DE LA RECHERCHE À L'INDUSTRIE

NEW EVALUATION OF THE RESOLVED AND UNRESOLVED RESONANCE RANGE OF PU239

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Outlines

Pu239 evaluation and its evolution
⇒ JEFF-31, ENDF\B-7.1 and JEFF-311

New Resolved Resonance Range WPEC\SG-34
⇒ SAMMY analysis below 2.5 keV (L. Leal)

Resonance-Parameters Covariance Matrix (RPCM)
⇒ CONRAD Marginalization

Investigation of the Unresolved Resonance Range [2.5 keV - 40 keV]
⇒ Use the URR option of TALYS

Investigation of the two-step (n,γf) process
⇒ CONRAD vs. AVXSF calculations

Study of the channel spin dependence of υ_p
⇒ See Eric Fort NSE 99, 375 (1988)

Benchmarking
⇒ ICSBEP, Mox fuel, Post Irradiated Experiments, …

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Pu239 evaluation and its evolution

Motivations for revising ^{239}Pu Resonance

•resonance range divided into three disjoint resonance parameter sets

•LSSF=0 in the unresolved resonance range

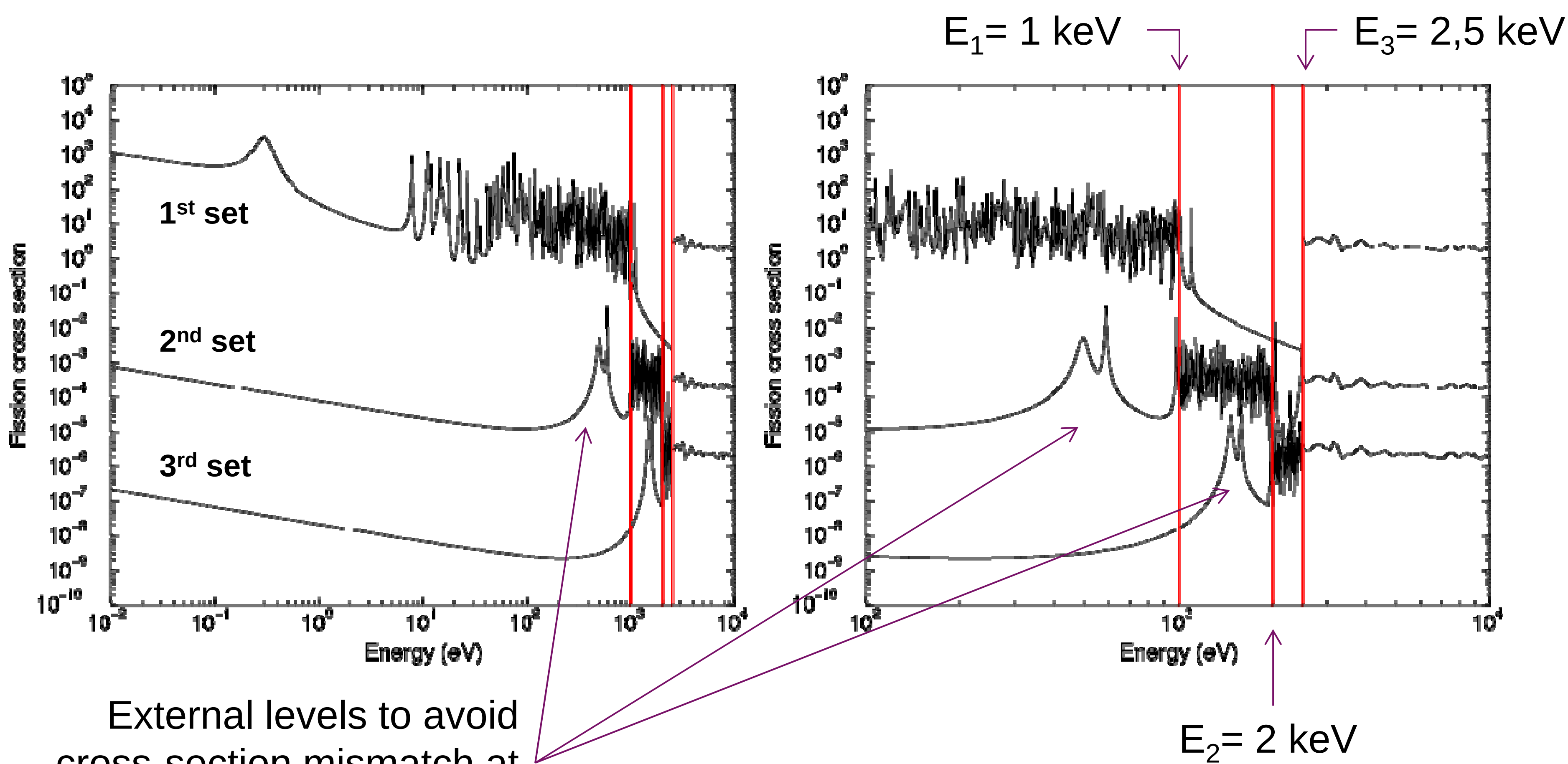
•cross section mismatch at the energy boundaries

•background cross section in the resolved resonance range

•no correlations between energy regions

Pu239 evaluation and its evolution

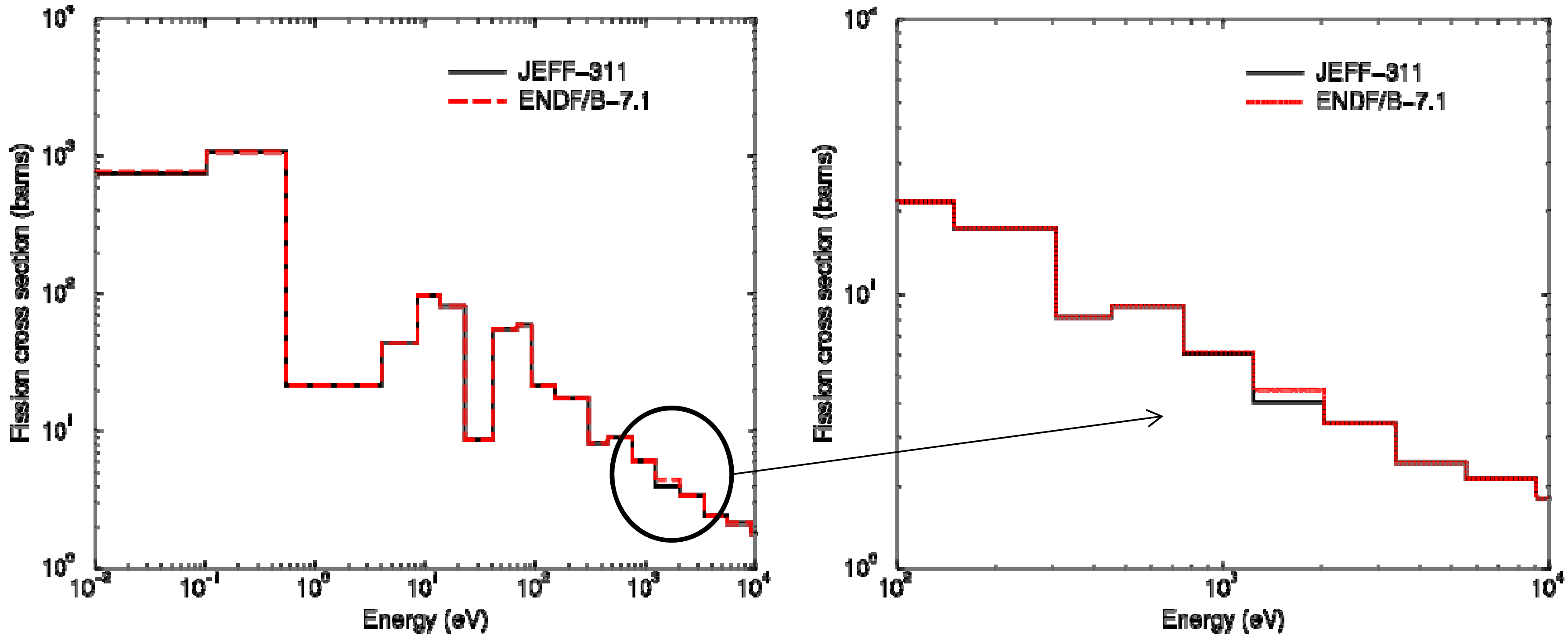
Resonance range divided into three disjoint resonance parameter sets (computer limitations)



