Status of the MYRRHA Project

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Outline

- What is & why MYRRHA, and present status
- MYRRHA Accelerator
- Pre-licensing and licensing efforts
- MYRRHA phased strategy, planning and funding
- Conclusion

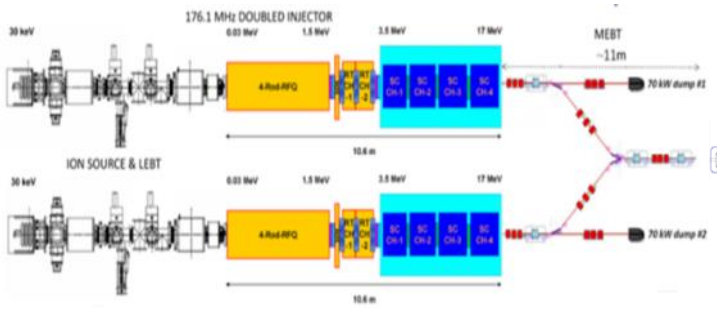
Key technical objective of the MYRRHA Project: an ADS

MYRRHA is an Accelerator Driven System

- Demonstrate the **ADS concept** at pre-industrial scale (coupling accelerator + spallation source + power reactor)

  → can work in critical and subcritical mode, accelerator controls criticality

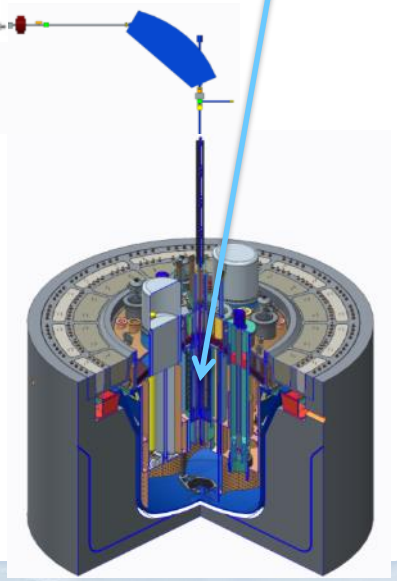
- Demonstrate **Transmutation**
- Fast neutron source → **Multipurpose and flexible irradiation facility**



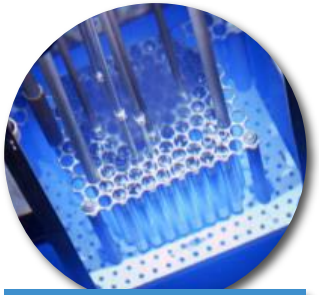
Accelerator	
particles	protons
beam energy	600 MeV
beam current	2.4 to 4 mA

Target	
main reaction	spallation
output	$2 \cdot 10^{17}$ n/s
material	LBE (coolant)

Reactor	
power	65 to 100 MW_{th}
k_{eff}	0,95
spectrum	fast
coolant	LBE



MYRRHA broad application portfolio



Fission GEN IV

Fusion

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

SNF*/ Waste

Fundamental research

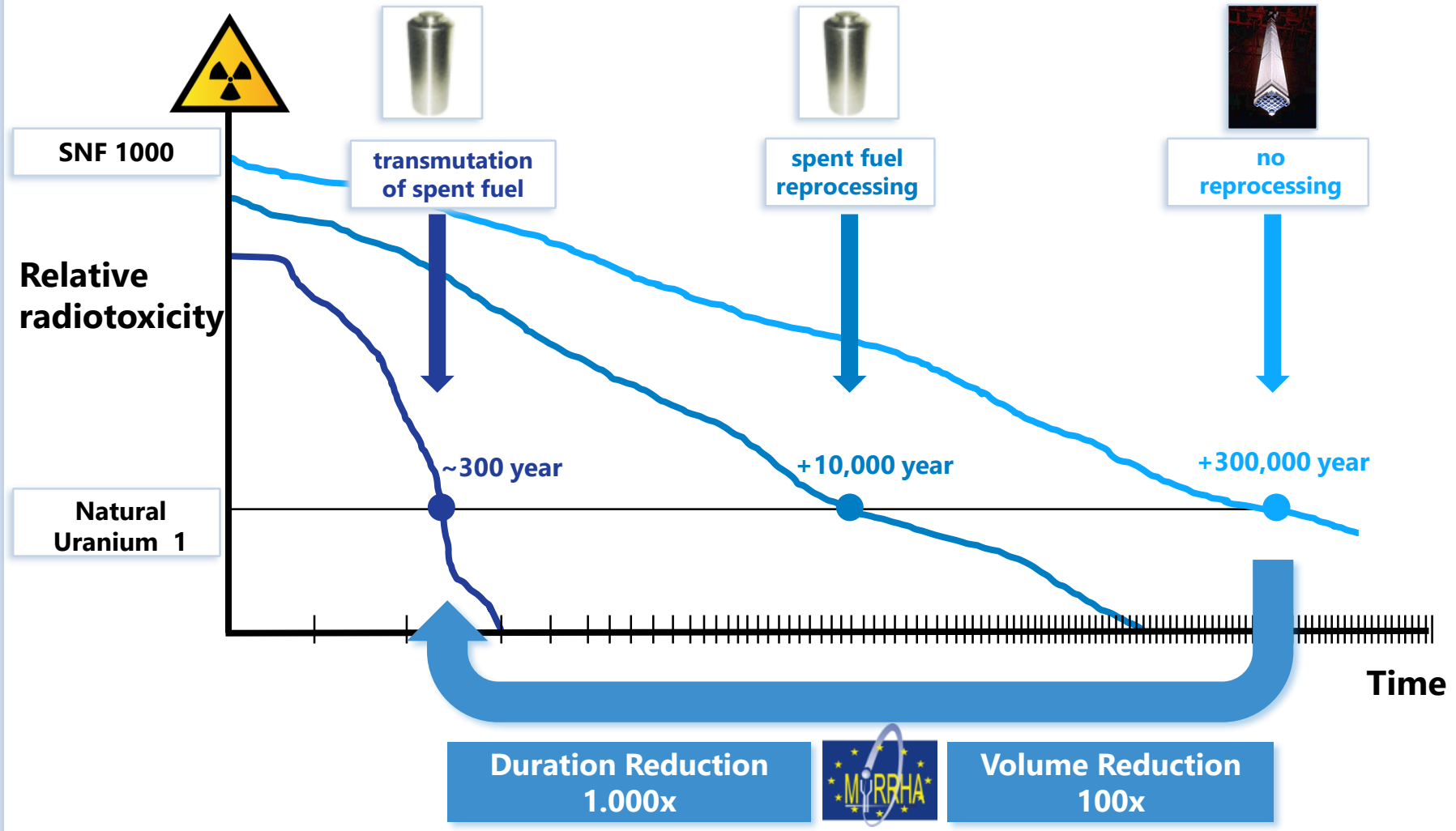
Radio-isotopes

SMR LFR

**SNF = Spent Nuclear Fuel*

Source: SCK•CEN MYRRHA Project Team, MYRRHA Business Plan

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

European Strategy for P&T (2005) with objective of possible industrialisation from 2030-35

