Jožef Stefan Institute

Summary of ND adjustment exercise & Examples of SINBAD shielding benchmarks suitable for ND validation

Ivo Kodeli
JSI, Ljubljana, Slovenia
ivo.kodeli@ijs.si

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History

- P. Miller, P. Nagel, M. Salvatores, E. Sartori
  Shielding Experimental Benchmark Base at the Nuclear Energy Data Bank, Proc: 7th Int. Conf. on Rad. Shielding, Bournemouth, UK 1988
  NEACRP-L-310
- A.K. McCracken (AEEW), E. Sartori (NEADB)
  A Proposed Structure for a Shielding Experimental Benchmark Data Bank, NEACRP-A-1020, 19 Sept. 1989
- Enrico Sartori worked on first benchmark compilations at ORNL/RSICC during **January-February 1992**
- The idea of the name SINBAD comes from Dan Ingersoll (ORNL) – 1992/1993

By now SINBAD includes a total of 102 benchmark compilations.

SINBAD Index – Sorted by Material

- [Air] Streaming Through Ducts (IRI-TUB)
- **[Air] FNG-ITER Neutron Streaming (integral)**
- **[Air] FNS Dogleg Duct Streaming**
- **[Air] FNS Skyshine**
- **[Air] Baikal-1 Skyshine Benchmark Experiment**
- [Air] RIKEN Quasi-monoenergetic Neutron Field in 70-210 MeV Energy Range
- [Air] TEPC-FLUKA Comparison- Simulation of energy deposition in biological cells
- [Air] CERF Bonner Sphere Spectrometer Response to Charged Hadrons
- [Air] MEPhI empty slits streaming experiment
- **[Aluminium] Aluminium Sphere (OKTAVIAN)**
- **[Aluminium] MSU experiment with He & C ions on Al target**
- **[Be, LiPb] FNG HCPB Tritium Breeder Module (integral measurements)**
- [Beryllium] KANT Spherical Beryllium Shells
- **[Bismuth] IPPE neutron transmission through bismuth shell**
- **[Concrete] HIMAC High energy Neutron (<800 MeV) Measurements in Concrete**
- [Concrete] KENS p-500 MeV shielding experiment using 4m Concrete at KEK
- **[Concrete] Transmission of Medium Energy Neutr. Through Concrete (AVF Cyclotron)**
- [Concrete] NAÏADE 1 Concrete Benchmark (60cm)
- [Copper] CERN 200 and 400 GeV/c protons activation experiments
- [Copper] CERF Neutron Spectra behind Shielding of a 120 GeV/c Hadron Beam Facility
- [Graphite] NAÏADE 1 Graphite Benchmark (60cm)
- **[Graphite] Winfrith Graphite Benchmark (ASPIS)**
- **[Graphite] FNS Integral Experiment on Graphite Cylindrical Assembly**
- [Iron] NAÏADE 1 Iron Benchmark (60cm)

SINBAD Index – Sorted by Material

- [Iron] Karlsruhe Iron Sphere
- **[Iron] Winfrith Iron Benchmark (ASPIS)**
- [Iron] Wuerenlingen Iron Benchmark (PROTEUS)
- **[Iron] Ispra Iron Benchmark (EURACOS)**
- **[Iron] Iron Sphere (OKTAVIAN)**
- **[Iron] Winfrith Iron 88 Benchmark (ASPIS)**
- **[Iron] Iron Slab Experiment (TUD)**
- [Iron] University of Tokyo-YAYOI Iron Slab
- [Iron] ORNL TSF Iron Broomstick
- [Iron] University of Illinois Iron Sphere (CF-252)
- [Iron] University of Illinois Iron Sphere (D-T)
- **[Iron] IPPE Iron Shells**
- **[Iron] HIMAC High energy Neutron (<800 MeV) Measurements in Iron**
- **[Iron, Concrete] ISIS Deep-Penetration Neutrons using p-800 MeV**
- **[Iron, Concrete, Polyethylene] TIARA 40 and 65 MeV Neutron Transmission**
- [Iron, Lead] ROESTI I, II and III (CERN)
- **[Lead] Neutron Spectra Generated by 590-MeV Protons on Thick Pb Target**
- [Lithium] Juelich Li Metal Blanket Experiment
- **[Manganese] Osaka Manganese Sphere (OKTAVIAN)**
- **[Nickel] Nickel Sphere (OKTAVIAN)**
- **[Niobium, Aluminum] BEVALAC Experiment with Nb Ions on Nb & Al Targets**
- [Nitrogen] ORNL TSF Nitrogen Broomstick
- **[Oxygen] FNS Liquid Oxygen**
- [Oxygen] ORNL TSF Oxygen Broomstick

SINBAD Index – Sorted by Material

- [Polyethylene] Polyethylene Reflected Pu Sphere: Subcritical N/G Measurements (~1987)
- **[Silicon] Silicon Sphere (OKTAVIAN)**
- **[Silicon Carbide] FNG Silicon Carbide (integral)**
- **[Silicon Carbide] FNG/TUD Silicon Carbide (spectra)**
- **[Sodium] Cadarache Sodium (HARMONIE)**
- **[Sodium] Ispra Sodium Benchmark (EURACOS)**
- [Sodium] ORNL TSF Sodium Broomstick
- [Sodium] ORNL Neutron Transport in Thick Sodium
- **[Sodium, Steel] JANUS Phase VIII (Neutron Transport Through Sodium and Mild Steel)**
- **[Steel] JANUS Phase I (Neutron Transport Through Mild and Stainless Steel)**
- **[Steel, Concrete] Photon Skyshine Experiment Benchmark**
- [Stainless Steel] ORNL TSF Stainless Steel Broomstick
- **[Stainless Steel] FNG-SS Shield (integral meas.)**
- [Iron and Stainless Steel] ORNL Neutron Transport Through Iron and SS - Part I
- [Stainless Steel and Poly] ORNL 14-MeV Neutron SS/Borated Poly Slab
- **[Stainless Steel, Poly, Copper] FNG-ITER Blanket Bulk Shield (integral)**
- **[Stainless Steel, Poly, Copper] FNG/TUD ITER Blanket Bulk Shield (spectra)**
- **[Stainless Steel, Perspex] FNG-ITER Dose Rate Experiment**
- **[Thorium] IPPE Th shell with 14 MeV and Cf-252 source neutrons**
- **[Tungsten] Tungsten Sphere (OKTAVIAN)**
- **[Tungsten] FNS Tungsten**
- **[Tungsten] FNG Tungsten (integral)**
- **[Tungsten] FNG/TUD Tungsten (spectra)**
- **[Vanadium] FNS Vanadium Cube**

SINBAD Index – Sorted by Material

- **[Vanadium] IPPE Vanadium Shells**
- **[Water] Winfrith Water Benchmark**
- [Water] Neutron Leakage from Water Spheres (NIST)
- [Water] NAÏADE 1 Light Water Benchmark (60cm)
- **[Water, Graphite, Iron] Transmission Through Shielding Materials of Neutrons and Photons Generated by 52 MeV Protons**
- [Water, Graphite, Lead] Transmission Through Shielding Materials of Neutrons and Photons Generated by 65 MeV Protons
- [Water, Iron] Pool Critical Assembly-Pressure Vessel Facility Benchmark
- **[Water, Iron] Winfrith Water/Iron Benchmark (ASPIS-PCA REPLICA)**
- **[Water, Steel] Winfrith N/Gamma Transport through Water/Steel Arrays (ASPIS)**
- **[Water, Steel, Aluminium] NESDIP-3 Benchmark (ASPIS)**
- **[Water, Steel, Aluminium] NESDIP-2 Benchmark (ASPIS)**
- [Water, Silicon-Dioxide, Sodium-Chloride] Photon Spectra from H_2O, SiO_2 and NaCl

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SINBAD Index – Sorted by Material

MULTIPLE (MORE THAN 3 Materials, either INTEGRAL or Separate)

- Radiation field parameters for pressure vessel monitoring in NRI LR-0 VVER-440 reactor
- Radiation field parameters for pressure vessel monitoring in NRI LR-0 VVER-1000 reactor
- Balakovo-3 VVER-1000 Ex-vessel Neutron Dosimetry Benchmark
- CERF Residual Dose Rates
- CERF Radionuclide Production
- H.B. Robinson-2 Pressure Vessel
- **JASPER Advanced Reactor Axial Shield Measurements**
- **JASPER Advanced Reactor Intermediate Heat Exchanger Measurements**
- **JASPER Advanced Reactor Radial Shield Measurements**
- Gamma-ray Production Cross Sections from Thermal Neutron Capture in 14 elements and SS
- Averaged Gamma-ray Production Cross Sections from Fast Neutron Capture in 14 ele. & SS
- **HIMAC experiments with He, C, Ne, Ar, Fe, Xe and Si ions on C, Al, Cu & Pb targets**
- **VENUS-3 LWR-PVS Benchmark**
- Photon Leakage Spectra from Al, Ti, Fe, Cu, Zr, Pb, U238 Spheres
- Neutron Production from Thick Targets of Carbon, Iron, Copper, and Lead by 30- and 52-MeV Protons
- Radioactivity induced by GeV-Protons and Spallation Neutrons using AGS accelerator
- FNS Experimental data for fusion neutronics benchmark
- Intermediate and High-Energy Accelerator Shielding Benchmarks

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SINBAD Index – Reactor Shielding (46)

- **Winfrith Iron Benchmark (ASPIS)**
- **Winfrith Iron 88 Benchmark (ASPIS)**
- **Winfrith Graphite Benchmark (ASPIS)**
- **Winfrith Water/Iron Benchmark (ASPIS-PCA REPLICA)**
- **Winfrith Water Benchmark**
- **Winfrith Neutron-Gamma Ray Transport through Water/Steel Arrays (ASPIS)**
- **NESDIP-2 Benchmark (ASPIS)**
- **NESDIP-3 Benchmark (ASPIS)**
- **JANUS Phase I (Neutron Transport Through Mild and Stainless Steel)**
- **JANUS Phase VIII (Neutron Transport Through Sodium Mild Steel)**
- **Ispra Sodium Benchmark (EURACOS)**
- **Ispra Iron Benchmark (EURACOS)**
- **Cadarache Sodium (HARMONIE)**
- Karlsruhe Iron Sphere
- Wuerenlingen Iron Benchmark (PROTEUS)
- Neutron Leakage from Water Spheres (NIST)
- Streaming Through Ducts (IRI-TUB)
- Gamma Production X-Sections from Thermal Neutron Capture in 14 elements & SS
- Averaged Gamma Production X-Sections from Fast Neutron Capture in 14 ele. & SS
- JASPER Advanced Reactor Axial Shield Measurements
- JASPER Advanced Reactor Intermediate Heat Exchanger Measurements
- JASPER Advanced Reactor Radial Shield Measurements

Reactor Shielding (46) (Cont.)

- ORNL TSF Iron Broomstick
- ORNL TSF Oxygen Broomstick
- ORNL TSF Nitrogen Broomstick
- ORNL TSF Sodium Broomstick
- ORNL TSF Stainless Steel Broomstick
- ORNL Neutron Transport Through Iron and SS - Part I
- ORNL Neutron Transport in Thick Sodium
- Pool Critical Assembly-Pressure Vessel Facility Benchmark
- University of Illinois Iron Sphere (CF-252)
- University of Tokyo-YAYOI Iron Slab
- Pressure vessel monitoring in NRI LR-0 VVER-440 reactor
- Pressure vessel monitoring in NRI LR-0 VVER-1000 reactor
- Balakovo-3 VVER-1000 Ex-vessel Neutron Dosimetry Benchmark
- **VENUS-3 LWR-PVS Benchmark**
- H.B. Robinson-2 Pressure Vessel
- Photon Leakage Spectra from Al, Ti, Fe, Cu, Zr, Pb, U238 Spheres
- Photon Spectra from H2O, SiO2 and NaCl
- **Baikal-1 Skyshine Benchmark Experiment**
- NAÏADE 1 Graphite Benchmark (60cm)
- NAÏADE 1 Iron Benchmark (60cm)
- NAÏADE 1 Light Water Benchmark (60cm)
- **IPPE Th shell with 14 MeV and Cf-252 source neutrons**
- **IPPE neutron transmission through bismuth shell**

SINBAD Index – FUSION (31)

- Osaka Nickel Sphere (OKTAVIAN)
- Osaka Iron Sphere (OKTAVIAN)
- Osaka Aluminium Sphere (OKTAVIAN)
- Osaka Silicon Sphere (OKTAVIAN)
- Osaka Tungsten Sphere (OKTAVIAN)
- Osaka Manganese Sphere (OKTAVIAN)
- FNS Experimental data for fusion neutronics benchmark
- FNS Clean Experiment on Graphite Cylindrical Assembly
- FNS Liquid Oxygen
- FNS Vanadium Cube
- FNS Tungsten
- FNS Skyshine
- FNS Dogleg Duct Streaming
- FNG-SS Shield (integral measurements)
- FNG-ITER Blanket Bulk Shield (integral measurements)
- FNG/TUD ITER Blanket Bulk Shield (spectra)
- FNG-ITER Neutron Streaming (integral)
- FNG-ITER Dose Rate Experiment
- FNG Silicon Carbide (integral measurements)
- FNG/TUD Silicon Carbide (spectra)
- FNG Tungsten (integral measurements)
- FNG HCPB Tritium Breeder Module (integral)
- FNG/TUD Tungsten (spectra)
- TUD Iron Slab Experiment

- **IPPE Vanadium Shells**
- **IPPE Iron Shells**
- ORNL 14-MeV Neutron SS/B Poly Slab
- University of Illinois Iron Sphere (D-T)
- KANT Spherical Beryllium Shells
- MEPhI empty slits streaming exp.
- Juelich Li Metal Blanket Experiment

SINBAD Index – Accelerator Shielding (23)

- **Transmission Through Shielding Materials of n/g Generated by 52 MeV Protons**
- Transmission Through Shielding Materials of n/g Generated by 65 MeV Protons
- **Transmission of Medium Energy Neutrons Through Concrete Shields**
- Neutron Production from Thick Targets of C, Fe, Cu & Pb by 30- and 52-MeV Protons
- **TIARA 40 & 65 MeV Neutron Transmission Through Iron, Concrete & Polyethylene**
- Radioactivity induced by GeV-Protons and Spallation Neutrons using AGS accelerator
- Intermediate and High-Energy Accelerator Shielding Benchmarks
- ROESTI I, II and III (CERN)
- CERF Bonner Sphere Spectrometer Response to Charged Hadrons
- CERF Radionuclide Production
- CERF Residual Dose Rates
- CERF Neutron Energy Spectra behind Shielding of a 120 GeV/c Hadron Beam Facility
- CERN 200 and 400 GeV/c protons activation experiments
- RIKEN Quasi-monoenergetic Neutron Field in 70-210 MeV Energy Range
- KENS p-500 MeV shielding experiment using 4m Concrete at KEK
- **HIMAC experiments with He, C, Ne, Ar, Fe, Xe and Si ions on C, Al, Cu & Pb targets**
- **HIMAC High energy Neutron (<800 MeV) Measurements in Iron**
- **HIMAC High energy Neutron (<800 MeV) Measurements in Concrete**
- **BEVALAC Experiment with Nb Ions on Nb & Al Targets**
- **MSU experiment with He & C ions on Al target**
- **Neutron Spectra Generated by 590-MeV Protons on Thick Pb Target**
- **ISIS Deep-Penetration Neutrons through Concrete & Fe Shields using p-800 MeV**
- TEPC-FLUKA Comparison

SINBAD: Re-evaluated Fe Shielding Benchmarks

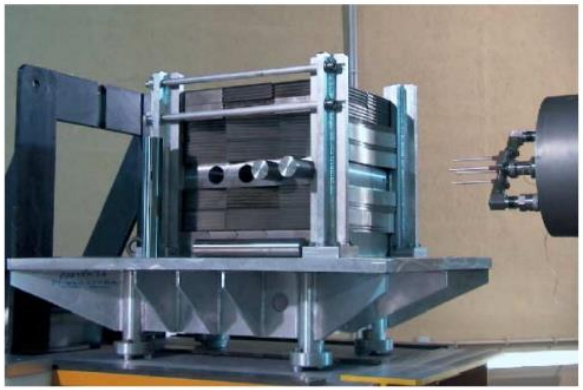
SINBAD Benchmark / quality	Additional information needed on; (new data)
OKTAVIAN Fe ~ ♦♦♦ or ♦♦	very large uncertainties of the measurements
FNS Iron dogleg-duct ♦♦	neutron source spectrum, detector response function
TUD Iron slab ~ ♦♦♦	neutron source, pulse height spectrum
FNG Stainless Steel ~ ♦♦♦	a comprehensive geometry description would be helpful
FNG ITER Dose Rate ♦♦♦	/
FNG/TUD ITER Bulk ~ ♦♦♦	n & γ flux uncertainties, original pulse-height distributions
FNG ITER Bulk ♦♦♦	/
IPPE-Fe 14 MeV n source	(new 2D & 3D MCNP5 models prepared)
JANUS phase I ♦♦♦ & VIII ♦♦♦	(new MCNP5 models)
ASPIS NESDIP 2 ♦/♦♦ & 3 ♦♦♦	neutron source spectrum approximations
Aspis Iron88 ♦♦♦	geometry model details & approximations, background ?
Ispra Iron ♦♦	n source, geometry model approximations, background ?
ISIS 800 MeV p^+ (120cm Concrete & 60cm Iron) ~ ♦♦♦	(new MCNPX model prepared)
HIMAC 400 MeV/nucleon C ions on Fe shield ~ ♦♦♦	large measurement uncertainties, unfolding & parameter uncertainties needed (new PHITS model prepared)
TIARA 43 & 68 MeV p^+ ♦♦♦	

SINBAD: FISSION NEUTRONICS

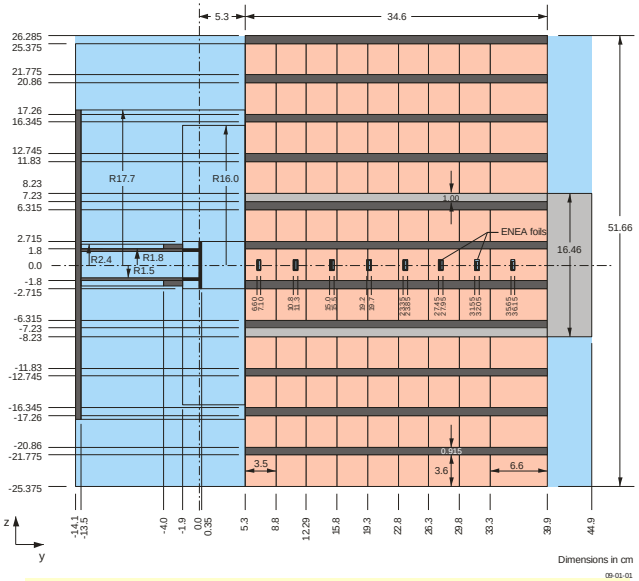
Benchmark / quality	Additional information needed on
ASPIS PCA REPLICA ♦♦♦	Supplementary information needed on: - set-up of the activation foils; - rear wall of the ASPIS cave
ASPIS Graphite ♦♦♦	New MCNP model. Additional information needed: - detectors arrangement (dimensions are inconsistent)
ASPIS Water ♦♦♦	New MCNP model. Supplementary information needed on: - NE-213 spectrometer - water tank (container, bowing effects) - experimental room
ASPIS n/γ water/steel arrays ~ ♦♦♦	Supplementary information needed on: - detectors arrangement - bowing of the water tanks - background subtraction - cave walls
EURACOS Na ~ ♦♦	New MCNP model, source model, uncertainty. Supplementary information needed on: source (spectrum, spatial distribution), energy structure of the proton recoil spectra, neutron spectrometers response functions, additional details on the geometry (room return), on geometry and material composition uncertainties. Limited applicability – fast neutron attenuation in iron only.
HARMONIE ♦	too simplified geometry, materials & n.source description

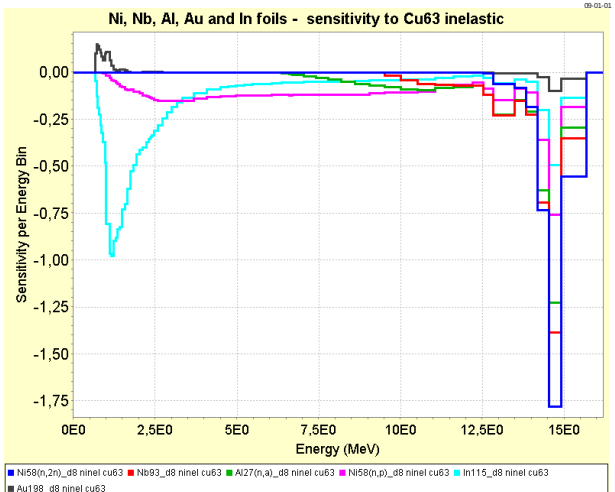
Benchmark Experiment on W (2002)

Validate EFF data for tungsten



Pre- and post-analysis for the design of the fusion mock-up neutronics benchmarks, in order to assess the uncertainty in measured quantities due to uncertainty in the relevant nuclear data.





FNG Fusion benchmarks (14 MeV DT source)

- FNG-SS Shield
- FNG-ITER Blanket Bulk Shield
- FNG-ITER Neutron Streaming
- FNG-ITER Dose Rate Experiment
- FNG Silicon Carbide
- FNG Tungsten
- FNG HCPB Tritium Breeder Module
- FNG HCLL Tritium Breeder Module
- FNG Cu (2013-2015)

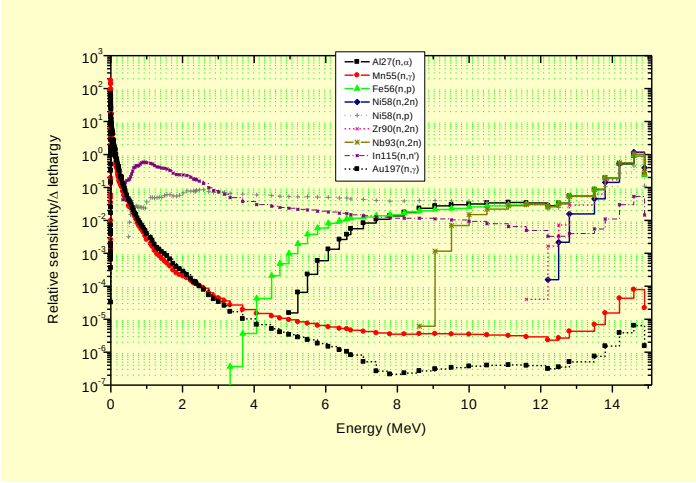
FNG W Benchmark

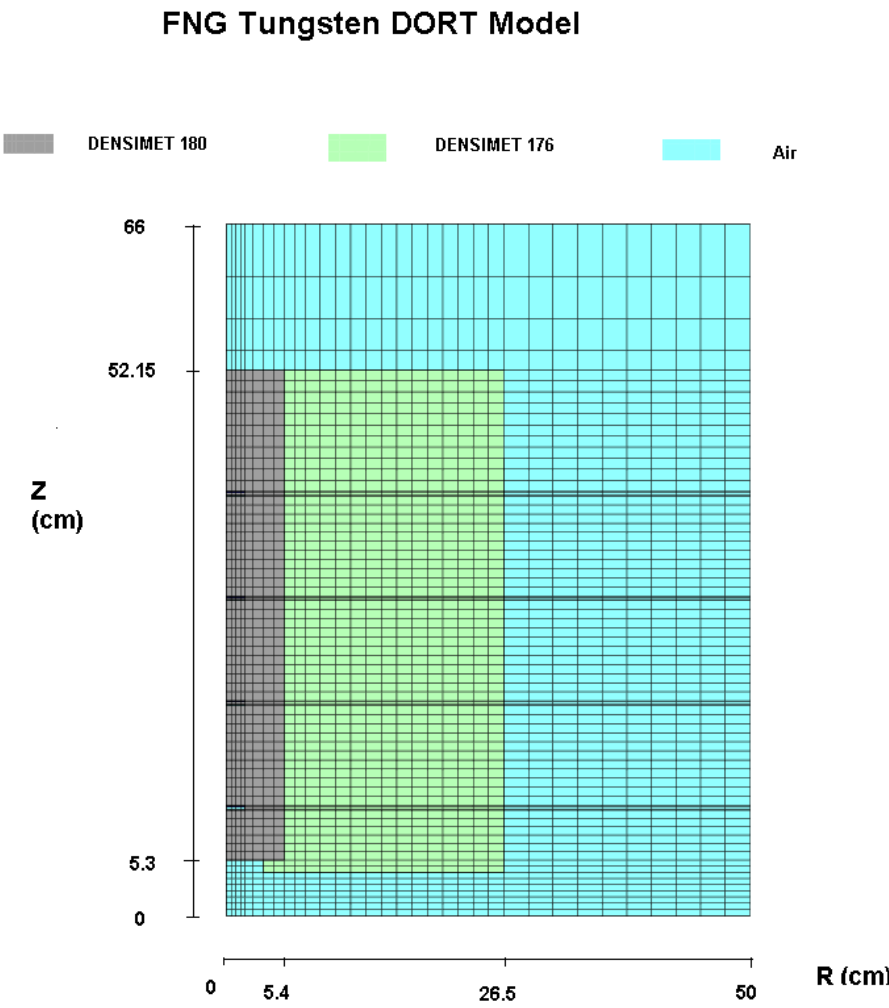
Measured reaction rates

- Ni-58(n,2n)
- Zr90(n,2n)
- Nb-93(n,2n)
- Al-27(n,α)
- Fe56(n,p)
- Ni-58(n,p)
- In115(n,n')
- Au-197(n,γ)
- Mn55(n,γ)

Detector positions:

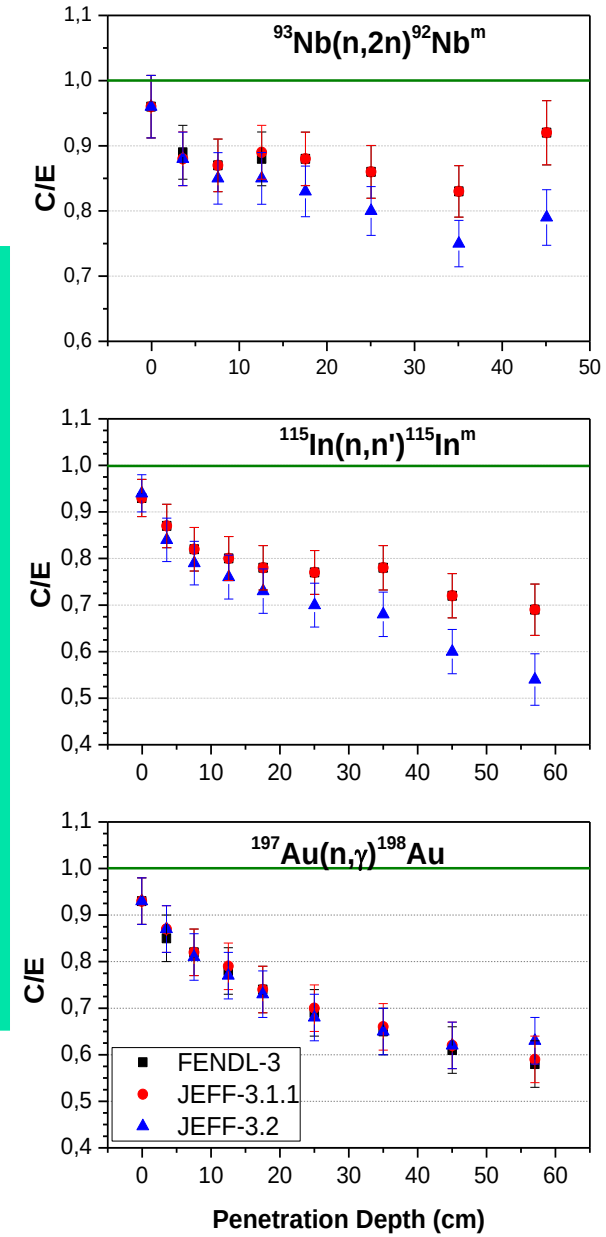
- 5 cm
- 15 cm
- 25 cm
- 35 cm





FNG-Cu: Uncertainties in calculated detector reaction rates due to cross-section uncertainties vs. C/E

Reaction rate / det. position	Uncertainty (%)		
	Transport cross-section		
	JEFF-3.2	ENDF/B-VI.8	TENDL-2013
^{58}Ni(n,p) -35cm	5.2	13.7	22.9
-57cm	9.9	27.2	41.9
^{115}In(n,n')-35cm	5.1	9.4	12.1
-57cm	8.9	18.7	23.5
^{27}Al(n,a) -57cm	13.1	33.2	51.9
^{93}Nb(n,2n)-57cm	13.8	34.7	53.4
^{197}Au(n,γ) -57cm	/	19.9	18.6
^{186}W(n,γ) -57cm	/	28.6	27.3
^{55}Mn(n,γ) -35cm	/	24.9	18.8



- *M. Angelone, D. Flammini, S. Loreti, F. Moro, M. Pillon, R. Villar, A. Klix, U. Fischer, I. Kodeli, R. L. Perel, W. Pohorecky,* Copper Benchmark Experiment for the Testing of JEFF-3.2 Nuclear Data for Fusion Applications, ND2016, Bruges
- I. Kodeli, K. Kondo, R.L. Perel, U. Fischer, Cross-section sensitivity and uncertainty analysis of the FNG copper benchmark experiment, Fus.Eng.Design 109–111 (2016) 1222–1226

Candidates for future SINBAD evaluations

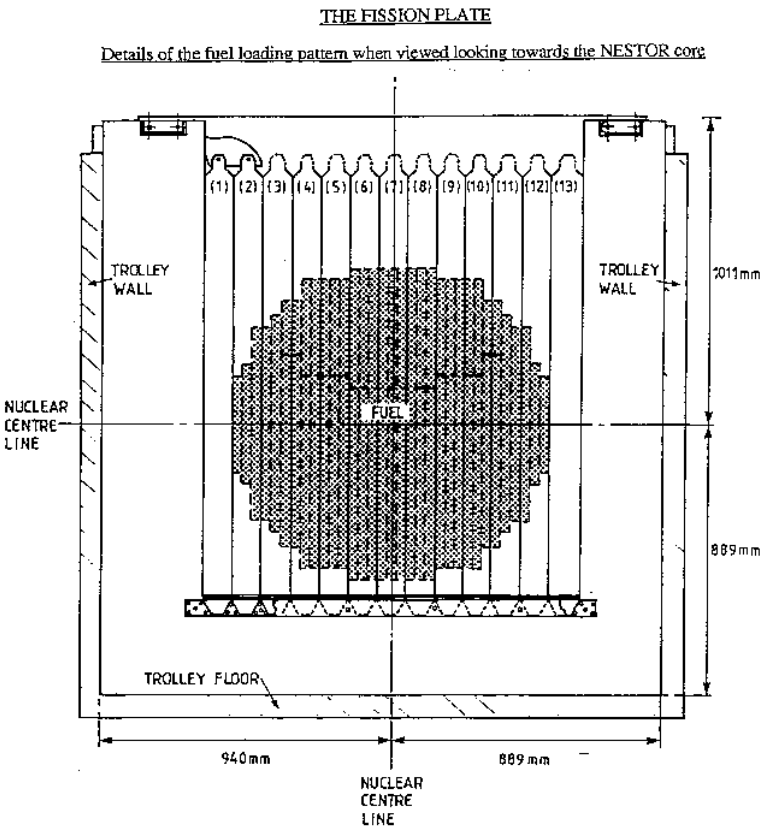
- **FNG-Cu**: F4E compilation finished (2018) MCNP, DORT model, sensitivities
- **FNG-HCLL**: F4E compilation (partly) finished (2018)
- **FNS Cu**, Mo, Ti, Li_2O: copyright issues between QST and JAEA
- **OKTAVIAN**: LiF, CF_2, Ti, Cr, Co, Cu, As, Se, Zr, Nb, Mo;
- **LLNL** spheres
- **IPPE**: BTiH, U, …
- **CIAE** leakage spectra from SiC, Fe, graphite (14 MeV neutrons)
- VENUS-1, VENUS-2 PV dosimetry experiment
- **JET:** SDR experiment (2012-2013), streaming, dose rate
- **KAMINI reactor** neutron attenuation in fast reactor shield materials, Indira Gandhi Centre for Atomic Research, India & Ghana Atomic Energy Commission, *Ann.Nucl.Energy* **53** (2013), Ferro Boron, Ferro-tungsten, mild steel shielding;
- Neutron Penetration through Fe & Concrete for 140-350-MeV Quasi-Monoenergetic Neutrons, RCNP, Osaka University, *Nucl. Tech.* **168** (2009) 298-303 & 304-309 (Prof. Takashi Nakamura)
- **JASMIN**: Japanese-American Study of Muon Interactions and Neutron Detection FERMILAB, Japan Fermilab -Conf-10-330-APC, Aug. 2010 (Prof. Takashi Nakamura)
- Measurements of reaction rates and induced activity in concrete exposed to secondary particles produced by intermediate energy heavy ions on Fe target HIMAC (NIRS).T.Ogawa et al, *NIM-B* **269** (2011), *NIM B* **271** (2012)

ASPIS IRON-88

- First SINBAD evaluation ~1997 (A. Avery, I. Kodeli)
- 2014/2016 quality reevaluation (Milocco, Kodeli):

- Neutron transport up to **67 cm in steel**.
- Fission plate (93% enriched UAl alloy) driven by thermal neutrons from the NESTOR reactor. Absolute source strength and spatial distribution is determined by fission product counting and ^{55}Mn(n,γ) RR measurements over XY front surface.
- Au, Rh, In, S and Al activation foils irradiated in 7.4-mm air gaps between 13 mild steel plates of the size of 1.8 m x 1.9 m x 5.1 cm

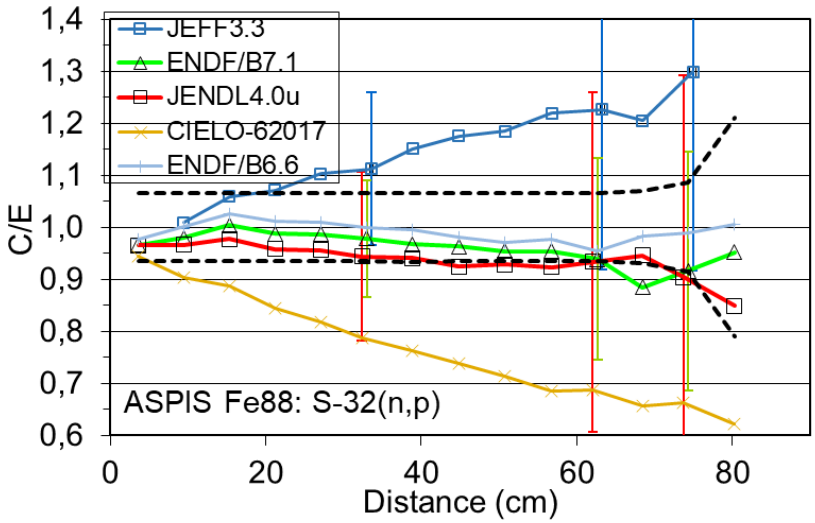
- ^{197}Au(n,γ) under Cd
- ^{32}S(n,p)
- ^{103}Rh(n,n')
- ^{115}In(n,n')
- ^{27}Al(n,α)

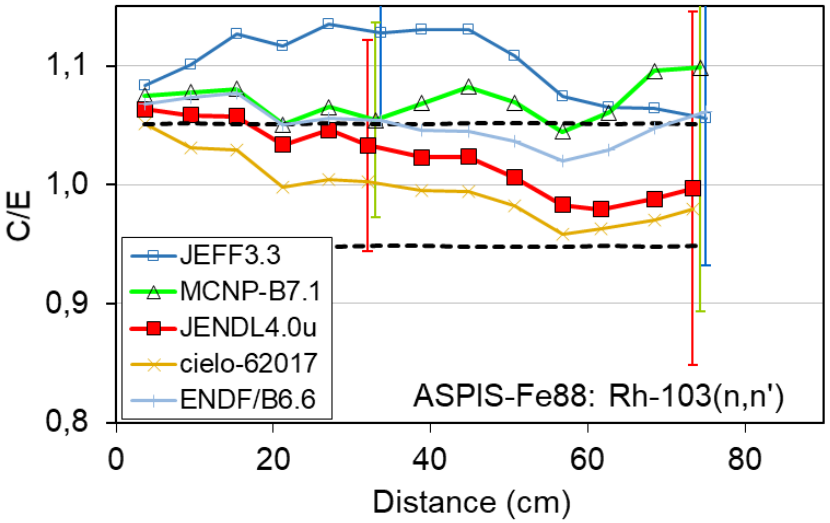


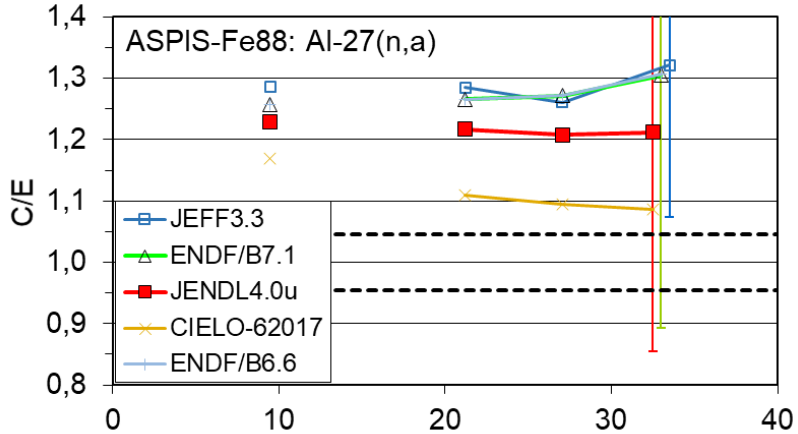
Use of IRON-88 benchmark:

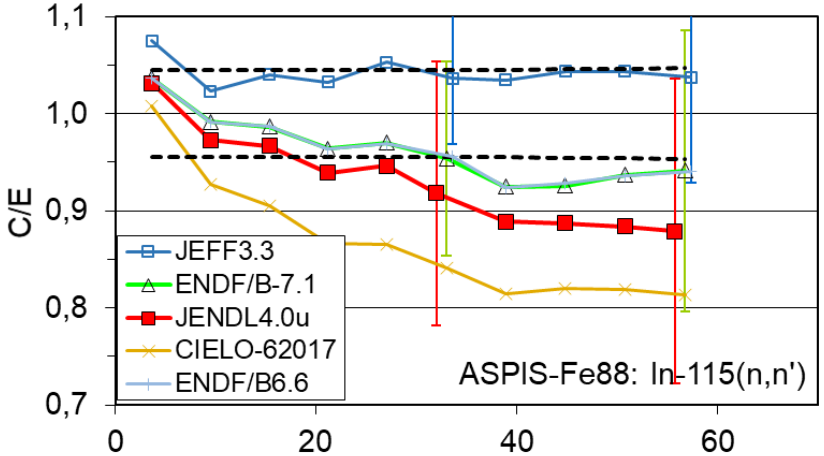
- **CIELO, CHANDA & F4E**: validation of the new Fe evaluation
- **WPEC SG39**: adjustment of ^{56}Fe XS
- Study acceleration using ADVANTG

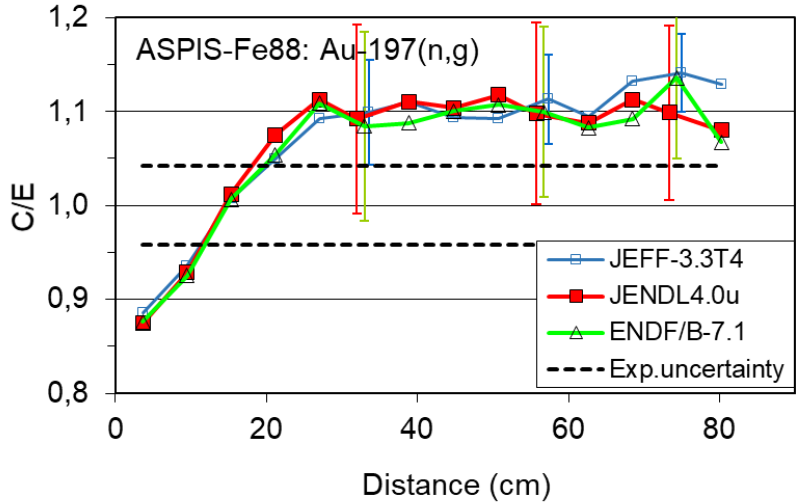
ASPIS-Fe88: C/E using JEFF-3.3, ENDF/B-VII.1, JENDL-4.0, CIELO, ENDF/B-VI.6









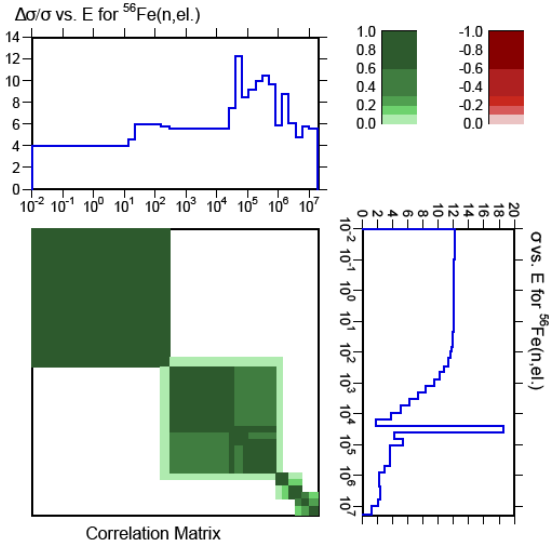


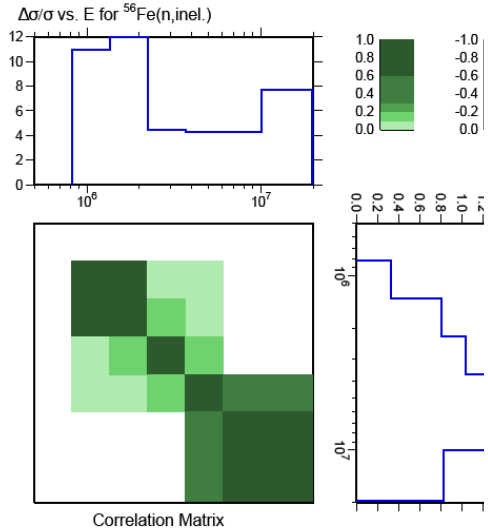
Uncertainties in calculated detector reaction rates due to cross-section uncertainties compared to measurement uncertainies

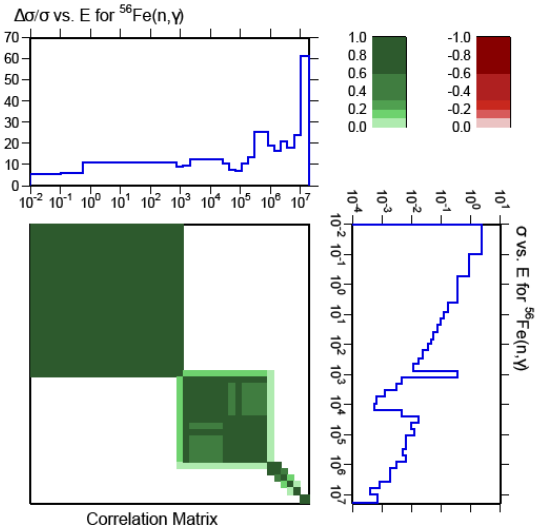
Reaction rate / det. position	Uncertainty (%)			
	ΔE	ΔC		
		JEFF-3.3	ENDF/B-VII.1	JENDL-4
^{197}Au(n,g): 26cm	4.2	5.1	9.9	9.2
46cm	4.2	4.3	8.8	8.8
62cm	4.2	3.7	8.1	8.5
^{103}Rh(n,n') 26cm	5.1	6.4	7.8	8.6
62cm	5.1	11.7	18.7	14.9
^{115}In(n,n'): 26cm	4.5	6.6	10.5	14.8
62cm	4.7	10.5	15.0	17.8
^{32}S(n,p): 26cm	6.5	13.3	11.5	17.2
52cm	6.5	25.0	20.8	35.0
62cm	8.6	29.3	25.1	42.9
^{27}Al(n,a): 26cm	4.7	18.8	31.5	29.5

ASPIS-Fe88: Uncertainties in calculated detector reaction rates due to cross-section uncertainties

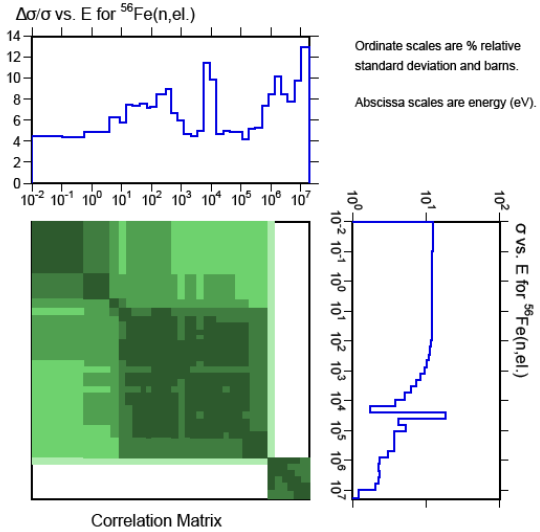
Reaction Position (cm)	$\Delta\Sigma_d$	$\Delta\Sigma_{tr}$(%)	ΔSAD (P_N) (%)	Δ PFNS (%)
	IRDFF	JEFF3.3 / ENDF7.1 / JENDL 4	JEFF3.3 / ENDF7.1 / JENDL 4	JEFF 3.3 / ENDF7.1 / JENDL 4
Au(ng) 26	1.5	4.9 / 9.8/ 9.0	0.03 / 0.1 / 0.3	0.1 / 0.6 / 0.5
46	1.5	4.0 / 8.7 / 8.7	0.1 / 0.1 /0.3	0.1 / 0.3 / 0.3
62cm	1.5	3.3 / 8.0 / 8.4	0.1 / 0.1 / 0.3	0.0 / 0.2 / 0.2
Rh(n,n') 26	5.4	3.4 / 5.5 / 6.7	0.3 / 0.3 / 1.0	0.4 / 0.9 / 0.8
62cm	7.9	8.7 / 17.0 / 12.7	0.3 / 0.3 / 1.1	0.3 / 0.7 / 0.6
In(n,n'): 26	2.1	6.1 / 10.0 / 14.5	0.6 / 0.6 / 1.0	0.9 / 2.0 / 1.7
62cm	2.8	10.1 / 14.7 / 17.6	1.0 / 1.0 / 1.1	0.6 / 1.4 / 1.2
S(n,p): 26	2.9	12.4 / 9.3 / 16.2	1.3 / 1.3 / 2.9	3.6 / 6.0 / 4.7
52	3.9	24.4 / 19.4 / 34.5	2.1 / 2.1 / 6.0	3.9 / 6.3 / 4.8
62cm	4.0	28.8 / 24.0 / 42.4	2.3 / 2.3 / 7.2	3.9 / 6.3 / 4.8
Al(n,a): 26	0.7	8.2 / 12.4 / 25.8	3.4 / 3.4 / 1.4	16.9 / 28.9 / 14.2

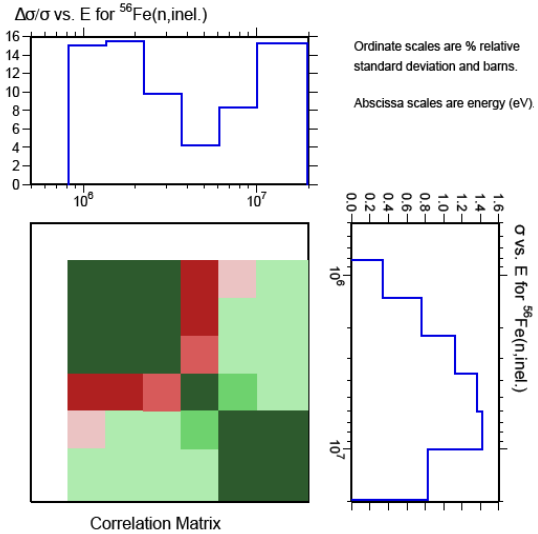


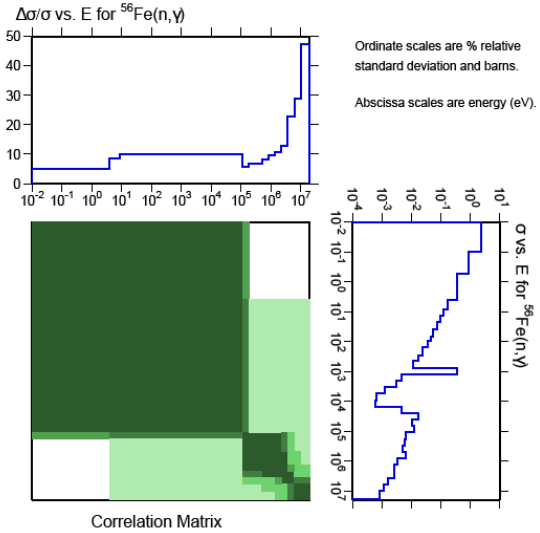




ENDF/BVII.1







JENDL4.0

WPEC SG39 Adjustment exercise

ASPIS Fe88 covariance matrix for the measured reactions rated. The power normalisation uncertainty was assumed to be completely correlated.

