IAEA 60 Years
Atoms for Peace and Development

Report on Nuclear Data Section activities at IAEA

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Division of Physical and Chemical Sciences NAPC
Department for Nuclear Sciences and Applications
IAEA, Vienna

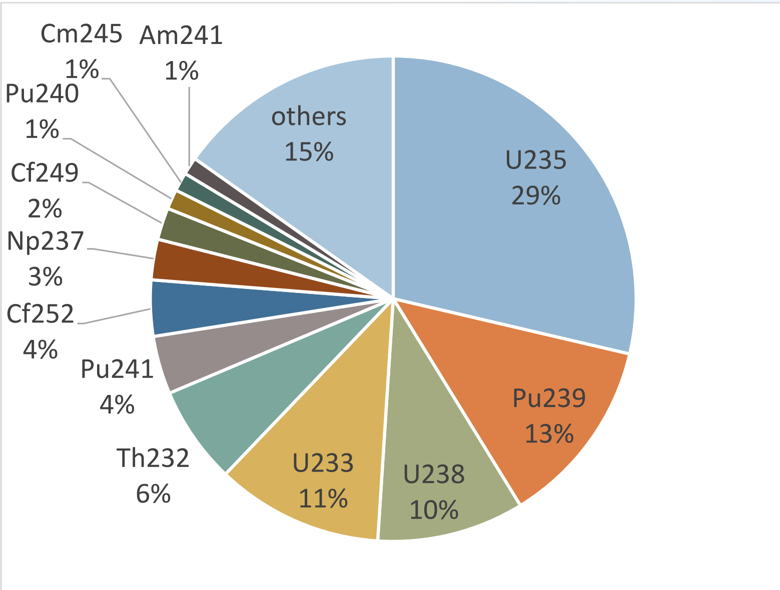
WPEC Meeting, June 27-28 2018, NEA, Paris

Nuclear Reaction Data Centres (NRDC)

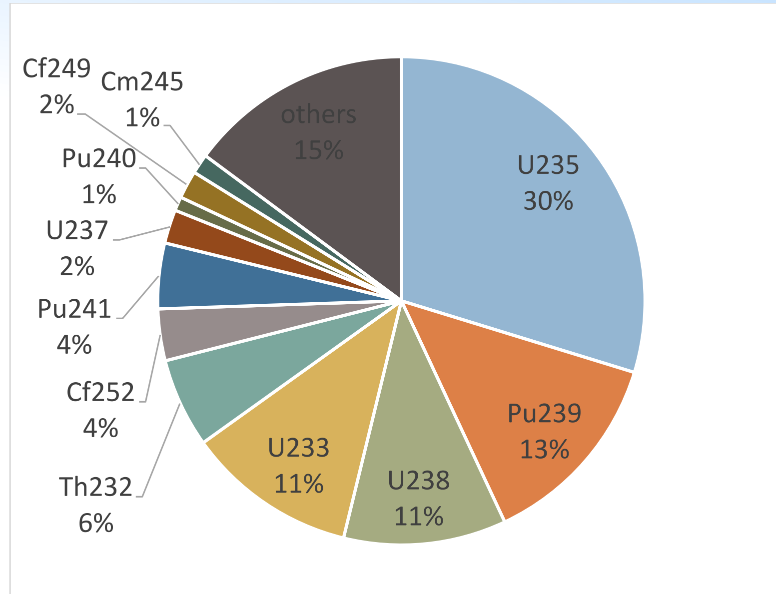
13 centres from 8 countries and 2 international organisations

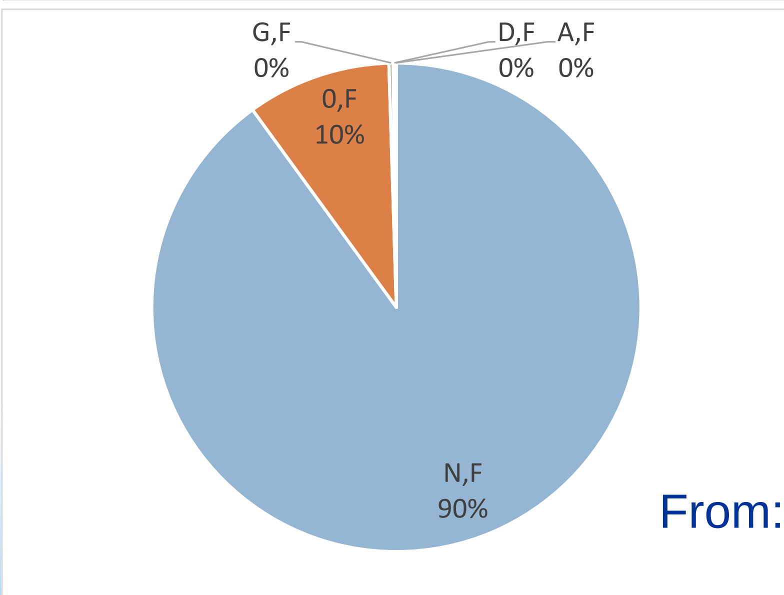
EXFOR: Extra effort in FY compilation

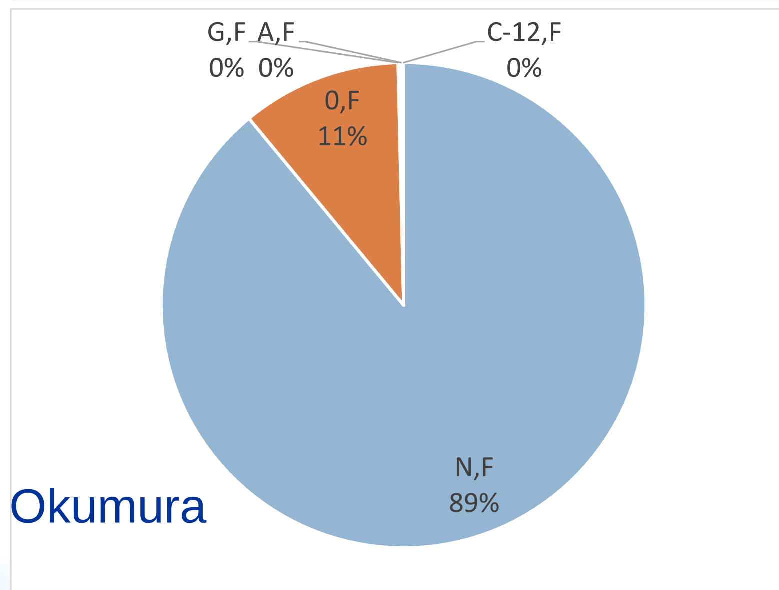
From England-Rider's list



From Mills' list







From: Shin Okumura

Fissile and reaction information were taken from CINDA.

Statistics of the completeness

Start to compile by the NRDC network.

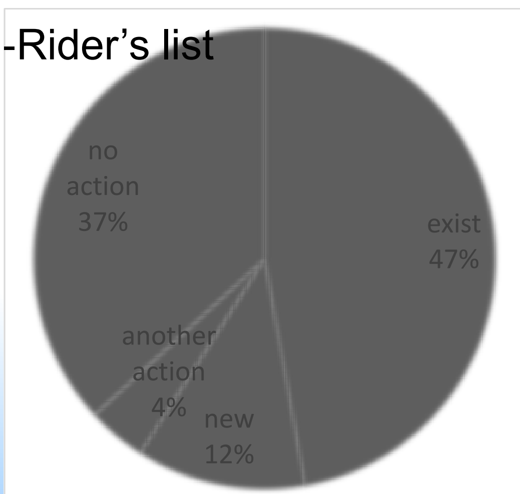
Area	E-R's list	Already in EXFOR	New entry	Another action	No action
1 United States	610	413	68	41	88
2 OECD countries	303	171	83	14	35
3 Others	155	103	24	8	20
4 Former Soviet Union countries	91	69	15	3	4
Not specified*	443				443
Total	**1602****	**756**	**190**	**66**	**590**

Area	Mills' list	Already in EXFOR	New entry	Another action	No action
1 United States	**321**	248	26	17	30
2 OECD countries	**149**	70	63	9	7
3 Others	**82**	53	22	3	4
4 Former Soviet Union countries	**73**	37	28	5	3
Not specified*	**20**				20
Total	**645**	**409**	**139**	**34**	**64**

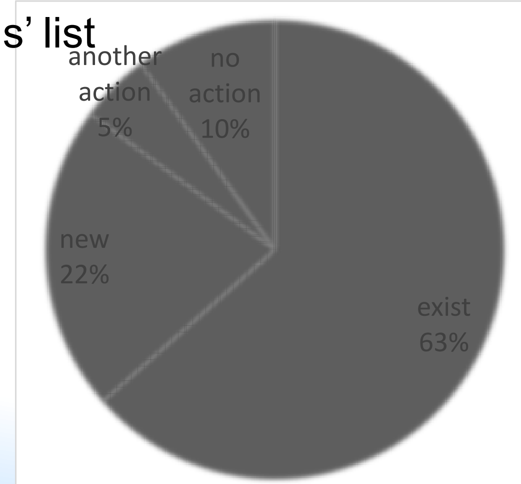
*Not specified due to private communications, Ph.D. theses, or classified reports. Also includes under checking.

**Only 924 articles are referred in the numerical data table used in the evaluation of ENDF/B-VI.

England-Rider's list



Mills' list



NSR (done by NNDC)

new entry 212
44%

Including neutron-, photo- and spontaneous- fission

From: Shin Okumura

Nuclear Structure and Decay Data

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ICTP-IAEA Workshop on NSDD, 15-26 Oct. 2018

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IAEA Neutron data standards

ELSEVIER

CrossMark

Available online at www.sciencedirect.com

ScienceDirect

Nuclear Data Sheets 148 (2018) 143–188

Nuclear Data Sheets

www.elsevier.com/locate/nds

Evaluation of the Neutron Data Standards

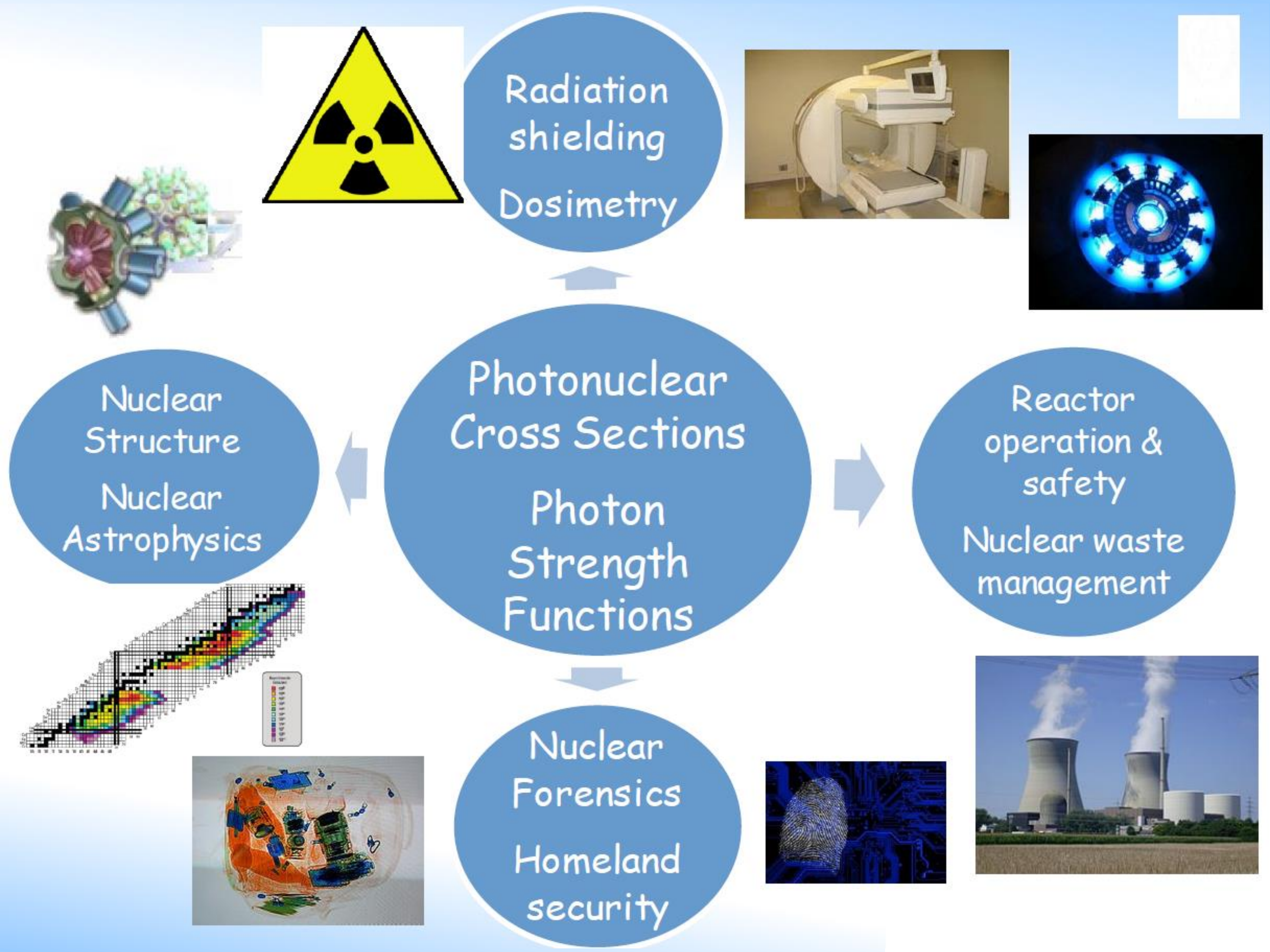
A.D. Carlson,[1,*] V.G. Pronyaev,[2] R. Capote,[3] G.M. Hale,[4] Z.-P. Chen,[5] I. Duran,[6] F.-J. Hambsch,[7] S. Kunieda,[8] W. Mannhart,[9] B. Marcinkevicius,[3,10] R.O. Nelson,[4] D. Neudecker,[4] G. Noguere,[11] M. Paris,[4] S.P. Simakov,[12] P. Schillebeeckx,[7] D.L. Smith,[13] X. Tao,[14] A. Trkov,[3] A. Wallner,[15,16] and W. Wang[14]

[1] *National Institute of Standards and Technology, 100 Bureau Drive, Stop 8463, Gaithersburg, MD 20899-8463, USA*
[2] *PI Atomstandart, State Corporation Rosatom, 117342, Moscow, Russia*
[3] *NAPC-Nuclear Data Section, International Atomic Energy Agency, Vienna, Austria*
[4] *Los Alamos National Laboratory, Los Alamos, NM 87545, USA*
[5] *Tsinghua University, Beijing, 100084, China*
[6] *Universidad de Santiago de Compostela, Spain*
[7] *EC-JRC-Directorate G, Unit G.2, B-2440 Geel, Belgium*
[8] *Japan Atomic Energy Agency, Nuclear Data Center, Ibaraki 319-1195, Japan*
[9] *Physikalisch-Technische Bundesanstalt, Org. 6.4, 38116 Braunschweig, Germany*
[10] *Uppsala University, Uppsala, Sweden*
[11] *SPRC/LEPh, CEA Cadarache, 13108 Saint Paul Les Durance, France*
[12] *Karlsruhe Institute of Technology, Hermann-von-Helmholtz-Platz 1 76344 Eggenstein-Leopoldshafen, Germany*
[13] *Argonne National Laboratory, Argonne, IL 60439, USA*
[14] *China Nuclear Data Center (CNDC), China Institute of Atomic Energy, Beijing, China*
[15] *Vera Laboratory, Faculty of Physics, University of Vienna, A-1090 Vienna, Austria*
[16] *Dept. of Nuclear Physics, The Australian National University, Canberra ACT 0200, Australia*

(Received 3 September 2017; revised received 30 October and 12 November 2017; accepted 20 November 2017)

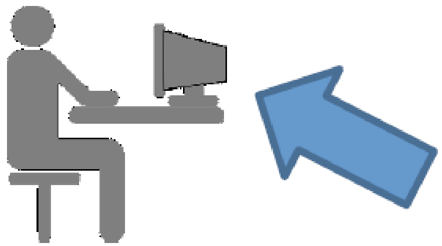
With the need for improving existing nuclear data evaluations, (*e.g.*, ENDF/B-VIII.0 and JEFF-3.3 releases) the first step was to evaluate the standards for use in such a library. This new standards evaluation made use of improved experimental data and some developments in the methodology of analysis and evaluation. In addition to the work on the traditional standards, this work produced the

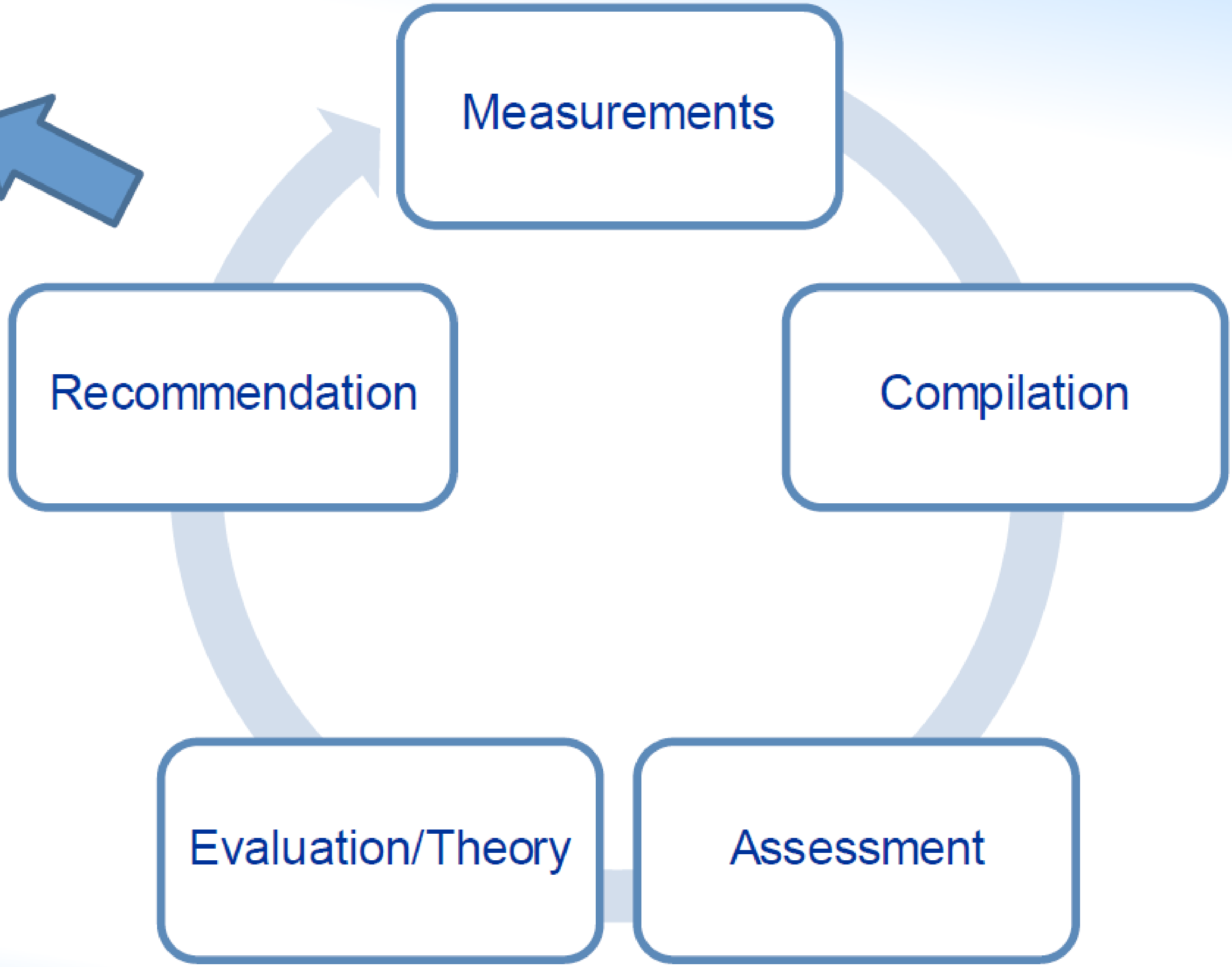
Ongoing: Consultancy meetings on Uncertainty quantification for Standards



Radiation shielding
Dosimetry
Nuclear Structure
Nuclear Astrophysics
Photonuclear Cross Sections
Photon Strength Functions
Reactor operation & safety
Nuclear waste management
Nuclear Forensics
Homeland security

Updating the Photonuclear Data Library & Generating Reference Database for Photon Strength Functions (2016-2019)

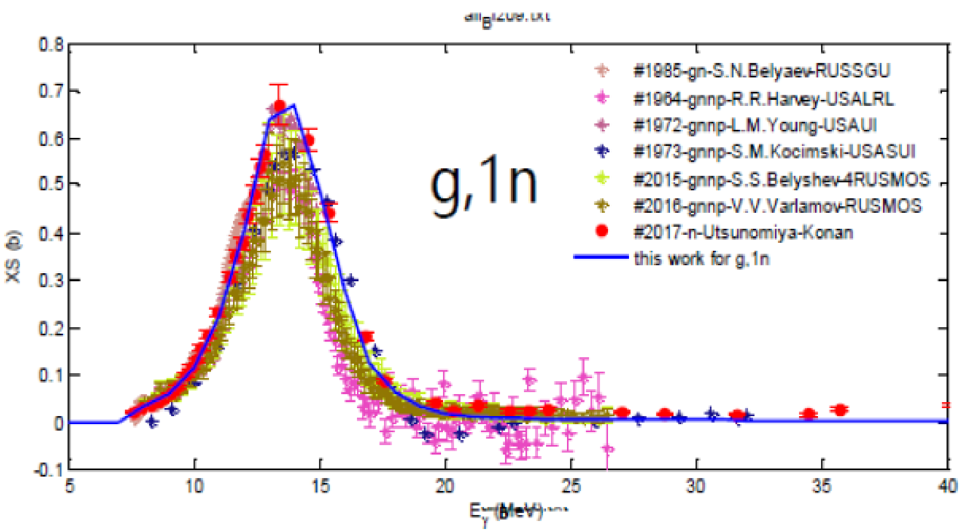


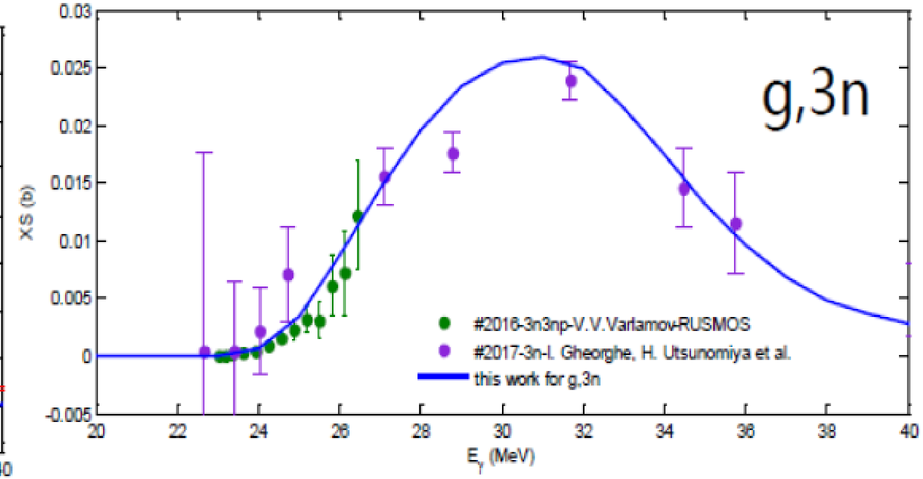


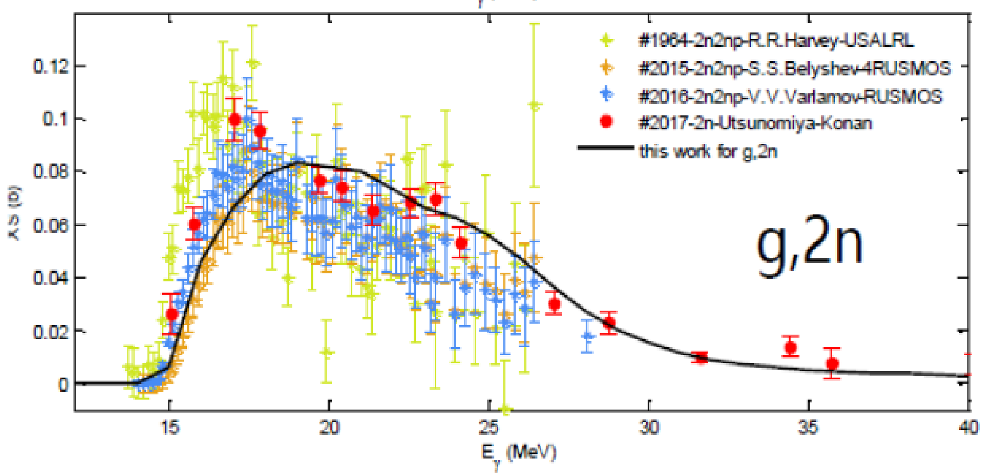
Onlline
database

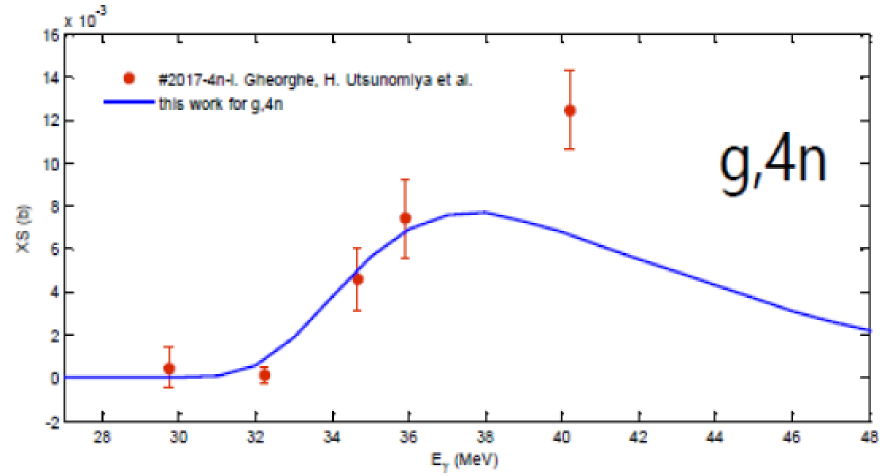
ENDF library

New results for $^{209}Bi(\gamma,xn)$









New data: A.I. Gheorghe+ (2017)

New IAEA Photonuclear Data Library

- 200 nuclides – incl. for medical isotope production
- Energies up to 200 MeV
- New GDR parameters
- New evaluation methods – improved modelling
- Available in ENDF-6 format and user-friendly interface
- Publication in preparation

Y.-S. Cho *S370*	KAERI
D. Filipescu, I. Gheorghe	IFIN-HH
N. Iwamoto	JAEA
X. Ruirui, X. Tao *R172*	CNDC
V. Varlamov	Moscow University
Review:	R. Capote T. Kawano Y-O. Lee O.Iwamoto

Final output

Eur. Phys. J. A manuscript No.
(will be inserted by the editor)

Reference Database for Photon Strength Functions

S. Goriely [1], P. Dimitriou [2], M. Wiedeking [3], T. Belgya [4], R. Firestone [5], J. Kopecky [7], M. Krtička [8], V. Plujko [9], R. Schwengner [10], S. Siem [11], H. Utsunomiya [12], S. Hilaire [13], S. Péru [13], Y. S. Cho [16], D. M. Filipescu [15], N. Iwamoto [16], T. Kawano [6], V. Varlamov [18], R. Xu [17]

All the data will be made available from an online interactive database

…and are included in the next release of TALYS

Ongoing project

- R-matrix theory: theory to describe individual resonances in the scattering of A+B and the non-resonant background between them

- IAEA Project on inter-comparison of R-matrix codes

  (2015-present): verify codes, compare fit procedures, validate R-matrix data fits and perform evaluations

- Codes: AZURE2, AMUR, EDA, RAC, SFRESCOX, SAMMY

- Verification has concluded (European Physical Journal A, in press) – next step is comparison of evaluations

New CRP (2019-): Updating Fission Yield Data for Applications

- Objective: improve existing evaluated Fission Product Yields (FPY)
- Scope:
  - Compilation of all new FFY and FPY experimental data
  - Improve systematics and models
  - Incorporate new knowledge in FPY evaluations: correct errors and inconsistencies, update evaluations, provide reliable estimate of uncertainties
  - Agree on treatment of covariances, provide FPY covariance data and propose suitable format for inclusion in ENDF-6
  - Validation of new evaluations
- Participant countries: Belgium, China, Finland, France, Germany, India, Japan, Russia, Sweden, UK, USA

Positron Emitters

K. Gul et al., IAEA TECDOC 1211, Vienna, 2001
F. T. Tarkanyi et al., J. Radioanalytical and Nucl. Chem. (2019) 319. 533-666

