-11%	$8.45E-03$ +/-7%	0.59	0.63	2.94
10.02	$2.73E-03$ +/-10%	$4.12E-03$ +/-11%	0.66	0.69	1.78
12.13	$1.68E-03$ +/-9%	$2.42E-03$ +/-17%	0.69	0.73	1.22
15.20	$1.01E-03$ +/-8%	$1.47E-03$ +/-23%	0.69	0.72	0.85
19.30	$6.55E-04$ +/-8%	$1.08E-03$ +/-24%	0.60	0.65	0.67
23.40	$4.96E-04$ +/-9%	$8.83E-04$ +/-23%	0.56	0.59	0.60
27.52	$4.05E-04$ +/-11%	$7.48E-04$ +/-22%	0.54	0.56	0.57
34.63	$2.91E-04$ +/-14%	$6.01E-04$ +/-20%	0.48	0.50	0.52
44.73	$1.97E-04$ +/-20%	$4.72E-04$ +/-18%	0.42	0.42	0.44
54.85	$2.08E-04$ +/-19%	$3.91E-04$ +/-16%	0.53	0.53	0.55
mean % diff. from E		86	77	77	78

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
W185m	W186(n,2n)W185m	1.6m	98.2	0.50	13%
Ta186	W186(n,p)Ta186	10.5m	100.0	0.66	13%

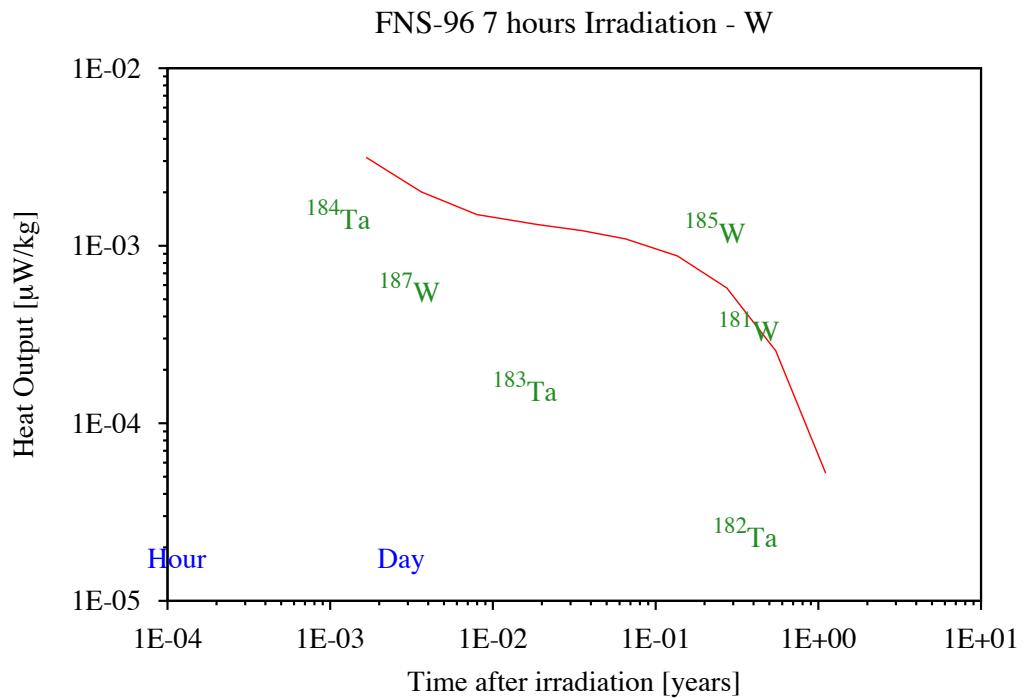




There seems to be a systematic 20-30% overestimation for some of the predominant isotopes, most probably for W181 and/or W185 in particular.

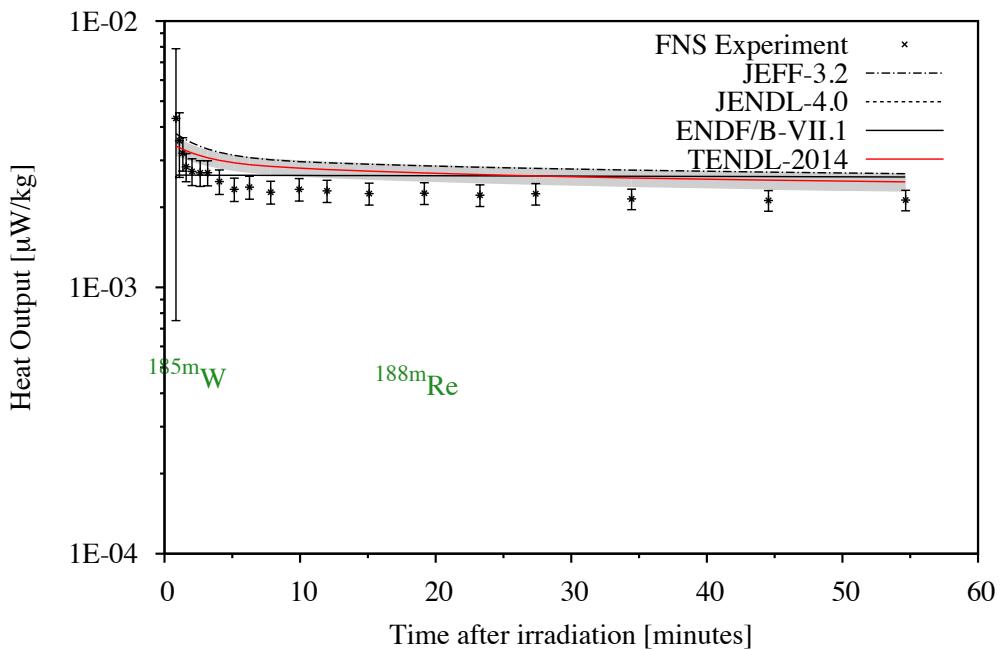
Times	FNS EXP. 7 hrs	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0	
Days	μW/g	μW/g	E/C	E/C	E/C	
0.61	$3.17E-03 +/- 7\%$	$3.15E-03 +/- 13\%$	1.01	0.91	0.92	0.94
1.33	$2.02E-03 +/- 9\%$	$2.01E-03 +/- 8\%$	1.00	0.96	0.96	1.00
2.91	$1.41E-03 +/- 15\%$	$1.50E-03 +/- 4\%$	0.94	0.92	0.93	0.95
6.88	$1.08E-03 +/- 15\%$	$1.32E-03 +/- 3\%$	0.82	0.80	0.82	0.82
12.87	$9.86E-04 +/- 15\%$	$1.22E-03 +/- 2\%$	0.81	0.78	0.81	0.81
23.87	$8.58E-04 +/- 15\%$	$1.09E-03 +/- 2\%$	0.79	0.76	0.79	0.79
49.71	$6.87E-04 +/- 15\%$	$8.76E-04 +/- 2\%$	0.78	0.75	0.79	0.79
99.90	$3.48E-04 +/- 15\%$	$5.79E-04 +/- 2\%$	0.60	0.58	0.60	0.60
200.12	$2.03E-04 +/- 15\%$	$2.56E-04 +/- 2\%$	0.79	0.77	0.79	0.80
402.95	$4.26E-05 +/- 21\%$	$5.24E-05 +/- 2\%$	0.81	0.77	0.81	0.80
mean % diff. from E		22	27	24	23	

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Ta184	W184(n,p)Ta184	8.7h	99.7	1.01	7%
W185	W186(n,2n)W185	75.1d	59.8	0.78	15%
	W186(n,2n)W185m	1.6m	40.0	0.78	15%
W181	W182(n,2n)W181	120d	99.4	0.79	15%
	W183(n,3n)W181	120d	0.6	0.79	15%

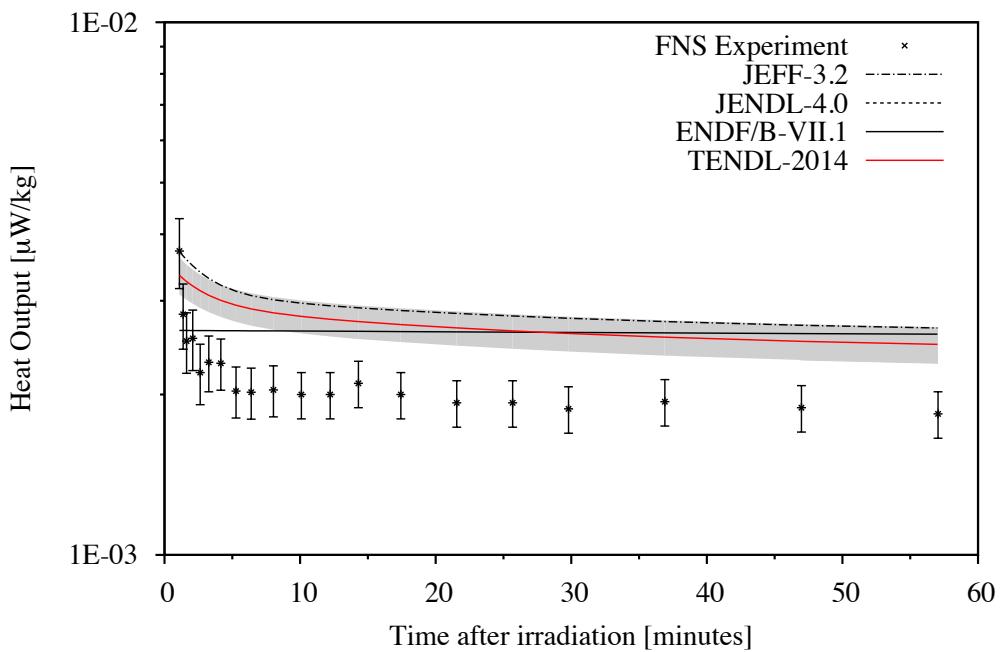


Rhenium

FNS-00 5 Min. Irradiation - Re



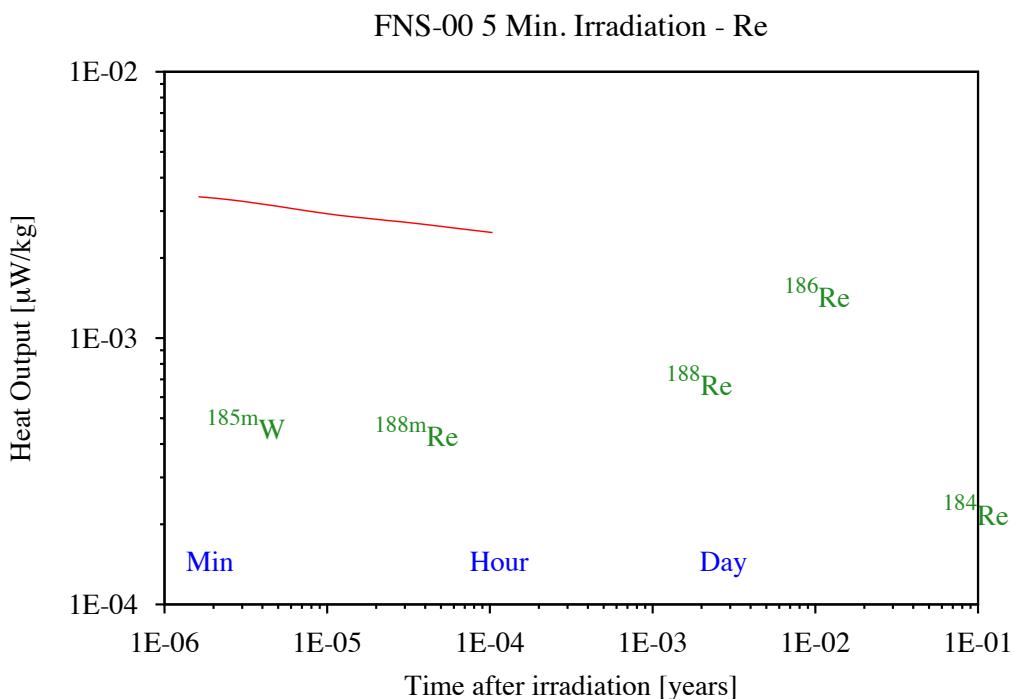
FNS-96 5 Min. Irradiation - Re



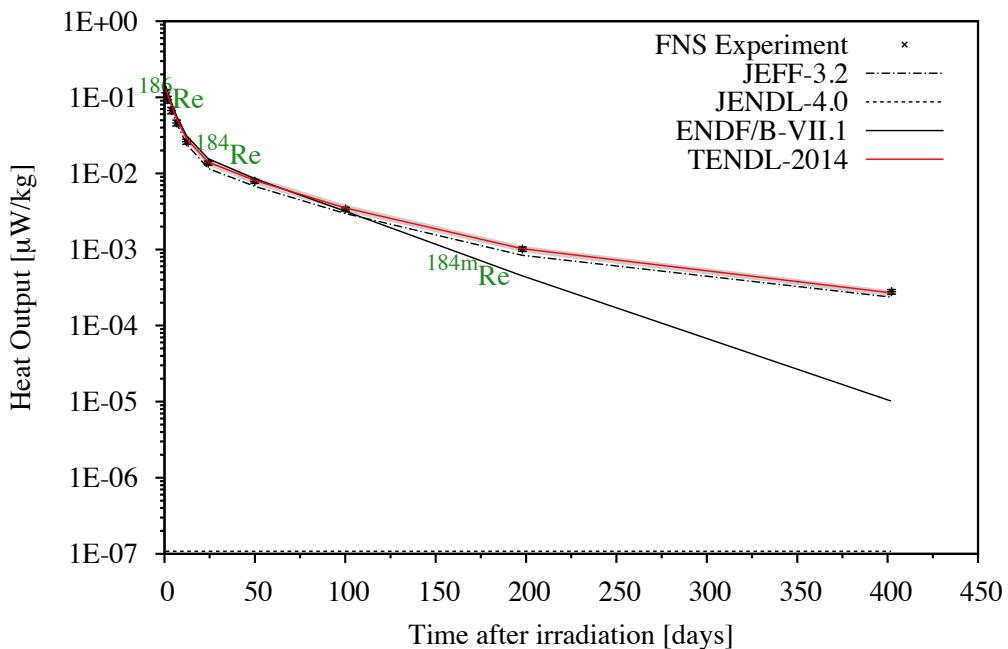
Rhenium: there was quite good agreement to the newer experimental results for this element with EAF-2010 [14], nearly within the experimental uncertainties. However, the experimental result from the 1996 batch is significantly different. This could be due to the rarely observed shadow or iceberg effect. Furthermore, Re188 response is overpredicted by all libraries, shadowing the Re186 one. Effect seen in the Log-Log graph on the next page. JENDL-4.0 library predicts poorly.

Times Min.	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0	
	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C	
0.85	$4.31E-03$ +/-83%	$3.39E-03$ +/-8%	1.27	1.63	1.14	0.00
1.10	$3.55E-03$ +/-27%	$3.35E-03$ +/-8%	1.06	1.35	0.96	0.00
1.35	$3.19E-03$ +/-14%	$3.30E-03$ +/-8%	0.97	1.21	0.88	0.00
1.60	$2.84E-03$ +/-12%	$3.26E-03$ +/-8%	0.87	1.07	0.79	0.00
2.03	$2.72E-03$ +/-12%	$3.20E-03$ +/-7%	0.85	1.03	0.78	0.00
2.63	$2.69E-03$ +/-11%	$3.12E-03$ +/-7%	0.86	1.02	0.79	0.00
3.18	$2.69E-03$ +/-11%	$3.07E-03$ +/-7%	0.88	1.02	0.81	0.00
4.05	$2.50E-03$ +/-11%	$3.00E-03$ +/-7%	0.83	0.95	0.78	0.00
5.15	$2.33E-03$ +/-10%	$2.93E-03$ +/-7%	0.80	0.89	0.75	0.00
6.27	$2.38E-03$ +/-10%	$2.89E-03$ +/-7%	0.82	0.90	0.77	0.00
7.83	$2.28E-03$ +/-10%	$2.85E-03$ +/-7%	0.80	0.87	0.76	0.00
9.93	$2.33E-03$ +/-10%	$2.80E-03$ +/-7%	0.83	0.89	0.79	0.00
11.98	$2.30E-03$ +/-10%	$2.77E-03$ +/-7%	0.83	0.88	0.79	0.00
15.10	$2.25E-03$ +/-9%	$2.73E-03$ +/-7%	0.82	0.86	0.78	0.00
19.17	$2.26E-03$ +/-9%	$2.69E-03$ +/-7%	0.84	0.86	0.79	0.00
23.27	$2.22E-03$ +/-9%	$2.65E-03$ +/-7%	0.84	0.85	0.79	0.00
27.38	$2.25E-03$ +/-9%	$2.62E-03$ +/-7%	0.86	0.86	0.80	0.00
34.45	$2.15E-03$ +/-9%	$2.58E-03$ +/-8%	0.83	0.82	0.78	0.00
44.55	$2.12E-03$ +/-9%	$2.53E-03$ +/-8%	0.84	0.81	0.78	0.00
54.67	$2.13E-03$ +/-9%	$2.49E-03$ +/-8%	0.85	0.82	0.80	0.00
mean % diff. from E			18	15	25	100

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
W185m	Re185(n,p)W185m	1.6m	90.7	0.87	12%
	Re187(n,t+nd)W185m		9.2	0.87	12%
Re188m	Re187(n, γ)Re188m	18.6m	99.9	0.84	9%
Re186	Re185(n, γ)Re186	3.7d	4.8	0.85	9%
	Re187(n,2n)Re186		95.2	0.85	9%



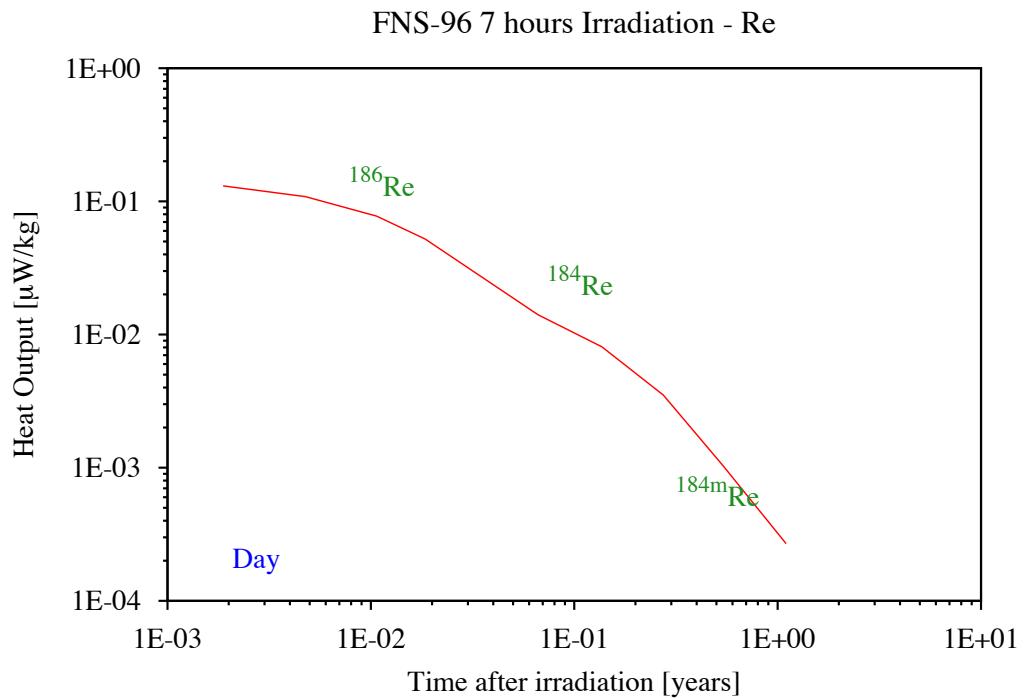
FNS-96 7 hours Irradiation - Re



A much better agreement, compared to the 5-minutes analysis, is seen from half a day up to more than a year of cooling. Note in this case the unusual occurrence of metastable isomer having a half-life greater than the ground (Re184m vs. Re184). JENDL-4.0 predicts poorly.

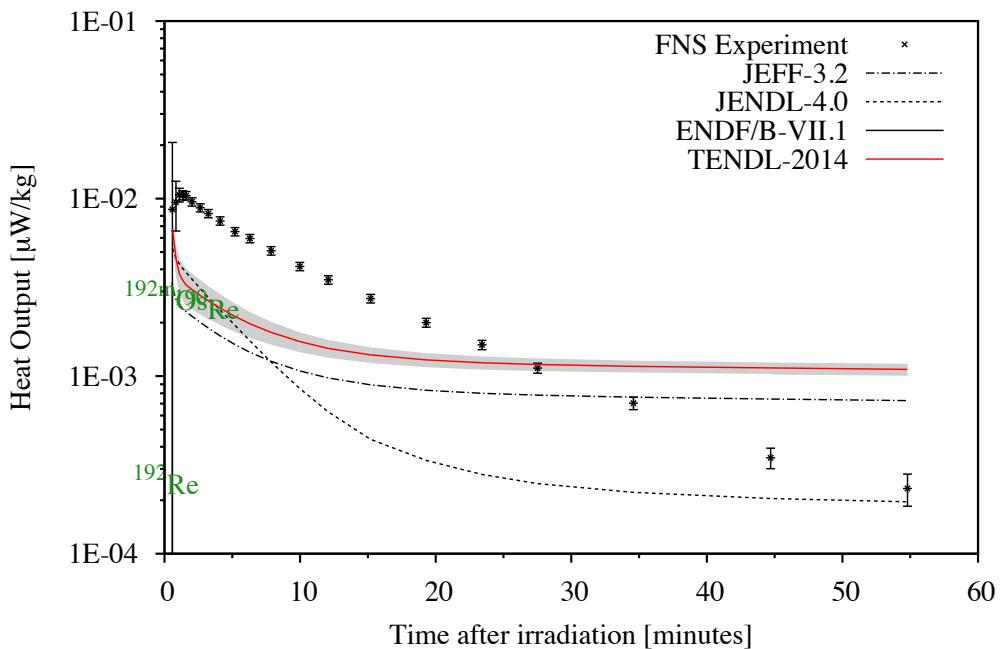
Times Days	FNS EXP. 7 hrs μW/g	TENDL-2014 μW/g	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.69	$1.14E-01$ +/-11%	$1.31E-01$ +/-11%	0.87	0.81	0.95	> 1000
1.74	$9.32E-02$ +/-10%	$1.08E-01$ +/-11%	0.86	0.80	0.97	> 1000
3.90	$6.71E-02$ +/-10%	$7.75E-02$ +/-11%	0.87	0.80	0.99	> 1000
6.76	$4.61E-02$ +/-9%	$5.21E-02$ +/-10%	0.88	0.81	1.02	> 1000
12.21	$2.61E-02$ +/-8%	$2.84E-02$ +/-9%	0.92	0.83	1.07	> 1000
24.22	$1.37E-02$ +/-6%	$1.41E-02$ +/-10%	0.97	0.88	1.18	> 1000
49.97	$7.88E-03$ +/-6%	$8.08E-03$ +/-11%	0.98	0.93	1.17	> 1000
100.10	$3.39E-03$ +/-6%	$3.52E-03$ +/-11%	0.96	1.06	1.14	> 1000
197.96	$1.01E-03$ +/-6%	$1.02E-03$ +/-9%	0.99	2.24	1.20	> 1000
402.17	$2.78E-04$ +/-7%	$2.69E-04$ +/-8%	1.04	27.28	1.18	> 1000
mean % diff. from E			8	30	9	100

Product	Pathways	T _{1/2}	Path %	E/C	ΔE%
Re186	Re187(n,2n)Re186	3.7d	99.6	0.87	10%
	Re185(n,γ)Re186	3.7d	0.0	0.87	10%
Re184	Re185(n,2n)Re184	37.9d	100.0	0.98	5%
Re184m	Re185(n,2n)Re184m	168d	100.0	0.99	6%



Osmium

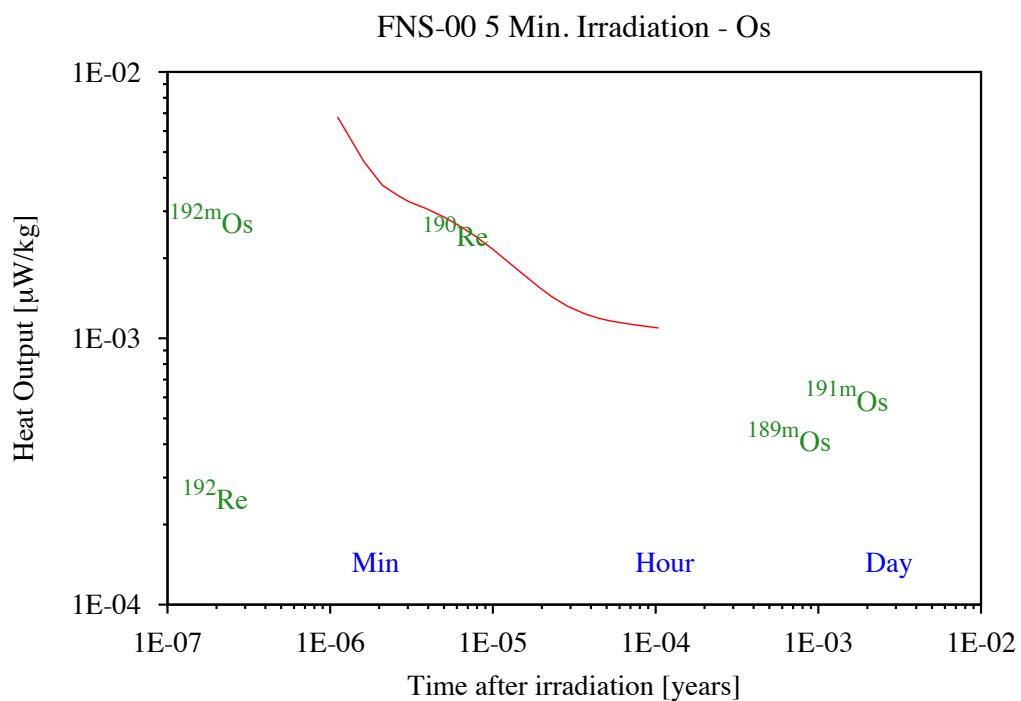
FNS-00 5 Min. Irradiation - Os

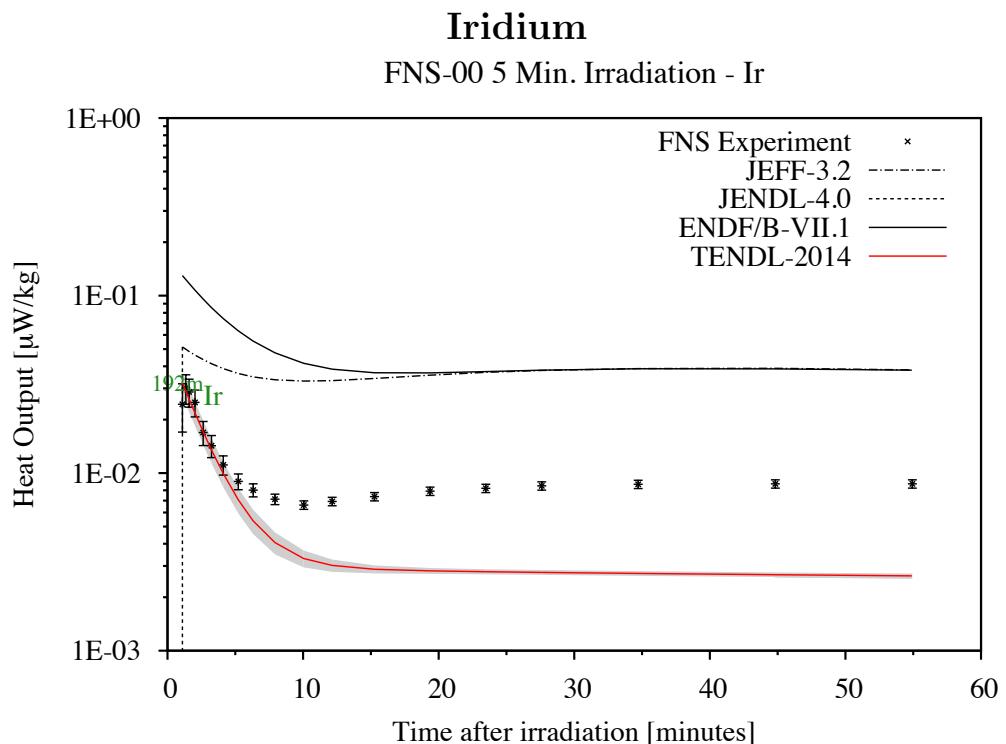


For Osmium, here again the correction made on a grossly overestimated (n,n') channel provide a better estimate of the heat output levels (compared with EAF-2010 [14]), although major disagreement still exists between databases for both the isotopic contributions and their heat-output levels. The disagreements may suggest problems related with half-lives and isomeric states.

Times Min.	FNS EXP. 5 mins $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.58	$8.70E-03 +/-138\%$	$6.78E-03 +/-17\%$	1.28	2.57	2.76	1.66
0.85	$9.54E-03 +/-31\%$	$4.59E-03 +/-20\%$	2.08	0.00	3.52	2.07
1.10	$1.05E-02 +/-9\%$	$3.76E-03 +/-23\%$	2.79	0.00	4.17	2.45
1.35	$1.04E-02 +/-6\%$	$3.46E-03 +/-23\%$	3.02	0.00	4.37	2.59
1.60	$1.04E-02 +/-5\%$	$3.26E-03 +/-24\%$	3.19	0.00	4.50	2.71
2.03	$9.59E-03 +/-5\%$	$3.07E-03 +/-23\%$	3.12	0.00	4.41	2.73
2.63	$8.88E-03 +/-5\%$	$2.85E-03 +/-22\%$	3.11	0.00	4.42	2.84
3.23	$8.24E-03 +/-5\%$	$2.66E-03 +/-21\%$	3.10	0.00	4.42	2.97
4.10	$7.48E-03 +/-5\%$	$2.42E-03 +/-20\%$	3.10	0.00	4.44	3.18
5.20	$6.51E-03 +/-5\%$	$2.17E-03 +/-18\%$	3.00	0.00	4.32	3.37
6.30	$5.96E-03 +/-5\%$	$1.97E-03 +/-17\%$	3.02	0.00	4.37	3.77
7.87	$5.08E-03 +/-5\%$	$1.76E-03 +/-15\%$	2.88	0.00	4.20	4.24
9.98	$4.15E-03 +/-5\%$	$1.56E-03 +/-13\%$	2.65	0.00	3.87	4.87
12.08	$3.49E-03 +/-5\%$	$1.43E-03 +/-11\%$	2.43	0.00	3.57	5.53
15.20	$2.74E-03 +/-6\%$	$1.32E-03 +/-10\%$	2.08	0.00	3.06	6.21
19.30	$2.00E-03 +/-6\%$	$1.24E-03 +/-9\%$	1.62	0.00	2.40	5.97
23.42	$1.50E-03 +/-6\%$	$1.19E-03 +/-8\%$	1.26	0.00	1.87	5.36
27.52	$1.11E-03 +/-7\%$	$1.16E-03 +/-8\%$	0.96	0.00	1.42	4.47
34.58	$7.04E-04 +/-8\%$	$1.14E-03 +/-8\%$	0.62	0.00	0.93	3.18
44.70	$3.47E-04 +/-13\%$	$1.11E-03 +/-7\%$	0.31	0.00	0.47	1.69
54.80	$2.33E-04 +/-21\%$	$1.09E-03 +/-7\%$	0.21	0.00	0.32	1.19
mean % diff. from E			78	98	76	65

Product	Pathways	T_{1/2}	Path %	E/C	ΔE%
Re190	Os190(n,p)Re190	3.1m	100.0	3.10	5%
Os191m	Os190(n, γ)Os191m	9.9m	0.9	0.31	13%
	Os192(n,2n)Os191m		99.1	0.31	13%

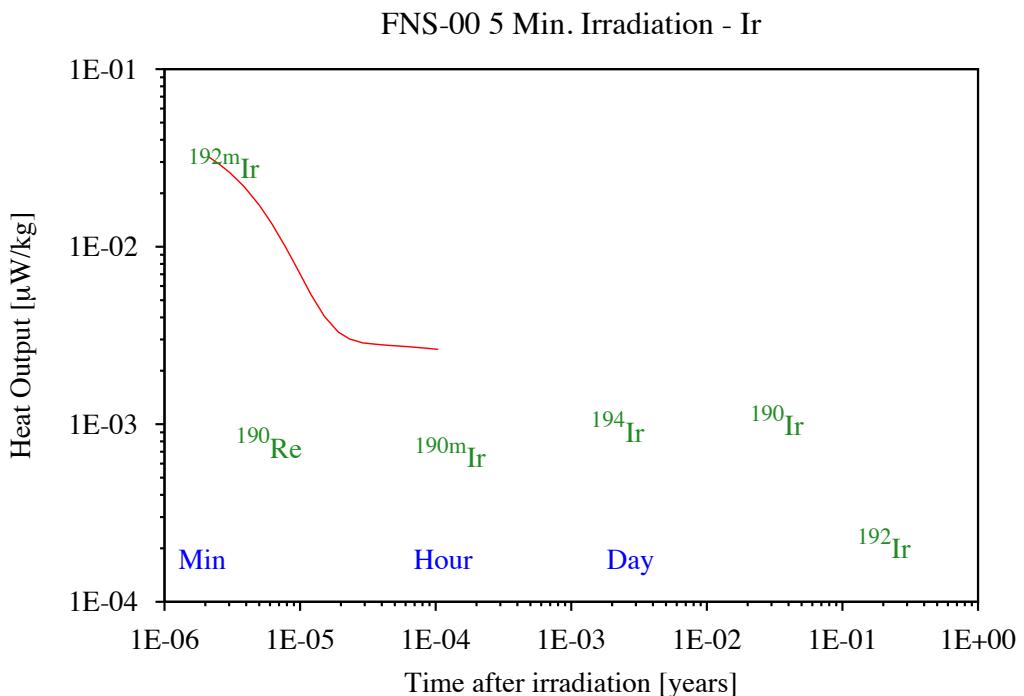




For Iridium, a most interesting experimental decay heat shape can be seen, underpinning an increase in heat due to the presence of an isomeric daughter with a half-life shorter than the parent, coupled with a potent decay heat. The Os190m (9.9m) and Ir192n (242y) production pathways that were present in EAF-2010 [14] lead to much better agreement. Note that along the potential direct production route for Os190m there is also a decay path from the long-lived Ir192n.

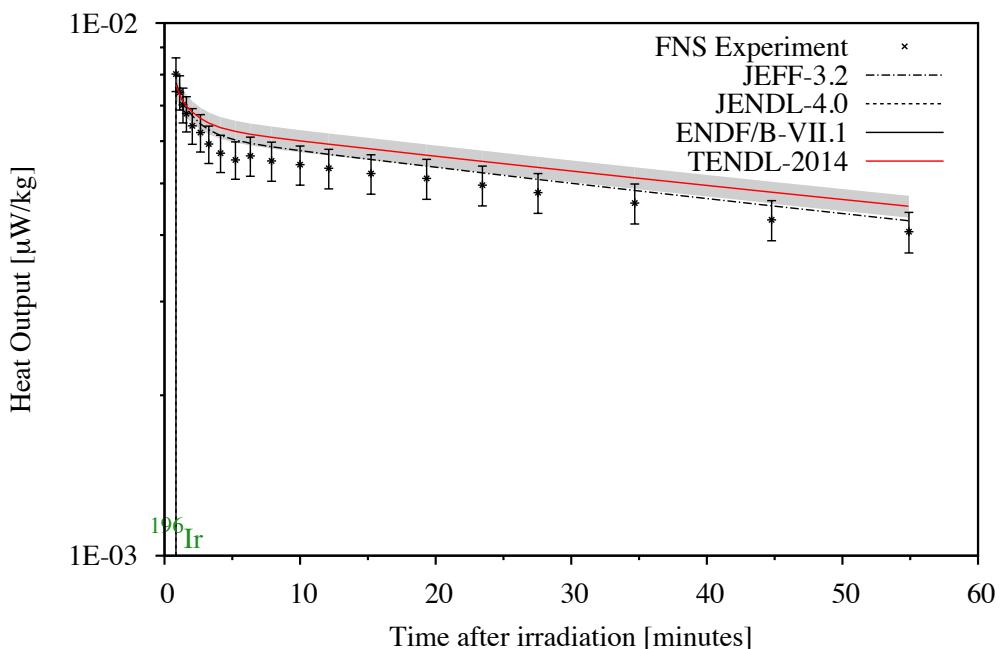
Times Min.	FNS EXP. 5 mins μW/g	TENDL-2014 μW/g	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
1.10	$2.44E-02$ +/-30%	$3.23E-02$ +/-15%	0.76	0.19	0.48	0.48
1.35	$3.01E-02$ +/-19%	$2.89E-02$ +/-15%	1.04	0.24	0.60	0.00
1.60	$2.87E-02$ +/-18%	$2.61E-02$ +/-15%	1.10	0.24	0.59	0.00
2.03	$2.50E-02$ +/-17%	$2.18E-02$ +/-16%	1.15	0.23	0.54	0.00
2.63	$1.69E-02$ +/-15%	$1.71E-02$ +/-16%	0.99	0.18	0.39	0.00
3.25	$1.43E-02$ +/-14%	$1.35E-02$ +/-16%	1.06	0.17	0.35	0.00
4.12	$1.11E-02$ +/-12%	$9.94E-03$ +/-16%	1.12	0.15	0.29	0.00
5.22	$8.98E-03$ +/-10%	$7.09E-03$ +/-16%	1.27	0.14	0.25	0.00
6.32	$8.02E-03$ +/-8%	$5.39E-03$ +/-16%	1.49	0.14	0.23	0.00
7.93	$7.13E-03$ +/-7%	$4.06E-03$ +/-14%	1.76	0.15	0.21	0.00
10.05	$6.61E-03$ +/-5%	$3.30E-03$ +/-11%	2.00	0.16	0.20	0.00
12.15	$6.92E-03$ +/-5%	$3.02E-03$ +/-8%	2.29	0.18	0.21	0.00
15.27	$7.38E-03$ +/-5%	$2.87E-03$ +/-5%	2.57	0.20	0.22	0.00
19.37	$7.91E-03$ +/-5%	$2.82E-03$ +/-4%	2.81	0.22	0.22	0.00
23.48	$8.22E-03$ +/-5%	$2.78E-03$ +/-3%	2.95	0.22	0.22	0.00
27.60	$8.48E-03$ +/-5%	$2.76E-03$ +/-3%	3.07	0.22	0.22	0.00
34.72	$8.66E-03$ +/-5%	$2.72E-03$ +/-3%	3.18	0.22	0.22	0.00
44.83	$8.70E-03$ +/-5%	$2.68E-03$ +/-3%	3.25	0.23	0.22	0.00
54.93	$8.70E-03$ +/-5%	$2.64E-03$ +/-3%	3.30	0.23	0.23	0.00
mean % diff. from E		39	429	271	101	

Product	Pathways	T_{1/2}	Path %	E/C	ΔE%
Ir192m	Ir191(n, γ)Ir192m	1.4m	33.0	1.07	15%
	Ir193(n,2n)Ir192m		65.8	1.07	15%
Ir194	Ir193(n, γ)Ir194	19.3h	99.9	3.30	5%
Ir190	Ir191(n,2n)Ir190	12d	99.6	3.30	5%



Platinum

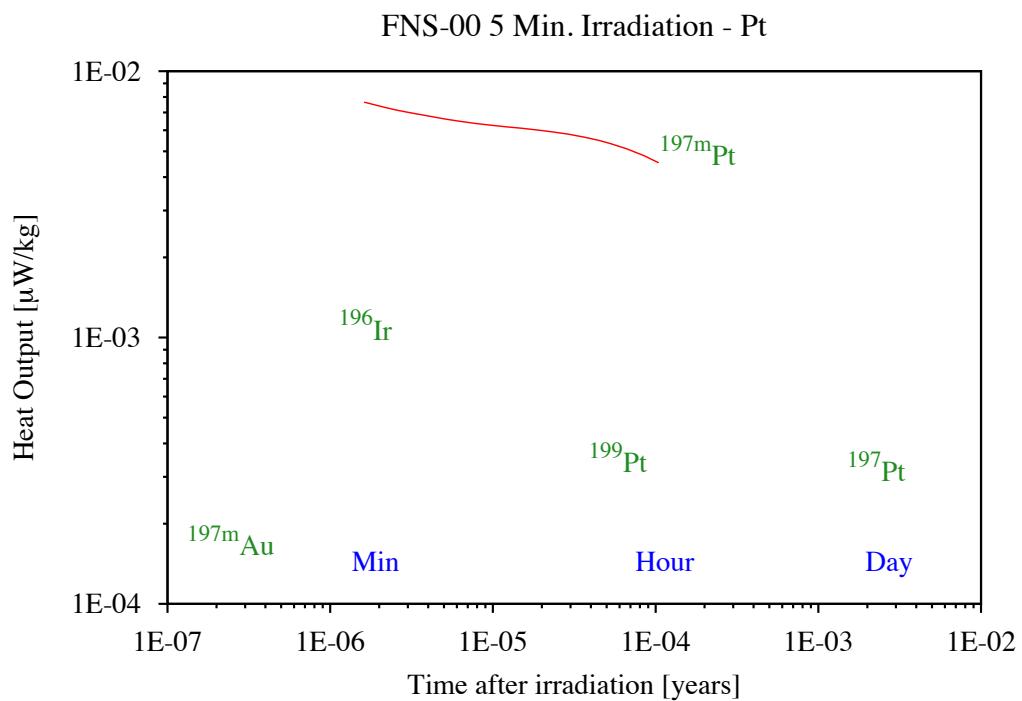
FNS-00 5 Min. Irradiation - Pt

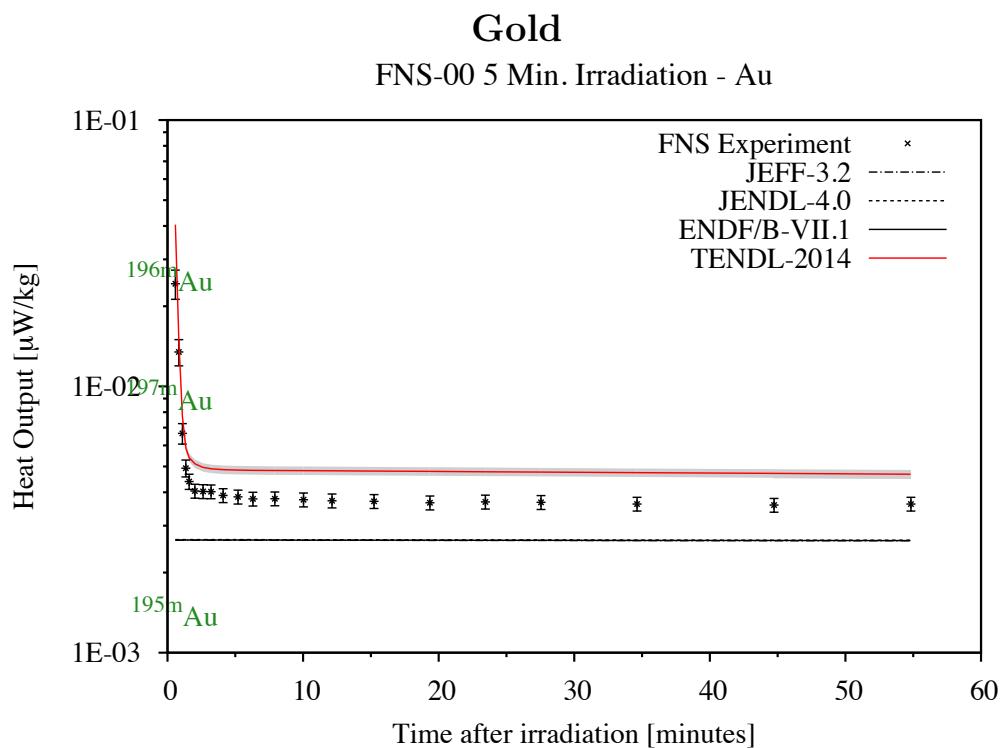


For Platinum, the above graph may indicate an under-prediction, of 10%, in the production of Pt197m when TENDL-2014 is used, while it is within the experimental uncertainty if it is JEFF-3.2. However, TENDL-2012 [14] gives even better results.

Times Min.	FNS EXP. 5 mins $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.85	$8.02E-03 +/- 7\%$	$7.65E-03 +/- 6\%$	1.05	1.05	1.04	1.05
1.12	$7.41E-03 +/- 7\%$	$7.34E-03 +/- 5\%$	1.01	0.00	1.01	0.00
1.37	$7.02E-03 +/- 8\%$	$7.13E-03 +/- 5\%$	0.98	0.00	0.99	0.00
1.62	$6.76E-03 +/- 8\%$	$6.99E-03 +/- 5\%$	0.97	0.00	0.98	0.00
2.05	$6.41E-03 +/- 8\%$	$6.81E-03 +/- 5\%$	0.94	0.00	0.96	0.00
2.65	$6.23E-03 +/- 8\%$	$6.62E-03 +/- 5\%$	0.94	0.00	0.96	0.00
3.27	$5.93E-03 +/- 8\%$	$6.49E-03 +/- 5\%$	0.91	0.00	0.94	0.00
4.13	$5.70E-03 +/- 8\%$	$6.36E-03 +/- 5\%$	0.90	0.00	0.93	0.00
5.23	$5.53E-03 +/- 8\%$	$6.26E-03 +/- 5\%$	0.88	0.00	0.92	0.00
6.33	$5.63E-03 +/- 8\%$	$6.18E-03 +/- 5\%$	0.91	0.00	0.95	0.00
7.90	$5.51E-03 +/- 8\%$	$6.10E-03 +/- 5\%$	0.90	0.00	0.94	0.00
10.00	$5.42E-03 +/- 8\%$	$6.01E-03 +/- 5\%$	0.90	0.00	0.94	0.00
12.12	$5.34E-03 +/- 9\%$	$5.92E-03 +/- 5\%$	0.90	0.00	0.94	0.00
15.23	$5.22E-03 +/- 9\%$	$5.80E-03 +/- 5\%$	0.90	0.00	0.94	0.00
19.33	$5.11E-03 +/- 9\%$	$5.65E-03 +/- 5\%$	0.90	0.00	0.95	0.00
23.45	$4.96E-03 +/- 9\%$	$5.50E-03 +/- 5\%$	0.90	0.00	0.95	0.00
27.55	$4.81E-03 +/- 9\%$	$5.36E-03 +/- 5\%$	0.90	0.00	0.94	0.00
34.68	$4.59E-03 +/- 9\%$	$5.12E-03 +/- 5\%$	0.90	0.00	0.95	0.00
44.78	$4.27E-03 +/- 9\%$	$4.81E-03 +/- 5\%$	0.89	0.00	0.94	0.00
54.90	$4.06E-03 +/- 9\%$	$4.53E-03 +/- 5\%$	0.90	0.00	0.95	0.00
mean % diff. from E			9	95	5	95

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Pt197m	Pt198(n,2n)Pt197m	1.5h	100.0	0.90	8%

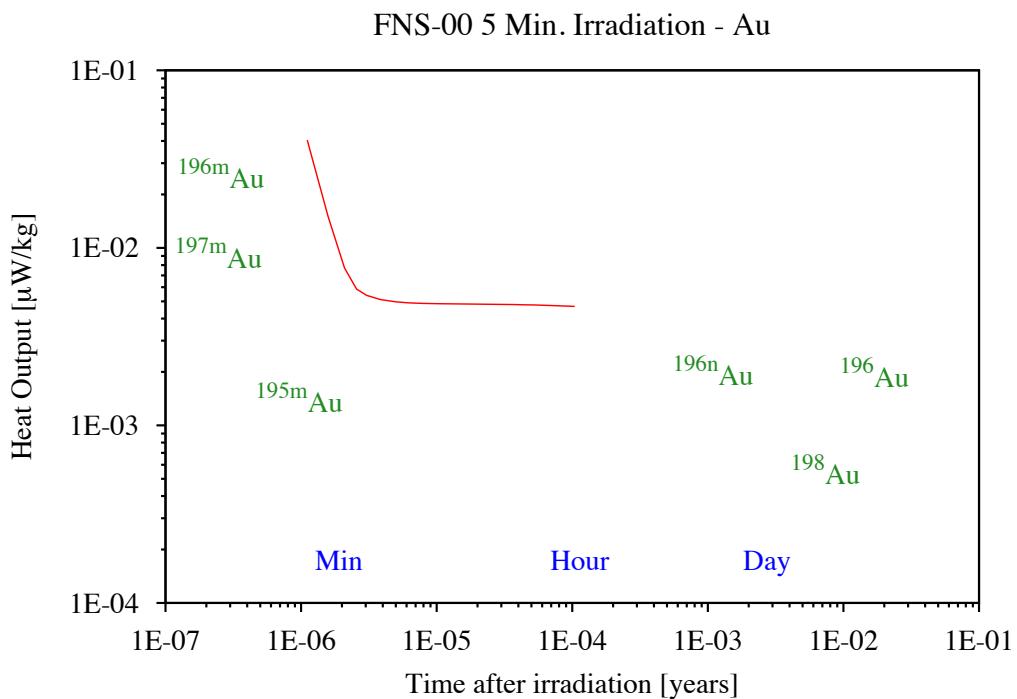




Gold: from such a picture above one may deduce that there could be an under-prediction for some of the libraries of the heat generated by the Au196 isomers at a level of about 40% and an over-prediction by TENDL-2014 of 20%. Noticeably, Au196n and Au196m production paths are missing in the different legacy libraries.

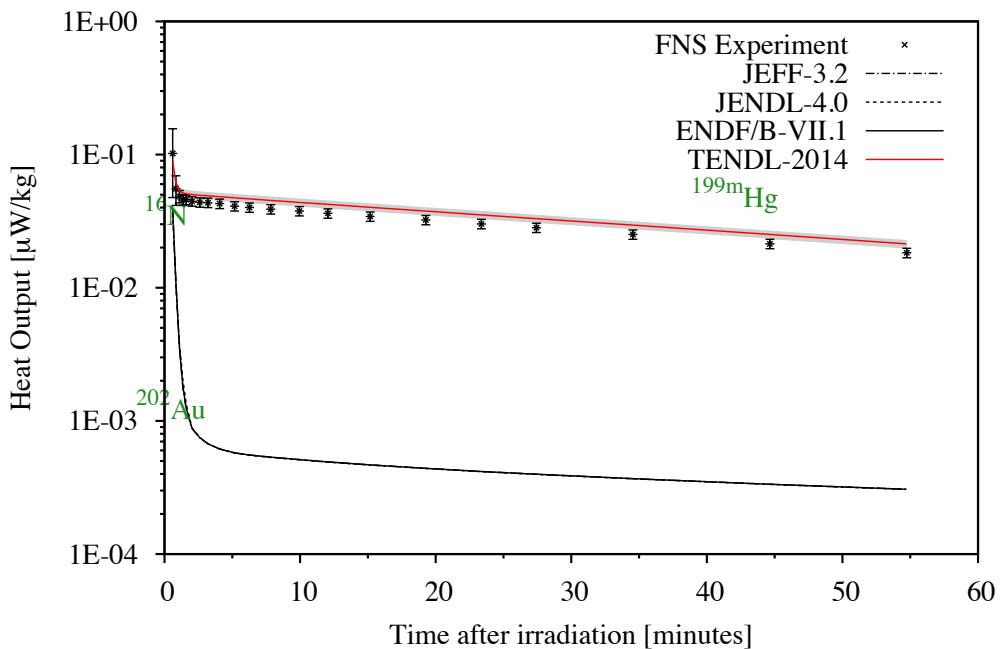
Times Min.	FNS EXP. 5 mins μW/g	TENDL-2014 μW/g	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.58	$2.43E-02 +/-13\%$	$4.04E-02 +/-6\%$	0.60	9.16	9.18	9.13
0.83	$1.35E-02 +/-11\%$	$1.50E-02 +/-4\%$	0.90	5.08	5.09	5.06
1.10	$6.66E-03 +/-9\%$	$7.70E-03 +/-3\%$	0.86	2.51	2.52	2.50
1.35	$4.93E-03 +/-7\%$	$5.87E-03 +/-4\%$	0.84	1.86	1.86	1.85
1.60	$4.39E-03 +/-7\%$	$5.40E-03 +/-4\%$	0.81	1.66	1.66	1.65
2.02	$4.05E-03 +/-6\%$	$5.12E-03 +/-4\%$	0.79	1.53	1.53	1.52
2.62	$4.03E-03 +/-6\%$	$4.97E-03 +/-4\%$	0.81	1.52	1.52	1.52
3.22	$4.02E-03 +/-6\%$	$4.90E-03 +/-4\%$	0.82	1.52	1.52	1.51
4.10	$3.89E-03 +/-6\%$	$4.87E-03 +/-4\%$	0.80	1.47	1.47	1.46
5.20	$3.85E-03 +/-6\%$	$4.85E-03 +/-4\%$	0.79	1.45	1.45	1.45
6.30	$3.78E-03 +/-6\%$	$4.84E-03 +/-4\%$	0.78	1.43	1.43	1.42
7.92	$3.79E-03 +/-6\%$	$4.83E-03 +/-4\%$	0.78	1.43	1.43	1.43
10.03	$3.75E-03 +/-6\%$	$4.82E-03 +/-4\%$	0.78	1.42	1.42	1.41
12.13	$3.72E-03 +/-6\%$	$4.82E-03 +/-4\%$	0.77	1.41	1.41	1.40
15.23	$3.70E-03 +/-6\%$	$4.81E-03 +/-4\%$	0.77	1.40	1.40	1.39
19.35	$3.66E-03 +/-6\%$	$4.79E-03 +/-4\%$	0.76	1.38	1.38	1.38
23.45	$3.68E-03 +/-6\%$	$4.78E-03 +/-4\%$	0.77	1.39	1.40	1.39
27.55	$3.67E-03 +/-6\%$	$4.77E-03 +/-4\%$	0.77	1.39	1.39	1.38
34.63	$3.62E-03 +/-6\%$	$4.74E-03 +/-4\%$	0.76	1.37	1.37	1.37
44.73	$3.58E-03 +/-6\%$	$4.71E-03 +/-4\%$	0.76	1.36	1.36	1.35
54.83	$3.62E-03 +/-6\%$	$4.68E-03 +/-4\%$	0.77	1.37	1.37	1.37
mean % diff. from E		28	38	38	38	

Product	Pathways	T_{1/2}	Path %	E/C	ΔE%
Au197m	Au197(n,n')Au197m	7.7s	100.0	0.60	13%
Au196	Au197(n,2n)Au196m	8.1s	63.3	0.77	6%
	Au197(n,2n)Au196	6.1d	36.7	0.77	6%
Au196m	Au197(n,2n)Au196m	8.1s	100.0	0.77	6%
Au196n	Au197(n,2n)Au196n	9.6h	100.0	0.77	6%



Mercury

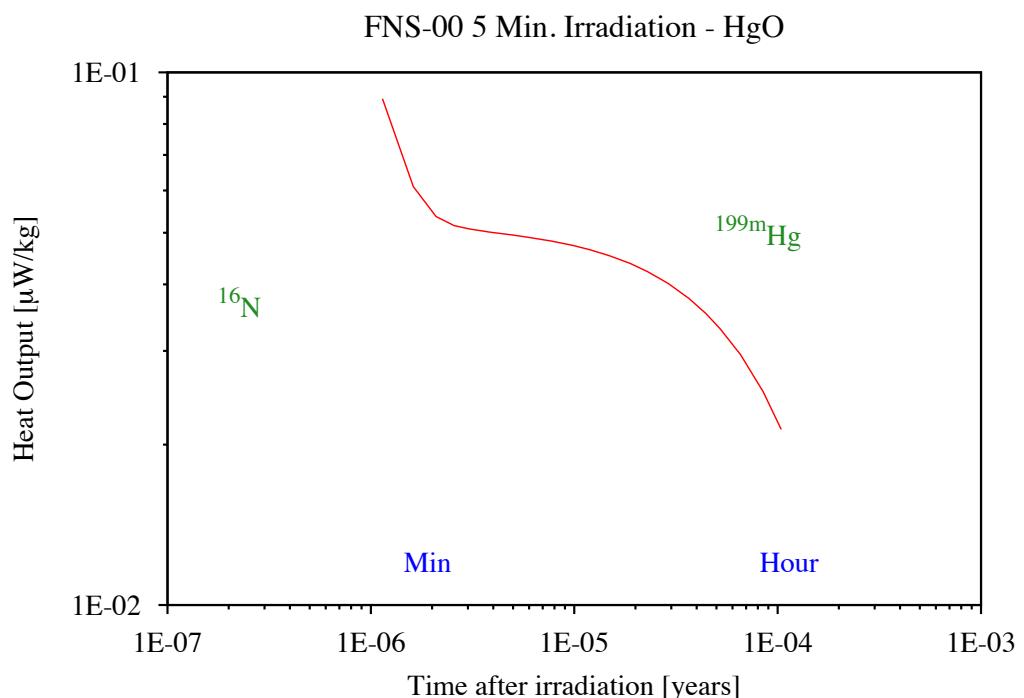
FNS-00 5 Min. Irradiation - HgO

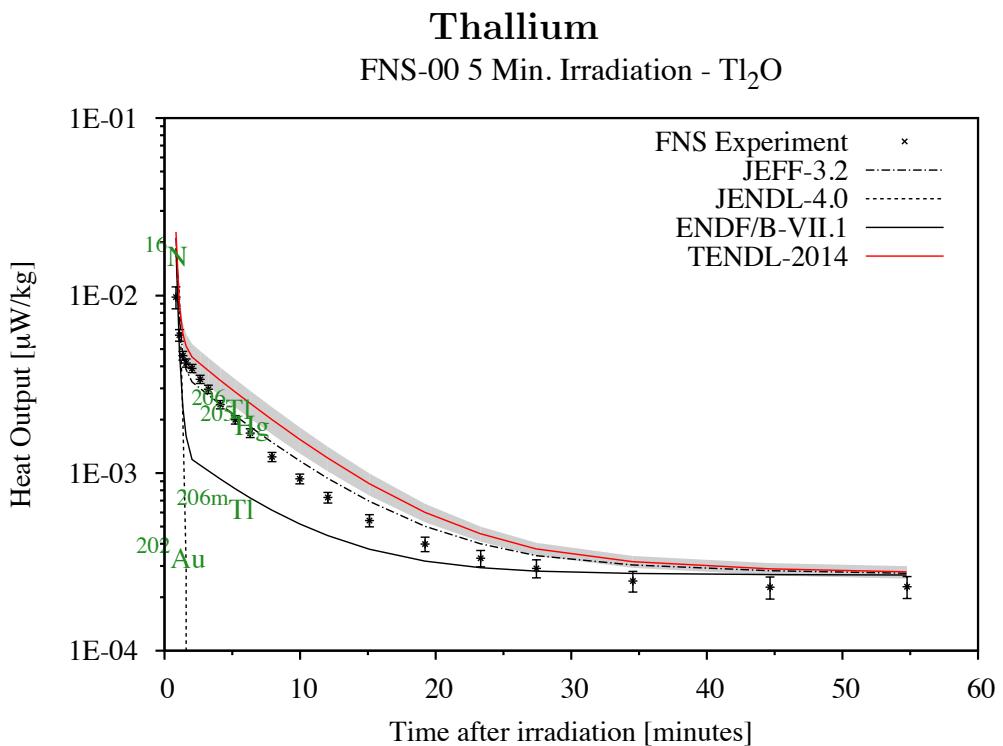


For Mercury, with both ($n,2n$) and (n,n') routes of production for the unique predominant Hg^{199m} isotope, the choices for small modification to TENDL-2014 are both many-fold and also subtle in their requirements. However, the TENDL-2014 C/E agreement is excellent. Experimental and calculational uncertainties are also fairly similar. A text book case to exemplify the impact of missing isomer production in ENDF/B-VII.1, JEFF-3.2 and JENDL-4.0.

Times Min.	FNS EXP. 5 mins $\mu W/g$	TENDL-2014 $\mu W/g$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.60	$1.02E-01$ +/-53%	$8.92E-02$ +/-4%	1.14	2.63	2.63	2.80
0.85	$5.54E-02$ +/-25%	$6.10E-02$ +/-6%	0.91	5.15	5.14	5.56
1.10	$4.85E-02$ +/-11%	$5.36E-02$ +/-7%	0.90	13.53	13.52	12.64
1.35	$4.56E-02$ +/-8%	$5.16E-02$ +/-7%	0.88	24.88	25.78	22.27
1.60	$4.58E-02$ +/-8%	$5.08E-02$ +/-7%	0.90	36.62	37.01	33.95
2.03	$4.46E-02$ +/-8%	$5.01E-02$ +/-7%	0.89	50.74	50.93	50.36
2.60	$4.38E-02$ +/-8%	$4.95E-02$ +/-7%	0.88	58.55	58.64	58.26
3.20	$4.35E-02$ +/-8%	$4.90E-02$ +/-7%	0.89	64.73	64.76	64.63
4.07	$4.28E-02$ +/-8%	$4.82E-02$ +/-7%	0.89	69.53	69.54	69.65
5.17	$4.10E-02$ +/-8%	$4.73E-02$ +/-7%	0.87	71.14	71.18	71.43
6.27	$4.00E-02$ +/-8%	$4.65E-02$ +/-7%	0.86	72.17	72.18	72.50
7.83	$3.89E-02$ +/-8%	$4.53E-02$ +/-7%	0.86	72.76	72.77	73.06
9.95	$3.76E-02$ +/-8%	$4.37E-02$ +/-7%	0.86	73.55	73.56	73.83
12.05	$3.62E-02$ +/-8%	$4.23E-02$ +/-7%	0.86	73.57	73.58	73.84
15.17	$3.43E-02$ +/-8%	$4.02E-02$ +/-7%	0.85	73.31	73.31	73.55
19.27	$3.23E-02$ +/-8%	$3.76E-02$ +/-7%	0.86	73.28	73.28	73.49
23.37	$3.01E-02$ +/-8%	$3.52E-02$ +/-7%	0.86	72.26	72.27	72.46
27.43	$2.82E-02$ +/-8%	$3.30E-02$ +/-7%	0.85	71.02	71.02	71.20
34.55	$2.51E-02$ +/-8%	$2.95E-02$ +/-7%	0.85	68.26	68.27	68.42
44.65	$2.14E-02$ +/-8%	$2.51E-02$ +/-7%	0.85	63.91	63.91	64.04
54.75	$1.83E-02$ +/-8%	$2.14E-02$ +/-7%	0.86	59.67	59.68	59.79
mean % diff. from E		15	95	95	96	

Product	Pathways	T _{1/2}	Path %	E/C	ΔE%
Hg199m	Hg199(n,n')Hg199m	42.1m	11.2	0.85	8%
	Hg200(n,2n)Hg199m		88.7	0.85	8%

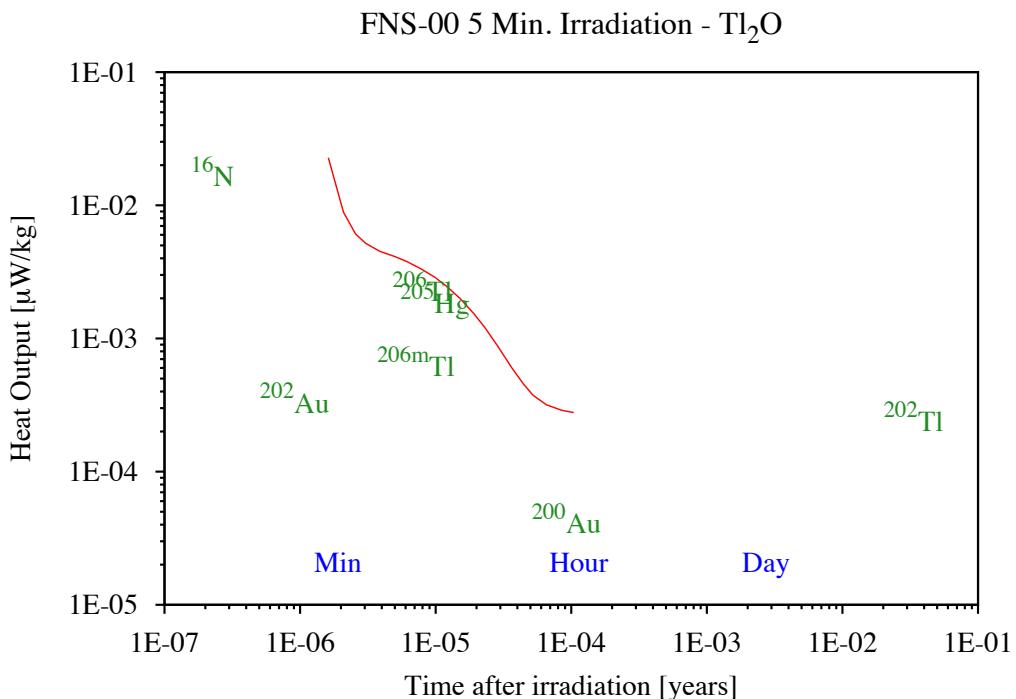




For Thallium, an excellent agreement can be seen when the TENDL-2014 and to a certain extend JEFF-3.2 databases are used. TENDL-2011 [15] performed poorly.

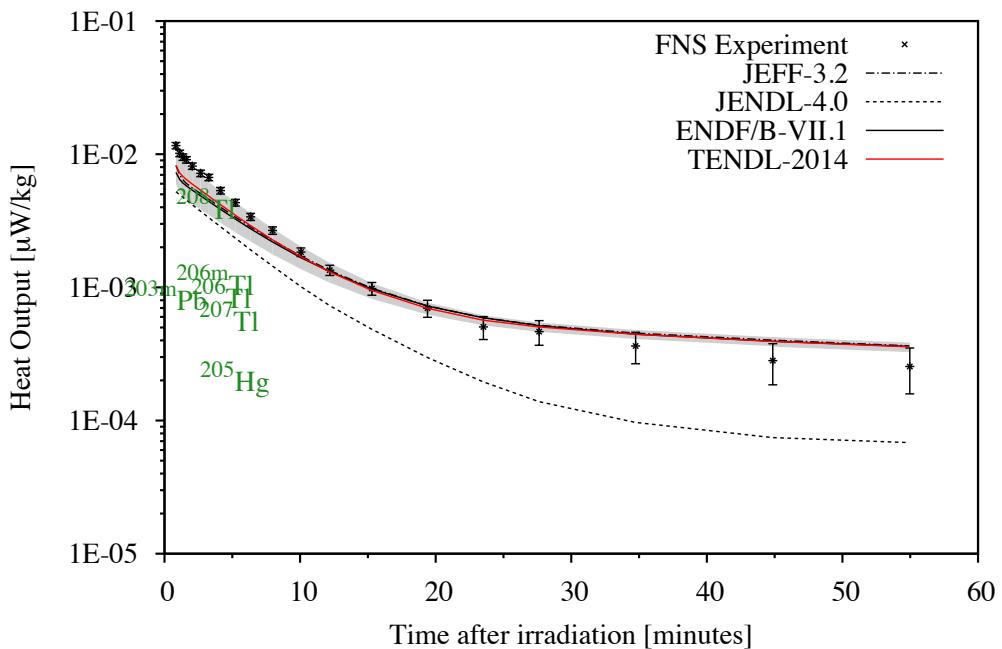
Times Min.	FNS EXP. 5 mins μW/g	TENDL-2014 μW/g	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C	
0.85	9.81E-03 +/-14%	2.28E-02 +/-5%	0.43	0.53	0.46	0.57
1.10	5.99E-03 +/-7%	8.86E-03 +/-11%	0.68	1.22	0.82	0.60
1.35	4.59E-03 +/-6%	6.10E-03 +/-15%	0.75	1.96	0.98	2.23
1.60	4.17E-03 +/-5%	5.19E-03 +/-17%	0.80	2.59	1.09	13.87
2.03	3.89E-03 +/-5%	4.51E-03 +/-18%	0.86	3.26	1.19	0.00
2.63	3.38E-03 +/-5%	4.12E-03 +/-18%	0.82	3.05	1.13	0.00
3.23	2.97E-03 +/-5%	3.78E-03 +/-18%	0.79	2.88	1.08	0.00
4.12	2.43E-03 +/-5%	3.33E-03 +/-18%	0.73	2.62	1.00	0.00
5.22	2.00E-03 +/-6%	2.87E-03 +/-18%	0.70	2.45	0.95	0.00
6.32	1.68E-03 +/-6%	2.47E-03 +/-18%	0.68	2.32	0.92	0.00
7.93	1.23E-03 +/-6%	2.00E-03 +/-17%	0.62	2.00	0.83	0.00
9.98	9.29E-04 +/-6%	1.55E-03 +/-17%	0.60	1.80	0.79	0.00
12.05	7.29E-04 +/-7%	1.22E-03 +/-16%	0.60	1.64	0.78	0.00
15.12	5.41E-04 +/-8%	8.73E-04 +/-14%	0.62	1.45	0.78	0.00
19.22	3.99E-04 +/-9%	6.01E-04 +/-12%	0.66	1.25	0.79	0.00
23.32	3.31E-04 +/-11%	4.55E-04 +/-10%	0.73	1.13	0.83	0.00
27.43	2.91E-04 +/-12%	3.74E-04 +/-8%	0.78	1.04	0.85	0.00
34.55	2.47E-04 +/-13%	3.17E-04 +/-8%	0.78	0.91	0.81	0.00
44.67	2.28E-04 +/-14%	2.89E-04 +/-8%	0.79	0.85	0.81	0.00
54.77	2.29E-04 +/-14%	2.78E-04 +/-8%	0.82	0.86	0.84	0.00
mean % diff. from E		44	42	22	95	

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Tl206	Tl205(n, γ)Tl206	4.2m	97.5	0.73	5%
	Tl205(n, γ)Tl206m	3.7m	97.5	0.73	5%
Hg205	Tl205(n,p)Hg205	5.2m	99.7	0.70	6%
Tl202	Tl203(n,2n)Tl202	12.2d	100.0	0.82	14%

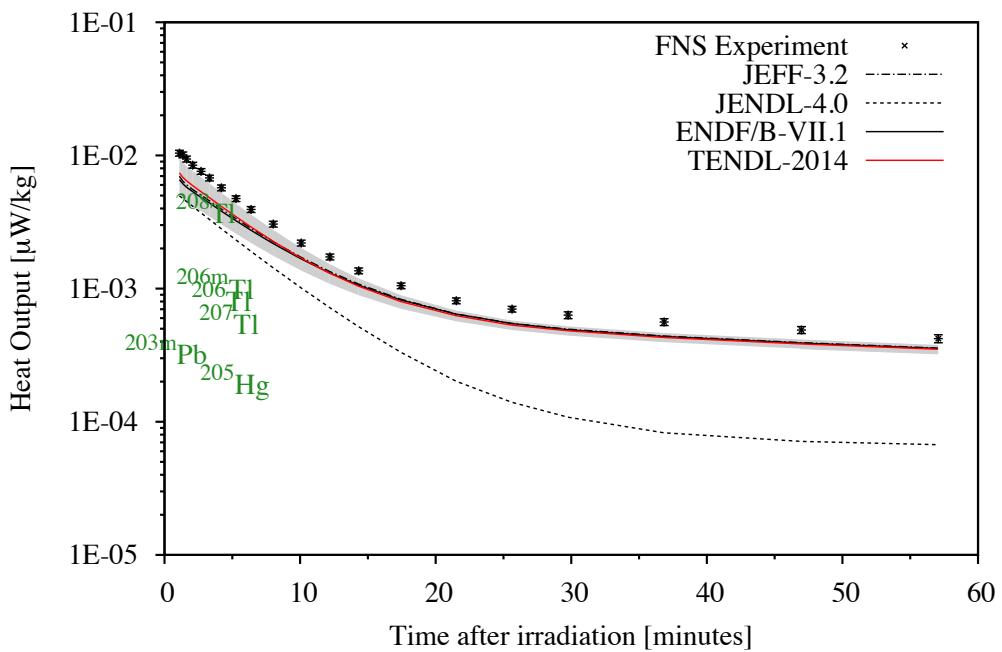


Lead

FNS-00 5 Min. Irradiation - Pb



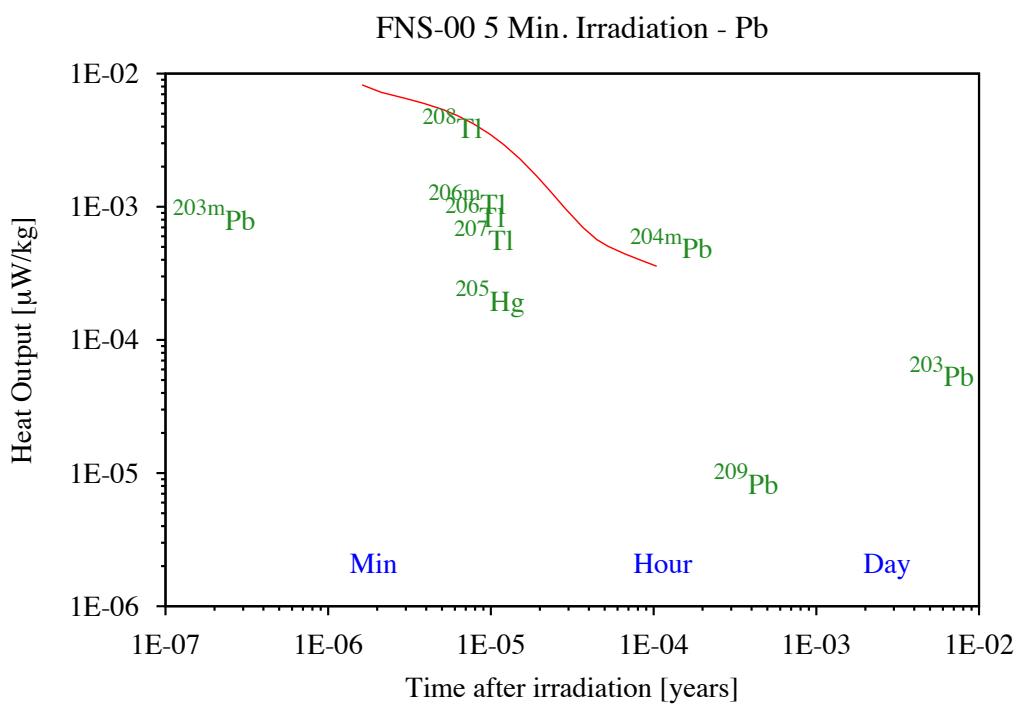
FNS-96 5 Min. Irradiation - Pb

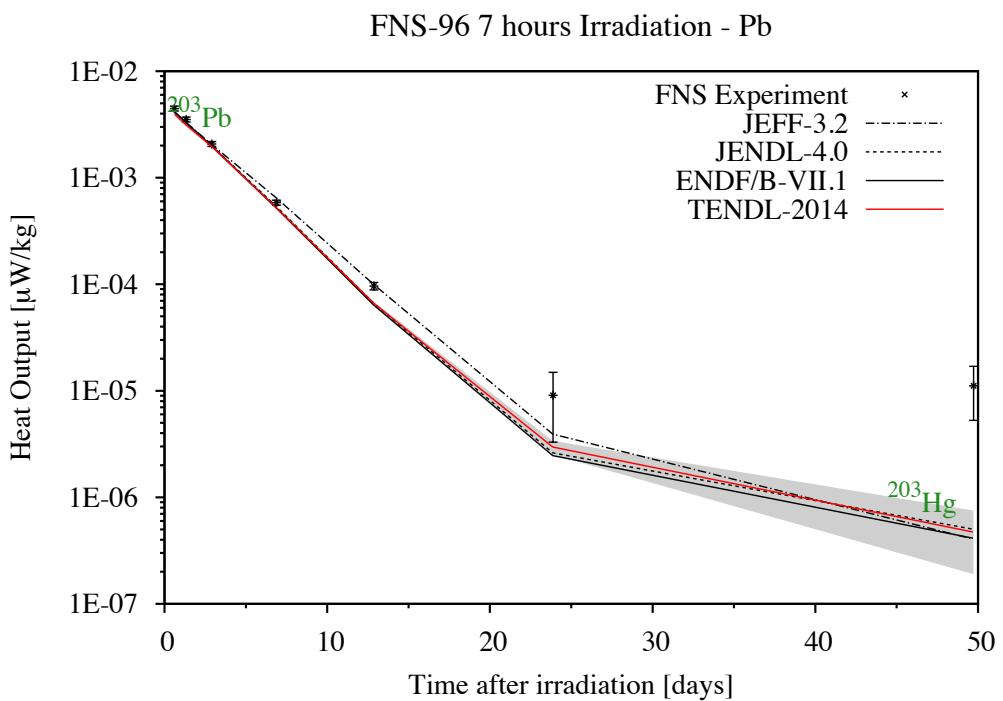


For Lead, the experimental data sets are somewhat different, although the more recent one seems better predicted by the calculations, particularly at longer cooling times. However, in both batches the short term heat predictions seem to be low compared with the measured ones.

Times Min.	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0	
	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C	
0.85	$1.16E-02 +/-6\%$	$8.21E-03 +/-27\%$	1.41	1.59	1.41	2.22
1.12	$1.01E-02 +/-6\%$	$7.23E-03 +/-29\%$	1.40	1.57	1.45	2.04
1.37	$9.53E-03 +/-6\%$	$6.79E-03 +/-30\%$	1.40	1.57	1.49	2.01
1.62	$9.09E-03 +/-6\%$	$6.45E-03 +/-30\%$	1.41	1.57	1.51	2.01
2.05	$8.14E-03 +/-6\%$	$5.96E-03 +/-29\%$	1.37	1.52	1.46	1.95
2.67	$7.19E-03 +/-6\%$	$5.37E-03 +/-28\%$	1.34	1.48	1.42	1.93
3.27	$6.69E-03 +/-6\%$	$4.84E-03 +/-28\%$	1.38	1.51	1.46	2.01
4.13	$5.32E-03 +/-6\%$	$4.17E-03 +/-27\%$	1.28	1.38	1.33	1.87
5.23	$4.33E-03 +/-6\%$	$3.48E-03 +/-25\%$	1.25	1.33	1.29	1.85
6.35	$3.39E-03 +/-6\%$	$2.91E-03 +/-24\%$	1.16	1.23	1.19	1.77
7.97	$2.67E-03 +/-6\%$	$2.28E-03 +/-22\%$	1.18	1.22	1.18	1.85
10.07	$1.84E-03 +/-7\%$	$1.70E-03 +/-19\%$	1.08	1.10	1.07	1.82
12.18	$1.35E-03 +/-9\%$	$1.31E-03 +/-17\%$	1.03	1.03	1.01	1.84
15.30	$9.80E-04 +/-11\%$	$9.49E-04 +/-14\%$	1.03	1.01	1.00	2.02
19.40	$6.98E-04 +/-15\%$	$6.97E-04 +/-10\%$	1.00	0.96	0.96	2.34
23.52	$5.04E-04 +/-19\%$	$5.67E-04 +/-9\%$	0.89	0.85	0.85	2.58
27.63	$4.65E-04 +/-21\%$	$5.04E-04 +/-8\%$	0.92	0.90	0.89	3.35
34.75	$3.63E-04 +/-27\%$	$4.45E-04 +/-8\%$	0.82	0.82	0.80	3.75
44.87	$2.82E-04 +/-34\%$	$3.93E-04 +/-8\%$	0.72	0.71	0.70	3.78
54.97	$2.55E-04 +/-38\%$	$3.57E-04 +/-8\%$	0.71	0.71	0.70	3.73
mean % diff. from E			20	24	22	54

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Pb203m	Pb204(n,2n)Pb203m	6.2s	97.4	1.41	6%
	Pb204(n,2n)Pb203n	480ms	2.6	1.41	6%
Tl208	Pb208(n,p)Tl208	3.0m	100.0	1.38	6%
Pb204m	Pb204(n,n')Pb204m	1.1h	100.0	0.71	38%

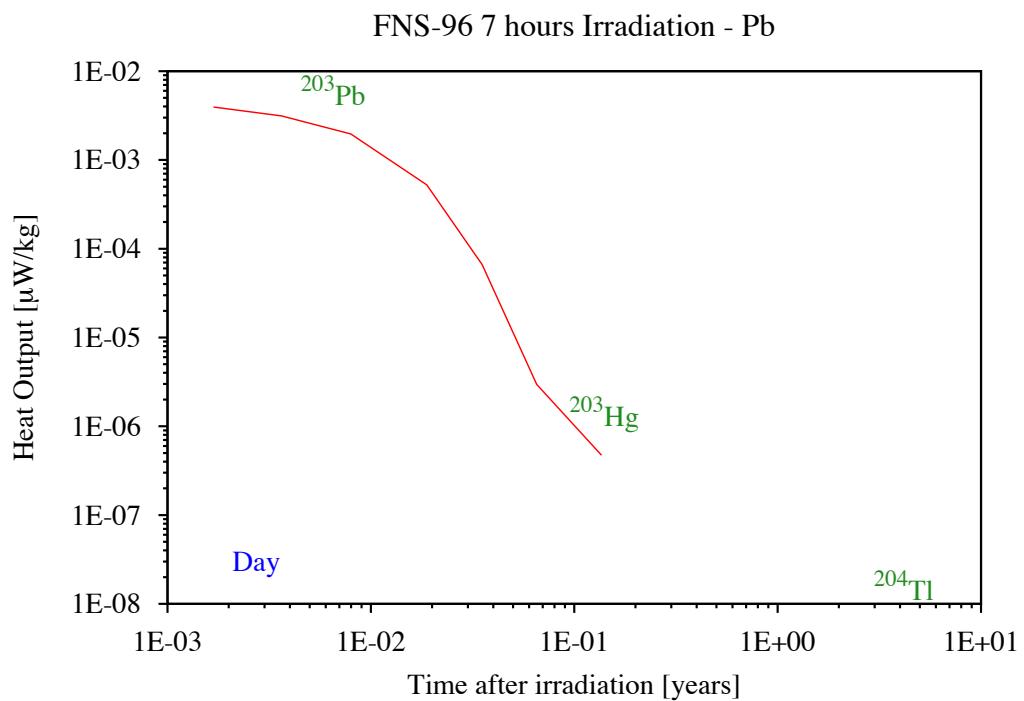




A good agreement is seen in the above graph, although large discrepancies and uncertainties occur in both the measurements and TENDL's results beyond 20 days of cooling.

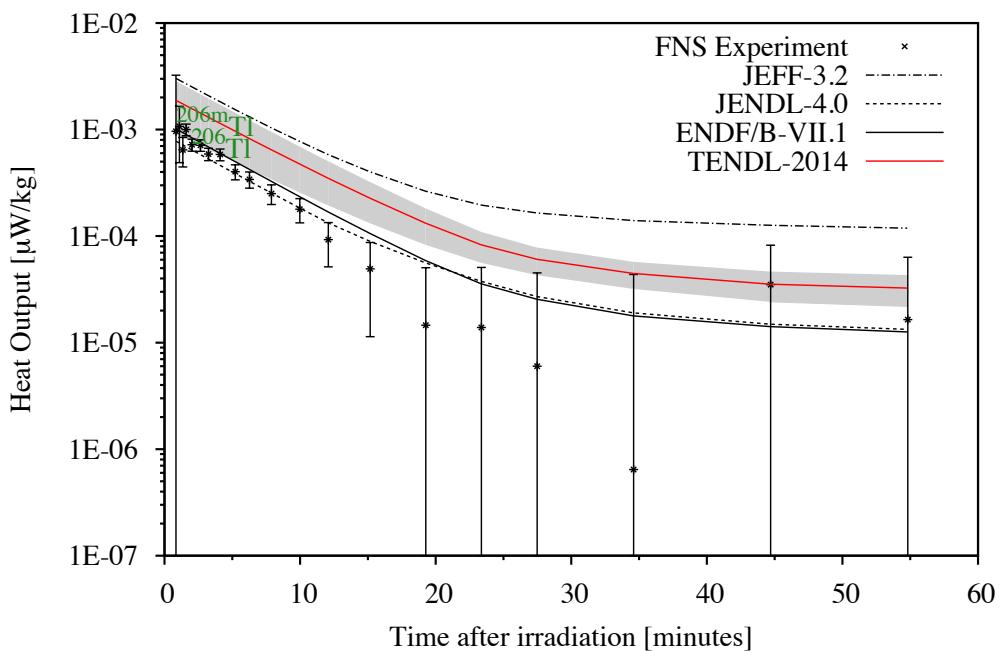
Times Days	FNS EXP. 7 hrs $\mu\text{W/g}$	TENDL-2014 $\mu\text{W/g}$	ENDF/B-VII.1 E/C	JEFF-3.2 E/C	JENDL-4.0 E/C
0.61	$4.46E-03 +/- 5\%$	$3.95E-03 +/- 4\%$	1.13	1.07	1.07
1.33	$3.52E-03 +/- 5\%$	$3.13E-03 +/- 4\%$	1.12	1.07	1.07
2.91	$2.08E-03 +/- 5\%$	$1.96E-03 +/- 4\%$	1.06	1.05	1.01
6.88	$5.83E-04 +/- 5\%$	$5.24E-04 +/- 4\%$	1.11	1.12	0.90
12.87	$9.62E-05 +/- 8\%$	$6.63E-05 +/- 4\%$	1.45	1.51	0.97
23.88	$9.09E-06 +/- 64\%$	$2.96E-06 +/- 14\%$	3.07	3.69	2.32
49.73	$1.11E-05 +/- 53\%$	$4.72E-07 +/- 59\%$	23.56	26.96	27.41
mean % diff. from E		33	33	26	32

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Pb203	Pb204(n,2n)Pb203	2.1d	51.7	1.06	5%
	Pb204(n,2n)Pb203m	6.2s	47.1	1.06	5%
	Pb204(n,2n)Pb203n	480ms	1.3	1.06	5%
Hg203	Pb206(n, α)Hg203	46.6d	98.2	3.07	64%
	Pb207(n,n α)Hg203	46.6d	1.8	3.07	64%

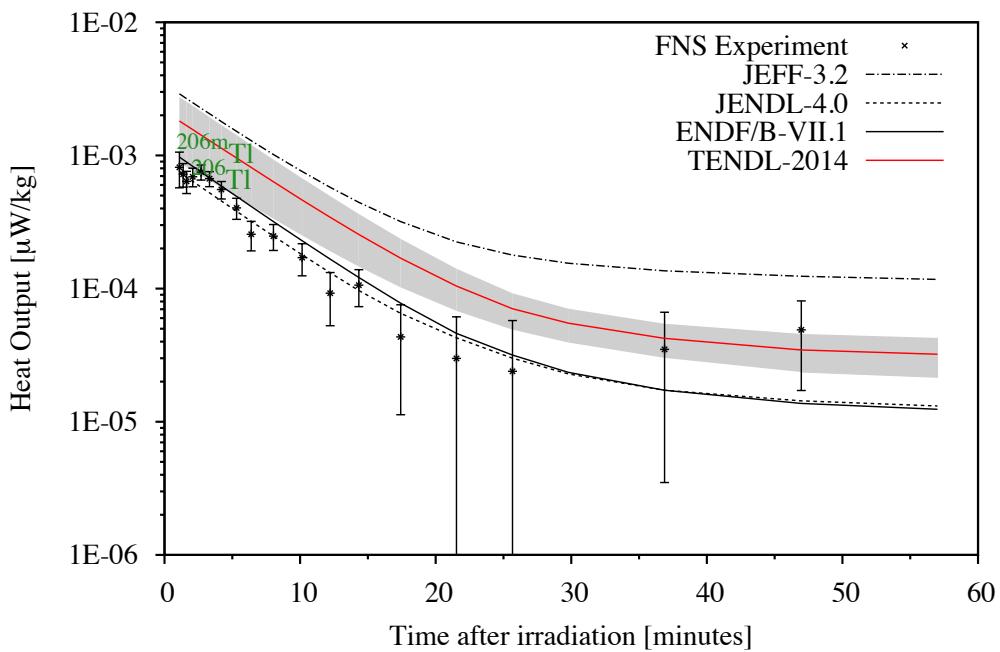


Bismuth

FNS-00 5 Min. Irradiation - Bi



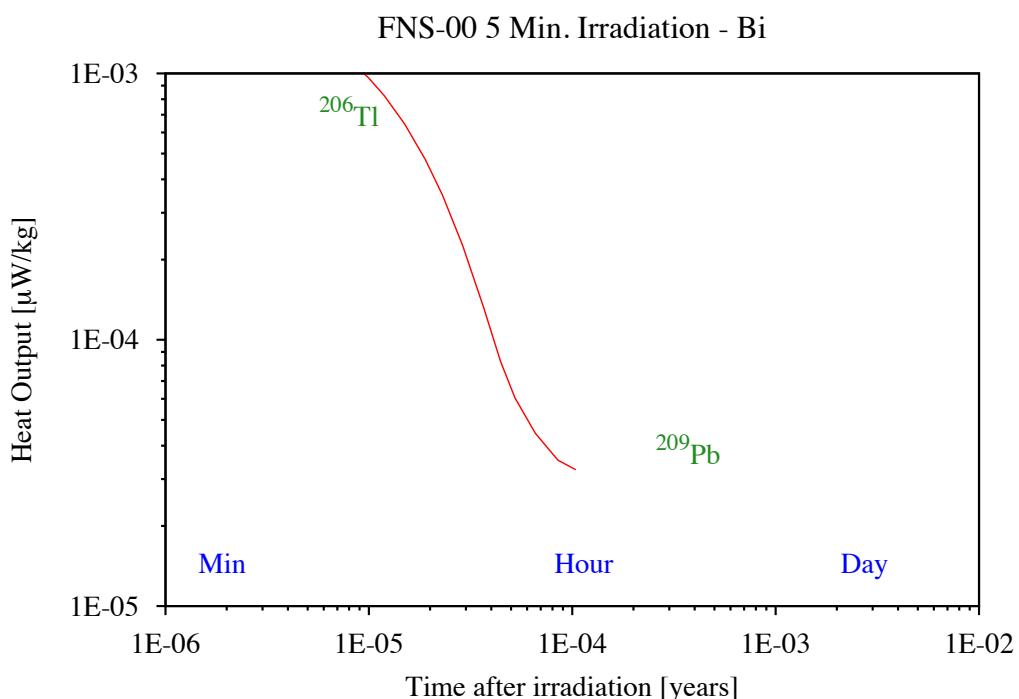
FNS-96 5 Min. Irradiation - Bi



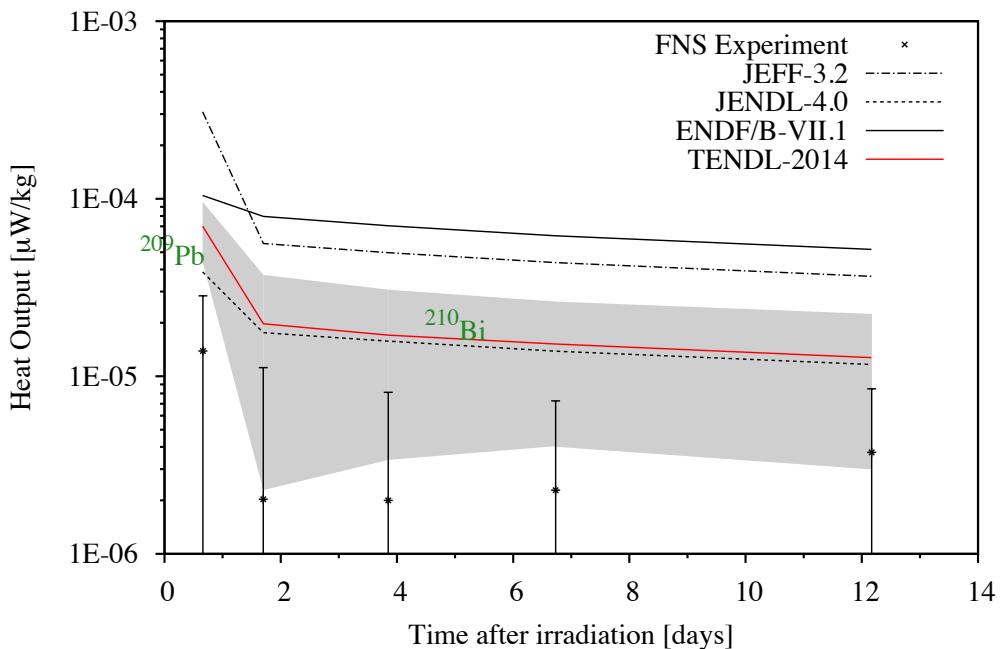
For Bismuth, some large differences and uncertainties can be seen between the two experimental data-sets. This is also the case in the predictions derived from the different databases.

Times	FNS EXP. 5 mins	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Min.	$\mu\text{W/g}$	$\mu\text{W/g}$	E/C	E/C	E/C
0.85	$9.65E-04 +/- 235\%$	$1.88E-03 +/- 52\%$	0.51	0.95	0.32
1.10	$1.07E-03 +/- 54\%$	$1.81E-03 +/- 52\%$	0.59	1.10	0.37
1.35	$6.44E-04 +/- 31\%$	$1.74E-03 +/- 51\%$	0.37	0.69	0.23
1.60	$1.00E-03 +/- 12\%$	$1.68E-03 +/- 51\%$	0.60	1.12	0.37
2.03	$7.20E-04 +/- 13\%$	$1.57E-03 +/- 51\%$	0.46	0.86	0.29
2.65	$7.12E-04 +/- 12\%$	$1.43E-03 +/- 50\%$	0.50	0.94	0.31
3.25	$5.89E-04 +/- 13\%$	$1.30E-03 +/- 50\%$	0.45	0.86	0.28
4.10	$5.83E-04 +/- 13\%$	$1.14E-03 +/- 50\%$	0.51	0.97	0.32
5.22	$4.02E-04 +/- 16\%$	$9.66E-04 +/- 49\%$	0.42	0.80	0.26
6.27	$3.41E-04 +/- 17\%$	$8.24E-04 +/- 48\%$	0.41	0.81	0.26
7.88	$2.51E-04 +/- 21\%$	$6.47E-04 +/- 47\%$	0.39	0.77	0.24
9.98	$1.79E-04 +/- 26\%$	$4.74E-04 +/- 46\%$	0.38	0.76	0.23
12.08	$9.27E-05 +/- 45\%$	$3.49E-04 +/- 44\%$	0.27	0.55	0.16
15.17	$4.92E-05 +/- 77\%$	$2.27E-04 +/- 42\%$	0.22	0.46	0.12
19.27	$1.46E-05 +/- 247\%$	$1.32E-04 +/- 37\%$	0.11	0.25	0.06
23.37	$1.39E-05 +/- 266\%$	$8.29E-05 +/- 32\%$	0.17	0.39	0.07
27.48	$6.00E-06 +/- 653\%$	$6.05E-05 +/- 29\%$	0.10	0.23	0.04
34.60	$6.43E-07 +/- 6683\%$	$4.46E-05 +/- 28\%$	0.01	0.04	0.00
44.70	$3.50E-05 +/- 134\%$	$3.53E-05 +/- 32\%$	0.99	2.48	0.28
54.82	$1.64E-05 +/- 285\%$	$3.25E-05 +/- 33\%$	0.51	1.30	0.14
mean % diff. from E		561	198	1626	202

Product	Pathways	$T_{1/2}$	Path %	E/C	$\Delta E\%$
Tl206	Bi209(n, α)Tl206	4.2m	93.7	0.51	16%
	Bi209(n, α)Tl206m	3.7m	7.3	0.51	16%
Pb209	Bi209(n,p)Pb209	3.2h	100.0	0.51	285%



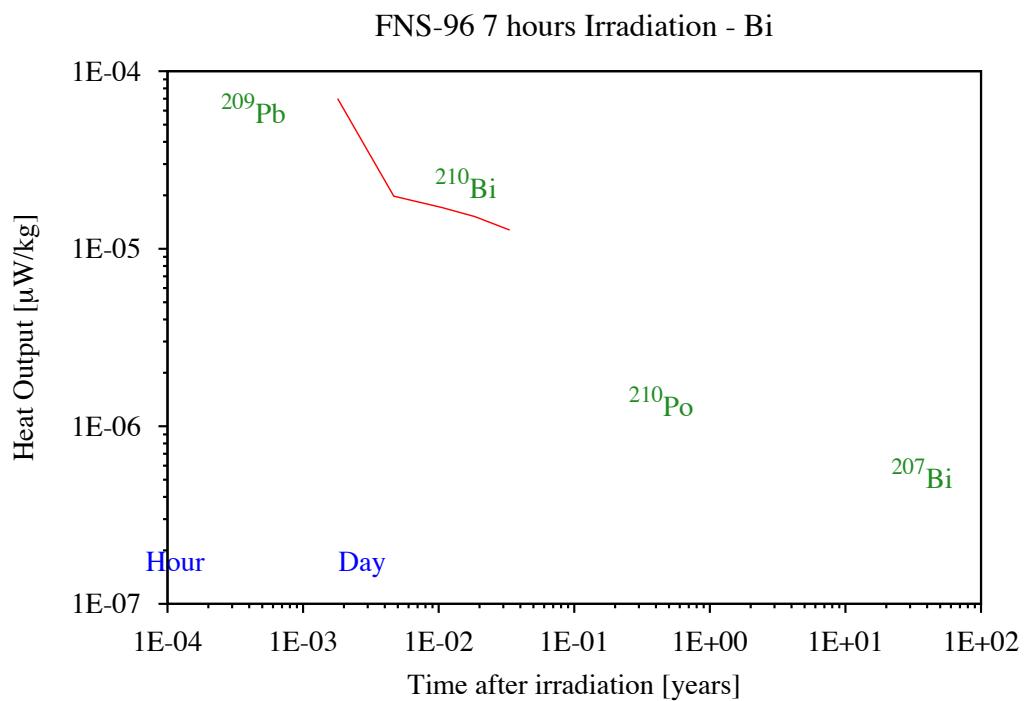
FNS-96 7 hours Irradiation - Bi



A poor C/E agreement on this important element, but the response profile seems to be reasonably shaped.

Times	FNS EXP. 7 hrs	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0	
Days	μW/g	μW/g	E/C	E/C	E/C	
0.66	1.39E-05 +/-105%	7.01E-05 +/-37%	0.20	0.13	0.04	0.36
1.70	2.03E-06 +/-451%	1.98E-05 +/-88%	0.10	0.03	0.04	0.12
3.85	2.00E-06 +/-307%	1.71E-05 +/-80%	0.12	0.03	0.04	0.13
6.73	2.28E-06 +/-218%	1.52E-05 +/-73%	0.15	0.04	0.05	0.16
12.17	3.73E-06 +/-128%	1.27E-05 +/-76%	0.29	0.07	0.10	0.32
mean % diff. from E		568	2358	1972	471	

Product	Pathways	T _{1/2}	Path %	E/C	ΔE%
Tl206	Bi209(n,α)Tl206	4.2m	73.1	0.20	105%
	Bi209(n,α)Tl206m	3.7m	26.9	0.20	105%
Pb209	Bi209(n,p)Pb209	3.2h	91.9	0.10	105%
Bi210	Bi209(n,γ)Bi210	5.0d	100.0	0.15	218%



5 Summary Tables

Here we present two summary tables, based on the 2000 5-minute and 1996 7-hour results, respectively. For each material we calculate a rough indicative measure of the quality of agreement between each nuclear library considered and the experimental results. This measure is the time-averaged absolute % difference between each calculated decay heat and its corresponding experimental value. In other words, each value in the following tables is calculated via:

$$\langle \% \Delta^x \rangle = \frac{1}{n_t} \sum_{t=1}^{n_t} \frac{100|C_t^x - E_t|}{E_t}, \quad (1)$$

where $\% \Delta^x$ is the % difference for library x , n_t is the total number of experimental points (times), C_t^x is the calculated decay heat at time t for library x , and E_t is the experimental measurement at t . Where there are no calculated values – due to deficiencies in a particular library – then the assumed difference contribution is 100%, which is mathematically correct but is perhaps a conservative estimate since in situations where a library severely overestimates the % difference may be much more than 100%. Note that the values in the summary tables below, and in the final row of the comparison tables for each material where they are also given, have been rounded to the nearest %. In the summary tables a colour coding is applied to the values, with green indicating a better than 10% agreement on average, orange better than 50%, and red worse than this.

Table of mean % differences from FNS-00 5 minute experiments, indicating the quality of agreement for different libraries for cooling times ranging from a few minutes up to 1 hour.

material	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Fluorine	2	2	96	5
Sodium	28	38	20	25
Magnesium	6	7	7	7
Aluminium	8	8	14	13
Silicon	7	14	8	4
Phosphorus	6	11	5	8
Sulphur	27	72	31	72
Chlorine	13	44	45	45
Potassium	4	18	28	18
Calcium	17	13	13	14
Scandium	5	64	10	63
Titanium	2	7	6	8
Vanadium	13	13	97	6
Chromium	17	15	14	19
Manganese	6	17	25	21
Iron	7	8	11	6
SS304	3	3	3	3
SS316	6	6	6	5

material	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Cobalt	10	5	5	3
Inconel-600	6	15	14	14
Nickel	15	37	37	44
Nickel-chrome	5	12	12	12
Copper	5	6	7	10
Zinc	11	6	21	6
Gallium	3	4	3	3
Germanium	11	14	9	14
Arsenic	14	17	14	9
Selenium	9	33	13	50
Bromine	2	28	3	26
Rubidium	5	94	4	95
Strontium	6	36	4	23
Yttrium	21	60	60	54
Zirconium	8	5	9	70
Niobium	13	97	97	97
Molybdenum	1	5	6	15
Ruthenium	3	29	71	29
Rhodium	221	111	232	117
Palladium	19	65	59	63
Silver	9	89	114	95
Cadmium	21	66	65	54
Indium	578	210	213	227
Tin	14	73	37	72
Antimony	21	68	78	78
Tellurium	8	172	85	105
Iodine	80	82	93	78
Caesium	59	58	59	59
Barium	14	80	77	78
Lanthanum	316	306	307	368
Cerium	41	95	91	114
Praseodymium	44	33	36	52
Neodymium	59	72	41	71
Samarium	8	13	14	13
Europium	113	91	90	92
Gadolinium	32	37	61	51
Terbium	74	78	79	80
Dysprosium	230	224	226	232
Holmium	20	31	31	100
Erbium	100	135	105	136
Thulium	77	82	77	77
Ytterbium	39	98	54	90
Lutetium	85	96	101	97
Hafnium	27	88	88	32

material	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Tantalum	13	58	53	51
Tungsten	86	77	77	78
Rhenium	18	15	25	100
Osmium	78	98	76	65
Iridium	39	429	271	101
Platinum	9	95	5	95
Gold	28	38	38	38
Mercury	15	95	95	96
Thallium	44	42	22	95
Lead	20	24	22	54
Bismuth	561	198	1626	202

Table of mean % differences from FNS-96 7 hour experiments, indicating the quality of agreement for different libraries for cooling times ranging from a few days up to approximately 1 year.

material	TENDL-2014	ENDF/B-VII.1	JEFF-3.2	JENDL-4.0
Sodium	14	18	4	27
Aluminium	48	58	100	48
Sulphur	9	8	13	8
Potassium	154	188	154	185
Calcium	6	5	5	22
Titanium	10	8	10	7
Vanadium	21	25	100	28
Chromium	27	27	26	26
Manganese	4	6	4	2
Iron	11	14	11	6
SS304	7	6	6	9
SS316	6	6	8	11
Cobalt	11	4	4	5
Inconel-600	2	3	3	7
Nickel	3	4	4	12
Nickel-chrome	3	4	3	10
Copper	10	13	15	20
Strontium	10	13	5	14
Yttrium	16	30	30	16
Zirconium	8	10	8	7
Niobium	6	98	98	98
Molybdenum	13	27	31	29
Tin	22	50	59	51
Barium	10	72	71	71
Tantalum	49	73	70	78
Tungsten	22	27	24	23
Rhenium	8	30	9	100
Lead	33	33	26	32
Bismuth	568	2358	1972	471

6 Analysis of the results

From such a validation exercise a lot of information can be extracted from the results. However, its uniqueness and specificities require caution to be applied when drawing or projecting conclusions from the results.

6.1 General comments

The time dependence of the comparison has been clearly established and it was not surprising to see some fluctuations in the degree of agreement with cooling time. This is due to the fact that the set of predominant radionuclides evolves with time in direct relation with their appropriate half-lives. A clear picture emerges in that the comparative results for short cooling times, less than one hour, tend to be worse than the results for cooling times greater than a day but shorter than a year. This was expected, since the nuclear database (production cross sections and decay data) tends to be less qualified for these short-lived nuclides. This is due to difficulties encountered when assessing short half-life isotopes and isomers. Having said that, the agreement reached on the prediction of some short lived isomers when the TENDL library is used is rather good – a specificity that is unique to a properly assembled nuclear data file that contains all necessary branching ratios. All the other major transport libraries are missing details of such information. The overall results are surprisingly good on exotic material samples, even more so when allowing for certain experimental difficulties.

What has been clearly demonstrated by this validation exercise is that the calculational method used by the FISPACT-II to predict the decay power and associated uncertainty of structural materials under a hard fusion neutron field is adequate. When the nuclear data are known with sufficient accuracy the code predictions are within the boundaries defined by the experimental uncertainty. However, the nuclear databases, TENDL-2014, ENDF/B-VII.1, JEFF-3.2 and JENDL-4.0 tend to give different results because of variation in the data they contain for the cross sections and decay of the radionuclides involved. The majority of the results are satisfactory and give credit to the work performed in assembling such large libraries. However, the level of accuracy of the cross sections and decay data tested by this validation exercise span from a few percent, which is acceptable, to orders of magnitude, which is not. When the latter case occurs then very specific and time consuming studies need to be performed before any action is taken to correct the nuclear databases. Such remarks are in line with the results of earlier international code comparisons on decay heat, including [4, 5] and some performed on fission fuel materials [18].

All the cross section paths linked with an E/C values greater than 10% have been analysed in line with other validation studies, (FNG Frascati, SNEG-13 Sergiev Posad, D-Be Cyclotron Karlsruhe, etc.) and compared with the experimental database EXFOR [16]. The decay data of the radionuclides produced still needs to be checked

in more detail. If the results corroborate one another there will be more incentive and firm grounds to apply an appropriate correction in the next generation of truly general-purpose nuclear data-files.

6.2 Experimental, calculational uncertainty and E/C

When concerned with uncertainties related to the activation calculations themselves, one has to acknowledge the complexity and magnitude of the nuclear data libraries. The TENDL-2014 general-purpose file [8] contains the neutron-induced reactions on stable and unstable targets including actinides. If a reaction can produce one, two or more isomers, the cross sections for producing the ground and the different isomeric states are all given separately.

In contrast the other libraries, ENDF/B-VII.1, JEFF-3.2 or JENDL-4.0, only contain a handful of isomeric states, which seriously impairs their ability to properly simulate any responses when these are predominant. This is particularly obvious at short cooling times, most important for operational safety. Furthermore, these three libraries are often identical to each other, containing the same data for legacy, pure criticality reasons, and thus have the same failures and deficiencies.

The TENDL-2014 library contains 2632 target nuclides ranging from ^1H to ^{281}Ds with all reactions kinematically allowed up to 200 MeV. Meanwhile the associated decay library contains data for 3875 nuclides, that may be produced by any combination of reactions and decays. Quite importantly covariance-variances information (mf31-35, 40) are uniquely stored for incident particles with energies from 10^{-5}eV up to 200 MeV. Above the upper energy of the resolved resonance range, for each of the 2630 isotopes, a Monte Carlo method, in which the covariance data come from uncertainties of the nuclear model calculations, is used. Short-range, self-scaling variance components are also specified for each (mt) reaction type. The data format used to store the variance-covariance information has been made fully compliant with the ENDF-6 format [19] description and the files are read directly by FISPACT-II without any further intermediate processing. Variance and covariance data are re-used by FISPACT-II to create uncertainty predictions and sensitivity analyses.

Systematic experimental uncertainty, calculational uncertainty and E over C values have been quoted and calculated in a way that allows a direct comparison to be made. The Total Monte Carlo (TMC) method used for the generation of qualitative variance information in TENDL-2014, compared to what was done in EAF_2010 uncertainty file is a significant achievement, when the calculational uncertainties quoted in the tables are of the same order of the E/C values. This demonstrates that the method chosen to calculate these uncertainties in the TALYS code system is not only valid but adequate. Of course, the same remarks as for the cross section and decay data file apply: even if the bulk of the data seems to be satisfactory, certain specific data entries need to be revisited in line with the findings of this validation exercise and other studies.

7 Conclusions

The experimental time-dependent decay-power measurement program at JAEA FNS combined with the code simulations performed in this study provide a unique check of the calculational method and nuclear databases associated with the prediction of decay power for the set of material samples analysed. The results of the comparison give confidence in most of the decay heat values calculated, although the predominantly 14 MeV neutron spectrum in FNS means that the low neutron energy reactions of importance in other devices have not yet been fully considered [20]. This statement limits the scope of validation and possible conclusions reached in this study to the decay power predicted through the identified pathways. However, it covers the decay data of all the isotopes involved irrespective of their production routes.

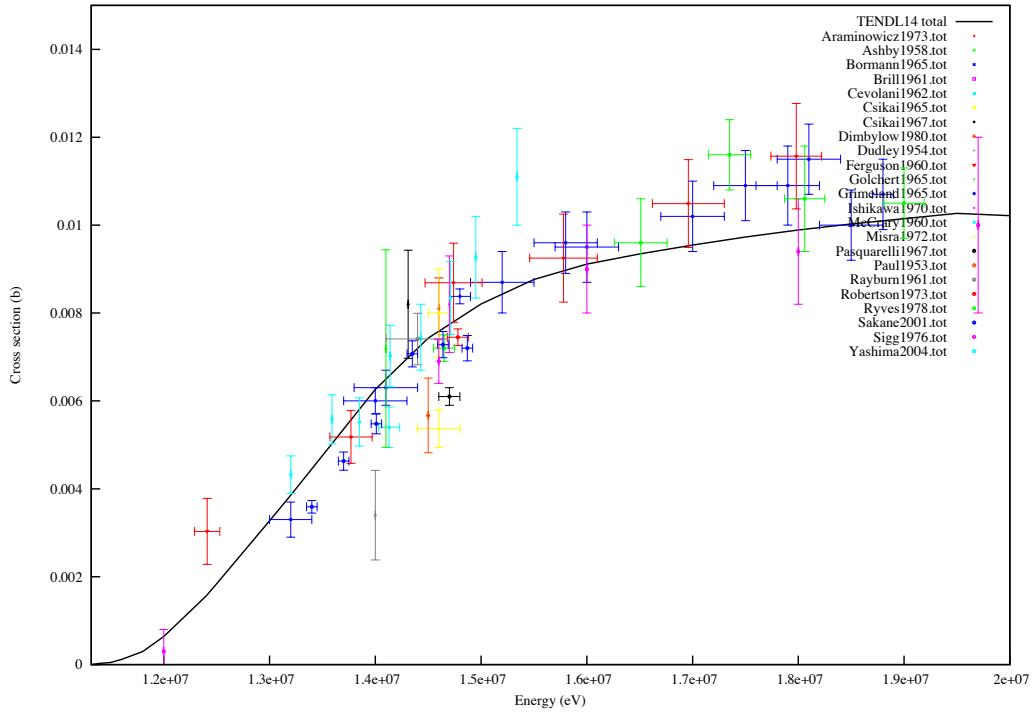
The experimental uncertainty, calculational uncertainty and E/C values have been systematically produced. Their direct comparison demonstrates that the method chosen to calculate and propagate these uncertainties in the EASY-II code system is verified and validated (V&V), and that the uncertainties file could be further improved along the same lines.

From the results, a set of inadequacies, not only in the cross sections but also in the decay libraries, have been identified that will require some corrective actions to be taken. These corrections and/or amendments will benefit the next generation of the TENDL library cross sections, associated variance and covariances, and decays data files. As expected, they impact both the production paths and/or decay data of some specific radionuclides without impairing the overall picture. A large proportion of the decay powers calculated in this validation exercise with TENDL-2014 are in good agreement (within a few %) with the experimental values for cooling times spanning from tens of seconds, and this is a unique insight, up to more than a year.

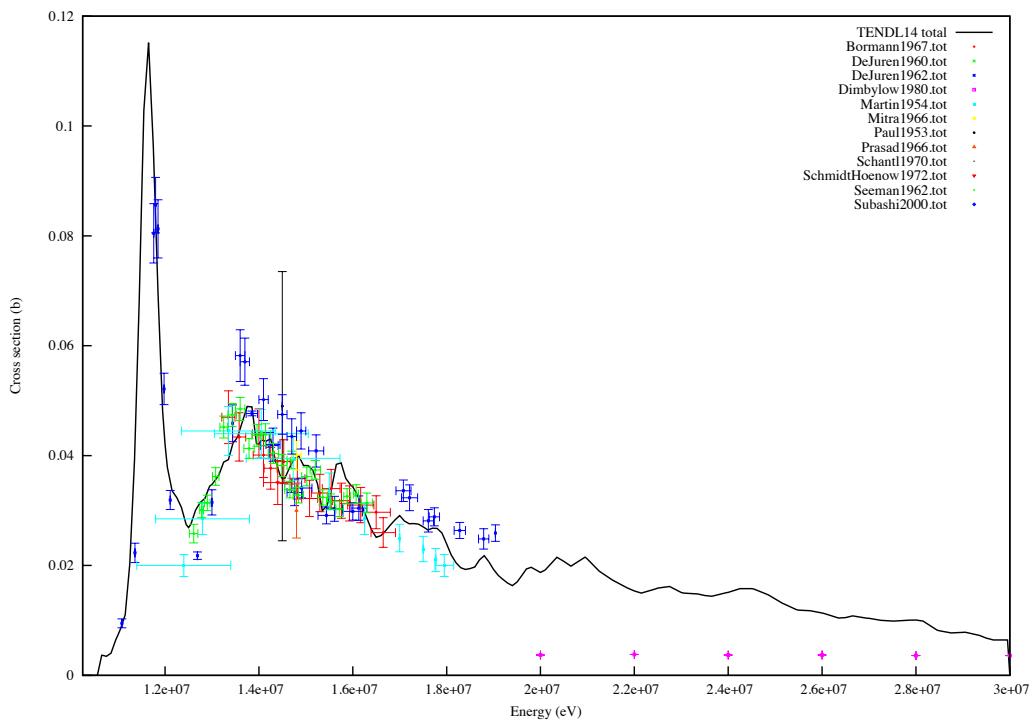
Maintenance and testing of activation inventory code systems and truly general purpose libraries is essential for many projects in order to present a sound and well validated safety assessment. Licensing authorities will require evidence of experimental validation. However, the relevance of the experimental irradiation conditions and set-up to those that are likely to exist in a device needs to be carefully considered in order for such an assessment and validation to be applicable to the data predicted for the next generation of plants.

