DE LA RECHERCHE À L'INDUSTRIE

# Thermal Scattering Law Data Files for JEFF

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www.cea.fr

# Context

**Evaluation work on “thermal scattering data” for JEFF was mainly performed at the Karlsruhe Institute of Technology (KIT) by J. Keinert and M. Mattes**

- 1981-2005 : this group produced Evaluated Nuclear Data Files (MF=7, MT=4) for H in H20, D in D20, H in ZrH, H in polyethylene, Graphite and Be metal

- 2003-2004: Three additional files were produced by CEA (H in CaH2, Ca in CaH2, Mg metal)

see also: “Thermal Scattering Law Data IAEA Nuclear Data Library”
https://www-nds.iaea.org/indltsl/

# List of thermal scattering law data files

| Material number | JEFF-3.1.1 | ENDF/B-VII | JENDL-4.0 |
|---|---|---|---|
| 1 | H(H20) | H(H2O) | H(H2O) |
| 2 | | Para Hydrogen | Para Hydrogen |
| 3 | | Ortho Hydrogen | Ortho Hydrogen |
| 7 | H(ZrH) | H(ZrH) | H(ZrH) |
| 8 | H(CaH2) | | |
| 11 | D(D2O) | D(D20) | D(D2O) |
| 12 | | Para Deuterium | Para Deuterium |
| 13 | | Ortho Deuterium | Ortho Deuterium |
| 26 | Be metal | Be metal | Be metal |
| 27 | | Be(BeO) | Be(BeO) |
| 28 | | O(BeO) | |
| 31 | Graphite | Graphite | Graphite |
| 33 | | Liquid Methane | Liquid Methane |
| 34 | | Solid Methane | Solid Methane |
| 37 | H(CH2) | H(CH2) | |
| 40 | | Benzine | Benzine |
| 45 | | Al metal | |
| 52 | Mg metal | | |
| 56 | | Fe metal | |
| 58 | | Zr(ZrH) | Zr(ZrH) |
| 59 | Ca(CaH2) | | |
| 75 | | O(UO2) | |
| 76 | | U(UO2) | |
| **Number of materials** | **9** | **20** | **14** |

# List of thermal scattering law data files

⇒ **Two different issues of the neutron scattering process as a function of the temperature**

