MYRRHA

Multipurpose h**Y**brid **R**esearch **R**eactor for **H**igh-tech **A**pplications Contributing to the 3rd Pillar of the European Strategy for P&T

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International Symposium on "Nuclear Back-end Issues and the Role of Nuclear Transmutation Technology after Fukushima Accident"
November 28, 2013, KURRI, Kyoto (JP)

SCK•CEN

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

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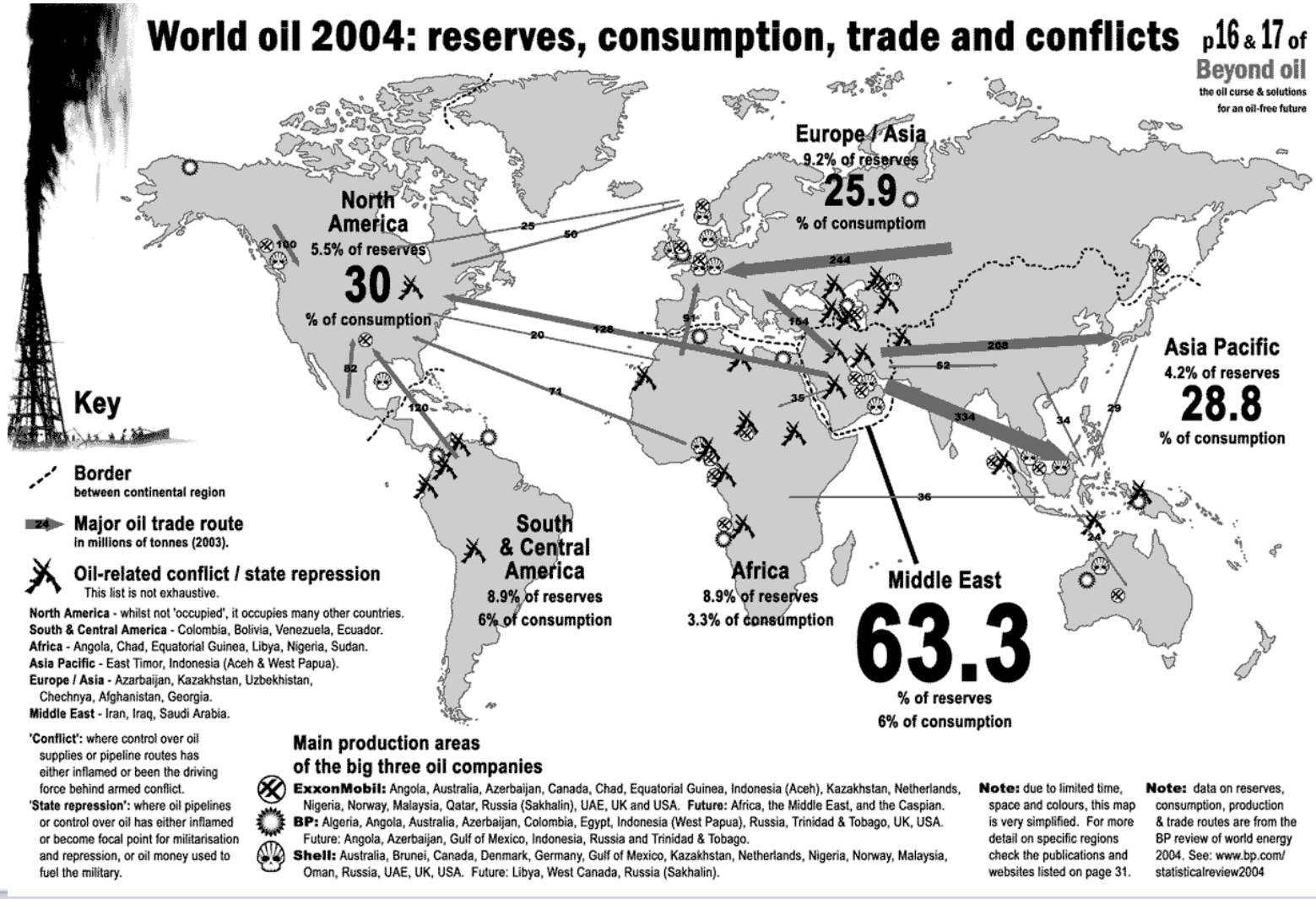
Energy challenges for our planet
correlation Oil reserves and trade / armed conflicts in the world



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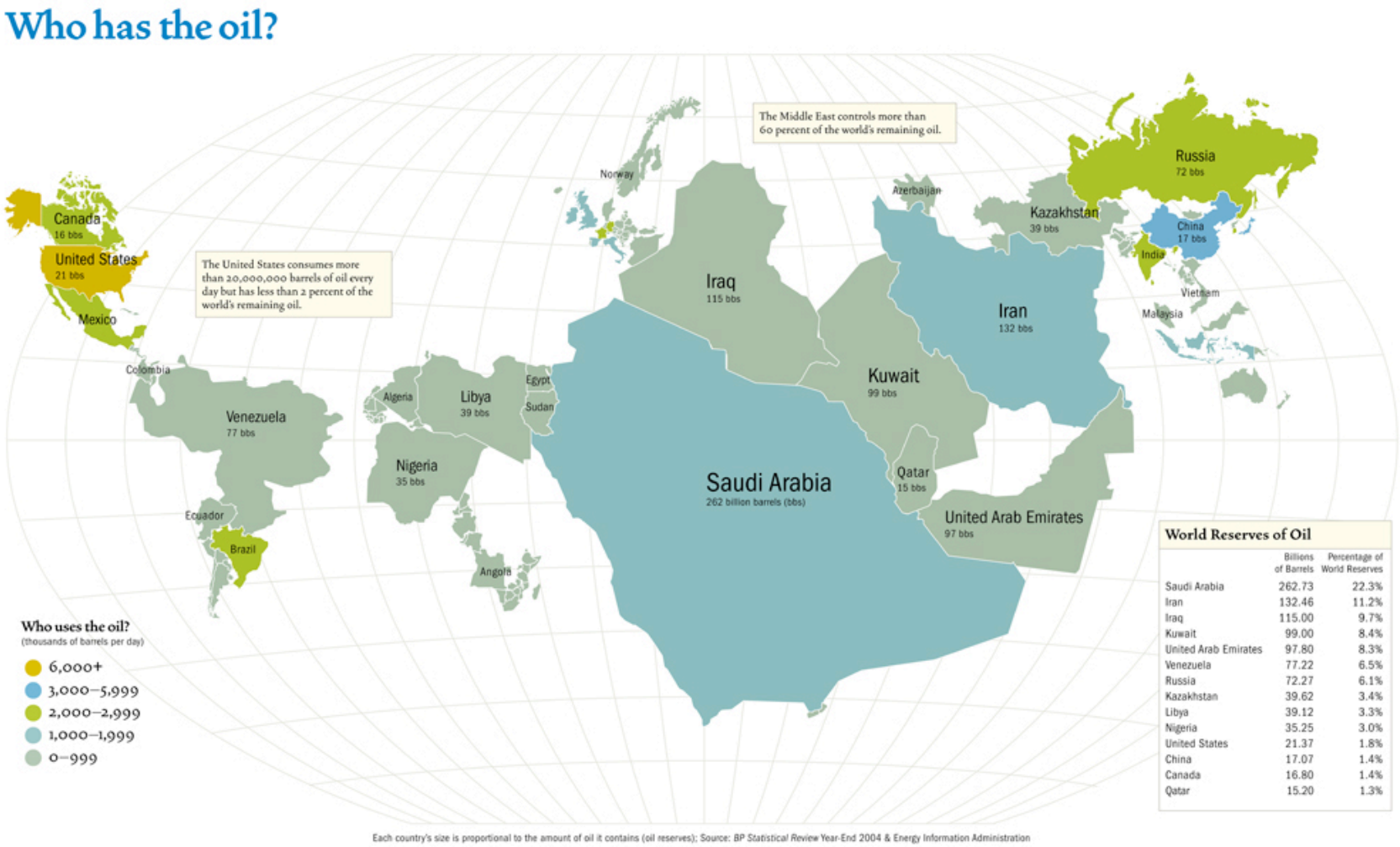
Energy challenges for our planet:
Another world map when it comes to classical oil resources



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What are the challenges for Nuc. R&D?

- **Attract new talents** and E&T them
- Continue to **address the nuclear safety** through highly instrumented experiments
- Come with **acceptable solution for nuclear waste**
- Develop **new nuclear fission energy technologies**: more **sustainable** and **compatible** with future energy environment
- Prepare the path for the nuclear fusion energy production
- Guarantee welfare of the population via nucl. Med.

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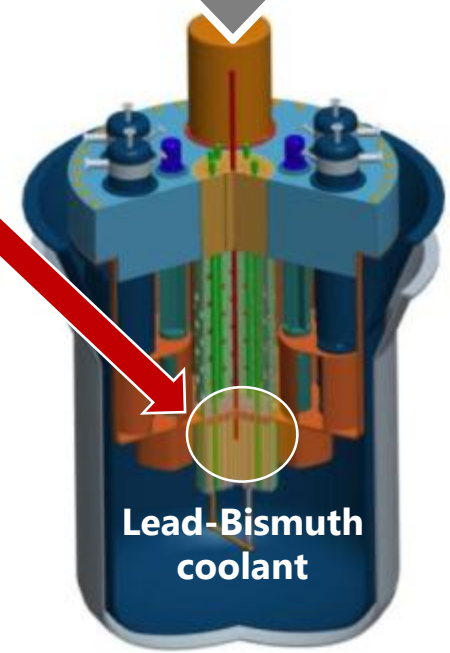
MYRRHA - Accelerator Driven System

Accelerator

(600 MeV - 4 mA proton)

Reactor

- Subcritical or Critical modes
- 65 to 100 MWth



Innovative & Unique

Spallation Source

Fast Neutron Source

Multipurpose Flexible Irradiation Facility

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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

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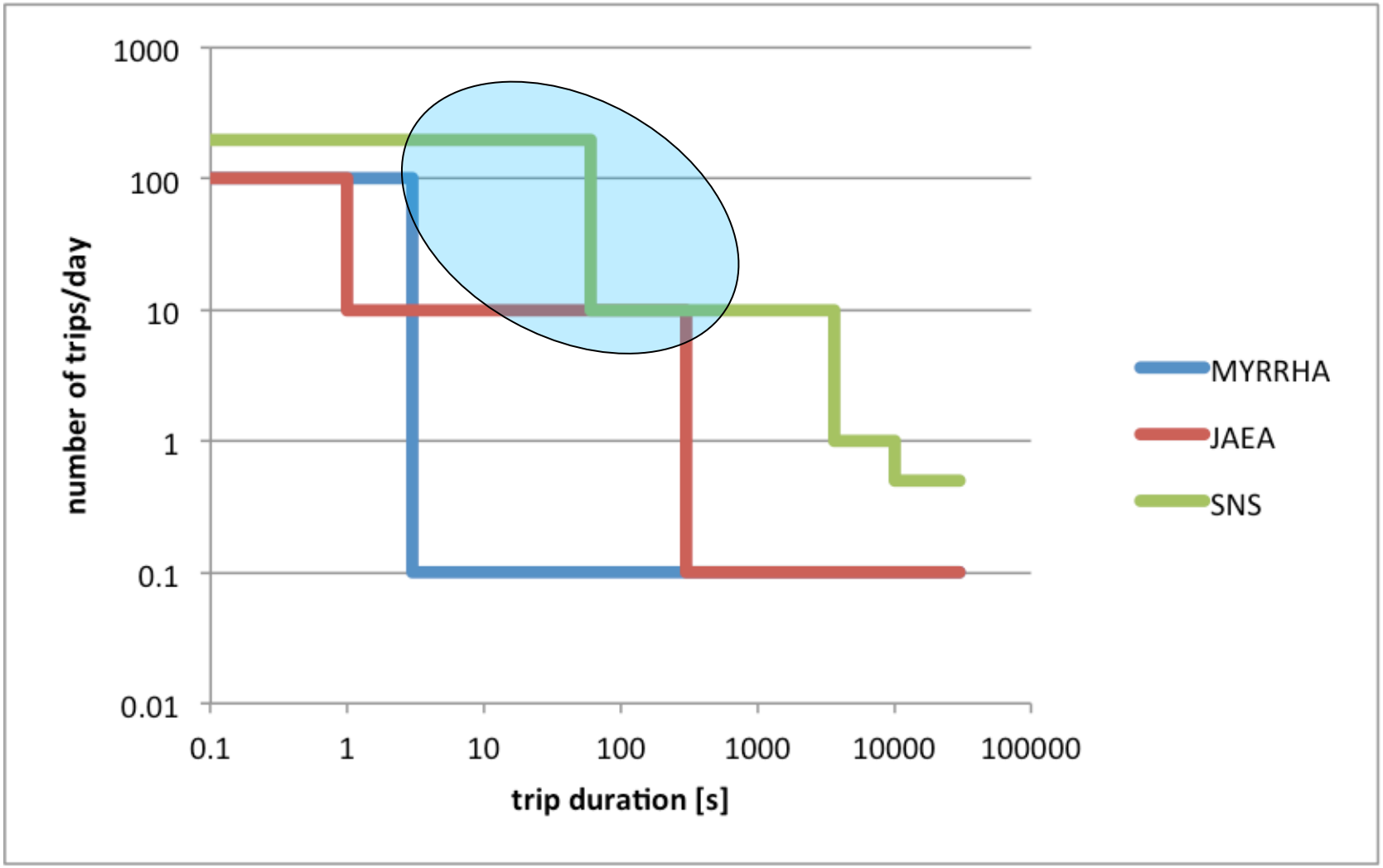
About beam trips



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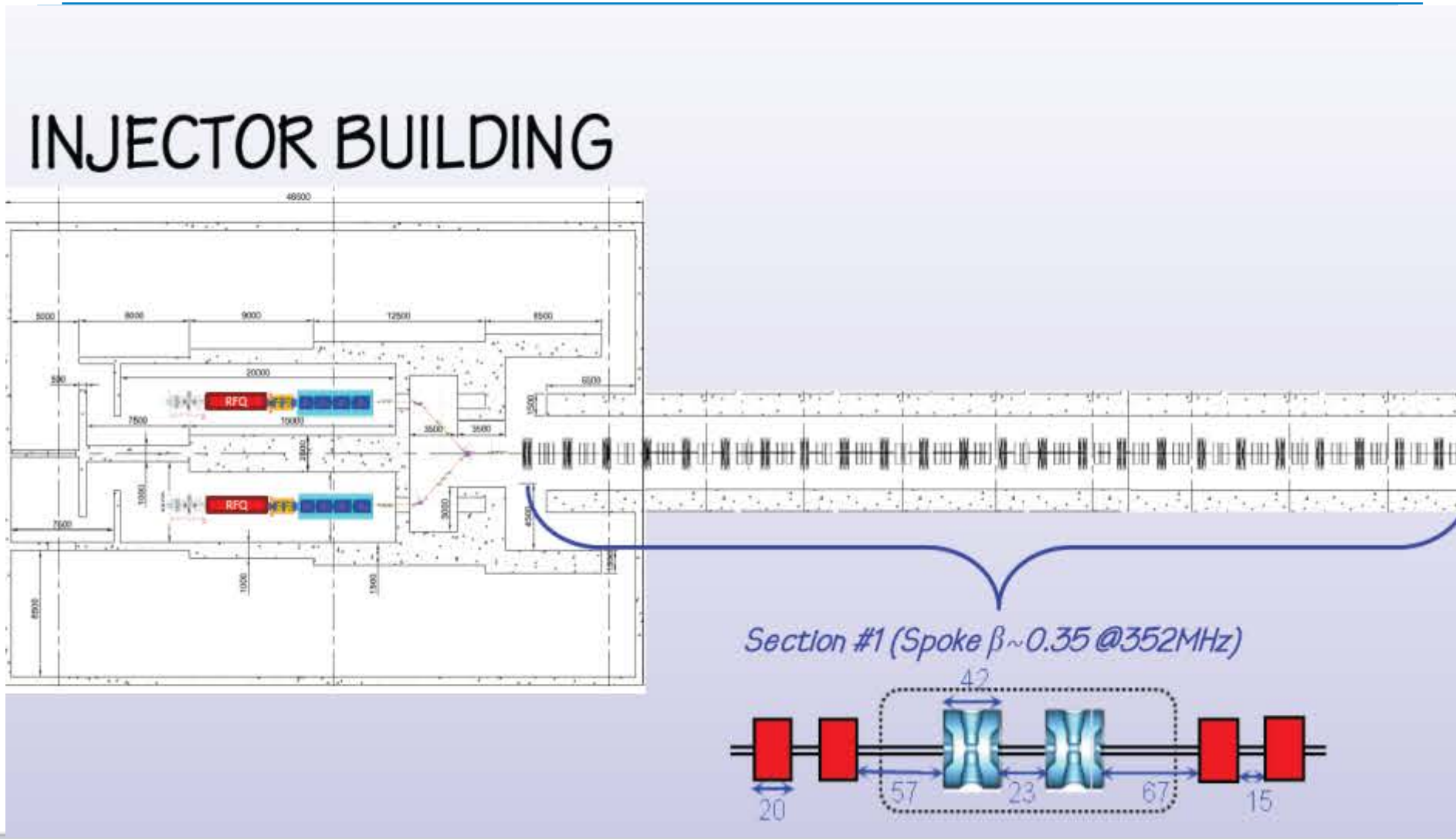
MYRRHA linac



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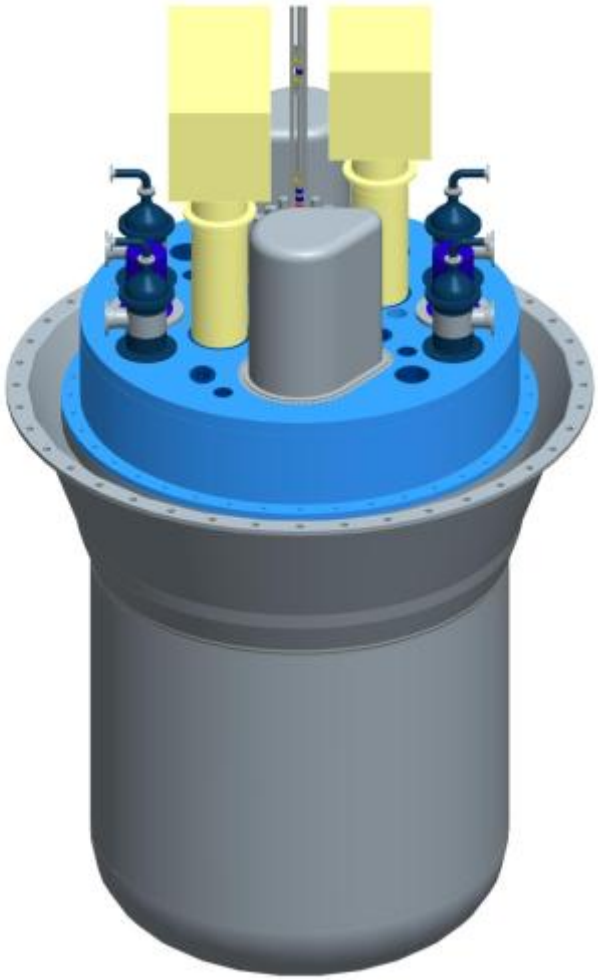
Reactor layout

- 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



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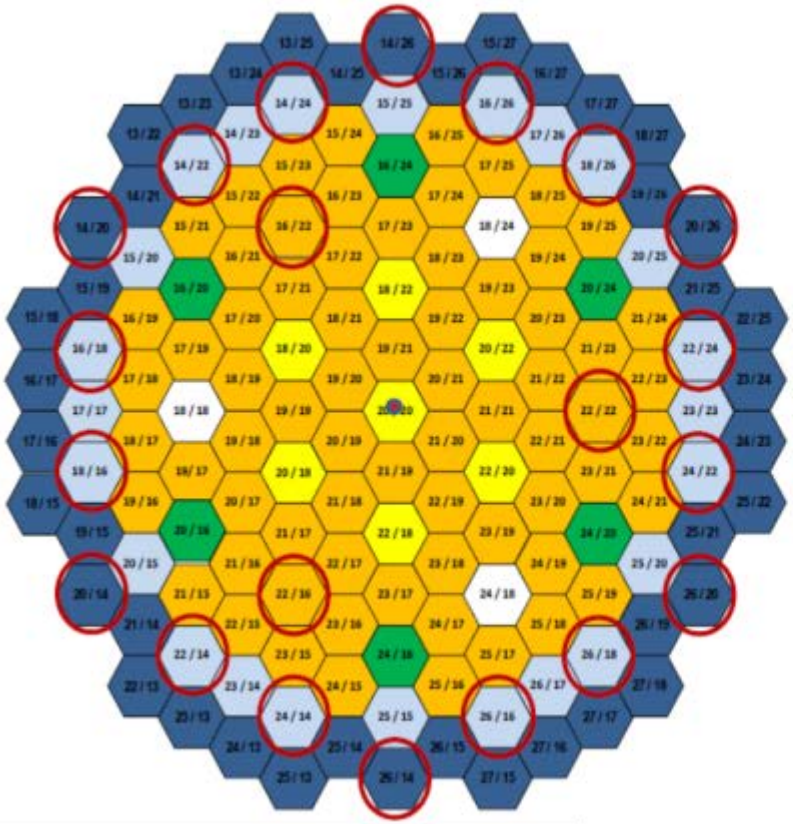
Core and Fuel Assemblies

- 151 positions
- 37 multifunctional plugs



69 FAs
7 (central) IPS
6 CR (buoyancy)
3 SR (gravity)
24 "inner" Dummy (LBE)
42 "outer" Dummy (YZrO)
151 S/As

Additional positions available for inserts from the top (21/37)

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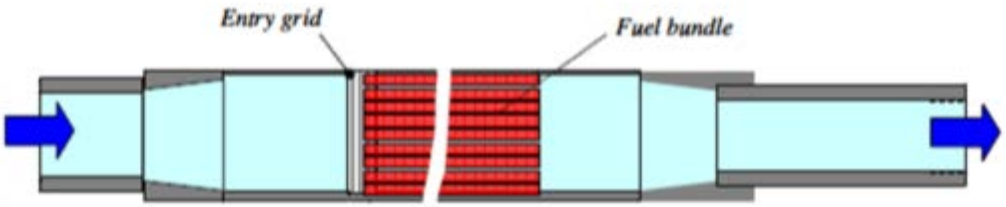
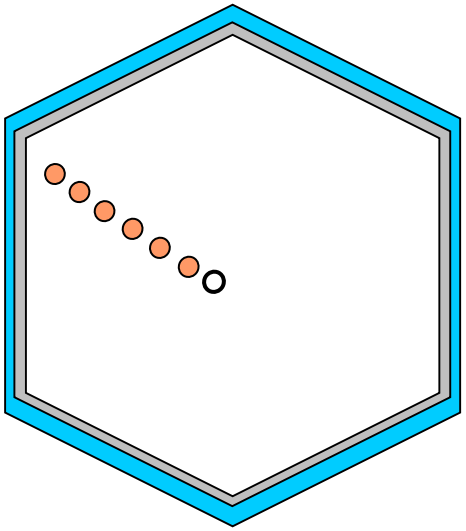
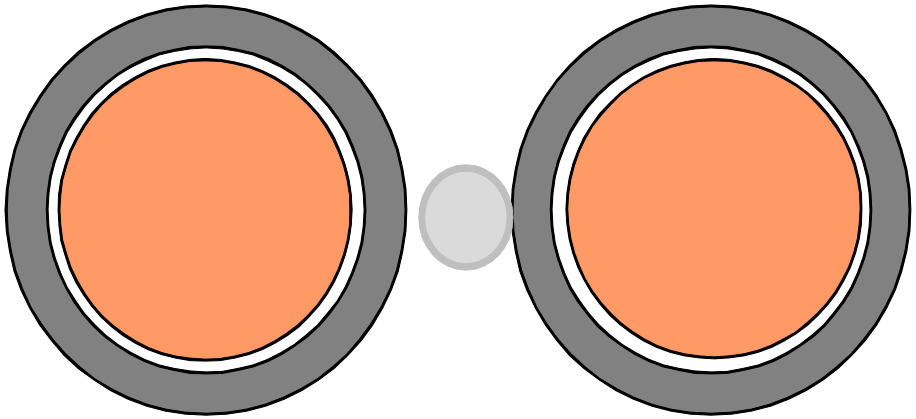
Core and Fuel Assemblies



- Fuel
  - Cladding in 15-15 Ti
  - Wire wrap
  - Wrapper in T91





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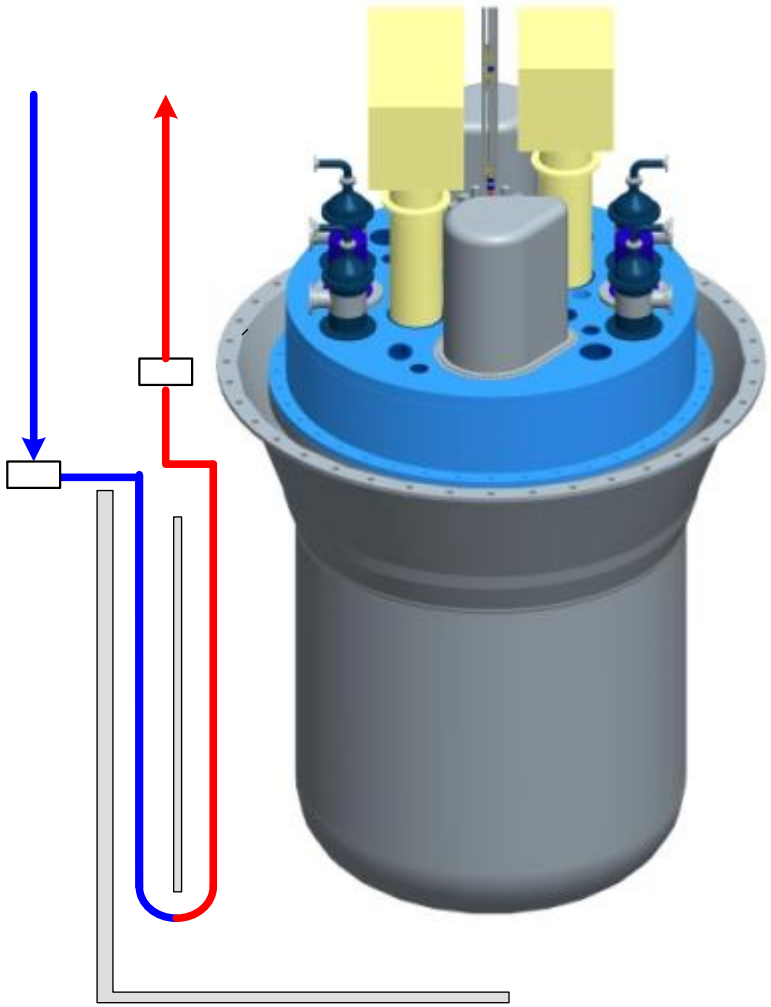
Cooling systems

- Decay heat removal (DHR) through secondary loops
  - 4 independent loops
  - redundancy (each loop has 100% capability)
  - passive operation (natural convection in primary, secondary and tertiary loop)
- Ultimate DHR through RVCS (natural convection)



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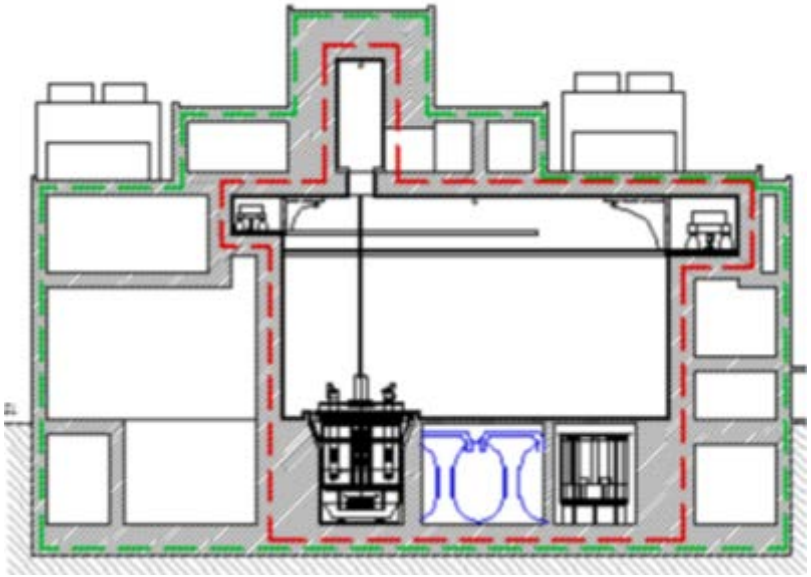
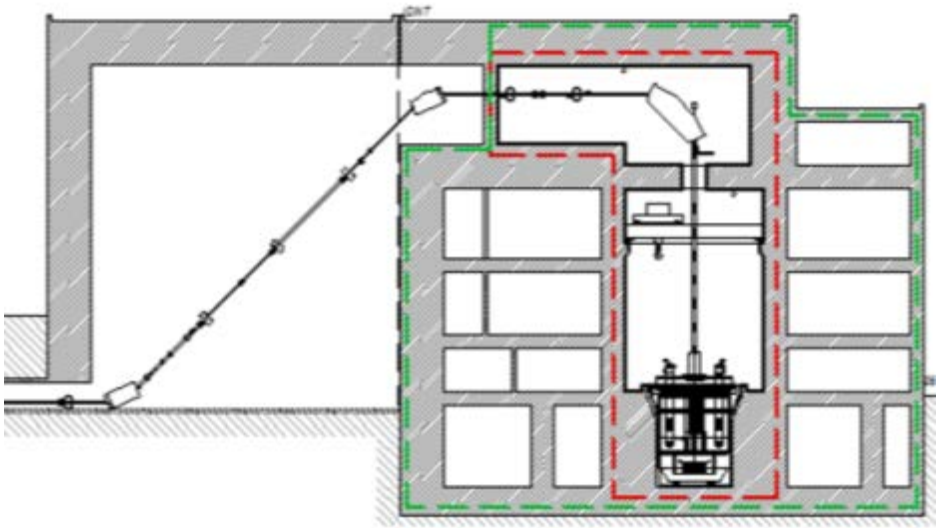
Integration into building





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Multipurpose LRI R&D facility

Fuel research
Φ_{tot} = 0.5 to 1.10^{15} n/cm^2.s

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

Fission GEN IV

Fusion

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

50 to 100 MWth
Φ_{Fast} = ~10^{15} n/cm^2.s
(En>0.75 MeV)

Waste

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

High energy LINAC
600 MeV – 1 GeV
Long irradiation time

Fundamental research

Radio-isotopes

Φ_{th} = 0.5 to 2.10^{15} n/cm^2.s
(En<0.4 eV)

Silicon doping

Φ_{th} = 0.1 to 1.10^{14} n/cm^2.s
(En<0.4 eV)

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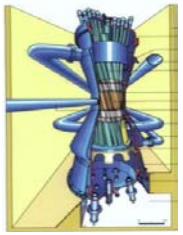
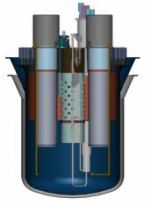
To attract new talents
Importance of LRI in the innovation loop

Investing in R&D infrastructure



BR2

but after 50 years…



MYRRHA

Attractiveness of R&D in Belgium

Attraction of talents

World-class R&D programmes

Outputs of R&D

Science = basic science

Technology = applied science

Services = sources of revenue

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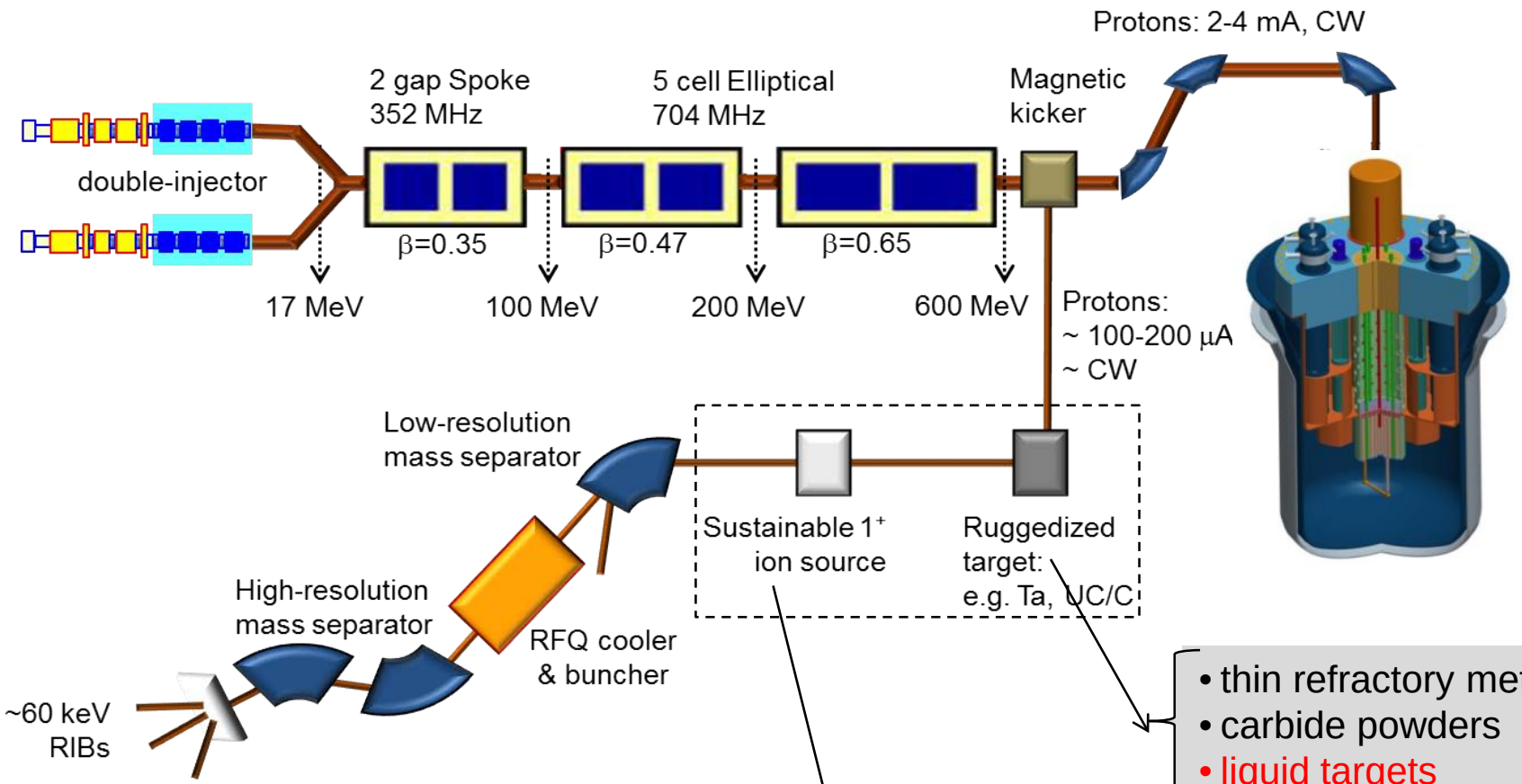
Educate & Train new talents
ISOL@MYRRHA - Concept



- thin refractory metal foils
- carbide powders
- liquid targets

- surface ion source
- ECR ion source
- RILIS

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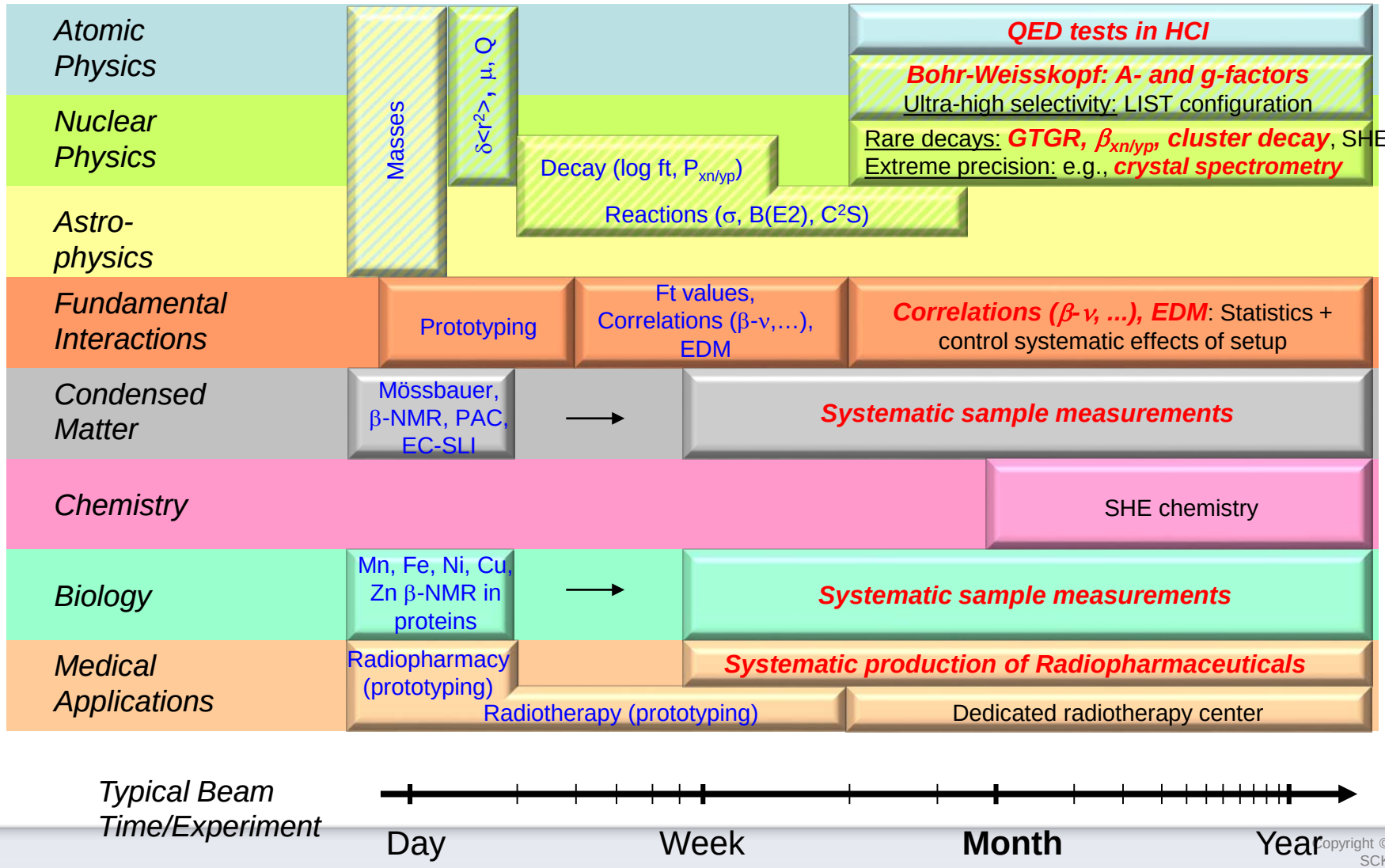
Applications in ISOL@MYRRHA



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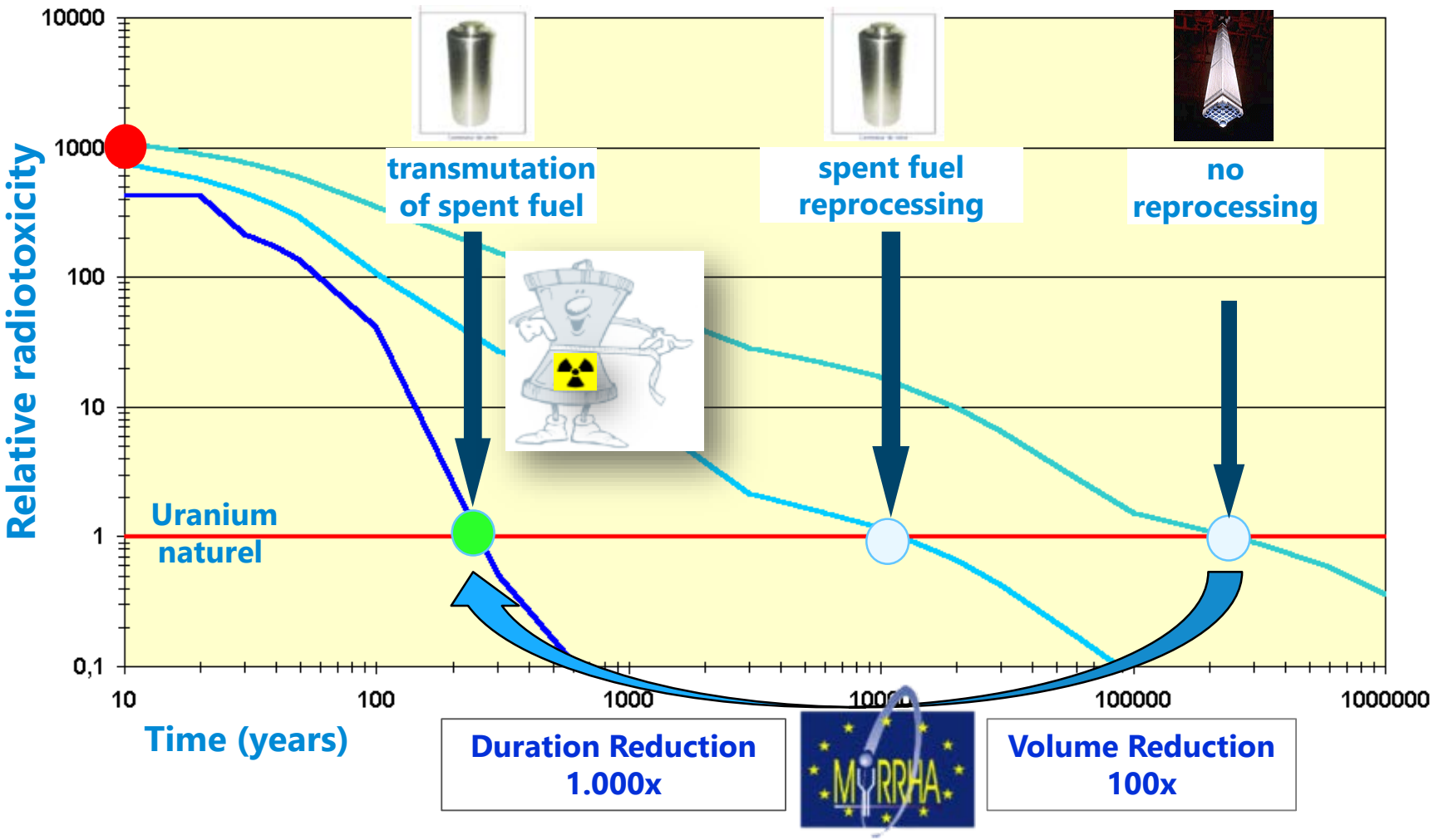
Come with acceptable solutions for HLW
Motivation for transmutation



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MYRRHA contributes to the European Strategy for P&T

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

  1. **Demonstration of the capability to process a sizable amount of spent fuel from commercial LWRs in order to separate plutonium (Pu), uranium (U) and minor actinides (MA),**
  2. **Demonstration of the capability to fabricate at a semi-industrial level the dedicated fuel needed to load in a dedicated transmuter, (JRC-ITU)**
  3. **Design and construction of one or more dedicated transmuters,**
  4. **Provision of a specific installation for processing of the dedicated fuel unloaded from the transmuter, which can be of a different type than the one used to process the original spent fuel unloaded from the commercial power plants, together with the fabrication of new dedicated fuel.**

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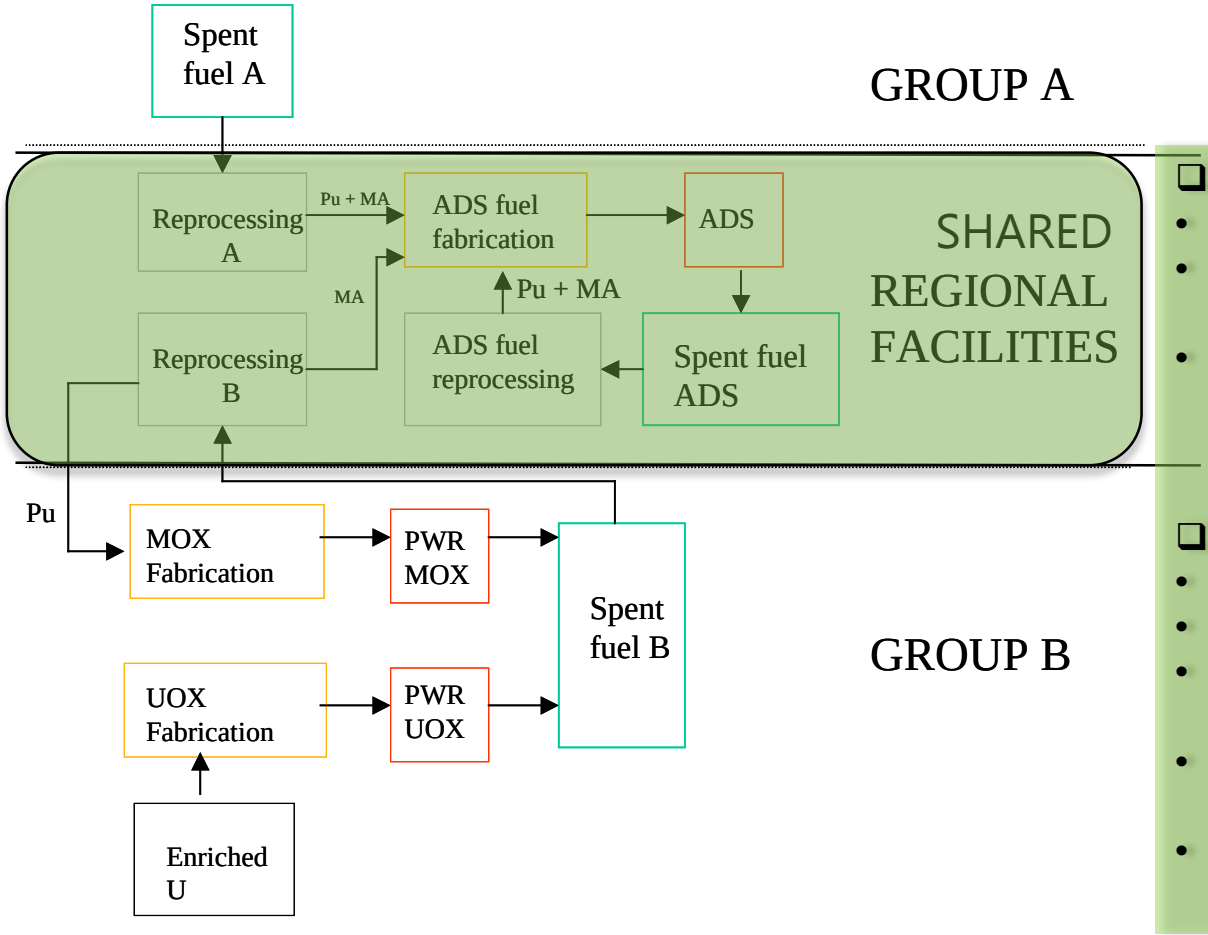
Even with completely different national NE policies European solution for HLW works with ADS



- **Advantages for A**
  - ADS shared with B
  - ADS burn A's Pu& MA
  - Smaller Fu-Cycle units & shared

- **Advantages for B**
  - ADS shared with B
  - ADS burn B's MA
  - A's uses B's Pu (part) as resource in FR
  - FR fleet not contam with MA's
  - Smaller Fu-Cycle units & shared

Scenario 1 objective: elimination of A's spent fuel by 2100

A = Countries Phasing Out, B = Countries Continuing

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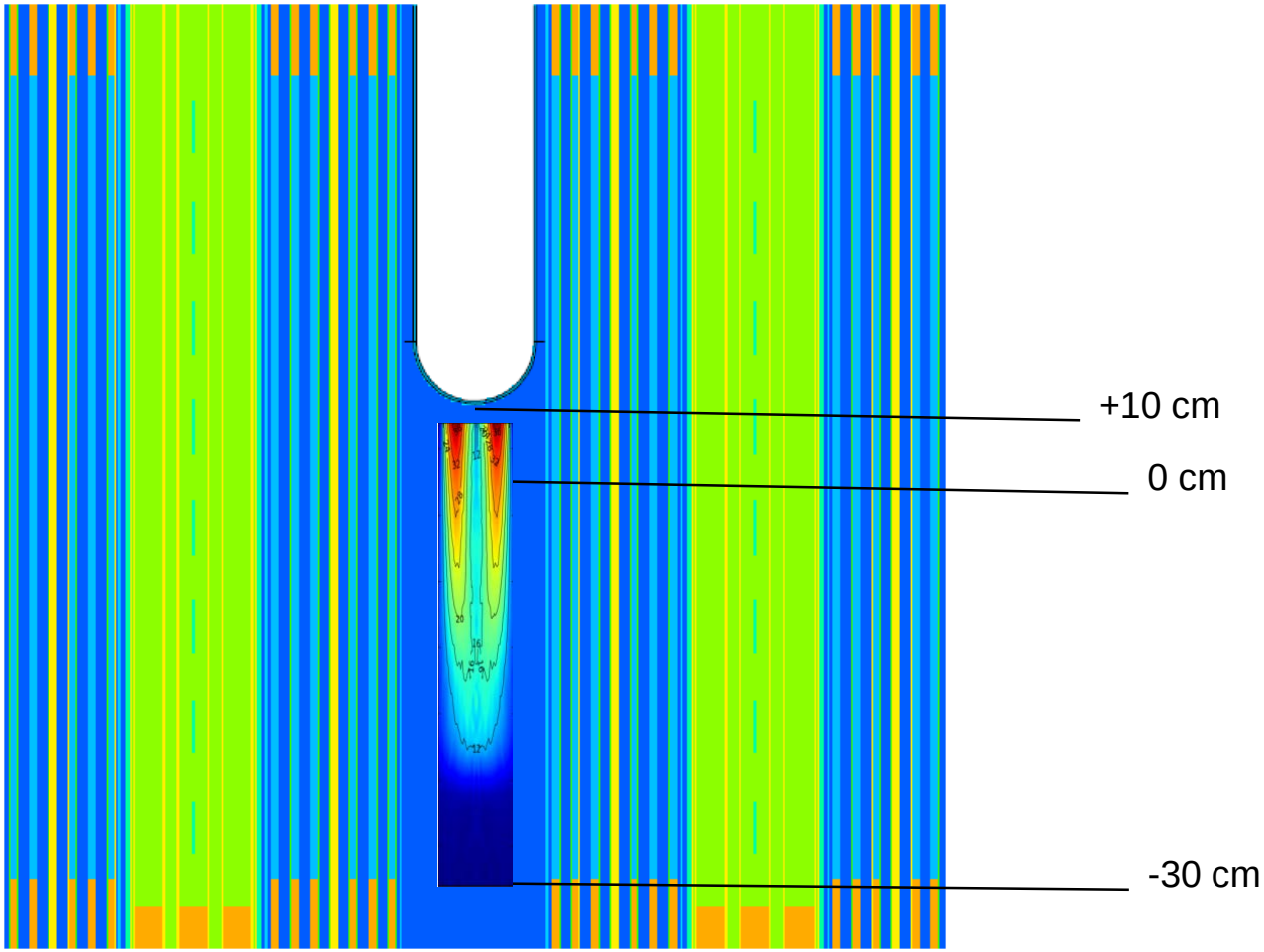
Prepare the path for Fusion DEMO
Irradiation capabilities in the spallation target



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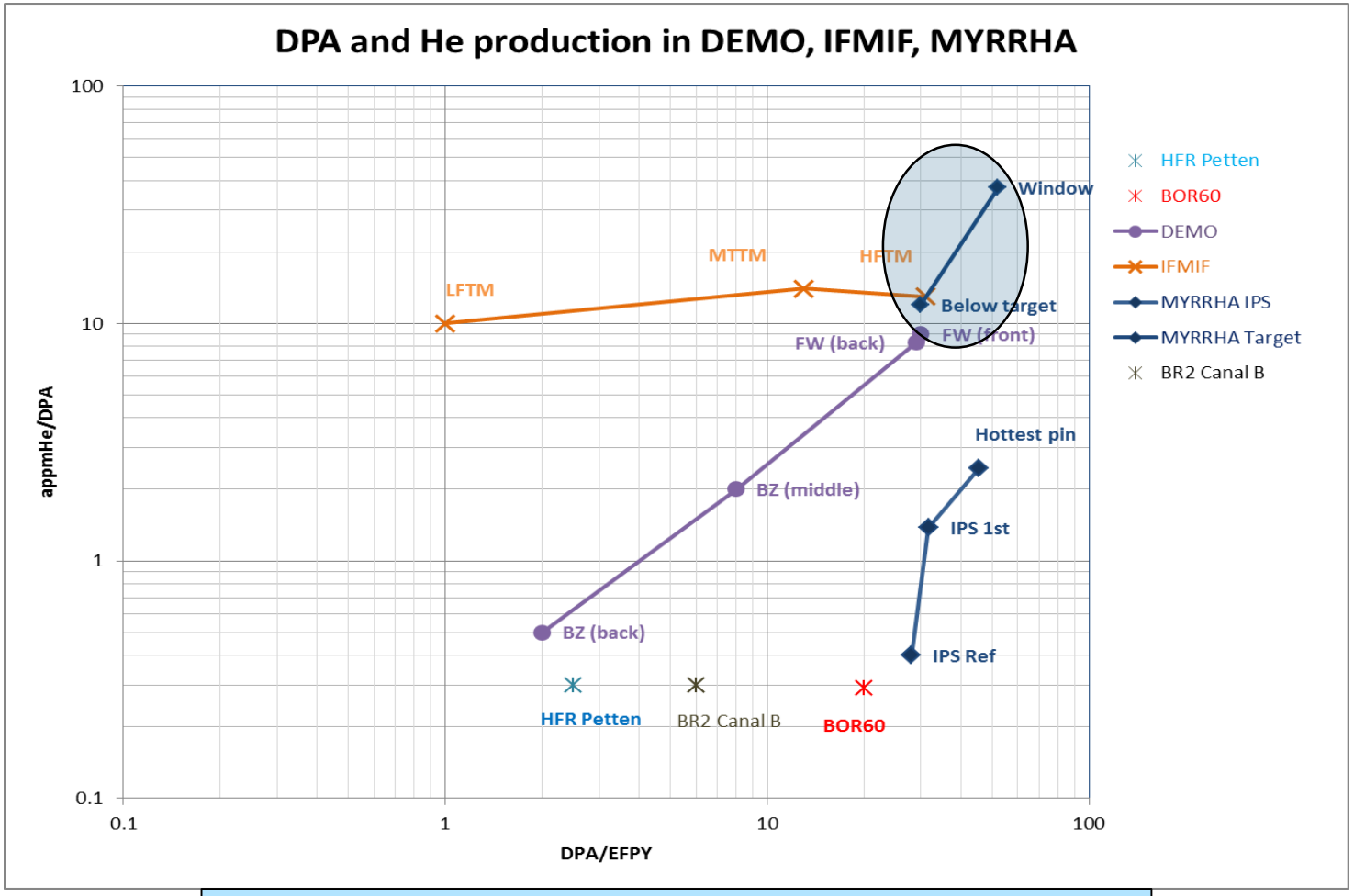
MYRRHA for fusion irradiations



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

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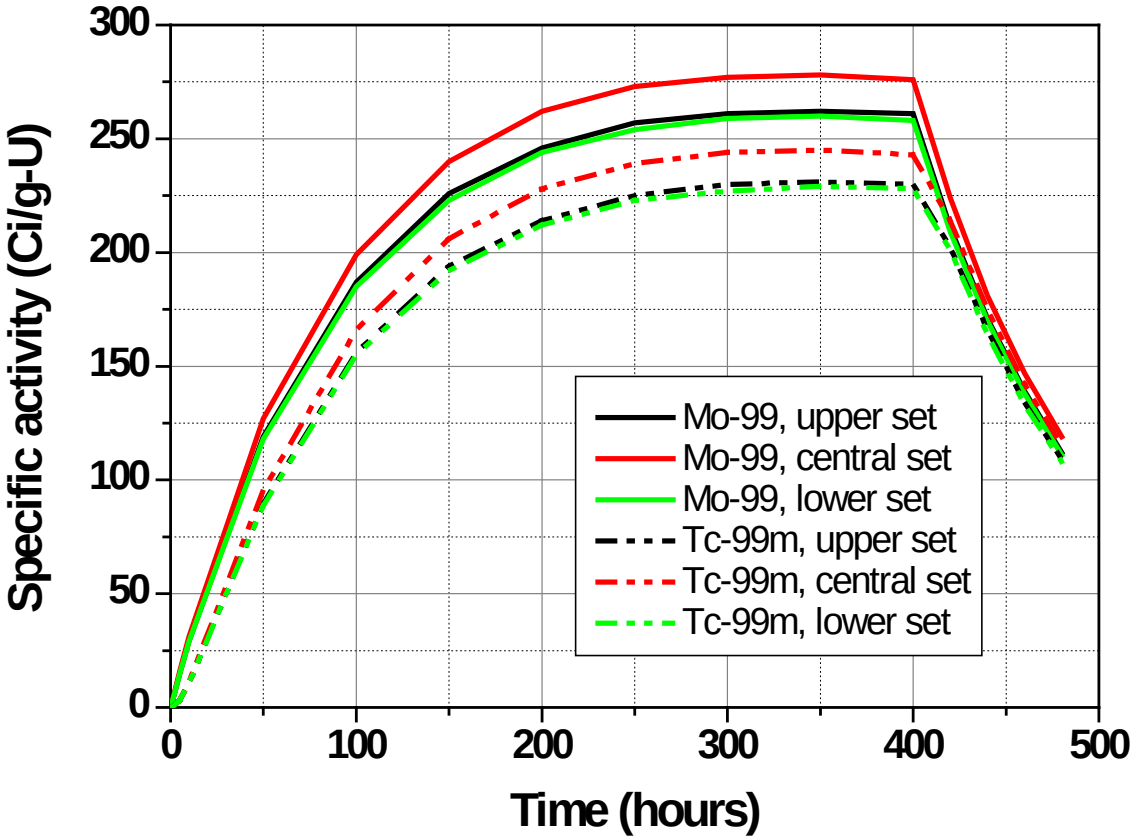
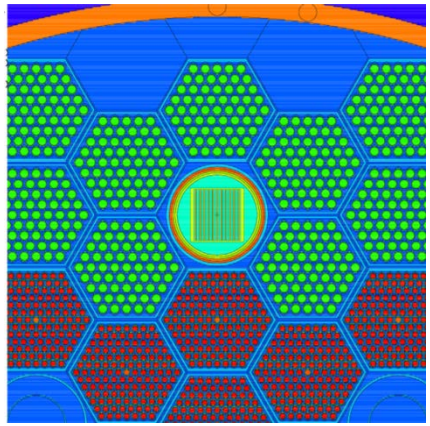
Guarantee welfare of the population via nucl. Med.
Radioisotope (Mo-99) production capability



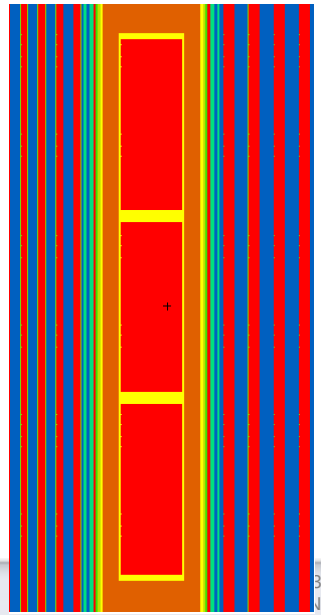


Average specific power

173 W/cm^2

184 W/cm^2

171 W/cm^2



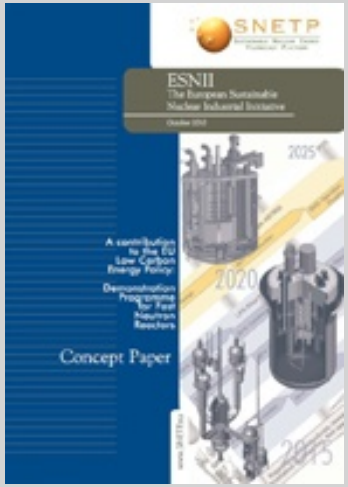
European Context

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)

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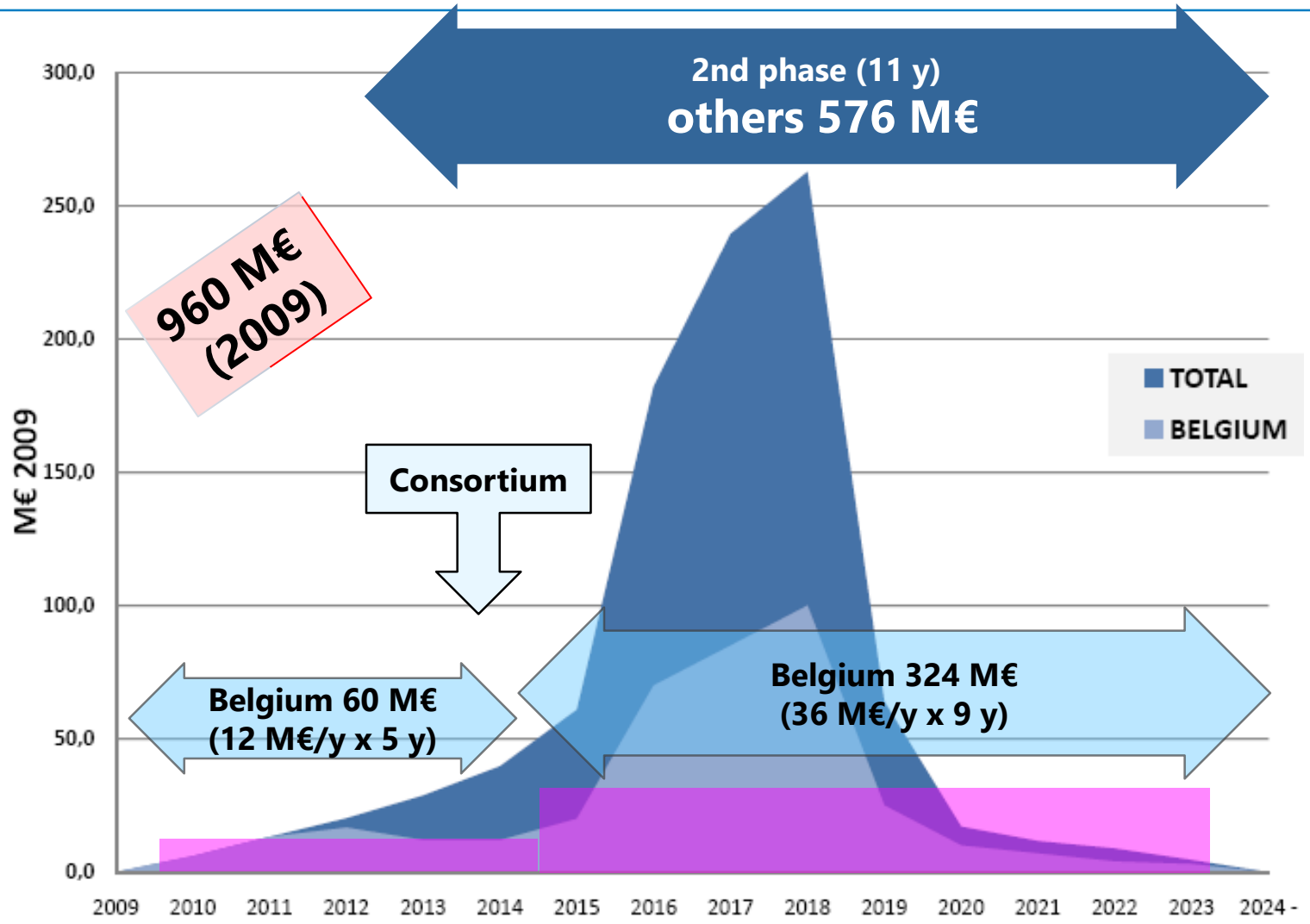
Belgian commitment: secured
International consortium: under construction



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The project schedule
Executing presently the FEED Phase: 2010-2014

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 x	Spallation target x	Sub-critical reactor
Secure the licensing	**PDP** preliminary dismantling plan	**PSAR** preliminary safety assesment	**EIAR** environmental impact assesment
Secure a sound management and investment structure	Central Project Team	Owner Consortium Group	Owner Engineering Team

FEED (Front End Engineering Design)

2010-2014

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MYRRHA: an international network
Japanese actors of today

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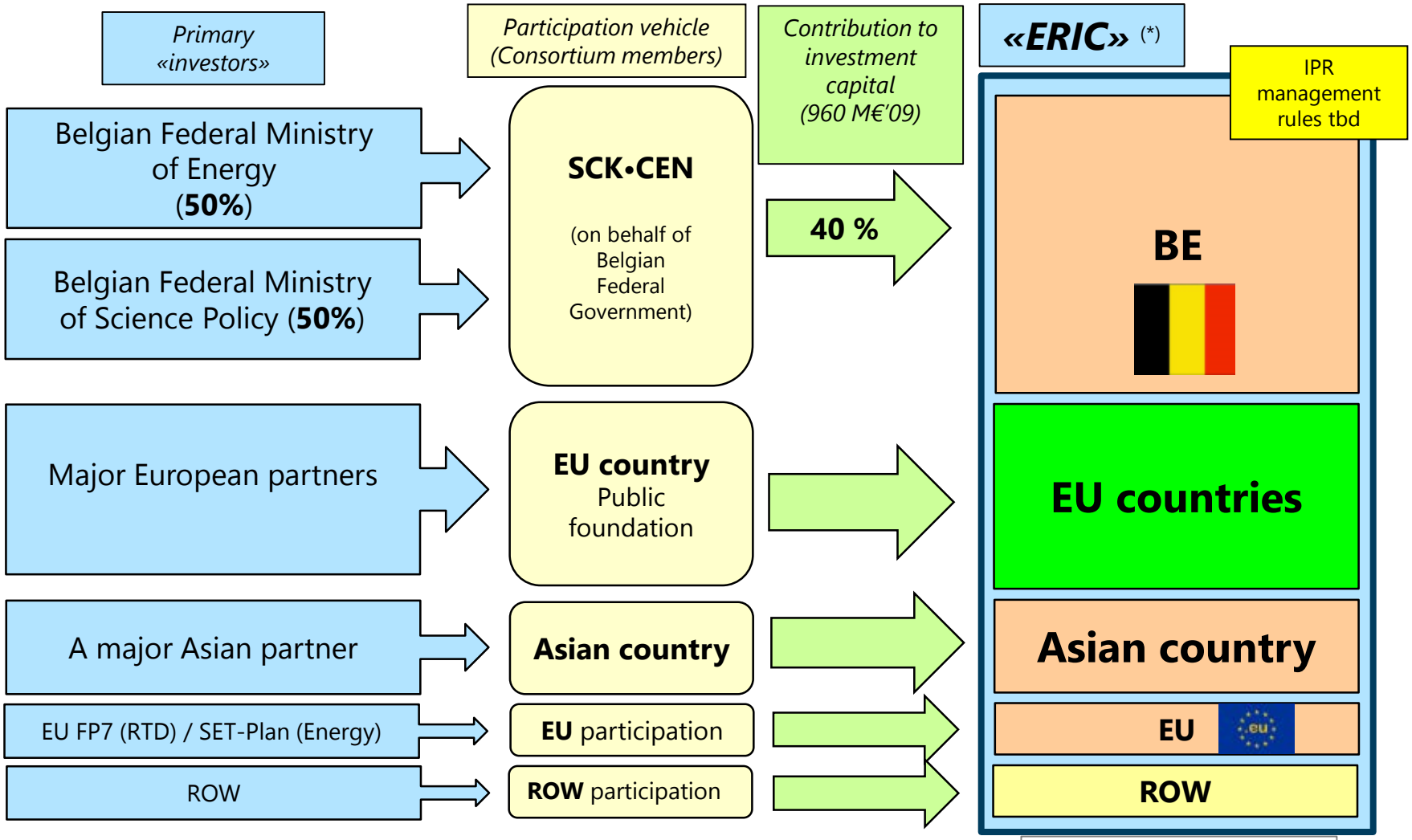
International Members Consortium – Phase 1
As of early 2012



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International Members Consortium - Phase 2

«ERIC» (*)

CLOSED/ SHARED INFORMATION

for MoC

OPEN INFORMATION

SHARED INFORMATION

for participants

CLOSED INFORMATION

for participants

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
- Independant 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 overal operation
- Priority of access
- Potential benefit of low price (compensation profit from commercial revenues)
- Capacity transfer flexibility (rules tbd)

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

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Conclusions
Europe should invest in its new LRI's
and open them widely

- **MYRRHA As a Multipurpose Fast Spetrum 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 materia**l research community towards the DEMO construction
  - **Secure society needs** for RI for medical applications and Dopped-Si for renewable Energy

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History of fruitfull collaboration between Japan & Belgium

- Japan is a pioneer in research on closed fuel cycle: OMEGA project through OECD/NEA launched in mid-80's
- Belgium pioneer in MOX fuel technology development & qualification for FRs and LWRs
- During the 90's decade a strong cooperation between Belgium (SCK•CEN & Belgonucléaire) and Japan Industry (MHI, TOSHIBA, CRIEPI) on MOX qualification for use in Japanese PWR's and BWR's
- Under EURATOM-Japan agreement: in 2004 first collaboration between EUROTRANS FP6 / JAEA on ADS Design and associated technologies
- In 2006, first agreement between JAEA and SCK•CEN on ADS development

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SCK•CEN / JAEA Collaboration Aggr. Signature in Brussels 23.11.2006

General Agreement in Nuclear Energy:

- Topic on ADS Development:
  1. **ADS design including experimental ones**
  2. **material study for fuel cladding**
  3. **Pb-Bi technology**
- Agreement renewed in 2011

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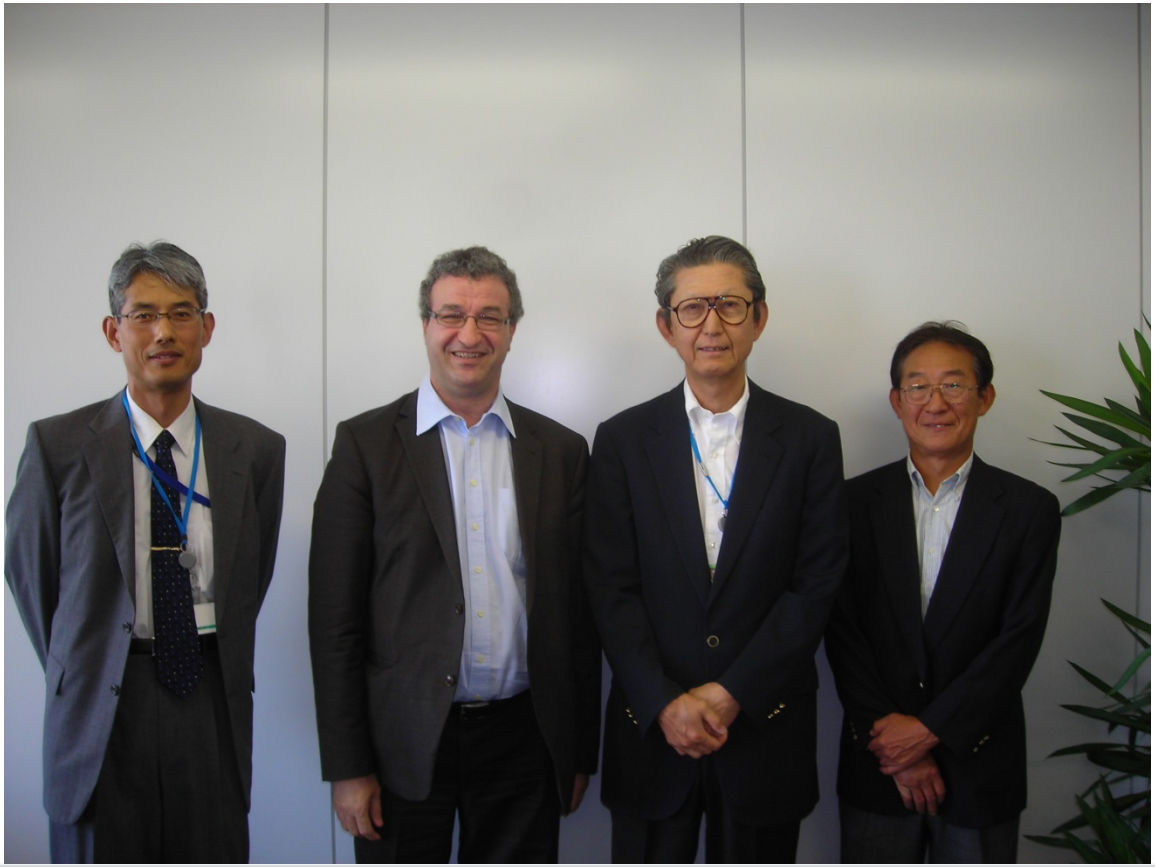
In 2012 EoI in MYRRHA sent by JAEA

Prof. Suzuki asking to start negotiation for Letter of Commitment
Beginning of 2013



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Interest of Japan and Belgium to collaborate on ADS GUINEVERE/TEF-P/TEF-T/MYRRHA/Industrial ADS

- JAEA and SCK•CEN are sharing a clear view on the role of ADS in a double-strata closed fuel cycle strategy
- SCK•CEN
  - has built from 2007 to 2009, licensed and is operating GUINEVERE a Zero Power Pb-based ADS driven by a D-T source. Presently it is used for running an experimental programme for preparing the licensing of MYRRHA
  - Since 1998 is advancing the design of MYRRHA a 100 MWth experimental ADS facility aiming to be the first worldwide power ADS to demonstrate the reliable and efficient operation of ADS
- JAEA has planned to build 2 experimental ADS facilities:
  - TEF-P: the Transmutation Experimental Facility for Physics a Zero Power ADS based on a spallation source generated with a proton very low power beam : 600 MeV* 17 nA that will act as GUINEVERE
  - TEF-T: the Transmutation Experimental Facility for Technology a spallation source generated with a proton average power beam : 600 MeV* 0.33 mA without a sub-critical core. TEF-T is intended as a small scale irradiation facility for ADS structural and fuel qualification.
- KURRI has coupled the KURRI reactor to a FFAG Accelerator
- **These facilities will pave the road towards the experimental large scale ADS (600 to 800 MWth)**

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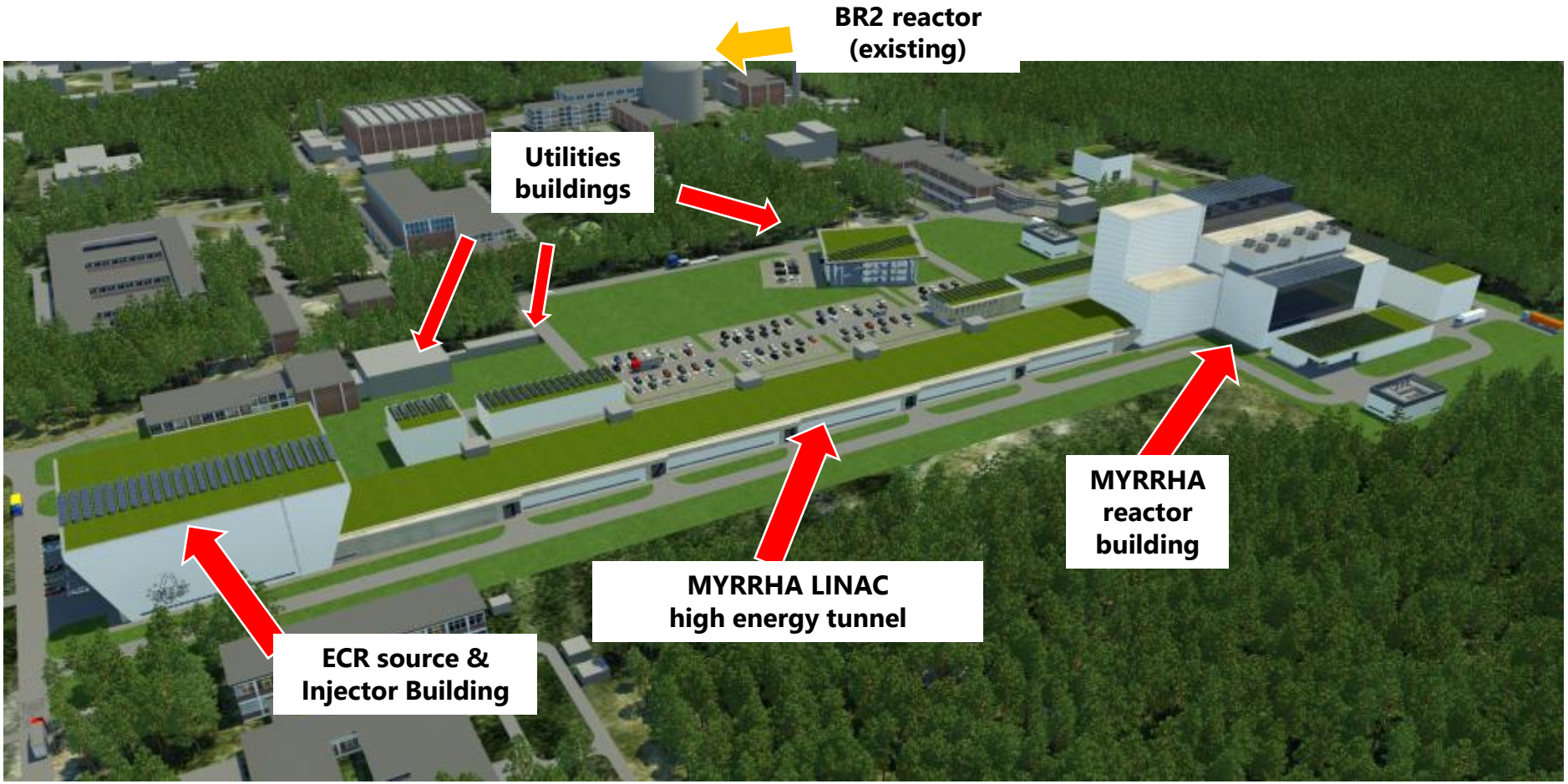
MYRRHA: EXPERIMENTAL ACCELERATOR DRIVEN SYSTEM
A pan-European, innovative and unique facility at Mol (BE)



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CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE