Update of Zirconium Evaluations for JEFF-3.2(beta)

G. Noguere, D. Bernard and A. Santamarina

CEA Cadarache, 13108 Saint Paul Les Durance, France

D. Bernard et al., JEF/DOC-1226, « Needs for Zr and O16 cross-section Improvements »

Overestimation of the capture resonance integral of the natural zirconium in JEFF-3.1

Natural Zr ⇒ ^{90}Zr (51.45%), ^{91}Zr (11.22%), ^{92}Zr(17.15%), ^{94}Zr(17.38%), ^{96}Zr(2.8%)

Corrections for JEFF-3.2β :

☒ **^{91}Zr** ⇒ new parameters for the resonance at 292.4 eV

☒ **^{96}Zr** ⇒ new parameters for the resonance at 301.1 eV

These two modifications lead to :

Decrease of the thermal capture cross section + capture resonance integral of the natural element in accordance with the value recommended in the « Atlas of Neutron Resonances »

Zr evaluations produced by WPEC SG23

JEFF-3.1 ⇒ JENDL-3.3 without improved description of the Resolved Resonance Range

WPEC Subgroup 23

Creation of International Library of Neutron Cross-Section Evaluations for the Bulk of Fission Products

SG23 Library Identification: International Fission Product Library (IFPL), NLIB=21 (NLIB assigned by A. Mengoni, IAEA, August 9, 2005).

SG23 Membership: 5 projects, 14 members

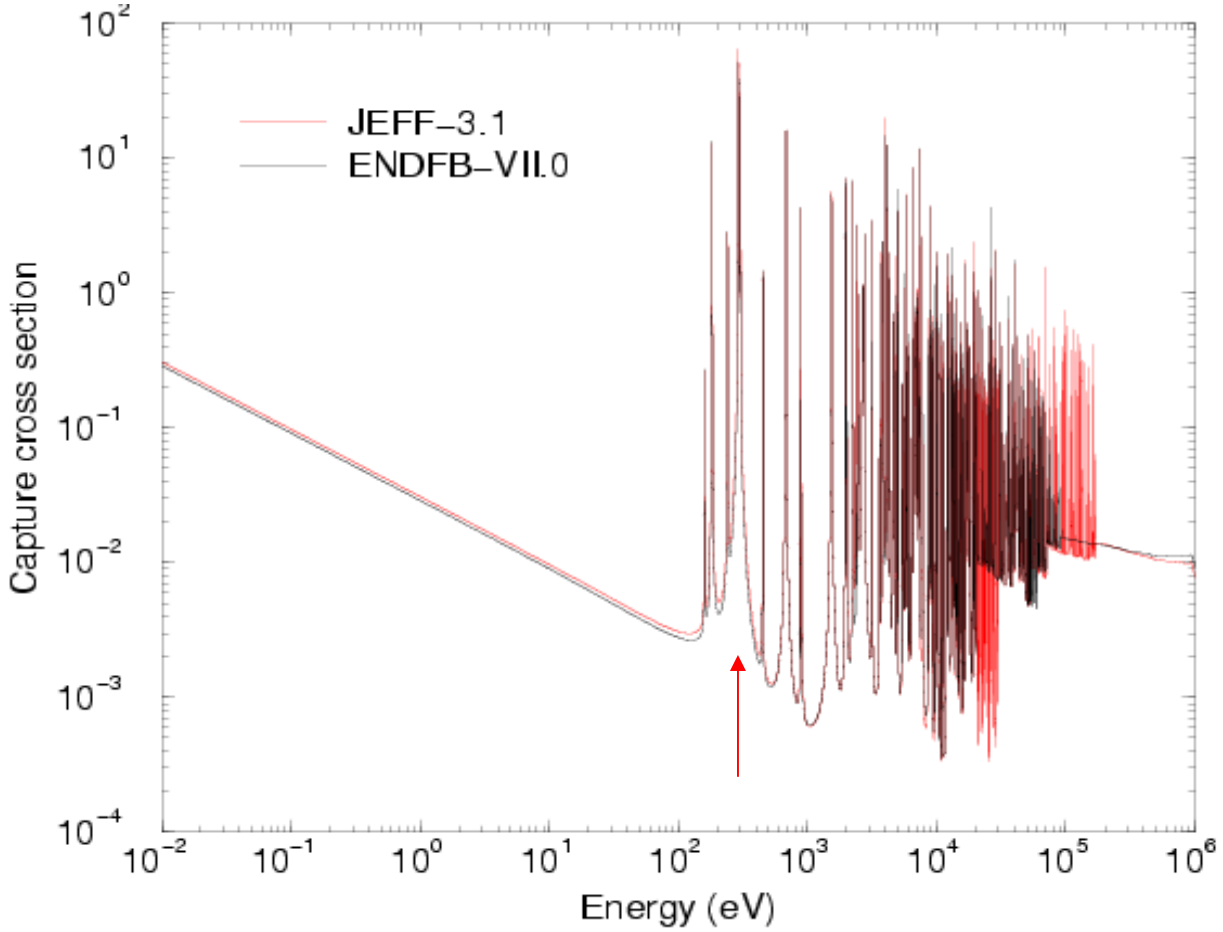
Chairman	P. Oblozinsky (ENDF project)
Monitor	R. Jacqmin (JEFF project)
ENDF	C. Dunford (BNL), M. Herman (BNL), S. Mughabghab (BNL), M. Dunn (ORNL)
JEFF	C. Dean (Winfrith), A. Trkov (IAEA)
JENDL	T. Nakagawa (JAERI), K. Shibata (JAERI)
BROND	V. Pronyaev (IPPE Obninsk), A.V. Ignatyuk (IPPE Obninsk)
CENDL	Ge Zhigang (CNDC), Chen Guochang (CNDC)

