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Joint Research Centre

European Commission

The Joint Evaluated Fission and Fusion (JEFF) Nuclear Data Library & the European nuclear data community

Arjan Plompen

OECD-NEA, WPEC, June 2019

European Commission

Contents

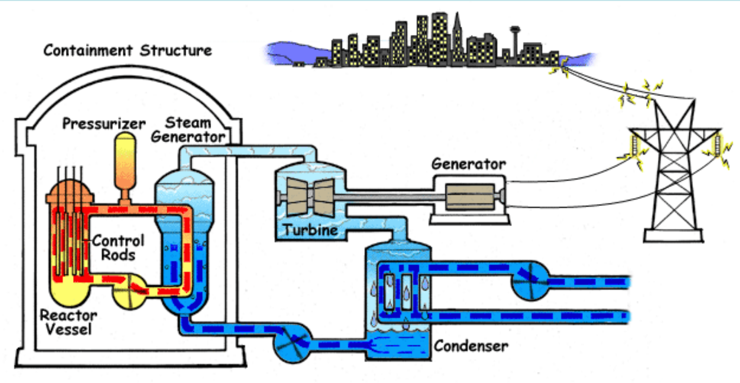
- Interests and collaborations
- JEFF-3.3
- JEFF-4.0 directions

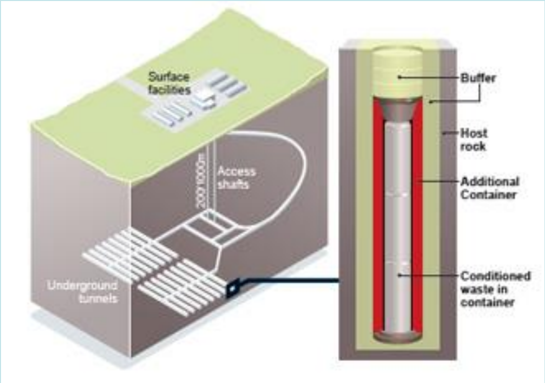
Nuclear data and applications of JEFF

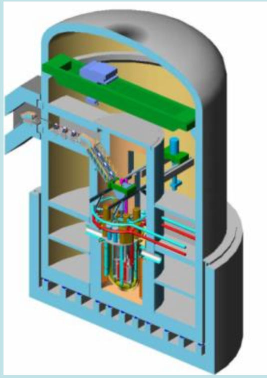
Towards a general purpose library

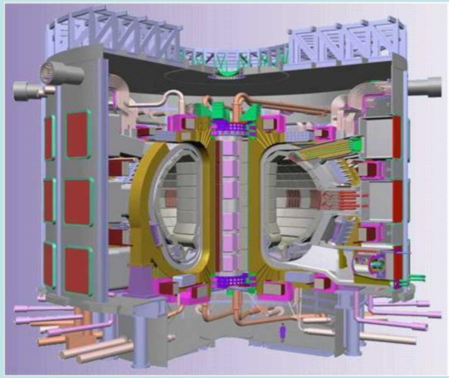
Applications: fission and fusion, radiation protection, nuclear medicine, (nuclear) security, object and materials analysis

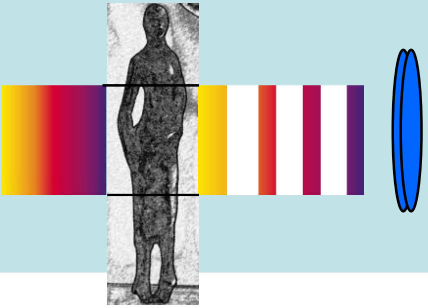
Science: reactions and structure of nuclei, astrophysics, basic physics

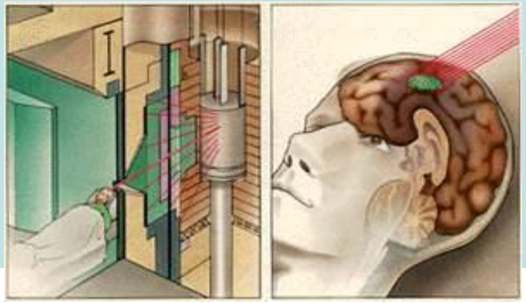












Challenge: Climate Change - carbon free energy

Nuclear energy can be an important component in the mix

2016	CO2	CO2-free	Nuclear	Bio+waste
world	81%	19%	5%	10%
EU 28	72%	**28%**	14%	10%
Belgium	71%	29%	20%	7%
France	47%	**53%**	42%	7%
Germany	79%	21%	7%	10%
Sweden	29%	**71%**	33%	25%

Countries with a high percentage CO_2-free energy use (nuclear) electricity for heating.

Still a lot to do for CO_2-free transport.

Data International Energy Agency, Total primary energy supply

Challenges for nuclear energy

- Cost of construction
- Perception of risk & public opinion

  Legacy of historical major accidents, Fukushima and Chernobyl, and the shadow they project over the future.
- Communication in a difficult era

European Commission

EUROfusion

Nuclear Data Activities of the EUROfusion Consortium

U. Fischer, KIT – I 423

Co-ordinator Power Plant Physics & Technology - Neutronics & Nuclear Data

Karlsruhe Institute of Technology

IFIN-HH

PAUL SCHERRER INSTITUT PSI

CCFE CULHAM CENTRE FOR FUSION ENERGY

UPPSALA UNIVERSITET

TU WIEN

UNED

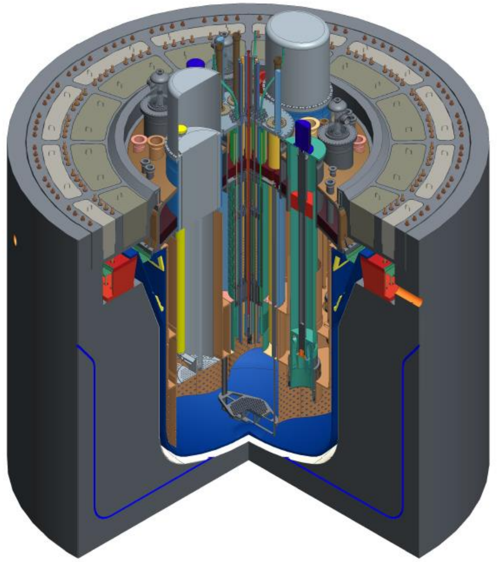
IJS

NEA NUCLEAR ENERGY AGENCY

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

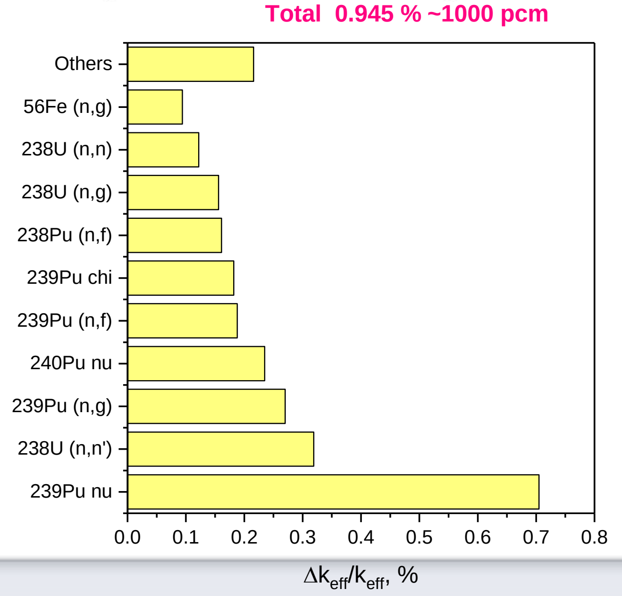
Alexey Stankovskiy R191 & R367

MYRRHA K_{eff} uncertainty and data priorities



Cov. data	$\Delta k_{eff}/k_{eff}$, %
SCALE-6.0m	0.945
COMMARA-2	~0.5
JENDL-4.0	0.553

Target accuracy satisfactory: $\frac{\Delta k_{eff}}{k_{eff}} \sim 300pcm$



Increase of confidence by reducing the uncertainties is needed for

- ^{239}Pu: (n,γ) both in resonance and fast energy region, (n,f) fast, χ and $\bar{\upsilon}$ fast
- ^{238}U: (n,n') fast, (n,γ) resonance and fast, (n,n) resonance and fast
- ^{56}Fe: (n,γ) resonance and fast
- ^{235}U: $\bar{\upsilon}$, (n,f), (n,γ) resonance and fast

Already covered by CIELO project

Not contributing essentially to k_{eff} and β_{eff} but impact fluxes, decay heat…

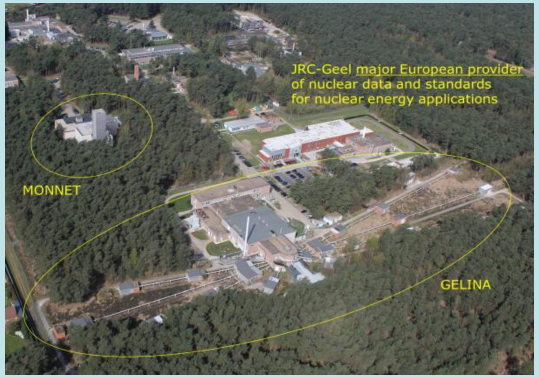
Impact burnup, decay heat

- ^{209}Bi (n,γ) and (n,n') resonance and fast
- ^{208}Pb (n,n) and (n,n') resonance and fast
- ^{241}Pu (n,f) resonance and fast
- ^{242}Pu (n,f) fast
- ^{240}Pu: $\bar{\upsilon}$ fast
- ^{238}Pu: (n,f) both resonance and fast

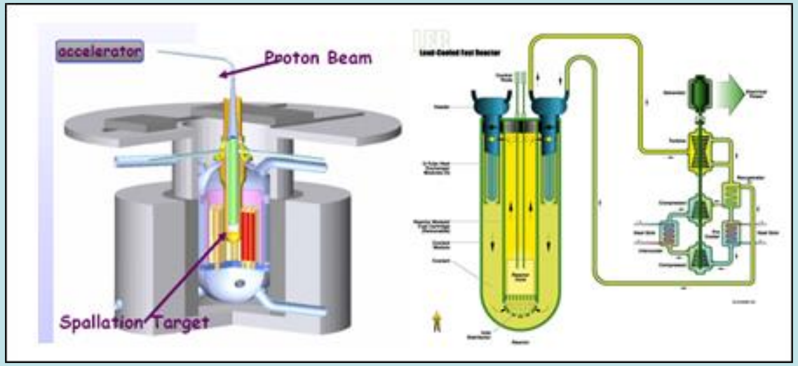
Focus on

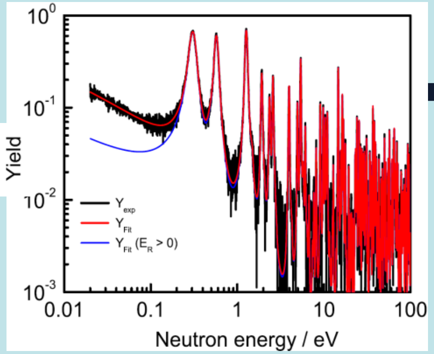
From science to application

Reactive versus proactive: ensure best science for every application



Feedback & new needs





Microscopic data

Theory

Benchmark data

Evaluation, verification & validation

Data Library

Research & Development

Industry

Regulatory bodies

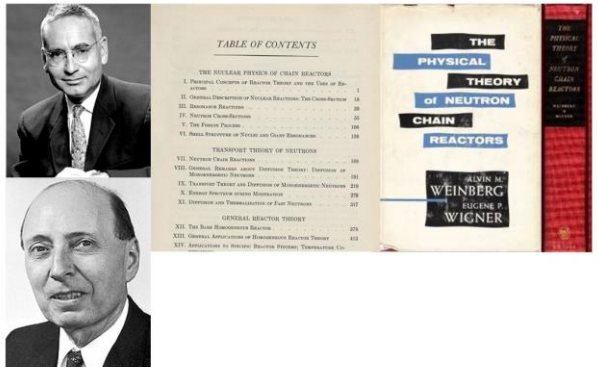
European Commission

Modeling for cost reduction

- Reliable predictions with credible uncertainty margins.
- We are a far cry from that in the nuclear field
- Lots of expert judgement and ad-hoc methods and codes.
- Lots of tests needed for innovative ideas.
- Knowledge management through data libraries, codes and procedures can make major steps forward with modern software technology
- JEFF-4 development goal for 2018-2024

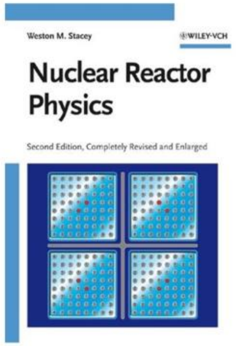
The physical theory of neutron chain reactors

Alvin M. Weinberg and Eugene P. Wigner, University of Chicago Press (1958)



Nuclear Reactor Physics

Weston M. Stacey, Wiley-VCH, 2nd ed. (2007)

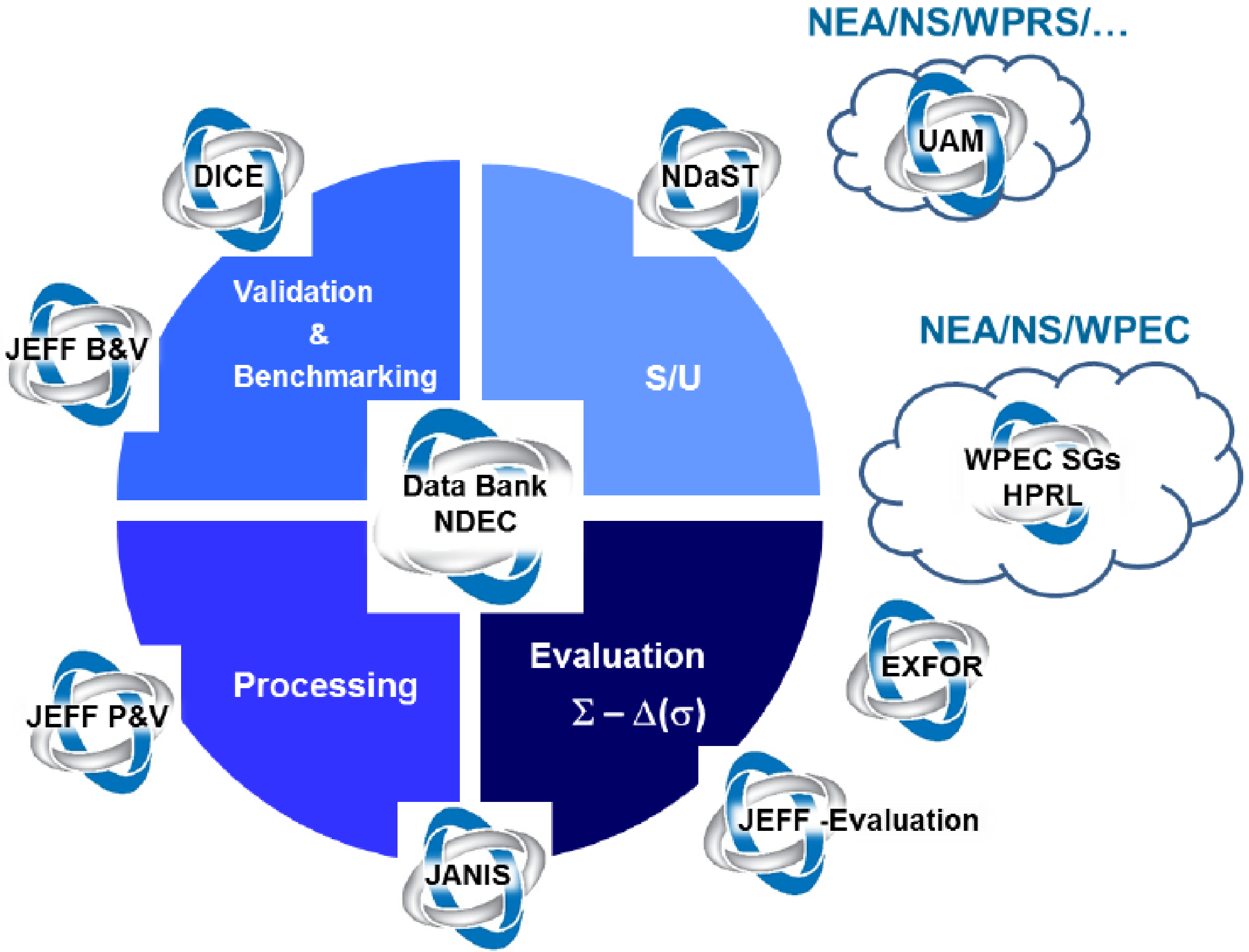


- One set of data for all applications
- One suite of modeling codes

The JEFF collaboration

- NEA Databank member countries
- Large fraction of contributors is from Europe
- 2 meetings per year
- 40-100 participants
- Voluntary contributions: resources of contributors
- Maintain close links with data projects in Europe
- Joint meetings.

NEA Data Bank: Tools and Databases



NEA Data Bank Services

- ❑ Secretariat activities
- ❑ Technical services:
  - Consistency checks
  - Conversion to formats
  - Testing/verification
  - Benchmarking (e.g. ICSBEP, ….
  - Web/Compilation library
  - Feedbacks
- ❑ New tool NDEC (Nuclear Data Evaluated Cycle).

Fig : NEA Data Bank tools and databases. JEFF Working Groups on Nuclear Data activities on Benchmarking & Validation (B&V), Processing & Verification (P&V) and Evaluation are shown

IAEA-NDS: CRPs, DDPs, CMs

- INDEN
- IRDFF
- Standards
- RIPL
- EXFOR
- Medical isotopes
- IBANDL
- …

CHANDA: SOLVING CHALLENGES IN NUCLEAR DATA FOR THE SAFETY OF EUROPEAN NUCLEAR FACILITIES

CP-CSA (Combination of Collaborative projects, Coordination and Support Actions) to the **EURATOM FP7-Fission-2013-4.1.2** (Support to a pan-European Integrated Research Infrastructure Initiative for increased safety of nuclear systems at EU level).

Start: 1 Dec. 2013.

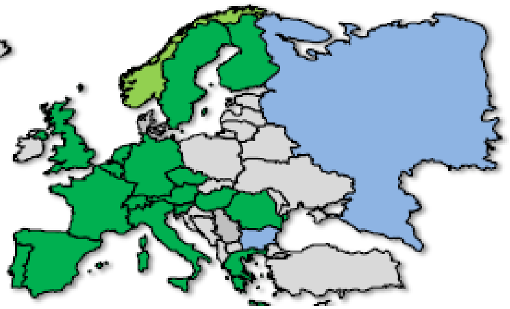
Duration: 54 months.

EU funding: 5.4 MEuro.

