UKAEA

WPEC SG47 SINBAD: Possible synergies with SG46

- **Ivo Kodeli**

WPEC SF46 Meeting, OECD/NEA, Nov. 11, 2020

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

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

Relevance to other NEA ND activities

Subgroup would work in tight 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.

Comments on different types of benchmark measurements

- Spectra measurements (scintillators): unfolding issues

$$g(E) = \int_{0}^{E_m} f(E, E')\Phi(E')dE$$

- Activation foil measurements

- TOF spectra

- Gamma-ray measurements

- Critical experiments (k-eff)

- kinetics measurements (beta-eff)

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

- 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.

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

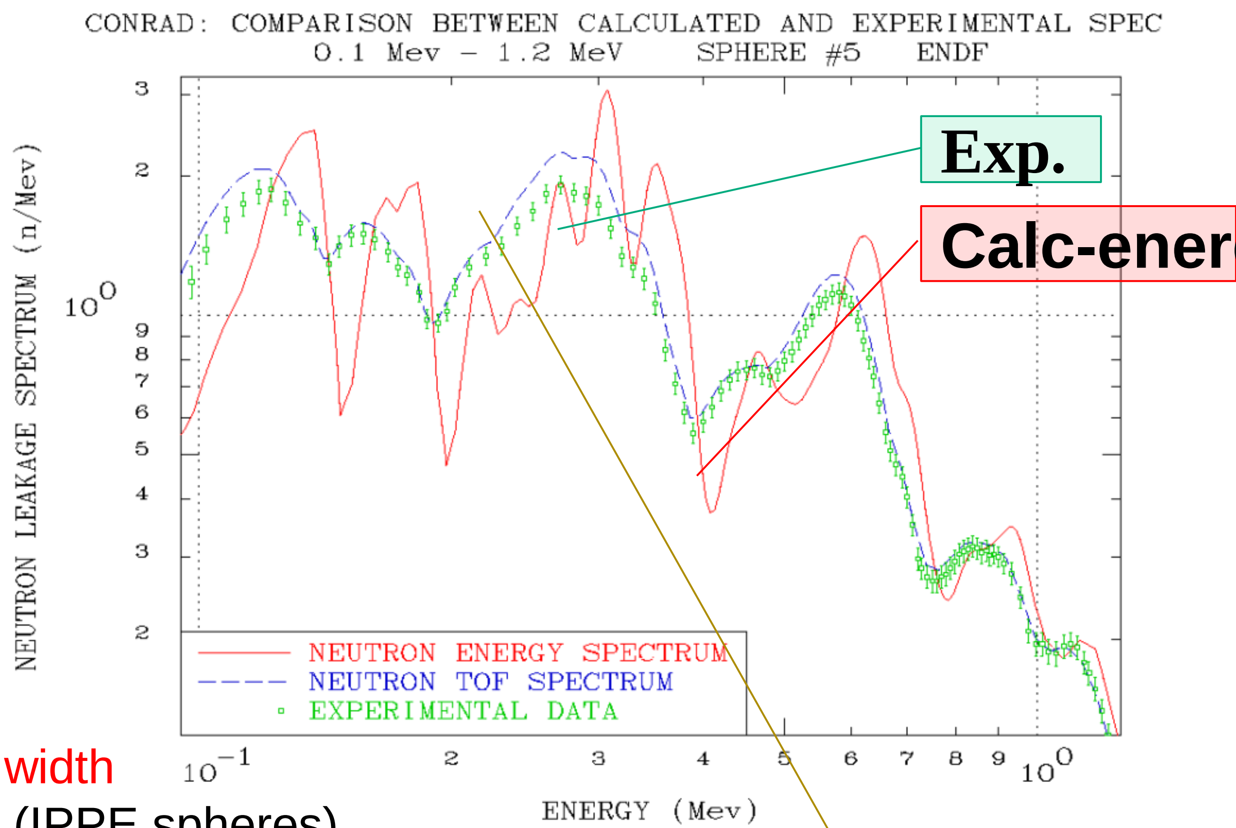
WPEC SG39 Adjustment exercise

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

TOF spectra

- Detector response function: detector time resolution, source pulse
- Interpretation of TOF and energy spectra (multiple scattering)

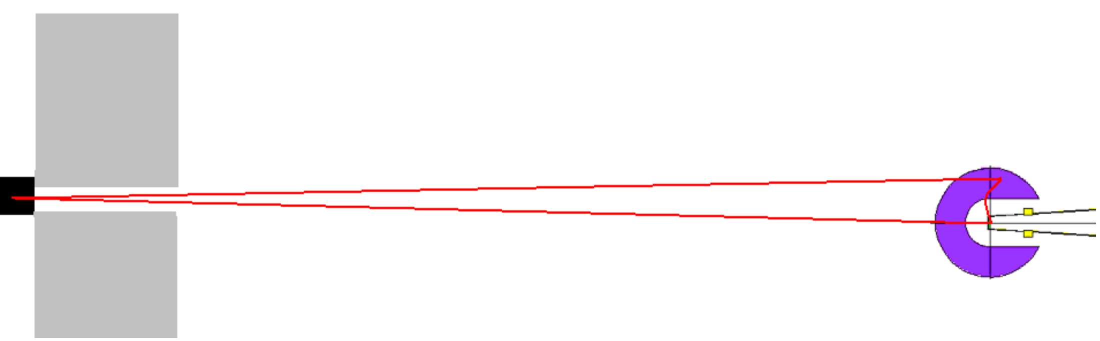


Collimator, detector time resolution and source pulse width

- detector response functions (IPPE spheres)
- (unphysical) neutron spectra measured without spheres as the neutron source (OKTAVIAN).

