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Seminar: decay data in FISPACT-II

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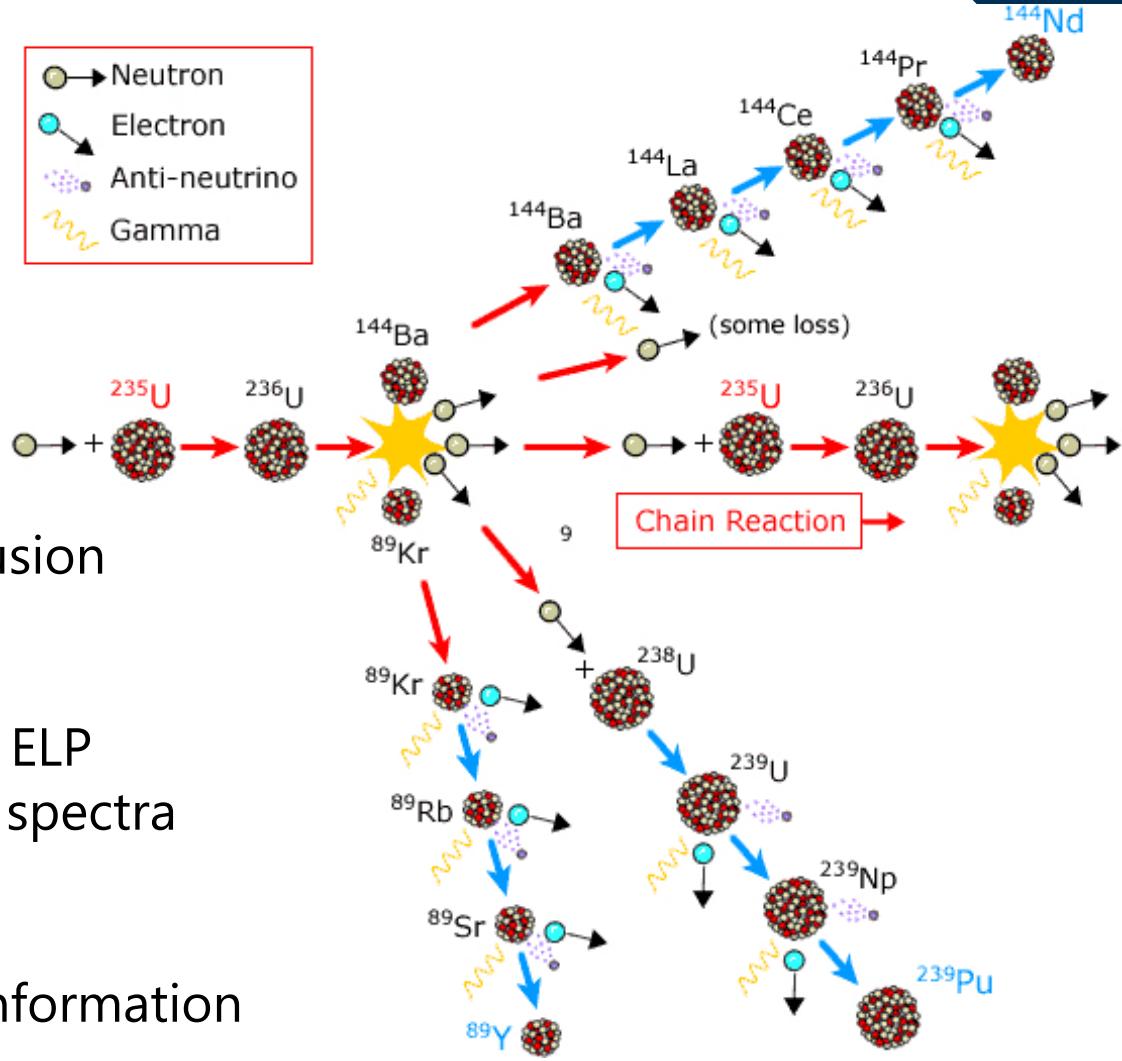
Nuclear decay data: what needs to be accurate

FISPACT-II can handle all ENDF-6 decay files including:

JEFF-3.X
JENDL-4.0u and 2015/16
IRDFF-II
ENDF/B-X.X
UKDD-12
as well as legacy EAF
…

