

PAUL SCHERRER INSTITUT



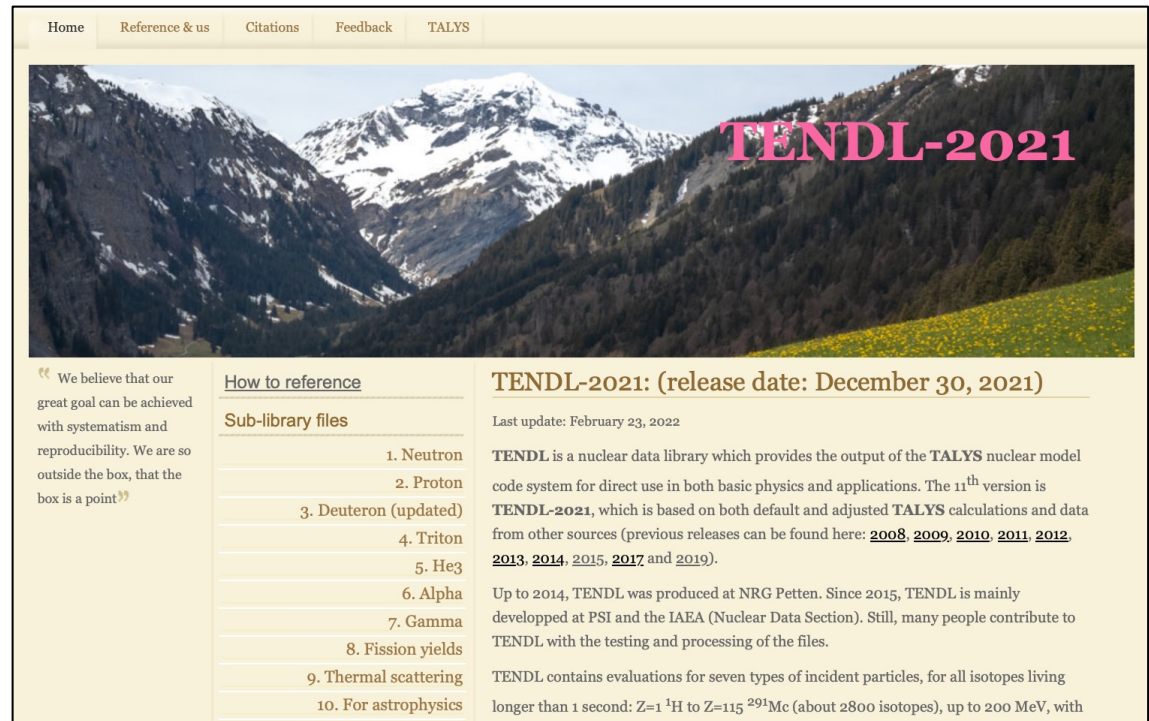
D. Rochman, A. Koning and S.C. van der Marck

The TENDL nuclear data library: for criticality calculations and more

ICNC 2023 – The 12th International Conference on Nuclear Criticality Safety,
October 1st – 6th, 2023, Sendai, Japan



- The TENDL library: what is behind ?
- Criticality applications
- Uncertainties for criticality
- More



Home Reference & us Citations Feedback TALYS

TENDL-2021

“ 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 (updated)
4. Triton
5. He3
6. Alpha
7. Gamma
8. Fission yields
9. Thermal scattering
10. For astrophysics

TENDL-2021: (release date: December 30, 2021)

Last update: February 23, 2022

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 11th version is TENDL-2021, 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](#) and [2019](#)).

Up to 2014, TENDL was produced at NRG Petten. Since 2015, TENDL is mainly developed 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 ¹H to Z=115 ²⁹¹Mc (about 2800 isotopes), up to 200 MeV, with

What is the TENDL project ?

- TENDL: TALYS evaluated nuclear data library,
- Goal: improve simulations for TENDL and/or other libraries, or solving

$$0 \leq \chi^2 \leq 1$$

$$\chi^2 = \frac{1}{n} \sum_{i=1}^n \left(\frac{C_i - E_i}{\Delta E_i} \right)^2$$

- Available at <https://tendl.web.psi.ch/home.html>
- Comes from T6 (software package)
- T6 leads to TENDL, TMC, BMC, HFR...
- See for instance [NDS 113 \(2012\) 2841](#), [ANE 51 \(2013\) 60](#), [NDS 139 \(2017\) 1](#), [NDS 155 \(2019\) 1](#)

What is the TENDL project ?

