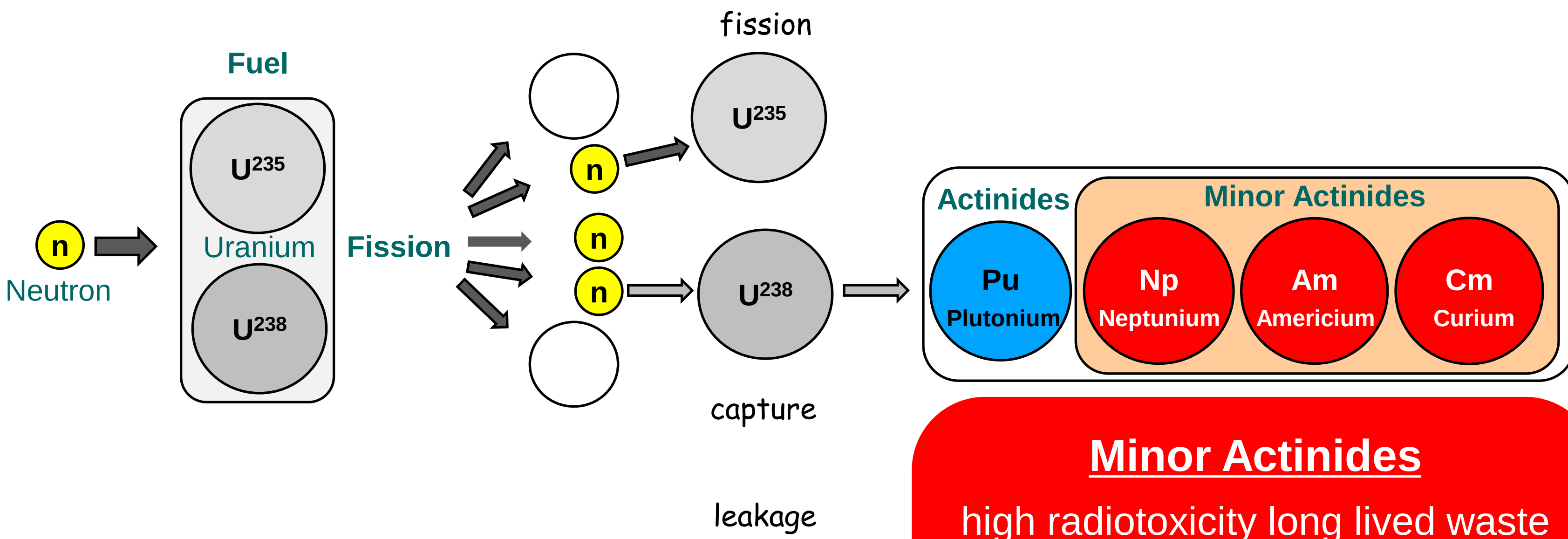
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

The MYRRHA ADS project

Paul Schuurmans for the MYRRHA Team

High Level Nuclear Waste



Minor Actinides

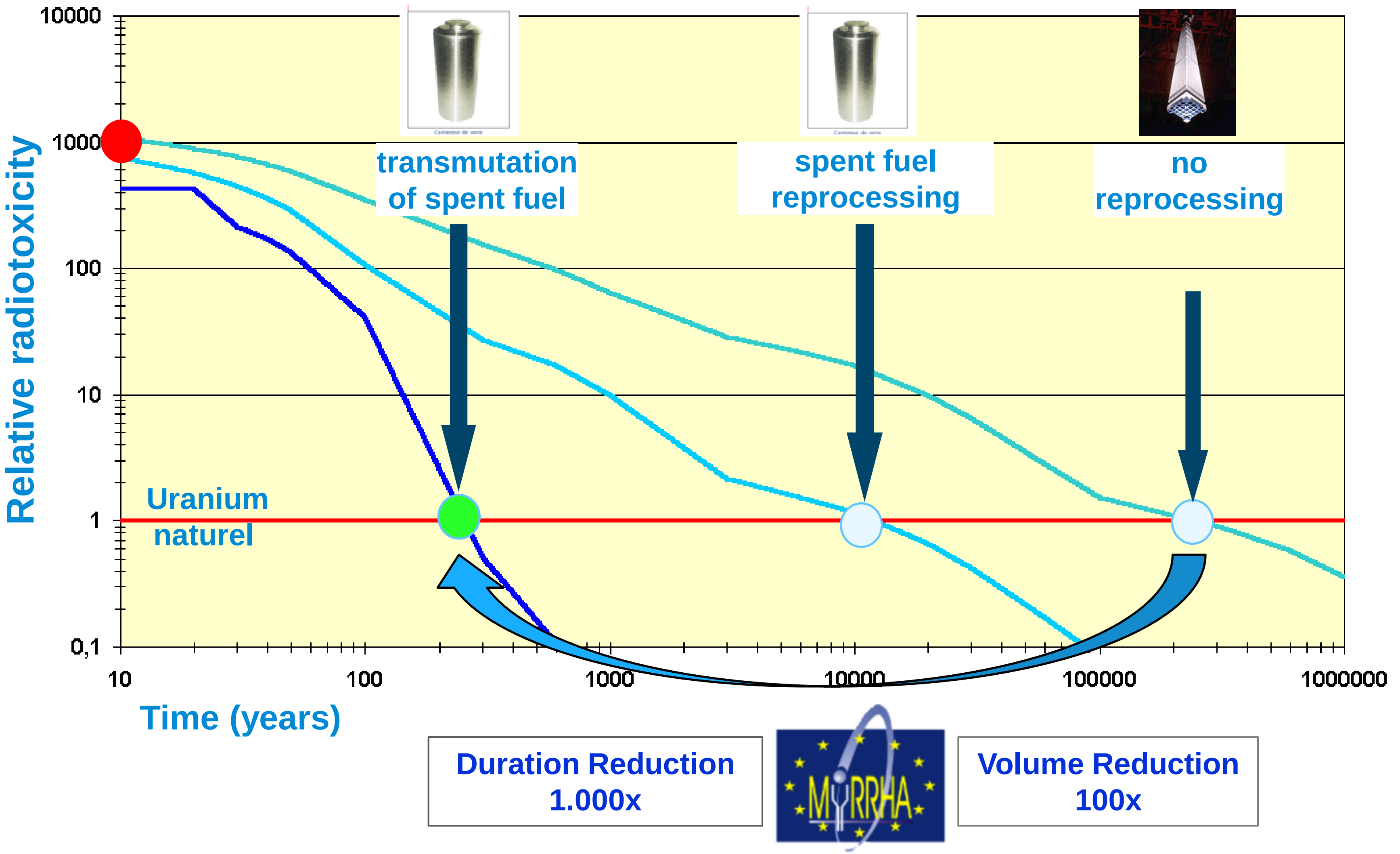
high radiotoxicity long lived waste that are difficult to store due to:

- **Long lived (>1,000 years)**
- **Highly radiotoxic**
- **Heat emitting**

$$n + U^{235} \Rightarrow 2\,FP + 2 \text{ or } 3\,n + 200\,MeV$$

(4 eV for combustion of C)

Motivation for Transmutation



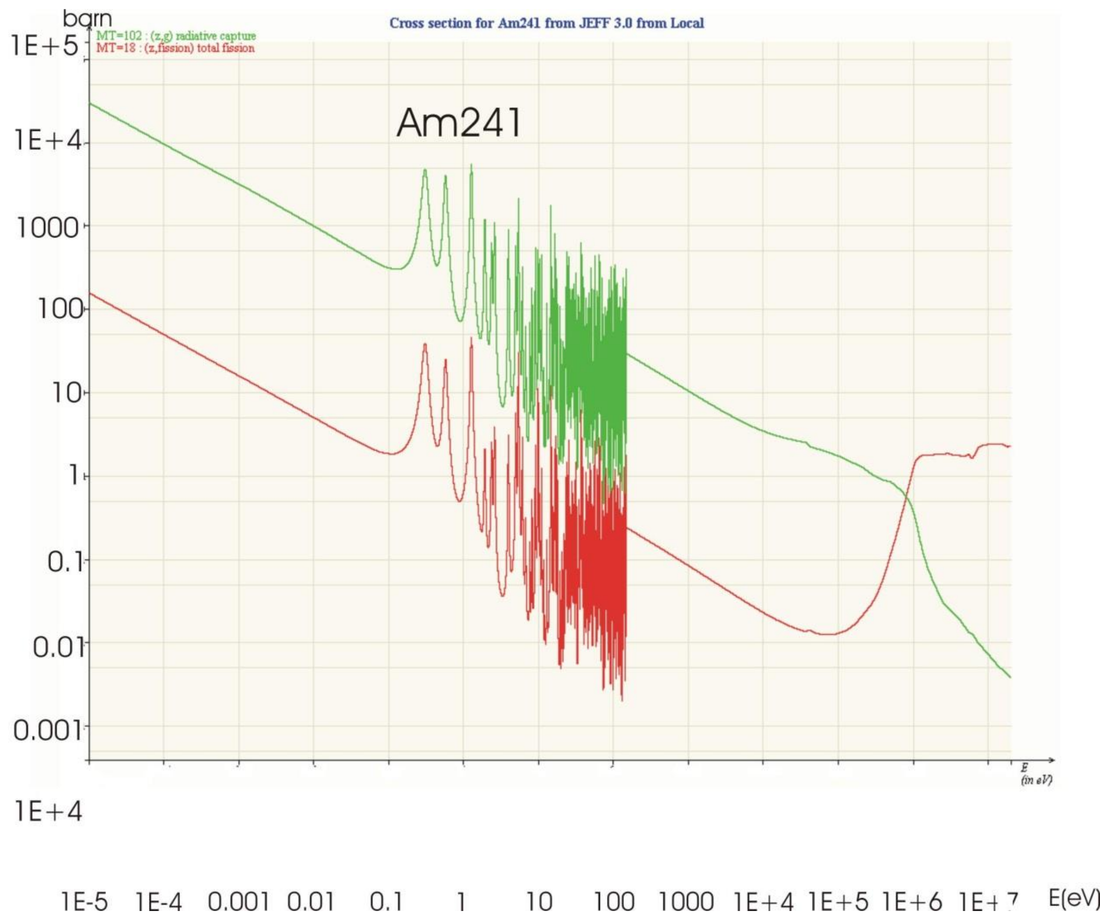
Fission of waste

- Fast neutron spectrum
  (>0.75MeV)

•With MA fuel

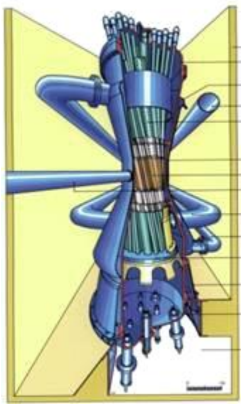
•MA reactor more difficult to control

•Maximum for critical fast spectrum power reactor : 1-1.5%



⇒ Fast spectrum Sub-critical system

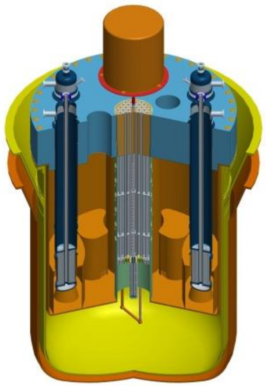
MYRRHA: a multipurpose irradiation facility at SCK-CEN



1962

BR2

- Material Testing Reactor (fission)
- Fuel testing for LWR & GEN II/GEN III
- Irradiation Services:
  - Medical RI
  - Silicium Doping
  - Others

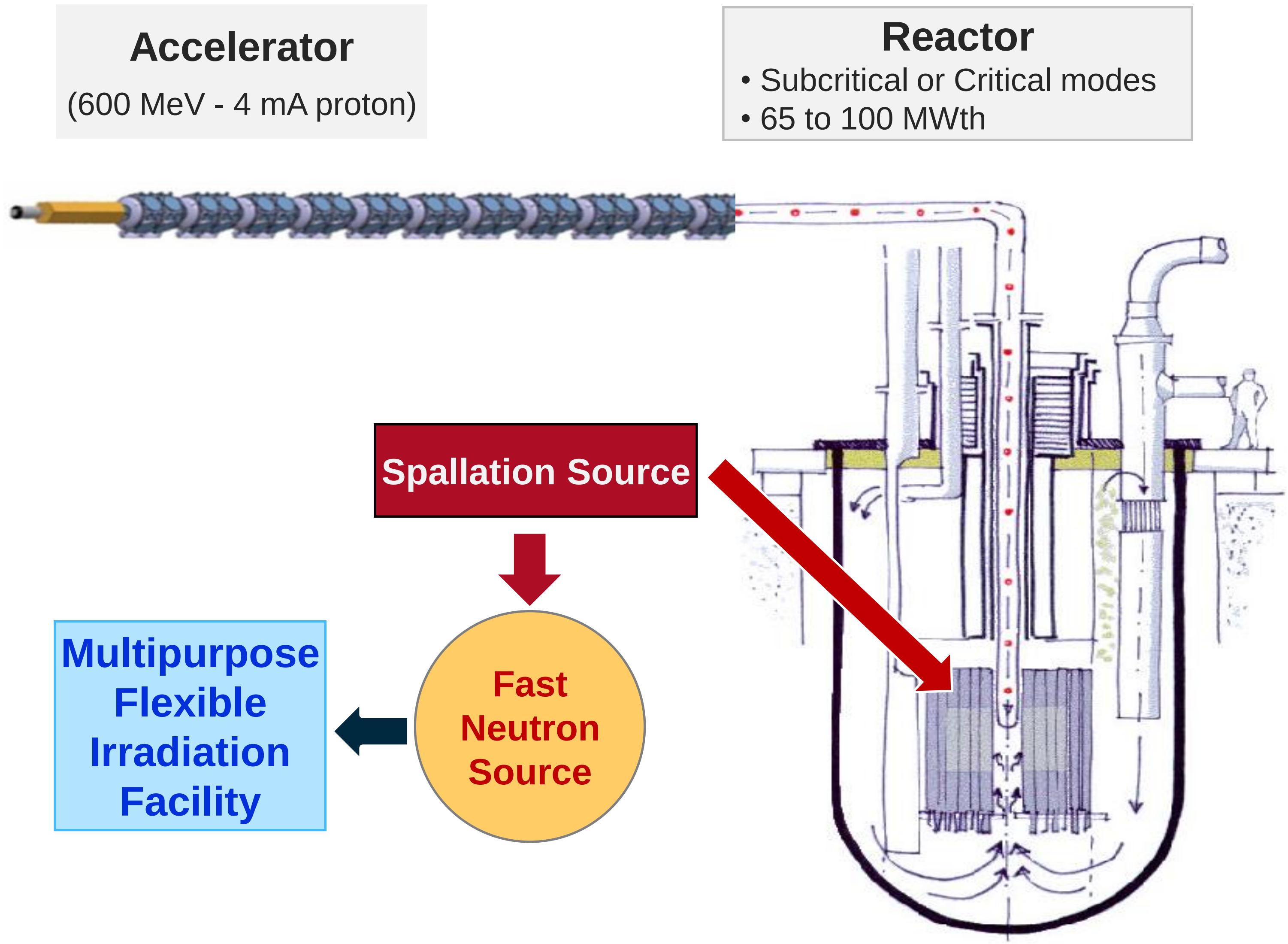


2024

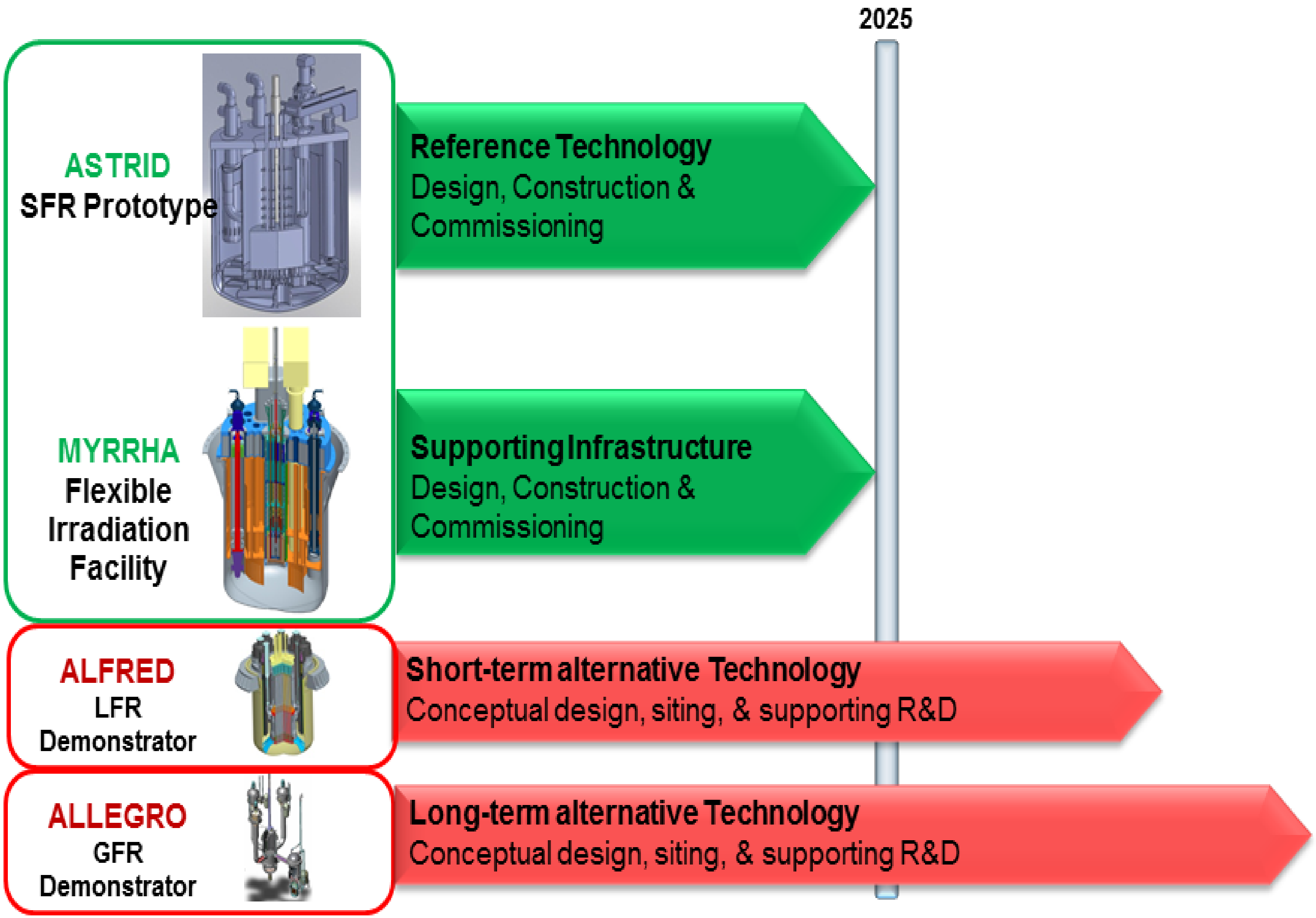
MYRRHA

- Fast Neutron Material Testing Reactor (fission + fusion)
- ADS-Demo + P&T Testing (Partitioning & Transmutation)
- Irradiation Services:
  - Medical RI
  - Silicium Doping
  - Others
- Fuel testing for LFT GEN IV
- LFR European Technology Pilot Plant (ETPP)

