The MYRRHA ADS project

Paul Schuurmans for the MYRRHA Team
High Level Nuclear Waste

Fuel

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

(4 eV for combustion of C)

Minor Actinides

- High radiotoxicity long lived waste that are difficult to store due to:
  - Long lived (>1,000 years)
  - Highly radiotoxic
  - Heat emitting
Motivation for Transmutation

- Transmutation of spent fuel
- Spent fuel reprocessing
- No reprocessing

**Graph:**
- Relative radiotoxicity vs. time (years)
- Uranium naturel
- Duration Reduction: 1.000x
- Volume Reduction: 100x
• 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

Objectives

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

Accelerator
(600 MeV - 4 mA proton)

Reactor
- Subcritical or Critical modes
- 65 to 100 MWth

Multipurpose Flexible Irradiation Facility

Fast Neutron Source

Spallation Source
MYRRHA part of ESNII
European Sustainable Nuclear Industrial Initiative

- **ASTRID**
  - SFR Prototype

- **MYRRHA**
  - Flexible Irradiation Facility

- **ALFRED**
  - LFR Demonstrator

- **ALLEGRO**
  - GFR Demonstrator

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**2025**

- **Reference Technology**
  - Design, Construction & Commissioning

- **Supporting Infrastructure**
  - Design, Construction & Commissioning

- **Short-term alternative Technology**
  - Conceptual design, siting, & supporting R&D

- **Long-term alternative Technology**
  - Conceptual design, siting, & supporting R&D
### MYRRHA design parameters

<table>
<thead>
<tr>
<th>General design parameters</th>
<th>MYRRHA-FASTEF rev. 1.4</th>
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<tbody>
<tr>
<td>Maximum core power</td>
<td>100 MW&lt;sub&gt;th&lt;/sub&gt;</td>
</tr>
<tr>
<td>Reactor power</td>
<td>110 MW&lt;sub&gt;th&lt;/sub&gt;</td>
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<tr>
<td><strong>Temperatures</strong></td>
<td></td>
</tr>
<tr>
<td>Cold shutdown state</td>
<td>200 °C</td>
</tr>
<tr>
<td>Maximum core inlet temp</td>
<td>270 °C</td>
</tr>
<tr>
<td>Maximum mean core ΔT</td>
<td>140 °C</td>
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<tr>
<td>Average core outlet temp</td>
<td>410 °C</td>
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<tr>
<td>Maximum hot plenum temp</td>
<td>350 °C</td>
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<tr>
<td><strong>Spallation target</strong></td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>Loopless spallation window</td>
</tr>
<tr>
<td>Number of core positions</td>
<td>One core position</td>
</tr>
<tr>
<td>Material</td>
<td>T91</td>
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<tr>
<td>Window Operating temp</td>
<td>450 °C</td>
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<tr>
<td><strong>Accelerator beam energy</strong></td>
<td>600 MeV</td>
</tr>
<tr>
<td><strong>Accelerator beam current</strong></td>
<td>4 mA max</td>
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</tbody>
</table>
MYRRHA project schedule

2010-2014
Front End Engineering Design

2015
Tendering & Procurement

2016-2018
Construction of components & civil engineering

2019
On site assembly

2020-2022
Commissioning

2023
Progressive start-up

2024-
Full exploitation

Minimise technological risks

Secure the licensing

Secure a sound management and investment structure

Accelerator
Spallation target
Sub-critical reactor

PDP
preliminary dismantling plan

PSAR
preliminary safety assessment

EIAR
environmental impact assessment

Central Project Team
Owner Consortium Group
Owner Engineering Team

FEED
(Front End Engineering Design)

2010-2014
### MYRRHA Accelerator Challenge

#### fundamental parameters (ADS)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>particle</td>
<td>p</td>
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<tr>
<td>beam energy</td>
<td>600 MeV</td>
</tr>
<tr>
<td>beam current</td>
<td>4 mA</td>
</tr>
<tr>
<td>mode</td>
<td>CW</td>
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<tr>
<td>MTBF</td>
<td>&gt; 250 h</td>
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</table>

*failure = beam trip > 3 s*

#### implementation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>superconducting linac</td>
<td></td>
</tr>
<tr>
<td>frequency</td>
<td>176.1 / 352.2 / 704.4 MHz</td>
</tr>
<tr>
<td>reliability = redundancy</td>
<td>double injector</td>
</tr>
<tr>
<td></td>
<td>“fault tolerant” scheme</td>
</tr>
</tbody>
</table>
Redundancy & modularity
Fault tolerant design

parallel scheme

serial scheme: IF

modularity
INJECTOR BUILDING

Section #1 (Spoke β~0.35 @352MHz)
- 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 @ $k_{eff}=0.95$

- 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 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

<table>
<thead>
<tr>
<th>Sample n°</th>
<th>IPS in Chan [0 0 0]</th>
<th>IPS in Chan [2 0 0]</th>
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<tr>
<td></td>
<td>dpa/EFPY</td>
<td>$\Phi_{tot}$</td>
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<tr>
<td>8</td>
<td>18.1</td>
<td>2.38E+15</td>
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<tr>
<td>7</td>
<td>23.0</td>
<td>2.85E+15</td>
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<td>6</td>
<td>25.9</td>
<td>3.19E+15</td>
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<td>5</td>
<td>27.5</td>
<td>3.37E+15</td>
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<tr>
<td>4</td>
<td>27.2</td>
<td><strong>3.39E+15</strong></td>
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<tr>
<td>3</td>
<td>25.7</td>
<td>3.23E+15</td>
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<tr>
<td>2</td>
<td>22.3</td>
<td>2.92E+15</td>
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<tr>
<td>1</td>
<td>17.3</td>
<td>2.50E+15</td>
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</table>
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
Estimated damage induced in DEMO and proposed irradiation conditions in IFMIF and MYRRHA-IMIFF
Radioisotope (Mo-99) production capability
Sub-critical @ 73 MW

- Mo-99, upper set
- Mo-99, central set
- Mo-99, lower set
- Tc-99m, upper set
- Tc-99m, central set
- Tc-99m, lower set

Average specific power:
- 173 W/cm²
- 184 W/cm²
- 171 W/cm²
Cooling systems
Cooling systems
Integration into building
Integration into building
### MYRRHA R&D in International context: Euratom FP projects

<table>
<thead>
<tr>
<th>TOPIC</th>
<th>FP5</th>
<th>FP6</th>
<th>FP7</th>
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<tr>
<td>Coupling</td>
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<td>DM2 ECATS</td>
<td>FREYA</td>
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<td>DM3 AFTRA</td>
<td>FAIRFUELS</td>
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<td>MEGAPIE</td>
<td>DM4 DEMETRA</td>
<td>MATTER</td>
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<td>SEARCH, SILER, MAXSIMA</td>
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**Notes:**
- FP5, FP6, FP7 refer to the Framework Programmes under the European Commission.
- The diagram illustrates the coupling and collaboration between different projects across the programmes.
- Projects like MUSE, DM2 ECATS, DM3 AFTRA, DM4 DEMETRA, DM1 DESIGN, FREYA, FAIRFUELS, MATTER, GETMAT, CDT, MAX, SERIM G4, THINS, LEADER, ADRIANA, SARGEN, NEWLANCER, ARCAS, SEARCH, SILER, MAXSIMA are listed, indicating their participation and contribution to the MYRRHA project.
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