- TENDL is in fact a by-product of a series of codes,
- This is one fundamental difference with other libraries (no manual work),
- It allows to perform „TMC“ for Total Monte Carlo (uncertainty propagation)
- Methods: reproductibility & completeness, development of a portable system, and making use of the knowledge included in other libraries (JEFF, ENDF/B, JENDL),
- Background: theoretical calculations (TALYS) with experimental inputs, with original resonance evaluations,
- Impact:
 - TENDL-2008 to 2023 releases (>2800 isotopes),
 - Neutrons, protons, deuterons, tritons, He3, alpha and gamma induced,
 - all isotopes, all cross sections with covariances, 0-200 MeV,
 - more than 300 isotopes in the NEA JEFF-3.3 library,
 - more than 50 isotopes in the US ENDF/B-VIII.0 library,
 - more than 450 publications using TENDL

TENDL: from MF-1 to MF-40, 200 MeV

- ☞ MF-1: Description + fission parameters
- ☞ MF-2: Resonance parameters (Reich-Moore or Multi-level Breit Wigner)
- ☞ MF-3: Cross sections (n,tot), (n,el), (n,non), (n,inl_i), ..., (n,γ), (n,p_i), (n,α_i)
- ☞ MF-4: Elastic angular distribution (Legendre Polynomials)
- ☞ MF-5: Fission neutron spectrum
- ☞ MF-6: Double differential distributions and spectra for (n,2n), ..., (n,α_i)
- ☞ MF- 8-10: Isomeric cross sections
- ☞ MF- 12-15: Gamma yields, angular distributions and spectra
- ☞ MF- 31-32-33-34-35, 40: nubar, Resonance parameter, cross section, angular distribution and fission neutron spectrum, radionuclide production.



Available online at www.sciencedirect.com

SciVerse ScienceDirect

Nuclear Data Sheets 113 (2012) 2841–2934

**Nuclear Data
Sheets**

www.elsevier.com/locate/nds

Modern Nuclear Data Evaluation with the TALYS Code System

A.J. Koning* and D. Rochman



Available online at www.sciencedirect.com

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Nuclear Data Sheets 155 (2019) 1–55