External levels to avoid cross-section mismatch at the energy boundaries

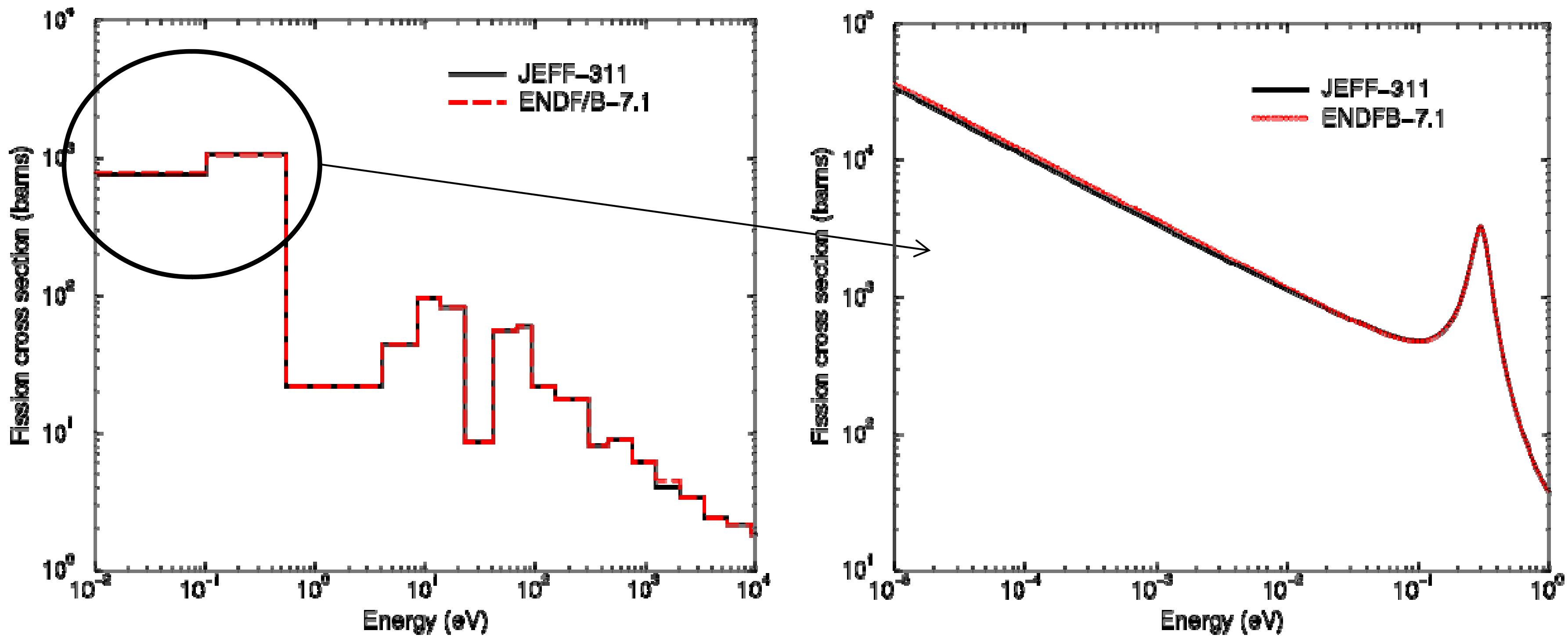
Pu239 evaluation and its evolution

Background cross section (for fission) not used in the resolved resonance range of JEFF-311



Pu239 evaluation and its evolution

Modification of α(Pu239) in JEFF-311 to improve the reactivity temperature coefficient (RTC) in EOLE experiments, cold conditions 20-80°C (JEF/DOC-1158)



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Coordinated evaluation of ^{239}Pu in the resonance region

WPEC Subgroup 34 (SG34)

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- SG34 proposal by R.D. McKnight and C. De Saint Jean, WPEC meeting, June 2009
- SG34 mailing list for questions, comments or to consult archives

Meetings

- NEA, Issy-les-Moulineaux, France, 2 June 2010
- NEA, Issy-les-Moulineaux, France, 21 May 2012

Test evaluation

- New resolved resonance parameters in ENDF format

Publications and documents

- L.C. Leal *et al.*, *^{239}Pu Resonance Evaluation for Thermal Benchmark System Calculations*, ND2013 contribution (Draft Feb. 2013).
- A.C. Kahler *et al.*, *Critical Eigenvalue Calculations of Selected ICSBEP Benchmarks with Various ^{239}Pu Evaluated Data Files*, WONDER 2012, Aix en Provence, France, September 25-28, 2012.

Related links

- WPEC Home Page

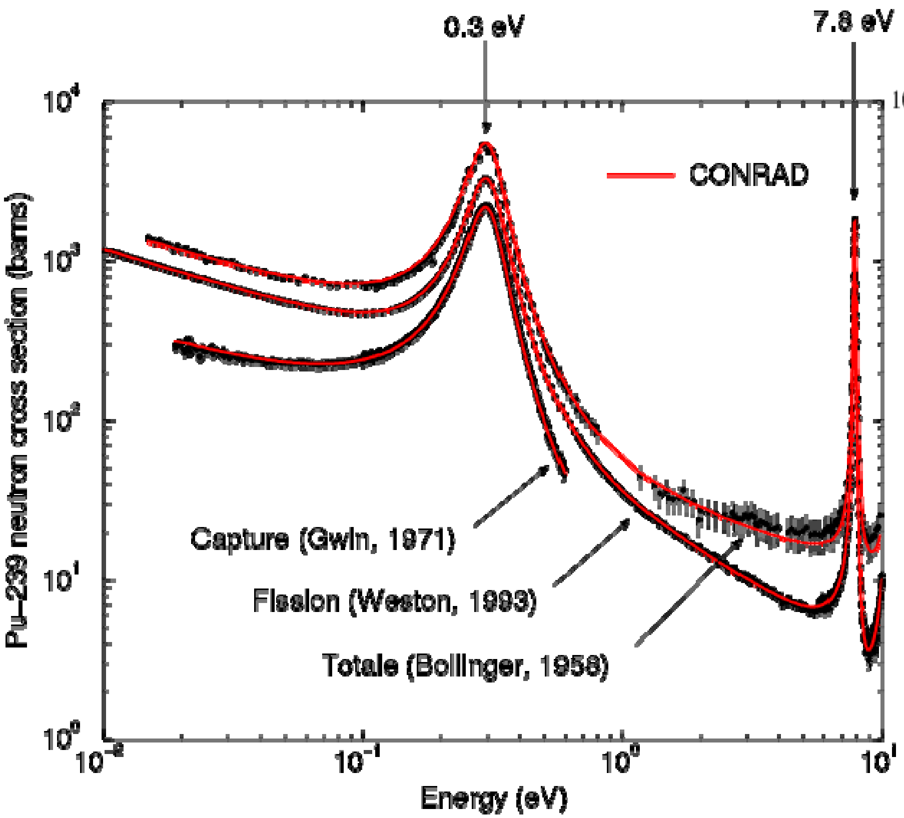
Co-ordinator: Cyrille De Saint Jean
NEA contact: Emmeric Dupont (wpec@oecd-nea.org)

