The Belgian MYRRHA ADS Project: Recent Developments and Future Perspectives

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SCK•CEN, Mol, Belgium

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Myrrha: Context & History

- Myrrha: What is the Project?
- Myrrha: technical planning and funding
- Myrrha: Reasons to invest in the Project
Context – MYRRHA History prior to 2010

- **1995-1997: Start of the MYRRHA Project**:
  - MYRRHA (Multi-purpose hYbrid Research Reactor for High-tech Applications) is a multifunctional research facility for innovative applications.
  - MYRRHA will be the world’s first prototype of a subcritical lead-bismuth cooled reactor driven by a particle accelerator. In an **Accelerator Driven System (ADS)**, the particle accelerator is used to generate a primary neutron source in the center of a subcritical core to initiate the chain reaction.

- **2005: DG Research of EC selects MYRRHA as the reference project for EU ADS**
  - In 2005, the European Commission DG Research & Innovation (DG RTD) outlined a co-ordinated strategy for advanced reactors at EU level, making **MYRRHA** the **basis for ADS** (Accelerator Driven System) **in the EU**
  - The EU commitment is translated financially in a cornerstone EU funding in Framework Programme 6 EUROTRANS, the then largest-ever, supplemented with a series of other FP6, FP7 and H2020 projects

- **2009: International independent review conducted by OECD/NEA**
  - In 2009, **the Belgian government mandated** the OECD Nuclear Energy Agency (NEA) to organise an independent international evaluation of the MYRRHA project
  - The **MYRRHA Independent Review Team (MIRT)** comprised experts from FR, DE, JP, NL, CH, UK & US
Context – The financial commitment of Belgium to MYRRHA and the international dimension

- **March 5th 2010: Commitment Belgium to MYRRHA 2010-2014**
  - On March 5th 2010, based on a positive evaluation by the OECD/NEA MIRT in 2009, the Belgian government decided to grant a 60 M€\text{2010} dedicated budget to MYRRHA for the period 2010-2014. At the same time, the Belgian government committed to finance the implementation phase for 40% of the total investment of the full infrastructure.

- **2015: Renewal commitment Belgium to MYRRHA**
  - In 2015, the Belgian government renewed its financial commitment towards MYRRHA with a special endowment of EUR 40m €\text{2015} for 2015-2017.

- **End 2017: Expected decision Belgium regarding the construction of MYRRHA**

- **International dimension of MYRRHA:**
  - European Commission has been supporting MYRRHA since ’99 through scientific framework programs.
  - In 2010, the European Strategic Forum for Research Infrastructures (ESFRI) promoted MYRRHA to its high priority list of major research infrastructures for energy.
  - MYRRHA is embedded in a wide network of international nuclear organisations incl. Nuclear Government Agencies, Nuclear Industry, Research Institutes, and Universities.
  - The MYRRHA Project Team currently pursues funding commitments from International Consortium Members and is in the process to obtain EIB funding.
Outline

• MYRRHA : Context & History

MYRRHA : What is the Project ?

• MYRRHA : technical planning and funding
• MYRRHA : Reasons to invest in the Project
Construction of an Accelerator-Driven System (ADS) consisting of

- A 600 MeV – 2.5 mA to 4.0 mA **proton linear accelerator**
- A **spallation target/source**
- A lead-Bismuth Eutectic (LBE) cooled **reactor** able to operate in subcritical & critical mode

### Accelerator

<table>
<thead>
<tr>
<th>particles</th>
<th>protons</th>
</tr>
</thead>
<tbody>
<tr>
<td>beam energy</td>
<td>600 MeV</td>
</tr>
<tr>
<td>beam current</td>
<td>2.4 to 4 mA</td>
</tr>
</tbody>
</table>

### Target

<table>
<thead>
<tr>
<th>main reaction</th>
<th>spallation</th>
</tr>
</thead>
<tbody>
<tr>
<td>output</td>
<td>$2 \times 10^{17}$ n/s</td>
</tr>
<tr>
<td>material</td>
<td>LBE (coolant)</td>
</tr>
</tbody>
</table>

### Reactor

<table>
<thead>
<tr>
<th>power</th>
<th>65 to 100 MW$_{th}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k_{eff}$</td>
<td>0.95</td>
</tr>
<tr>
<td>spectrum</td>
<td>fast</td>
</tr>
<tr>
<td>coolant</td>
<td>LBE</td>
</tr>
</tbody>
</table>

Source: SCK•CEN MYRRHA Project Team
What is an ADS?

An **Accelerator-Driven-System** is:

- a subcritical neutron multiplication assembly (nuclear reactor, $k_{\text{eff}} < 1$),
- driven by an external neutron source,
- obtained through the spallation mechanism with high energy (~1GeV) protons,
- impinging on massive (high Z) target nuclei (Pb, Pb-Bi, W, Ta, U).
MYRRHA is a multipurpose research facility, addressing end-markets with both significant societal and economic impact.
Fission generates High-Level Nuclear Waste

Minor Actinides

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

Source: SCK•CEN MYRRHA Project Team
Transmutation is the better solution for Spent Nuclear Fuel

*SNF = Spent Nuclear Fuel

Source: European Commission Strategy Paper on Partitioning & Transmutation (2005), SCK•CEN MYRRHA Project Team
**EU P&T Strategy 2005:** “The implementation of P&T of a large part of the high-level nuclear wastes in Europe needs the demonstration of its feasibility at an “engineering” level. The respective R&D activities could be arranged in four “building blocks”:

<table>
<thead>
<tr>
<th>P&amp;T building blocks</th>
<th>Description</th>
<th>Name &amp; Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Partitioning</td>
<td>Demonstrate capability to process a sizable amount of spent fuel from commercial Light Water Reactors to separate plutonium, uranium and minor actinides</td>
<td>Atalante (FR)</td>
</tr>
<tr>
<td>2 Fuel production</td>
<td>Demonstrate the capability to fabricate at a semi-industrial level the dedicated fuel needed to load in a dedicated transmuter</td>
<td>JRC-ITU (EU)</td>
</tr>
<tr>
<td>3 Transmutation</td>
<td>Design and construct one or more dedicated transmuters</td>
<td>MYRRHA (BE)</td>
</tr>
<tr>
<td>4 Fuel unloading</td>
<td>Specific installation to process fuel unloaded from transmuter</td>
<td></td>
</tr>
</tbody>
</table>

The European Commission contributes to the 4 building blocks and fosters the national programmes towards this strategy for demonstration at engineering level.
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MYRRHA’s phased implementation strategy

Benefits of phased approach:
- Reducing technical risk
- Spreading investment cost
- First R&D facility available in Mol end of 2024
### High power proton beam (up to 2.4 MW)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton energy</td>
<td>600 MeV</td>
</tr>
<tr>
<td>Beam current</td>
<td>0.1 to 4.0 mA</td>
</tr>
<tr>
<td>Repetition rate</td>
<td>CW, 250 Hz</td>
</tr>
<tr>
<td>Beam duty cycle</td>
<td>10⁻⁴ to 1</td>
</tr>
<tr>
<td>Beam power stability</td>
<td>&lt; ± 2% on a time scale of 100ms</td>
</tr>
<tr>
<td>Beam footprint on reactor window</td>
<td>Circular Ø85mm</td>
</tr>
<tr>
<td>Beam footprint stability</td>
<td>&lt; ± 10% on a time scale of 1s</td>
</tr>
<tr>
<td># of allowed beam trips on reactor longer than</td>
<td>10 maximum per 3-month operation</td>
</tr>
<tr>
<td>3 sec</td>
<td>period</td>
</tr>
<tr>
<td># of allowed beam trips on reactor longer than</td>
<td>100 maximum per day</td>
</tr>
<tr>
<td>0.1 sec</td>
<td></td>
</tr>
<tr>
<td># of allowed beam trips on reactor shorter than</td>
<td>unlimited</td>
</tr>
<tr>
<td>0.1 sec</td>
<td></td>
</tr>
</tbody>
</table>

**Extreme reliability level: MTBF > 250 hrs**
Reactor – Current Primary System design (v1.6)

- Reactor layout
  - Vessel
  - Cover
  - Core barrel and Multi-functional plugs
  - Above Core Structure
  - Cradle, Core Restraint System, beam line and window target
  - Si-doping units, Mo-irradiation units, control rods and safety rods
  - Primary Heat Exchangers
  - Primary Pumps
  - In-Vessel Fuel Handling Machines, Fuel Transfer Devices, Failed Fuel Detection Devices, Extraction Pumps
  - Diaphragm and support structure
  - Reactor pit, Reactor Vessel
  - Auxiliary Cooling System