61 Deliverables

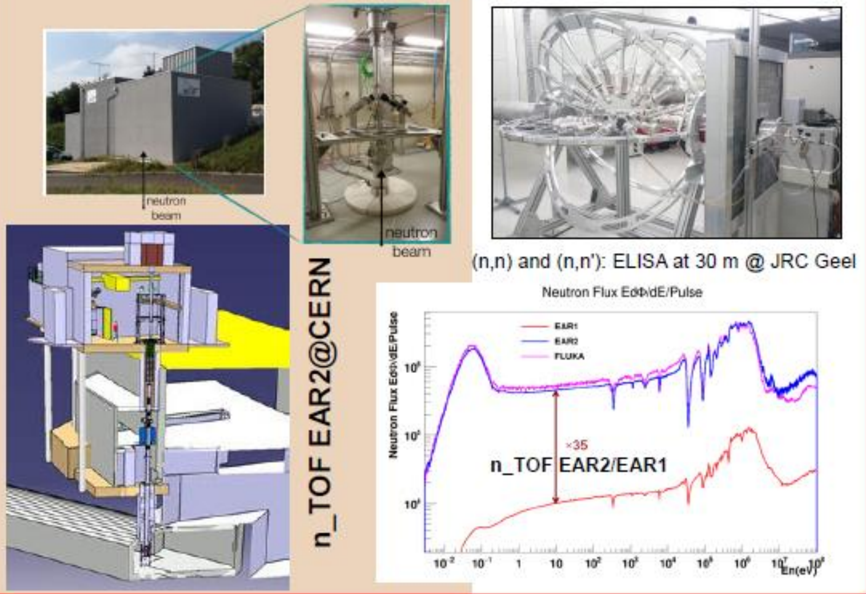
Participants:

CIEMAT, ANSALDO, CCFE, CEA, CERN, CNRS, CSIC, ENEA, GANIL, HZDR, IFIN-HH, INFN, IST-ID, JRC, JSI, JYU, KFKI, NNL, NPI, NPL, NRG, NTUA, PSI, PTB, SCK, TUW, UB, UFrank, UMainz, UMan, UPC, UPM, USC, UU, UOslo. +U.Seville



CHANDA: 36 participants (18 countries)

New facilities

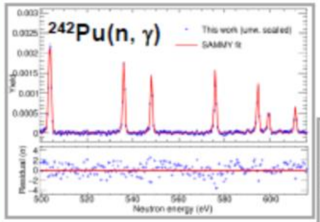


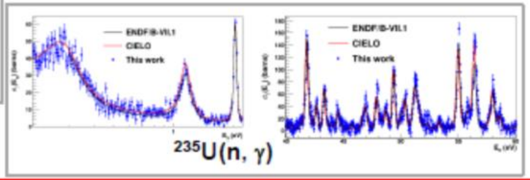
Differential measurements at CHANDA

(n,f) cross sections	(n,n), (n,xn) and (n,n'γ) cross sections
^{240,242}Pu(n,f)	^{nat}Fe(n,n)
^{237}Np(n,f)	^{nat}C(n,n)
^{235,238}U(n,f)	^{238}U(n,n'e-)
(n,γ) cross sections	^{48}Ti(n,n'γ)
^{235}U(n,γ)	^{7}Li(n,n'γ)
^{242}Pu(n, γ)	^{233}U(n,n'γ)
^{238}U(^{3}He,^{4}He)^{237}U, ^{238}U(^{3}He,t)^{238}Np, ^{238}U(^{3}He,d)^{239}Np	

Decay data	
^{95}Rb, ^{95}Sr, ^{98}Y, ^{98m}Y, ^{98}Nb, ^{98m}Nb, ^{99}Y, ^{100}Nb, ^{100m}Nb, ^{102}Nb, ^{102m}Nb, ^{103}Mo, ^{103}Tc, ^{108}Mo, ^{137}I, ^{138}I, ^{140}Cs, ^{142}Cs	γ ray and β decay emission probabilities with TAGS at JYFL
^{98,98m,99}Y, ^{135}Sb, ^{136}Te, ^{138,139,140}I	Neutron emission probabilities with the BELEN detector at JYFL

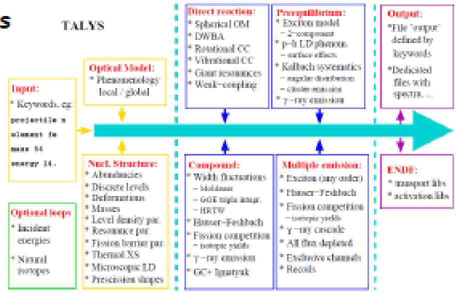
Fission yields	
^{238}U(n,f)	Penning trap at JYFL
^{233,235}U(n,f)	Isobaric beams at ILL
^{239,241}Pu(n,f)	Isobaric beams at ILL
^{235}U(n,f)	STEFF spectrometer at n_TOF/EAR2
^{235}U(n,f)	Orphee reactor at CEA/Saclay
^{238}U, ^{239}Np, ^{240}Pu, ^{244}Cm, ^{250}Cf	VAMOS spectrometer at GANIL
^{234,235,236,238}U(g,γ)	FRS spectrometer at GSI
^{238}U(n,f)	LICORNE + MINIBALL at IPN/Orsay

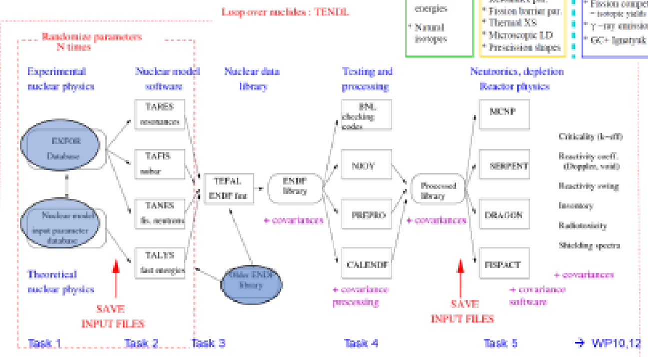




Evaluation: TALYS-1.9 and TENDL

From basic nuclear physics to nuclear technology

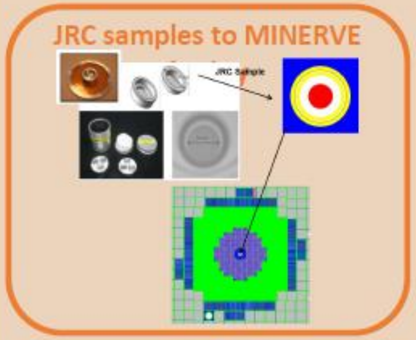




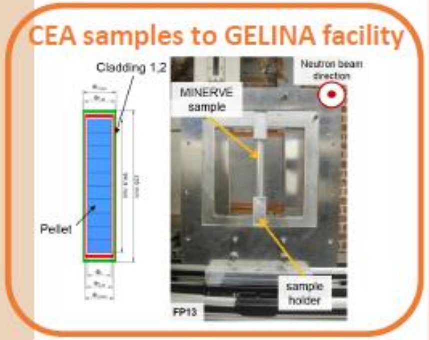
+ Systematic and comprehensive uncertainties and correlation libraries in the evaluation.

Validation: Innovative Integral Experiments

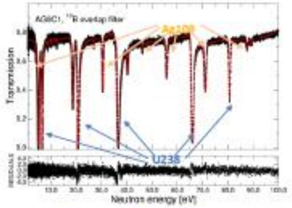
JRC samples to MINERVE



CEA samples to GELINA facility



- ⇨ First of a kind in the cross-check of experimental techniques based on common samples
- ⇨ Feasibility and interest demonstrated for using oscillation samples in ToF experiments



Plus validation using existing benchmark libraries and past and new integral experiments

SUPPLYING ACCURATE NUCLEAR DATA FOR ENERGY AND NON-ENERGY APPLICATIONS

Basic data

Coordinator: CIEMAT, Enrique Gonzalez Romero

H2020 Grant Agreement number: 847552

A proposal in negotiation for the EURATOM WP2018 for NFRP-2018-4

Proposed Start date: 01/09/2019

Duration: 48 months

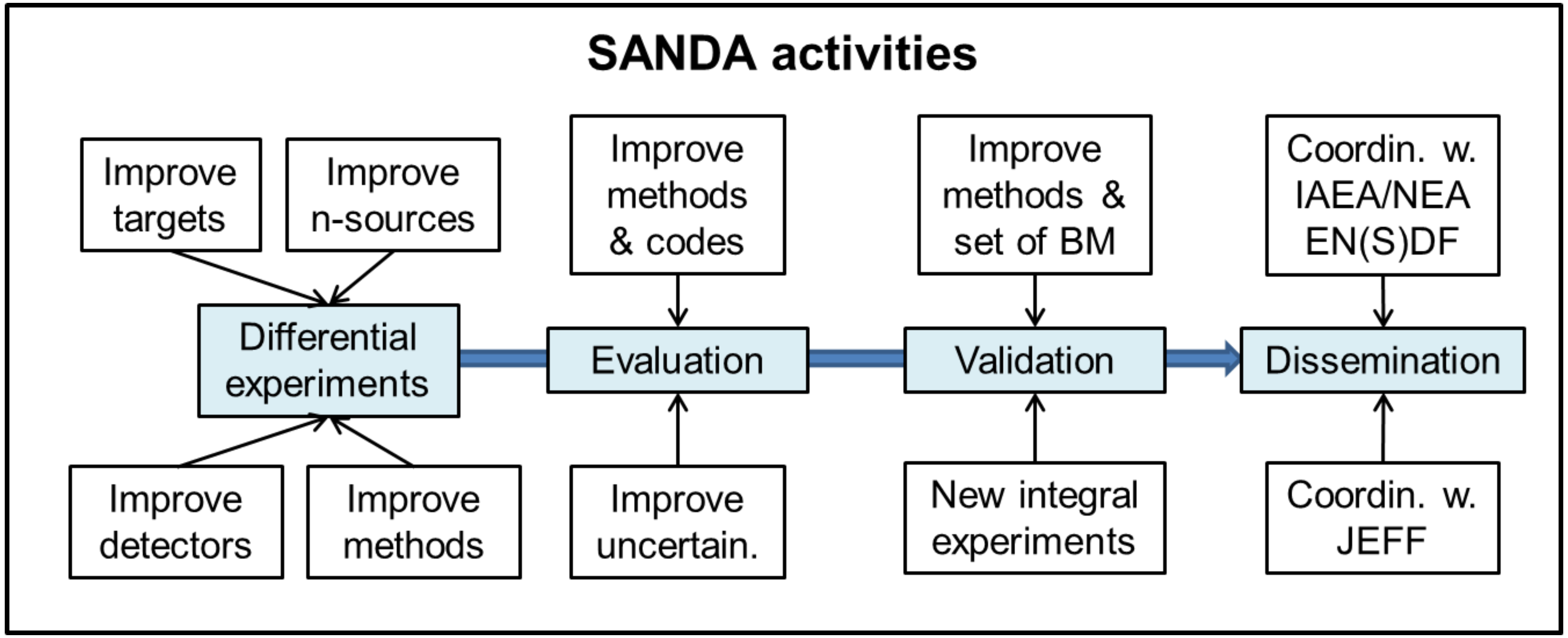
Requested contributions: 3.5 MEuros

35 Partners: *CIEMAT*, Atomki, CEA, CERN, CNRS, CSIC, CVREZ, ENEA, HZDR, IFIN-HH, IRSN, IST-ID, JRC, JSI, JYU, KIT, NPI, NPL, NRG, NTUA, PSI, PTB, SCK-CEN, Sofia, TUW, UB, ULODZ, UMAINZ, UMANCH, UOI, UPC, UPM, USC, USE, UU.

19 countries (A, B, Bg, Cz, D, Es, Fi, F, Gr, H, I, NL, Pol, Pt, Ro, Slo, S, UK)

SANDA Objectives

- Address aspects of nuclear data research producing accurate and reliable data, codes and methodologies for the safety of nuclear energy and non-energy applications.
- Take into account the High Priority Nuclear Data from OECD/NEA and needs identified by IAEA-NDS.
- Prepare experimental infrastructures, detectors, measurement capabilities and methodologies.
- Maintain close contact with OECD/NEA, the IAEA Nuclear Data Section and the organizations contributing to the JEFF project.
- Maintain close contacts with the ARIEL proposal for access to Nuclear Data related facilities also approved by EURATOM WP 2018 NFRP7.



ARIEL

Accelerator and Research Reactor Infrastructures for Education and Learning

- EURATOM WP 2018 Coordination and Support Action
- Scheme offering access to research & training facilties
  ➔ Integration of access to neutron facilties with education and training in collaboration with ENEN
  - 23 participants, 1.7 M€
- Activities linked with the SANDA project, OECD/NEA, IAEA/NDS and TSOs (GRS, IRNS)
- Experiments in international teams at first rate facilities as „hands on“ training for early stage researchers
  PAC to select projects of highest scientific value
- Maintenance of competencies and development of multidisciplinary nuclear competencies

This could be Your logo

ARIEL main activities

- Transnational Access to Neutron facilities
  (30 typical experiments, 3000 beam time hours and 4 users per experiment supported)
- Training of early stage researchers and scientific visits
  (30 research stays of up to 12 weeks)
- Summer schools and scientific workshops

  4 summer schools reach to attract students to the nuclear data field organized by University of Seville, CIEMAT, Johannes Gutenberg University and Uppsala University

  3 scientific meetings to keep the nuclear data network: JRC, NPL,IPN Orsay

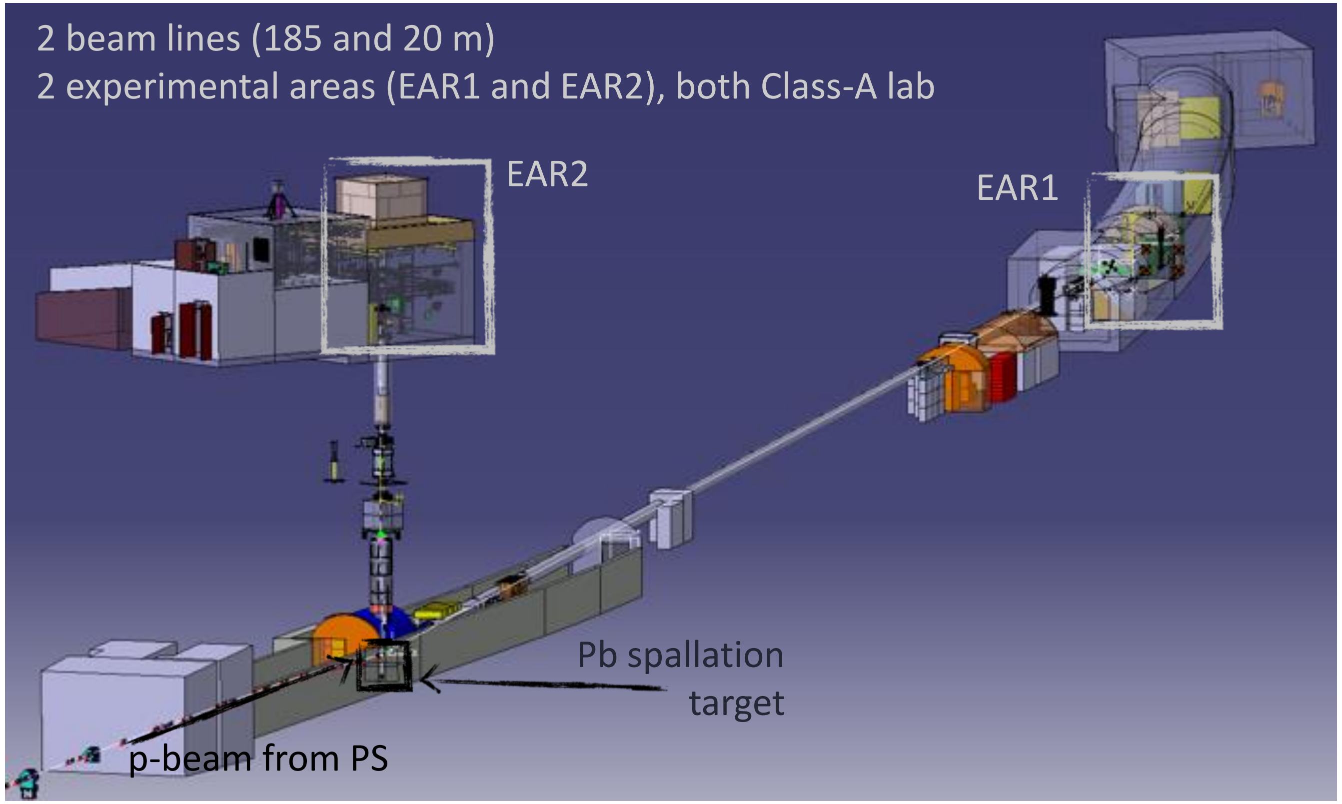
Education and Training

Maintaining Competence – building the young generation






CERN n_TOF – Enrico Chiaveri I135



42 Institutions

(EU, India, Japan, Russia and Australia)

130 scientists

2 experimental areas at CERN

Nuclear Astrophysics

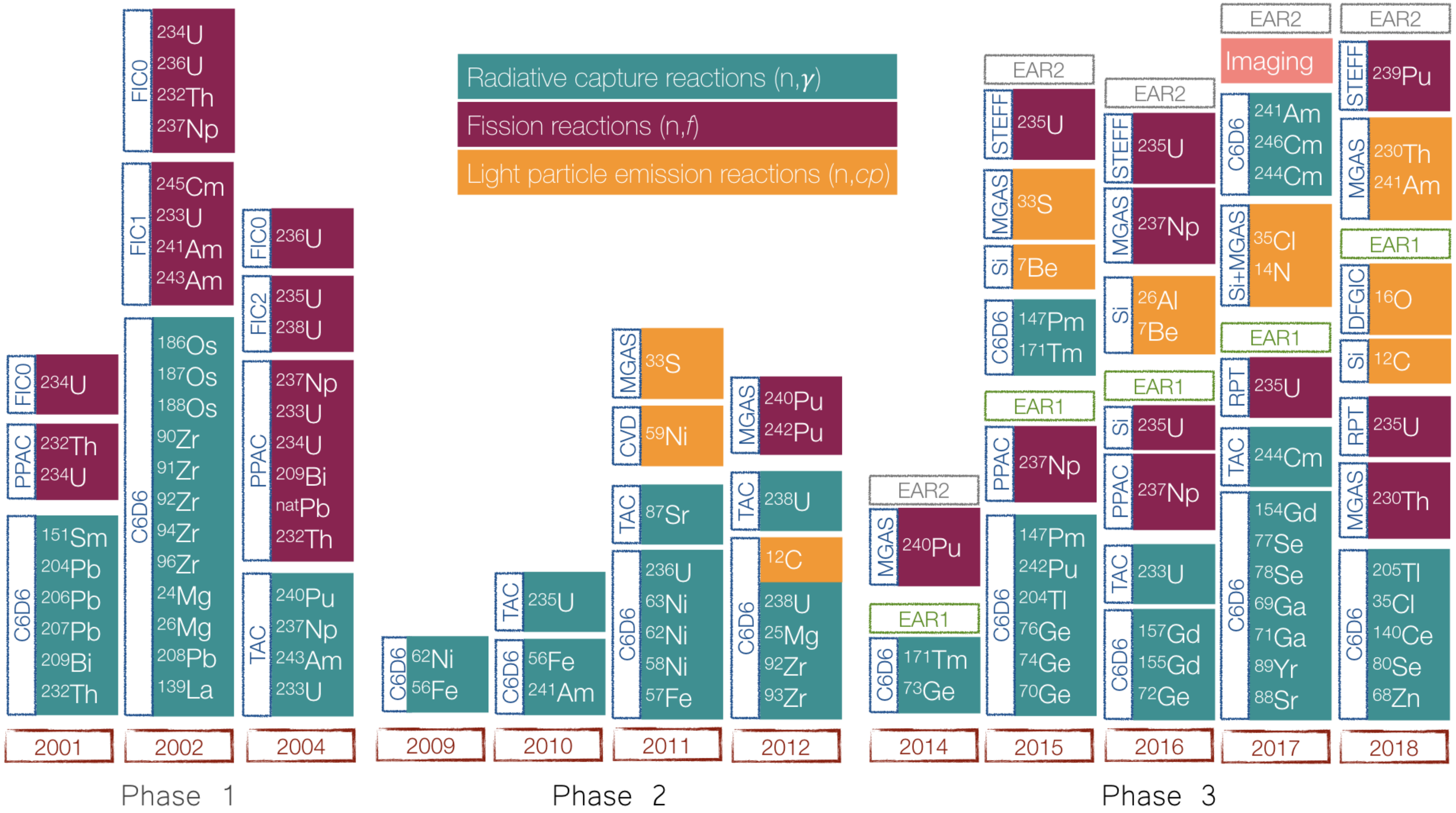
Nuclear Physics

Nuclear Application:

- Nuclear reactors (fission and fusion)
- Nuclear Waste Transmutation
- Nuclear Medicine

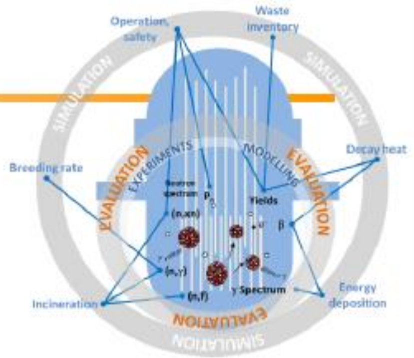
- Main feature of n_TOF is the synthesis of extremely high instantaneous neutron flux and excellent energy resolution
- Unique facility for measurements of radioactive isotopes (maximize S/N)
  - Branch point isotopes (astrophysics)
  - Actinides (nuclear technology)

The n_TOF physics program: neutron-induced reaction measurements



http://dx.doi.org/10.1051/epjconf/201714607003
http://www.nea.fr/dbdata/nds_jefreports/
http://dx.doi.org/10.1016/j.nds.2018.02.001
http://dx.doi.org/10.3327/jnst.48.1
https://twiki.cern.ch/NTOFPublic/DataDissemination

NACRE : some figures



7 IN2P3 laboratories, 4 CEA directions and 1 IRSN department clustered in NACRE.

Manpower:

CEA : 13 m.year,

CNRS : 12 m.year,

IRSN : 0,2 m.year.

For and with

Member States

OECD-NEA
IAEA

International partners

European Commission

Nuclear facilities at JRC Geel (Jan Heyse I080)

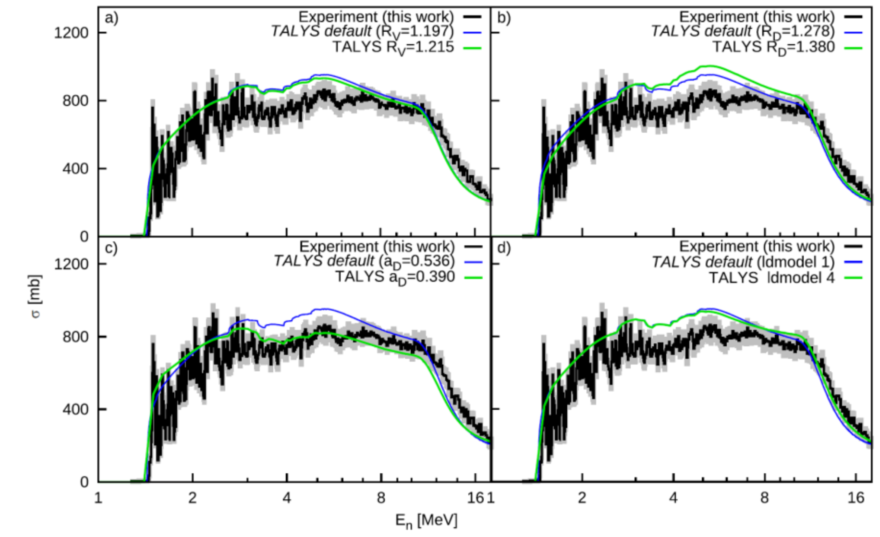
GELINA
neutron time-of-flight facility for high-resolution neutron measurements

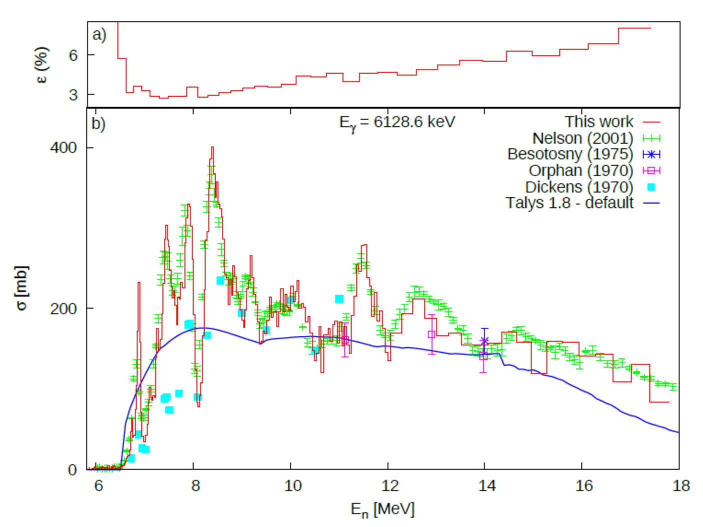
MONNET
tandem accelerator based fast neutron source

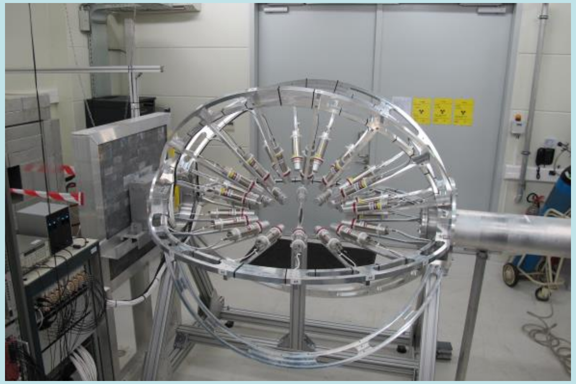
- ^{209}Bi + n with SCK•CEN and JAEA
- Crit. Safety with ORNL
- ^{154,155,157}Gd + n – Cristian Massimi R095
- ^{107,109}Ag RP < 1000 eV – L. Salamon S097
- ^{241}Am capture and transmission normalization free
- Neutron resonance and transmission analysis (NDA)
- Setup development for scattering and fission
- Neutron multiplicities and FF 239Pu(n,f)

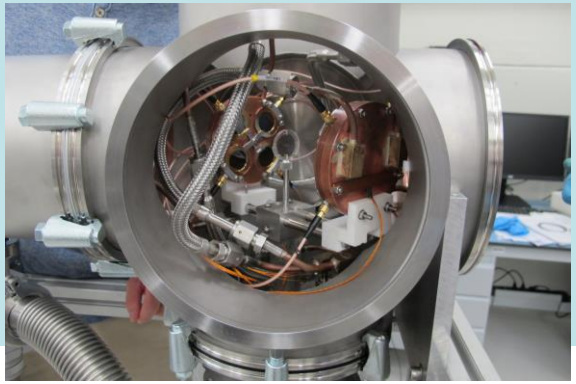
Inelastic scattering with GAINS & Grapheme
Collaboration with CNRS-IPHC, HZDR, IFIN-HH, PTB

- Reaction mechanisms & nuclear structure from (n,xng): Maelle Kerveno R236
- Gamma production cross sections - GAINS Overview: Alexandru Negret I075
- ^{54}Fe: 2+ to g.s. decay - Adina Olacel R077
- ^{16}O: example of 3- to g.s. decay - Marian Boromiza R076
- ^{7}Li: Roland Beyer R078
- New setups Markus Nyman I127



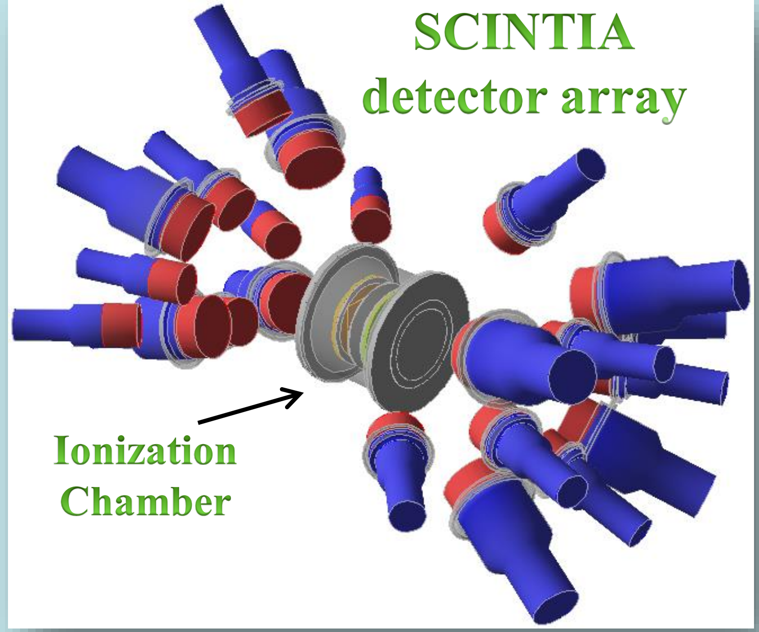




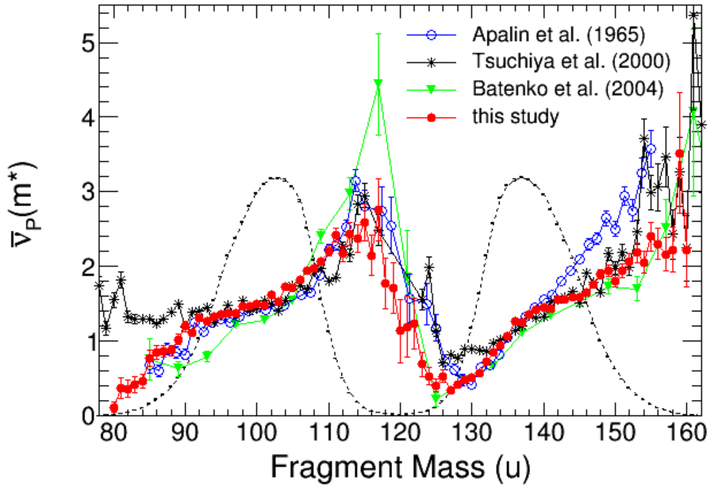


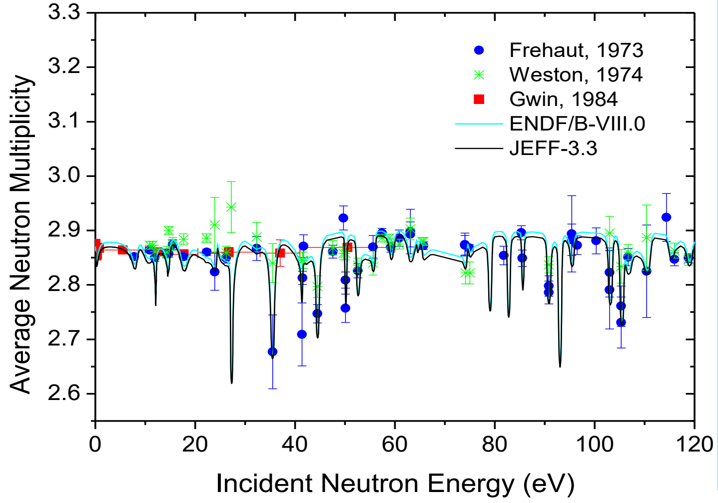
Neutron multiplies and fission fragments in $^{239}Pu(n,f)$

Alf Göök R259



- Measurements related to NEA – High priority request (99H)
  - new $\nu_p(E_n)$ data in resonance neutron induced fission
  - Fluctuating $\nu_p(E_n)$ in resonance range
  - Fluctuating fragment Y(A,TKE)
- Experiment to investigate correlation ν_p(A,TKE) at GELINA





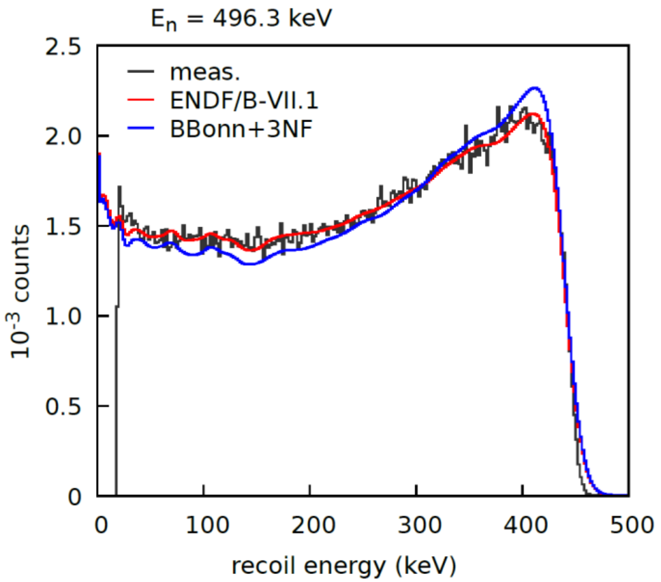
European Commission

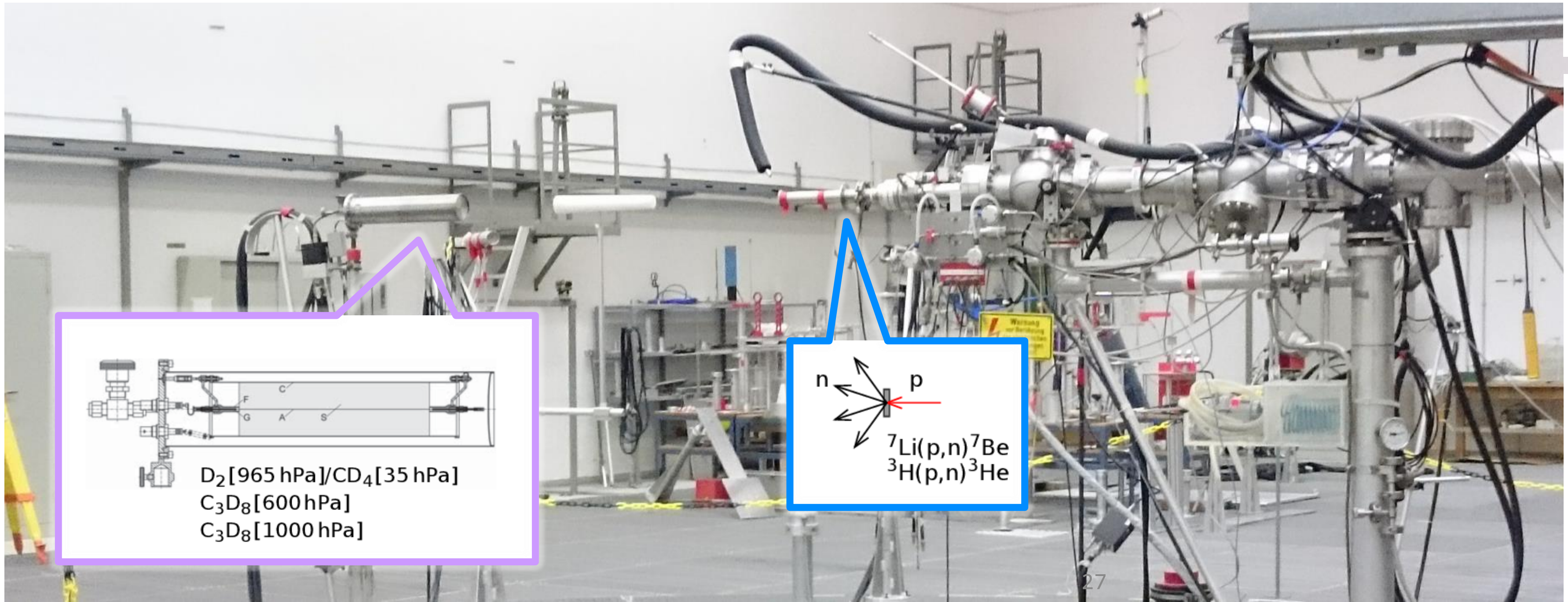
n-d scattering by recoil spectra in a proportional counter

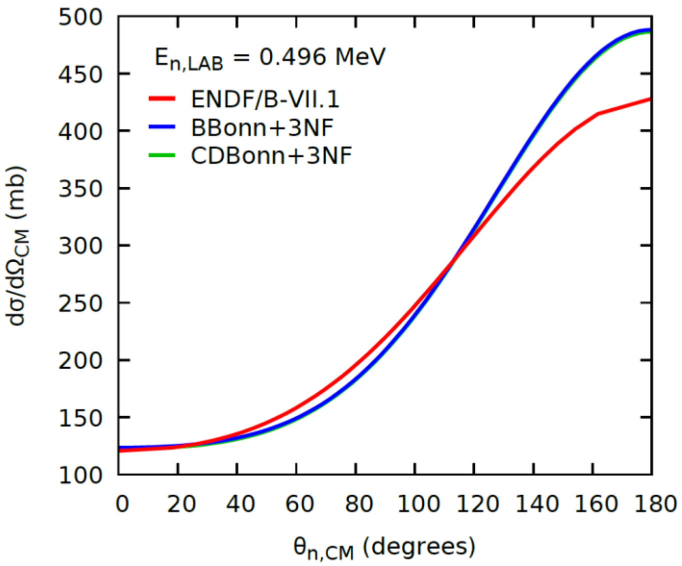
Elisa Pirovano – R079

- measurement at the PTB VdG
- quasi-monoenergetic neutrons via $^{7}Li(p,n)$ or $^{3}H(p,n)$ (400 – 875 keV; 875 – 2500 keV)
- energy range 400 keV – 2.5 MeV
- different gas mixtures/pressures to limit the escape of recoil deuterons

D_2/CD_4	neutron energy:	400 – 625 keV
C_3D_8 600 hPa		625 keV – 1.25 MeV
C_3D_8 1000 hPa		1.25 – 2.5 MeV