8 Appendix of differential plots

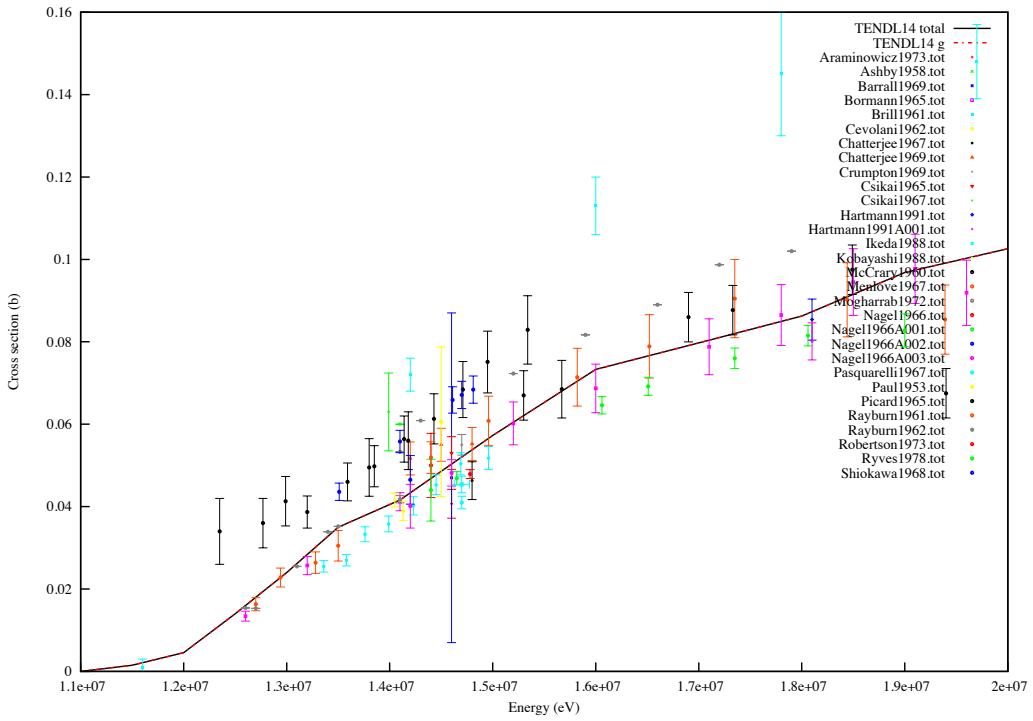
N14(n,2n)N13



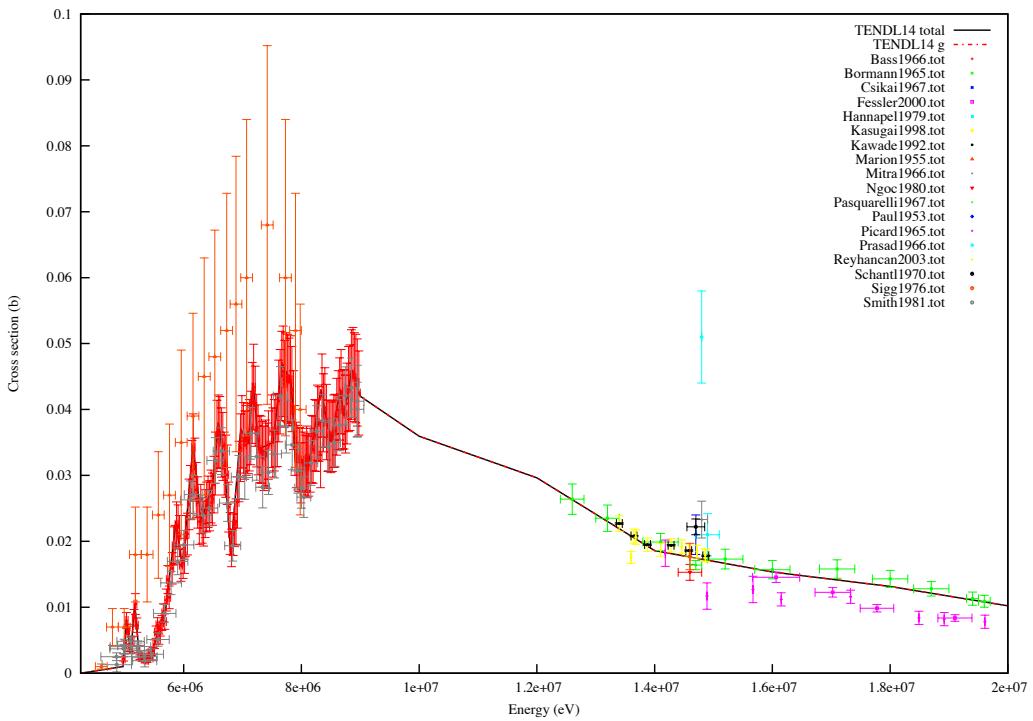
O16(n,p)N16



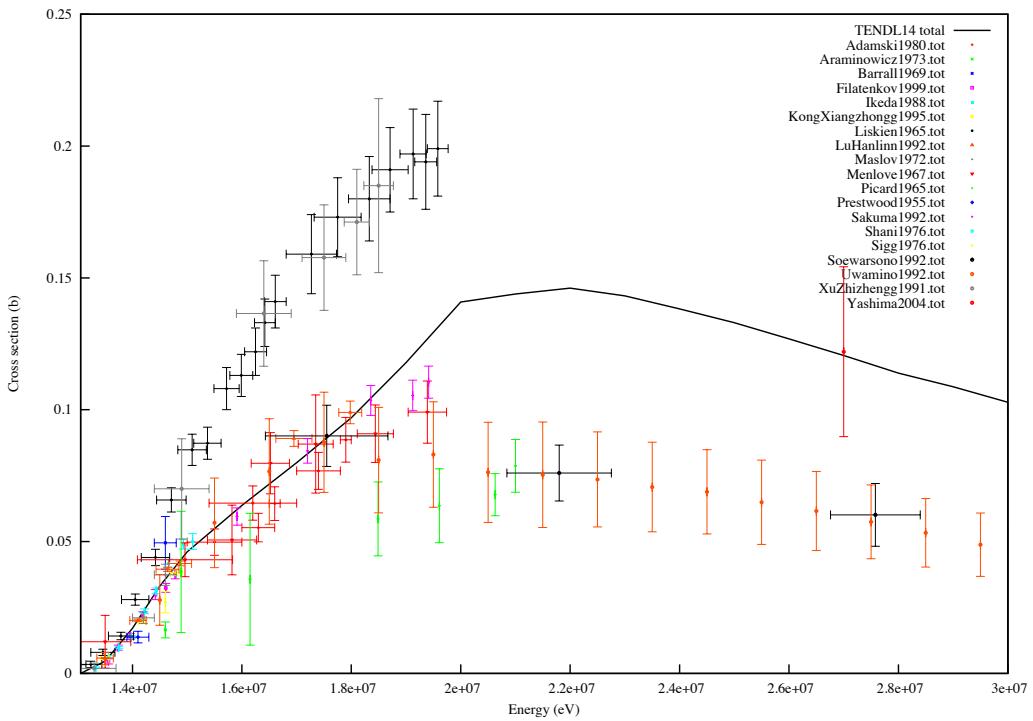
F19(n,2n)F18



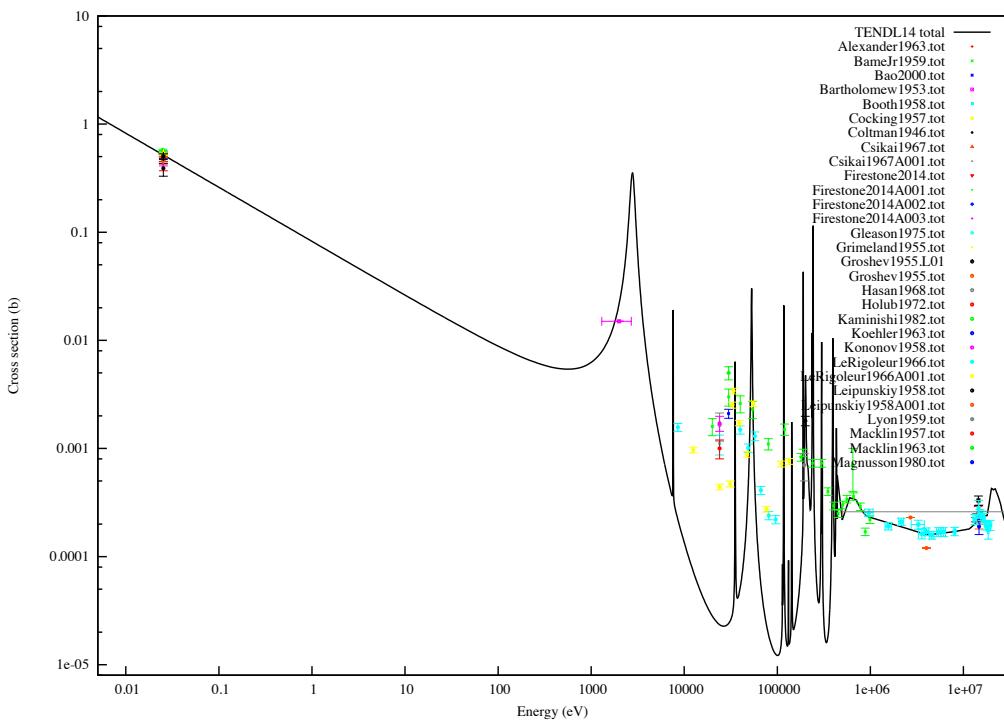
F19(n,p)O19



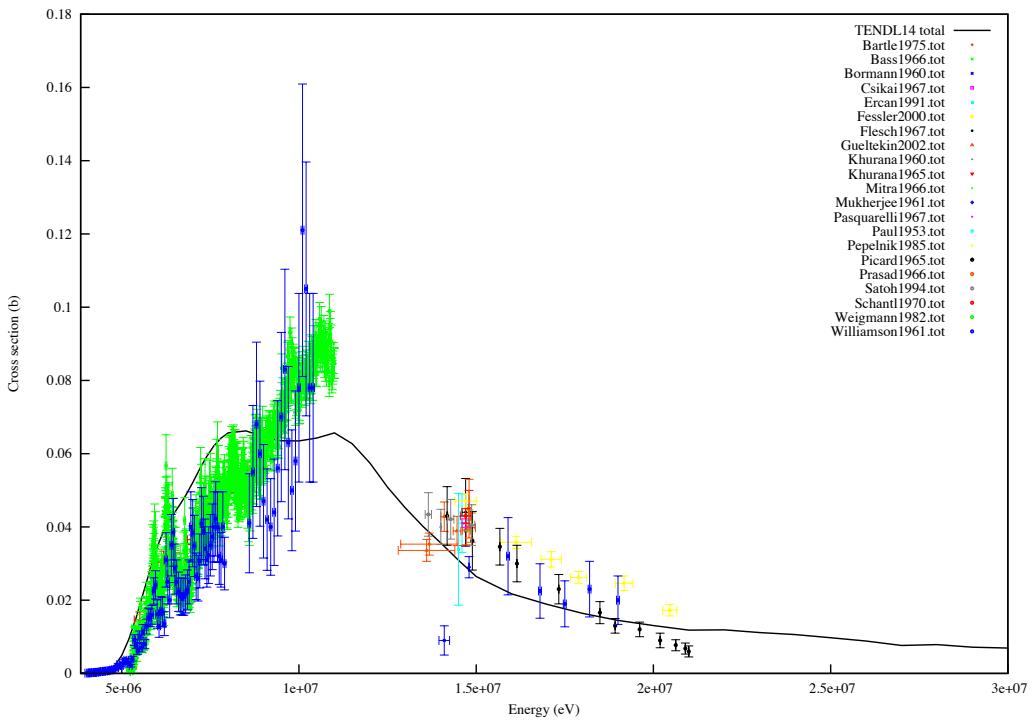
Na23(n,2n)Na22



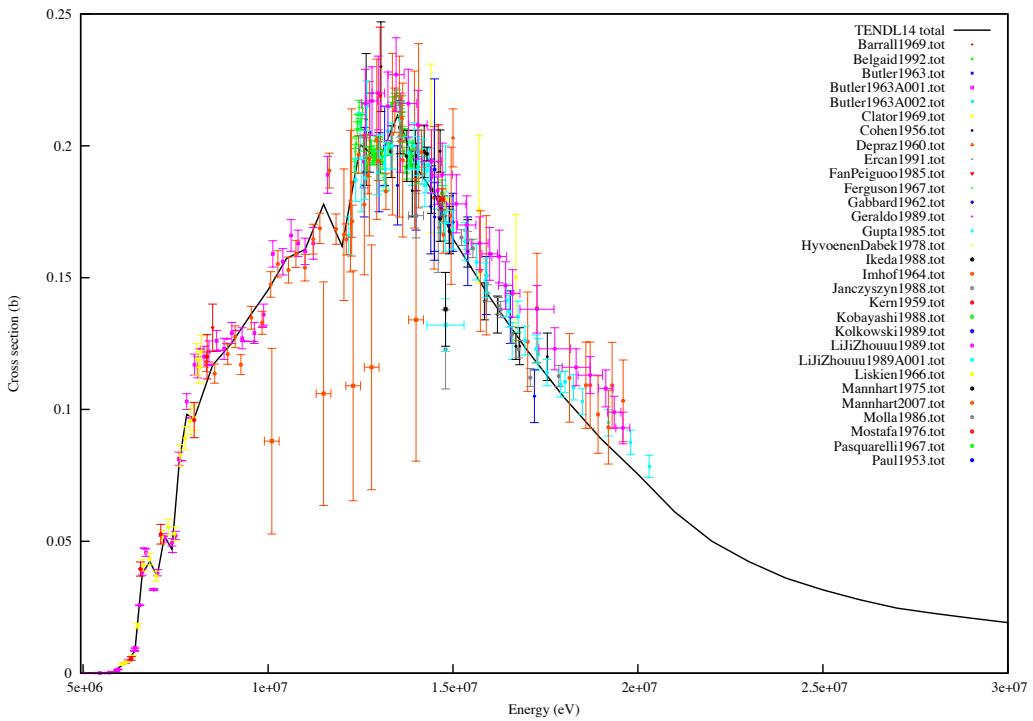
Na23(n, γ)Na24



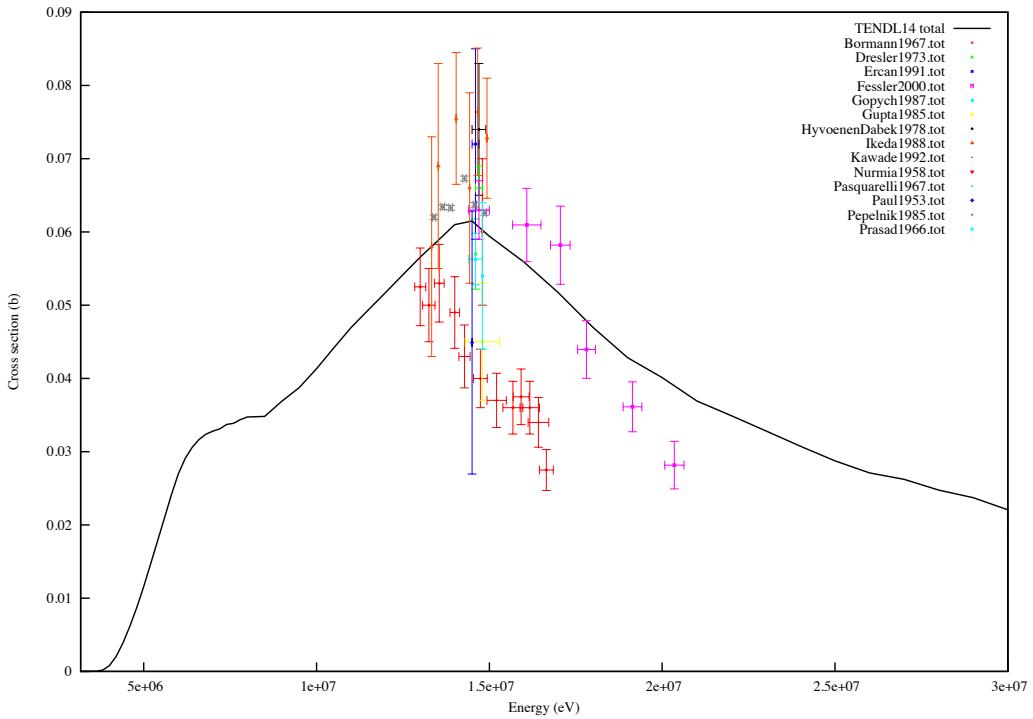
Na23(n,p)Ne23



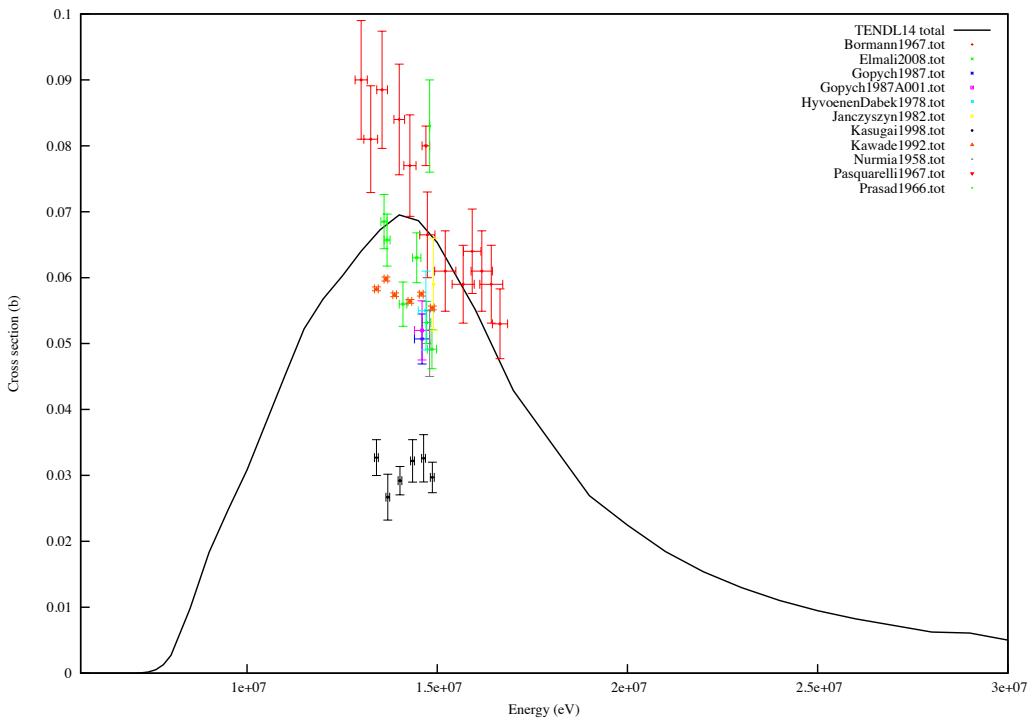
Mg24(n,p)Na24



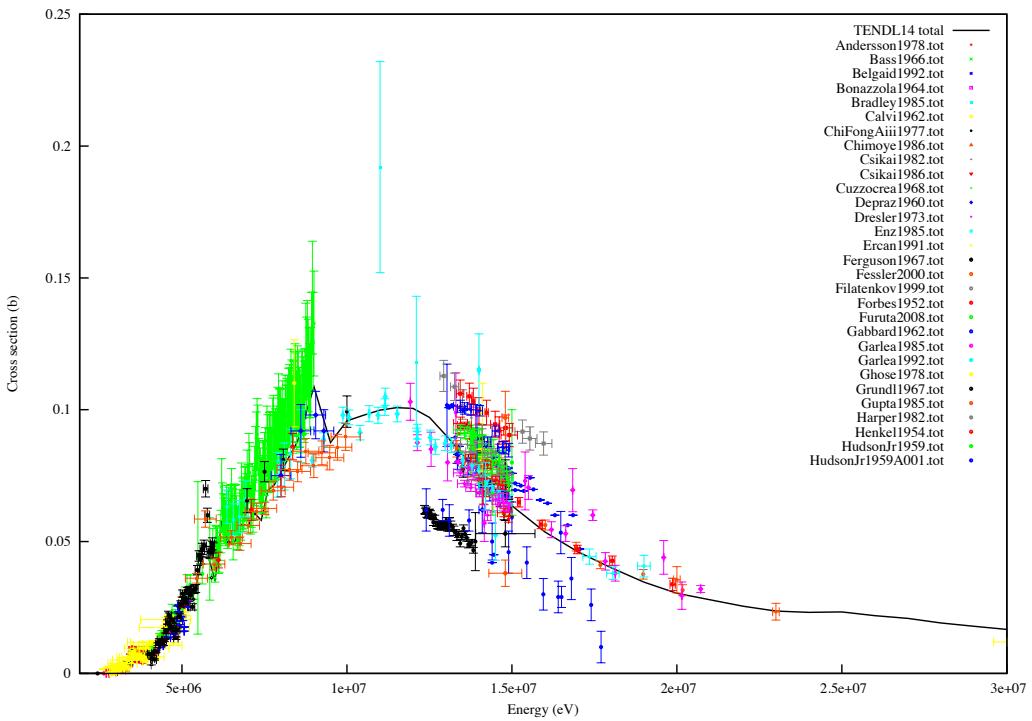
Mg25(n,p)Na25



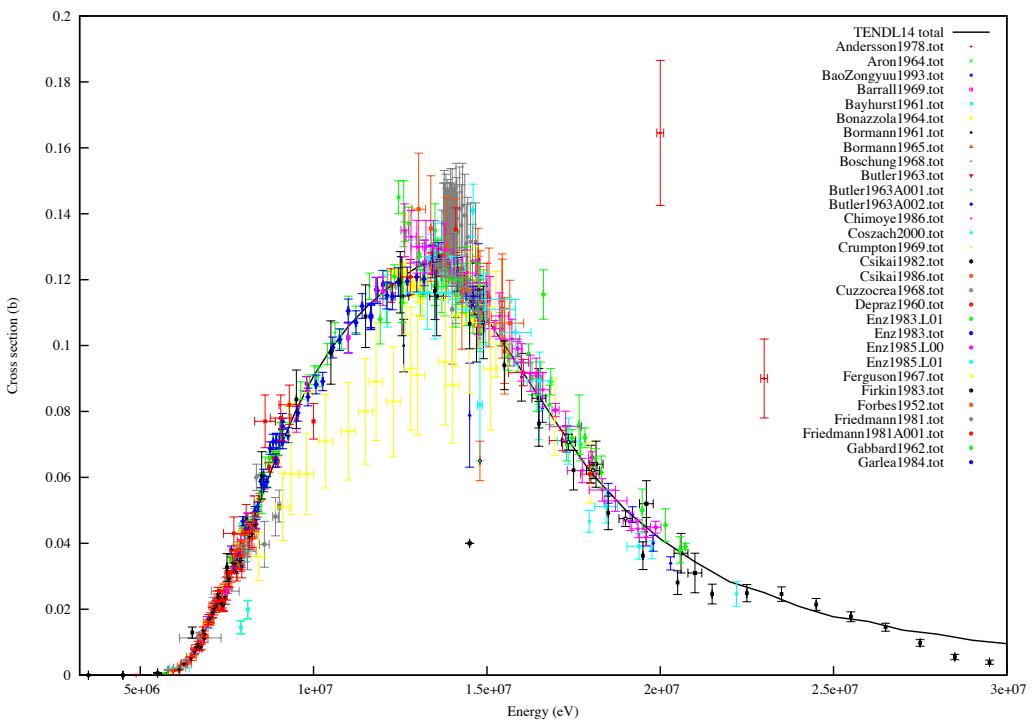
Mg26(n, α)Ne23



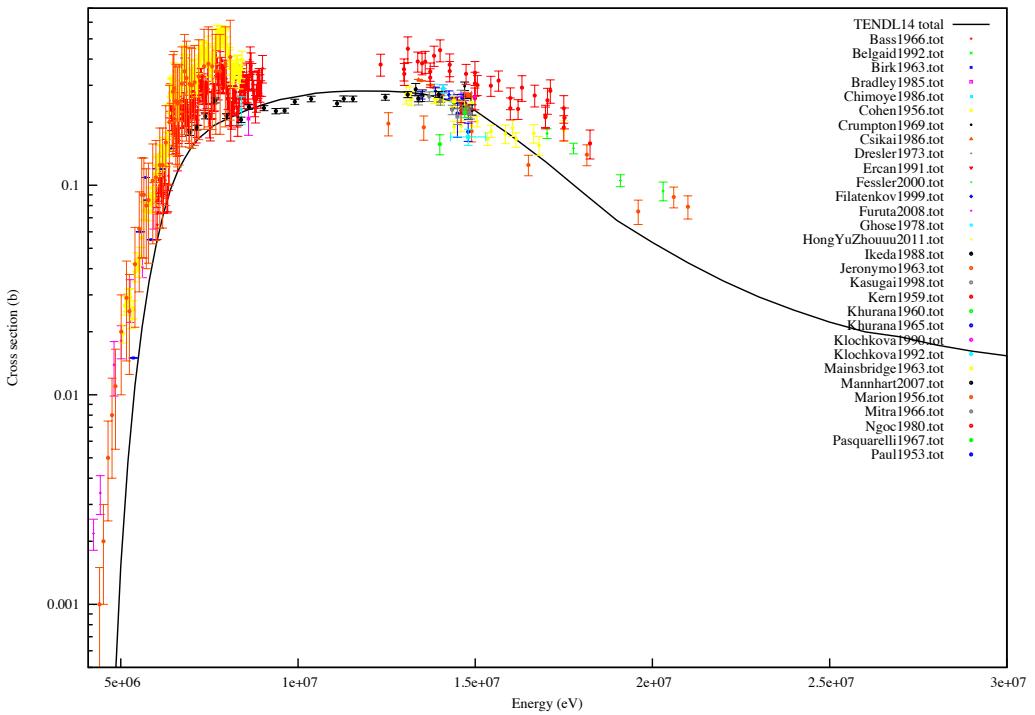
Al27(n,p)Mg27



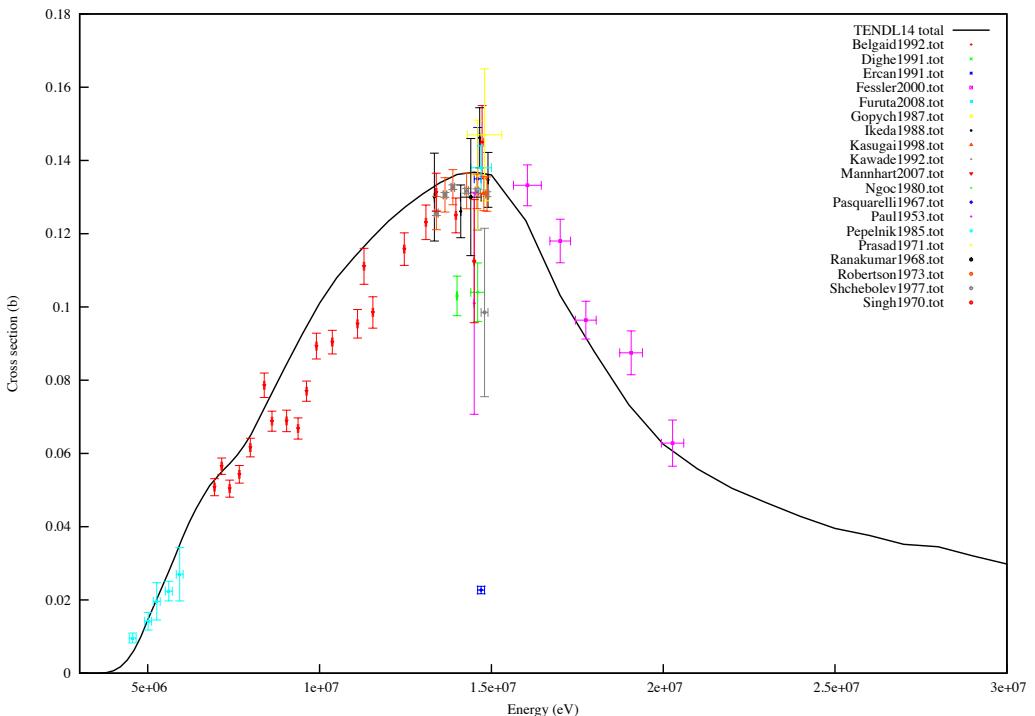
Al27(n, α)Na24



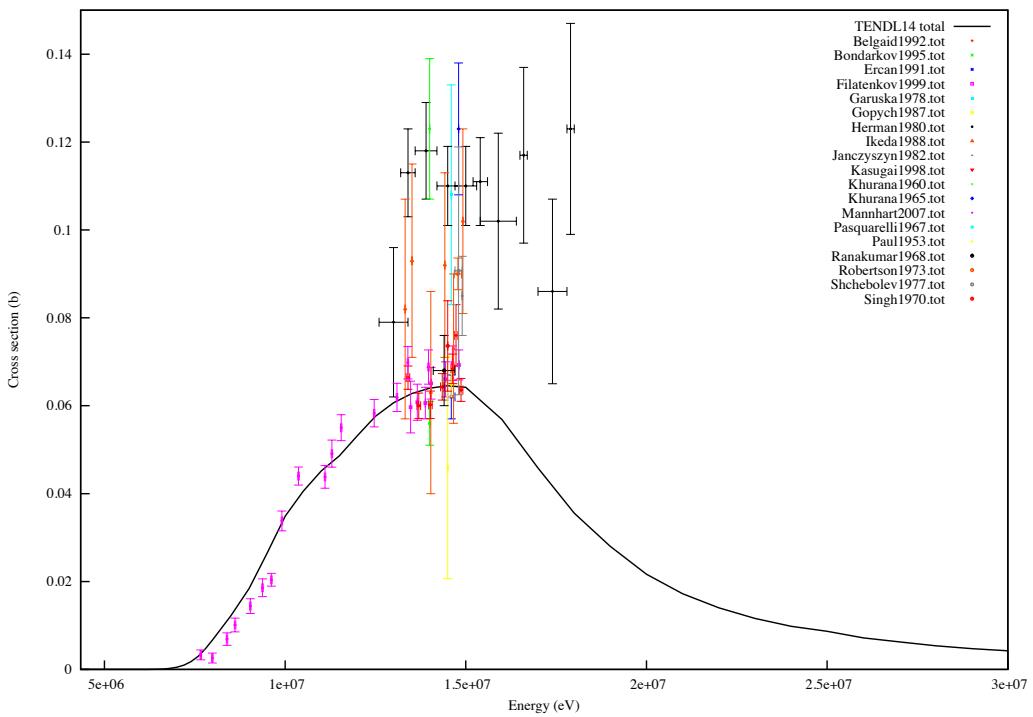
Si28(n,p)Al28



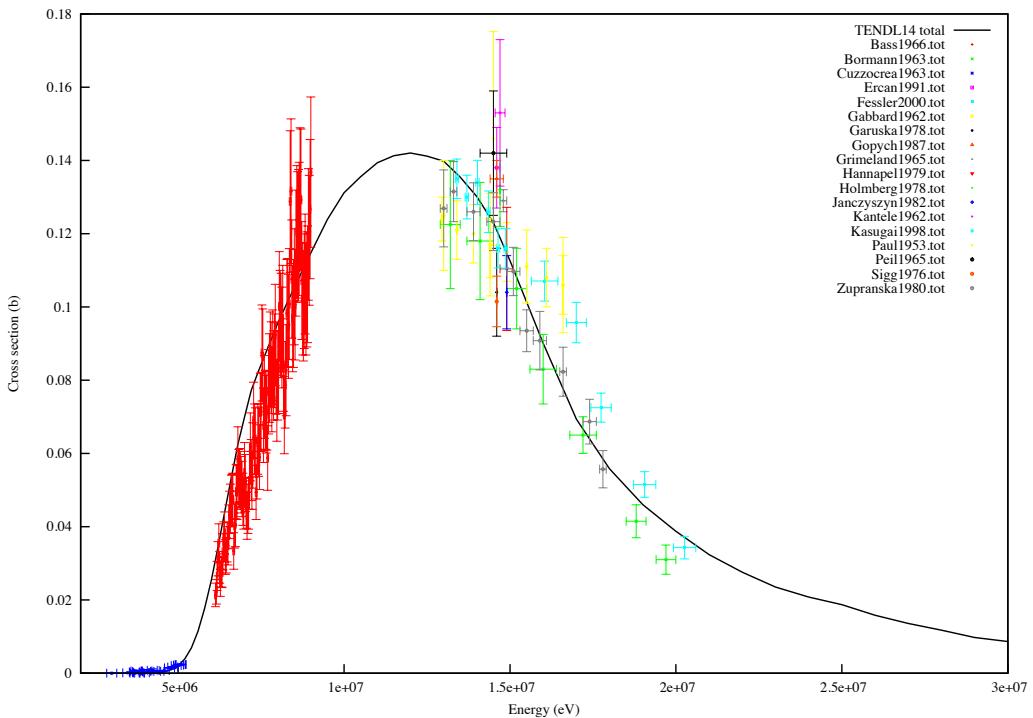
Si29(n,p)Al29

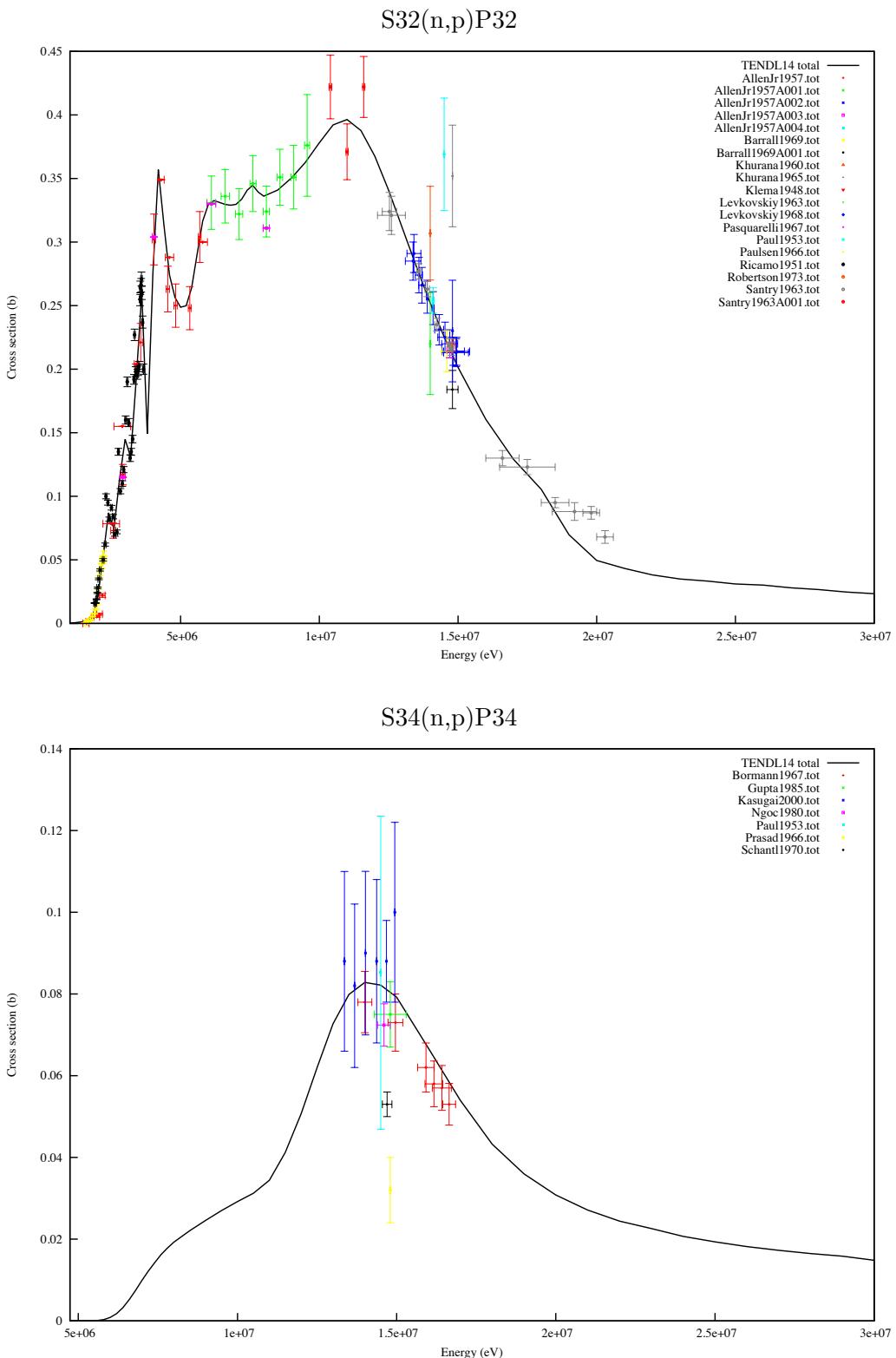


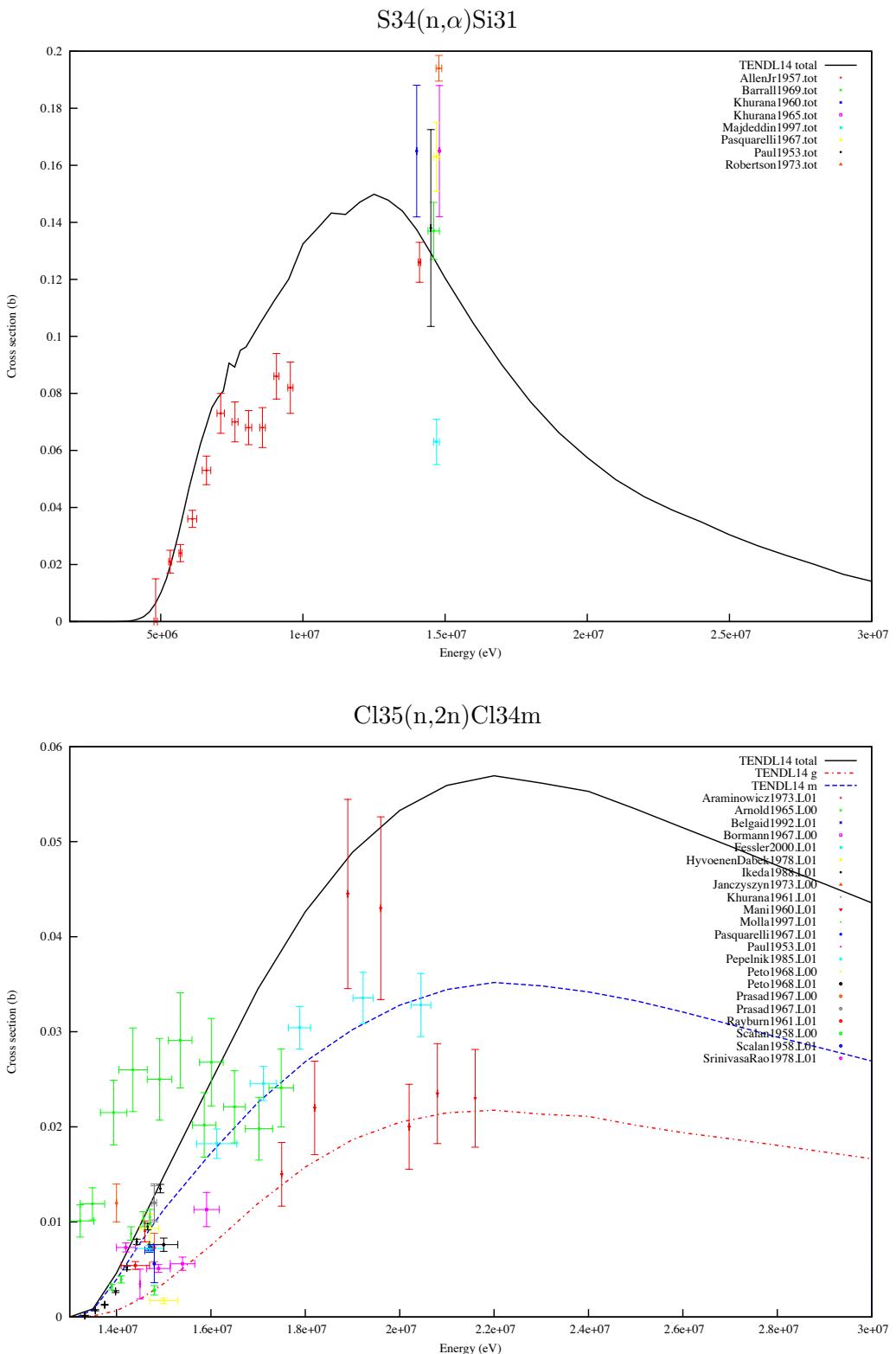
$\text{Si}^{30}(\text{n},\alpha)\text{Mg}^{27}$



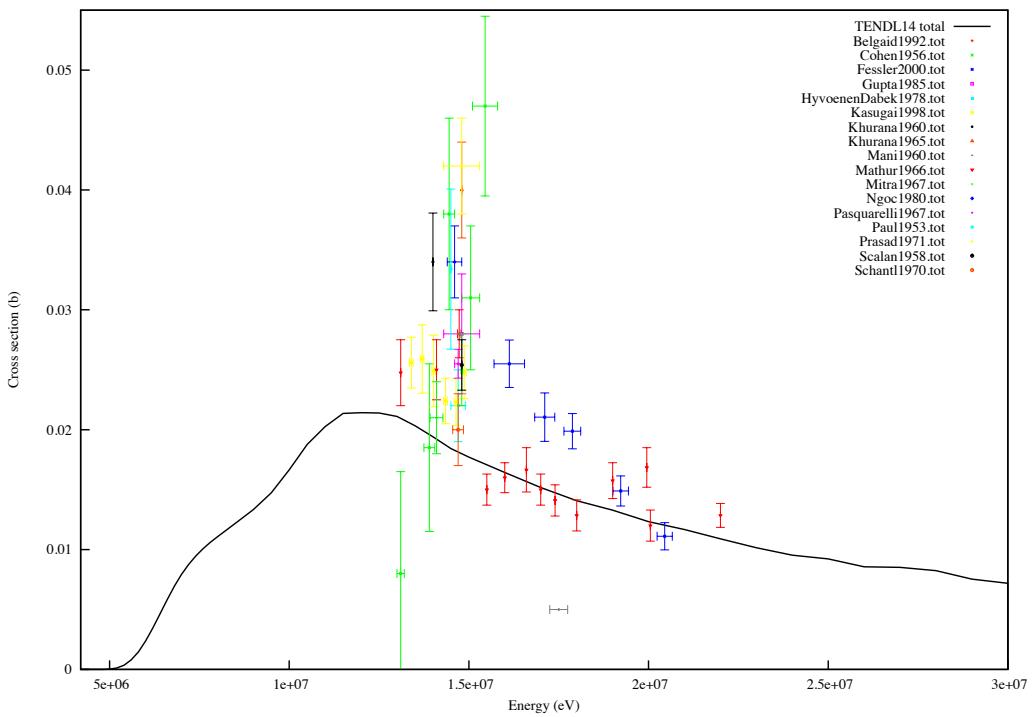
$\text{P}^{31}(\text{n},\alpha)\text{Al}^{28}$



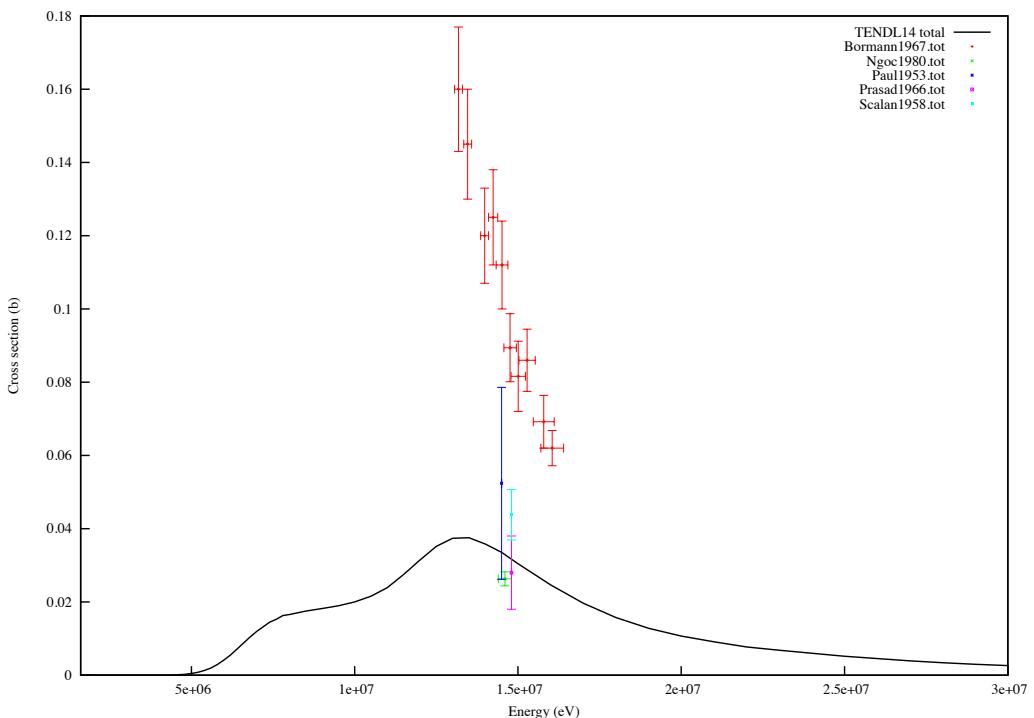




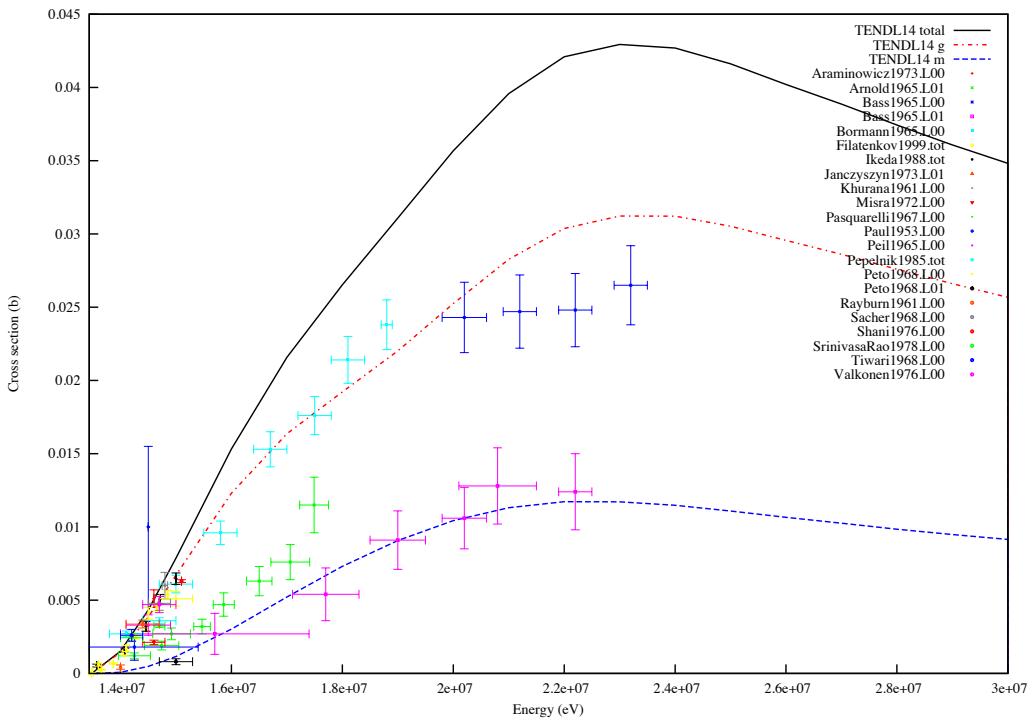
Cl37(n,p)S37



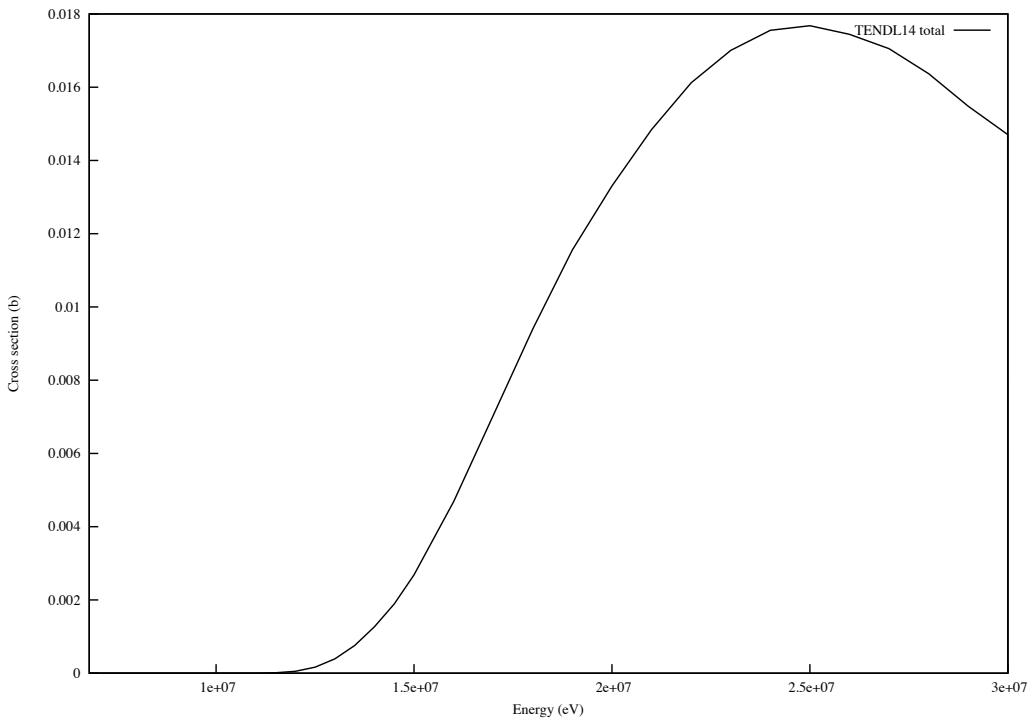
Cl37(n, α)P34



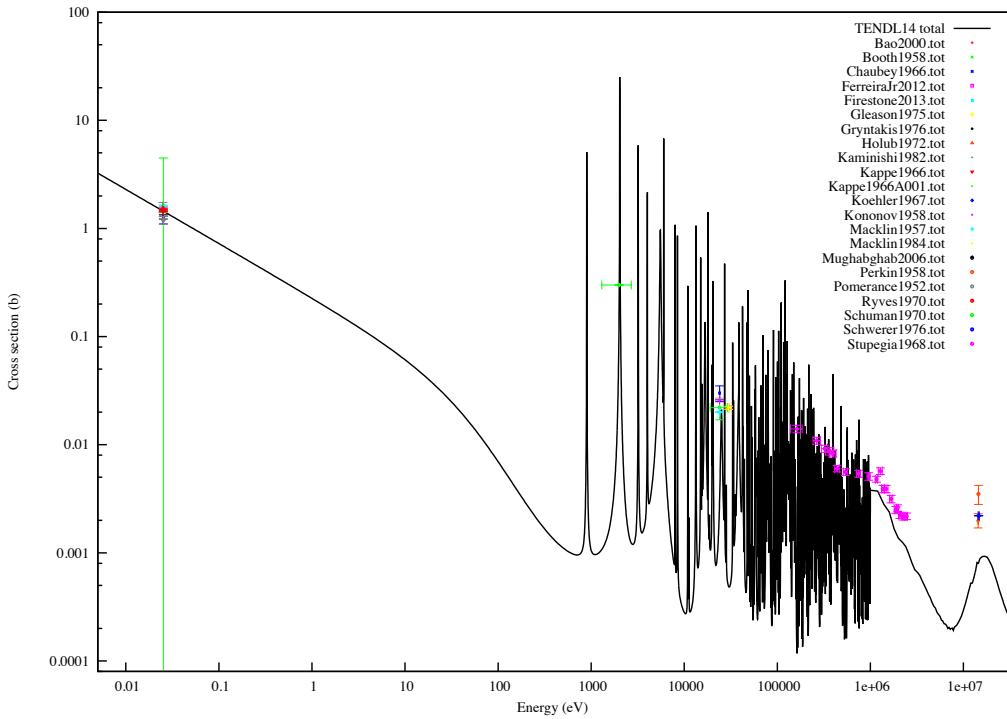
K39(n,2n)K38g



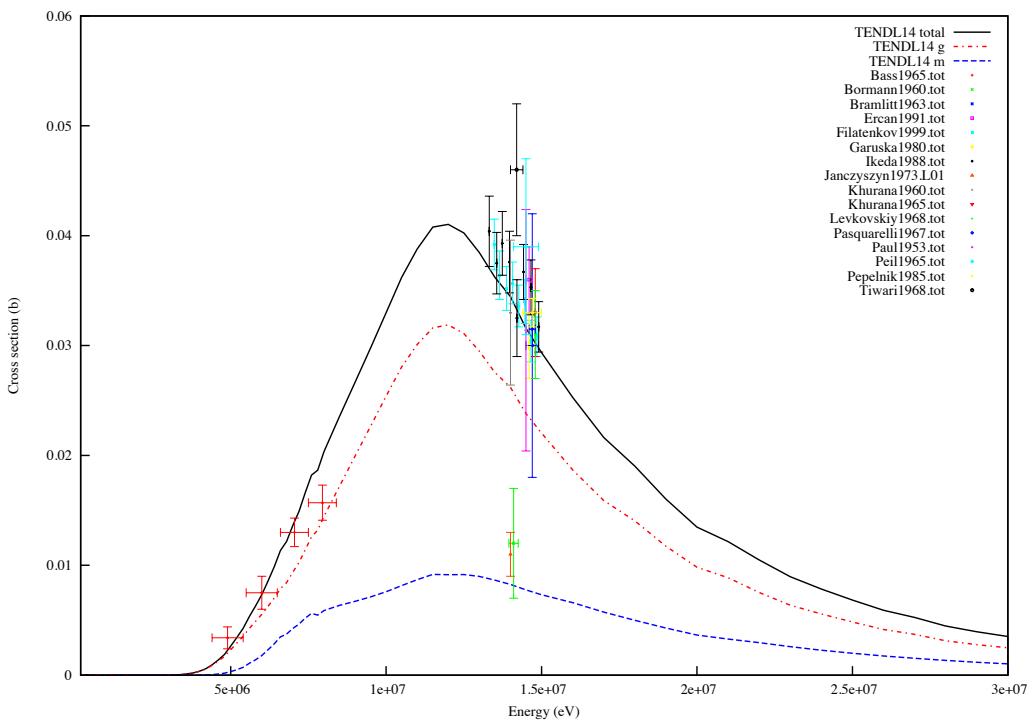
K39(n,p α)S35



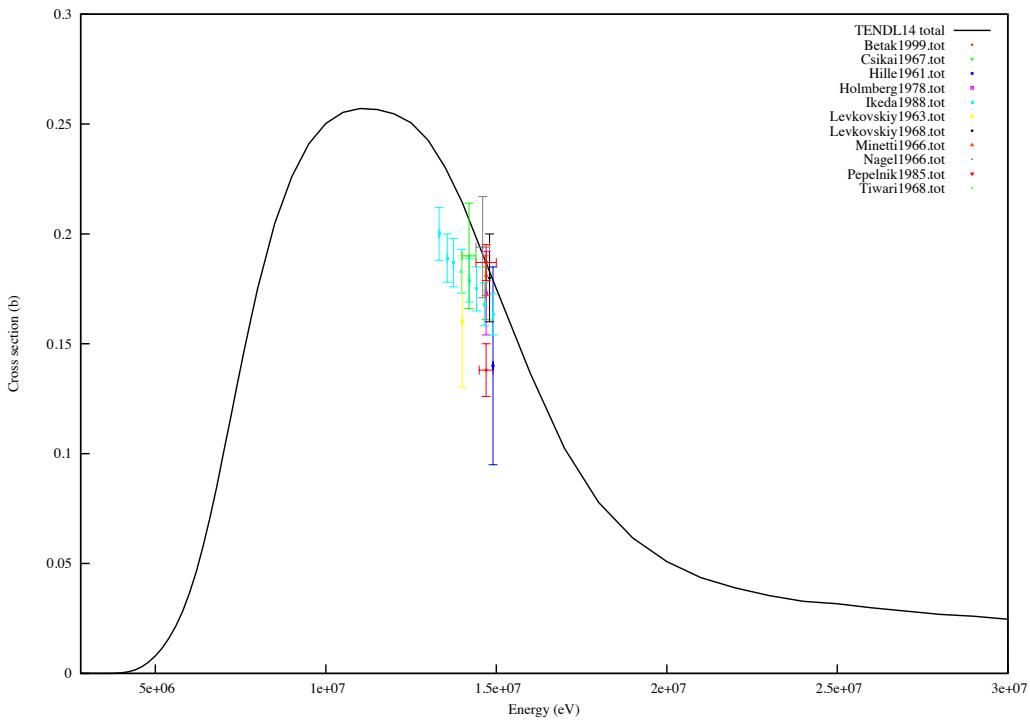
K41(n,γ)K42



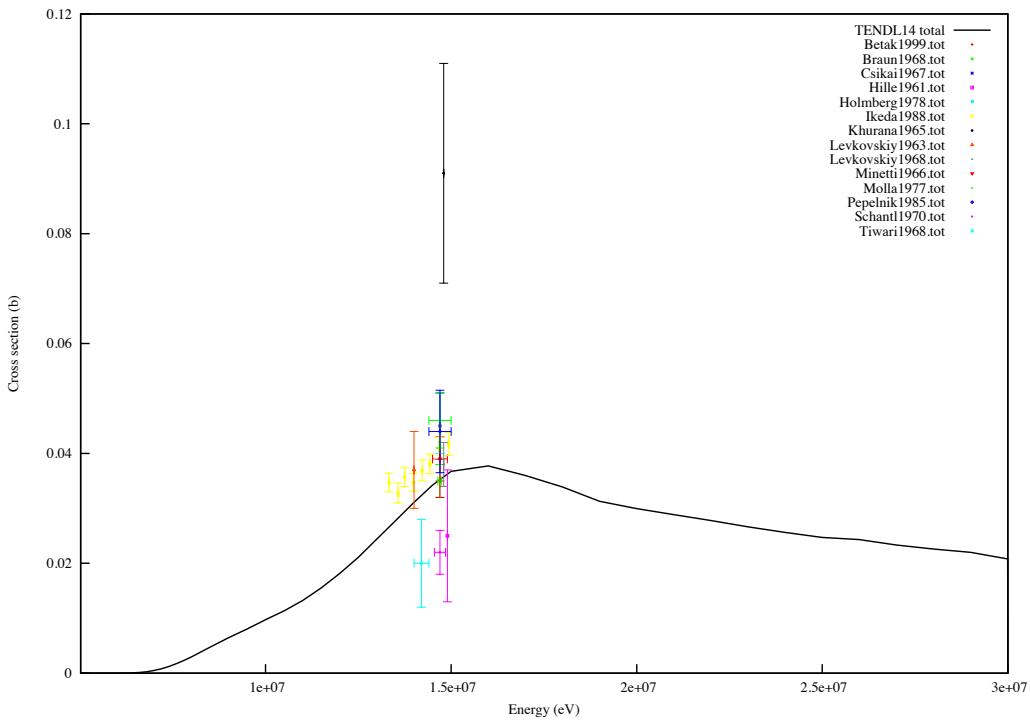
K41(n,α)Cl38



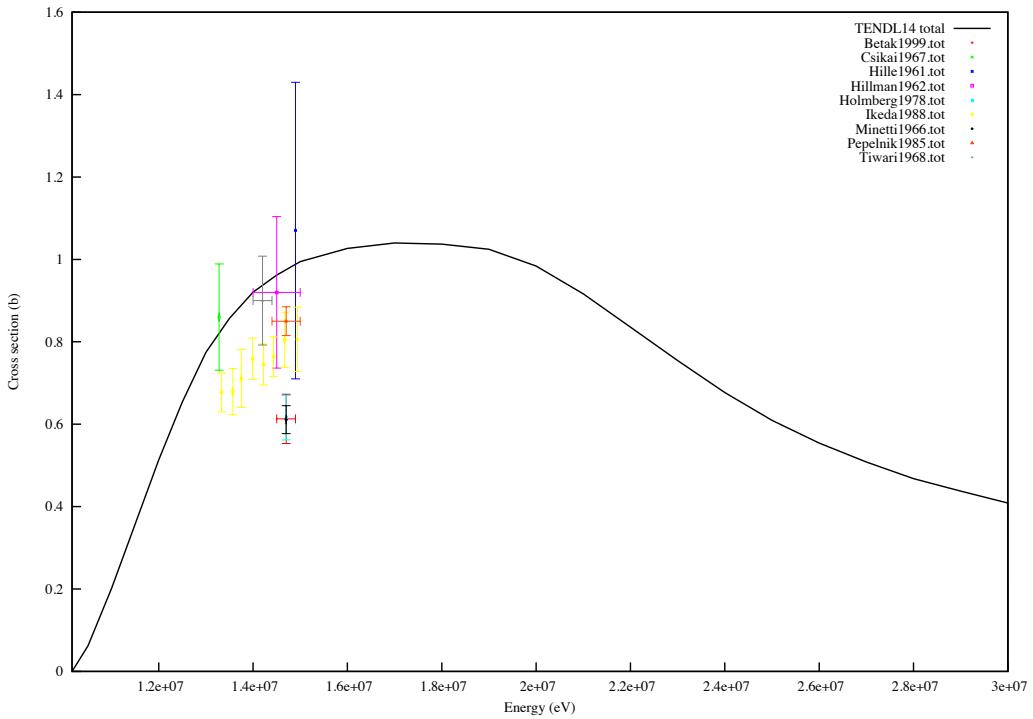
Ca42(n,p)K42



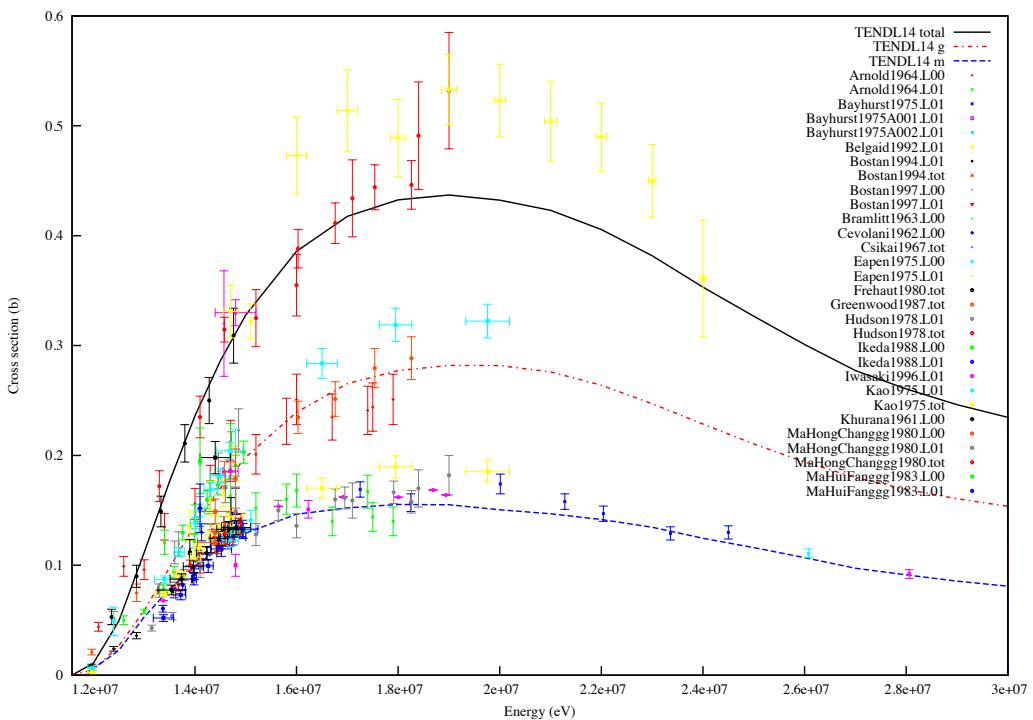
Ca44(n,p)K44

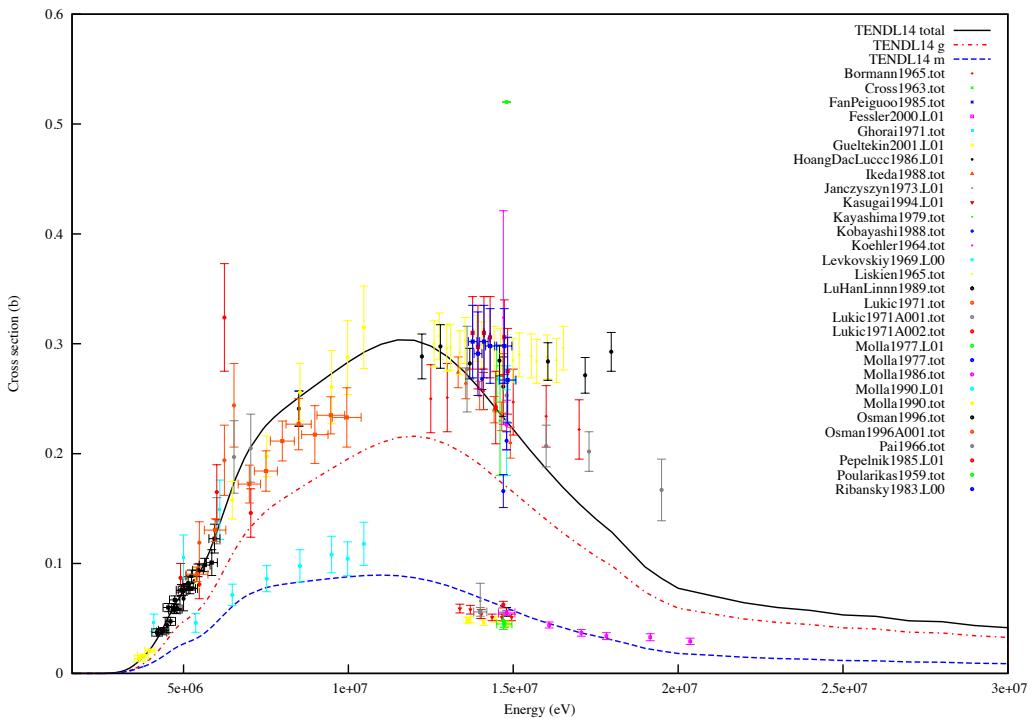
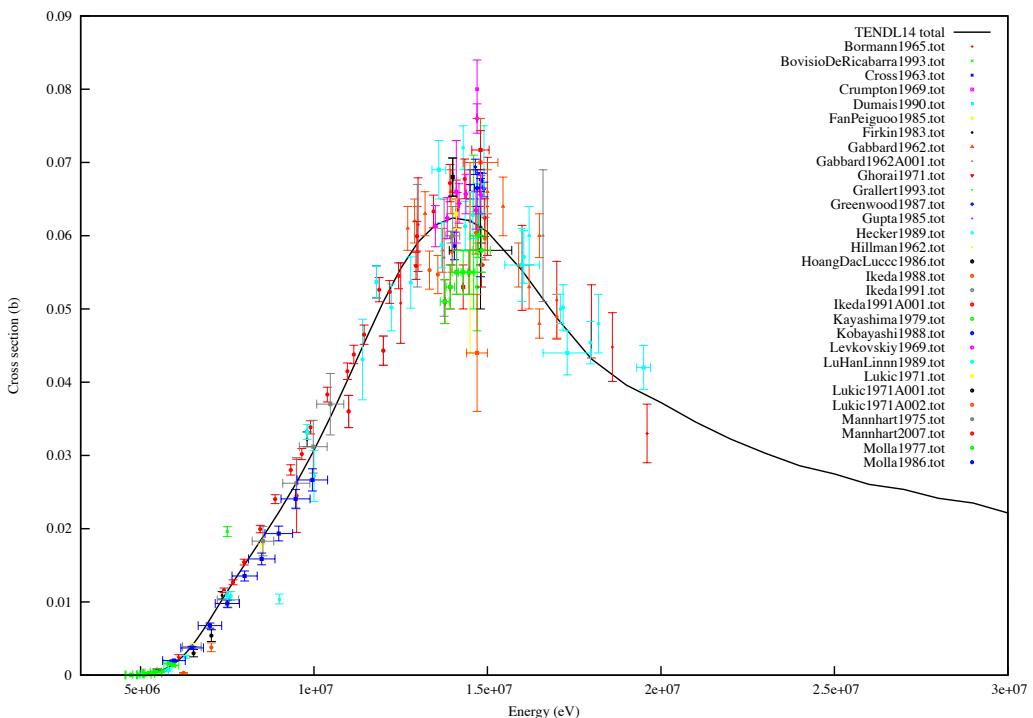


