JEFF

The Joint Evaluated nuclear data library for Fission and Fusion

Arjan Plompen, EC-JRC Geel, Belgium

WPEC 13 May 2021

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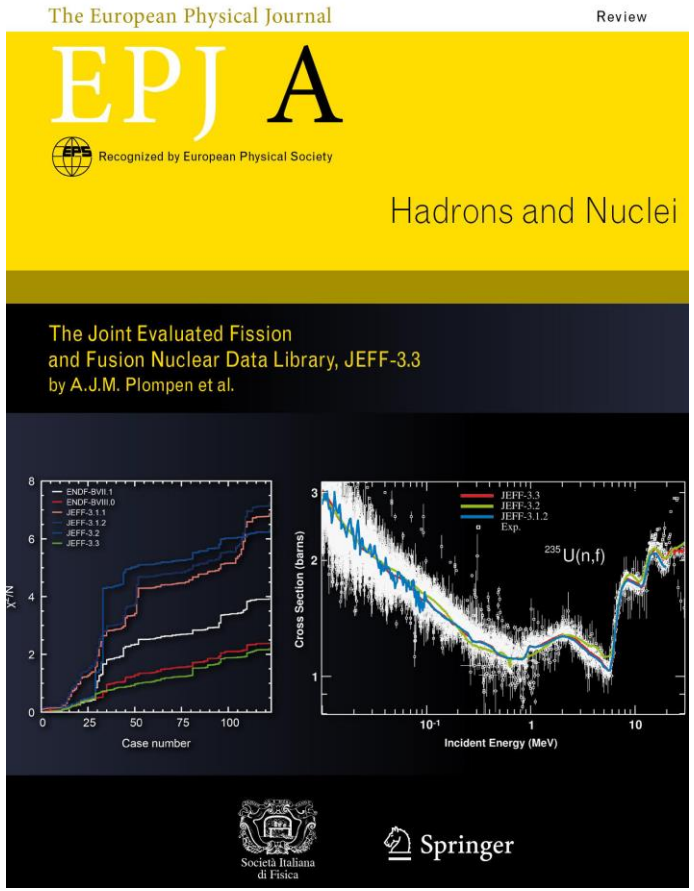

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THE EUROPEAN PHYSICAL JOURNAL A

Review

The joint evaluated fission and fusion nuclear data library, JEFF-3.3

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- 80 authors
- 36 affiliations, 30 EU
- Description of the library
  - JEFF-3.3 and JEFF-3.2
- Benchmarking and impact
- True joint effort

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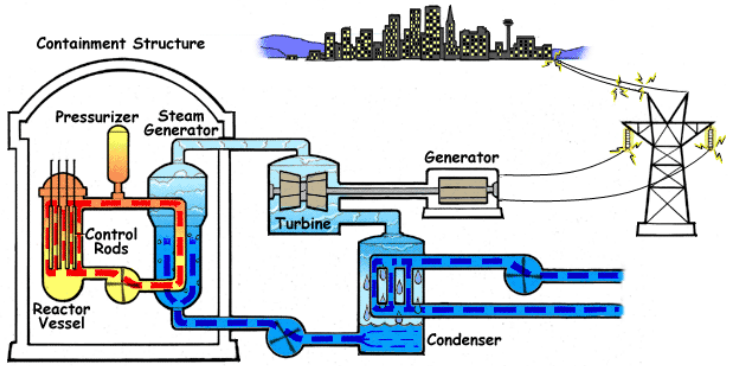
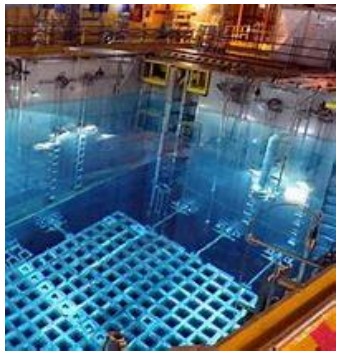
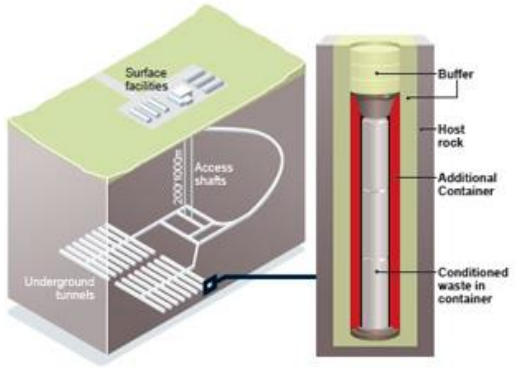
European Commission

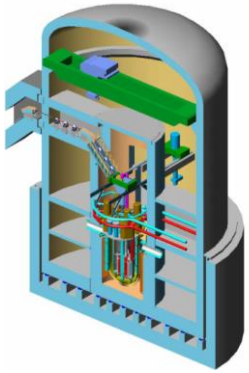
JEFF-4

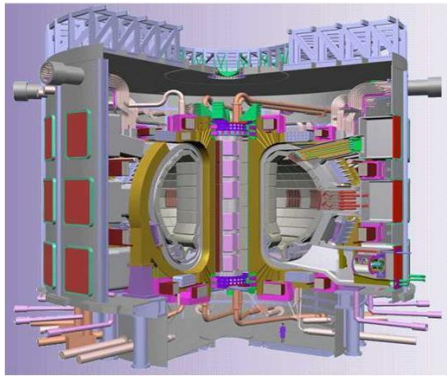
- Target date: December 2024
- Status: JEFF-4T0, October 2020
- Goals
  - True general purpose
    - Broaden range of application
  - Best available science for users
  - Improved focus on stakeholders
  - Improved production methods
  - Improved uncertainty estimation
  - Unadjusted & adjusted library

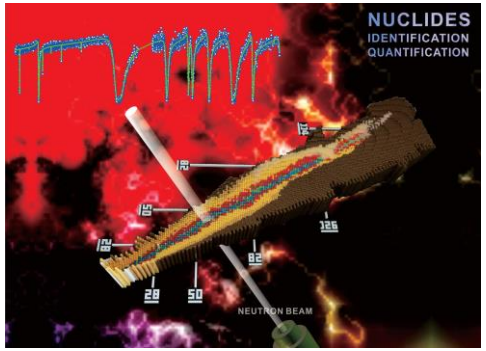


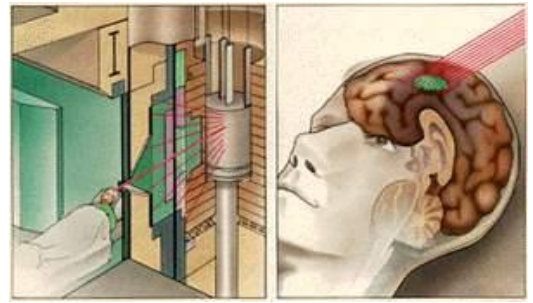












European Commission

Recommendations JEFF Stakeholder meeting
NEA/MBDAV/DOC(2019)5

I. Ensure JEFF-4 is developed targeting its potential use in future industry applications

- New fuel development: ATF, higher enrichment, innovative FC
- Small modular reactors
- Decomm., waste, final disposal
- ADS (MYRRHA)
- Fusion (IFMIF/DONES etc.)
- Non-energy applications
  - Medical (radionuclides production)
  - Academia (astrophysics, …)

II. Demonstrate the impact, in applications of interest, of updating to a new JEFF library

III. Function of the Data Bank: strengthen QA infrastructure dedicated to JEFF and actively manage JEFF's user base

- *Enhance the co-ordination role of the Data Bank JEFF – stakeholders*
- Enhance role Data Bank in pre-release V&V phases of JEFF libraries