More details: https://www.oecd-nea.org/dbdata/data/nds_eval_libs.htm

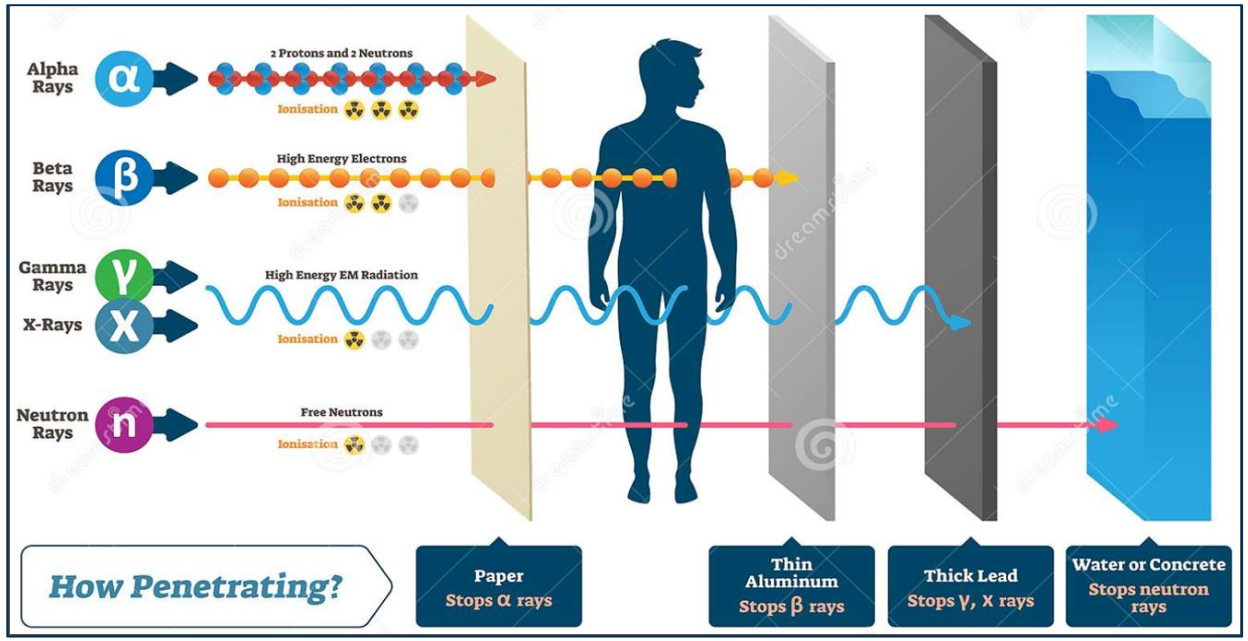


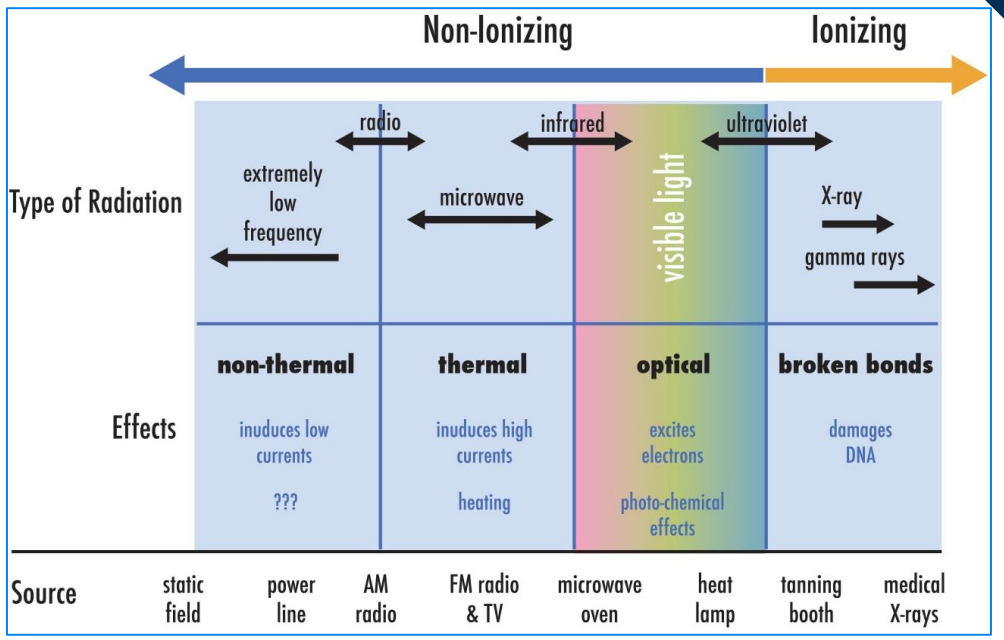
Decay Data Files:

