Coordinated evaluation of 239Pu in the resonance region

Contribution of the Nuclear Data Group of Cadarache

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Outlines

Resonance-Parameters Covariance Matrix (RPCM)
⇒ CONRAD Marginalization

Investigation of the Unresolved Resonance Range
⇒ Use the URR option of TALYS

Investigation of the two-step (n,γf) process
⇒ See Eric Fort NSE 99, 375 (1988)

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

Resonance-Parameters Covariance Matrix (RPCM)

$M_x \Rightarrow$ Resonance-Parameter Covariance Matrix provided by the fitting model

$M_\theta \Rightarrow$ Covariance matrix between the nuissance parameters

The covariance matrix can be partionioned as follow :

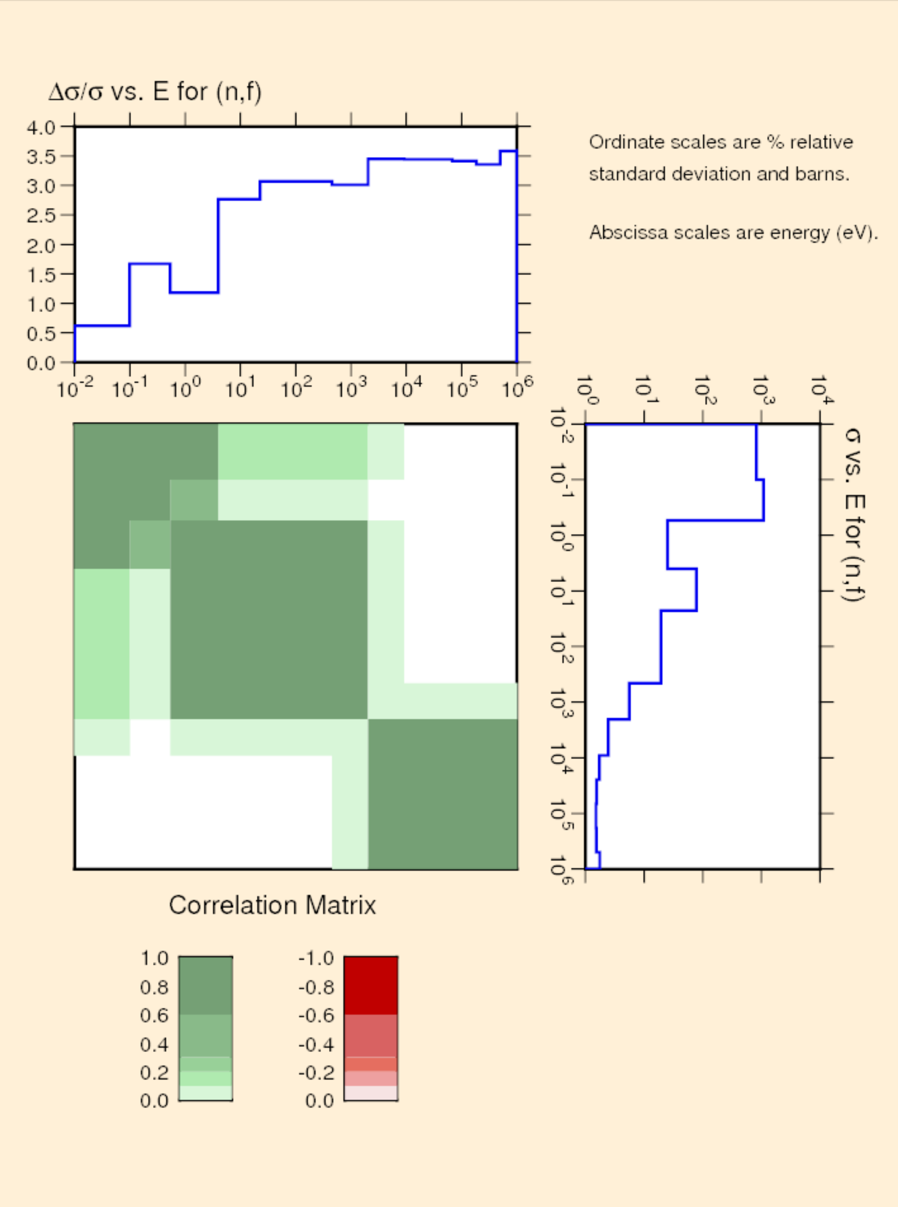
$$\Sigma = \begin{pmatrix} \Sigma_{11} & \Sigma_{12} \\ \Sigma_{21} & \Sigma_{22} \end{pmatrix}$$

