Some User' Feedbacks

and

Potential new Demands

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https://conferences.iaea.org/event/395/

Abstract

- The aim of this presentation is to present a collection of personal - failure and success - feedbacks with different nuclear data tools and nuclear data management systems (NDMS).
- I hope, this presentation will stimulate the discussion on a broad range of issues in NDMS and retrieval/visualization tools, to identifying potential new features to enhance the usage and the quality of these systems.
- A summary of dissemination/training activities with students and users will be presented within the UPM and the EU/ Gre@tPioneer project.

DISCLAIMER

The opinions expressed and arguments employed are those of the author. Without any intention to offend any work done by Institutions/people and/or to anyone.

Motivation of this presentation…

(My) USER Needs:

1) What's the aim of my work?

- comparison of experimental data with evaluated data (new and past releases)
- show evidences (plots, statistics,…) of the better evaluation
- show trends (outliers,…) in ND that may help to understand integral responses

2) What type of nuclear data?

- cross-sections
- angular distributions
- energy distributions
- differential cross-section
- multiplicities
- …

Then, I need tools to assess the quality (good/bad) of experimental and evaluated data!!!

1. Main sources of information

1.1 Archiving – new and legacy evaluations

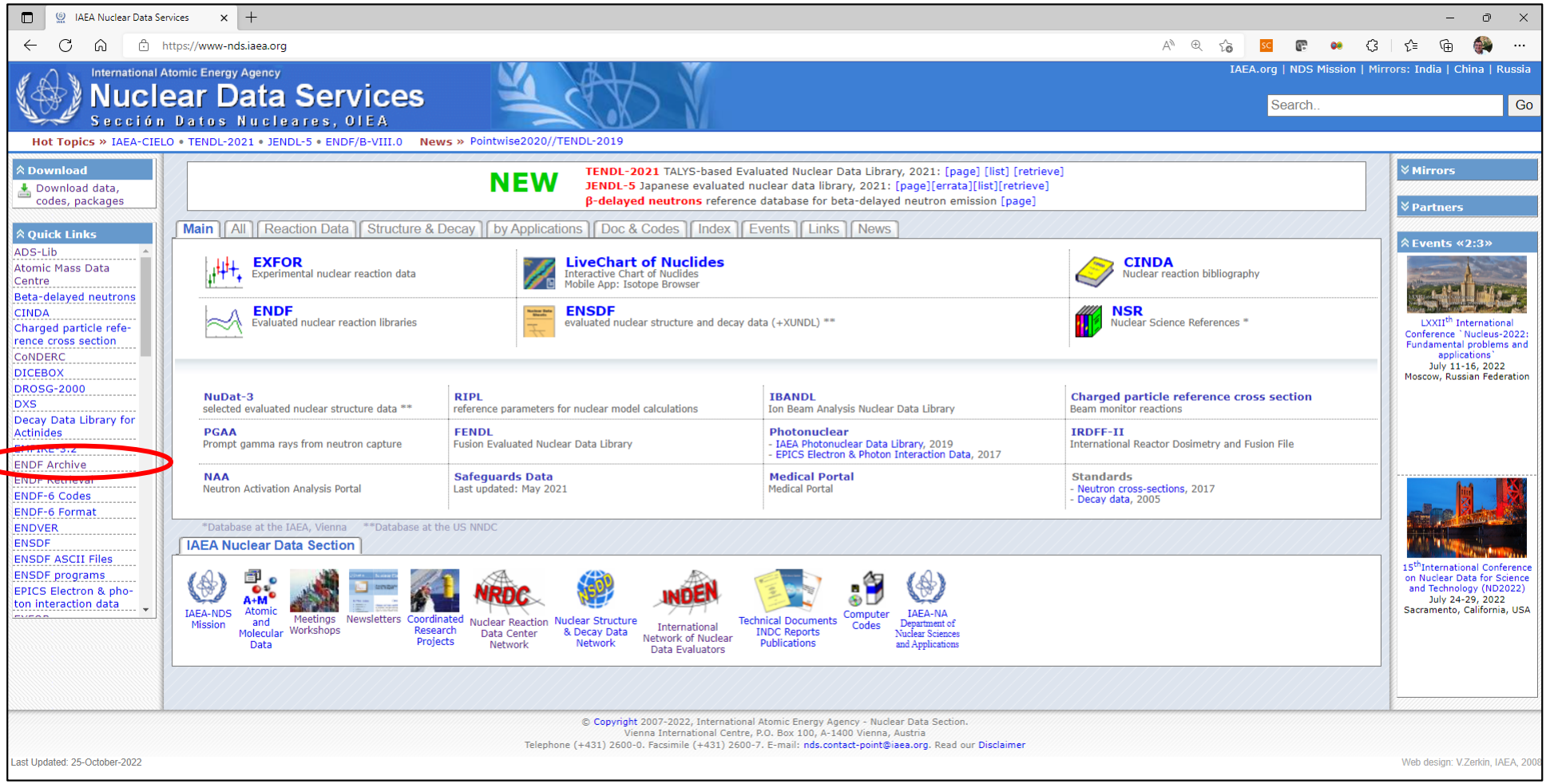
1.2 EXFOR files/formats

1. Databases:
-> ENDF Archive

IAEA/NDS – ENDF Archive

https://www-nds.iaea.org/public/download-endf/

Q/A: How many "mouse clicks" do you need from IAEA/NDS to find the "ENDF Archive"?

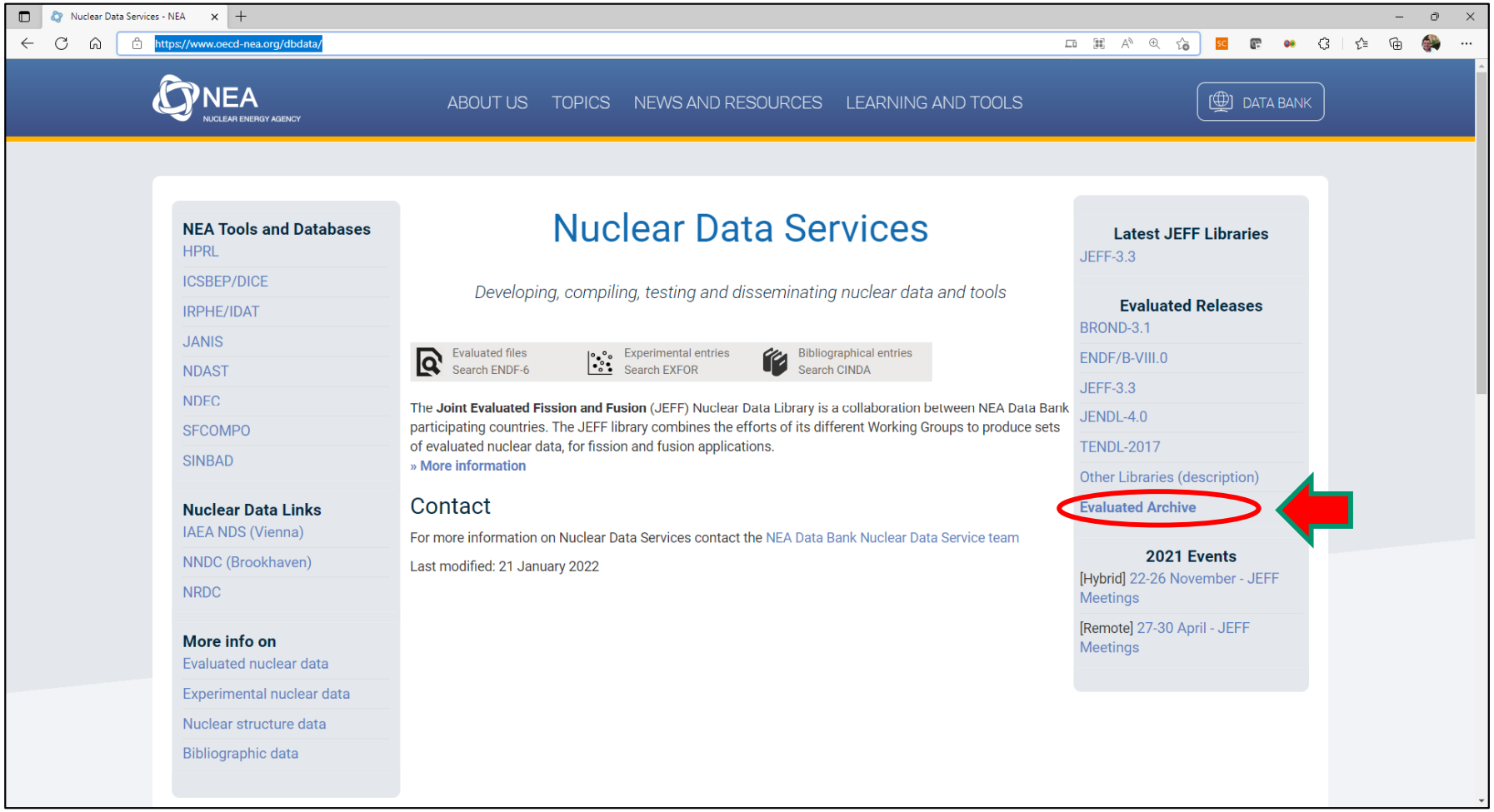


1. Databases:
-> ENDF Archive

OECD/NEA – Data Bank Archive

https://www.oecd-nea.org/dbdata/

Q/A: How many "mouse clicks" do you need from OECD/NEA/Data Bank/ND Services to find the "ENDF Archive"?



1. Databases: -> ENDF Archive: "different content?"

Q/A: Will you have the same information for the JEFF-3.3 evaluation at https://ww-nds.iaea.org and at https://www.oecd-nea.org/dbdata/jeff/jeff33/ ? YES or **NO**

At **https://www-nds.iaea.org/public/download-endf/**

- n-induced reactions (562) — TSL libraries (20)
- Spontaneous Fission Yields (3) — N-induced Fission Yields (19) — Decay data (3852)

At **https://www.oecd-nea.org/dbdata/jeff/jeff33/**

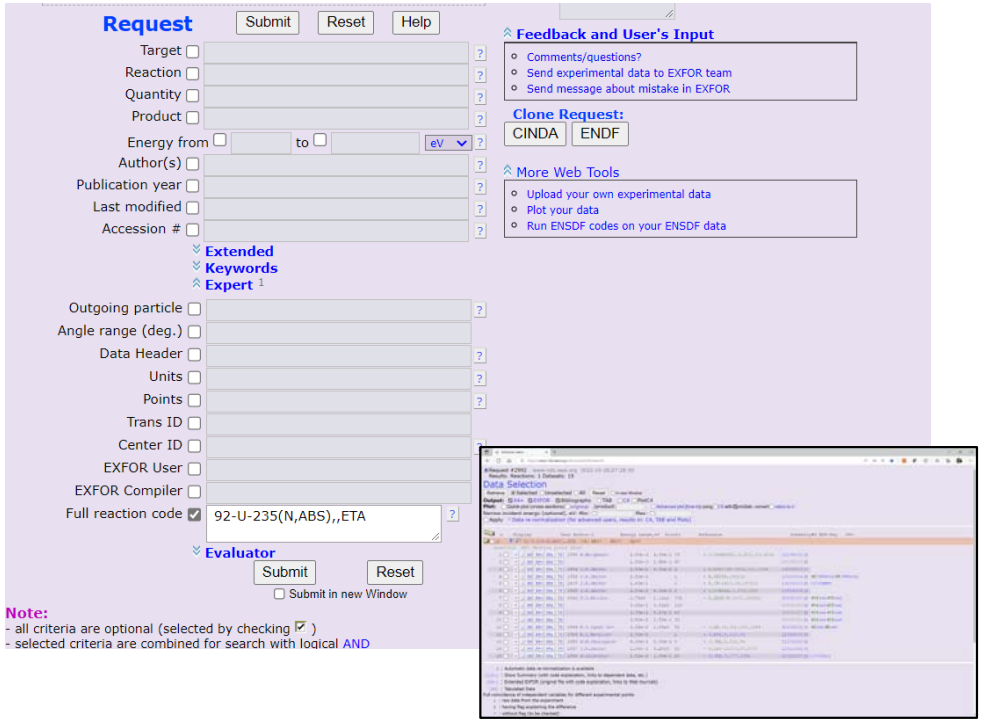
- n-induced reactions (562) — TSL libraries (20)
- Processed files in ACE format at different temperatures
  - 293K, 600K, 900K, 1200K, 1500K and 1800K
  - TSL at the temperatures available
- Neutron activation files
- Spontaneous Fission Yields (3) — N-induced Fission Yields (19) — Decay data (3852)
- Alpha induced reactions — Deuteron induced reactions — Gamma induced reactions
- He3 induced reactions — Proton induced reactions
- DPA sub-library for atomic displacement

