



STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

MYRRHA

Multipurpose **hY**brid **R**esearch **R**eactor for **H**igh-tech **A**pplications



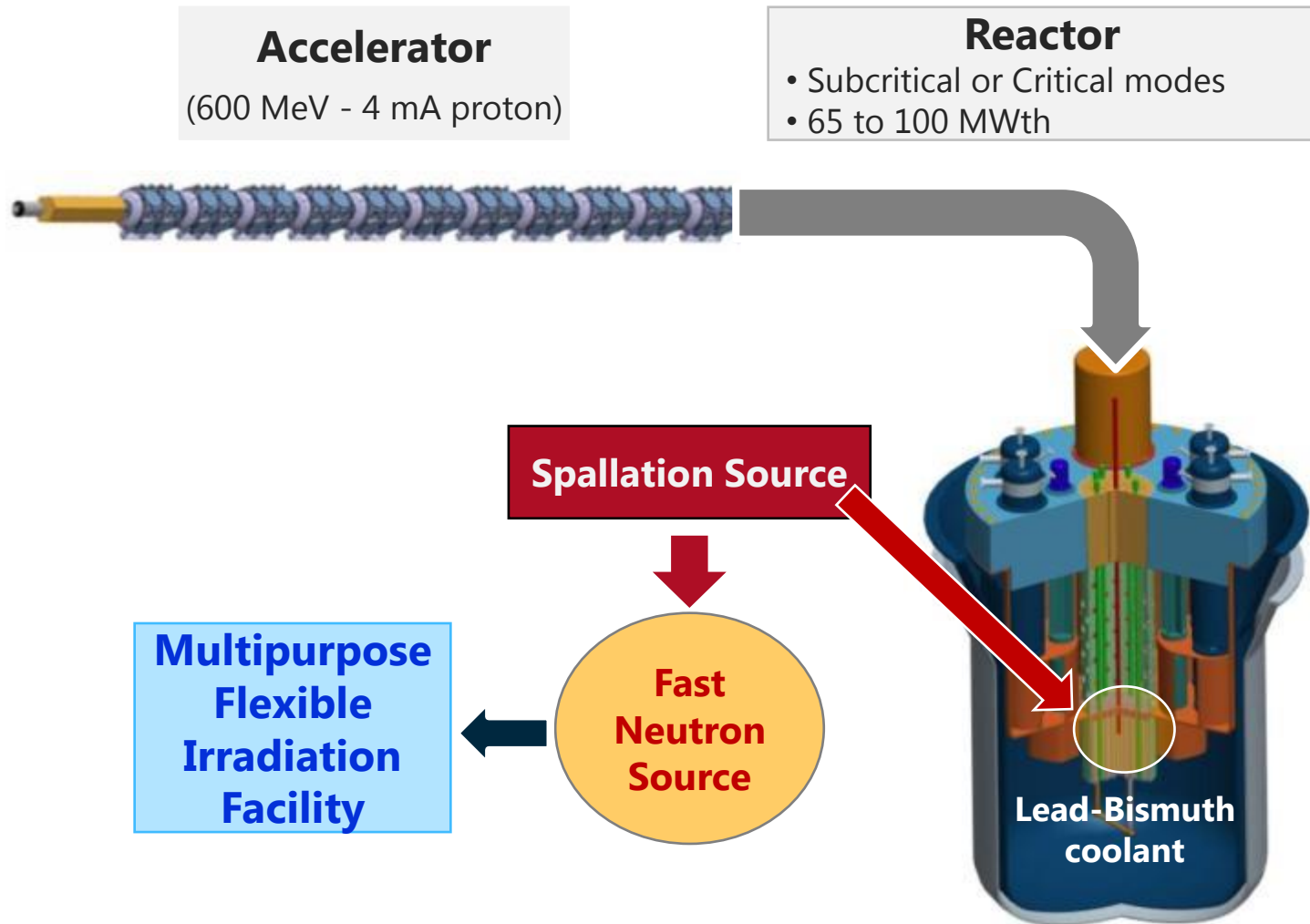


Current status **MYRRHA Project**

70th Board Meeting of the EPS Nuclear Physics Division
Leuven Belgium, 15-16 October 2015

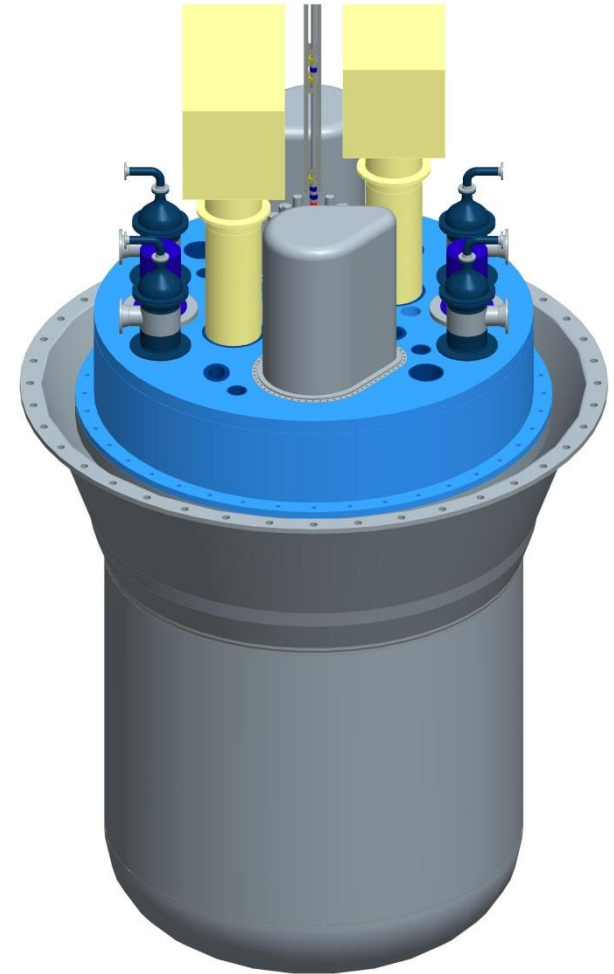
SCK•CEN, Boeretang 200, 2400 Mol, Belgium
mschyns@sckcen.be or myrrha@sckcen.be

MYRRHA - Accelerator Driven System

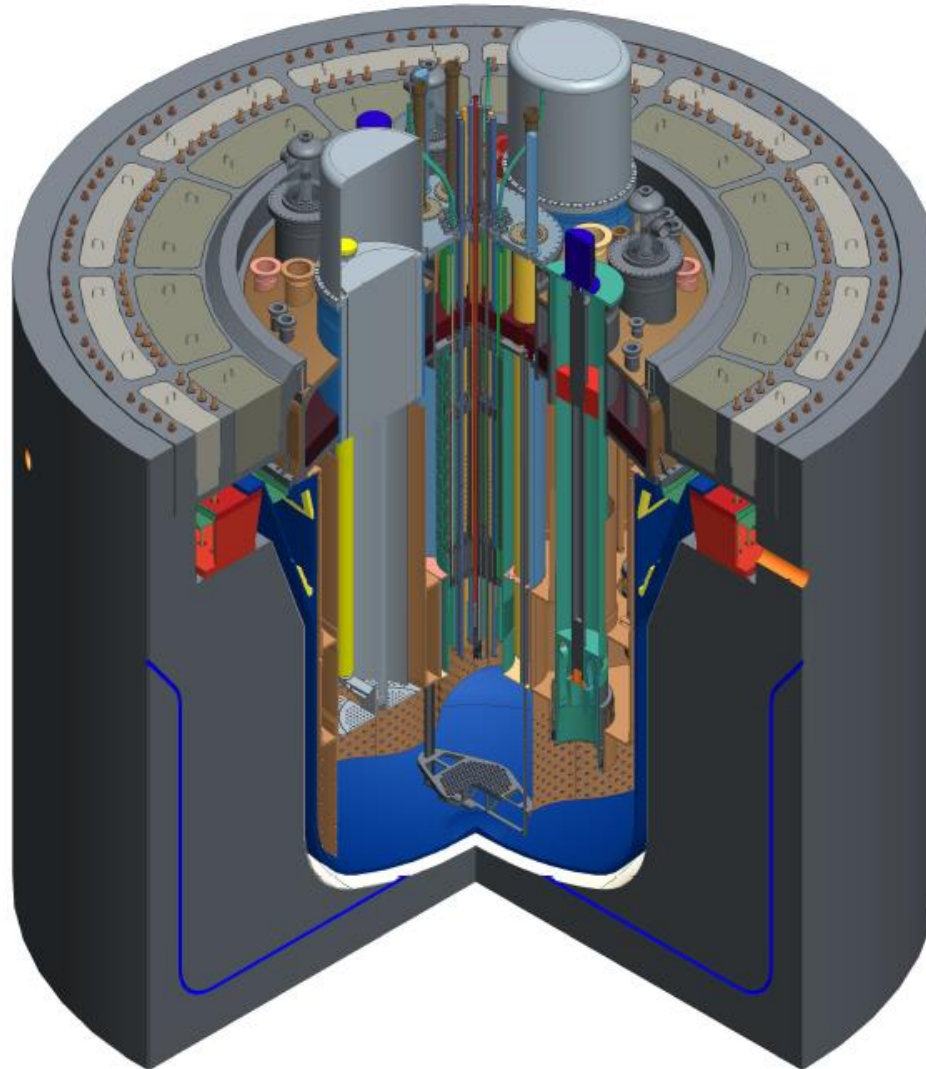


General reactor layout

- 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



MYRRHA rev. 1.6



R&D Topics

- Materials
- Fuel
- LBE Technology
 - Components & Experiments
 - Chemical Conditioning Programme
- Instrumentation & Control
- Computer code
- Accelerator
- ISOL@MYRRHA

Role of materials research for development of MYRRHA

Design tools:

- Nuclear manufacturing codes: **RCC-MRx**, ...
- Fuel codes
- FE calculations

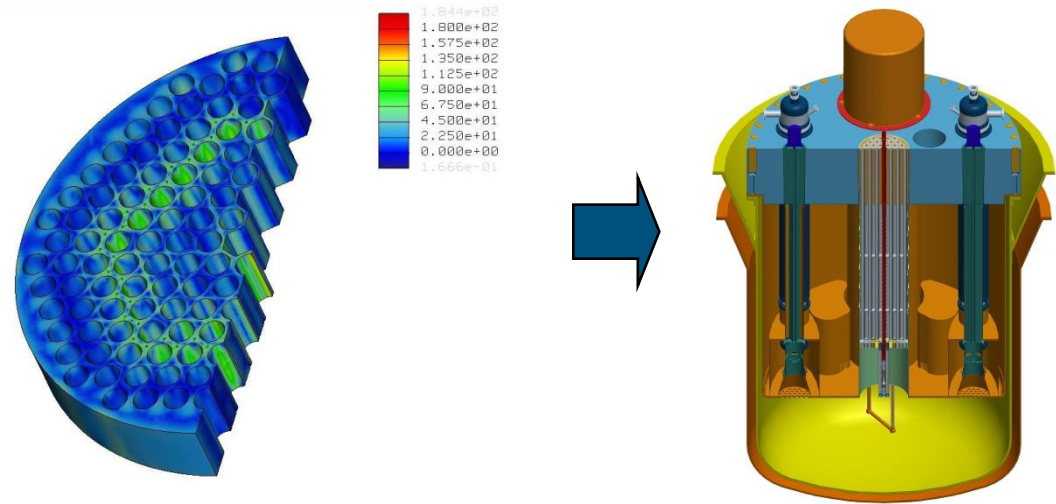
Materials properties

Design

Construction

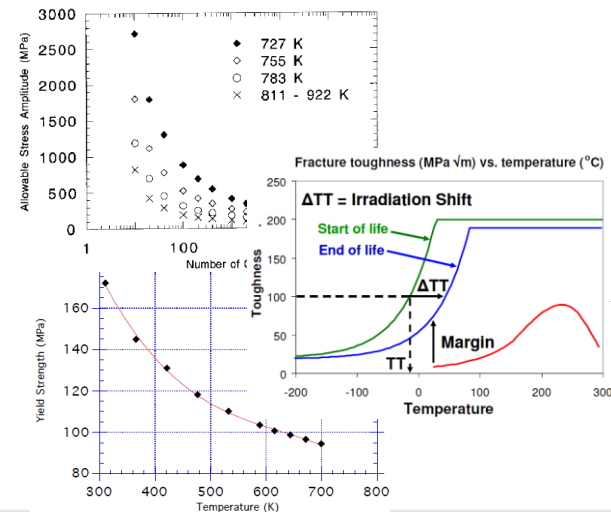
Approaches

Data



Missing data for MYRRHA:

- Basic characteristics of candidate materials
- Effects of LBE & irradiation on material properties
- Physical effects



