UK Atomic Energy Authority

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SINBAD Project and Outcomes of WPEC SG47 on Shielding Benchmark Use

- Ivo Kodeli, Oscar Cabellos, Luiz Leal

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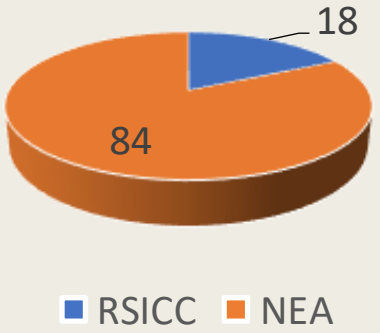
SINBAD (Radiation Shielding Experiments Data Base)

- Preserve results from expensive experiments
- Past experiments contribute to the present state-of-the-art in designing existing reactors or fuel cycle installation.
- Validation of
  - *radiation transport codes*
  - *nuclear data performance*
  - *reactor design concepts / components*
- Developing an approach of global method and data validation, using integral experiments
- Education & training
- 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
- Joint effort between RSICC, the Nuclear Energy Agency (NEA) Nuclear Science Committee (NSC) and NEA Data Bank
- **OECD/NEA Working Party on Scientific Issues of Reactor Systems (WPRS)** Expert Group on Physics of Reactor Systems (EGPRS): monitor, steer and support the continued development of the SINBAD database.
- **WPEC-SG47** "Use of SINBAD for Nuclear Data Validation" **2019 – 2022**
- **NEA Task Force**
- **IAEA role**

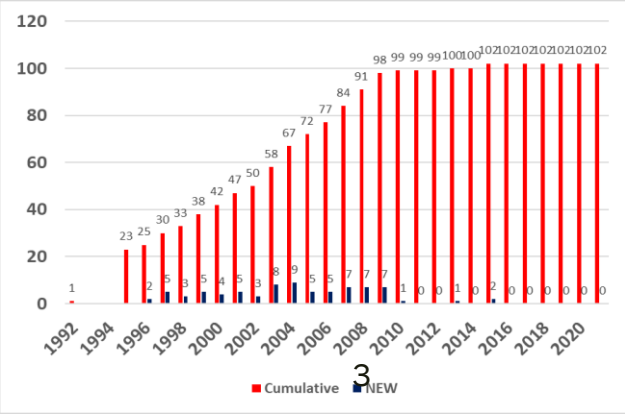
SINBAD - Radiation Shielding Experiments

- Objective: 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)
- Available from OECD/NEA and RSICC.



Distribution on CD-ROM by the NEA DB and the RSICC.

- https://www.oecd-nea.org/science/wprs/shielding/sinbad/
- http://www-rsicc.ornl.gov/BENCHMARKS.aspx



Uncertainties in calculated detector reaction rates due to cross-section uncertainties compared to measurement uncertainties (ASPIS Fe88)

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

SINBAD (Radiation Shielding Experiments Data Base)

Shielding Materials

- Fe/SS (27 benchmarks)
- H_2O (11)
- Air (9)
- Na (6)
- Concrete (5)
- Pb, W, Si/SiC (4)
- Graphite, Al (3)
- O, V, Cu (2)
- Li, Mn, Ni, N, Nb, Be, Th, Bi, $(CH_2)_{2n}$ (1)
- Multiple materials (18)

Critical remarks on SINBAD

Primary objective of benchmark databases is to provide a framework for storing standard and validated sets of experiments needed for validation and verification of nuclear data and models in computer.

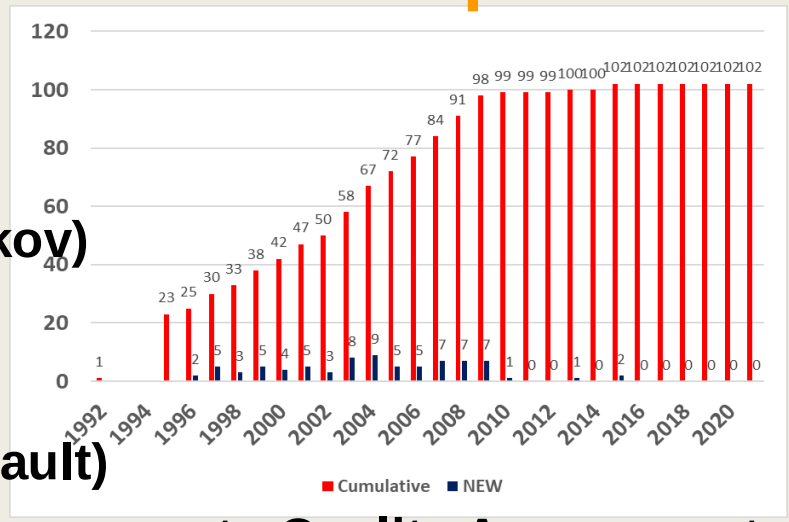
- Few new evaluations included since last 10 years; 19 recent benchmarks (> 2000), 23 older benchmarks <1980
- Quality evaluation and independent review process is mandatory: measurement uncertainty assessment needs to be improved and studied more in detail; quality evaluation started ~2009 to be finished for the remaining benchmarks
- Computer code inputs missing for some benchmarks
- Format issues: differences with IRPhE/ICSBEP; New format(s) for SINBAD
- Benchmark model to be provided as part of benchmark evaluation => computational model accurately describes the experimental arrangement
- Preparing an “ISO” standard for benchmarks was proposed by Enrico >20 years ago. Time to do it?

