FP7-269665: Fast Reactor Experiments for hYbrid Applications

Mid-term review meeting

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Deliverable D2.1

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Deliverable D2.1
MYRRHA Sub-critical Mock-up Definition

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D2.1 - Contents

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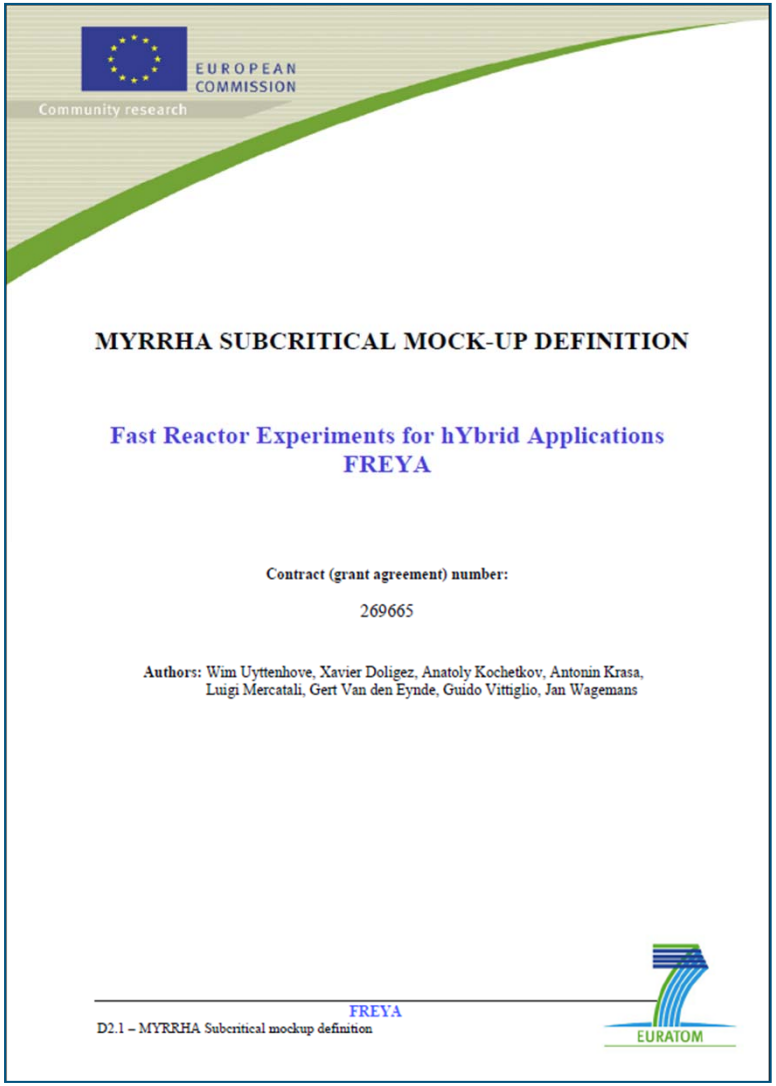
EUROPEAN COMMISSION
Community research

MYRRHA SUBCRITICAL MOCK-UP DEFINITION

Fast Reactor Experiments for hYbrid Applications
FREYA

Contract (grant agreement) number:

269665

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FREYA
D2.1 – MYRRHA Subcritical mockup definition

