Karlsruhe Institute of Technology

Towards the MYRRHA Mock-up in VENUS-F
Part I - WP2

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A new core layout in FREYA - WP2

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One form per Work Package

Work package number [53]	WP2	Type of activity [54]	RTD
Work package title	Subcritical configuration for design and licensing of MYRRHA/FASTEFF		
Start month	18		
End month	32		
Lead beneficiary number [55]	2		

Today: *M38!*

Objectives

An experimental programme in support of the design and licensing of MYRRHA/FASTEF subcritical core.

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.

Task 2.2: MYRRHA Subcritical Mock-up Characterisation (Task leader: INFN)
Then, standard characterisation core measurements will be accomplished. These are axial and radial flux distributions, spectral indices, control rods worth measurements and minor actinide responses by fission chambers. Different fuel loading patterns according to the different steps in a reloading scheme will be analysed and characterised. The precise determination of flux gradients and subsequent hot temperature points is of importance.

Task 2.3: MYRRHA Subcritical Mock-up Reactivity Effects (Task leader: UPM)
Different reactivity effects can further be investigated such as temperature effects, void effects, water ingress effects and fuel agglomeration effects. Finally in this WP the reactivity effects from the introduction of experimental devices such as in-pile-section (IPS) irradiation facilities, Na and H2O loops, will be investigated. These IPS have been discussed for the MYRRHA/FASTEF design and will be simulated by the proper materials and will be inserted in the proper place of the MYRRHA/FASTEF mock-up subcritical VENUS-F core.

Task 2.4: MYRRHA subcriticality monitoring (Task leader: CIEMAT)
In this task, the methodology for on-line reactivity monitoring developed in WP1 will be applied to the MYRRHA core. Application of neutron noise methods is also under consideration and a detailed evaluation of such measurements by Monte Carlo simulations is planed. The uncertainties and biasses associated with this methodology will be checked by repeating a sub-set of experiments of WP1.

Task 2.5: Transposition to MYRRHA/FASTEF (Task leader: SCK•CEN)
The results obtained in the WP1 and WP2 will be transposed to MYRRHA/FASTEF.

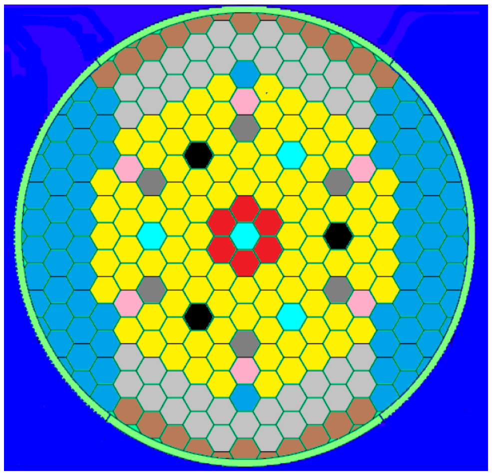
Experimental campaign in VENUS-F to support the design and licensing of MYRRHA planned in September 2014

We are here

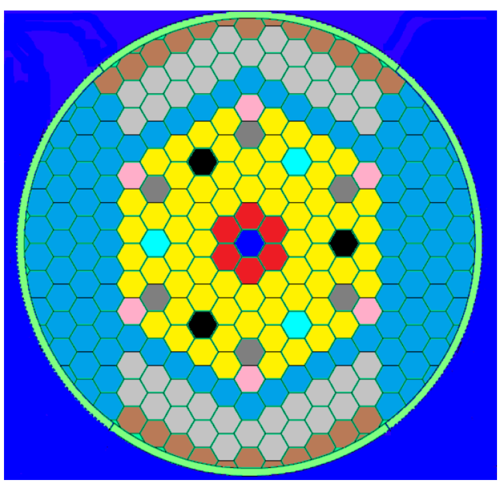
Core certificate

From September 2014

MYRRHA: CR and SR cores

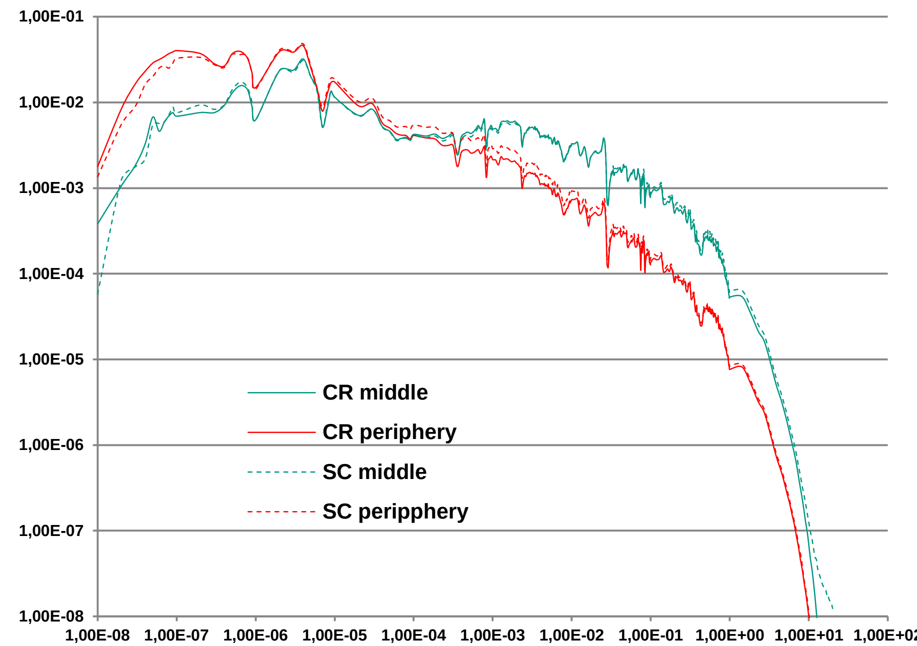


- FA (108)
- IPS (4)
- Control rod (3)
- SCRAM FA (6)
- BeO Reflector
- SS jacket
- LBE (dummy)