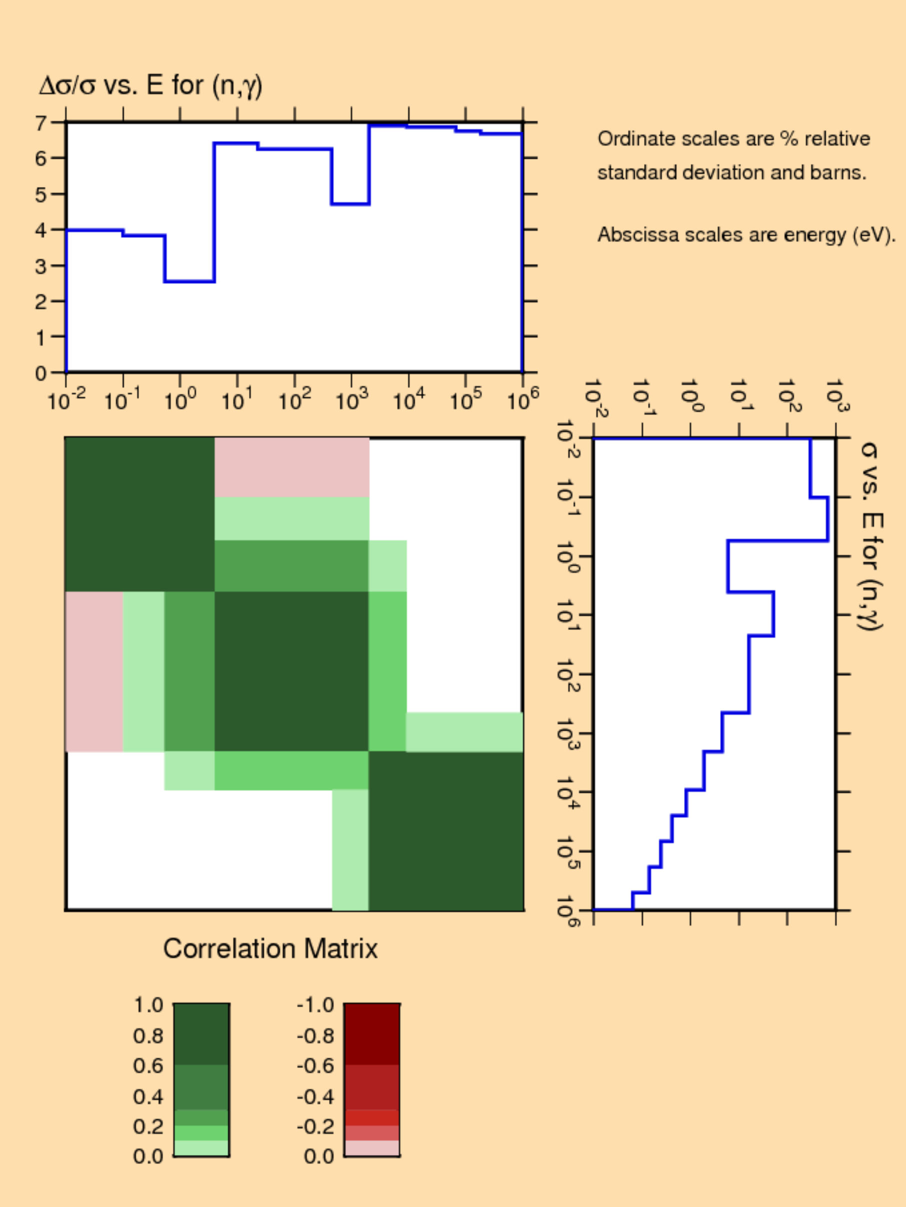
$$\begin{cases} \Sigma_{11} = M_x + \left(G_x^T G_x\right)^{-1} G_x^T G_\theta M_\theta G_\theta{}^T G_x \left(G_x^T G_x\right)^{-1} \\ \Sigma_{12} = -(G_x^T G_x)^{-1} G_x^T G_\theta M_\theta \\ \Sigma_{22} = M_\theta \end{cases}$$

With :

