CHANDA WP10: Development of nuclear data for MYRRHA reactor safety analyses

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Motivation

Previous experience with nuclear data for ADS:
- NUDATRA within IP-EUROTRANS,
- ANDES

They mostly focused on an ADS system dedicated to waste transmutation using innovative fuels.

Before operating an ADS using such fuels, the roadmap for ADS development foresees the construction and operation of a demonstration facility.
Multipurpose hybrid Research Reactor for High-tech Applications
MYRRHA – Accelerator Driven System

**Accelerator**
(600 MeV - 4 mA proton)

**Spallation Source**

**Multipurpose Flexible Irradiation Facility**

**Lead-Bismuth coolant**

**Fast Neutron Source**

**Spallation Source**

**Reactor**
- Subcritical or Critical modes
- 65 to 100 MWth
- Fast neutron spectrum
- High neutron flux (~$3 \times 10^{15} \text{n}/(\text{cm}^2\text{s})$)

Innovative & Unique
Multipurpose facility

Fission GEN IV
- Fuel research in entire reactor
- Material research in large volumes
- Transmutation in entire reactor
- Waste
- Radio-isotopes: Tc-99m in dedicated positions

Fusion
- Highly representative conditions below target
- Improved conditions in dedicated positions
- Fusion reactor for high-tech applications
- Fundamental research
- Silicon doping
- Large ingots outside of reactor core

High energy LINAC 600 MeV – 1 GeV
Long irradiation time

Multipurpose hybrid reactor for high-tech applications
MYRRHA part of ESNII (European Sustainable Nuclear Industrial Initiative)

2008

SFR

Reference technology

LFR

2012

MYRRHA
Fast spectrum irradiation facility

GFR

Supporting infrastructures, research facilities

2020

ASTRID
Prototype (SFR)

MYRRHA
ETPP European demonstration reactor (LFR)

ALLEGRO
Experimental reactor (GFR)
Critical and sub-critical configuration:

- 600 MeV, < 4mA proton beam
- 65 - 75 MWth
- \( K_{\text{eff}} \approx 0.95 - 0.96 \)
- LBE spallation target (with beam window)
- LBE pool
Radioisotope production

Spallation target

CR, SR

Si doping ingots
Requirement of licensing authorities:

The codes and data libraries must be selected and validated. This validated set of codes & data must be used for reference safety-related neutronics calculations of MYRRHA
WP10: Development of nuclear data for MYRRHA reactor safety analyses

Goals:

- To analyze nuclear data required for the development, safety assessment and licensing of MYRRHA

- To elaborate recommendations for improvements of data

- Focus on existing experimental data and evaluated libraries
Task 10.1

Sensitivity analysis

Co-ordinator: UPM
Partners: CIEMAT, JSI, SCK•CEN

A sensitivity analysis of the latest MYRRHA design to identify the reactions which are most relevant from neutronic point of view. The sensitivity profiles will be calculated with SCALE/TSUNAMI, SUSD3D, and MCNP codes. These sensitivities will be calculated for different criticality safety parameters (e.g. keff, reactivity coefficients, \( \beta_{\text{eff}} \), etc).

- Latest design of the critical core has to be used (subcritical: only MCNP/X can handle).
- Description of the methodology to assess sensitivity
- Sensitivity analysis
- Ranking of the isotopes important for the safety-related neutronics calculations
- Sensitivity profiles to identify most important energy regions
Preliminary priority list to improve uncertainty data

- $^{239}\text{Pu}$ neutron capture and fission neutron yields,
- $^{238}\text{Pu}$ fission, capture and (n,2n) cross-sections,
- $^{240}\text{Pu}$ fission neutron yield,
- $^{241}\text{Pu}$ fission and elastic scattering cross-sections,
- $^{56}\text{Fe}$ neutron capture, elastic and inelastic scattering cross-sections,
- $^{55}\text{Mn}$ neutron capture cross section,
- $^{209}\text{Bi}$ neutron capture and (n,2n) cross-sections
Task 10.1 preliminary: sensitivity profiles

