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International Atomic Energy Agency
*Atoms for Peace and Development*

# Production of EXFOR Entry Files and EXFOR Master Files with ForEXy codes (A75)

**Naohiko Otsuka**

**IAEA Nuclear Data Section, IAEA, Vienna, Austria**

# Prof. Akira Ohnishi (1964-2023)


**Vicki McLane and Akira Ohnishi (NRDC 2004 @ BNL)**

Hokkaido Univ. (1994 – 2008), Yukawa Institute, Kyoto Univ. (2008-2023)

He was a keyperson when I got my first nuclear data job in Japan.

# ForEX family

- DIC227:Produce Archive Dictionary 227 from a NUBASE file.
- DICA2J: Convert Archive dictionaries to a JSON Dictionary.
- DICDIS: Prepare Archive and Backup dictionaries for distribution.
- DICJ2A: Convert a JSON Dictionary to Archive dictionaries.
- DICJ2T: Convert a JSON Dictionary to a Transmission dictionary.
- DIRINI: Split an EXFOR library tape into EXFOR entry files.
- **DIRUPD: Update the EXFOR entry files with an EXFOR transmission tape.**
- EXTMUL: Extraction of a dataset from a multiple reaction formalism subentry.
- J4TOX4: Convert a J4 file to an EXFOR file.
- MAKCOV: Produce a data table and covariance matrix from a J4 file.
- **MAKLIB: Merge EXFOR entry files into a single library tape.**
- POIPOI: Remove pointers from a J4 file.
- SEQADD: Add record identification to an EXFOR file.
- SPELLS: Check English spell in free text in EXFOR format.
- X4TOJ4: Convert an EXROF file to a J4 file.

# When release of TRANS.XXX is announced

The **EXFOR Entry Files** on the NRDC website are updated by DIRUPD of the ForEXy package:

```
% x4_dirupd.py -t trans.XXX -d entry
```

(“entry” is the directory where the EXFOR Entry Files are stored.)

Now the EXFOR-Entry-File repository of **NRDC GitHub** is synchronized with EXFOR Entry Files automatically on a trial basis.