$^{11}\mathrm{C}$
$^{14}\mathrm{N}(p,\alpha)^{11}\mathrm{C}$

$^{13}\mathrm{N}$
$^{16}\mathrm{O}(p,\alpha)^{13}\mathrm{N}$

$^{15}\mathrm{O}$
$^{15}\mathrm{N}(p,n)^{15}\mathrm{O}$

$^{14}\mathrm{N}(d,n)^{15}\mathrm{O}$

$^{18}\mathrm{F}$
$^{18}\mathrm{O}(p,n)^{18}\mathrm{F}$

$^{nat}\mathrm{Ne}(d,x)^{18}\mathrm{F}$

$^{44}\mathrm{Sc}$
$^{44}\mathrm{Ca}(p,n)^{44}\mathrm{Sc}$

$^{44}\mathrm{Ca}(d,2n)^{44}\mathrm{Sc}$

$^{43}\mathrm{Ca}(d,n)^{44}\mathrm{Sc}$

$^{45}\mathrm{Sc}(p,2n)^{44}\mathrm{Ti}$

$^{45}\mathrm{Sc}(d,3n)^{44}\mathrm{Ti}$

$^{52m}\mathrm{Mn}$
$^{nat}\mathrm{Ni}(p,x)^{52}\mathrm{Fe}$

$^{55}\mathrm{Mn}(p,4n)^{52}\mathrm{Fe}$

$^{50}\mathrm{Cr}(\alpha,2n)^{52}\mathrm{Fe}$

$^{52}\mathrm{Cr}(p,n)^{52m}\mathrm{Mn}$

$^{52}\mathrm{Cr}(d,2n)^{52m}\mathrm{Mn}$

$^{52}\mathrm{Mn}$
$^{52}\mathrm{Cr}(p,n)^{52}\mathrm{Mn}$

$^{52}\mathrm{Cr}(d,2n)^{52}\mathrm{Mn}$

$^{55}\mathrm{Co}$
$^{58}\mathrm{Ni}(p,\alpha)^{55}\mathrm{Co}$

$^{54}\mathrm{Fe}(d,n)^{55}\mathrm{Co}$

$^{56}\mathrm{Fe}(p,2n)^{55}\mathrm{Co}$

$^{61}\mathrm{Cu}$
$^{61}\mathrm{Ni}(p,n)^{61}\mathrm{Cu}$

$^{60}\mathrm{Ni}(d,n)^{61}\mathrm{Cu}$

$^{64}\mathrm{Zn}(p,\alpha)^{61}\mathrm{Cu}$

$^{62}\mathrm{Cu}$
$^{63}\mathrm{Cu}(p,2n)^{62}\mathrm{Zn}$

$^{63}\mathrm{Cu}(d,3n)^{62}\mathrm{Zn}$

$^{nat}\mathrm{Ni}(\alpha,x)^{62}\mathrm{Zn}$

$^{62}\mathrm{Ni}(p,n)^{62}\mathrm{Cu}$

$^{62}\mathrm{Ni}(d,2n)^{62}\mathrm{Cu}$

$^{66}\mathrm{Ga}$
$^{66}\mathrm{Zn}(p,n)^{66}\mathrm{Ga}$

$^{63}\mathrm{Cu}(\alpha,n)^{66}\mathrm{Ga}$

$^{68}\mathrm{Ga}$
$^{68}\mathrm{Zn}(p,n)^{68}\mathrm{Ga}$

$^{65}\mathrm{Cu}(\alpha,n)^{68}\mathrm{Ga}$

$^{nat}\mathrm{Ga}(p,x)^{68}\mathrm{Ge}$

$^{69}\mathrm{Ga}(p,2n)^{68}\mathrm{Ge}$

$^{72}\mathrm{As}$
$^{75}\mathrm{As}(p,4n)^{72}\mathrm{Se}$

$^{nat}\mathrm{Br}(p,x)^{72}\mathrm{Se}$

$^{nat}\mathrm{Ge}(p,x)^{72}\mathrm{As}$

$^{nat}\mathrm{Ge}(d,x)^{72}\mathrm{As}$

$^{73}\mathrm{Se}$
$^{75}\mathrm{As}(p,3n)^{73}\mathrm{Se}$

$^{72}\mathrm{Ge}(\alpha,3n)^{73}\mathrm{Se}$

$^{76}\mathrm{Br}$
$^{76}\mathrm{Se}(p,n)^{76}\mathrm{Br}$

$^{77}\mathrm{Se}(p,2n)^{76}\mathrm{Br}$

$^{75}\mathrm{As}(\alpha,3n)^{76}\mathrm{Br}$

$^{82m}\mathrm{Rb}$
$^{82}\mathrm{Kr}(p,n)^{82m}\mathrm{Rb}$

$^{82}\mathrm{Kr}(d,2n)^{82m}\mathrm{Rb}$

$^{82}\mathrm{Rb}$
$^{nat}\mathrm{Rb}(p,x)^{82}\mathrm{Sr}$

$^{85}\mathrm{Rb}(p,4n)^{82}\mathrm{Sr}$

$^{86}\mathrm{Y}$
$^{86}\mathrm{Sr}(p,n)^{86}\mathrm{Y}$

$^{88}\mathrm{Sr}(p,3n)^{86}\mathrm{Y}$

$^{85}\mathrm{Rb}(\alpha,3n)^{86}\mathrm{Y}$

$^{89}\mathrm{Zr}$
$^{89}\mathrm{Y}(p,n)^{89}\mathrm{Zr}$

$^{89}\mathrm{Y}(d,2n)^{89}\mathrm{Zr}$

$^{90}\mathrm{Nb}$
$^{93}\mathrm{Nb}(p,x)^{90}\mathrm{Nb}$

$^{89}\mathrm{Y}(\alpha,3n)^{90}\mathrm{Nb}$

$^{94m}\mathrm{Tc}$
$^{92}\mathrm{Mo}(\alpha,x)^{94m}\mathrm{Tc}$

$^{94}\mathrm{Mo}(p,n)^{94m}\mathrm{Tc}$

$^{110m}\mathrm{In}$
$^{nat}\mathrm{In}(p,x)^{110}\mathrm{Sn}$

$^{108}\mathrm{Cd}(\alpha,2n)^{110}\mathrm{Sn}$

$^{110}\mathrm{Cd}(p,n)^{110m}\mathrm{In}$

$^{110}\mathrm{Cd}(d,2n)^{110m}\mathrm{In}$

$^{107}\mathrm{Ag}(\alpha,n)^{110m}\mathrm{In}$

$^{118}\mathrm{Sb}$
$^{115}\mathrm{Sn}(\alpha,n)^{118}\mathrm{Te}$

$^{116}\mathrm{Sn}(\alpha,2n)^{118}\mathrm{Te}$

$^{nat}\mathrm{Sb}(p,x)^{118}\mathrm{Te}$

$^{nat}\mathrm{Sb}(d,x)^{118}\mathrm{Te}$

$^{120}\mathrm{I}$
$^{120}\mathrm{Te}(p,n)^{120}\mathrm{I}$

$^{122}\mathrm{Te}(p,3n)^{120}\mathrm{I}$

$^{122}\mathrm{I}$
$^{124}\mathrm{Xe}(p,x)^{122}\mathrm{Xe}$

$^{127}\mathrm{I}(p,6n)^{122}\mathrm{Xe}$

$^{127}\mathrm{I}(d,7n)^{122}\mathrm{Xe}$

$^{128}\mathrm{Cs}$
$^{133}\mathrm{Cs}(p,6n)^{128}\mathrm{Ba}$

$^{140}\mathrm{Pr}$
$^{141}\mathrm{Pr}(p,2n)^{140}\mathrm{Nd}$

$^{141}\mathrm{Pr}(d,3n)^{140}\mathrm{Nd}$

$^{nat}\mathrm{Ce}(^{3}\mathrm{He},x)^{140}\mathrm{Nd}$

Last edited by: S. Takacs: Aug. 2018.

Medical Isotope Browser

- Based on TENDL + IAEA medical isotope database
- Release: Oct 2019 at IAEA radiopharmaceutical symposium

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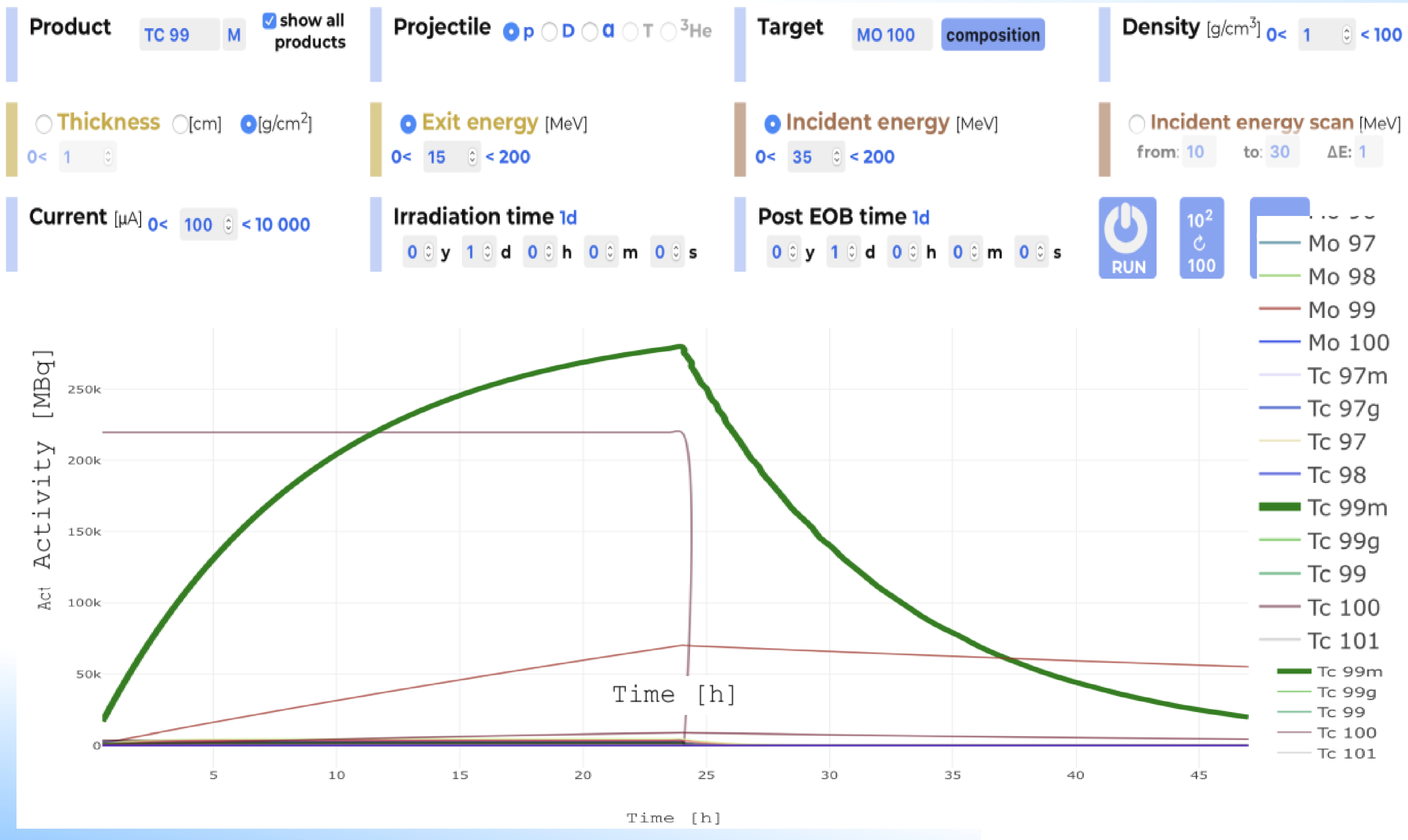


