DE LA RECHERCHE À L'INDUSTRIE

New evaluations of photon production for JEFF3

WONDER 2012 | Simon Ravaux, David Bernard, Alain Santamarina

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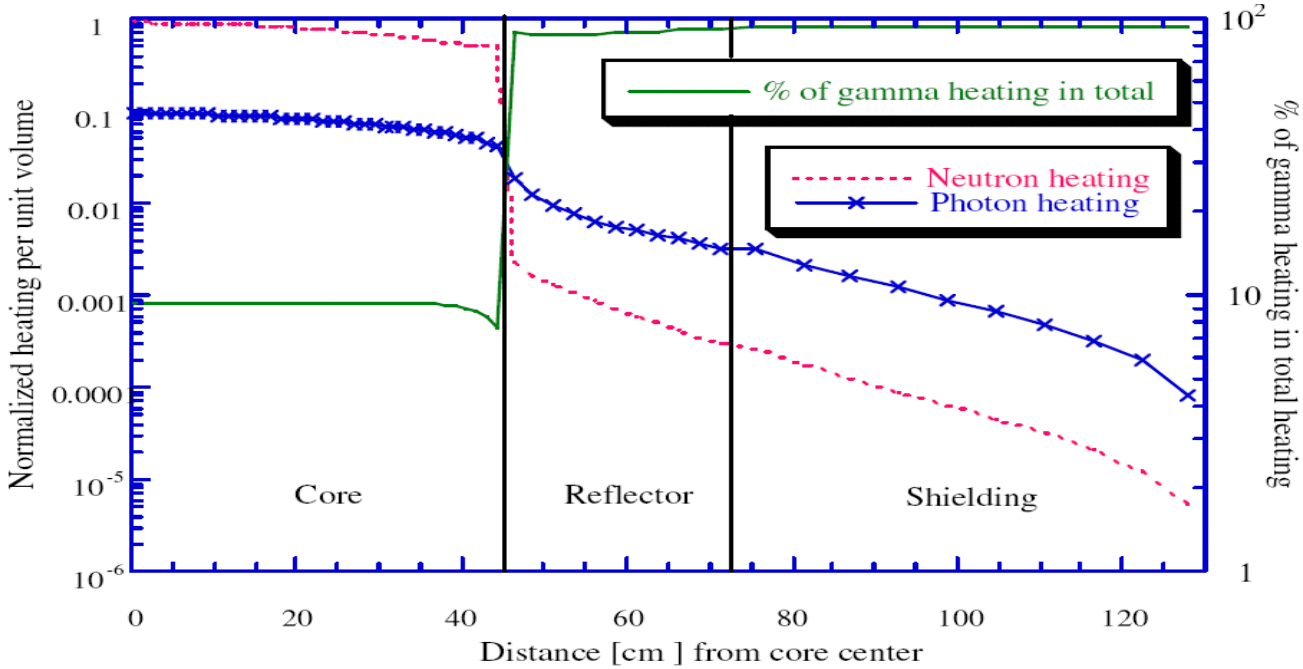
Importance of the gamma transport in power reactors

From Lüthi's thesis

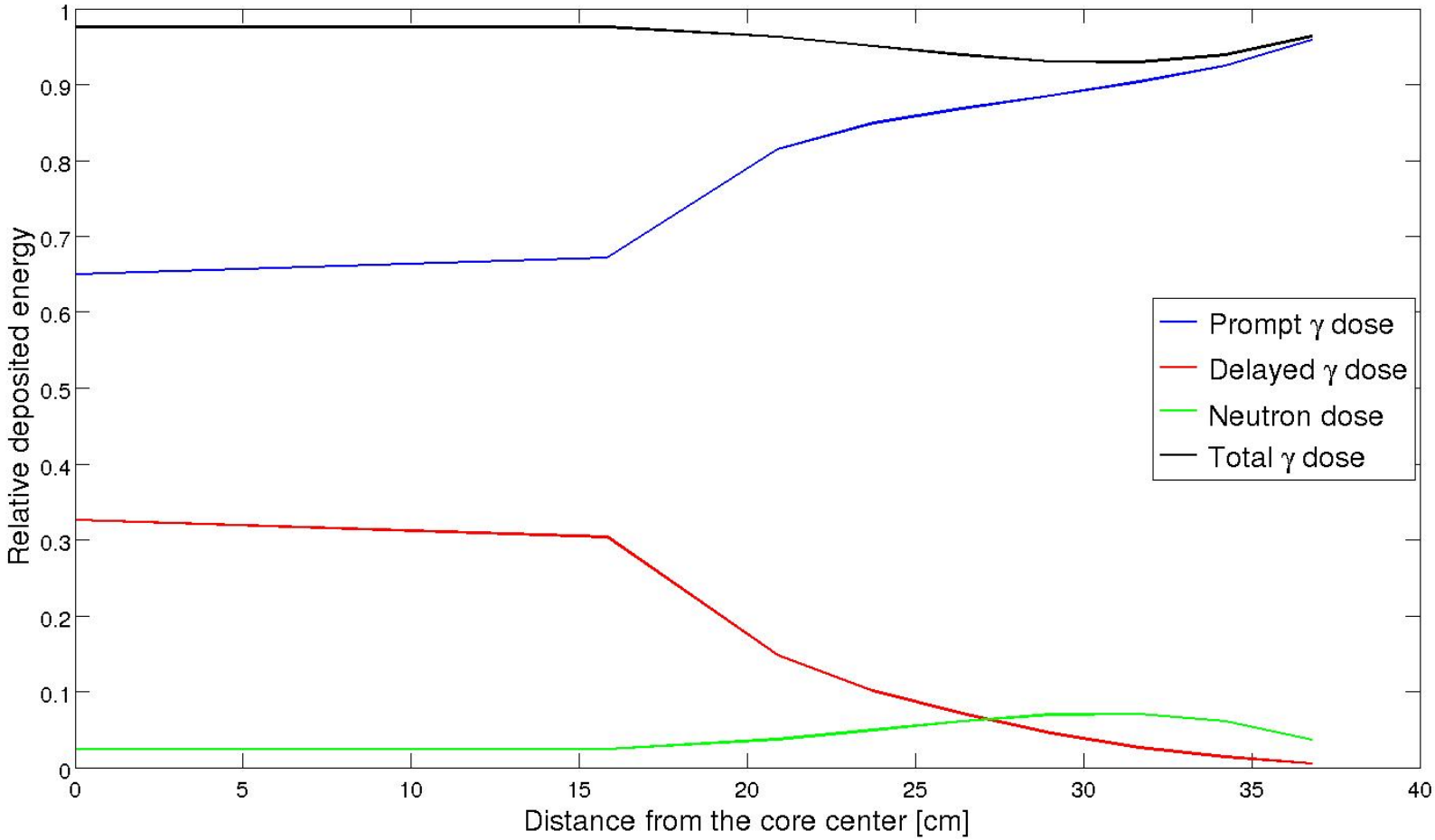
(EPFL 1999)



Neutron and gamma heating (total normalized to unity at core center) along the mid-plane of the MASURCA ZONA2B configuration. The relative contribution of gamma heating to the total heating is also indicated.

Photon heating predominant in fast reactor's vessels

Importance of the gamma transport in power reactors



Photon heating predominant in water reactor's vessel

Needed tools for gamma heating calculations

Coupled neutron and photon transport code :

- APOLLO2, (deterministic)
- TRIPOLI4, MCNPX (Monte Carlo)

Neutron transport library :

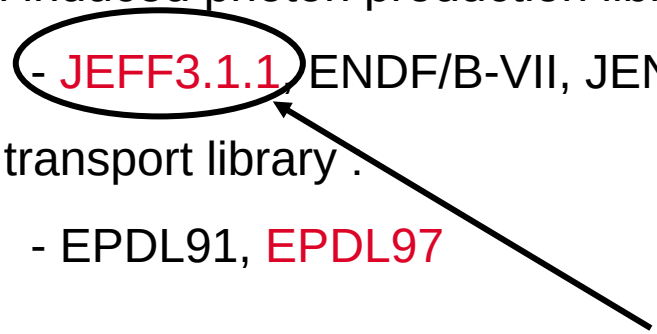
- JEFF3.1.1, ENDF/B-VII, JENDL4.0

Neutron induced photon production library :

- JEFF3.1.1, ENDF/B-VII, JENDL4.0

Photon transport library :

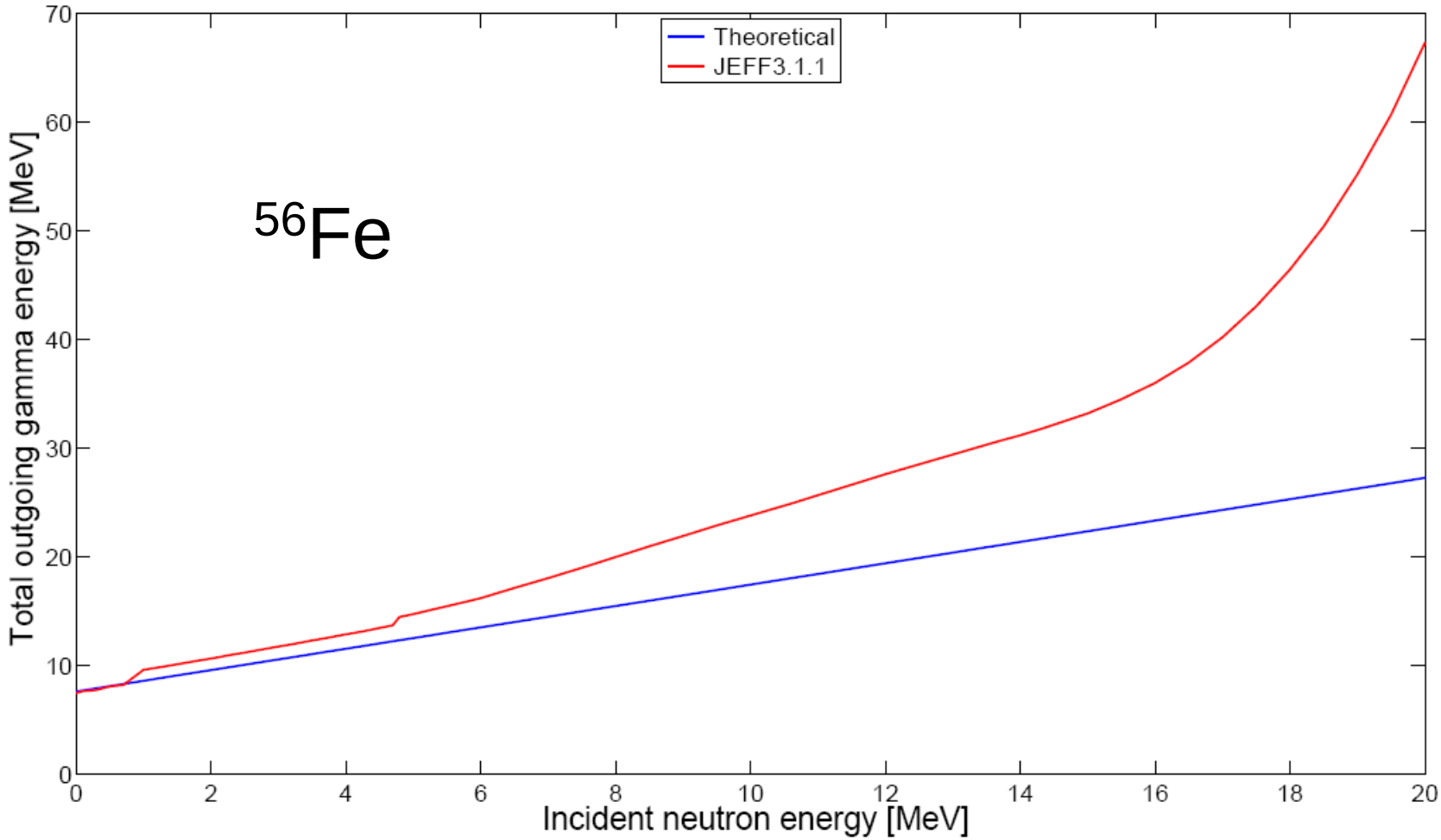
- EPDL91, EPDL97



Gamma production spectrum and multiplicities

Need improvements

Needed improvements for JEFF3.1.1



Energy inconsistencies in JEFF3.1.1 in the gamma production spectrum from neutron capture

Needed improvements for JEFF3.1.1

No photon production for all neutron interaction

Gd, Cd, Ag, In, …

Inconsistent total gamma energy emitted after a radiative neutron capture

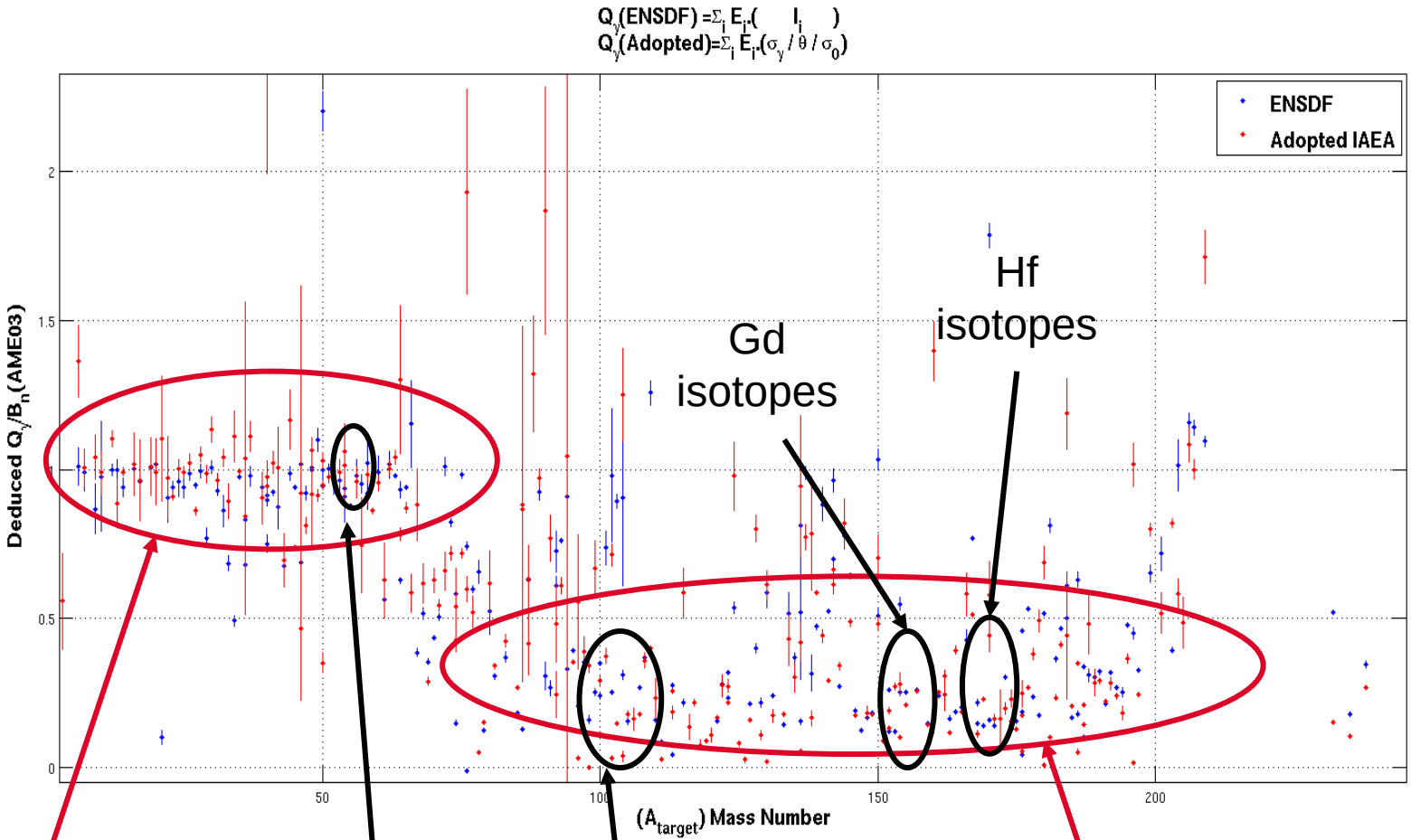
^{54}Fe,^{56}Fe,^{57}Fe,^{58}Fe

No primary gamma emitted after a radiative neutron capture

^{54}Fe,^{57}Fe, ^{58}Fe, Hf

→ Need to generate new gamma production evaluations

Processing new gamma production spectra



Processing new gamma production spectra

Measurements performed by Groshev et al. In the 50's

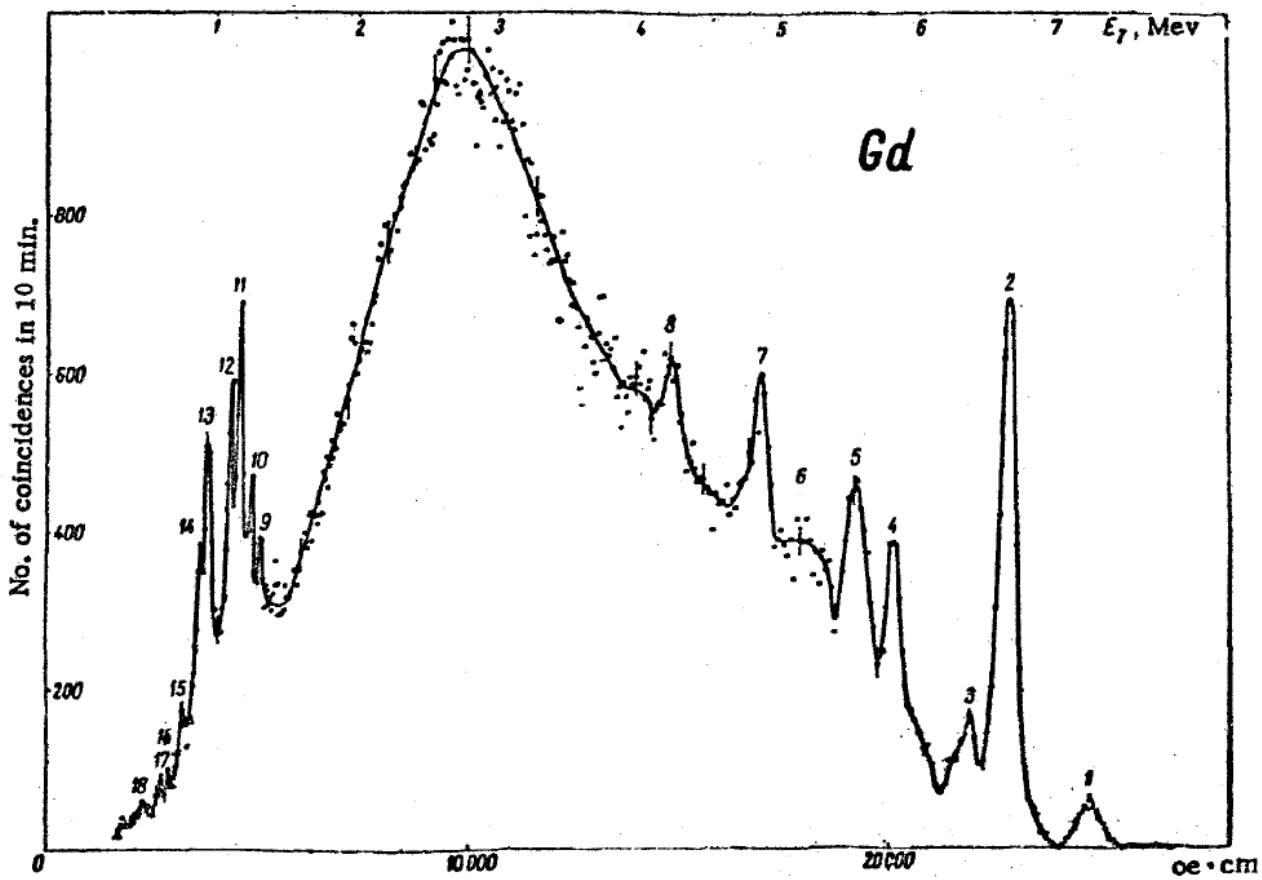


Fig. 1. Experimental γ-ray spectrum of Gd_2O_3.

Highlighting of the continuum and discrete gamma production spectrum induced by neutron capture on gadolinium

Processing new gamma production spectra

TALYS : A modelling nuclear reaction code

-A common development between CEA/DAM and NRG (Holland)

-A deterministic solver of the compound nucleus equation

-5 strength function models and 4 level density models

-Account for well-known discrete levels

-Coupling with the TEFAL code to produce new evaluations at the ENDF format

Processing new gamma production spectra

Composite Gilbert-Cameron model

$$\rho_T^{\mathrm{tot}}(E_x) = \frac{dN(E_x)}{dE_x} = \frac{1}{T}\exp(\frac{E_x - E_0}{T})$$

$$\rho_F^{\mathrm{tot}}(E_x) = \frac{1}{\sqrt{2\pi}\sigma}\frac{\sqrt{\pi}}{12}\frac{\exp\left[2\sqrt{aU}\right]}{a^{1/4}U^{5/4}}$$

Generalized Lorentzian model

$$f_{E1}(E_\gamma, T) = K_{E1}\left[\frac{E_\gamma \tilde{\Gamma}_{E1}(E_\gamma)}{(E_\gamma^2 - E_{E1}^2)^2 + E_\gamma^2 \tilde{\Gamma}_{E1}(E_\gamma)^2} + \frac{0.7\Gamma_{E1}4\pi^2T^2}{E_{E1}^3}\right]\sigma_{E1}\Gamma_{E1}$$