- **USERs should be careful searching data in those repositories**

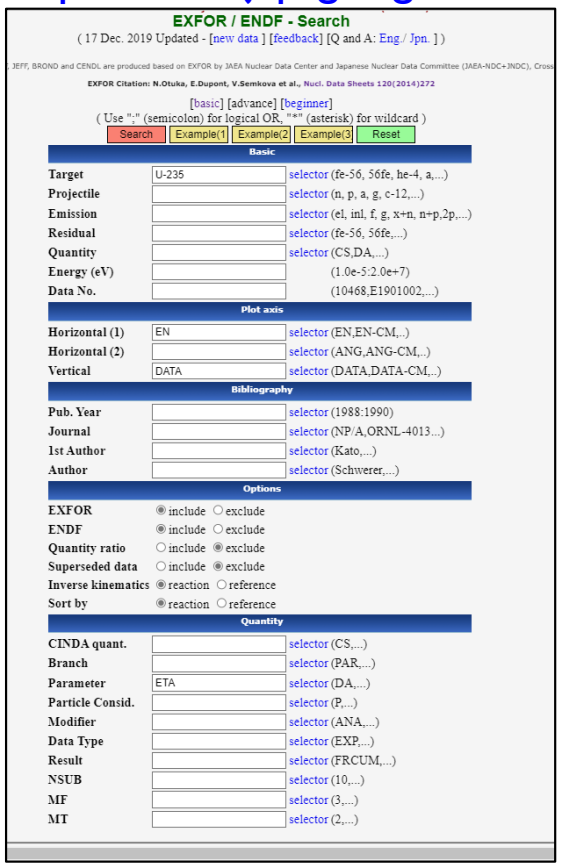
1. Databases:
-> Searching specific data?"

Q/A: Identify EXFOR entries for the eta-value in ^{235}U. Search **ETA data** using https://www-nds.iaea.org/exfor/ (select: **advance Expert**) and/or using https://www.jcprg.org/exfor/ (select: **advance user**)

Q/A: How many entries do you find using https://www-nds.iaea.org/exfor/? **15**



Q/A: How many entries do you find using https://www.jcprg.org/exfor/ ? **15**

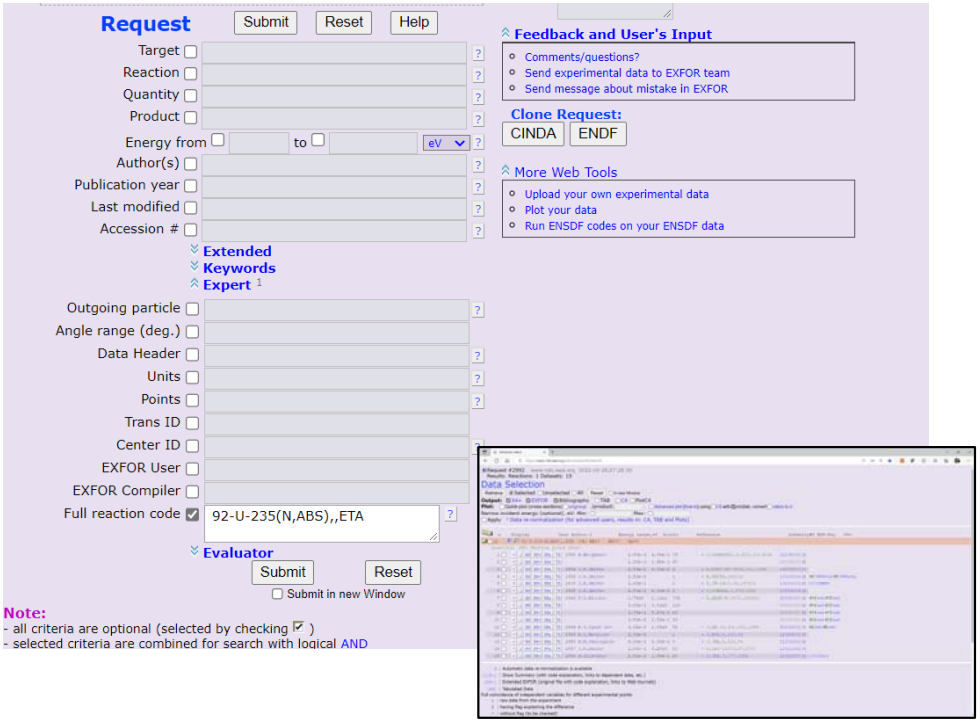


- Please, can you try it in **JANIS** (https://www.oecd-nea.org/janis) ? ….

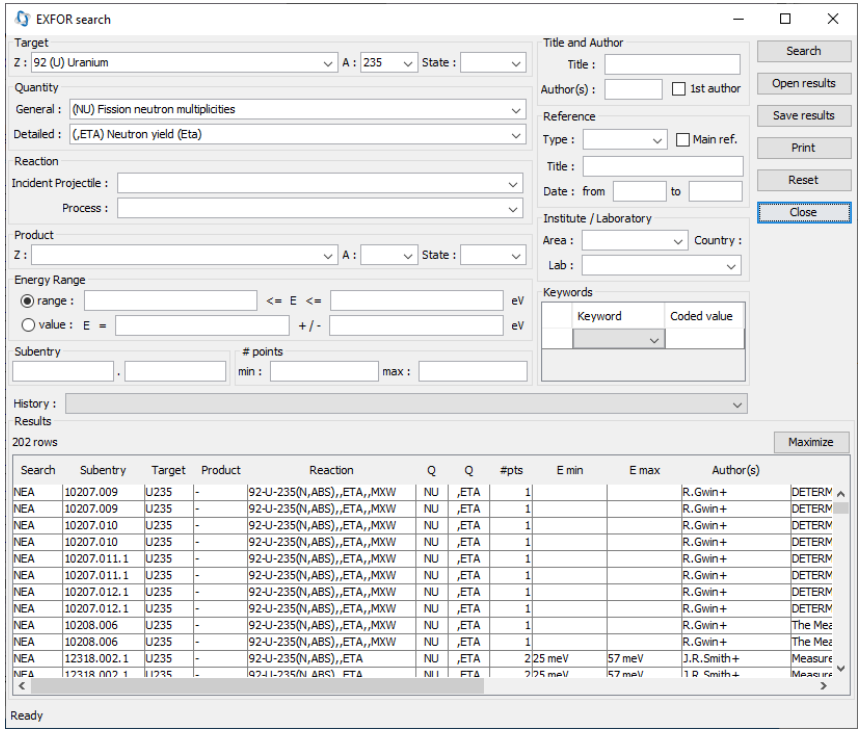
1. Databases:
-> Searching specific data?"

Q/A: Identify EXFOR entries for the eta-value in ^{235}U. Search **ETA data** using searching tool in JANIS – "NEUTRON MULTIPLICITIES+ ETA" https://www.oecd-nea/janis/

Q/A: How many entries do you find using https://www-nds.iaea.org/exfor/? **15**



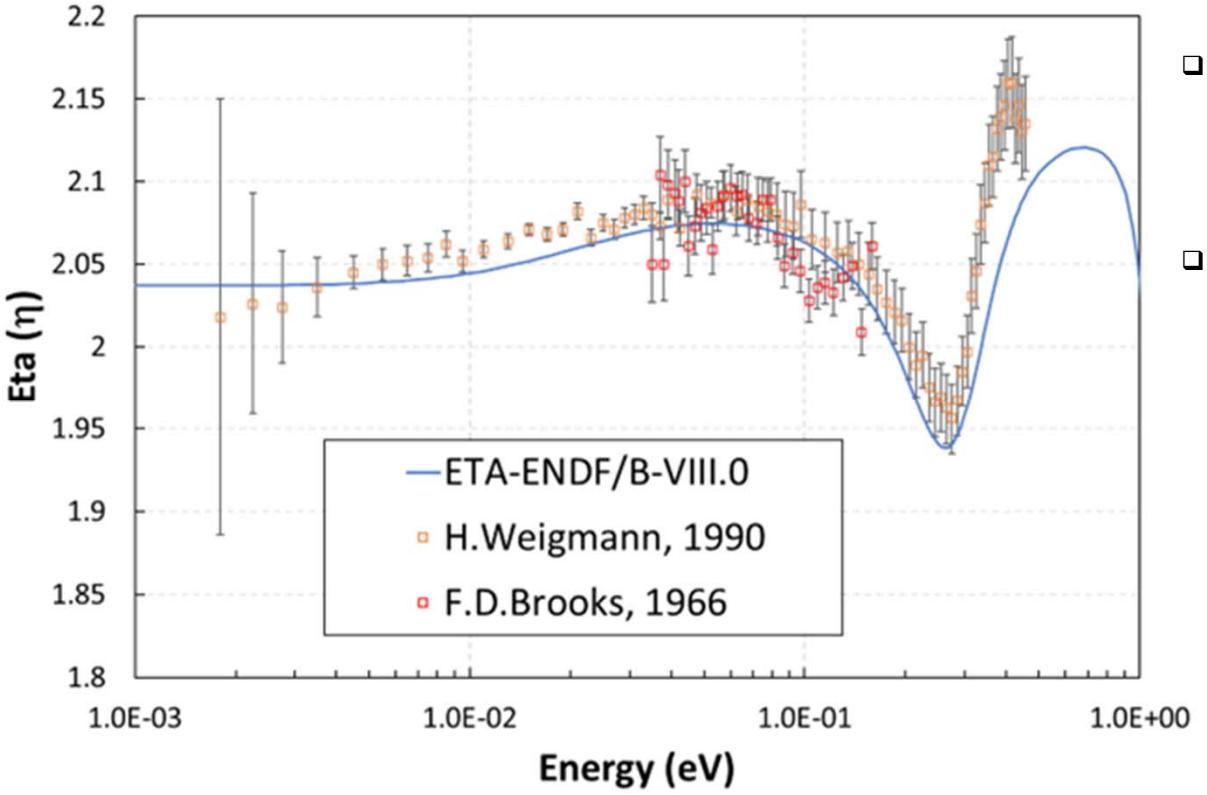
Q/A: How many entries do you find using https://www.oecd-nea/janis/ ? **25**



- **USERs may need additional filtering of data depending on the NMDS**

1. Databases:
-> Searching specific data?”

Figure 1. Eta (η) for ^{235}U for thermal neutron energy.



