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RRR for minor actinides in TENDL-2021

INDEN Consultancy Meeting on actinide evaluations in the RRR/URR,
IAEA virtual meeting, November 1st - 4th, 2021

Zertifiziertes Managementsystem
STARS
ISO 9001

Summary

- Overview of TENDL for RRR/URR
- Comparison of libraries for RRR and some minor actinides
- Conclusion

Overview of TENDL in RRR/URR

- New T6:
  - Newest code versions,
  - more verifications,
  - Linux RedHat/Mac,
  - tested with latest compilers

- TENDL-2021 Beta version available (https://tendl.web.psi.ch/tendl_2021/tendl2021.html)

- Similar structure as the previous TENDL libraries
  - 2813 isotopes, 200 MeV, with covariances (t1/2> 1sec)
  - Neutrons, protons, deuterons, tritons, He3, alphas, and gammas
  - PENDF, ACE, HDF5, GNDS/Xml
  - ENDF-6 files in different options (MF3 MT5 at 0, 20 or 60 MeV)
  - EAF files
  - MF32 and/or MF33
  - Input files
  - Random files

Overview of TENDL in RRR/URR

- TARES-1.4: resonance formatting and analyzing tool

- Measured/compiled/evaluated resonances:
  - Based on latest JENDL-4.0, ENDF/B-VIII.0 and JEFF-3.3
  - Based on the latest Atlas, 6th edition (2018)
  - Based on the Sukhoruchkin 2009 and 2015

- Statistical resonances:
  - Based on CALENDF
  - Translating the unresolved range from TALYS into statistically resolved range
  - Consistency between the RRR, URR and fast range

- Covariances in MF32 and MF33
  - Consistency between both format
  - Consistent with the random files (using the ENDSAM from IJS)

TENDL for minor actinides

TENDL-2021 Nuclear data library

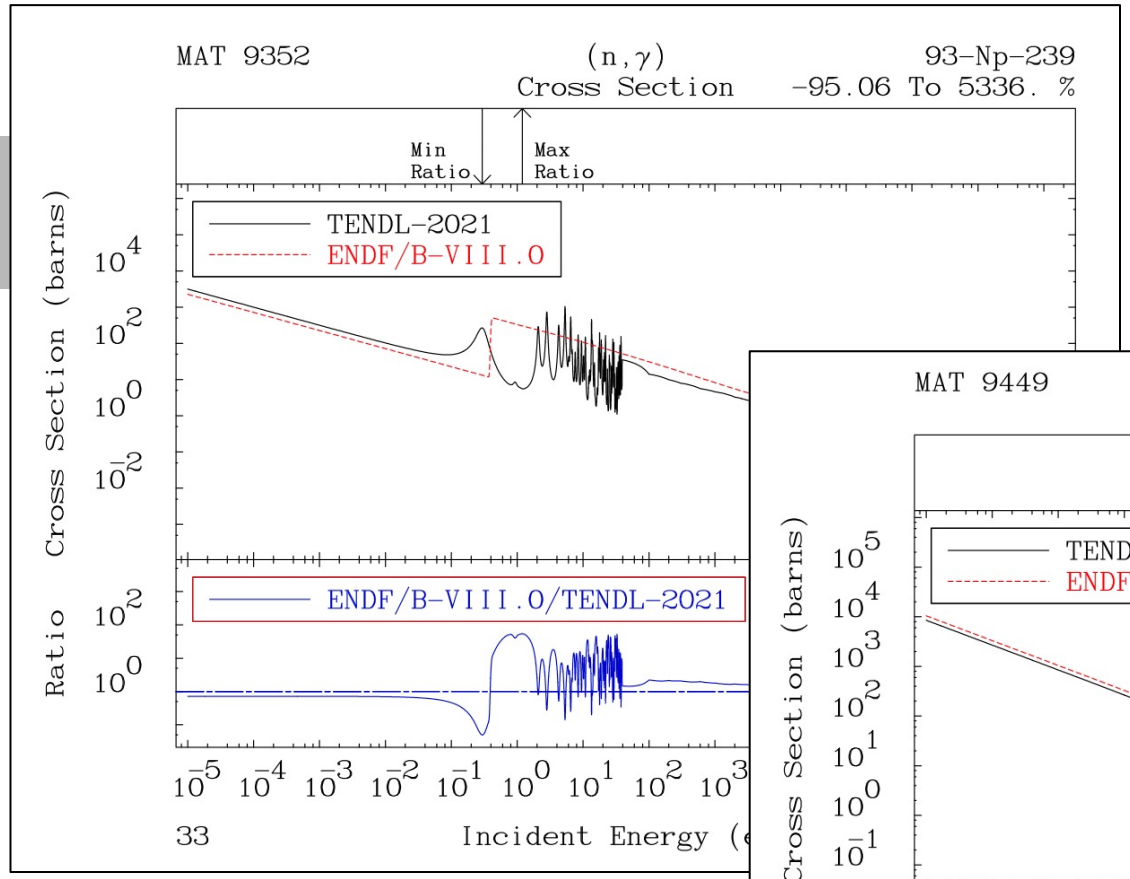
Neutron sub-library

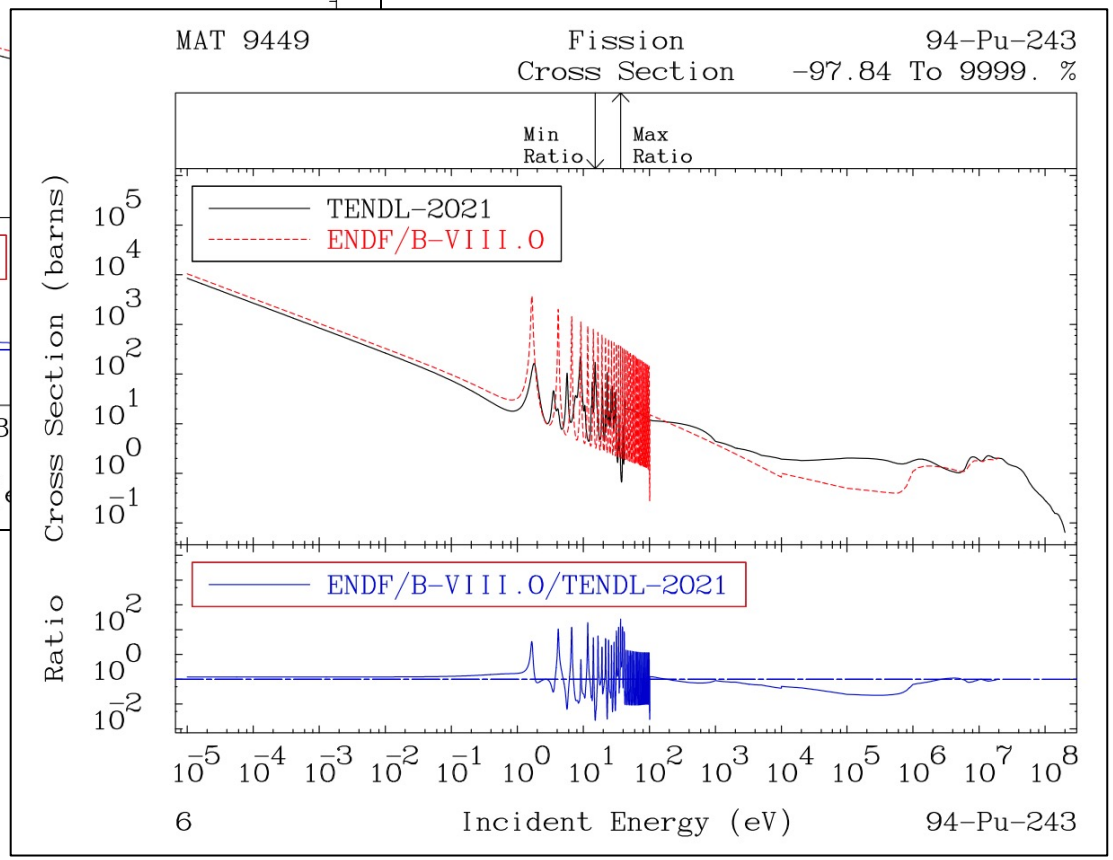
Group #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period																		
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	**	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Uus	118 Uuo
* Lanthanoids			57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
** Actinoids			89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

- From Ac (Z=88) to Mc (Z=115): 448 isotopes
- All unique RRR/URR
- Including adjusted TALYS parameters (impacting the statistical RRR/URR)

