

Short History of SINBAD and WPEC-SG47 Objectives

I. Kodeli

Jožef Stefan Institute, Jamova 39, Ljubljana, Slovenia, ivan.kodeli@ijs.si

Nuclear data and method validation

OECD/NEA/NSC sponsored projects on integral benchmark experiment databases:

- ***SINBAD - Radiation Shielding Experiments***
- ICSBEP - International Handbook of Evaluated Criticality Safety Benchmark Experiments
- IRPhEP - Reactor Physics Experiments
- IFPE - Fuel Performance Experiments

C/E for critical & shielding benchmarks

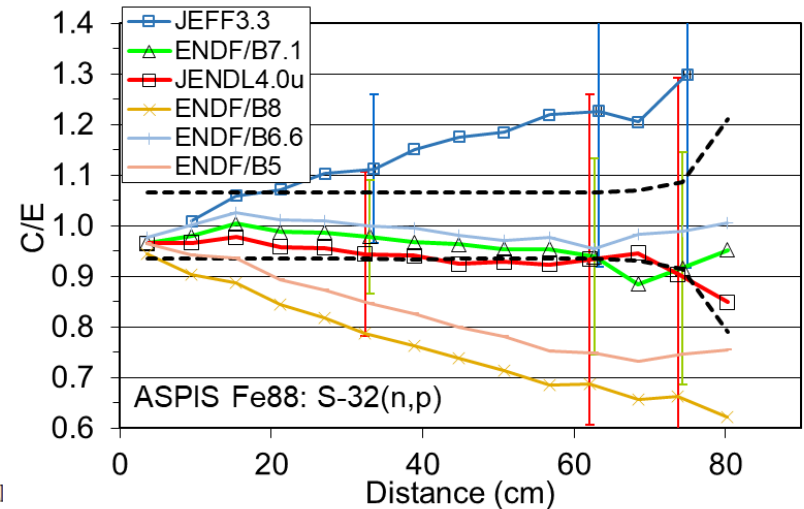
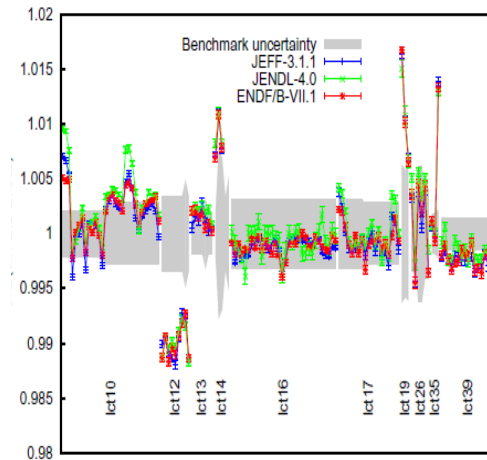
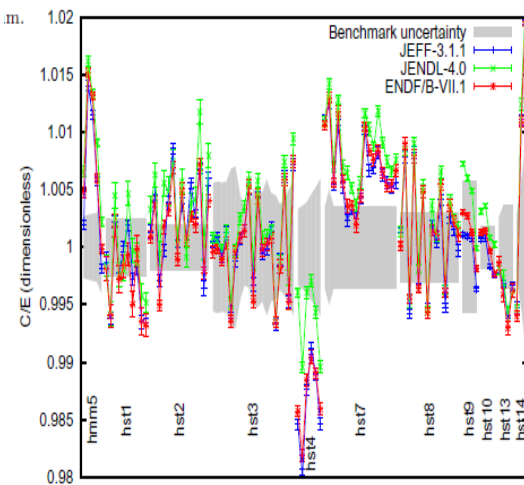


FIG. 5: Results for the HEU benchmarks with a thermal spectrum (continued).
G. 10: Results for the LEU benchmarks with a thermal spectrum (continued).