MYRRHA - Accelerator Driven System



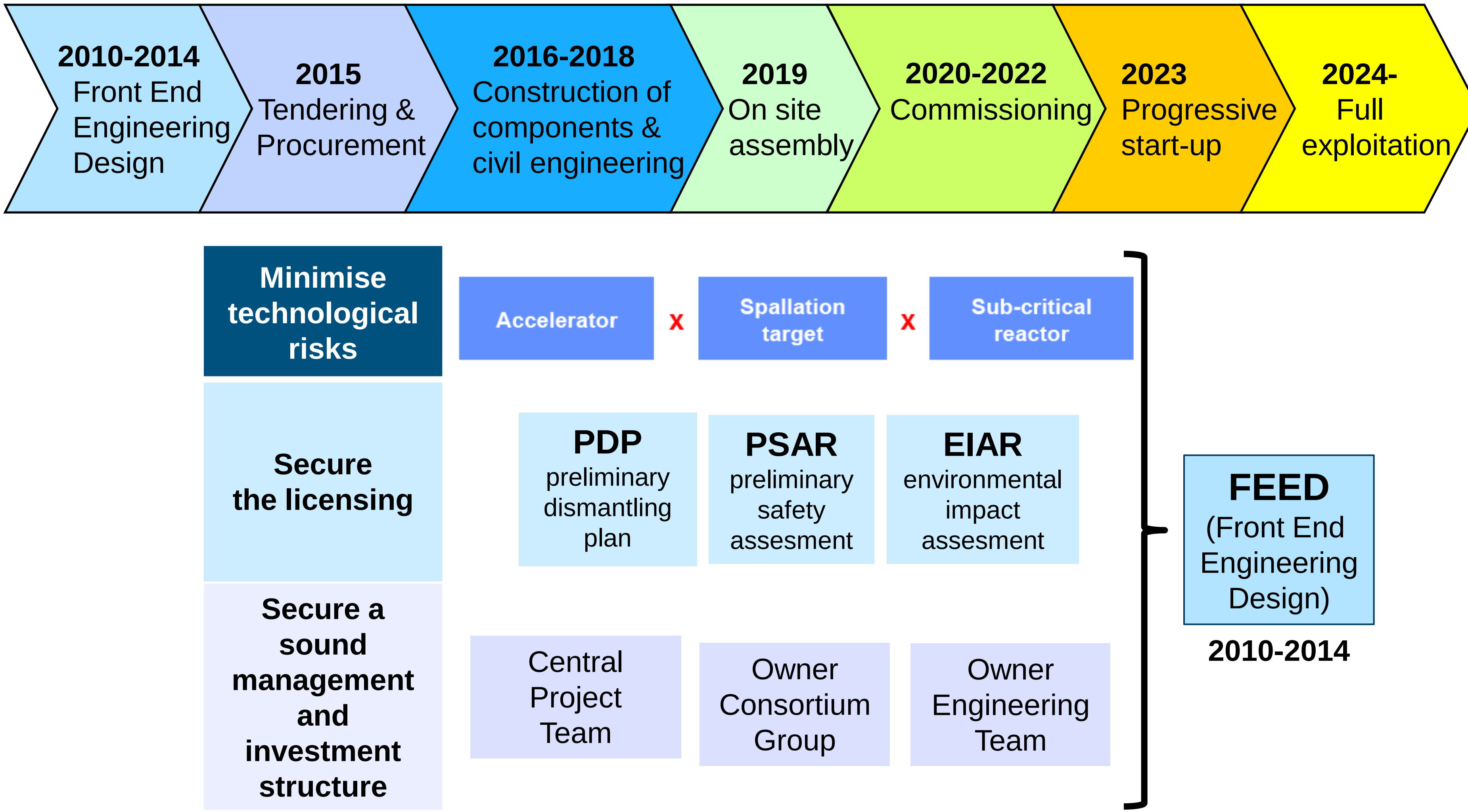
MYRRHA part of ESNII
European Sustainable Nuclear Industrial Initiative



MYRRHA design parameters

General design parameters	MYRRHA-FASTEF rev. 1.4
Maximum core power	100 MW_{th}
Reactor power	110 MW_{th}
Temperatures	
Cold shutdown state	200 °C
Maximum core inlet temperature	270 °C
Maximum mean core ΔT	140 °C
Average core outlet temperature	410 °C
Maximum hot plenum temperature	350 °C
Spallation target	
Type	Loopless spallation window
Number of core positions	One core position
Material	T91
Window Operating temperature	450 °C
Accelerator beam energy	600 MeV
Accelerator beam current	4 mA max

MYRRHA project schedule



MYRRHA Accelerator Challenge

fundamental parameters (ADS)	
particle	p
beam energy	600 MeV
beam current	4 mA
mode	CW
MTBF	> 250 h

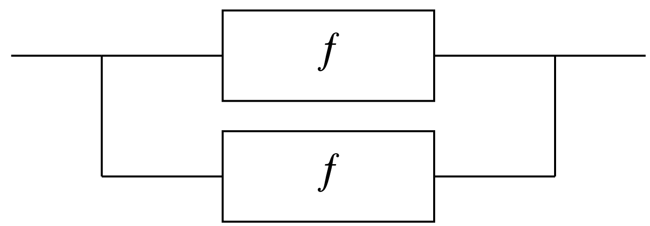
challenge !

failure = beam trip > 3 s

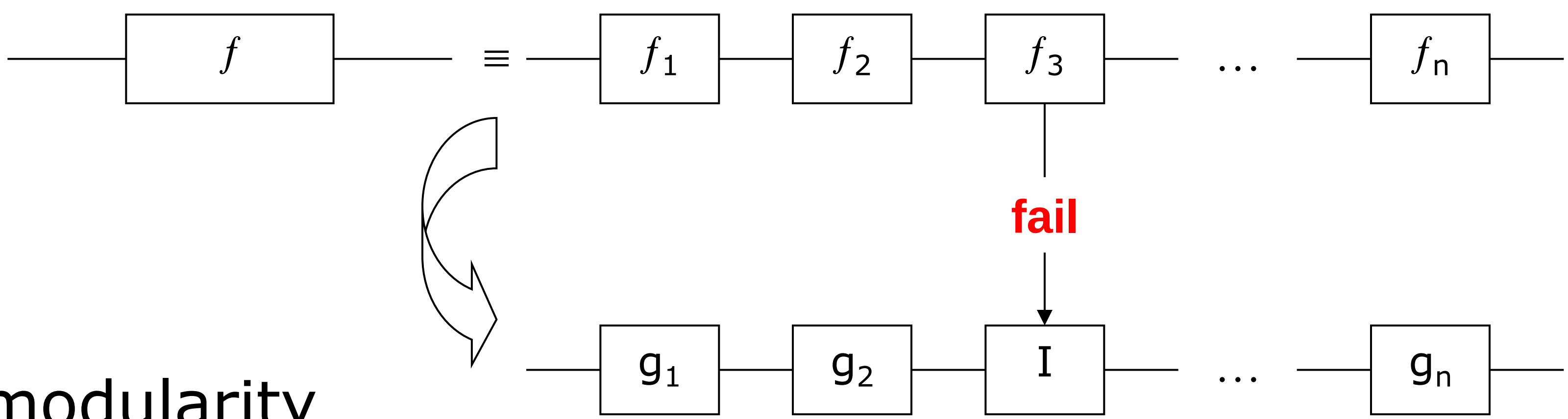
implementation	
superconducting linac	
frequency	176.1 / 352.2 / 704.4 MHz
reliability = redundancy	double injector
	"fault tolerant" scheme