Calc-time

$$E = m_0 c^2 \left(1/\sqrt{1-(L/ct)^2} - 1\right)$$

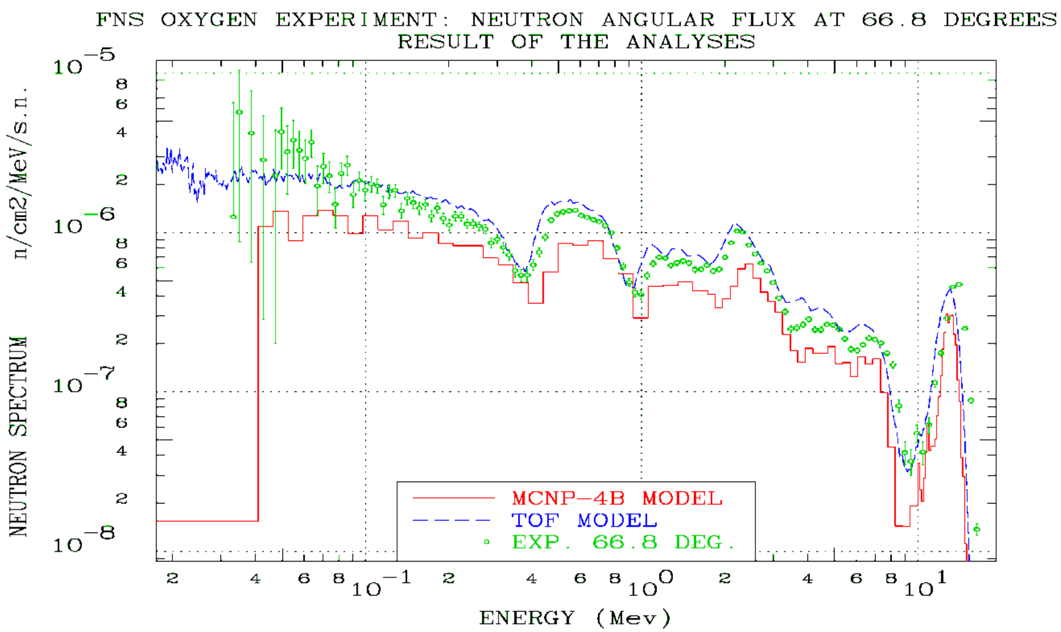


CONRAD Project, ICRS11: Kodeli, Milocco, Trkov: HOW NOT TO MISINTERPRET A TOF-BENCHMARK

SINBAD TOF Benchmarks

Improvements

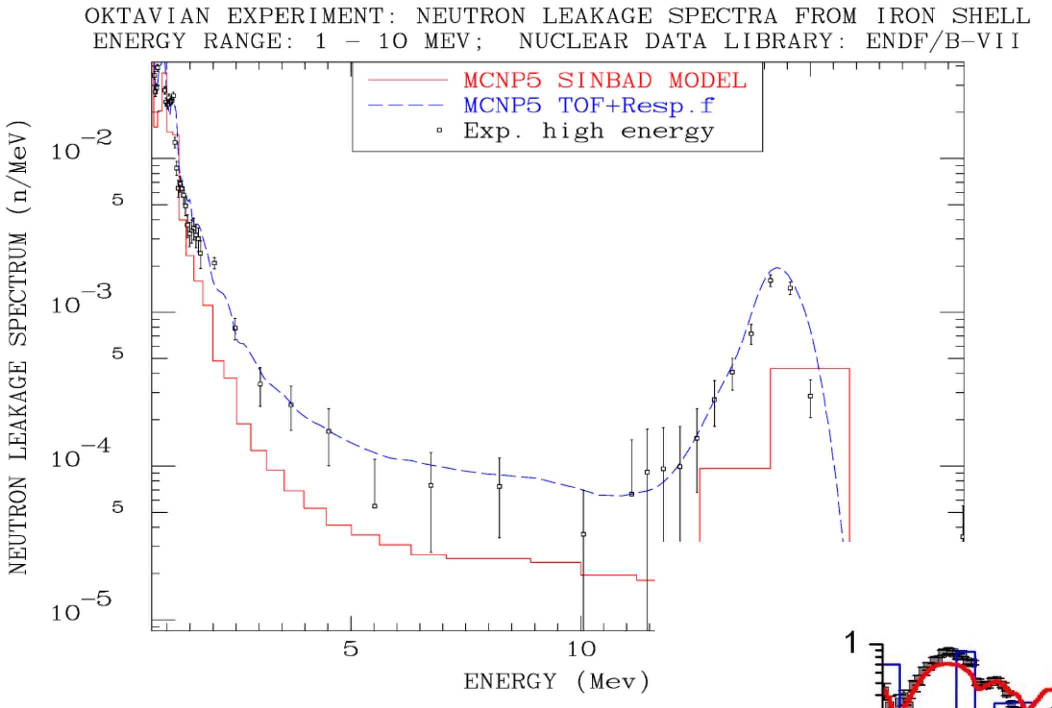
- more experimental information from literature
- refinement of D-T source model
- experimental source spectra simulations
- new MCNP5/X models for TOF analyses