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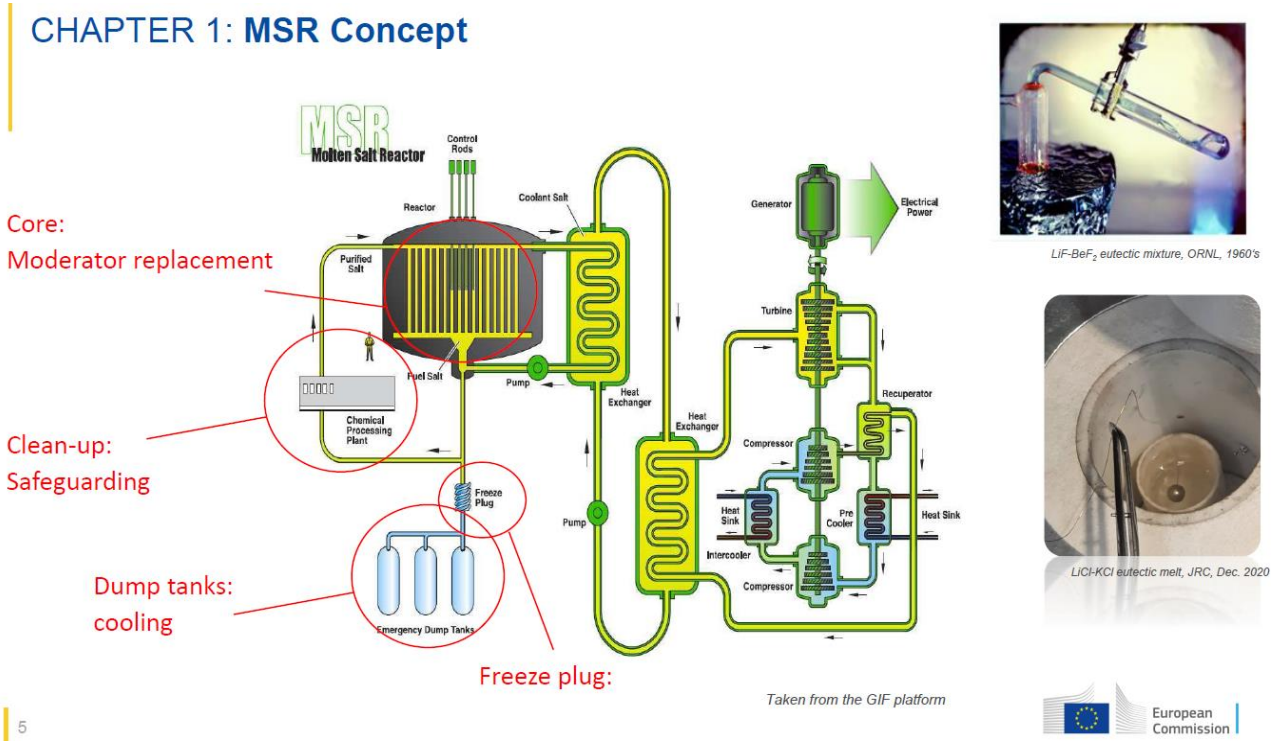
Small modular reactors, Molten salt reactors

- No sensitivity analysis, so difficult to identify and prioritize data needs.
- MSRs are innovative and specificities for predictive and modeling needs of neutronics and source terms are not clear.



Slide Ondrej Benes

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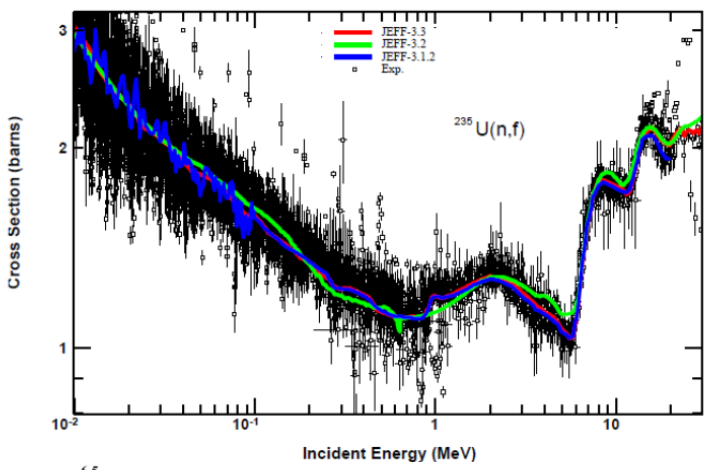
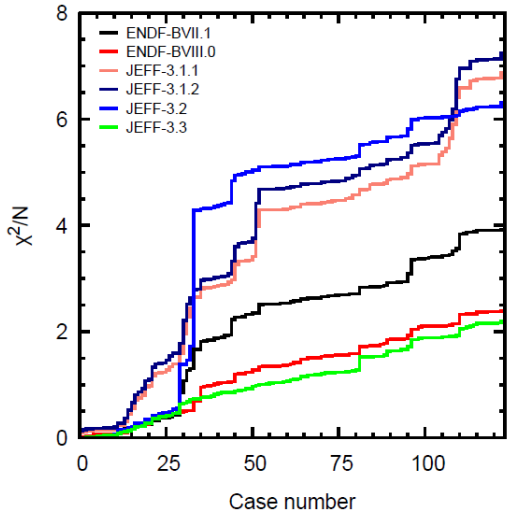
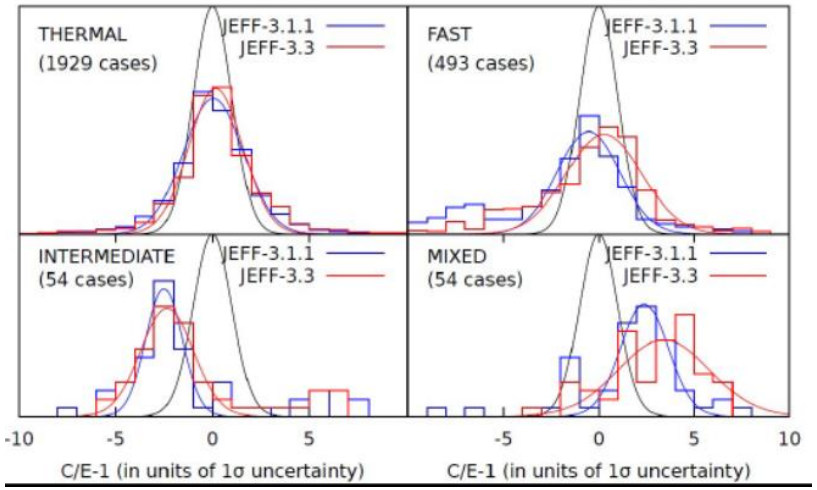
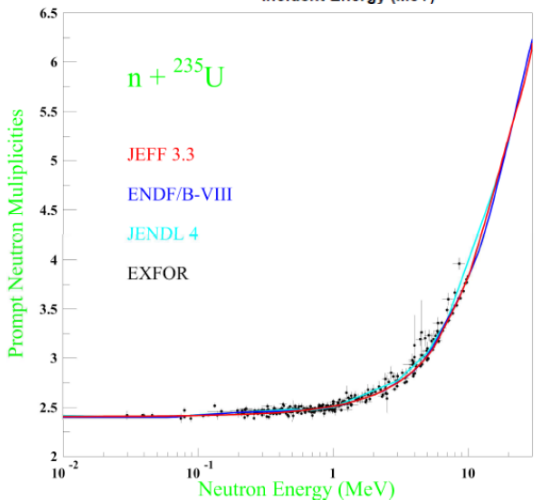
Challenge: Best physics to applied performance









- We achieved improvement for selected benchmarks.
- How well do we do in real applications?
- How relevant is our benchmarking?
- Is best physics working in benchmarks … our targeted applications?

