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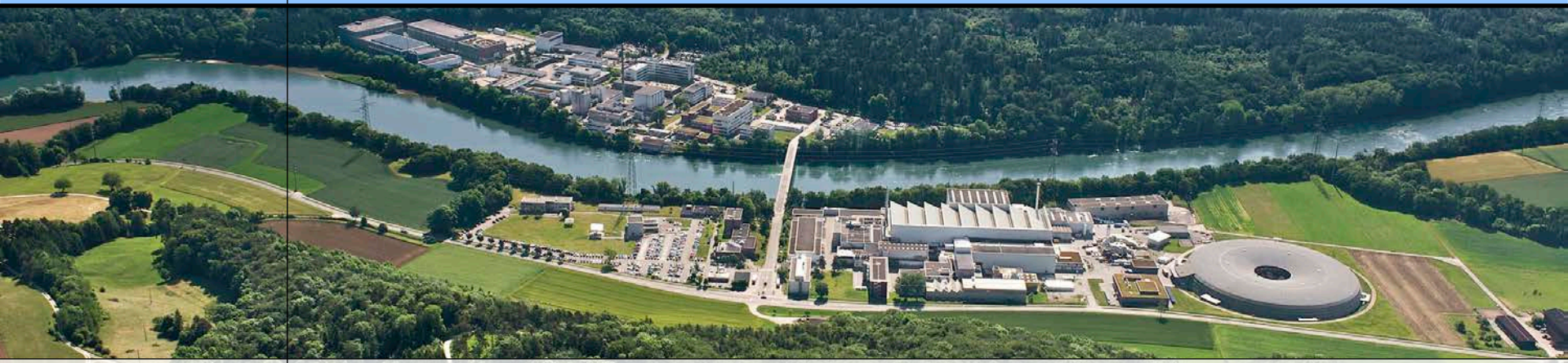
PSI



Wir schaffen Wissen – heute für morgen

MEGAPIE Final Technical Review Meeting (TRM)
October 23. – 24.2014, Bregenz, Austria

MEGAPIE - Post Irradiation Phase

M. Wohlmuther for the PSI MEGAPIE Team

MEGAPIE – The Post Irradiation Phase

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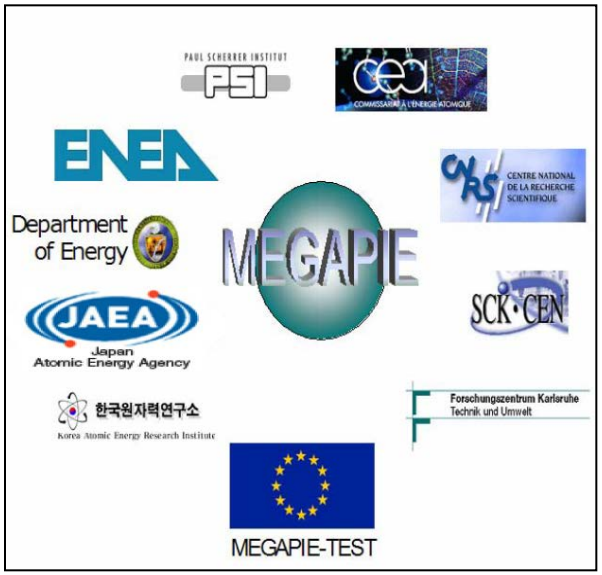
Ch. Zumbach, and many more, all PSI

and

Ch. Hösli, R. Erne, F. Bugmann, B. Binkert, D. Moosmann, R. Emch, R. Keller, R. Leuzinger, A. Keller, D. Gubler, A. Wegmüller, M. Meier, T. Blank, M. Miotti and M. Meier all ZWILAG

Motivation

MEGAPIE - MEGAwatt Pilot Experiment



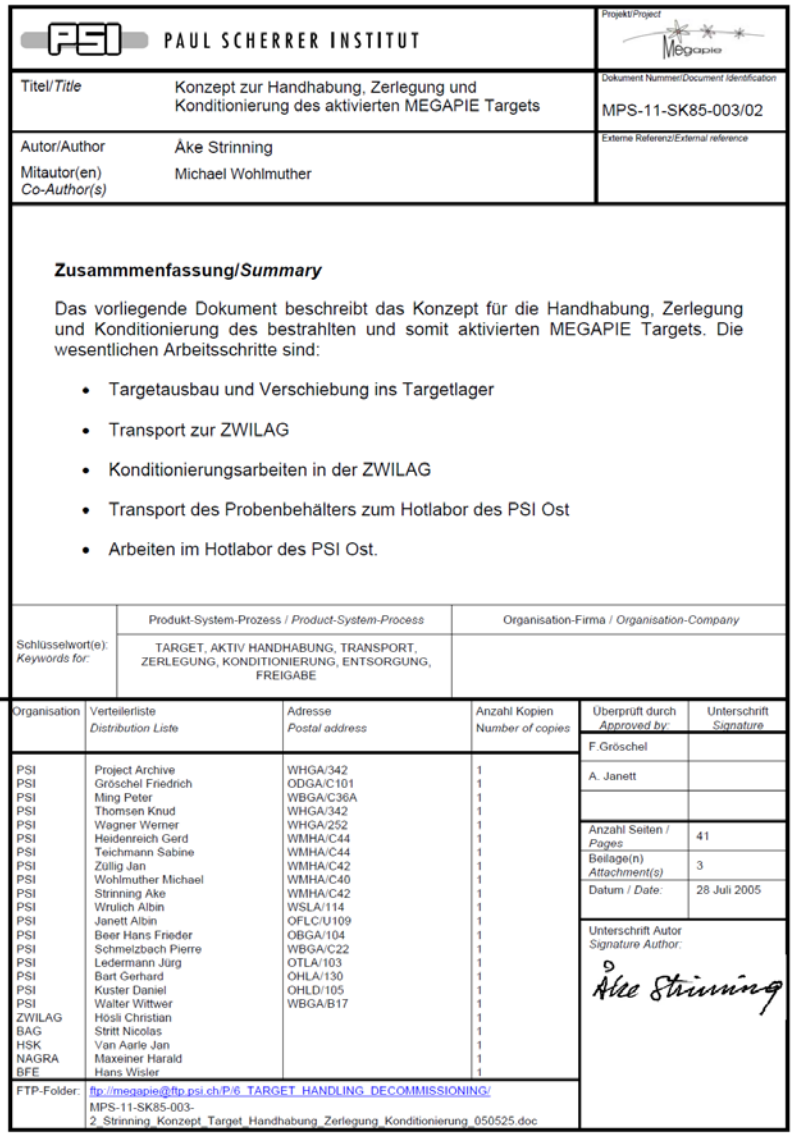
- **Joint international initiative to design, build, license, operate, dismantle and explore a liquid metal LBE*) spallation target for the 1 MW beam power regime for the first time (started ~ September 1999).**

***) 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 challenges 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 an 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

The way to the PIE Samples



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Projekt/Project: Megapie

Titel/*Title*	Konzept zur Handhabung, Zerlegung und Konditionierung des aktivierten MEGAPIE Targets
Dokument Nummer/*Document Identification*	MPS-11-SK85-003/02
Autor/Author	Åke Strinning
Mitautor(en) *Co-Author(s)*	Michael Wohlmuther
Externe Referenz/*External reference*	

Zusammmenfassung/*Summary*

Das vorliegende Dokument beschreibt das Konzept für die Handhabung, Zerlegung und Konditionierung des bestrahlten und somit aktivierten MEGAPIE Targets. Die wesentlichen Arbeitsschritte sind:

- Targetausbau und Verschiebung ins Targetlager
- Transport zur ZWILAG
- Konditionierungsarbeiten in der ZWILAG
- Transport des Probenbehälters zum Hotlabor des PSI Ost
- Arbeiten im Hotlabor des PSI Ost.

Schlüsselwort(e): *Keywords for:*	Produkt-System-Prozess / *Product-System-Process*	Organisation-Firma / *Organisation-Company*
	TARGET, AKTIV HANDHABUNG, TRANSPORT, ZERLEGUNG, KONDITIONIERUNG, ENTSORGUNG, FREIGABE	

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NAGRA	Maxeiner Harald		1
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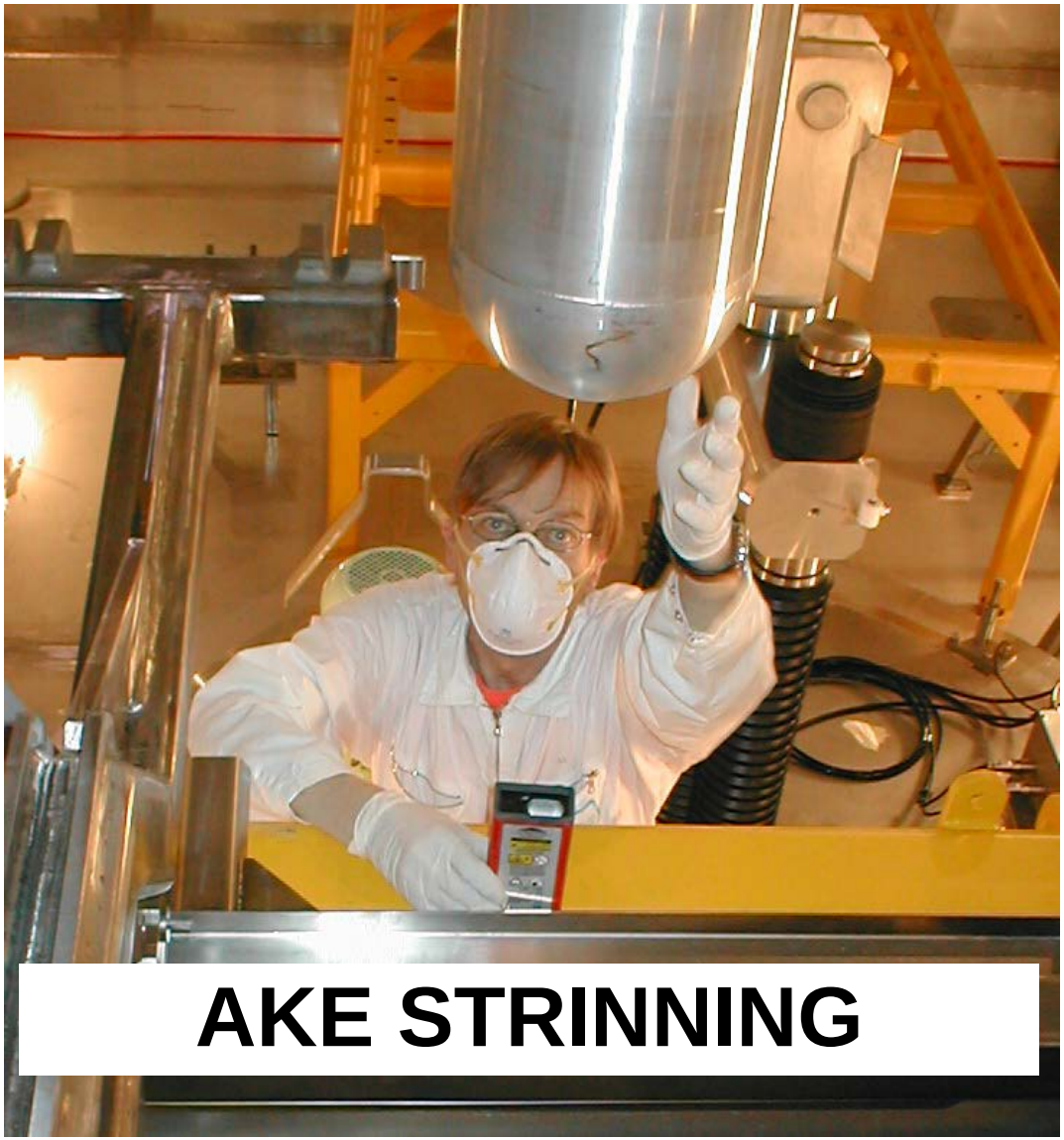
Åke Strinning

FTP-Folder: ftp://megapie@ftp.psi.ch/P/6_TARGET_HANDLING_DECOMMISSIONING/MPS-11-SK85-003-2_Strinning_Konzept_Target_Handhabung_Zerlegung_Konditionierung_050525.doc

- Ake Strinning developed the concept for the dismantling, disposal and PIE sample preparation. This work was started around 2000.
- This document served as the «script» for all processes up to the PIE sample shipment to the international partners, i.e. CEA, JAEA, KIT, LANL, (PSI) and SCK·CEN.

MISTER DISMANTLING

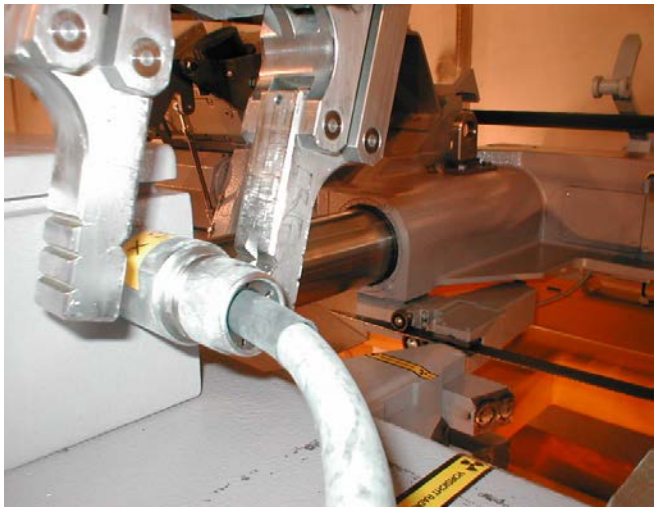


MEGAPIE- On the way to PIE samples

- Internal Transfer to the SINQ Target Storage Area
- Test(s) of dismantling procedures and devices at ZWILAG
- Transport of MEGAPIE from PSI West to ZWILAG
- Cutting of the Target, Disposal of 92/85 % (mass/activity) of MEGAPIE
- Test(s) of the PIE sample preparation procedures and devices at the PSI Hot Laboratory
- Transfer of Target Sample Pieces from ZWILAG to the PSI Hot Laboratory
- Unpacking, Non-destructive Tests, Melting out of LBE, Raw Cutting, Cleaning and Fine Cutting of the MEGAPIE PIE samples
- Disposal of primary and secondary waste from the PIE Sample Preparation
- Shipment of PIE samples to CEA, JAEA, KIT, LANL, SCK·CEN, (PSI)
- PIE Sample Investigation

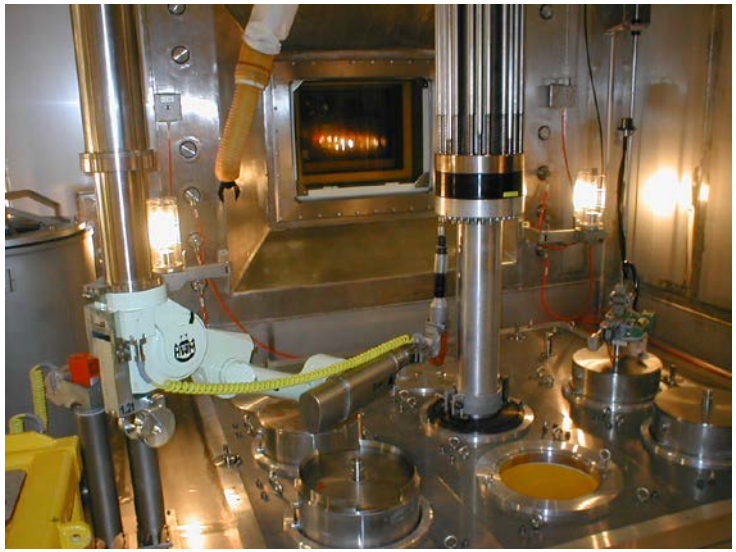
Testing, Testing, Testing

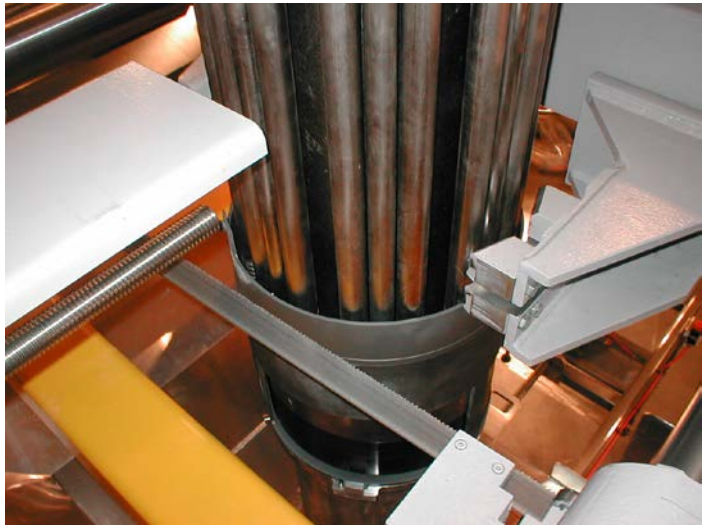
First tests of dismantling started in January 2007 and continued until the end of 2008 – below accessibility tests for the power manipulator

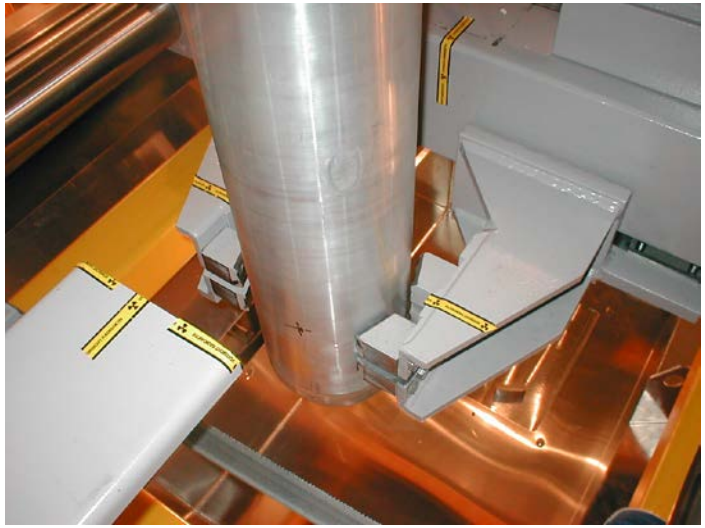


Testing, Testing, Testing

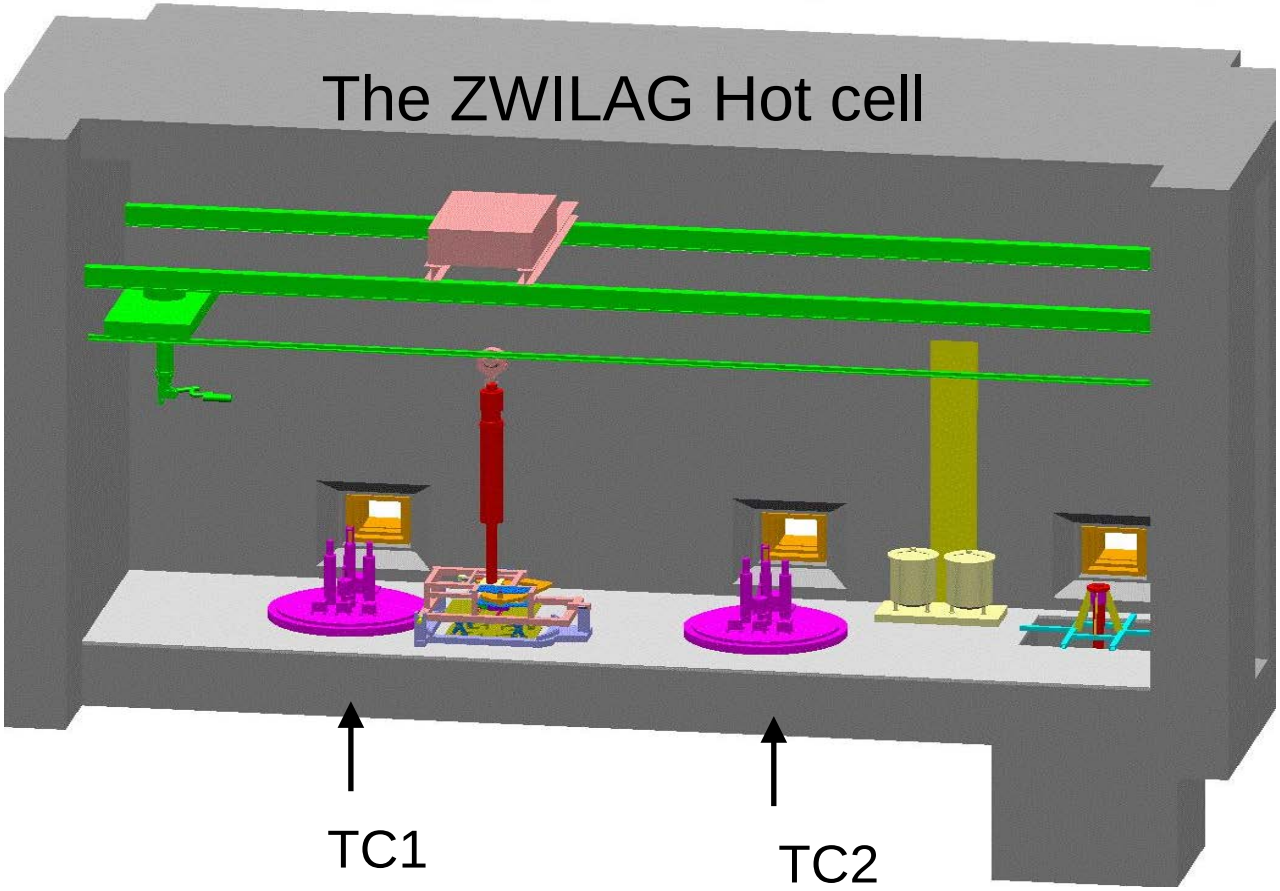
Target preparation and cutting





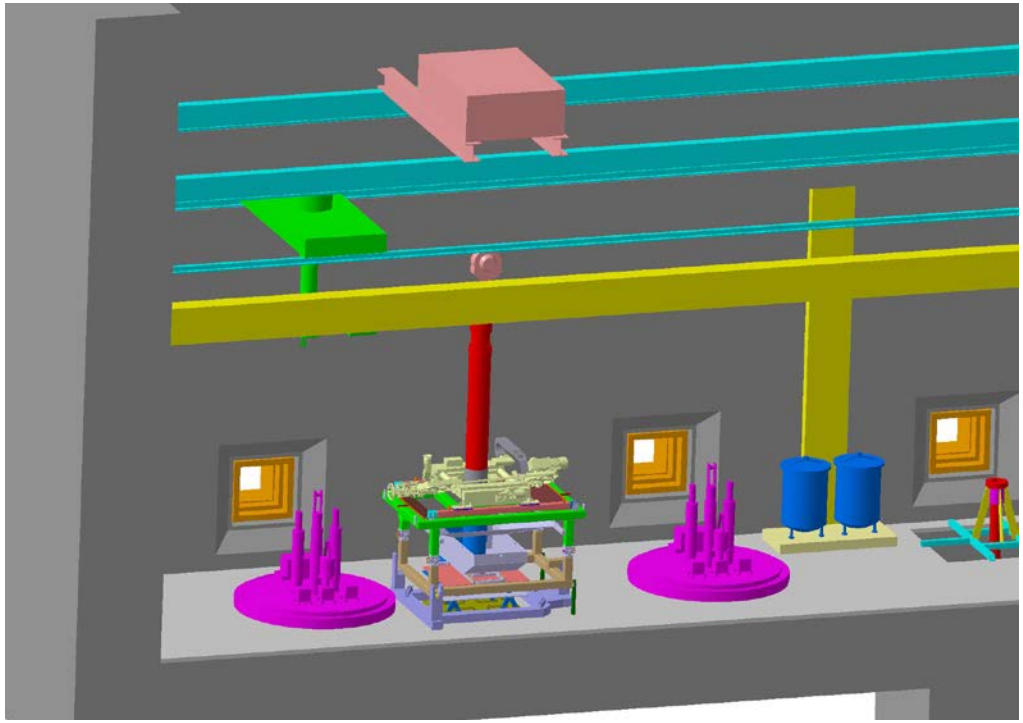


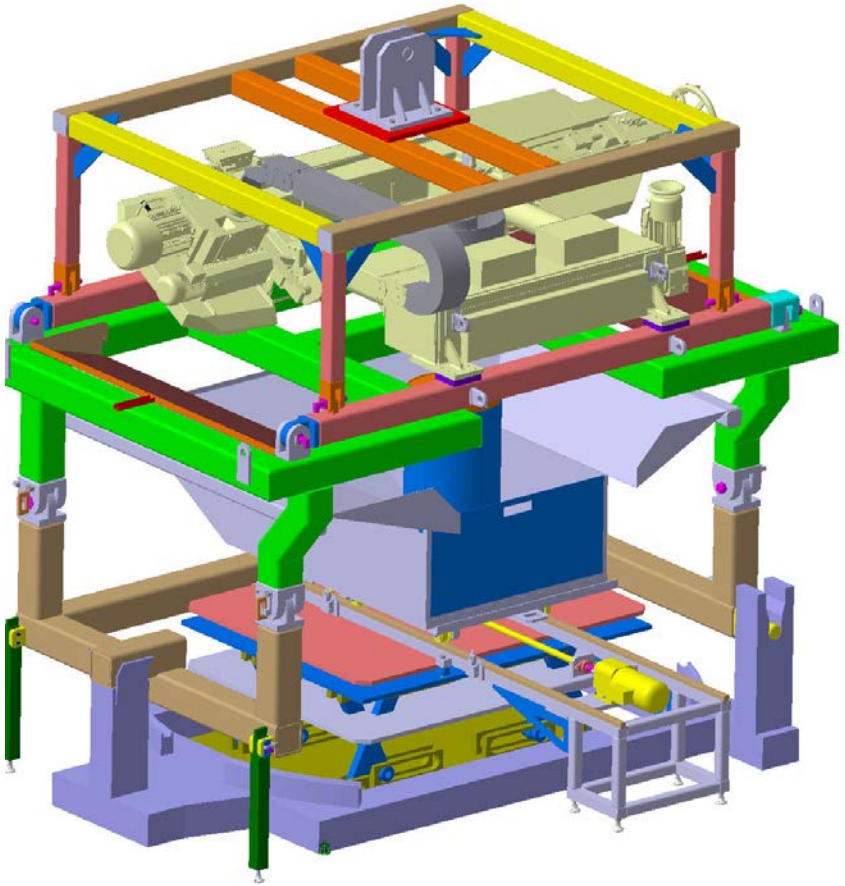
Work at ZWILAG



- Cutting the MEGAPIE target with band saw
- 8 wt% of the target were used as target sample pieces and sent to the Hot Laboratory at PSI East for NDT and PIE sample preparation.
- The remaining target pieces (92% of mass) were conditioned in steel cylinder in KC-T12 concrete container (TC2).

Work at ZWILAG



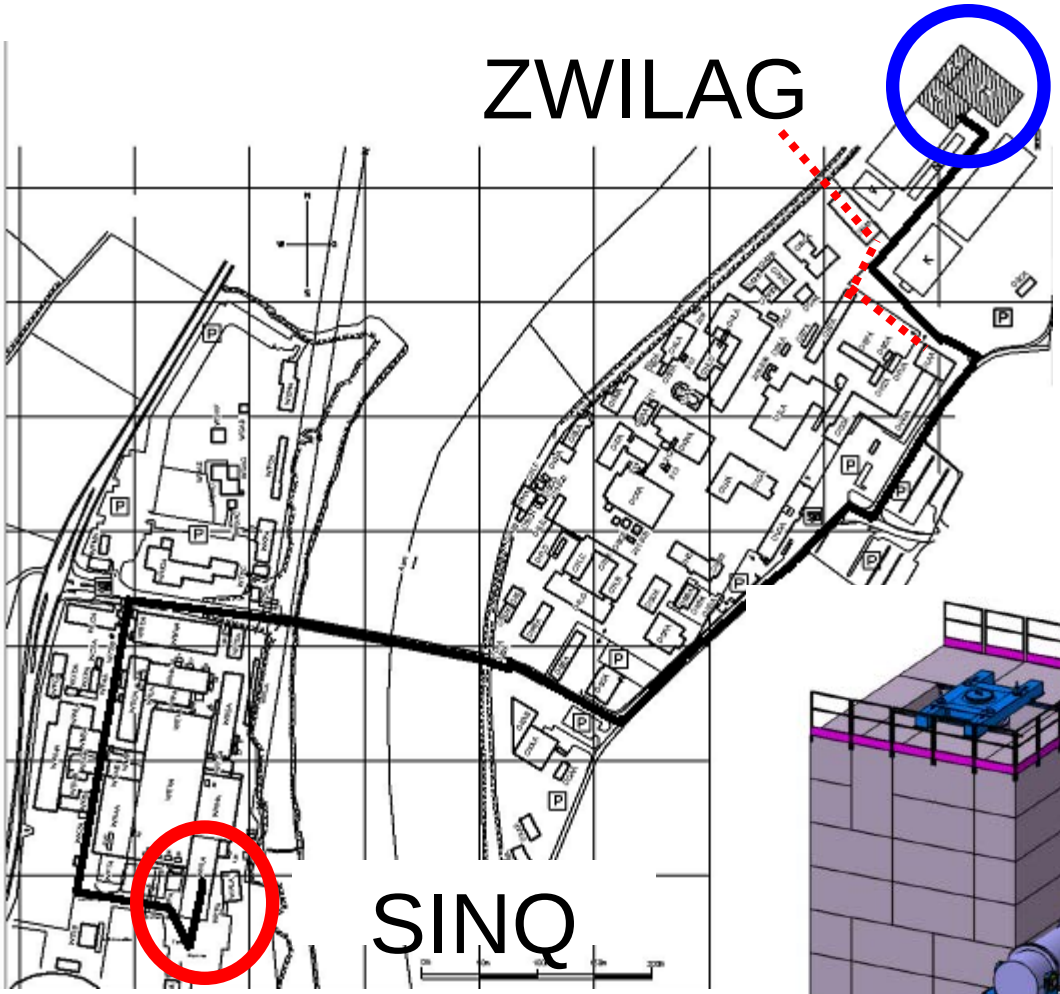


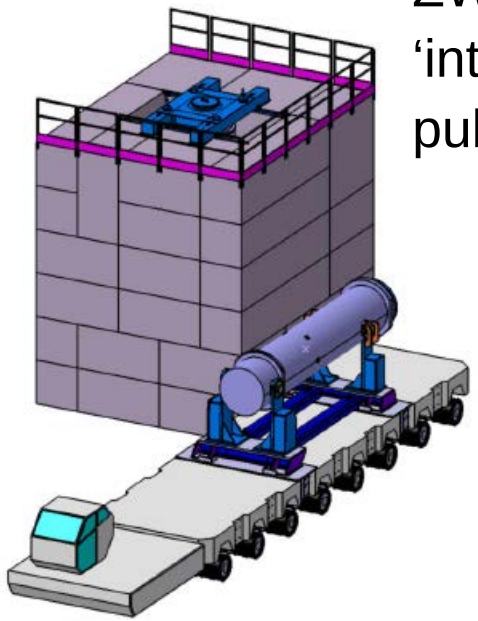
Cutting of the MEGAPIE Target, hanging on the crane with a band saw (no cooling) into 21 pieces.

ZWILAG Hot cell, ready to receive MEGAPIE

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

TRANSPORT PSI to ZWILAG

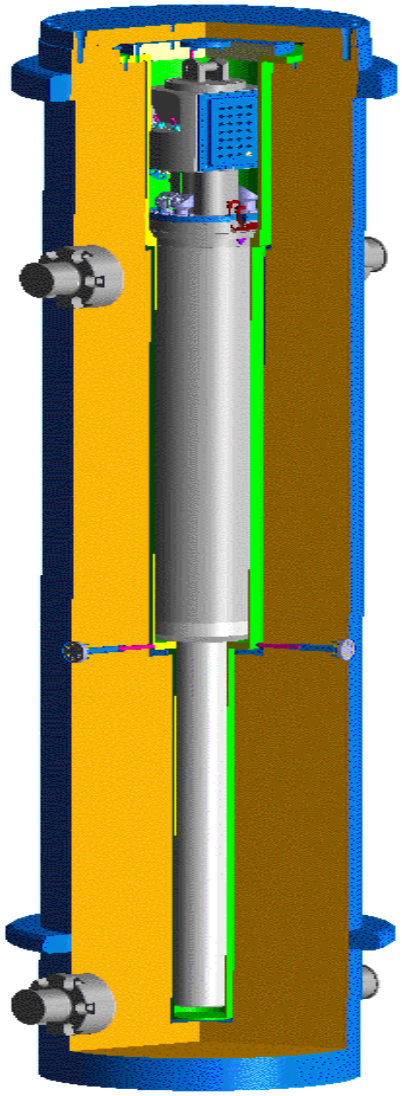




July 6th 2009

- Loading MEGAPIE target in the transport container TC1.
- TC1 is put on transport vehicle in the SINQ hall.
- Transport from the SINQ to ZWILAG; mostly PSI ‘internal’ road, last part public road.

TRANSPORT PSI to ZWILAG



Transport container TC1

- A2-Index of the target was calculated to be ~3000 after 9 months of cooling, ~1200 @T_c=1 year, ~ 270 T_c=2 years (90 % caused by Po-210) → special safeguard planning
- Steel container made of 2 concentric Parts (inner contamination protection and Shielding)
- 2 lids (with O-ring)
- Wall thickness min. 30 cm
- Length ~ 6 m; diameter ~ 1.4 m
- Compatible to the hot cell at ZWILAG
- Integrity after a drop from 2.5 m height must be assured (calculation)
- Fabricated at SKODA (Czech Republic)

TRANSPORT PSI to ZWILAG

- On July 6th 2009 the MEGAPIE target was transferred with a special transport container (TC1), fabricated by Skoda, from PSI to ZWILAG (Interim storage facility of Swiss 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.

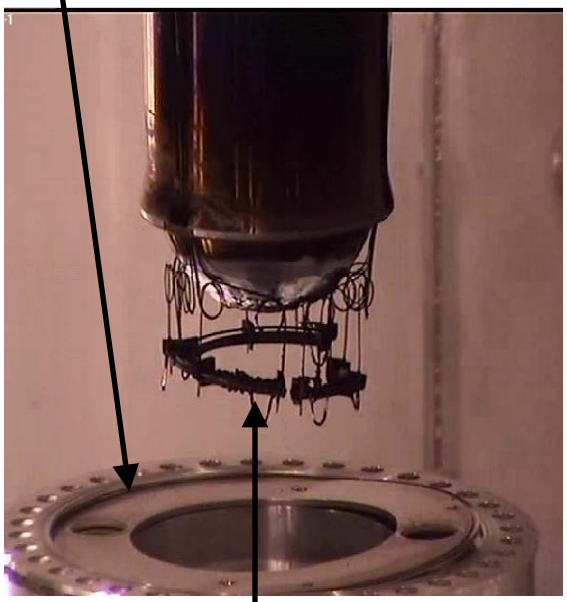
Target to Hot Cell (HC)

MEGAPIE with LTE

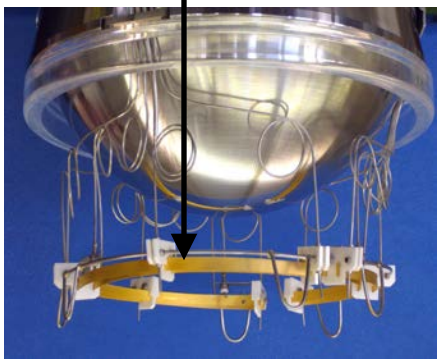
- TC1 docked to HC from below.
- The MEGAPIE target was connected to the crane of the hot cell and pulled out of TC1 into HC (July 9th 2009).
- First visual inspection by rotation the target. No special findings; slight color change in high neutron flux region.
- The Lower Target Enclosure (Aluminum Safety shroud, LTE) was unscrewed.