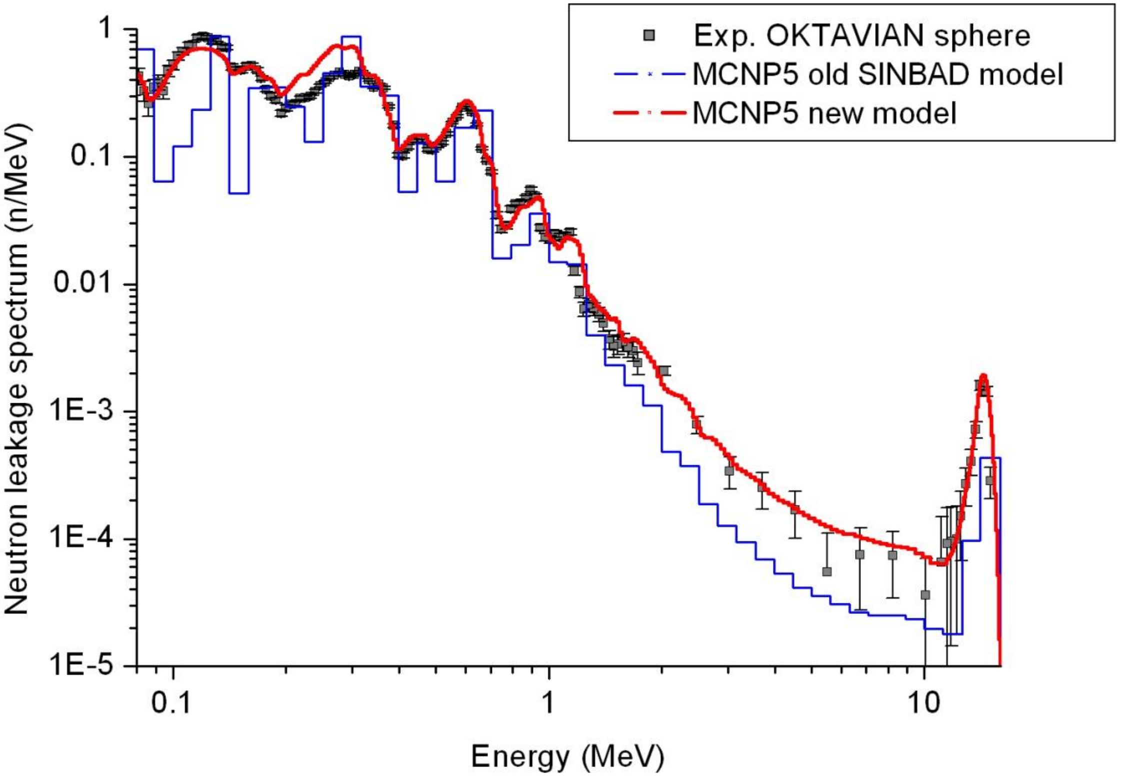


Benchmark quality review reports:

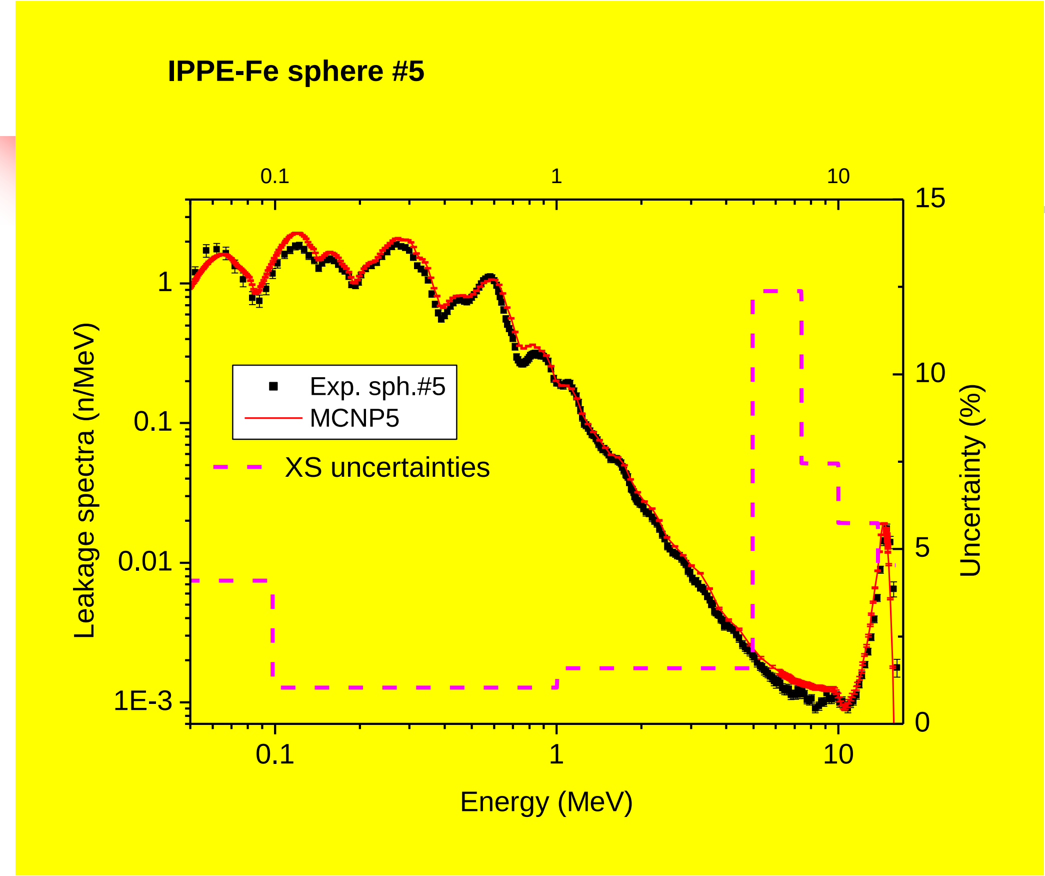
- I. Kodeli, A. Milocco, A. Trkov, Lessons Learned From The TOF-Benchmark Intercomparison Exercise Within EU Conrad Project (How Not to Misinterpret a TOF-Benchmark), *Nuclear Technology*, Vol. **168** (Dec. 2009) 965-969
- A. Milocco, A. Trkov, I. Kodeli, The OKTAVIAN TOF experiments in SINBAD: Evaluation 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.

