Wir schaffen Wissen – heute für morgen

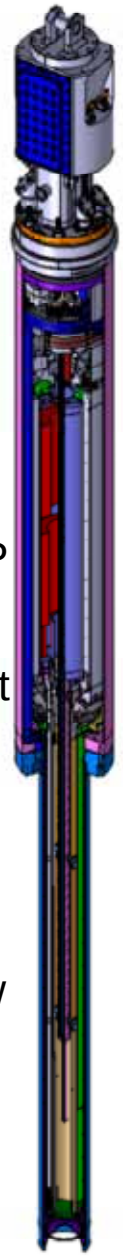
Feedback for Instrumentation & Control

(safety, operations and experiment)

MEGAPIE Final TRM, Bregenz, October 2014

K. Thomsen, S. Dementjevs

Paul Scherrer Institut



Target Head feedthroughs

Target Shielding

Expansion volume

Main EMP Flowmeter

12 Pin Heat Exchanger

Bypass EMP Flowmeter

Upper Target Enclosure

Main Guide Tube

Central Rod Heaters and Neutron Detectors

Bypass Flow Guide Tube

T91 Lower Liquid Metal Container

LBE Leak Detector

Lower Target Enclosure

Instrumentation devices:

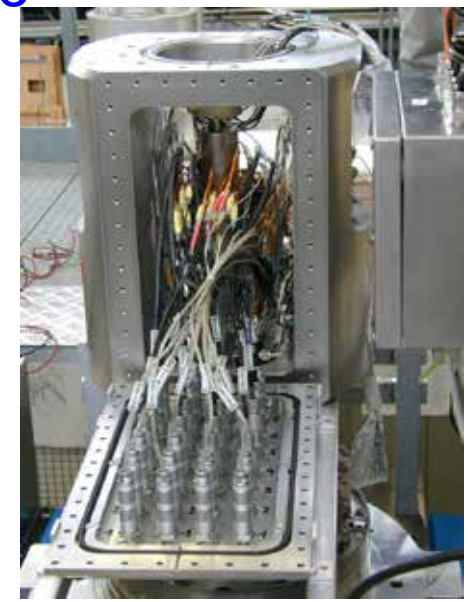
About 100 TCs
Tens of PT100
Heaters
EM Flowmeters
Pressure gages
Fission chambers

For process control & safety

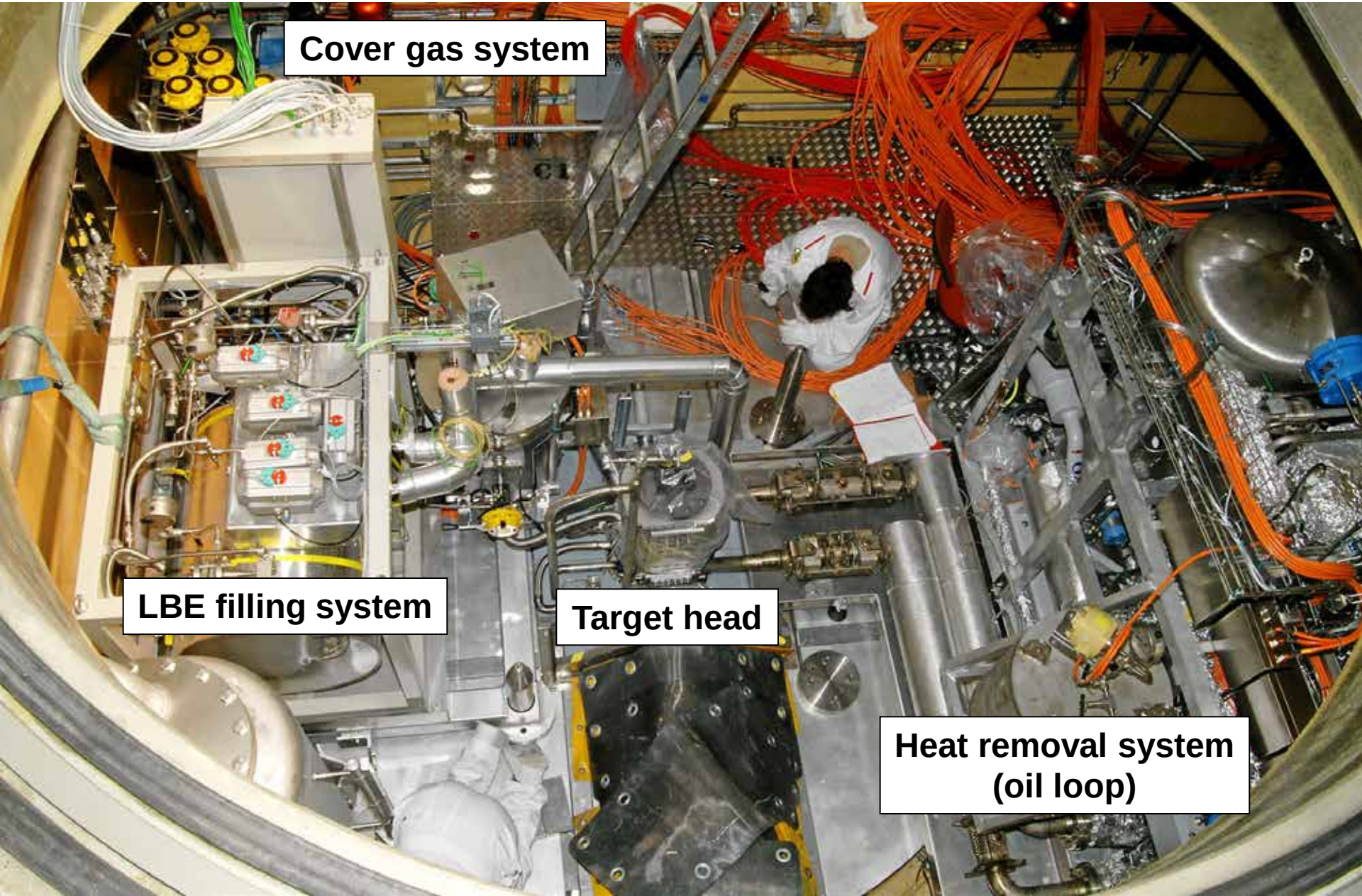
internal, e.g.,
level meters & leak detectors,
plus
dedicated safety devices
(slit, current, VIMOS)

Final Assembly of the Target

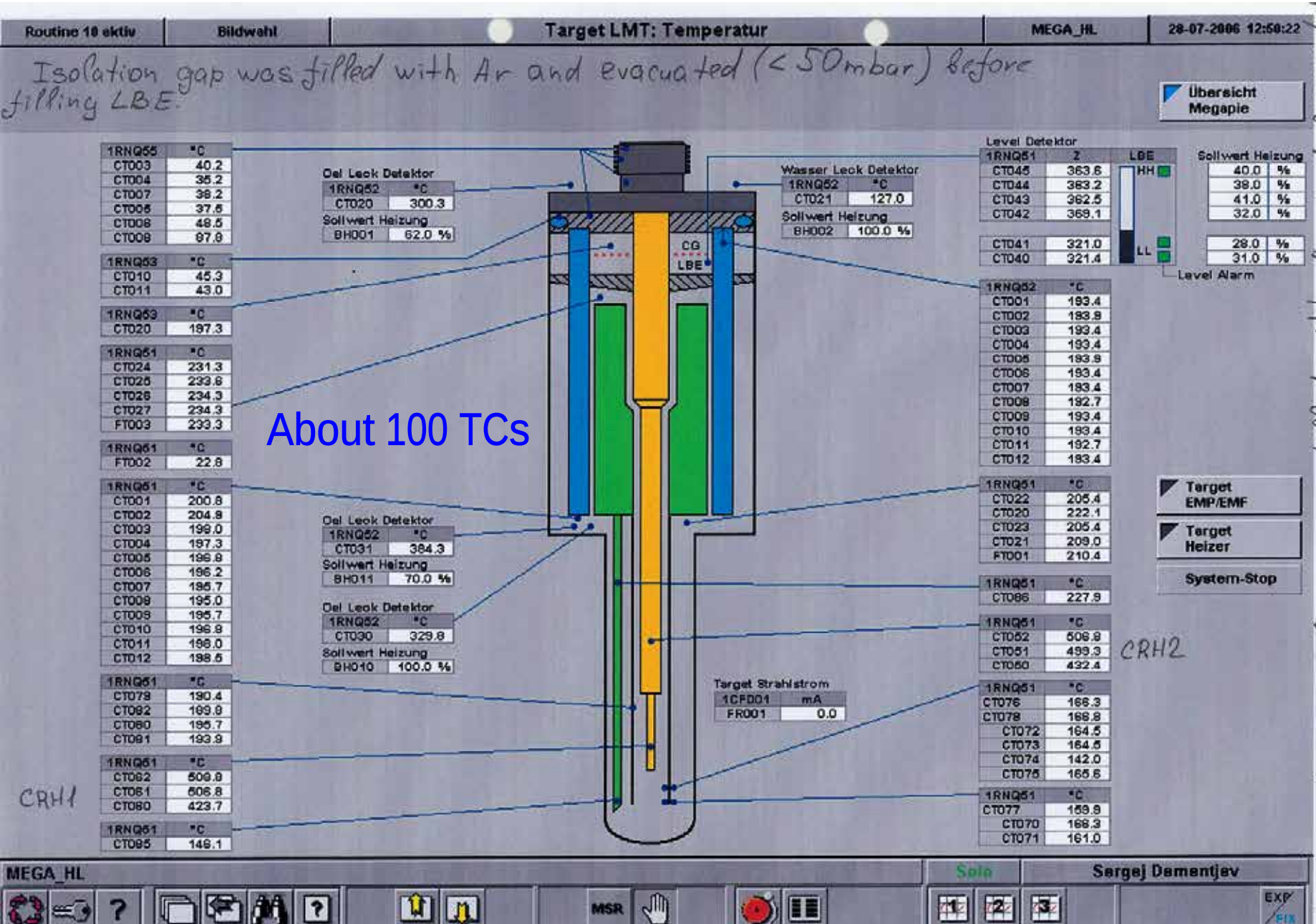
January – March 2006



Target Head Enclosure (TKE) full with stuff



Preheated target, ready for filling with LBE



1st: new MEGAPIE Safety Systems

Transmission Monitor

Slit KHNY30

VIMOS

Beam Losses

EFFECTORS

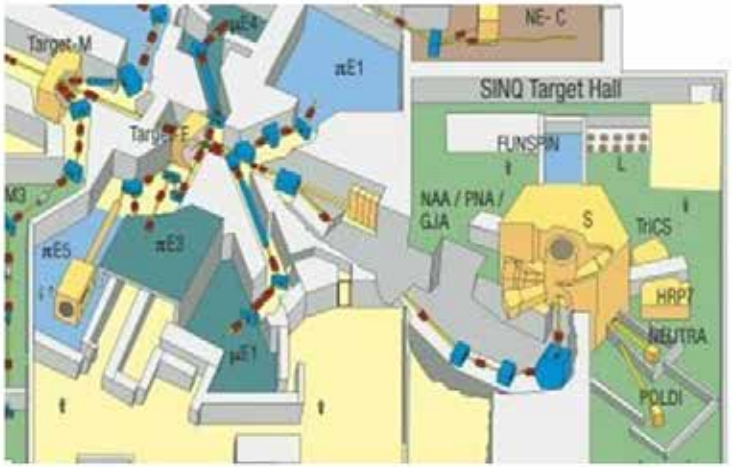
TC LBE Leak Detector

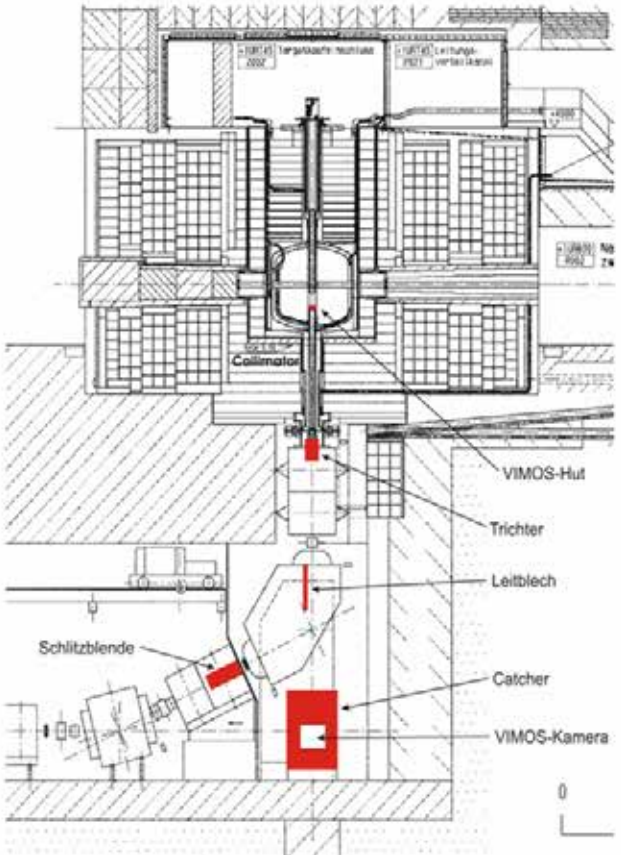
Stripe Sensor (~~LBE Leak Detector~~)

Requirements:

The beam had to be switched off

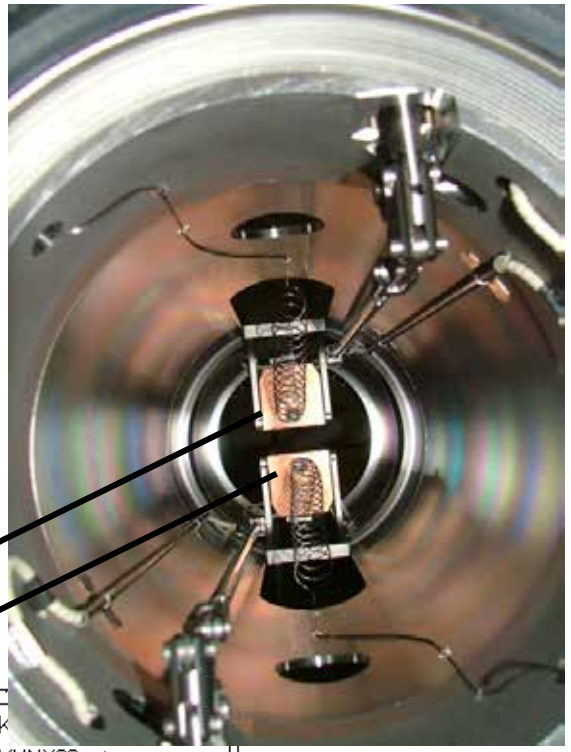
- **within 100 ms if 10 % of the protons by-pass Target E (corresponding to factor 2 in peak intensity)**
- **within 1 sec if LBE leaks out of the Liquid Metal Container**