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| | H(ZrH) | H(ZrH) | H(ZrH) |
| | H(CaH2) | | |
| | D(D2O) | D(D20) | D(D2O) |
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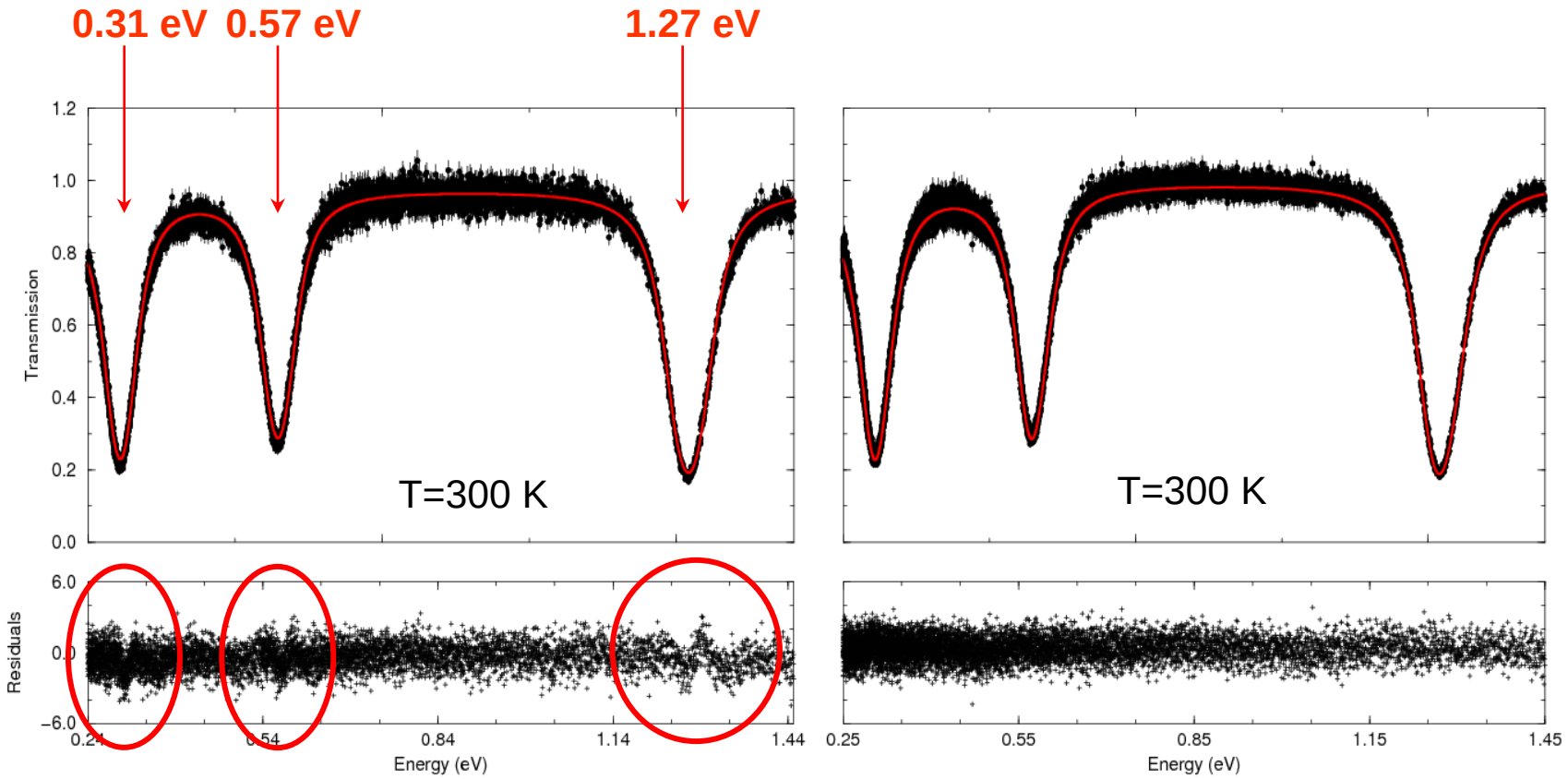
**Moderator for light and heavy water reactors**

**Cristal lattice effect in UOX fuel**

# Capture of neutrons by atoms in a crystal lattice

## Am241 transmission measurements at the GELINA facility, IRMM, Geel

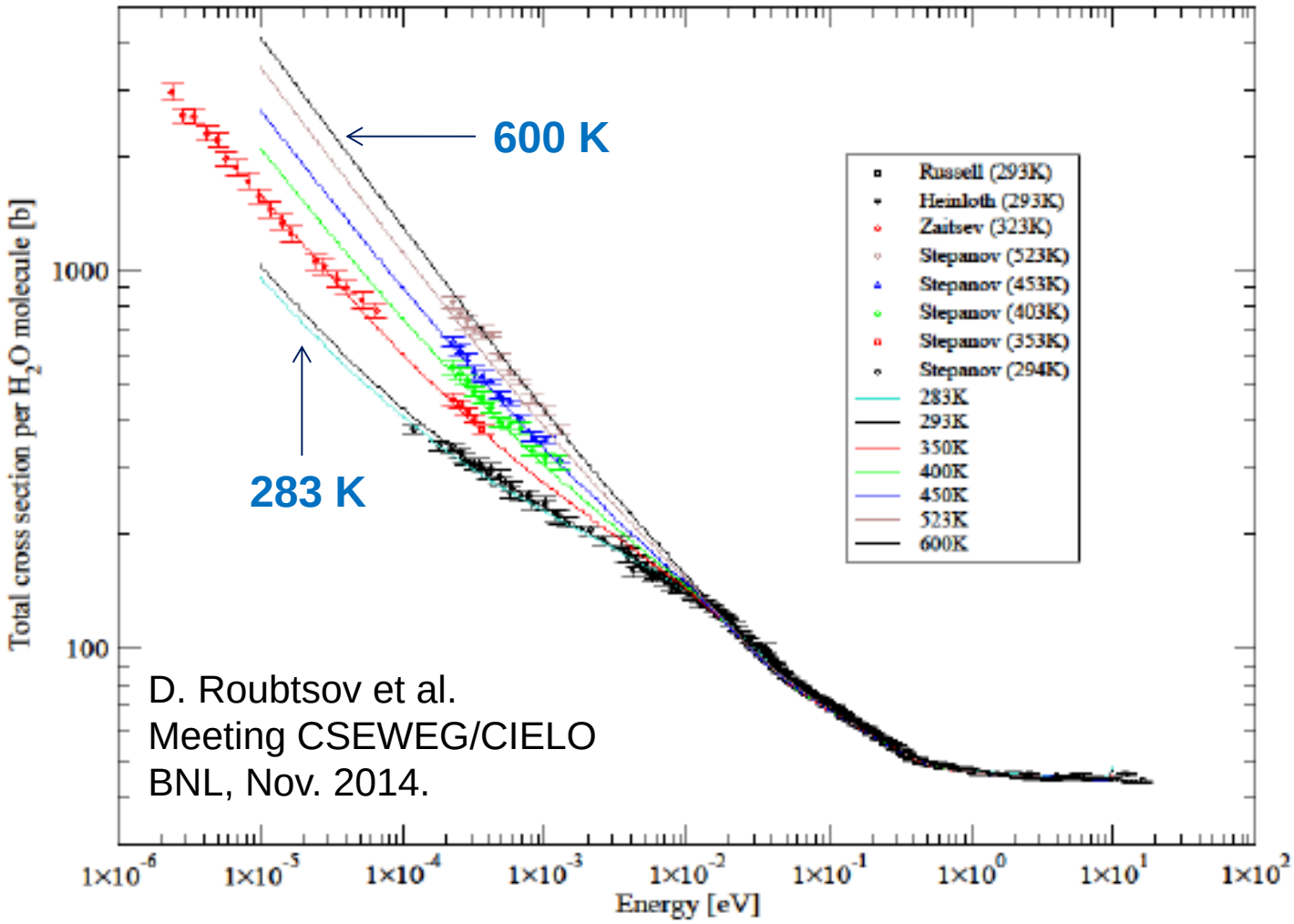
C. Lampoudis et al. Eur. Phys. J. Plus, 128, 86 (2013)




Free Gas Model (FGM)

Cristal Latice Model (CLM)

# Scattering of neutrons by Hydrogen bound in water



# Scattering law of H in H20

One of the most important data for light water reactors is the scattering law of **H in H20**.

Since the release of JEFF-311, KIT evaluation is continuously used in many neutronic calculations to simulate experimental and power reactors.

| Mat. | JEFF-3.1.1 | Temp. (K) | Year | Authors | Institute | Code |
|---|---|---|---|---|---|---|
| 1 | H(H20) | 293.6<br>323.6<br>373.6<br>423.6<br>473.6<br>523.6<br>573.6<br>623.6<br>647.2<br>800.0<br>1000.0 | Jan.<br>2004 | J. Keinert<br>M. Mattes | Karlsruhe Institute of Technology | LEAPR<br>NJOY-99.90++ |

