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PSI

Wir schaffen Wissen – heute für morgen

MEGAPIE – unexpected behaviors and findings during operation and dismantling

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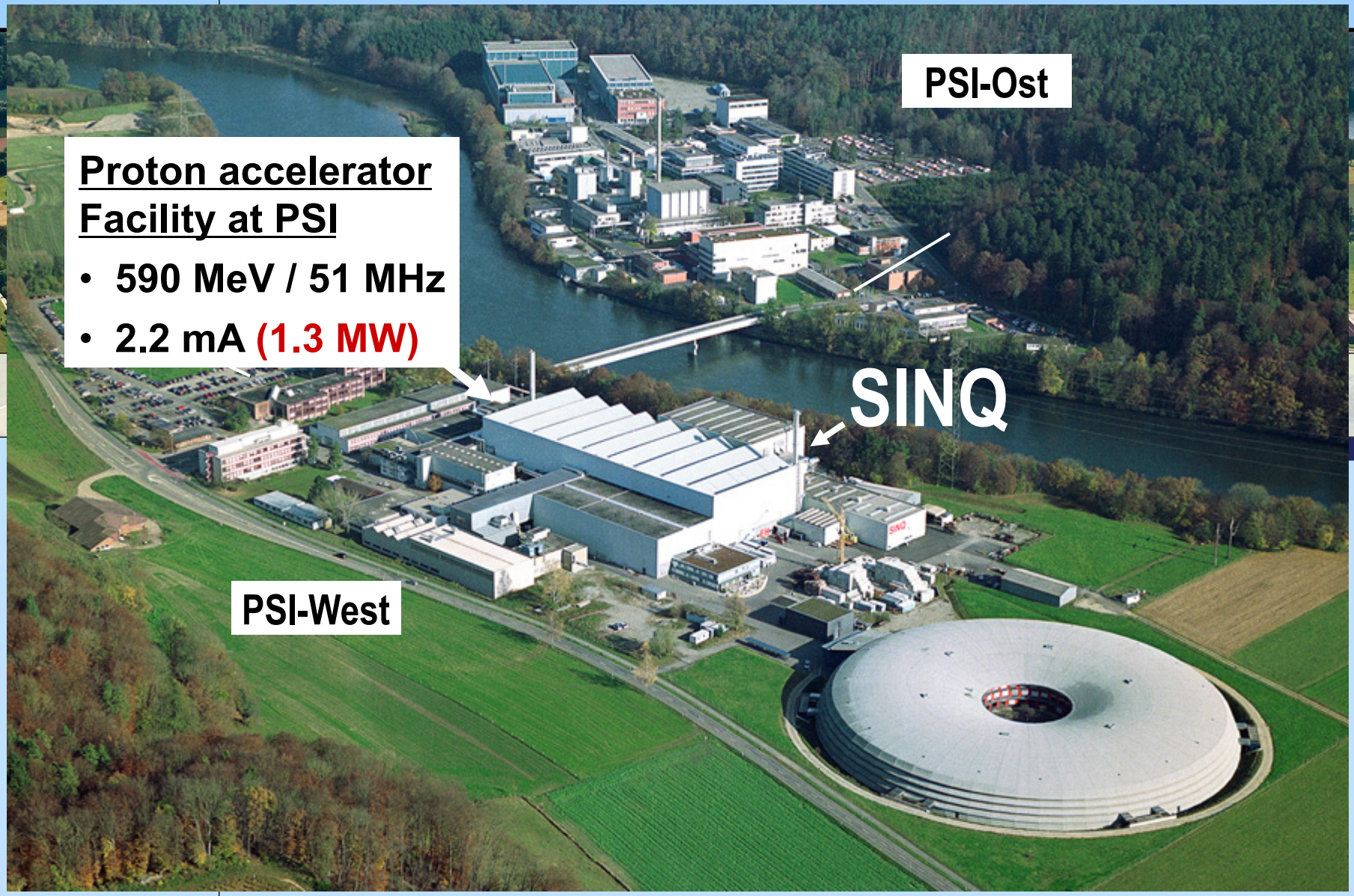
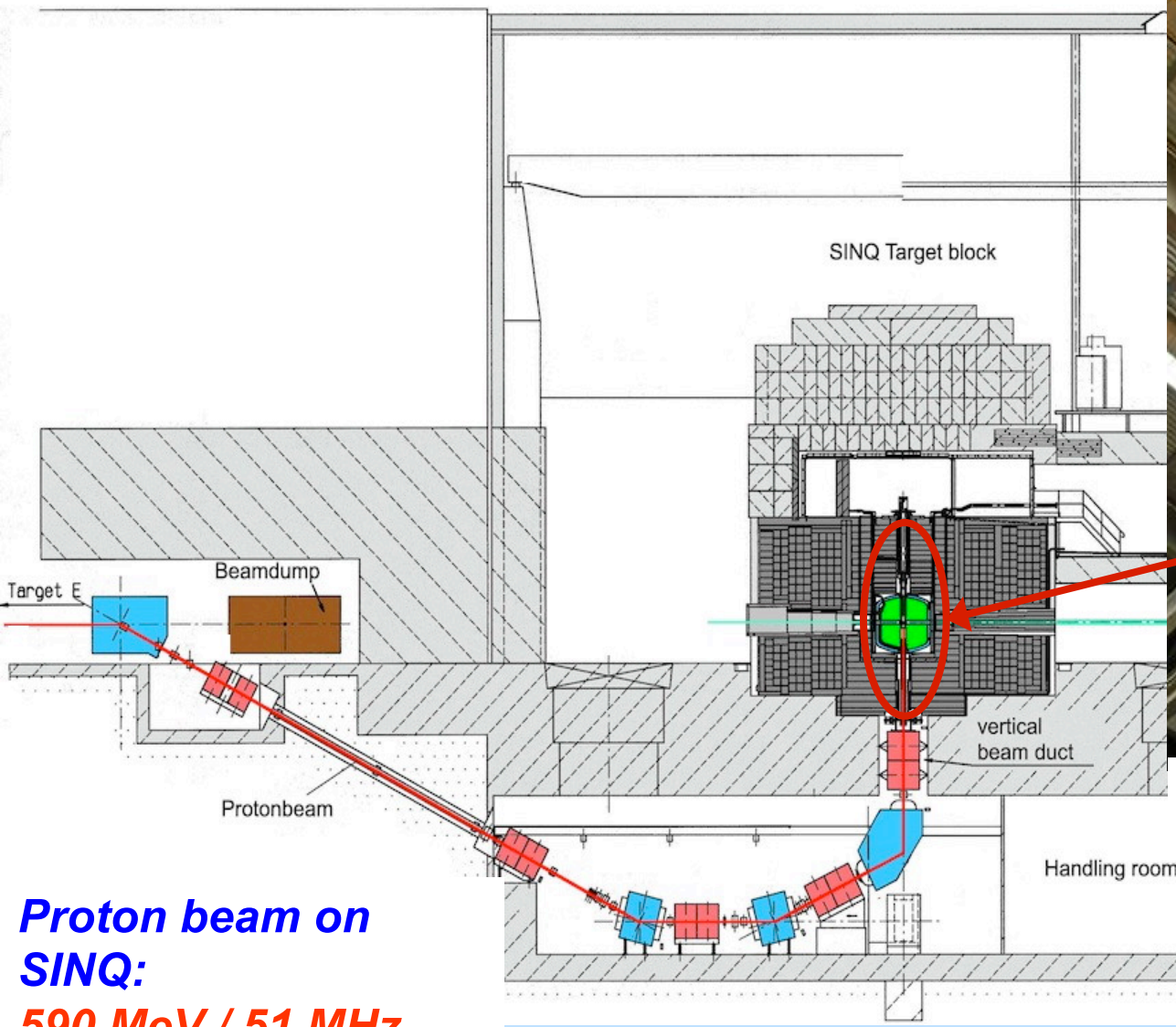




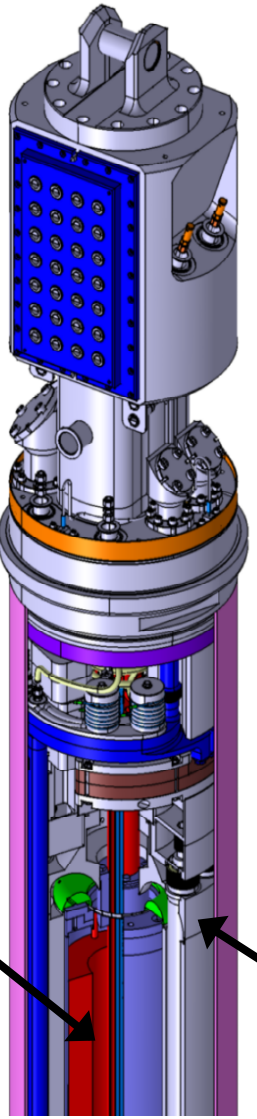
MEGAPIE target

Proton beam on SINQ:
590 MeV / 51 MHz
p-Current: 1,5 mA
Power: 0.9 MW

SINQ Target Station

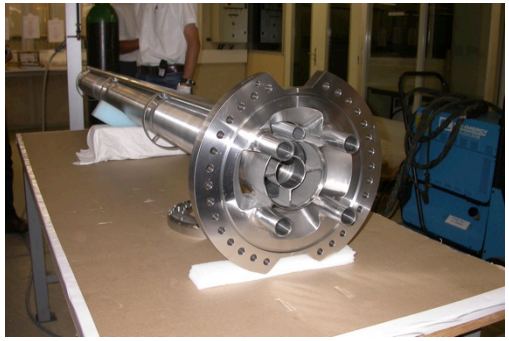
MEGAPIE target features

target head

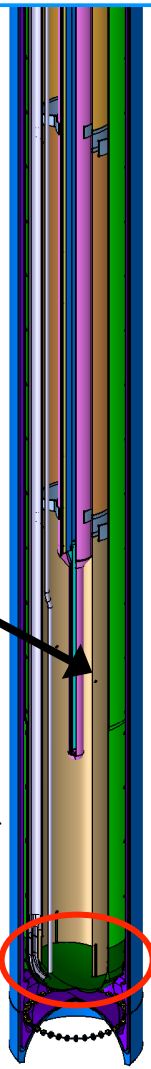


electro-magnetic pumps

heat exchanger

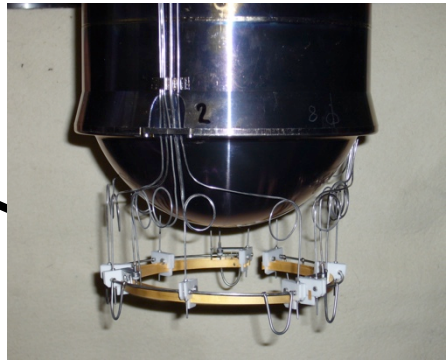


central flow guide tube



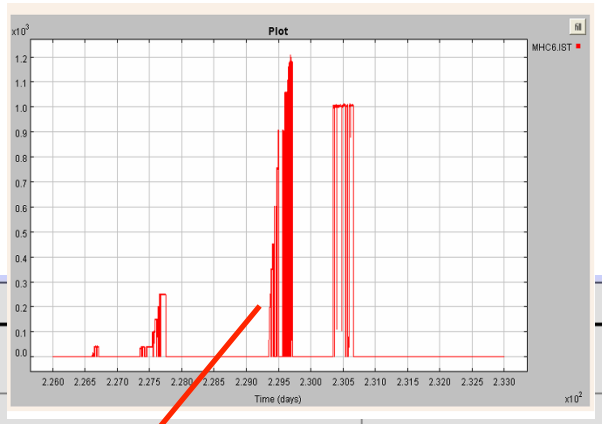
safety shroud

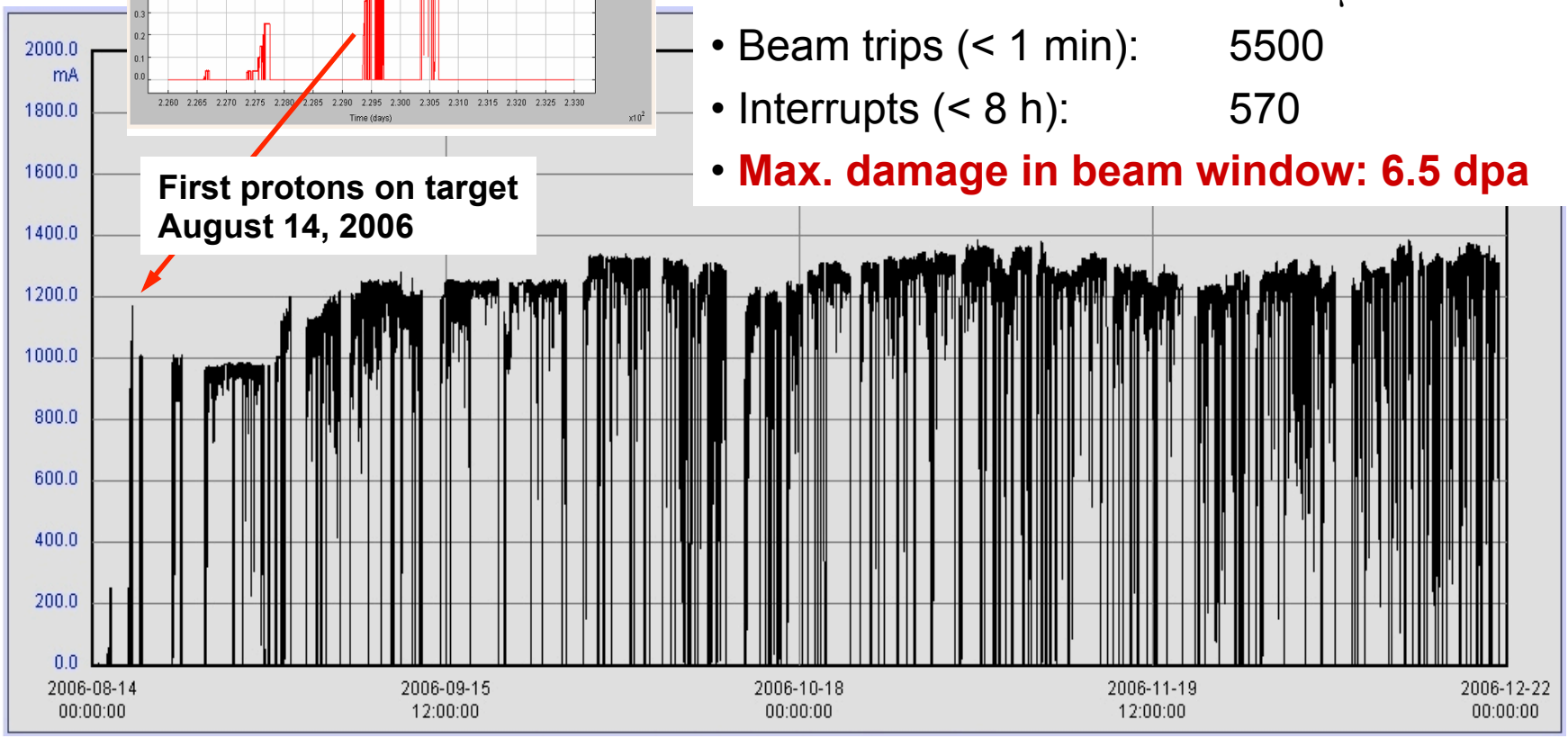
beam window with leak detector



lower target assembly

MEGAPIE Target Operation: full history





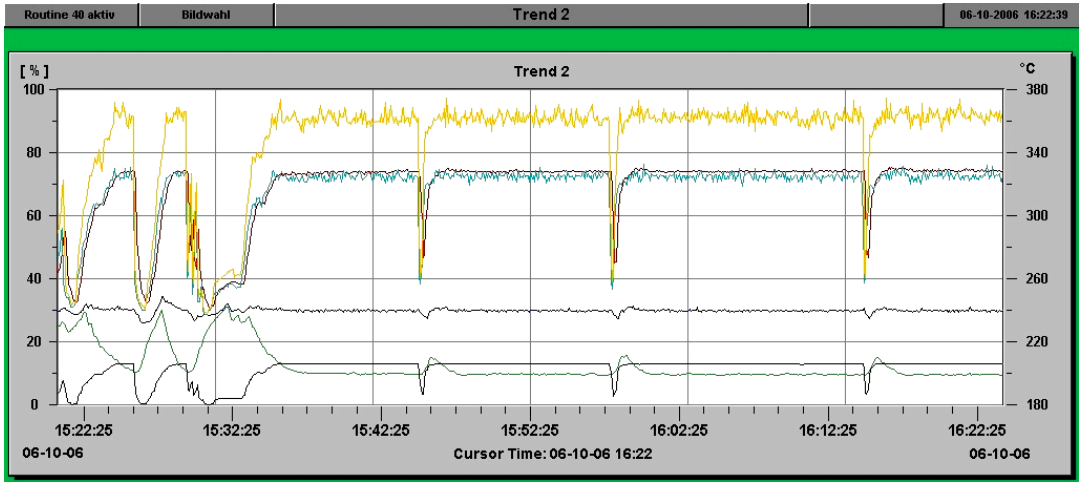
First protons on target
August 14, 2006

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**

Operation

- Operation „smoothly“: System behaviour, e.g. temperatures and –transients as expected
- EMPs without indication for degradation
- Measured neutron flux increase of roughly ~80 % to Target 6 (operated before MEGAPIE)



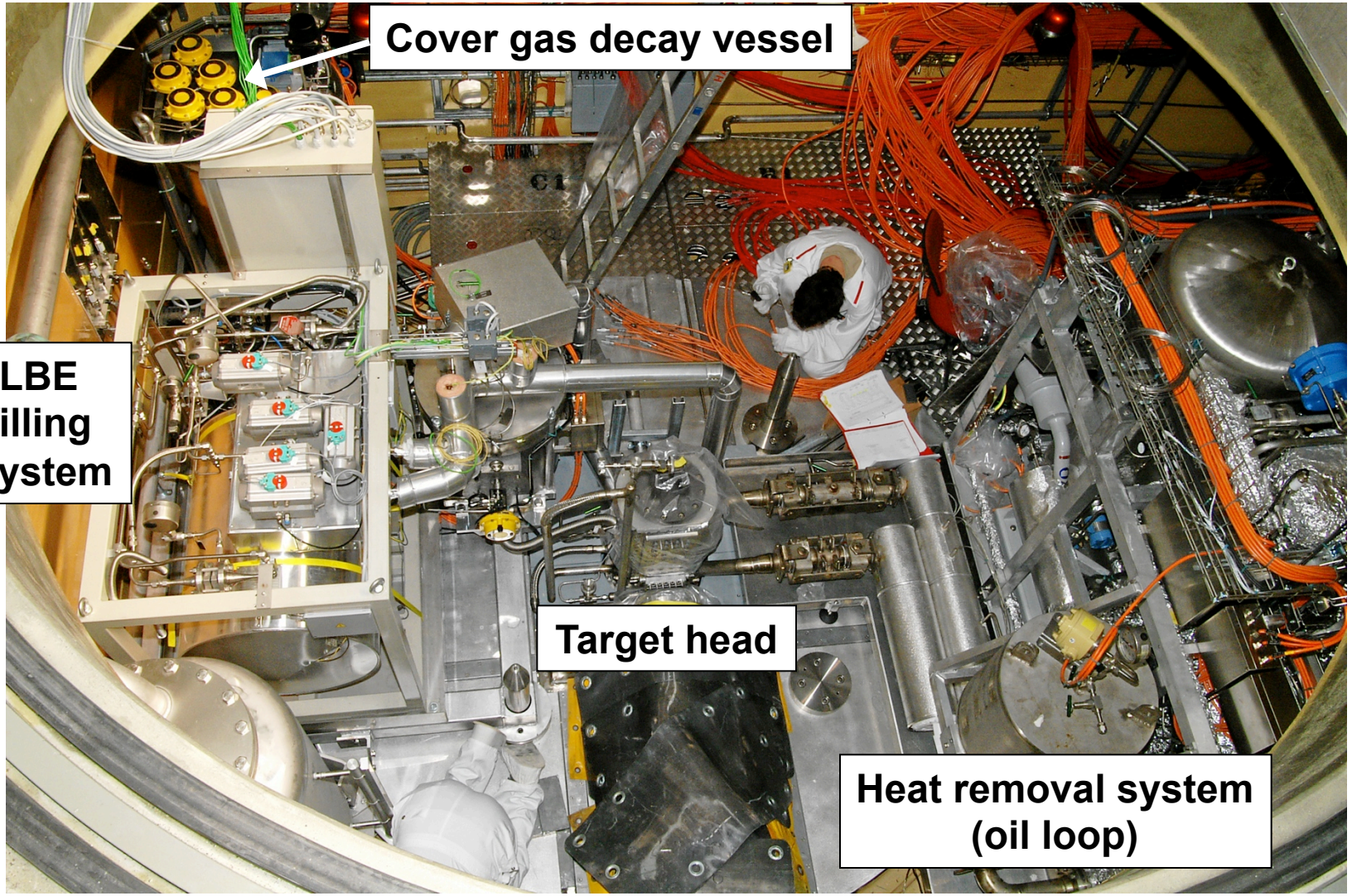
	SINQ 2005	Err. (%)	MEGAPIE 2006	Err. (%)	ratio
ICON	3.8E+8	~5	6.89E+8	~5	1.81
NEUTRA	2.6E+7	~5	4.80E+7	~5	1.85
EIGER	6.5E+8	~5	1.04E+9	~5	1.61
NAA	**5.8E+12**	~5	1.04E+13	~5	1.79

Ancillary systems:

lessons learnt

System integration in SINQ (Jan.– July 2006)

Main ancillary systems in Target Head Enclosure Chamber (TKE)



Lessons learnt: CGS and IGS

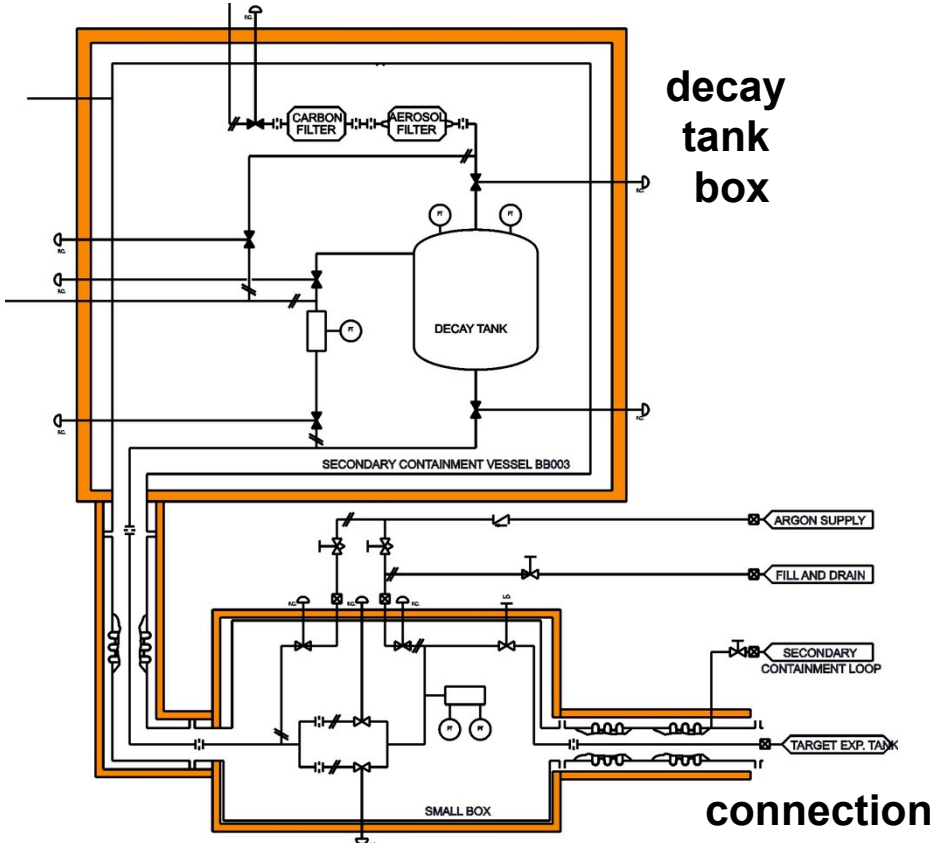
Cover gas and insulating gas systems: CGS & IGS

handling of radioactive gases: stringent requirements

- leak tightness
- second containment
- shielding
- operation procedures

in practice: complex and expensive

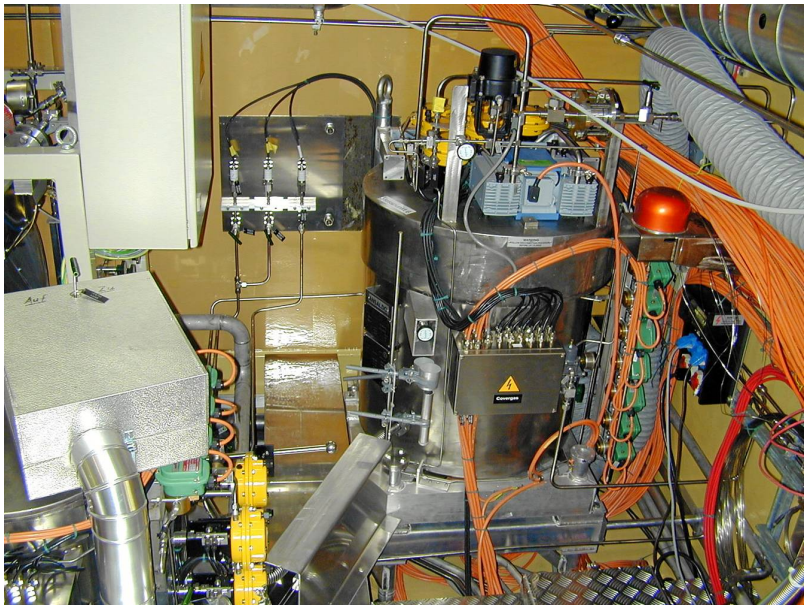
CGS schematic layout



decay tank box

small box

connection to target



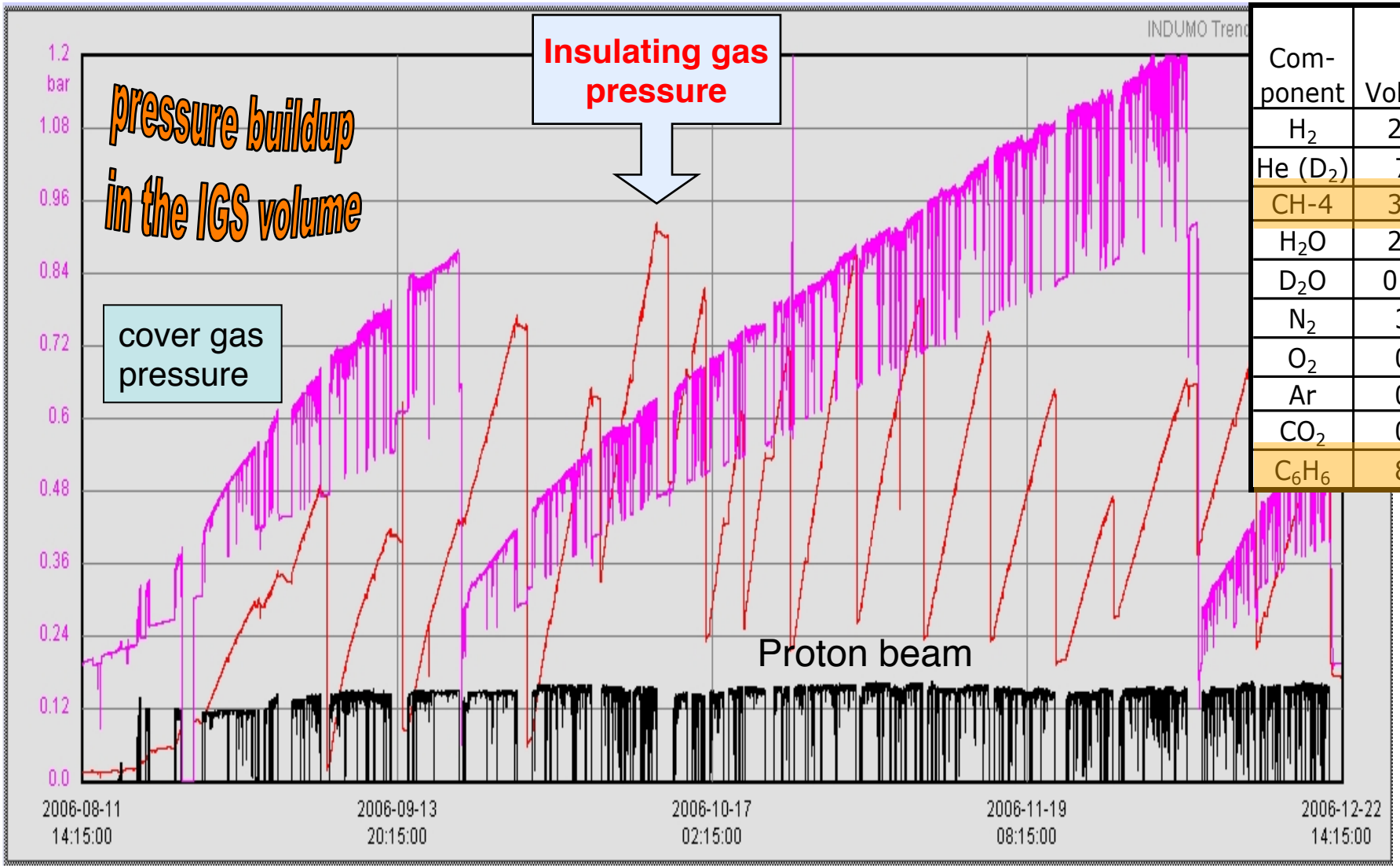
decay tank box in TKE

Taking gas samples in the TKE

Cover Gas decay and sampling tank

‚small box‘

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

IGS: insulation gas volume

Problem:

continuous pressure increase by ~5 mbar/h

..slightly *contaminated* by (radioactive) covergas

- *decay period* and *gas sampling* required before venting

Remedial actions:

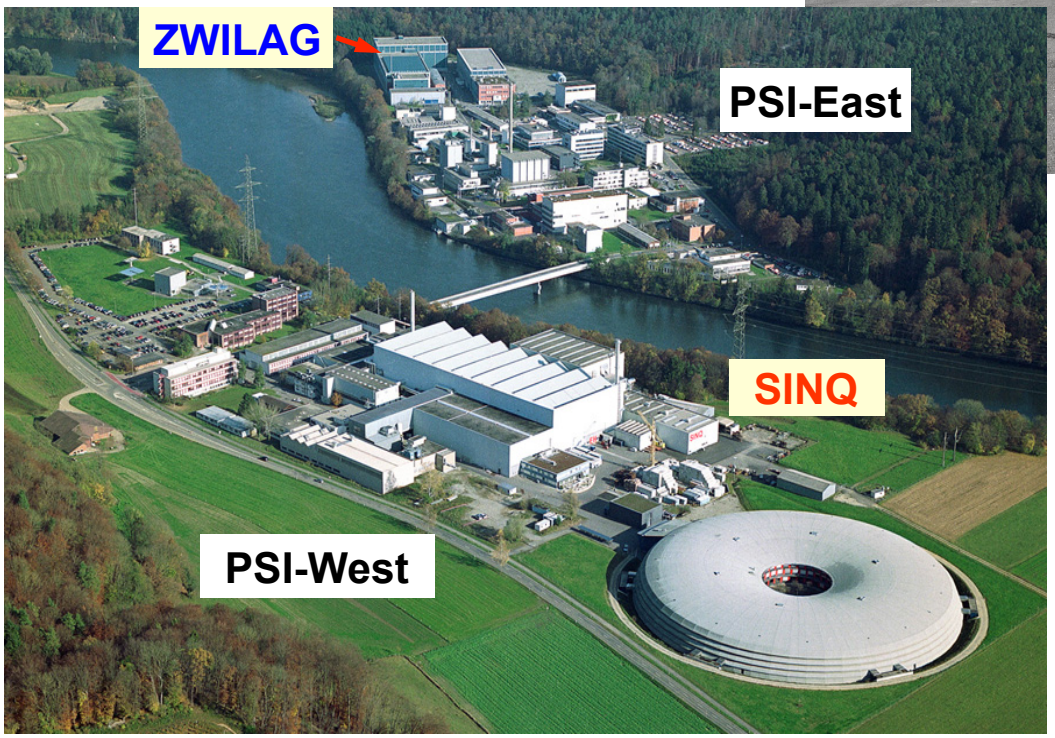
installation of 180 l decay vessels in cooling plant

regular (weekly) venting into the exaust system

Target dismantling, cutting and packing

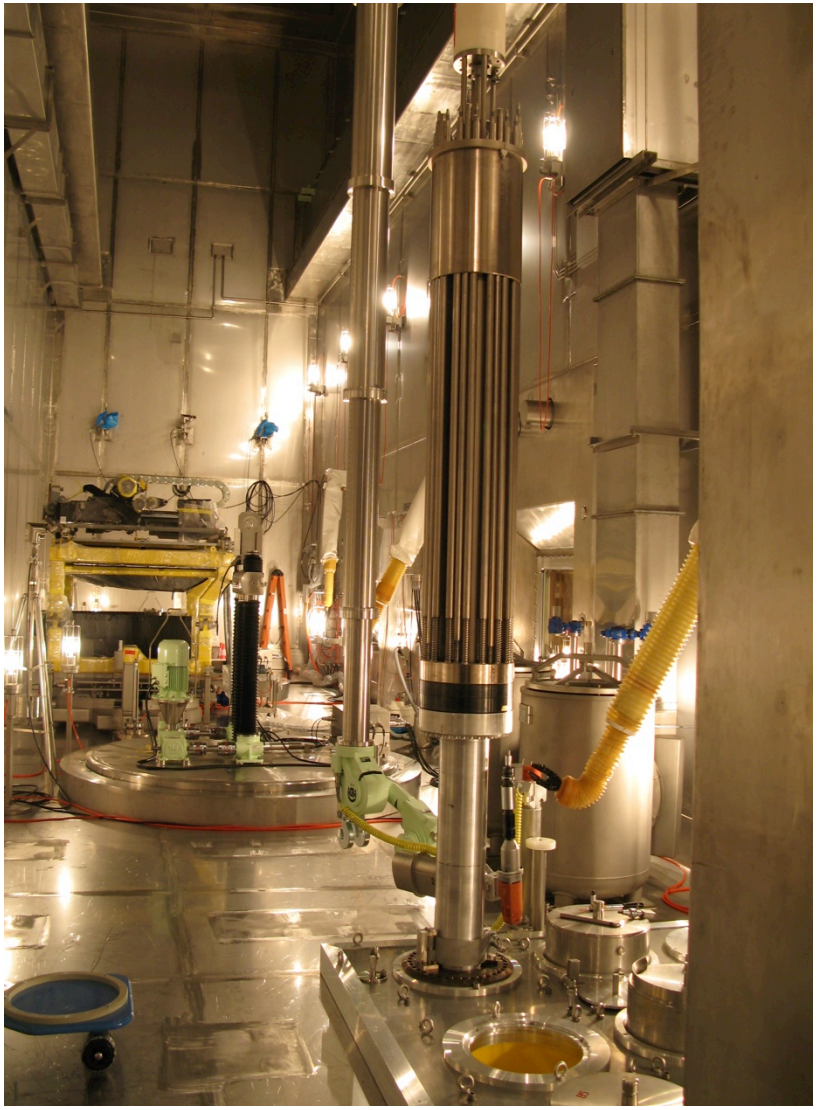
Target transfer from PSI to ZWILAG

(July 6th, 2009)

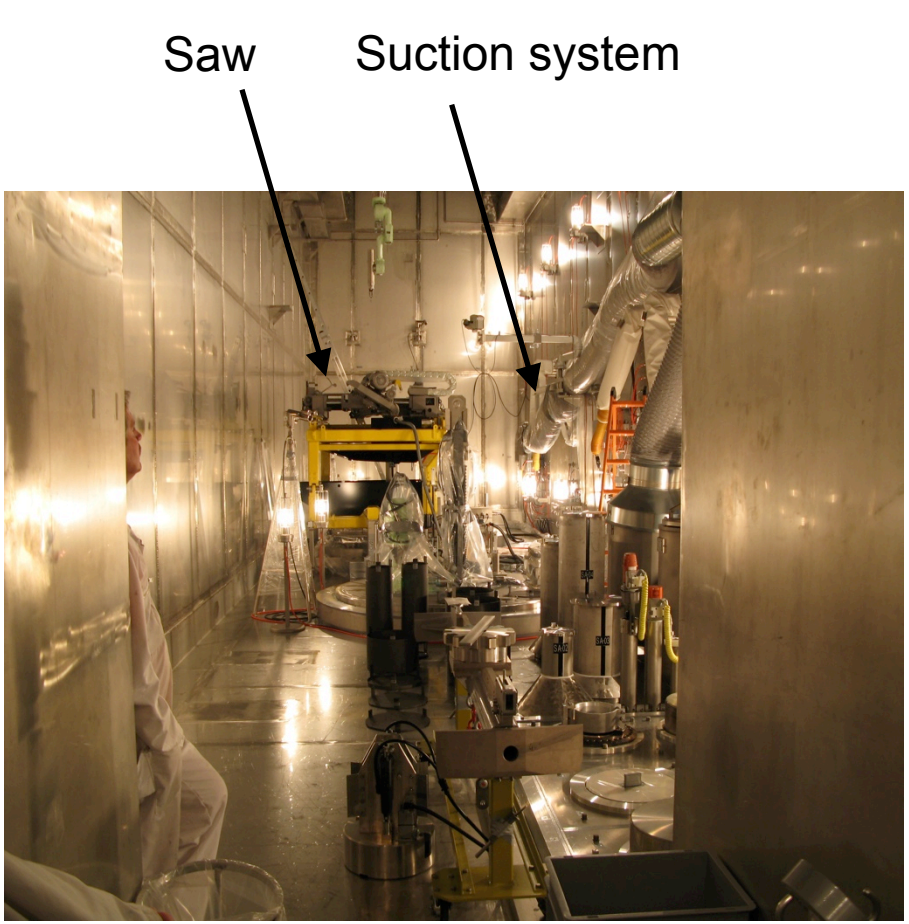


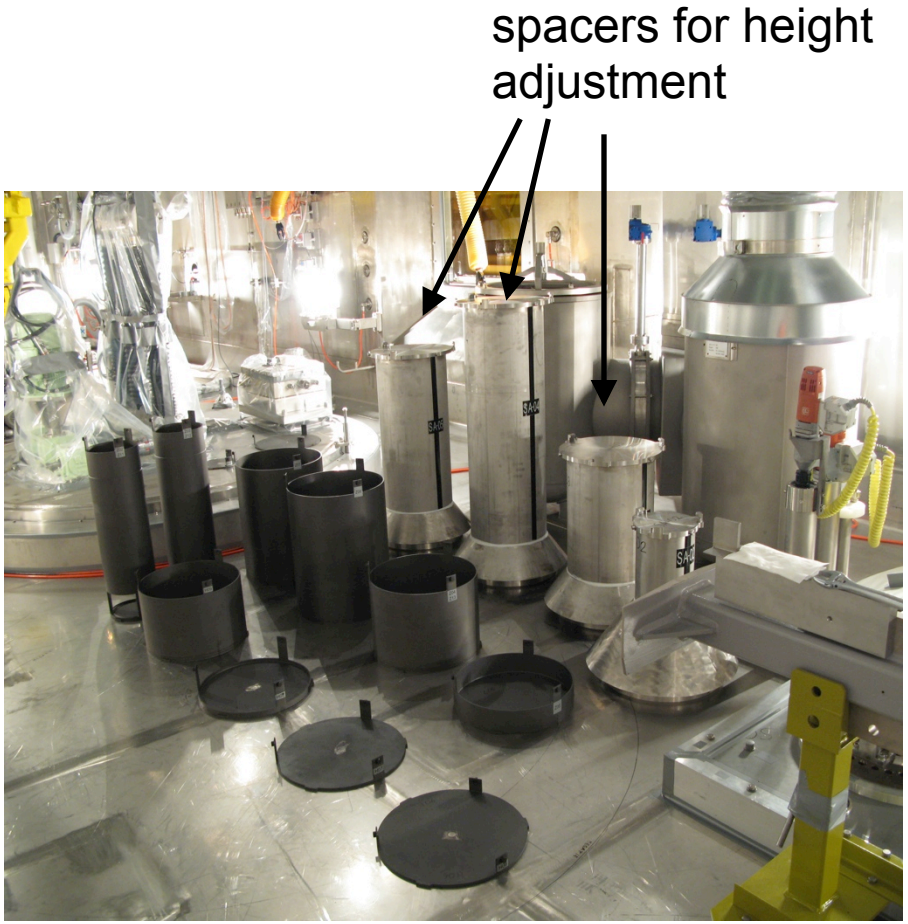
Hotcell of ZWILAG

‚Cold tests' for target dismantling



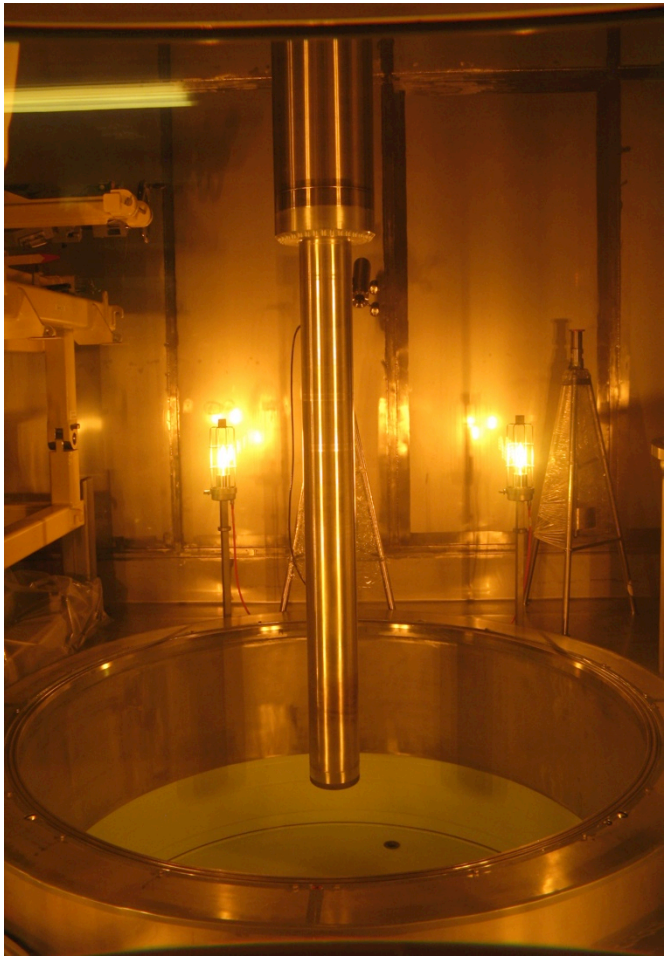
Hot cell of ZWILAG, prepared for receiving MEGAPIE





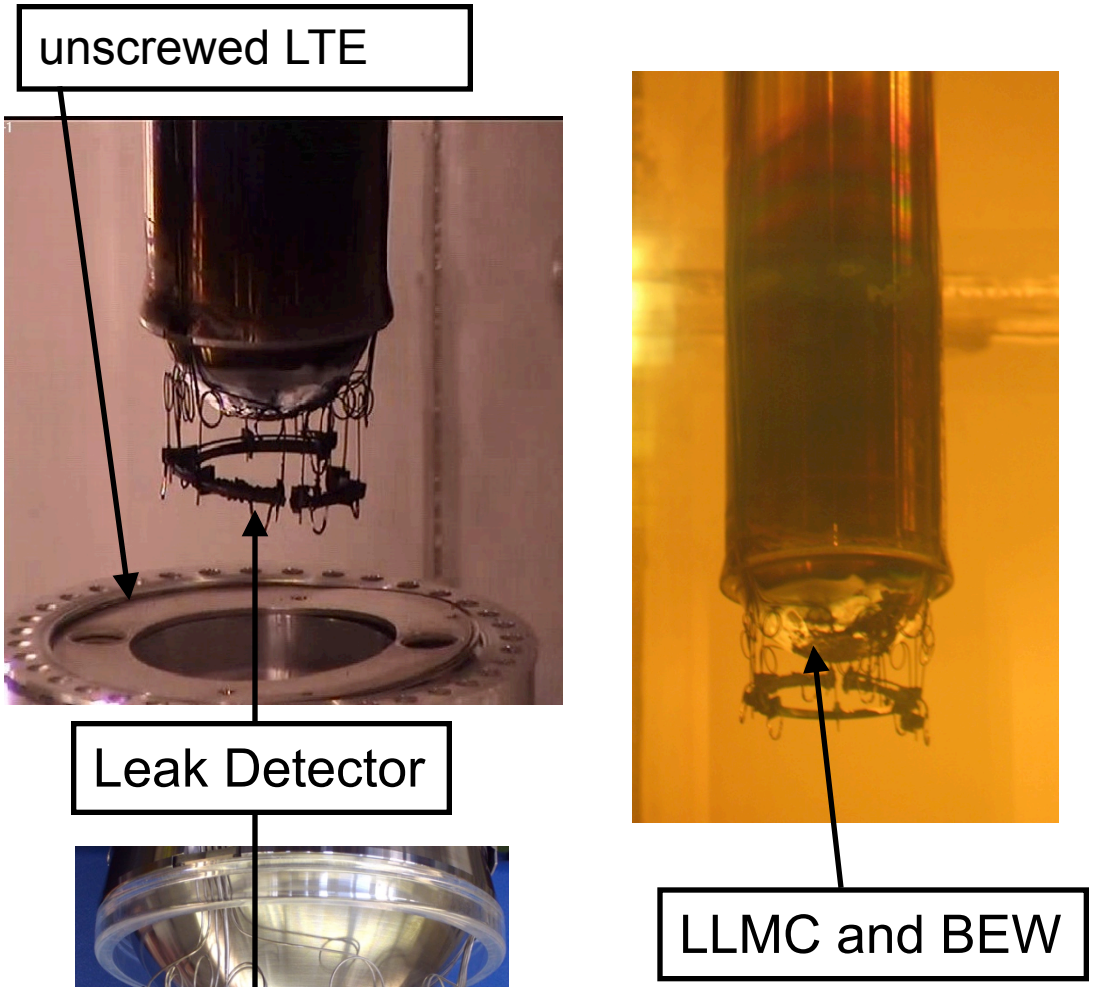
The hot cell of ZWILAG had been fully equipped with the saw, a special suction system and all tools needed for the dismantling

Lifting the target into the Hot Cell (HC)

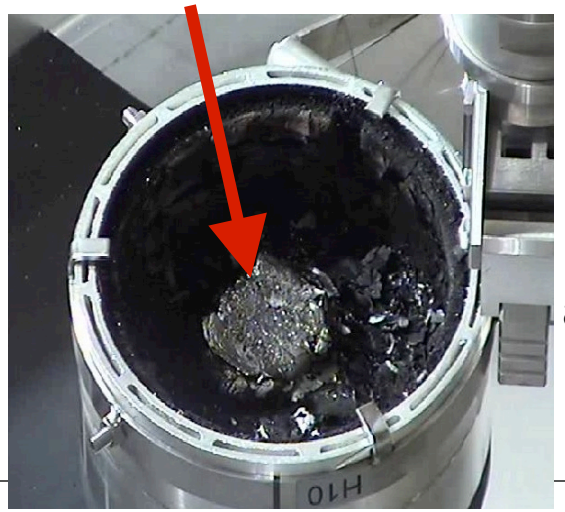


- TC1 docked to HC from below
- The MEGAPIE target was lifted by the crane of the hot cell
- First visual inspection by rotating the target: No special findings; slight stain in high neutron flux region.
- Next step: The Lower Target Enclosure (Aluminum Safety shroud, LTE) was unscrewed.

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 flakes inside the safety hull calotte, and a metallic shining piece of material



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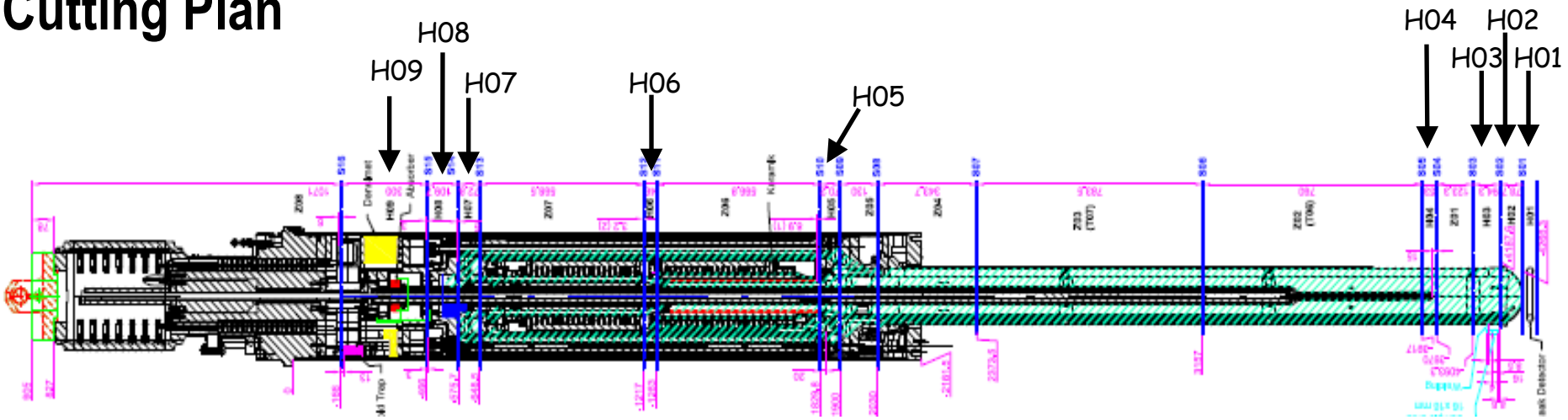
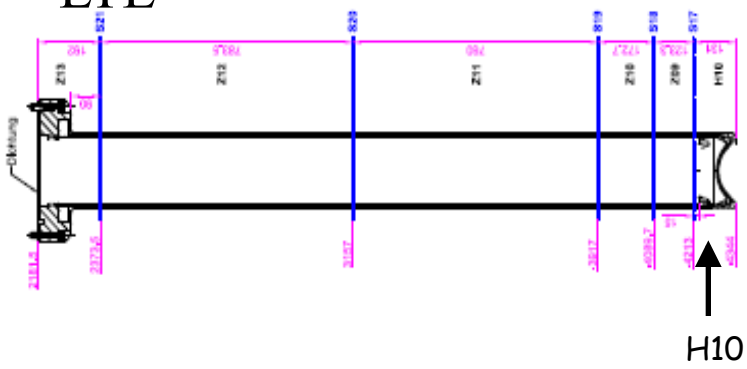
Cutting Plan

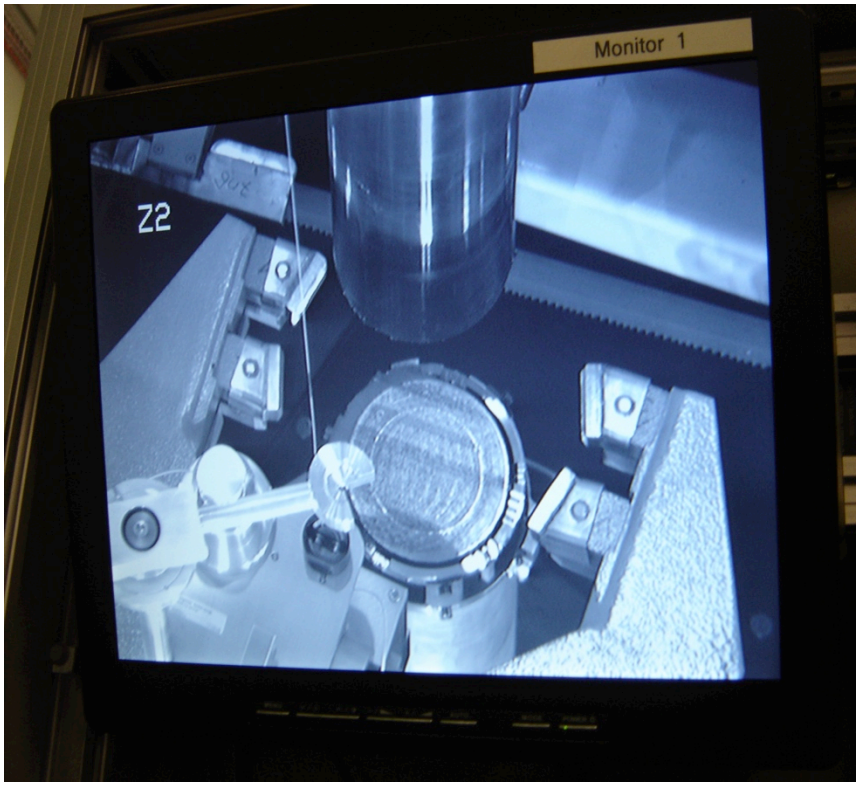


LTE



- 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

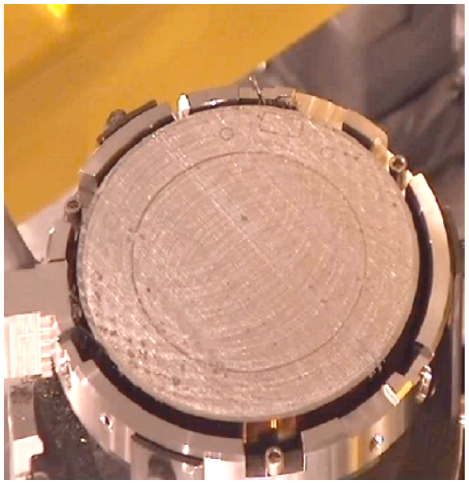


The first cut removed the Beam Entrance Window

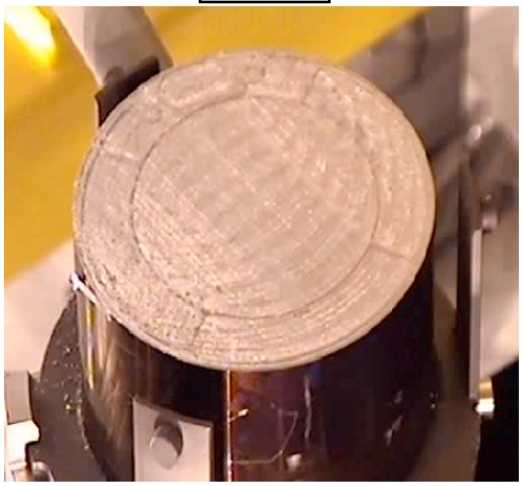
Samples - cutting the lower liquid metal container

- 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.

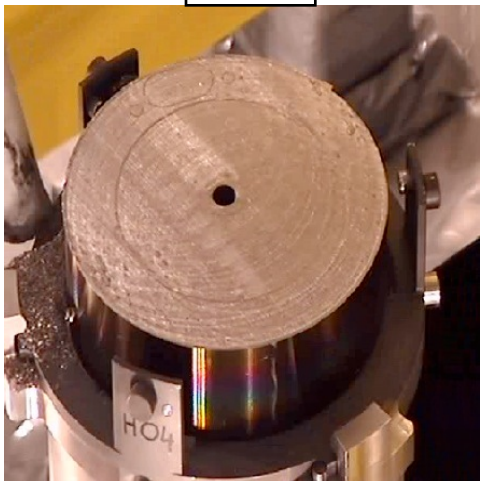
H02 – The Beam Entrance Window



H03

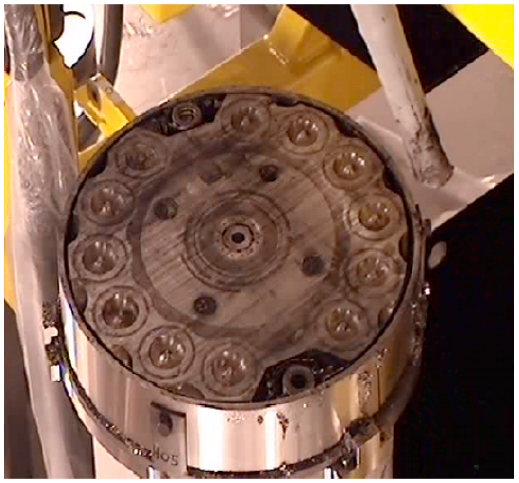


H04



Samples – Cutting the upper part

H05

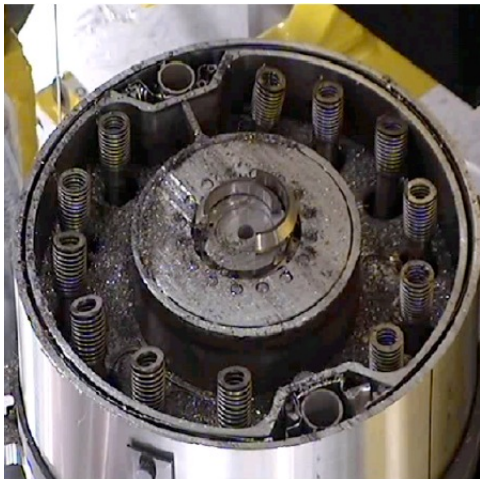


H06

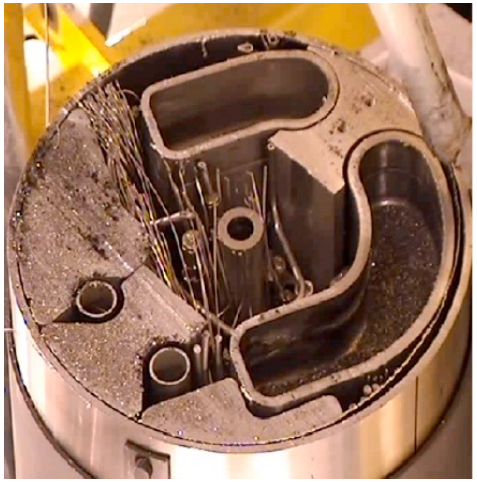
H07

- 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



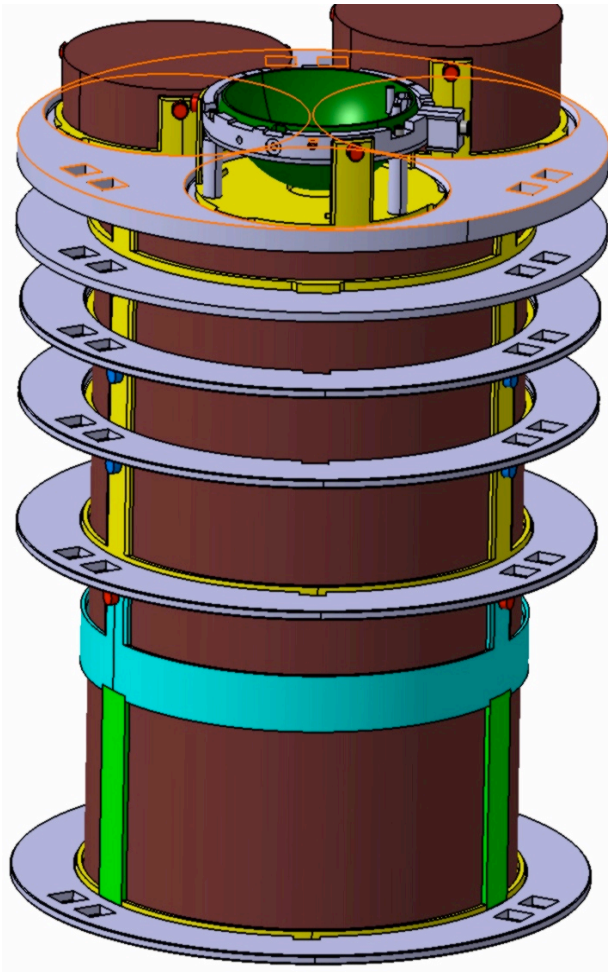
Hotcell work in ZWILAG

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 was temporarily stored in ZWILAG, until the transfer to the Hot Laboratory of PSI could be done
- **transfer to PSI done: April 5, 2011**

B10



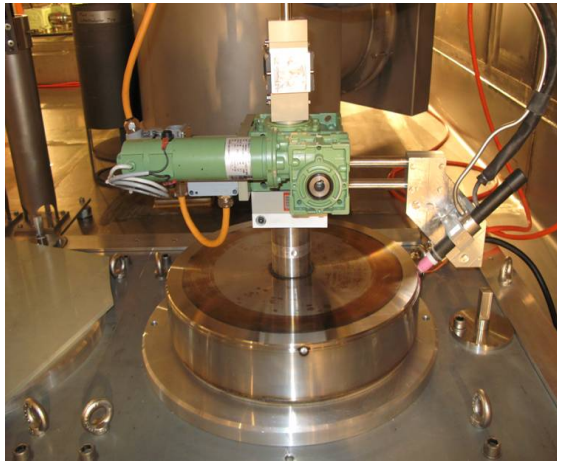
TC3

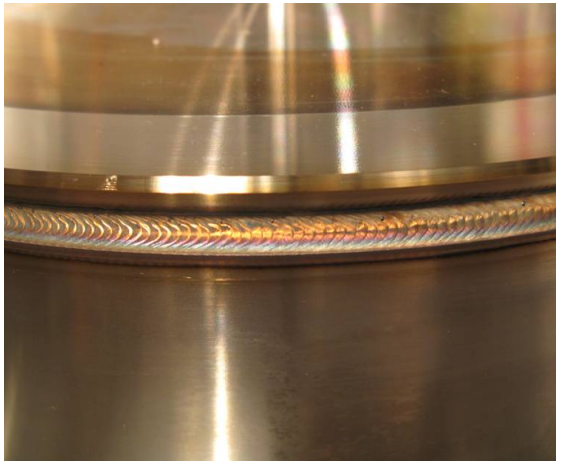
Waste conditioning

- 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 activities for sample extraction and PIE

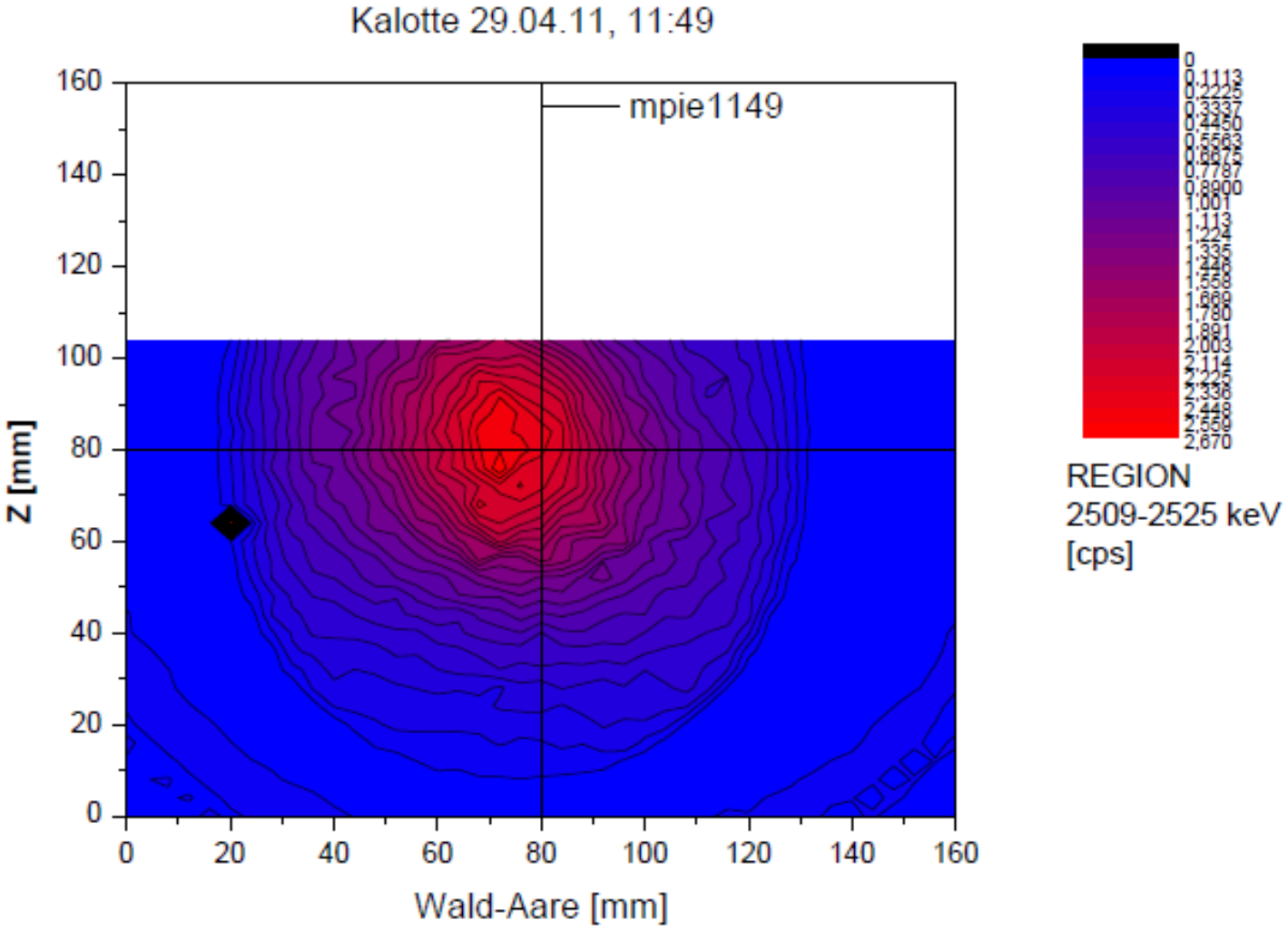
Preparation of PIE sample extraction

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

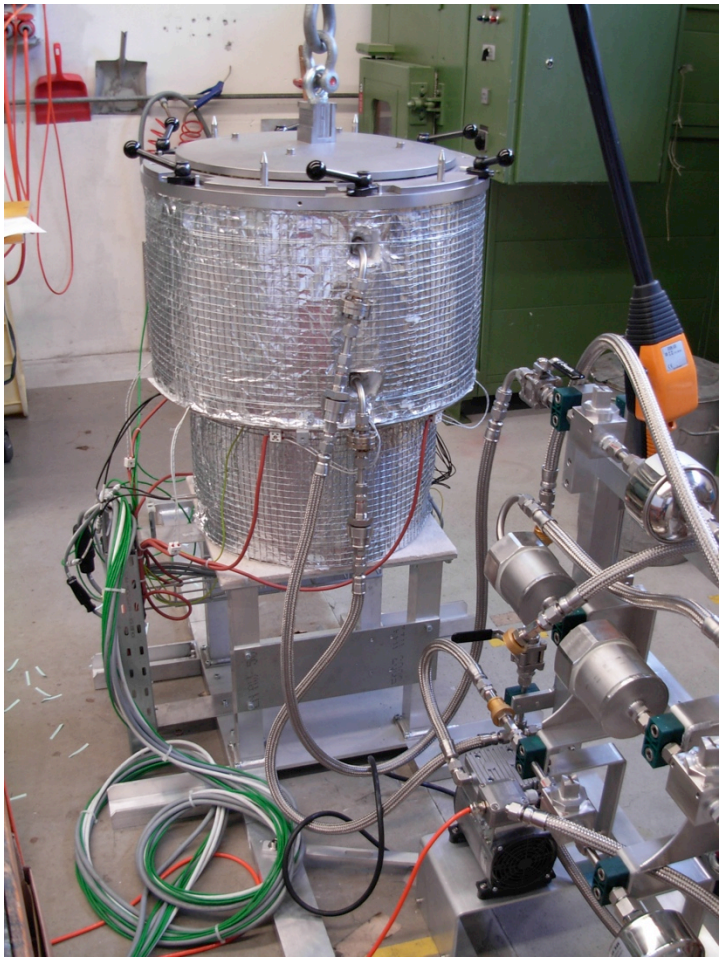
1. Visual inspection of all sample pieces delivered from ZWILAG
2. Gamma mapping of the tip of the AlMg3 safety shroud
3. Thickness measurements of the beam entrance window
4. LBE sample taking
5. Melting out the LBE from structural materials
6. Raw-Cutting of the PIE structural material samples
7. Cleaning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

Gamma mapping of the tip of the AlMg3 safety shroud

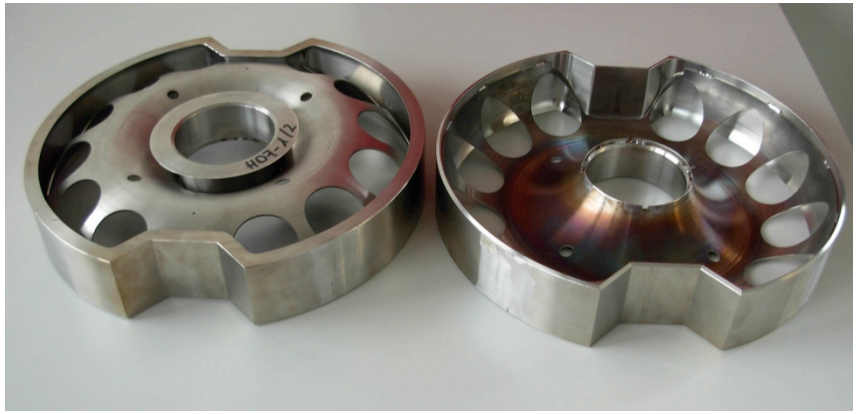


Segregation of LBE and structural materials



- **To melt out the LBE from the structural materials, a special oven** has been designed
- **The pieces to be melted 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 were successfully done**

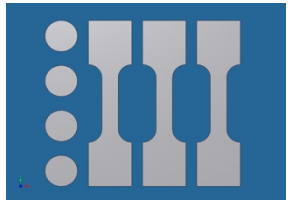
Cutting tests of the structural material



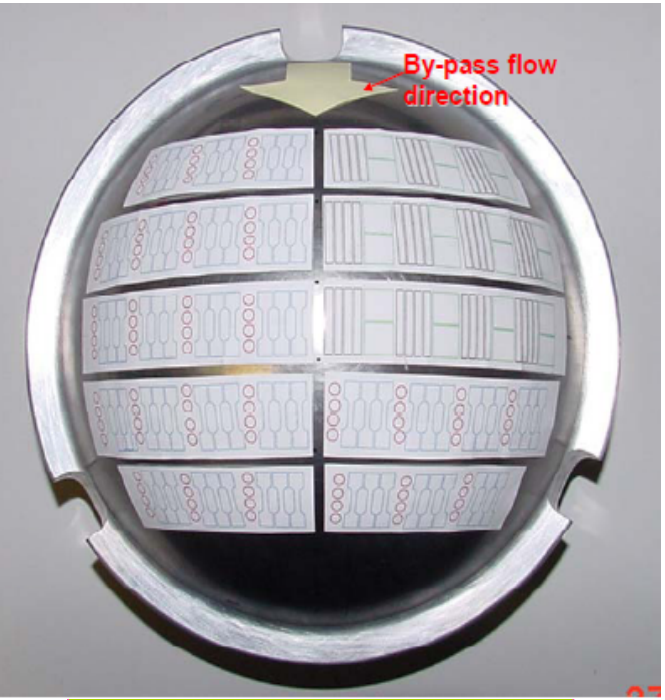
- 1:1 mock-ups of all sample types have been manufactured with original materials and dimensions.
- Groups of samples will first be 'raw-cut' using a diamond disk
- ..and 'fine-cut' by diamond blade saw for samples with LBE (Type 1)
- ..or wire-cut with an EDM machine for tensile and TEM samples *(not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

Type 1

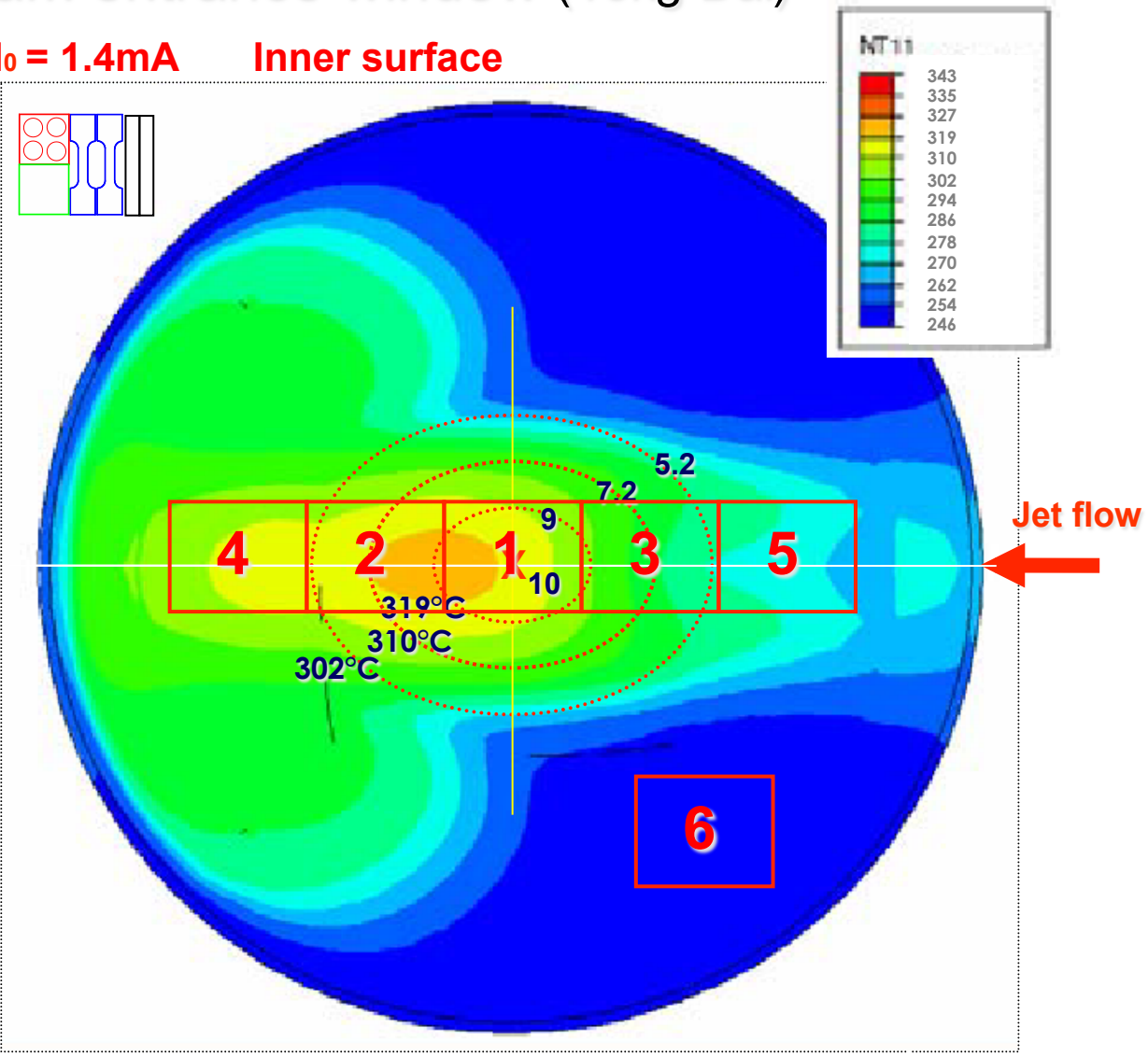
Type 2



Cutting plan for the beam entrance window (Yong Dai)



I_0 = 1.4mA Inner surface



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

Summary

MEGAPIE - unexpected behaviors and findings…:

- **The target survived** 4 months operation at full beam power
- **Neutron yield** higher than predicted
- **Thermo-hydraulic** behavior as predicted
- **EMPs** worked reliably without degradation
- ‚none-too-pleasant' **leaking of hydrocarbons (oil)** into the IGS
- **Small leaks** of redioactive volatiles into the second containment
- **Dismantling and cutting** the target without (major) spread of contamination (NO Po-210 !!)
- **Preparation of sample extraction** concluded
- **PIE has started**

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