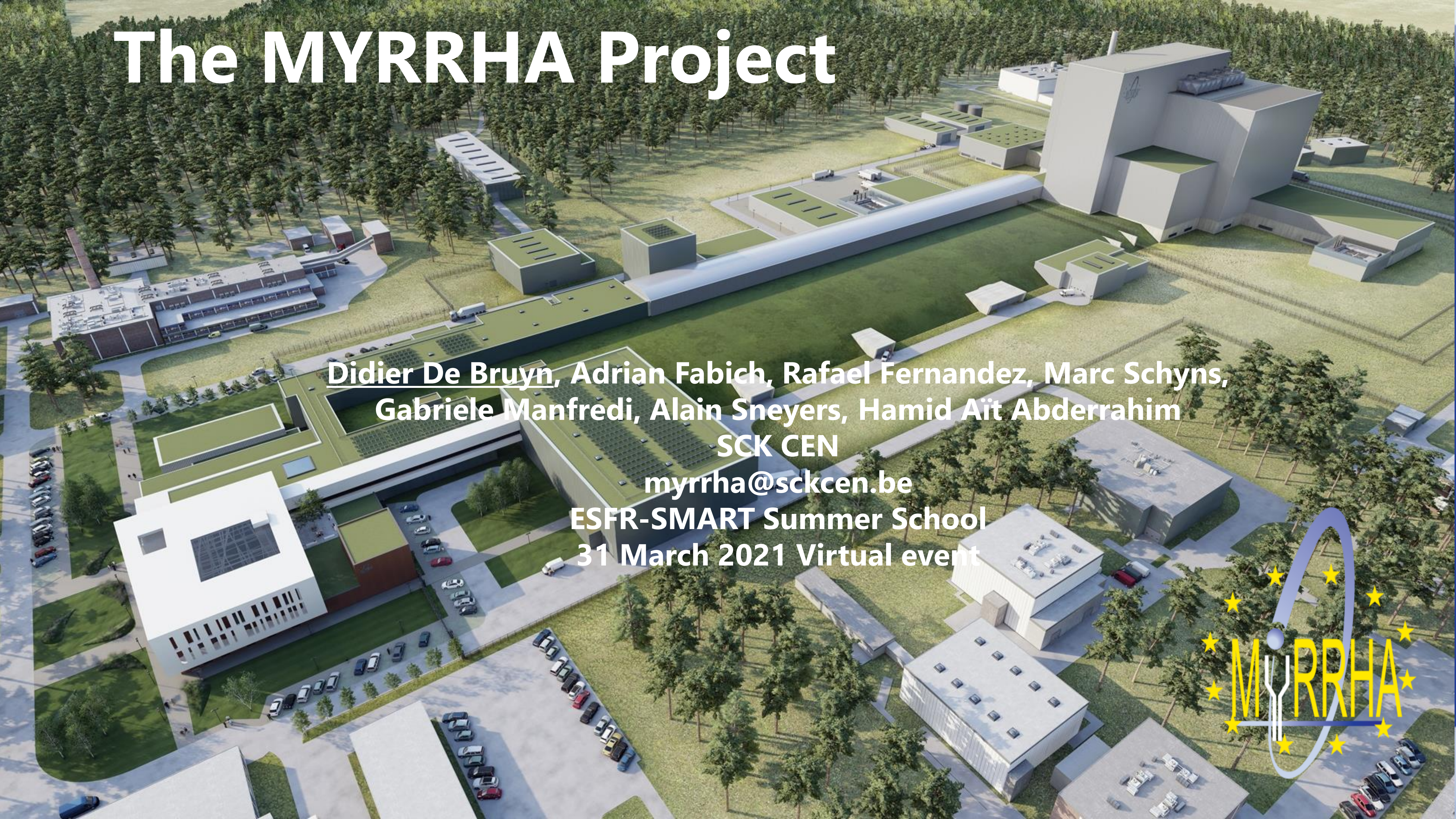
The MYRRHA Project



Didier De Bruyn, Adrian Fabich, Rafael Fernandez, Marc Schyns,
Gabriele Manfredi, Alain Sneyers, Hamid Aït Abderrahim
SCK CEN
myrrha@sckcen.be

ESFR-SMART Summer School
31 March 2021 Virtual event

Belgian Government decision of 7 September 2018

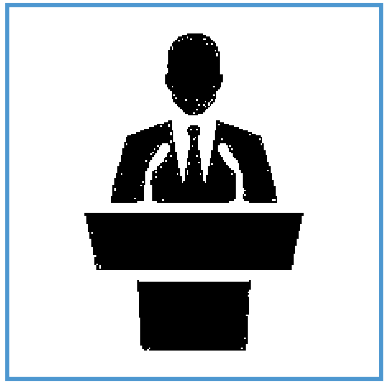
Decision to build MYRRHA as large new research infrastructure in Mol, Belgium

Belgium **allocates** € 558 m for 2019-2038

- € 287 m for 2019-2026: construction of MINERVA (linac 100 MeV + PTF & FTS)
- € 115 m for 2019-2026: design, R&D and licensing for Phases 2 (extended linac 600 MeV) & 3 (reactor)
- € 156 m for 2027-2038: MINERVA operations (linac 100 MeV)

Establishment of **international non-profit organisation**

MYRRHA AISBL/IVZW



Government support for establishing MYRRHA partnerships

Belgium appoints cabinet ministers to promote and negotiate international partnerships

Source: Belgian minister of Energy, Environment & Sustainable Development

MYRRHA: Accelerator Driven System

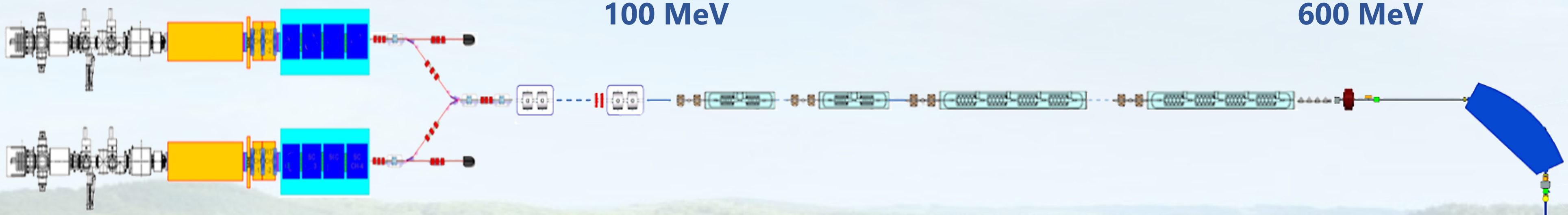
Phase 1

100 MeV

Linear accelerator

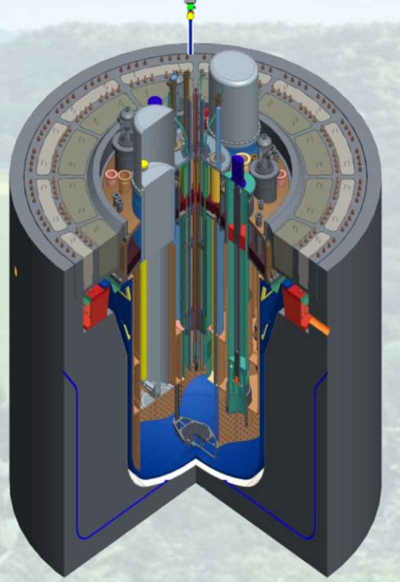
Phase 2

600 MeV



Phase 3

Reactor



- ✓ Transmutation demonstration
- ✓ ADS at pre-industrial scale
- ✓ Flexible irradiation facility

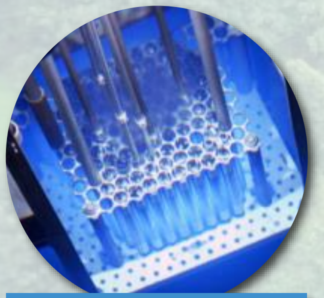
MYRRHA's Application Portfolio

SNF*/ Waste

Radio-isotopes

Multipurpose
h**Y**brid
Research
Reactor for
High-tech
Applications

Fusion

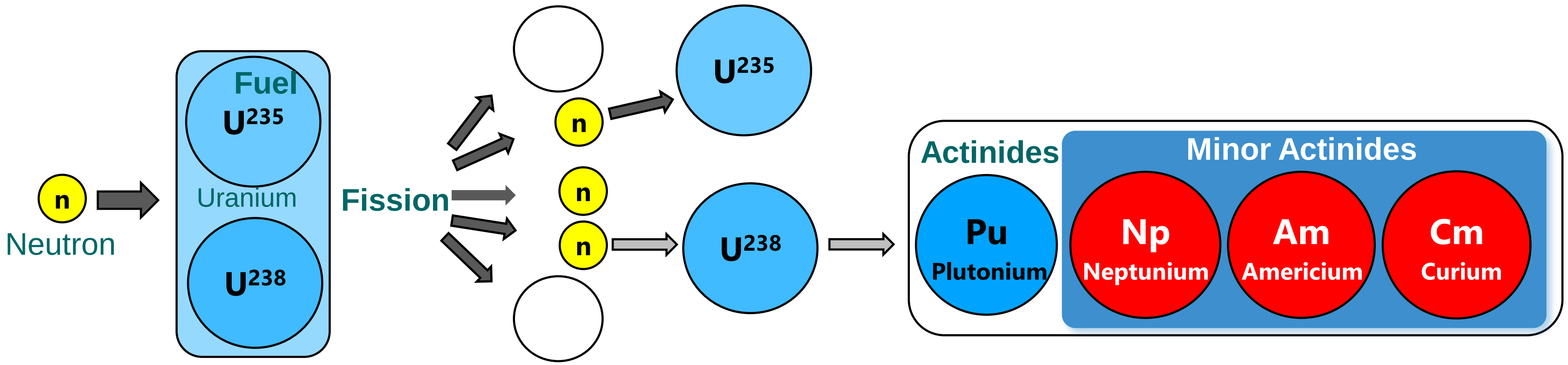


Fission GEN IV

Fundamental research

*SNF = Spent Nuclear Fuel

Fission generates High-Level Nuclear Waste



1 ton of spent nuclear fuel contains:

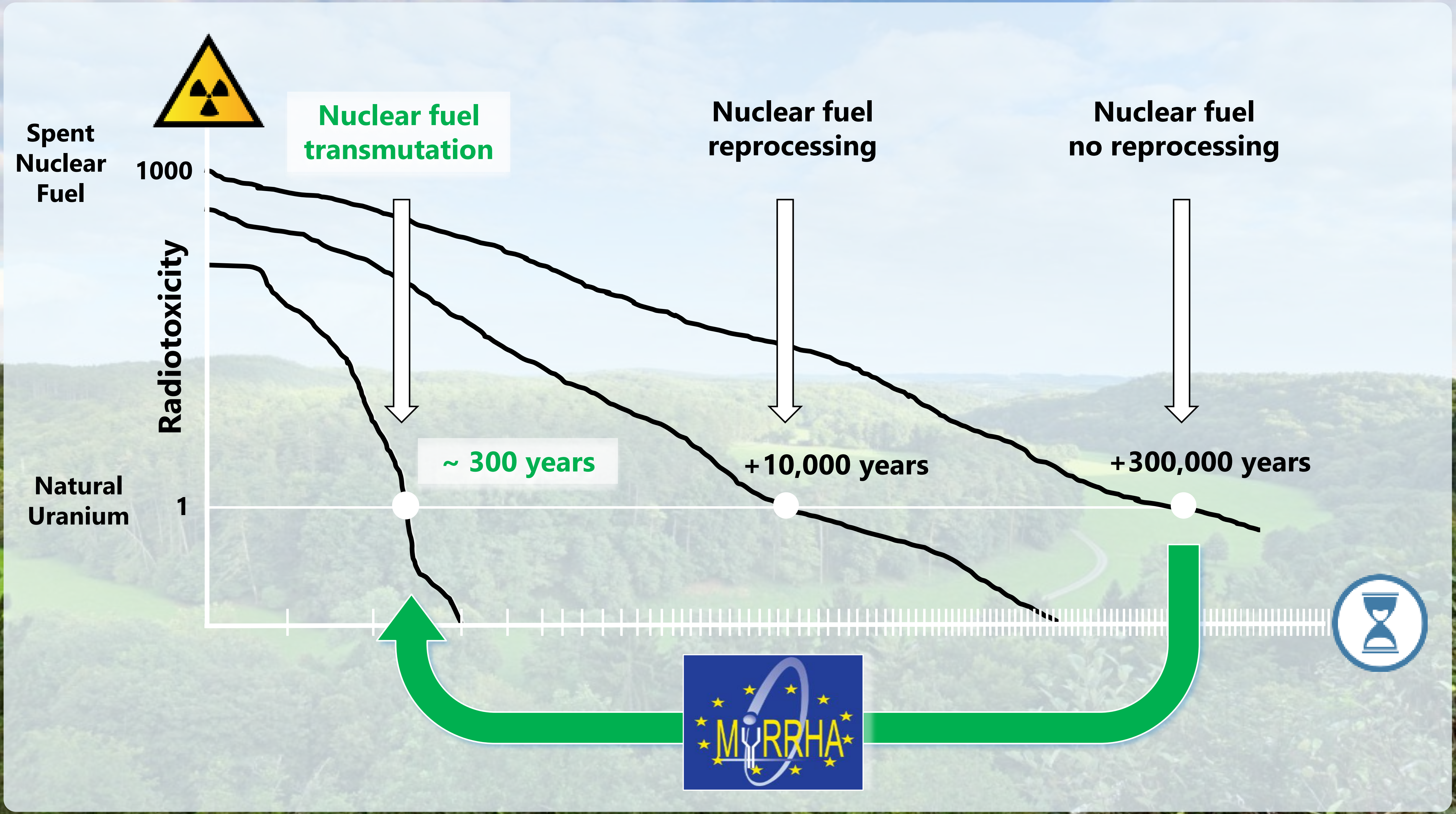
- **935 kg of U (recycle into MOX)**
- **12 kg of Pu (recycle into MOX)**
- **~2.5 kg of Minor Actinides:**
  - **1 kg of Np**
  - **0.8 kg of Am**
  - **0.6 kg of Cm**
- **~50.5 kg of FPs**

