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Towards the renewal of the European Area of Experimental Research Reactors
The MYRRHA project

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(SCK-CEN; VUB)

IGORR Conference, September, Knoxville, US

Key role of Research Reactors (RR)

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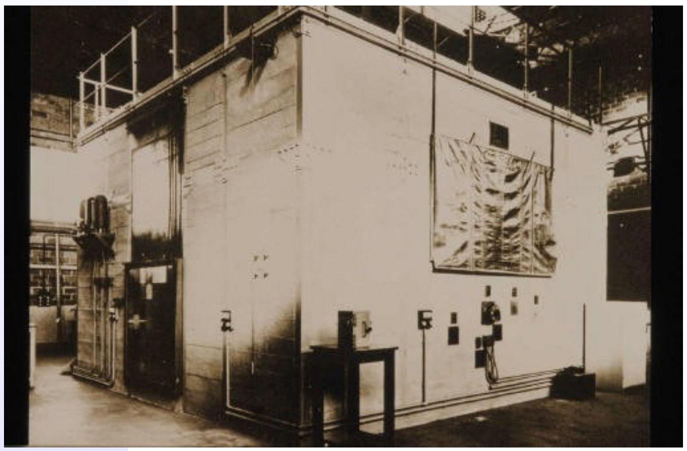
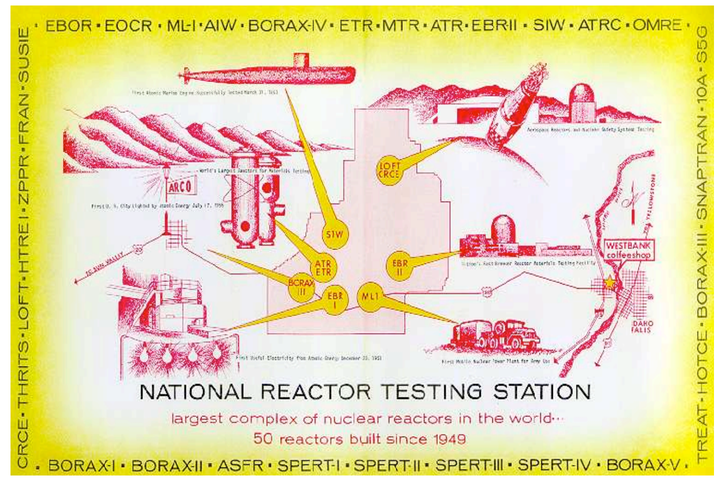
- Flexible irradiation reactors (MTR)
  - R&D in nuclear engineeering (materials and fuel)
  - Production of radioisotopes
- Neutron beam reactors with high neutron flux beams.
  - High neutron fluxes are probing matter and fundamental laws
  - Basic science
  - Neutronography
- Critical assemblies (Zero Power Reactor)
- Reactors for safety research programs
- Reactors for teaching and training
- Technology Pilot Plants, demonstration reactors and prototypes for new reactor type development

The golden age of research reactors (50-70)

- In France about 30 RR were built between 1948 and 1980
- In the US, at INL 50 RR were built in the same nuclear center



ZOE (1948-1976)



- After the golden age of the research reactors (1950 to 1970's….), modification of operating rules and ageing infrastructures have lead to a significant decrease in available research reactors.

Examples of current fleet of RR (2009)

- Europe
  - France: 8 RR (7 by CEA – HFR by ILL) in a wide range of activities:
    - 3 Zero Power Reactors for reactor physics studies
    - 1 dedicated reactors for safety experimentation
    - 2 neutron source reactors for fundamental research
    - 1 Material Testing Reactor for studies under irradiation
    - 1 education and training reactors
  - Belgium: 4 RR
    - BR1, BR2, BR3, VENUS

- US at INL: mainly 2 RR in operation
  - ATR and ATR-C

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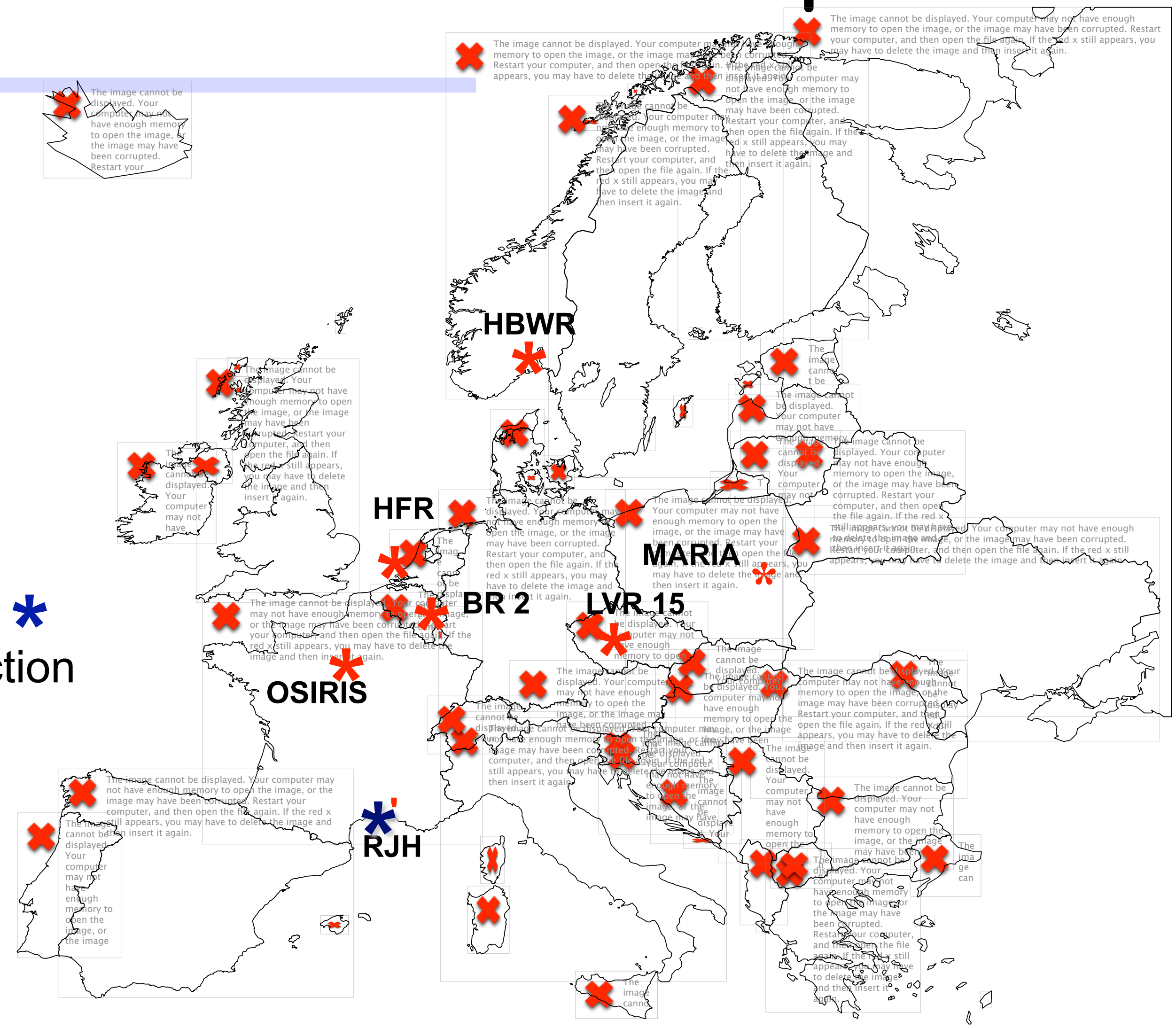
European Situation: an ageing fleet of MTR in Europe



under construction *

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The Radio Isotopes Crisis

- Tc-99m, derived from Molybdenum99 (Mo-99), is used in over 80% of nuclear medicine procedures
  - About 70 millions of medicine procedures per year
- Due to successive closure of several old reactors (as R2 in Sweden) , today 95% of the production is supplied by 5 reactors in the world : Safari in South Africa (13%), HFR in Netherlands (33%), OSIRIS in France (8%), BR2 in Belgium (10%), and NRU in Canada.(31%)
- These reactors are now old and the cost of maintenance and refurbishment are drastically increasing .
- Moreover some Radio Isotopes production dedicated reactor like MAPPLE in Canada, will never start.(AECL decision in may 2008).

Solutions for radio-isotopes production?

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- At short term, repair and maintain the old reactors
- Increase the capacity of existing reactors
  - BR2: additional cycle, 6 instead 4 RI production rigs
- In the medium term use the possibilities of other reactors (as FRM2, LVR-15, MARIA)
  - main difficulty: transportation
- Prepare the renewal of the ERAER
- In any case, we have to increase the irradiation cost.

Towards the renewal of the European Experimental Reactors

- Necessity to define and implement a consistent EER policy:
  - Meeting industry and public bodies needs
  - Keeping a high level of scientific expertise
  - With a limited number of EER's (compromise between specialisation, complementarities and back-up capacities)
  - To be put in operation in this decade or in the next one
  - To be consistent with the roadmap for new infrastructures for sustainable nuclear development (ESNII)

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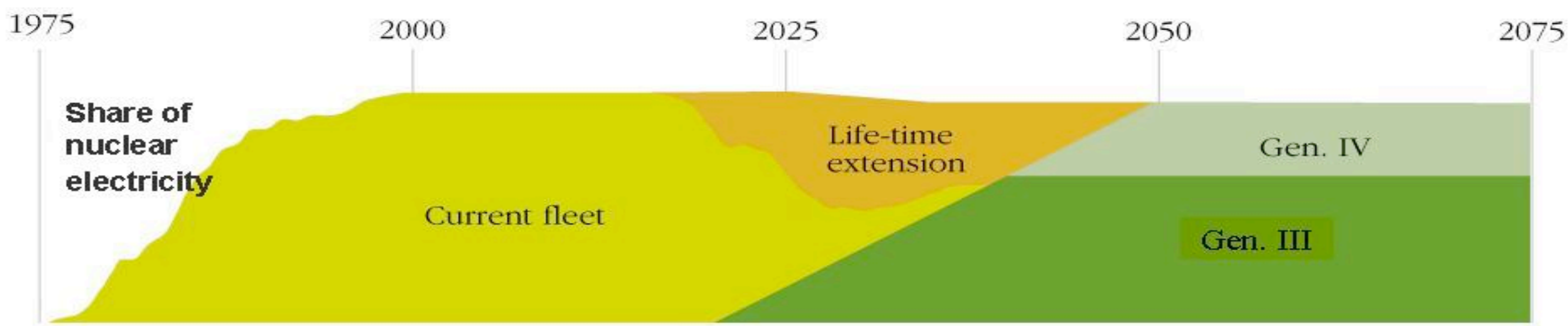
Towards sustainable nuclear energy

- **Gen IV:**
  - Sustainability and U resource preservation: x 50-100,
  - Waste management Improvement.



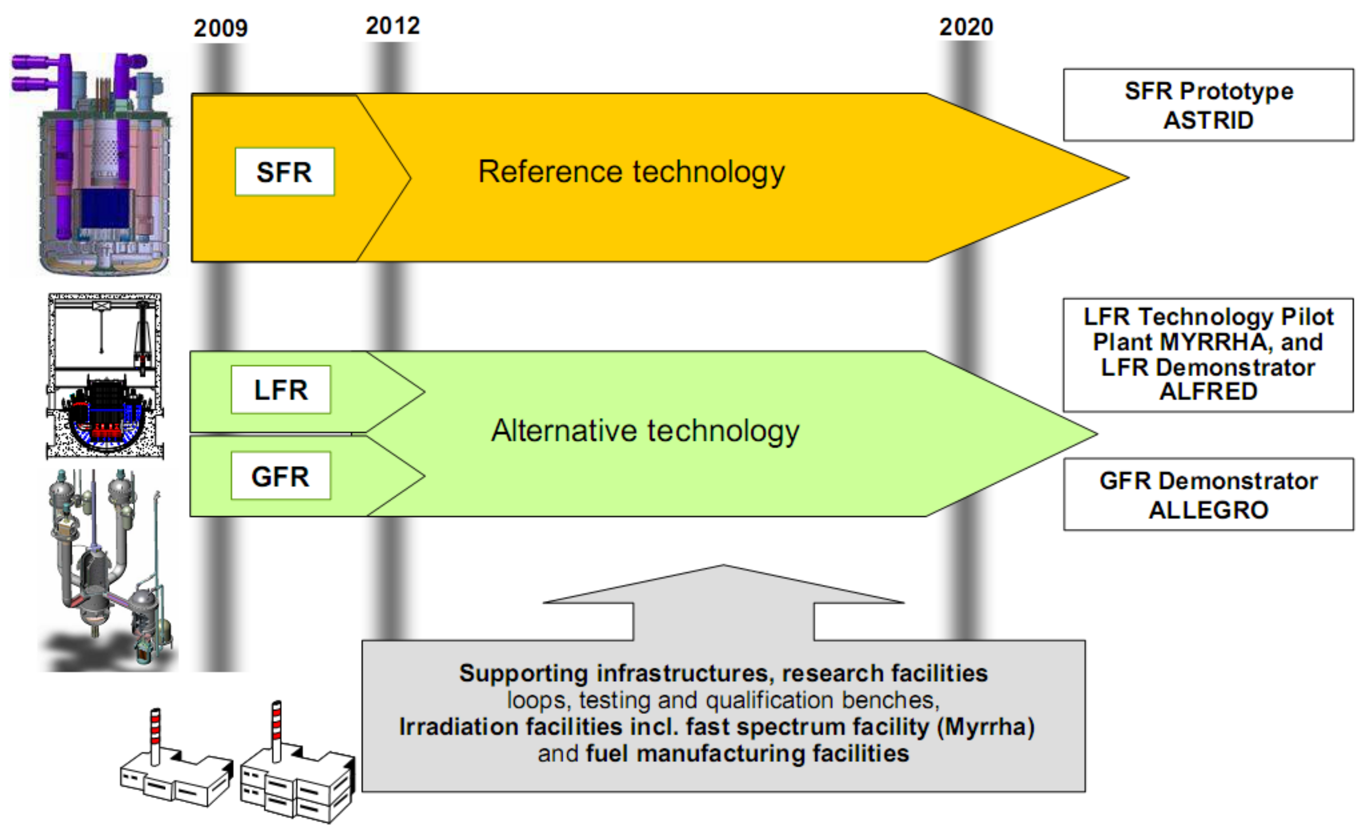
- **Major role of LWRs in the 21st century:**
  - Current PWRs (Gen II): life time management (> 40yr),
  - Gen III PWRs : starting around 2015.

- **Deployment of fast neutron systems (around 2040)**

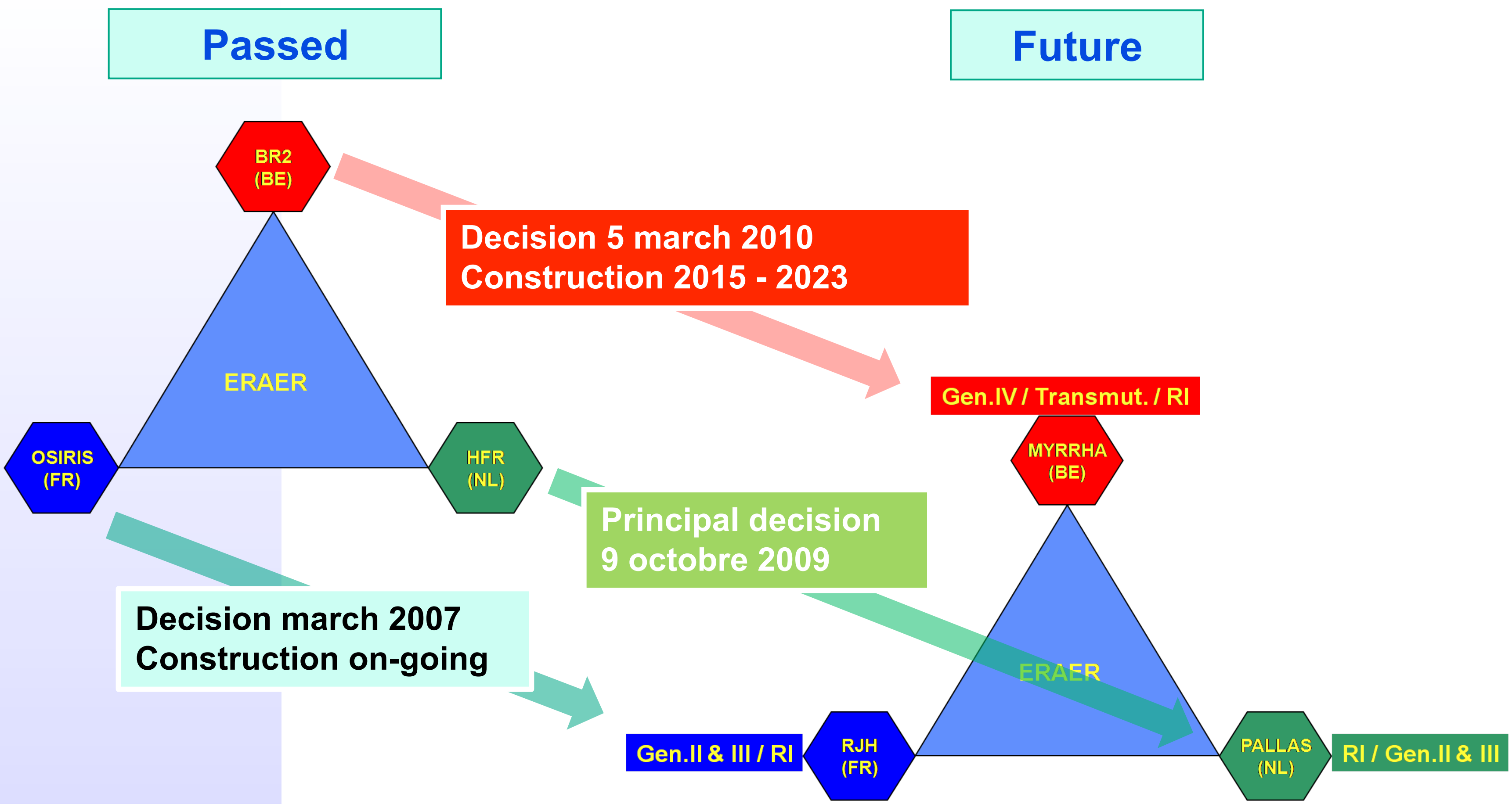
➔ **European Sustainable Nuclear Industrial Initiative (ESNII) within the SET-plan of Europe**

The European Sustainable Nuclear Industrial Initiative

2040: Target for the deployment of Gen-IV Fast Neutron Reactors with Closed Fuel Cycle.



European Research Area on Experimental Reactors Perspective



ERAER = European Research Area for Experimental Reactors

Goals of MYRRHA

- A flexible fast-spectrum neutron irradiation facility as successor of the SCK•CEN MTR BR2 (100 MW)
  - for material and fuel research
  - for the production of medical radioisotopes
- A full step ADS demo facility for transmutation of long-lived high-level waste
- Play the role of European technology Pilot Plant (ETPP) for LFR
- Fundamental research facility at the accelerator

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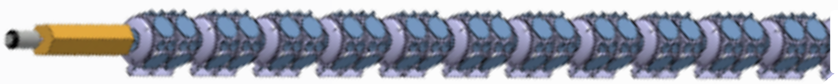
MYRRHA: innovative and unique

Accelerator
(600 MeV – 4 mA proton)

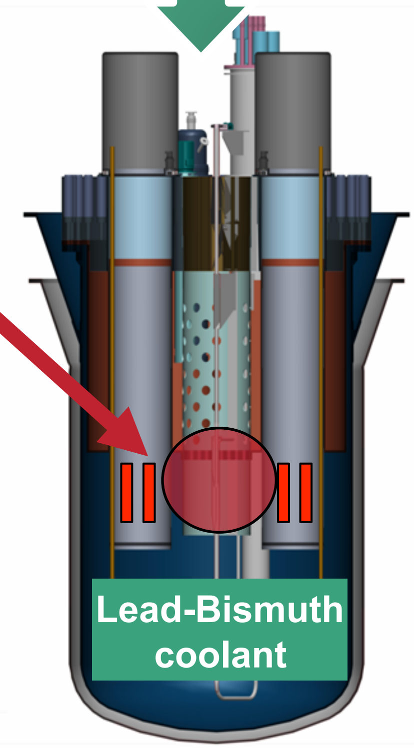


Reactor
- subcritical mode (50-100 MWth)
- critical mode (~100 MWth)

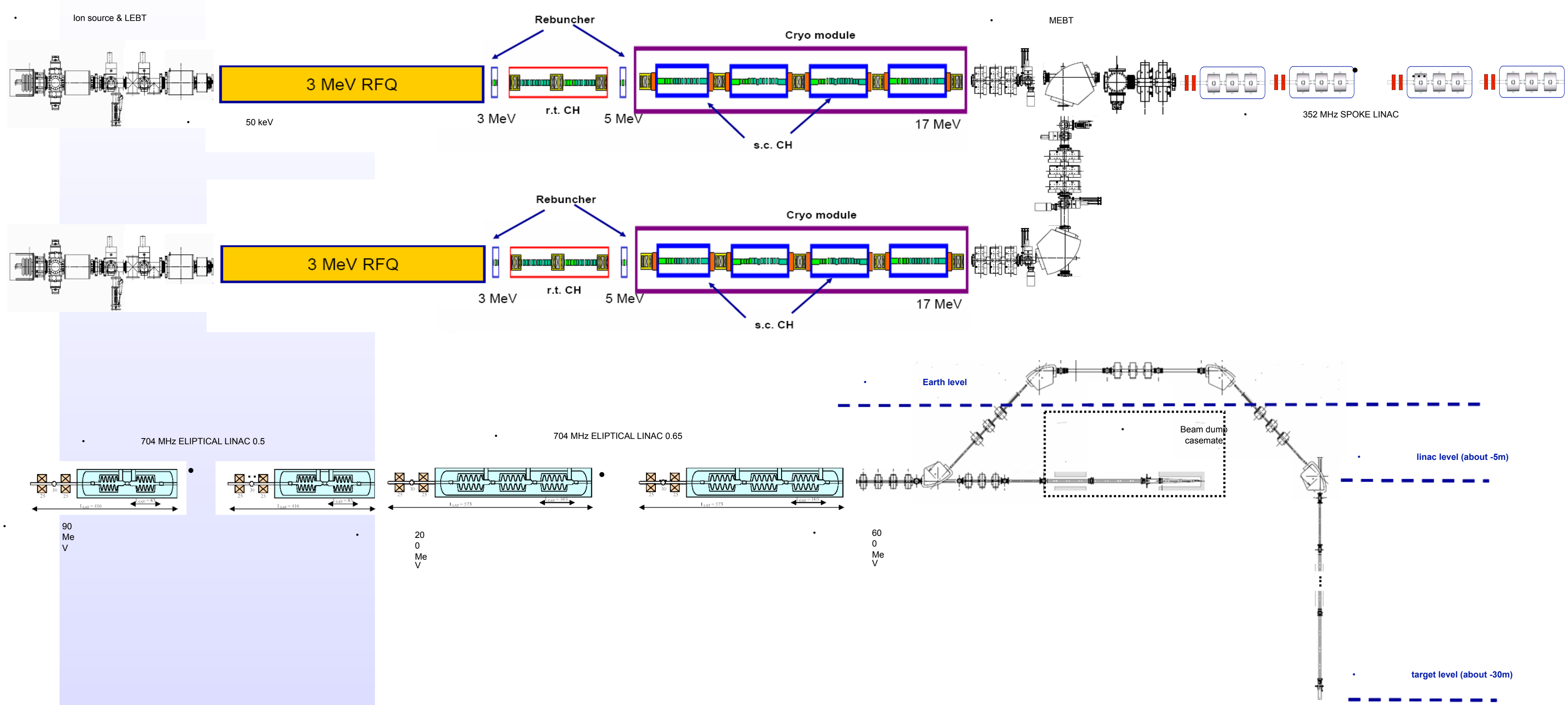
Spallation source

Fast neutron source

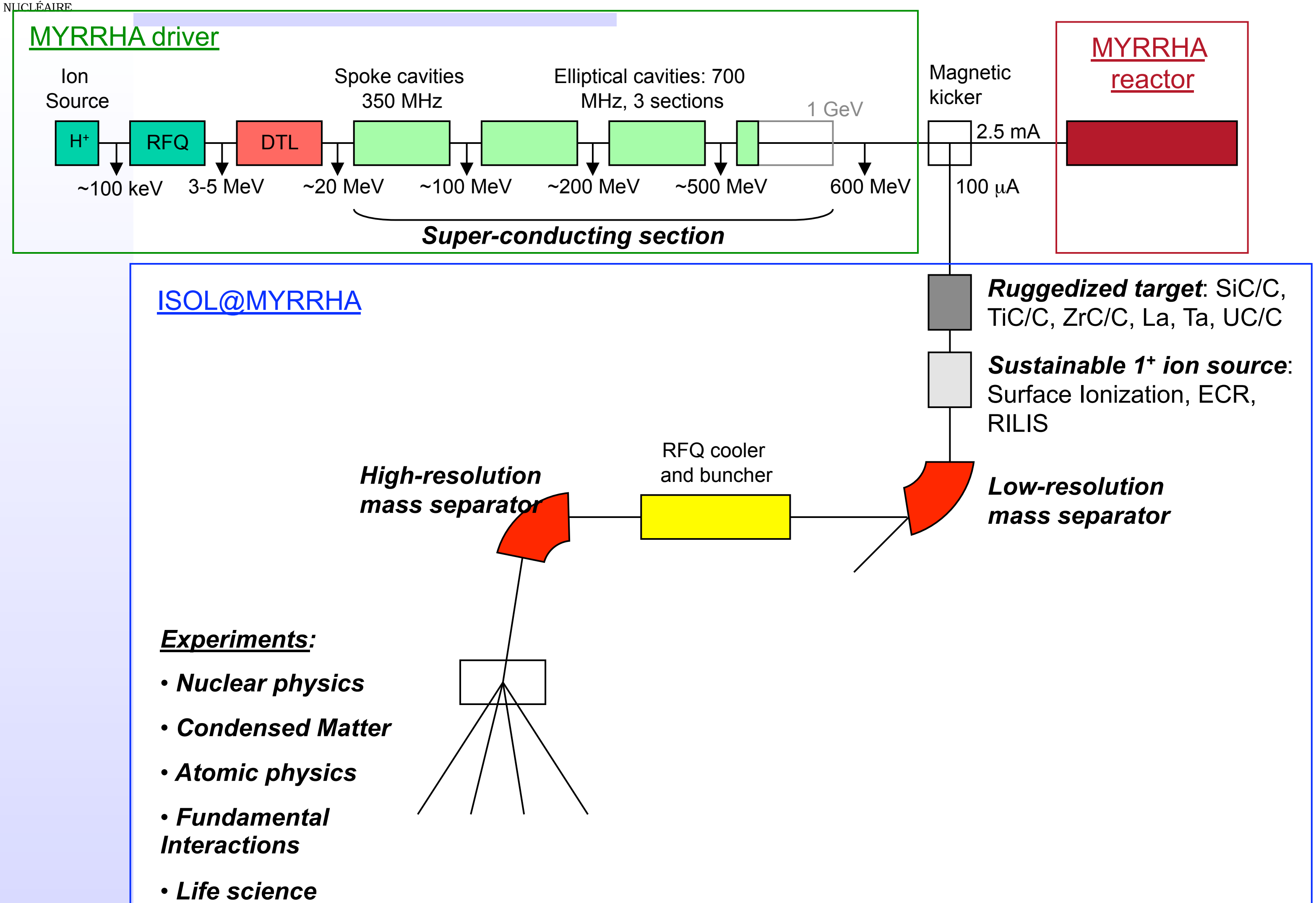
Multipurpose flexible irradiation facility



Accelerator - layout



ISOL@MYRRHA lay-out



Reactor layout

Inner vessel

Cover

Core structure

Spallation window

Heat exchangers

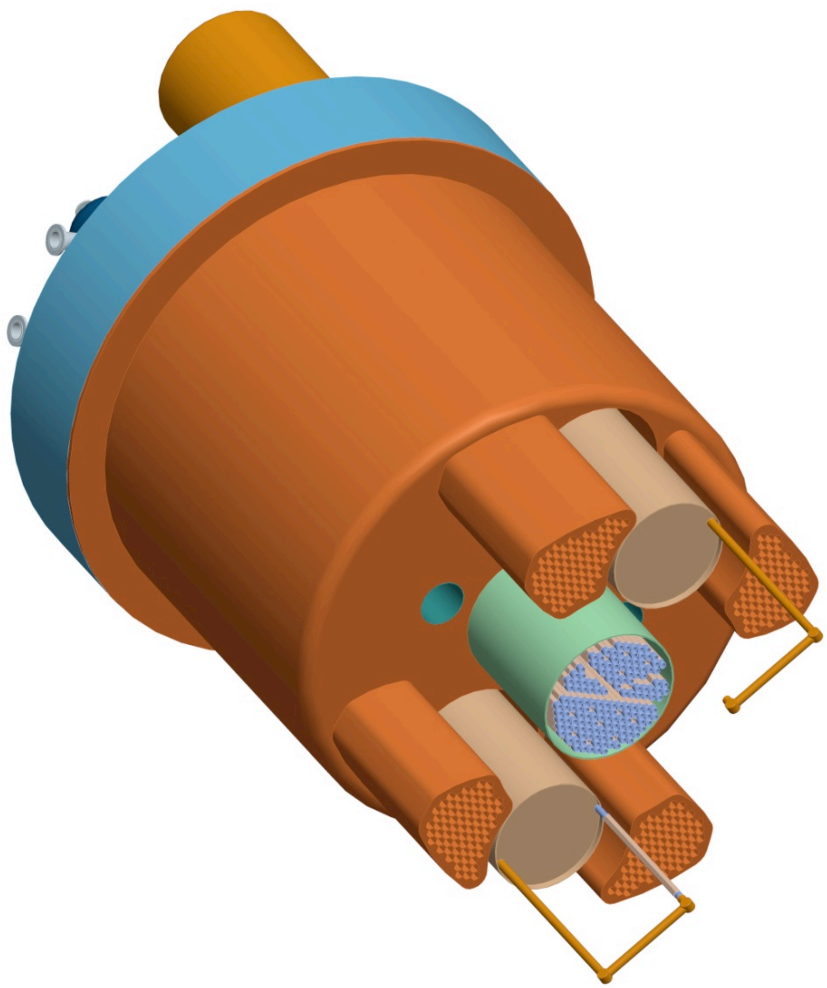
Pumps

Diaphragm

Fuel manipulators

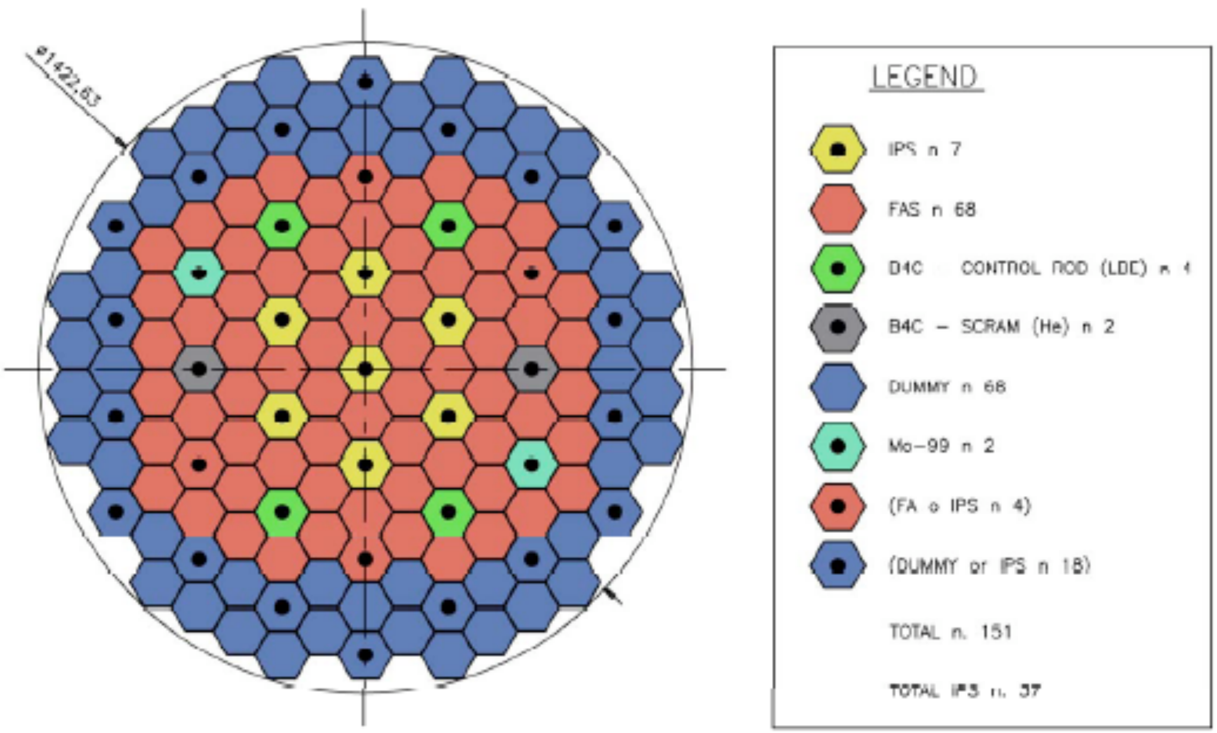
Guard vessel

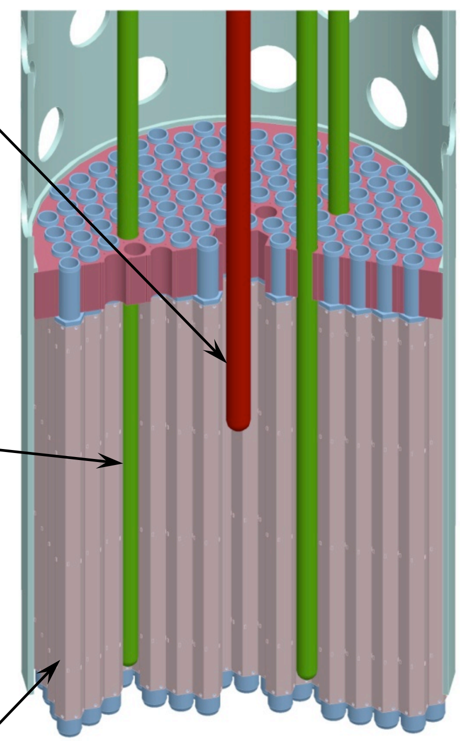
Fuel storage



Reactor layout – 1. Core

- k_{eff}≈0.95 (ADS mode)
- 30-35 % MOX fuel
- 7 IPS positions





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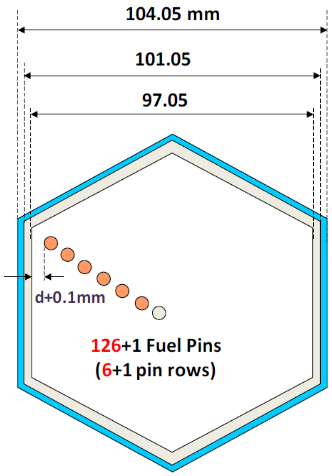
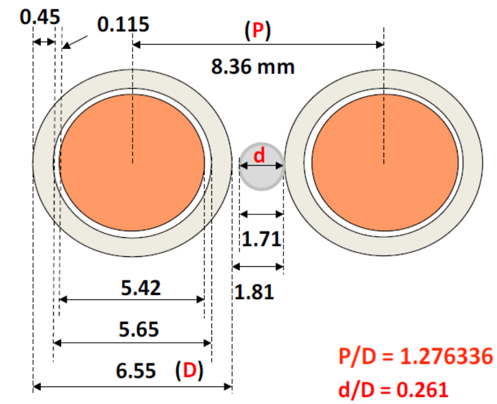
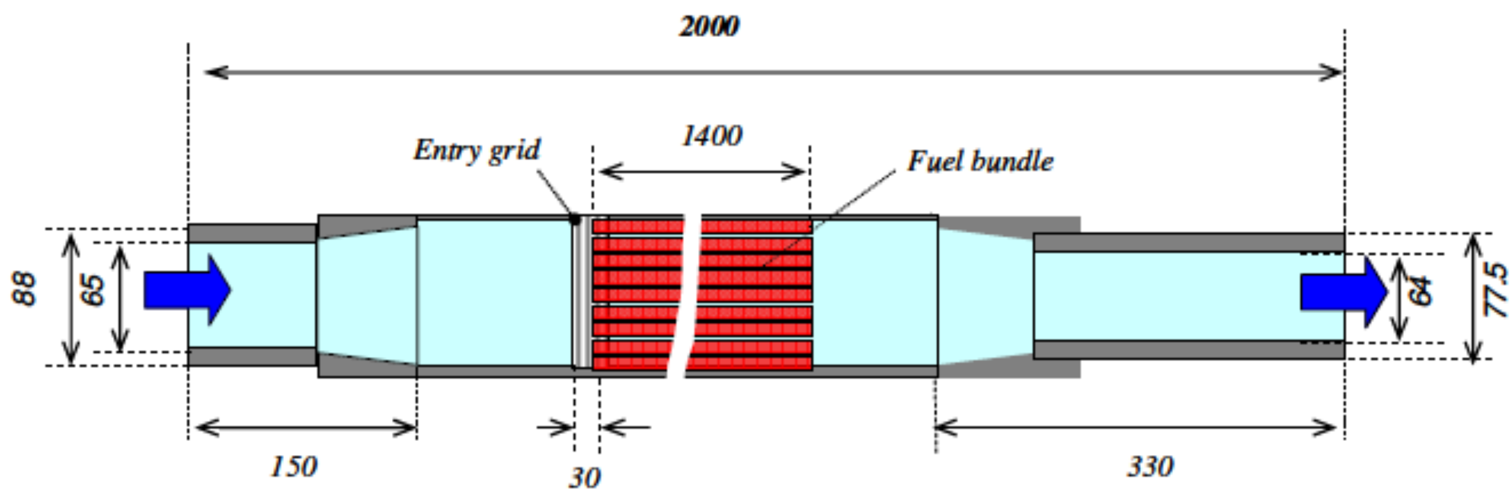
Reactor layout – 2. Fuel assembly

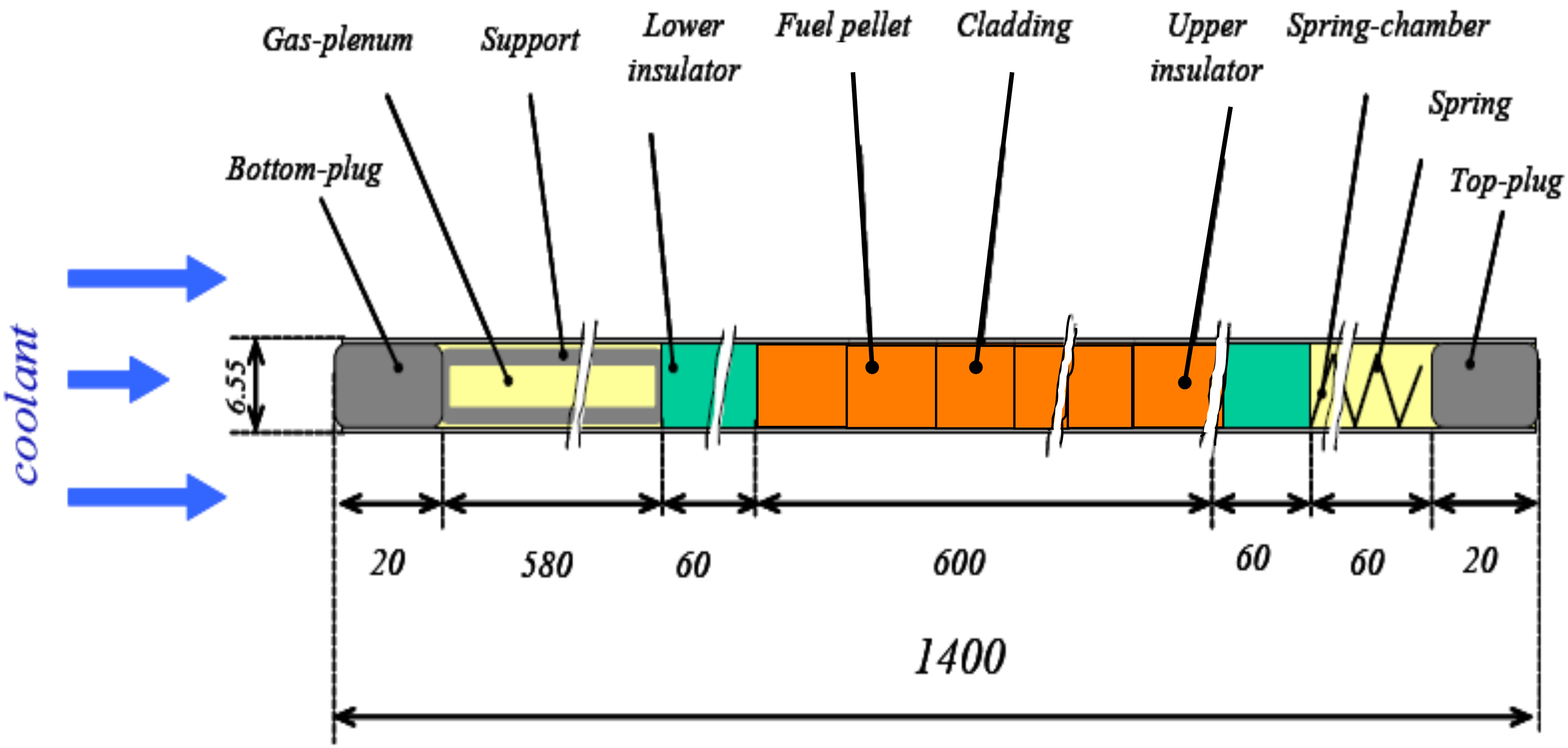
- Phenix fuel
  - Cladding in 15-15 Ti
  - Wire wrap



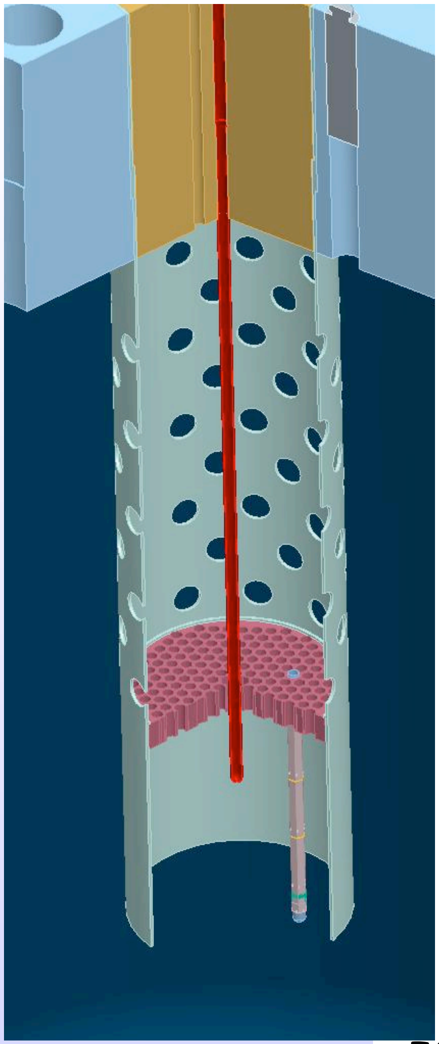




Reactor layout – 3. Fuel pin

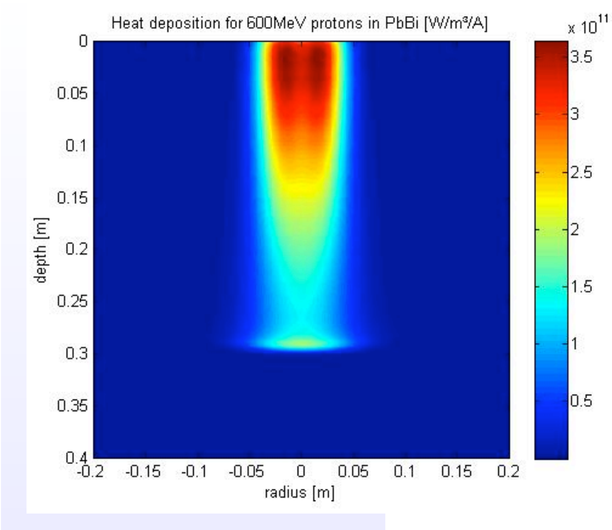


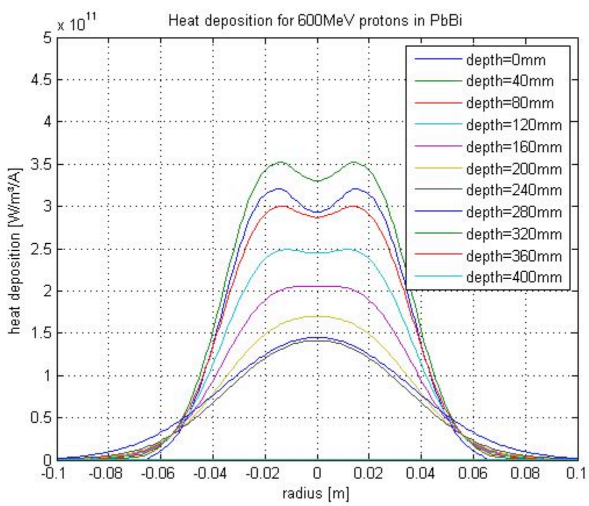
Spallation target window (1/2)



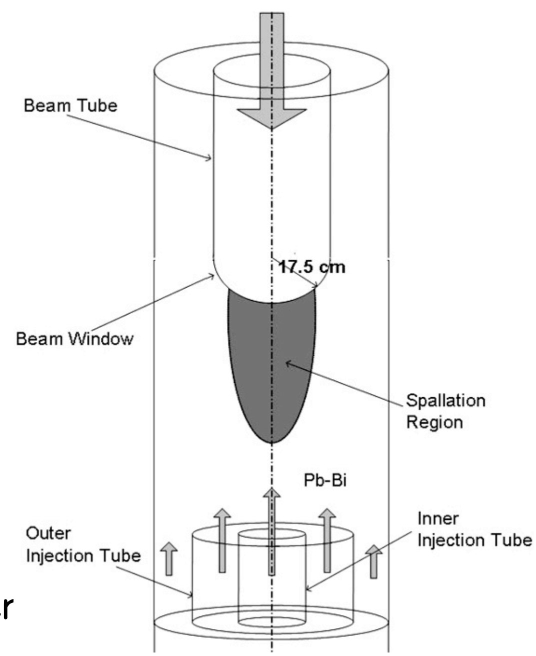
- produce about 10^{17} neutrons/s at the reactor mid-plane to feed subcritical core @ keff=0.95
- fit into a central hole in core
  - compact target
  - remove produced heat
- accept megawatt proton beam
  - 600 MeV, 3.5 mA → ~2.1 MW heat
  - Cooling of window is feasible
- Material challenges
  - Preferential working temperature: 450 – 500°C
  - Service life of at least 3 full power months (1 cycle) is achievable

Spallation target window (2/2)

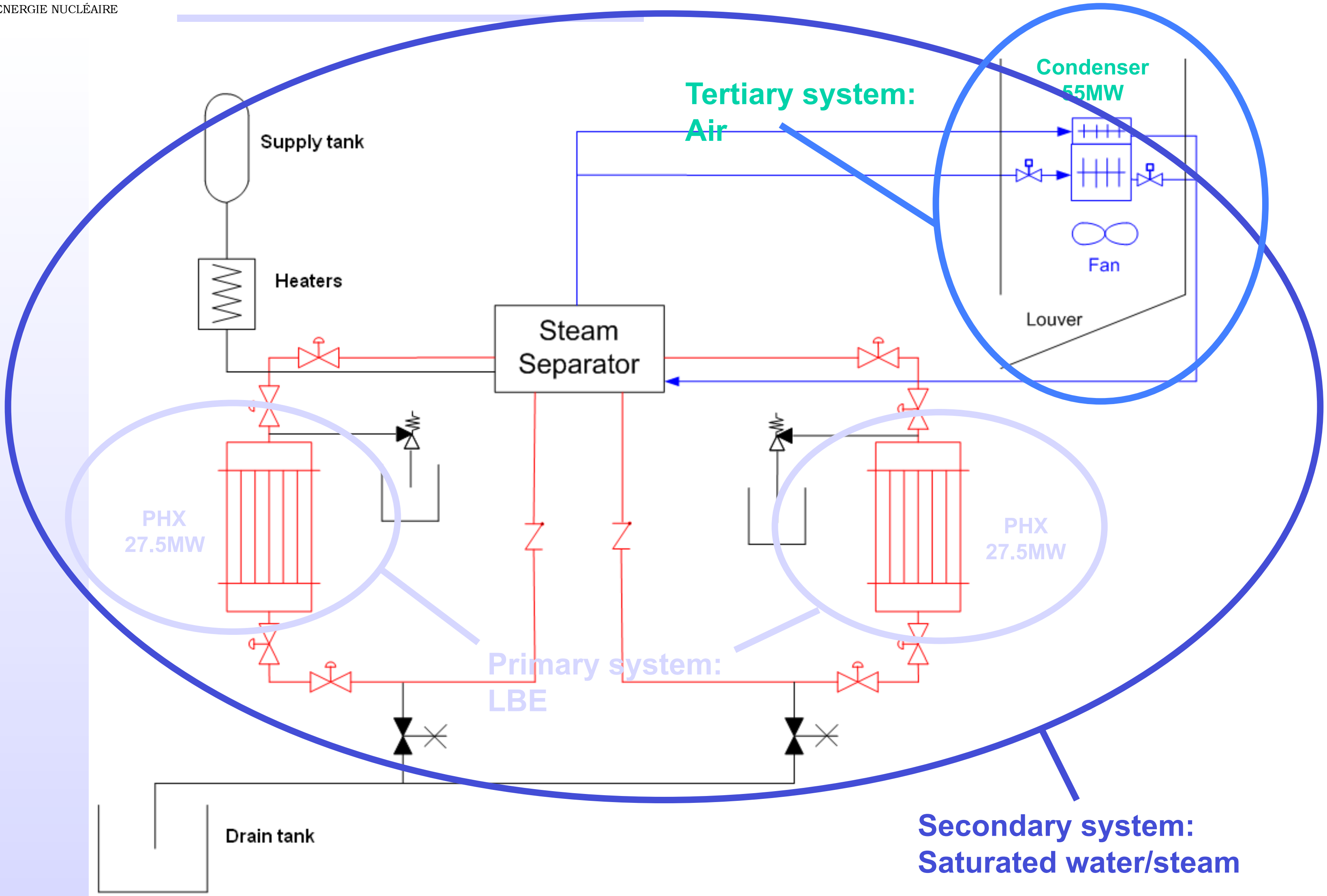




- Rotating beam σ 15 mm sweep 25 mm
- Limited heat deposition at stagnation point
- Multi tube concept
  - 3 Concentric inlet tubes



Cooling systems – secondary and tertiary system



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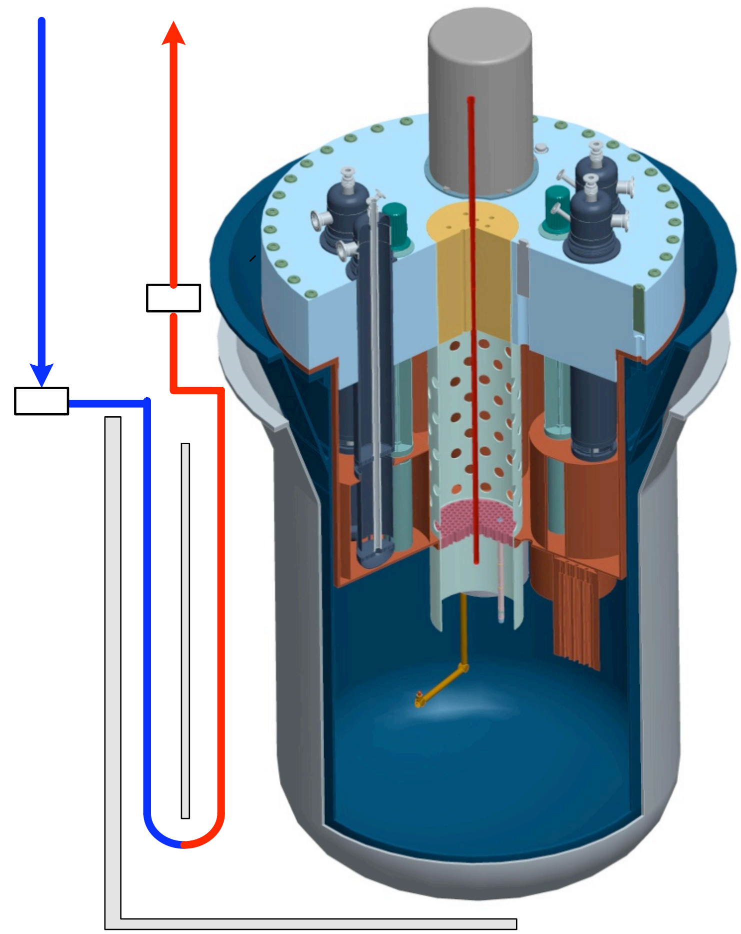
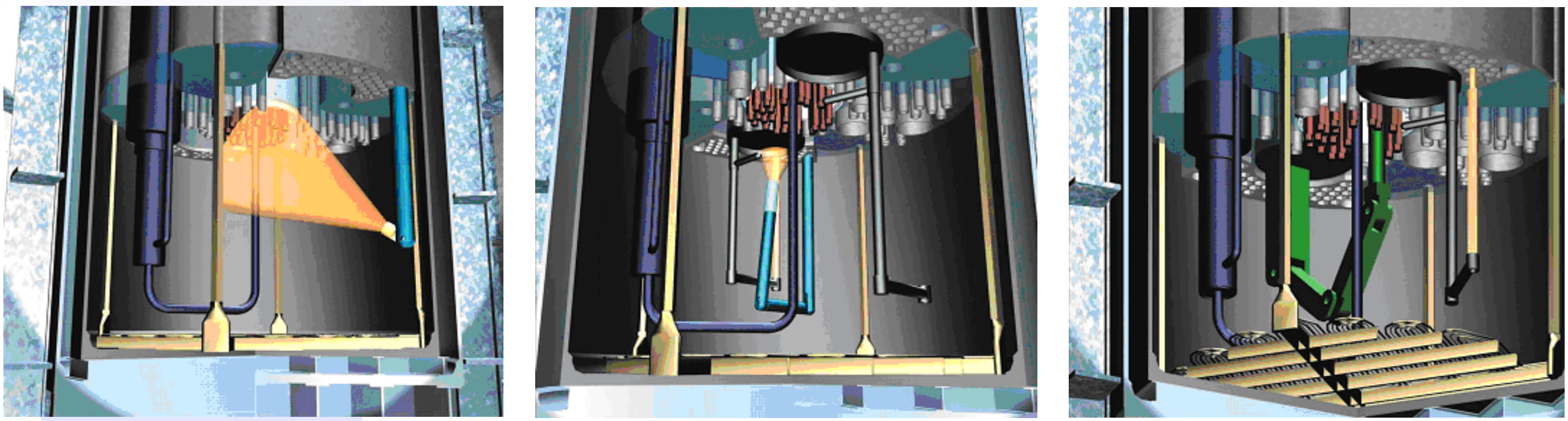
Cooling systems – secondary and tertiary system

- Decay heat removal (DHR) through secondary loops
  - 2 independent loops
  - redundancy (each loop has 100% capability – min. sized for 3% continuous power)
  - passive operation (natural convection in primary, secondary and tertiary loop)
- Ultimate DHR through RVCS (natural convection)



Operation and maintenance In service inspection with US and in-vessel repair



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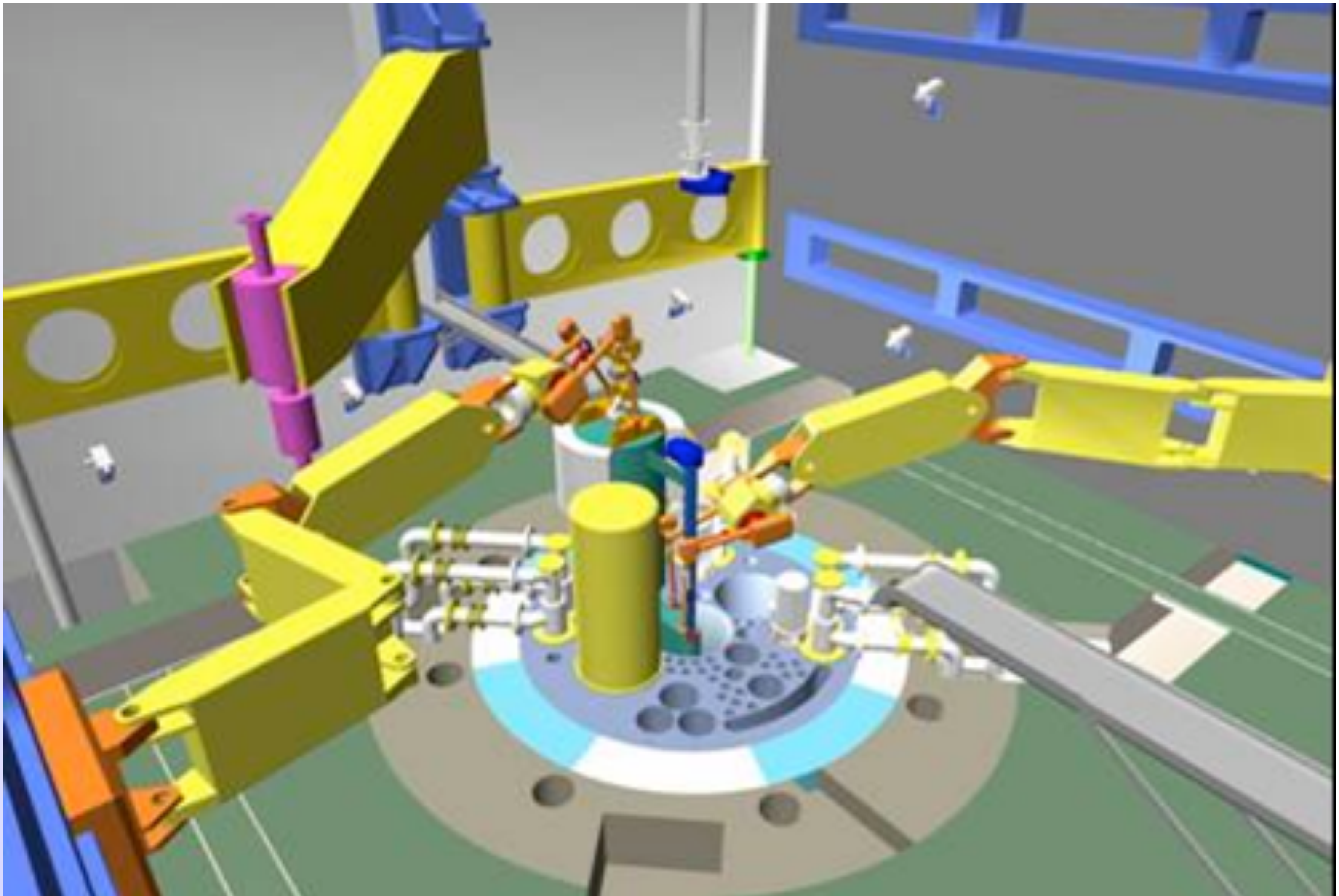
Operation and maintenance
Ex-vessel remote handling



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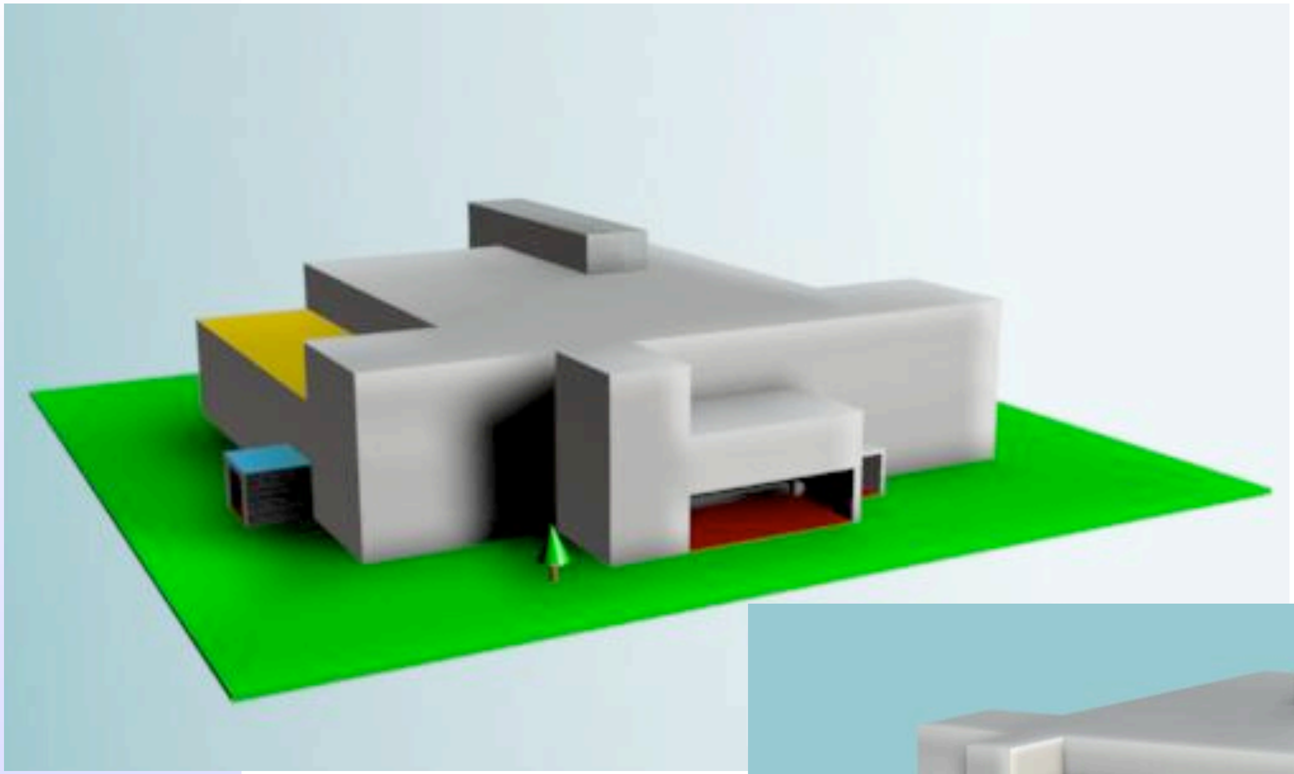
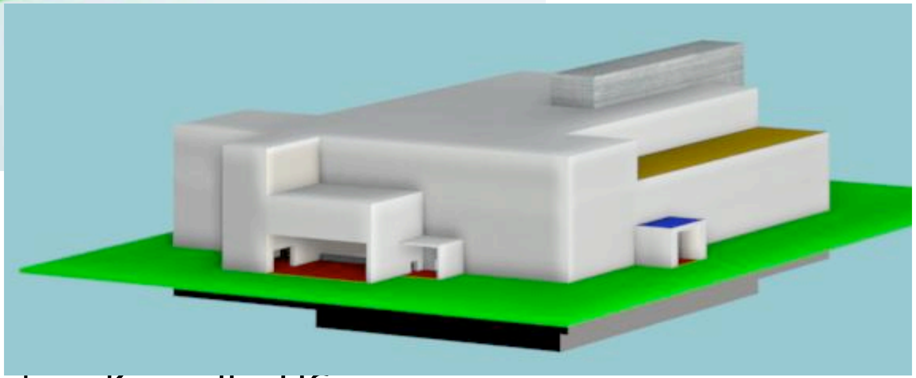
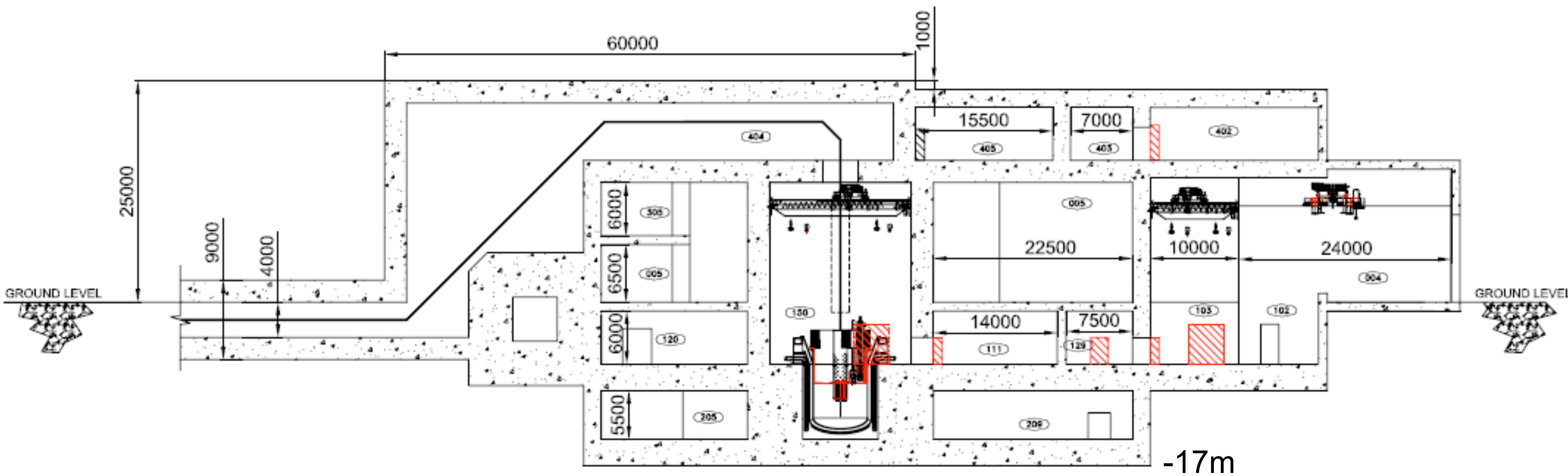
Building layout and reactor hall – the reactor building





Building layout and reactor hall – the reactor building



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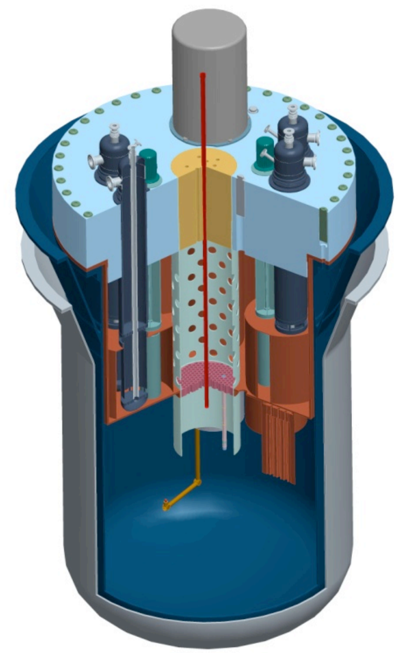
Project schedule

- **2010-2014** Front End Engineering Design
- **2014-2015** Specifications Drafting & Tendering
- **2016-2018** Construction of components & Civil engineering
- **2019** On site assembly
- **2020-2022** Commissioning
- **2023** Progressive start-up
- **2024-** Full exploitation

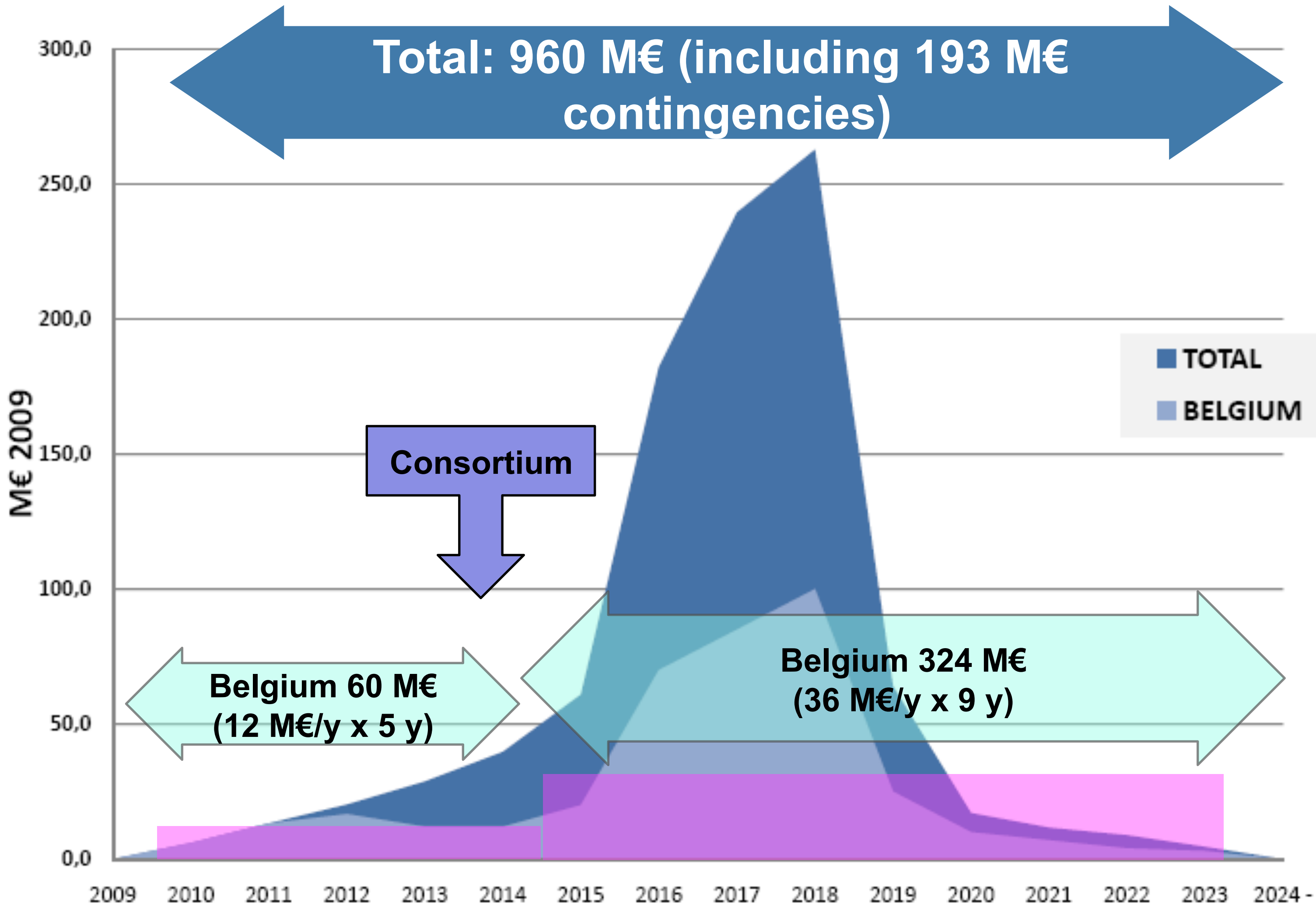








MYRRHA Investment



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MYRRHA 2010-2014 Project Plan

1	**Minimise technological risks**	Accelerator x	Spallation target x	Sub-critical reactor	
2	**Secure the licensing**	**PDP** preliminary dismantling plan	**PSAR** preliminary safety assesment	**EIAR** environmental impact assesment	**FEED** (Front End Engineering Design)
3	**Implement a sound management structure**	Int. Members Consortium	Central Project Team	FEED Engineer	

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International Members Consortium

Primary «investors»	*Participation vehicle (Consortium members)*	*Contribution to investment capital (960 M€'09)*	***«ERIC»*** (*)
Belgian Federal Ministry of Economy and Climate change (**50%**) Belgian Federal Ministry of Science Policy (**50%**)	**SCK•CEN** (on behalf of Belgian Federal Government)	**40 %**	**BEL**
Major asian partner	**Asian partner** Participation Vehicle	**… 20 %**	**Asian partner**
EU countries + EU	**EU countries** (national institutes) **+** **EU participation**	**< 30 %**	**EU countries**
ROW countries (US, KZ,…)	**ROW** participation	**> 10 %**	**ROW**

(*) European Research Infrastructure Consortium

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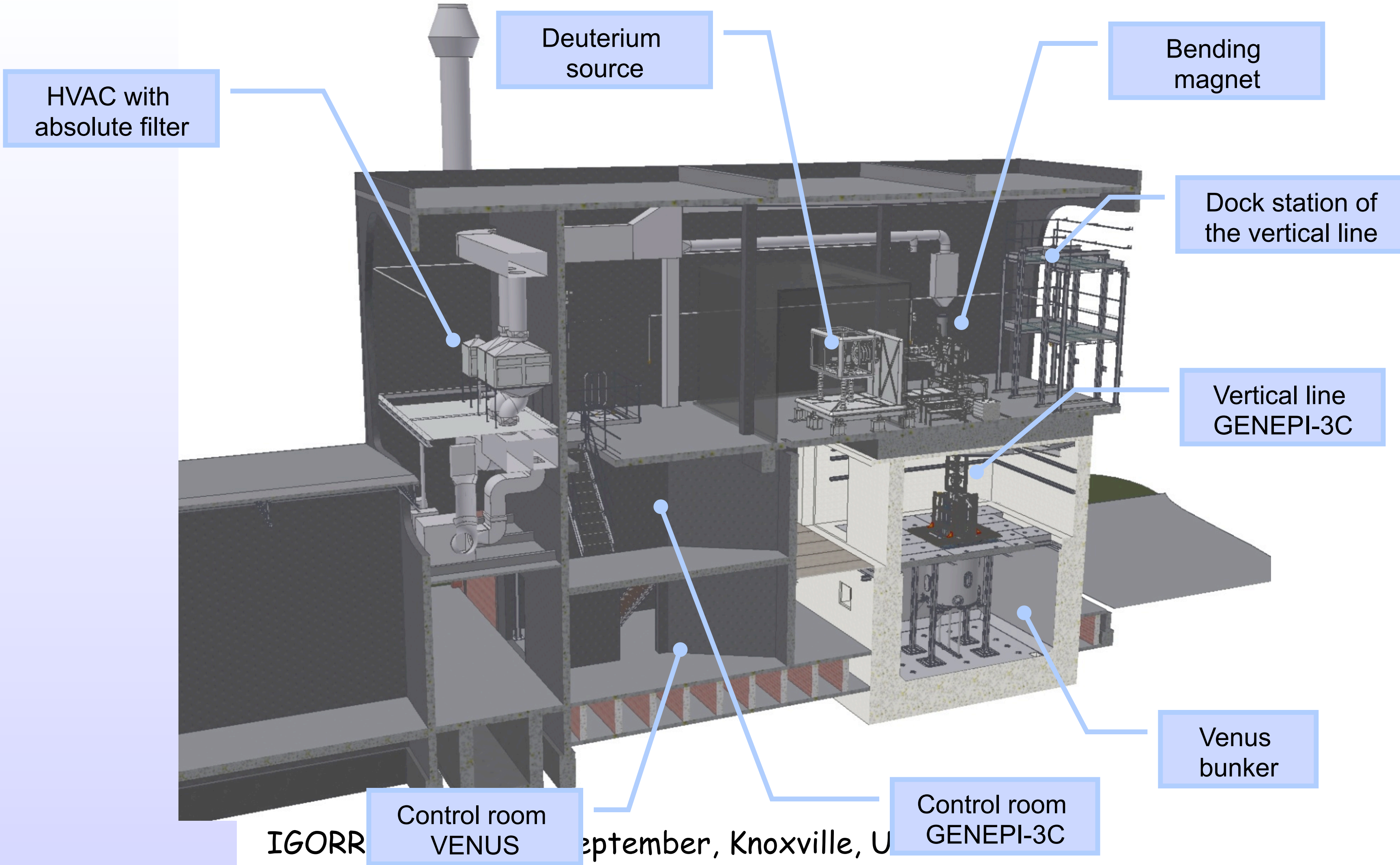
From VENUS to GUINEVERE: the accelerator room



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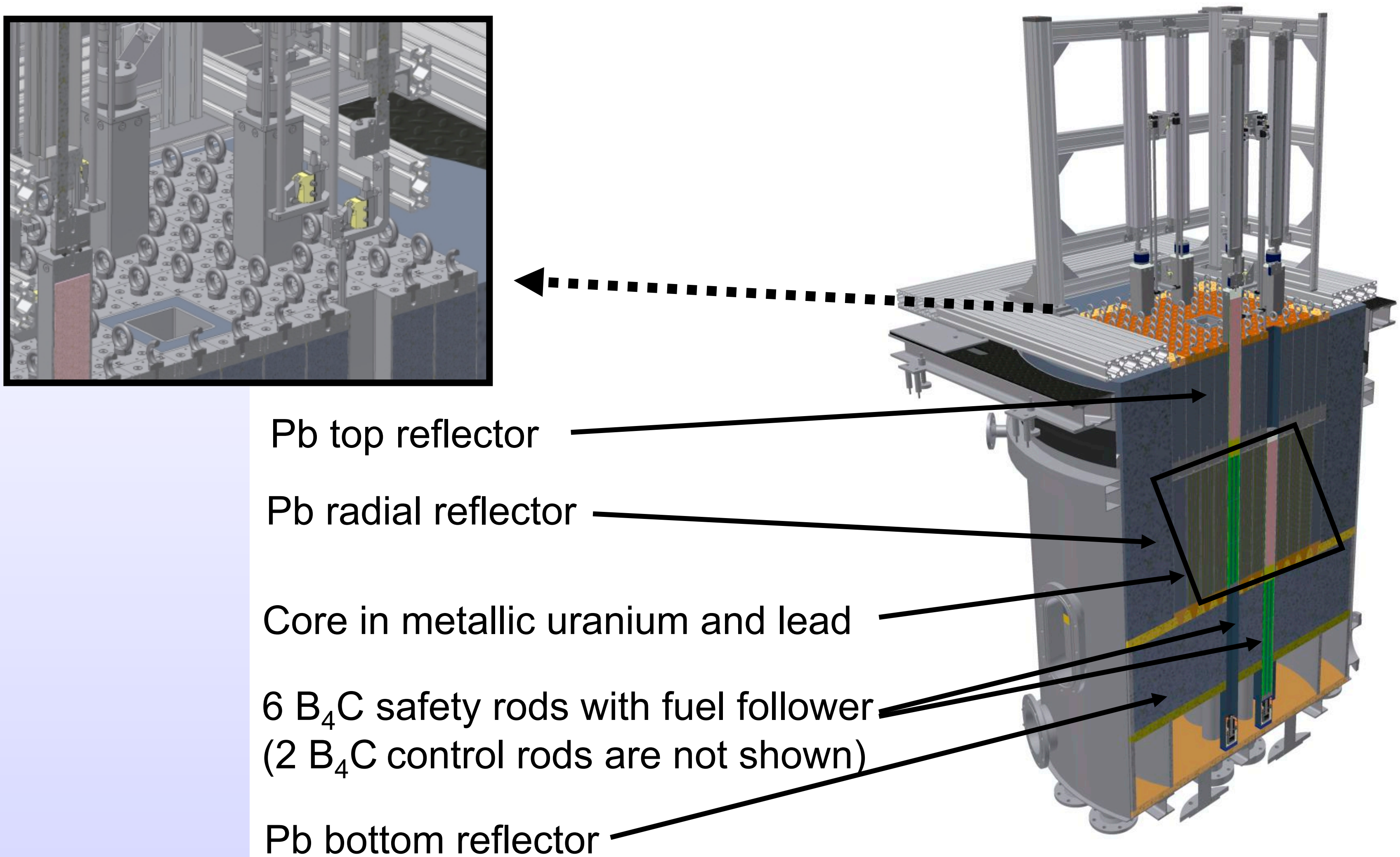
From VENUS to GUINEVERE: set-up of a modular reactor design



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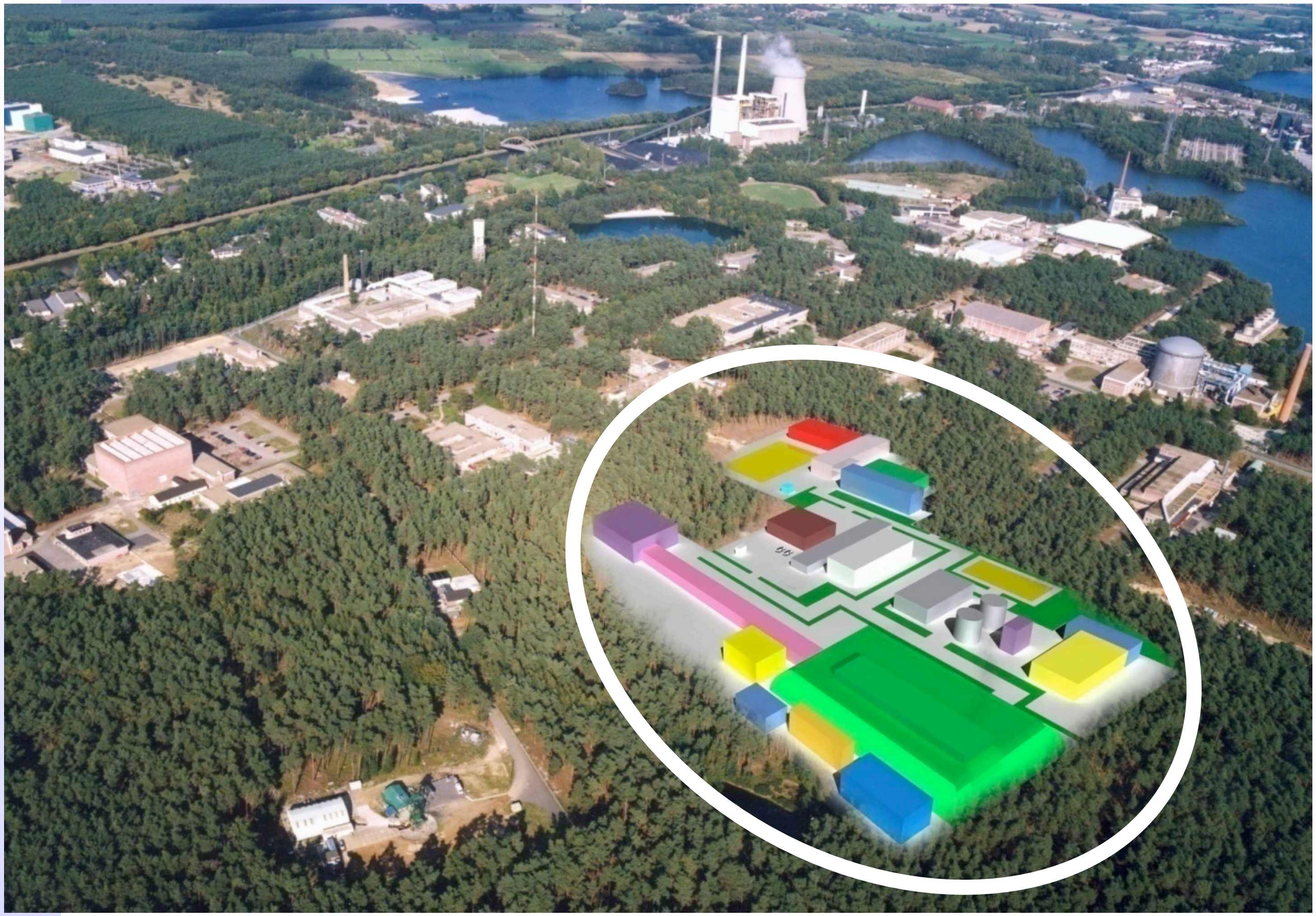
Conclusions

- Networking of existing RR and construction of new ones is necessary for:
  - meeting R&D needs
  - advancing the European Research Area (ERA)
  - attracting new generation of scientists and engineers
- To obtain a sustainable implementation of nuclear energy, fast reactor technology with a closed fuel cycle is necessary
  - European Sustainable Nuclear Industrial Initiative
- Identified Major European Experimental Reactors:
  - JHR, MYHRRA, PALLAS, ASTRID
- SCK•CEN will contribute to the renewal of the ERAER by hosting the fast spectrum experimental facility MYRRHA
- In support of the MYRRHA-project already a zero power reactor GUINEVERE was constructed in 2009 and will be critical in 2010.

MYRRHA hosted by SCK•CEN



IGORR Conference, September, Knoxville, US