# MYRRHA Draft-2 Design File

## State-of-the-art of the project at Mid-2005 and prospects for realisation


Hamid Aït Abderrahim

SCK•CEN

haitabde@sckcen.be

myrrha@sckcen.be


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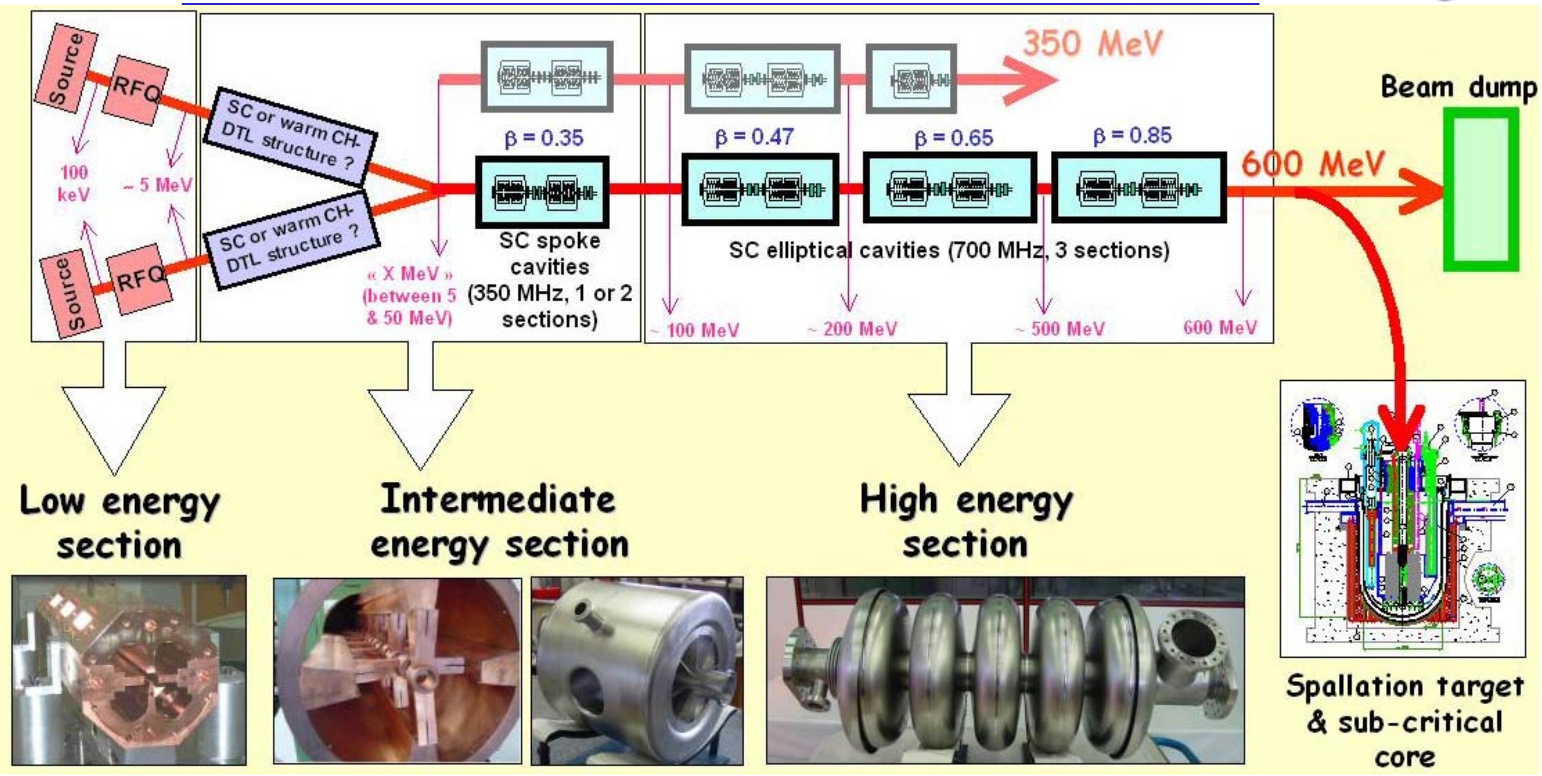
# Summary

- Introduction
- MYRRHA Components
- Perspectives for implementation
  1. SCK-CEN Committment
  2. Opening to Europe
  3. Fast Spectrum Irradiation Facility
  4. Link ADS/Gen.IV LFR
  5. Comprehensive Support R&D
- Roadmap for deployment
- Conclusion

# Introduction (2)
# MYRRHA in a European scene

- the RJH (F) project, a thermal spectrum MTR, is the only planned testing reactor for the moment
- MYRRHA would be the natural fast spectrum complementary facility.
- This will put Europe in a strong position towards the support of Gen. III and development of Gen. IV reactors.

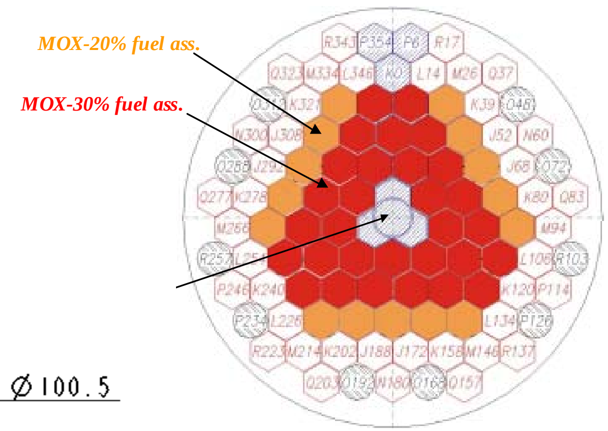
# MYRRHA Accelerator: the LINAC solution

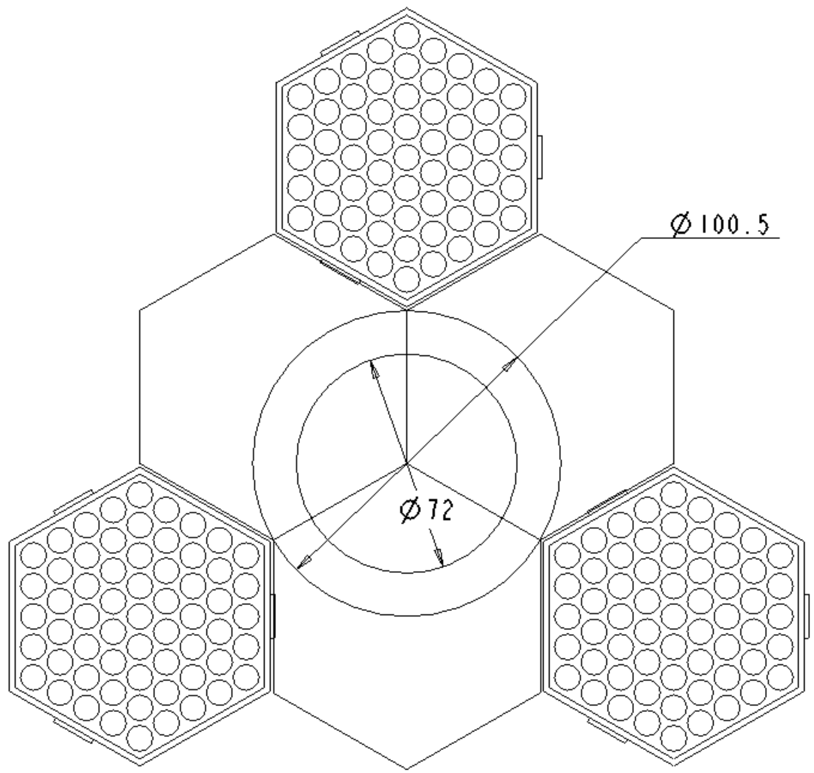



Strong R&D & construction programs for SC linacs are underway worldwide for many applications (Spallation Sources for Neutron Science, Radioactive Ions & Neutrino Beam Facilities, Irradiation Facilities)

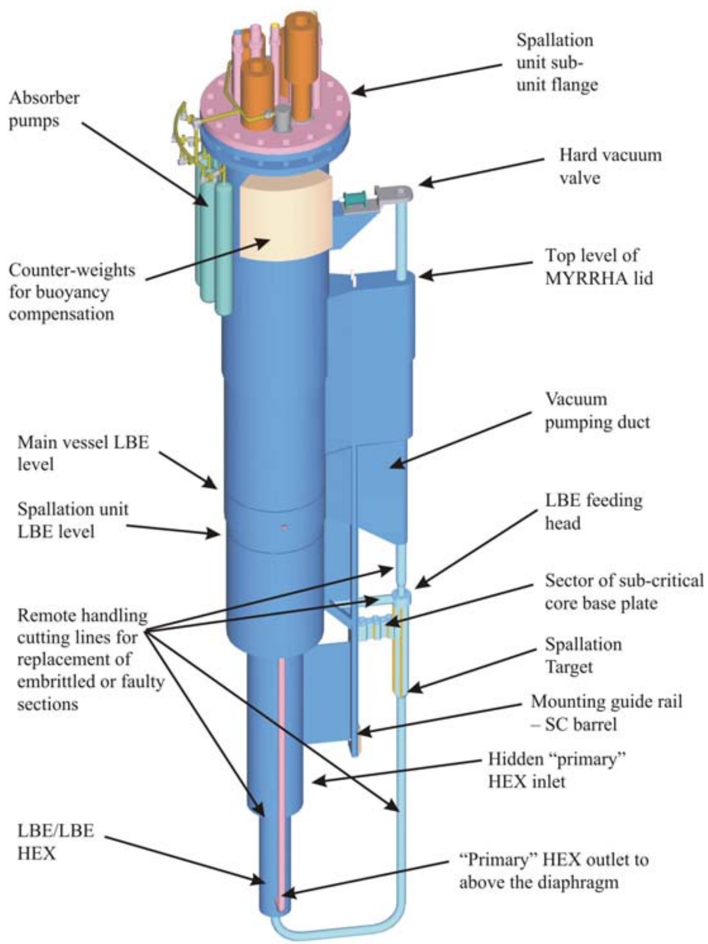
# Spallation Target: Radial Geometrical Constraints

