A Dedicated Beam Interrupt System for the safe Operation of the MEGAPIE Liquid Metal Target

HPPA5

6-9 May 2007, Mol, Belgium

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MEGAPIE Safety Systems:

Transmission Monitor

Slit KHNY30

VIMOS

Beam Losses

EFFECTORS

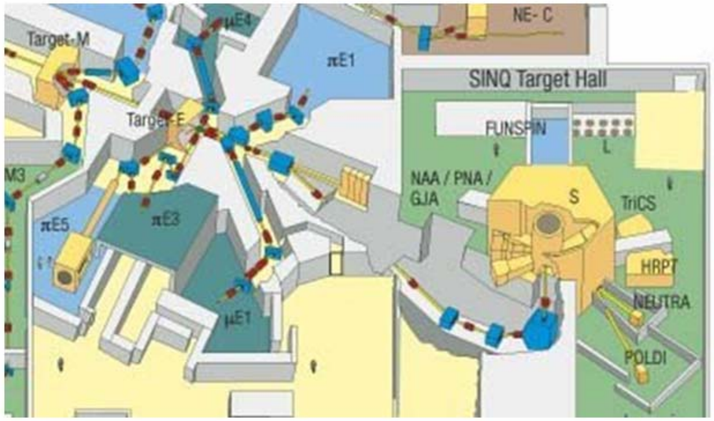
TC LBE Leak Detector

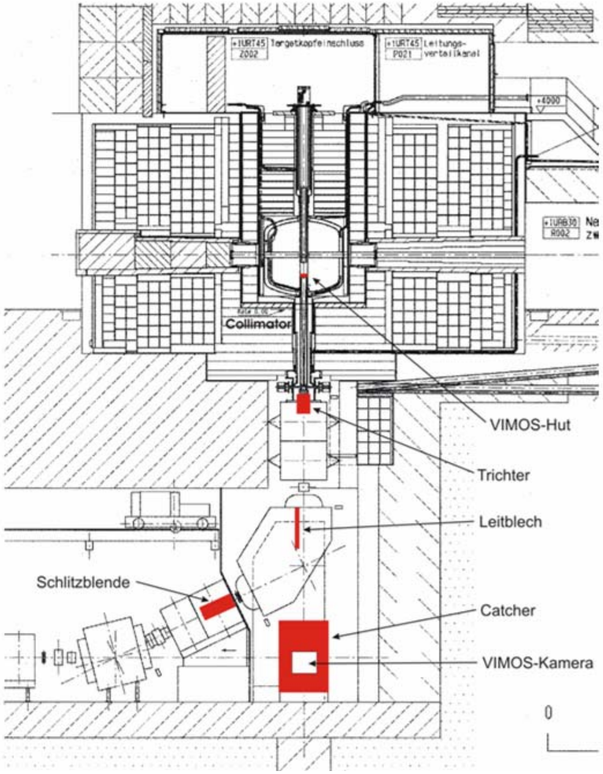
Stripe LBE Leak Detector

Requirements:

The beam has 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**





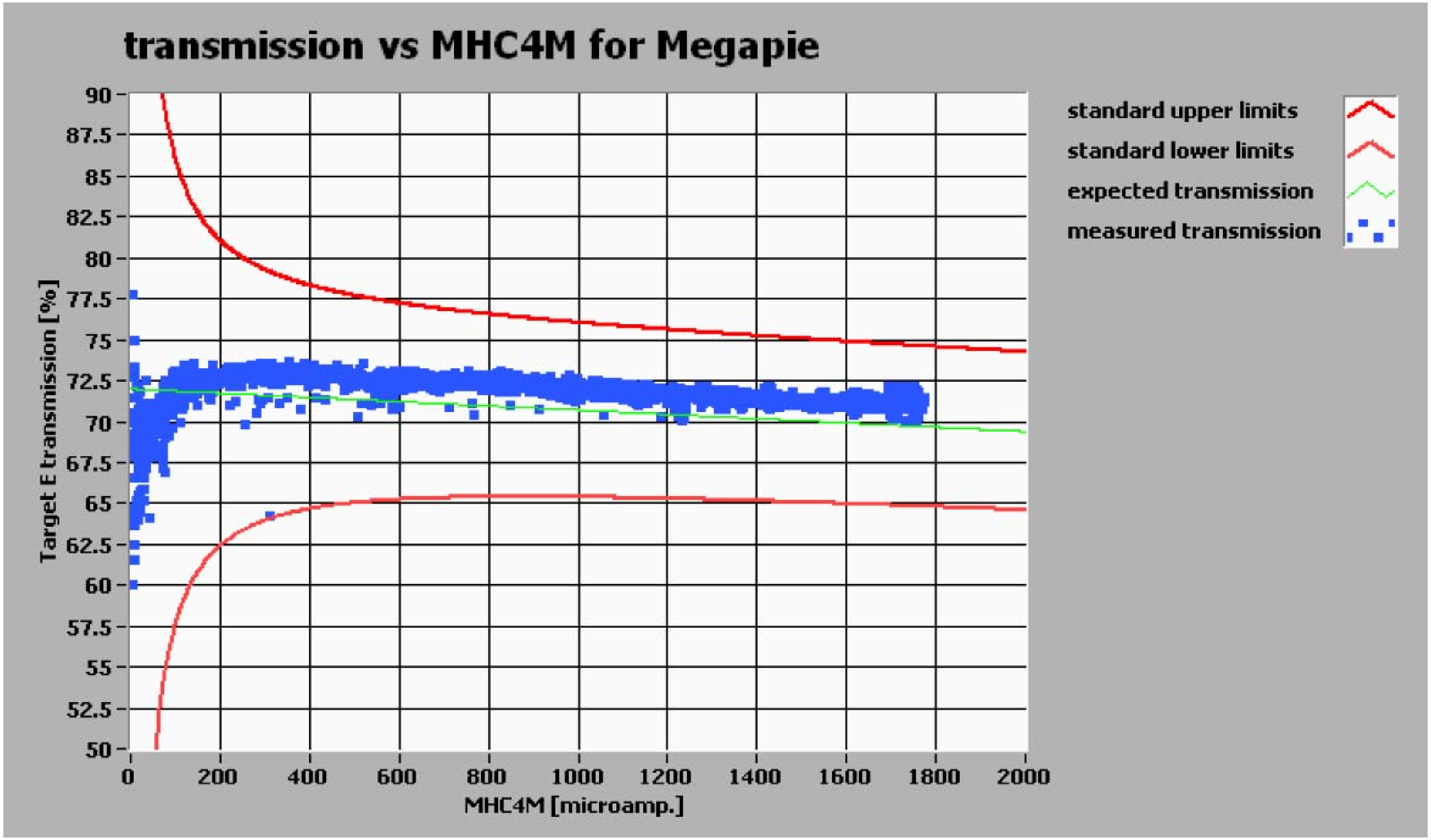
For Megapie, ~~three~~ four (new) Systems watch for correct scattering in Target E and proper Beam Transport

- **Improved Transm. Monitor** (intensity)
- **Slit KHNY30** (beam energy / path)
- **VIMOS** (beam footprint & intensity)
- **Distribution of Losses along Beam Line**

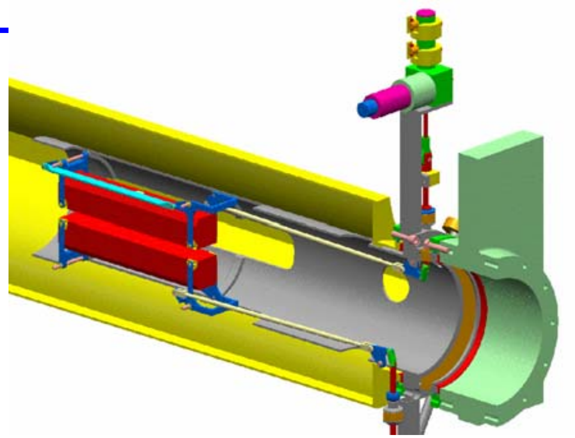
Transmission Monitor

- Total beam current can be measured absolutely to a few % (with calibration)
- Formerly unused signals from existing sensor hardware is employed for additional MEGAPIE current measurements (MHC4/5)
- Main improvement: new (shorter) cables
- Interlock is handled by the SINQ Schnelles AbschaltSystem „SAS“
- Performance compatible with 10 % threshold