Steven C. van der Marck, Benchmarking ENDF/B-VII.1, JENDL-4.0 and JEFF-3.1.1 with MCNP6, Nuclear Data Sheets, **113**, Issue 12, (2012): **C/E for almost 50% of over 2000 benchmarks from ICSBEP are within $1 \sigma_E$!**

Possible mathematical explanations:

➔ ΔC is negligible

➔ C and E are correlated for k_{eff} benchmarks, but not (or less) for shielding

Note that k_{eff} is a very global parameter

C/E, ΔE vs. ΔC for shielding benchmarks

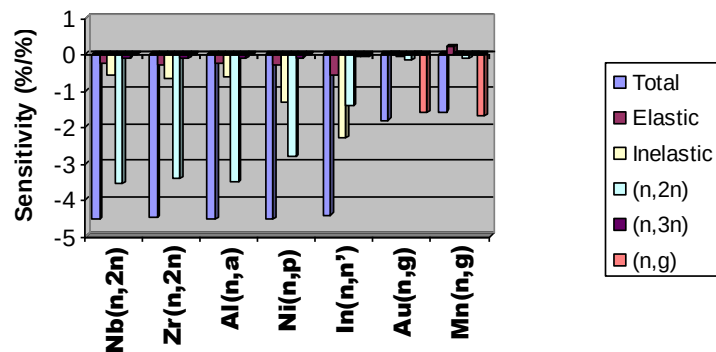
ASPIS-Fe88

Reaction & position (cm)	ΔC Total			ΔE (%)
	JEFF-3.3	ENDF/B7.1	JENDL4	
$^{32}\text{S}(n, p)$ 26	13.3	11.5	17.2	6.5
	52	25.0	35.0	6.5
	62	29.3	42.9	8.6
$^{115}\text{In}(n, n')$ 26	6.6	10.5	14.8	4.5
	46	10.5	17.8	4.7
$^{103}\text{Rh}(n, n')$ 26	6.4	7.8	8.6	5.1
	62	11.7	14.9	5.1
$^{27}\text{Al}(n, \alpha)$ 26	18.8	31.5	29.5	4.7
$^{197}\text{Au}(n, \gamma)$ 26	5.1	9.9	9.2	4.2
	46	4.3	8.8	4.2
	62	3.7	8.1	4.2