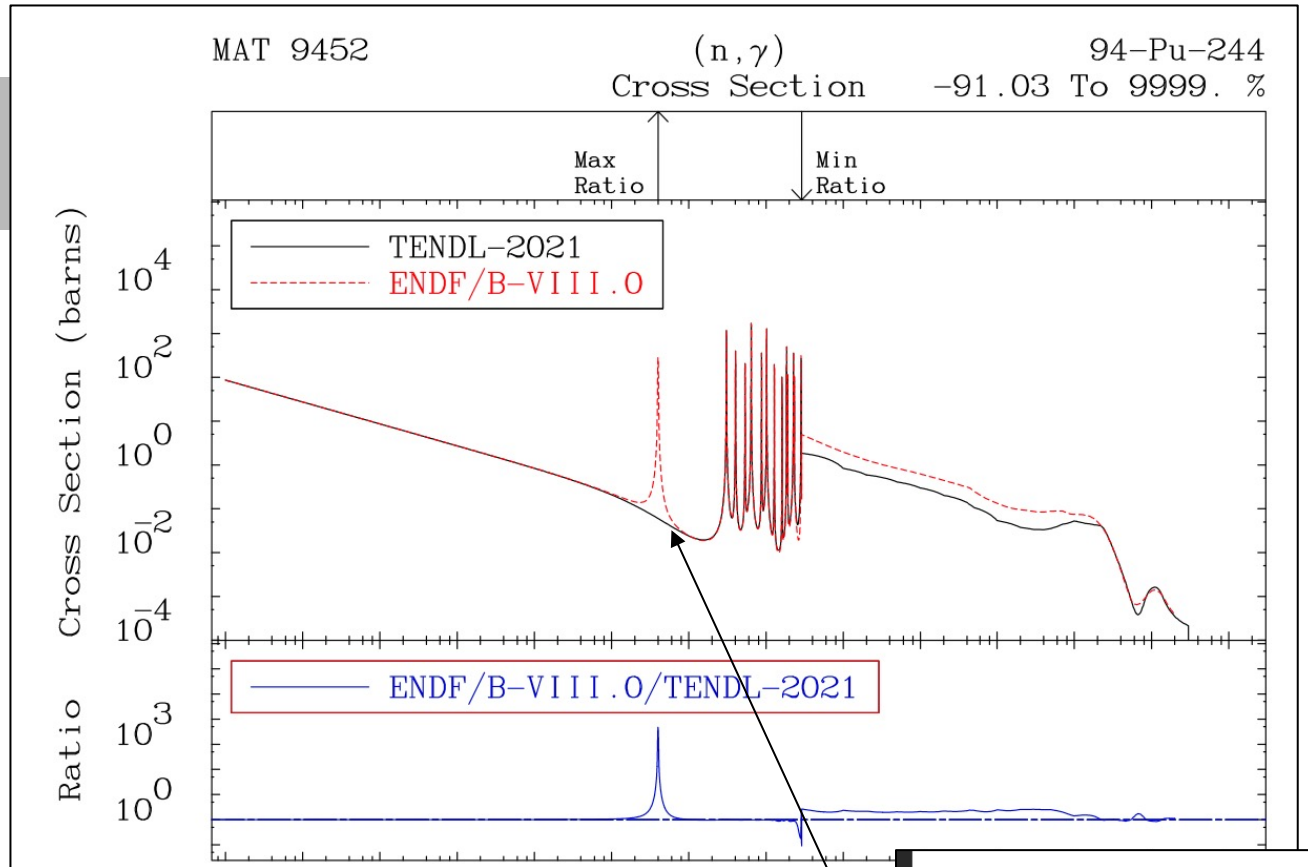
- JEFF-3.3: 95 isotopes
- JENDL-4.0: 82 isotopes
- ENDF/B-VIII.0: 90 isotopes

TENDL for minor actinides: no measured RRR





TENDL for minor actinides: measured RRR



Atlas-2018

I^{π} = 0+

σ_γ(+) = 0.26 b

σ_γ(B) = 1.45 b

E_0 (eV)	J	l	$g\Gamma_n$ (meV)	Γ_γ (meV)	$g\Gamma_n^0$ (meV)
-6	1/2	0		(20)	0.636
a-4	1/2	0		(20)	0.0135
30.7±0.1	1/2	[0]	2.17±0.08	(20)	0.39 ±0.02
40.3±0.1	1/2	[0]	1.04±0.05	(20)	0.162 ±0.009