EU P&T Strategy 2005: *"The **implementation of P&T** of a large part of the high-level nuclear waste **in Europe needs the demonstration of its feasibility at an "engineering" level**. The respective **R&D** activities could be **arranged in four "building blocks"**:*

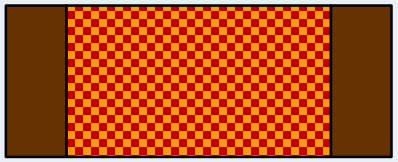
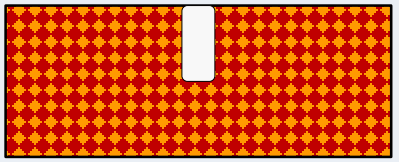
P&T building blocks	Description	Name & Location
1 **Partitioning**	▪ Demonstrate capability to process a sizable amount of **spent fuel** from commercial Light Water Reactors to **separate** plutonium, uranium and minor actinides	▪ Atalante (FR)
2 **Fuel production**	▪ Demonstrate the capability **to fabricate** at a semi-industrial level the **dedicated fuel** needed to load in a dedicated transmuter	▪ JRC-ITU (EU)
3 **Transmutation**	▪ **Design and construct one or more dedicated transmuters**	▪ **MYRRHA (BE)**
4 **Fuel unloading**	▪ Specific installation to process fuel unloaded from transmuter ▪ Not necessarily the same as type to process original spent fuel unloaded from commercial power plants	

The European Commission contributes to the 4 building blocks and fosters the national programmes towards this strategy for **demonstration at engineering level**

Source: European Commission Strategy Paper on Partitioning & Transmutation (2005)

Three options for Minor Actinide transmutation Studied in ARCAS FP7 project

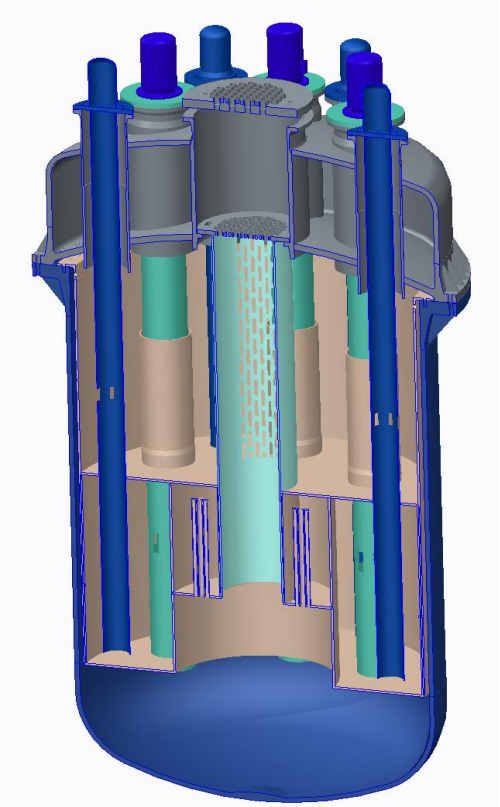
EU is presently considering two approaches for transmutation: via FR or ADS

FR heterogeneous	FR homogeneous	ADS
		
Driver fuel Blanket with MA	Fuel with MA Blanket	Fuel with MA

Core safety parameters limit the amount of MA that can be loaded in the critical core for transmutation, leading to transmutation rates of:

- FR = 2 to 4 kg/TWh
- ADS = **35 kg/TWh** (based on a 400 MW_{th} EFIT design)

MYRRHA reactor design update



Option 0 is now the reference design under further optimisation

Four MYRRHA primary system design options investigated to reduce the dimension of the reactor vessel (& associated cost)

Option	Reactor type	Description
0	Pool	Updated rev. 1.6 Innovative IVFHM & double-walled PHX
1	Pool	Reduced size Innovative IVFHM & double-walled PHX
2	Loop	Bottom loading Existing IVFHM concept & external double-walled PHX
3	Loop	Top loading

IVFHM = In Vessel Fuel Handle Machine
PHX = Primary Heat Exchanger

Contact: Peter Baeten (pbaeten@sckcen.be)

MYRRHA Accelerator - Specific requirements

→ **High power proton beam (up to 2.4 MW)**

Proton energy	600 MeV
Beam current	0.1 to 4.0 mA
Repetition rate	CW, 10 to 250 Hz
Beam duty cycle	10^{-4} to 1
Beam power stability	< ± 2% on a time scale of 100ms
Beam footprint on reactor window	Circular ∅85mm
Beam footprint stability	< ± 10% on a time scale of 1s
# of allowed beam trips on reactor longer than 3 sec	10 maximum per 3-month operation period
# of allowed beam trips on reactor longer than 0.1 sec	100 maximum per day
# of allowed beam trips on reactor shorter than 0.1 sec	unlimited

→ **Extreme reliability level: MTBF > 250 hrs**

MYRRHA Accelerator - Roadmap to Reliability

Design

- **Involving major accelerator labs** in Europe and specific **industrial partners**
- **Incorporating fault tolerant** schemes
- **Validation** with reliability model
- **Reviewed by panel of international** accelerator peers

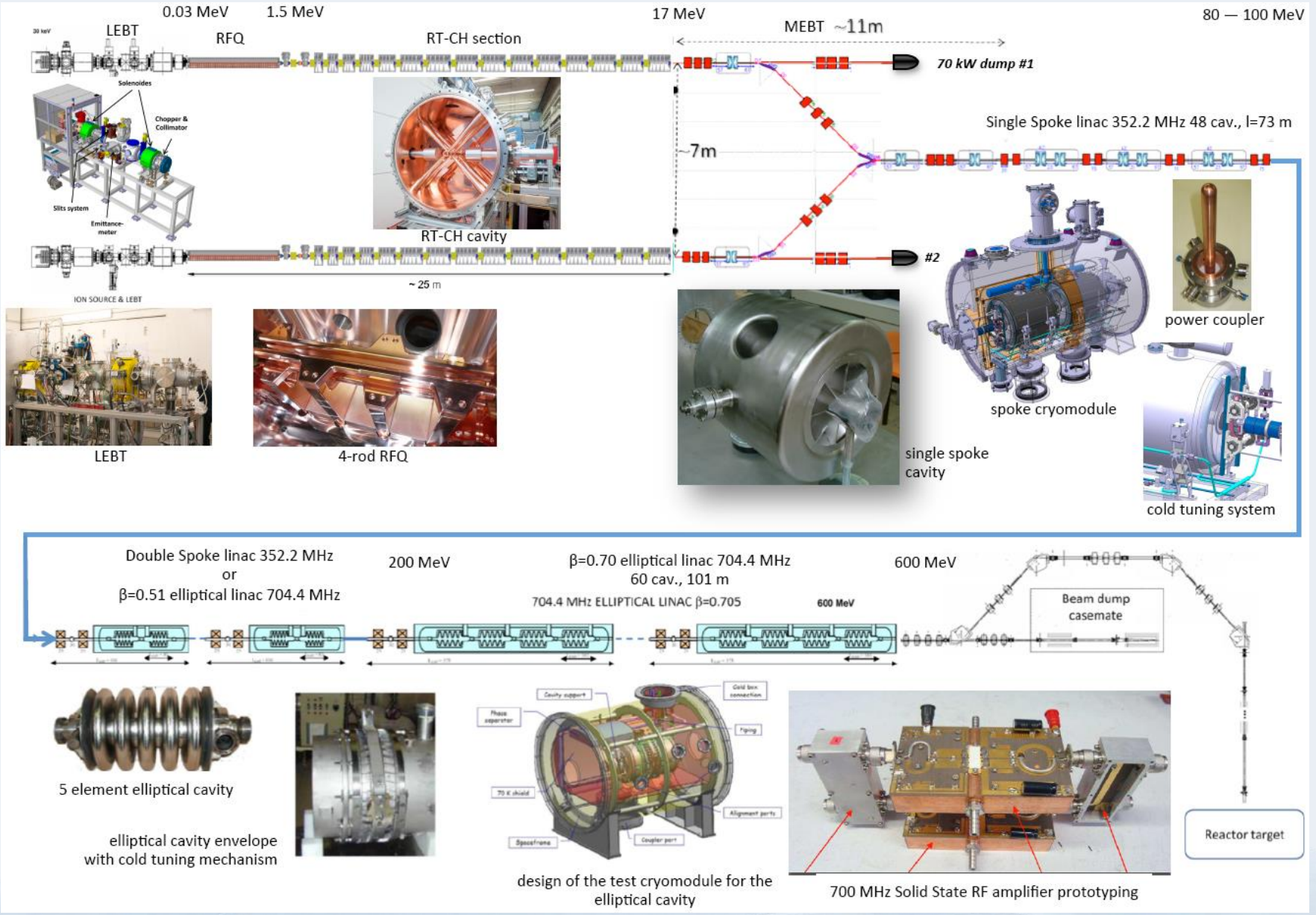
Prototyping

- **Key elements:** Ion source, LEBT, RFQ, CH cavities, Spoke cavities,…
- **Set-up of an experimental test-bench**: 5.9 MeV accelerator @CRC, UCL in LLN
- **Hands-on experience** for the team, **return of experience** for manufacturing phase, start of **engineering work** in view of the construction and integration

Scenario 1 100 MeV

- **Representative unit** in view of the 600 MeV accelerator
- **Implementation** of fault tolerant schemes
- **Testing and validation** of technological choices
- **Evaluation of the reliability goal** for the full MYRRHA Linac
- **Applications :** production of (medical) radioisotopes, nuclear applications, and nuclear physics research

MYRRHA Accelerator – Overview

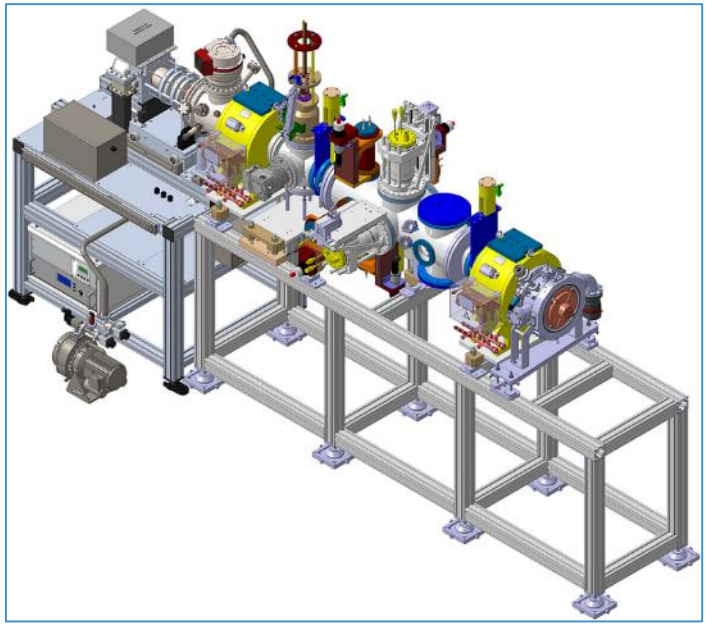


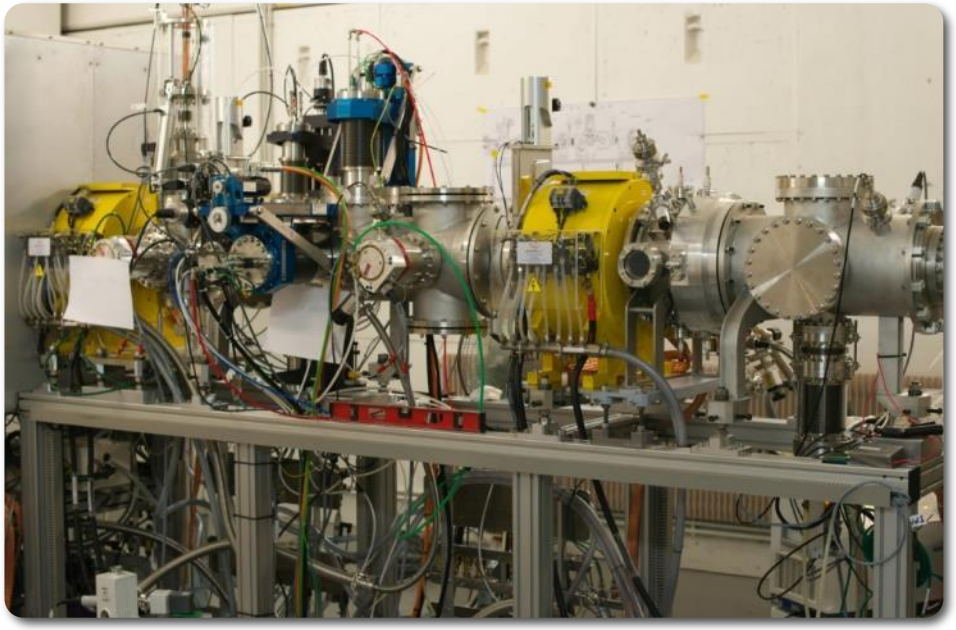
MYRRHA Accelerator - Components

- Ion source
- LEBT
- RFQ
- MEBT 1 & MEBT 2
- RT CH cavities (in 2 sections)
- MEBT3
- Single spoke cavity
- Double-Spoke cavity / Elliptical cavity
- HEBT

Source:

Ion source & LEBT



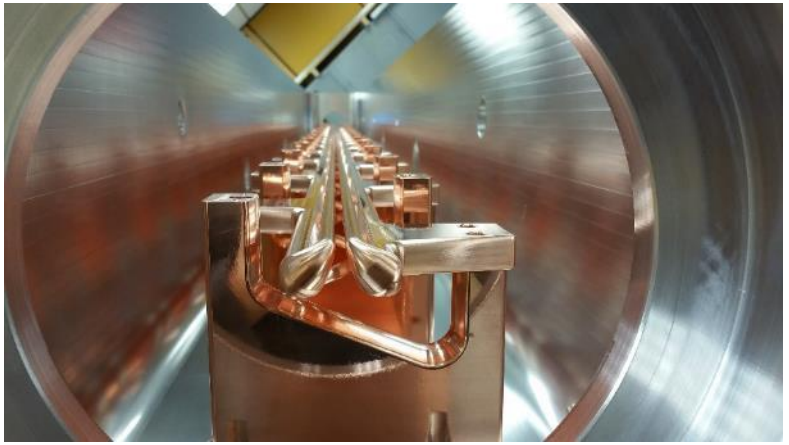


LEBT built and complete system commissioned at LPSC Grenoble

It will be installed at CRC/UCL in Louvain-la-Neuve (Belgium) in September 2017

RFQ – Radiofrequency quadrupole

- **First accelerating structure**
  - **4-rod**
  - **30 keV →1.5 MeV**
  - **176.1MHz**
  - **4m long aluminium structure**
  - **Stems:**



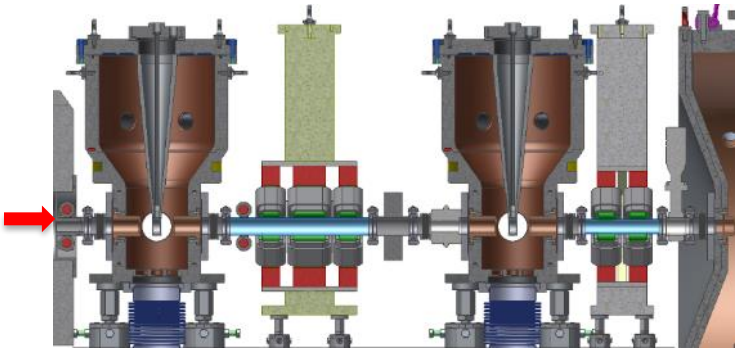
MYRRHA Accelerator – full Injector

Normal conducting linac:

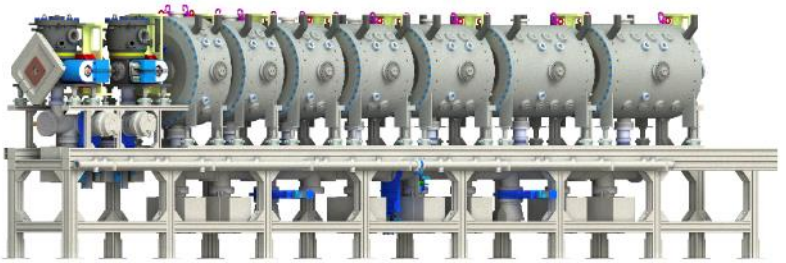
Linac Frequency:	*176.1 MHz*
Power RF-Amplifier:	*12-100 kW cw*

Name:	Elements:	Energy:
MEBT-1	2 QWR-Re-Buncher	1.5 MeV
CH-Section 1	7 CH-Cavities	5.9 MeV
MEBT-2	1 CH-Re-Buncher	5.9 MeV
CH-Section 2	7 CH-Cavities	16.6 MeV
MEBT-3	Fast Switching Magnet	16.6 MeV

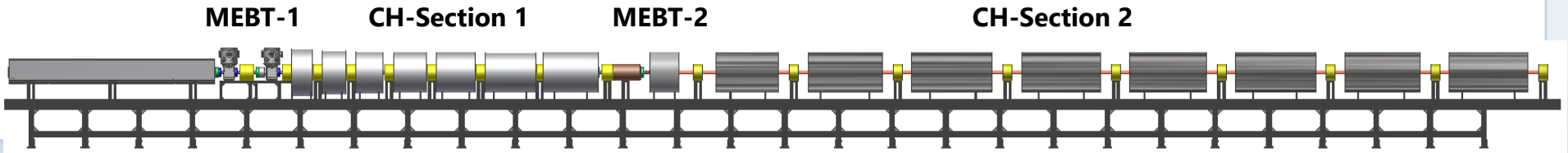
MEBT-1 in cross section



MEBT-1 & CH-Section 1



Full Injector up to 16.6 MeV (*Length: ~28.5 m*)



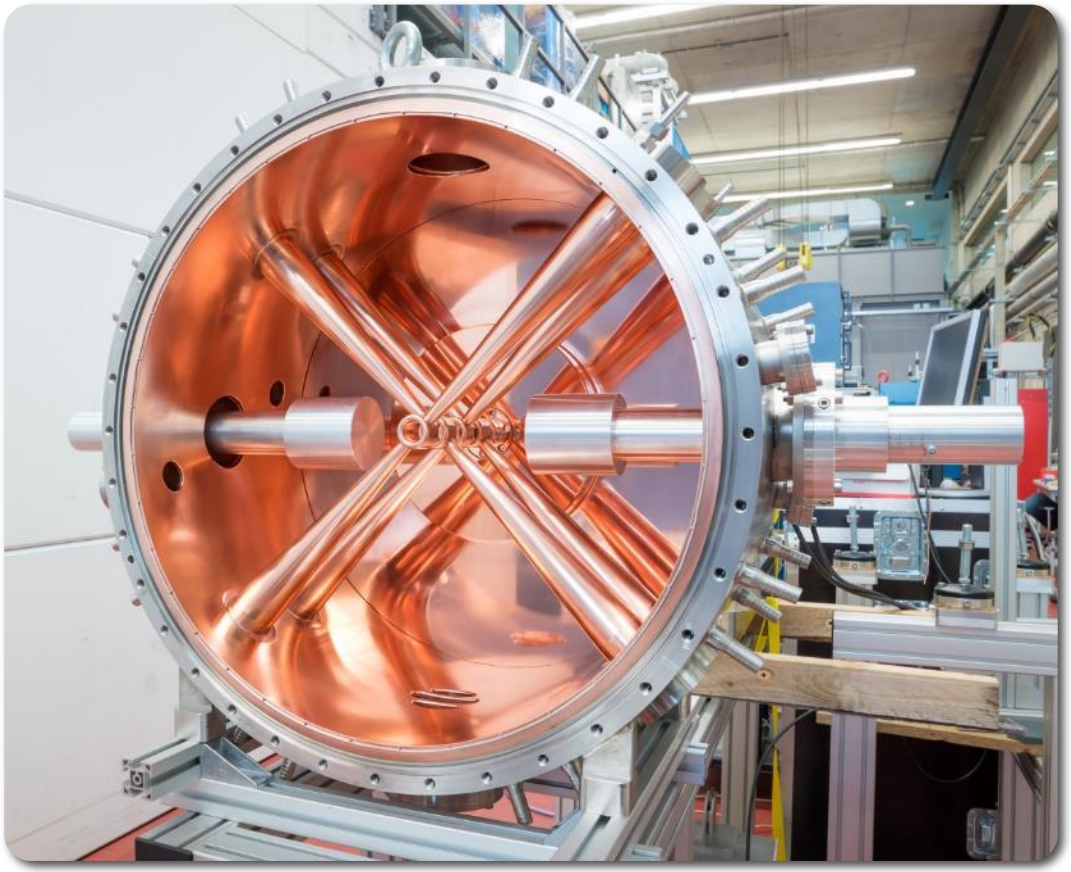
Source:

Room temperature CH cavities

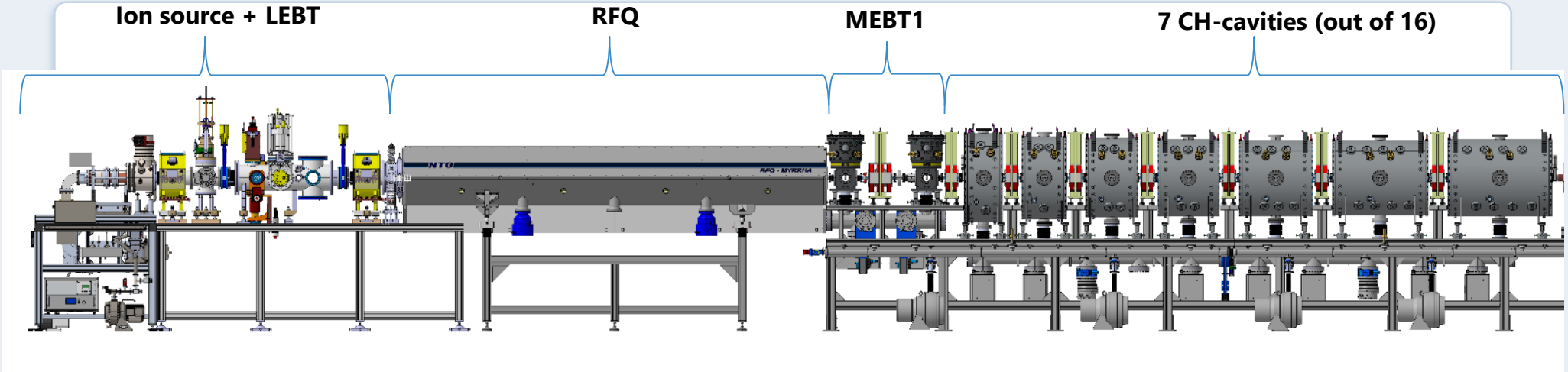
- **Second accelerating section**
  - 1.5MeV → 17MeV
  - 176.1MHz
- **Stainless steel structures**
  - Thin copper plating

Prototype ready

Two first cavities are under construction, will be progressively installed starting in Spring 2018



MYRRHA Accelerator – Injector up to 5.9 MeV



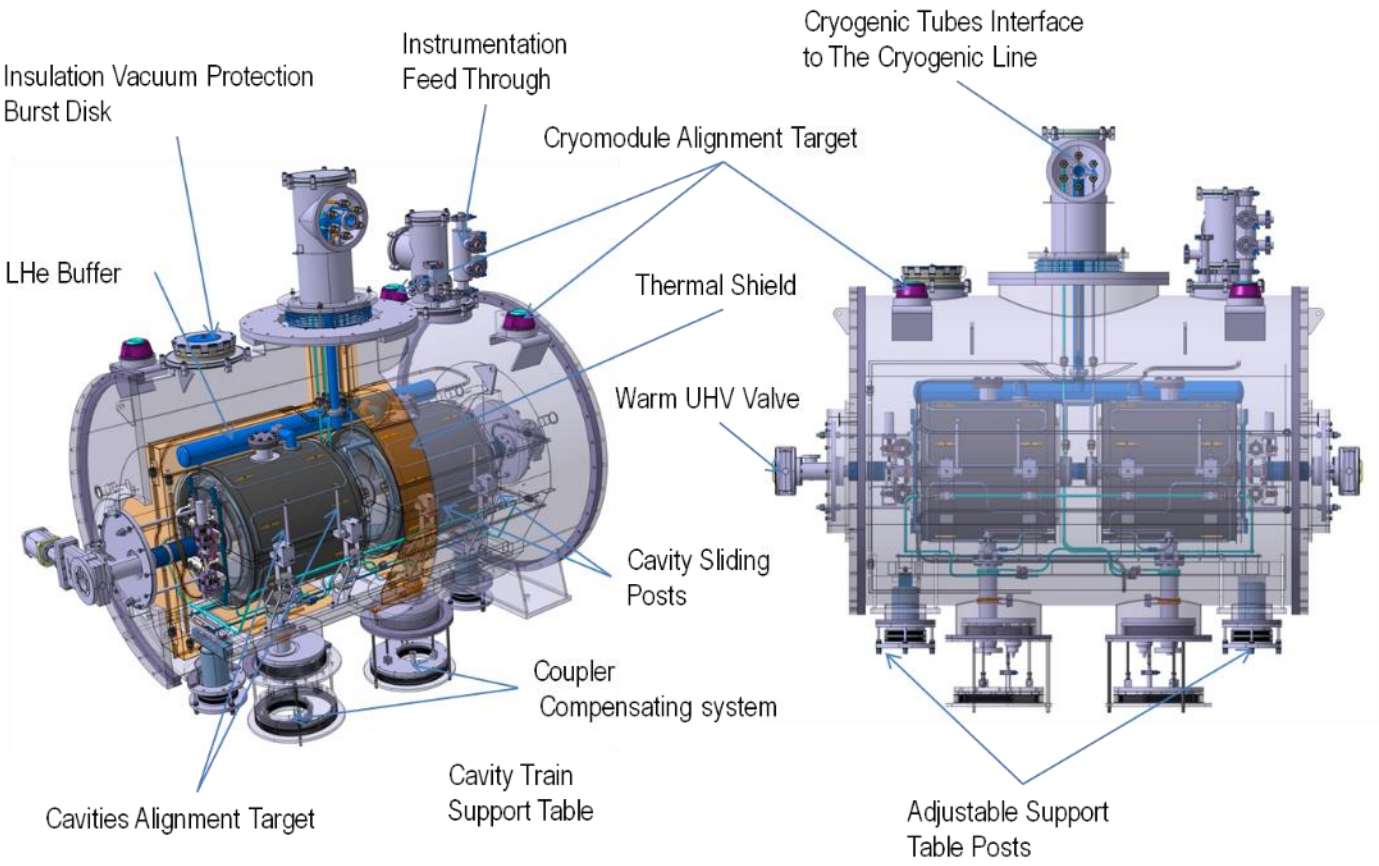
- Injector up to 5.9 MeV will be installed at CRC/UCL in Louvain-la-Neuve from September 2017 and will be commissioned while prototyping is continued and 100 MeV accelerator buildings & auxiliaries are built at SCK•CEN site in Mol
- The "5.9 MeV Injector" is a test platform for:
  - reliability related basic technological choices
  - SS RF amplifiers
  - LLRF controls (µTCA based)
  - beam diagnostic instruments
  - control system options
  - beam dynamics modeling (virtual accelerator)
  - integration methodology
  - operational management tools