Set-ups for mechanical tests in LBE



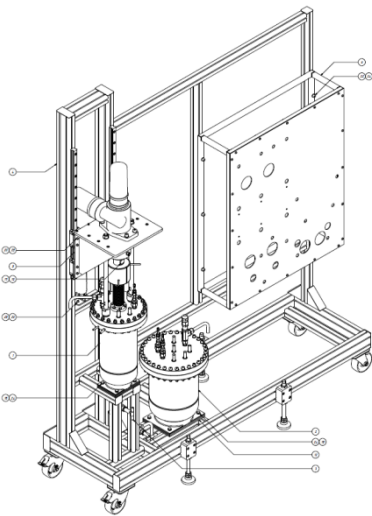
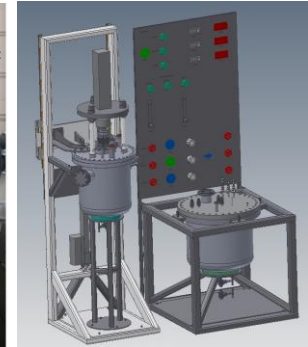
LIMETS 1

Tensile & Fracture
toughness tests in LBE



LIMETS 3

Fatigue tests in LBE



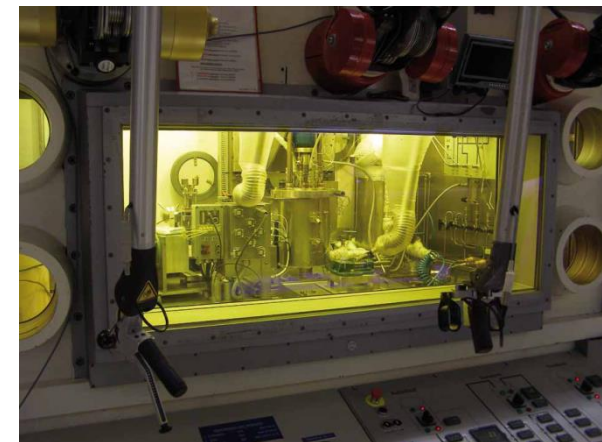
LIMETS 4

Tensile & Fracture
toughness tests in LBE

Hot cell 12 & LIMETS 2

Tensile and FT tests
of irradiated* steels in
liquid metal

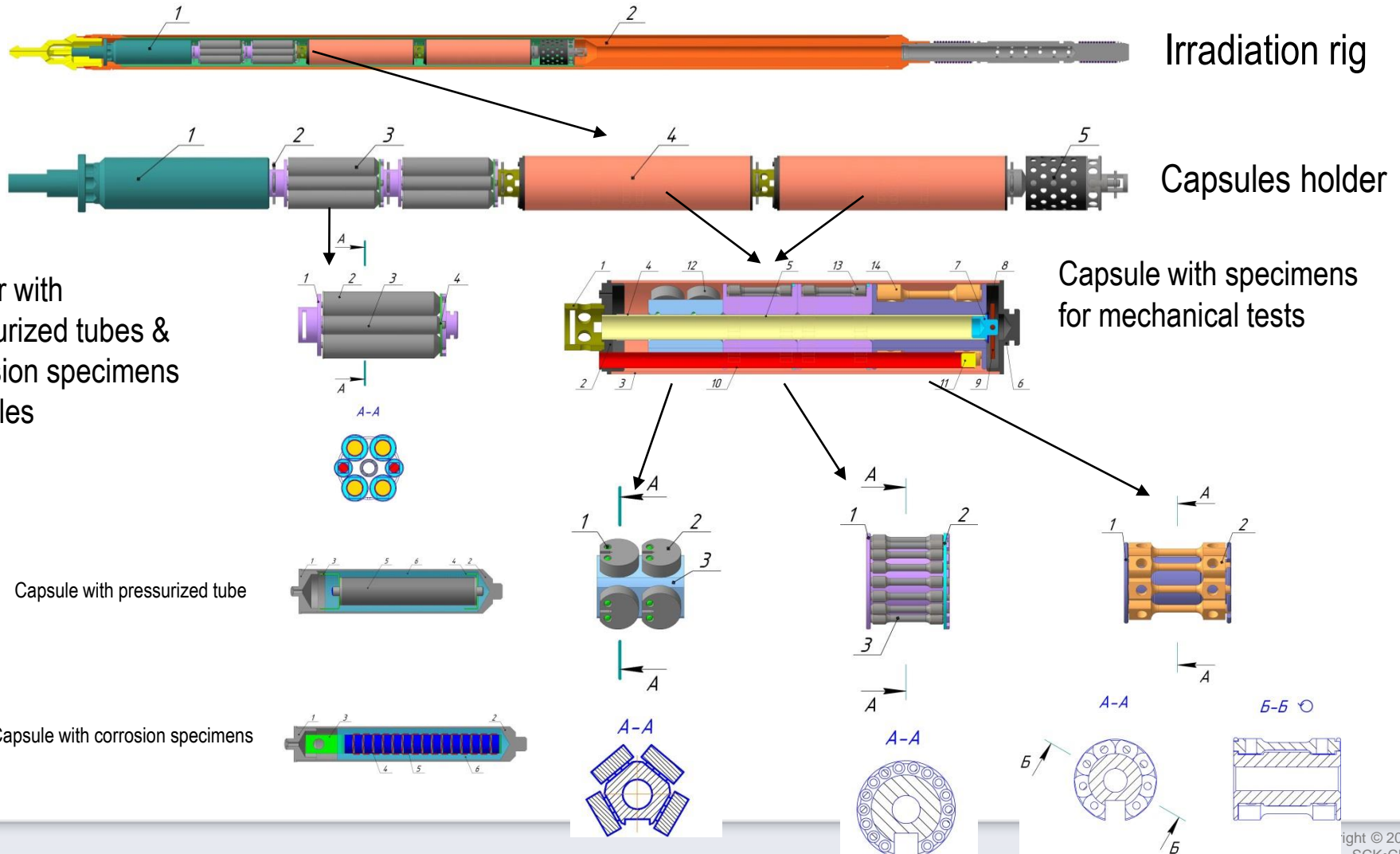
*Licensed for α (Po)
contaminated specimens

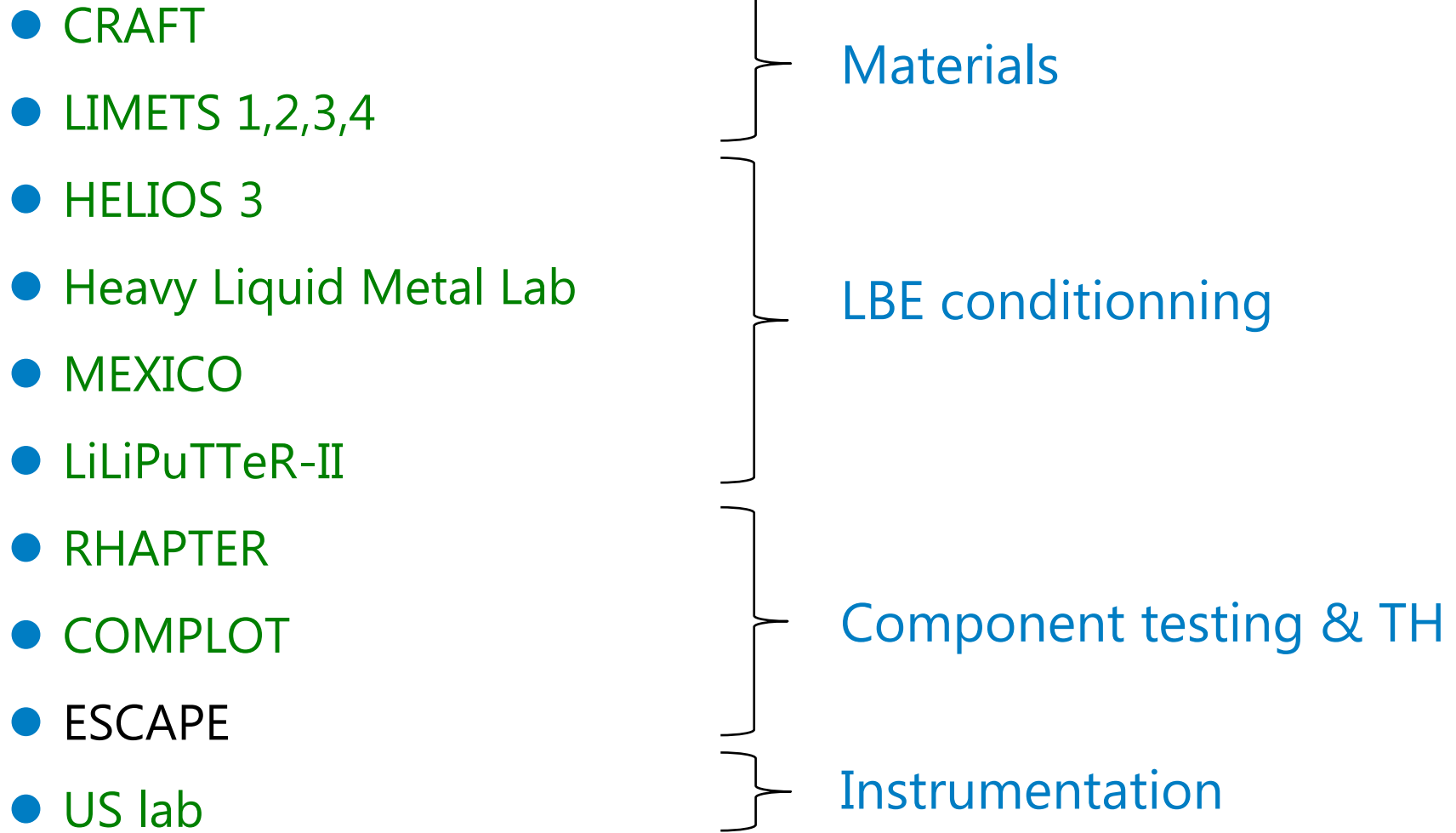


Irradiation of materials : LEXUR II, RIAR (Russia), BR2

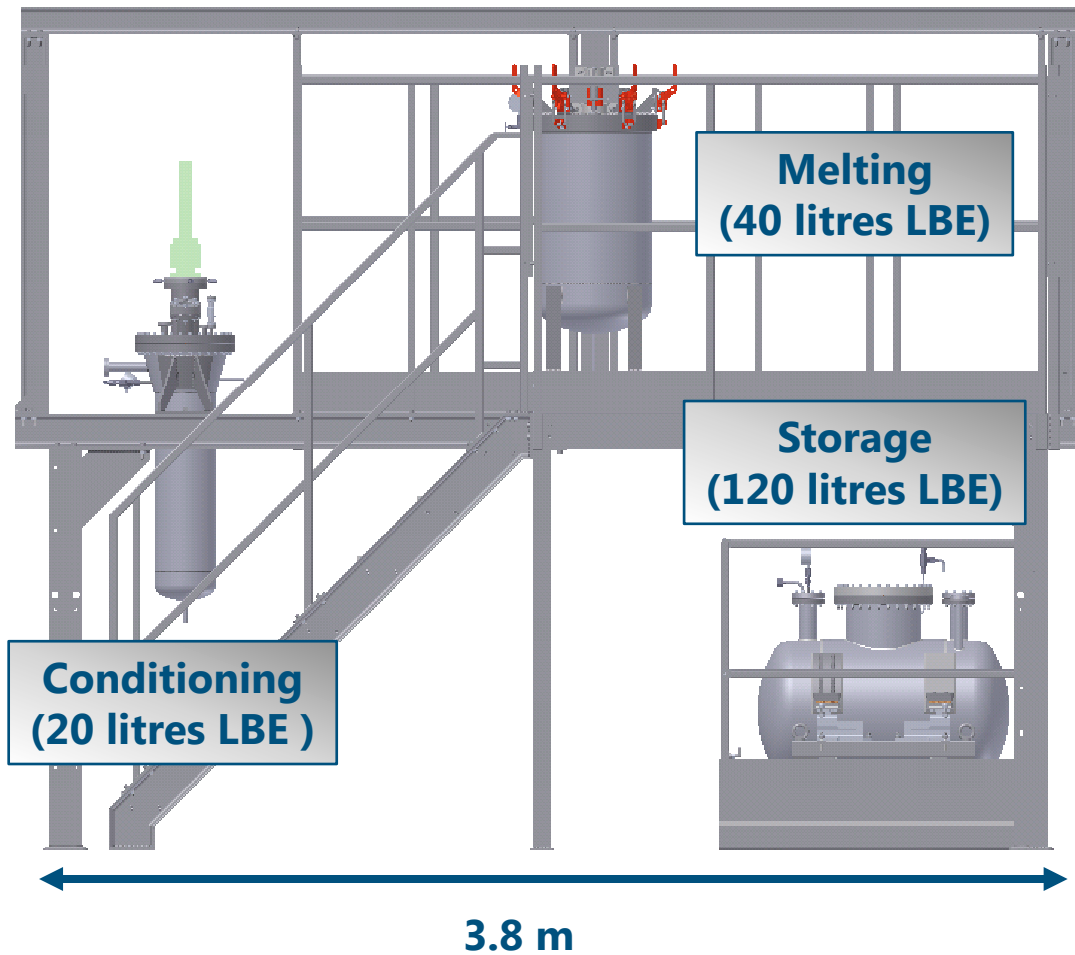
Irradiation of MYRRHA candidate materials in LBE environment