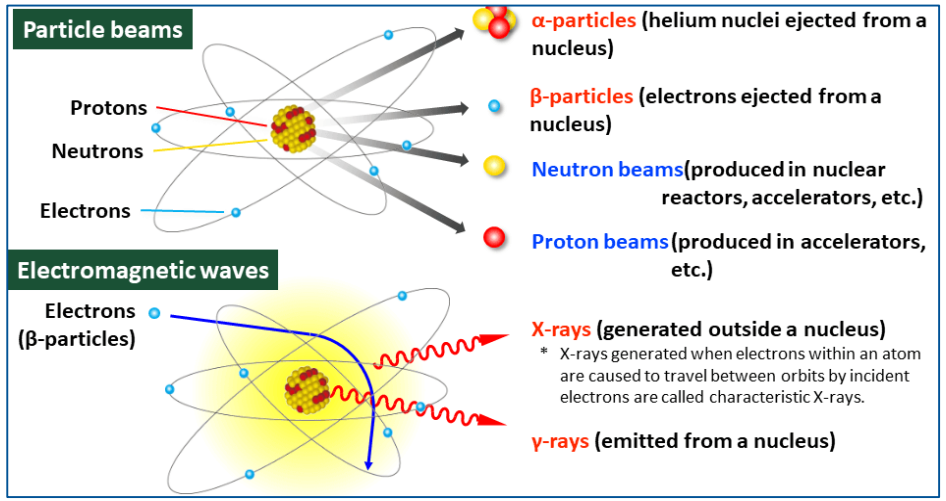
- radionuclides: inclusion
- half-life
- decay modes
- Q-values, EEM and ELP
- associated α, β, γ – spectra
- (anti)neutrinos
- … prompt/delayed particle emission information

Comparisons between libraries can quickly demonstrate unresolved issues in xs/decay/FY data that might affect the simulation results