# EXFOR Entry Files


https://nds.iaea.org/nrdc/exfor-master/entry/

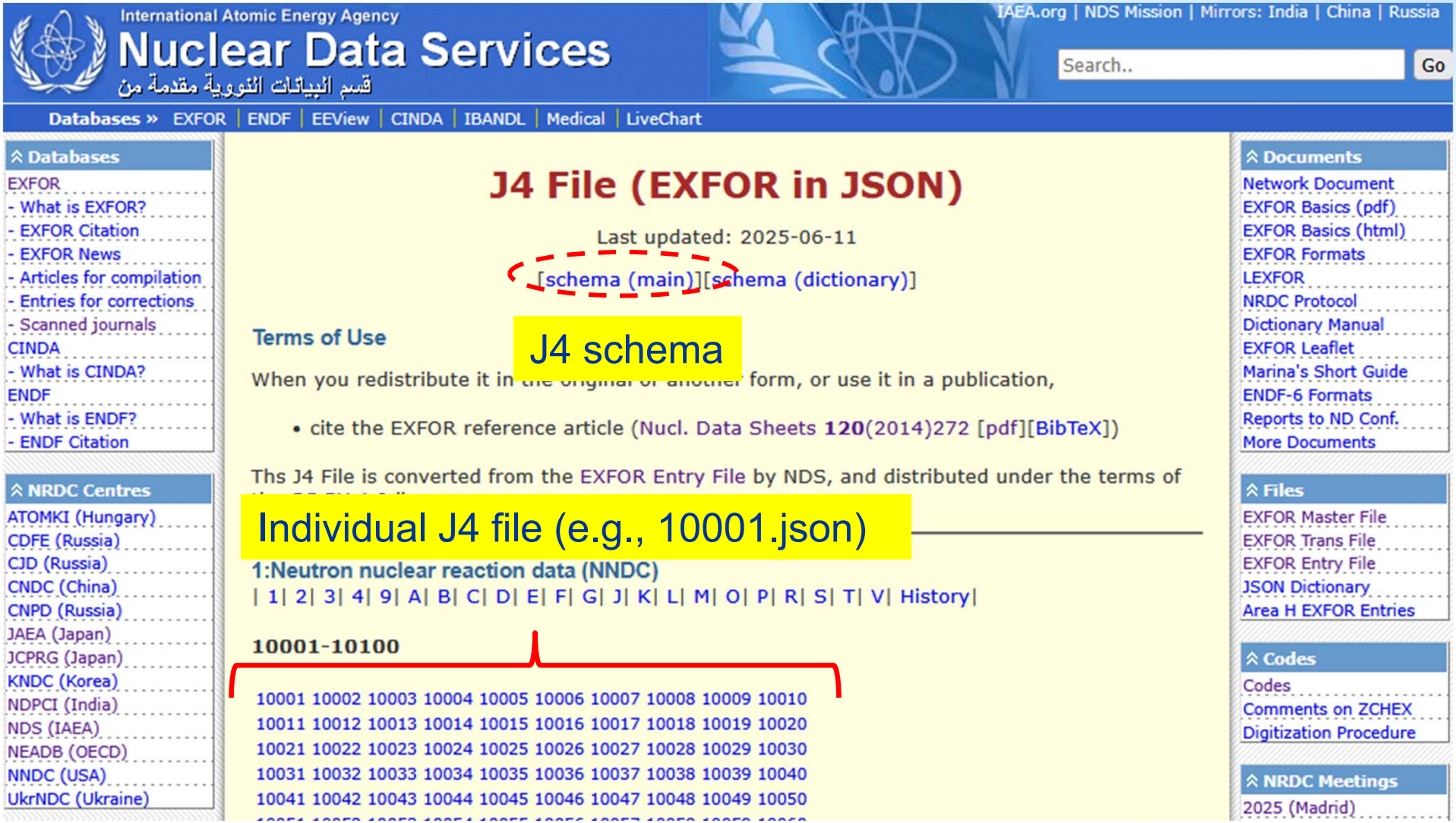
# When EXFOR Entry File is updated …

The **J4 Files** (EXFOR in JSON) on the NRDC website are updated by X4TOJ4 of the ForEXy package:

```
% x4_x4toj4.py -i $entry.txt -d dict_9131.json -o $entry.json
```

(Loop for `$entry` over all entries in TRANS.XXX.)

# J4 Files




**https://nds.iaea.org/nrdc/exfor-master/j4/**

(This is not yet an official distribution and not linked from the NRDC homepage.)

# At the end of 202Y

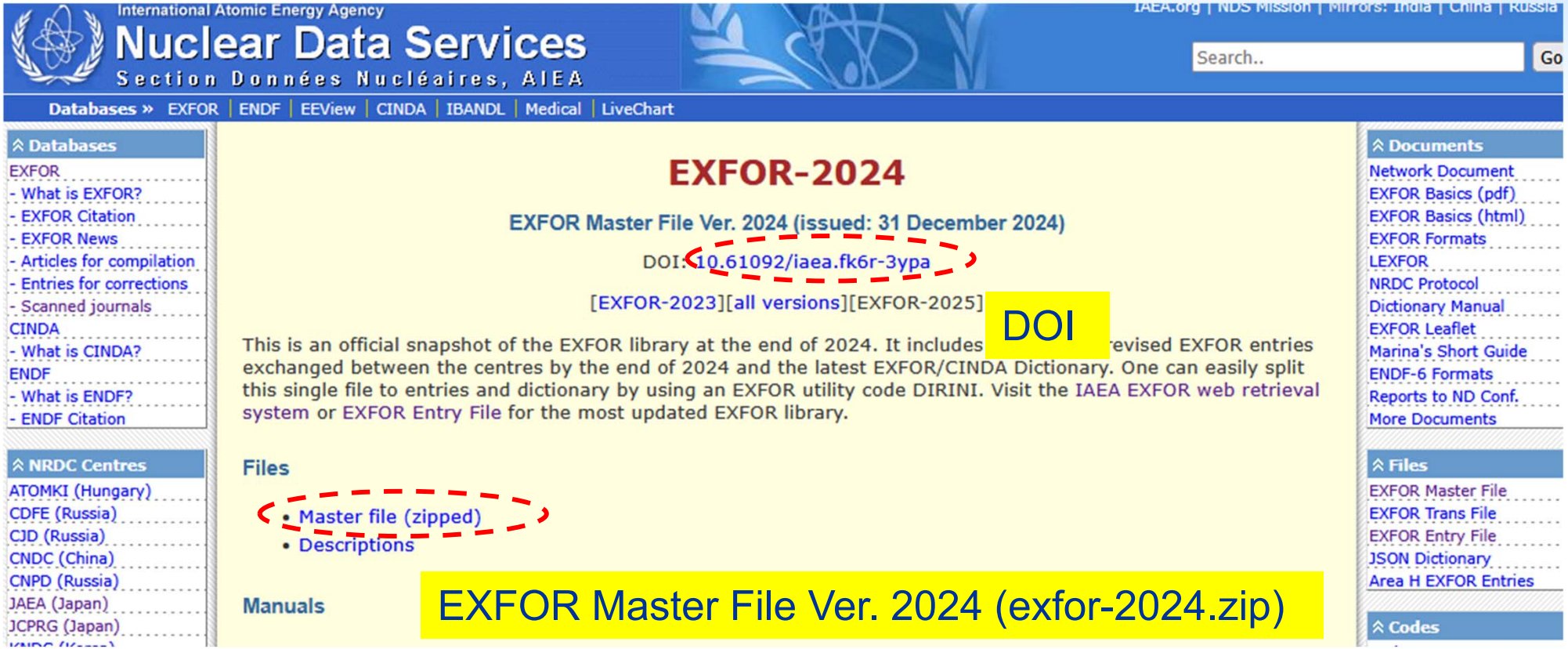
The **EXFOR Entry Files** on the NRDC website are merged into a single library file by MAKLIB of the ForEXy package:

```
% x4_maklib.py -d entry -l library.txt -i 202Y
% x4_seqadd.py -i library.txt -o exfor-202Y.txt
```

to generate a new **EXFOR Master File** “exfor-202Y.txt”.

(SEQADD is for addition of sequential numbers etc, like ZORDER.)

# EXFOR Master File




https://nds.iaea.org/nrdc/exfor-master/

# Everyone can reproduce EXFOR Entry/Master Files with

- EXFOR Entry Files (starter)

  https://nds.iaea.org/nrdc/exfor-master/entry/

- Trans files:

  https://nds.iaea.org/nrdc/exfor-master/trans/

- ForEXy codes:

  https://nds.iaea.org/nrdc/nrdc_sft/

  https://pypi.org/project/forexy/

# ForEXy article: Just published!

Applied Radiation and Isotopes 225 (2025) 111903

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## EXFOR utility codes (ForEXy) and their application to neutron fission cross section evaluation

Naohiko Otuka [a,*], Vidya Devi [b], Osamu Iwamoto [c]

[a] Nuclear Data Section, Division of Physical and Chemical Sciences, Department of Nuclear Sciences and Applications, International Atomic Energy Agency, A-1400 Wien, Austria
[b] Department of Physics, Panjab University, Chandigarh-160014, India
[c] Nuclear Data Center, Japan Atomic Energy Agency, Tokai-mura, Ibaraki 319-1195, Japan

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ABSTRACT

We developed a set of EXFOR utility codes (ForEXy) to process the information of the experimental nuclear reaction data stored in the EXFOR library. We designed a new JSON format (J4) for the EXFOR library, and developed a code converting the information in an EXFOR file to a J4 file (X4TOJ4) and another code converting it to an EXFOR file (J4TOX4) as a core part of this new code package. We also developed some other codes for management of the EXFOR storage, bibliography and dictionary. As an application of the new code package, we constructed covariance matrices for the fast neutron induced fission cross sections of neptunium-237 in the EXFOR library by using the new codes, and applied them to evaluation of the cross section between 100 keV and 200 MeV.

**Elsevier offers you free access till 31 July 2025:**

https://authors.elsevier.com/a/1lFgS3SWWgInpv

(also in **arXiv** https://arxiv.org/abs/2505.03758)