Layout of irradiation rig



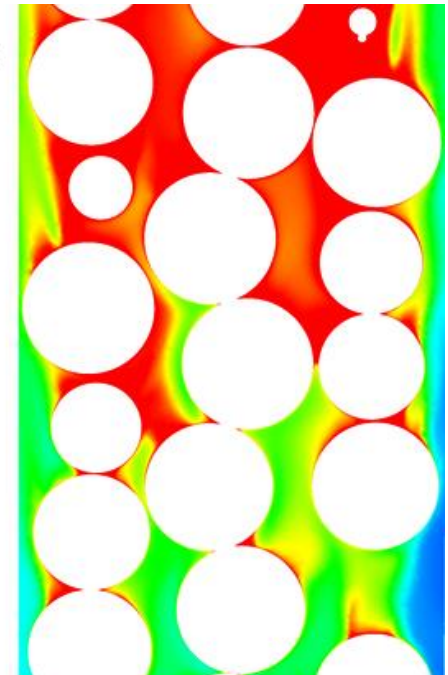
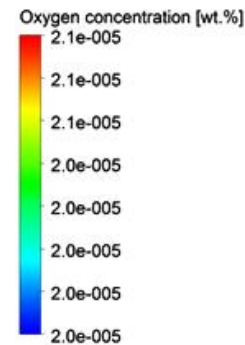


HELIOS 3 layout



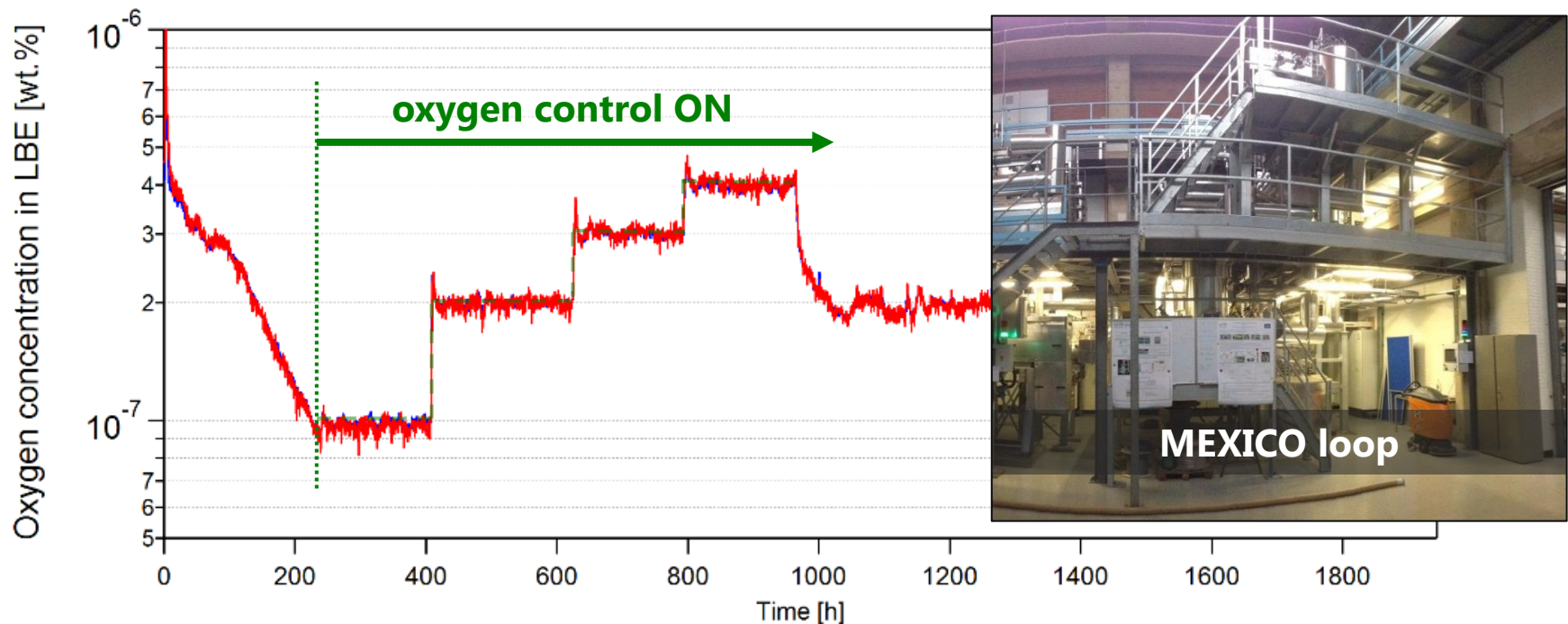
MEXICO Loop Purpose

To develop and verify oxygen control system with PbO mass exchanger, electrochemical oxygen pumps, filter and cold trap



MEXICO LBE loop

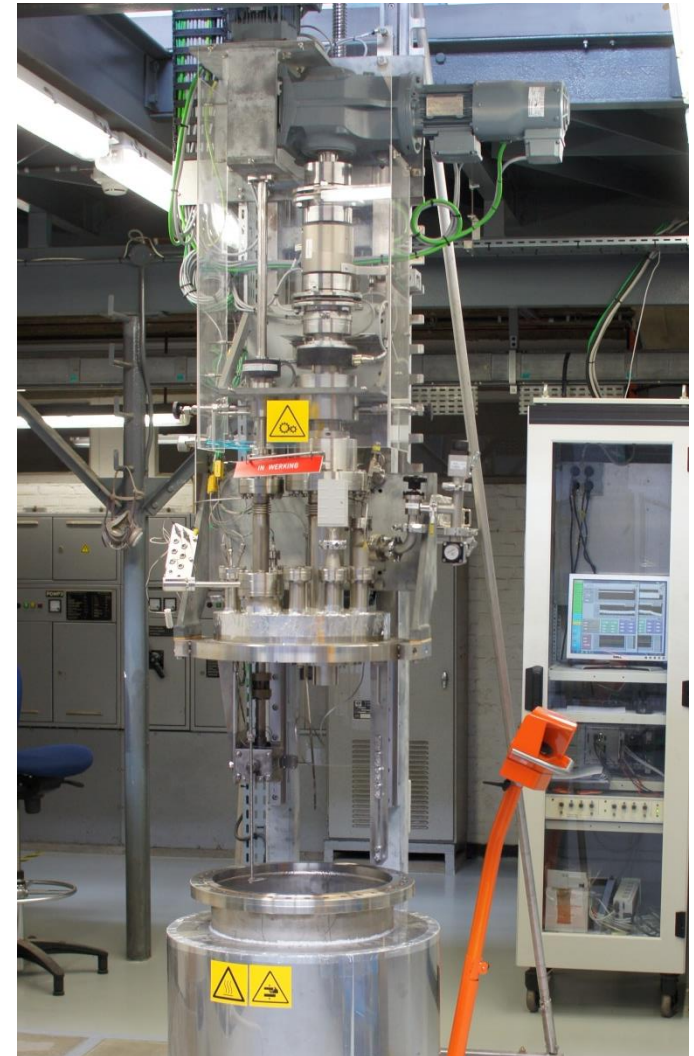
- over 3000 h of experiment time, $30 \cdot 10^6$ kg LBE circulated
pilot-scale demonstration of oxygen control technologies:
- accurate & stable oxygen control of 7000 kg of LBE




RHAPTER

Mechanical component tests for in-LBE robotics

- Isothermal pool facility
- Interchangeable test modules
- Specifications
 - 150 - 450°C
 - 50 l LBE
 - Vacuum or gas cover
- Drive axle and load axle
 - Variable torque and rotation speed
- Instrumentation
 - Torque sensor
 - Position encoder
 - Accelerometer
 - Thermocouples
 - Pressure gauge
- Status: in operation since September 2011

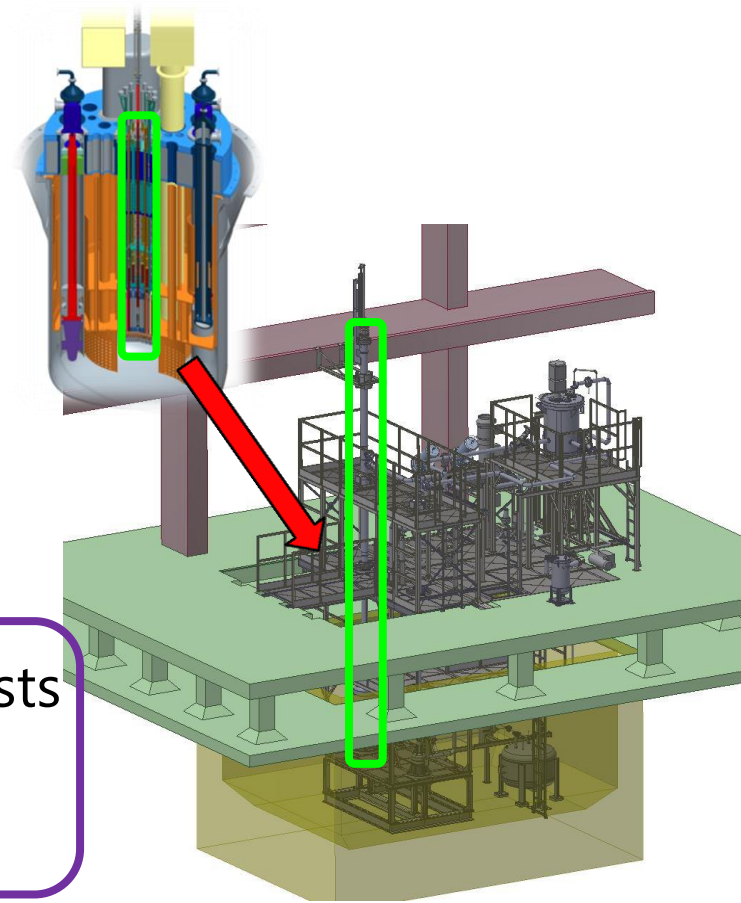


RHAPTER Programme

- 
- Bearing tests
 - Roller bearings for use in remote handling
 - Status: screening tests finished
 - verification of test methods (chemical analysis, microscopy, SEM, vibration analysis)
 - On-going : long term tests, reciprocating
 - Cable tests
 - Mineral insulated cables in rotating motion for use in Remote Handling
 - Fatigue reduction
 - Other RHAPTER tests
 - Linear drive (lead screw)
 - Journal bearings
 - Gears

Important facility for testing Reactor components (Scale 1/1)

- Fuel assembly hydraulic tests
 - Pressure losses
 - Vibration tests
- Spallation target hydraulic tests
 - Pressure losses, flow distribution
 - Vibration tests
- Control and safety rod hydrodynamic tests
 - Drag, insertion speed, vibration
 - Long term reliability tests



COMPLIT LBE loop

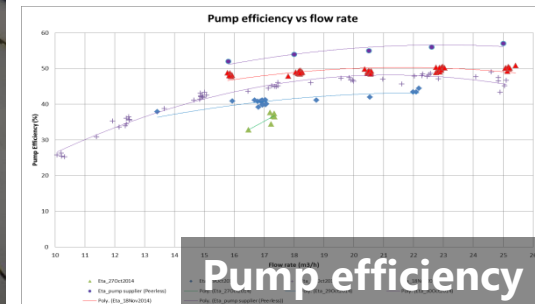
- hydraulic and hydrodynamic behaviour of full-scale MYRRHA components in LBE: fuel assembly, spallation target, control and safety rods
- commissioning and hydraulic characterisation of instrumentation and equipment with a flow rate of 75 kg/s at 200 °C

COMPLIT



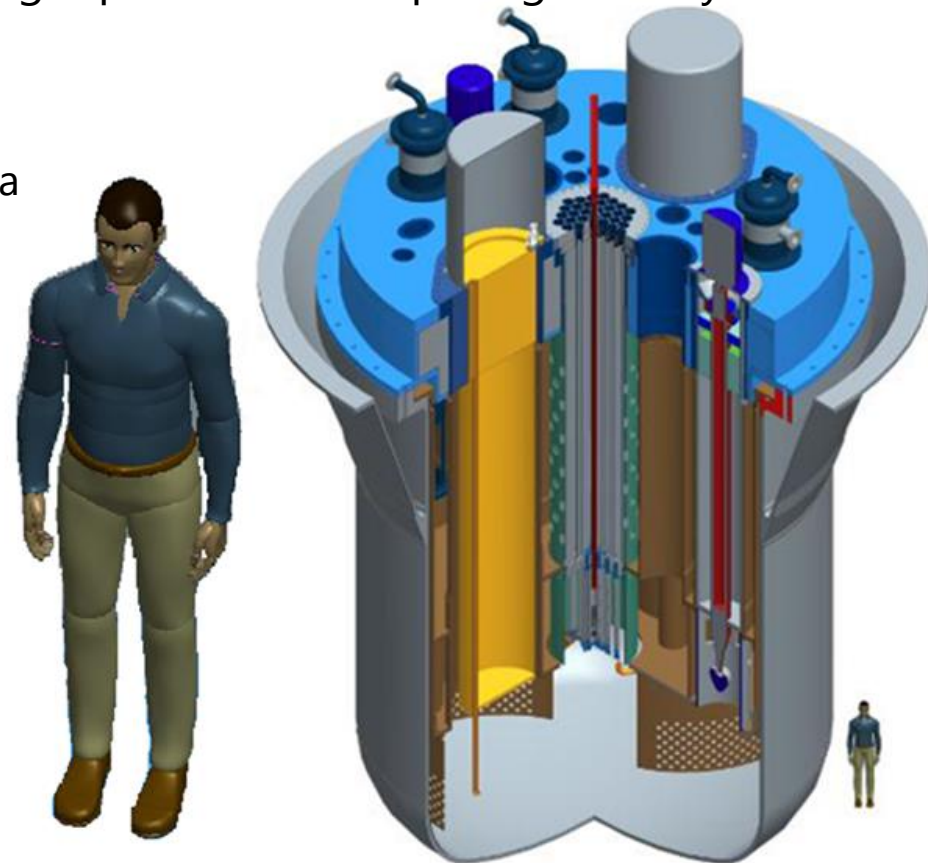
COMPLIT

Fuel mock-up



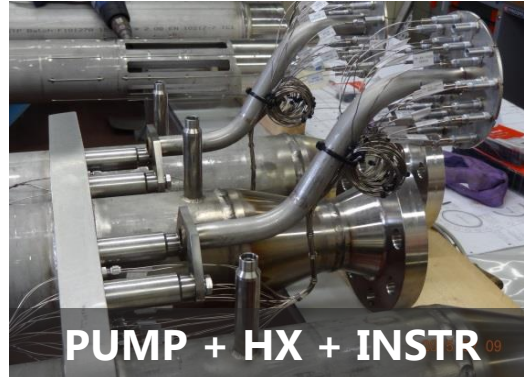
E-SCAPE

- E-SCAPE = **E**uropean **SCA**led **P**ool **E**xperiment
- Thermal-hydraulic behaviour of a flowing liquid metal in a pool geometry
- Purpose
 - Characterisation of pool T/H phenomena
 - Qualification of CFD and system tools
 - Operational experience on LBE systems
- Characteristics
 - 1/6 geometrical scale factor
 - LBE as working fluid
 - Forced and natural circulation
- Partially funded by FP7 THINS



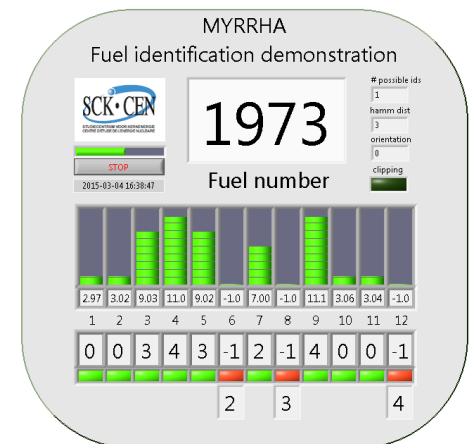
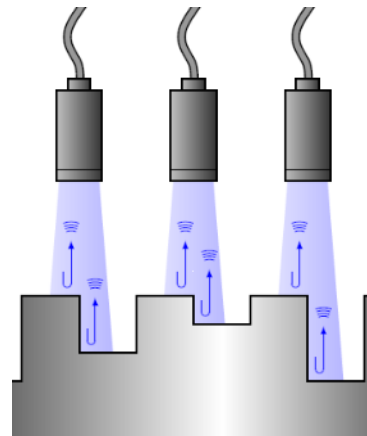
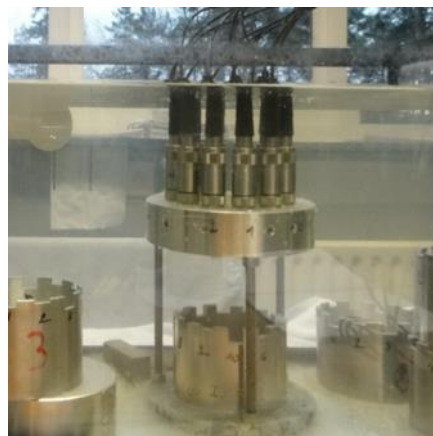
TODAY

E-SCAPE facility



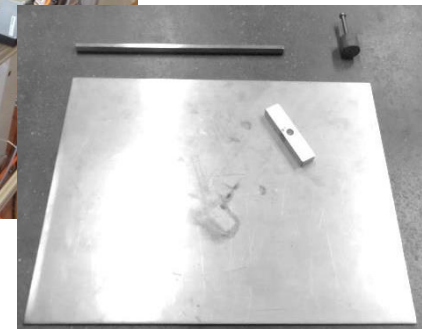
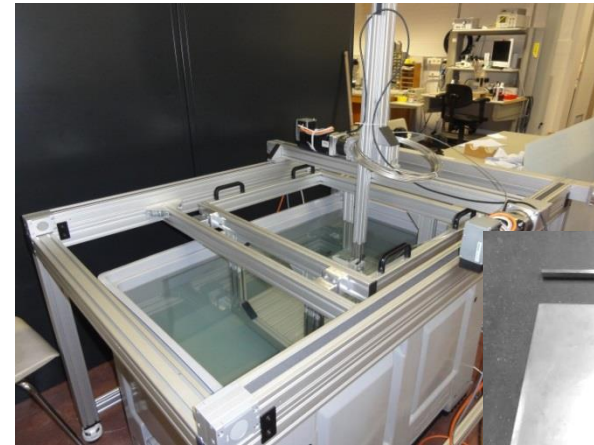
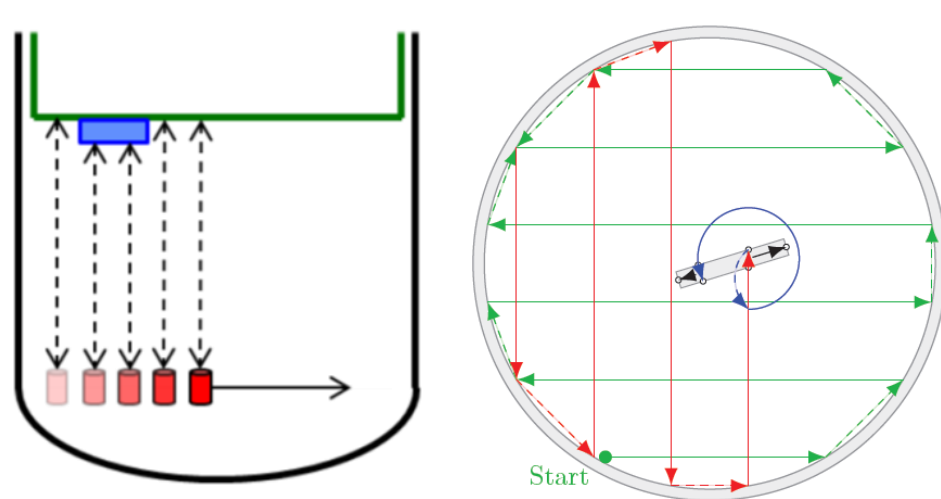
Fuel identification system

- Physical code on fuel assemblies
 - 12 notches at the entrance nozzle of a MYRRHA fuel assembly
 - Each notch can have five different depths
- Ultrasonic code reader
 - 12 ultrasonic transducers at the gripper of the fuel manipulators
 - Differential depth measurement allows for reliable notch depth measurement
 - Error detection and error correction algorithms make the system robust against failing transducers or other misreadings



Lost fuel localization system

- A single transducer scans the diaphragm from a safe distance
 - Any disturbance in arrival time or amplitude of the reflected pulse is an indication for the presence of the lost assembly
- A rough grid-like search path is followed to determine a first point on the lost fuel assembly
 - More detailed inspection around the first point allows for full determination of the position of the lost fuel assembly



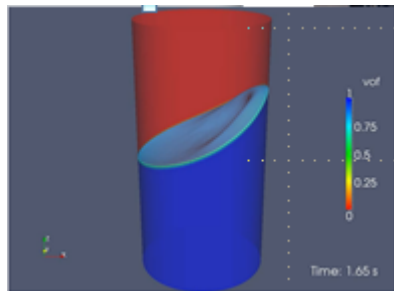
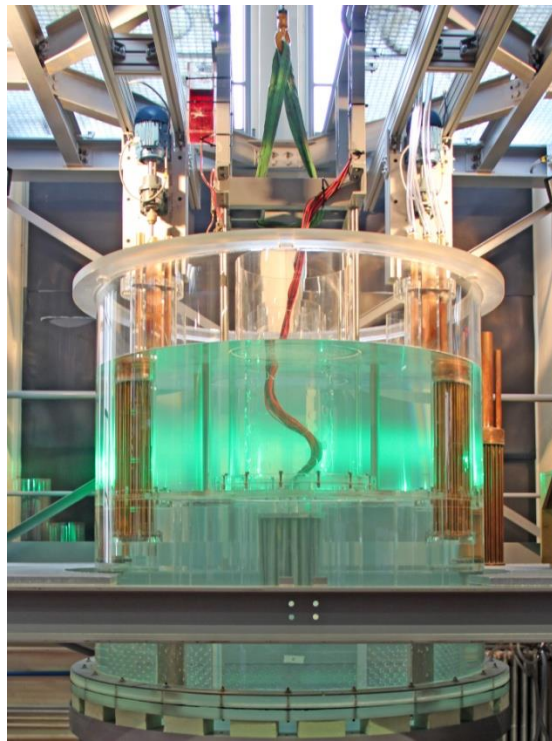


von Karman Institute collaboration

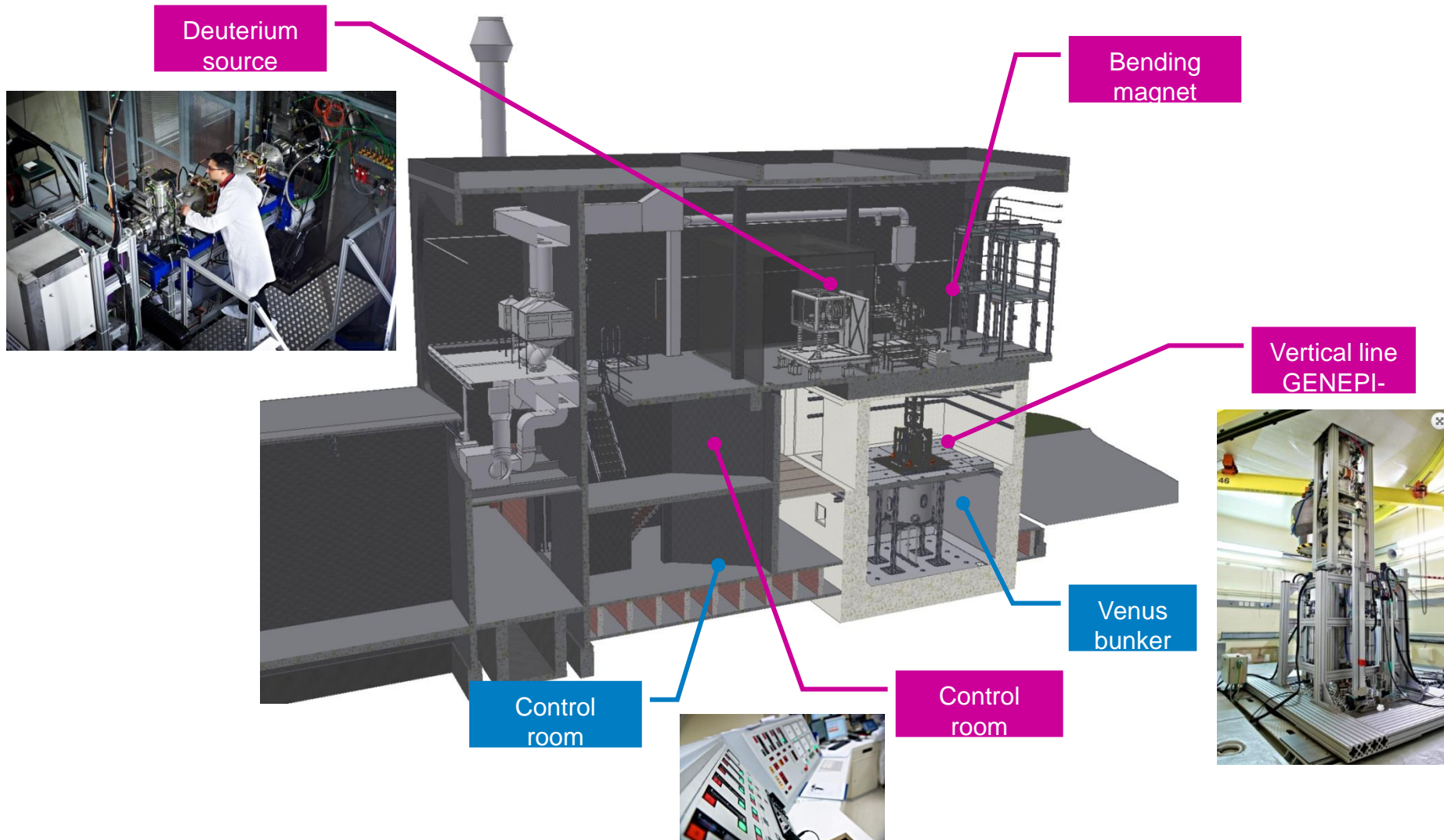
- Thermohydraulic Study on MYRRHA Model
- Design of the Lead-Bismuth Eutectic (LBE) Primary Pumps
- Ultrasonic Imaging in the LBE Pool
- Computer Fluid Dynamics (CFD) Study of Steam & Solids Dispersion
- Sloshing Study in MYRRHA Vessel