Long Term Stability of Current Monitor

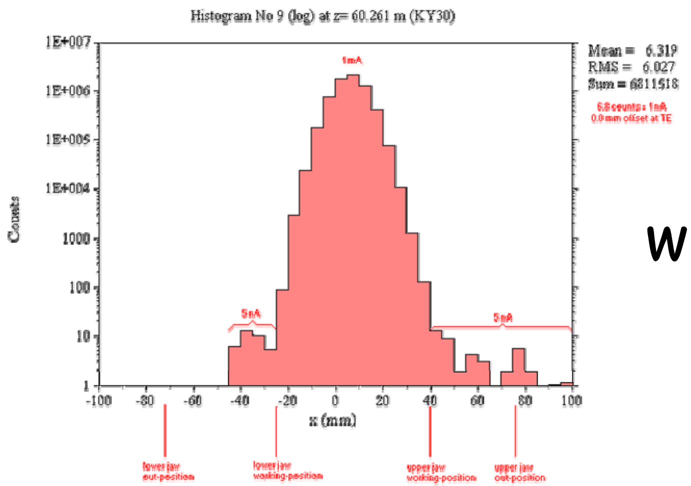


Slit KHNY30

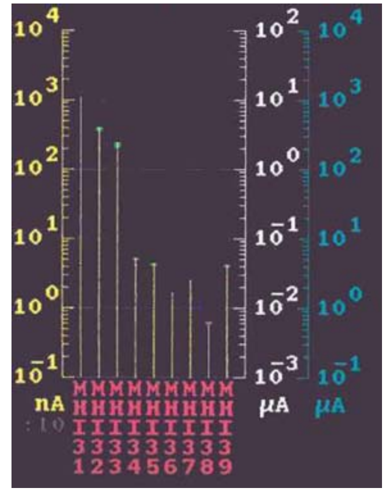


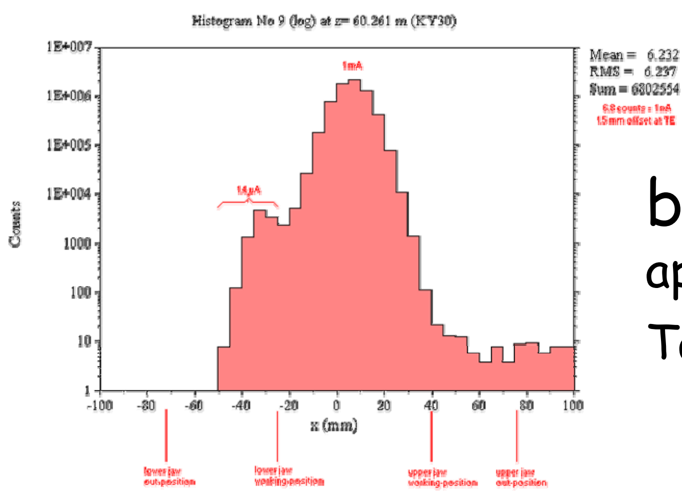
- Path for improperly scattered protons will be blocked, current of jaws will be monitored
- Massive copper bars provide even short-term passive safety
- Interlock is handled by the SINQ Schnelles AbschaltSystem „SAS“ (and the machine „Run Permit System“)
- aided by secondary sensors (e.g. vacuum)
- Confirmed sensitivity at the 0.1 % level

Effect of 0.1 % beam by-passing Target E



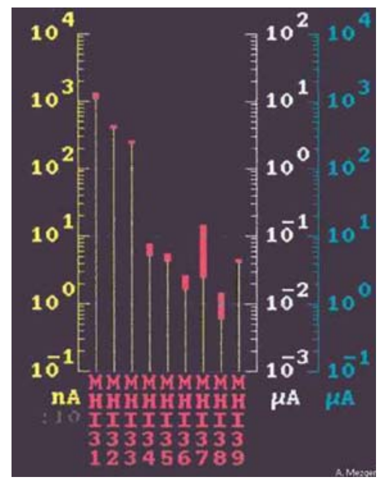
well centered beam





beam shifted 1.5 mm

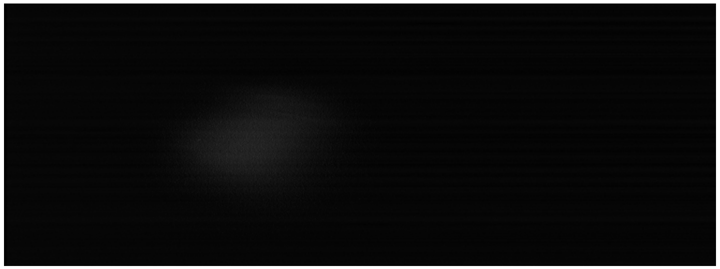
appr. 0.1 % protons by-pass Target E

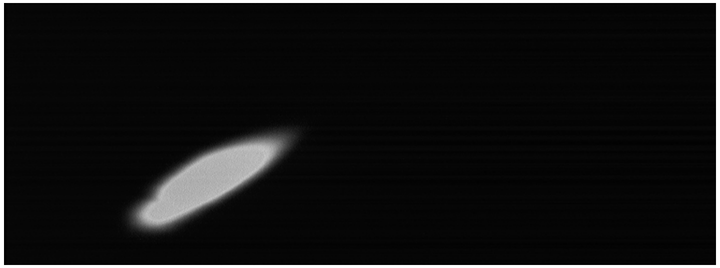


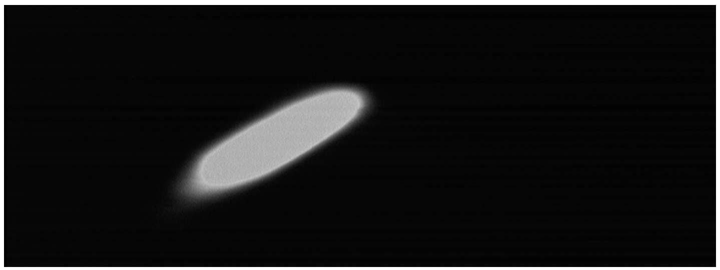
VIMOS

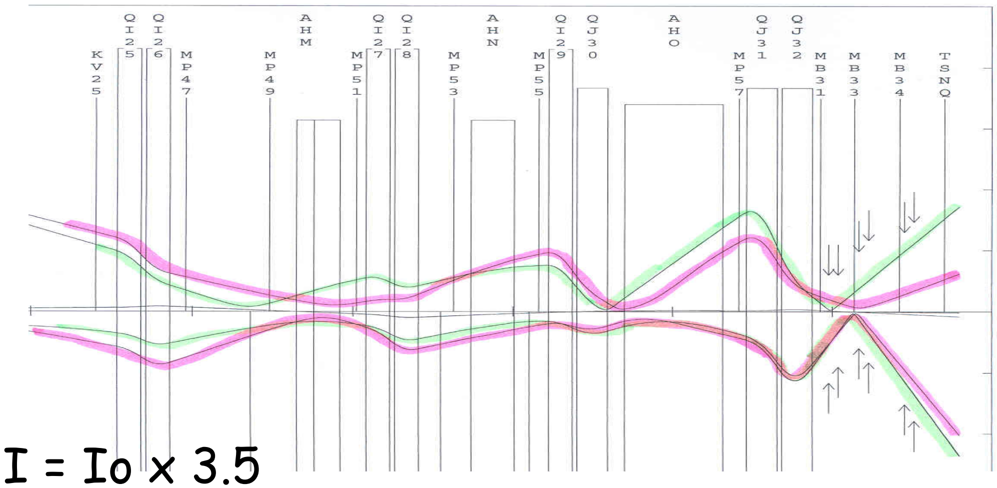
- Beam intensity distribution measured directly in front of the SINQ target
- Glowing of mesh monitored via special optical measurement chain and software
- Two criteria proved to be most effective:
  - Intensity in Regions of Interest (ROIs)
  - Transients in intensity ratios between ROIs
- Interlock is handled by the SINQ Schnelles AbschaltSystem „SAS“
- Performance demonstrated during mishap October 2004