Ca48(n,2n)Ca47

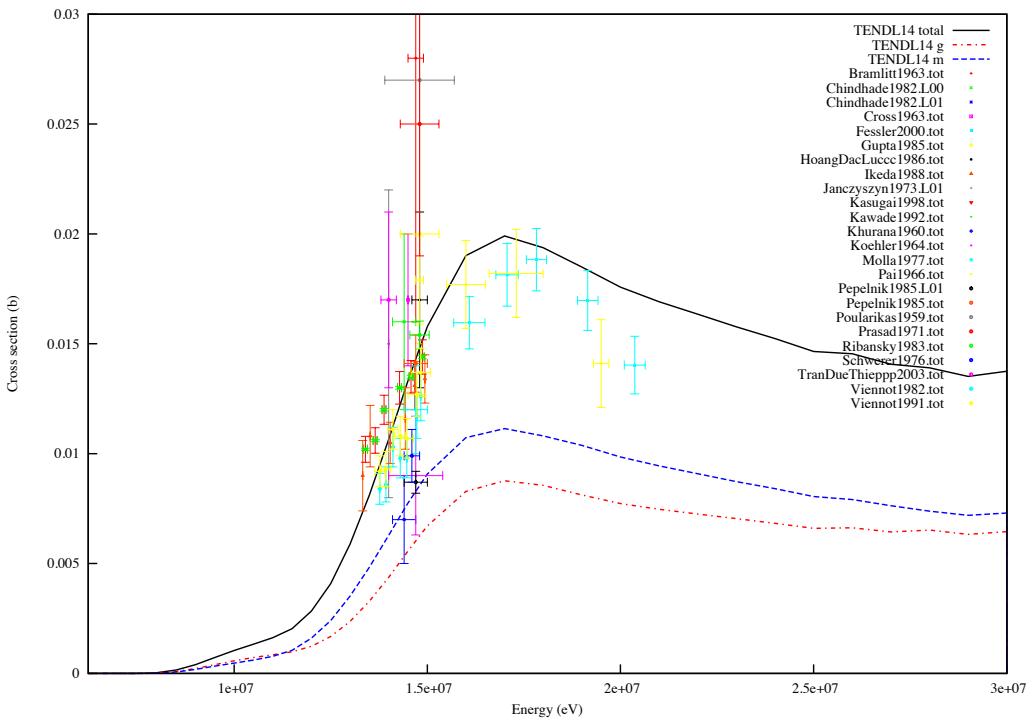


Sc45(n,2n)Sc44g

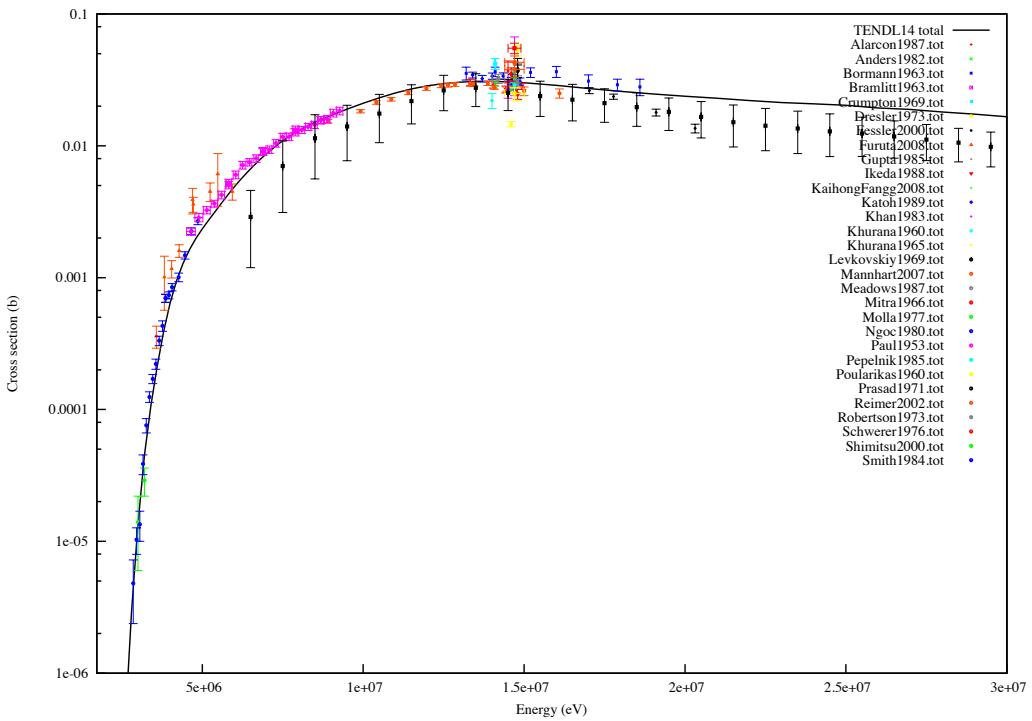


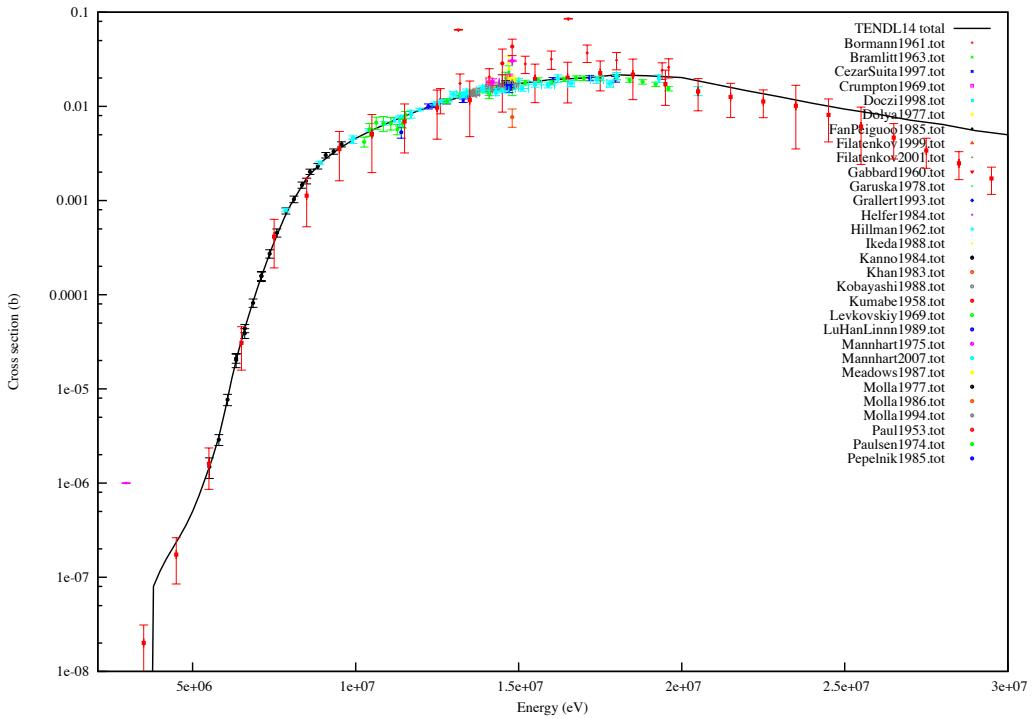
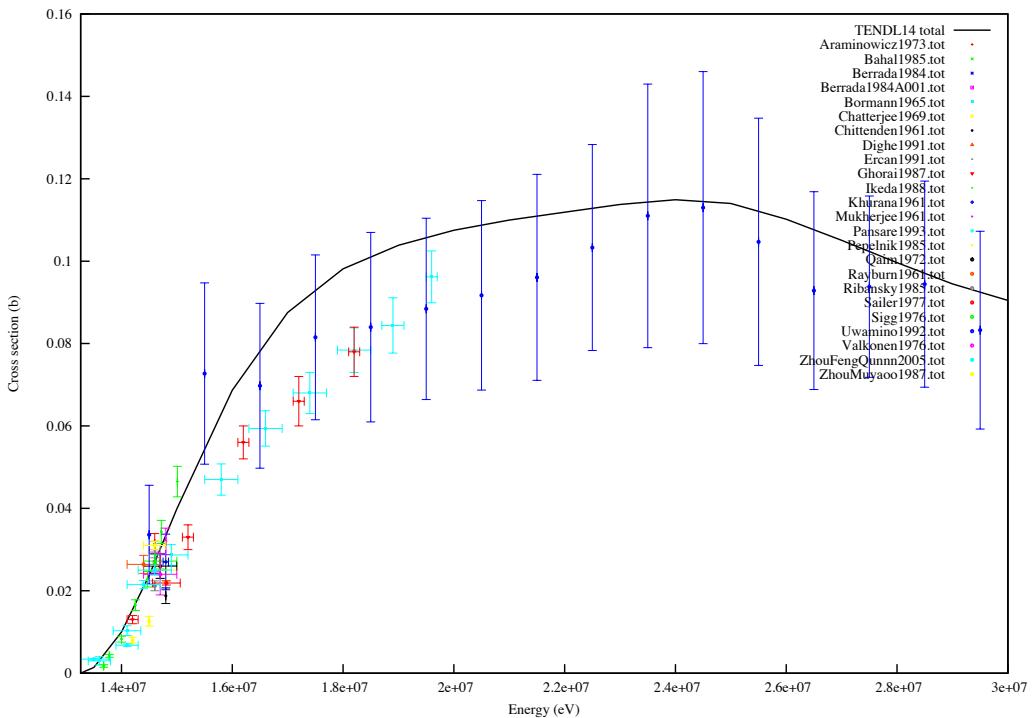
$\text{Ti46}(\text{n},\text{p})\text{Sc46}$  $\text{Ti48}(\text{n},\text{p})\text{Sc48}$ 

Ti50(n,p)Sc50

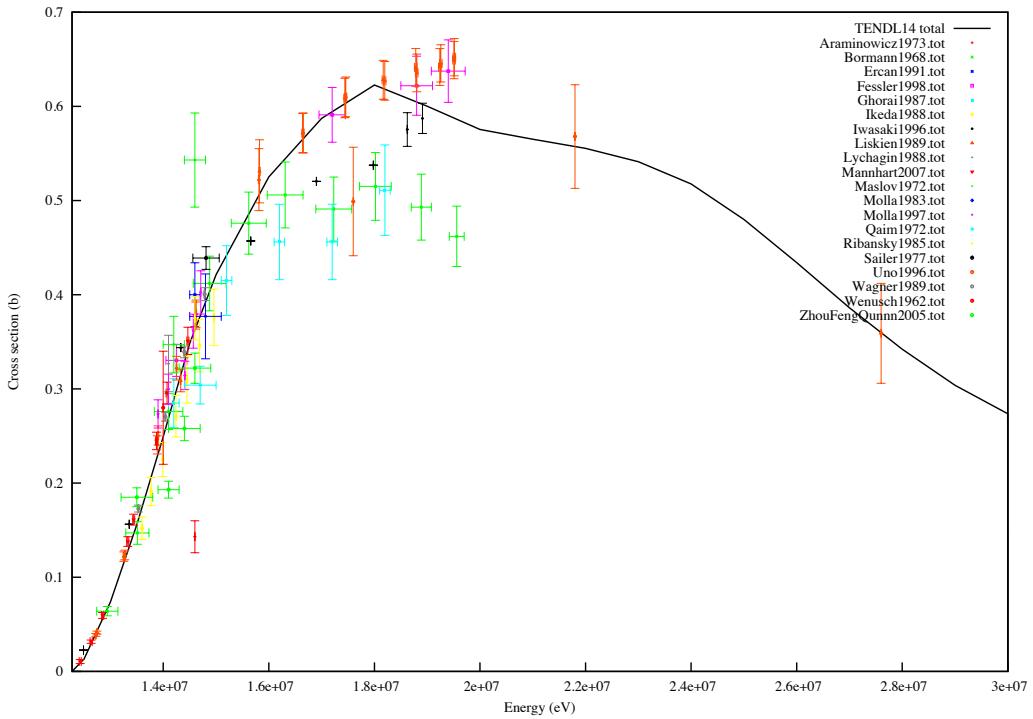


V51(n,p)Ti51

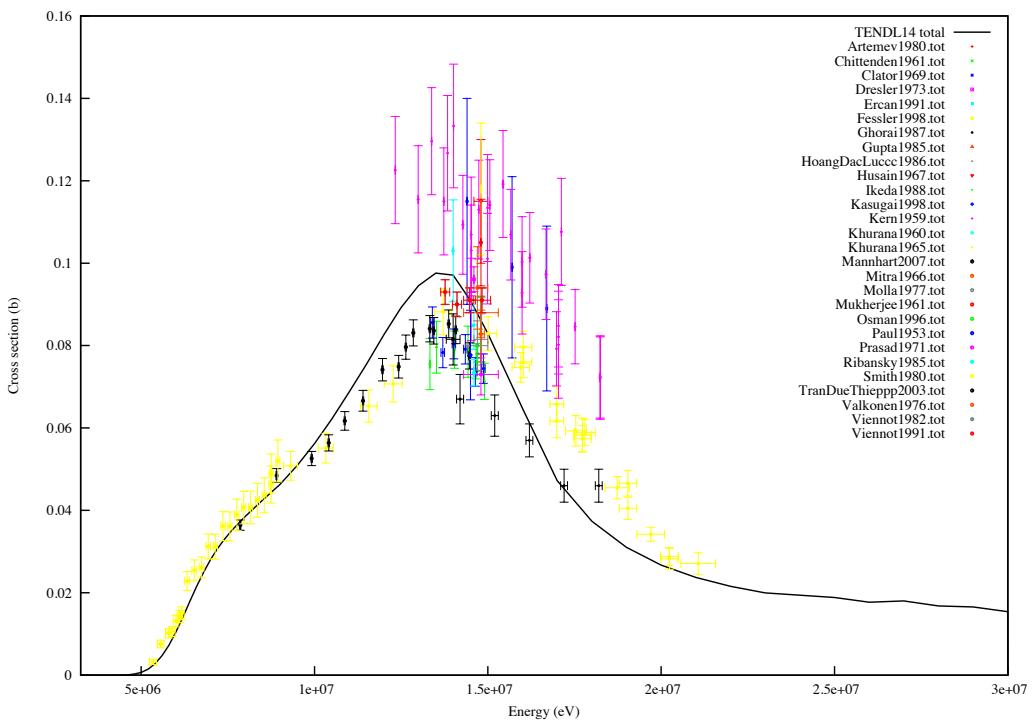


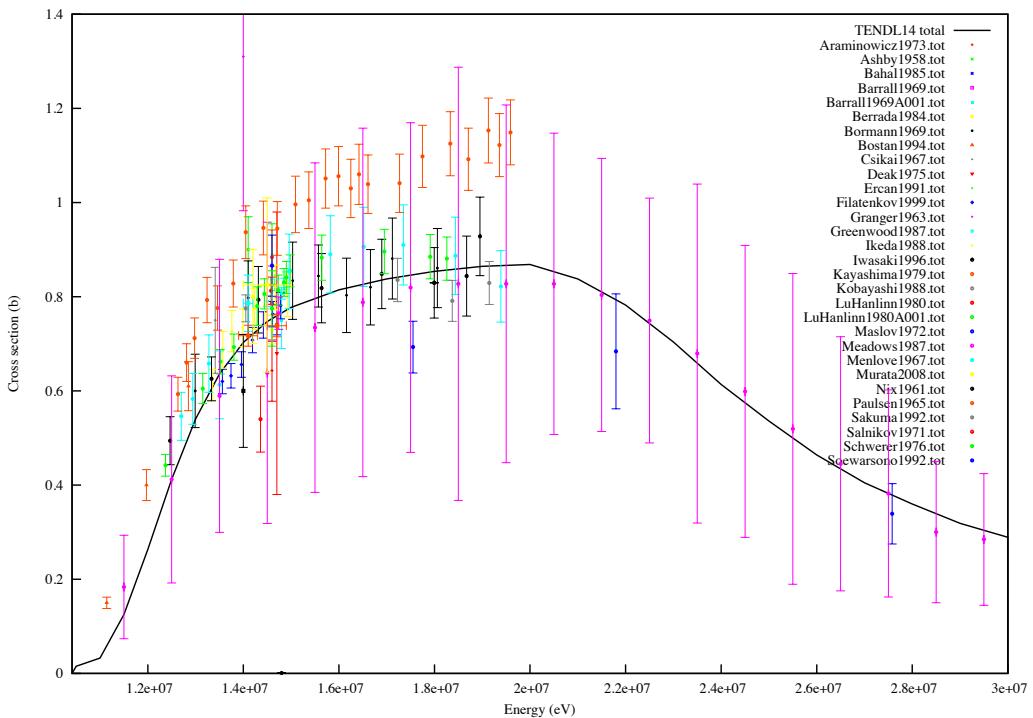
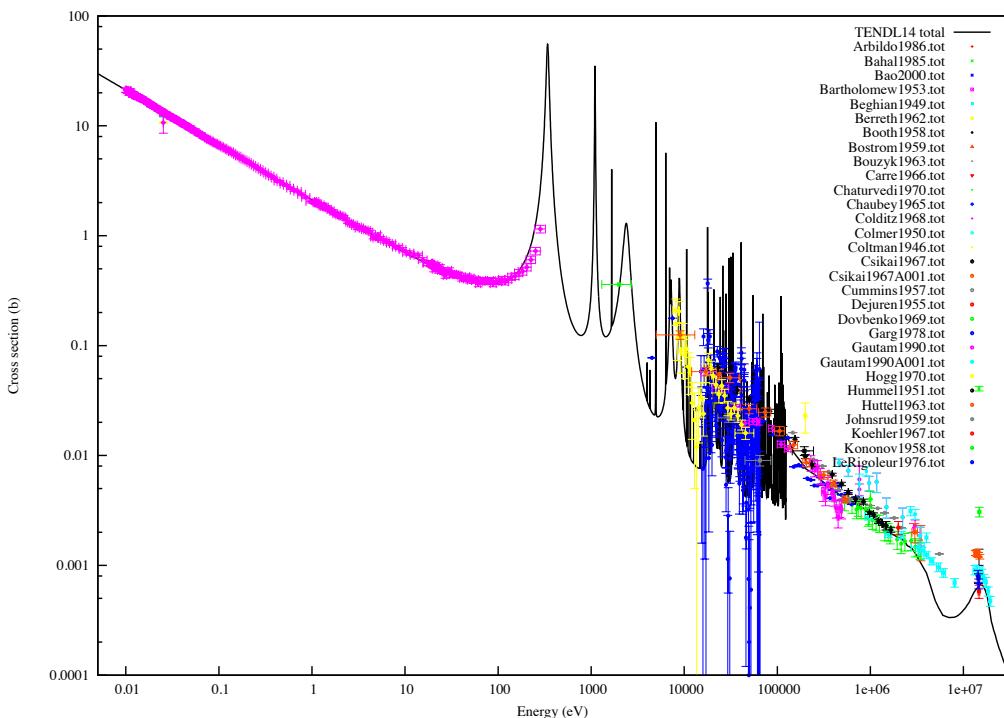
$V51(n,\alpha)Sc48$  $Cr50(n,2n)Cr49$ 

Cr52(n,2n)Cr51

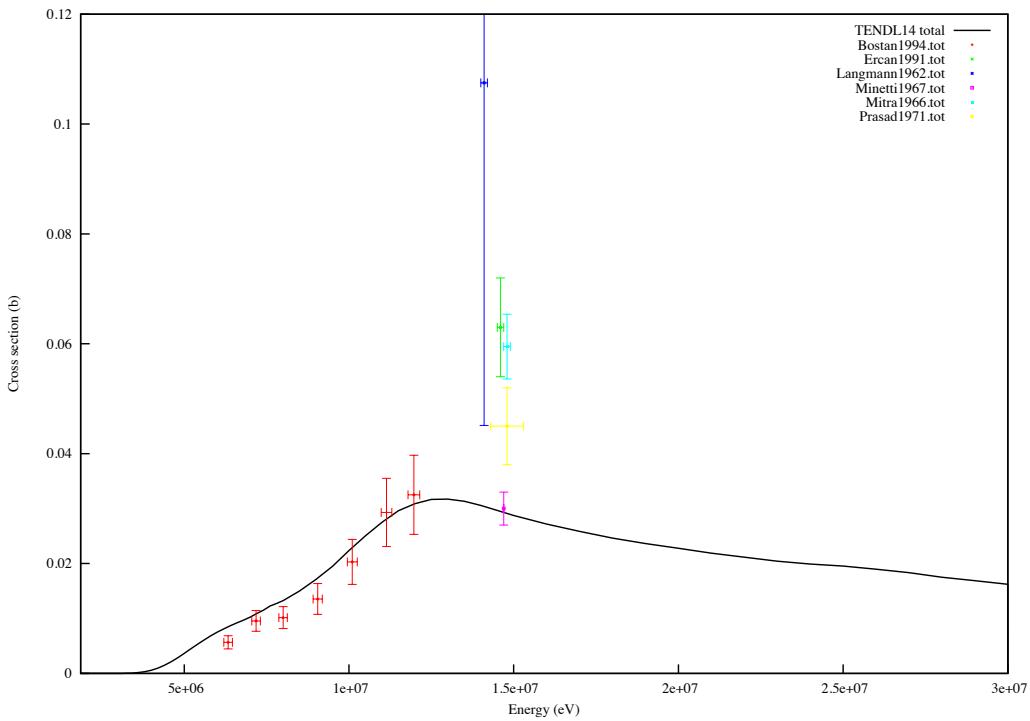


Cr52(n,p)V52

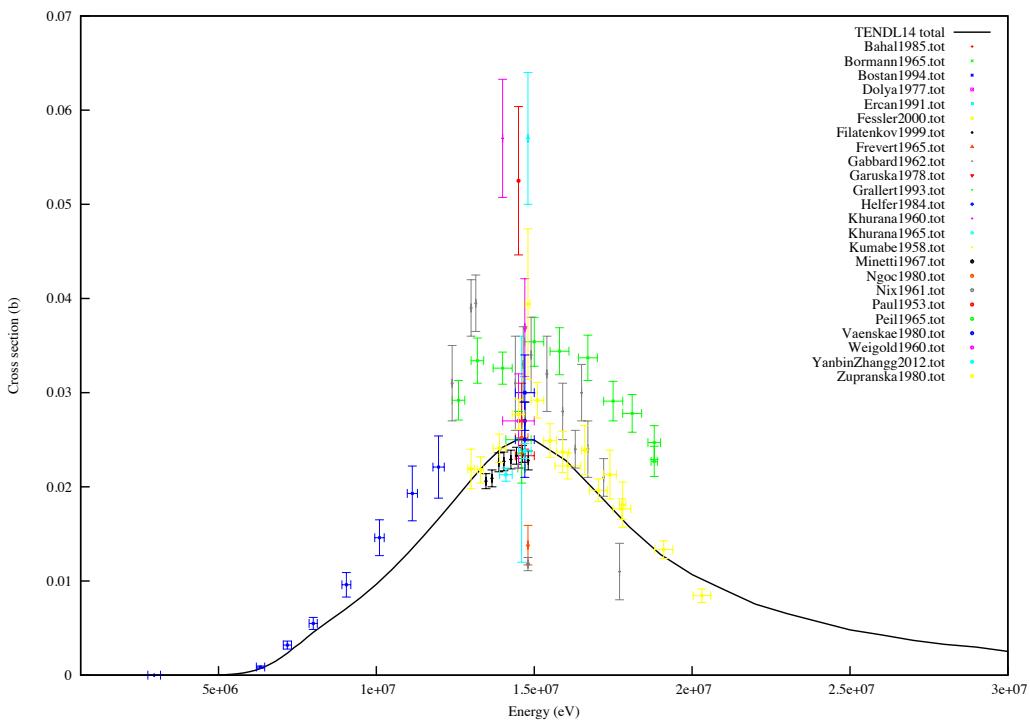


$\text{Mn}^{55}(\text{n},2\text{n})\text{Mn}^{54}$  $\text{Mn}^{55}(\text{n},\gamma)\text{Mn}^{56}$ 

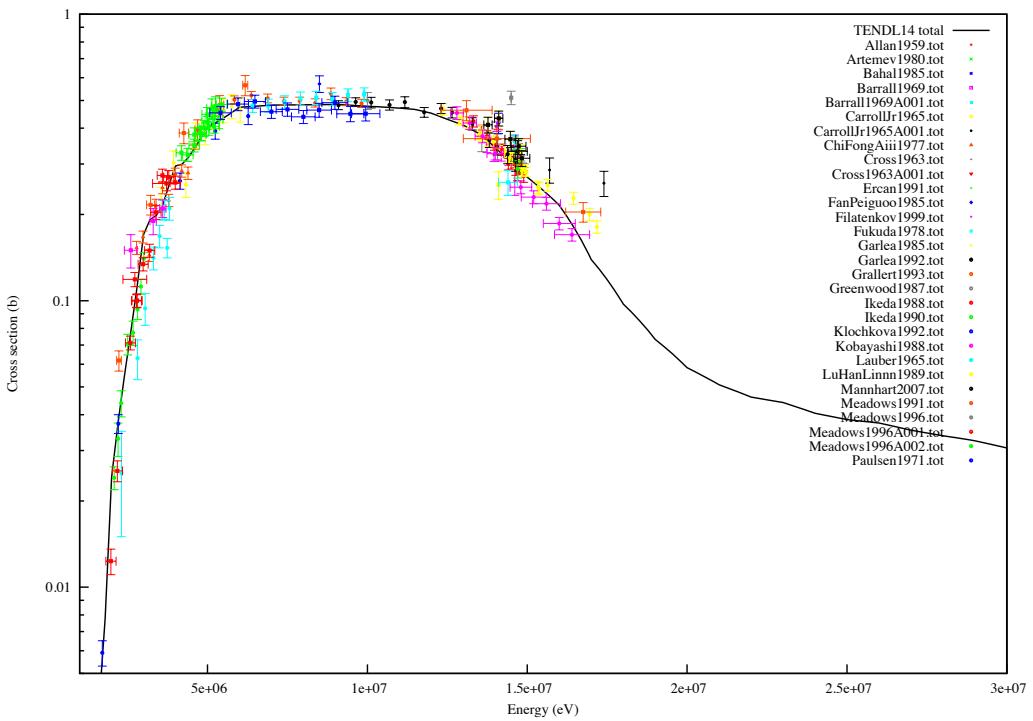
Mn55(n,p)Cr55



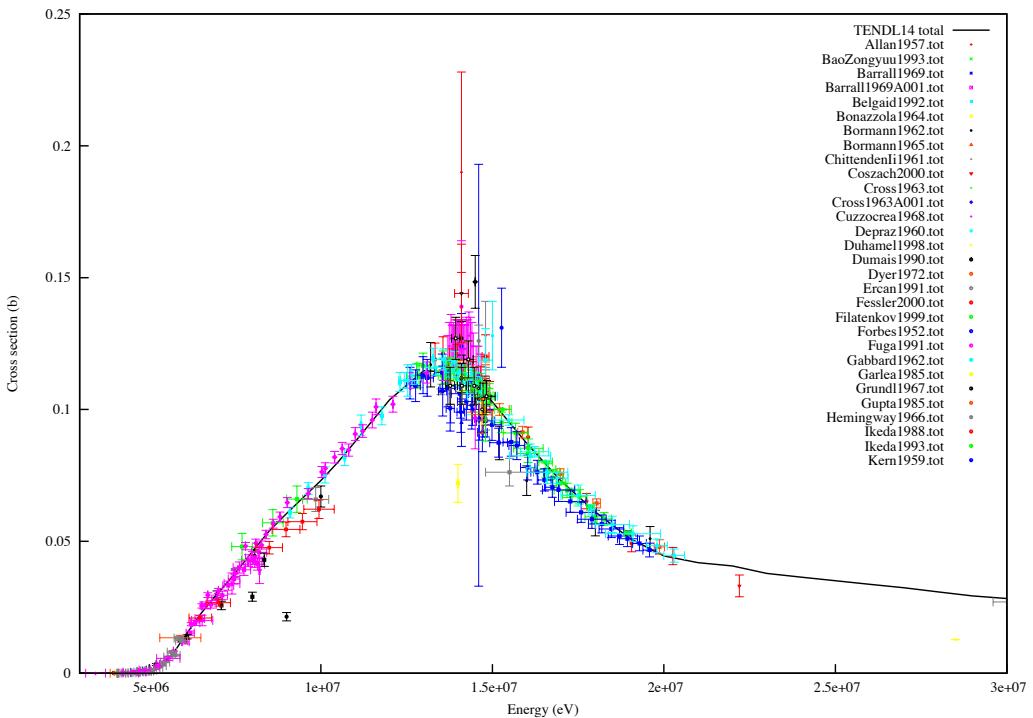
Mn55(n, α)V52

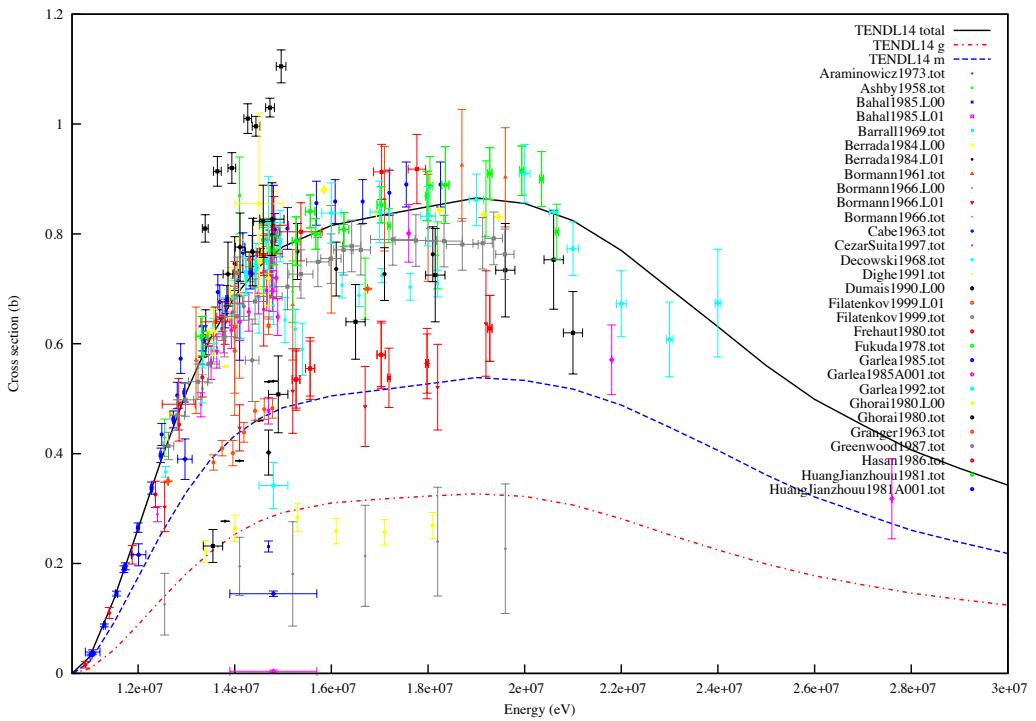
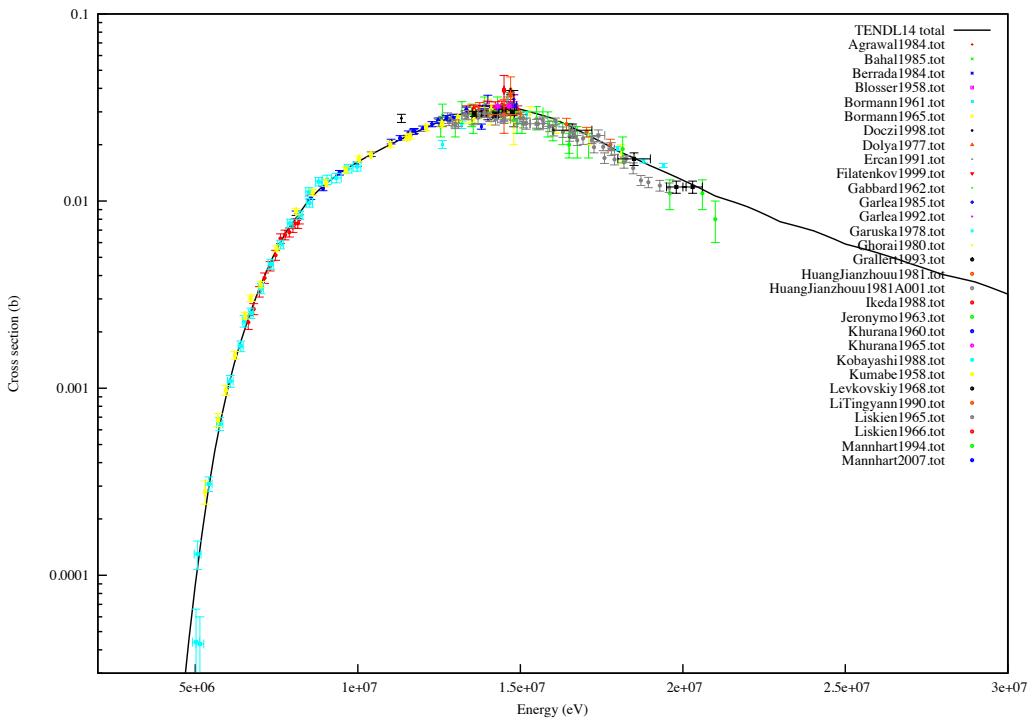


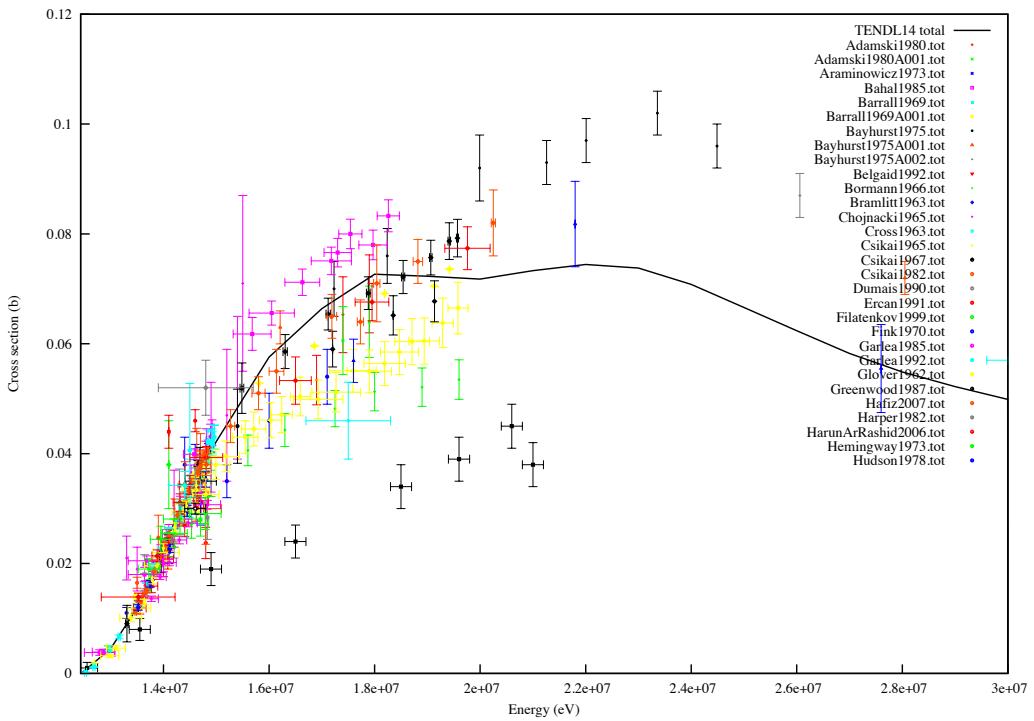
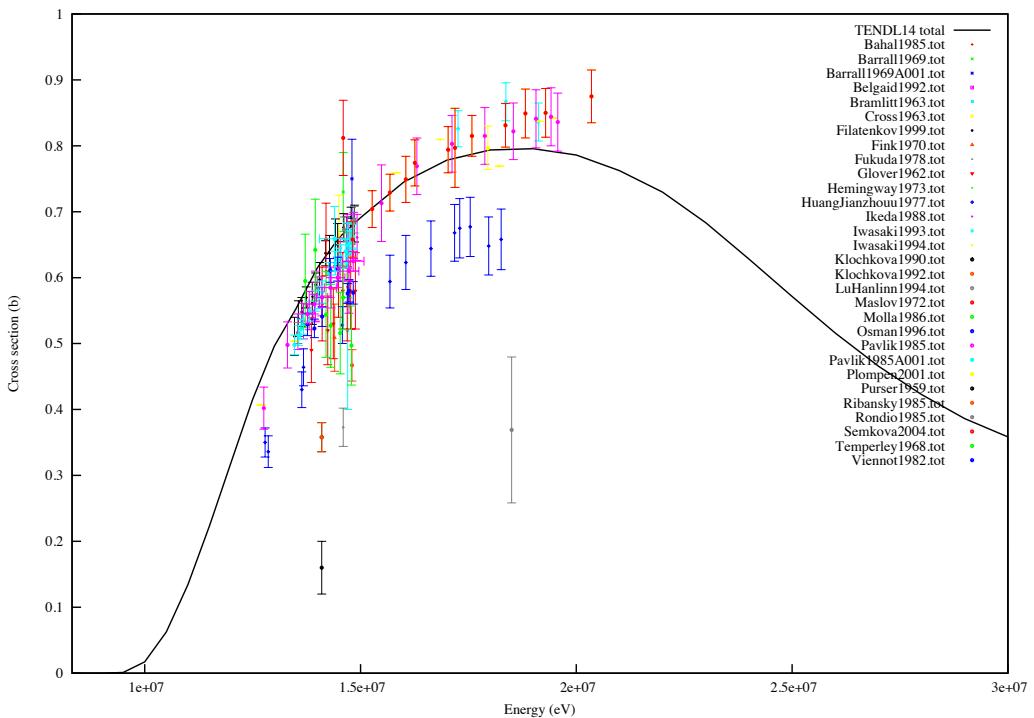
Fe54(n,p)Mn54



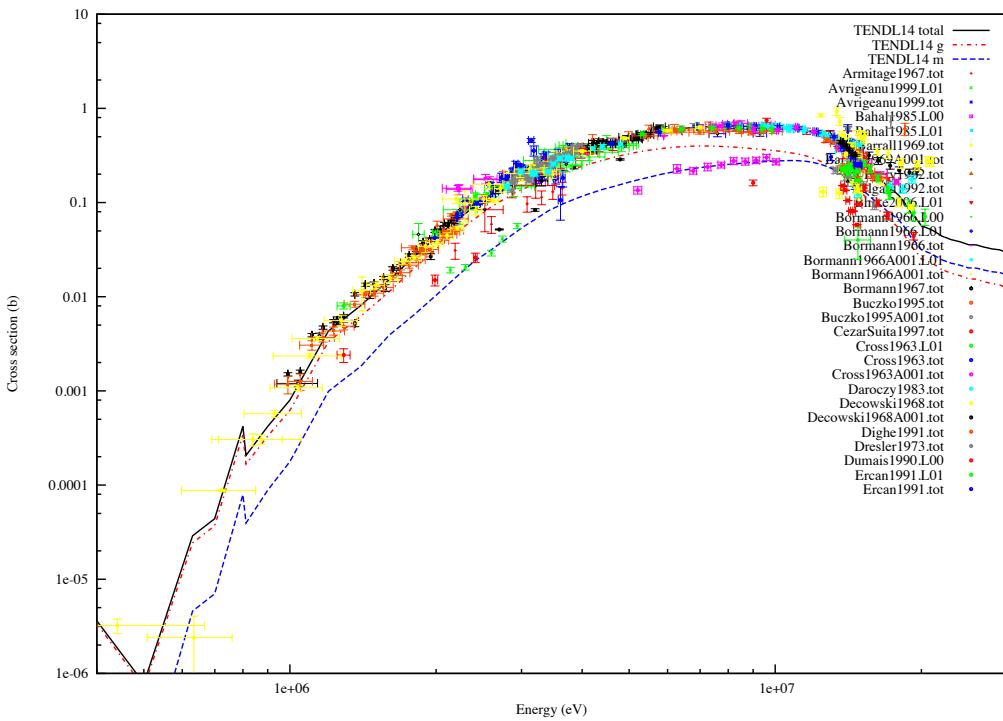
Fe56(n,p)Mn56



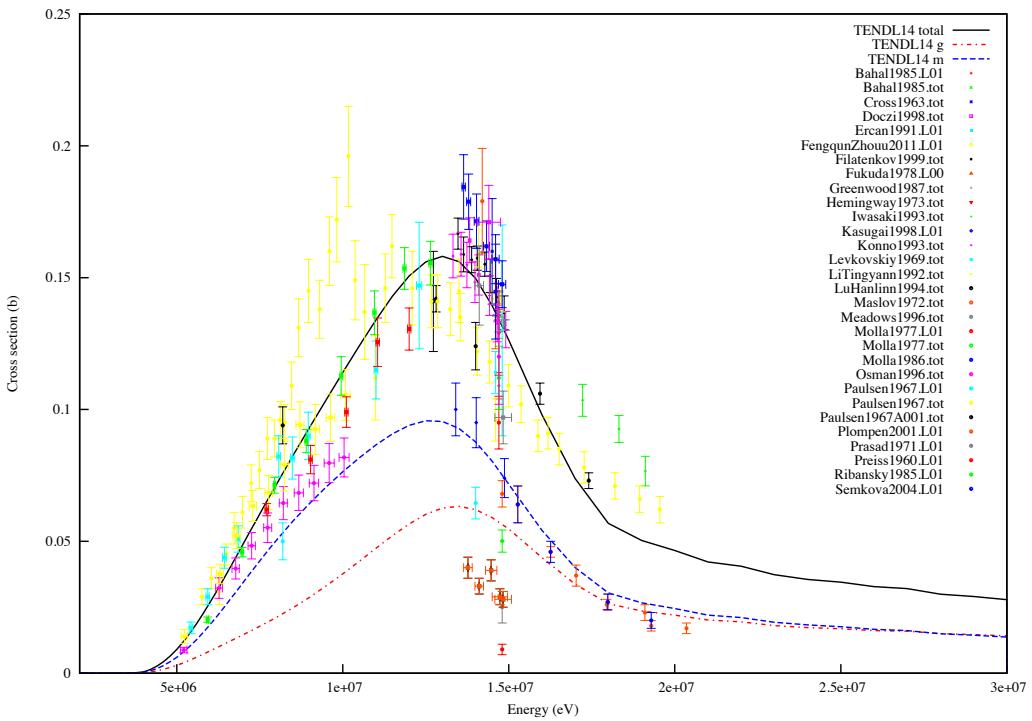
$\text{Co59}(n,2n)\text{Co58m}/\text{Co58}$  $\text{Co59}(n,\alpha)\text{Mn56}$ 

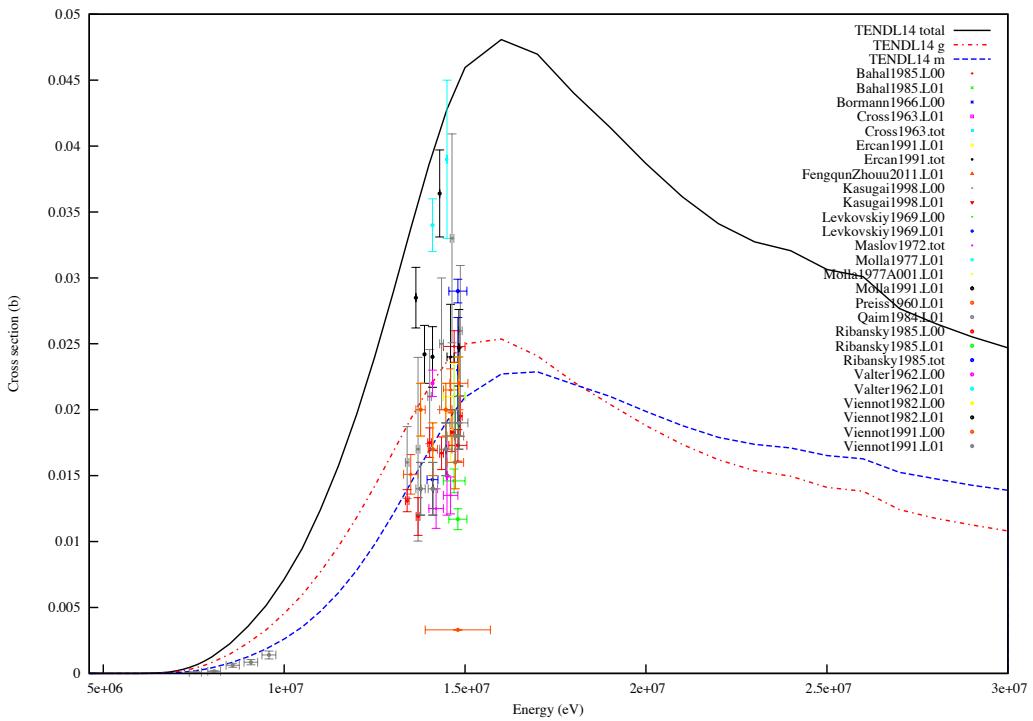
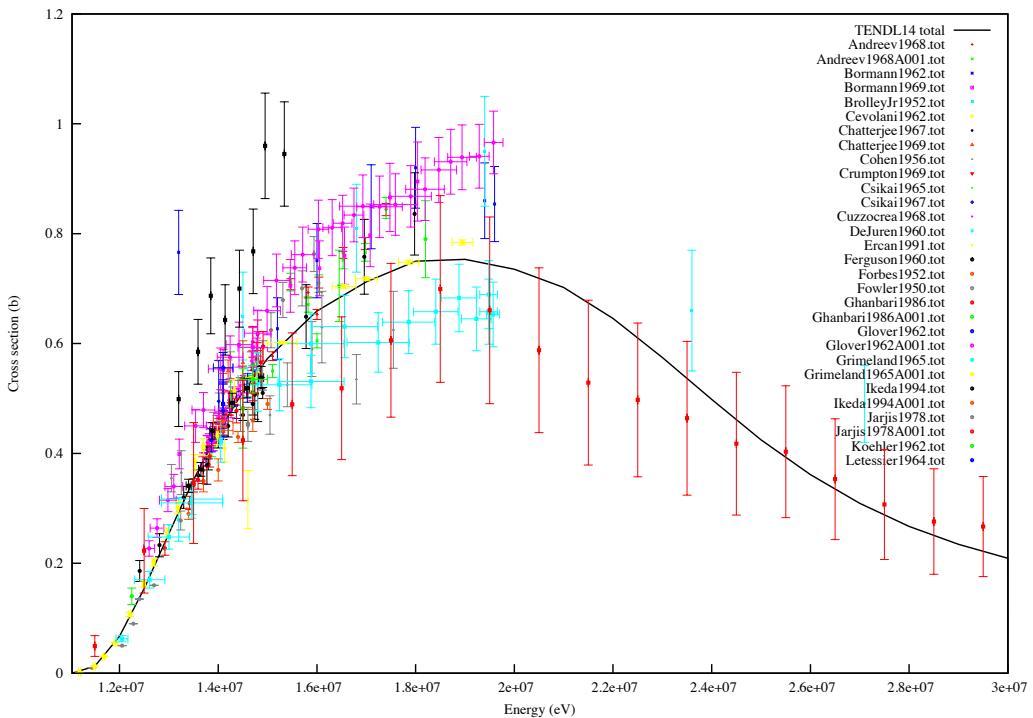
$\text{Ni}^{58}(\text{n},\text{2n})\text{Ni}^{57}$  $\text{Ni}^{58}(\text{n},\text{np})\text{Co}^{57}$ 

Ni58(n,p)Co58

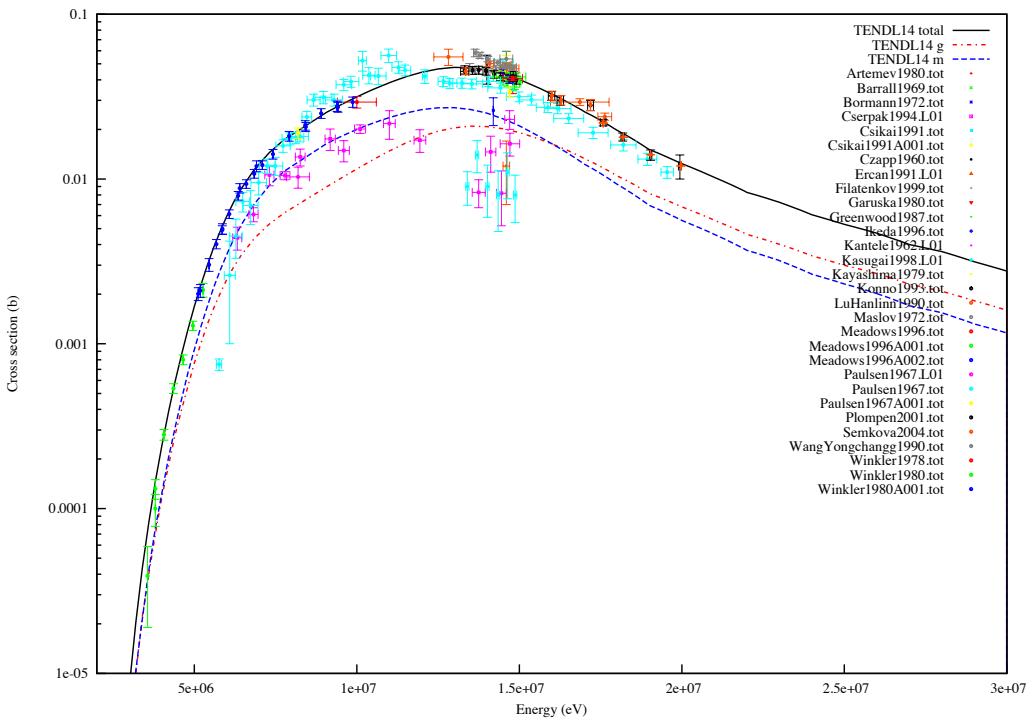


Ni60(n,p)Co60m

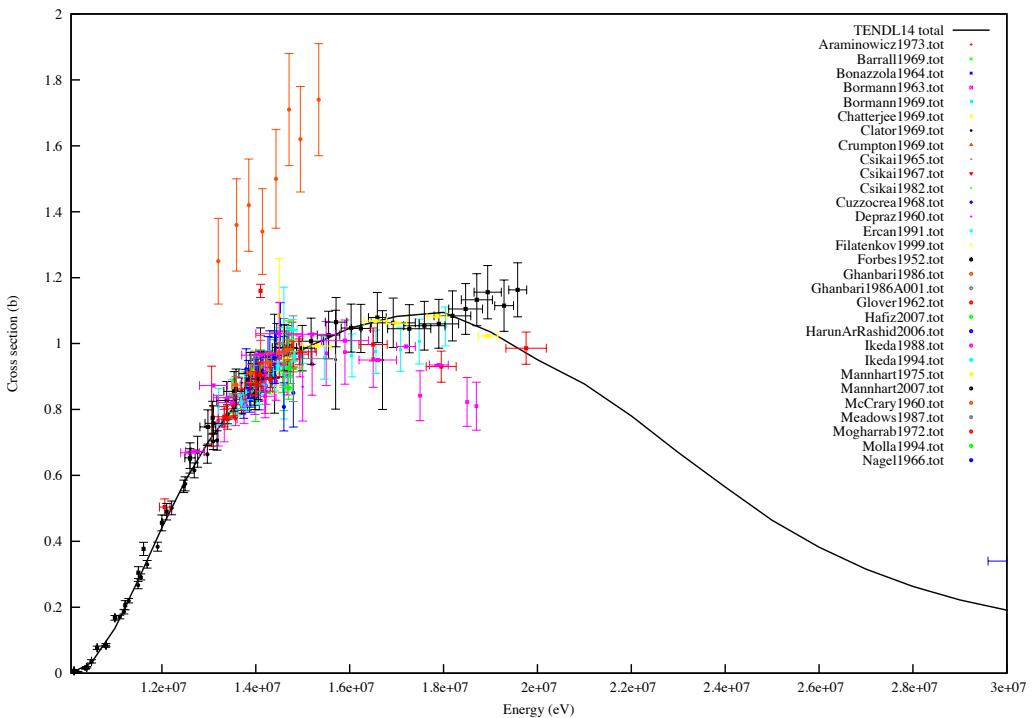


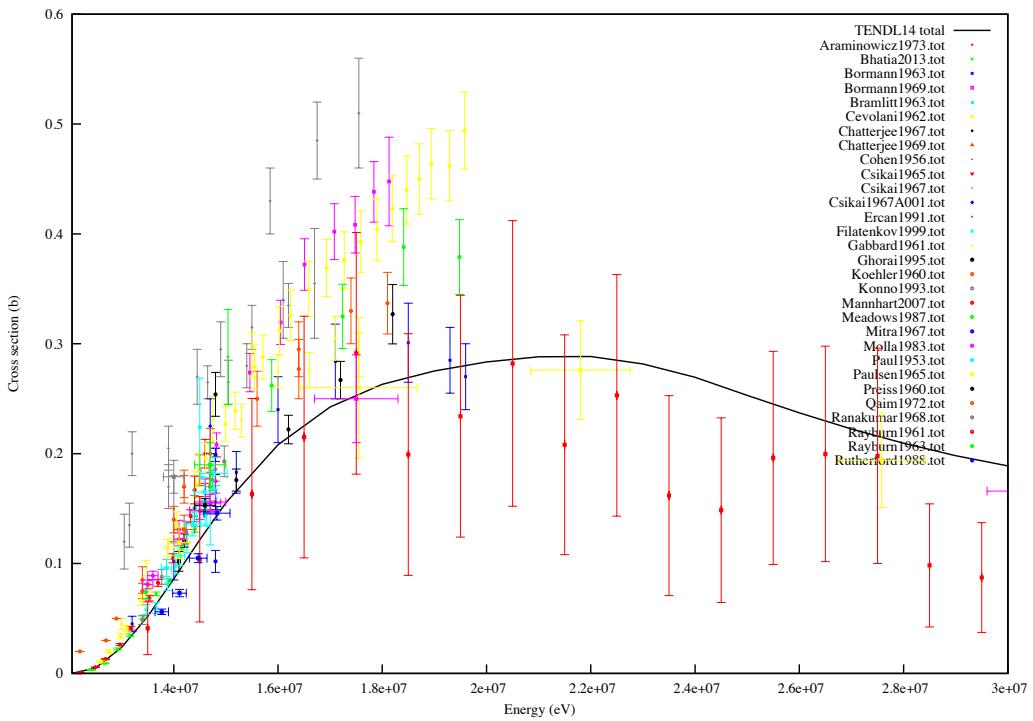
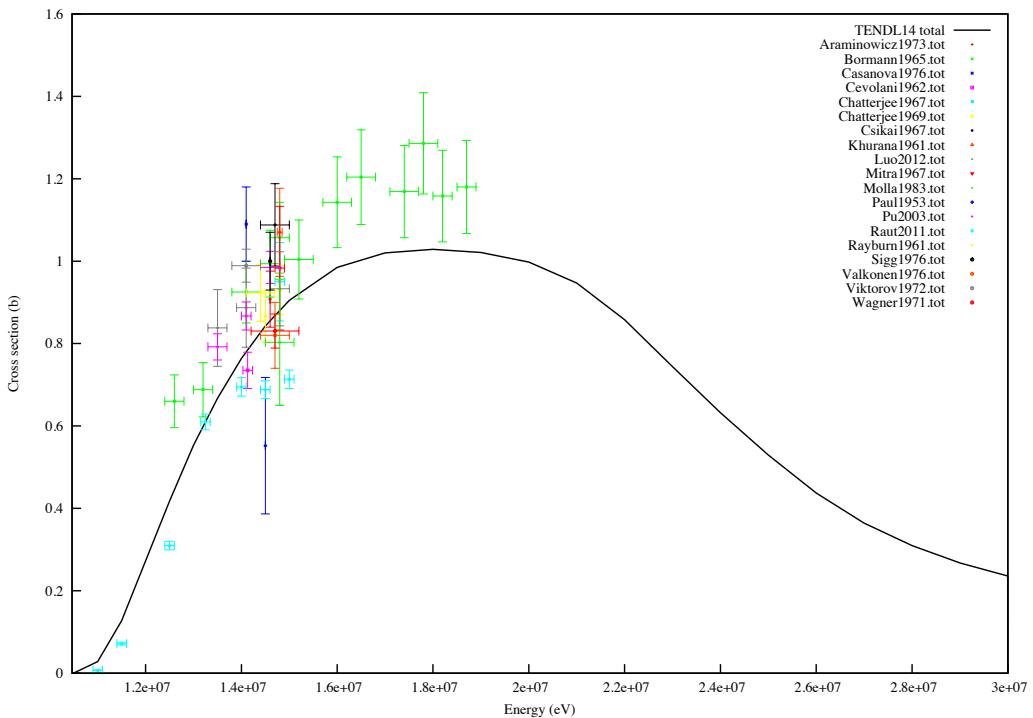
$\text{Ni}^{62}(\text{n},\text{p})\text{Co}^{62}\text{g}/\text{Co}^{62}\text{m}$  $\text{Cu}^{63}(\text{n},2\text{n})\text{Cu}^{62}$ 

