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FOREVER



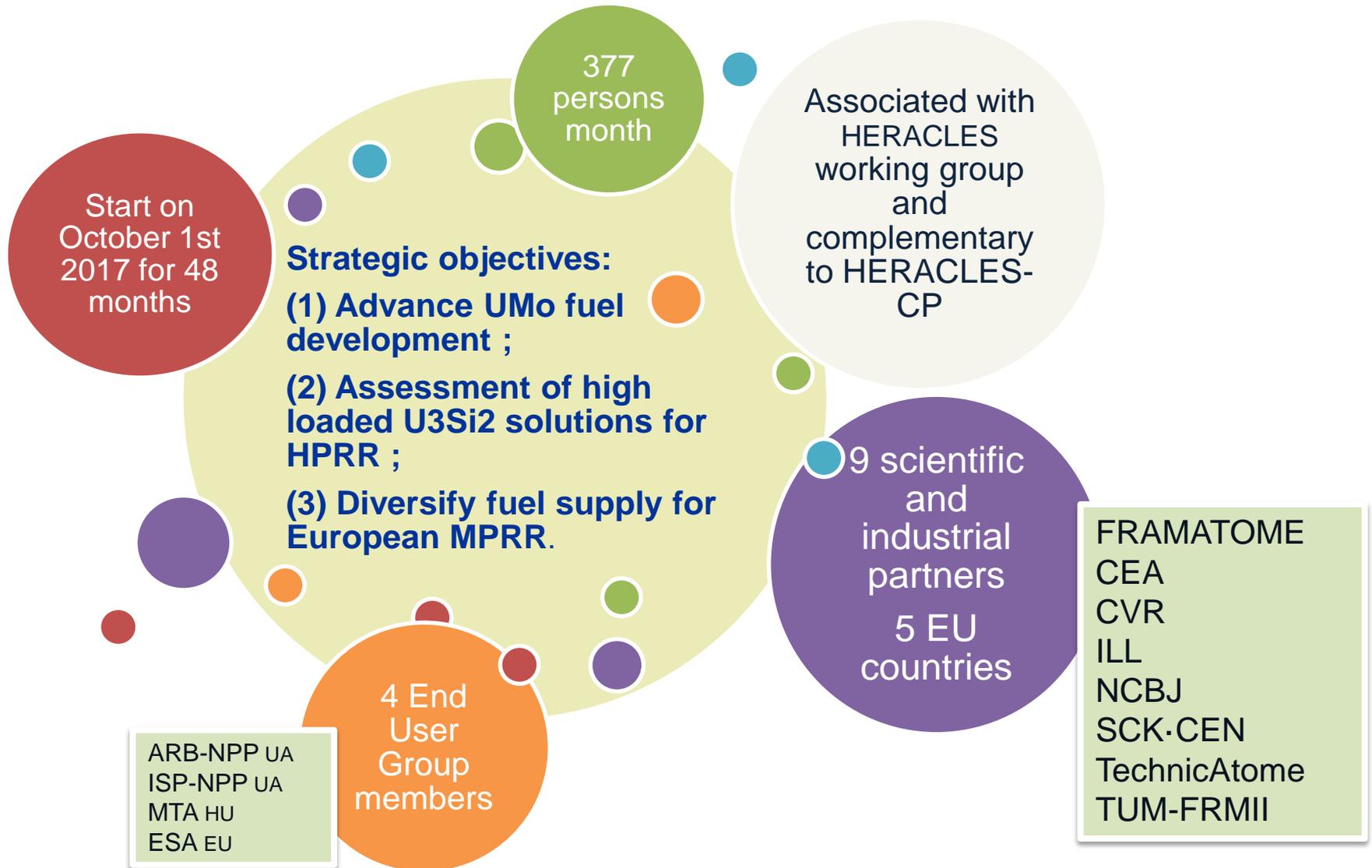
This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 754378

LEU fuels for medium and high power research reactors in Europe: project LEU-FOREVER

