Karlsruhe Institute of Technology

Optimization studies for a MYRRHA mock-up configuration in the VENUS-F facility

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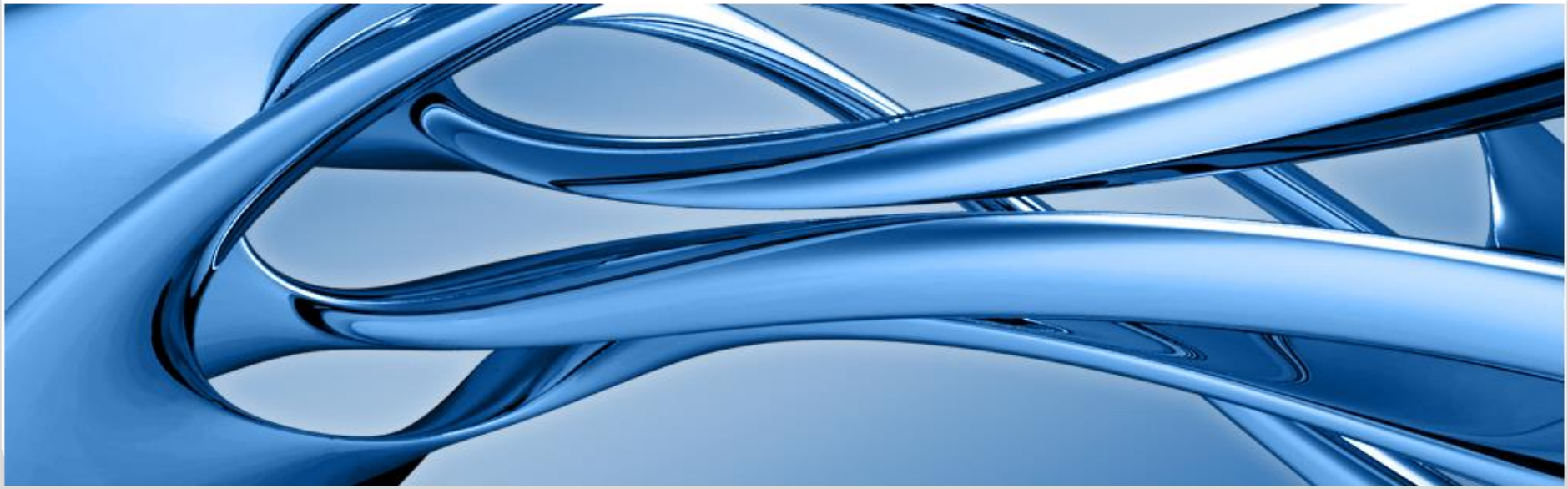


Preamble

Description of work and role of partners
This work package is divided in five separate tasks. Task 2.1: MYRRHA Subcritical Mock-up Definition (Task leader: SCK•CEN) In this case, another core configuration than in WP1 of the FREYA project, could be chosen and assembled for the VENUS-F facility. Within the constraints of available fuel at the VENUS facility during the FREYA-project, this core shall be as representative as possible of the MYRRHA/FASTEF core design: fuel/"coolant" features (volume fraction, fuel enrichment), control rods, etc. The definition and realisation at VENUS-F of this mock-up core is the first task of WP2.

WP2

Description of work and role of partners
This work package is divided in three separate tasks. Task 3.1: MYRRHA critical Mock-up Definition (Task leader: SCK•CEN) In this case, another core configuration than in WP2 of the FREYA project, could be chosen and assembled for the VENUS-F facility. Within the constraints of available fuel at the VENUS facility during the FREYA-project, this core shall be as representative as possible of the MYRRHA/FASTEF core design: fuel/"coolant" features (volume fraction, fuel enrichment), control rods… The definition and realisation at VENUS-F of this mock-up core is the first task of WP3.

WP3

- Even in WP2 a reference critical configuration is needed: is this going to be the actual core layout within WP3?
- Calculations on WP2 core layout started at KIT/INR-RPD on November 2012 as a continuation of the work of M. Carta (ENEA) and X. Doligez (CNRS)