- FA (78)
- IPS (3)
- Control rod (3)
- SCRAM FA (6)
- BeO Reflector
- SS jacket
- LBE (dummy)
- LBE (spallation target)

Ratios of spectral indexes (SC/RC)				
	F28/F25	F49/F25	F40/F25	C28/F49
FUEL inner ring	1.14	1.02	1.09	0.95
LBE inner ring	1.17	1.01	1.12	0.96
FUEL outer ring	0.85	0.96	0.85	1.06
LBE outer ring	1.00	0.91	1.01	1.03
IPS	0.92	1.00	0.94	1.07

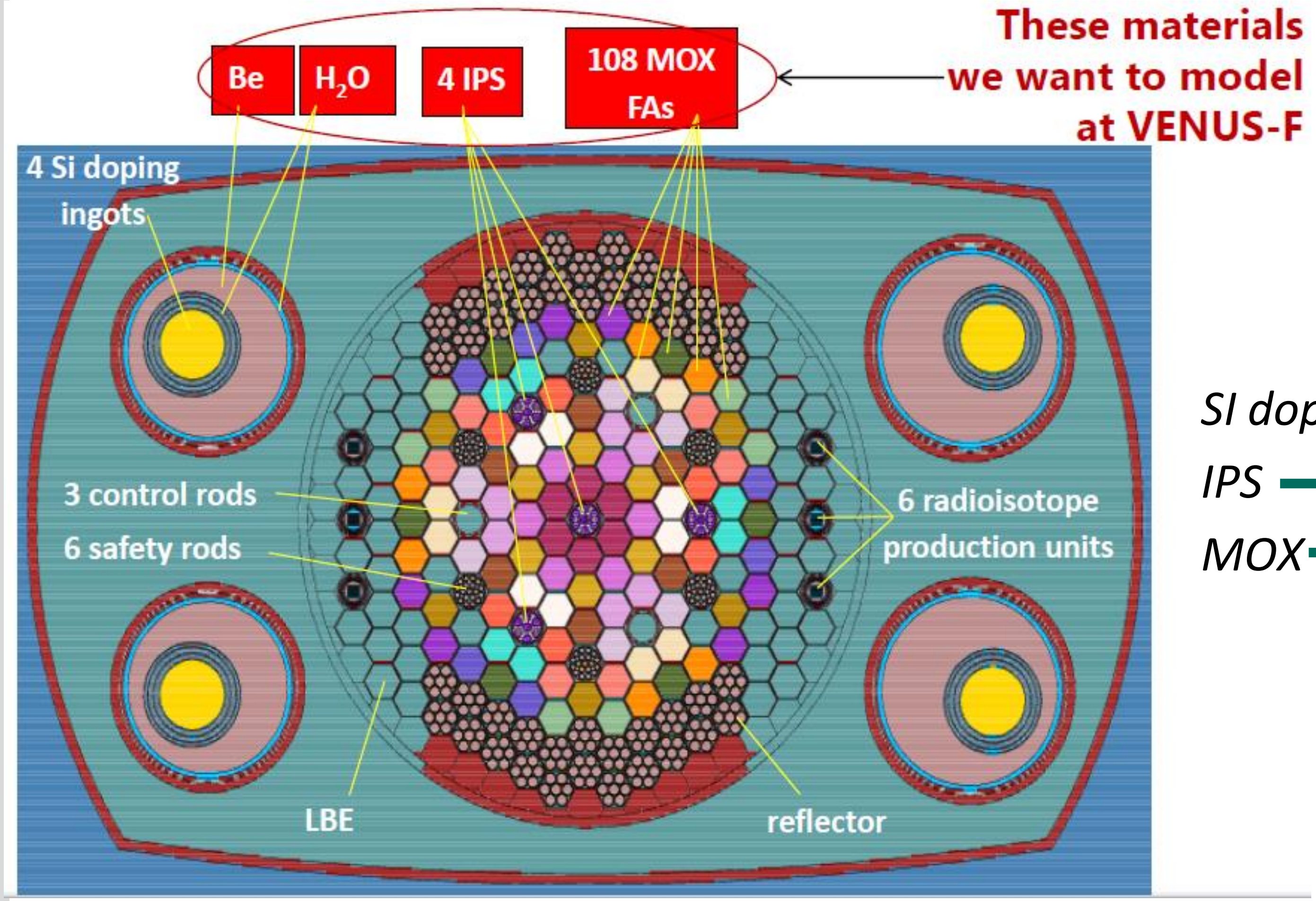


neutron spectra

Proposal for WP2 and WP3

- **FAs for VENUS-F in WP2 (sub-critical) and WP3 (critical) will be the same**
- Task 2.1 (*Sub-critical mock-up definition*) and Task 3.1 (*Critical mock-up definition*) performed in parallel
- Due to the need of a reference critical even in sub-critical experiments, **the core for Task 2.2 and Task 3.2 will be the same**
  - Start WP2 experiments fulfilling Task 3.2 and *Task 3.3*
  - *Task 2.2 (Sub-critical Mock-up Characterization)*
  - *Task 2.3 (Sub-critical Mock-up Reactivity Effects)*
  - *Task 2.4 (MYRRHA subcriticality monitoring)*
  - *Task 2.5 (Transposition to MYRRHA/FASTEF)*

The MYRRHA mock-up (from the last meeting in Brussels)