VIMOS saw wrong Parameter File

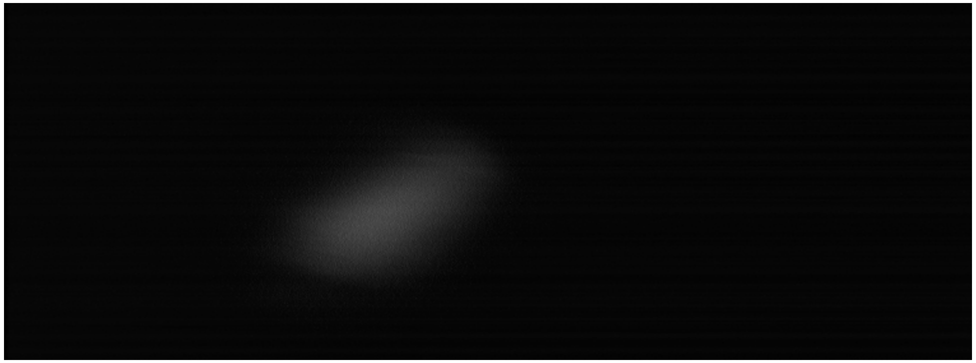








I = Io x 3.5



```
Wed Oct 27 21:20:52 2004

Lost frames: 0
bm1_30911: Mean1:131.175100, Mean2:46.695600, Ratio:2.809153
bm2_30911: Mean1:129.106525, Mean2:46.758324, Ratio:2.761145
bm3_30911: Mean1:130.704061, Mean2:46.765639, Ratio:2.794874
bm4_30911: Mean1:129.476032, Mean2:46.566844, Ratio:2.780434
bm5_30911: Mean1:131.050932, Mean2:46.630073, Ratio:2.810438
```

One more Experts Group is Checking Safety Installations:

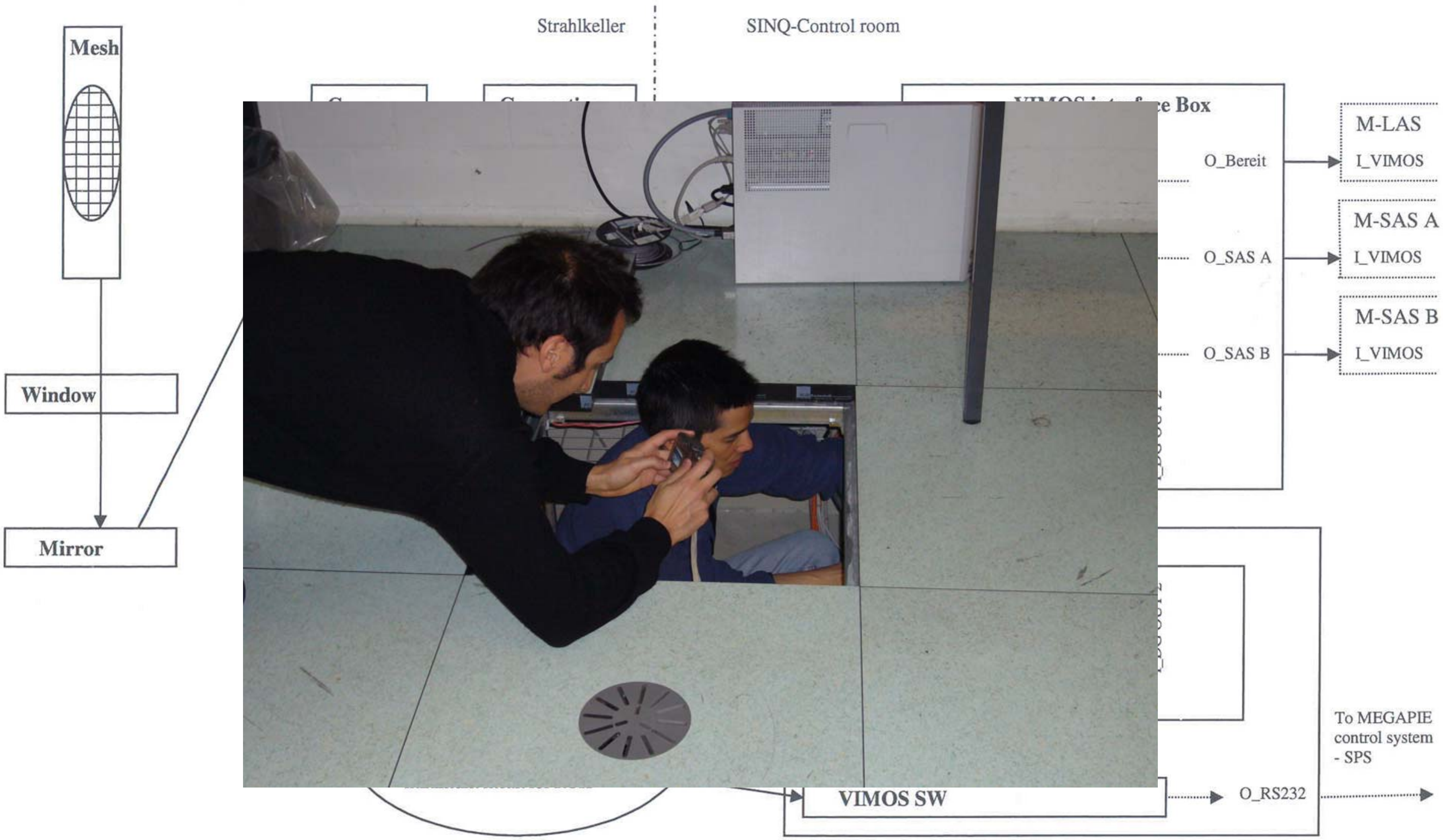
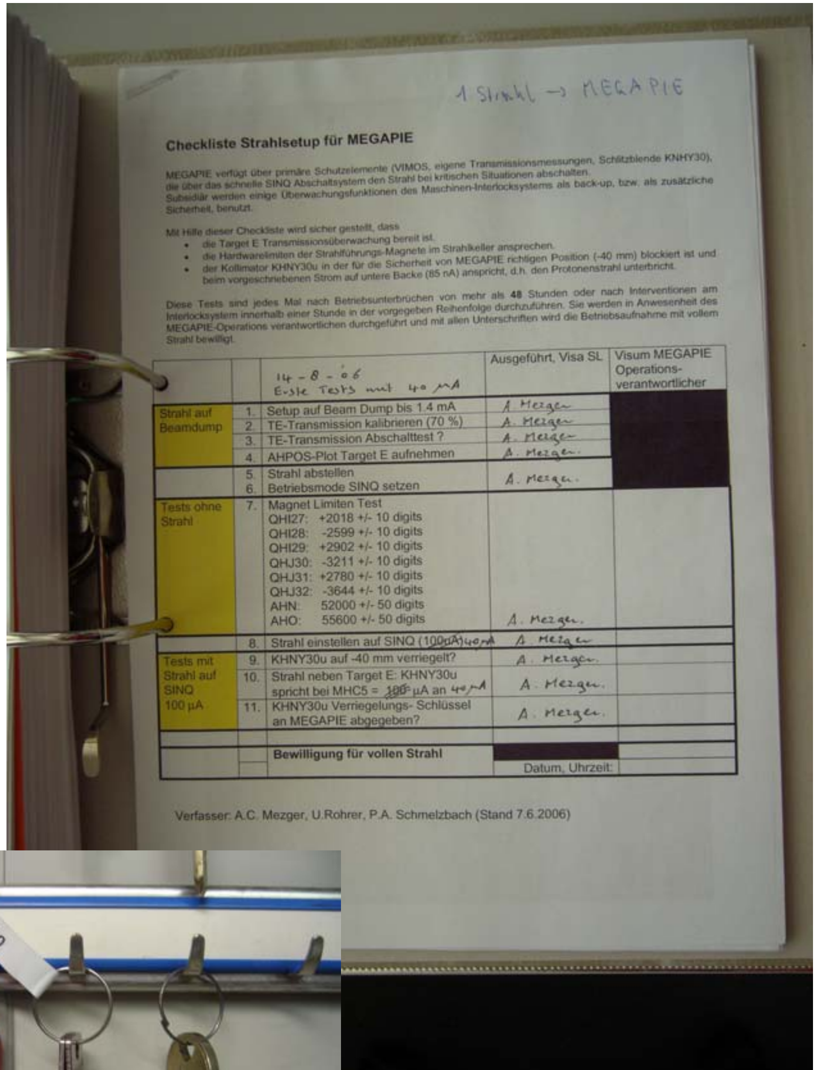
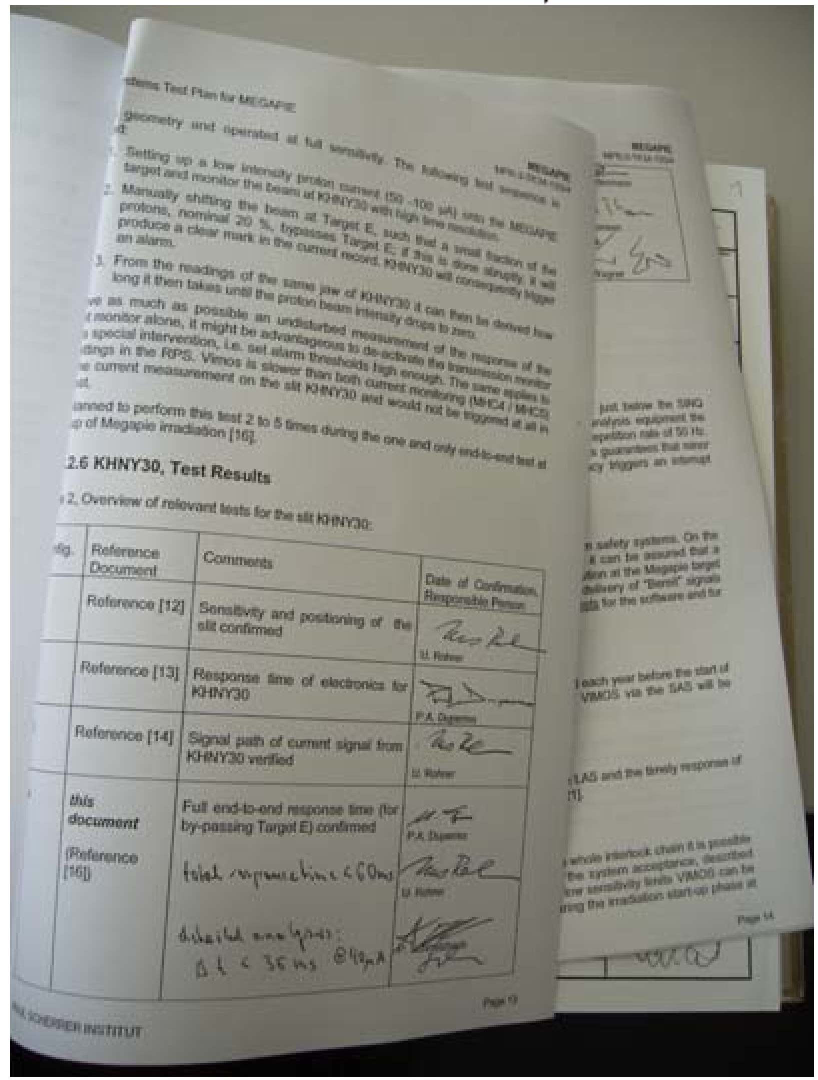