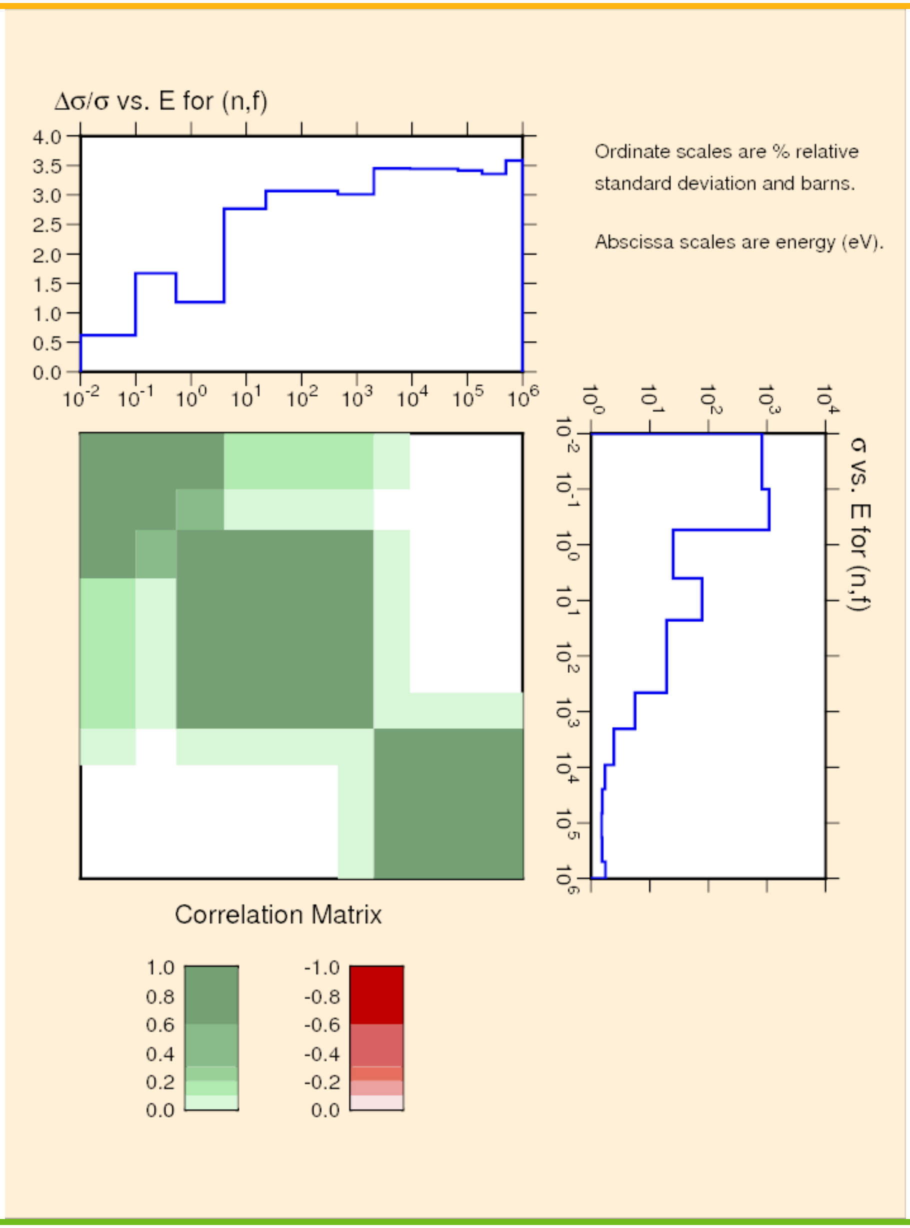
$$G_x = \begin{pmatrix} \frac{\partial y_1}{\partial x_1} & \cdots & \frac{\partial y_1}{\partial x_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial y_k}{\partial x_1} & \cdots & \frac{\partial y_k}{\partial x_n} \end{pmatrix} \qquad G_\theta = \begin{pmatrix} \frac{\partial y_1}{\partial \theta_1} & \cdots & \frac{\partial y_1}{\partial \theta_m} \\ \vdots & \ddots & \vdots \\ \frac{\partial y_k}{\partial \theta_1} & \cdots & \frac{\partial y_k}{\partial \theta_m} \end{pmatrix}$$

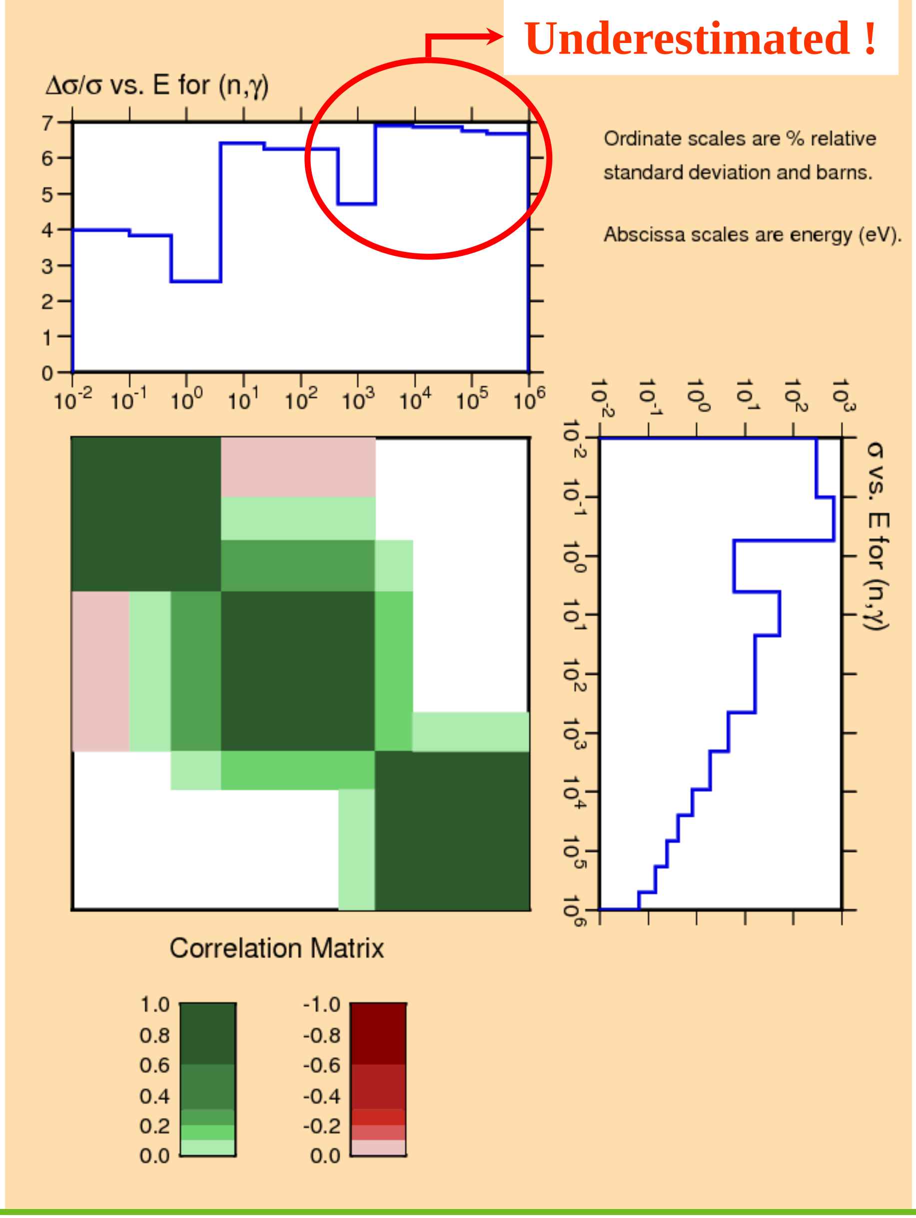
Resonance-Parameters Covariance Matrix (RPCM)