Minor Actinides

- high radiotoxicity

- long-lived

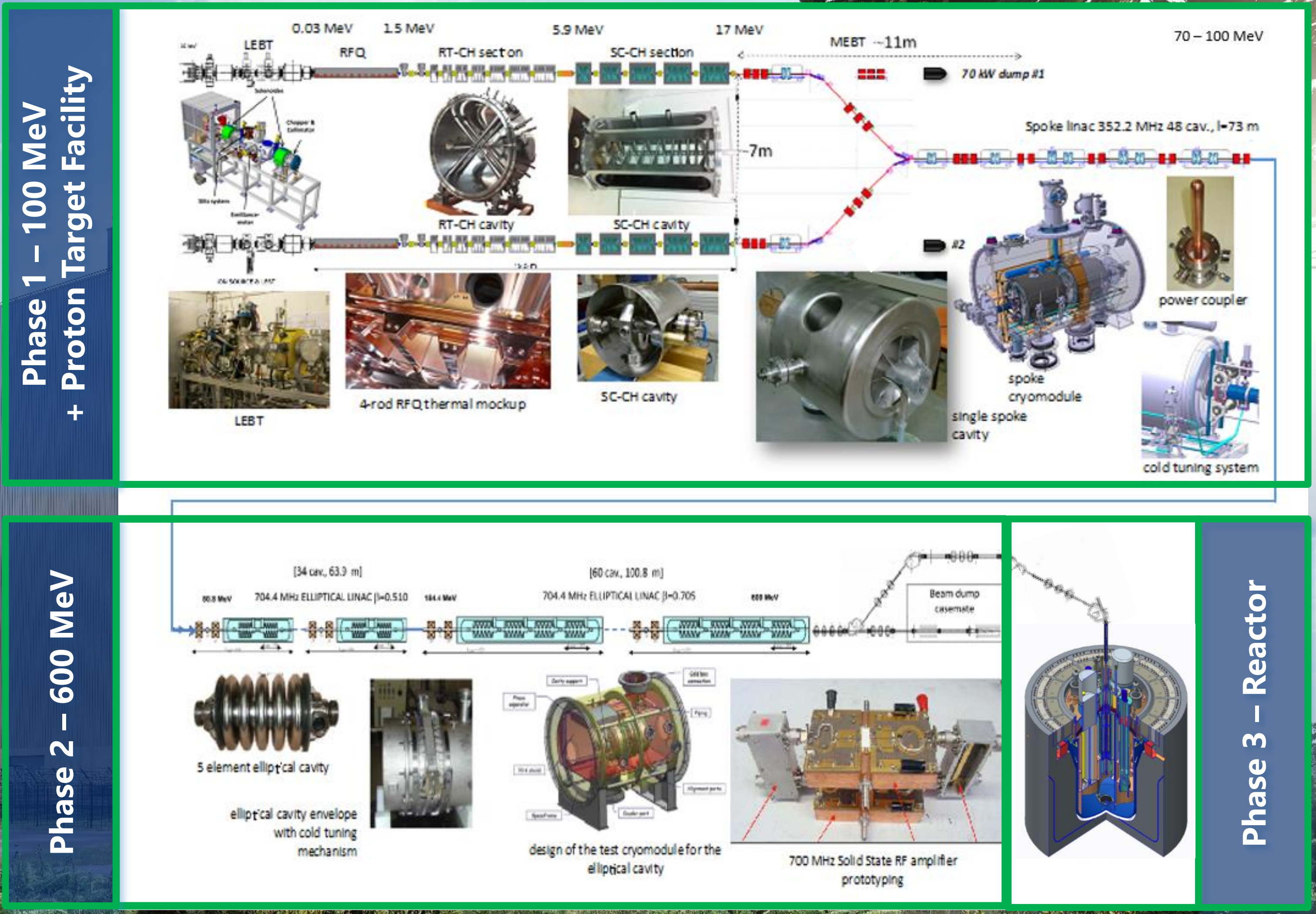
- heat emitting


Spent
Nuclear
Fuel
1000
Radiotoxicity
Natural
Uranium
1
Nuclear fuel
transmutation
Nuclear fuel
reprocessing
Nuclear fuel
no reprocessing
~ 300 years
+10,000 years
+300,000 years
MYRRHA

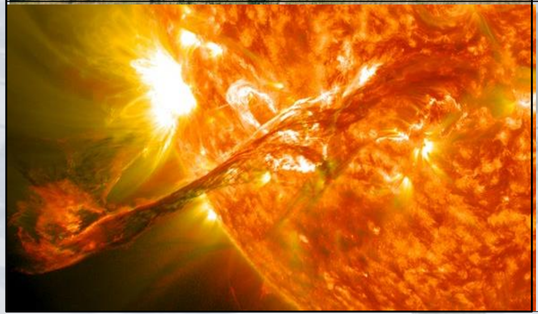
MYRRHA's PHASED IMPLEMENTATION STRATEGY

Benefits of the phased approach:

- already a first operational facility available in Mol at **<u>end of 2026</u>**
- spreading the investment costs
- successful milestone then next step >> reducing technical & financial risks



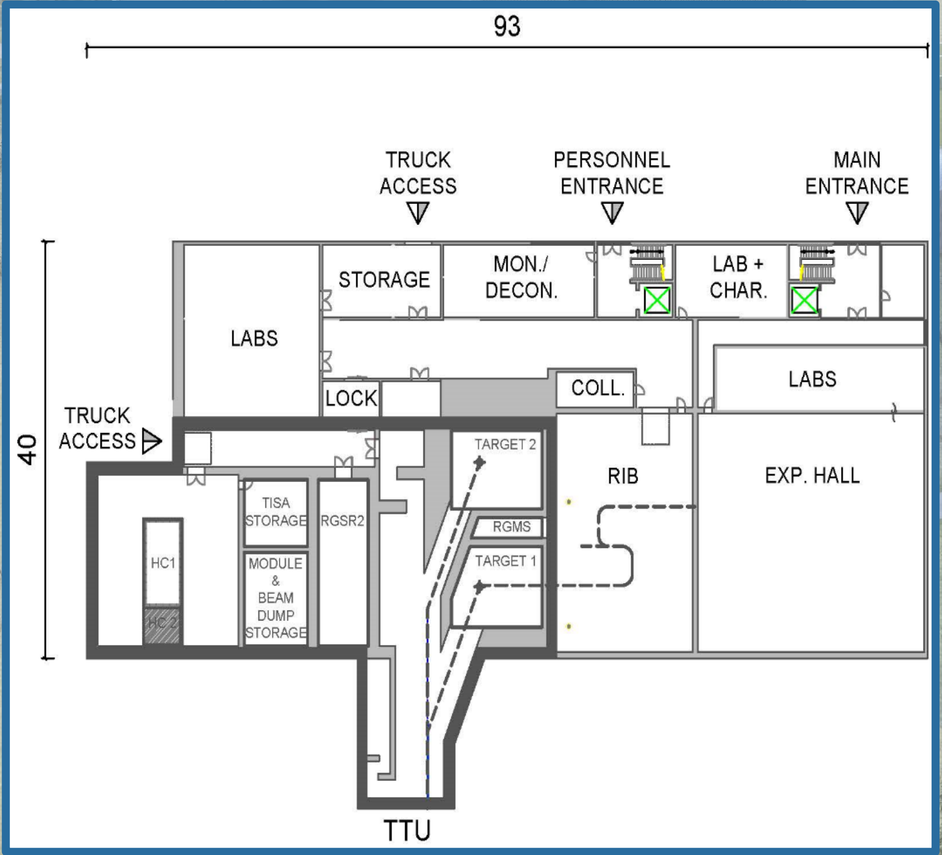
Source: SCK CEN MYRRHA Project Team

Applications	Description	MYRRHA phase 1 2026	MYRRHA phase 2 2032	MYRRHA phase 3 2036
	**Spent fuel transmutation** >> Reduce radio-toxicity: • in volume (factor 100) • in duration (factor 1,000 from 300,000 years to 300 years)	✗	✗	✓
	**Innovative radioisotopes** Produce new diagnostic and therapeutic medical isotopes for research and clinical use	✓	✓	✓
	**Fundamental research** A landmark project on the ESFRI high priority list contributing a.o. to fundamental research in nuclear physics science and nuclear medicine	✓	✓	✓
	**Fusion energy** Conducting advanced materials research, qualification and testing for fusion energy	✓	✓	✓

MYRRHA Phase 1 *(MINERVA)*: implementation in 2026

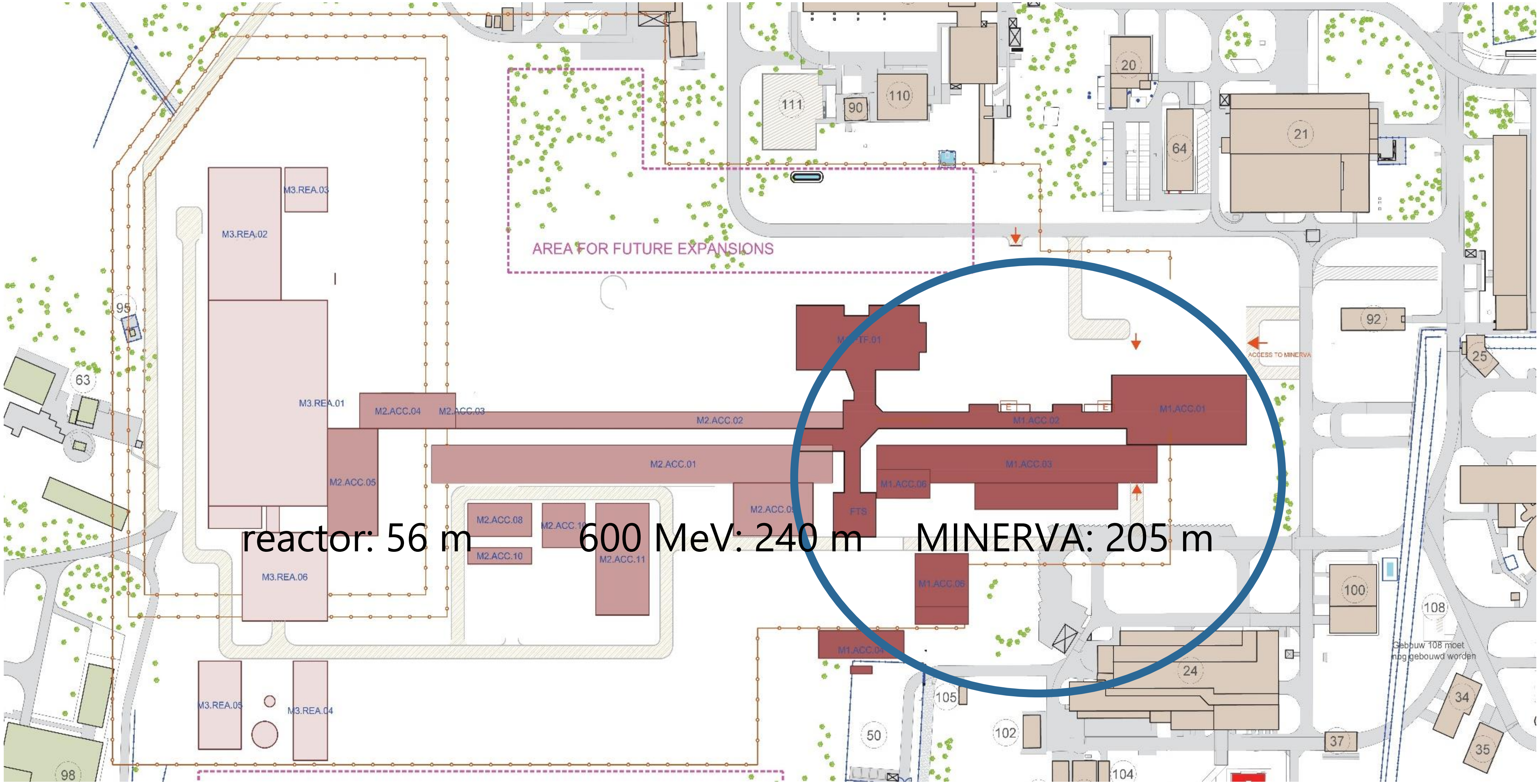
MINERVA = Linac 100 MeV + Proton Target Facility