Advised models by Kopecky-Uhl

Processing gamma production spectra

$1\mu eV<E_n<1keV$

~ 90% of the radiative capture rate in a PWR

Discrete part processed with EGAF measurements

If needed, continuum part processed with TALYS ($E_{cont}=S_n-E_{EGAF}$)

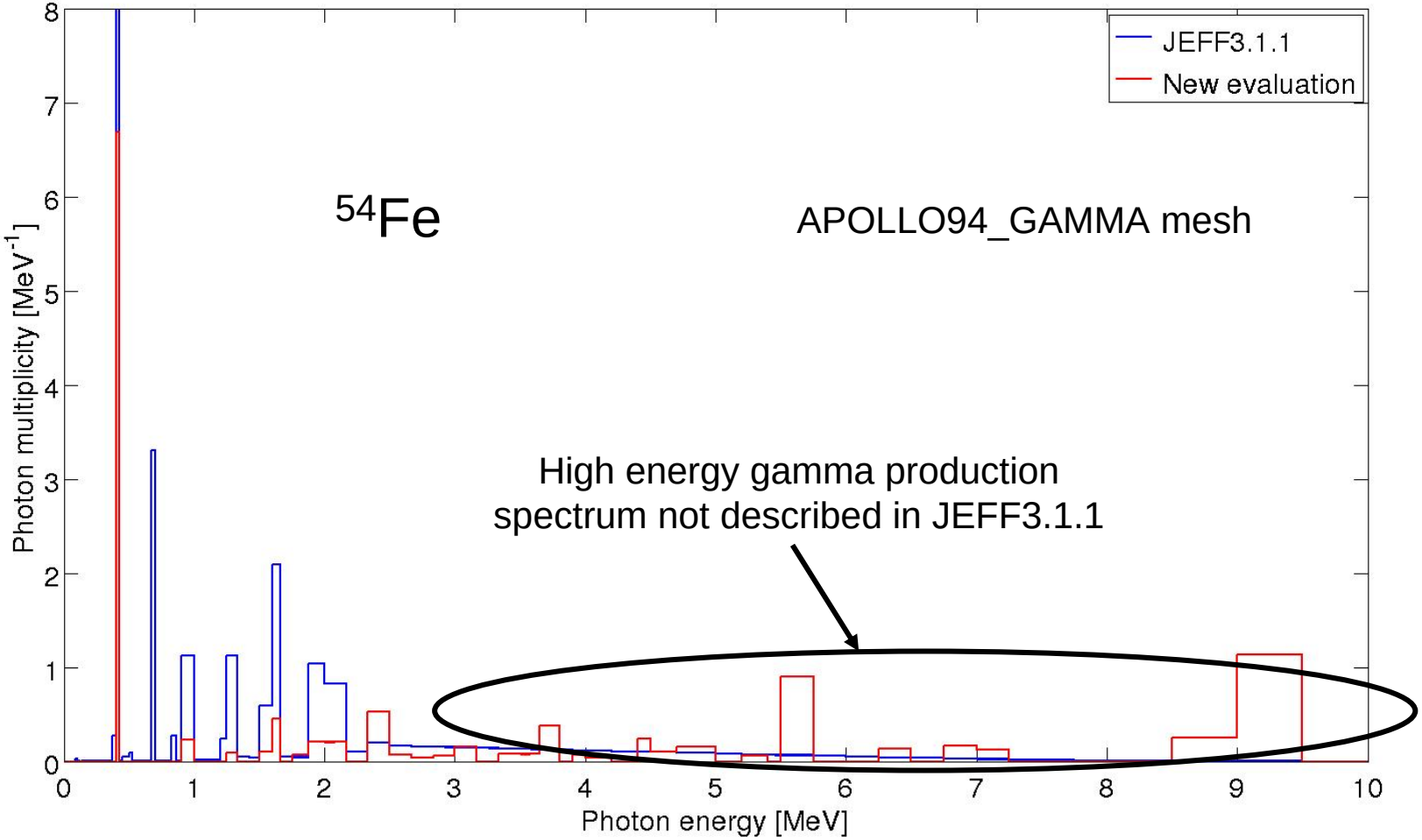
$E_n>1keV$

All the spectrum processed with TALYS

Spectrum placed in MF6MT102 in the ENDF format

16 nuclei : ^{54}Fe, ^{56}Fe, ^{57}Fe, ^{58}Fe, ^{107}Ag, ^{109}Ag, ^{113}In, ^{115}In, ^{113}Cd, ^{155}Gd, ^{57}Gd , ^{174}Hf, ^{177}Hf, ^{178}Hf, ^{179}Hf, ^{180}Hf

Comparison between JEFF and the new evaluations



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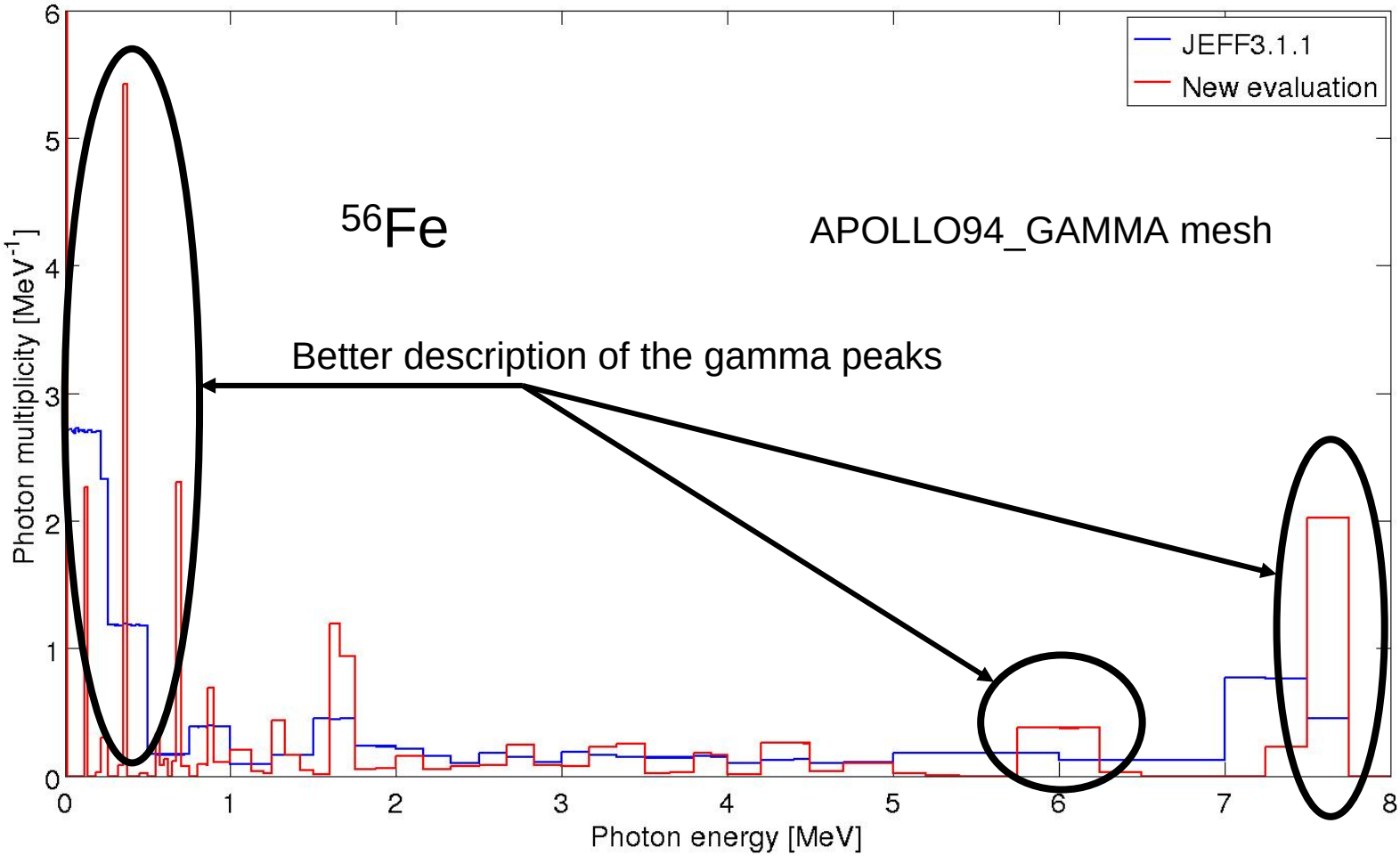