von Karman Institute collaboration



2010: GUINEVERE at VENUS



GUINEVERE – a tool for data/code validation



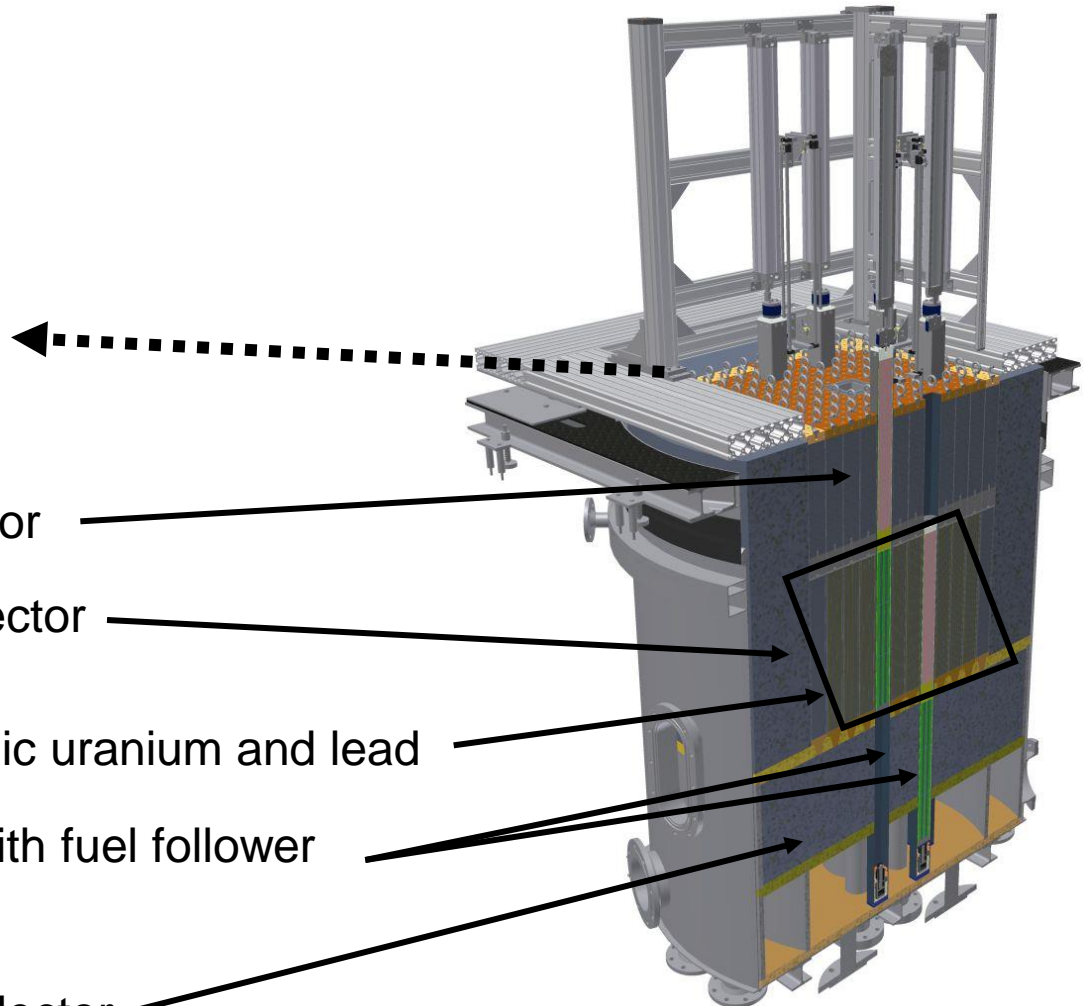
Pb top reflector

Pb radial reflector

Core in metallic uranium and lead

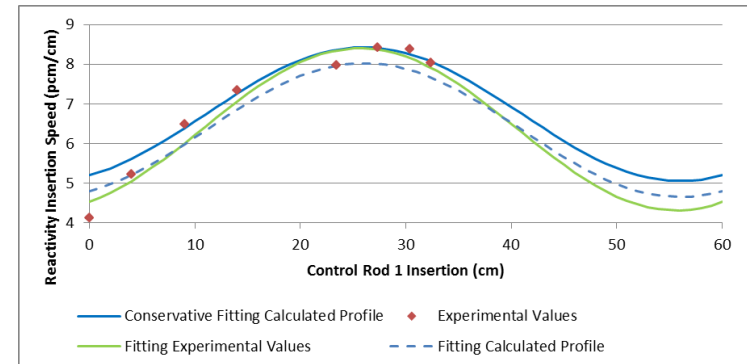
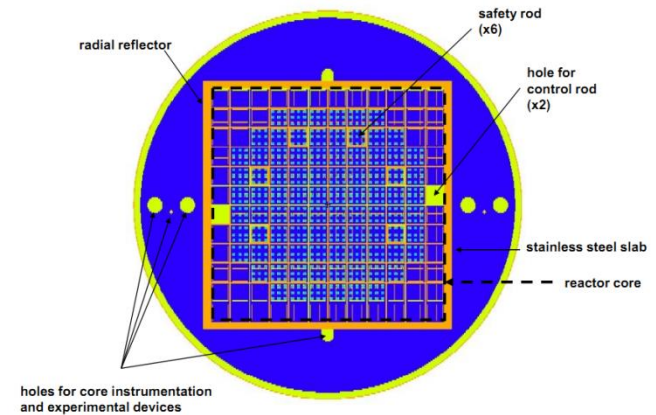
Safety rods with fuel follower

Pb bottom reflector



GUINEVERE – a tool for data/code validation

- Model vs reality
 - geometry
 - materials
- Experimental validation of
 - Flux traverses
 - Control rod worth
- Will be a pillar for the V&V for the licensing of MYRRHA



MYRRHA Accelerator Challenge

fundamental parameters (ADS)	
particle	p
beam energy	600 MeV
beam current	4 mA
mode	CW
MTBF	> 250 h

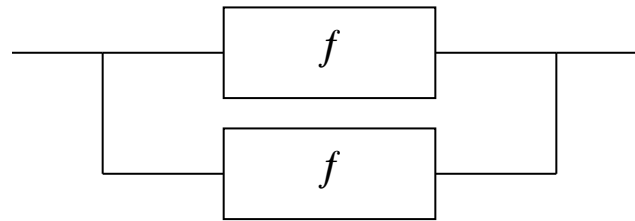
challenge !

failure = beam trip > 3 s

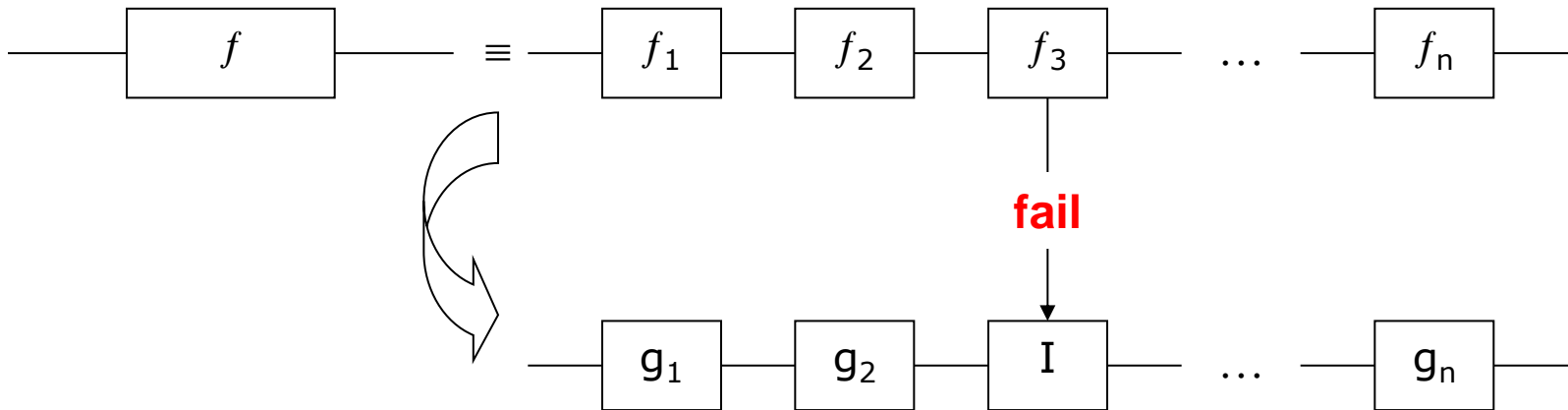
implementation	
superconducting linac	
frequency	176.1 / 352.2 / 704.4 MHz
reliability = redundancy	double injector
	"fault tolerant" scheme

