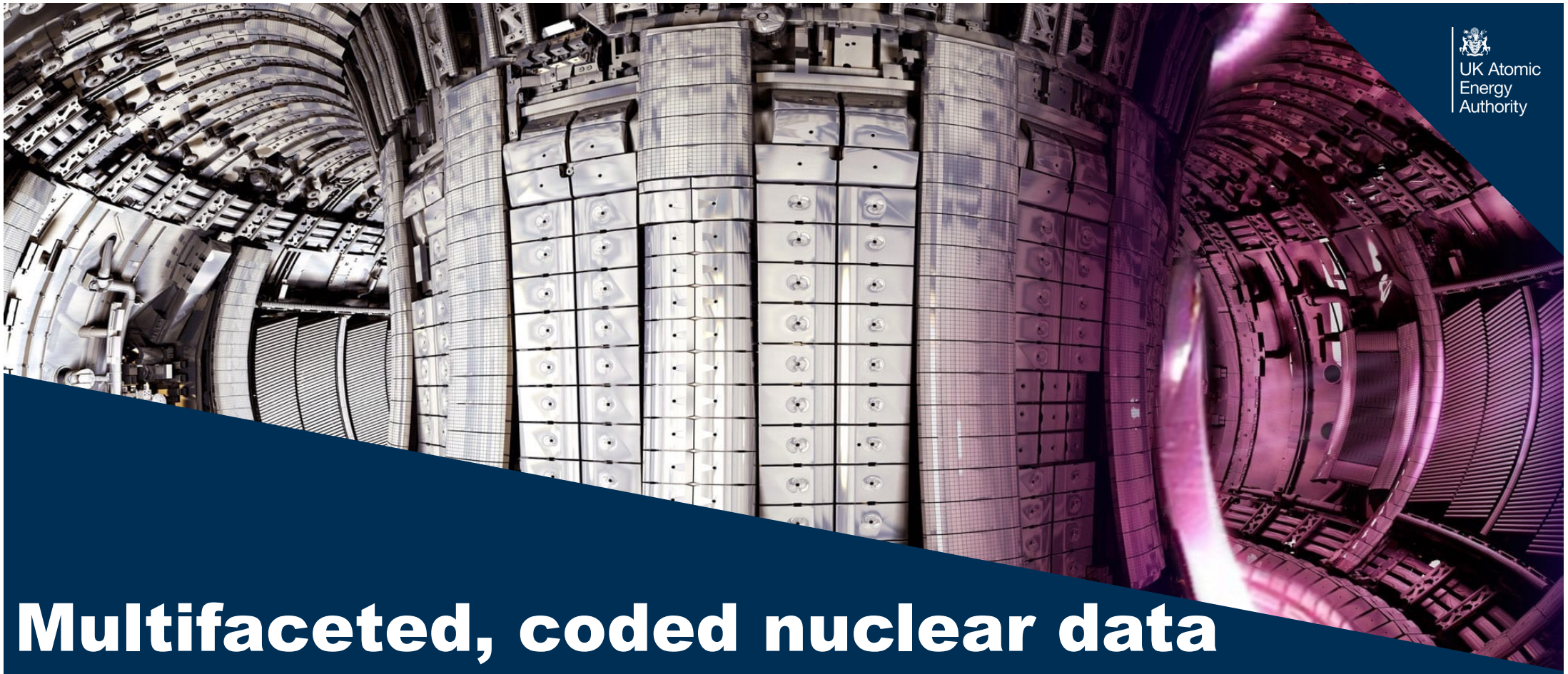

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Multifaceted, coded nuclear data libraries assemblage: TENDL-2023

Jean-Christophe Sublet[1], Arjan Koning[2] and Dimitri Rochman[3]

[1]UKAEA, [2]IAEA, [3]PSI

The making of TENDL-2023 – repeatability and innovation

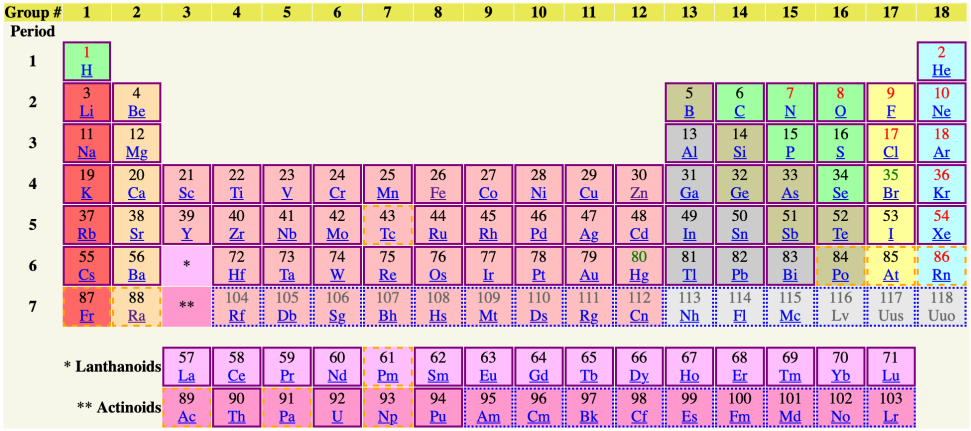
UK Atomic Energy Authority

7 incident particles: alpha, gamma, deuteron, proton, helium, triton and neutron induced libraries

2850 targets Z=1-115, Hydrogen to Moscovium, **including as target some 519 m (1st), 29 n (2nd) isomeric states (T½ > 1s)**

TENDL describes all open reaction channels, product yields, emitted spectra, and short-lived daughter radionuclides (T½ > 0.1s) up to 200 MeV, with covariance derived from **reference input parameters variation**

12th version



Nuclear landscape: Isotopic targets: 2850

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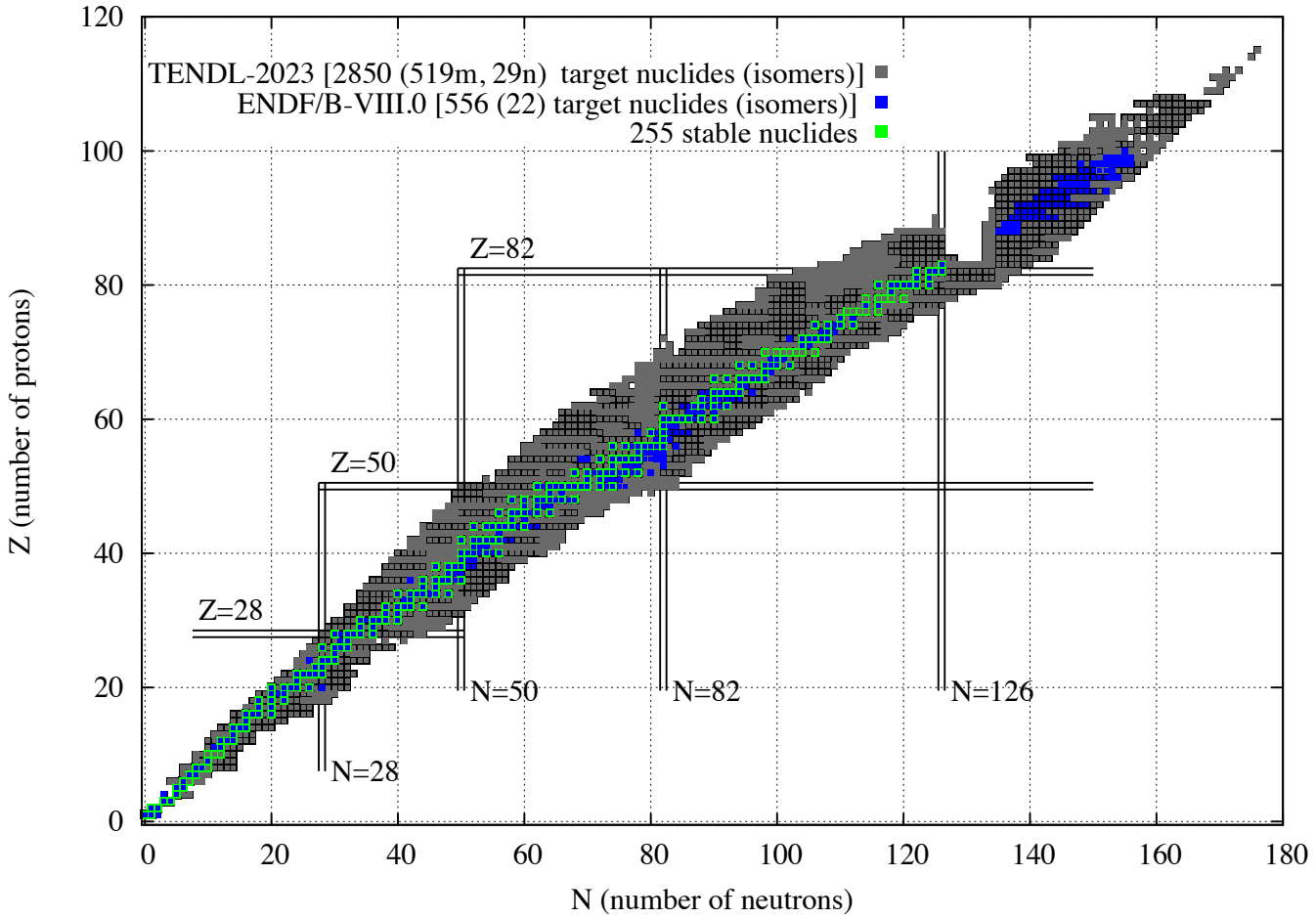
7 incident particles

- neutron*
- gamma
- proton
- deuteron
- triton
- alpha
- helion

*complete for transport, activation-transmutation-material sciences in term of MF's, targets and daughters