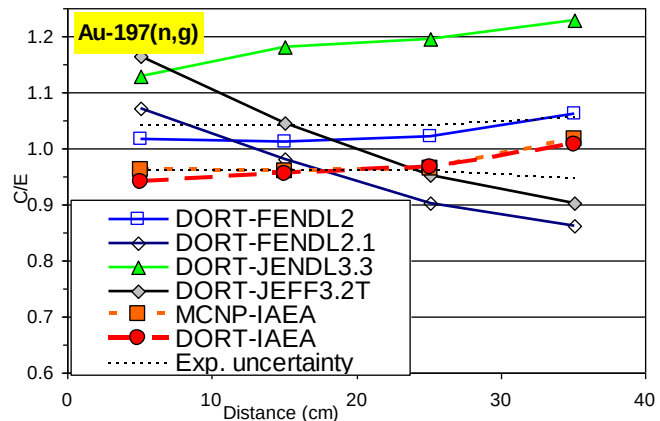
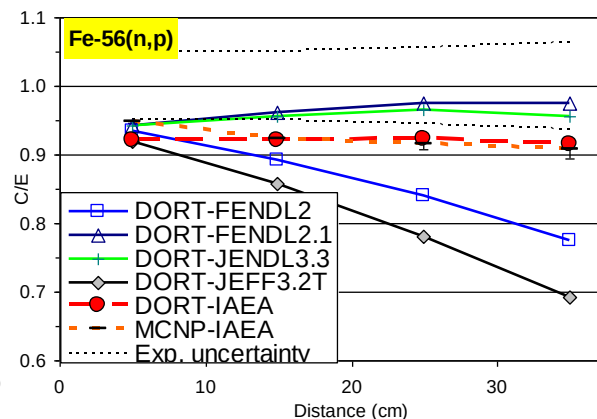
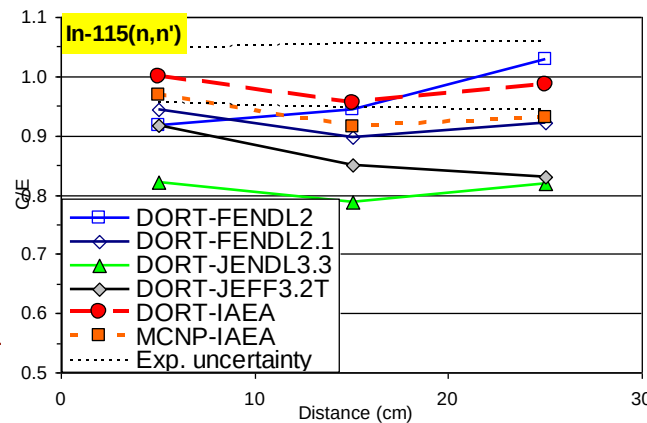
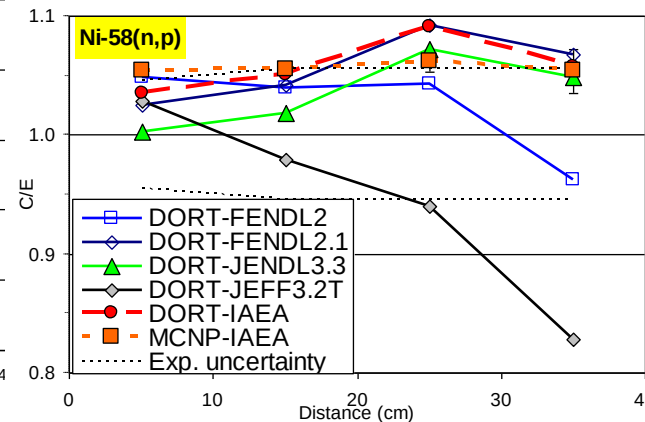
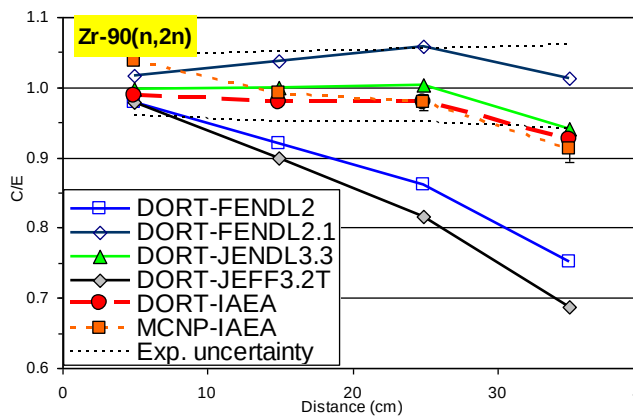
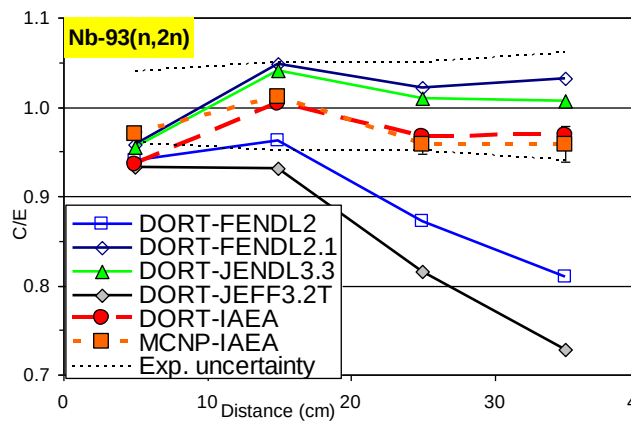
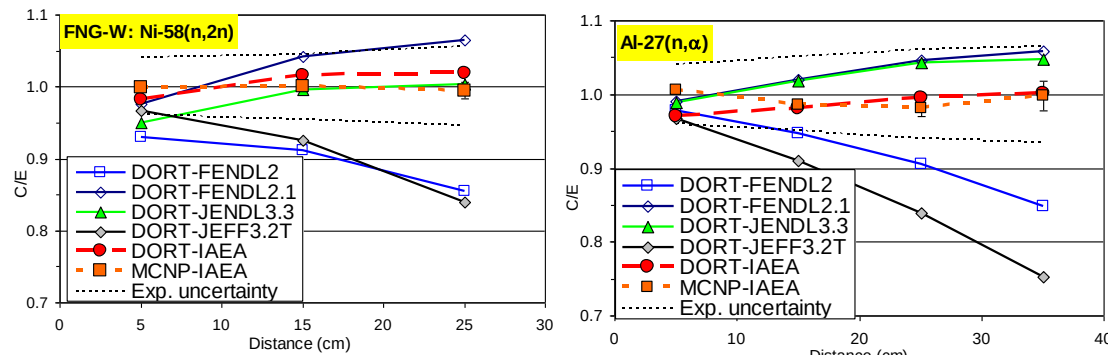
FNG-Cu

