Validation activities at Centro Atomico Bariloche

J.I. Márquez Damián
Florencia Cantargi
Rolando Granada

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Argentina

CSEWG Meeting
Nuclear Data Week
November 2016

- The Neutron Physics Group at Centro Atomico Bariloche has a long ($>$ 40 years) experience working on low energy neutron physics for moderators.
- This led to the evaluation and study of over 25 materials: moderators, cold moderators and neutron filters.
- In the three years we started reaching out to transfer our developments to the evaluated nuclear data libraries.
- In particular, in 2015 of our evaluation of the TSL for H in H_2O and D,O in D_2O was presented to CSEWG in collaboration with Danila Roubtsov from Canadian Nuclear Laboratories.
- I will summarize the validation activities in our group during the last year.

EPJ Nuclear Sci. Technol. **2**, 28 (2016)

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Regular Article Open Access

Impact of the thermal scattering law of H in H_2O on the isothermal temperature reactivity coefficients for UOX and MOX fuel lattices in cold operating conditions

Juan Pablo Scotta[1], Gilles Noguere[1,*], David Bernard[1], Jose Ignacio Marquez Damian[2], and Alain Santamarina[1]

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ELSEVIER

Effective temperatures and scattering cross sections in water mixtures determined by Deep Inelastic Neutron Scattering

CrossMark

J. Dawidowski[a,*], L.A. Rodríguez Palomino[a], J.I. Márquez Damián[a], J.J. Blostein[a], G.J. Cuello[b]

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IL NUOVO CIMENTO **38 C** (2015) 178
DOI 10.1393/ncc/i2015-15178-x

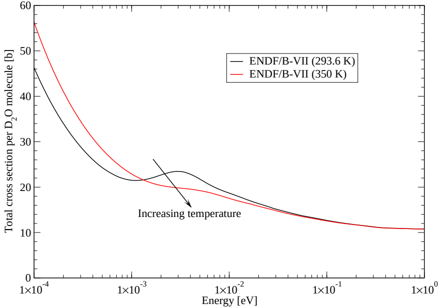
COLLOQUIA: UCANS-V

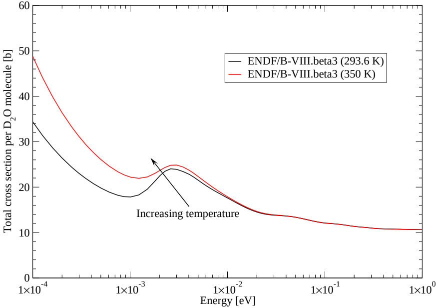
Measurement of the total cross section of heavy water in the 0.1 meV–1 eV energy range at 20 and 50 °C

J. I. MÁRQUEZ DAMIÁN(1)(*), J. R. GRANADA(1), D. V. BAXTER(2), S. R. PARNELL(2)(3) and D. C. EVANS(2)

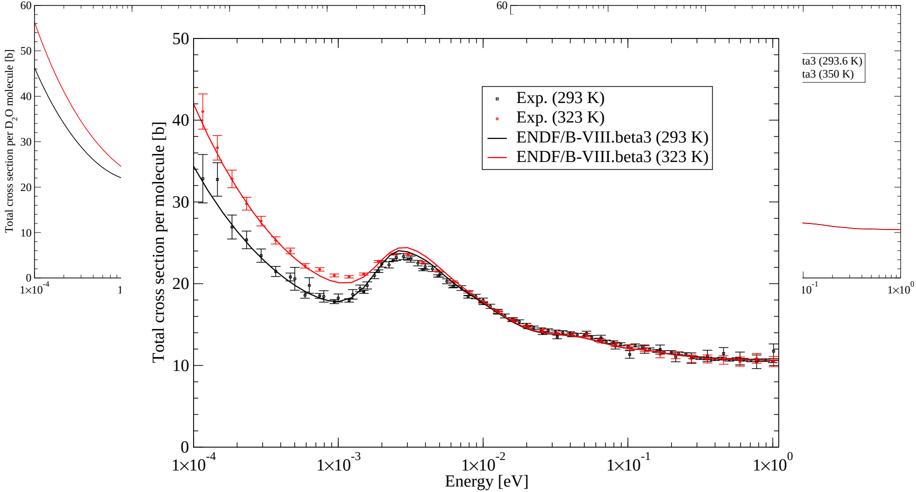
(1) *Neutron Physics Department and Instituto Balseiro, Centro Atomico Bariloche Rio Negro, Argentina*
(2) *Center for the Exploration of Energy and Matter, Indiana University Bloomington, IN, USA*
(3) *Faculty of Applied Sciences, Delft University of Technology - Delft, The Netherlands*

received 22 February 2016

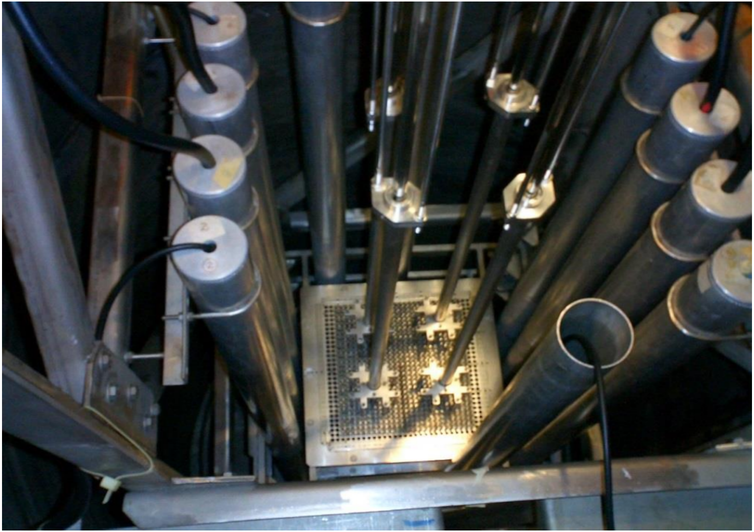

ENDF/B-VII (293.6 K)
ENDF/B-VII (350 K)
Increasing temperature
Total cross section per D_2O molecule [b]
Energy [eV]
0
10
20
30
40
50
60
1×10^{-4}
1×10^{-3}
1×10^{-2}
1×10^{-1}
1×10^{0}

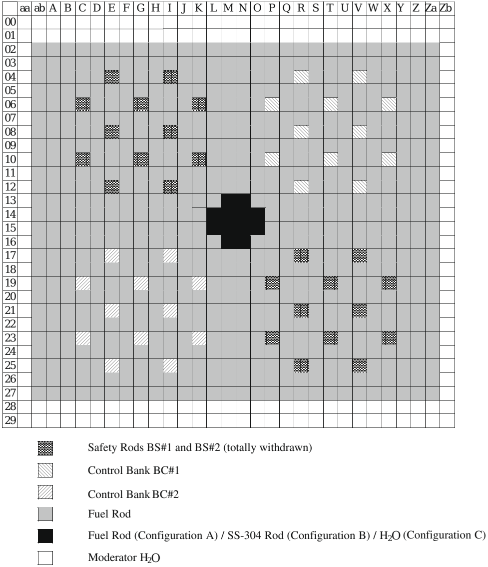

ENDF/B-VIII.beta3 (293.6 K)
ENDF/B-VIII.beta3 (350 K)
Increasing temperature
Total cross section per D_2O molecule [b]
Energy [eV]
0
10
20
30
40
50
60
1×10^{-4}
1×10^{-3}
1×10^{-2}
1×10^{-1}
1×10^{0}

Total cross section mesurements for heavy water



- Collaboration between IPEN, Brazil (A. dos Santos) and IRSN, France (L. Leal). Our contribution was limited to provide thermal scattering libraries.
- Measurements of the reactor temperature coefficient and inversion temperature ($\alpha_{\text{iso}} < 0 \rightarrow \alpha_{\text{iso}} > 0$).
- Three configurations were considered:
  - Configuration A: standard core.
  - Configuration B: standard core with SS-304 rods in the central positions.
  - Configuration C: standard core with water in the central positions.




aa ab A B C D E F G H I J K L M N O P Q R S T U V W X Y Z Za Zb
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Safety Rods BS#1 and BS#2 (totally withdrawn)
Control Bank BC#1
Control Bank BC#2
Fuel Rod
Fuel Rod (Configuration A) / SS-304 Rod (Configuration B) / H_2O (Configuration C)
Moderator H_2O

Reactor temperature coefficient experiments at IPEN/MB-01

NUCLEAR SCIENCE AND ENGINEERING: **133**, 314–326 (1999)

The Inversion Point of the Isothermal Reactivity Coefficient of the IPEN/MB-01 Reactor—1: Experimental Procedure

A. dos Santos,* H. Pasqualeto, L. C. C. B. Fanaro, R. Fuga, and R. Jerez

Instituto de Pesquisas Energéticas e Nucleares—IPEN/CNEN-SP
05508-900 Butantã, Cidade Universitária, S.P., Brazil

Received October 29, 1998
Accepted March 30, 1999

Abstract—*A new experimental quantity is presented to serve as a benchmark to verify the adequacy of the newly released ^{235}U thermal and subthermal cross sections for the determination of the reactivity coefficients of light water reactors. Such a quantity is denominated the inversion point, and by definition it is the temperature for which the isothermal reactivity coefficient of a reactor system becomes positive. The experimental bases for its determination are discussed. The experiment has been performed in the IPEN/MB-01 reactor facility. Instead of heating the reactor system as usual in experiments considering temperature variations, the reactor system is cooled to ~8.5°C. By means of a heating/cooling system, the temperature is allowed to increase slowly in a stepwise manner. For each step, the control bank critical position is recorded, and by analyzing its behavior as a function of temperature, the inversion point is inferred. The inversion point has been found to be an adequate experimental quantity to validate the thermal and subthermal ^{235}U cross section because it does not require any sort of calculated correction factors or any quantity that comes either from the calculational methodologies or from another experiment. In addition, the inversion point is an experimental quantity that can be measured with an excellent level of accuracy due mainly to the very precise characteristics of the control bank system of the IPEN/MB-01 reactor. The final value obtained for the IPEN/MB-01 reactor is 14.99 ± 0.15°C.*

NUCLEAR SCIENCE AND ENGINEERING: **133**, 314–326 (1999)

The Inversion Point of the Isothermal Reactivity Coefficient of the IPEN/MB-01 Reactor—1: Experimental Procedure

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Instituto de P
05508-

Abstract—*A new experimental*
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NUCLEAR SCIENCE AND ENGINEERING: **151**, 237–250 (2005)

The Inversion Point of the Isothermal Reactivity Coefficient of the IPEN/MB-01 Reactor—II: Theoretical Analysis

A. dos Santos* and G. S. de Andrade e Silva

Instituto de Pesquisas Energéticas e Nucleares – IPEN/CNEN-SP
Av. Prof. Lineu Prestes, 2242, Cidade Universitária, Sao Paulo, Brazil 05508-000

and

A. G. Mendonça, R. Fuga, and A. Y. Abe

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Received September 8, 2004
Accepted November 2, 2004

Abstract—*TORT, an S_N three-dimensional transport code, is employed for the analysis of the inversion point of the isothermal reactivity coefficient of the IPEN/MB-01 reactor. The analyses are performed in companion NJOY, AMPX-II, and TORT systems considering the data libraries ENDF/B-VI.8, JENDL3.3, and JEF3.0. The analyses reveal that for this peculiar problem, there is a need to convert all the computer codes to DOUBLE-PRECISION as well as to increase to seven the number of digits of the ANISN library generated by XSDRNPM. Contrary to the traditional diffusion theory codes, TORT k_{eff} results are very sensitive to the number of both fine and broad groups. For instance, the traditional and very well known two- and four-group structure, largely utilized in several diffusion codes, produced simply unacceptable k_{eff} results. The highest deviation between calculated and experimental values found for the inversion point was -4.48°C. At first glance, there appears to be a significant discrepancy. However, in terms of reactivity coefficient, this discrepancy means a deviation of -0.90 ± 0.05 pcm/°C, which indicates that the calculational methodology and related nuclear data libraries meet the desired accuracy (-1.0 pcm/°C) for the determination of this parameter for thermal reactors.*

NUCLEAR SCIENCE AND ENGINEERING: **133**, 314–326 (1999)

The Inversion Point of the Isothermal Reactivity Coefficient of the IPEN/MB-01 Reactor—1: Experimental Procedure

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Annals of Nuclear Energy 36 (2009) 1740–1746

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/anucene

ELSEVIER

New experimental results for the inversion point of the isothermal reactivity coefficient of the IPEN/MB-01 reactor

Adimir dos Santos [a,*], Graciete S. de Andrade e Silva [a], Arlindo G. Mendonça [b], Rinaldo Fuga [b], Alfredo Y. Abe [b]

[a] Instituto de Pesquisas Energéticas e Nucleares – IPEN/CNEN-SP, Av. Prof. Lineu Prestes, 2242 – Cidade Universitária – SP – 05508-000, Brazil
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A B S T R A C T

New experiments for the inversion point of the isothermal reactivity coefficient of the IPEN/MB-01 research reactor facility have been successfully conducted. The experiments considered the removal of 12 central fuel rods. These positions of the core were filled either by stainless steel rods or by water. The purpose of the experiments was to give more physical insight of the reactivity coefficient behavior of the IPEN/MB-01 reactor. Particularly, it was shown that in these conditions, when compared to the previous work, the inversion point moves to higher temperatures which are in a very much agreement to the model proposed in the previous work. TORT, a S_N 3-D transport code, is employed for the analysis of this set of new experiments. The analyses were performed in a companion NJOY, AMPX-II and TORT systems considering the data libraries ENDF/B-VI.8, ENDF/B-VII.0 and a third case which considers all nuclides from ENDF/B-VI.8 but ^{235}U which was taken from the work of Haicheng-Wu. The theoretical analysis reveals that the best result for the calculated and experimental comparison was found when the ^{235}U data which was taken from the work of Haicheng-Wu. However, all libraries considered in this work meets the desired accuracy (−1.0 pcm/°C) for the determination of this integral parameter for thermal reactors fuelled with slightly enriched uranium.

Reactor temperature coefficient experiments at IPEN/MB-01

NUCLEAR SCIENCE AND ENGINEERING: 133, 314–326 (1999)

The Inversion Point of the Isothermal Reactivity Coefficient of the IPEN/MB-01 Reactor—1: Experimental Procedure

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New experimental results for coefficient of the IPEN/MB-01

Adimir dos Santos [a,*], Graciete S. de And

[a] Instituto de Pesquisas Energéticas e Nucleares – IPEN/CNEN-SP,

[b] Centro Tecnológico da Marinha em São Paulo – CTMSP, Av. Pro

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ABS

New e research 12 cent The pu of the I vious w model set of n conside from E reveals which desired fuelled

The Impact of the New Nuclear Data Libraries on the Isothermal Reactivity Coefficient Determination

Adimir dos Santos and Graciete Simões de Andrade e Silva

Instituto de Pesquisas Energéticas e Nucleares
Av. Prof. Lineu Prestes, 2242 CEP 05508-000
São Paulo, SP Brazil
asantos@ipen.br

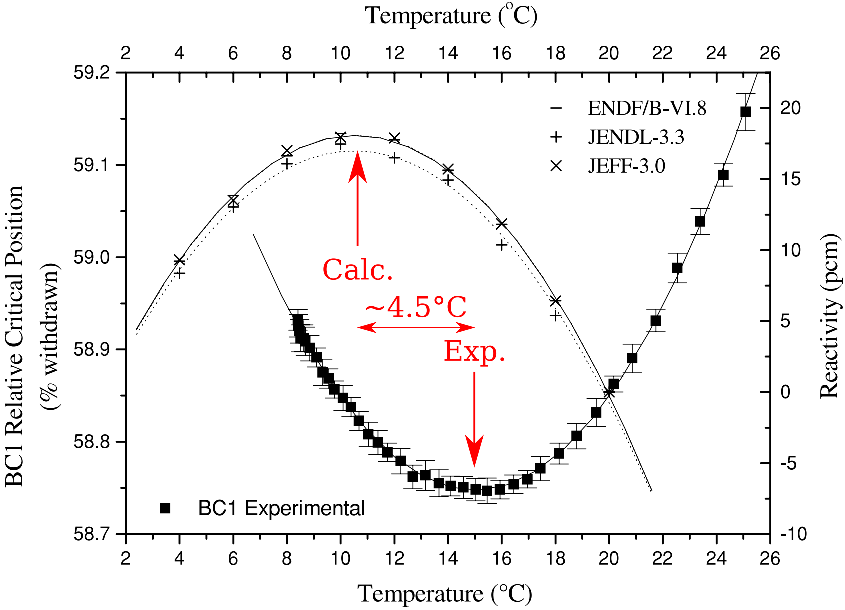
INTRODUCTION

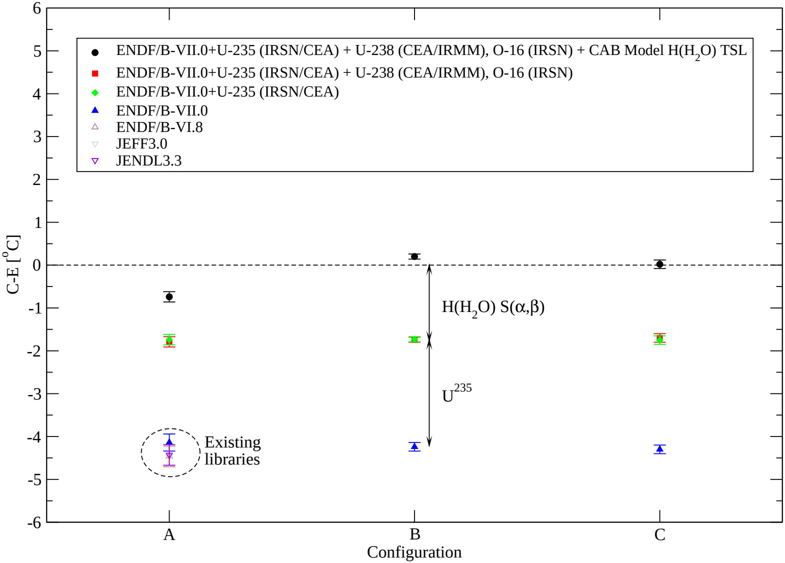
New evaluations for ^{235}U[1], ^{238}U[2,3], ^{16}O[4], and S(α,β) for hydrogen bound[5] in water were recently completed and made available for the reactor physics community. These new nuclear data are now under several benchmark tests and verification and they will become important part of the future nuclear data libraries for which new releases are expected to be in 2017. The choice of appropriate benchmarks to verify the adequacy of these evaluations in the determination of specific reactor response is crucial for the establishment of their accuracy. The purpose of this paper is to address the impact of these new nuclear data evaluations in the determination of a very important reactor response related to the safety of the facility; i.e., the isothermal reactivity coefficient.

need the experimental determination of the reactivity. The reactivity between two points of temperature is not measured directly; instead it is inferred employing an inverse kinetics method together with a set of delayed neutron parameters. These last parameters are obtained either by numerical approach or by experiments. However, the delayed neutron parameters are physical quantities of very difficult experimental or numerical determination which will impose very restrictive uncertainty on the isothermal reactivity coefficient.

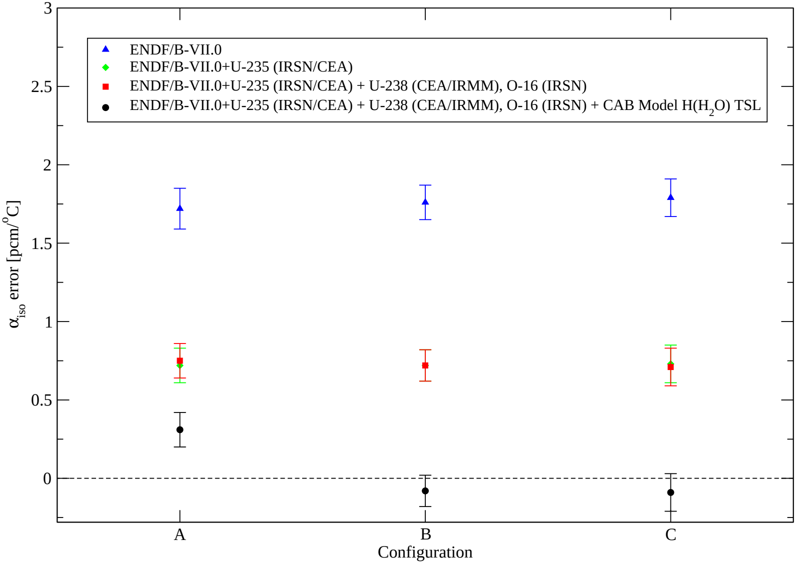
The IPEN/MB-01 research reactor is a zero power critical facility specially designed for measurements of a wide variety of reactor physics parameters to be used as benchmark experimental data for checking the calculation methodologies and related nuclear data libraries commonly used in the field of reactor physics. This facility is located in