Library partial (March - August 2005) ⇒ ENDF\B-VII.0
Zr-90 : resonance parameters from BROND + new evaluation with EMPIRE
Zr-91, 92, 94, 96 : resonance parameters from "Atlas of Neutron Resonances" + JENDL-3.3

SG23 Library complete (January 2006) ⇒ used in this work for **JEFF-3.2beta**

See NNDC web site : http://www.nndc.bnl.gov/sg23/

Capture cross section of natural Zr …



- **Zr-91** ⇒ loss of neutrons heavily influenced by neutron capture by the **292.4 eV** resonance
- **Zr-96** ⇒ Even though the Zr-96 isotope is present to only 2.8% in natural Zr, capture in the **301.1 eV** resonance is also important.

History …

Problem with spin attribution

inconsitent radiation width (JEF-2.2)

	Zr-91					Zr-96			
Author	E_0	J^π	Γ_γ	Γ_n	$g\Gamma_n$	E_0	Γ_γ	Γ_n	A_γ
Lopez (1968)	292	3^+	120±30	635±40	370±23				
Bartolome (1969)		3^+	180±30	570±70	332±41				
Morgenstern (1969)	292.37	3^+	100±50	670±30	391±17				
Rimawi (1969)	292.0±0.3	2^+	150±30	762±48	317±20	302±1	250±20	190±30	108±21
Macklin (1977)	292.36	2^+	86.8±2.2	866±11	361±5				
Musgrove (1977)	292.7	2^+	87	766±20	319±8				
Brusegan (1978)	292.41	3^+	121±14	612±6	357±4				
Coceva (1979)		3^+		634±17		301.1±0.3	258±15	215±23	117±8
Salah (1985)	292.4±0.1	3^+	131±10	665±5	388±3	301.14±0.1	285±38	223±7	125±19
Leinweber (2000)	292.5±0.1	3^+	125.9±2.1	645.0±2.2	376.2±1.3	301.1±0.1	143.3±7.0	221.6±2.7	87±5
JEFF-3.1	292.41	3^+	170.0	634.3	370.0	301.1	285.0	223.0	125.1

J=3
solved by A. Brusegan
and confirmed by Salah

Inconsistent with measured capture resonance integral of 511±7 meV
(Cf. « Atlas of Neutron Resonances »)

JEFF-3.1 ⇒ Γ_γ values too high

Longstanding problem around 300 eV …

☒ Problem with the resonance shape analysis of the doublet (^{91}Zr+ ^{96}Zr)

☒ Last measurements give inconsistent sets of resonance parameters

☒ Coceva (1979)

⇒ new analysis of the data reported by A. Brusegan (IRMM) with data reported by Musgrove (Harwell) suggests to increase the Zr-91 neutron width value to 634±17 meV (old value = 612 ± 6 meV)

☒ Salah (1985)

⇒ problems with isotopic composition of natural Zr sample

⇒ Zr-91 content was taken to 11.32%, representative isotopic composition is 11.22(5)%

⇒ Zr-96 content was taken to 2.46%, representative isotopic composition is 2.80(9)%

☒ Leinweber (2000)

⇒ gives a Zr-96 radiation width lower than previous results

⇒ problems with the capture detector efficiency for Zr-96 (hard gamma-ray spectrum)

⇒ REFIT calculations performed with an effective abundance (8% lower)

⇒ problems with resolution function (“bounce target”) ?