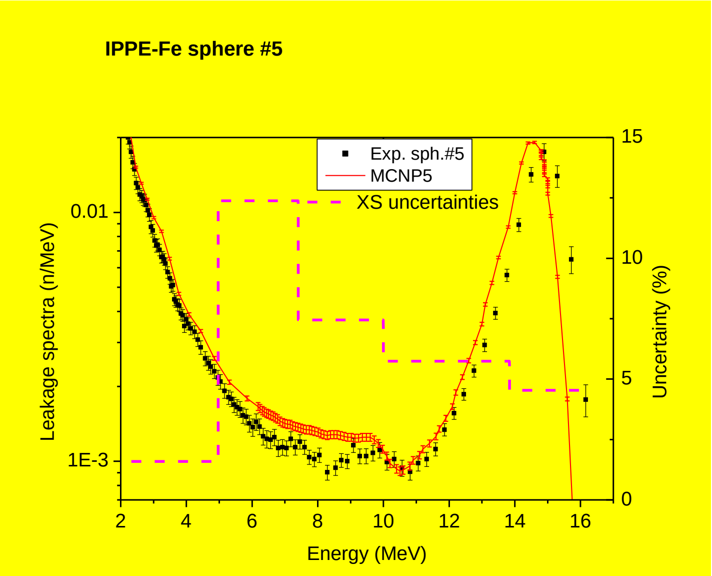
OKTAVIAN Fe sphere

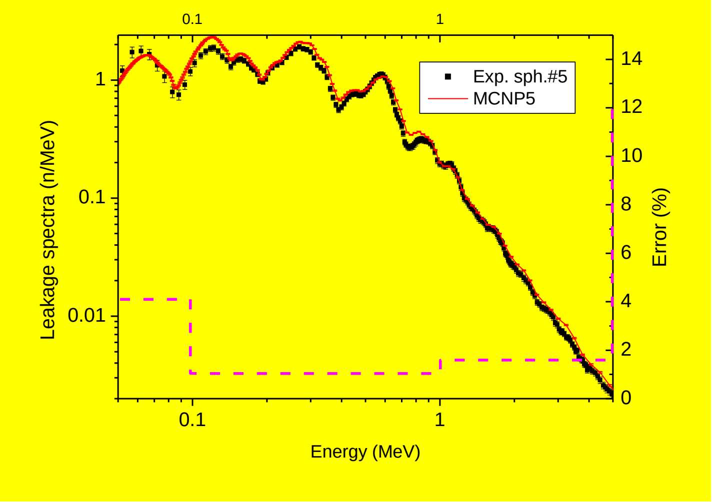




IPPE Fe sphere # 5: C/E compared to XS uncertainties







Main difficulties:

•**Detector response function**: detector time resolution, source pulse width, collimator & detector system

• Interpretation of **TOF and energy spectra** (multiple scattering)

Gamma spectra benchmarks: RCFC-VNIITF benchmarks

- **NEA-1517/74: Photon Leakage Spectra from Al, Ti, Fe, Cu, Zr, Pb, U238 Spheres** with a Central 14-MeV Neutron Source
- **NEA-1517/80: RFNC Photon Spectra from H2O, SiO2 and NaCl** with a Central 14-MeV Neutron Source
- **Authors :** A.I. Saukov, V.D. Lyutov, E.N. Lipilina Institution: RFNC-VNIITF

