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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)

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# Key role of Research Reactors (RR)

- 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

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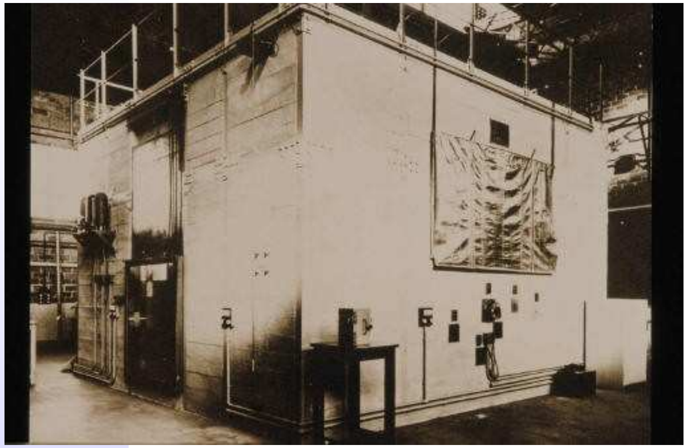
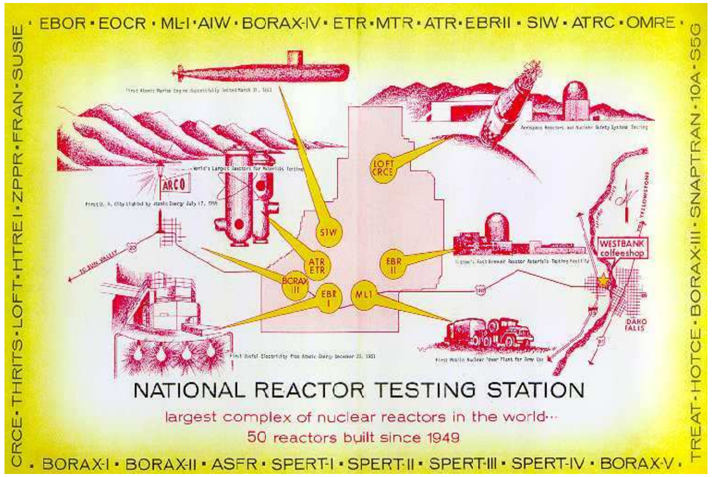
# The golden age of research reactors (50-70)

- 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)

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- 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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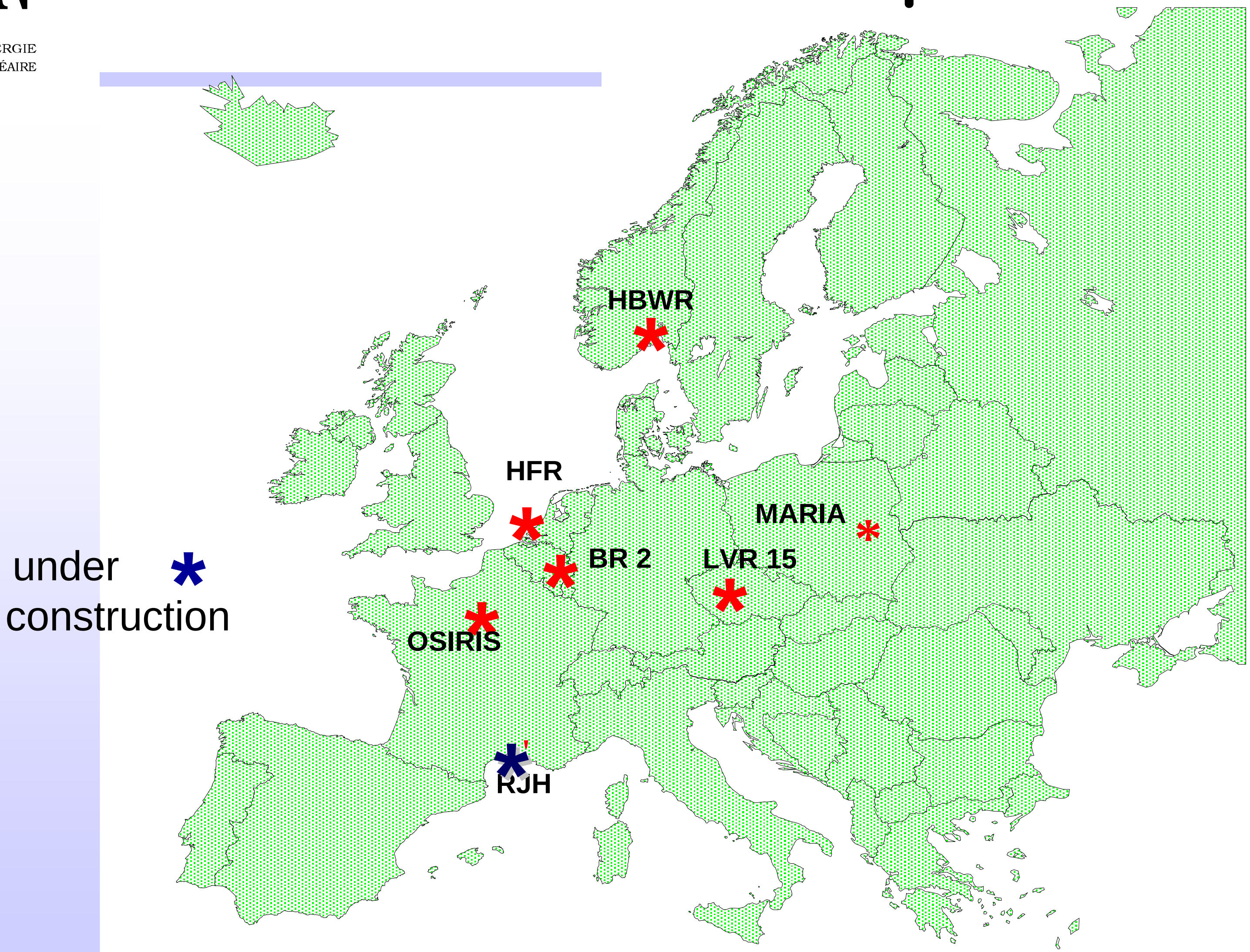
# European Situation: an ageing fleet of MTR in Europe



# 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?

- 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

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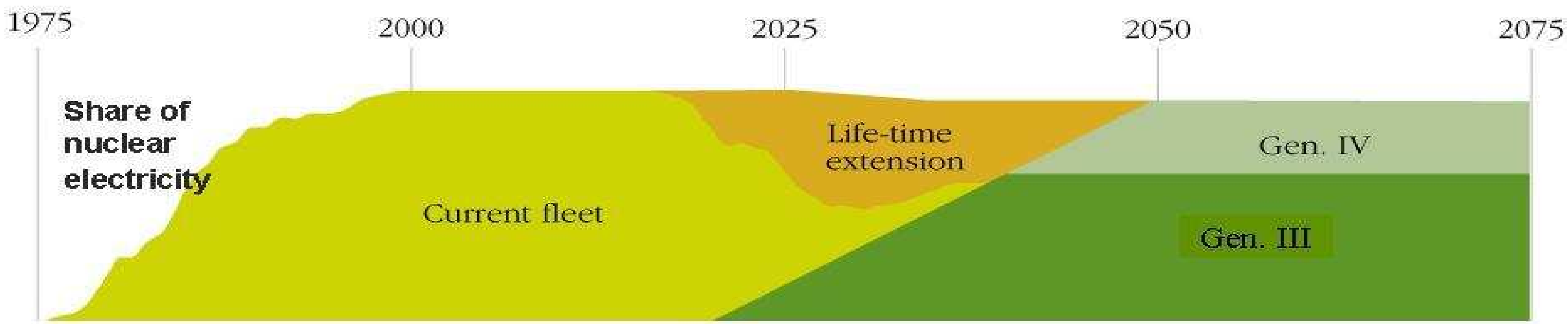
- Necessity to define and implement a consistent EER policy:
  - Meeting industry and public bodies needs
  - Keeping a high level of scientific expertise
  - With a limited number of EER's (compromise between specialisation,complementarities and back-up capacities)
  - To be put in operation in this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

# 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**

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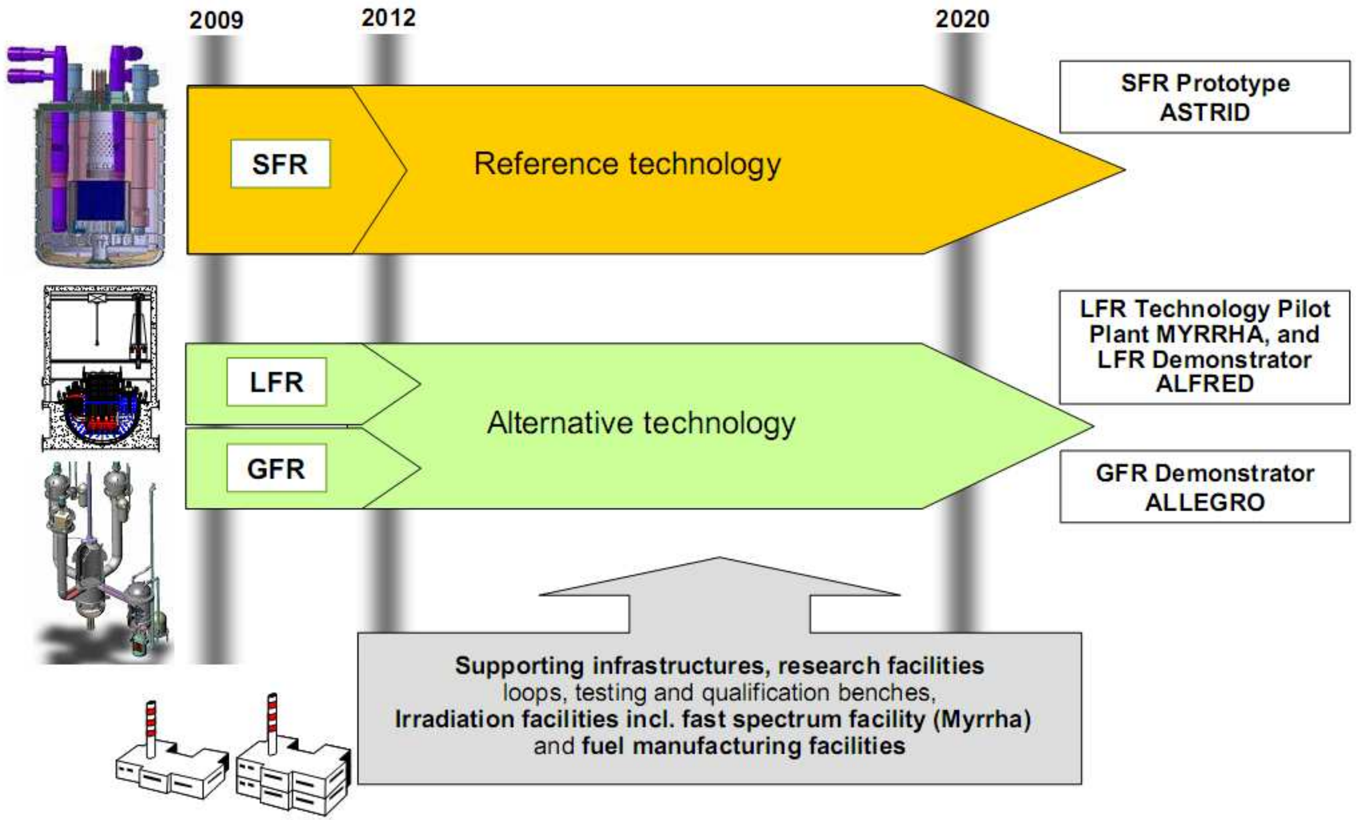
# The European Sustainable Nuclear Industrial Initiative

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



# European Research Area on Experimental Reactors Perspective

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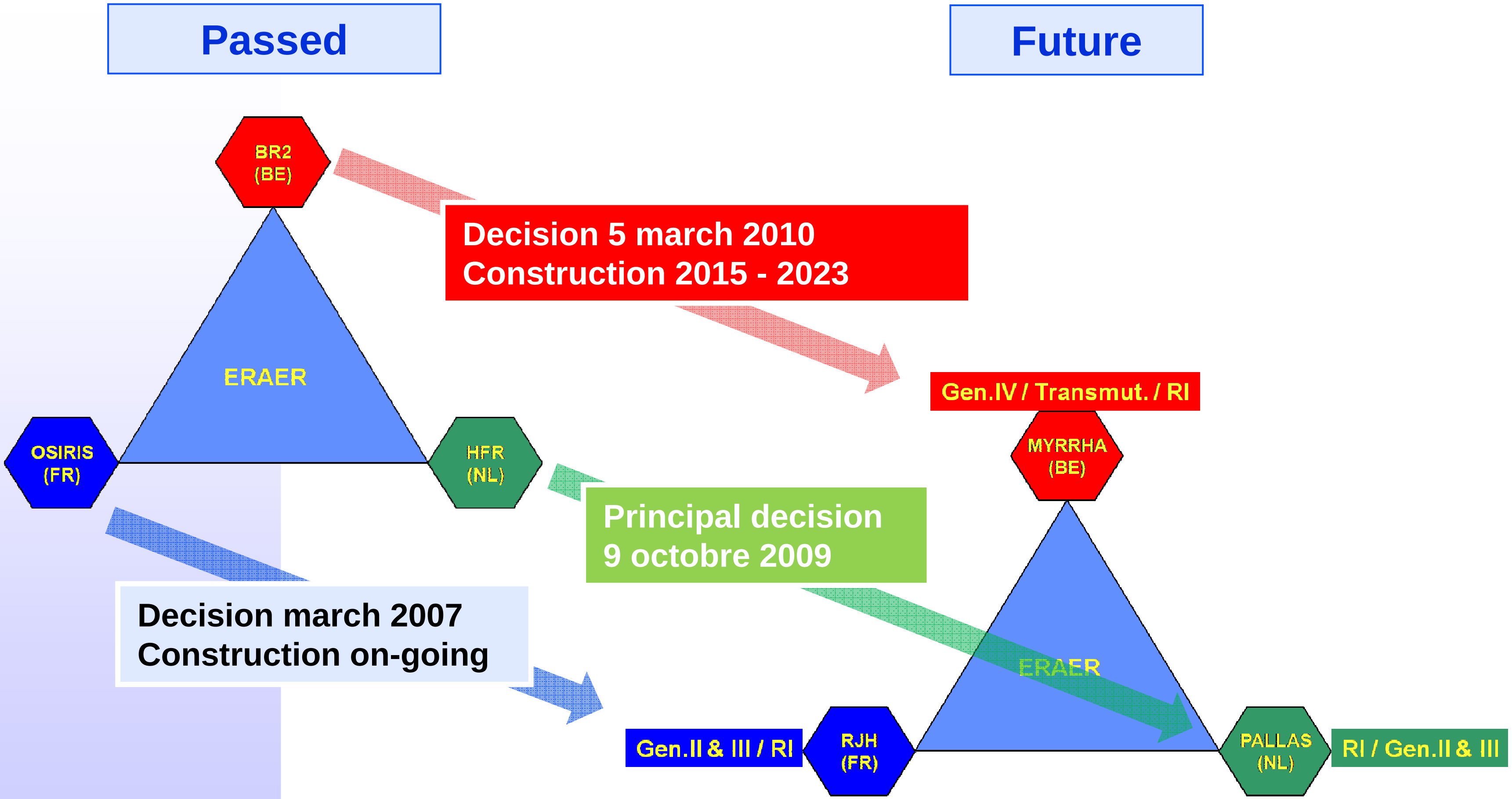


**ERAER = European Research Area for Experimental Reactors**

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# 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

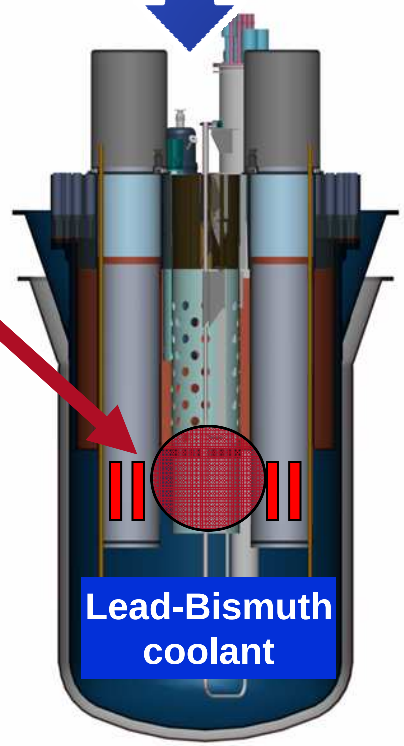
**Accelerator**
(600 MeV – 4 mA proton)