Reaction & position (cm)	Uncertainty (%)			C/E	
	JEFF-3.3	ENDF/B-VI.8	TENDL-2013	FENDL3	JEFF3.2
$^{58}\text{Ni}(n, p)$ 35	4.8	13.7	22.9	1.03	0.98
	57	9.1	27.2	1.03	0.91
$^{115}\text{In}(n, n')$ 35	8.2	9.4	12.1	0.78	0.68
	57	12.7	18.7	0.69	0.54
$^{27}\text{Al}(n, \alpha)$ 57	12.5	33.2	51.9	0.88	0.77
$^{93}\text{Nb}(n, 2n)$ 57	13.3	34.7	53.4	0.92	0.79
$^{197}\text{Au}(n, \gamma)$ 57	15.3	19.9	18.6	0.58	0.63
$^{186}\text{W}(n, \gamma)$ 57	23.2	28.6	27.3	0.41	0.37

FNG - W: Cross-section sensitivity



FNG W Benchmark



WPEC Subgroup 47

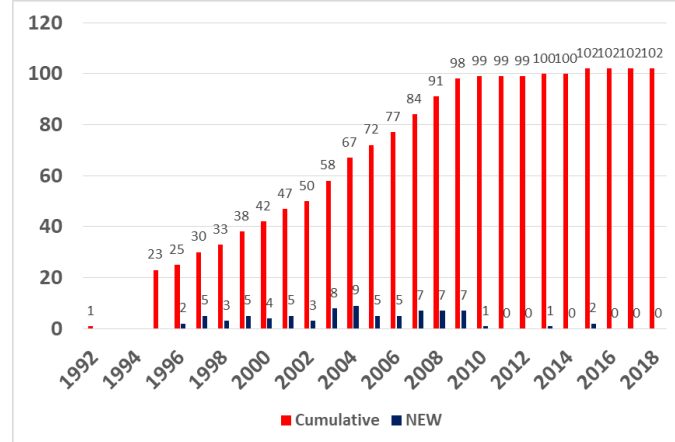
- **Critical remarks on SINBAD:**

- Few new evaluations included since last 10 years
- **Quality evaluations:** measurement uncertainty assessment needs to be improved and studied more in detail; **quality standards**
- **Format issues:** differences with IRPhE/ICSBEP;

More new formats produced in last years than evaluations!

- **Direct discussion with ND experts needed**

- **WPEC SG47** proposed and discussed at EGRTS meeting (Feb. 2018), JEFF Co-ordination Group, Madrid (20 April 2018)
- approved at WPEC Meeting, NEA Paris, May 17-18, 2018



WPEC Subgroup 47 (SG47) on Use of Shielding Integral Benchmark Archive and Database for ND Validation

Justification for a Subgroup

- Integral benchmark experiments have proven to be valuable for validation of nuclear cross-sections.
- In recent years, the evaluations have been predominantly validated against criticality benchmarks, and are “tuned” to better match the measurements. However, the effective multiplication factor **(k_{eff}) is a very global parameter**, dependent on many “free” parameters.
- **Including shielding benchmarks in the validation process** is expected to provide a complementary view and would allow broader evaluation of the performance of the nuclear data. This would ultimately contribute to a production of general-purpose cross-section evaluations.