WPEC Subgroup 47 (SG47) on the Use of Shielding Integral Benchmark Archive and Database for ND Validation (2019-2022)

Objective: promote and facilitate wider use of shielding benchmarks.

- To **provide feedback on the existing SINBAD 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 NEA EGPRS WPRS, in establishing the review group and organisation of pilot exercise of SINBAD evaluations: FNG (Cu** and others), **LLNL spheres, Rez Iron spheres, ASPIS IRON88, JANUS, TIARA (Fe, concrete), FNS, OKTAVIAN** benchmark evaluations.

Data received during WPEC SG47 - pending evaluations/updates

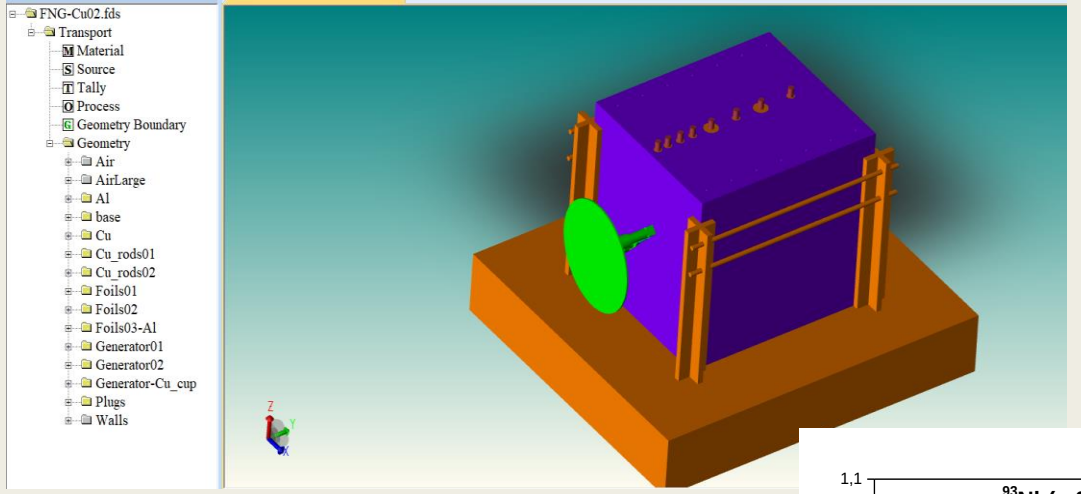


- New and updated SINBAD evaluations
  - FNG-Copper (Kodeli)
  - KFK Fe spheres g-leakage & ORNL O broomstick (S. Simakov)
  - CIAE Iron slab (Y. Ding, H. Wu)
  - TIARA benchmark (Y. Iwamoto)
  - ASPIS Iron88, JANUS (L. Buiron, A. Hajji, I. Kodeli, G. Rimpault)
  - ASPIS PCA Replica & NESDIP 3 (David Hanlon, Jacobs, Responses to Quality Assessment Concerns)
  - LLNL spheres (S. Kim, D. Neudecker, O. Cabellos)
  - BALSAC/MASURCA (CEA Cadarache 1988): fast reactors A. Hajji, G. Rimpault, L. Buiron
  - PETALE program in CROCUS on stainless steel (Vincent Lamirand, EPFL)
  - FNS Liquid Oxygen flux definition/effective area (A. Milocco, S. Simakov, I. Kodeli)
  - IAEA CoNDERC initiative (J.-C. Sublet)
- New computer code inputs:
  - MCNP, ADVANTG, SuperMC/INEST Hefei, TRIPOLI, SERPENT, OpenMC, GEANT, DORT & TORT, FLUKA, PHITS, MARS, MCBEND

Data available on WPEC SG47 GitLab

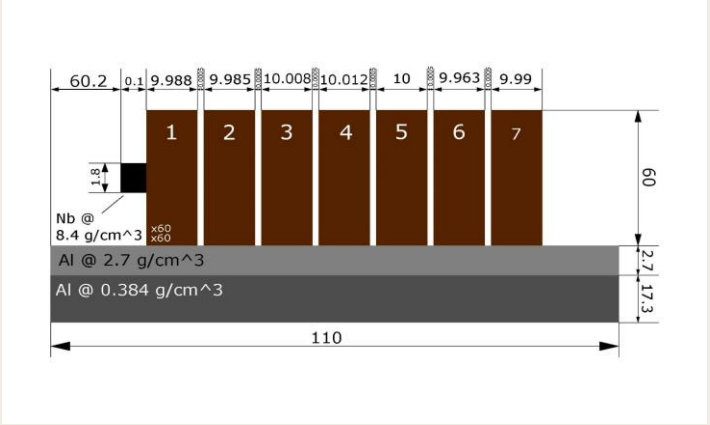
- ASPIS Iron88 Benchmark
- IJS-CCFE_ASPIS-Fe88_stp
- FNG-Copper
- KFK Fe spheres g-leakage
- ORNL O broomstick
- NRG Suite
- TIARA benchmark
- UPM suite