795 for n-JENDL-5
816 for EAF-2010
~550 for n-ENDF/B, JEFF, and CENDL



Nuclear landscape: Isotopic residuals & decays

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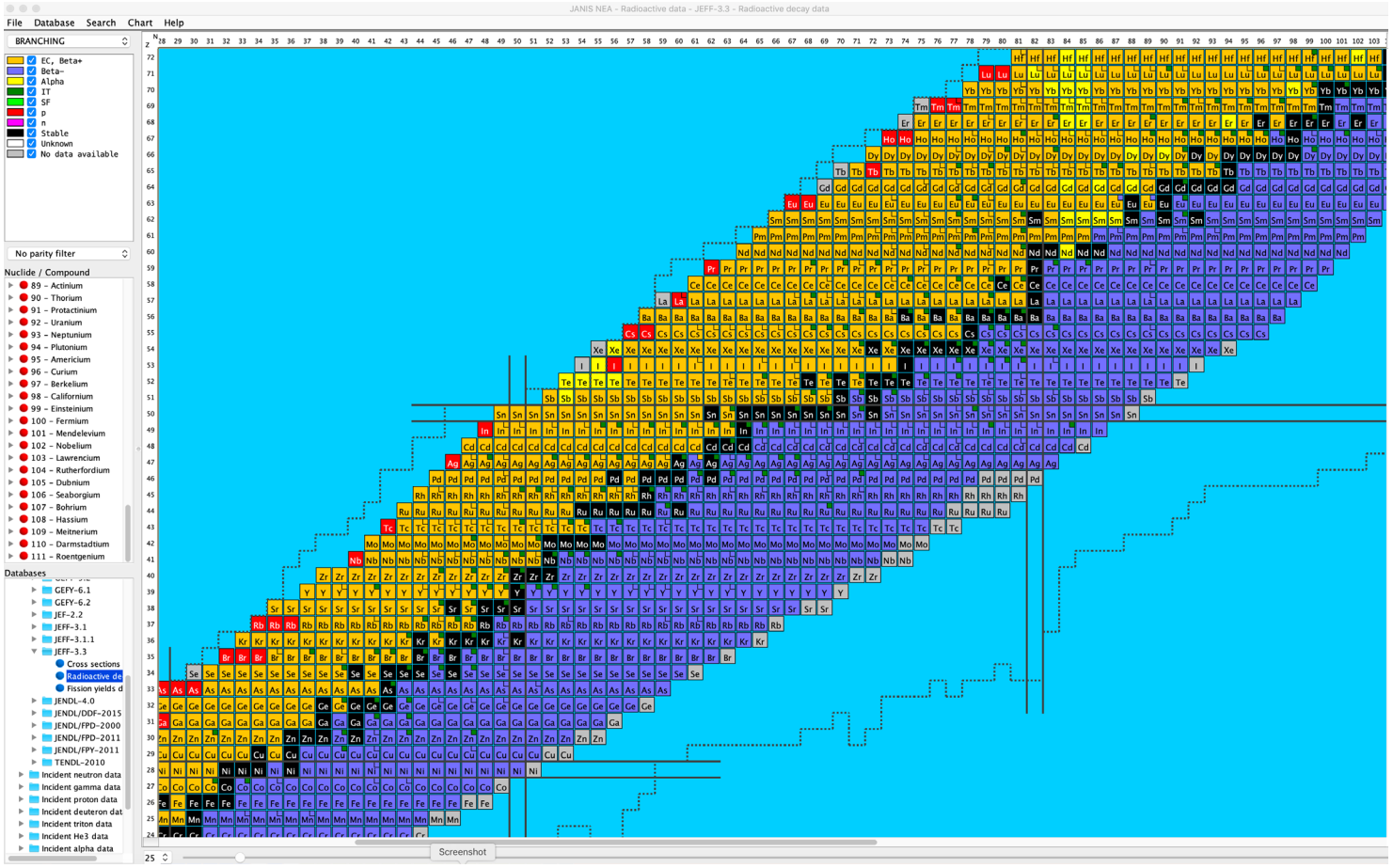
Radioactive decay products: 4035 “reaction daughters” or “residuals”

Ground and isomeric daughters: ($T_{½}$ > 0.1s)

Decay data files are not a part of TENDL

but

MF-8 contains the metastable Elevel from RIPL-4



Portal https://tendl.web.psi.ch/tendl_2023/tendl2023.html

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ENDF-6: explicit s30
GNDS
Special: 600 MeV
Tabular forms
Astrophysics

TENDL-astro 2023

Cross sections, reaction rates and MACS for astrophysics

Recommended quantities

Cross sections

1. (n,g) (n,p), (n,a),
2. (p,g) (p,n), (p,a),
3. (a,g) (a,n), (a,p),

Reaction rates

1. (n,g) (n,p), (n,a),
2. (p,g) (p,n), (p,a),
3. (a,g) (a,n), (a,p),

Normalized partition function G(T)

30 keV Laboratory Maxwellian Averaged (n,g) Cross Sections MACS

Description of TALYS models

Below are various links to 8892 isotopes for astrophysics applications (cross sections, reaction rates and MACS) based on TALYS calculations (version 1.96).

Different reaction "model sets" were used: "a model set" represents a combination of 9 TALYS models:

1. Gamma strength function (values 8 or 9): either Gogny D1M HFB+QRPA, or SMLO
2. Level density (values 1, 2 or 5): Constant temperature + Fermi gas model, or Back-shifted Fermi gas model, or Microscopic level densities (Skyrme force)
3. JLM microscopic optical model potential or KD optical model (values y or n)
4. Gamma strength function for M1 (values 3 or 8): Hartree-Fock BCS tables or Gogny D1M HFB+QRPA
5. Collective enhancement (values y or n): yes or no
6. Width fluctuation (values 0, 1 or 2): Moldauer model, or Hofmann-Richert-Tepel-Weidenmueller model
7. Mass model (values 0, 1, 2 or 3): Duflo-Zuker formula, Moeller table, Goriely HFB-Skyrme table, or HFB-Gogny D1M table (except for known masses, w used)
8. Alpha optical model (values 5 or 6): Demetriou/Goriely, or Avrigeanu
9. Fission model (values 1 or 5): "experimental" fission barriers, or WKB approximation for fission path model.

Each of the set models is named with 9 values, such as "91n3n1261" (default TALYS model), or 85n8n1261. These values correspond to the ones in the TALYS i

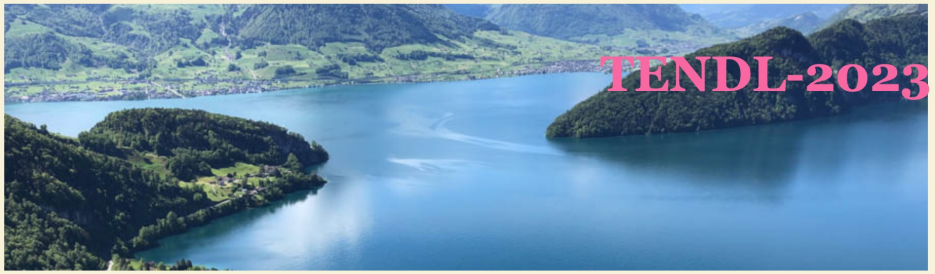
Application libraries & tar

Last update: 21 December 2023

1. Neutron
   - -- 2850 ENDF files (s30 files, 2.9 Gb, with H1, H2, H3, He3, He4, Li6, Li7, B10, B11, Be7, Be9, C12, C13, N14, N15, O16, O17, O18, F19, Th232, U233, U235, U238 and Pu239 from ENDF/B-VIII.0
   - -- 2864 special 600 MeV ENDF files (3.9 Gb),
   - -- 2841 special s60 ENDF files (6.1 Gb),
2. Proton
   - -- 2855 ENDF files (s30 files, 2.0 Gb with H1, H2, H3, He3, He4, Li6, Li7, Be9, C12, C13, N14 and O16 from ENDF/B-VIII.0),
   - -- 2850 special s0 ENDF files (1.1 Gb),
   - -- 2850 special 600 MeV ENDF files (5.3 Gb),
3. Deuteron
   - -- 2850 ENDF files (s30 files, 2.7 Gb with H2, H3, He3, Li6, Li7 from ENDF/B-VIII.0),
   - -- 2860 special s0 ENDF files (1.3 Gb),
   - -- 2846 special 600 MeV ENDF files (7.5 Gb),
4. Triton
   - -- 2865 ENDF files (s30 files, 2.3 Gb, with H3, He3 and Li6 from ENDF/B-VIII.0),
   - -- 2860 special s0 ENDF files (1.3 Gb),
   - -- 2850 special 600 MeV ENDF files (6.7 Gb),
5. He3
   - -- 2821 ENDF files (s30 files, 2.4 Gb, with He3 and Li6 from ENDF/B-VIII.0),
   - -- 2820 special s0 ENDF files (1.2 Gb),
   - -- 2848 special 600 MeV ENDF files (6.2 Gb),
6. Alpha
   - -- 2835 ENDF files (s30 files, 1.4 Gb),
   - -- 2855 special s0 ENDF files (1.0 Gb),
   - -- 2850 special 600 MeV ENDF files (2.0 Gb),
7. Gamma
   - --- 2825 ENDF files (s30 files, 1.4 Gb, with H2 from ENDF/B-VIII.0),
   - --- 2864 special s0 ENDF files (1.0 Gb),
   - --- 2526 special 600 MeV ENDF files (3.3 Gb),

TALYS-based evaluated nuclear data library

Home | Reference & us | Citations | Feedback | TALYS



"We believe that our great goal can be achieved with systematism and reproducibility. We are so outside the box, that the box is a point"

How to reference

Sub-library files

1. Neutron
2. Proton
3. Deuteron
4. Triton
5. He3
6. Alpha
7. Gamma
8. Fission yields
9. Thermal scattering
10. For astrophysics

Application libraries & tar files (ENDF, GND, ACE, PENDF...)

V&V

Total Monte Carlo files

3. Random ENDF-6 files from other libraries
4. Random ACE files based on ENDF/B-VII.1

TENDL-2023: (release date: December 22, 2023)

Last update: December 21, 2023

TENDL is a nuclear data library which provides the output of the **TALYS** nuclear model code system for direct use in both basic physics and applications. The 12th version is **TENDL-2023**, which is based on both default and adjusted **TALYS** calculations and data from other sources (previous releases can be found here: 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2017, 2019 and 2021).

Up to 2014, TENDL was produced at NRG Petten. Since 2015, TENDL is mainly developped at PSI and the IAEA (Nuclear Data Section). Still, many people contribute to TENDL with the testing and processing of the files.

TENDL contains evaluations for seven types of incident particles, for all isotopes living longer than 1 second: Z=1 ^{1}H to Z=115 ^{291}Mc (about 2850 isotopes), up to 200 MeV, with covariances (test files up to 600 MeV are also provided).

TENDL is **not** a default or shadow library. Not a single neutron evaluation is based on default calculations. With the HFR approach, all resonances follow statistical hypothesis. For major isotopes, greater care was used during the evaluation process.

All TENDL-2023 neutron files are original except 24. The 24 following files are taken from ENDF/B-VIII.0 for neutrons: ^{1,2,3}H, ^{3,4}He, ^{6,7}Li, ^{10,11}B, ^{7,9}Be, ^{12,13}C, ^{14,15}N, ^{16,17,18}O, ^{19}F, ^{232}Th, ^{233,235,238}U and ^{239}Pu.

A set of tools, called T6, was used to produce it. T6 stands for TALYS, TEFAL, TASMAN, TARES, TAFIS and TANES. Each code produces a part of the library. Processing tools such as NJOY, CALENDF, PREPRO are also used in T6. These codes, and the processing steps are developed by A.J. Koning, D. Rochman and J.Ch. Sublet. Still, the help and feedback of the whole nuclear data, processing and user community is extremely useful. TENDL would not exist without the constructive remarks from all over the world.