Source: SCK•CEN MYRRHA Project Team
Phased implementation plan MYRRHA Project (2016-2030)

Phase 1: ‘16-'24
- 1st Facility at Mol in 2024

Phase 2&3: ‘25-'30
- Tendering and Construction Reactor
- 600MeV Accelerator Prototyping & Construction
- 600MeV Accelerator Building Start construction
- 600MeV Pilot Beam & Commissioning
- 100 MeV Accelerator Prototyping & Construction
- 100 MeV Accelerator Building Start construction
- 100 MeV Accelerator reliability tests
- Pre-Construction Engineering and Design (including R&D Programmes)

Source: SCK•CEN MYRRHA Project Team
P&T & MYRRHA inspired many Euratom FP projects

<table>
<thead>
<tr>
<th>TOPIC</th>
<th>FP5</th>
<th>FP6</th>
<th>FP7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coupling</td>
<td>MUSE, FUTURE, MEGAPIE</td>
<td>DM2 ECATS, DM3 AFTRA</td>
<td>FREYA, FAIRFUELS</td>
</tr>
<tr>
<td>Fuels</td>
<td>SPIRE, TECLA, PDS-XADS</td>
<td>DM4 DEMETRA</td>
<td>MATTER, GETMAT</td>
</tr>
<tr>
<td>Materials</td>
<td>ADOPT</td>
<td>DM1 DESIGN</td>
<td>CDT, MAX, SILER</td>
</tr>
<tr>
<td>Design</td>
<td>ASCHLIM</td>
<td>EUROTRANS</td>
<td>THINS</td>
</tr>
<tr>
<td>Thermal-Hydraulics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LFR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infrastructures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario Studies</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 28 M€  
- 31 M€  
- 31 M€
MYRRHA continuous getting support in H2020

- **H2020-NFRP-2014-2015**

- **H2020-NFRP-2016-2017**
  - IL TROVATORE: Innovative cladding materials for advanced accident-tolerant energy systems, 31 partners, total budget: 5 M€ – granted budget EC 100%, start: 1/10/2017, duration: 54 months, coordinator: SCK•CEN
MYRRHA is embedded in an international R&D network
Outline

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MYRRHA: Reasons to invest in the Project
Reasons to invest in Project MYRRHA

1. **Solution for nuclear legacy**: MYRRHA closes the nuclear fuel cycle with a sustainable and economic solution for spent nuclear fuel legacy (over 180,000 tons* globally)

2. **Crucial medical radio-isotopes**: MYRRHA saves lives in the form of medical radio-isotopes which are crucial for radio-diagnostics and radio-therapy

3. **Direct financial return**: investment re-paid over lifetime, pay-back time of 24 years

4. **Indirect financial return**: MYRRHA creates over 2,500 full-time jobs

5. **Economics from Intellectual Property**: Valorisation and commercialisation of components of MYRRHA, e.g. radio-isotopes, SMR, Oxygen sensor and control,…

6. **Contributes to strategic EU objectives**: MYRRHA recognized by EU to support objectives of a knowledge-based economy (on ESFRI Roadmap, MYRRHA is 1 out of only 4 EU Research Infrastructures in category “Energy”) and Energy Union (SET Plan)

7. **Large R&D network**: MYRRHA is embedded in a worldwide R&D network from academia, research organisations and industries

Source: “The MYRRHA ESFRI Project” report by EC Commissioner G. Oettinger and Secretary of State M. Watelet, May 2013; SCX-CEN MYRRHA Project Team, MYRRHA Business Plan

Note: *Excluding weapon-grade material
Conclusion

- Advanced nuclear fuel cycles are required to meet now the objective of making nuclear fission sustainable.
- The objectives of sustainability: waste minimisation, better use of the natural resources and reduced proliferation risks can be met with both fast reactors and dedicated burners (ADS).
- Design studies have been performed within and outside Europe; prototypes should be planned and realized, to go from paper work to real work.
- Through the new MYRRHA research infrastructure, Belgium is contributing to this international endeavour.
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