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The MYRRHA project: Current design status & Evolution ADS to FR system

Didier De Bruyn

Nuclear Research Centre of Belgium
SCK•CEN
Belgium

didier.de.bruyn@sckcen.be

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Outline

- History of the project;
- MYRRHA ADS design in 2005;
- Evolution of MYRRHA into XT-ADS;
- Further evolution to a critical facility FASTEF;
- --- exercise : what has to be modified ? ---
- Finally FASTEF specifications.

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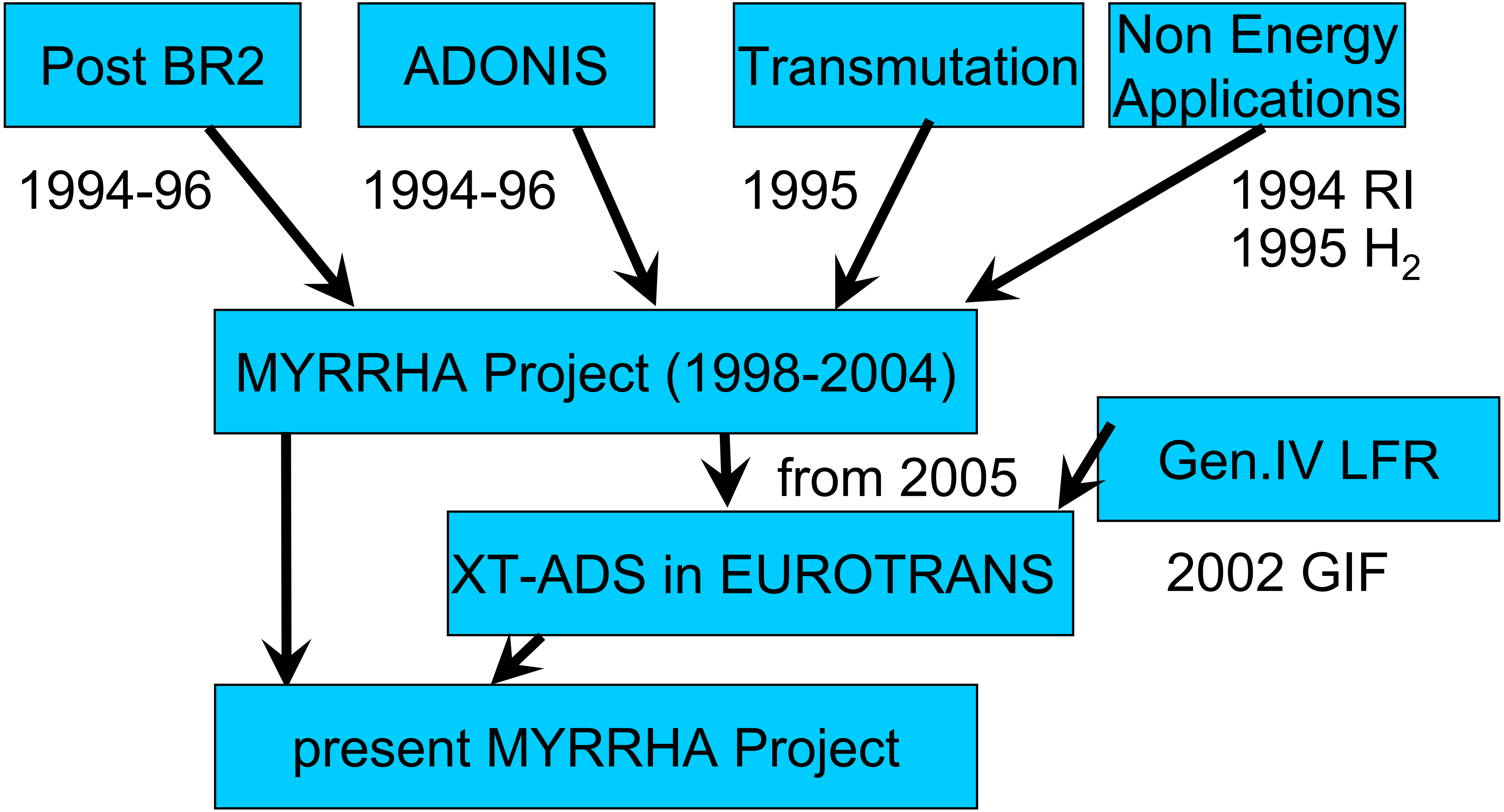
Genesis of MYRRHA project & its evolution



Why MYRRHA at SCK•CEN ?

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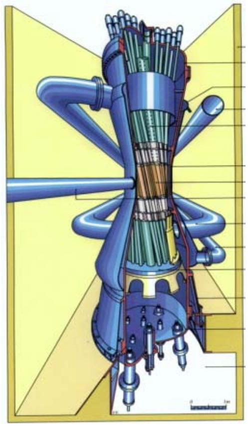
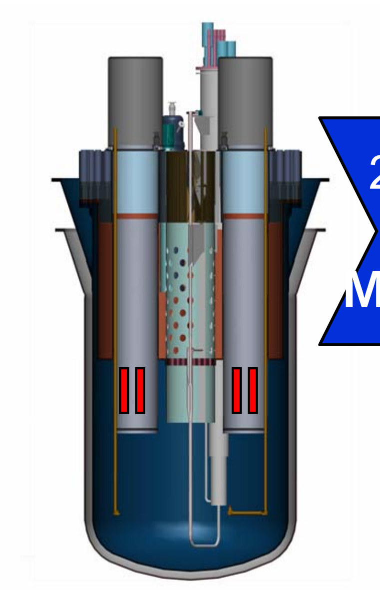


1962

BR2

Fast Neutron Material Testing Reactor (fission)	Fuel testing For LWR & GEN II/GEN III	Irradiation Services: -Medical RI - Silicium doping - Others



2020

MYRRHA

Very Fast Neutron Material Testing Reactor (fission + fusion)	ADS-Demo + P&T testing (Partitioning & Transmutation)	Irradiation Services: -Medical RI - Silicium doping - Others
	Fuel testing For LFR GEN IV	

LFR GEN IV technology demonstration

What is MYRRHA going to be ?

- A flexible neutron irradiation testing facility as successor of the SCK•CEN MTR BR2 (100 MW)
- An attractive fast spectrum testing facility in Europe for Gen.IV and Fusion
- A full step ADS demo facility and P&T testing facility
- A technological prototype as test bench for LFR Gen.IV
- An attractive tool for education and training of young scientists and engineers
- A medical radioisotope production facility
- A fundamental research facility at the accelerator