Subgroup Monitor(s): O. Cabellos, L. Leal

Subgroup Coordinator: I. Kodeli

WPEC Subgroup 47 (SG47) on Use of Shielding Integral Benchmark Archive and Database for ND Validation

Multiple challenges and objectives to be considered, including:

- To **provide feedback on the existing database** and contribute in this way to the quality review: verification of the completeness and the consistency of the experimental information (on the geometry, material composition, the procedure to derive data-unfolding, etc.), in particular concerning the evaluation of experimental sources of uncertainty.
 - **Provide recommendations on the SINBAD evaluations** based on the experience, needs and expectations of the nuclear data community;
 - To participate in **establishing the priority list of relevant benchmarks** according to the needs of ND community, in particular among new and recent benchmarks; promote including the selected benchmarks in SINBAD; contribute sensitivity profiles.
 - To participate, in coordination with EGRTS WPRS, in establishing the **review group and organisation of pilot exercise of SINBAD evaluations**. FNG, LLNL, ASPIS, Rez benchmark evaluations are good candidates for pilot exercises.
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WPEC Subgroup 47 (SG47) on Use of Shielding Integral Benchmark Archive and Database for ND Validation

Relevance to other NEA ND activities:

SG would work in close coordination with other NEA activities such as EGRTS, WPEC SG45, SG46, CIELO and JEFF project, where this work could be used to guide the evaluations. Feedback from these groups on the specific needs and the use of SINBAD data is expected. SINBAD evaluation work could be coordinated with the interest of SG46 on “Efficient and Effective Use of Integral Experiments for Nuclear Data Validation”.

Past experience in integral benchmark evaluations from the ICSBEP, IRPhE and SINBAD projects will be valuable.

WPEC Subgroup 47 (SG47) on Use of Shielding Integral Benchmark Archive and Database for ND Validation

Time-Schedule and Deliverables:

- Year 1:

- In coordination with other SGs and EGRTS identify potential SINBAD benchmarks to serve as pilot evaluations for review procedure
- Identify other potential benchmarks not yet included in SINBAD to be used in this work
- Organise the review group participants; use of different nuclear data and transport codes is encouraged;

- Year 2:

- Benchmark analysis of the subset of shielding benchmarks and collection of the experience and results from the participants;
- Contribute the available sensitivity profiles to be included in the database;
- Distribute & discuss the review of selected shielding benchmarks serving as prototype for future work;
- Select benchmarks from the priority list to promote the evaluation in the SINBAD.

- Year 3:

- Coordinate with EGRTS new benchmark evaluations and benchmark reviews, for the integration in SINBAD and release of the evaluation to be used by other SGs;
- Draw conclusions on the evaluation process and provide recommendation of good practices useful for future ND validations using Shielding and Transmission Benchmarks. Of particular interest is the feedback on the completeness and consistency of the available uncertainties and correlations, which shall contribute to the revision and consolidation of uncertainties, including those in neutron sources, engineering and others.

WPEC Subgroup 47 (SG47) on Use of Shielding Integral Benchmark Archive and Database for ND Validation

Shielding benchmarks to be considered within WPEC SG47:

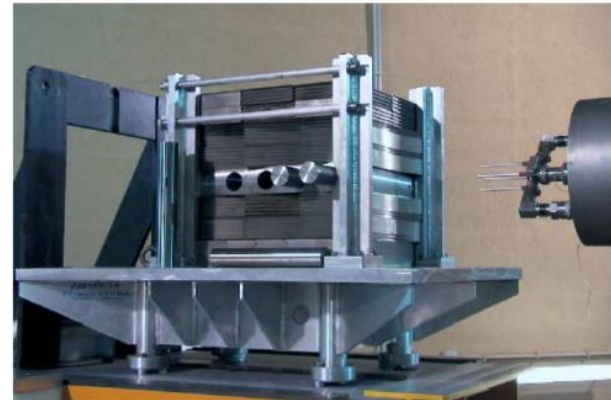
- FNG SS, ITER Blanket, ITER Streaming, SiC, W, HCPB, (HCLL), Cu
- LLNL spheres
- ASPIS IRON88
- JANUS phase I to VIII (Fe, Na)
- TIARA (Fe, concrete)
- FNS
- OKTAVIAN
- Rez Iron spheres