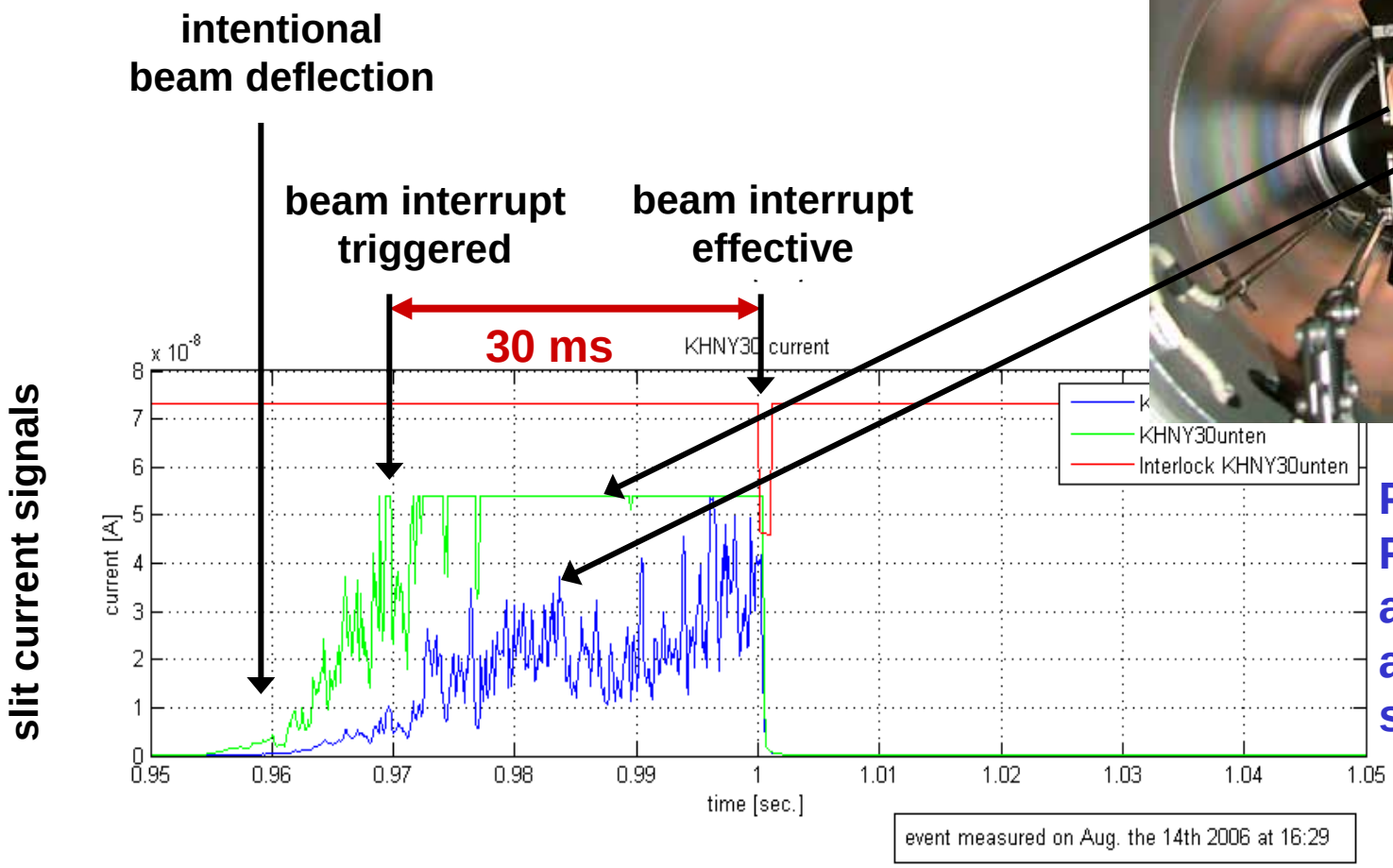




Collimating («Rohrer-») slit in the proton beamline

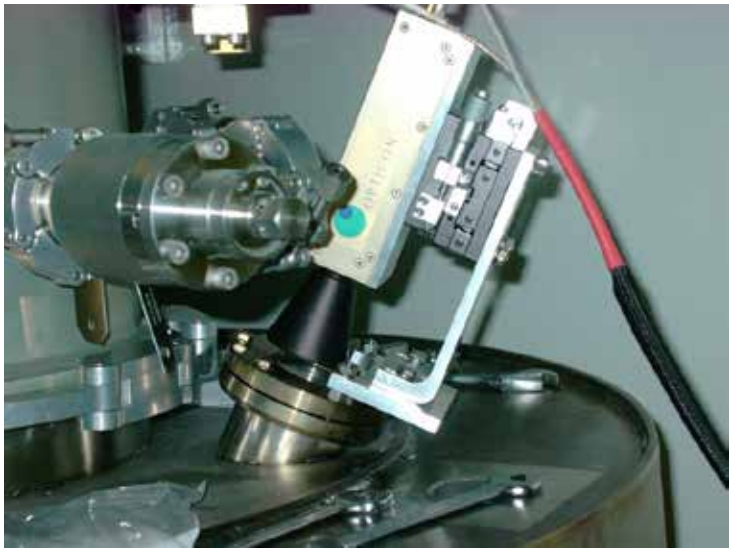
Beam interrupt system: End-to-end Test @ 40 µA

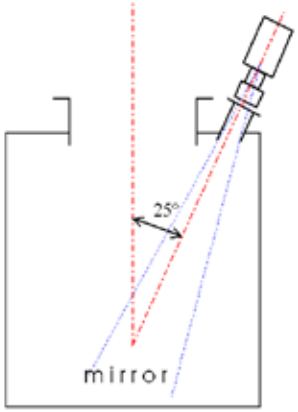


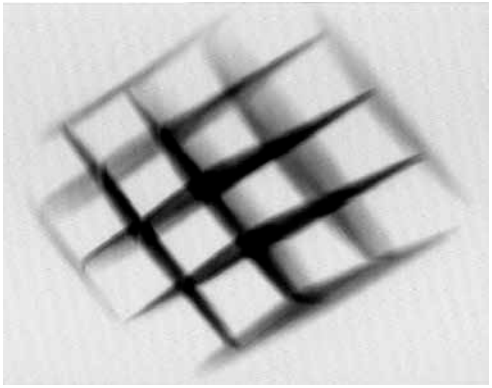


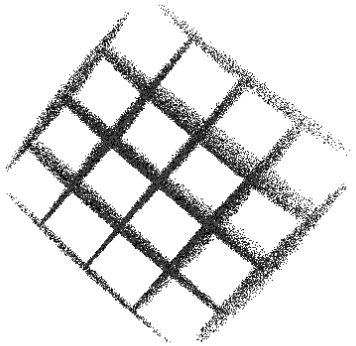
Proof of Functionality and Sensitivity at very low signal level

VIMOS, basic set-up









Glowing signal of tungsten mesh produced by the proton beam heating is monitored via 1 mirror in the visual band

VIMOS triggered correctly @ 900 µA

```
Thu Aug 17 13:56:33 2006

Lost frames: 0
bm1_22547: Mean1:12.440595, Mean2:9.807785, Ratio:1.268441,X-Center of ROI1:227, Y-Center of ROI1:162,X-Center of ROI2 and ROI1 :230, Y-Center of ROI2 and ROI1 :154

bm2_22547: Mean1:12.471129, Mean2:9.817343, Ratio:1.270316,X-Center of ROI1:227, Y-Center of ROI1:162,X-Center of ROI2 and ROI1 :230, Y-Center of ROI2 and ROI1 :154

bm3_22547: Mean1:12.461930, Mean2:9.817775, Ratio:1.269323,X-Center of ROI1:227, Y-Center of ROI1:162,X-Center of ROI2 and ROI1 :230, Y-Center of ROI2 and ROI1 :154

bm4_22547: Mean1:12.533764, Mean2:9.835573, Ratio:1.274330,X-Center of ROI1:227, Y-Center of ROI1:162,X-Center of ROI2 and ROI1 :230, Y-Center of ROI2 and ROI1 :154

bm5_22547: Mean1:12.569779, Mean2:9.853515, Ratio:1.275664,X-Center of ROI1:227, Y-Center of ROI1:162,X-Center of ROI2 and ROI1 :230, Y-Center of ROI2 and ROI1 :154
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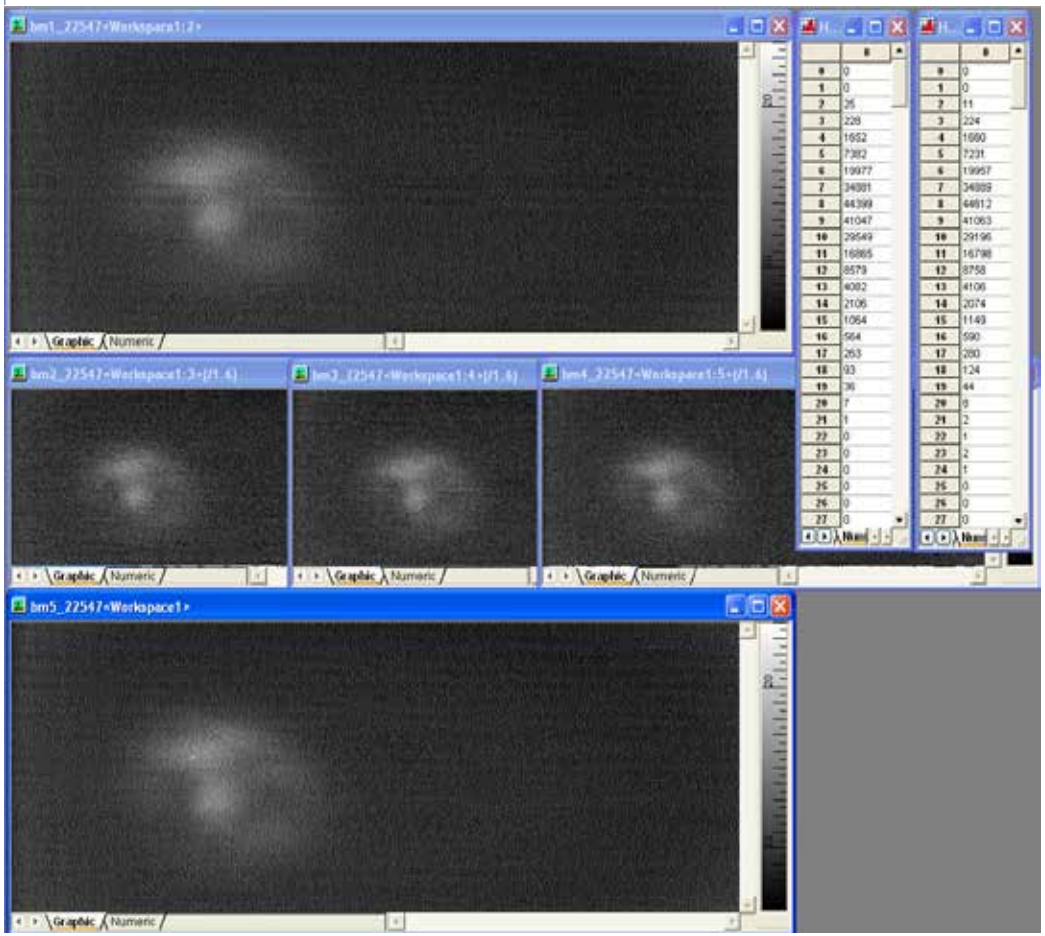
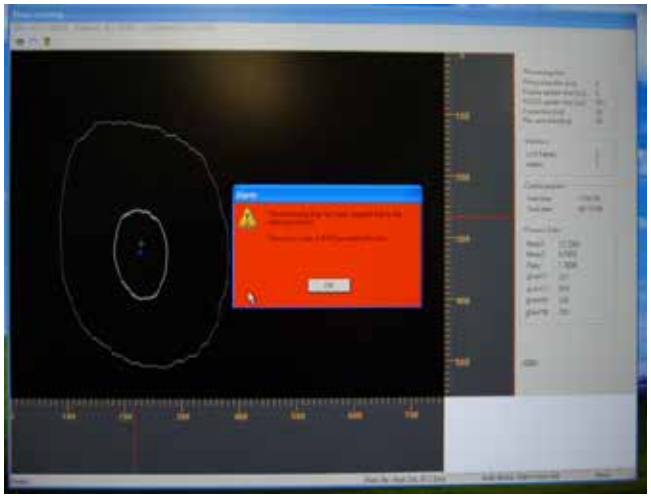
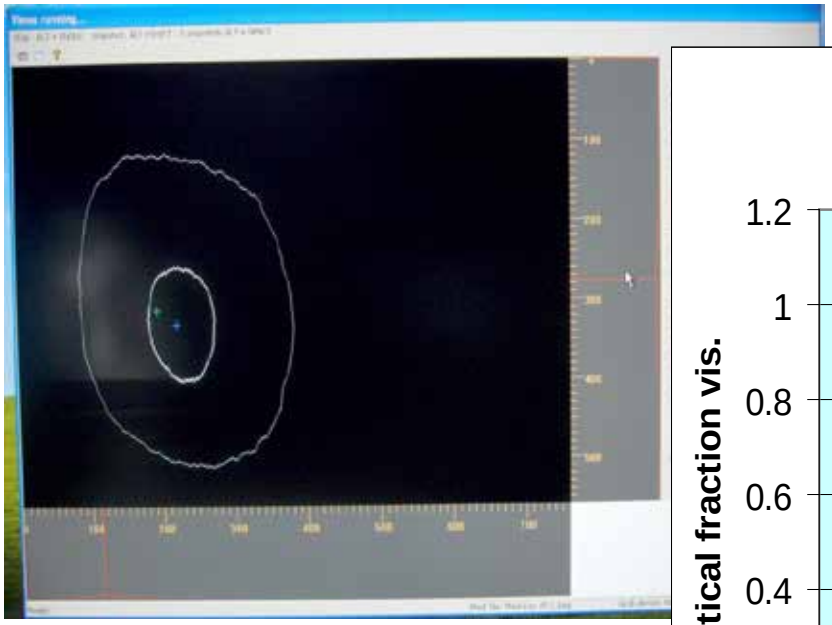
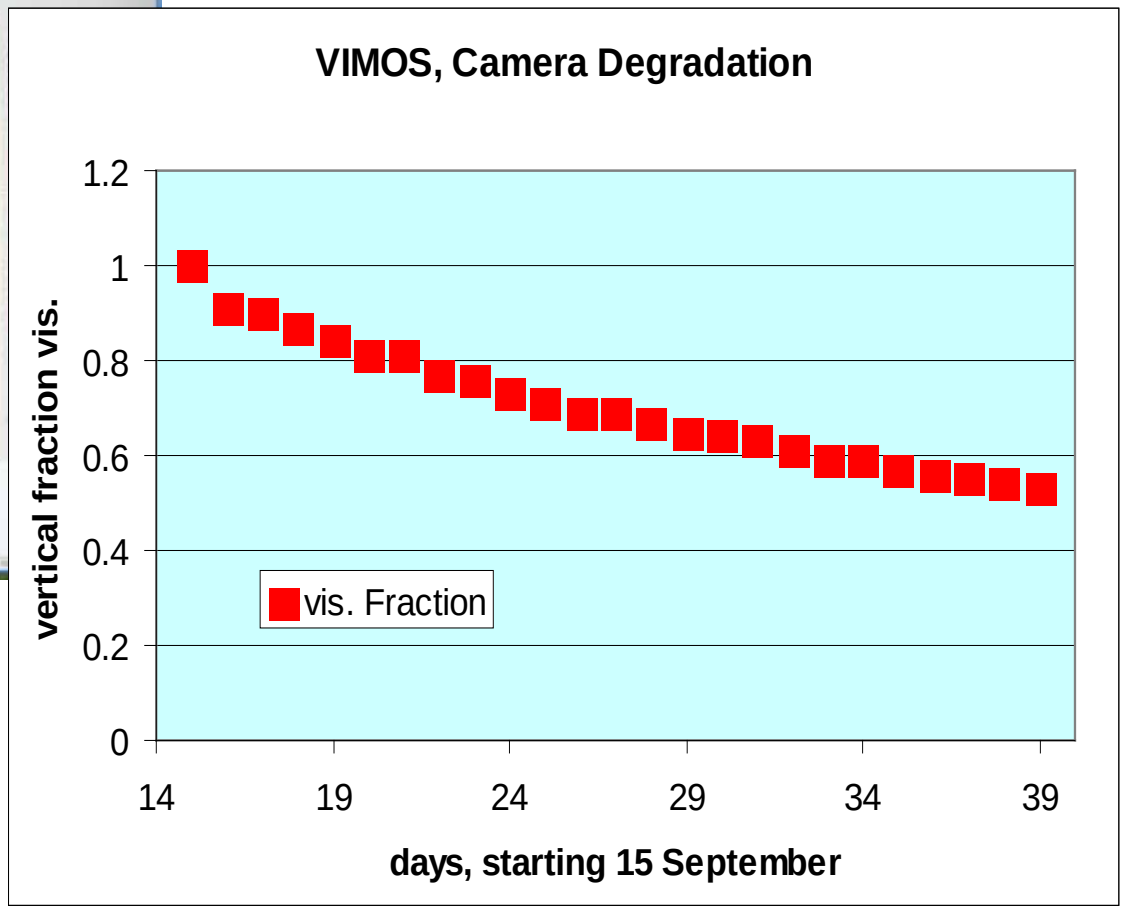




Proof of Functionality and Sensitivity at very low Signal Level (frames enhanced)



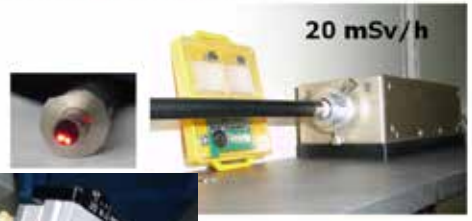


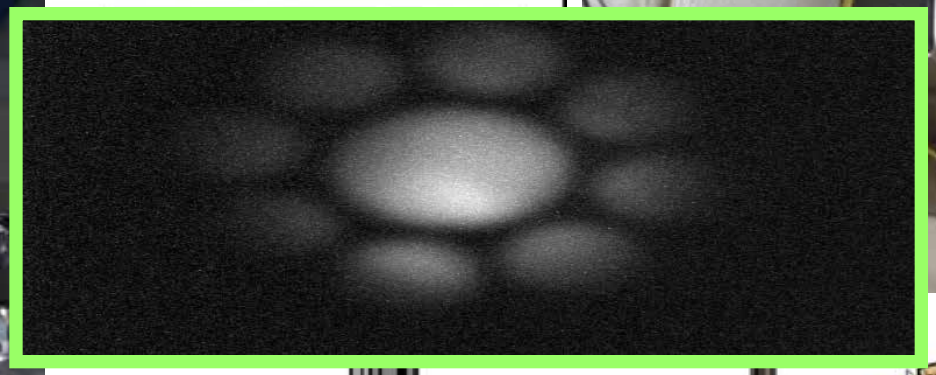
1. New Mask, 2. New Camera

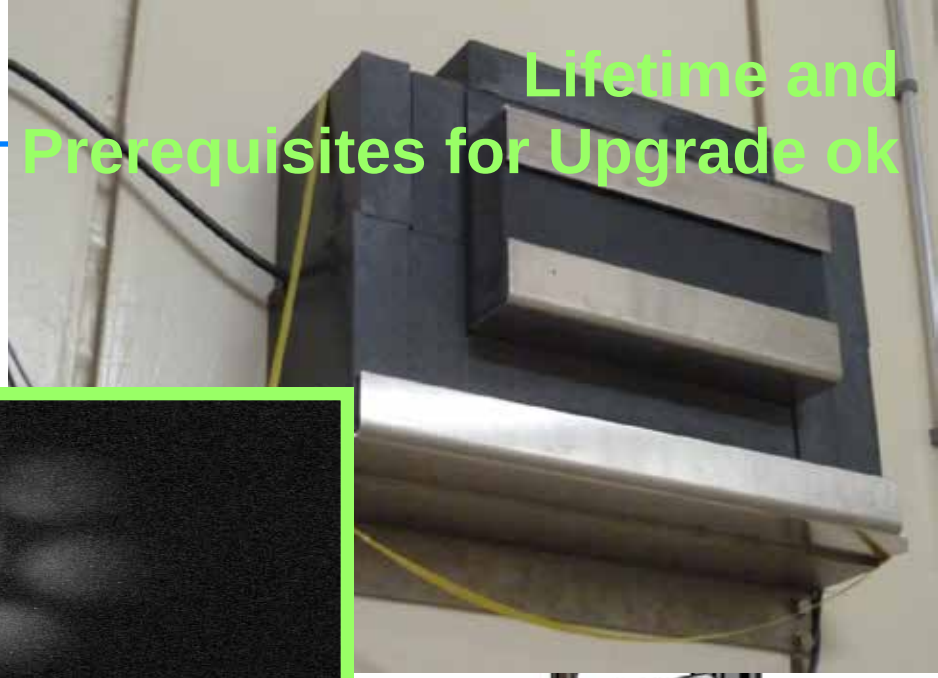
PAUL SCHERRER INSTITUT

Extend camera life time (...reduce cost)

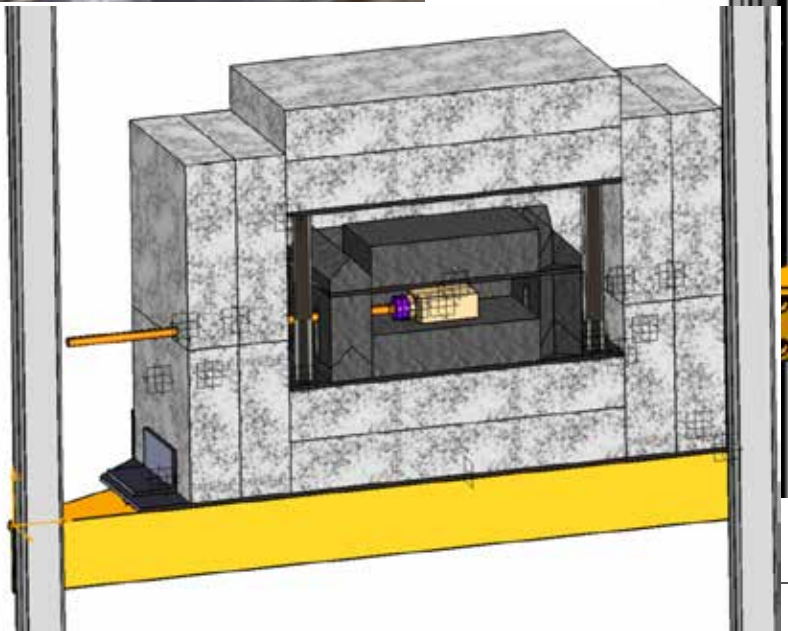
by moving camera away from hot area

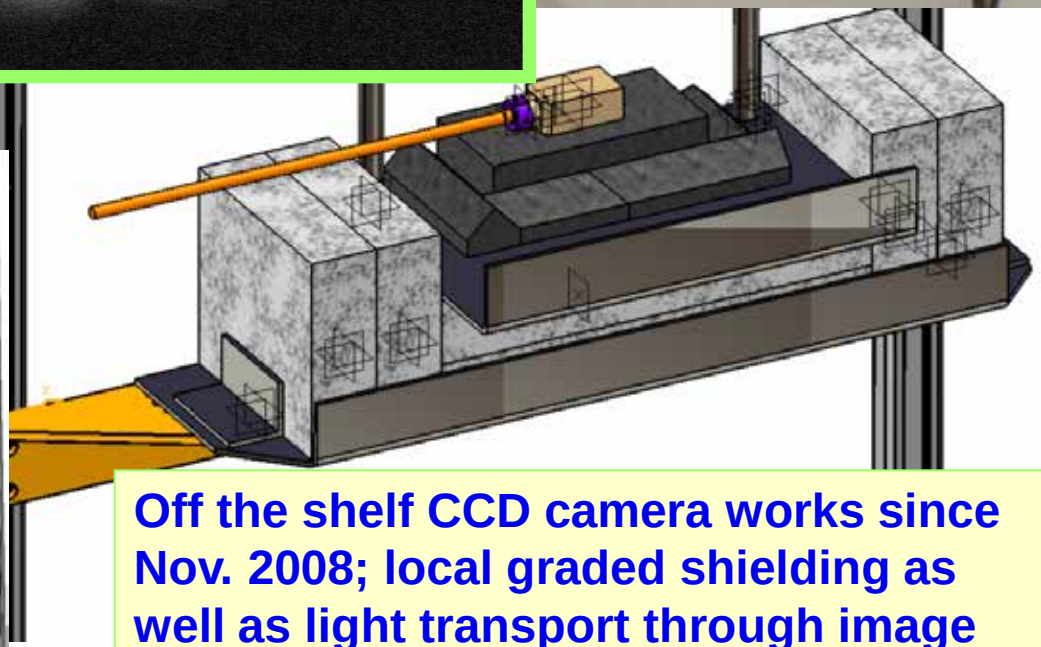






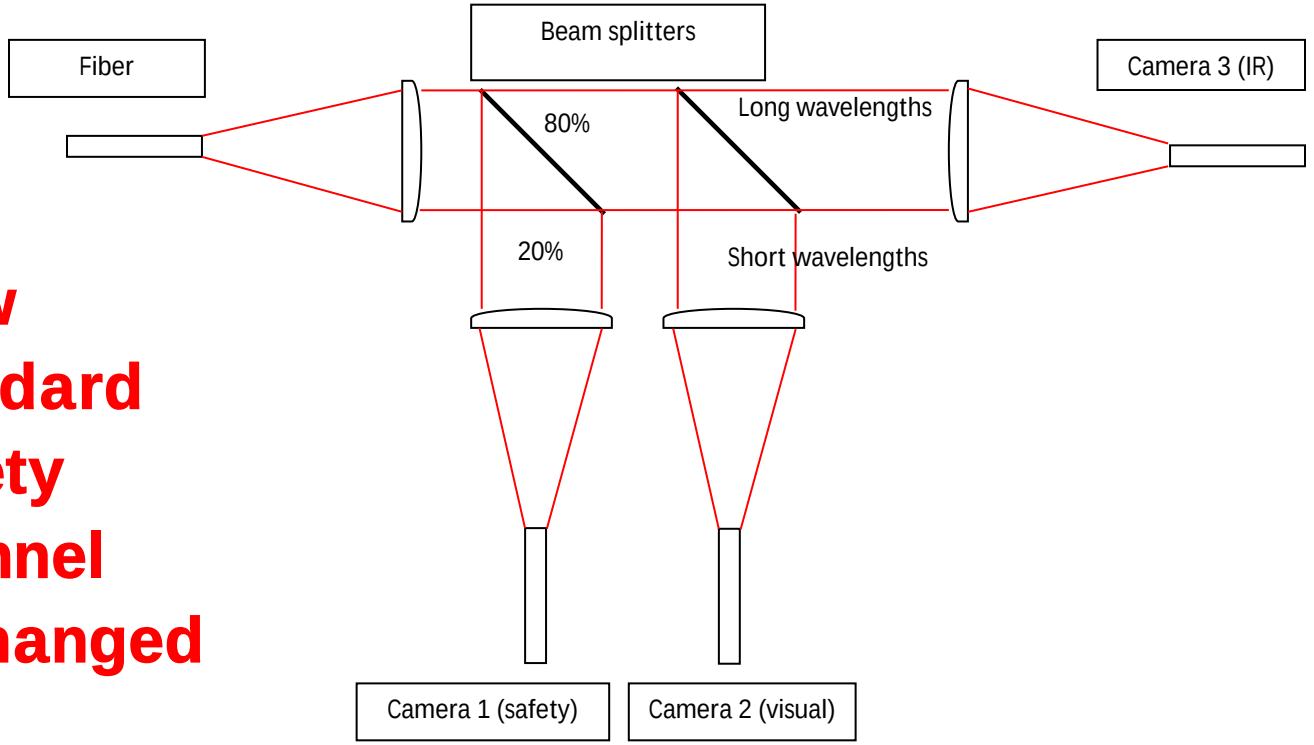
Lifetime and Prerequisites for Upgrade ok





Off the shelf CCD camera works since Nov. 2008; local graded shielding as well as light transport through image fiber are effective and allow for upgrade

