



Presentation of Belgium & EU P&T and ADS programme at a glance

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High Level Waste Mgt status in the world at a glance

		No Recycling Once Through	Today's Recycling PUREX (La Hague)	Tomorrow Recycling
1 ton UO ₂ used fuel (50 GWd/t)	935 kg U	Nearly 1 ton as HLW to Geological Disposal	U + Pu recycled	U + Pu recycled
	12 kg Pu			
	1 kg Np	Presently adopted in US, SE, FIN Decision for industrial Geol. Disp., under construction	53 kg HLW to Geolo. Disp. In vitrified waste form Presently adopted in FR, JP, UK ... No formal decision for industrial Geol. Disp. yet	MA recycled & ~50 kg HLW to Geolo. Disp. In specific packaging Presently R&D programme (FR, JP, EU, BE, CN, ROK, USA)
	0,8 kg Am			
	0,6 kg Cm			
	~50 kg FP (3,5 kg LLFP)	Burden of HLW for more than 300,000 y	Burden of HLW for more than 10,000 y	Burden of HLW for ~300 y
		Industrial scale	Industrial scale	R&D level

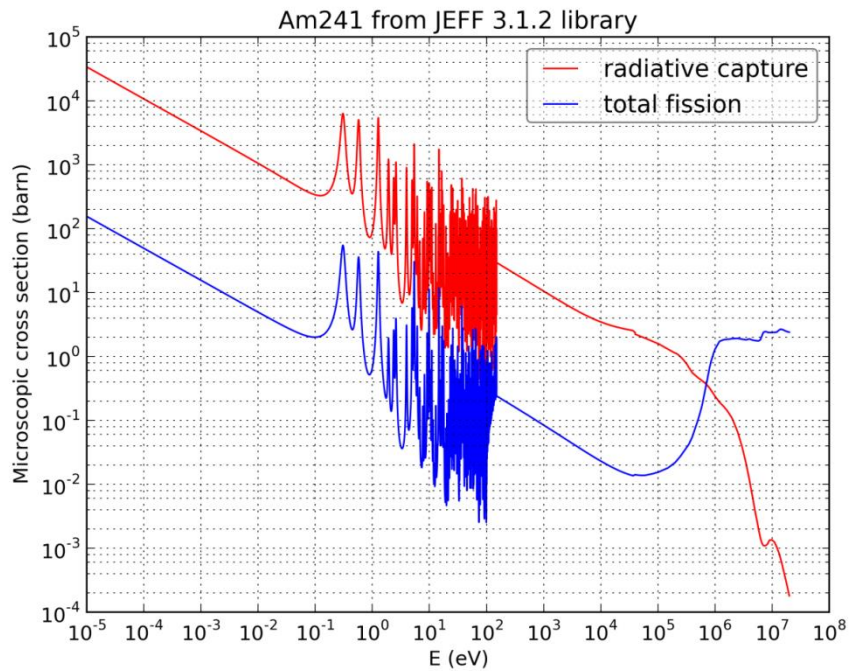
Demonstration of P&T at engineering level at the centre of the European Commission Strategy

- The EC and EU Member States R&D activities consists of four “building blocks” (BB):
 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, → MYRRHA
 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.

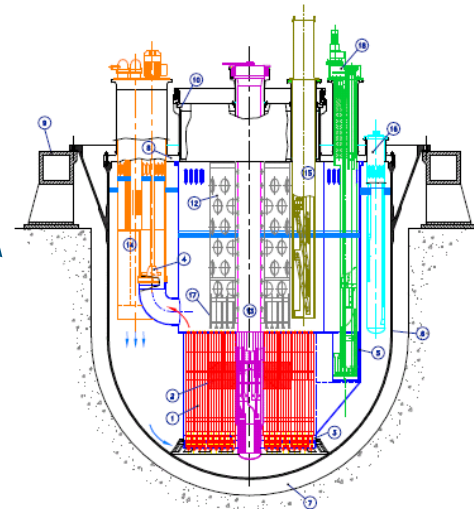
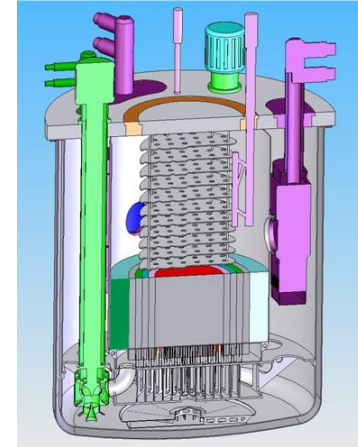
EC contributes to the 4 BB and fosters the national programmes towards this strategy.