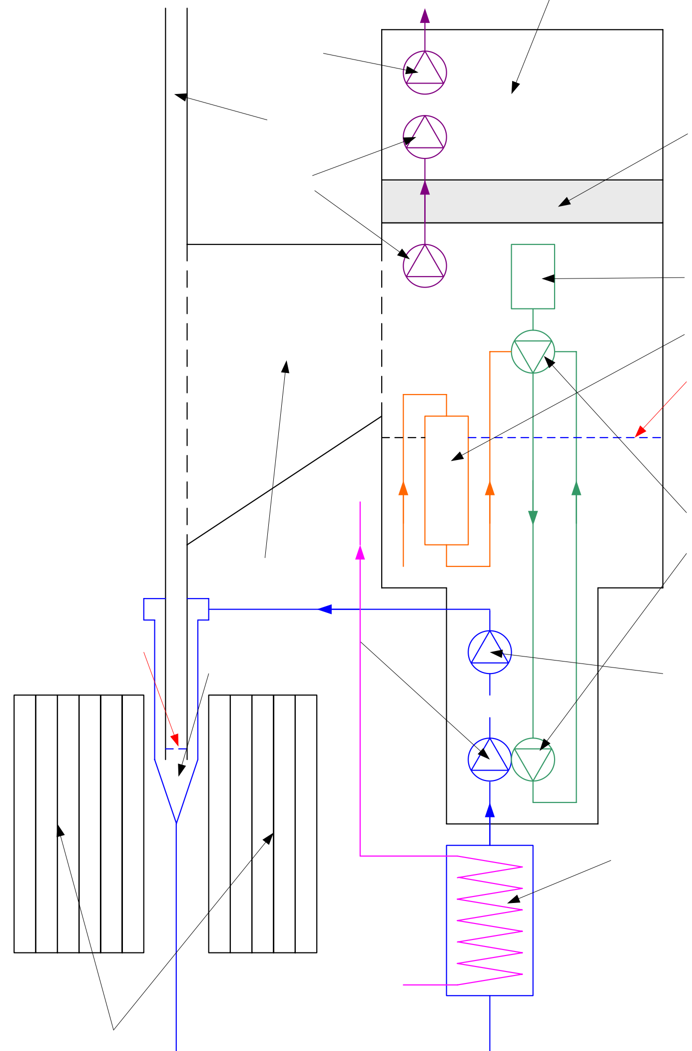
- Due to the high performances desired in the core, we limited drastically the central hole in the core for housing the spallation source



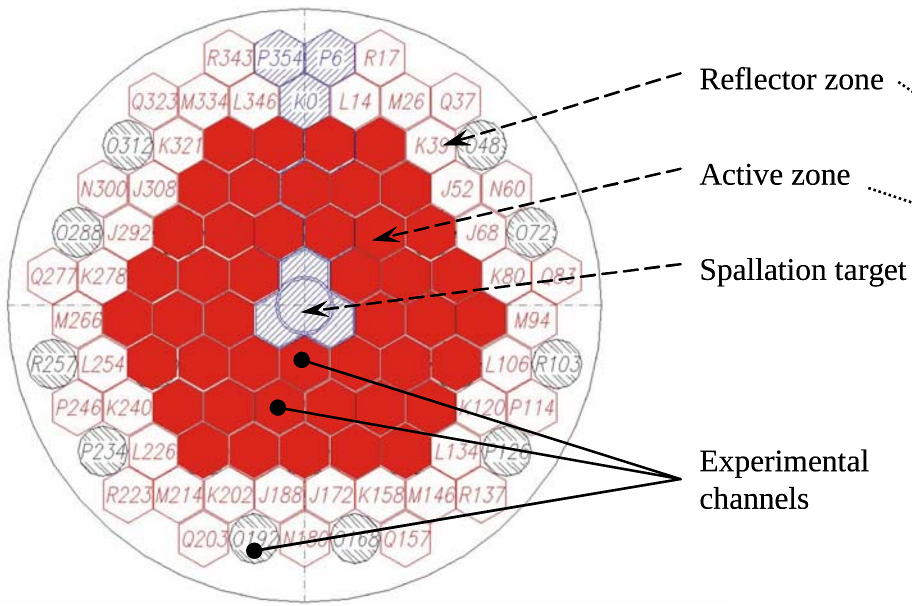



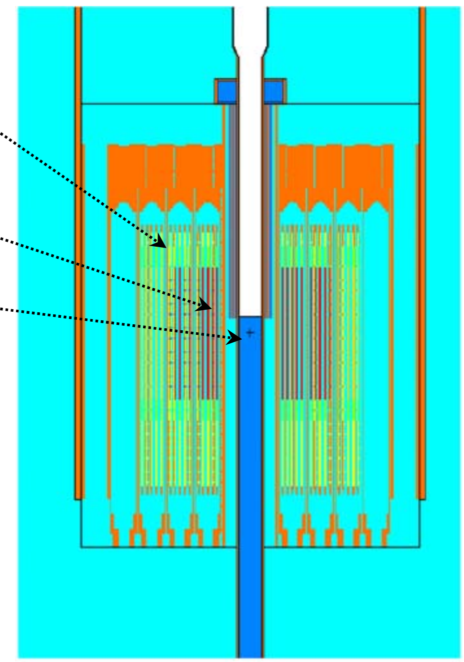
# MYRRHA Spallation Target

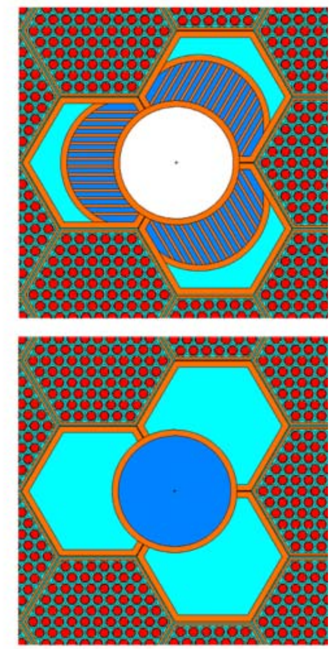


# Core configuration





- 99 + 3 hexagonal cells ("macro-cells")
- Target-block hole is made by 3 removed FA in the central region
- Surrounding active zone composed of 45 (or more) FA
- Outer reflector zone composed of 54 (or less) reflector assemblies

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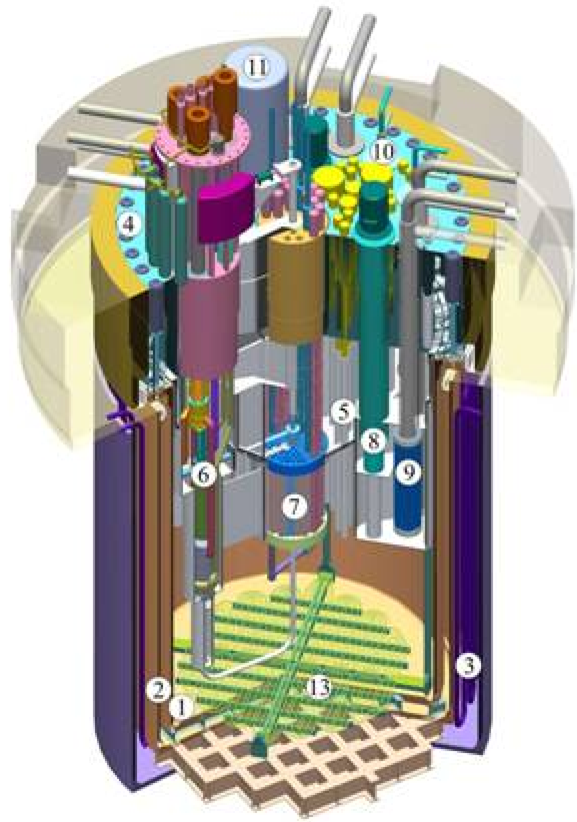
# Design of MYRRHA
# Overall configuration

