ESS Target Options

ESS Target Division

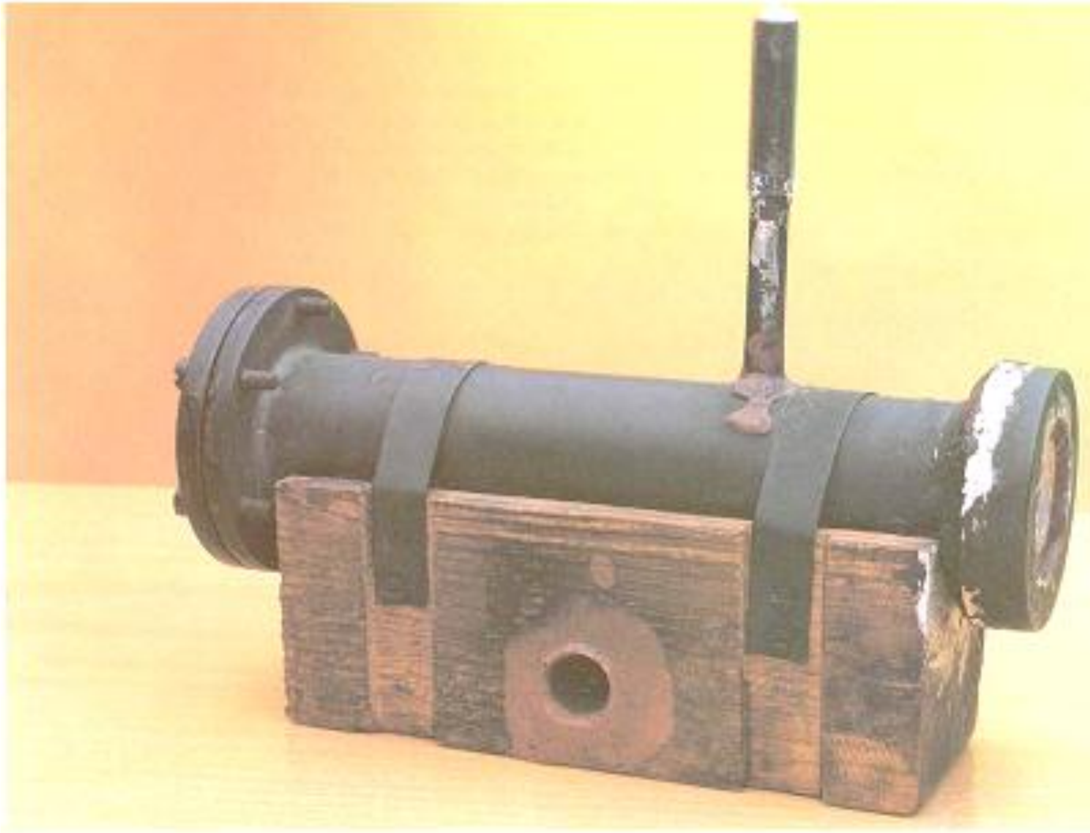
Pb/Bi loop target for EURISOL

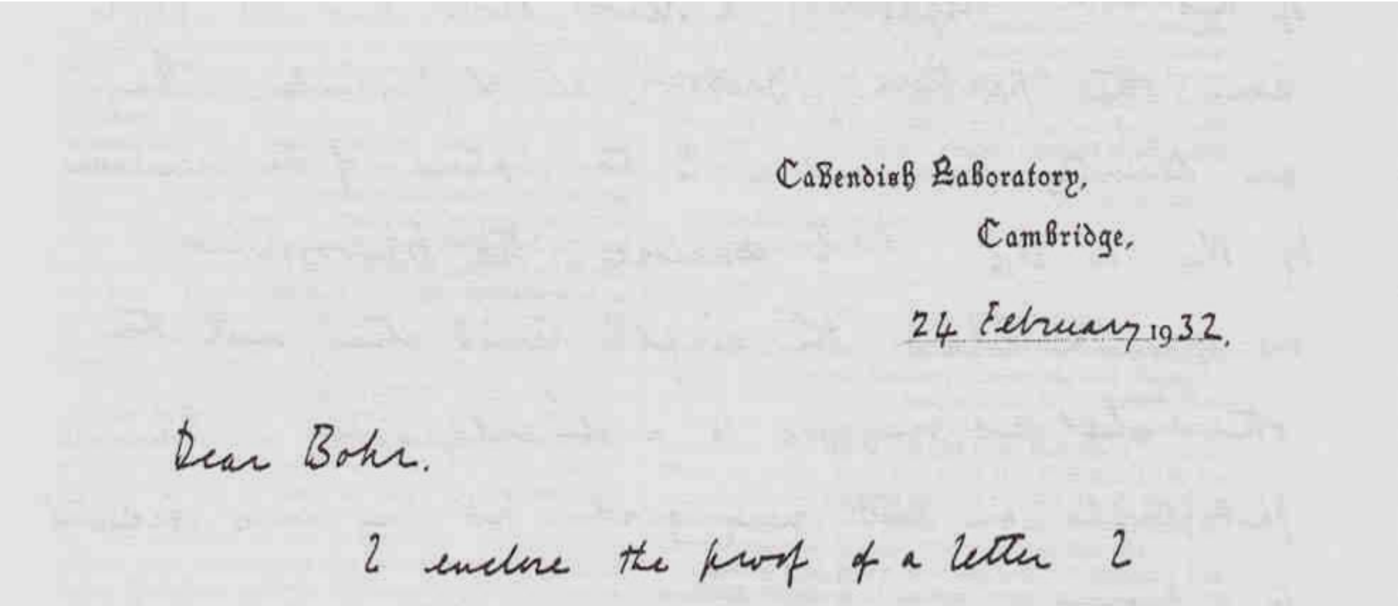
May 10th 2012, CERN

Outline

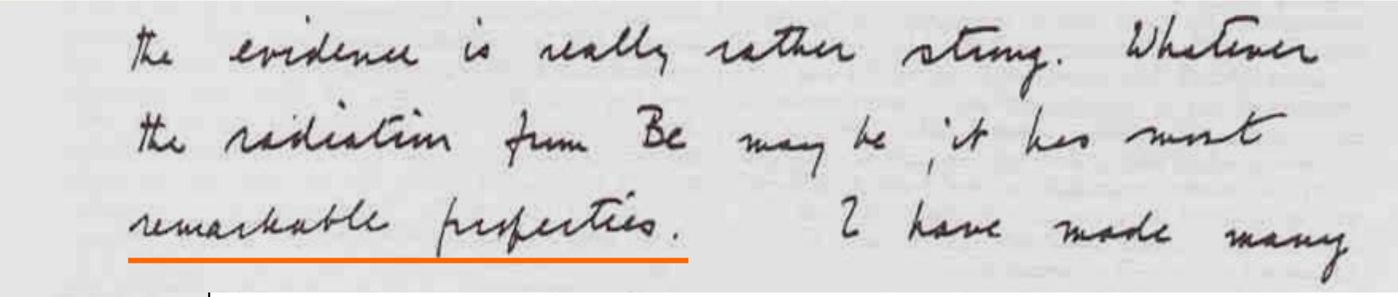
- ESS general project status
- Target concept selection
- ESS TSDU project
- Baseline tungsten target
- Comparative LBE target

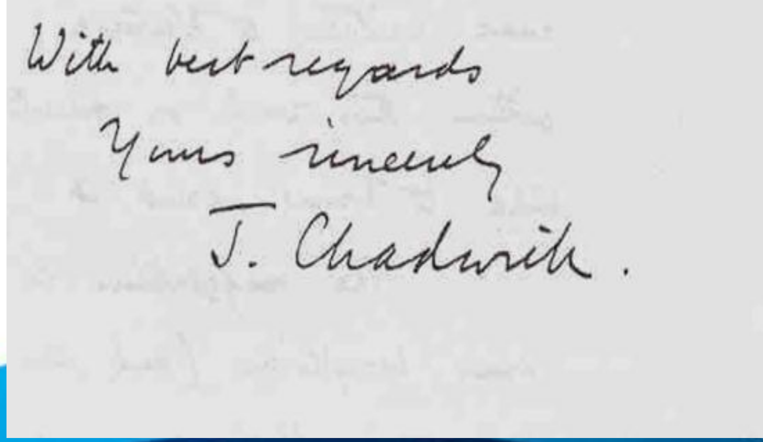
Discovery of neutrons

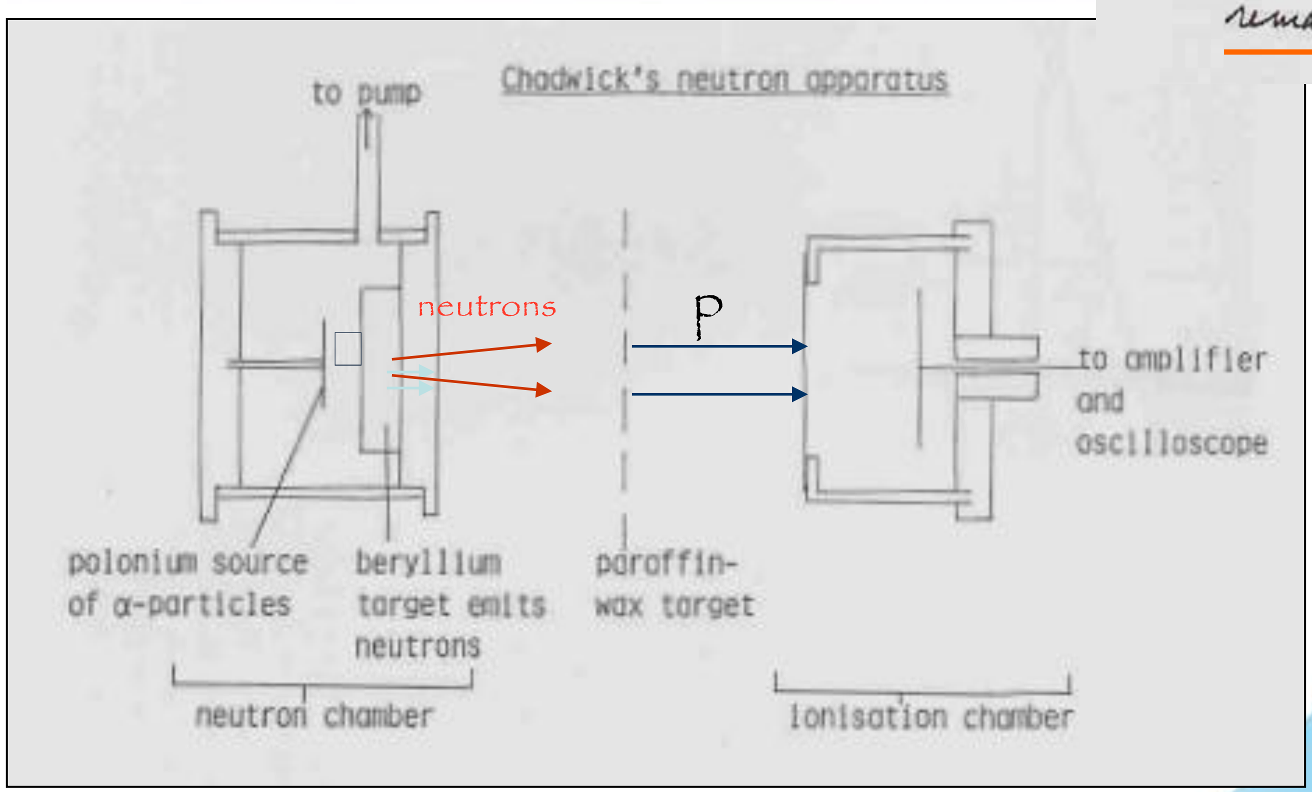



Cavendish Laboratory,
Cambridge,
24 February 1932.

Dear Bohr,
I enclose the proof of a letter I


the evidence is really rather strong. Whatever
the radiation from Be may be, it has most
remarkable properties. I have made many

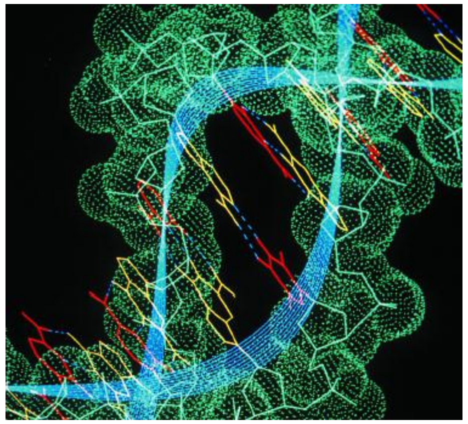

With best regards
Yours sincerely
J. Chadwick.

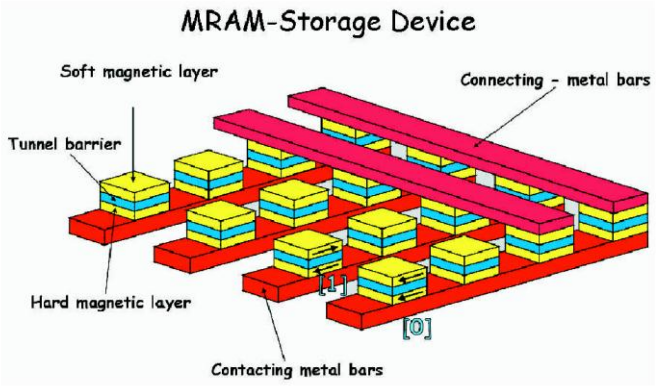


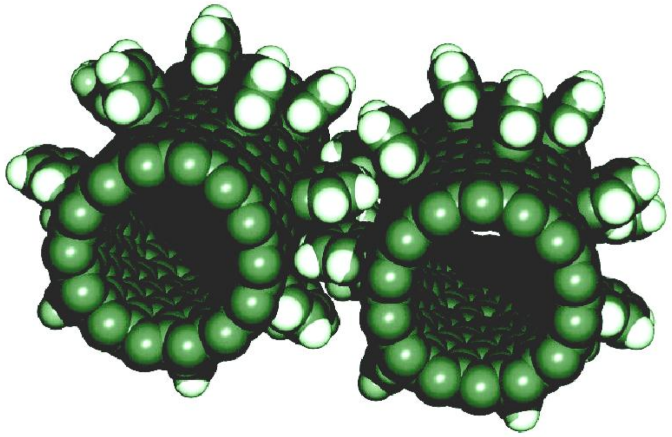
EUROPEAN SPALLATION SOURCE

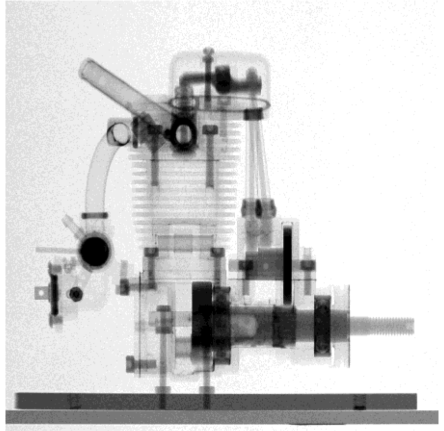
Neutrons 80 yrs ON

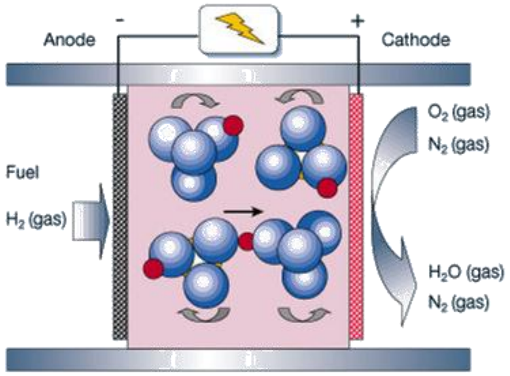
Materials science	Bio-technology	Nano science
Energy Technology	Hardware for IT	Engineering science











- Neutrons can provide unique information on almost all materials.

- Information on both structure and dynamics simultaneously. ”Where are the atoms and how do they behave?”

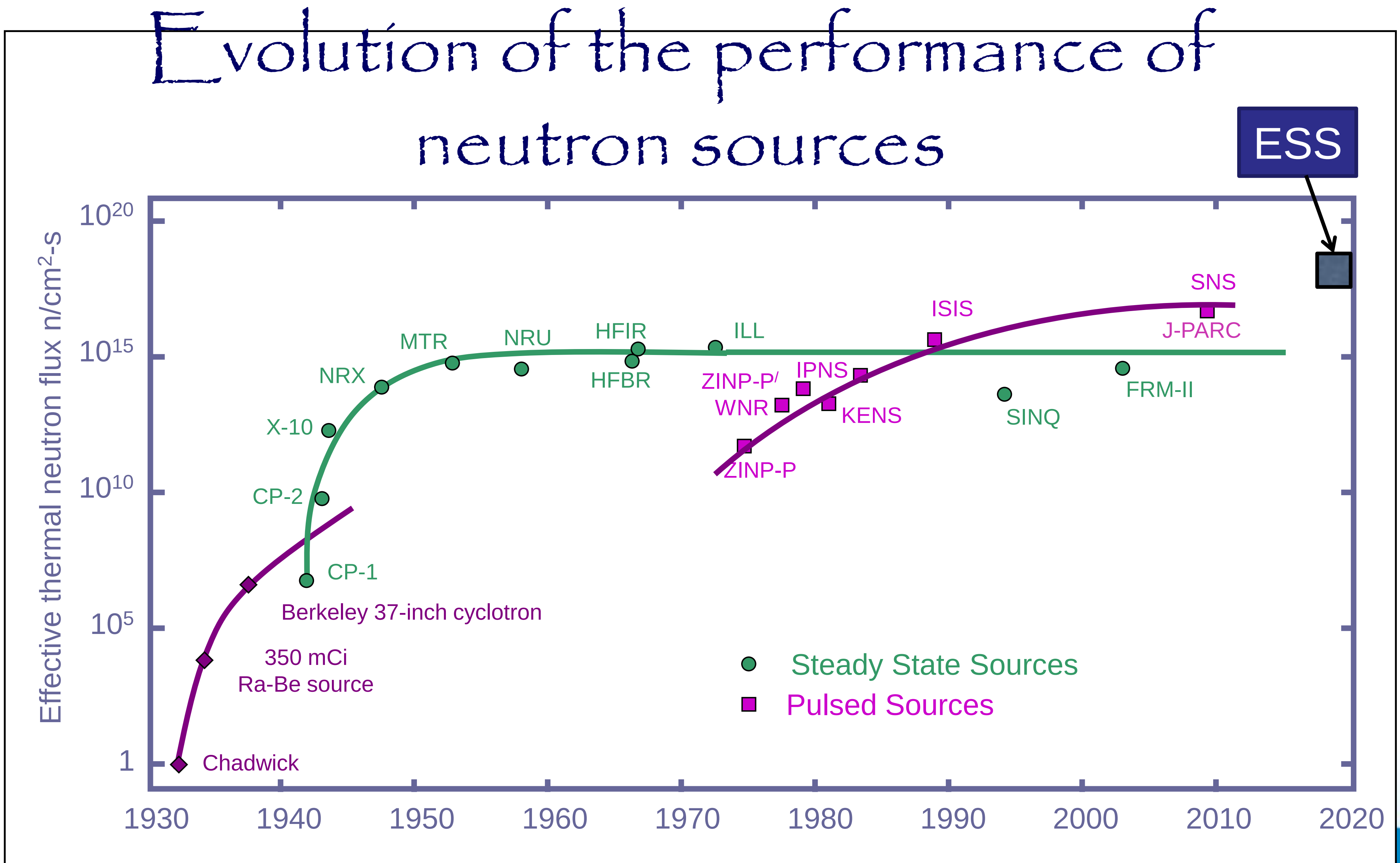
- 5000 users in Europe today.