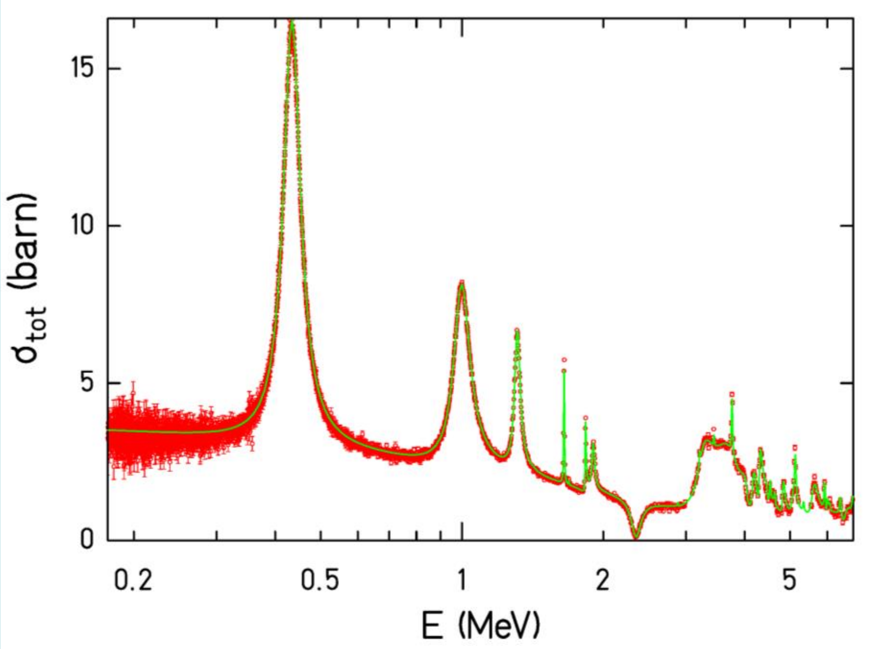


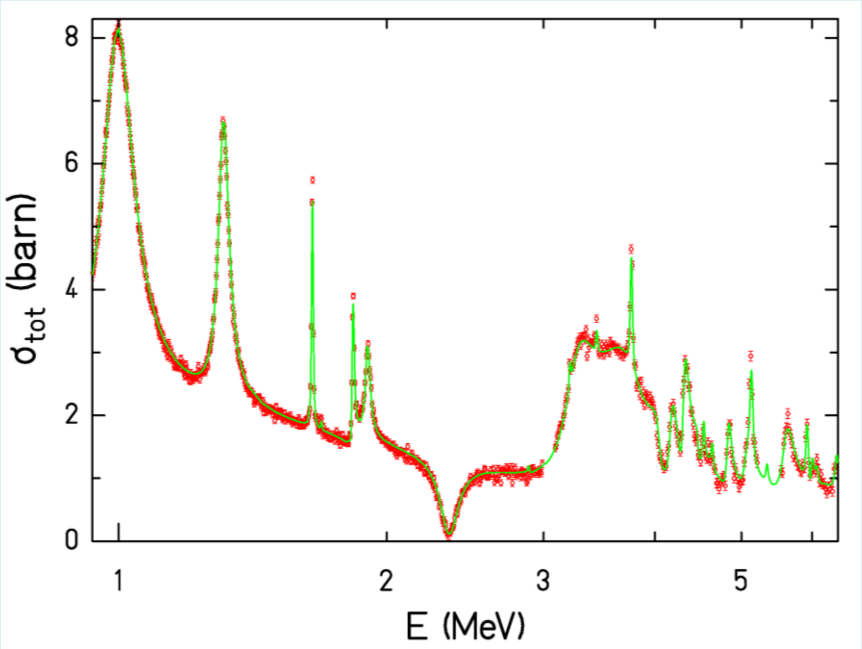




O(n,tot) – HZDR (CHANDA)

- Transmission station HZDR – nELBE (see I240)
- JEFF-3.2, response folded (green); data (red)



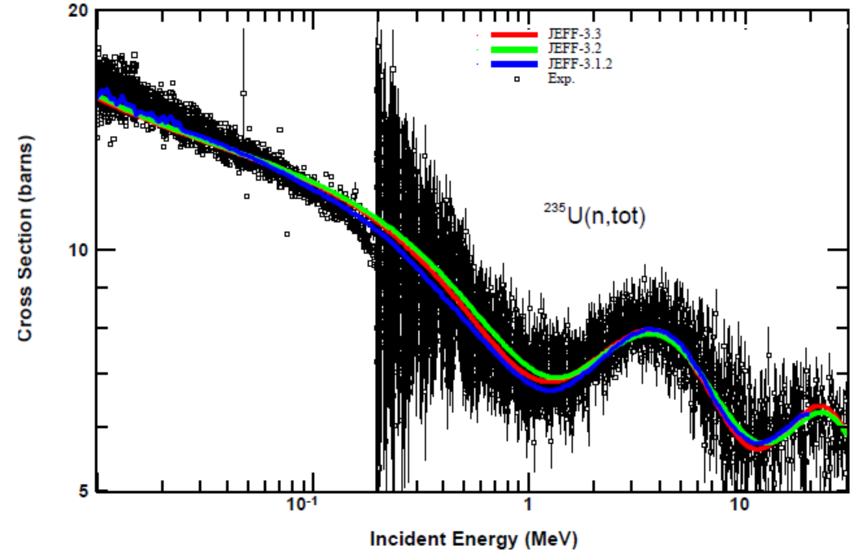


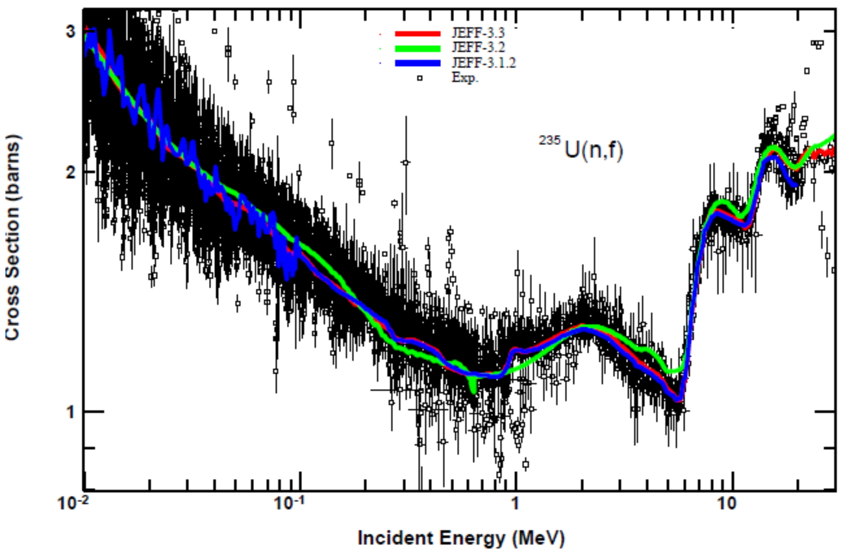
JEFF – 3.3, 20 November 2017

- New major actinides (CEA Cadarache & Bruyeres-le-Chatel, IRSN)
- FY beta file UKFY3.7 (NNL)
- Radioactive Decay Data File (CEA Saclay)
- New covariances
- Increased reliance on TENDL for completeness and decay heat (D. Rochman, M. Fleming)
- New Cu files (Pereslavtsev, Leal) solved important issue with JEFF-3.2
- Improved gamma-emission data (C. Jouanne, R. Perry, G. Noguere, O. Serot, …)
- Restoration of 8 group structure for delayed neutrons (P. Leconte)
- New thermal scattering data (Cantargi, Granada, Marquez Damian, Noguere)
- Removal of legacy files, update of adopted files to latest release
- Many issues resolved (many contributors)

European Commission

JEFF-3.3 U-235





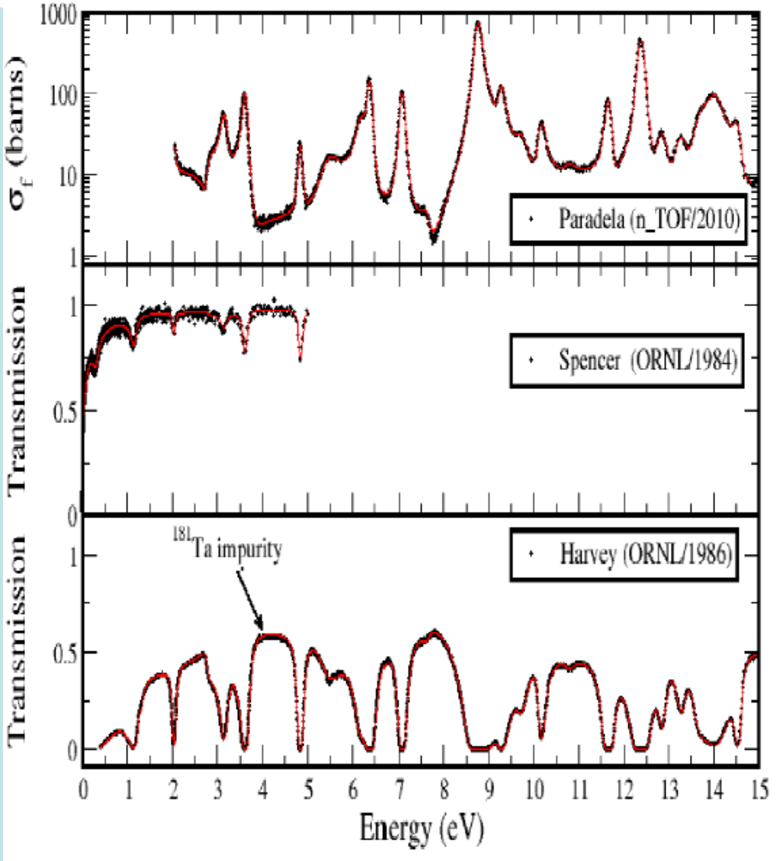


Table 3: Standard values and resonance parameters results for 0.0253 eV

Parameter	Standard Values (b)	Values obtained with the new resonance parameters (b)
σ_f(b)	584.4 ± 1.0	584.4
σ_γ(b)	99.30 ± 0.73	99.23
σ_s(b)	14.09 ± 0.22	14.09
Fission integral in the 7.8-11 eV range (b eV)	246.4 ± 1.2	246.9

European Commission

JEFF-3.3 Pu-239

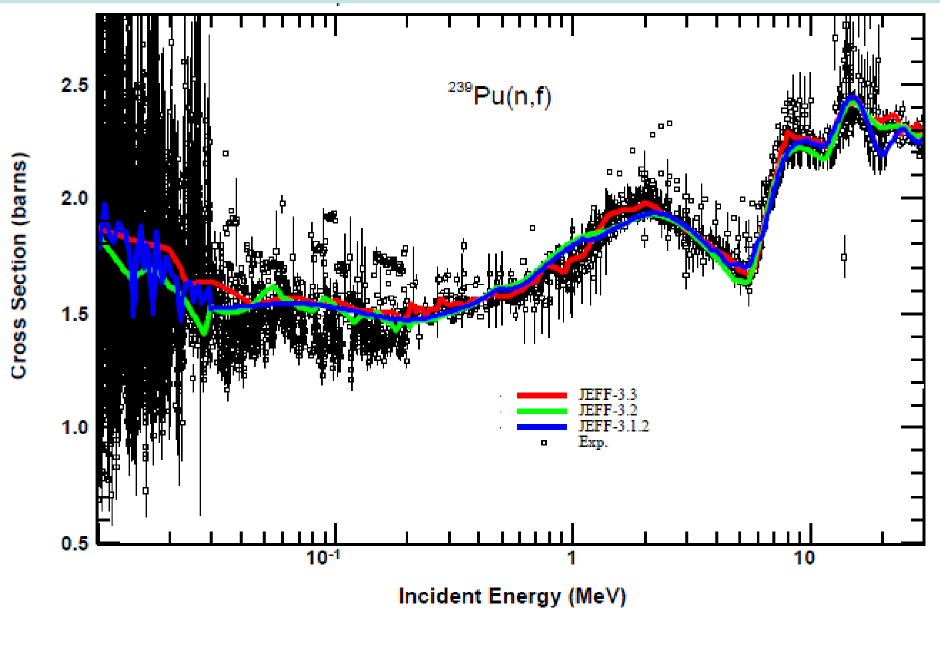
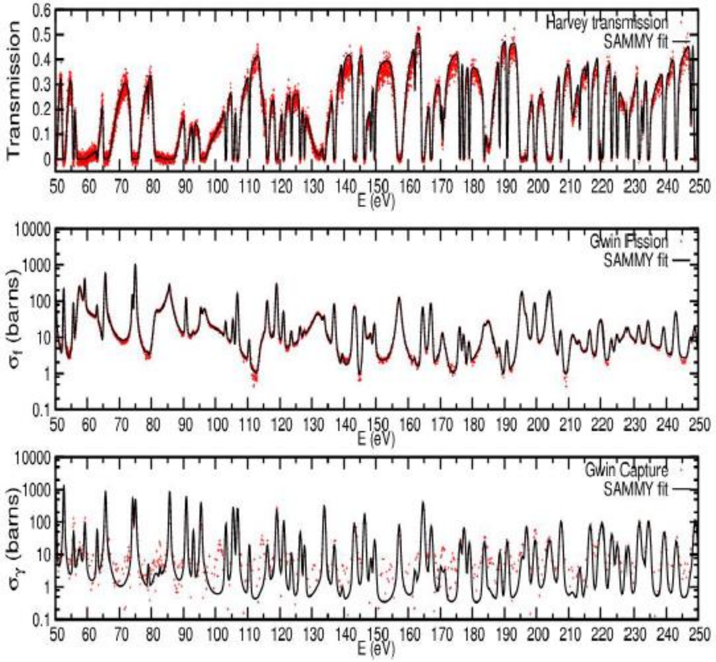


Table 7: Standard average fission integral

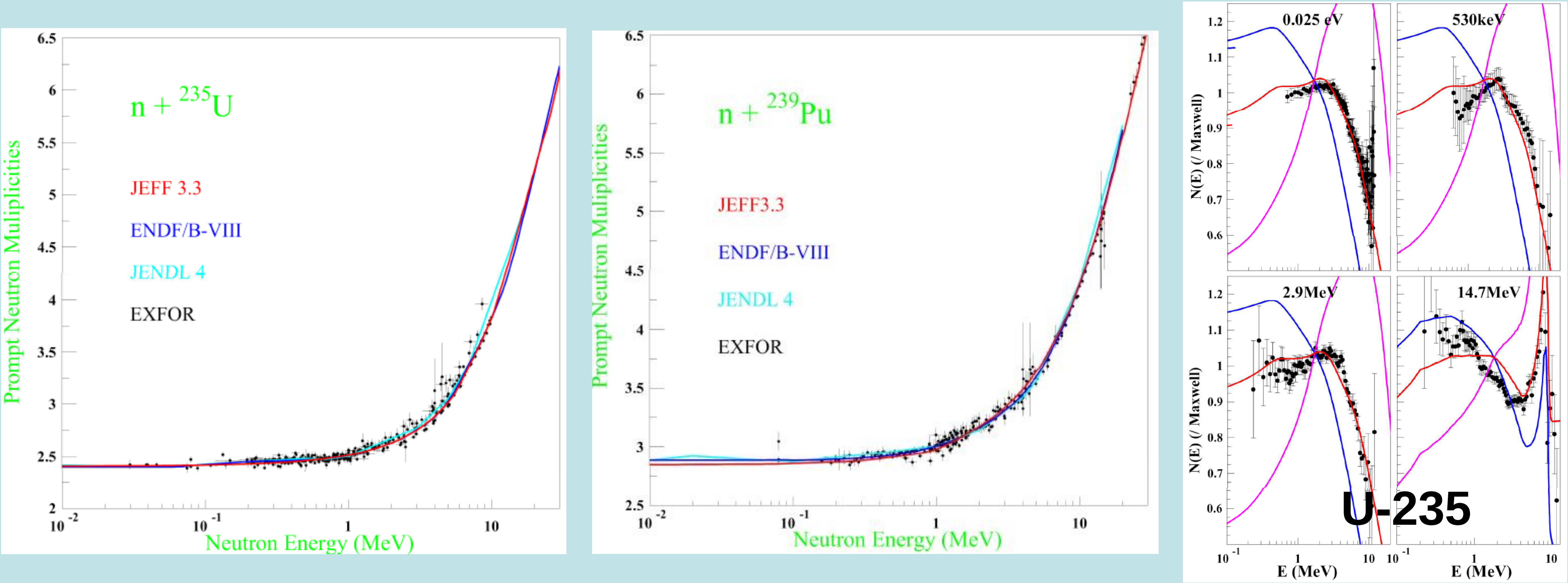
Energy Interval (eV)	Standard recommended values and uncertainties (barns)	Average fission cross section obtained with the new resonance parameter (barns)
100 - 200	18.709 (93)	18.547
200 - 300	17.859 (89)	17.832
300 - 400	8.562 (51)	8.309
400 - 500	9.567 (48)	9.564
500 - 600	15.489 (77)	15.495
600 - 700	4.523 (27)	4.286
700 - 800	5.654 (34)	5.508
800 - 900	5.039 (30)	4.859
900 - 1000	8.384 (50)	8.496
1000 - 4000	4.515 (31)	4.369



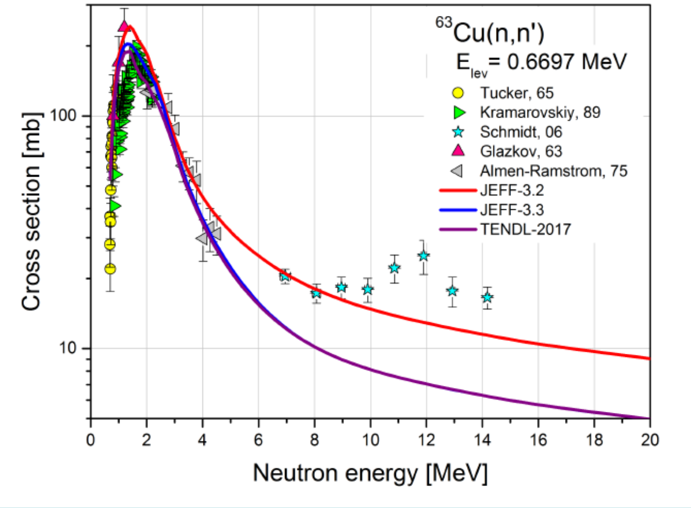
	ANR	JEFF-3.1.1	JEFF-3.2	JEFF-3.3
σ_γ	269.1 ± 2.9	272.61	270.06	271.3
σ_f	748.1 ± 2.0	747.08	747.19	749.0
σ_s	7.94 ± 0.36	8.0	8.1	7.76