Redundancy & Fault tolerant design

parallel scheme

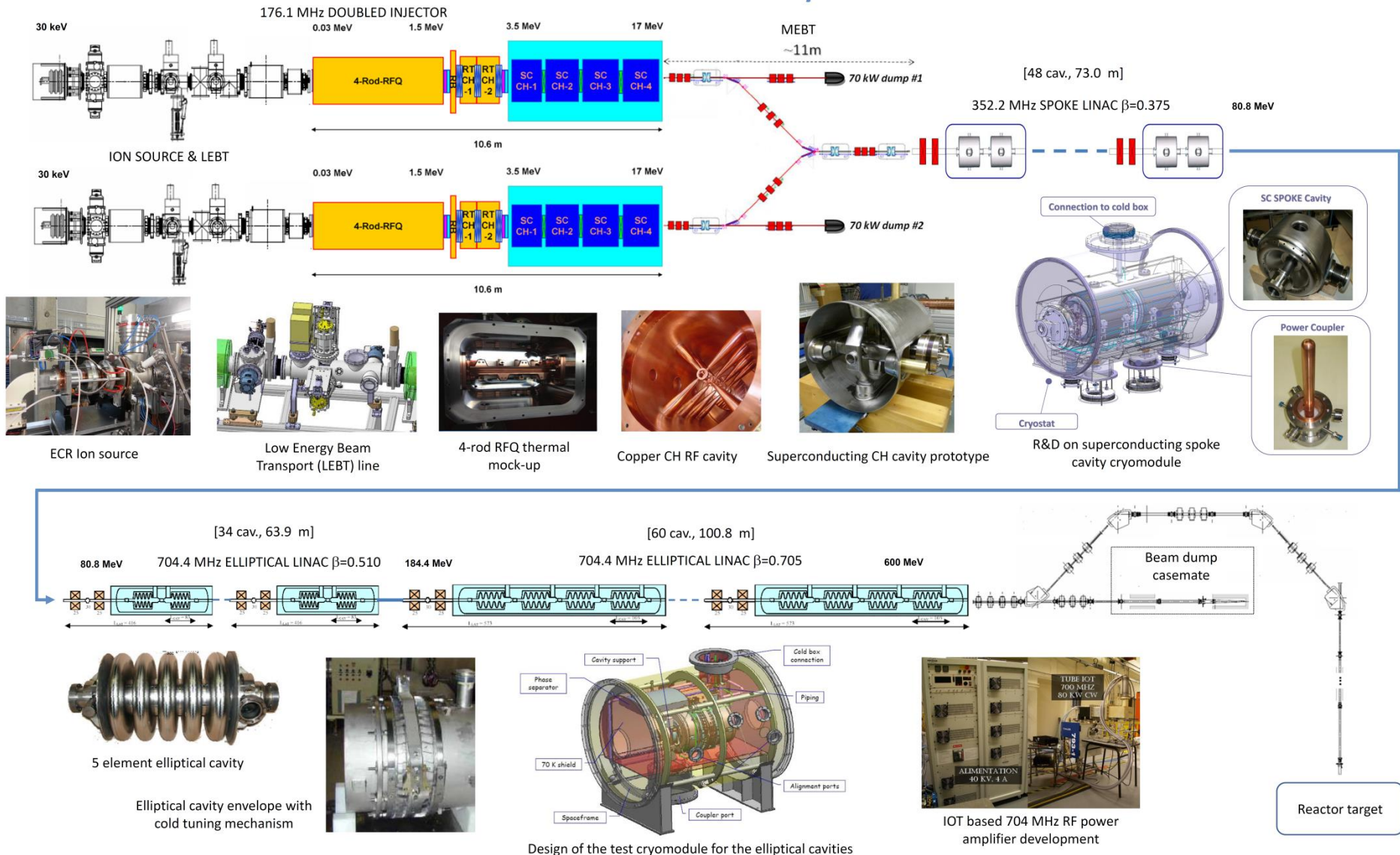


serial scheme: IF



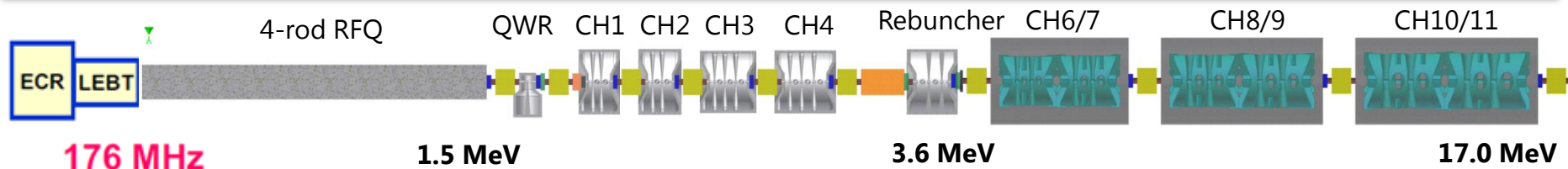
modularity

MYRRHA Linear Accelerator: R&D fields



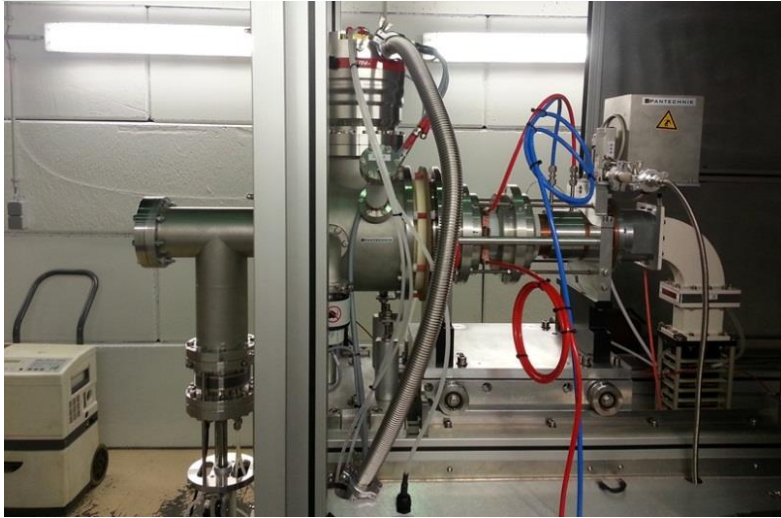
INJECTOR@UCL

Goals	<ul style="list-style-type: none">• Test platform: experimentally address the <u>injector design though prototyping</u>• tool for <u>relevant reliability minded experience</u>
Main topics: <ul style="list-style-type: none">• Beam characterization• CW operation of the 4-rod RFQ• SS RF amplifier @ 176.1 MHz–160kW• Diagnostics for high current beams• 3-tier Control System• Long reliability runs	Principal partners: <ul style="list-style-type: none">• FP7 -MAX• H2020 MYRTE• Research organisations: CERN, CEA, IPNO, LPSC, IAP, UCL/CRC,, U Darmstad,• industries: ACS, ADEX,EA,IBA, Thales ED, NTG, Pantechnik, Cosylab



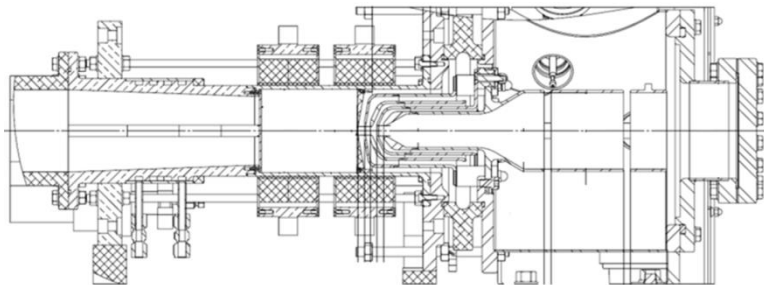
The ECR proton source

 **PANTECHNIK**



Pantech Monogan 1000 ECR Ion source – 30keV, 20mA

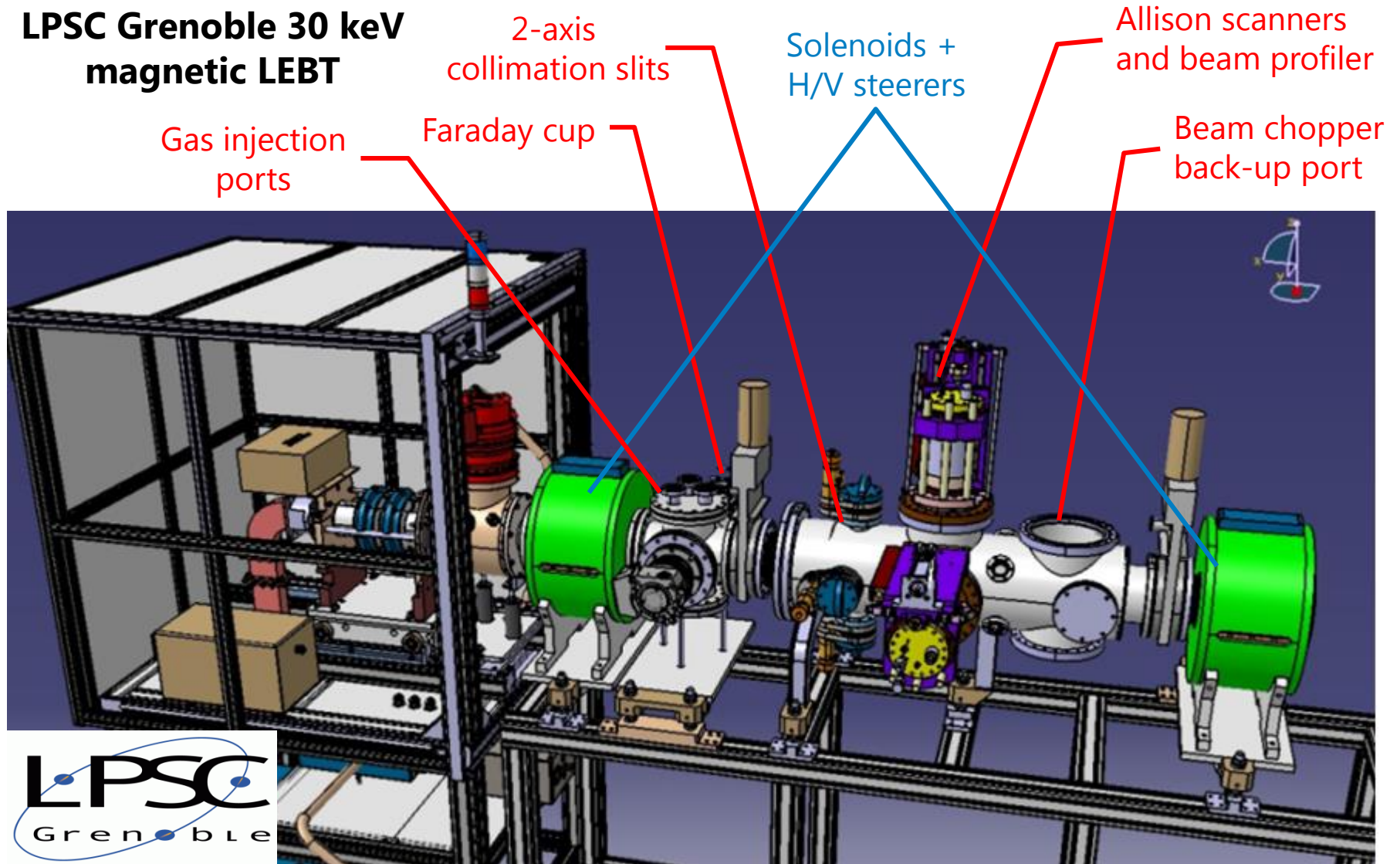
- Electron Cyclotron Resonance, 2.45 GHz
- multi-electrodes extraction system
- flat magnetic profile configuration by PMs
- tapered axial RF injection
- Einzel electrostatic focusing lens



voltage	30 kV (40 kV capable)
beam current	20 mA DC
RF	2.45 GHz, 1200 W
transverse emittance @ 5 mA	0.1 π·mm·mrad RMS norm.
magnetic system	Permanent Magnets
autonomous control system	NI CompactRIO
provisions for reliability/repairability	
beam diagnostics devices incl.: Faraday Cup, Allison scanner	

The Low Energy Beam Transport (LEBT) line

LPSC Grenoble 30 keV magnetic LEBT



MYRRHA: a Multipurpose Large Research Infrastructure

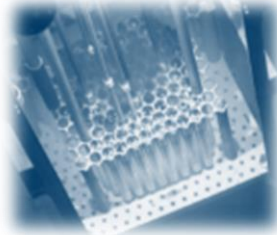
Fuel research

$$\Phi_{\text{tot}} = 0.5 \text{ to } 1.10^{15} \text{ n/cm}^2.\text{s}$$

Material research

$$\Phi_{\text{Fast}} = 1 \text{ to } 5.10^{14} \text{ n/cm}^2.\text{s}$$

($E_n > 1 \text{ MeV}$) in large volumes



Fission GEN IV



Fusion

$$\Phi = 1 \text{ to } 5.10^{14} \text{ n/cm}^2.\text{s}$$

(ppm He/dpa ~ 10)
in medium-large volumes

50 to 100 MWth

$$\Phi_{\text{Fast}} = \sim 10^{15} \text{ n/cm}^2.\text{s}$$

($E_n > 0.75 \text{ MeV}$)



HL Waste

Multipurpose
hYbrid
Research
Reactor for
High-tech
Applications

High energy LINAC
600 MeV – 1 GeV
Long irradiation time



**Fundamental
research**

**Radio-
isotopes**



$$\Phi_{\text{th}} = 0.5 \text{ to } 2.10^{15} \text{ n/cm}^2.\text{s}$$

($E_n < 0.4 \text{ eV}$)

**Silicon
doping**

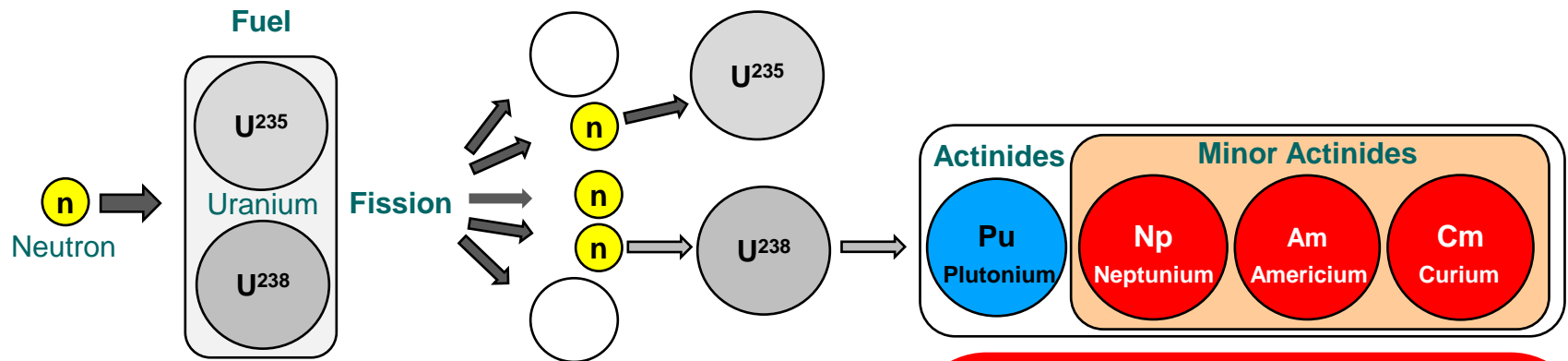


$$\Phi_{\text{th}} = 0.1 \text{ to } 1.10^{14} \text{ n/cm}^2.\text{s}$$

($E_n < 0.4 \text{ eV}$)

Introduction

- Fission generates High-Level Nuclear Waste



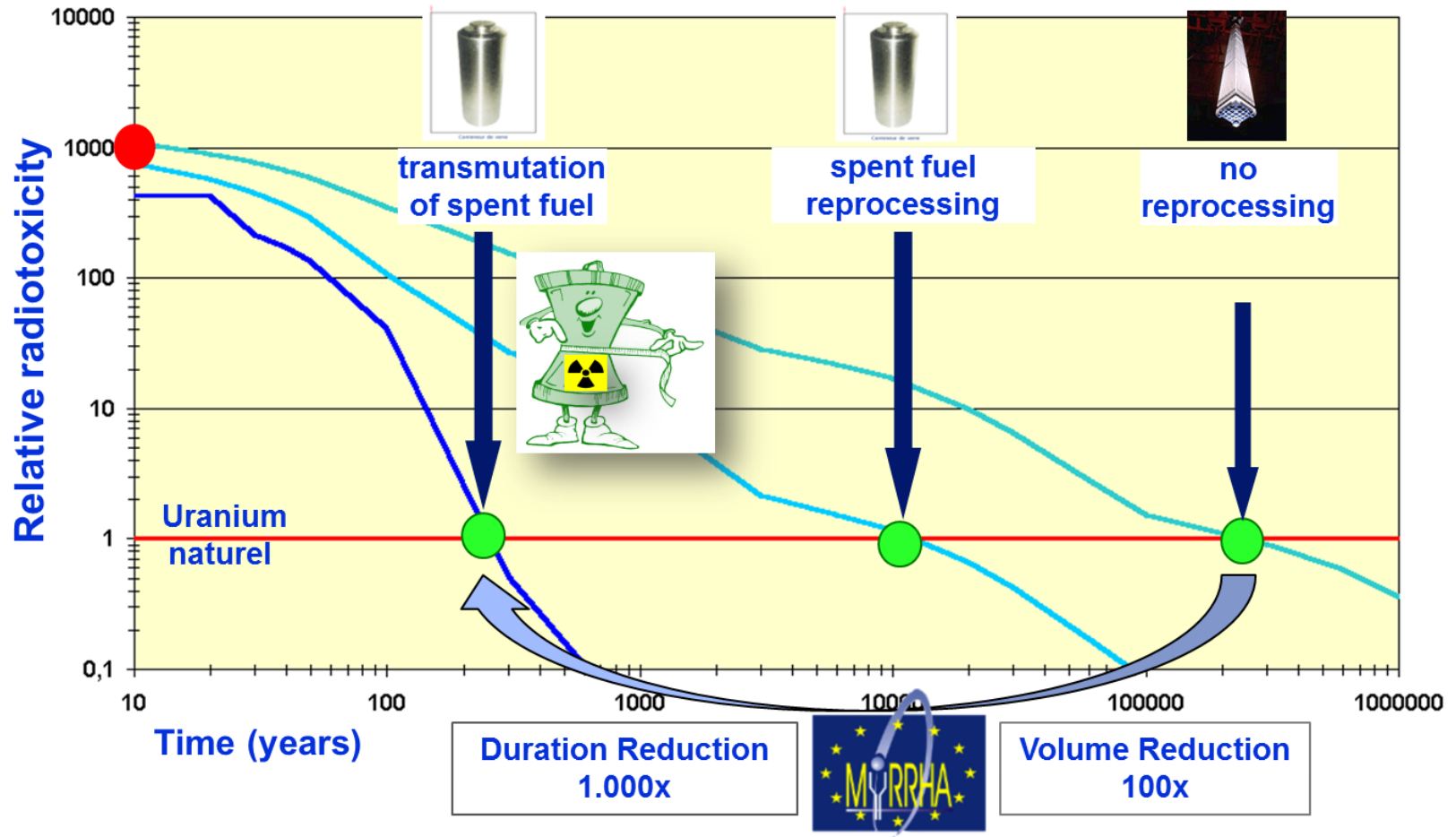
Minor Actinides

high radiotoxicity long lived waste
that are difficult to store due to:

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

Introduction

● Motivation for Transmutation



MYRRHA is recognized in Europe thanks to its innovation **but also thanks to the BE Gov support**

ESFRI

European
Strategic
Forum for
Research
Infrastructure

SET Plan

European
Strategic
Energy Plan

Knowledge Economy



Energy Independence



10.12.2010

**Included in NuPPEC
Long Range Plan**

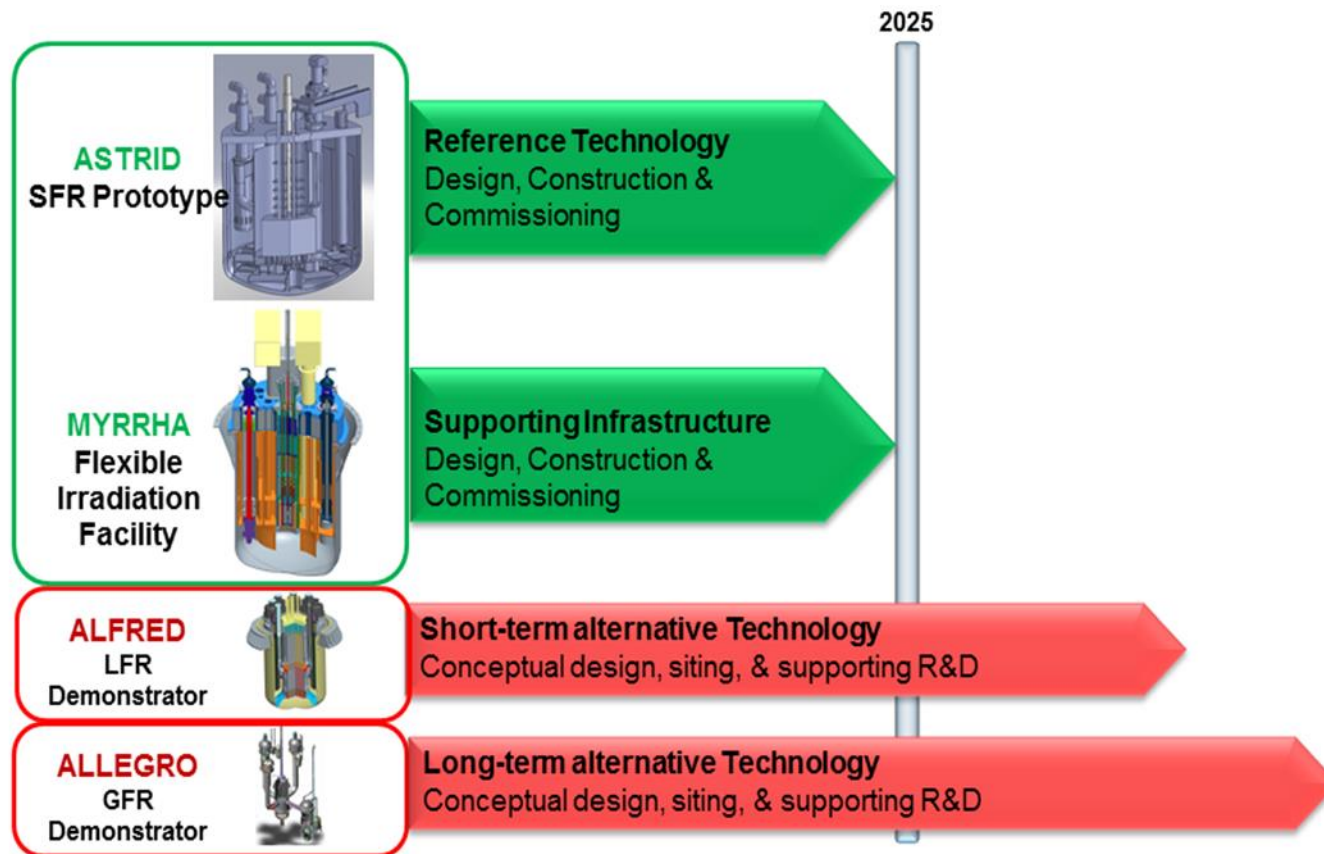
27.11.2010

**Confirmed on ESFRI
priority list projects**

15.11.2010

**in ESNII
(SNETP goals)**

- MYRRHA part of the European Sustainable Nuclear Industrial Initiative (ESNII)



MYRRHA in the 2014 BE Gov. Declaration

De regering zal het behoud van excellentie in het onderzoek naar de nucleaire veiligheid en informatie voor de burger, de omgeving en nucleaire infrastructuur op Belgisch grondgebied nastreven.

Ze zal het MYRRHA-project of evenwaardige projecten van het SCK progressief ondersteunen om het noodzakelijke onderzoek naar innovatieve oplossingen voor hoogradioactief afval, naar de kwalificatie van fusiereactormaterialen, naar het behoud van de medische radio-isotopenproductie in ons land en naar fundamenteel kernfysisch onderzoek optimaal verder te zetten in een internationale context, in samenwerking met universiteiten, onderzoekscentra en zusterorganisaties van het SCK.

Le gouvernement visera le maintien de l'excellence dans la recherche dans les domaines de la sûreté nucléaire et de l'information du citoyen, de l'environnement et des infrastructures nucléaires sur le territoire belge.

Il soutiendra progressivement le projet MYRRHA ou des projets équivalents du CEN en vue de poursuivre de manière optimale, dans un contexte international, les recherches nécessaires concernant des solutions innovantes pour les déchets hautement radioactifs, la qualification des matériaux des réacteurs à fusion, le maintien de la production de radio-isotopes médicaux dans notre pays et de recherche nucléaire fondamentale, en collaboration avec les universités, les centres de recherche et les organisations sœurs du CEN.

De
ond
nuc
beh
infra
isot
in
gemoderniseerd worden.

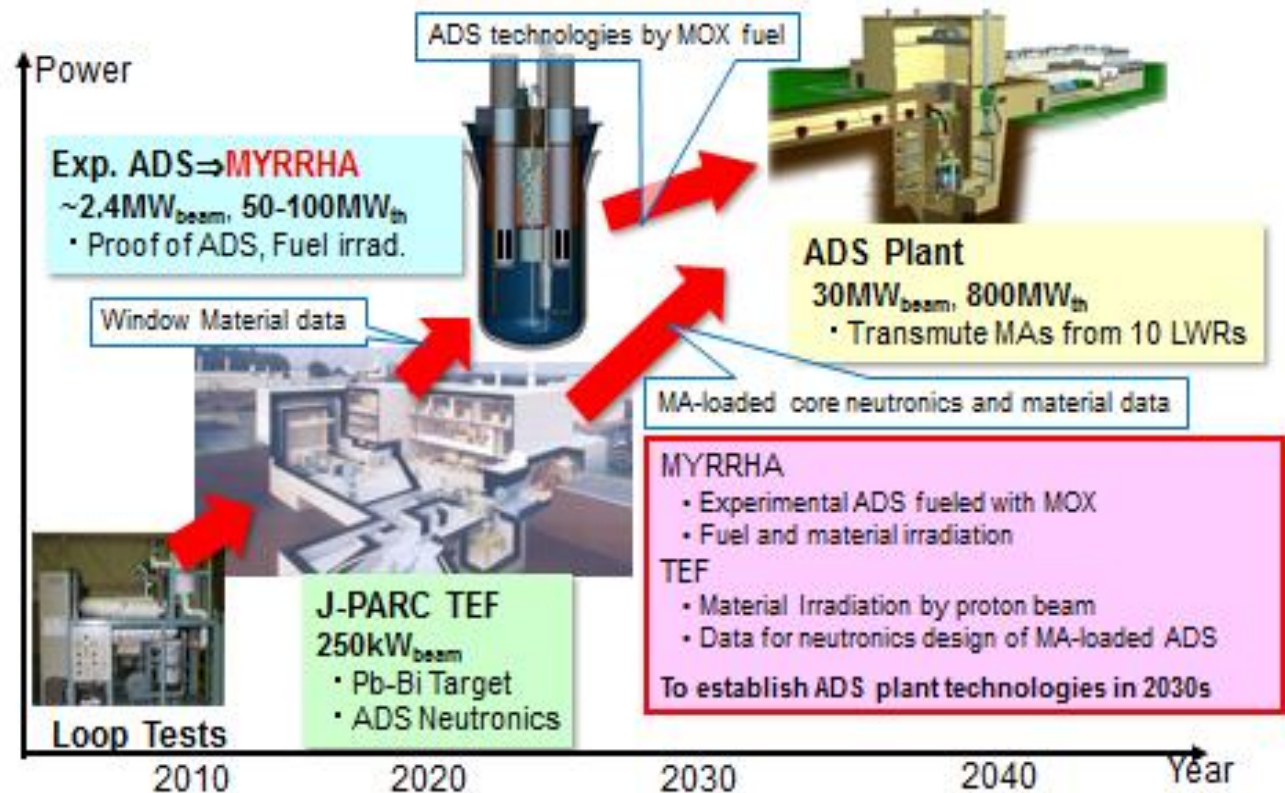
The Belgian Government will support in a progressive way the MYRRHA project or any equivalent project at SCK•CEN aiming to continue the needed research for innovative solutions for High level waste, qualification of materials for fusion, the production of radioisotopes for medical applications in our country and fundamental nuclear research in collaboration with the universities and sister organisation of SCK•CEN

exploitatie in veiliger omstandigheden en moderniseren.