# ForEXy article: Just published! (cont)

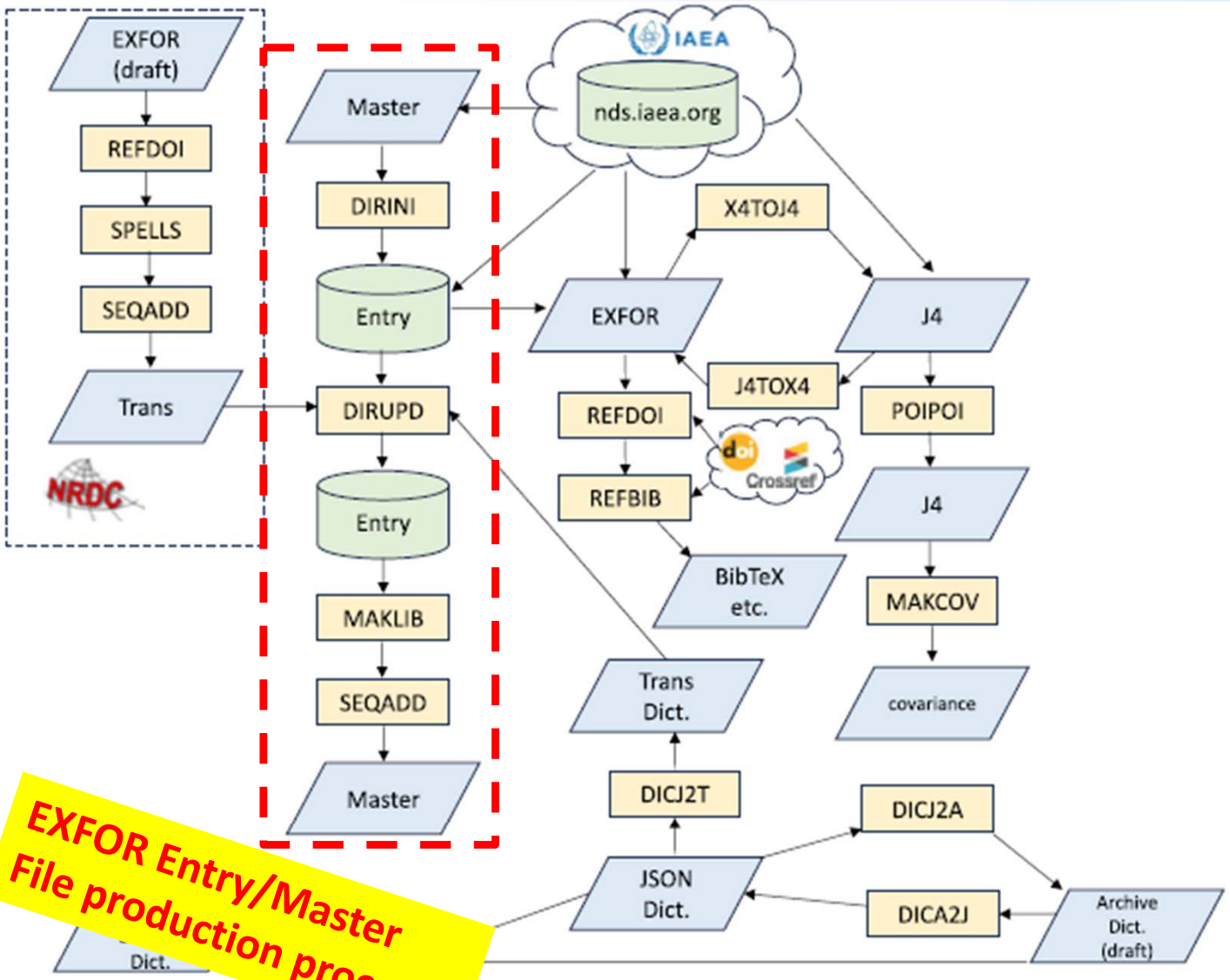



**Fig. 1.** Flow of processing of EXFOR library and dictionary ... ForEXy codes. "Master", "Entry" and "Trans" are the abbreviations of the EXFOR Master File, EXFOR Entry Files and EXFOR Trans File, respectively. The JSON Dictionary is also used by J4TOX4, MAKCOV, POIPOI, REFBIB and X4TOJ4, but their use is not shown in the figure for better readability.

Appl.Radiat.Isot.225(2025)111903

# ForEXy article: Just published! (cont)

*2.2. EXFOR storage maintenance (DIRINI, DIRUPD, MAKLIB)*

About 500 new EXFOR entries are added to the EXFOR library every year, and we want to satisfy users who cannot wait the next release of the EXFOR Master File. The NRDC requested the IAEA Nuclear Data Section to develop and release a tool generating the next EXFOR Master File (e.g., EXFOR-2024) by updating the previous one (e.g., EXFOR-2023) with the EXFOR entries submitted in the current year (e.g., 2024) (Otuka and Brown, 2023). The three tools DIRINI, DIRUPD and MAKLIB have been developed to satisfy these needs.