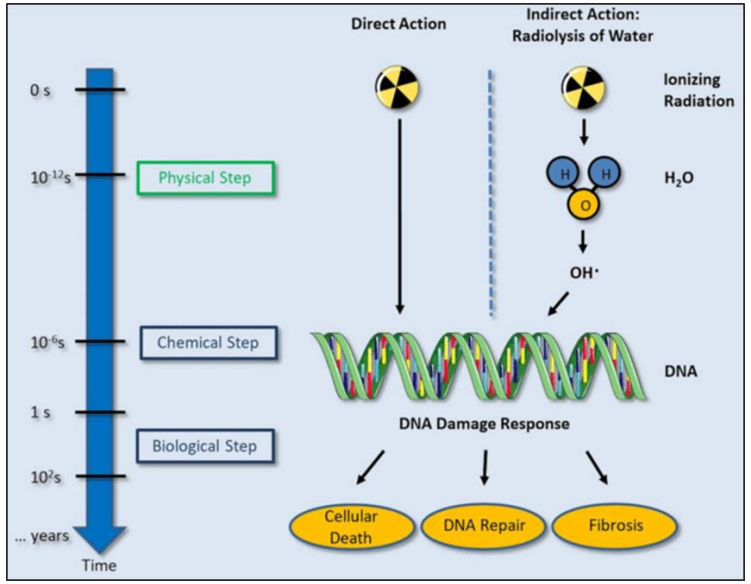
Types of radiation: reference sheet



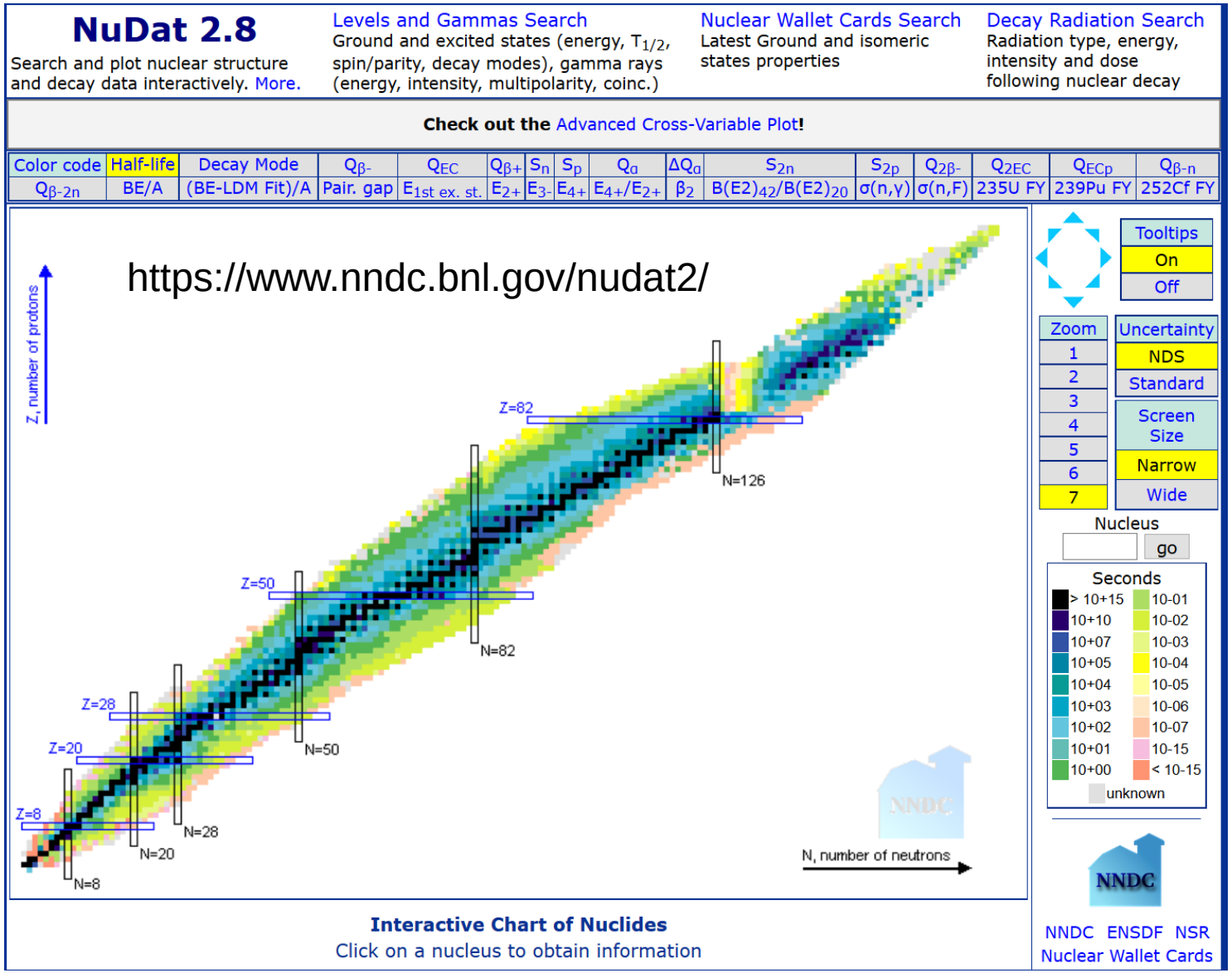




Type of ionizing radiation	Radiation weighting factor
X–rays, γ–rays, electrons and muons	1
neutrons, of various kinetic energies E_{kin}:	
$E_{kin} \leq 10$ keV	5
10 keV $< E_{kin} \leq$ 100 keV	10
100 keV $< E_{kin} \leq$ 2 MeV	20
2 MeV $< E_{kin} \leq$ 20 MeV	10
$E_{kin} >$ 20 MeV	5
protons	5
α–particles, fission fragments, heavy nuclei	20