Drawbacks, critics:

- evaluations and review process less complete/thorough than ICSBEP/IRPhE
- format (EGRTS)
- (MCNP) computer code inputs missing
- long CPU time calculations

Benchmark Experiment on W (2002)

Validate EFF data for tungsten



Relevance to other OECD/NEA and International activities

- **EGRTS** - Expert Group on Radiation Transport and Shielding
 - **WPEC** - Working Party on Evaluation Cooperation:
 - WPEC-SG39 “Methods and approaches to provide feedback from nuclear and covariance data adjustment for improvement of nuclear data files”
 - SG40 (CIELO): validation of Fe and O
 - SG44: Investigation of Covariance Data in General Purpose ND Libraries
 - SG45: Validation of Nuclear Data Libraries (VaNDaL) Project
 - SG46: Efficient and Effective Use of Integral Experiments for ND Validation
 - **CHANDA & SANDA** projects of EC, JEFF project
 - European Fusion Programme – Fusion for Energy (**F4E**) & **EUROfusion**
 - **SINBAD review meeting** in conjunction with ICSBEP/IRPhE meetings
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SINBAD - main purpose and applications

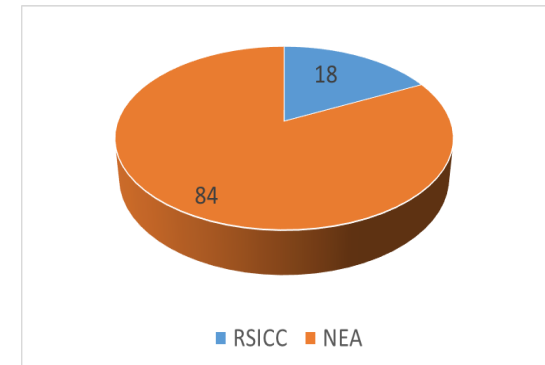
- Joint effort between RSICC, the Nuclear Energy Agency (NEA) Nuclear Science Committee (NSC) and NEA Data Bank
- NEA Nuclear Science Committee (NSC) Working Party on Scientific Issues of Reactor Systems (WPRS) Expert Group on Radiation Transport and Shielding (**EGRTS**) responsible for promoting SINBAD and organisation of quality review
 - Preserve information on expensive experiments
 - Validation of nuclear data & computer code for ND processing & radiation transport
 - Reactor design and set-up studies
 - Training & education
 - Provide record of experimental data on which present data & methods are based
 - Developing an approach of global method and data validation, using integral experiments
- two main “philosophies”:
 - a) - mock-up of the reference configuration (core, shielding, storage lattice etc.)
 - b) – mock-up investigating separately basic data & phenomena.
- Synergies with ICSBEP & IRPhE

SINBAD History

- Miller P, Nagel P, Salvatores M, Sartori E.
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
- H. T. Hunter, D. T. Ingersoll, R. W. Roussin, C. O. Slater, E. Sartori, I. Kodeli, SINBAD-Shielding Integral Benchmark Archive and Database, Proc. ANS Topical Meeting on Rad. Prot.&Shielding, Cape Cod, Massachusetts (1996)

Good cooperation with ICSBEP/IRPhE (BAIKAL-1, VENUS-3).