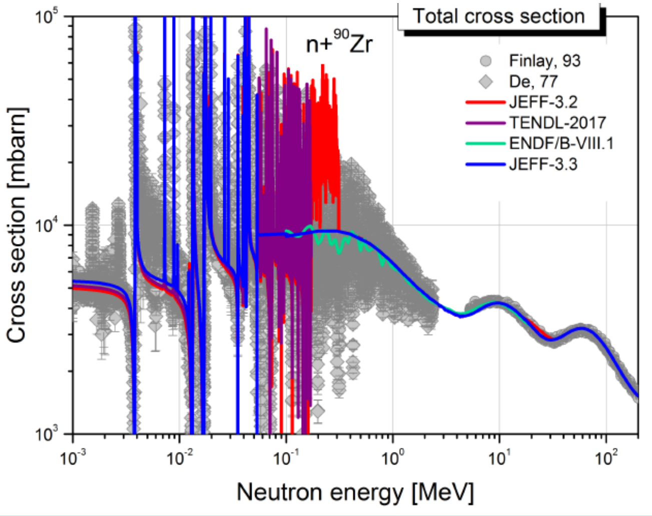
European Commission

U-235, Pu-239 nu-bar and pfns



Structural materials, coolants





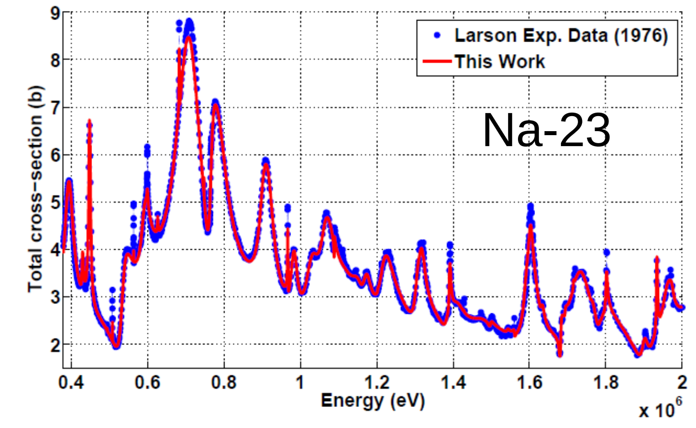
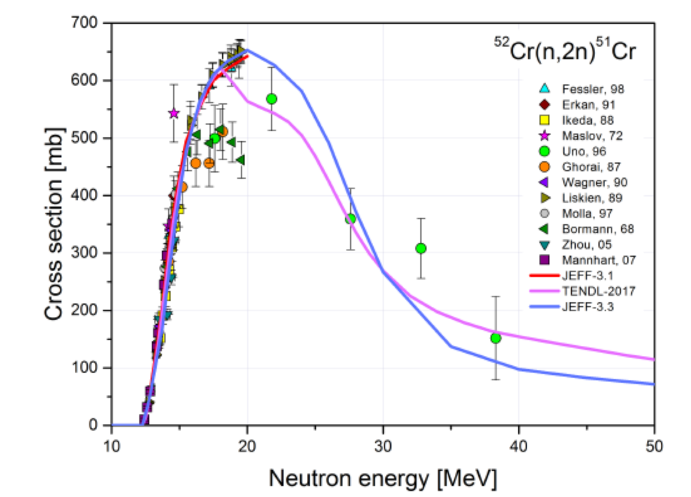
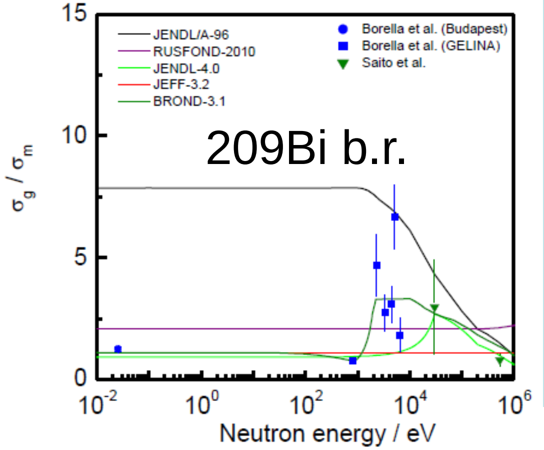
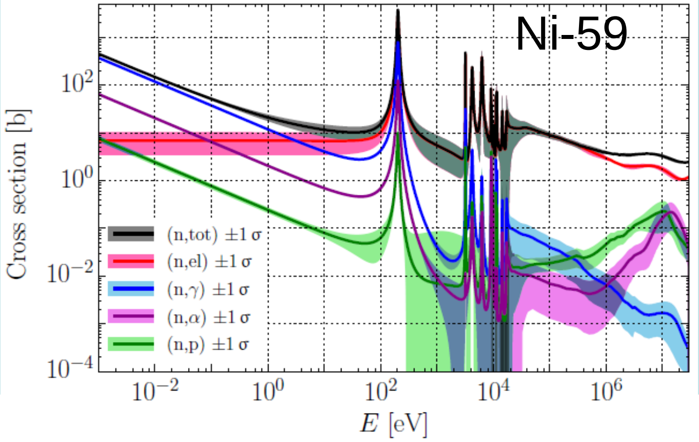


Fig. 31: Evaluated ^{23}Na total cross-section (red) compared to Larson experimental data (blue dots)





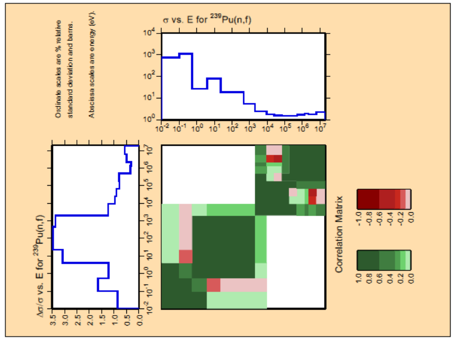


European Commission

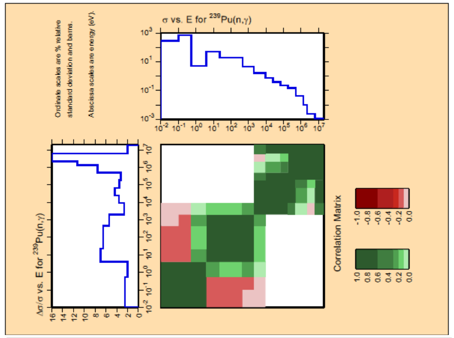
Cyrille De Saint Jean

^{239}Pu

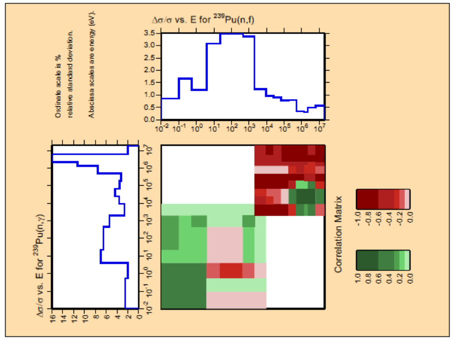
(n,f)



(n,g)

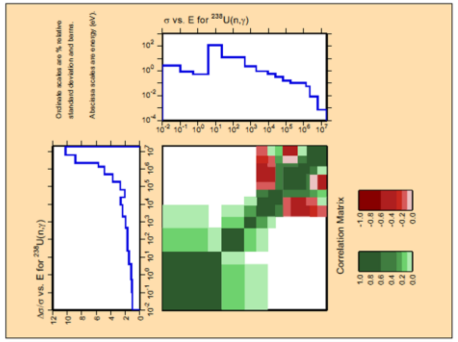


(n,f) x (n,g)

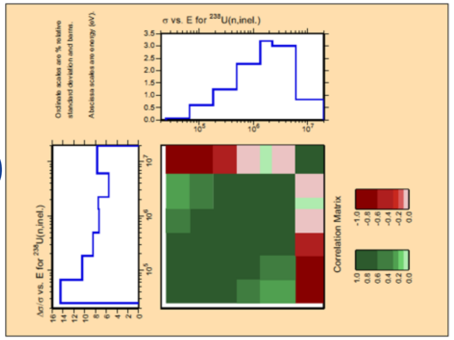


^{238}U

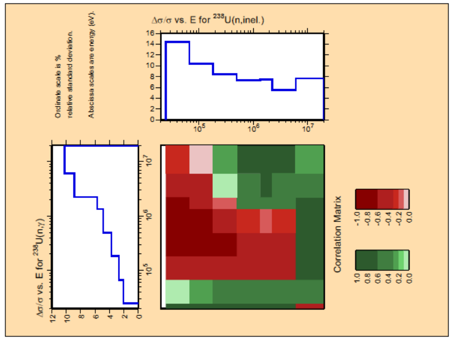
(n,g)



(n,inl)

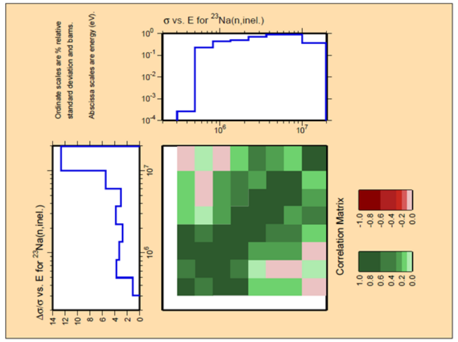


(n,g) x (n,inl)



^{23}Na

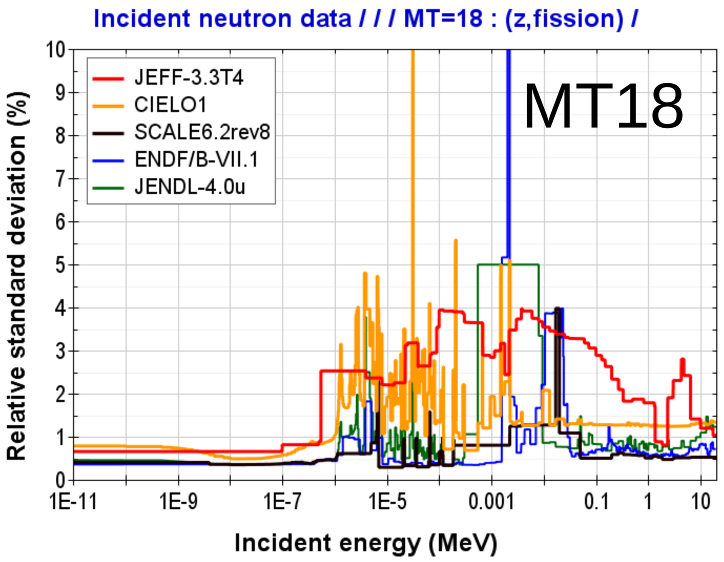
(n,inl)

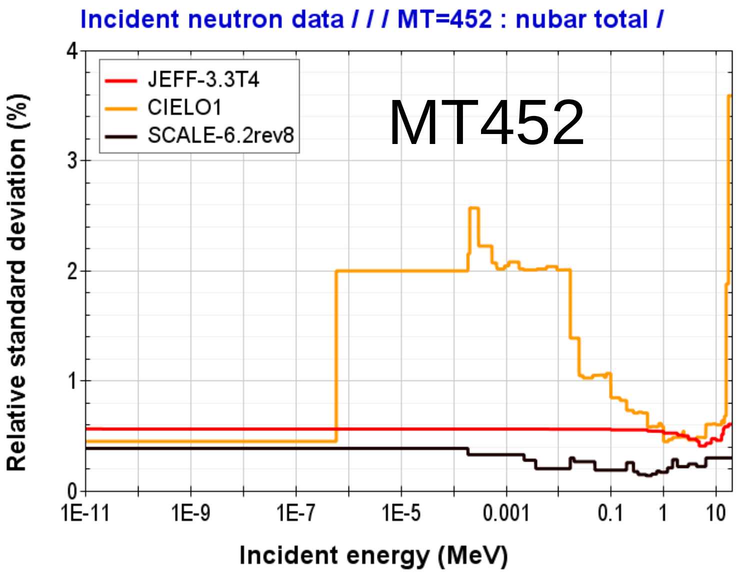


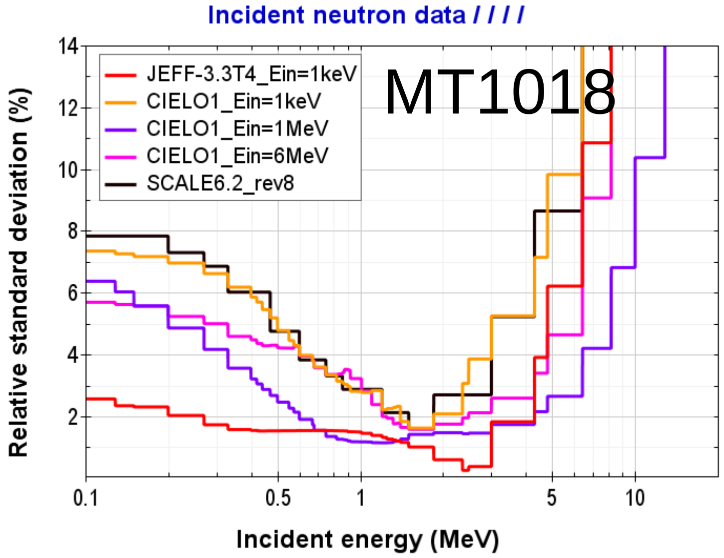
Further covariances for Hf

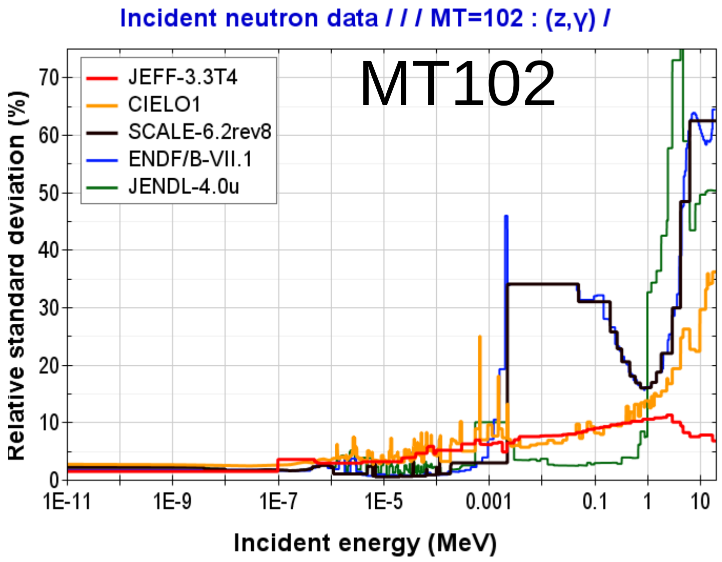
Many from TENDL (D. Rochman)

❑ U-235









European Commission

Robert Mills, NNL, UKFY-3.7 = JEFF-3.3 FY

Max. Fraction of Fission Rate			
>10%	1-10%	0.1%-1%	Spont. fission
nuclides: 5	2	12	3
*^{233}U TFH	*^{240}Pu F	*^{232}Th FH	^{252}Cf Sp
*^{235}U TFH	^{245}Cm TF	^{234}U F	^{242}Cm Sp
*^{238}U FH		^{236}U F	^{244}Cm Sp
*^{239}Pu TF		^{237}Np TF	
*^{241}Pu TF		^{238}Np TF	
		^{238}Pu TF	
		^{242}Pu F	
		^{241}Am TF	
		^{242m}Am TF	
		^{243}Am TF	
		^{243}Cm TF	
		^{244}Cm TF	

* Nuclides in UKFY1 and previous UK libraries.
T Thermal fission.
F Fast fission.
H 14Mev Fission.
Sp Spontaneous fission.

Neutron spectra	Fissioning nuclide	UKFY3.6	New data	UKFY3.7
Thermal	Th229	337	72	409
Thermal	U233	757	188	945
Thermal	U235	2390	151	2541
Thermal	Np238	115	63	178
Thermal	Pu239	861	225	1086
Thermal	Pu241	334	63	397
Thermal	Cm245	161	219	380
Thermal	Cf249	305	239	544
Fast	U235	724	5	729
Fast	Pu239	390	5	395
Fast	Pu241	111	5	116

New JEFF-3.3 DD file, Mark Kellett, CEA Saclay

• From JEFF-3.1.1 to JEFF-3.3

JEFF-3.3 (released October 2016):

Complete re-assessment and update to all 900 evaluations coming from ENSDF

Assessment of IAEA actinide decay data (85 nuclei)

Assessment of IRDFF decay data library (~80 nuclei)

Inclusion of updated UKPADD-6.12 library (~50 additional nuclei)

Assessment of new DDEP evaluations (~30 additional nuclei)

Inclusion of initial TAGS results from University of Valencia *(2010)*

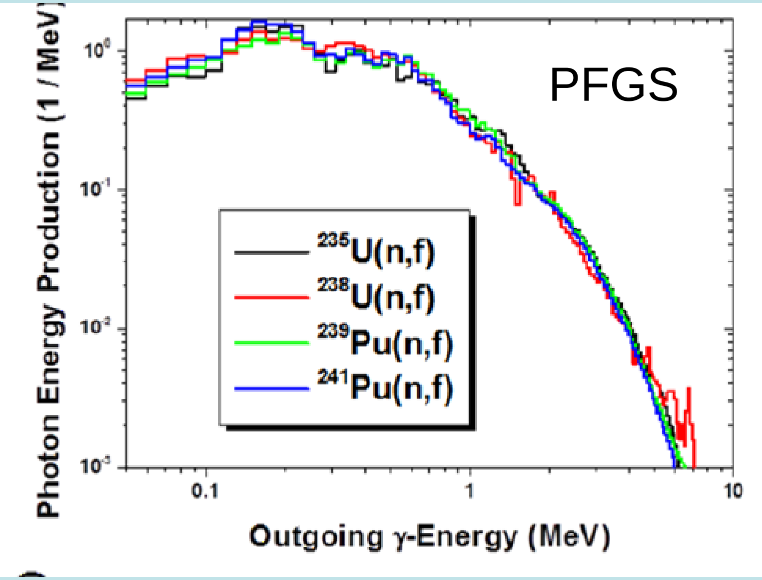
Inclusion of first TAGS results from University of Nantes *(2015)*

Inclusion of further TAGS results from University of Valencia *(2016)*

Corrections based on limited feedback to JEFF-3.1.1

JEFF-3.3 Gamma yields

- Prompt fission (Serot)
- Capture (Perry, Noguere, Serot)
- Inelastic (Jouanne)



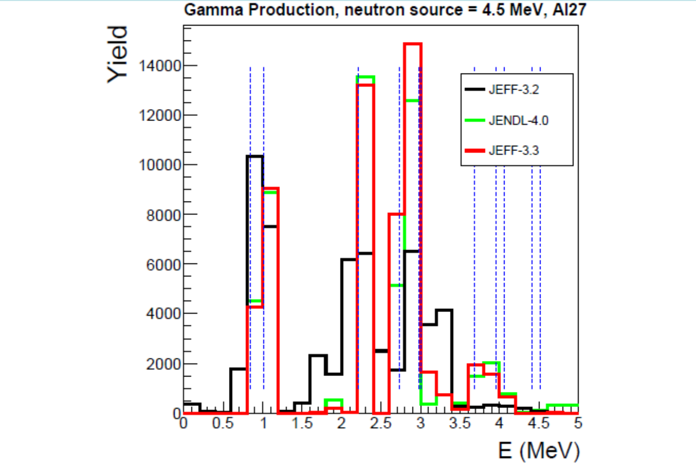
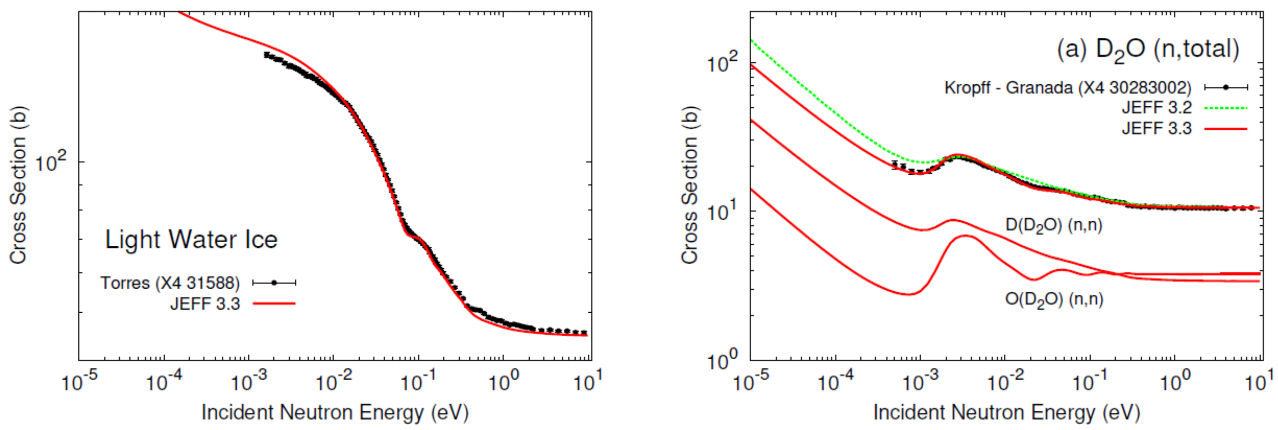


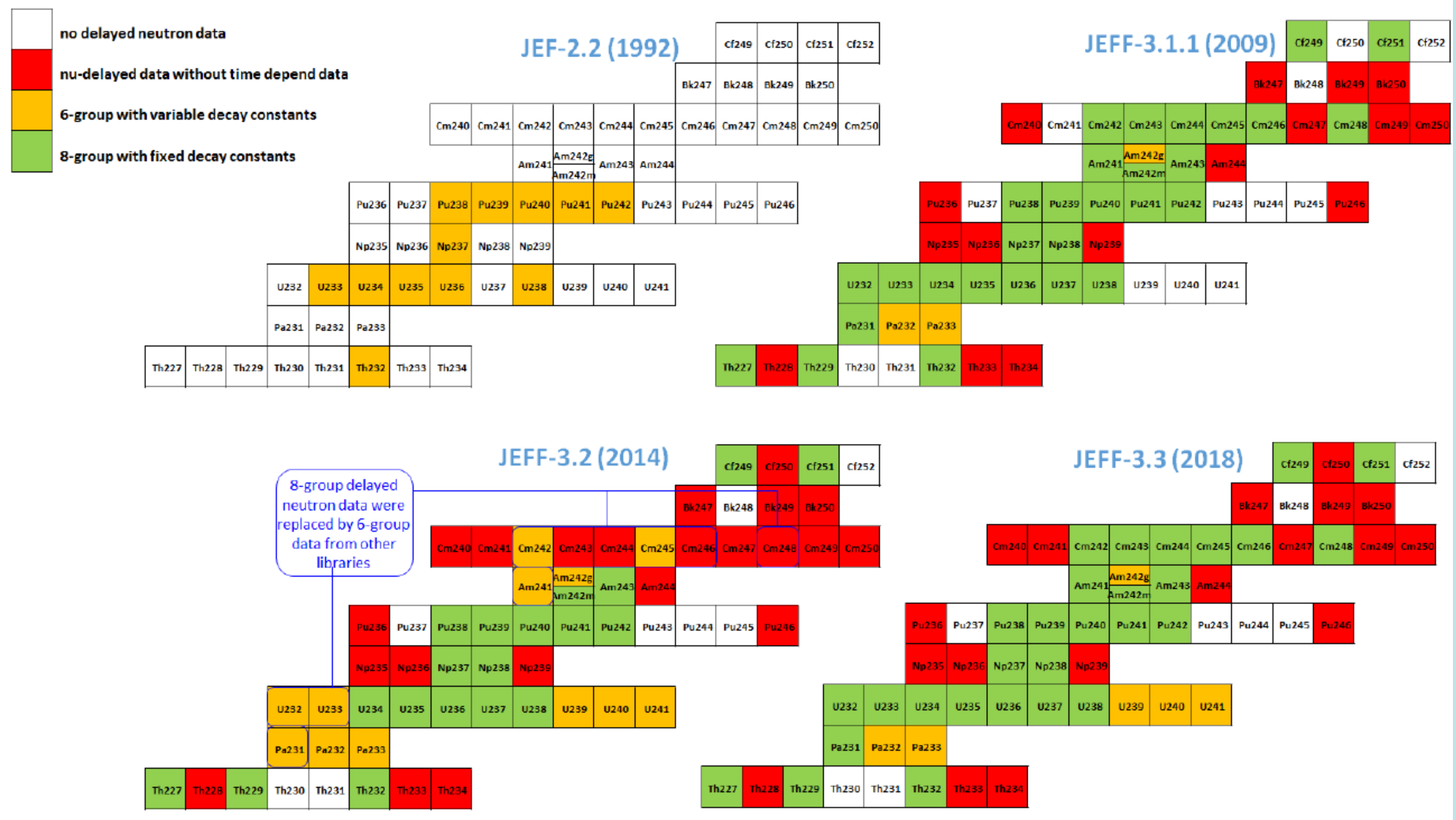
Fig. 71: Monte-Carlo simulations of gamma spectra from Al-27 inelastic scattering with 4.5 MeV neutrons, with excited level energies of Al-27 shown in blue.

Thermal scattering

- 20 files, 14 new, first covariances for H in H_2O.
- Cantargi, Granada, Marquez Damian
  - D in D_2O, Ortho D_2, Para D_2
  - H in ice, mesitylene, Ortho H_2, Para H_2, toluene
  - O-16 in D_2O, Al_2O_3
  - Al in $Al2O_3$
  - Si in Si
- Mg in Mg (Mounier)
- H in CaH_2, Ca in CaH_2 (Serot)
- Keinert, Mattes
  - H in H_2O, CH_2, ZrH (Keinert, Mattes)
  - Be in Be (Keinert, Mattes)
  - C in graphite (Keinert, Mattes)

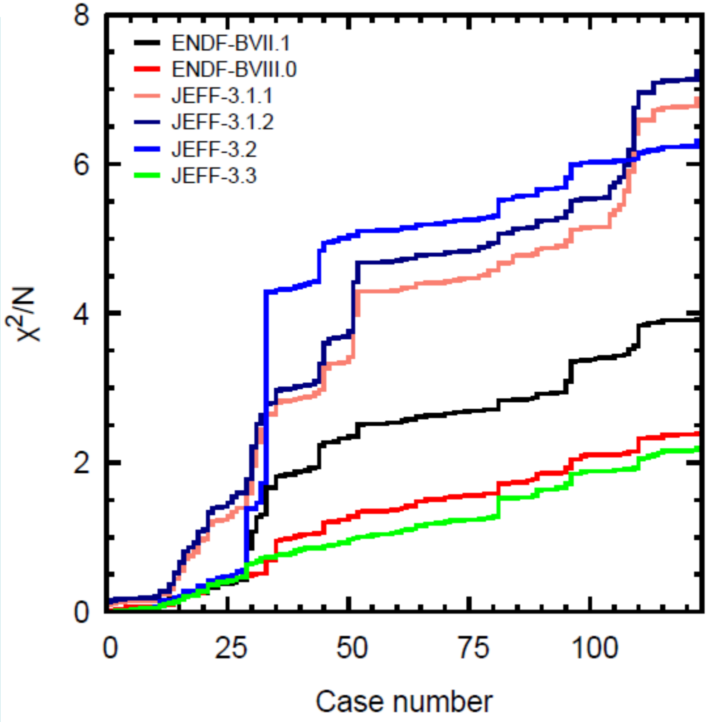


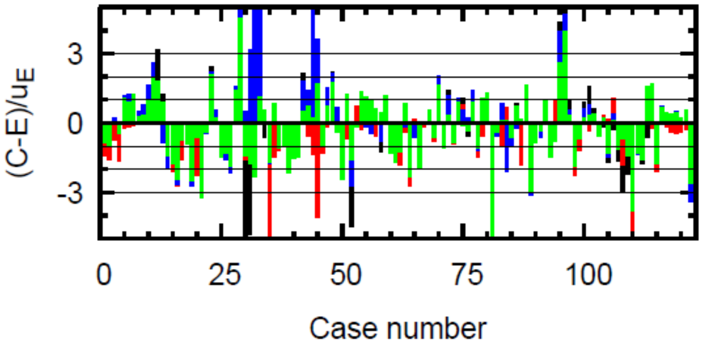
Delayed neutrons – 8 groups structure



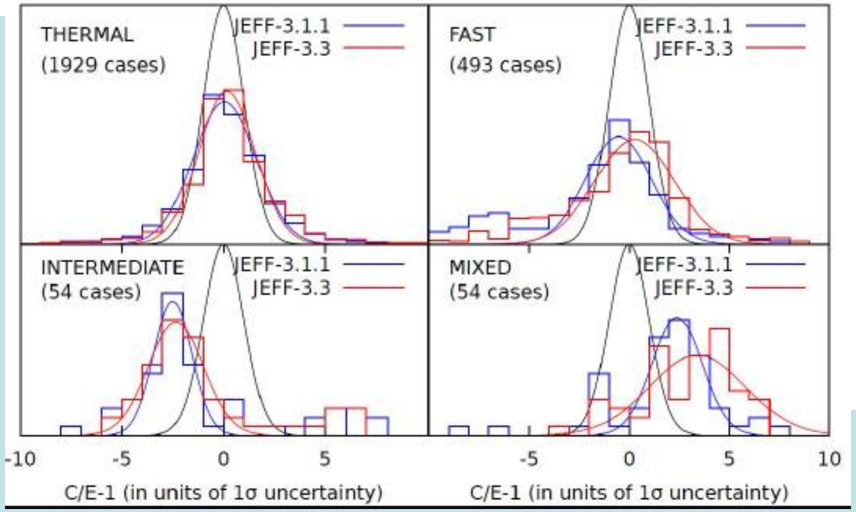
Benchmarking

NEA-Mosteller

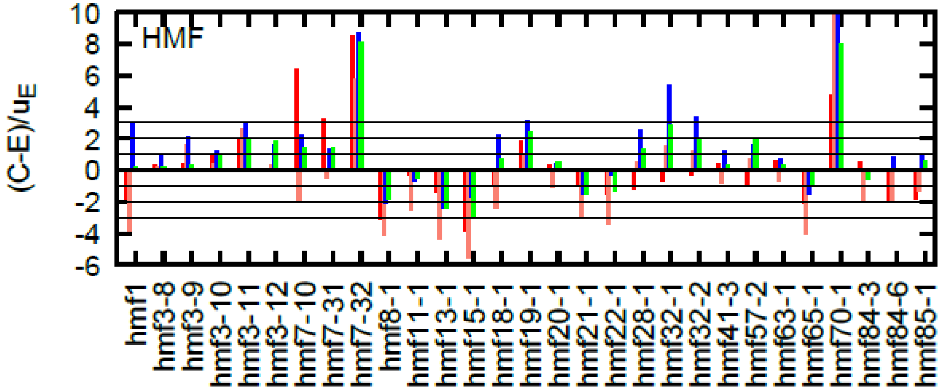


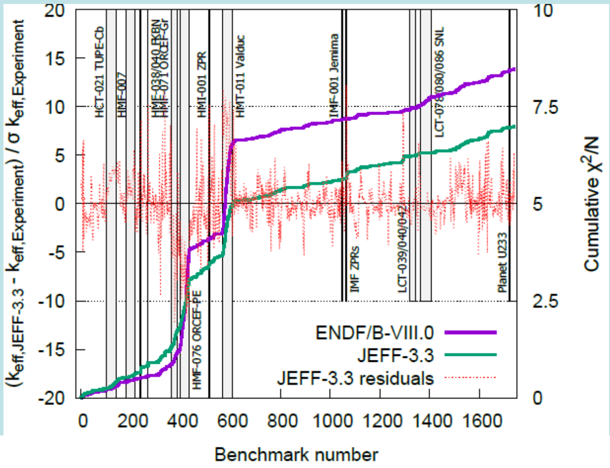


NRG - Van der Marck



IRSN - Leclaire





Trkov

JEFF-3.3 is considerably better than JEFF-3.2 and JEFF-3.1.1&2

JEFF-3.3 is comparable to ENDF/B-VIII.1

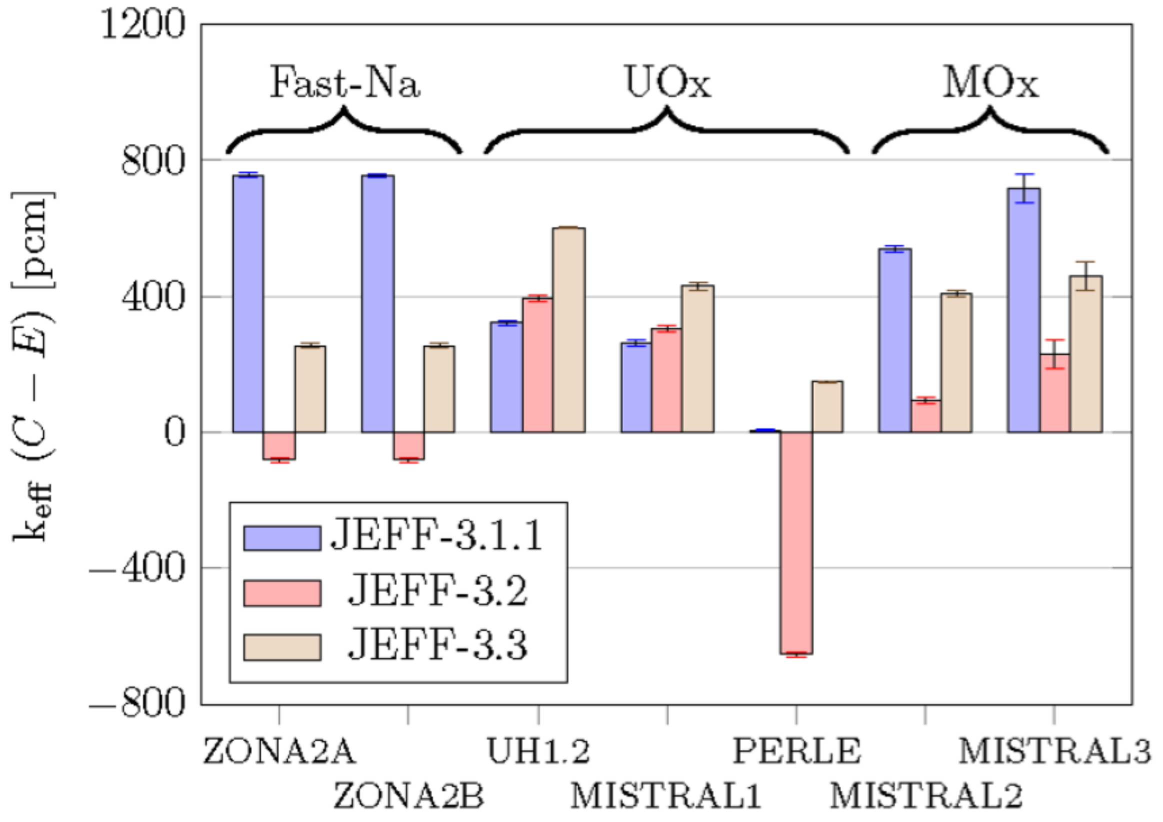
Distributions over benchmarks are strongly affected by outliers

Outlier analysis

- NEA+IRSN suite implied materials other than actinides (2-3s and **>3s**)
- The remainder of outliers (16 out of 45) are **actinide+water+oxygen** only.
- IAEA suite: 1/3 of cases are outliers > 2s. Many due to small benchmark unc.
- PE, Be/BeO, F, Al, concrete, S, steel, Cu, Er, W, Pb, Th
- (D2O, C, Hf, Np) … (Gd, Cr).
- Most important remain the major actinides

mat.	N	Cases
PE	2	**lmt5-1**, pmf31-1
D_2O	1	hst20-5
Be&BeO	5	hmf9-2, **hst46-1**, **pmf21-2**, **hmf38-1**, **hci4-1**
C	3	hmf19-1, hmi6-3, hst46-1
F	2	**hmf7-32**, hst20-5
Al	3	**hmf70-1**, imf6-1, **lmt5-1**
concrete	1	**hst7-1**
S	1	**hst46-1**
Steel	4	hmf13, hmf7-1, lct34-17, **hmi1-1**
Cu	2	**hmf73**, hmi6-1
Er	1	**lmt5-1**
Hf	1	lct29-8
W	2	**umf4-2**, **hmf70-1**
Pb	5	hmf57-2, **lct27-1 to** -4,
Th	1	**pmf8-1**
Np	1	smf8-1

Additional critical experiments



VENUS-F

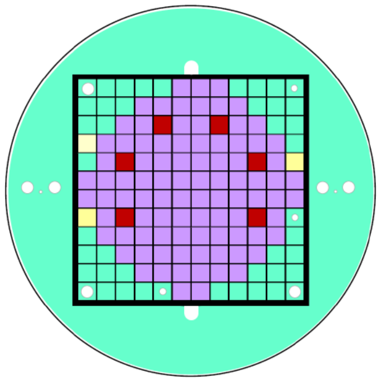
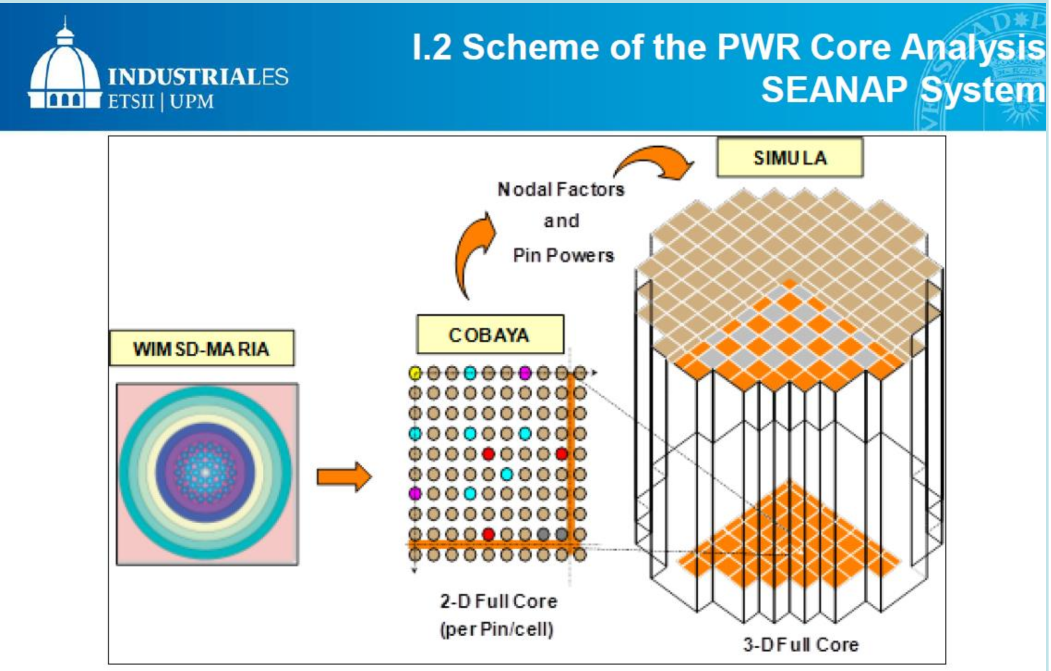


Table 32: Calculated k_{eff} -values for the VENUS-F CR0 core. The statistical uncertainty of the calculated values is less than 5 pcm.

library	k_{eff}	library	k_{eff}
JEFF-3.1.2	1.0059	JENDL-4.0	1.0031
JEFF-3.2	1.0083	ENDF/B-VII.1	1.0069
JEFF-3.3	1.0073	ENDF/B-VIII.0	1.0054

Application to PWR – UPM – SEANAP

Boron concentration and axial offset



SEANAP: WIMS-D4 (ND-1981+some updates (e.g. Gadolinium)) + COBAYA + SIMULA

		Boron concentration (ppm)			Axial Offset (%)		
Power (%)	Burnup (GWd/tM)	Meas. (ppm)	SEANAP Original Calculated (ppm)	SEANAP Upgraded Calculated (ppm)	Meas. (%)	SEANAP Original Calculated (%)	SEANAP Upgraded Calculated (%)
50	0.015	1200	1150	1165	7.7	5.6	5.9
75	0.031	1113	1071	1085	3.8	3.7	3.9
100	0.134	985	1000	1011	-0.7	0.7	0.8
100	1.34	870	897	896	-1.6	-1.2	-1.2
100	2.487	779	806	797	-2.4	-2.9	-2.9
100	2.842	755	778	768	-2.8	-3	-3.1
100	3.591	688	714	701	-3.8	-4.9	-5
100	4.441	604	645	629	-3.2	-3.8	-3.9
100	5.549	504	544	526	-3.9	-4.4	-4.6
100	6.692	412	439	420	-4.2	-4.4	-4.5
100	7.716	319	340	321	-4.7	-5.1	-5.2
100	8.823	227	239	219	-3.6	-2.8	-2.8
100	10.284	101	100	79	-3.5	-1.6	-1.5
100	11.351	4	-7	-29	-3.4	-2.1	-2.1

- JEFF-3.3 does very well when applied to an actual PWR code system

Delayed neutron testing

- Beta-eff versus 20 cases in literature and VENUS-F
- JEFF-3.3 comes out well (JEFF-3.1.1 somewhat better)

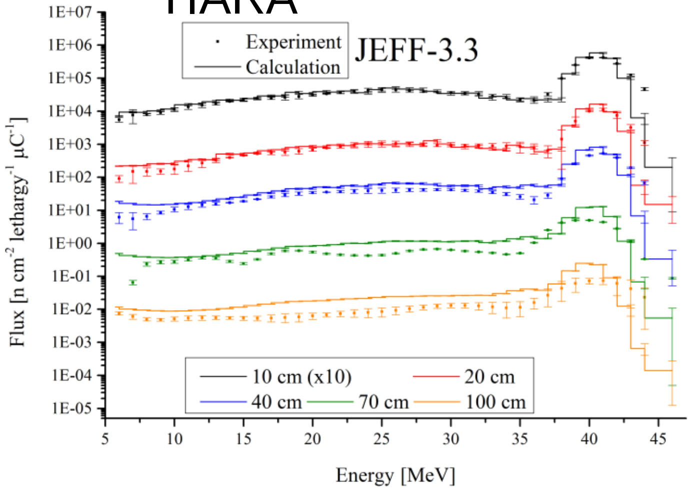
	Experiment β_{eff}		JEFF 3.3	JEFF 3.1.1
TCA	771	(2.2%)	2.3±0.8	3.9±0.7
IPEN/MB01	742	(0.9%)	4.2±0.9	4.6±1.0
Masurca/R2	721	(1.5%)	2.1±1.1	2.9±1.1
Masurca/ZONA2	349	(1.7%)	2.6±1.7	1.1±1.7
FCA/XIX-1	742	(3.2%)	3.0±1.2	3.6±1.2
FCA/XIX-2	364	(2.5%)	3.3±1.6	3.8±1.6
FCA/XIX-3	251	(1.6%)	4.4±1.9	-1.2±2.0
SNEAK/9C1	758	(3.2%)	-1.8±1.1	-0.8±1.1
SNEAK/7A	395	(5.1%)	1.0±1.5	-1.0±1.5
SNEAK/7B	429	(4.9%)	3.5±1.4	3.7±1.3
SNEAK/9C2	426	(4.5%)	-4.9±1.5	-5.4±1.5
ZPR-9/34	667	(2.2%)	0.7±2.2	4.2±2.2
ZPR-U9	725	(2.3%)	2.6±1.9	0.8±1.9
ZPPR-21/B	381	(2.4%)	-8.9±2.3	-4.5±2.2
ZPR-6/10	222	(2.3%)	5.9±3.8	3.9±0.7
Godiva	659	(1.5%)	0.3±1.1	-1.7±1.1
Topsy	665	(2.0%)	4.1±1.0	2.4±1.0
Jezebel	194	(5.2%)	-3.1±1.6	-1.0±1.6
Popsy	276	(2.5%)	7.6±1.7	4.3±1.4
Skidoo	290	(3.4%)	0.7±1.4	1.7±1.4
Flattop	360	(2.5%)	3.1±1.3	4.2±1.3

	Experiment Rossi$-\alpha$		JEFF 3.3	JEFF 3.1.1
SHE/core8	6.53e-3	(5.2%)	-1.5±1.0	-3.5±1.0
Sheba-II	200.3e-6	(1.8%)	-4.4±1.4	4.7±1.4
Stacy/run-029	122.7e-6	(3.3%)	-2.9±1.2	3.5±1.2
Stacy/run-033	116.7e-6	(3.3%)	-0.6±1.2	0.2±1.2
Stacy/run-046	106.2e-6	(3.5%)	-0.1±1.1	0.7±1.1
Stacy/run-030	126.8e-6	(2.3%)	-1.1±1.2	0.9±1.2
Stacy/run-125	152.8e-6	(1.7%)	-4.1±1.2	3.2±1.2
Stacy/run-215	109.2e-6	(1.6%)	-4.6±1.1	0.0±1.2
Winco	1109.3e-6	(0.1%)	-4.4±1.0	0.7±1.0
Big Ten	117.0e-6	(0.9%)	0.1±1.4	-0.3±1.5

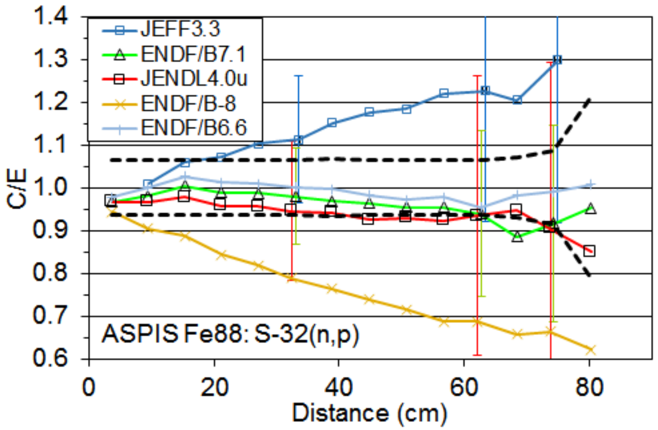
library	β_{eff}	library	β_{eff}
JEFF-3.1.2	730	JENDL-4.0	724
JEFF-3.2	733	ENDF/B-VII.1	727
JEFF-3.3	729	ENDF/B-VIII.0	727
Experiment	730(11)		

Cross section validation using shielding benchmarks from SINBAD Ivo Kodeli I443

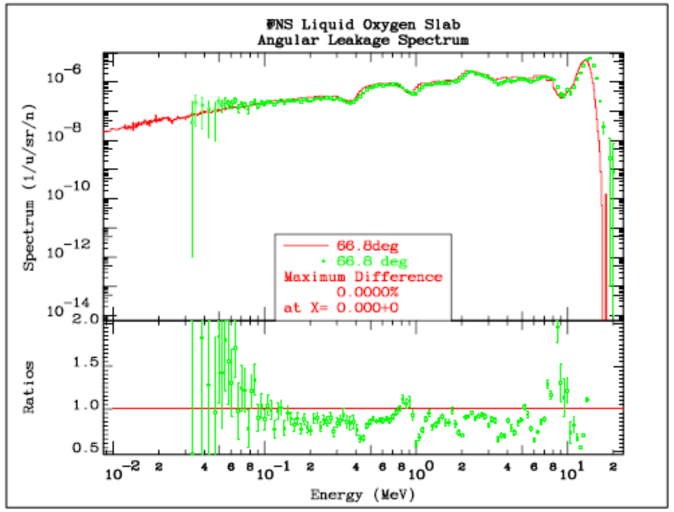
TIARA



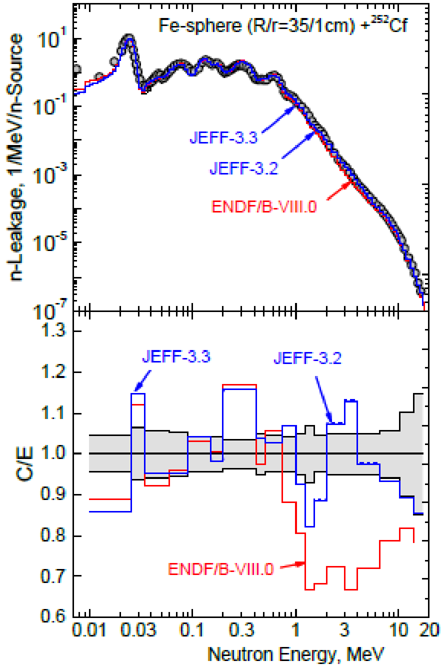
ASPIS IRON-88

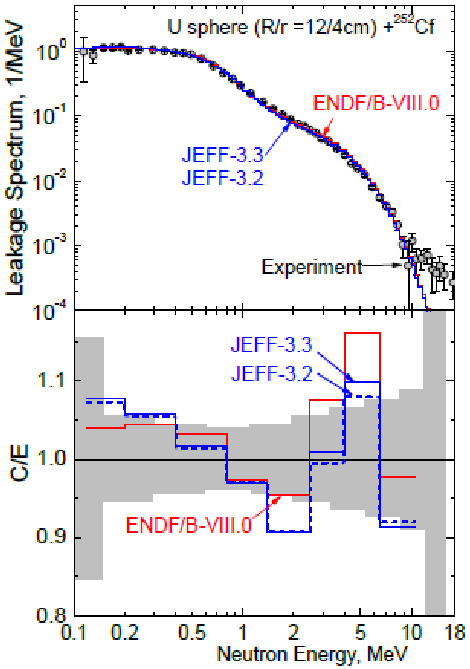


FNS Oxygen



Cf-252 leakage spectra Fe and U - IPPE





Decay Heat, Pu-239 & Inconel-600 examples

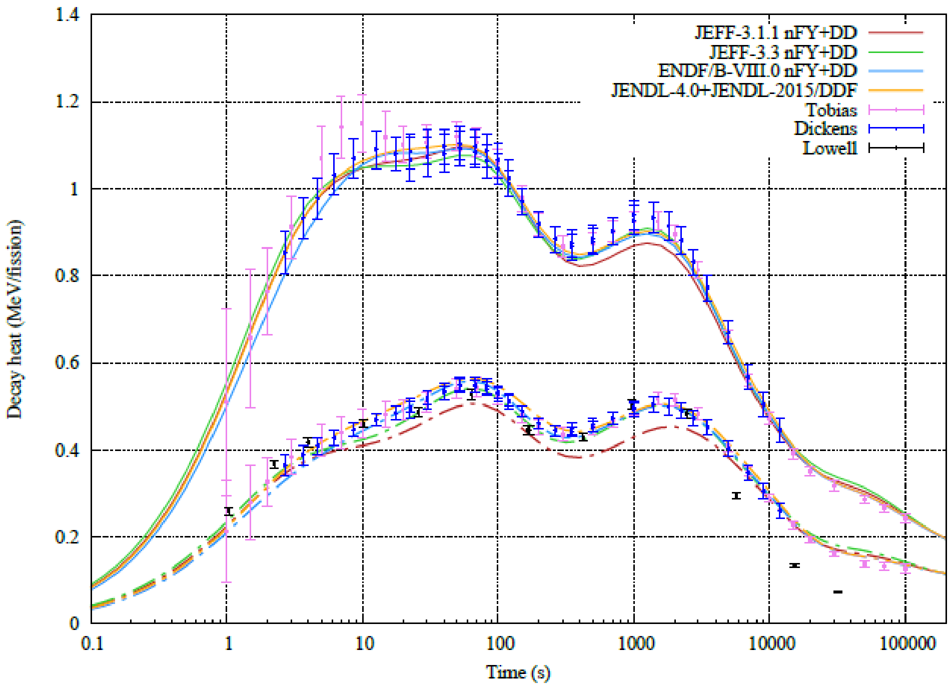


Fig. 98: Total and gamma fission decay heat pulse for ^{239}Pu, showing simulations with a range of nuclear data files, as calculated by FISPACT-II. Note the significant under-prediction of gamma heat for JEFF-3.1.1, over a range of cooling periods from 10 to 2000 seconds.

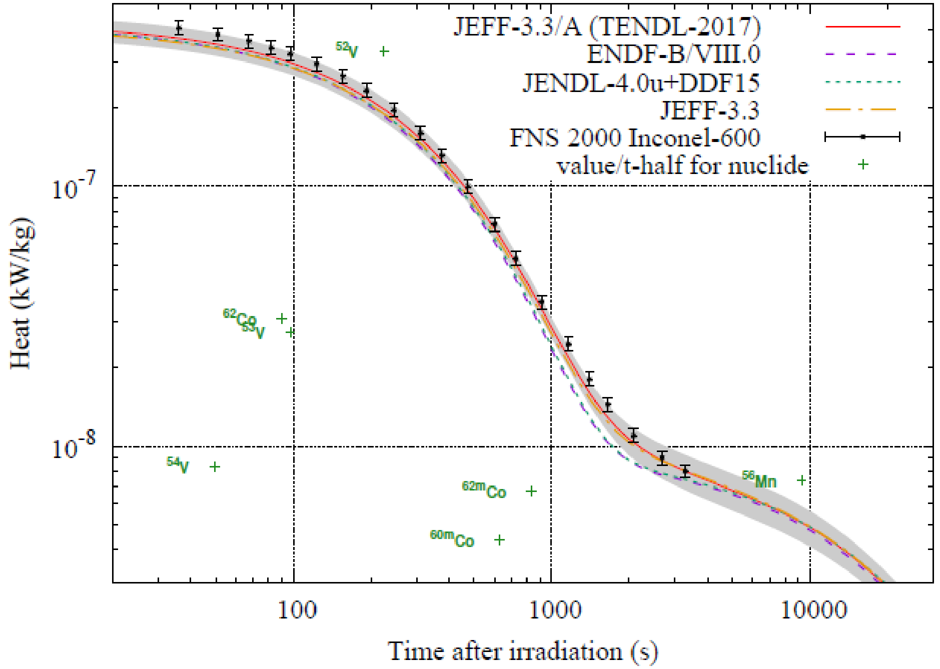


Fig. 100: Decay heat simulations and measurements from the JAEA Fusion Neutron Source, considering Inconel-600 irradiation and the most recent nuclear data libraries. Dominant nuclides are labeled at (x,y) coordinates that are their half-life and post-irradiation quantity, respectively.

European Commission

JEFF-4.0

- We want JEFF-4 to be a fundamental change
- Best knowledge for users – best physics
- Completeness – large reliance on TALYS and TENDL
- Agreed ways of integrating contributions
- Version and documentation control
- Use modern tools for inspection and checking
- Use modern tools for benchmarking and validation
- Eliminate limitations (formats, correlated emissions)
- Method development 2018-2020
- JEFF-4 development 2021-2024

CEA model development for improved evaluations

Summary

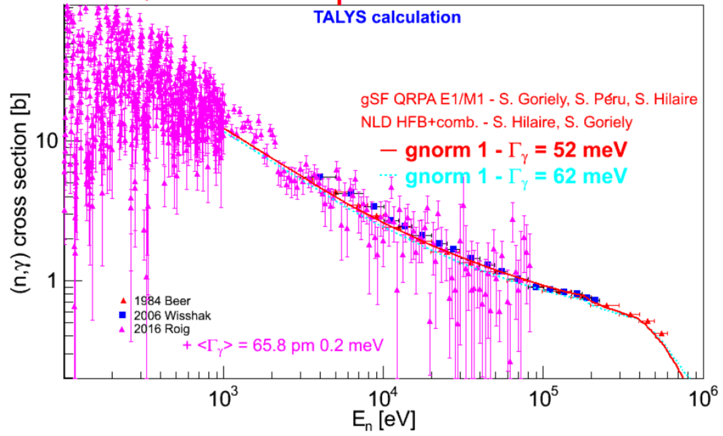
- Using better models allows to better reproduce experimental data
  Ex: OMP, Statistical models, Level densities, $\Gamma\gamma$, fission transmission

- Microscopic models are able to compute model ingredients from nuclear interaction + many body formalism (no adjustment)

- Use of better (more microscopic) reduce the dynamics of model parameter adjustment.
  + parameter values more physical
  - fine adjustments still needed for optimal agreement with data
  Ex: OMP, level densities, $\Gamma\gamma$, fission transmission

- Examples shown for cross sections in the continuum
but conclusions also relevant for PFNS, PFGS, and in the resonance region

What about QRPA microscopic calculations?



Hilaire R180

Quantification of model defects into the covariance matrix is needed
BUT using better models will reduce the amplitude of such defects.

