

IAEA Nuclear Data Section: Progress Report for period 2019-2021

Summary of Nuclear Data Activity by Staff of the IAEA Nuclear Data Section April 2019 – March 2021

IAEA Technical Meeting, 4-7 May 2021
(Virtual)

Web: <https://nds.iaea.org/>
E-mail: nds.contact-point@iaea.org

1. Staff Changes

The authorized staff level of the Nuclear Data Section (NDS) consists of a total of 16.25 professionals and support staff. The latest staff changes include:

- Vivian Dimitrou (Nuclear Physicist) rotated out in June 2019.
- Alex Oechs (Team Assistant) retired in October 2019.
- Georg Schnabel (Nuclear Physicist) joined in January 2020.
- Andrej Trkov (Nuclear Data Physicist) retired January 2020.
- Charisse Monfero (Team Assistant) joined in March 2020.
- Vivian Dimitriou (Nuclear Data Physicist) joined in January 2021.

2. Compilations

2.1 EXFOR transmission

During the reporting period, the following final tapes have been transmitted:

- 13 neutron final TRANS tapes (3188–3198, V037-V038) containing 111 new entries and 100 revised entries;
- 16 CPND final TRANS tapes (B029-B030, D120-D129, S026-S029) containing 208 new entries and 156 revised entries;
- 4 PhND final TRANS tapes (G043-G046) containing 52 new entries and 17 revised entries.

These include contributions from NDS (**146 new entries**), five other centres (ATOMKI, CNDC, KNDC, NDPCI, UkrNDC) as well as two compilers (Timur Zholdybayev, Myagmarjav Odsuren).

Timur Zholdybayev (Institute of Nuclear Physics, Almaty) is coordinating compilation of data measured in Central Asia (*e.g.*, Kazakhstan, Uzbekistan) for area 3, D and G

Myagmarjav Odsuren (National Univ. of Mongolia, Ulaanbaatar) is compiling heavy-ion induced reaction data measured in area 2 countries (*e.g.*, France, Germany, Italy) for area D.

Three regular transmissions of the EXFOR/CINDA dictionaries (TRANS.9120–9123) were done in TRANS, DANIEL (backup) and archive format.

Number of new entries transmitted by final tapes since the NRDC 2019 meeting
(TZ: Timur Zholdybayev, MO: Myagmarjav Odsuren)

	NDS	ATOMKI	CNDC	KNDC	NDPCI	UkrNDC	TZ	MO	Sum
Neutron	36		26	3	40	2	4		111
CPND	47	12	26	3	68	15	17	20	208
PhND	21			4	2	24		1	52
Sum	146	12	52	10	110	41	21	21	413

2.2 EXFOR quality control

During the reporting period, **172 preliminary tapes** (PRELIM) were uploaded to the NDS open area for checking by NDS and other centres. Both ZCHEX and JANIS TRANS Checker are regularly used. The finalized tapes are also checked against comments from centres before uploading to the NDS open area. NDS also registers comments on EXFOR entries from users and centres to the **EXFOR Feedback List** (<https://nds.iaea.org/nrdc/error/>) and monitors the correction process by checking each preliminary tape against the feedback list.

2.3 EXFOR coverage control

Under the EXFOR compilation control system, **39 journal titles** are regularly scanned by NDS and registered to the EXFOR Compilation Control System (X4CoCoS), and they are listed in the **Article Allocation List** (<https://nds.iaea.org/nrdc/alloc/>). This list also includes the scanning records of 14 journal titles received from other centres. The newly published articles are also listed on <https://nds.iaea.org/exfor-master/x4compil/>. EXFOR statistics for compilers was extended by indicating waiting time for PRELIM files.

2.5 CINDA

Regular automatic updates using the EXFOR and NSR databases have been frozen because NSR database is not available. CINDA database maintenance was migrated from Windows to Linux. Import from EXFOR was performed once for testing the new maintenance system. Complete MySQL CINDA database was sent to BARC (India) and “Atomstandart” (Russia).

2.6 Evaluated data libraries, files and programs

Various new and revised evaluated data libraries, files and programs for data checking, processing and graphical presentation were added, developed and distributed via the NDS Web site (see below).