Objectives = accelerator reliability + radioisotopes + ISOL physics + fusion material R&D



Source:

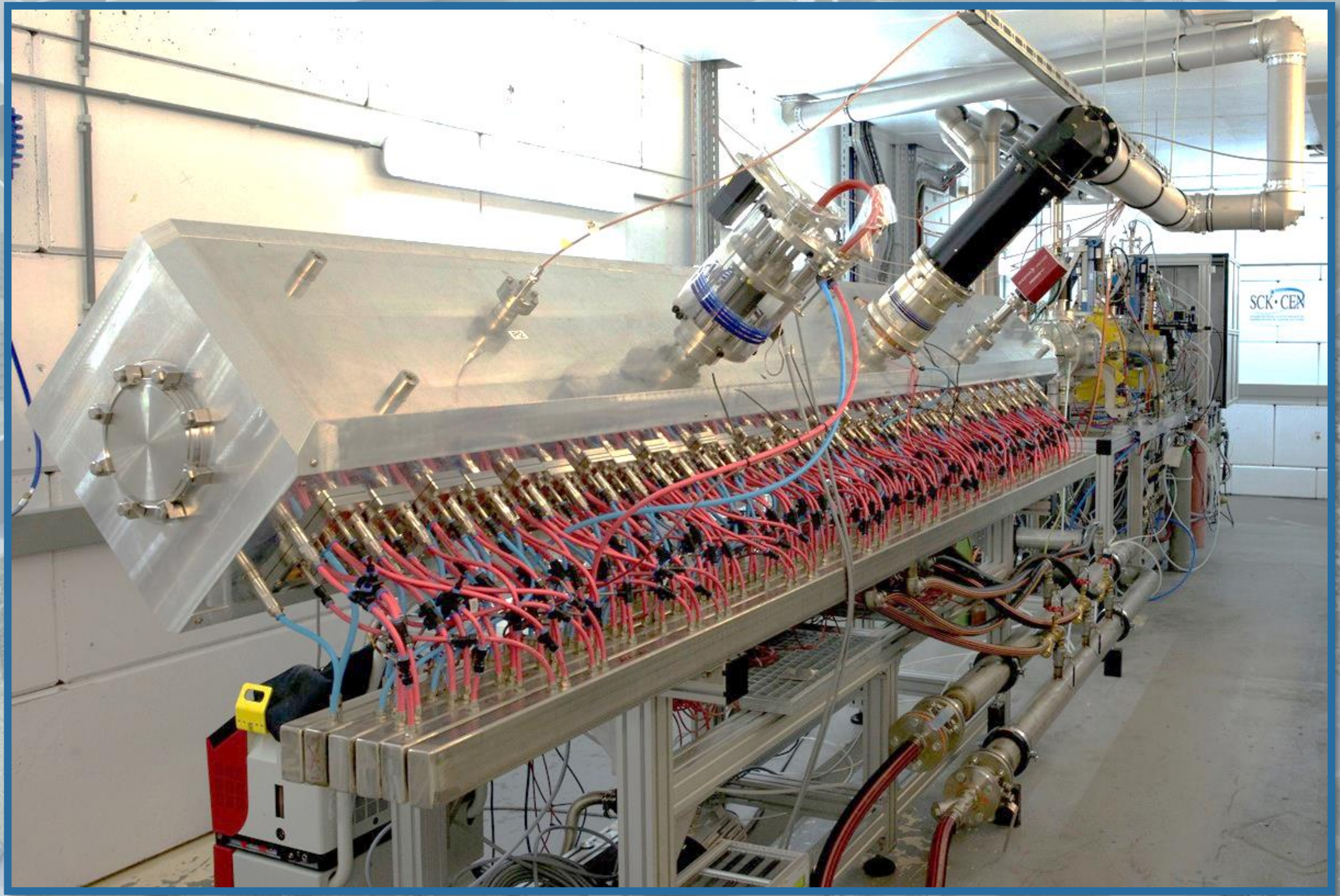
MYRRHA masterplan



The MYRRHA accelerator takes shape in LLN

MYRRHA protons accelerated successfully

☆ ***30 June 2020***



The cryomodule prototype of MYRRHA ready for testing

Superconductivity and French prototype: a crucial milestone coming up for MYRRHA

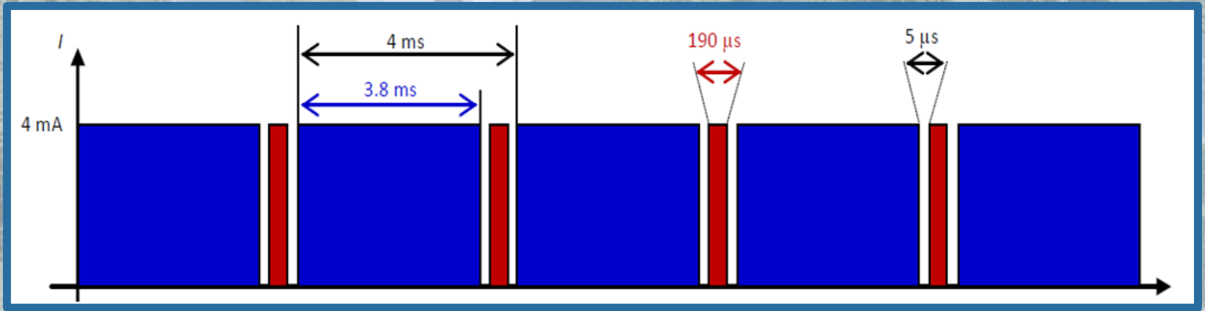
☆ *27 November 2020*

The 4-rod RFQ shines in LLN

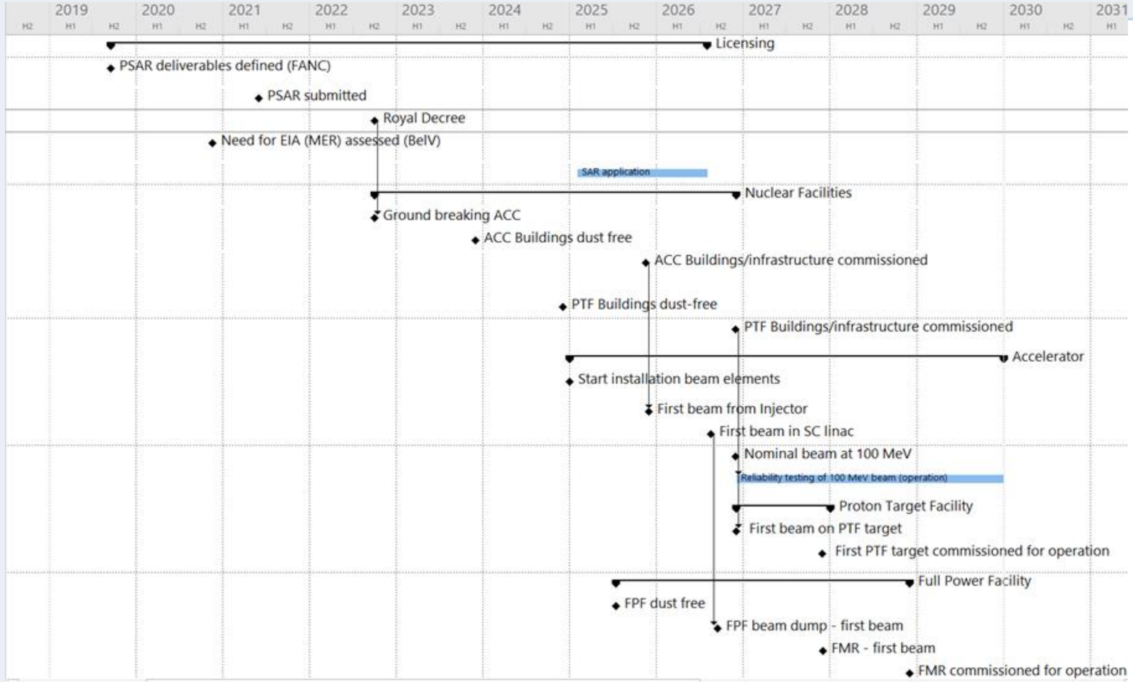
The MYRRHA 4-rod RFQ reach its first success: nominal proton beam delivered intensity of 4 mA and energy of 1,5 MeV