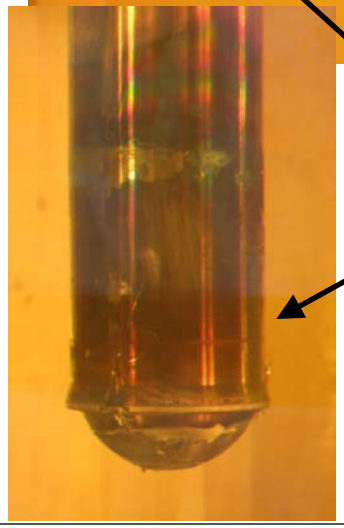
Unscrewing of LTE

Unscrewed LTE



Leak Detector (LD)





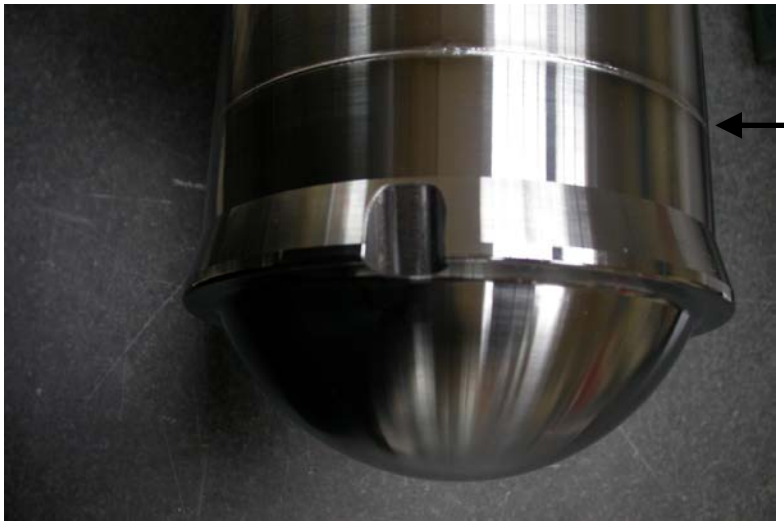
- The LTE was unscrewed (July 9th 2009).
- First visual inspection of the Lower Liquid Metal Container (LLMC, T91 steel).
- Black smut was deposited on one side of the LD (which partly fell off when the target was moved).
- The sides of the LLMC were covered with dark debris.

LLMC and BEW

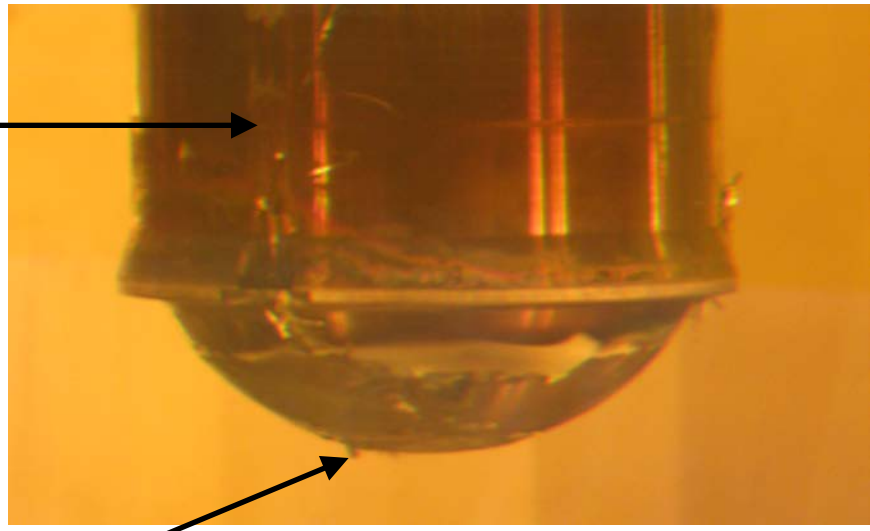
At BEW a whitish coverage was observed.

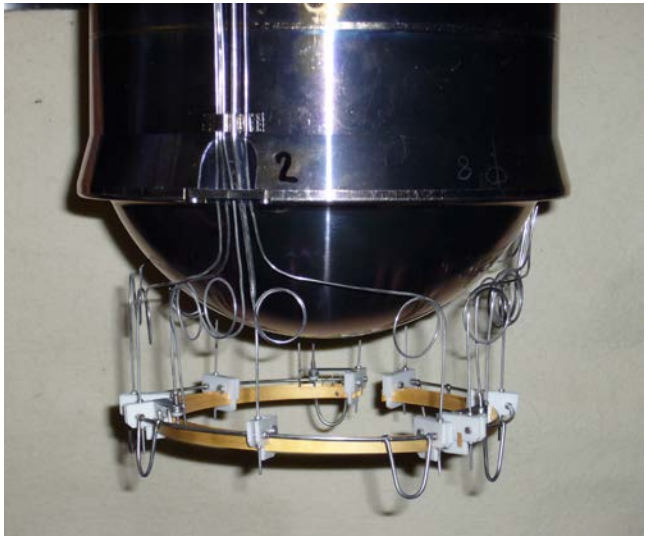
Before & After Irradiation

T91 Lower Liquid Metal Container (Calotte + Leak Detector)

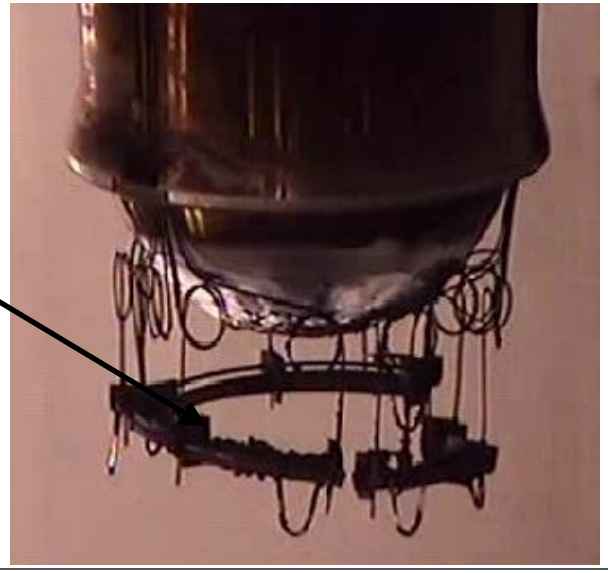


EBW

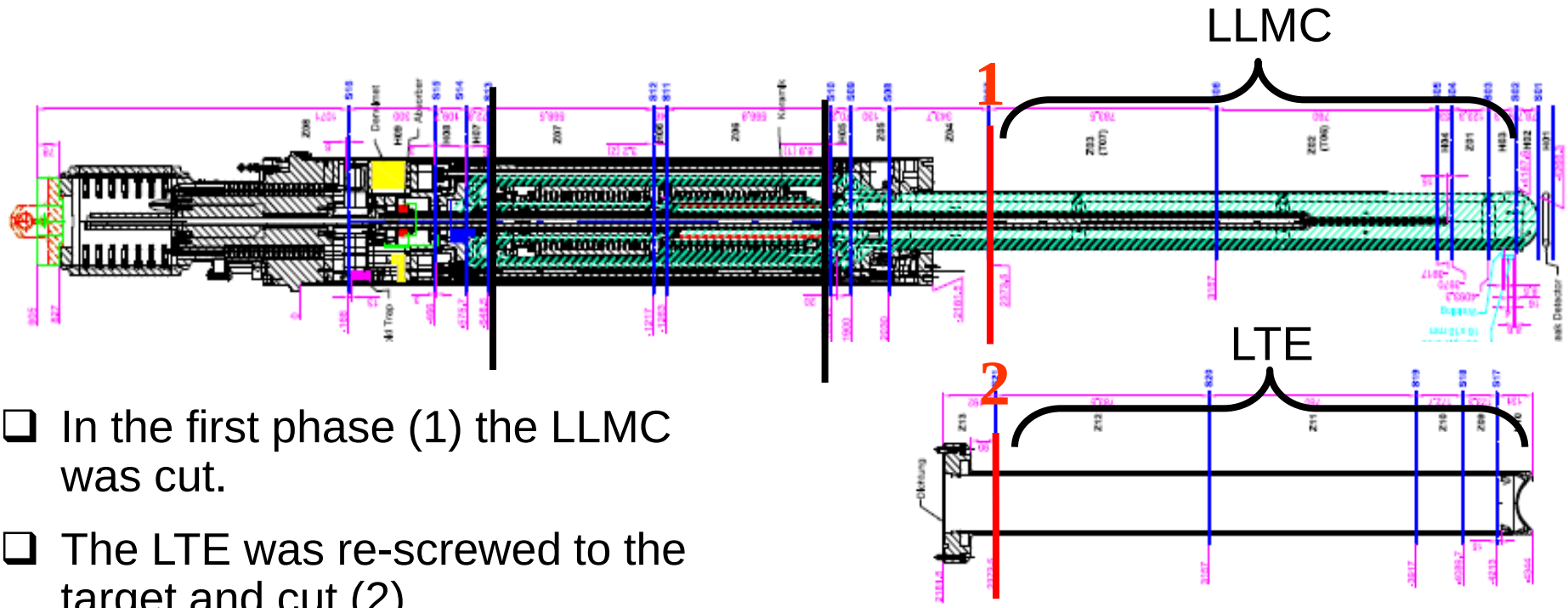




Material Deposit



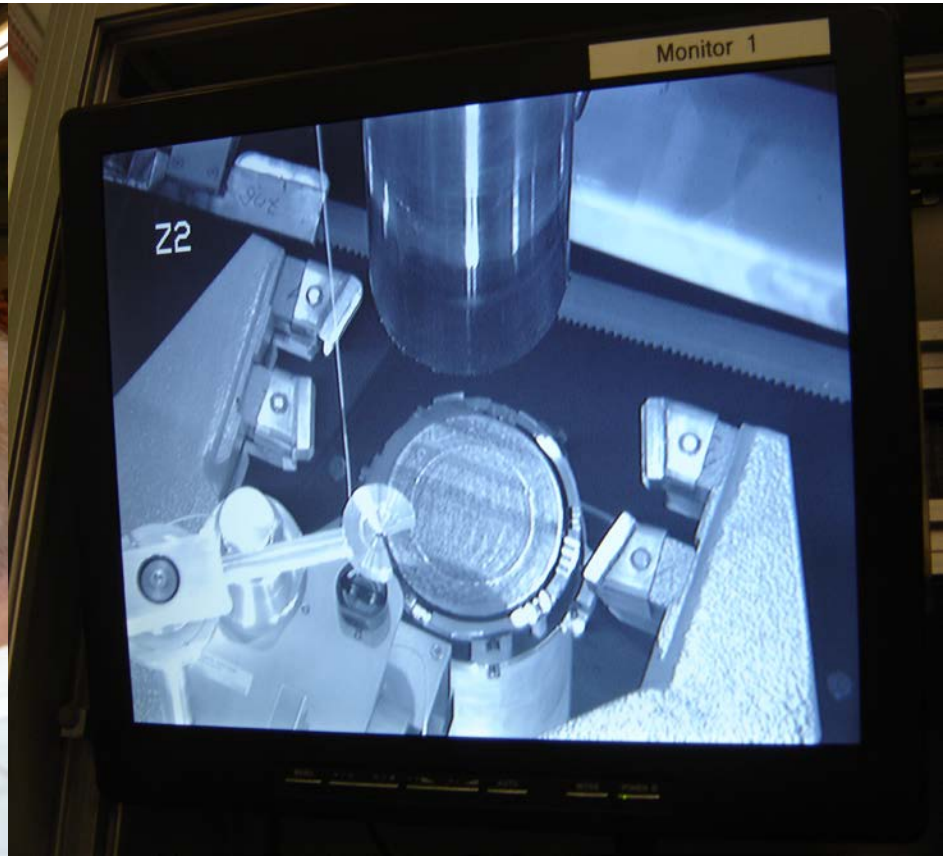
Cutting Plan



- In the first phase (1) the LLMC was cut.
- The LTE was re-screwed to the target and cut (2).
- Cutting times were on the order of 45 minutes.
- In the last phase the upper part of the target was cut.
- Cutting times increased to over 2 hours.

- No problems in phase 1 and 2.
- Strong degradation of the saw band while cutting upper (steel) part of the target.
- The nominal cutting speed was 5 mm/min, band velocity 15 m/min.

The first cut, July 15th 2009

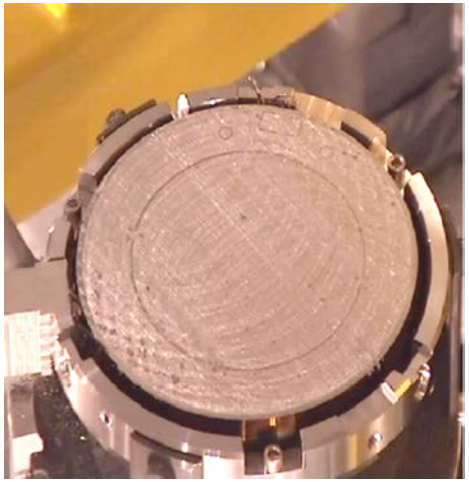


As the target had to be cut from bottom to top (hanging on a crane) the first cut was already one of the most important ones, the Beam Entrance Window.

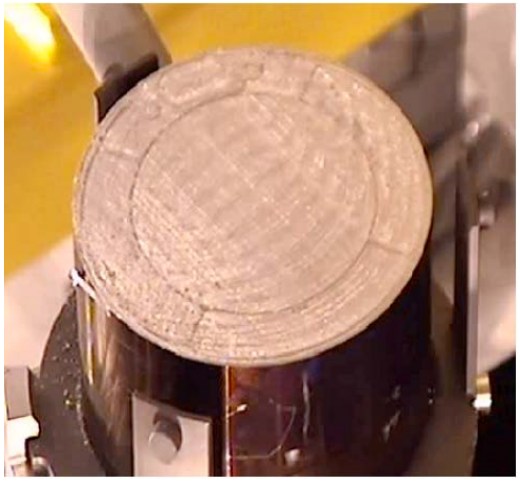
Samples - LLMC

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

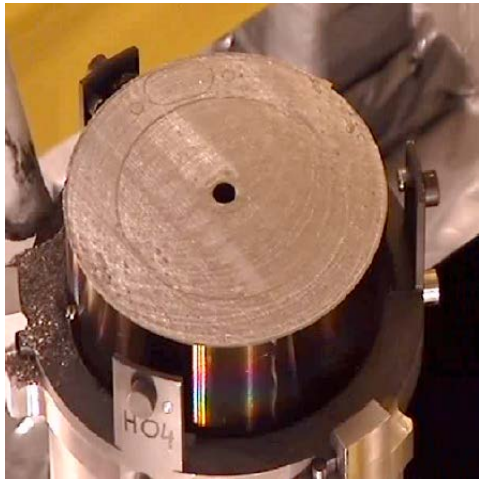
H02 – The Beam Entrance Window (BEW)

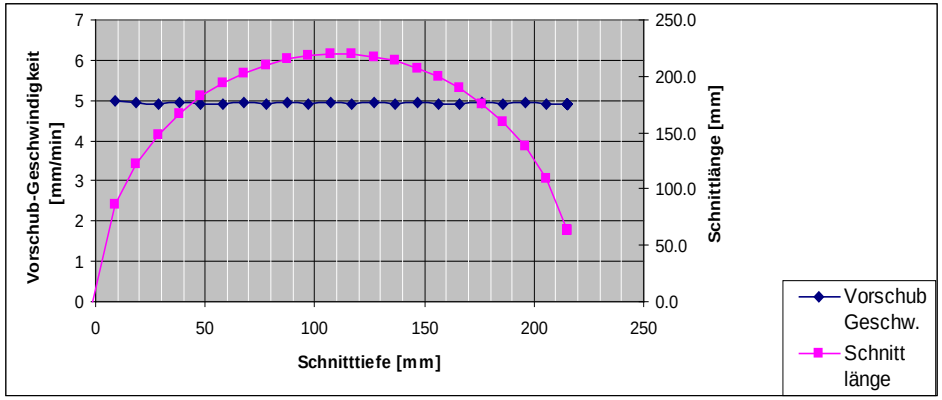


H03

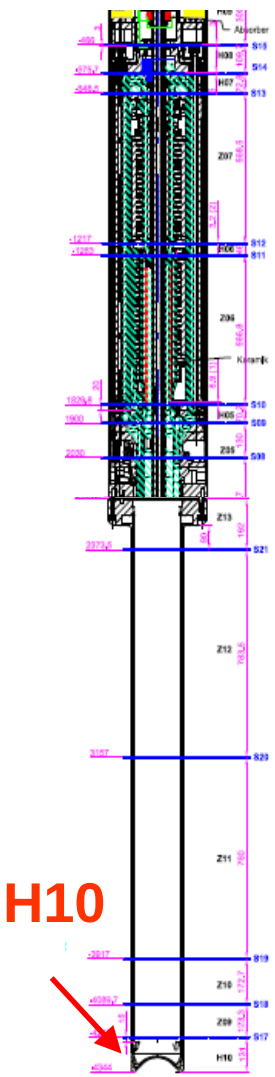


H04



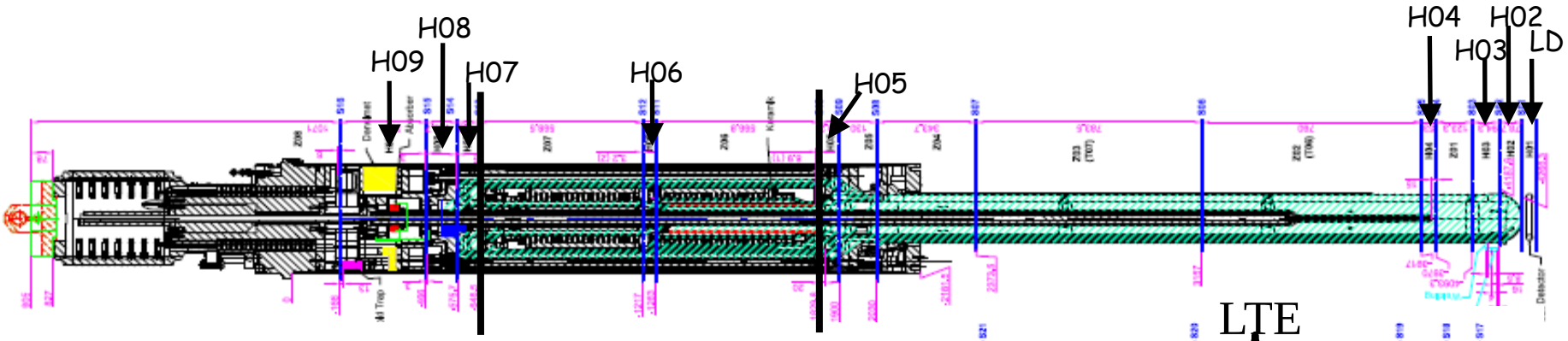


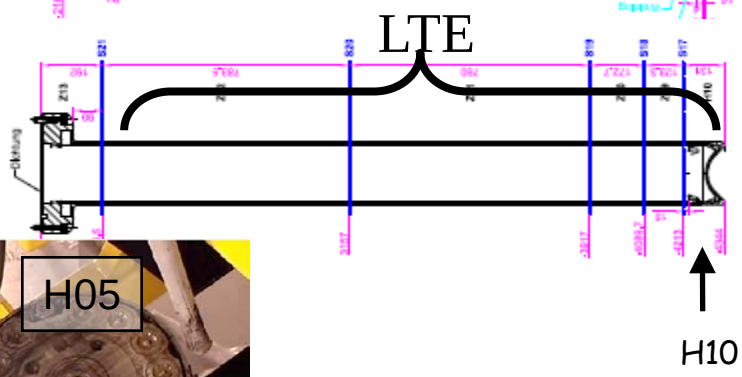
Cutting the LTE



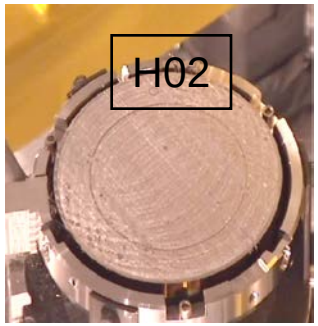
- After cutting the lowest part of the LTE (beam entrance region), sample piece H10, a metallic gleaming piece of material (Carbon) was found inside the AlMg3 shroud.
- The piece of material was loose, sitting in the center of inverted calotte (ø 5 – 7 cm, thickness ~ 2 cm).
- The side walls and bottom part of H10 were covered with black flaky smut (remains of oil that entered the insulation gap system).
- Together with some of the flaky smut the material piece has been put in a plastic bag and will be shipped to the Hot Laboratory for detailed analysis.

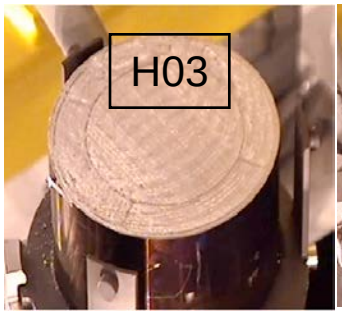
Cutting & Disposal of MEGAPIE at ZWILAG

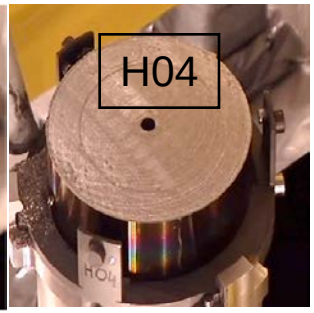


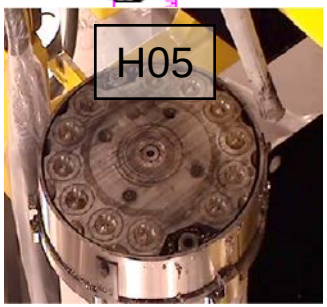


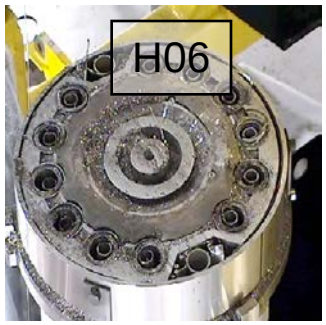
Cutting of MEGAPIE – Target Sample Pieces

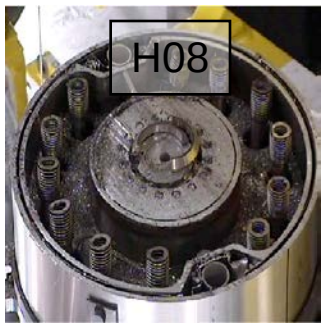


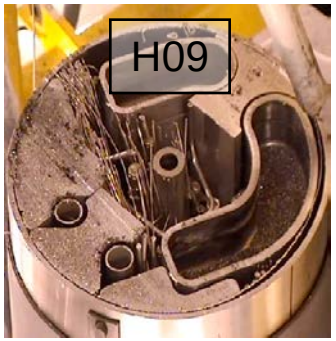












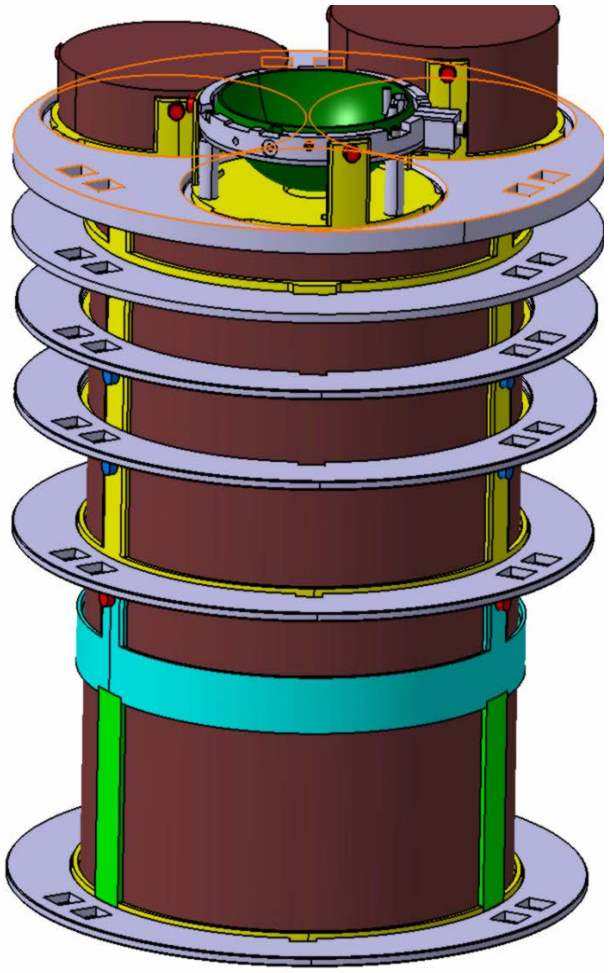
ZWILAG – Change of saw blade

Changing the saw blade in the separate «service cell»

Packing the Target sample pieces

- The target sample pieces were stacked in a barrel (B10)
- B10 was subsequently placed in a special transport container (TC3).
- TC3 was tested for tightness and currently was temporarily stored in ZWILAG, until the transfer to the Hot Laboratory of PSI.

B10



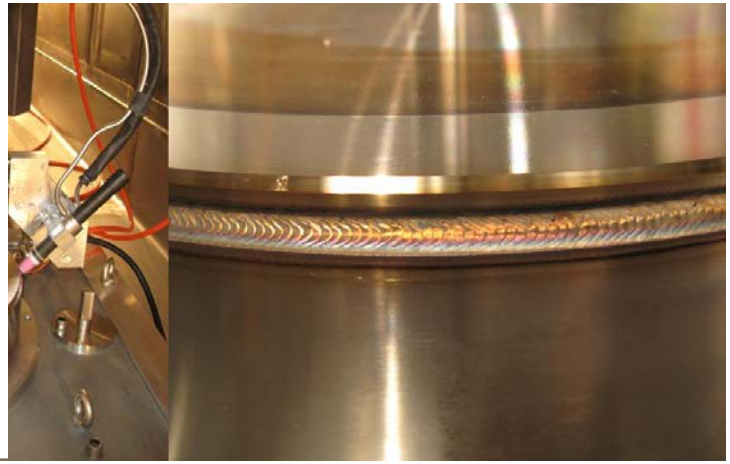
TC3

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.

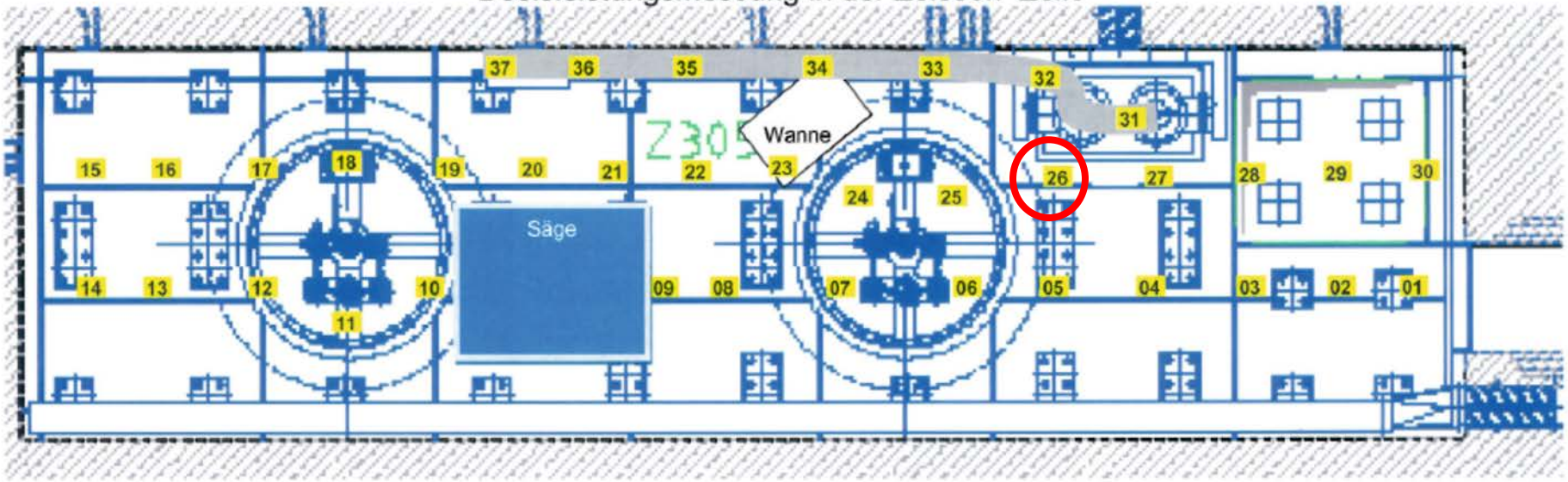
TC2

Welding device



Status of ZWILAG HC after dismantling

Dosisleistungsmessung in der Zeissen Zelle



Messpunkt	Messung (µSv/h)	Messpunkt	Messung (µSv/h)	Messpunkt	Messung (µSv/h)	Messpunkt	Messung (µSv/h)	DL Lüftungsschlauch in 5cm Abstand		DL Rundfilter in 5cm Abstand	
Nr.1	12	Nr.9	42	Nr.17	9	Nr.25	88	Messpunkt	Messung (µSv/h)		
Nr.2	10	Nr.10	27	Nr.18	4	Nr.26	230	Nr.31	128	240µSv/h	
Nr.3	18	Nr.11	17	Nr.19	10	Nr.27	80	Nr.32	124	800 µSv/h	
Nr.4	30	Nr.12	8	Nr.20	13	Nr.28	25	Nr.33	89		
Nr.5	40	Nr.13	5	Nr.21	25	Nr.29	13	Nr.34	122	650 µSv/h	
Nr.6	37	Nr.14	3	Nr.22	32	Nr.30	5	Nr.35	131		
Nr.7	68	Nr.15	5	Nr.23	38			Nr.36	115		
Nr.8	76	Nr.16	10	Nr.24	35			Nr.37	90		

Bemerkung: Gemessene DL nach dem entfernen der Quellen in der Heissen Zelle.

Datum: 06.10.2009

Visum:

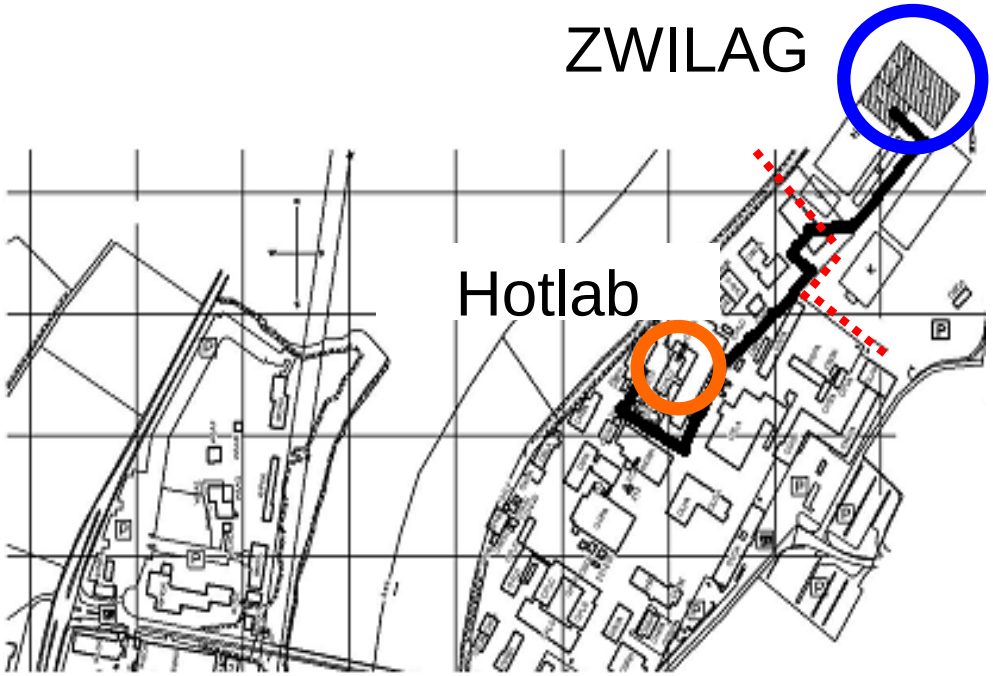
TRANSPORT

TRANSPORT OF SAMPLES
PIECES OF MEGAPIE

TC3

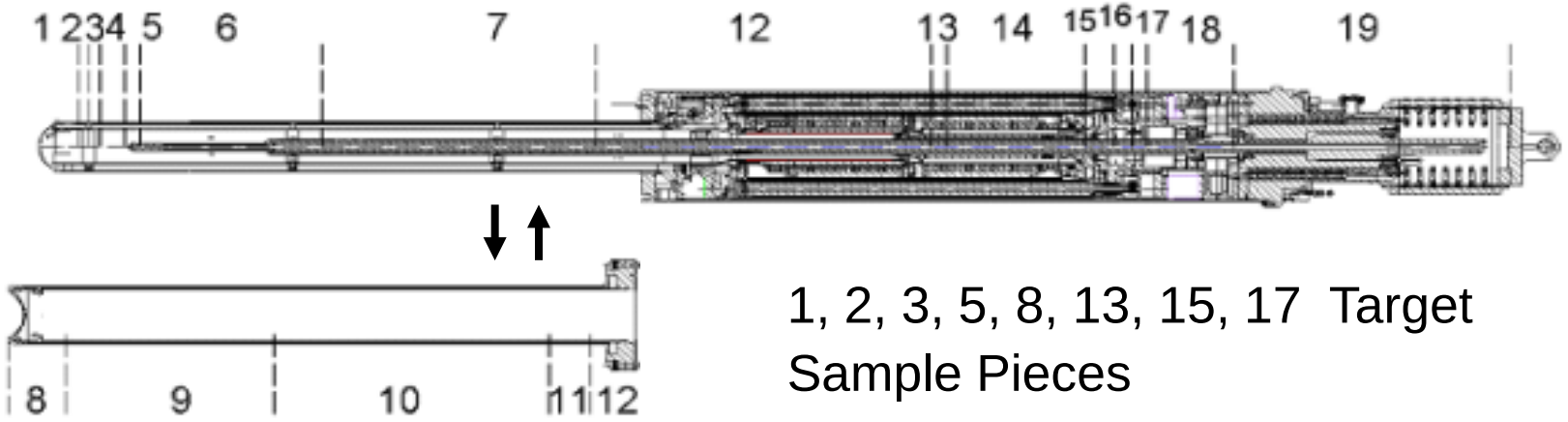
ZWILAG to HOT CELL
PSI EAST

TRANSPORT



AFTER CUTTING in ZWILAG

- Transport of sample material in TC3
- ADR/SDR Transport with special agreement of HSK
- Directly over border via BZL hall
- ~15 % of Target activity ➔ ~ 500 A2



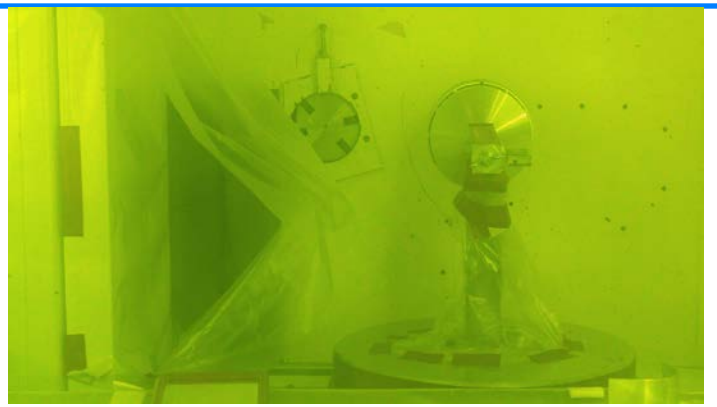
1, 2, 3, 5, 8, 13, 15, 17 Target Sample Pieces

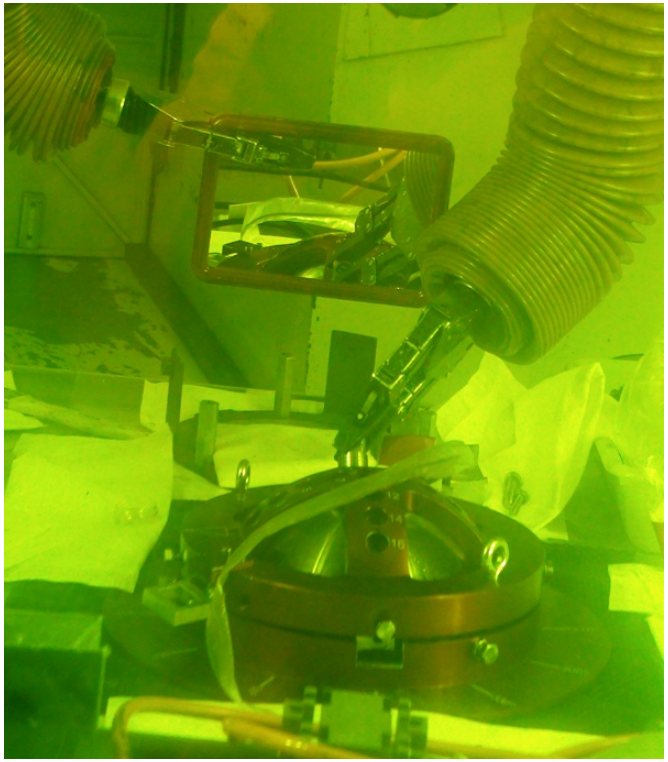
MEGAPIE PIE Sample Preparation

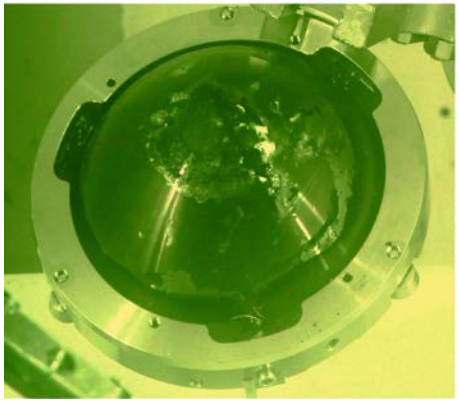
- Safety Analysis of each Handling Step and Clearance from the Safety Authorities (mainly Swiss Nuclear Safety Inspectorate, ENSI)
- Non Destructive Tests (NDT)
  - Determination of the Time-Averaged Proton Beam Profile
  - Visual Inspection
  - Analysis of Black/Whitish Material in the BEW Region
  - Measurement of Thickness of T91 BEW (Corrosion Effects)
- LBE (and Absorber Foils) Sample Taking & Analysis
- Segregation of LBE and Structural Material (Steel) Parts
- First Conditioning of Waste in the Hot Laboratory
- Raw Cutting of Structural Material Sample Pieces
- Cleaning of Raw Cut Structural Material Sample Pieces
  - Mechanical Cleaning
  - Chemical Cleaning
- Electrical Discharge Machining (EDM) of 82 PIE Sample Groups
- Packing & Transport of PIE Sample Groups to Partner Laboratories
- Preparation of Structural Material Samples with LBE Layer
- Final Waste Disposal and Cleaning of the Hot Cell(s)

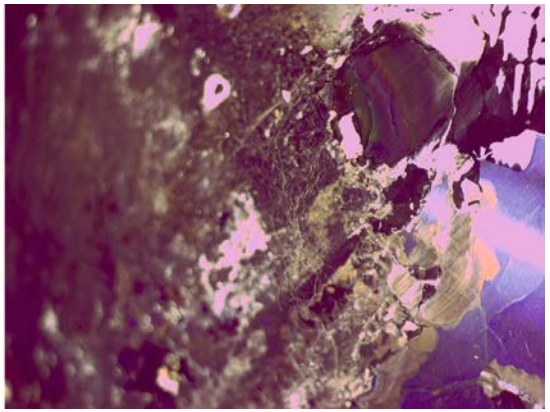
Non Destructive Testing

- Gamma Mapping of the AlMg3 safety shroud (LTE)
- Investigation of material sticking on the BEW (OM, SEM, EDX)
- Ultrasonic thickness measurement of the BEW









Talk of Yong Dai @ TRM Meeting

LBE Sample Taking & Analysis

Core drilling tool

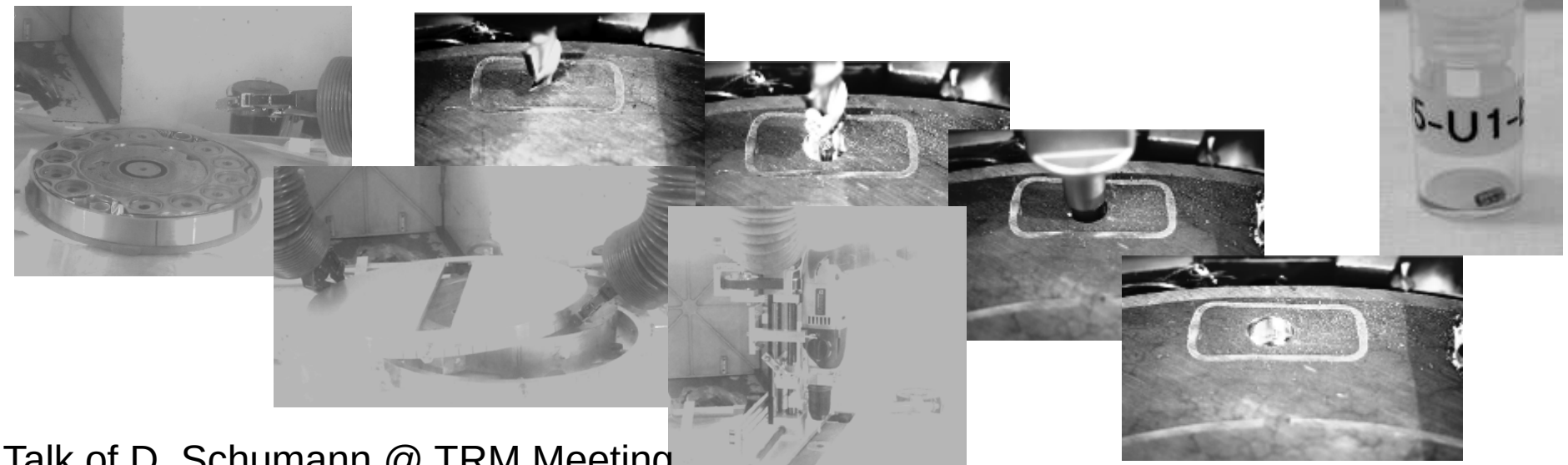
Sample breaking device

LBE Sample Sizes

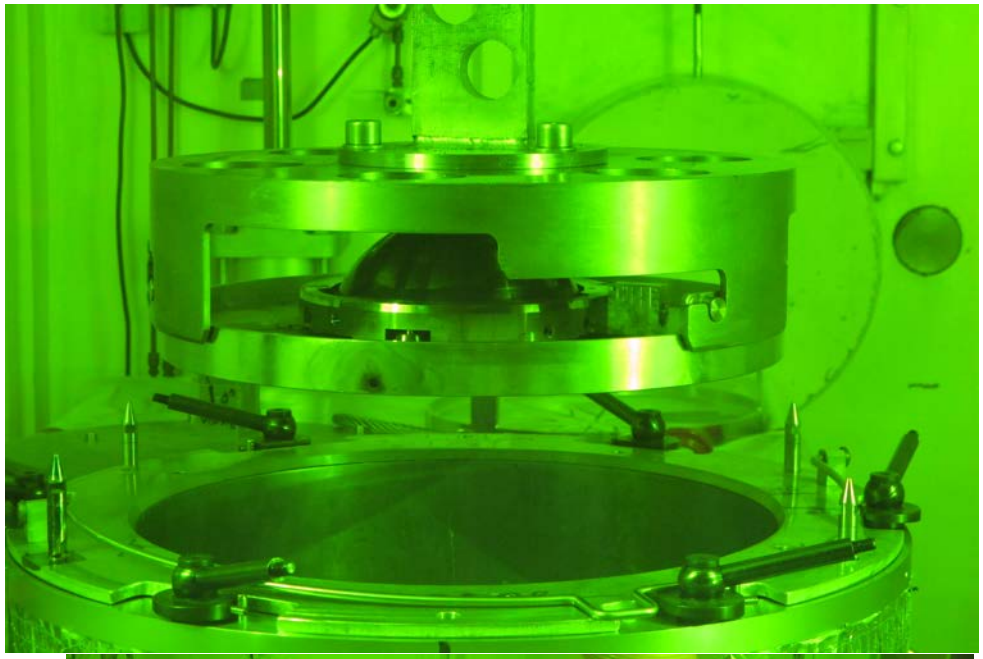
Length 5 mm
Diameter 1.5 – 2.0 mm

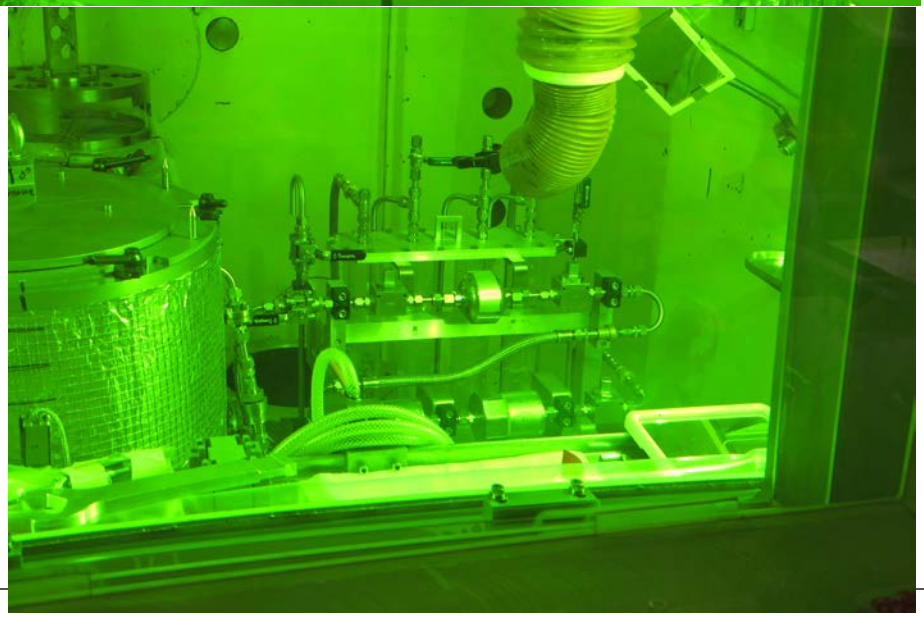
Dose rates 5 – 10 µSv/h
in 10 cm distance

Cold test (above) + Sample taking in Hotcell (below)

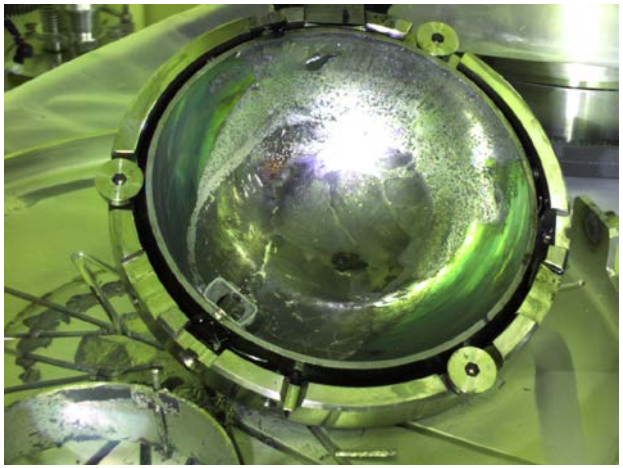


LBE melting – example H02

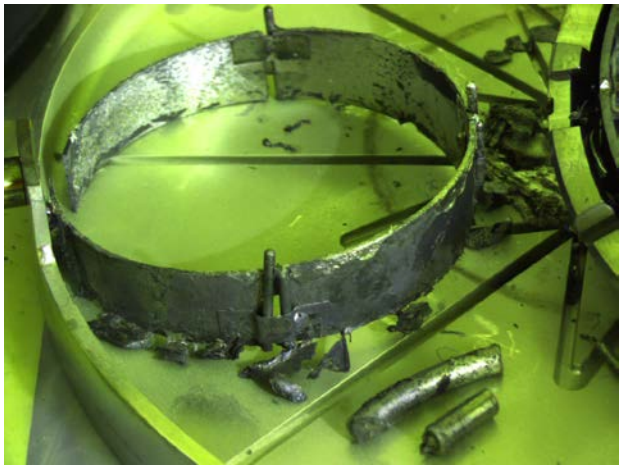




H02 BEW (T91)



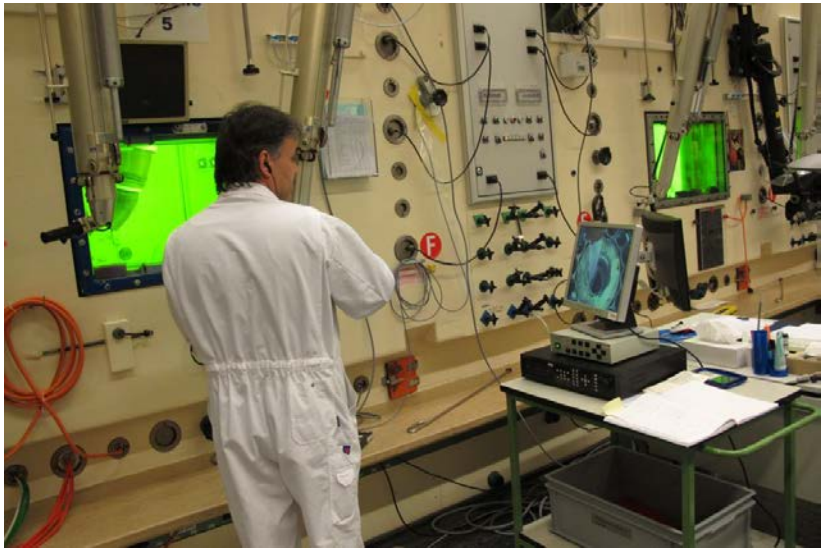
H02 FGT (316L)

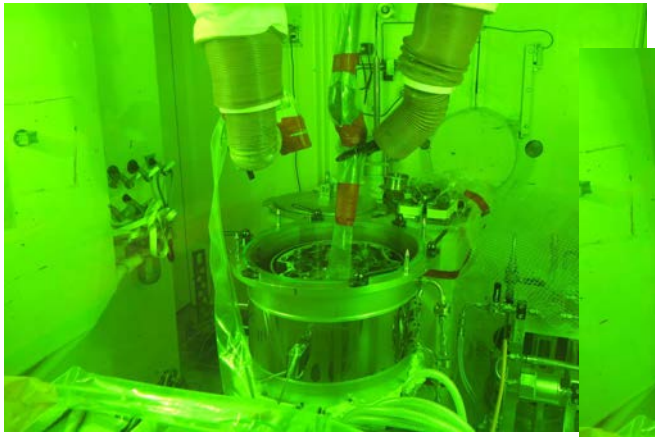


1st Waste conditioning - Cementation of oven

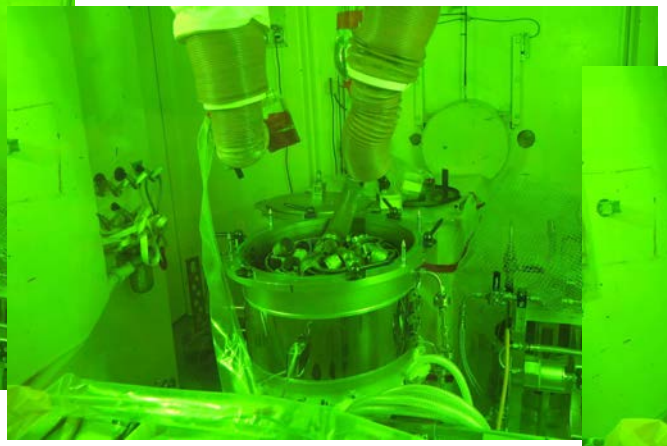
Cement filling from top of the cell

Control and conduct from front window of the cell



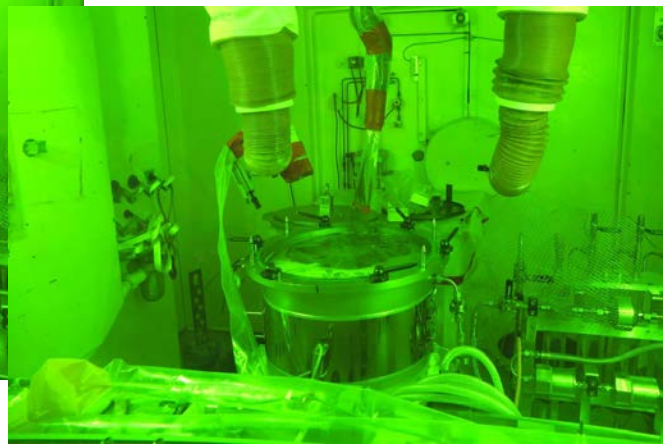


Filling the LBE container

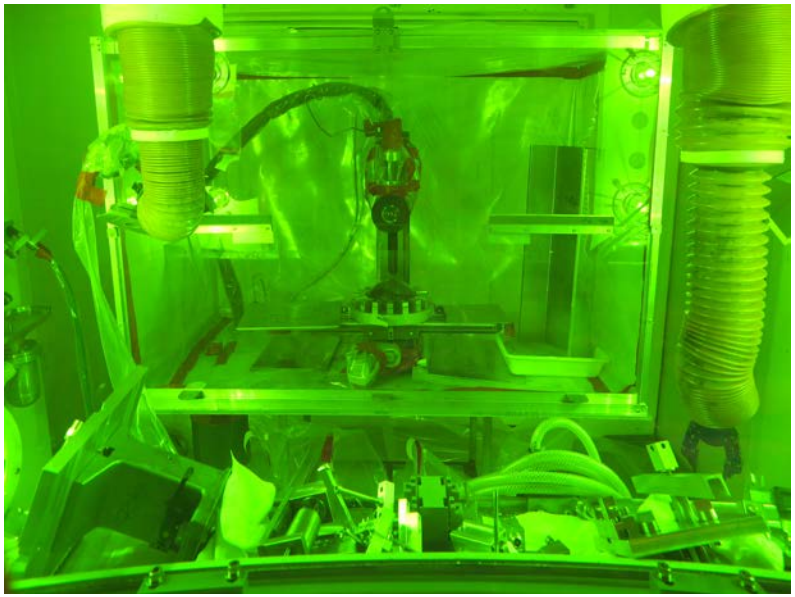


Adding highly active waste pieces

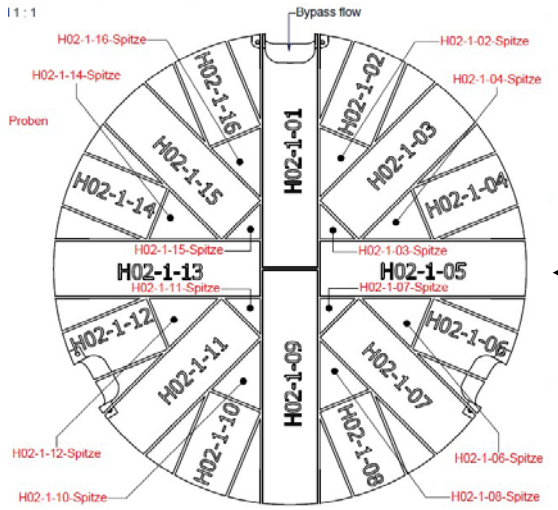
Filling up the oven with cement

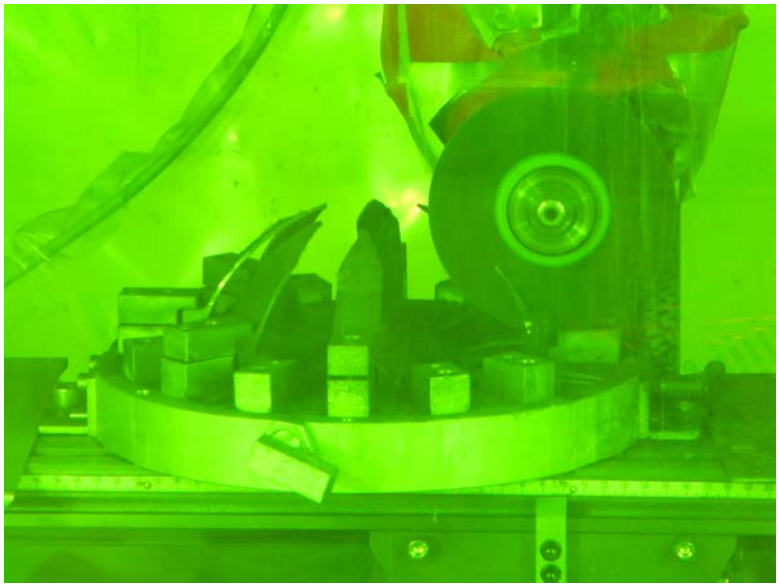


Raw cutting of PIE samples



- EDM cutting & cleaning not easily feasible with the (large) target sample pieces.
- Cut H02 (beam entrance window,BEW), H03-1 (lower liquid metal container, LLMC), H03-2 (flow guide tube, FGT), H04-1 (LLMC) and H04-2 (FGT) with grinder disc.
- Cutting done in substeps to minimize temperature rise. Grinder discs exchanged after cutting 1 sample piece.

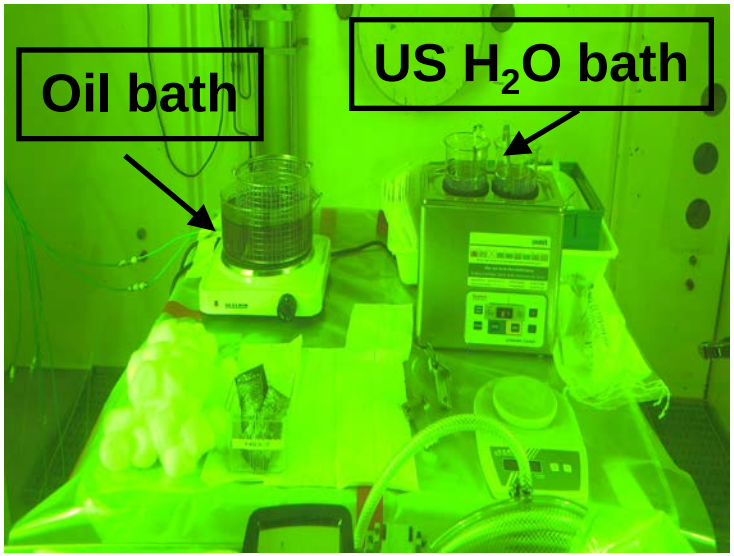


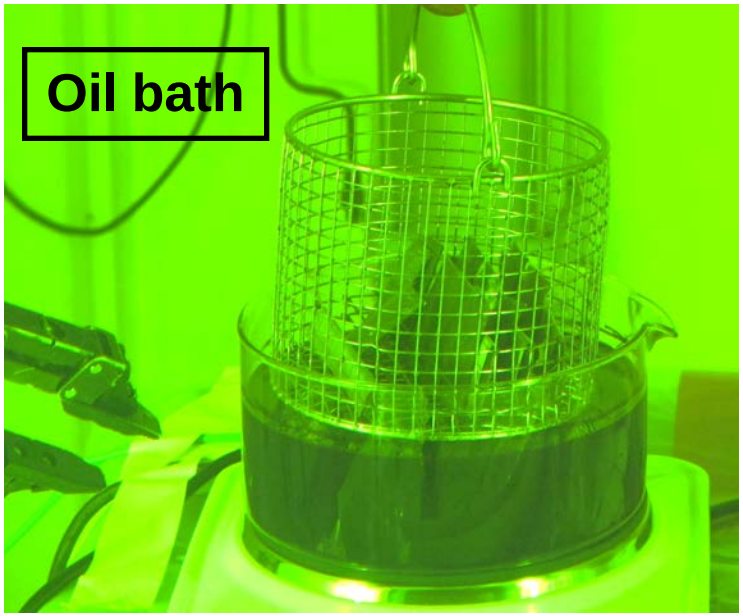


Raw cutting scheme of the BEW into 28 pieces

Cleaning raw cut sample pieces

- The original cleaning scheme of raw cut sample pieces is a 4-step process proposed by Yong Dai
  - ‚Mechanical cleaning' with heated oil (UCON-HTF @ 190° C max.)
  - Ultrasonic bath in de-ionized H_2O
  - ‚Chemical cleaning' in 5 molare HNO_3
  - Ultrasonic bath in de-ionized H_2O
- Measurements after step 4 showed still ‚high' removable (α-) activity
- Tests to clean with EDTA (**E**thylen**d**iamin-**t**etra-**a**cetic di-sodium-salt) instead of H_2O. Not significantly better, but disposal more complicated → cleaning continued with H_2O
- 2 – 4 additional cleaning steps in ultrasonic H_2O bath per target sample piece

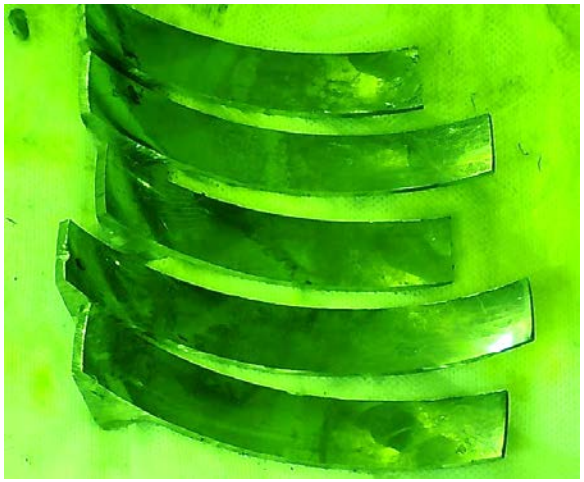




Cleaning raw cut sample pieces

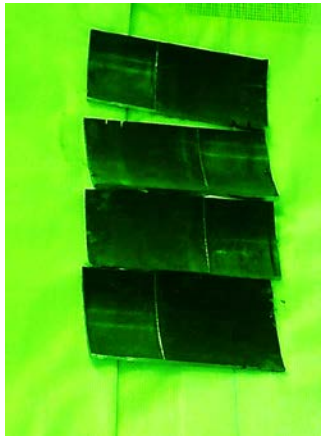
H02 raw cut samples before oil bath

H02 raw cut samples after oil bath



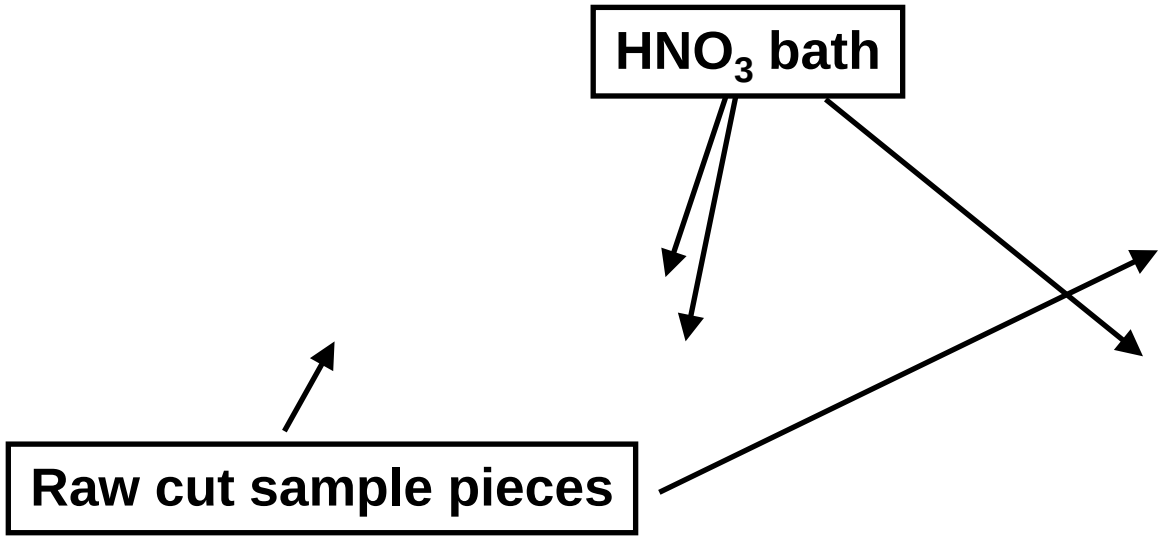
- Each raw cut sample piece at least put twice (for 5 – 10 minutes) into the oil bath (UCON-HTF, Poly-ethylene glycol).
- Sticking LBE wiped off with tissue.

H03-1 before oil bath



H03-1 after oil bath

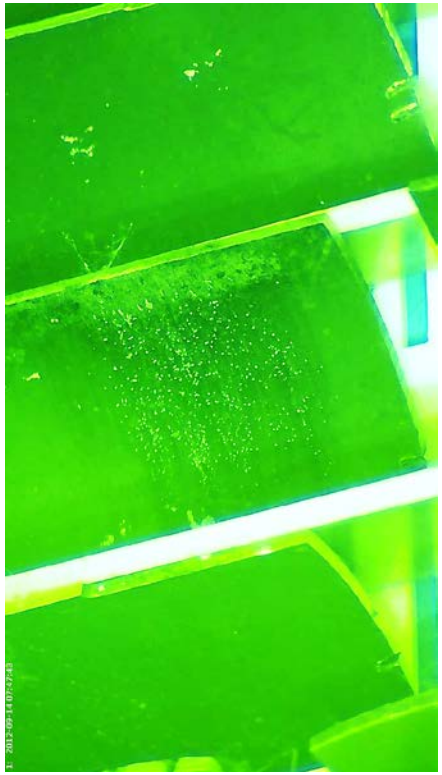
Cleaning raw cut sample pieces



- Raw cut samples remained in HNO_3 bath for 3 minutes 30 seconds.
- US H_2O baths followed.

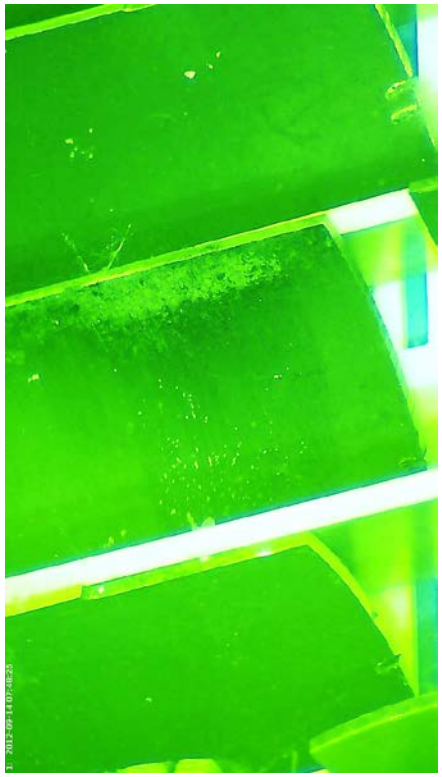
Time evolution in HNO_3 acid

After 1 minute in HNO_3



Gravity

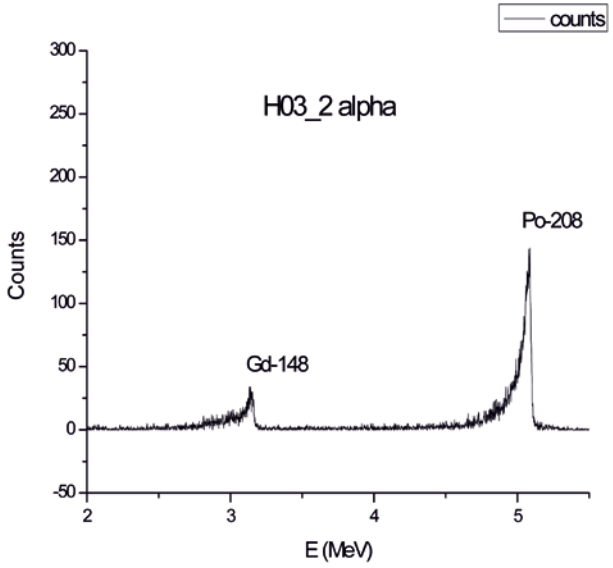
After 2 minutes in HNO_3

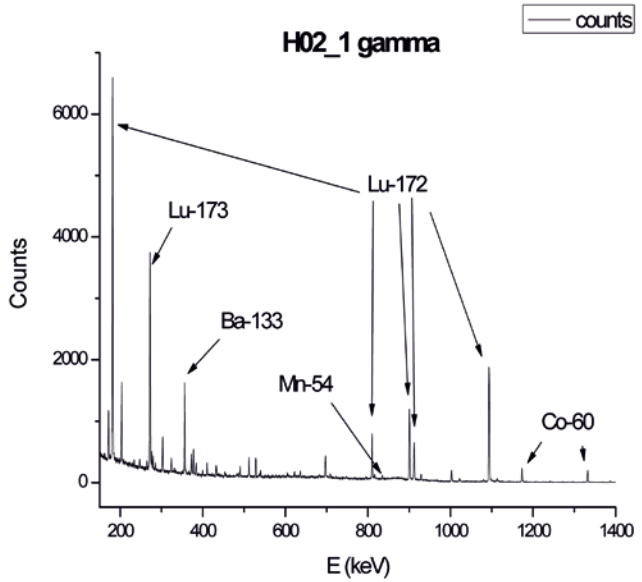


LBE disolved in the 5 molare HNO_3 acid and moves down the raw cut samples.

Cleaning raw cut sample pieces

α- and γ-spectra of wipe test taken from H02/03 raw cut sample

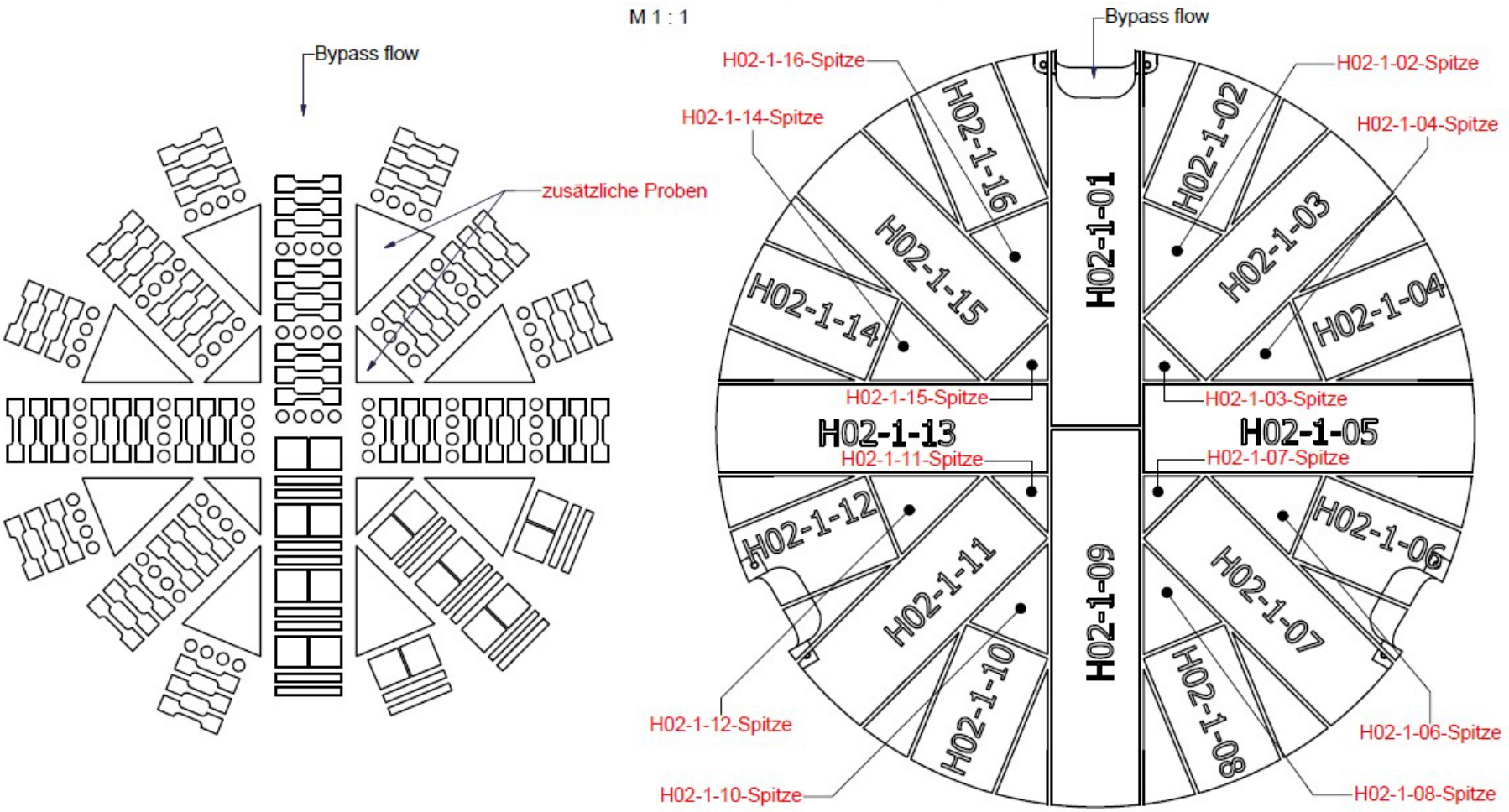




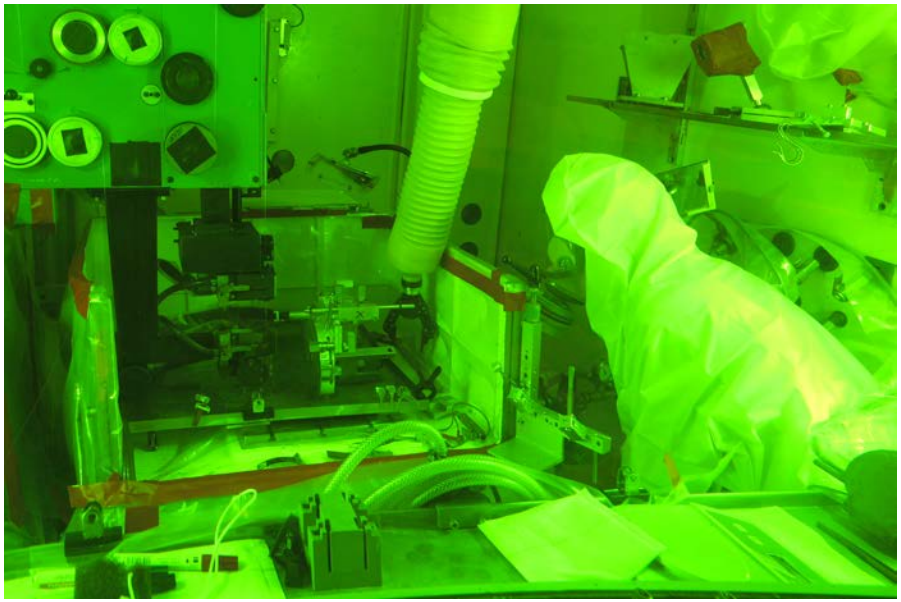
- After cleaning procedure (mechanical cleaning, US bath, chemical cleaning, US bath) α-activity was still too high to be accepted by some of partner laboratories (especially LANL).
- More cleaning (➔ trial with EDTA ➔ same efficiency as H_2O) ➔ further cleaning with H_2O
- 2 – 4 additional cleaning sessions with de-ionized H_2O

EDM cutting

EDM cutting plan for the T91 BEW



EDM Cutting



EDM type: AGIE 250

Technical data:
Dimensions : 2000x1290x1300mm
Weight : 1350kg

Cutting samples without LBE

- Set-up of the EDM machine in hot cell → 5 weeks
- Inactive cutting tests performed in hot cell, before cutting active raw cut sample pieces.
- Only then active cutting.

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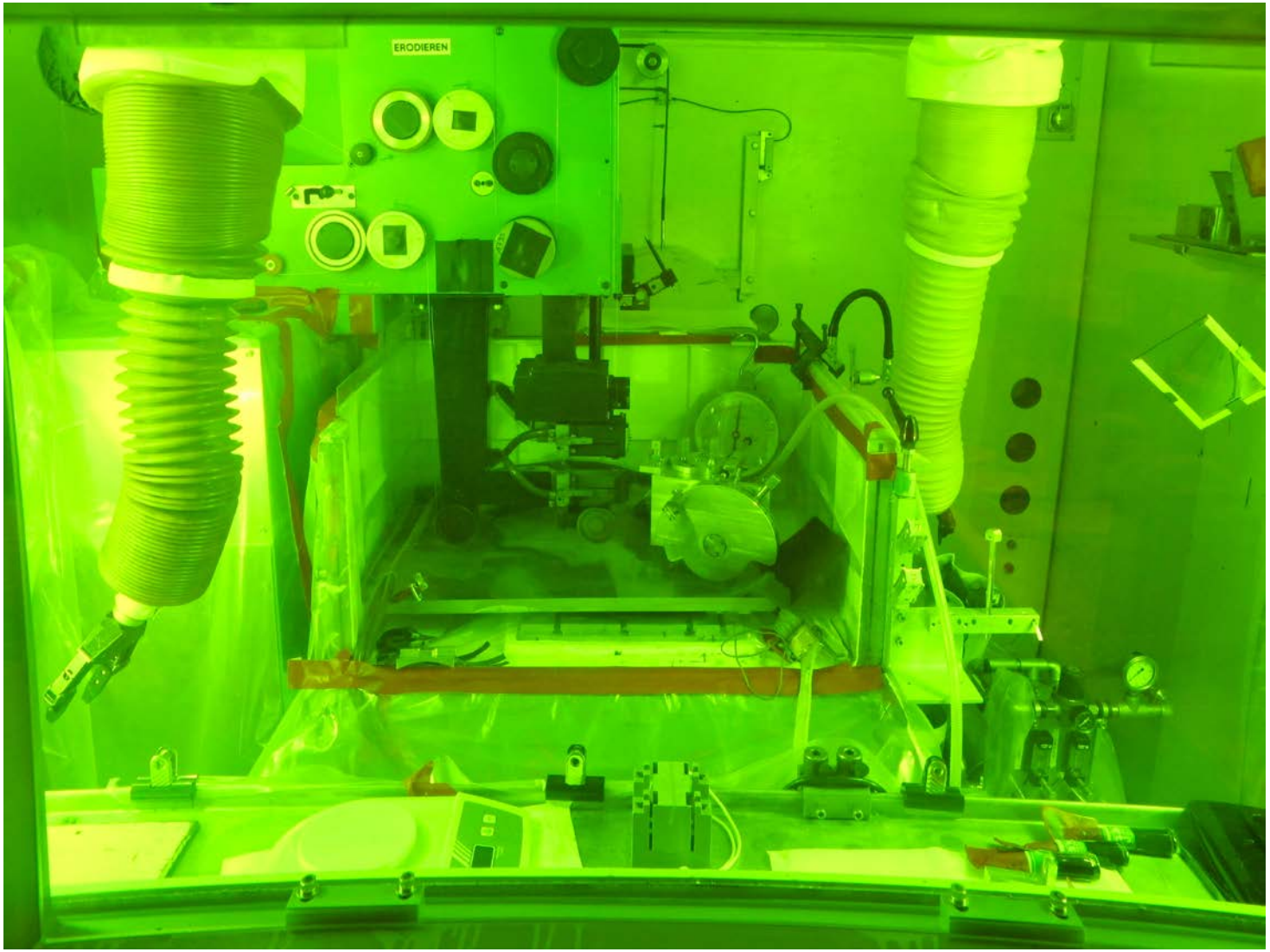
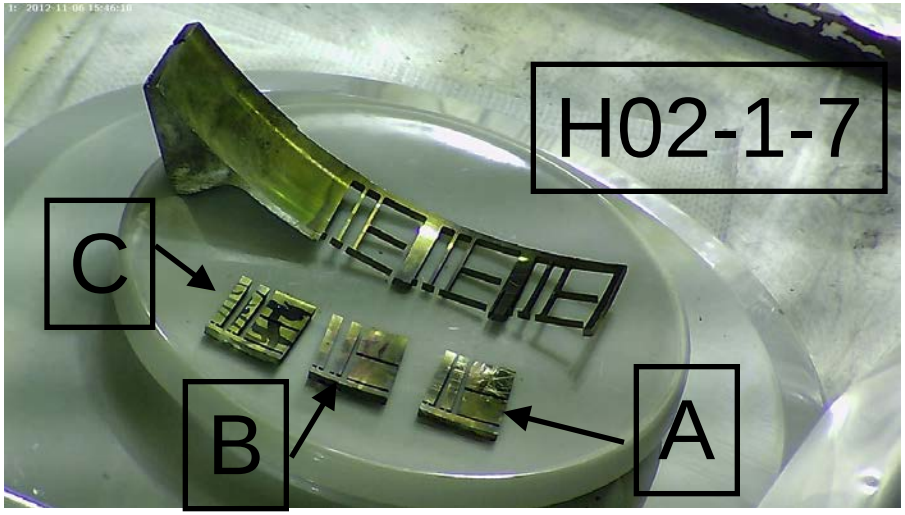
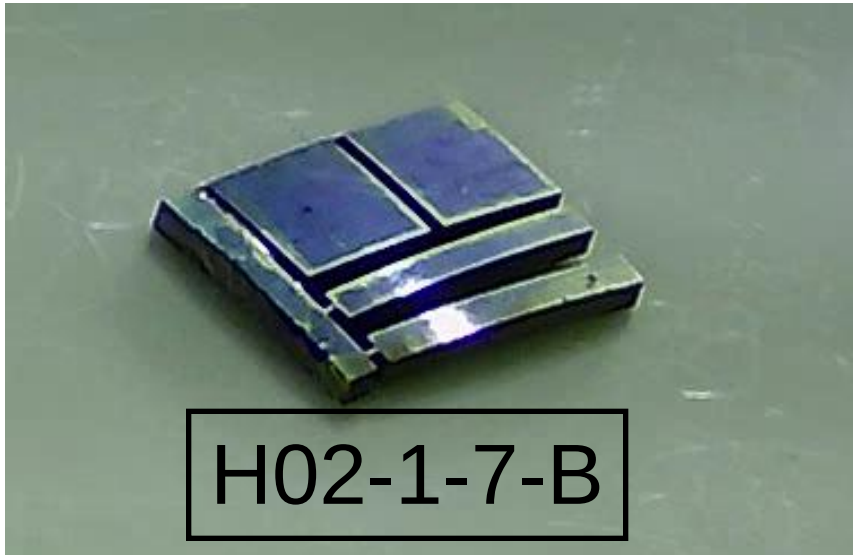
EDM Cutting



EDM Cutting





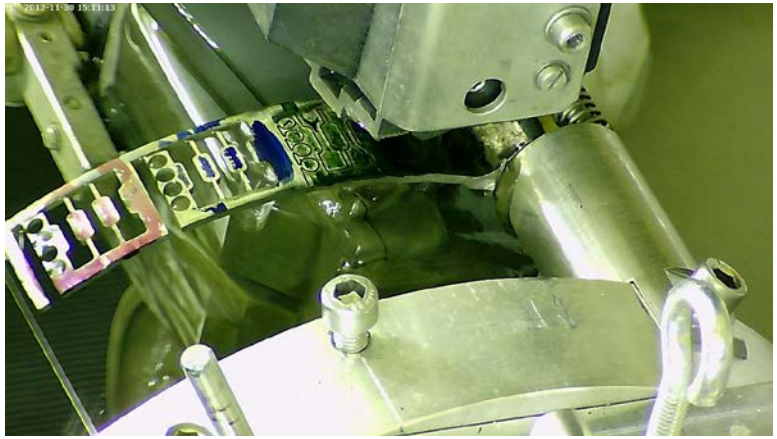
- H02-1-7 was successfully cut on 5th of November 2012.
- While cutting the sample group H02-1-7-B the wire of the EDM broke. Reason unclear.
- Cutting speed: maximum 2 - 3 sample groups per day.

EDM Cutting – H02-1

H02-1-02

H02-1-05

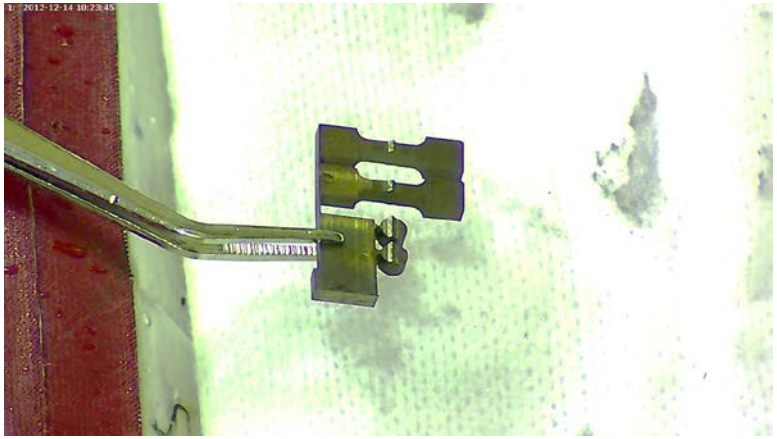
H02-1-13



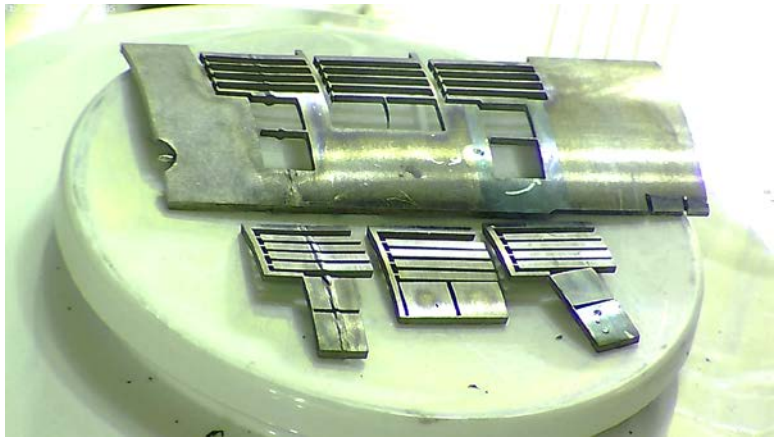
EDM cutting – H03-1/2

H03-1-01-A

H03-1-01-A

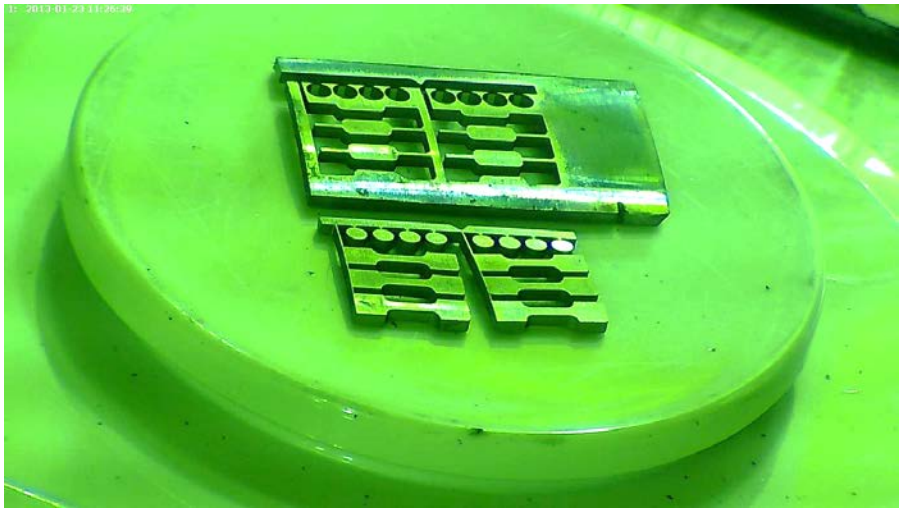


H03-2-B2

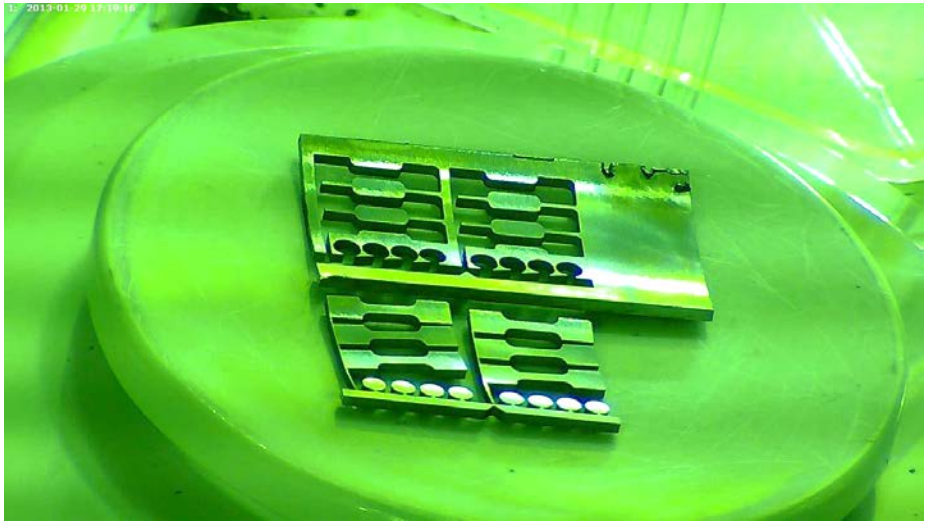


EDM Cutting – H04-1/2

H04-1-A

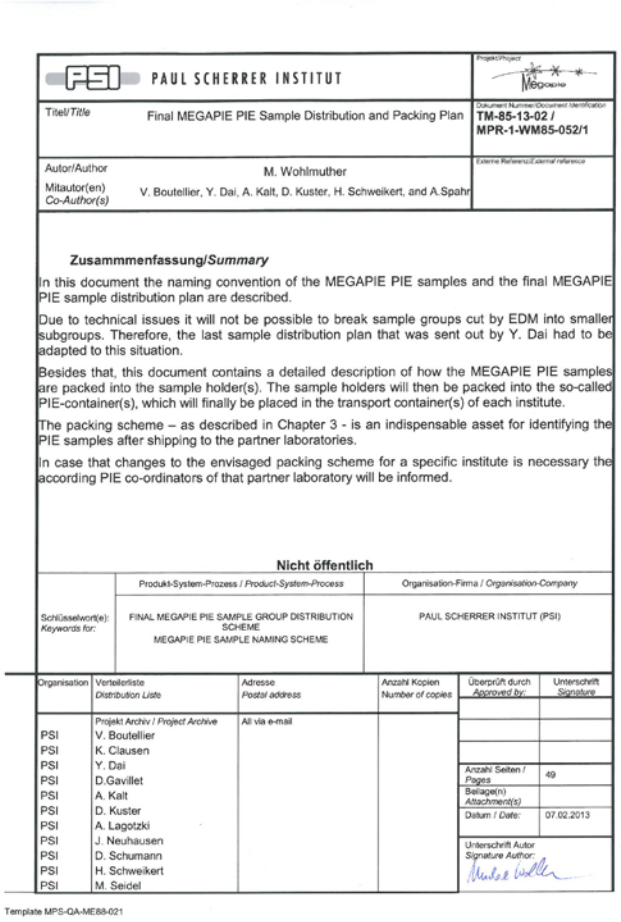


H04-2-A



- LBE samples have been taken from the different target sample pieces to investigate the behavior of radionucildes in MEGAPIE.
- All 82 sample groups, in total 793 samples without LBE on the surface have successfully cut.
- In addition a number of samples with LBE left on their surface were machined.

Sample naming and final distribution plan



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Projekt/Project: MEGAPIE

Titel/Title	Final MEGAPIE PIE Sample Distribution and Packing Plan
Dokument Nummer/Document Identification	TM-85-13-02 / MPR-1-WM85-052/1
Autor/Author	M. Wohlmuther
Mitautor(en) Co-Author(s)	V. Boutellier, Y. Dai, A. Kalt, D. Kuster, H. Schweikert, and A.Spahr
Externe Referenz/External reference	

Zusammmenfassung/*Summary*

In this document the naming convention of the MEGAPIE PIE samples and the final MEGAPIE PIE sample distribution plan are described.

Due to technical issues it will not be possible to break sample groups cut by EDM into smaller subgroups. Therefore, the last sample distribution plan that was sent out by Y. Dai had to be adapted to this situation.

Besides that, this document contains a detailed description of how the MEGAPIE PIE samples are packed into the sample holder(s). The sample holders will then be packed into the so-called PIE-container(s), which will finally be placed in the transport container(s) of each institute.

The packing scheme – as described in Chapter 3 - is an indispensable asset for identifying the PIE samples after shipping to the partner laboratories.

In case that changes to the envisaged packing scheme for a specific institute is necessary the according PIE co-ordinators of that partner laboratory will be informed.

Nicht öffentlich

Schlüsselwort(e): Keywords for:	Produkt-System-Prozess / Product-System-Process	Organisation-Firma / Organisation-Company
	FINAL MEGAPIE PIE SAMPLE GROUP DISTRIBUTION SCHEME MEGAPIE PIE SAMPLE NAMING SCHEME	PAUL SCHERRER INSTITUT (PSI)

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Überprüft durch Approved by:	Unterschrift Signature
Anzahl Seiten / Pages	49
Beilage(n) Attachment(s)	
Datum / Date:	07.02.2013
Unterschrift Autor Signature Author:	

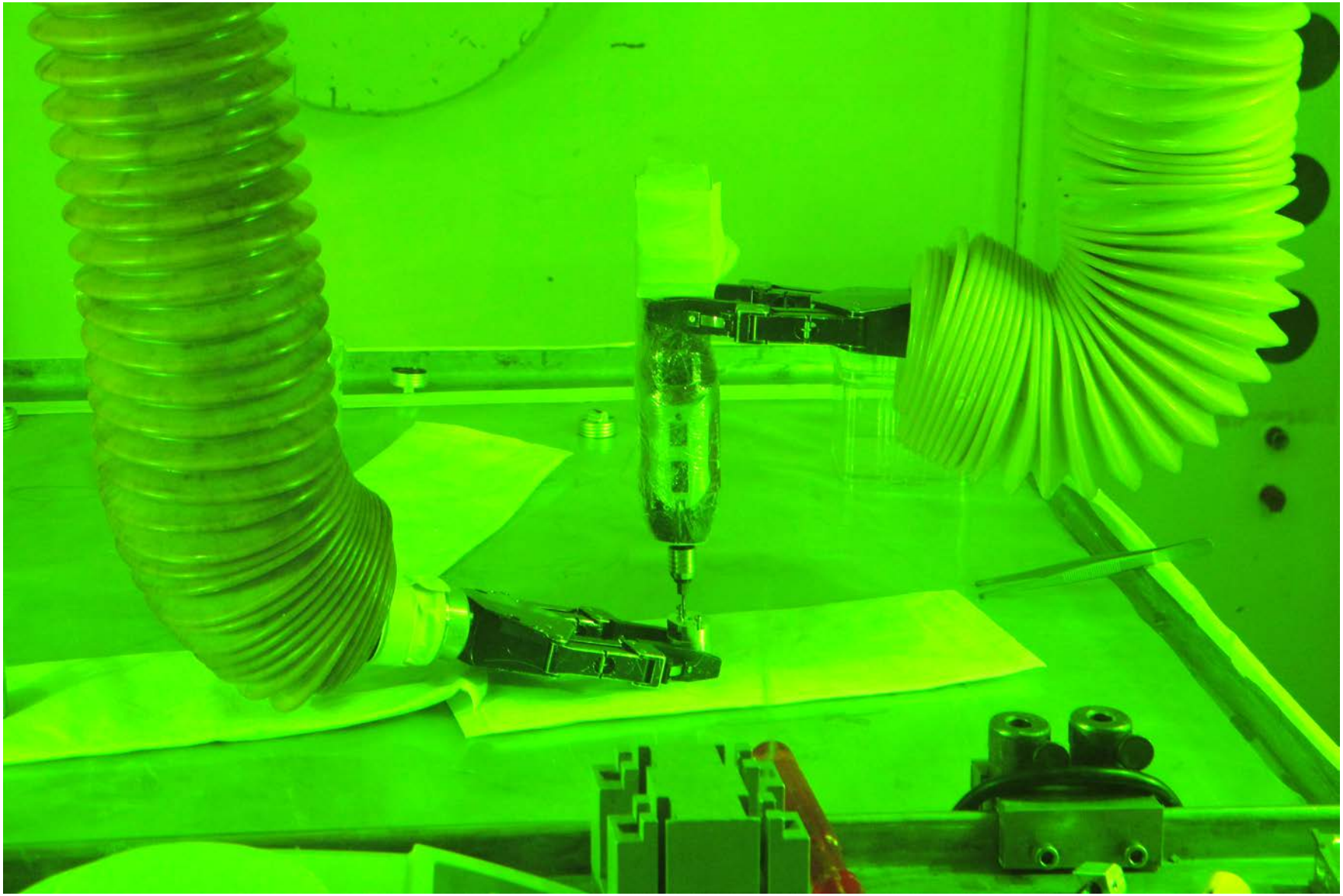
Template MPS-QA-ME88-021

A document with the sample naming scheme and a detailed final distribution plan of all sample groups has been issued and distributed – MPR-1-WM85-052/1.

A revised version (MPR-1-WM85-052/2) has been issued together with the final document about all packed/shipped sample groups – MPR-1-WM85-053/1.

Only minor adjustments were necessary during packing.

PIE sample Packing and Transport



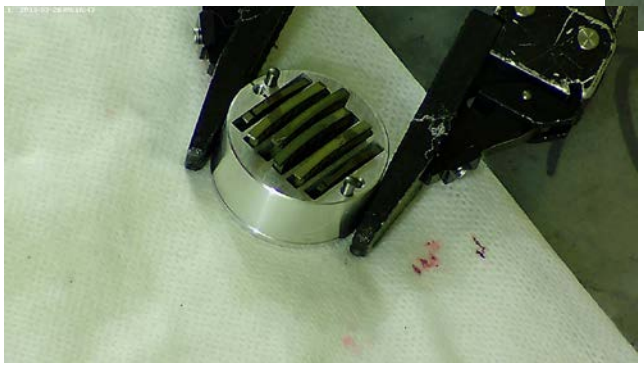
PIE sample Packing and Transport

CEA03

JAEA01

KIT01

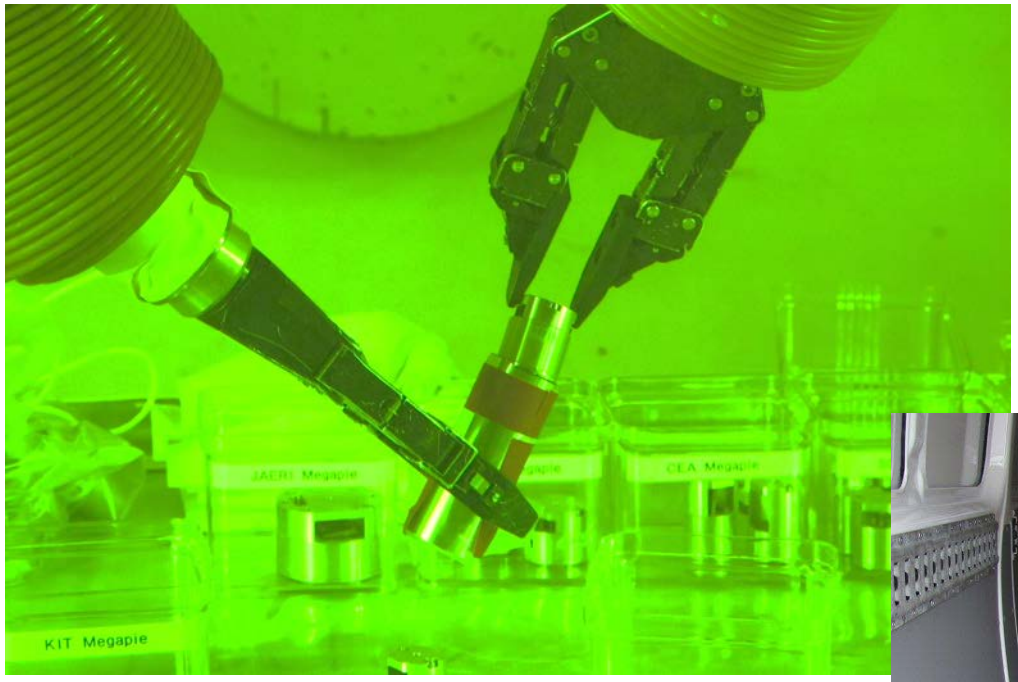
LANL02



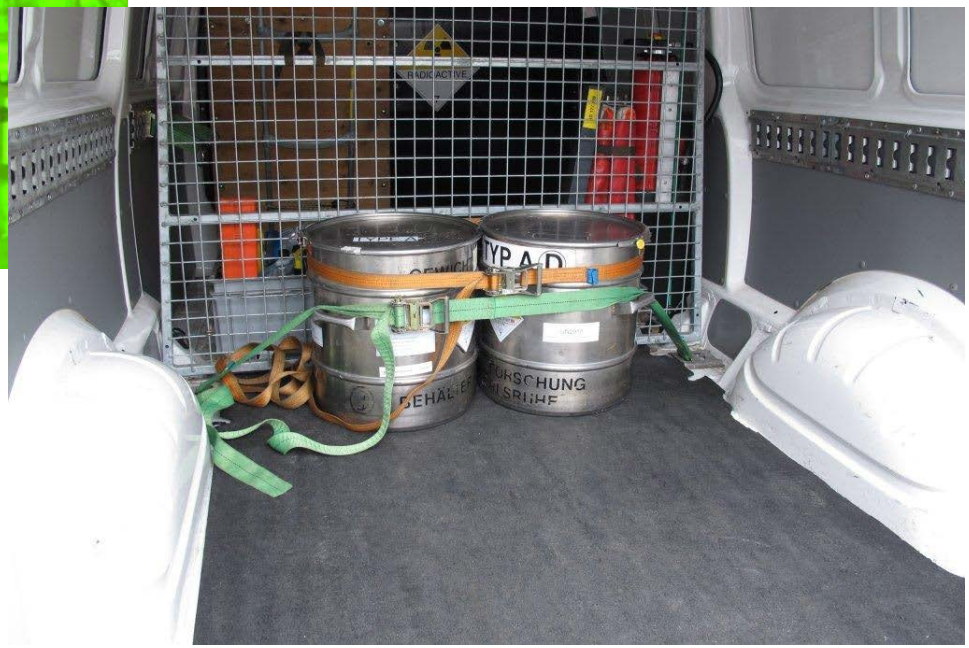
SCK04

PIE sample Packing and Transport

Sample holders put into sample containers



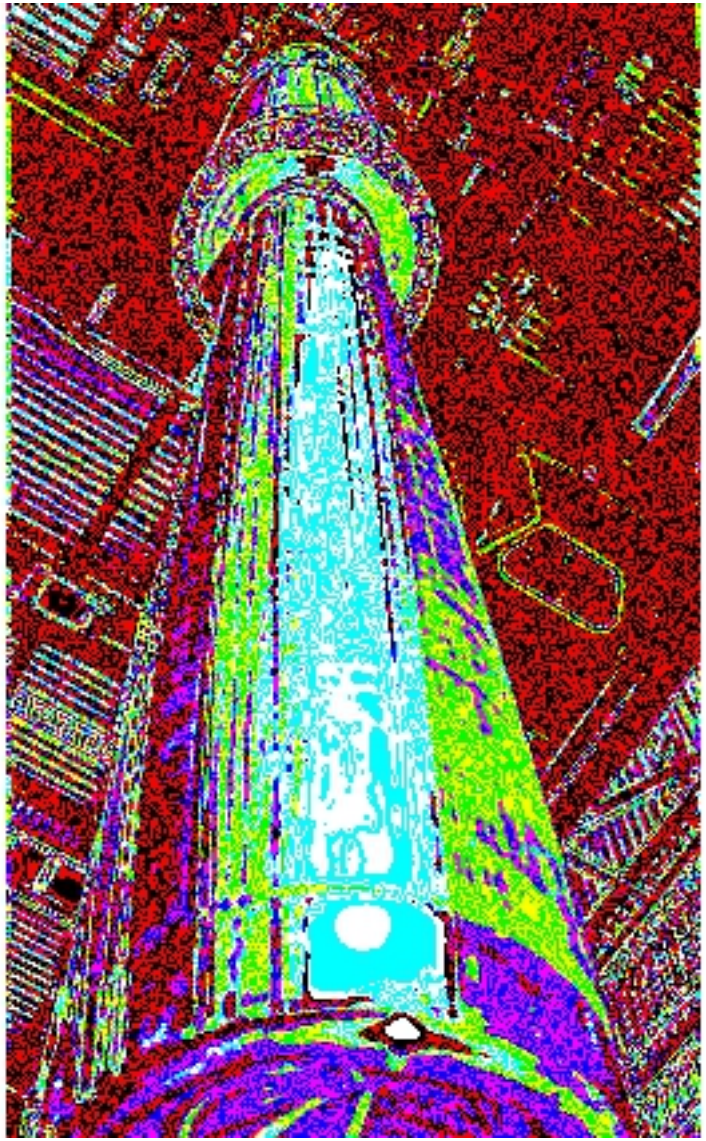
The first PIE sample transport - to KIT - left PSI on April 4th 2013.



Summary

- The first phase of dismantling in ZWILAG was performed without any problems. All cuts were done with an accuracy of ~ 1 mm.
- The transports from PSI to ZWILAG and back to the PSI Hot Laboratory were successful.
- The PIE sample preparation in the Hot Laboratory at PSI produced 783 different samples.
- CEA (71 samples), JAEA (67 samples), KIT (83 samples), LANL (71 samples) and SCK·CEN (80 samples) received 47% of all (LBE cleaned) samples in spring 2013.
- The PIE sample analysis is ongoing – the results are very promissing.

The whole Post Irradiation Phase of the MEGAPIE project was a big success thanks to the dedication and commitment of many colleagues at PSI and all around the world!



YES WE CAN!

PAUL SCHERRER INSTITUT

PSI

Thank you for your attention.