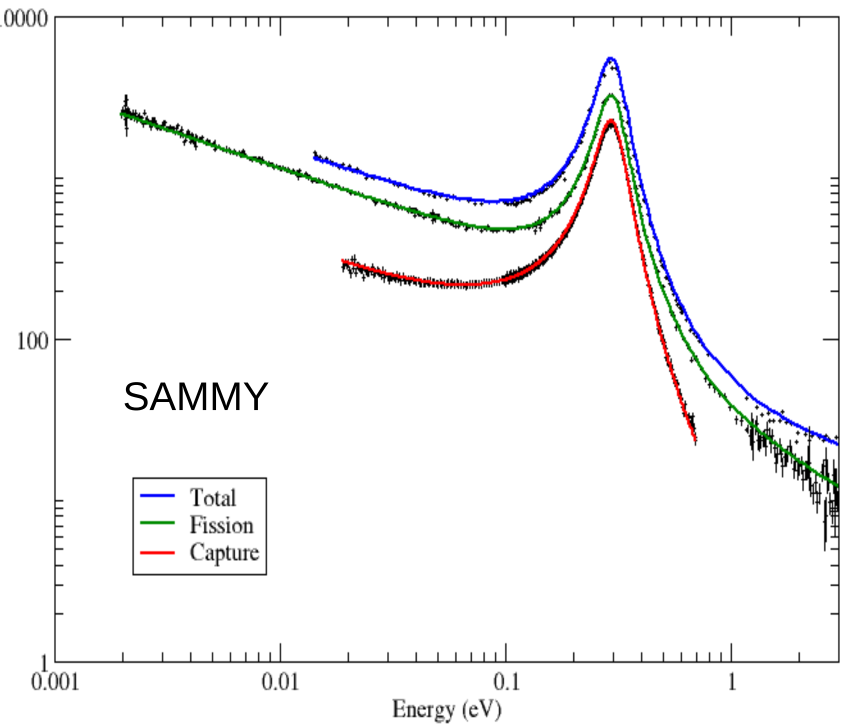
Experimental data base for the Neutron Resonance Shape Analysis for the SAMMY analysis (L. Leal)

Reference	Energy Range (eV)	Facility	Measurement
Bollinger et al. (1956)	0.01 – 1.0	Chopper	Total Cross Section
Gwin et al. (1971)	0.01 – 0.5	ORELA	Fission and Absorption at 25.6 m
Gwin et al. (1976)	1.0 – 100.0	ORELA	Fission and Absorption at 40.0 m
Gwin et al. (1984)	0.01 – 20.0	ORELA	Fission at 8 m
Weston et al. (1984)	9.0 – 2500.0	ORELA	Fission at 18.9 m
Weston et al. (1988)	100.0 – 2500.0	ORELA	Fission at 86 m
Weston et al. (1993)	0.02 – 40.0	ORELA	Fission at 18.9 m
Wagemans et al. (1988)	0.002 – 20.0	GELINA	Fission at 8 m
Wagemans et al. (1993)	0.01 – 1000.0	GELINA	Fission at 8 m
Harvey et al. (1985)	0.7 – 30.0	ORELA	Transmission at 18 m
Harvey et al. (1985)	30.0 – 2500.0	ORELA	Transmission at 80 m

New Resolved Resonance Range WPEC/SG-34

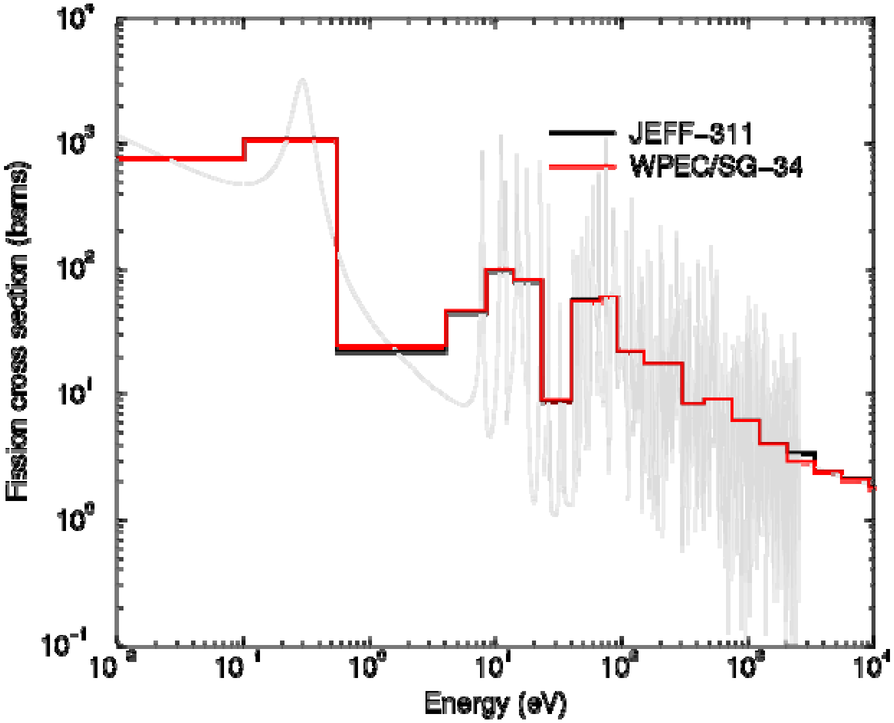
Cross-check of the resonance parameters (low energy) with the CONRAD and SAMMY codes

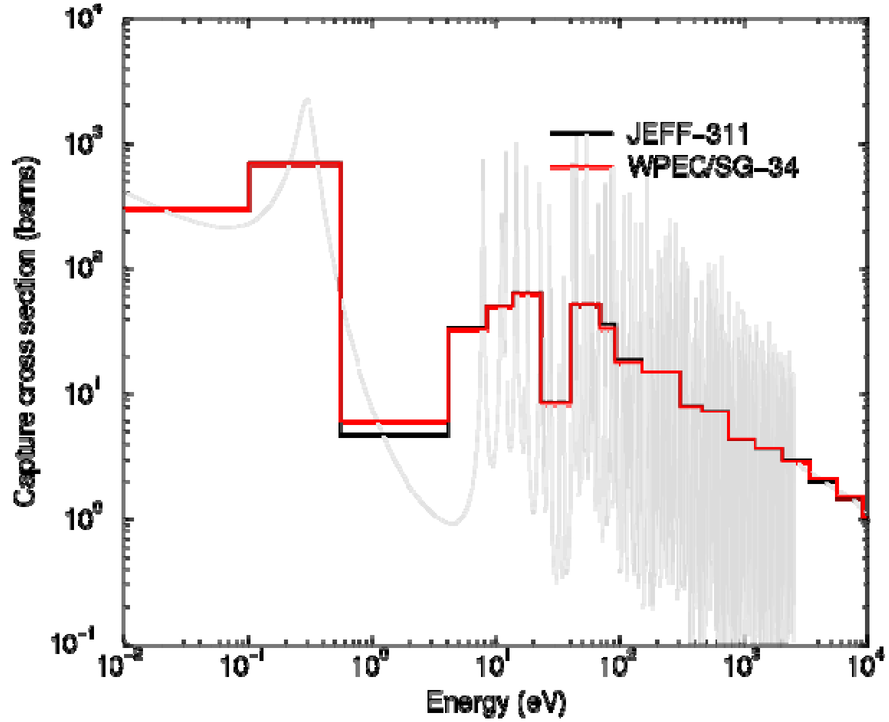




New Resolved Resonance Range WPEC/SG-34

Broad-group average cross-sections: good agreement with JEFF-311





New Resolved Resonance Range WPEC\SG-34

Thermal values and integral quantities calculated with SAMMY

Quantity	Atlas	ENDF/B-VII.1 (JEFF-3.1)	JEFF-311	WPEC/SG-34
σ_γ	269.3 ± 2.9	270.6	272.7	270.1
σ_f	748.1 ± 2.0	747.7	747.08	747.2
g_f	1.0553 ± 0.0013	1.054	1.050	1.052
g_a	1.077 ± 0.003	1.078	1.075	1.077
$\bar{\nu}$	2.879 ± 0.006	2.873	2.873	2.873
I_γ	180 ± 20	181.4	181.5	180.1
I_f	303 ± 10	302.6	303.6	309.1