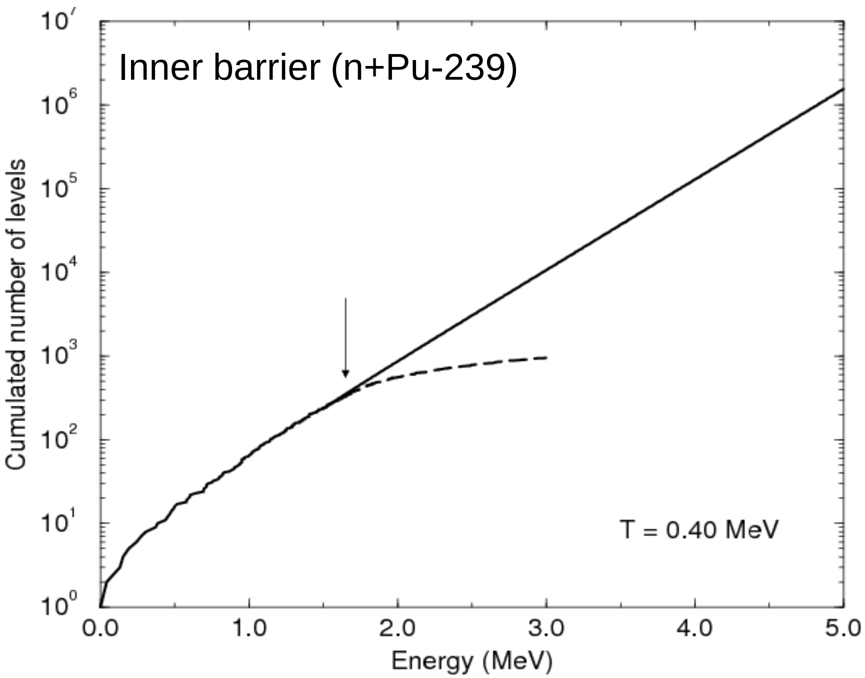
Resonance-Parameters Covariance Matrix (RPCM)

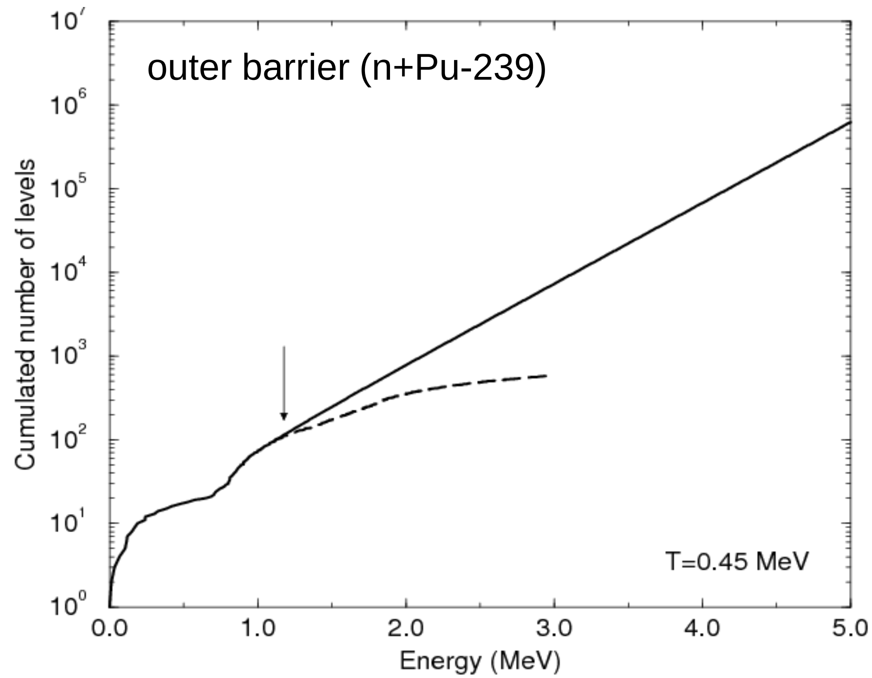




TALYS calculations

head-band states based on the work of Olivier Bouland (LANL/CEA collaboration)