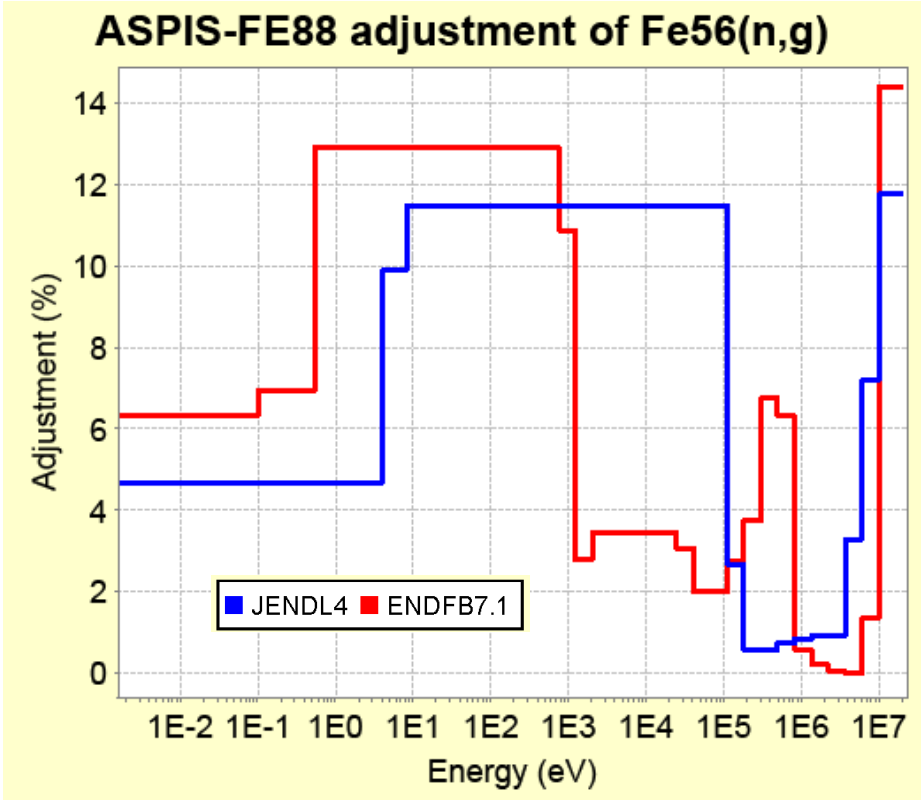
			Au			Rh		In		S			Al
	Pos		A7	A11	A14	A7	A14	A7	A11	A7	A12	A14	A7
		1σ (%)	4,2	4,2	4,2	5,1	5,1	4,5	4,7	6,5	6,5	8,6	4,7
Au	A7	4,2	1,00	0,95	0,95	0,75	0,75	0,85	0,81	0,59	0,59	0,44	0,81
	A11	4,2	0,95	1,00	0,95	0,75	0,75	0,85	0,81	0,59	0,59	0,44	0,81
	A14	4,2	0,95	0,95	1,00	0,75	0,75	0,85	0,81	0,59	0,59	0,44	0,81
Rh	A7	5,1	0,75	0,75	0,75	1,00	0,96	0,70	0,67	0,48	0,48	0,37	0,67
	A14	5,1	0,75	0,75	0,75	0,96	1,00	0,70	0,67	0,48	0,48	0,37	0,67
In	A7	4,5	0,85	0,85	0,85	0,70	0,70	1,00	0,93	0,55	0,55	0,41	0,76
	A11	4,7	0,81	0,81	0,81	0,67	0,67	0,93	1,00	0,52	0,52	0,40	0,72
S	A7	6,5	0,59	0,59	0,59	0,48	0,48	0,55	0,52	1,00	0,97	0,73	0,52
	A12	6,5	0,59	0,59	0,59	0,48	0,48	0,55	0,52	0,97	1,00	0,73	0,52
	A14	8,6	0,44	0,44	0,44	0,37	0,37	0,41	0,40	0,73	0,73	1,00	0,40
Al	A7	4,7	0,81	0,81	0,81	0,67	0,67	0,76	0,72	0,52	0,52	0,40	1,00

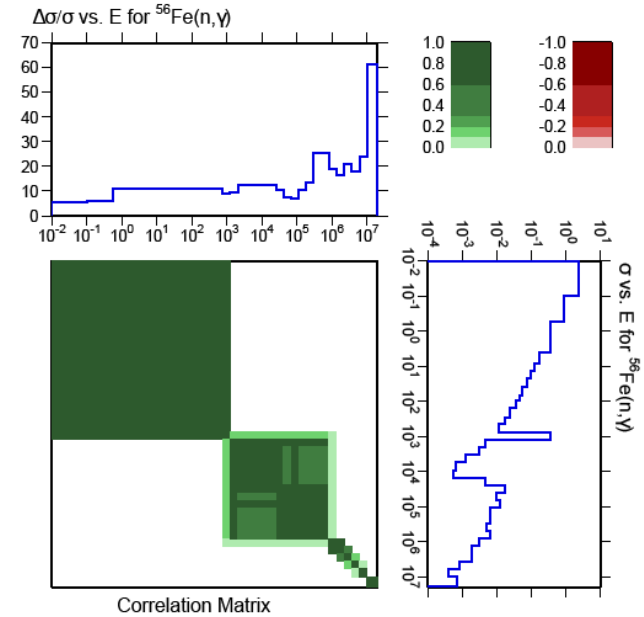
WPEC SG39 Adjustment exercise

ASPIS Fe88 covariance matrix for the **ratios** of measured + calculated reactions rated.

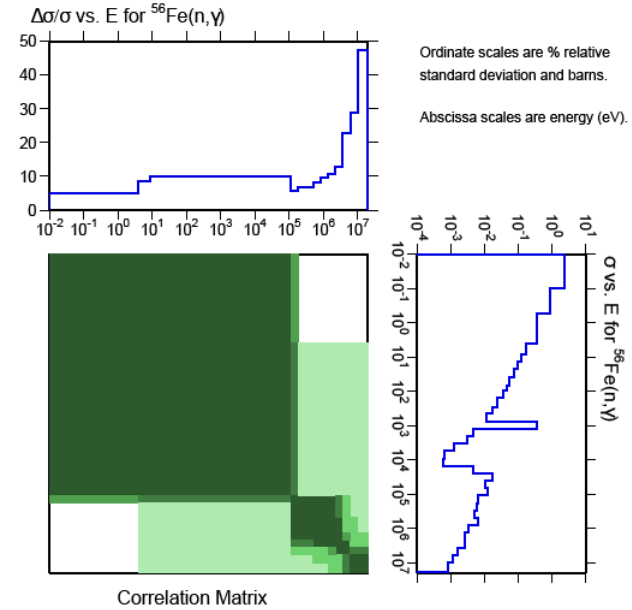
			Au		Rh	In	S		Al
	Pos.		**A11/A7**	**A14/A7**	**A14/A7**	**A11/A7**	**A12/A7**	**A14/A7**	**A7**
		1σ (%)	2,0	2,1	1,8	2,0	2,9	7,7	6,1
Au	A11/A7	2,0	1,00	0,50	0	0	0	0	0
	A14/A7	2,1	0,50	1,00	0,	0	0	0	0
Rh	A14/A7	1,8	0	0	1,00	0	0	0	0
In	A11/A7	2,0	0	0	0	1,00	0	0	0
S	A12/A7	2,9	0	0	0	0	1,00	0,05	0
	A14/A7	7,7	0	0	0	0	0,05	1,00	0
Al	A7	6,1	0	0	0	0	0	0	1,00

WPEC SG-39 adjustment exercise: ENDF/BVII.1 vs. JENDL-4.0



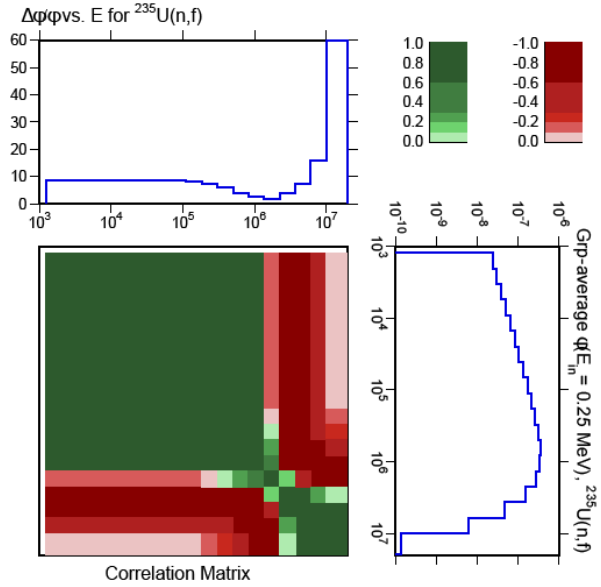


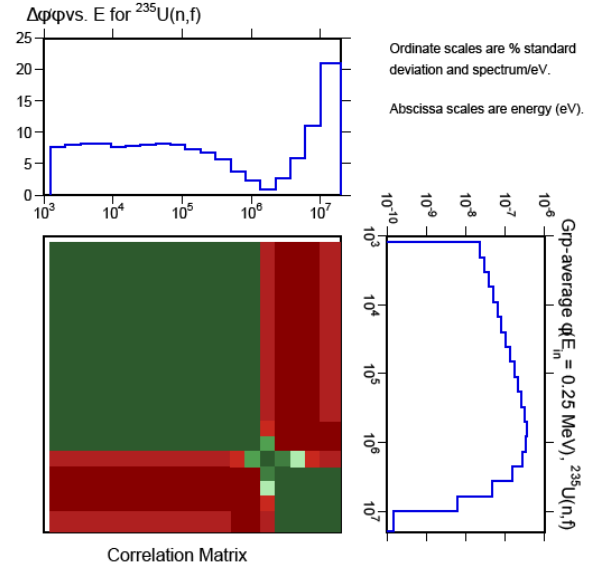
ENDF/BVII.1



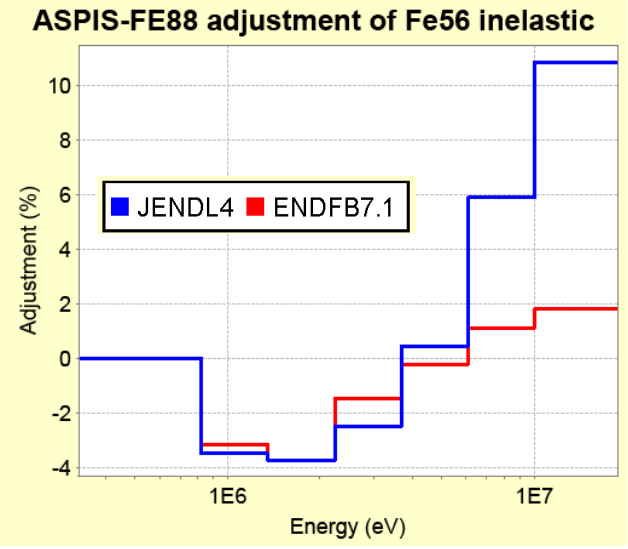
JENDL4.0

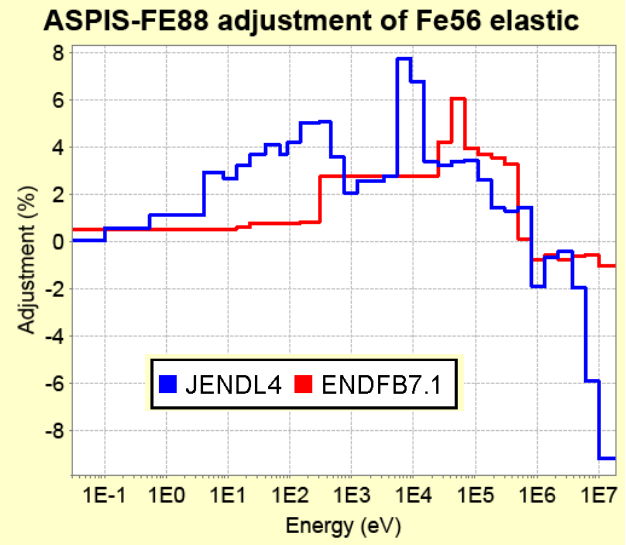
WPEC SG-39 adjustment exercise: ENDF/BVII.1 vs. JENDL-4.0