Cu63(n,α)Co60

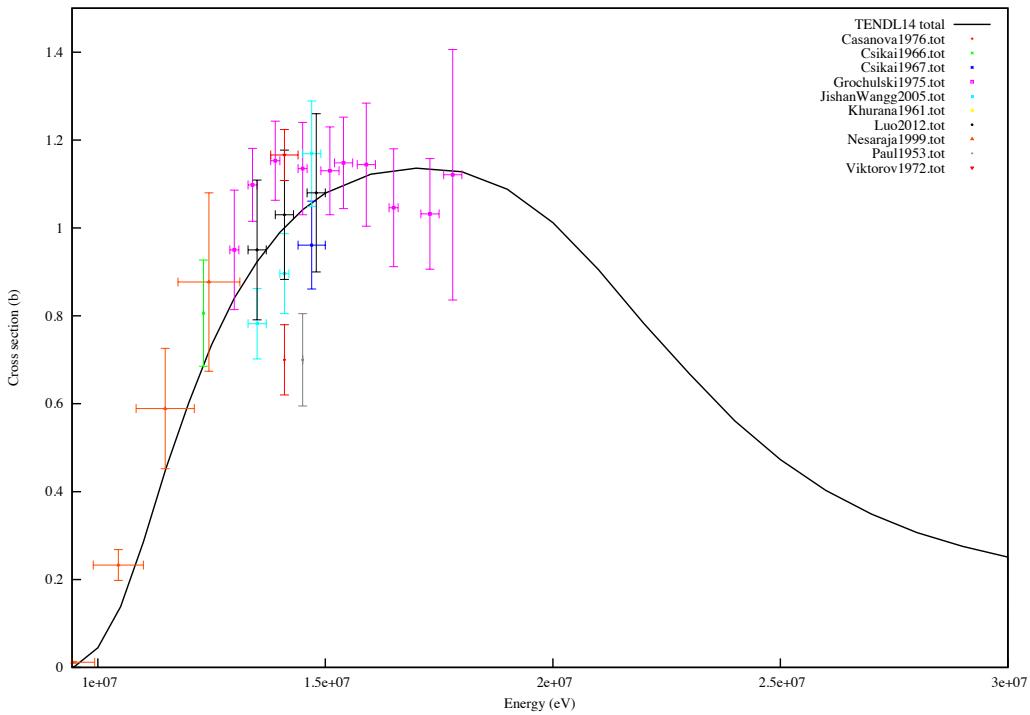


Cu65($n,2n$)Cu64

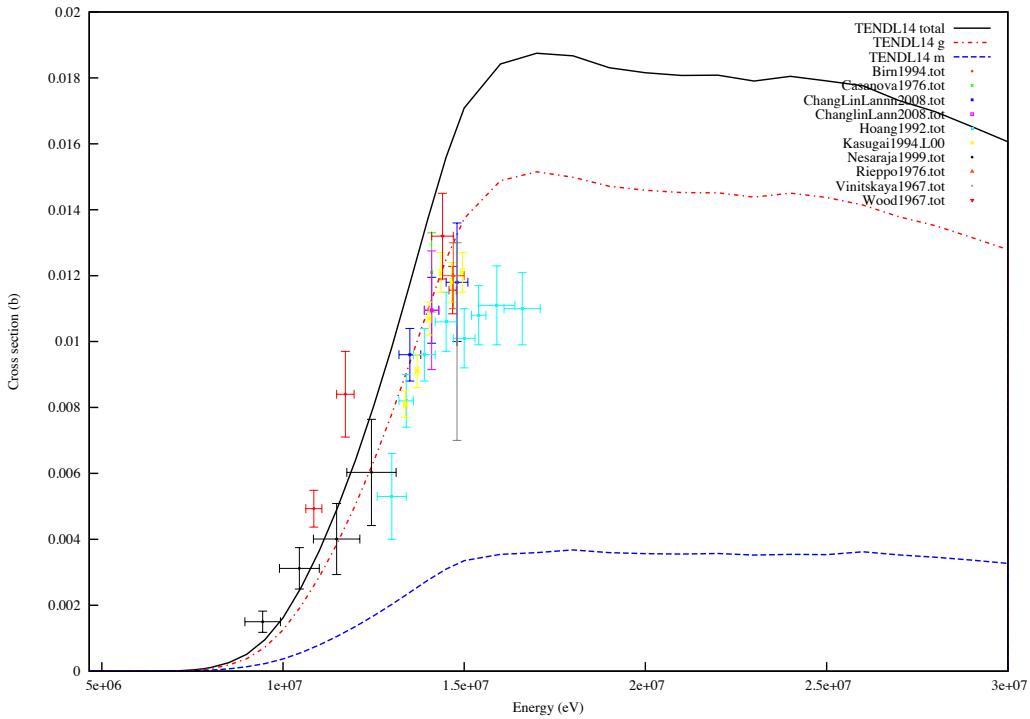


$Zn64(n,2n)Zn63$  $Ga69(n,2n)Ga68$ 

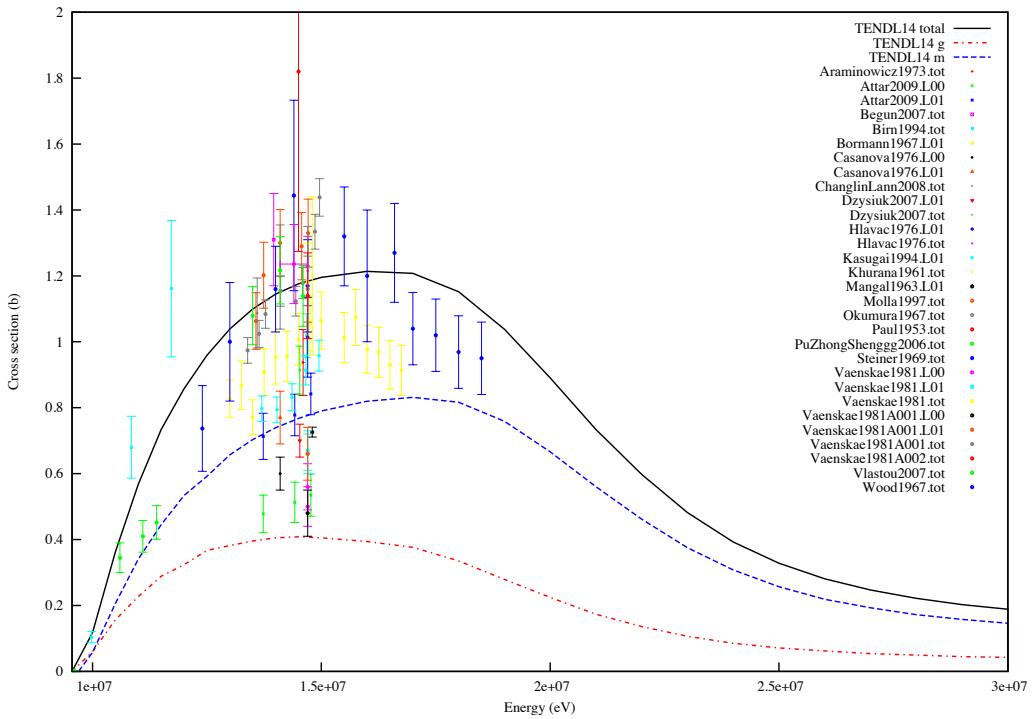
Ga71(n,2n)Ga70



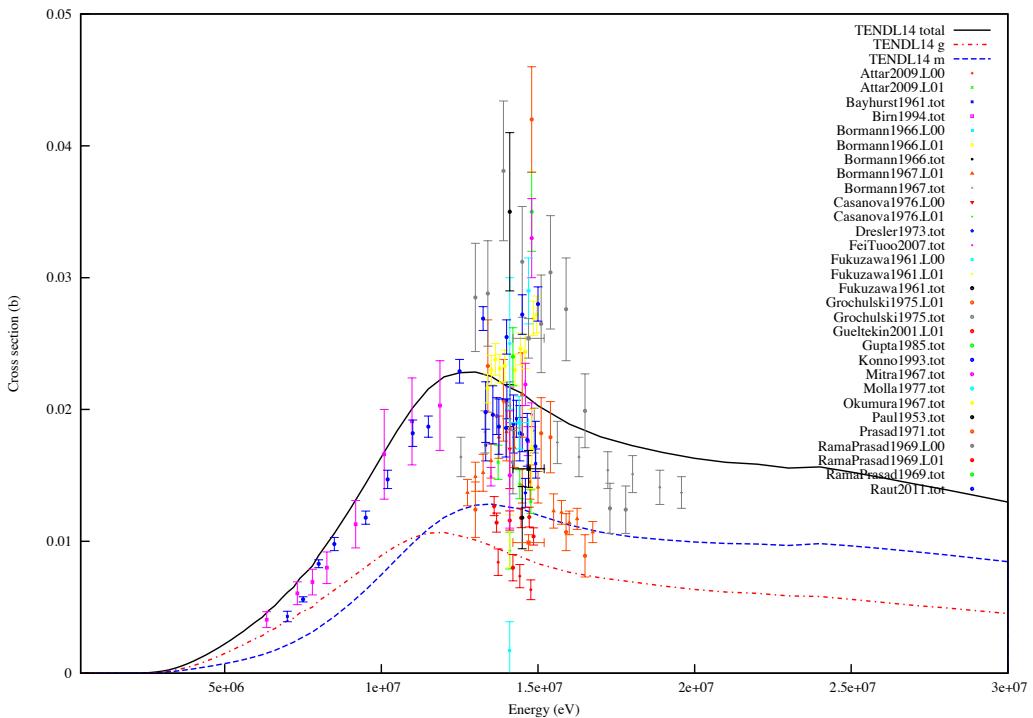
Ge74(n,p)Ga74



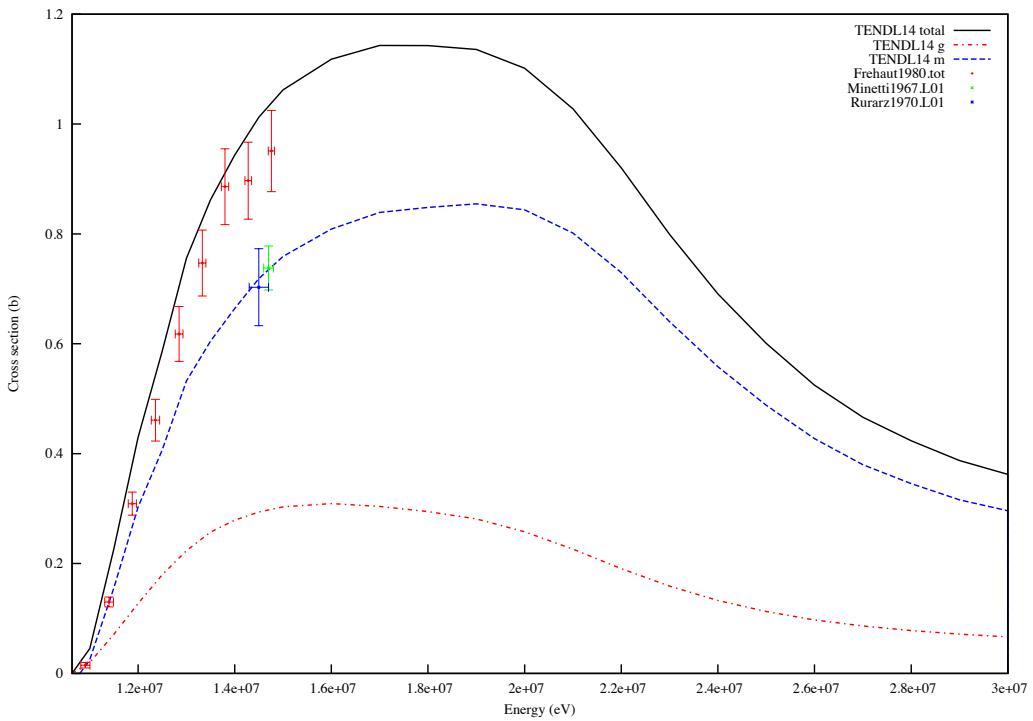
Ge76(n,2n)Ge75m/Ge75



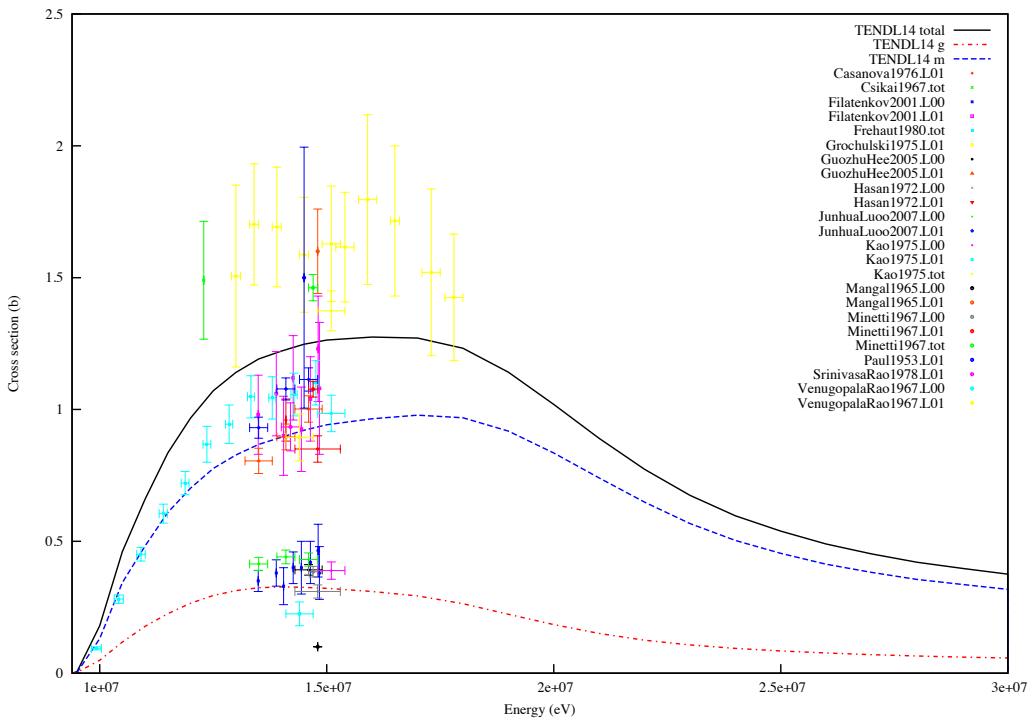
As75(n,p)Ge75m/Ge75



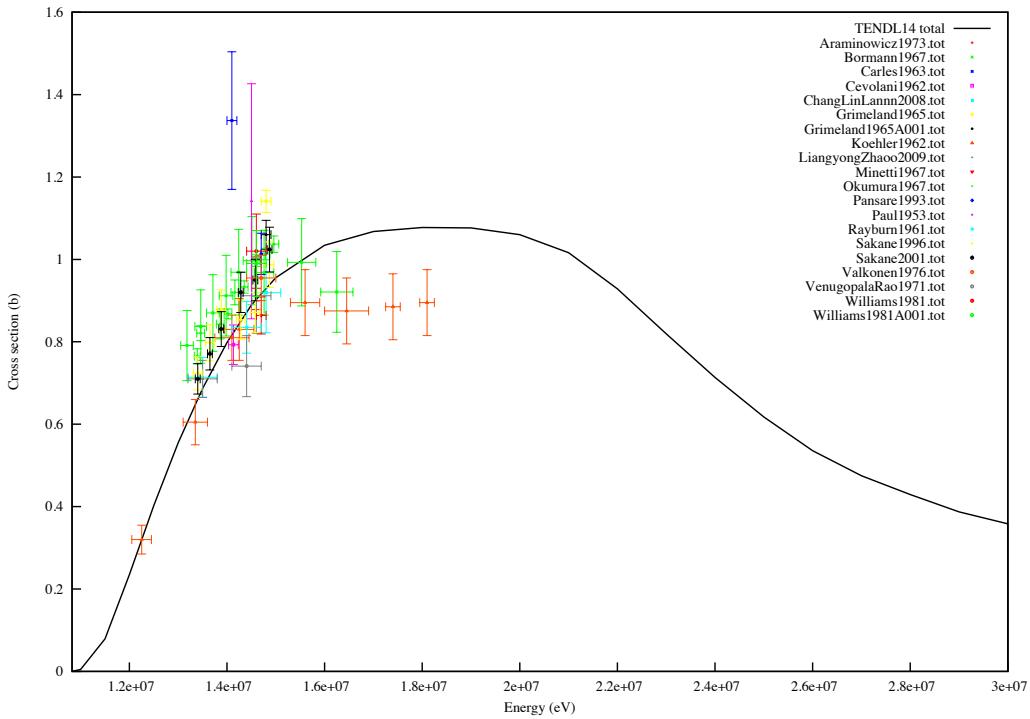
Se78(n,2n)Se77m



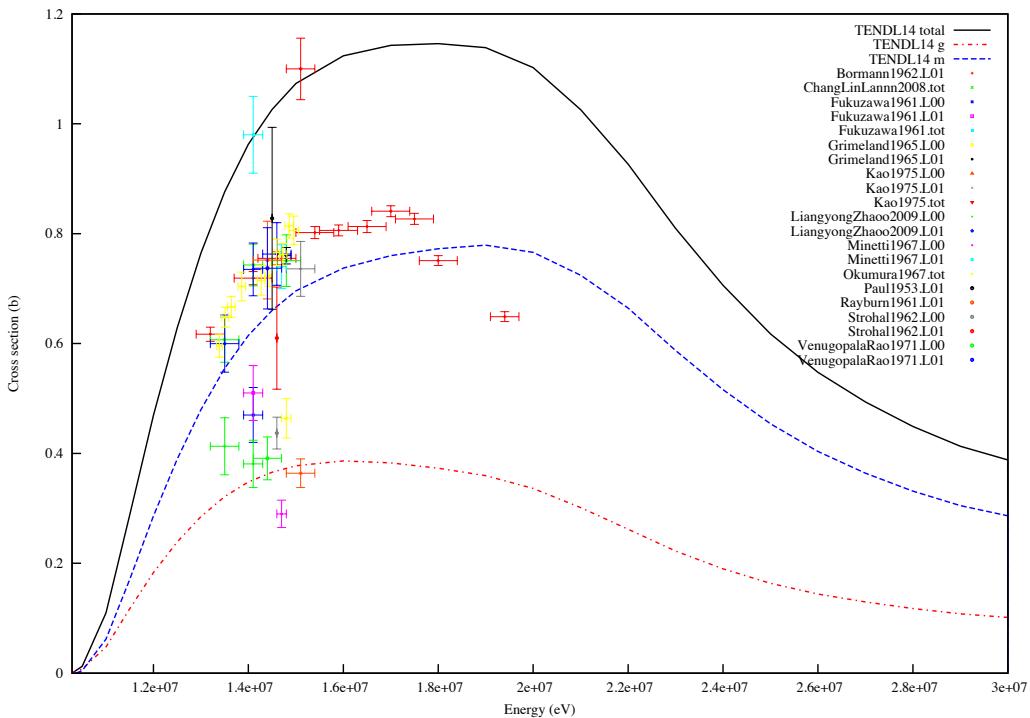
Se82(n,2n)Se81

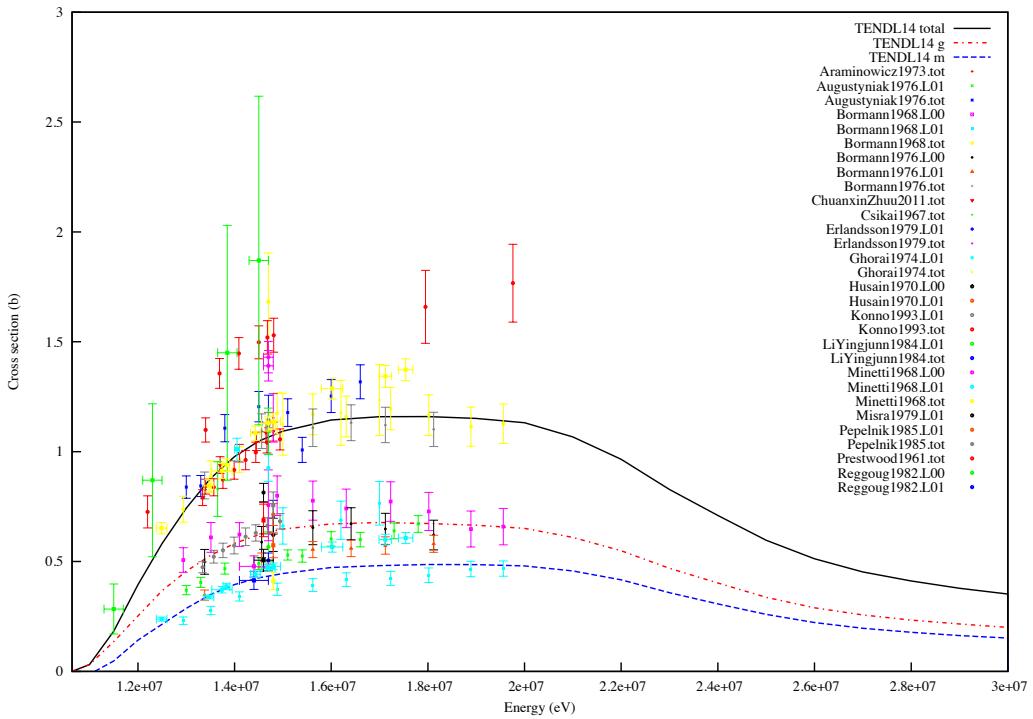
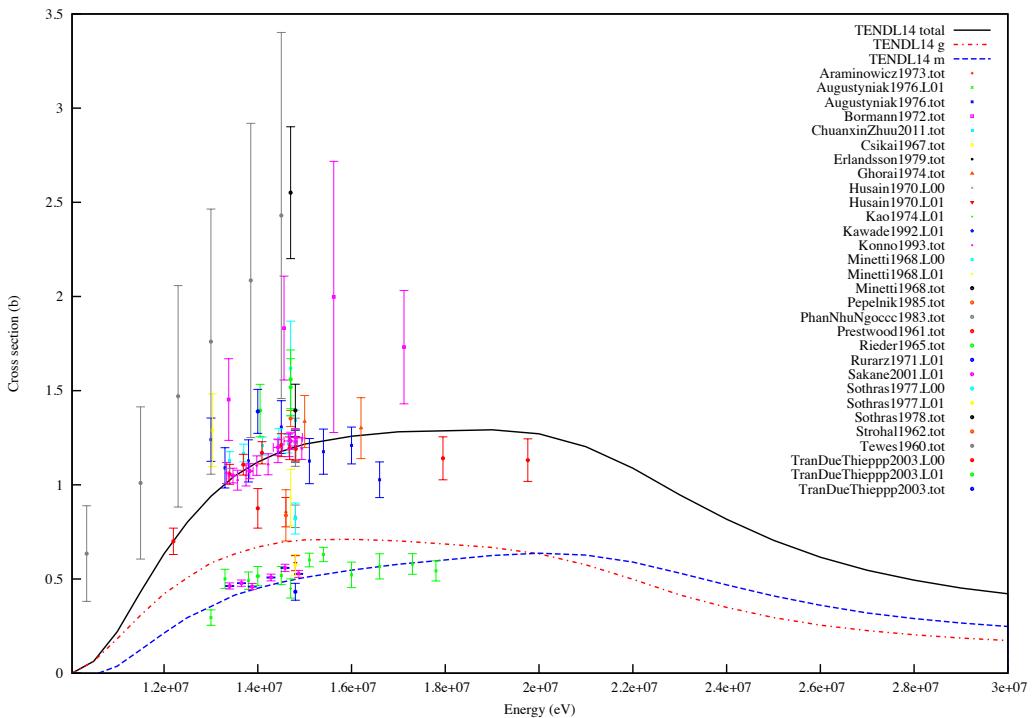


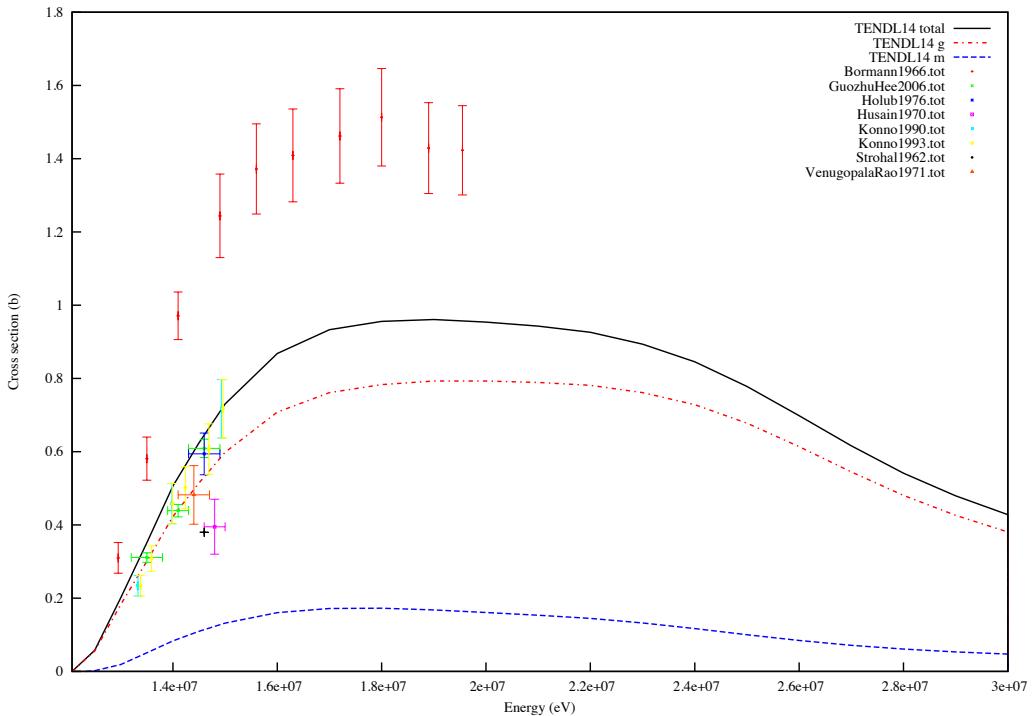
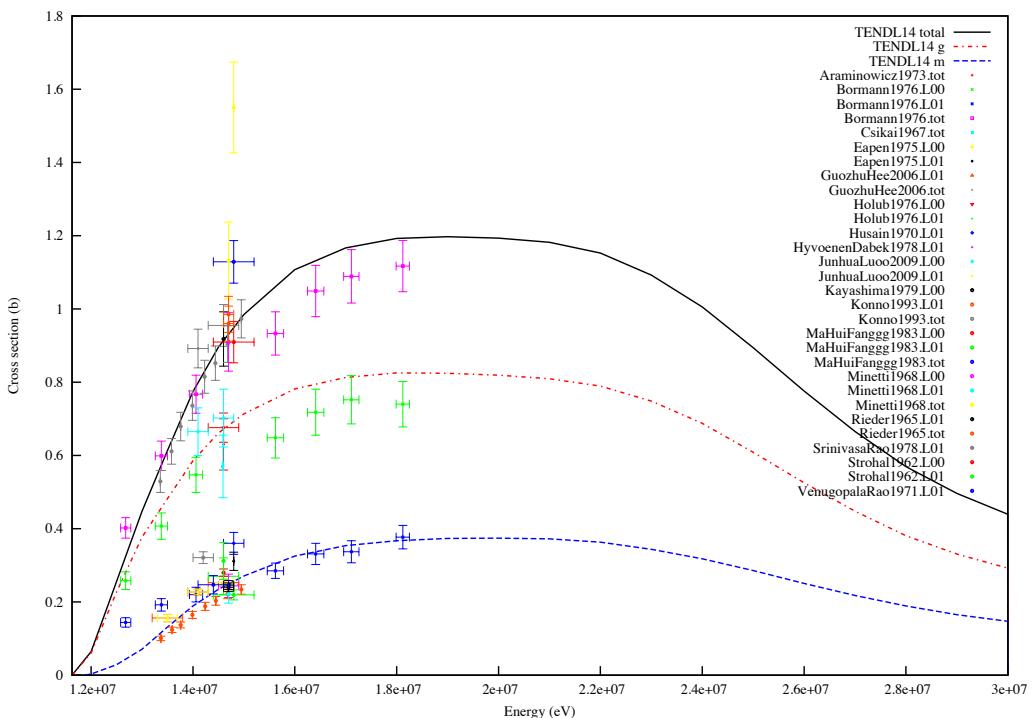
Br79(n,2n)Br78

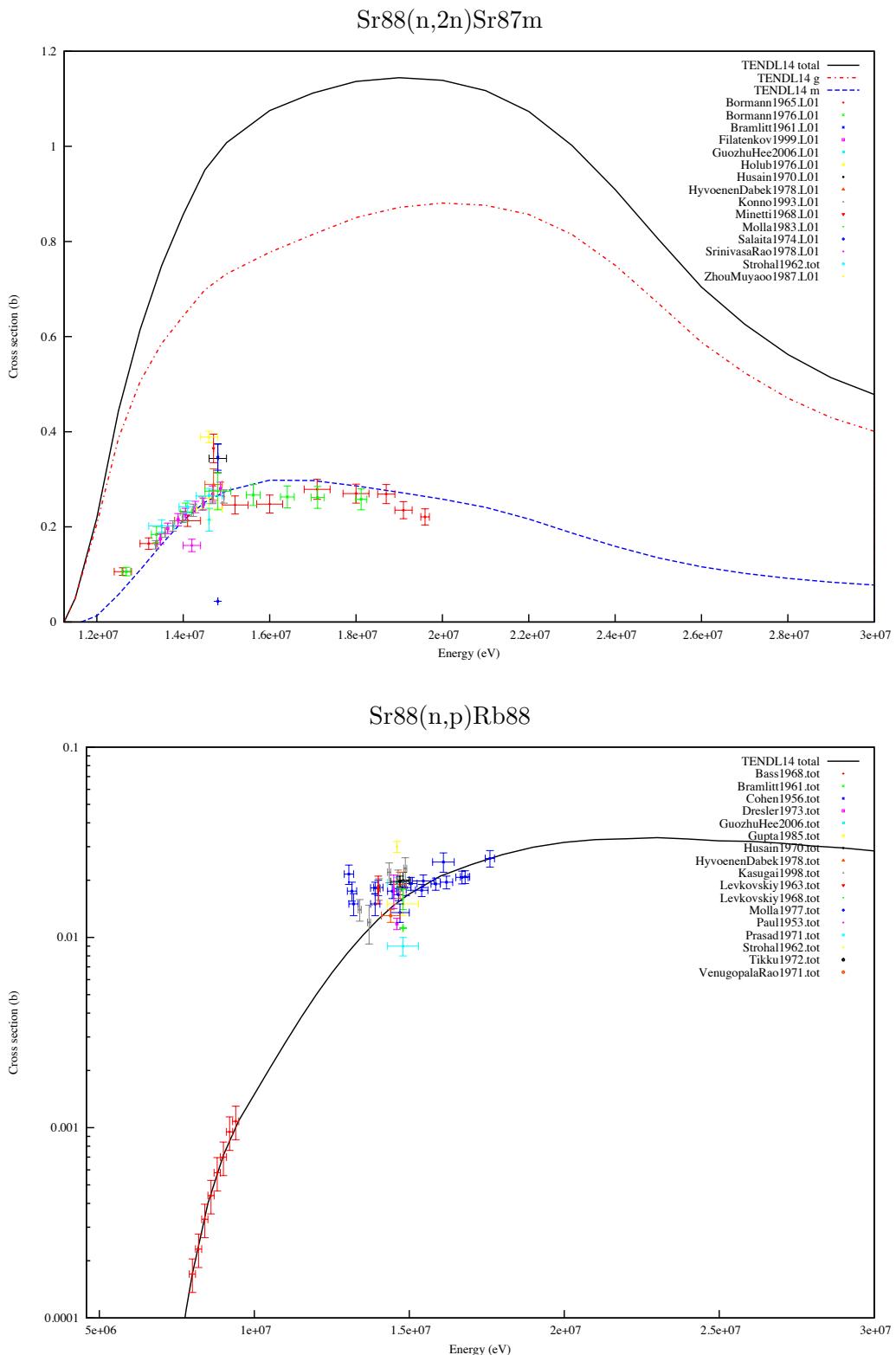


Br81(n,2n)Br80g

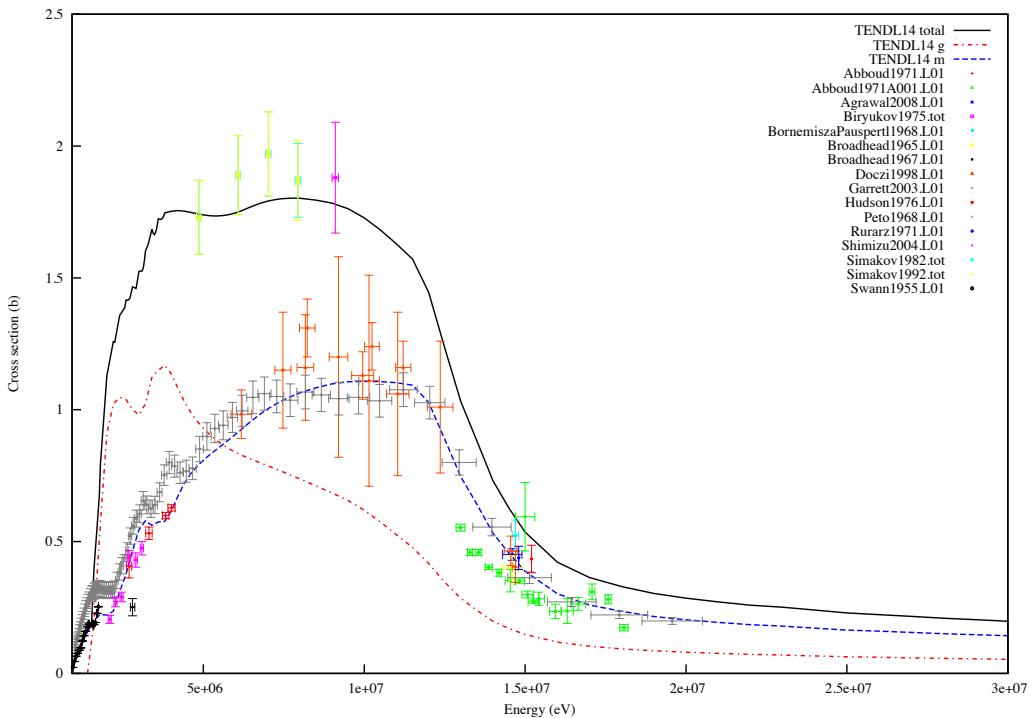


$\text{Rb85}(n,2n)\text{Rb84}$  $\text{Rb87}(n,2n)\text{Rb86m}$ 

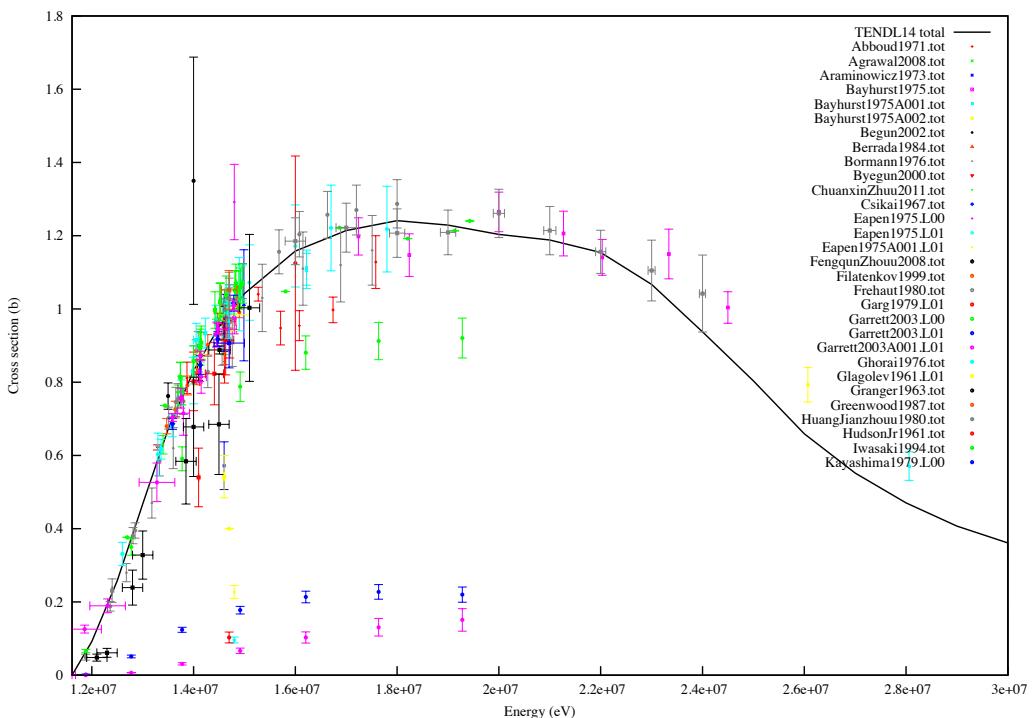
$\text{Sr}^{84}(\text{n},\text{2n})\text{Sr}^{83}$  $\text{Sr}^{86}(\text{n},\text{2n})\text{Sr}^{85}$ 