Neutron Resonance Parameters for Pu-244 (Plutonium) 2

$I_o^{\pi} = 0^+$ $T_{1/2} = 8.00(9) \cdot 10^7$ y $S_n = 4699(13)$ keV

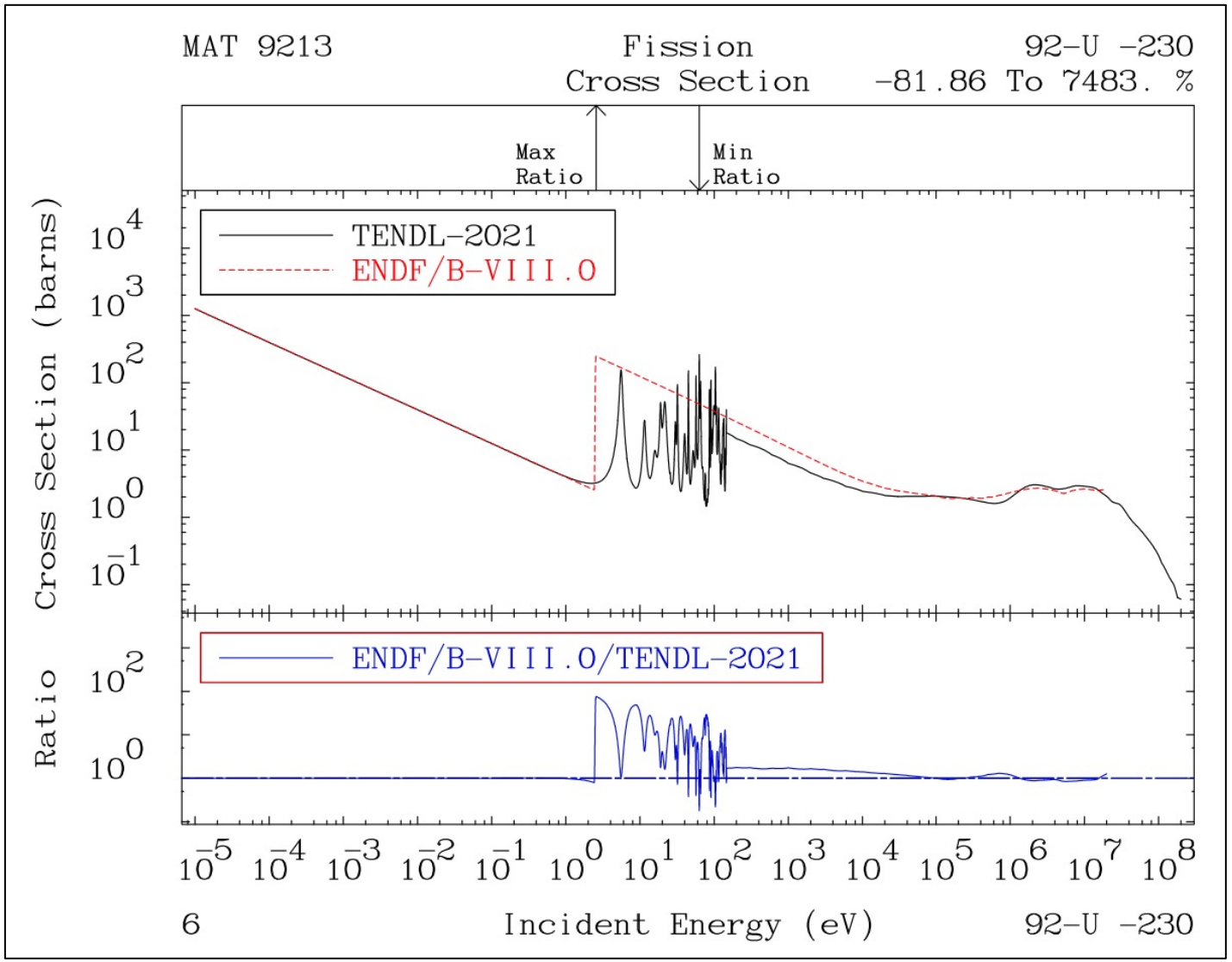
Sukhoruchkin 2015 $^{244}_{94}$Pu

$\sigma_\gamma = 1.71(10)$ b $RI_\gamma = 48(21)$ b $\sigma_f = 1.715$ mb $RI_f = 4.9(6)$ b

$\sigma_{\gamma\,30\,keV} = 0.33(11)$ b $\sigma_{f\,30\,keV} = 8.725$ mb

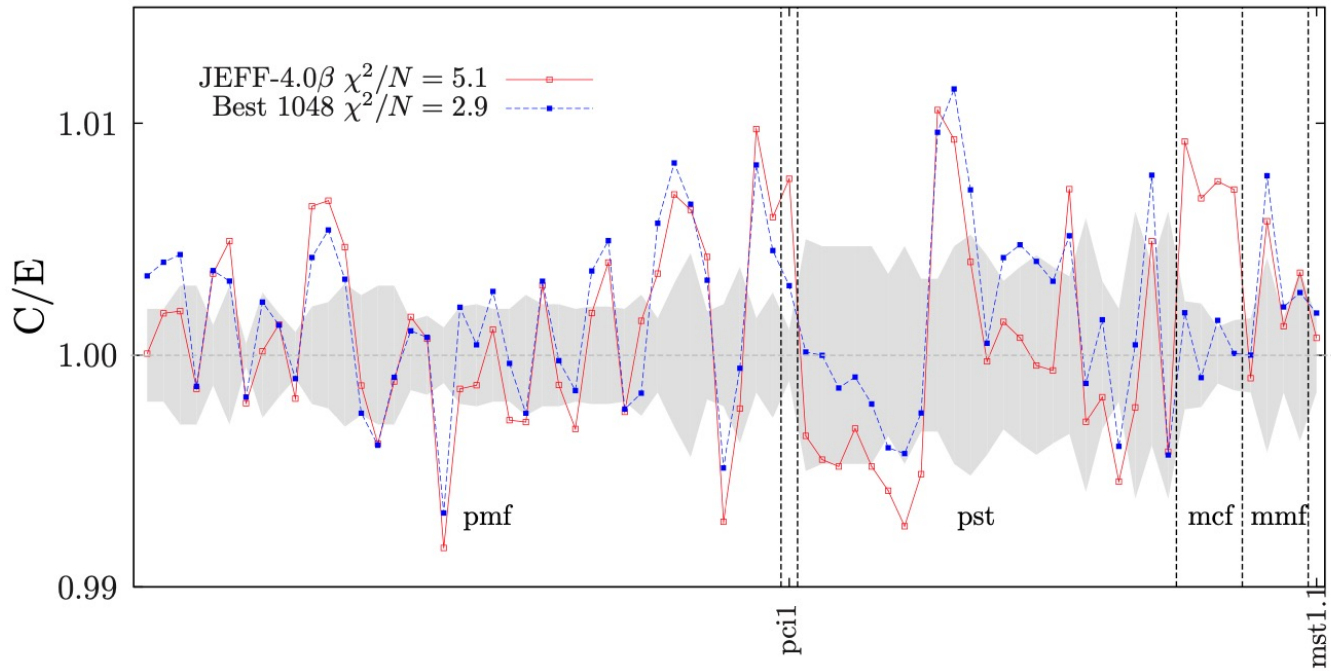
E_o [eV]	J	ℓ	$g\Gamma_n$ [meV]	$g\Gamma_n^0$ [meV]	Γ_γ [meV]	$\sigma\cdot\Gamma_\gamma$ [b·eV]	$\sigma\cdot\Gamma_f$ [b·eV]	$g\Gamma_n\Gamma_f/\Gamma$ [meV]	$g\Gamma_n\Gamma_\gamma/\Gamma$ [meV]	E^* [keV]	Ref.
-6	⟨1/2⟩	⟨0⟩		0.636	⟨20⟩					4773.89	06MuZX
4.0	⟨1/2⟩	⟨0⟩	0.026	0.0135	⟨20⟩					4772.90	06MuZX
30.7(1)	⟨1/2⟩	⟨0⟩	2.2(1)	0.397(18)	⟨20⟩	166(6)			1.95(7)	4772.93	71Au06 84MuZY 06MuZX
40.3(1)	⟨1/2⟩	⟨0⟩	1.03(6)	0.162(9)	⟨20⟩	64(3)			0.99(5)	4772.94	71Au06 84MuZY 06MuZX

TENDL for minor actinides: measured thermal (n,f)



TENDL for minor actinides

- In TENDL, a number of minor actinides is already available, but not “perfect”
- As for JEFF-4.0beta, we can include any RRR in a TENDL file, following your advice.
- Last point related to the past discussion: random RRR parameters and benchmarking for Pu239



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Wir schaffen Wissen – heute für morgen