3. Services

3.1 Web Services

Further improvements have been implemented in the Web EXFOR-CINDA-ENDF-IBANDL database retrieval systems and Web-Tools for nuclear data compilers and evaluators since the last NRDC meeting:

- ENDF (Evaluated Nuclear Data Files):
 - new and updated evaluated libraries in the ENDF database:
 - JENDL/DEU-2020 Deuteron Reaction Data File, Japan, 2020
 - FENDL-3.2-beta Fusion Evaluated Nuclear Data Library, IAEA, 2021
 - UKDD-12 UK Decay Data Library, 2012
 - TENDL-2015.s60 TALYS-based Nuclear Data Library (selected materials), 2015
 - ADS-HE High energy library for accelerator driven systems, IAEA, 2013
 - ADS-2.0 Accelerator driven systems nuclear data library, IAEA, 2008
 - JENDL/PD-2016.1 Photonuclear Data File 2016 revision 1, Japan, 2020
 - JENDL/ImPACT-2018 JENDL LLFP Transmutation Cross Section File, Japan
 - INDEN-2020-beta evaluations produced by International Nuclear Data Evaluators Network (coordinated by the IAEA)
 - IAEA-PD-2019 IAEA-Photonuclear Data Library, 2019
 - W3000 Proton activation cross section data on W (up to 3 GeV), Germany, 2012
 - CENDL-3.2 Chinese evaluated neutron data library, issued in 2020
 - TENDL-2019 TALYS-based Evaluated Nuclear Data Library, 2019
 - IRDFF-II International Reactor Dosimetry and Fusion File, IAEA 2019
 - software news:
 - output cross sections (MF3) with uncertainties and covariances (MF33) in JSON
 - radioactive decay data (MF8.MT457): output to JSON, plot, comparison data of different libraries
 - plotting groupwise data running GROUPIE code on the fly (725 groups)
 - API for search and download data in JSON (not yet public)
- EXFOR:
 - systematic/statistical/partial uncertainties in C5, propagated to R33
 - public online versioning of Entry/Subent (+comparison)
 - new output: JSON-X4 (original EXFOR data), JSON-FY (computational values)
 - storage in EXFOR database and Web access to current PRELIM files
 - “Evaluators’ flagging system”: database and Web interface
 - API for search and download data in text/JSON/C5/XML (not yet public)

- EXFOR-NRS PDF database
 - updates: 159, added 16,309 PDF files
 - open public Web access to Lab reports of one organization (KINR, Ukraine)
 - database content (PDF files):
 - total: +16,309 => 220,258
 - EXFOR-PDF: +2,486 => 25,823 (75.5% of 34,237)
 - NSR-PDF: +13,832 => 187,066 (~78.6% of 238,204)
- IBANDL:
 - 4 database updates
- Web-ZVView:
 - output currently plotted data to JSON and html tables

Development of the Web-Tools for EXFOR compilers, ENDF and ENSDF evaluators:

- MyExfor: 4 updates by new versions of ZCHEX and new Dictionaries
- MyEnsdf: added code BetaShape v2: calculation of electron capture decays (France)

The Web EXFOR-CINDA-ENDF database retrieval system is functioning at NNDC (USA), BARC (India) and “Atomstandart” (Russia). Statistics for usage of the Web retrieval system are presented in figures below.

3.2 Packages for Web downloading (former CD/DVD-ROM's)

New and updated packages:

- “EXFOR-CINDA for Applications”: database retrieval systems (Linux, Windows and MacOS). Includes Endver/GUI package integrated with full EXFOR database
- two releases of GRUCON, ENDF data processing code (V.Sinitsa, Kurchatov Institute, Moscow, Russia).
- new packages X4Apps and X4Lite replacing old “EXFOR-CINDA CD-ROMs”: based on SQLite, implementing interactive GUI and programmatic API's for EXFOR data retrievals and conversion to X4+, C5, XML, JSON-X4. (Pilot project: extending EXFOR relational database with original and computational data in JSON.)

3.3 Document Services

Nuclear Data Services Unit (NDSU) continued supporting the Member States in providing the reports published, as well as distributing data libraries on CDs and DVDs as requested. Following the introduction of the webpage (<https://nds.iaea.org/cdroms/>) for download to ensure quicker and easier service, the number of requests for physical copies decreased.

We create INDC reports for unpublished documents (*e.g.*, theses, internal reports) reporting experimental works compiled in EXFOR. During the reporting period, the following one report was published for this purpose in collaboration with the authors:

- M. Boromiza et al, Neutron inelastic scattering cross sections on ^{16}O and ^{28}Si , INDC(EUR)-0035 (for EXFOR 23456)
- L. Salamon et al., Results of time-of-flight transmission measurements for $^{\text{nat}}\text{Ag}$ at a 10 m station of GELINA, INDC(EUR)-0036 (for EXFOR 23533)
- R. Mucciola et al., Results of time-of-flight transmission measurements for $^{155,157}\text{Gd}$ at a 10m station of GELINA, INDC(EUR)-0037 (for EXFOR 23727)
- D.H. Moon et al., Results of time-of-flight transmission measurements for ^{142}Ce at a 50 m station of GELINA, INDC(EUR)-0038 (for EXFOR 23729)
- F. Käppeler and R. Reifarth, Activation data from Karlsruhe revisited, INDC(GER)-0053 (for update of many EXFOR entries)

Any improvement suggestions should be sent to our contact address (nds.contact-point@iaea.org).

Number of INDC reports published between April 2019 and March 2021

Report code	Country of origin	Reports
INDC(AUS)	Austria	1
INDC(CCP)	Russia	1
INDC(CZR)	Czech Republic	1
INDC(EUR)	European Commission	5
INDC(GER)	Germany	1
INDC(JPN)	Japan	2
INDC(KAS)	Kazakhstan	1
INDC(NDS)	Nuclear Data Section	38
INDC(SLO)	Slovenia	1

3.4 Nuclear Data Newsletters

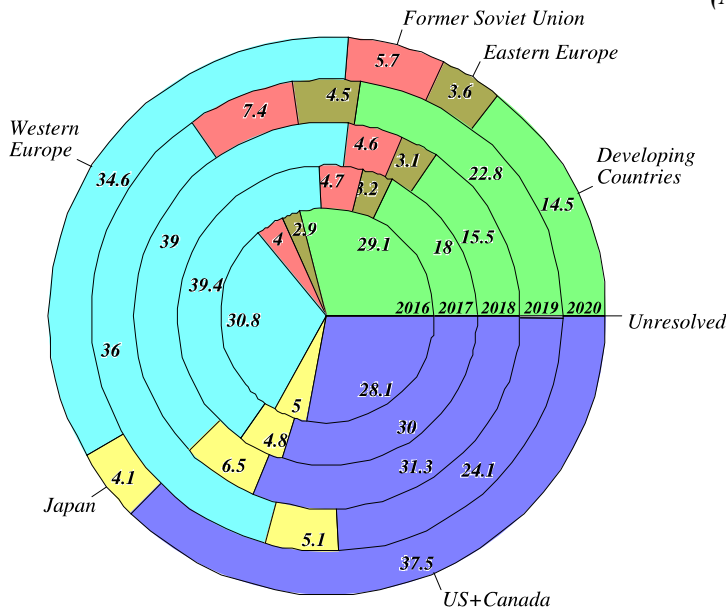
The Nuclear Data Newsletter is published biannually to inform the scientific community about actual NDS work. During the reporting period, we published four issues of the Newsletter (67-70). Latest one, No 70 was published in February 2021. We have currently 97 recipients of hardcopies and 1277 recipients of electronic version.

4. Visits and Inter-centre Cooperation

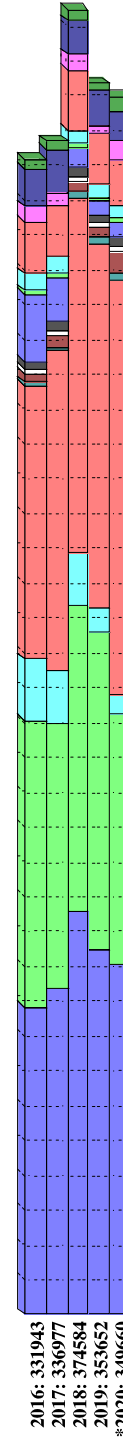
- V. Zerkin (NDS) visited NNDC from 23 September to 11 October 2019 to deploy and further develop software for ENDF-EXFOR-PDF database management, Web retrieval system and tools; to extend ENDF and common EXFOR-NSR PDF databases.
- N. Otsuka (NDS) visited JAEA from 21 July to 3 August 2019 to review and revise the EXFOR entries compiling fast neutron fission cross sections for uranium and plutonium nuclides.
- N. Otsuka (NDS) visited CNDC from 12 to 19 October to review and finalize the EXFOR entries prepared by the China Nuclear Data Centre (CNDC).

IAEA Nuclear Data Services: Web Statistics 2016-2020

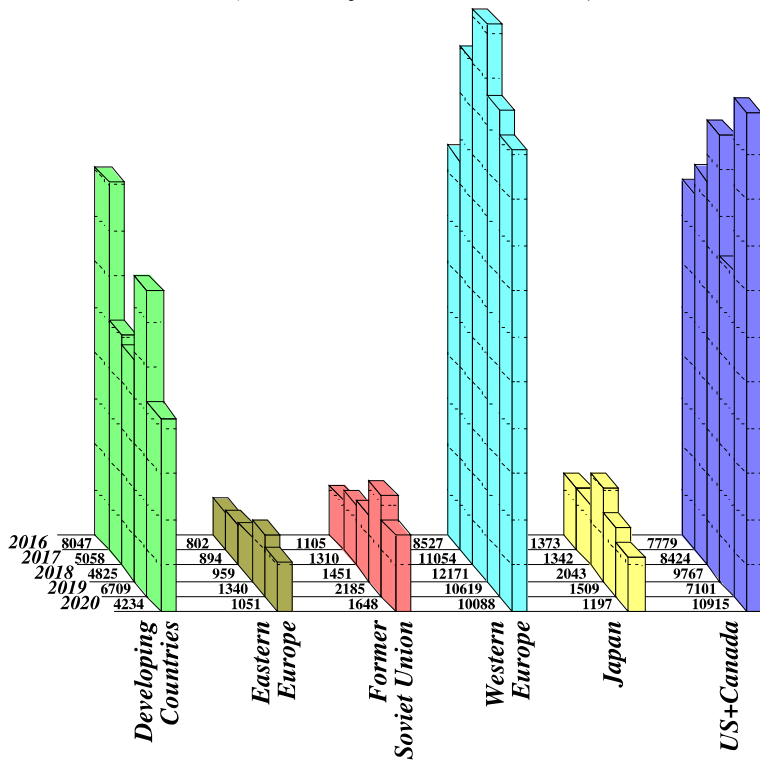
Geographical Distribution



Total per Year (Number of accesses + retrievals) *2020: extrapolated 5 months



Average per Month (Number of accesses + retrievals)



- | Service | Comment |
|------------------------|--------------|
| Computer Codes | |
| Documents | |
| OtherData | |
| IBANDL | |
| PGAA | |
| PhotoNuclear | |
| RIPL | Theory |
| FENDL | Fusion |
| Masses | |
| IRDF | Dosimetry |
| Thermal Capture | |
| Wallet Cards | |
| Med.Radioisotope.Prod. | |
| NGAtlas | Activation |
| RNAL | |
| ENSDF | Structure |
| MIRD | Medical |
| LiveChart of Nuclides | |
| CINDA+NSR Bibliography | |
| EXFOR | Experimental |
| ENDF | Energy |

5. Nuclear Data Developments

The Nuclear Data Section undertakes long term nuclear data development by implementing Coordinate Research Projects (CRP) and Data Development Projects (DDP). The staff members of NDS who manage NRDC also follow the currently running CRPs and DDPs to observe the actual trends and needs for nuclear reaction data.

5.1. Coordinated Research Projects (CRP)

- Updating photonuclear data library and generating a reference database for photon strength functions (2016-2019): *Finished*.
- Recommended Input Parameter Library (RIPL) for fission cross section calculations (2017-2021): *Ongoing*.
- Updating fission yield data for applications (2020-2025): *Ongoing*.

5.2 Data Development Project (DDP)

- Intercomparison of PIGE analysis codes to calculate PIGE yields for the analysis of bulk samples: *Ongoing*
- Evaluation of nuclear moments: *Ongoing*
- Verification of data processing codes for generating ACE-formatted files: *Ongoing*
- Stopping power database: *Ongoing*
- Study of scission neutrons: *Finished*
- Nuclear data libraries for advanced systems: Fusion devices: *Ongoing*
- Revision of EPICS (Electron Photon Interaction Cross Sections): *Finished*
- Nuclear Data for Medical Applications: *Ongoing*
- Maintain the international Neutron Standards file and evaluation techniques: *Ongoing*

6. Training Activities (Schools, Workshops)

- Joint ICTP-IAEA Workshop on “Radiation Damage in Nuclear Systems: from Bohr to Young”, 2020, Trieste, Italy (postponed).
- Joint ICTP-IAEA Workshop on “Monte Carlo radiation transport and associated data needs for medical applications”, 2020, Trieste, Italy (postponed).
- IAEA Workshop on Experimental nuclear reaction data (EXFOR) compilation, 2020, Vienna, Austria (postponed)

7. Nuclear Data Journal Publications (2019-2021)

Erratum to "Uncertainty propagation in activation cross section measurements"

[*Radiat. Phys. Chem.* **140** (2017) 502-510]

N. Otuka, B. Lalremruata, M.U. Khandaker, A.R. Usman, L.R.M. Punte, *Radiat. Phys. Chem.* **140** (2021) 109440.

Testing of various neutron filters in reference neutron field in LR-0 reactor for nuclear data validation and verification

M. Kostal, R. Capote, et al., *Appl. Radiat. Isot.* **169** (2020) 109566.

Completeness of neutron-, photo-induced and spontaneous fission yields data

B. Pritychenko, O. Schwerer, J. Totans, V. Zerkin and O. Gritzay, *EPJ Web of Conferences* **239** (2020) 09003.

Extension of the Hauser-Feshbach fission fragment decay model to multichance fission

A. E. Lovell, T. Kawano, S. Okumura, et al., *Phys. Rev. C* **103** (2020) 014615.

Evaluation of fission product yields and associated covariance matrices

K. Tsubakihara, S. Okumura, et al., *Nucl. Sci. Technol.* **58** (2020) pp. 151-165.

The fission yield calculations with Langevin model, Hauser-Feshbach statistical decay, and beta decay

Shin Okumura, Toshihiko Kawano and Satoshi Chiba, *EPJ Web of Conferences* **239** (2020) 03005.

Completeness Check of Experimental Fission Product Yield Data in EXFOR Database

Shin Okumura, *EPJ Web of Conferences* **242** (2020) 02002.

Ratio of spectral averaged cross sections measured in standard $^{252}\text{Cf(sf)}$ and $^{235}\text{U(n_{th},f)}$ neutron fields

M. Schulc, R. Capote, et al., *EPJ WEb Conf* **239** (2020) 19004.

A reference neutron field for measurement of spectrum averaged cross sections

M. Kostal, R. Capote, et al., *Ann. Nucl. En.* **140** (2020) 107119.

Results of the Collaborative International Evaluated Library Organisation (CIELO) Project

M. Fleming, R. Capote, et al., *EPJ WEb Conf.* **239** (2020) 15003.

Dispersive optical model description of nucleon scattering on Pb and Bi isotopes

Xiuniao Zhao, R. Capote, et al., *Phys. Rev. C* **101** (2020) 064618.

Comprehensive validation of silicon cross sections

T. Czako, R. Capote, et al., *Nucl. Eng. Technol.* **52** (2020) 2717-2724.

Excitation function of $^{nat}\text{Cu}(^3\text{He},x)^{65}\text{Zn}$ nuclear reaction for ^3He beam monitoring purpose

M.U. Khandaker, K. Nagatsu, H. Obata, K. Minegishi, M.R. Zhang, S.K.I. Ali, N. Otuka, *EPJ Web Conf.* **230** (2020) 20009.

Erratum: Nucleon scattering on actinides using a dispersive optical model with extended couplings [Phys. Rev. C **94, 064605 (2016)]**

E.Sh. Soukhovitski, R. Capote, J.M. Quesada, S. Chiba and D.S. Martyanov, *Phys. Rev. C* **102** (2020) 059901.

Progress in international collaboration on EXFOR library

N. Otuka, B. Pritychenko, M. Fleming, Y. Jin, G. Pikulina, R. Suzuki, V. Devi, M. Mikhailiukova, S. Okumura, N. Soppera, T. Tada, S. Takács, S. Taova, V.V. Varlamov, J.M. Wang, S.C. Yang, V. Zerkin, *EPJ Web Conf.* **239** (2020) 15001.

Uncertainties of calculated coincidence-summing correction factors in gamma-ray spectrometry

V. Semkova, N. Otuka, A.J.M. Plompen, *EPJ Web Conf.* **239** (2020) 12003.

Completeness of experimental fission product yields in EXFOR database

T. Fukuda, S. Okumura, N. Otuka, *EPJ Web Conf.* **239** (2020) 05013.

Covariance analysis on the thermal neutron capture cross sections using an Am-Be neutron source

P. Panikkath, N. Otuka, P. Mohanakrishnan, *EPJ Web Conf.* **239** (2020) 01027.

Data assimilation of post-irradiation examination data for fission yields from GEF

D. Siefman, G. Schnabel, et al., *EPJ Nuclear Sci. Technol.* **6** (2020) 52.

Strangeness production in the new version of the Liège Intra-Nuclear Cascade model

J. Hirtz, G. Schnabel, et al., *Phys. Rev. C* **101** (2020) 014608.

Production of Hypernuclei and Strange Particles in Spallation Reactions at a Few GeV Using an Intranuclear Cascade Approach

Jean-Christophe David, Georg Schnabel, et al., Proc. Int. Conf. Few-Body Problems in Physics, *Recent Progress in Few-Body Physics* **FB22 2018** (2020) pp. 959-963.

Unrecognized Sources of Uncertainties (USU) in Experimental Nuclear Data

R. Capote, G. Schnabel, A.D. Carlson, et al., *Nucl. Data Sheets* **163** (2020) pp.191-227.

How to search on EXFOR

N. Otuka, N. Soppera, *J. Phys. Conf. Ser.* **1555** (2020) 012009

Bayesian updating for data adjustments and multi-level uncertainty propagation within Total Monte Carlo

E. Alhassan, D. Rochman, P. Helgesson, H. Sjostrand, A. Vasiliev, and A.J. Koning, *Ann. Nucl. En.* **139** (2020) 107239.

A statistical analysis of evaluated neutron resonances with TARES for JEFF-3.3, JENDL-4.0, ENDF/B-VIII.0 and TENDL-2019

D. Rochman, A.J. Koning, J.-Ch. Sublet, *Nucl. Data Sheets* **163** (2020) 163.

Excitation functions of deuteron-induced nuclear reactions on erbium in the energy range of 4-24 MeV

M.U. Khandaker, H. Haba, Y. Komori, N. Otuka, *Nucl. Instrum. Meth. B* **470** (2020) pp. 1-9.

Production cross sections of thulium radioisotopes for alpha-particle induced reactions on holmium

A.R. Usman, M.U. Khandaker, H. Haba, N. Otuka, M. Murakami, *Nucl. Instrum. Meth. B* **469** (2020) pp. 42-48.

IRDF-II: A New Neutron Metrology Library

A. Trkov, R. Capote, et al., *Nucl. Data Sheets* **163** (2019) 1-108.

${}^7\text{Li}(p, n){}^7\text{Be}$ cross section from threshold to 1960 keV and precise measurement of the ${}^{197}\text{Au}(n, \gamma)$ spectrum-averaged cross section at 30 keV

Guido Martín-Hernández, Pierfrancesco Mastinu, Elizabeth Musacchio González, Roberto Capote, Hector Lubián, and Miguel Macías, *Phys. Rev. C* **99** (2019) 034616.

Analysis of neutron bound states of ${}^{208}\text{Pb}$ by a dispersive optical model potential

Xiuniao Zhao, Weili Sun, E.Sh. Soukhovitski, D.S. Martyanov, J.M. Quesada and R. Capote, *J. Phys. G: Nucl. Part. Phys.* **46** (2019) 055103.

Recommended nuclear data for medical radioisotope production: diagnostic gamma emitters

F.T. Tarkanyi, R. Capote, et al., *J. Radioanal. Nucl. Chem.* **319** (2019) 487-531.

Applying a Template of Expected Uncertainties to Updating ${}^{239}\text{Pu}(n, f)$ Cross-section Covariances in the Neutron Data Standards Database

D. Neudecker, R. Capote, et al., *Nucl. Data Sheets* **163** (2019) pp. 228-248.

Quasiparticle nature of excited states in random-phase approximation

E.V. Chimanski, B.V. Carlson, R. Capote, and A.J. Koning, *Phys. Rev. C* **99** (2019) 014305.

${}^7\text{Li}(p, n){}^7\text{Be}$ cross section from threshold to 1960 keV and precise measurement of the ${}^{197}\text{Au}(n, \gamma)$ spectrum-averaged cross section at 30 keV

R. Capote, et al., *Phys. Rev. C* **99** (2019) 034616.

Analysis of neutron bound states of ${}^{208}\text{Pb}$ by a dispersive optical model potential

R. Capote, et al., *J. Phys. G: Nucl. Part. Phys.* **46** (2019) 055103.

Recommended nuclear data for medical radioisotope production: diagnostic gamma emitters

R. Capote, et al., *J. Radioanal. Nucl. Chem.* **319** (2019) 487-531.

Recommended nuclear data for medical radioisotope production: diagnostic positron emitters

R. Capote, et al., *J. Radioanal. Nucl. Chem.* **319** (2019) 533-666.

Recommended Nuclear Data for the Production of Selected Therapeutic Radionuclides

R. Capote, et al., *Nucl. Data Sheets* **155** (2019) 56-74.

A reference neutron field for measurement of spectrum averaged cross sections

R. Capote, et al., *Ann. Nucl. Energy* (2019) 107119.

Recommended Nuclear Data for the Production of Selected Therapeutic Radionuclides

R. Capote, et al., *Nucl. Data Sheets* **155** (2019) 56-74.

TENDL: Complete Nuclear Data Library for innovative Nuclear Science and Technology

A.J. Koning, D. Rochman, J.-Ch. Sublet, N. Dzysiuk, M. Fleming, and S. van der Marck, *Nucl. Data Sheets* **155** (2019) 1.

The gamma-ray strength function for Thallium isotopes relevant to the ^{205}Pb - ^{205}Tl chronometry

H. Utsunomiya, T. Renstroem, G.M. Tveten, S. Goriely, T. Ari-izumi, D. Filipescu, J. Kaur, W. Luo, S. Miyamoto, T. Glodariu, Y.-W. Lui, S. Miyamoto, A.-C. Larsen, S. Hilaire, S. Peru, and A.J.Koning, *Phys. Rev. C* **99** (2019) 024609.

Correlation nubar-sigma for U-Pu in the thermal and resonance neutron range via integral information

D. Rochman, A. Vasiliev, H. Ferroukhi, S. Pelloni, E. Bauge, and A.J. Koning, *Eur. Phys. J. Plus* **134** (2019) 453.

Gamma-ray strength function for Barium isotopes

H. Utsunomiya, T. Renstroem, G.M. Tveten, S. Goriely, T. Ari-izumi, V.W. Ingeberg, B.V. Kheswa, Y.-W. Lui, S. Miyamoto, S. Hilaire, S. Peru, and A.J.Koning, *Phys. Rev. C* **100** (2019) 034605.

Our future nuclear data needs

L.A. Bernstein, D.A. Brown, A.J. Koning, B.T. Rearden, C.E. Romano, A.A. Sonzogni, A.S. Voyles and W. Younes, *Annu. Rev. Nucl. Part. Sci.* **69** (2019).

Compilation of experimental nuclear reaction data measured in Kazakhstan and Uzbekistan for the EXFOR Library

N.Kenzhebeyev, T.K.Zholdybayev, F.Kh.Ergashev, N.Otuka *Bull. Russ. Acad. Sci. Ser. Phys.* **83**(2019)pp. 1429-1432.

Measurement of thermal neutron capture cross section of ^{71}Ga with dual monitor foils and covariance analysis

P. Panikkath, N. Otuka, Y. Iwamoto and P. Mohanakrishnan, *Eur. Phys. J. A* **55** (2019) p.91.

Neutron-induced damage simulations: Beyond defect production cross-section, displacement per atom and iron-based metrics

J.-Ch. Sublet et al., *Eur. Phys. J. Plus* **134** (2019) 350.

Recommended nuclear data for medical radioisotope production: diagnostic positron emitters

F.T. Tarkanyi, R. Capote, et al., *J. Radioanal. Nucl. Chem.* **319** (2019) 533-666.

Recommended Nuclear Data for the Production of Selected Therapeutic Radionuclides

J.W. Engle, R. Capote, et al., *Nucl. Data Sheets* **155** (2019) 56-74.