Decay data: databases and projects

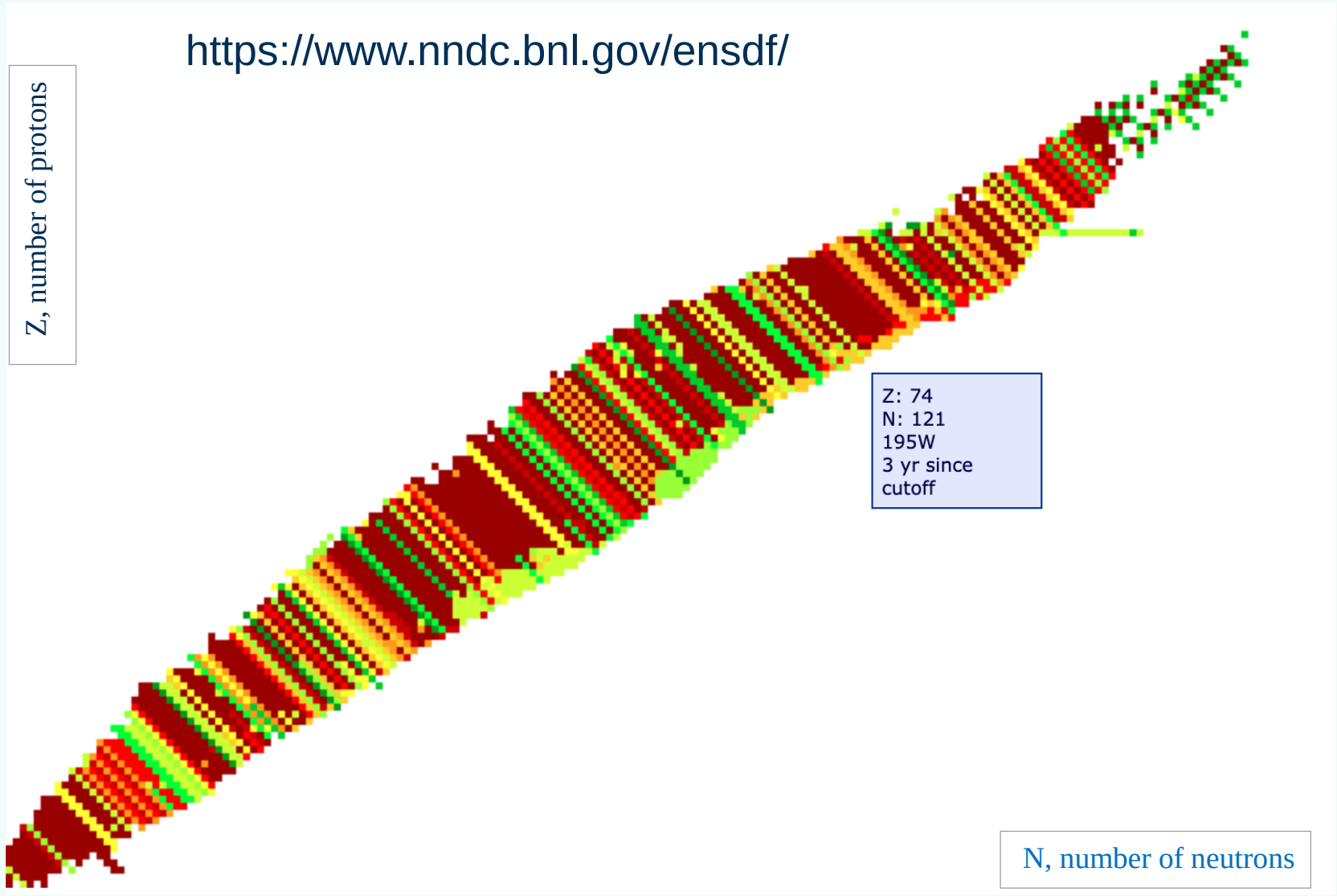


- **ENSDF** (3349 nuclides), ongoing updates
- **NUBASE2016** (3437 nuclides)

  http://amdc.in2p3.fr/web/nubase_en.html
- **Decay Data Evaluation Project - DDEP** (210 nuclides)

  Vol.1-6 (2004-2011), Vol.7 (2013), Vol.8 (2016), *Vol.9 (2020 planned)*
  http://www.lnhb.fr/ddep_wg/

ENSDF: quick look at the updates per nuclide



Time elapsed since the last revision of the datasets for the nuclides:

- ≤ 1 yr since cutoff
- 2 yr since cutoff
- 3 yr since cutoff
- 4 yr since cutoff
- 5 yr since cutoff
- 6 yr since cutoff
- 7 yr since cutoff
- 8 yr since cutoff
- 9 yr since cutoff
- 10 yr since cutoff
- ≥ 11 yr since cutoff

"Cutoff" refers to the literature cutoff date for the evaluation

Decay data libraries: the latest releases

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- **decay_2012 file:** 3875 nuclides, for use of FISPACT-II & TENDL

An updated version is on the way, current beta-version: decay_2020_v2 (https://fispact.ukaea.uk/nuclear-data/)

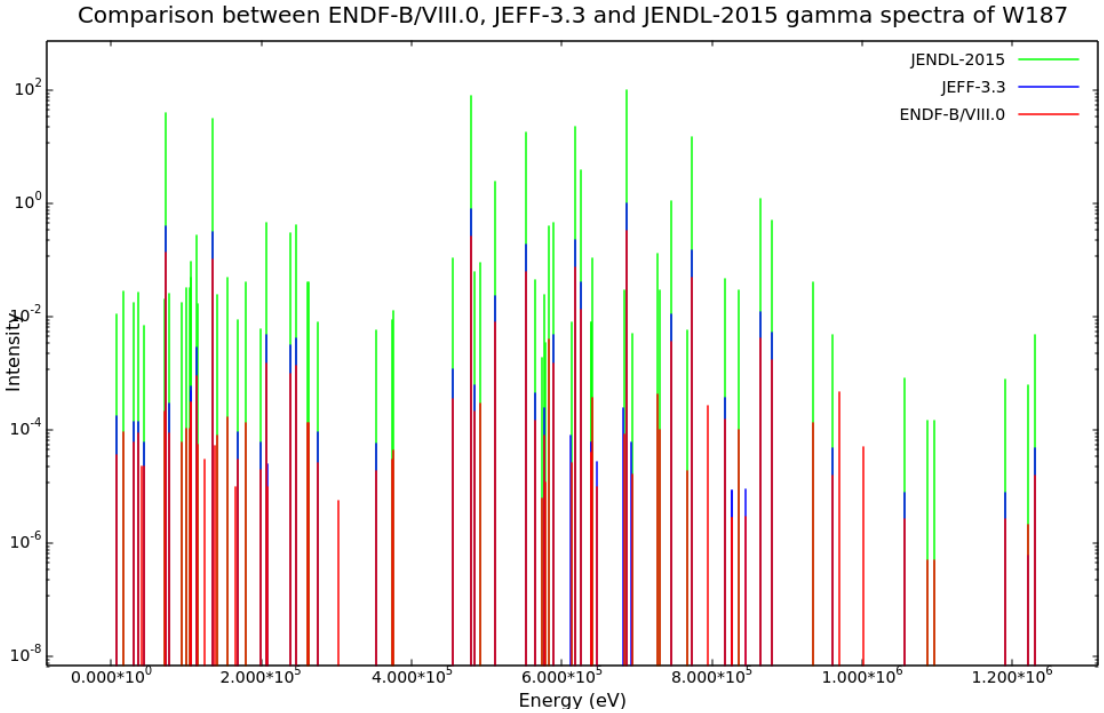
- **JEFF-3.3 (3852 nuclides), 2017 :** included DDEP, UKPADD-6.12 (2013) and UKHEDD2.6 (2008) evaluations, NUBASE and TAGS data; only evaluations having an energy balance better than 2% were taken from ENSDF

- **ENDF/B-VIII.0 DD sublibrary (3820 nuclides), 2018 :** has included many new evaluations with TAGS data and underwent a number of checks and updates, mainly on the beta intensities following β^--decay, X-ray energies for actinide nuclides

- **JENDL-2015 DDL (3236+n) :** has a new improved DD file (released in 2016), particularly for short-lived nuclides

- **IRDFF-II DD (73 nuclides), 2020 :** recommended gamma and beta nuclear decay data for residual activation products for reactions relevant to the neutron metrology community

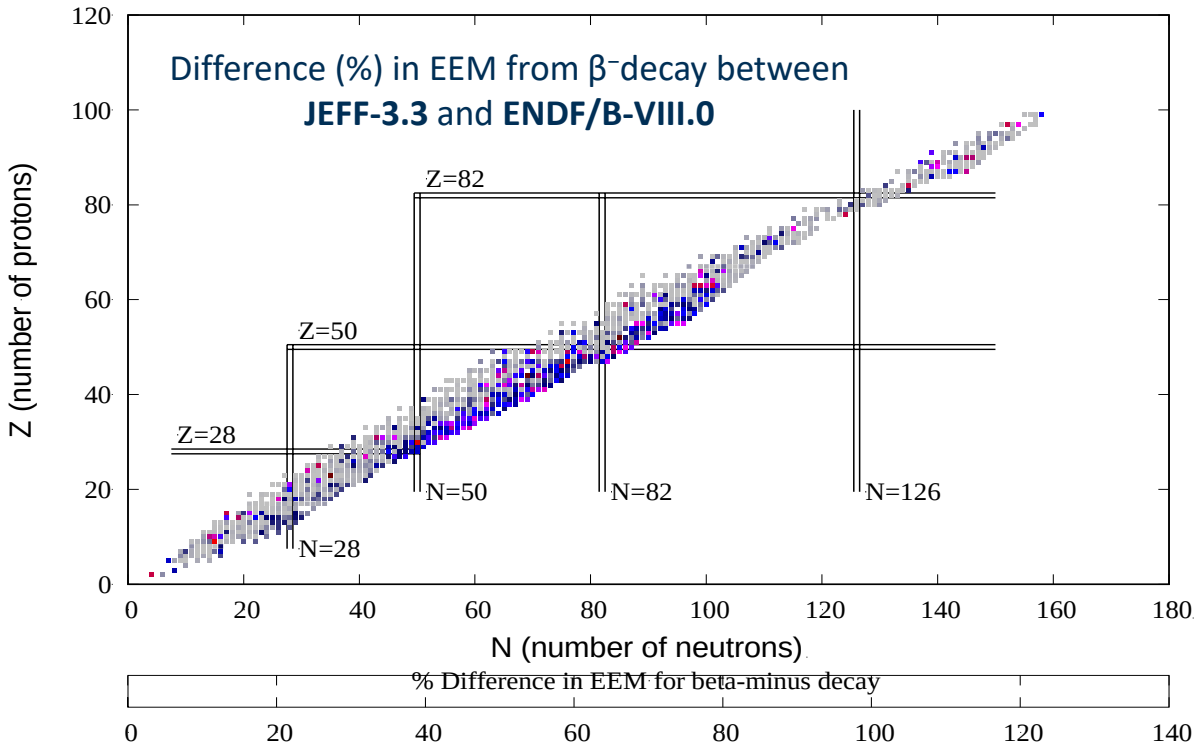
Beneficial comparisons of included decay data