Portal https://tendl.web.psi.ch/tendl2023/tendl2023.html

UK Atomic Energy Authority

Tabular forms

YANDF-0.2

Angle, xs direct and compound

Special: 600 MeV

6 ENDF forms

Processed plots

TENDL-2023 Nuclear data library

Neutron sub-library for C (Z=6) and A=11

Tabulated data (fast neutron range)

1. Tabular angular distributions (En - angle - cross section)
2. Tabular residual cross sections (En - Residual product - cross section)
3. Tabular total and partial cross sections (En - cross section)

Evaluated formatted data (i.e. ENDF)

1. The TENDL file
2. Special ENDF file with MF12/MT102 (so-called s20 file)
3. Special ENDF file similar to the TENDL file, but with a transition to MT5 at 60 MeV (so-called s60 file)
4. Special file (= the TENDL file, but up to 600 MeV)
5. EAF file (European Activation File) and associated covariances
6. ACF file (Activation File)

Processed plots

1. Plots of the cross sections and other quantities: plot
2. Plots from PREPRO: plot
3. Processed cross sections and covariances with NJOY in 187 groups: matrix

T6 input files

acf.inp	acf.inp_cov	eaf.inp	eaf.inp_cov	energies	gpf.inp	gpf.inp_cov	gpfs20.inp
gpfs20.inp_cov	gpfs60.inp	gpfs60.inp_cov	njoy.inp	talys.inp	talys.inp.0000	talys.inp.0001	talys.inp.0002
talys.inp.0003	talys.inp.9999	tasman.inp					

TALYS 2.0 & 1.97 https://nds.iaea.org/talys/

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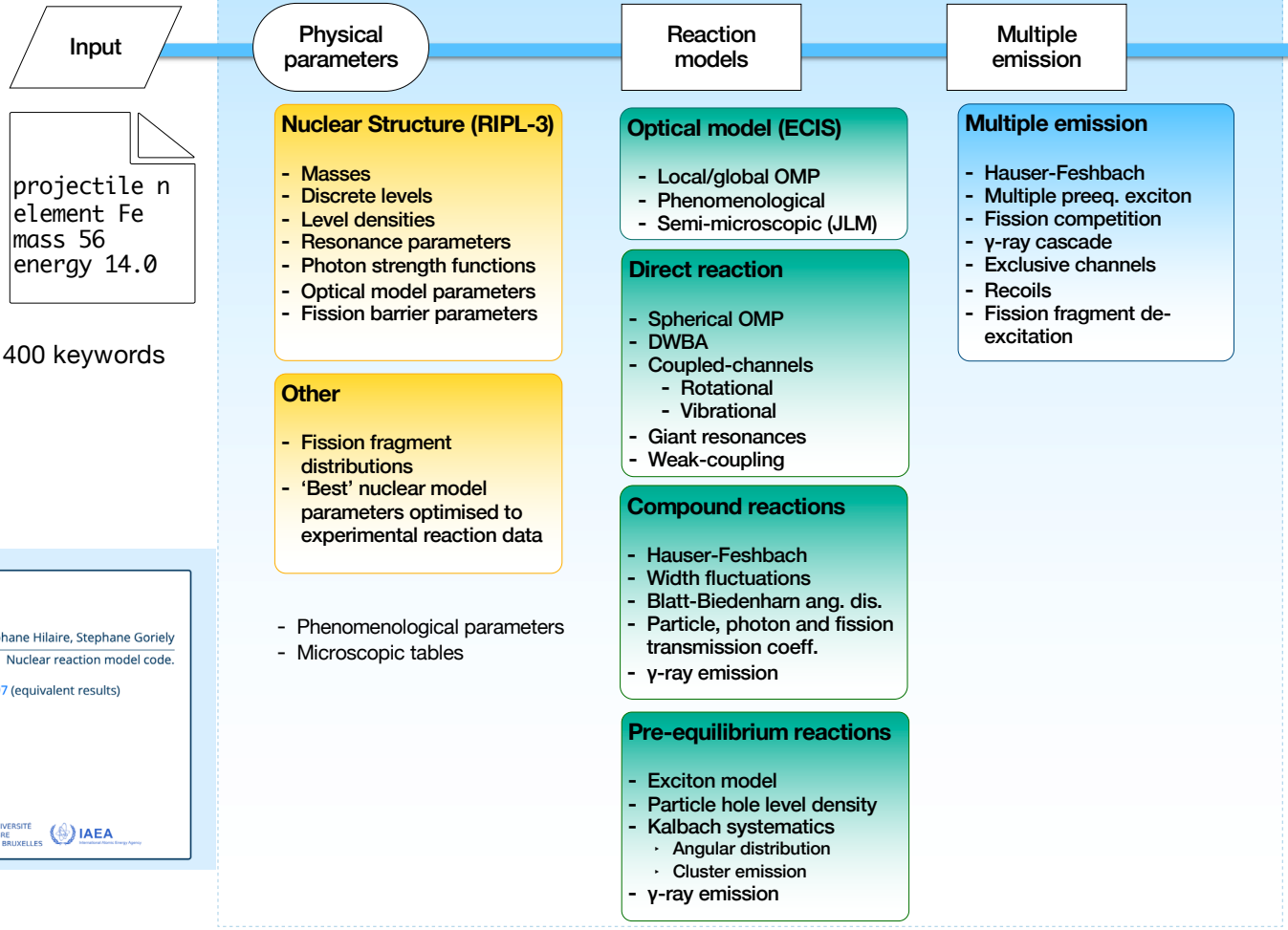
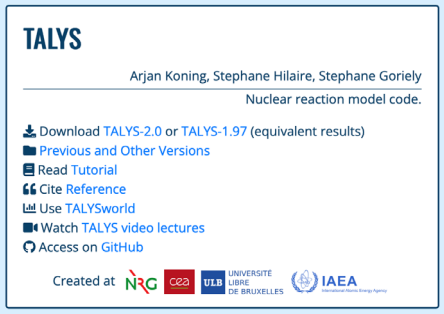


+ some 400 keywords

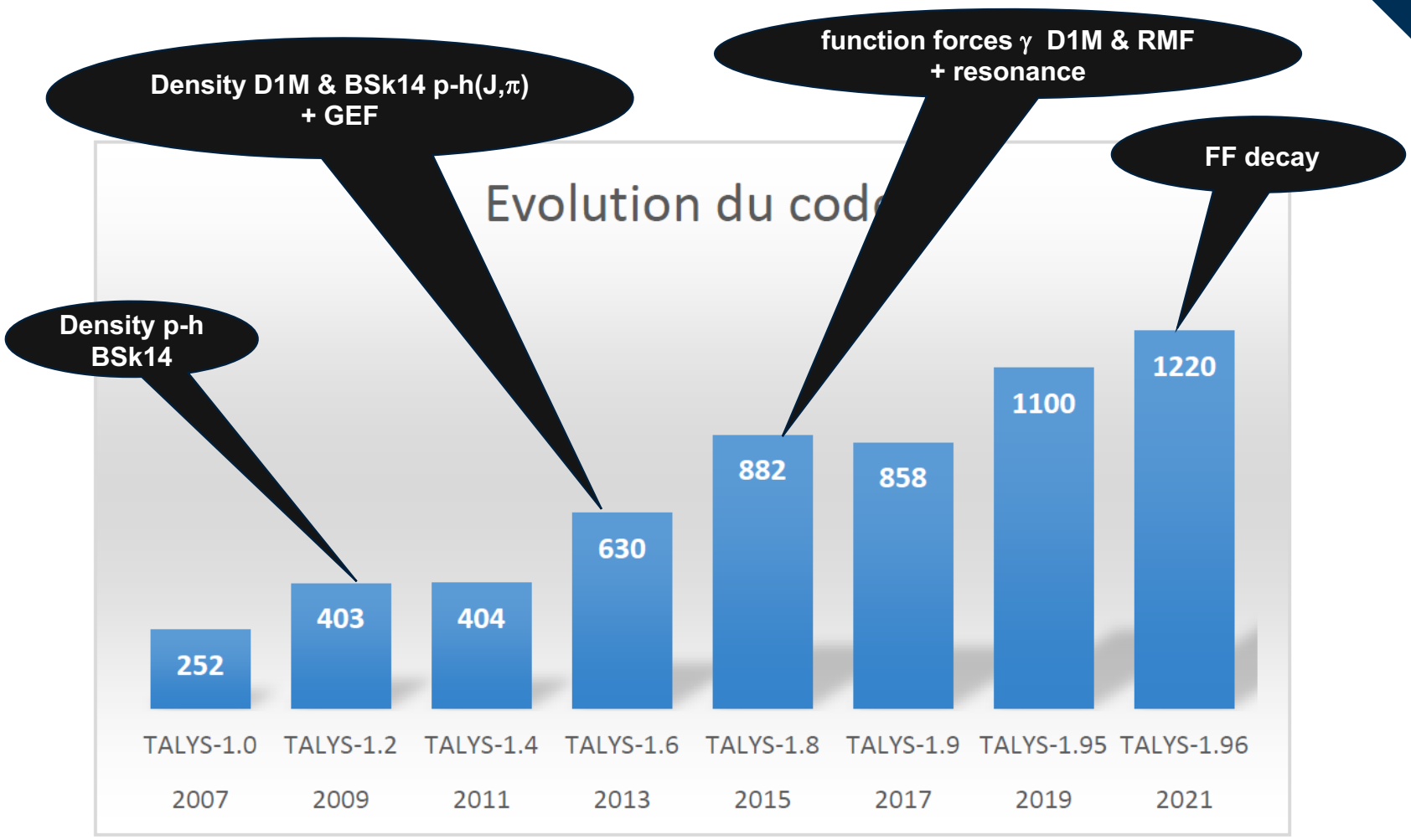
- Phenomenological parameters
- Microscopic tables



Output files per reaction channel

- Cross sections
  - Total
  - Exclusive: (n,γ), (n,f), (n,n'), (n,2n), (n,p) etc.
  - Per level
  - Residual production
  - Particle production
  - γ-ray production
- Emission spectra
  - Single-differential
  - Double differential
  - Recoils
- Angular distributions
  - Elastic
  - Per level
- Particle multiplicities
- Fission yields, neutron observables
- Astrophysical reaction rates, MACS
- …