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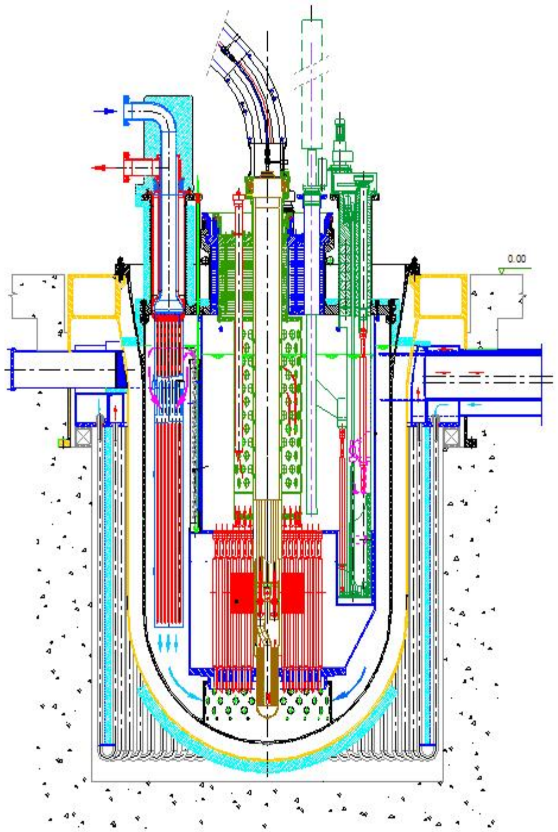
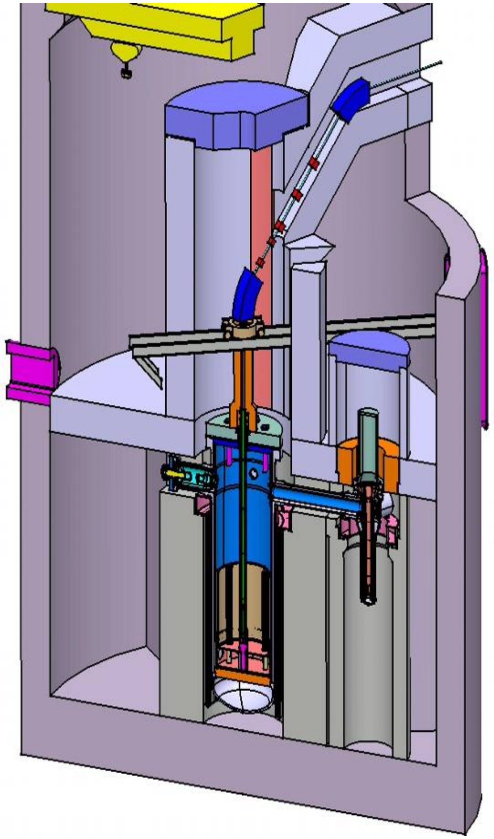
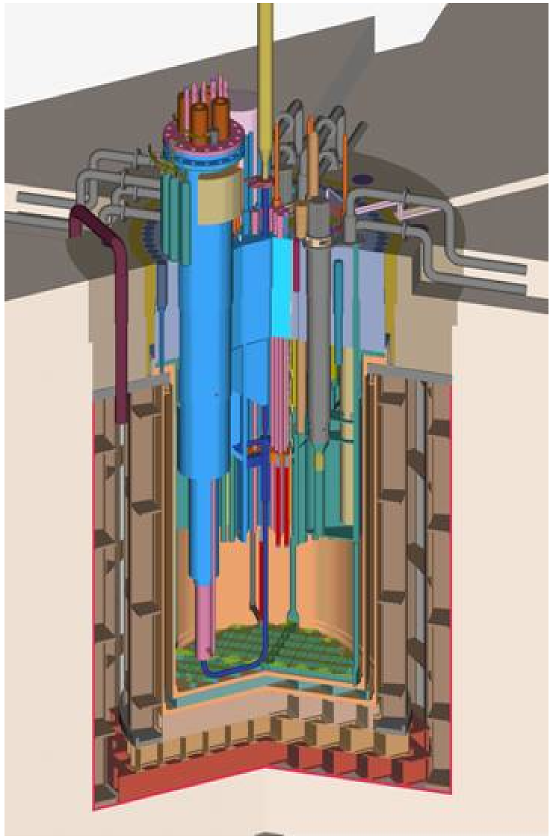
Design Concepts – FP5 PDS-XADS project

80MWth Pb-Bi cooled XADS	80MWth Gas-cooled XADS	50MWth Pb-Bi cooled MYRRHA
		
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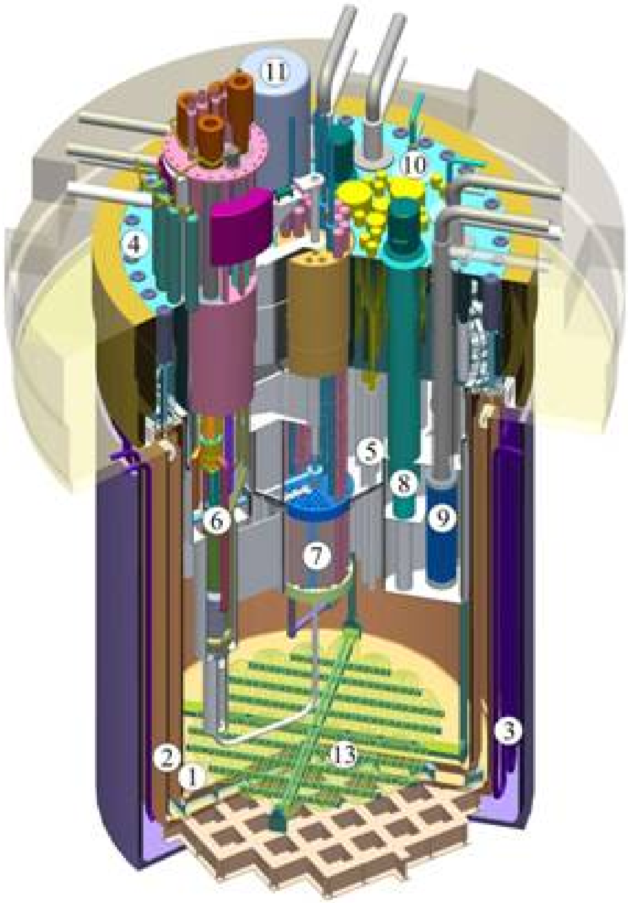
MYRRHA 2005 overall configuration



1. inner vessel
2. guard vessel
3. cooling tubes
4. cover
5. diaphragm
6. spallation loop
7. sub-critical core
8. primary pumps
9. primary heat exchangers
10. emergency heat exchangers
11. in-vessel fuel transfer machine
12. in-vessel fuel storage
13. coolant conditioning system