Source: SCK-CEN

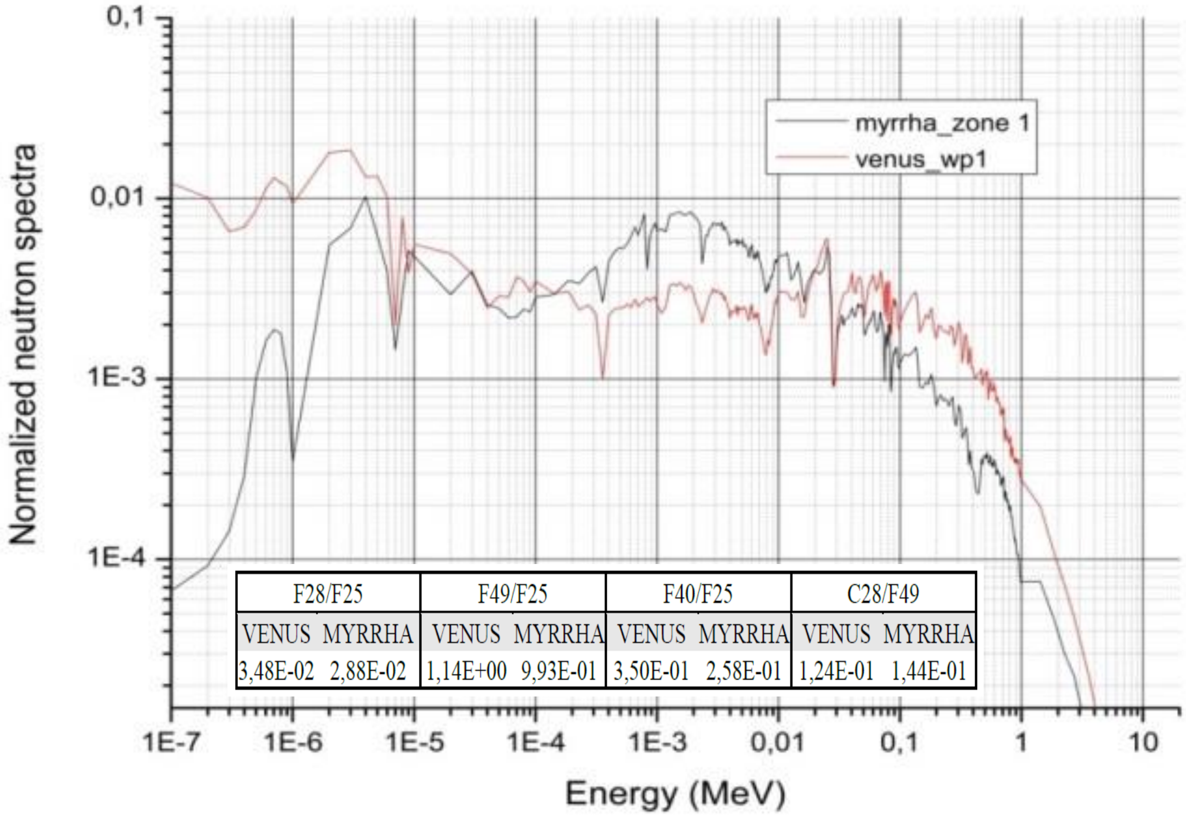
SI doping → polyethylene

IPS → stainless stell

MOX → Al_2O_3

Representativity criteria

- **Neutron spectrum**



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

- **Kinetics parameters**

  βeff: 722 pcm (VENUS-F), 320 pcm (MYRRHA)

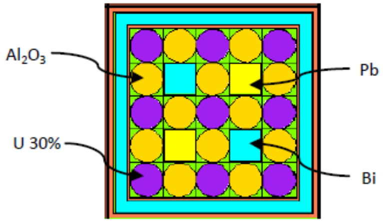
Institute for Neutron Physics and Reactor Technology (INR)

Choice of the fuel assembly (1)

- The 14% MOX variant is published in D2.1 (July 2013) but not longer considered at this stage of the project due to:
  - ✓ Technical difficulties
  - ✓ Volume fractions not representative of MYRRHA
  - ✓ Long time needed to receive the permission

- $Al2O3$ already bring essential effect on the MYRRHA simulation. The introduction of $Al2O3$, inside the metallic uranium fuel, produces a spectrum that is very close to that of MOX, where the epithermal part is wider and the peak of flux between 200-400 keV is absent.

- In order to mimic the MYRRHA coolant (LBE), Bi will be introduced inside the VENUS-F core. The neutronic effect is negligi



Choice of the fuel assembly (2)

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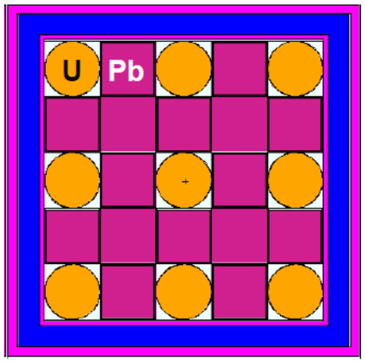
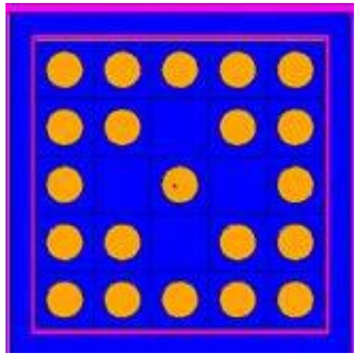
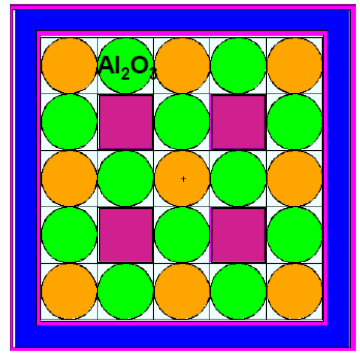


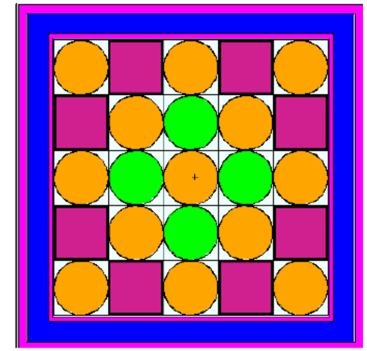
WP1



MOX



U9Al12Pb4 (WP2?)



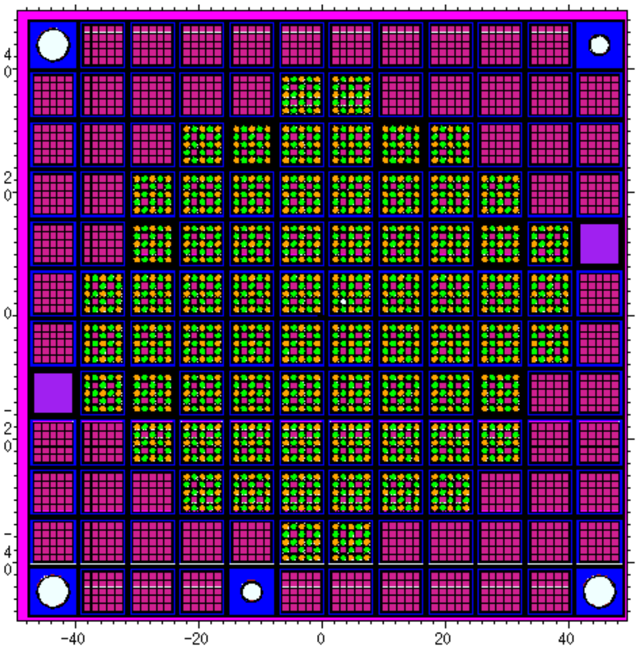
U13Al4Pb8 (WP2?)

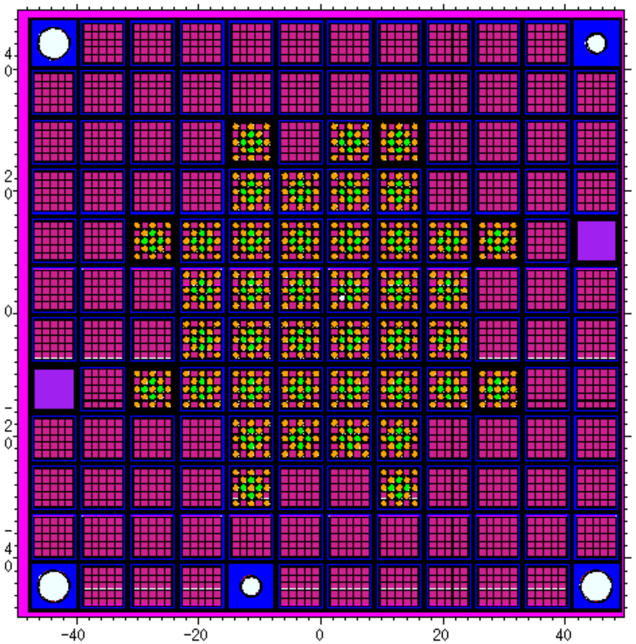
MYRRHA	%
Fuel total	27.1
fissile	5.1
O2	3.6
SS	22.1
LBE	44.3
Pb	19.5
Bi	24.8
He	2.9

		Under consideration		
	CR0 core	U9-ALO12	U13-ALO4	14% MOX
Fuel	17.1	17.1	24.7	15.1
fissile	5.1	5.1	7.4	1.4
O2	0.0	11.0	3.7	2.0
SS	15.8	14.6	15.4	13.6
Pb all	58.1	29.6	38.9	59.4
Pb (rod)	37.8	9.3	18.6	-
Pb (plate)	20.4	20.4	20.4	-
Air	9.0	15.4	13.2	3.6
Al	0.0	12.4	4.1	5.5 (Zr)

Choice of the fuel assembly (3)

- Two new candidate configurations in VENUS-F (From the last meeting, November 2013)
  - **70 FAs: 9 U rodlets + 12 Al2O3 rodlets + 4 Pb blocks**
  - **41 FAs: 13 U rodlets + 4 Al2O3 rodlets + 8 Pb blocks**

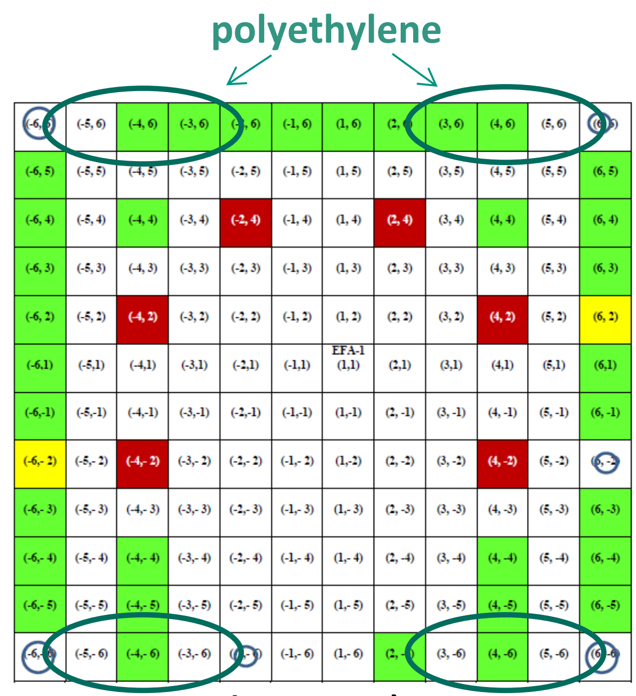




Approach to the MYRRHA mock-up (1)

Exercise (blind) between KIT (MCNP) and ENEA (ERANOS)

1. *Reference critical core*
   - *simple, only FAs and PbAs*
2. *Mock-up for Si doping*
   - *4 islands of PE in the reflector*
3. *Mock-up of material and fuel test station*
   - *3 SS assemblies + 1 MOX assembly*
4. *Critical MYRRHA mock-up*
   - *PE + SS + MOX*

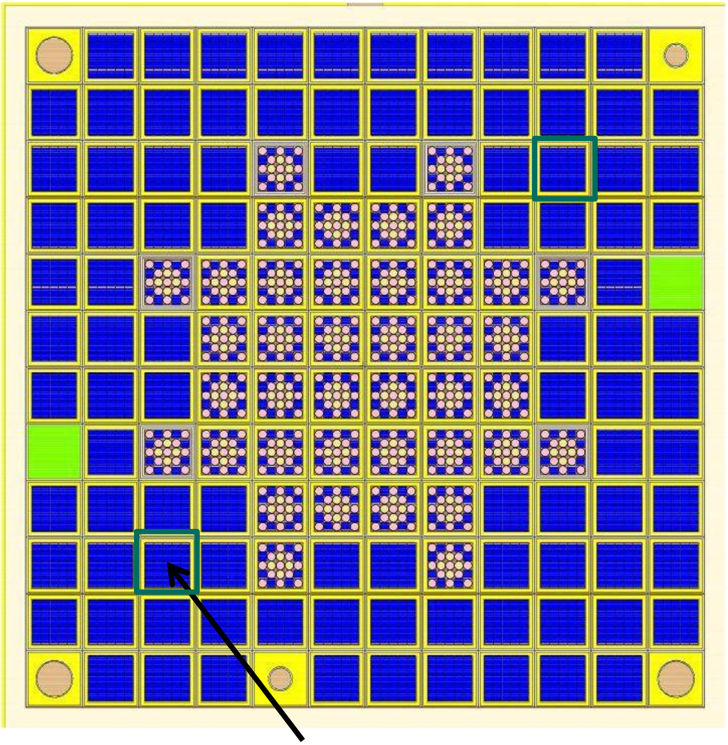


Parameters investigated: k_{eff} (to be between 1.006 and 1.010), CRs (alternative positions) and SRs worths

Calculations by means of MCNP5/JEFF3.1

U13Al8Pb4 (1)

Reference critical



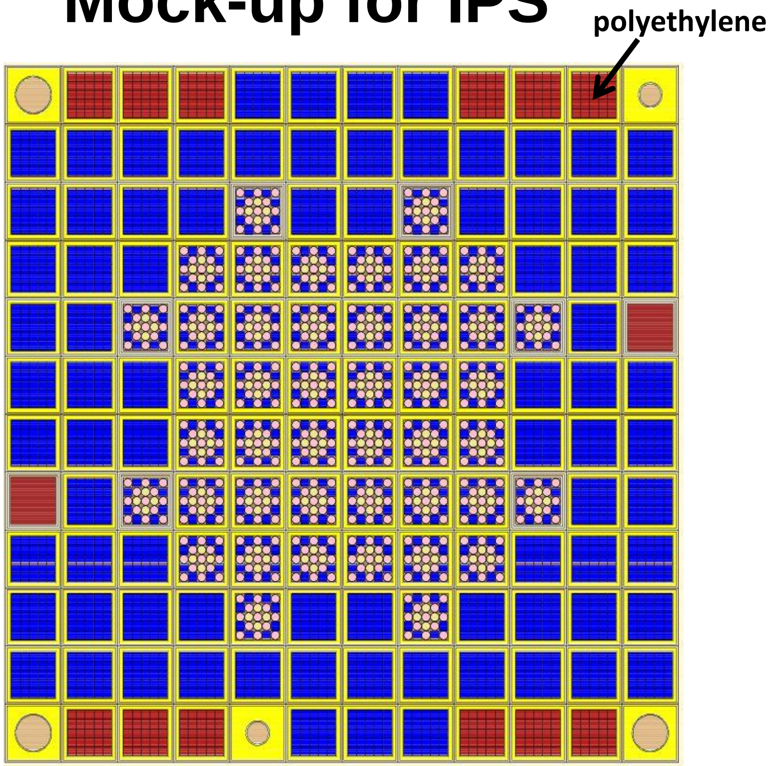
40 FAs

CRs [6,-2]= 572 pcm (0.79$)

CRs [4,-4]= 852 pcm (1.18$)

SRs = 8567 pcm (11.9$)

Mock-up for IPS



44 FAs

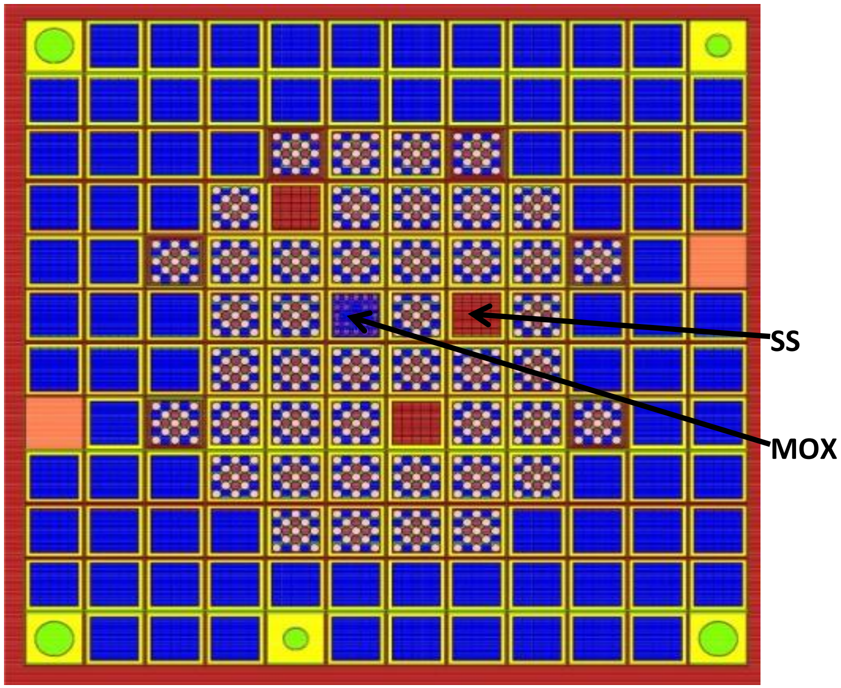
CRs [6,-2]= 397 pcm (0.55$)

CRs [4,-4]= 551 pcm (0.76$)

SRs = 7670 pcm (10.59$)

U13Al8Pb4 (2)