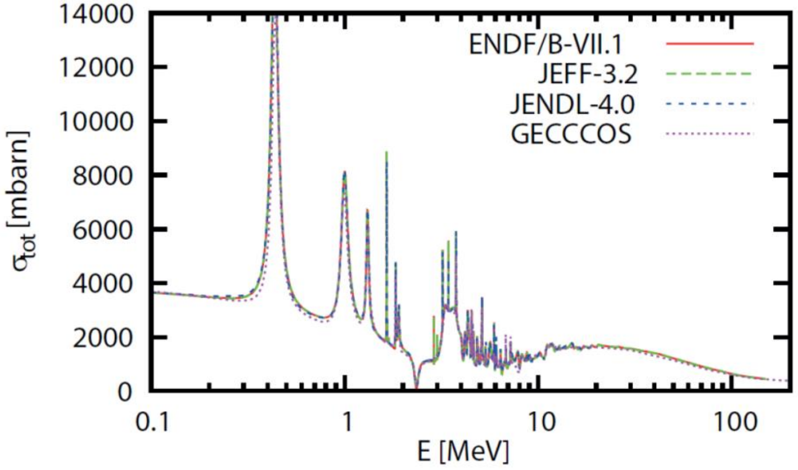
Evaluation of n + ^{16}O cross-section data using Hybrid R-Matrix approach

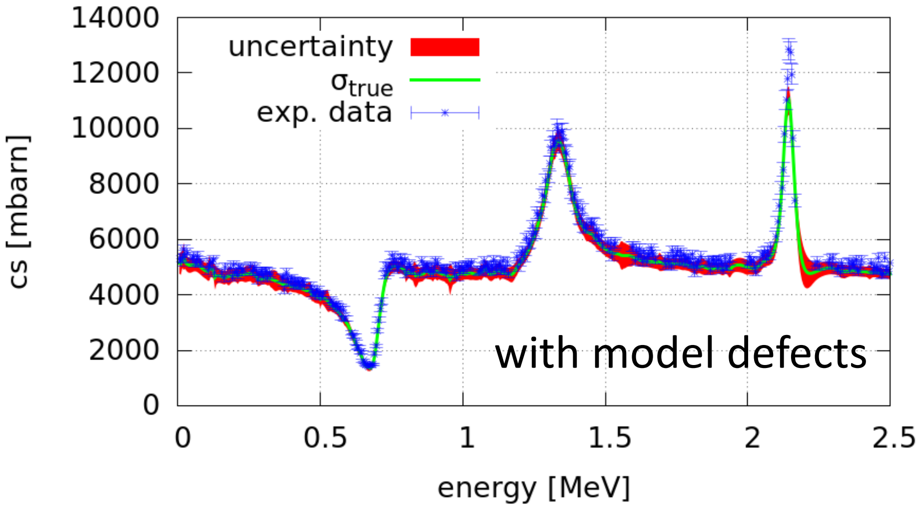
- ***Hybrid R-matrix fit*** *in energy range 1 keV – 14 MeV using TUW code system* ***GECCCOS***
- *Statistical model fit using TALYS with optimized optical potentials (1 keV – 200 MeV)*
- *Unified Bayesian evaluation* ***accounting for model defects*** *(in resonance and statistical energy range) providing co-variance matrices*

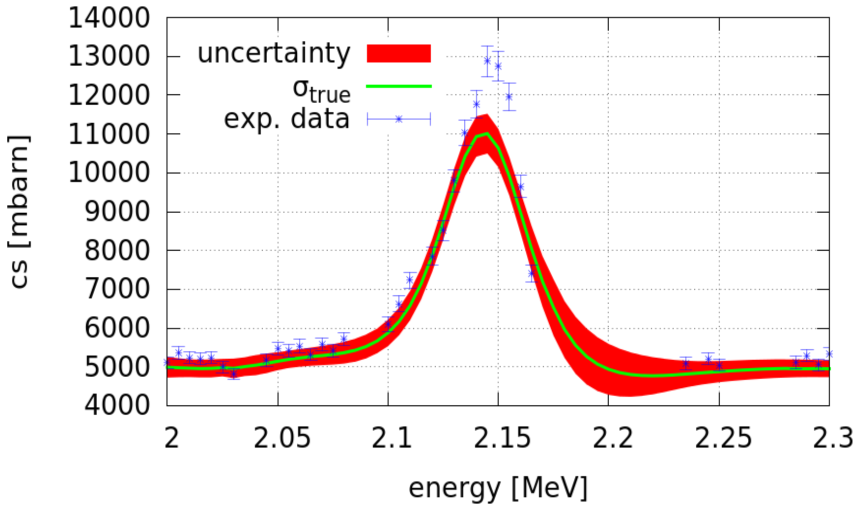
⇒ *Production of full ENDF prototype data file for use in benchmark analyses*

⇒ H. Leeb, R046

Total cross-section n + ^{16}O



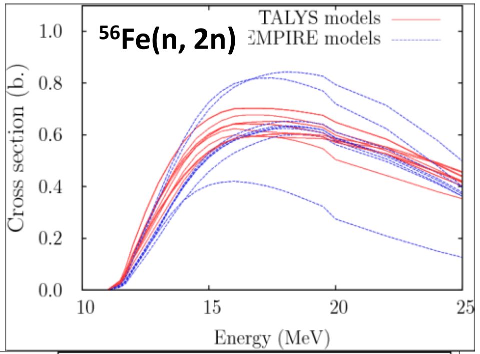


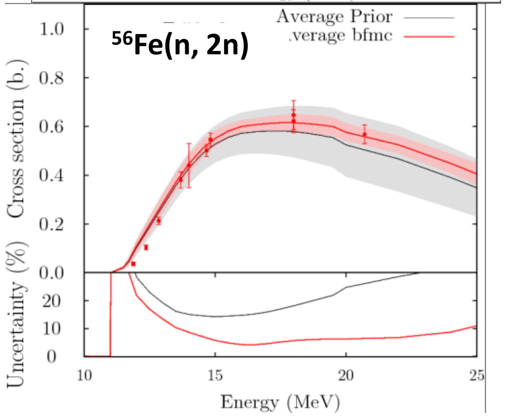


Evaluation of fast n + ^{56}Fe cross-sections using advanced evaluation methodologies Arjan Koning L451

PAUL SCHERRER INSTITUT PSI

- ***Randomly generated nuclear data evaluations/files***
  - *Extension of TMC method (A. Koning, D. Rochman)*
  - *Varying nuclear models (e. g. gamma strength functions, leve densities, optical models, … from TALYS & EMPIRE) and parameters (n + ^{56}Fe: 18 000 random files created)*
  - *BMC/BFMC method to find best final evaluation*
  - *Testing with criticality and shielding benchmarks*





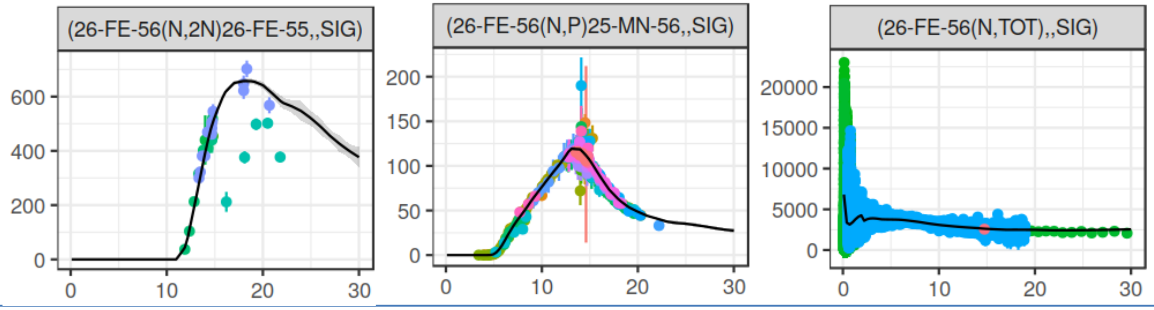
- ***Model defects to describe imperfect physical models and data inconsistencies***

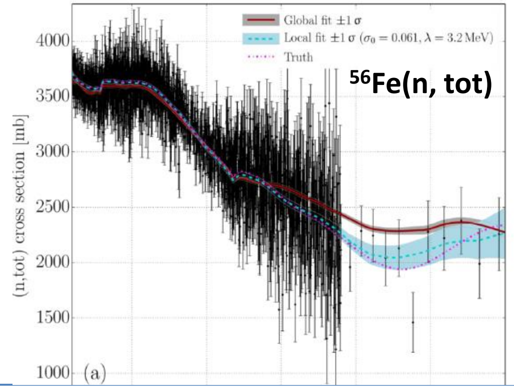
⇒ G. Schnabel, R033

UPPSALA UNIVERSITET

  - *Simulation of model defects by energy-dependent parameters in TALYS code*
  - *Parameter functions modelled as Gaussian processes fitted together with energy-independent parameters*

⇒ *Demonstration ENDF data file up to 30 MeV*

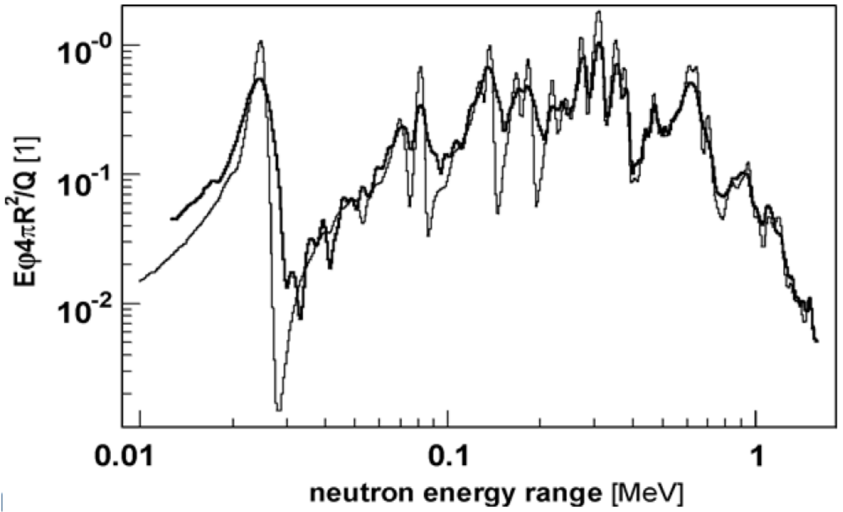




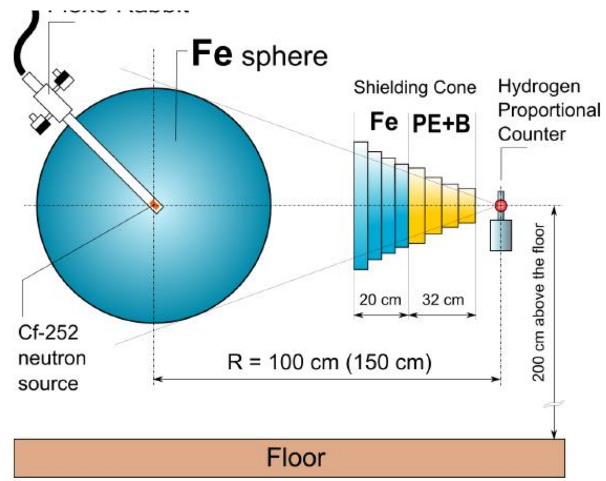
jefdoc-1918

NEA Nuclear Data Week - JEFF Meetings
18 - 20 April 2018, CIEMAT, Moncloa Centre,
Madrid, Spain

Research Centre Rez. Czech Republic



Iron-56, problem with the elastic cross section in neutron energy region around 300 keV and natural iron isotopes influence on the neutron transport through iron



B. Jansky.1.*, J. Rejchrt .1, M.Schulc.1, A. I. Blokhin. 2

1 Department of Neutron Physics. Research Centre. Rez. Czech Republic
2 Nuclear Safety Institute. Russian Academy of Sciences. Moscow. Russia

Resonance range evaluations

JRC & partners

- Au (500 eV <->5 keV)

CEA/Cadarache

- Lu
- Ag

KAERI

- Rh
- Gd (+ INFN Bologna + ENEA)

JAEA

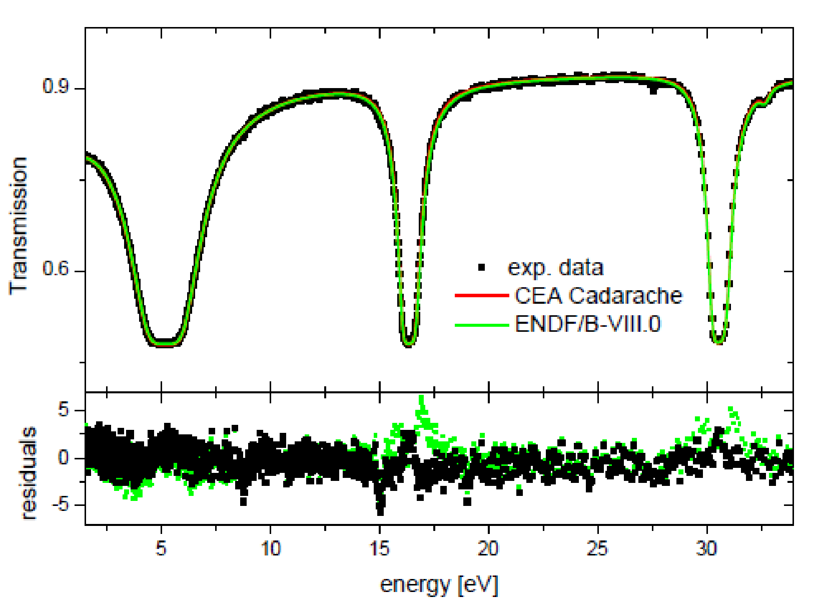
- Cu
- Bi (+SCK-CEN)

INFN Bari

- Y
- Zr

IRSN priority list ***(to be completed)***

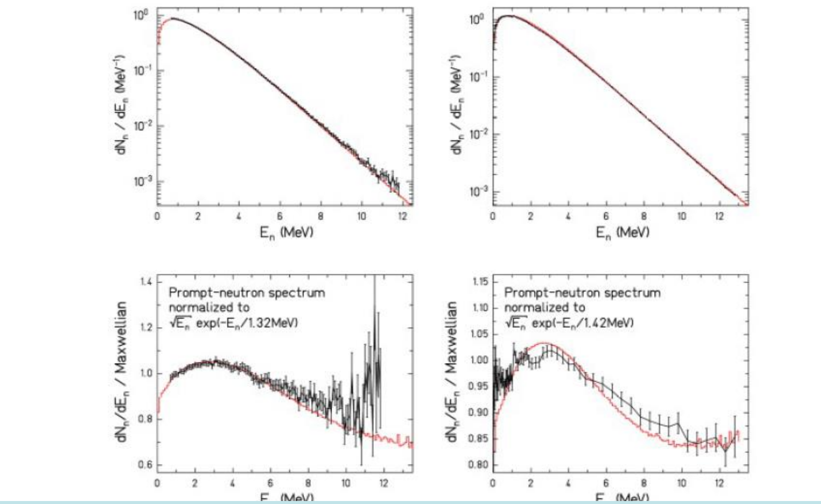
Pu-239
Pu-240, Pu-241, Am-241,
U-235, U-238, U-234
Gd isotopes, Mo isotopes, Fe-54, Fe56, Pb-204, Pb-206, Pb-207, Pb-208
Cl-35, Cl-37, F-19, Nickel isotopes, Sm-149, Sm-152, Cs-133, Si isotopes, Ca isotopes, Mn-55, Nd-143



- CEA Cadarache
- ^{237}Np,
- ^{240,242}Pu,
- ^{241,243}Am,
- ^{103}Rh,
- ^{99}Tc,
- ^{234}U,
- ^{235,238}U,
- ^{239}Pu

Fission yields

- Support for new evaluation was very fragile
- Considerable new experimental and modeling efforts
- Database needs to be secured
- Evaluation process needs to be secured
- Alignment with radioactive decay data evaluation
- Completeness is possible using FIFRELIN & GEF
- Resolution needed between accuracy from experiment and complete modeling (similar to reaction evaluations)



From fission yield measurements to evaluation

Status on statistical methodology for the covariance question

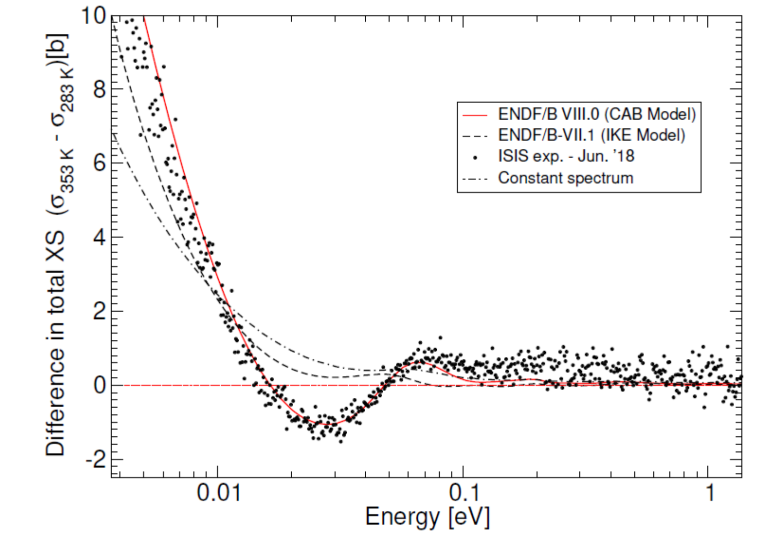
B.Voirin [12], G.Kessedjian[1], A.Chebboubi[2] & O.Serot[2]

Comparative study between experiment, evaluation and GEF

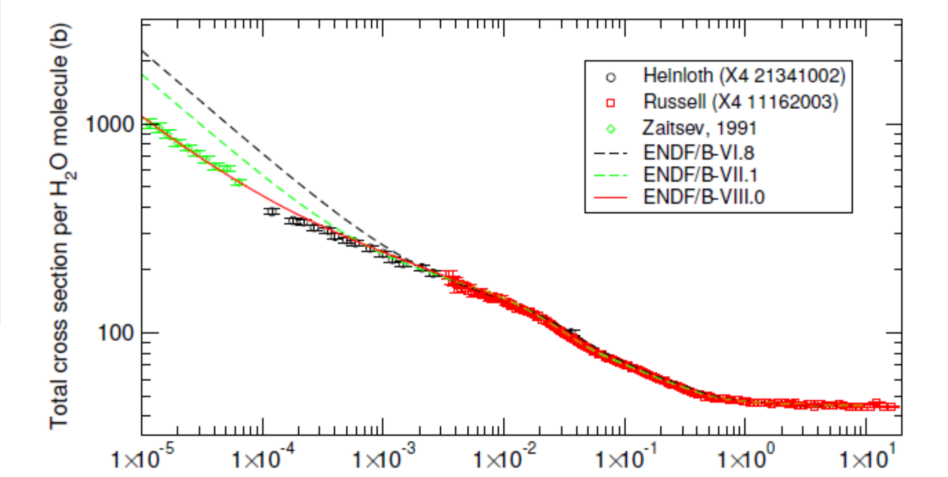
Karl-Heinz Schmidt

Subatech, Nantes

Thermal scattering



- Important new modeling developments.
- New experimental data.
- Only partly on board in JEFF-3.3.
- We should fully adopt the new modeling as it is supported by old and new data, better than JEFF-3.3.
- Use covariance information.



Summary

- Successful collaboration in Europe on nuclear data
- Close relation with JEFF project, WPEC and IAEA
- JEFF-3.3 delivered in November 2017 – good performance
- JEFF-4 is expected in 2024.
- Important developments are underway.

European Commission