**Nuclear Data
Sheets**

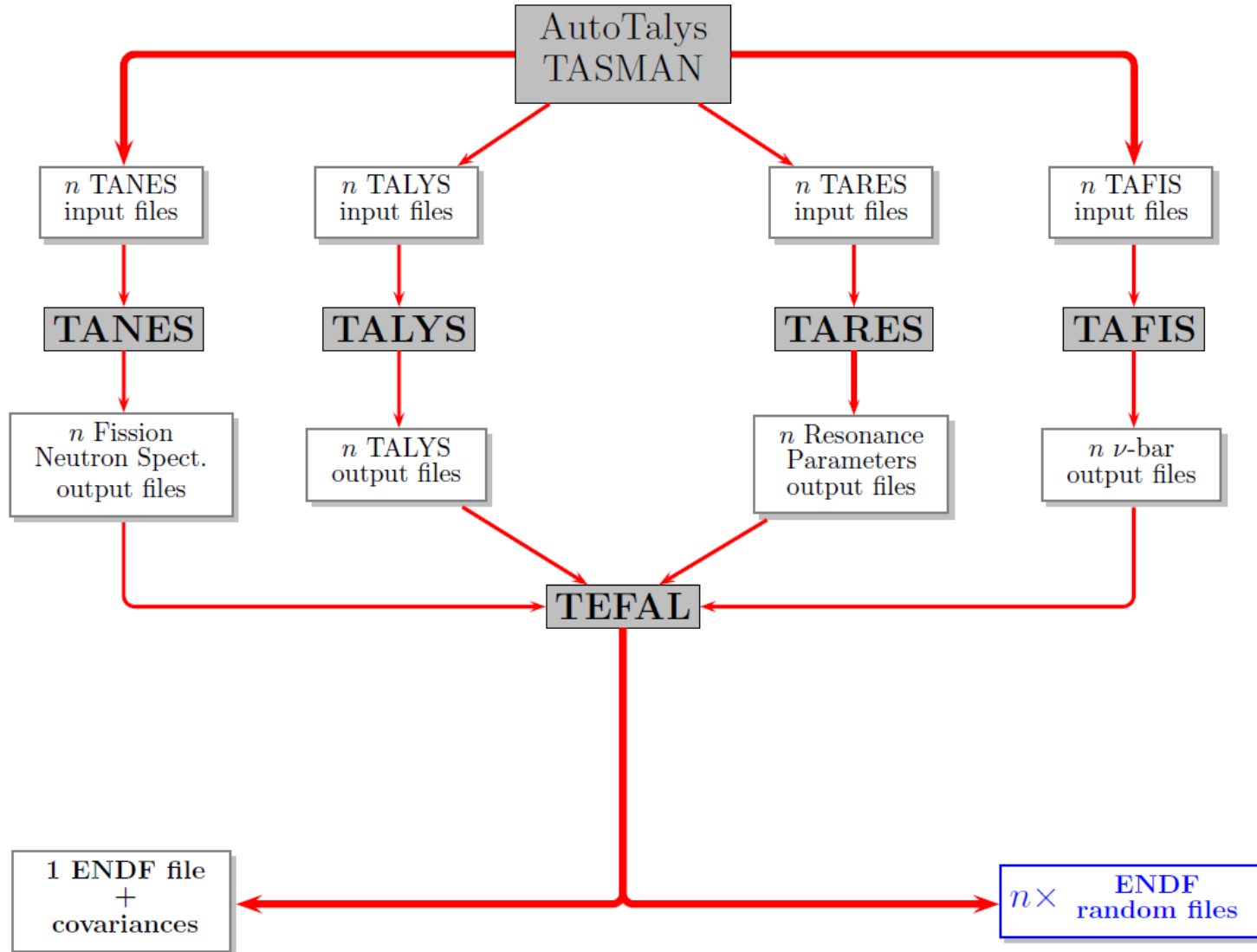
www.elsevier.com/locate/nds

**TENDL: Complete Nuclear Data Library for Innovative Nuclear Science and
Technology**

A.J. Koning,^{1,2,*} D. Rochman,³ J.-Ch. Sublet,¹ N. Dzysiuk,^{4,5} M. Fleming,^{6,7} and S. van der Marck⁴

The TENDL library

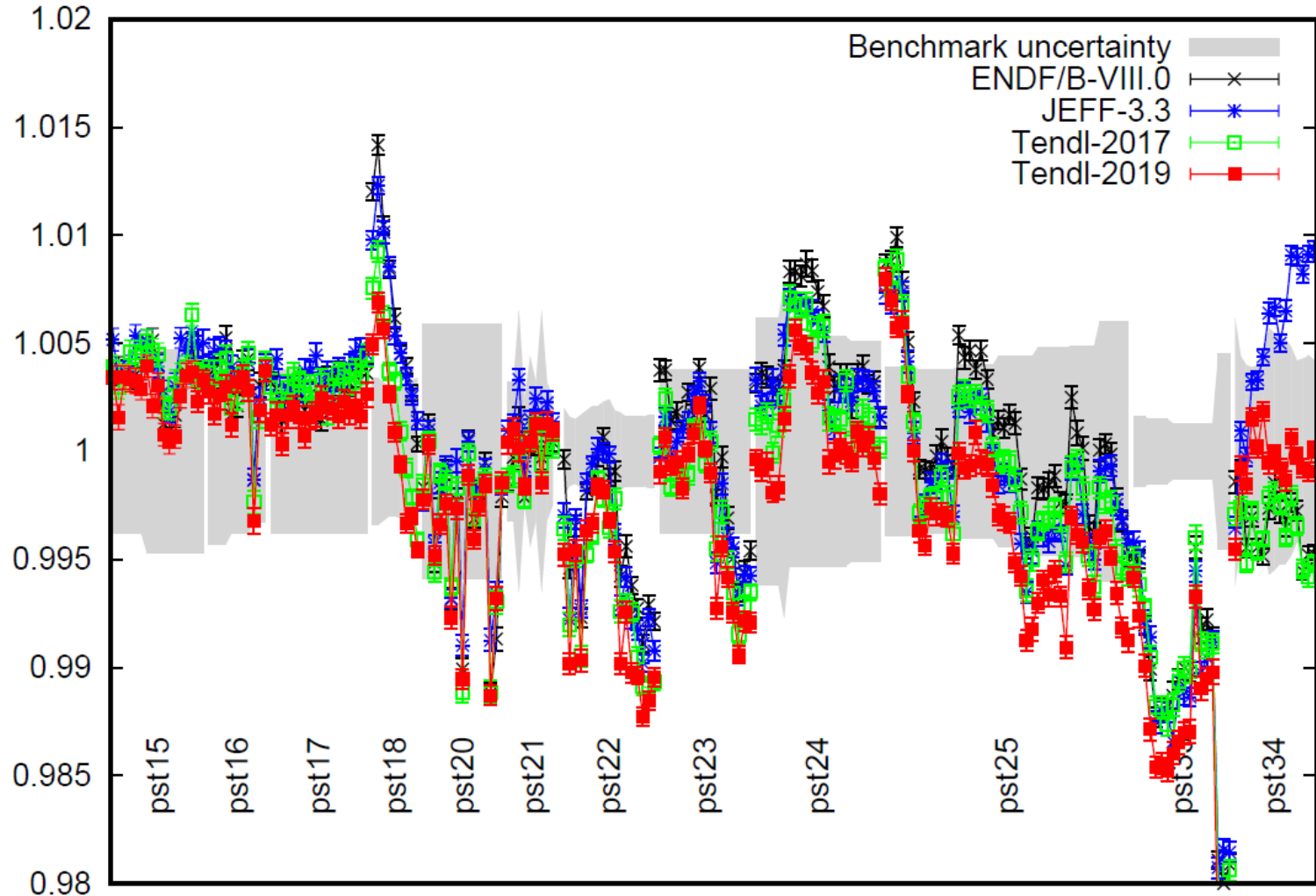
- Method: Quality evaluation, production automation, open source



TENDL: validation for criticality benchmarks

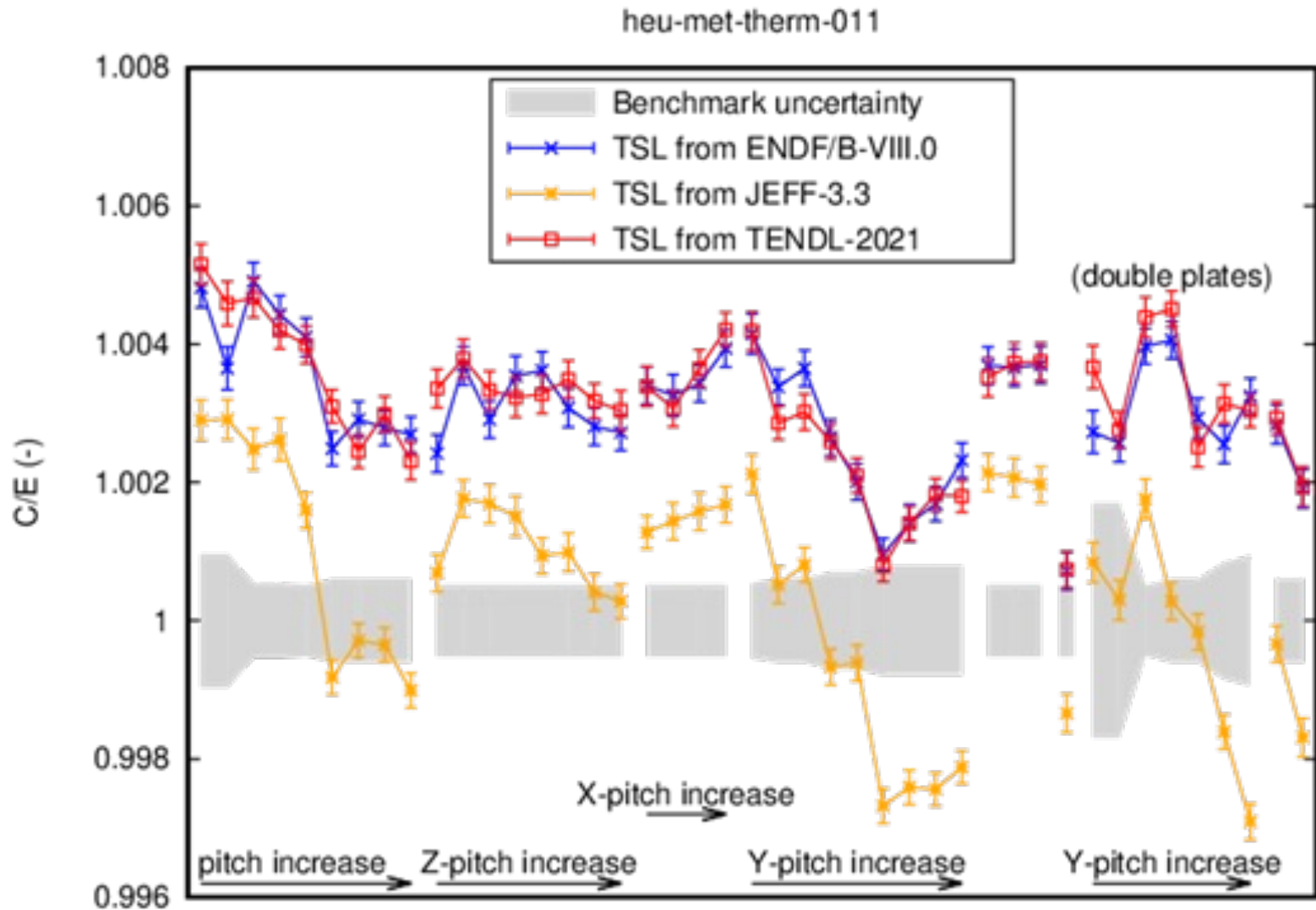
- Example on PST cases

pu-sol-therm (2)