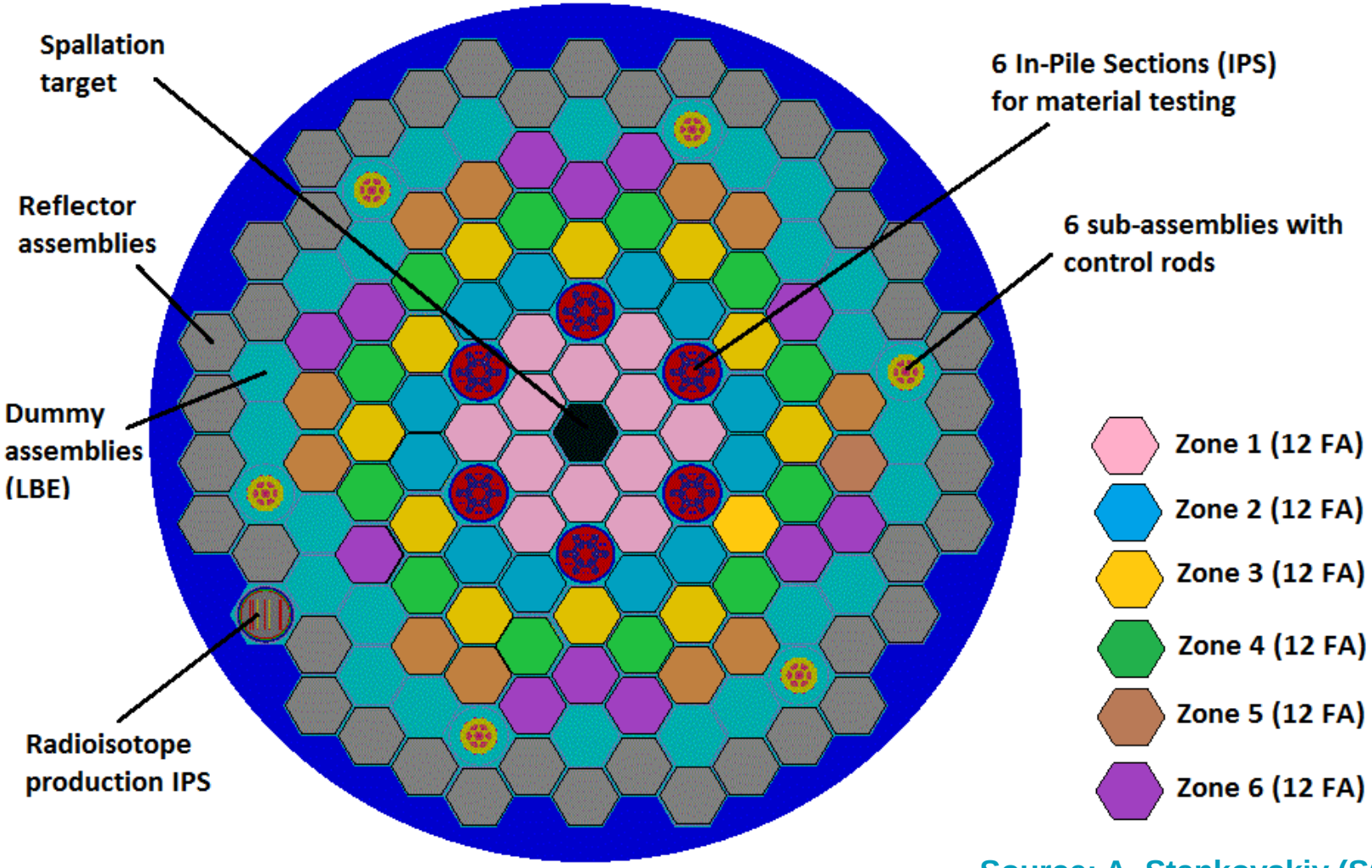
A new core layout in VENUS-F

- **Experimental campaign at the VENUS-F in support to the design and licensing of MYRRHA planned in 2015**

- **Two criteria for the representativity**
  1. Neutron spectrum
     - cross-section measurements, code validation and Doppler effect simulations
  2. Kinetics parameters:
     - reactivity coefficients

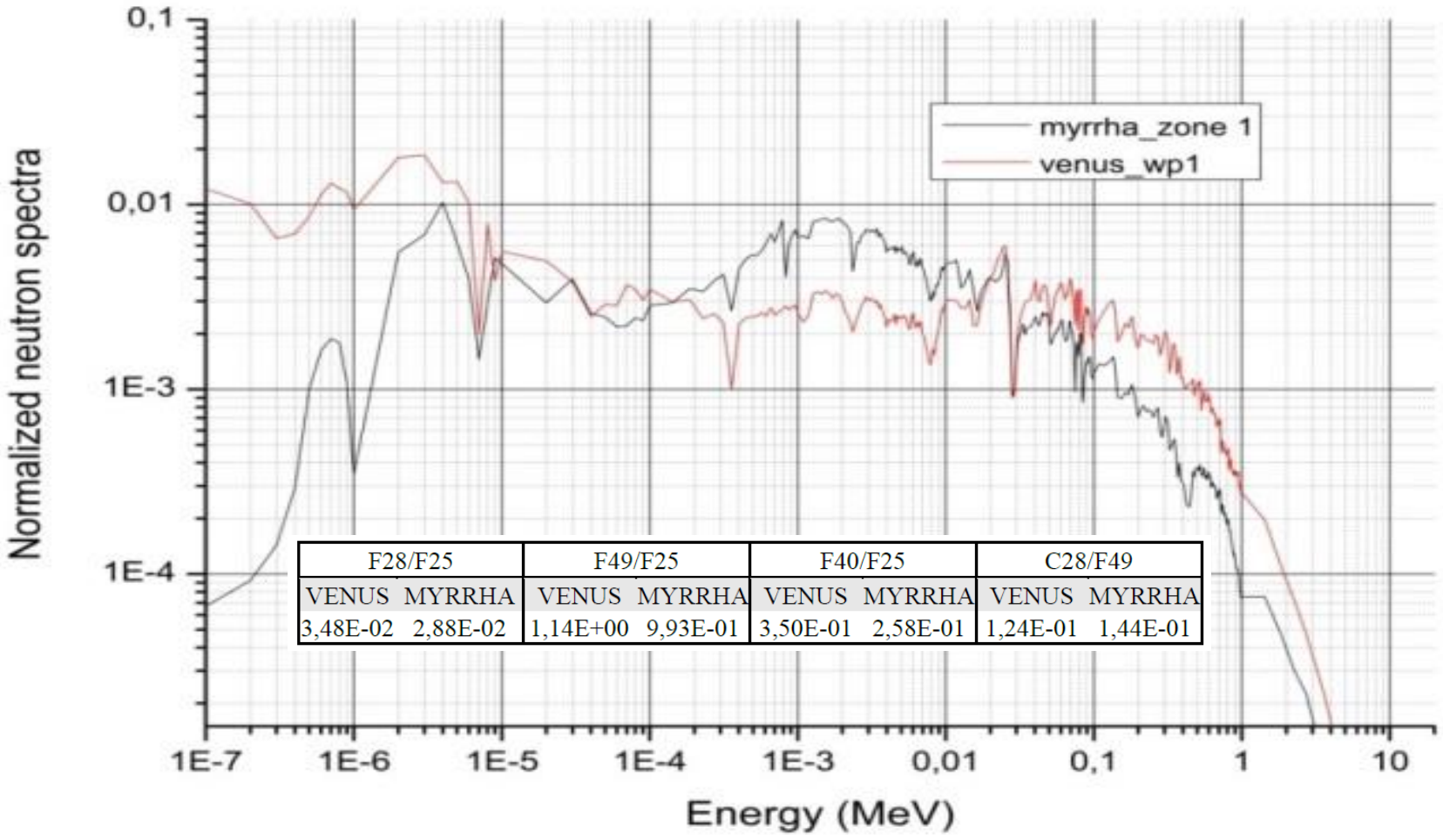
- **β_{eff}: 740 pcm (VENUS-F), 320 pcm (MYRRHA)**

