PAUL SCHERRER INSTITUT

PSI

Wir schaffen Wissen – heute für morgen

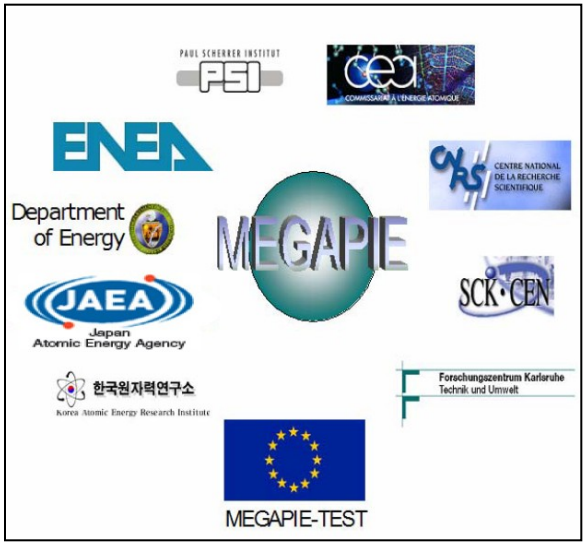
Paul Scherrer Institut

Michael Wohlmuther for the MEGAPIE project

MEGAPIE – The (almost) whole life of a Liquid Metal

CERN, 23rd June 2011

MEGAPIE - MEGAwatt Pilot Experiment



- **Joint international initiative to design, build, license, operate, dismantle and explore a liquid metal LBE*) spallation target for 1 MW beam power.**

*) **LBE: Lead-Bismuth-Eutectic**

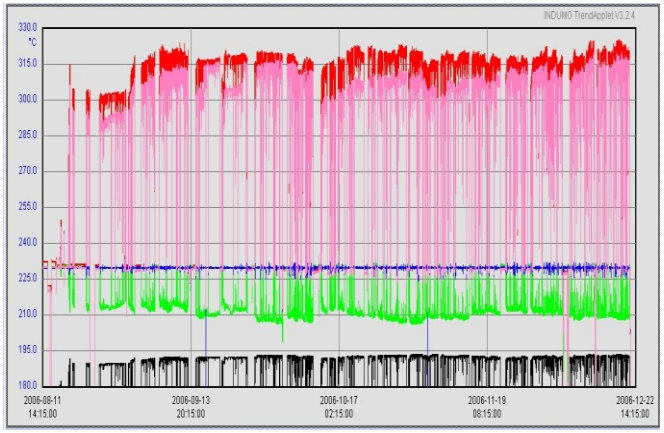
T_m=125°C

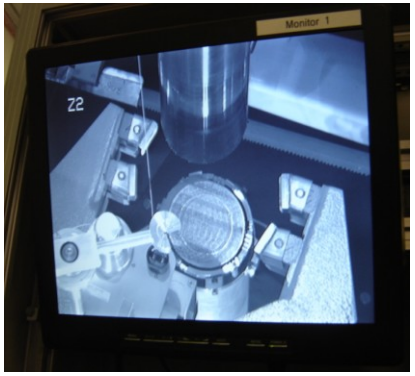
„Accelerator Driven Systems (ADS) and transmutation technologies are becoming important for the sustainable development of nuclear energy all over the world, but have technical challanges spread over a wide range of fields. ***Thus sharing experimental efforts in a systematic way is highly desirable, MEGAPIE being a good precursor for such international collaboration.“****

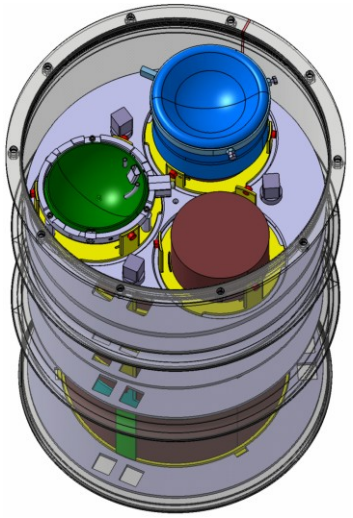
*“Research and Test Facilities Required in Nuclear Science and Technology”, Nuclear Energy Agency (NEA) Report, NEA No. 6293, OECD 2009, ISBN 978-92-64-99070-8

Timeline of MEGAPIE

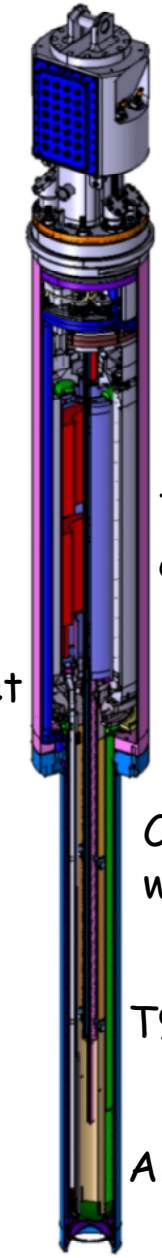
- Design Phase 2001 – 2004
- Construction and Test Phase 2004 – 2006
- Operation Phase August –December 2006
- Preparation of 1st dismantling phase 2006 – 2008
- 1st dismantling Phase in ZWILAG August – December 2009
- Preparation of PIE sample production 2010 – April 2011
- Transfer of Target Sample pieces to Hot Laboratory at PSI 5. April 2011
- PIE Sample Production April 2011 – March/April 2012
- Final disposal of remaining of Target Sample pieces

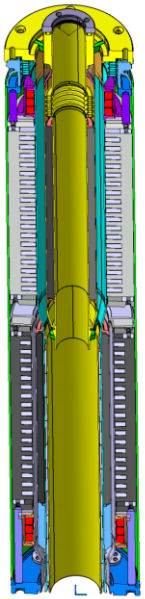


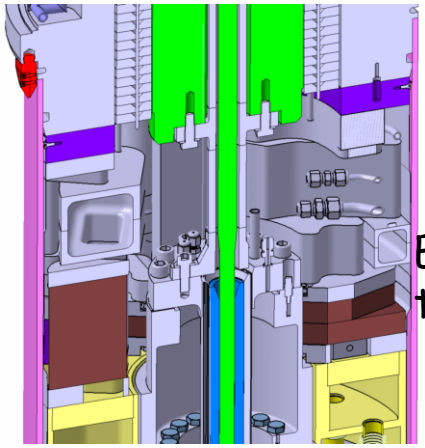


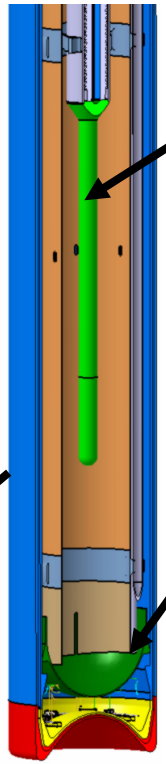


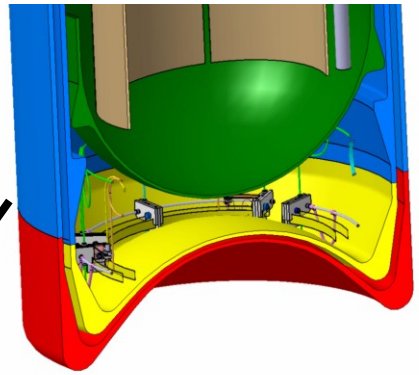
Design and construction





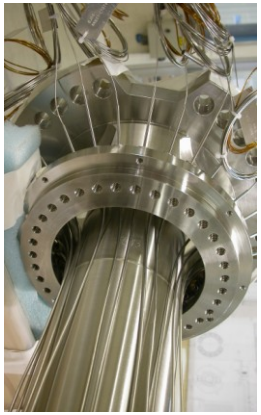




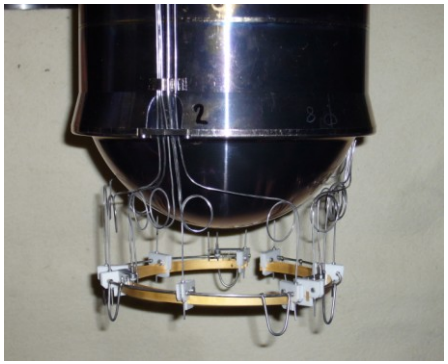


Design and construction

Flow guide tube



Beam entrance window with leak detector

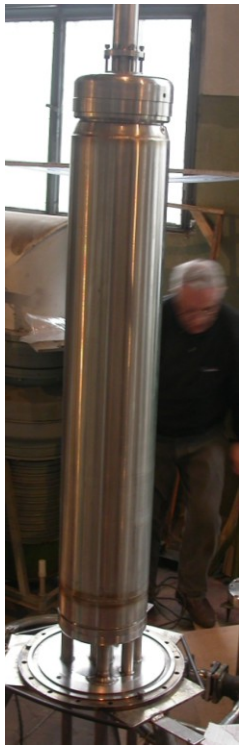


LLMC

Heat exchanger

Absober foils

EMPs



Safety shroud

MEGAPIE Target assembled

CGS Expansion tank

Central rod

The PSI Proton Accelerator Complex

Injector II Cyclotron 72 MeV

isotope production
(I_b <100μA)

Ring Cyclotron 590 MeV

2.2 mA /1.3 MW

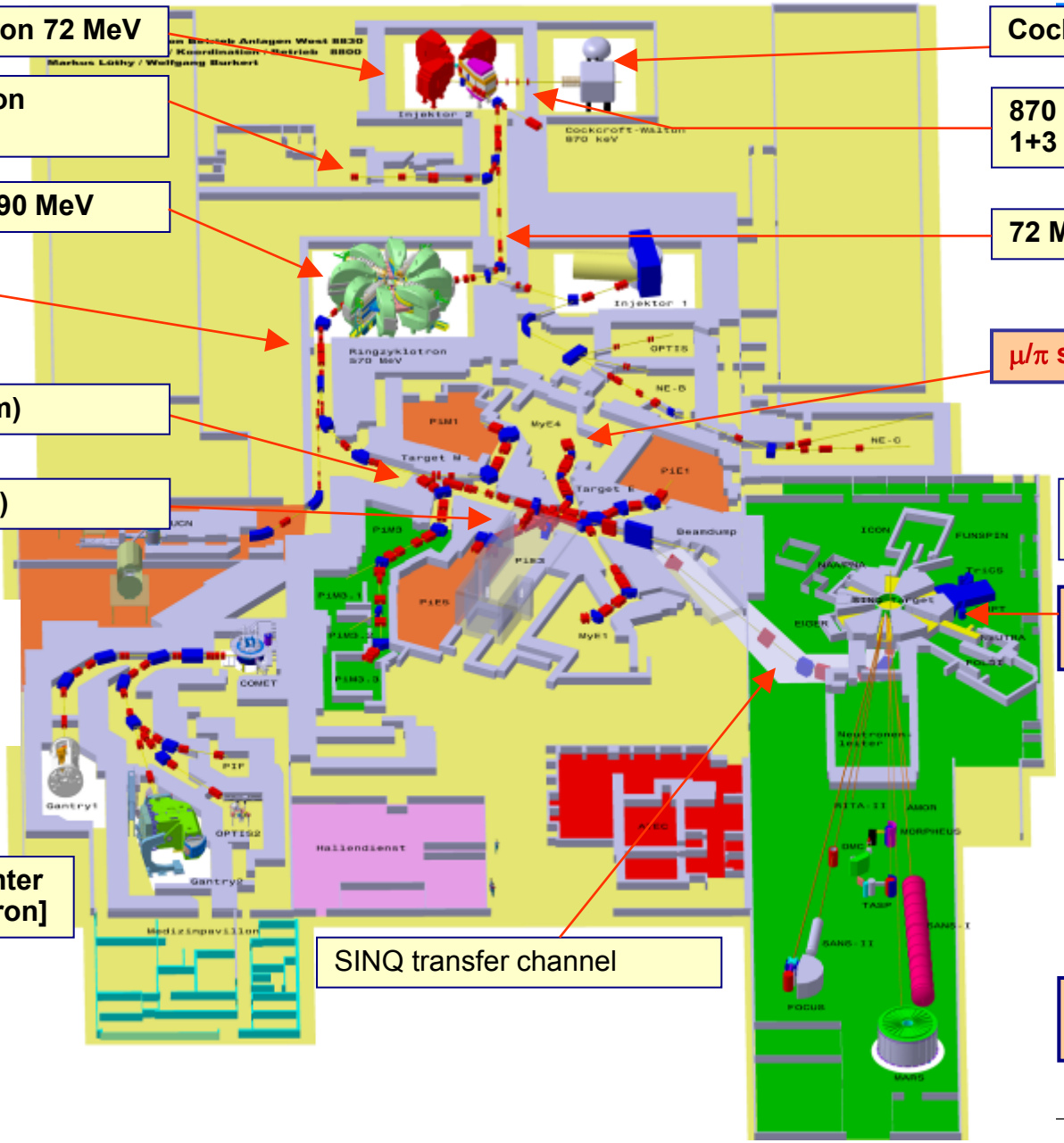
target M (d = 5mm)

target E (d = 4cm)

dimensions:

120 x 220m²

proton therapie center
[250MeV sc. cyclotron]



Cockcroft Walton

870 keV transfer channel
1+3 harmonic buncher

72 MeV transfer channel

μ/π secondary beamlines

1.4 mA /0.8 MW
CW operation

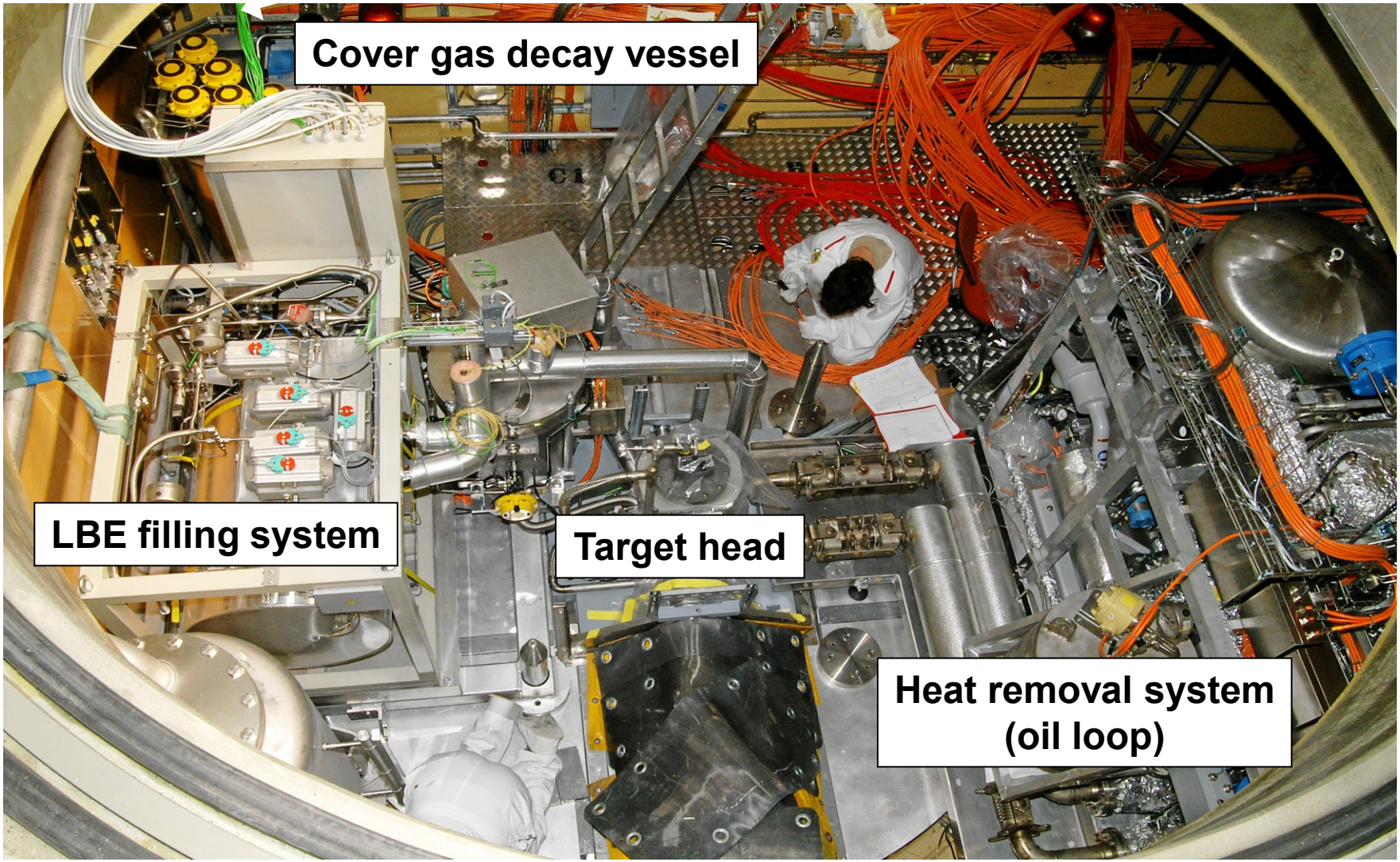
SINQ
spallation source

SINQ transfer channel

SINQ
instruments

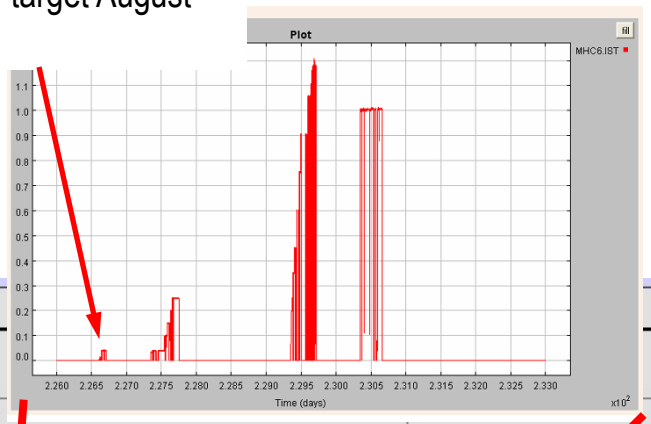
Operation

Shortly before operation



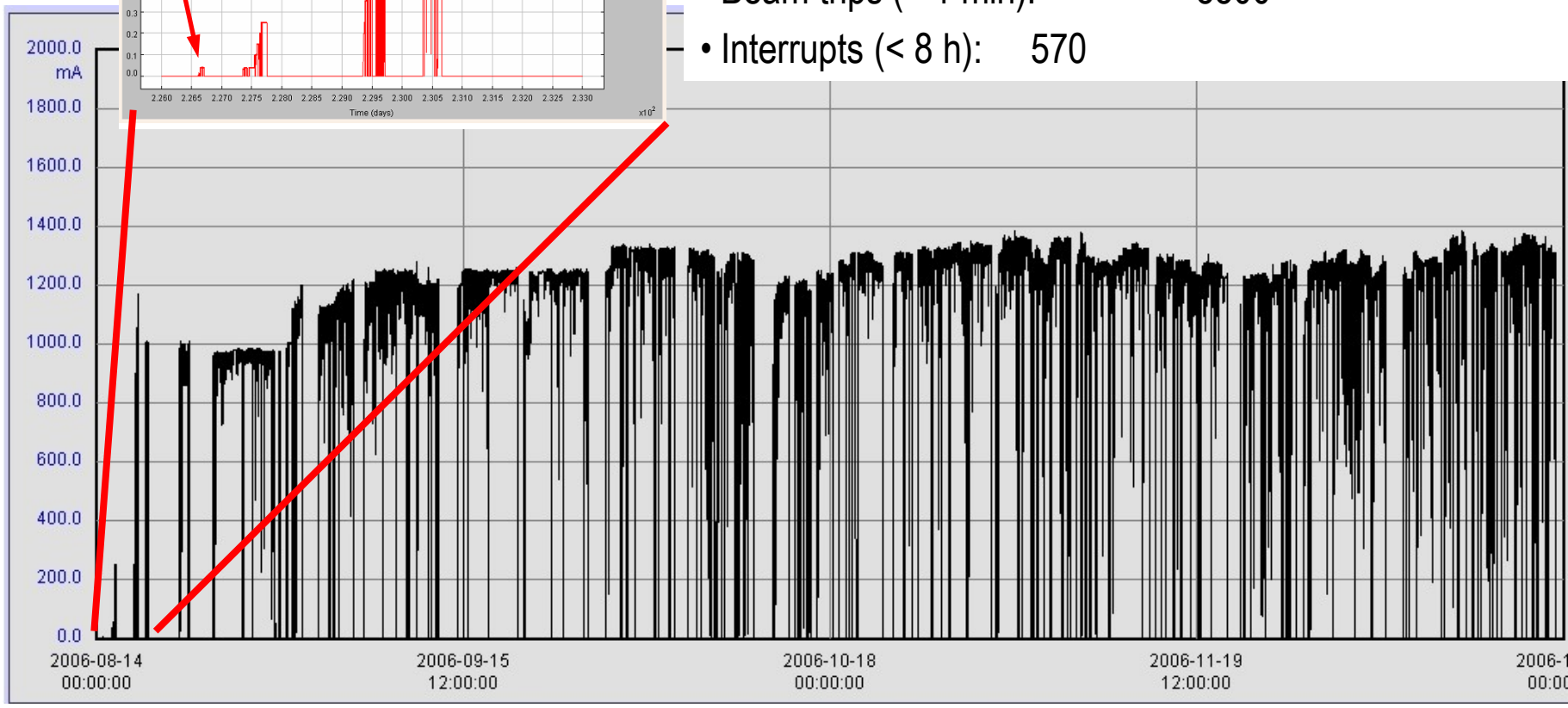
MEGAPIE Target Operation: full history

First protons on target August 14, 2006

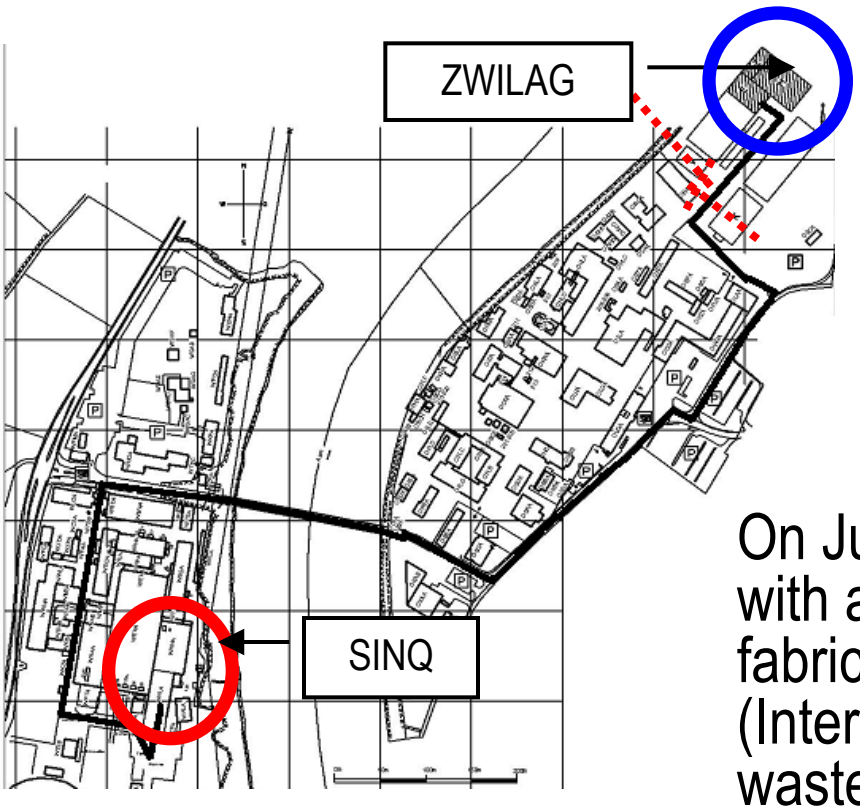


Beam: August 14 – December 21, 2006

- Accumulated charge: 2.8 Ah
- Peak Current: 1400 mA
- Beam trips (< 1 min): 5500
- Interrupts (< 8 h): 570



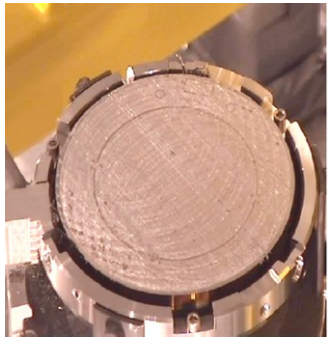
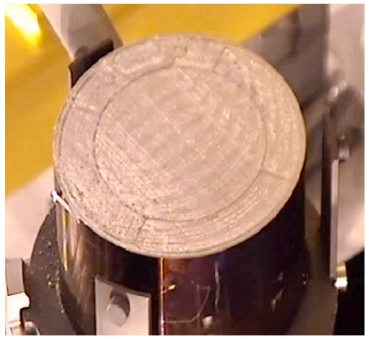
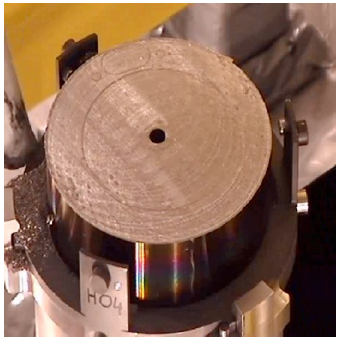
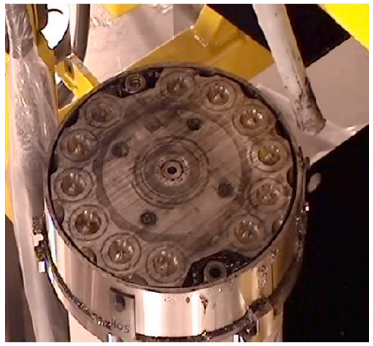
Transfer of MEGAPIE



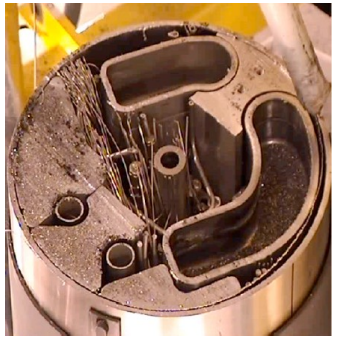
On July 6th the MEGAPIE target was transferred with a special transport container (TC1), fabricated by Skoda, from PSI to ZWILAG (Interim storage facility for nuclear power plant waste).
Dose rate at surface of TC1 ~ 1 µSv/h.
The transfer started at ~21:10 and took roughly 2 hours.
Authorities (BAG/ENSI) were present and monitored the procedure.

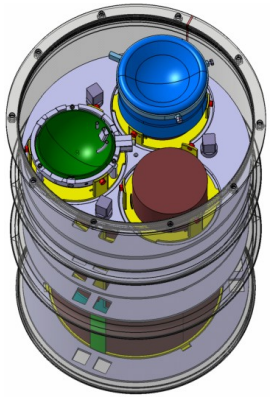
MEGAPIE @ ZWILAG

The dismantling of the MEGAPIE Target in ZWILAG has been completed. All cuts of the target could be accomplished successfully. Overall 10 sample pieces have been produced. They were shipped from to PSIs' Hot Laboratory (on April 5th 2011).

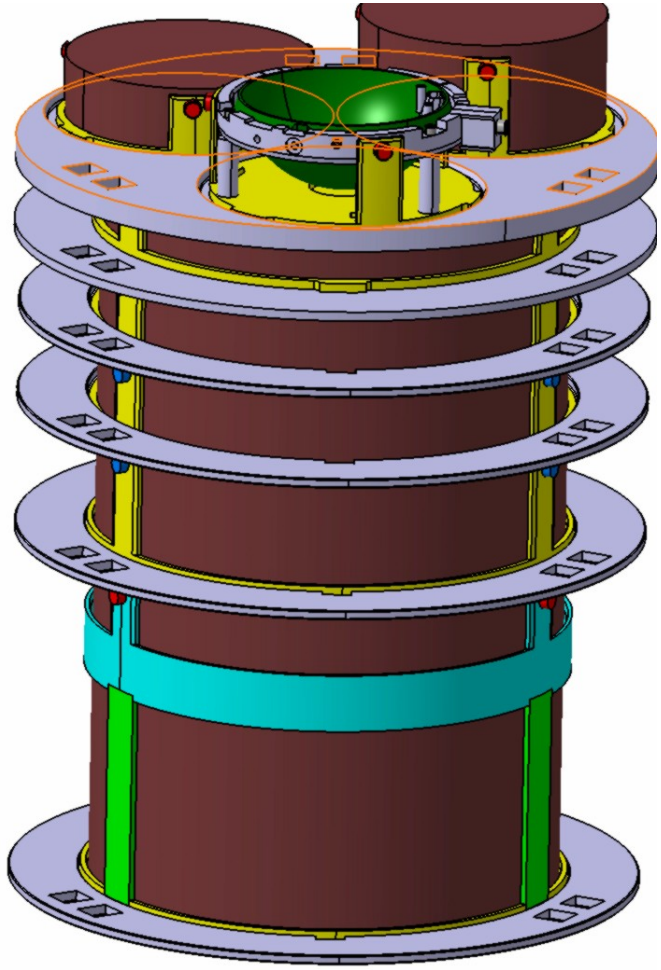






Package of the target sample pieces

The shipment of the sample container (TC3) from ZWILAG to the Hot Laboratory (HL) of PSI was done in April 2011.



MEGAPIE @ ZWILAG

The Hot Cell of ZWILAG was cleaned and now can be entered by personnel again.

Most of the devices used during the dismantling process could be cleaned in the β-γ box of ZWILAG and have been delivered back to PSI.

The TC1 container is currently stored at ZWILAG and will be shipped to PSI in the 4th quarter of 2010 for decontamination (only the inner container is contaminated do to slight scraping of the AlMg3 safety hull during insertion).

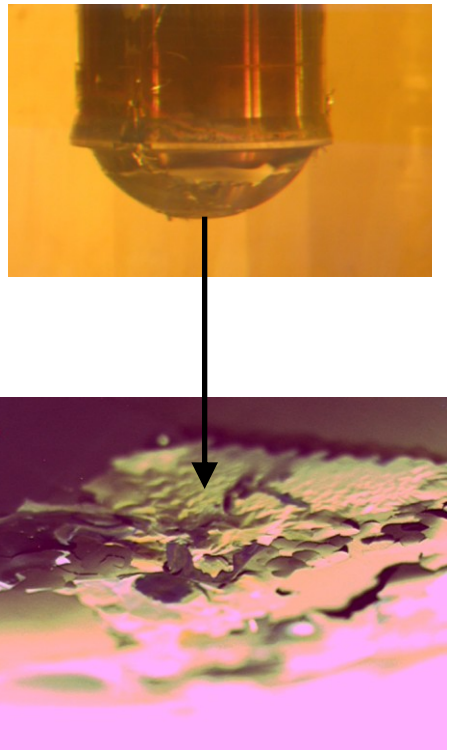
The dismantling campaign in ZWILAG was a full success and is finished.

Preparation of PIE sample extraction

The sample extraction process in the HL consists of 6 major steps:

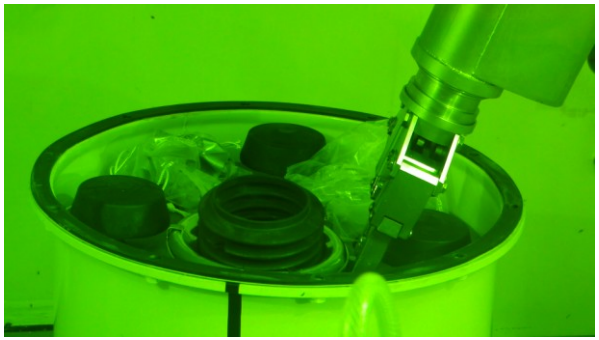
1. Visual inspection of all sample pieces delivered from ZWILAG. Gamma scan of the tip of the AlMg3 safety hull. Thickness measurements of the beam entrance window.
2. LBE PIE Sample taking.
3. Segregation of LBE from structural materials by melting the LBE in an oven.
4. Raw-Cutting of the PIE structural material samples.
5. Cleaning (where needed) of the PIE structural material samples.
6. Fine-Cutting of the PIE structural material samples.

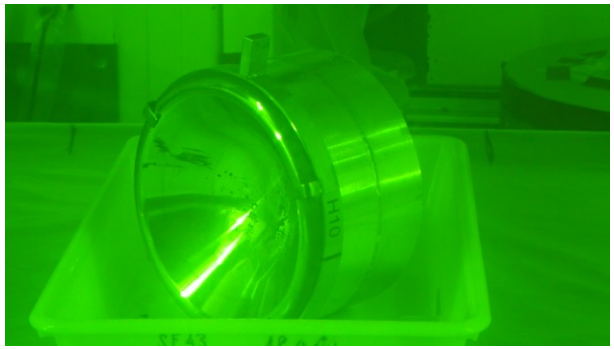
PIE sample extraction – Visual Inspection

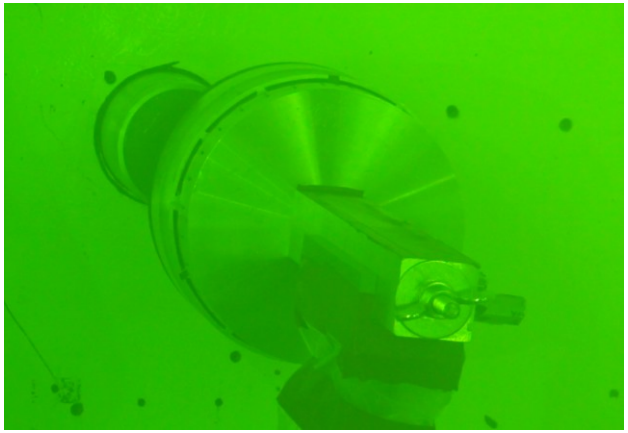


The status of each target sample piece delivered from ZWILAG shall be investigated. Photos of all pieces shall be made with the highest possible accuracy. The aim is to document the condition of the target pieces, and to identify changes e.g. cracks, deposits, and so forth.

PIE sample extraction – Gamma scan



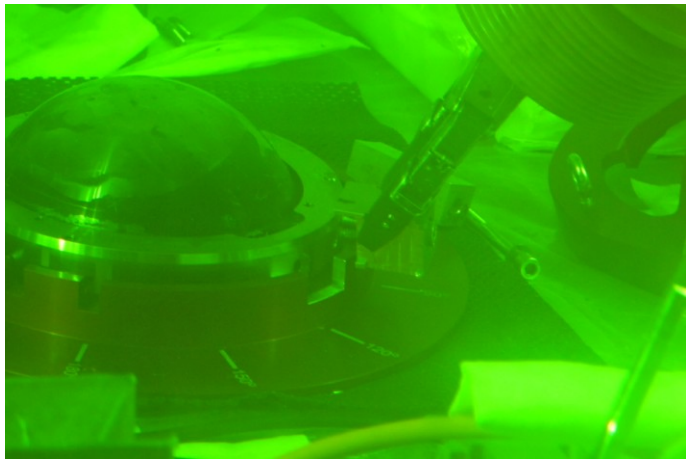


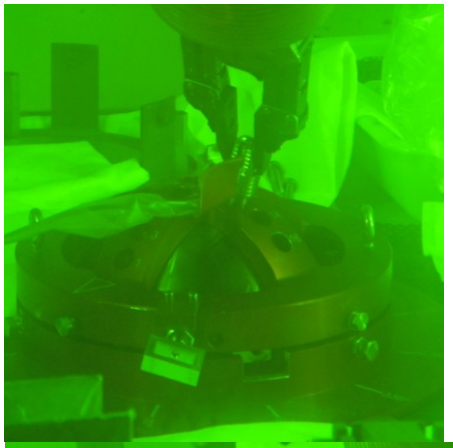


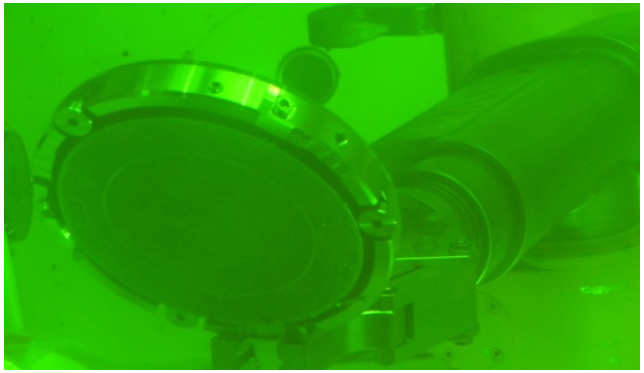
A gamma scan of the AlMg3 safety hull tip was done. This gamma scan measures the time-averaged proton beam profile on the MEGAPIE target.

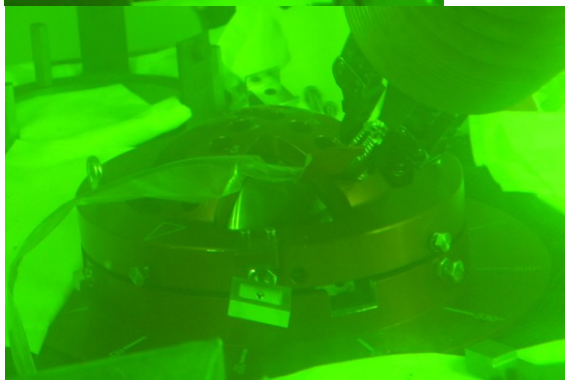
The obtained profile will be used as an input condition to Monte-Carlo calculations of the X9 group to establish new and more realistic calculations of dpa-rates for the different sample regions of interest. This will directly support the PIE program.

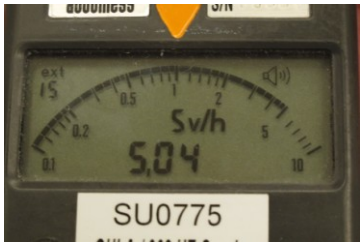
Ultrasonic measurement of BEW











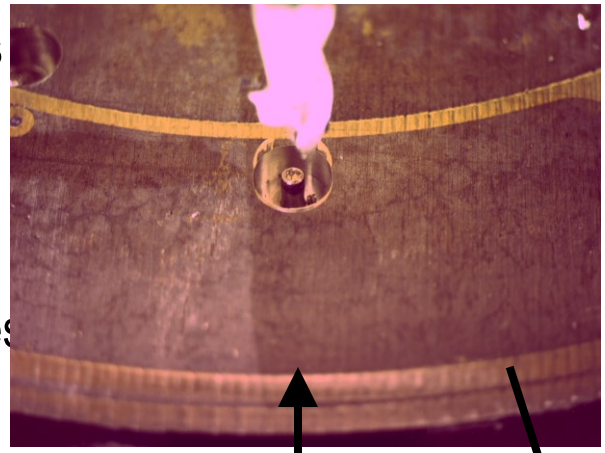
The ultrasonic measurement of the tip of the LLMC (BEW) was performed. These measurements will be directly compared to pre-operation measurements of the calotte performed by Y. Dai.

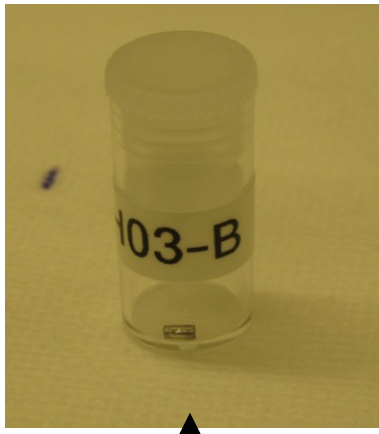
The information gained will give insight to erosion and/or corrosion issues at the beam entrance window. Data still under evaluation.

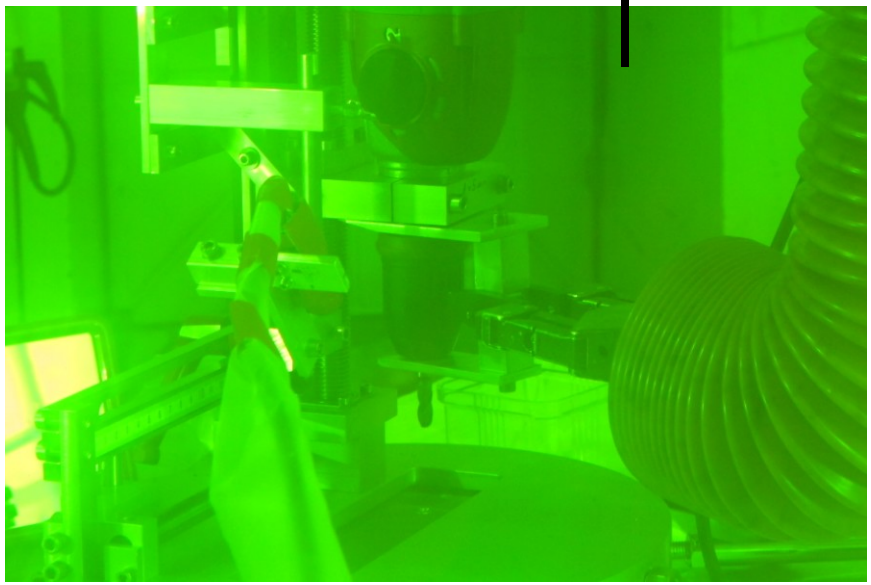
PIE sample extraction – LBE sample taking

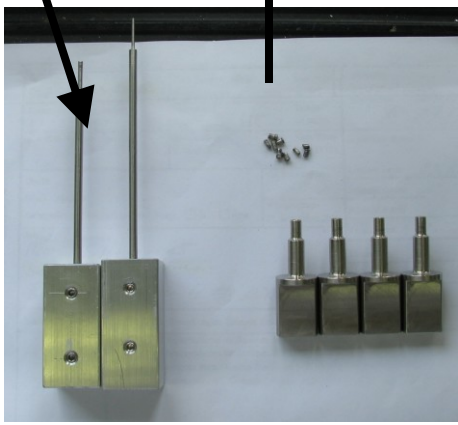
A special drilling device for the LBE sample taking has been designed (50 LBE samples to be taken), constructed, and tested by the HL.

The tests showed that the devices for the LBE sample taking works reliably. Difficulties to take LBE samples in the vicinity of structural materials (vibrations) have been solved.

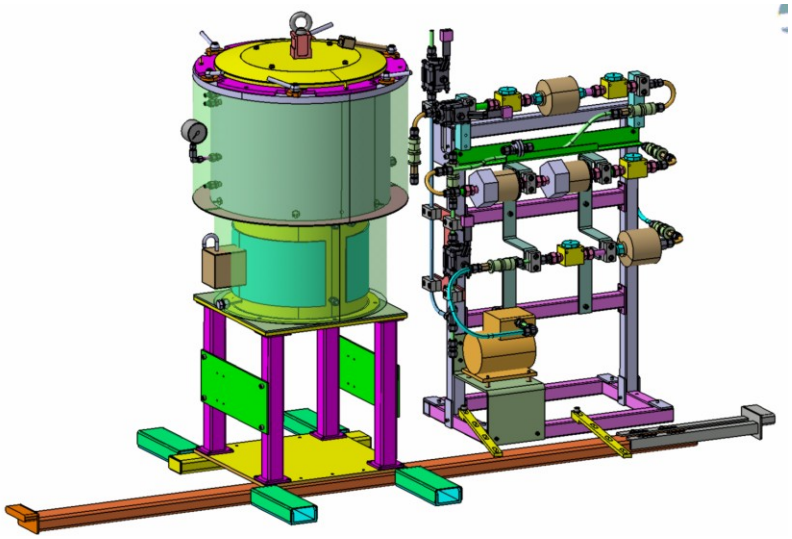


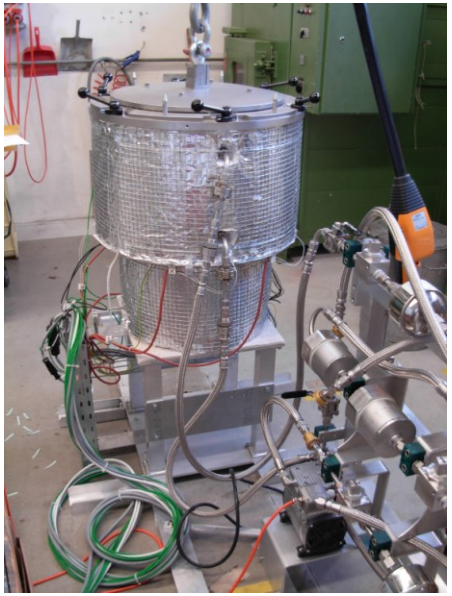






Segregation of LBE and structural materials





To segregate the structural materials from the LBE a special oven has been designed and constructed by the engineering department of PSI.

The oven is heated with 6 heaters (0.8 kW each) built into the intermediate floor on which the target sample pieces are positioned. The lower part of the oven serves as a collector of the LBE and can be separately heated (heater band of 1.5 kW).

The oven was vacuum tested – a leak was found and tightened. First heating tests showed a slow temperature response in the most upper part of the oven.

Therefore, an additional strip heater (1.5 kW) was installed.

Tests have successfully been conducted.

Oven tests

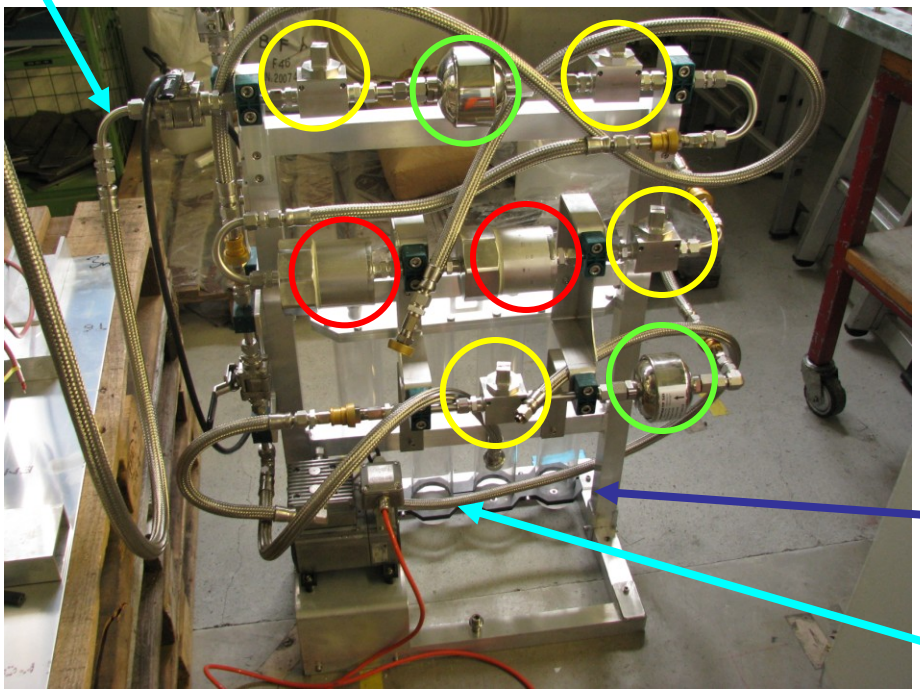
Segregation of LBE and structural materials

Filters:

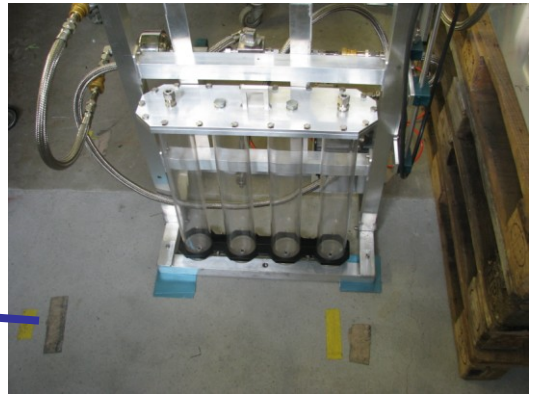
- Aerosol
- Activated carbon filter
- Tritium filter

air sampling

gas inlet from the oven



exhaust gas



Tritium filter

Cutting of the structural material samples

After the LBE has been molten, the structural material samples (more than 700) will be raw cut. To test the handling of the diamond/grinder disks, 1:1 mock-ups all sample pieces have been manufactured with original materials and dimensions.

The cutting tests have partly been performed by HL personnel and are still ongoing.

Cutting of the samples

Clean cut with grinding disc

Left:

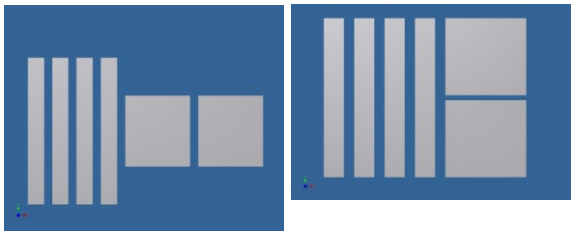
Cutting devices to do the raw cutting with; a grinding disc will be used.

Right:

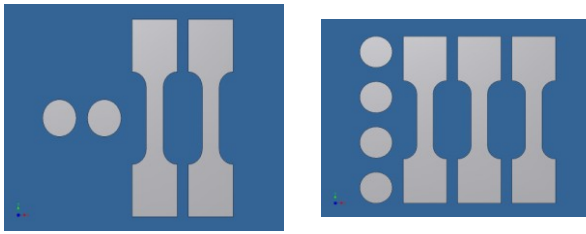
Fine cutting of samples (in total 4 groups).

A diamond blade saw will be used for samples with LBE.

An EDM machine will be used for tensile and TEM samples.

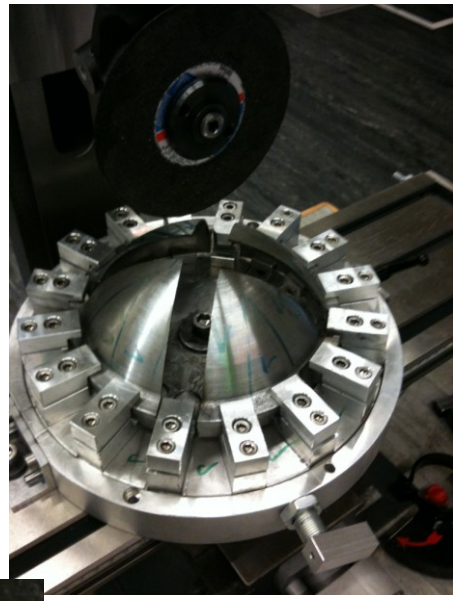


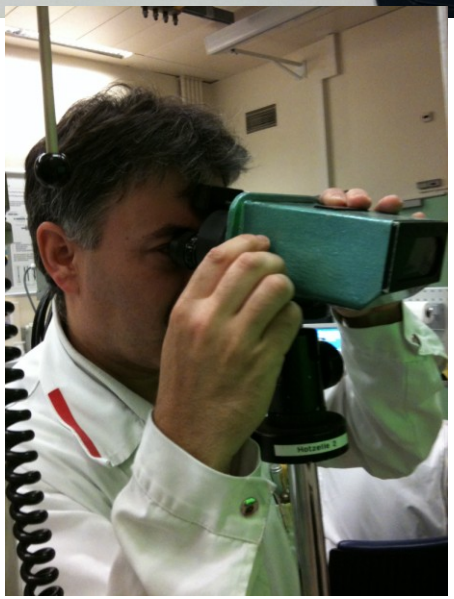
Cutting with diamond blade saw



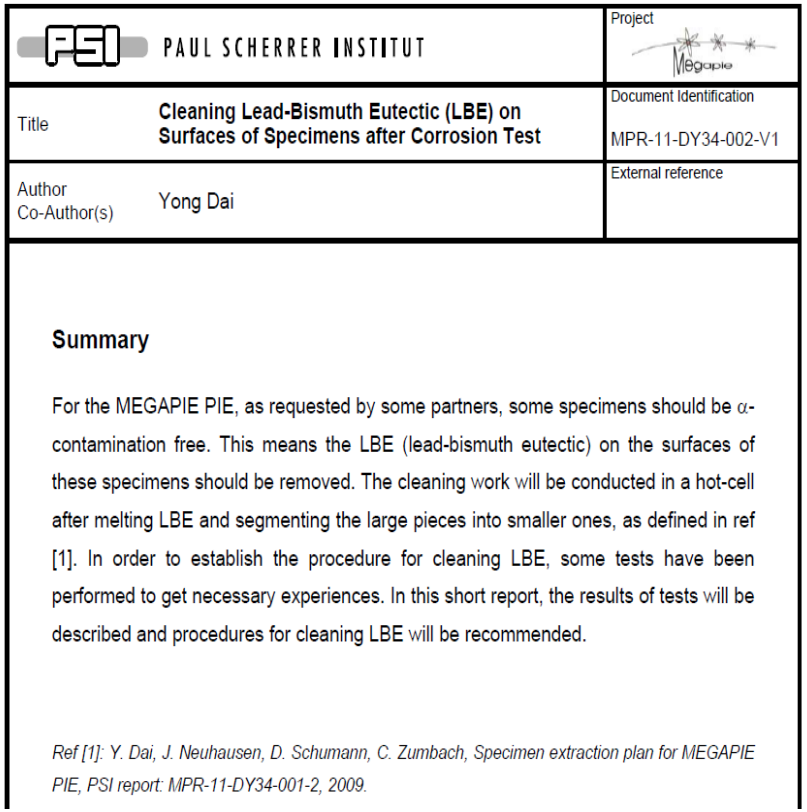
Wire cutting

Cutting of samples - Tests





Cleaning of structural material samples



PAUL SCHERRER INSTITUT

Project: Megapie

Title	**Cleaning Lead-Bismuth Eutectic (LBE) on Surfaces of Specimens after Corrosion Test**
Author Co-Author(s)	Yong Dai

Document Identification: MPR-11-DY34-002-V1

External reference:

Summary

For the MEGAPIE PIE, as requested by some partners, some specimens should be α-contamination free. This means the LBE (lead-bismuth eutectic) on the surfaces of these specimens should be removed. The cleaning work will be conducted in a hot-cell after melting LBE and segmenting the large pieces into smaller ones, as defined in ref [1]. In order to establish the procedure for cleaning LBE, some tests have been performed to get necessary experiences. In this short report, the results of tests will be described and procedures for cleaning LBE will be recommended.

Ref [1]: Y. Dai, J. Neuhausen, D. Schumann, C. Zumbach, Specimen extraction plan for MEGAPIE PIE, PSI report: MPR-11-DY34-001-2, 2009.

A good fraction of the structural material samples has to be cleaned, in order to minimize the remainder of LBE on the surface. Hence, cleaning procedures have been developed and tested by Y. Dai.

A report on the most promising procedures has been issued. Two possible cleaning scenarios are described.

The most promising proposed process consists of five steps:

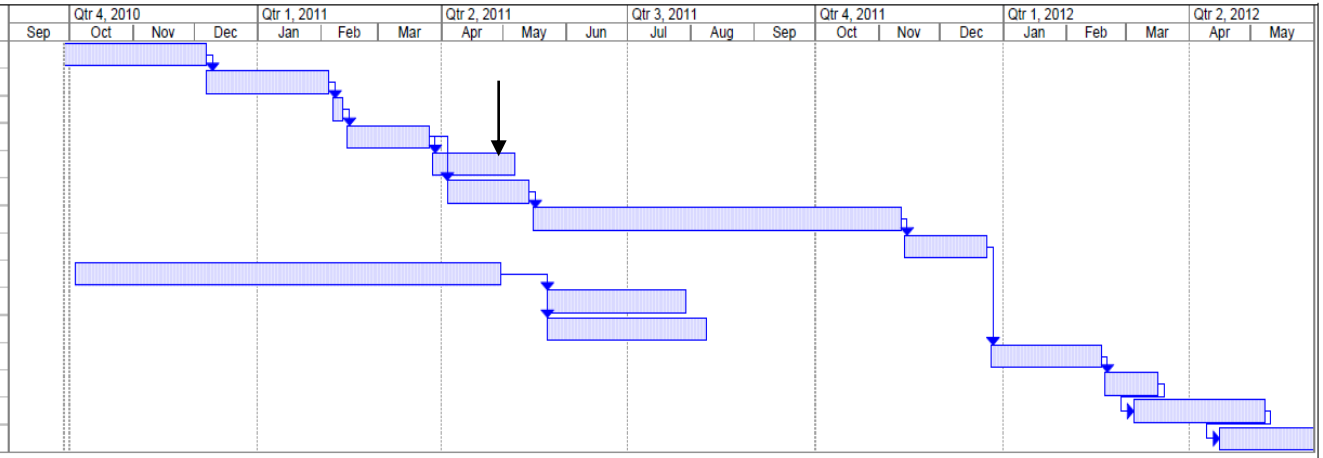
- Sweeping off LBE after bath in 150ºC a special Oil.
- Cleaning in Ultrasonic bath
- Cleaning with nitric acid
- Cleaning in Ultrasonic bath

Small amounts of LBE might still be on the samples..

PSI cannot guarantee 100% α-free samples!

Schedule

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



The PIE phase of the MEGAPIE project is well on track. However, a small time shift of +1 month was needed to finalize tests of the oven.

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Thank you for your attention