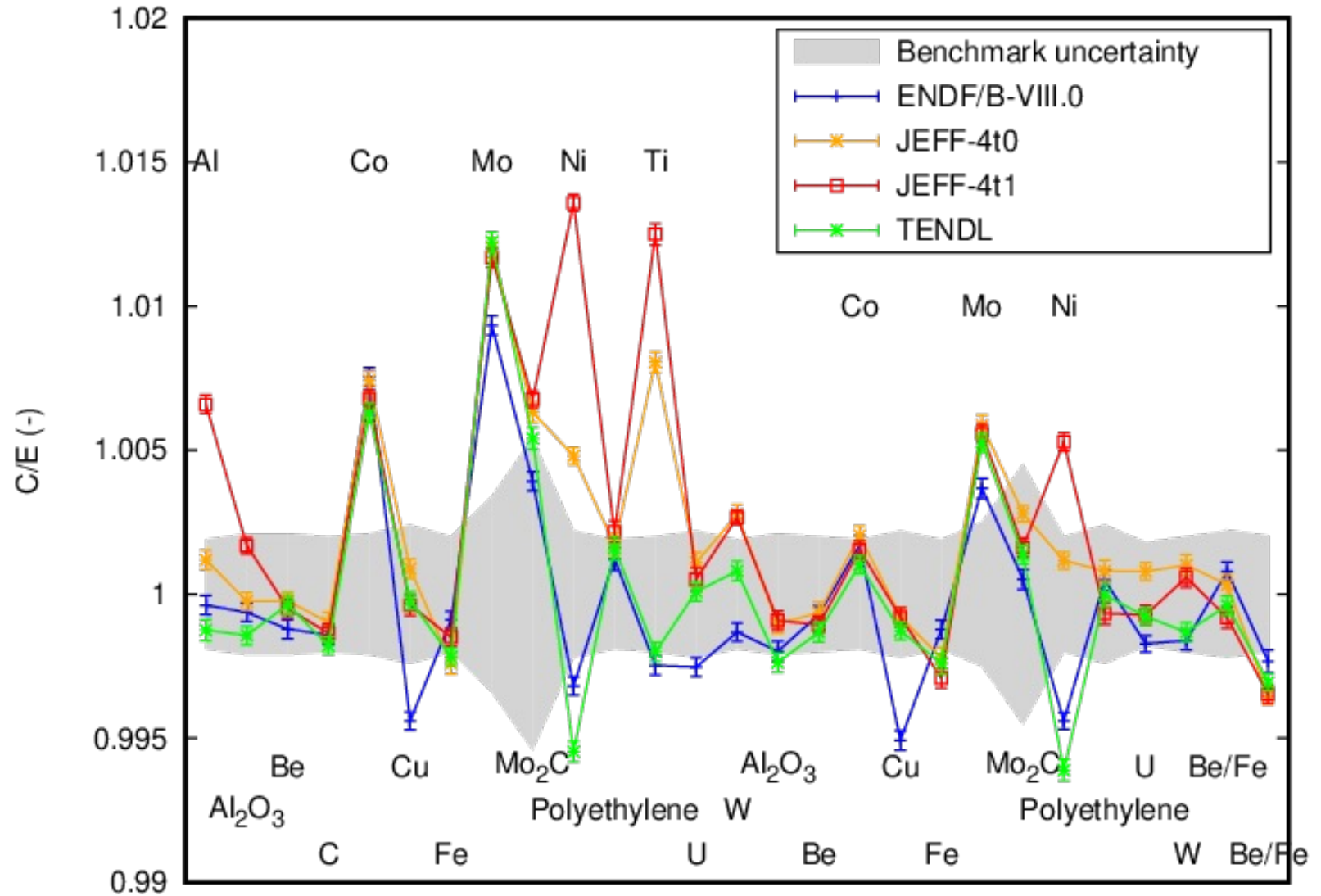
TENDL: validation for criticality benchmarks