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

**Spallation source**

**Fast neutron source**

**Multipurpose flexible irradiation facility**



# Accelerator - layout

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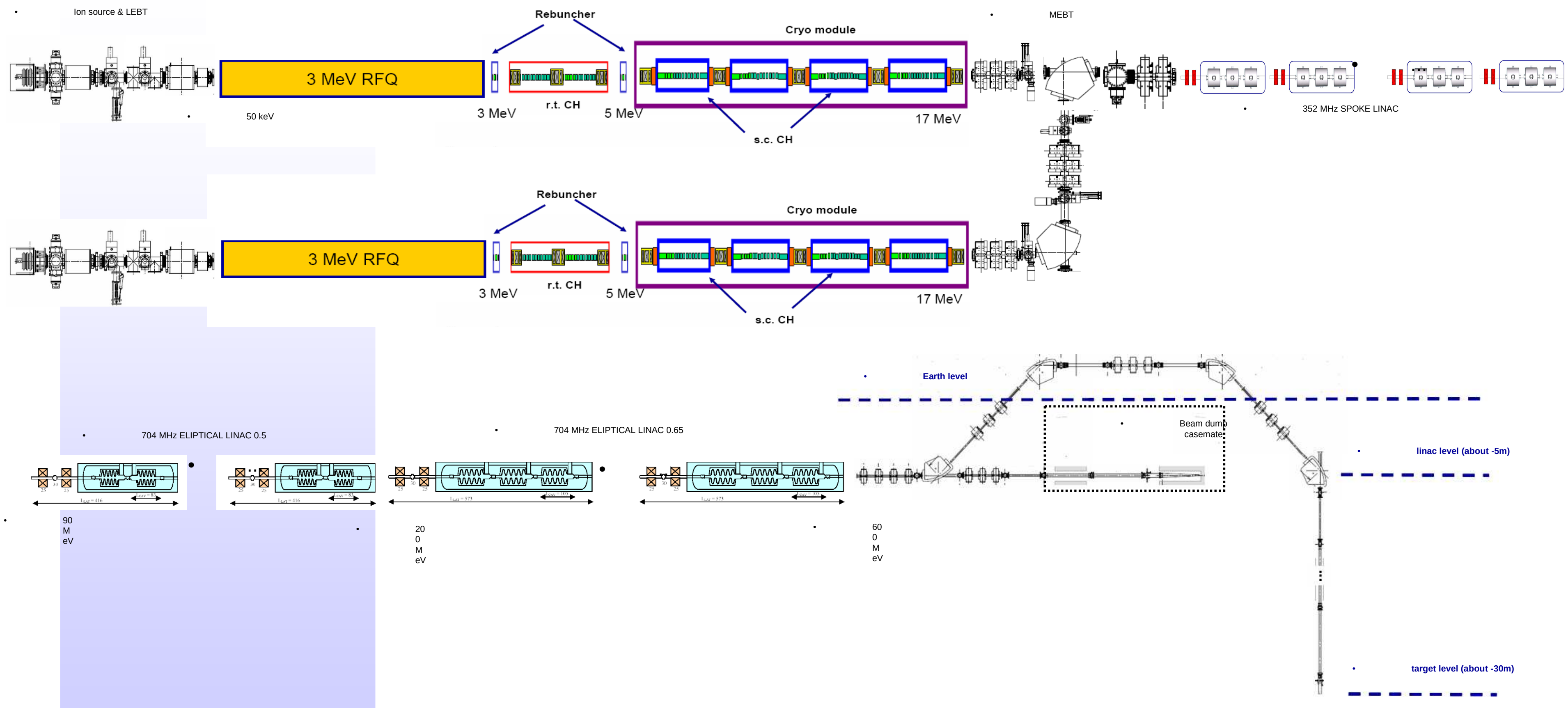
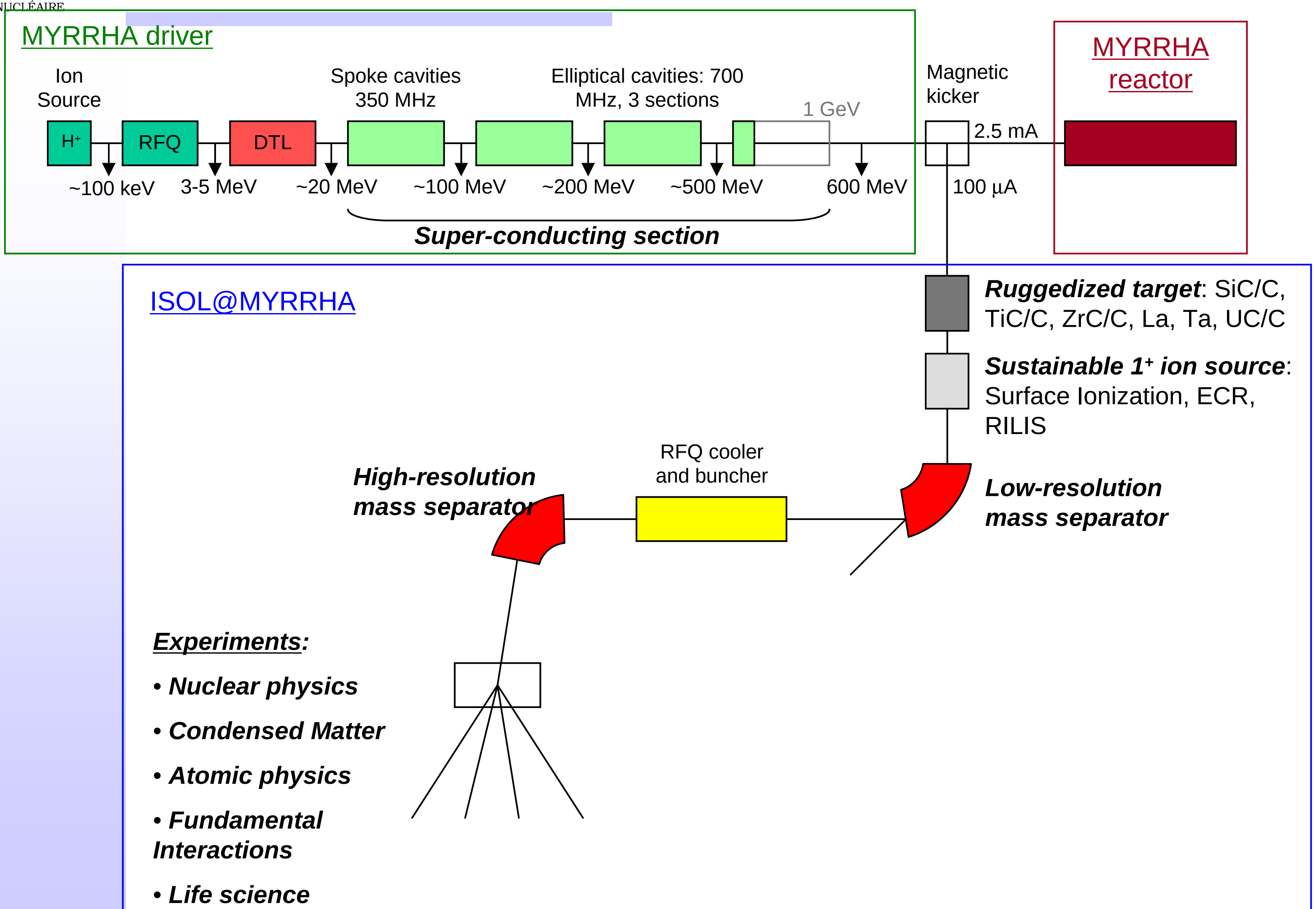
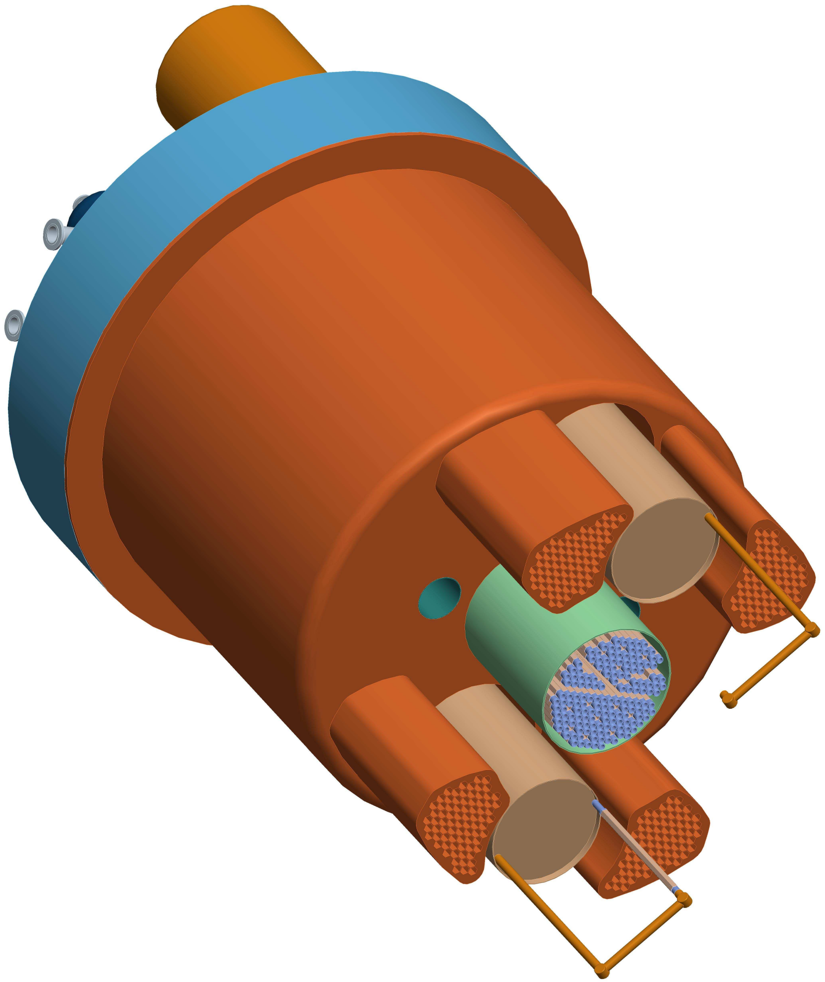