- $^{56}$Fe $(n,n')$, $(n,n)$, $(n,\gamma)$
- $^{238}$Pu $(n,f)$, $(n,\gamma)$

Sensitivity (% / %) x 10^3 vs. Energy (eV)
## Task 10.1

<table>
<thead>
<tr>
<th>Contributions</th>
<th>PM (total 14)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPM</td>
<td>5</td>
<td>calculation of sensitivity profiles with SCALE/TSUNAMI</td>
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<tr>
<td>CIEMAT</td>
<td>3.6</td>
<td>calculation of sensitivity profiles with MCNP PERT, KPERT and KSEN card</td>
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<td>JSI</td>
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<td>calculation of sensitivity profiles with SUS3D</td>
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<tr>
<td>SCK•CEN</td>
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<td>identification of the list of reactions and criticality safety parameters for which the sensitivity profiles must be calculated</td>
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</table>

**Deliverable D10.1**

(month 12): Report on sensitivity analysis of MYRRHA with list of key reactions
Comparison of evaluated data libraries

Co-ordinator: UPM
Partners: SCK•CEN

Cross sections in evaluated data libraries of the most relevant reactions as identified in previous studies and those resulting from Task 10.1 will be compared.

- comparison of the nuclear data libraries, evaluations and experimental data will be carried out for those reactions pointed out by the sensitivity analysis conclusions
- comparison of the performance of the nuclear data libraries, by substituting selected reaction cross sections in one evaluation by data taken from another evaluation
Task 10.2 preliminary: comparison of $^{56}$Fe data

MCNPX 2.7.0 calculations
Base library: JEFF-3.1.2
Critical core Beginning-of-Cycle (CR out)

<table>
<thead>
<tr>
<th>$^{56}$Fe file</th>
<th>Modified part</th>
<th>$k_{\text{eff}}$</th>
<th>$\Delta k_{\text{eff}}$ (pcm)</th>
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<tr>
<td>JEFF-3.1.2</td>
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<td>$1.05374\pm0.00008$</td>
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<tr>
<td>ENDF/B-VII.1</td>
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## Task 10.2

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<td>List of the evaluated files to be studied by UPM will be defined upon completion of Task 10.1</td>
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<td>SCK•CEN</td>
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<td>List of the evaluated files to be studied by SCK•CEN will be defined upon completion of Task 10.1</td>
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**Deliverable D10.2 (month 18):**
Report on comparison of evaluated libraries and identification of existing experimental data
### Task 10.3

**Identification of existing experimental cross section data**

**Co-ordinator: UPM**  
**Partners: JRC-IRMM, JSI**

Identify existing experimental data (e.g. results from ANDES) that can be used to improve the data libraries for reactions resulting from Task 10.2.

<table>
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<tr>
<th>Contributions</th>
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<td>UPM</td>
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<td>review of ANDES results</td>
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<tr>
<td>JRC-IRMM</td>
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<td>review of EXFOR data and JRC-IRMM data not yet available in EXFORD</td>
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<tr>
<td>JSI</td>
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<td>review of EXFOR data</td>
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**Deliverable D10.3 (month 24):**  
Report on improvements made to existing evaluations
Identification of data for validation and execution of new validation experiments

Co-ordinator: JRC-IRMM
Partners: JSI

Identify data that can be used to validate the relevant cross section data. This part of the project will concentrate on the optimum use of data resulting from lead slowing down spectrometers and neutron transmission experiments (i.e. shell and thick sample transmission measurements).

<table>
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<tr>
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<tr>
<td>JSI</td>
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Deliverable: none, to be integrated with the deliverable of Task 10.5
Task 10.5

Improvement and validation of data libraries

Co-ordinator: JSI
Partners: JRC-IRMM, SCK•CEN, UPM

Implement changes to data library and validate by using available experimental data.

<table>
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<tr>
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Deliverable D10.4 (month 30):
Report on the validation of improved data libraries
Task 10.6

Recommendations to the JEFF project

Co-ordinator: JRC-IRMM
Partners: JSI, SCK•CEN, UPM

Recommendations to the JEFF project for cross section data relevant to MYRRHA, taking into account the results of tasks 10.1 – 10.5.

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<td>UPM</td>
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<td>Report to JEFF community</td>
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Deliverable D10.5 (month 36):
Report with recommendations for the JEFF project on cross section data relevant to MYRRHA, taking into account the results of tasks 10.1 to 10.5
MYRRHA: EXPERIMENTAL ACCELERATOR DRIVEN SYSTEM
A pan-European, innovative and unique facility at Mol (BE)