Redundancy & modularity
Fault tolerant design

parallel scheme

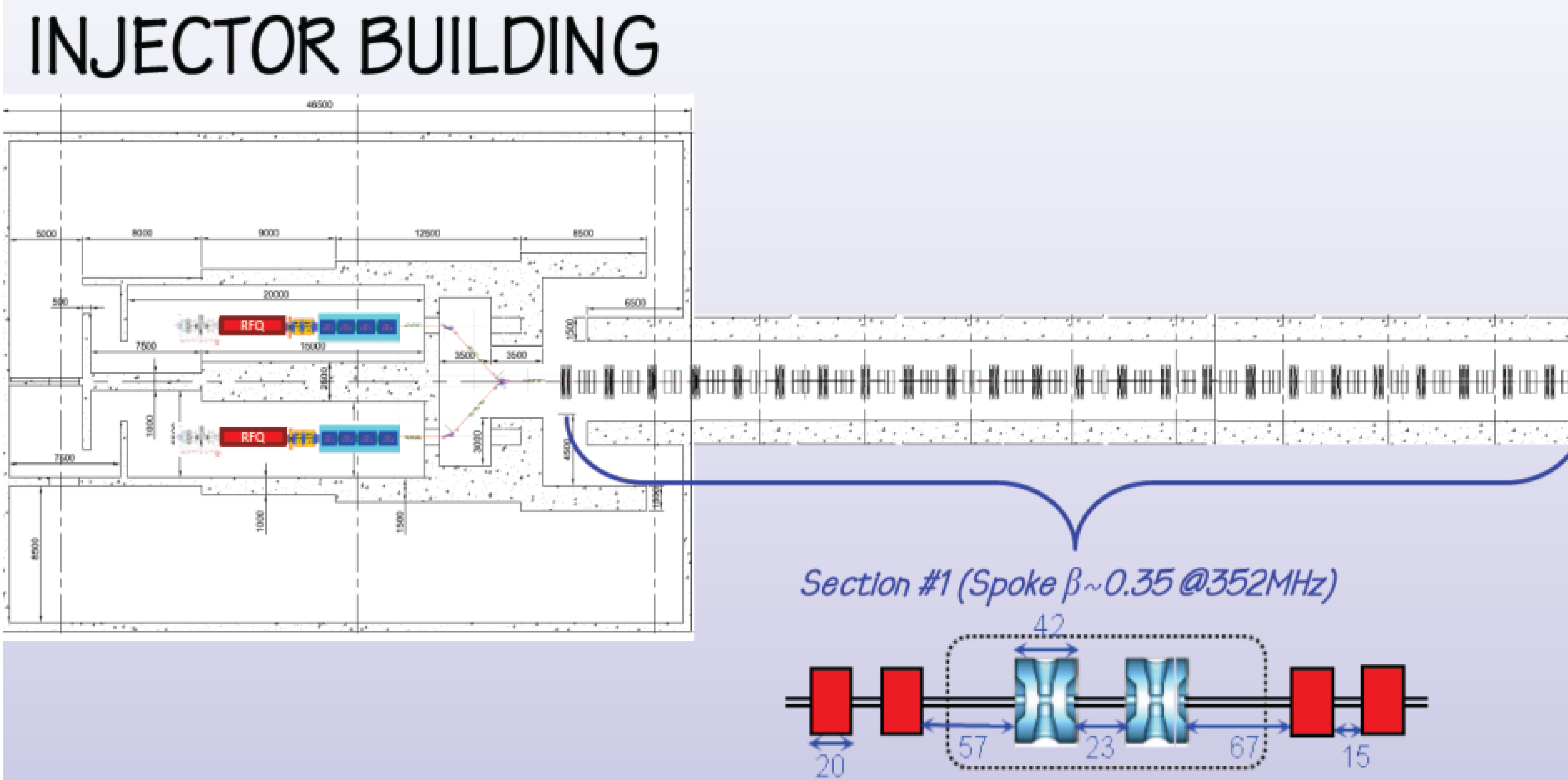


serial scheme: IF



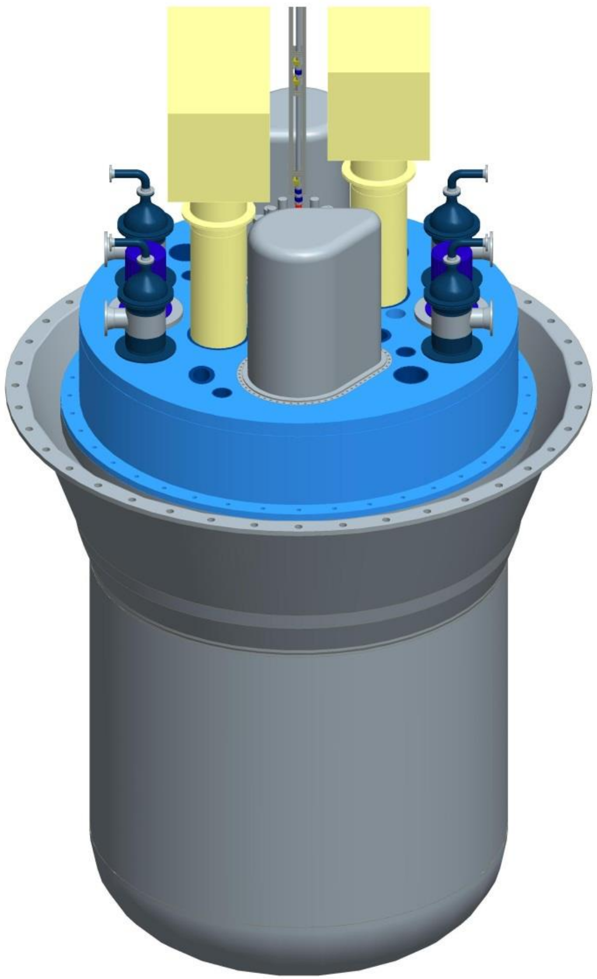
modularity

MYRRHA linac

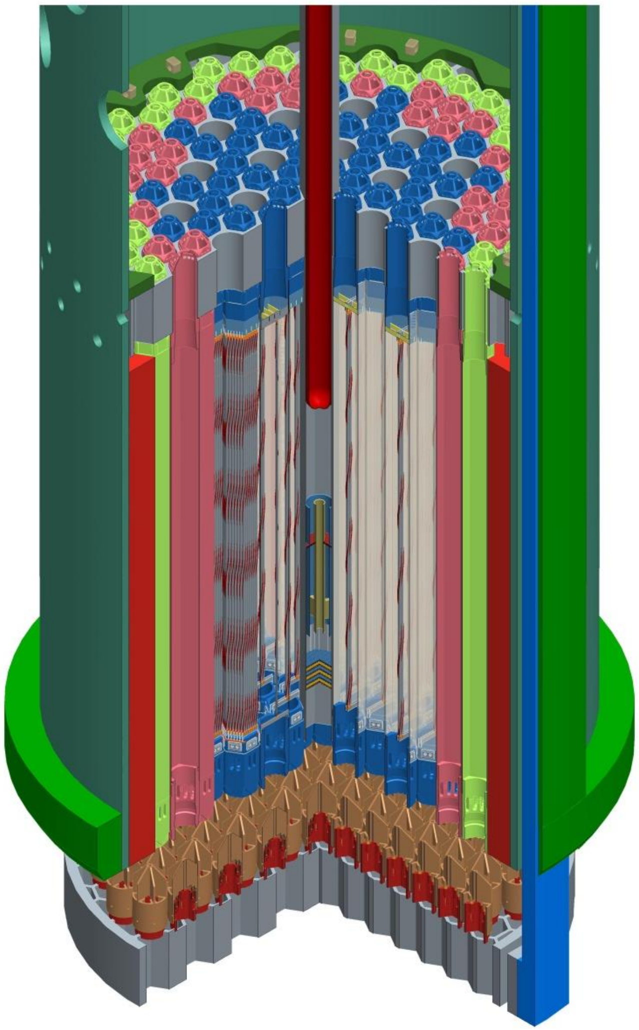


Reactor layout

- Reactor Vessel
- Reactor Cover
- Core Support Structure
  - Core Barrel
  - Core Support Plate
  - Jacket
- Core
  - Reflector Assemblies
  - Dummy Assemblies
  - Fuel Assemblies
- Spallation Target Assembly and Beam Line
- Above Core Structure
  - Core Plug
  - Multifunctional Channels
  - Core Restraint System
- Control Rods, Safety Rods, Mo-99 production units
- Primary Heat Exchangers
- Primary Pumps
- Si-doping Facility
- Diaphragm
  - IVFS
- IVFHS
  - IVFHM

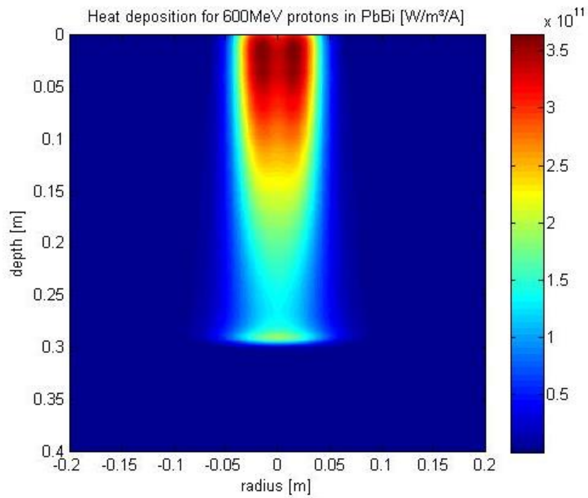


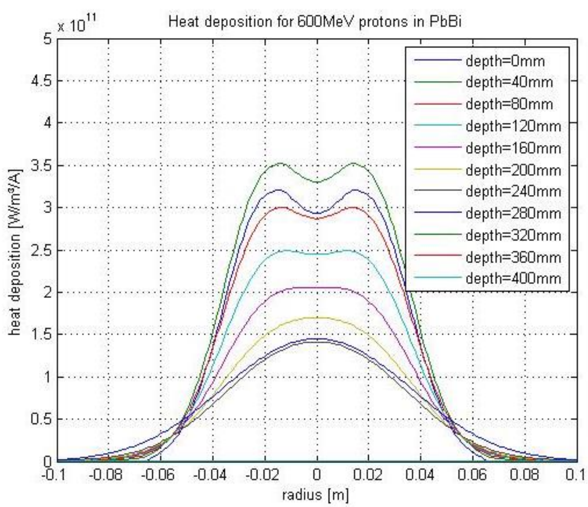
Spallation Target Assembly



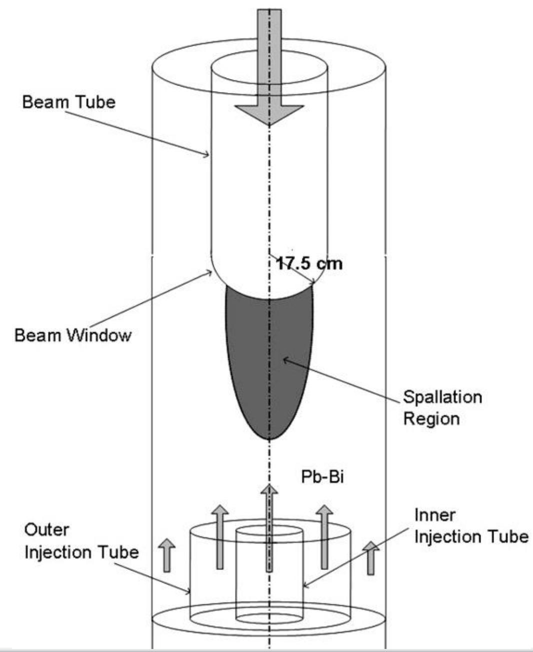
- Produces about 10^{17} neutrons/s at the reactor mid-plane to feed subcritical core @ keff=0.95
- Fits into a central hole in core
- Accepts megawatt proton beam
- Material challenges
- Dimensions
  - Length: about 12.5 m
  - Diameter: about 105 mm