# Integral validation

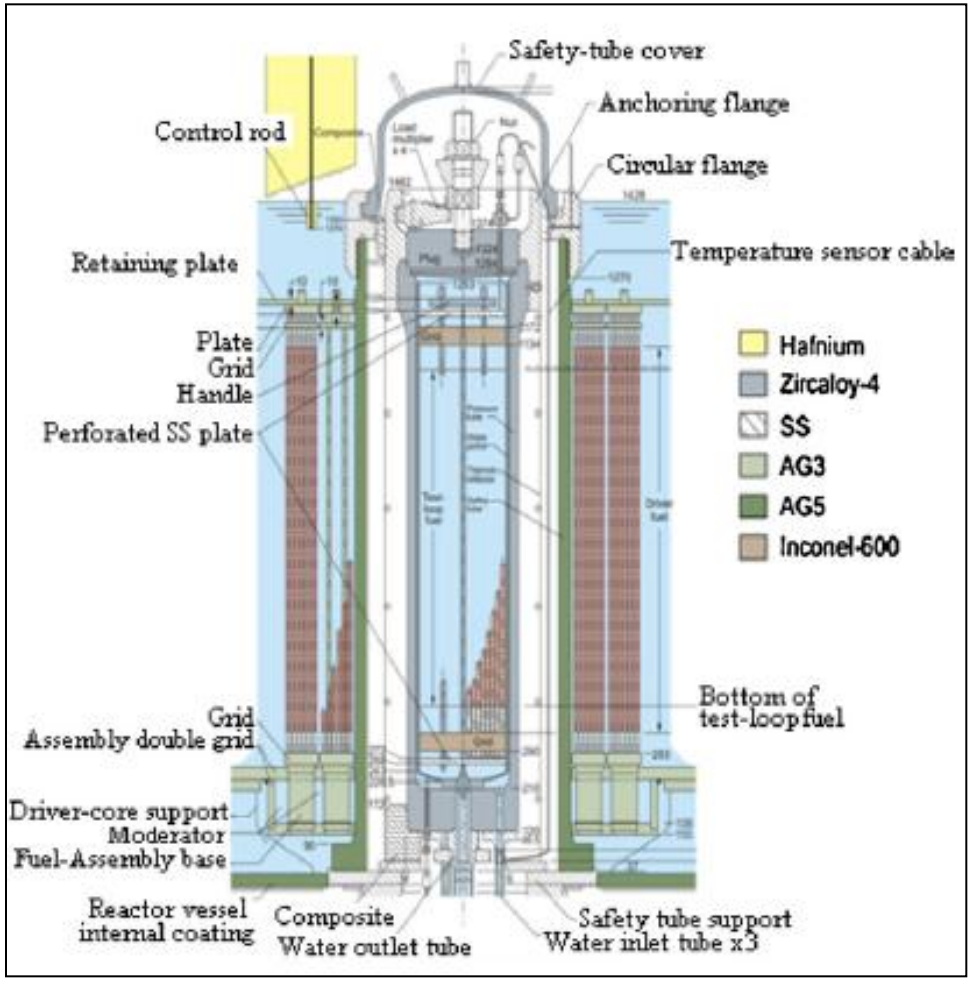
## Reactivity Temperature Coefficient (RTC)

Contributions of different physical phenomena to the **Reactivity Temperature Coefficient (RTC)** in typical light water moderated lattices have been investigated using the **APOLLO2** code with a multi-group cross-section library based on JEFF data

For **UOX fuel**, two integral experiments were performed in the **EOLE facility** of CEA Cadarache:

- **CREOLE experiment**
  ⇒ 20°C to 289°C (P=120 bar)
- **MISTRAL-1 experiment**
  ⇒ 10°C to 80°C

# Integral validation

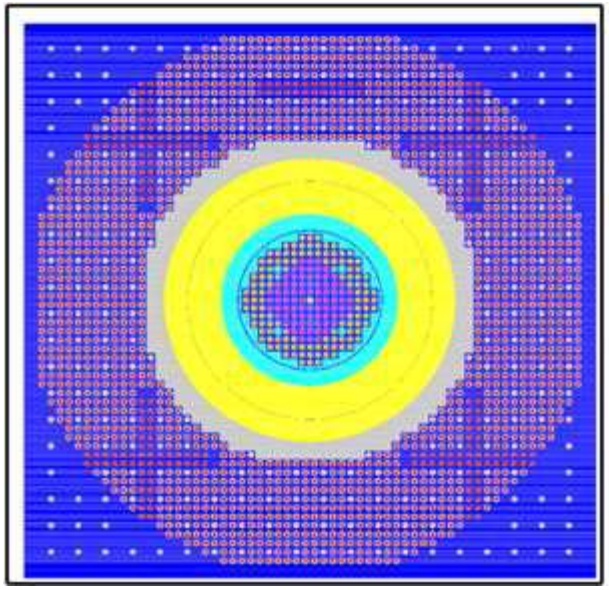



Vertical cross section of the CREOLE facility showing the safety-tube vacuum gap and driver assemblies.