- Compilation of high quality experiments for validation and benchmarking of computer codes and nuclear data used for radiation transport and shielding problems encompassing:
 - reactor shielding, PV dosimetry **(48)**
 - fusion blanket neutronics **(31)**
 - accelerator shielding **(23)**
- Low and inter-mediate energy particles applications.
- **Contains 102 experiments of varying quality** (benchmark quality, additional info needed, suitable for education & training)



New since 2009: FNG-HCPB, OKTAVIAN-Mn, NAÏADE 1 Concrete Benchmark (60cm), ORNL Skyshine, Polyethylene/Pu Metal Sphere (Sandia Lab) (FNG-Cu & HCLL)

SINBAD - Radiation Shielding Experiments: **Contributing Institutions**

- AEAT, United Kingdom
 - CEA, France
 - CERN SPS
 - ENEA, Italy
 - European Commission JRC Ispra
 - FZDresden, Germany
 - FZKarlsruhe, Germany
 - Georgia-Tech, USA
 - IAEA, Vienna
 - IPPE Obninsk, Russian Federation
 - IRI Delft, Netherlands
 - JAEA, Japan
 - JNC, Japan
 - JSI, Slovenia
 - KEK, Japan
 - LANL, USA
 - Lawrence Berkeley Nat. Lab. USA
 - MEPhI, Moscow , Russian F.
 - Michigan State Univ. USA
 - NIRS, Japan
 - NIST, USA
 - ORNL, USA
 - PSI, Switzerland
 - RAL, UK
 - RIKEN, Japan
 - SCK-CEN Belgium
 - Tohoku University, Japan
 - TU Budapest ,Hungary
 - TU Dresden, Germany
 - University of Illinois, USA
 - University of Osaka, Japan
 - University of Pavia, Italy
 - University of Tokyo, Japan
 - VNIITF (RFNC), Snezhinsk, RF
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SINBAD (Radiation Shielding Experiments Data Base)

- SINBAD data include benchmark information **in standard form**:
 - (1) experimental facility and radiation source;
 - (2) benchmark geometry and material composition;
 - (3) detection system, measured data, and an error analysis.
- Peer review of the compilations by two scientists;
- Include graphical information on experimental geometry, measured quantities, computer code inputs for the analysis, reports used in the compilation, QA report and peer review report
- **Format: html with links to text, figures, pdf and computer inputs; List of experiments by laboratory, materials tested, topics, year;** main report in PDF (previously in html). Computational models in future.
- Simplicity of use; easy & low-cost maintenance
- Distribution on CD-ROM by the RSICC and the NEA DB.

<https://www.oecd-neo.org/science/wprs/shielding/sinbad/>

<https://rsicc.ornl.gov/Benchmarks.aspx>

New features

- New SINBAD benchmark evaluations prepared in 2018 in the scope of the Fusion for Energy (F4E) programme (FNG-Cu & HCLL);
 - New features included in recent SINBAD evaluations:
 - Acceleration of MCNP calculations using ADVANTG
 - CAD geometry: easy conversion to different transport codes;
 - Sensitivity profiles: already prepared for FNG-Cu and ASPIS Iron-88 benchmark evaluations;
 - Quality review
 - Computational model(s)
 - **WPEC SG47** on Use of SINBAD for ND validation.
 - SINBAD evaluation group (cooperation with ICSBEP/IRPhE)
-

Quality Assessment of SINBAD Shielding Benchmarks

- **Since the experimental data presently available in SINBAD are of varying quality, a revision and classification of the benchmark experiments according to the completeness and reliability of information is being undertaken** in order to provide users with easier choices and help them make better use of the experimental information.
- **34 + 17 experiments** were revised and updated SINBAD compilations released (2008-2011). (Alberto Milocco (80%), Gašper Žerovnik, Pedro Ortego);
 - New experimental information from the literature
 - Refinement of source model where possible
 - New MCNP5/X models reproducing the experiment as exactly as reasonably possible, avoiding unnecessary approximations
 - Sensitivity studies to study the impact of neutron source description, composition and geometry uncertainties where available

SINBAD – example of quality evaluations (2012-2014)