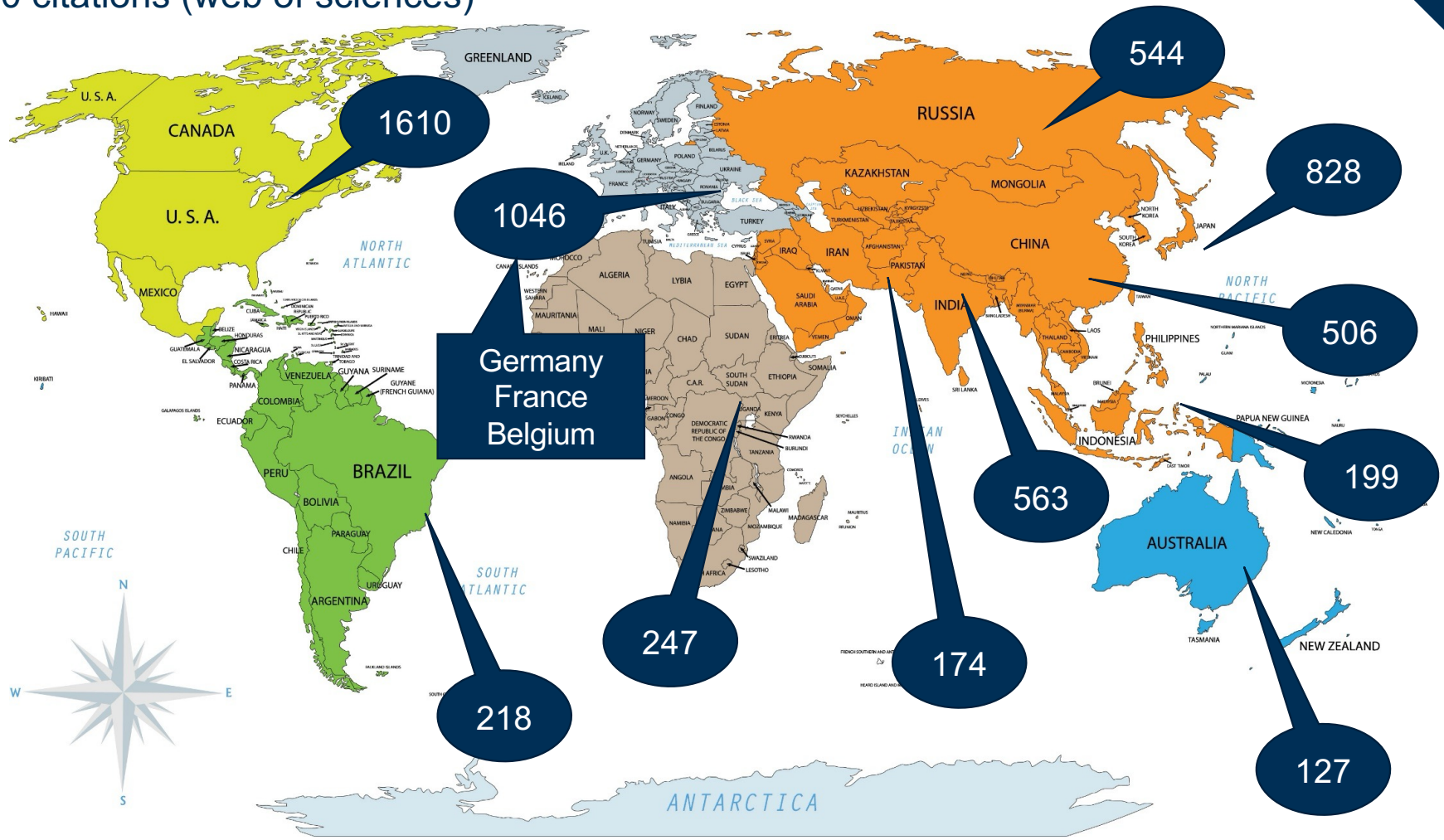
TALYS time steps evolution



TALYS around the World

UK Atomic Energy Authority

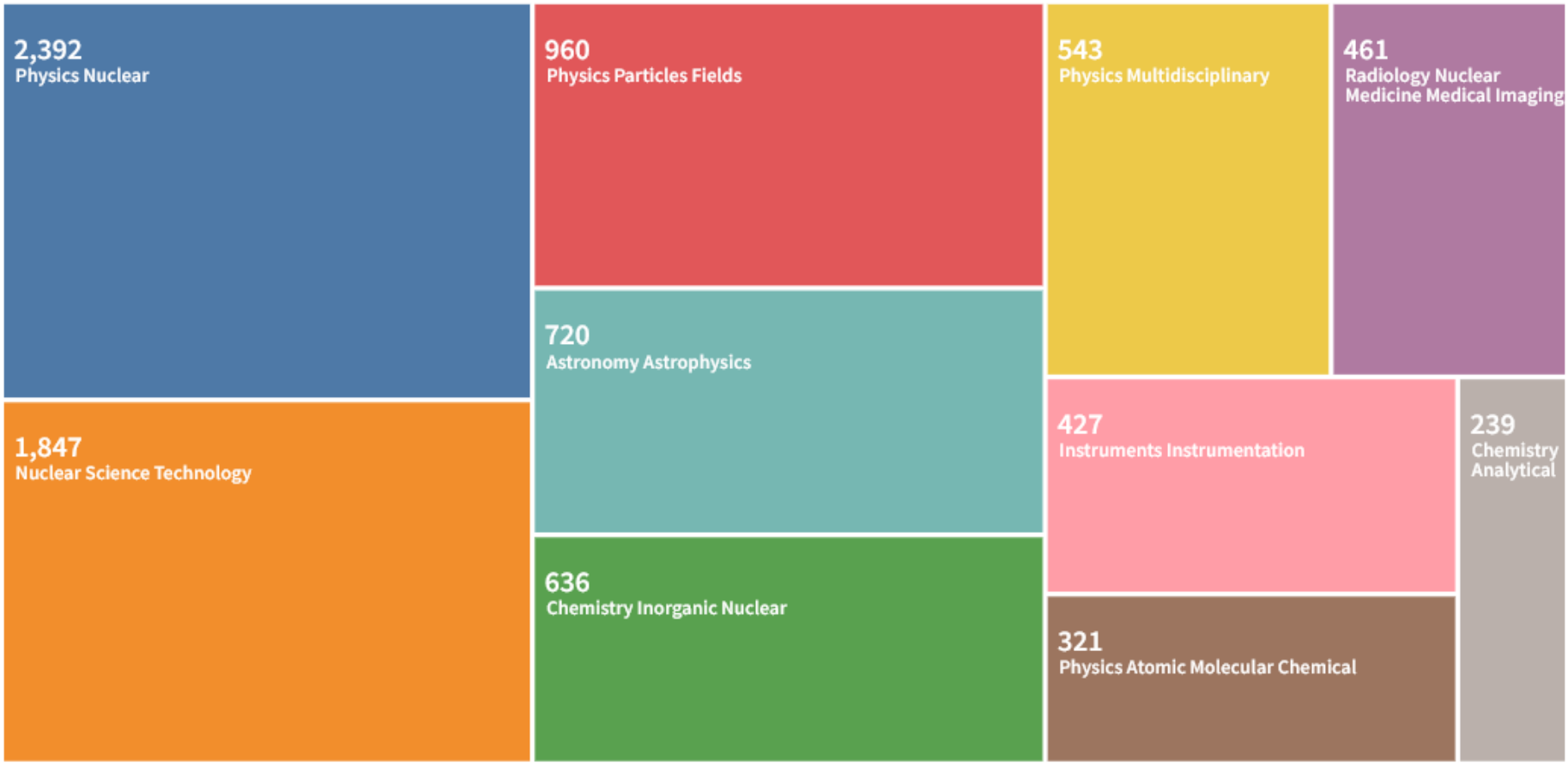
Around 5500 citations (web of sciences)



TALYS applications in the World

UK Atomic Energy Authority

Around 5500 citations (web of sciences)



Previous T6: automatisation – reproducibility - robustnes

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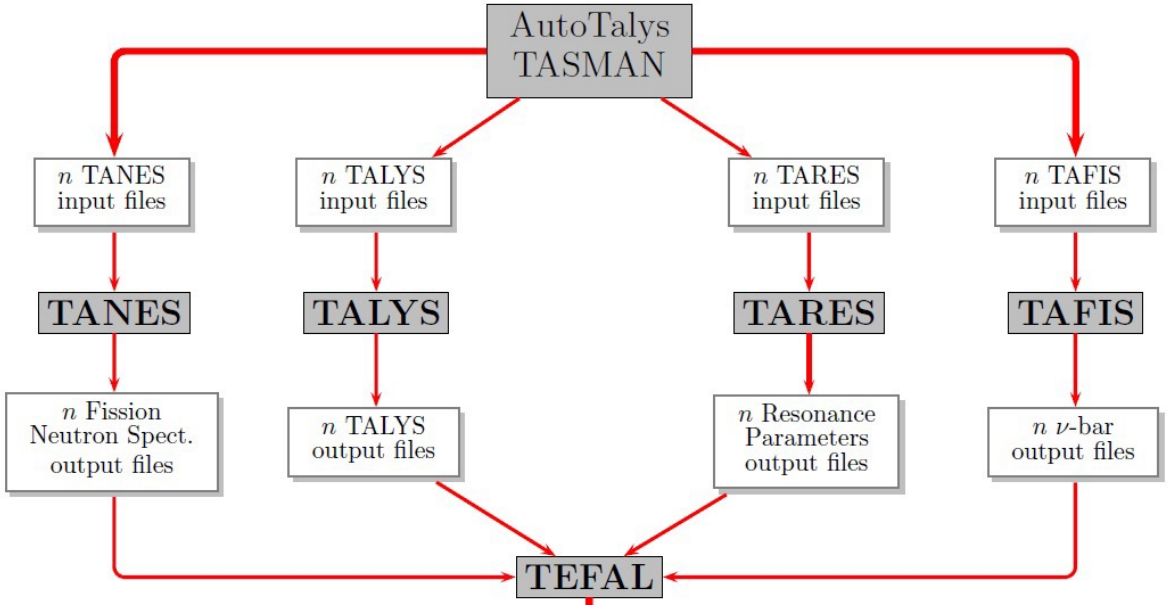
TALYS, TANES, TARES, TAFIS, TEFAL, TASMAN



New T3: automatisation – reproducibility - robustnes

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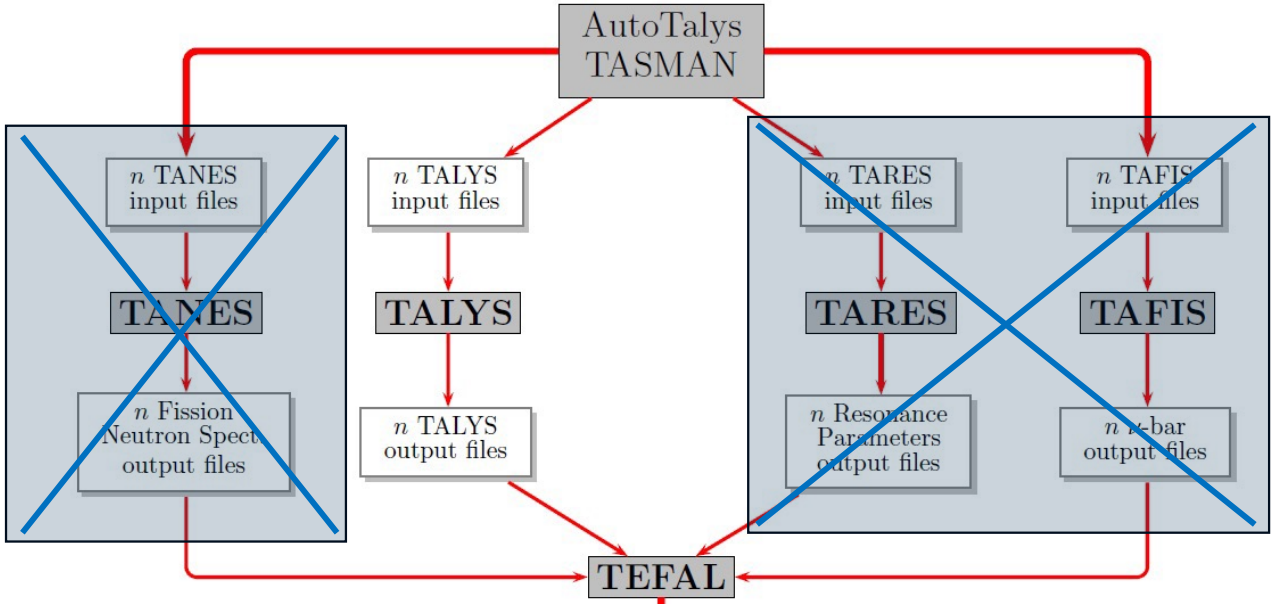
TALYS, TEFAL, TASMAN



Replace by databases

Default models input parameters

Randomized models input parameters

T3: TALYS, TEFAL, TASMAM + resbase

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TALYS & Related Software

TALYS and the related packages are open source software and datasets (MIT License) for the simulation of nuclear reactions.

TALYS

Arjan Koning, Stephane Hilaire, Stephane Goriely

Nuclear reaction model code.