Good agreement with the values compiled in the Atlas of Neutron Resonances

New Resolved Resonance Range WPEC\SG-34

Measurement of the K1 value in the MINERVE and DIMPLE reactor (oscillation technique)

Type of data		$K1=\upsilon\sigma_f-\sigma_a$
Compilation	Atlas	1177
Evaluation	ENDF/B-7.1	1166
	JEFF-311	1156
	WPEC/SG-34	1161
Experimental value	MINERVE/DIMPLE (CERES-Pu)	1185 ± 20

New Resolved Resonance Range WPEC\SG-34

Conclusions for RRR:

•New resonance parameters (E<2.5 keV) available on the WPEC/SG-34 web site

•Parameters were included in the latest European library JEFF-3.2

•New transmission measurement of the 1st resonance is needed

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Benchmarking
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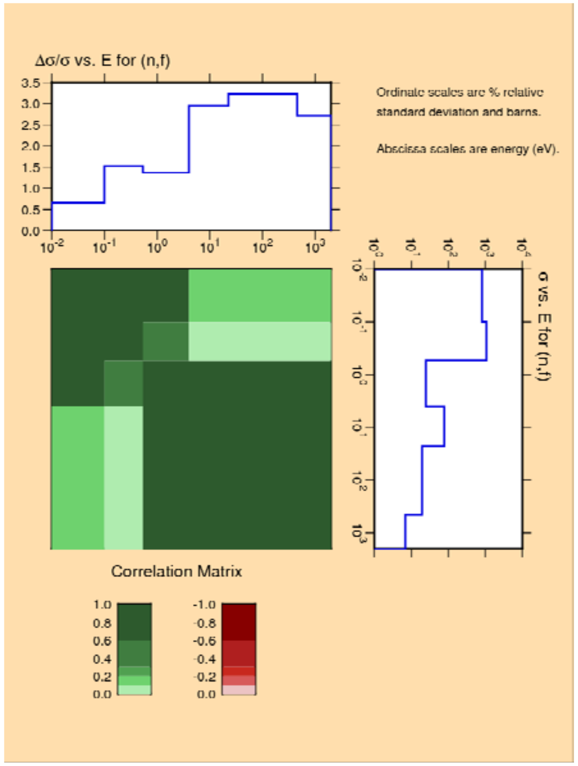
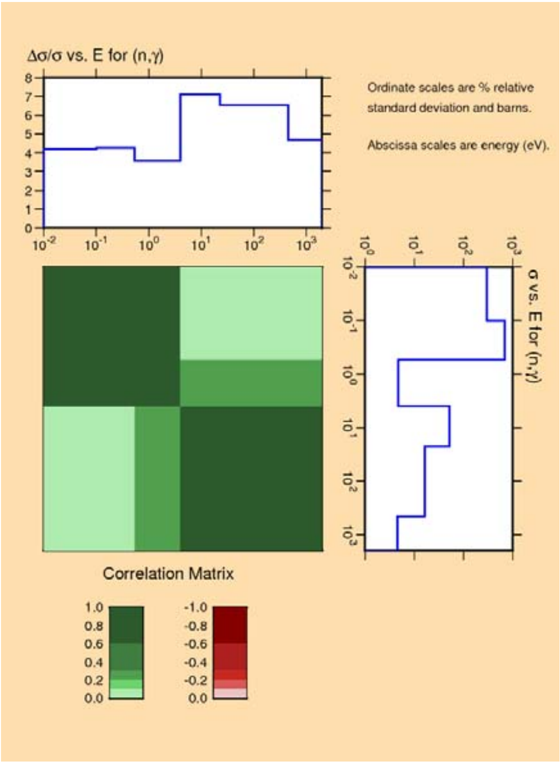
Resonance Parameter Covariance Matrix (RPCM)

Marginalization procedure (CONRAD code)

The RRR was divided in three energy range to account for the thermal cross section, the 1st resonance (0.3 eV) and the resonance integral (E>0.5 eV)





Resonance Parameter Covariance Matrix (RPCM)

Problems to store and process large RPCM

•neutron width selection was used to reduce the size of the RPCM

•selection is based on the truncated Porther-Thomas integral distribution

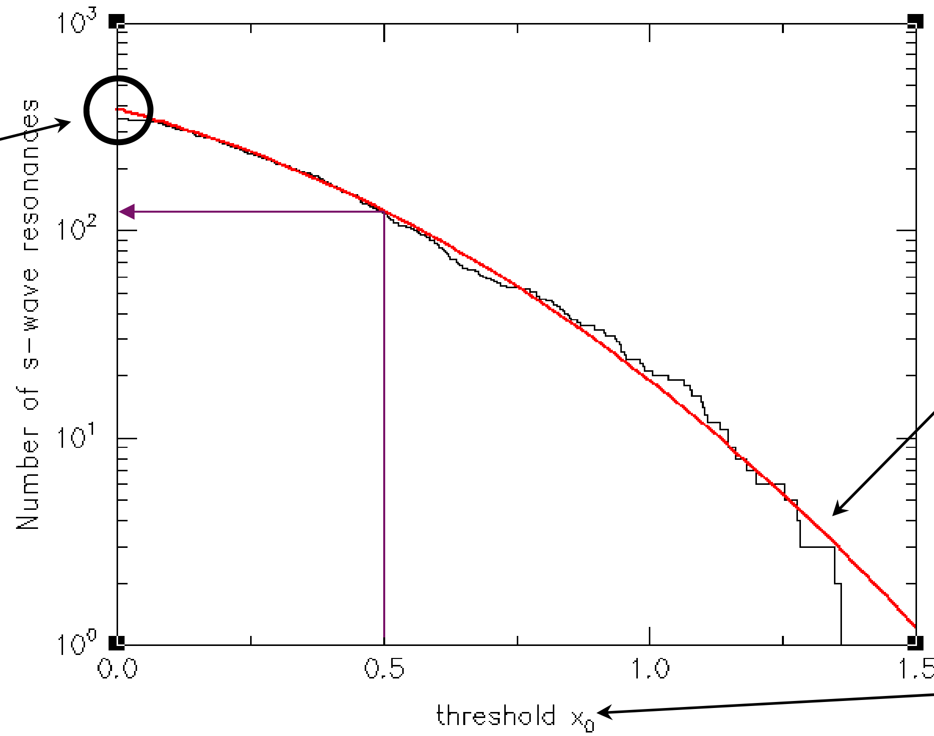
Resonance Parameter Covariance Matrix (RPCM)