- Science with neutrons is limited by the performance of today’s neutron sources. ESS performance will open new frontiers.

Motivation for ESS

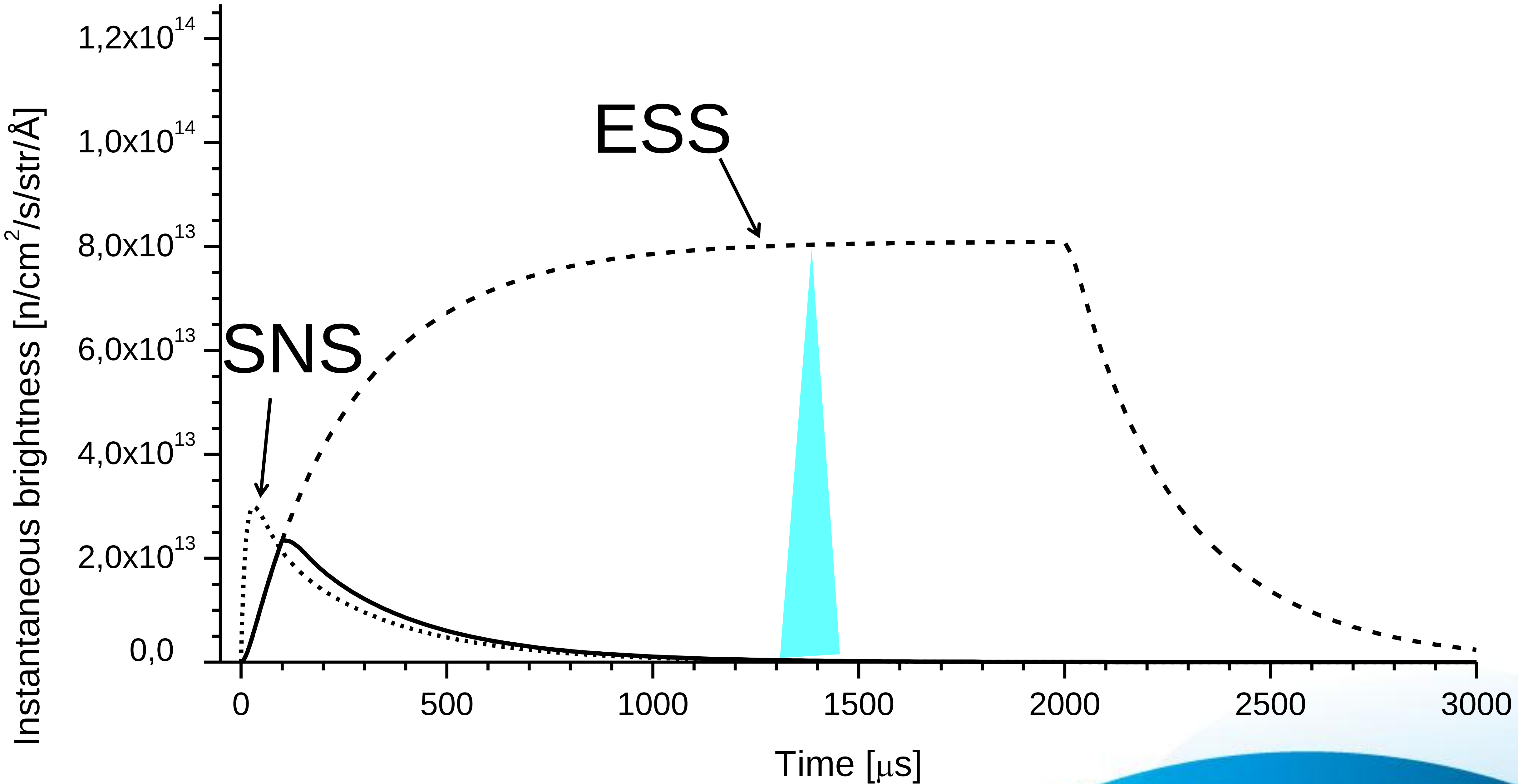
- Many research reactors in Europe are aging and will be closed before 2020:
  - Up to 90% of the use is with cold neutrons
- There is an urgent need for a new **high flux cold neutron** source in Europe:
  - The vast majority of users will profit from a pulsed structure
  - A large fraction of the users are fully satisfied by a long pulse source (approx 2 ms, 20 Hz)
  - Existing short pulse sources (ISIS, JPARC and SNS) can supply the present and imminent future need of short pulse users
  - Construction must start now for use in 2018-2019

Motivation for ESS (2)



(Updated from *Neutron Scattering*, K. Skold and D. L. Price, eds., Academic Press, 1986)

Motivation for long pulse



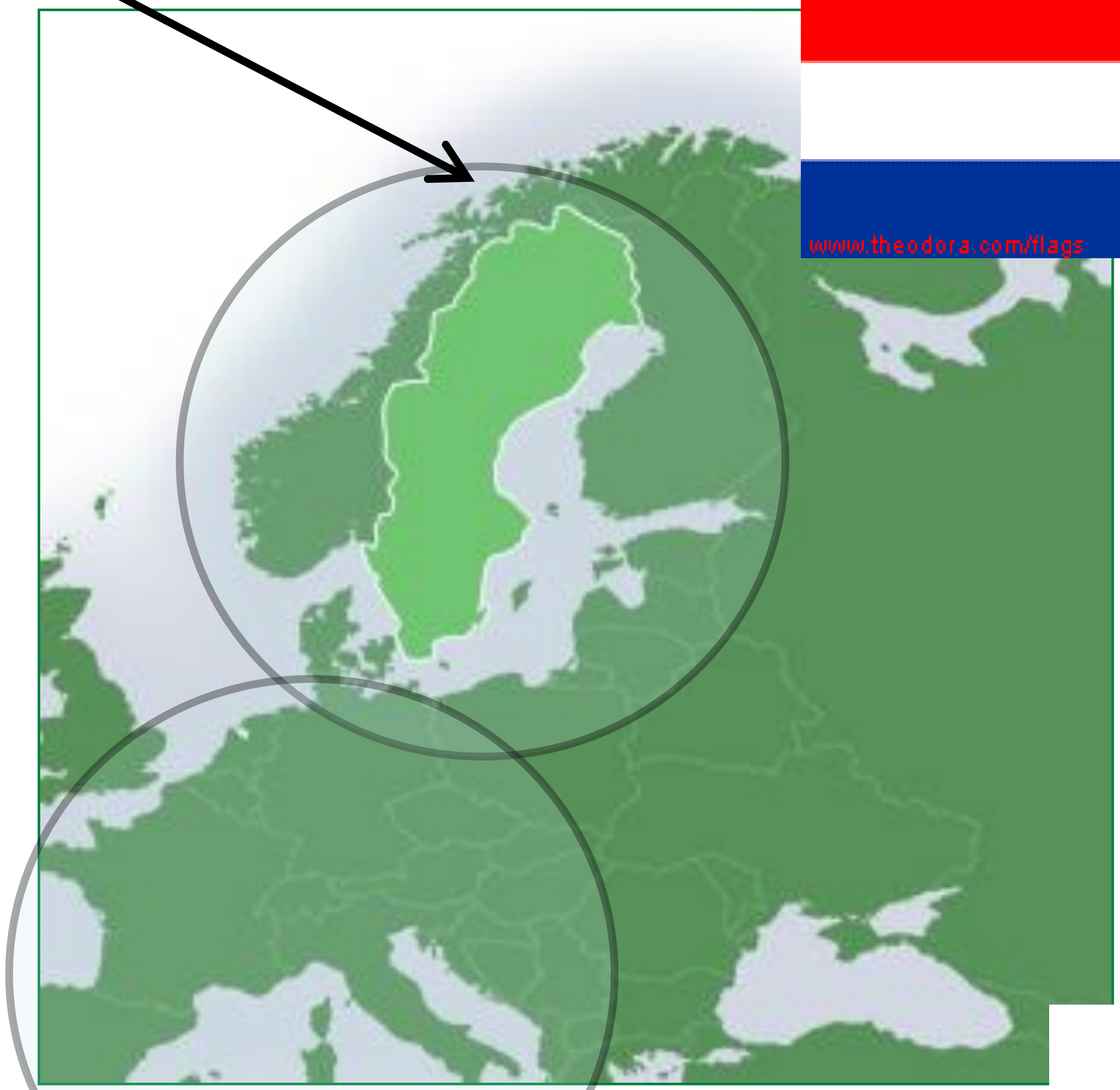
Lund: host site for ESS

- Neutrons and SR at the same site
  - MAX-IV and ESS
- A World-leading cluster of science facilities
  - XFEL, ESS, PETRA and MAX-IV
- Excellent Communications
  - 33 minutes to airport
  - 125 direct destinations
  - A cross-roads for 10 European countries
- Intellectual capital
  - 10,000 scientists - 140,000 students
  - 3rd biopole in Europe
  - Lund University 3rd largest attractor of EU R&D funds
  - IDEON - MEDICON Village

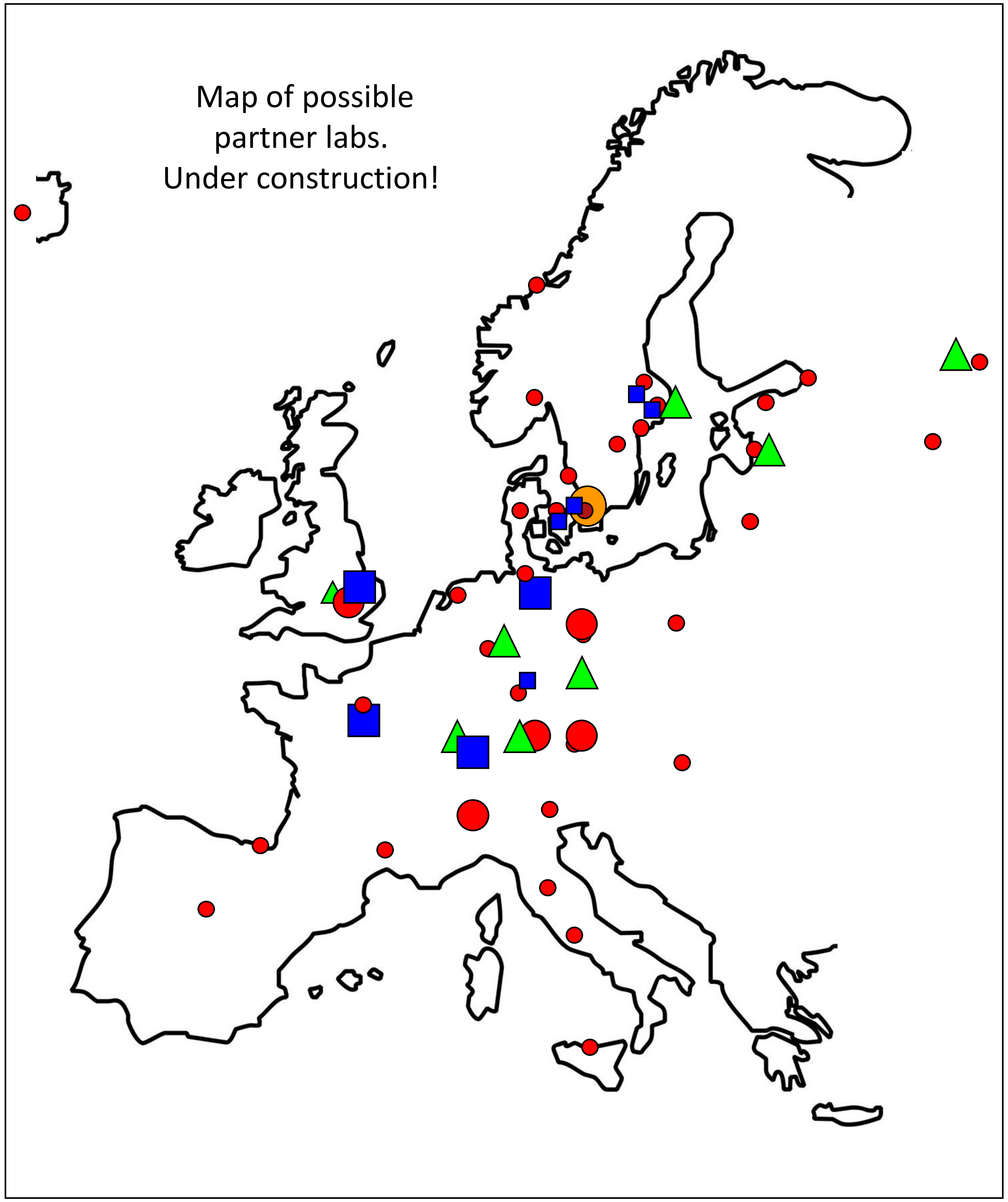
ESS partner countries

Sweden, Denmark and Norway
50% of construction costs

17 Partners
today



ESS partner institutes



Collaboration partners for work-packages and in-kind contributions:

Instruments and use:
Networks involving ILL, RAL, FRMII, HMI, FZJ, CTH, UU, LU LLB, …

Target: PSI, FZJ, KTH, CERN, IDOM, KIT, CEA …

Accelerator: CEA/IN2P3, INFN, UU, Århus U, TEKNIKER, CERN, ….

Systems Integration, Project management, Safety, Data handling, Construction :
ESS central team

ESS baseline parameters

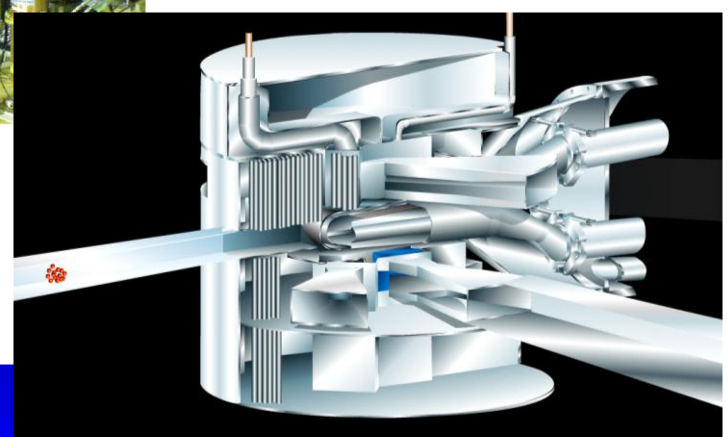
Proton beam

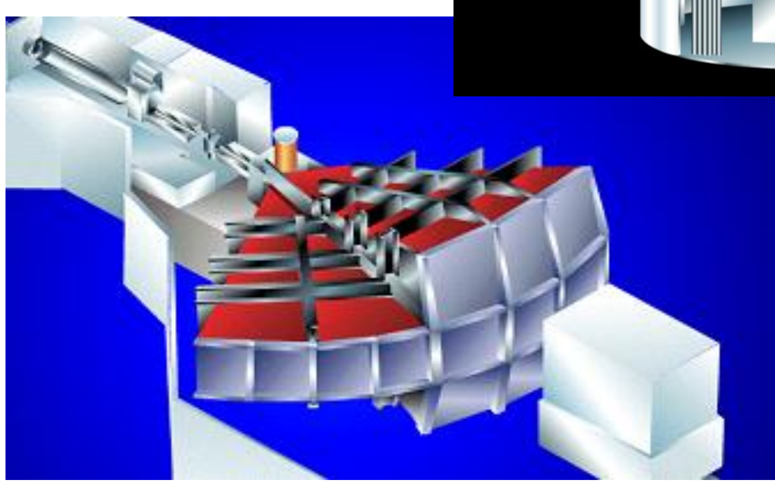
- 2.5 GeV proton linac
- 2 mA average beam current
- 2.86 ms pulse length
- 14 Hz rep. frequency

Target options:

- Baseline: Solid Tungsten (or W alloy)
- Comparative: Molten LBE

ESS main elements





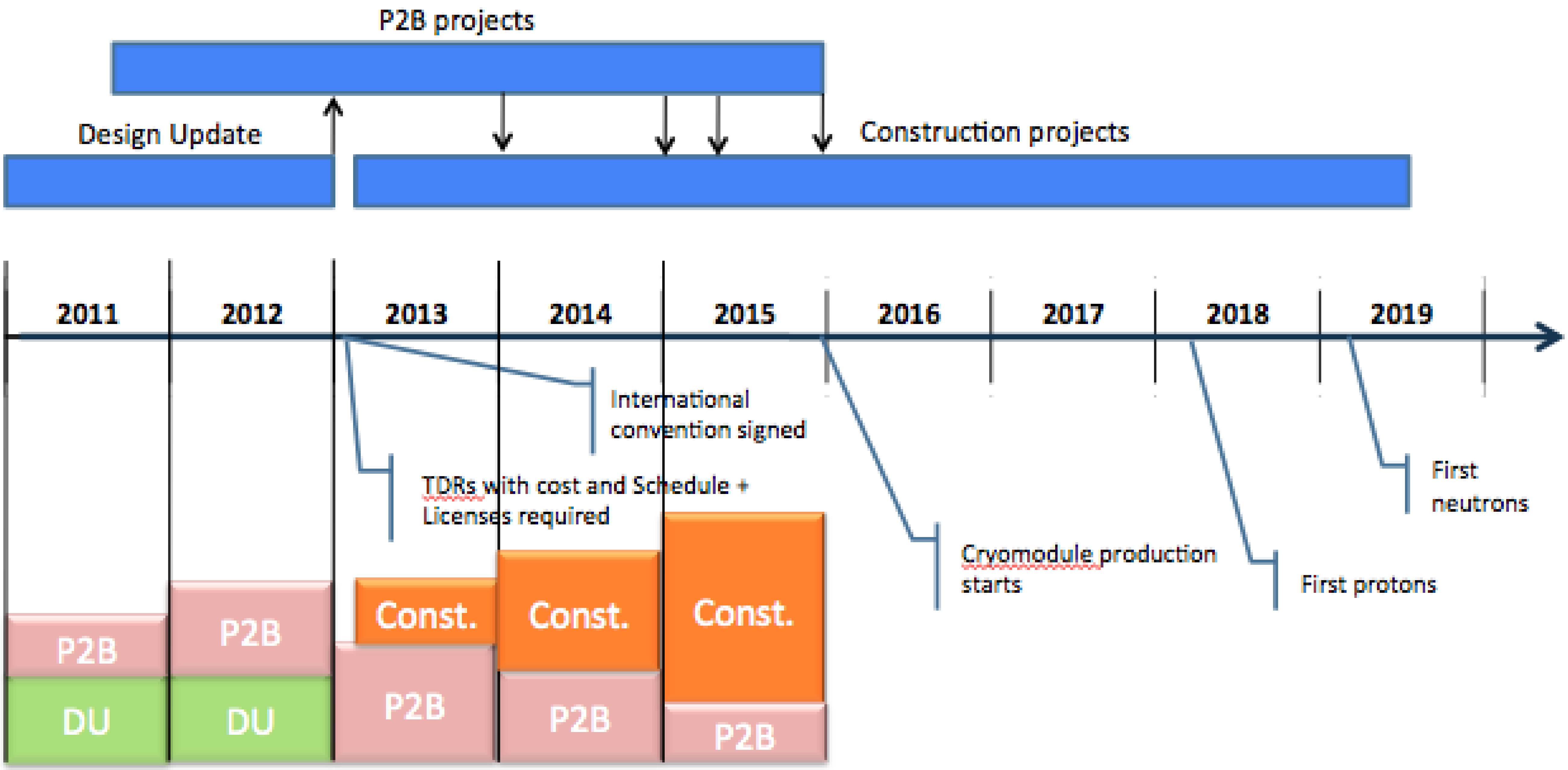
> **Proton linac (~400 M€)**
- Cavities, cryomodules
- High power RF
- Cryogenics, vaccuum, cooling
- Shielding