# ISOL@MYRRHA lay-out



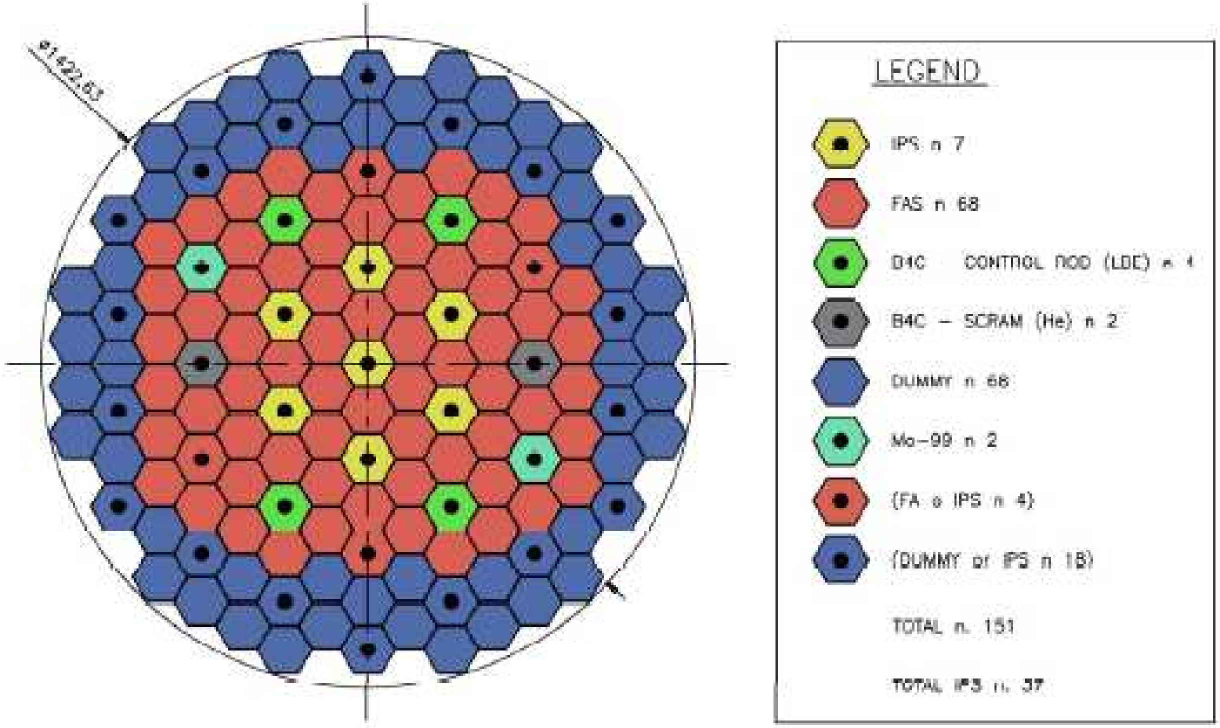
# Reactor layout

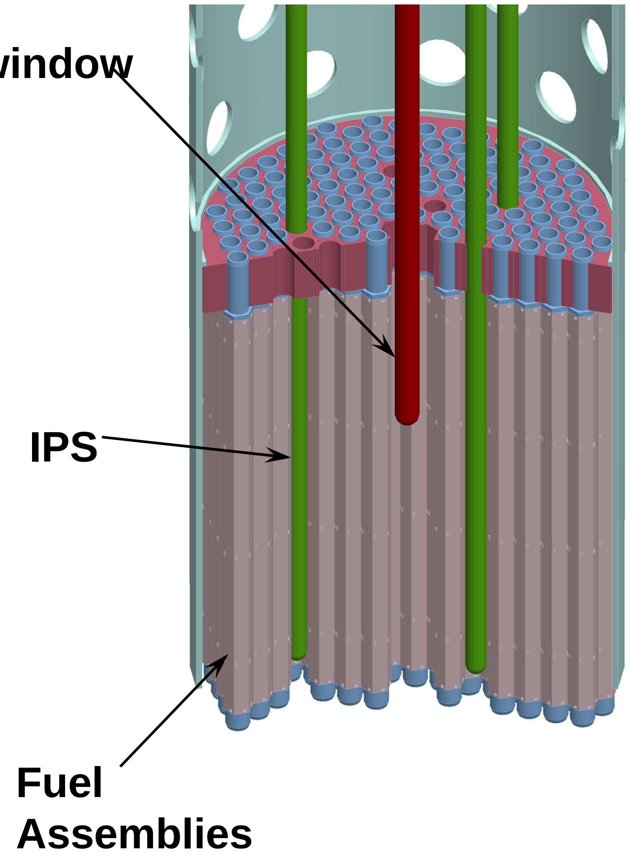
- Inner vessel
- Cover
- Core structure
- Spallation window
- Heat exchangers
- Pumps
- Diaphragm
- Fuel manipulators
- Guard vessel
- Fuel storage



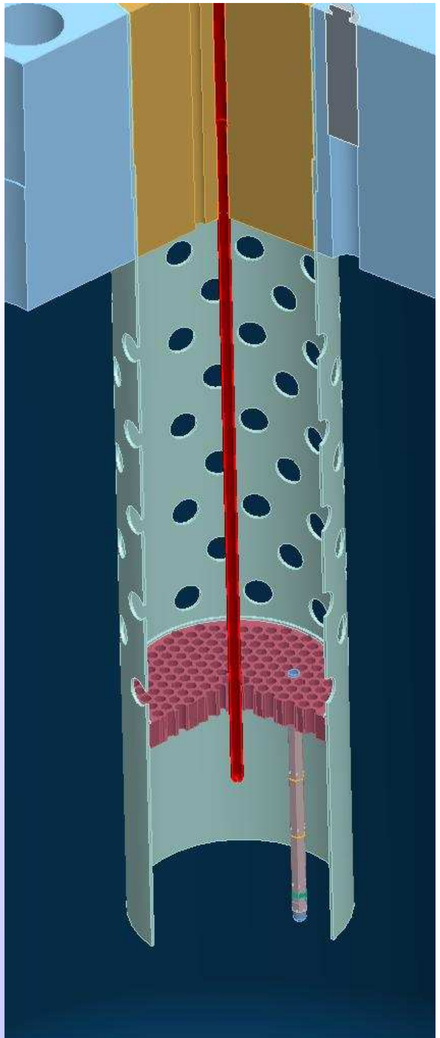
# Reactor layout – 1. Core

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



# 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

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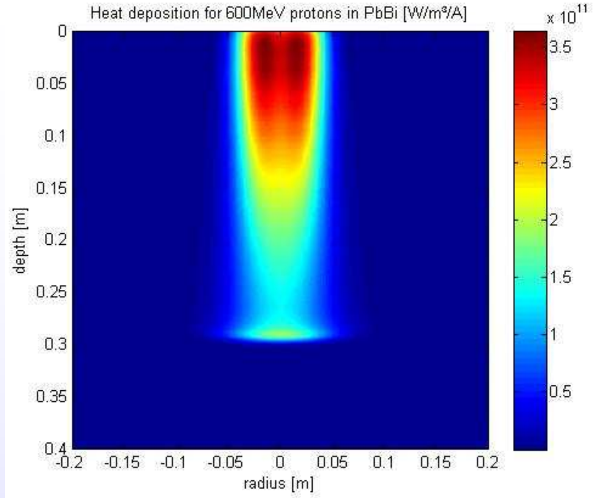
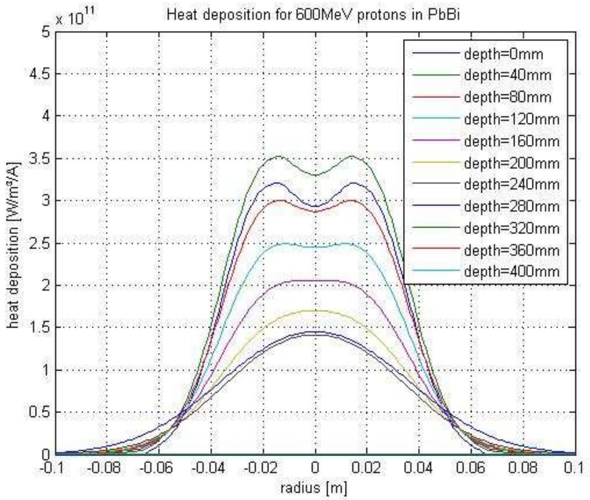
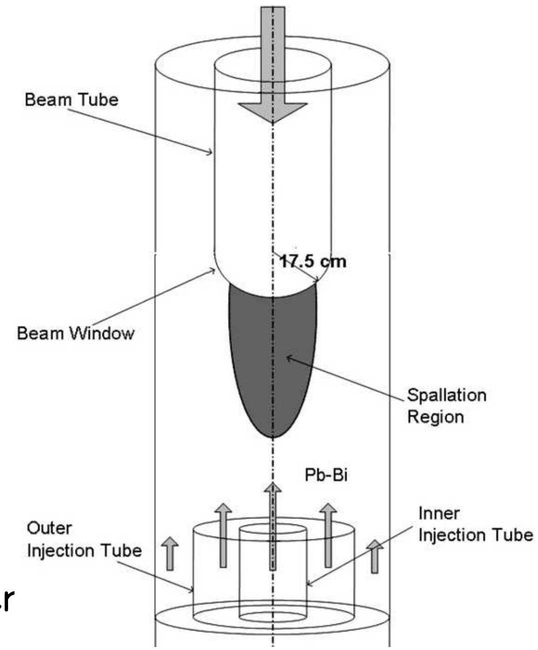
# Spallation target window (2/2)

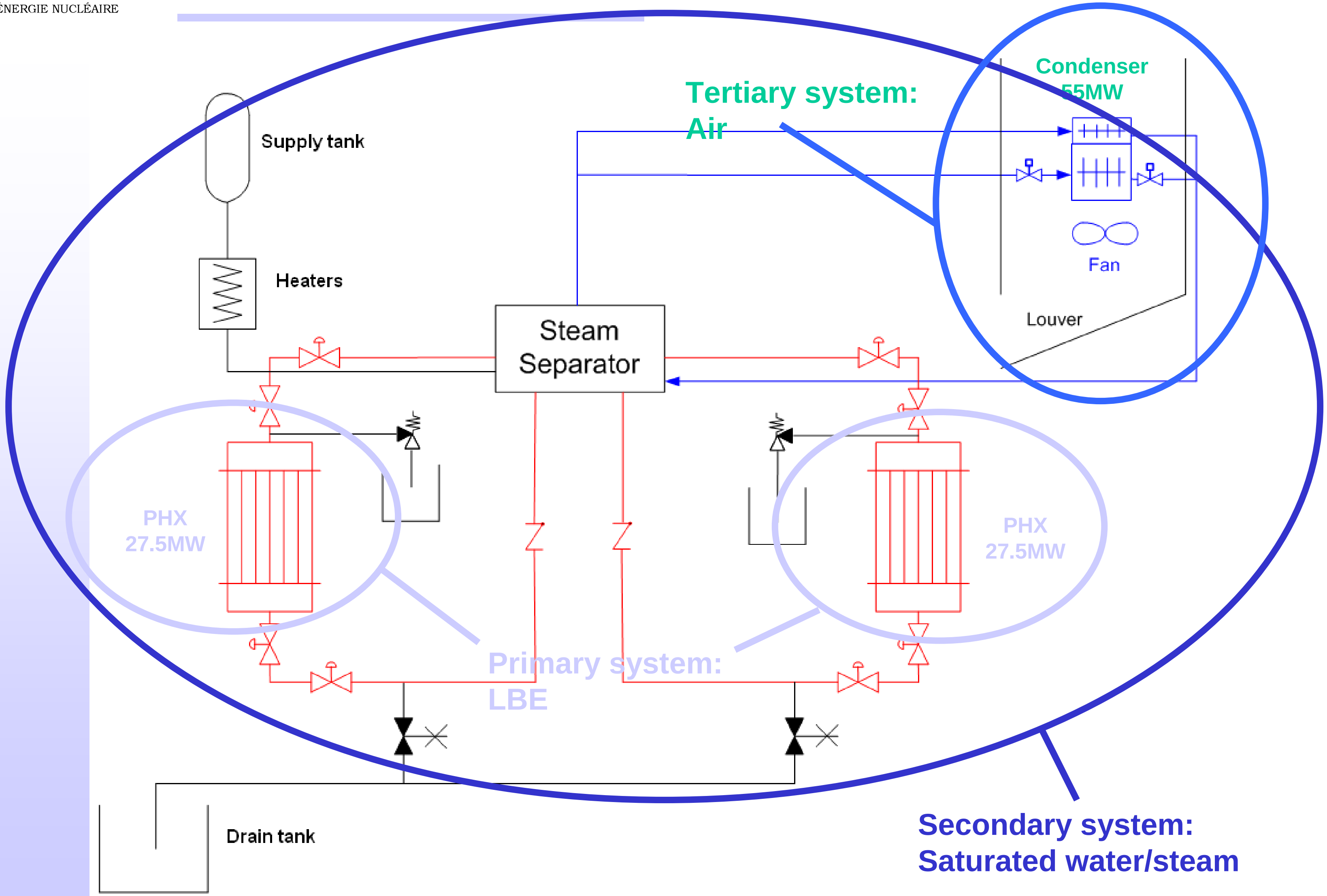



- Rotating beam σ 15 mm sweep 25 mm
- Limited heat deposition at stagnation point
- Multi tube concept
  - 3 Concentric inlet tubes



# Cooling systems – secondary and tertiary system



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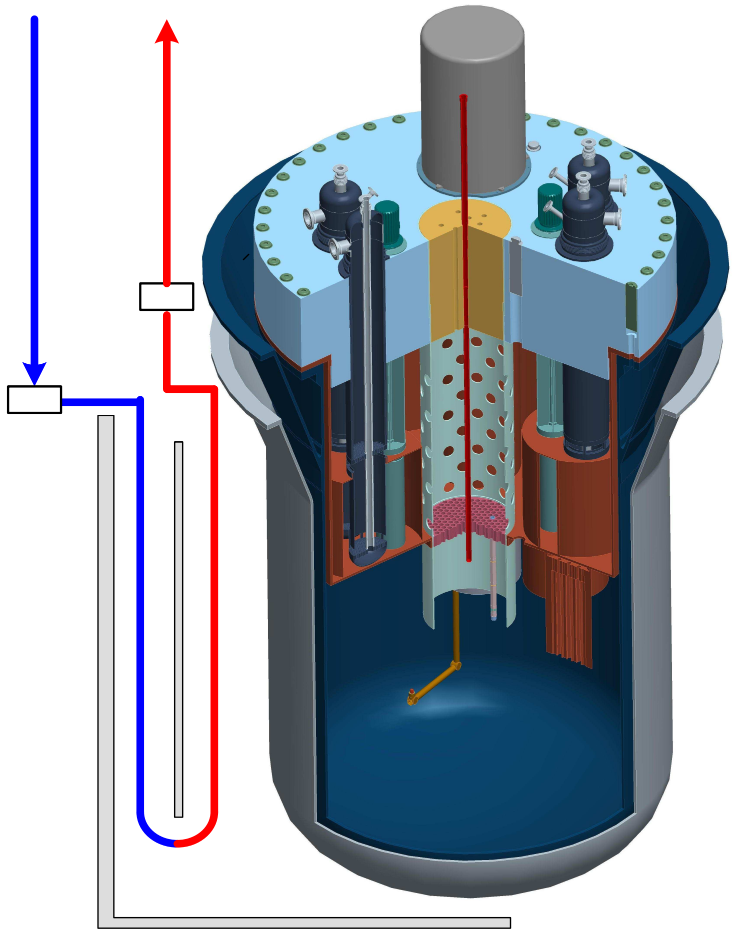
# Cooling systems – secondary and tertiary system

- 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)



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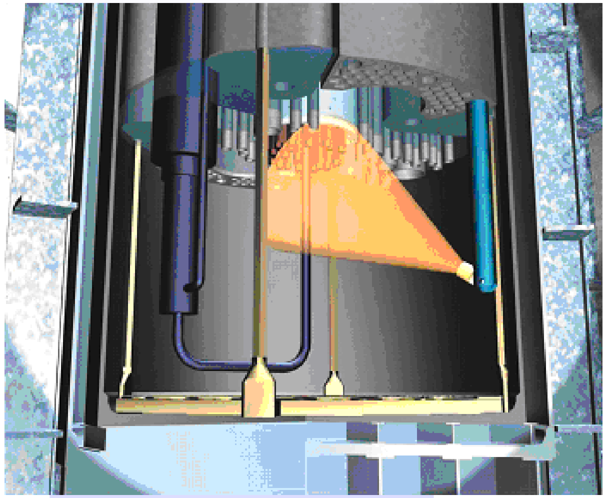
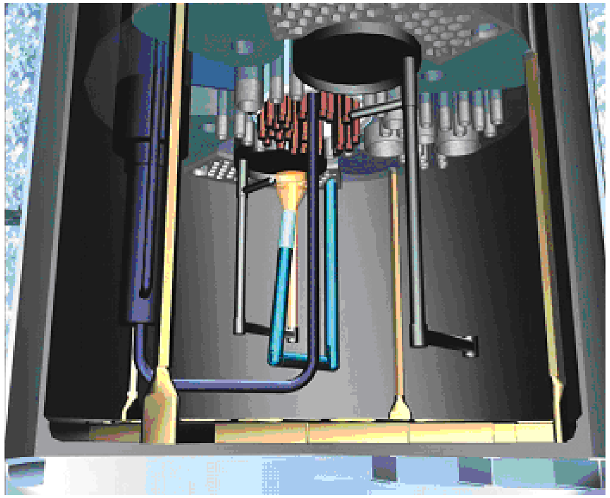
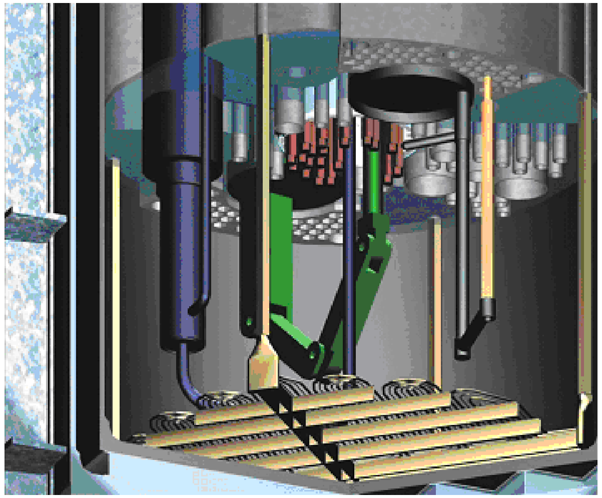
# Operation and maintenance In service inspection with US and in-vessel repair







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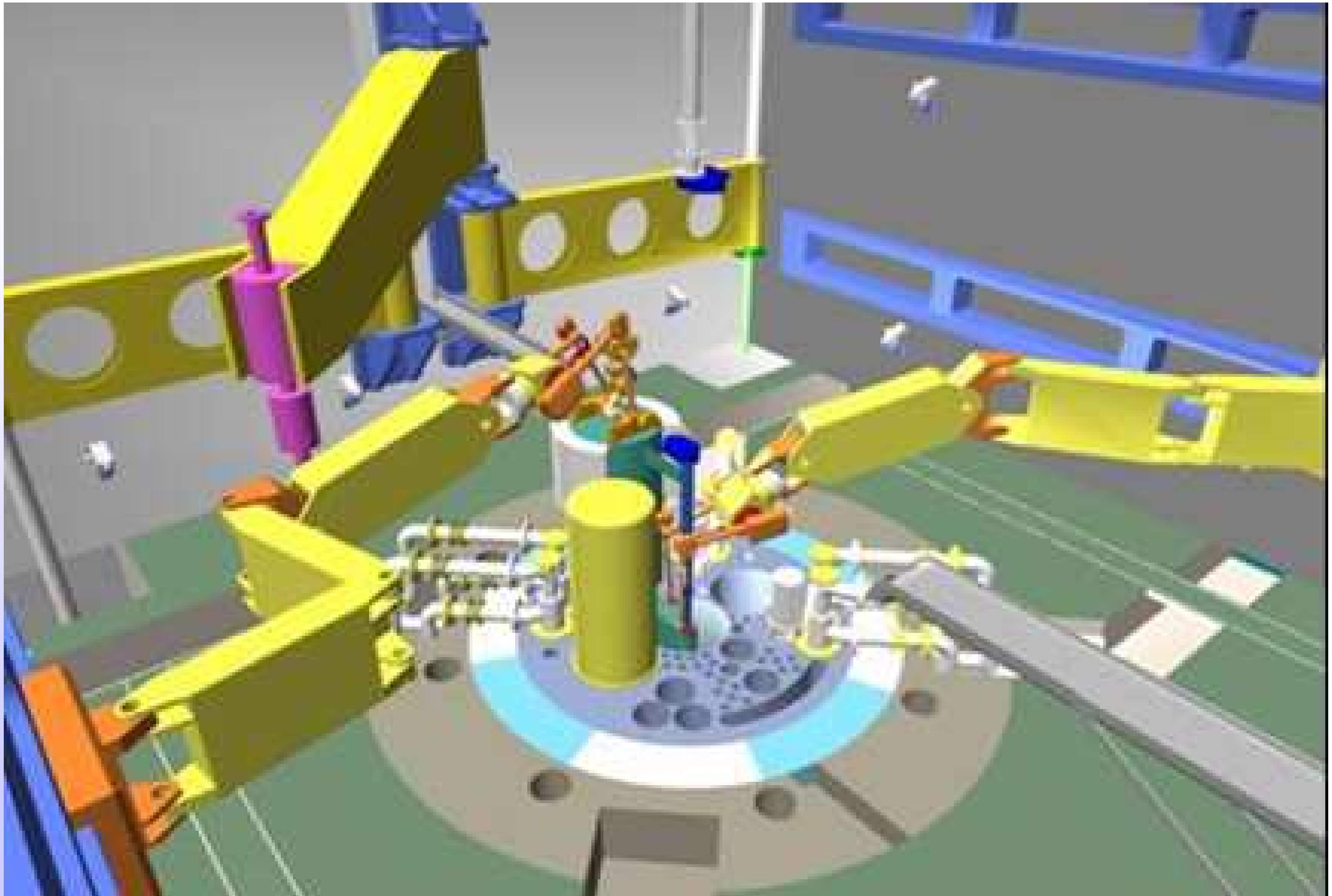
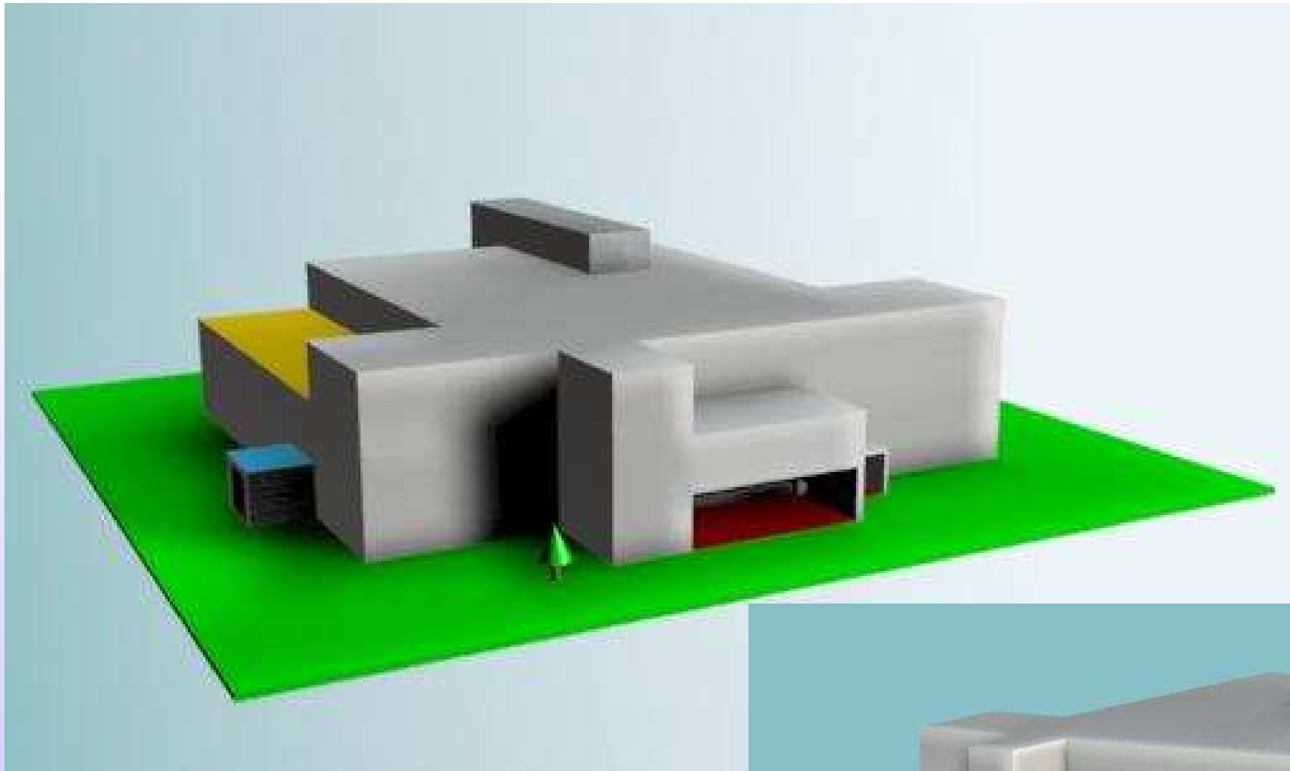
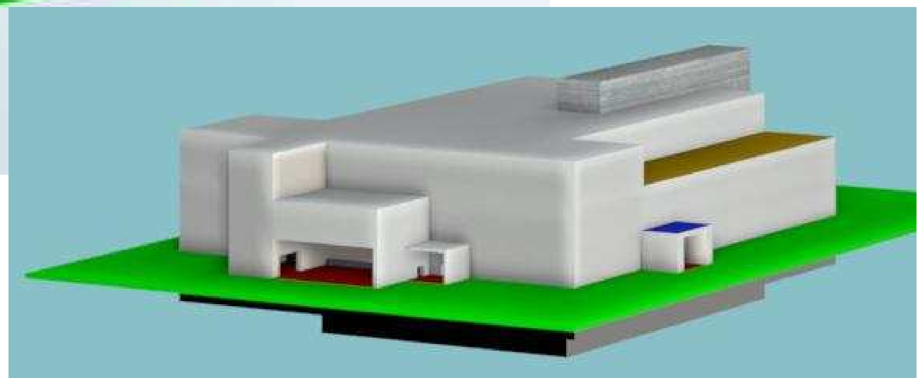
# Operation and maintenance
# Ex-vessel remote handling



# Building layout and reactor hall – the reactor building





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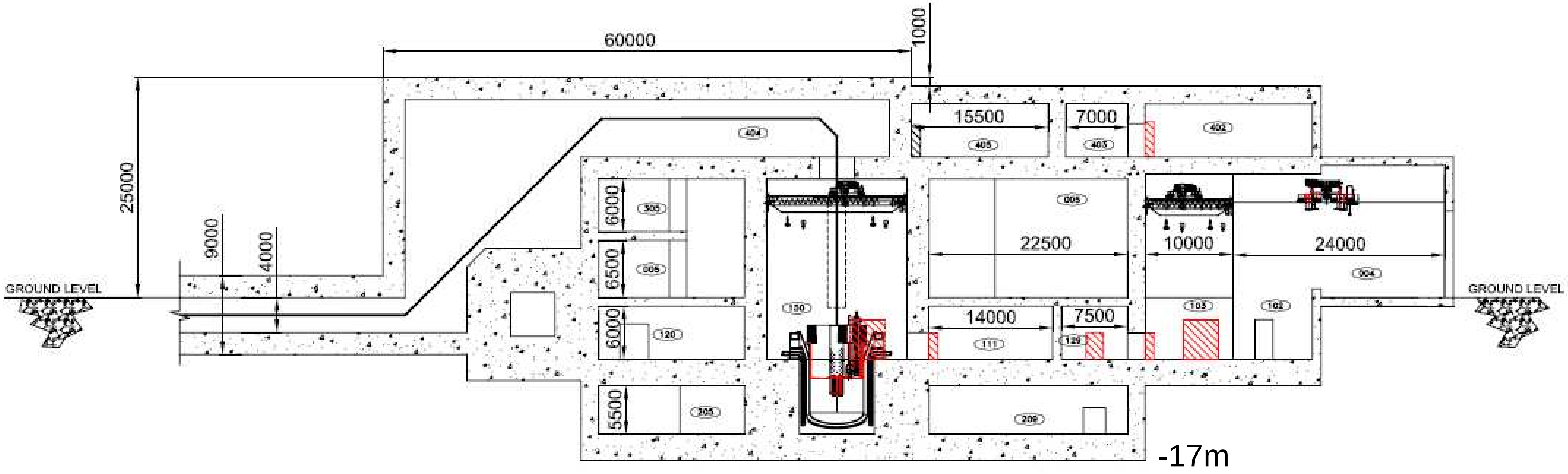

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# Project schedule

**2010-2014**
Front End Engineering Design

**2014-2015**
Specifications Drafting & Tendering

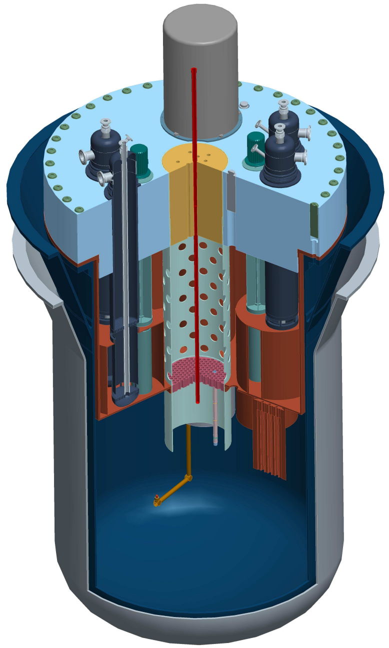
**2016-2018**
Construction of components & Civil engineering

**2019**
On site assembly

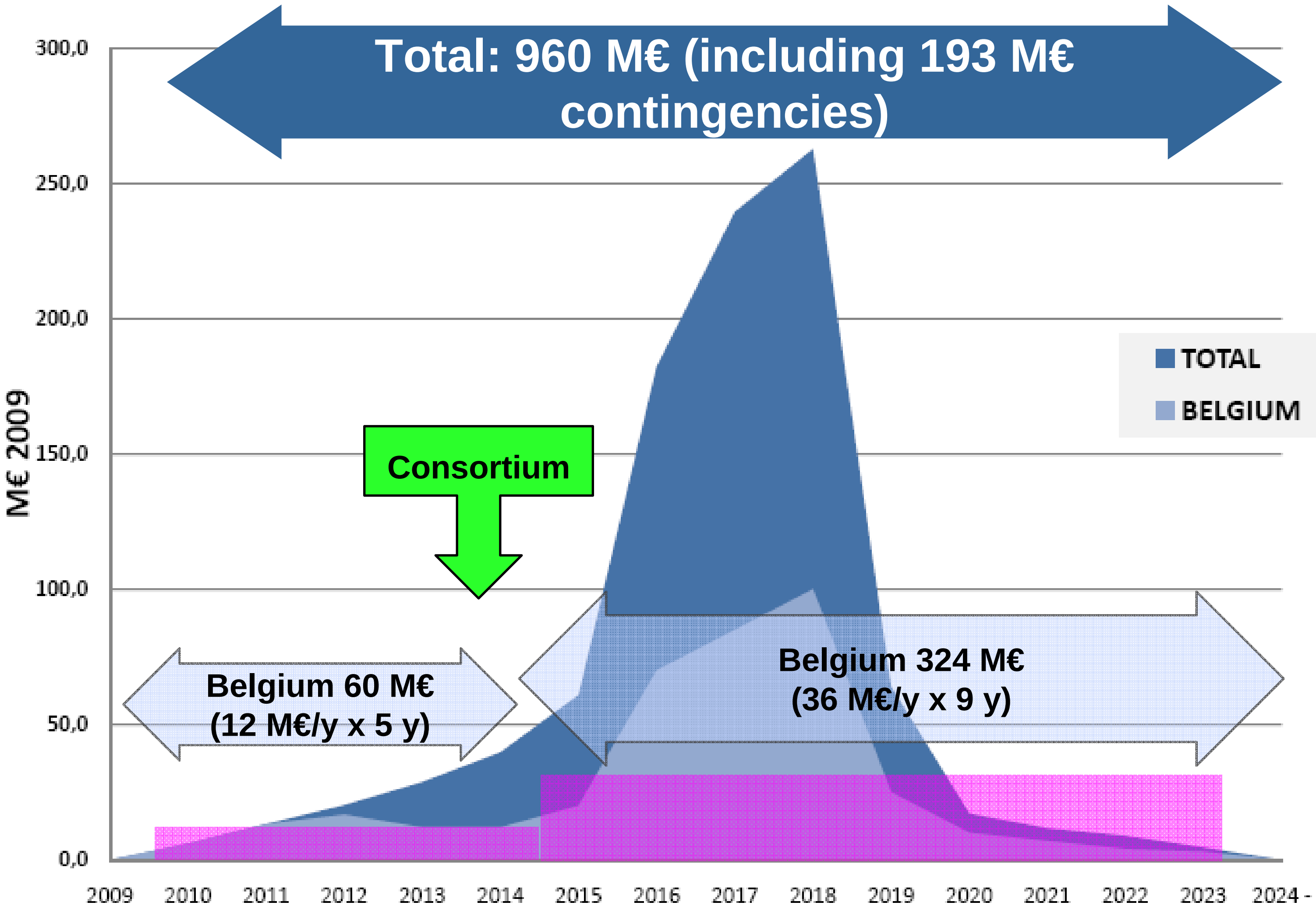
**2020-2022**
Commissioning

**2023**
Progressive start-up

**2024-**
Full exploitation

# MYRRHA Investment



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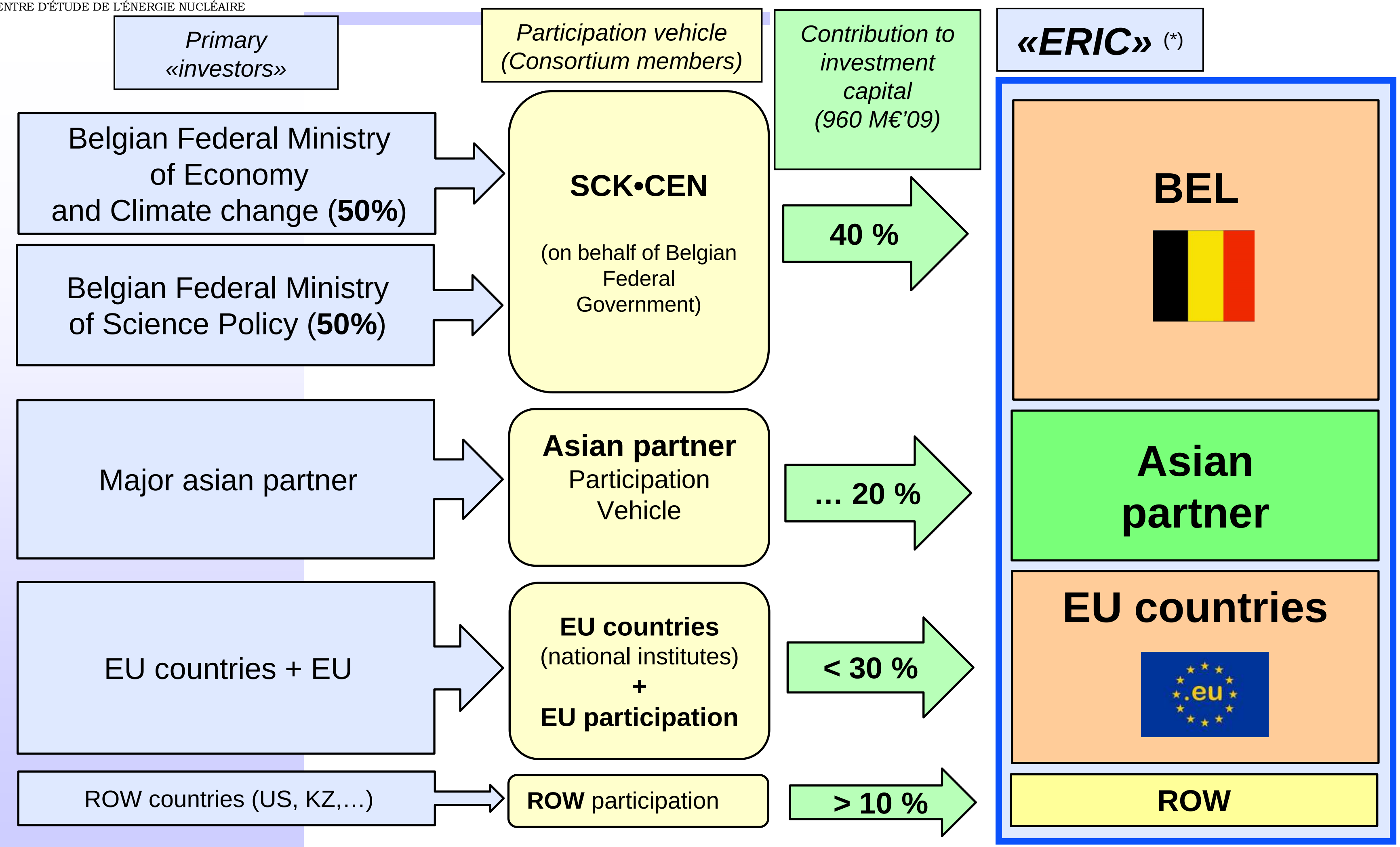
# MYRRHA 2010-2014 Project Plan

| | | | | |
|---|---|---|---|---|
| 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 |
| 3 | **Implement a sound management structure** | Int. Members Consortium | Central Project Team | FEED Engineer |

**FEED** (Front End Engineering Design)

# International Members Consortium




(*) European Research Infrastructure Consortium

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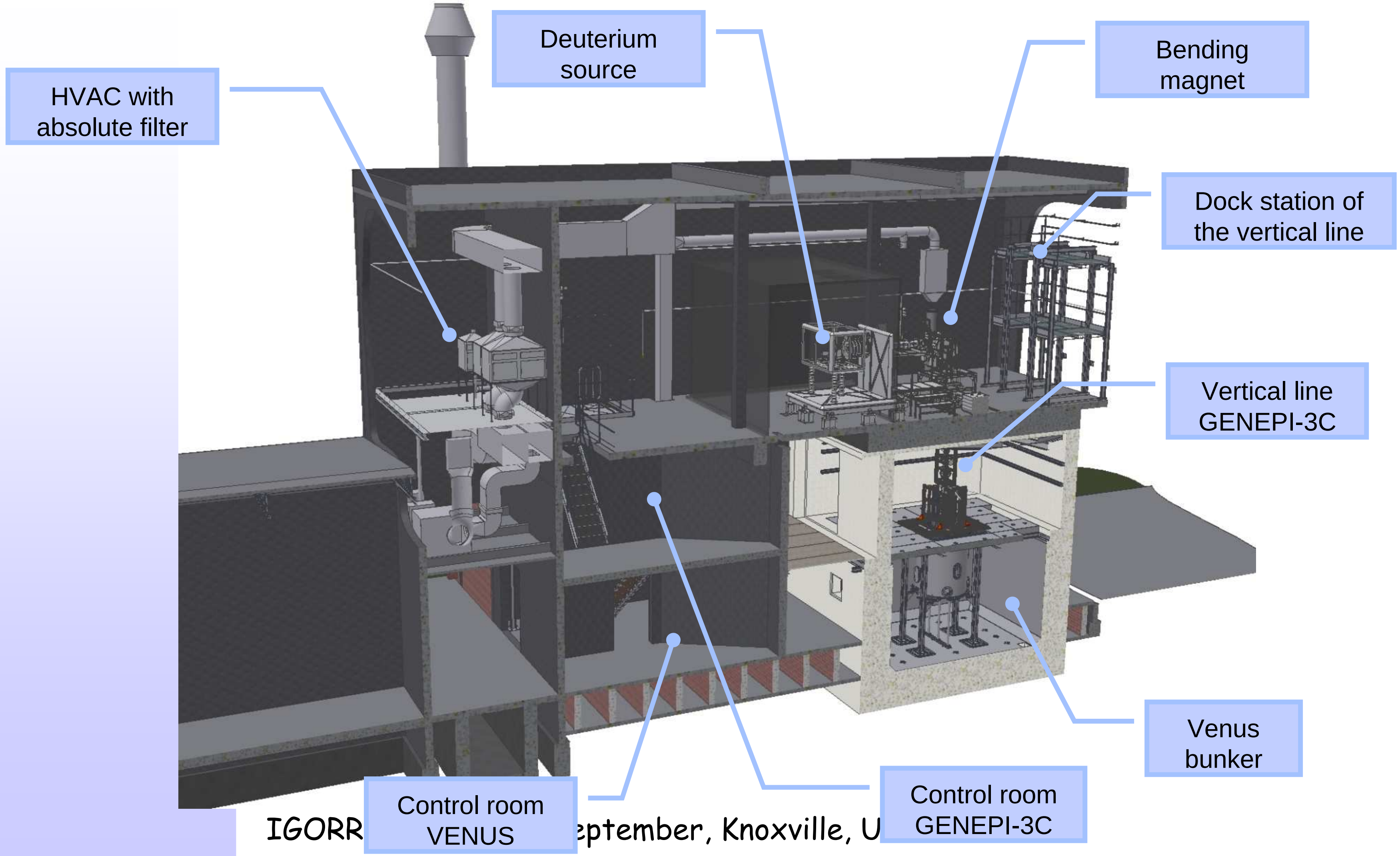
# From VENUS to GUINEVERE: the accelerator room



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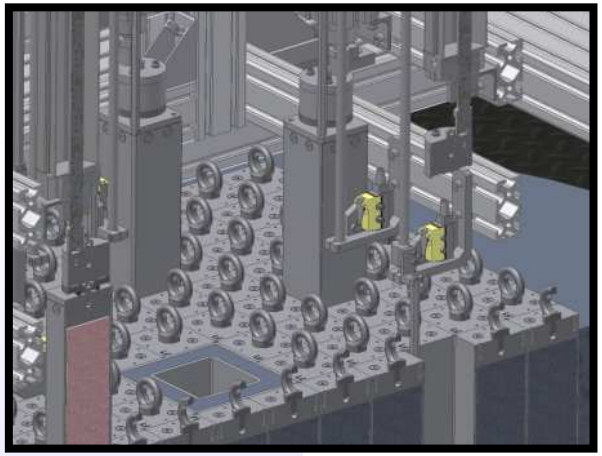
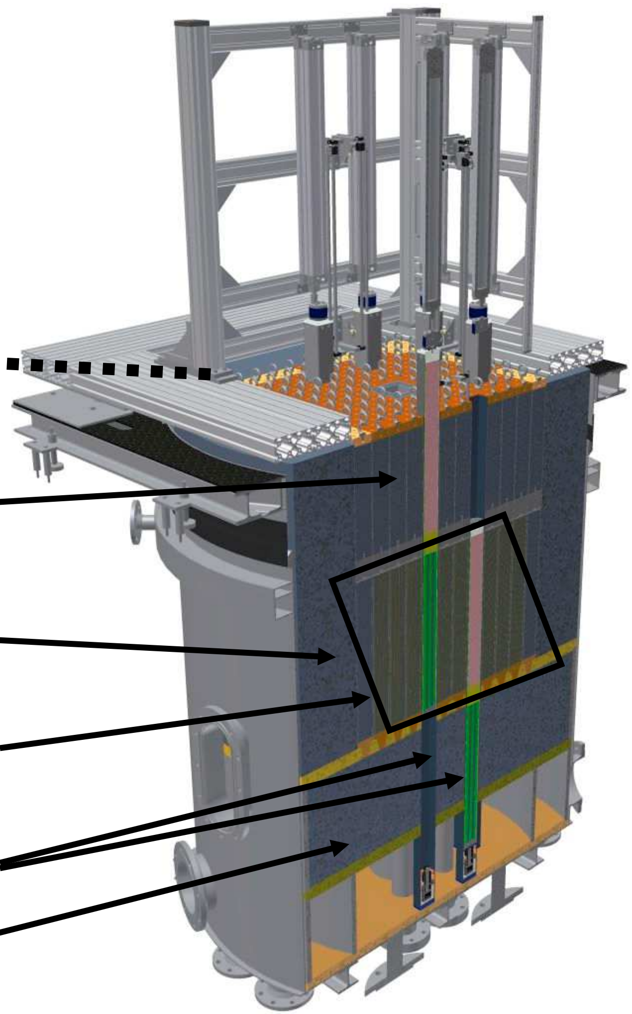
# From VENUS to GUINEVERE: set-up of a modular reactor design





Pb top reflector

Pb radial reflector

Core in metallic uranium and lead

6 $B_4C$ safety rods with fuel follower
(2 $B_4C$ control rods are not shown)

Pb bottom reflector

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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.

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# MYRRHA hosted by SCK•CEN