The MYRRHA core



Source: A. Stankovskiy (SCK-CEN)

Spectra comparison

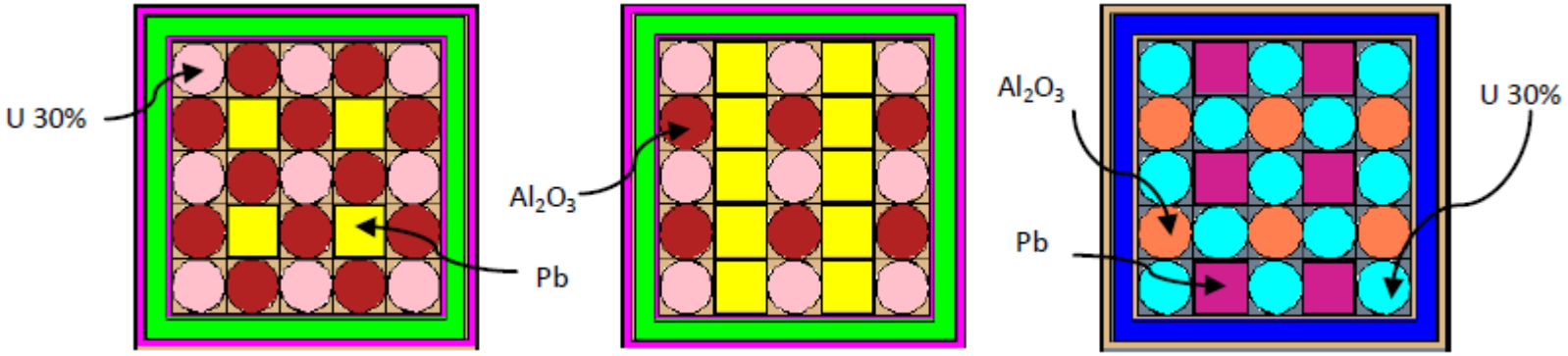


F28/F25		F49/F25		F40/F25		C28/F49	
VENUS	MYRRHA	VENUS	MYRRHA	VENUS	MYRRHA	VENUS	MYRRHA
3,48E-02	2,88E-02	1,14E+00	9,93E-01	3,50E-01	2,58E-01	1,24E-01	1,44E-01

Spectra optimization (1)

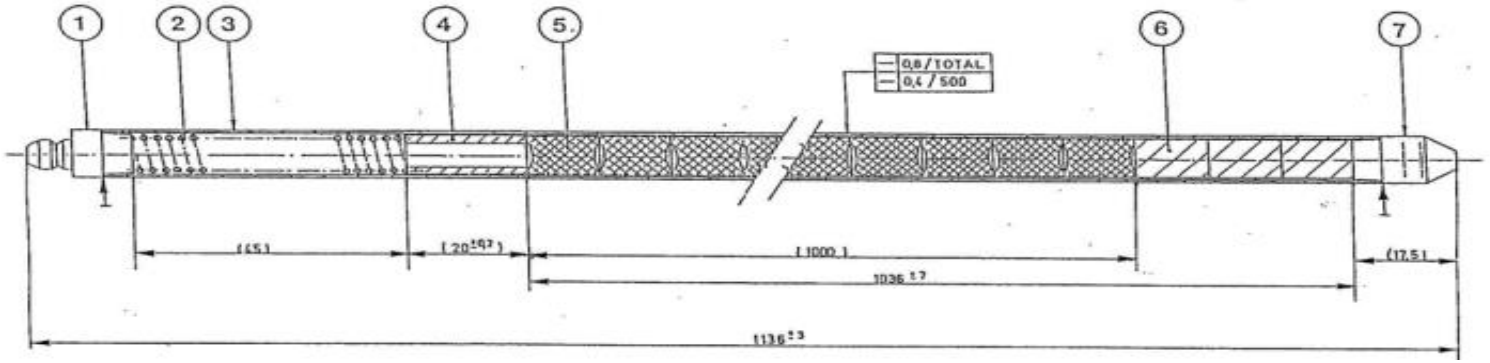
- Investigations on the feasibility of a critical configuration loaded with MOX 30% FAs have been performed in the past (not longer possible due to the lack of fuel). The general shape of the neutron spectrum is mainly dominated by the oxygen present in the fuel: VENUS-F loaded with UOx would have a similar “behavior” of VENUS-F loaded with MOX.

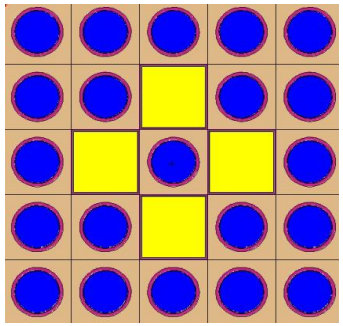
- Possibility to “simulate” the UOx by means of a combination of metallic uranium and aluminum oxide (Al_2O_3) rodlets.



Spectra optimization (2)

- **Introduction of MOX 14% (230 pins available)**



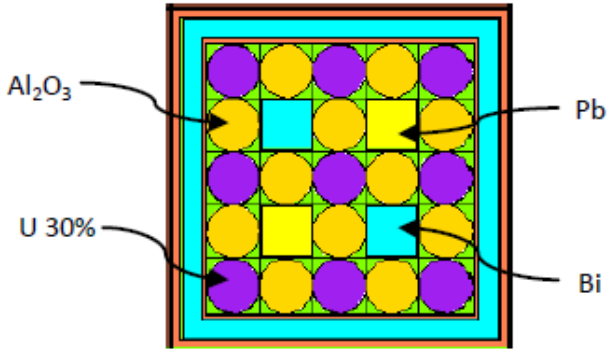


MOX 14% FA

k_{inf} = 1.04

The introduction of Bismuth

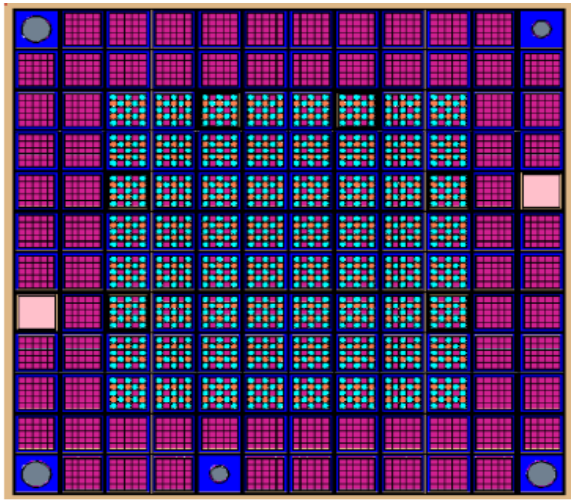
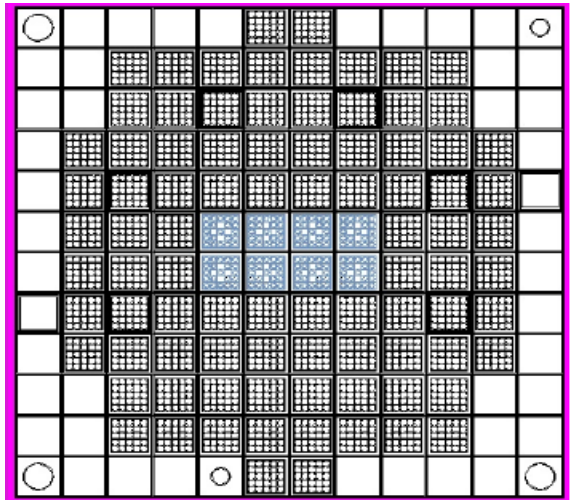
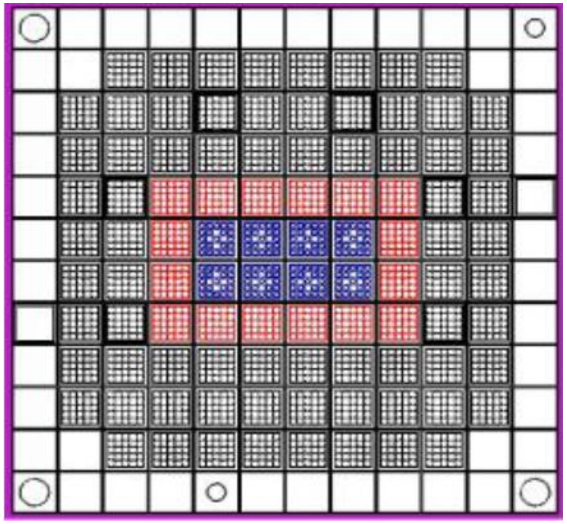
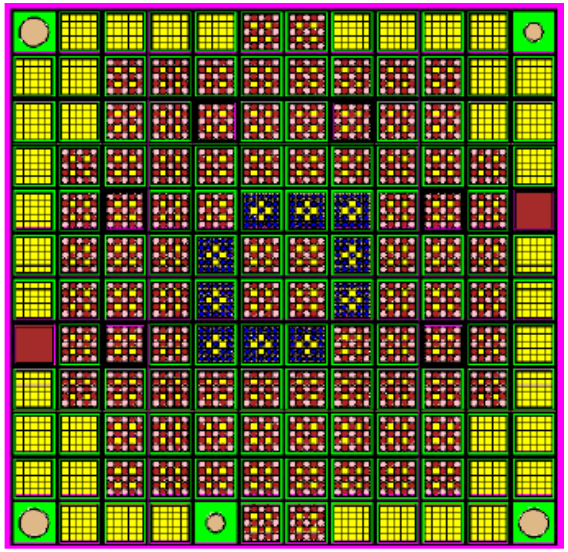
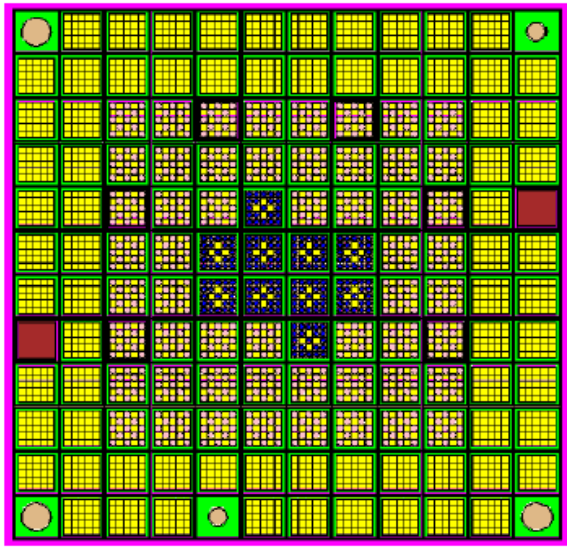
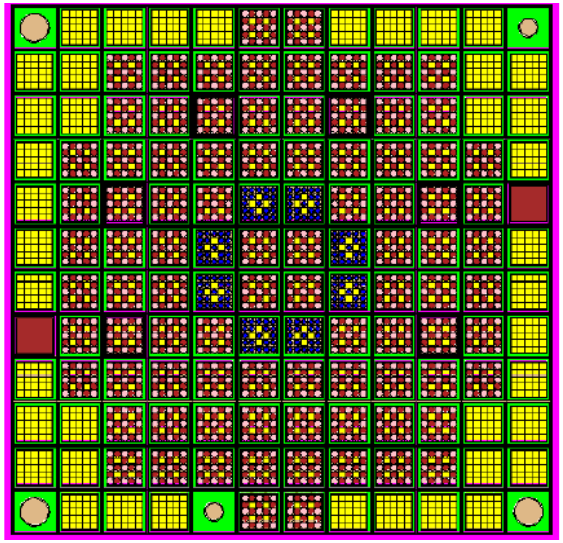
- Small negative effect on reactivity
- Future investigations: insertion of Bi in the reflector



U9-Al-LBE FA

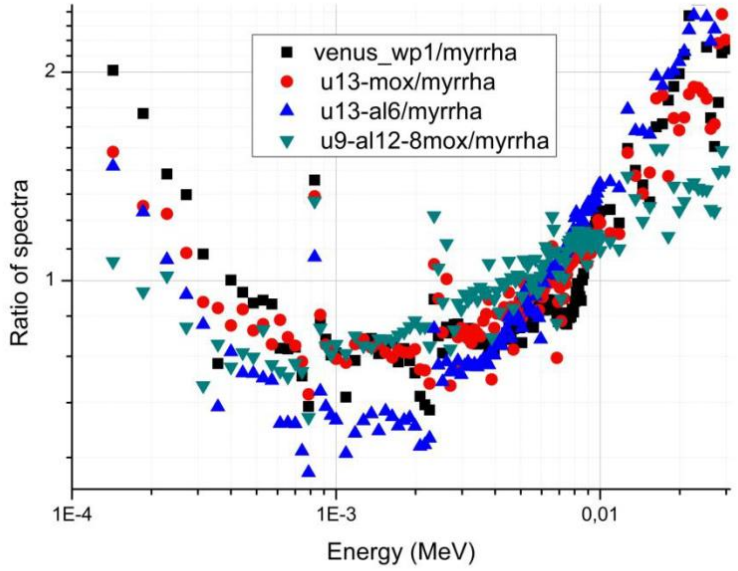
	k_{eff} – Pb	k_{eff} -Bi	Δρ (pcm)
VENUS-F WP1	1.00354 ± 0.00032	1.00061 ± 0.00029	292
U13-Al6	1.10878 ± 0.00032	1.10246 ± 0.00034	517
U9-Al12-Mox	1.00420 ± 0.00031	1.00315 ± 0.00031	104
U9-Al6-Mox	1.02910 ± 0.00031	1.02678 ± 0.00030	219
U9-Al12-Mox_8FAs	1.00506 ± 0.00032	1.00473 ± 0.00046	33

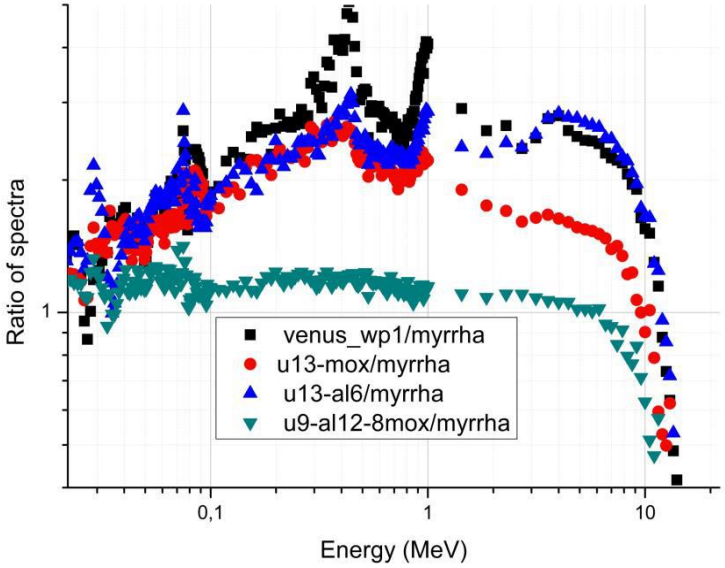
Core configurations

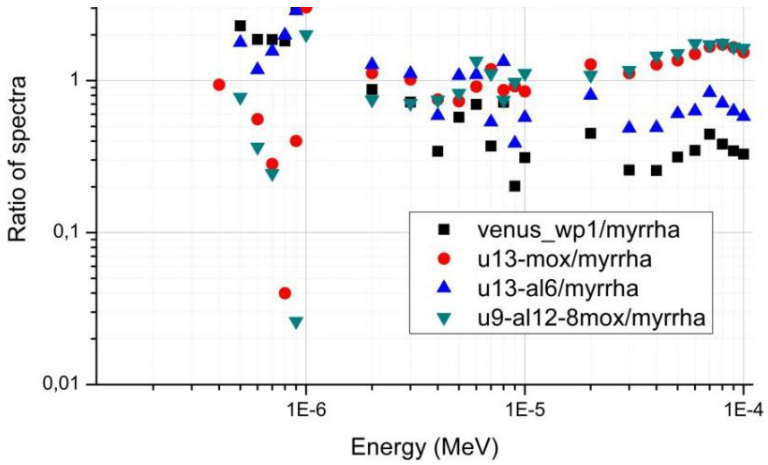







Ratio of spectra

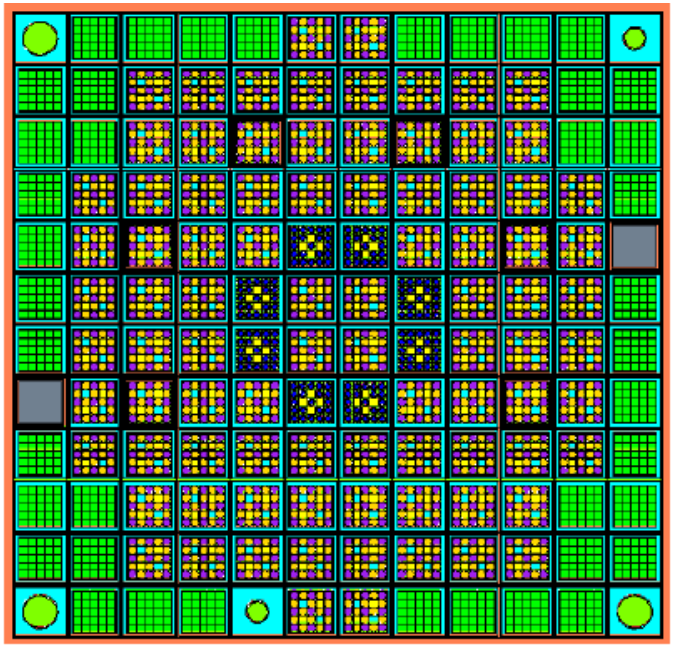
1. 0 ≤ E ≤ 100eV
2. 100 < E ≤ 30 keV
3. 30 keV < E ≤ 20 MeV







U9-Al12-8MOX-LBE configuration



k_{eff} = 1.00339 ± 0.0044

β_{eff} = 718 pcm

Spectral indexes

	F28/F25	F49/F25	F40/F25	C28/F49
VENUS-F	0.0348	1.14	0.350	0.124
MYRRHA	0.0288	0.993	0.258	0.144
U9-A112-8MOX averaged over the fuel	0.0333	1.04	0.284	0.125
U9-A112-8MOX in a central U fuel assembly	0.0175	0.991	0.184	0.279
U9-A112-8MOX in central MOX fuel assembly	0.0159	0.981	0.178	0.271

Representativity study

- Principle: measure a number of quantities which are relevant for the reference system and then transpose these to the system itself.

- Assessment of the behaviour of selected integral parameters (i.e. spectral indexes) to be measured in the VENUS-F core due to some global perturbation imposed into the core

- By GPT methodologies (ERANOS code):

$$\mathbf{R}_{BA} = \frac{\mathbf{S}_B^T \mathbf{D} \mathbf{S}_A}{\sqrt{\mathbf{S}_B^T \mathbf{D} \mathbf{S}_B}\sqrt{\mathbf{S}_A^T \mathbf{D} \mathbf{S}_A}}$$

A -> VENUS-F+MOX

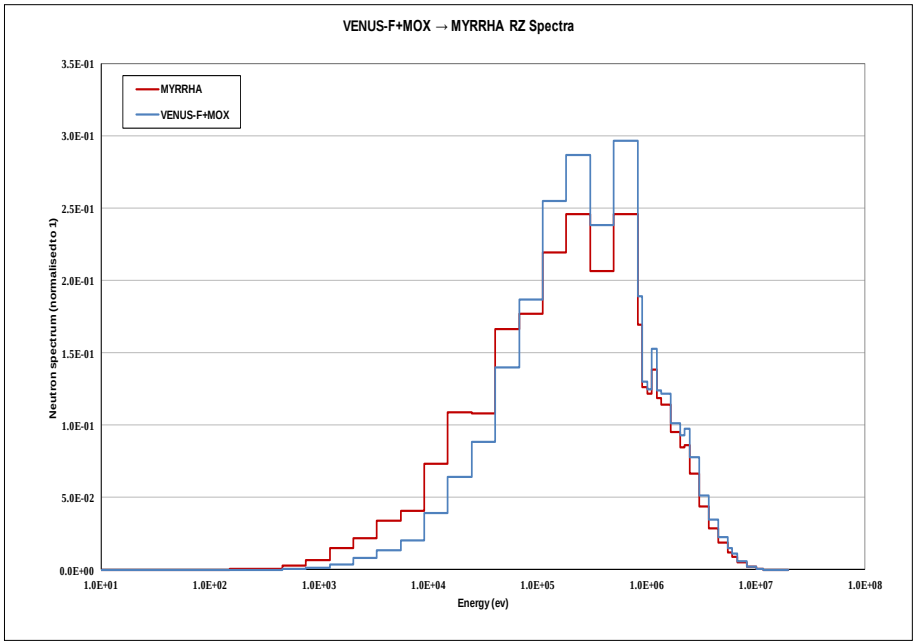
B -> MYRRHA

Representativity study (2)

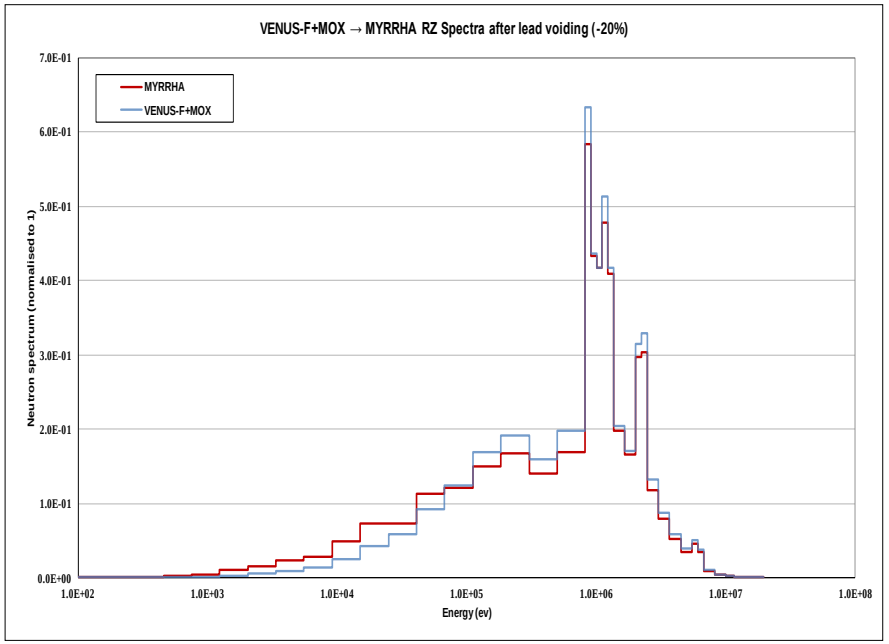
Imposed perturbation: 20 % coolant voiding

Spectral indexes investigated: (F9/F5), (F8/F5), (F7/F5)

Δk/k = ~400 pcm (VENUS-F) and ~500 pcm (MYRRHA)

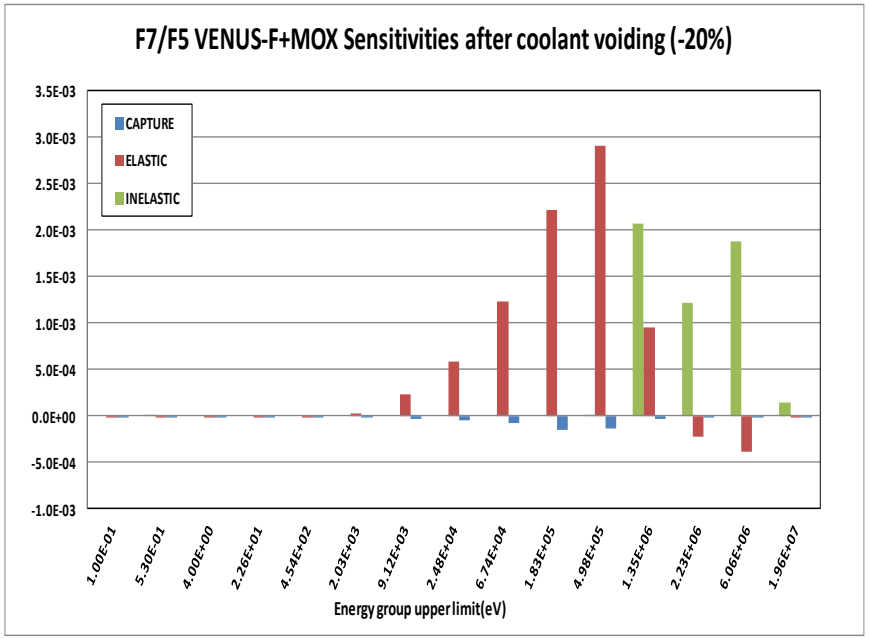


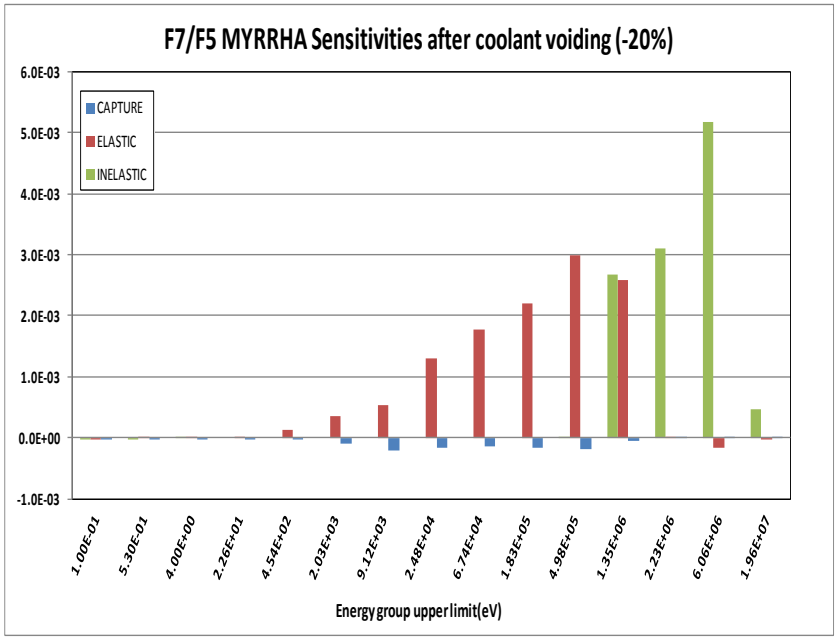
Reference state



Perturbed state

Representativity study (3)





	VENUS-F+MOX → MYRRHA
F9/F5	9.63e-01
F8/F5	9.78e-01
F7/F5	9.59e-01

Very good correlation!

Summary and future work

- With all the available 230 pins of MOX 14% arranged in a *Type* 21 MOX FA, a critical configuration is possible which would require almost the total amount of metallic uranium available. The MOX “island” inserted would represent a very small part of the core and the spectrum would be representative of MYRRHA in the centre.
- It is also possible to simulate the neutron slowing down by adding oxygen via aluminium and in this case the spectrum would be additionally softened towards a general shape quite representative of MYRRHA.
- The criteria for the representativity of the spectrum should be more precisely defined based on the type of experiments one want to perform (what do we want to measure and where)
- The representativity of the mock-up with respect to the sub-criticality monitoring techniques should be assessed
- The impact of introducing Bismuth in the reflector need also to be evaluated

Summary and future work

- None of the options considered are relevant for MYRRHA in terms of kinetics parameters (higher by a factor of ~2 with respect to the target values)
- Results reported on:
  - FREYA D2.1 "*MYRRHA Subcritical Mockup Definition*"
  - L. Mercatali, X. Doligez, A. Kochetkov, G. Vittiglio, W. Uhyttenhove, G. Bianchini, M.Carta, V. Peluso, A. Gandini, V. Fabrizio, "*Optimization studies for a MYRRHA-like mock up configuration in the VENUS-F facility*", Proceedings of *AccApp13 Conference*, August 2013, (Brugge, Belgium)