CEA | CVR | Framatome | ILL | LGI | NCBJ
SCK-CEN | TechnicAtome | TUM – FRM II

RRFM 2018 München | Stéphane Valance | CEA Cadarache

Project main facts



Project breakdown



Work package	Strategic objectives		
	Advance UMo fuel development	Assess U_3Si_2 solution for HPRR	Diversify fuel supply for European MPRR
Manufacturing		robust and existing process for U_3Si_2	
		improvement of existing technology for U_3Si_2	
	improving UMo manufacturing technology		
	control QA: UT measurements		
UMo fuel comprehension	PIE analysis EMPIRE monolithic mini-plates		
	thermo-mechanical modelling MAIA		
Fuel utilization in RR			EU MPRR fuel requirement assessment
			EU MPRR reliable and robust fuel supply
			FOAK controlled and standard fuel assemblies preliminary design
	TRL assessment		
Safety, licensing and Demonstration			general safety and licensing requirements
			scale 1 demonstration and qualification 4everTest
	high loaded U_3Si_2 evaluation - HiPROSIT		

Coordination: CEA

PMO: LGI

(0) LEU context

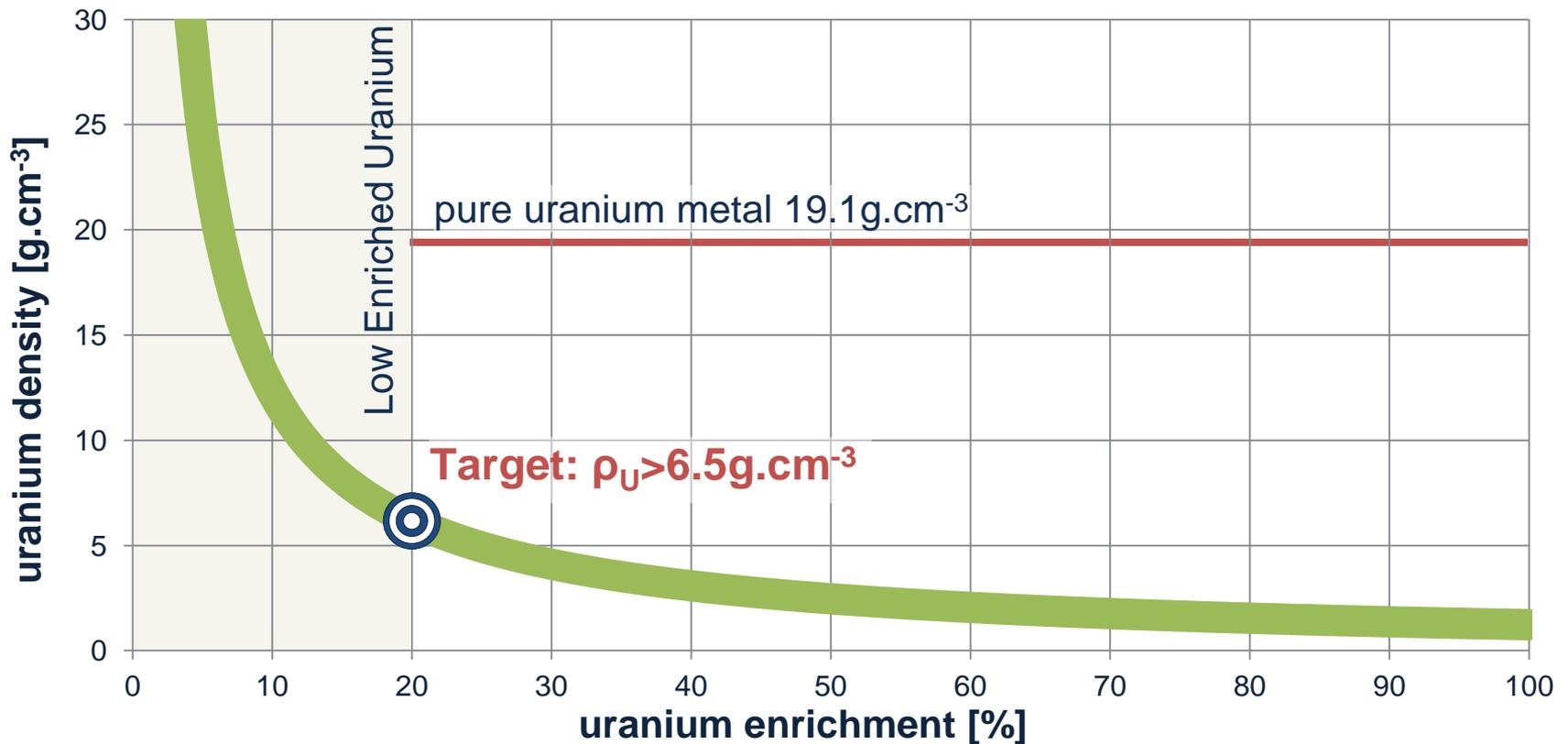


LEU:

- ☒ Prevent proliferation;
- ☒ Enrichment below 20%.