## CREOLE experiment

The experimental facility consists of a pressurized central test loop in which it was possible to achieve operating conditions of a large PWR power reactor in terms of pressure and moderator temperature

⇒ **20°C to 289°C (P=120 bar)**



Horizontal cut-off

# Integral validation

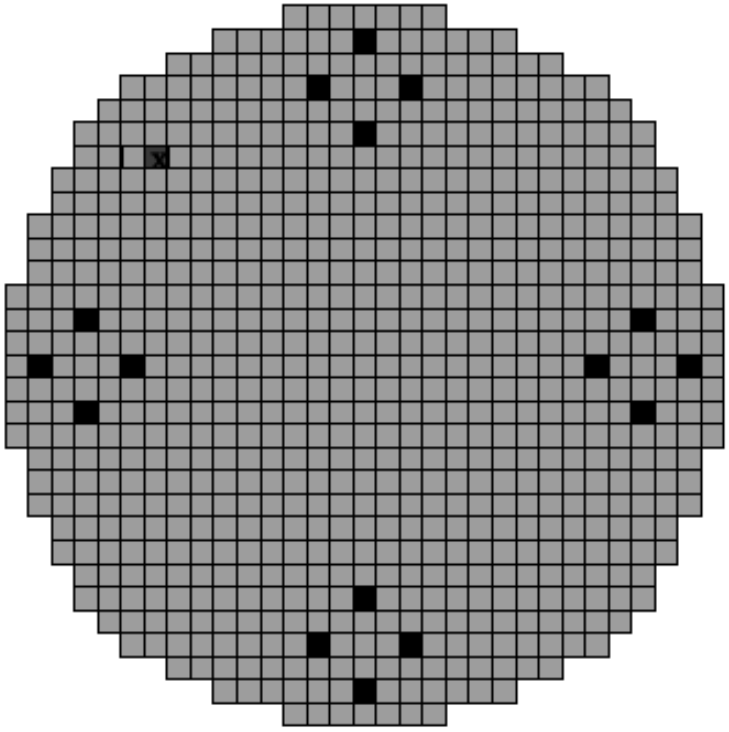



Fig. 7. Radial cross section of the MISTRAL-1 core.

## MISTRAL-1 experiment

The MISTRAL program was carried out in the EOLE facility from 1996 to 2000 in the framework of a collaboration between the CEA and the Japan organization NUPEC.

MISTRAL-1 is a regular enriched UO2 (~3.7% of 235U) core with about 750 fuel pins in a square pitch of 1.32 cm. The criticality was obtained by adjusting the soluble boron concentration.

The reactivity measurements were carried out in atmospheric conditions with temperatures ranging from **10°C to 80°C by steps of 5°C.**

# Integral validation

## Summary of the results expressed in terme of « total RTC error » (C-E) in pcm/°C

**Hot Zero Power (HZP) condition**

| CREOLE experiment | | | | |
|---|---|---|---|---|
| Code | 20-111°C | 111-186°C | 186-242°C | 242-289°C |
| TRIPOLI4 | + 0.01±0.13 | + 0.12±0.15 | + 0.08±0.17 | 0.00±0.20 |
| APOLLO2 | + 0.10±0.12 | + 0.17±0.14 | + 0.17±0.16 | + 0.20±0.18 |

| MISTRAL-1 experiment | | | |
|---|---|---|---|
| Code | 10-40°C | 40-80°C | 10-80°C |
| APOLLO2 | 0.0±0.3 | - 0.1±0.4 | 0.0±0.3 |

**« Cold » conditions in atmospheric pressure**

Excellent results with JEFF in « cold » and HZP conditions (UOX fuel)

# Perspectives

Ten years after the release of the latest “scattering data” files, **R&D activities on this topic are no longer discussed within the JEFF project.**

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New measurements of the scattering laws + total cross section of H(H20) in « cold » and HZP conditions are needed (steps of 5°C + as a function of pH) ⇒ **production of covariance matrices**

⇒ See presentation of Oscar Cabellos about the propagation of nuclear data uncertainties for PWR core analysis

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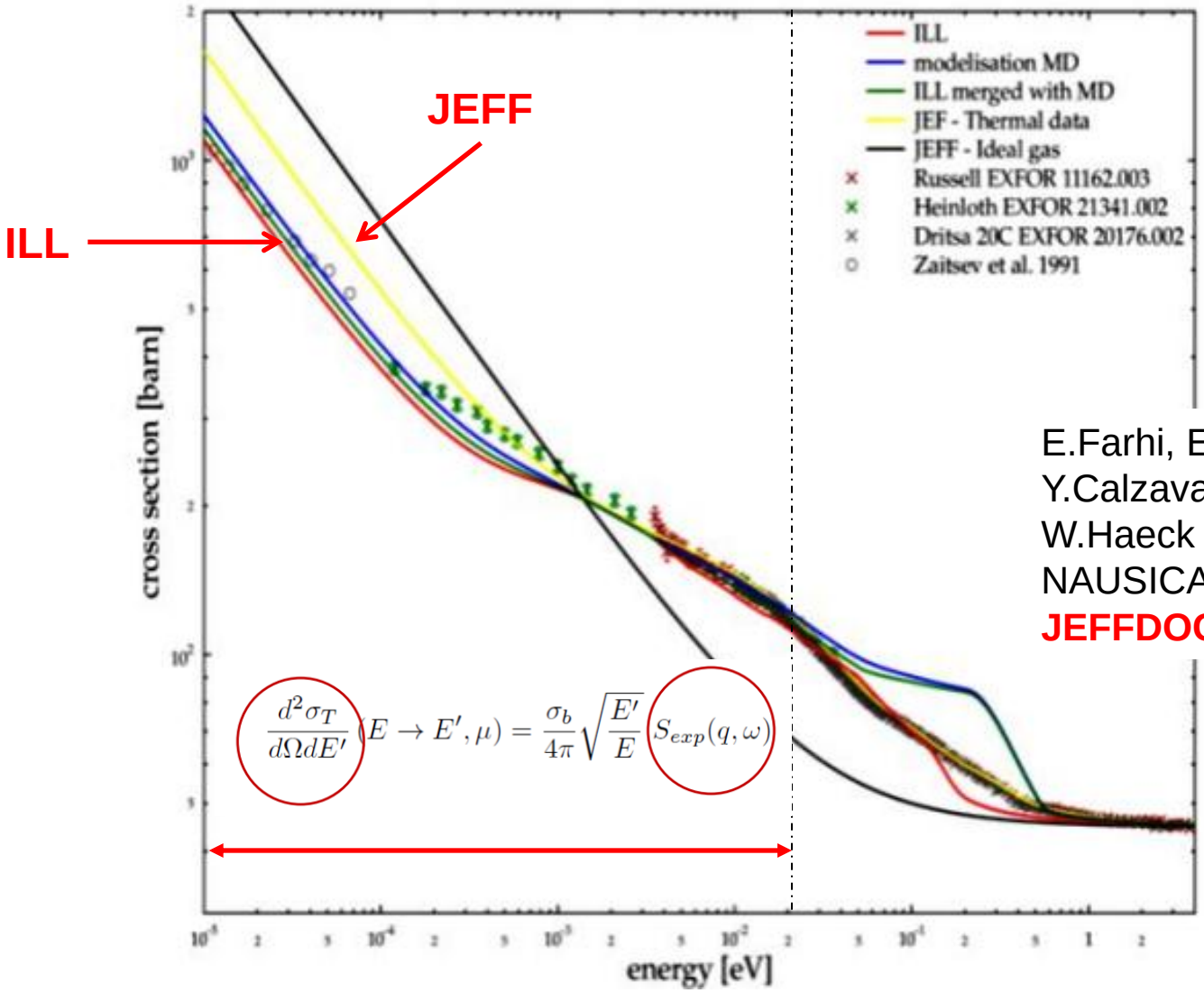
Replace LEAPR by recent experimental results, obtained using ILL neutron inelastic scattering instruments + Molecular Dynamic calculations ⇒ **see JEFFDOC-1578**

# Perspectives

## Ex: H20 cross section




E.Farhi, E.Pellegrini, Y.Calzavara, G.Ferran, W.Haeck , E.Guarini, NAUSICAA project, **JEFFDOC-1578**

# Perspectives

- **NAUSICAA collaboration** ⇒ First workshop in **July 2014** was the kick-off meeting of a collaborative project aiming to increase the accuracy of thermal neutron cross section data thanks to a new way to evaluate these data (ILL initiative).

- **Proposal for a JEFF working group on "thermal scattering data"** ⇒ kick off meeting at the NEA during the JEFF meeting of **April 2015**

- **Proposal for a new working group of the WPEC (Working Party on International Nuclear Data Evaluation Co-operation)** ⇒ kick off meeting at the NEA in **May 2015** before the WPEC meeting

+ new PhD thesis (Juan Pablo Scotta, CEA Cadarache) started in October 2014