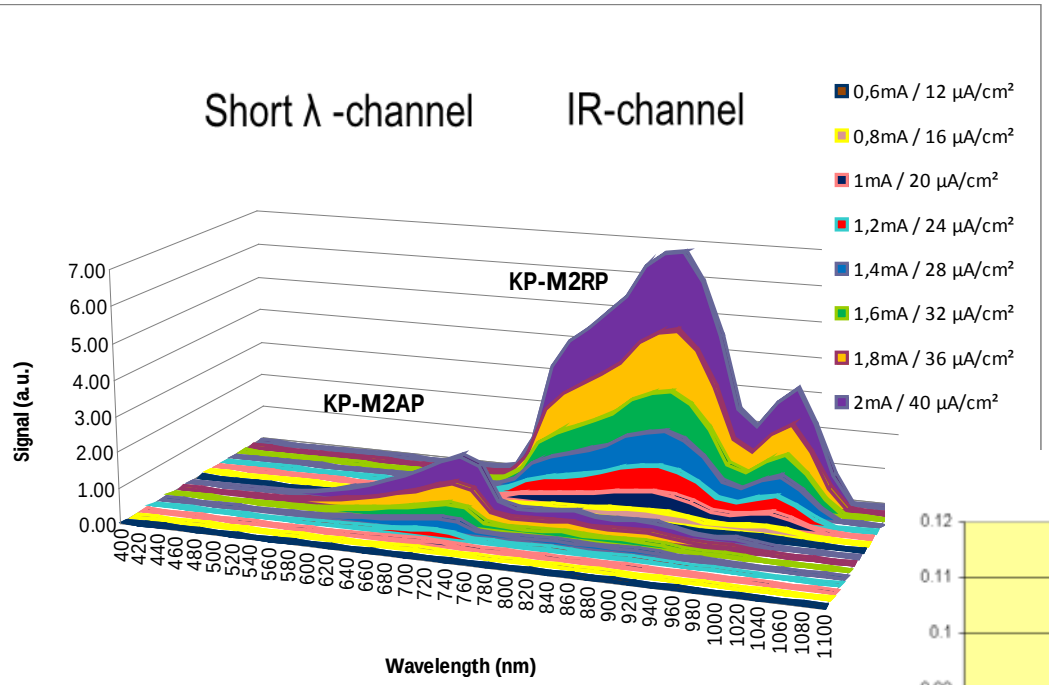
Attempted Upgrade of Diagnostics´ Capapbility



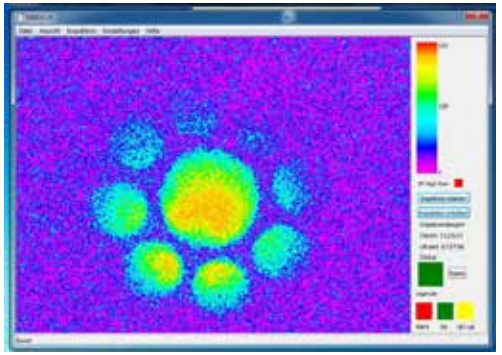
Now standard Safety channel unchanged

- In addition to the existing safety-channel („camera 1“)
  two more images will be sampled, i.e. another visual channel („camera 2“) and a near-IR one („camera 3“)
- from the ratio of the intensities in these wavelenght bands
  local temperatures and thus current densities can be derived

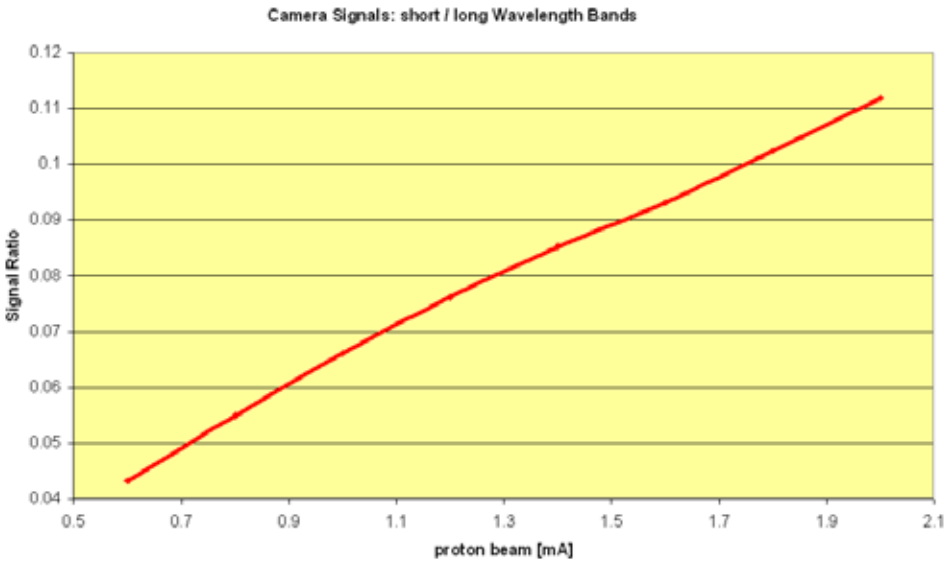
Upgrade was fine in Theory and Laboratory Tests



The relative weight of short wave-length visible light rises with increasing temperature

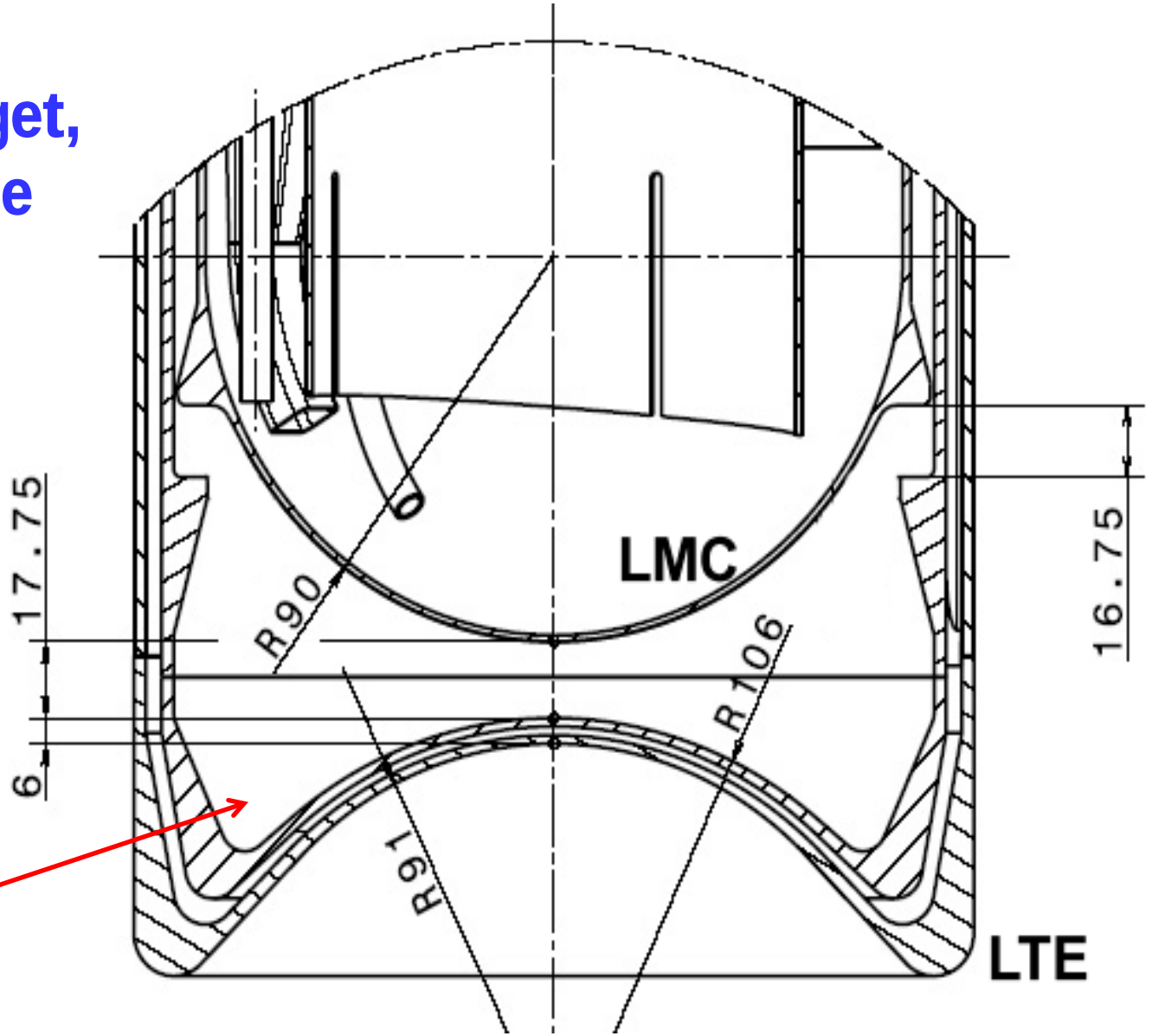


Calibration looked ok:



1st Operation yielded partly Surprising Results:
Fiber Deterioration due to Radiation Exposure Limits Usefulness

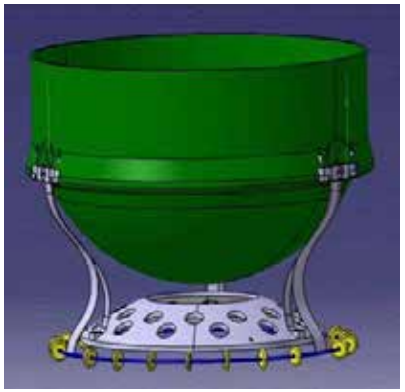
MEGAPIE Target, Tip of the nose

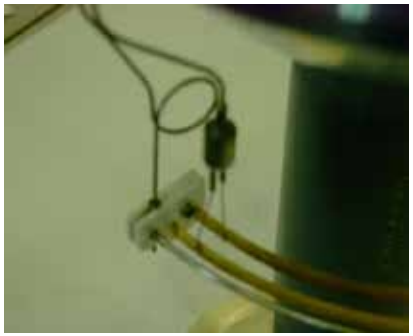


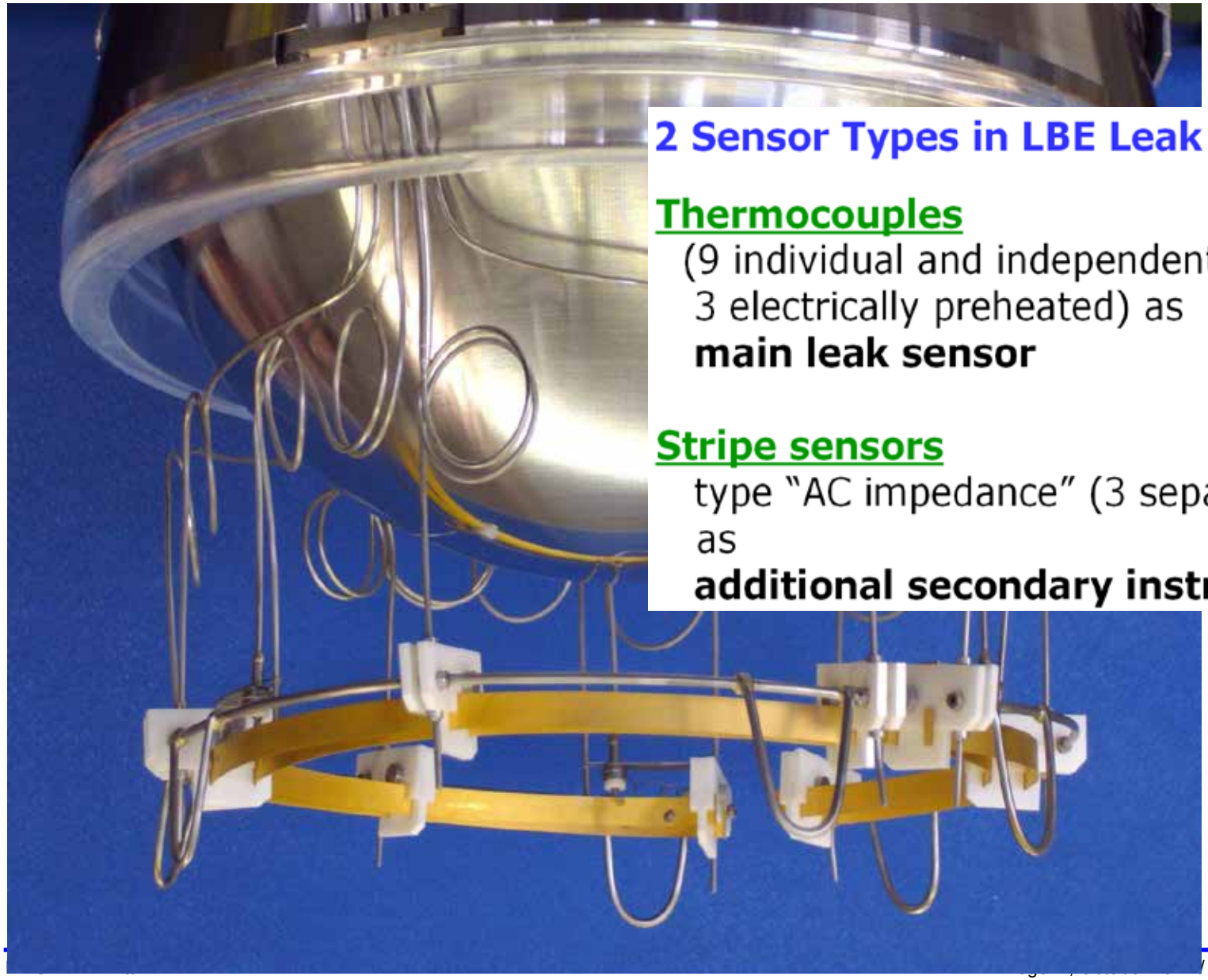
Leak Detectors

Concept Selection Oct. 2004

Requirement	Ring Det.	Skull Cap	Thermocouples	Stripes
< 1/2 Liter	ok	ok	ok	ok
< 1 Minute	ok	ok	ok	ok
Reliability	?	?	ok	ok
Detection Prob.			ok	ok
False Alarms			ok	ok
Qualification			*OK*	n.a. (ok)
Radiation Res.			ok	ok
Temperature Res.			ok	ok
No High Voltage			ok	ok
Verifiability			ok	ok
Not Self-Resetting			ok	ok
No Interference			ok	ok
Calibration			o	o
Ready Next Year			ok	ok
Redundancy	x	x	ok	ok
Oil and D2O			ok	ok
Done			o	x







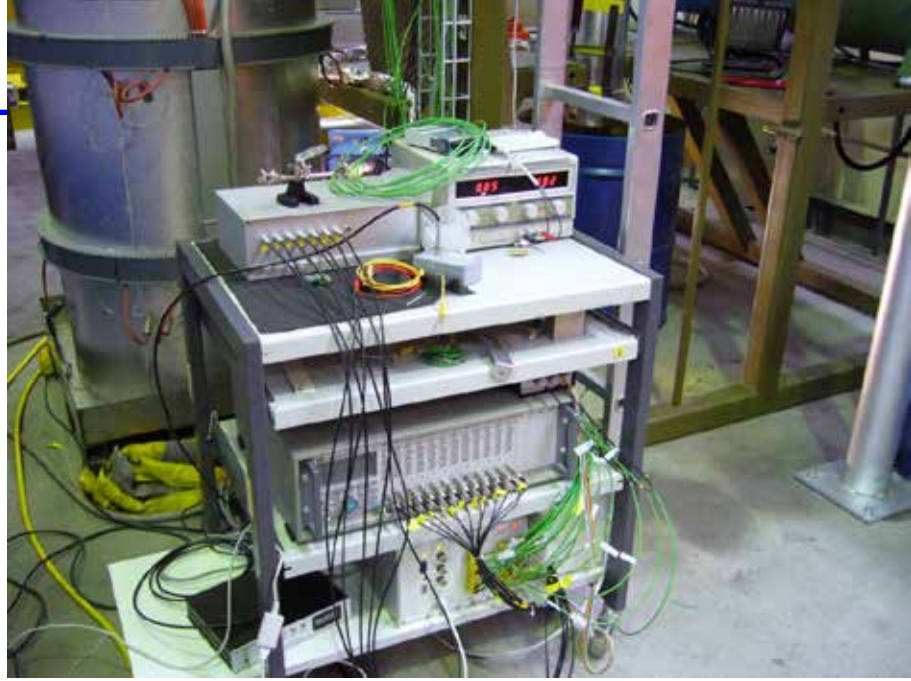
2 Sensor Types in LBE Leak Detector:

Thermocouples

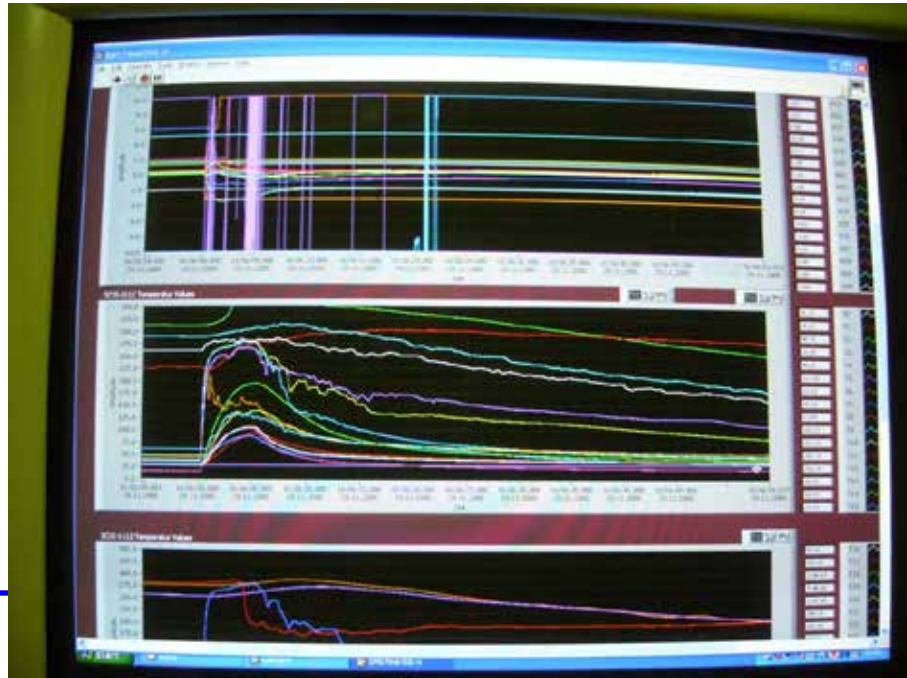
(9 individual and independent sensors, 3 electrically preheated) as **main leak sensor**

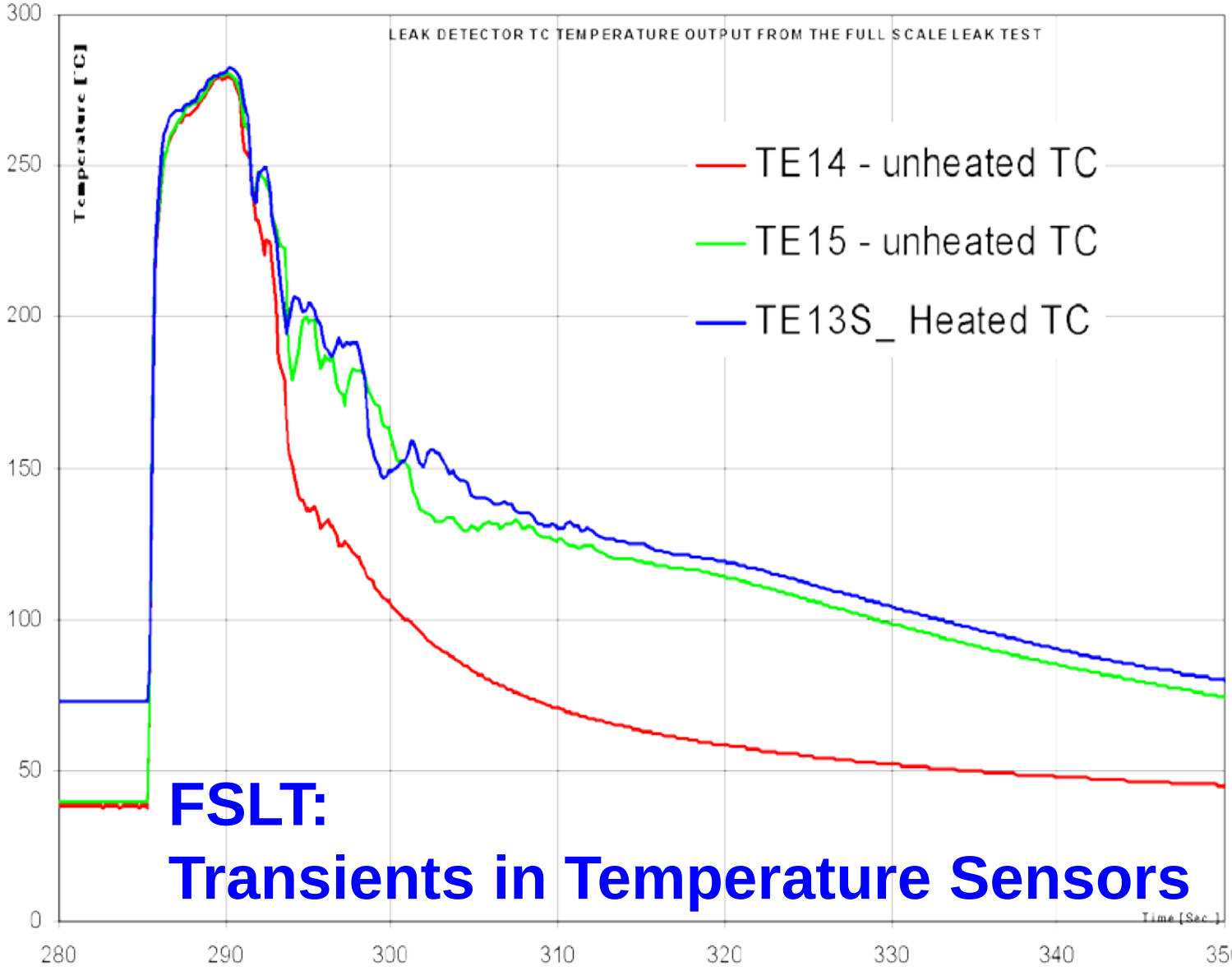