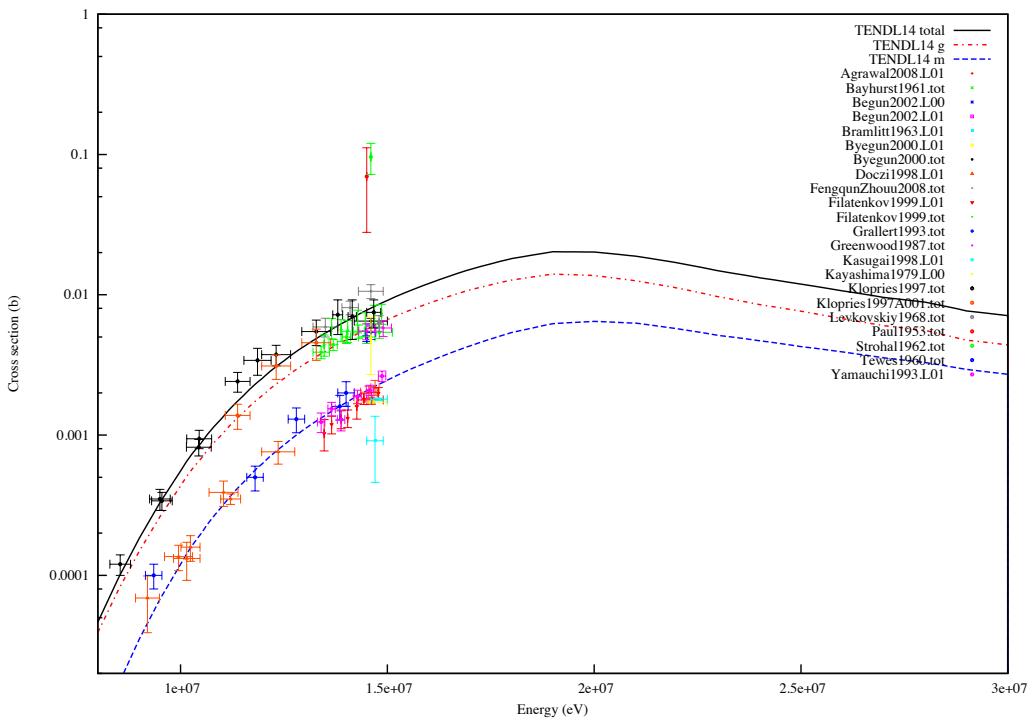


Y89(n,n')Y89m

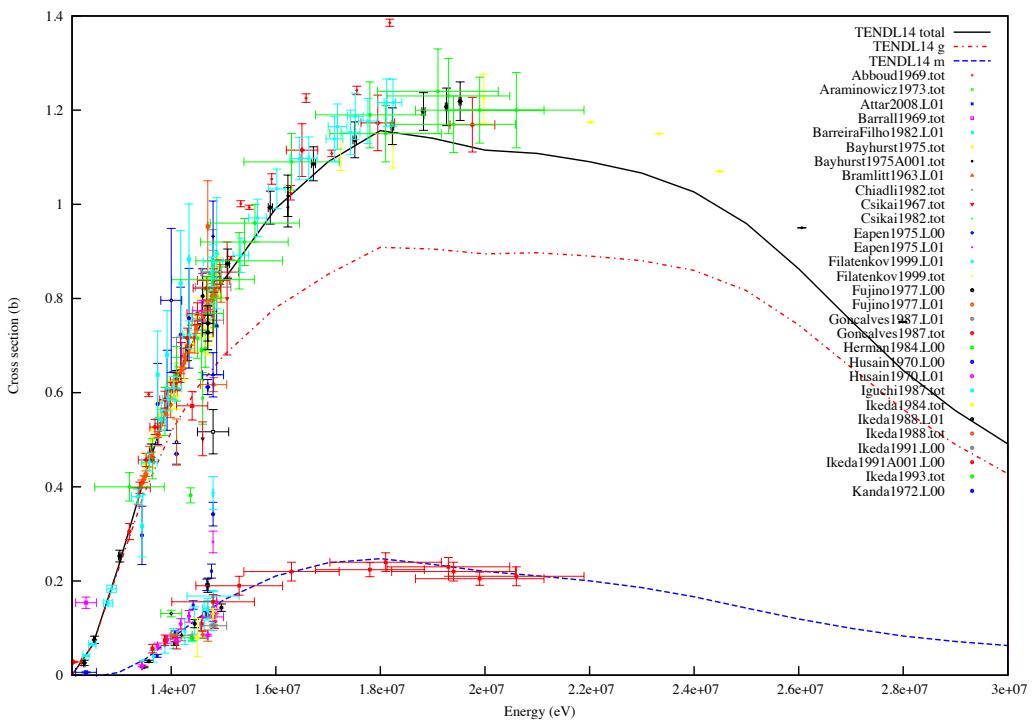


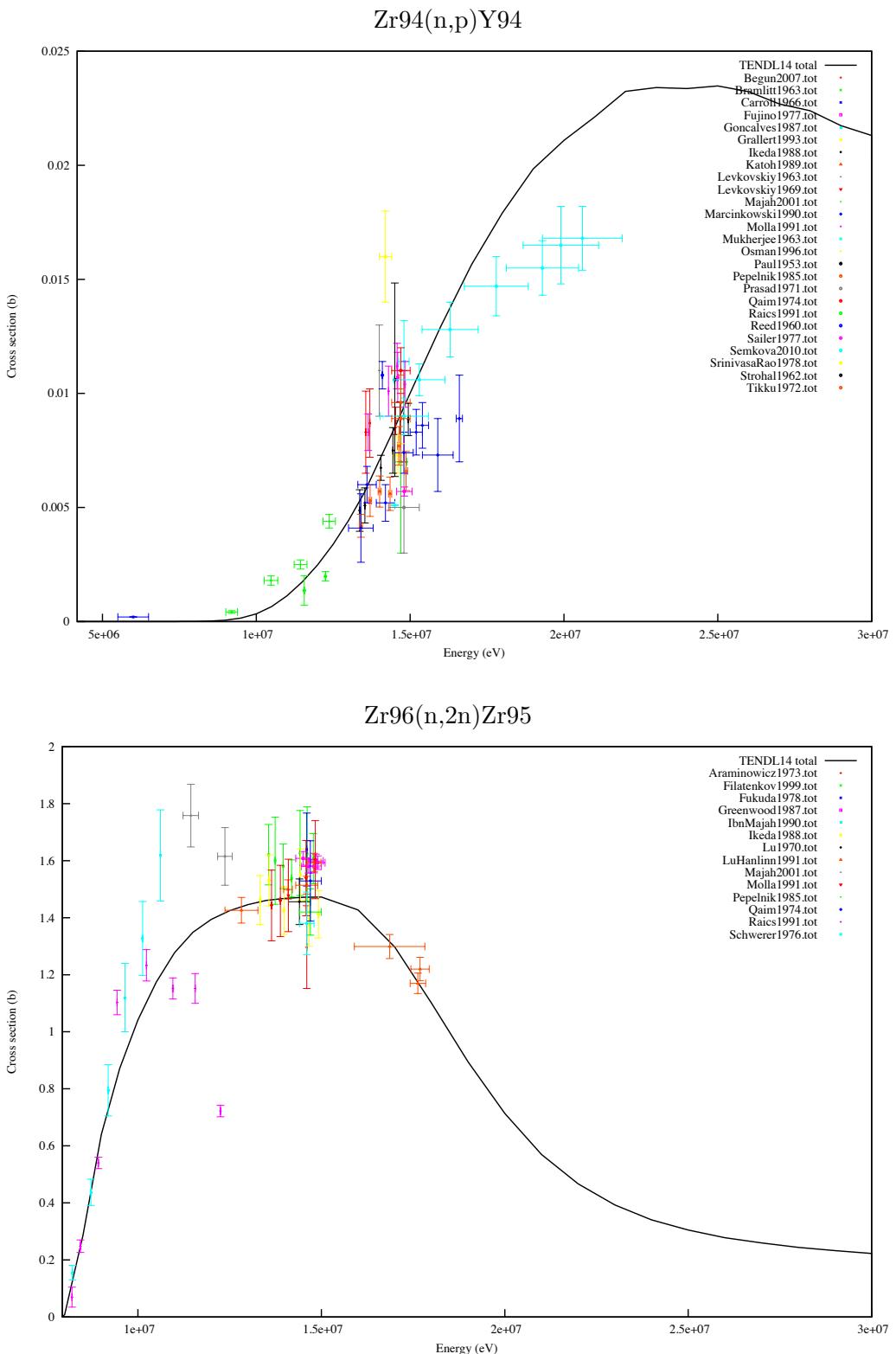
Y89(n,2n)Y88



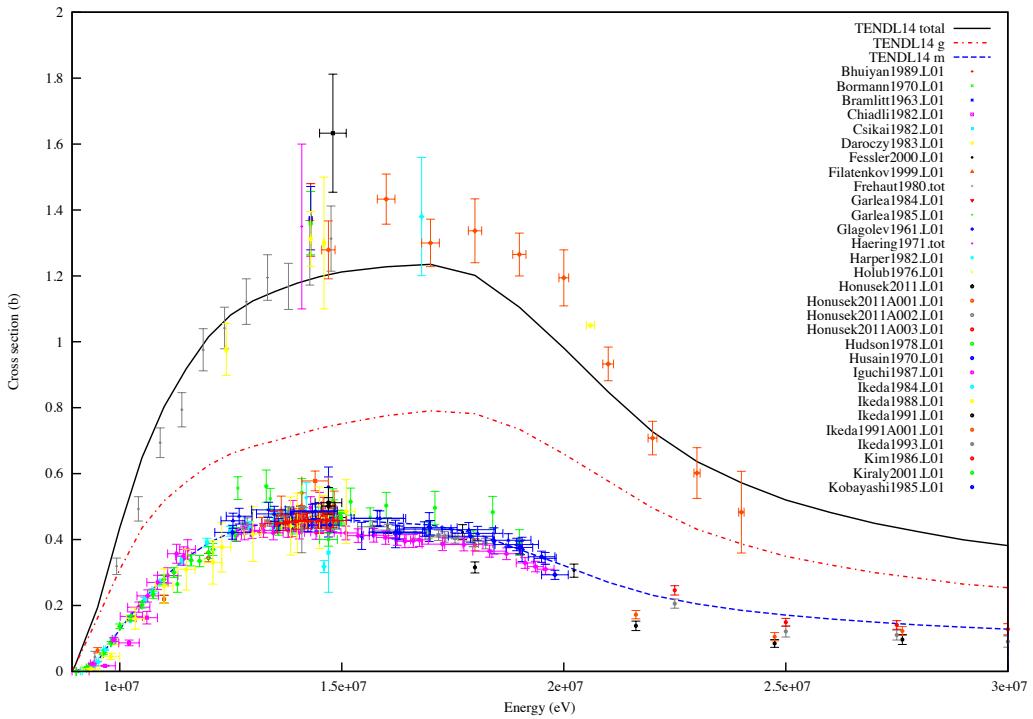
Y89(n, α)Rb86m

Zr90(n,2n)Zr89m/Zr89

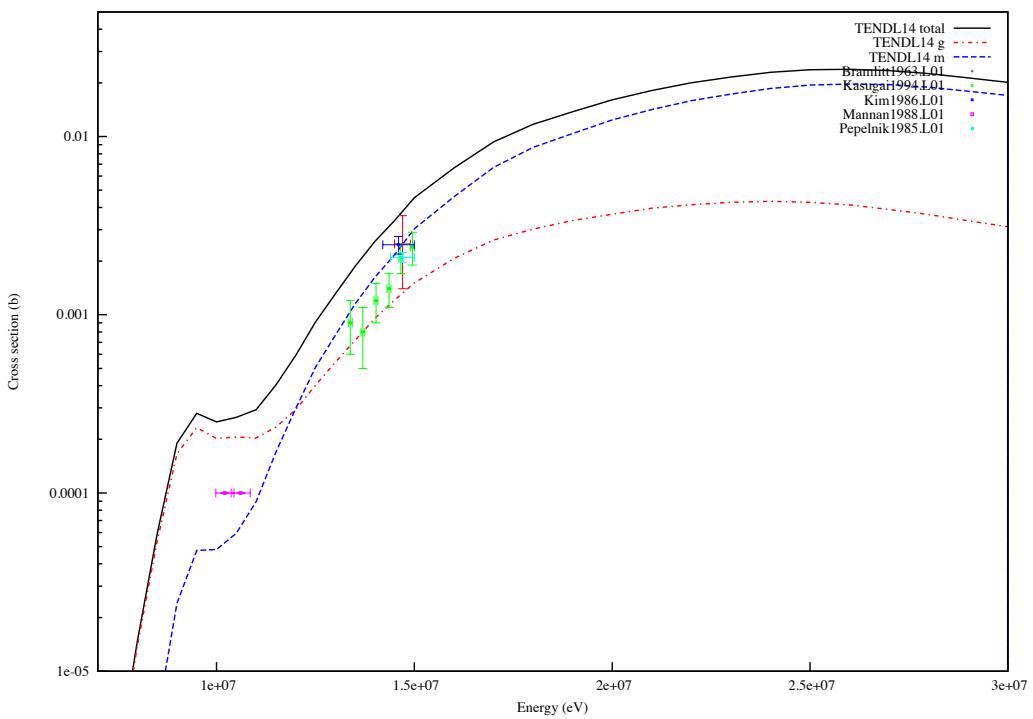




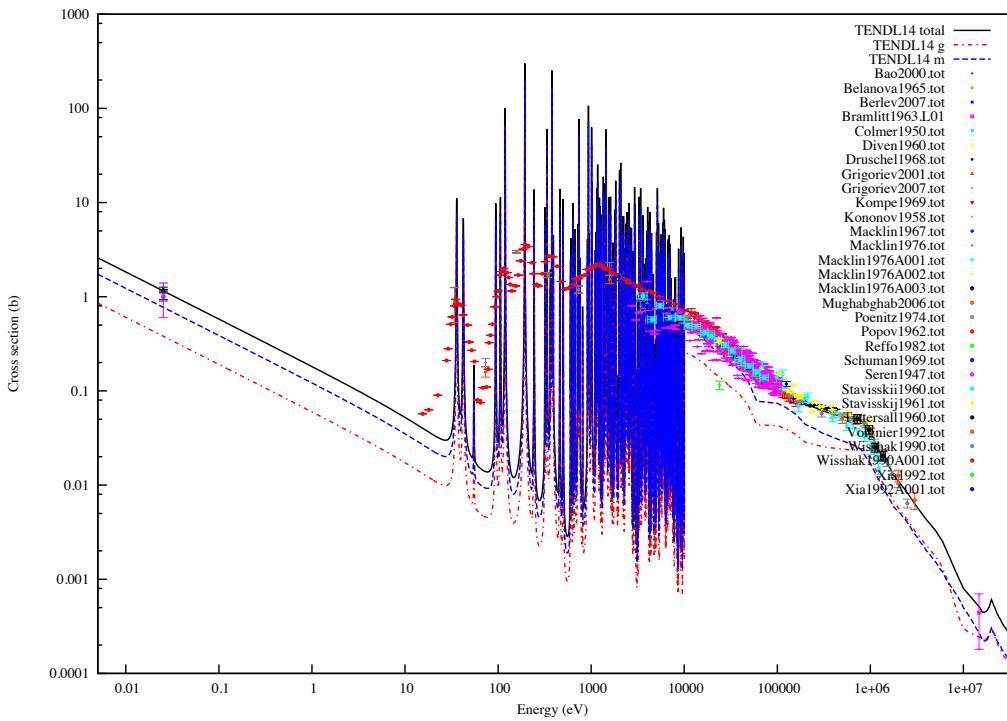
Nb93(n,2n)Nb92m



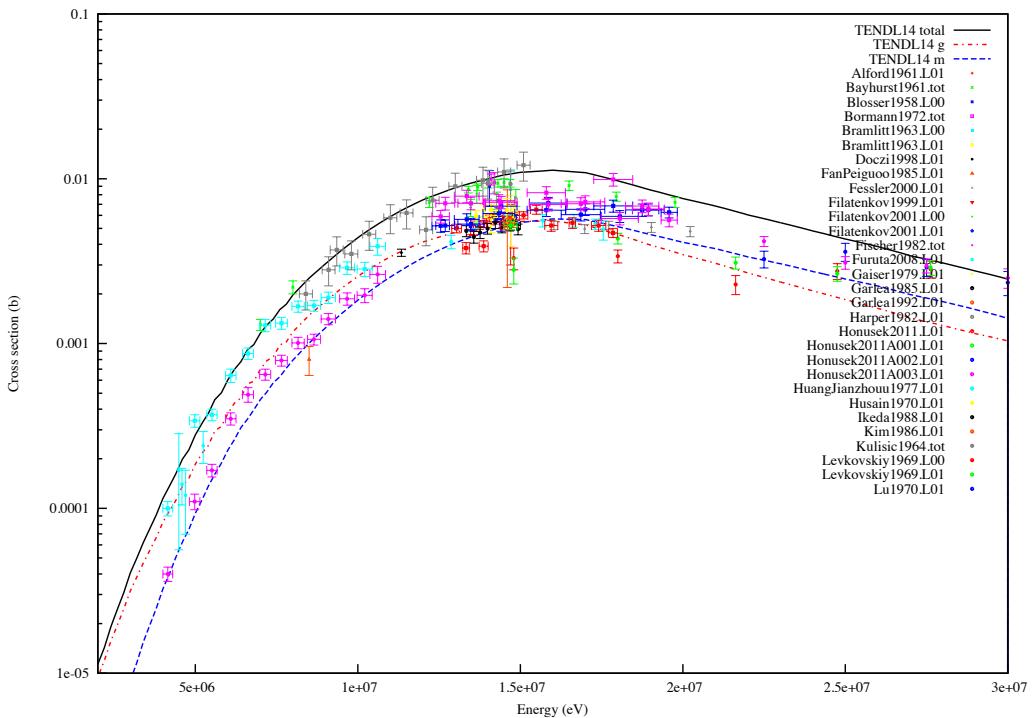
Nb93(n,n α)Y89m



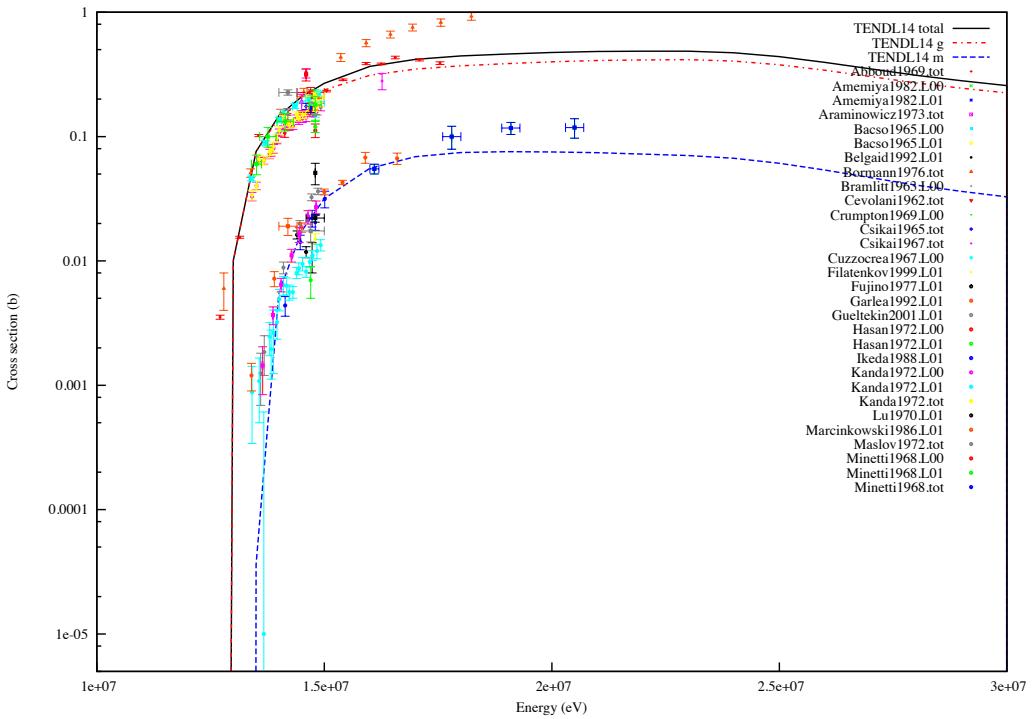
Nb93(n,γ)Nb94m



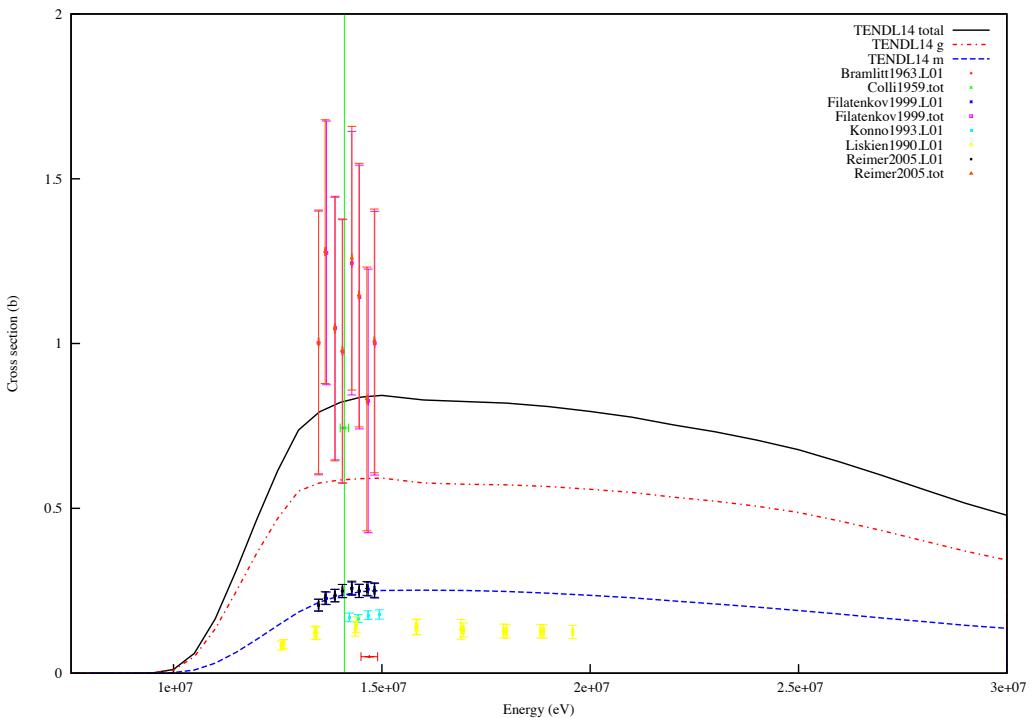
Nb93(n,α)Y90m



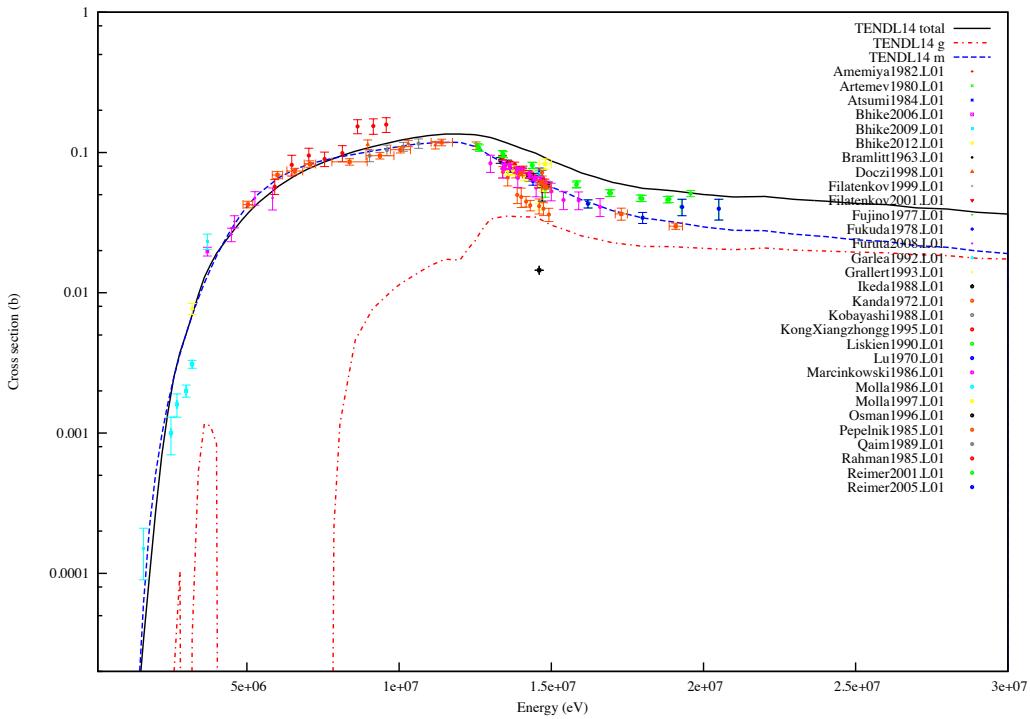
Mo92(n,2n)Mo91



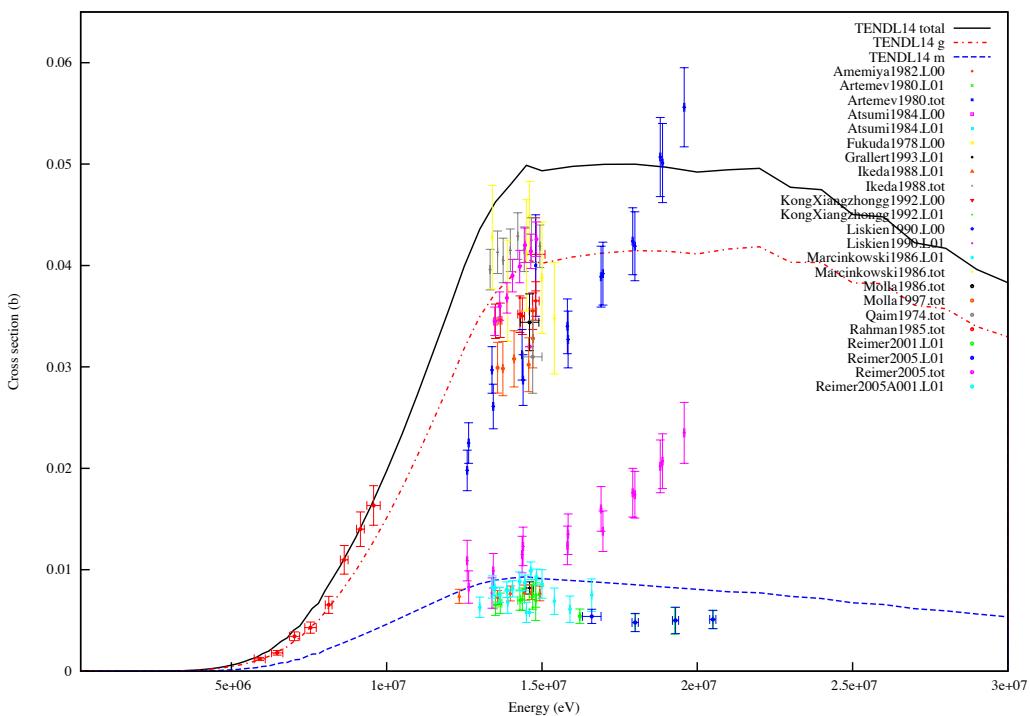
Mo92(n,np)Nb91m



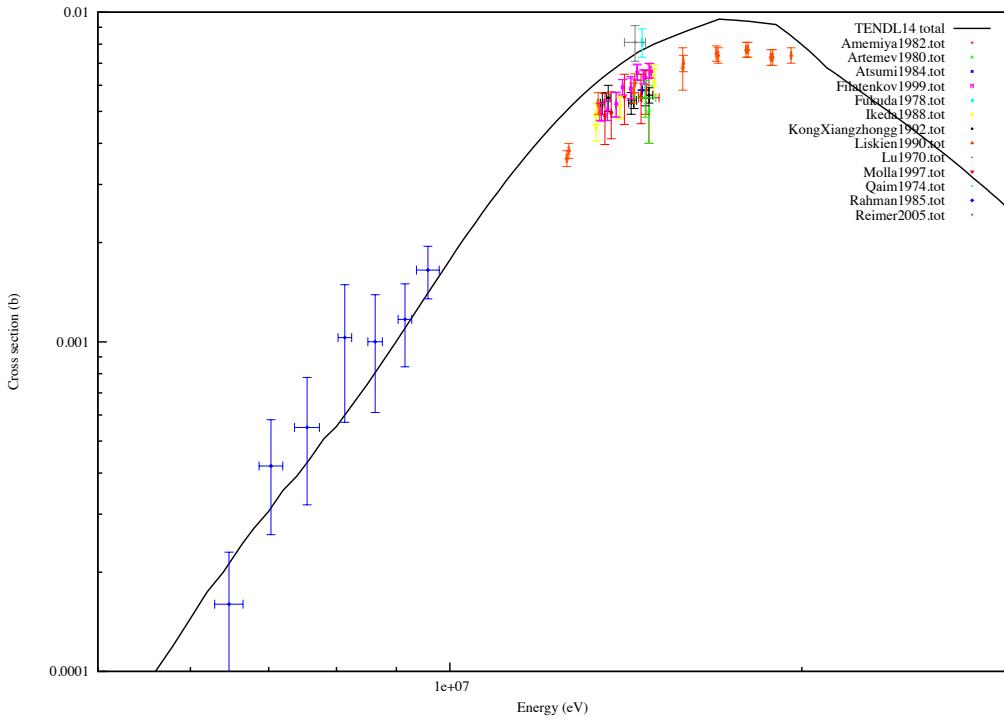
Mo92(n,p)Nb92m



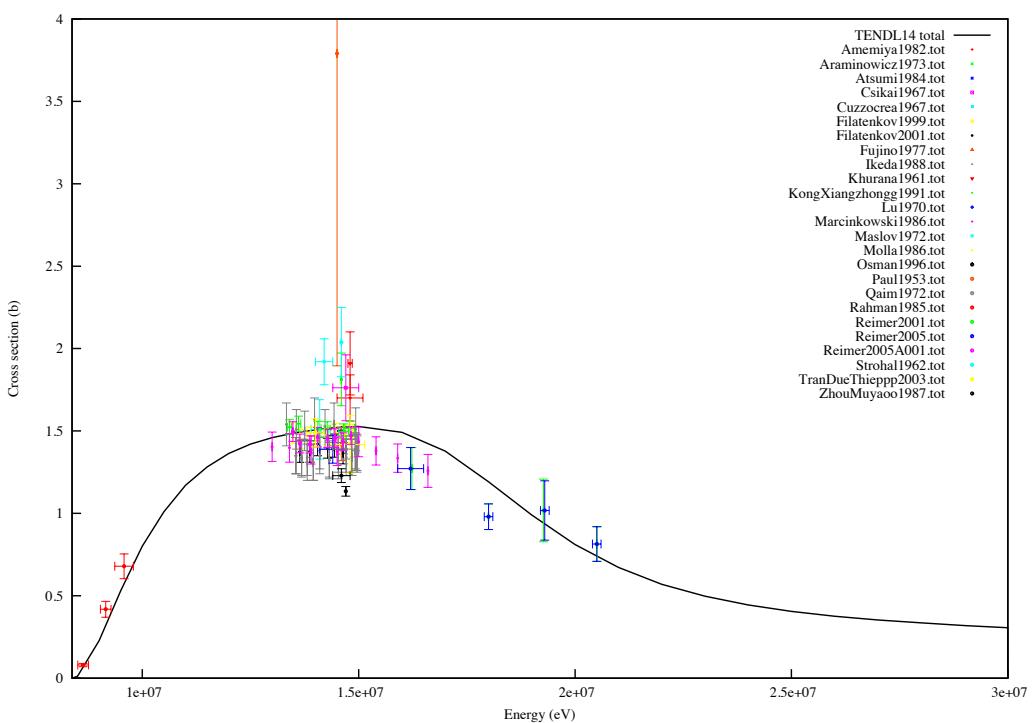
Mo95(n,p)Nb95g



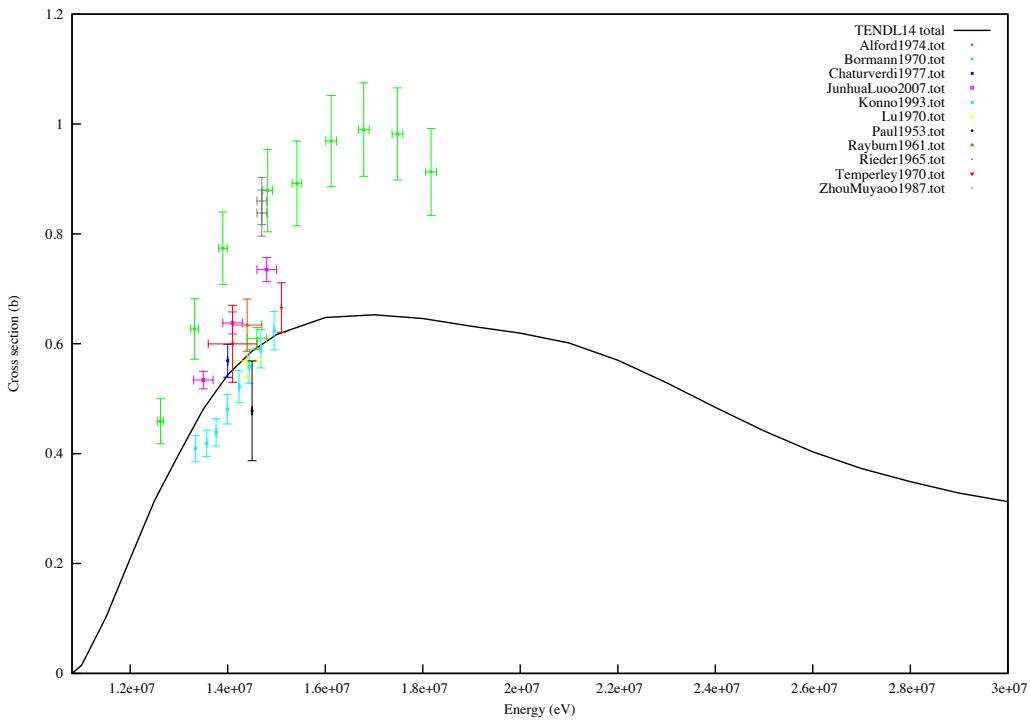
Mo98(n,α)Zr95



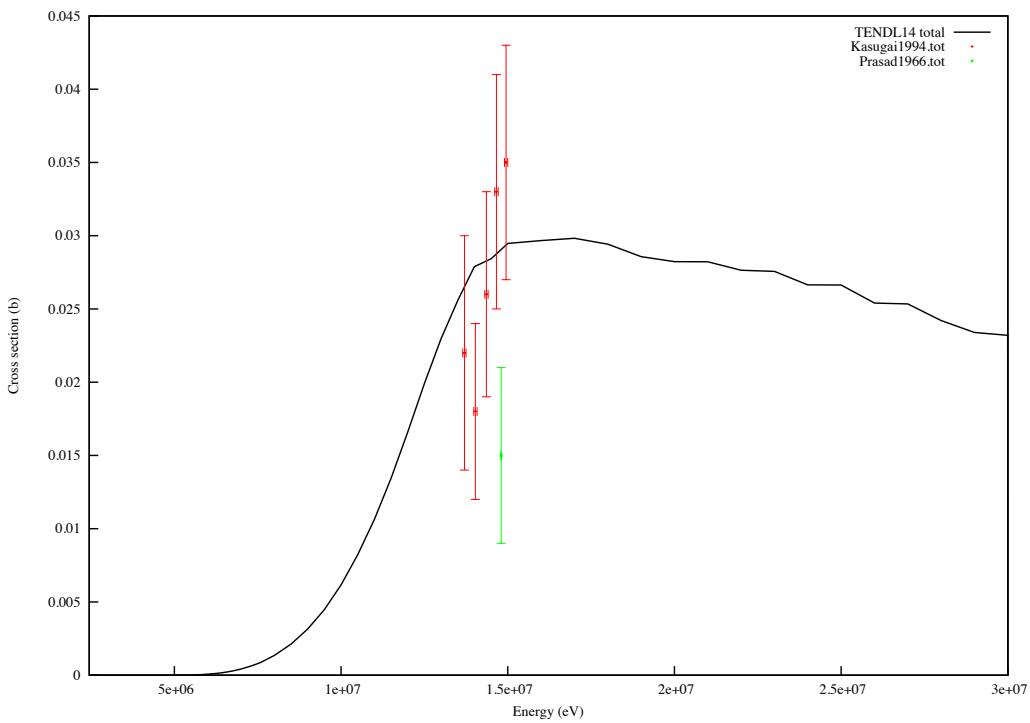
Mo100($n,2n$)Mo99



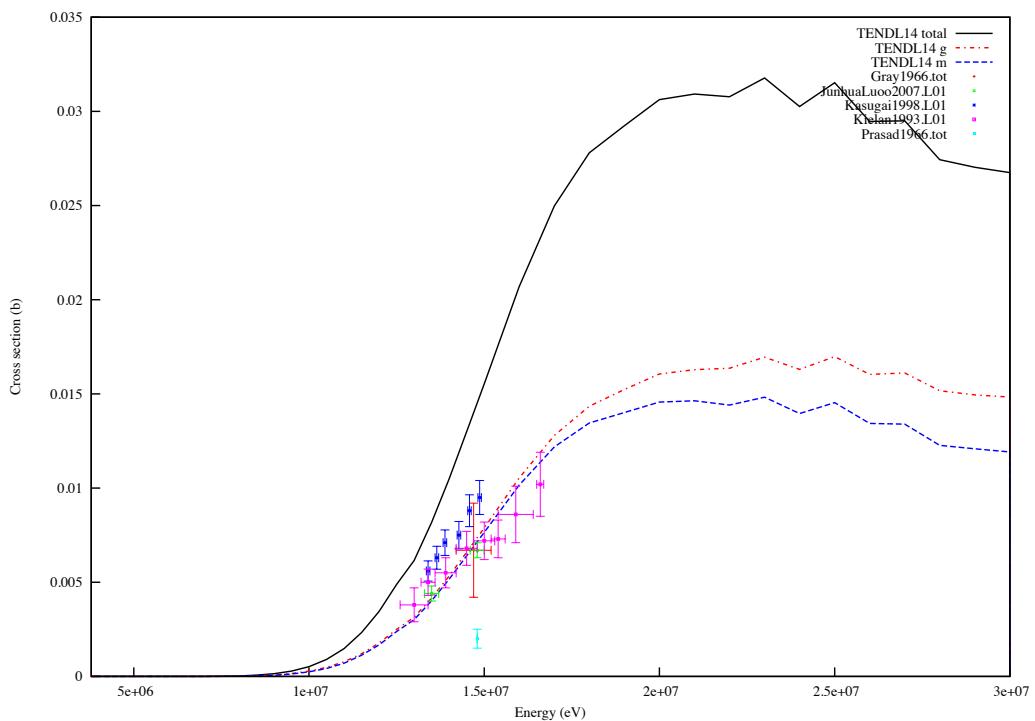
Ru96(n,2n)Ru95



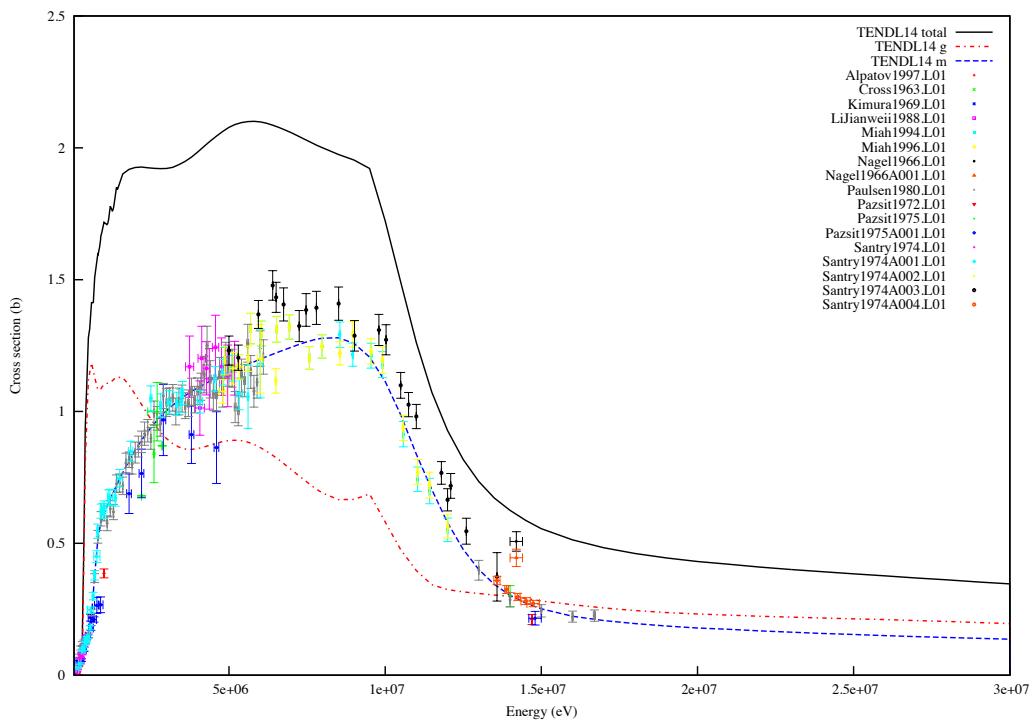
Ru100(n,p)Tc100



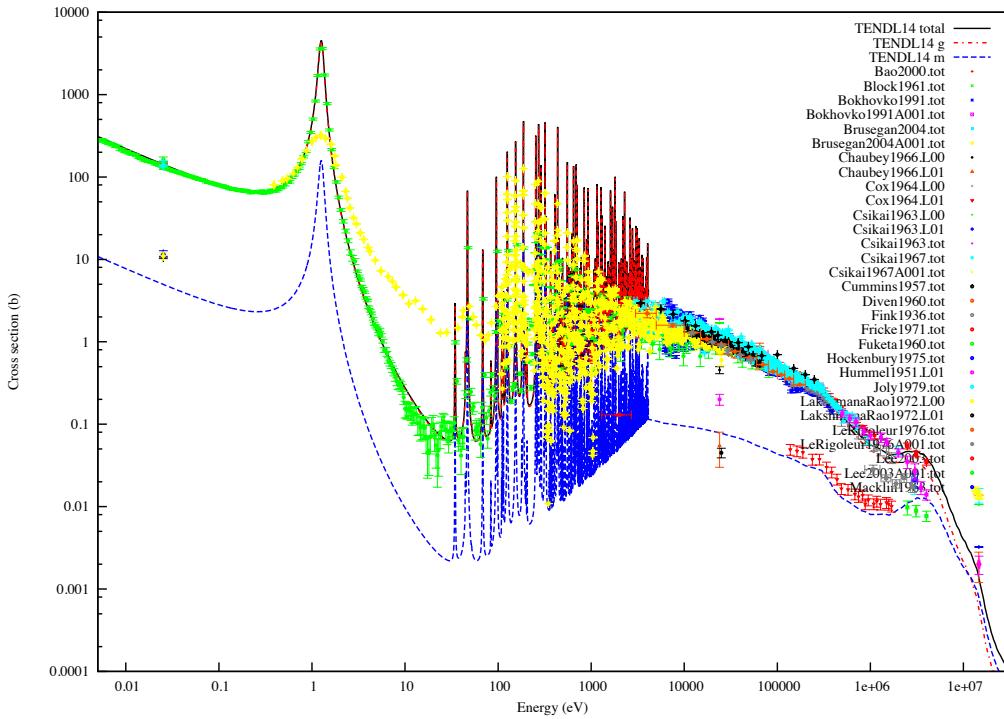
Ru102(n,p)Tc102m



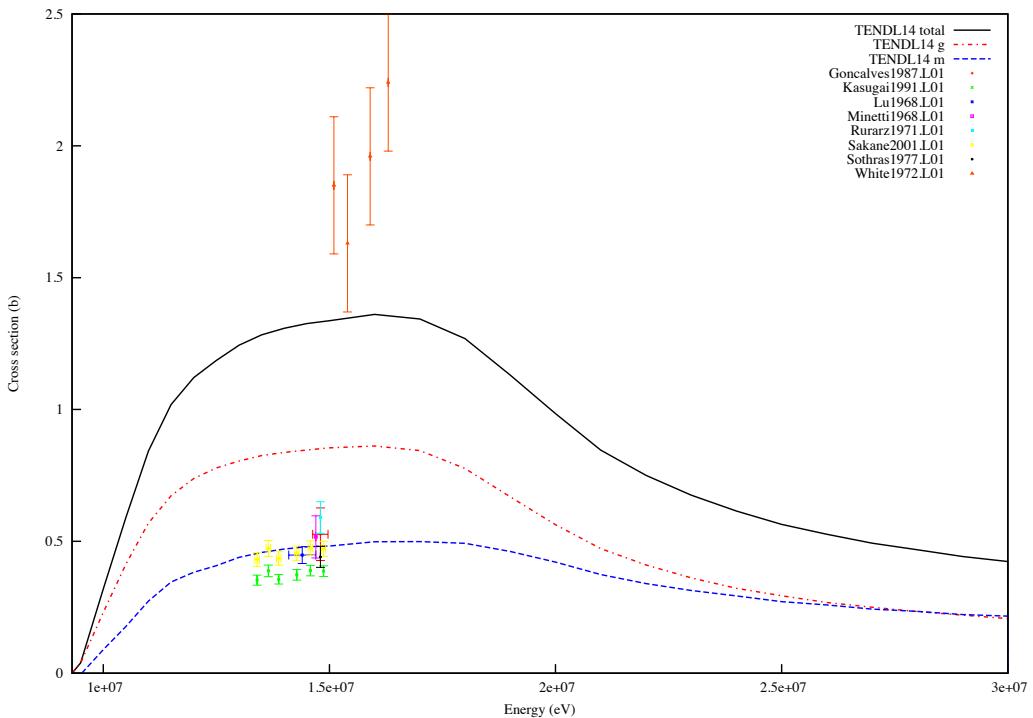
Rh103(n,n')Rh103m

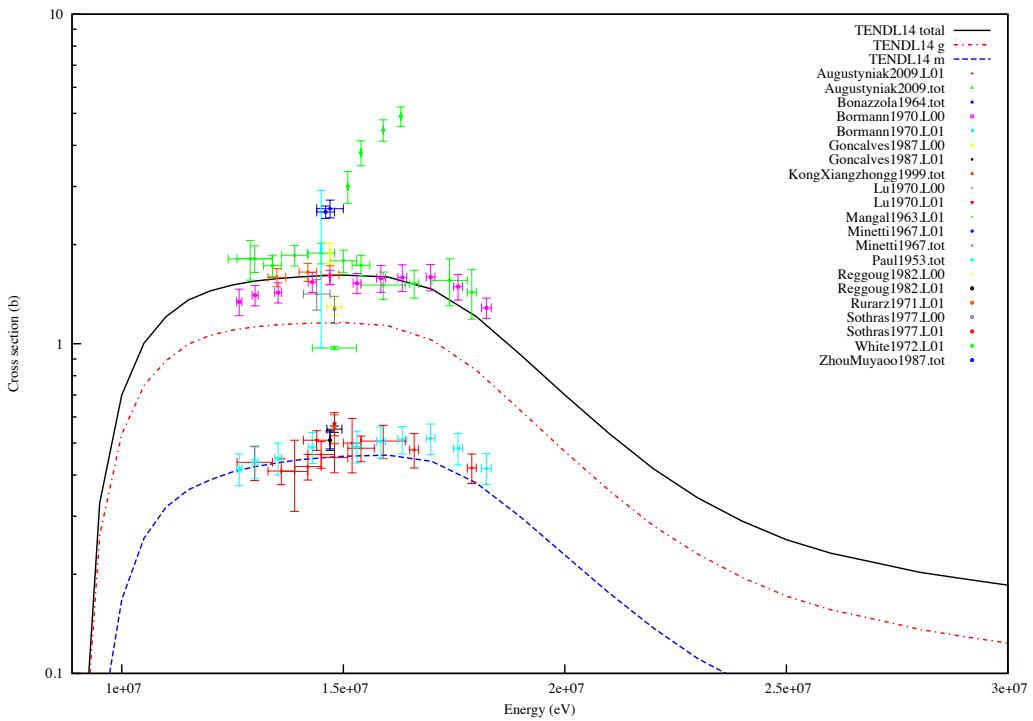
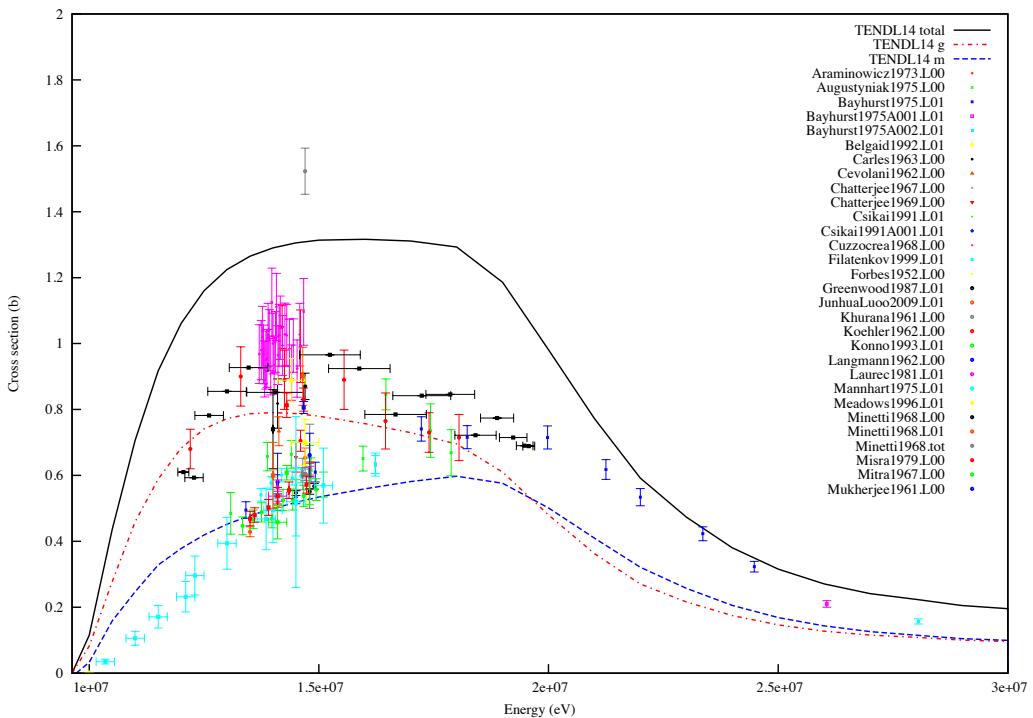


Rh103(n, γ)Rh104

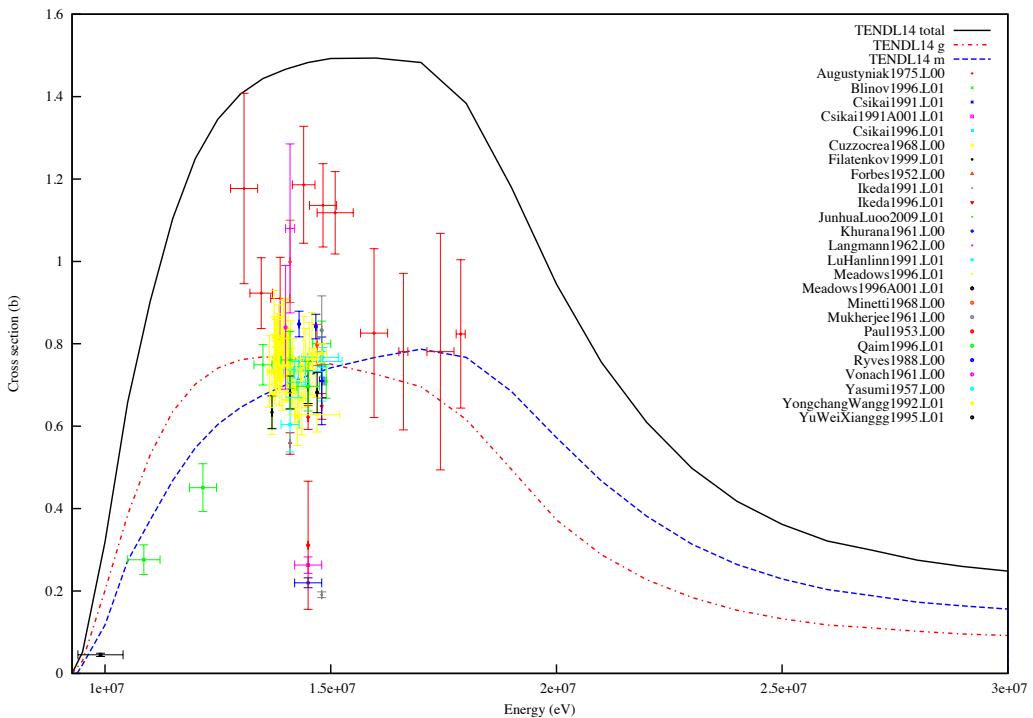


Pd108(n,2n)Pd107m

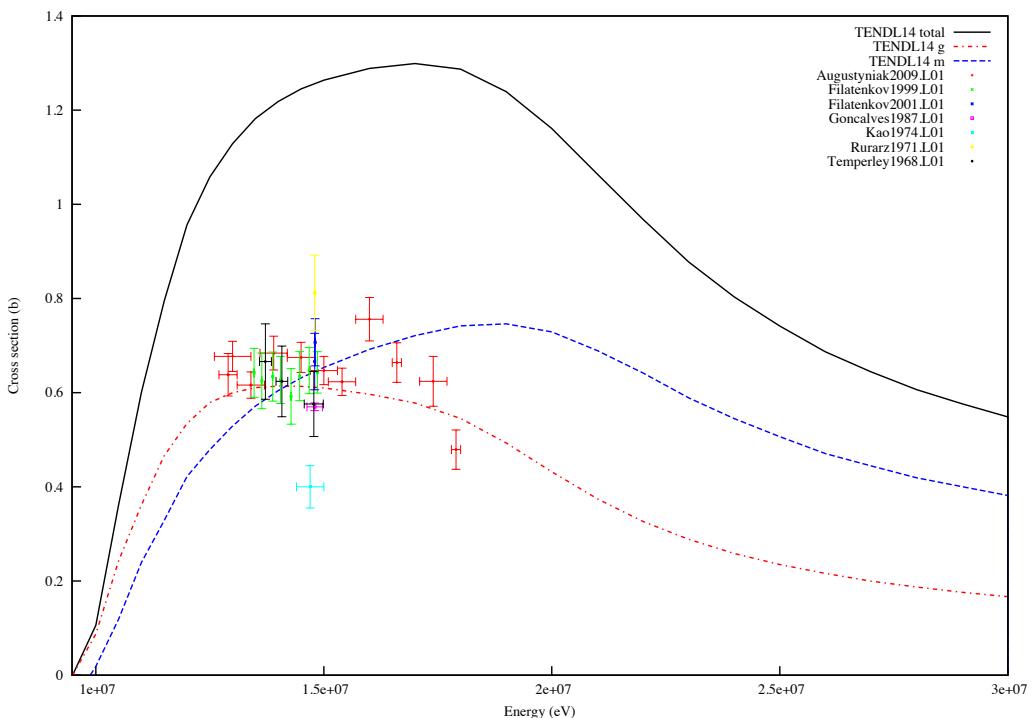


$\text{Pd110}(\text{n},\text{2n})\text{Pd109m}/\text{Pd109}$  $\text{Ag107}(\text{n},\text{2n})\text{Ag106g}$ 