Principle of the neutron width selection

•The number of s-wave resonances included in the marginalization procedure was selected according to the threshold x_0

•The threshold x_0 should satisfy the condition $\sigma_g(x_0=0)\approx\sigma_g(x_0>0)$

$$N=\frac{E_{max}-E_{min}}{D_0}+1$$



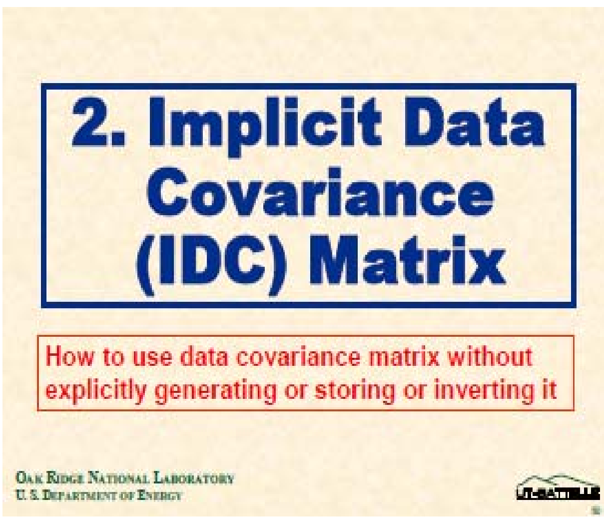
$$N(x_0)=N\ erfc\left(\sqrt{\frac{x_0}{2}}\right)$$

$$x_0=\frac{g_J\Gamma_n}{D_0S_0\sqrt{E_\lambda}}$$

Resonance Parameter Covariance Matrix (RPCM)

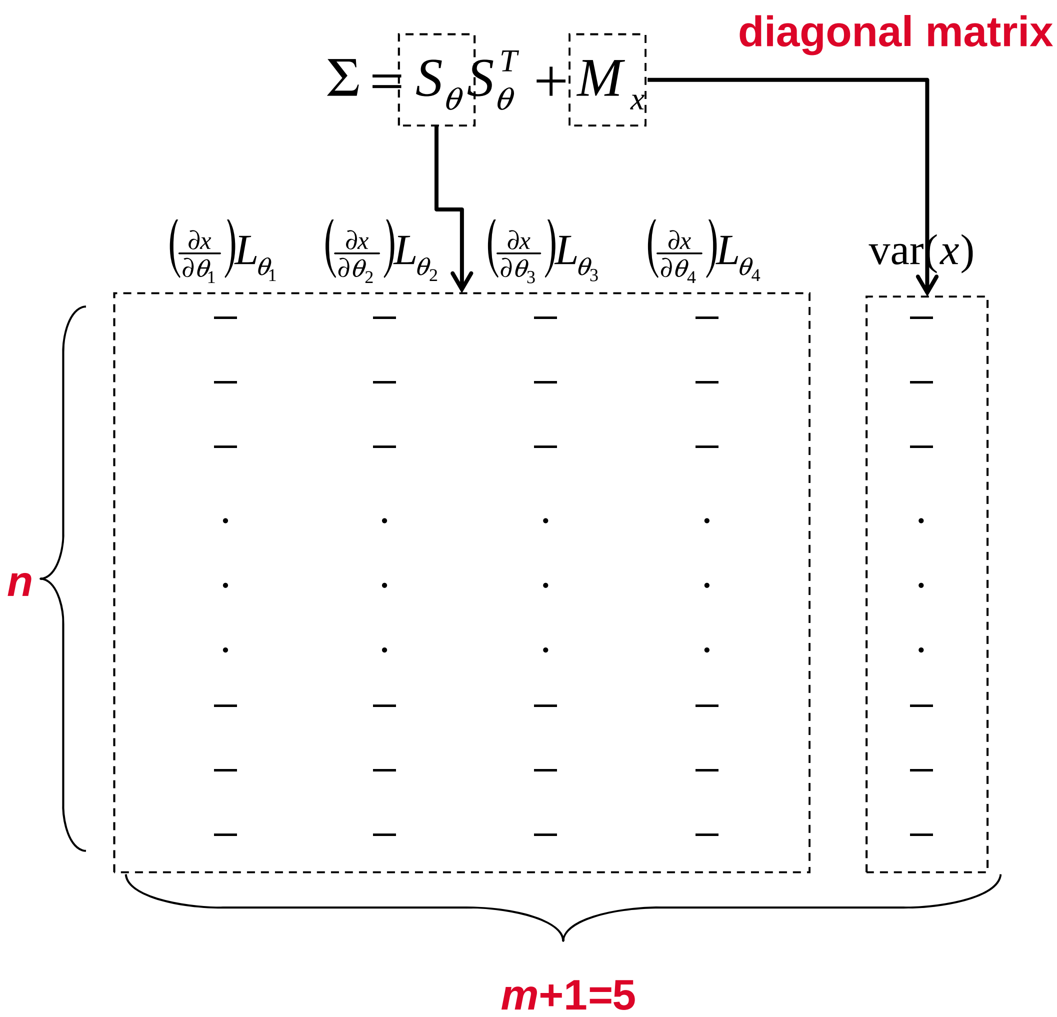
Solution to store and process large RPCM

The AGS format (or the IDC format of the SAMMY code) may provide a concise method for storing and communicating large Resonance Parameter Covariance Matrices



- Available in SAMMY and CONRAD to read AGS covariance file (used at the IRMM)
- Cf. WPEC/SG-36 «Evaluation of experimental data in the resolved resonance region»

Resonance Parameter Covariance Matrix (RPCM)



Resonance Parameter Covariance Matrix (RPCM)

Conclusions for RPCM:

•Resonance Parameter Covariance Matrix included in JEFF-3.2

•Use Implicit Data Covariance (or AGS) format to store large RPCM

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Unresolved Resonance Range

Long standing problem between CALENDF and NJOY

keff results obtained with TRIPOLI4+CALENDF and MCNP5+NJOY

Code system	**TRIPOLI4**+CALENDF	**MCNP5**+NJOY
with PT(^{239}Pu)	1.15688 (± 4 pcm)	1.15426 (± 4 pcm)
without PT(^{239}Pu)	1.15491 (±4 pcm)	1.15519 (± 4 pcm)
impact PT(^{239}Pu)	**- 150 pcm**	**+ 70 pcm**

The discrepancies due to the processing codes were solved in JEFF-32 by using LSSF=1

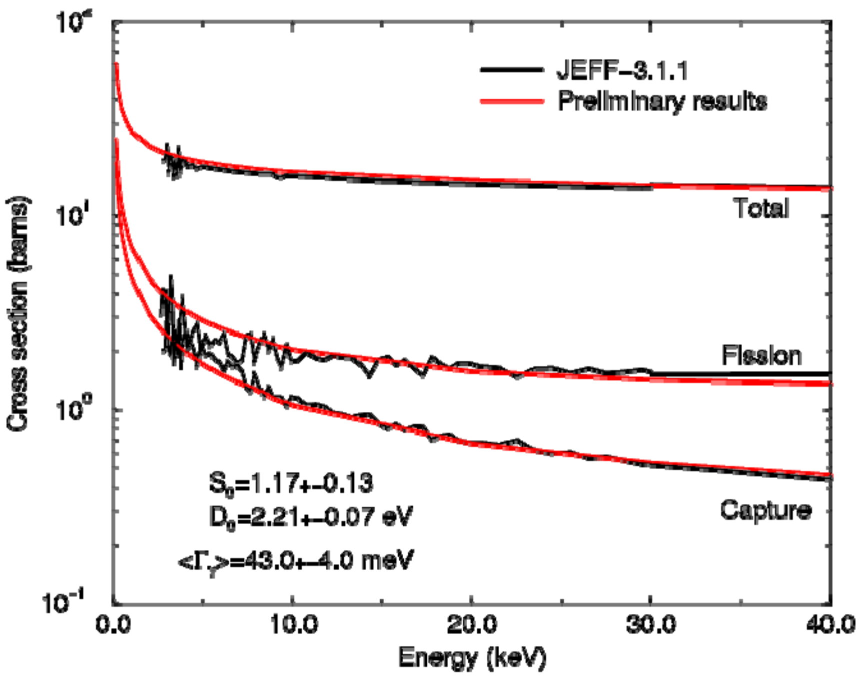
(See WPEC/SG32)

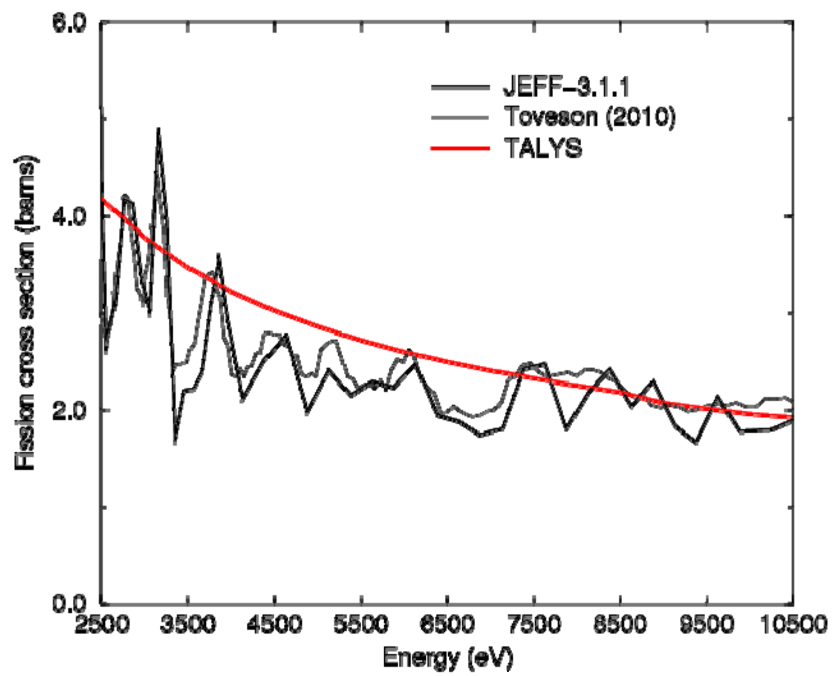
Unresolved Resonance Range

URR option of the TALYS code

•the URR option of the TALYS code was used to produce preliminary average cross sections (capture, fission, elastic, inélastic and total)

•The average resonance parameters (compound nucleus contribution) are calculated by TALYS (compatible with the URR formalism of NJOY)





Unresolved Resonance Range

Conclusions for URR:

•Improved URR model is needed to account for the structures observed in the fission cross section

•New measurement of the fission cross section is needed in the URR

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Investigation of the (n,γf) process

The observed fission is the sum of the « direct » fission and of the two-step (n,γf) reaction:

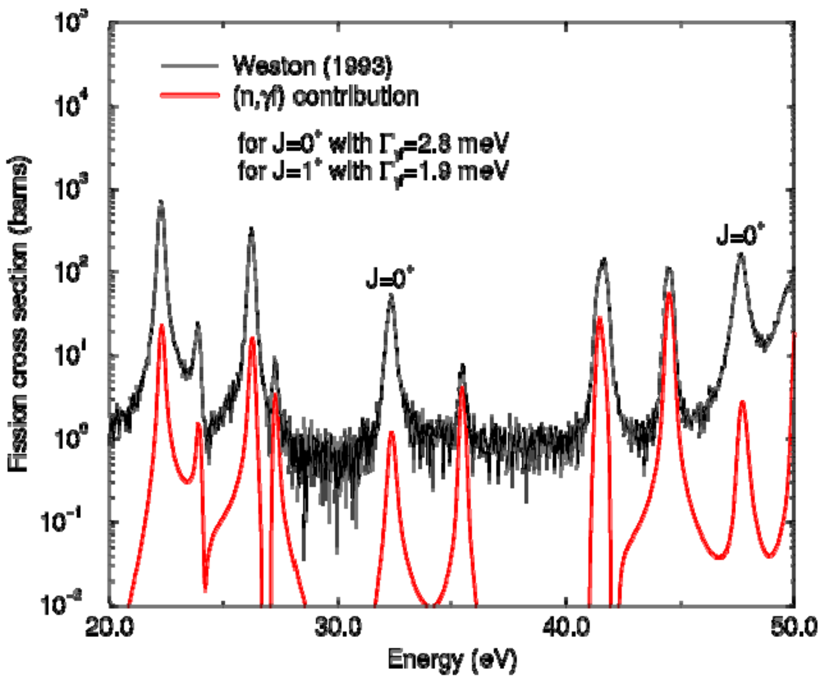
$$\sigma_{f,obs}(E)=\sigma_{(n,f)}(E)+\sigma_{(n,\gamma f)}(E)$$

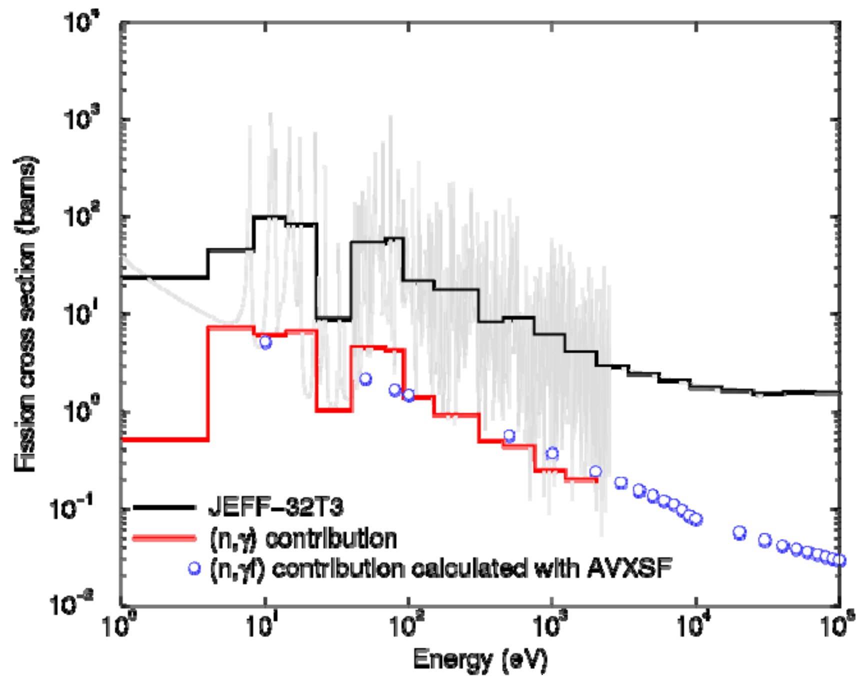
Channel widths for the direct fission (n,f) and for the two-step (n,γf) reaction

- Two openened fission channels for $J^{\pi}=0^{+} \Rightarrow \Gamma_{f1}(0^{+})$ and $\Gamma_{f2}(0^{+})$
- One openened fission channels for $J^{\pi}=1^{+} \Rightarrow \Gamma_{f}(1^{+})$
- Two J-dependent widths for the (n,γf) reaction $\Rightarrow \Gamma_{\gamma f}(0^{+})$ and $\Gamma_{\gamma f}(1^{+})$

