The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

1858-14

School on Physics, Technology and Applications of Accelerator Driven Systems (ADS)

19 - 30 November 2007

Engineering Design of the MYRRHA (Design Evolution from MYRRHA to XT-ADS) Part IX

Didier DE BRUYN

Myrrha Project Coordinator,
Nuclear Research Division, SCK CEN
BE-2400 Mol (Belgium)

SCK•CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

MYRRHA

Design evolution from MYRRHA to XT-ADS

Didier De Bruyn

On behalf of the MYRRHA team at SCK•CEN

SCK • CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

Contents

- History of MYRRHA project
- The 2005 design, internally called “Draft-2”
  - Fuel pin & fuel assembly design
  - Neutronics calculations
  - Primary system design
  - System operation, inspection, maintenance
  - (these chapters were presented at the 2005 workshop)
- (afternoon) Exercises on fuel design
- (afternoon) From the 2005 MYRRHA design to the EUROTRANS XT-ADS design

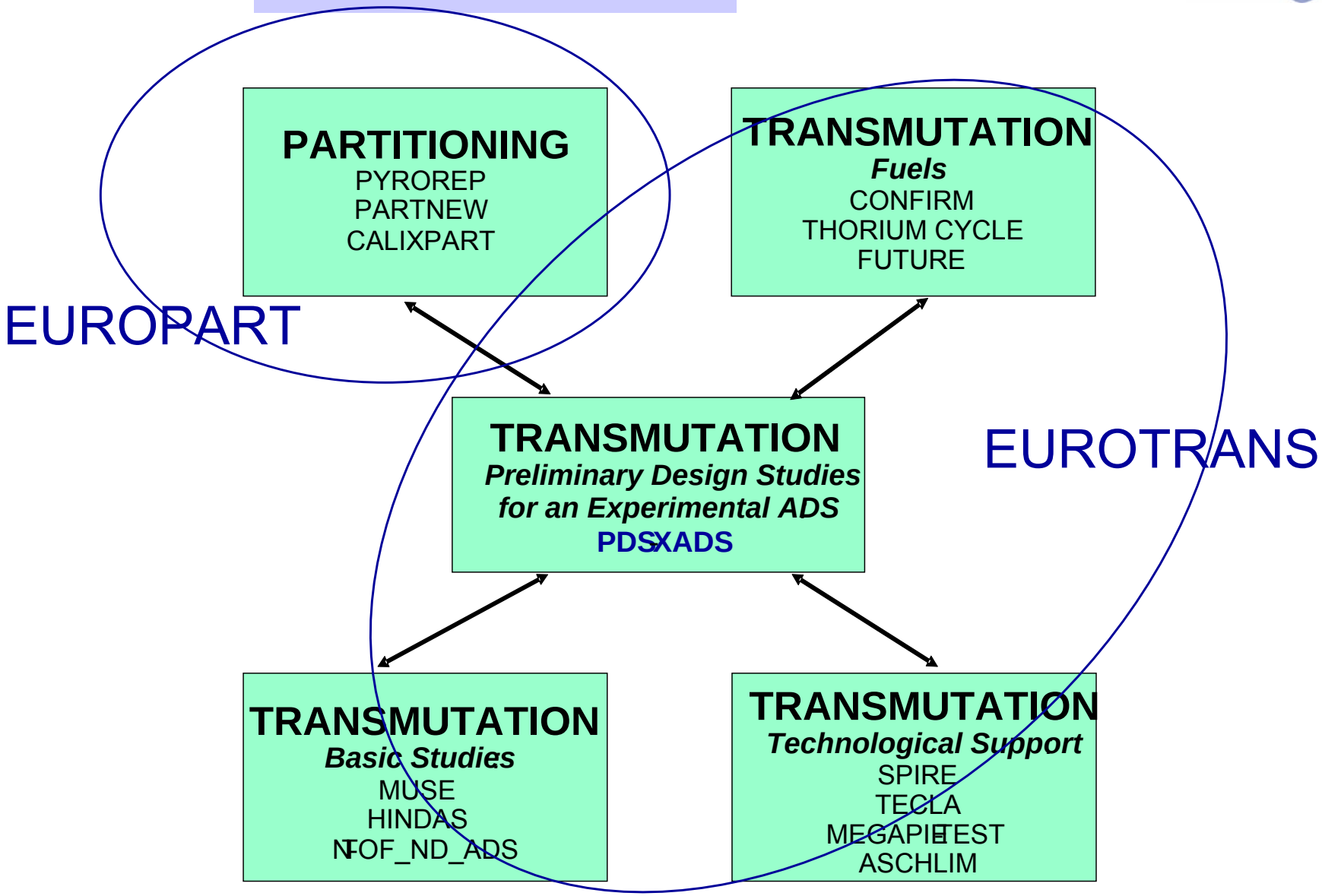
SCK•CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

Some key dates

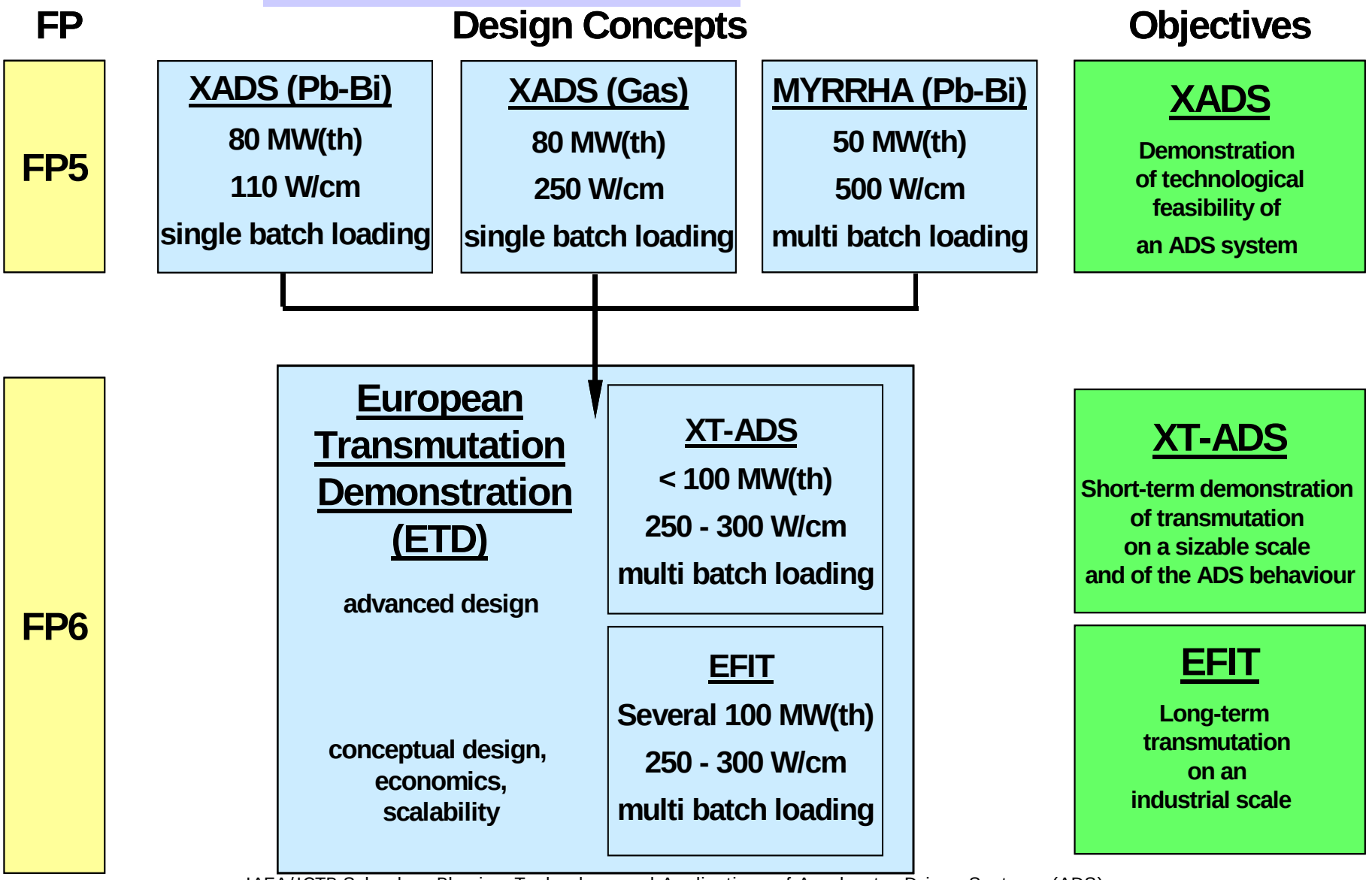
MYRRHA

- MYRRHA started as a collaboration project between SCK•CEN (B) and IBA (B) in 1998,
- … since then enlarged to other partners through bilateral collaboration agreements (CEA, CNRS, ENEA, FZK, CIEMAT, JAEA, ISTC, OTL, IUS_KTU, IPUL, …),
- … since March 2005 serves as basis of the experimental ADS (XT-ADS) under development within the FP6 integrated project EUROTRANS within a consortium of 48 partners,
- … this EUROTRANS project runs until March 2009.

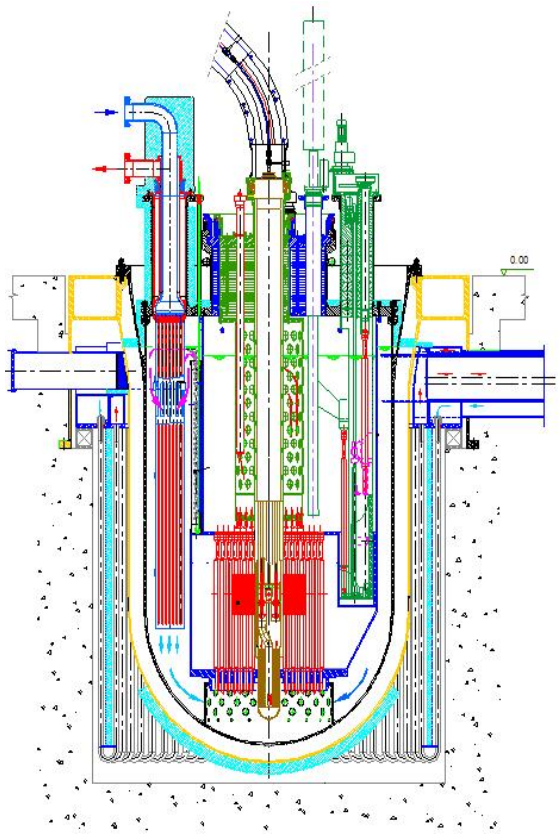
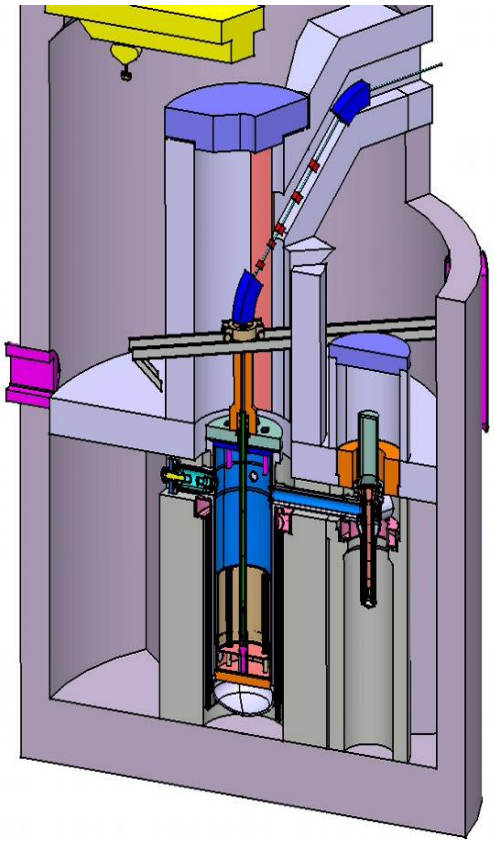
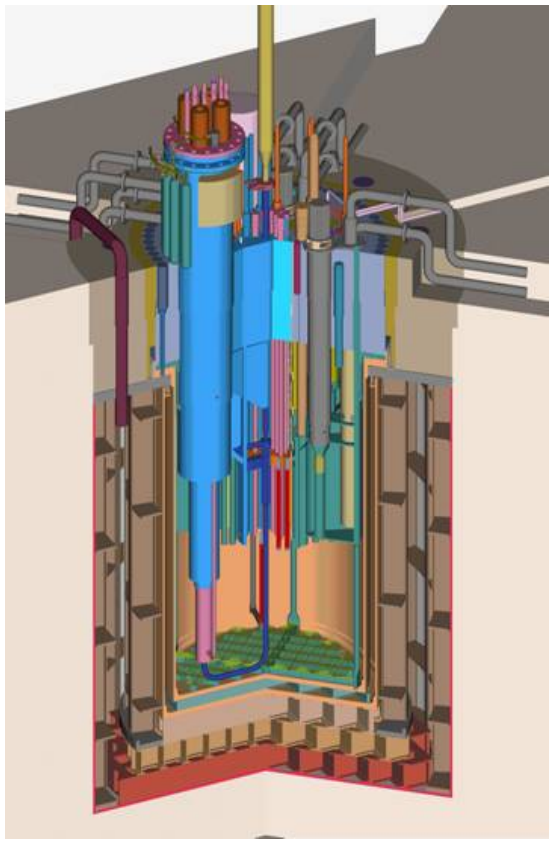
From separate projects in FP5 to integrated ones in FP6



From separate projects in FP5 to integrated ones in FP6



Design Concepts of PDS-XADS

80MWth Pb-Bi cooled XADS	80MWth Gas-cooled XADS	50MWth Pb-Bi cooled MYRRHA
		
Ansaldo	Framatome ANP	SCK•CEN

SCK • CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

XT-ADS versus MYRRHA (1/3)

MYRRHA

	XT-ADS	MYRRHA
Design level	Advanced design	Conceptual design
Coolant	Pb-Bi	Pb-Bi
Primary System	Integrated	Integrated
Power	~70 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

SCK • CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

XT-ADS versus MYRRHA (2/3)

MYRRHA

	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

SCK • CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

XT-ADS versus MYRRHA (3/3)

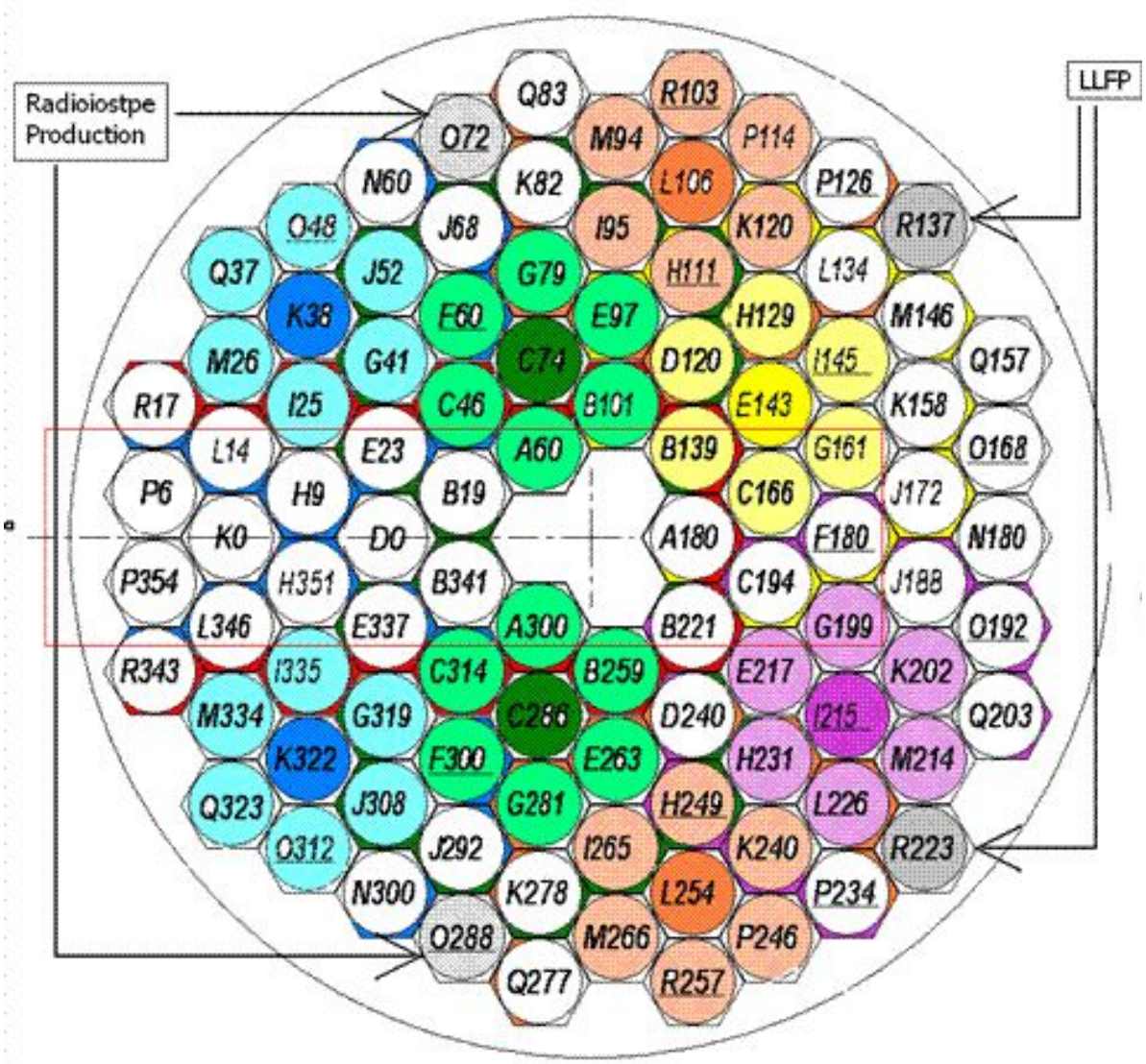
MYRRHA

	XT-ADS	MYRRHA
MOX Fuel type	from reprocessing	reactor grade
Fuel pin hole	yes (Φ=1.6 mm)	no
Pu content	>31%	20 & 30%
Fuel Assembly centre – to centre	96.2 mm	87.0 mm
FA in core	72	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

SCK • CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

MYRRHA core and In-Pile Section configuration

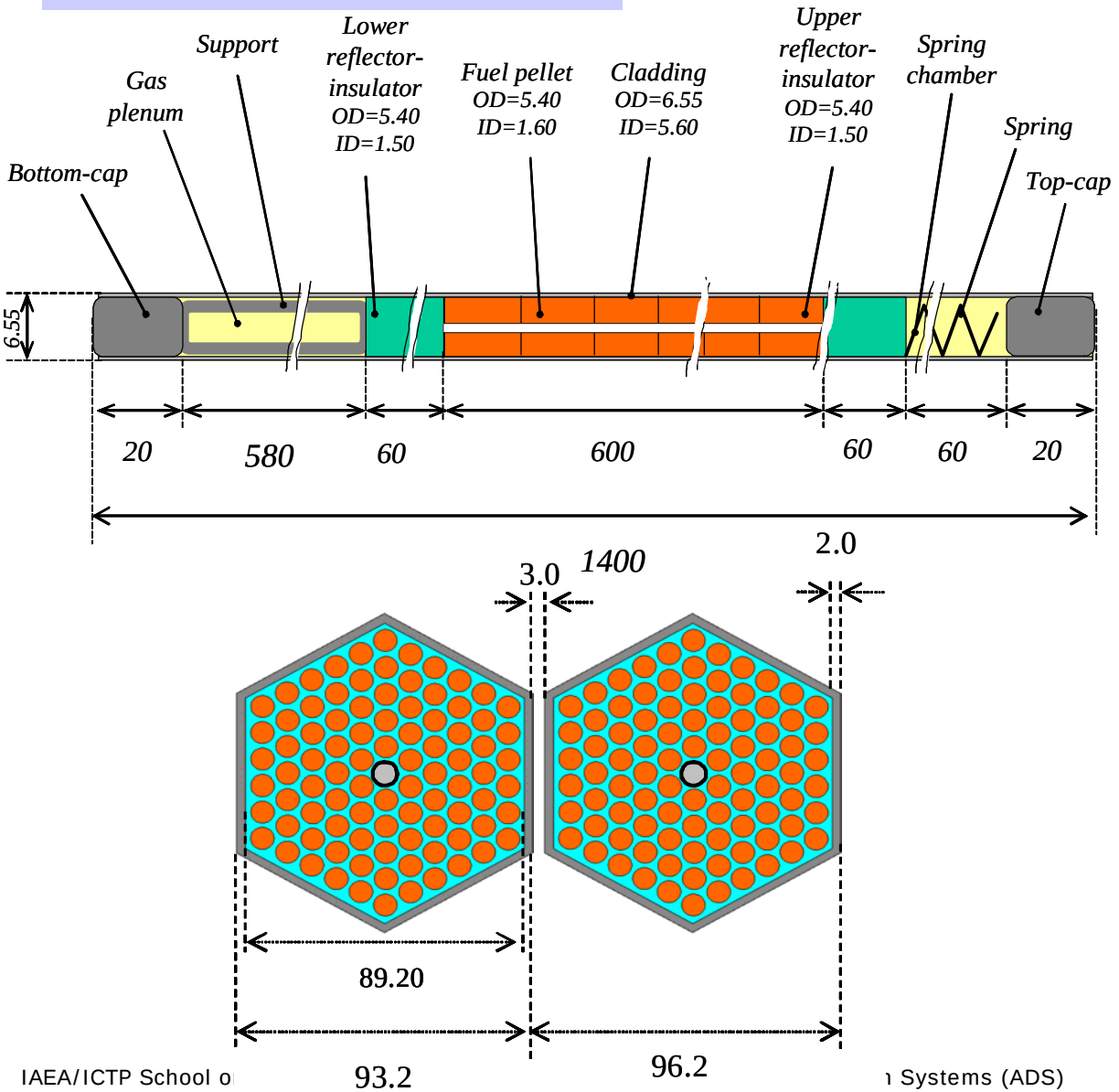
MYRRHA



SCK • CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

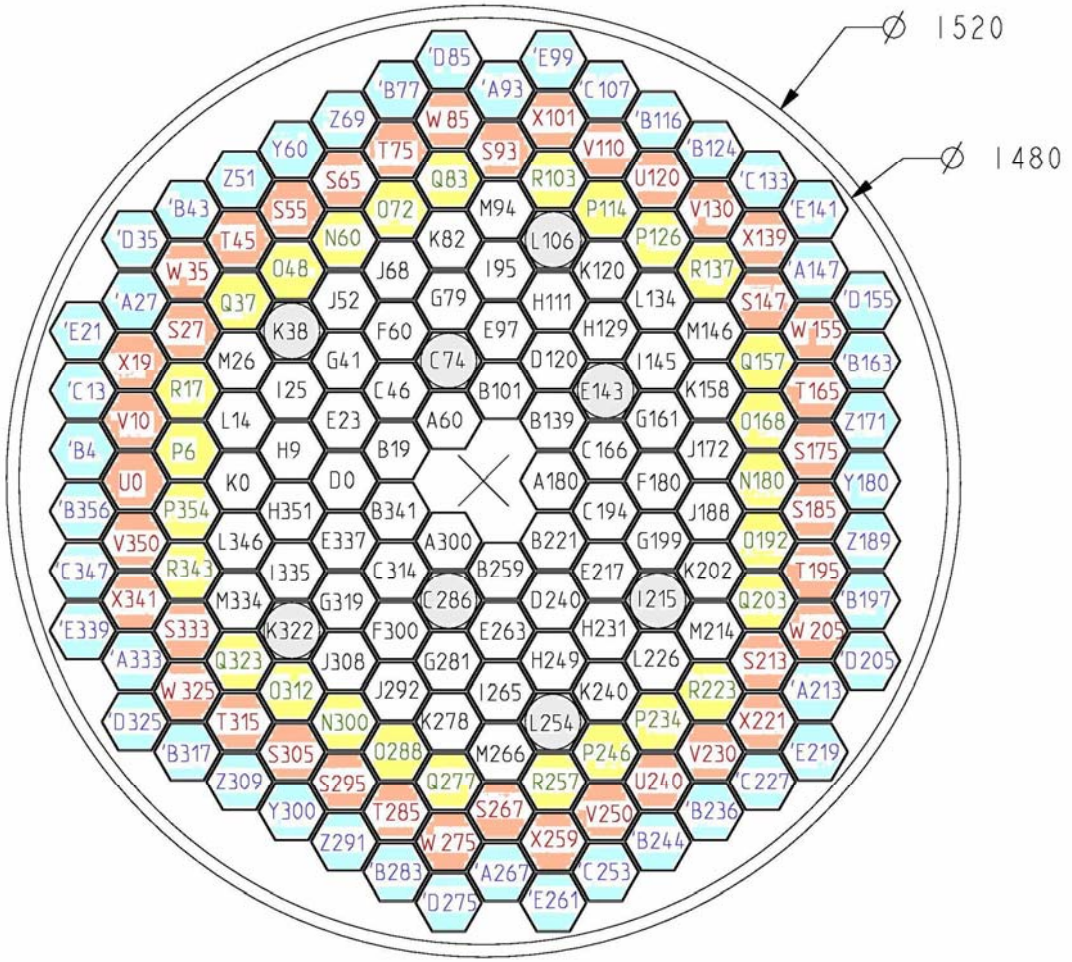
XT-ADS fuel pin & fuel assembly

MYRRHA

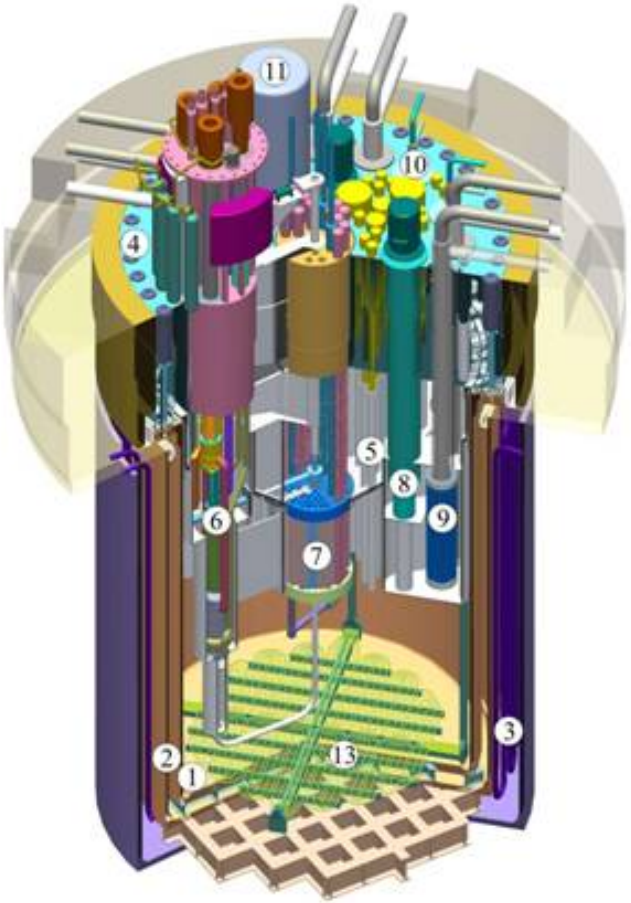


XT-ADS reference core architecture

- 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



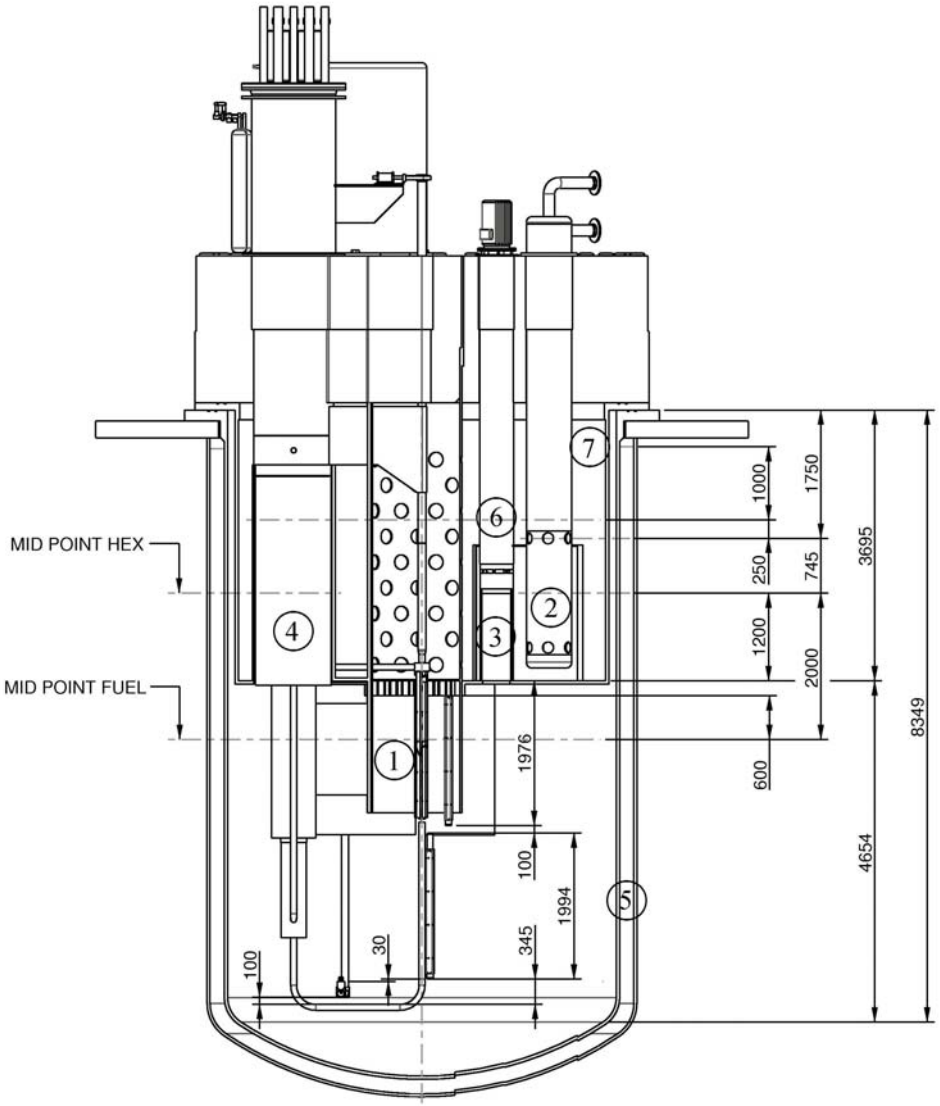
MYRRHA 2005 design: Overall configuration

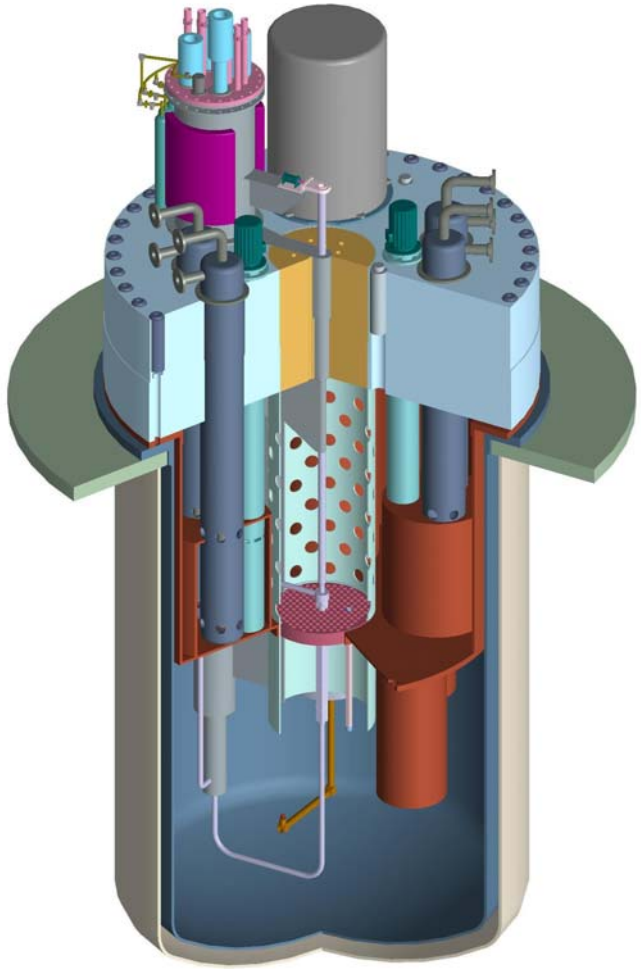


1. inner vessel
2. guard vessel
3. cooling tubes
4. cover
5. diaphragm
6. spallation loop
7. sub-critical core
8. primary pumps
9. primary heat exchangers
10. emergency heat exchangers
11. in-vessel fuel transfer machine
12. in-vessel fuel storage
13. coolant conditioning system

XT-ADS new configuration (1/3)
Vertical section

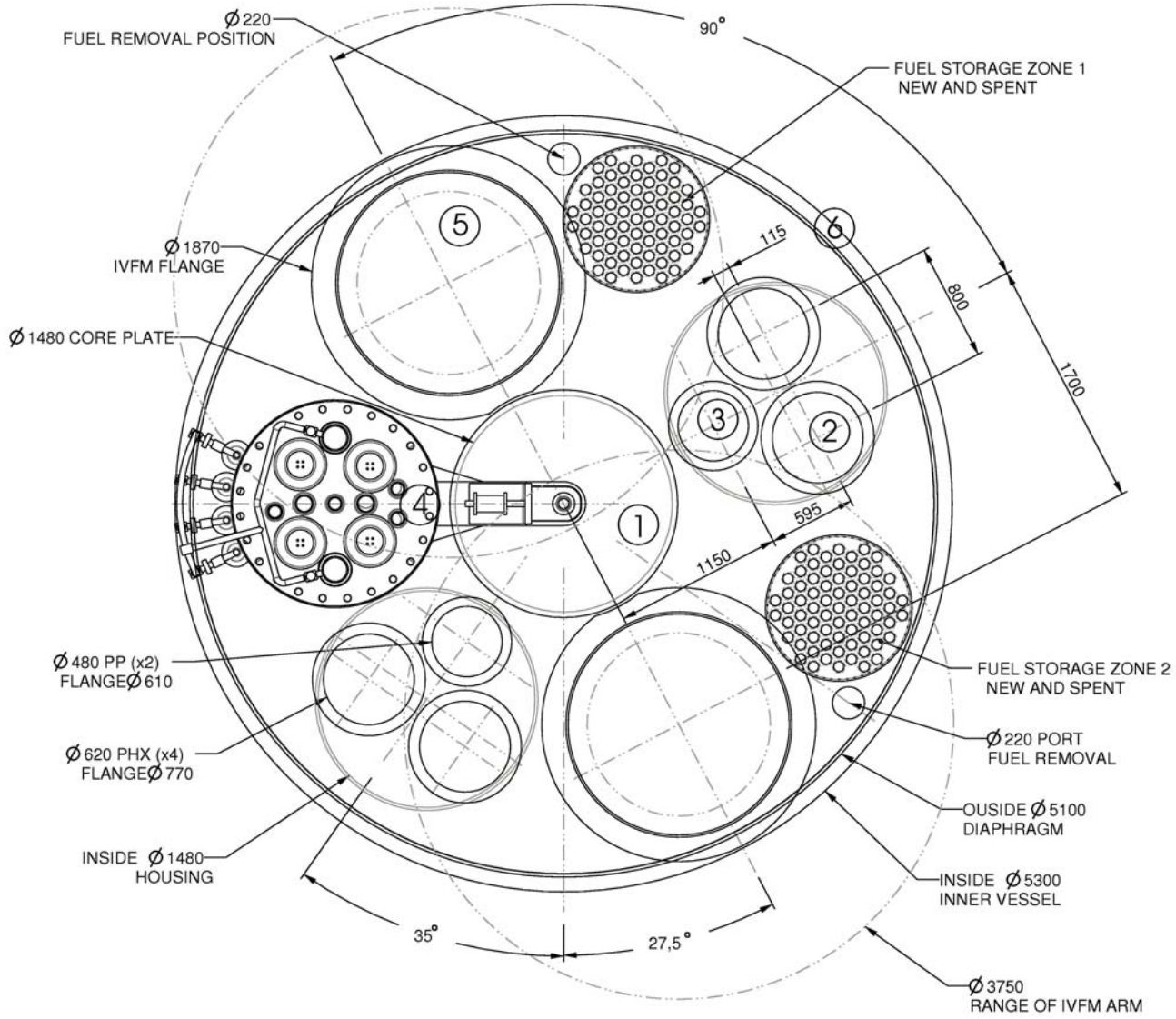
1. Core
2. Heat exchangers (2 x 2)
3. Pumps (2 x 1)
4. Spallation loop
5. Vessels
6. LBE hot level
7. LBE cold level





XT-ADS new configuration (2/3)
Horizontal section

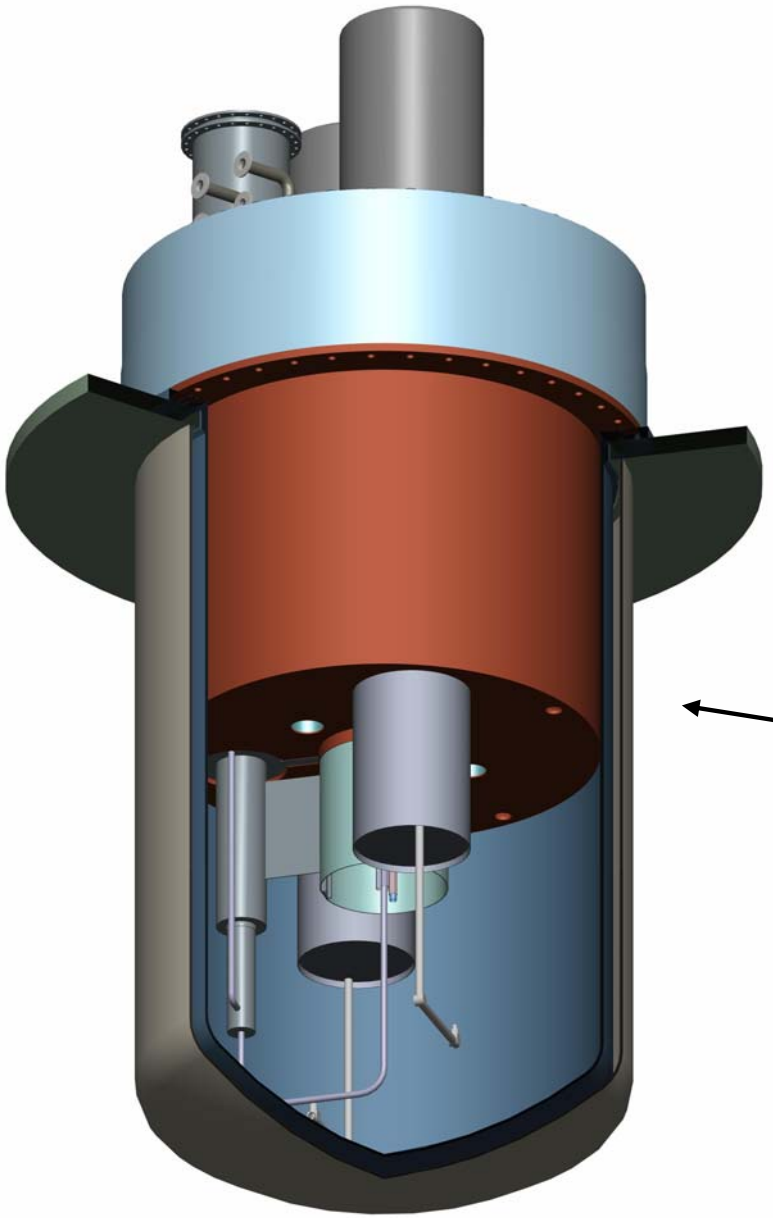
1. Core
2. Heat exchangers (2 x 2)
3. Pumps (2 x 1)
4. Spallation loop
5. Fuel manipulators (2 units)
6. Vessel

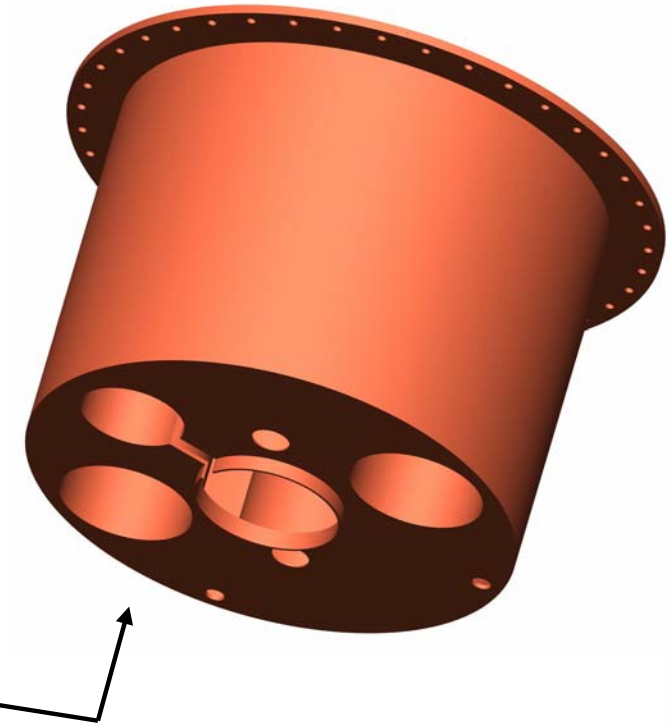


SCK • CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

XT-ADS new configuration (3/3)
The diaphragm has been simplified

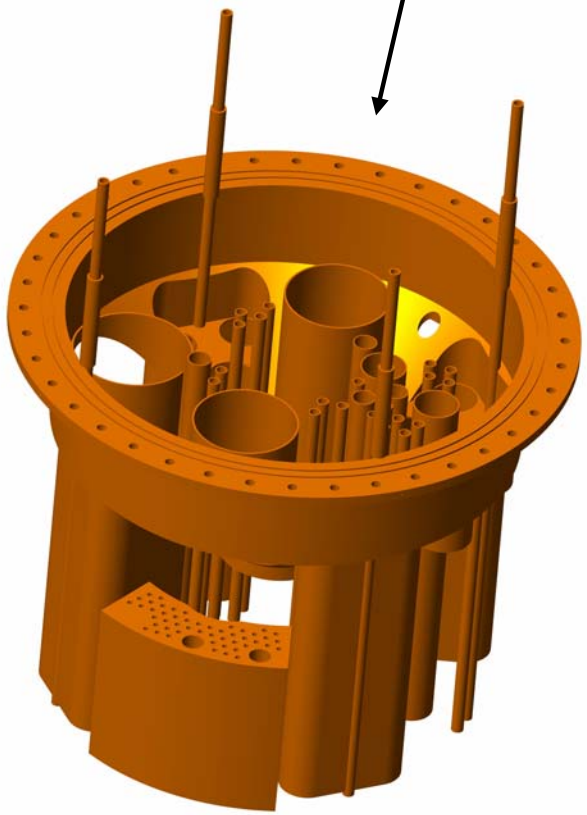
MYRRHA





XT-ADS

MYRRHA



SCK • CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

Remaining technical challenges

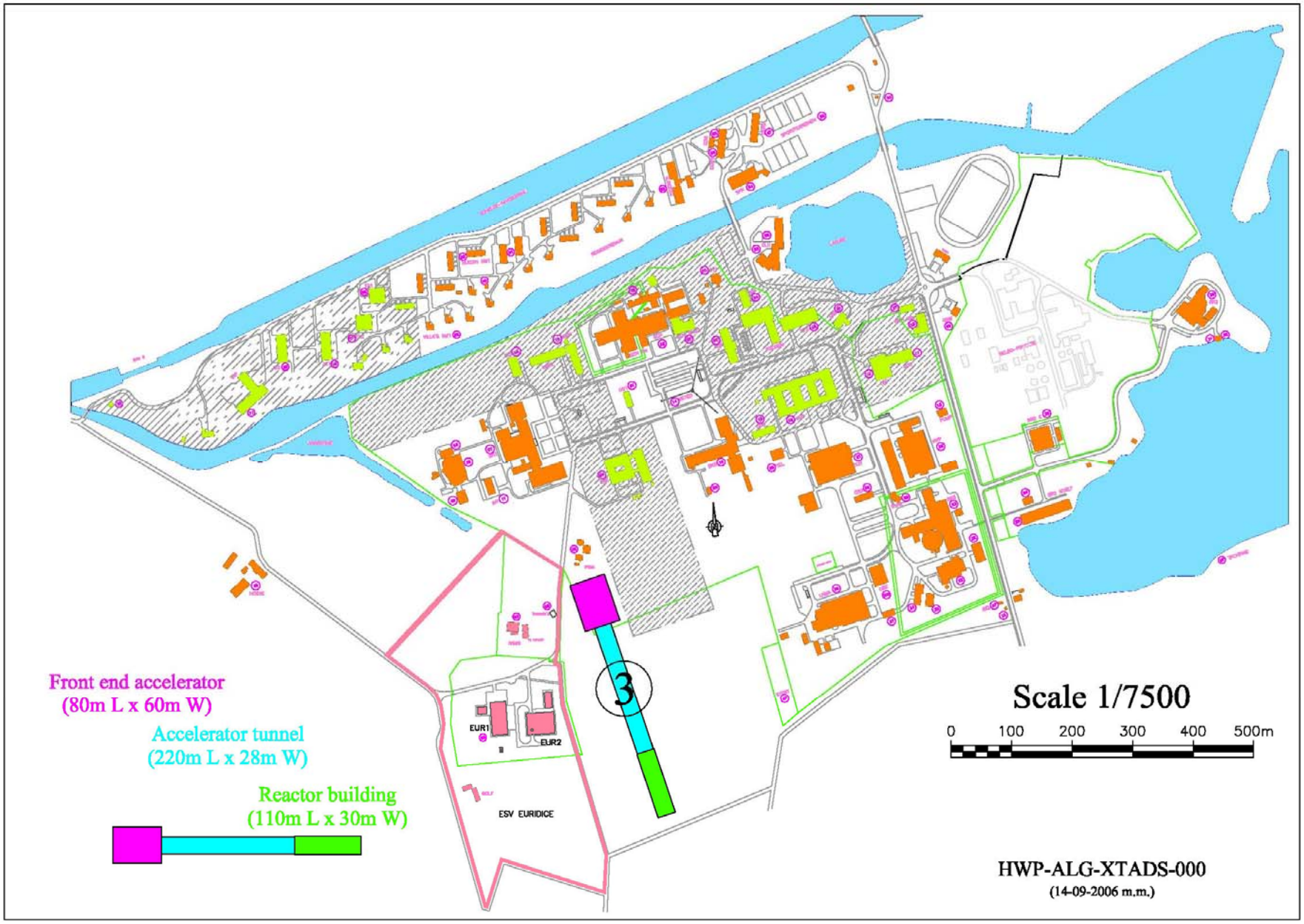
MYRRHA

- A comprehensive support R&D programme is addressing the following technical challenges:
  - Accelerator reliability improvement
  - Windowless spallation target design, including vacuum interface compatibility
  - Pb-Bi technology: impurities filtering, Po migration
  - Material corrosion & erosion
  - Material embrittlement due to irradiation and LME,
  - MOX fuel qualification under LBE and irradiation