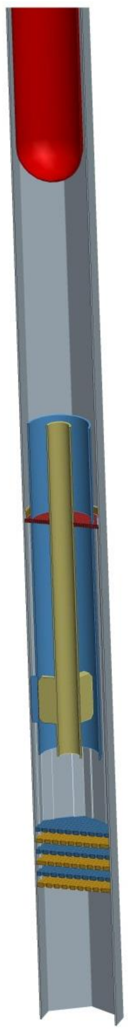
Spallation Target Assembly



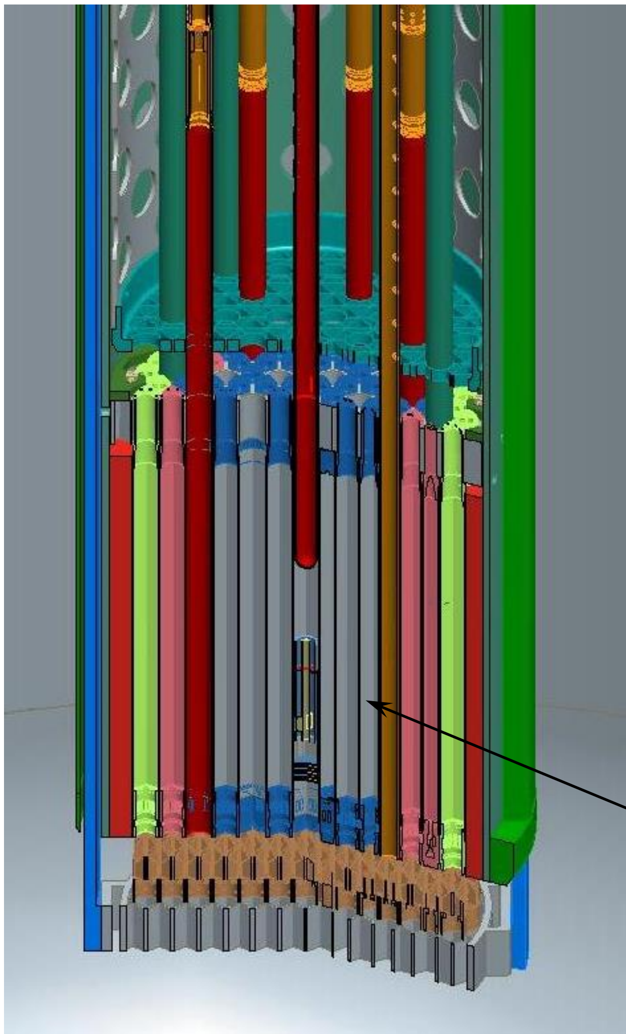


- Rotating beam σ 15 mm sweep 25 mm
- Limited heat deposition at stagnation point
- Multi tube concept
  - 3 Concentric inlet tubes