- Example on HMT-11 cases



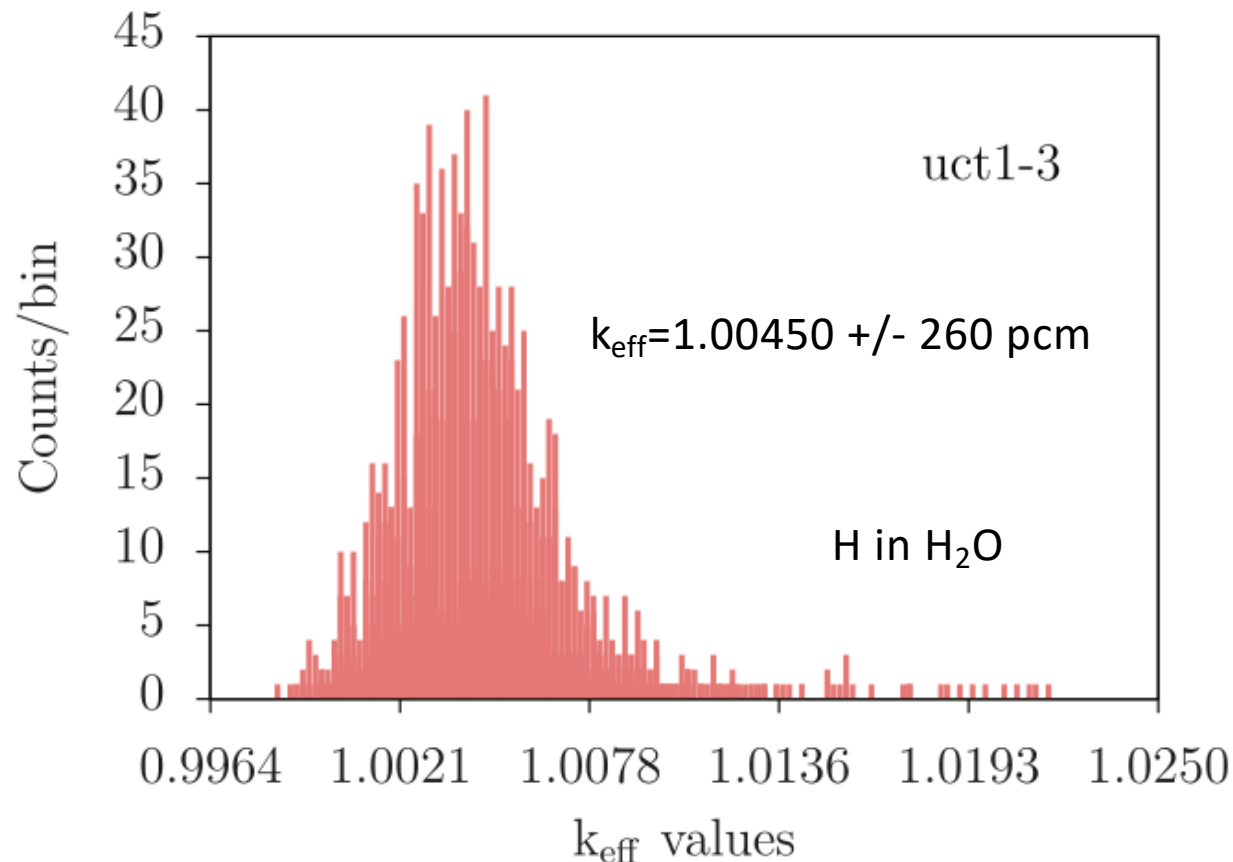
TENDL: validation for criticality benchmarks

