Wir schaffen Wissen – heute für morgen

The MEGAPIE target on the way to PIE

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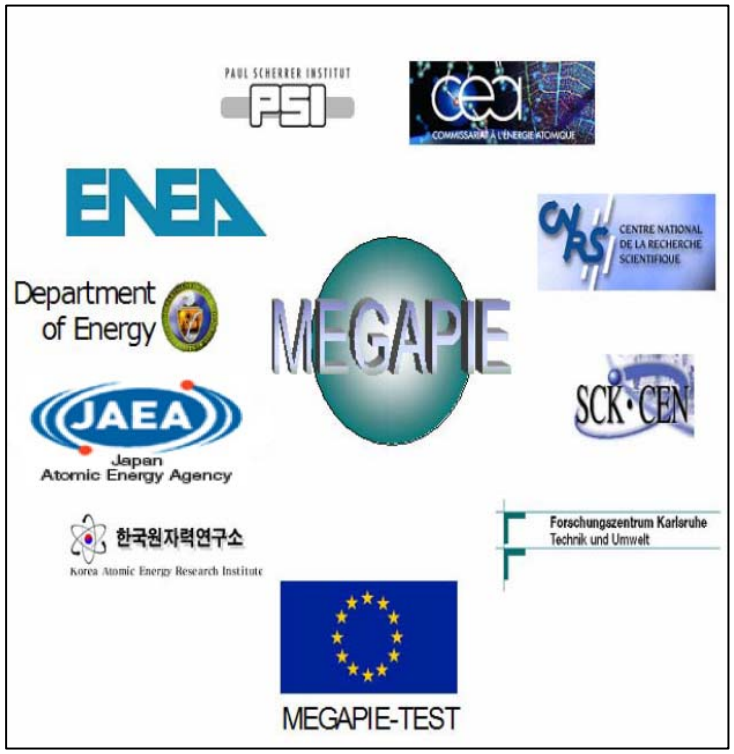
Switzerland
on behalf of the MEGAPIE team and collaboration

MEGAPIE MEGAwatt Pilot Experiment:

A joint international initiative to design, build, licence, operate and explore an LBE*) liquid metal spallation target for 1 MW beam power

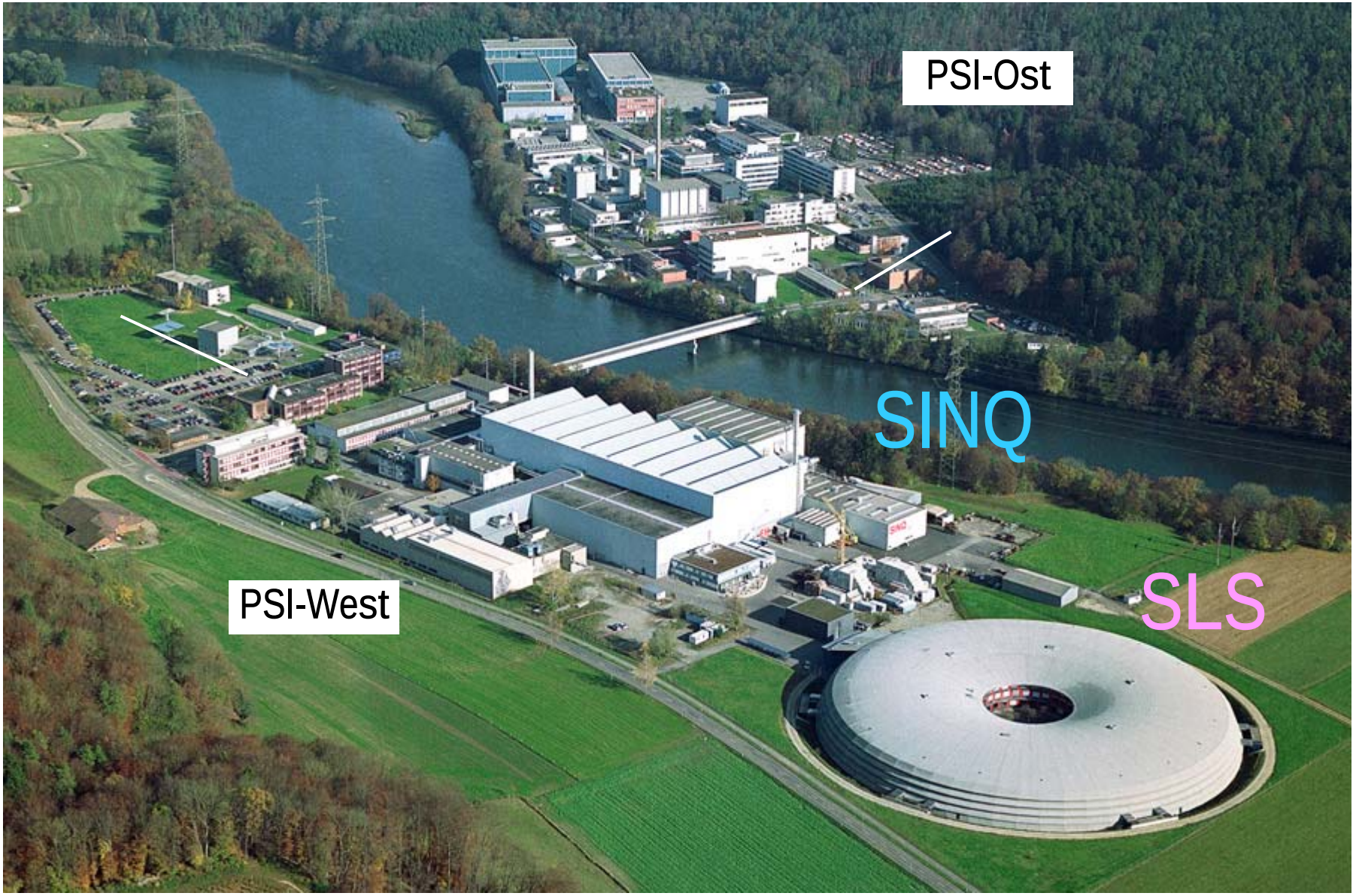


*) **Lead Bismuth Eutectic, T_m=125°C**

Goals of MEGAPIE:

- fathom the capabilities in neutron yield
- Demonstrate the feasibility of a liquid metal target for high-power spallation and ADS applications
- Establish a sound database from the operational experience and from PIE for future projects

