UK Atomic Energy Authority

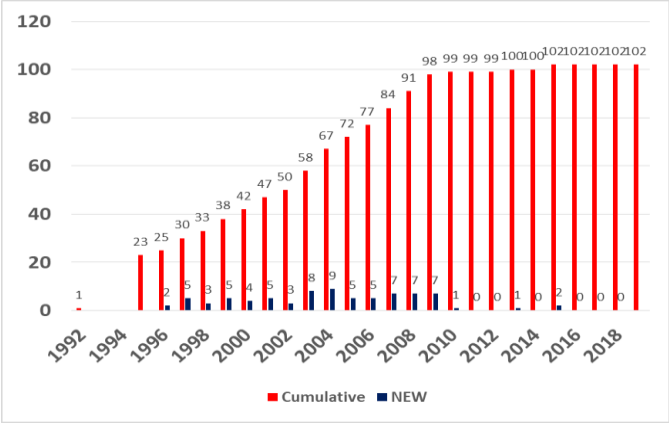
UKAEA

SINBAD database – gaining momentum again

- **Ivo Kodeli**

WPEC SG47 Virtual Meeting, Dec. 7, 2020

Some proposed topics



- Feedback from SINBAD users, experience using benchmark evaluations, V&V, collecting computer code inputs
- Quality review to continue for the remaining ~50 SINBAD benchmarks
- New SINBAD evaluations – priority list
- New SINBAD features:
  - Choice of CAD format to be adopted for future SINBAD evaluations: STP, FDS; available in new FNG-Cu
  - Sensitivity profiles: included in new FNG-Cu evaluation; available for ASPIS-FE88 (WPEC SG39), most FNG benchmarks (F4E), etc.; formats available in SensitivitiesPlot (N. Soppera)
- Coordination & cooperation with other WPEC SGs, IRPhE & ICSBEP.

NEACRP discussions in 1980's on creation of shielding benchmark database - topics discussed

-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
A.K. McCracken, E. Sartori, A Proposed Structure for a Shielding Experimental Benchmark Data Bank, NEACRP-A-1020, 19 Sept. 1989

- **Code-dependent vs. code-independent strategy,**
- **Sensitivity analysis** should be carried out whenever practicable
- Some automatic analysis of results should be carried out within the data base itself
- The system should include relevant information both on measurement and calculation
- The system should contain every significant fact about both experiment and calculation. Any relevant matters not covered in the experiential report and corrections which are necessary to the report would be included in general experimental commentary report,
- **External correlations** with other experiments through the use of common source or common counting system should be reported
- **Quality of information in measure reaction rates is likely to be much higher than that of measured spectra,** which depends on the quality of the processing of pulse-heights through unfolding algorithm. The derivation of a reliable dispersion matrix for spectra is difficult to achieve.

CCFE/UKAEA Interest in Shielding Benchmarks & Related Activities

- JET, MAST-U, STEP, ITER, DEMO
- CAD formats (STEP), availability of benchmark data and computational models
- Examples of fusion relevant materials: W, Cu, Fe, V, Mo, Cr, Y, Ti, C, Zr, Li, Pb, Be, Si,…
- **Review document is under preparation at CCFE** on SINBAD shielding benchmarks and candidate benchmarks for future evaluations focusing on fusion benchmarks.

CAD Geometry

- In the past a drawing was sufficient to describe simple benchmark models
- CAD computer readable 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; many modern codes or handling tools support CAD formats
- SuperMC provides useful features to produce CAD geometry (.FDS).
- To cover future evolution, selected CAD format should be ideally general & **code-independent**, suitable for most transport codes and at the same time provide as **accurate and faithful description** as possible. Indeed nontrivial.
- CAD format to be adopted for future SINBAD evaluations: **STP + json material definition**; **FDS** – material definition in a single file
- **Test case** to define & study the procedure: **ASPIS Fe88** geometry files.