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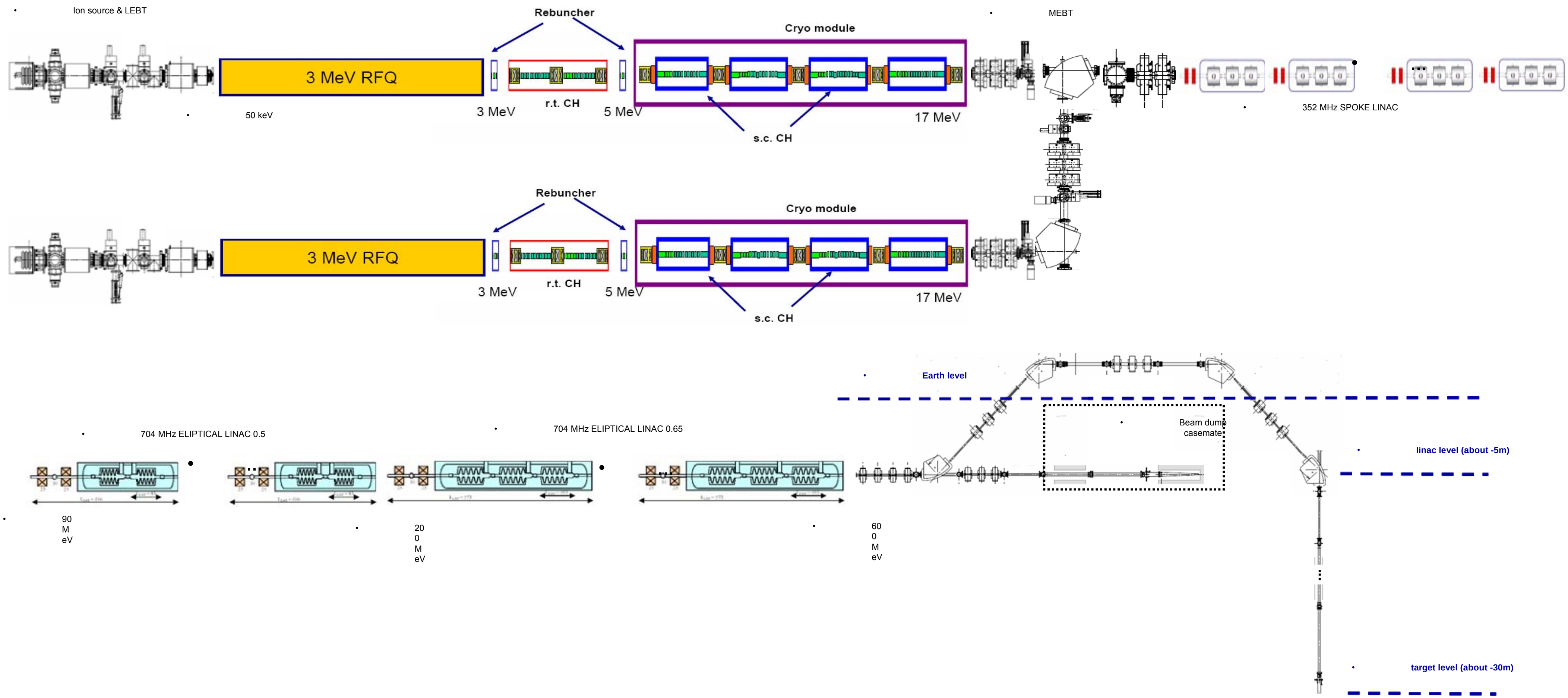
From FP5 PDS-XADS to FP6 IP_EUROTRANS

FP	Design Concepts			Objectives
FP5	**XADS (Pb-Bi)** 80 MW(th) 110 W/cm single batch loading	**XADS (Gas)** 80 MW(th) 250 W/cm single batch loading	**MYRRHA (Pb-Bi)** 50 MW(th) 500 W/cm multi batch loading	**XADS** Demonstration of technological feasibility of an ADS system
FP6	**European Transmutation Demonstration (ETD)** advanced design	**XT-ADS** < 100 MW(th) 250 - 300 W/cm multi batch loading		**XT-ADS** Short-term demonstration of transmutation on a sizable scale and of the ADS behaviour
	conceptual design, economics, scalability	**EFIT** Several 100 MW(th) 250 - 300 W/cm multi batch loading		**EFIT** Long-term transmutation on an industrial scale

IP_EUROTRANS Objectives

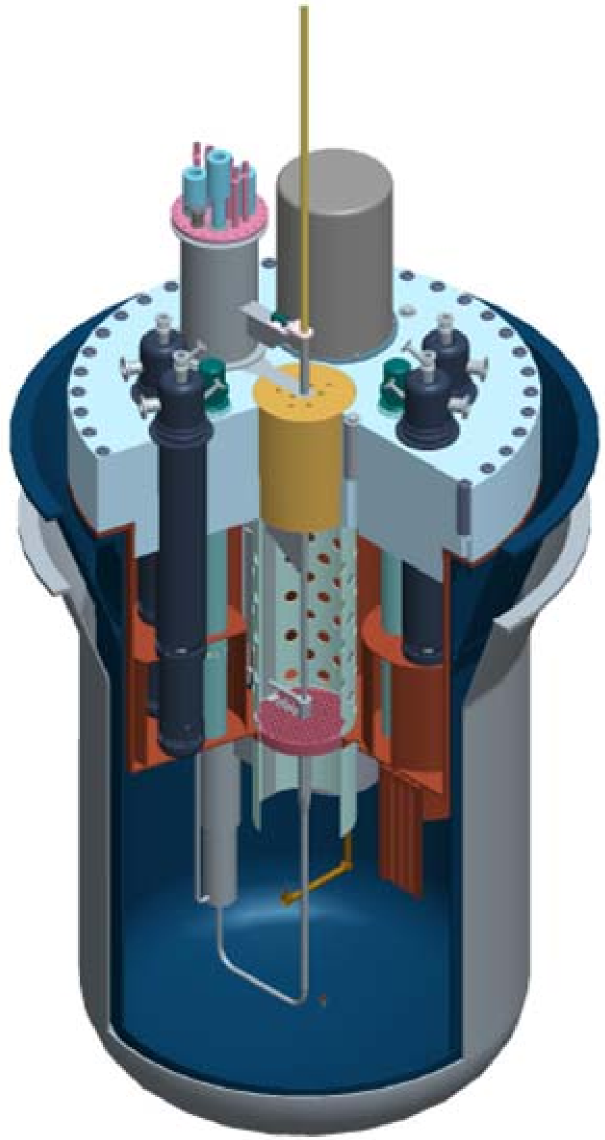
- First, to define a long-term European Transmutation Demonstrator (ETD) of several hundred MWth called EFIT (for European Facility on Industrial scale Transmuter) able to transmute nuclear waste on a industrial scale; EFIT will be cooled either with Lead or with Helium.
- Then, to design a short-term eXperimental Transmuter based on ADS concept (ETD/XT-ADS) able to demonstrate both the feasibility of the ADS concept and to accumulate experience when using dedicated fuel sub-assemblies or dedicated pins within a MOX fuel core.
- Both plants will rely in a LINAC accelerator (although of different sizes) since it is the only type able to achieve the requested reliability.