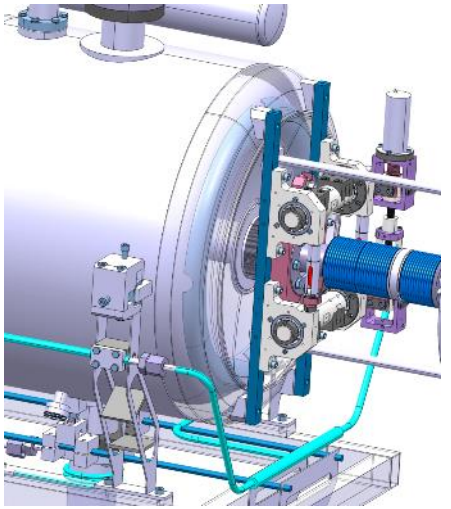
MYRRHA Accelerator - Single spoke cavity

Surface preparation process tested at IPN Orsay with these 2 cavities

Two new final cavities will be constructed and tested (collaboration agreement with French CNRS/IN2P3)

MYRRHA Accelerator - Single spoke cavity cryomodules





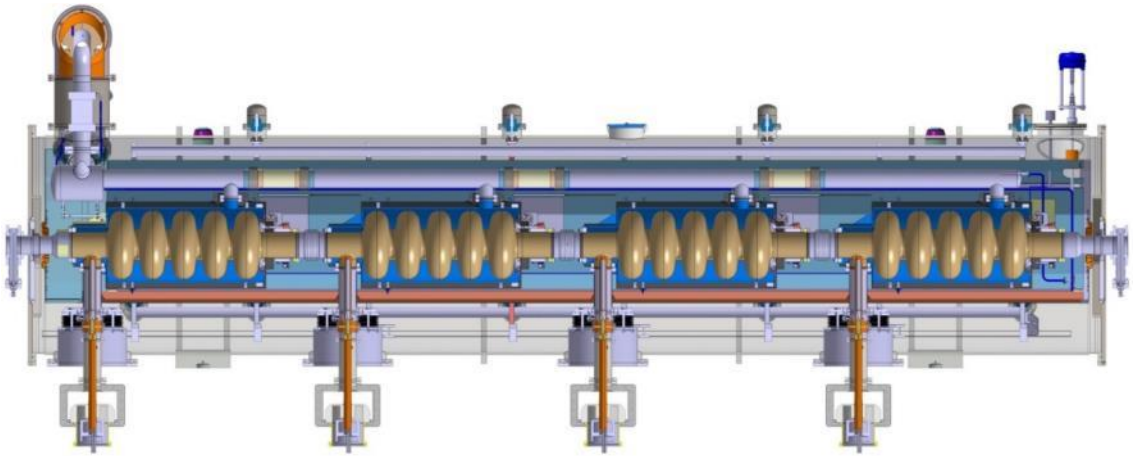
In view of a series of 29 cryomodules → prototype for: SC cavity preparation, cold valve box, RF power coupler, cold tuning mechanisms, instrumentation, assembly and long term operation

MYRRHA Accelerator - Fourth and fifth accelerating sections (HEBT)

Section 100 MeV to 600 MeV

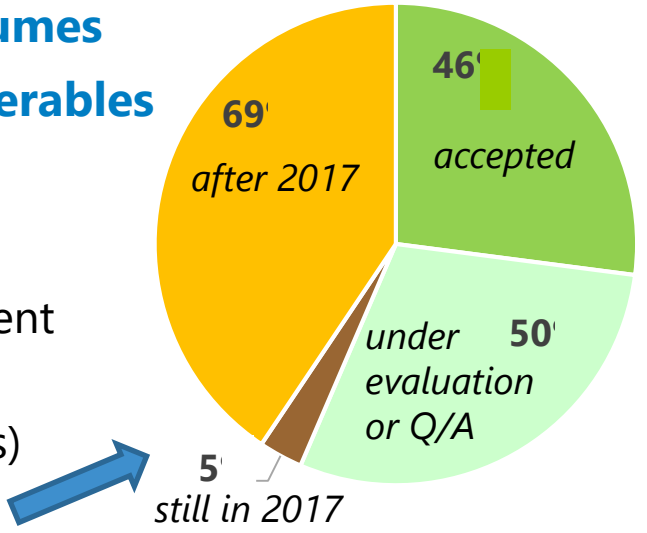
- **Superconducting RF structures**
  - **100 – 200 MeV**: double spoke (ESS design experience) or medium β Nb elliptical cavities (352.2 or 704.4MHz)
  - **200 – 600 MeV**: high β Nb elliptical cavities (704.4MHz)

- **2 cavity cryomodules: ~ 3m long**
- **4 cavity cryomodules: ~ 8m long**



MYRRHA pre-licensing / licensing

- **Large effort devoted to pre-licensing / licensing since 2010**
- Contractual relation with **FANC/Bel-V** (BE licensing authority and its TSO) for pre-licensing of MYRRHA ADS, resulted in:
  - **Design guidelines** → quantitative safety objectives compatible with the existing Belgian regulatory framework
  - **DOPF (Design Option Provisions file) in 4 volumes**
  - **17 Focus Points themes** identified → **170 deliverables**
- <u>Status at the end of June 2017</u>:
  - **Design guidelines** (safety demonstration, external hazards, radiological consequences) applied in current reactor design
  - **DOPF** : 4 volumes submitted (V1&2 iterated 2 times)
  - **170 Deliverables** (2 to 3 iteration per deliverable)



