MYRRHA
An innovative and unique irradiation research facility

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Overview

- The MYRRHA Project
- The Belgian Approval Process
- MYRRHA in a European and World Context
- Conclusions
MYRRHA Genesis & History

- **Post BR2** (1994)
- **ADONIS** (1994-96)
- **Transmutation** (1995)
- **Non Energy Applications** (1994 RI, 1995 H₂)

MYRRHA Project (1998-2004)

- **XT-ADS in EUROTRANS** from 2005

- **Gen.IV LFR** 2002 GIF

*current MYRRHA Project (2010)*
<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>2001</td>
<td>International Strategic Guidance Committee</td>
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<tr>
<td>2002</td>
<td>International Technical Guidance Committee</td>
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<tr>
<td>2003</td>
<td>Review by Russian Lead Reactor Technology Experts (ISTC#2552p project)</td>
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<tr>
<td>2007</td>
<td>International Assessment Meeting of the Advanced Nuclear Systems Institute</td>
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<tr>
<td>2008</td>
<td>European Commission FP7 Project Central Design Team (CDT) at Mol for MYRRHA detailed design</td>
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<tr>
<td>2009</td>
<td>MIRT of OECD/NEA on request of Belgian Government (see further)</td>
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MYRRHA is an innovative and exciting project and the facility would be unique in the world

MYRRHA could play a role:

- in decisions related to and the development of the technology of the transmutation of nuclear waste
- in the development of advanced nuclear reactors, especially lead-cooled reactors
- as a fast neutron irradiation facility for materials and component testing for fission and fusion reactors
- as serving the needs of accelerator-based scientific communities (radioactive beams, proton therapy, proton-based isotope production, accelerator science, …)
- as a neutron irradiation facility for silicon crystal doping and manufacturing of radioactive isotopes for medical and industrial sources
Accelerator
(600 MeV – 2.5 mA proton)

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

Spallation source

Multipurpose fast spectrum irradiation facility

Fast neutron source

Lead-Bismuth coolant
### Meeting long term needs of society

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Solution</th>
<th>MYRRHA contribution</th>
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<tbody>
<tr>
<td><strong>Fission</strong></td>
<td></td>
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<tr>
<td>High radiotoxic level waste</td>
<td>Transmutation</td>
<td>ADS demo</td>
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<tr>
<td><strong>Fission GEN IV</strong></td>
<td>Demonstrate concept</td>
<td>Build demonstrators</td>
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<tr>
<td><strong>Fusion</strong></td>
<td>Extreme operating conditions</td>
<td>Material testing &amp; development</td>
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<tr>
<td><strong>Fundamental research</strong></td>
<td>Pushing the limits of knowledge</td>
<td>Access to proton beam</td>
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<td><strong>Renewable energies</strong></td>
<td>Efficient power electronics</td>
<td>High efficiency transistors (NTD-Si)</td>
</tr>
<tr>
<td><strong>Healthcare</strong></td>
<td>Ageing population</td>
<td>A long term source of medical radioisotopes</td>
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</table>

- **LFR technology demo**
- **Fast spectrum irradiation facility**
- **Long term experiments with radioactive ion beams (RIB)**
- **Securing NTD-Silicon production**
- **Securing radioisotopes production (existing and new ones)**
Objective

1962
BR2

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

Fast Neutron Material Testing Reactor (fission + fusion)
ADS-Demo + P&T testing (Partitioning & Transmutation)
Fuel testing For LFR GEN IV

LFR European Technology Pilot Plant (ETPP)

2023
MYRRHA
## Rationale

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Requirements</th>
<th>Choices</th>
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</thead>
<tbody>
<tr>
<td>Flexible</td>
<td>• 1.10^{15} \text{n/cm}^2.s (&gt;0.75 \text{MeV}) in large volumes (3 l)</td>
<td>• small target</td>
</tr>
<tr>
<td>Fast Spectrum</td>
<td>• availability (65%)</td>
<td>• HLM cooling</td>
</tr>
<tr>
<td>Irradiation facility</td>
<td>• flexibility</td>
<td>• pool-type</td>
</tr>
<tr>
<td></td>
<td>• no high temperatures required</td>
<td>• in-vessel storage</td>
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<td></td>
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<td>• FA manipulation beneath core</td>
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<tr>
<td></td>
<td></td>
<td>• in-vessel inspection &amp; repair</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• IPS manipulation above core</td>
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<tr>
<td></td>
<td></td>
<td>• replaceability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• LBE cooling</td>
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### Objectives

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Choices</th>
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<tbody>
<tr>
<td>ADS demonstration</td>
<td><strong>•</strong> LINAC (600 MeV, 4 mA)</td>
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<tr>
<td>• high power accelerator</td>
<td></td>
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<tr>
<td>• reliability</td>
<td></td>
</tr>
<tr>
<td>• target</td>
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### LFR demo

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Choices</th>
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</thead>
<tbody>
<tr>
<td>• HLM technology &amp; components</td>
<td><strong>•</strong> MYRRHA/FASTEF</td>
</tr>
<tr>
<td>• <em>Critical mode operation</em></td>
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### Operational in 2023

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Choices</th>
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<tr>
<td>• Use of mature technology where possible</td>
<td><strong>•</strong> FR MOX 30-35% fuel</td>
</tr>
<tr>
<td>• Innovation where needed</td>
<td><strong>•</strong> 15-15-Ti AS → T91 MS</td>
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<tr>
<td></td>
<td><strong>•</strong> LBE</td>
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</tbody>
</table>
Inner vessel
Cover
Core structure
Spallation window
Heat exchangers
Pumps
Diaphragm
Fuel manipulators
Guard vessel
Fuel storage
Reactor layout – In-vessel fuel manipulation
Reactor layout - Core

- $k_{\text{eff}} \approx 0.95$ (ADS mode)
- 30-35% MOX fuel
- 7 IPS positions
Reactor layout - Fuel and fuel procurement

- Reference option for the first cores
  - 30% – 35% MOX fuel
  - Phenix fuel pin
    - 15-15 Ti cladding
    - OD 6.55mm, 0.45mm wall thickness
  - Wire wrap
  - Solid pellet
  - Known experience (BN, Phenix)
  - Large existing database
- Possible fuel providers
  - France, UK, Japan, ..
● Phenix fuel
● Cladding in 15-15 Ti
● Wire wrap
Reactor layout – Fuel pin
Reactor layout – The heat exchanger

- Primary Heat Exchanger
  - Shell and Tube
  - Double walled design
  - Length of tubes: 1.5m
  - Diameter of tubes: 16mm
  - 700 tubes
  - Shroud: 850mm
  - Total length: about 8m
  - Internal pressure: 16bar
Reactor layout – The control/scram rods

- Gravity driven scram rods
  - Ballasted
  - Forced injection
- Buoyancy driven control/scram rods
<table>
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<tr>
<th>Accelerator</th>
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<tr>
<th><strong>Proton energy</strong></th>
<th>600 MeV</th>
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<tr>
<td><strong>Beam intensity (CW)</strong></td>
<td>Max 4 mA</td>
</tr>
<tr>
<td><strong>Beam entry</strong></td>
<td>vertically from above</td>
</tr>
<tr>
<td><strong>Beam stability</strong></td>
<td>energy ±1% intensity ±2%, size ±10%</td>
</tr>
<tr>
<td><strong>Footprint on target</strong></td>
<td>“donut”-shaped, ( r_{in} ) 25 mm ( r_{out} ) 50 mm</td>
</tr>
<tr>
<td><strong>Reliability</strong></td>
<td>Trips &gt; 3s = max 10 per cycle</td>
</tr>
<tr>
<td><strong>Time structure</strong></td>
<td>CW, ( I=0 ) holes 200 ( \mu s ), 1 Hz pulsed mode capable (50 Hz)</td>
</tr>
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</table>
Accelerator

* IFMIF

- SC linac
- RFQ
- isotope production
- cyclotron
- synchrotron
- RIB - ISOL
- ADS
- HE FT
- HE collider
- particle therapy
Accelerator - Reliability

parallel scheme (redundancy)

serial scheme: IF

modularity

\[ f \equiv f_1 \rightarrow f_2 \rightarrow f_3 \rightarrow \ldots \rightarrow f_n \]

\[ g_1 \rightarrow g_2 \rightarrow I \rightarrow \ldots \rightarrow g_n \]
Accelerator - layout

Ion source & LEBT

- 3 MeV RFQ
- 50 kV
- 50 MeV
- 200 MeV
- 600 MeV

MEBT

- 352 MHz SPOKE LINAC

Beam dump casemate

Earth level

Linac level (about -50m)

Target level (about -30m)
Section of RFQ has been brazed in July 2009 at Annecy

2 Spoke resonators @352 MHz ($\beta$ 0.15 & 0.35) fabricated and tested

CH cavity tested successfully
Building layout and reactor hall
Building layout and reactor hall – the reactor building
Building layout and reactor hall – the reactor building
Building layout and reactor hall – the reactor building
Detailed budget: balancing costs & revenues

**Investment 960 M€**
- Building 196 M€
- Equipment 370 M€
- Engineering 202 M€

**Contingencies 192 M€**

**Operational Budget**
- Operational costs 46.6 M€/y
- Organisation reinforcement 14.6 M€/y

**Revenues**
- Consortium endowment 25.2 M€/y
- Science & Tech. revenues 17.1 M€/y
- Services revenues >18.8 M€/y

**2010 - 2023**

**2024 ~ 2054**
Belgian commitment: secured
International consortium: under construction

Belgium 60 M€
(12 M€/y x 5 y)

Belgium 324 M€
(36 M€/y x 9 y)

2nd phase (11 y)
others 576 M€
The next phase of work: 2010-2014

Minimise technological risks

Secure the licensing

Secure a sound management and investment structure

Accelerator x

Spallation target x

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)
Updated project schedule 2010 - 2024

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<tbody>
<tr>
<td>Phase</td>
<td>Detailed engineering design (FEED)</td>
<td>Specifications drafting &amp; tendering</td>
<td>Construction of components &amp; civil engineering</td>
<td>On site Assy</td>
<td>Commissioning (inclusive coupling)</td>
<td>Startup</td>
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<tbody>
<tr>
<td>R&amp;D works</td>
<td>Front End Engineering Design</td>
<td>Specifications drafting &amp; tendering</td>
<td>Construction of components &amp; Civil engineering</td>
<td>On site Assy</td>
<td>Commissioning (inclusive coupling)</td>
<td>Progress, Startup</td>
<td>Full Exploitat.</td>
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What is left to do?

today

action plan 2010 - 2014

2015 - 2023
Forging strong partnerships and alliances in Europe and worldwide

- **In-cash**
  - FP7
  - EII
  - Engineering
- **In-kind**
  - EU Member States
  - EU
  - ROW
- **Loan**
  - EIB
  - Equipment

**Owners’ Consortium Group**
- Co-sharing investment cost
- Co-sharing exploitation cost
- Privileged access conditions

**Alliances**
- Securing revenues from Users’ Group
MYRRHA in ESNII & FP7

to reach the SNETP goals for Gen.IV FR

Supporting infrastructures, research facilities
loops, testing and qualification benches,
Irradiation facilities incl. fast spectrum facility
and fuel manufacturing facilities

2008  2012  2020

SFR  LFR  GFR

Reference proven technology

Alternative technology

ASTRID Prototype (SFR)
CP-ESFR
ETPP European Demonstration Reactor (LFR) (MYRRHA)
LEADER
ALLEGRO experimental reactor (GFR)
ADRIANA
GoFastR
CDT

2008  2012  2020
MYRRHA has strong relations to European and worldwide institutions
The final sprint

preparing to go...

already passed!
Belgium is welcoming international participation in the MYRRHA consortium

Membership eligibility for the international MYRRHA consortium is based on a **balanced in-cash/in-kind contribution**

**Until end 2014, our objectives are:**

- to collect **Letters of Intent** for participation in the MYRRHA International Consortium (deadline end 2011)
- to sign **Memoranda of Understanding** for collaboration in MYRRHA with international partners (deadline end 2013)
- To finalise the **Consortium legal framework** (deadline mid 2014)
Implementation of P&T Strategy

- Implementation of P&T of a large part of the high level nuclear wastes in Europe needs demonstration of the feasibility of several installations at an “engineering” level leading to arrangement of R&D activities in four “building blocks”, so as:
  1. To process a sizable amount of spent fuel from commercial power plants (i.e. LWR) in order to separate Pu and MA,
  2. To fabricate at semi-industrial level the dedicated fuel needed to load a dedicated transmuter,
  3. To make available one or more dedicated transmuters,
  4. To process the dedicated fuel unloaded from the transmuter and fabrication of new dedicated fuel.
Conclusion

- International Collaboration is a must in P&T
- National motivated initiatives are paramount triggers
- Belgium is contributing through MYRRHA to the 3rd Building Block of the European Vision on P&T
MYRRHA: EXPERIMENTAL ACCELERATOR DRIVEN SYSTEM
A European, innovative and unique project.

Time horizon: full operation ~ 2023.
Costs: ~ EUR 1 Billion.
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Centre d'Etude de l'Energie Nucléaire

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