How:

- ☒ Increase uranium density;
- ☒ Use of UMo or U_3Si_2 compounds.



(0) highlight: LEU manufacturing



U_3Si_2 :

- ☒ Process optimization

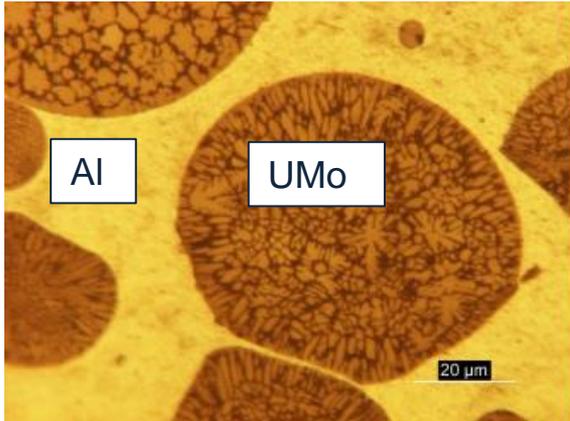
UMo:

- ☒ Assessment of the UMo powder coating equipment (PVD & ALD)
- ☒ EMPIrE monolithic plates PIE
- ☒ Optimization of the PVD monolithic coating process and pilot equipment
- ☒ C2TWP for full-size plates
- ☒ Manufacturing of a thickness gradient in foils
- ☒ C2TWP on graded foils
- ☒ UT QA measurement equipment

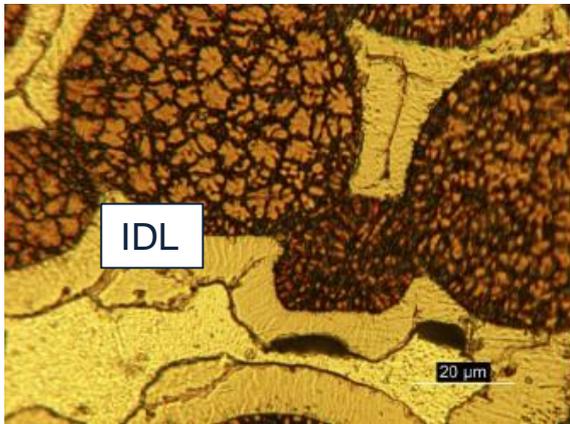
(1) UMo: background



FUTURE, BOL



FUTURE, EOL

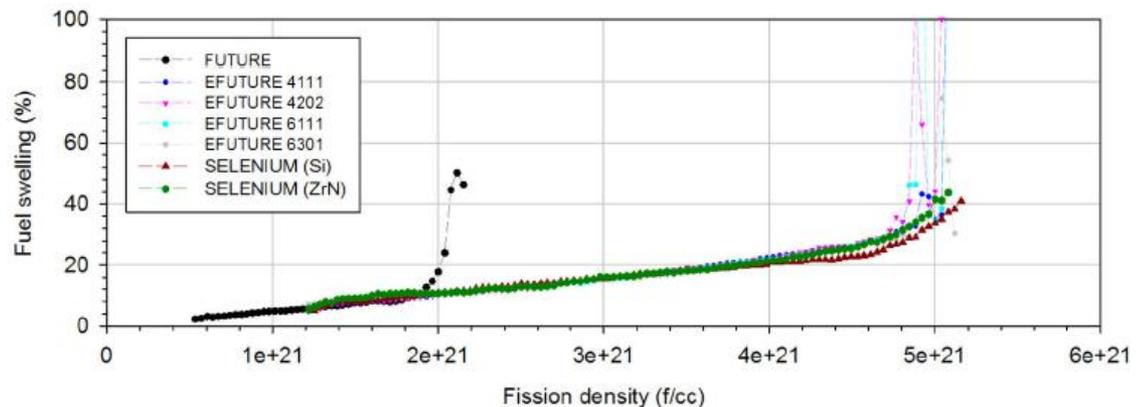


UMo fuel types:

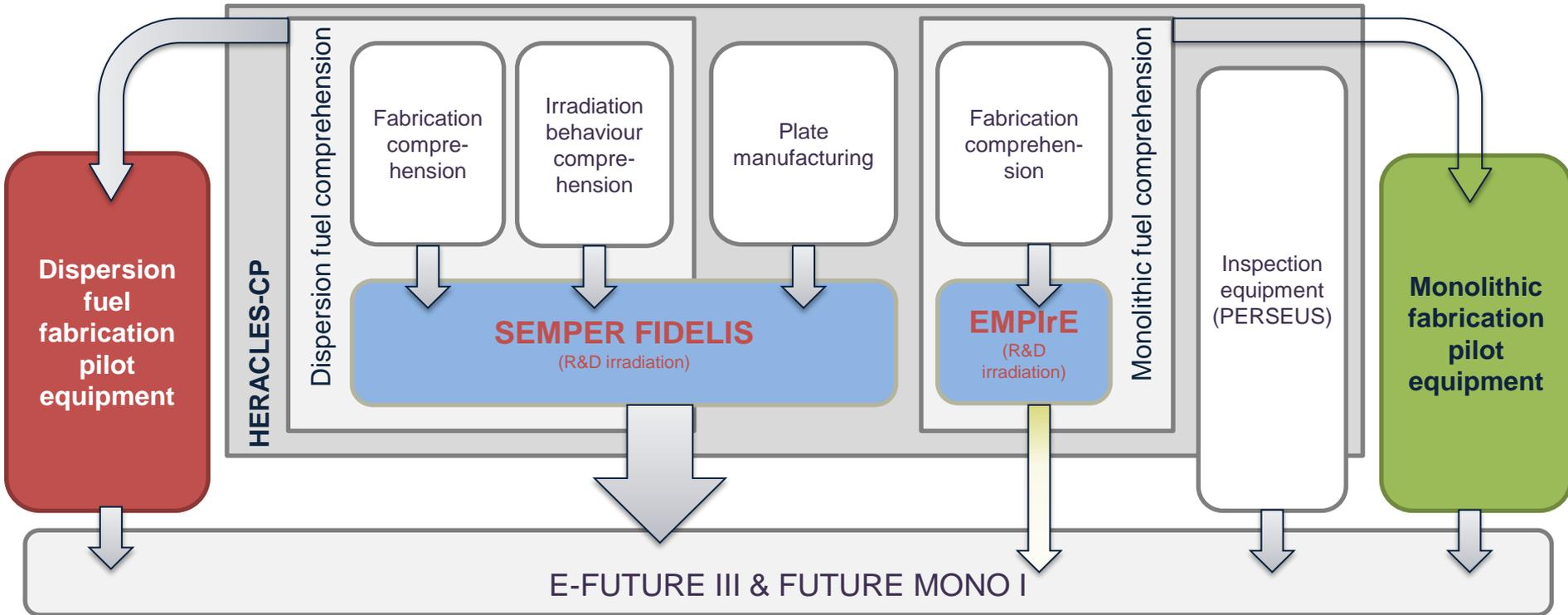
- ☒ U 7% wgt. Mo dispersion;
- ☒ U 10% wgt. Mo monolithic.

UMo dispersion behavior:

- ☒ no barrier (FUTURE) Inter-Diffusion Layer (IDL) formation -> breakaway swelling;
- ☒ partial barrier (E-FUTURE) reduced IDL formation -> breakaway swelling;
- ☒ barrier (SELENIUM) scarce IDL formation-> accelerated swelling.



(1) UMo: Heracles-CP \cap FOREvER



Examinations on UMo

- ☒ X. Iltis et al., poster A0084;
- ☒ F. Vanni et al., poster A0121.

Irradiations

- ☒ Stepnik et al., presentation A0120;
- ☒ Glagolenko et al., presentation A011.

(1) highlight: MAIA computations



MAIA code:

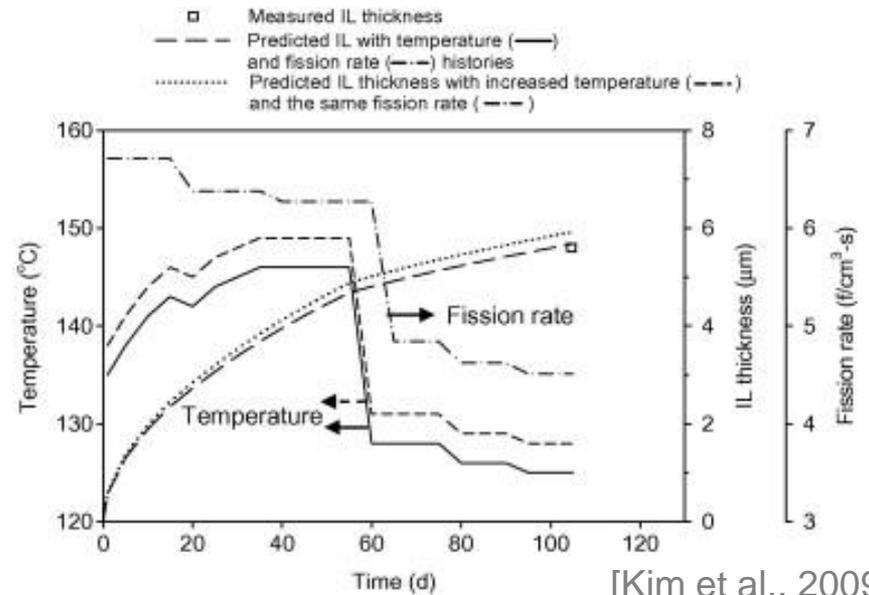
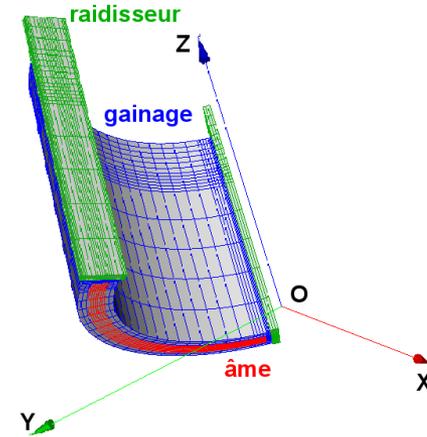
- ∞ FE computation of MTR fuel plates;
- ∞ Predefined meshes for flat and curved fuel plates;
- ∞ Material laws available for U_3Si_2 and UMo fuel core.

Utilization:

- ∞ Thermo-mechanical simulations of SEMPER-FIDELIS irradiations (UMo);
- ∞ Pre-dimensioning of HiPROSIT (U_3Si_2).

SEMPER-FIDELIS simulation objective:

- ∞ Compute fissile core temperature evolution during irradiation;
- ∞ Understand relationship between IL formation and temperature.



[Kim et al., 2009]

(2) high loaded U_3Si_2 for HPRR

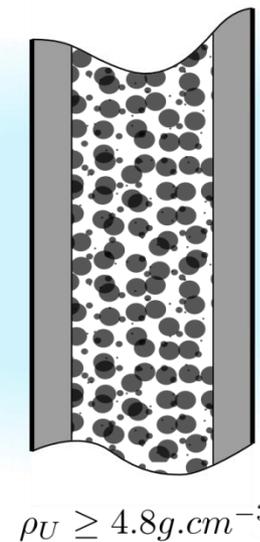
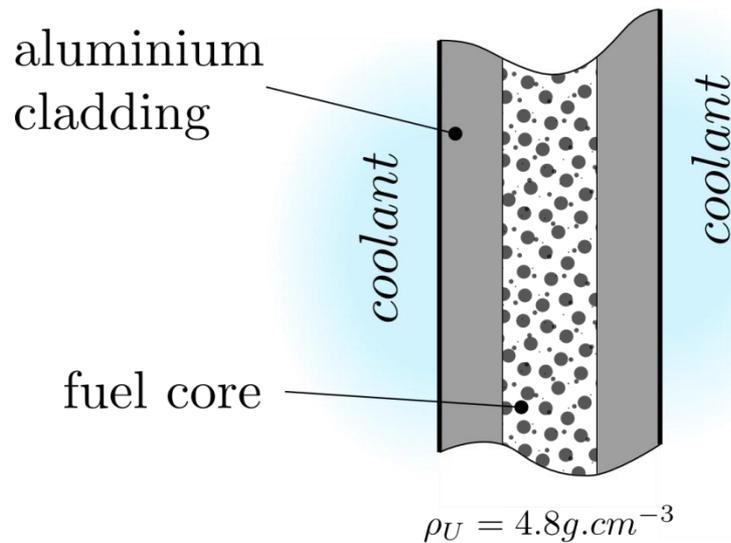


High loaded U_3Si_2 principle:

- ☒ Higher plate thickness;
- ☒ Lower cladding thickness;
- ☒ Higher U_3Si_2 density in the Al matrix.