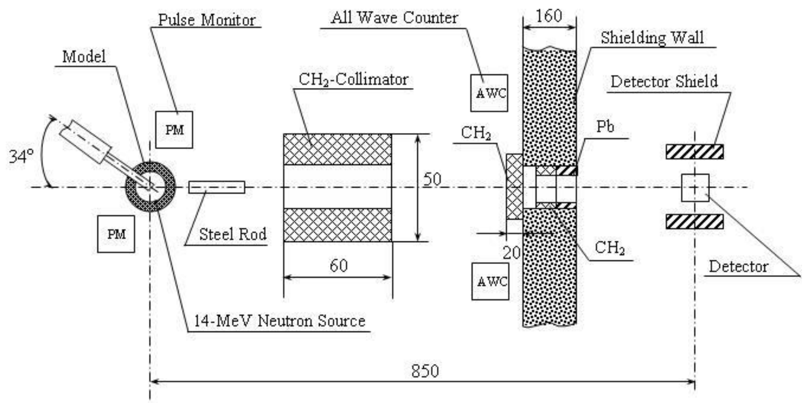
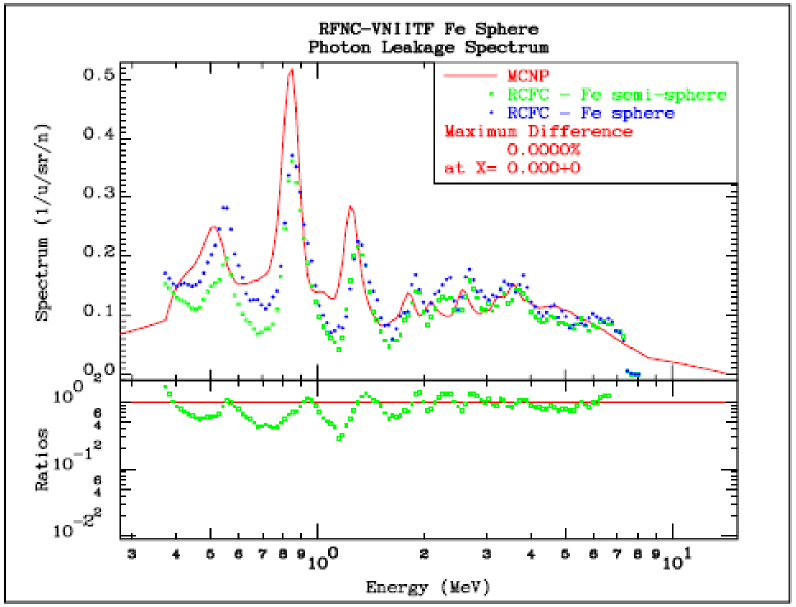
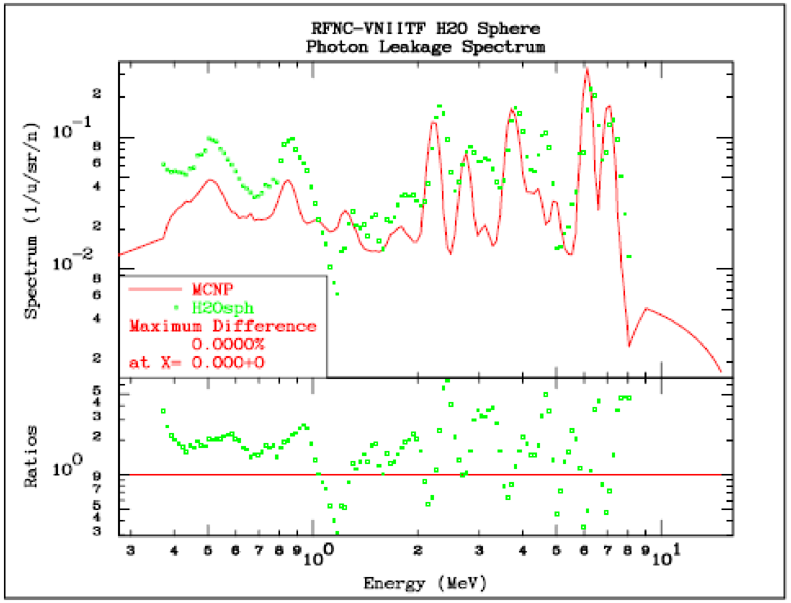


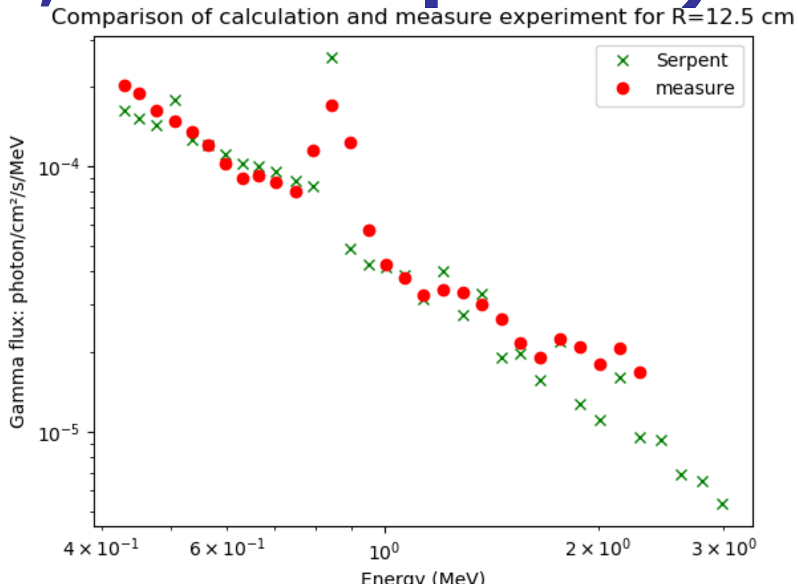
Figure 1. Experimental Arrangement (cm)

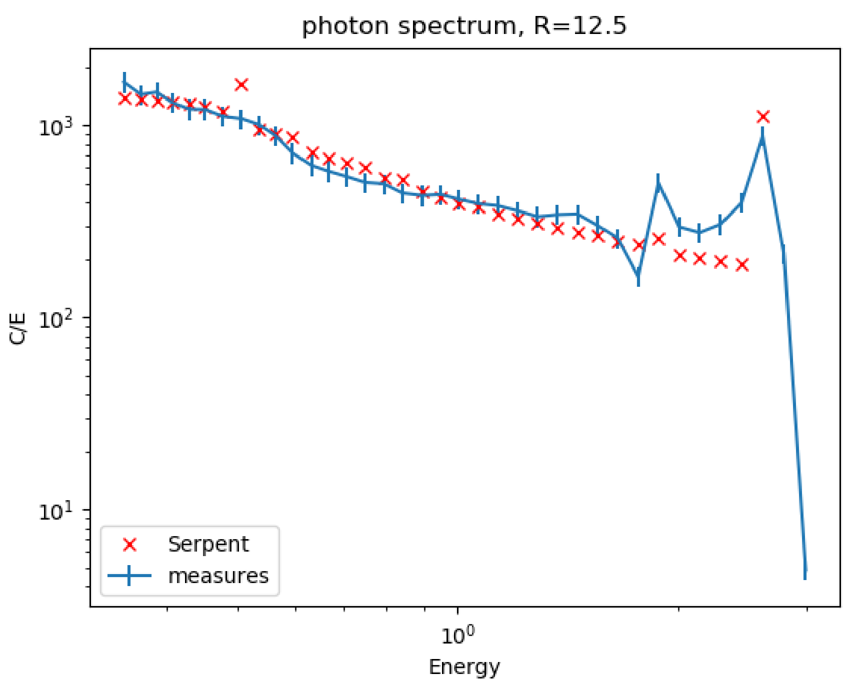


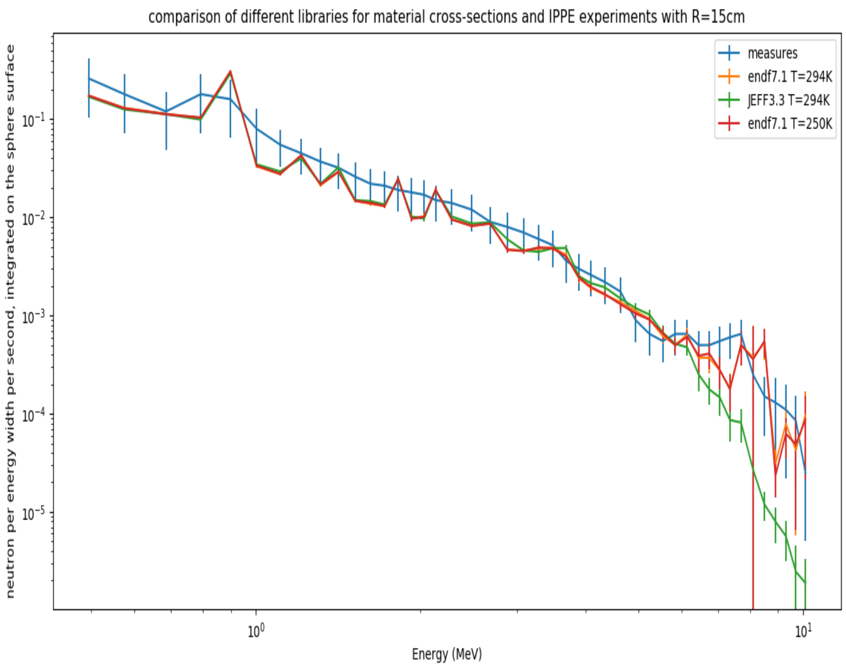


Gamma spectra benchmarks: IPPE & KZK77 Iron spheres (Victor du Buat, internship work)

- **KFK-1977: "Measurement and calculation of 252Cf-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**