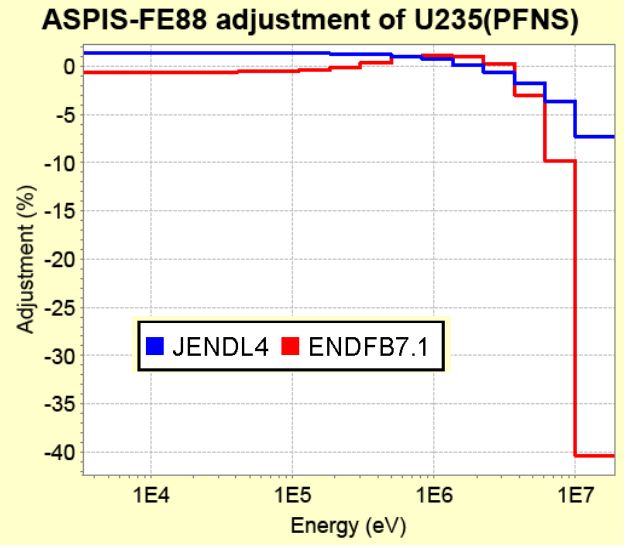




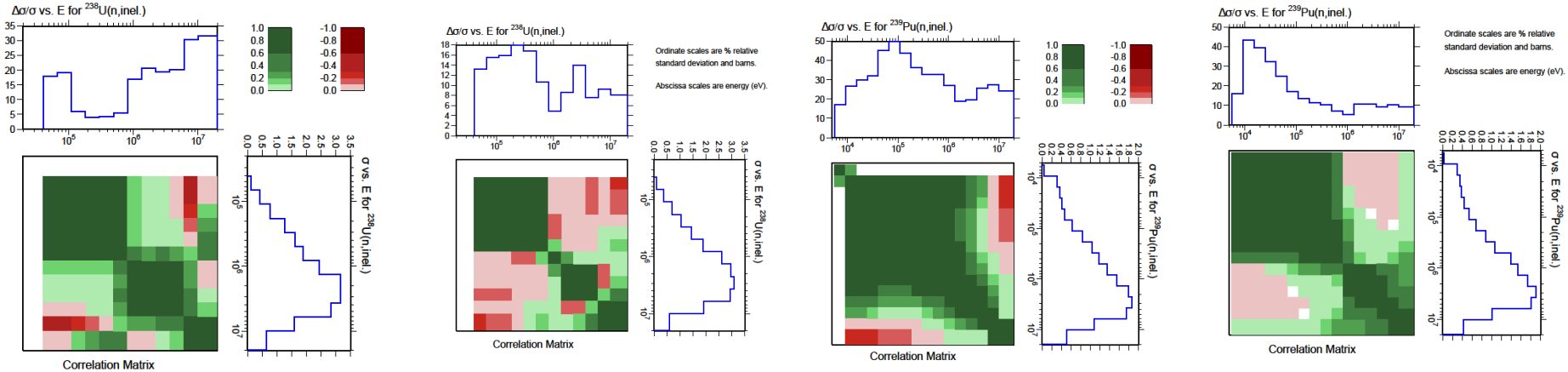
ENDF/BVII.1 **JENDL4.0**

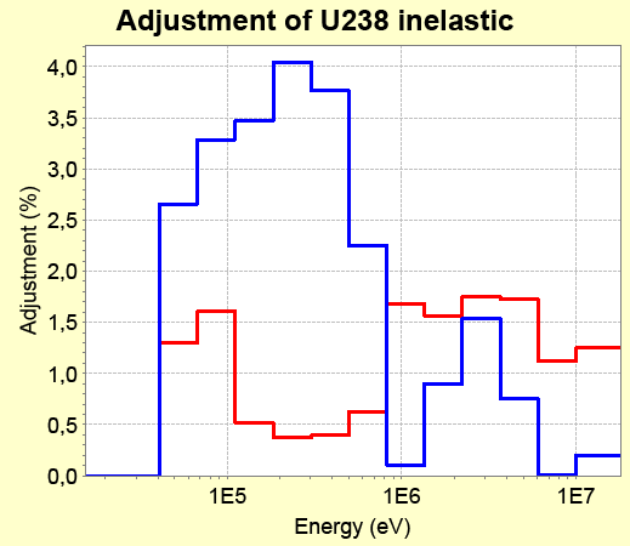


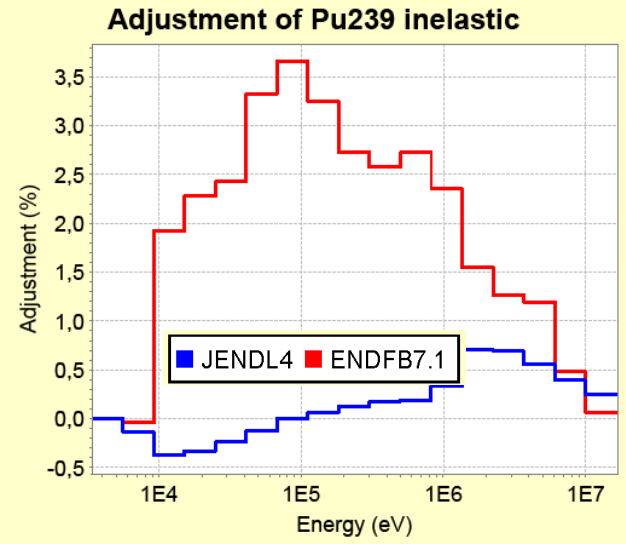




Adjustment ENDF/BVII.1 vs. JENDL-4.0

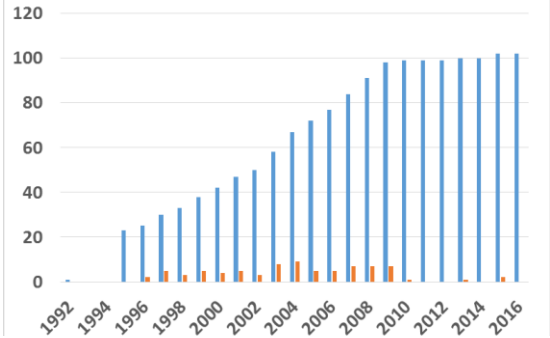




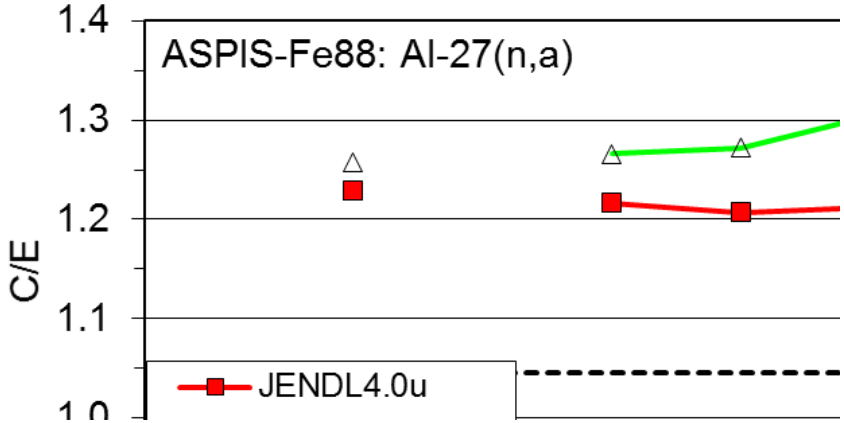


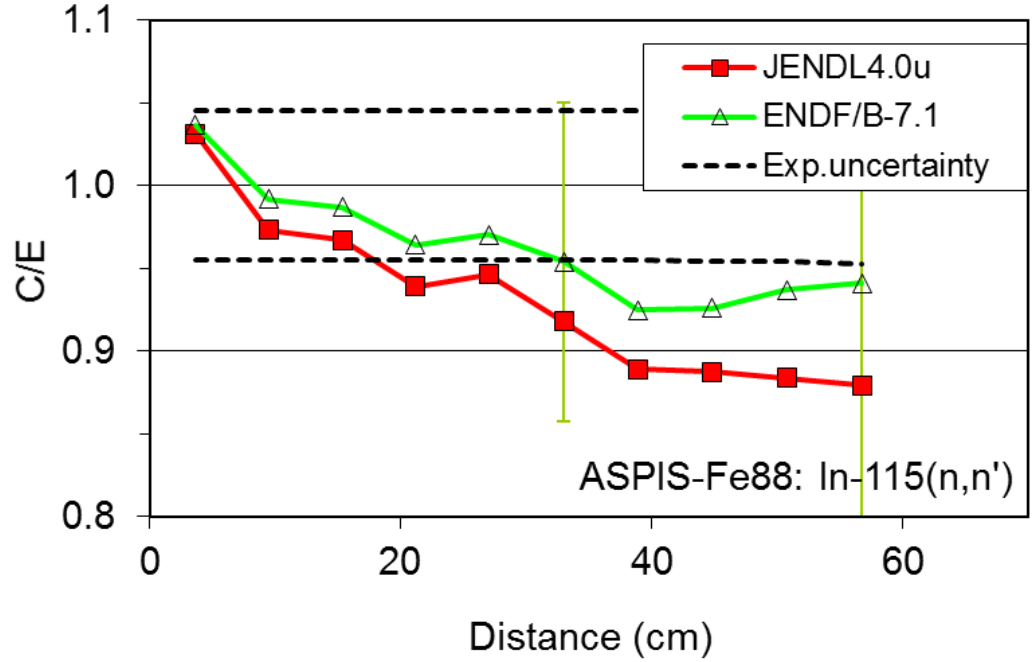
I. Kodeli, L. Plevnik, Nuclear data adjustment exercise combining information from shielding, critical and kinetics benchmark experiments ASPIS-Iron 88, Popsy and SNEAK-7A/7B, *Progress in Nuclear Energy* **106** (2018) 215 - 230

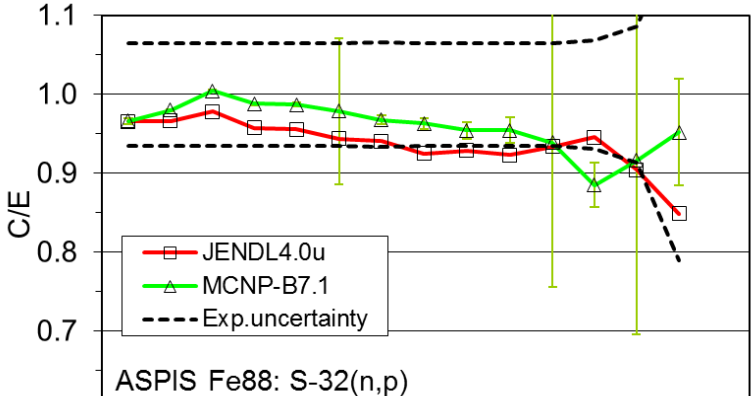
CONCLUSIONS

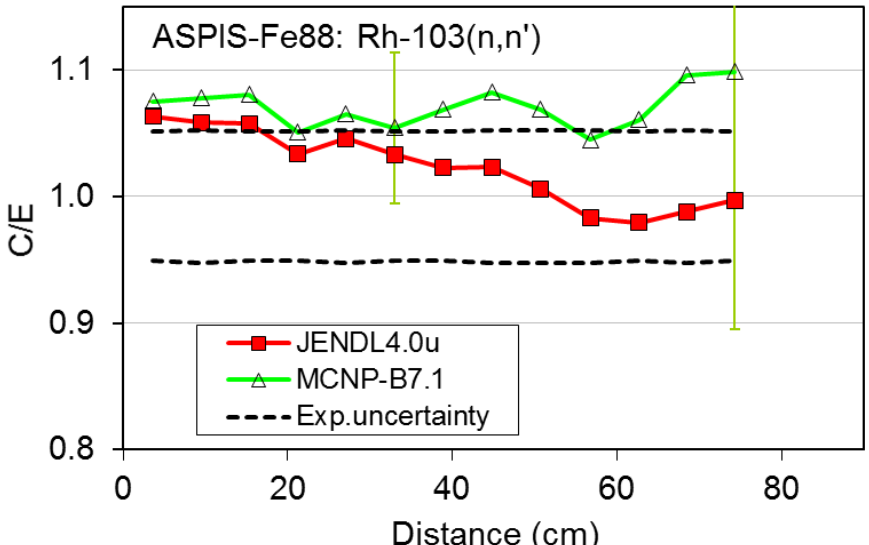


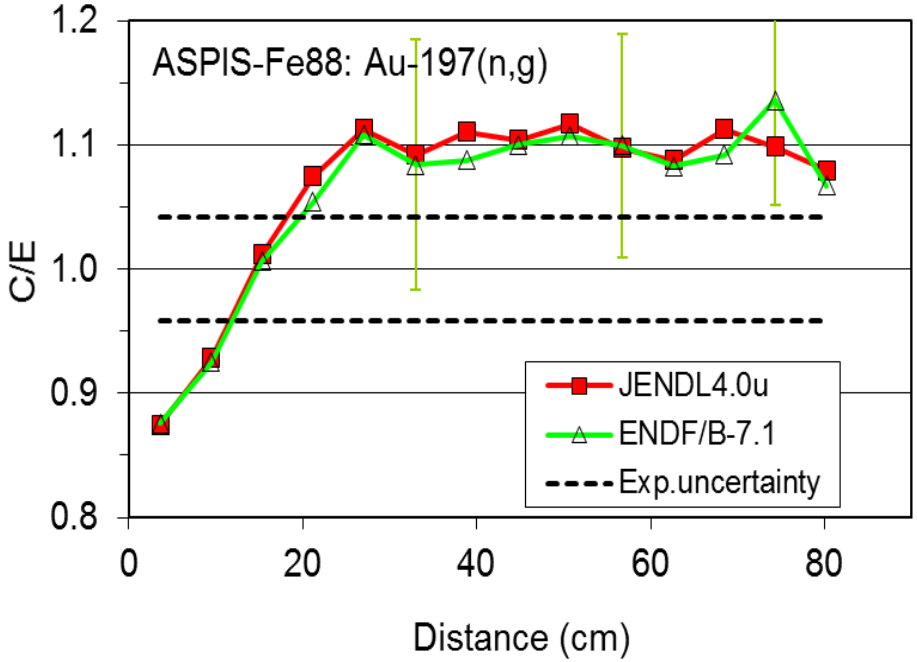
- Analysis including adjustment exercise using ASPIS IRON 88 from SINBAD demonstrated that shielding benchmarks can be useful for validation of modern nuclear data evaluations and codes, in combination with criticality, kinetics and other benchmarks.
- Several shielding banchmarks can be identified as potentially useful for future ND validations
- Challenges:
  - New SINBAD compilations (such as ASPIS Fe88, FNG-Cu & HCLL)
  - Careful evaluations including correlations among measured & calculated values are crucial for uncertainty quantification and adjustment applications.

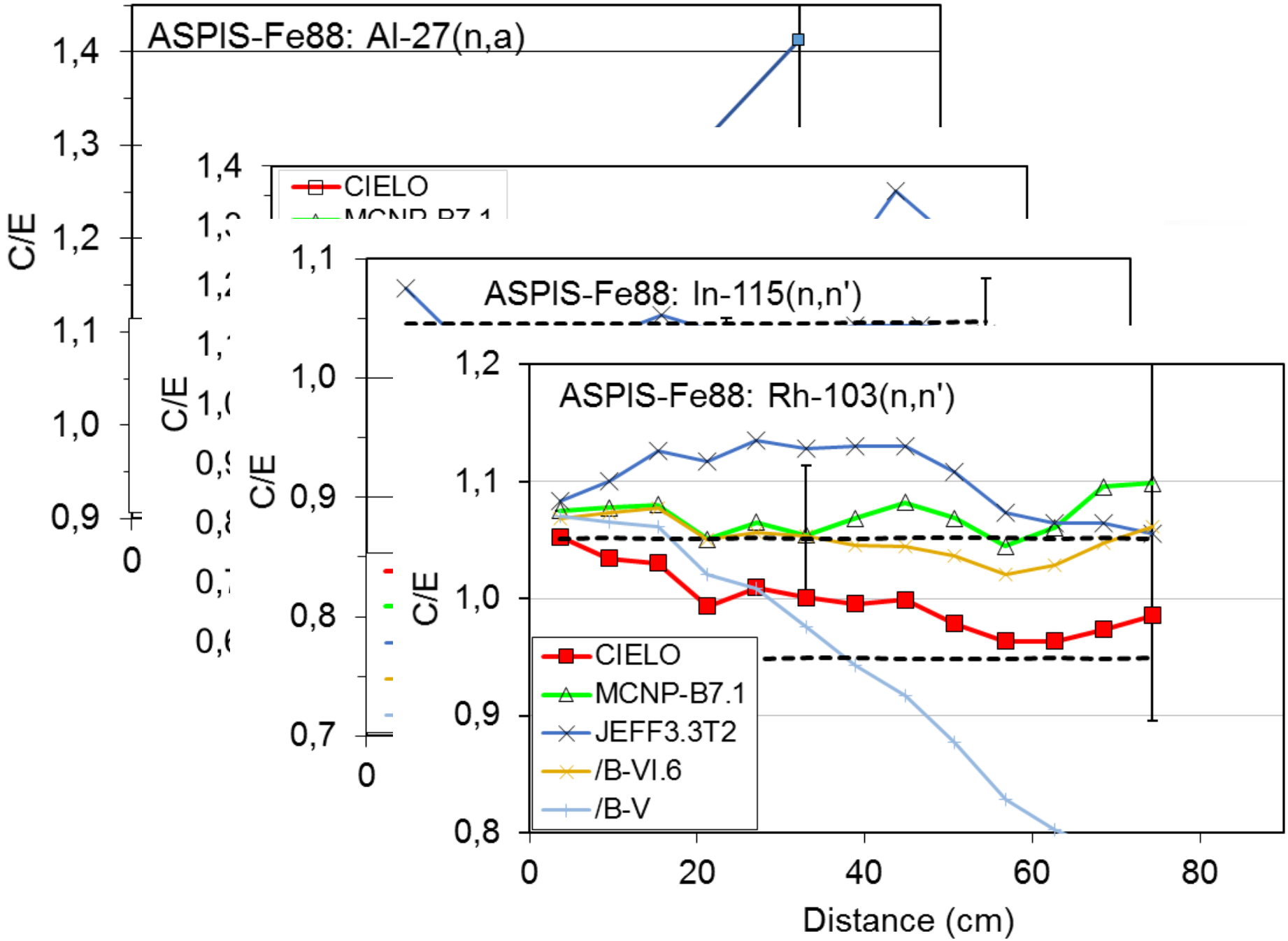

ASPIS-Fe88: Al-27(n,a)
C/E
1.4
1.3
1.2
1.1
JENDL4.0u


JENDL4.0u
ENDF/B-7.1
Exp.uncertainty
C/E
1.1
1.0
0.9
0.8
ASPIS-Fe88: In-115(n,n')
0
20
40
60
Distance (cm)


C/E
1.1
1.0
0.9
0.8
0.7
JENDL4.0u
MCNP-B7.1
Exp.uncertainty
ASPIS Fe88: S-32(n,p)


ASPIS-Fe88: Rh-103(n,n')
C/E
1.1
1.0
0.9
0.8
JENDL4.0u
MCNP-B7.1
Exp.uncertainty
0
20
40
60
80
Distance (cm)


ASPIS-Fe88: Au-197(n,g)
C/E
1.2
1.1
1.0
0.9
0.8
JENDL4.0u
ENDF/B-7.1
Exp.uncertainty
0
20
40
60
80
Distance (cm)


ASPIS-Fe88: Al-27(n,a)
ASPIS-Fe88: In-115(n,n')
ASPIS-Fe88: Rh-103(n,n')
C/E
Distance (cm)
CIELO
MCNP-B7.1
JEFF3.3T2
/B-VI.6
/B-V

IRDF-2002 vs. IRDFF Validation