> **Target station (~200 M€)**
- Nuclear tech/safety systems
- Hot cell / remote handling
- Cooling & Cryogenics
- Shielding – Steel & Concrete

> **Conventional facilities (~400 M€)**
- Buildings – labs & offices
- Cooling, heating, electric systems (energy)
- Computers & Controls

> **Instruments (~250 M€)**
- Shielding
- Detectors
- Neutron guides, choppers
- Electronics
- …

ESS Project Timeline



Accelerator - progress

Accelerator Design Update is launched – kick off meeting in Lund 24/3

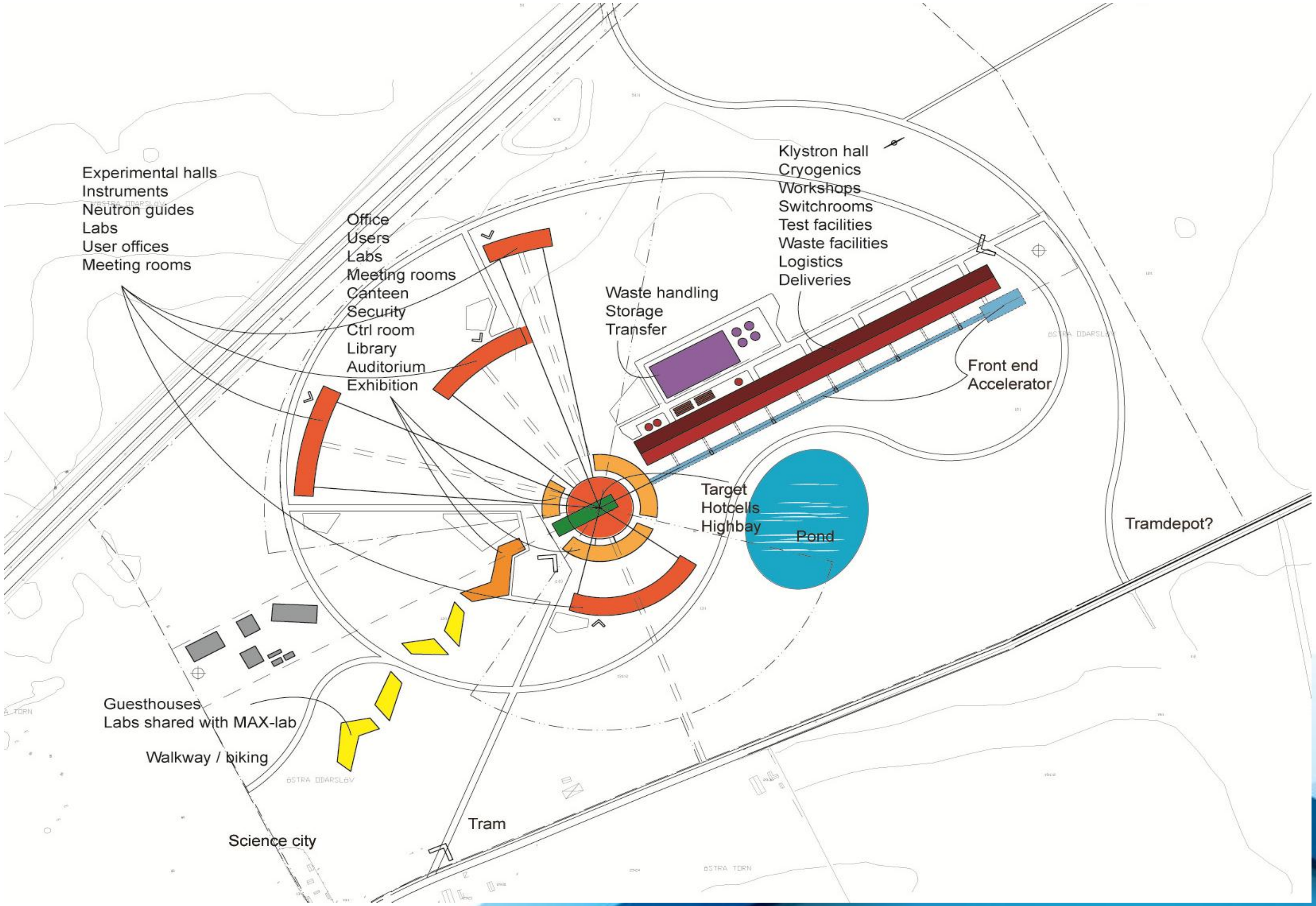
- WP1 Management - ESS AB work funded & started
- WP2 Accelerator Science - ESS AB work funded & started
- WP3 Infrastructure - TEKNIKER – contract signed, but made void since funding was not yet received
- WP4 & WP5 Elliptical & Spokes - CEA, CNRS contracts signed, work started
- WP6 Front end - INFN – contract agreed, awaiting signature and funding in weeks, work started
- WP7 HEBT & Magnets - Aarhus University – contracts signed and funding is there, work started
- WP8 RF - Uppsala University – Contract agreed – only about 1 M€ missing for complete funding

Important to secure funding so contracts can be signed, not to loose coherence.

EUROPEAN SPALLATION SOURCE

Conventional facilities - progress

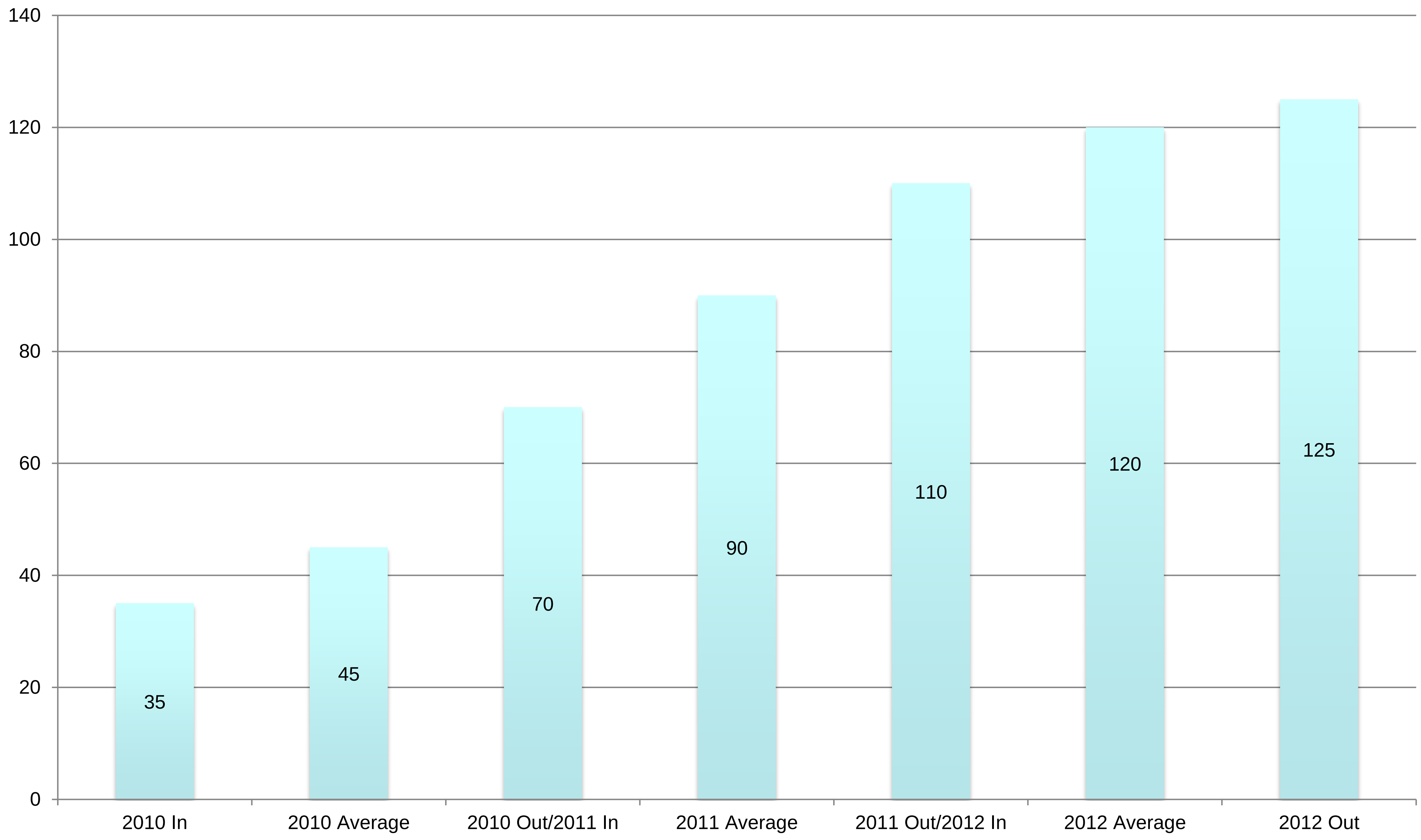
- Project plan, organisation, contract forms
- Refined site layout with zones for buildings and activity types
- Takes elaborated requests from science directorate into account



Licensing - progress

- General Safety Objectives
- PSAR – work is ongoing, focusing on Target Design Concepts
- EIA – work is ongoing
- Safety Advisory Committee set up
  - Required by authorities
  - Foreign and domestic experts. Some cross membership with TAC.
- The required licenses are foreseen to be available by early 2013, with a slight reservation for the time needed by the Environmental Court. Risks are mitigated by Swedish government permissibility right.

Staff numbers – pre-construction phase



Target concept – decision process

> Target Station Concept Selection	Completed end 2010 as a European collaboration
> Target baseline and fallback internal decision	May 16, 2011 ESS Lund (CCB & EPG)
> Workshop to discuss decision	Lund May 31st, 2011 Collaboration on Target
> Review by Technical Advisory Committee	July 11-12 TAC
> Endorsement by Steering Committee	October 2011 STC

Target Station Design Update Project

> The TSDU project aims at integrating most recent worldwide knowledge, experience and state-of-the-art technology into an updated target design for ESS. Its main goals are:

- Providing information needed for the **environmental licensing** of the ESS Target Station on two design options.
- Producing a **Technical Design Report** for the ESS Target Station by end 2012.

TSDU Work Packages

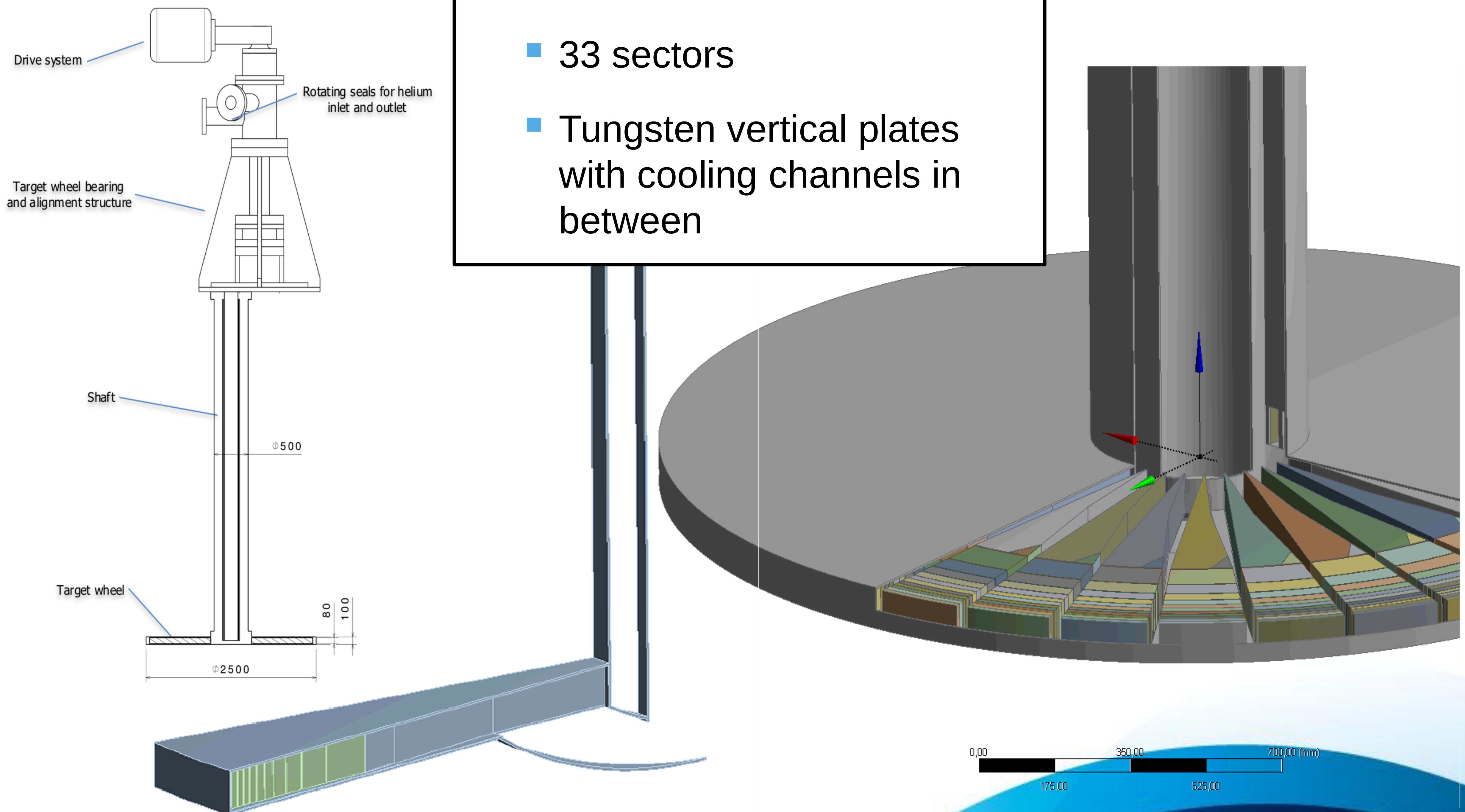
- WP1: Project Management, Coordination of Global Design Effort and overall system integration
- WP2: Target Performance Modelling and Optimisation
- WP3: Material Properties
- WP4: The RoTHeTa Concept – Replaceable systems
- WP5: The RoTHeTa Concept – Permanent systems
- WP6: Liquid Metal Target
- WP7: Premoderator, Moderator and Reflector Engineering Design
- WP8: Shielded Target Monolith System and Beam Extraction
- WP9: Infrastructure Services and Utilities
- WP10: Hot cell, Handling of used Targets, Moderators, Reflectors outside Target Shielding Monolith – Beam dumps
- WP11: Waste Disposal, Emissions, Dismantling and Decommissioning
- WP12: Control Systems for Target Station

Some Recent ESS Documentation

	Date issued/due	Completed?	LBE?
Evaluation of ESS safety relevant concerns assuming two basic target concepts for the target station	September 2011	Yes	Yes
Target Station Design Update Baseline	December 2011	Yes	No
Project specification for the ESS Target Station Design Update Project	February 2012	Yes	Yes
TAC4 documentation	February 2012	Yes	No
ESS Conceptual Design Report	February 2012	Yes	Yes
ESS Technical Design Report	December 2012	No	Yes

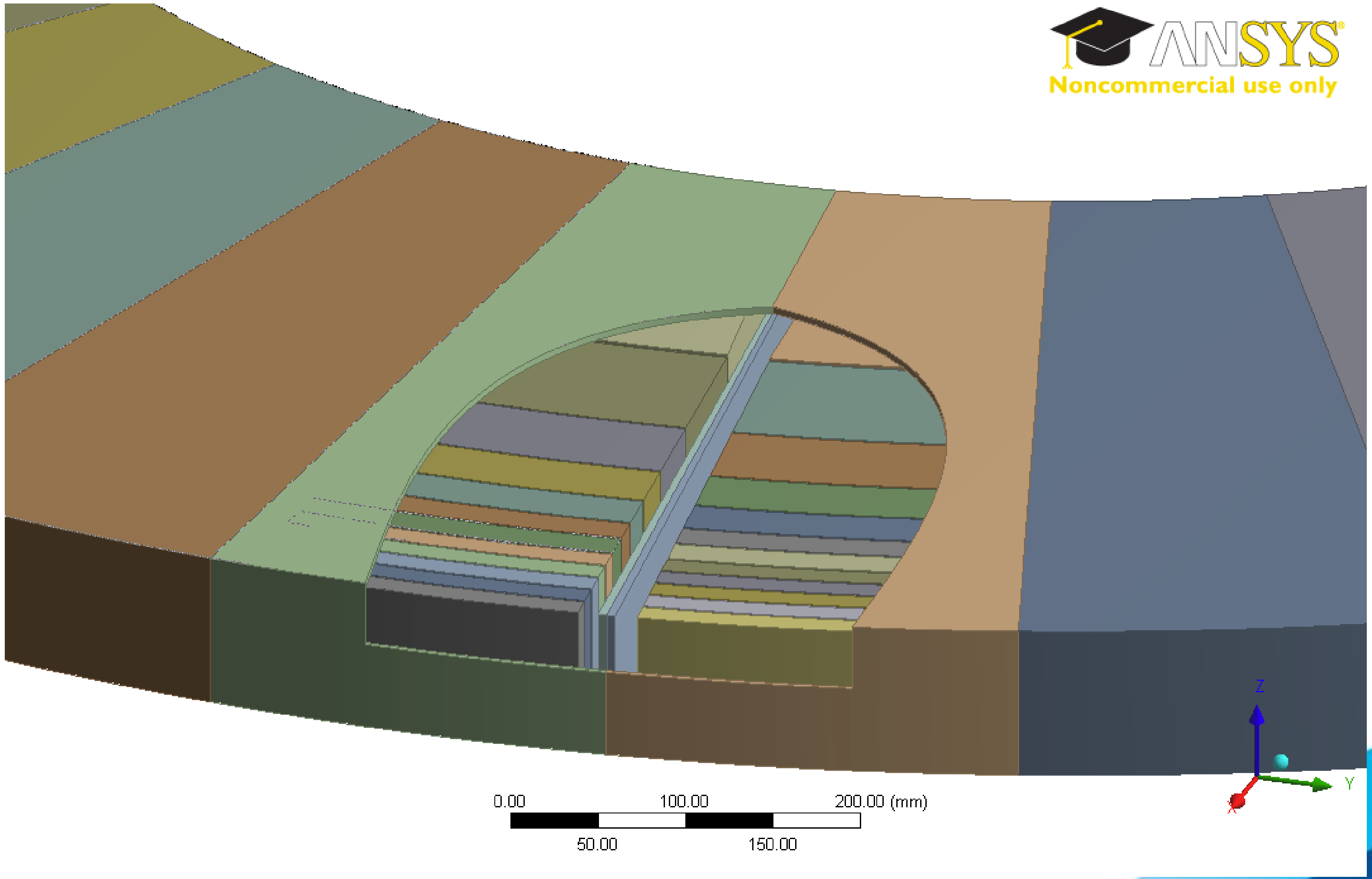
The RoTHeTa Concept

- ø2.5m
- 33 sectors
- Tungsten vertical plates with cooling channels in between

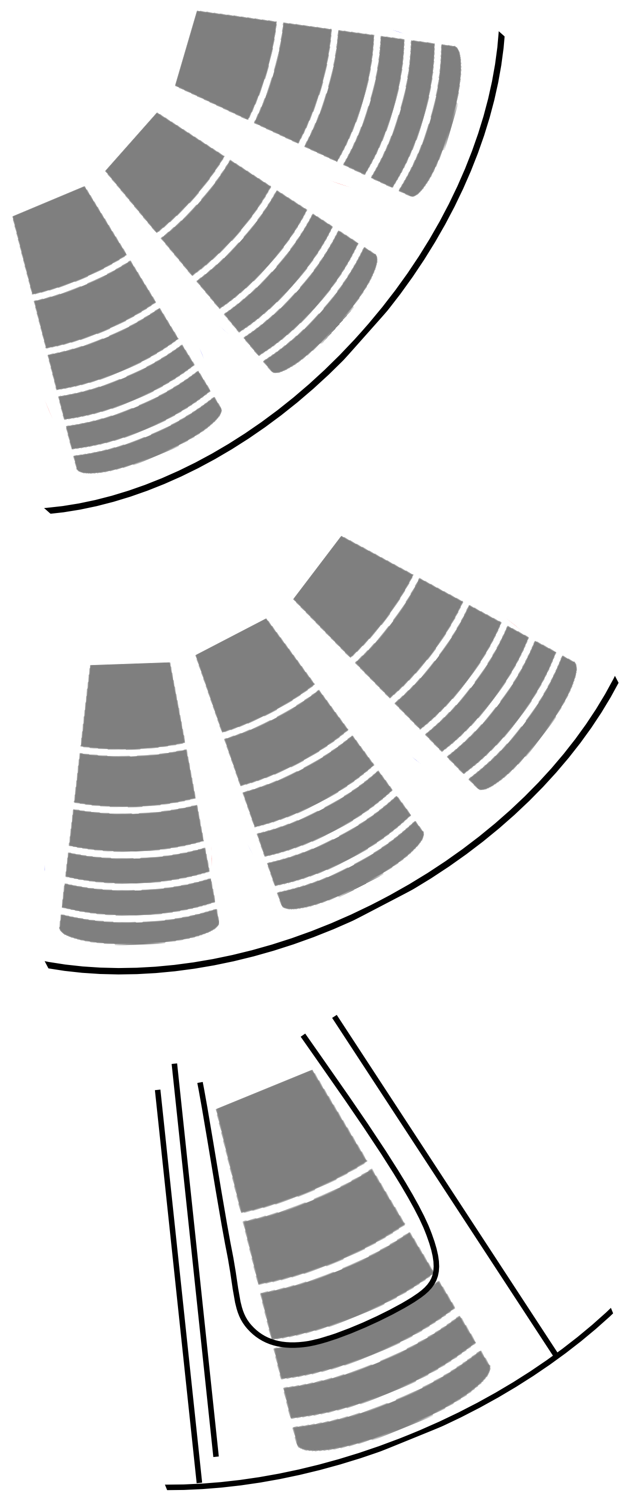


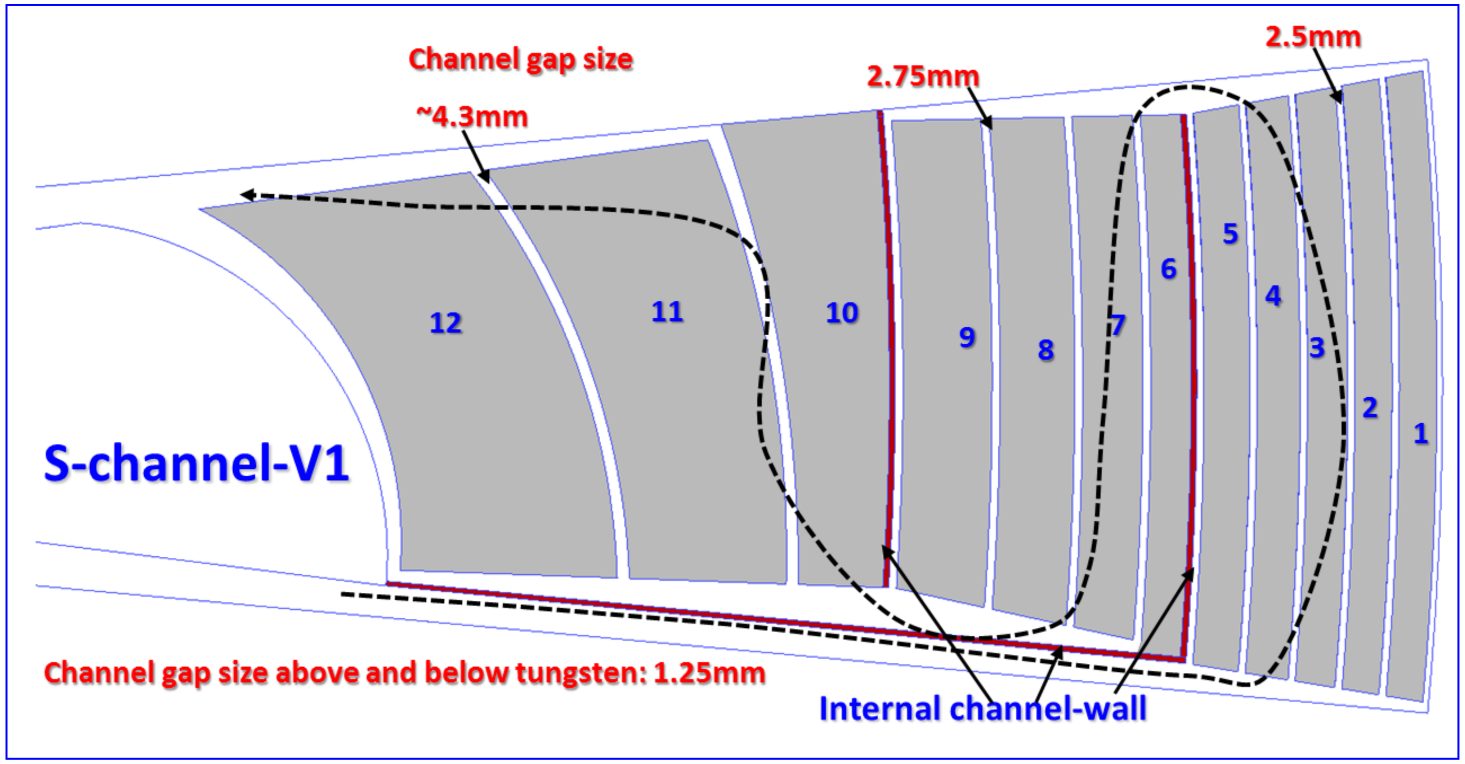
RoTHeTa Wheel Velocity

- 33 slices in total
- Beam repetition rate is 14Hz
- Angular velocity should be 0.42Hz, 25.45rpm
- Each section sees on average 1/33 of the beam.

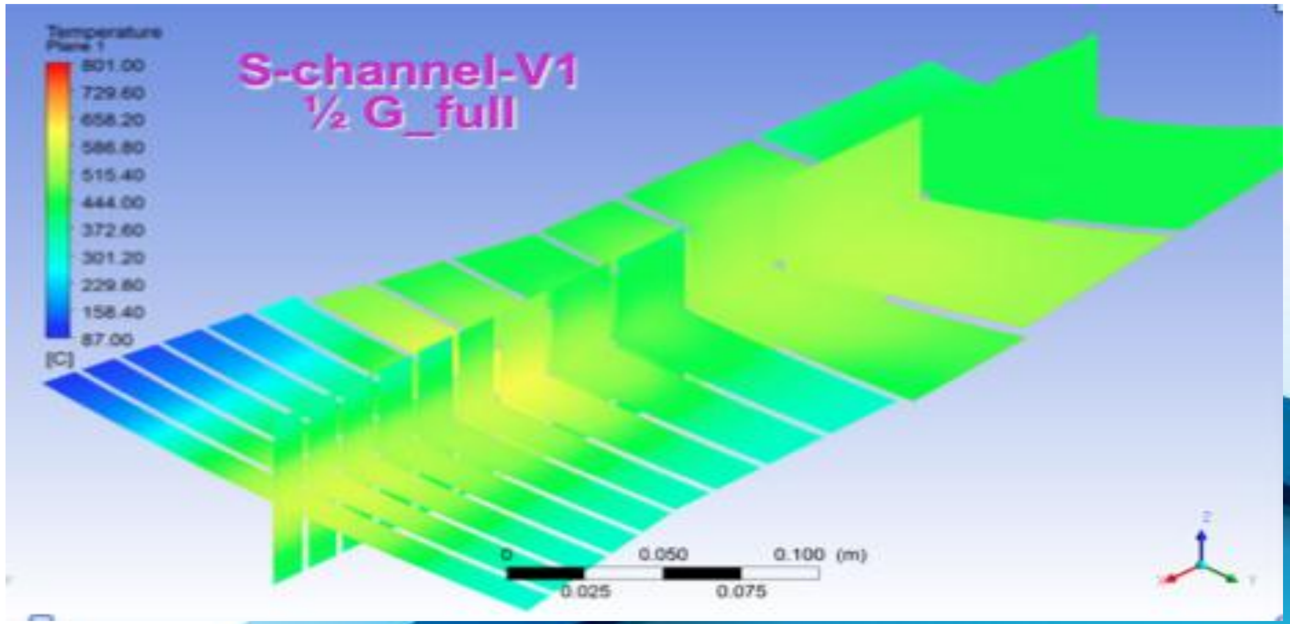


RoTHeTa Flow Pattern

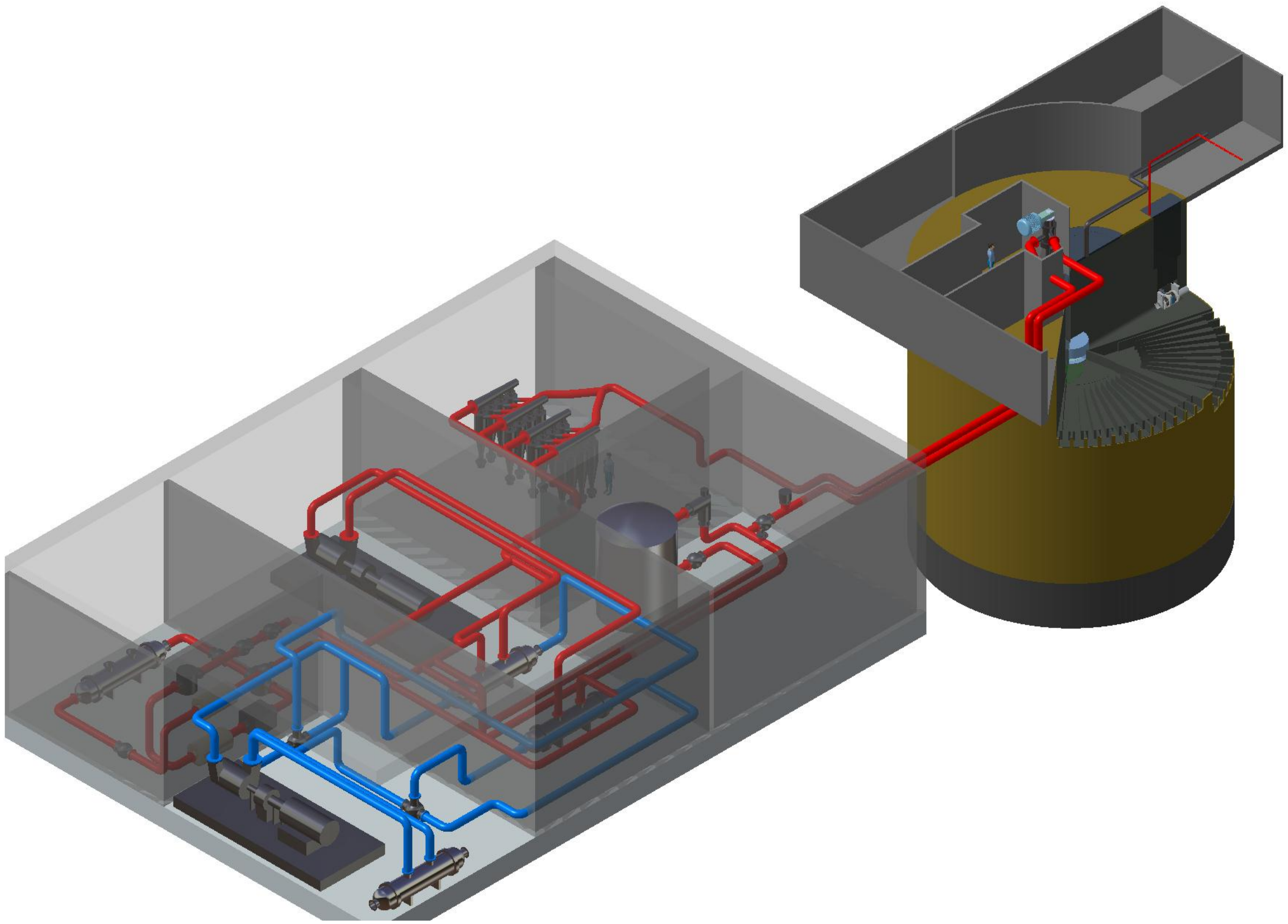


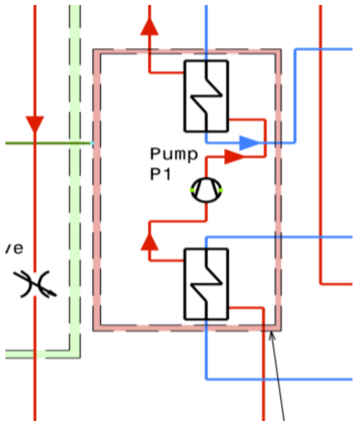


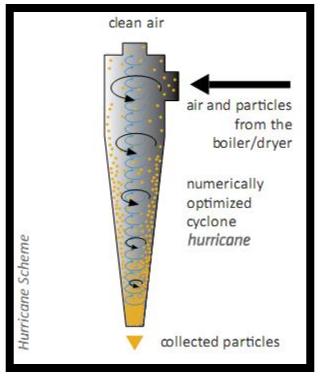
S-channel: Lower W max. temperature

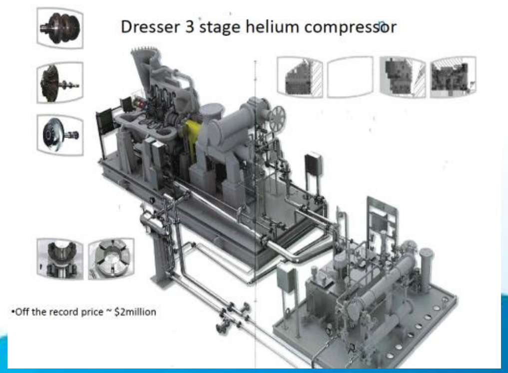


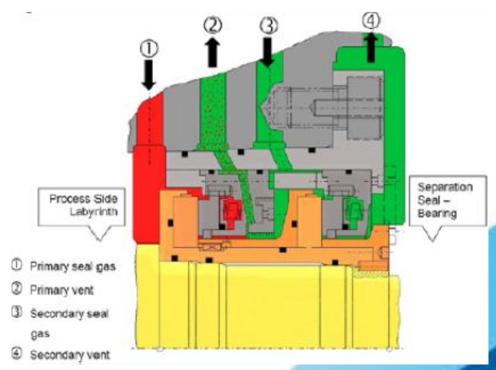
RoTHeTa Helium Loop







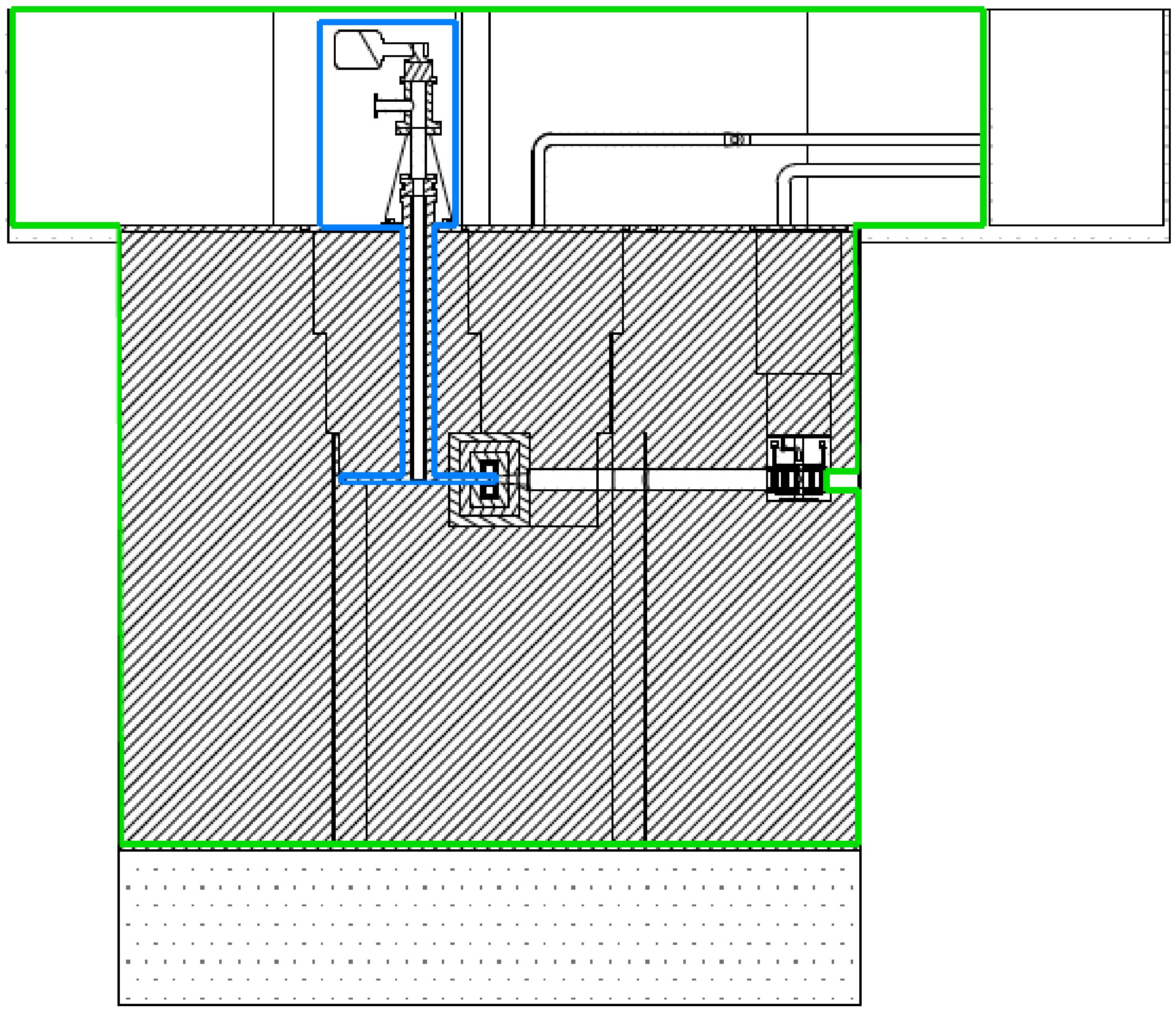


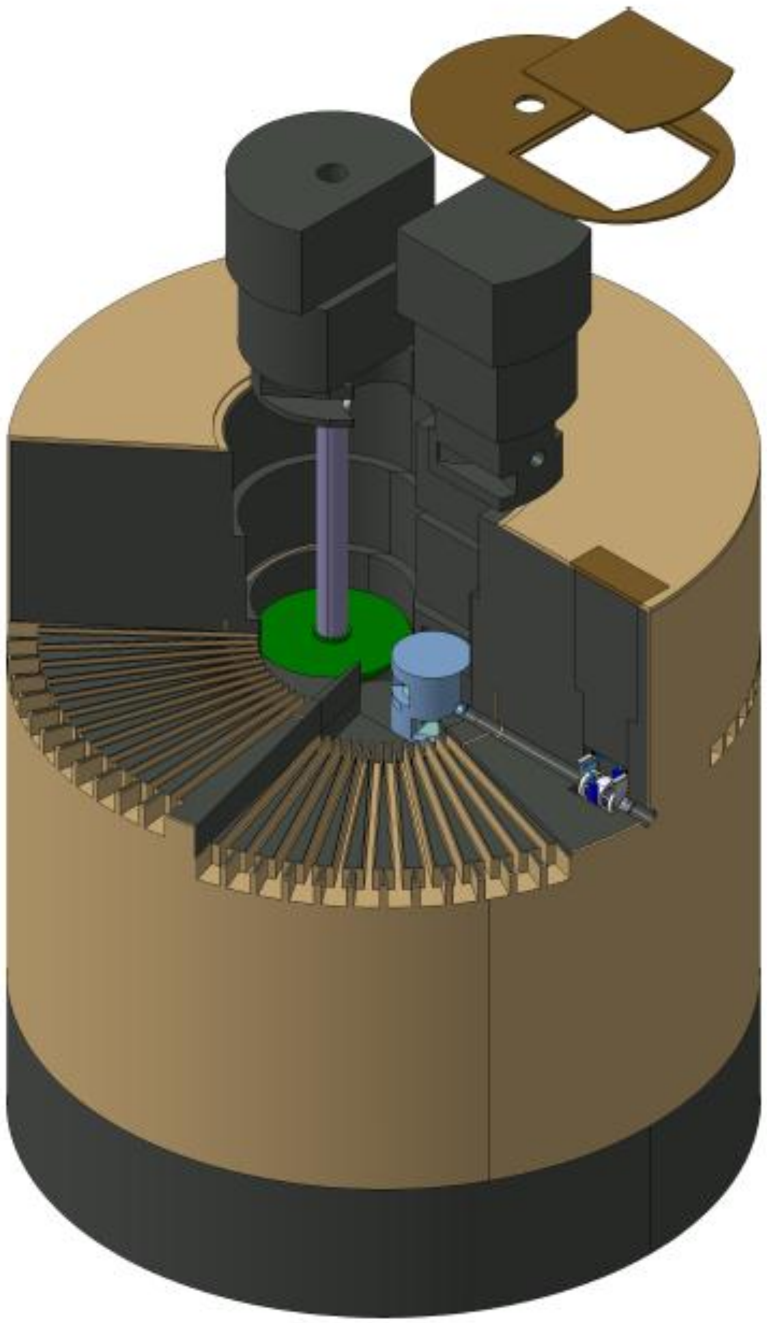


RoTHeTa Helium Loop Parameters

Parameter	Units	Value
Pressure head at the pump	Bar	1
Inlet pressure	Bar	3
Design pressure (relative)	Bar	3.5
Helium mass flow	$kg.s^{-1}$	3
Pumping power	kW	800
Helium bulk temperature at target inlet	°C	20
Helium bulk temperature at target Outlet	°C	220
Pipe diameter	mm	250-300
Pipe total length	m	185
Total volume of the loop	m^3	22.9
Leak rate	$Nm^3.hr^{-1}$	0.7 - 2.1
Number of 200 bar Helium bottle (50l) for 50 days operation	-	80 - 300
Cost of Helium for 50 days operation	k€	4 - 15

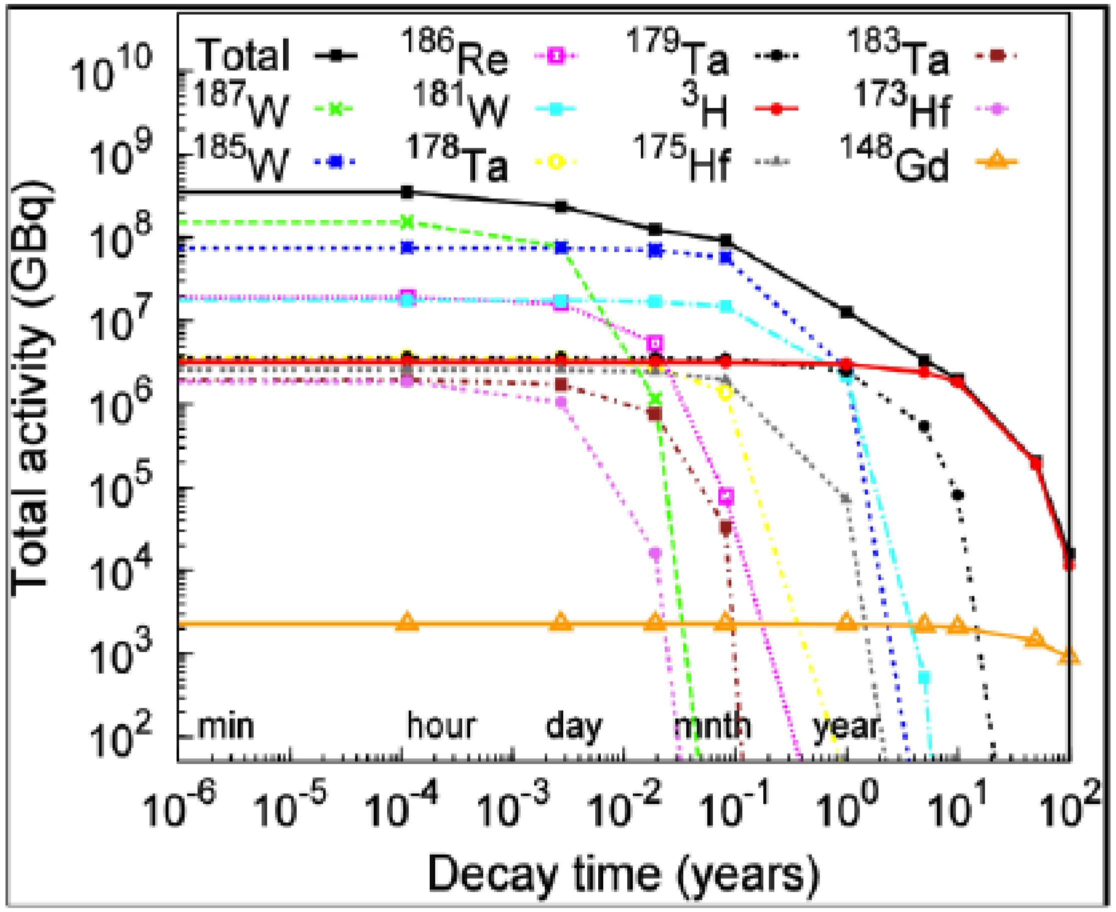
Target Station For a Rotating Target



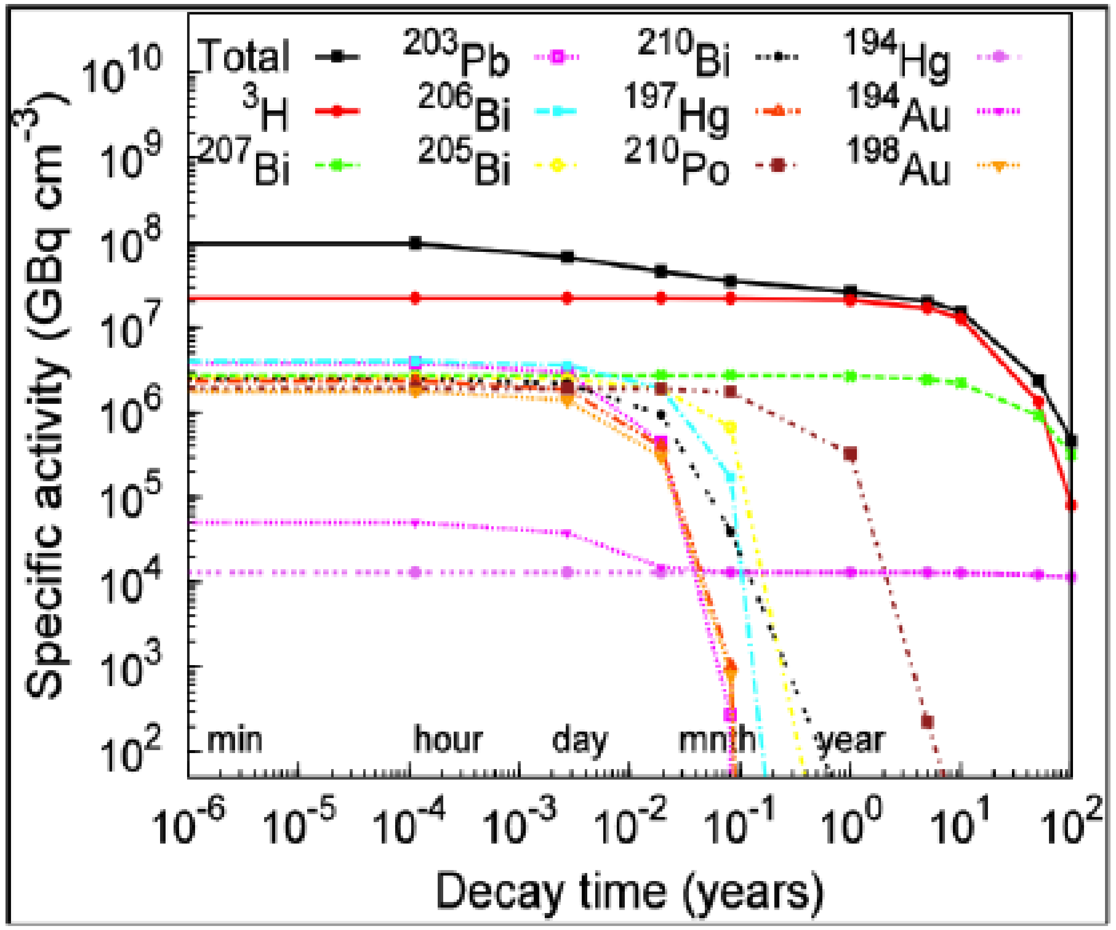


Total activity: W vs LBE

W target @ 5 years



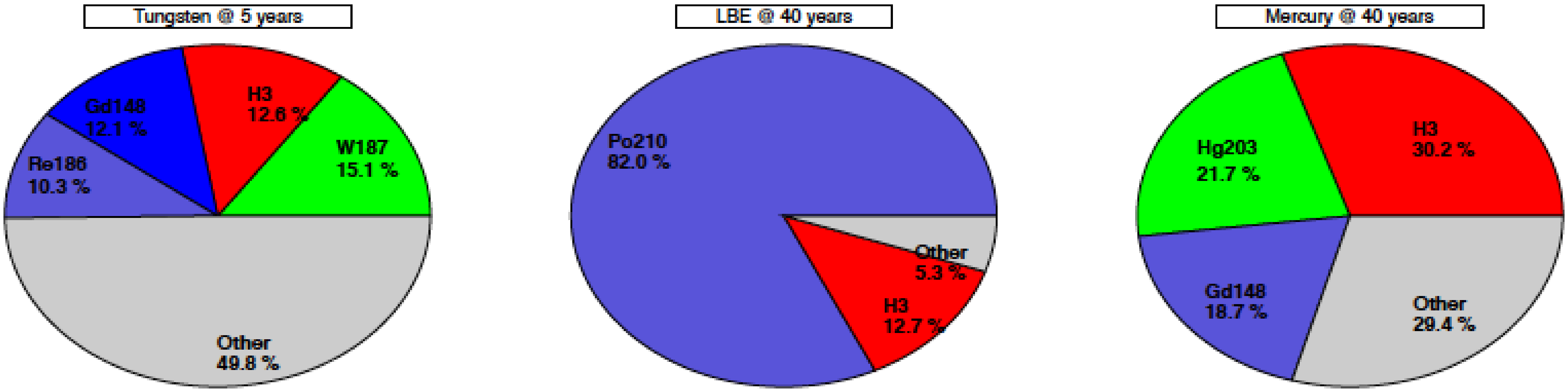
LBE target @ 40 years



D. Ene

Hazard index for different options

Most active isotopes at shutdown



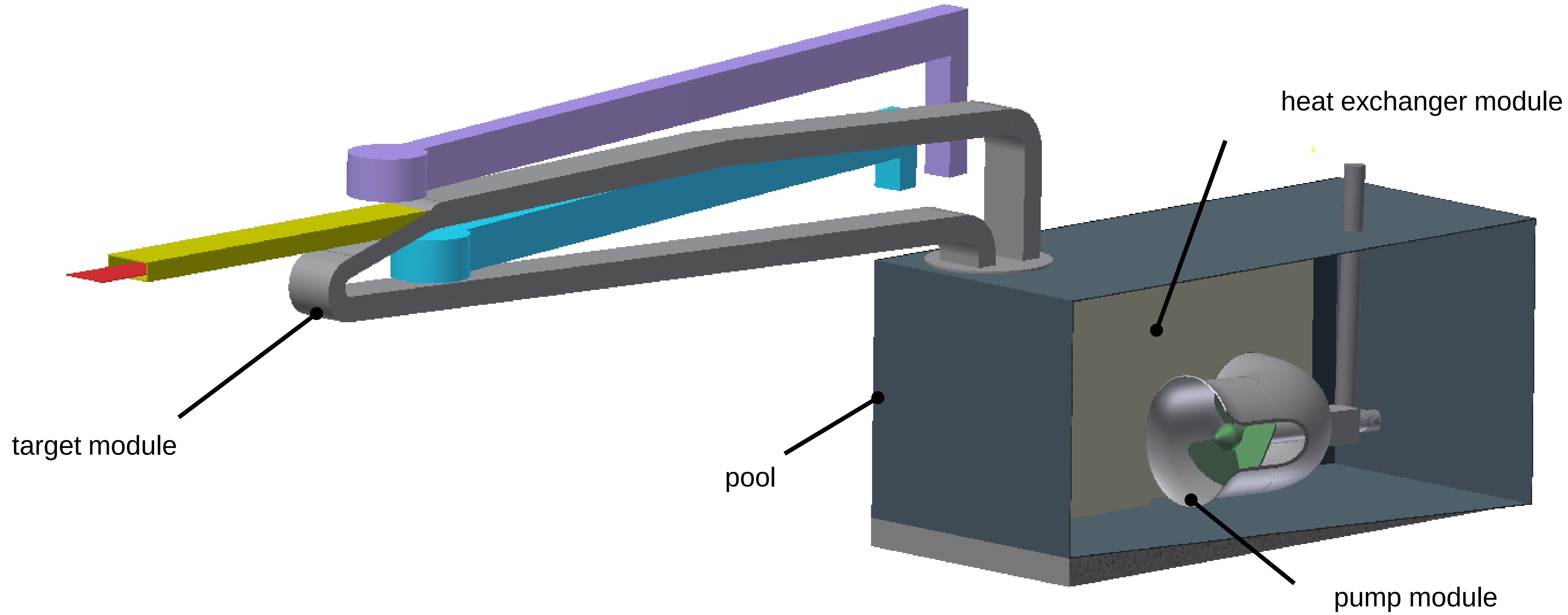
$$HI = \sum_i (A_i \times RF_i \times DCF_i)$$

Mercury	1
LBE	6.96
Tungsten	0.66

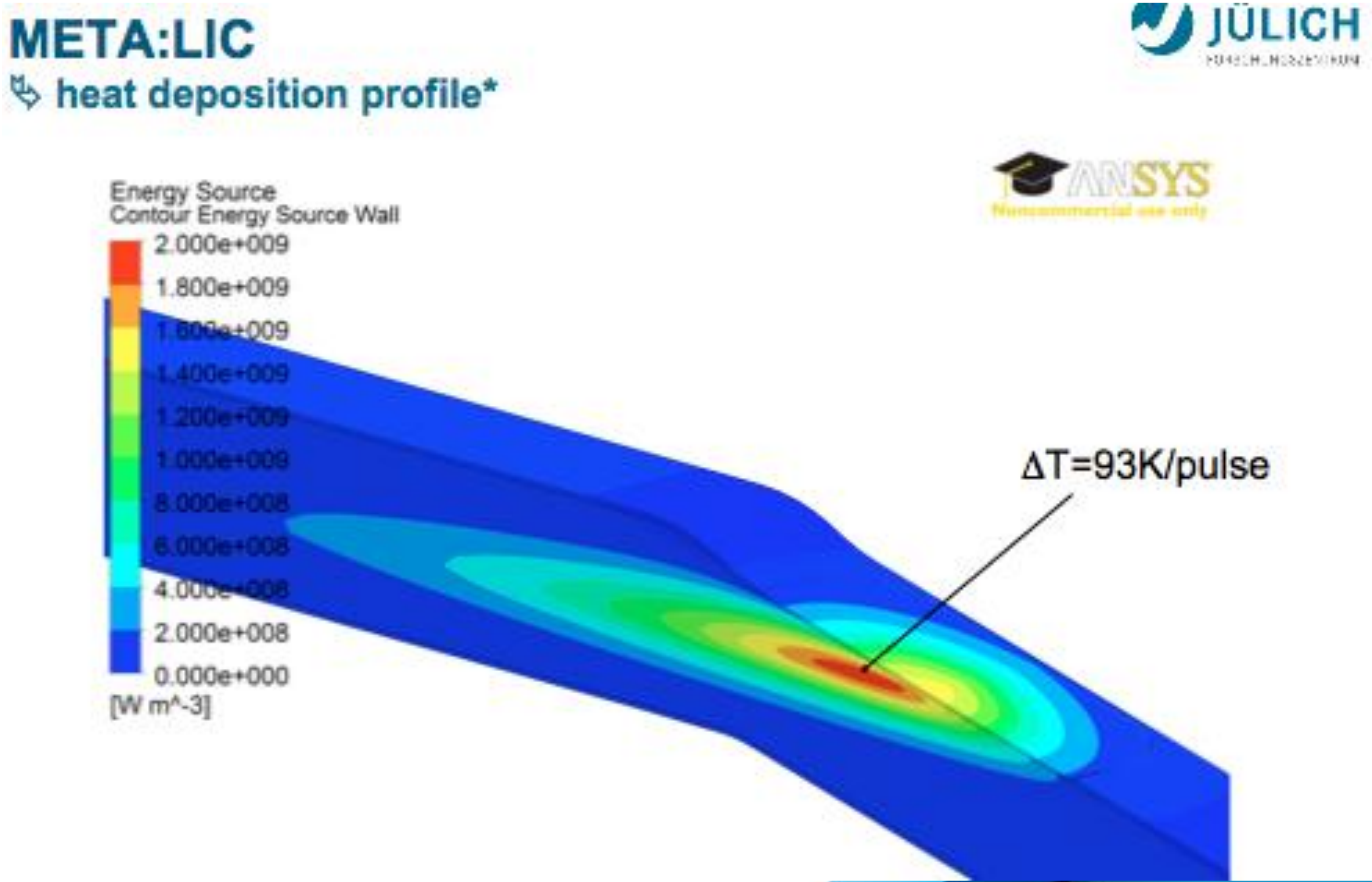
- A_i activity of the radionuclide i present in the target at the moment of evaluation [Bq];
- RF_i release fraction for the radionuclide i for a given or representative accident;
- DCF_i effective dose commitment per inhaled activation for the radionuclide i [Sv/Bq];

D. Ene

LBE META:LIC Layout

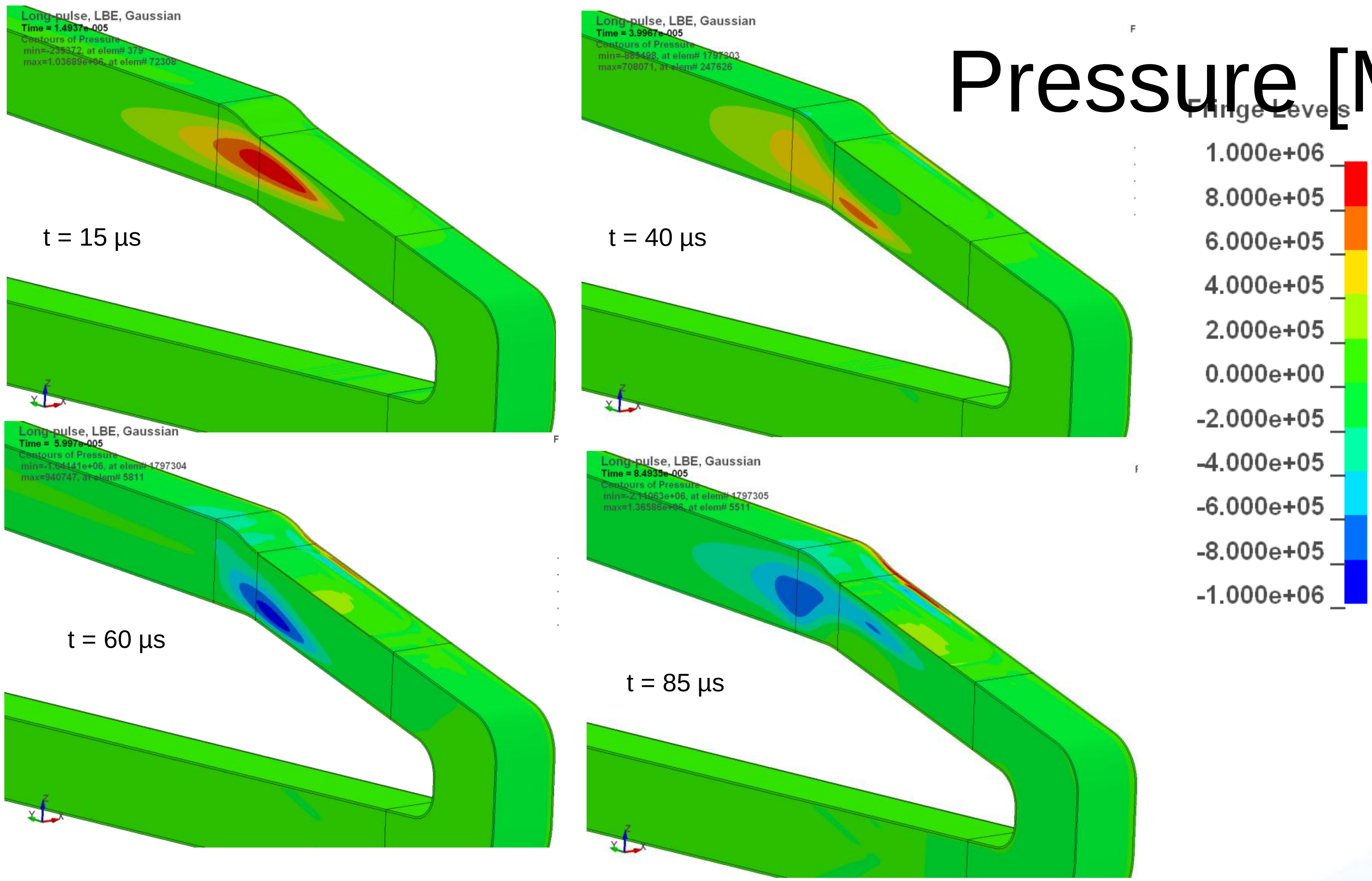


Pressure pulse issue

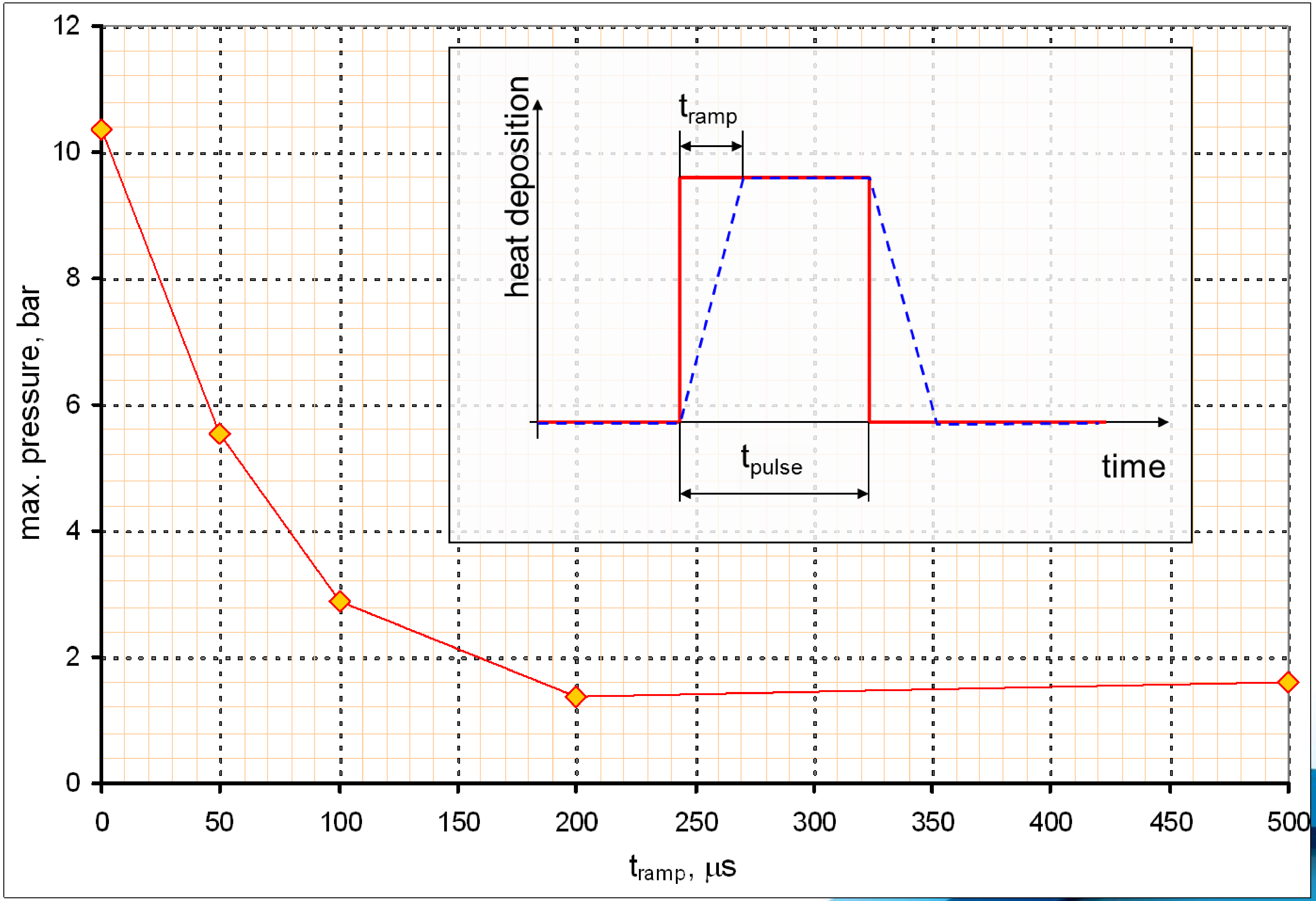


J. Wolters

Pressure pulse problem

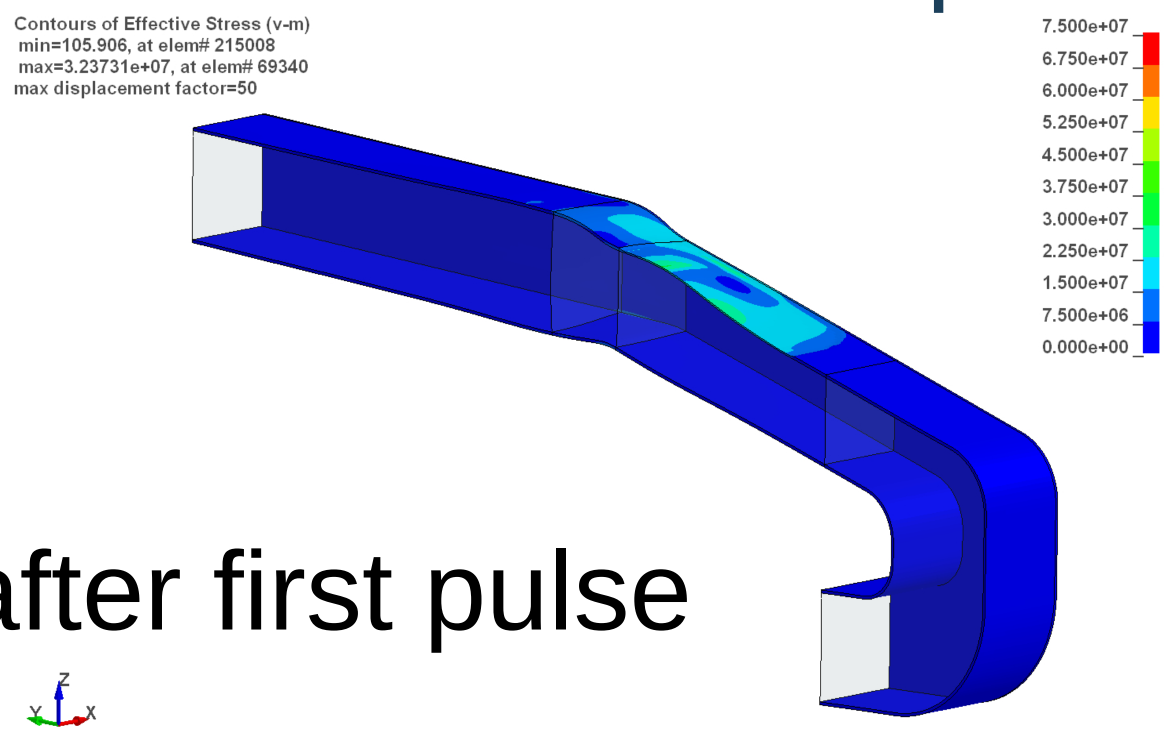


Effect of pulse ramp

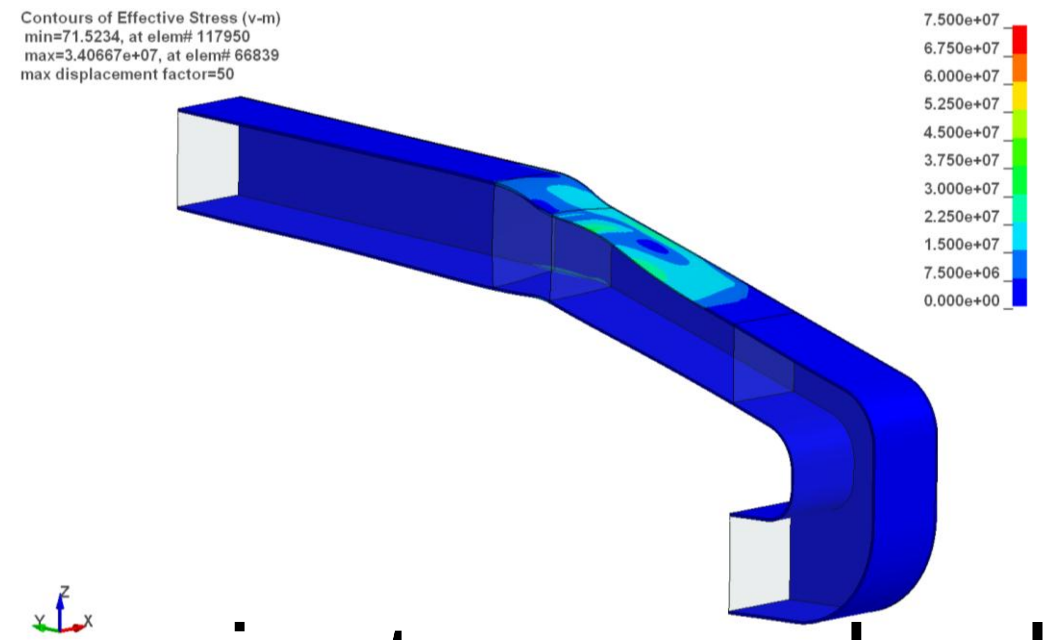


J. Wolters

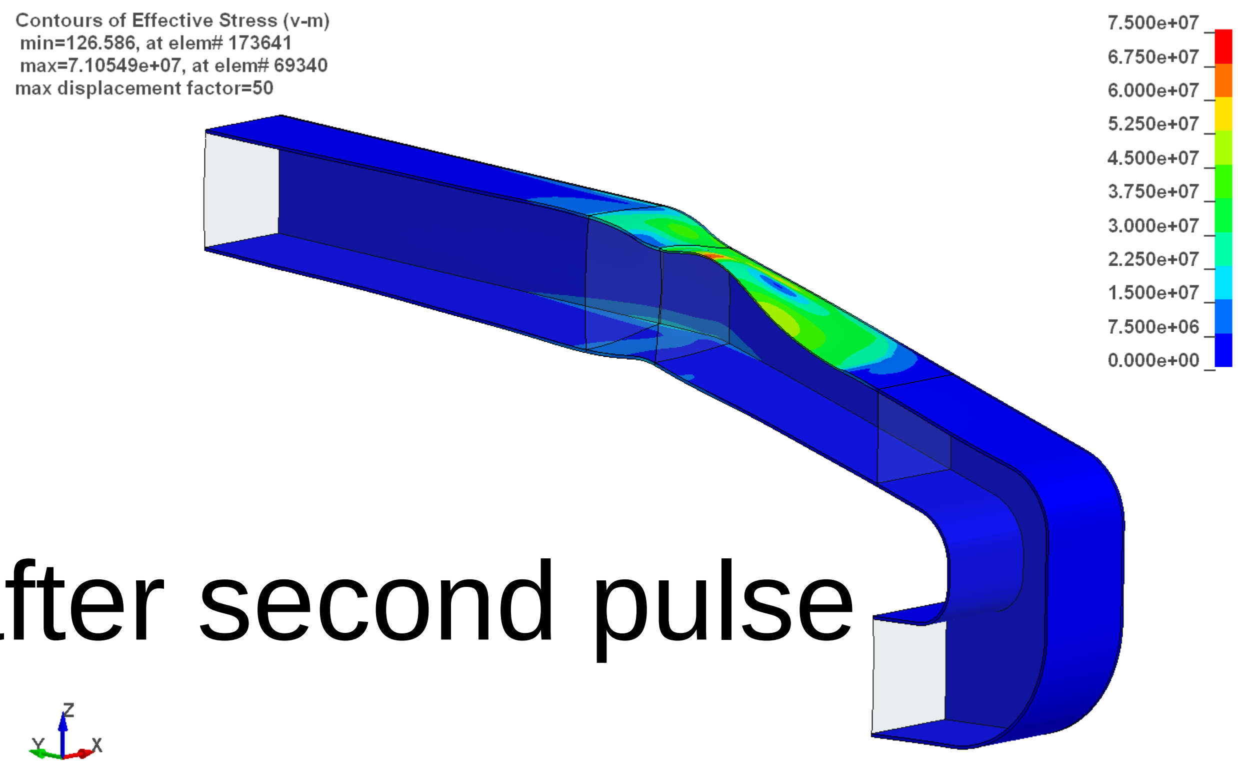
Time dependent stresses in container



after first pulse



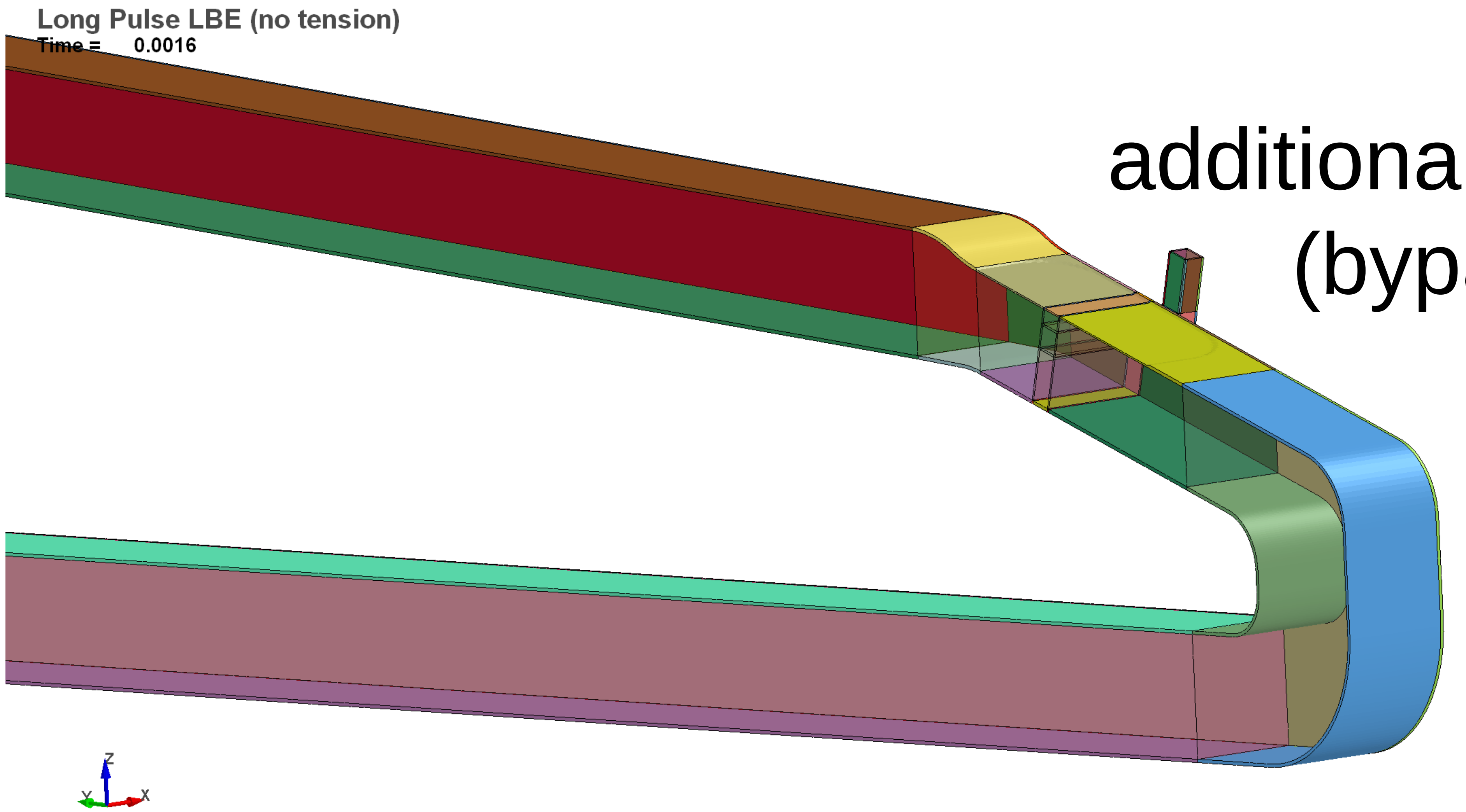
prior to second pulse



after second pulse

To avoid accumulation of stresses for transient events like a beam trip, an additional spillway can be used. Dimensioning and demonstration of the effectiveness is one of the next tasks.

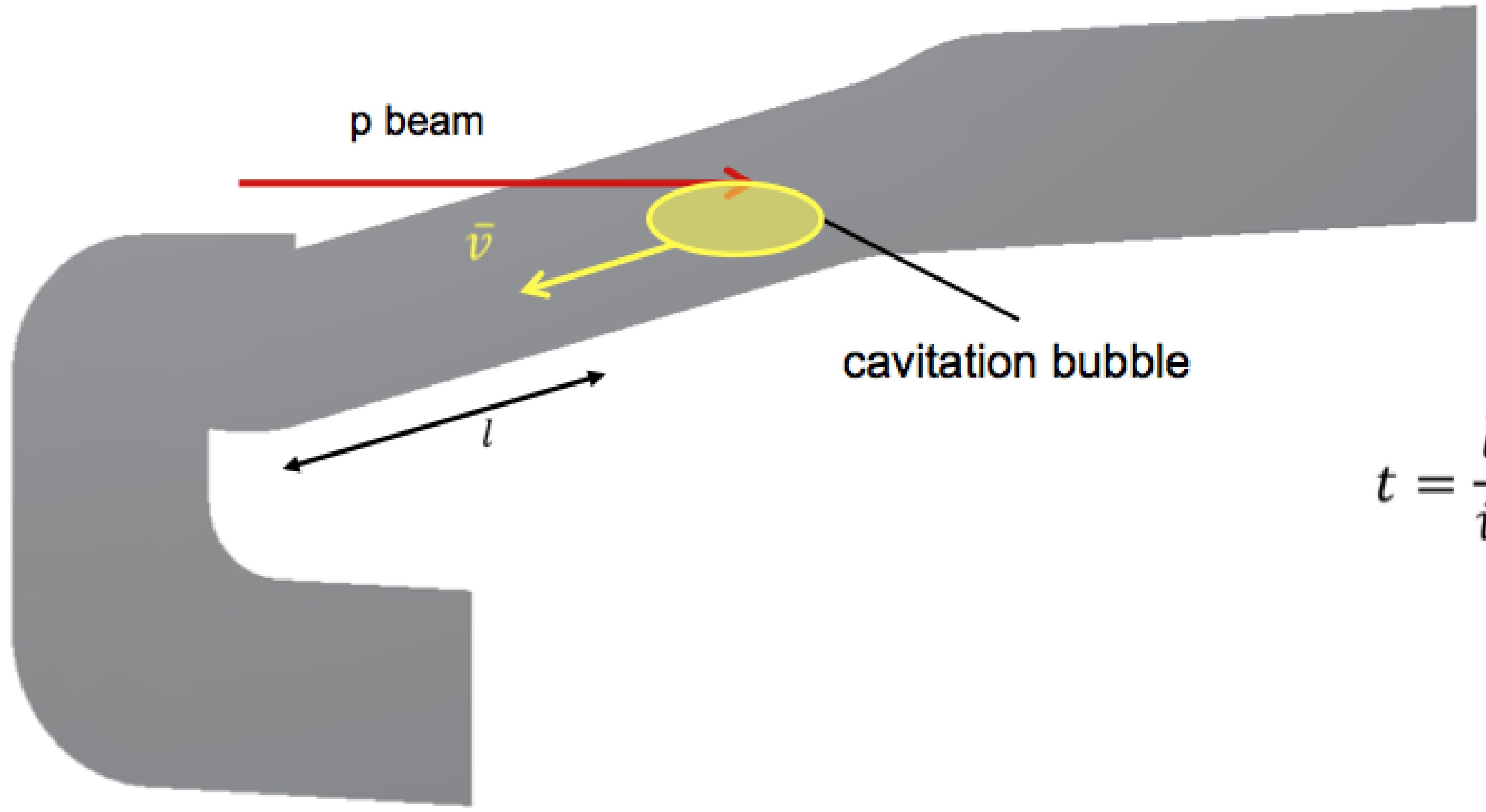
Bypass to diffuse stresses



additional spillway (bypass)

Dealing with beam trips I/II

- Water hammer beam trip on → off



$$t = \frac{l}{\bar{v}} \approxeq 2\,pulses$$

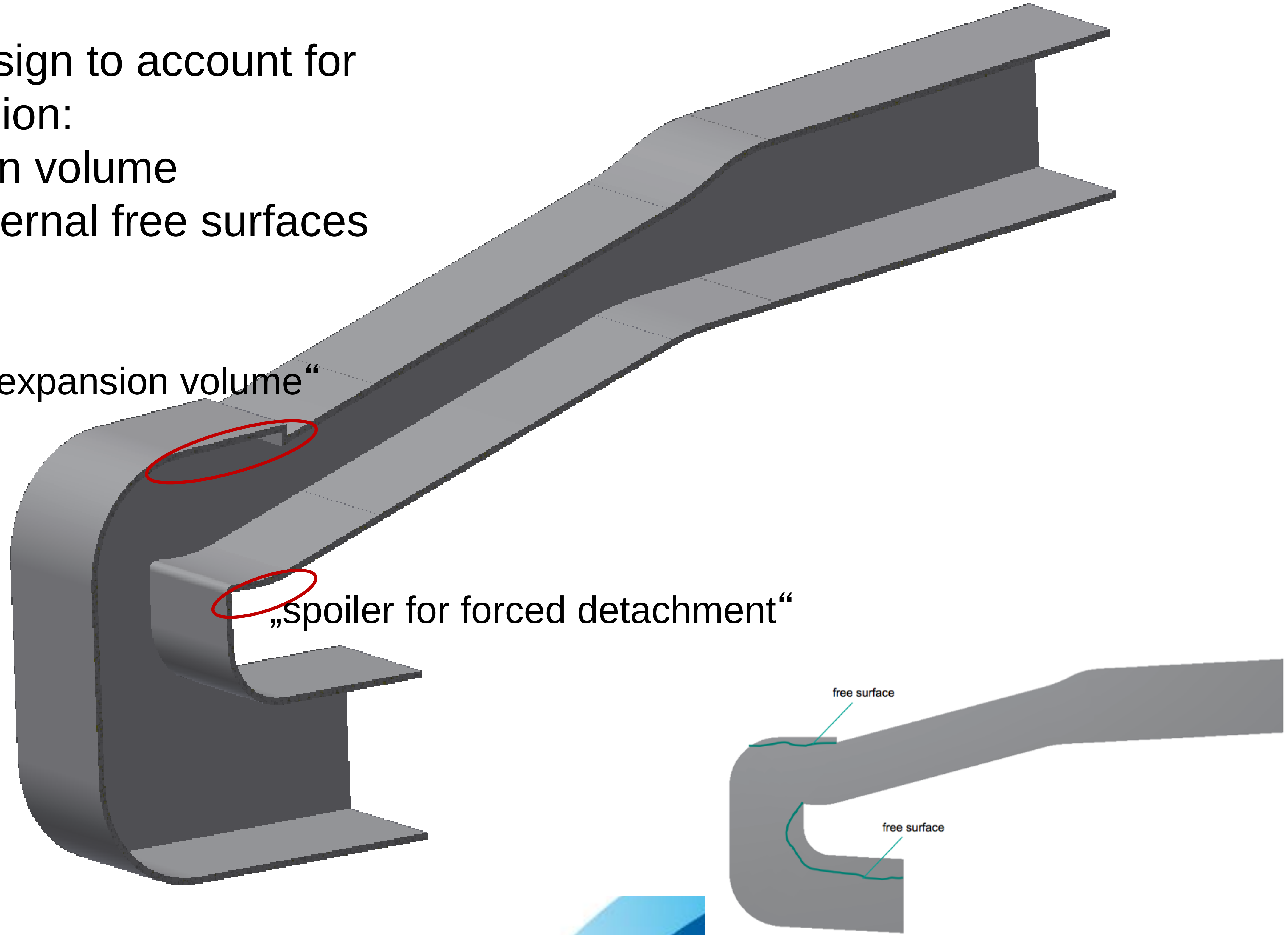
- time for the cavitation bubble to be neutralized at the free surfaces: approx. 2 pulses

Dealing with beam trips II/II

Modified design to account for LBE expansion:

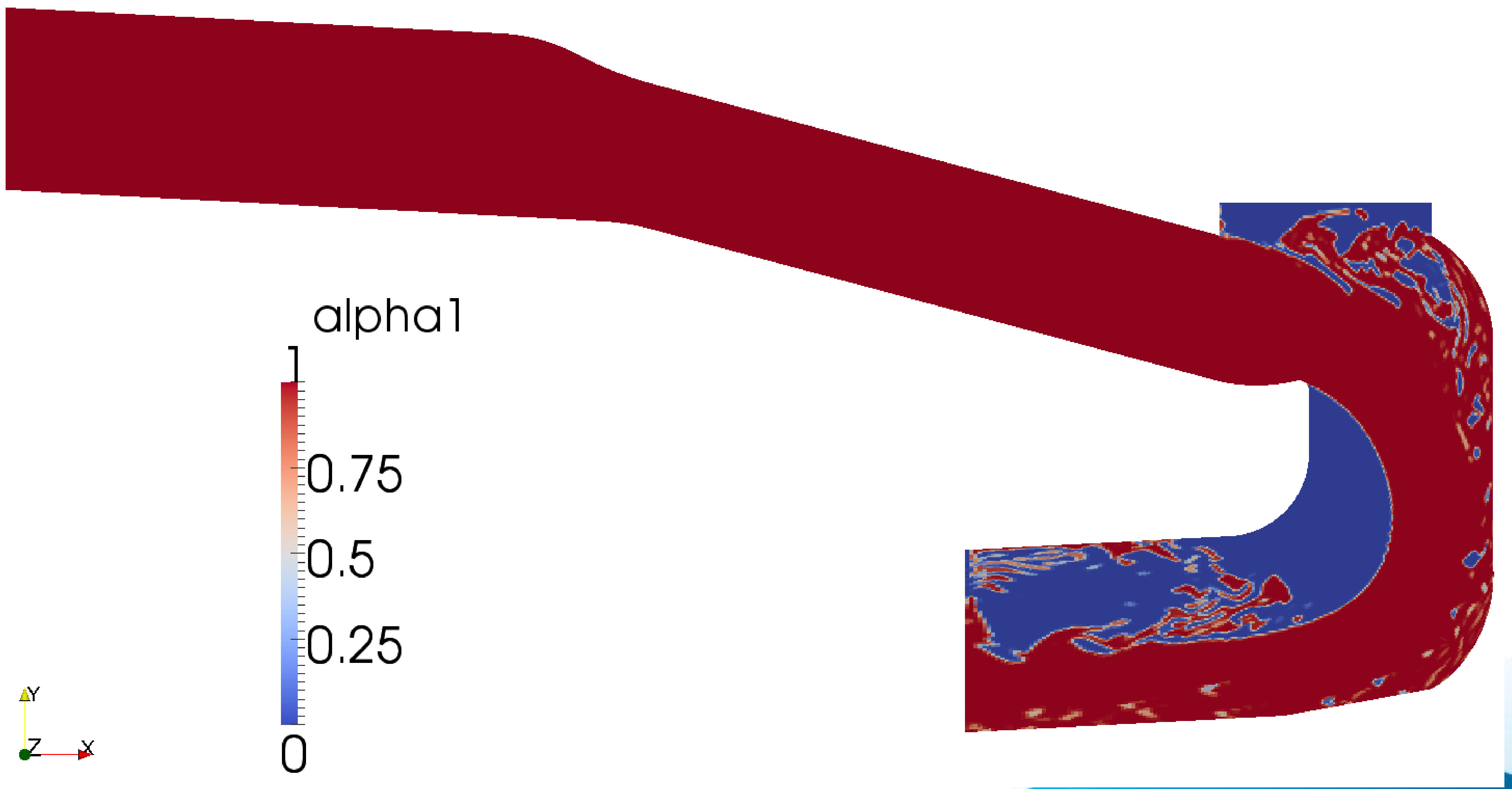
expansion volume

- 2 internal free surfaces



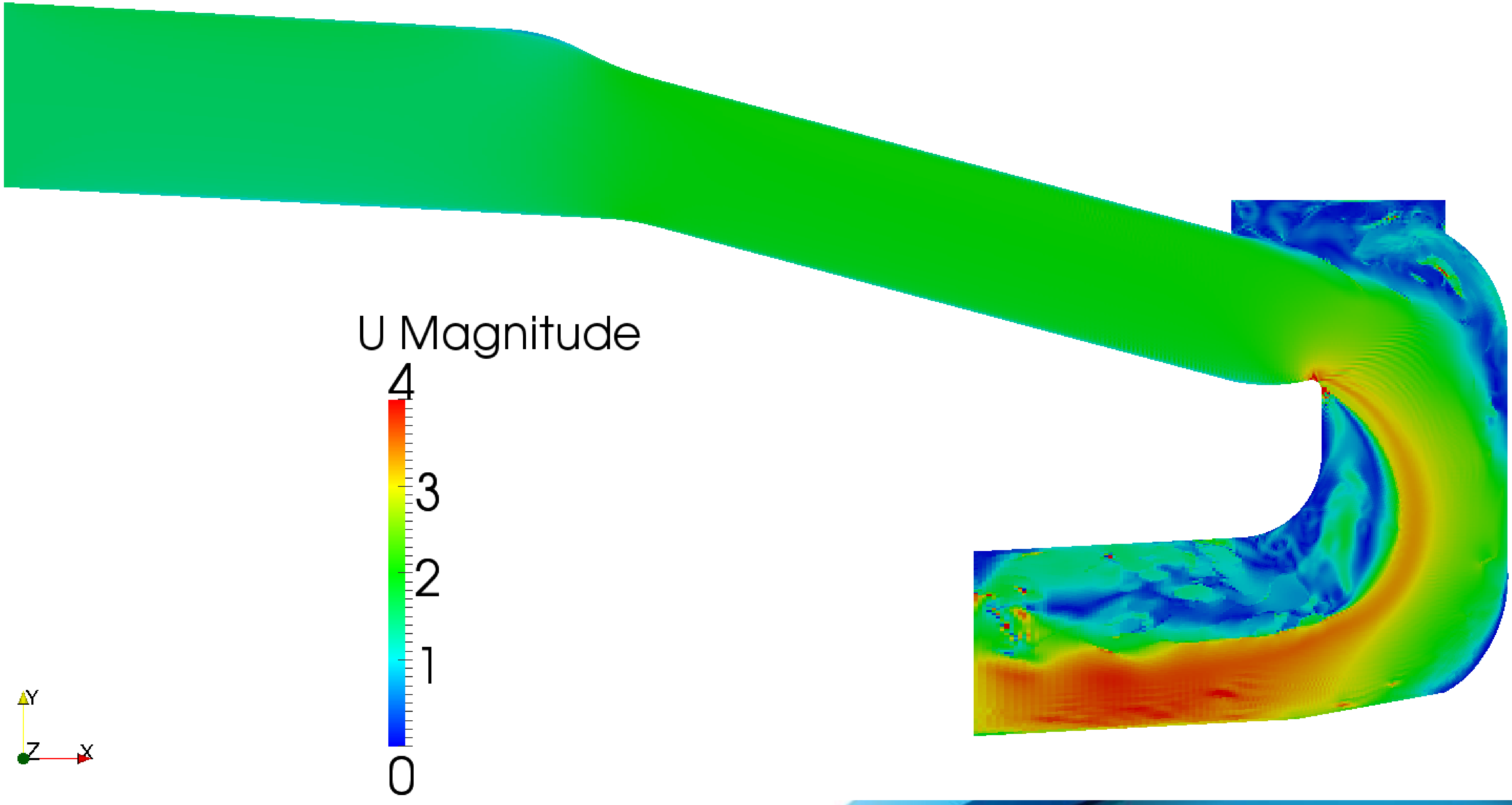
Free surfaces

Internal free surfaces at t = 1.75 s



Velocity distribution

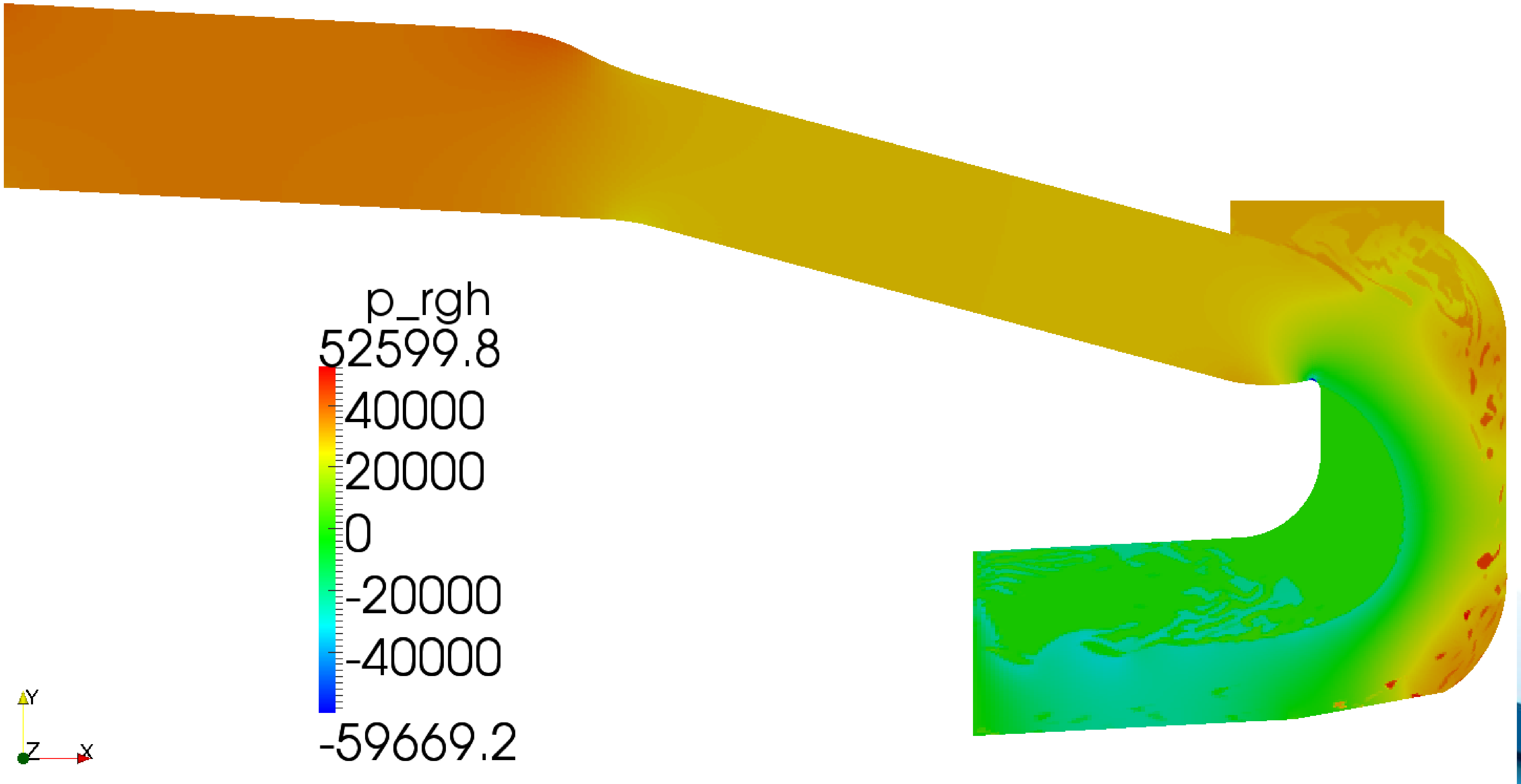
Velocities at t = 1.76 s



A. Class

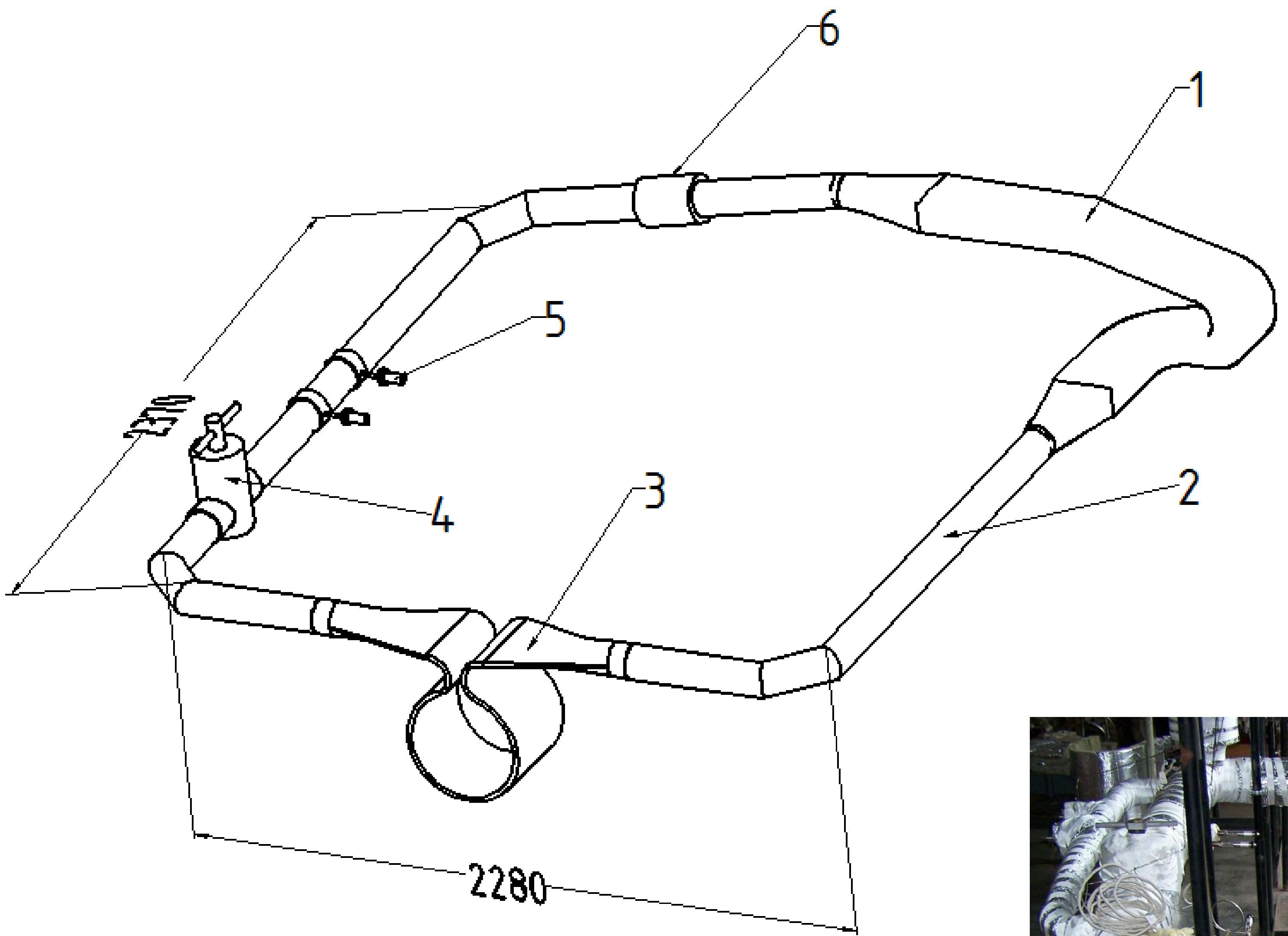
Pressure distribution

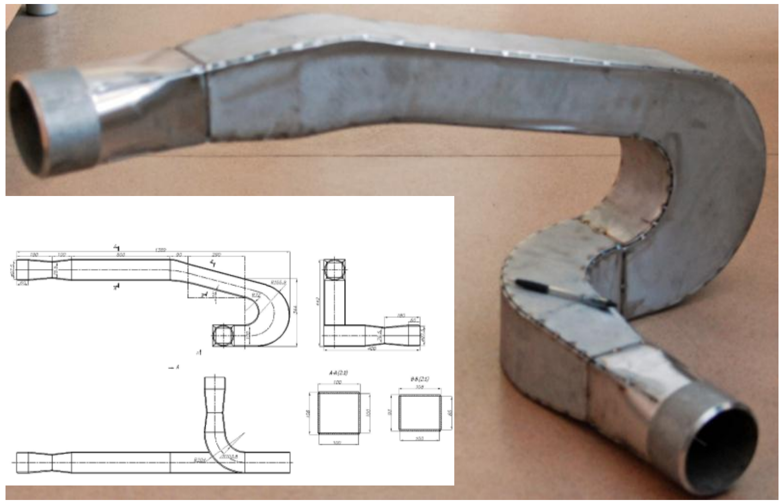
Pressures at t = 1.76 s

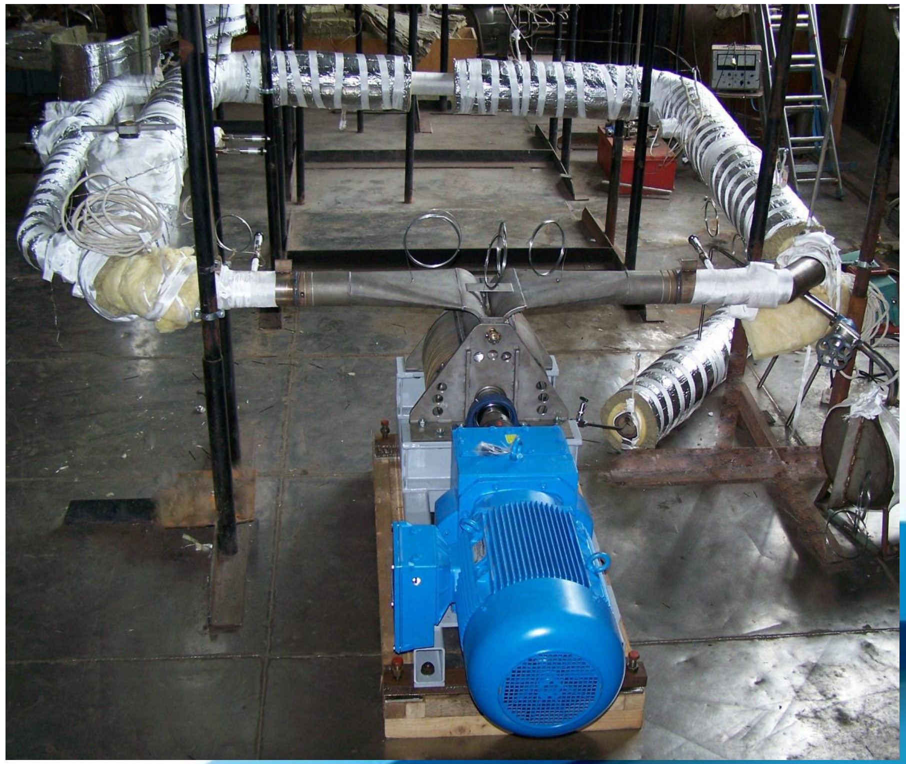


A. Class

META:LIC Test Stand at IPUL







1-Module of Target body;
2-PbBi loop (diameter 108 x 4.0; SS316L);
3-Channel of EMP;
4-Valve;
5-Venturi tube;
6-Electromagnetic Q-meter

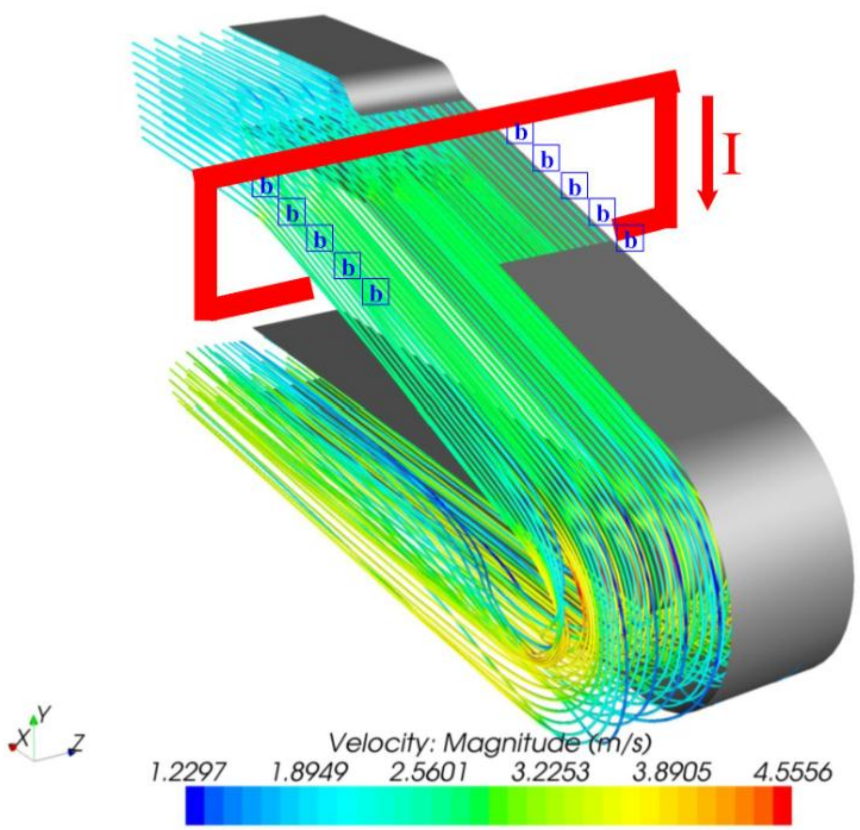
Operating parameters:

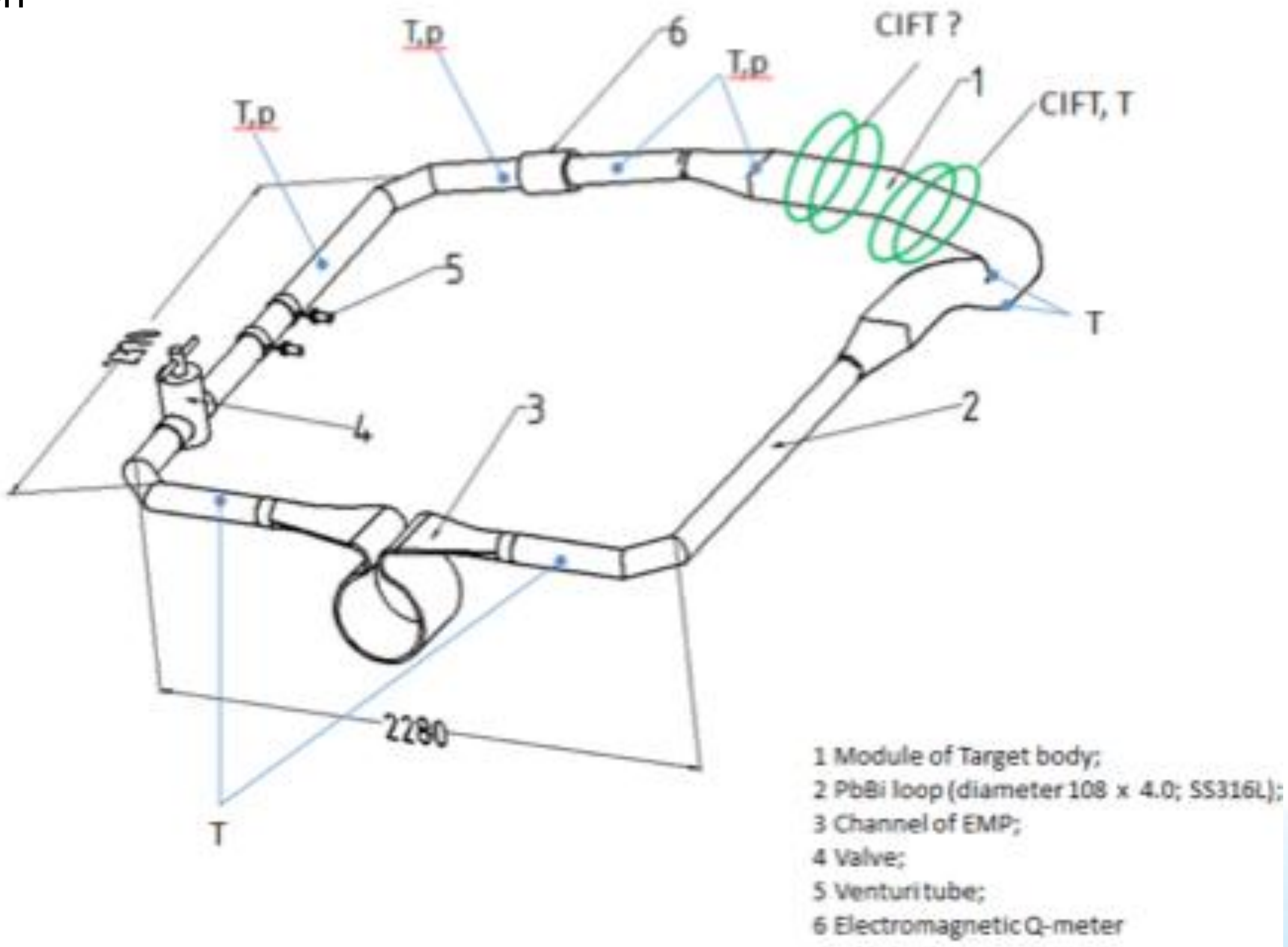
Temperature, ^{0}C	up to 400;
Flowrate, L/S	up to 11;
Pressure, bars	4

Expansion tank, supply vessel, heaters etc. are not showed

Instrumentation

- Differential pressure across circular to rectangluar transition
- temperature ahead & after pump
- Temperature >3 ahead of the test section
- CIFT inflow channel?
- bulk velocity
  - EHM
  - Venturi





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LBE ESS TDR Contributions

- Introduction (C. Fazio)
- Design requirements and configuration selection (A. Class, U. Fischer)
- Neutronic design (U. Fischer)
- Engineering design (A. Class with input from FZJ J. Wolters)
- Instrumentation of liquid metal flow (S. Eckert, F. Stefani and K. Thomsen PSI)
- Trolley design and interface to monolith (J. Fetzer, A. Class)
- Needed ancillary systems (K. Thomsen – include here experience from MEGAPIE)
- Target module validation (E. Platacis, A. Class with input from all involved partners in the experiment)
- Corrosion and erosion properties of structural steels in contact with liquid metal coolant (A. Weisenburger)
- Potential needs for licensing, dismantling and final disposal (K. Thomsen PSI taken from the MEGAPIE experience – calculation of spallation products is done by Dana (ESS))

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Thank you for your attention!