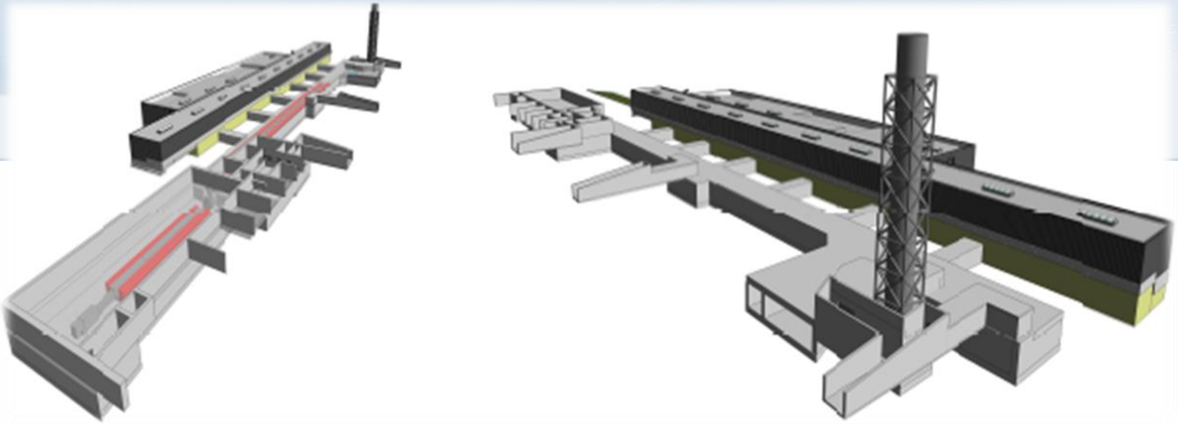
- **Transmission through RFQ 98%**
- **Beam holes ✓, Duty cycle (99,75%: 95% MYRRHA Reactor + 4,75% PTF**

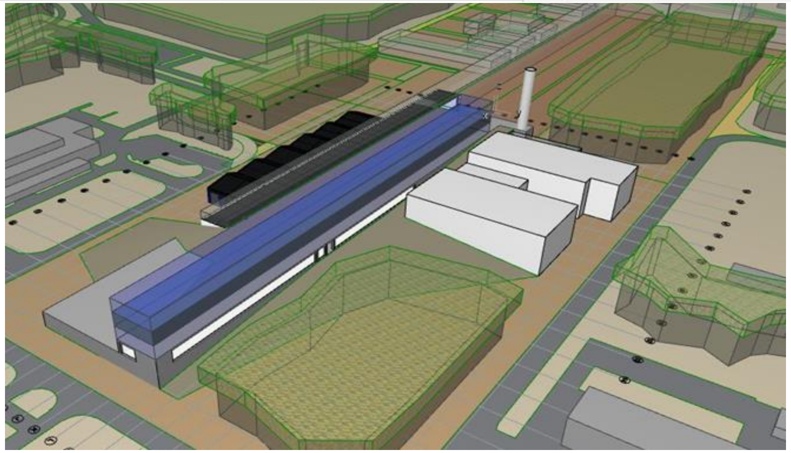
☆ ***4 December 2020***



MINERVA, planning







	Stage	Periode
Design	LINAC conceptual	2016 – Q2 2020
	PTF conceptual	2016 – Q4 2020
	LINAC basic	Q3 2020 – Q4 2021
	PTF basic	Q1 2021 – Q1 2022
	LINAC detailed	Q1 2022 – Q4 2024
	PTF detailed	Q2 2022 – Q4 2025
Construction	LINAC	Q2 2022 – Q4 2025
	PTF	Q2 2023 – Q4 2026
Commissioning	LINAC	Q4 2025 – Q4 2026
	PTF	Q4 2026 – Q4 2027

MYRRHA Reactor: implementation in 2036

Objectives = transmutation + radioisotopes + fusion material R&D + technology platform

Source:

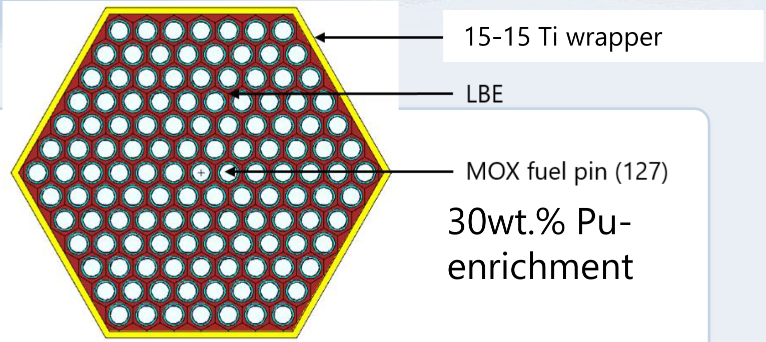
From design Revision 1.6 to Revision 1.8

- Objective of the Revision 1.8 design :
- Address the technical issues identified in Revision 1.6
  - Reduce the size and cost
  - Po-H_20 interaction (in-case of HX tube rupture)
  - Corrosion in LBE at high temperatures
  - Reactor cavity leak tightness and integrity
- Satisfy the application catalogue and top-level technical requirements

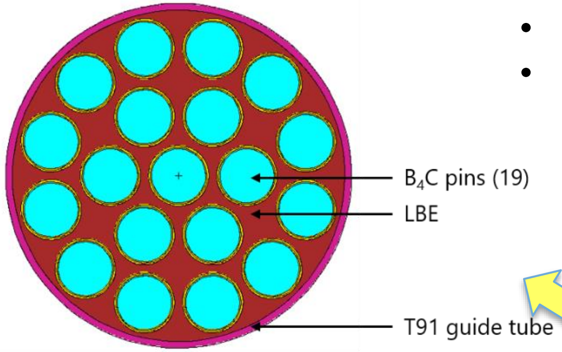
Subcritical (BOC) core layout

- **LBE dummy channels (30)**
- **beam tube + spallation target**

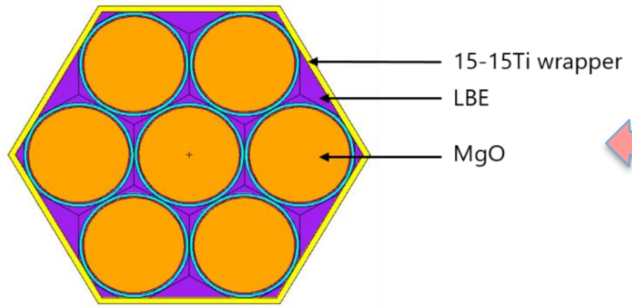
fuel assembly (78)