The Paul Scherrer Institut



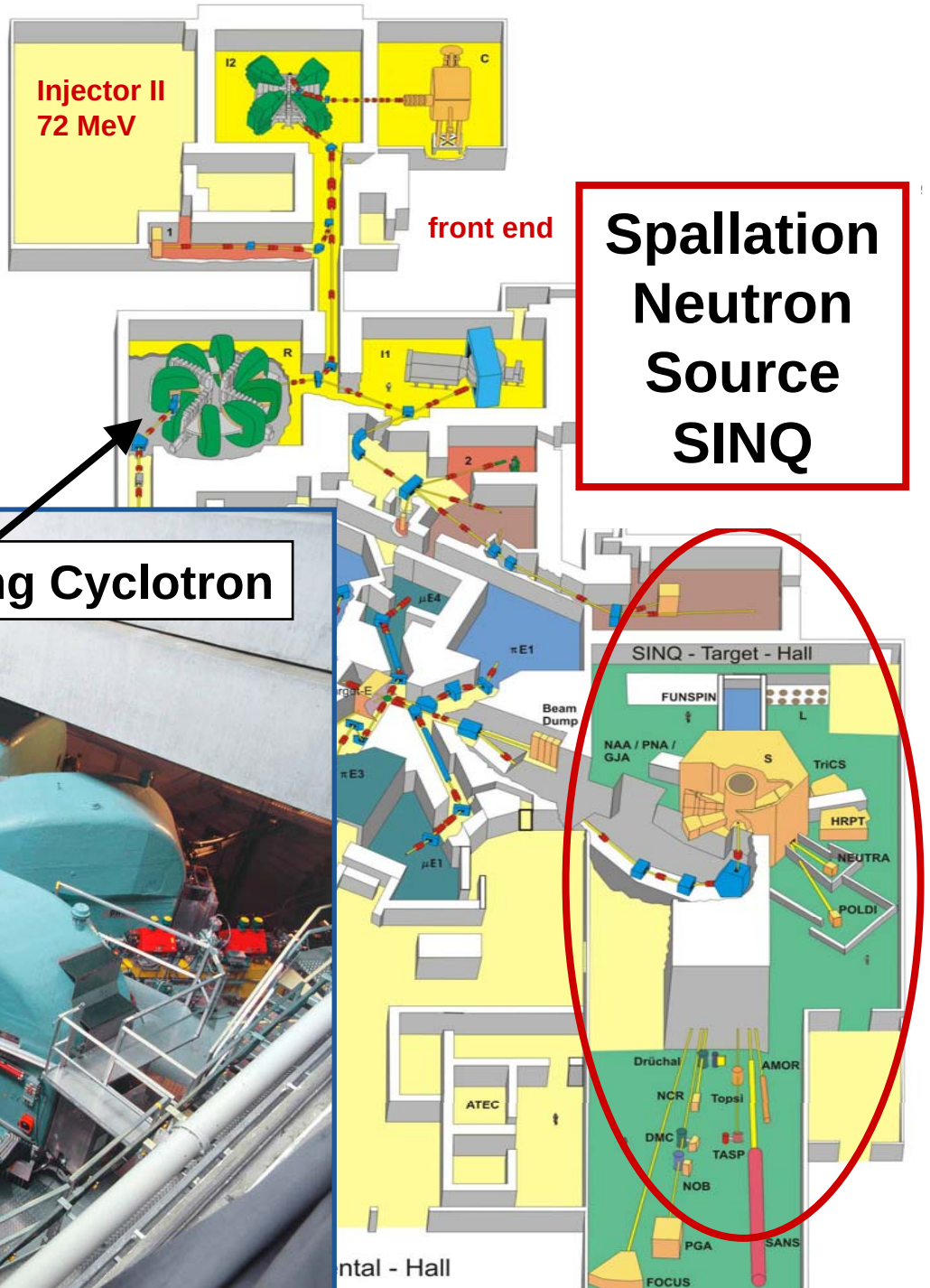
Proton accelerator Facility at PSI

- 590 MeV
- 2.2 mA (1.3 MW)

upgrade launched

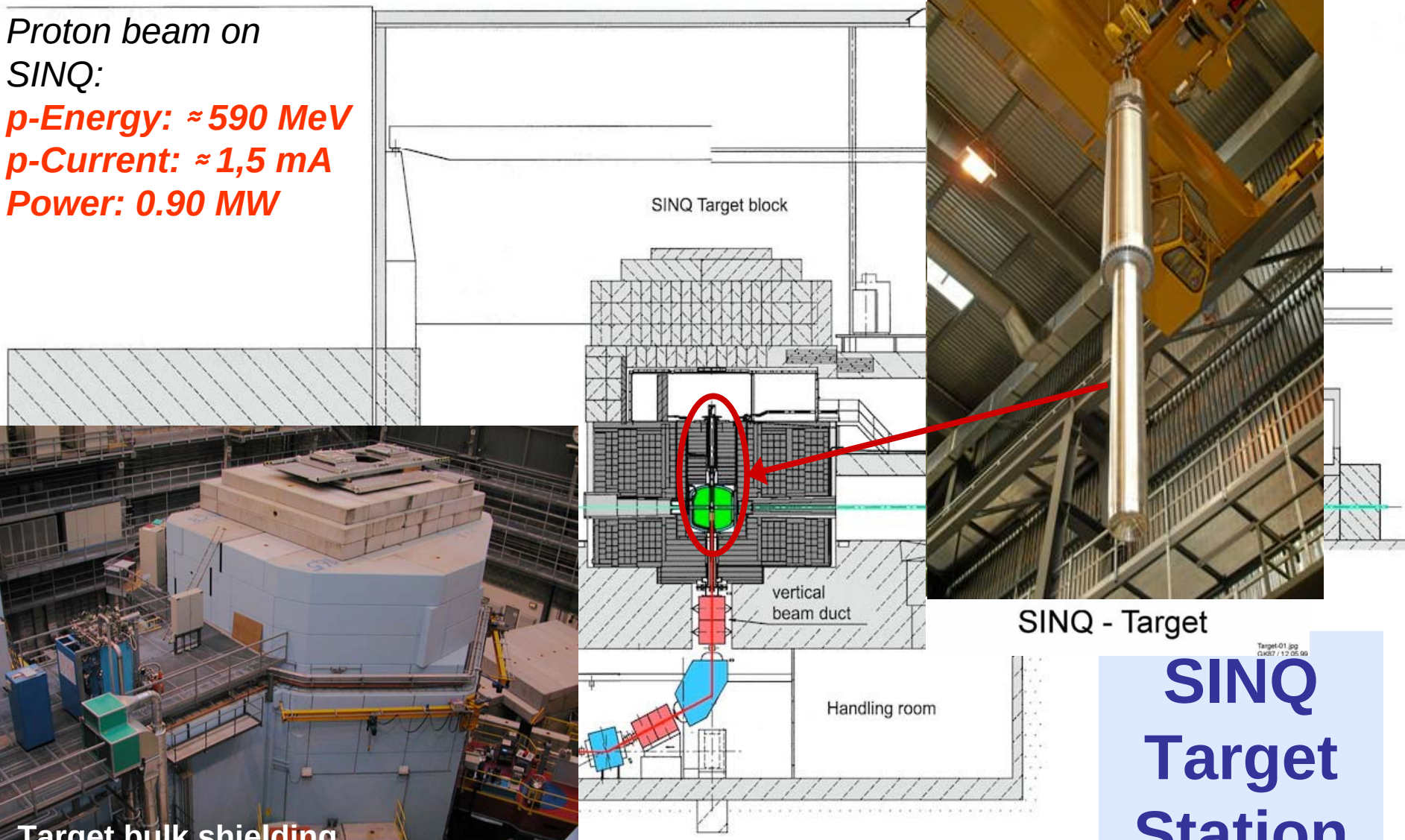
⇨ 3.0 mA (1.8 MW)

Main Ring Cyclotron



Proton beam on SINQ:

p-Energy: ≈590 MeV
p-Current: ≈1,5 mA
Power: 0.90 MW



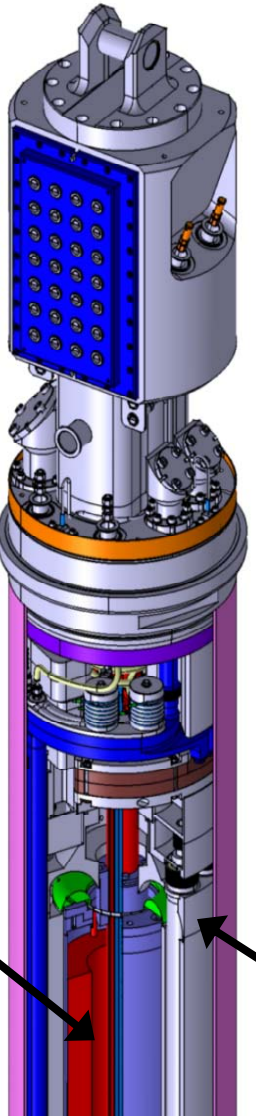
SINQ - Target

Target bulk shielding

SINQ Target Station

MEGAPIE target features

target head



central flow guide tube

lower target assembly

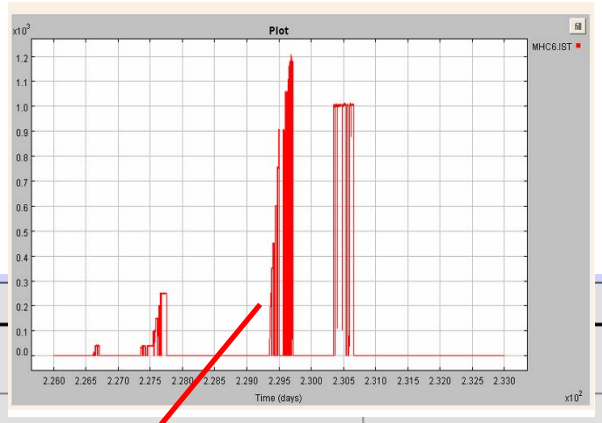
electro-magnetic pumps

heat exchanger

safety hull

beam window

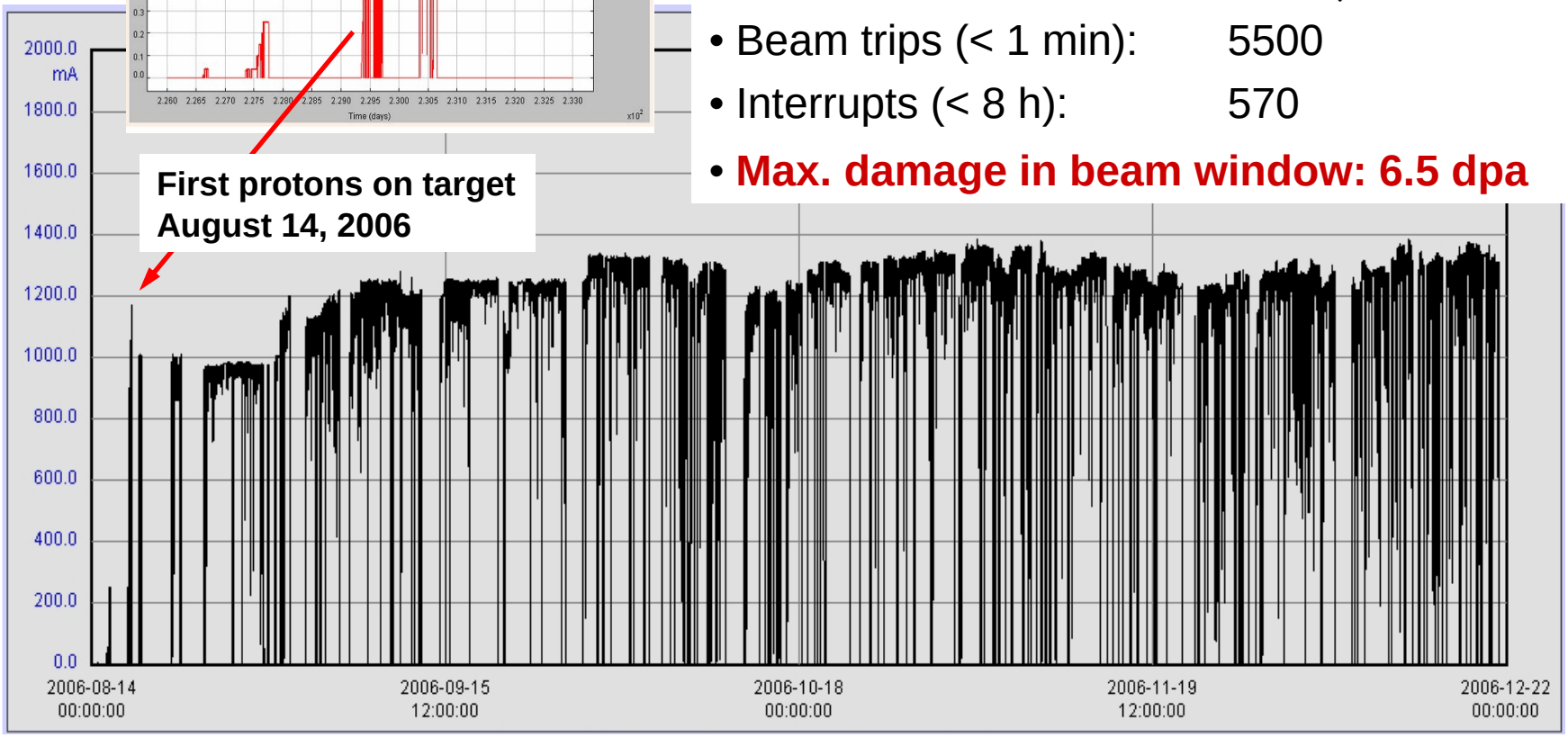
MEGAPIE Target Operation: full history



First protons on target
August 14, 2006

On beam: August 14 – December 21, 2006

- Accumulated charge: 2.8 Ah
- Peak Current: 1400 μA
- Beam trips (< 1 min): 5500
- Interrupts (< 8 h): 570
- **Max. damage in beam window: 6.5 dpa**



MEGAPIE on the way to PIE

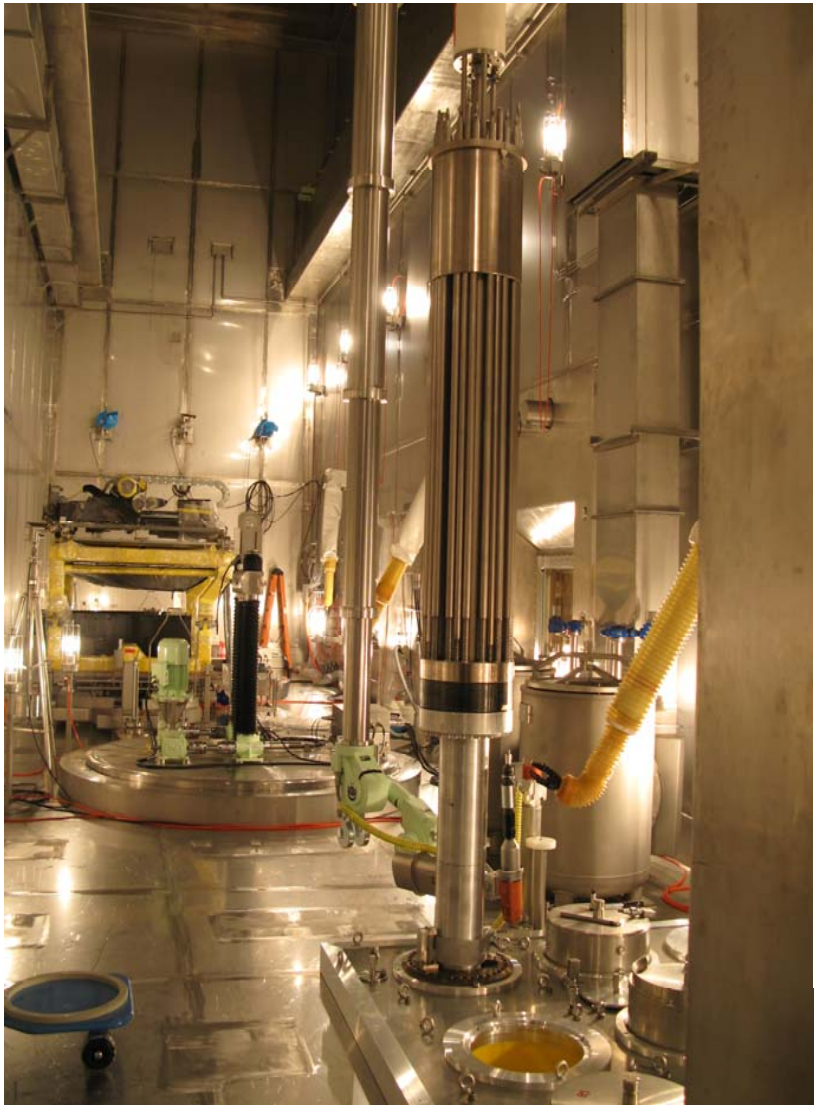
Target dismantling, cutting and packing

Target transfer from PSI to ZWILAG

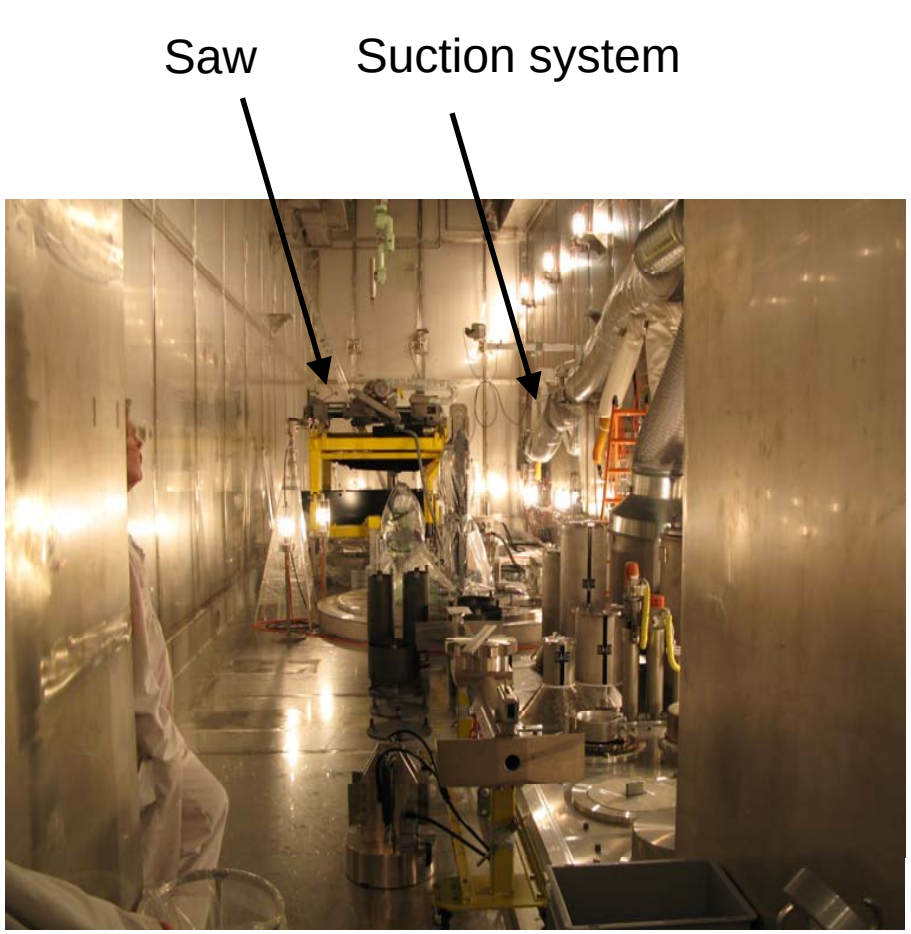
(July 6th, 2009)

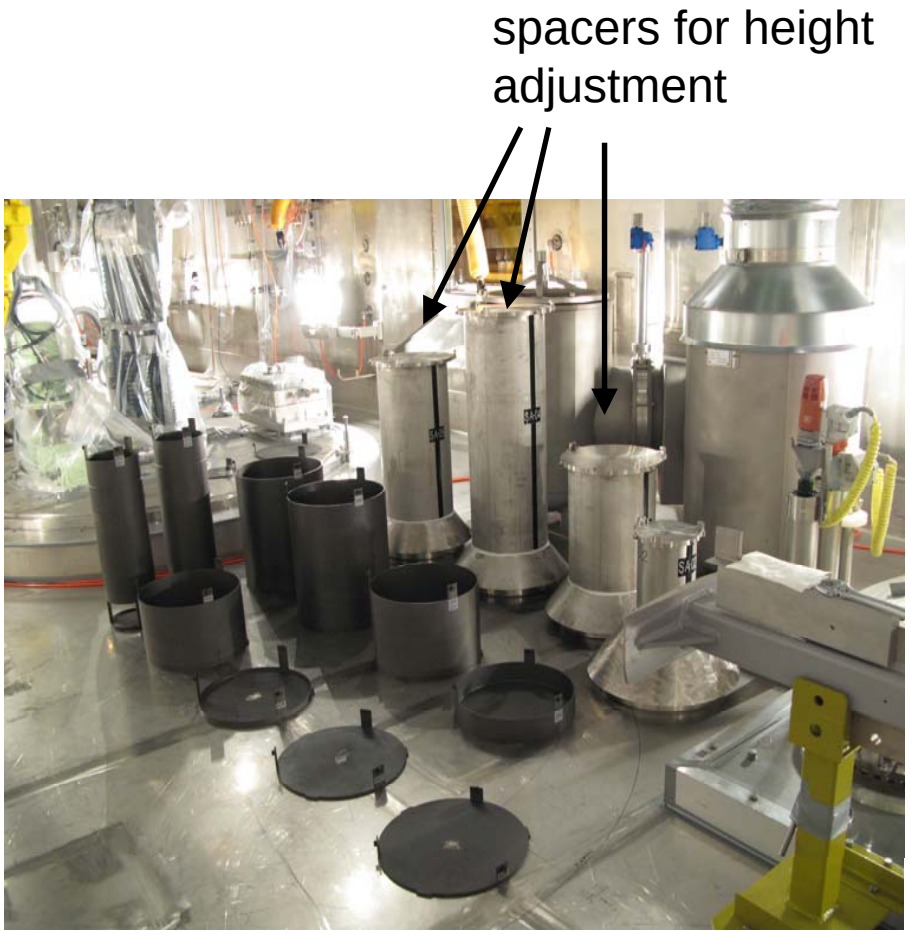
Hotcell of ZWILAG

‚Cold tests' for target dismantling



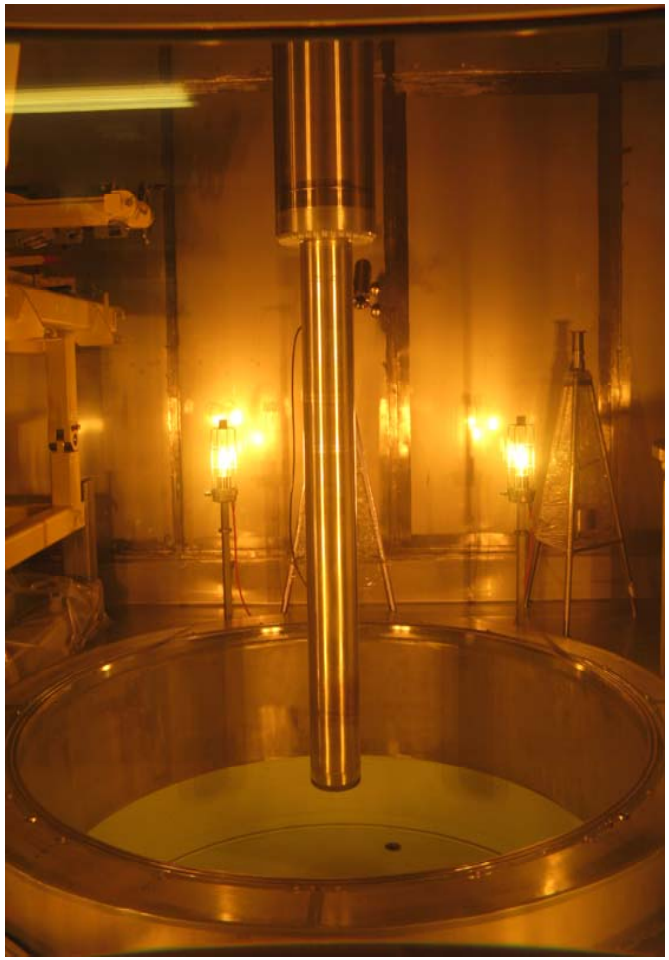
Hot cell of ZWILAG, prepared for receiving MEGAPIE





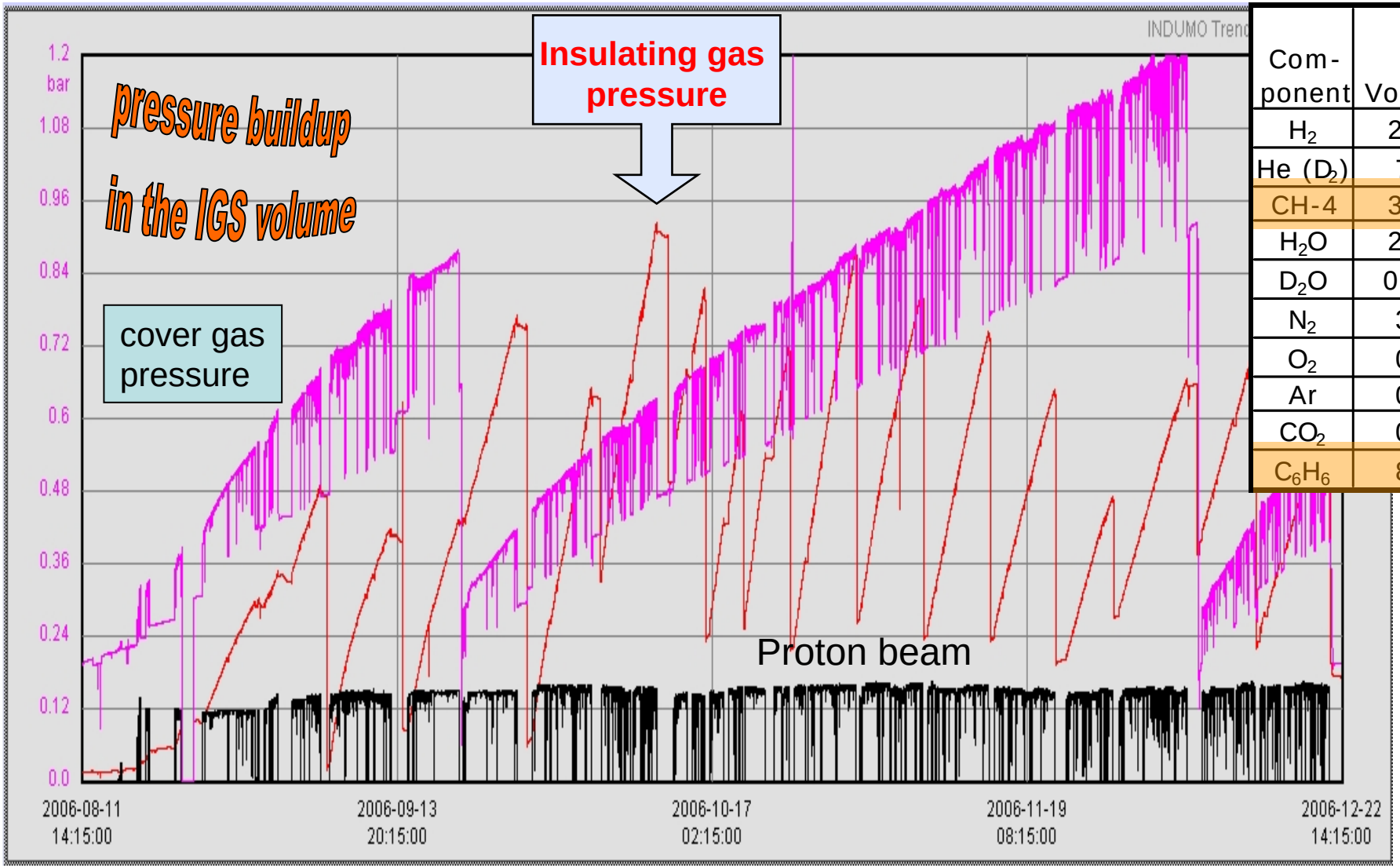
The hot cell of ZWILAG had been fully equipped with the saw, a special suction system and all tools needed for the dismantling

Lifting the target into the Hot Cell (HC)



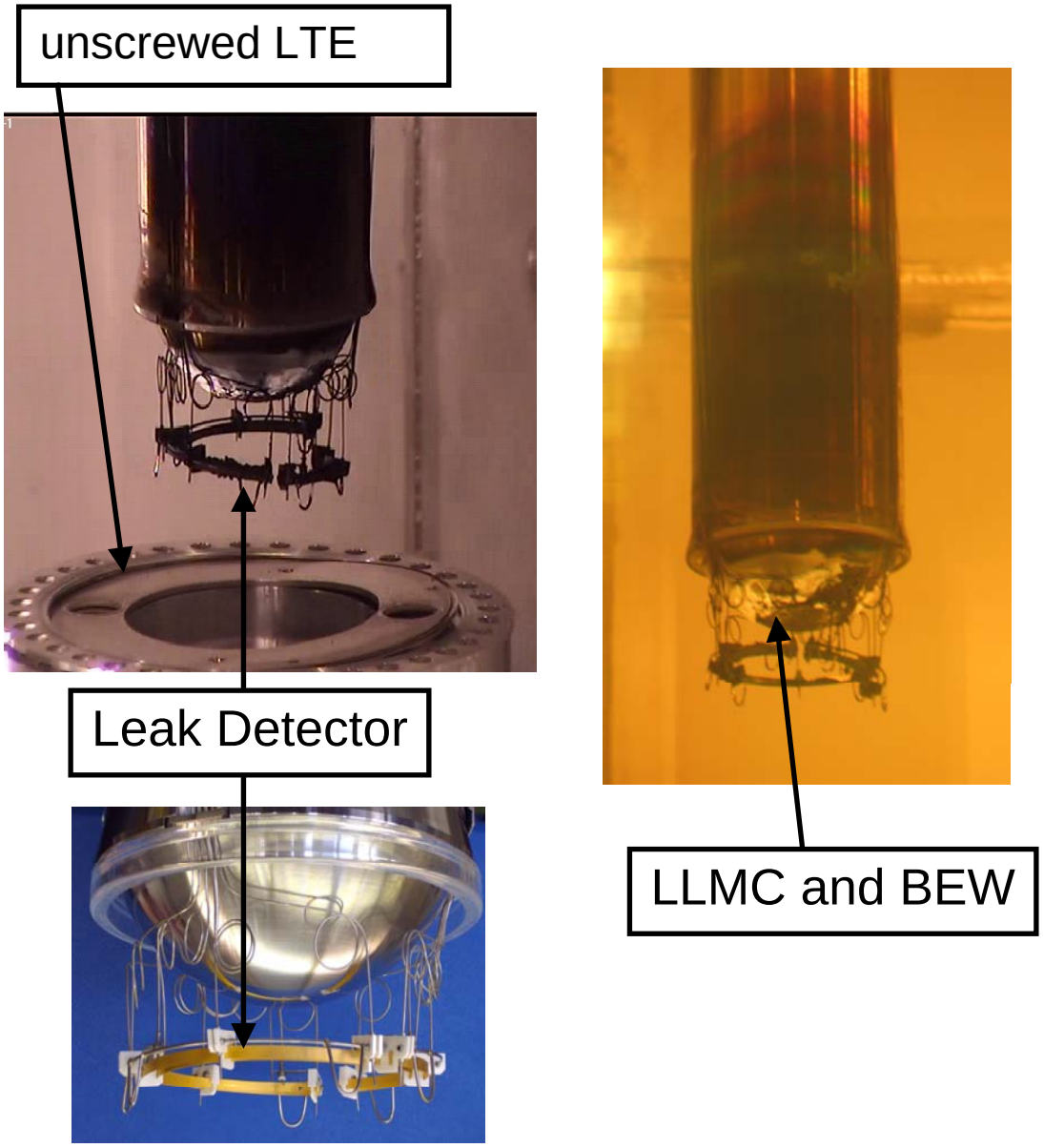
- TC1 docked to HC from below
- The MEGAPIE target was lifted by the crane of the hot cell
- First visual inspection by rotating the target: No special findings; slight stain in high neutron flux region.
- Next step: The Lower Target Enclosure (Aluminum Safety shroud, LTE) was unscrewed.

Cover gas & Insulating Gas Pressures during Irradiation

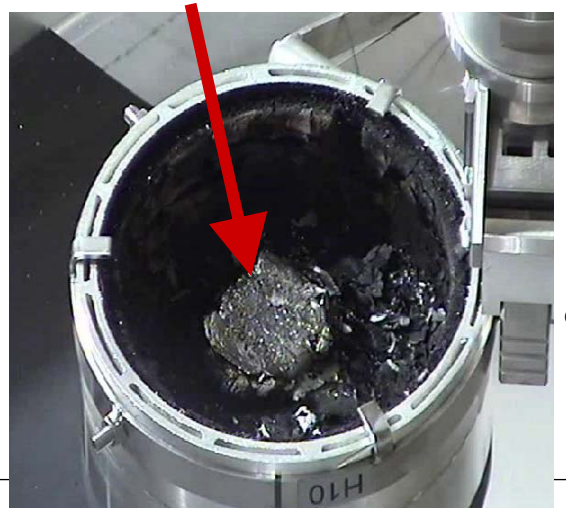


Com-ponent	Vol-%
H_2	25
He (D_2)	7
CH-4	35
H_2O	22
D_2O	0.2
N_2	3
O_2	0
Ar	0
CO_2	0
C_6H_6	8

Next step: Unscrewing and removing LTE



- First visual inspection of the Lower Liquid Metal Container (LLMC, T91 steel).
- Black smut was deposited on the leak detector (which partly fell off when the target was moved).
- The sides of the LLMC were covered with dark debris.
- black flaky smut inside the safety hull calotte, and a metallic gleaming piece of material



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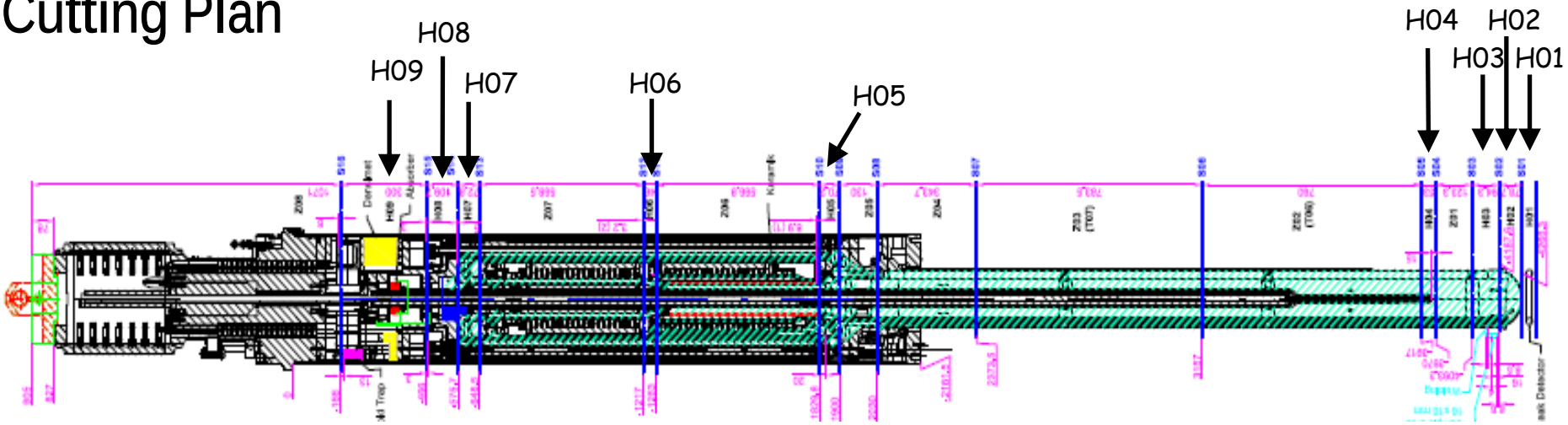
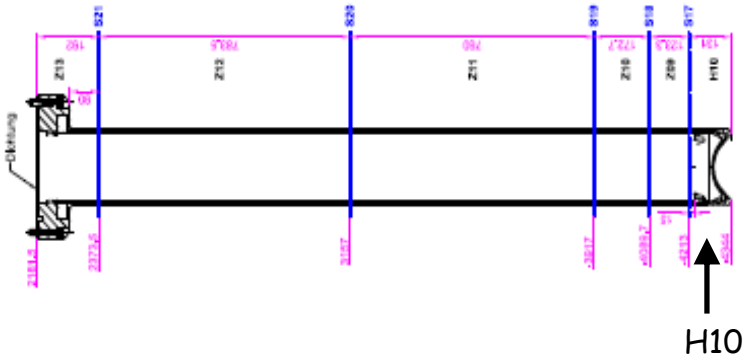
Cutting Plan

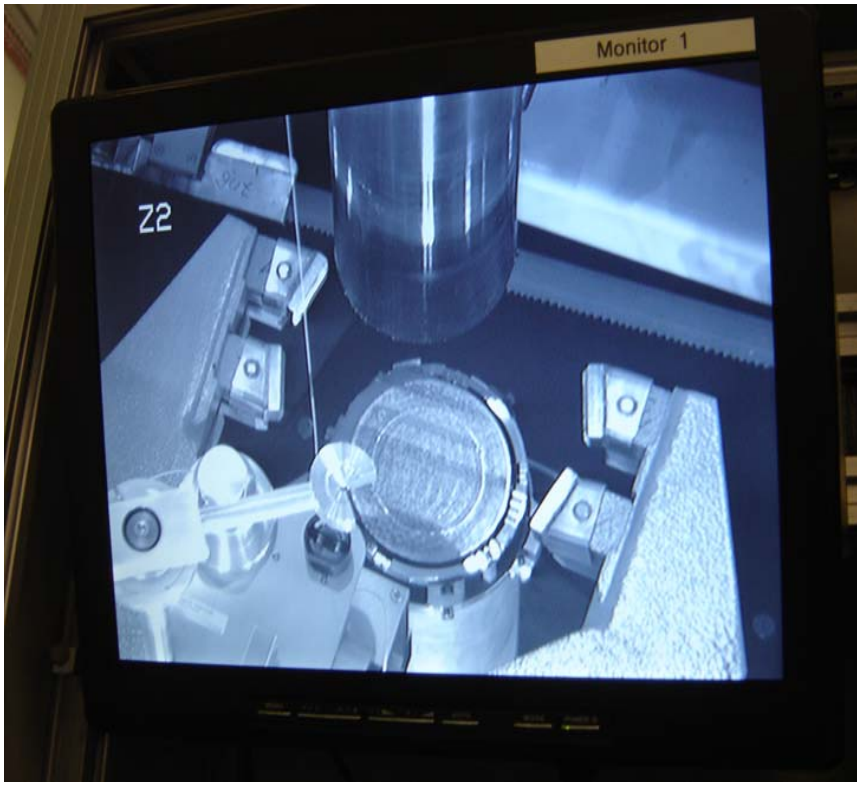


LTE



- 10 slices (H01-H10) were foreseen to extract sample material for the PIE of MEGAPIE
- …the others to be packed and conditioned for storage and disposal
- The cutting started at the beam entrance window and was continued upwards (LLMC)

The first cut of the LLMC, July 15th 2009

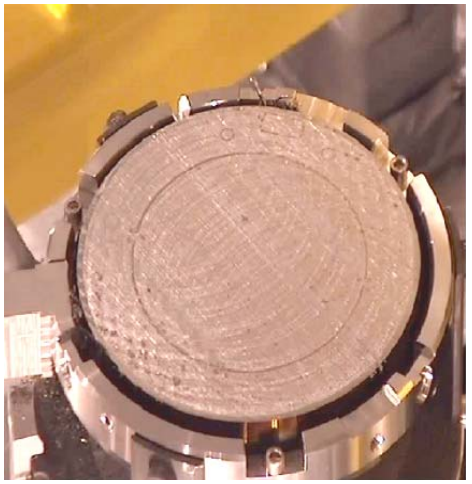


The first cut removed the Beam Entrance Window

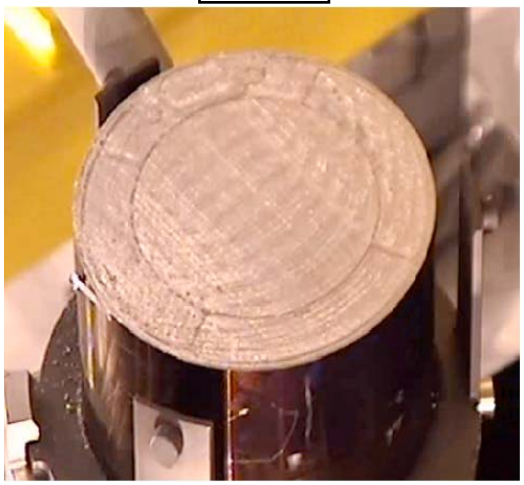
Samples - cutting the lower liquid metal container

- Each piece cut from the target was held in a special steel basket, which could be moved with a special lifting devices.
- After each cut the piece was cleaned using a vacuum cleaner and subsequently lifted to an interim parking position using the power manipulator of ZWILAG hot cell.
- The cutting of the LLMC could be done with a single saw blade. No degradation was observed.

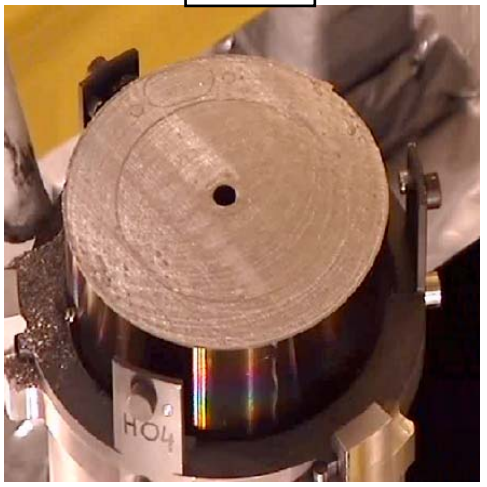
H02 – The Beam Entrance Window



H03

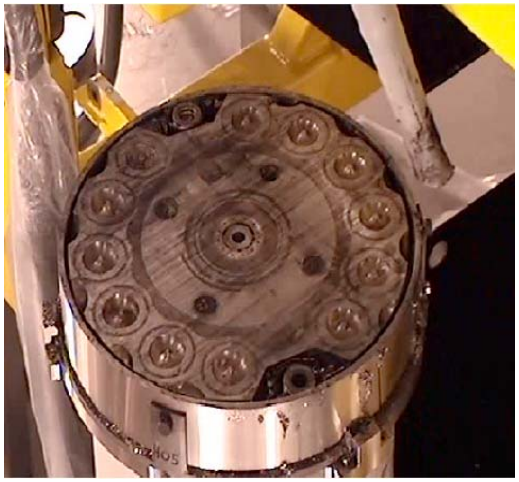


H04



Samples – Cutting the upper part

H05



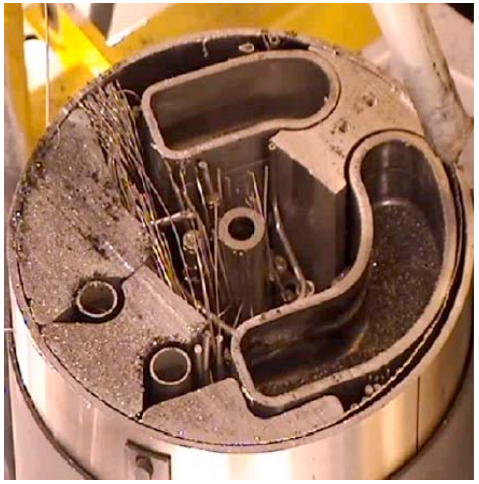
H06

H07

- When cutting the sample piece H05 some remains of oil from the heat exchanger was found in one of the THX pins
- For the upper cuts the saw blade had to be changed twice (by hands-on operation in a separate service cell)
-

H08

H09



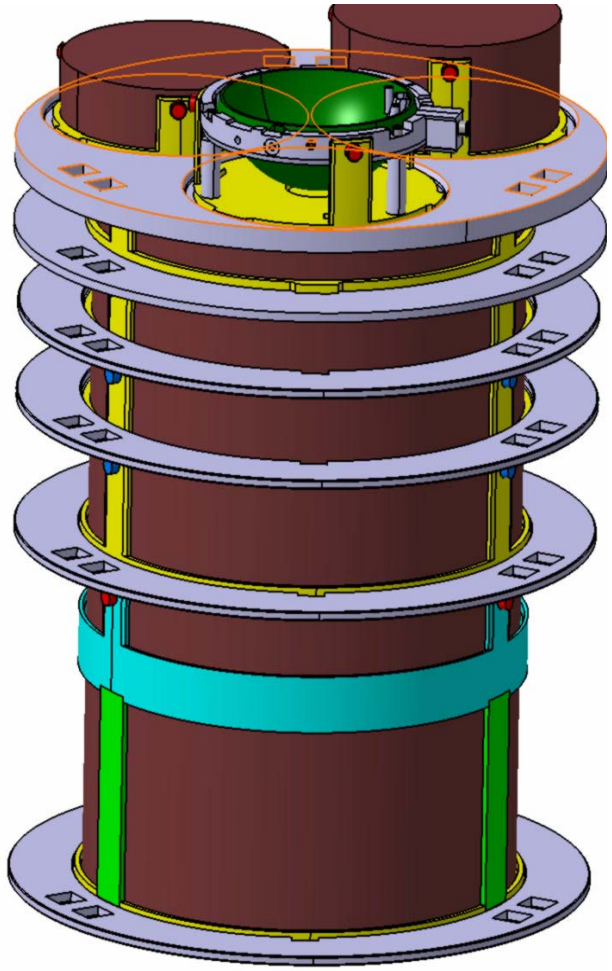
Hotcell work in ZWILAG

Changing the saw blade in a separate service cell

Packing the sample slices

- The sample slices were stacked in a barrel (B10)
- B10 was subsequently placed in a special transport container (TC3).
- TC3 was tested for tightness and currently is temporarily stored in ZWILAG, until the transfer to the Hot Laboratory of PSI can be done
- the transfer is expected for Feb. 2011

B10



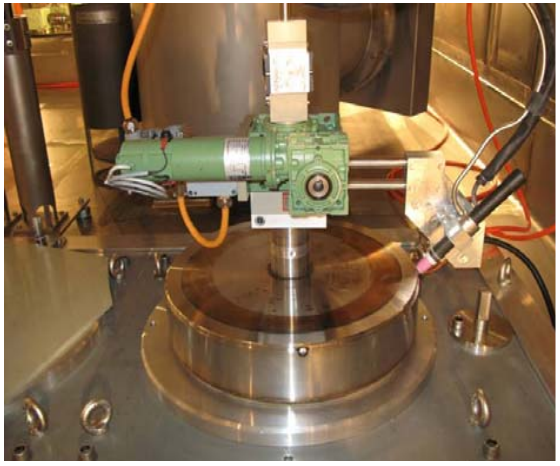
TC3

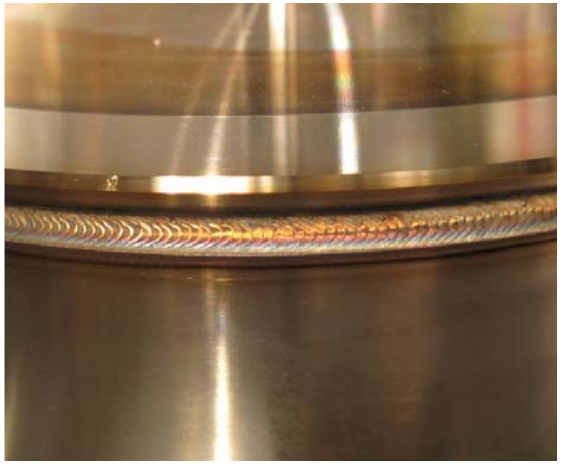
Waste conditioning

- All waste pieces were packed into the so-called “primary containers”, made from steel.
- The whole hot cell was cleaned with a vacuum cleaner. The collected flakes were as well put into one of the “primary containers”.
- The containers were closed and welded.
- ..and placed into a reinforced standard PSI waste container – TC2.
- This container has been prepared for disposal in a final repository by filling it with concrete.

TC2

Welding device





PSI hotlab preparation for sample extraction

Preparation of PIE sample extraction

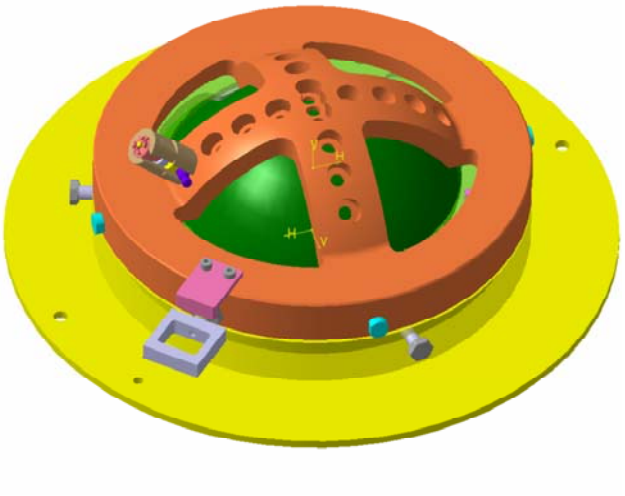
The sample extraction process in the HL will consist of 8 major steps:

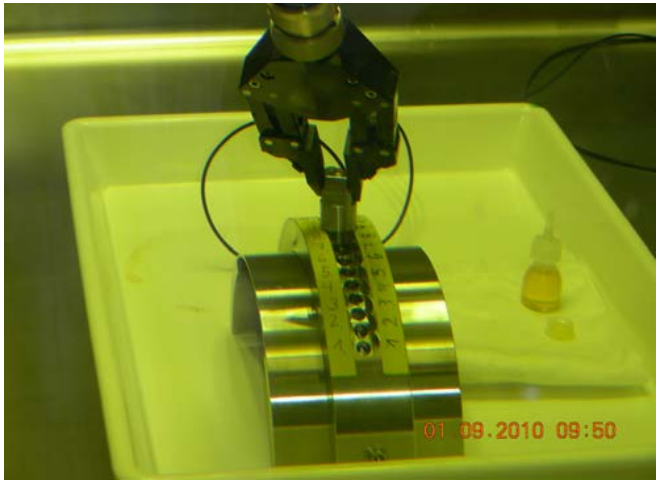
1. Visual inspection of all sample pieces delivered from ZWILAG
2. Gamma mapping of the tip of the AlMg3 safety hull
3. Thickness measurements of the beam entrance window
4. LBE sample taking
5. Melting out the LBE from structural materials
6. Raw-Cutting of the PIE structural material samples
7. Cleaning of the samples from LBE (where needed)
8. Fine-Cutting of the PIE structural material samples

All steps need to be tested with representative non-active materials

Ultrasonic measurement of BEW

UPG-07CW



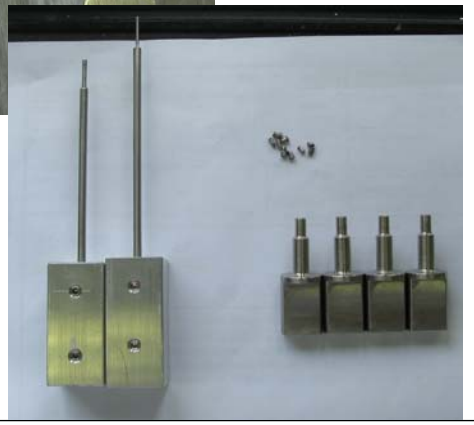


- Thickness measurements by Ultrasonic profiling of the beam entrance window will be performed. These measurements will be directly compared to pre-operation measurements of the same calotte
  - aimimg to gain information on erosion and/or corrosion issues at the beam entrance window.
- A mock-up (see picture) has been tested in the HL and will now, with minor adjustments, be fabricated in the workshop of PSI.

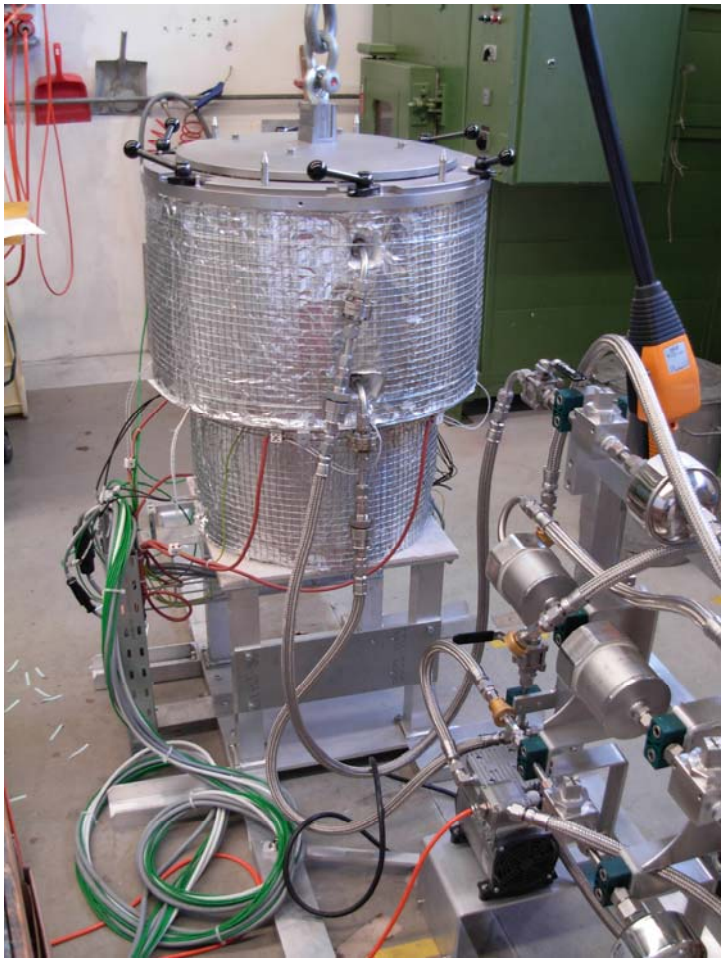
PIE sample extraction – LBE sample taking

- **A special drilling device for the LBE sample taking** has been designed (50 samples to be taken), manufactured, and tested in the HL.
- The tests showed that the devices for the LBE sample taking works reliably
- …even in the close vicinity to steel walls

The device is ready for usage.



Segregation of LBE and structural materials



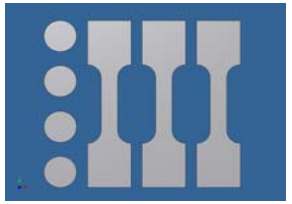
- **To melt out the LBE from the structural materials, a special oven** has been designed
- **The pieces to be smelted are placed in the upper part**
- **The lower part of the oven serves as a collector of the LBE**
- The oven was tested for proper functioning
- **Test to melt LBE (dummy-)samples are under way**

Cutting tests of the structural material

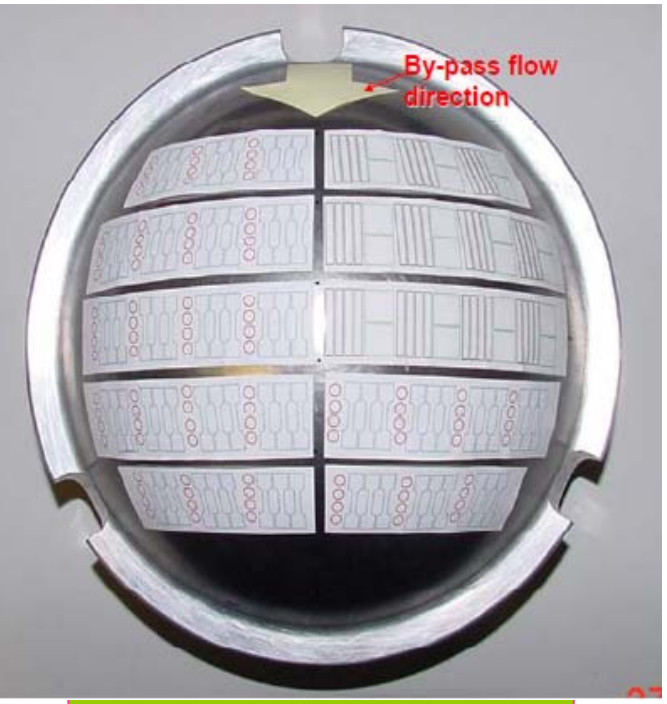
- 1:1 mock-ups of all sample types have been manufactured with original materials and dimensions.
- Groups of samples will first be ‘raw-cut’ using a diamond disk
- ..and ‘fine-cut’ by diamond blade saw for samples with LBE (Type 1)
- ..or wire-cut with an EDM machine for tensile and TEM samples *(not allowing LBE contamination)*

Type 1

Type 2

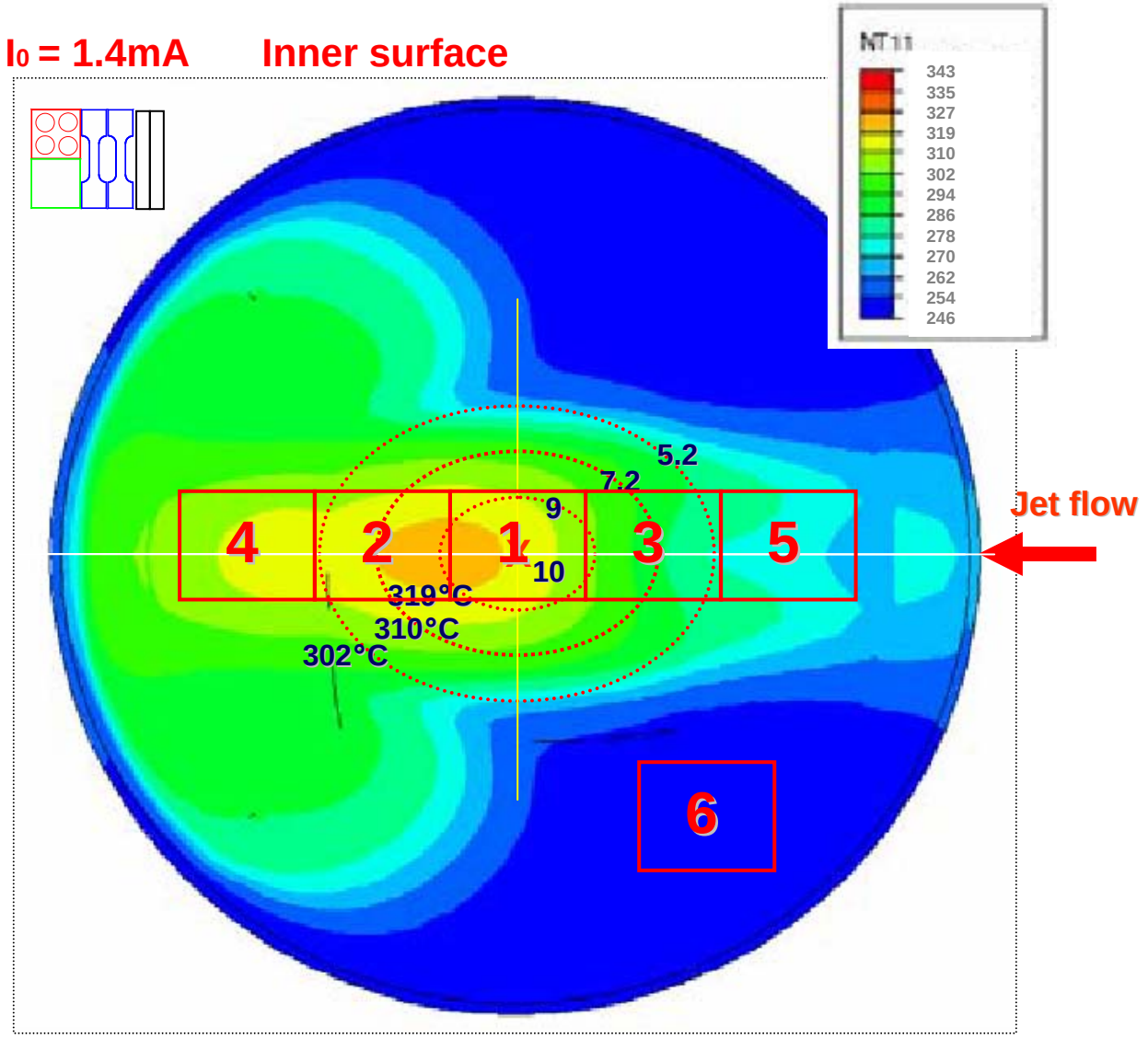


Cutting plan for the beam entrance window (Yong Dai)



6 conditions (or more):

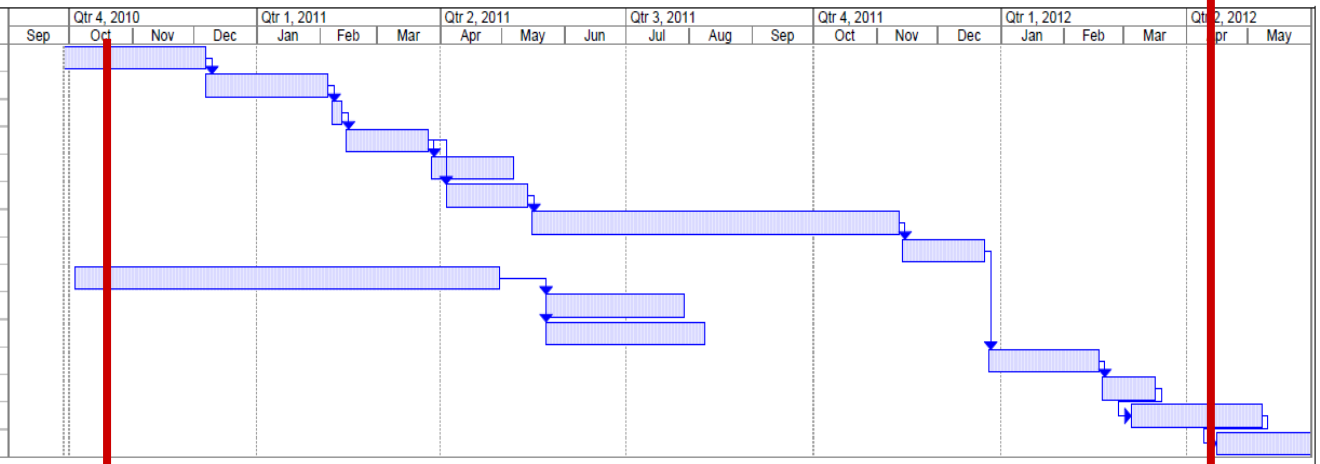
1: highest dpa & T
2: high T, medium dpa
3: medium dpa & T
4: low dpa, medium T
5: low dpa & T, high flow
6: low dpa, T & flow



Schedule

April 2012

ID	Task Name
1	Test of oven (inactive)
2	Implementation of oven in Hot cell
3	Ship target sample pieces from ZWILAG to HL
4	Unpacking, Visual inspection, Gamma scan, US profile of BEW
5	LBE sample taking
6	Preparation of Hot cell for melting
7	Melting out of LBE
8	Cleaning of the hot cell
9	Preparation of sample cutting
10	Cold test of cutting
11	Programming of cutting machine
12	Cutting of samples
13	Sample cleaning
14	Fine cutting of samples
15	PIE samples ready for transport



today

PIE samples ready for transport

Many thanks to the MEGAPIE partner institutes and to the numerous people involved in the project