MYRRHA

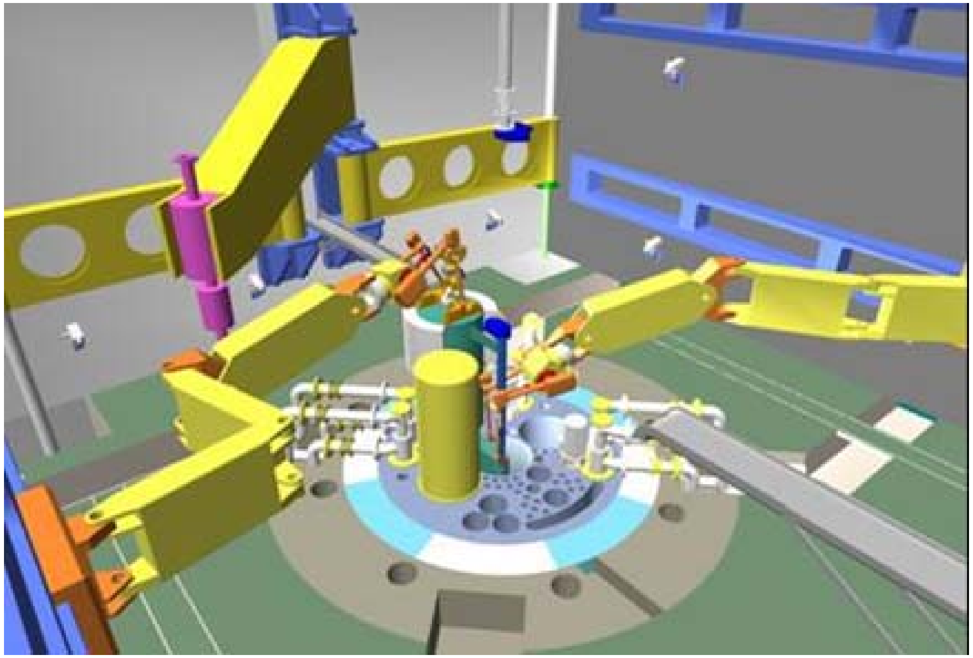


1. inner vessel
2. guard vessel
3. cooling tubes
4. cover
5. diaphragm
6. spallation loop
7. sub-critical core
8. primary pumps
9. primary heat exchangers
10. emergency heat exchangers
11. in-vessel fuel transfer machine
12. in-vessel fuel storage
13. coolant conditioning system

# Design of MYRRHA: Remote handling

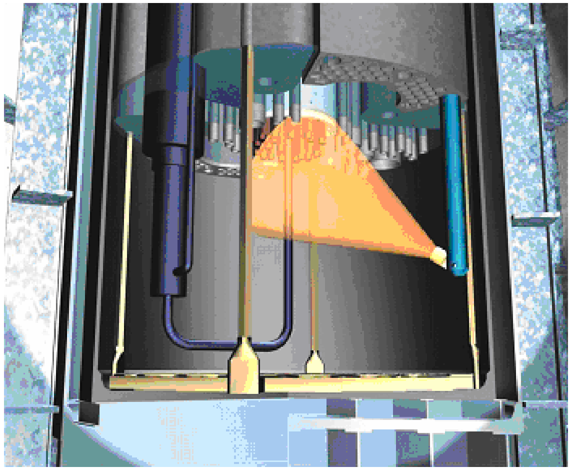
All MYRRHA maintenance operations on the machine primary systems and associated equipment are performed by remote handling, which is based on the *Man-In-The-Loop principle*:

- force reflecting servomanipulators
- Master-Slave mode: the slave servo-manipulators are commanded by remote operators using kinematically identical master manipulators
- supported with closed-cycle TV (CCTV) feedback

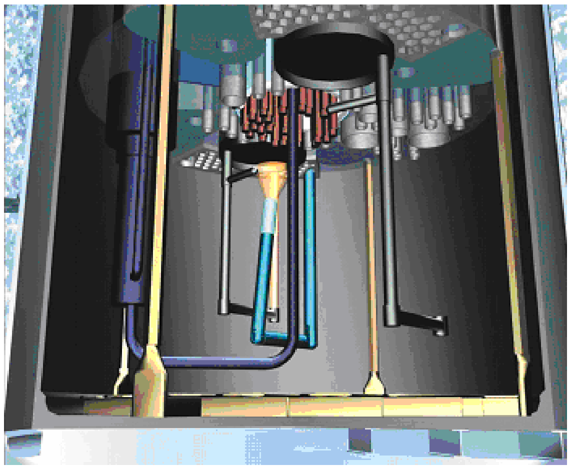


OTL concludes positive on the feasibility of the proposed RH approach.

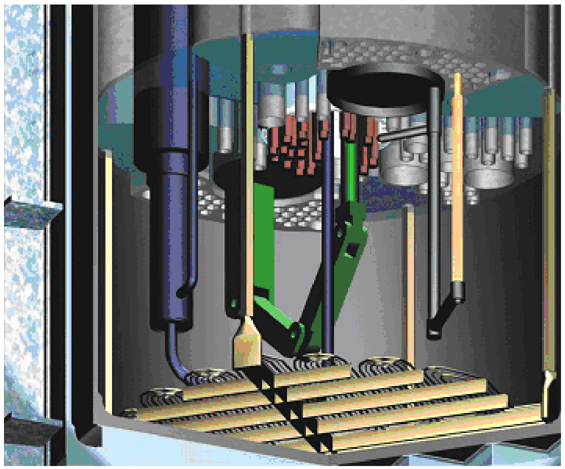
# Design of MYRRHA: In-service inspection and repair



Two permanently installed *inspection* manipulators with US camera to provide a general *overview*. (periscope type device with three degrees of freedom)



The second *inspection* manipulator positions the camera close to critical components for *detailed* inspection. (anthropomorphic type device with five degrees of freedom)



The *repair* manipulator recovers debris or deploys specialised tooling for repair. (anthropomorphic type device with eight degrees of freedom)

OTL concludes positive on the feasibility of the proposed RH approach.

# Perspectives for Implementation

# 1-SCK•CEN Committment

- SCK•CEN Mgt has declared its readiness to welcome a fast spectrum irradiation facility at its technical site in Mol
- SCK•CEN is working out a business plan and a funding plan that will be made available to the potential partners
- Bilateral discussions with some potential partners are already going on

# 2-Opening MYRRHA to Europe => XT-ADS

- MYRRHA Draft-2 has been made available to the EUROTRANS Community
- SCK•CEN is studying in collaboration with EUROTRANS partners the modifications needed to achieve the XT-ADS objectives
- Considering Joint Undertaking for setting up the frame for the realisation at European level

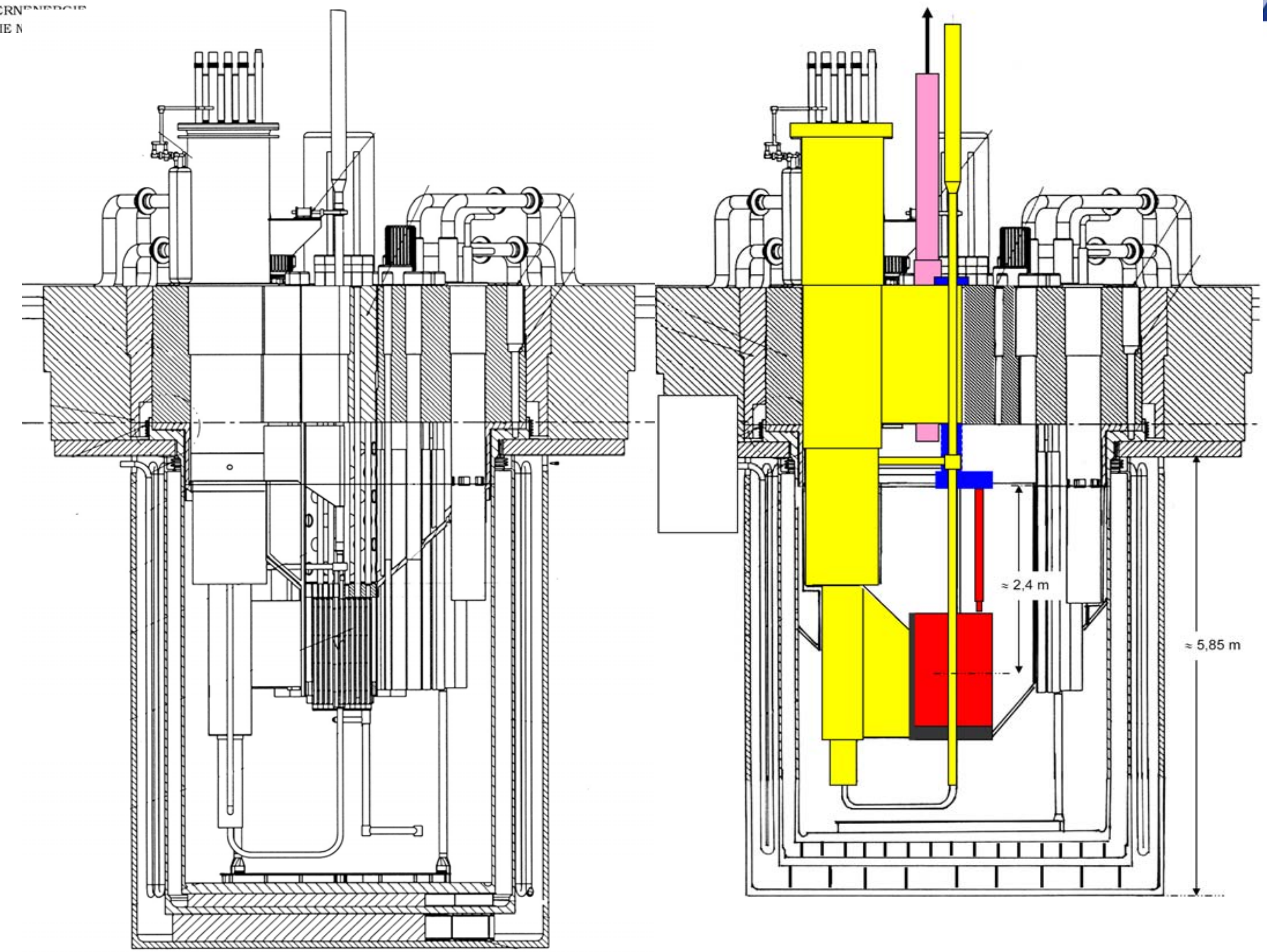
# Design Parameters of XT-ADS and MYRRHA (1/2)

| | XT-ADS | MYRRHA Draft-2 |
|---|---|---|
| Design level | Advanced design | Conceptual design |
| Coolant | Pb-Bi | Pb-Bi |
| Primary System | Integrated | Integrated |
| Power | 50 to 100 MWth | ~50 MWth |
| Core Inlet Temp | 300°C | 220°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 $W/cm^3$ | ~1000 $W/cm^3$ |
| Fuel pin spacer | Grid | Wire |
| Fuel Assembly type | Wrapper | Wrapper |
| Fuel Assembly cross section | Hexagonal | Hexagonal |

# Design Parameters of XT-ADS and MYRRHA (2/2)

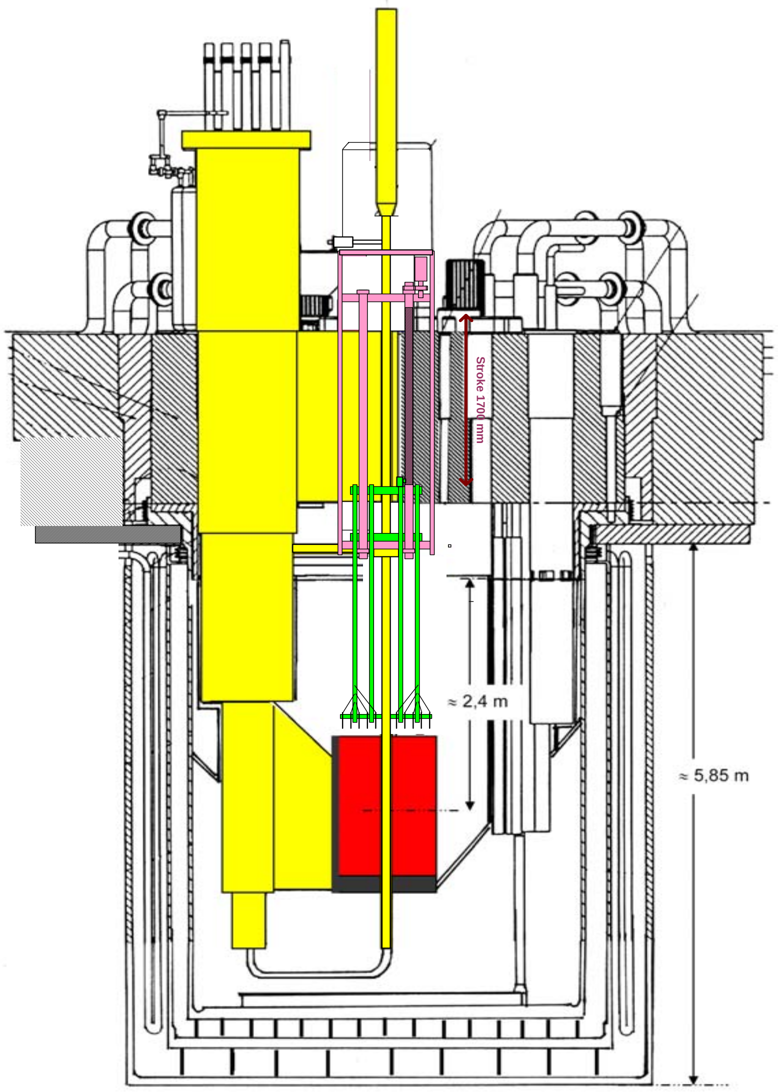
| | XT-ADS | MYRRHA Draft-2 |
|---|---|---|
| Fuel loading | Top To Be Assessed / Bot. | Bottom |
| Fuel monitoring | T and FF (per FA) | T and FF (per FA) |
| External fuel handling | RH oriented | RH oriented |
| Primary coolant circulation in normal operation | Forced with mechanical pumps | Forced 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 | TBD (site specific) | TBD (site specific) |
| Structural Material | T91 and A316L | T91 and A316L |
| Accelerator | LINAC (350 MeV*5 mA or 600 MeV*2.5 mA) | LINAC (350 MeV*5 mA) |
| Beam Ingress | Top | Top |

# Ongoing MYRRHA Revision 1/3



# Further investigations on FH feasibility from the top 2/3

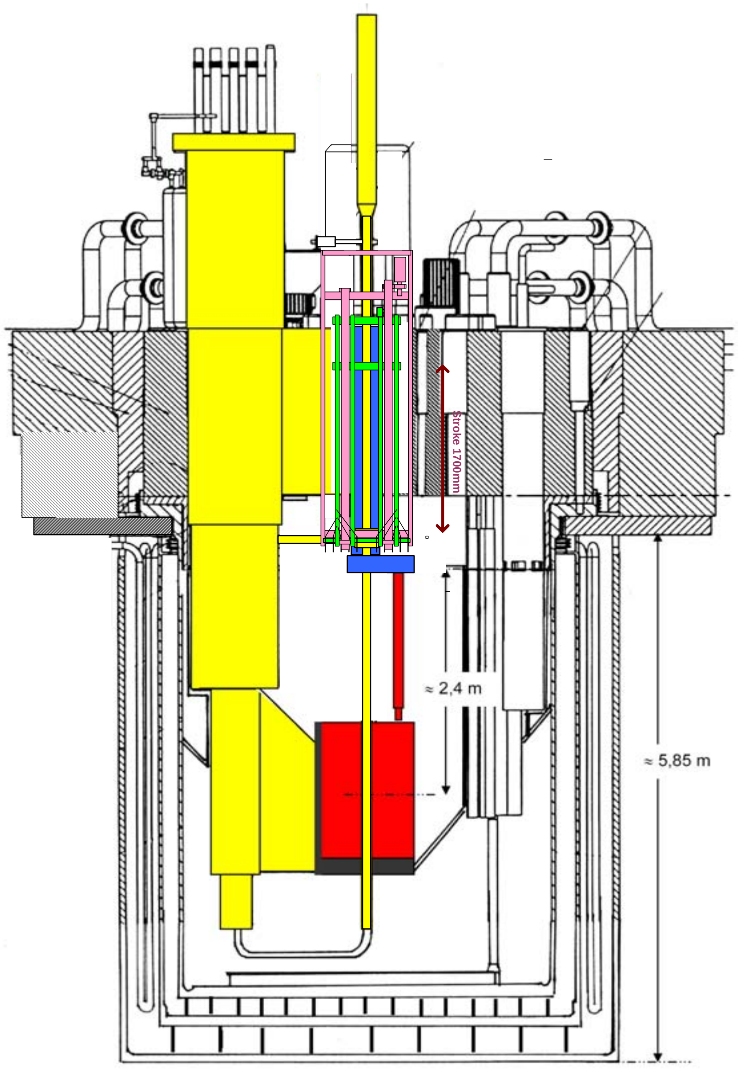
- The small diameter and size of the ACS and the limited stroke makes it compatible with an integrated mechanical lifting system (such as F.H machines with a worm screw)
- No problem of leak tightness at roof level with a sealed component
- Nearly all S/A position can be covered by instrumentation (except target patch, same as before)



# Further investigations on FH feasibility from the top 3/3

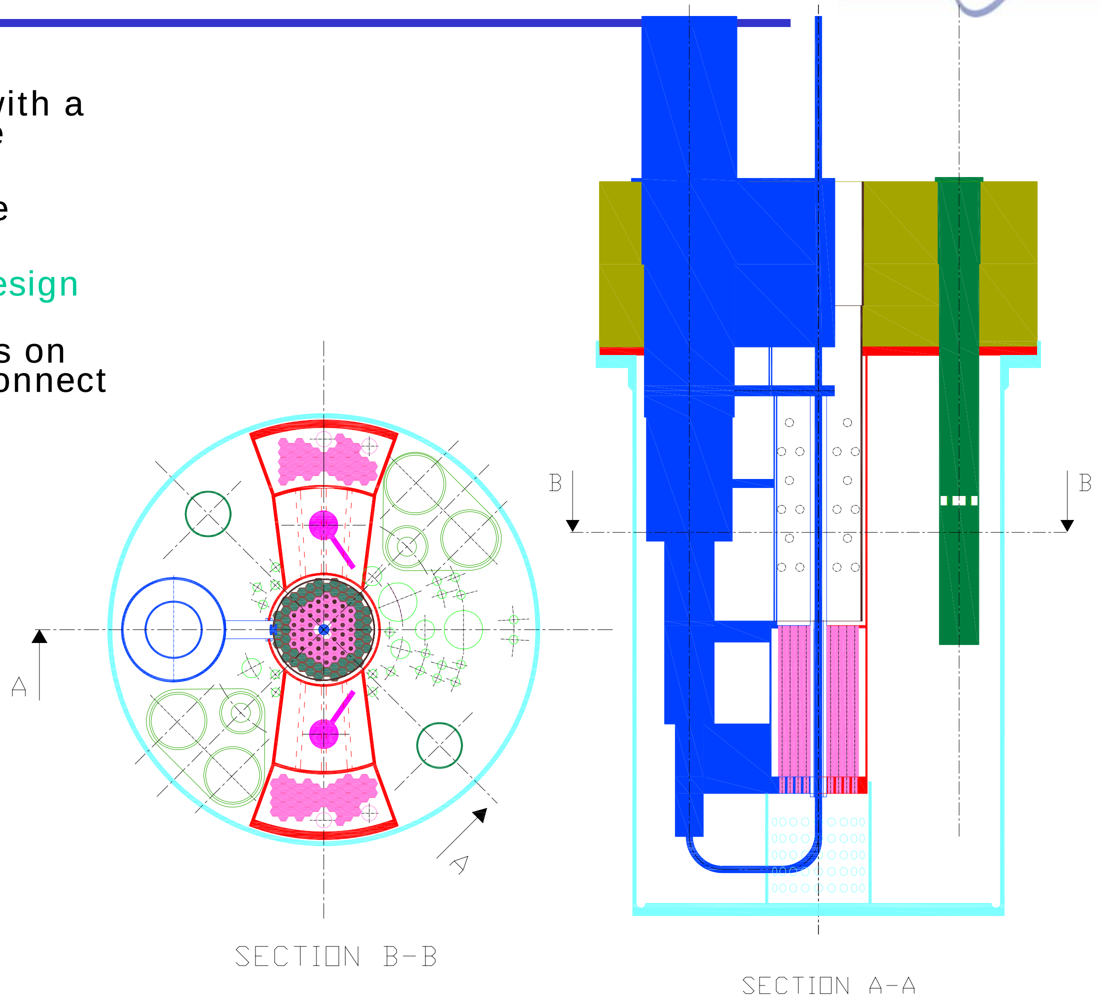
- For FH operations, the ACS is lifted of about 1.7m with the worm screw device sliding along the guide tubes,

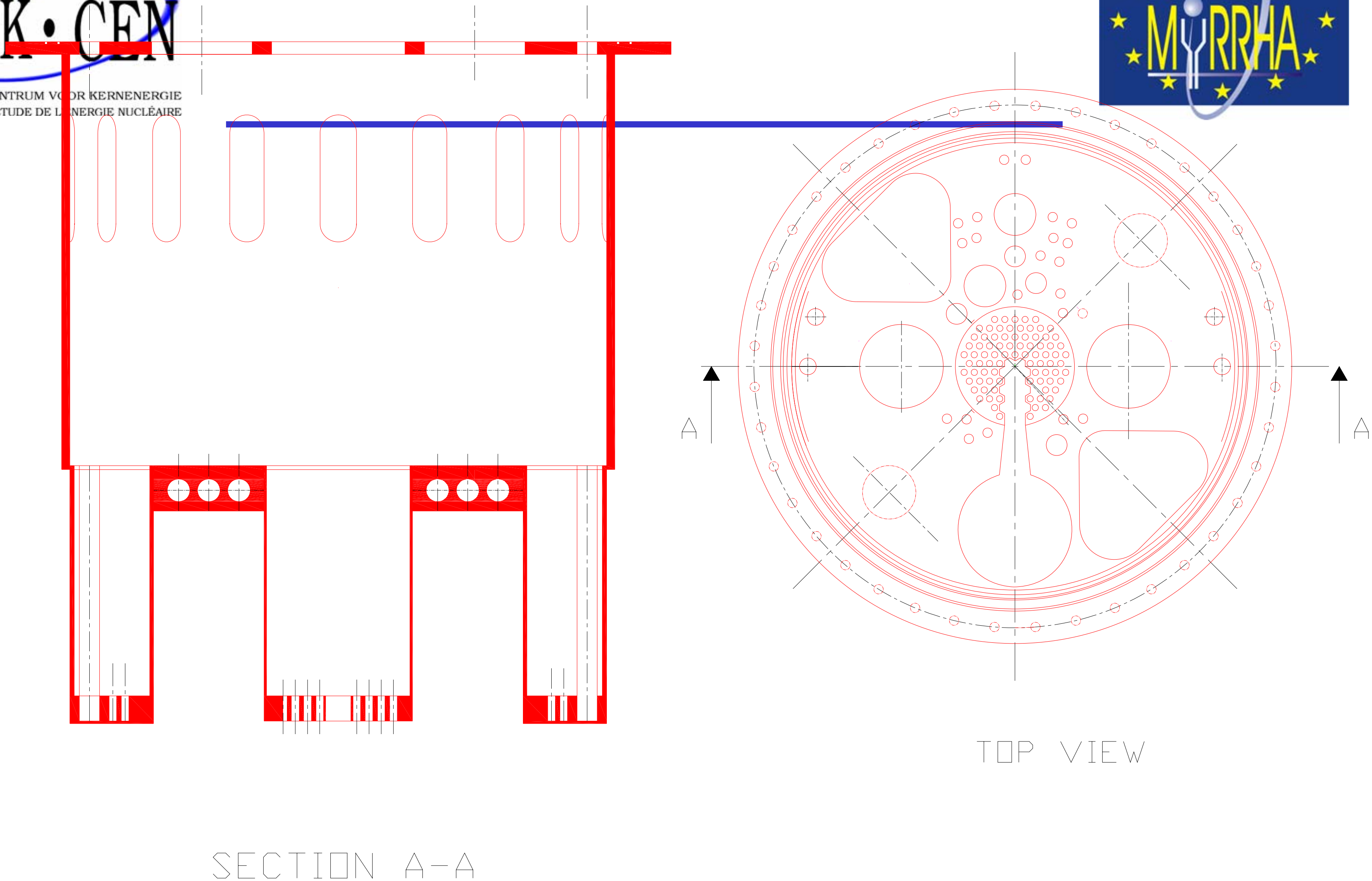
- The space above the core is made free for the rotation of the transfer arm.



# Variant C – Vertical separation

- Rectangular shape Inner Vessel with a lower cylinder containing the core
- FH from top (design option)
- At sides two pools for fuel storage
- FH by pantograph machines
- Pumps at hot leg temperature (design option)
- Suppression of many penetrations on Inner Vessel but radial pipes to connect Primary components casings



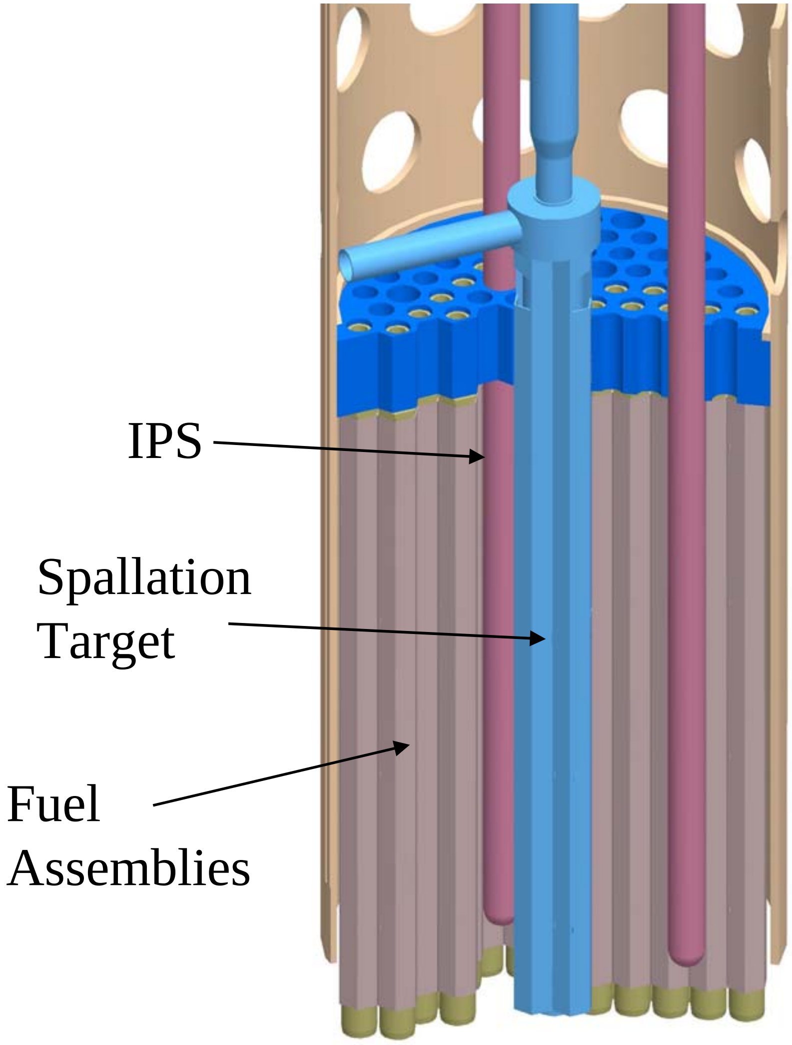

SECTION A-A
A
A
TOP VIEW

# 3-Holding the objective of Fast irradiation facility

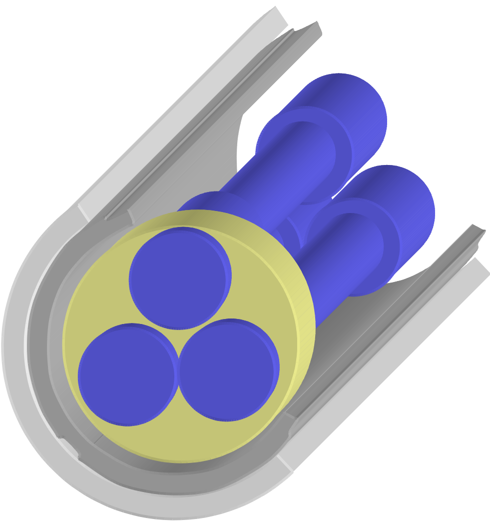
- Multi-irradiation channels available
- High performance levels
- Multiple irradiation conditions secured to the user

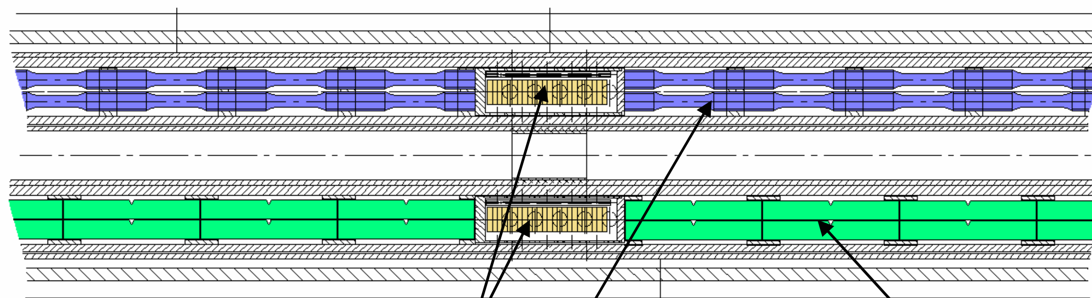
# Material Irradiation in MYRRHA

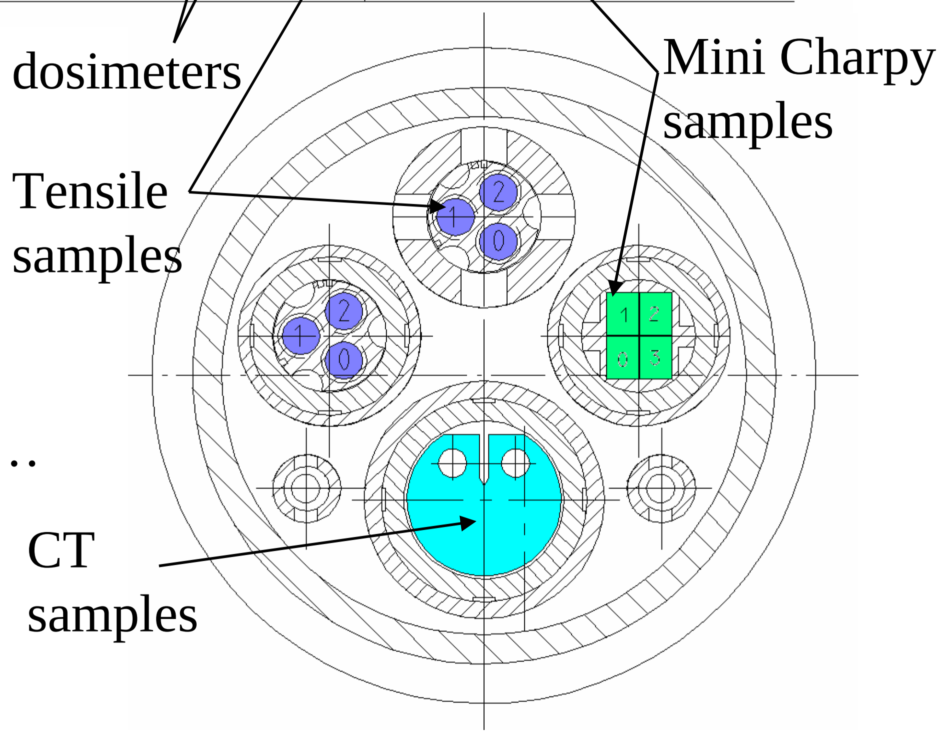
- IPS Location in the core



# IPS Material Testing typical Layout

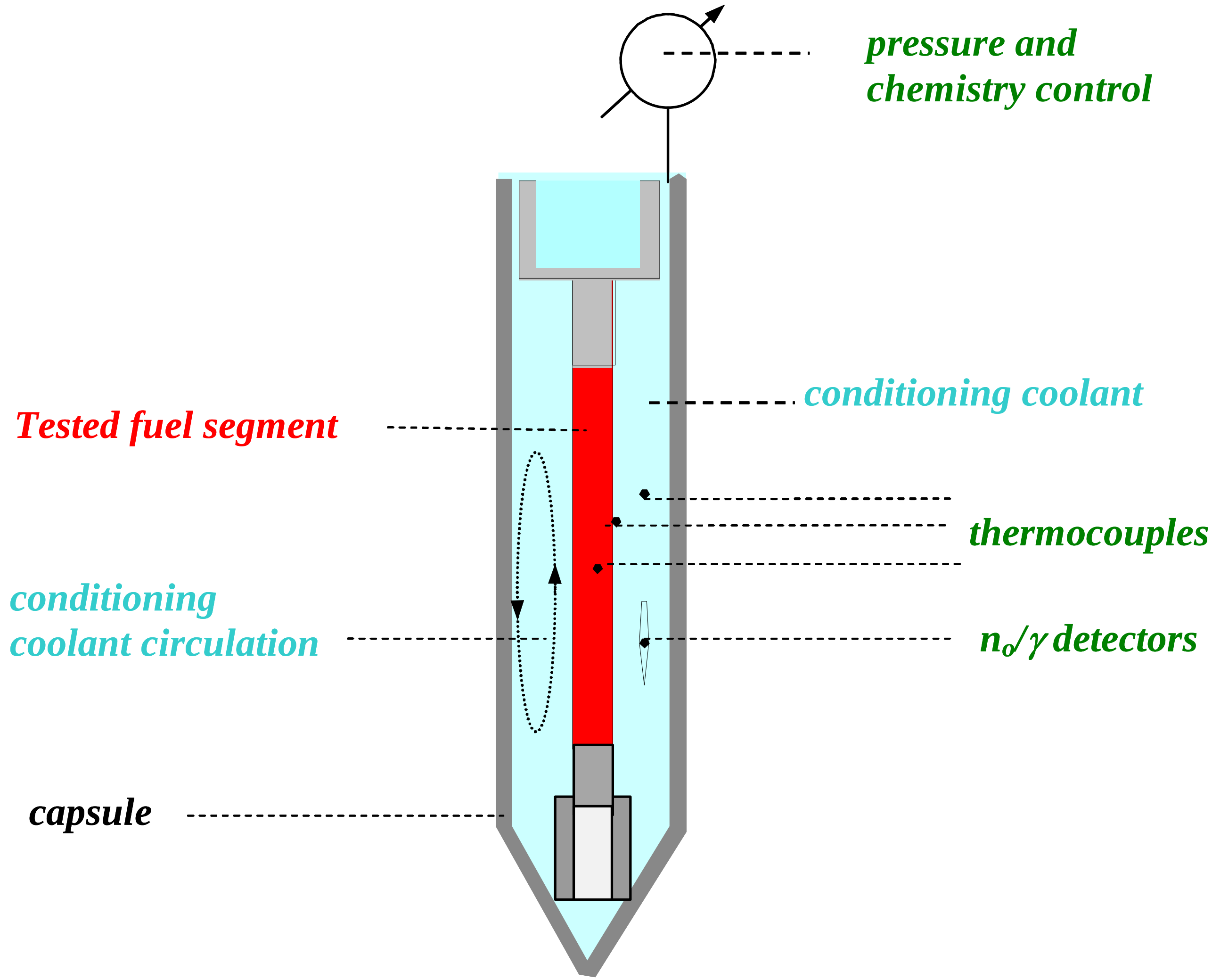




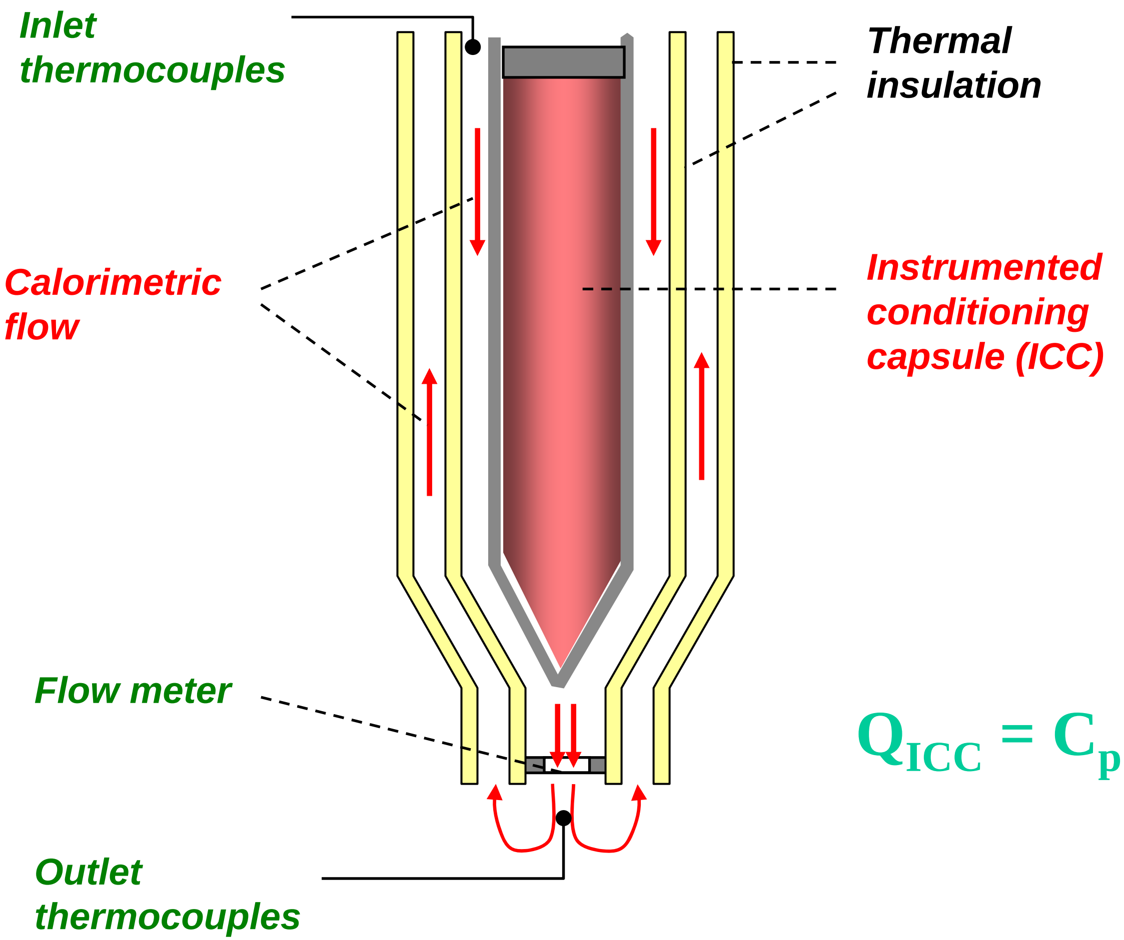



IPS outside diameter 80 mm
Relevant length for irradiation test 600 mm
Instrumentation : dosimeter, thermocouple,…

# Fuel Irradiation in MYRRHA Instrumented and Conditioned Capsule (ICC)

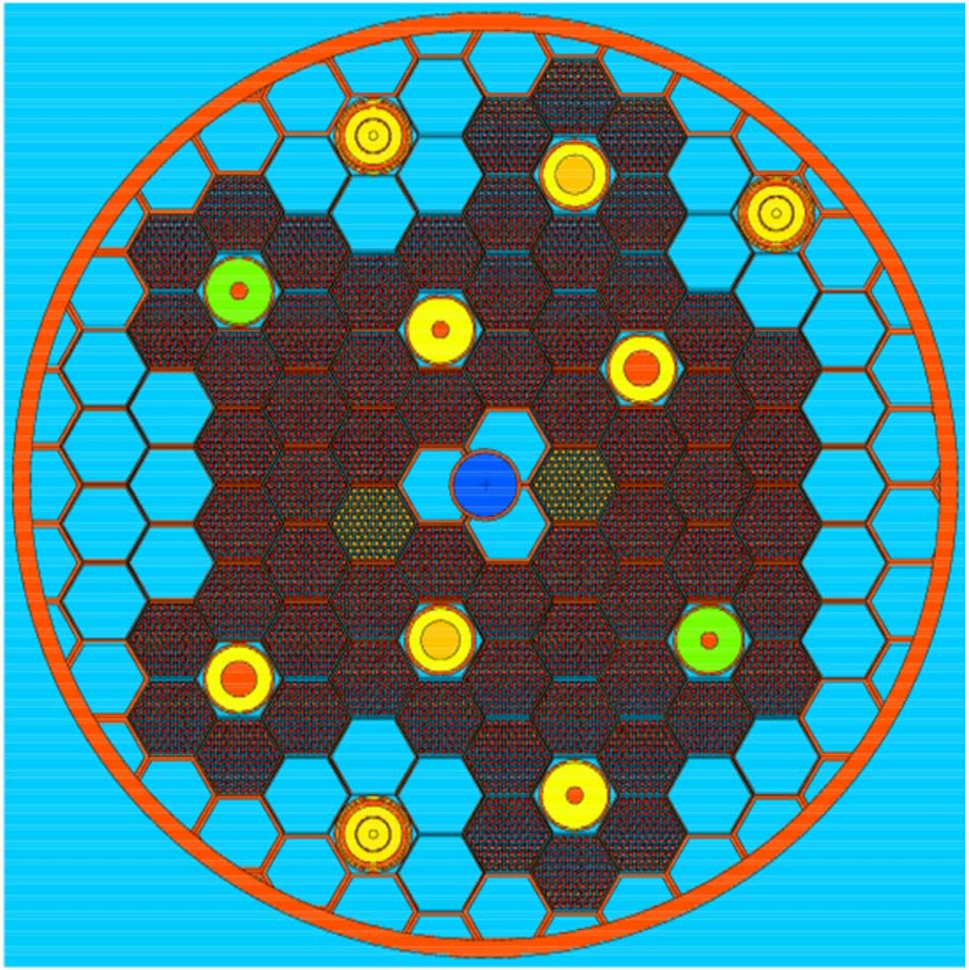


# Fuel Irradiation in MYRRHA Calorimetric Calibration Device (CCD)



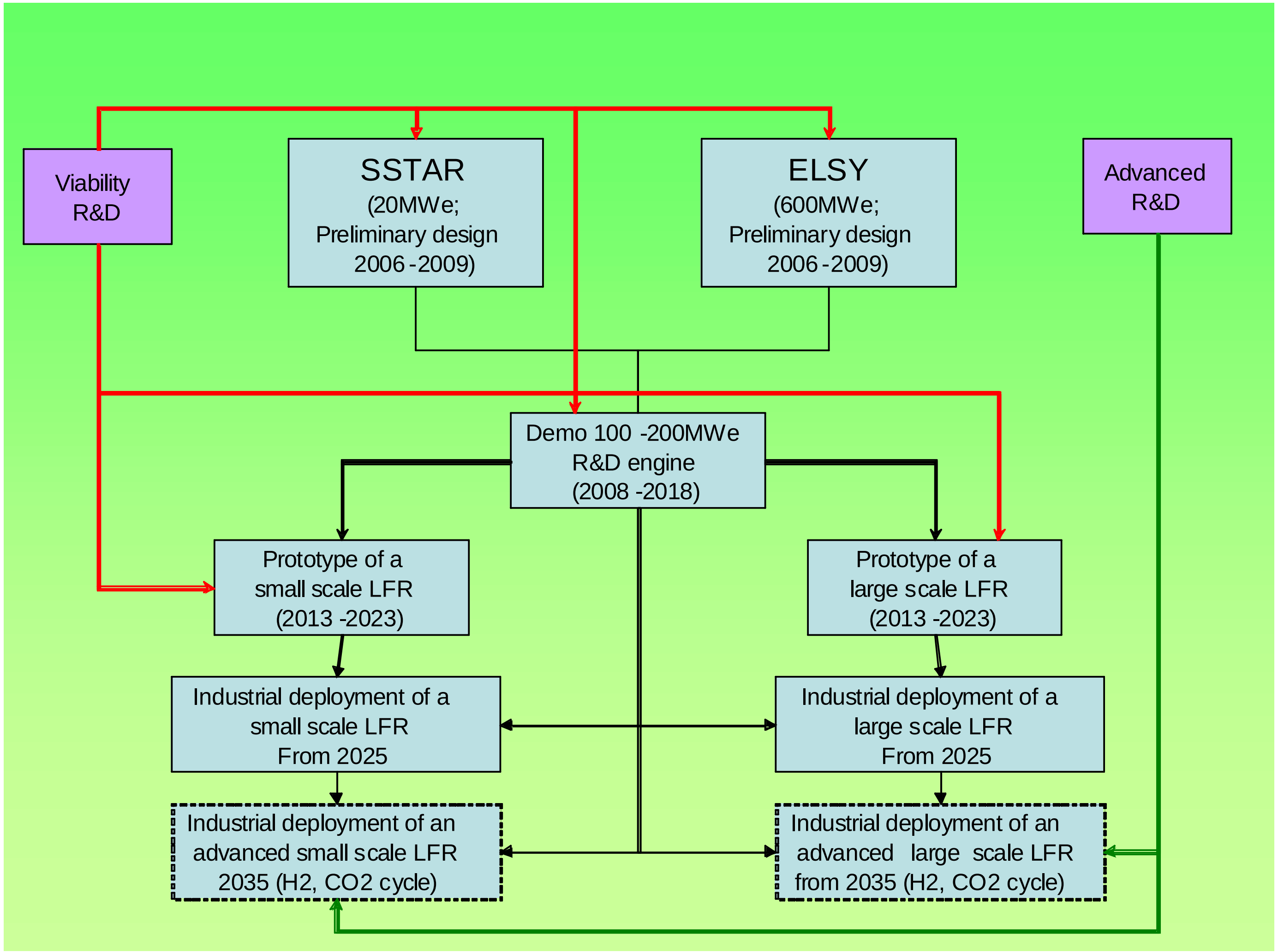

$$Q_{ICC} = C_{p\ cool} \cdot G_{cool} \cdot \Delta T$$

# Typical MYRRHA core configuration with experimental rigs



- 61 MOX-fuel assemblies
- 2 U-free MA (MgO matrix) assemblies
- 6 rigs with Steel samples
  - 2x2 He-cooled
  - 2 lead-cooled
- 2 rigs with SiC samples
- 3 $H_2O$-moderated IPS
- Keff= 0.95181 ± 0.00025
- Ks = 0.95960
- Power : 52.3 MW

# 4-Link ADS – Gen.IV LFR



# 5-Well established and design driven support R&D Programme

- Pluri-annual R&D support programme established around the MYRRHA project inside SCK•CEN
- A bilateral collaboration network of quality
- The support R&D programme enhanced thanks to EUROTRANS

# The MYRRHA R&D Programme

- Since the beginning of the MYRRHA project, we decided to accompany the project by a comprehensive support R&D programme including:
  - Windowless spallation target thermal-hydraulic design.
  - Vacuum Interface compatibility,
  - LBE technology: Po migration, visibility under LBE through ultrasonic cameras,
  - Material Corrosion & erosion and their mitigation,
  - LBE conditioning and monitoring,
  - Material embrittlement due to irradiation and LME,
  - MOX fuel qualification under LBE and irradiation up to high targeted burn up (100 GWd/t) and high dpa (100) and also under representative transient conditions,
  - Instrumentation development: $O_2$-meters (< 200°C), HLM free surface monitoring, sub-criticality monitoring, ultrasonic visualisation
  - Robotics : development of a robot arm to be deployed under LBE for testing and qualification

# MYRRHA Collaboration Network (1/3)

- **IBA**, Belgium: cyclotron design and/or Intermediate energy section of the LINAC (normal conducting);
- **ENEA**, Italy: spallation source thermal-hydraulics design, core dynamics;
- **UCL**, Belgium: spallation source design water experiment, CFD modelling, Advanced CFD development;
- **FZR**, Germany: instrumentation for the spallation target;
- **FZK**, Germany: windowless spallation source testing with Pb-Bi in KALLA, Material Corrosion studies, Neutronics of sub-critical systems;
- **NRG**, The Netherlands: Spallation Source CFD modelling and system safety assessment;

# MYRRHA Collaboration Network (2/3)

- **CEA**, France: subcritical core design, MUSE experiments;
- **CNRS/IN2P3**, France: LINAC development and components design, Windowless Spallation Target design, T91 structural material research, sub-critical core physics,
- **PSI**, Switzerland: basic spallation data, MEGAPIE;
- **IPUL**, Latvia: windowless spallation source testing with Hg,
- **Belgonucléaire**, Belgium: MOX Fuel manufacturer fuel pin and assembly design, fuel loading policy and fuel procurement;
- **CIEMAT**, Spain: Neutronic core design;
- **KTH**, Sweden: development and validation on basis of experimental results of adapted burn up codes for ADS,
- **IPPE**, Russia: design of the MYRRHA sub-critical reactor;

# MYRRHA Collaboration Network (3/3)

- **Suez-Tractebel,** Belgium: confinement building and auxiliary systems, Safety analysis studies.
- **OTL**, UK: Remote Handling & Robotics design and development;
- **USI_KU**, Lithuania: development of US sensors operational under LBE and aggressive radiation environment, development of associated visualisation camera and signal treatment;
- **AFCN and AVN**, Belgium: Licensing authorities
- Contacts that may lead to additional collaborations exist with:
  - ISTC: JINR-Dubna, Russia, YALINA-Minsk, Belarus
  - DoE and LANL; USA
  - JAEA, Japan
  - CIAE, China

# MYRRHA/XT-ADS Challenges – Status - Actions (1/3)

| Challenge | Status | On-going Actions |
|---|---|---|
| **Spallation target** | | |
| ➢ Thermal Hydraulics design | ➢ Basic design finished<br>➢ Feasibility shown | ➢ Fine tune design : optimise flow stability |
| ➢ Vacuum Interface | ➢ Feasibility shown | ➢ Vacuum system design/ volatile spallation product confinement (FP6) |
| **Materials (316 L/T91)** | | |
| ➢ Corrosion | ➢ 316L : OK w.o coating<br>➢ T91 ok to 550°C | ➢ High T long term corrosion tests<br>➢ FeAl coating (FP6) |
| ➢ Irradiation | ➢ 316L : ok in low dose regions<br>➢ T91 promising for high dose regions & cladding) | ➢ Demonstration T91 ongoing (BR2/HFR/Megapie) |

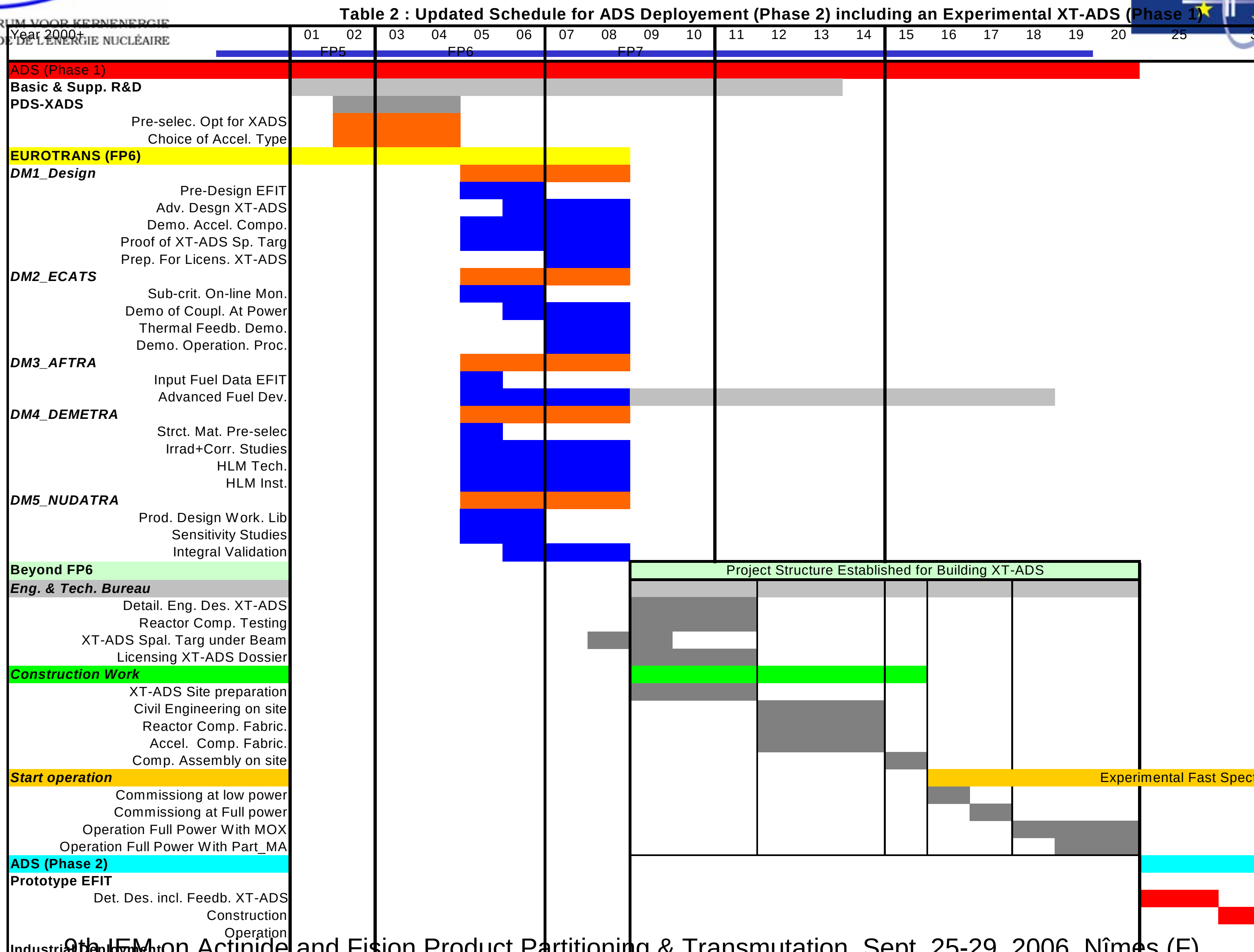
# MYRRHA/XT-ADS Challenges – Status - Actions (2/3)

| Challenge | Status | On-going Actions |
|---|---|---|
| **Pb-Bi Chemistry** | | |
| ➢Oxygen Control | ➢Control (H2/Ar or PbO) demonstrated | ➢In-vessel oxygen control system |
| ➢Oxygen sensors | ➢YSZ ceramic + Metal/metaloxide probes developed | ➢Improve reliability/stability |
| ➢Filtering | ➢Sintered metal/fiber mesh filters | ➢in-vessel filtering |
| **Visualisation LBE** | | |
| ➢Ultrasound sensors | ➢High T US sensors OK<br>➢γ-radiation resistant | ➢neutron irradiation<br>➢Optimise bonding technology |
| ➢Visualisation Technology | ➢Reconstruction of basic shapes | ➢Development of scene reconstruction<br>➢Camera development (embarked technology) |

# MYRRHA/XT-ADS Challenges – Status - Actions (3/3)

| Challenge | Status | On-going Actions |
|---|---|---|
| Fuel Qualification | | |
| | ➢Existing fuel (30% MOX) with new clad (T91) | ➢Qualify clad material (FP6)<br>➢Qualify fuel pin thermo-hydraulics (FP6)<br>➢Fuel pin irradiation (BOR60, to be initiated) |
| Remote handling | | |
| | ➢Existing technology in air (JET) | ➢Qualify in LBE<br>➢Design & components test |
| Accelerator | | |
| | ➢High power proton accelerators exist (LANCE, PSI) | ➢Drastic reliability improvement<br>➢Design, build & test each key component (FP6) |

# Roadmap for ADS deployment



# Contribution to the European Research Area

- SCK•CEN in collaboration with other European actors is encouraging to establish a European Research Area in the field of Experimental Reactors in order to secure the needed large research infrastructures for a sustainable nuclear fission energy
- SCK•CEN will be helping to reach these objectives through its participation to the various FP6 projects such as EUROTRANS, RED-IMPACT, VELLA, ELSY, PATEROS and SNF-TP and through its bilateral collaboration with the main actors aiming at the nuclear energy renaissance