Belgium contributes to the EC P&T strategy by focusing on BB3 through the realisation of MYRRHA as a pre-industrial ADS demonstrator and R&D facility

Options for transmutation



Fast neutron spectrum
is essential



Three options for Minor Actinide loading

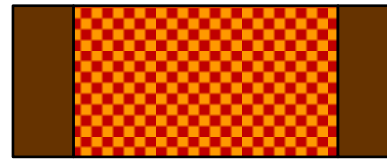
Like in Japan, EU is presently considering two approaches for transmutation: via FR or ADS

FR
heterogeneous



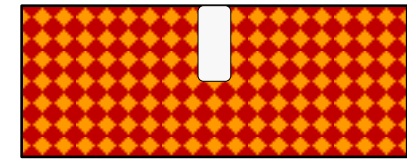
Driver fuel
Blanket with MA

FR
homogeneous



Fuel with MA
Blanket

ADS



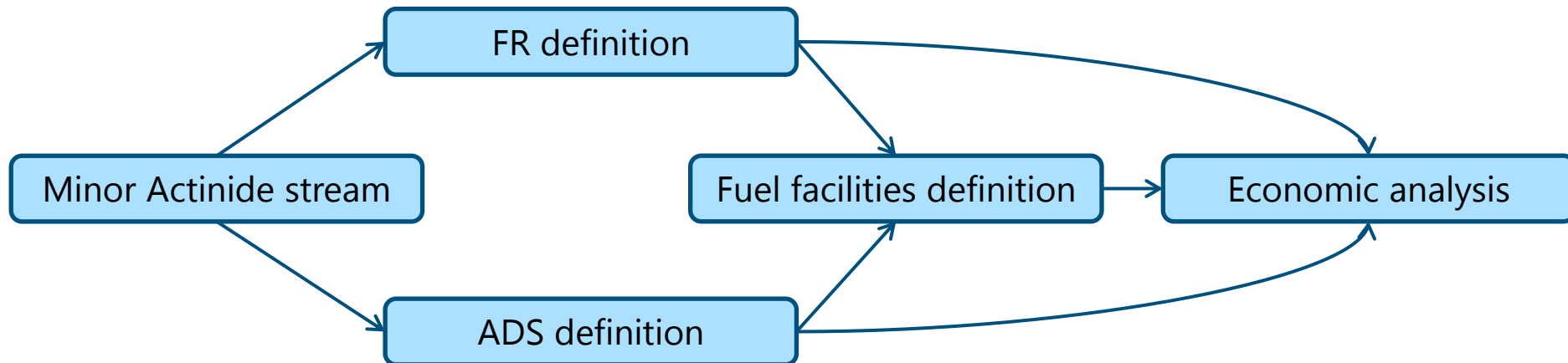
Fuel with MA

Core safety parameters limit the amount of MA that can be loaded in the 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)

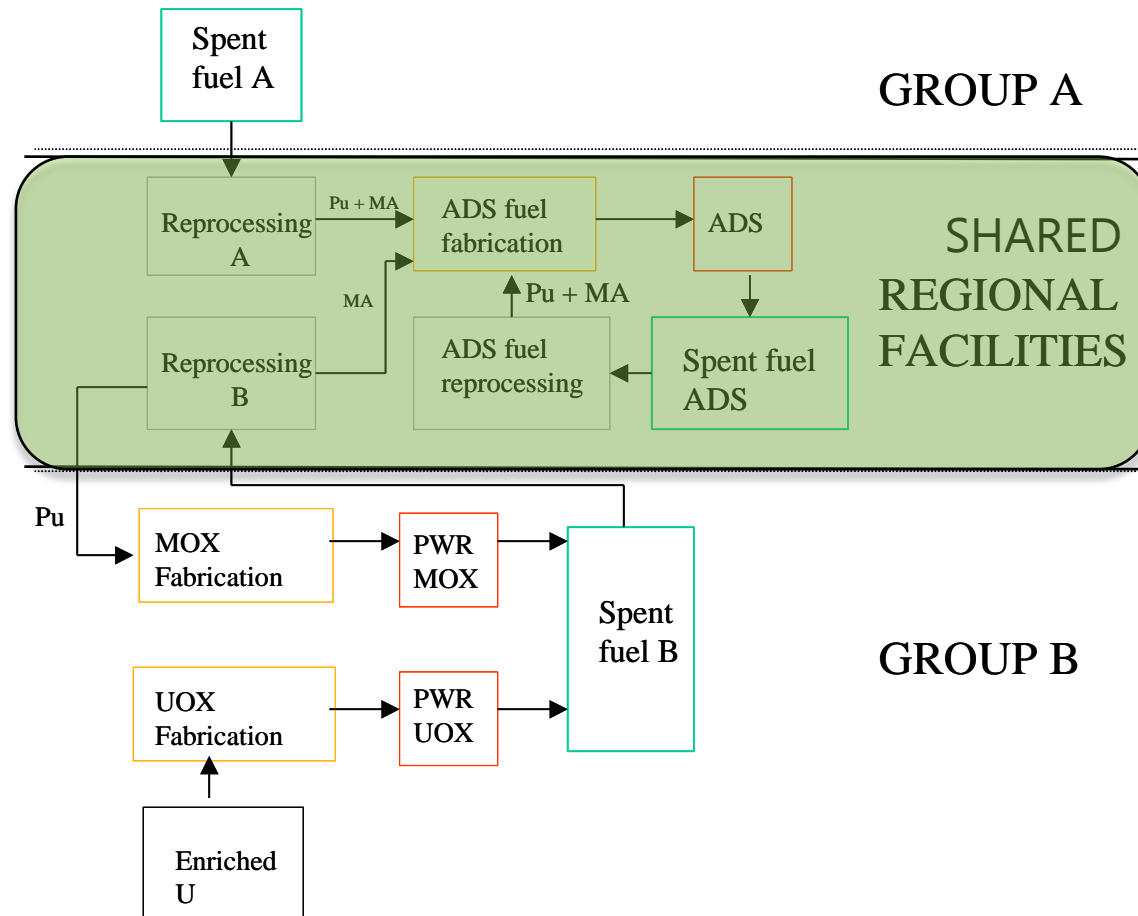
Feasibility of P&T from technologies to economics

- FP7 Project ARCAS – 2010-2012
- 11 partners*
 - research institutes
 - industrial companies
 - universities



* SCK•CEN (BE), KIT (DE), NRG (NL), CIEMAT (ES), UPM (ES), CNRS (FR), NRI (CZ), NNL (UK), Transnubel (BE), EC-JRC-ITU, UNIMAN (UK)

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



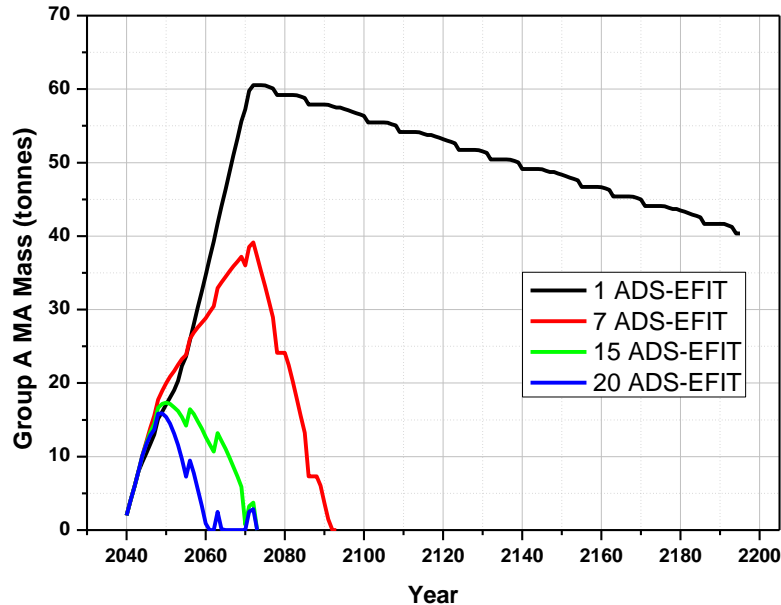
- ❑ **Advantages for A**
 - ADS shared with B
 - ADS burn A's Pu & MA
 - Smaller Fu-Cycle units & shared
- ❑ **Advantages for B**
 - ADS shared with A
 - ADS burn B's MA
 - A's uses B's Pu (part) as resource in FR
 - FR fleet not contam with MA's
 - Smaller Fu-Cycle units & shared

Scenario objective: elimination of A's spent fuel by 2100
A = Countries Phasing Out, B = Countries Continuing

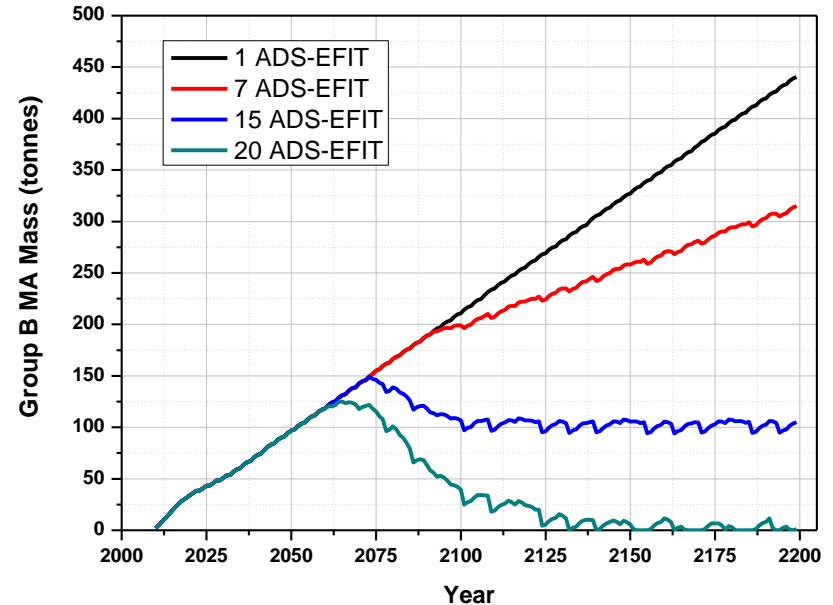
Industrial implementation of ADS in a regional approach

From PATEROS FP6/ARCAS FP7 projects

EU countries phasing out NE



EU countries continuing NE



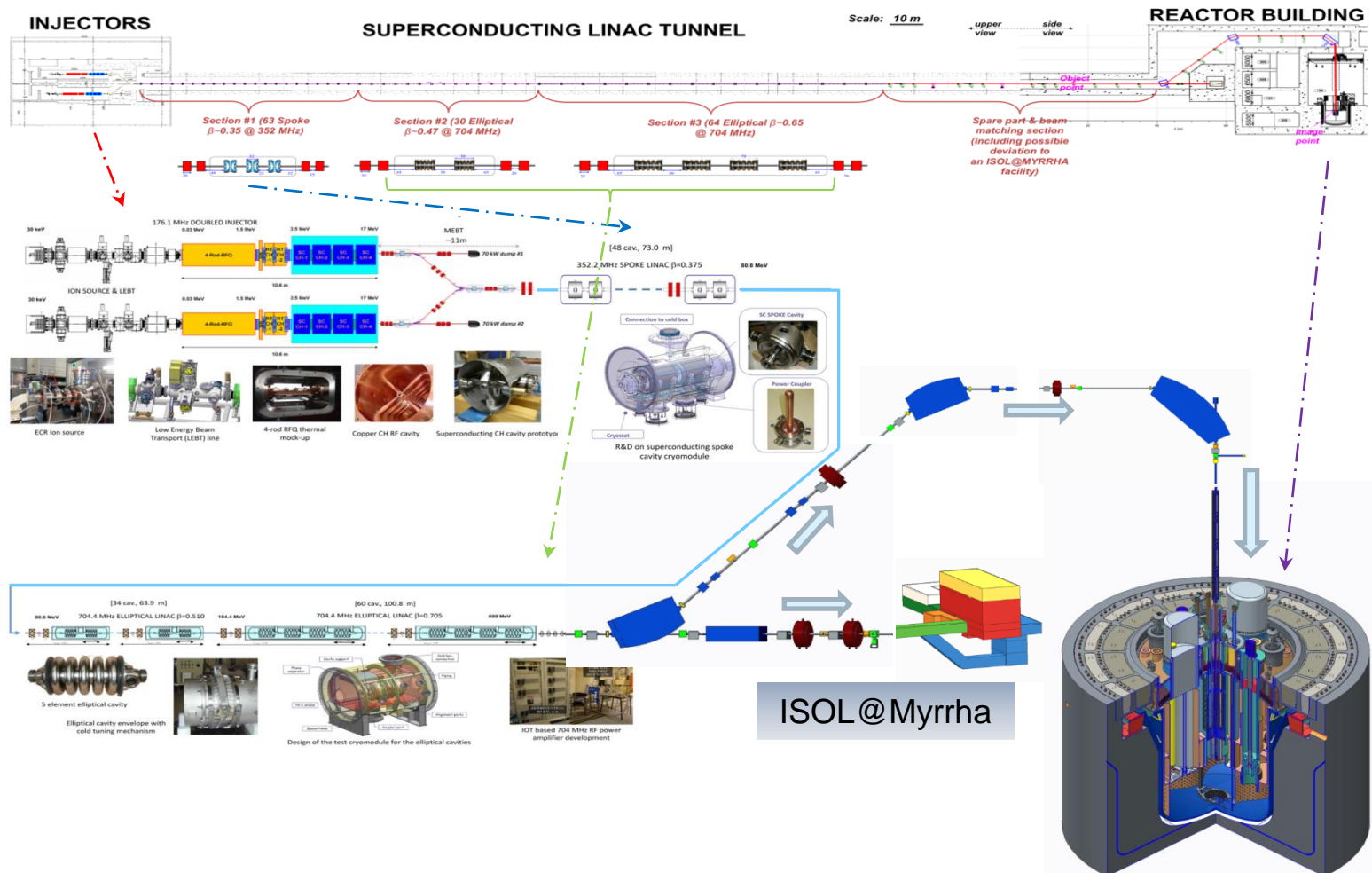
- ADS technology enables present generation to avoid transferring the burden of HLW to future generations

* SCK•CEN (BE), Ansaldo Nucleare (IT), CEA (FR), CIEMAT (SP), CNRS (FR), ENEA (IT), AREVA NP (FR), FZK (DE), ITU (EU), KTH (SE), NRG (NL), NRI (CZ), PSI (CH), UPM (SP), ITN (PT), Nexia Solutions (UK), Manchester University (UK)

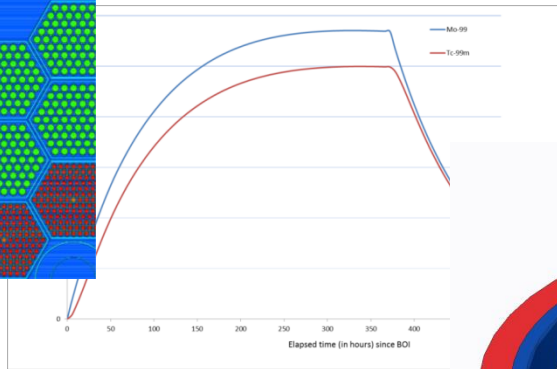
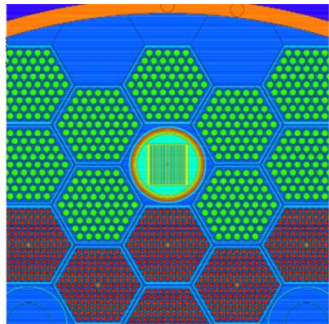
Economics evaluation need validations

- Investment – capacity needed
- Operational costs
- Fuel cycle costs
- Transportation costs
 - Spent LWR fuel
 - Homogeneous MA fuel for Fast Reactors
 - Heterogeneous MA fuel for Fast Reactors
 - ADS fuel
- Technological Readiness Levels are low → very hard to estimate costs
- **We need pre-industrial level demo facilities for the various stages of P&T at international level**

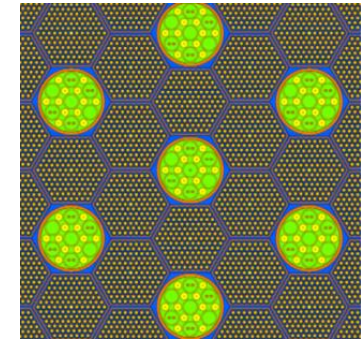
MYRRHA, a prototype ADS



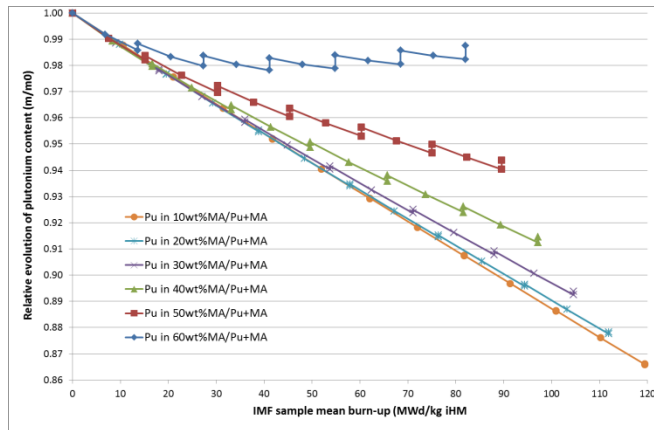
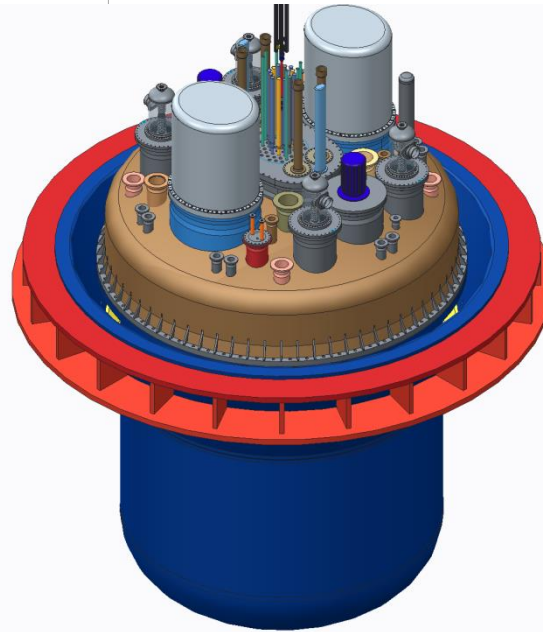
MYRRHA – Application catalogue



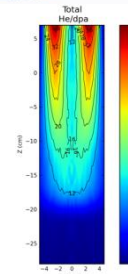
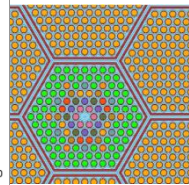
Radioisotope production



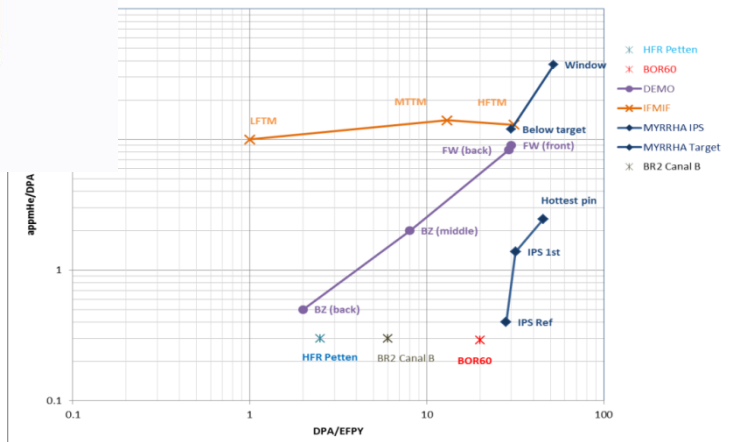
Material irradiation



MA irradiation studies



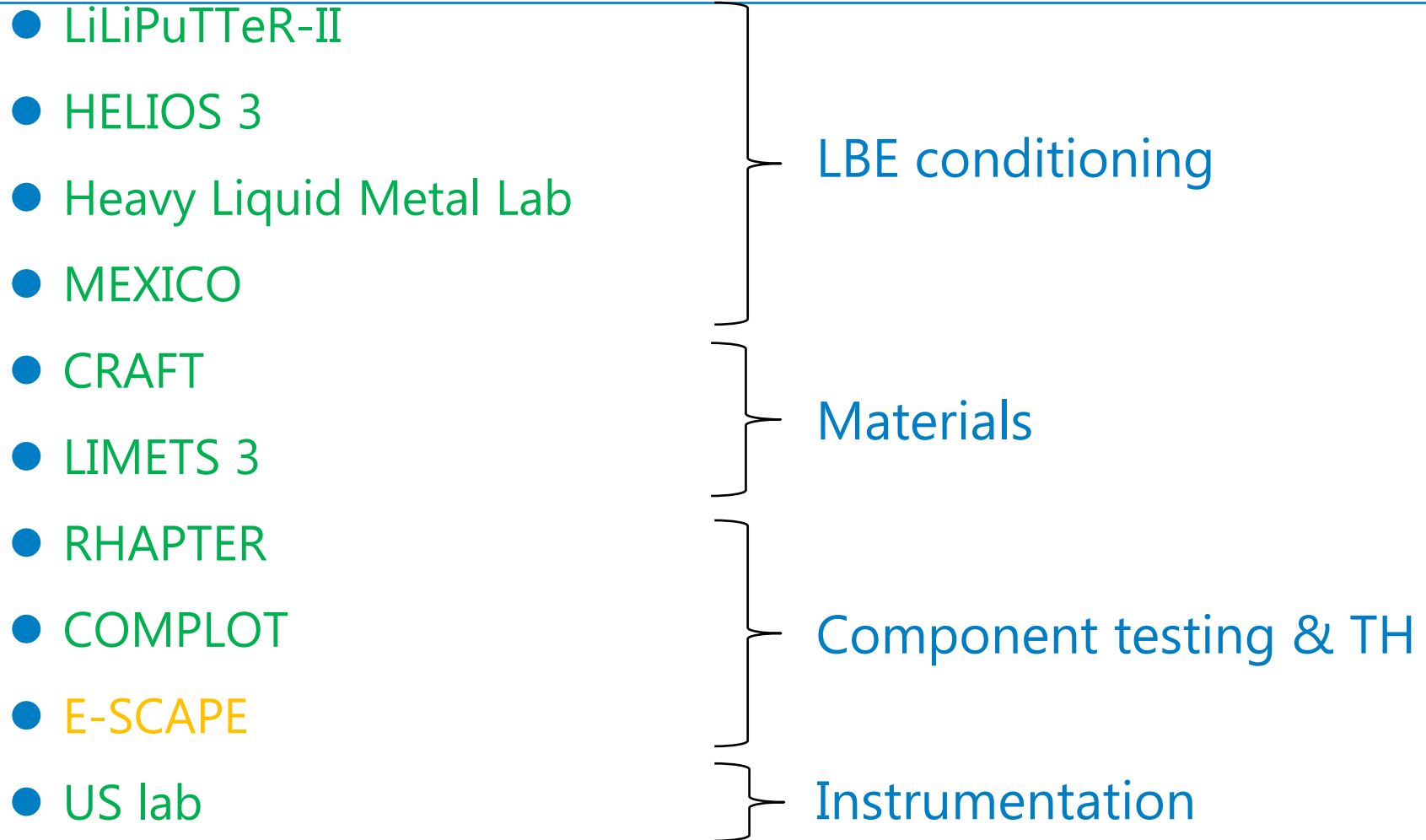
DPA and He production in DEMO, IFMIF, MYRRHA



P&T inspired many Euratom FP projects that were/are beneficial to MYRRHA

TOPIC	FP5	FP6	FP7
Coupling	MUSE	DM2 ECATS	FREYA
Fuels	FUTURE	DM3 AFTRA	FAIRFUELS
Materials	MEGAPIE	DM4 DEMETRA	MATTER
	SPIRE, TECLA		GETMAT
Design	PDS-XADS	DM1 DESIGN	CDT
			MAX
	ADOPT	EUROTRANS	SERIM G4
Thermal-Hydraulics	ASCHLIM		THINS
LFR	-	ELSY	LEADER
Infrastructures	-	VELLA, MTRI3	ADRIANA, SARGEN, NEWLANCER
Scenario Studies	-	PATEROS	ARCAS
Safety	-	-	SEARCH, SILER, MAXSIMA
	28 M€	31 M€	31 M€