CAD Geometry- ASPIS Fe88 test case

- ASPIS FE88 geometry files were prepared by **Žiga Deutschbauer** and **Bor Kos**, IJS, using Rhinoceros 3D, SpaceClaim, SuperMC
- Reviewed by **Alex Valentine**, several a few proposed and implemented
- Zone volume consistency checked between CAD model, MCNP input and volumes calculated with MCNP based on the SuperMC model created using the CAD model
- Material compositions & densities: jason file with materials definitions for each individual step file.
- CADs available for several other benchmarks: FNG-Cu, TIARA, FNG-HCPB, ASPIS, etc.
- Establishing a **review procedure & group** to look and check the files before being included in SINBAD: **action on NEA**?

ASPIS – IRON88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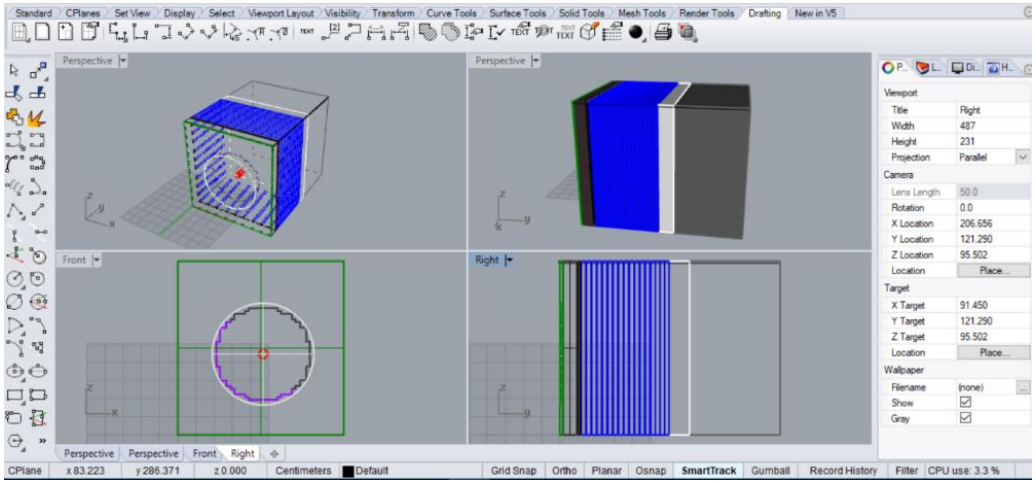
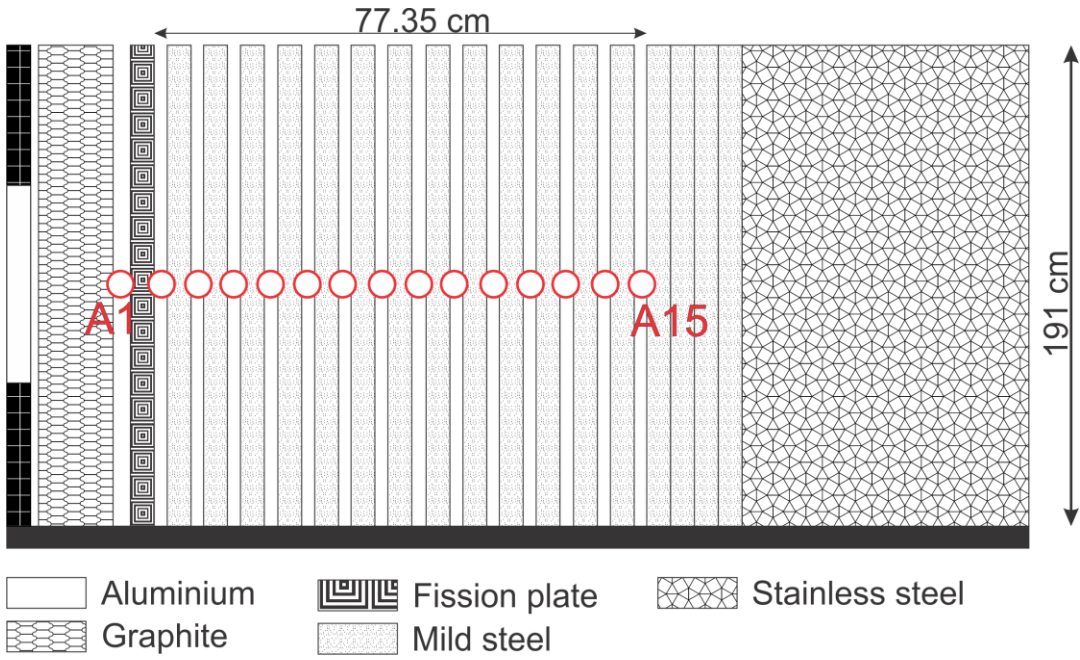