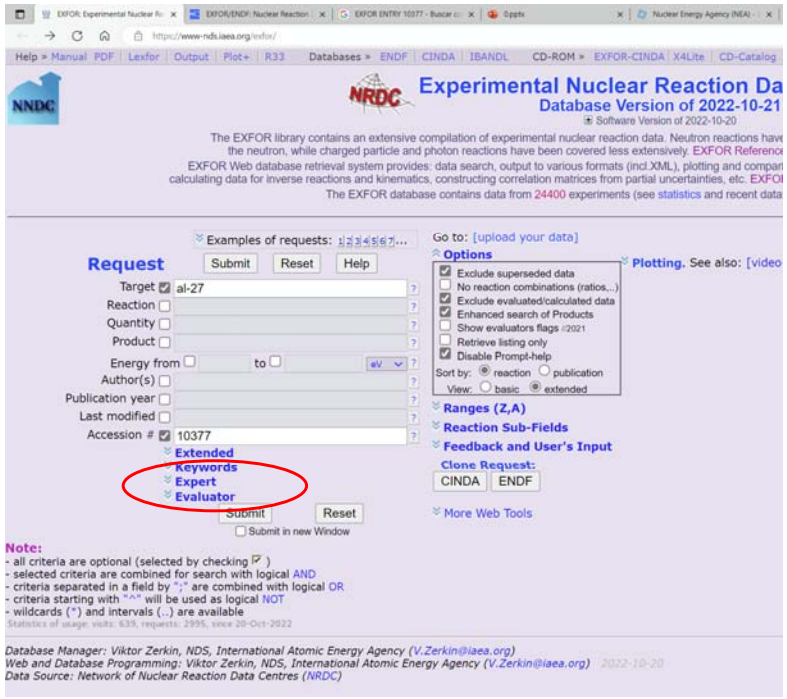
- EXFOR data are obtained using EXFOR retrieval tool for the reaction code: “92-U-235(N,ABS),,ETA.”
- PENDF data with:
  - PREPRO (see Sublet’s talk)
  - JANIS (compute function)

- **USERs may need additional statistical information EXFOR vs ENDF (errors, χ2, etc…) during the visualization of this plot. Can we provide such statistical information on-the-fly?**

1. Databases:
-> Searching EXFOR raw data?"

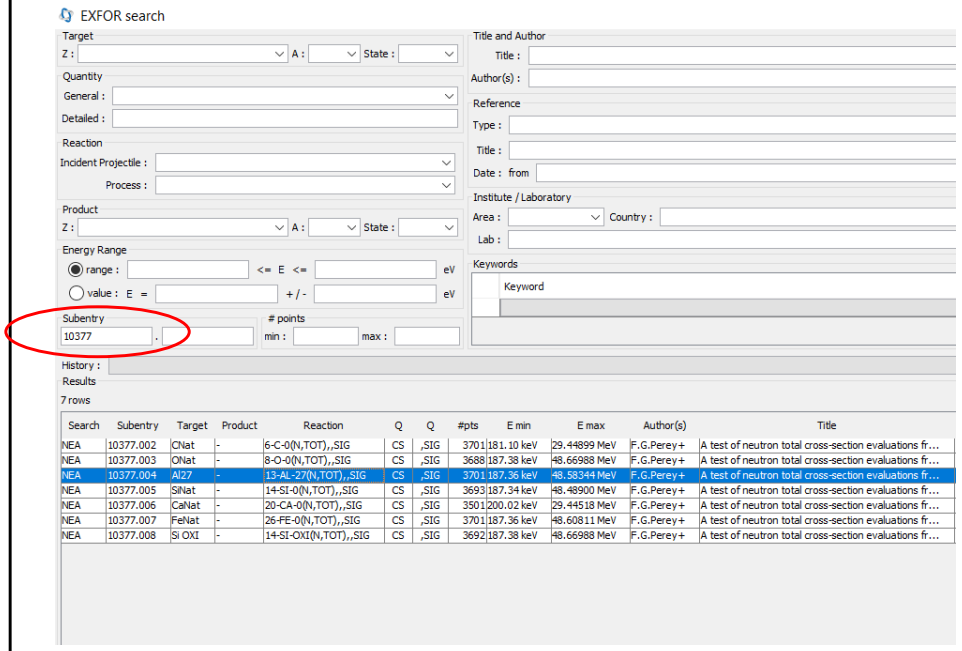
Q/A: Search and download: EXFOR "ENTRY-10377" for Al-27 from using https://www-nds.iaea.org/exfor/ or https://www.oecd-nea.org/janis

Q/A: How many experimental point contains this entry using IAEA/EXFOR retrieval system? 3701



Q/A: Are you able to download **X4 file** using EXFOR retrieval system ? **YES**

Q/A: How many experimental point contains this entry using JANIS Tool? 3701



Search	Subentry	Target	Product	Reaction	Q	Q	#pts	E min	E max	Author(s)	Title
NEA	10377.002	CNat	-	6-C-0(N,TOT),,SIG	CS	,SIG	3701	181.10 keV	29.44899 MeV	F.G.Perey+	A test of neutron total cross-section evaluations fr...
NEA	10377.003	ONat	-	8-O-0(N,TOT),,SIG	CS	,SIG	3688	187.38 keV	48.66988 MeV	F.G.Perey+	A test of neutron total cross-section evaluations fr...
NEA	10377.004	Al27	-	13-AL-27(N,TOT),,SIG	CS	,SIG	3701	187.36 keV	48.58344 MeV	F.G.Perey+	A test of neutron total cross-section evaluations fr...
NEA	10377.005	SiNat	-	14-SI-0(N,TOT),,SIG	CS	,SIG	3693	187.34 keV	48.48900 MeV	F.G.Perey+	A test of neutron total cross-section evaluations fr...
NEA	10377.006	CaNat	-	20-CA-0(N,TOT),,SIG	CS	,SIG	3501	200.02 keV	29.44518 MeV	F.G.Perey+	A test of neutron total cross-section evaluations fr...
NEA	10377.007	FeNat	-	26-FE-0(N,TOT),,SIG	CS	,SIG	3701	187.36 keV	48.60811 MeV	F.G.Perey+	A test of neutron total cross-section evaluations fr...
NEA	10377.008	Si OXI	-	14-SI-OXI(N,TOT),,SIG	CS	,SIG	3692	187.38 keV	48.66988 MeV	F.G.Perey+	A test of neutron total cross-section evaluations fr...

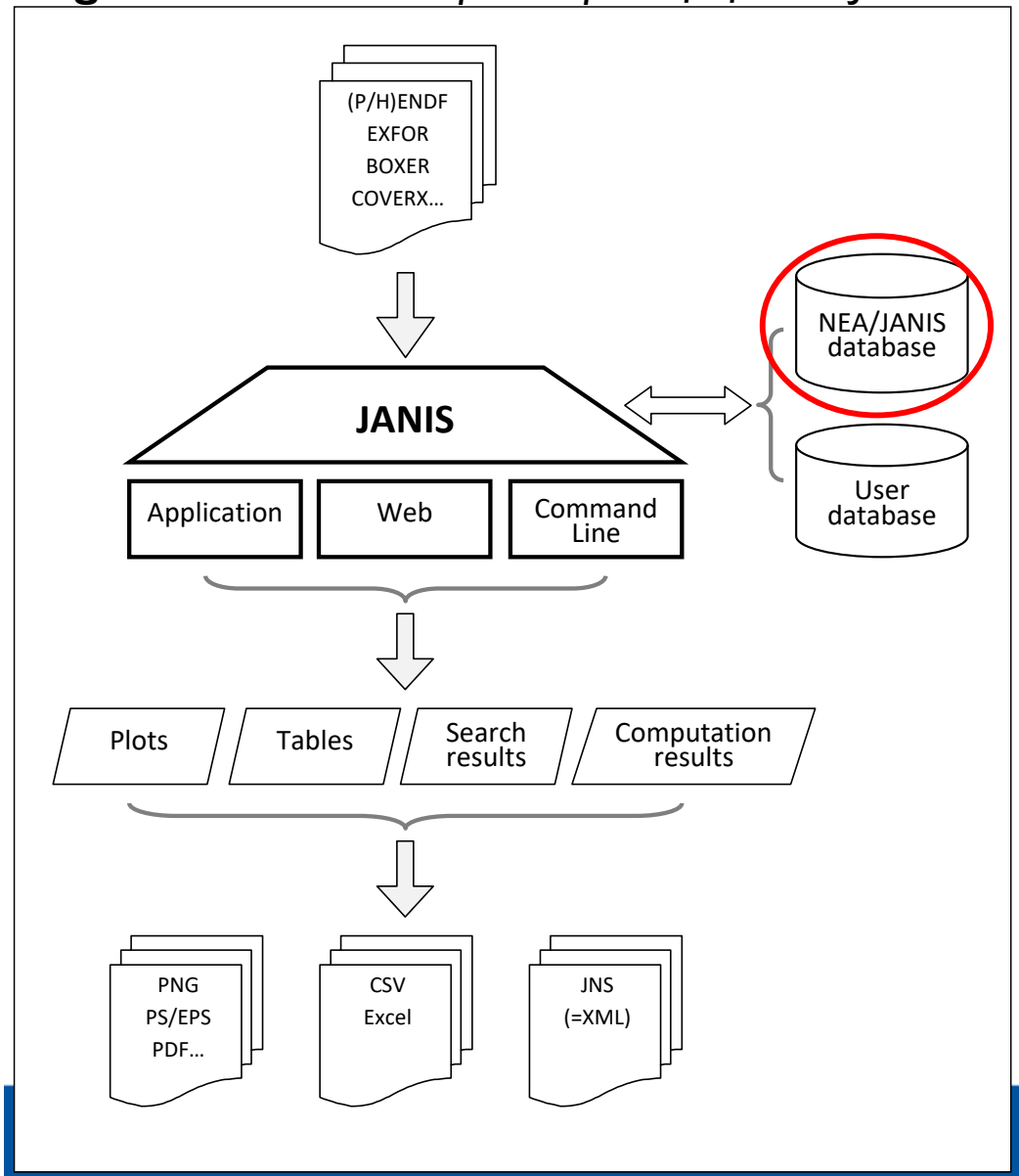
Q/A: Are you able to download **X4 file** using JANIS? **NO**

- **USERs may (or may not) find different sources of data in different retrieval systems**

Q&A – "Official" Databases … should they give some "Disclaimers"?

This is just an example...

Fig 2. *Databases and input/output info flow in JANIS*



PENDF - Processing data

- Official version of processing code (NJOY99.??, NJOY2016.??, PREPRO-20??,…)
- Temp. Broadening : 293.6K?, 300K?

EXFOR Database

- When do they update new entries?
  - Loading finalized TRANS file one-by-one (IAEA/NDS, NNDC, JCPRG)
  - Relying on which "EXFOR Master File" (NEA/DB-JANIS) ?

ENDF Database

- When do they update major libraries?
  - See latest cases: JENDL-5 (2021) , TENDL(2023), and ENDF/B-VIII.1 (2024)
- … and beta-libraries? it relies on users?!

… Do they say any DISCLAIMER if there are errors?