Parameters for JEFF-3.2beta …

Zr-91

average value of results found in the litterature

<Γγ> = 129 ± 8 meV <Γn> = 637 ± 4 meV

suggests to decrease the radiation width in JEFF-3.1 (Γγ = 170 meV)

Mughabghab recommend RPI results

Zr-96

average value of results found in the littérature

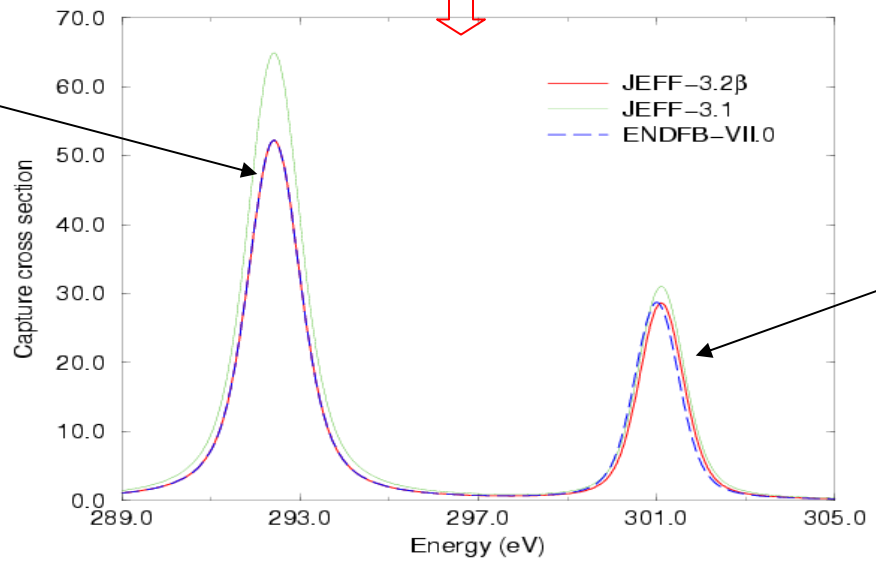
<Aγ> = 109 ± 8 meV **<Γn> = 212 ± 7 meV**

correction of Salah results for the Zr-96 content gives <Aγ> ≅ 109 meV

average radiation width from <Aγ> and <Γn> is close to **<Γγ> ≅ 225 meV**

JEFF-3.2beta = « Atlas of Neutron Resonance »

Γγ = 126 ± 10 meV
Γn = 642.8 ± 7.3 meV



Γγ = 223 ± 7 meV
Γn = 215.0 ± 2.5 meV

Capture resonance integral for JEFF-3.2beta ⇒ decreased by 10%

Thermal cross section

Often used to accommodate σ_0 of natural Zr
!!! **Zr-90** thermal capture cross section could have non-negligible impact on integral trends

		A=90 (51.45 %)	A=91 (11.22 %)	A=92 (17.15 %)	A=94 (17.38 %)	A=96 (2.8 %)	natural element
ENDF\B-VII	total	5.59	10.62	7.38	8.71	5.76	7.01
	elastic	5.51	9.79	7.14	8.66	5.74	6.83
	capture	0.078	0.83	0.23	0.0499	0.0228	0.182
	I_0	0.19	5.88	0.70	0.32	5.16	1.08
JEFF-3.1	total	5.41	11.89	7.38	6.23	6.18	6.64
	elastic	5.39	10.64	7.15	6.18	6.16	6.44
	capture	0.011	1.25	0.23	0.0498	0.0228	0.194
	I_0	0.17	6.93	0.70	0.31	5.86	1.20
JEFF-3.2beta	total	5.41	**11.84**	7.38	6.23	**6.18**	**6.63**
	elastic	5.39	**10.64**	7.15	6.18	**6.16**	**6.44**
	capture	0.011	**1.20**	0.23	0.0498	**0.0228**	**0.189**
	I_0	0.17	**6.10**	0.70	0.31	**5.15**	**1.09**
Atlas 2006	elastic	5.3 ± 0.3	10.7 ± 0.6	7.02 ± 0.39	8.59 ± 0.41	6.6 ± 0.4	6.40 ± 0.04
	capture	0.077 ± 0.016	0.83 ± 0.08	0.26 ± 0.08	0.0494 ± 0.0017	0.0229 ± 0.0010	0.185 ± 0.003
	I_0	0.17 ± 0.02	5.76 ± 0.40	0.64	0.28 ± 0.01	5.28 ± 0.11	1.10 ± 0.15
Prelim. **Mughanghab Private com. 2007**	elastic						
	capture	0.014 ± 0.006	1.3 ± 0.1	0.14 ± 0.08	0.0494 ± 0.0017	0.0229 ± 0.001	0.186 ± 0.003
	Io						

Lower limit for σ_0 of **Zr-91** reported by Nakamura et al. (2007) $\Rightarrow$ σ0 = 130 mbarns

Accurate thermal capture cross section for **natural Zr** reported by Lone (1981)

Good agreement between JEFF-3.2beta and new (prelim.) recommended values

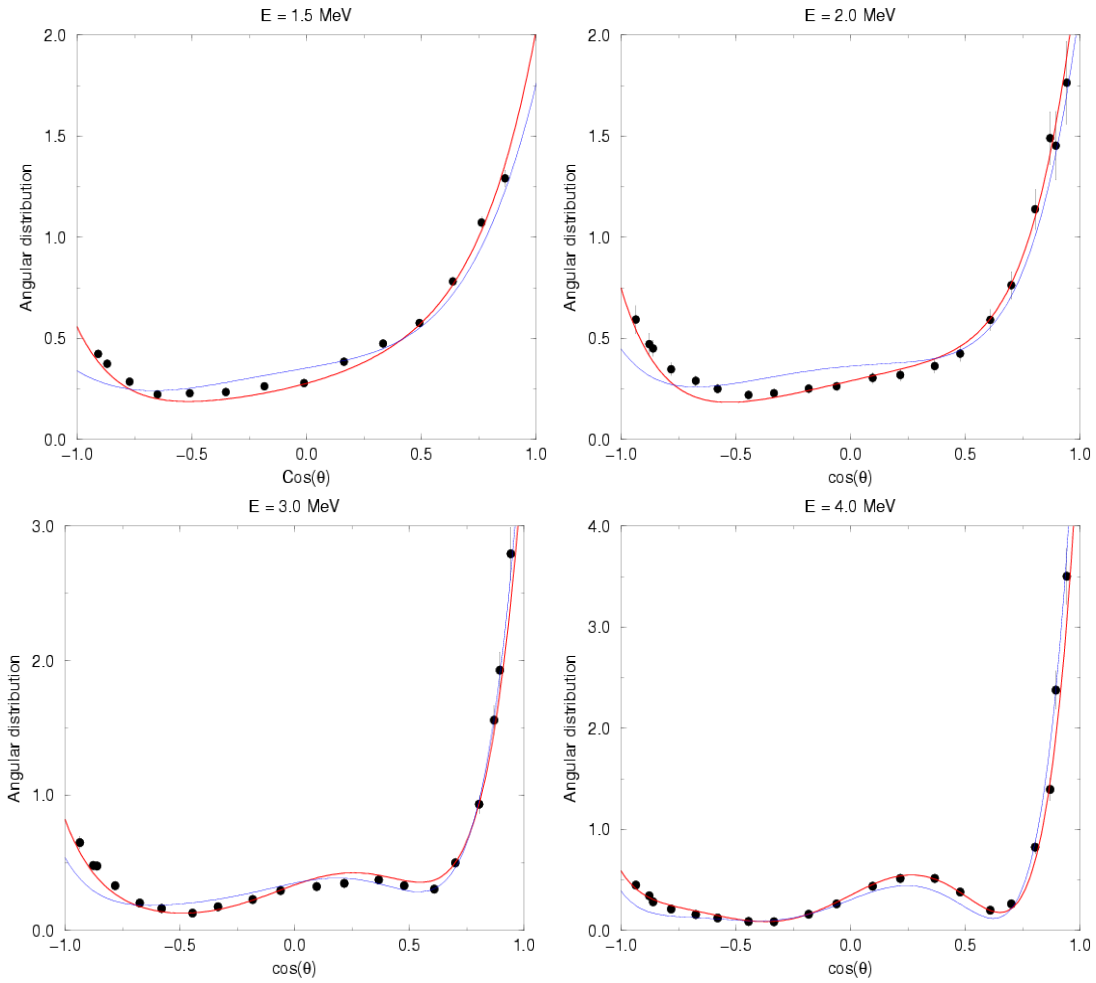
Last problem …

ENDF\B-VII.0 (blue curve)

New evaluation ⇒ available experimental data were interpreted using nuclear reaction model code EMPIRE by M. Herman et al.

JEFF-3.1 (red curve)

Japanese evaluation ⇒ better agreement with experimental data



^{90}Zr available in JEFF-3.1 is better than new evaluation produced for ENDF\B-VII.0

Conclusions

HPRL …
⇒ needs for high resolution total cross section of natural element

NUDAME …
⇒ transmission measurements at the IRMM (natural element)

New evaluation …
⇒ with capture data measured at the nTOF facility by Moreau et al (enriched samples)

Validation …
⇒ use the PEREN facility (LPSC, Grenoble)