Quality review of SINBAD benchmarks

- Started around 2008 to investigate on **how useful (older) benchmarks are to improve today's high quality cross section evaluations:** geometry and source description simplifications, reliability and completeness of uncertainty information
- **Old benchmarks give lessons on how to perform new benchmarks**. Detained information on the quality, eventual drawbacks should be included in SINBAD.
- Quality note and a list of missing items if any are listed
- 51 SINBAD benchmarks went though QR, some still not included in SINBAD (4 accelerators from 2013, could NEA **check the status**)
- **<u>QR for the remaining 51 benchmarks needed ASAP</u>**

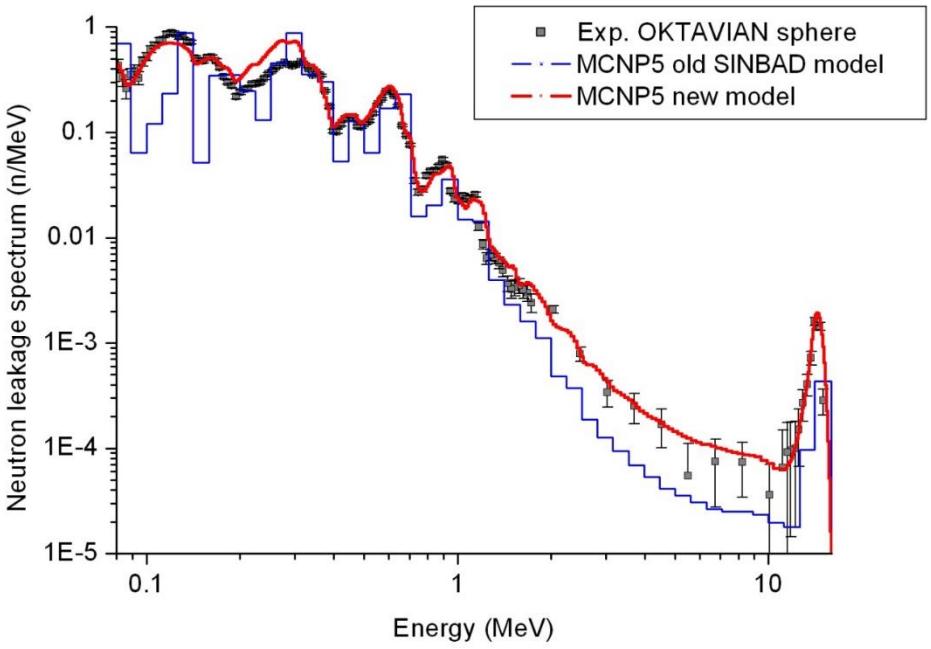
New benchmarks should be evaluated in benchmark databases ASAP, not only published in journals ! Example FNG benchmarks.