2. Working with the data

2.1 The JANIS save mode JNS

2.1 The JANIS command line tool

2.2 The X4Pro and JANIS

2.1 The JANIS save mode JNS

- **JANIS save workspace in "*.jns"**
  - EXPORT (PNG, EPS) and **SAVE** (JNS) : "File > Save..."

```
...
 <data refs="~N~ENDF/B-VII.1~SIG~Al27~MT1~xs">
      <layer>
        <color>#ff0000</color>
        <stroke>1.0|2|0|10.0|null|0.0</stroke>
      </layer>
    </data>
    <data refs="~N~JEFF-3.2~SIG~Al27~MT1~xs">
      <layer>
        <color>#00ff00</color>
        <stroke>1.0|2|0|10.0|null|0.0</stroke>
      </layer>
    </data>
    <data refs="~N~JENDL-4.0~SIG~Al27~MT1~xs">
      <layer>
        <color>#0000ff</color>
        <stroke>1.0|2|0|10.0|null|0.0</stroke>
      </layer>
    </data>
...
```

JANIS identifiers

- **Saving Workspace**
- **It allows automatizing tasks**

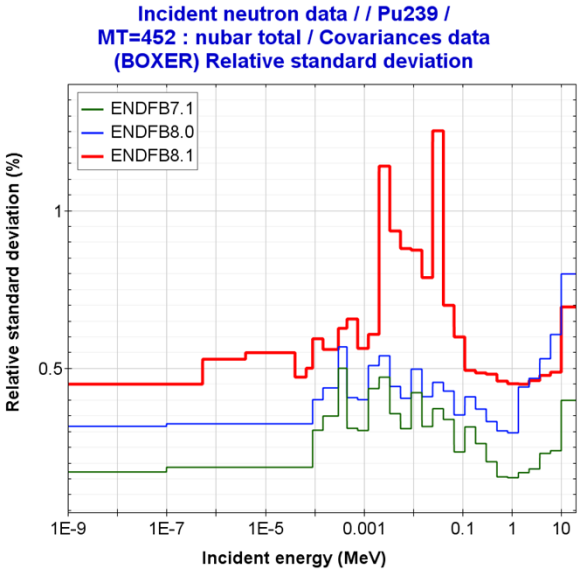


Figure 3. Relative standard deviation (in %) for the 239Pu(nubar) processed with NJOY2016 in 33 energy groups

Ref.1: O. Cabellos, "ENDF/B-VIII.1 testing covariances", CSEWG Nov 2024

2.2 The JANIS command line tool… important for ML users?

- **JANIS in command-line: "the Great Unknown"**

Since JANIS-4.2; Ref: JANIS/ND2016 paper, JEFDOC-2041, JEFDOC-2224 …)

Download: http://www.oecd-nea.org/janis/webstart/Janis_all_jars.zip

Run:
```
C:\ java -jar janis.jar -help
```

Examples:
```
C:\ java -jar janis.jar -renderer NEA N JEFF-3.1.2 SIG N15 MT1 xs
C:\ java -jar janis.jar -search NEA covariances inc=n lib=JEFF-3.3 fmt=BOXER
C:\ java -jar janis.jar -search NEA endf z=Pb a=206 inc=n mf=3 mt=102
C:\ java -jar janis.jar -render my_input.jns t0 csv
```

Ref.1: *Selecting & identifying "activation" data for branching calculations in NEA database for* $^{196}Pt(n,p)^{196}Ir$, INDC-SPN-0004(https://nds.iaea.org/publications/indc/indc-spn-0004/)

- Searching:
```
C:\ java -jar  janis.jar -o OUTPUT.txt -list NEA N JEFF-3.3 SIG Pt-196 MT103 activation
```

⇨
```
covariances
section_Ir196q
section_Ir196
calc[Yield for Ir196]
calc[Yield for Ir196q]
```

- Extracting "activation" data in 1D (X-Y) format:
```
C:\ java -jar  janis.jar -o PENDFg.txt -table NEA N JEFF-3.3 SIG Pt-196 MT103 activation  section_Ir196
C:\ java -jar  janis.jar -o PENDFm.txt -table NEA N JEFF-3.3 SIG Pt-196 MT103 activation  section_Ir196q
```

2.3 The X4Pro and JANIS

▪ X4Pro vs JANIS for plotting angular differential cross-sections

The aim is to plot EXFOR + User's PENDF angular differential cross-sections to assess new LRF7 evaluations:

JANIS:

- is able to plot $\sigma(E,\Omega)$ and EXFOR
- is not able to able to plot "EXFOR + PENDF" data in the same plot
- is very easy to plot own PENDF data

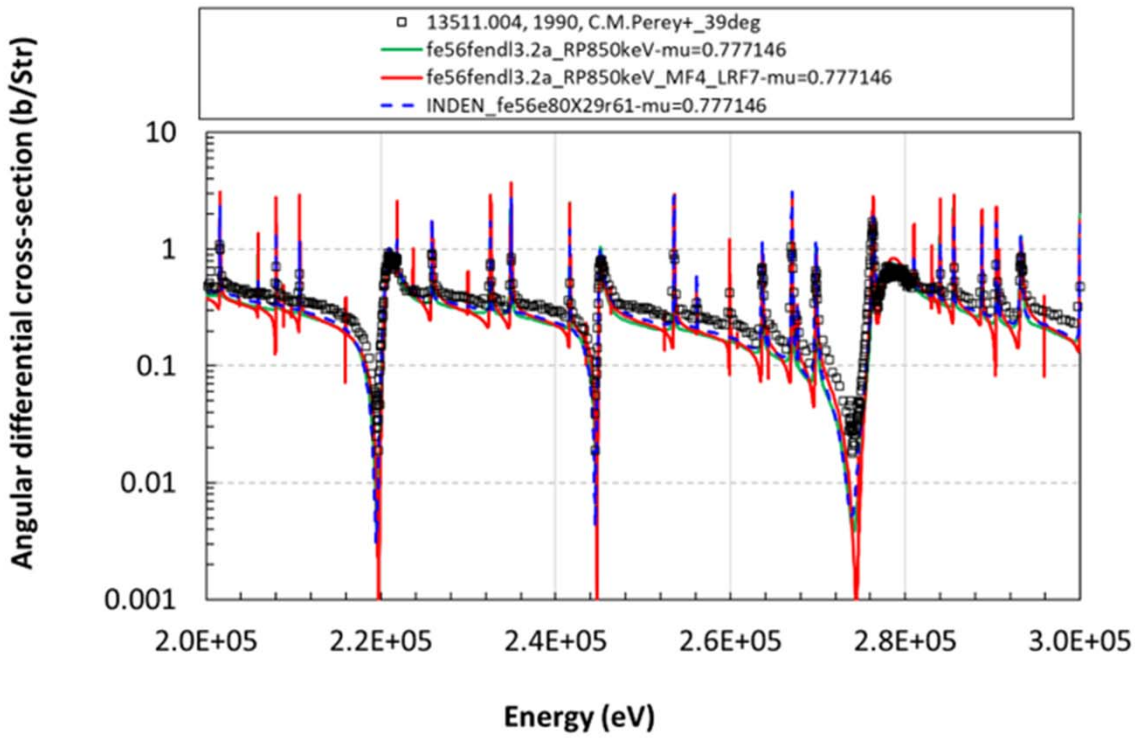
X4Pro :

- is able to plot/extract EXFOR data
- is able to plot PENDF data.
- comparison with JANIS showed differences between X4Pro and JANIS (~1/4p). **This work allows Viktor Zerkin to correct a mistake in X4Pro!!**
- is difficult to upload own data

…

Finally …I was plotting using **EXCEL …** 😕

Figure 4. Angular differential cross-section ^{56}Fe(n,el) – ang=39º



Ref.1: JEFDOC-2211: Processing files with LRF7 option for the reconstruction of the MF4, pros and cons, Nov 2022

Ref.2: Technical Meeting on Nuclear Data Processing, 29November - 2 December 2022, IAEA Headquarters, Vienna, Austria

4. Data Mining for Machine Learning

4.1 Outlier identification in EXFOR

- Some examples/efforts

4.2 ML to create new evaluations

- Can we implement this in current systems?
  - Lack of features in the models with current databases
  - Others? … the own ML models

4.1. ML: Outlier detection

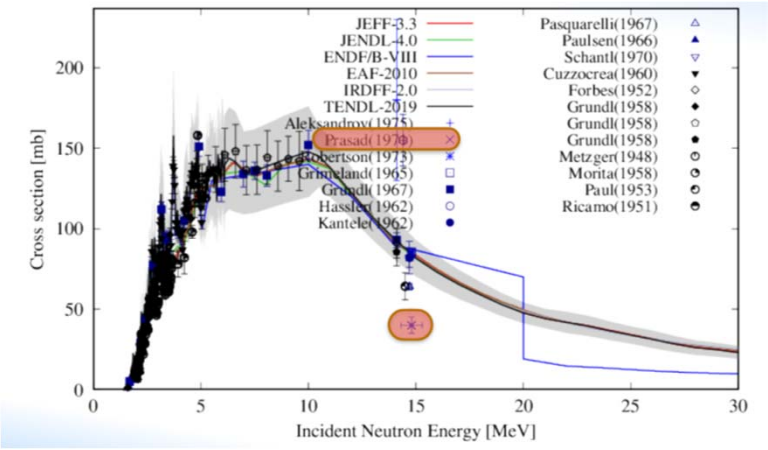
Ref.: A. Koning, *"EXFOR and outliers", JEFF meeting on Machine Learning, November 23, 2021, NEA, Paris. JEFDOC-2085*

Technique: Traditional outlier detection in EXFOR

- Quality scoring
- Numerical goodness-of-fit estimators (F, χ^2,…)
- Graphical estimation

Ref: Arjan Koning, "Statistical verification and validation of the EXFOR database: (n,gamma), (n,n'), (n,2n), (n,p), (n,alpha) and other neutron induced reaction cross sections", NEA/DB/DOC(2017)1.

Figure 5. Cross-section ^{31}P(n,p)^{31}Si



Objective: Outlier identification and *quality assignment of EXFOR data*

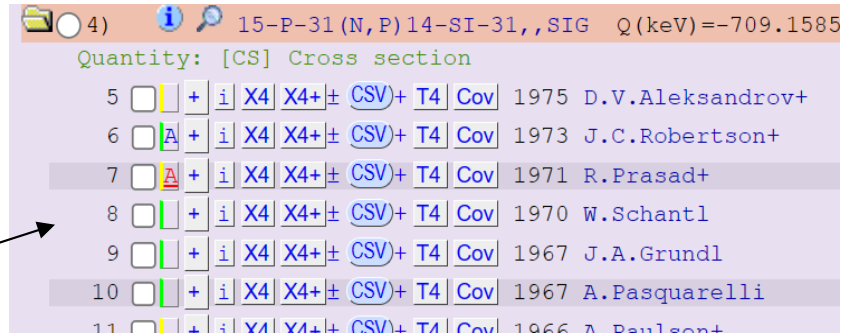
- Do we have any change with standards/normalization?

Ref. Arjan Koning Statistical Verification of EXFOR neutron-ind. Reactions XS (2020)

#flag=R2 #[R]Reviewed #[2] Doubtful

https://www-nds.iaea.org/exfor/

Figure 4. Screen-shot with ***"Quality Assignment"*** for cross-section ^{31}P(n,p)^{31}Si



4.1. ML: Outlier detection – NEA Activities

Ref.: NEA Activities

Between 2011-2017

- NEA (2011), “Statistical methods for the verification of databases”, **NEA News**, Volume 29, No. 1, OECD, Paris.
- (2011) “Exploratory Data Analysis of the EXFOR Database”, E. Dupont, A. Koning, N . Otsuka, **Journal of the Korean Physical Society**, Vol. 59, No. 2, August 2011, pp. 1333~1336
- NEA (2012), “NEA contributions to the worldwide collection, compilation and dissemination of nuclear reaction data”, **NEA News**, Volume 30, No. 2, OECD, Paris
- (2014) “Cross checking of large evaluated and experimental nuclear reaction databases”, **ND2014**, Nuclear Data Sheets, Volume 120, pp. 277-280.
- (2014) EXFOR: Improving the quality of international databases, E. Dupont, **News briefs**, NEA News 2014 – No. 32.1/32.2
- NEA (2014), “Statistical verification and validation of the EXFOR database”, NEA Data Bank Report,

  NEA/DB/ DOC(2014)3, OECD, Paris.
- (2016) Verification of the databases EXFOR and ENDF, G. Berton et al., **ND2016**, EPJ Web Conf, Volume 146, 2017
- (2016) **JEFDOC-1778**, Verification of the EXFOR and ENDF Databases, Gottfried Berton, Nov 2016
- (2017) **JEFDOC-1909**, Checking the resolved resonance region in EXFOR database, Gottfried Berton, Nov 2017

4.1. ML: The Data Mining – An example: EXFOR and Evaluated Data

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- **My own 1D (X-Y Data) generation**

./EXFOR.ALL/
001_H_000.c4
001_H_001.c4
…
100_Fm_257.c4

(626 Files)

./ENDFB71/
(423 Files)
./JEFF32/
(472 Files)
./TENDL-2014/
(2488 Files)
./JENDL-4.0-2010/
(406 Files)

RUN: *.\python.exe parseC4.py C4-2015-01-07.xc4*

"**parseC4.py**"Created by Caleb Mattoon on 2010-06-28.
start with .xc4 file containing full exfor library in one file
(obtain latest from http://www-nds.iaea.org/x4toc4-master/?C=M;O=D)

sorts the library by projectile, target, MF, MT and incident energy separate directories are created for each projectile, and separate files for each target