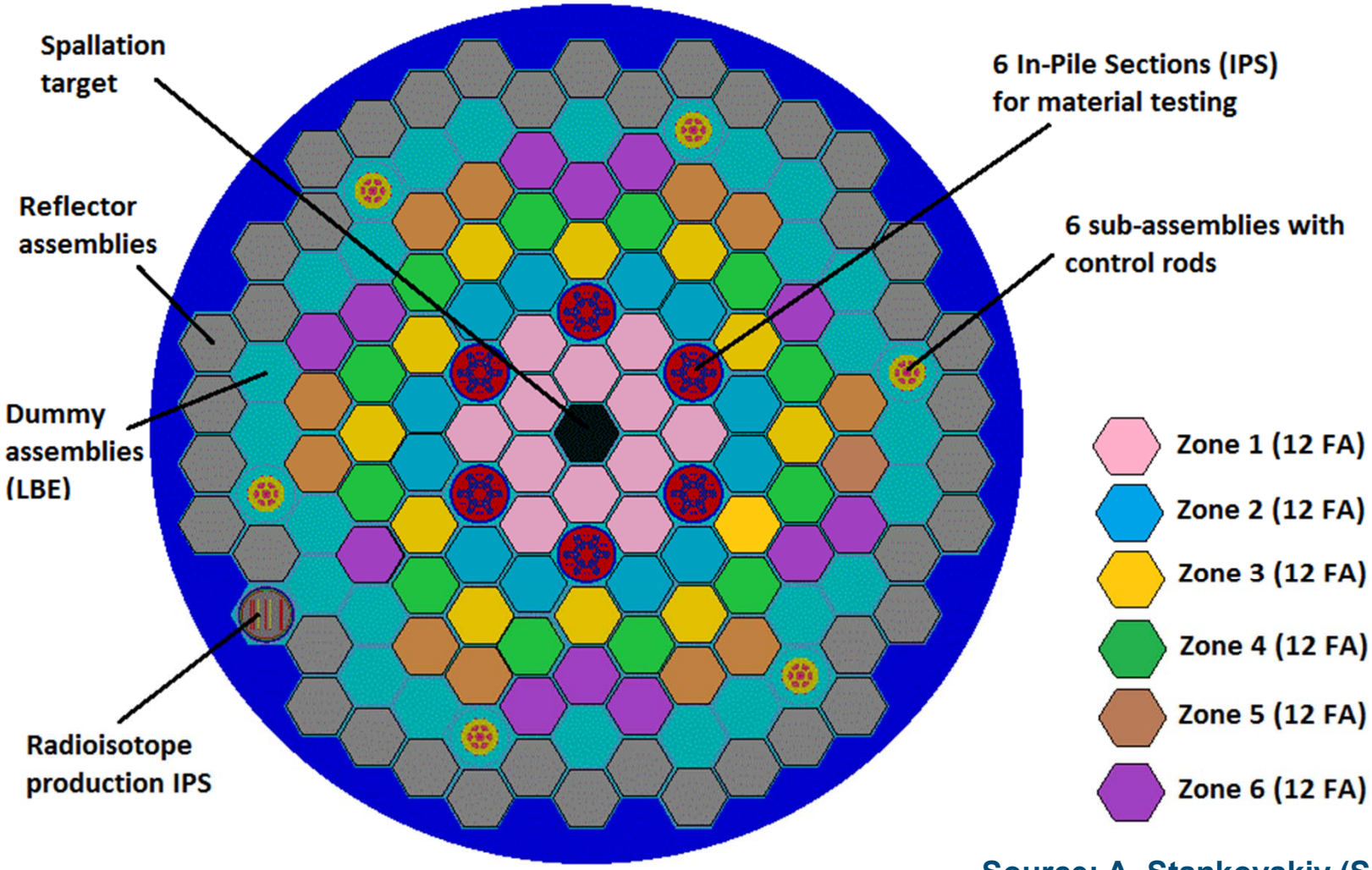
EURATOM

Task 2.1: MYRRHA Subcritical Mock-up Definition
(Task leader: SCK•CEN)