Investigation of the (n,γf) process

Good agreement is obtained between the (n,γf) reaction deduced from the RRR and the AVXSF calculations (LANL/CEA collaboration)





The smallest resonances with $J^{\pi}=1^{+}$ are dominated by the (n,γf) process

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Neutron multiplicity

Channel widths for the direct fission (n,f) and for the two step (n,γf) reaction

- Two openened fission channels for $J^{\pi}=0^{+} \Rightarrow \Gamma_{f1}(0^{+})$ and $\Gamma_{f2}(0^{+})$ $\Rightarrow$ **$\Gamma_{f}(0^{+})$**
- One openened fission channels for $J^{\pi}=1^{+}$ $\Rightarrow$ **$\Gamma_{f}(1^{+})$**
- Two J-dependent widths for the (n,γf) reaction $\Rightarrow$ **$\Gamma_{\gamma f}(0^{+})$ and $\Gamma_{\gamma f}(1^{+})$**

Four partial widths are introduced in the phenomenological description of υ_p

$$\upsilon_p(E) \approx \sum_{i=1}^{4} \nu_i P_i(E) \qquad P_i(E) = \frac{\sigma_i(E)}{\sigma_{(n,f)}(E) + \sigma_{(n,\gamma f)}(E)}$$

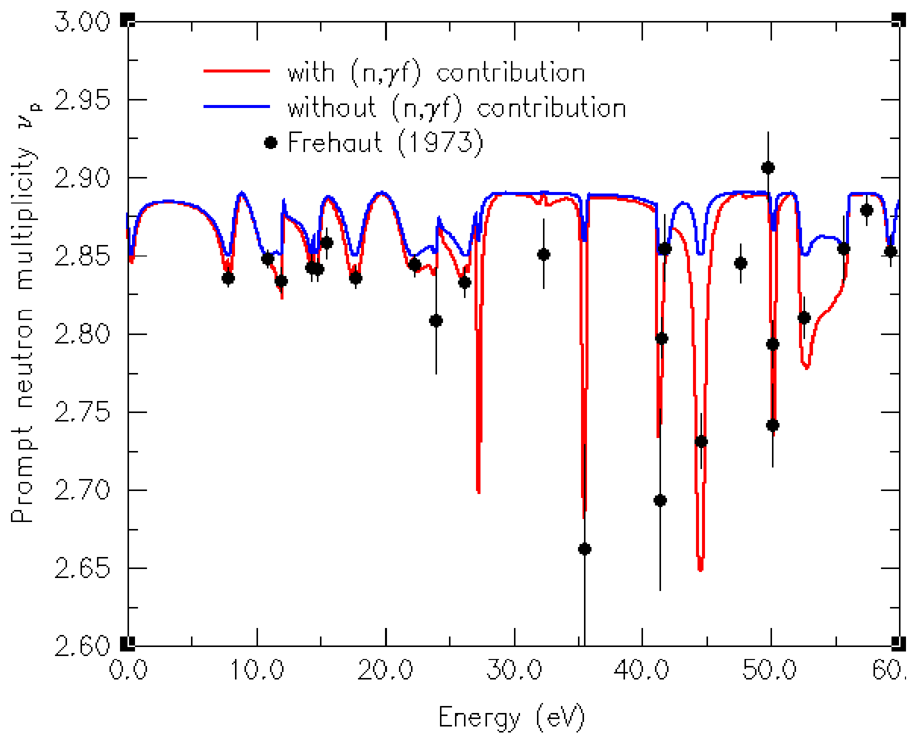
Neutron multiplicity

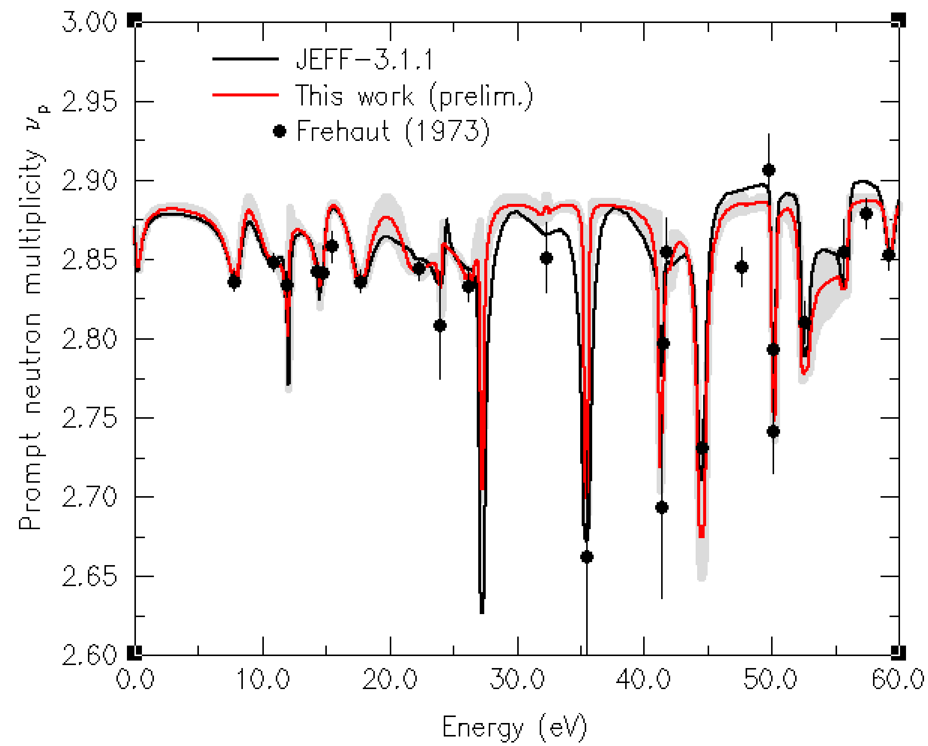
Constant terms υi obtained with CONRAD from the least-squares fit of the Frehaut data. Preliminary results are compared with the results of E. Fort

Reaction	J^π	This work (Prelim.)	O. Serot and E. Fort (Prelim.)	E. Fort (1988)
(n,f)	1^+	2.85	2.85	2.86
(n,f)	0^+	2.89	2.89	2.88
(n,γf)	1^+	2.62	2.69	2.66
(n,γf)	0^+	2.62	2.69	2.80

Neutron multiplicity

Contribution of the (n,γf) process can be observed for resonances with $J^{\pi}=1^{+}$





Neutron multiplicity

Conclusions for (n,γf) reaction and neutron multiplicity:

•Futur evaluations of actinide should include the two-step (n,γf) reaction

•The partial υ_i should be determined from the simultaneous adjustment of the cross-sections and υ_p data

•New measurement of υ_p is needed

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Benchmarking
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Benchmarking : JEFF-32T2