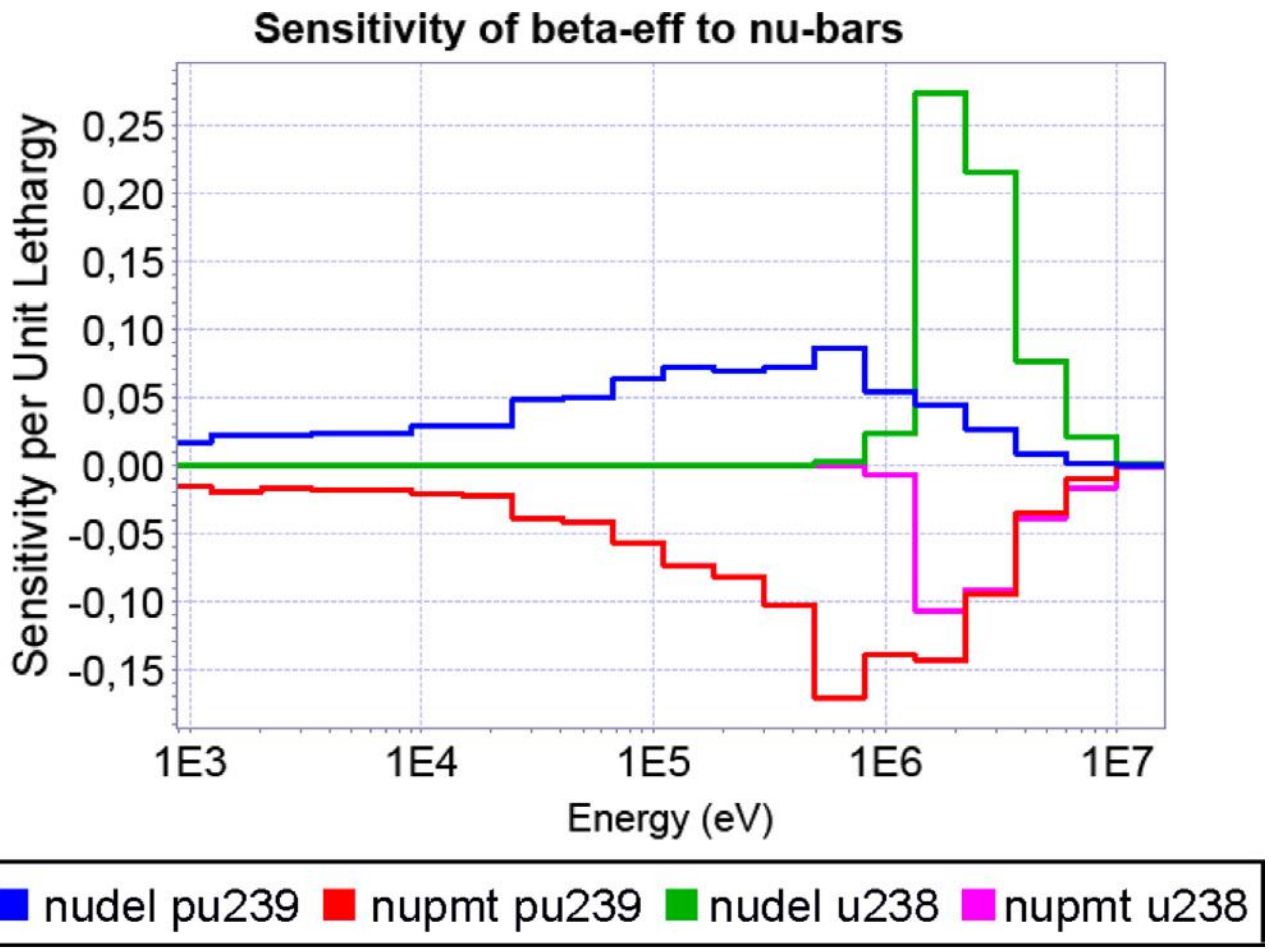




MYRRHA: Sensitivity of β-eff to ND (ν_d, ν_T, ^{238}U inelastic)

β_{eff}(MYRRHA)=322 pcm

β (pcm):
^{233}U: 260
^{235}U: 650
$^{238}U_f$: 1480
^{239}Pu: 210
^{240}Pu: 270
^{241}Pu: 490



Sensitivity & uncertainty in β_{eff}

$$\frac{\sigma}{\beta_{eff}}\frac{\partial \beta_{eff}}{\partial \sigma} = \frac{k_p}{k\beta_{eff}}\left(S_k - S_{kp}\right)$$

1) k-ratio derivation sensitivity method

2) Second order derivative of k-eff to delayed nu-bar

Remaining issues:
- Delayed fission spectra covariances
- Correlations among ν_d

I. Kodeli, Sensitivity and uncertainty in the effective delayed neutron fraction (βeff), Nucl. Instr. & Meth. in Phys. Research A 715 (2013) 70–78

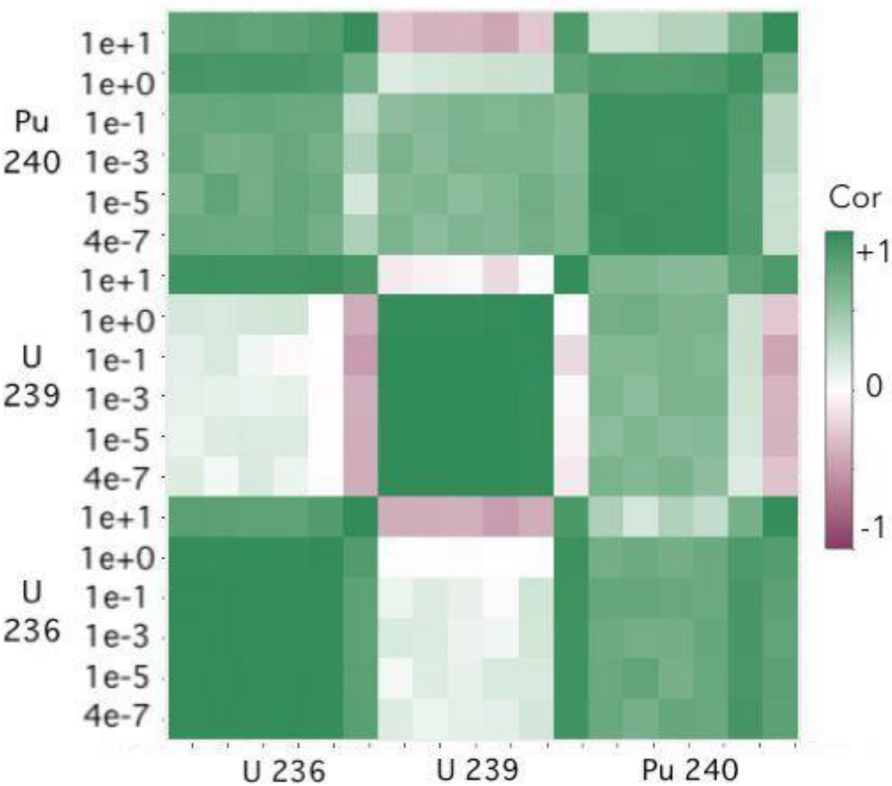
I. Kodeli, Beta-Effective Sensitivity and Uncertainty Analysis of MYRRHA Reactor for Possible Use in Nuclear Data Validation and Improvement, Annals of Nuclear Energy 113 (2018) 425-435.