- Download TALYS-2.0 or TALYS-1.97 (equivalent results)
- Previous and Other Versions
- Read Tutorial
- Cite Reference
- Use TALYSworld
- Watch TALYS video lectures
- Access on GitHub

Created at NRG cea ULB UNIVERSITÉ LIBRE DE BRUXELLES IAEA International Atomic Energy Agency

https://nds.iaea.org/talys/

TASMAN

Arjan Koning

Statistical software for TALYS: Uncertainties, sensitivities and optimization.

- Download TASMAN-2.0
- Read Tutorial
- Cite Reference
- Access on GitHub

TEFAL

Arjan Koning

Code to make ENDF-6 nuclear data libraries from TALYS.

- Download TEFAL-2.0
- Read Tutorial
- Cite Reference
- Access on GitHub

RESONANCETABLES

Arjan Koning, Dimitri Rochman

Database for thermal cross sections, MACS and average resonance parameters.

- Download RESONANCETABLES-2.0
- Read Tutorial
- Cite Reference
- Access on GitHub

Created at IAEA International Atomic Energy Agency PAUL SCHERRER INSTITUT PSI

TALYS coded input parameters & GOF

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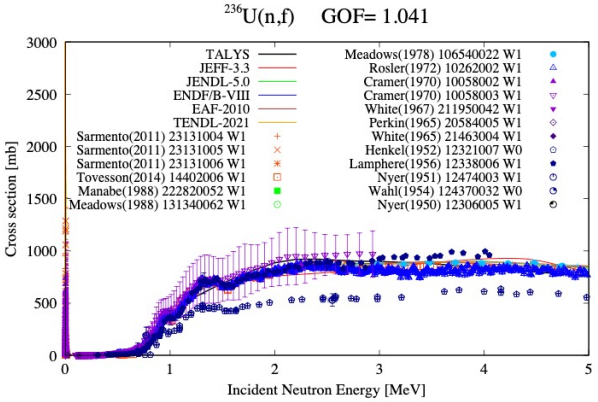
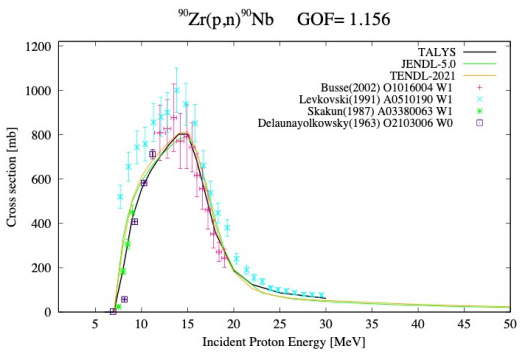
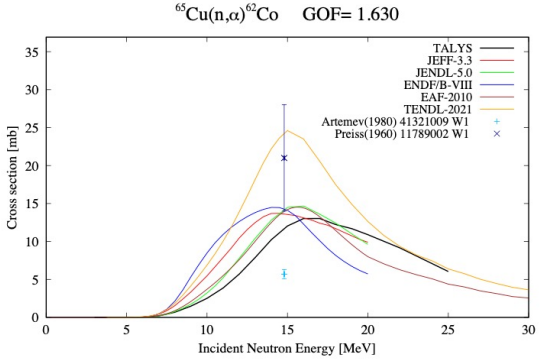
Optimized parameters

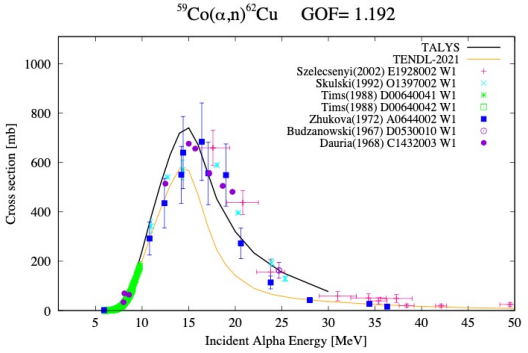
Weight allocation on exp.



Reaction	Nuclides						
(n,γ)	278	wtable					
(n,f)	34	vfiscor	betafiscor	ctable(1)	ptable(1)	ctable(2)	ptable(2)
(n,n';2n;p)	210	rv(p)	$g_{ph}(0)$	$g_{ph}(n)$	ctable(n)	ctable(p)	
(n,α)	157	rv(α)	Cstrip(α)	$g_{ph}(0)$	ctable(α)		
(p,n)	142	rv(p)	rwd(p)	rv(n)	$g_{ph}(0)$	$g_{ph}(n)$	ctable(n)
(γ,n)	77	wtable	ftable	etable			
(α,n)	93	rv(α)	rwd(α)	rv(n)	$g_{ph}(0)$	ctable(α)	
(d,n)	40	rv(p)	rwd(p)	rv(n)	$g_{ph}(0)$	$g_{ph}(n)$	ctable(n)







TALYS coded input parameters & GOF

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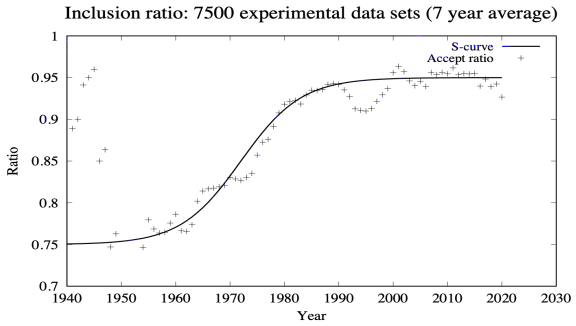
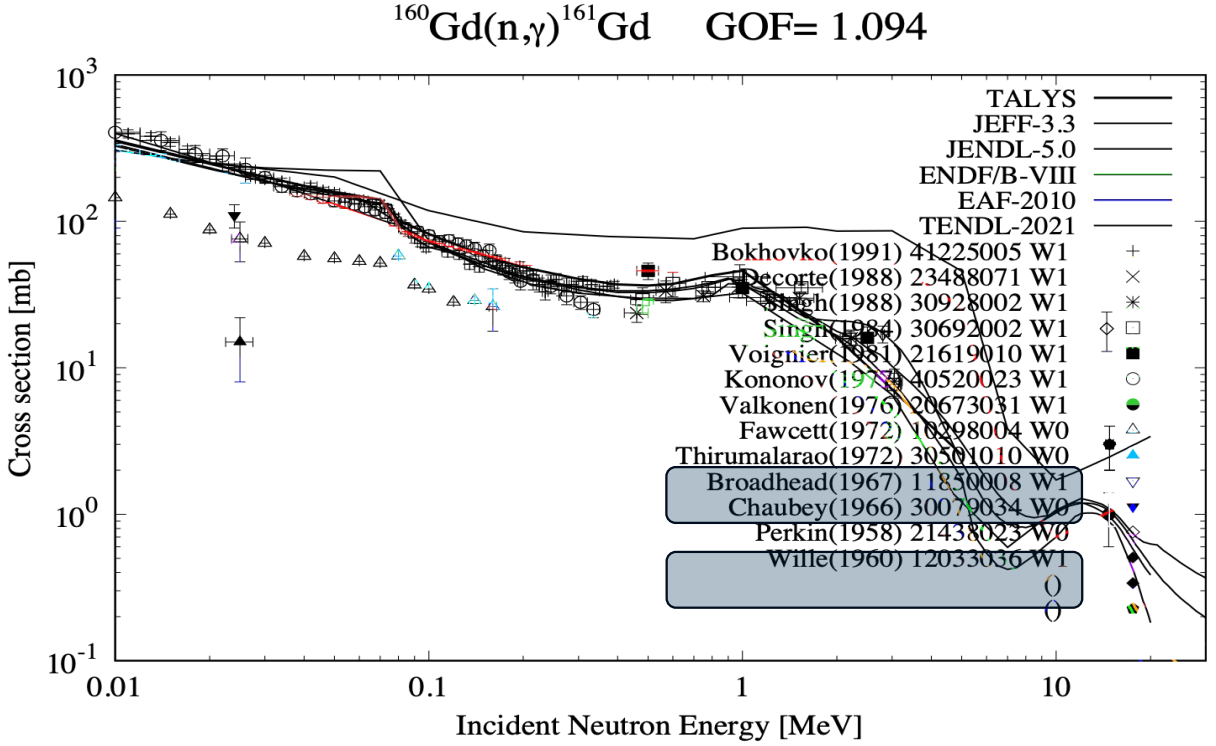
Outlier assignment (W0) and optimised TALYS model parameters per nuclide and reaction channel

7500 experiments, age weighted, subjective, but..





Scouting the nuclear lanscapes

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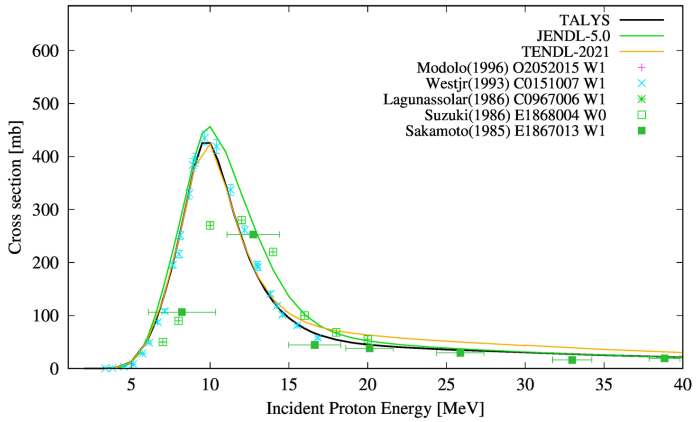
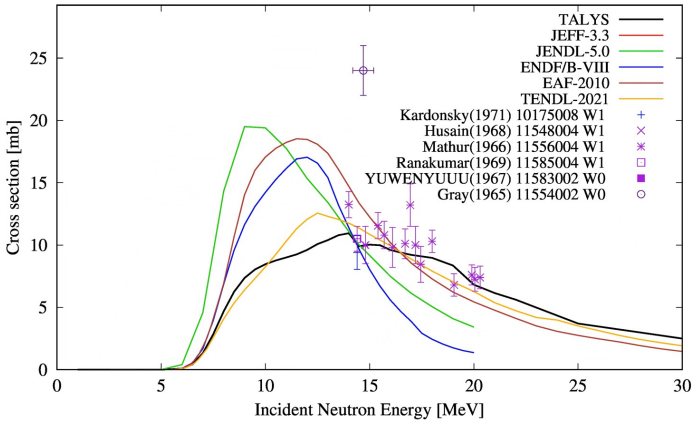
(α,n), (n,α) and (p,n) **films**