Recent advances in modeling fission cross sections over intermediate structures

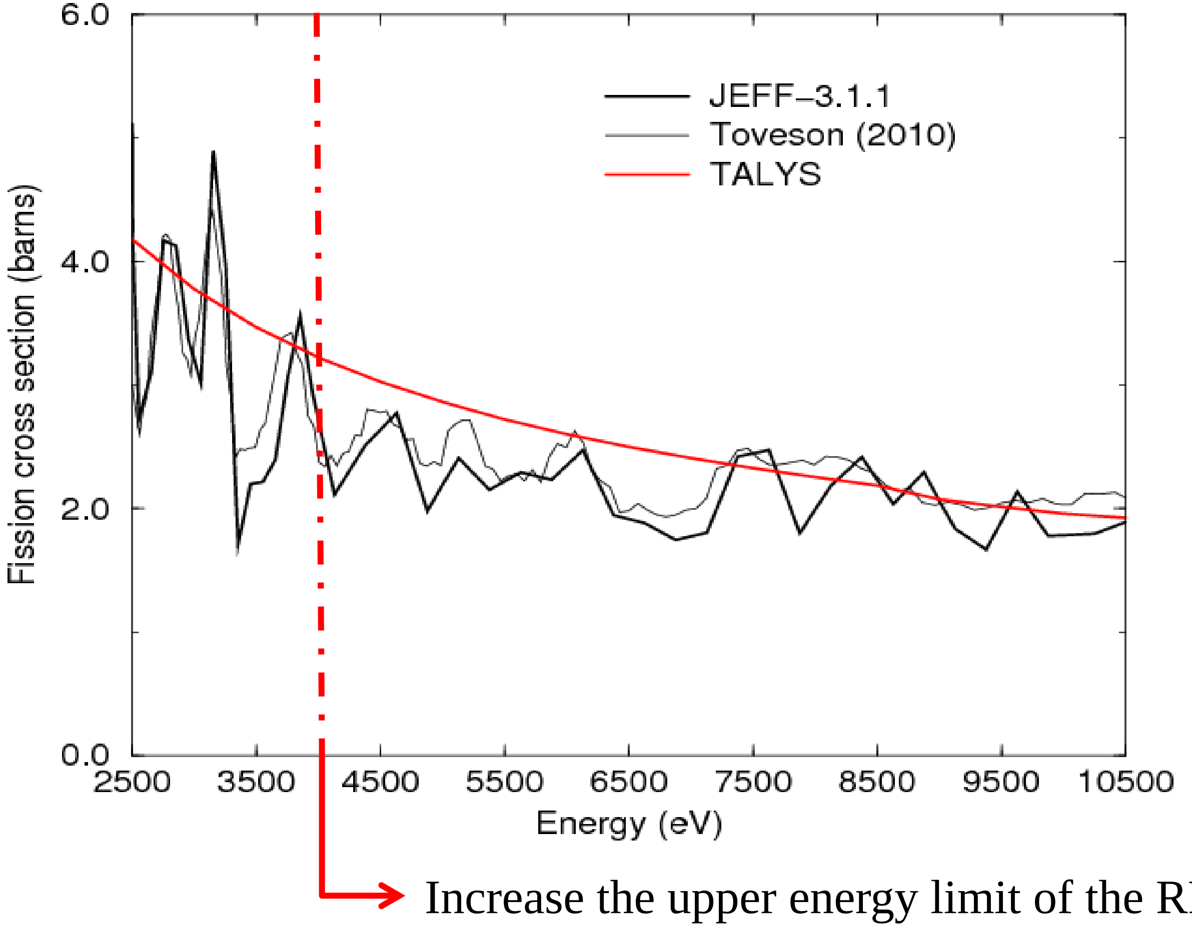
O. Bouland, E. Lynn and P.talou, LA-UR-09-07470

Analysis of the (n,f) reaction in the plutonium isotopes

*O. Bouland, E. Lynn and P.talou, Third International Workshop on Compound-Nuclear Reactions and Related Topics (CNR*11)*

Investigation of the Unresolved Resonance Range

How to describe the fluctuations observed in the fission cross section ?



Increase the upper energy limit of the RRR to 4 keV

Impact probability tables PT(Pu-239)

The interpretation of the URR parameters by CALENDF and NJOY gives differents Probability Tables. For Pu-239, CALENDF uses a group-wize representation in agreement with the work of Herve Derrien. NJOY uses a point-wize representation. (See WPEC/SG32)

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**

⇒ discrepancies due to the processing codes : max 220 pcm

⇒ this problem can be solved by using LSSF=1

Investigation of the two-step (n,γf) process

1959 : unpublished estimation of the $\Gamma_{\gamma f}$ width for the (n,γf) reaction by E. Lynn

1965 : On the slow neutron, gamma-fission reaction, E. Lynn, Phys. Lett. 18

1967 : Evaluation des données neutroniques pour le Pu-239, G. LeCoq, PhD thesis

1973 : Etudes des sections efficaces de réaction des neutrons de resoanance avec Pu239, H. Derrien, PhD thesis

1974 : Etude des neutrons et des rayons gamma émis lors de la fission induite dans 235U et 239Pu par neutrons lents: mise en évidence de la réaction (n,gamma f), D. Shackleton, PhD thesis