REACTOR

- Ispra Iron Benchmark (EURACOS) [**]
- Ispra Sodium Benchmark (EURACOS) [**]
- Cadarache Sodium (HARMONIE) [*]
- JANUS Phase I (Neut. Transport Through Mild & Stainless Steel) [***]
- JANUS Phase VIII (Neutron Transport Through Sodium & Mild Steel) [***]
- NESDIP-2 Benchmark (ASPIS) [*/**]
- NESDIP-3 Benchmark (ASPIS) [***]
- 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) [***]

ACCELERATOR

- TIARA 43 & 68 MeV PROTONS [***]
 - BEVALAC [***]
 - AVF 75MeV [*/**]
 - PSI-590MeV [*/**]
-

SINBAD: FISSION NEUTRONICS

Benchmark / quality	Additional information needed on
ASPIS Iron ~ ♦♦	n source description, positioning / dimension uncertainty, some specifications inconsistent or not complete
ASPIS Iron-88 ~ ♦♦♦	New MCNP model. Additional information needed: - detectors arrangement (e.g. stacking) - gaps between the slabs - absolute calibration of neutron source & dilution factor - effect of the cave walls
ASPIS Graphite ♦♦♦	New MCNP model. Additional information needed: - detectors arrangement in the slots (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

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
NESDIP-2 ♦ / ♦♦	New MCNP model. Supplementary information needed on: - activation foils positioning & housing - background subtraction method, calibration
NESDIP-3 ♦♦♦	- „ -
JANIS-1 ♦♦♦	- „ -
JANIS-8 ♦♦♦	- „ -
EURACOS Iron ~ ♦♦	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.
EURACOS Na ~ ♦♦	- „ -
HARMONIE ♦	too simplified geometry, materials and neutron source description

Interaction with other database projects IRPhEP, ICSBEP

- Approved evaluations stored in IRPhE and/or ICSBEP (alarm systems - streaming and skyshine) should be adopted in SINBAD as is in order to avoid duplication and confusion. For these, any proposed changes or revisions should go through IRPhE or ICSBEP.
- Keep formats compatible in order to prevent duplication of activities and take advantage and benefit of work carried out in each of the projects.
- ICSBEP guide for expressing uncertainties

Examples: VENUS-3, Skyshine (already included)

- **ALARM-CF-AIR-SHIELD-001** Neutron and Photon Leakage Spectra from CF-252 Source at Center of 40-cm Diameter Iron Sphere
 - **ALARM-CF-FE-SHIELD-001** Neutron and Photon Leakage Spectra from CF-252 Source at Center of 40-cm Diameter Iron Sphere
 - **ALARM-CF-PB-SHIELD-001** Neutron and Photon Leakage Spectra from Cf-252 Source at Center of Lead Spheres of Various Diameters
 - **ALARM-CF-AIR-LAB-001** Neutron Fields in 3-Section Concrete Labyrinth From CF-252 Source
 - **ALARM-CF-CH2-LAB-001** Neutron Fields in 3-Section Concrete Labyrinth From CF-252 Source
 - **ALARM-REAC-SKY-001** Baikal-1 Skyshine Experiment **(DONE)**
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Conclusions

- SINBAD was successfully used in the scope of Fusion for Energy (F4E), EUROfusion, CHANDA, SANDA, WPEC CIELO, SG39, SG46, EFF-4 and IAEA activities and demonstrated to be **suitable for validation of modern nuclear data evaluations and codes, in combination with criticality, kinetics and other benchmarks.**
 - The SINBAD database currently contains compilations and evaluations of experiments for **48 reactor shielding** problems, **31 for fusion neutronics shielding** and **23 for accelerator shielding cases. 51 quality reviewed experiment-** some evaluations need to be updated. Few new data since 2009.
 - **WPEC SG47 objectives:**
 - Provide feedback on present SINBAD benchmarks
 - Recommendations for improvements
 - Priority list for future evaluations
 - In cooperation with EGRTS WPRS participate in future evaluations
 - **New features: acceleration using ADVANTG, CAD geometry, sensitivity profiles, computational model(s), QA,**
 - **(ISO) standards for benchmark experiments (?)**
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