Mock-up for IPS



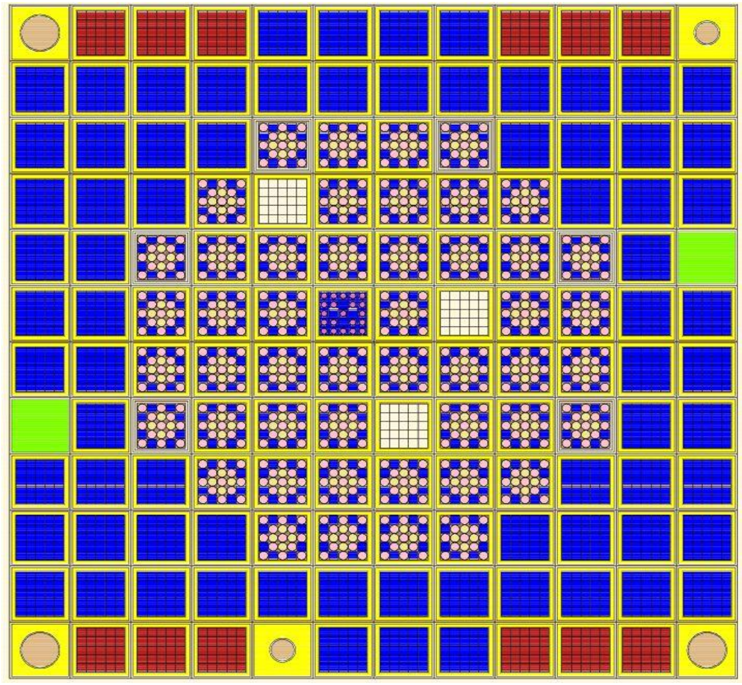
44 FAs + 1 MOX + 3 SS

CRs [6,-2]= 564 pcm (0.78$)

CRs [4,-4]= 964 pcm (1.34$)

SRs = 9266 pcm (12.87$)

MYRRHA Mock-up



48 FAs + 1 MOX + 3 SS

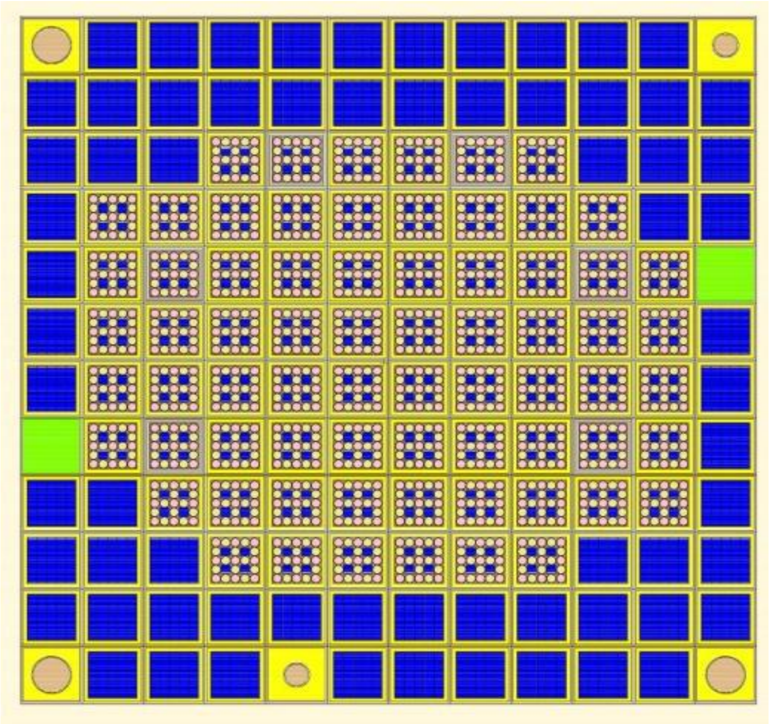
CRs [6,-2]= 505 pcm (0.70$)

CRs [4,-4]= 593 pcm (0.82$)

SRs = 8723 pcm (12.05$)

U9Al12Pb8 (1)

Reference critical



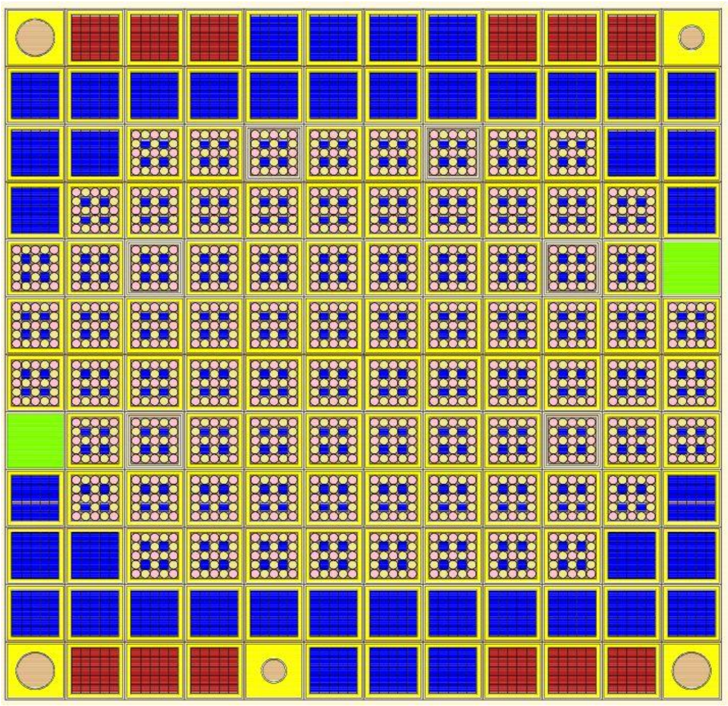
70 FAs

CRs [6,-2]= 739 pcm (1.03$)

CRs [4,-4]= 1087 pcm (1.51$)

SRs = 11382 pcm (15.8 $)

