Experimental investigation of a free surface spallation target window for a heavy liquid metal cooled ADS

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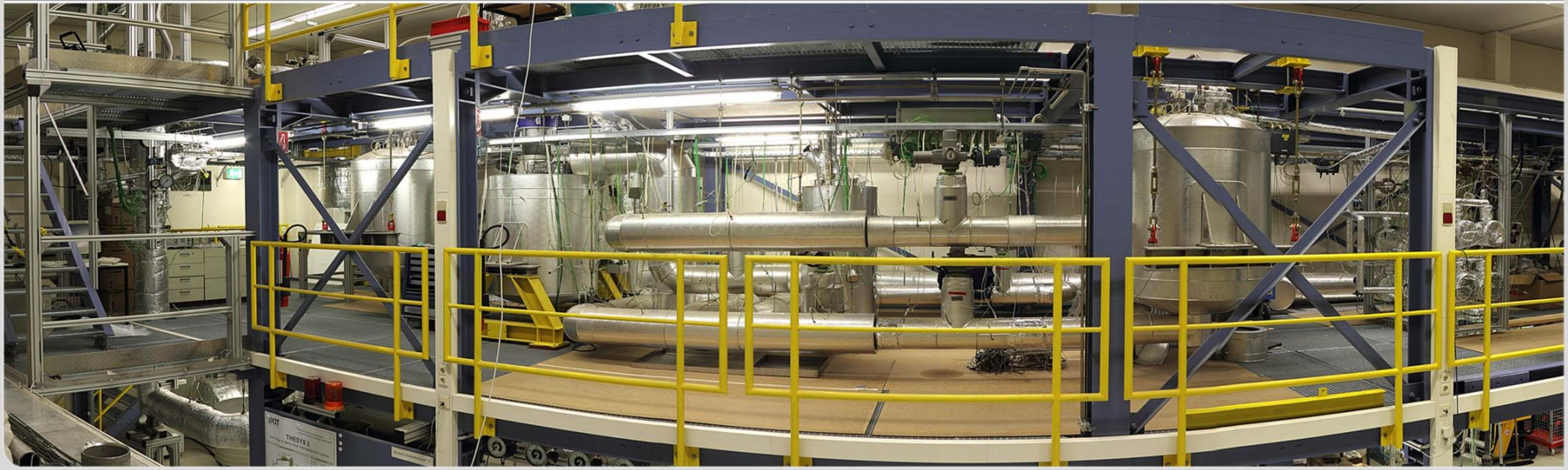
Institute for Nuclear and Energy Technologies



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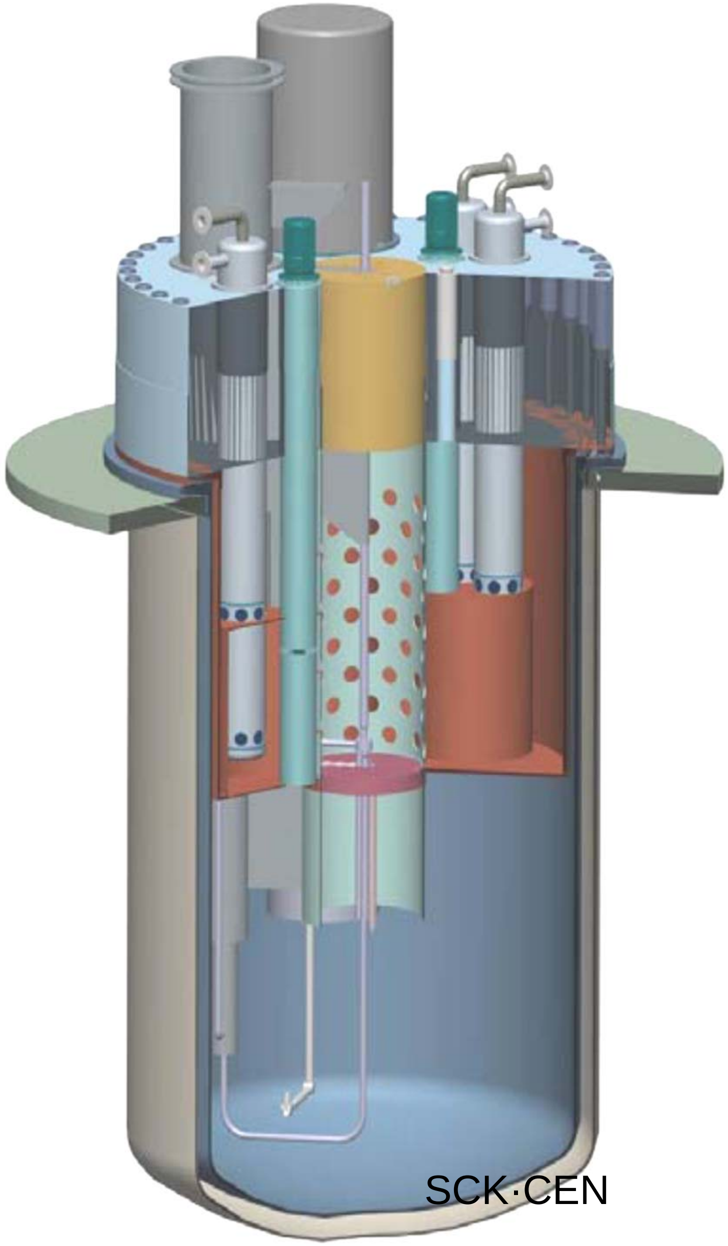
The Integrated Project EUROTRANS (EUROpean Research Programme for the TRANSmutation of High Level Nuclear Waste in Accelerator Driven System) aims to demonstrate feasibility of transmutation in an advanced 50 to 100 MW_{th} facility.



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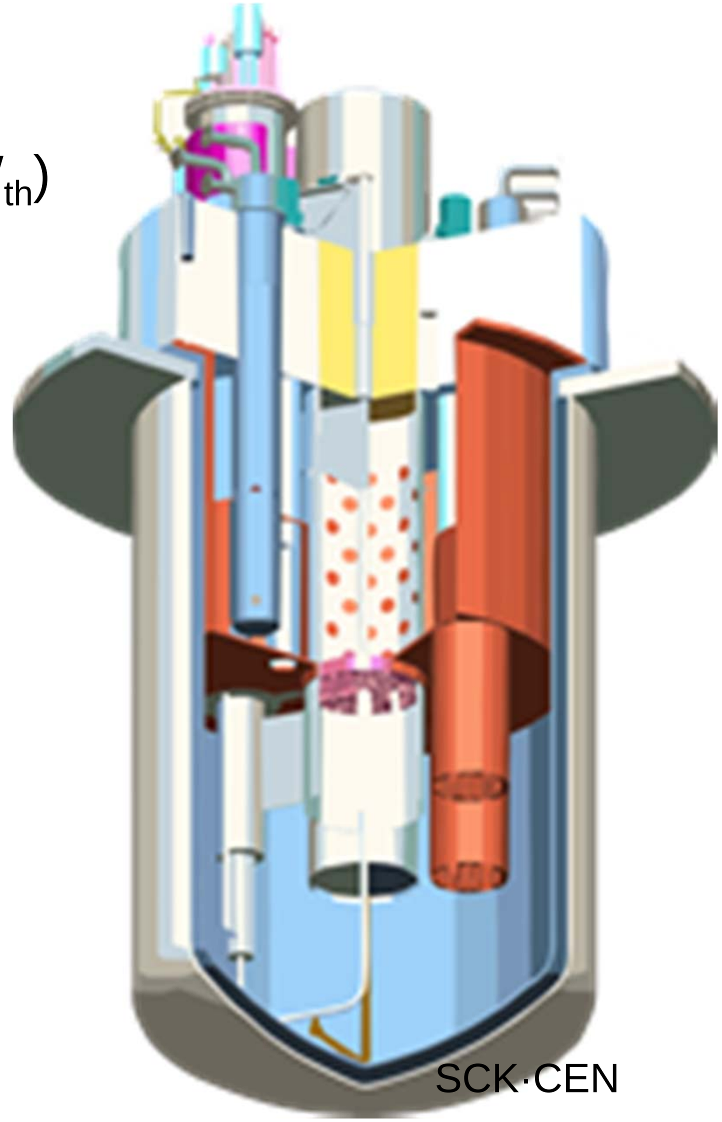
Introduction

MYRRHA fast spectrum research reactor (50-100 MW_{th})

- sub-critical ADS
- 600MeV proton accelerator
- Spallation target
- LBE pool type reactor

Time schedule

- Design and licensing 2010-2014
- Construction 2015-2022
- Full power operation 2023
- Costs: 960 M€



MYRRHA design

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Target design

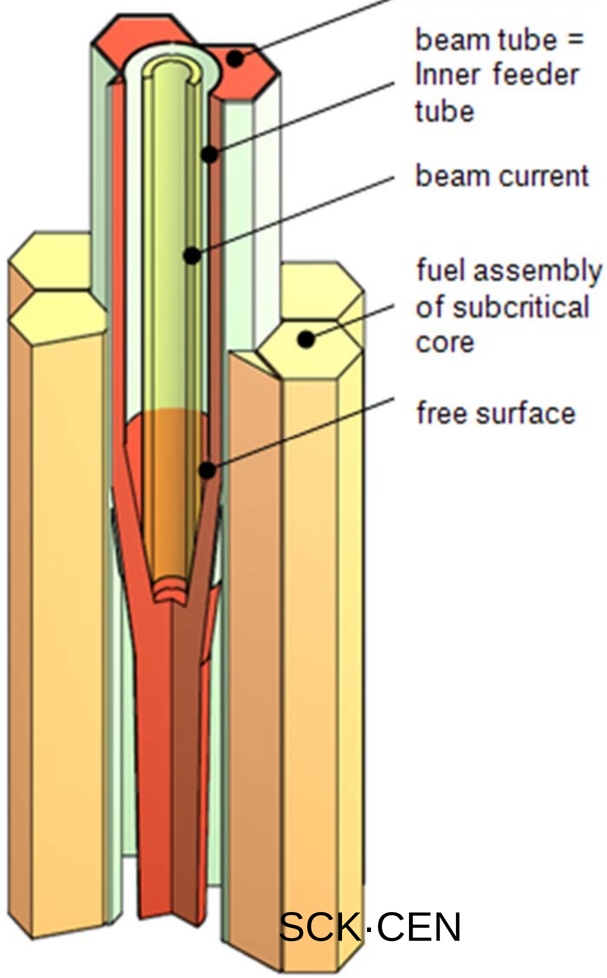
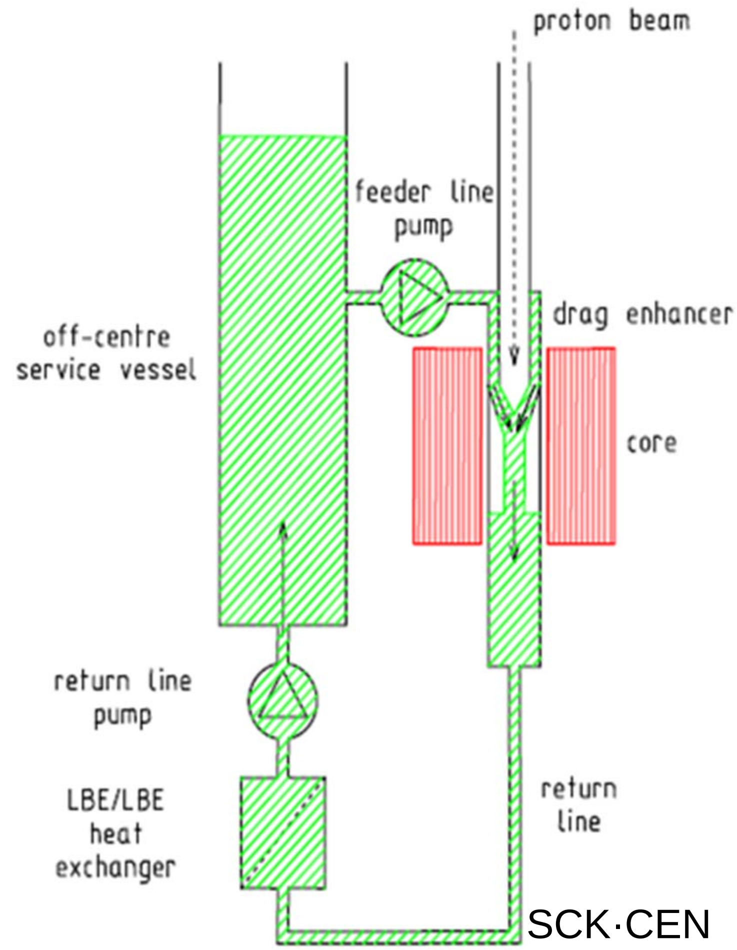


Illustration of target inserted into reactor core replacing 3 fuel assemblies



Layout of the loop with three free surfaces and level control by two pumps

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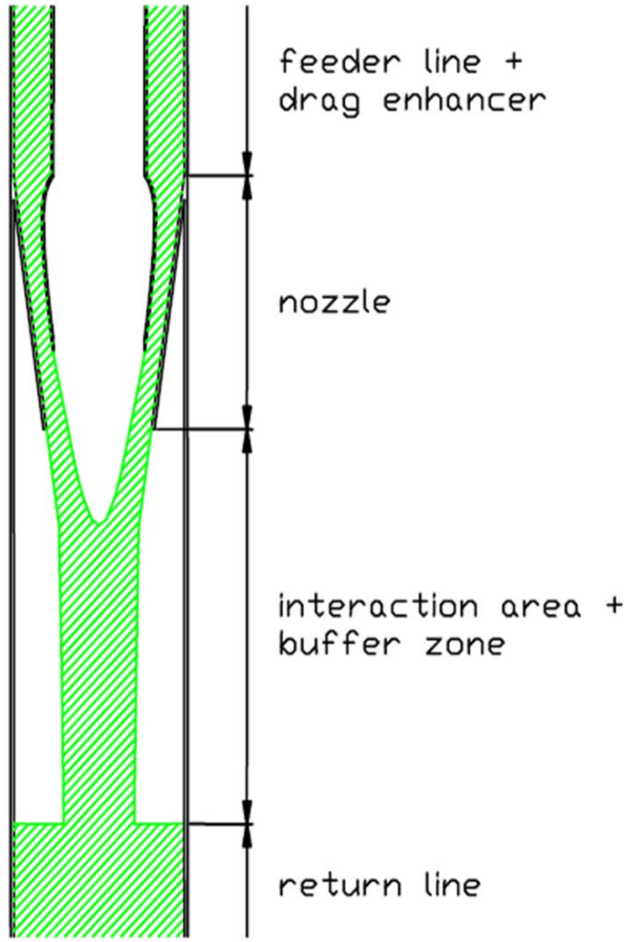
Target design rules

- Small nozzle outer angle:
  - small radial momentum
  - small recirculation zone
- Forced detachment:
  - Sharp edge of nozzle
  - free falling jet
  - weak influence from outflow
- Converging nozzle
  - vacuum at nozzle outlet
  - acceleration compensates gravity and prohibits cavitation
- Feeder
  - friction fins enlarge pressure head and suppress cavitation



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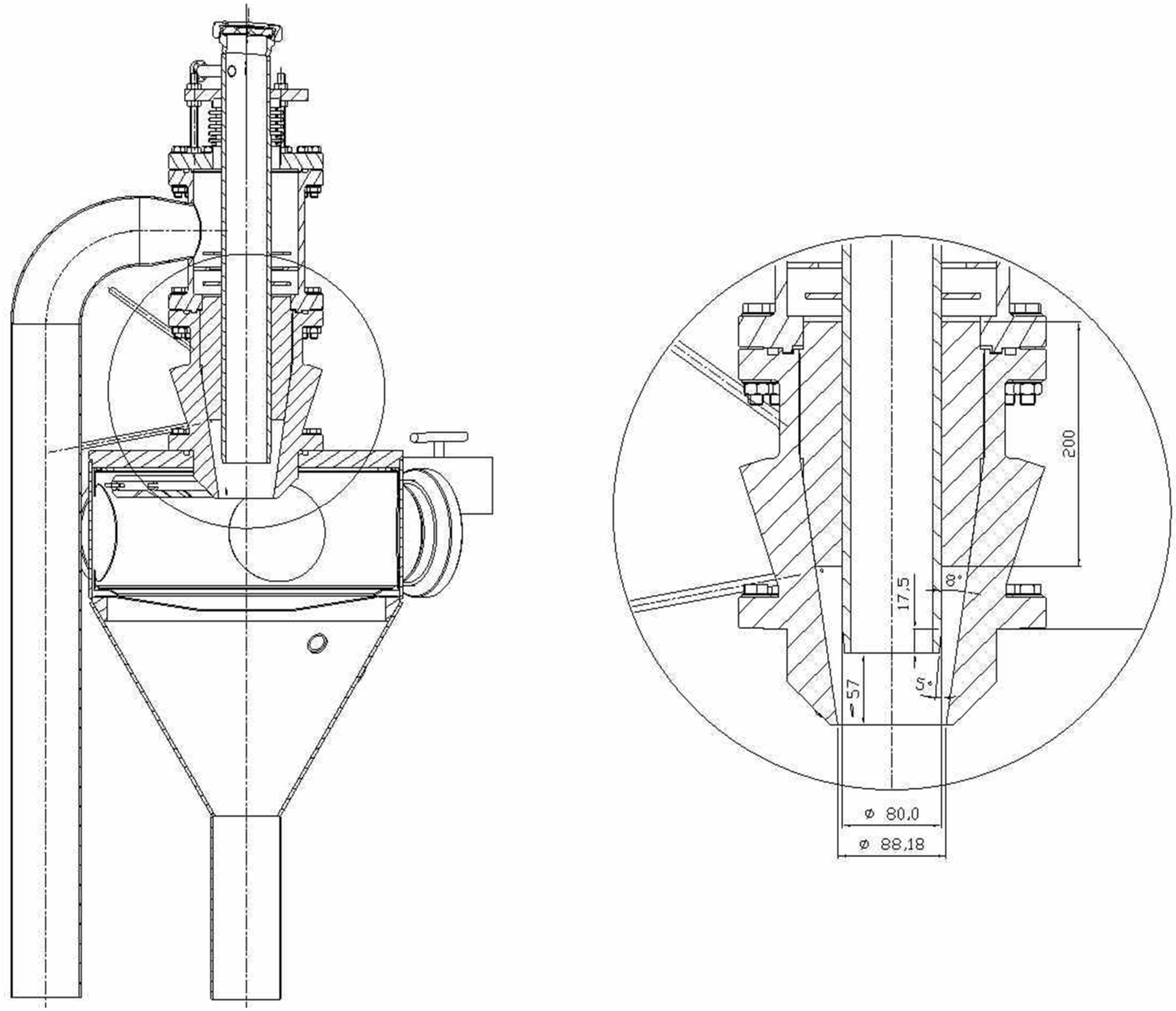
Target experiment design

Different designs were discussed in DEMETRA project. Changes in the last design steps are:

- Shorter feeder to enable higher mass flow rate
- Slightly modified beam pipe at the tip and outer radius to get higher acceleration to avoid cavitation for lower flow rates.



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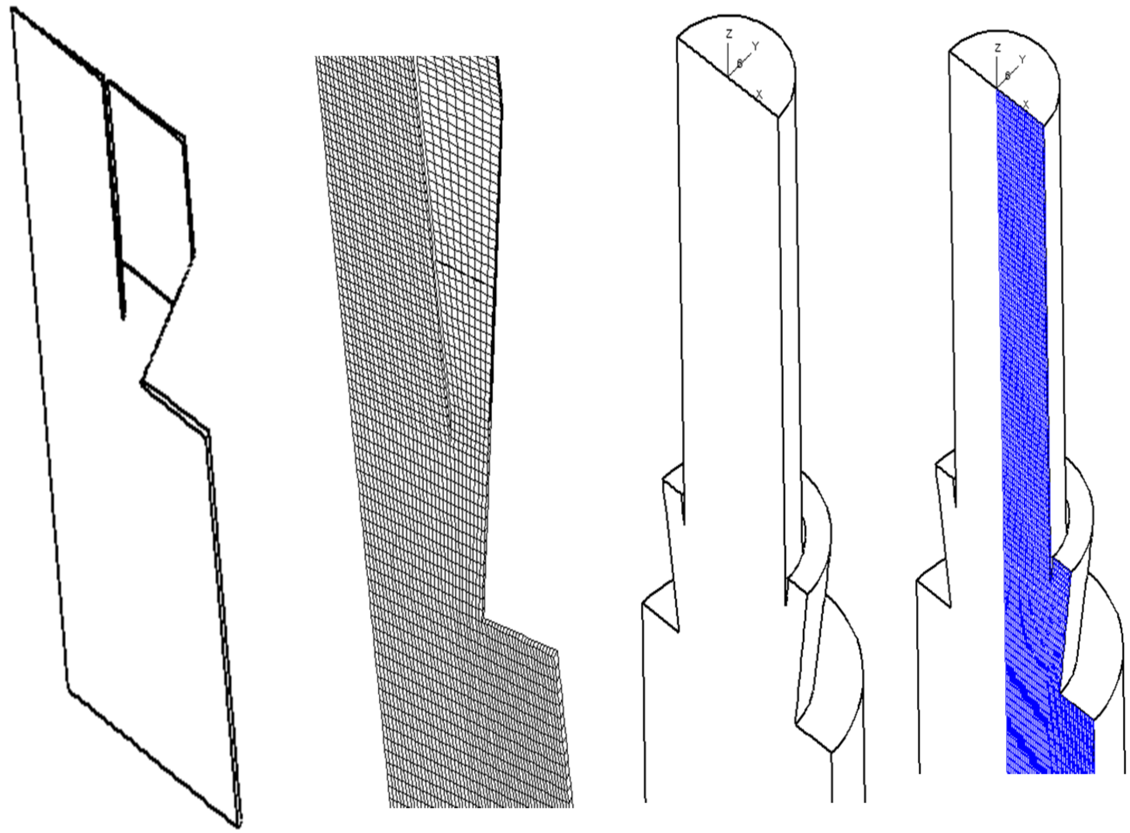
Numerical study setup

- Standard high Re k-ε-turbulence model
- Cavitation model:
  - Volume of Fluid
  - Phase change described by Rayleigh model (bubble growth)
  - Constant fluid properties for each phase
  - High resolution interface capturing
- Grid independence and turbulence model effect have been analyzed
- Domain selected based on symmetry consideration



1.8° geometry and mesh ~ 20.000 cells

180° geometry and mesh ~ 500.000 cells

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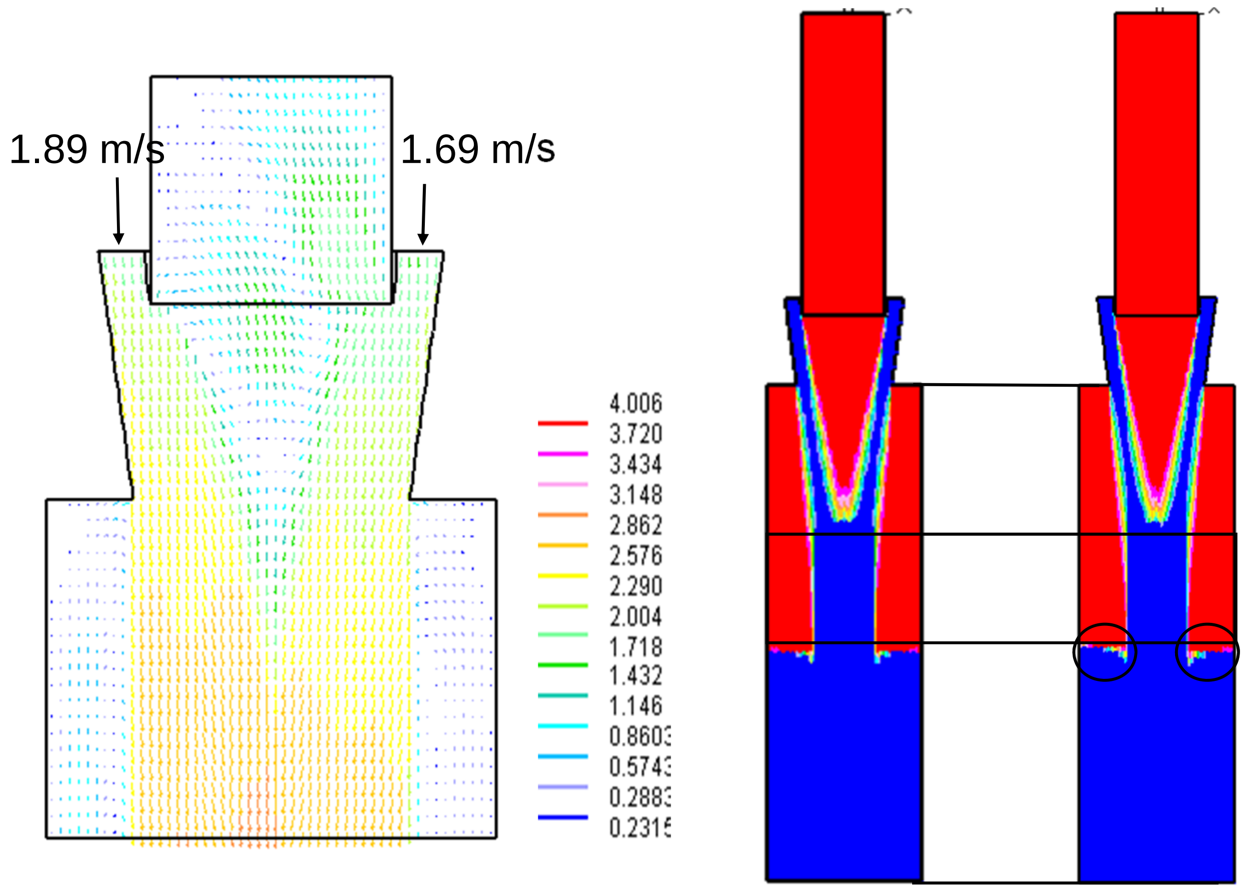
Numerical study results

- Comparison of 1.8° and 180° domain shows negligible asymmetries
- Small domain saves up to 90% calculation time



velocity vectors, asymmetric

10.3 l/s Symmetric

10.3 l/s Asymmetric

Velocity vectors near inlet; comparison of HLM vapour volume fraction

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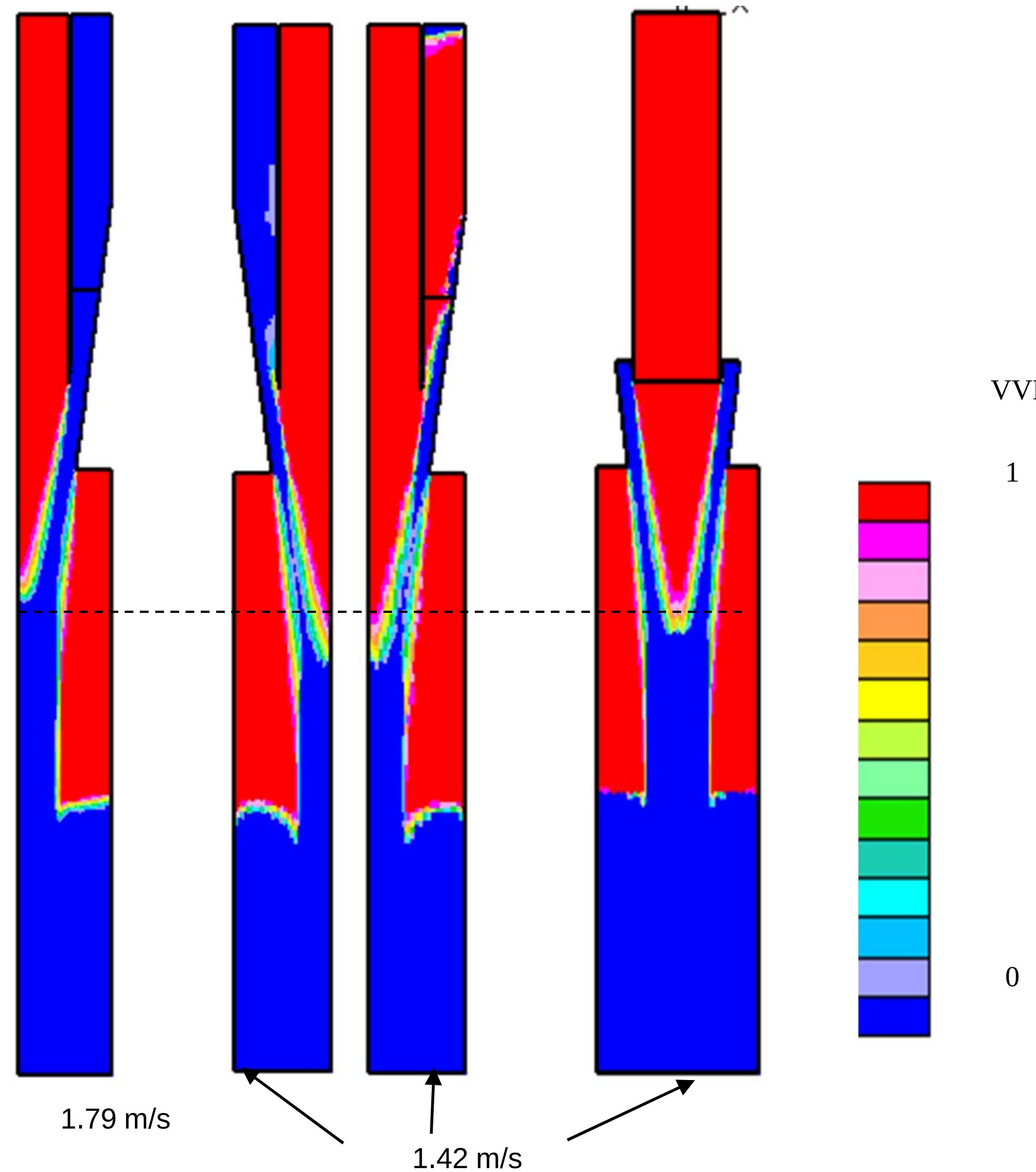
Numerical study results

- Comparison of different inlet velocity
- Effect on the vapour volume fraction (VVF) for the 1.8° and 180° domains



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Numerical study conclusions

- Results of different tested codes (StarCD, StarCCM+, CFX) deliver near similar results
- Different domains with 1.8° and 180° sector of the target show near identical results. This increases confidence in the codes and the selected domains.
- For low asymmetry of the studied range (11%) virtually no changes of the free surface location are observed.
- The simulations show that the proposed target geometry is delivering a robust flow. It represents a promising candidate for a real target.
- More details -> Abdalla Batta

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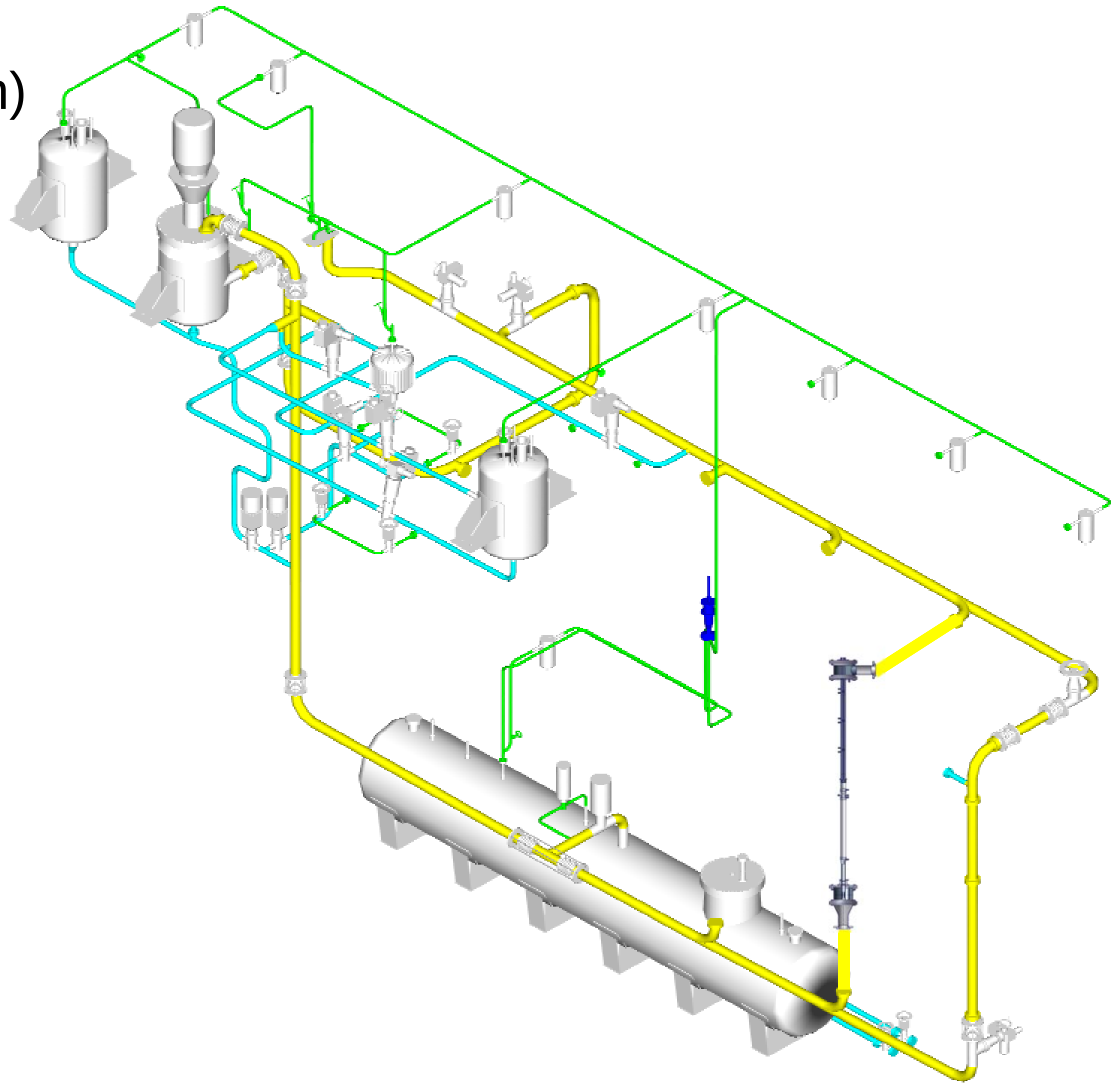
Experimental facility at KALLA (**Ka**rlsruhe **L**iquid Metal **La**boratory)

LBE Loop THEADES
(**The**rmalhydraulics and **A**DS **Des**ign)



Technical details:

Temperature	190°C - 450°C
Flow rate	47 m³/h
Pressure	5,9 bar
Test ports	3
Port height	3400 mm
O2 Control	
LBE-Inventory	4 m³ (42 to)
Inner tube diameter	107mm
Thermal power loss	
at 200°C	9,0 kW
at 300°C	14,5 kW

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Target components

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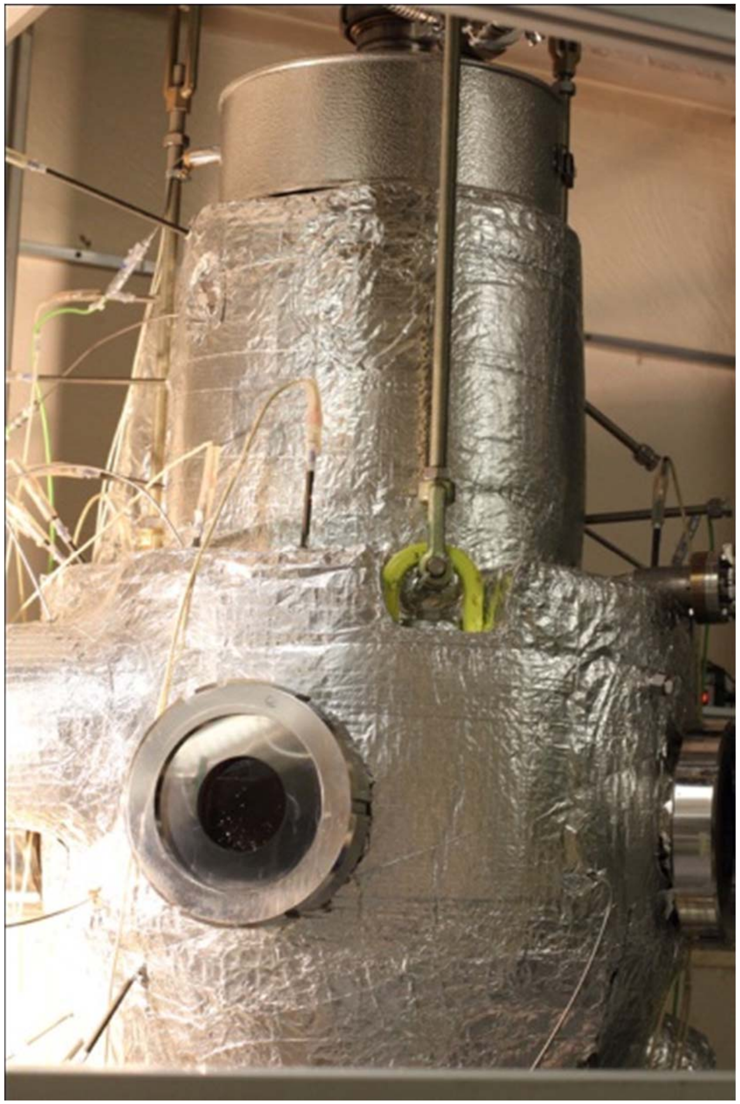
Component assembly



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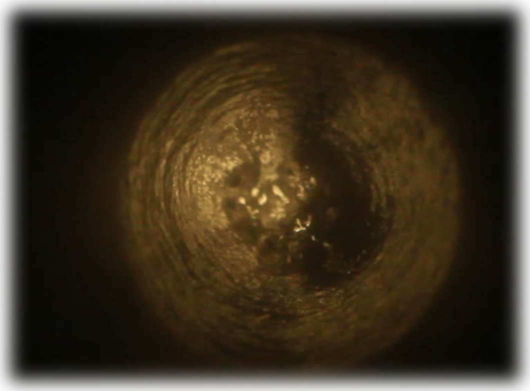
Experimental results

- Start up, flow rate 0 l/s - 2.8 l/s

- Free surface, flow rate 4.6 l/s

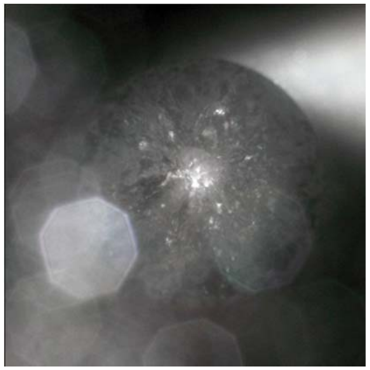
- Operating conditions, flow rate 8.1 l/s

- Free surface, flow rate 8.1 l/s



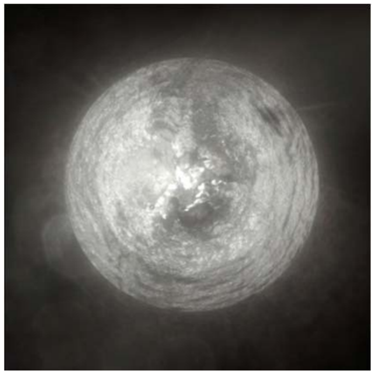
Experimental results

- Comparison of different flow rates

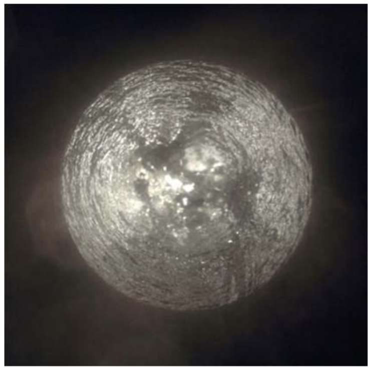


4.6 l/s

5.8 l/s



7.0 l/s



8.1 l/s

- Stable surface for flow rates > 7 l/s
- No cavitation even for low flow rates

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Conclusion

- Experiments show stable free surface for the target design
- No cavitation
- Experimental results agree with CFD
- Measured data has to be evaluated and compared with numerical predictions

Outlook

- Enhanced instrumentation
- Numerical investigation of the complete target

Acknowledgements

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