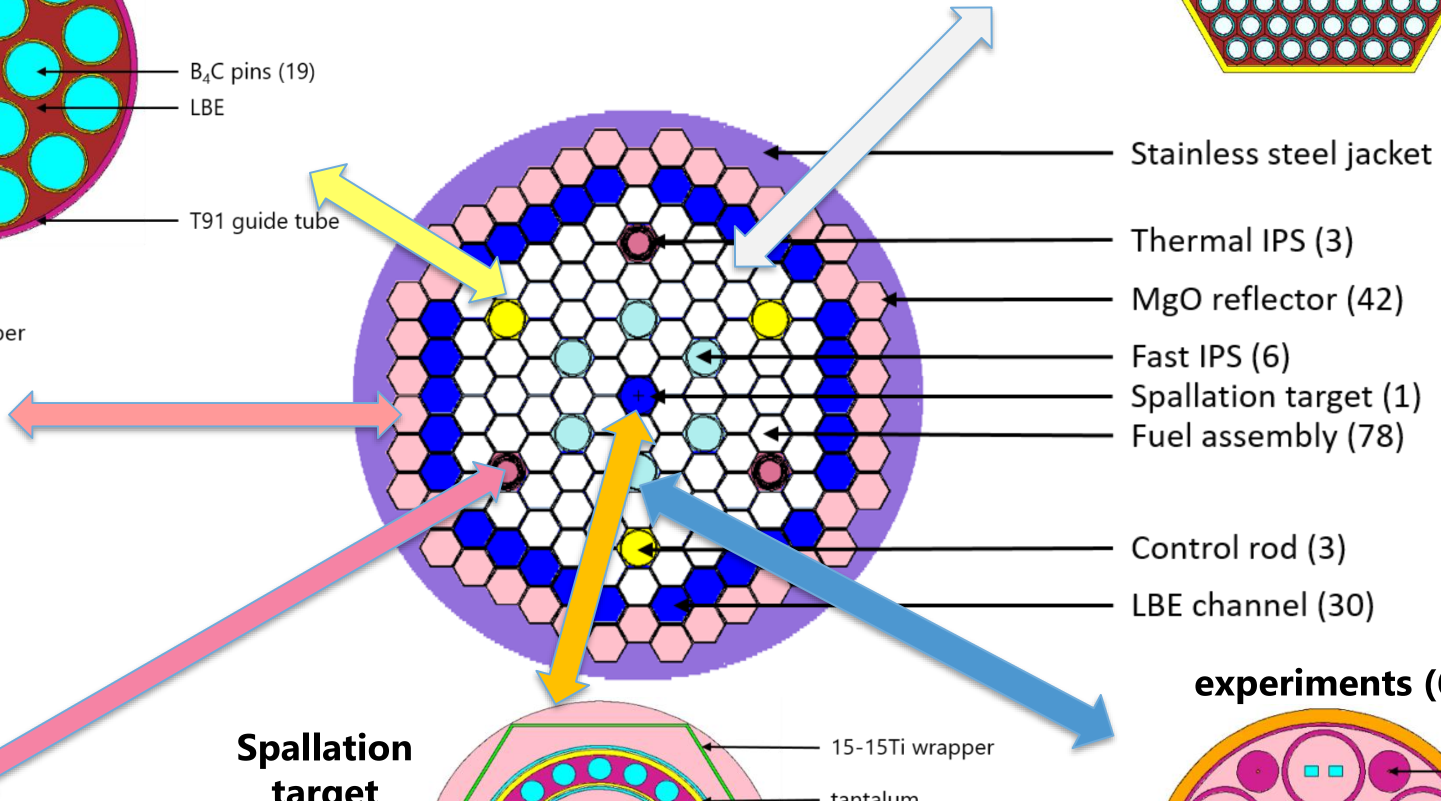


control rods (3)



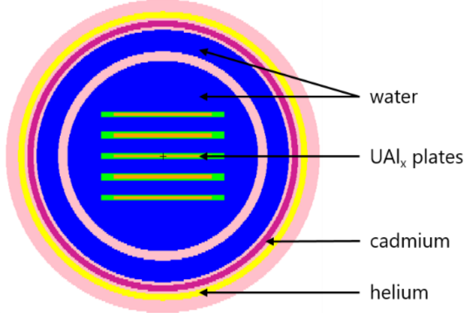
MgO reflector (42)



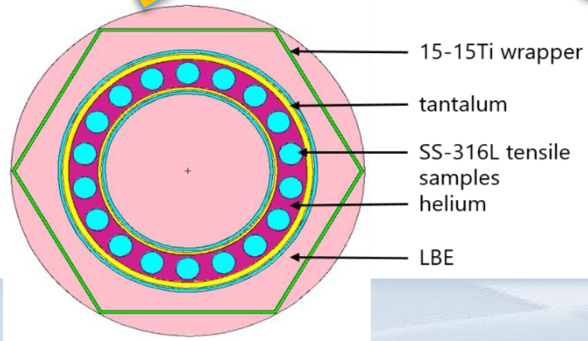


Parameter	Value
k_{eff}	0.92891
Core power (MW)	60
Beam current (mA)	3.63

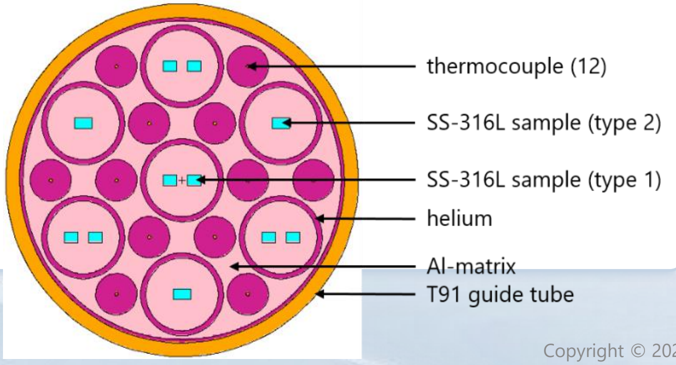
thermal islands (3)



Spallation target assembly (1) – view of irr. targets

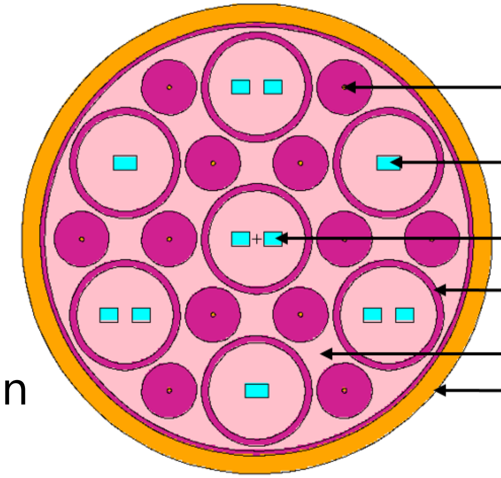


experiments (6)

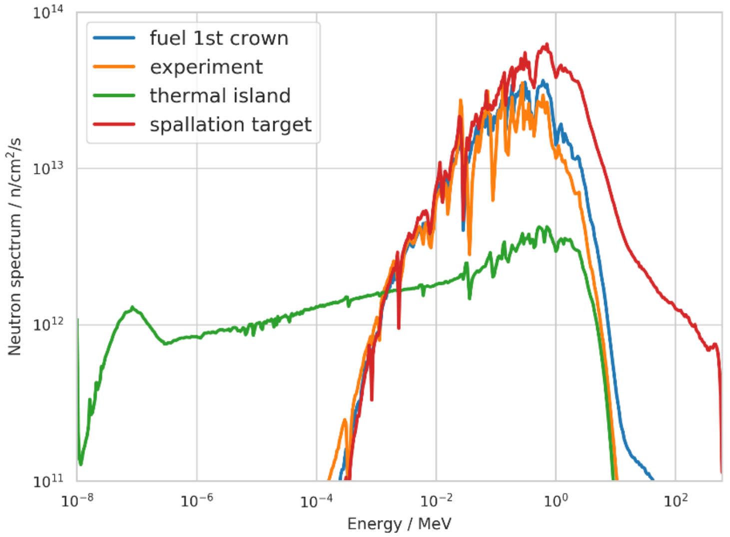


Irradiation performances

- Setup:
  - 7 sub-channels with samples
  - vertical stacks of samples in Al matrix
  - thermally isolated
- Constant irradiation levels during operation