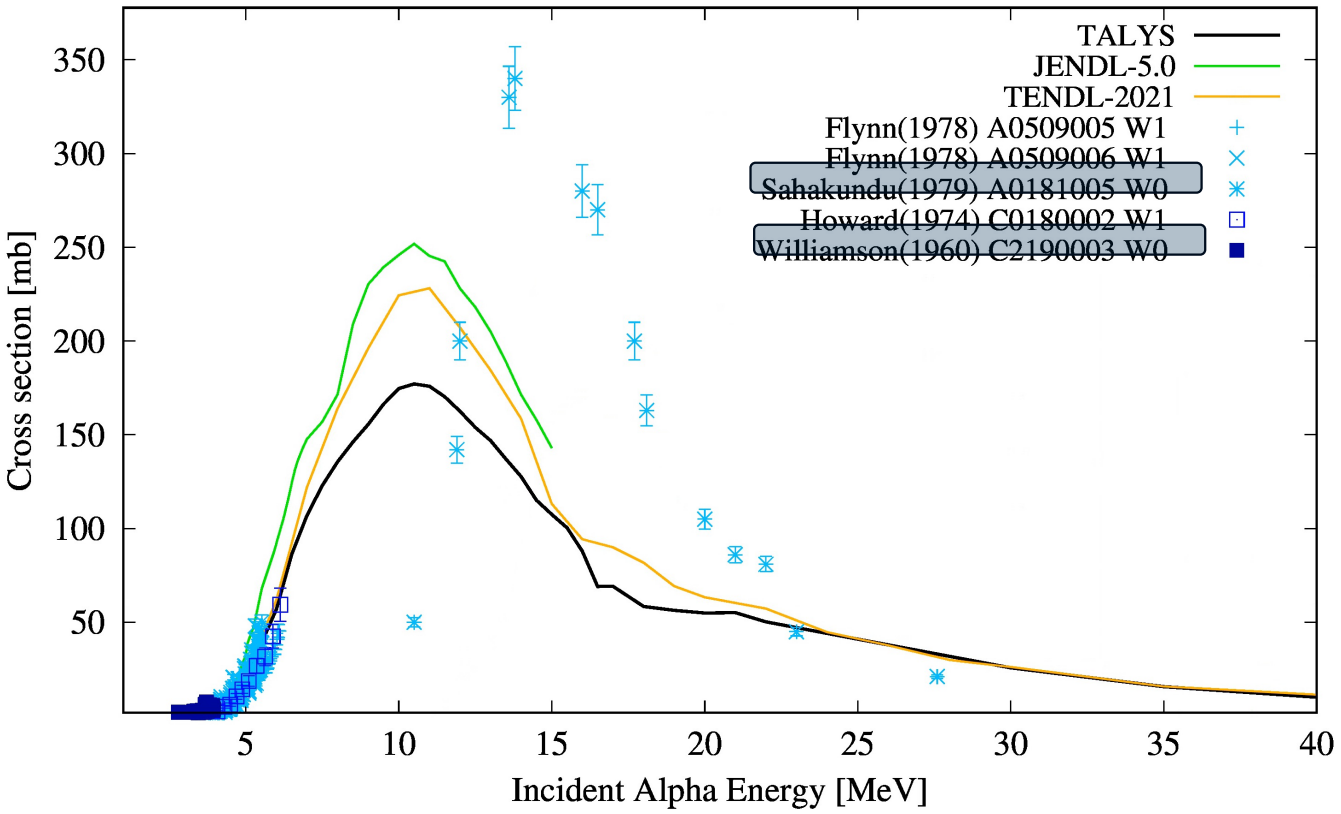
$^{127}I(p,n)^{127}Xe$ GOF= 1.33



$^{40}Ar(n,\alpha)^{37}S$ GOF= 1.05



$^{27}Al(\alpha,n)^{30}P$ GOF= 1.31



TALYS default or optimized parameters in the MF-1

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to xs, 0.0253 eV

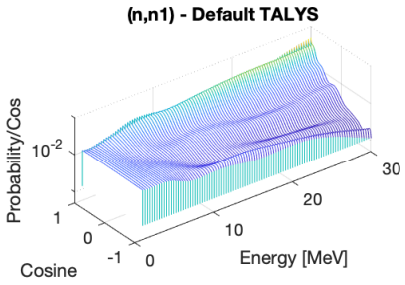
to MACS, 30 Kev

to Maxw., SPA

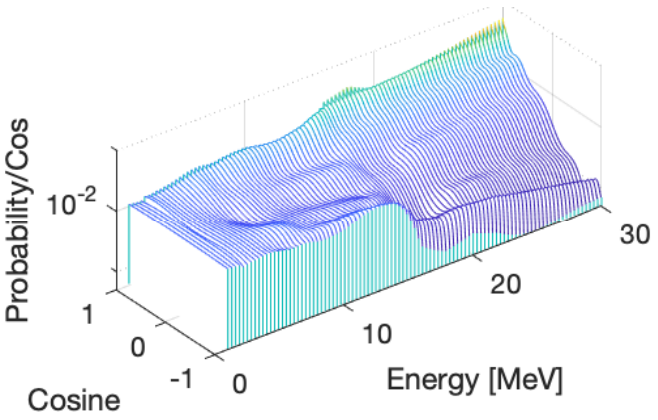
to xs, < 1 MeV

to angles

…




```
                Adjusted TALYS input parameters                  2631 1451
#                                                                2631 1451
# General                                                        2631 1451
#                                                                2631 1451
ldmodel 2                                                        2631 1451
#                                                                2631 1451
# (n,tot), (n,el), (n,inl)                                       2631 1451
#                                                                2631 1451
awdadjust n 1. awdadjust-n.table                                 2631 1451
#                                                                2631 1451
# (n,p), (n,2n), (n,np)                                          2631 1451
#                                                                2631 1451
rvadjust p 0.99                                                  2631 1451
avadjust p 0.99                                                  2631 1451
gnadjust 26 57 0.90                                              2631 1451
gpadjust 26 57 0.90                                              2631 1451
aadjust 25 56 1.12                                               2631 1451
pshiftadjust 26 56 -0.2                                          2631 1451
pshiftadjust 25 56 0.1                                           2631 1451
#                                                                2631 1451
# (n,a)                                                          2631 1451
#                                                                2631 1451
cknock a 1.1                                                     2631 1451
cstrip a 1.1                                                     2631 1451
#                                                                2631 1451
# (n,g)                                                          2631 1451
ldmodelCN 1                                                      2631 1451
#                                                                2631 1451
# Other: Isomers, (n,d), (n,t), (n,h) etc.                       2631 1451
#                                                                2631 1451
***************************** T A L Y S ************************2631 1451
```



Form & Format

UK Atomic Energy Authority

GNDS

```
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  <crossSection>
    <resonancesWithBackground label="eval">
      <resonances href="/reactionSuite/resonances"/>
      <background>
        <resolvedRegion>
          <XYs1d>
            <axes>
              <axis index="1" label="energy_in" unit="eV"/>
              <axis index="0" label="crossSection" unit="b"/></axes>
            <values>
              1.00000000e-05 0.00000000e+00 2.25000000e+03 0.00000000e+00</values></XYs1d></resolvedRegion>
        <fastRegion>
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            <values>
              2.25000000e+03 2.32822500e+00 2.50000000e+03 2.20619000e+00 3.00000000e+03 2.03074000e+00 3.50000000e+03 1.8976900
```

TALYS-1.97

```
# n + 235U     : (n,g)              Total
# Q-value     = 6.54552E+00
# E-threshold= 0.00000E+00
# # energies =     24
#      E           xs         gamma xs   xs/res.prod.xs
 1.00000E-02 2.07936E+03 1.13814E+04 1.00000E+00
 2.00000E-02 1.43254E+03 7.88163E+03 1.00000E+00
 4.00000E-02 1.17702E+03 6.52455E+03 1.00000E+00
 7.00000E-02 9.83417E+02 5.49190E+03 1.00000E+00
 1.00000E-01 8.45338E+02 4.74815E+03 1.00000E+00
 2.00000E-01 5.62366E+02 3.19982E+03 1.00000E+00
```

EXFOR

```
TITLE      New precision measurements of the 235U(n,g) cross
            section
AUTHOR     (M.Jandel, T.A.Bredeweg, E.M.Bond, M.B.Chadwick,
            A.Couture, J.M.O'Donnell, M.Fowler, R.C.Haight,
            T.Kawano, R.Reifarth, R.S.Rundberg, J.L.Ullmann,
            D.J.Vieira, J.M.Wouters, J.B.Wilhelmy, C.Y.Wu,
            J.A.Becker)
INSTITUTE  (1USALAS,1USALRL)
REFERENCE  (J,PRL,109,202506,2012) Final (n,g) and alpha
           (J,NIM/B,261,986,2007)  Prelim. (n,g) and (n,f) in figs
           (C,2007NICE,1,607,2008) Prelim. (n,g) and (n,f) in figs
FACILITY   (LINAC,1USALAS) Lujan Neutron Scattering Center of
```

EXFOR tables

```
# Target Z    :  92
# Target A    : 235
# Target state:
# Projectile  : n
# Reaction    : (n,g)
# Final state :
# Quantity    : Cross section
# Frame       : L
# MF          :   3
# MT          :  102
# X4 Subentry : 141490072
# X4 Reaction : 92-U-235(N,G)92-U-236,,SIG
# Author      : Jandel
# Year        : 2012
# Data points :    66
#    E(MeV)       xs(mb)      dxs(mb)     dE(MeV)
  5.00036E-04  2.61329E+03  5.78510E+02  1.15100E-06
  5.07024E-04  3.55298E+03  3.12190E+02  5.83701E-06
  5.18834E-04  4.99961E+03  3.47930E+02  5.97351E-06
  5.30919E-04  5.00055E+03  3.10070E+02  6.11151E-06
```

ENDF

```
 9.223500+4 2.330248+2          0          0          0          09228 3102
 6.544430+6 6.544430+6          0          0          1       1119228 3102
        111          2                                          9228 3102
1.000000-5 0.000000+0 2.250000+3 0.000000+0 2.250000+3 2.047808+09228 3102
2.370000+3 1.711010+0 2.650000+3 1.881410+0 3.000000+3 1.828870+09228 3102
3.350000+3 1.963650+0 3.750000+3 1.838280+0 4.000000+3 1.676190+09228 3102
4.200000+3 1.534880+0 4.700000+3 1.626720+0 5.300000+3 1.145940+09228 3102
```