Mock-up for IPS



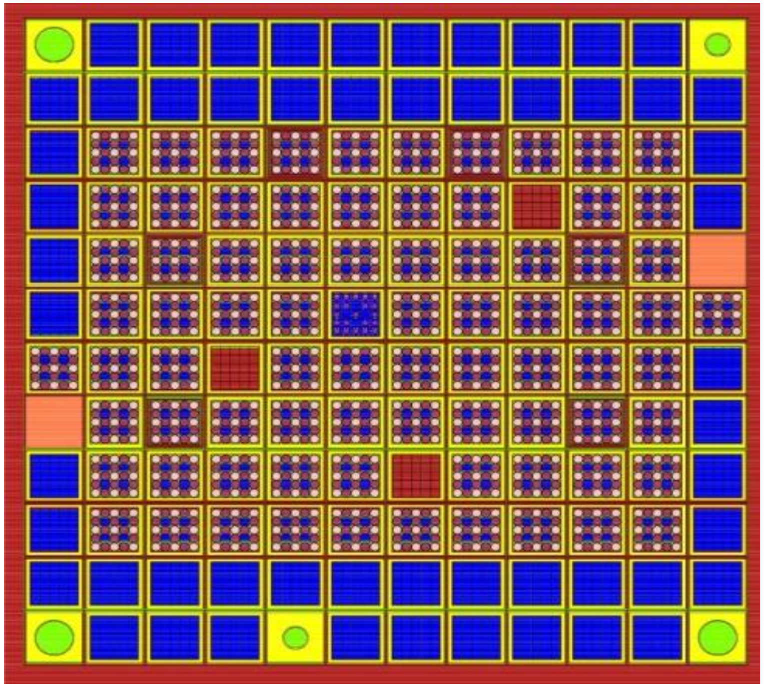
82 FAs

CRs [6,-2]= 837 pcm (1.16$)

SRs = 11019 pcm (15.22$)

U9Al12Pb8 (2)

Mock-up for IPS

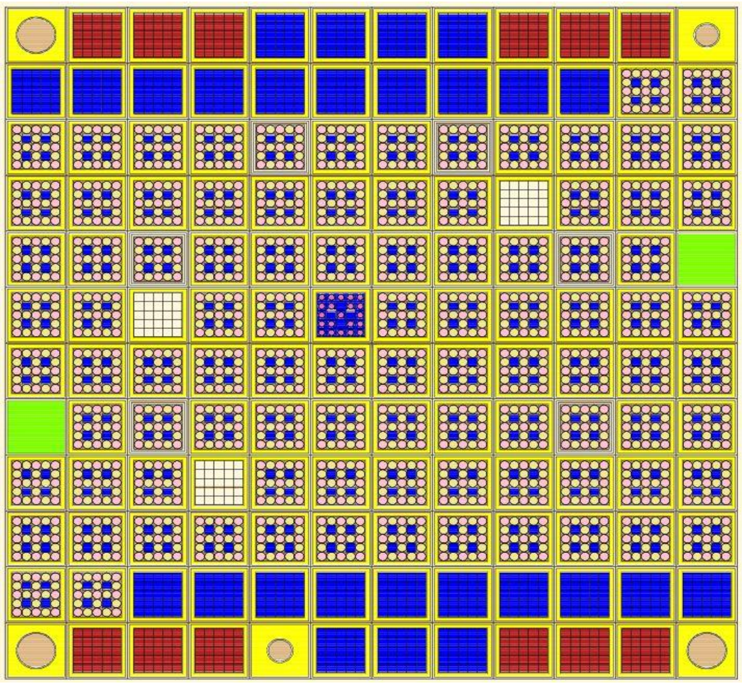


62 FAs + 1 MOX+ 3 SS

CRs [6,-2]= 932 pcm (1.29$)

SRs = 12414 pcm (17.24$)