- 3D reactor deterministic reactor calculations using XSDRNPM (S_{64}, 620 groups, 7 digit precision) and TORT (S_{16}, 16 groups).
- Cross section libraries were generated with NJOY/AMPX every $2°C$.
- Evaluations benchmarked:
  - Base ENDF/B-VII.0 library.desired
  - U-235 – IRSN/CEA evaluation (resolved resonance region from IRSN and high energy from CEA).
  - U-238 – CEA/IRMM (resolved resonance region from IRMM and high energy from CEA).
  - O-16 – IRSN (resolved resonance region up to 6 MeV from IRSN, the remaining from LANL Gerry Hale).
  - $H(H_2O)$ TSL – CAB Model (generated at the request temperatures from LEAPR).


Temperature (°C)
2 4 6 8 10 12 14 16 18 20 22 24 26
59.2
59.1
59.0
58.9
58.8
58.7
BC1 Relative Critical Position (% withdrawn)
Reactivity (pcm)
20
15
10
5
0
-5
-10
ENDF/B-VI.8
JENDL-3.3
JEFF-3.0
Calc.
~4.5°C
Exp.
BC1 Experimental
Temperature (°C)



ENDF/B-VII.0+U-235 (IRSN/CEA) + U-238 (CEA/IRMM), O-16 (IRSN) + CAB Model H(H2O) TSL
ENDF/B-VII.0+U-235 (IRSN/CEA) + U-238 (CEA/IRMM), O-16 (IRSN)
ENDF/B-VII.0+U-235 (IRSN/CEA)
ENDF/B-VII.0
ENDF/B-VI.8
JEFF3.0
JENDL3.3
C-E [°C]
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
H(H2O) S(α,β)
U235
Existing libraries
A
B
C
Configuration


ENDF/B-VII.0
ENDF/B-VII.0+U-235 (IRSN/CEA)
ENDF/B-VII.0+U-235 (IRSN/CEA) + U-238 (CEA/IRMM), O-16 (IRSN)
ENDF/B-VII.0+U-235 (IRSN/CEA) + U-238 (CEA/IRMM), O-16 (IRSN) + CAB Model H(H$_2$O) TSL
α_{iso} error [pcm/^{o}C]
3
2.5
2
1.5
1
0.5
0
A
B
C
Configuration

- Experiments sensitive to ^{235}U cross section and H-H_2O TSL.
- Combination of ^{235}U CIELO evaluation and the ENDF/B-VIII.β H-H_2O TSL produce excellent results:
  - Inversion point: $C - E < 1°$C
  - Isothermal reactor temperature coefficient: α_{iso}error < 0.5 pcm/°C.
- Results will be presented by A. dos Santos at M&C 2017 (April 2017).
- Benchmark will be available in the next release of the IRPhE Handbook (March 2017).

Temperature interpolator for LEAPR models

- Work in collaboration with D. Roubtsov from CNL.
- Goal: to produce evaluations at any temperature (within a temperature range), in a traceable way.
  - Errors found by validation can be traced back to the standard evaluation.
  - Improvements will benefit all users.
- What we have:
  - Set of Python scripts to parse, verify, and interpolate LEAPR inputs.
  - The scripts use XML as an intermediate format.
  - Still require NJOY (or a separate implementation of LEAPR).
- Ready to be deployed (working on this with IAEA-NDS).

Summary and conclusions

- New validation activities involving the Neutron Physics Department at Centro Atomico Bariloche, and colaborators abroad: Canada, France, U.S.A, Brazil, and the IAEA.
- In general: the performance of the new libraries is similar or better than existing models.
- Validation data will be available (when possible) in open databases: EXFOR, IRPhE.
- In particular:
  - new total cross section experiments show the new library solves a discrepancy the total cross section for heavy water.
  - the proposed TSL for light water helps solving a >15 year discrepancy in reactor temperature coefficient calculations.
- To support this we prepared a LEAPR input interpolator, which we hope will be available for the users soon.