Status of INDEN evaluations

On behalf of the INDEN collaboration

Uranium-238 - Status

New information from integral testing since ENDF/B-VIII.0 release & publications

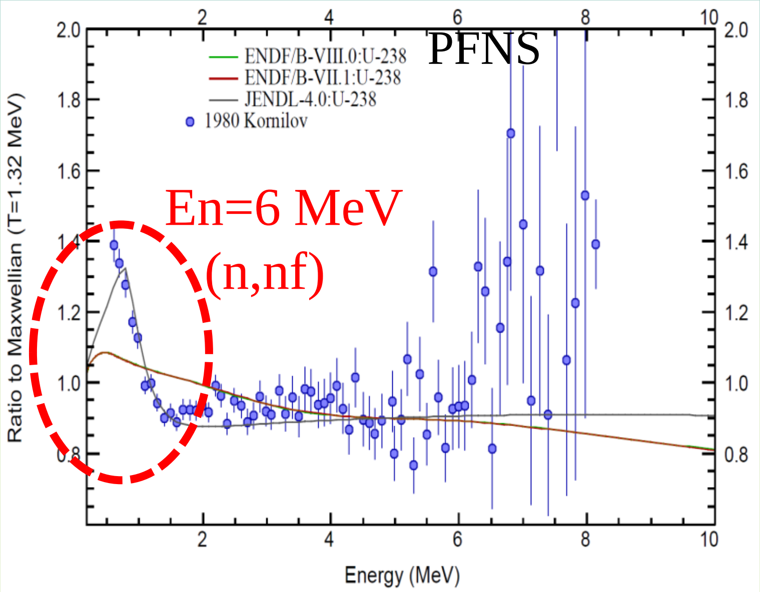
Criticality performance: any new/unexpected findings? ***No***

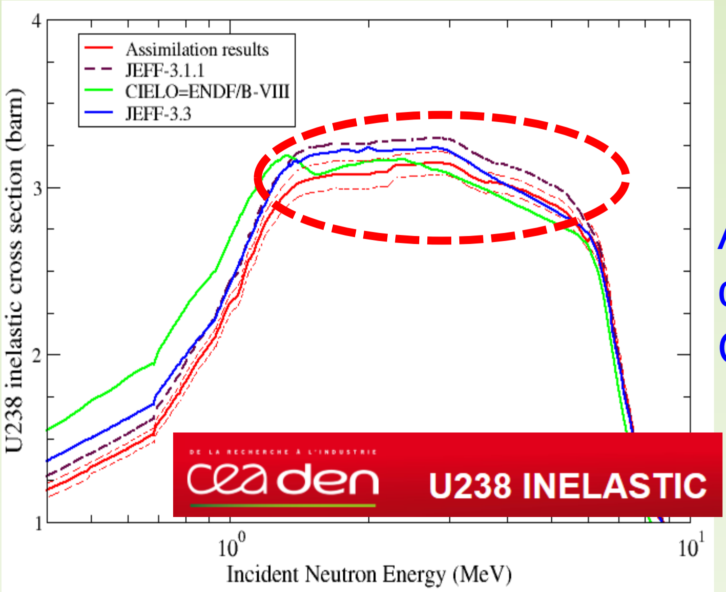
Neutron transmission: any new/unexpected findings? ***PFNS 5-8 MeV***

(n,xn) activations: any new/unexpected findings? ***No***

Known deficiencies/gaps:

- **Ongoing ChiNu experiments to precisely measure PFNS.** The current set of data will be completed within a year or two, and should impact next ENDF
- An updated ^{238}U resonance analysis (JRC EC Geel)
- **(n,n'g) experiment & eval. – BNL/LLNL**
- **FPY, DN, Decay energy, PFGS**, would benefit from various upgrades



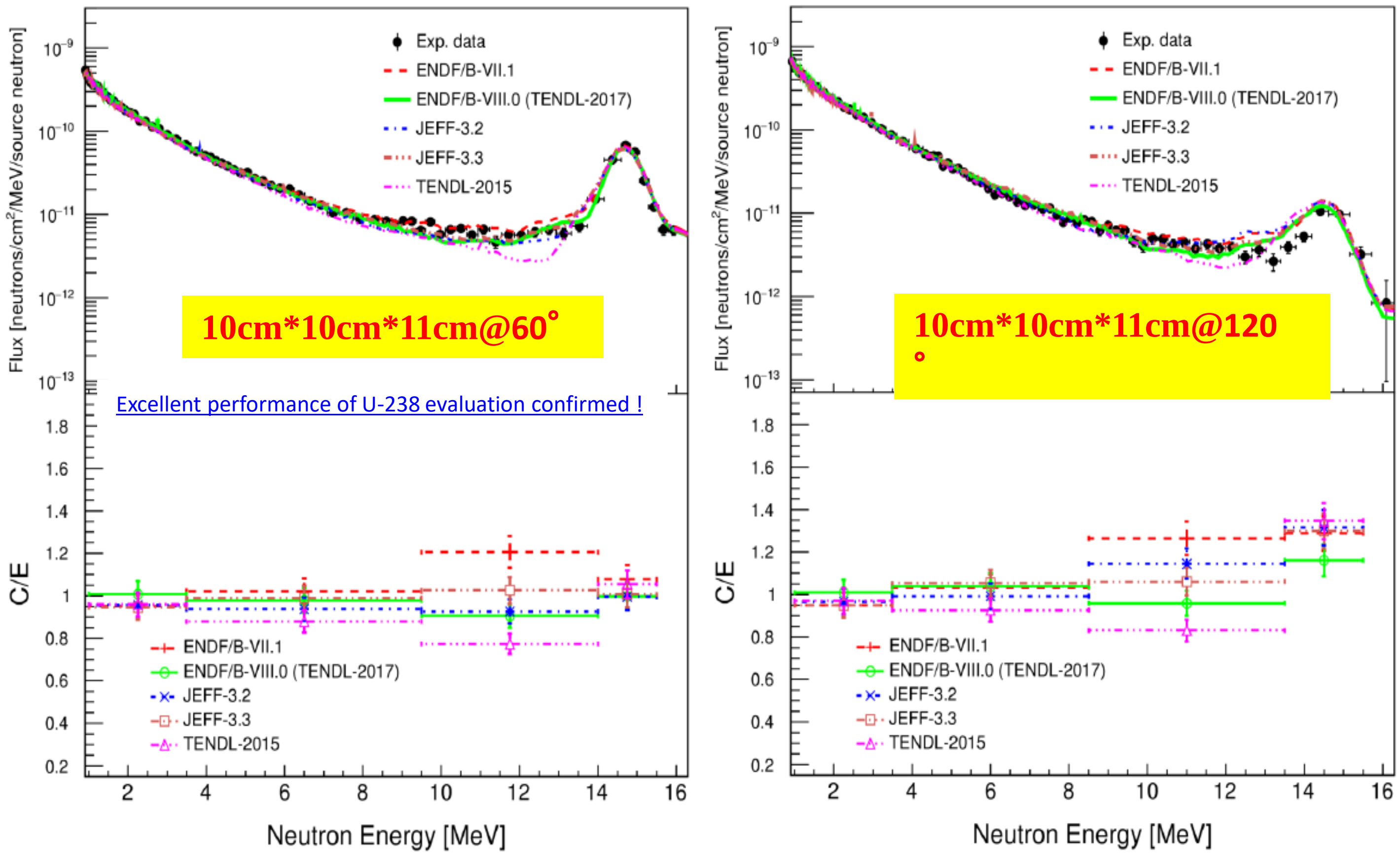


An important ENDF/B-VIII.0/CIELO trend in ^{238}U(n,inl) confirmed by CEA Cadarache adjustment studies (see G. Rimpault present., WONDER 2018)

Agreement in the plateau within quoted 7% uncertainties in ENDF/B-VIII.0 evaluation !!

IAEA Uranium-238 CIELO evaluation - Validation

CIAE benchmarks, slabs, 14MeV n + ^{238}U



Uranium-235 - Status

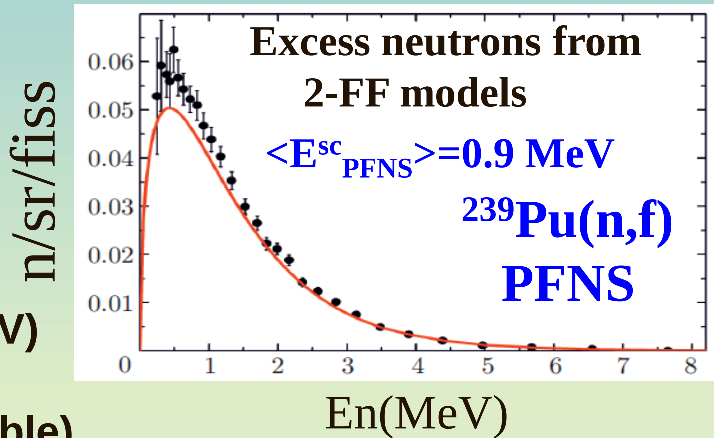
New information from integral testing since ENDF/B-VIII.0 release & publications

Criticality performance: any new/unexpected findings? **No**

Neutron transmission: any new/unexpected findings? **No**

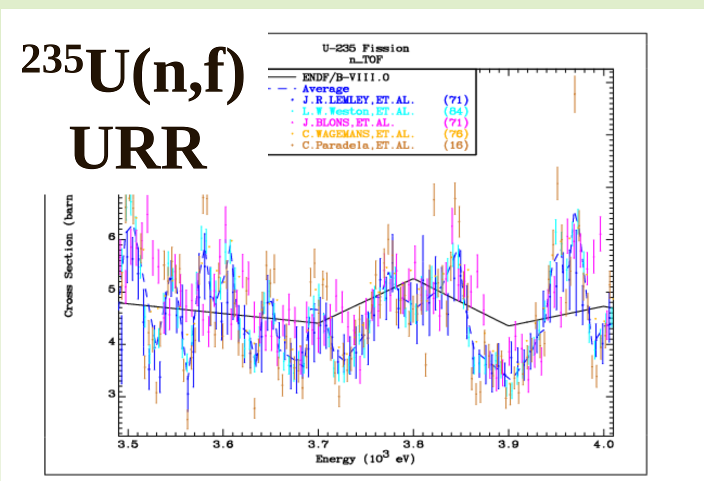
(n,xn) activations: any new/unexpected findings? **No**

$$p_s(E) = p_0 \frac{E}{T_0^2} \exp\left(-\frac{E}{T_0}\right)$$



Known deficiencies/gaps:

- **Ongoing evaluations of ChiNu experiments to be used (low energy "scission" neutrons ~ .05n/fission ~ 2% to be added as model defect to MN model??)**
- **New thermal PFNS exp. in agreement with <E>**
- **Small 1% nubar fluctuations confirmed (Gook et al)**
- **Measured (n,2n) SACS validated ^{235}U(n_{th},f) PFNS (>8 MeV) (n,2n) on ^{169}Tm, ^{90}Zr, ^{89}Y, ^{127}I, ^{23}Na, ^{19}F, ^{59}Co, ^{55}Mn, ^{197}Au (Rez ^{252}Cf(sf)+LR0 reactor, on-going @ ILL reactor Grenoble)**
- **An updated URR evaluation of fission cross section (no criticality change)**



- **RPI quasi-int/ exp. to verify fission, elastic/inelastic**
- **Inelastic and (n,2n) discrepancies with CEA/DAM evaluation being further studied**
- **FPY, DN, Decay energy, PFGS, would benefit from various upgrades**

Other

- Yearly Technical meeting on nuclear data processing, including all ongoing processing code projects in the world
- INDEN on Light elements (in combination with R-matrix code development) and structural materials.
- FENDL library
- Technical Meeting on Nuclear Data Structure Network (NSDD)
- Technical Meeting on anti-neutrino spectra and their applications
- Technical Meeting on nuclear data for medical applications

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Thank you!