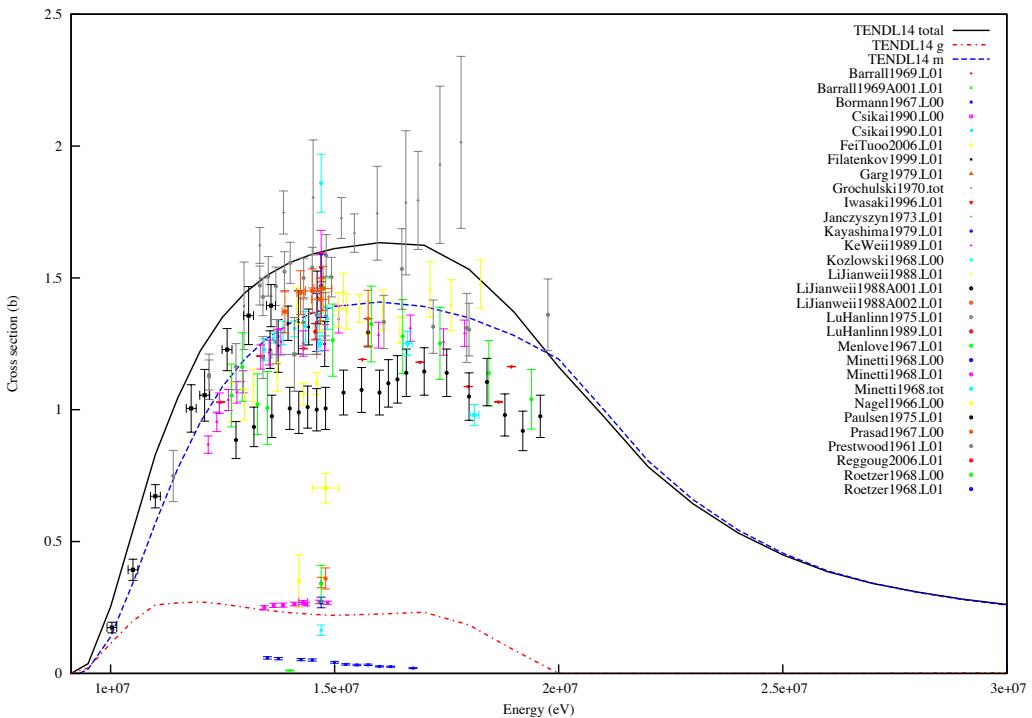
Ag109(n,2n)Ag108g



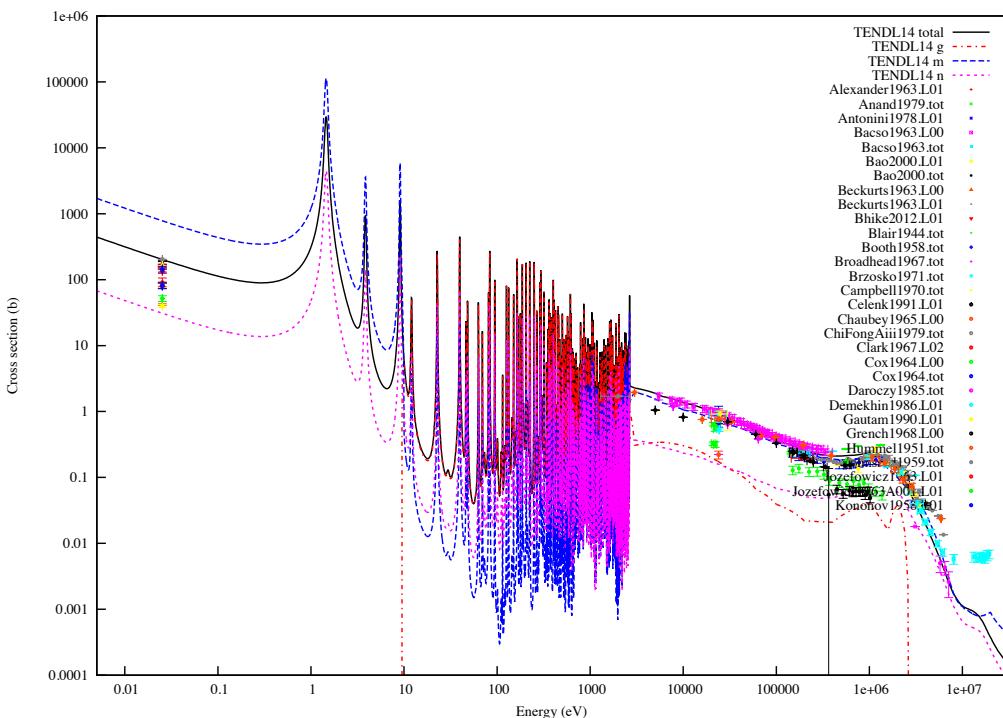
Cd112(n,2n)Cd111m



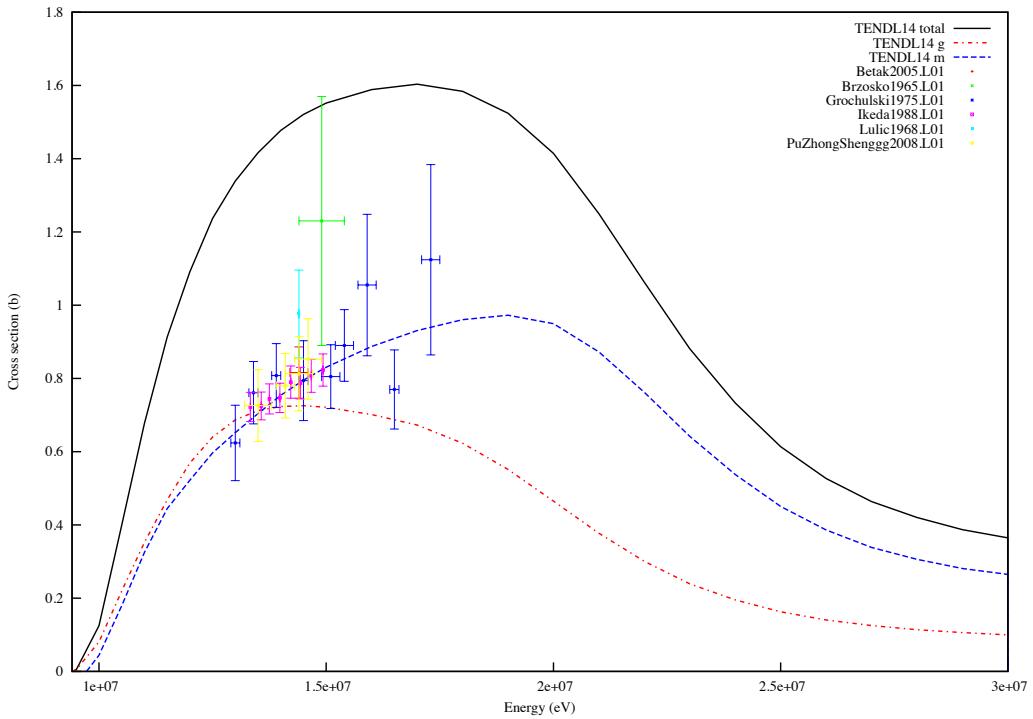
In115(n,2n)In114g



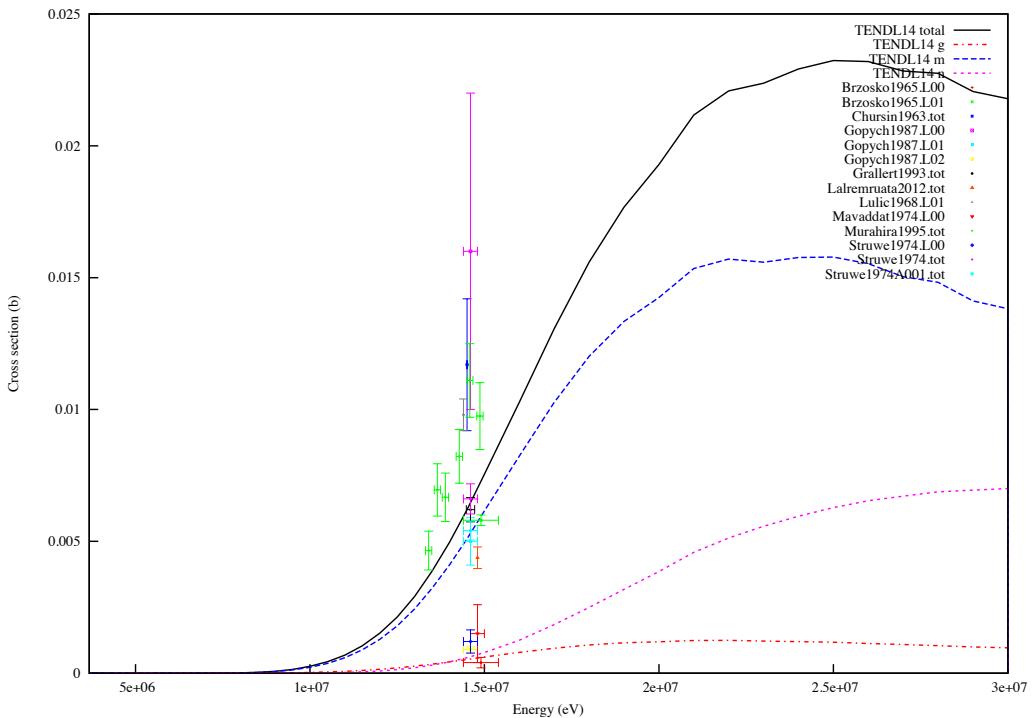
In115(n, γ)In116



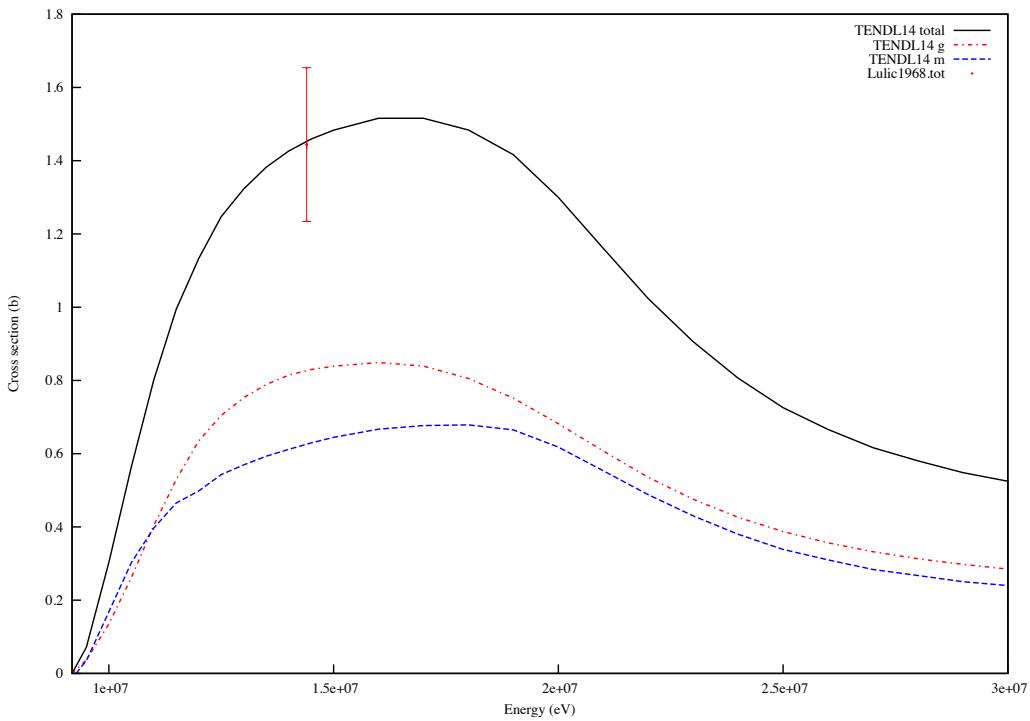
Sn118(n,2n)Sn117m



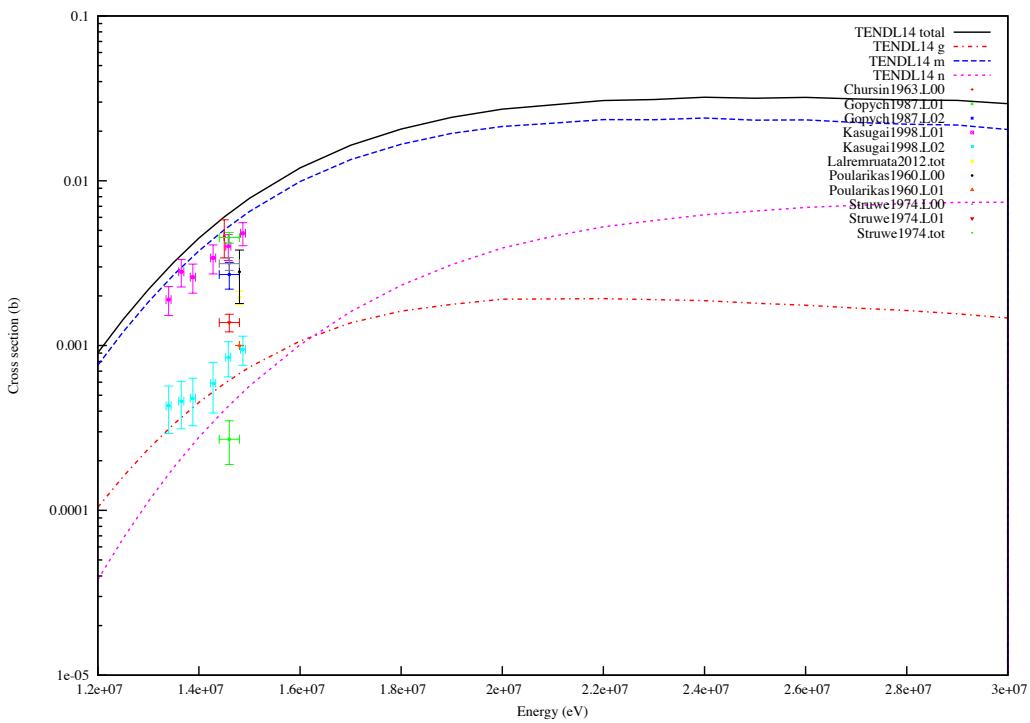
Sn118(n,p)In118m



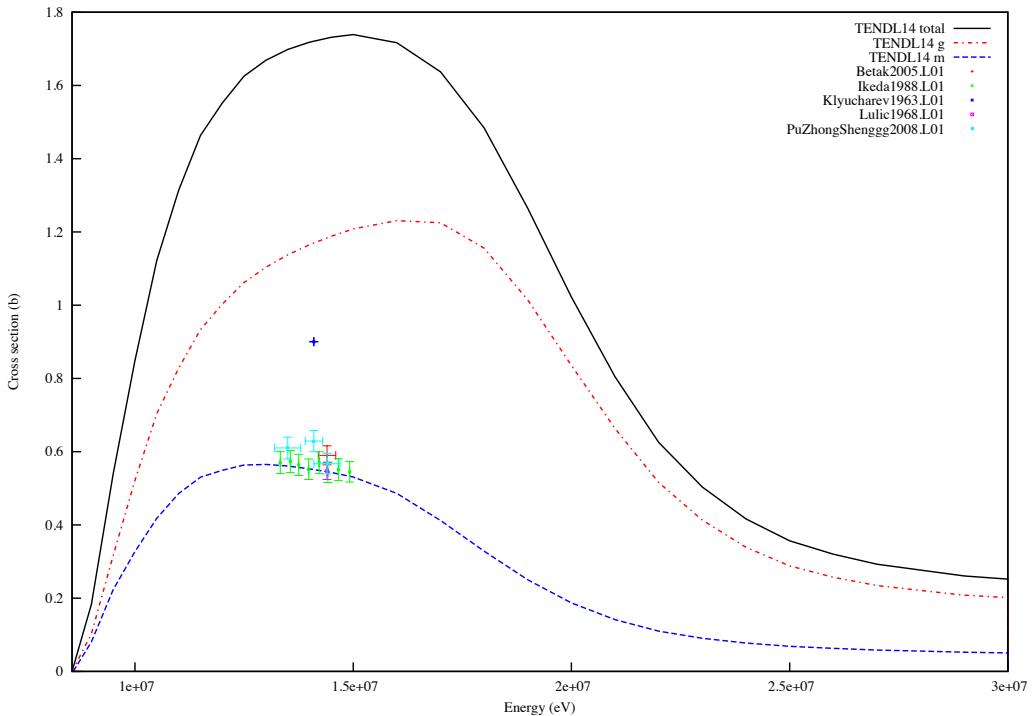
Sn120(n,2n)Sn119m



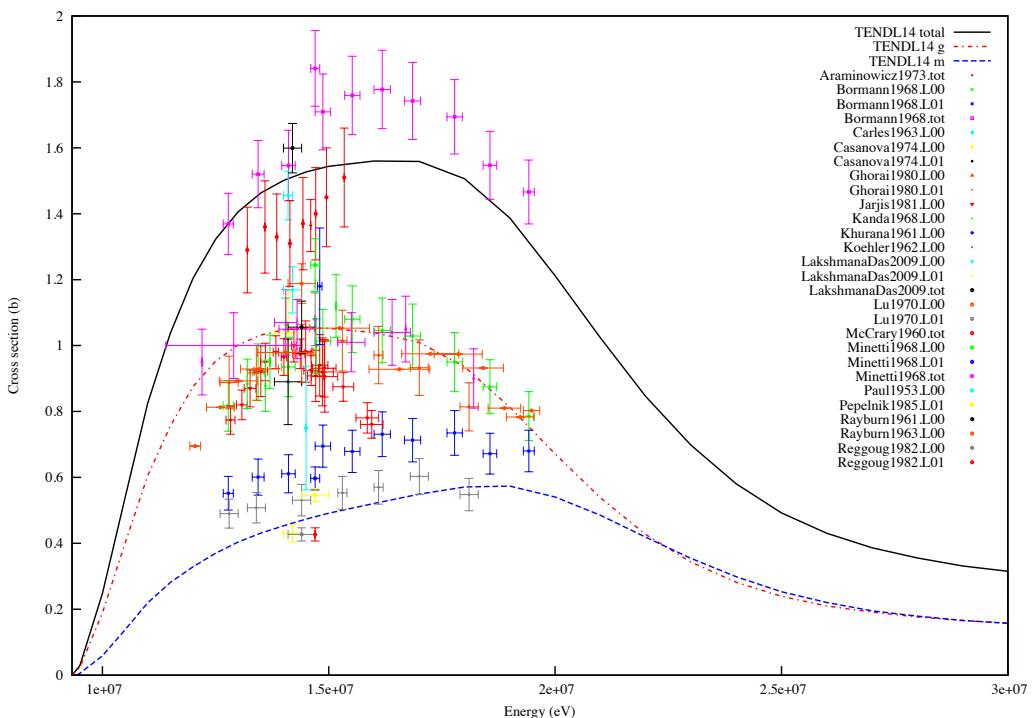
Sn120(n,p)In120m



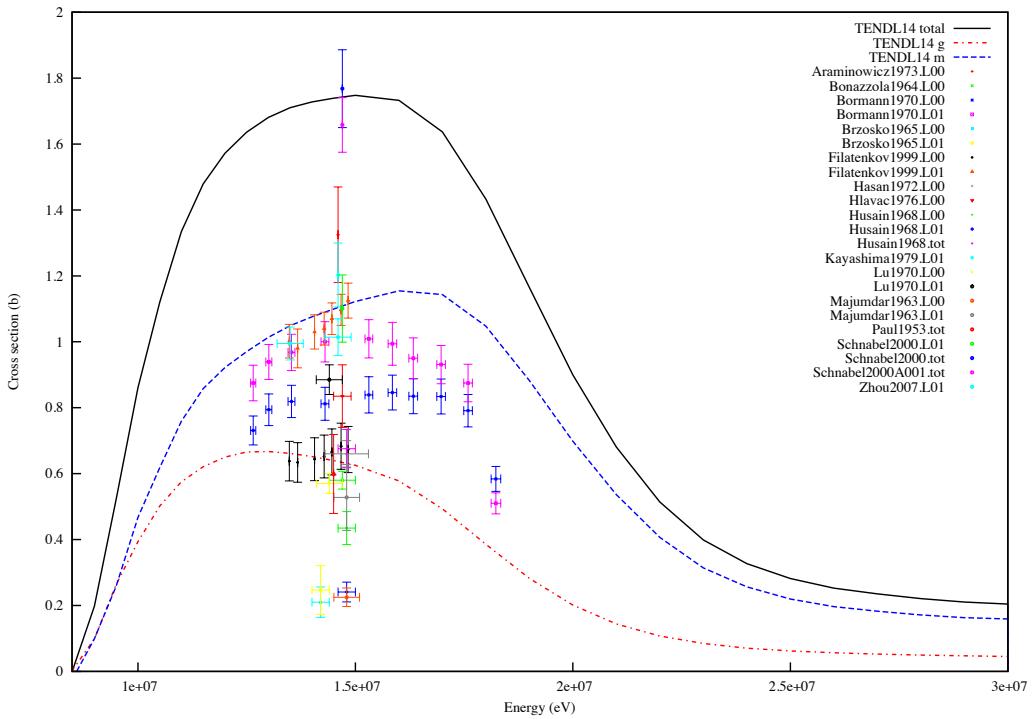
Sn124(n,2n)Sn123g/Sn123m



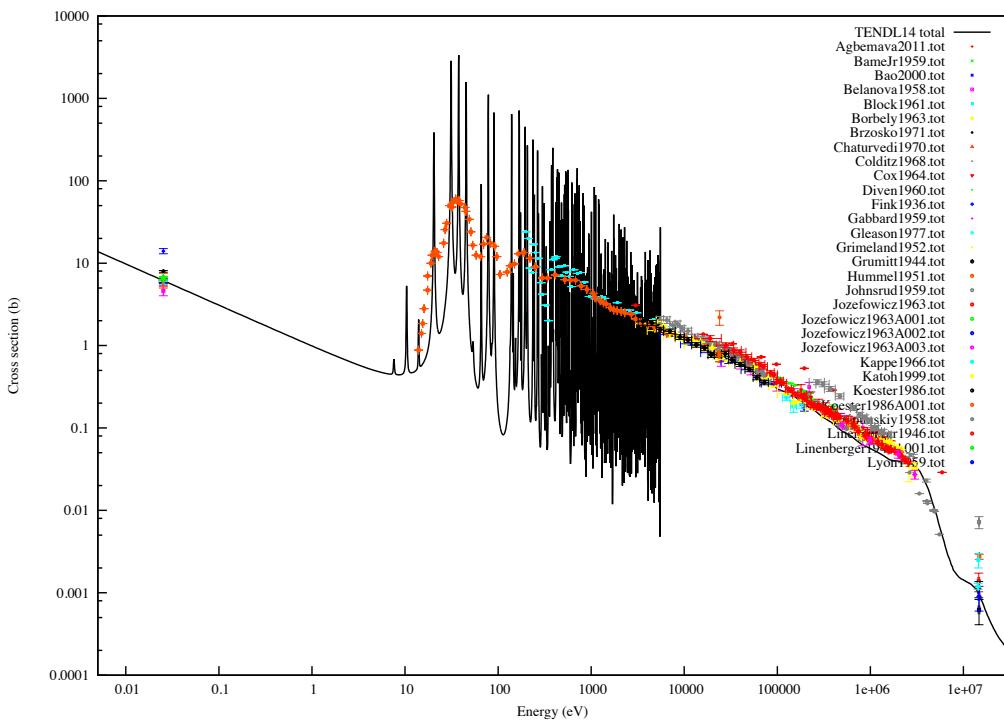
Sb121(n,2n)Sb120g



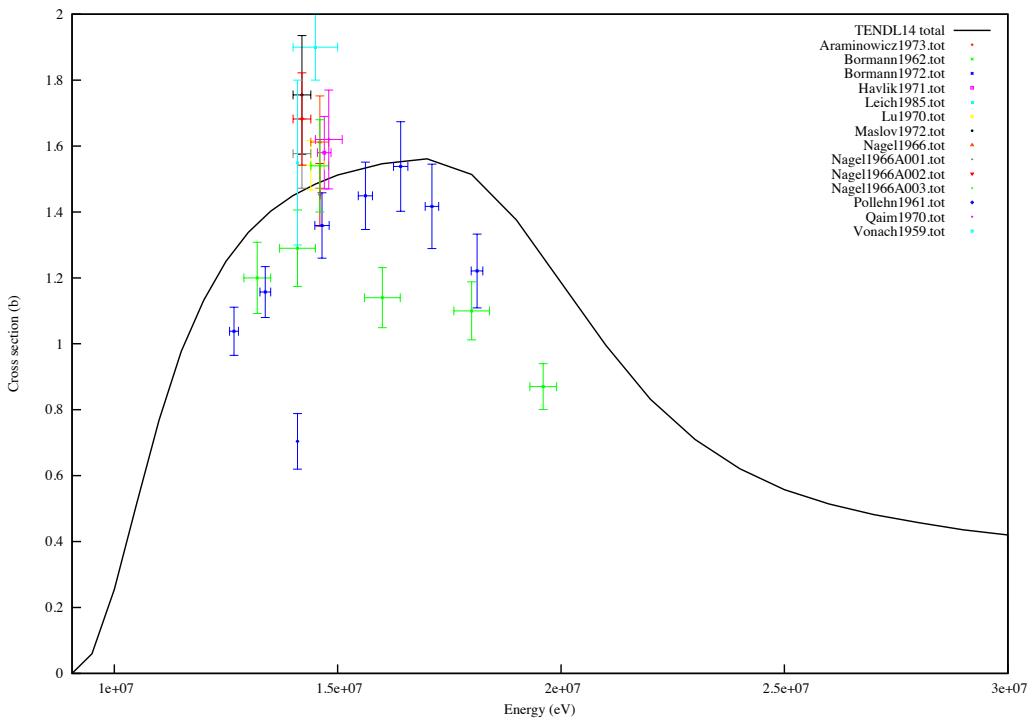
Te130(n,2n)Te129g



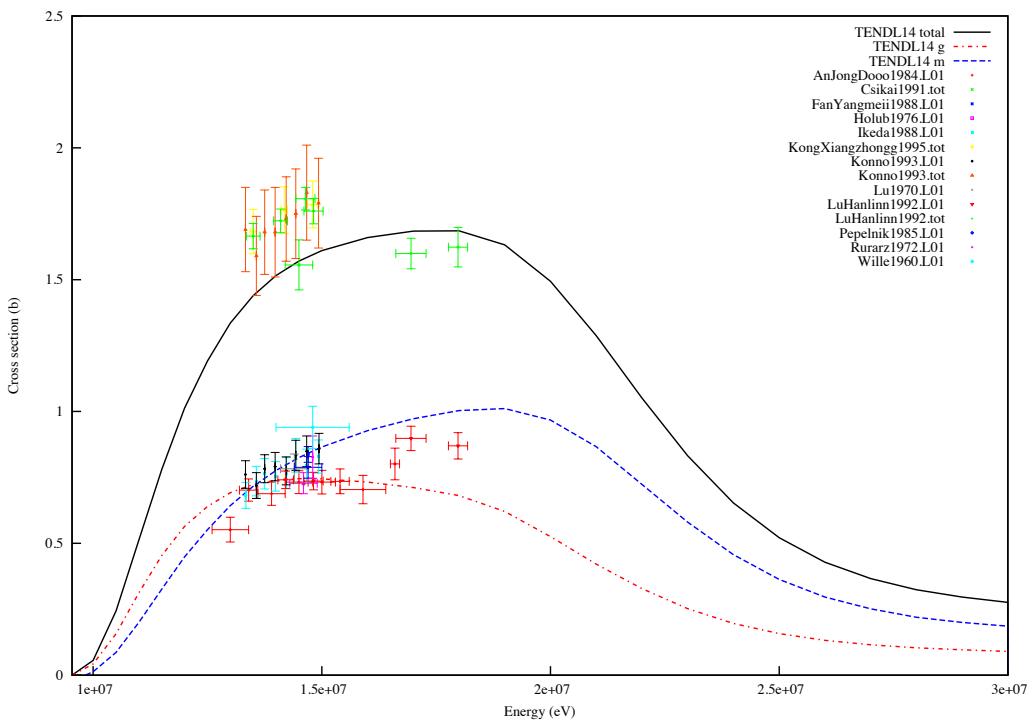
I₁₂₇(n, γ)I₁₂₈



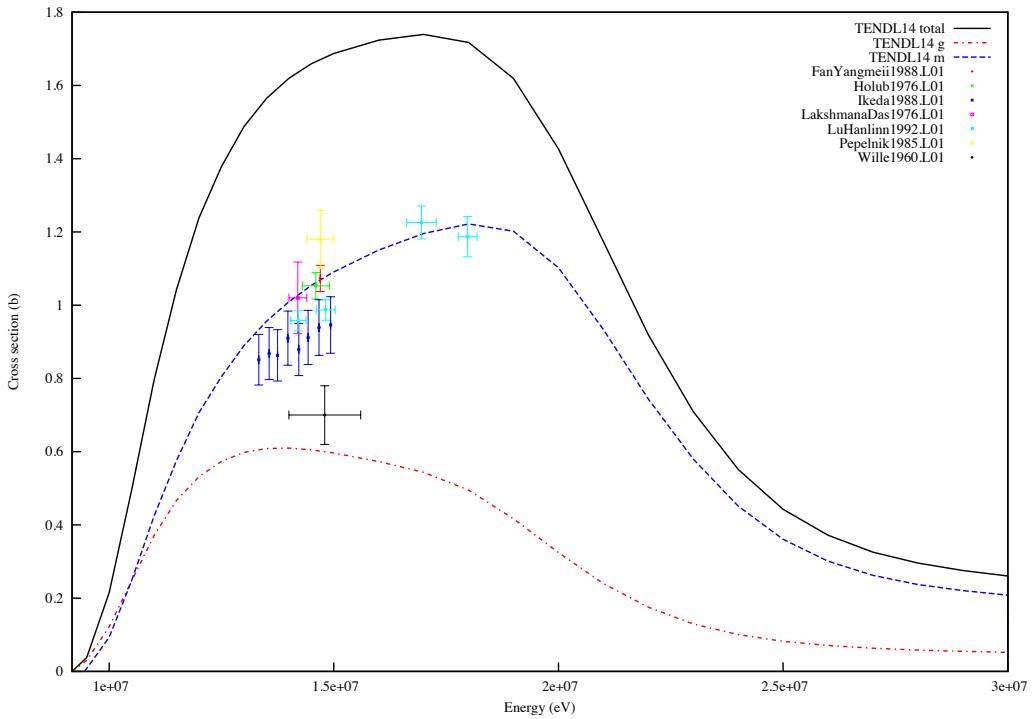
Cs133(n,2n)Cs132



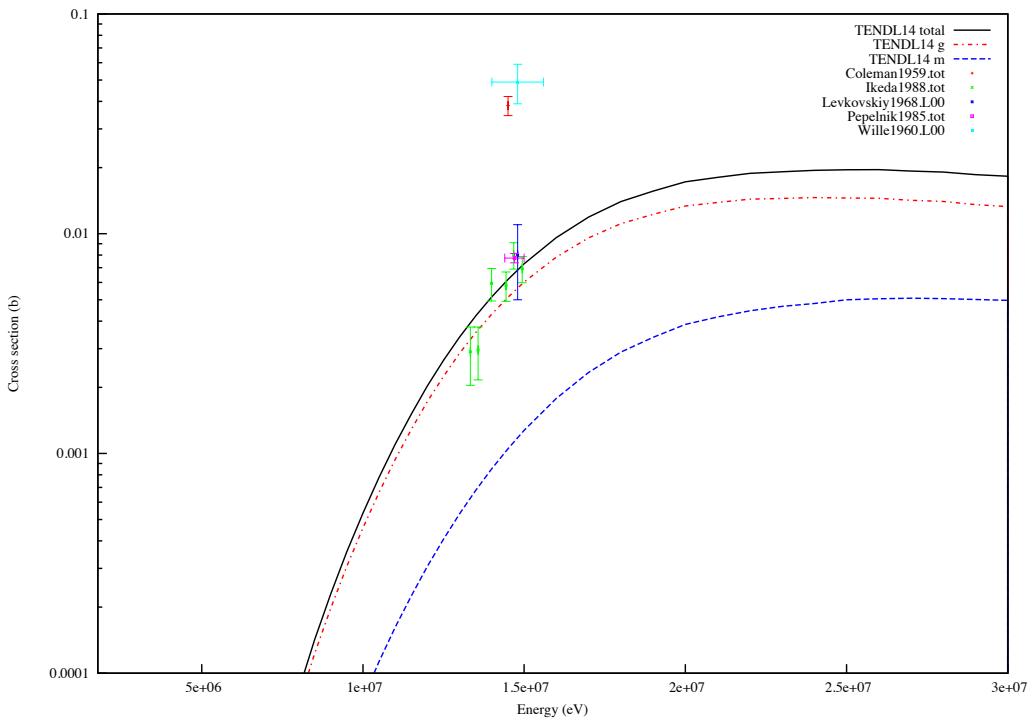
Ba134(n,2n)Ba133m



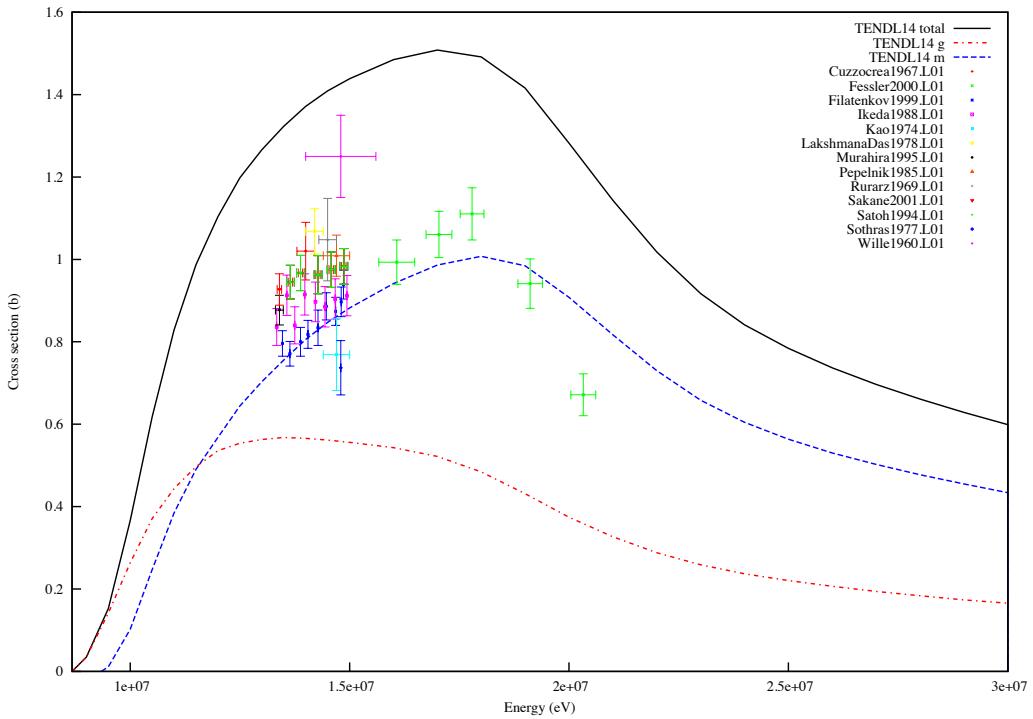
Ba136(n,2n)Ba135m



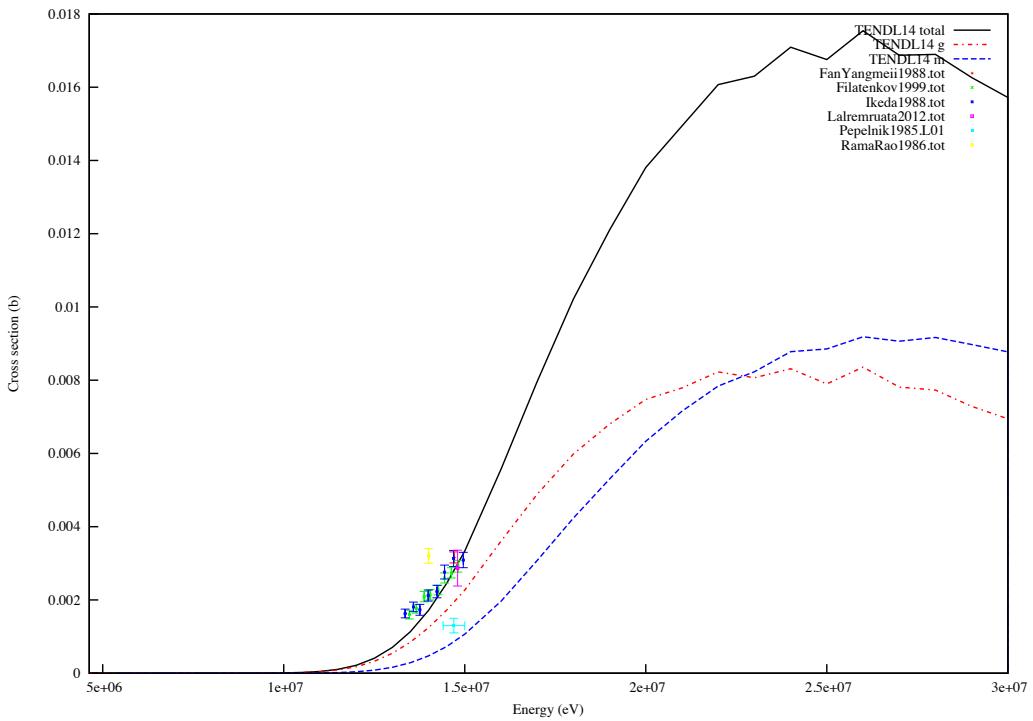
Ba136(n,p)Cs136



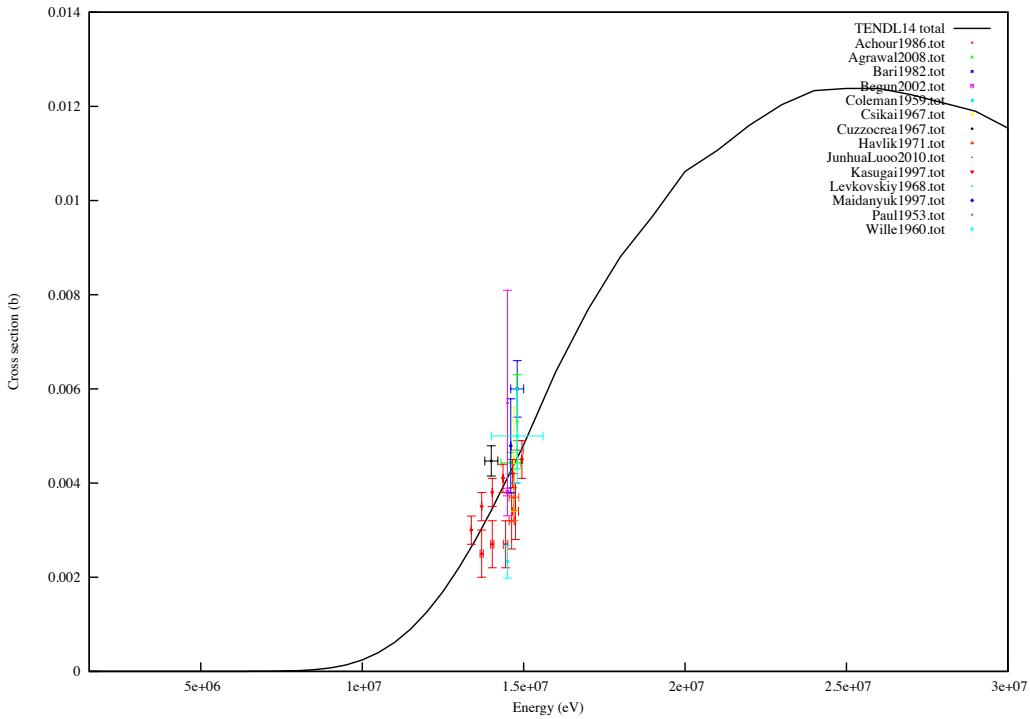
Ba138(n,2n)Ba137m



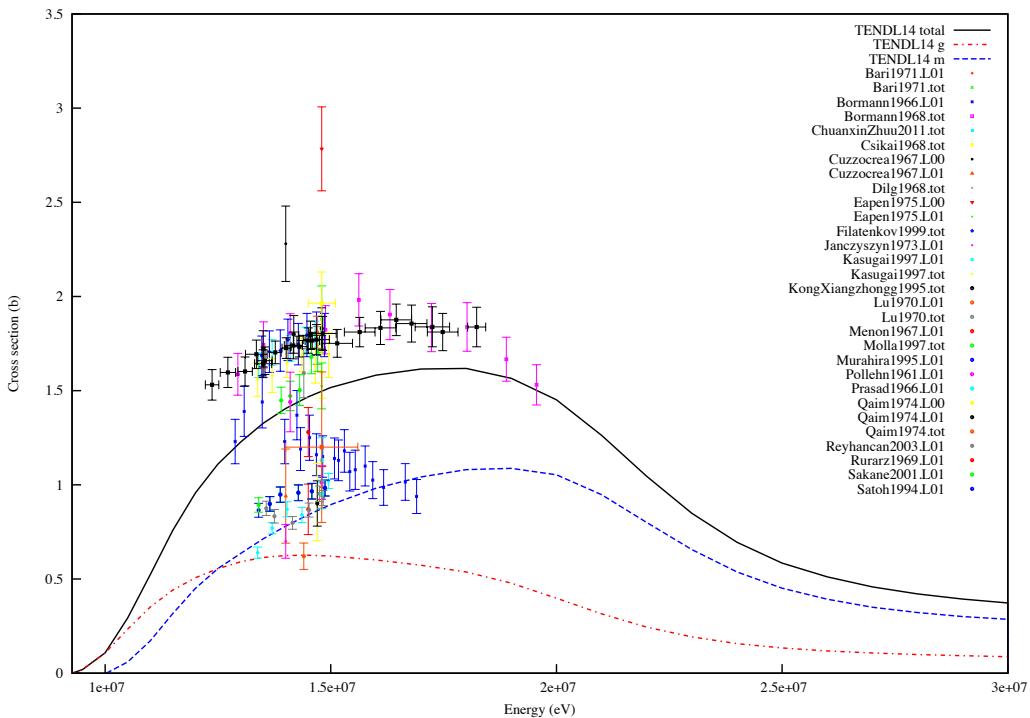
Ba138(n,p)Cs138



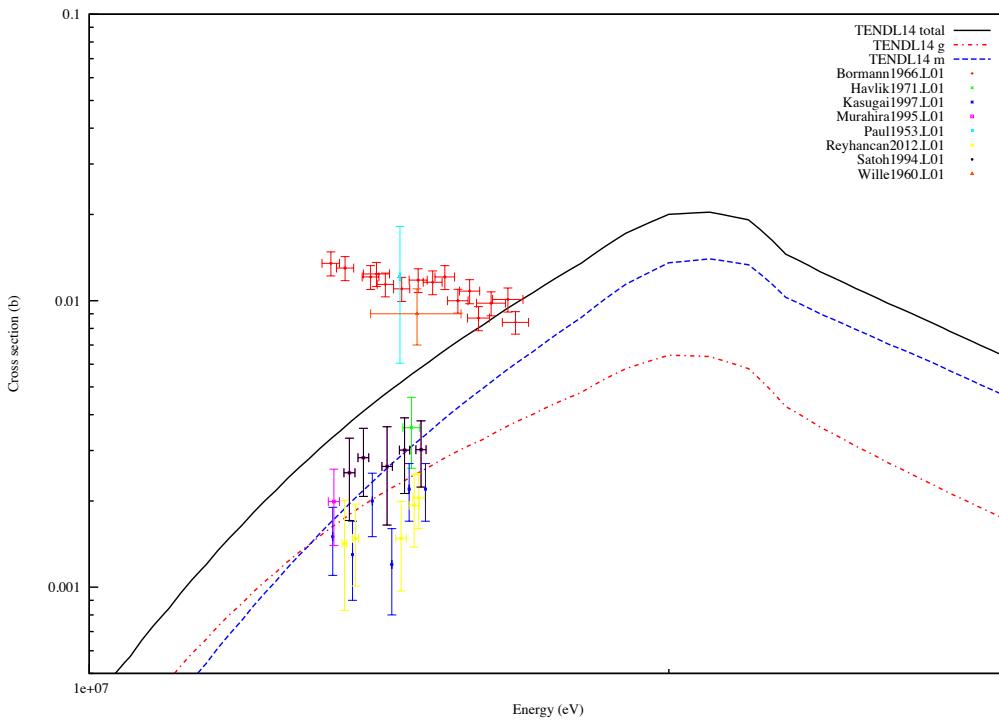
La139(n,p)Ba139



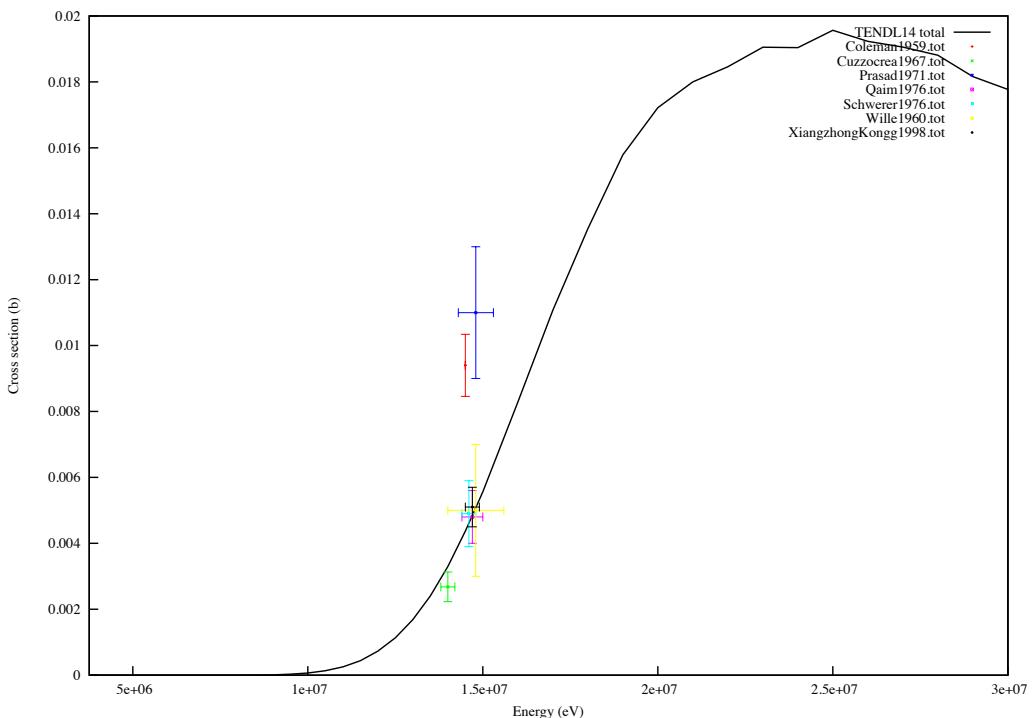
Ce140(n,2n)Ce139m



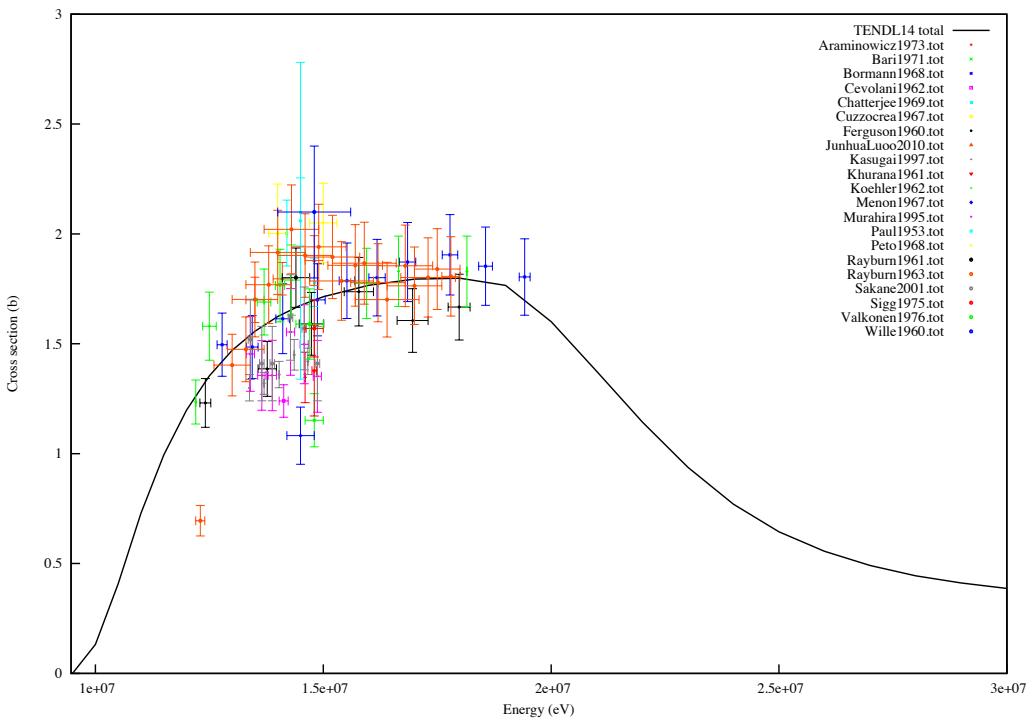
$\text{Ce140}(\text{n},\alpha)\text{Ba137m}$



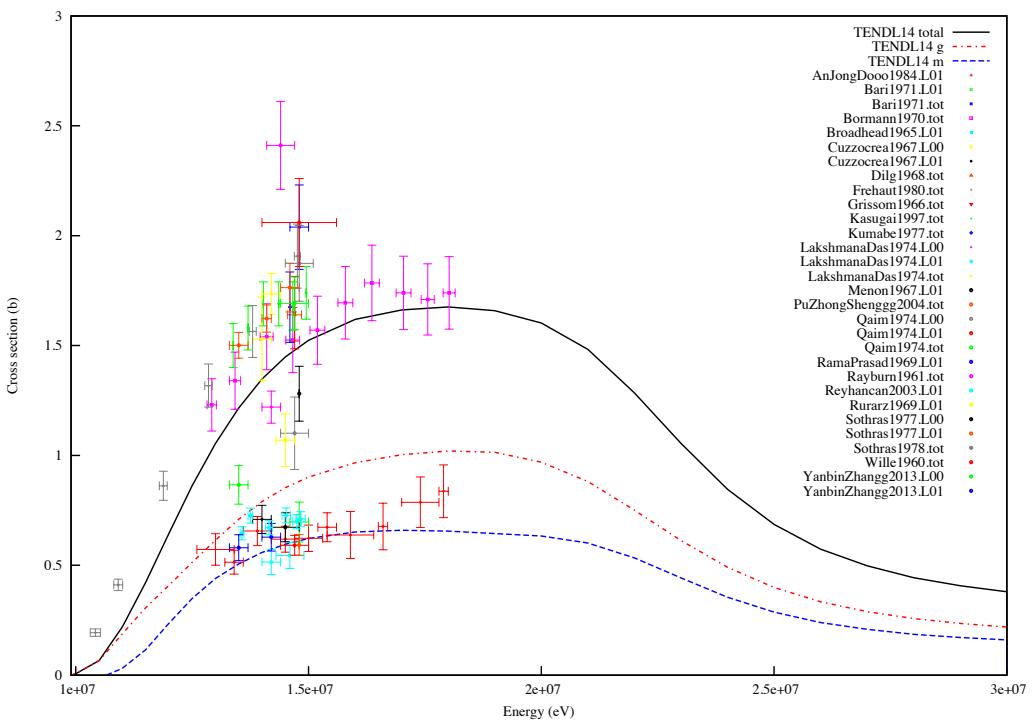
$\text{Ce142}(\text{n},\text{p})\text{La142}$

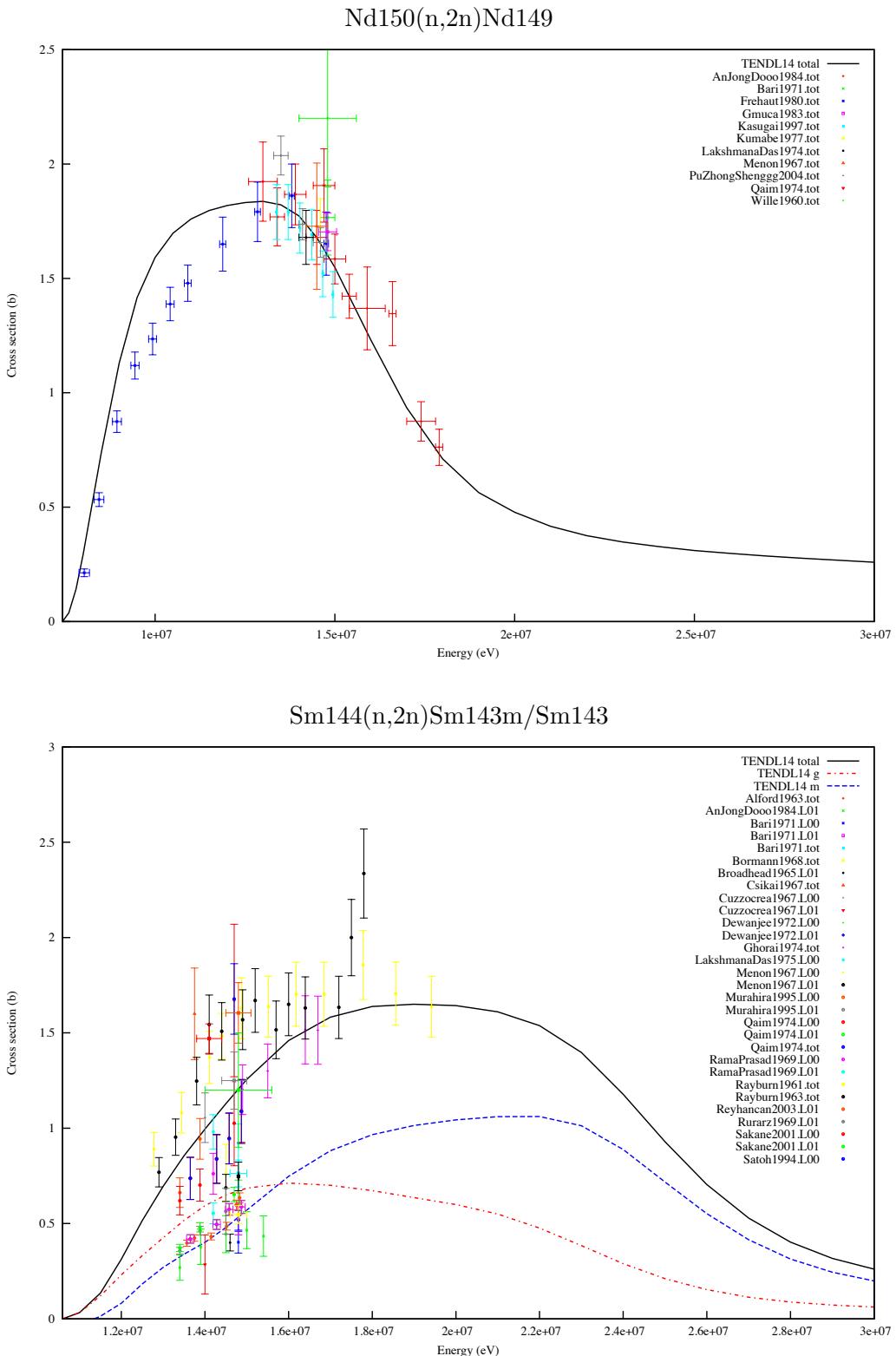


Pr141(n,2n)Pr140

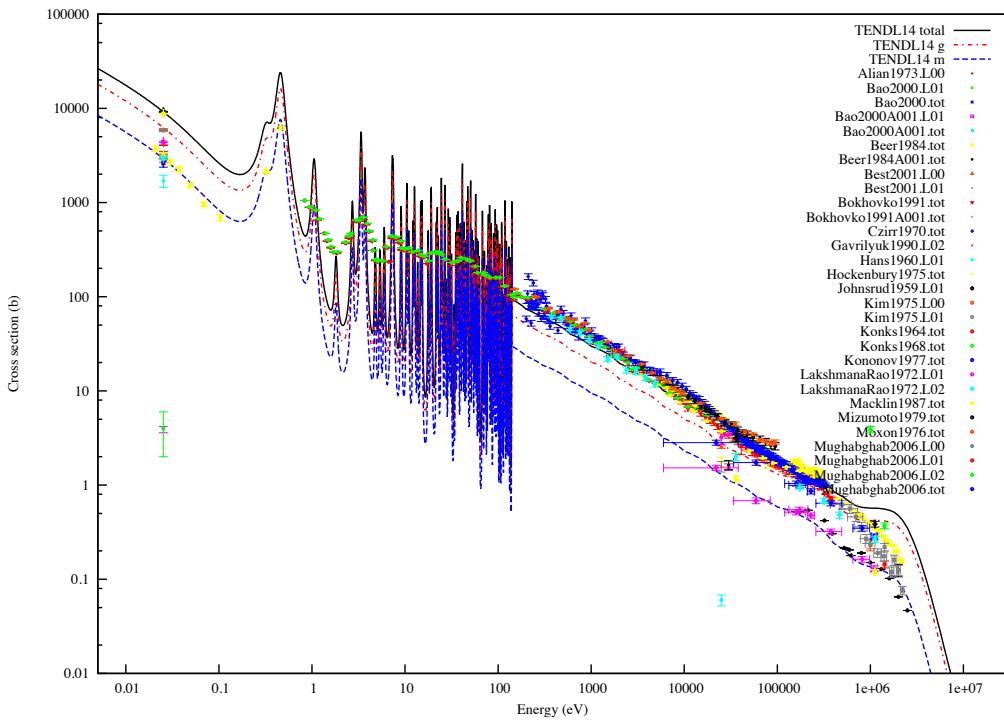


Nd142(n,2n)Nd141m

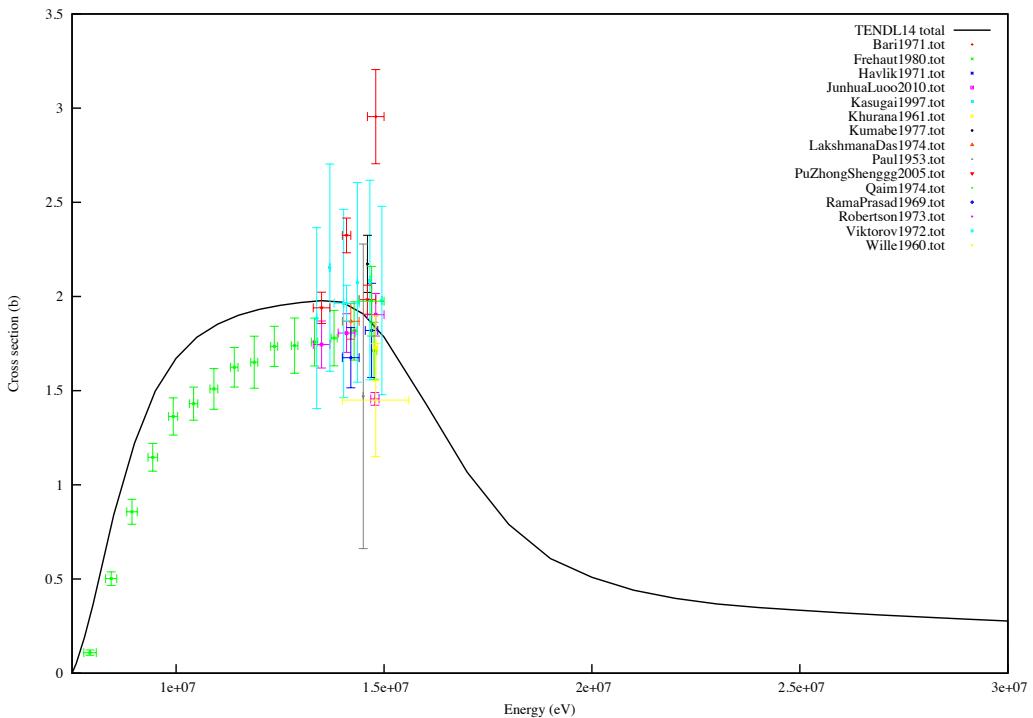




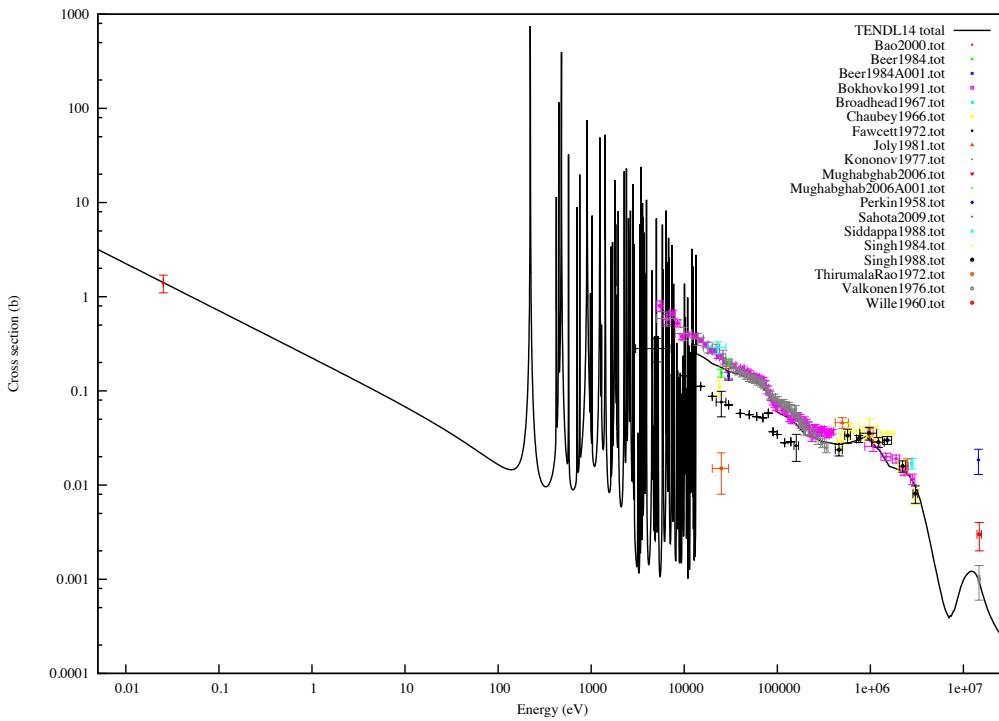
Eu151(n,γ)Eu152m



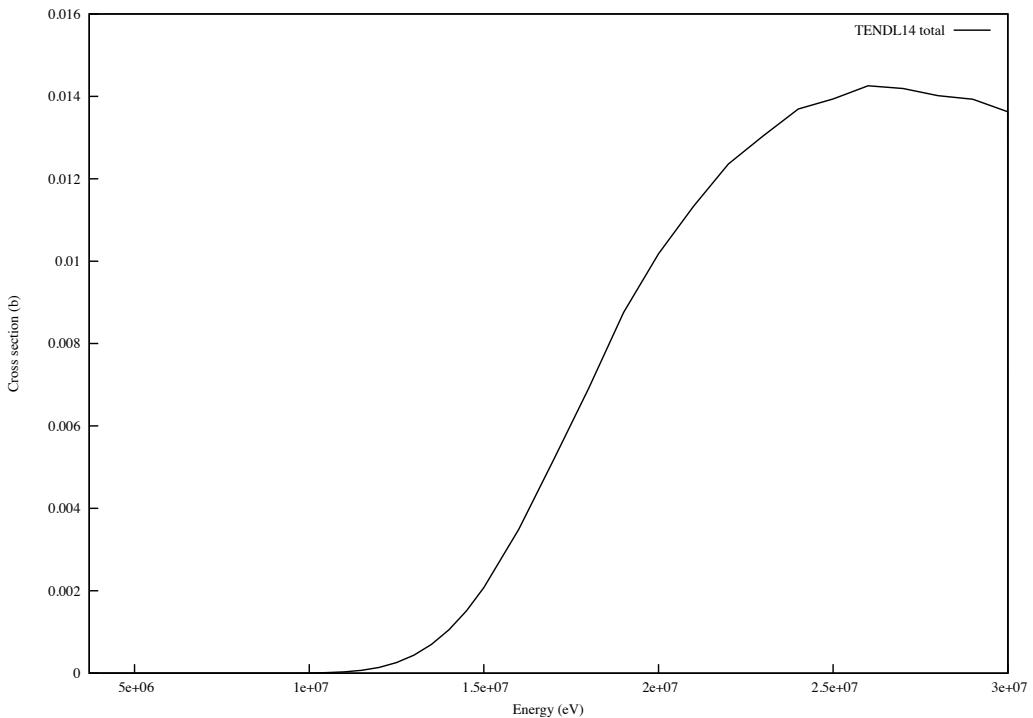
Gd160($n,2n$)Gd159



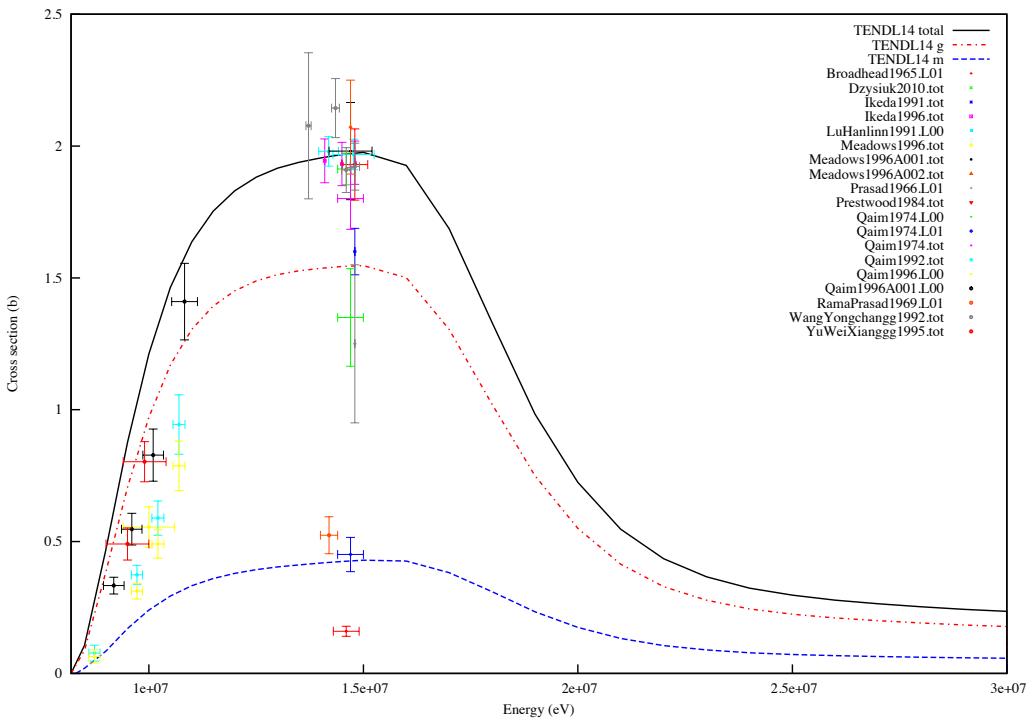
Gd160(n,γ)Gd161



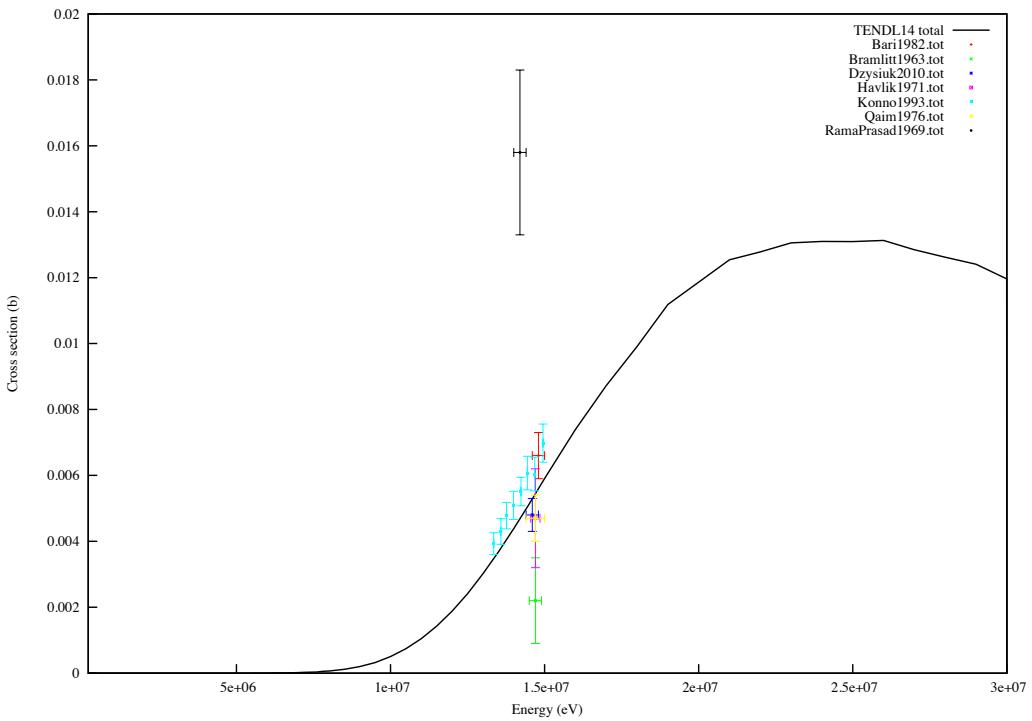
Gd160(n,p)Eu160



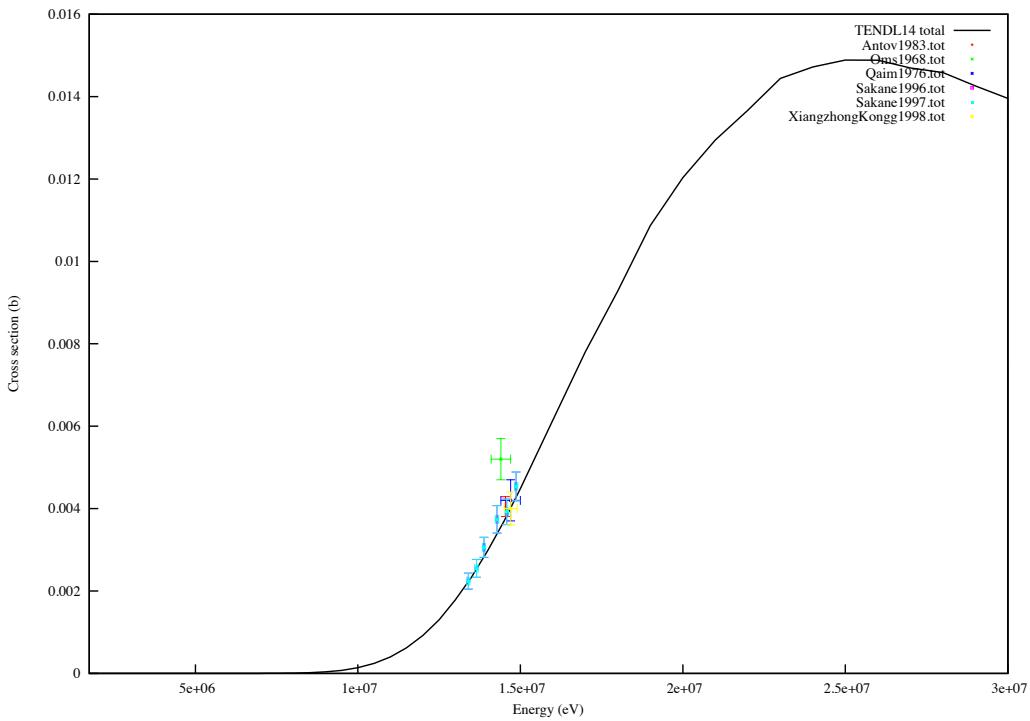
Tb159(n,2n)Tb158m



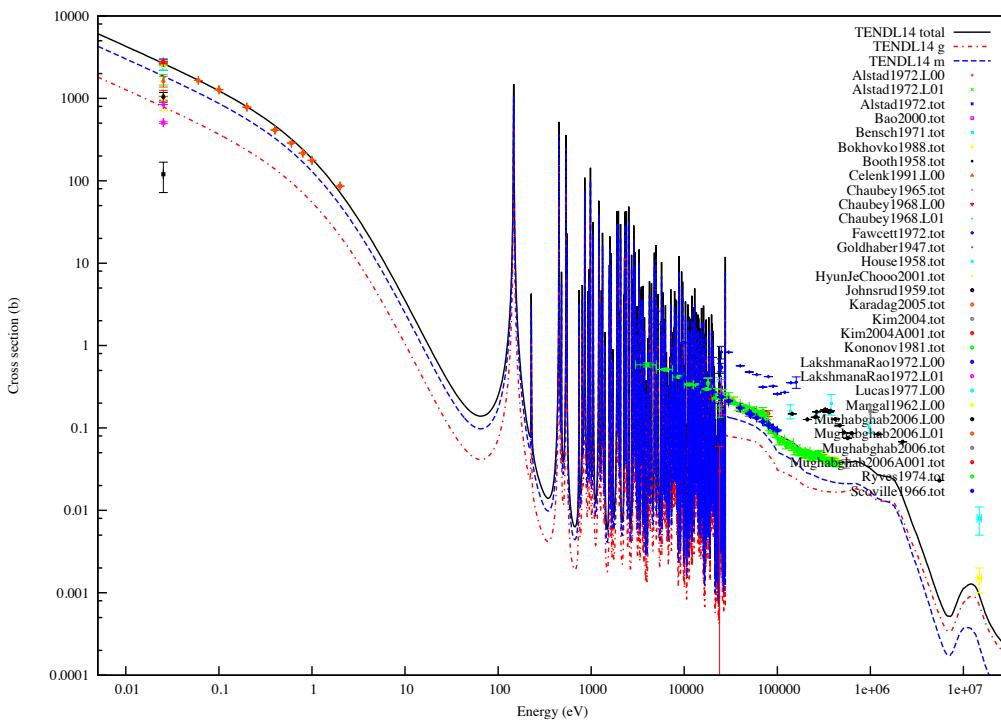
Tb159(n,p)Gd159



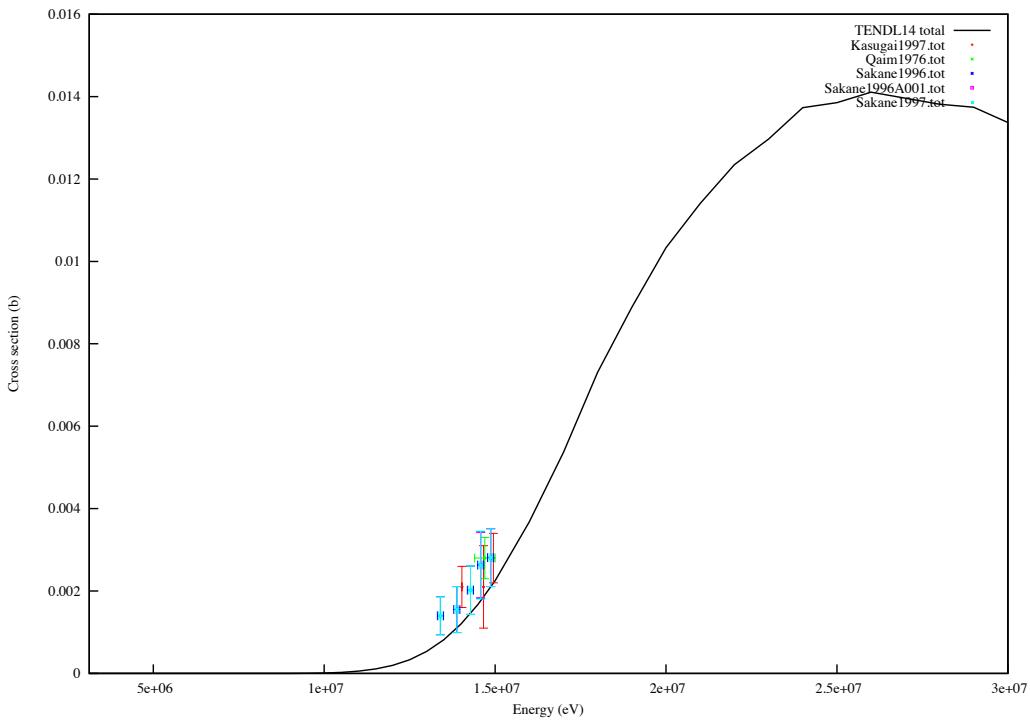
Dy162(n,p)Tb162



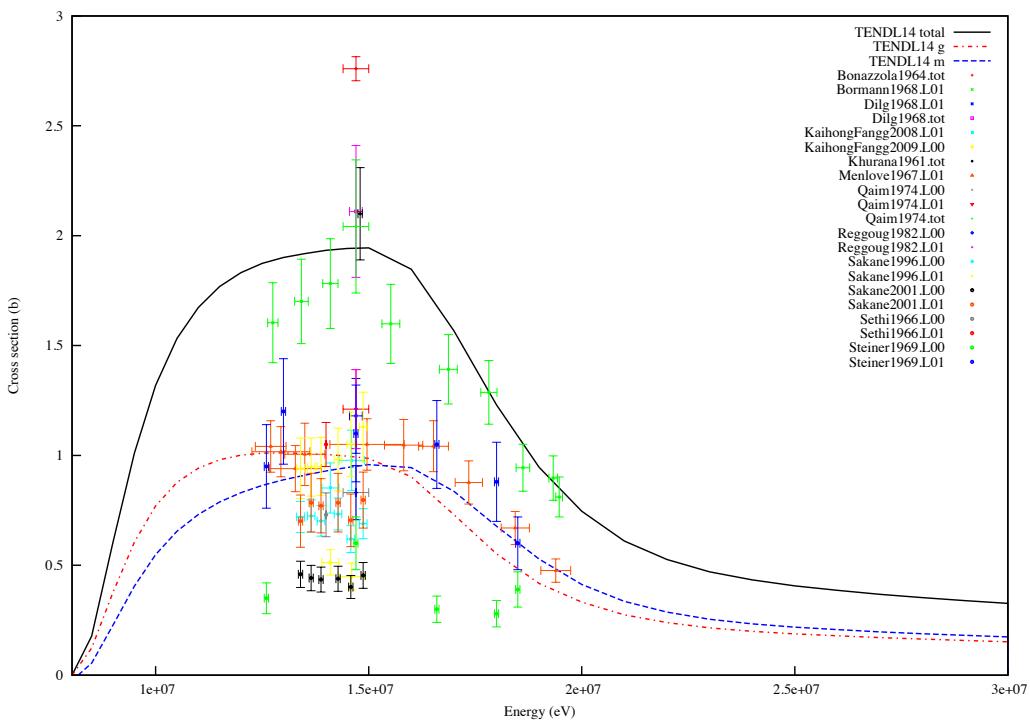
Dy164(n, γ)Dy165m/Dy165

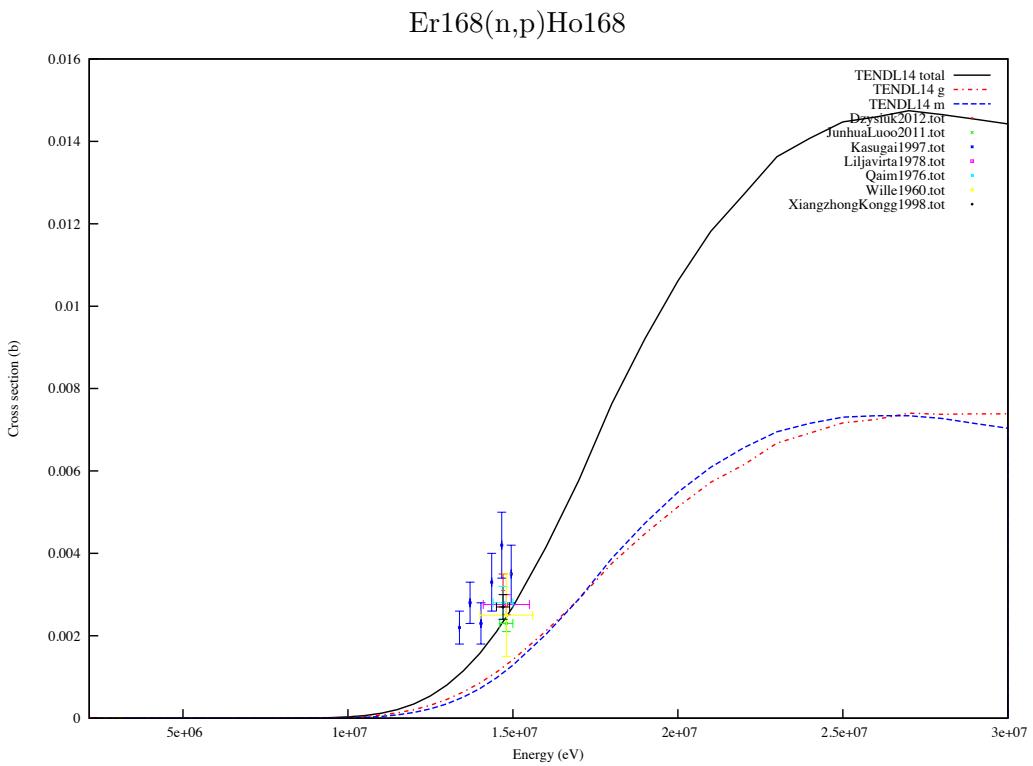
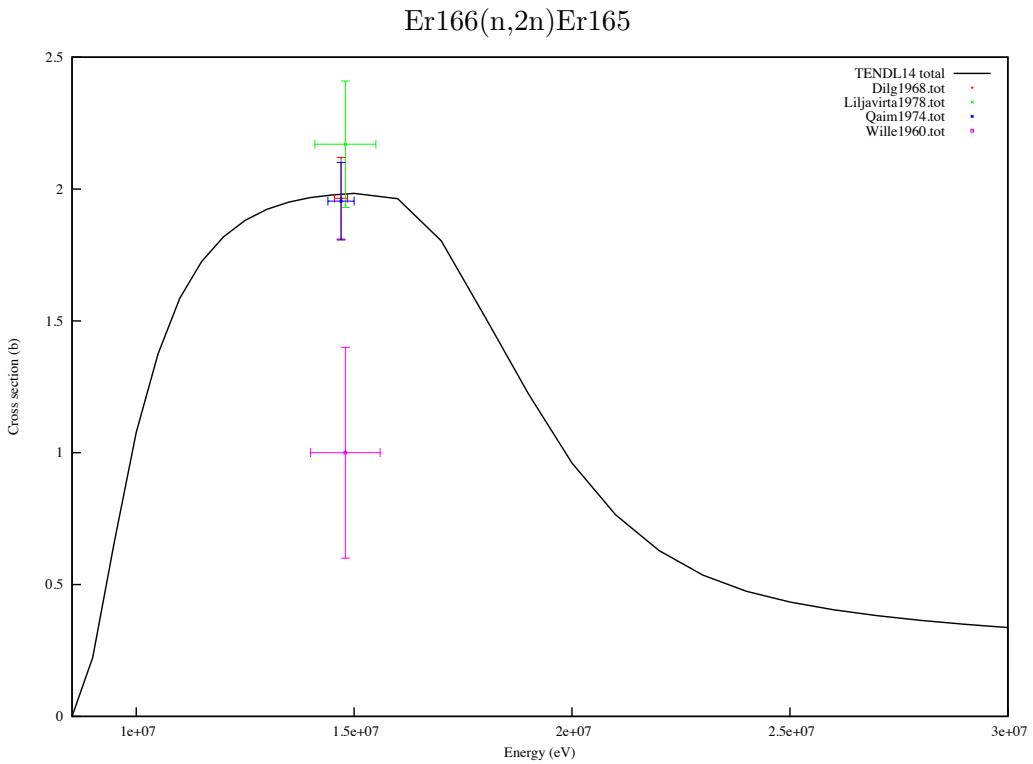