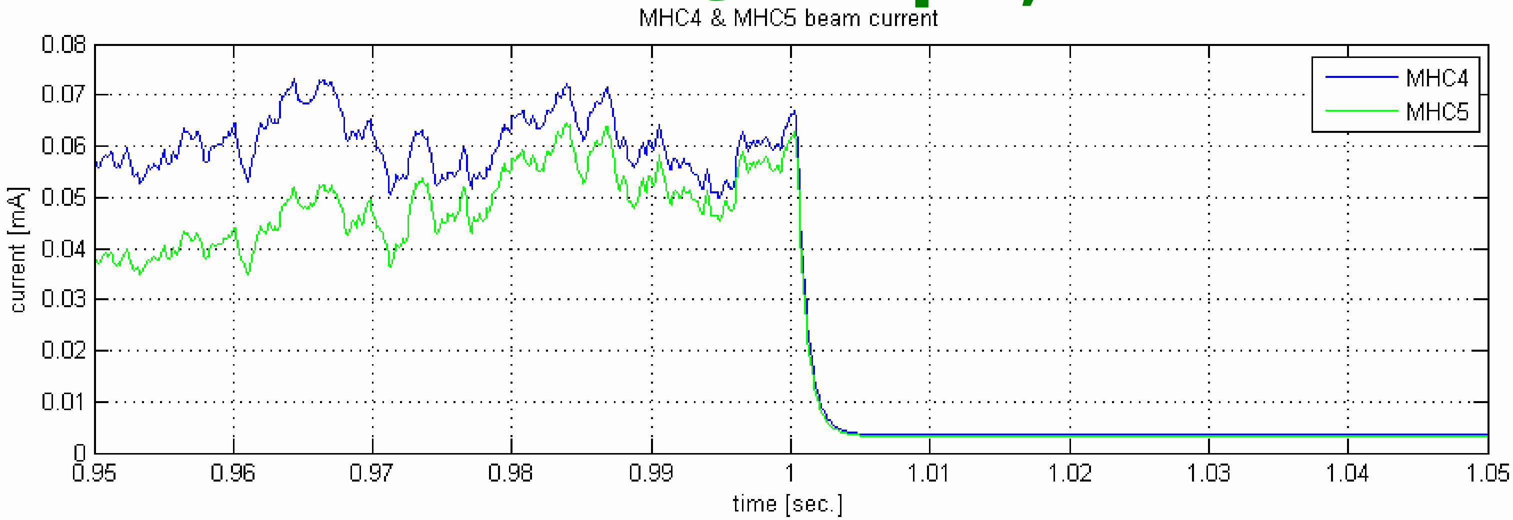
Figure A-3 PSA model of the VIMOS system. Ovals indicate parameters to be set by operator.