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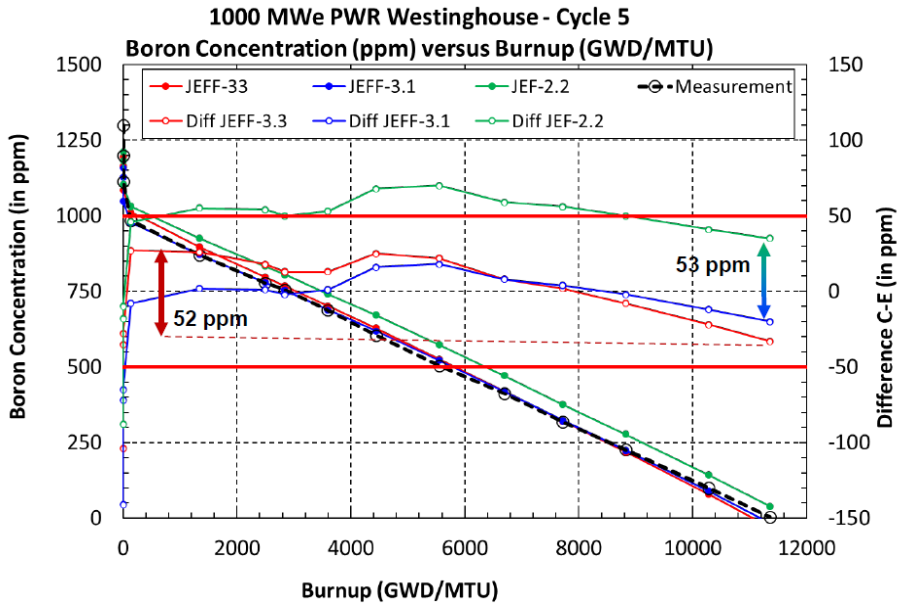
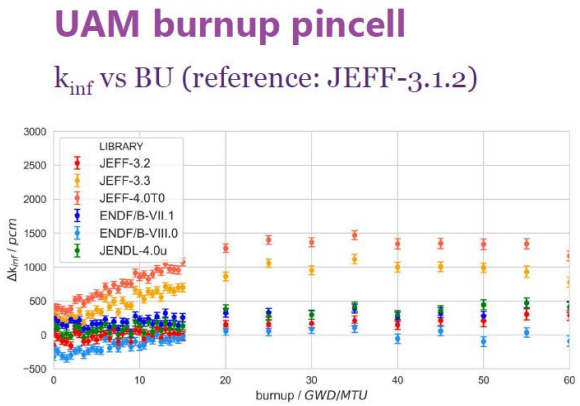
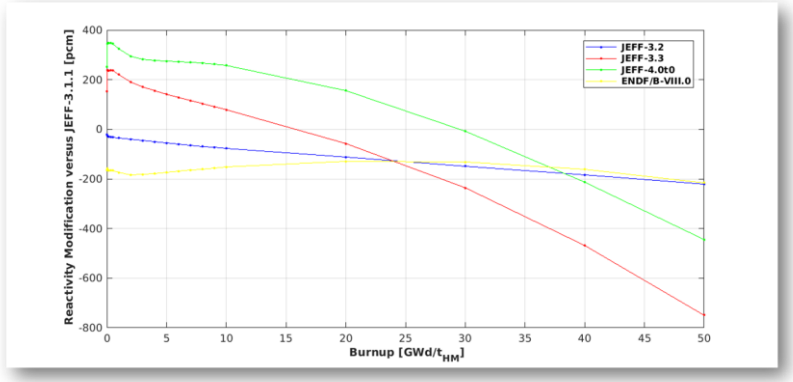
Challenge: Reactor applications

jefdoc-1991, O. Cabellos; jefdoc-1996 D. Bernard; jefdoc-2000 R. Ichou (Apr 2020)
jefdoc-2017 L. Fiorito; jefdoc-2022 A. Trkov (Nov 2020) ; jef-mtg Jan 2021

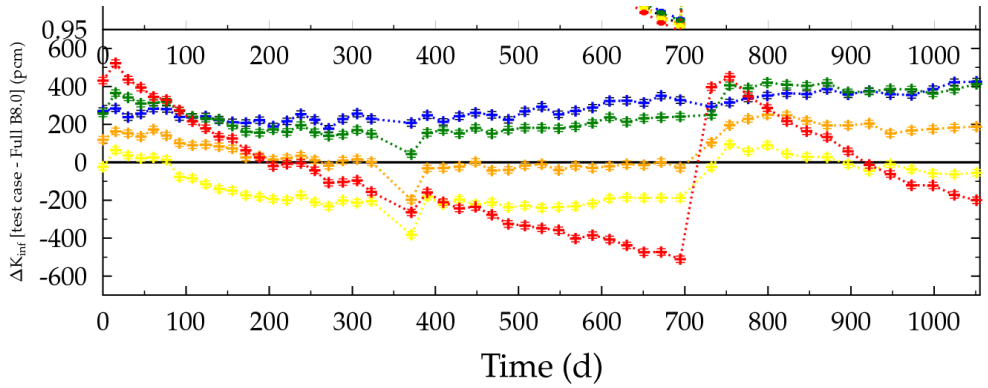






LWR pin cell

- Significant trends with burnup
  - Major actinides
  - FY
  - Some FP cross sections



GU3, sfcompo, Physor 2020

Challenge: Reactor and spent fuel applications

D. Rochman, JEFF jan. 2021

- PIE, 52 MWd/kg, UO2
- Significant role of FY/DD (FY)
- Large difference Sm-151
- Significant differences for FP

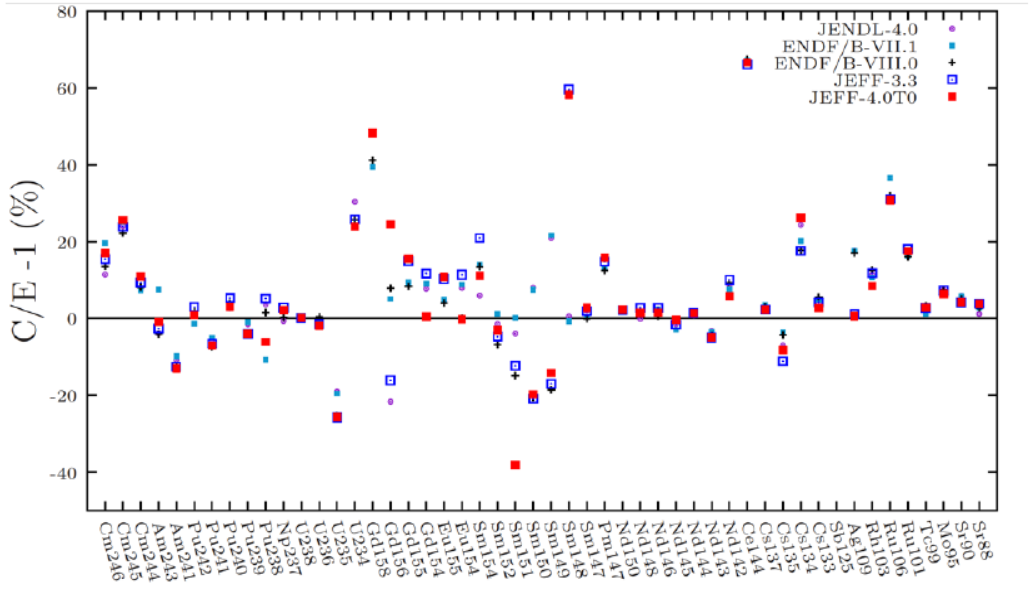
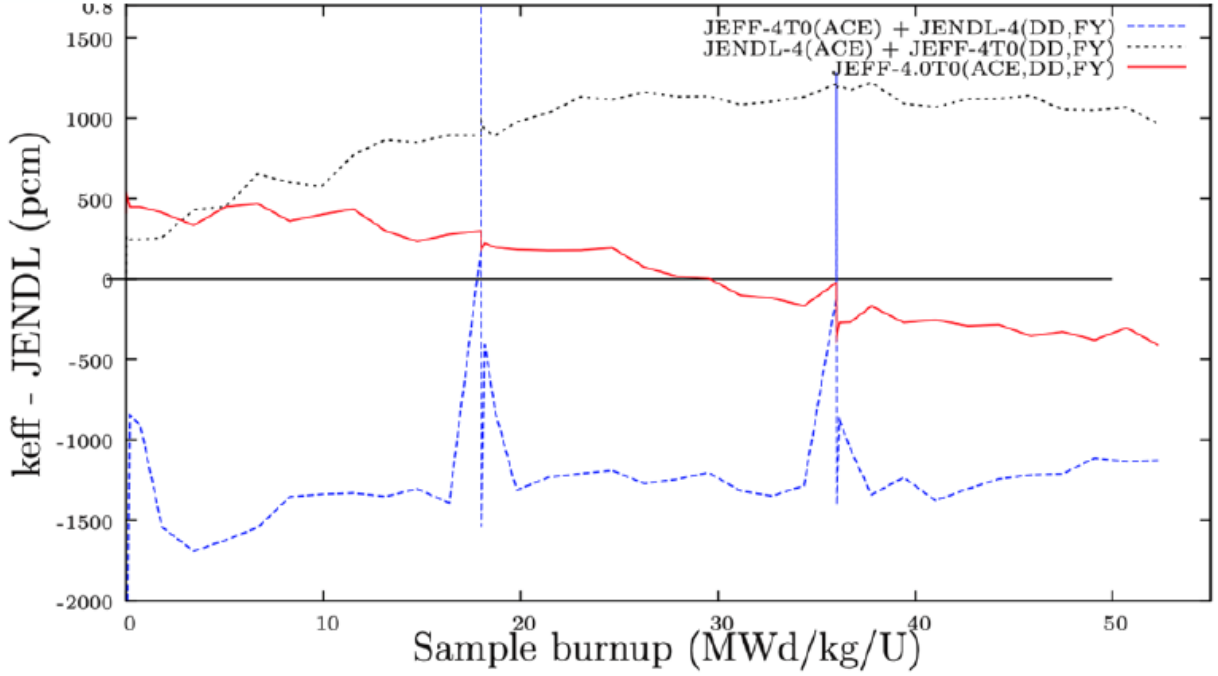


Figure 4: PIE Swiss UO2 sample - 52 MWd/kgU - Isotopic concentration comparison



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Challenges: benchmarks matching applications

- Use of sensitivity profiles with representativity factors
  - Which benchmarks have similar sensitivity profiles as a PWR for boron let-down or for inventory evolution (O.Cabellos nov. 2020 Pu-pst034)?
  - Can we be more systematic about that?
  - From pin-cell trends to icsbep?
- Use of reaction rate ratios in critical benchmarks (O.Cabellos, apr., nov. 2020)
  - Reaction rates in benchmark spectra from thermal to fast.
  - U5 ratios in P9 benchmarks to test U5 cross section ratios directly (no impact on spectrum)
  - U5 ratios in U5 benchmarks to include spectrum modification effect.
  - Similar for Pu ratios
  - Use of cross ratios
- Reaction ratios to test leakage?

JEFF-4t0

jefdoc-2018, D. Foligno, nov 2020

- Changes due to feedback
- TENDL replacing legacy files
- New evaluations not in JEFF-3.3

	Isotope	JEFF-3.3	JEFF-4T0	Comments
IRSN-2020				
	8-O-16g	LANL-2005	IRSN-2020	RRR(IRSN-low)—>TENDL-2019
	45-Rh-103g	CAD-BRC-2005	IRSN-2020	RRR(IRSN)—>TENDL-2019
	64-Gd-155g	NEA-1986	IRSN-2020	RRR(IRSN)—>TENDL-2019
	64-Gd-156g	NEA-1982	IRSN-2020	RRR(IRSN)—>TENDL-2019
	64-Gd-157g	NEA-1982	IRSN-2020	RRR(IRSN)—>TENDL-2019
	64-Gd-158g	NEA-1982	IRSN-2020	RRR(IRSN)—>TENDL-2019
	64-Gd-160g	NEA-1982	IRSN-2020	RRR(IRSN)—>TENDL-2019
	92-U-235g	IRSN-CEA-2014	IRSN-2020	RRR(IRSN)—>TENDL-2019
KIT-2020				
	74-W-180g	NRG-TENDL-2015	KIT-2020	
	74-W-182g	FZK-IRS-2005	KIT-2020	
	74-W-183g	FZK-IRS-2005	KIT-2020	
	74-W-184g	FZK-IRS-2005	KIT-2020	
	74-W-186g	FZK-IRS-2005	KIT-2020	

	Isotope	JEFF-3.3	JEFF-4T0	Comments
CAD-2020				
	43-Tc-99g	CEA-NRG-2005	CAD-2020	RRR(CEA-JRC)—>TENDL-2019
	47-Ag-107g	NRG-TENDL-2015	CAD-2020	RRR(CEA-JRC)—>TENDL-2019
	47-Ag-109g	NEA-1983	CAD-2020	RRR(CEA-JRC)—>TENDL-2019
	63-Eu-151g	NEA-1982	CAD-2020	RRR(CEA)—>TENDL-2019
	63-Eu-153g	JAEA-2009	CAD-2020	RRR(CEA)—>TENDL-2019
	63-Eu-154g	CNDC-BNL-2005	CAD-2020	RRR(CEA)—>TENDL-2019
	63-Eu-155g	CNDC-1999	CAD-2020	RRR(CEA)—>TENDL-2019
	71-Lu-173g	NRG-TENDL-2015	CAD-2020	RRR(CEA)—>TENDL-2019
	71-Lu-175g	NRG-TENDL-2015	CAD-2020	RRR(CEA)—>TENDL-2019
	71-Lu-176g	NRG-TENDL-2015	CAD-2020	RRR(CEA)—>TENDL-2019
	94-Pu-238g	JAEA-2010	CAD-2020	RRR(CEA)—>TENDL-2019
	94-Pu-239g	IRSN-CEA-2016	CAD-2020	RRR(JEFF-3.2)+HE(JEFF-3.3)
	94-Pu-240g	CEA-2016	CAD-2020	RRR(CEA)—>TENDL-2019
	94-Pu-242g	ENEA-IJS-1998	CAD-2020	RRR(CEA)—>TENDL-2019
	95-Am-241g	CEA-2012	CAD-2020	RRR(CEA)—>TENDL-2019

JEFF-4t0

jefdoc-2018, D. Foligno, nov 2020

- Updates to adopted evaluations
- Some backing up
- New TSL H in H2O (Bariloche)

	Isotope	JEFF-3.3	JEFF-4T0	Comments
ENDF/B-VIII.0				
	1-H-1g	LANL-2005	ENDF/B-VIII.0	ENDF/B-VIII.0 == LANL-2016
	1-H-3g	LANL-2001	ENDF/B-VIII.0	ENDF/B-VIII.0 == LANL-2001
	2-He-4g	JAERI-1987	ENDF/B-VIII.0	ENDF/B-VIII.0 == LANL-2010
	3-Li-6g	LANL-2006	ENDF/B-VIII.0	ENDF/B-VIII.0 == LANL-2017
	3-Li-7g	LANL-1988	ENDF/B-VIII.0	ENDF/B-VIII.0 == LANL-1988
	5-B-10g	LANL-2006	ENDF/B-VIII.0	ENDF/B-VIII.0 == LANL-2017
	5-B-11g	LANL-1989	ENDF/B-VIII.0	ENDF/B-VIII.0 == LANL-1989
	6-C-12g	LANL-ORNL-1996	ENDF/B-VIII.0	ENDF/B-VIII.0 == LANL-ORNL-2015
	27-Co-59g	ANL-ORNL-1989	ENDF/B-VIII.0	ENDF/B-VIII.0 == LANL-ORNL-2016
JENDL-4u				
	9-F-19g	CNDC-ORNL-1990	JENDL-4u	JENDL-4.0 == JAERI-1989
	95-Am-242g	MINSK-1997	JENDL-4u	JENDL-4.0 == JAEA-2010
	95-Am-242m	MINSK-1996	JENDL-4u	JENDL-4.0 == JAEA-2010
	98-Cf-251g	NEA-1982	JENDL-4u	JENDL-4.0 == JAEA-2010
	98-Cf-252g	NEA-1982	JENDL-4u	JENDL-4.0 == JAEA-2010

	Isotope	JEFF-3.3	JEFF-4T0	Comments
JEFF-3.1.1				
	72-Hf-174g	CEA-AMEC-2016	JEFF-3.1.1	JEFF-3.1.1 == CAD-2005
	72-Hf-176g	CEA-AMEC-2016	JEFF-3.1.1	JEFF-3.1.1 == CAD-2005
	72-Hf-177g	CEA-AMEC-2016	JEFF-3.1.1	JEFF-3.1.1 == CAD-2005
	72-Hf-178g	CEA-AMEC-2016	JEFF-3.1.1	JEFF-3.1.1 == CAD-2005
	72-Hf-179g	CEA-AMEC-2016	JEFF-3.1.1	JEFF-3.1.1 == CAD-2005
	72-Hf-180g	CEA-AMEC-2016	JEFF-3.1.1	JEFF-3.1.1 == CAD-2005

JEFF-4t0

- Some bugfixing

1-H-2g	48-Cd-110g	54-Xe-124g	91-Pa-232g	96-Cm-242g
2-He-3g	48-Cd-111g	54-Xe-126g	91-Pa-233g	96-Cm-243g
4-Be-9g	48-Cd-112g	54-Xe-127g	92-U-232g	96-Cm-244g
7-N-14g	48-Cd-113g	54-Xe-128g	92-U-233g	96-Cm-245g
7-N-15g	48-Cd-114g	54-Xe-129g	92-U-234g	96-Cm-246g
11-Na-23g	48-Cd-116g	54-Xe-130g	92-U-237g	96-Cm-247g
24-Cr-50g	49-In-113g	54-Xe-131g	92-U-238g	96-Cm-248g
24-Cr-52g	49-In-115g	54-Xe-132g	92-U-241g	96-Cm-249g
24-Cr-53g	50-Sn-112g	54-Xe-133g	93-Np-235g	96-Cm-250g
24-Cr-54g	50-Sn-113g	54-Xe-134g	93-Np-236g	97-Bk-247g
25-Mn-55g	50-Sn-114g	54-Xe-135g	93-Np-237g	97-Bk-249g
26-Fe-54g	50-Sn-115g	54-Xe-135m	93-Np-238g	97-Bk-250g
26-Fe-56g	50-Sn-116g	54-Xe-136g	93-Np-239g	98-Cf-249g
26-Fe-57g	50-Sn-117g	79-Au-197g	94-Pu-236g	98-Cf-250g
26-Fe-58g	50-Sn-118g	82-Pb-206g	94-Pu-241g	98-Cf-253g
28-Ni-59g	50-Sn-119g	82-Pb-207g	95-Am-243g	98-Cf-254g
29-Cu-63g	50-Sn-120g	82-Pb-208g	95-Am-244g	99-Es-253g
29-Cu-65g	53-I-127g	83-Bi-209g	95-Am-244m	99-Es-254g
48-Cd-106g	53-I-129g	90-Th-232g	96-Cm-240g	99-Es-255g
48-Cd-108g	54-Xe-123g	91-Pa-231g	96-Cm-241g	100-Fm-255g

- TENDL updates

6-C-13g	16-S-32g	20-Ca-43g	23-V-51g	28-Ni-63g	33-As-71g	36-Kr-80g	39-Y-89g	42-Mo-93g	44-Ru-105g
8-O-17g	16-S-33g	20-Ca-44g	24-Cr-51g	28-Ni-64g	33-As-72g	36-Kr-82g	39-Y-89m	42-Mo-94g	44-Ru-106g
8-O-18g	16-S-34g	20-Ca-45g	25-Mn-52g	28-Ni-66g	33-As-73g	36-Kr-83g	39-Y-90g	42-Mo-95g	45-Rh-99g
10-Ne-20g	16-S-35g	20-Ca-46g	25-Mn-53g	29-Cu-64g	33-As-74g	36-Kr-84g	39-Y-91g	42-Mo-96g	45-Rh-101g
10-Ne-21g	16-S-36g	20-Ca-47g	25-Mn-54g	29-Cu-66g	33-As-75g	36-Kr-85g	40-Zr-88g	42-Mo-97g	45-Rh-102g
11-Na-22g	17-Cl-35g	20-Ca-48g	26-Fe-55g	29-Cu-67g	33-As-76g	36-Kr-86g	40-Zr-89g	42-Mo-98g	45-Rh-104g
12-Mg-24g	17-Cl-36g	21-Sc-44g	26-Fe-59g	30-Zn-64g	33-As-77g	37-Rb-85g	40-Zr-90g	42-Mo-99g	45-Rh-105g
12-Mg-25g	17-Cl-37g	21-Sc-45g	26-Fe-60g	30-Zn-65g	34-Se-74g	37-Rb-86g	40-Zr-91g	42-Mo-100g	46-Pd-102g
12-Mg-26g	18-Ar-36g	21-Sc-46g	27-Co-56g	30-Zn-66g	34-Se-75g	37-Rb-87g	40-Zr-92g	43-Tc-96g	46-Pd-103g
12-Mg-27g	18-Ar-37g	21-Sc-47g	27-Co-57g	30-Zn-67g	34-Se-76g	37-Rb-88g	40-Zr-93g	43-Tc-97g	46-Pd-104g
13-Al-26g	18-Ar-38g	21-Sc-48g	27-Co-58g	30-Zn-68g	34-Se-77g	38-Sr-83g	40-Zr-94g	43-Tc-98g	46-Pd-105g
13-Al-27g	18-Ar-39g	22-Ti-44g	27-Co-58m	30-Zn-70g	34-Se-78g	38-Sr-84g	40-Zr-95g	44-Ru-96g	46-Pd-106g
14-Si-28g	18-Ar-40g	22-Ti-46g	27-Co-60g	31-Ga-67g	34-Se-79g	38-Sr-85g	40-Zr-96g	44-Ru-97g	46-Pd-107g
14-Si-29g	18-Ar-41g	22-Ti-47g	27-Co-62m	31-Ga-69g	34-Se-80g	38-Sr-86g	41-Nb-91g	44-Ru-98g	46-Pd-108g
14-Si-30g	19-K-39g	22-Ti-48g	28-Ni-56g	31-Ga-71g	34-Se-82g	38-Sr-87g	41-Nb-92g	44-Ru-99g	46-Pd-110g
14-Si-31g	19-K-40g	22-Ti-49g	28-Ni-57g	32-Ga-70g	35-Br-77g	38-Sr-88g	41-Nb-93g	44-Ru-100g	47-Ag-106m
14-Si-32g	19-K-41g	22-Ti-50g	28-Ni-58g	32-Ga-72g	35-Br-79g	38-Sr-89g	41-Nb-94g	44-Ru-101g	47-Ag-108g
15-P-31g	20-Ca-40g	23-V-48g	28-Ni-60g	32-Ga-73g	35-Br-81g	38-Sr-90g	41-Nb-94m	44-Ru-102g	47-Ag-110g
15-P-32g	20-Ca-41g	23-V-49g	28-Ni-61g	32-Ga-74g	35-Br-82g	39-Y-87g	41-Nb-95g	44-Ru-103g	47-Ag-110m
15-P-33g	20-Ca-42g	23-V-50g	28-Ni-62g	32-Ga-76g	36-Kr-78g	39-Y-88g	42-Mo-92g	44-Ru-104g	47-Ag-111g

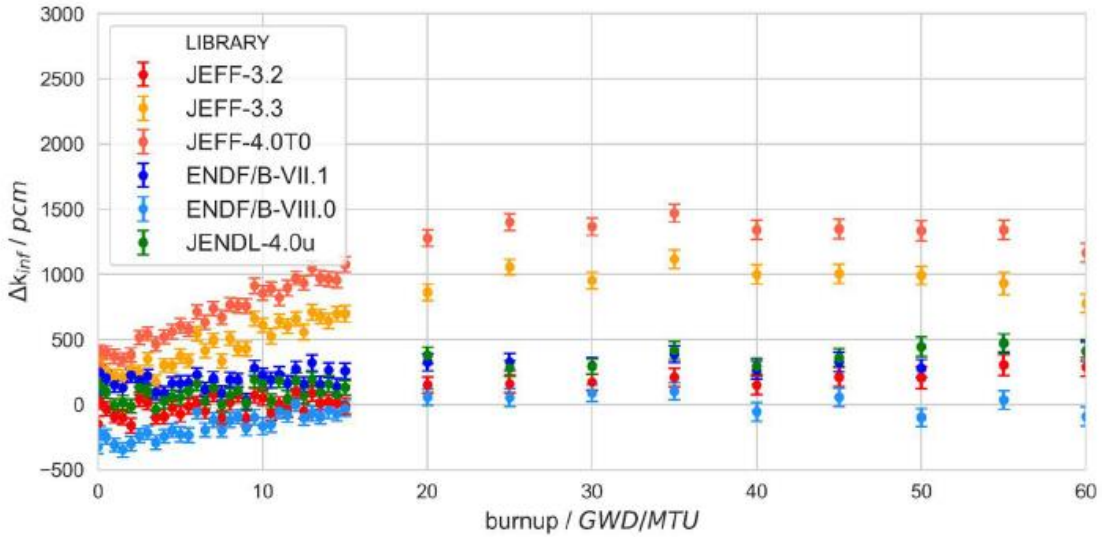
First testing of JEFF-4t0

O. Cabellos jefdoc-2015; L. Fiorito jefdoc-2017

- **Mosteller Suite (123): Criticality Benchmarks**

Table: Reduced-chi squared values given in DICE

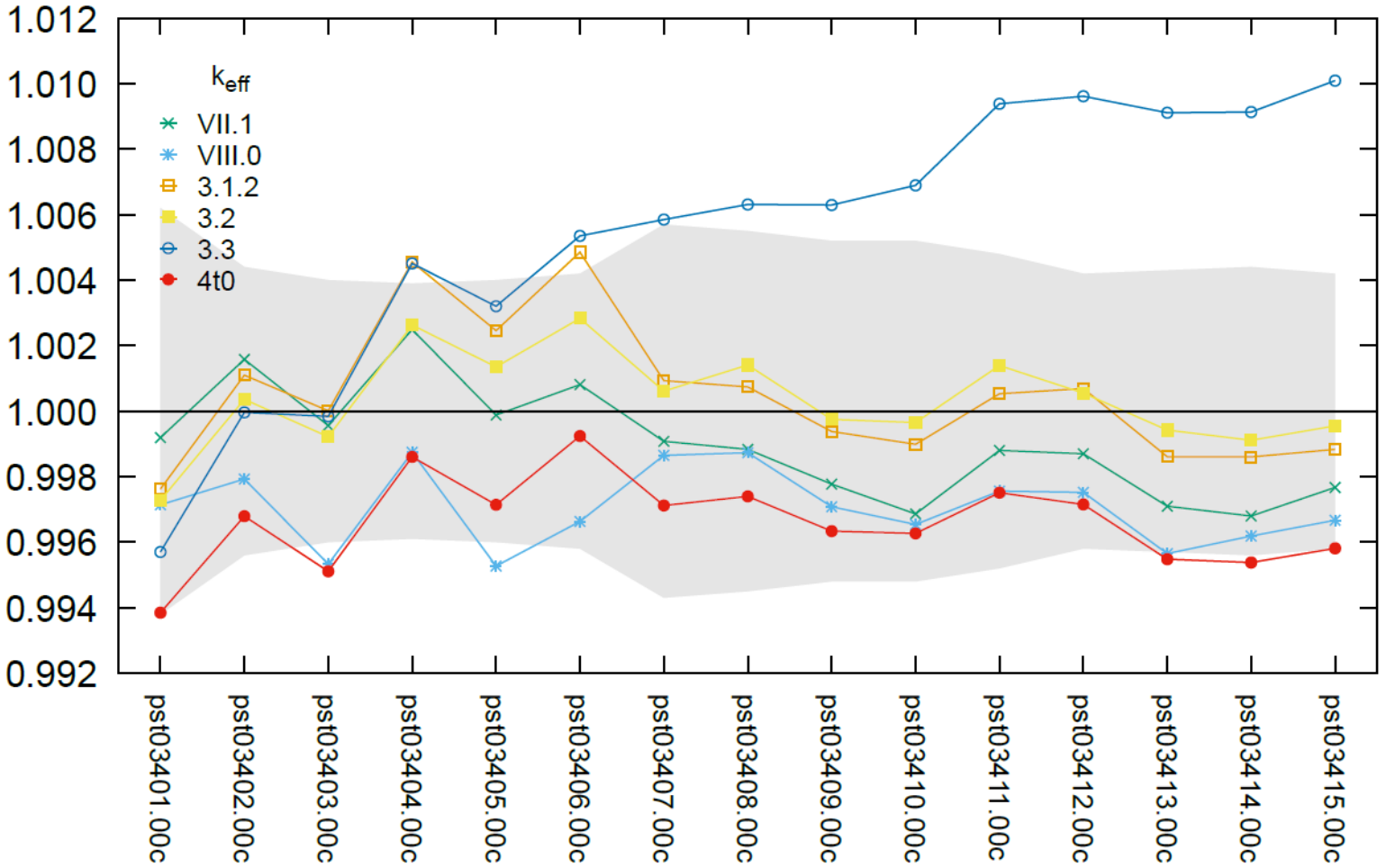
	JEFF-3.3	JEFF-4.0T0
PU	3.05	3.13
HEU	2.64	**6.76**
IEU	3.33	4.29
LEU	2.14	2.60
U233	1.55	2.35
MIX	0.91	0.88
SPEC (C/E) Δexp=0.00340	0.99173	0.99479
All	2.25	3.80



European Commission

First testing of JEFF-4t0

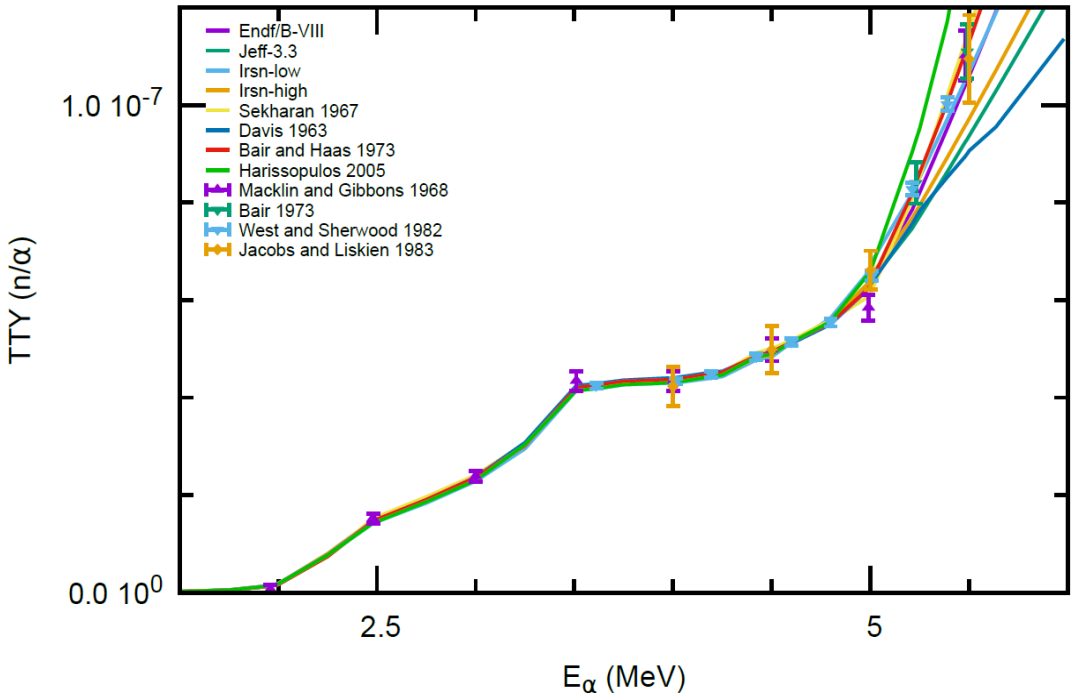
pst034 – increasing Gd concentration

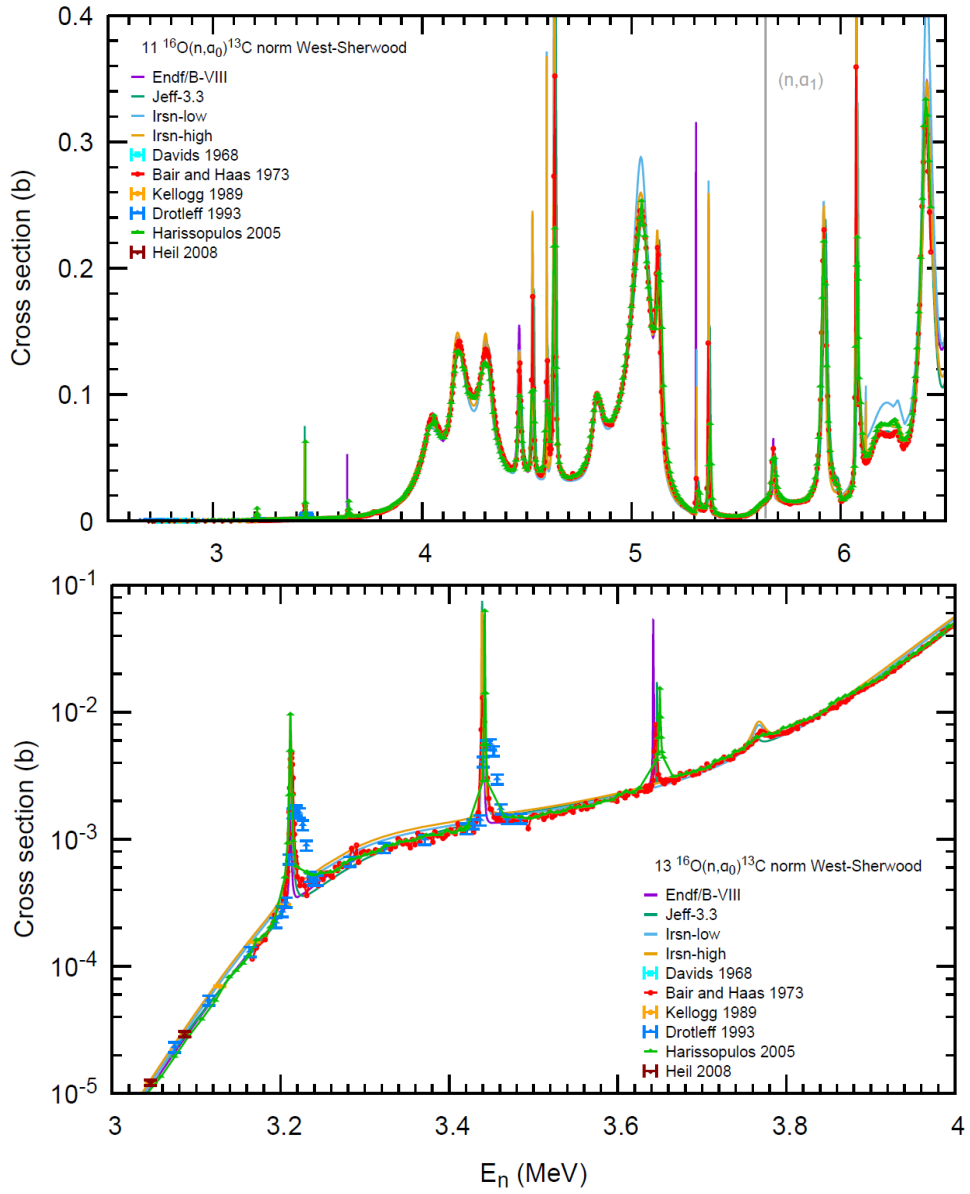


European Commission

New developments – $^{16}O(n,a)$

- $^{13}C(a,n)$ TTY normalize thin target data
- Time reversal below 5 MeV for $^{16}O(n,a)$
- Set of renormalization factors
- New evaluation Luiz Leal ongoing
- Include transmission data Junghans





European Commission

New developments – ^{56}Fe

- Controversy over the data for inelastic scattering
- Challenge to get good overall performance in benchmarks (criticality and shielding)
- Difficulty with modeling due to OMP not matching the average total below 5 MeV.
- New shielding benchmark evaluation (vd Marck)
- New experimental campaign on scattering planned (JRC, IFIN-HH, PTB, KVI, …)
- New evaluations ongoing (IRSN, IAEA, UU, …)

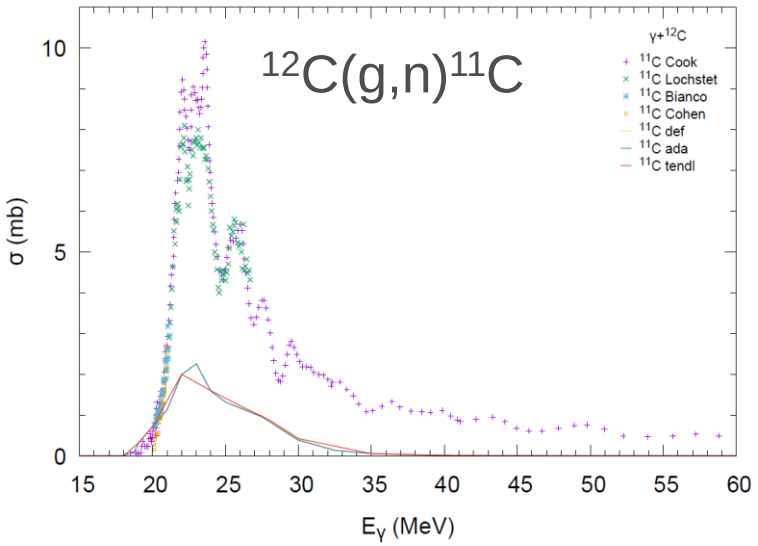
New developments – “Other”

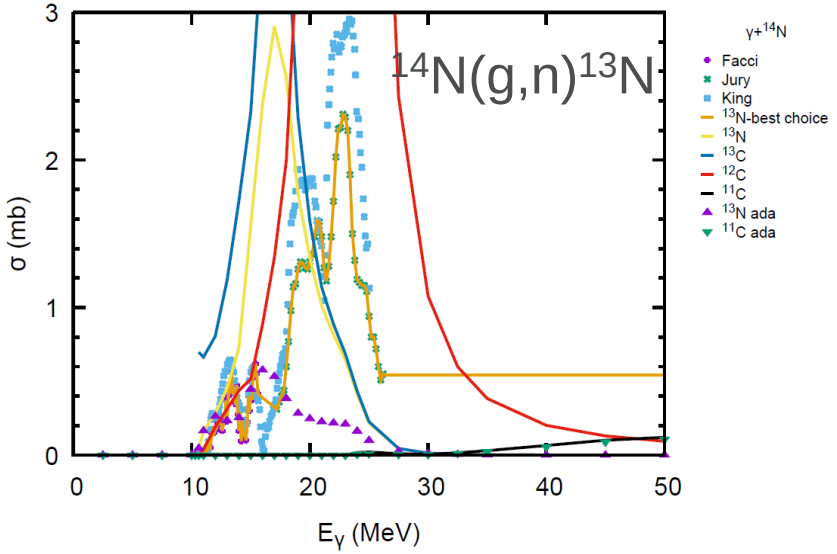
See the jefdocs for more information

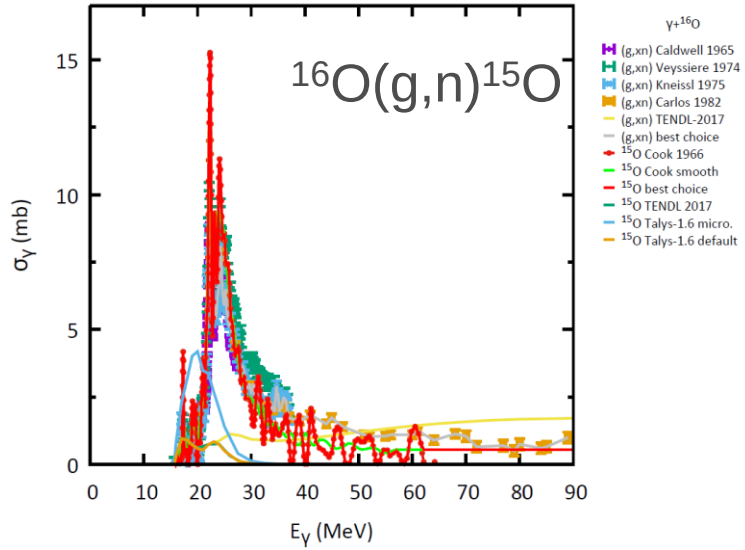
- New actinide evaluations
  - IRSN, CEA
  - New PFN data spectra and multiplicity (CEA @LANL)
- Resonance range evaluations FPs a.o. integrated in full TENDL approach
  - Fine tuning needed
  - Working group starting
- Model development for better actinide evaluations (CEA, …)
- Further benchmarking to establish nuclide deficiencies (IRSN)
- Inclusion of correlated gamma data for inelastic scattering (and capture; CEA)
- Method development for future FY evaluations
- ……

Further challenges: accelerator photon data

- Electron accelerators, air activation
- For many common materials in accelerator design there are no good activation cross sections
- Unless ‘hardwired’ in codes as Fluka







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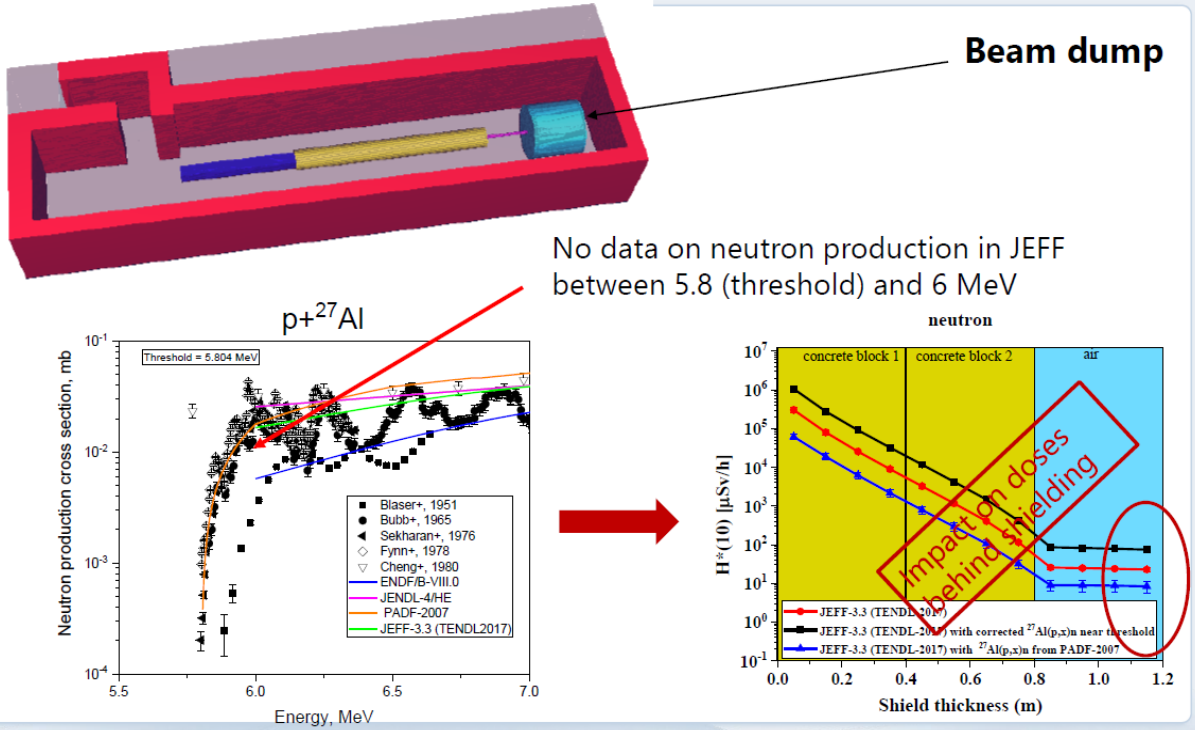
Further challenges: accelerator proton data

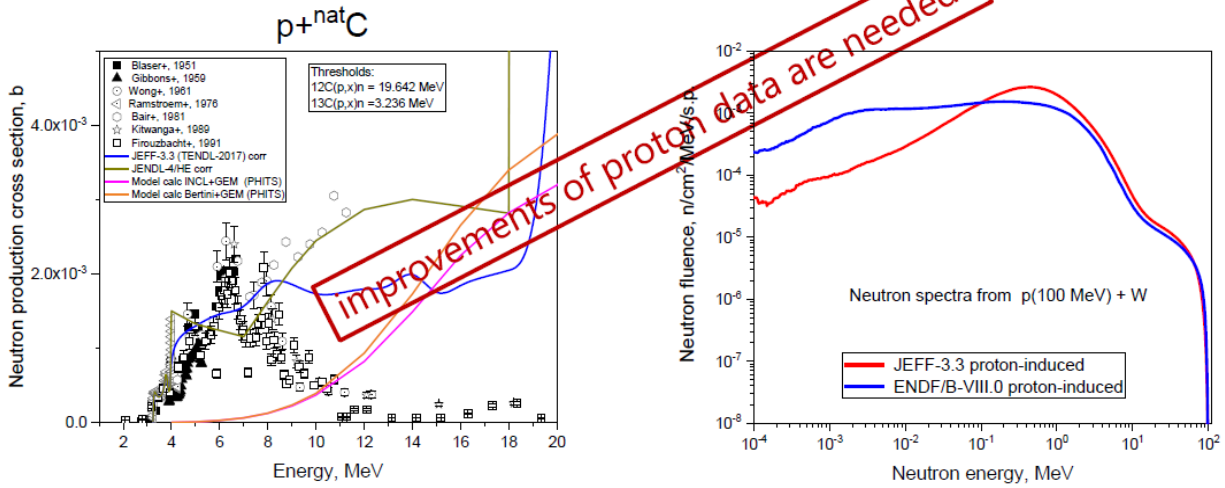
jefdoc-1956 A. Stankovskij (Baeten stakeholder mtg)

5.9 MeV beam dump shielding



Shielding of ISOL targets:
Huge discrepancies between libraries/experimental data, especially for protons + light nuclei

Material irradiation (fusion targets):
Huge discrepancies both in neutron spectra and total neutron yield from p+W



Jefdoc-1956 (Baeten, stakeholder mtg)

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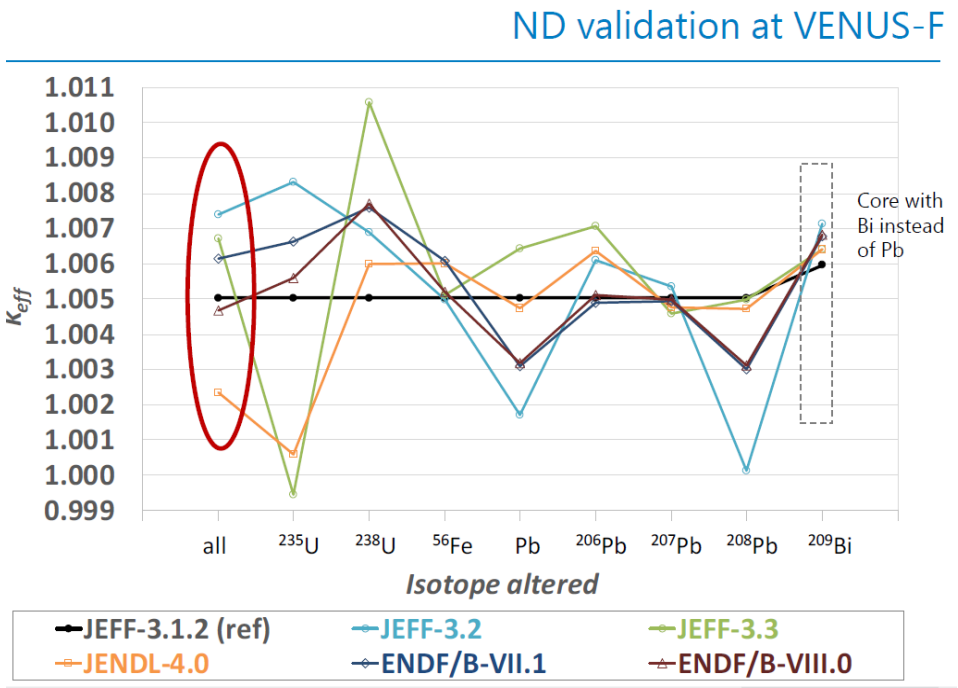
Further challenges: accelerator driven systems

- MYRRHA, A. Stankovskij jefdoc-1891
  - CIELO-1 files seems reliable but
    - ^{241}Pu(n,f) has to be improved
    - ^{56}Fe(n,γ) has to be confirmed
  - ^{210}Bi(n,γ) and branching ratio can be adopted from BROND-3.1, more experimental data on branching ratio at 0.1-10 keV is needed
  - Reliable covariances are needed (example of ^{235}U(n, γ) in fast region)
  - Proton JEFF-4 library is needed, containing among others complete ^{232}Th and ^{238}U files
  - Neutron and proton files for W: covariances > 20 MeV
  - Extension of files, both proton and neutron, to 600 MeV can be a bonus!
- Jefdoc-1926



Challenge: from microscopic to adjusted library

- Candidate methodologies are many.
- Systematic approach is not yet clear.
- Which benchmarks?
- Can it be done on a large scale?
- Do we understand sufficiently well what will happen?

Summary

JEFF is a collaborative project involving many institutes

Advanced reactors & fuel-cycle, current fleet, Gen-III, waste management, fusion, accelerator applications (ADS), forensics, characterization, medical radionuclides, astrophysics …

There is considerable emphasis on benchmarking and validation

Mustering human resources for evaluations of cross sections, decay data and fission yields is considerably more challenging

Many data remain unevaluated (e.g minor actinides from EU projects, photon-induced and proton-induced activation data)

We want to cater to stakeholder interests among the participating organisations including their industrial stakeholders and engage the latter better.

There is considerable interest in JEFF to work with WPEC and IAEA-NDS for mutual benefit