MYRRHA

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MYRRHA

Multipurpose hYbrid Research Reactor for High-tech Applications

Contributing to the European Strategy for P&T
MYRRHA - Accelerator Driven System

Accelerator
(600 MeV - 4 mA proton)

Reactor
• Subcritical or Critical modes
• 65 to 100 MWth

Spallation Source

Fast Neutron Source

Multipurpose Flexible Irradiation Facility

Lead-Bismuth coolant
## MYRRHA Accelerator Challenge

### fundamental parameters (ADS)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>particle</td>
<td>p</td>
</tr>
<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>
</tr>
<tr>
<td>MTBF</td>
<td>&gt; 250 h</td>
</tr>
</tbody>
</table>

*challenge!*

failure = beam trip > 3 s

### implementation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<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>“fault tolerant” scheme</td>
<td></td>
</tr>
</tbody>
</table>
MYRRHA linac

INJECTOR BUILDING

Section #1 (Spoke $\beta \sim 0.35 @352\text{MHz}$)
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
Multipurpose facility

- **Fission GEN IV**
  - Material research
    - $\Phi_{\text{Fast}} = 1 \text{ to } 5 \times 10^{14} \text{ n/cm}^2\cdot\text{s}$
    - (En > 1 MeV) in large volumes

- **Fusion**
  - $\Phi = 1 \text{ to } 5 \times 10^{14} \text{ n/cm}^2\cdot\text{s}$
    - (ppm He/dpa ~ 10)
    - in medium-large volumes

- **Waste**
  - 50 to 100 MWth
  - $\Phi_{\text{Fast}} = \sim 10^{15} \text{ n/cm}^2\cdot\text{s}$
    - (En > 0.75 MeV)

- **Multipurpose Hybrid Reactor for High-tech Applications**
  - Fuel research
    - $\Phi_{\text{tot}} = 0.5 \text{ to } 1 \times 10^{15} \text{ n/cm}^2\cdot\text{s}$

- **Fundamental research**
  - $\Phi_{\text{tot}} = 0.5 \text{ to } 1 \times 10^{15} \text{ n/cm}^2\cdot\text{s}$
    - $\Phi_{\text{th}} = 0.1 \text{ to } 1 \times 10^{14} \text{ n/cm}^2\cdot\text{s}$
      - (En < 0.4 eV)

- **Radio-isotopes**
  - $\Phi_{\text{th}} = 0.5 \text{ to } 2 \times 10^{15} \text{ n/cm}^2\cdot\text{s}$
    - (En < 0.4 eV)

- **Silicon doping**
  - High energy LINAC
    - 600 MeV – 1 GeV
    - Long irradiation time
Motivation for transmutation

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

Duration Reduction: 1,000x
Volume Reduction: 100x

Relative radiotoxicity vs. Time (years)
Fast Neutron are unavoidable for transmutation

- To transmute MAs, we need to fission them
- The ratio Fission/Capture is more favorable with fast neutrons
Is sub-criticality a luxury?

Both Critical reactors as well as ADS can be used as Minor Actinides transmuters.

Critical reactors, heavily loaded with MAs, can experience severe safety issue due to reactivity effect induced by a smaller fraction of delayed neutrons.

ADS can operate in a more flexible and safer manner even if heavily loaded with MAs hence leading to efficient transmutation.

Therefore we say that sub-criticality is not a luxury but a necessity.
Multipurpose facility

Material research
\( \Phi_{\text{Fast}} = 1 \text{ to } 5.10^{14} \text{ n/cm}^2 \cdot \text{s} \) (En>1 MeV) in large volumes

Fission GEN IV

Fuel research
\( \Phi_{\text{tot}} = 0.5 \text{ to } 1.10^{15} \text{ n/cm}^2 \cdot \text{s} \)

Fusion

Material research
\( \Phi_{\text{Fast}} = 1 \text{ to } 5.10^{14} \text{ n/cm}^2 \cdot \text{s} \) (En>1 MeV) in large volumes

Fusion

\( \Phi = 1 \text{ to } 5.10^{14} \text{ n/cm}^2 \cdot \text{s} \) (ppm He/dpa ~ 10) in medium-large volumes

50 to 100 MWth
\( \Phi_{\text{Fast}} = \sim 10^{15} \text{ n/cm}^2 \cdot \text{s} \) (En>0.75 MeV)

Waste

\( \Phi_{\text{th}} = 0.5 \text{ to } 2.10^{15} \text{ n/cm}^2 \cdot \text{s} \) (En<0.4 eV)

Radio-isotopes

\( \Phi_{\text{th}} = 0.1 \text{ to } 1.10^{14} \text{ n/cm}^2 \cdot \text{s} \) (En<0.4 eV)

Silicon doping

Fundamental research

High energy LINAC
600 MeV – 1 GeV
Long irradiation time

Multipurpose Hybrid reactor for high-tech applications

Filter
Prepare the path for Fusion DEMO
Irradiation capabilities under the spallation target
MYRRHA for fusion irradiations

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

- **Fission GEN IV**
  - Material research
  - \( \Phi_{fast} = 1 \text{ to } 5 \times 10^{14} \text{ n/cm}^2 \cdot \text{s} \)
  - \( \Phi_{tot} = 0.5 \text{ to } 1 \times 10^{15} \text{ n/cm}^2 \cdot \text{s} \)
  - \( \Phi_{fast} \approx 1 \text{ to } 5 \times 10^{14} \text{ n/cm}^2 \cdot \text{s} \)
  - \( \Phi_{tot} = 0.5 \text{ to } 1 \times 10^{15} \text{ n/cm}^2 \cdot \text{s} \)

- **Fusion**
  - \( \Phi = 1 \text{ to } 5 \times 10^{14} \text{ n/cm}^2 \cdot \text{s} \)
  - (ppm He/dpa \( \approx 10 \))
  - in medium-large volumes

- **Material research**
  - \( \Phi_{fast} = 1 \text{ to } 5 \times 10^{14} \text{ n/cm}^2 \cdot \text{s} \)
  - (En\( \geq 0.75 \text{ MeV} \))
  - \( \Phi_{tot} = 0.5 \text{ to } 1 \times 10^{15} \text{ n/cm}^2 \cdot \text{s} \)

- **Fuel research**
  - \( \Phi_{th} = 0.1 \text{ to } 1 \times 10^{14} \text{ n/cm}^2 \cdot \text{s} \)
  - (En\( \leq 0.4 \text{ eV} \))

- **Waste**
  - 50 to 100 MWth

- **Fundamental research**
  - High energy LINAC
  - 600 MeV – 1 GeV
  - Long irradiation time

- **Multipurpose Hybrid Reactor for High-tech Applications**
  - \( \Phi_{th} = 0.5 \text{ to } 2 \times 10^{15} \text{ n/cm}^2 \cdot \text{s} \)
  - (En\( \leq 0.4 \text{ eV} \))

- **Radio-isotopes**
  - \( \Phi_{th} = 0.1 \text{ to } 1 \times 10^{14} \text{ n/cm}^2 \cdot \text{s} \)
  - (En\( \leq 0.4 \text{ eV} \))

- **Silicon doping**
  - \( \Phi_{tot} = 0.5 \text{ to } 1 \times 10^{15} \text{ n/cm}^2 \cdot \text{s} \)
ISOL@MYRRHA - Concept

- thin refractory metal foils
- carbide powders
- liquid targets

- surface ion source
- ECR ion source
- RILIS
Beam-Splitting System (Concept)

Proton-beam duty cycle

MYRRHA

ISOL@MYRRHA

Magnetic kicker

Magnetic septum

ISOL target

600 MeV ~ 100 - 200 μA pulsed beam (up to 250 Hz)

D1

D2

Qpoles

MYRRHA
Multipurpose facility

Fission GEN IV

- Material research
  - $\Phi_{\text{Fast}} = 1$ to $5 \times 10^{14} \text{n/cm}^2\text{s}$
  - (En>1 MeV) in large volumes

- Fuel research
  - $\Phi_{\text{tot}} = 0.5$ to $1 \times 10^{15} \text{n/cm}^2\text{s}$