RUN: **PREPRO** (Linear, Recent, Sigma1, Activate, Legend , Fixup, Dictin, Merger, **Mixer**)

RUN: **NJOY** (covariances: MODER,GROUPR, ERRORR, COVR)

RUN: **Utilities** (ang_mu, mu_bar, sixtab, c4sort, lsttab, pltlst)

The **set of reactions analysed**:

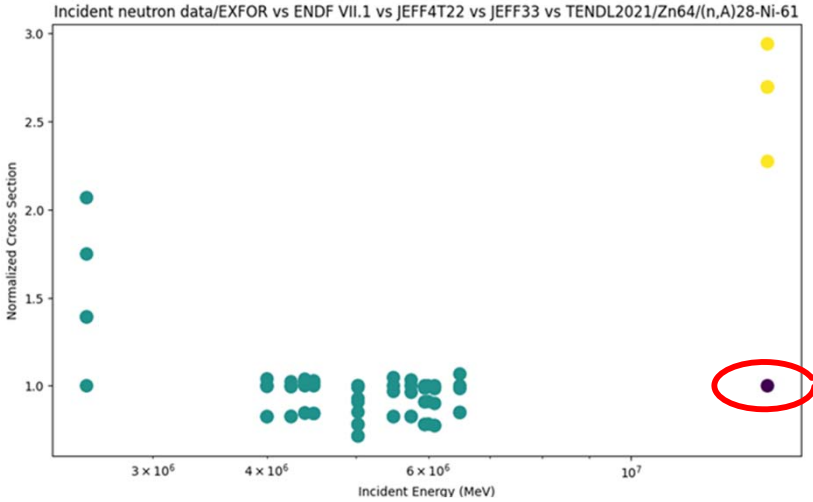
- MF3 for all **isotopes** and **natural elements**, except MT51 for natural elements
- MF3/MT251 (mu-bar) processed with MU_MAR.exe program
- MF4/MT2 for isotopes
- MF10 for isotopes

4.1. ML: Outlier detection - UPM Students

Ref.: M. González-Torre et al., "Feedbacks on Processing and Verification for JEFF-4T2.2", JEFF Nuclear Data Week April 2023.JEFDOC-224

Technique: Unsupervised ML algorithm - DBSCAN (Density-Based Spatial Clustering of Applications with Noise)

Objective: To identify anomalous data in EXFOR database



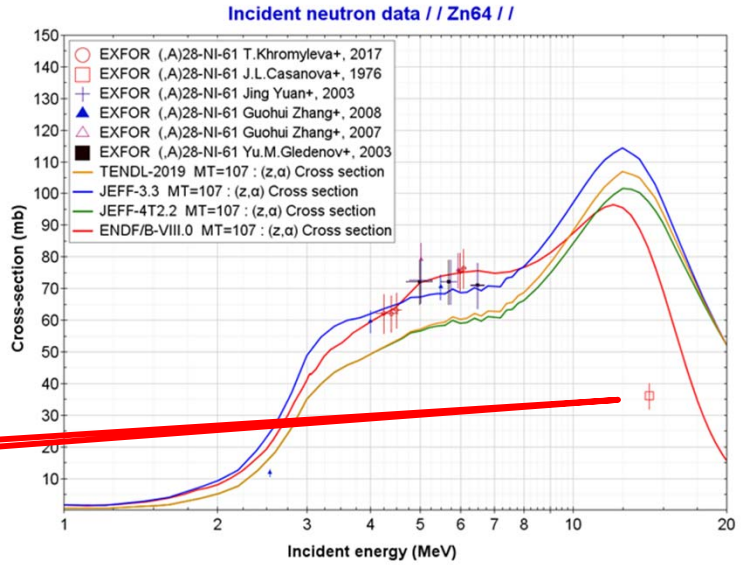


Figure 6. Comparison between EXFOR and some recent evaluated data for the ^{64}Zn(n,alpha) reaction cross-section as a function of neutron energy

Objective: Outlier identification

4.1. ML: Outlier detection - UPM Students

Ref.: J.A. Monleon, "Enhancing the EXFOR Nuclear Data Library Using Machine Learning Techniques", Master Thesis Project, 2023

Review of different Techniques for identifying outliers:

- **Statistical Techniques:** Z-Score or Standard Score, Modified Z-Score Method, QR Method:
- **Machine Learning:** Clustering Algorithms (K-Means or DBSCAN), Anomaly Detection Algorithms, Neural Networks

Preprocessing and Data Mining: "EXFORTABLES" :

- data extraction, transformation (scaling)
- encoding categorical data, manipulation and grouping the data
- preparation to machine learning applications

Objective: To identify anomalous data in "EXFOR proton reactions"

- **After in-depth review by Expert Judgment (Naohiko Otsuka) …. many "potential" outliers were "false outliers"**

Ref.: GitHub EXFOR-Proton Reactions Analysis Repository.:

https://github.com/monleon96/EXFOR-ProtonReactions-Analysis

5. New updates and compilations in NDMS

5.1 Compilation of new ENDF Evaluations

The JEFF Mapping tool

5.2. Tool for merging ENDF files

The JANIS Hybrid format

5.3 User updates for visualization

The JANIS Wizard tool

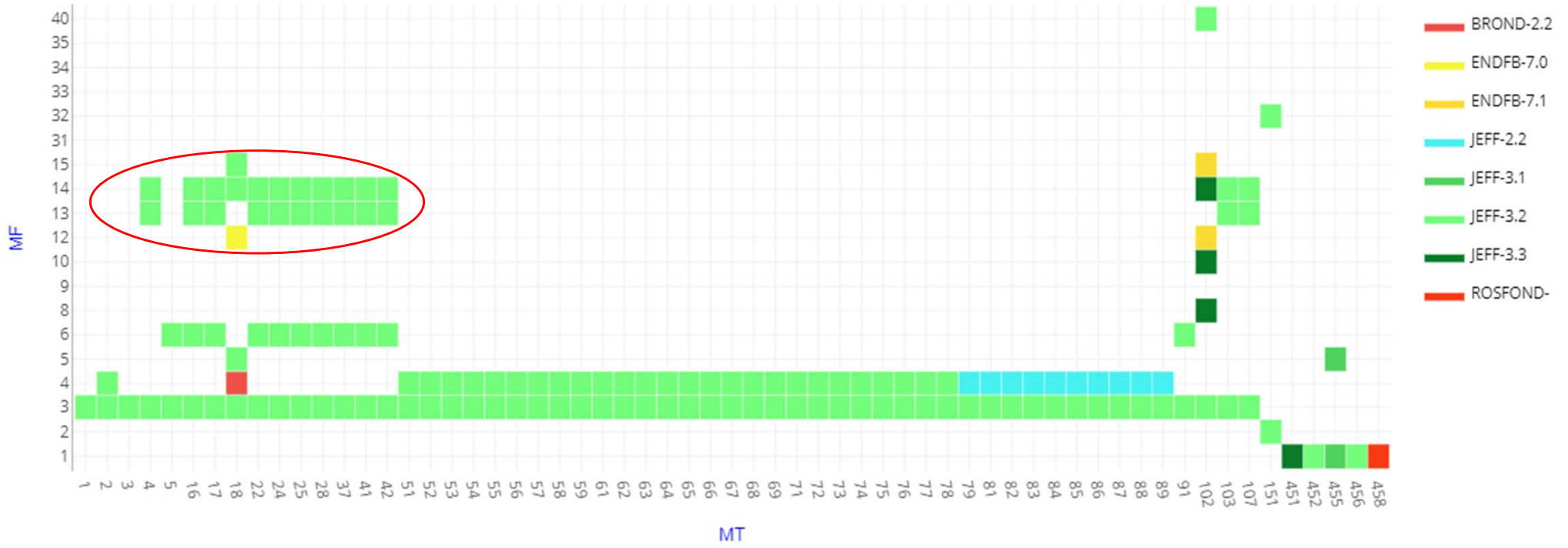
5.1 The origin of evaluated files

❑ The JEFF Mapping tool

Example: Explore the map of information of 95-AM-241g/JEFF-3.3

https://www.oecd-nea.org/dbdata/jeff/jeff33/Maps.html

Total MFs/MTs	**146**
Updated (changed from previous evaluations: JEFF-3.2)	**6**
New (included in ENDF/B-VII.1)	**2**
Unchanged	**138**
Erased (from JEFF-3.2)	**2**



- **This is very important to guaranty that legacy work is kept!! e.g. MF12/MF14 and MF15 in JEFF files**

5.1 The origin of evaluated files

❑ The UPM Mapping tool: JEFF-4T5

#	Evaluation/Date 28459 files
1	1991-01-CENDL-2
2	1991-01-JEFF-2.2
3	1992-01-BROND-2.2
4	1994-01-JENDL-3.2
5	2001-09-ENDFB6.8
6	2002-01-JEFF-3.0
7	2002-01-JENDL-3.3
8	2005-01-JEFF-3.1
9	2006-01-ENDFB7.0
10	2009-01-CENDL-3.1
11	2009-01-JEFF-3.1.1
12	2010-01-JENDL-4.0
13	2010-01-ROSFOND
14	2011-01-ENDFB7.1
15	2012-01-JEFF-3.1.2
16	2012-12-TENDL-2012
17	2014-01-JEFF-3.2
18	2014-12-TENDL-2014
19	2016-01-BROND-3.1
20	2016-01-JENDL-4.0u
21	2017-11-JEFF-3.3
22	2018-02-ENDFB-8.0
23	2018-03-TENDL-2017
24	2019-01-ENDFB-8.0T1
25	2019-12-TENDL-2019
26	2020-01-CENDL-3.2
27	2021-11-JENDL-5.0
28	2022-02-TENDL-2021
29	2023-01-JENDL-5.0T1
30	2023-12-TENDL-2023
31	2024-08-ENDFB81
32	2025-02-INDEN_LAST
33	2025-03-TENDL2025b

FULL New Evaluation without MFs/MTs of different evaluations

First appearance at …:	#	Examples:
2017-11-JEFF-3.3	1	2-he-3g.jeff4t5
2018-02-ENDFB-8.0	1	6-c-13g.jeff4t5
2025-03-TENDL2025b	**36**	**10-ne-20g.jeff4t5**
JEFF-4T5	**47**	**25-mn-52g.jeff4t5**
Total=	**85**	

MIX Evaluation with MFs/MTs of different evaluations

Last contributor …:	#	Examples:
2010-01-JENDL-4.0	3	97-bk-247g.jeff4t5
2011-01-ENDFB7.1	3	1-h-3g.jeff4t5
2014-01-JEFF-3.2	5	96-cm-240g.jeff4t5
2017-11-JEFF-3.3	12	11-na-23g.jeff4t5
2018-02-ENDFB-8.0	9	17-cl-35g.jeff4t5
2021-11-JENDL-5.0	15	1-h-1g.jeff4t5
2022-02-TENDL-2021	4	22-ti-44g.jeff4t5
2025-02-INDEN-LAST	7	24-cr-52g.jeff4t5
2025-03-TENDL2025b	**164**	**10-ne-21g.jeff4t5**
JEFF-4T5	**272**	**12-mg-24g.jeff4t5**
Total=	**494**	

FULL New Evaluation with a mix of MFs/MTs of different evaluations

First appearance at …:	#	Examples:
2017-11-JEFF-3.3	4	96-cm-242g.jeff4t5
2025-02-INDEN-LAST	1	25-mn-55g.jeff4t5
JEFF-4T5	**9**	**92-u-232g.jeff4t5**
Total=	**14**	
Total=	**593**	

5.2 User's updates for visualization: Processing into JANIS format...

- **Processing ENDF/B-VIII.1 into JANIS format:**
  - **HENDF + INTER + BOXER**

Figure 1. Flowchart of processing JANIS database from ENDF tapes

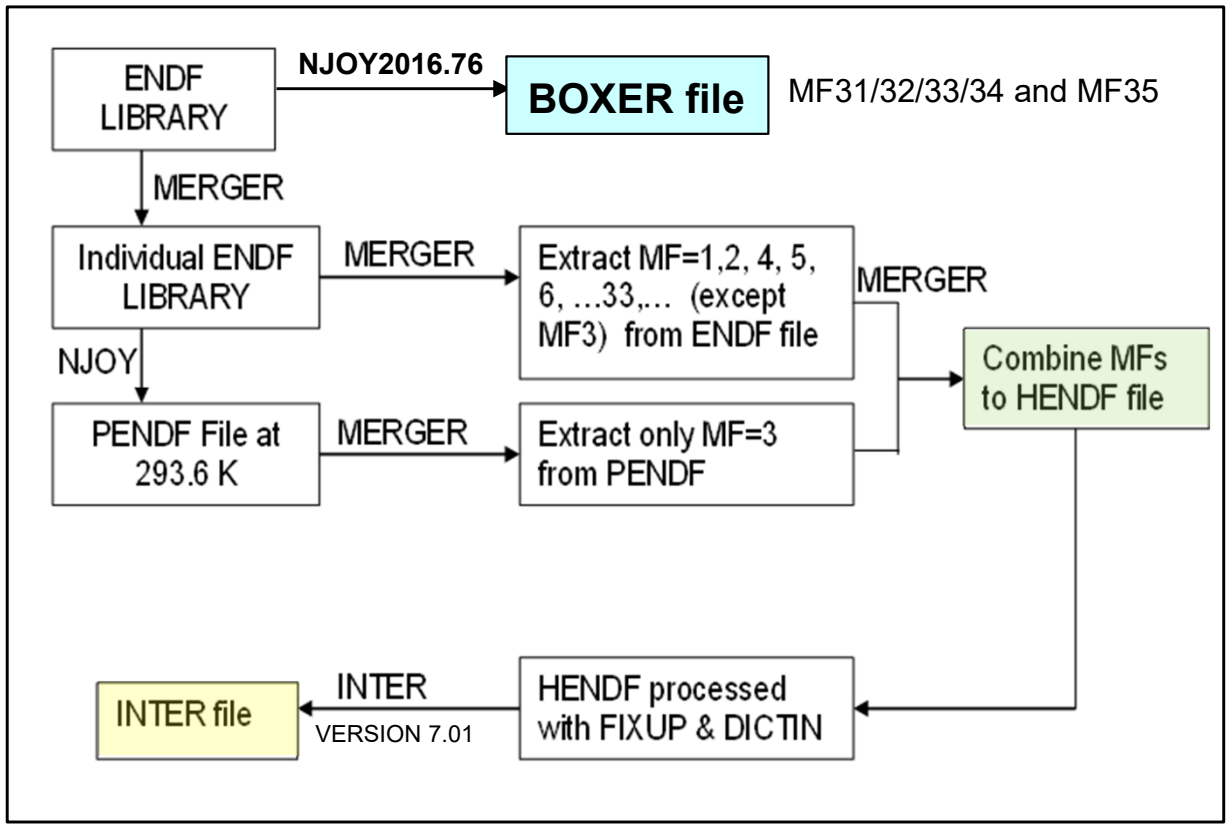


Figure 2. Example of input deck to process in PENDF format

```
moder /tape20 from MERGER                          tape20 = ENDF file
 20 -31                                            ==================
reconr /Reconstruct XS data
-31 -32
' PENDF tape          ' /
9437 2 /
.005 /
' MAT=pu239  ENDF Library:JENDL-5.0upd' /
' Processed NJOY2016-UPM,2023                '
0/
broadr /Doppler broaden XS
-31 -32 -33
9437 1 /
.005 /
 293.60
0/
thermr / Add thermal scattering data
 0 -33 -34
 0 9437 12 1 1 0 0 1 221 0
 293.60
0.005 10.0
unresr
-31 -34 -35
9437 1 1 0 /
 293.60
1.0e+10 /
0/
heatr / Add heating kerma and damage energy
-31 -35 -36 40/
   9437 7 0 0 0 2/
 302 303 304 318 401 403 407 /
heatr / Add heating kerma and damage energy
-31 -36 -37 41/
   9437 6 0 0 0 2 0 1/
 442 443 444 445 446 447 /
gaspr /Gas production
-31 -37 -38
moder
-38 26
 stop
```

5.3 User's updates for visualization: The JANIS Wizard tool

❑ Processing ND libraries into JANIS format:

- **JEFF-4T?, JENDL-5.0-upd, …**
- **ENDF/B-VIII.1**
  - Logs reported when importing JANIS database

- HENDF: Hybrid format ENDF+PENDF **including KERMA and DAMAGE cross-sections**
- INTER
- BOXER: covariances **MF31, MF32/MF33, MF34 and MF35**

Download at the following links – "UN-OFFICIAL JANIS Databases":

ENDF/B-VIII.1 with BOXER in 33g: **https://drive.upm.es/s/mzGbRoZt5CBw20G**
password: janis

"Readme.txt" file, it explains how to download and import the database in JANIS

❑ Import WIZARD tool: Use the "Database > Import Wizard"

Steps:
- Use "JANIS toolbar -> Database –> Load" function
- Set ".h2.db file" to select the downloaded "h2.db" file
- Set "Root Folder" to the folder where the "h2.fb" is located

(Leave the other default options are they are)

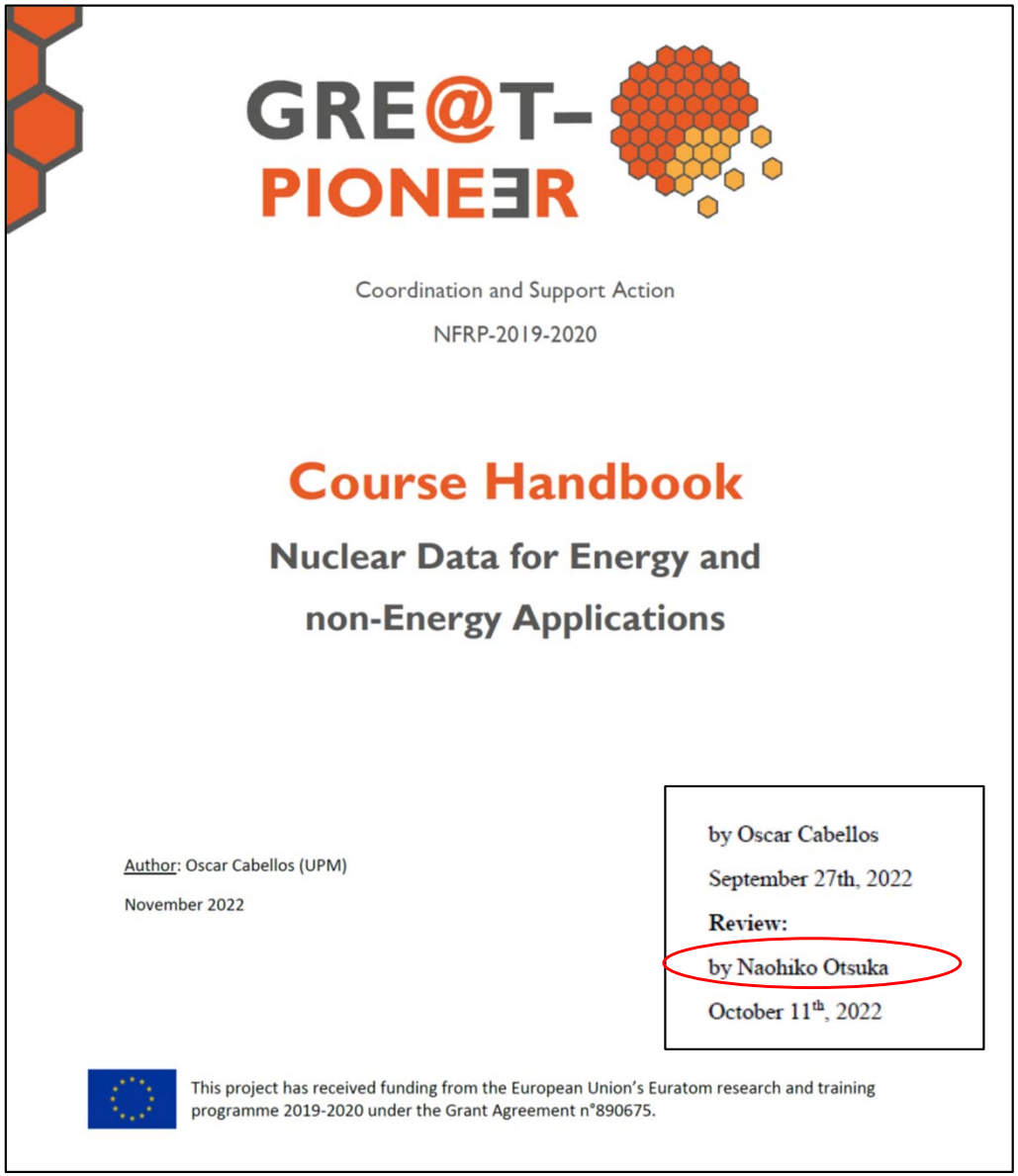
6. Dissemination and training

6.1The EU/Gre@tPionner Project

6.2 The UPM/INGENIA - CDIO Course

6.1 Dissemination and training:

The EU/Gre@tPionner course (https://great-pioneer.eu/)


GRE@T–
PIONEER

Coordination and Support Action

NFRP-2019-2020

Course Handbook

Nuclear Data for Energy and non-Energy Applications

Author: Oscar Cabellos (UPM)

November 2022

by Oscar Cabellos

September 27th, 2022

Review:

by Naohiko Otsuka

October 11th, 2022

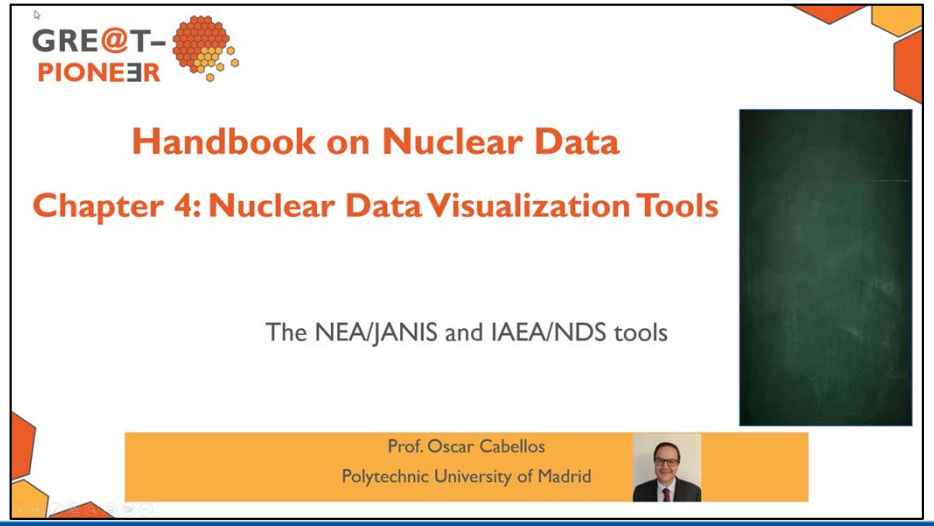
This project has received funding from the European Union's Euratom research and training programme 2019-2020 under the Grant Agreement n°890675.

Handbook on ND – Content

- Chapter 1: Nuclear Data for Nuclear Applications (pp.1-70)
- Chapter 2: The Experimental Nuclear Data (pp.1-43)
- Chapter 3: Evaluated Data Libraries (pp. 1-55)
- Chapter 4: Nuclear Data Visualization Tools (pp.1-24)
- Chapter 5: Tools for Processing Nuclear Data (pp.1-84)
- Chapter 6: Benchmarking and Validation (pp.1-35)
- Chapter 7: Sensitivity Analysis and Uncertainty Quantification (pp. 1-27)
- Chapter 8: Nuclear Data Adjustment Methodologies (pp. 1-21)
- Chapter 9: Nuclear data needs (pp. 1-16)
- Chapter 10: Overview of International Organizations (pp.1-13)

Quizzes/tests/videos + exercises

Methodology: Active Learning + Flipped Classes + Hybrid – onsite/online (3 ECTS – 30h + 30h)



6.1 Dissemination and training:

The EU/Gre@tPionner course (https://great-pioneer.eu/)

Next GRE@T-PIONEeR course on
"Nuclear data for energy and non-energy applications"

See info at: https://great-pioneer.eu/

Registration is open till June 29th, 2025 !!

A total of 10 ENEN2+ mobility grants available

- **Asynchronous sessions between August 8 - September 7, 2025**
- **Synchronous course Chalmers University (Sweden)- September 8-12, 2025**

Web https://great-pioneer.eu/

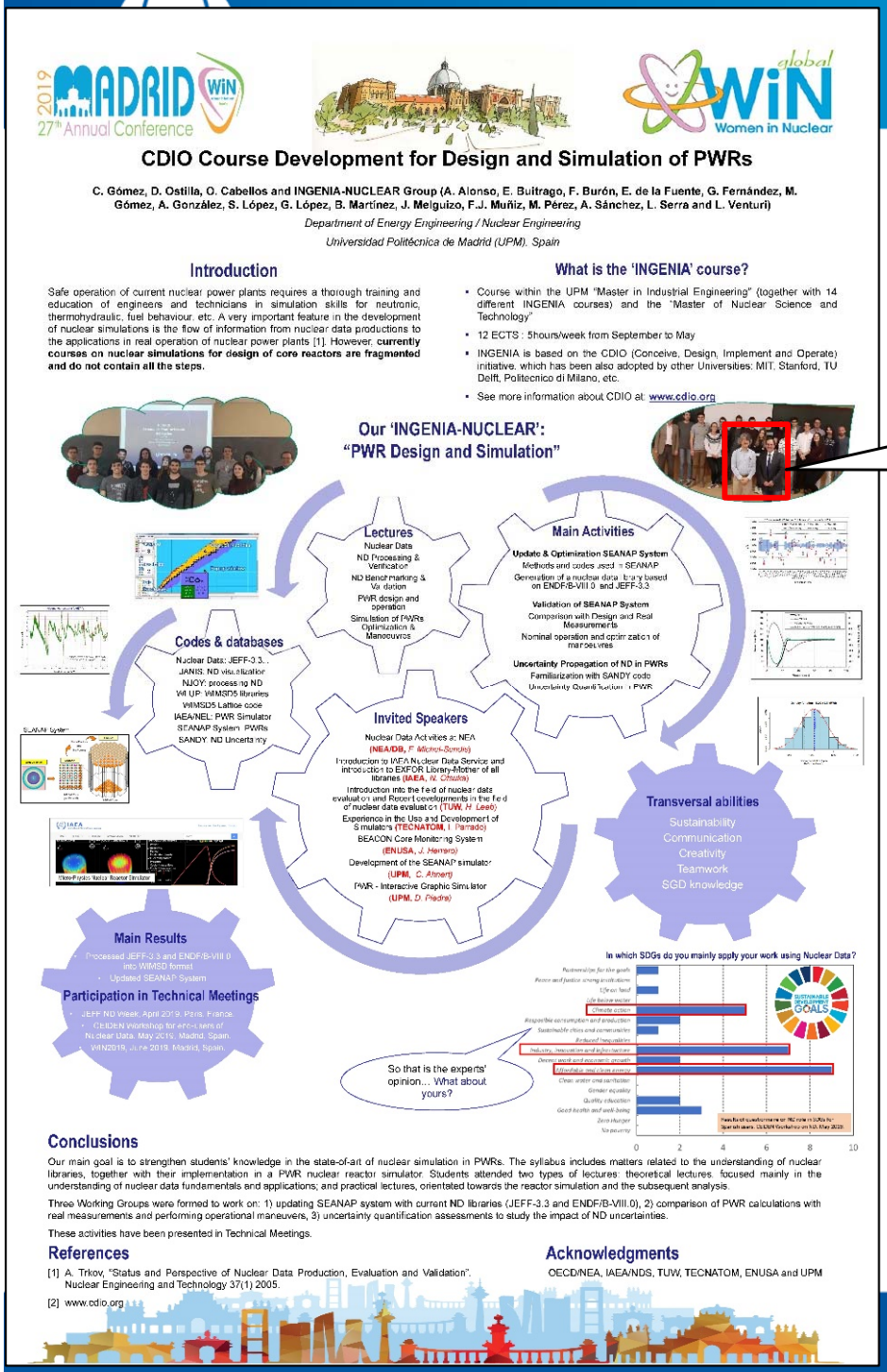
@GREATPIONEeR_EU

@GREAT-PIONEER

GRE@T-PIONEER

6.2 Dissemination and training:

"INGENIA/NUCLEAR" at the UPM since 2018



2019 MADRID WiN 27th Annual Conference

global WiN Women in Nuclear

CDIO Course Development for Design and Simulation of PWRs

C. Gómez, D. Ostilla, O. Cabellos and INGENIA-NUCLEAR Group (A. Alonso, E. Bultrago, F. Burón, E. de la Fuente, G. Fernández, M. Gómez, A. González, S. López, G. López, B. Martínez, J. Melguizo, F.J. Muñiz, M. Pérez, A. Sánchez, L. Serra and L. Venturi)

Department of Energy Engineering / Nuclear Engineering

Universidad Politécnica de Madrid (UPM). Spain

Introduction

Safe operation of current nuclear power plants requires a thorough training and education of engineers and technicians in simulation skills for neutronic, thermohydraulic, fuel behaviour, etc. A very important feature in the development of nuclear simulations is the flow of information from nuclear data productions to the applications in real operation of nuclear power plants [1]. However, **currently courses on nuclear simulations for design of core reactors are fragmented and do not contain all the steps.**

What is the 'INGENIA' course?

- Course within the UPM "Master in Industrial Engineering" (together with 14 different INGENIA courses) and the "Master of Nuclear Science and Technology"
- 12 ECTS : 5hours/week from September to May
- INGENIA is based on the CDIO (Conceive, Design, Implement and Operate) initiative, which has been also adopted by other Universities: MIT, Stanford, TU Delft, Politecnico di Milano, etc.
- See more information about CDIO at: www.cdio.org

Our 'INGENIA-NUCLEAR': "PWR Design and Simulation"

Lectures
Nuclear Data
ND Processing & Verification
ND Benchmarking & Validation
PWR design and operation
Simulation of PWRs Optimization & Manoeuvres

Main Activities
Update & Optimization SEANAP System
Methods and codes used in SEANAP
Generation of a nuclear data library based on ENDF/B-VIII.0 and JEFF-3.3
Validation of SEANAP System
Comparison with Design and Real Measurements
Nominal operation and optimization of manoeuvres
Uncertainty Propagation of ND in PWRs
Familiarization with SANDY code
Uncertainty Quantification in PWR

Codes & databases
Nuclear Data: JEFF-3.3...
JANIS: ND visualization
NJOY: processing ND
WIMS-D: WIMSD5 libraries
WIMSD5: Lattice code
IAEA/NEL: PWR Simulator
SEANAP System: PWRs
SANDY: ND Uncertainty

Invited Speakers
Nuclear Data Activities at NEA (NEA/DB, F. Michel-Sendis)
Introduction to IAEA Nuclear Data Service and introduction to EXFOR Library-Mother of all libraries (IAEA, N. Otsuka)
Introduction into the field of nuclear data evaluation and Recent developments in the field of nuclear data evaluation (TUW, H. Leeb)
Experience in the Use and Development of Simulators (TECNATOM, I. Ferrado)
BEACON Core Monitoring System (ENUSA, J. Herrero)
Development of the SEANAP simulator (UPM, C. Ahnert)
PWR - Interactive Graphic Simulator (UPM, D. Piedra)

Transversal abilities
Sustainability
Communication
Creativity
Teamwork
SGD knowledge

Main Results
- Processed JEFF-3.3 and ENDF/B-VIII.0 into WIMSD format
- Updated SEANAP System

Participation in Technical Meetings
- JEFF ND Week, April 2019, Paris, France.
- CIEMEN Workshop for experts of Nuclear Data, May 2019, Madrid, Spain.
- WIN2019, June 2019, Madrid, Spain.

Conclusions

Our main goal is to strengthen students' knowledge in the state-of-art of nuclear simulation in PWRs. The syllabus includes matters related to the understanding of nuclear libraries, together with their implementation in a PWR nuclear reactor simulator. Students attended two types of lectures: theoretical lectures focused mainly in the understanding of nuclear data fundamentals and applications; and practical lectures, orientated towards the reactor simulation and the subsequent analysis.

Three Working Groups were formed to work on: 1) updating SEANAP system with current ND libraries (JEFF-3.3 and ENDF/B-VIII.0), 2) comparison of PWR calculations with real measurements and performing operational maneuvers, 3) uncertainty quantification assessments to study the impact of ND uncertainties.

These activities have been presented in Technical Meetings.

References

[1] A. Trkov, "Status and Perspective of Nuclear Data Production, Evaluation and Validation", Nuclear Engineering and Technology 37(1) 2005.

[2] www.cdio.org

Acknowledgments

OECD/NEA, IAEA/NDS, TUW, TECNATOM, ENUSA and UPM

Methodology: CDIO – Conceive + Design + Implement + Operate (https://cdio.org/)

12 ECTS - 5h/week – 2 semesters

TOPICS "… from nuclear data to nuclear applications"

2018-2019: Design and simulations of PWRs

2019-2020: … ATFs

2020-2021: … ML

2021-2022: … SMRs

2022-2023: … Nuclear Data – P&V – B&V

2023-2024: … Space Applications

2024-2025: …Medical Applications

2025-2026: …Medical Applications

7. Conclusion

My Christmas/Summer wishes for the nuclear data community…

- **The "manipulation" of ENDF data**
  - **ENDFtk** (see Haeck's talk)
  - **ENDFparser_py** (see Schnabel's talk)
  - **FRENDY** (see Tada-san's talk)
  - T. Kawano, **DeCE**: the ENDF-6 data interface and nuclear data evaluation assist code, Journal of Nuclear Science 439 and Technology 56 (2019) 1029–1035. doi:10.1080/00223131.2019.1637797
    - facilitates all ENDF-6 data file manipulations, for example, add two data sections, renormalize data, add/delete data point,
    - convert model calculation results into ENDF-6 format,
    - reconstruct pointwise cross sections from resonance parameters,
    - convert ENDF-6 formatted data file into more human friendly format.

    https://github.com/toshihikokawano/DeCE

- **Would we be able in a short-term playing as Evaluators to create "Frankenstein" files? with no–errors merging different data?**

My Christmas/Summer wishes for the nuclear data community…

- **The "compilation" of EXFOR data**
  - **Would we be able in a short-term playing as EXFOR's consultant to create "EXFOR" files? with no–errors and/or lack of crucial experimental information? NO**

EXFOR compilation of thermal neutron scattering data

Consultants' Meeting, November 2015

- The purpose of the meeting is to discuss the key characteristic of the thermal neutron scattering measurement and evaluation techniques to provide **guidelines for compilation** of such data in the EXFOR data library.

EXFOR Data in Resonance Region and Spectrometers' Response Function

Consultants' Meeting, October 2013

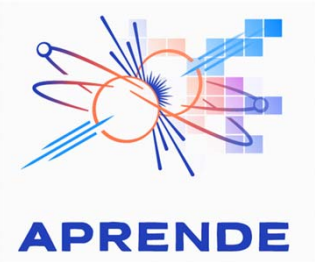
- **Prepare templates** that include the information required to be compiled in EXFOR and submit such information for different type of experiments and facilities based on the developed templates

"In an idyllic world any experimentalist could be an EXFOR compiler (at least with a 90% of the entry file completed with default templates)." O. Cabellos, Nov. 13th, 2024.

… in practice very very few experimentalists are doing it… how to increase these numbers?...

Acknowledgments

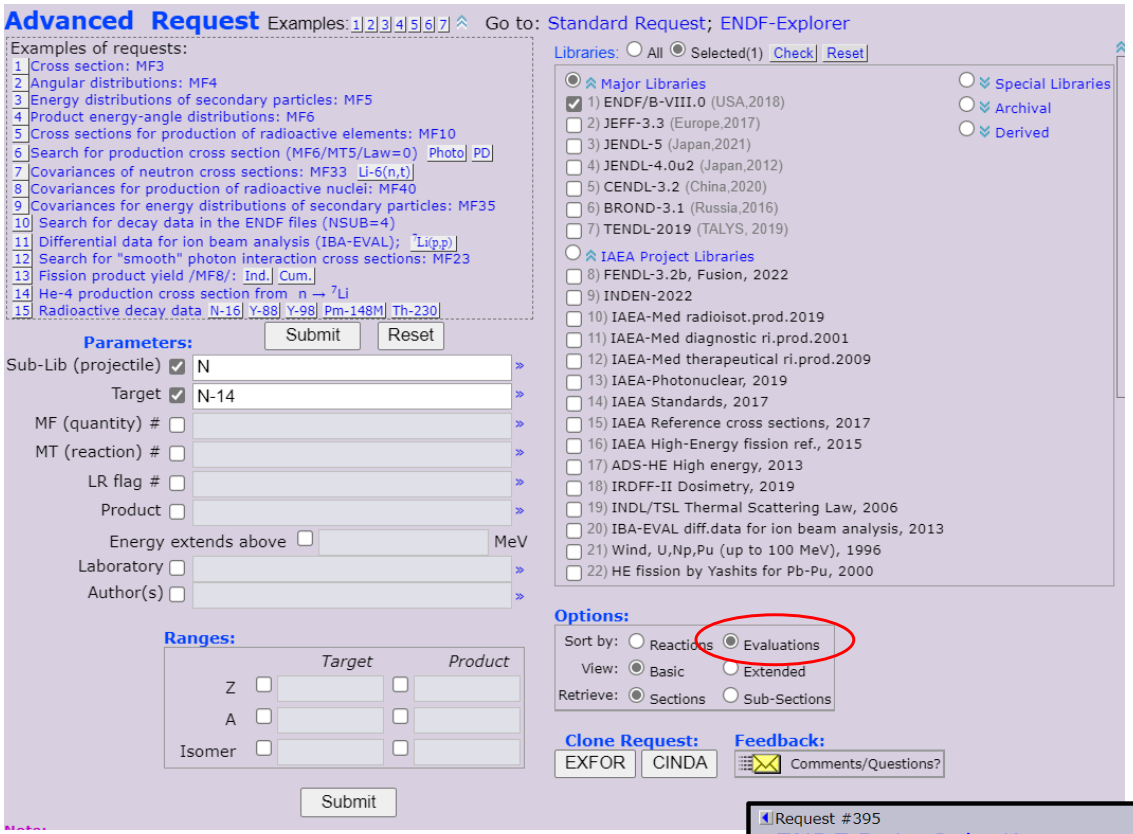
*This work is part of the APRENDE project (**A**ddressing **PR**iorities of **E**valuated **N**uclear **D**ata in **E**urope) that has received funding from the European Union's HORIZON-EURATOM under grant agreement No. 101164596*



Back-up Slides

1. Databases: -> Searching data in different formats?"

Q/A: Explore the different formats of the evaluated. Download libraries in different formats with: https://www-nds.iaea.org/exfor/endf.htm .How many formats do you find?

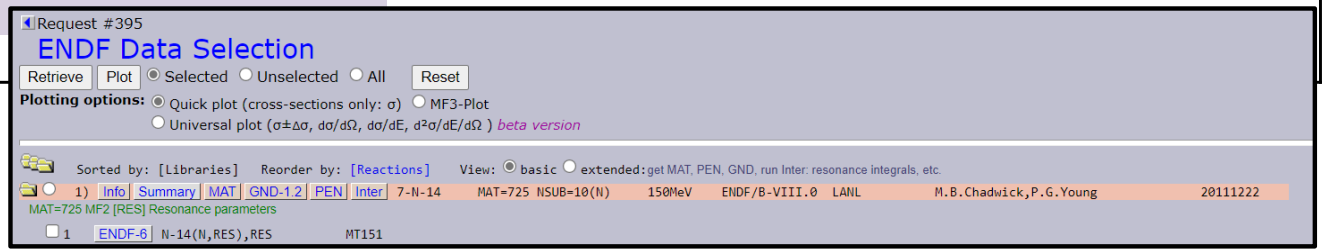


Downloaded formats….

- MAT is **ENDF-6** format - original
- **GNDS format**
- **PENDF** is pointwise at 293.16K
- **INTER** is output of INTER code

…

- JSON format
- Plot
- Tabulated – 293K



- **USERs may find different sources of data (formats) in different retrieval systems**

3. Formats

3.1 Visualization tools able to read/transform formats

- ACE files: **ACELST** - Summarize contents of ACE file and convert into PENDF
  https://www-nds.iaea.org/index-meeting-crp/CM_Data_Processing_2015/codes/acelst.for
  - **How to use it? Use FRENDY -> perturbation/random n-ACE files -> run n-ACELST to create n-PENDF/WIMSD -> run "n-Burnup" WIMSD5 cases to assess sensitivity/uncertainty in reactivity loss.**
- WIMSD/E: XnWlup within WLUP project: https://www-nds.iaea.org/wimsd/download/XnWlup.zip

3.2 Visualization of other Evaluated data

- GNDS ⇔ ENDL (LLNL) → ENDF6

3.3 Full visualization of the evaluation

- Visualization of MF32 (identify issue in MF32/Cu63 –ENDF/B-VIII.1?), MF34

3.4 Checking formats, anomalous values, etc… on-the-fly

- CHECKR, FIZCON,…. MODER …How to interpret warnings/errors? Logs in JANIS?
- Checking processed covariances: definite positive, very high values, etc…

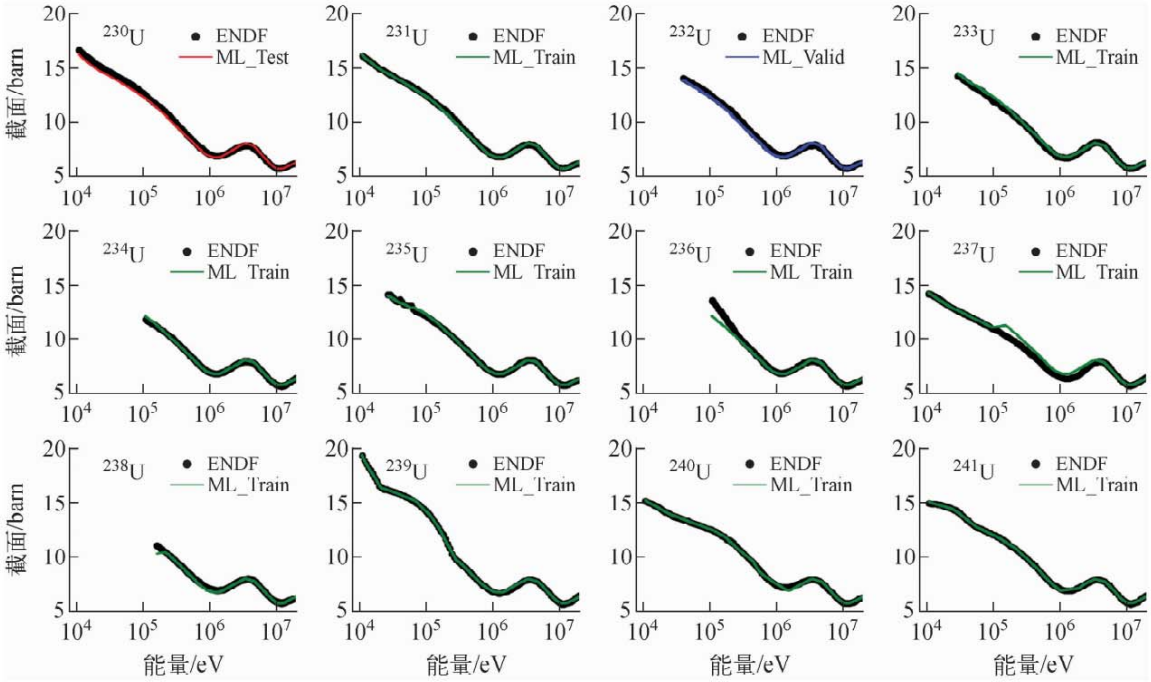
4.2. ML: ND Models – nuclear reactions models

Ref.: HU Zehua et al. , *"Learning Fast Neutron Cross Section by Deep Neural Network"*, Atomic Energy Science and Technology, 2023, Vol. 57 ›› Issue (4): 812-817.

Technique: Deep neural networks

Objective: Evaluation Uranium files

Results: New U evaluations in the fast energy range



- Features assessed in the model
  - A, Z
  - ENDF data at energy E
  - Sn
  - **Others ?**

- **Can we find this info in current ND Databases?**
  - ^{230}U is used as test
  - ^{232}U is used for verification
  - other 10 U nuclides are used as training data

Figure 7. Calculation results, total cross-sections for U

4.2. ML: ND Models – nuclear reactions models

Ref.: X. Sun et al. , *"Study of (n,2n) Reaction Cross Section of Fission Product based on Neural Network and Decision Tree Models"*, WONDER 2023, June 5-9, 2023

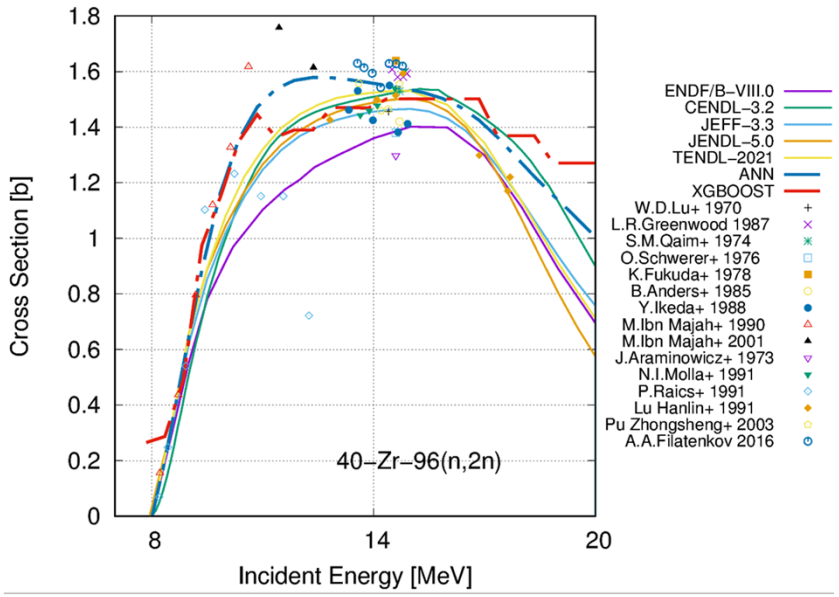
Technique: Artificial neural network (ANN) and decision tree (DT) models

Objective: To predict the (n,2n) reaction cross section, especially those lack of experimental measurements

- Importance of features assessed
  - Z, A
  - Sn and Sp
  - Shell P-Casten factor, the level density
  - the pairing correction, and the incident energy

- **Can we find this info in current ND Databases?**

Figure 8. Cross-section ^{96}Zr(n,2n)



- **Results:** $\sigma_{(n,2n)}$ = f(incident neutron energy)

"The ML model can predict the nuclear reaction cross section of a large number of nuclei without the requirement for manual and careful parameter optimization."