1980 : The double-humped fission barrier, S. Bjornholm and E. Lynn, Rev. Mod. Phys. 52

1988 : Evaluation of υ_p for Pu-239, E. Fort et al. Nucl. Sci. Eng. 99

Neutron multiplicity evaluation ν_p takes into account

. 2 openened fission channels for $J^{\pi}=0^{+} \Rightarrow \Gamma_{f1}(0)$ and $\Gamma_{f2}(0) \Rightarrow$ **$\Gamma_f(0^+)$**

. 1 openened fission channels for $J^{\pi}=1^{+} \Rightarrow$ **$\Gamma_f(1^+)$**

. J-dependent width for the (n,γf) reaction $\Rightarrow$ **$\Gamma_{\gamma f}(0^+)$** and **$\Gamma_{\gamma f}(1^+)$**

Phenomenological description

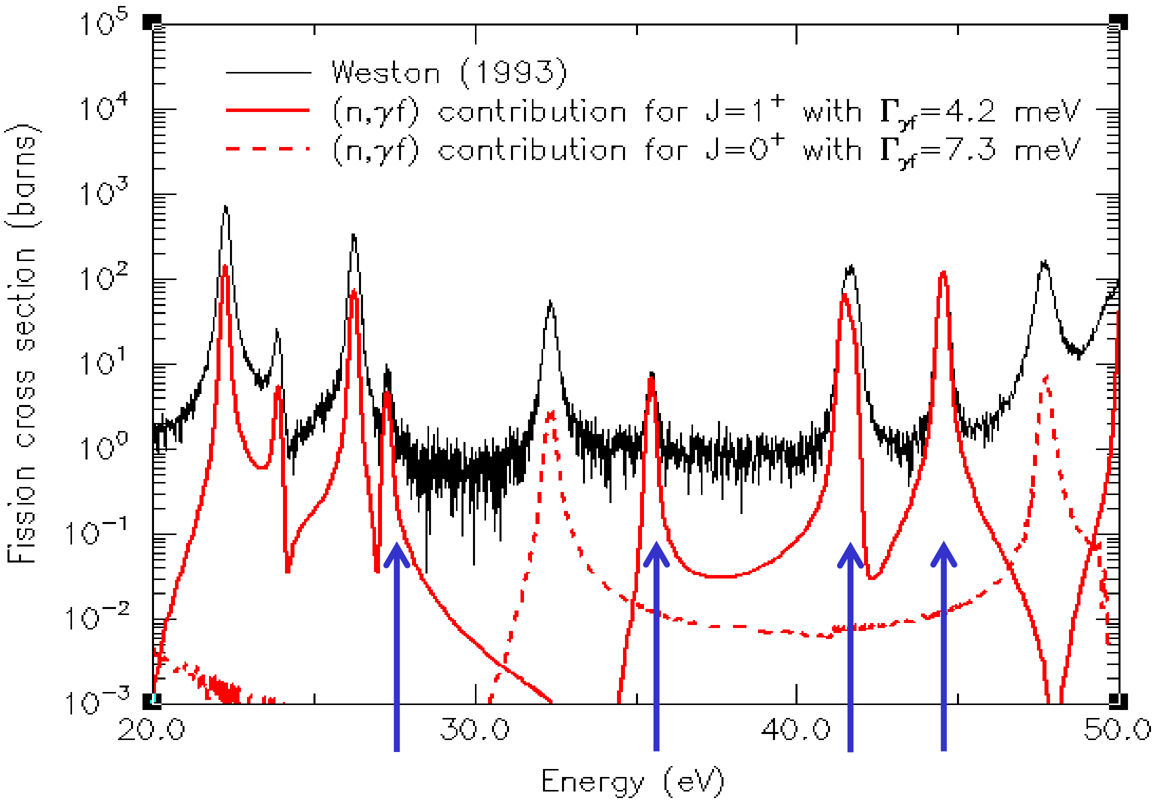
$$\upsilon_p(E) \approx \sum_{i=1}^{4} \nu_i P_i(E)$$