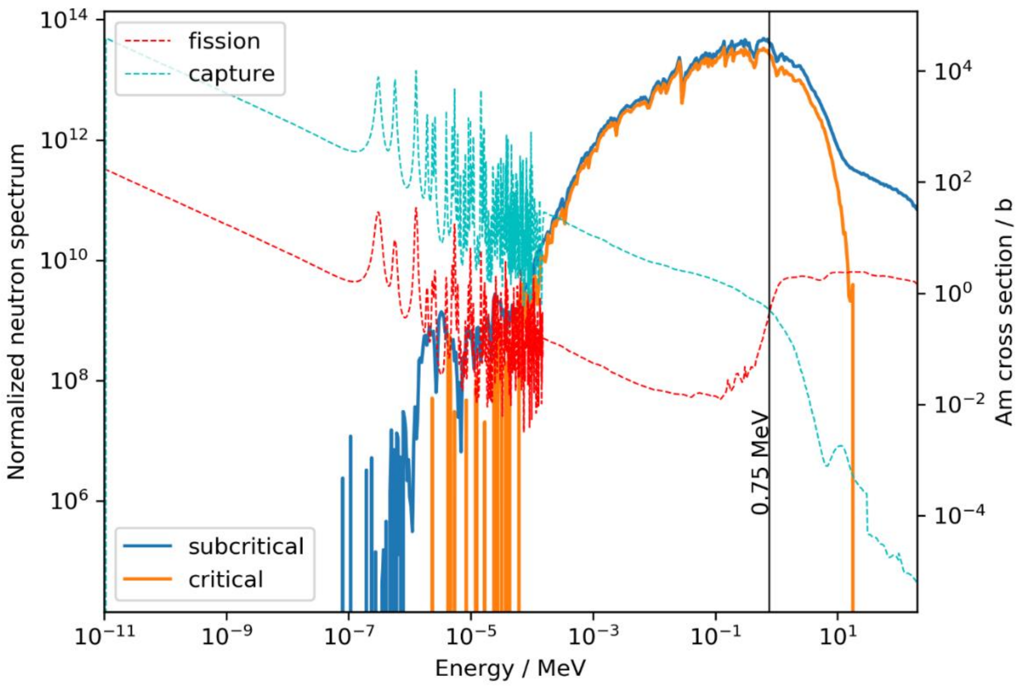
	unit	sub-critical	critical
Reactor power	MWth	70	70
Beam current	mA	3.6	-
DPA damage in IPS	dpa/y	**14**	**13**
Neutron Flux in IPS			
Φ≥ 0.75 MeV	$n/cm^2/s$	3.8×10^{14}	3.6×10^{14}
Φtot	$n/cm^2/s$	2.3×10^{15}	2.2×10^{15}



Core Design: performance in subcritical mode

- Minor actinides (MAs) transmutation
  - MAs transmutation in high fast neutron fluxes
  - Two transmutation paths:
    - ✓ Neutron-induced fission
    - ✓ Radiative capture
  - Fluxes > 0.75 MeV to maximize fission over capture

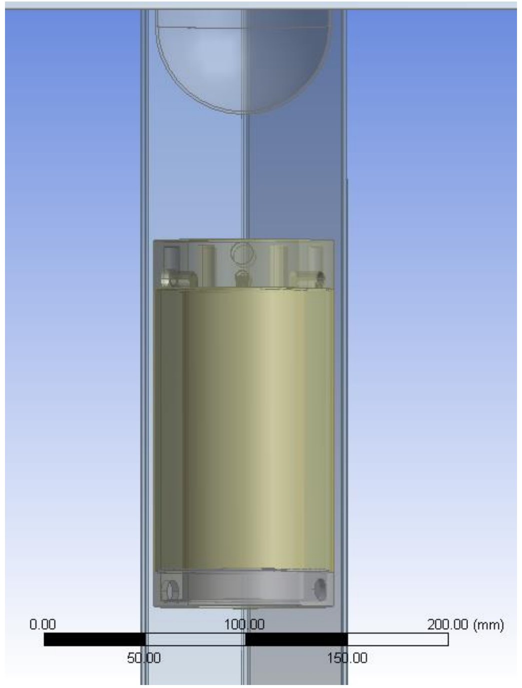
Isotope	fission (%) / cycle	Δ mass (%) / cycle
Am-241	1.0	**4.3**
Np-237	1.2	**3.9**

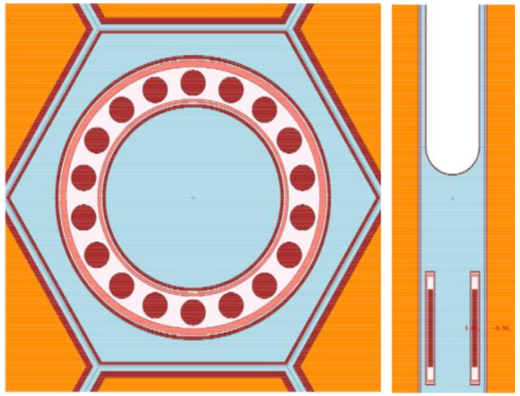


Spallation target module for Fusion material irradiations

The neutron production zone in LBE should not be perturbed → below it (~20 cm below the spallation target) some volume can be envisaged to place samples

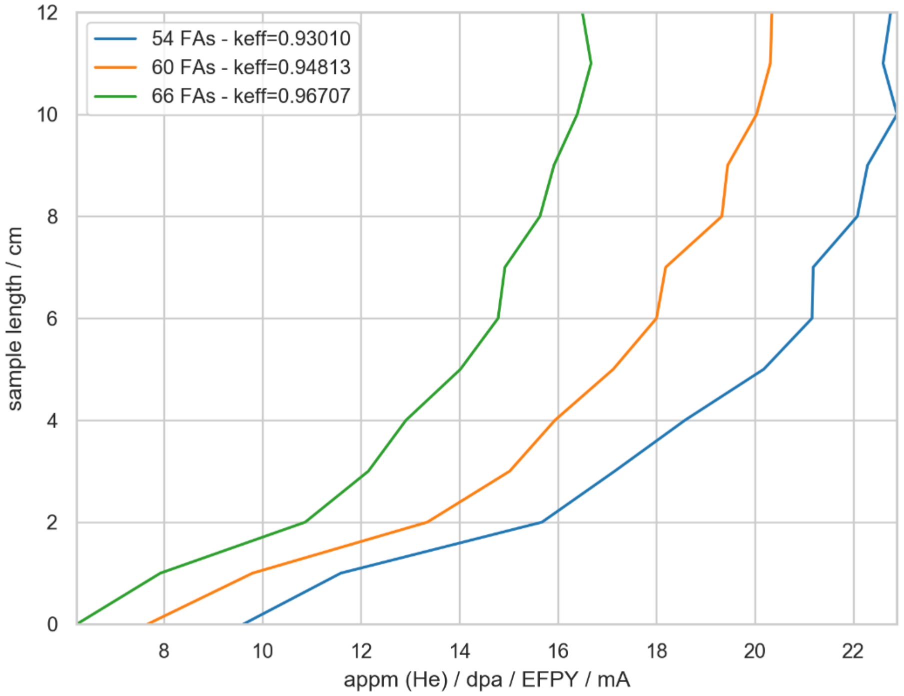
- Samples are placed in a dedicated holder below the spallation target
- Setup:
  - 3 rings of samples
  - 18 samples / ring
- Sample volume
  - Length: 3 x 4 cm
  - Diameter: 7 mm / sample
- Active cooling



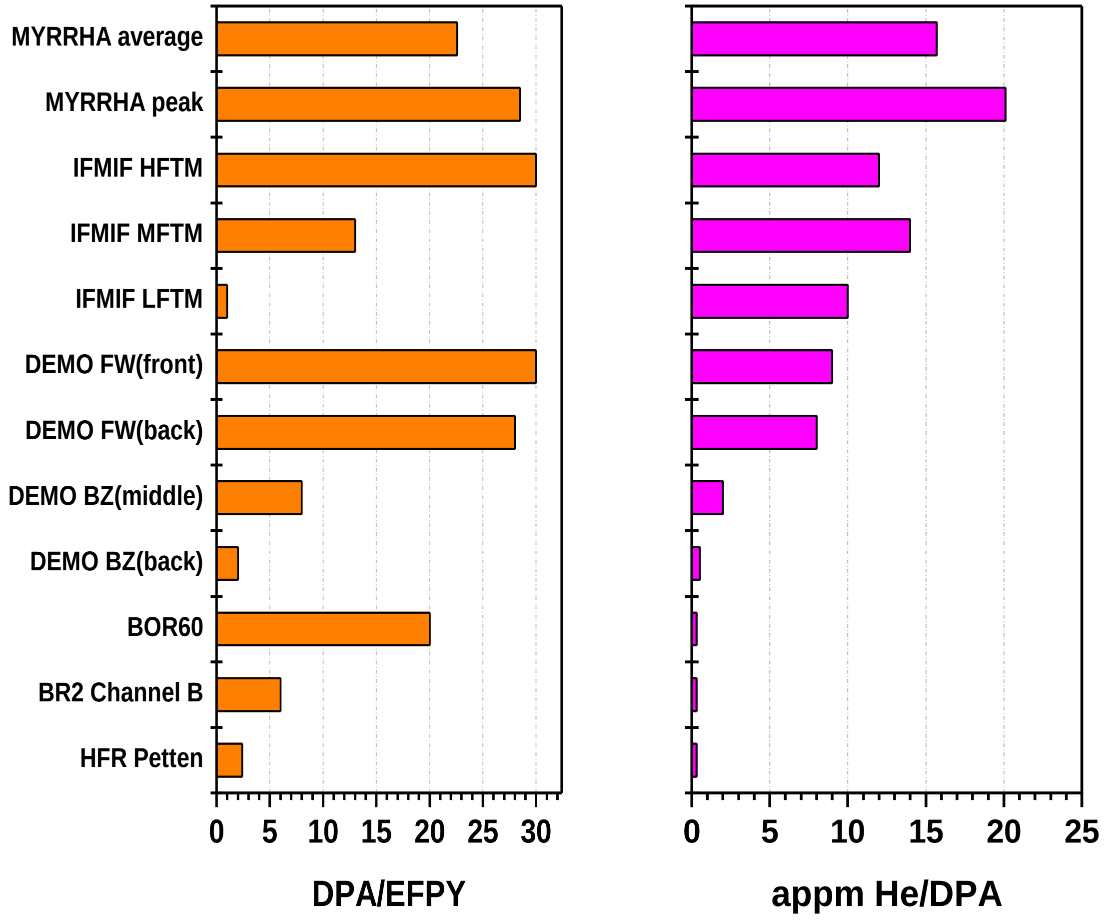


Spallation target module for Fusion material irradiations

- Irradiation levels can be optimized by varying
  - ✓ position of the irradiation rig
  - ✓ proton beam current
  - ✓ k_{eff}