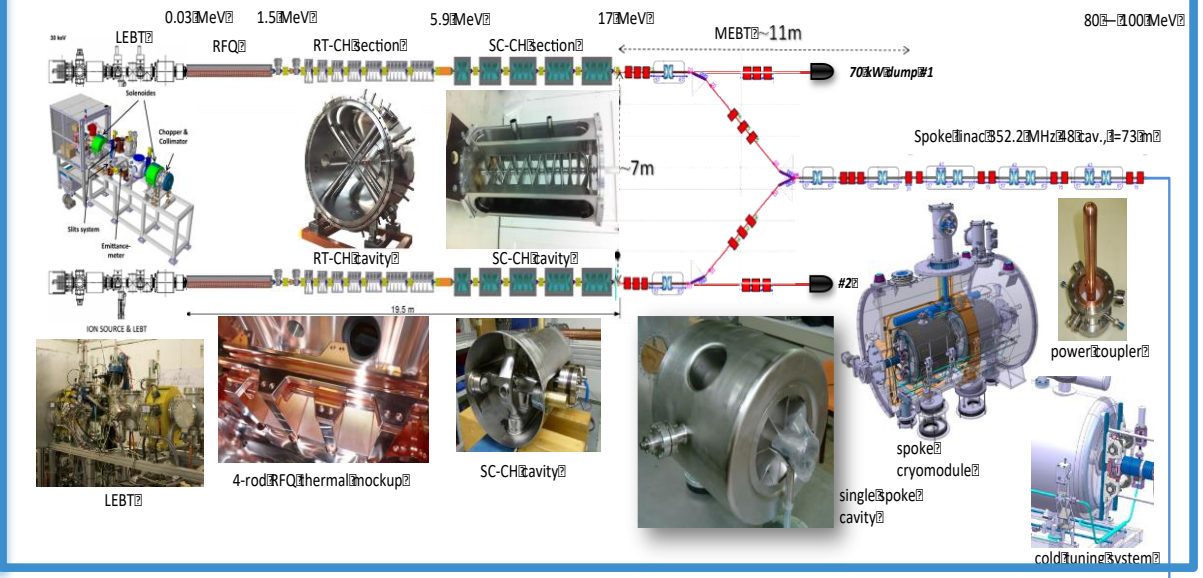
- **Opinion from FANC/Bel V expected by the end of 2017**
- **Licensing of the MYRRHA 100 MeV accelerator started in 2016**

MYRRHA Project Phased Implementation Strategy

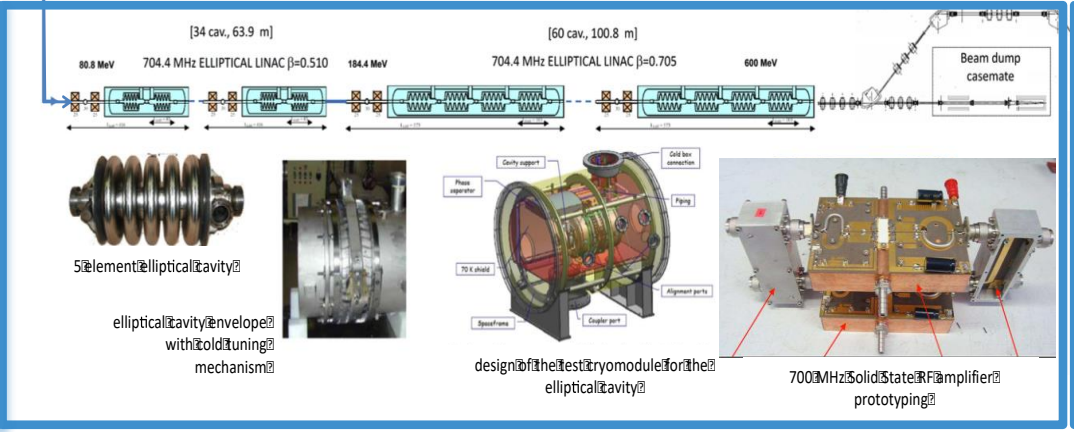
Benefits of phased approach:

- Reducing technical risk
- Spreading investment cost
- First R&D facility available in Mol by the end of 2024

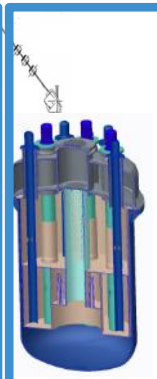
Phase 1 – 100 MeV



Phase 2 – 600 MeV

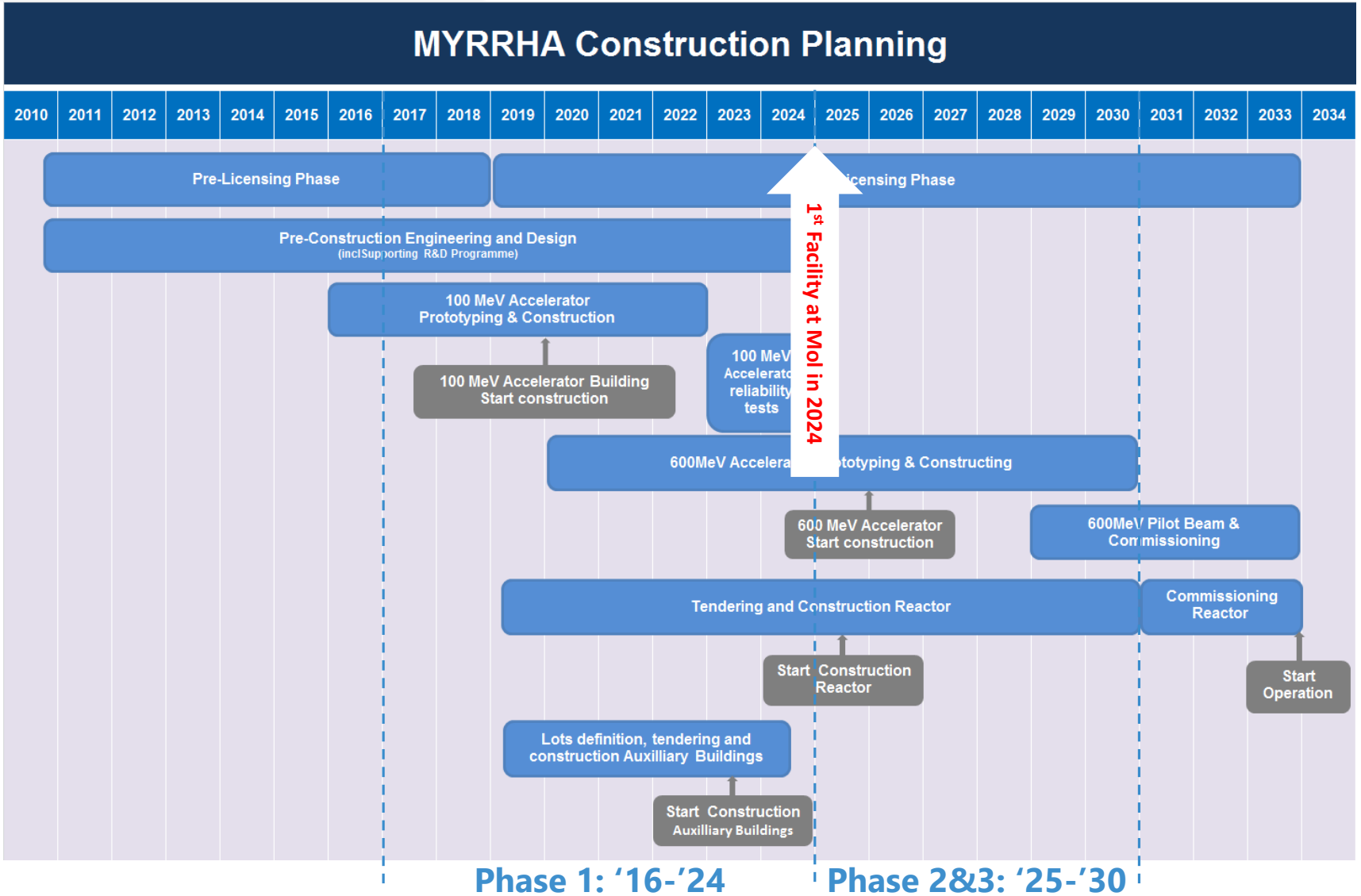


Phase 3 – Reactor



MYRRHA Project Phased implementation plan (2016-2030)

> Implementation High-Level overview



Source: SCK•CEN MYRRHA Project Team

MYRRHA is recognized in Europe to contribute to strategic objectives of both Energy and Knowledge economy

ESFRI
European Strategic Forum for Research Infrastructure

SET Plan
European Strategic Energy Technologies Plan

EIB InnovFin	MYRRHA is selected by the **European Investment Bank (EIB)** as a potential project for financing and benefits from advisory services from EIB InnovFin
Juncker Plan	MYRRHA is on the list of projects candidate to be financed by the **European Fund for Strategic Investments** (**EFSI**, also called **"Juncker plan"**)

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

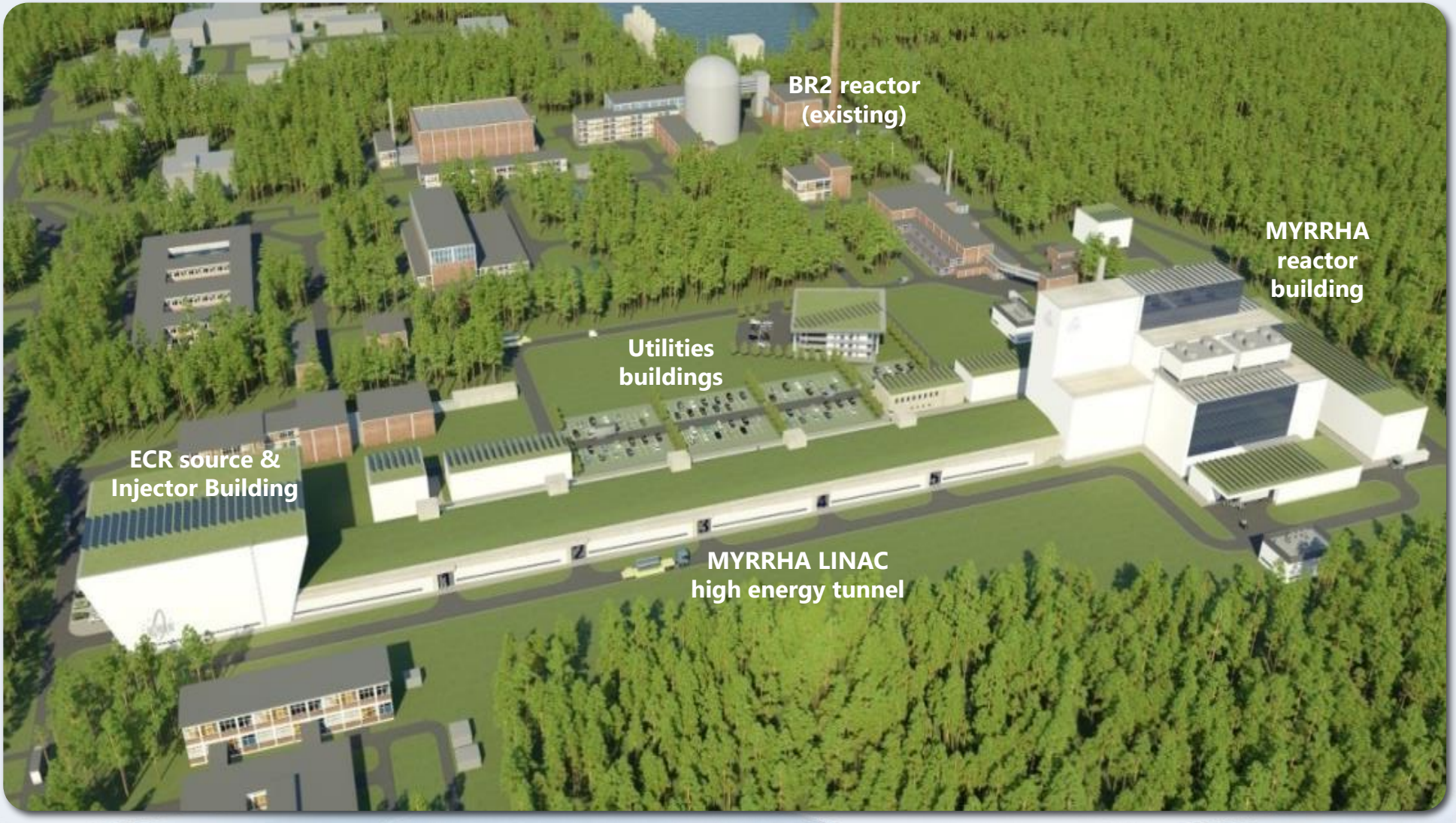
MYRRHA is embedded in an international R&D network

Source: SCK•CEN MYRRHA Project Team

Conclusion

- MYRRHA main objective is **demonstration of transmutation** as a viable solution to reduce the radiotoxicity of long-life nuclear waste → MYRRHA is one of the 4 building blocks of EU strategy for P&T demonstration at Engineering level.
- MYRRHA is benefiting from **SCK•CEN continuous support** since 1998, has been **endorsed by Belgian Government** since 2010 and is supported by a dedicated financial endowment.
- MYRRHA profits since 2001 from the **results of many projects** co-funded by the successive European FP and in particular 6 dedicated projects to MYRRHA design and associated prototyping and technologies.
- MYRRHA Design and R&D programme involve **more than 100 engineers and researchers** at SCK•CEN and collaborations with national and international industry, research centres and academia.
- MYRRHA **phased implementation strategy** allows reducing technical risk, spreading investment cost, and having the first R&D facility available in Mol by the end of 2024.
- **In parallel** to test of the MYRRHA injector up to 5.9 MeV, continuation of reactor R&D programme, accelerator components prototyping, and construction of the buildings and auxiliary infrastructure in Mol are conducted.
- Large efforts dedicated to **pre-licensing and licensing**. The 100 MeV Accelerator licensing, as *stand-alone* facility, started in 2016.
- *Last but not least*, MYRRHA is on the **ESFRI Project priority list since 2010 and put by Belgian Gov. and EC DG RTD on the EFSI** (Juncker Plan), benefits from EIB assistance for due diligence for **bankability for EFSI** or **INNOVFIN loans**.

A jump in the future for pioneering innovation in Belgium
For sustainable nuclear energy in Europe



http://myrrha.sckcen.be


MYRRHA

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Studiecentrum voor Kernenergie
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Belgian Nuclear Research Centre

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