Large LBE related infrastructure at SCK-CEN



Not only hardware development, also software

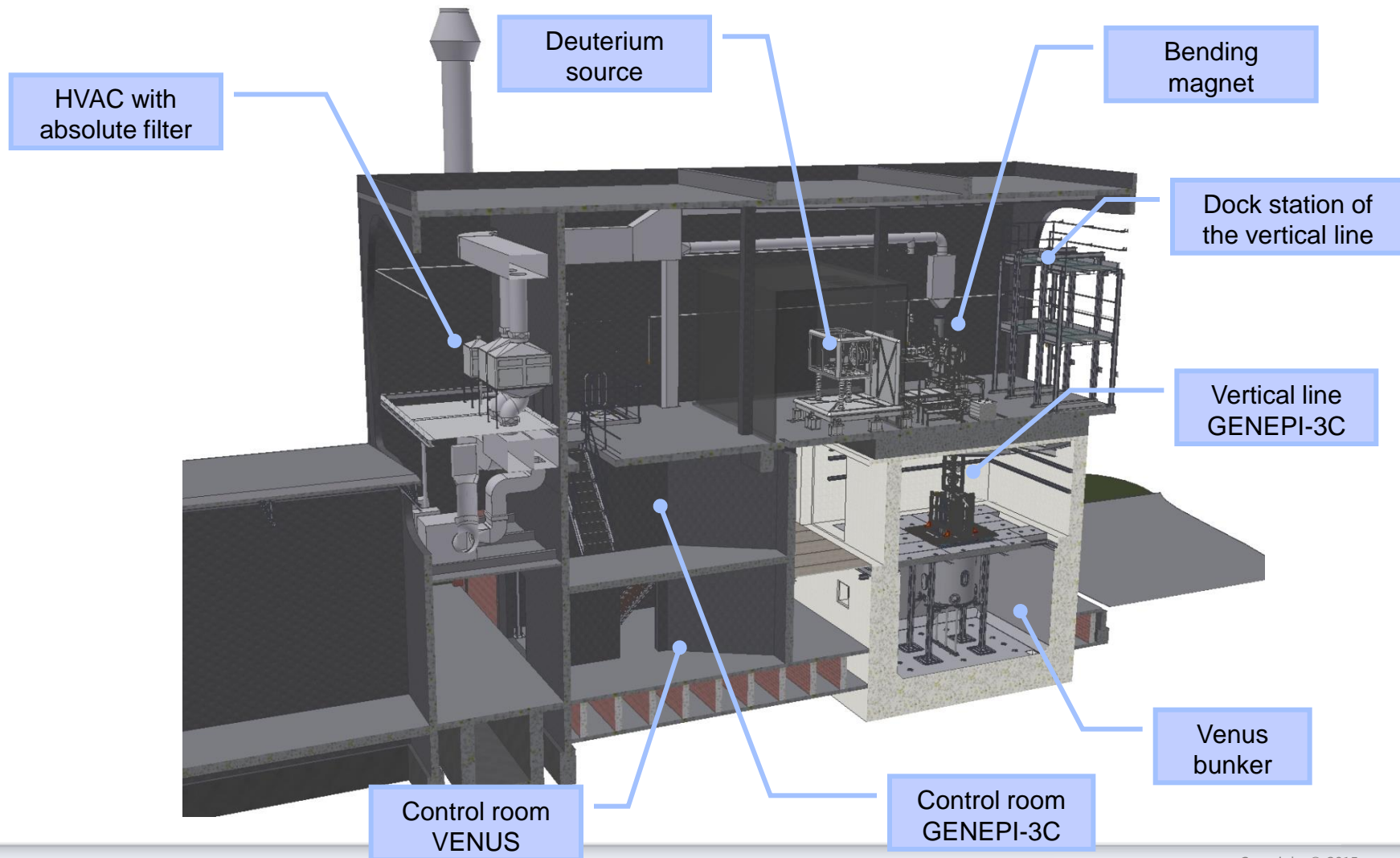
- ALEPH2 is a versatile code to calculate the time-dependent isotopics in a nuclear system
- Physics included
 - Fission
 - Spallation
 - Activation
- Derived quantities calculated
 - Source term (alpha, beta, gamma)
 - Decay heat
- Current research: include uncertainty quantification (BEPU)

ALEPH2 code: Versatility and data consistency

- ALEPH2 designed for critical and source-driven systems.
 - ADS analysis “from the protons onward”
 - Number of burn-up zones only limited by possible computer memory requirements
- Data for Monte Carlo simulation and those for subsequent burnup calculations come from the same source (JEFF-3.1.1, ENDF/B-VII, JENDL-4).
 - General purpose neutron and proton files are used both for transport and time evolution calculations.
 - For time-evolution, additional specific purpose data from the same library release are used, namely:
 - activation data for the reactions not present in general purpose files
 - Neutron-induced fission and spontaneous fission yield data
 - Radioactive decay data (decay heat, ...)

