Updating of activation cross-sections: preliminary list

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NRG, Petten, The Netherlands,

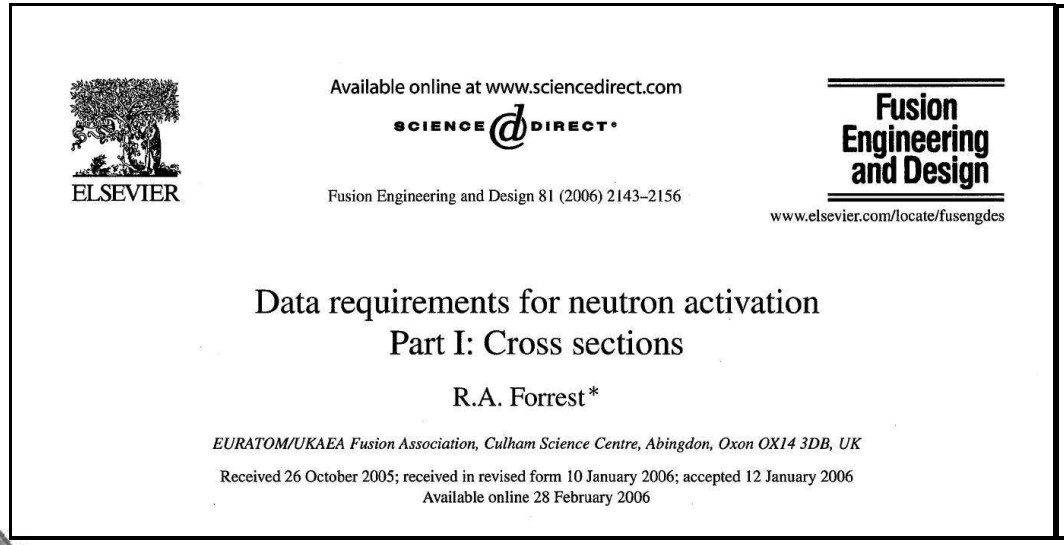
JEFF Fusion meeting, Paris, 26-27 November 2014

Contents

Objective of FPA-168.02

Task 5.2: A priority list for improvements to fusion relevant activation cross sections shall be elaborated by reviewing and updating the available list (*e.g.* by R. Forrest, UKAEA, [R1]) bases on recent experimental and theoretical work as provided *e.g.* with recent TENDL data. The review should also address specific needs for further validation and/or evaluation.

Work based on the two following publications and on the validation performed by J. Kopecky.



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Fusion Engineering and Design 81 (2006) 2143–2156

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Data requirements for neutron activation
Part I: Cross sections

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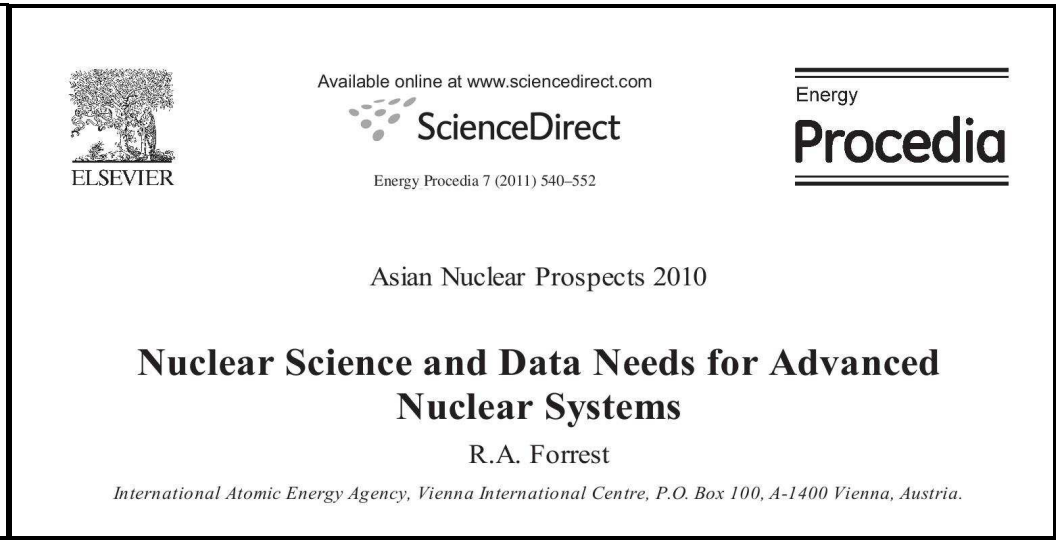
Available online 28 February 2006



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Energy Procedia 7 (2011) 540–552

Energy Procedia

Asian Nuclear Prospects 2010

Nuclear Science and Data Needs for Advanced Nuclear Systems

R.A. Forrest

International Atomic Energy Agency, Vienna International Centre, P.O. Box 100, A-1400 Vienna, Austria.

Content of R. Forrest's publications

- Fus. Eng. and Design 81 (2006) 2143

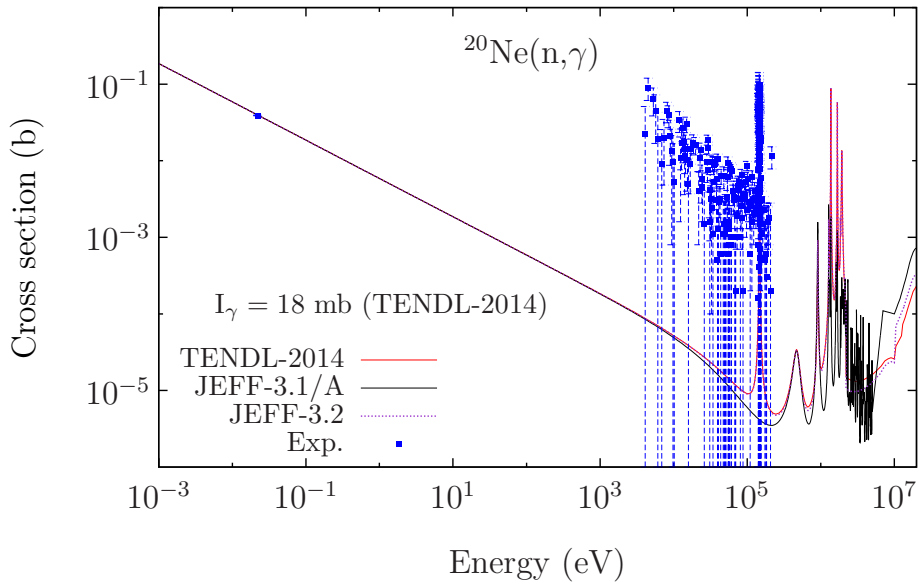
  1. Table 2: Reactions with no data, judged difficult to measure (339 reactions),
  2. Table 3: Reactions with no data, judged to be measurable (65 reactions),
  3. Table 4: Reactions with discrepant data (35 reactions).

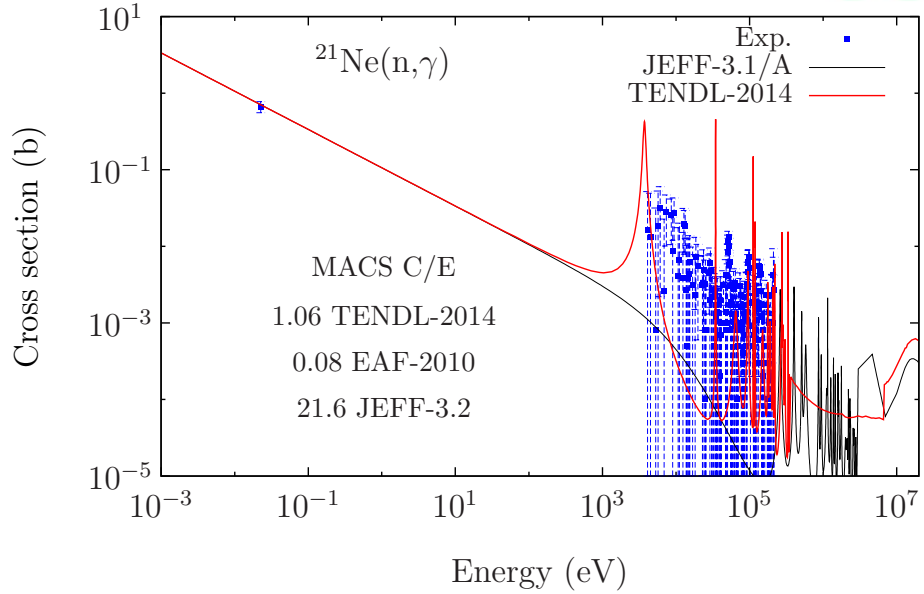
- Energy Procedia 7 (2011) 540

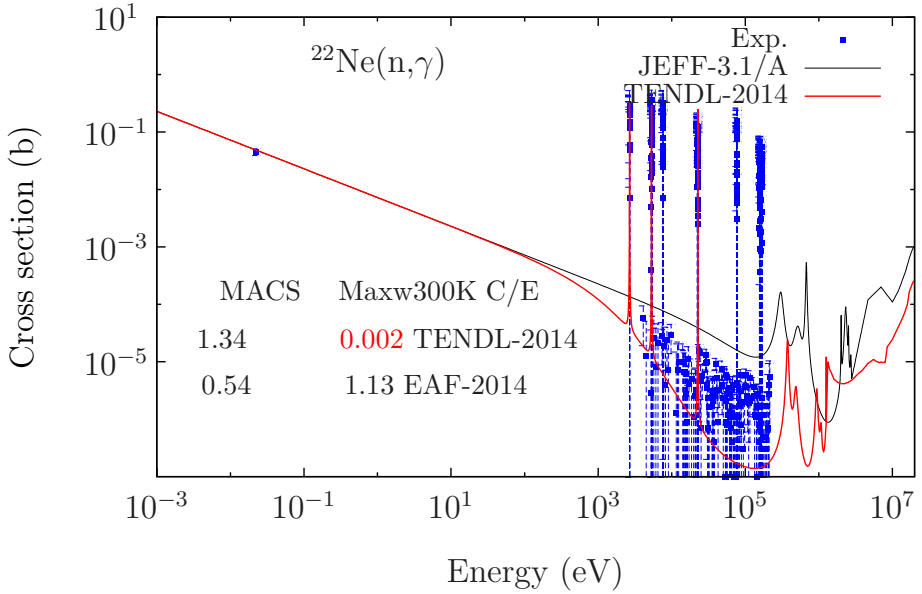
  1. Table 1: contained in FED 81 (Table 2),
  2. Table 2: contained in FED 81 (Table 3)