- Example on HMF-84 cases



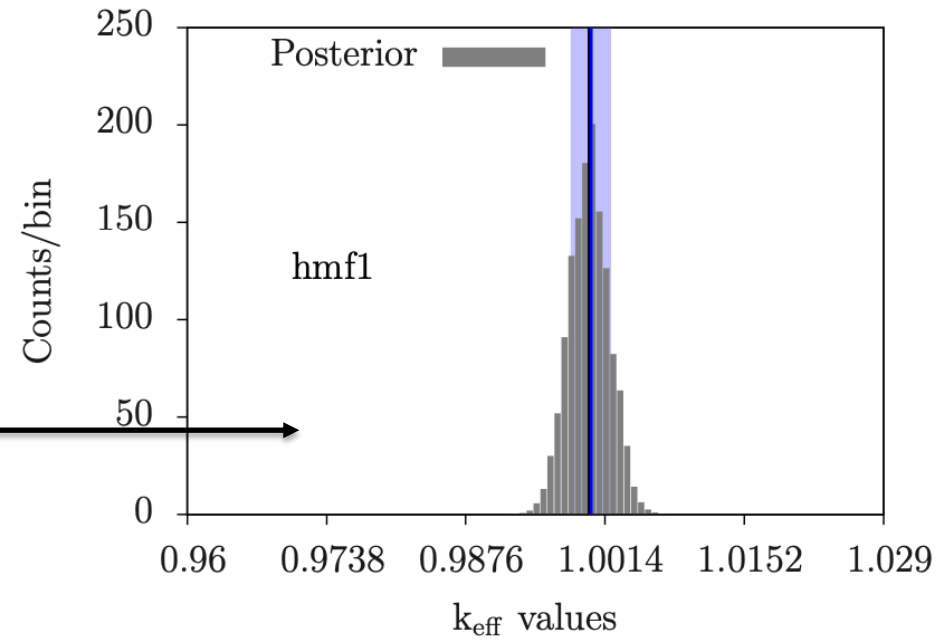
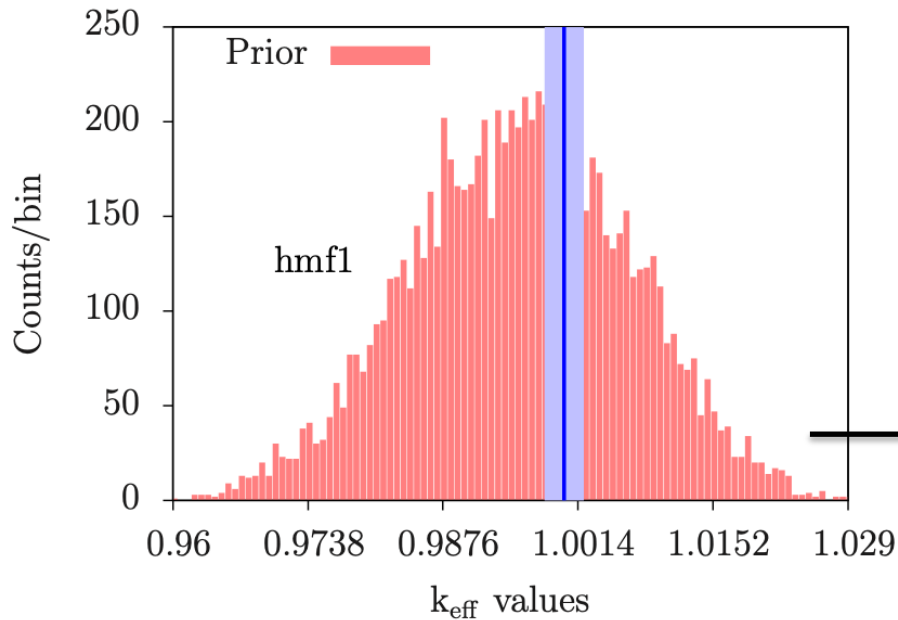
TENDL: uncertainties due to nuclear data

- Uncertainties for criticality benchmarks due to many aspects of nuclear data:
 - Cross sections, nubar, pfns
 - Angular distribution (shielding)
 - Thermal scattering data (TSL)
 - Based on covariances (sensitivity) or random files (TMC)



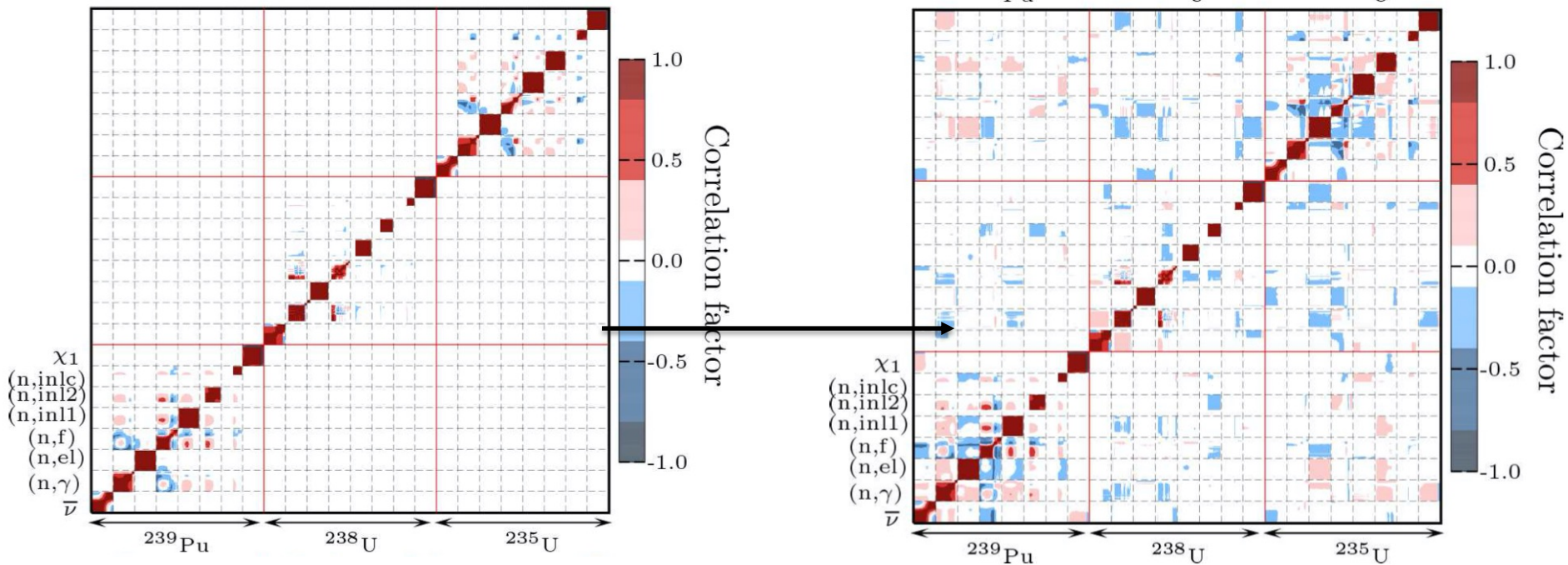
TENDL + ICSBEP = nuclide correlation

- Based on criticality benchmarks and the BMC method:
 - Posterior uncertainties
 - Correlations between isotopes



TENDL + ICSBEP = nuclide correlation

- Based on criticality benchmarks and the BMC method:
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TENDL-2023: new library

- Method: Quality evaluation, production automation, open source

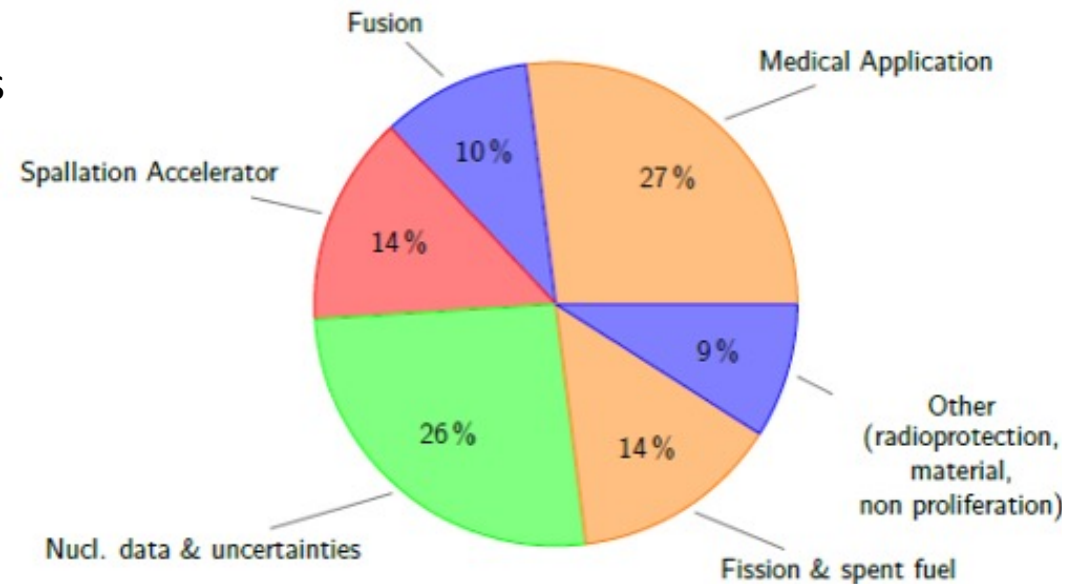
The screenshot shows the website for the TALYS-based evaluated nuclear data library. The main heading is "TALYS-based evaluated nuclear data library". Below the navigation menu (Home, Reference & us, Citations, Feedback, TALYS), there is a large banner image of a lake with the text "TENDL-2023" overlaid in pink. To the left of the banner, there is a quote: "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". Below the banner, there are several sections: "How to reference", "Sub-library files" (listing 10 items: Neutron, Proton, Deuteron, Triton, He3, Alpha, Gamma, Fission yields, Thermal scattering, For astrophysics), "Application libraries & tar files (ENDF, GND, ACE, PENDF...)", "V&V", and "Total Monte Carlo files" (listing 4 items: Random ENDF-6 files from other libraries, Random ACE files based on ENDF/B-VII.1). The footer contains the copyright information: "© PSI Villigen, 2023 | IAEA NDS" and a "credit here" link.

New:

- • model variation for astrophysical reaction rates and MACS
- ENDF-6 files up to 600 MeV for accelerator application

Conclusions

- TENDL is performing well on criticality benchmarks
- Consistent format, processing, included information
- With covariance and random files for uncertainty propagation
- One unique information source for various applications
- Open-source software to produce the library
- Open unexpected opportunities



Wir schaffen Wissen – heute für morgen