Stripe sensors

type "AC impedance" (3 separate units) as **additional secondary instruments**

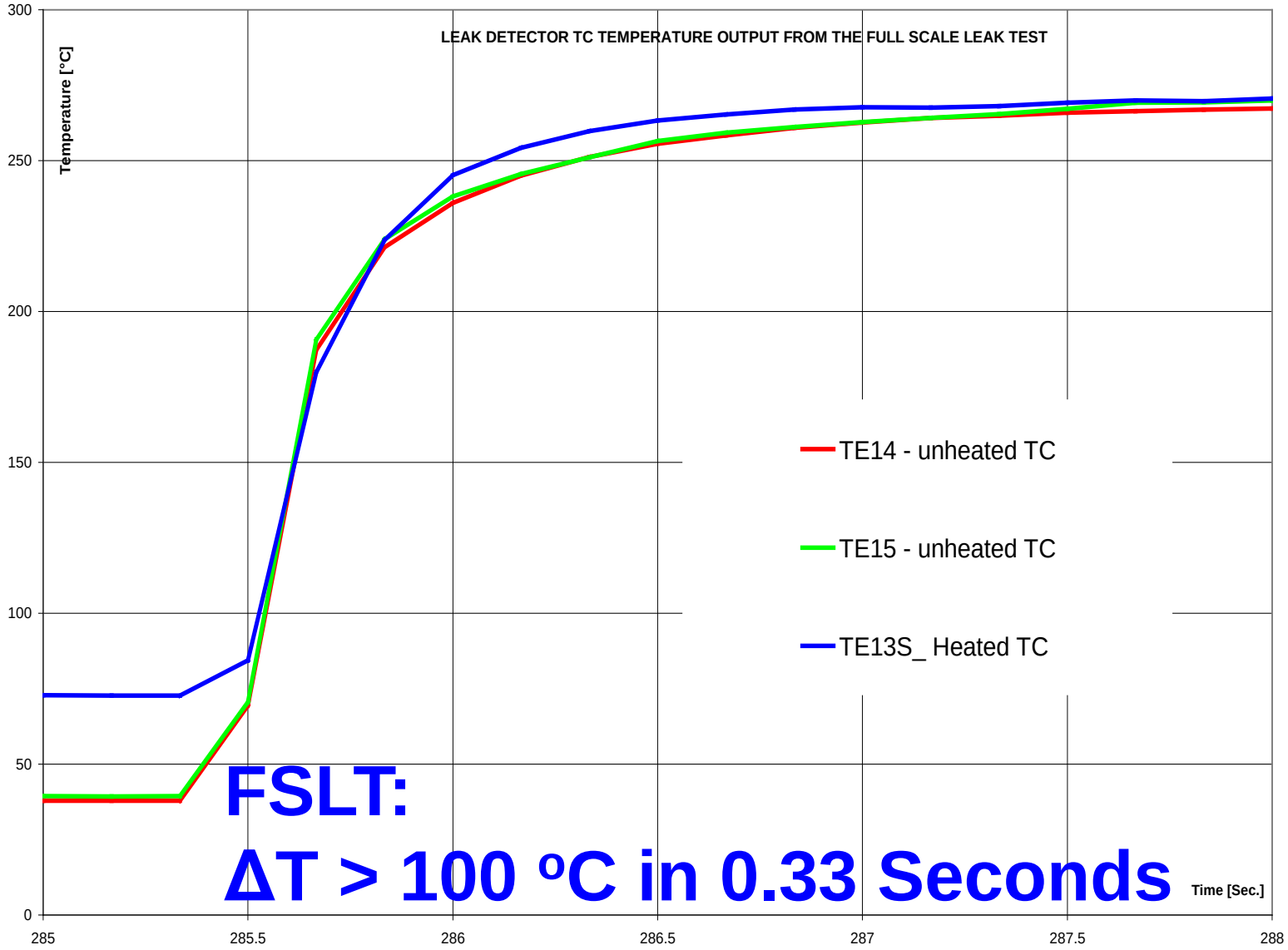


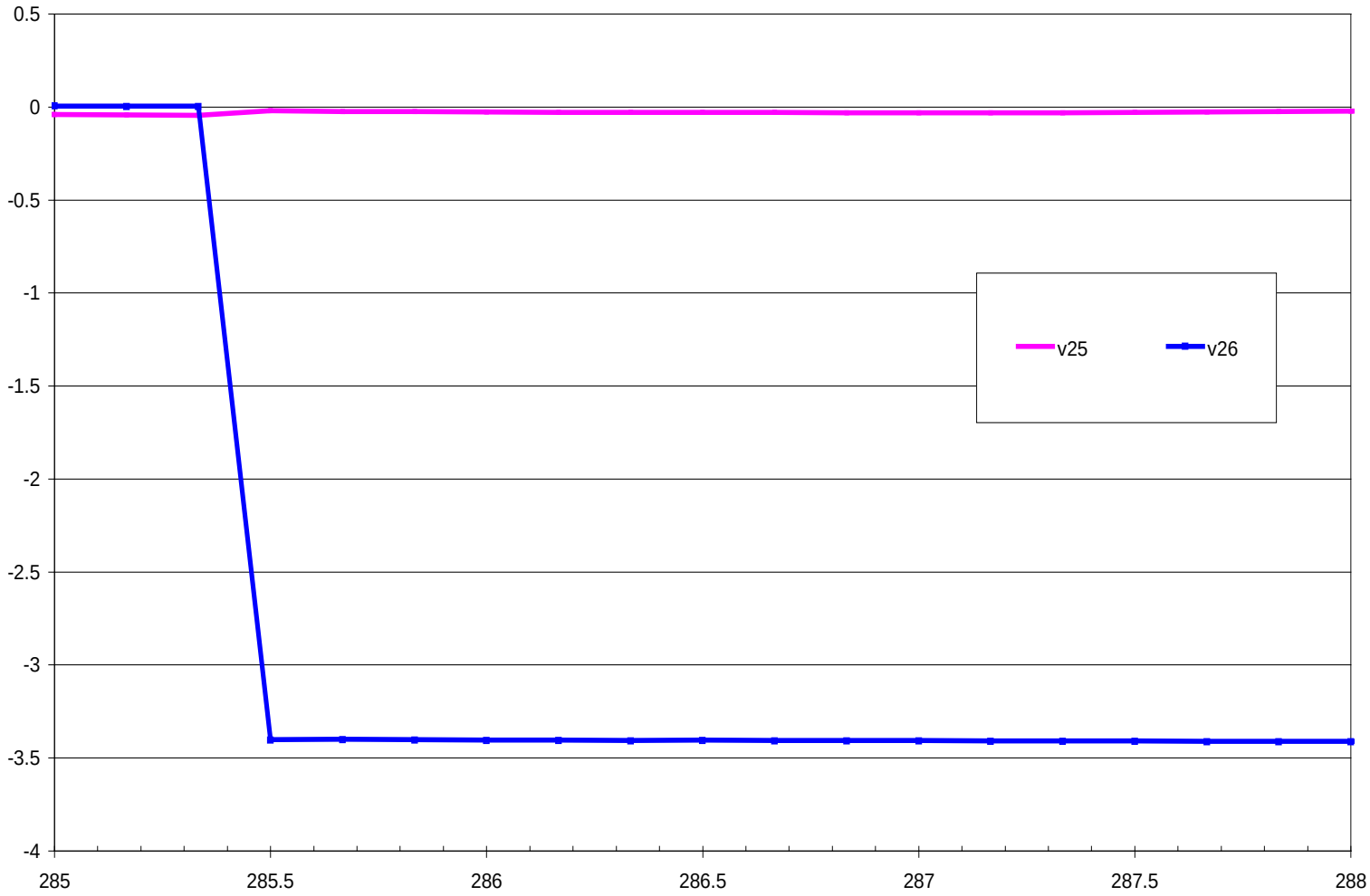
Full Scale Leak Test FSLT





FSLT: Transients in Temperature Sensors

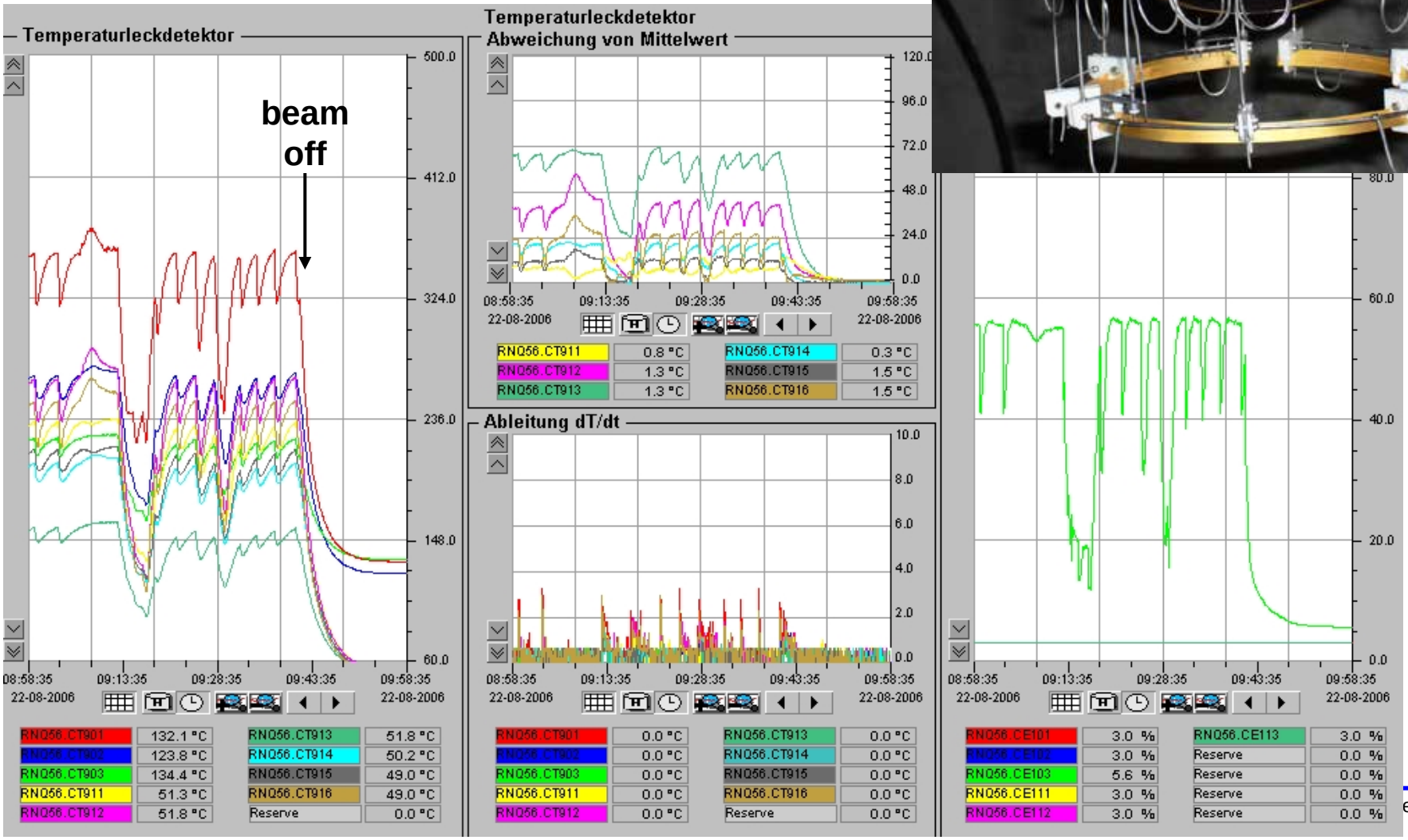

LEAK DETECTOR TC TEMPERATURE OUTPUT FROM THE FULL SCALE LEAK TEST
Temperature [°C]
300
250
200
150
100
50
0
285
285.5
286
286.5
287
287.5
288
Time [Sec.]
TE14 - unheated TC
TE15 - unheated TC
TE13S_ Heated TC
FSLT:
ΔT > 100 °C in 0.33 Seconds



FSLT: Stripes show Full Contakt in < 167 ms

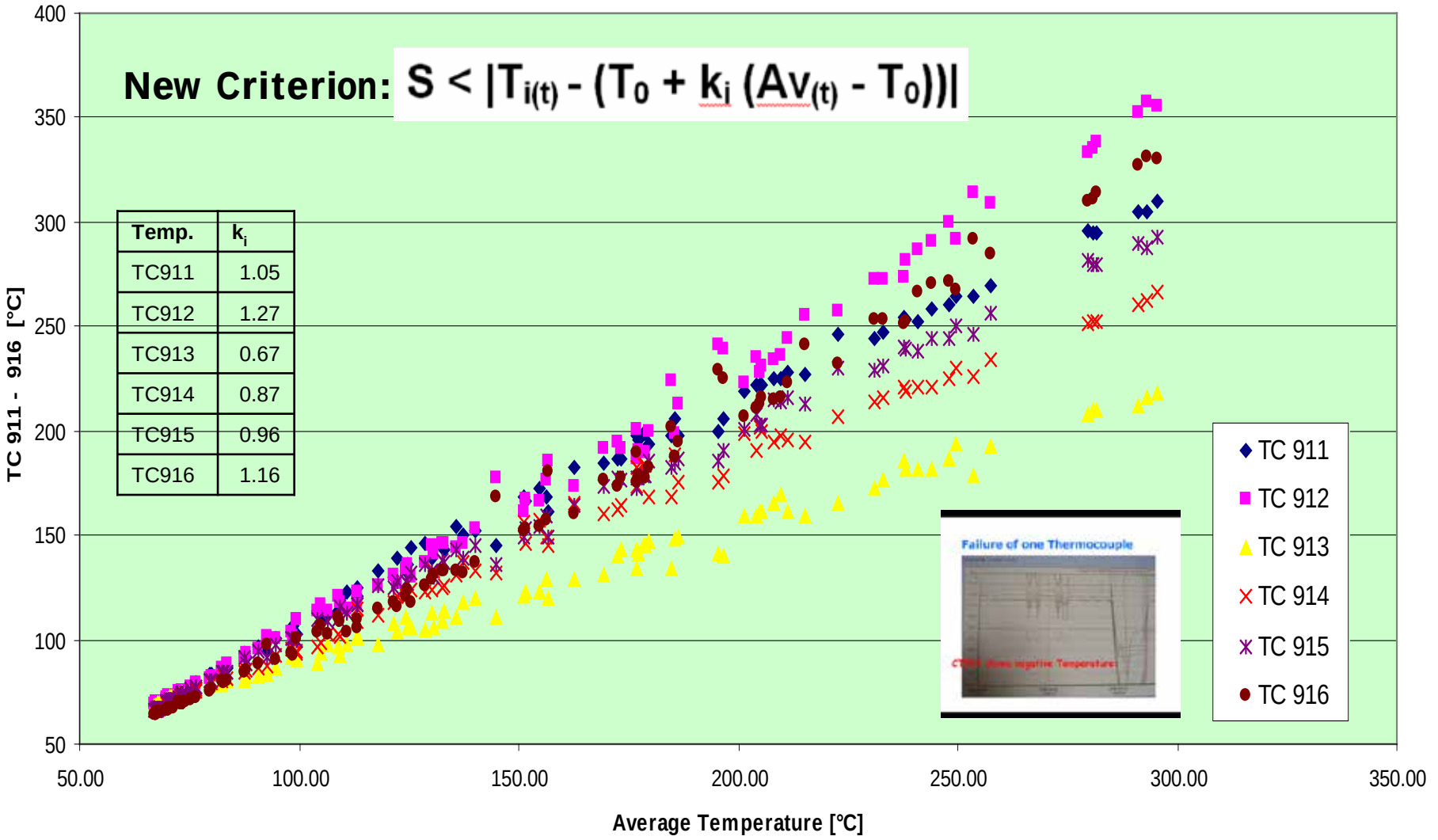
LBE leak detectors:

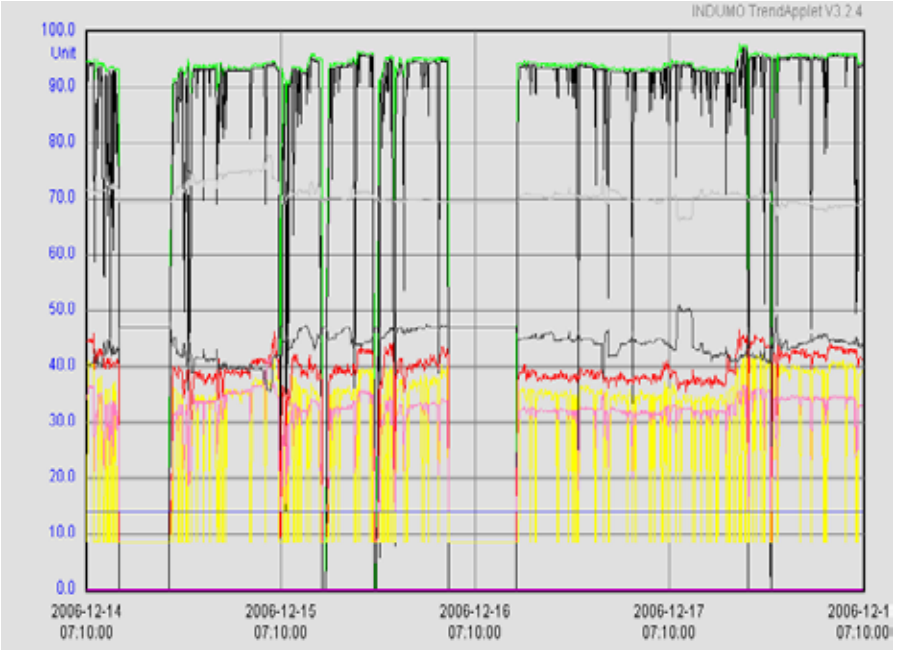
awaking with beam-on

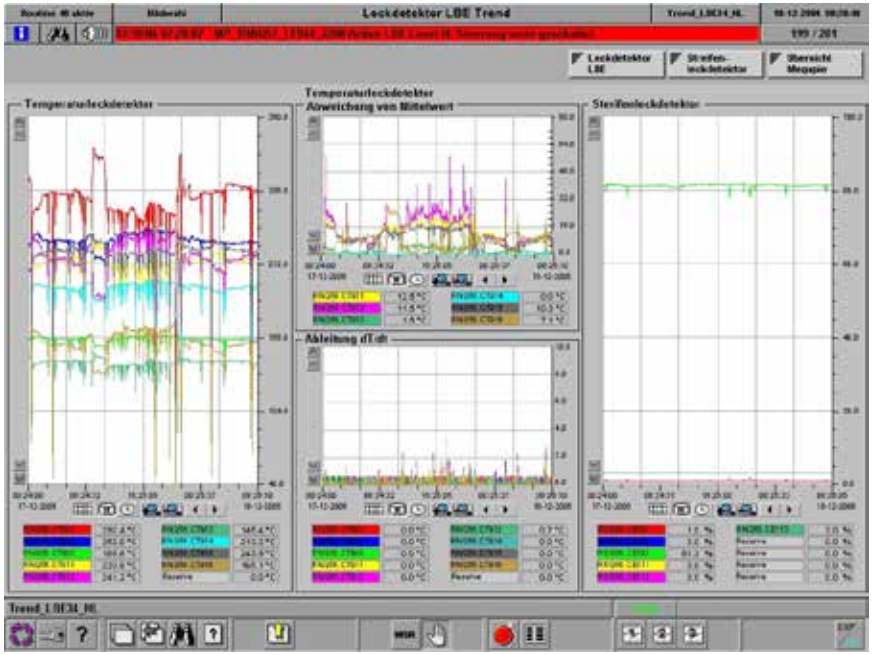


TC-based Leak Detector worked Fine

LBE Leak Detector, Temperatures / Average of Unheated TCs

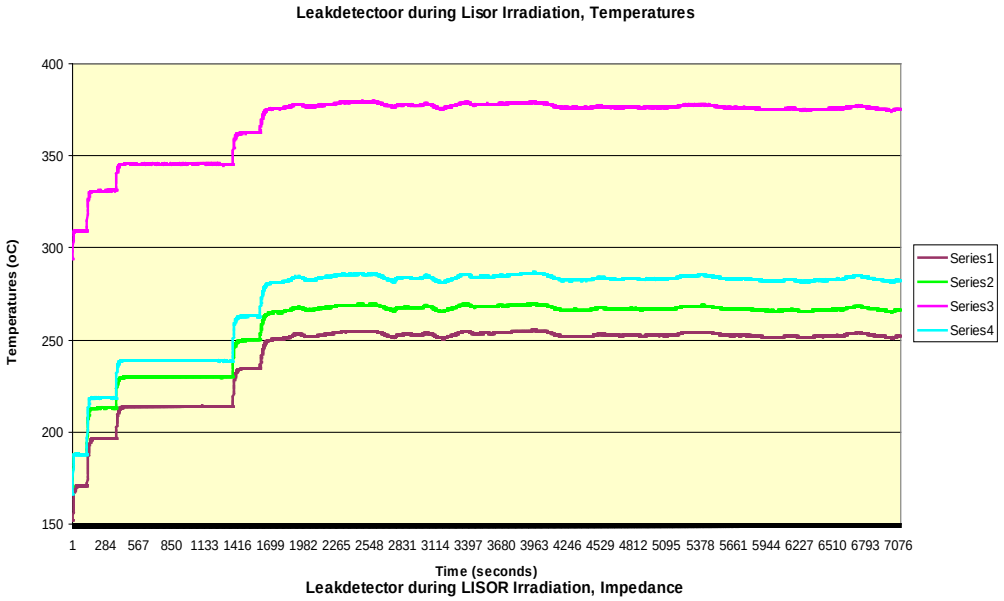


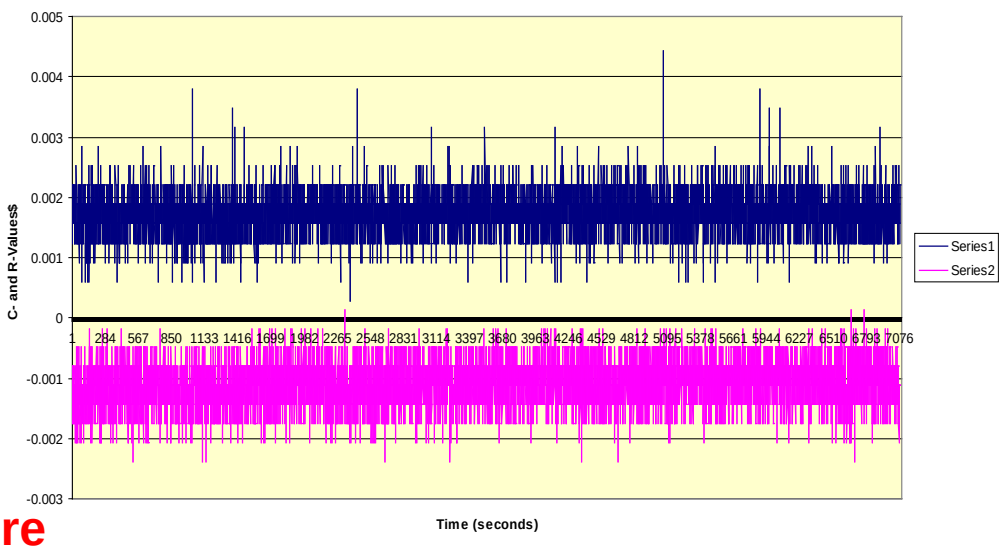




TC based LBE Leak Detectors yielded the most sensitive Beam Diagnostics
(standard halo-monitor at every new spallation target)

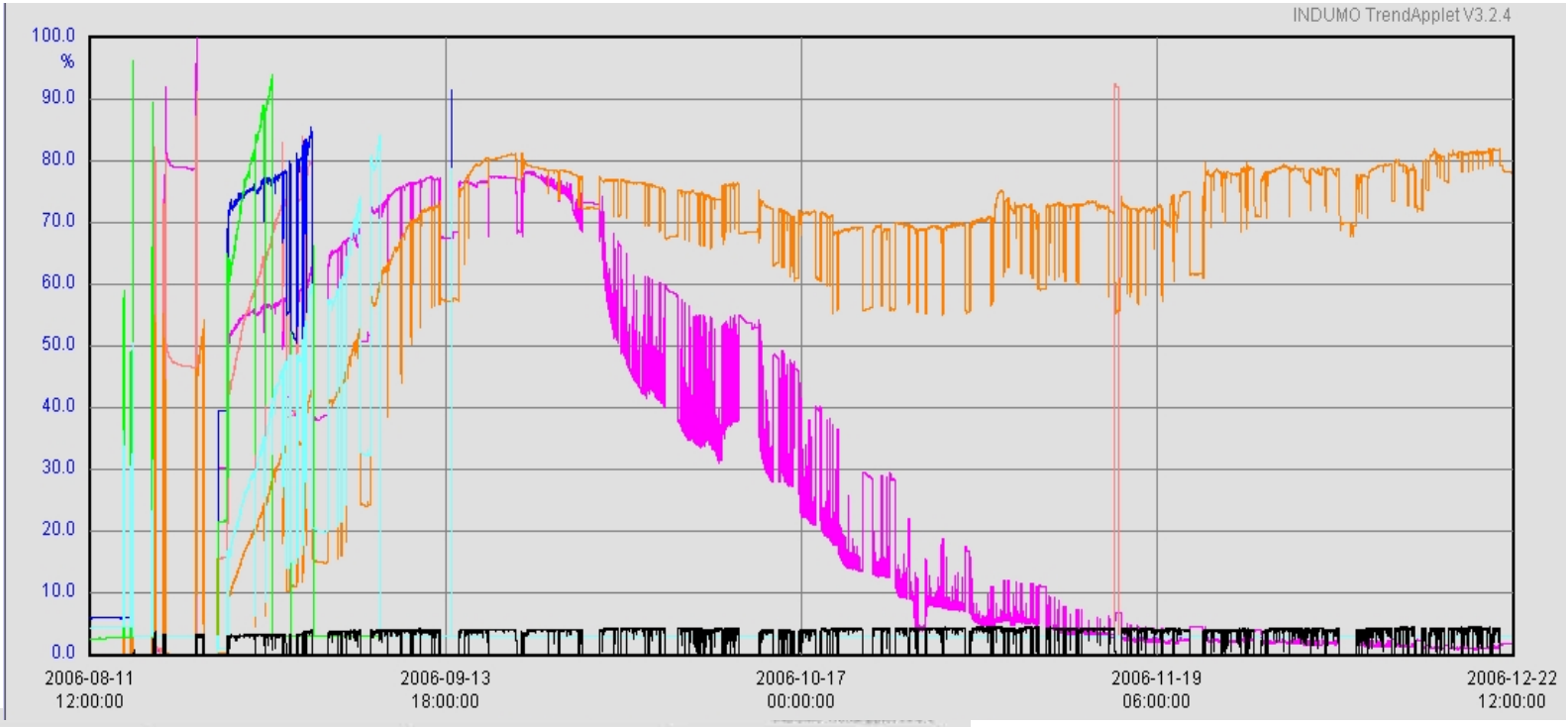
LISOR irradiation of stripe sensors showed no effect

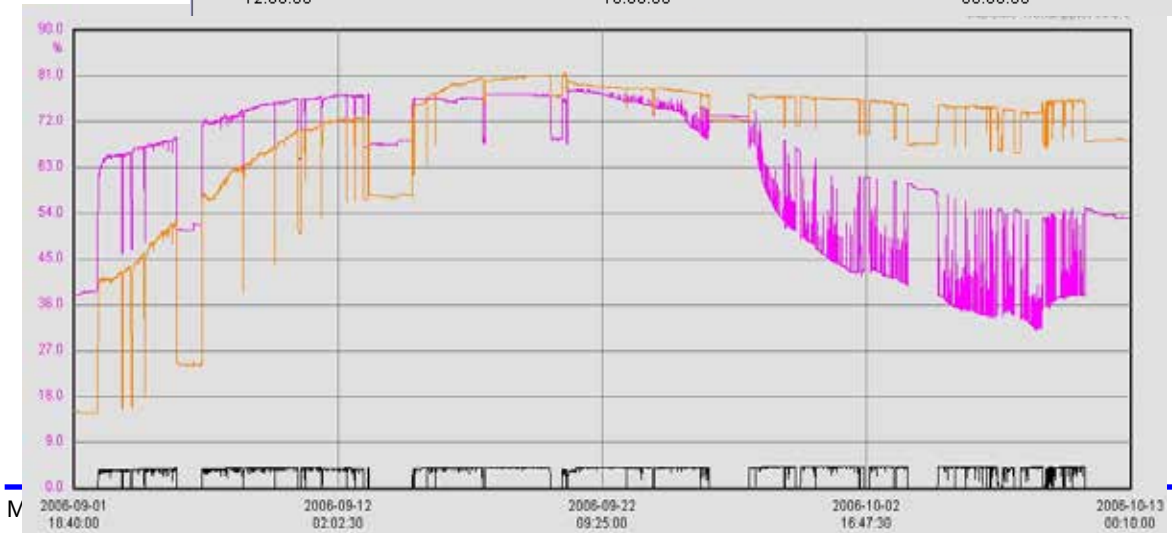




in «representative» helium atmosphere

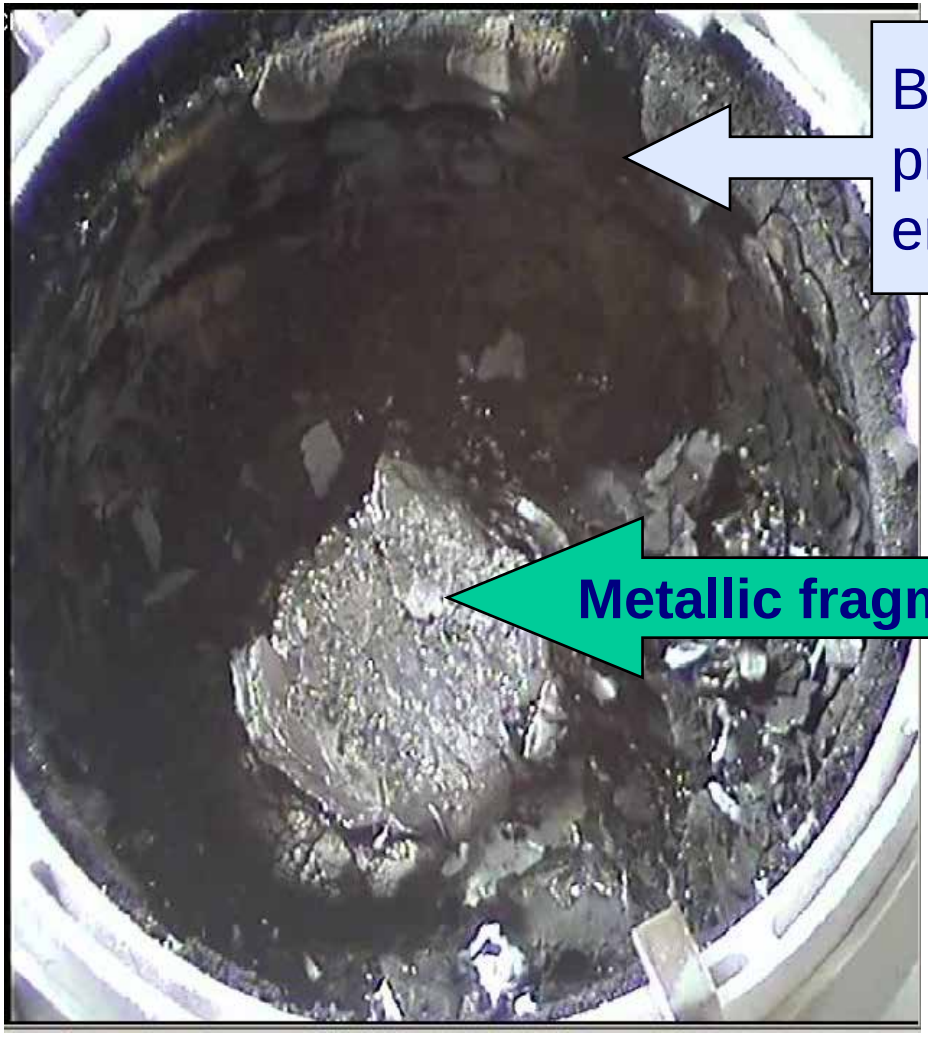
Partly Unexpected Results





Variable Behavior of Stripe Signals during the MEGAPIE Irradiation Period

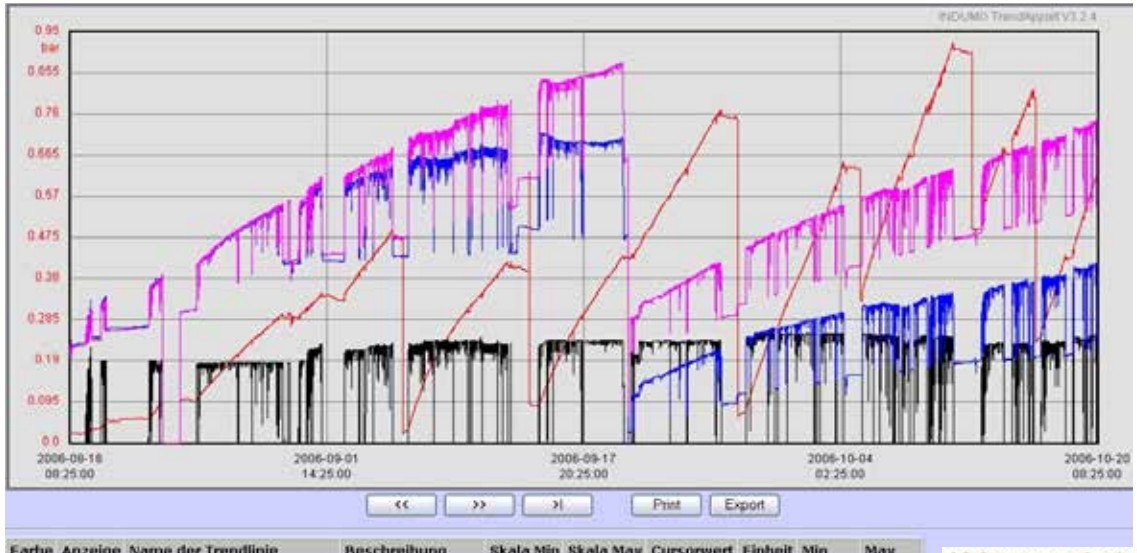
Inside of safety hull calotte after cutting up MEGAPIE



Black flaky smut inside calotte is probably remains of oil that entered the insulation gas system

Metallic fragmer

IG (and CG) pressure development since start

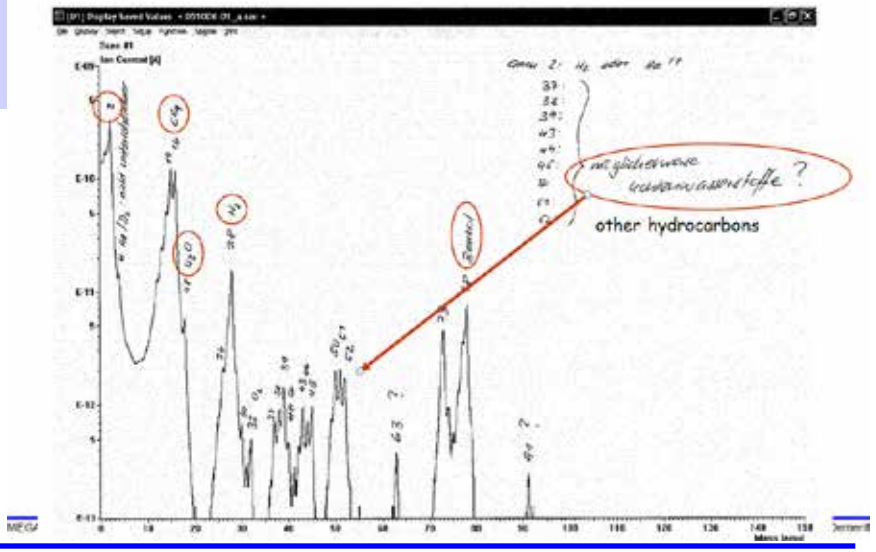


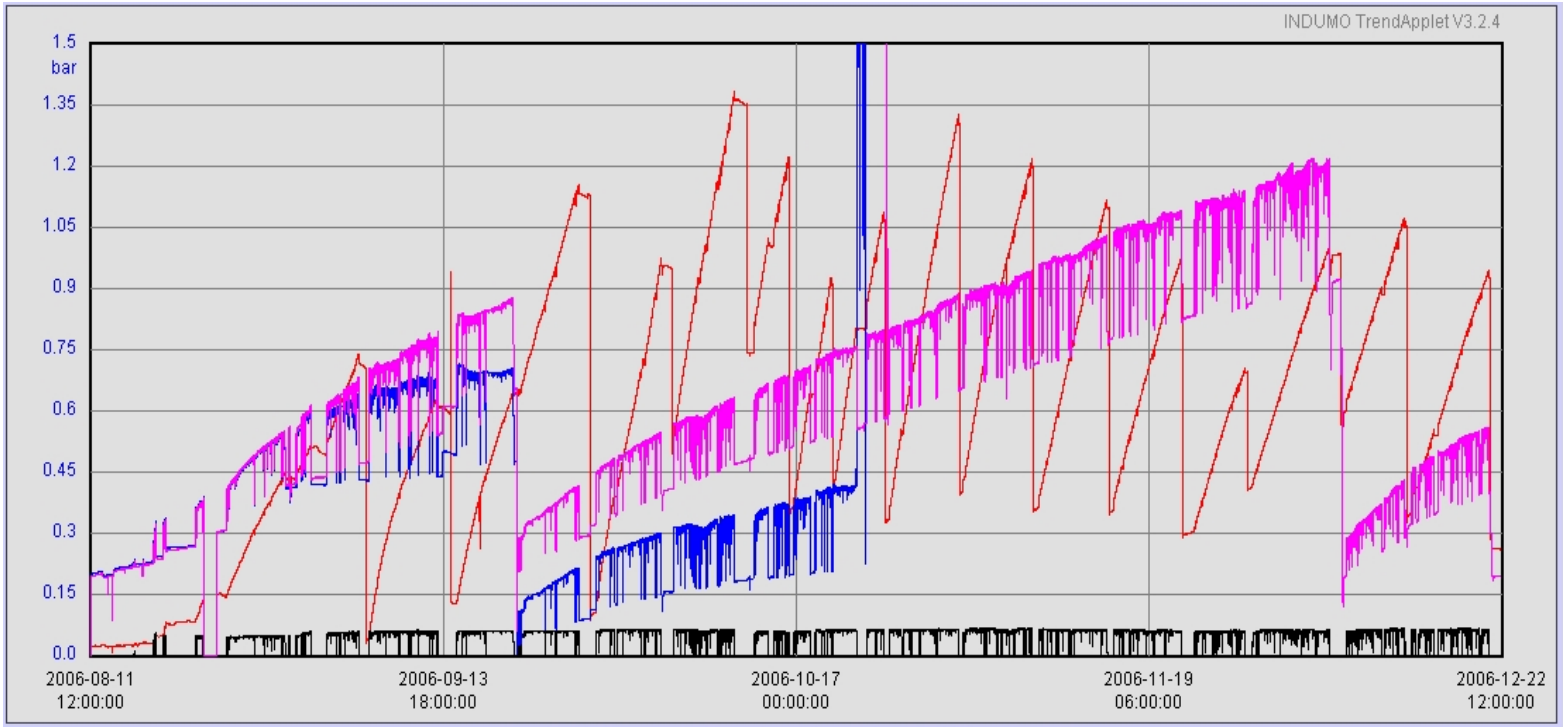
Farbe	Anzeige	Name der Trendlinie	Beschreibung	Skala Min	Skala Max	Cursorwert	Einheit	Min	Max
	☑	MP_1KGH71_CP001_Z400_AVG	Absolutdruck	0	1	0	bar	0	0.95
	☑	_1CFD01_FR001_RZ400_AVG	Protonenstrahlstrom	0	2000	0	mA	0	5000
	☑	MP_1KGA10_CP001_Z400_AVG	Absolutdruck	0	4	0	bar	0	0.95
	☑	MP_1KGA10_CP002_Z400_AVG	Absolutdruck	0	4	0	bar	0	0.95

leaking oil into the insulation gap!

The Stripe Sensor detected leaks better than ever imagined!!

IGS gas analysis (mass spectroscopy):



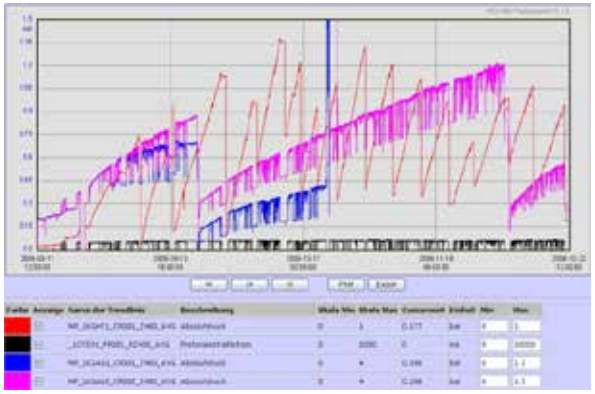


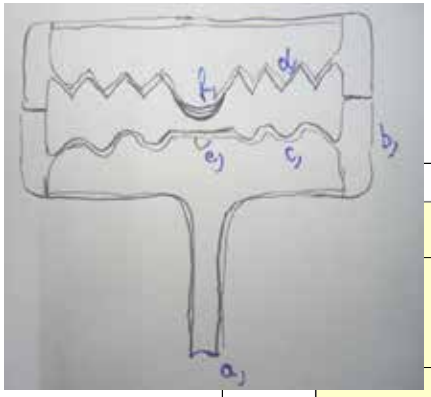
Farbe	Anzeige	Name der Trendlinie	Beschreibung	Skala Min	Skala Max	Cursorwert	Einheit	Min	Max
	☑	MP_1KGH71_CP001_Z400_AVG	Absolutdruck	0	1	0.177	bar	0	1
	☑	_1CFD01_FR001_RZ400_AVG	Protonenstrahlstrom	0	2000	0	mA	0	30000
	☑	MP_1KGA10_CP001_Z400_AVG	Absolutdruck	0	4	0.198	bar	0	1.5
	☑	MP_1KGA10_CP002_Z400_AVG	Absolutdruck	0	4	0.198	bar	0	1.5

CG and IG pressure development during start of MEGAPIE

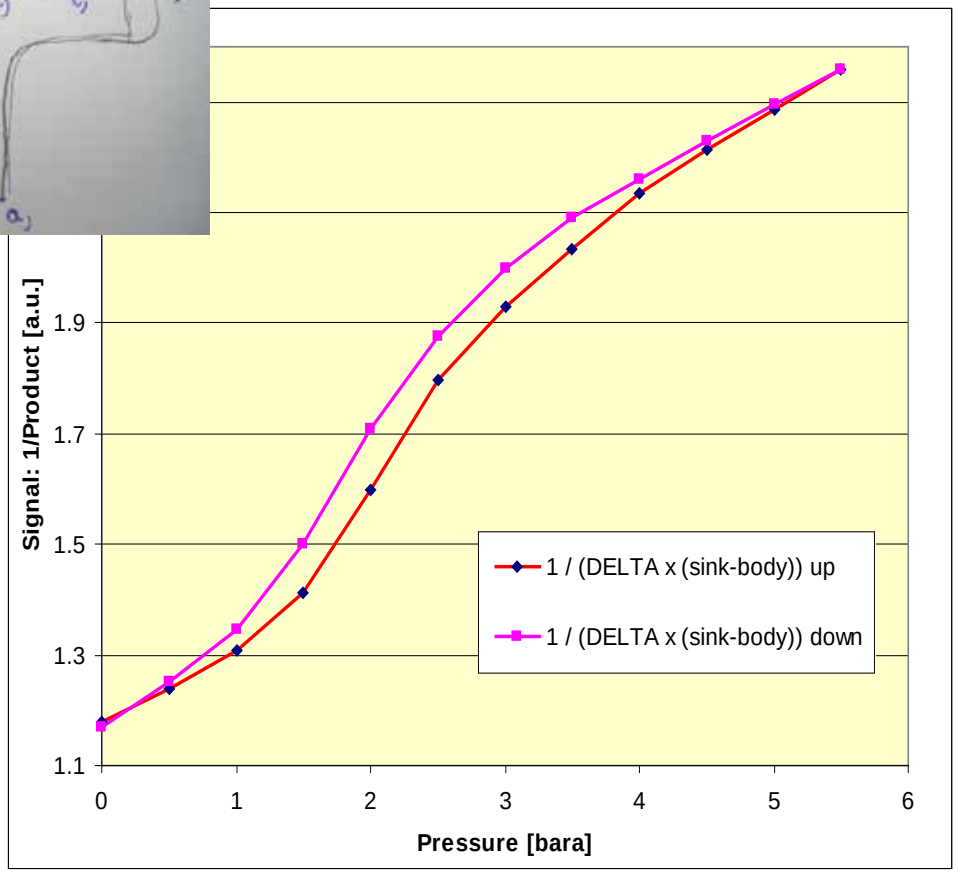
Thermocouple based radiation resistant pressure gage:

(Pat. Appl. No. 08002395.5-1236)



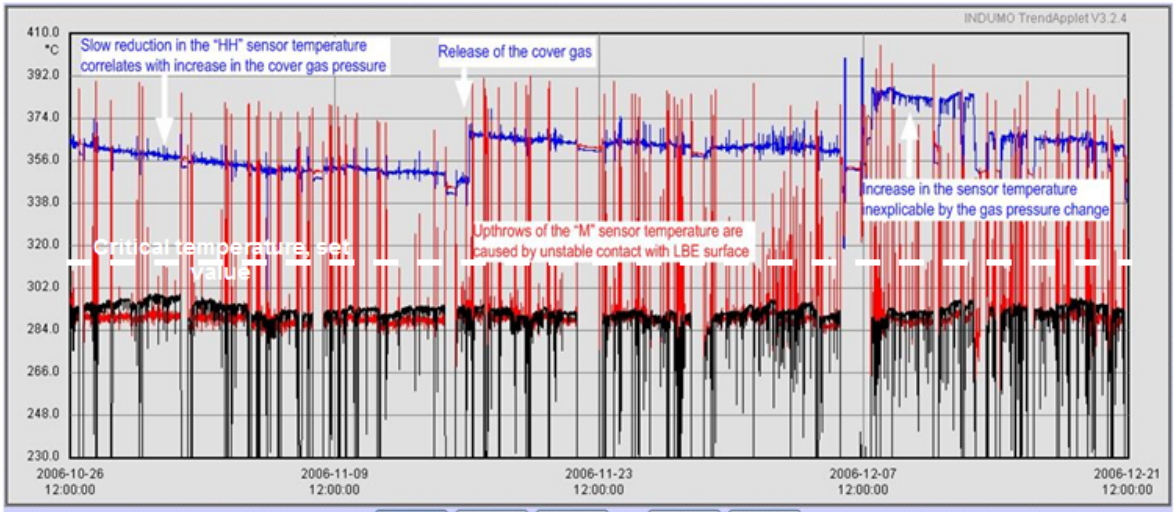


a) Gas connection
b) Body in two parts, vacuum tight welded (e-beam), enclosing a volume with vacuum / gas of reference pressure
c) Membrane (“soft”), polished with low thermal conductivity
d) Membrane (“hard”), polished with low thermal conductivity
e) Contact point 1 with temperature sensor
f) Contact point 2 with temperature sensor and heater (electrical)

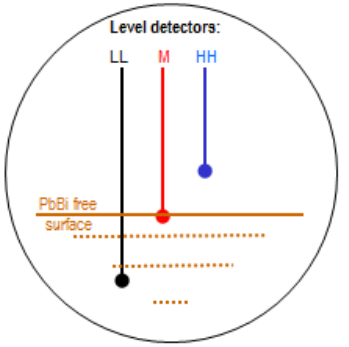


Example: Nitrogen up to 5.5 bara, 0.5 bar steps, 350 mW heating

TC-based level sensors had problems



Farbe	Anzeige	Name der Trendlinie	Beschreibung	Skala Min	Skala Max	Cursorwert	Einheit	Min	Max
	☑	MP_1RNQ51_CT045_Z400_AVG	Level LBE HH Temperatur	-270	1372	0	°C	230	410
	☑	MP_1RNQ51_CT043_Z400_AVG	Level LBE M Temperatur	-270	1372	0	°C	230	410
	☑	MP_1RNQ51_CT040_Z400_AVG	Level LBE LL Temperatur	-270	1372	0	°C	230	410



Lesson learned:

Evidently the heated thermocouples was not an optimal solution for the LBE level and leak detectors. Temperature and cooling conditions in the target are unstable therefore the sensors signals interpretation has not a single meaning. It may well be that it is better to return to conductive type sensors, which has very stable signal independent on temperature, gas pressure etc.

Some more problems and lessons learned

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Complications during the target filling

Very long and small diameter filling pipe without temperature control: risk of LBE freezing during filling the target.

Lesson learned: A special heater for the filling pipe is necessary.

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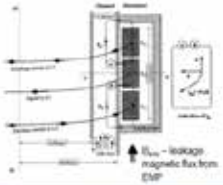
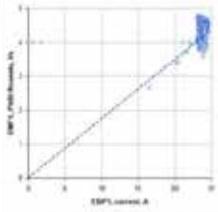
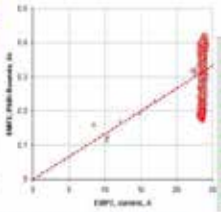
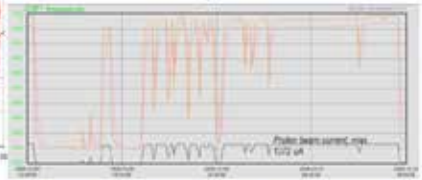
Unacceptable performance of the PbBi flowmeters

Leakage magnetic flux from EMP is imposed upon magnetic field of the EMF. That destroys symmetry of magnetic field in the flowmeter channel and causes drift of the signal.









Relative error of PbBi fowrate measurements: EMF1 - app 30%, EMF2 – 60%

Thermal stresses deform the flowmeter mechanical structure. That leads to corresponding realignment in magnetic field and to a drift of the flowmeter signal.

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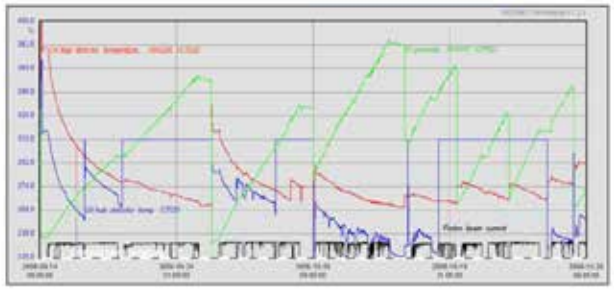
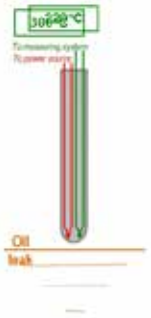
Some uncertainties in the oil leakage detectors indications





No lesson learned for today. Reasons of the strange behavior is unclear at least before PIE.

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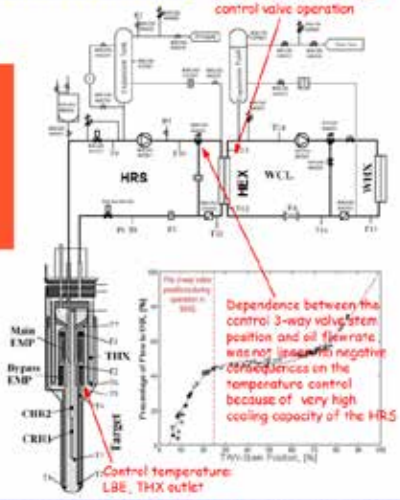
Heat Removal System operated well, but…

A failure of the control valve during MEGAPIE integral test

Lesson learned:

It is necessary to optimize the HRS design to ensure an effective temperature control at more stable temperature regime of the HEX



Acknowledgements

to all these people and many more

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The MEGAPIE-TEST project: Supporting research and lessons learned in first-of-a-kind spallation target technology

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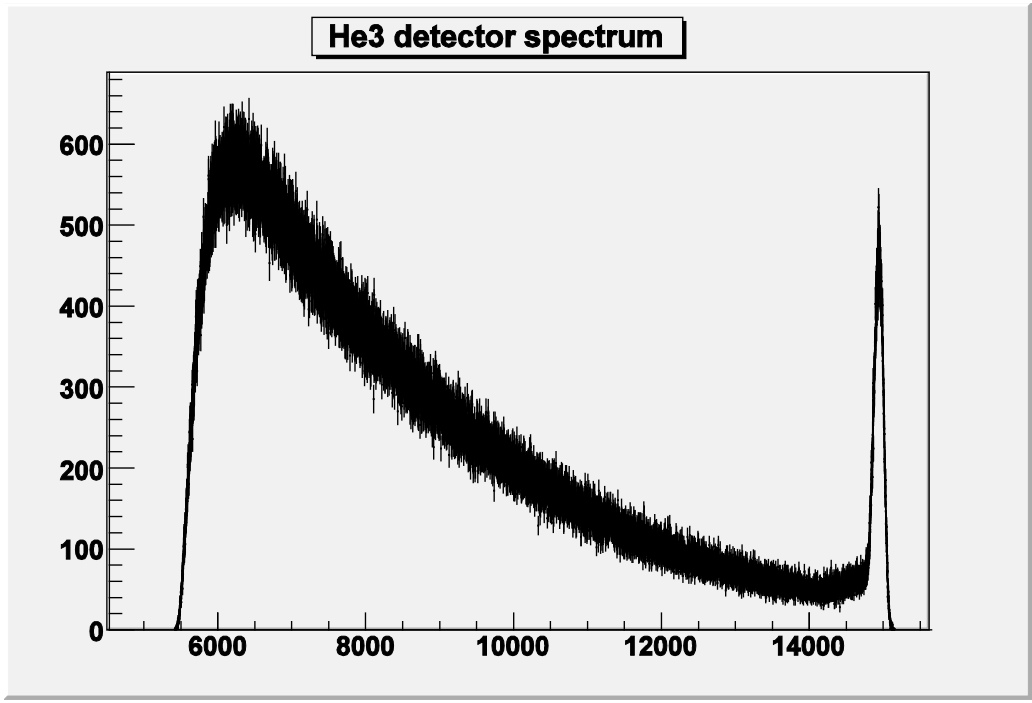
Delayed Neutron measurement

(n-detector in the TKE)

D. Doré, X. Ledoux, S. Panebianco, A. Prevost, D. Ridikas, *CEA, France*

Objective:

- **Investigate the spontaneous (βn)-decay reaction of spallation products**
- **Besides general interest: Relevance for activation and safety issues in flowing media**



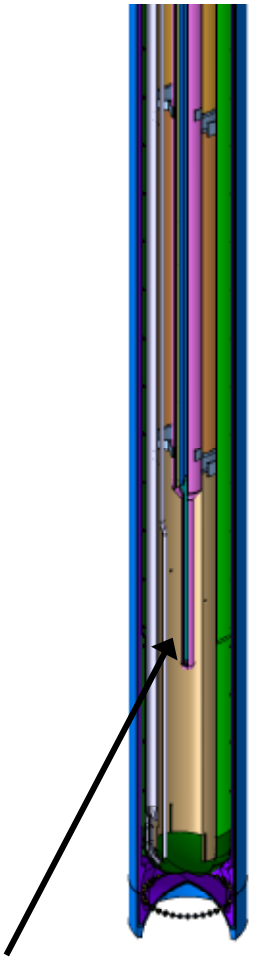
raw analog signal distribution coming from pre-amplifier, taken at 40 µA.

Neutron flux by fission chambers

A. Letourneau, S. Chabod, Ph. Beauvais, E. Dupont, P. Lotrus, F. Molinie, S. Panebianco, J.C. Toussaint, S. Breaud, L. Oriol, F. Chartier *CEA France*

Objectives:

- Test of newly developed **miniaturized „thermocouple-sized“ fission detectors** in a realistic temperature/radiation environment
- **Neutron flux measurements** in the **immediate vicinity** of the spallation zone, **distinguishing thermal, epithermal and fast components**
- Measurement of **transmutation rates** of selected minor actinides (e.g. Am)



central rod housing arrays of fission chambers