Fusion

- $\Phi = 1$ to $5 \times 10^{14} \text{n/cm}^2\text{s}$
  - (ppm He/dpa ~ 10) in medium-large volumes

Hybrid

- 50 to 100 MWth
  - $\Phi_{\text{Fast}} = \sim 10^{15} \text{n/cm}^2\text{s}$
  - (En>0.75 MeV)

Waste

- $\Phi_{\text{tot}} = 0.5$ to $1 \times 10^{15} \text{n/cm}^2\text{s}$
- $\Phi_{\text{th}} = 0.1$ to $1 \times 10^{14} \text{n/cm}^2\text{s}$
  - (En<0.4 eV)

Radio-isotopes

- $\Phi_{\text{th}} = 0.5$ to $2 \times 10^{15} \text{n/cm}^2\text{s}$
  - (En<0.4 eV)

Silicon doping

- High energy LINAC
  - 600 MeV – 1 GeV
  - Long irradiation time

Fundamental research

- $\Phi_{\text{th}} = 0.1$ to $1 \times 10^{14} \text{n/cm}^2\text{s}$
  - (En<0.4 eV)
Production of radioisotopes in MYRRHA thermal neutron flux-traps

Core lay-out:
- In reflector positions
- Cooled by water
- In thermalized neutron field
- Transport by rabbit system
- Positions also usable for testing of materials in thermal field!

=> Both are possible in MYRRHA:
- Testing of materials/fuels in fast (core) field
- Testing of materials/fuels in thermalized (peripheral) field
European Context

ESFRI
European Strategic Forum for Research Infrastructure

SET Plan
European Strategic Energy Plan

Knowledge Economy

Energy Independence

27.11.2010
Confirmed on ESFRI priority list projects

15.11.2010
in ESNII (SNETP goals)
Belgian commitment: secured
International consortium: under construction

2nd phase (11 y)
others 576 M€

960 M€ (2009)

Belgium 60 M€ (12 M€/y x 5 y)
Belgium 324 M€ (36 M€/y x 9 y)
The 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

- Accelerator
- Spallation target
- Sub-critical reactor

Secure the licensing

PDP preliminary dismantling plan
PSAR preliminary safety assessment
EIAR environmental impact assessment

Secure a sound management and investment structure

Central Project Team
Owner Consortium Group
Owner Engineering Team

FEED
(Front End Engineering Design)

2010-2014
MYRRHA international network
International Members Consortium - Phase 2

**Members of Consortium** (~25%)
- Individual research of a member of Consortium
- Collaborative research amongst members of Consortium
- 3 years program commitment

**Open User Facility** (~25%)
- Governments funding
- Criteria of research excellence
- Independent program access committee (PAC)

**Collaborative research** (~25%)
- Distribution of information to participants

**Contract research Commercial services** (~25%)
- RI
- NTD Silicon

**Benefits for Members of Consortium**
- Board position to control overall operation
- Priority of access
- Potential benefit of low price (compensation profit from commercial revenues)
- Capacity transfer flexibility (rules tbd)

**SCK•CEN**
as qualified and licensed operator of the MYRRHA infrastructure under contractual arrangement with ERIC

(*) European Research Infrastructure Consortium
Conclusions

- **MYRRHA** As a Multipurpose Fast Spectrum irradiation facility selected by ESFRI, is responding to:
  - The issue of addressing the nuclear waste legacy of present reactor technology through advance options (**ADS**, **P&T**)
  - The SNETP need for a **multipurpose research infrastructure** expressed in its Strategic Research Agenda whatever the considered technology for Gen.IV systems
  - The Objective of Belgium and SCK•CEN to **maintain a high level expertise in the country** in the nuclear safety, nuclear technology and nuclear competencies independently of the future of NE
  - The objective of the European Commission to make available a series of **relevant irradiations facilities for the fusion material** research community towards the DEMO construction
  - **Secure society needs** for RI for medical applications and Doped-Si for renewable Energy
MYRRHA: EXPERIMENTAL ACCELERATOR DRIVEN SYSTEM
A pan-European, innovative and unique facility at Mol (BE)