The LINAC layout



The XT-ADS machine

- MOX-fueled, Pb-Bi cooled
- MYRRHA 2005 as input
- Accelerator
  - 600 MeV x 2.5 mA
- Spallation target
  - Windowless
- Subcritical
  - $k_{eff} \approx 0.95$
- Power
  - 50-100 MWth



XT-ADS (2009) versus MYRRHA (2005) (1/3)

	XT-ADS	MYRRHA
Design level	Advanced design	Conceptual design
Coolant	Pb-Bi	Pb-Bi
Primary System	Integrated	Integrated
Core Power	57 MWth	~50 MWth
Core Inlet Temp	300°C	200°C
Core Outlet Temp	400°C	340°C
Target Unit interface	Windowless	Windowless
Target Unit geometry	Off-center	Off-center
Fuel	MOX (accept for a few MA Fuel Assemblies)	MOX (accept for a few MA Fuel samples)
Fuel Power density	700 W/cm³	~1000 W/cm³
Fuel pin spacer	Grid	Wire
Fuel Assembly type	Wrapper	Wrapper
Fuel Assembly cross section	Hexagonal	Hexagonal

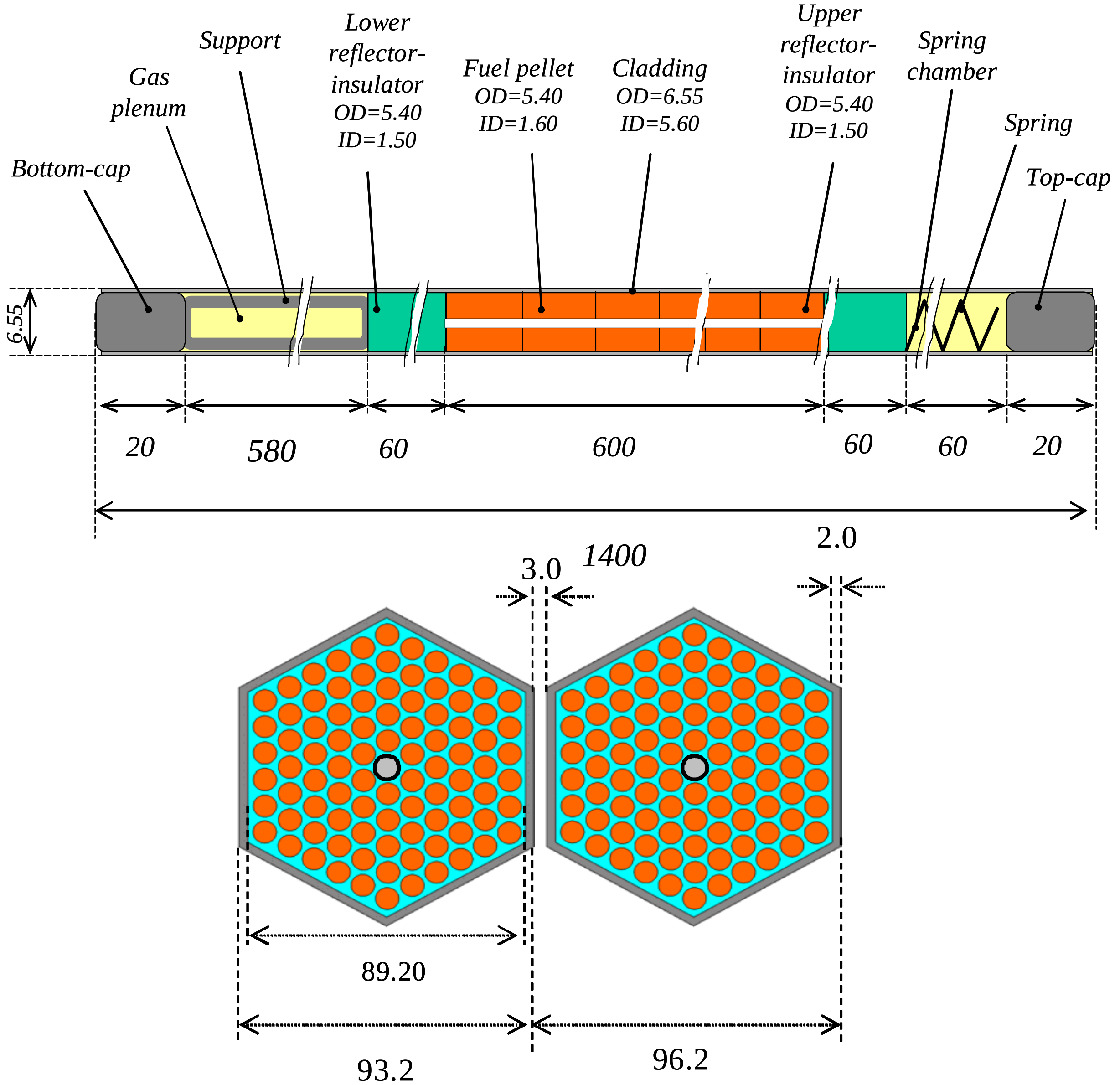
XT-ADS (2009) versus MYRRHA (2005) (2/3)

	XT-ADS	MYRRHA
Fuel loading	Bottom (top was studied)	Bottom
Fuel monitoring	T and FF (per FA)	T and FF (per FA)
External fuel handling	RH oriented	RH oriented
Primary coolant circulation in normal operation	Forced with mechanical pumps	Forced with mechanical pumps
Primary coolant circulation for DHR	Natural + Pony motor	Natural circulation
Secondary coolant	Low pressure boiling water	High pressure water / Low pressure boiling water
Reactor building	Below grade	Below grade
Seismic design	was studied; is ok	TBD (site specific)
Structural Material	T91 and A316L	T91 and A316L
Accelerator	LINAC (600 MeV*2.5 mA or 350 MeV*5 mA)	LINAC (350 MeV*5 mA)
Beam Ingress	Top	Top

XT-ADS (2009) versus MYRRHA (2005) (3/3)

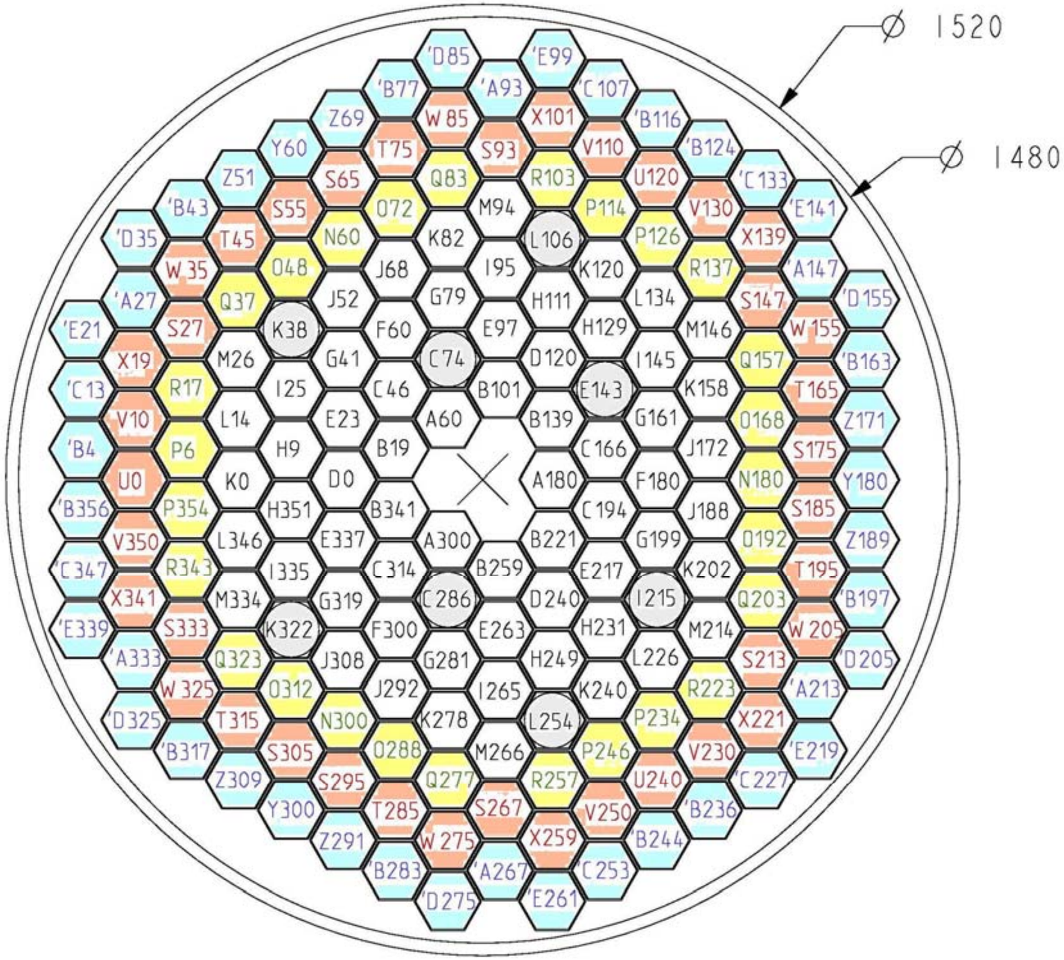
	XT-ADS	MYRRHA
MOX Fuel type	from reprocessing	reactor grade
Fuel pin hole	yes (Φ=1.6 mm)	no
Pu content	~35%	20 & 30%
Fuel Assembly centre – to centre	96.2 mm	87.0 mm
FA in core	75	45
number of possible IPS	8	17
Vessel type	hanging	standing
Vessel bottom	elliptical	flat
Number of groups HX + PP	2	4
ultimate decay heat removal	vault cooling system	emergency cooling loops

XT-ADS fuel pin & fuel assembly



XT-ADS reference core (1/2)

- 99 'MYRRHA' positions :
  - 72 positions for fuel assemblies (8 IPS positions included) (white and grey)
  - 27 additional positions for fuel assies or dummy assies (filled with LBE) (yellow)
- 84 additional (orange and light blue)
- 183 positions in total



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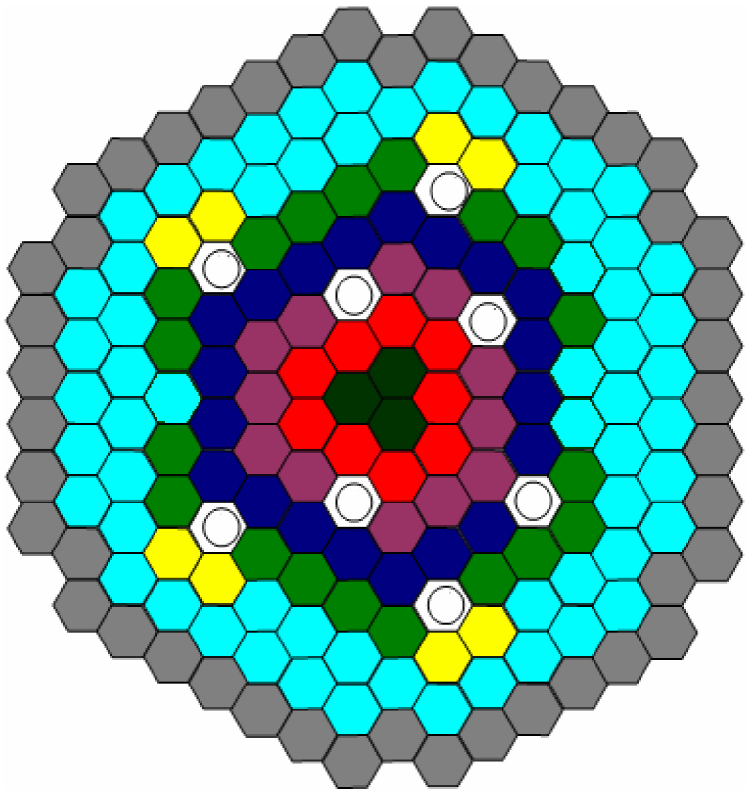
XT-ADS reference core (2/2)

Parameter	Unit	Value
Proton beam energy	MeV	600
Proton beam current	mA	2.1
Proton beam deposited heat	MW	0.94
Total neutron yield per incident proton		15.3
Neutron source intensity	10^{17} n/s	2.23
Initial fuel mixture	MOX	$(U\text{-}Pu)O_2$
Initial Pu enrichment	wt%	35
k_{eff}		0.955
k_S =		0.960
MF = $1/(1-k_S)$		25
Source importance φ^*=		1.12
Thermal power	MW	57
Specific power	kW/kgHM	66.22
Peak linear power (hottest pin)	W/cm	225
Average linear power (hottest pin)	W/cm	146
Max Φ_{total} in the core near hottest pin		3.1
Max $\Phi_{>1MeV}$ in the core near hottest pin	10^{15} n/(cm^2.s)	0.50
Max $\Phi_{>0.75\ MeV}$ in the core near hottest pin		0.66



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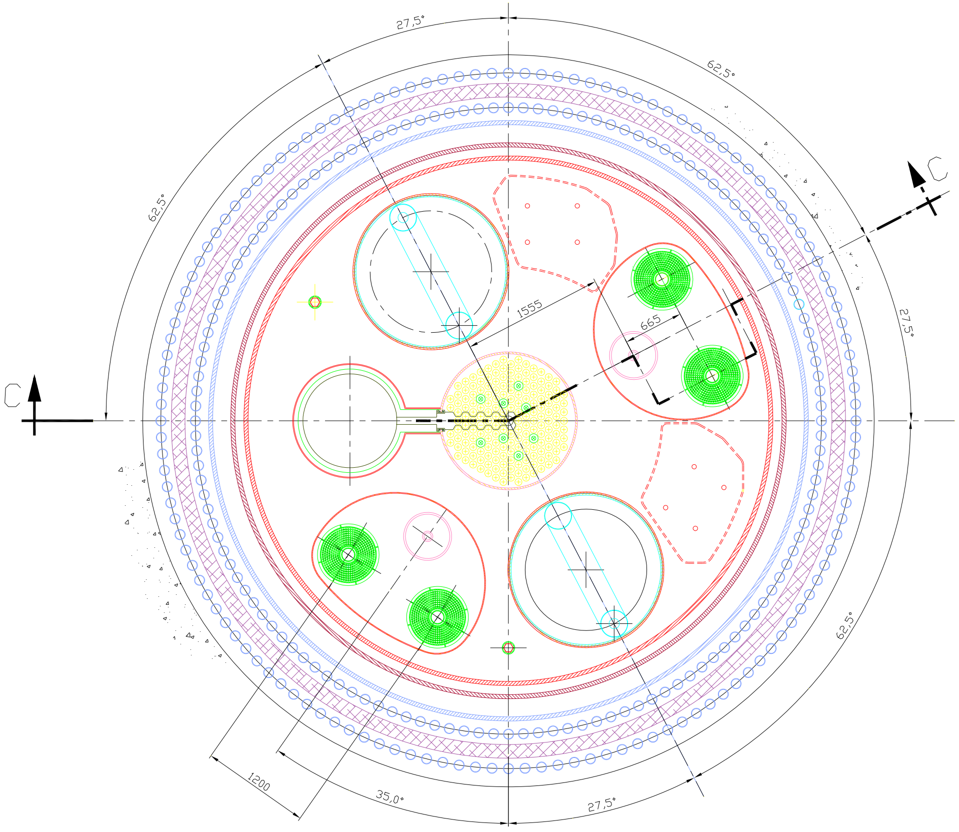
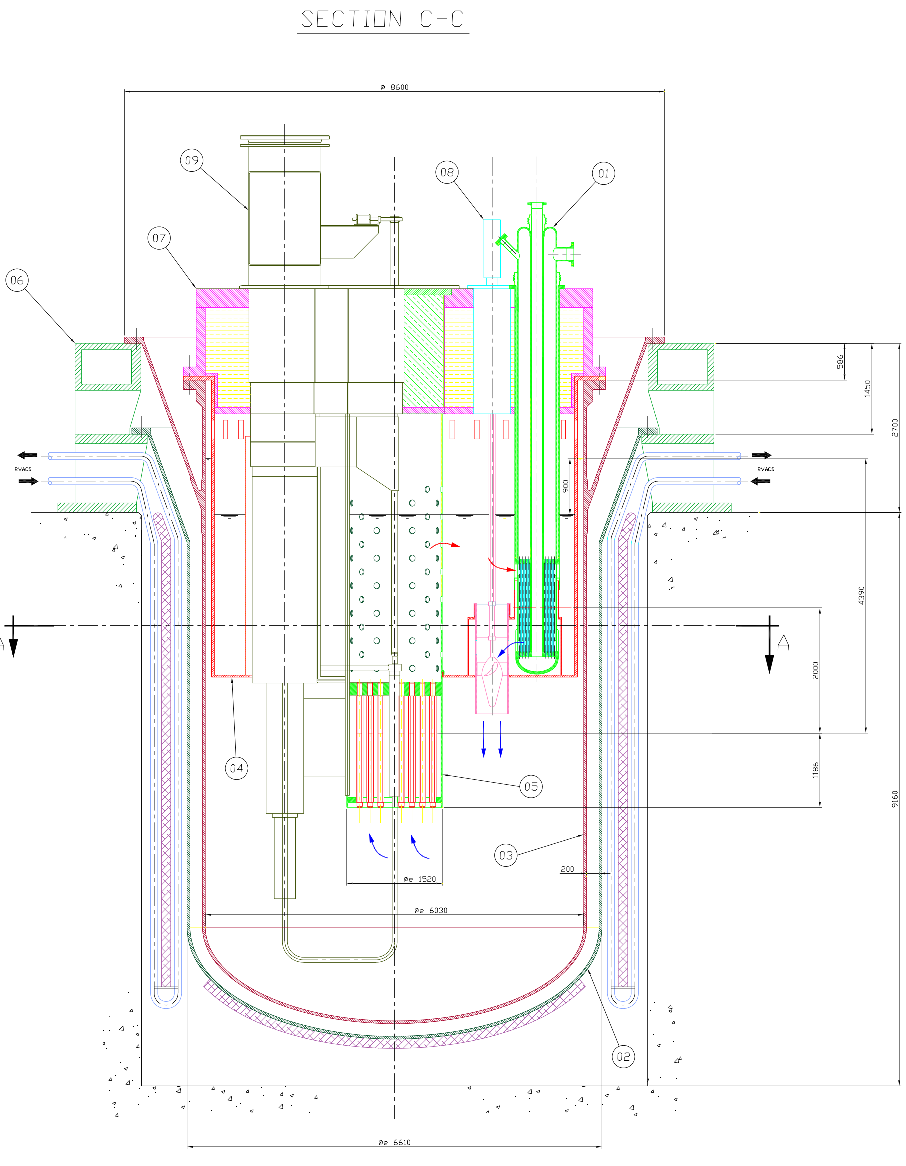
XT-ADS reactor assembly

1. PHX (2X2)
2. Safety Vessel
3. Reactor Vessel
4. Inner Vessel
5. Core Barrel
6. Support
7. Reactor Cover
8. Primary Pumps (2X1)
9. Spallation loop