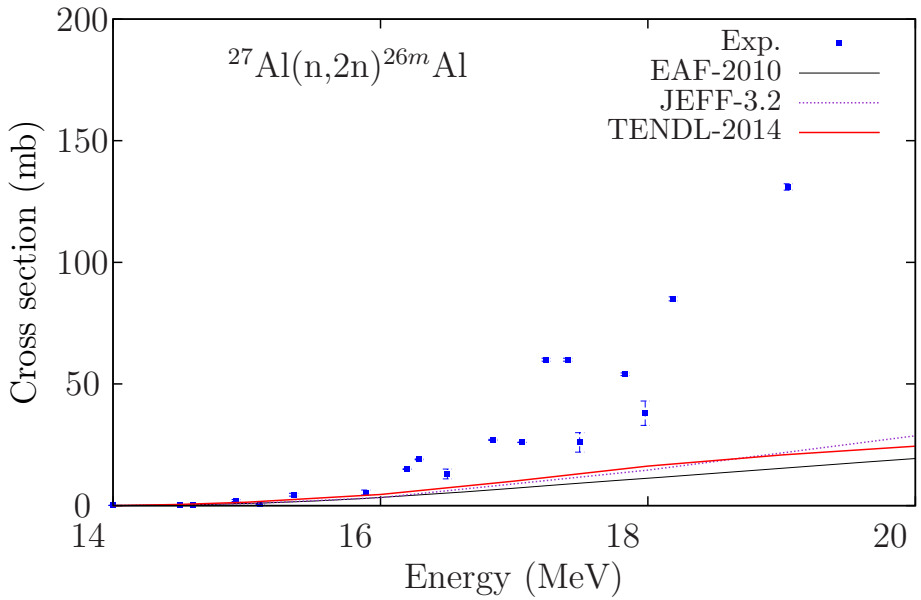
We propose to use Table 4 of FED 81 (2006) 2143 as the other tables don't contain reactions with experimental data.

Isotopes from Table 4 of FED 81 (2006) 2143, plots 1/6

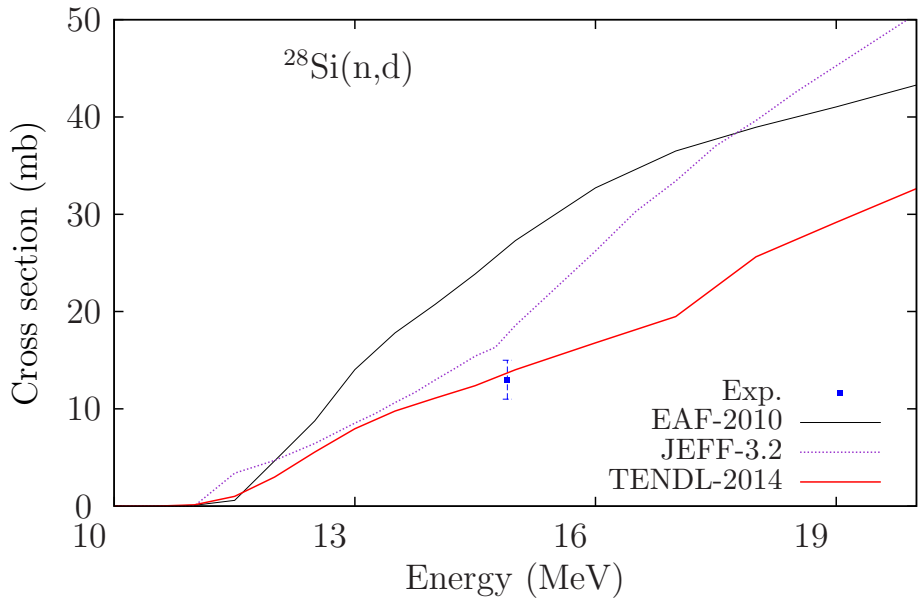


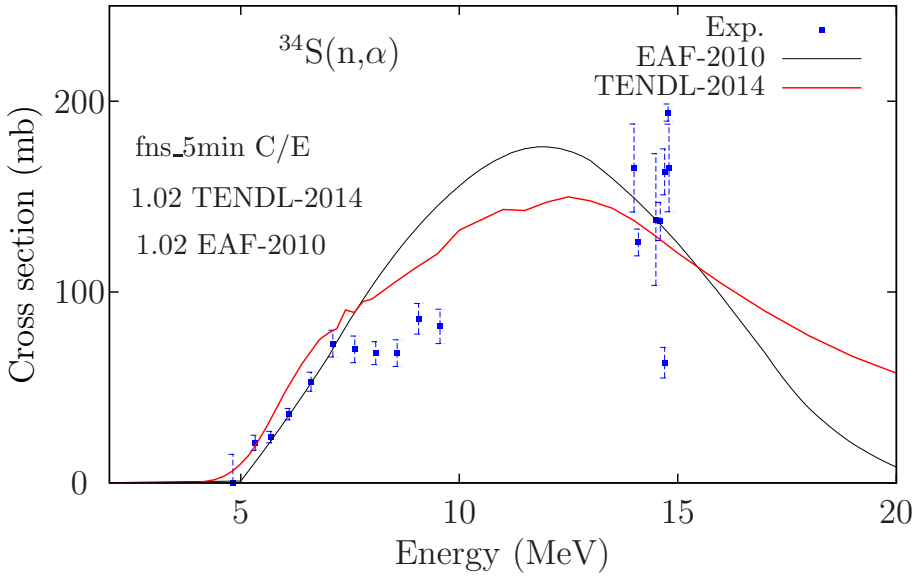


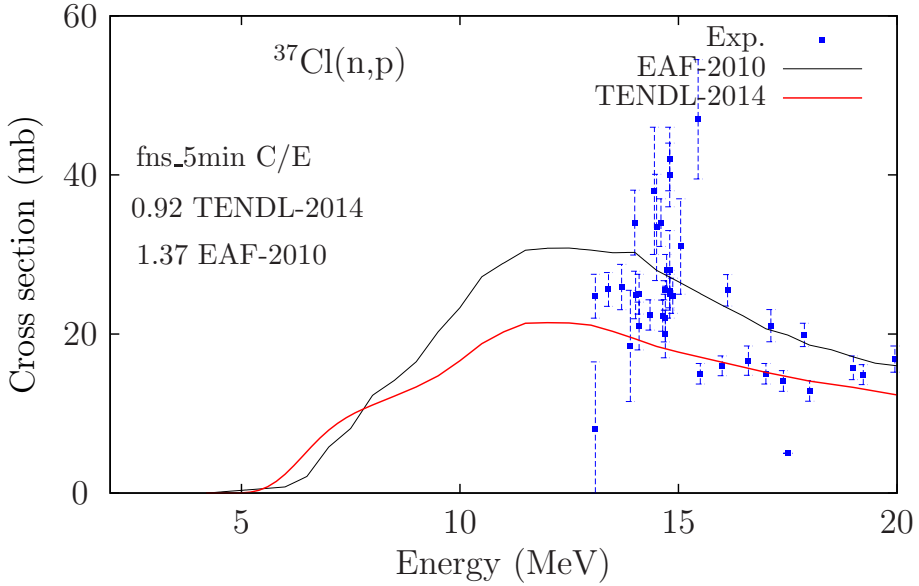


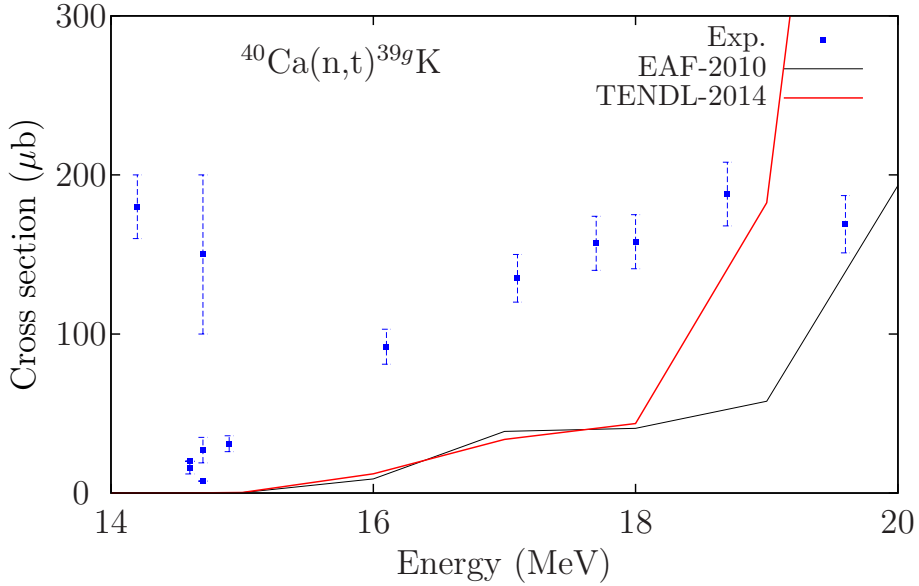


Isotopes from Table 4 of FED 81 (2006) 2143, plots 2/6

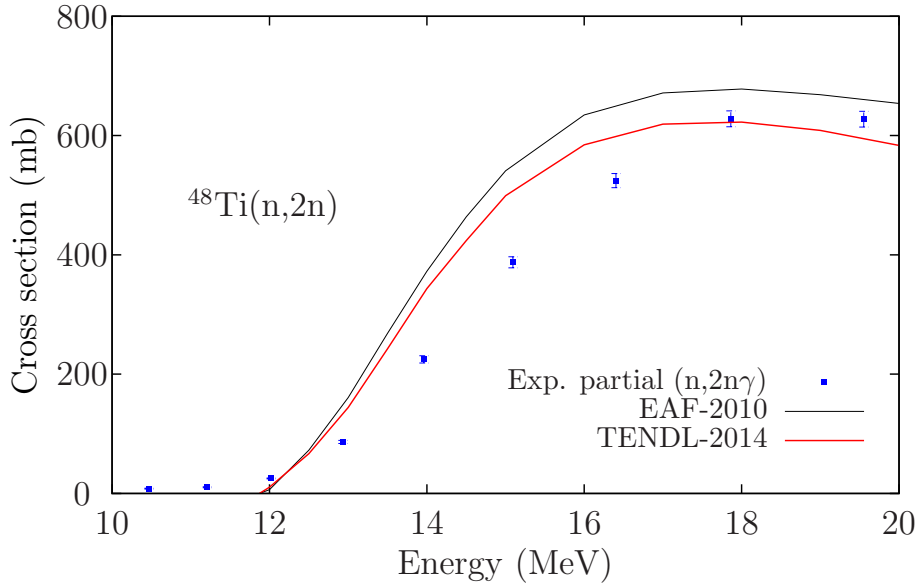


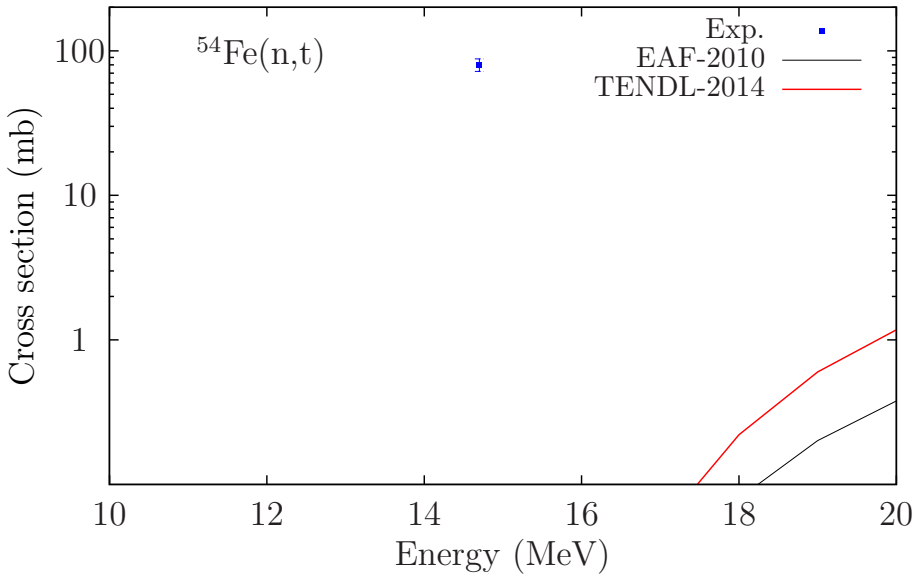


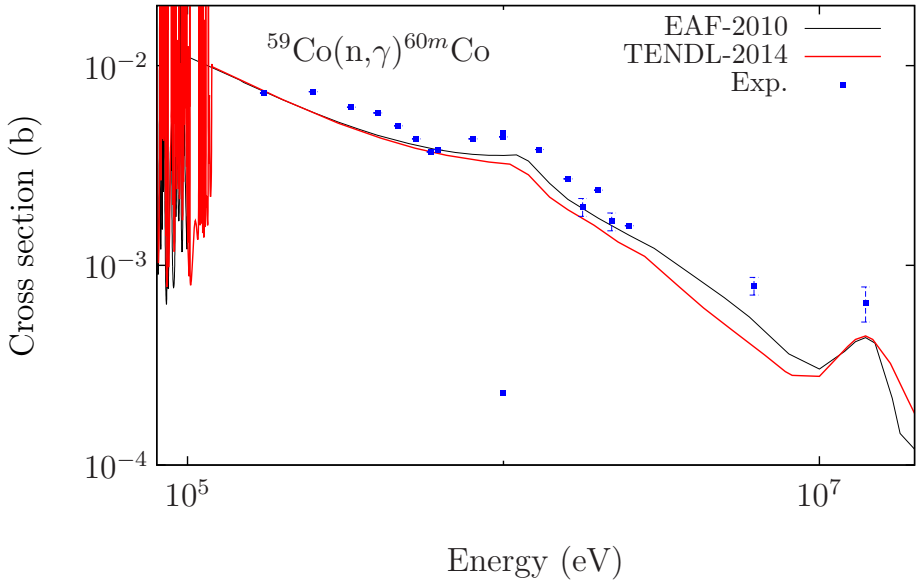


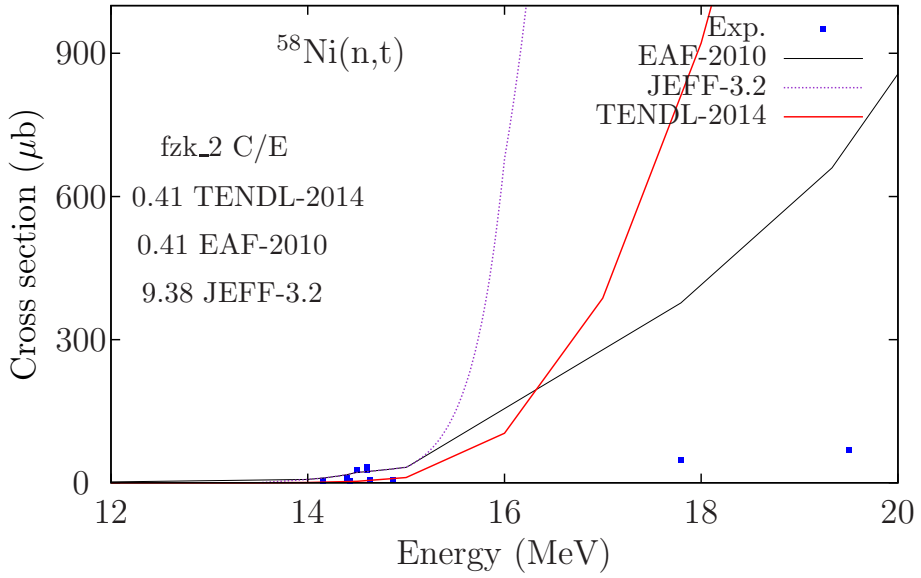


Isotopes from Table 4 of FED 81 (2006) 2143, plots 3/6

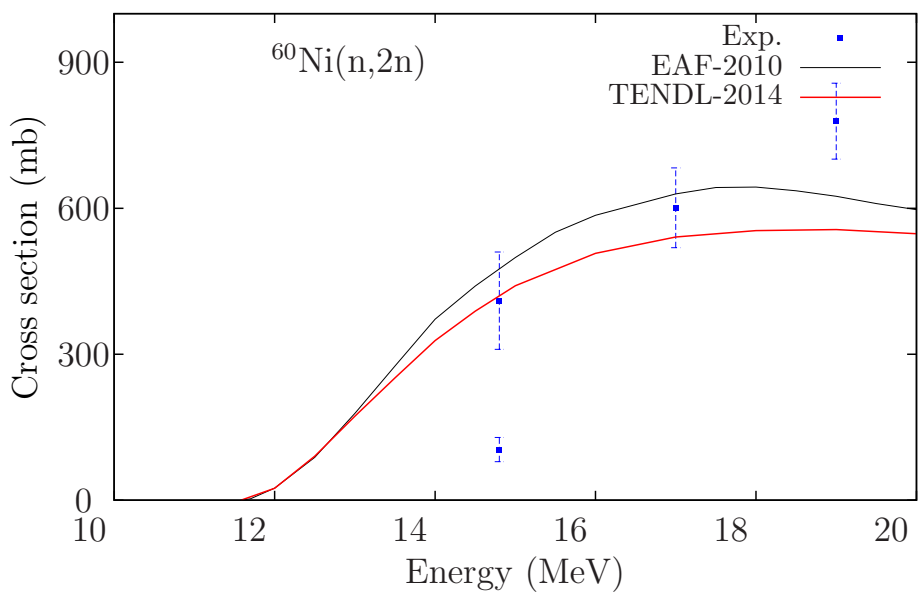


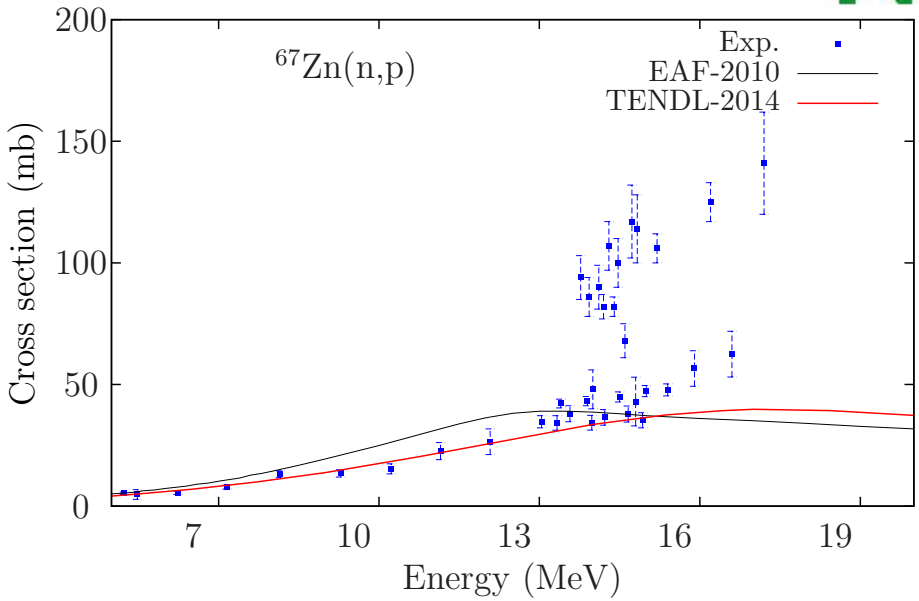


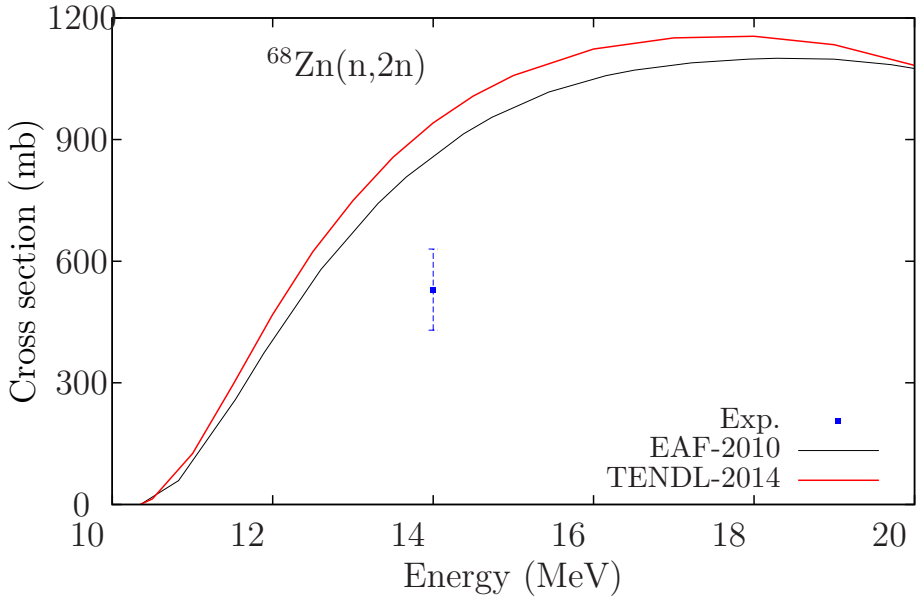


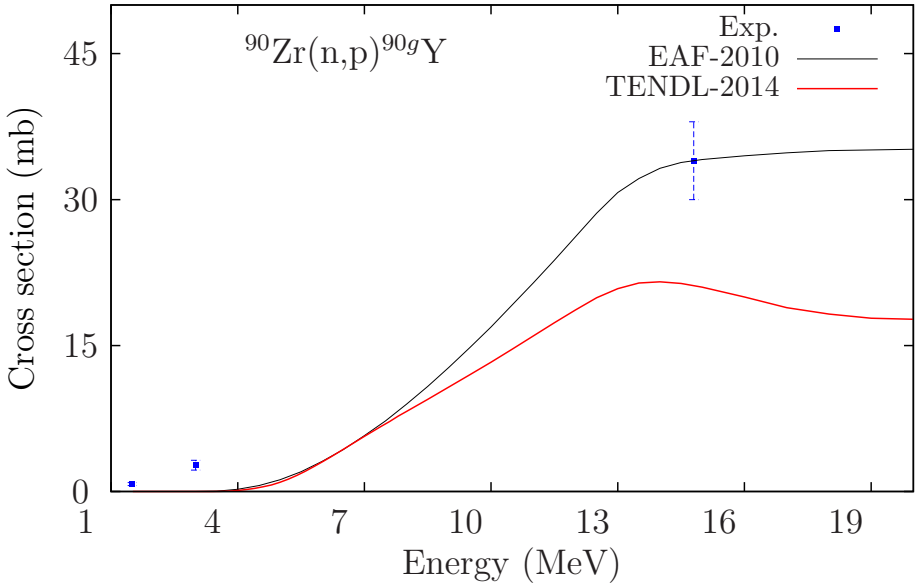


Isotopes from Table 4 of FED 81 (2006) 2143, plots 4/6

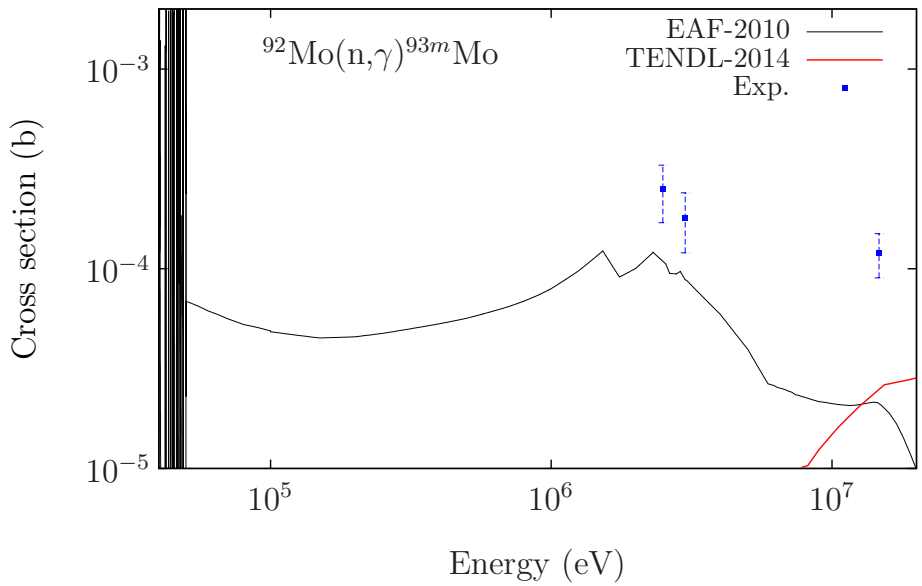


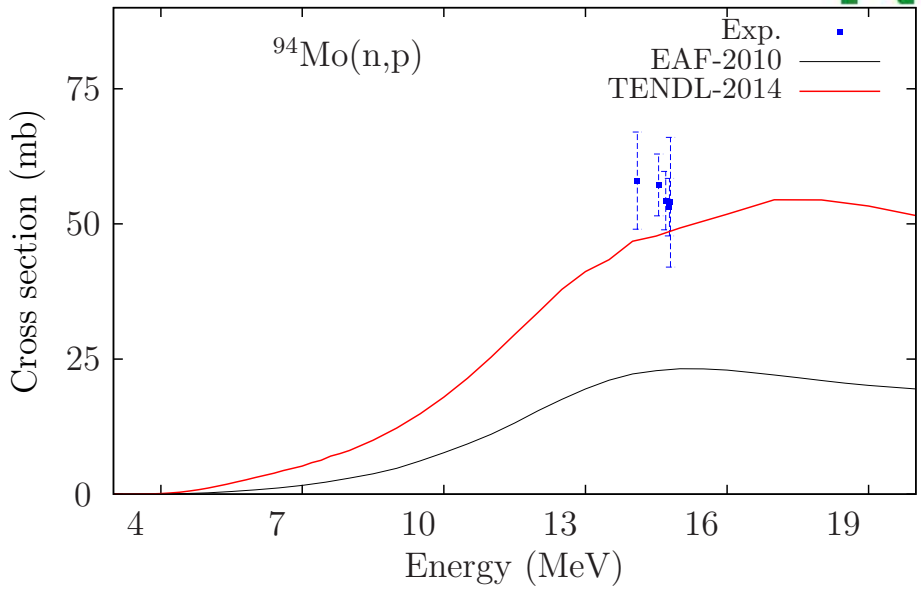


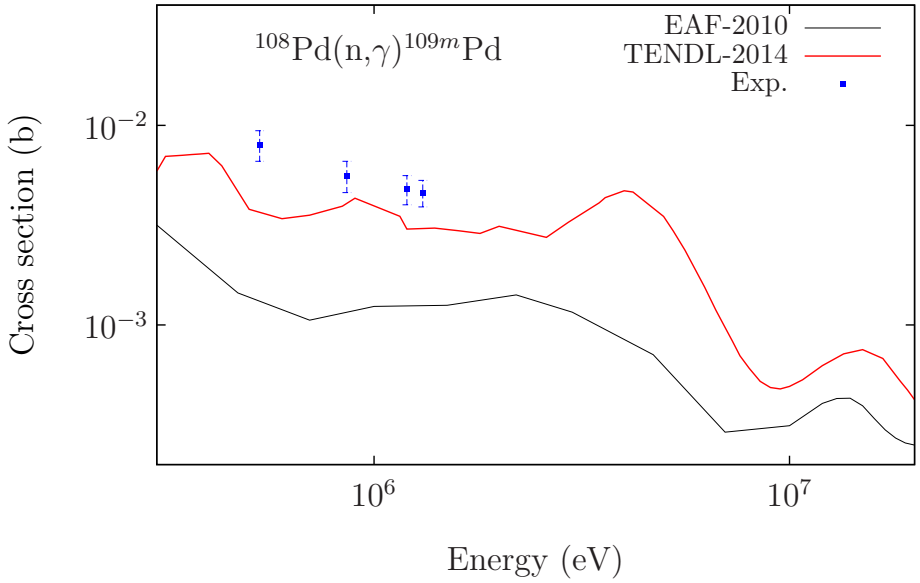


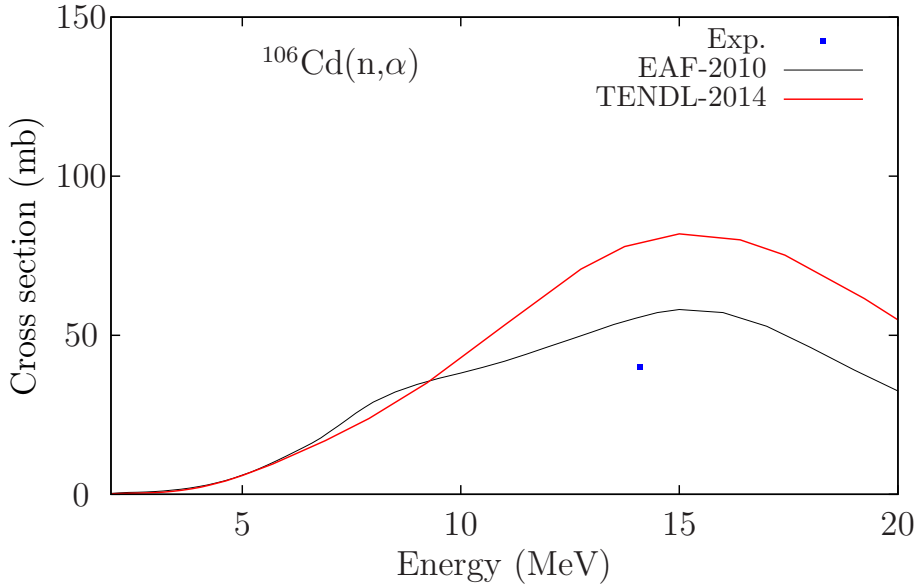


Isotopes from Table 4 of FED 81 (2006) 2143, plots 5/6

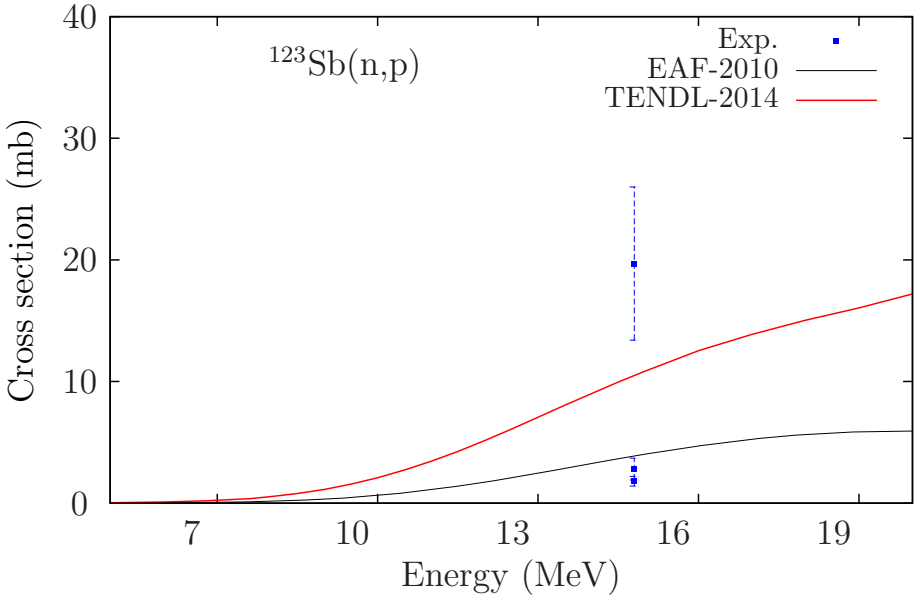


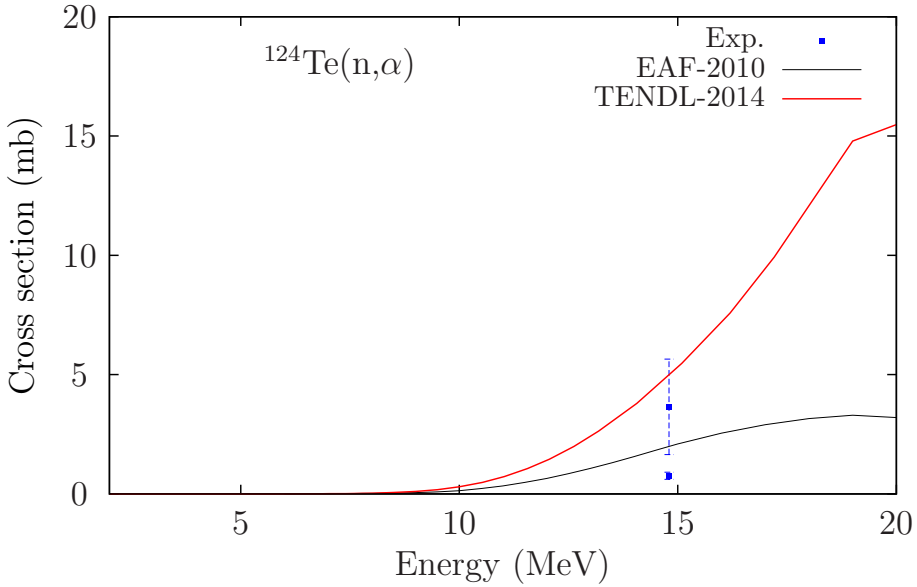






Isotopes from Table 4 of FED 81 (2006) 2143, plots 6/6





Summary from FED 81 (2006) 2143

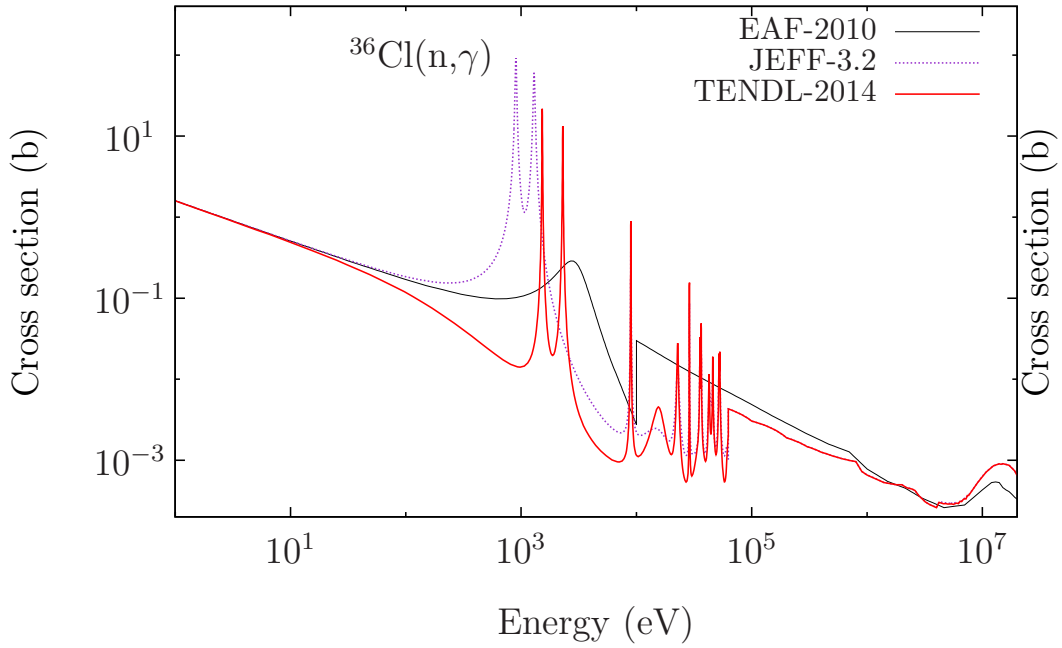
- 35 reactions: (n,p), (n,α), (n,γ), (n,t), (n,d), (n,2n)
- 10 worth improving:

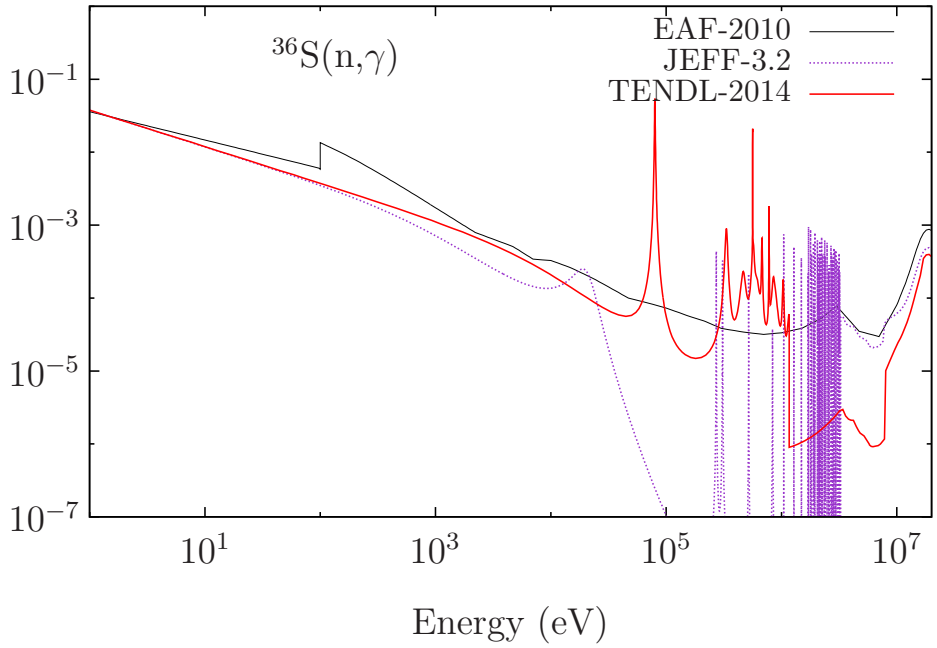
1. ^{22}Ne(n,γ)
2. ^{27}Al(n,2n)^{26m}Al
3. ^{40}Ca(n,t)^{39g}K
4. ^{58}Ni(n,t)^{56}Co
5. ^{67}Zn(n,p)
6. ^{90}Zr(n,p)^{90g}Y
7. ^{92}Mo(n,γ)^{93m}Mo
8. ^{106}Cd(n,α)
9. ^{123}Sb(n,p)
10. ^{124}Te(n,α)

Possible additionnal reactions can be found in the validation performed by J. Kopecky using integral data
(see next slides)

Some reactions based on Kopecky's validation 1/7

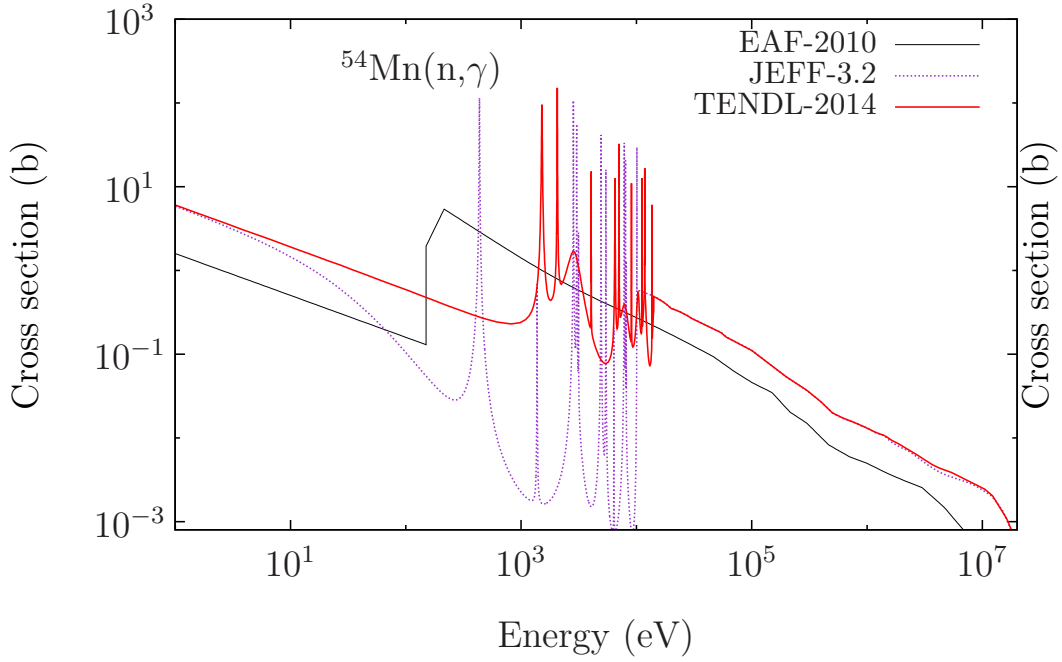
reaction	spectrum	σ (b)	EAF-2010 (C/E)	TENDL-2013 (C/E)	TENDL-2014 (C/E)	JEFF-3.2 (C/E)
^{36}Cl(n,γ)	MACS 30 keV	0.012	1.03	5.19	0.52	1.25
	I_γ	3.80	1.26	2.42	1.19	3.09
^{36}S(n,γ)	MACS 30 keV	0.00017	0.88	3.48	4.42	0.25
	I_γ	0.17	0.72	0.60	0.60	0.58

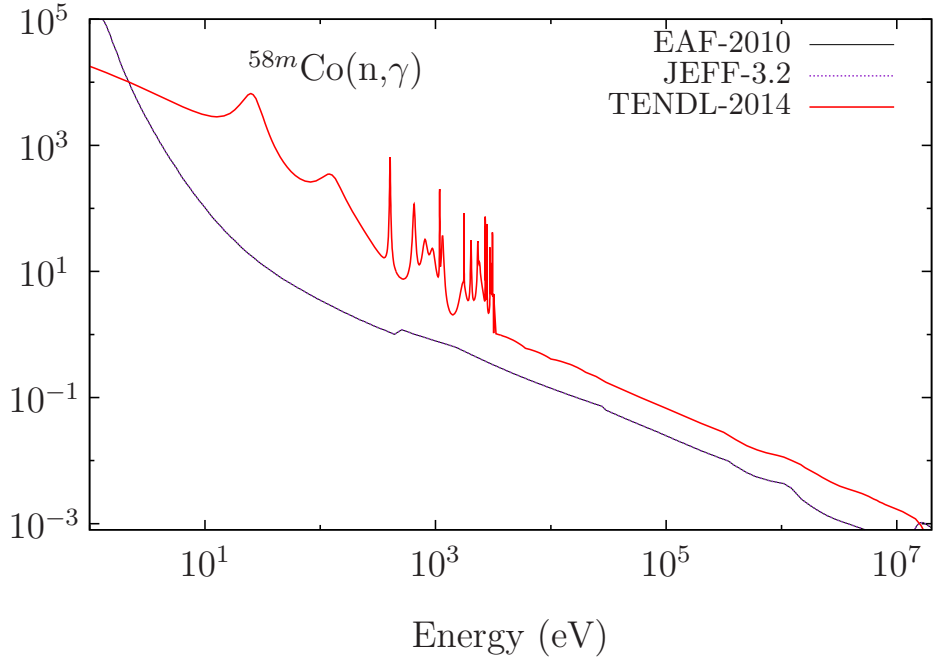




Some reactions based on Kopecky's validation 2/7

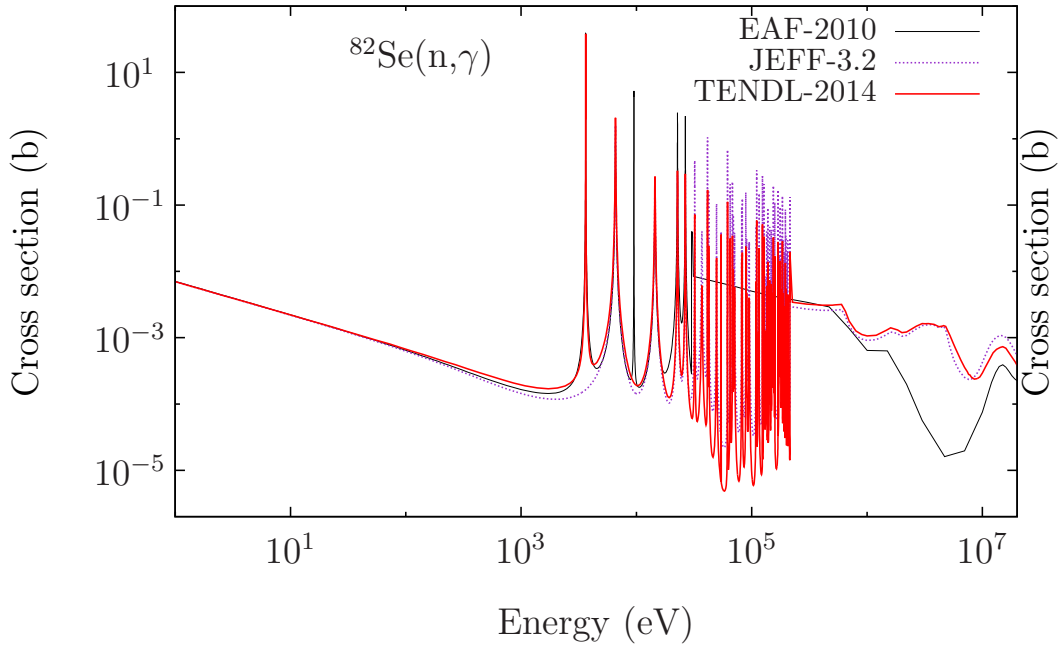
reaction	spectrum	σ (b)	EAF-2010 (C/E)	TENDL-2013 (C/E)	TENDL-2014 (C/E)	JEFF-3.2 (C/E)
^{54}Mn(n,γ)	I_γ	17.0	0.70	3.83	1.20	0.90
^{58m}Co(n,γ)	I_γ	1.4e^5	0.91	0.27	0.27	0.91

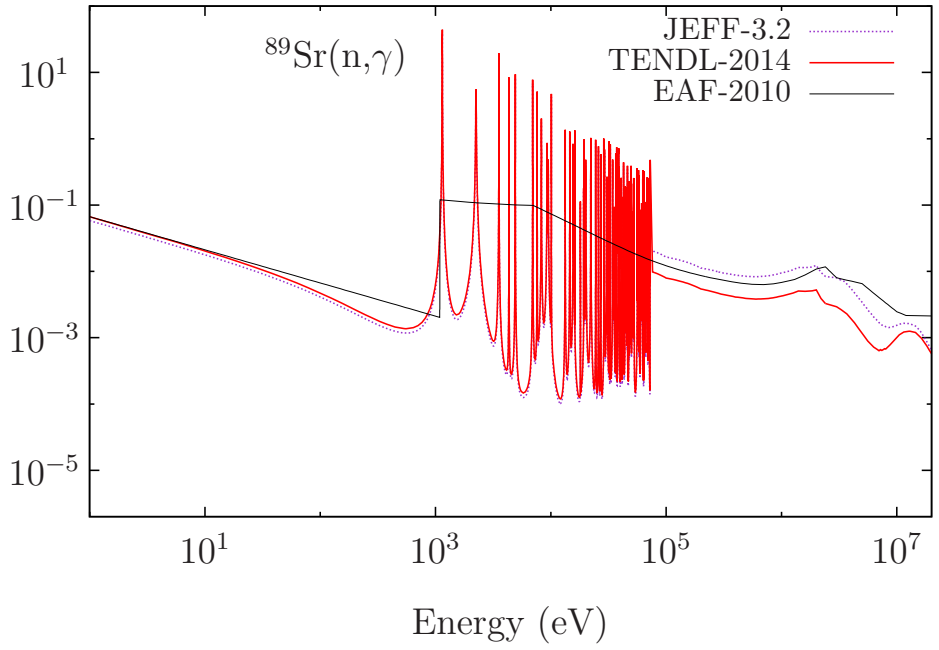




Some reactions based on Kopecky's validation 3/7

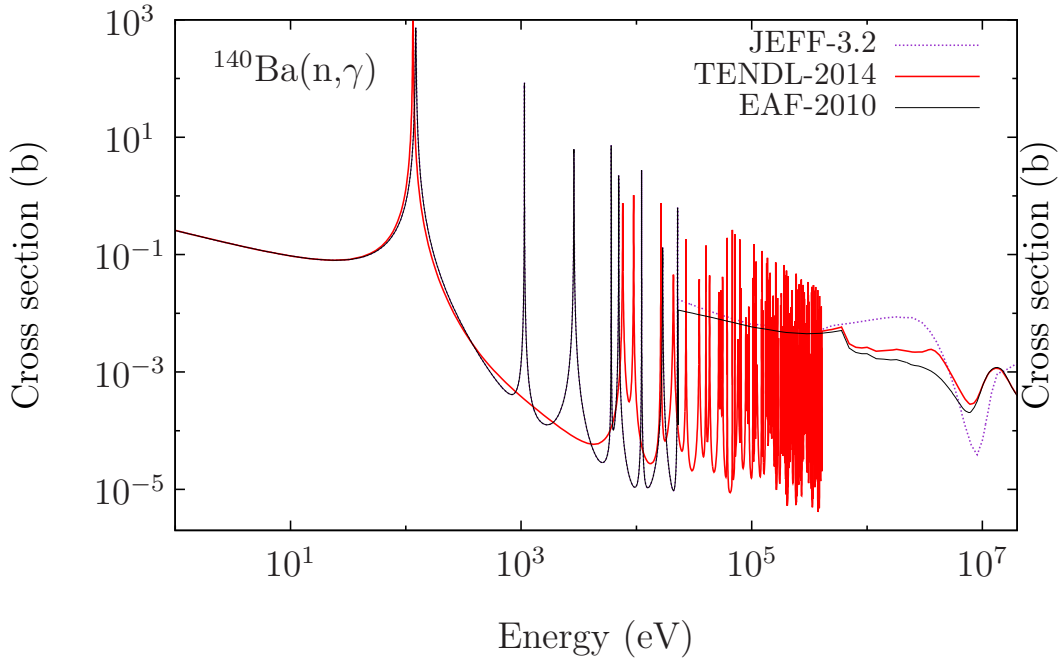
reaction	spectrum	σ (b)	EAF-2010 (C/E)	TENDL-2013 (C/E)	TENDL-2014 (C/E)	JEFF-3.2 (C/E)
^{82}Se(n,γ)	MACS 30 keV	0.009	1.64	0.29	0.45	0.50
^{89}Sr(n,γ)	I_γ	0.42	1.17	1.34	1.68	1.16
	MACS 30 keV	0.019	1.53	2.38	0.76	0.82

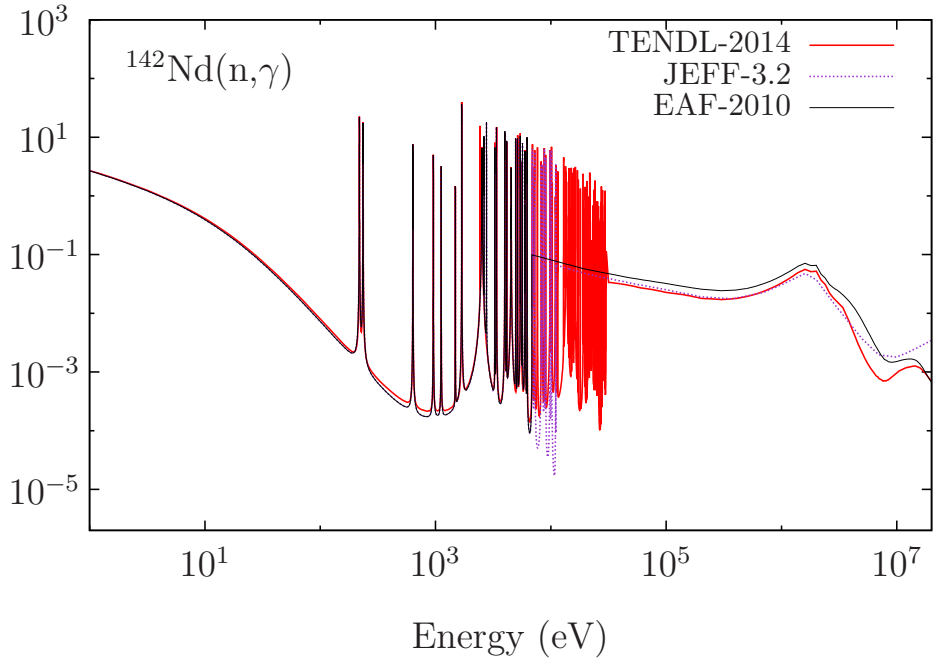




Some reactions based on Kopecky's validation 4/7

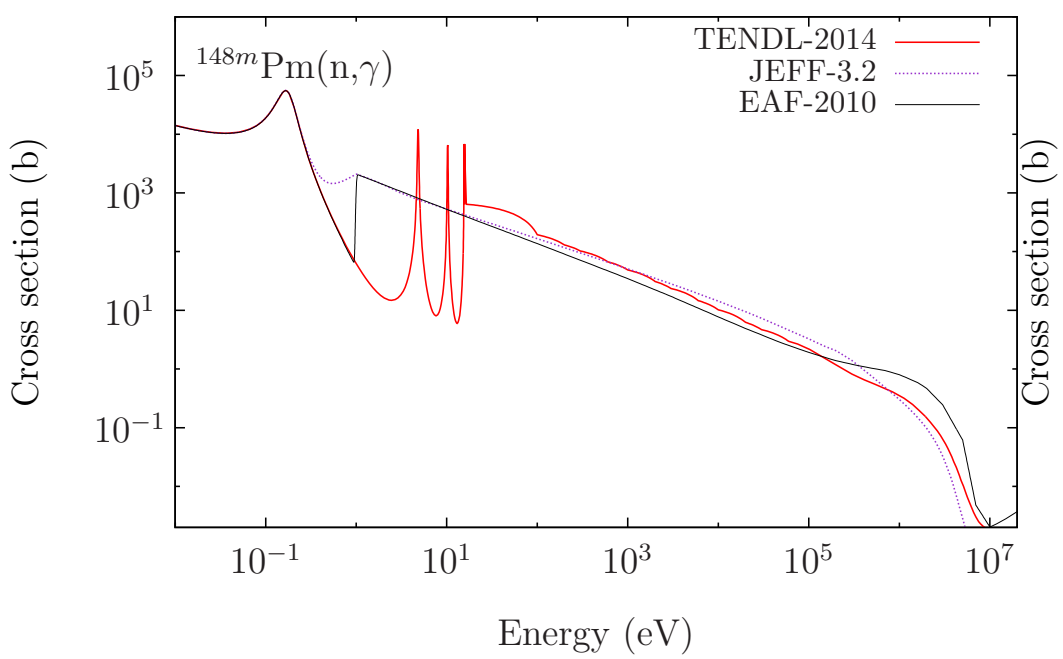
reaction	spectrum	σ (b)	EAF-2010 (C/E)	TENDL-2013 (C/E)	TENDL-2014 (C/E)	JEFF-3.2 (C/E)
^{140}Ba(n,γ)	I_γ	13.6	1.05	0.06	1.48	1.05
^{142}Nd(n,γ)	I_γ	34.0	0.18	0.17	0.17	0.18
	MACS 30 keV	0.035	1.43	1.17	1.02	1.17

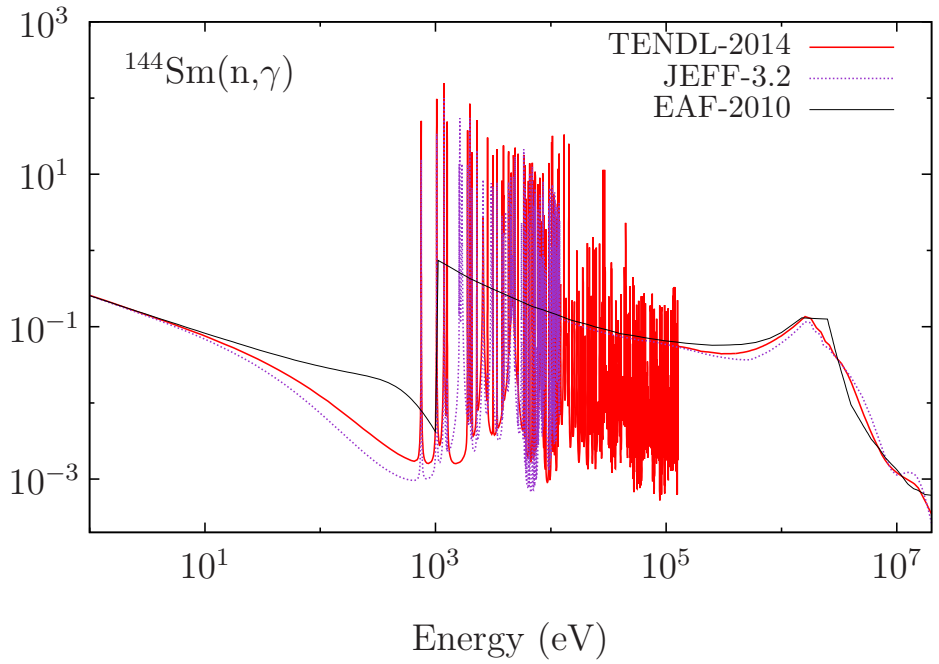




Some reactions based on Kopecky's validation 5/7

reaction	spectrum	σ (b)	EAF-2010 (C/E)	TENDL-2013 (C/E)	TENDL-2014 (C/E)	JEFF-3.2 (C/E)
^{148m}Pm(n,γ)	I_γ	3600	1.01	0.23	0.57	1.33
^{144}Sm(n,γ)	I_γ	2.38	0.73	0.78	0.86	0.68
	MACS 30 keV	0.092	1.07	0.48	0.48	0.95





Some reactions based on Kopecky's validation 6/7

	reaction	spectrum (b)	σ (C/E)	EAF-2010 (C/E)	TENDL-2013 (C/E)	TENDL-2014 (C/E)	JEFF-3.2
1	^{22}Na(n,γ)	Maxw_300 keV	198	1.13	0.002	153	1.13
2	^{24}Mg(n,γ)	fission_WIMS	$6e^{-4}$	0.61	0.25	0.25	0.52
2	^{30}Si(n,γ)	fission_WIMS	0.0011	0.60	0.22	0.22	0.52
3	^{36}Cl(n,γ)	MACS 30 keV	0.012	1.03	5.19	0.52	1.25
4	^{37}Cl(n,γ)	fission_WIMS	$7.4e^{-4}$	0.74	0.33	0.33	0.65
5	^{36}S(n,γ)	MACS 30 keV	0.00017	0.88	3.48	4.42	0.25
6	^{50}Ti(n,γ)	fission_WIMS	0.0019	0.24	0.25	0.25	0.42
7	^{54}Mn(n,γ)	I_γ	17.0	0.70	3.83	1.20	0.90
8	^{58m}Co(n,γ)	I_γ	$1.4e^{5}$	0.91	0.27	0.27	0.91
9	^{74}Ge(n,γ)	fission_WIMS	0.012	0.49	0.49	0.49	0.49
10	^{82}Se(n,γ)	MACS 30 keV	0.009	1.64	0.29	0.45	0.50
11	^{86}Kr(n,γ)	fission_WIMS	0.008	0.16	0.15	0.15	0.16
12	^{88}Sr(n,γ)	fission_WIMS	0.0021	1.11	2.38	2.38	1.90
13	^{89}Sr(n,γ)	I_γ	0.42	1.17	1.34	1.68	1.16
		MACS 30 keV	0.019	1.53	2.38	0.76	0.82
14	^{96}Zr(n,γ)	fission_WIMS	0.041	0.36	0.17	0.17	0.14
15	^{103}Rh(n,γ)	fns_5min	0.0268	2.50	2.45	2.51	2.74
16	^{140}Ba(n,γ)	I_γ	13.6	1.05	0.06	1.48	1.05
17	^{142}Nd(n,γ)	I_γ	34.0	0.18	0.17	0.17	0.18

Some reactions based on Kopecky's validation 7/7

	reaction	spectrum (b)	σ (C/E)	EAF-2010 (C/E)	TENDL-2013 (C/E)	TENDL-2014 (C/E)	JEFF-3.2
18	^{148m}Pm(n,γ)	I_γ	3600	1.01	0.23	0.57	1.33
19	^{144}Sm(n,γ)	MACS 30 keV	0.092	1.07	0.48	0.48	0.95
20	^{152}Gd(n,γ)	I_γ	2020	0.49	0.50	0.50	0.50
21	^{163}Ho(n,γ)	MACS 30 keV	2.13	0.72	2.82	2.82	0.72
22	^{171}Tm(n,γ)	I_γ	118	3.97	8.07	8.20	6.93
23	^{205}Tl(n,γ)	MACS 30 keV	0.054	0.73	2.00	2.02	1.05
24	^{205}Pb(n,γ)	MACS 30 keV	0.125	0.44	1.70	1.70	2.06
25	^{22}Na(n,p)	I_γ	$1.37e^{5}$	0.11	0.09	0.09	0.11
26	^{36}Cl(n,p)	I_γ	0.42	0.50	49.3	2.33	0.50
27	^{46}Ti(n,p)	sneg_1	0.431	0.52	0.30	0.30	0.52
28	^{48}Ti(n,p)	fzk_1	$4.6e^{-3}$	2.81	3.04	2.88	2.73
29	^{95}Mo(n,p)	cf252_flux_1	0.022	0.01	0.01	0.01	0.01
30	^{46}Ti(n,2n)	cf252_flux_1	$9.3e^{-5}$	0.15	0.15	0.14	0.14
31	^{166}Er(n,2n)	fns_5min	0.375	4.61	4.74	4.74	4.74
32	^{46}Ti(n,α)	fng_vanad	0.00919	0.71	0.19	1.18	0.73
33	^{89}Y(n,α)	fng_Y	0.0142	0.44	0.38	0.53	0.42

Summary of the possible reactions

1. ^{22}Ne(n,γ)
2. ^{27}Al(n,2n)^{26m}Al
3. ^{40}Ca(n,t)^{39g}K
4. ^{58}Ni(n,t)^{56}Co
5. ^{67}Zn(n,p)
6. ^{90}Zr(n,p)^{90g}Y
7. ^{92}Mo(n,γ)^{93m}Mo
8. ^{106}Cd(n,α)
9. ^{123}Sb(n,p)
10. ^{124}Te(n,α)
11. ^{24}Mg(n,γ)
12. ^{30}Si(n,γ)
13. ^{36}Cl(n,γ)
14. ^{37}Cl(n,γ)
15. ^{36}S(n,γ)
16. ^{50}Ti(n,γ)
17. ^{54}Mn(n,γ)
18. ^{58m}Co(n,γ)
19. ^{74}Ge(n,γ)
20. ^{82}Se(n,γ)
21. ^{86}Kr(n,γ)
22. ^{88}Sr(n,γ)
23. ^{89}Sr(n,γ)
24. ^{96}Zr(n,γ)
25. ^{103}Rh(n,γ)
26. ^{140}Ba(n,γ)
27. ^{142}Nd(n,γ)
28. ^{148m}Pm(n,γ)
29. ^{144}Sm(n,γ)
30. ^{152}Gd(n,γ)
31. ^{163}Ho(n,γ)
32. ^{171}Tm(n,γ)
33. ^{205}Tl(n,γ)
34. ^{198}Hg(n,γ)
35. ^{204}Hg(n,γ)
36. ^{205}Pb(n,γ)
37. ^{22}Na(n,p)
38. ^{36}Cl(n,p)
39. ^{46}Ti(n,p)
40. ^{48}Ti(n,p)
41. ^{95}Mo(n,p)
42. ^{180}Hf(n,p)
43. ^{46}Ti(n,2n)
44. ^{166}Er(n,2n)
45. ^{46}Ti(n,α)
46. ^{89}Y(n,α)
47. ^{206}Pb(n,α)

Summary

① List of reactions established based on Forrest's and Kopecky's works for TENDL-2014,

② From Forrest's publications: 10 possible reactions (based on differential cross sections),

③ From Kopecky's validation: at least 37 reactions can be improved (based on integral activation measurements),

④ Based on available funds and amount of work (per reactions), some of these reactions can be improved for the next release of the TENDL library.