Dy164(n,p)Tb164

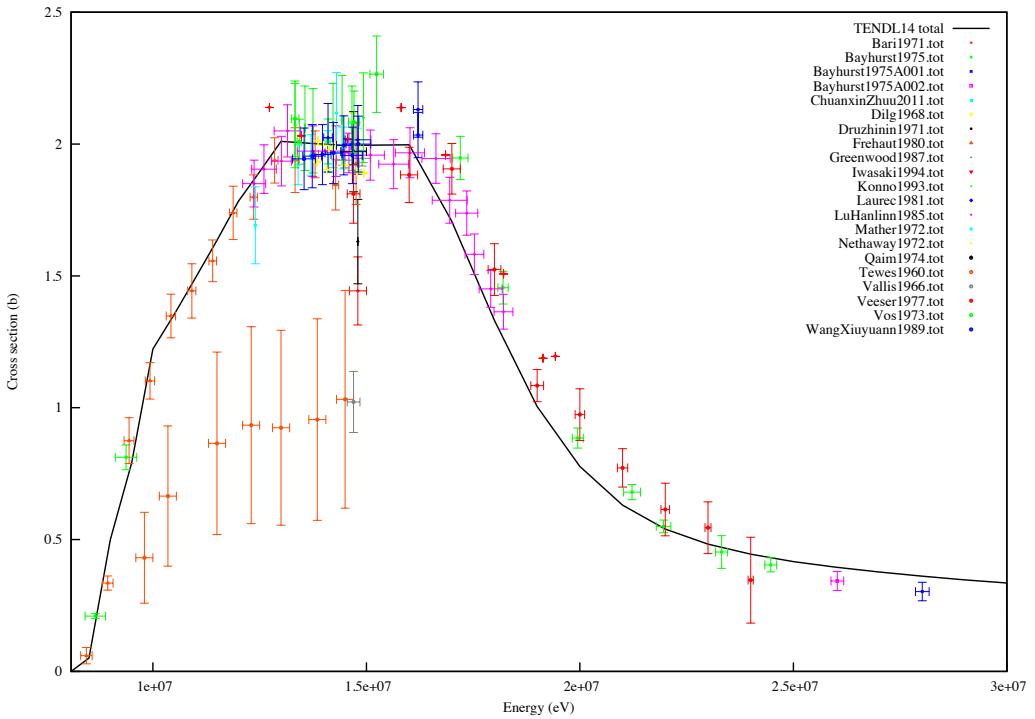


Ho165(n,2n)Ho164m/Ho164

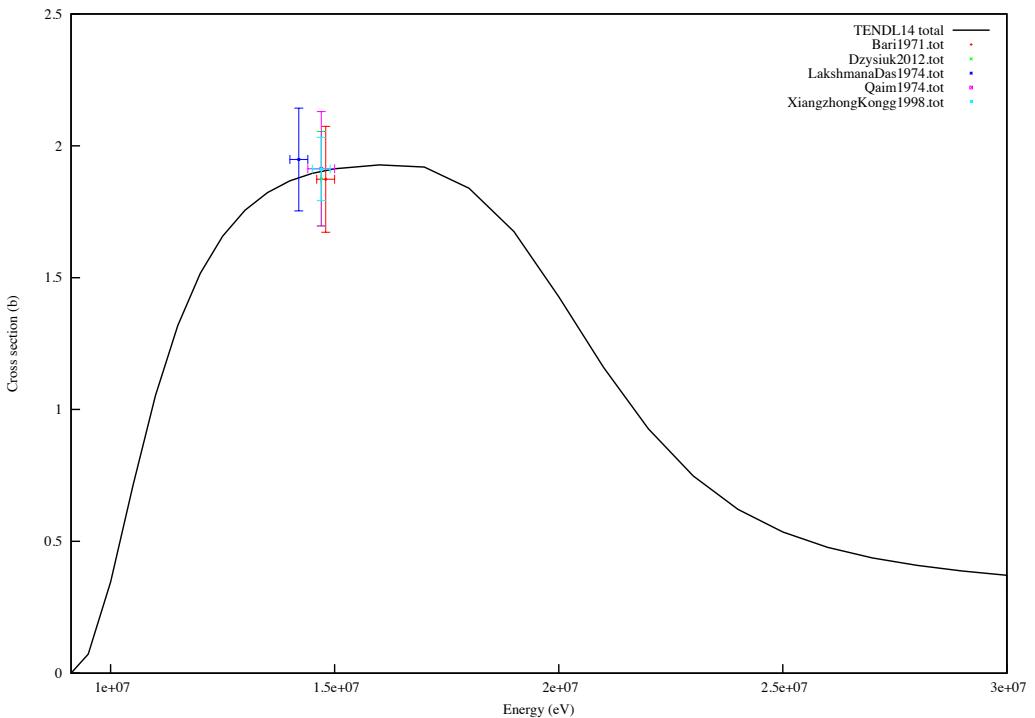




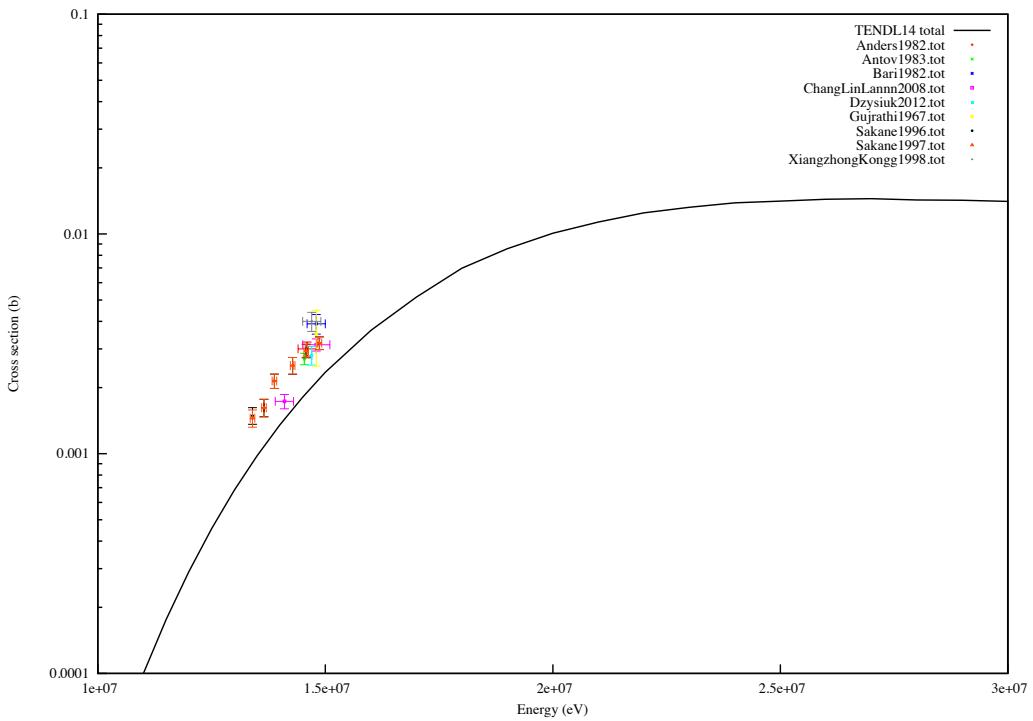
Tm169(n,2n)Tm168



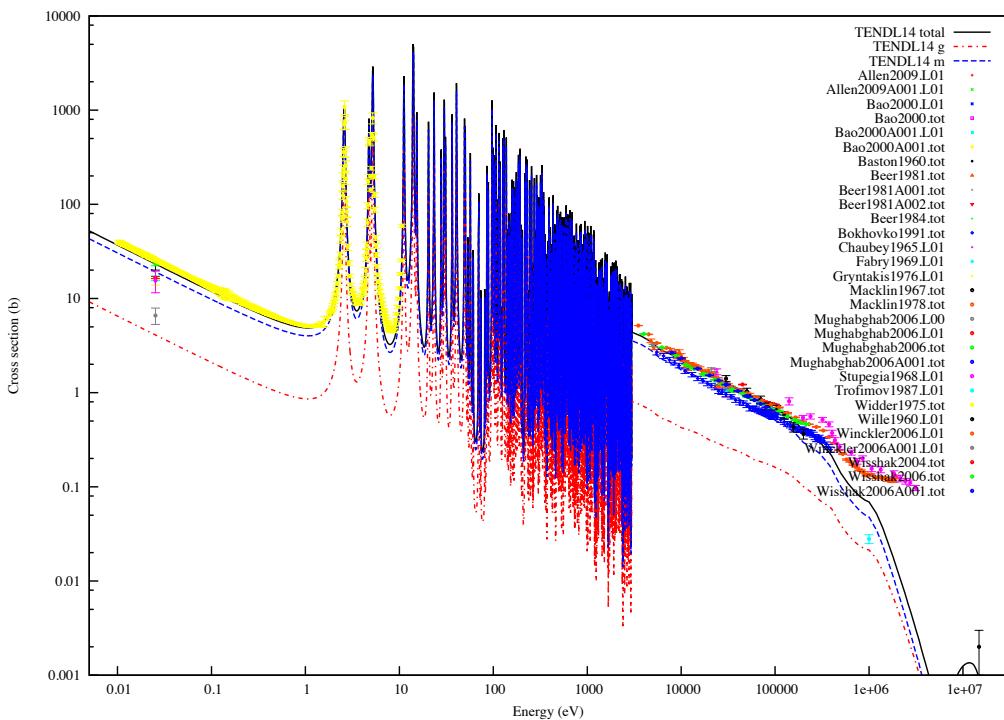
Yb168(n,2n)Yb167



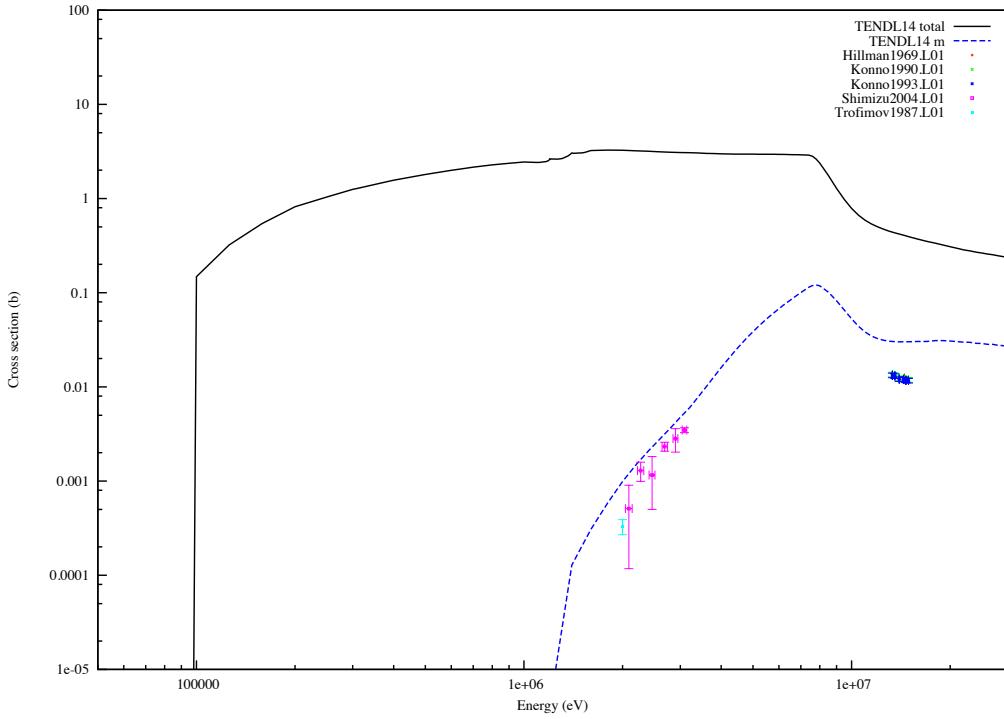
Yb174(n,p)Tm174



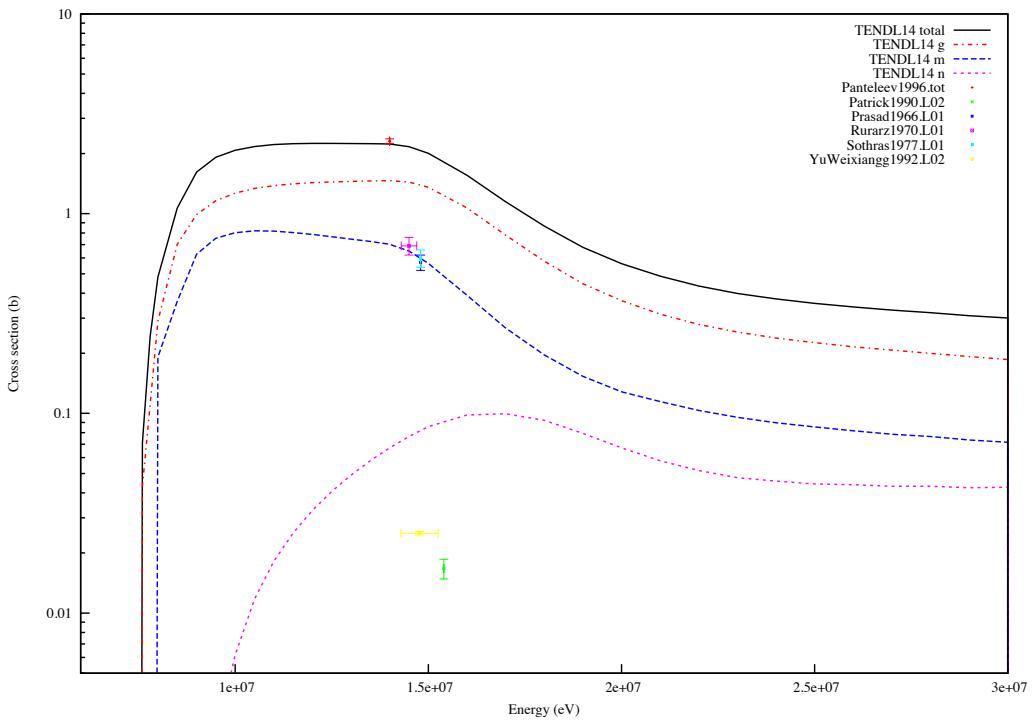
Lu175(n, γ)Lu176m



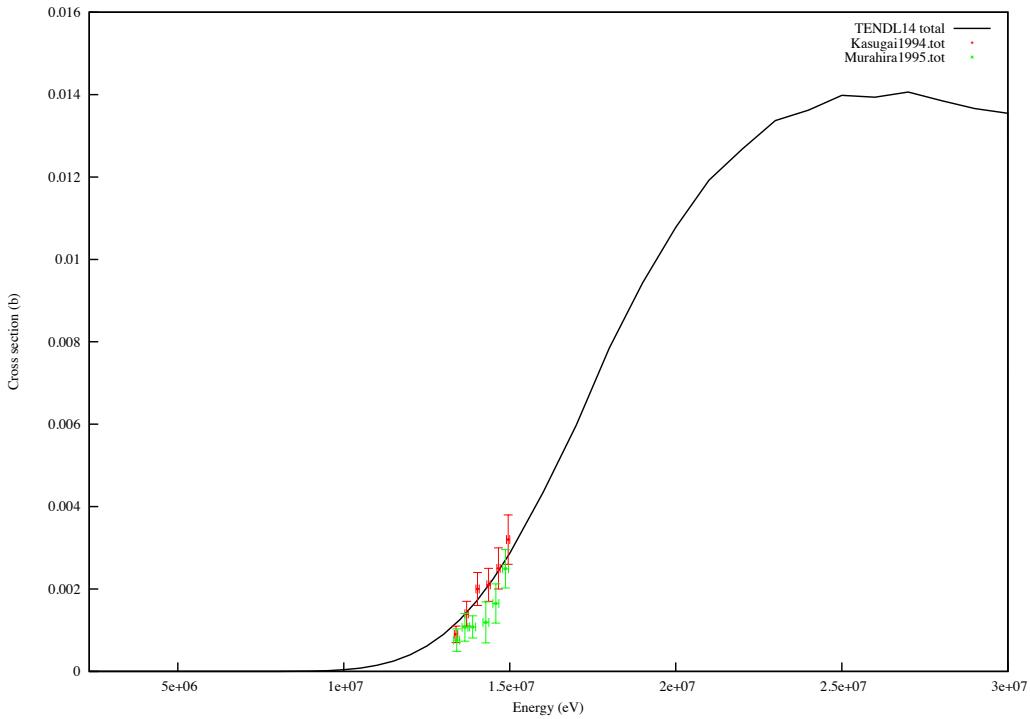
Hf180(n,n')Hf180m



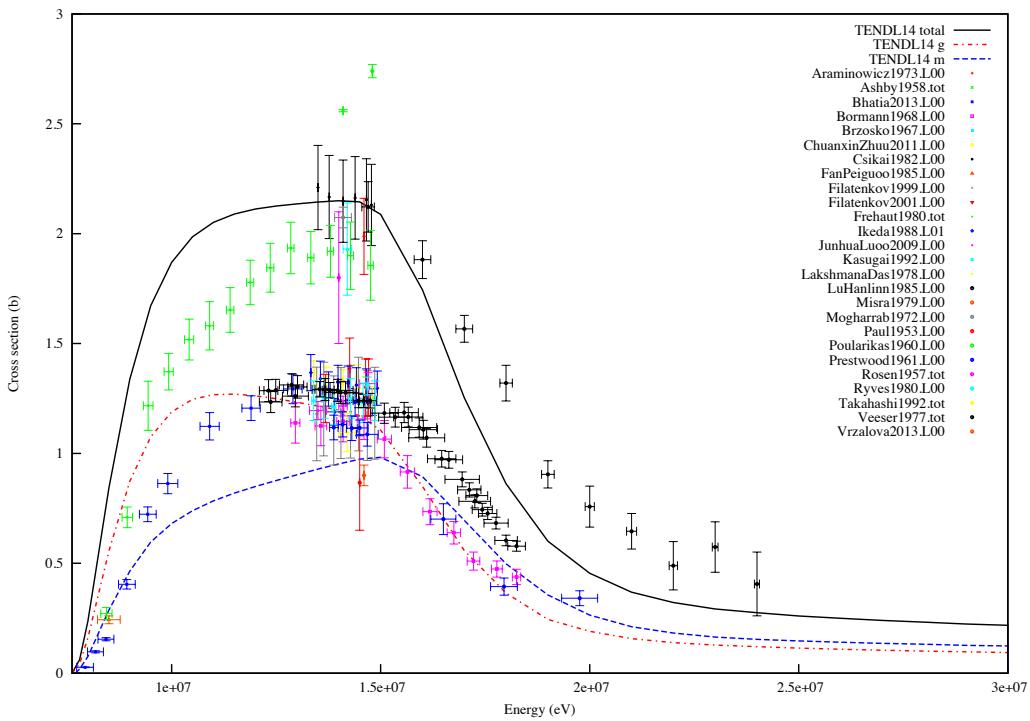
Hf180(n,2n)Hf179m



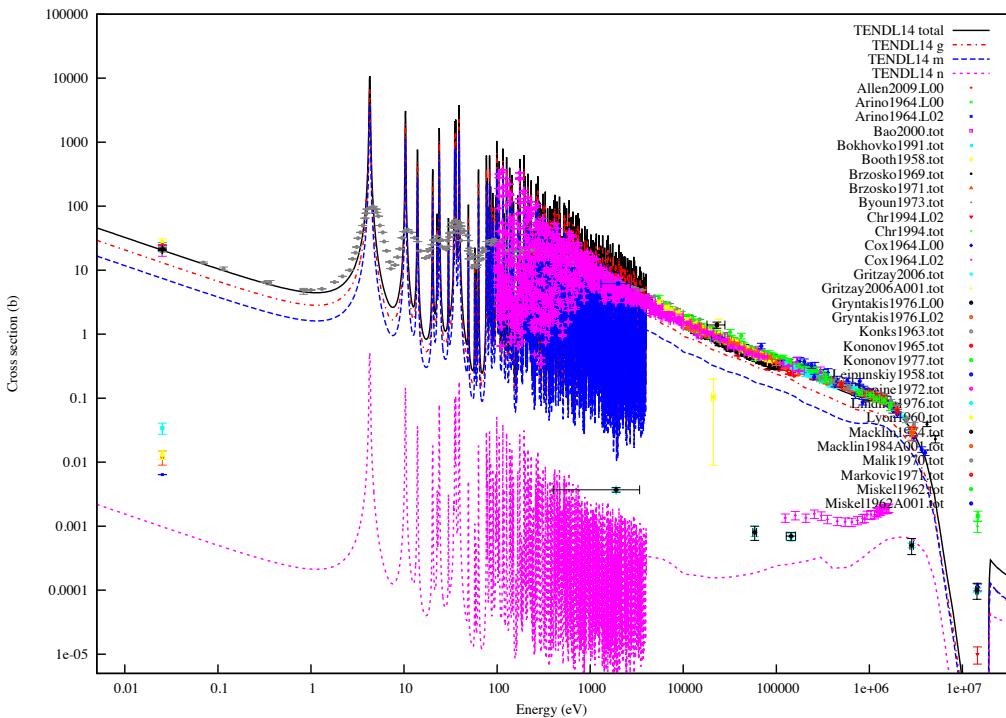
Hf180(n,p)Lu180



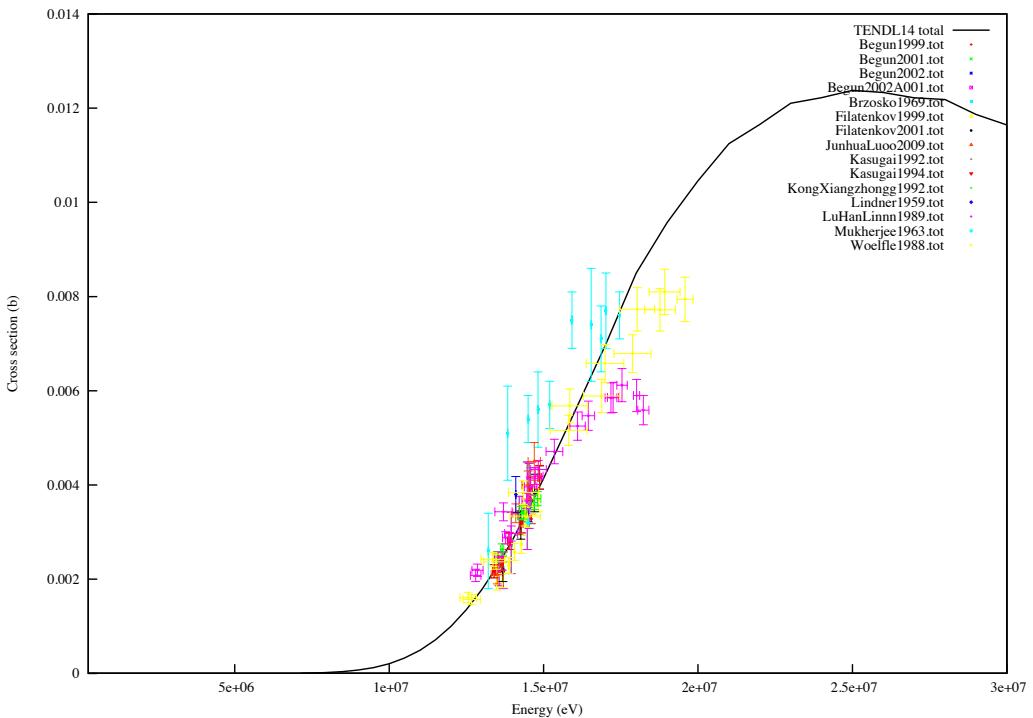
Ta181(n,2n)Ta180g



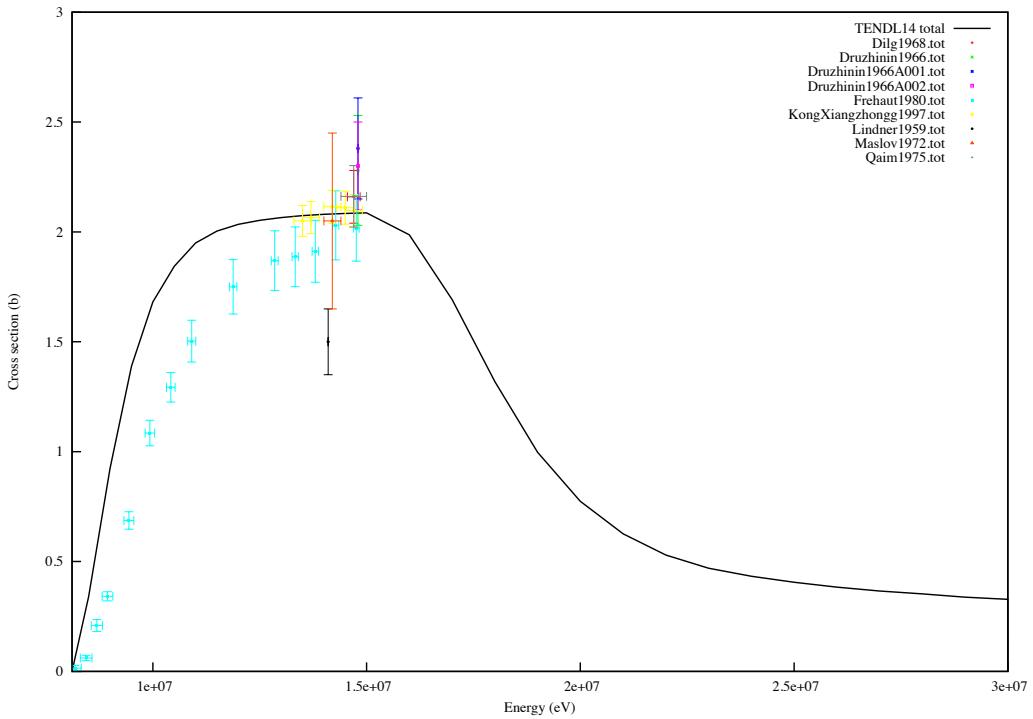
Ta181(n, γ)Ta182



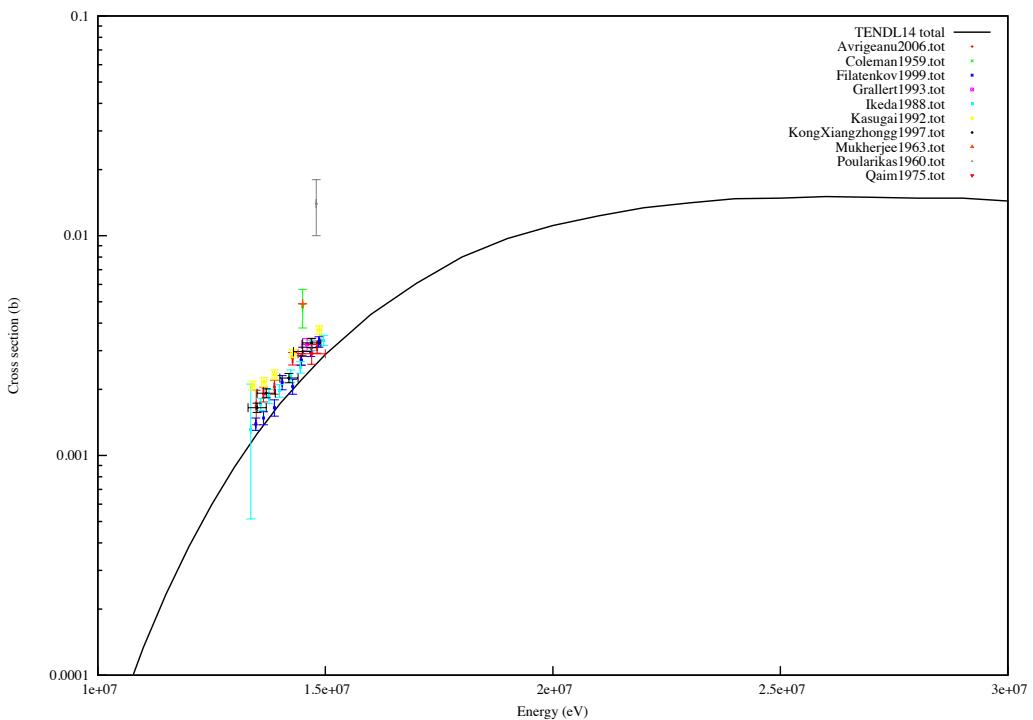
Ta181(n,p)Hf181



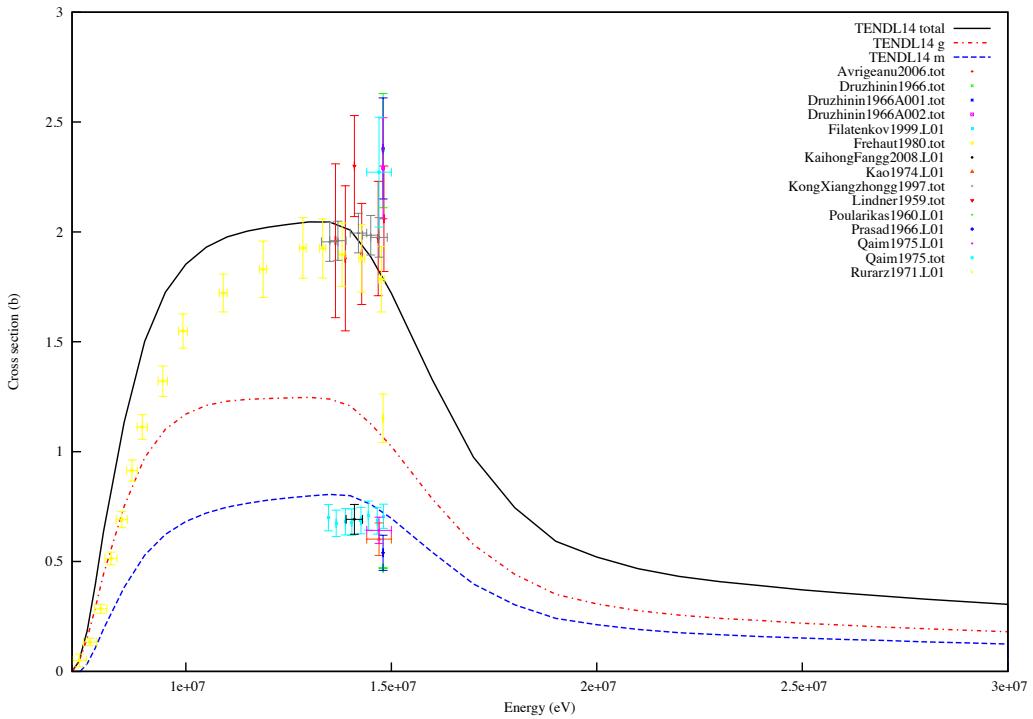
W182(n,2n)W181



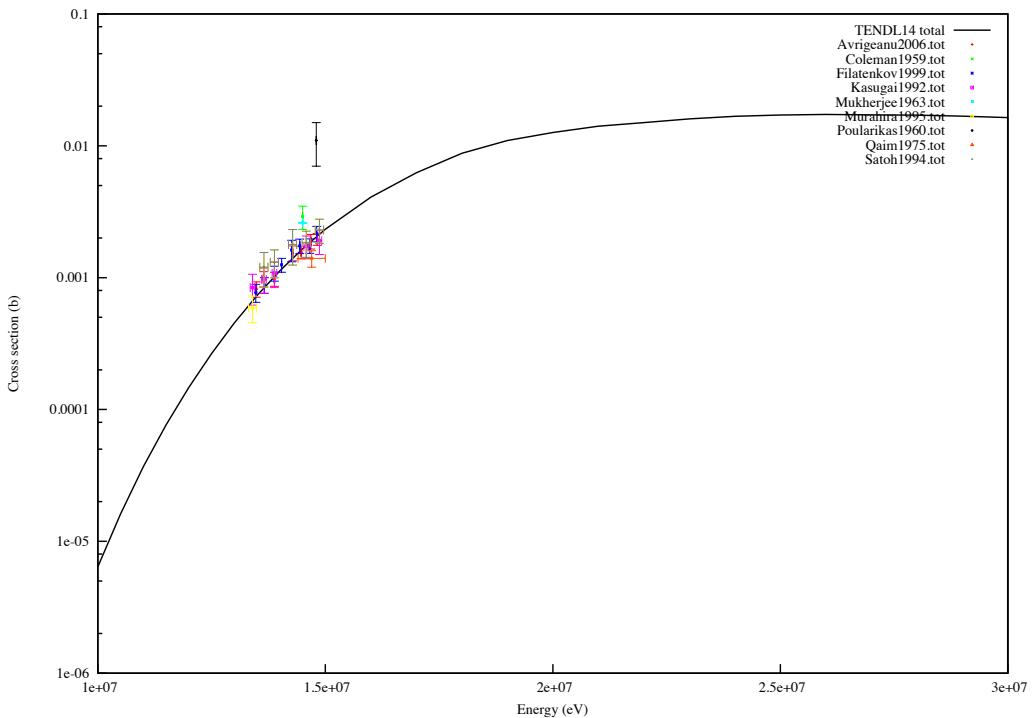
W184(n,p)Ta184



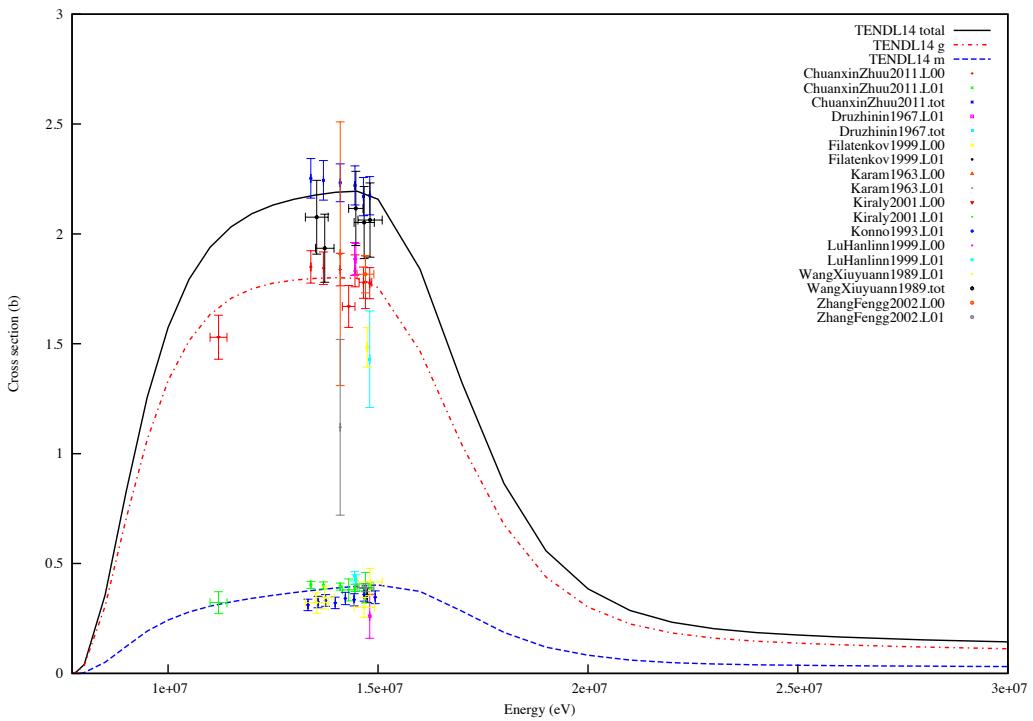
W186(n,2n)W185m/W185



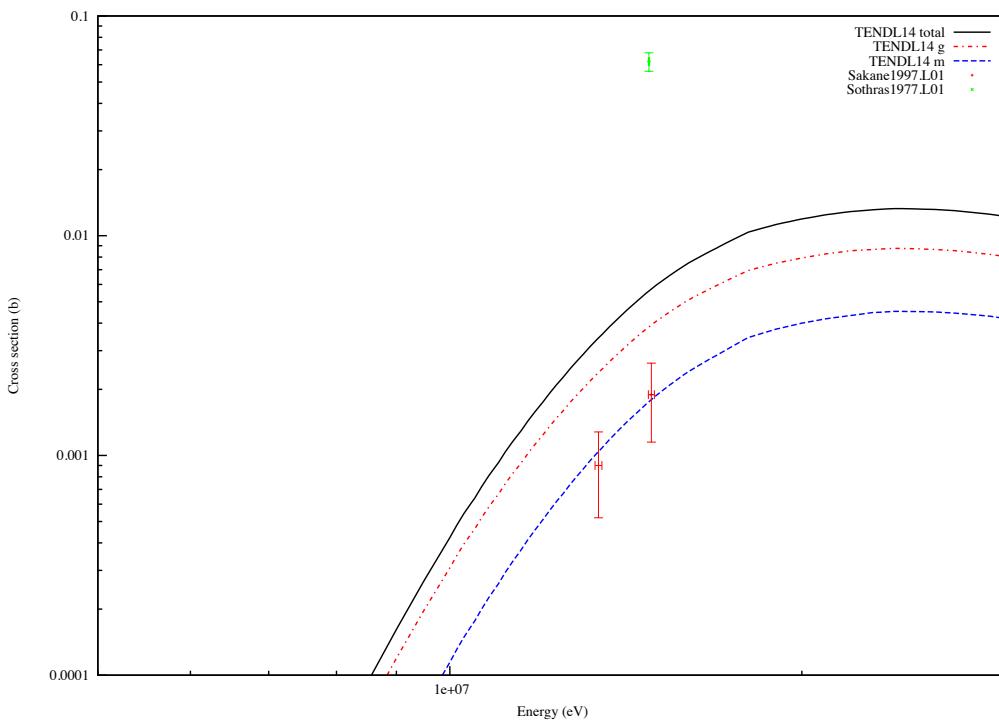
W186(n,p)Ta186



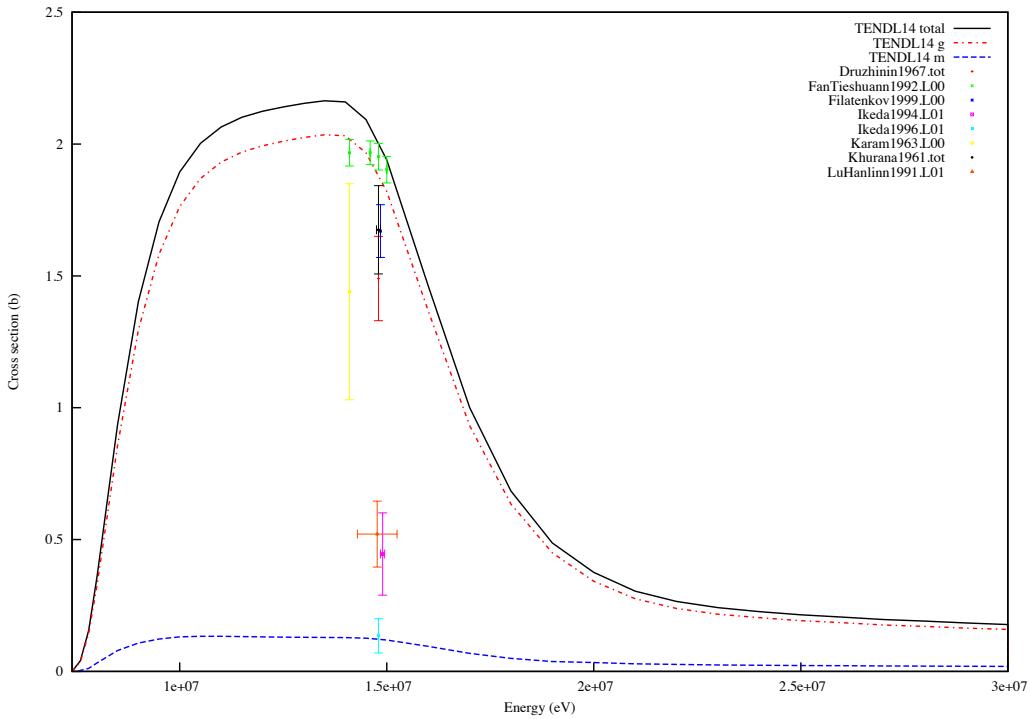
Re185(n,2n)Re184g/Re184m



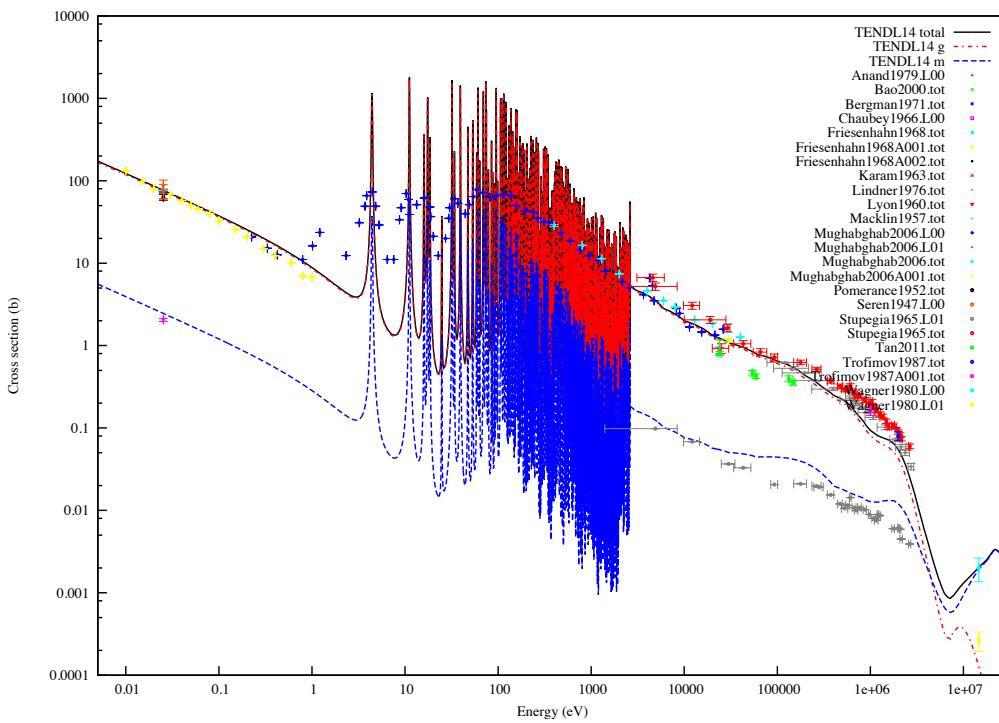
Re185(n,p)W185m



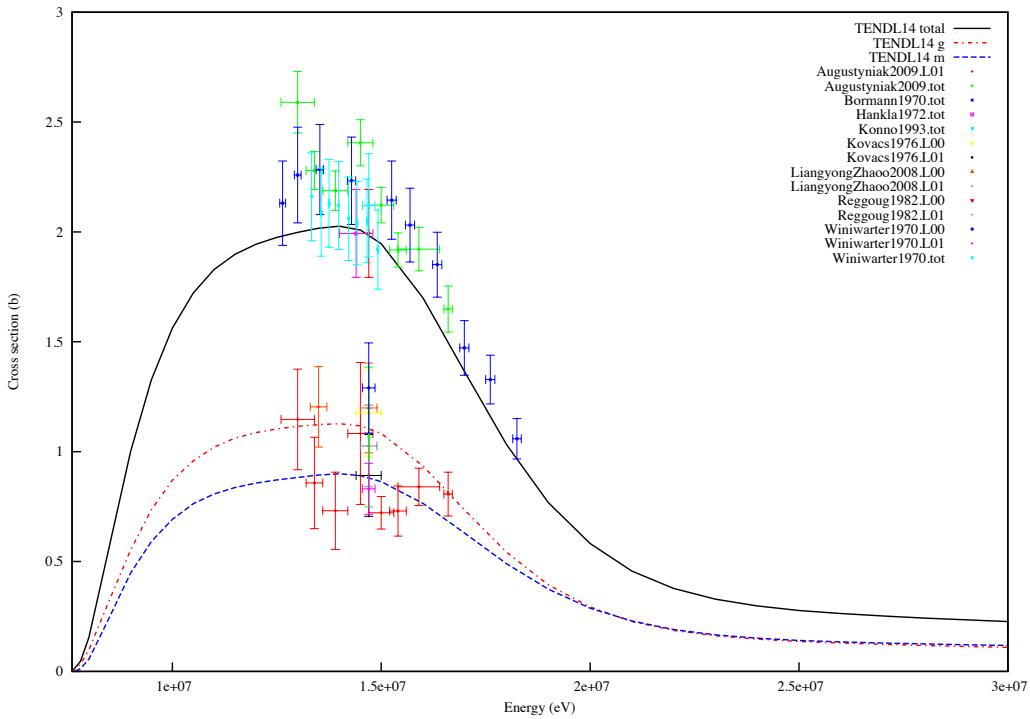
Re187(n,2n)Re186g



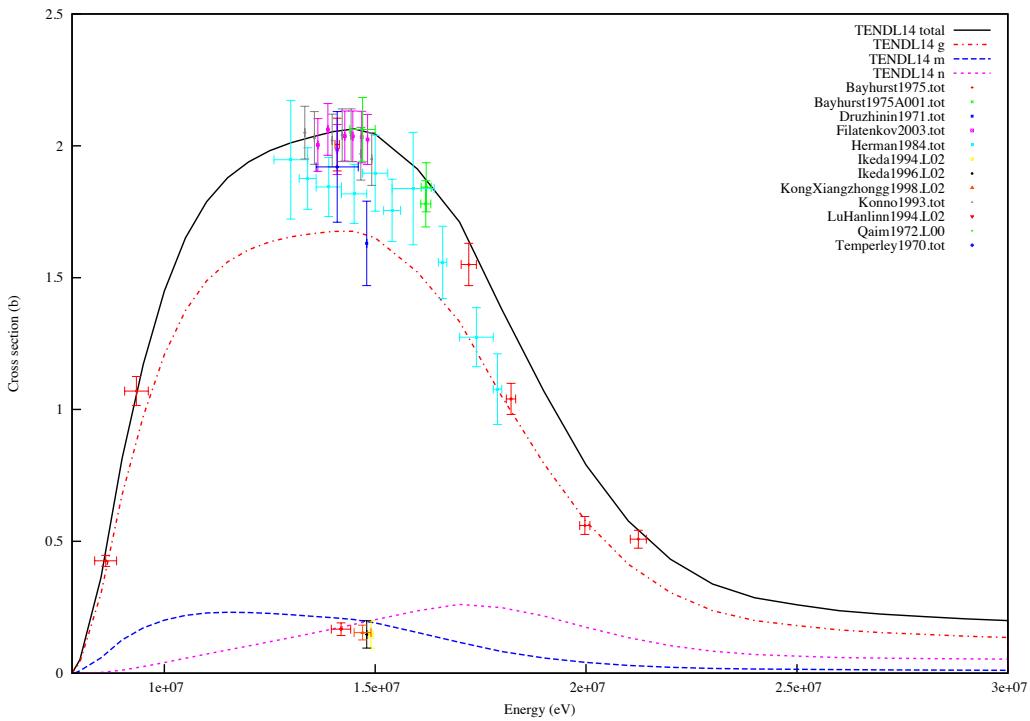
Re187(n, γ)Re188m

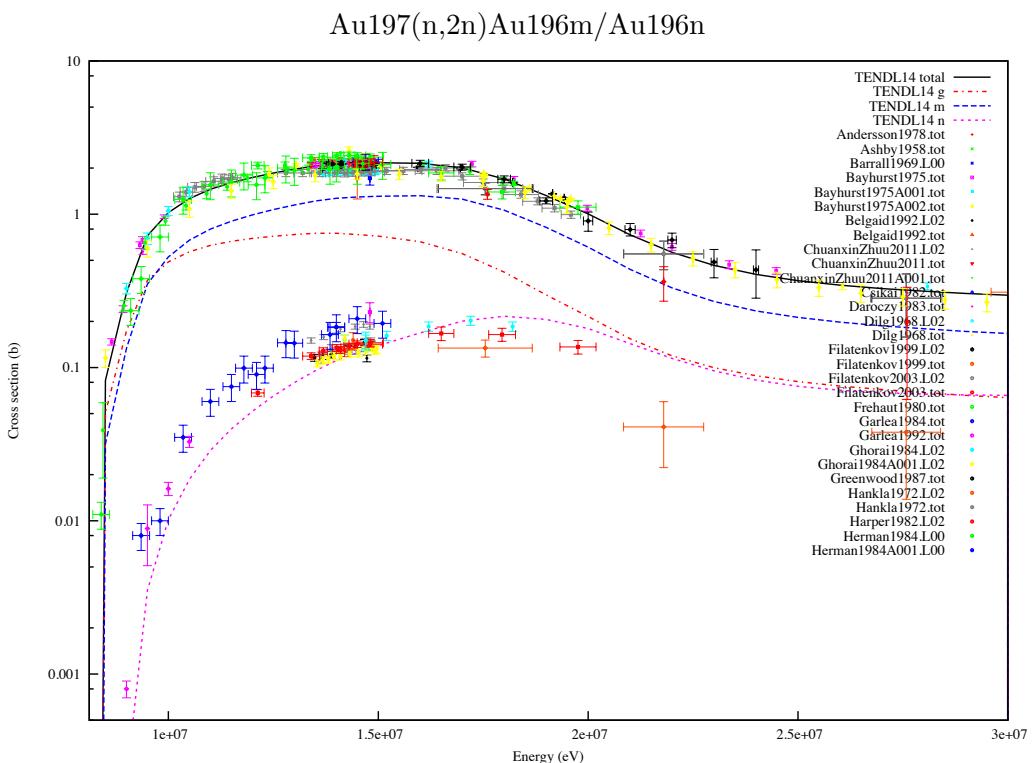
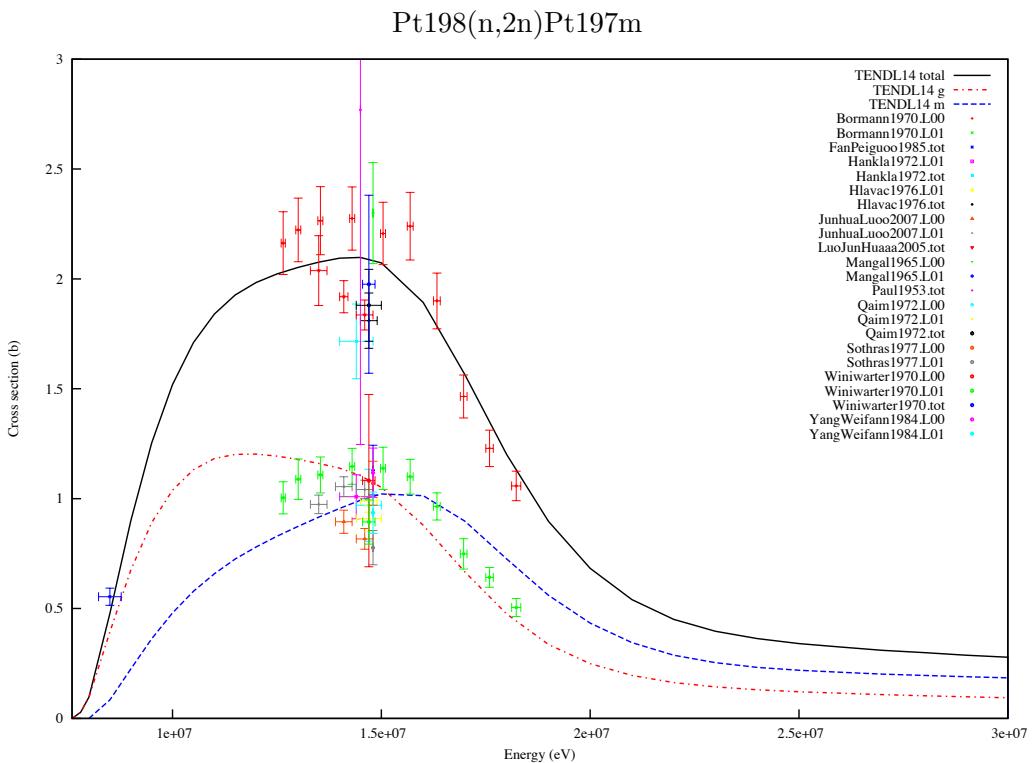


Os192(n,2n)Os191m

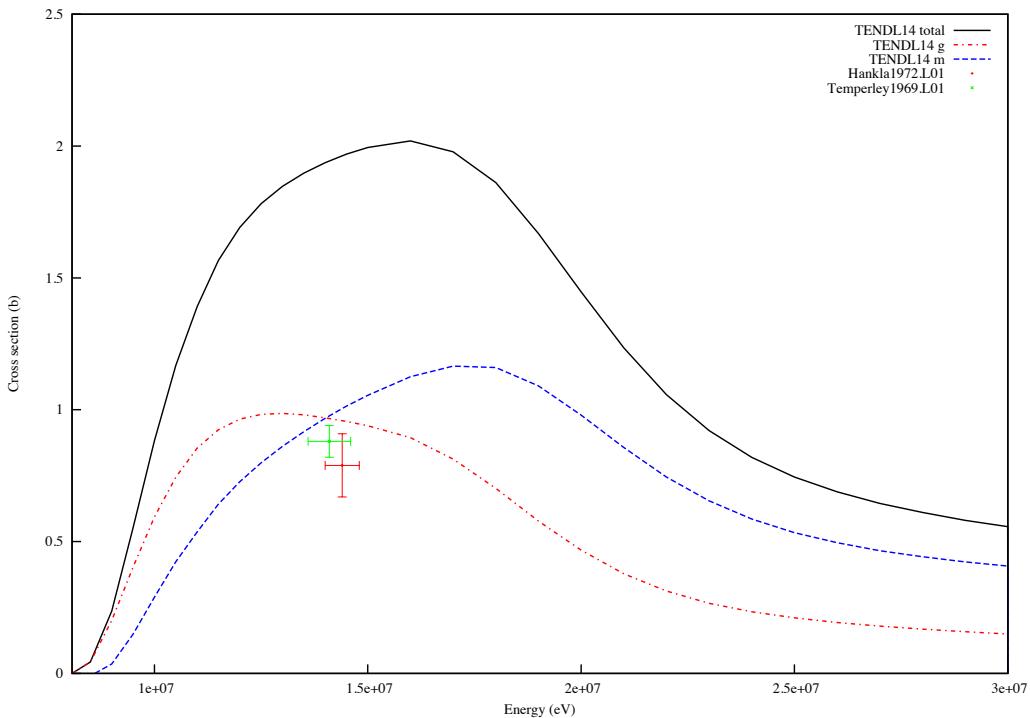


Ir193(n,2n)Ir192m

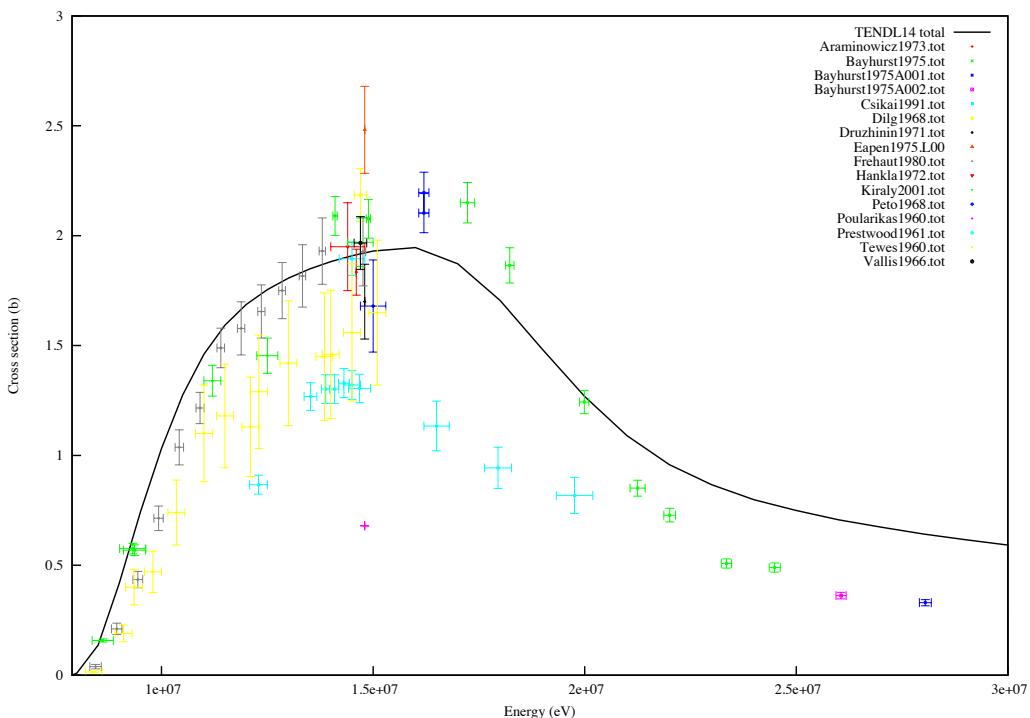




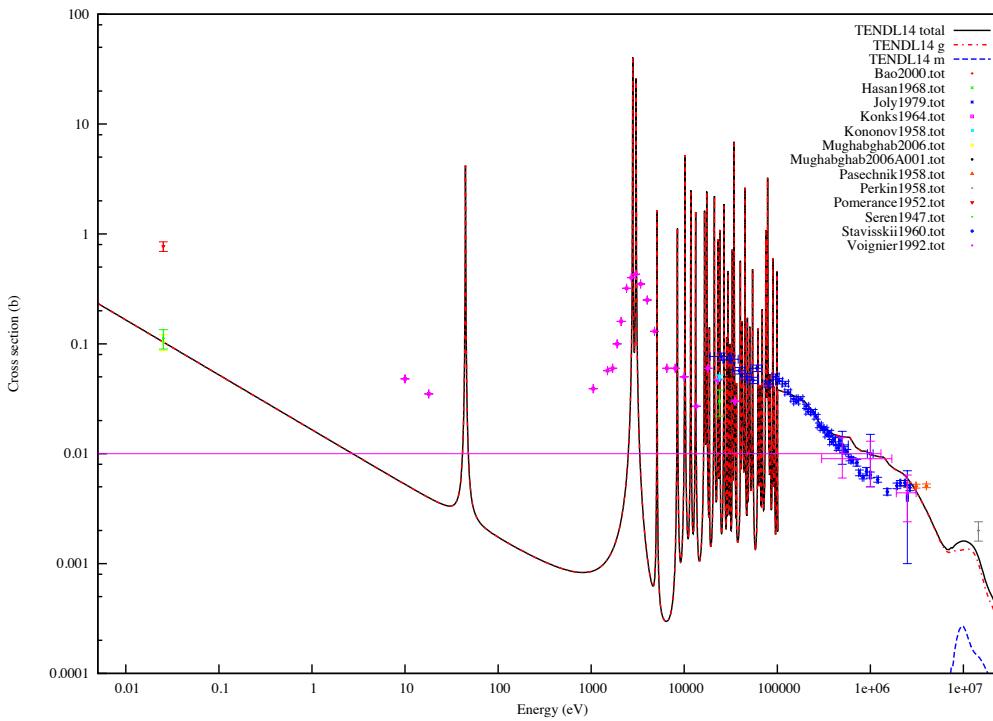
Hg200(n,2n)Hg199m



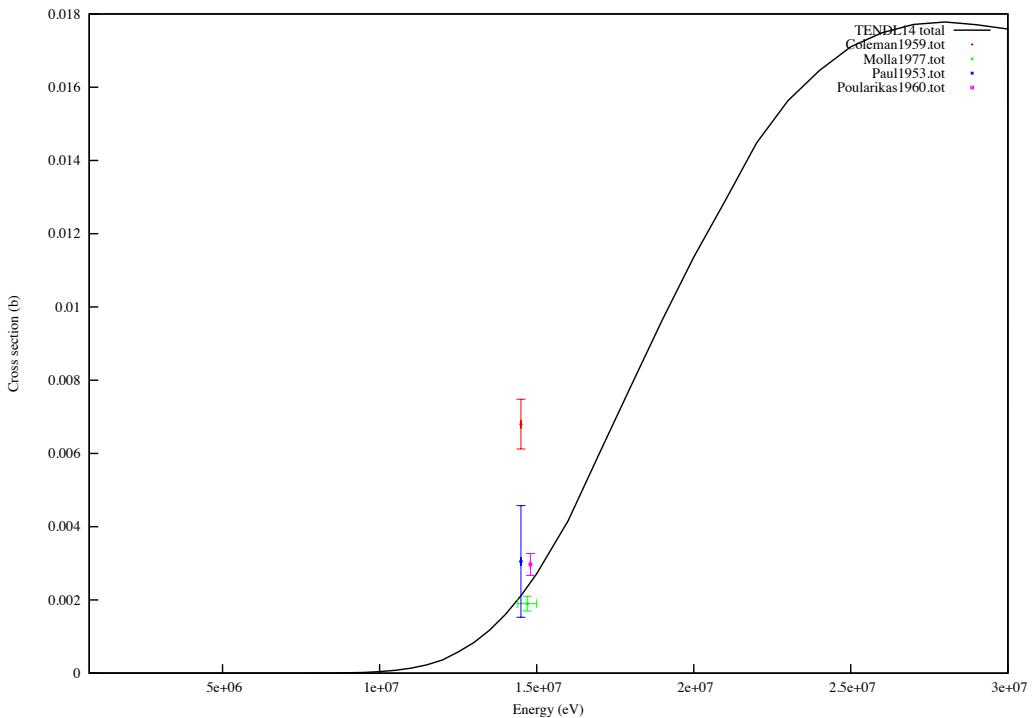
Tl203(n,2n)Tl202



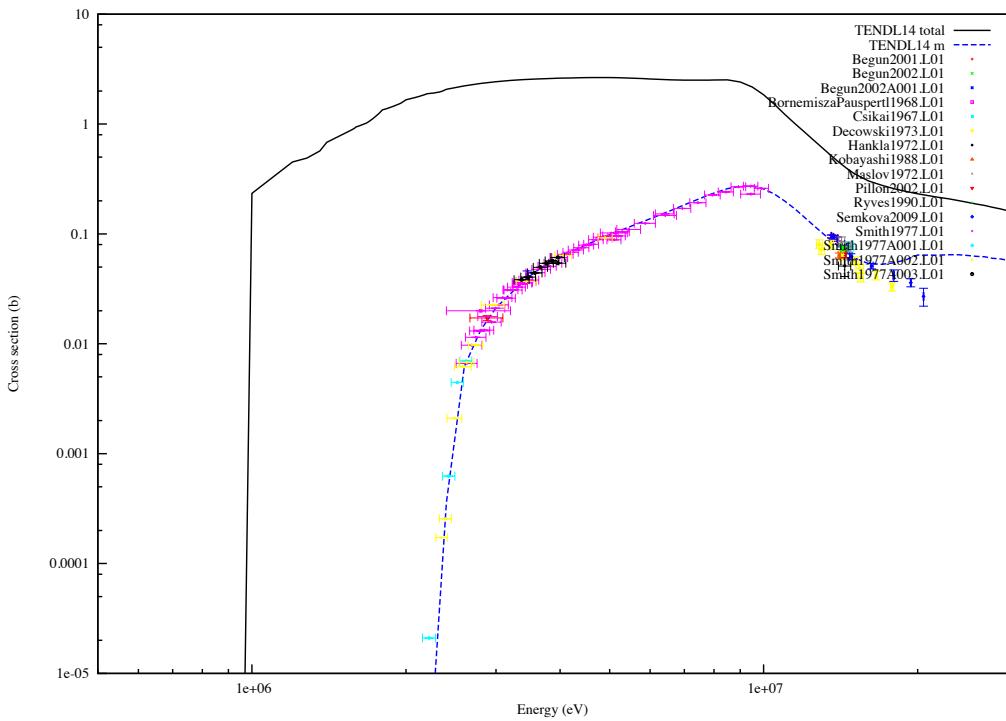
$Tl^{205}(n,\gamma)Tl^{206}$



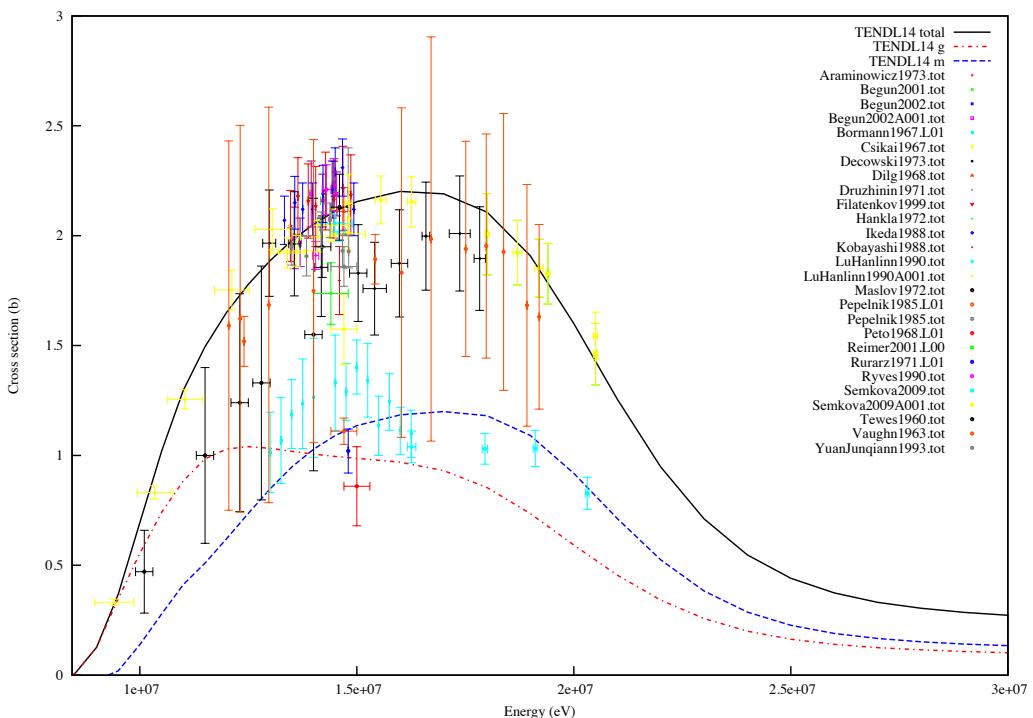
$Tl^{205}(n,p)Hg^{205}$



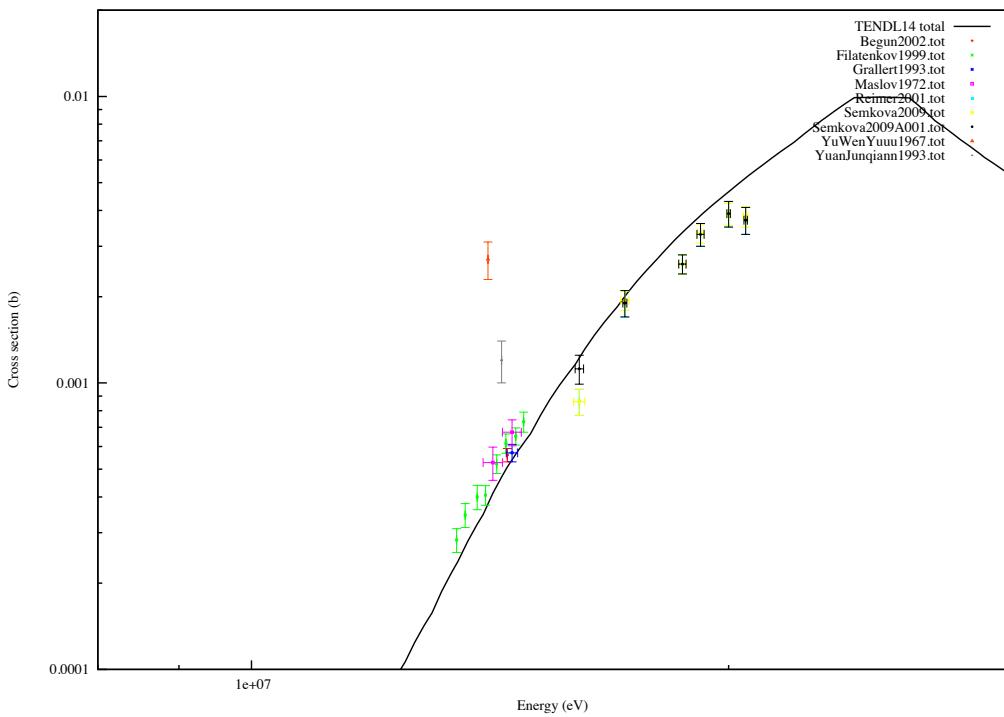
Pb204(n,n')Pb204m



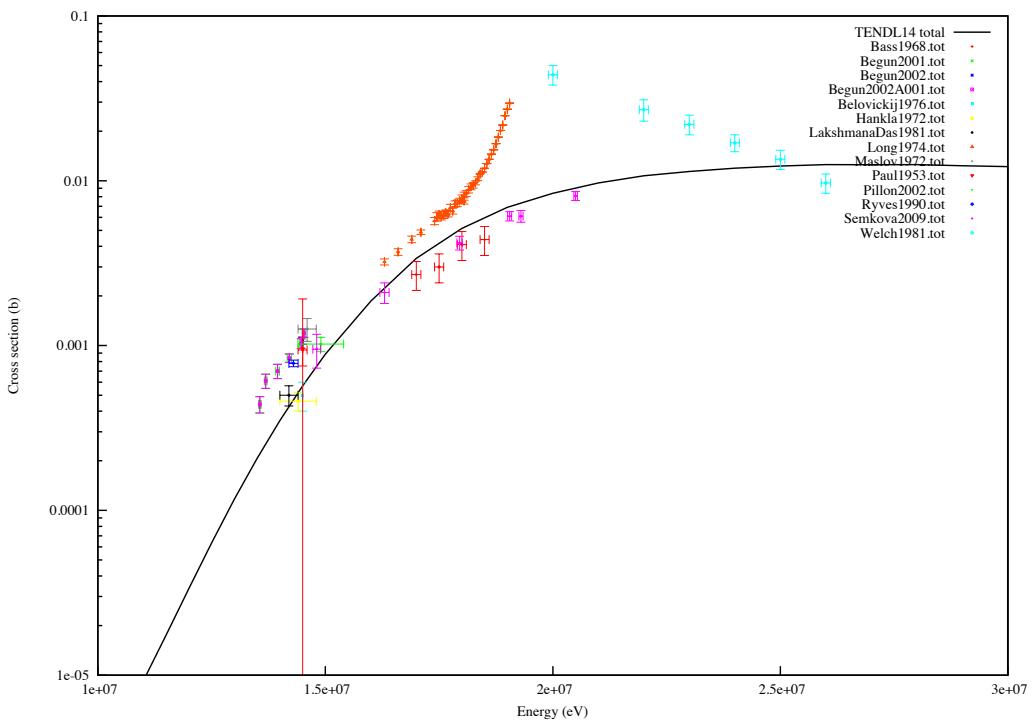
Pb204(n,2n)Pb203m/Pb203



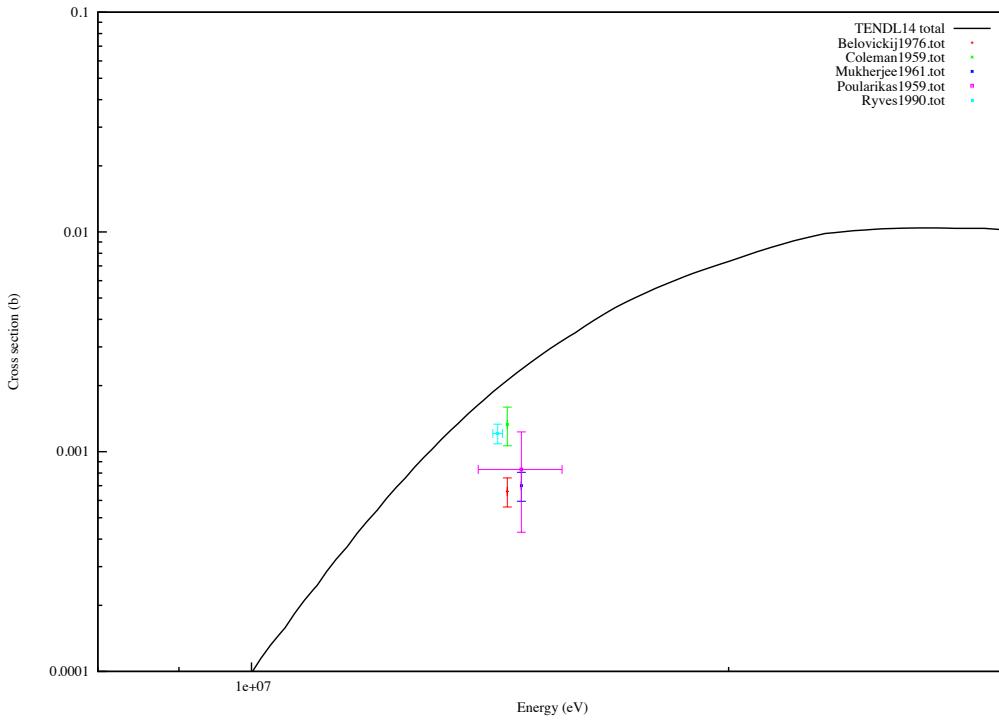
Pb206(n, α)Hg203



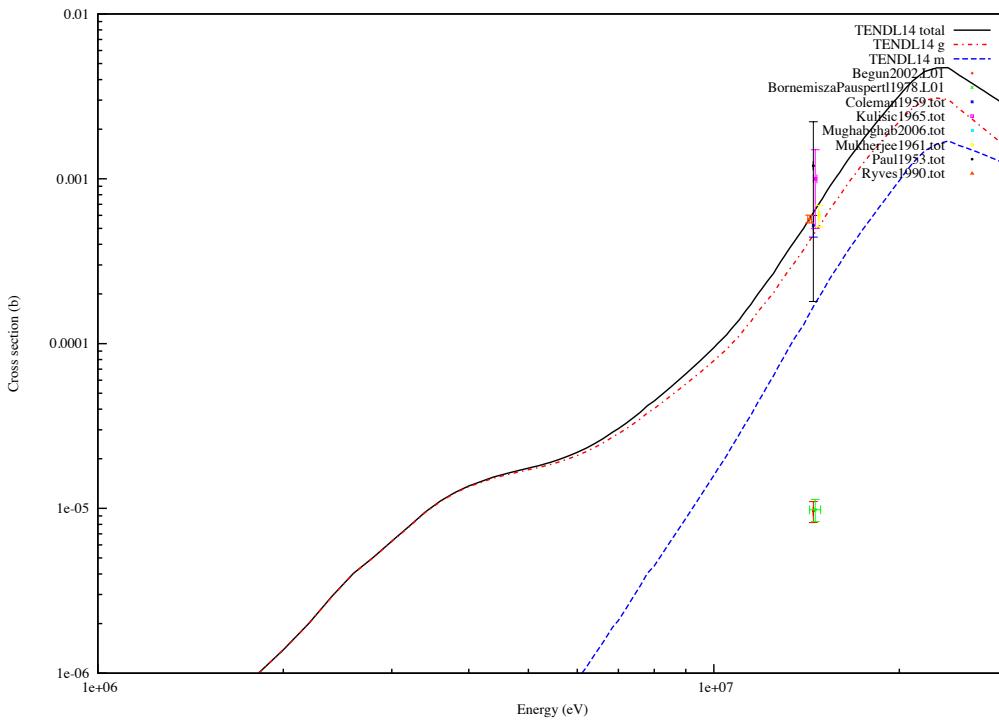
Pb208(n,p)Tl208



Bi209(n,p)Pb209



Bi209(n, α)Tl206



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