No degradation of the average values obtained over several ICSBEP benchmarks

Bench.	JEFF-311	JEFF-32T2	Δ
Plutonium Solution Thermal (PST)	+167 pcm	**+117 pcm**	-50 pcm

$$\Delta\rho(JEFF) = \frac{1}{keff\,(\text{exp.})} - \frac{1}{keff\,(JEFF)}$$

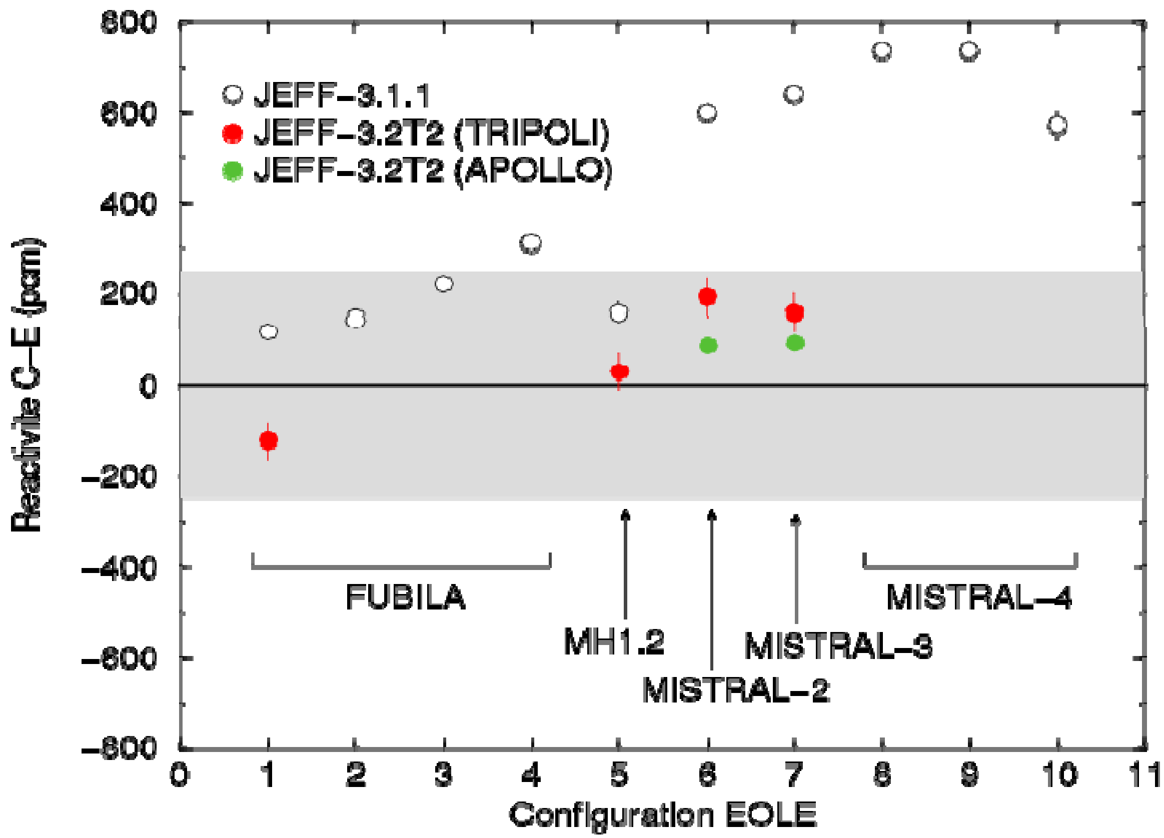
Benchmarking : JEFF-32T2

We expect a slight degradation of the reactivity temperature coefficient (RTC) in EOLE experiments, cold conditions 20-80°C

JEFF library	Total RTC error (pcm/°C)
JEFF-31	-1.6 ± 0.3
JEFF-311	-1.0 ± 0.3
JEFF-32	≈ -1.3

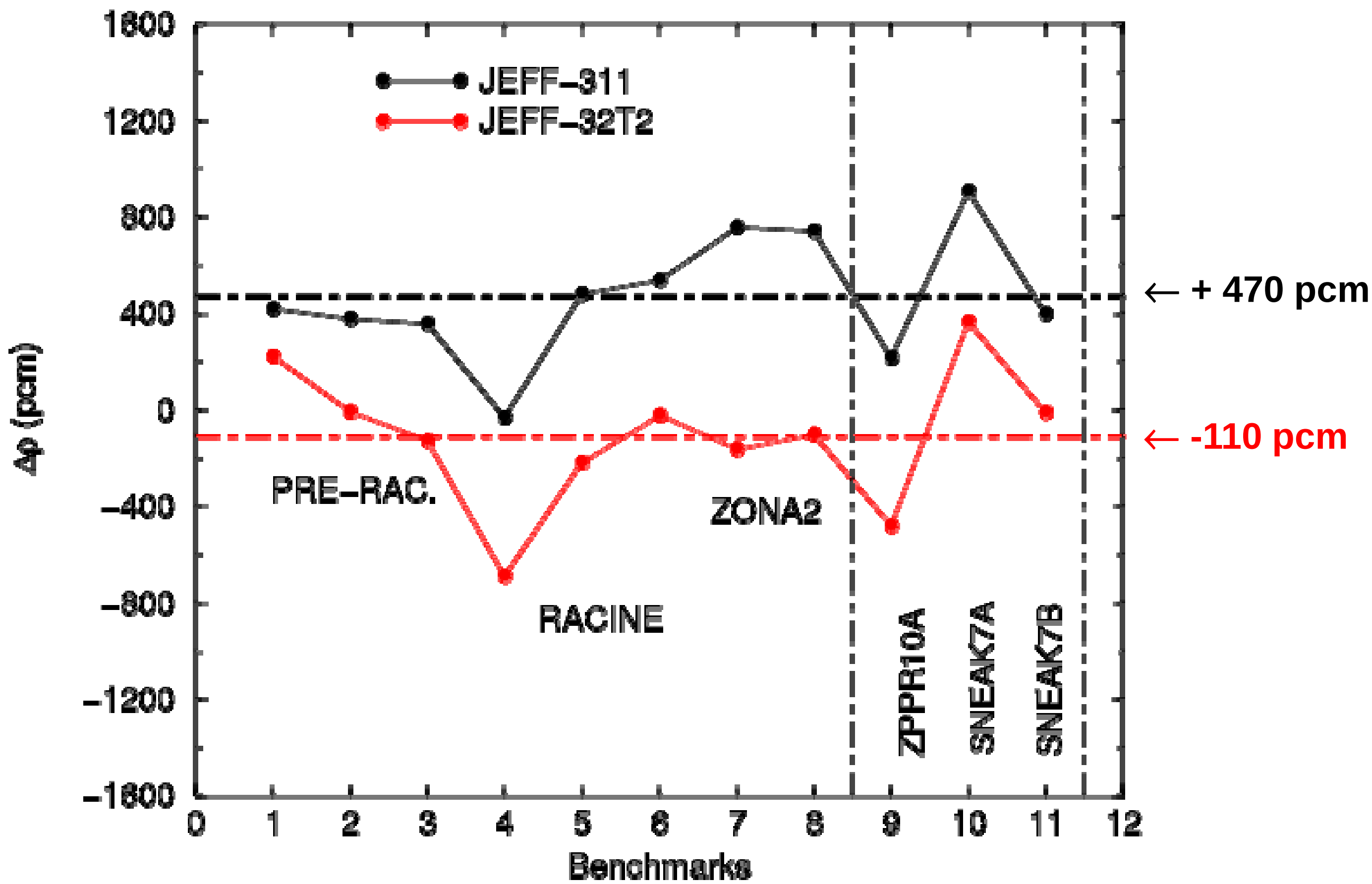
Benchmarking : JEFF-32T2

Keff results for MOX fuel (thermal system)



Benchmarking : JEFF-32T2

Keff results for MOX fuel (fast system)



Conclusions

Experimental needs :

•Transmission measurement of the 1st resonance

•Fission cross section in the URR

•Neutron multiplicity in the RRR

•Capture yield measurement

Evaluation needs:

•Include the (n,γf) reaction

•"on-the-fly" calculation of υ_p in the RRR and URR

•take into account the structure observed in the URR of the fission cross section

Benchmarking needs:

•More integral feedback on the WPEC/SG-34 evaluated file