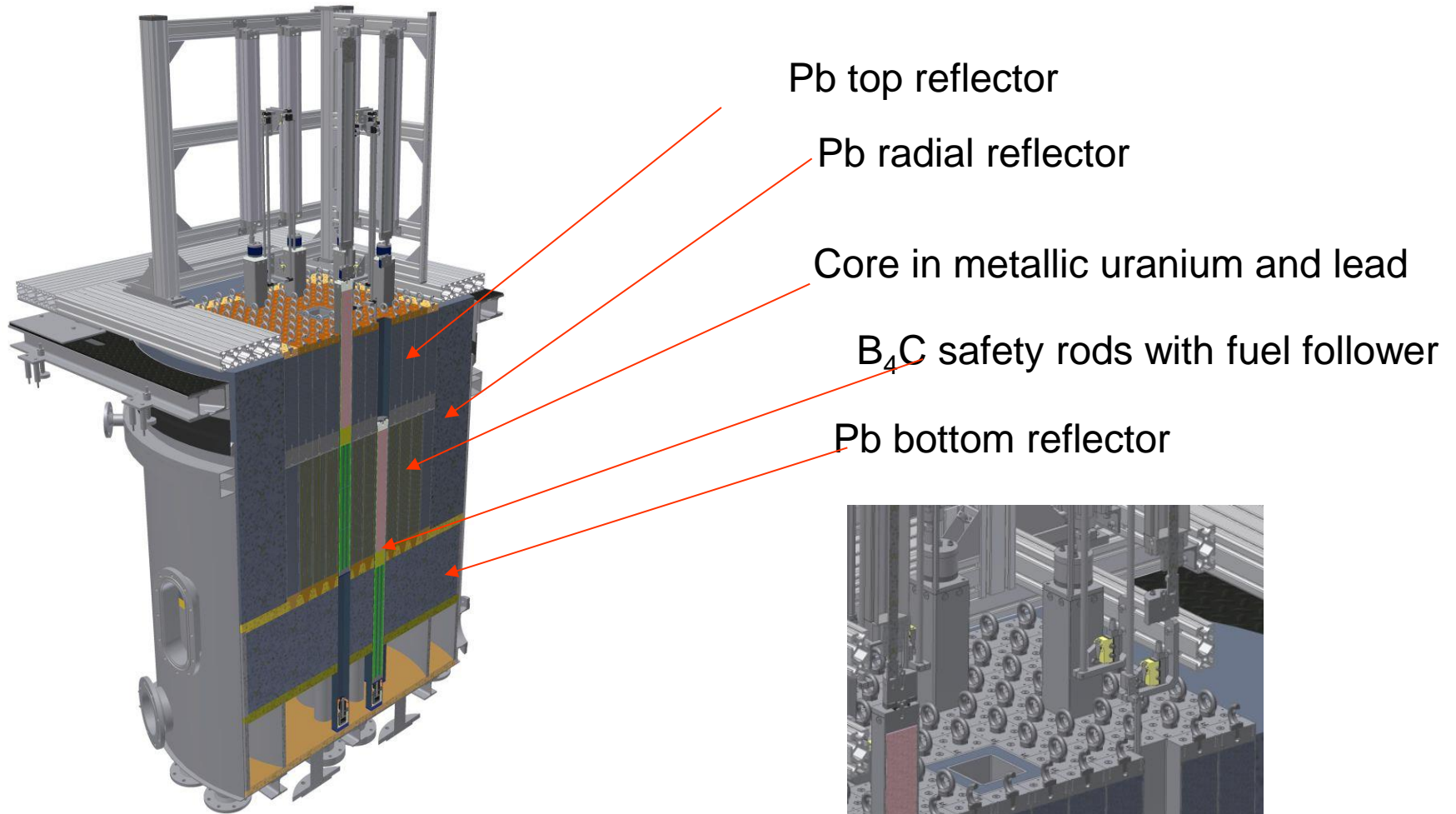
- Many questions from the safety authorities on MYRRHA related topics
 - Accelerator
 - LBE technology
 - Neutronics
 - Code use, verification & validation
- All gather in “Focus points”
 - Questions to be answered in written form
 - Q&A sessions

Baby-MYRRHA: GUINEVERE at VENUS



VENUS- new Fast core

Fast core based on metallic Uranium and solid lead



- P&T should allow us to make nuclear energy more sustainable but it requires
 - R&D efforts that culminate in demo facilities
 - Synergies between countries/regions (see INPRO/GAINS, INPRO/SYNERGIES, EC-FP6 PATEROS, EC-FP7 ARCAS)
- MYRRHA can serve as
 - Prototype ADS
 - Fast neutron irradiation facility (in support of fission and fusion)
 - Technology demonstrator for LBE and Pb technology
- Development of MYRRHA has triggered many R&D programmes