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MYRRHA

Design of the MYRRHA/XT-ADS spallation target

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on behalf of the MYRRHA Team & EUROTRANS WP 1.4

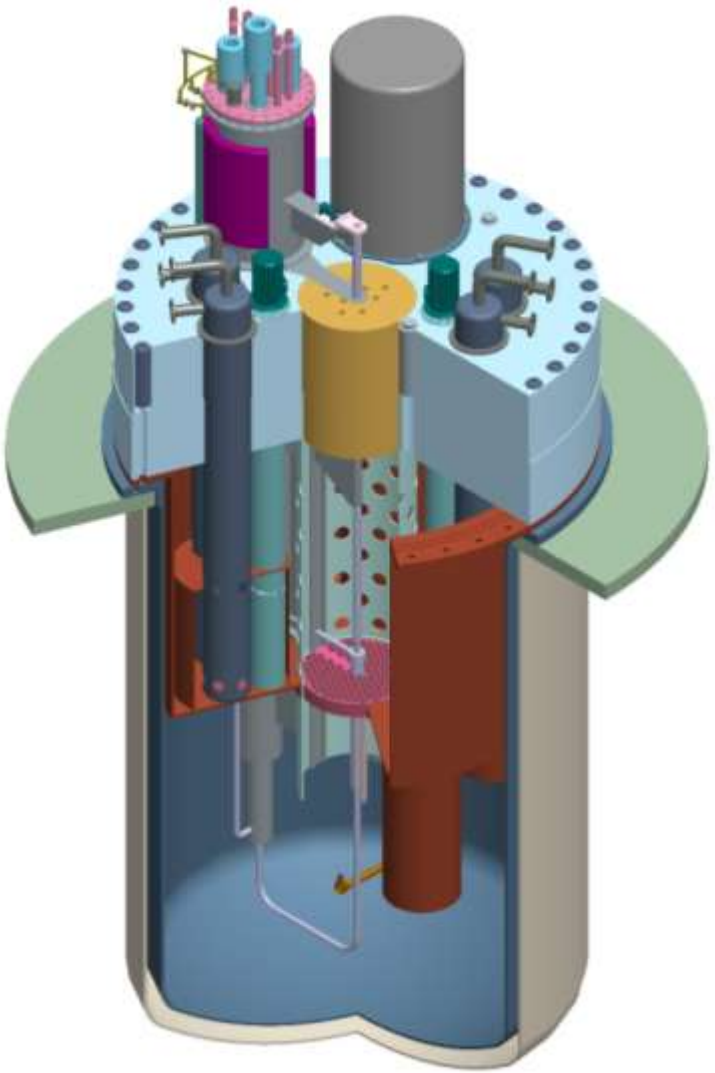
MYRRHA

- ADS first step demo facility at power (50-100 MW)
- Flexible irradiation facility
  - Fast spectrum
  - GenIV
  - Materials & fuel research
  - Medical isotope production
  - Replacement of BR2

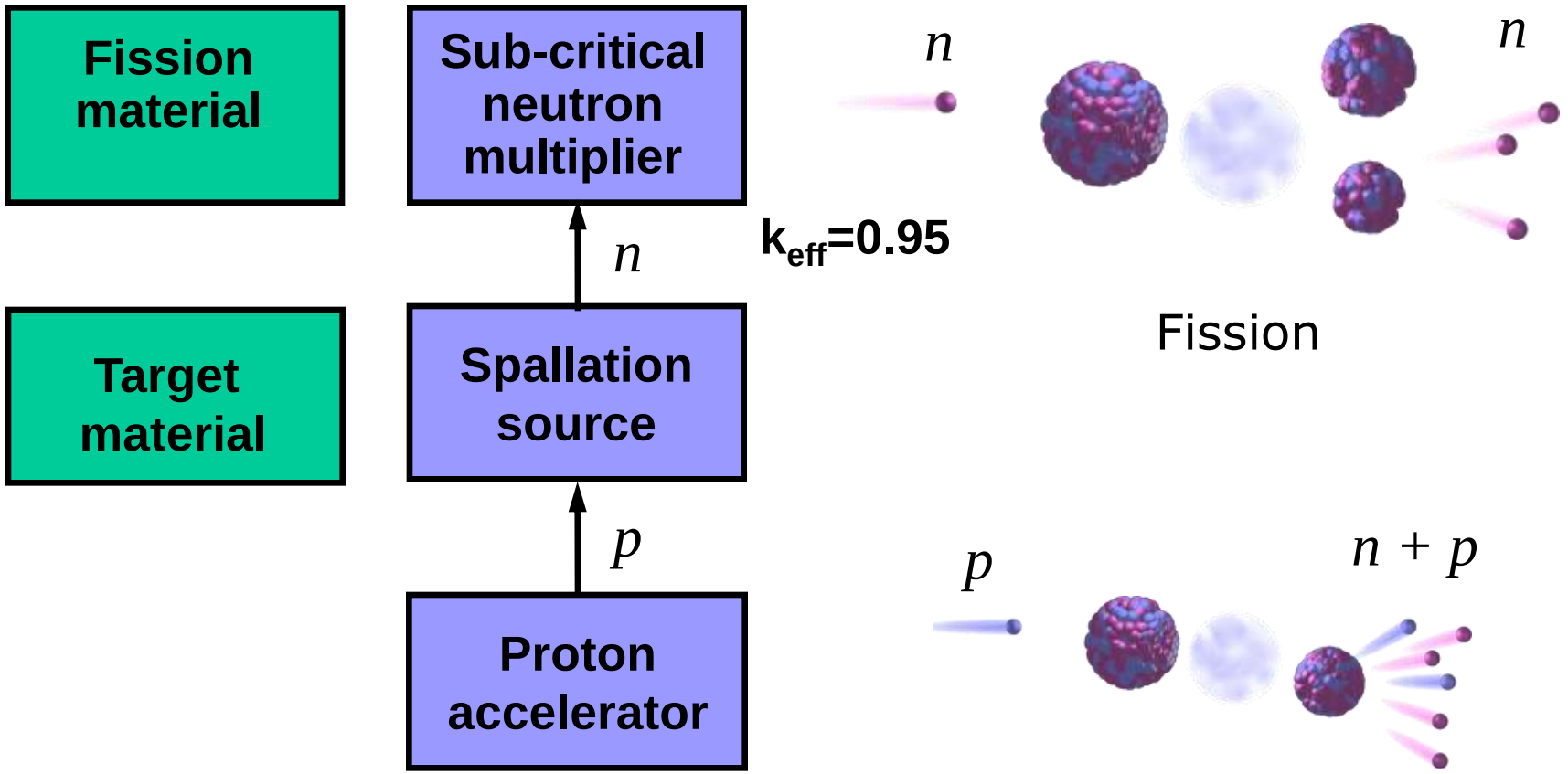
Need for high performance core :