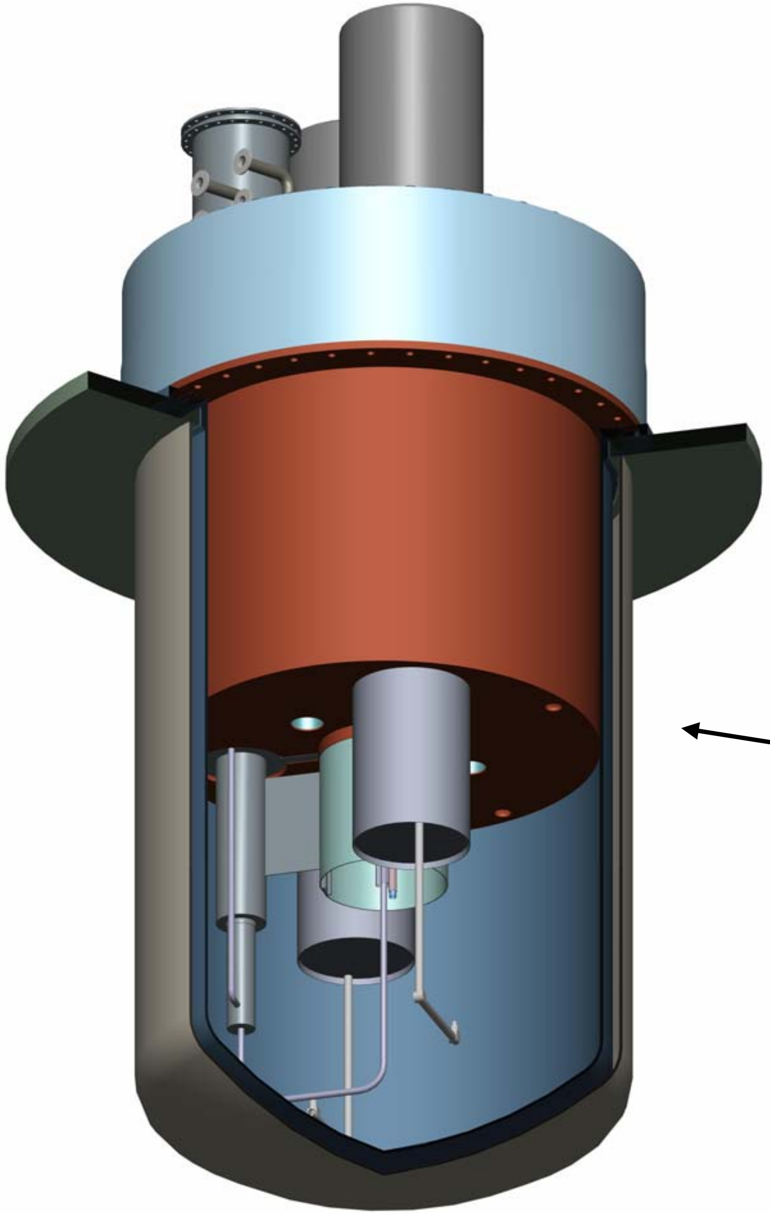


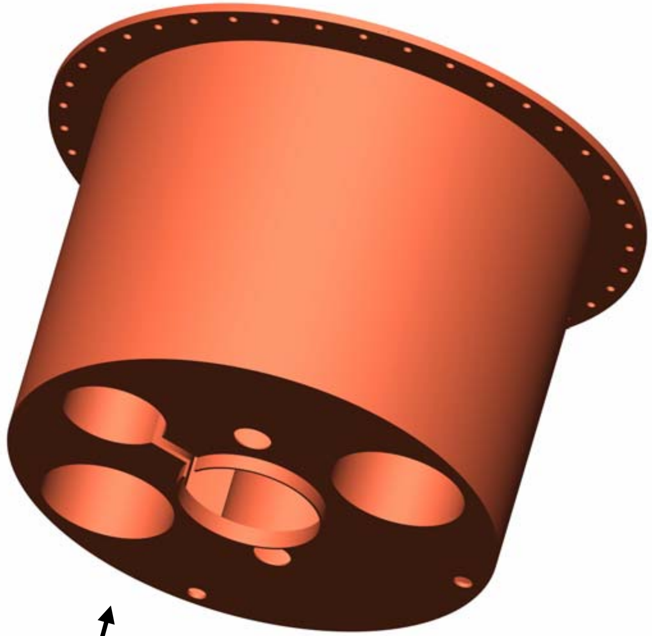


XT-ADS conclusions and perspectives (1/2)

- For XT-ADS we have been using MYRRHA (version 2005) as a starting sheet;
- The EUROTRANS partners have issued now (2009) a revised sheet;
- The most important revision concern the plant size
  - Power to be evacuated by the HEX: 75 MWth
  - Accelerator: 600 MeV x 2.5 mA
- And a simplification of the internals (HEX, diaphragm)
- While other assumptions have been confirmed, among others:
  - Spallation target: Windowless one
  - Subcritical core: $k_{eff} \approx 0.95$
  - MOX-fueled, Pb-Bi cooled
  - Fuel loading from the bottom

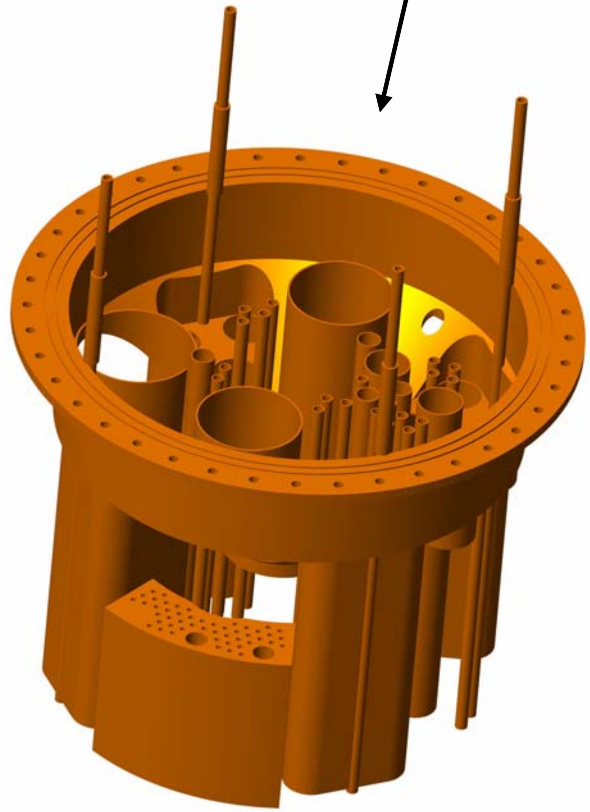
Example: the simplified diaphragm





XT-ADS

MYRRHA



XT-ADS conclusions and perspectives (2/2)

These characteristics give to the plant :

- More flexibility to the irradiation performance of the plant
- An improved Safety
  - reduced damage to core barrel and cover plate;
  - better transient behaviour

The plant will require further analysis within IP_EUROTRANS

- to finalize documentation (design, safety, cost evaluation)
- ⇨ trying to get financial support to build it is the final aim

While remaining topics will be studied in the next programmes

- see later in this presentation

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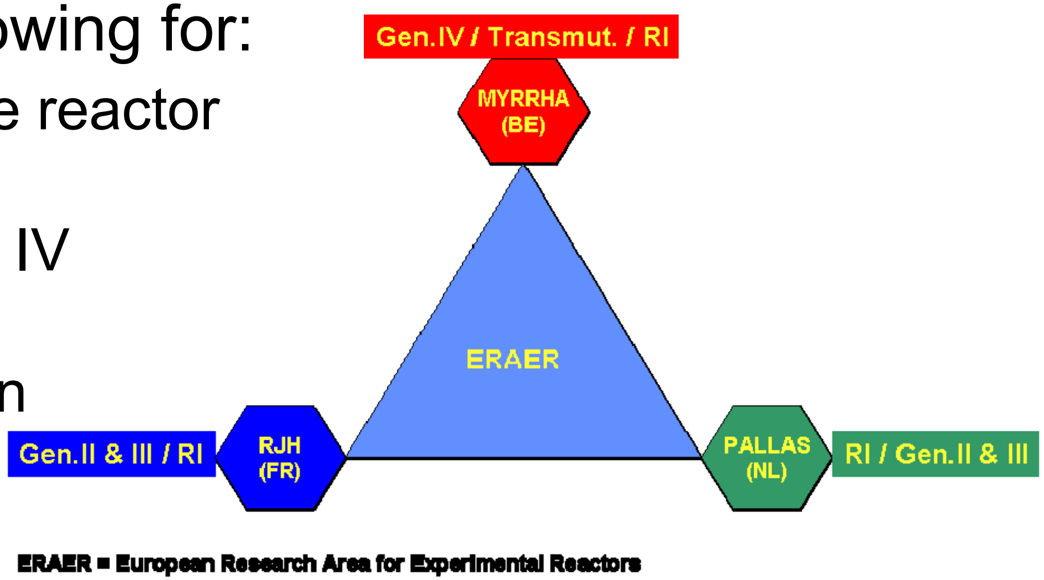
MYRRHA/FASTEF objectives (1/2)

- To be operated as a flexible fast spectrum irradiation facility working in subcritical and critical mode allowing for:
  - fuel developments for innovative reactor systems;
  - material developments for GEN IV systems;
  - material developments for fusion reactors;
  - radioisotope production;
  - industrial applications, such as Si-doping;
  - To allow the study of the efficient transmutation of high-level nuclear waste (MA) requesting high fast flux intensity ($\Phi_{>0.75MeV}$ = 10^{15} $n.cm^{-2}.s^{-1}$);



MYRRHA/FASTEF objectives (2/2)

- To demonstrate the ADS full concept by coupling the three components (accelerator, spallation target and sub-critical reactor) at reasonable power level to allow operation feedback, scalable to an industrial demonstrator;
- To contribute to the demonstration of LBE technology and to demonstrate the critical mode operation of a heavy liquid metal cooled reactor as an alternative technology to SFR

MYRRHA/FASTEF implementation (1/2)

- 2018-2020: Commissioning in both modes of operation
- 2020: Full operation of MYRRHA as ADS during several years
  - Demonstration of ADS concept
  - Operation as a flexible fast spectrum irradiation facility in subcritical mode
  - Contribute to heavy liquid coolant technology in reactor conditions
  - ISOL@MYRRHA (part of beam line devoted to physics applications)

MYRRHA/FASTEF implementation (2/2)