High loaded U_3Si_2 development:

- ☒ Manufacturability;
- ☒ Testing;
- ☒ Adaptation to targeted research reactors.



(2) highlight: HiPROSIT irradiation

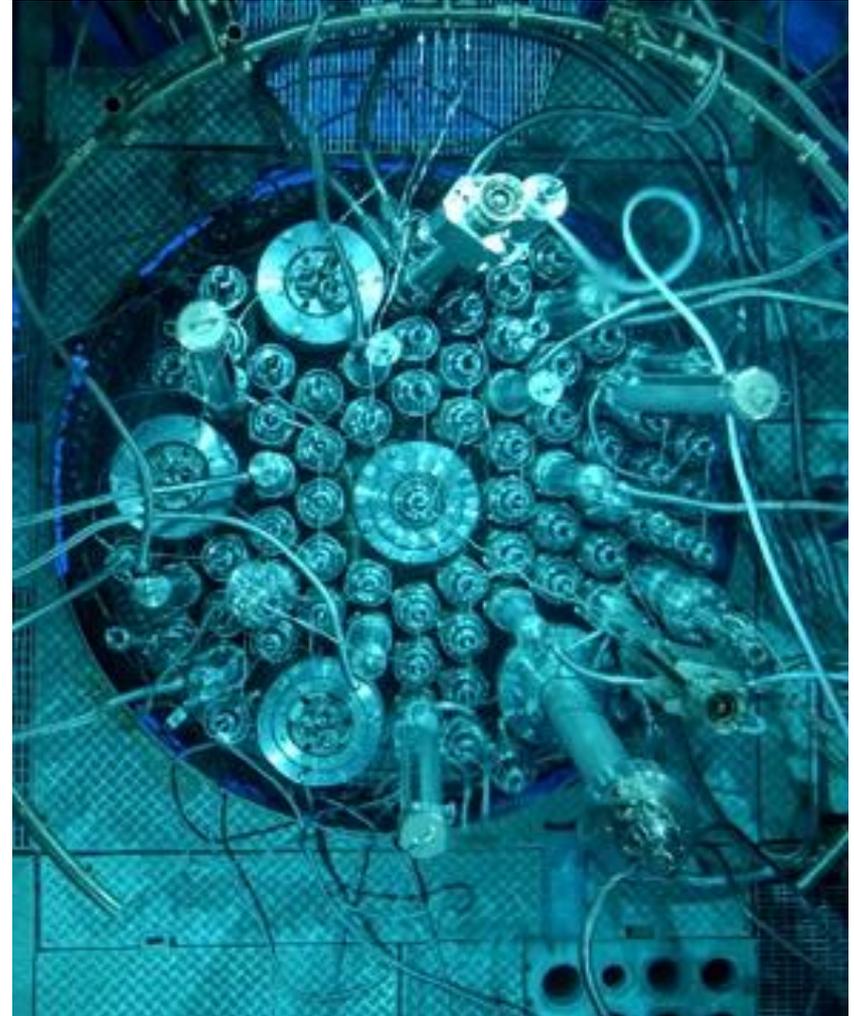


Irradiation HiPROSIT in the BR-2 reactor

- ☒ 4 full scale fuel plates;
- ☒ Maximum power 470 W.cm^{-2} ;
- ☒ Target BU up to 80% ^{235}U consumption.

Tested parameters

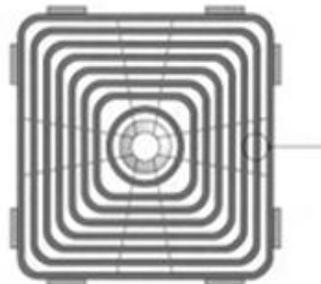
- ☒ Thinner cladding, down to 0.3 mm;
- ☒ Thicker fuel core, up to 0.7 mm;
- ☒ Higher uranium density, up to 5.6 g.cm^{-3} .