D2.1 - Preamble

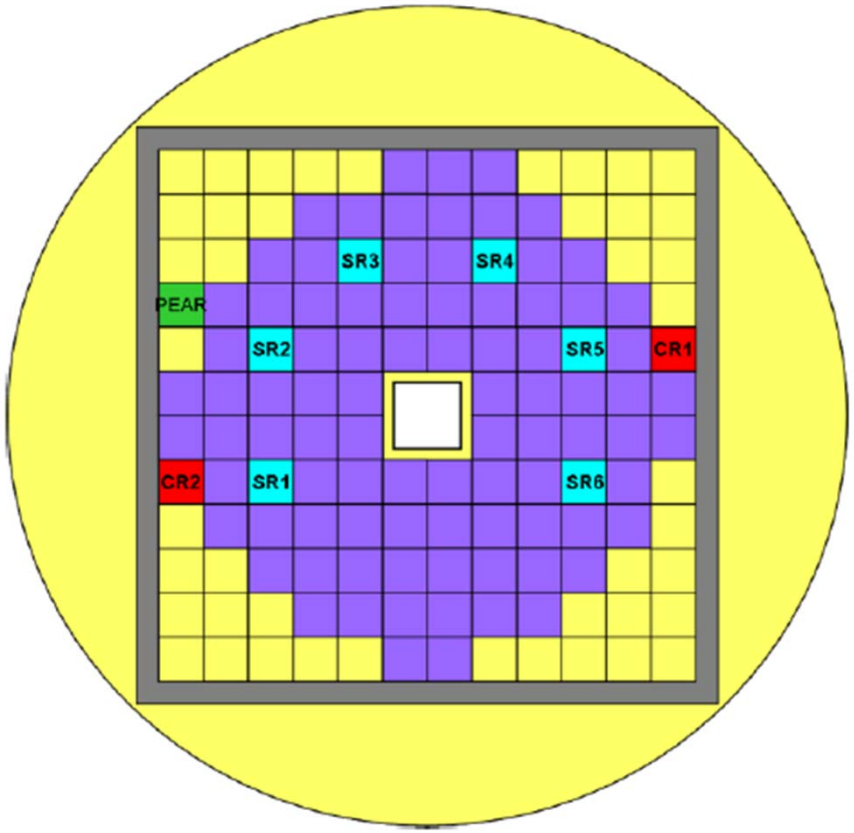
- Due to the correlation between WP3 and WP2, when performing **Task 2.1** one is also performing **Task 3.1.**
- Since 2013 a number of studies based on a number of different ideas have been conducted in order to define a new VENUS-F configuration „representative“ of the MYRRHA core.
- MCNP (KIT, SCK-CEN, CNRS, ENEA) and ERANOS (ENEA) calculations have been performed.
- Some of the ideas have been discarded due to different reasons and D2.1 is a summary of the major findings updated at **30.10.2013**
- Even if officially closed, a huge deal of work has continued since D2.1 due to the interaction with the MYRRHA team which from time to time has provided new input to the FREYA community → **D3.1** issued on **06.10.2014.**
- On January 2015 some modifications of the MYRRHA design have been introduced and additional requests were made to WP2.

