MYRRHA Technology and Research Facilities in support of Heavy Liquid Metal SMR Fast Reactors

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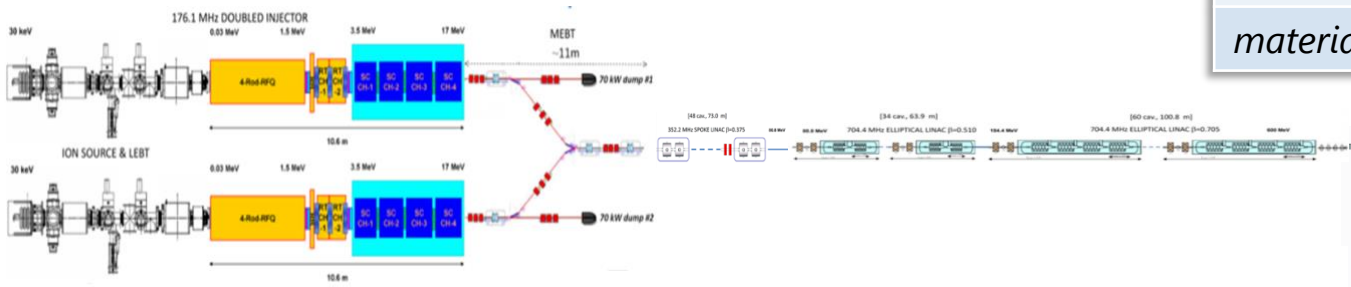
Motivation of MYRRHA

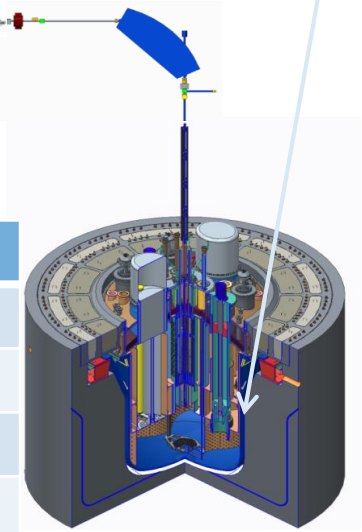
- MYRRHA – An Accelerator Driven System
  - Demonstrate the ADS concept at pre-industrial scale
    - Can operate in critical and sub-critical modes
  - Demonstrate transmutation
  - Fast neutron source → multipurpose and flexible irradiation facility

Target	
main reaction	spallation
output	$2 \cdot 10^{17}$ n/s
material	LBE (coolant)

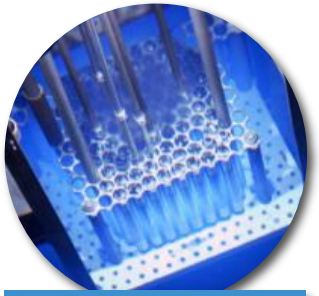


Accelerator	
particles	protons
beam energy	600 MeV
beam current	2.4 to 4 mA

Reactor	
power	65 to 100 MW_{th}
k_{eff}	0,95
spectrum	fast
coolant	LBE



MYRRHA is a multipurpose research facility, addressing end-markets with both significant societal and economic impact