FNG Cu Benchmark



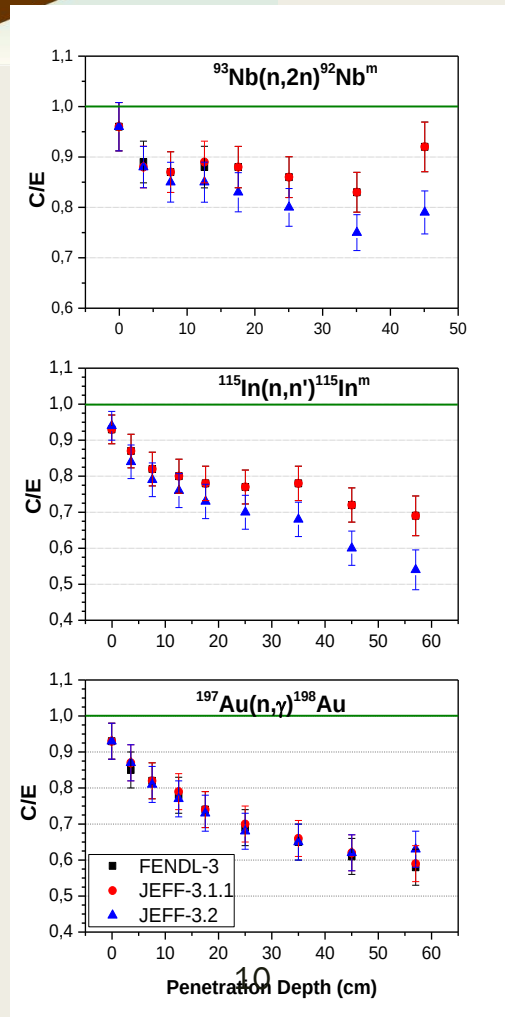
SINBAD data include:

- **Abstract file** in **HTML**
- **Main benchmark description** in **PDF** **including uncertainty evaluations**
- **Computer code inputs**
- **CAD geometry**
- **Sensitivity profiles**
- **Reference documents in PDF**



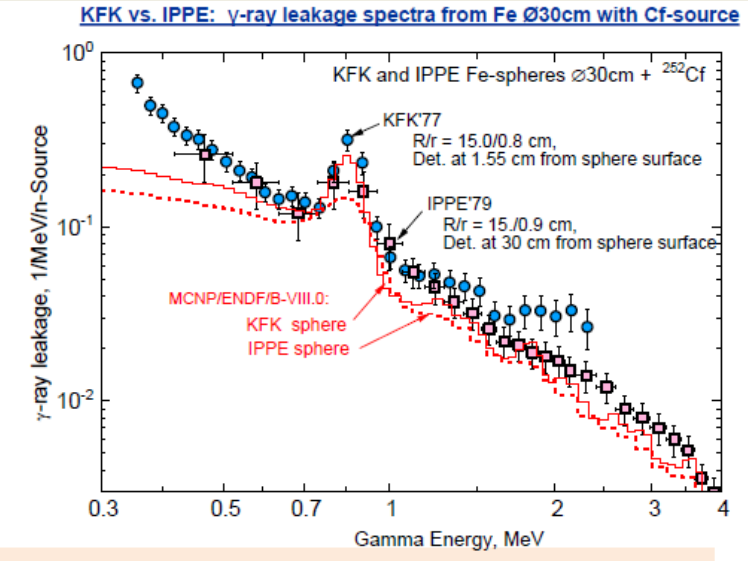
Computational models:

- **MCNP5/6** reference detailed model; n source description:
  - D-T neutron source subroutine
  - **MCUNED**;
  - **SDEF cards**
- MCNP & DORT simplified models
- Cross-section sensitivity/uncertainty analysis by **SUSD3D** & **MCSEN**



Stanislav Simakov,

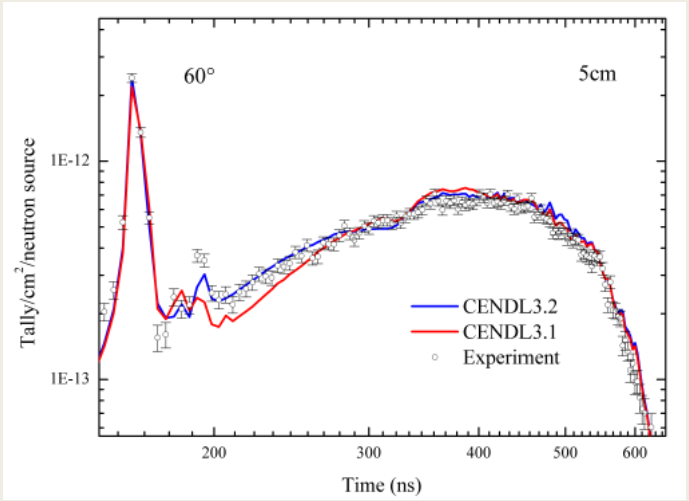
- KFK γ-ray leakage (new evaluation)
- ORNL O-broomstick transmission (SINBAD update)

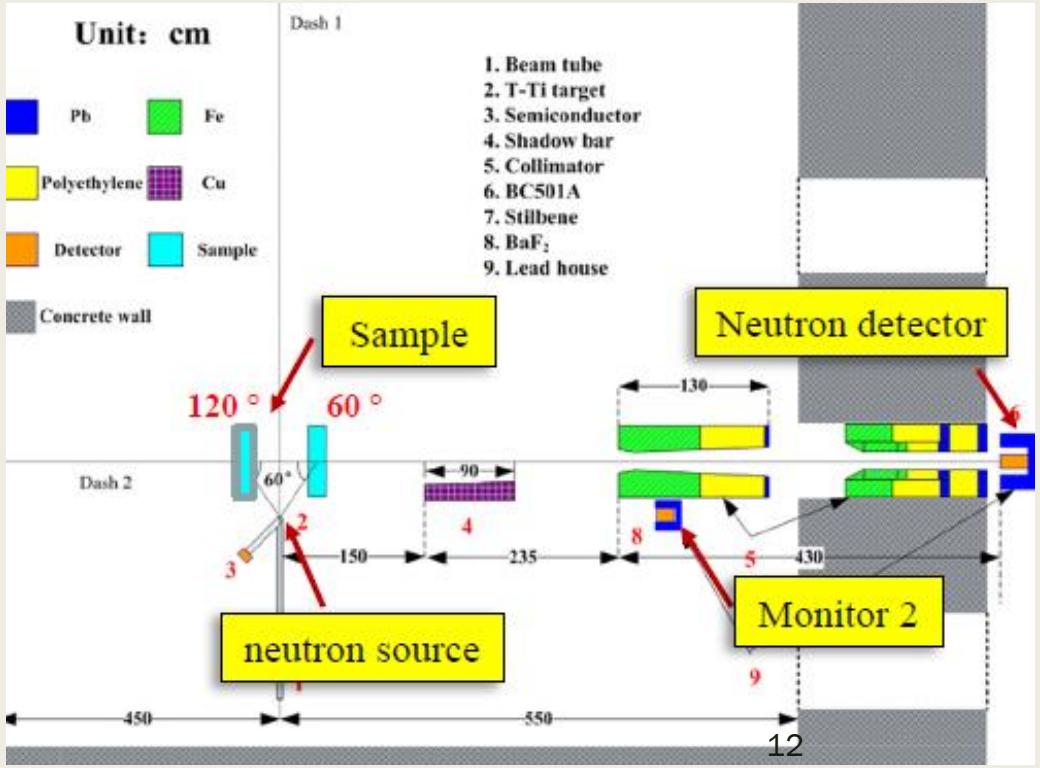


- SINBAD evaluation of KFK-1977 measured gamma from bare ^{252}Cf(s.f.) source and from Ø25, 30 and 35 cm Fe spheres was prepared, including detailed descriptions of facility, methods and final numerical results with uncertainties.
- Update of SINBAD evaluation on ORNL/TSR-II 60”(152.4 cm) Oxygen broomstick with MCNP model input, quality assessment and report on validation analysis and recommendations. Benchmarks are useful for total cross section validation;
- Experimental neutron transmission spectra for 24” (60.96cm), 36”(91.44cm) and probably 72” (182.88 cm) could not be found.
- Importance of evaluating a reference PFGS & DFGS of ^{252}Cf was raised.

Yanyan Ding: Benchmark experiment on iron with D-T neutrons at CIAE

- CIAE Neutron leakage spectra measurements from iron slab with D-T neutrons were presented, including the uncertainty quantification (systematic, random) and computational models. TOF spectra were measured at 60^0 and 120^0. C/E for CENDL-3.1, ENDF/B-VIII.0, JENDL-4.0 and JEFF-3.3 were shown and discussed.
- SINBAD evaluation in preparation to be presented at ICSBEP/IRPhE/SINBAD TRG meeting.
- CIEA performed benchmarks on ^{238}U, Be, Fe, Ga, W, C, SiC, Pb, Pb-Bi, ThO_2, Bi, Nb.





CAD based M/C modelling

- **CAD format** could provide a safer (less error prone) ADDITIONAL description of the geometry, useful for describing increasingly more complex benchmark geometry of recent benchmarks.
- CAD allows „automatic“ model preparation for different transport codes
- CAD (Computer-Assisted-Design) to CSG (Constructive solid geometry)
- STEP, FDS, STEP 242, SAT (ACIS kernel), libfive, OpenSCAD, McCAD
- Requirements for CAD formats:
  - Open rather than commercial/proprietary software
  - User friendly
  - Likely to be supported in future
- CAD models prepared using SuperMC available through GitLab:
  - ASPIS Fe88: STEP + json material definition
  - FNG Copper: FDS – material, geometry, source & tally definition in a single file.

Recommendations, feedback

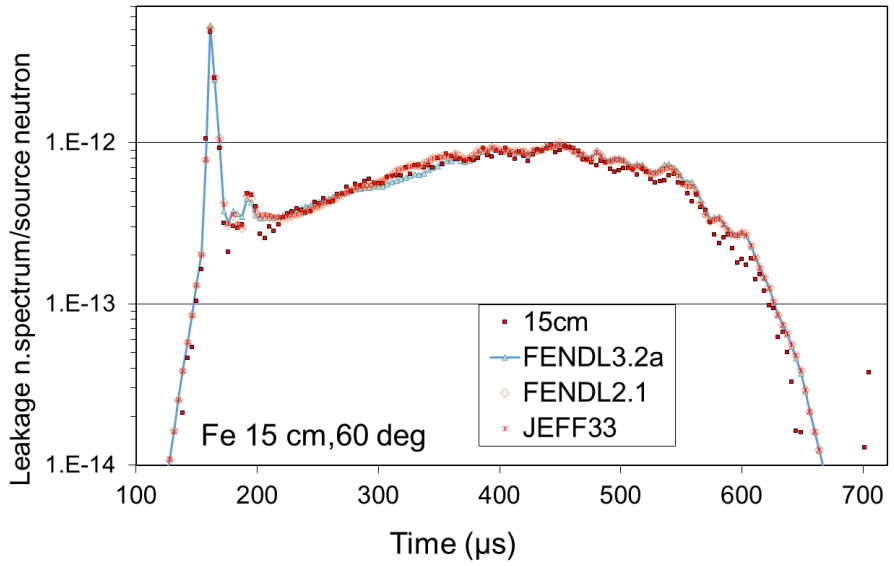
- **New benchmarks should be evaluated in SINBAD ASAP, not only published in journals;**
- **Careful verification of benchmark information** is mandatory for completeness and consistency of experimental information. Correct and complete interpretation of measured results and understanding of uncertainties & correlations.
- **NEA Task Force:** ~ICSBEP format (PDF), computational model and results (C/E); **Review process should involve shielding experts & users,**
- **Indexing and search of measured data: text format vs. PDF, experimental information must be available in computer readable form**
- Separate **experimental measurements (static databases) and computational data (dynamic database for models, C/E, specific code tools and data); "EXFOR" for integral experiments**
- **SINBAD distribution policy should be beneficial for SINBAD project progress and the users.**
- **Continue (re-start) quality review as initiated ~2008**

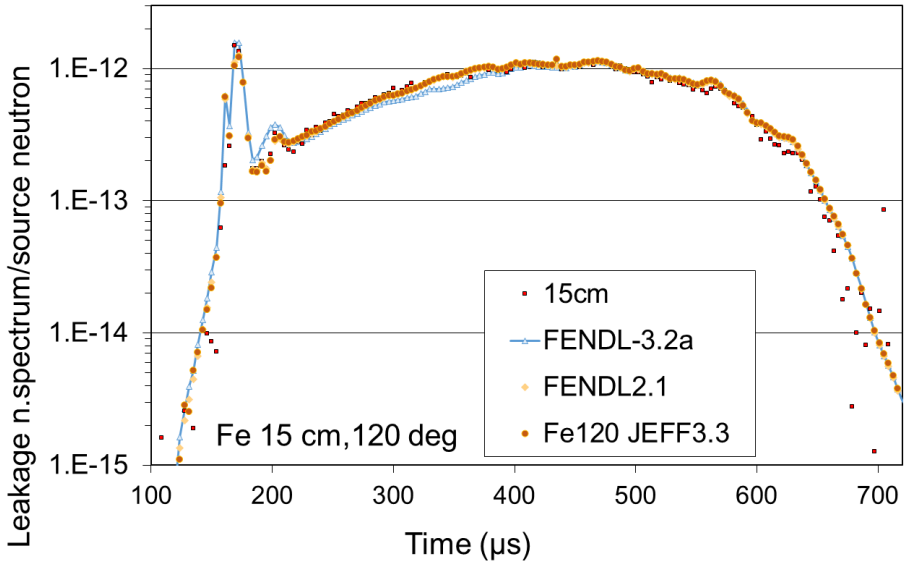
***	**valid for nuclear data and code benchmarking**
**	**suitable for education & training**
*	**benchmarks of historical interest**

Benchmarking activities at UKAEA

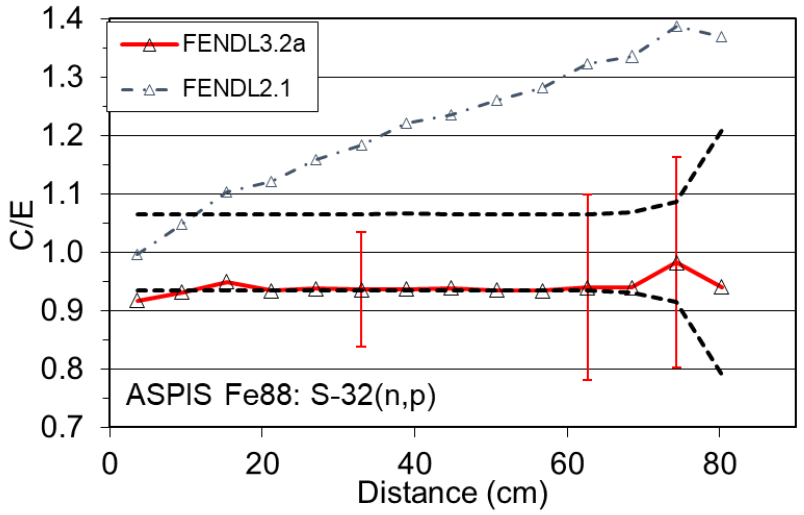
- Focus on nuclear fusion: analyses typically involve large and complex geometries, neutron & gamma source terms, higher energy neutrons than fission.
- Involved in fusion reactor projects such as **JET, ITER, STEP, MAST-U, DEMO**;
- **Fusion research** needs (W, Cu, Fe, V, Mo, Cr, Y, Ti, C, Zr, Li, Pb, Be, Si,...)
- Predominantly MCNP Monte Carlo calculations using acceleration methods, but use of alternative codes is actively studied: **Serpent2, OpenMC, GEANT4, TRIPOLI**,
- SINBAD database serves for validation of transport codes and nuclear data, **CAD based computational workflows**
- Project on automation of benchmark analysis.
- Nuclear data **sensitivity and uncertainty** analysis
- Activation & nuclear waste studies (**Fispact II**)
- Open to international collaboration: with IAEA in ND, Conderc project

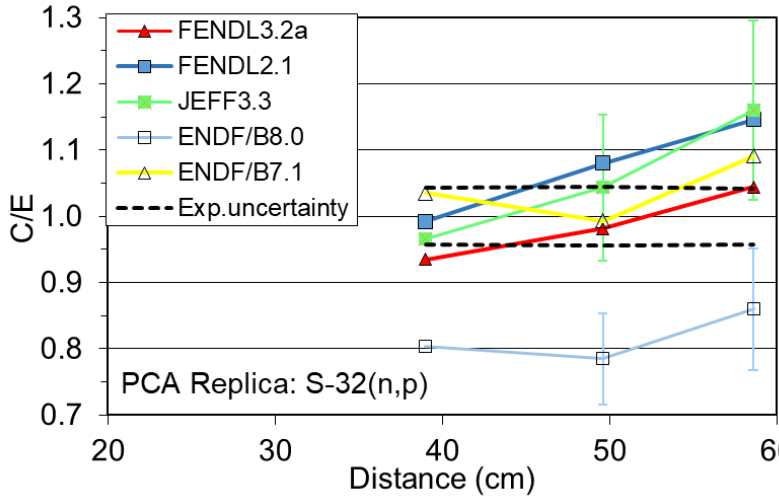
CCFE recent work: Validation of FENDL-3.2 (ASPIS, FNG, IPPE …)

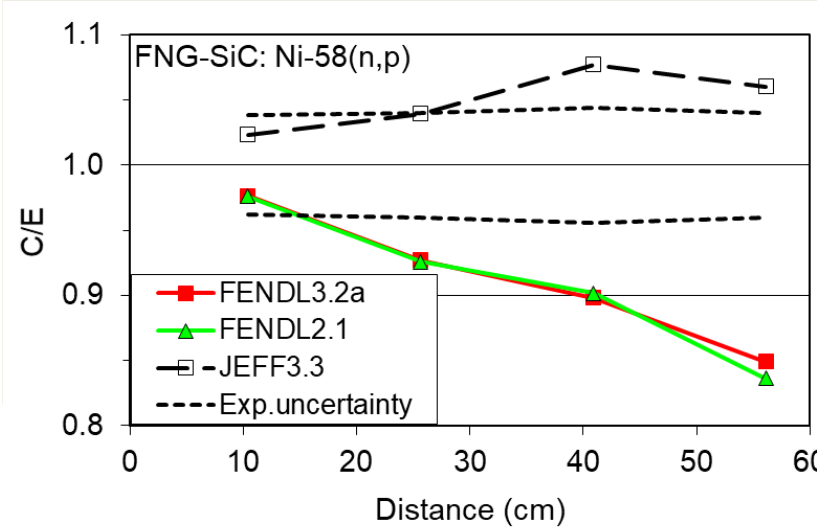


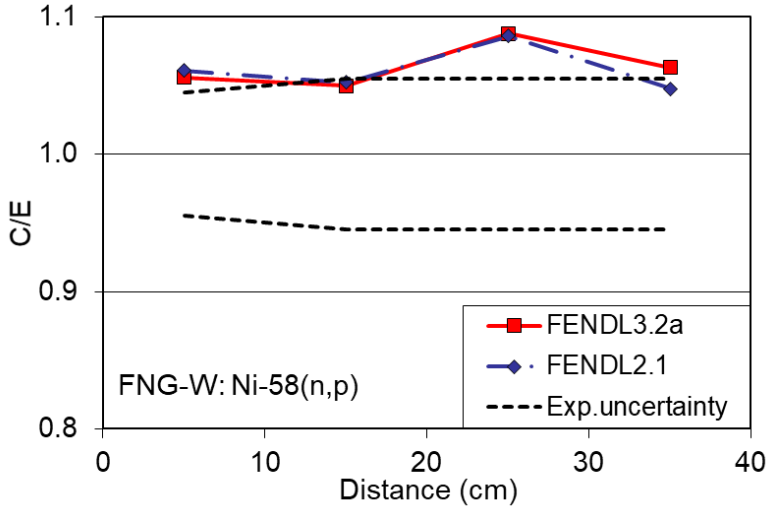


CIAE 15 cm Fe slab, TOA spectra at $60^0/120^0$ using MCNP inputs provided by CIAE.

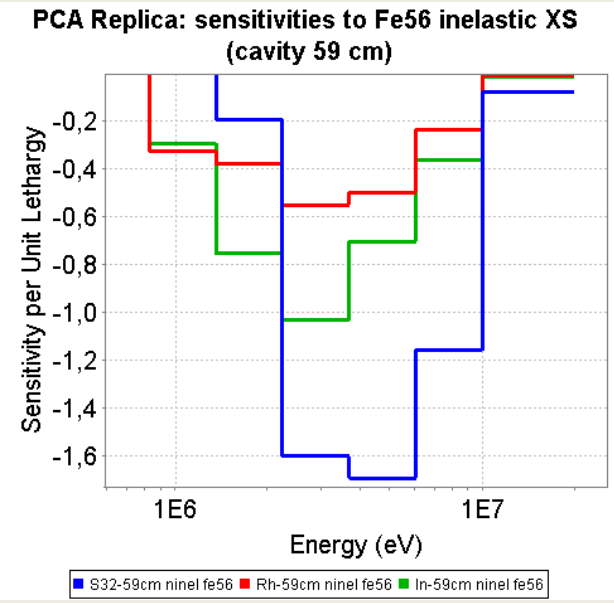


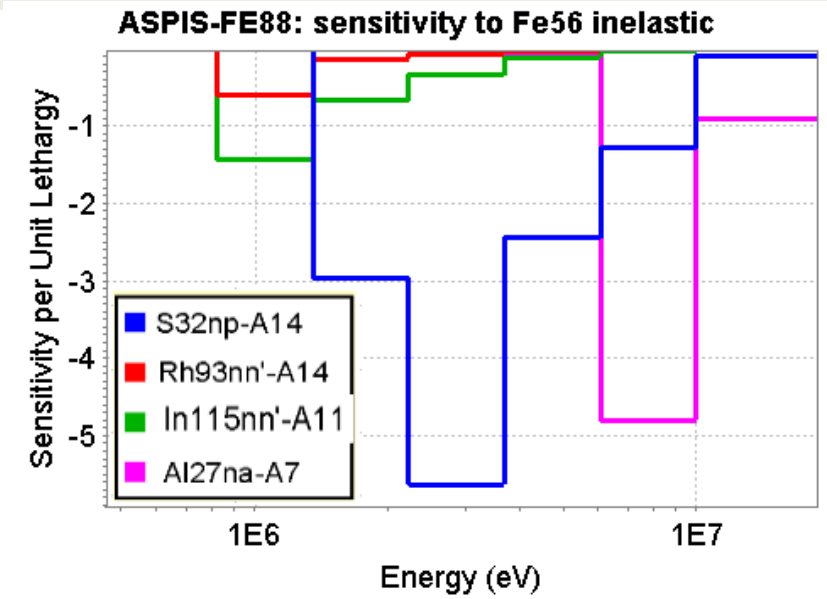






Sensitivity profiles

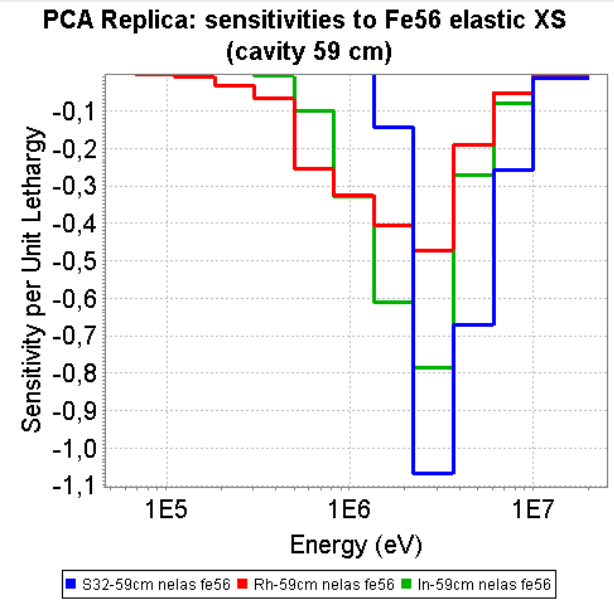


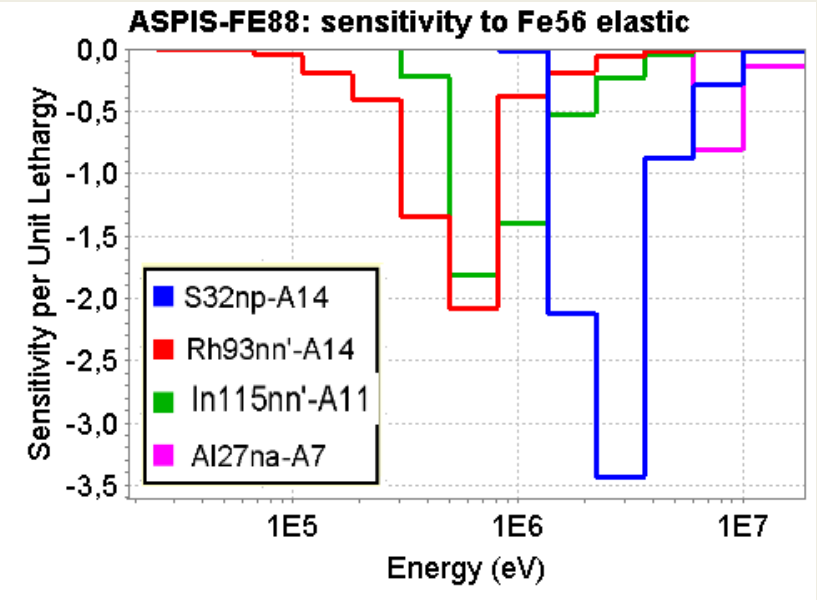


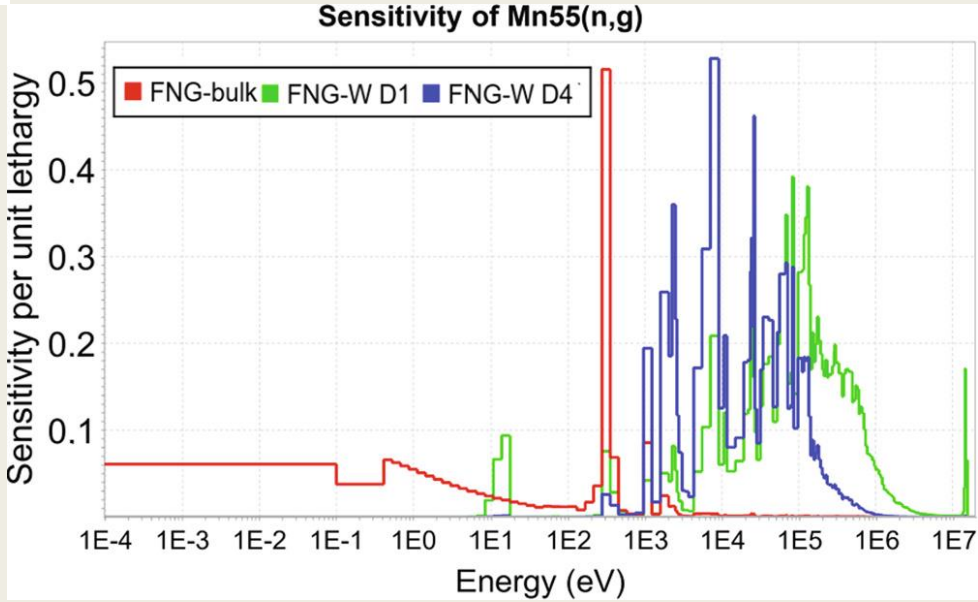
- **S/U provide uncertainty in the result**
- **Ranking key parameters** (most sensitive, contributing the most to the uncertainty)
- **Gives confidence in the simulation results**
- **sensitivity profiles: ASPIS Fe88, PCA Replica, FNG (Cu, W, HCPB, HCLL, …), VENUS-3, LLNL.**

Format: SensitivitiesViewer (N.Soppera)

https://www.oecd-nea.org/sensitivities-viewer/webstart/SensitivitiesViewer.jnlp







Conclusions

SINBAD provides framework for storing standard and validated sets of experiments needed for V&V of nuclear data, codes and computational models.

Supplementary benchmark information and new benchmark evaluations were prepared as part of SG47 activity. These data cover nuclides of key importance (Fe, O, Cu, …), neutrons, gamma & charged particles.

Feedback on future evolution of SINBAD is needed:

- **Quality review**
- **Is ICSBEP format to be adopted & suitable for SINBAD users:**
  - ***Static vs. dynamic benchmark databases: storing experimental & computational data ("integral EXFOR")***
  - ***Indexing and search of measured data: text format vs. PDF***
- **Distribution policy should consider the benefits for SINBAD project progress and for the users**
- **More active involvement of fission, fusion & accelerator users would allow to better focus SINBAD project, shielding experts needed,**
- **IAEA has wide membership; interest and space for more intensive cooperation?**

Web pages for SINBAD Database

- at RSICC:

  http://www-rsicc.ornl.gov/BENCHMARKS.html

- at OECD/NEA

  http://www.nea.fr/html/science/shielding/sinbad/sinbadis.htm

THANK YOU FOR YOUR ATTENTION