D2.1 – MYRRHA sub-critical core description

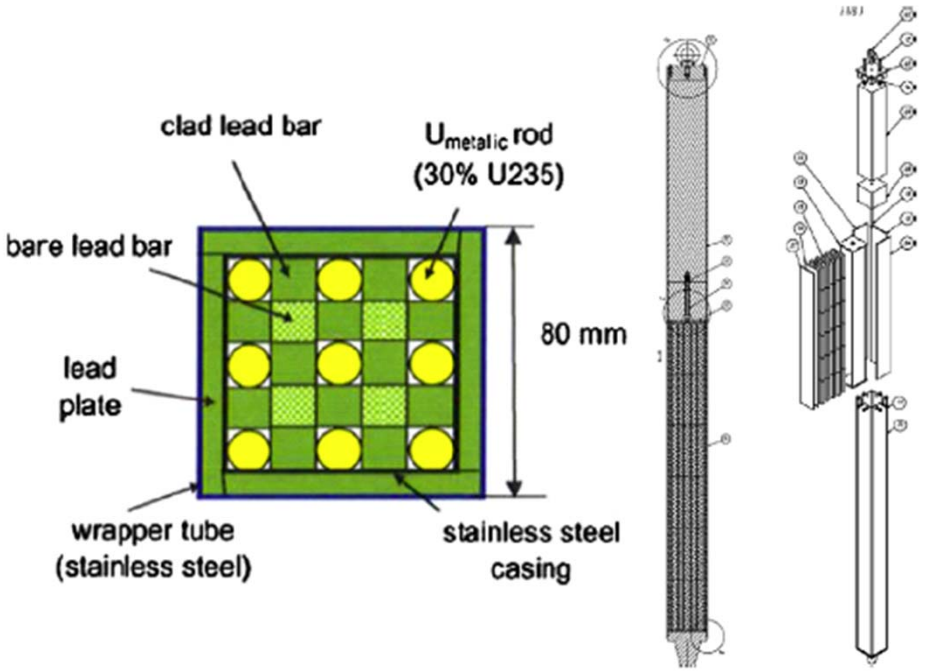


Source: A. Stankovskiy (SCK-CEN)

D2.1 – VENUS-F/WP1 descritpion

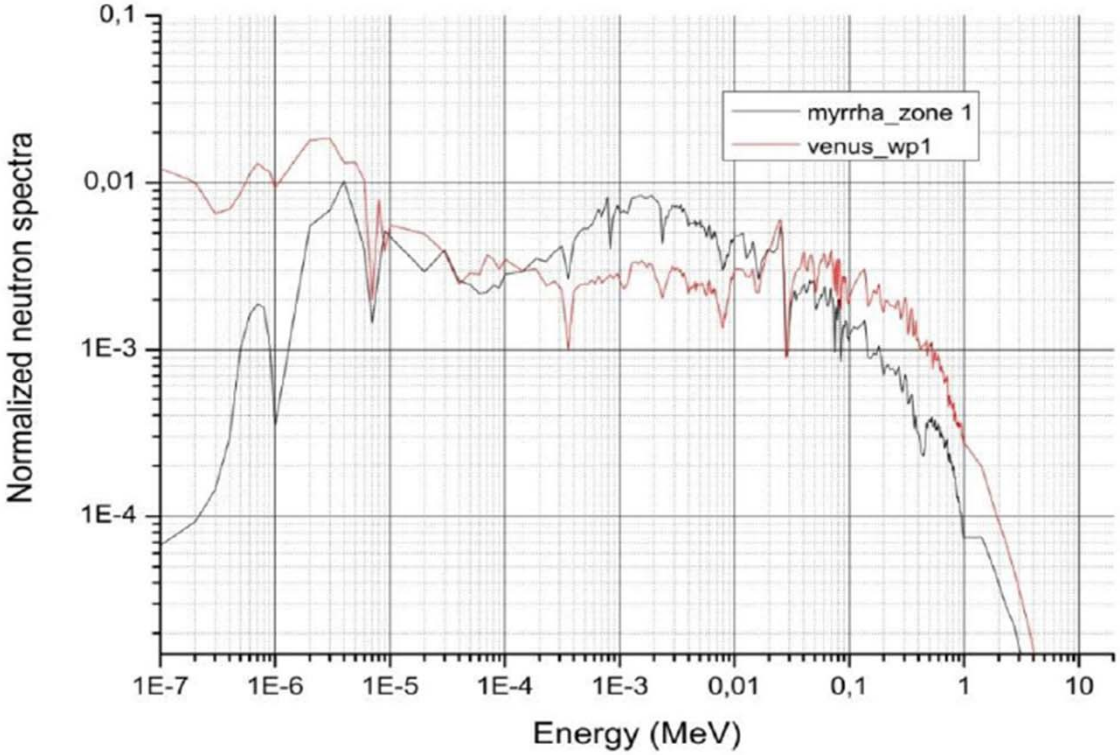


VENUS_F subcritical core (WP1)