(3) 4ever irradiation test in LVR15

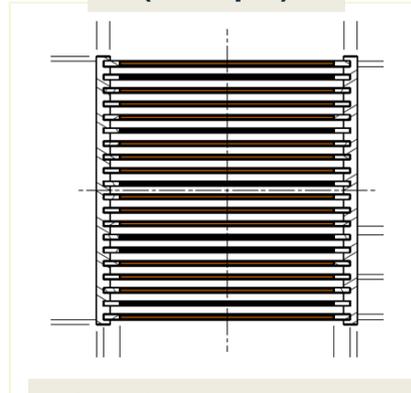


Current Qualified FA
(IRT-4M)



($\text{UO}_2 - \text{Al}$)

Alternative FA
(example)



Qualified fuel element
($\text{U}_3\text{Si}_2 \text{ Al}$) – $4.8 \text{ g}_U \cdot \text{cm}^{-3}$



A path toward fuel supply diversification:

- ☒ Assess legal background and safety rules;
- ☒ Design technically and economically viable substitution Fuel Assemblies (FA);
- ☒ Manufacture and test under irradiation in LVR15 the designed FA → 4EVER test;
- ☒ Post irradiation characterizations to validate its behavior under irradiation.

(3) highlight: design to cost

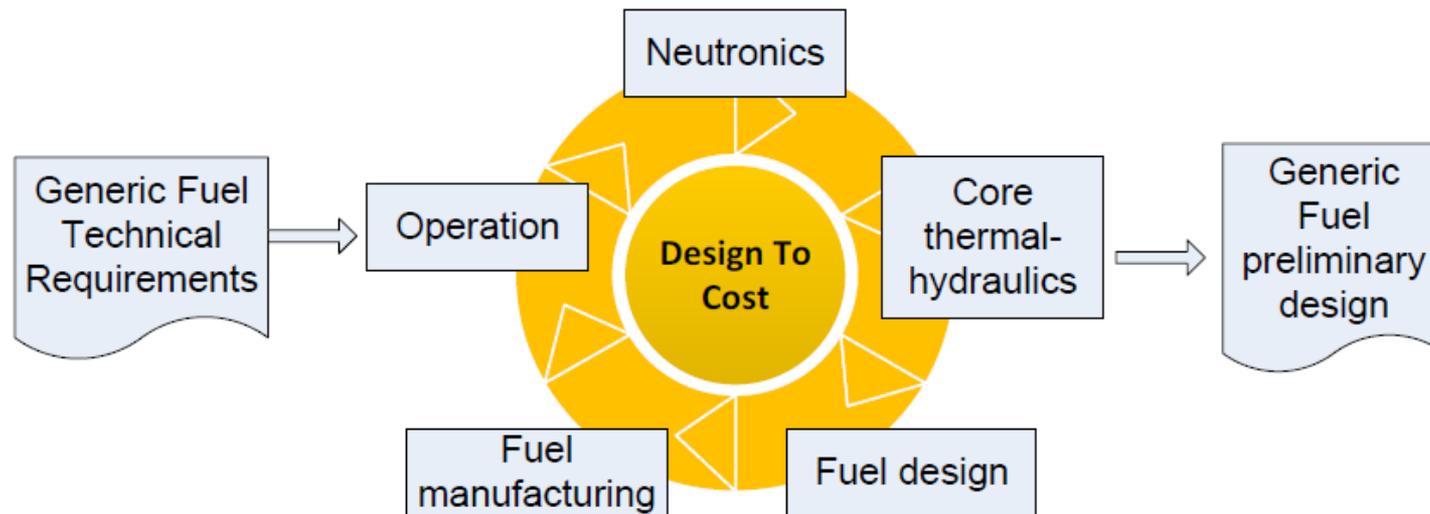


Main hypothesis (to be cost effective)

- ☒ Core and experimental load performances: at least, at the same level;
- ☒ Safety methodologies: no change of the current one;
- ☒ Main interfaces: Neither change of the control and shutdown systems components nor of the cooling systems, nor of the experimental devices, nor of the I&C, nor the core grid.

Key drivers

- ☒ A good data gathering and synthesis;
- ☒ An innovative approach of the new fuel design based on U_3Si_2 proven technology.



Summer school

☒ Place

☒ Date

Content

☒ XXX

☒ XXXX

☒ XXX

☒ XXX

Picture of the intended location

Stay tuned!

Summary

H2020 project funded until 2021 for the development of LEU fuel for HPRR and MPRR.

Robust evaluation of substitution solutions for HPRR reactors.

Complementary to HERACLES-CP H2020 project.

Framework for the development of fuels for European MPRR.

Actions targeting every levels of development: design, test, examinations, manufacturability etc.



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