YANDF-0.2

TALYS 2.0 output file: rp039090.L02 and nnang.L01

‘#’ for direct use in various software, e.g. Gnuplot

Without ‘#’: YAML 2 spaces indentation per level

Parsing to JSON should be easy

Only **5 main attributes for nuclear reactions**

TALYS: 2 main attributes: **‘parameters’ and ‘observables’**

EXFOR: All specific metadata after the data block

```
# header:
#   title: Nb93(n,x)Y90m cross section
#   source: TALYS-2.0
#   user: Arjan Koning
#   date: 2024-01-11
#   format: YANDF-0.1
# target:
#   Z: 41
#   A: 93
#   nuclide: Nb93
# reaction:
#   type: (n,x)
#   Q-value [MeV]:  4.248473E+00
#   E-threshold [MeV]:  0.000000E+00
#   ENDF_MF: 6
#   ENDF_MT: 5
# residual:
#   Z: 39
#   A: 90
#   nuclide: Y90m
#   mass [amu]:  8.990714E+01
#   level:
#     number: 2
#     energy [MeV]:  6.820100E-01
#     spin:  7.000000E+00
#     parity: 1
#     isomer: 1
#     half-life [sec]:  1.148000E+04
# datablock:
#   quantity: cross section
#   columns: 3
#   entries: 25
##       E             xs       Isomeric ratio
##     [MeV]           [mb]             []
   2.000000E-01   0.000000E+00   0.000000E+00
   4.000000E-01   0.000000E+00   0.000000E+00
   6.000000E-01   0.000000E+00   0.000000E+00
   8.000000E-01   0.000000E+00   0.000000E+00
   1.000000E+00   0.000000E+00   0.000000E+00
   1.200000E+00   0.000000E+00   0.000000E+00
   1.400000E+00   8.135896E-05   0.000000E+00
   1.600000E+00   1.296808E-04   1.266436E-01
   1.800000E+00   2.699952E-04   1.644318E-01
   2.000000E+00   5.832345E-04   2.057970E-01
```

```
# header:
#   title: C12(n,n_1) angular distribut
#   source: TALYS-2.0
#   user: Arjan Koning
#   date: 2024-02-19
#   format: YANDF-0.2
# target:
#   Z: 6
#   A: 12
#   nuclide: C12
# reaction:
#   type: (n,n_1)
#   ENDF_MF: 4
#   ENDF_MT: 51
#   E-incident [MeV]:  5.000000E+00
#   level:
#     number: 1
#     energy [MeV]:  4.439820E+00
#     spin:  2.000000E+00
#     parity: 1
# datablock:
#   quantity: angular distribution
#   columns: 4
#   entries: 91
##     Angle          xs          Direct        Compound
##     [deg]        [mb/sr]       [mb/sr]       [mb/sr]
   0.000000E+00   1.676661E+01   5.253240E-01   1.624129E+01
   2.000000E+00   1.676645E+01   5.252810E-01   1.624117E+01
   4.000000E+00   1.676595E+01   5.251530E-01   1.624080E+01
   6.000000E+00   1.676513E+01   5.249390E-01   1.624020E+01
   8.000000E+00   1.676399E+01   5.246370E-01   1.623935E+01
   1.000000E+01   1.676251E+01   5.242470E-01   1.623827E+01
   1.200000E+01   1.676072E+01   5.237660E-01   1.623695E+01
   1.400000E+01   1.675860E+01   5.231930E-01   1.623540E+01
   1.600000E+01   1.675616E+01   5.225260E-01   1.623363E+01
   1.800000E+01   1.675340E+01   5.217600E-01   1.623164E+01
   2.000000E+01   1.675033E+01   5.208940E-01   1.622944E+01
   2.200000E+01   1.674695E+01   5.199230E-01   1.622703E+01
   2.400000E+01   1.674327E+01   5.188450E-01   1.622442E+01
```

TALYS-2.0 /Work

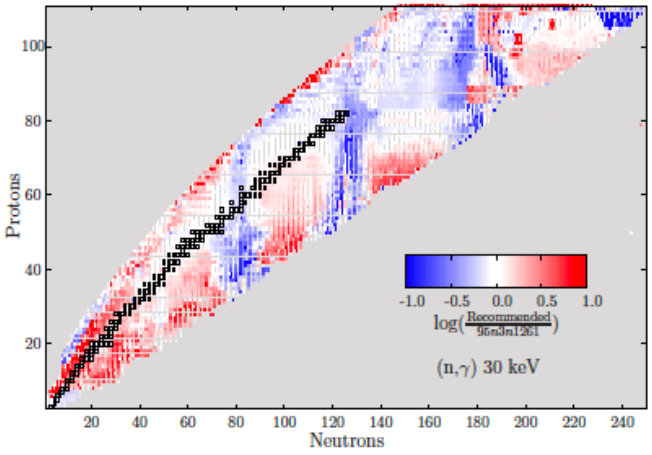
UK Atomic Energy Authority

TENDL-2023 ASTRO https://tendl.web.psi.ch/tendl_2023/astro/astro.html

UK Atomic Energy Authority

Started August 10th, 2022 and still goin on…~8000 nuclides

200 cores, up to 480 model combinations x isotopes x **4 metrics**



model 95n3n1261

TENDL-astro 2023

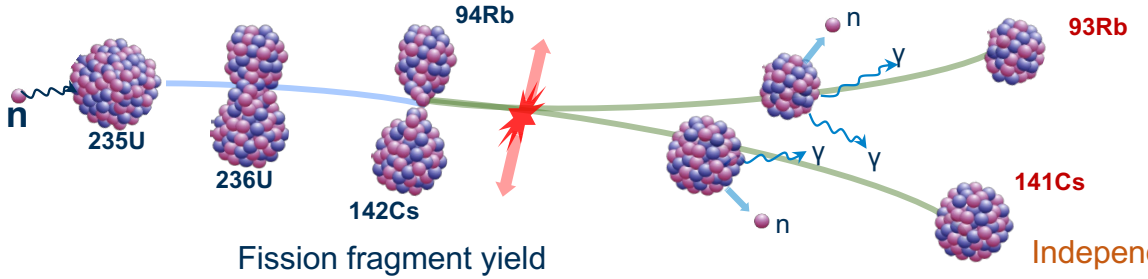
Cross sections, reaction rates and MACS for astrophysics

Quantities with uncertainties

	10 models	480 models (A< 210)	960 models (A≥210)
1. cross sections:	(n,g) (n,p) (n,a)	(n,g) (n,p) (n,a)	(n,g) (n,p) (n,a)
2. cross sections:	(p,g) (p,n) (p,a)	(p,g) (p,n) (p,a)	(p,g) (p,n) (p,a)
3. cross sections:	(a,g) (a,n) (a,p)	(a,g) (a,n) (a,p)	(a,g) (a,n) (a,p)
4. reaction rates:	(n,g) (n,p) (n,a)	(n,g) (n,p) (n,a)	(n,g) (n,p) (n,a)
5. reaction rates:	(p,g) (p,n) (p,a)	(p,g) (p,n) (p,a)	(p,g) (p,n) (p,a)
6. reaction rates:	(a,g) (a,n) (a,p)	(a,g) (a,n) (a,p)	(a,g) (a,n) (a,p)
7. Normalization function:	G(T)	G(T)	G(T)
8. Maxwellian Averaged (n,g) :	MACS	MACS	MACS

TALYS: prompt fission observable and fission yields

UK Atomic Energy Authority



Fission fragment yield

Independent yield

TALYS treats a fission fragment as an excited nucleus and applies the Hauser-Feshbach statistical decay to the fission fragment de-excitation (prompt decay) and loops over all fission fragments.

Fission fragment generator

Monte Carlo
- GEF (ffmodel1)
- FREYA (ffmodel5?)

Micro/Macroscopic Theory
- SPY model (ffmodel3)
- 4D Langevin by TokyoTech (ffmodel4?)

Phenomenological
- Wahl systematics
- Katakura systematics
- Experimental data fitting (ffmodel2)

Charge distribution
- Z_P model

Energy sorting
- Energy sharing hypothesis

TALYS

Model parameters → Reaction simulations → Multiple emissions → Output

Nuclear structure (RIPL-3)
- Masses, abundance
- Discrete levels
- Level densities
- Neutron resonances
- Fission barrier parameter
- Photon strength function

Optical model (ECIS)
- Phenomenology local/global optical model

Compound reaction
- Width fluctuations
- Gilbert-Cameron + Ignatyuk
- γ-ray emission

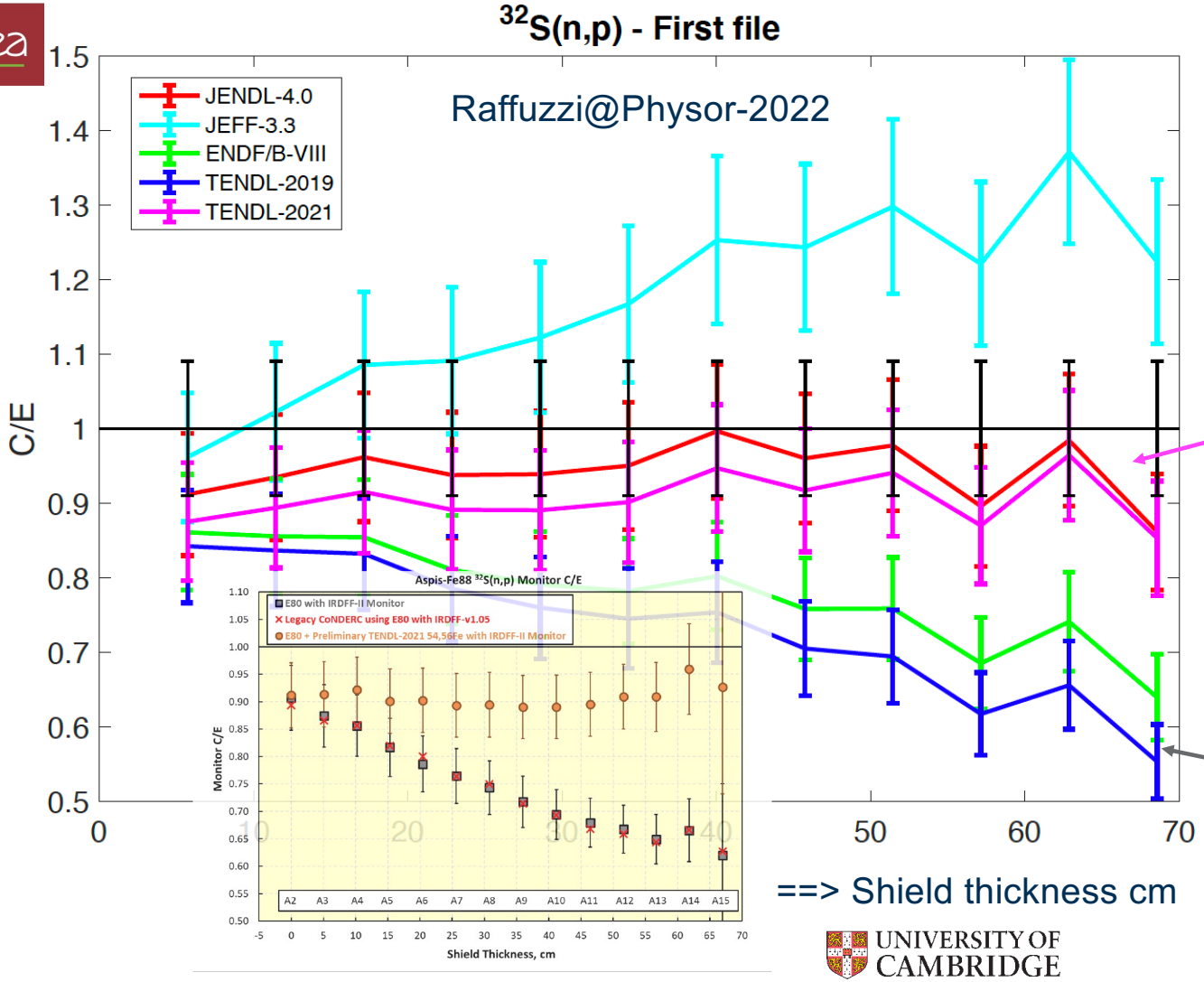
Compound reaction
- Hauser-Feshbach
- γ-ray cascade
- Exclusive channels
- Recoils

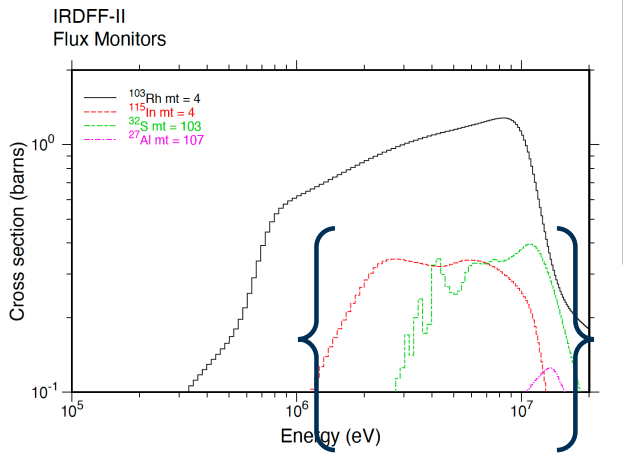
Fission observables
- PFNS, PFGS (LAB frame conversion, Maxwellian ratio)
- nu n, g
- Yield

Fission fragments
-Mass, charge, yield, excitation energy

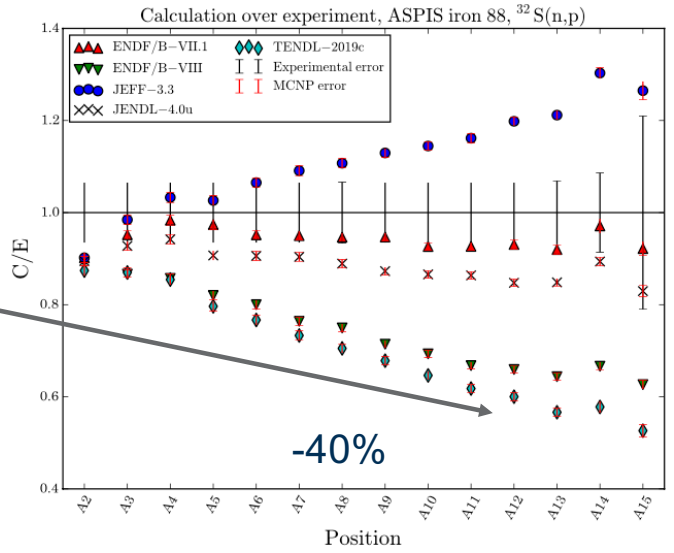
東京工業大学 Tokyo Institute of Technology

V&V TRIPOLI4® & MCNP6® Shielding ASPIS





TENDL-23 as performant as JENDL-4



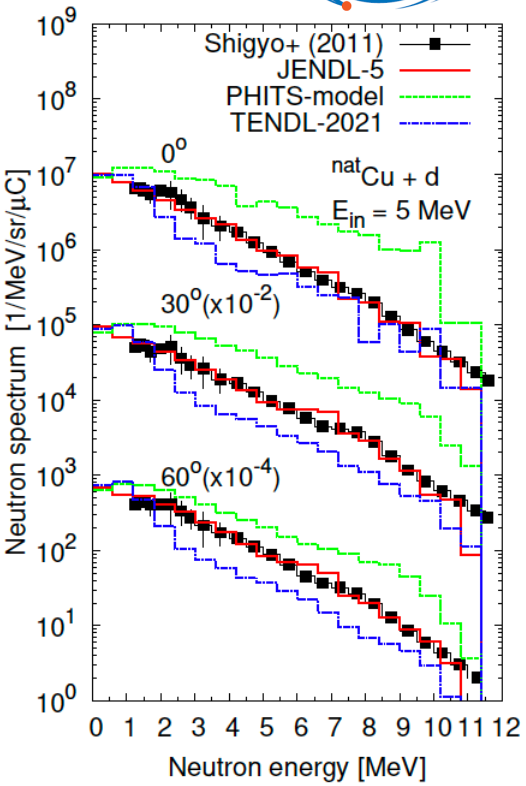
==> Shield thickness cm

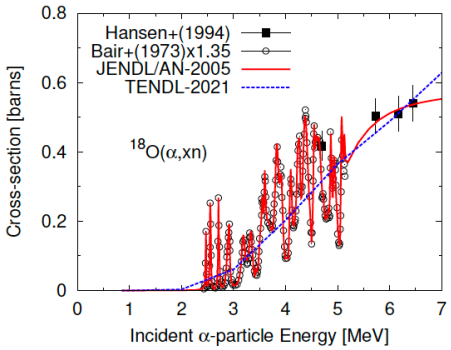
UNIVERSITY OF CAMBRIDGE

CP's V&V deuteron, alpha, gamma induced libraries

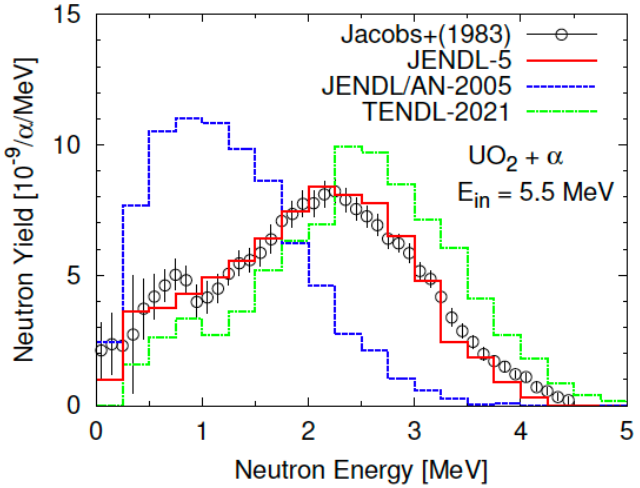
UK Atomic Energy Authority

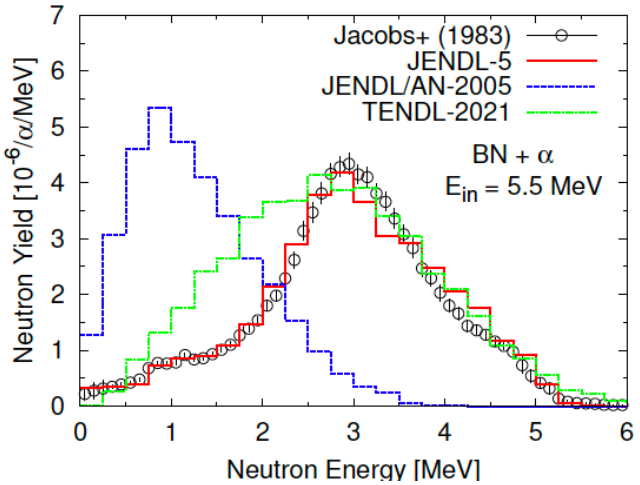
5 MeV deuteron on thick Copper





- 5.5 MeV alpha on UO_2 and Boron nitride

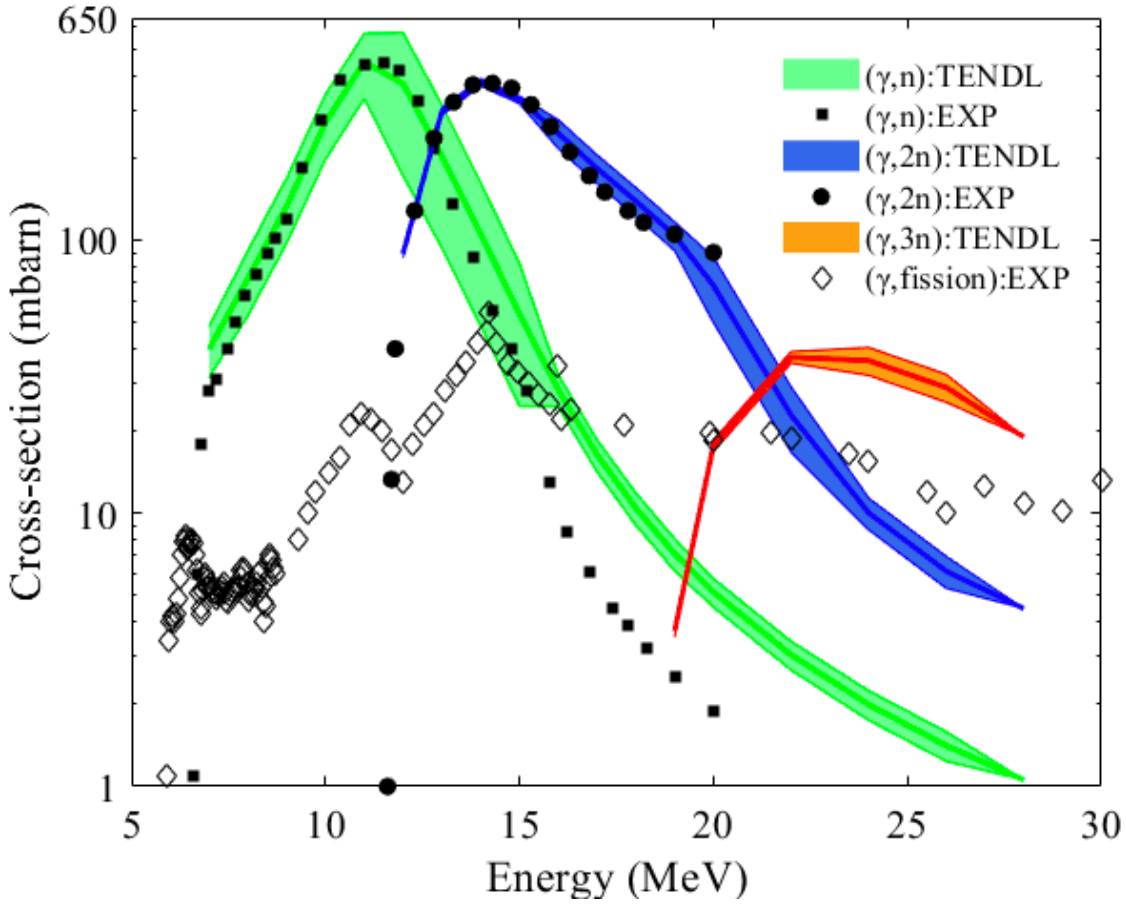




CP's V&V deuteron, alpha, gamma induced libraries

UK Atomic Energy Authority

- Gamma on ^{232}Th



Caveat:

γ-fission in MF-10 !!

TENDL-2023 innovation

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Usage of an enhanced, complete, resonance parameter database

Major update of the experimental differential and integral databases

Covariances information on all **seven incident particles**

- from 2 to 100 TASMAN (depending on the half-life of the target nuclei)

Re-written, modernized codes, GitHub accessible

Autotalys default parameters script enhancement, verification

```
$autotalys -element Na -mass 24 -proj n -E30 -nocovar >&  n-Na024.log

$loopnuc

$allnuccheck
```

200 cores times ~3 months, Swiss power @ PAUL SCHERRER INSTITUT PSI

ENDF, GNDS forms processes

UK Atomic Energy Authority

Processing system convert ENDF, GNDS forms into forms useful for **practical applications**: fission, fusion, stockpile stewardship, criticality safety, radiation shielding, nuclear medicine procedures, earth, space exploration and more

Processed nuclear data forms are numerous, rich, abundant, diverse. Some are observable, other not, all have a specific importance for **at least one application: GIDI+: GNDS to GEANT4 NDL, and LLNL's ADRDA, MERCURY MC**

Processing **enhances, enriches, deepens** the evaluated nuclear data to **forms useful for applications** and **well beyond** cross-section or pile criticality studies only

ENDF, GNDS tabulated forms

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Evaluated forms are **hybrid specimen** assembled from

- experimental information & R Matrix formalism
- nuclear model & structure
- nuclear model & structure & differential tweak
- nuclear model & structure & differential tweak & integral adjustment

Evaluated forms are just a commencement, although it is seen as an end by an entire community

The laws of Physics allow many verification (not validation) processes to take place during the making, assemblage and processing of evaluated file: T3 infrastructure