VENUS-F standard fuel assembly

D2.1 – Neutronic characterization of the existing VENUS-F core compared to MYRRHA



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

Spectral indexes

Representativity criteria:

1. **Neutron spectrum**
2. ***Kinetics parameters***

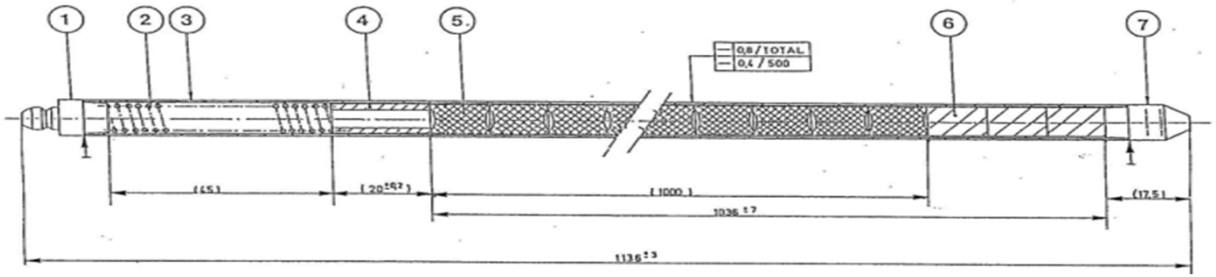
   β_{eff} *= 722 ± 10 pcm (VENUS-F)*

   β_{eff} *= 320 ± 10 pcm (MYRRHA)*

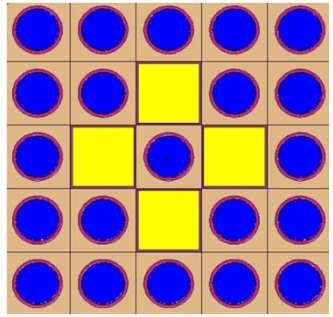
D2.1 – Pathways for the MYRRHA mock-up in VENUS-F (1)

Combining MOX fuel with the existing metallic U fuel

- Investigations on the feasibility of a critical configuration loaded with MOX 30% FAs have been performed in the past (ENEA).
- No longer possible due to the lack of fuel.
- 230 MOX 14% enriched pins are available at SCK-CEN



MOX 14% Type 21 FA



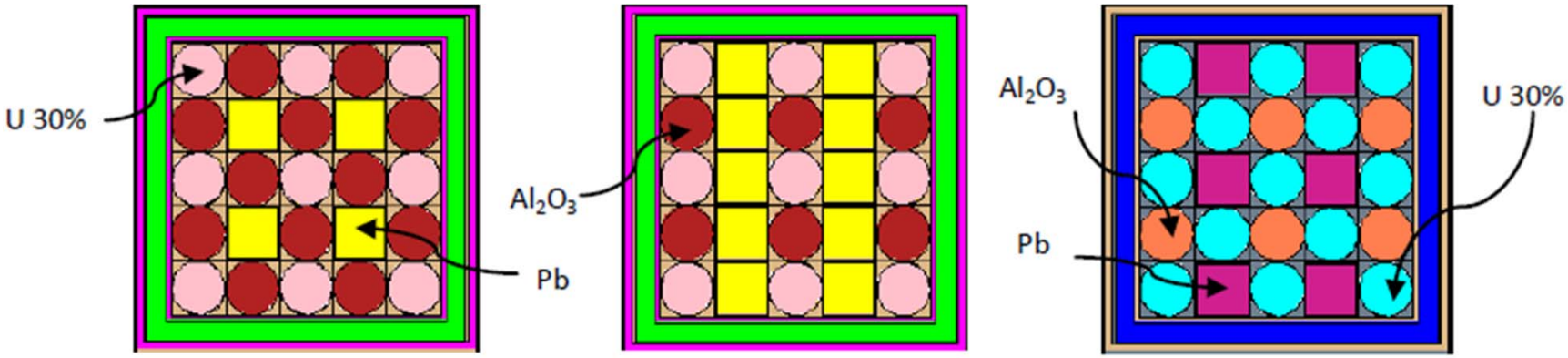
Type21 MOX FA with 14% MOX pins; k_{inf} = 1.04

D2.1 – Pathways for the MYRRHA mock-up in VENUS-F (2)

Introduction of Al_2O_3 in the VENUS-F core

- 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.