high power density in limited volume

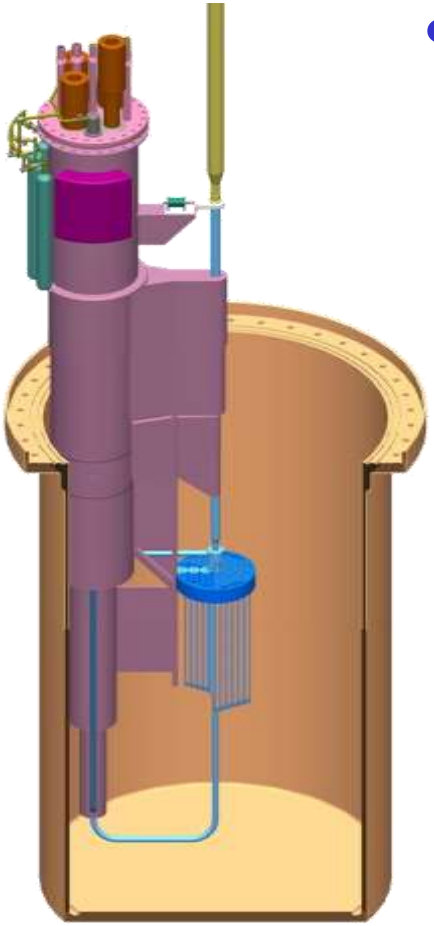
- Φ_{th} ~1.2x10^{15} n/cm^2 .s)
- $\Phi_{>0.75\ MeV}$ ~0.8 10^{15} n/cm^2 .s)



Accelerator driven system Concept

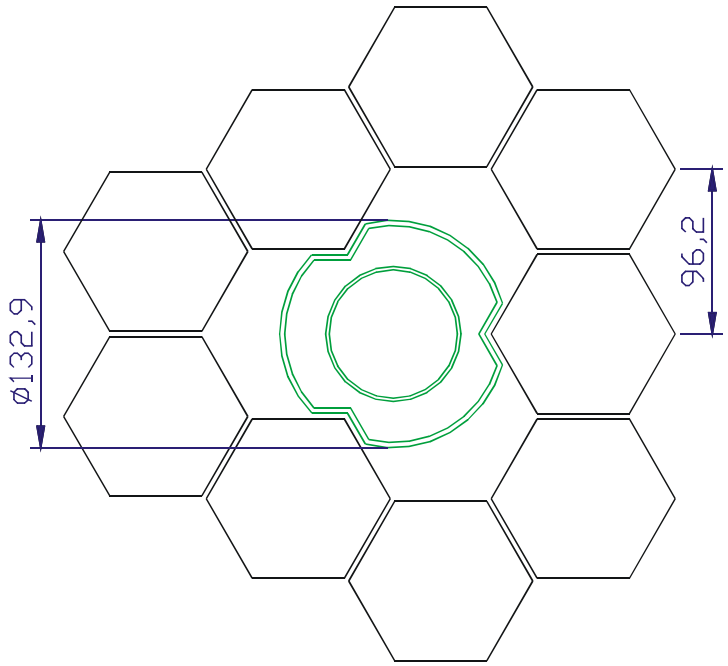


Spallation target
requirements & boundary conditions



- Tasks
  - Produce 10^{17} neutrons/s to feed subcritical core @ k_{eff}=0.95
  - Accept megawatt proton beam
    - **600 MeV, 2.5-3 mA ⇒ ≈1-1.2 MW heat**
  - Fit into central hole in core (3 fuel hexagons removed)
    - compact target
    - Off-axis geometry
  - Match MYRRHA purpose as experimental irradiation machine
    - flexible remote handling
  - Survive (lifetime)

Target Design : Conceptual properties



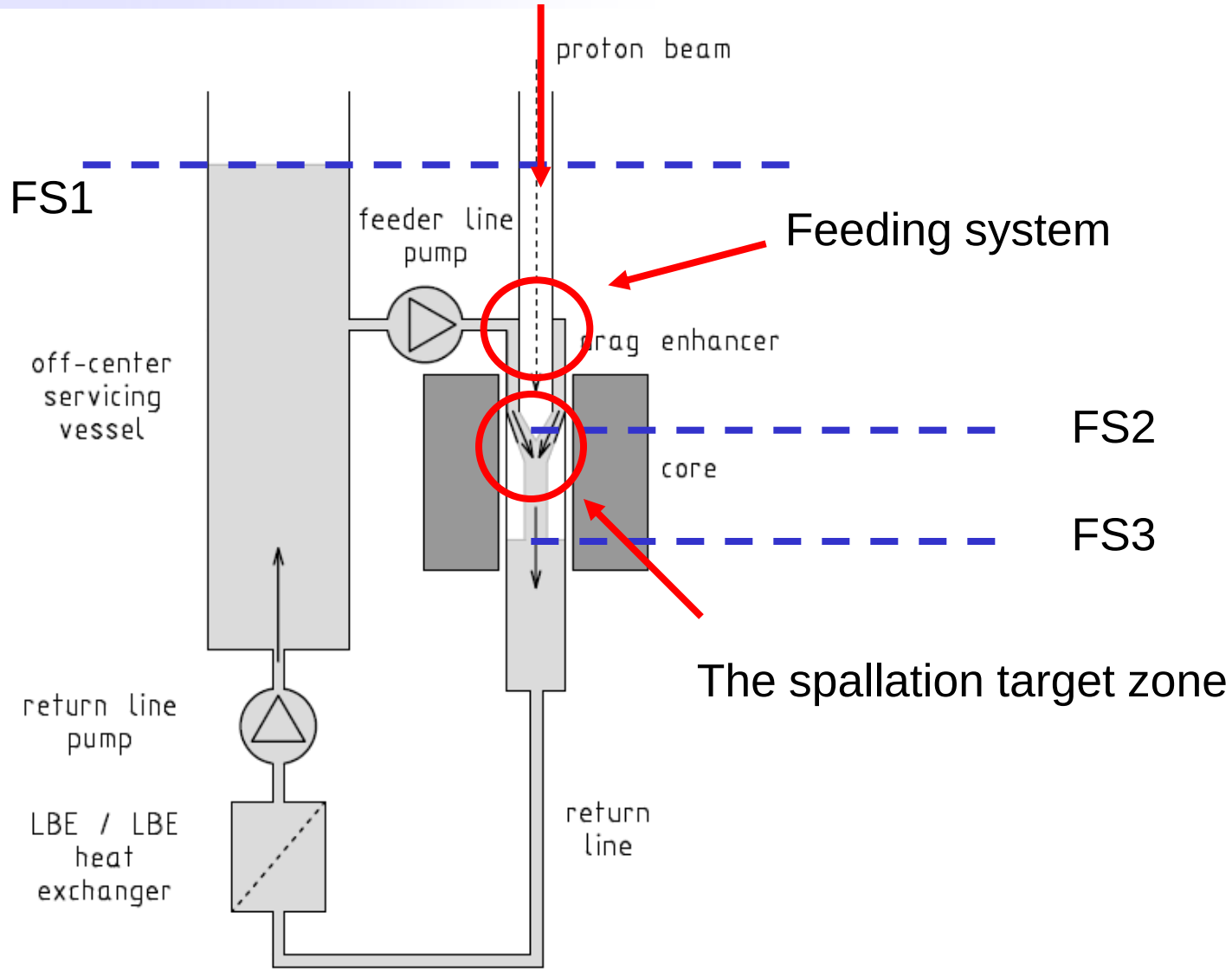
- Windowless target
  - Beam current density
  - Avoid most loaded part of system
  - Precautions in case of window failure to be taken anyway
- Vertical coaxial confluent LBE flow
  - Space consideration
  - Free surface formation
- Off axis servicing unit (pumps…)
  - Leave top & bottom of core free
    ⇒ Accessibility
  - Loop away from high radiation zone
    ⇒Lifetime

Target Design : Conceptual properties

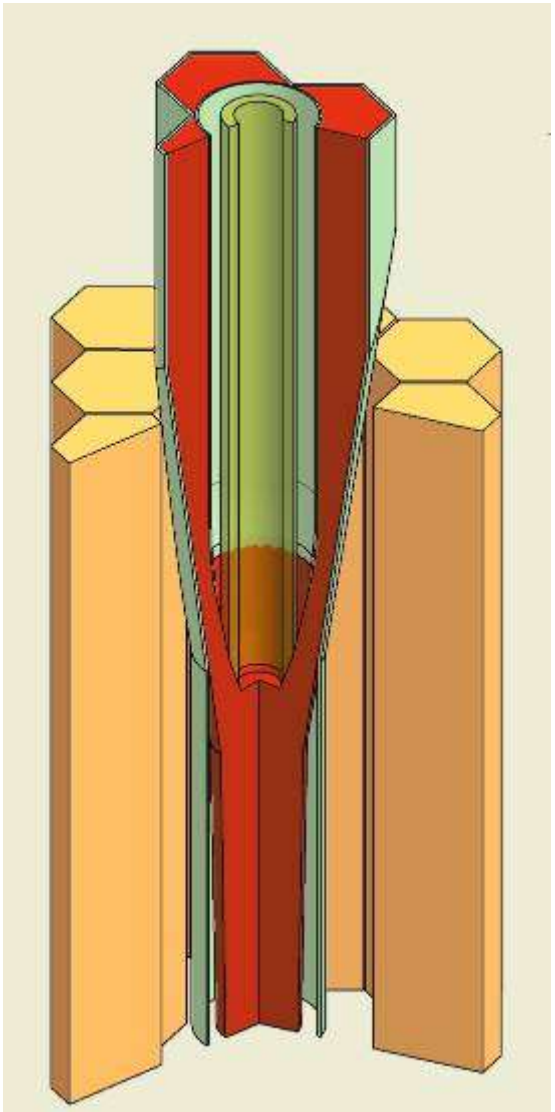
- PbBi as target material
  - Low temperature possible (T_{melt}≈125°C)
  - Low vapour pressure

  (PbBi is also primary system coolant)
- PbBi flow & cooling
  - Forced convection (13 l/s nominal flow)
  - $T_{max(LBE\ surface)}$=450°C; ΔT< 100 °C
  - Heat exchanger to main vessel coolant
- Service by remote handling
  - Entire spallation unit removable from main vessel after core unloading
  - Separate sub-unit with all active elements

Target principle



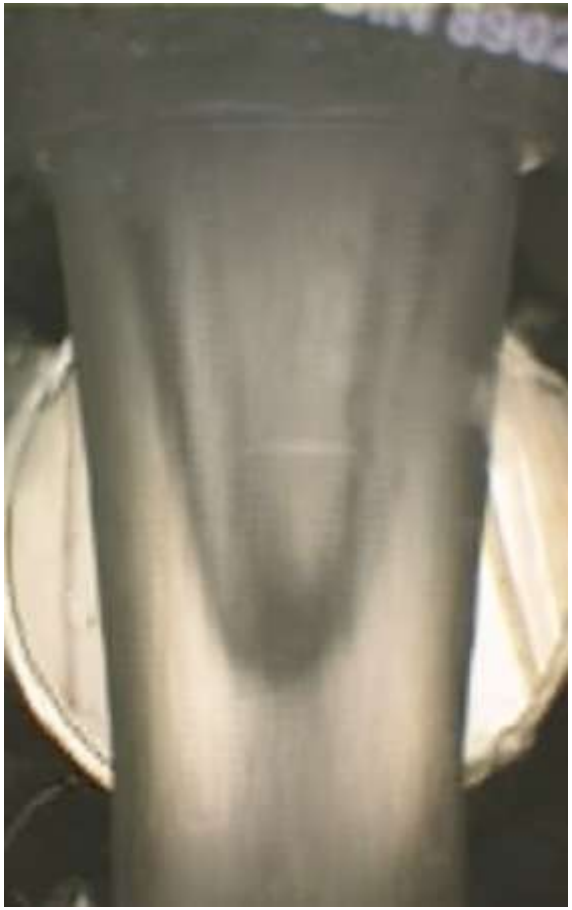
Windowless Spallation target Thermalhydraulics

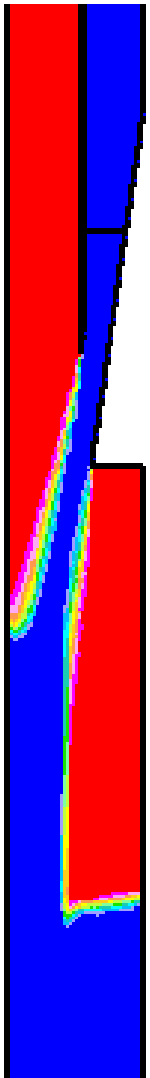


Formation of target free surface

- Confluence of Vertical coaxial flow
- Drag enhancer

Windowless Spallation target Thermalhydraulics



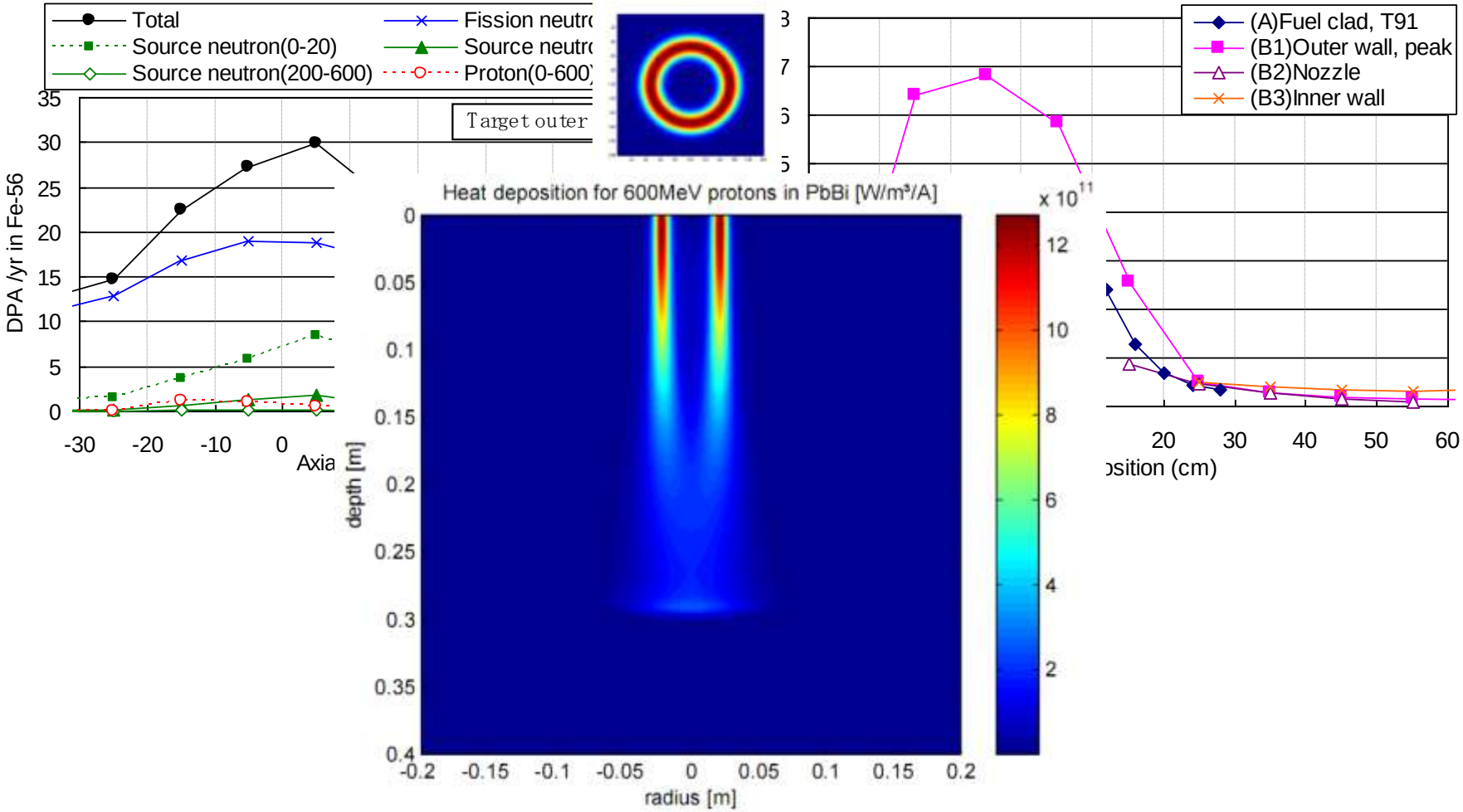


Formation of target free surface

- Forced detachment
  - ♣ Decoupled inlet-outlet flow
  - ♣ Buffer during beam transients
- Recirculation zone : in check
- Feedback necessary (slow)
- Proton beam distribution
  - ♣ Circular path (200 Hz)

more details : talk by Abdalla Batta

Windowless Spallation target
Heat deposition & Radiation damage assessment



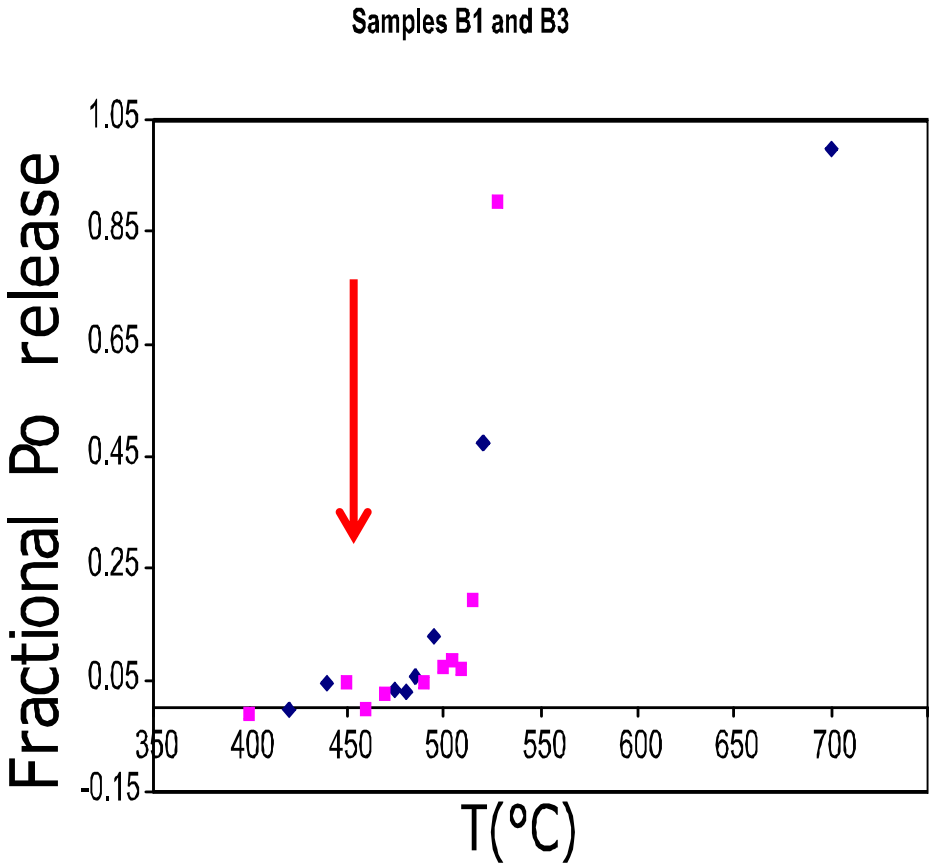
Windowless Spallation target
Vacuum interface issue

- No Vacuum compatibility conflict
  - Outgassing OK (3.10^{-7} mbar @400°C)
  - Gas load of spallation products : OK
  - LBE evaporation : ok (Sleeve)
- Vacuum system assessment
  - Composition of gas load
  - Quantification of vacuum pump effect of flowing PbBi (WIPE experiment)

Windowless Spallation target
Vacuum interface issue

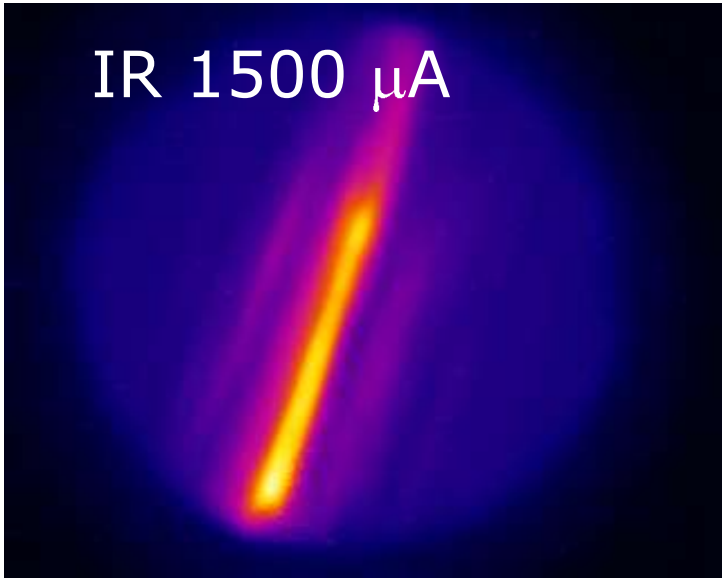
- Spallation product confinement
  - Main issues with Po & Hg
- Design of vacuum system
  - Expansion volume (≈10 mbar) (large free surface)
  - 2 stage cold trap (H_2O, 77K)
  - Turbopump to decay tank
  - Getters & Batch-wise removal

J. Neuhausen (PSI)



Windowless Spallation target
Beam Target interaction

- Simulate beam-surface interaction with electron beam (7 MeV)
- Various tests at beam currents up to 10mA
  (= 100 x XT-ADS)
  - No shockwave effects detected
  - No significant droplet ejection effects
  - No significant evaporation enhancement



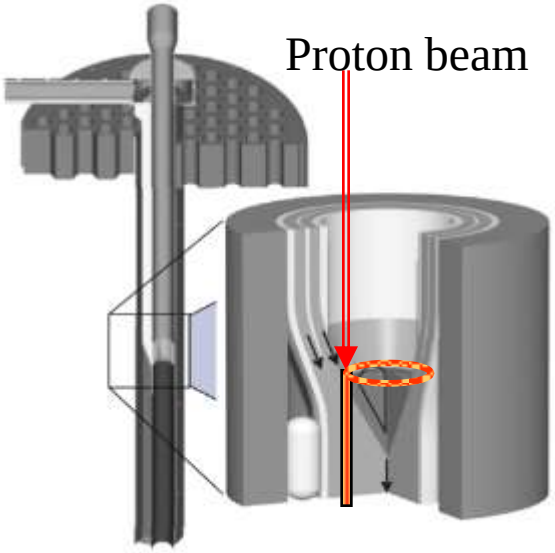
➔ WEBEXPIR free surface flow was not disturbed by the interaction with the electron beam

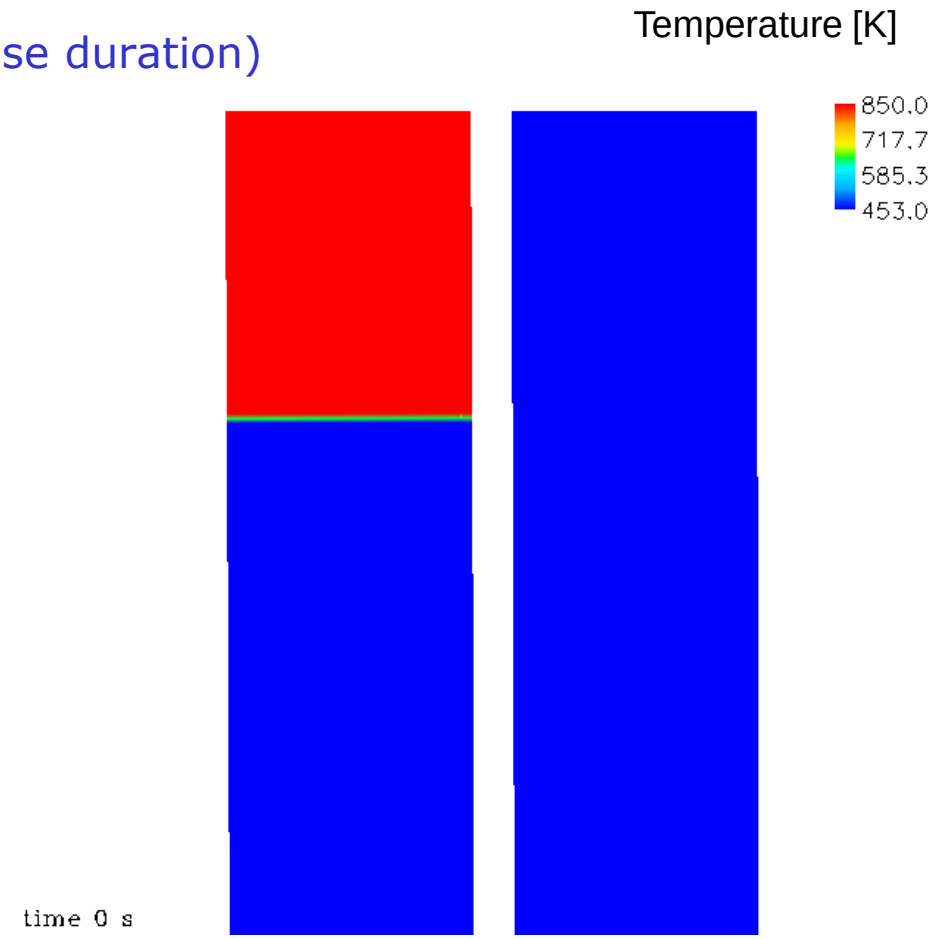
➔ vacuum conditions stay well within the design specifications

➔ Bulk heating effects :
CFD modelling

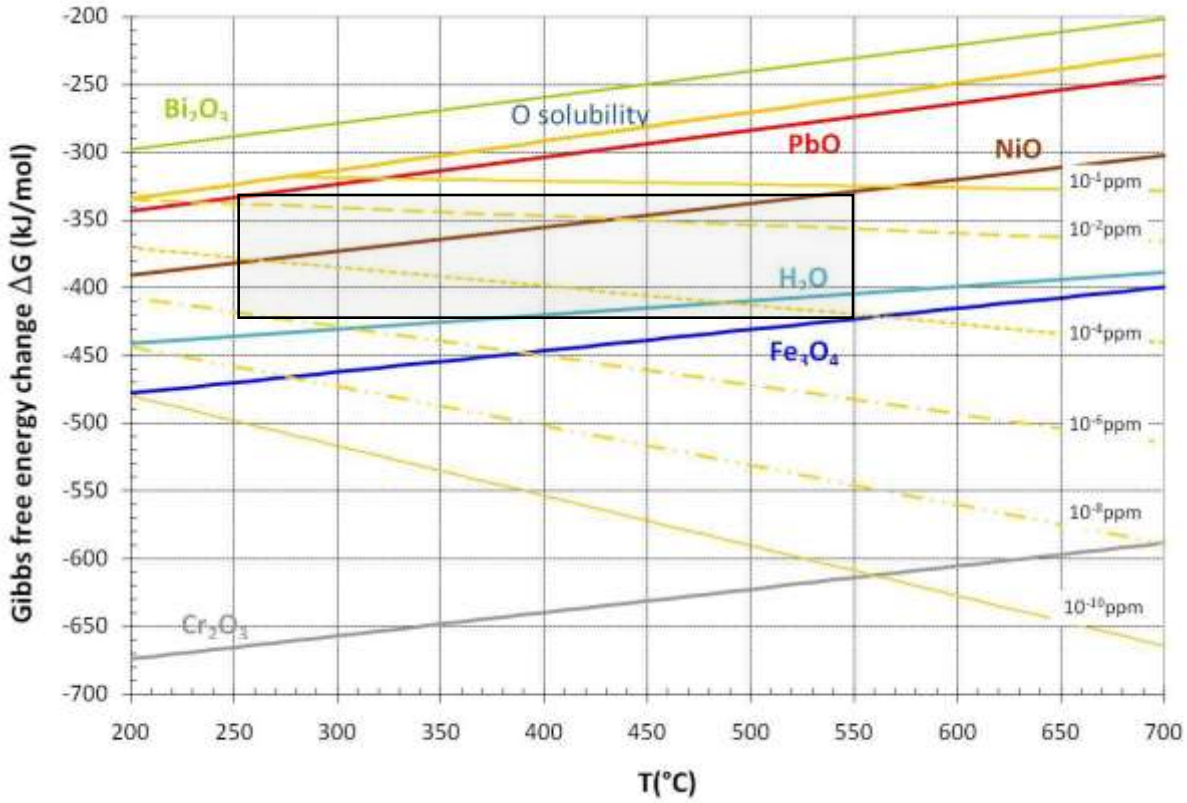
Beam impact study (First results by NRG)

- Simulation in stagnant LBE
- Rotating beam (200 Hz)
- Splashing seems "slow" (1500x pulse duration)
- Real effect ? (codes in disagreement)
- LBE flow prevents splashing ?
  convection is dominant ?





Spallation target
Corrosion in PbBi



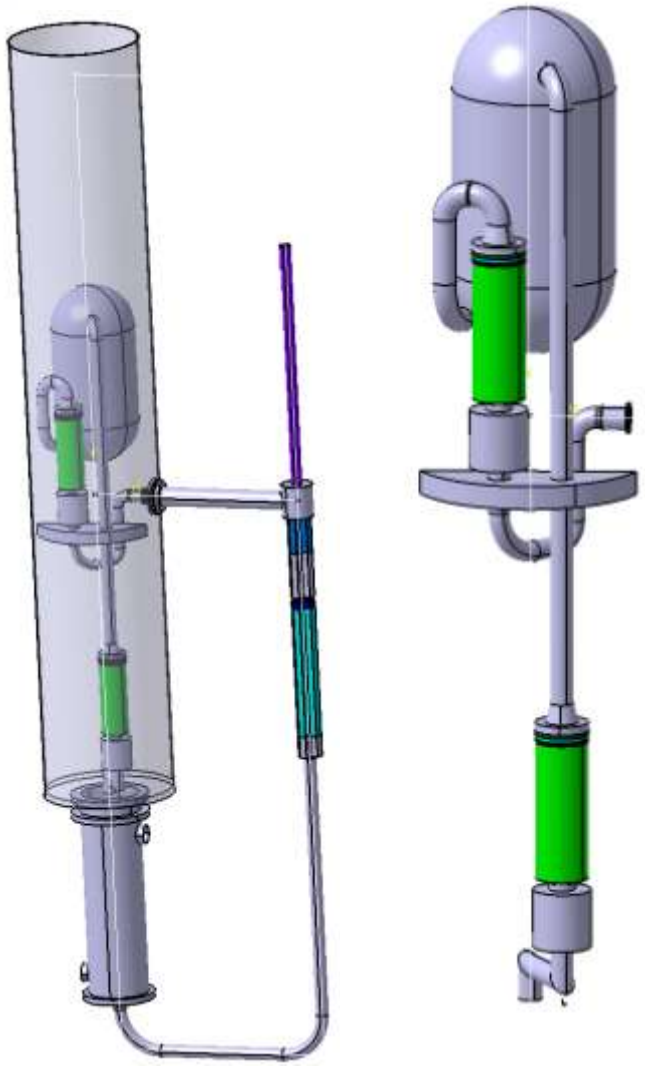
- Oxygen control
  - Balance of Gibbs free energy

Spallation target
Corrosion in PbBi

- 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-off line vessel
    - ♣ separate conditioning tank (heating issue)
- Filtering ?
  - magnetic filtering before MHD pump
  - pool-type filtering (surface accumulation)

New issues in the pipeline

- Non-submerged pumps
- completely separate non-submerged target loop
  - ☺ less LBE volume
  - ☺ less waste during intervention
  - ☺ Extra confinement barrier
  - ☺ More independent temperature regulation for pumps
  - ☹ 2 gas tight remote handling seals req.
  - ☹ draining required at each interventior
  - ☹ Extra gas based cooling circuit
  - 😐 Space allocation ?



- Evaluation (comparision with) window target

Summary

- Design of XT-ADS/MYRRHA spallation target loop
- fundamental properties :
  - no target window
  - compact vertical confluent flow for target formation
  - off-axis servicing
  - two pump uncoupled LBE pumping system

  - Spallation target nozzle : detached flow
  - pumps system : active pump in feeder line
  - Vacuum system
  - Oxygen control unit
- R&D Confirmation…
- Design review