  - Instrumentation development: O_2-meters, HLM free surface monitoring, sub-criticality monitoring, ultrasonic visualisation
  - Robotics development for operation under Pb-Bi.

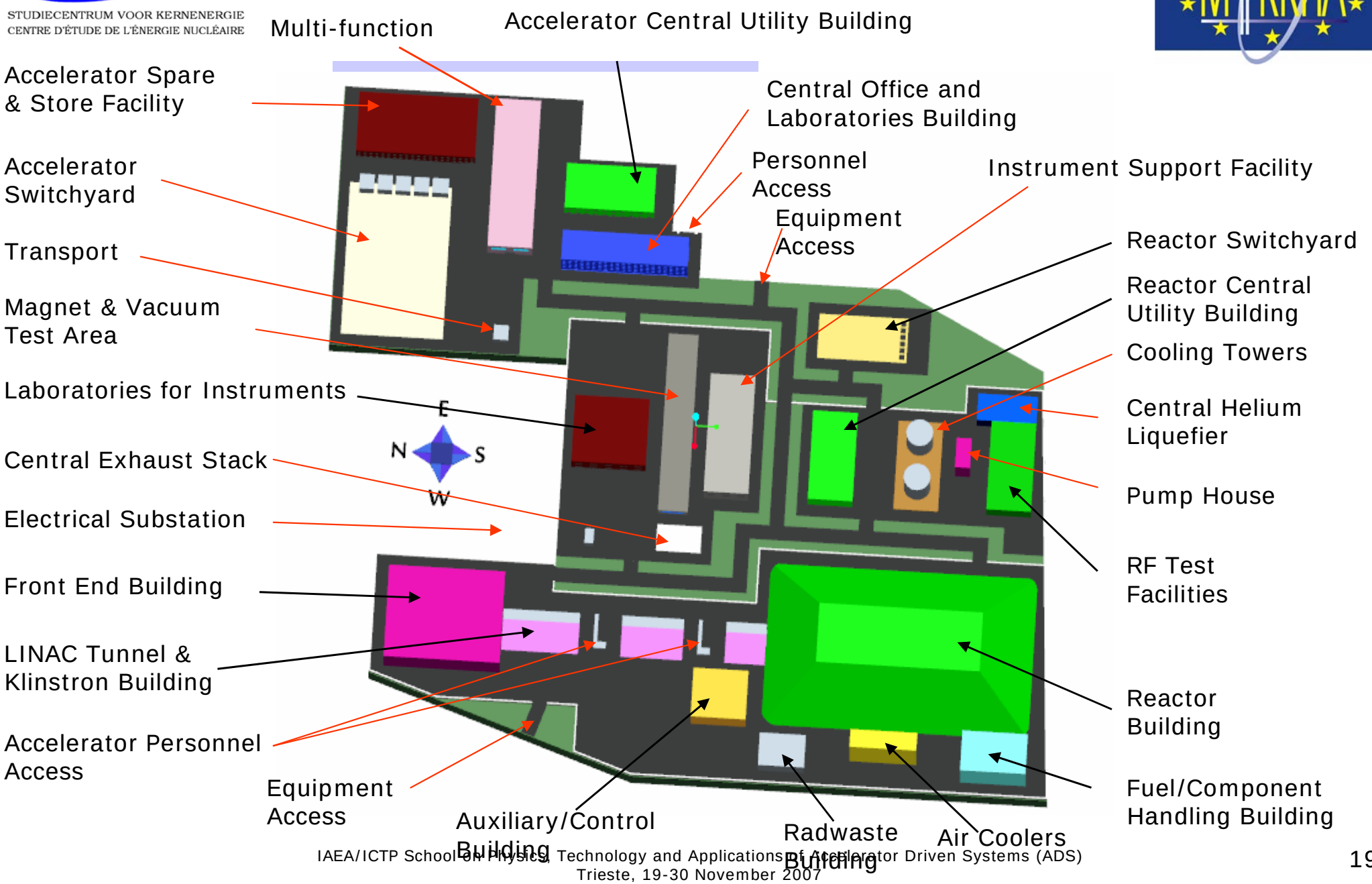
SCK • CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

One of the suitable options for installing XT-ADS

MYRRHA



… with the auxiliary buildings



SCK•CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

Conclusions

MYRRHA

- SCK•CEN has started the MYRRHA project as a national programme with several national & international bilateral collaboration agreements;
- The project (as XT-ADS) has now evolved as an European integrated project in the frame of IP_EUROTRANS;
- Beyond 2008 (at the end of IP_EUROTRANS) perspectives are under consideration with the Belgian authorities, several EU partners and the EC, for structuring the implementation and deployment of the XT-ADS.