Fission GEN IV

Waste

Multipurpose
h**Y**brid
Research
Reactor for
High-tech
Applications

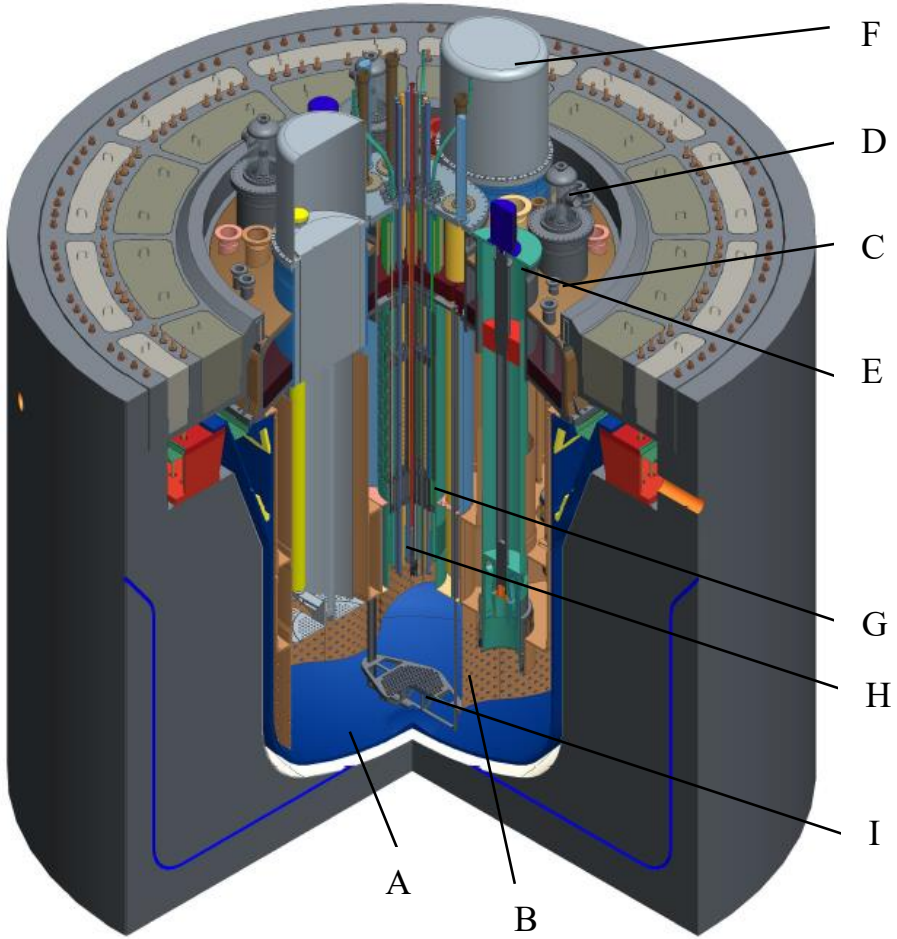
Fusion

Fundamental research

Radio-isotopes

SMR LFR

MYRRHA Current design



A. Reactor vessel
B. Diaphragm
C. Reactor Cover
D. Primary Heat Exchanger
E. Primary Pump
F. In-Vessel Fuel Handling Machine
G. Core Barrel
H. Reactor core
I. Core Restraint System

MYRRHA's phased implementation strategy

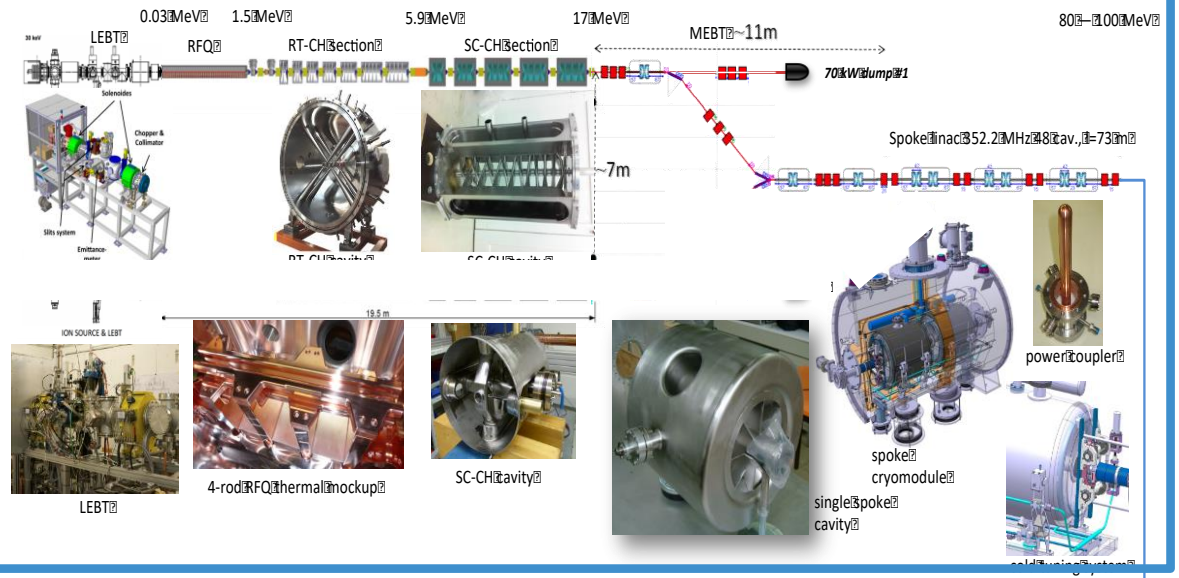
Benefits of phased approach:

- Reducing technical risk
- Spreading investment cost
- First R&D facility available in Mol end of 2026

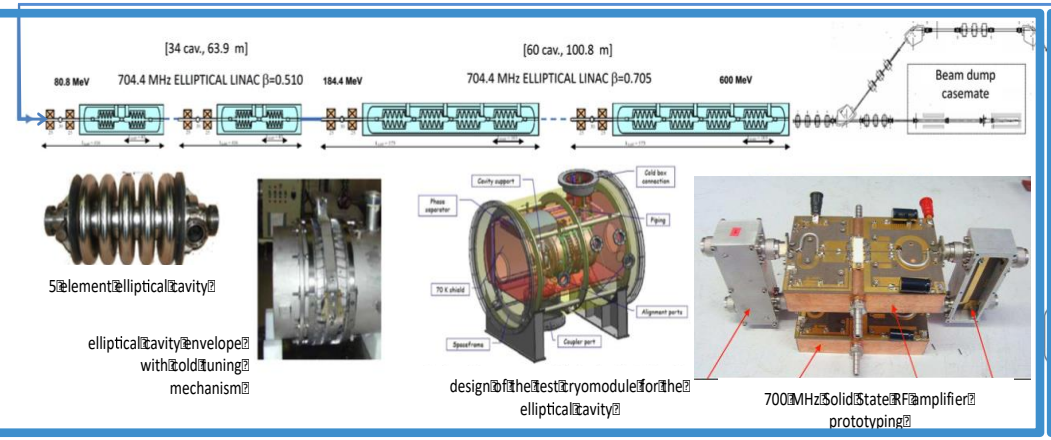
On 07/09/2018 the Belgian government secured **558 M€** to finance:

- The construction and operation of phase 1
- The preparation of phase 2 (R&D 600 MeV)
- The preparation of phase 3 (Reactor R&D and design)