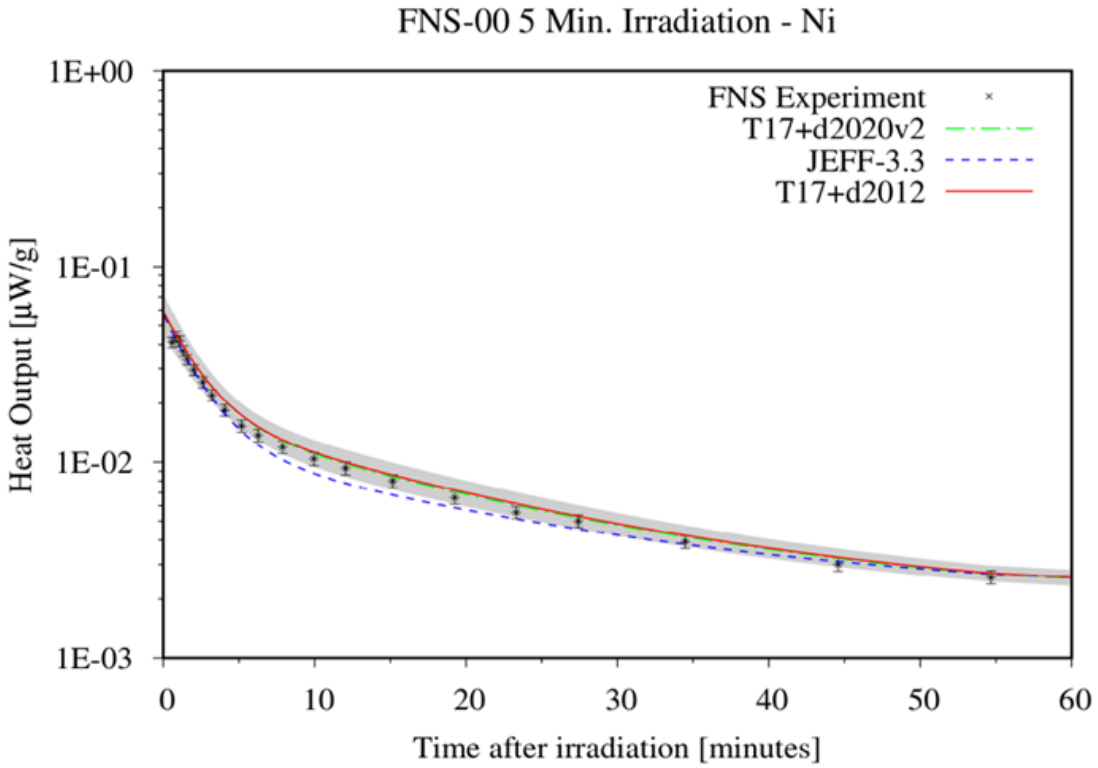
- Example of the comparisons for γ-spectrum of fusion-relevant nuclides: following ^{187}W decay between DDLs
- In most cases, JEFF-3.3 and ENDF/B-VIII.0 do not show many differences in the included γ-energies (JENDL-2015 intensities shown are not multiplied by the FD factors)

Nuclide Chart comparisons for JEFF-3.3 and ENDF/B-VIII.0 :

- $T_{1/2}$
- Q-values
- average energy values for EEM, ELP in different decay channels
- missing data (EEM or ELP values, spectral data)