Where

$$P_i(E) = \frac{\sigma_{fi}(E)}{\sigma_f(E) + \sigma_{\gamma f}(E)}$$

Investigation of the two-step (n,γf) process

For $J^{\pi}=1^{+}$, the smallest resonances are due to the (n,γf) process



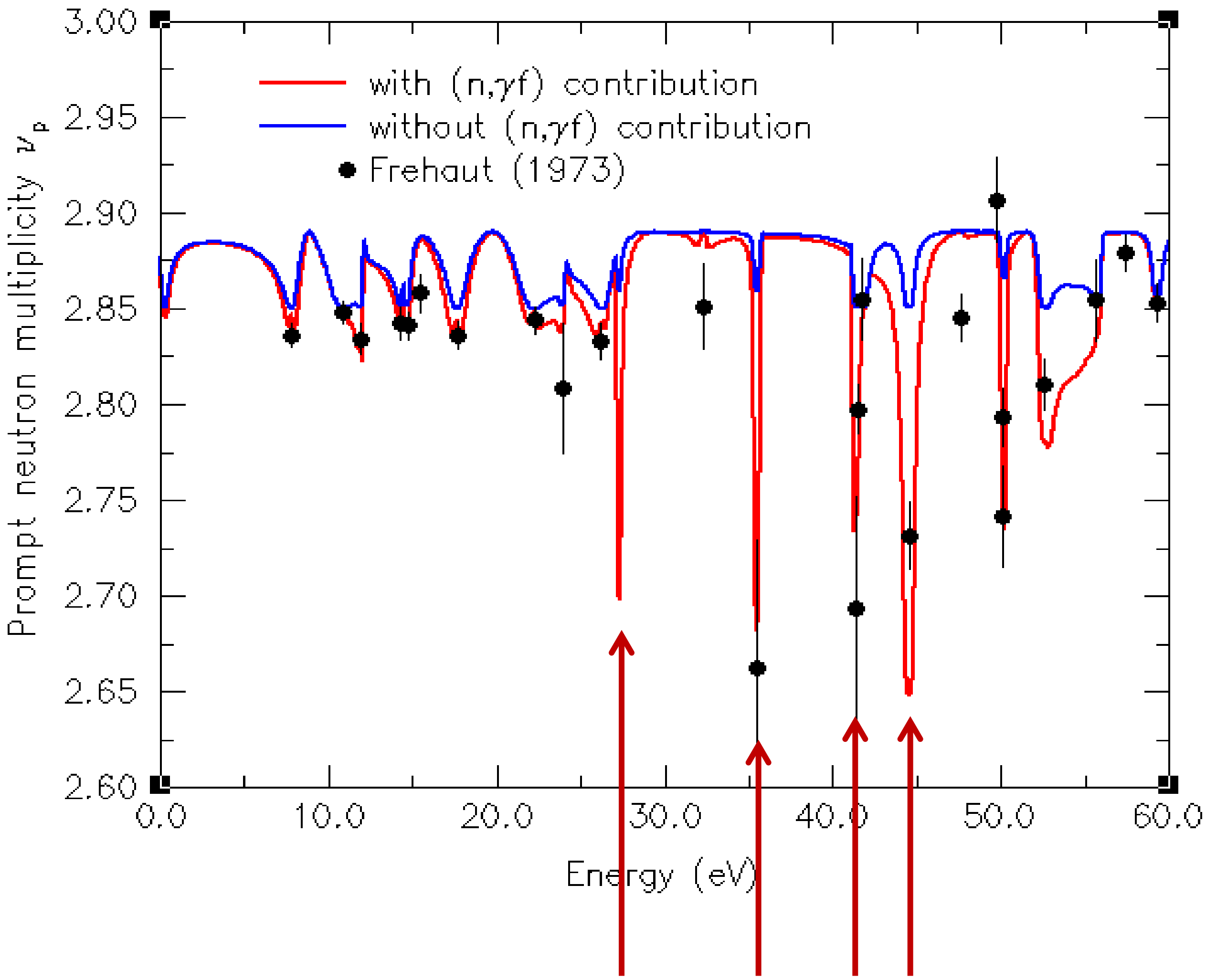
Problem !!!

. in the evaluated file they are considered as simple (n,f) reaction

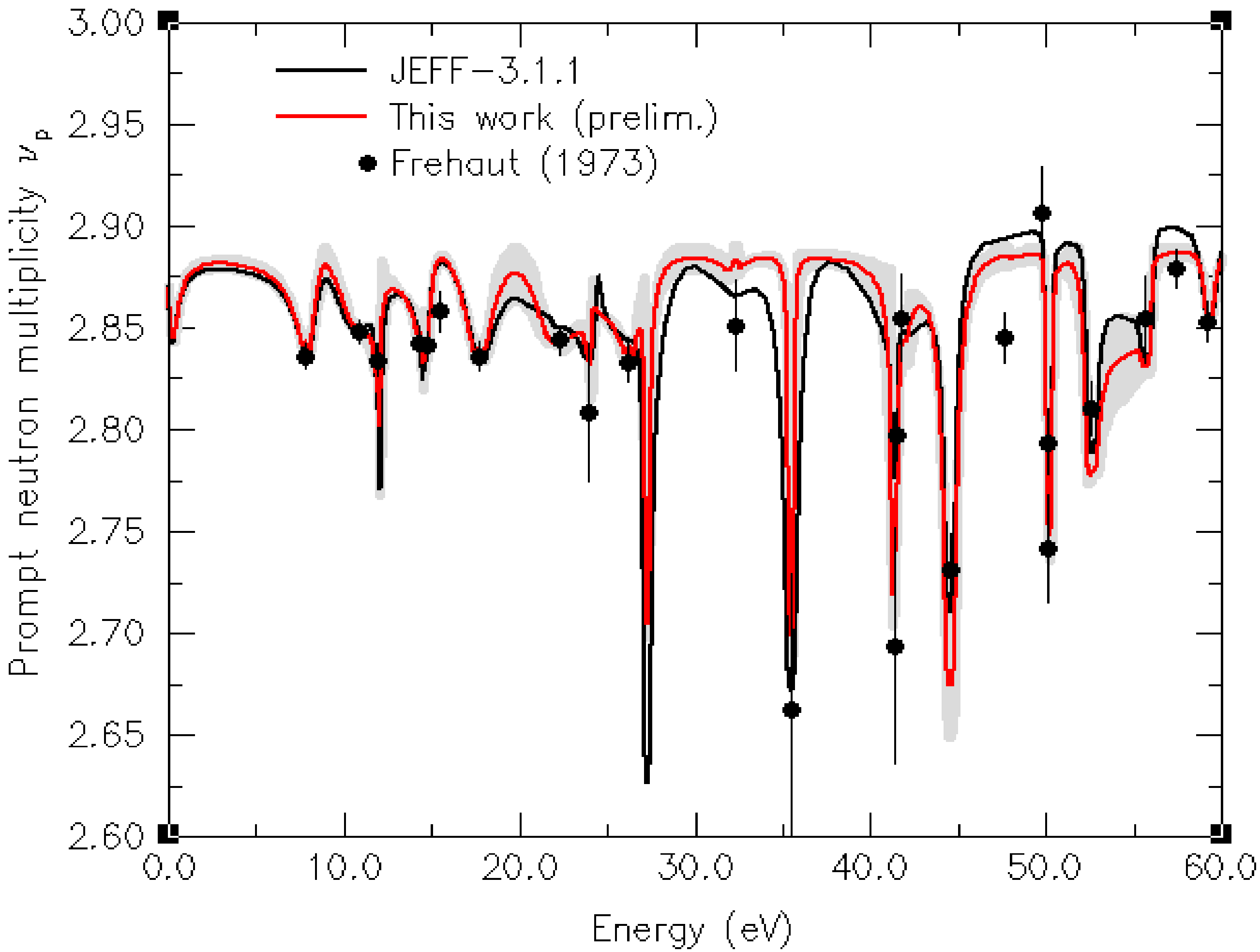
. possible overestimation of the radiative capture ⇒ Cf. production of Pu-240

Investigation of the two-step (n,γf) process

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



Investigation of the two-step (n,γf) process



Investigation of the two-step (n,γf) process

Constant terms υ_i obtained with CONRAD from the least-squares fit to 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

Benchmarking

PST001.4 PST004.1	EALF = 0.0154 eV EALF = 0.0531 eV	5 % Pu-240 0.5 % Pu-240
MH1.2 (EOLE, Cadarache)	PWR-MOx miwed core	4 years
BASALA-Hot (EOLE, Cadarache)	BWR-MOx BWR-MOx	12 years 13 years
MISTRAL-2 (EOLE, Cadarache)	PWR-MOx	8 years
MISTRAL-3 (EOLE, Cadarache)	PWR-MOx	9 years
MISTRAL-4 (EOLE, Cadarache)	MOx-REF MOx-AIC MOx-Hf MOx-B4C	10 years 10 years 10 years 10 years
FUBILA-Hot (EOLE, Cadarache)	BWR-REF (EPICURE) BWR-NORM (EPICURE) BWR-70% Void (EPICURE) BWR-10×10 (EPICURE) BWR-UGD (EPICURE)	1 years (16-17 years) 1 years (16-17 years) 1 years (16-17 years) 1 years (16-17 years) 1 years (16-17 years)
ERASME (EOLE, Cadarache)	ERASME/R, HCPWR ERASME/S	
OSMOSE (MINERVE, Cadarache)	Oscillation measurements (R1U02 and R1MOX lattices)	
Post Irradiated Experiments (PIE)	GRAVELINE (ALIX-HTC), GUNDREMMINGEN, DAMPIERRE, …	

Benchmarking

With new Pu-239 ORNL/CEA collaboration (V11.7a)		ENDF\B-VII	JEFF-3.1.1	CEA2005V4	
Codes		MCNP	T4	AP2 (Chabint)	AP2 (GALILEE)
PST001.4	± 500	1.00221 (19)	1.001127 (15)	1.00118	
PST004.1	± 470	1.00039 (15)	1.001266 (13)	1.00166	
MH1.2 (PWR-MOx mixed core)	± 250		270 (50)	⇒ ~50 pcm	
BASALA-Hot (BWR-MOx)	± 250				
BASALA-Cold (BWR-MOx)	± 250				
MISTRAL-2 (PWR-MOx)	± 250		615 (50)	⇒ ~132 pcm	
MISTRAL-3 (PWR-MOx) keff at 20°C	± 250		692 (50)	⇒ ~ 113 pcm	
MISTRAL-4 (MOx-REF)	± 250				
MISTRAL-4 (MOx-AIC)	± 250				
MISTRAL-4 (MOx-Hf)	± 250				
MISTRAL-4 (MOx-B4C)					
FUBILA-Hot (BWR-REF)	± 250		351 (50)	⇒ ~ 70 pcm	
FUBILA-Hot (BWR-NORM)	± 250				
FUBILA-Hot (BWR-70% VOID)	± 250				
FUBILA-Hot (BWR-10×10)					
FUBILA-Hot (BWR-UGD)	± 250				
MISTRAL-3 (PWR-MOx) RTC 10-80°C	± 0.4			-1.3 ± 0.3	
OSMOSE (R1U02 Lattice)	± 2.8				-2.5
OSMOSE (R1MOX Lattice)	± 4.3				-0.7

With new Am-241 IRMM/CEA

+ Pu240, Pu241 …