Comparison with different facilities

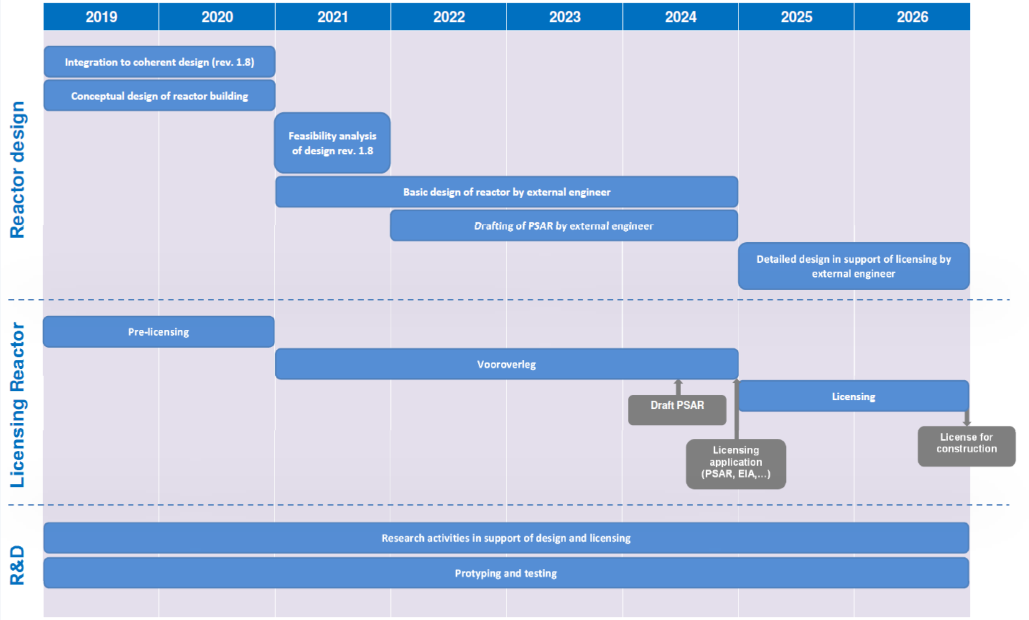


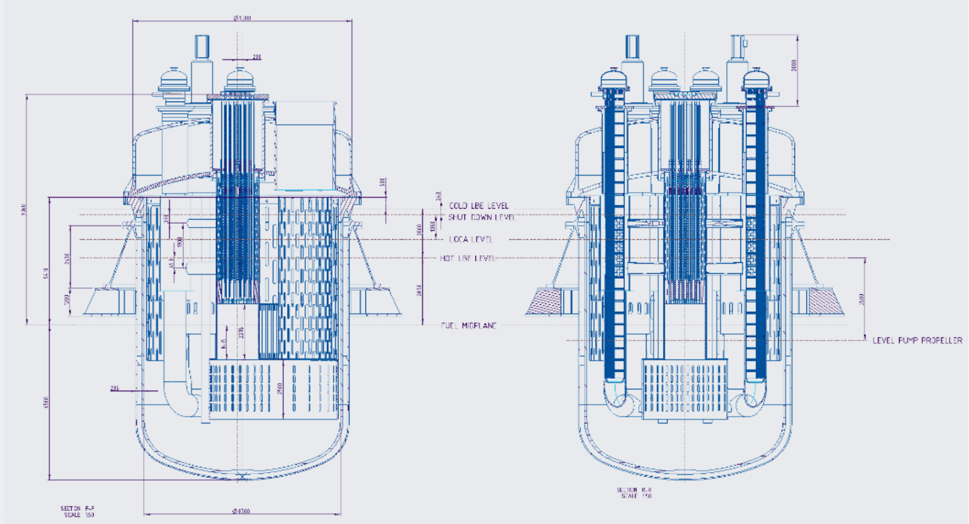
Revision 1.8 in numbers

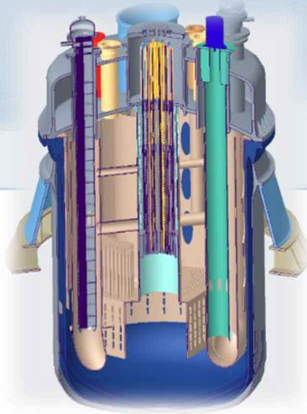
Parameter	Unit	Rev. 1.6	Rev. 1.8
Max. Core Power	MW_{th}	100	64
Design power	MW_{th}	110	70
Vessel diameter	m	10.2	8.3
Vessel height	m	15.9	11.9
Total reactor height	m	20.2	16.3
Longest component length (Pump)	m		14
LBE inventory	m^3	725	525[1]
Total mass	ton	10000	6682[2]

- [1] 2000 ton reduction in LBE coolant for the LBE coolant compared to Rev. 1.6
- [2] 1300 ton reduction in steel mass

MYRRHA reactor, Planning







- **2020**
  - Description of Rev. 1.8 concept, including the reactor building
  - Final report of the pre-licensing phase
  - R&D Status report
- **2022 – Stage-Gate**
  - Conceptual design
  - Commitment of consortiumpartner
- **2024 – Stage-Gate**
  - Feasibility of conceptual design
  - Positive advise from safety authorities
- **2026**
  - Basic design with consortiumpartner
- **2030**
  - Authorization of construction

MYRRHA contributes to EU strategic objectives

Knowledge Economy

ESFRI
European Strategic Forum for Research Infrastructure

Energy Independence

SET Plan
European Strategic Energy Technologies Plan

EIB InnovFin	MYRRHA selected by **European Investment Bank (EIB)** as potential project for EIB financing **procedure underway**
Juncker Plan	MYRRHA is on **European Fund for Strategic Investments** (**EFSI** - **“Juncker Plan”**) candidate project list for financing

Source: European Strategy Forum on Research Infrastructures (ESFRI), European Strategic Energy Plan (SET), EIB InnovFi
SCK CEN MYRRHA Project Team

MYRRHA contributes to Belgian strategic objectives

Knowledge Economy

(Visie-Vision 2030)

Nationaal Pact voor Strategische Investeringen

Pacte National pour les Investissements Stratégiques

Energy Independence

(2021-2030)

Geïntegreerd Nationaal Energie- en Klimaatplan

Plan National intégré Energie Climat

International R&D network - 1

Universities

Research

Source: SCK CEN MYRRHA Project Team
* Acquired by Veolia

International R&D network - 2

Private Sector

TRACTEBEL ENGIE
EMPRESARIOS AGRUPADOS
iba
ACS ACCELERATORS AND CRYOGENIC SYSTEMS
THALES
ADEX
SENER
BEVATECH
NNC
OXFORD TECHNOLOGIES *
COSYLAB
NTG
TA TechnicAtome
ANSALDO NUCLEARE Ansaldo Energia Group

Authorities

FANC AFCN federaal agentschap voor nucleaire controle agence fédérale de contrôle nucléaire
BEL V
JAEA
VERI TAS LUX MEA

Source: SCK CEN MYRRHA Project Team
* Acquired by Veolia

Innovation in Belgium for Europe

Towards sustainable & innovative nuclear energy and applications

Thanks for your attention !

SCK CEN
Belgian Nuclear Research Centre

Stichting van Openbaar Nut
Fondation d'Utilité Publique
Foundation of Public Utility

Registered Office: Avenue Herrmann-Debrouxlaan 40 – B-1160 BRUSSELS
Operational Office: Boeretang 200 – B-2400 MOL