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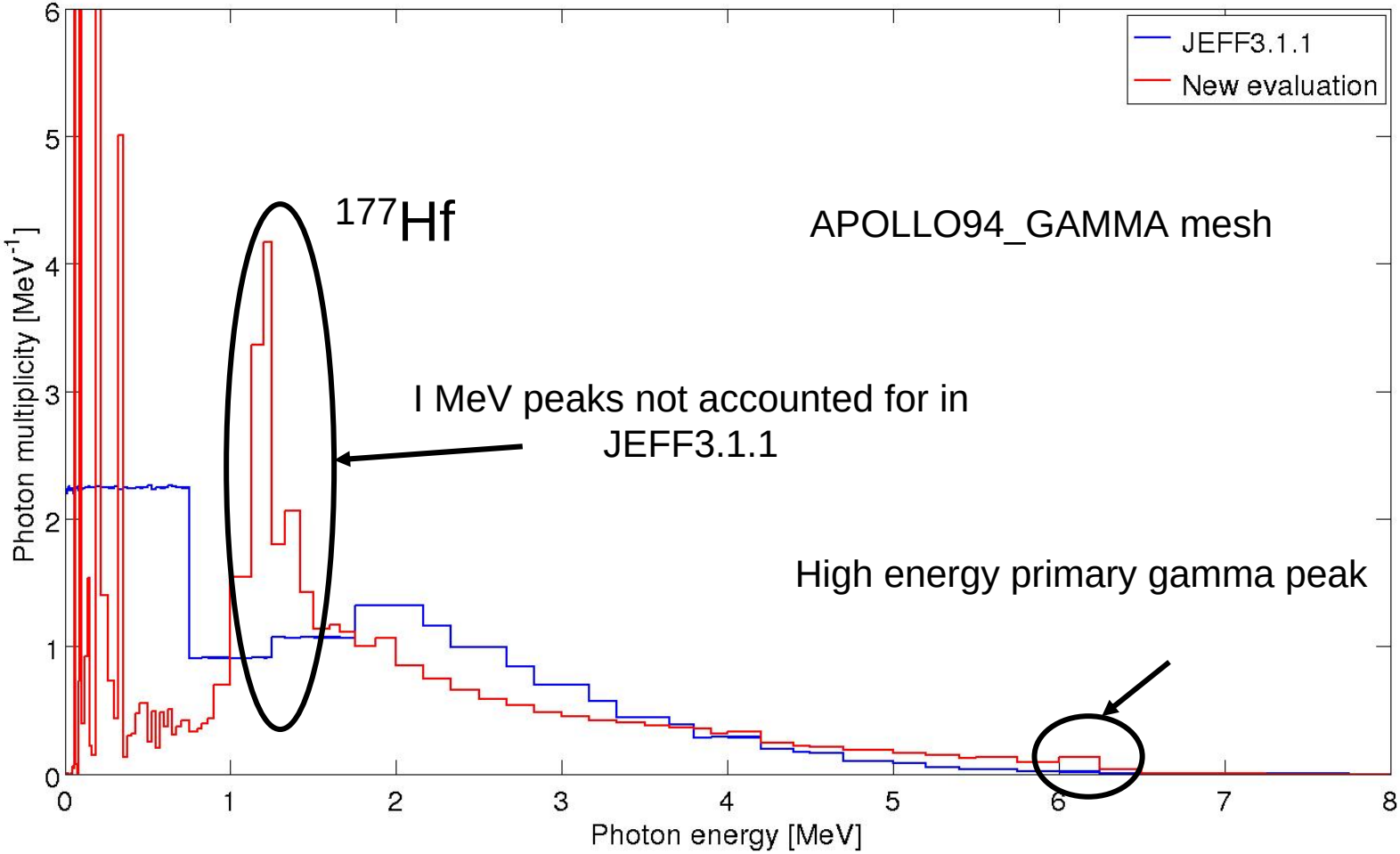

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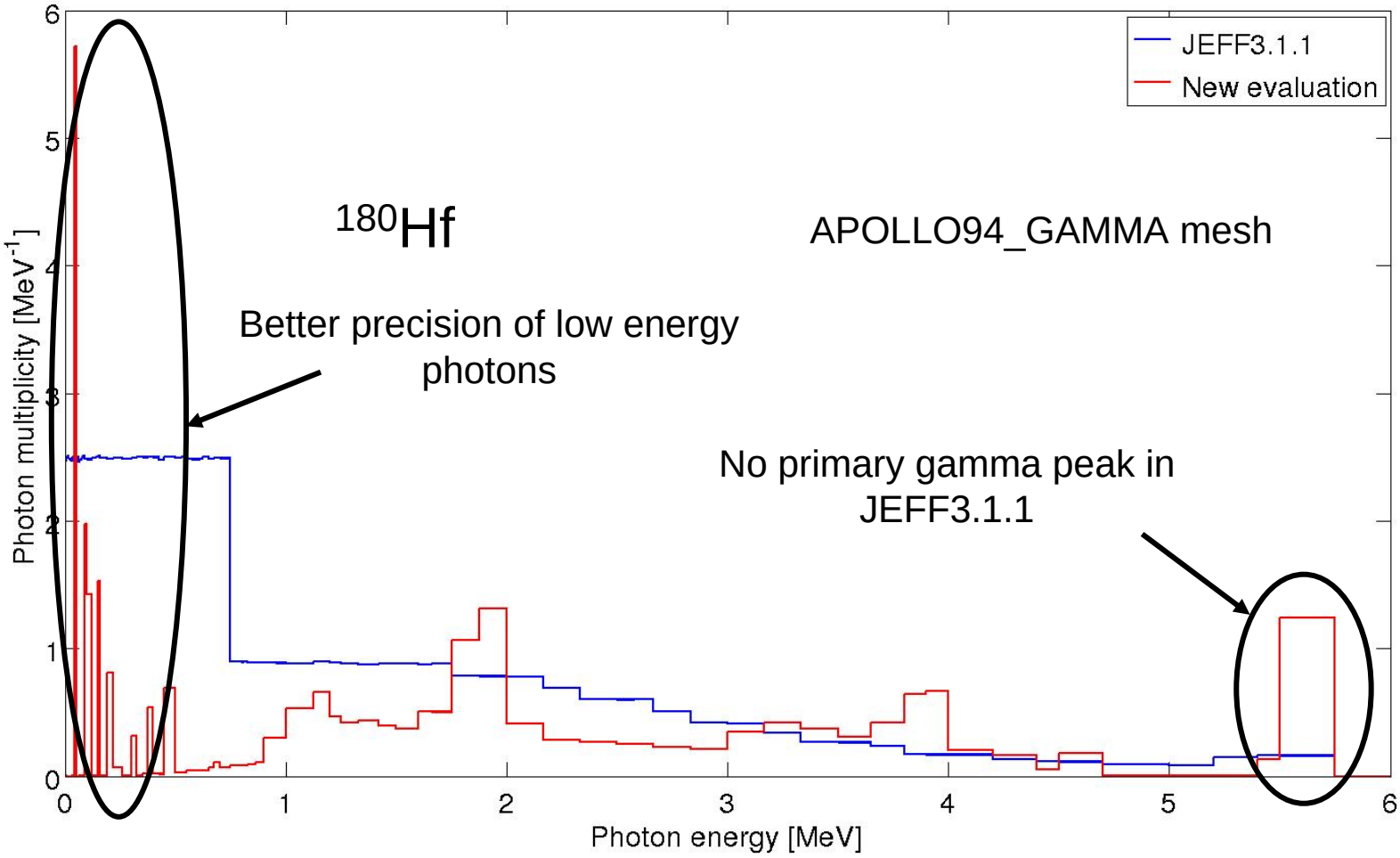
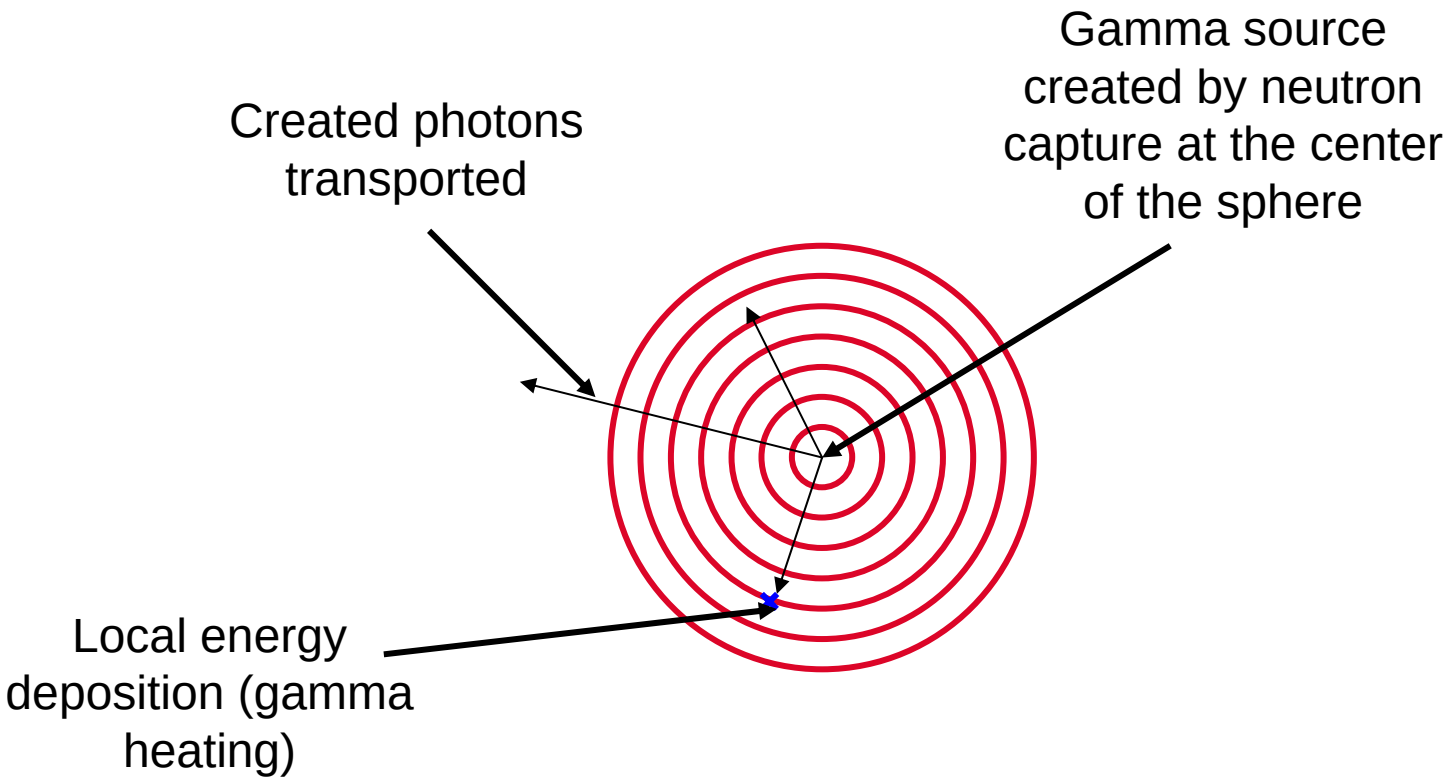


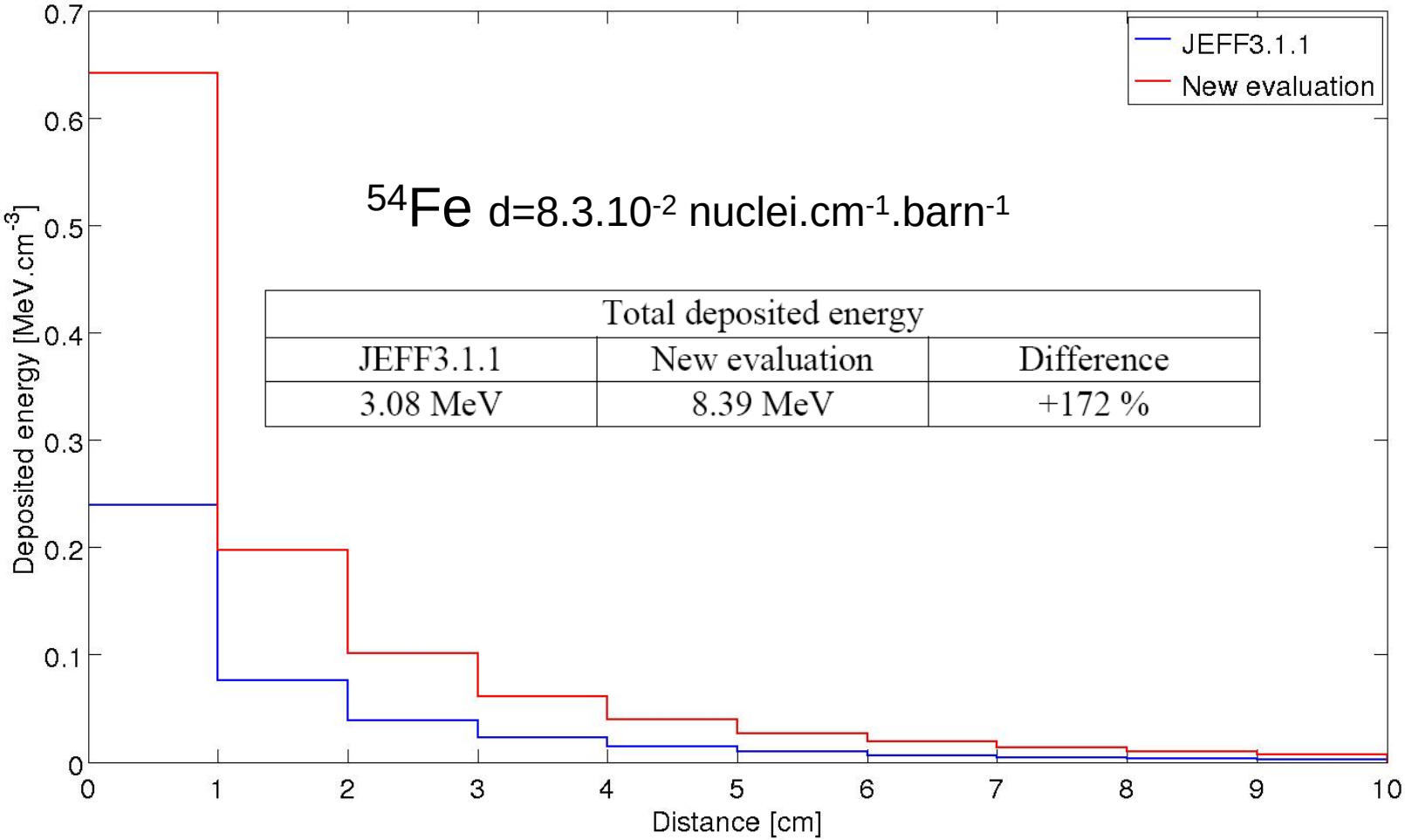
Effects of the new evaluations



Calculation of the gamma heating in each shells with TRIPOLI4

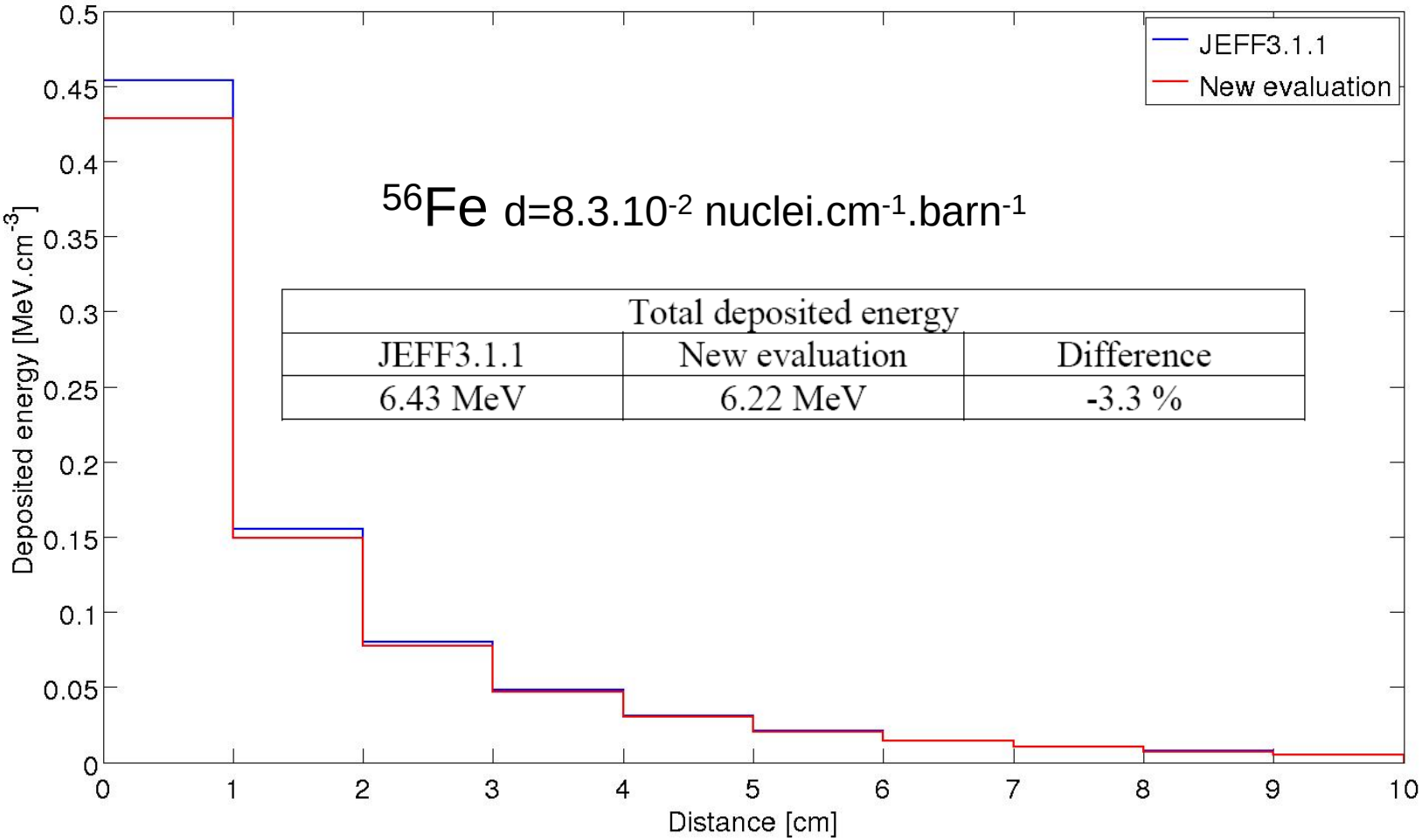
Comparison between JEFF3.1.1 and the new evaluations

Test of the new evaluations



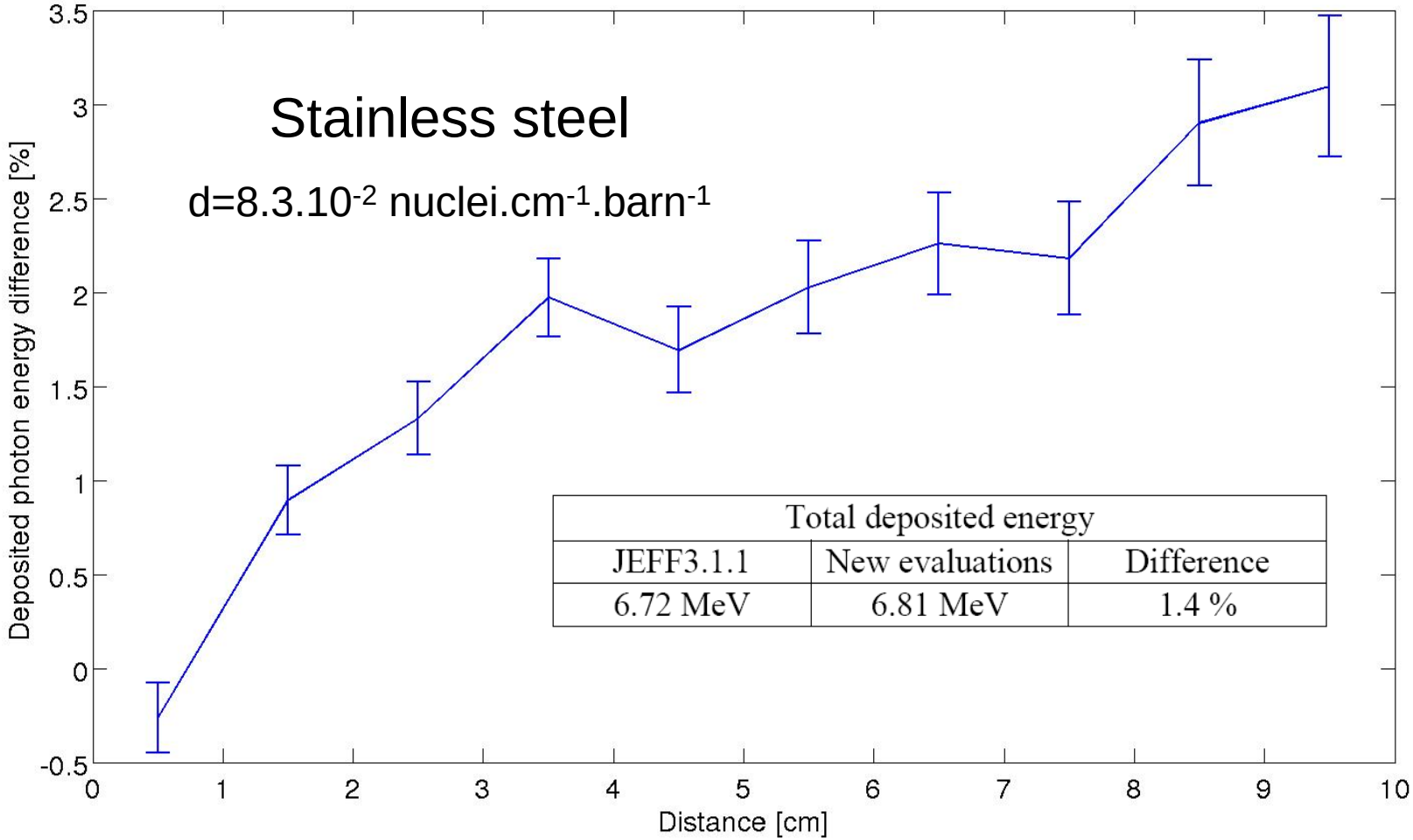
Total deposited energy		
JEFF3.1.1	New evaluation	Difference
3.08 MeV	8.39 MeV	+172 %

Test of the new evaluations



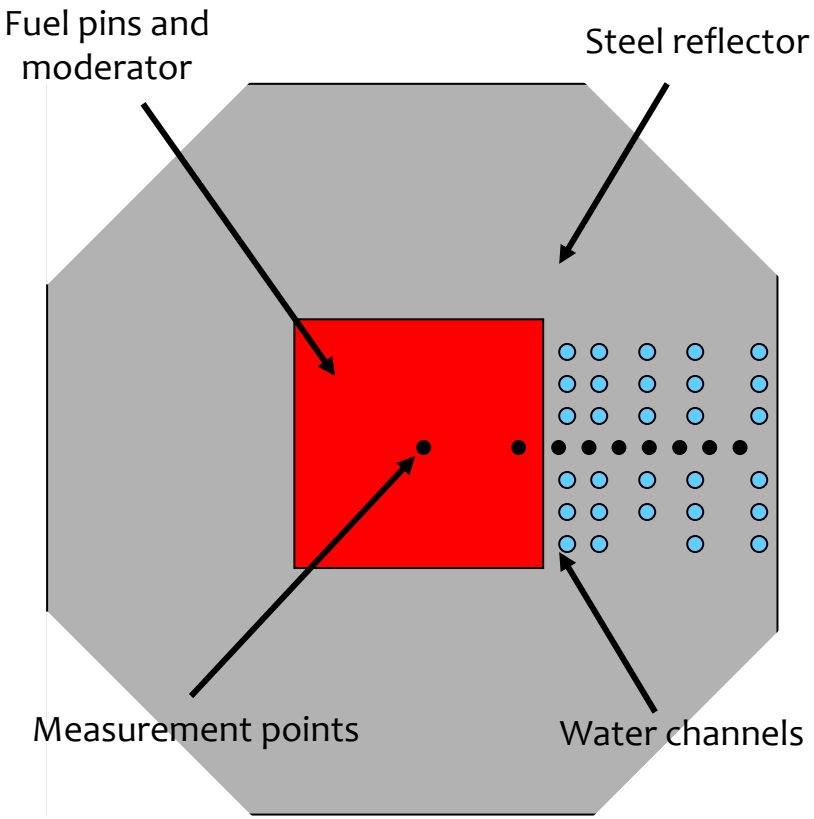
Total deposited energy		
JEFF3.1.1	New evaluation	Difference
6.43 MeV	6.22 MeV	-3.3 %

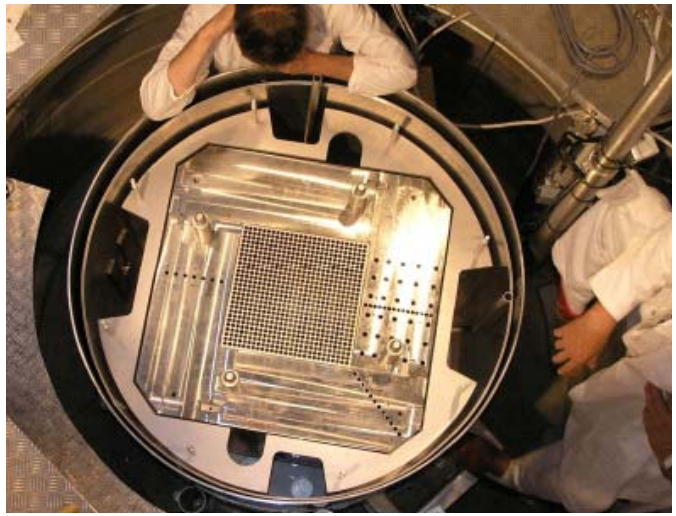
Test of the new evaluations



Total deposited energy		
JEFF3.1.1	New evaluations	Difference
6.72 MeV	6.81 MeV	1.4 %

The PERLE experiment





-A stainless steel reflector

-9 measurements points of the gamma heating

With JEFF3.1.1, underestimation of the gamma heating in the reflector

-7.5 ± 6 % (1σ)

The PERLE experiment

Distance from the core center [cm]	Differences with JEFF3.1.1 C2/C1-1 [%]
20.9	0.9
23.76	1.3
26.4	1.5
29.01	1.5
31.66	2.3
34.2	2.3
36.8	-0.5

The new evaluations allow to decrease the gamma heating calculation bias

Conclusion and perspectives

Before in JEFF3.1.1 :

- Bad accuracy of the gamma production spectra
- Energy inconsistencies

Now :

- 14 new evaluations proposed for JEFF3.2
- Accounting for the latest EGAF measurements
- Improvement of the gamma heating calculation in a stainless steel reflector

Future :

- Calculation of the gamma heating in Hafnium with the new evaluations

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