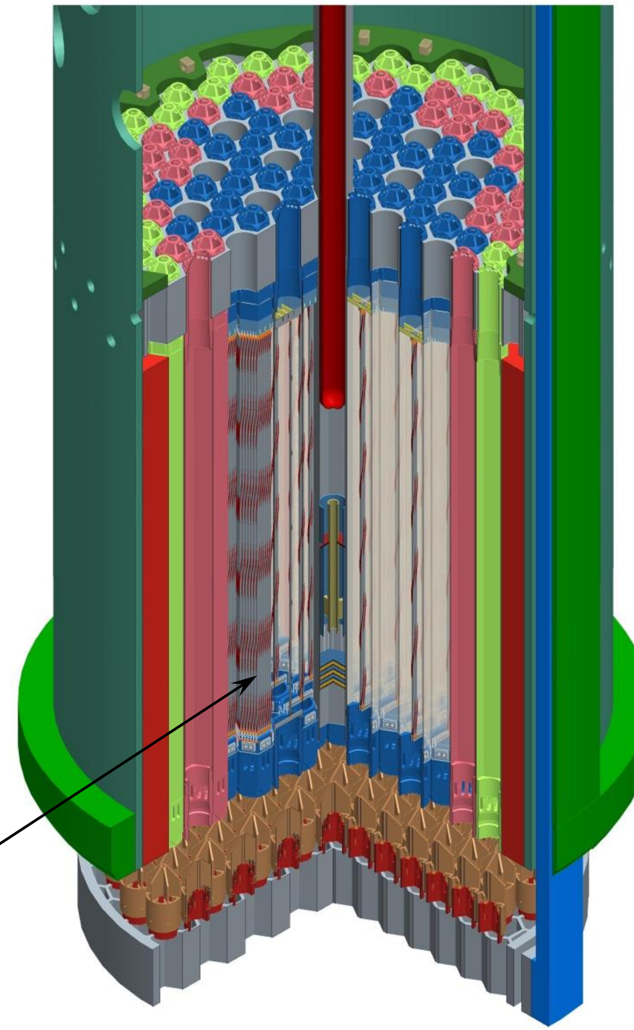




Core and Fuel Assemblies

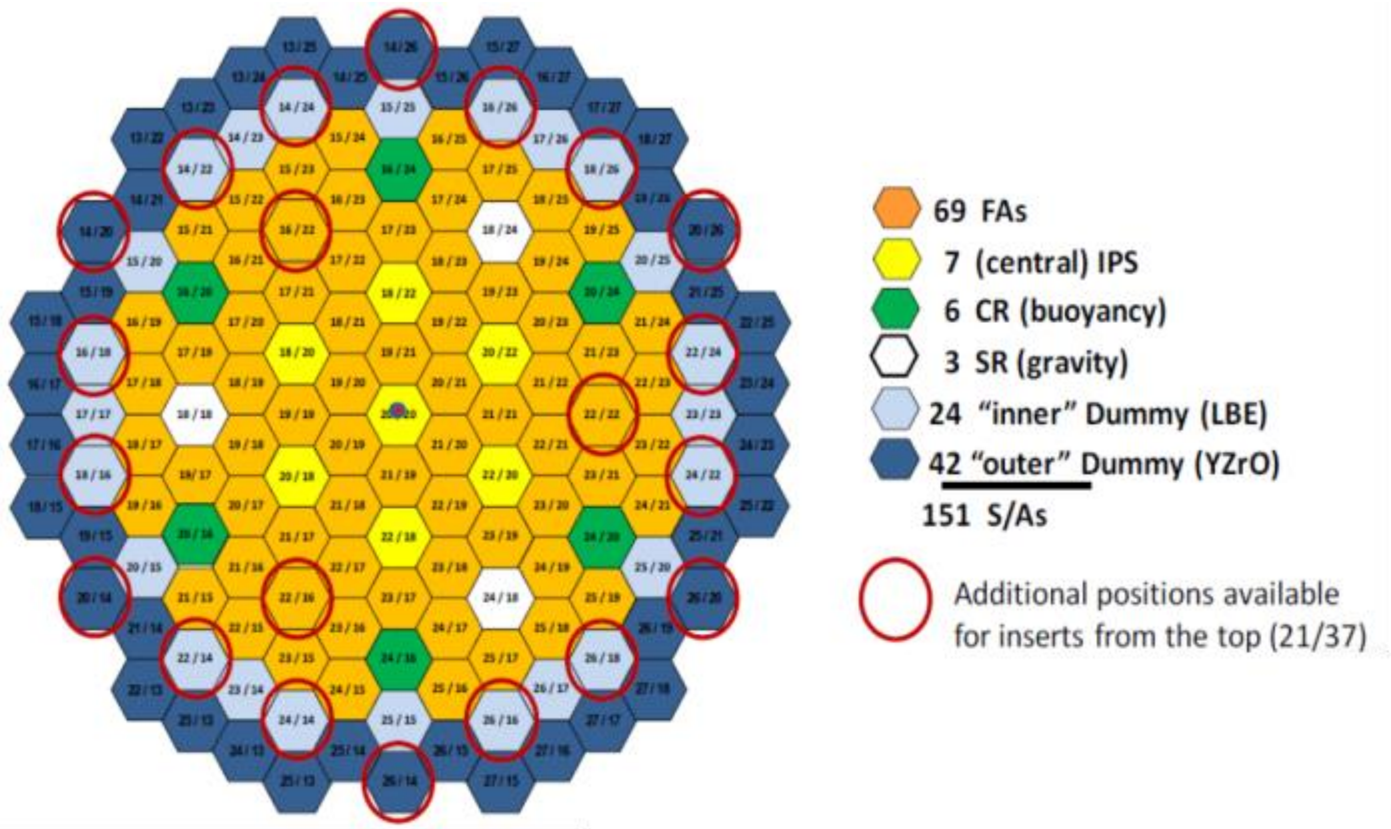


Fuel Assemblies

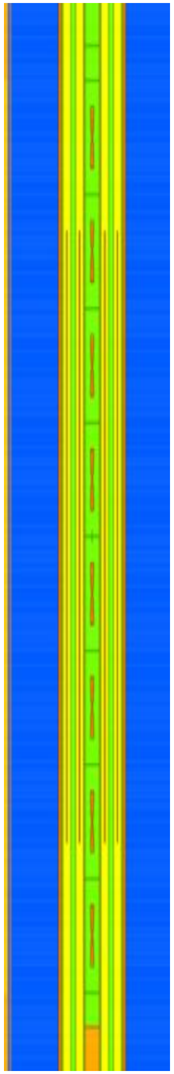


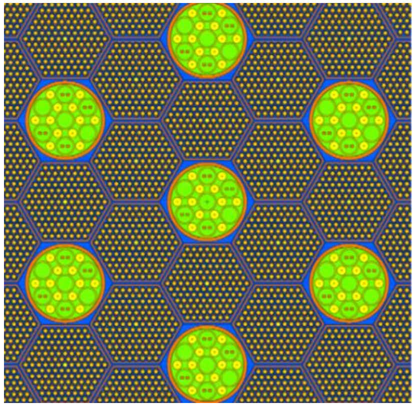
Core and Fuel Assemblies

- 151 positions
- 37 multifunctional plugs



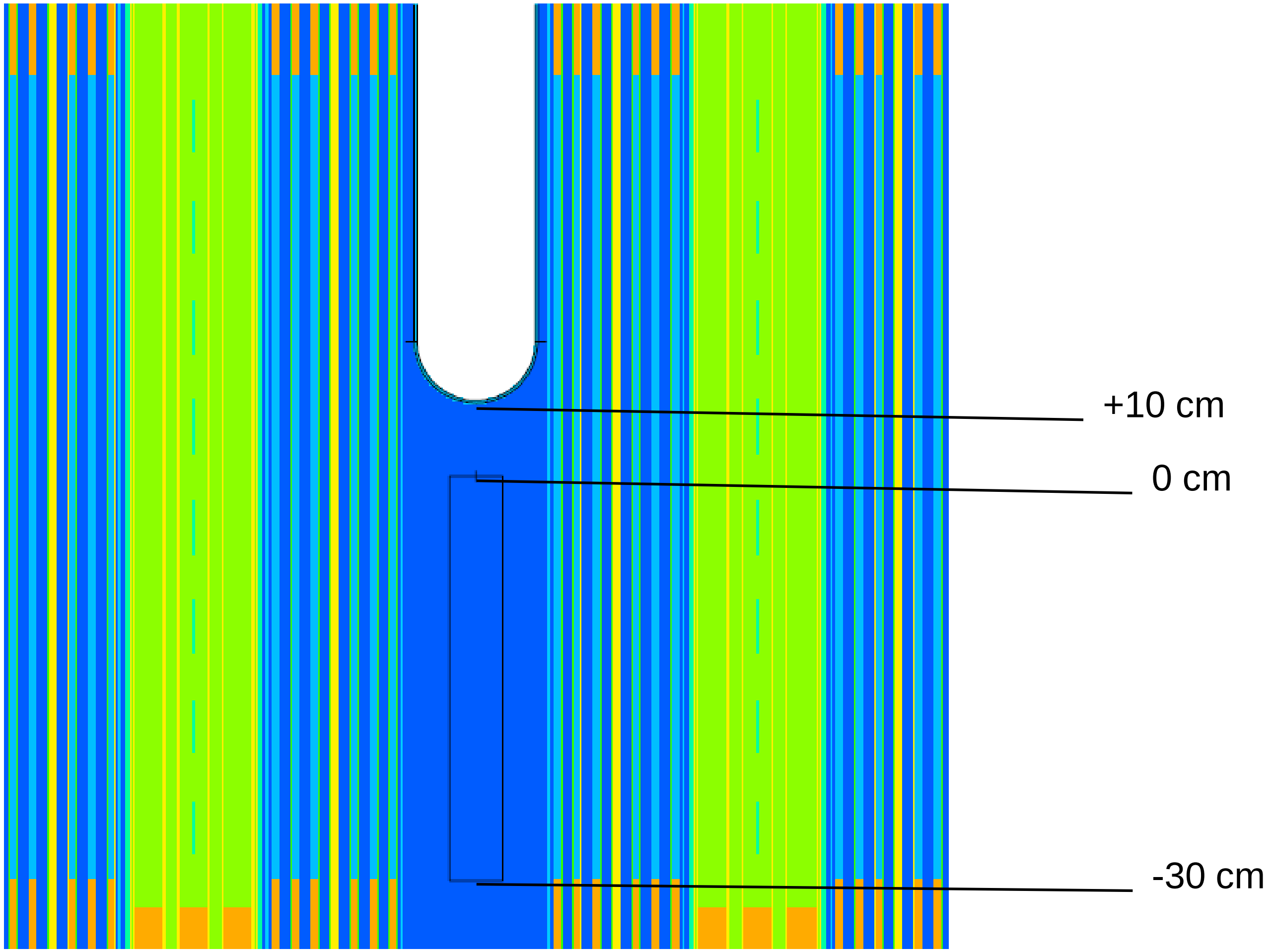
Material Irradiation Performances for FR Reactors Critical@100 MW



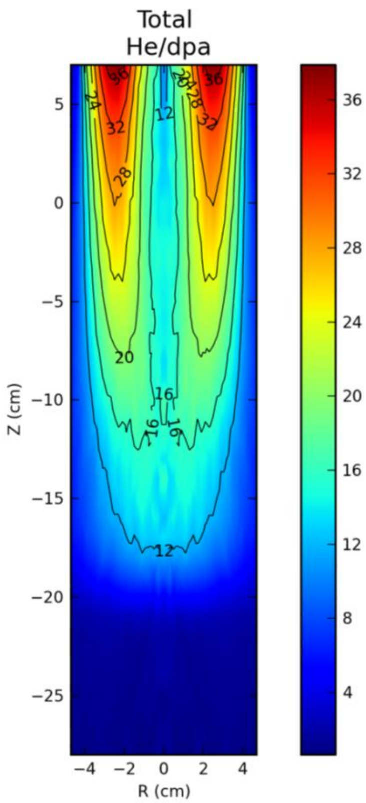


Sample n°	IPS in Chan [0 0 0] dpa/EFPY	IPS in Chan [0 0 0] Φ_{tot}	IPS in Chan [2 0 0] dpa/EFPY	IPS in Chan [2 0 0] Φ_{tot}
8	18.1	2.38E+15	16.2	2.12E+15
7	23.0	2.85E+15	20.7	2.54E+15
6	25.9	3.19E+15	23.3	2.85E+15
5	27.5	3.37E+15	24.5	3.02E+15
4	27.2	**3.39E+15**	24.5	**3.03E+15**
3	25.7	3.23E+15	22.9	2.89E+15
2	22.3	2.92E+15	19.9	2.62E+15
1	17.3	2.50E+15	15.5	2.23E+15

Irradiation capabilities in the spallation target subassembly (below the target)