DIRINI is a tool to initialize the EXFOR files of a local storage. Creation of a new storage under the directory *entry* and its initialization with the EXFOR Master File Ver. 2023 can be done by

```
x4_dirini.py -l exfor-2023.txt -d entry
```

where *exfor-2023.txt* is downloaded from the NRDC EXFOR Master File website (International Network of Nuclear Reaction Data Centres, 2024e) prior to the DIRINI operation. When this operation completes, we see an ASCII file of each EXFOR entry under a subdirectory structure (e.g., *entry/1/10001.txt*, *entry/1/10002.txt*, ··· *entry/a/a0001.txt*, ···). Each subdirectory has a single character name corresponding to the first character of the entry number (area character), which characterizes the location of the measurement and projectile.[4]

DIRUPD updates the local storage with the EXFOR entries released after production of the EXFOR Master File installed in the storage by DIRINI. Each originating centre assembles newly created and revised EXFOR entries as a Trans file and submits it to other centres. The Trans files are distributed from the EXFOR Trans File website (International Network of Nuclear Reaction Data Centres, 2024c). The storage initialized with EXFOR-2023 can be updated by

```
x4_dirupd.py -t trans.2318 -d entry
x4_dirupd.py -t trans.o098 -d entry
...
x4_dirupd.py -t trans.2319 -d entry
...
```

where *trans.2318* and *trans.o098* are the first and second EXFOR Trans files released in 2024. This operation can be done for each area separately as long as it is done in chronological order for each area. For example, one can load *trans.2319* immediately after *trans.2318*, but *trans.o098* should be loaded before *trans.o099*.

**How to run DIRINI and DIRUPD?**

Appl.Radiat.Isot.225(2025)111903

# ForEXy article: Just published! (cont)

We developed X4TOJ4 for conversion of an EXFOR file to a J4 file, and J4TOX4 for conversion of a J4 file to an EXFOR file. X4TOJ4 reads an EXFOR file (e.g., *exfor.txt*) containing a single EXFOR entry or several EXFOR entries, and converts it to a J4 file (e.g., *exfor.json*) by

```
x4_x4toj4.py -i exfor.txt -d dict_9131.json -o exfor.json
```

where *dict_9131.json*

**How to run X4TOJ4 / J4TOX4?**

```
"DECAY-DATA": {
  "coded_information": "(43-TC-99-M,6.0082HR,DG,140.5,0.885)"
},
```

```
"DECAY-DATA": {
  "coded_information": {
    "flag": null,
    "nuclide": "43-TC-99-M",
    "half-life": {
      "value": 6.0082,
      "unit": "HR"
    },
    "radiation": {
      "radiation_type": "DG",
      "energy": 140.5,
      "intensity": 0.885
    }
  },
}
```

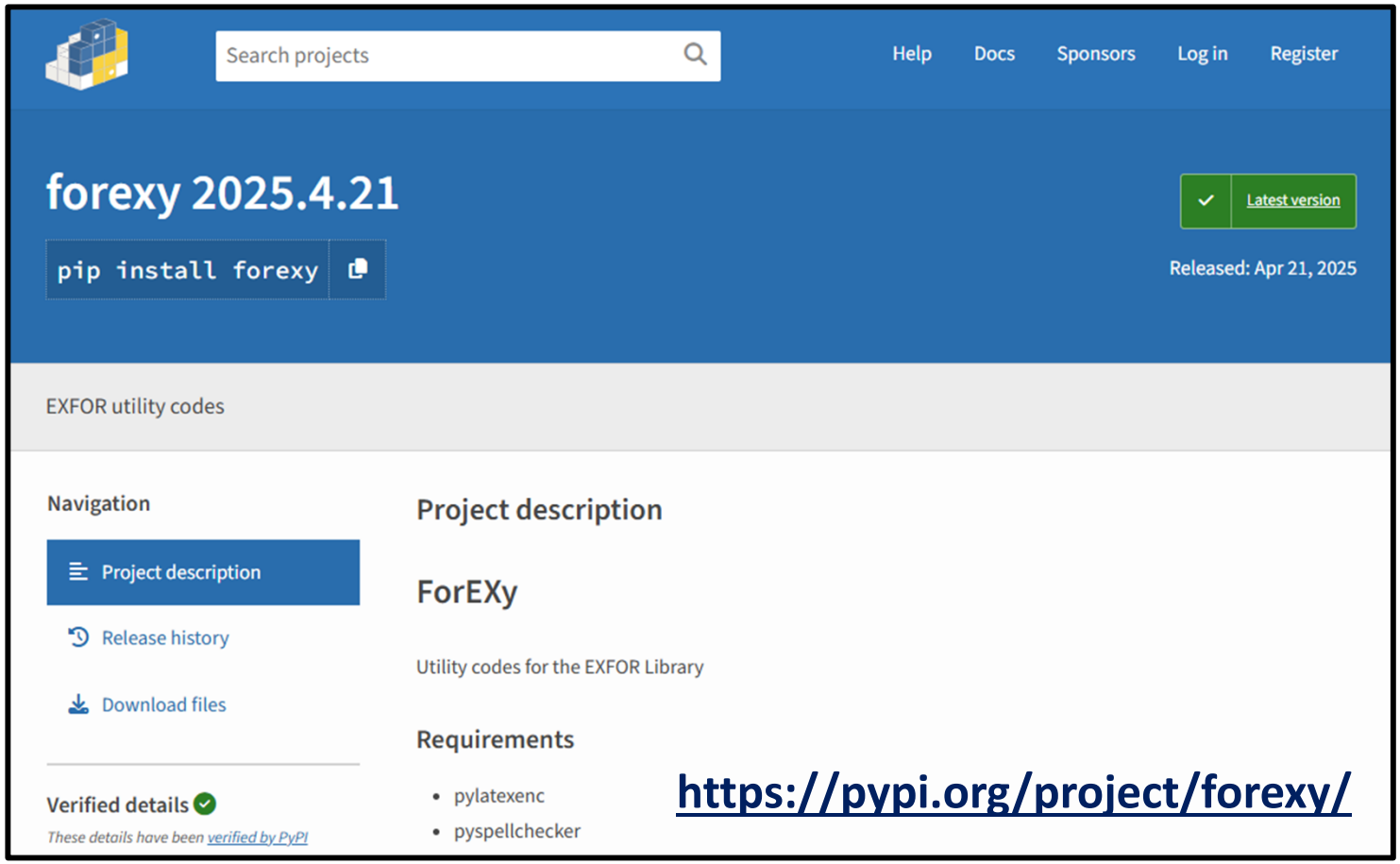
**How to improve JSON for better machine readability?**

**Fig. 2.** Two JSON representations for the decay data of $^{99m}$Tc adopted in an activation cross section measurement ($T_{1/2}$ = 6.0082 h, $E_\gamma$ = 140.5 keV, $I_\gamma$ = 88.5%) (Takács et al., 2015). The second example is simplified from the actual J4 file of EXFOR D4322.002.

Appl.Radiat.Isot.225(2025)111903

# ForEXy on PyPI repository

I created a PyPI repository for ForEXy (Thanks, Georg!)




```
% pip install forexy
```

# Automatic generation of TITLE and AUTHOR (REFBIB)

```
% ./x4_refbib.py -i 10.1016/j.nds.2014.07.065

REFBIB (Ver.2025.04.21) run on 2025-06-19
-----------------------------------------
Family name of the first author ------------------> any
JSON Dictionary [dict_9131.json] ----------------->
output bibliography file [x4_refbib_out.txt] ----->
output format [doi] ------------------------------> exfor
your email address -------------------------------> n.otsuka@iaea.org

DOI:   10.1016/j.nds.2014.07.065

REFBIB: Processing terminated normally.
```

My usual procedure for n_TOF articles with many authors

**Output file (e.g., Hlaváč → Hlavac)**

```
TITLE       Towards a more complete and accurate experimental
             nuclear reaction data library (EXFOR):
             international collaboration between nuclear
             reaction data Centres (NRDC)
AUTHOR      (N.Otuka, E.Dupont, V.Semkova, B.Pritychenko,
             A.I.Blokhin, M.Aikawa, S.Babykina, M.Bossant, G.Chen,
             S.Dunaeva, R.A.Forrest, T.Fukahori, N.Furutachi,
             S.Ganesan, Z.Ge, O.O.Gritzay, M.Herman, S.Hlavac,
             K.Kato, B.Lalremruata, Y.O.Lee, A.Makinaga,
             K.Matsumoto, M.Mikhaylyukova, G.Pikulina,
             V.G.Pronyaev, A.Saxena, O.Schwerer, S.P.Simakov,
             N.Soppera, R.Suzuki, S.Takacs, X.Tao, S.Taova,
             F.Tarkanyi, V.V.Varlamov, J.Wang, S.C.Yang, V.Zerkin,
             Y.Zhuang)
```

# Feedback to the manuscript

"Using the information provided in the paper, the NRDC website and the manual, **I was able to successfully run the codes** (I've tested dirini, dirupd, makelib, x4toj4 and j4tox4)."

"The different file types (master, entry, trans and dictionary files) can be **easily accessed from the NRDC website** (nds.iaea.org/nrdc). I think the **huge effort of NRDC**, in particular of the authors of the paper, to provide all these files along with information on proper usage will be **very much appreciated by the nuclear data community**."

# Feedback to the manuscript (cont)

"Proper credit of data resources is an important topic. The provision of the data under the well-known **CC-BY-4.0 license is an important measure** to give end users clear guidance on how the data can be used."

# What is “compilation” in scientific fields?

the EXFOR files. Katharine Way et al. define compilation in scientific fields as follows (Way et al., 1969):

> To compile, says Webster, is “to compose out of material from other documents”. But in scientific fields the juxtaposition of values obtained by different authors for a given quantity is of little use unless the values have first been made comparable by making sure they are based on the same standards, include the same corrections, present uncertainties calculated in the same way, etc. Thus the compiler’s first task is to produce this *comparability* or to note the impossibility of doing so in special cases. By a “compilation” of scientific data we will mean a collection of results of different authors in which the values have been made comparable.

To make the EXFOR library as a collection of comparable datasets, EXFOR compilers have to (1) select an experimental dataset useful for comparison from an article, (2) tag the dataset with a reaction/quantity identifier defined in the EXFOR dictionary and rule (REACTION coding) in spite of the variety in the nomenclature and symbols, and (3) collect from the experimentalist the numerical data including the

**Katharine Way 1902-1995 (Wikipedia)**

Appl.Radiat.Isot.225(2025)111903

**Compiler’s first task is to produce *comparability***

# Extraction from summary (my personal view)

We believe that development and improvement of the IT infrastructure for EXFOR processing are beneficial for the community. For example, we saw in Section 3.2 that MACKOV automatises construction of experimental covariance from EXFOR files, and it simplifies least-squares analysis of experimental data drastically. However, this automatisation does not solve the main bottleneck in the flow of the information from experimentalists to users since the quality of the experimental inputs still heavily relies on the quality of the contents in the EXFOR files. Katharine Way et al. define fields as follows (Way et al., 1969):

reference data required for comparison (e.g., decay data, standard or monitor value) adopted in the data reduction process.[13] It is obvious that a nuclear physicist can start reasonable EXFOR compilation only after training given by an experienced EXFOR compiler and also only after establishing good relationship with the experimentalists of the region. AI/ML may assist drafting of an EXFOR entry file, but the EXFOR compiler must revise and finalise the draft against the source information (e.g., article) as a nuclear physicist before proofread by the experimentalists. Therefore, the community should allocate resource to sustain access to the experimental data and their comparability over the next decades. For example, the Asian NRDC members (CNDC, JAEA, JCPRG, KNDC, NDPCI) periodically organise regional workshops in co-operation with the IAEA to enhance capabilities of EXFOR compilation in their region (Takibayev et al., 2014; Saxena, 2015; Sarsembayeva et al., 2015; Chen and Otuka, 2017; Odsuren et al., 2018; Yang and Otuka, 2019; Zholdybayev and Otuka, 2019), and NDPCI also organises the biennial workshop to transfer the knowledge of EXFOR to young nuclear physicists in India. As discussed in Section 1, there is an editor

Appl.Radiat.Isot.225(2025)111903

# ForEXy is an Open Source package

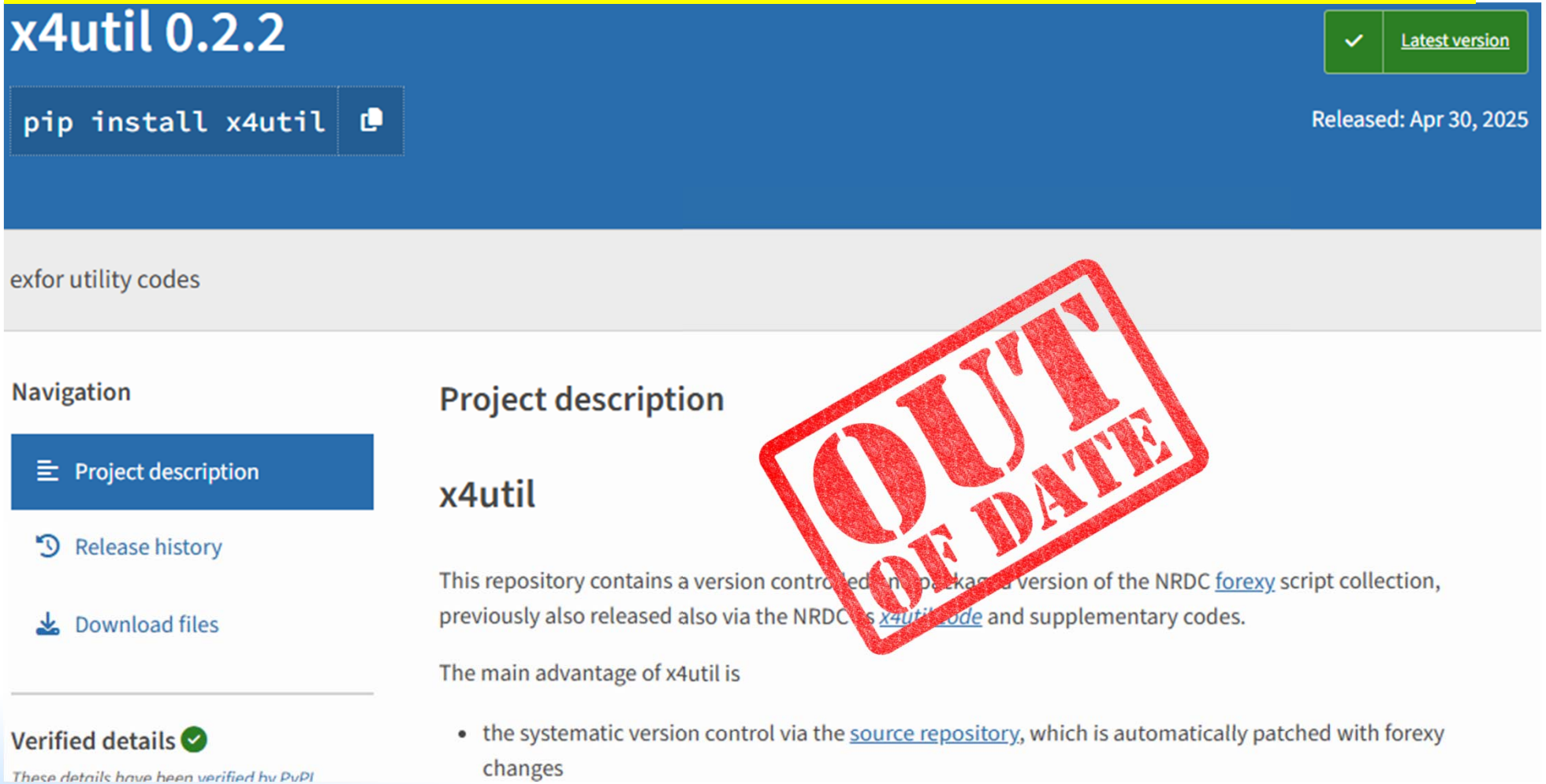
- ForEXy is under **MIT license with an additional sentence** "*Nothing in this license shall be construed as a waiver, either express or implied, of any of the privileges and immunities accorded to the IAEA by its Member States.*" (Thanks, Ludmila!)

- Feel free to modify and include in your tools (e.g., EXFOR editor)

- I would be happy if proper **citation** (i.e., the ARI article) is given. (though I do not know if citation is a common practice in the IT community…)

# Recommendation to NEA DB's x4util PyPI repo

I superseded x4util by ForEXy. Therefore, please consider to
/1/ Mention clearly x4util is **superseded by ForEXy**
/2/ **Cite** (Appl.Radiat.Isot.225(2025)111903) with its DOI.



# *Thank you!*


View of Vienna International Centre (VIC) Buildings from Kaiserwasser
(Courtesy of Kazufumi Nagashima)