- 202?: Possible decoupling of accelerator and irradiation facility
  - Demonstration of the critical mode operation of a heavy liquid cooled reactor as an alternative technology based on sodium
  - Operation of the flexible fast spectrum facility in critical mode (as current MTR's do today)
  - ISOL@MYRRHA full exploitation of accelerator by the nuclear physics community

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Status of MYRRHA/XT-ADS in 2009

- Primary system at an advanced engineering level
- Safety studies completed, but feedback on MYRRHA/XT-ADS design not implemented
- Balance of Plant and I&C: limited work done
- Further improvements needed to respond to all applications catalogue of the flexible irradiation facility
- Update design characteristics to accommodate both critical and subcritical operation modes

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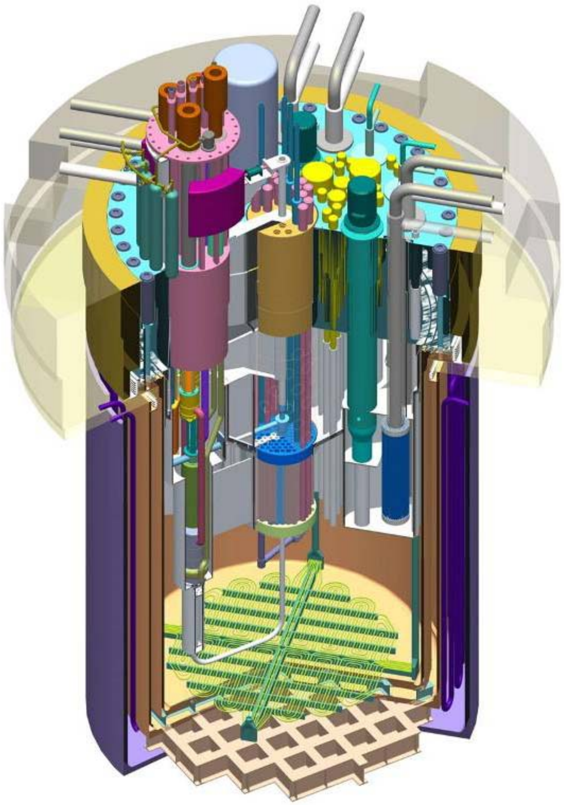
The purpose of CDT project (1/2)

- Build on what has been accomplished up till now in the FP5, FP6 projects and national programmes projects related to this topic (starting from MYRRHA/XT-ADS)
- Obtain an advanced design of all parts of a flexible fast spectrum irradiation facility working in sub-critical mode (ADS) and critical mode
- Set up of a centralised multi-disciplinary team
  - Based at the Mol-site (core group)
  - Members from industry and research organisations

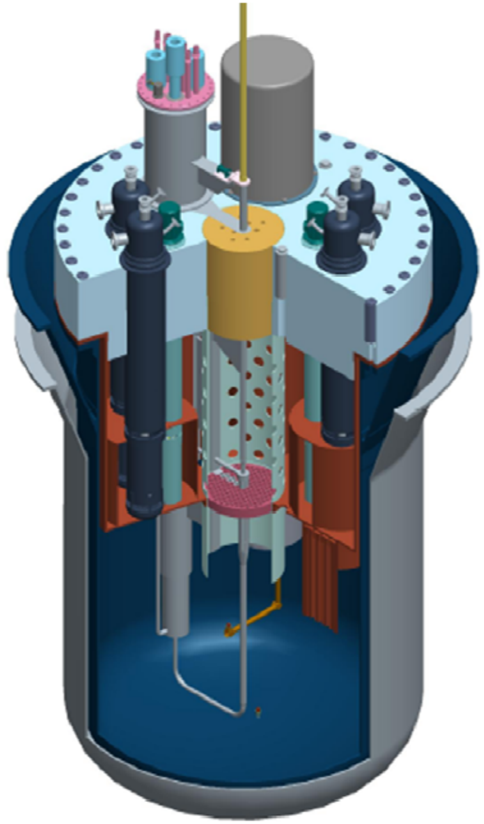
The purpose of CDT project (2/2)



MYRRHA

2005

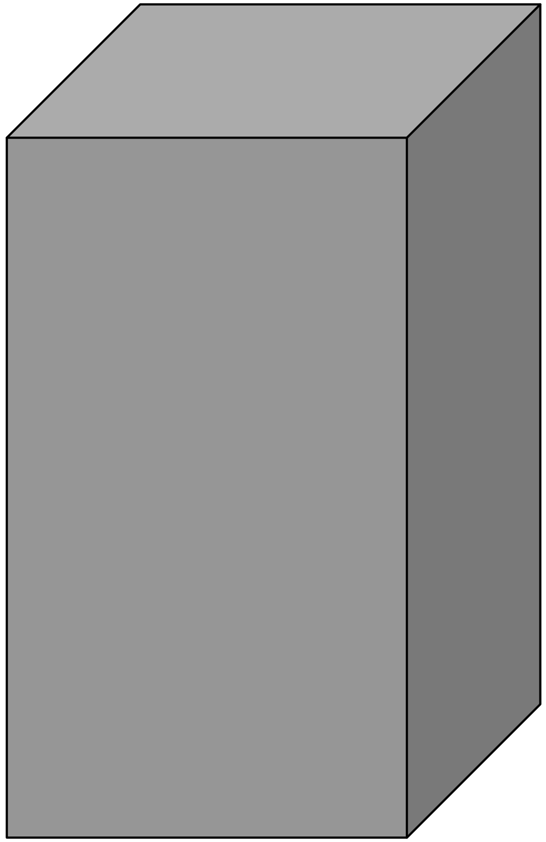
⇨



XT-ADS

2009

⇨



FASTEF

2012

MYRRHA design evolution

Internal exercise

Draft 2 2005	XT-ADS 2006-2009	XT-ADS-HF end 2009	FASTEF 2012
LINAC 350MeV	LINAC 600MeV	LINAC 600MeV	Subcritical design optimisation and critical operation
High power density core Safety ‘ULOF’	Low power density core	Low power density core	
Low core power 52MW	Low core power 57MW	High core power 85MW	
Neutron flux 10^{15}n/cm²s (>0.75MeV)	Neutron flux 7.10^{14}n/cm²s (>0.75MeV)	Neutron flux 10^{15}n/cm²s (>0.75MeV)	

XT-ADS HF core performances

Parameter	(unit)	XT-ADS HF
Core power	MW_{th}	85
Active core average power density	W/cm^3	246
Fast flux above 0.75 MeV	$n/cm^2.s$	10^{15}
Inlet temperature	°C	270
Coolant ΔT	°C	130
LBE Velocity (fuel rod)	m/s	1.72
LBE Velocity (spacer-grid)	m/s	2.50
Temperature at clad surface	°C	496
Maximum linear power	W/cm	372
Pressure drop	mb	1066

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Some ideas ?

- Simplify critical components
- Limit the modifications from ADS to FR
  - Some components should be present from the beginning;
  - Some dimensions (like vessel diameter) cannot be modified;
- Operation of accelerator after decoupling:
  - Plant layout to be adapted

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The FASTEF specifications

- To be added later

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Registered Office: Avenue Herrmann-Debrouxlaan 40 – BE-1160 BRUSSEL
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