MYRRHA Mock-up

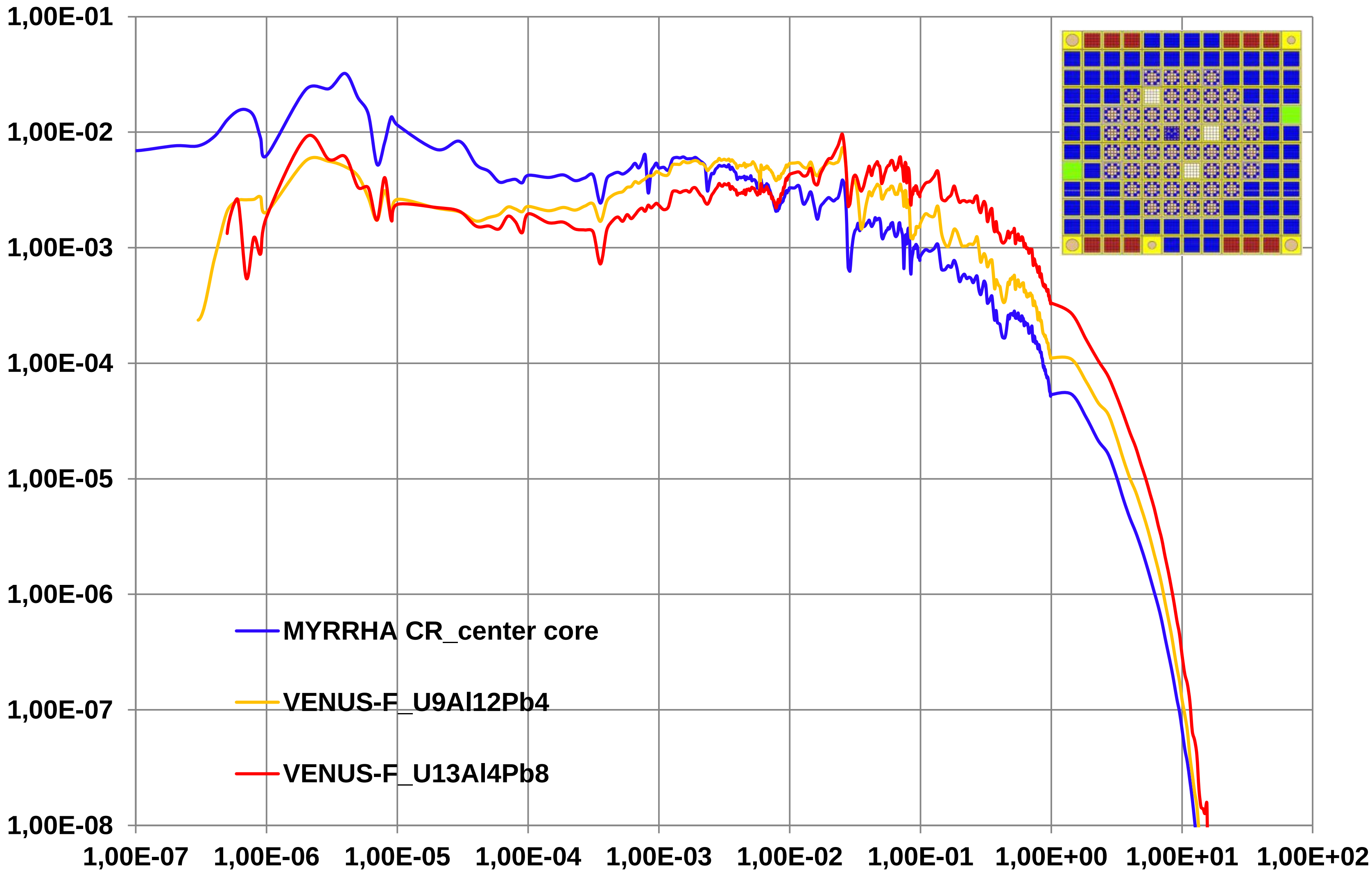


94 FAs + 1 MOX + 3SS

CRs [6,-2]= 985 pcm (1.36$)

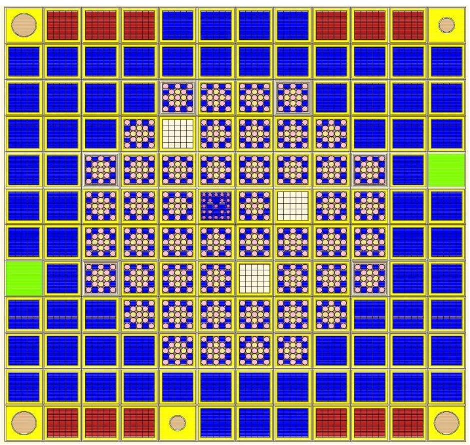
SRs = 11510 pcm (15.90$)

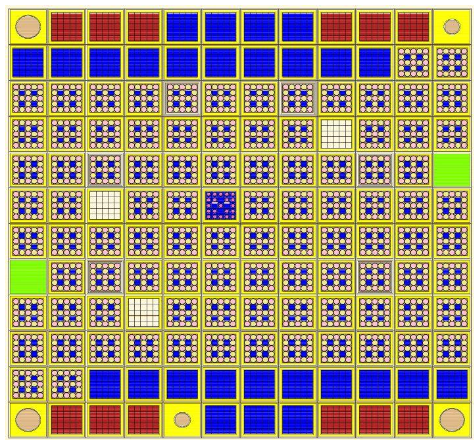
Neutron spectra

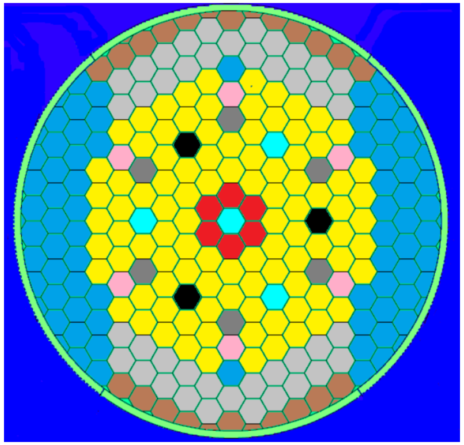


Spectral indexes

FA-type	F28/F25			F49/F25		
	[-1,1]	[1,2]	[1,-4]	[-1,1]	[1,2]	[1,-4]
VENUS-F_CR0	-	3.7E-02	-	-	1.16	-
U13Al4Pb8	3.3E-02	4.2E-02	3.8E-02	1.12E+00	1.14E+00	1.17E+00
U9Al12Pb4	2.7E-02	3.3E-02	2.9E-02	1.01E-00	1.03E+00	1.08E+00
MYRRHA (CR)	3.0E-02 (middle core) 2.7E-02 (periphery)			9.85E-01 (middle core) 9.44E-01 (periphery)		
MYRRHA (SC)	1.6E-02(middle core) 1.5E-02 (periphery)			1.01E+00 (middle core) 9.15E-01 (periphery)		


U13Al4Pb8


U9Al12Pb4


MYRRHA

Conclusions (1)

- Since the last technical meeting (November 2013) the criteria for the definition of the critical MYRRHA mock-up in VENUS-F have been defined more realistically and the scoping calculations performed at KIT and ENEA provide now the needed information for the final selection of the FAs to use in the WP2&3 experiments.

- The decision is urgent due to the necessary safety studies to be performed by SCK-CEN before the summer (presentation from Antonin in the afternoon) in order for the experiments to start in September 2014.

- In principle criticality can be achieved with both options U9 and U13 and even if the U9 spectrum is more similar to the one of MYRRHA, the corresponding critical configuration containing IPS and PE would require almost the total amount of metallic uranium available (94 FAs out of 97) making this solution the less preferable one.

Conclusions (2)

- The U13 core is more representative of MYRRHA for the FA volume fractions and leads to a smaller core, allowing for a better flexibility to accommodate the experimental devices.

- Control and safety rods are less effective in the U13 configuration:
  - SRs and CRs worths higher for U9 with repsect to U13 by ~ 40% and ~ 50%
  - Is 500-600 pcm still within the safety margins for the operational control?

- None of the options considered is relevant for MYRRHA in terms of kinetics parameters (higher by a factor of ~ 2 with respect to the target values)

Thank you to SCK-CEN (Antonin, Anatoly) and ENEA (Mario, Valentina, Giancarlo, Vincenzo) for the nice collaboration in the past months.