4. MYRRHA Consortium status Japan



International Collaboration with MYRRHA



Consortium promising perspectives

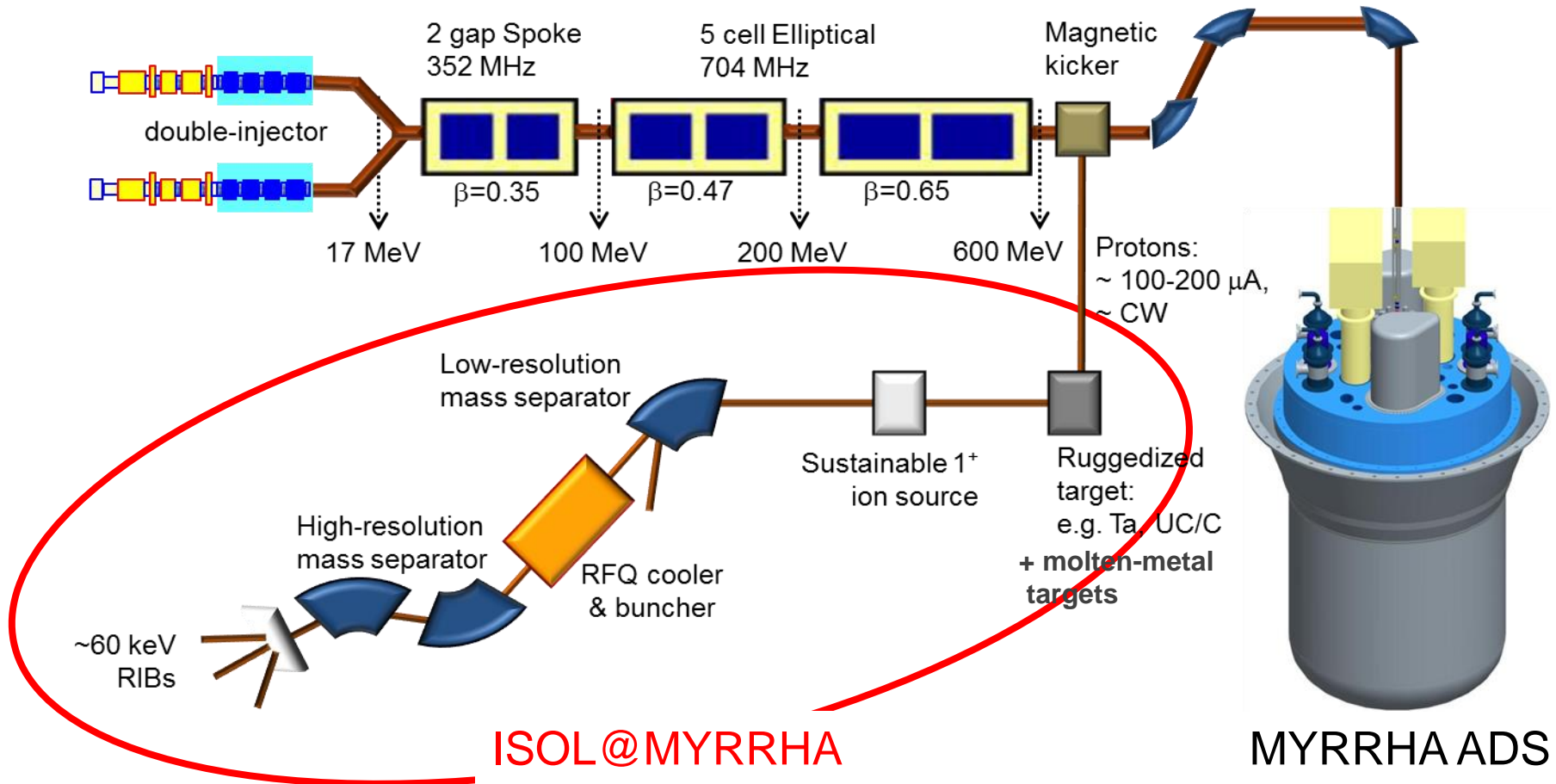
- Japan via MEXT and JAEA declared regularly in the last months willingness to participate in MYRRHA (125 M\$)
- EU supports MYRRHA as promised by Commissioner G. Oettinger in April 2014:
 - H2020 MYRTE project 11,25 M€
 - MYRRHA selected in InnovFin by EIB
- Germany expressed a technical interest to be confirmed politically

R&D European Projects

- MATERIALS (GETMAT, MATTER, MATISSE)
- FUEL (MAXSIMA, MYRTE)
- CODE (FREYA, ARCAS, ANDES, MYRTE)
- ACCELERATOR (MAX, MYRTE)
- LBE Technology
 - Components & Experiments (THINS, SEARCH, MAXSIMA, MYRTE, SESAME)
 - Chemical Conditioning Programme (SEARCH, MYRTE)
- Safety related experiments (THINS, SEARCH, MAXSIMA)
- Instrumentation & Control (CDT, LEADER, ESNII+)
- Design & Licensing (SARGEN, SILER, CDT)

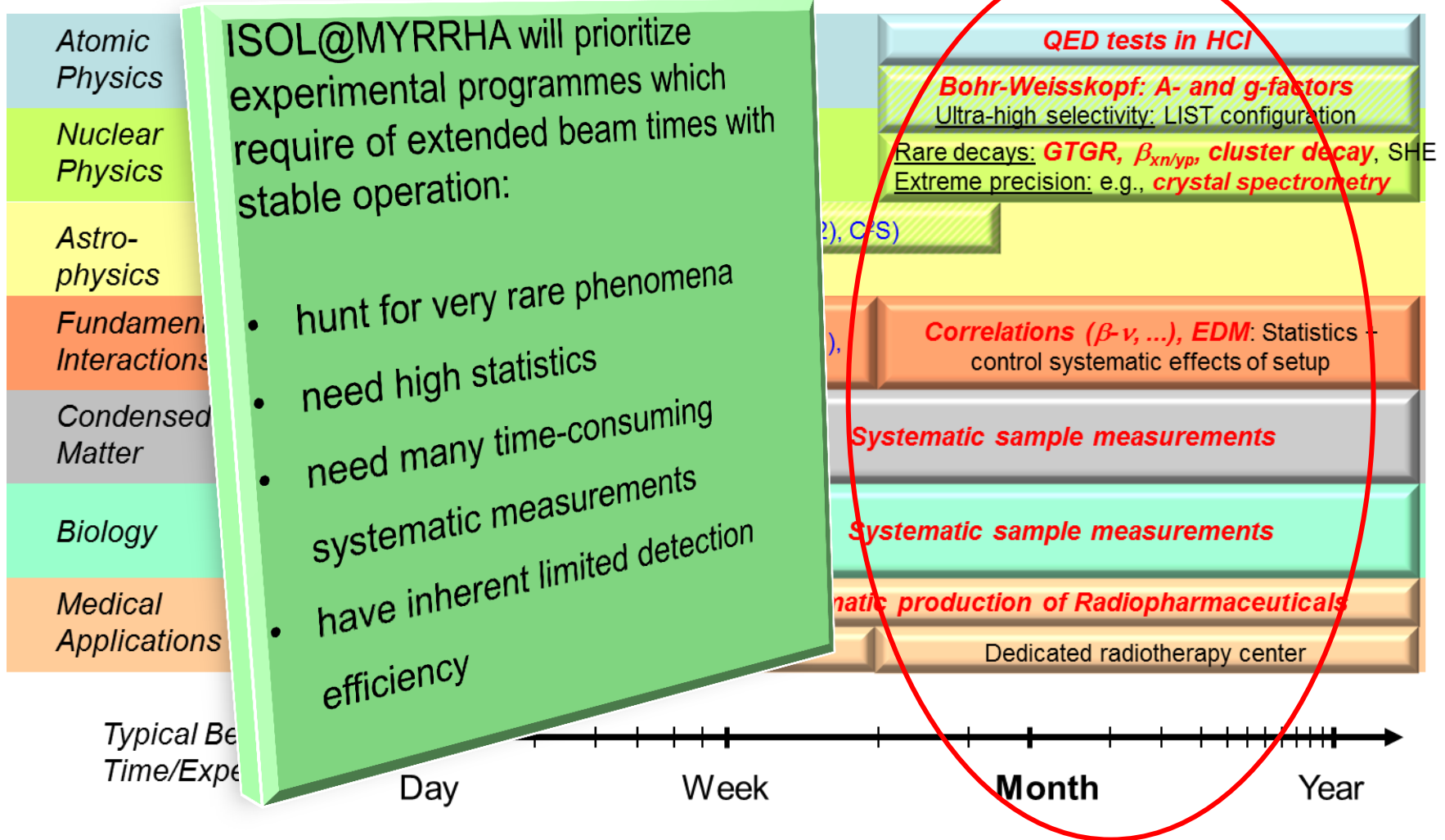
ISOL@MYRRHA Concept

Protons: 2-4 mA, CW



Focus on long-term operation without interruption

ISOL@MYRRHA Applications



ISOL@MYRRHA Project

- ISOL@MYRRHA Feasibility Study (pre-conceptual design and scientific case) carried out within BriX-IAP6 (2007-2012)
- Technical & Scientific report submitted to NuPECC
 - ➔ 2010 – Technical Design of ISOL@MYRRHA included in the long-range plan of NuPECC
- Detailing the Design, updating the Scientific Case and building the Users Group - BriX-IAP7 (2012-2017)
- Belgian EURISOL Consortium (BEC) – created in 2013
 - Coordinated RTD programme – ISOL developments
 - Joining EURISOL collaboration (MOU signed in July 2014)



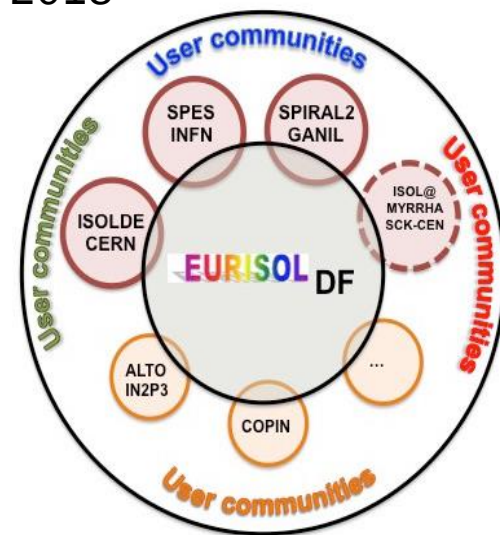
ISOL@MYRRHA part of EURISOL Distributed Facility

● Goals of EURISOL-DF

- Prepare a strong scientific case for RIB science and applications
- Support, upgrade, optimize and coordinate ISOL-based European facilities and projects as a necessary step towards EURISOL
- Foster R&D on RIB production and Instrumentation towards EURISOL
- Get EURISOL-DF on the ESFRI list as a candidate project by 2018
- EURISOL as a single site facility as a long term goal

● Working groups (*BEC representatives*)

- WG 1 Science and Application (*Riccardo Raabe*)
- WG 2 Acceleration (*Dirk Vandeplasseche*)
- WG 3 Beam handling (*Lucia Popescu*)
- WG 4 Spectrometer and Detector (*Hilde de Witte*)
- WG 5 EURISOL-DF Relationships and Legal structure (*Alain Sneyers*)



Copyright © 2015 - SCK•CEN

PLEASE NOTE!

This presentation contains data, information and formats for dedicated use ONLY and may not be copied, distributed or cited without the explicit permission of the SCK•CEN. If this has been obtained, please reference it as a "personal communication. By courtesy of SCK•CEN".

SCK•CEN

Studiecentrum voor Kernenergie
Centre d'Etude de l'Energie Nucléaire
Belgian Nuclear Research Centre

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

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