Phase 1 – 100 MeV

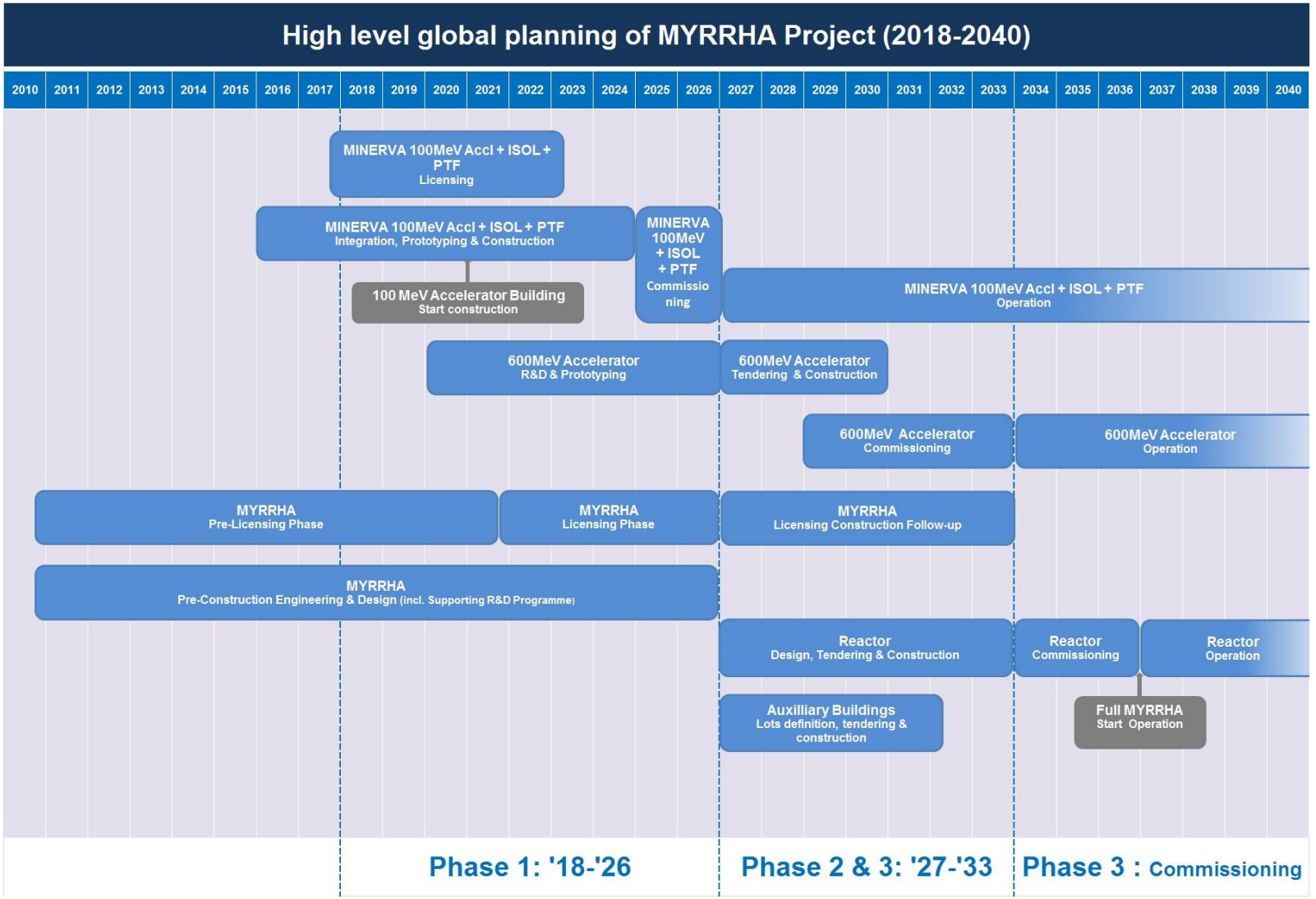


Phase 2 – 600 MeV



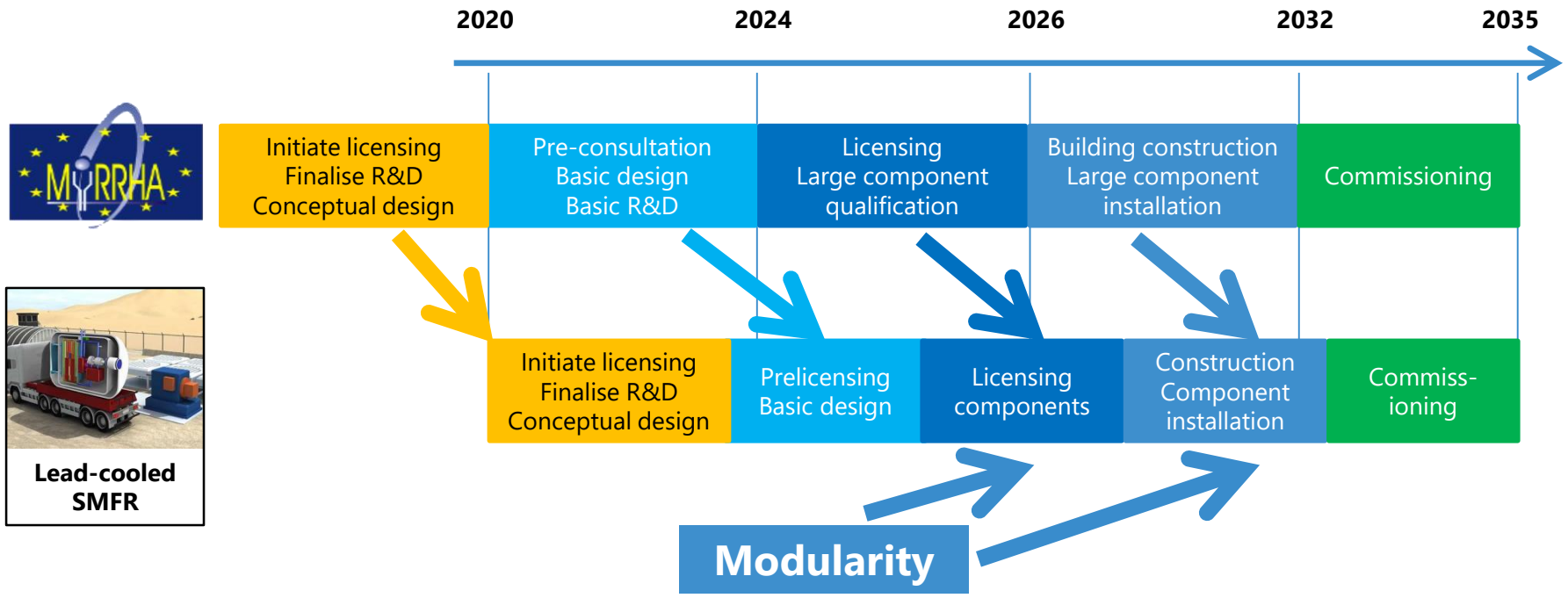
Phase 3 – Reactor

MYRRHA Schedule



Deployment strategy

- Maximize technology transfer from MYRRHA to lead-cooled SMR to benefit from development of MYRRHA



Applicability of MYRRHA R&D for the development of lead SMR

- Component testing and thermal hydraulics
  - ESCAPE
  - Complot
  - HEXACOM
  - RHAPTER
- LBE Chemistry and conditioning
  - MEXICO
  - HELIOS
  - LILIPUTTER-II
  - Heavy Metal Lab
- Materials
  - CRAFT
  - LIMITS

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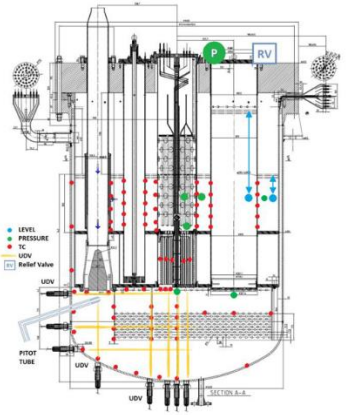
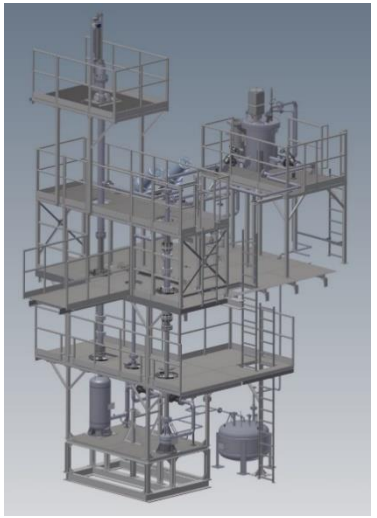
ESCAPE – European Scale Pool Experiment

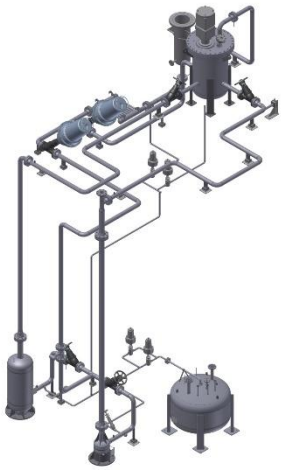
- 1/6 thermal scale model
- Thermal hydraulic behaviour of HLM in a complex pool geometry
- 27 tons of LBE at 200°C – 350°C
- 100 kW core simulation
- Forced and natural circulation
- Heavily instrumented
- Can be upgraded to 400°C



COMPLOT – Components Loop Testing

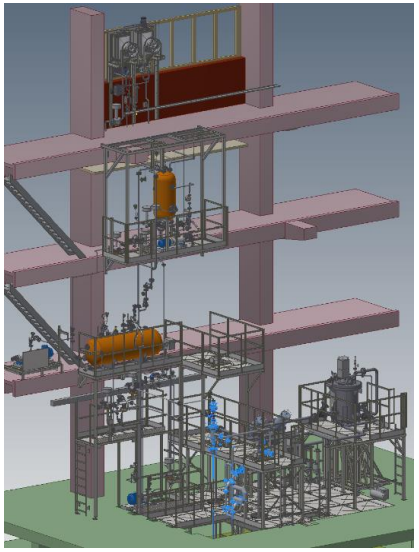
- Isothermal experimental loop for hydraulic and hydrodynamic behaviour
- Full-scale reactor core components hydraulic tests (12 m tall)
- Temperature range 200 °C – 400 °C
- Mass flow rate 3.5 kg/s – 104.8 kg/s
- Active coolant chemistry control
- 9 tons of LBE

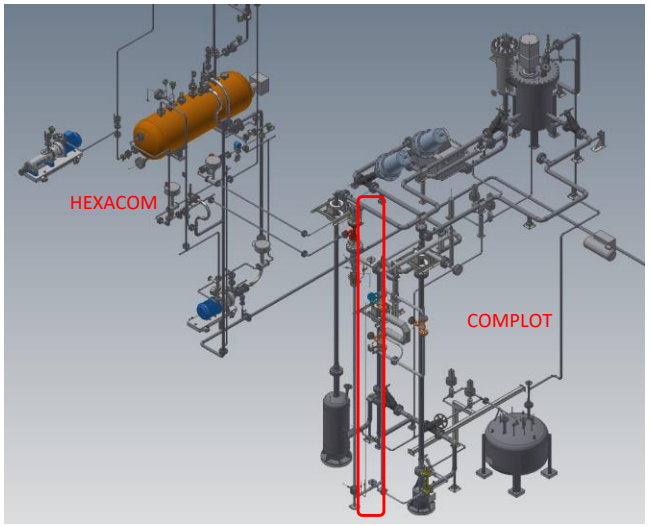




HEXACOM – Heat Exchanger at Complot

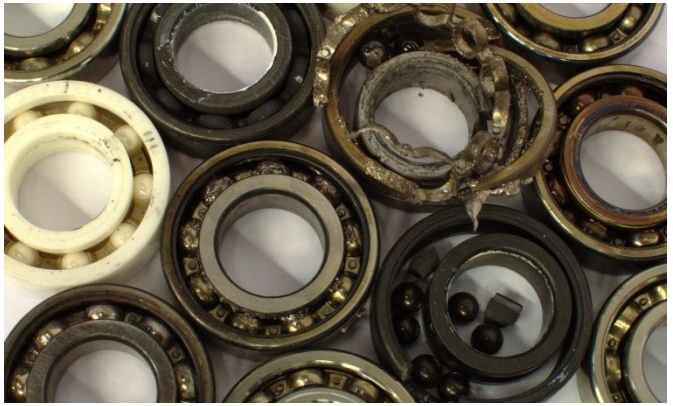
- Two-phase water-steam steam loop connected to COMPLOT
- Representative of MYRRHA Secondary Cooling System
- 100 kW of power
- Testing of heat-transfer performance of reactor heat exchanger tubes at full scale
- Testing of forced and natural circulation in the Secondary Cooling System
- Testing of anti-freezing strategies
- Design parameters secondary system: 25 bar, 250 °C and 1.1 m^3/h
- Modular design allowing different arrangements
- LBE parameters defined by COMPLOT





RHAPTER – Remote Handling Proof-of-principle

- Test and validate mechanical components submerged in LBE
- Components: bearings, gears, springs, moving electrical cabling, …
- Test of mechanical components up to 445 mm diameter and 350 mm height
- Temperatures from 150 °C to 450 °C
- Two shafts to power the component and create different loading situations
- Can be upgraded with a conditioning system



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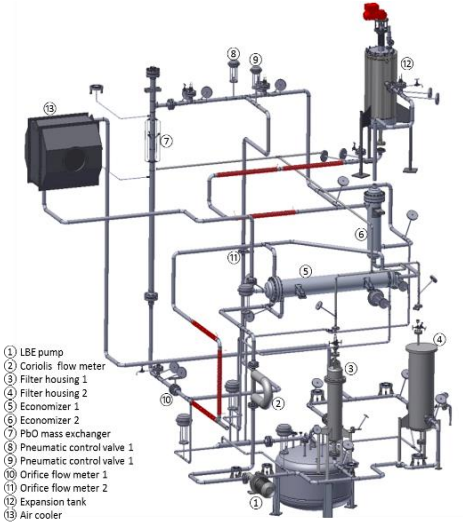
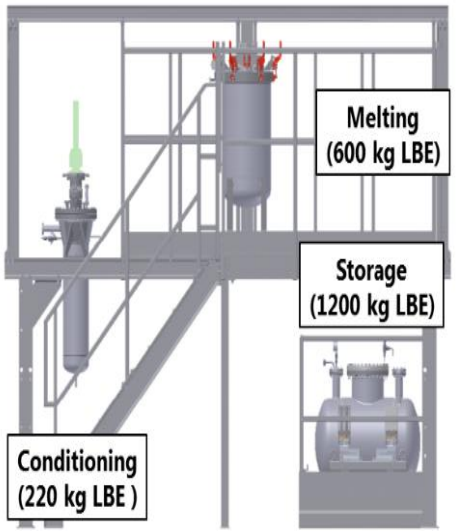
MEXICO – Mass Exchange In Continuous Operation

- Testing of different oxygen control systems
- Evaluation of efficiency and expected life time of filtration systems for purifying LBE of oxides
- 7 tons of LBE
- Temperatures range from 200 °C to 450 °C
- Upgradable from 350 °C to 550 °C



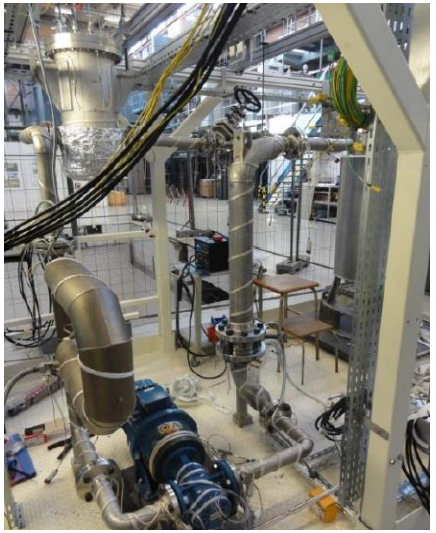
HELIOS – Heavy Liquid metal Oxygen conditioning System

- LBE conditioning and storage setup
- Investigate conditioning systems
- Study calamity mitigation strategies after possible steam ingress
- Testing of spargers and impellers inserts for gas bubbling
- Operating at 450 °C



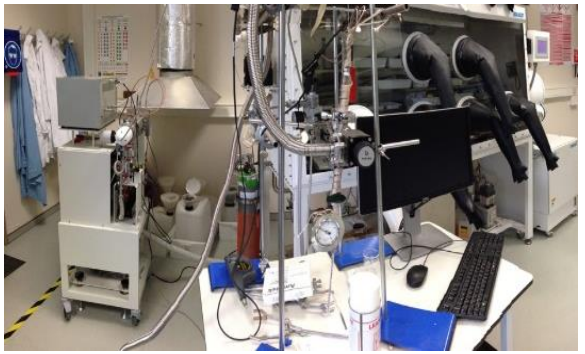
LILIPUTTER-II – Liquid Lead alloy Innovative Pump Technology Test Rig

- Small LBE pump test loop modified for filter testing
- Upgraded with oxygen control system for cold trap development
- Limited to 200 °C by a screw spindle pump but upgradable to 400 °C



Heavy Metal Lab

- Laboratory for chemistry experiments with heavy metals
- Study of impurity evaporation from heavy metals under various conditions of temperature and gas atmosphere composition
- Dedicated setups for evaporation up to 1000 °C
- Autoclaves for oxygen sensor and oxygen-pump testing, and for corrosion studies up to 500 °C
- A dedicated lab for polonium release studies from LBE or lead up to 1000 °C under flowing Ar, H2 and H2O and deposition of Po-species on different media



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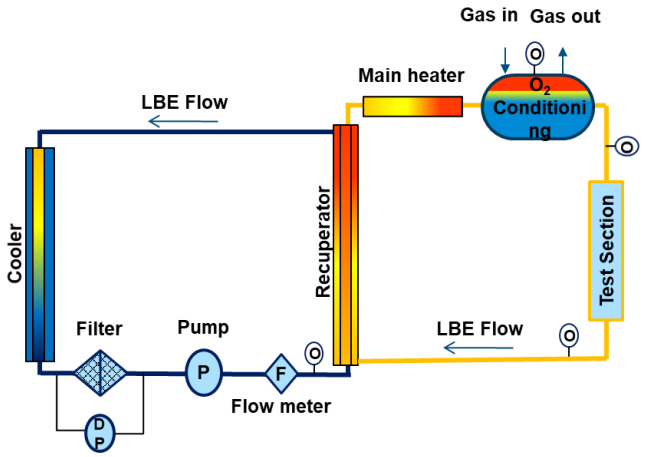
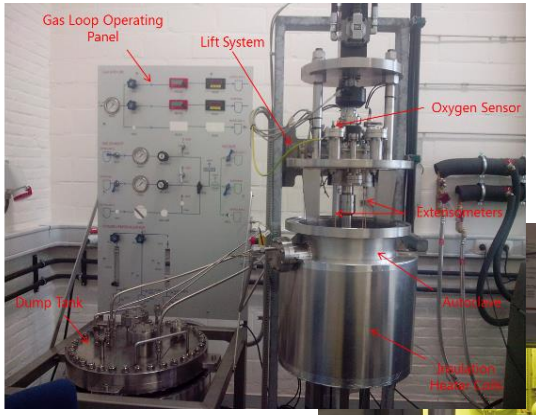
CRAFT – Corrosion Research for Advanced Fast reactor Technology

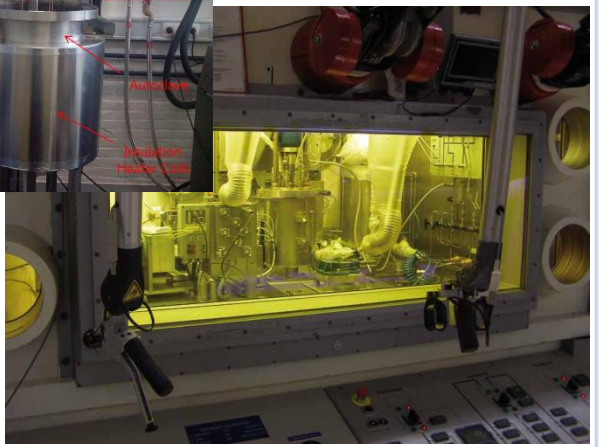
- Installation for long term corrosion experiments on candidate materials in flowing LBE
- Operates at representative conditions of temperatures, LBE velocities and dissolved oxygen concentrations of MYRRHA
- Cold leg runs at 200 °C but is designed for 450 °C
- Hot leg is equipped with two material-test sections which can run up to 550 °C
- 4 tons LBE, 10 kg LBE/s, flow velocities up to 5 m/s
- Equipped with oxygen control and monitoring system for long term experiments
- Also equipped with 12 test stations for stagnant corrosion tests in oygen free environment for tests in PbBi, Pb, PbLi and Li

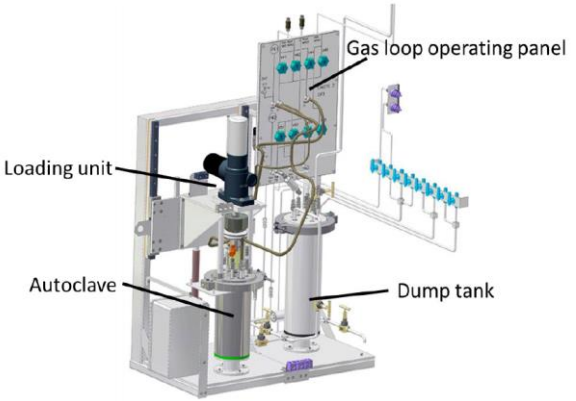


LIMITS – Liquid Metals Test Stands

- Experimental set-ups for mechanical testing of materials in stagnant LBE
- 4 Installations in operation
- Controlled oxygen concentration and continuously monitored
- Temperature up to 550 °C
- Equipped to perform tensile, fracture toughness, slow strain rate, constant load and crack growth rate experiments
- One set-up in a hot-cell for testing of irradiated and alpha-contaminated samples
- One set-up for fatigue tests in liquid metal with an extensometer on the sample



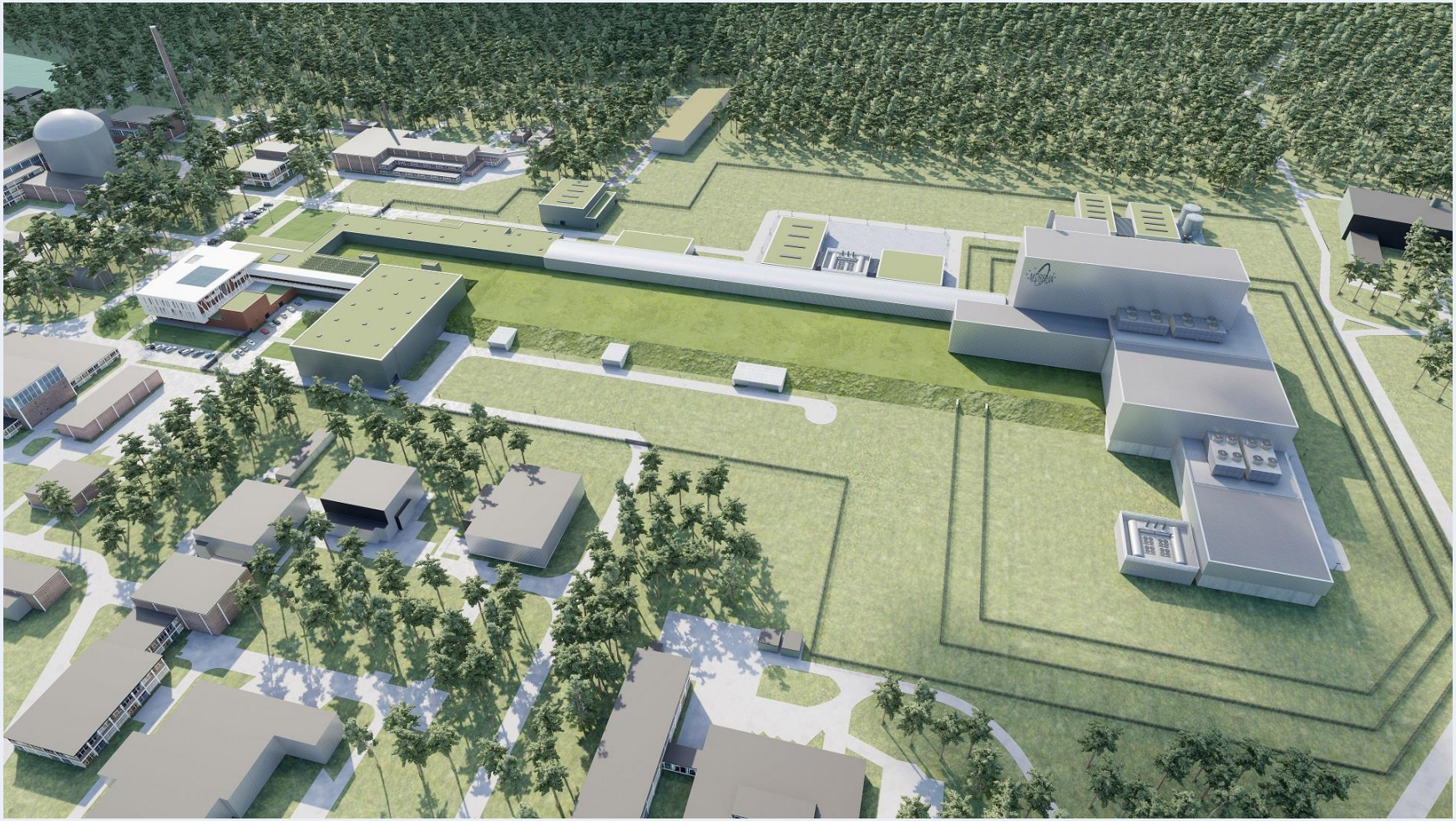




Conclusion

- MYRRHA as technology test platform for Heavy Liquid Metal cooled reactor technology for Gen IV systems and HLM-based SMR's
  - The MYRRHA reactor programme with its associated R&D and licensing experience can support the development of SMR working with LBE or Lead as coolant.
  - The R&D facilities can be converted or upgraded to the specific needs of lead and contribute to the qualification of materials and components of these systems
  - The design and licensing experience gained during the MYRRHA development can help to accelerate the deployment of the lead fast reactors of the SMR type
  - In a later phase MYRRHA can be used for the further qualification of materials, fuel and components which will help to improve these first generation of lead based SMR's

A jump in the future for innovation in Belgium



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