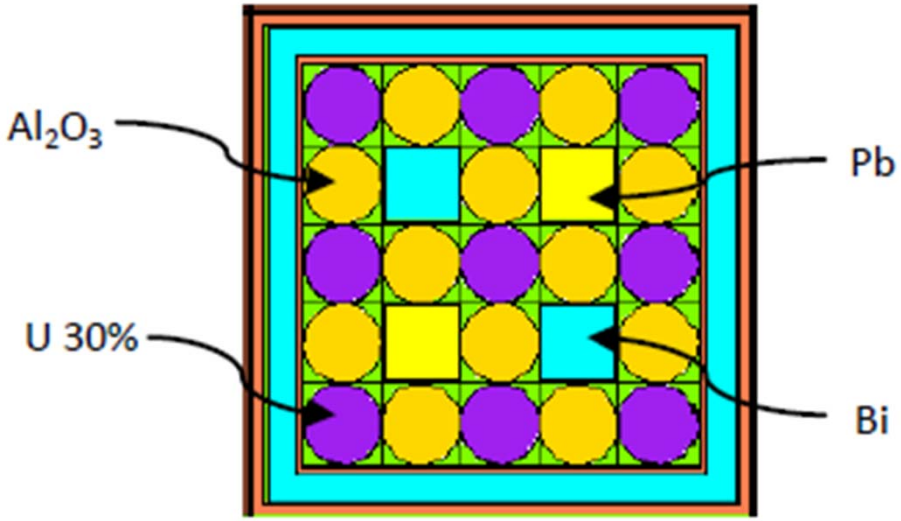
- Possibility to “simulate” the UOx by means of a combination of metallic uranium and aluminum oxide (Al_2O_3) rodlets.



U9Al12 U9Al6 U13Al6

D2.1 – Pathways for the MYRRHA mock-up in VENUS-F (3)

Introduction of Bismuth in the VENUS-F core

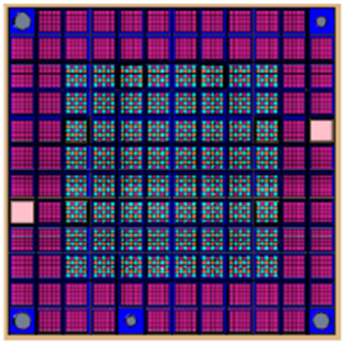


D2.1 – Main results

- **A calculation campaign has been performed with the MCNP5 code and JEFF3.1 nuclear data with the purpose to get a critical configuration assuming a limited availability of materials**
  - *97 Type-9 FAs/67 Type-13 FAs*
  - *2400 Al_2O_3 rodlets (30 cm length)*
  - *2000 Bismuth rodlets (30 cm length)*
  - *10 Type 21 MOX 14% FAs*

- Effects on reactivity:
  - **MOX: negative**
  - **Al_2O_3 positive**
  - **Bi: negative**

D2.1 – VENUS-F configurations (MYRRHA-like)

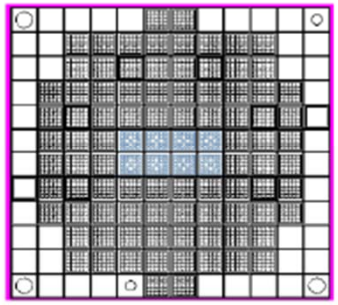


U13-Al6

64 FAs U13-Al-6-type

k_{eff} = 1.10878 ± 0.00032

β_{eff} = 681 pcm

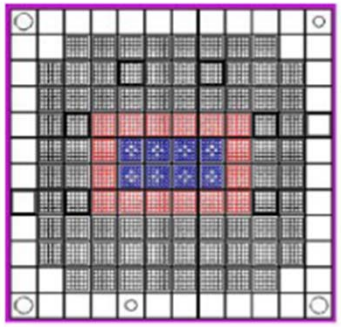


U9-Al12-MOX

88 FAs U9-Al12-type
8 FAs MOX-type

k_{eff} = 1.00420 ± 0.00031

β_{eff} = 688 pcm

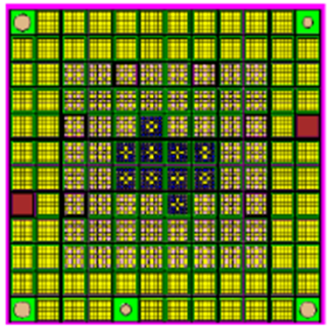


U9-Al6-MOX / U13-Al6-MOX

72 FAs U9-Al6-type
8 FAs MOX-type
16FAs U13-type

k_{eff} = 1.02910 ± 0.00031

β_{eff} = 680 pcm

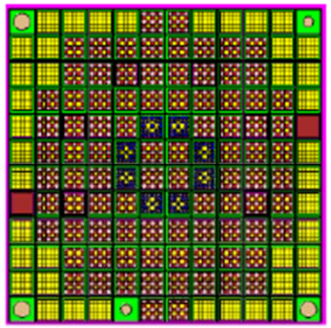


U13-MOX

54 FAs U13-type
10 FAs MOX-type

k_{eff} = 1.00331 ± 0.00030

β_{eff} = 718 pcm

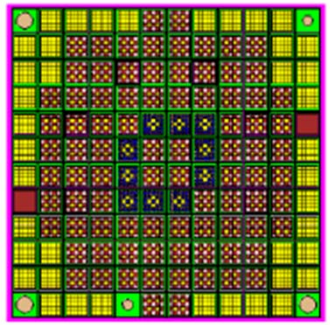


U9-Al12-8MOX

88 FAs U9-Al12-type
8 FAs MOX-type

k_{eff} = 1.00506 ± 0.00032

β_{eff} = 714 pcm



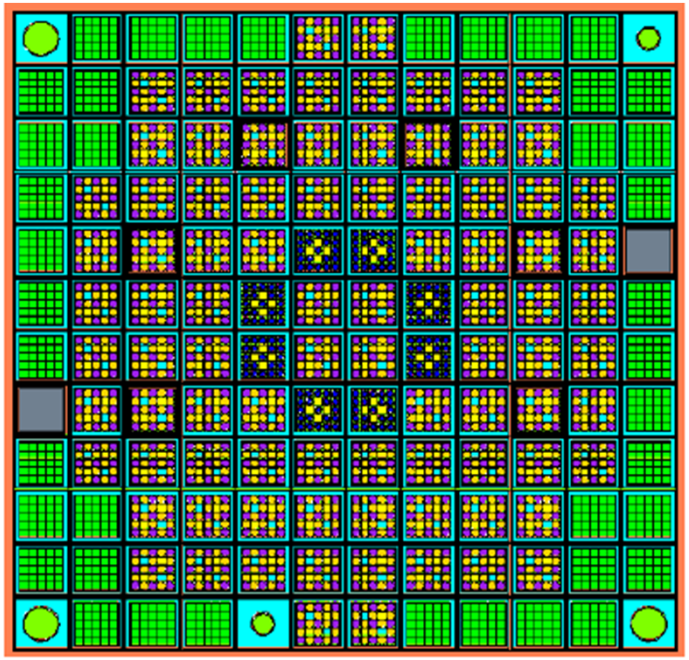
U9-Al12-10Mox

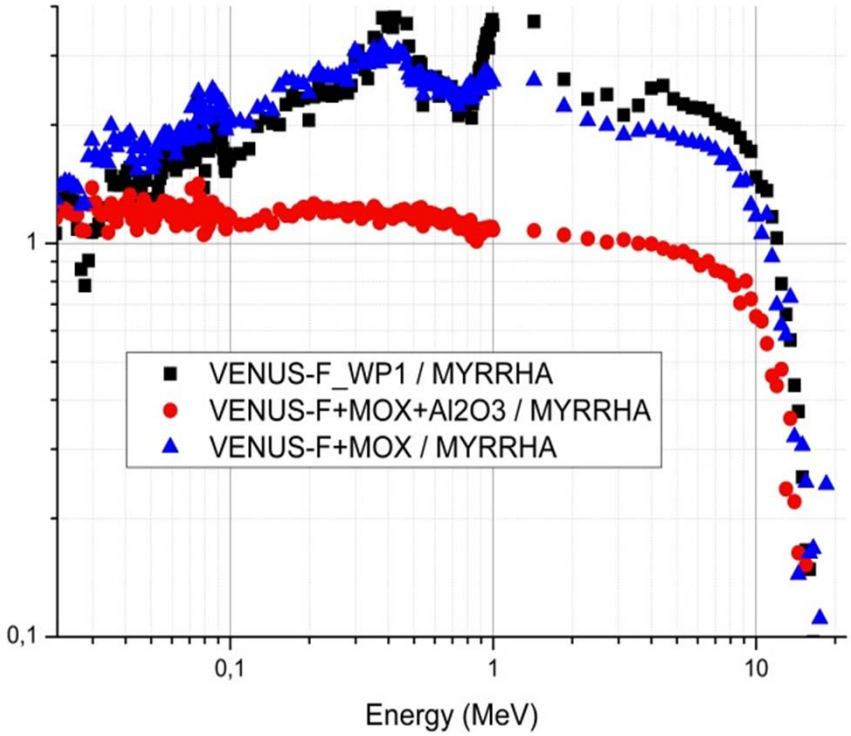
86 FAs U9-Al12-type
10 FAs MOX-type

k_{eff} = 0.99521 ± 0.00031

β_{eff} = 733 pcm

D2.1 – The U9Al12-8MOX-LBE configuration





88 U9-Al-LBE FAs

8 MOX Type 21 FAs

k_{eff} = 1.00339 ± 0.0044

β_{eff} = 718 pcm ± 10 pcm

	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-Al12-8MOX averaged over the fuel	0.0333	1.04	0.284	0.125
U9-Al12-8MOX in a central U fuel assembly	0.0175	0.991	0.184	0.279
U9-Al12-8MOX in central MOX fuel assembly	0.0159	0.981	0.178	0.271

D2.1 - Conclusions

- **In FREYA/WP2 the methodology for on-line sub-criticality monitoring should be tested on a MHYRRA-like sub-critical mock-up inside VENUS-F.**
- **With all the available 230 pins of MOX 14% arranged in a *Type* 21 FA a critical configuration is possible but it 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 slightly 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.**
- **None of the options considered are relevant for MYRRHA in terms of kinetics parameters (β_{eff} higher by a factor of ~2 with respect to the target values).**

D2.1 - Follow-up studies

- The insertion of the MOX island into VENUS-F leads to technical challenges and longer time for licensing. These complications are not compensated by the addedd value of the MOX insertion → **the MOX option is abandoned within FREYA/WP2** (maybe it will be considered again in the future).

- The Al_2O_3 is confirmed to be a valuable option to simulate the oxyde behaviour within the WP2 experiments but a new FAs has been proposed and selected for the core loading of WP2/WP3: the U13Al4Pb8 FA

- In deliverable D3.1 the updated reference critical configuration for the WP2 experiments is described (see presentation by A. Krása)

- Since January 2015 slighly new modifications are being proposed