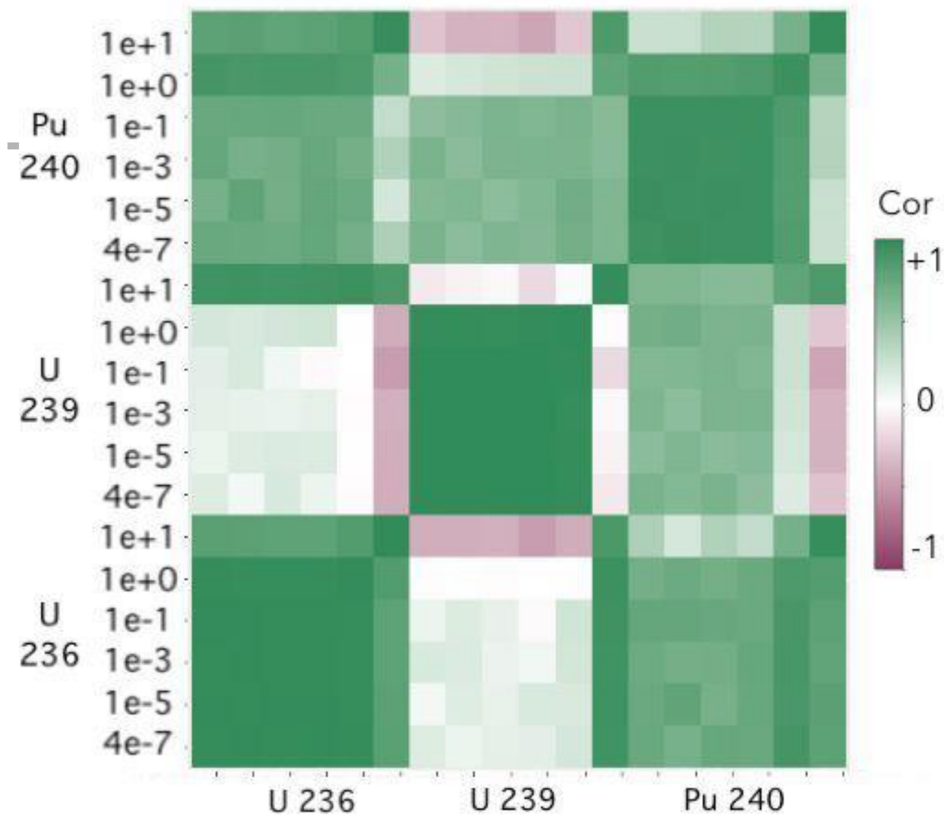
I. Kodeli, M. Aufiero, W. Zwermann, Comparison of Deterministic and Monte Carlo Codes SUSD3D, Serpent and XSUSA for Beta-Effective Sensitivity Calculations, PHYSOR-2016, May 1-5, 2016, Sun Valley, Idaho, USA

β_{eff} uncertainty (MYRRHA)

Reaction	Sensitivity (%/%)	$\Delta\beta_{eff}/\beta_{eff}$ (%)		
		JENDL-4.0m	COMMARA-2	SCALE-6.0
^{239}Pu $\bar{\nu}_d$	0.418	**1.715**	/	/
^{238}U-238 $\bar{\nu}_d$	0.307	**1.040**	/	/
^{241}Pu $\bar{\nu}_d$	0.138	**0.689**	/	/
^{238}U (n,n')	-0.034	**0.376**	**0.678**	**0.674**
^{56}Fe (n,n')	-0.027	**0.317**		**0.084**
^{240}Pu $\bar{\nu}_d$	0.063	0.307	/	/
^{239}Pu χ	0/1	0.249		0.184
^{242}Pu $\bar{\nu}_d$	0.023	0.220	/	/
^{238}U $\bar{\nu}_p$	-0.131	0.082	0.158	0.212 $\bar{\nu}_T$
^{235}U $\bar{\nu}_d$	0.035	0.092	/	/
^{238}Pu(n,f)	-0.010			0.192
^{241}Pu(n,f)	0.068	0.099	0.045	0.074
^{238}U(n,f)	0.195	0.089	0.104	0.107
^{239}Pu(n,f)	-0.164	0.071	0.083	0.082
^{240}Pu $\bar{\nu}_p$	-0.113	0.022	0.311	0.114 $\bar{\nu}_T$
^{209}Bi(n,n')	-0.018			0.078
^{16}O elastic	-0.012	0.070		0.027
^{238}U(n,γ)	-0.010	0.052	0.036	0.035
^{239}Pu $\bar{\nu}_p$	-0.608	0.097	0.044	0.262 $\bar{\nu}_T$
^{241}Pu $\bar{\nu}_p$	-0.113	0.038	0.016	0.020 $\bar{\nu}_T$
^{242}Pu $\bar{\nu}_p$	-0.026		0.063	
^{239}Pu(n,n')	-0.004	0.043	0.069	0.071
^{239}Pu(n,γ)	-0.007	0.029	0.061	0.055
^{240}Pu(n,n')	-0.002	0.018	0.069	0.032
^{240}Pu(n,f)	-0.036		0.066	0.022
TOTAL		**2.24 %**	**(~0.8 %)**	**(~0.8 %)**

Correlation between delayed nu-bars of ^{235,238}U, ^{239}Pu





S. Tarride, I. Kodeli, K.-H. Schmidt, P. Dossantos-Uzarralde, Mathematical Aspects of Nuclear Data Covariance Matrix Preparation - An Example of Delayed Neutron Data, Proc. NENE-2017, Bled, Sept. 2017

T. Cordier, I. Kodeli, K.-H. Schmidt, P. Dossantos-Uzarralde, Estimation of Delayed Fission Yield Covariance Information and Corresponding Uncertainty to Improve Nuclear Data of ^{235}U, ^{238}U, ^{239}Pu and ^{241}Am, proc. NENE-2018 conference, Portorož, Sept. 2019

Conclusions

- SINBAD database currently contains compilations and evaluations for 48 reactor shielding problems, 31 fusion neutronics shielding and 23 accelerator shielding cases. 17 experiment re-evaluations to be updated. Few new data since 2009.
- Validation of nuclear data & codes vs. nuclear design
- **(Dis-)advantages of measurements using: scintillator spectra, activation foils, TOF spectra, k-eff, kinetics**
- **Gamma-ray experiments**
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Close coordination and feedback between WPEC SG46 % 47 expected