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

SINBAD TOF Benchmarks: IPPE, OKTAVIAN, FNS

Improvements

- more experimental information from literature
- refinement of D-T source model
- experimental source spectra simulations
- new MCNP5/X models for TOF analyses



OKTAVIAN Fe sphere

Benchmark quality review reports:

- I. Kodeli, A. Milocco, A. Trkov, Lessons Learned From The TOF-Benchmark Intercomparison Exercise Within EU Conrad Project (How Not to Misinterpret a TOF-Benchmark), *Nuclear Technology*, Vol. **168** (Dec. 2009) 965-969
- A. Milocco, A. Trkov, I. Kodeli, The OKTAVIAN TOF experiments in SINBAD: Evaluation of the experimental uncertainties, *Annals of Nuclear Energy* **37** (2010)
- A. Milocco, I. Kodeli, A. Trkov, The 2010 Compilation of SINBAD: Quality Assessment of the Fusion Shielding Benchmarks, Proc. NEMEA-6 Scientific workshop on Nuclear Measurements, Evaluations and Application, Krakow, Poland, 25-28 Oct. 2010.

SINBAD: FISSION NEUTRONICS

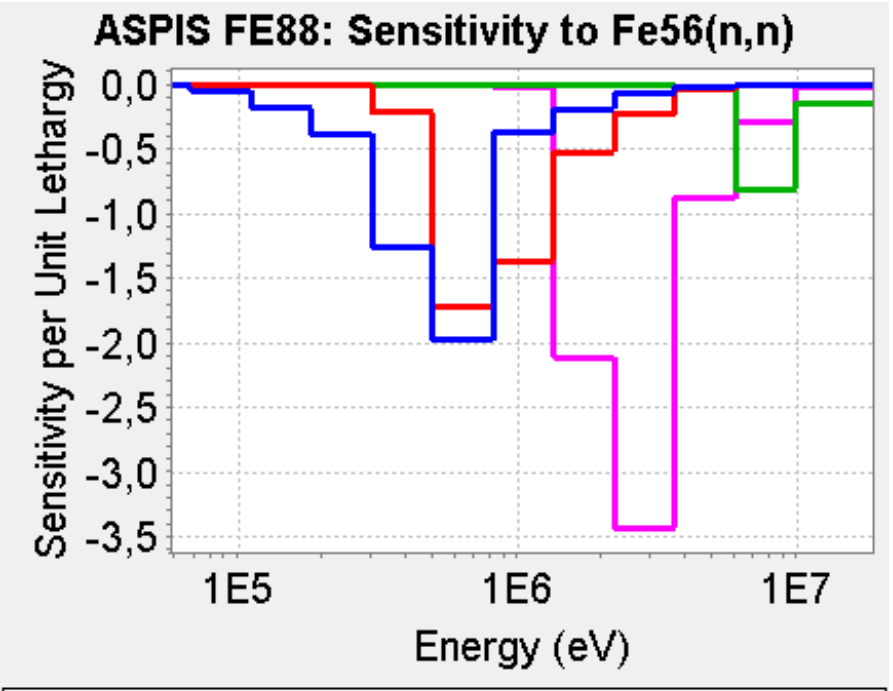
Benchmark / quality	Additional information needed on
ASPIS PCA REPLICA ♦♦♦	Supplementary information needed on: - set-up of the activation foils - rear wall of the ASPIS cave
NESDIP-2 ♦ / ♦♦	New MCNP model. Supplementary information needed on: - activation foils positioning & housing - background subtraction method, calibration No absolute calibration
NESDIP-3 ♦♦♦	New MCNP model. Supplementary information needed on: - activation foils positioning & housing - background subtraction method, calibration
JANUS-1 ♦♦♦	- same as above -
JANUS-8 ♦♦♦	- same as above -

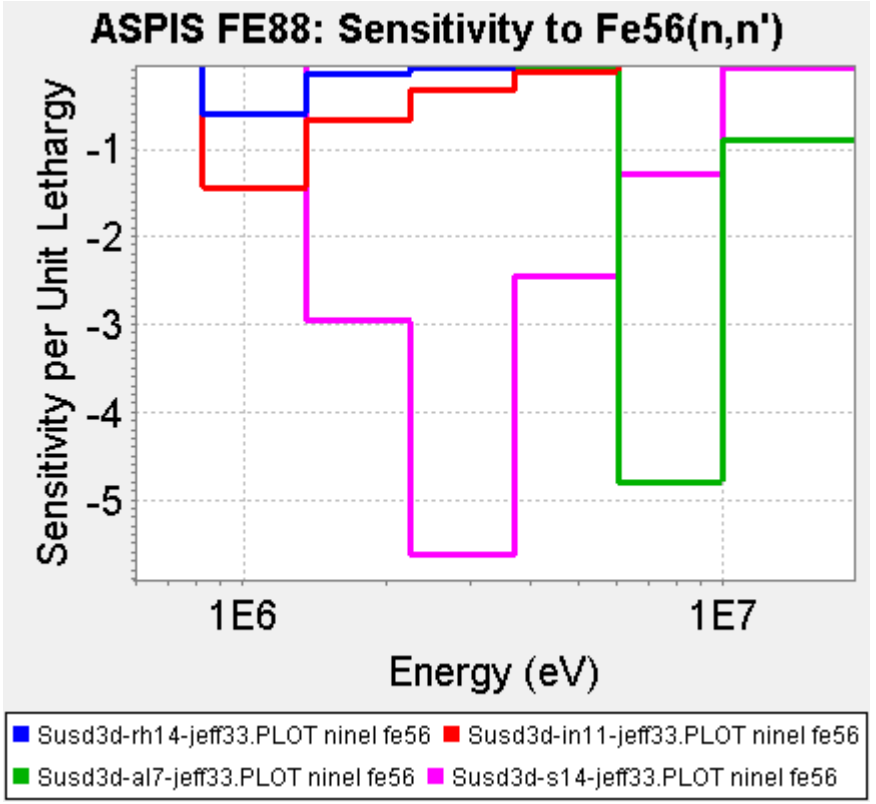
♦ ♦ ♦	**valid for nuclear data and code benchmarking**
♦ ♦	**suitable for education & training**
♦	**benchmarks of historical interest**

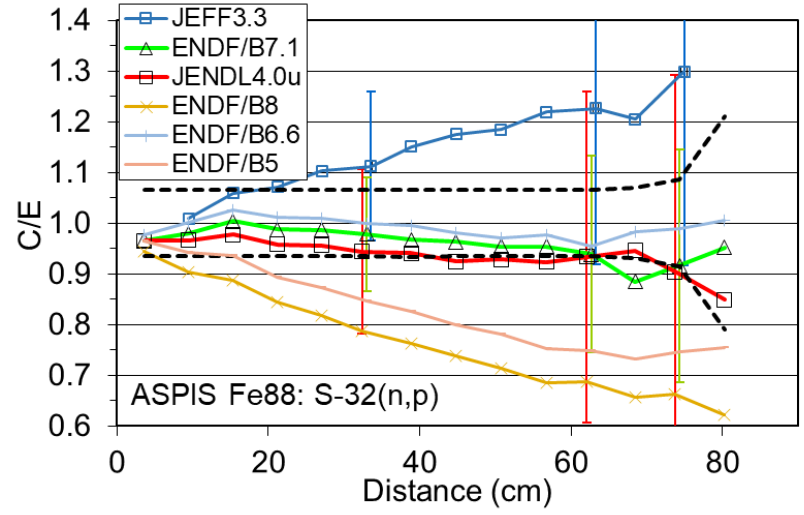
SINBAD: FISSION NEUTRONICS

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/g water/steel arrays ~ ♦♦♦	Supplementary information needed on: - detectors arrangement - bowing of the water tanks - background subtraction - cave walls

ASPIS – FE88







Reaction & position (cm)		ΔC Total JEFF-3.3	ENDF/B7.1	JENDL4	ΔE (%)
$^{32}S(n,p)$	26	13.3	11.5	17.2	6.5
	52	25.0	20.8	35.0	6.5
	62	29.3	25.1	42.9	8.6
$^{115}In(n,n')$	26	6.6	10.5	14.8	4.5
	46	10.5	15.0	17.8	4.7
$^{103}Rh(n,n')$	26	6.4	7.8	8.6	5.1
	62	11.7	18.7	14.9	5.1
$^{27}Al(n,\alpha)$	26	18.8	31.5	29.5	4.7
$^{197}Au(n,\gamma)$	26	5.1	9.9	9.2	4.2
	46	4.3	8.8	8.8	4.2
	62	3.7	8.1	8.5	4.2

WPEC SG39 Adjustment exercise

Several physics, k_{eff}, β_{eff}, shielding benchmarks used.
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

JANUS experimental Fast reactor programme (1984-87, AEA Reactor Services Winfrith & CEA Cadarache):

- **Phase 1: 40.4 cm SS, 56.7 cm MS**
- Phase 2: 22.4 cm SS, 91.4 cm Na
- Phase 3: 25.0 cm SS, 91.4 cm Na
- Phase 4: 10 cm SS, 5 cm B4C. 10 cm SS, 90 cm Na
- Phase 5: 15 cm SS, 5 cm B4C. 5 cm SS, 90 cm Na
- Phase 6: 10 cm SS, 10 cm B4C. 5 cm SS, 90 cm Na
- Phase 7: 50 cm B4C, 120 cm Na
- **Phase 8: 282 cm Na**
- Phase 9: 26 cm SS, 10 cm B4C, 22 cm SS, 90 cm Na

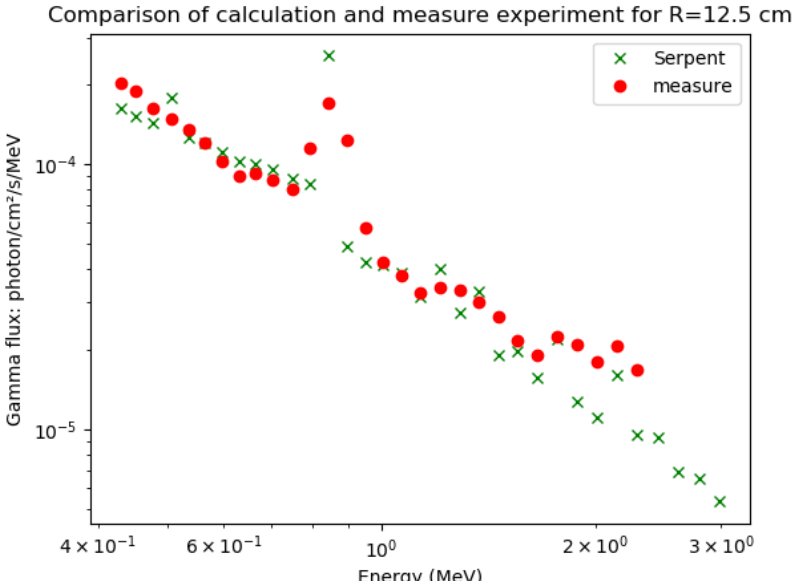
Clearance needed from UK/Winfrith (relaunch action to ?)

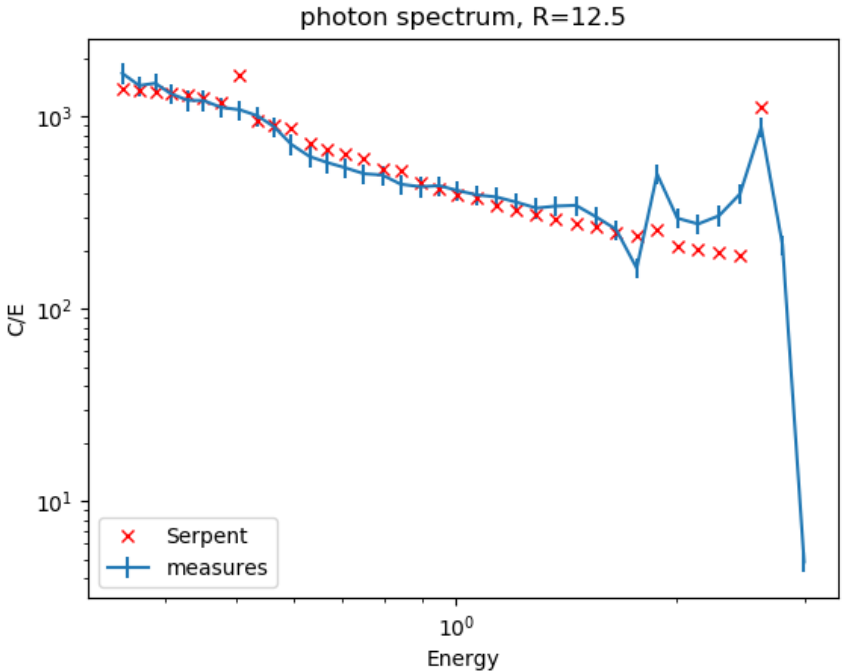
SINBAD News & Ongoing activities

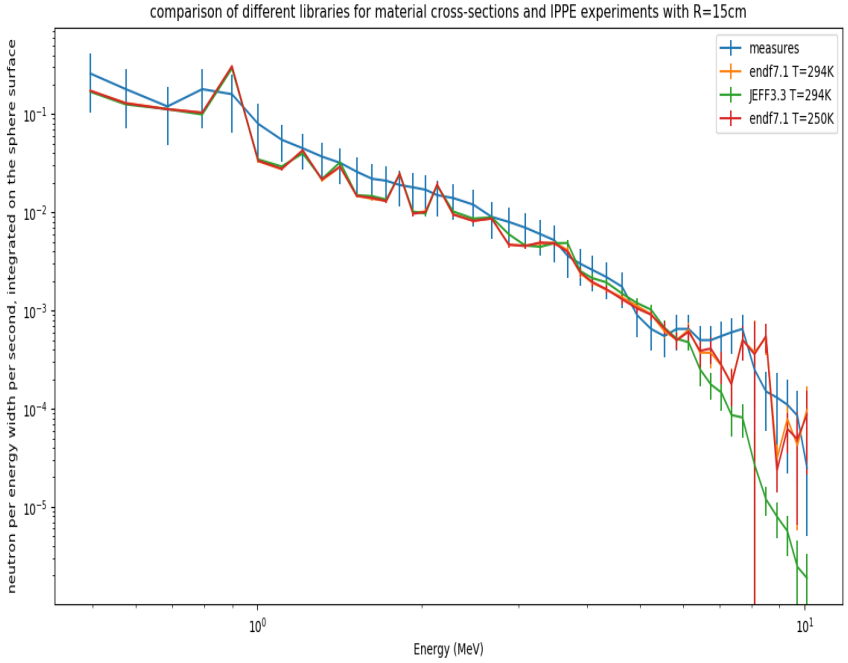
- **Quality review** & MCNP inputs by A. Milocco (2015) added in updated SINBAD: Janus-1 & -8, Nesdip-2, Aspis water, Aspis n/g, Aspis graphite, Aspis Fe, PCA Replica
- Updating of NESDIP-3, ASPIS-Fe88 is ongoing;
- SINBAD evaluation & independent review within **ICSBEP/IRPhE/SINBAD meeting (Oct. 2020): Rez Fe spheres (FNG Copper, FNG-HCLL & HIMAC still ongoing).**
- **Quality review and new SINBAD evaluations (2021):**
  - **TIARA (Bor Kos)**
  - **OKTAVIAN Cr (new evaluation to be performed by Bor Kos using the experience from QR by A. Milocco)**
- **Other pending updates, data received:**
  - **SuperMC/ INEST Hefei:** Oktavian (Al, Fe, W, Si, Ni), FNS (C, O, V, W, Skyshine, Dugled Duct), FNG (SiC, SS, Bulk shield, Streaming, Dose rate, W), TUD (W, Fe, SiC, Bulk shield), IPPE (Th), Kant (Be), ISPRA (Fe)
  - **SERPENT: CCFE, KIT, JSI:** FNG benchmarks, **CEA Cadarache:** ASPIS-Fe88
  - **ASPIS Fe88:** MCNP, DORT/TORT inputs from **IJS, ENEA Bologna**

Gamma spectra benchmarks: IPPE & KZK77 Iron spheres (Victor du Buat, internship work, Uni. Grenoble)

- KFK-1977: "Measurement and calculation of ^{252}Cf-fission neutron induced gamma fields in iron" S. H. Jiang, H. Werle
- ^{228}Th & ^{252}Cf source, r=7.5 - 17.5 cm
- IPPE: ^{252}Cf source, r=10 - 35 cm
- SERPENT model
- **Valuable and quick feedback from the author Prof. Shiang-Huei Jiang was highly appreciated**







Candidates for future SINBAD evaluations

- **FNG-Cu & -HCLL**: F4E evaluation, under review IRPhE/ICSBEP/SINBAD
- **FNG-WCLL**: ongoing -- " --
- **Rez spheres** (Fe, H2O) (1m) AmBe source, under review IRPhE/ICSBEP/SINBAD
- **LLNL** spheres: 75 pulsed-sphere neutron-leakage spectra for 20 different materials
- **CIAE** leakage spectra from SiC, Fe, graphite (14 MeV n), MCNP inputs (Haicheng)
- **HINEG** benchmark experiments (DFLL TBM)
- **FNS Cu**, Mo, Ti, Li_2O: **copyright issues between QST and JAEA (action to NEA?**
- **OKTAVIAN**: LiF, CF_2, Ti, Cr, Co, Cu, As, Se, Zr, Nb, Mo;
- **IPPE**: BTiH, U, …
- **NESDIP 4&6, JANUS II-VII** (Christophe Murphy) clearance needed (**action to NEA?**
- VENUS-1, VENUS-2 PV dosimetry experiment
- **JET**: SDR experiment (2012-2013), streaming, dose rate
- 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-US Study of Muon Interactions&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)
- **KFK-1977**: gamma fields in iron with ^{228}Th & ^{252}Cf source (proposed by S. Simakov)

Other Issues requiring further investigations

- **FNS (Liquid Oxygen**): definition of measured quantity - flux or current; feedback from experimentalists needed and/or systematic study (Stanislav, myself)
- **KFK 1977** gamma spectra in Fe spheres
- **Alarm system** benchmarks, comments by S. Simakov on IPPE gamma measurements: to be mirrored in SINBAD after update
- **Oxygen Broomstick**: review & updates needed, MCNP or analytic input (S. Simakov)
- **PCA benchmark**: presentation of Steven van der Marck at JEFF meeting (action to provide data).

Conclusions

- SINBAD database currently contains compilations and evaluations for 102 shielding benchmarks. Few new data since 2009; Computer code inputs missing for some experiments
- Ongoing activities, new acquisitions:
  - SuperMC input files (large number of fusion relevant benchmarks)
  - ASPIS, FNG, LLNL, and other benchmarks are studied within WPEC SG47
  - **Quality re-evaluated SINBAD benchmarks** ASPIS, JANUS, NESDIP (8 + 2 ongoing),
  - Several new SINBAD evaluations under review at the ICSBEP/IRPhE/SINBAD meeting (last in October 2020)
- **New features:** acceleration of M/C calculations (ADVANTG), **CAD geometry** (.stp format?), **sensitivity profiles** (formats of SensitivitiesPlot, N. Soppera?), computational model(s)
- Name **Chimera** was proposed by Jim for NEA SINBAD online utility; (Nicolas)
- **Quality evaluations and classification:** QR of ~50% of SINBAD benchmarks was performed between 2008 and 2015. QR needed for the remaining ~ 50 benchmarks; ongoing for TIARA, ASPIS Fe88
- **Evaluation of new shielding benchmarks** according to the priority (wish) list
- **Distribution policy** & availability needs clarification
- Financing will be needed.

Conclusions

- **WPEC SG47 objectives:**
  - **Provide feedback on present SINBAD benchmarks and recommendations for improvements based on the experience, needs and expectations of the nuclear data community**
  - **Priority list for future evaluations**
  - **In cooperation with EGRTS WPRS participate in future evaluations**