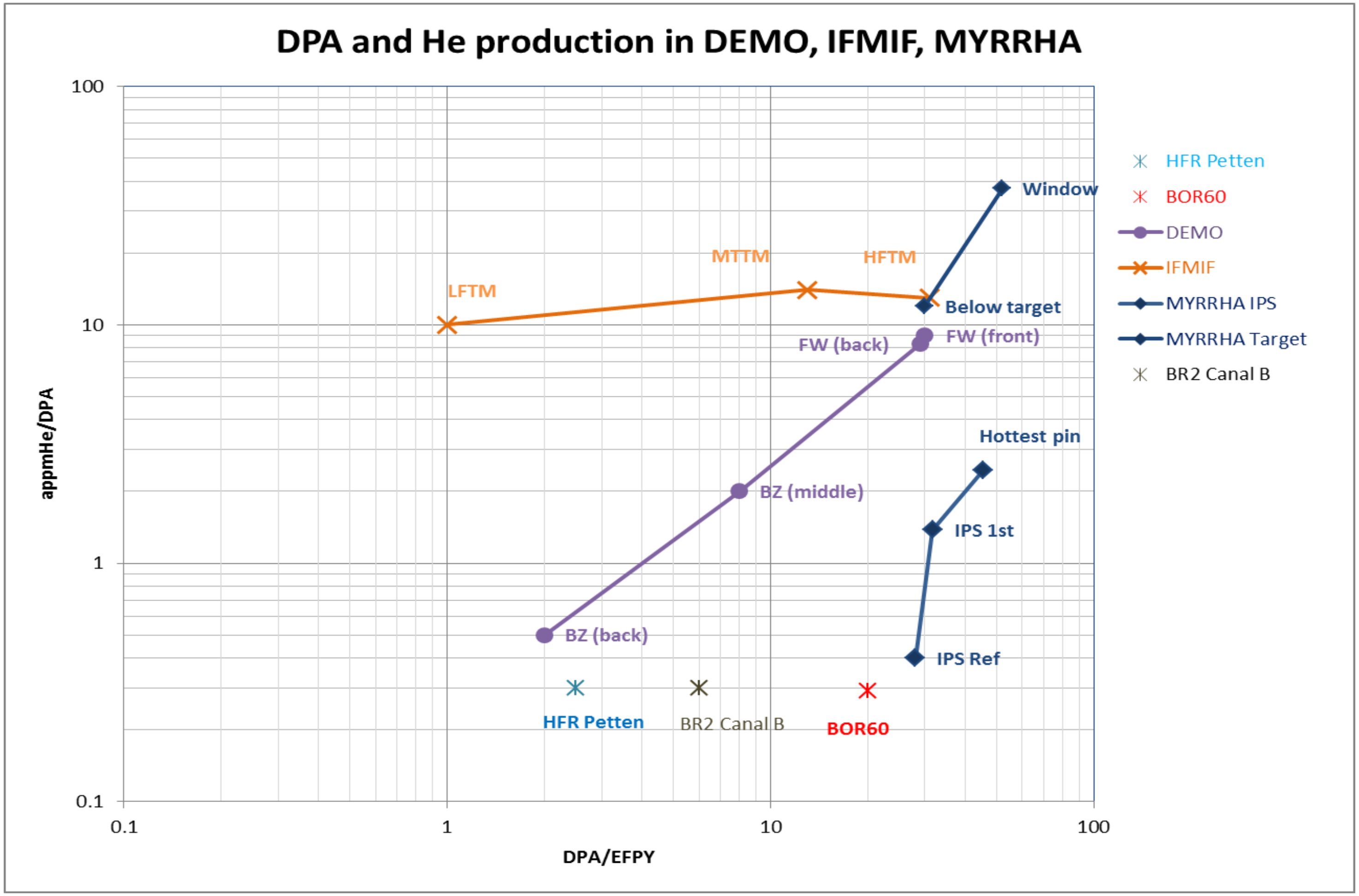


MYRRHA-IMIFF for fusion material



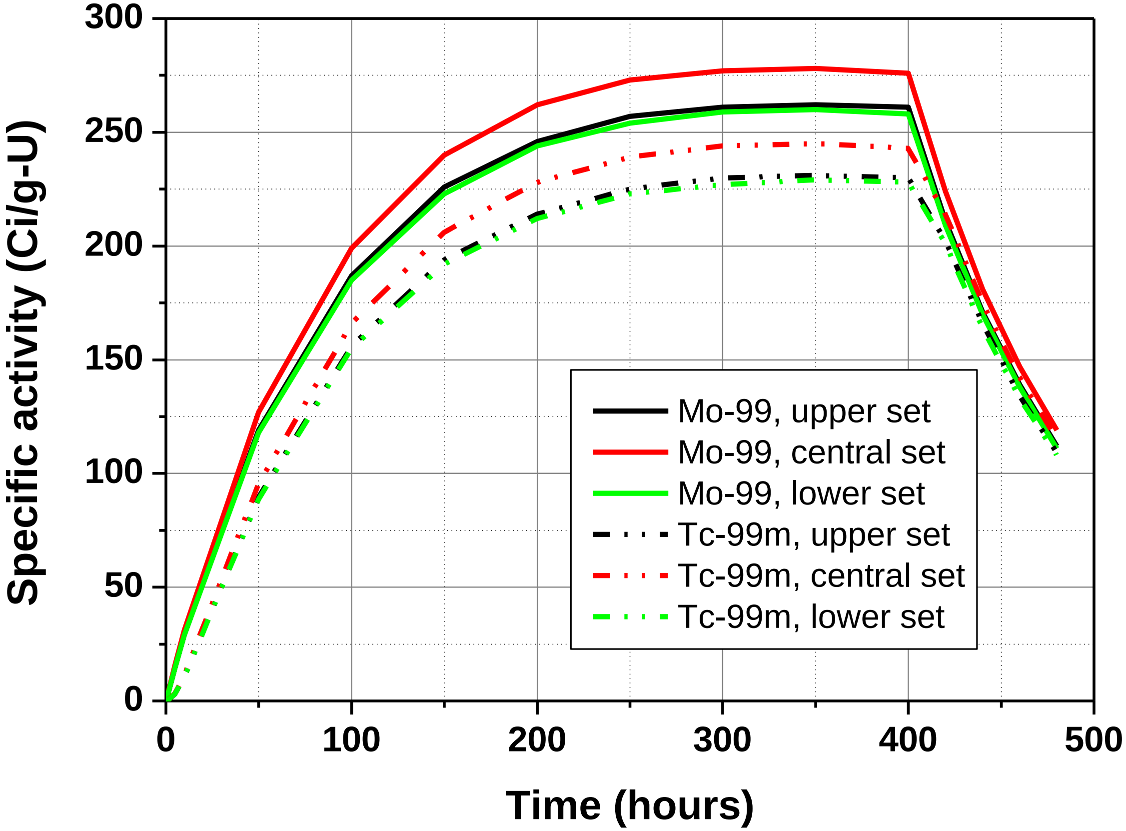
- In critical mode (fast reactor), appmHe/dpa ~ 0.2 to 1 ➔ not optimal for fusion materials experiments
- In sub-critical mode (ADS), high appmHe/dpa ratio is reached, specially in the region of the window of spallation source
- Volume of 1 lt with appmHe/dpa ~ 12 close to spallation target

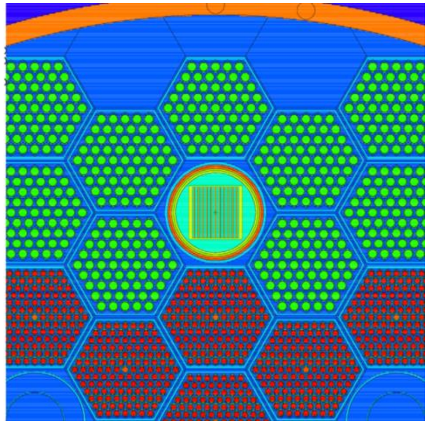
MYRRHA for fusion irradiations



Estimated damage induced in DEMO and proposed irradiation conditions in IFMIF and MYRRHA-IMIFF

Radioisotope (Mo-99) production capability
Sub-critical @ 73 MW



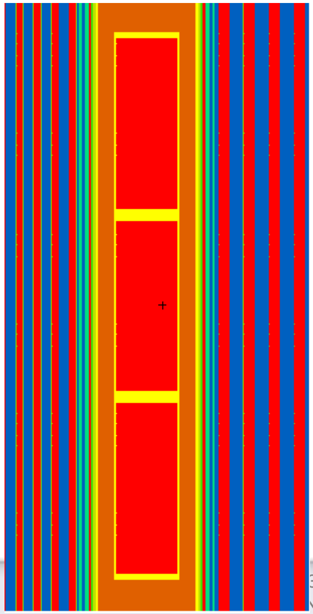


Average specific power

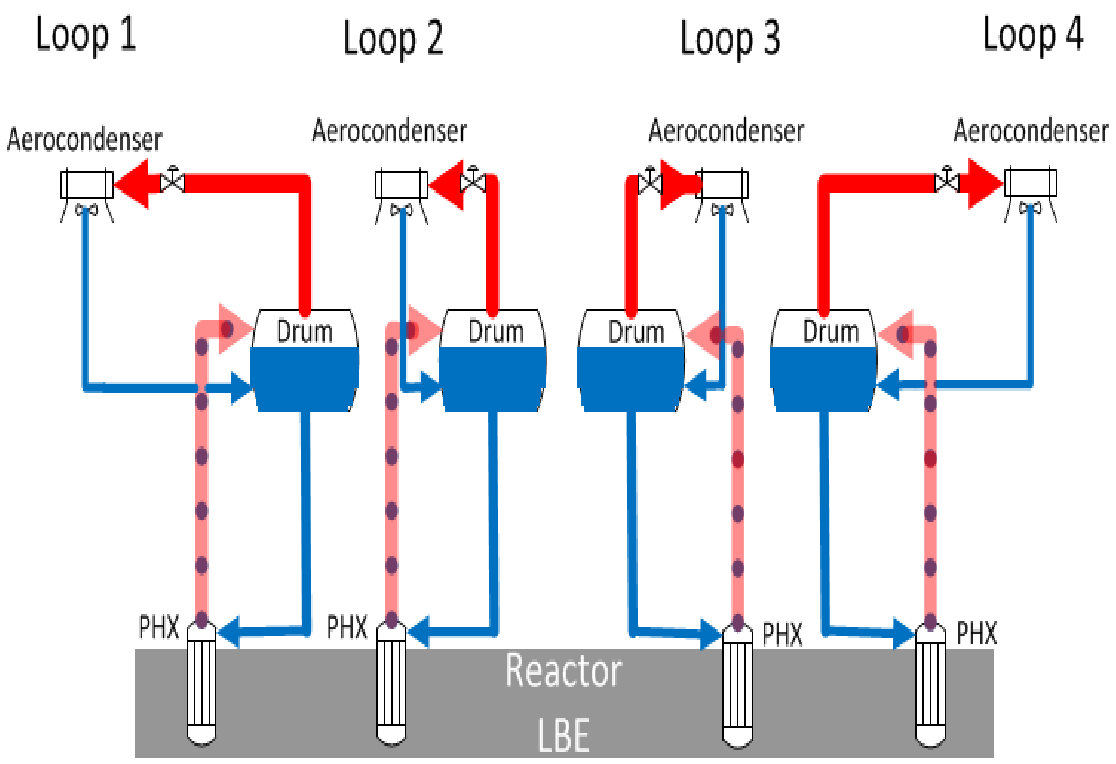
173 W/cm^2

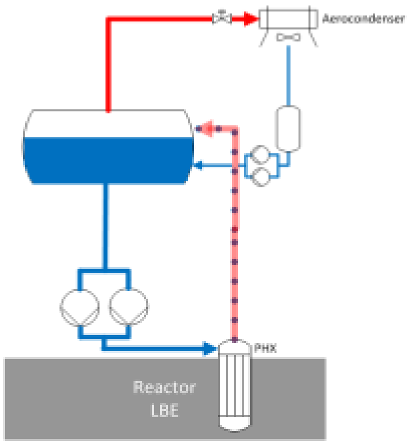
184 W/cm^2

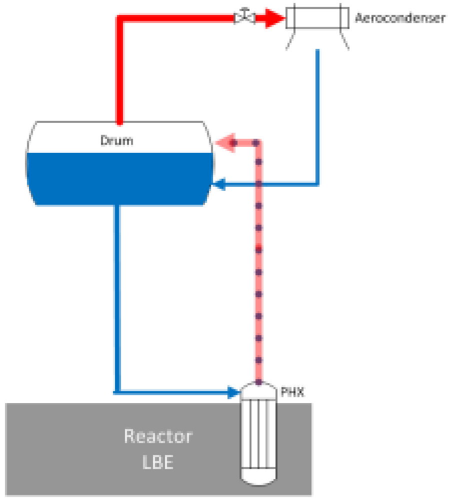
171 W/cm^2



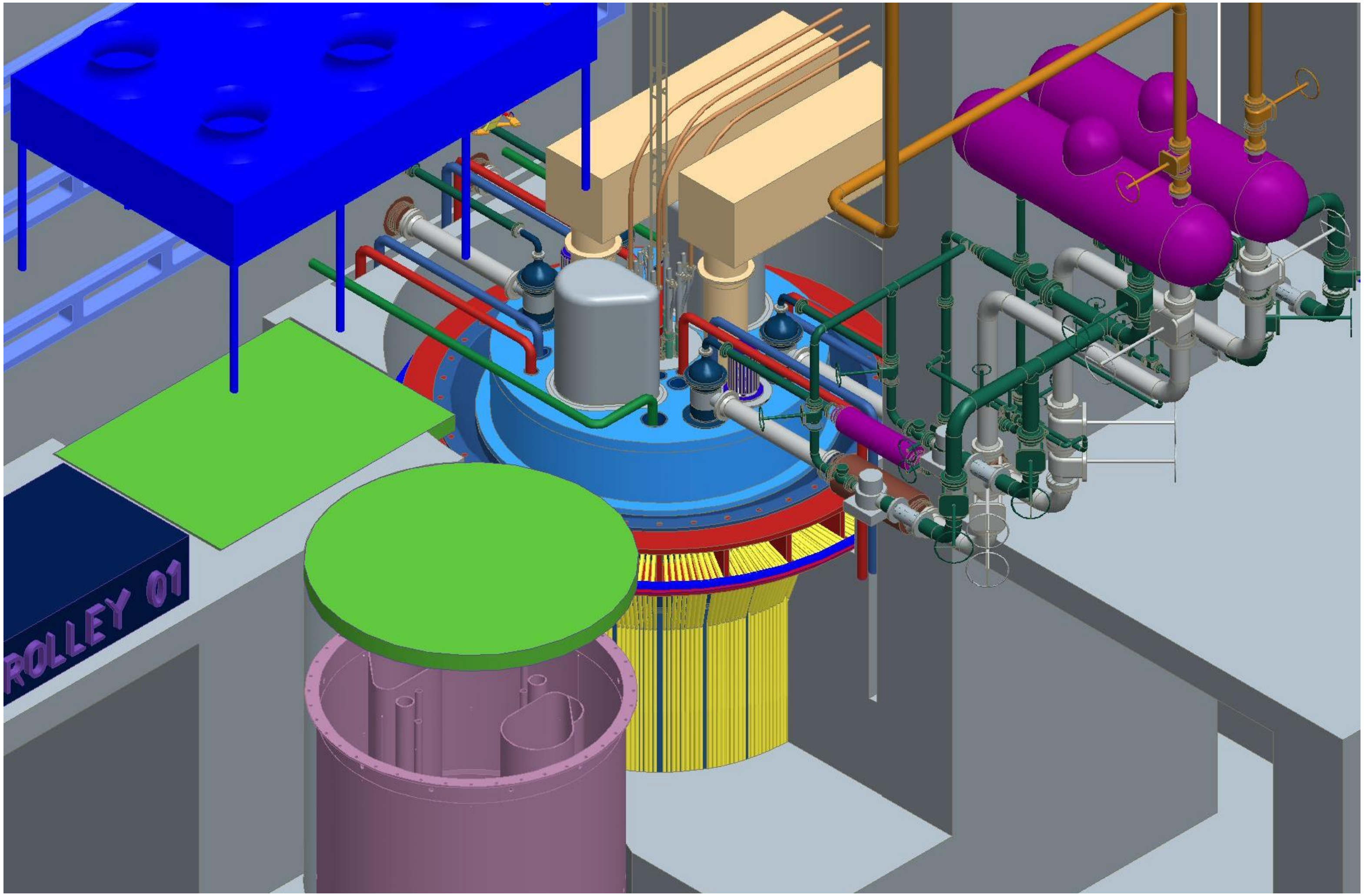
Cooling systems





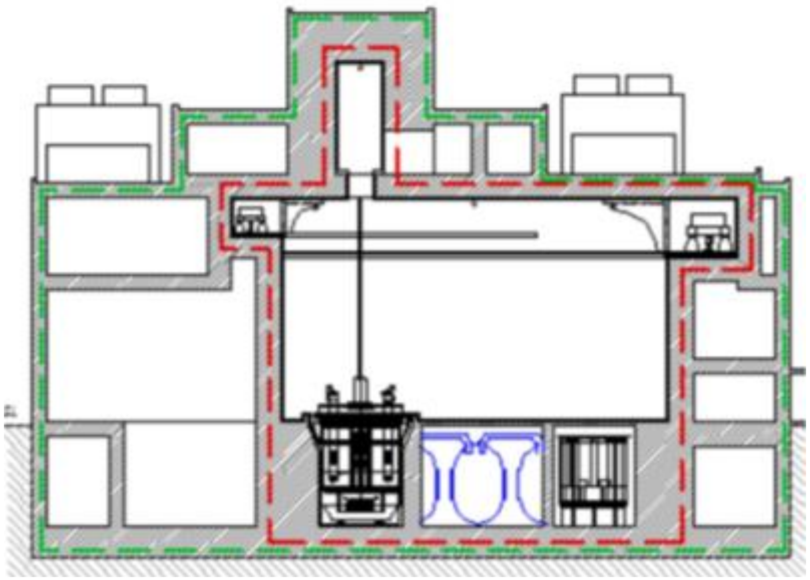


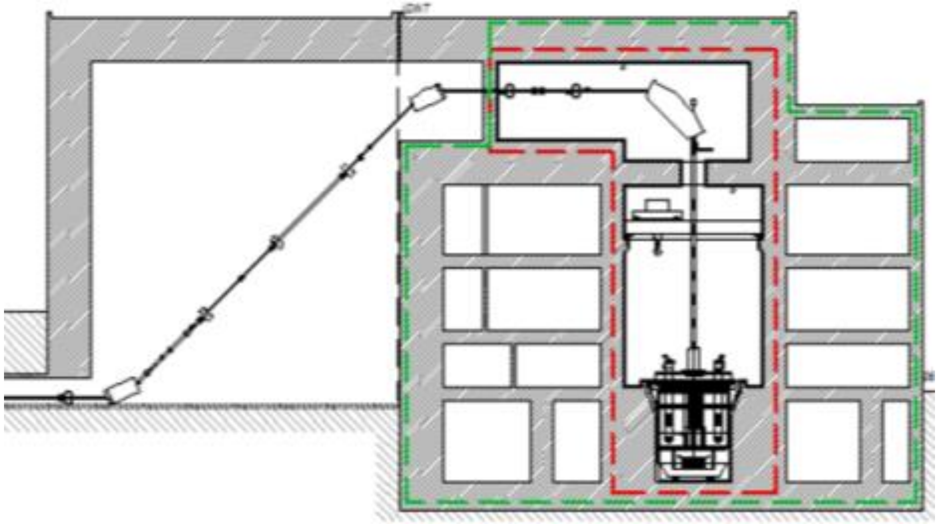
Cooling systems



Integration into building

Integration into building





MYRRHA R&D in International context : Euratom FP projects

TOPIC	FP5	FP6	FP7
Coupling	MUSE	DM2 ECATS	**FREYA**
Fuels	FUTURE	DM3 AFTRA	**FAIRFUELS**
Materials	MEGAPIE	DM4 DEMETRA	**MATTER**
	SPIRE, TECLA		**GETMAT**
Design	PDS-XADS	DM1 DESIGN	**CDT**
			MAX
	ADOPT	EUROTRANS	**SERIM G4**
Thermal-Hydraulics	ASCHLIM		**THINS**
LFR	-	ESLY	**LEADER**
Infrastructures	-	VELLA, MTRI3	**ADRIANA, SARGEN, NEWLANCER**
Scenario Studies	-	PATEROS	**ARCAS**
Safety	-	-	**SEARCH, SILER, MAXSIMA**

Recent evolutions

- Licensing
  - Guidances on accidental aircraft crash and seismic hazard issued by FANC
  - Content of the focus points fully described
  - Vol 1 & 2 of DOPF sent by SCK•CEN to FANC
- Primary system
  - Review of RVACS
  - Introduction of severe accident cooling system
  - Release of version 1.6 in January 2014
- Balance of Plant
  - FEED contract awarded to the consortium
    AREVA, ANSALDO, Empresarios Agrupados

MYRRHA: EXPERIMENTAL ACCELERATOR DRIVEN SYSTEM

A pan-European, innovative and unique facility

SCK•CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE