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STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

MYRRHA

Design and R&D support of the XT-ADS Spallation Target Loop

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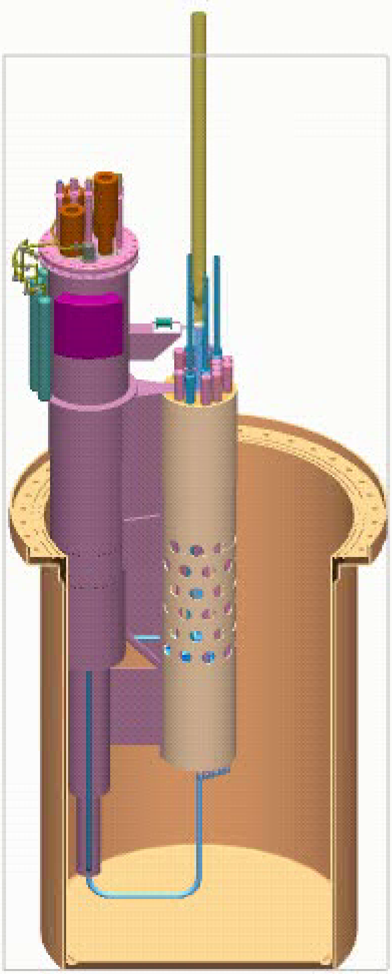
on behalf of the XT-ADS spallation target design

Contents

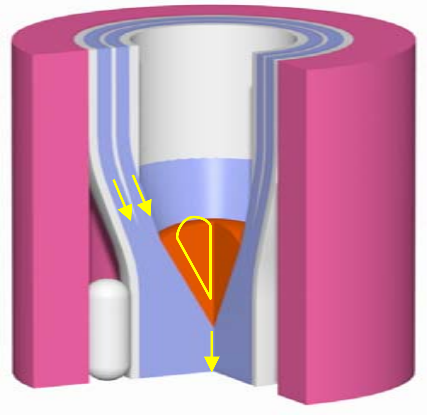


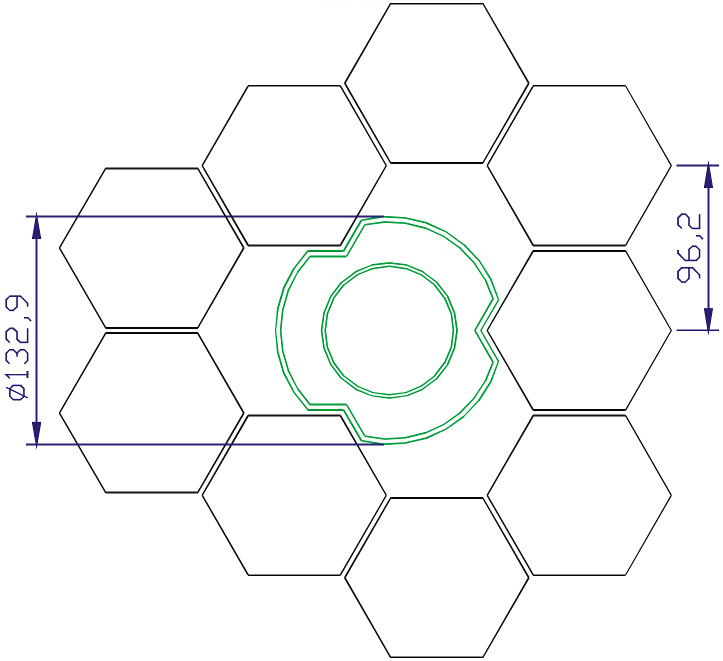
- Conceptual properties
- Loop configuration
- Layout
- Spallation target
- Spallation loop components
- Conclusions

Spallation target function

- Target tasks & boundary conditions
  - Produce ~10^{17} neutrons/s to feed subcritical core @ k_{eff} ≈0.95
  - Accept 600 MeV x 2.5 mA proton beam (up to 4 mA for burn-up compensation)
  - Evacuate deposited heat : 1-1.56 MW
  - Space limitation: three central assemblies in core : 96.2 mm fuel assembly pitch
  - Lifetime: > 1y
  - Flexibility in use (XT ADS purpose as experimental irradiation machine)

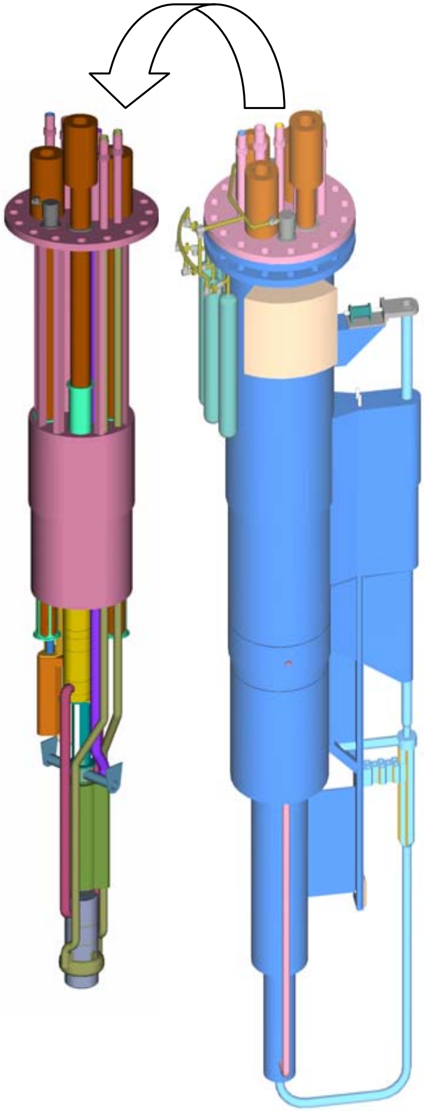
Target Design : Conceptual properties





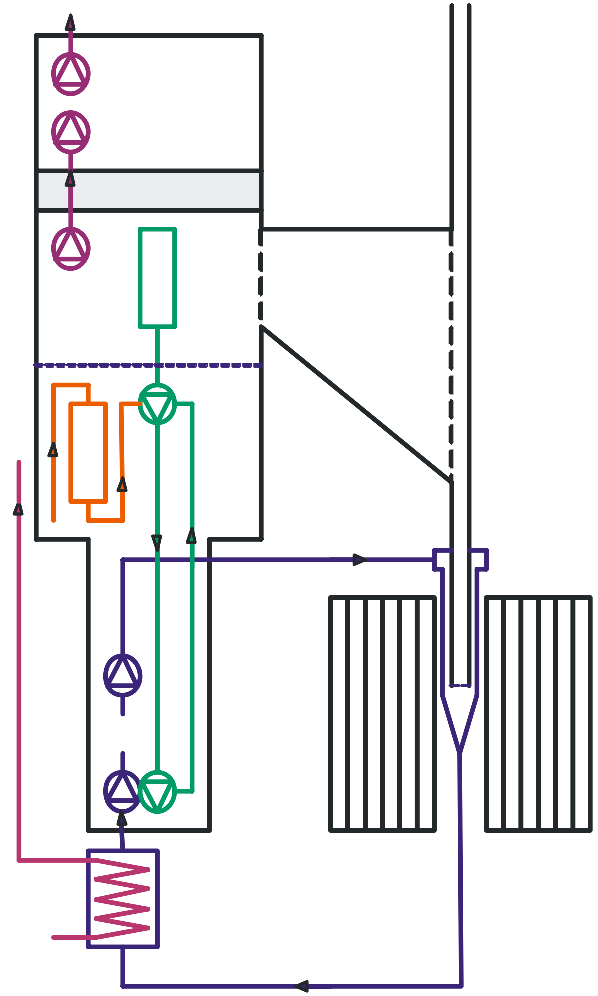
- Windowless target
  - ➢ Beam current density
- Vertical coaxial confluent LBE flow
  - ➢ Space consideration
  - ➢ Free surface formation
- Target inflow via 3-feeder design
- Off axis LBE servicing
  - ➢ Leave top & bottom of core free
    - ⇒ Accessibility
  - ➢ Loop away from high radiation zone
    - ⇒ Lifetime

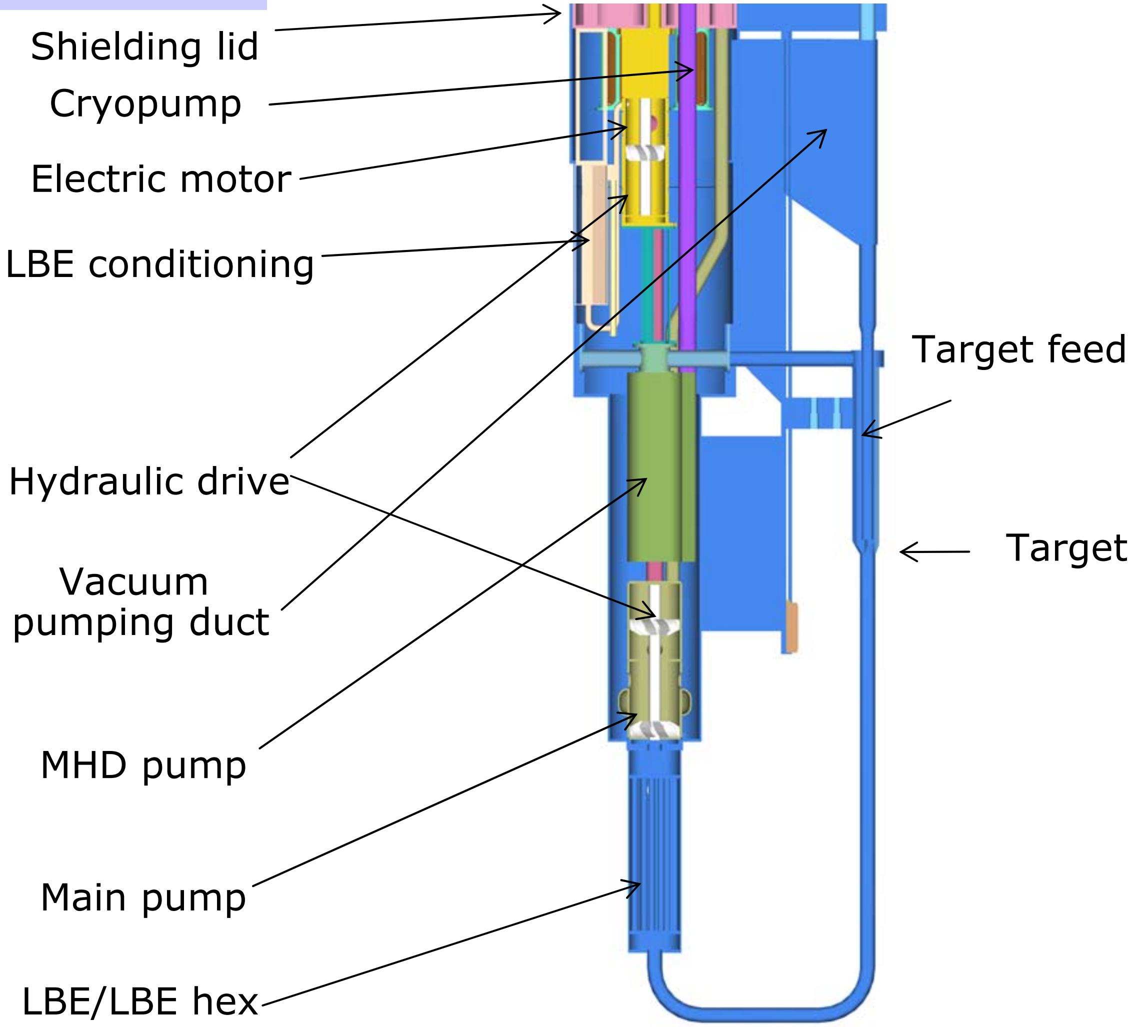
Loop configuration



- LBE flow & cooling
  - ➢ Forced convection (10-20 l/s)
  - ➢ $T_{max(LBE\ surface)}$=450°C; $\Delta T < 100$ °C
  - ➢ Heat exchanger to main vessel coolant
- Vacuum requirements
  - ➢ Pressure above target <10^{-3}-10^{-4} mbar
  - ➢ Confinement of volatile spallation products
- LBE conditioning
  - ➢ Corrosion inhibition, -Filtering
- Service by remote handling
  - ➢ Entire spallation unit removable from main vessel after core unloading
  - ➢ Separate sub-unit with all active elements

Loop layout schematics: MYRRHA draft 2





Shielding lid

Cryopump

Electric motor

LBE conditioning

Hydraulic drive

Vacuum pumping duct

MHD pump

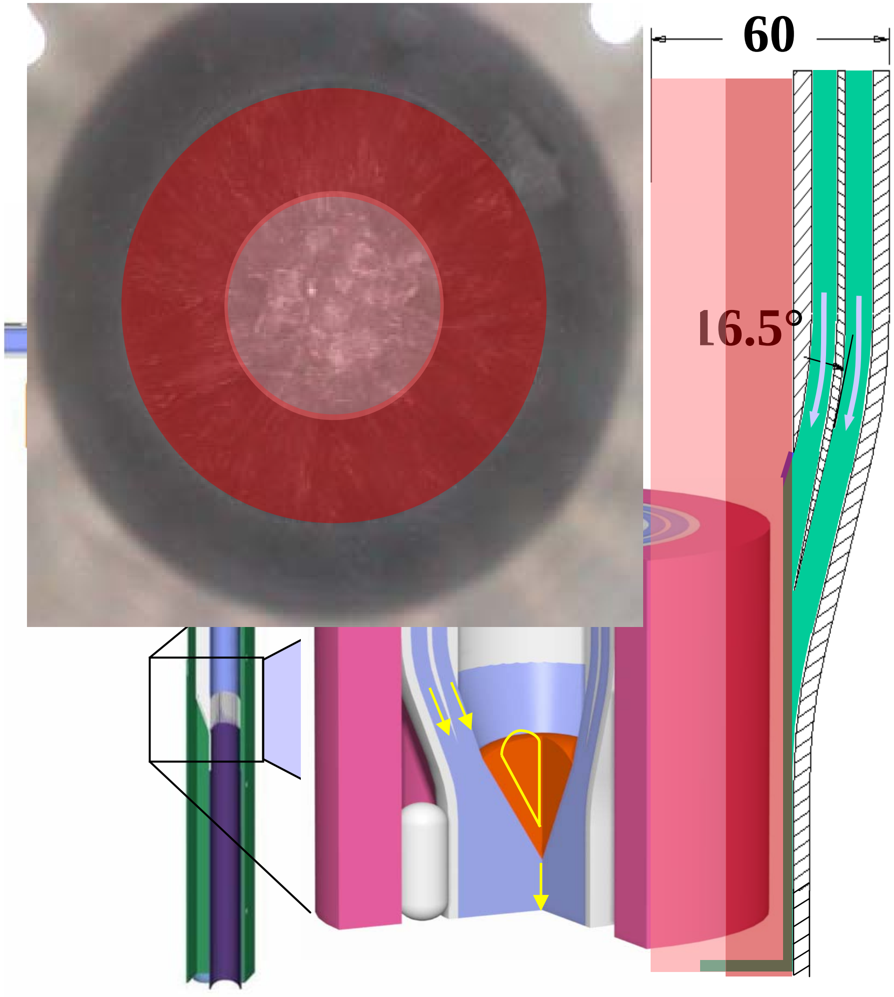
Main pump

LBE/LBE hex

Target feed

Target

Spallation target



- Formation of target free surface
  - ➢ Confluence of Vertical coaxial flow
  - ➢ Level : balance inlet-outlet flow
  - ➢ Recirculation zone : in check
    - ♣ Level balance Δh_{max}=3 mm
  - ➢ Feedback necessary
    - ♣ LIDAR level detection
  - ➢ Proton beam distribution
    - ♣ Avoid recirculation zone heating

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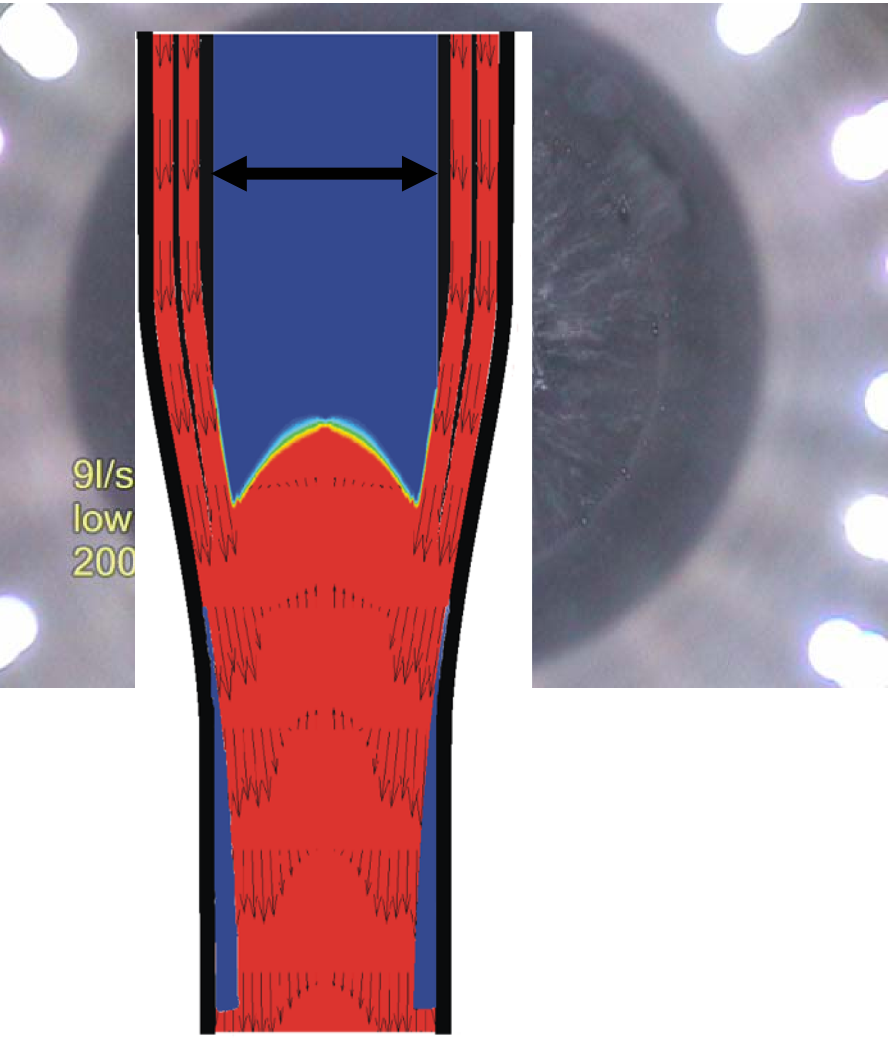
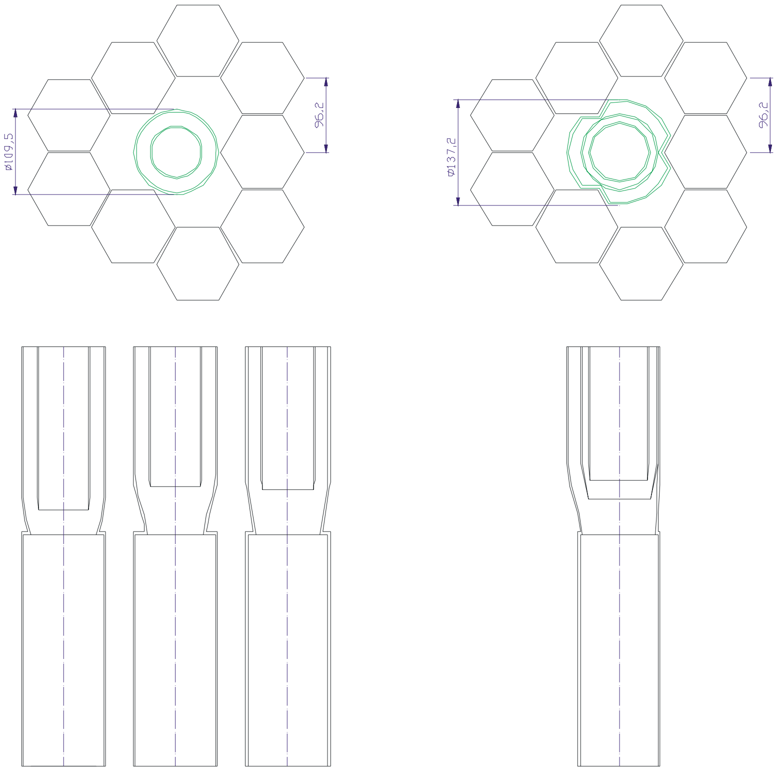
Spallation target



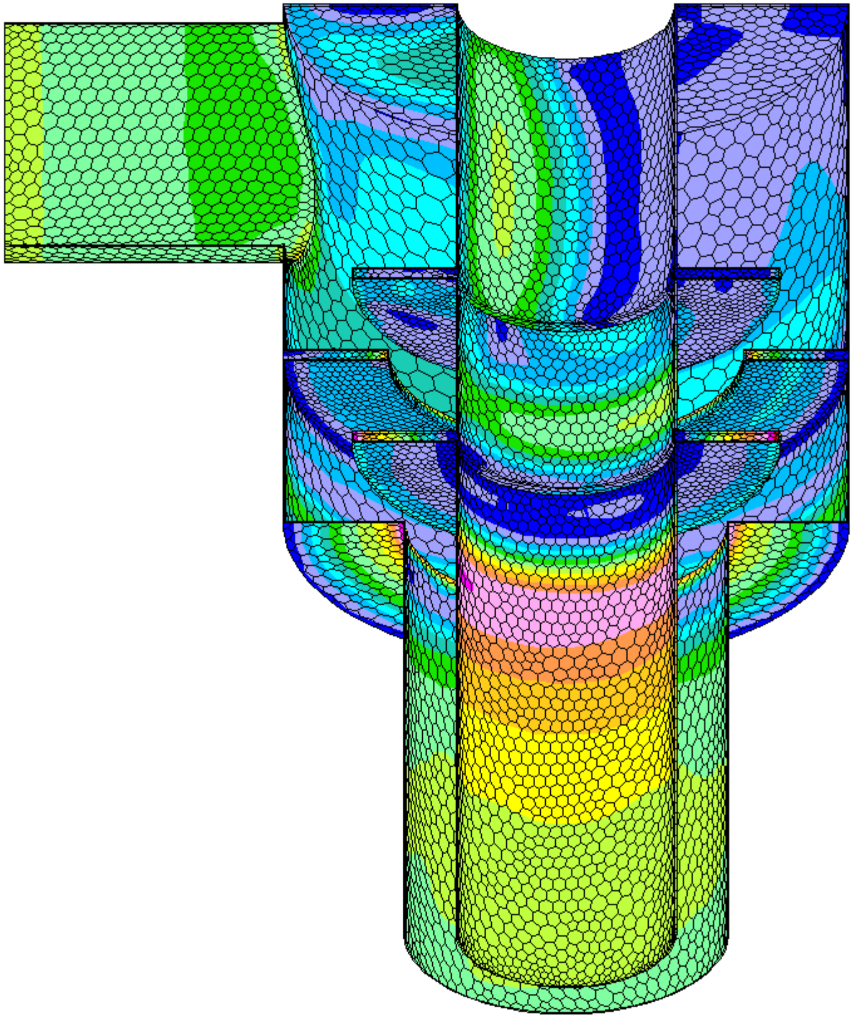
- Flow detachment required for stability→ build into design
  - Void below target interface
  - inlet & outlet flow decoupled
  - allow sufficient space to accommodate beam-on beam-off volume change
    - LIDAR feedback can be slower
  - LBE evaporation : OK
  - Wall cooling : OK
- Increase target surface
  - Maximum use of 3 feeder lobes

Spallation target nozzle: next activities



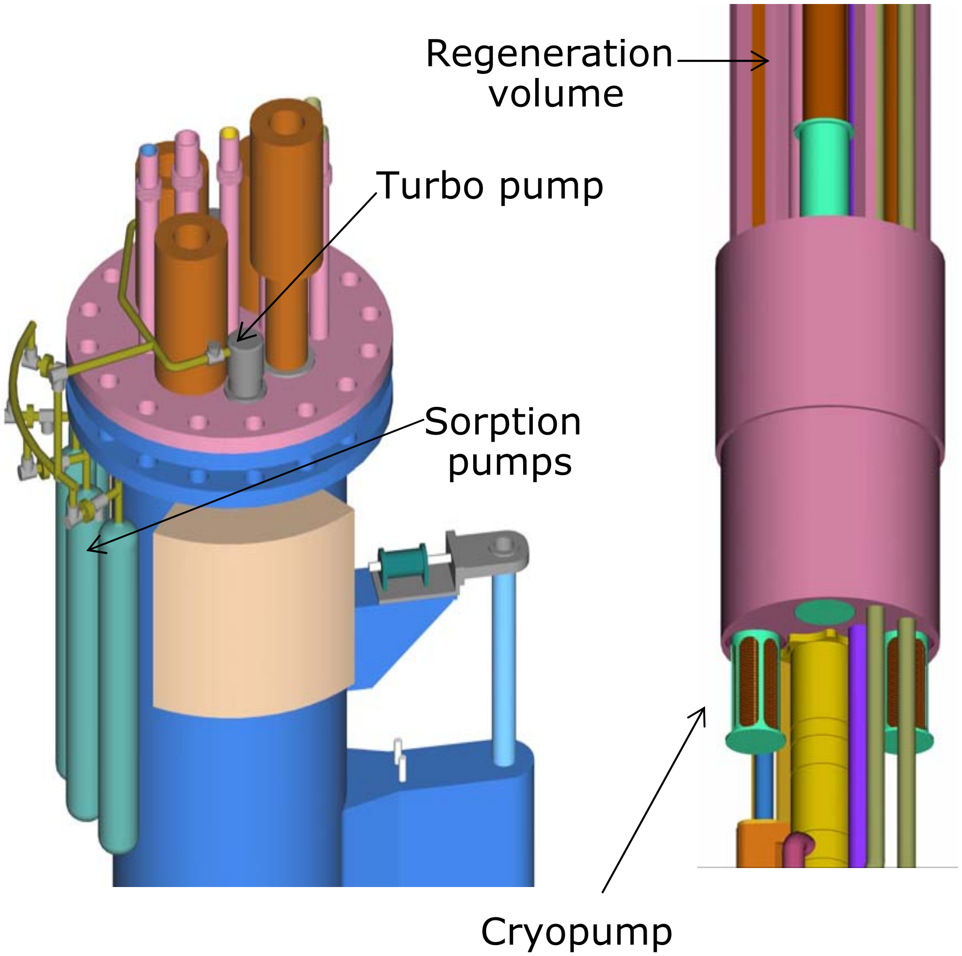
- Improvement of flow stability
    - ➢ Feeder :
      Drag limitation vs accelerated flow
    - ➢ Position of detachment point vs confluence point
    - ➢ Swirl
- Check different design options with CFD
- Flow experiments on selected designs

Spallation target: feeder head



- Design feeder head
- CFD simulations
  (V. Moreau CNRS, StarCD)
- Distribution plates
  - Destroy flow history
  - Homogeneous velocity distribution

Vacuum system : MYRRHA Draft 2



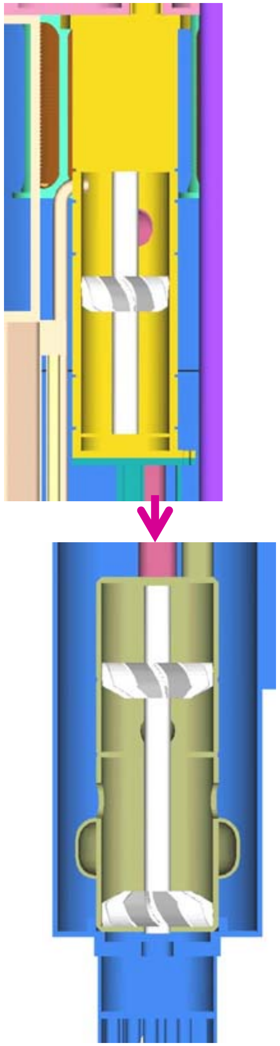
- Vacuum duct
- Cryopumps
  - 3 stage ($H_2$0, 77 K, 6K)
  - Active inner surface
  - 10000 l/s pumping speed
  - Hydraulically movable for regeneration
- Turbo pump
  - 400 l/s magnetic bearing
- Sorption pumps
  - Cooled zeolyte sorption (all condensables)
  - Active Zr-V-Fe getter (H, D,T)
  - Batch-wise removal

Spallation target

Vacuum system

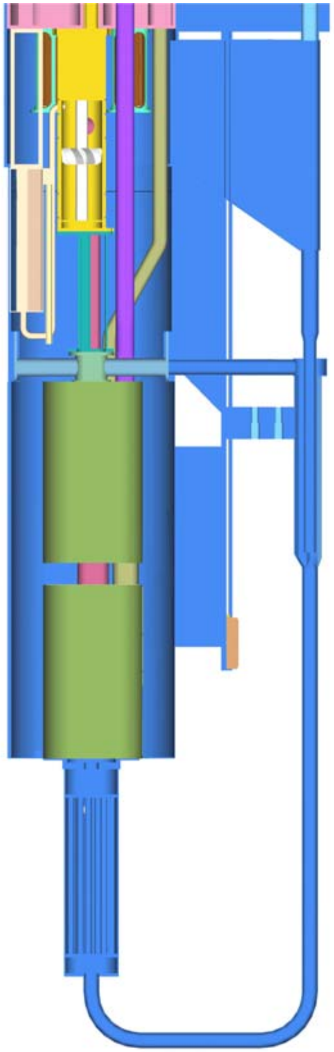
- Target shell : UHV
  - leaktightness
  - Cleanliness
- Maintaining vacuum above target : OK
- Vacuum pump effect of flowing LBE
  - diffusion of spallation products ?
  - to be quantified
- Free surface 1 (top)
  - Focus on spallation product confinement
  - Close off vacuum duct
  - Relax vacuum conditions (O 1 mbar)
  - Remove 6 K stage from cryopump →condensing station
- Regeneration during maintenance
  - Magnetic bearing Turbopump
  - Decay tank
  - Sorption pumps

Circuit pumps : MYRRHA Draft 2



- MHD pump
  - Fast regulator (little inertia)
  - Modified “Megapie” type
    - lower slip ratio (LBE-field velocity match)
    - increased pump length (1.2 m)
  - short active periods during transients
- Main mechanical pump
  - restore potential LBE energy $\Delta p=4.4$ bar
  - driven by hydraulic drive
    - LBE from target loop
    - 10 kW canned electromotor, pump, turbine
  - LBE pump options
    - impeller : accelerating fluid
    - helix (screw-spindle) : volume displacement

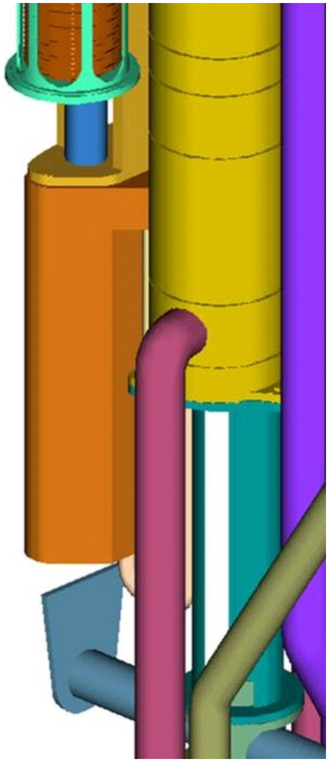
Spallation target Components
Circuit pumps



- Pump system
  - ➢ Q=10-20 l/s
  - ➢ total Δp=4.4 bar
- Detached flow in nozzle
  - ➢ Fast regulator not required
- Active feeder line MHD pump
- Active return line pump
  - ➢ Mechanical
    - ♣ impeller : accelerating fluid
    - ♣ helix (screw-spindle) : volume displacement
    - ♣ Hydraulic drive or long shaft
  - ➢ MHD
    - ♣ Efficiency
    - ♣ Space (ϕ≈800 mm, L≈1000 mm)

Spallation target Components

Conditioning unit



- Oxygen control
  - sensors
  - Adding/removing oxygen (steady state)
    - continuous control via PbO pebble basket
    - most spallation products chemically reducing
    - exchange rate by temperature in conditioning vessel
  - Gross Oxygen reduction
    - gas treatment in-vessel only off-line
    - separate conditioning tank (heating issue)
- Filtering ?
  - magnetic filtering before MHD pump
  - pool-type filtering (surface accumulation)

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Summary

- Conceptual design of XT-ADS spallation target loop
- Confirmation of MYRRHA draft 2 fundamental properties :
  - no target window
  - compact vertical confluent flow for target formation
  - off-axis servicing
  - two pump uncoupled LBE pumping system
- Modifications to MYRRHA draft 2 :
  - boundary conditions
  - Spallation target nozzle : detached flow
  - pumps system : active pump in feeder line
  - Vacuum system
- R&D Confirmation…