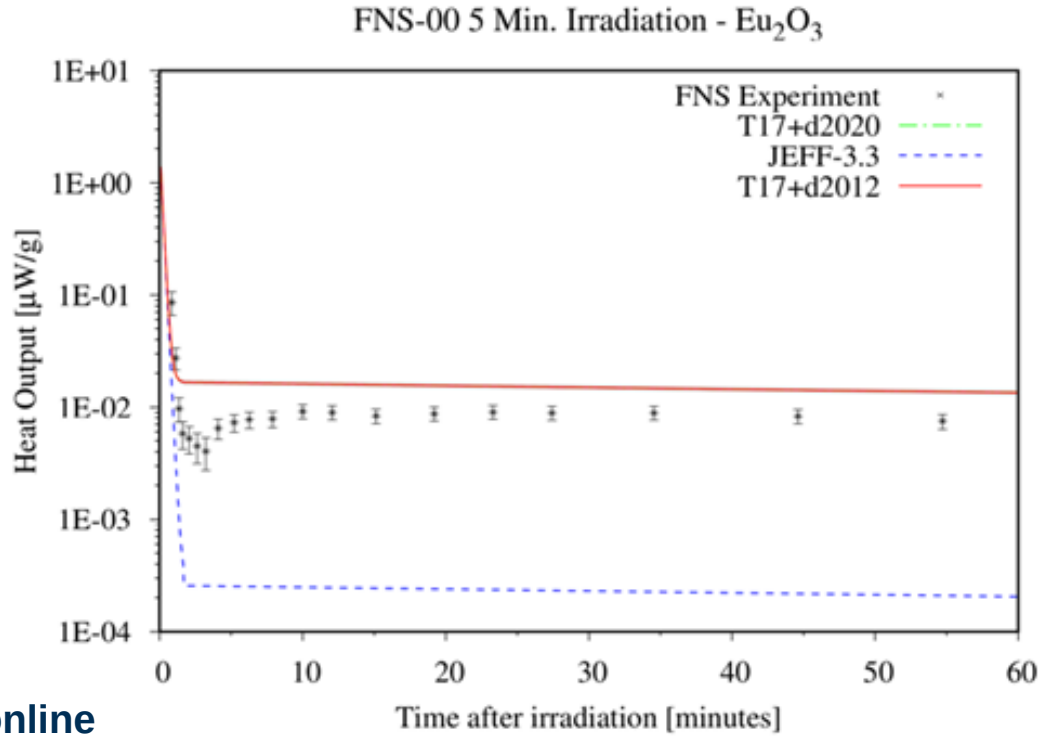


FNS decay heat benchmark: noted issues for different libraries



- **Ni-5min experiment**: no considerable differences are observed in performance of decay_2020_v2 compared to decay_2012
- FISPACT-II log file warning for this run: spectral data is <u>not</u> available for more than 20% of the nuclides that contribute to the dose rate
- pathway analysis helped to establish that the JEFF-3.3 files for Co62m and Fe61 (included in decay_2020_v2) that were contributing to the decay heat did not include the spectral data (the case of conversion from NUBASE)

Eu-5min experiment:
the discrepancy in the simulation results performed with TENDL-2017& JEFF-3.3 highlights the importance of the metastable isomers inclusion in both cross section and decay data libraries



Summary

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- The choice of a decay data library (and the cross section library) depends on the the purposes of a particular project : the checks for inclusion/consistency of the files for the considered nuclides is beneficial
(newer library version does not always guarantee the best results)
- The analysis results of the initial decay_2020_v2 test against the FNS decay heat validation suite shows promising results and has not revealed considerable differences in performance of decay_2020_v2 compared to decay_2012
- Nonetheless, decay_2020_v2 has improvements in the number of included nuclides with new decay data evaluations and contains available re-evaluations for fusion-critical nuclides from the latest releases of the decay data libraries and databases (https://fispact.ukaea.uk/nuclear-data/).
  - planned prototyping of DD files for the nuclides added in TENDL-2019 release (123): files for 116 nuclides need prototyping as soon as sufficient/experimentally confirmed nuclear decay data and/or a better-defined decay mode is available
  - release of final decay_2020 file and extensive V&V after evolving corrections of any inconsistencies

- To date, most of the included DD files contain discrete beta-spectra: spectra mean energies are often included, these are the transition probabilities and daughter level energies, meaning little or no information on neutrino energies or spectra. Continuum spectra are available for some of the fission-relevant nuclides in cases of beta delayed neutron decays. Continuum nature of beta and neutrino spectra can affect light particle heating and bremsstrahlung corrections to photon spectra (see Greg's presentation on beta-spectra)