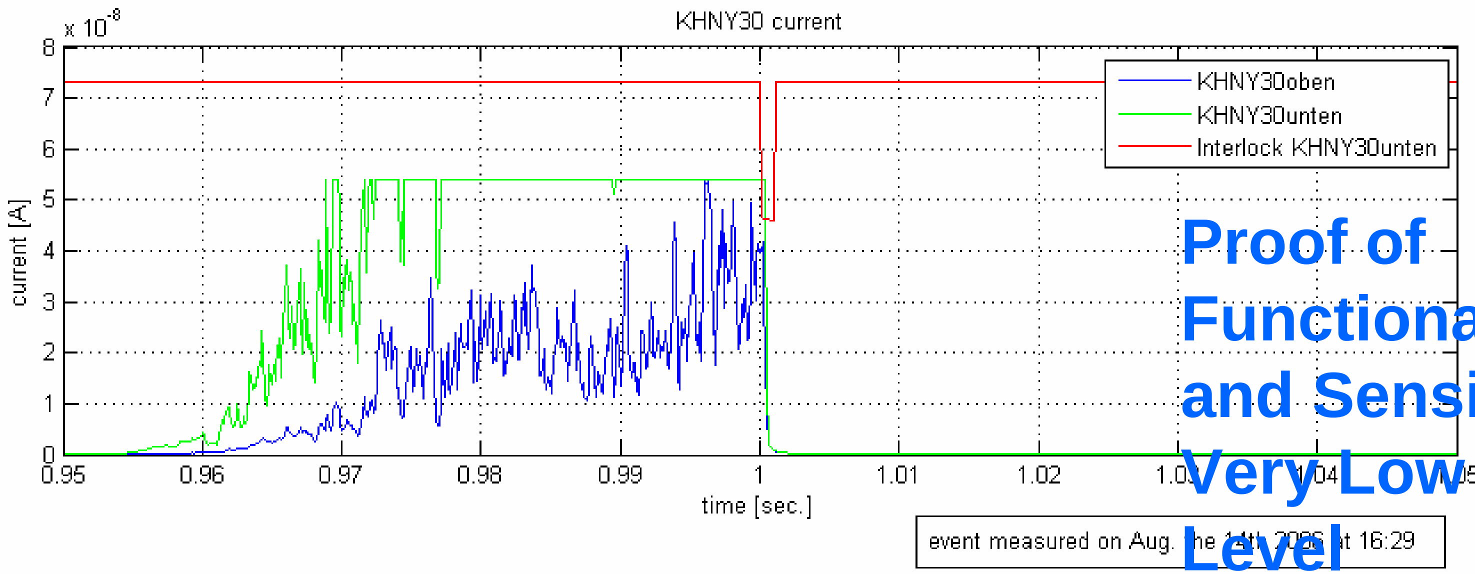




Administartive Measures were applied and Rules were strictly adhered to

End-to-end Test @ 40 µA, Δt < 40 ms





Proof of Functionality and Sensitivity at Very Low Signal Level

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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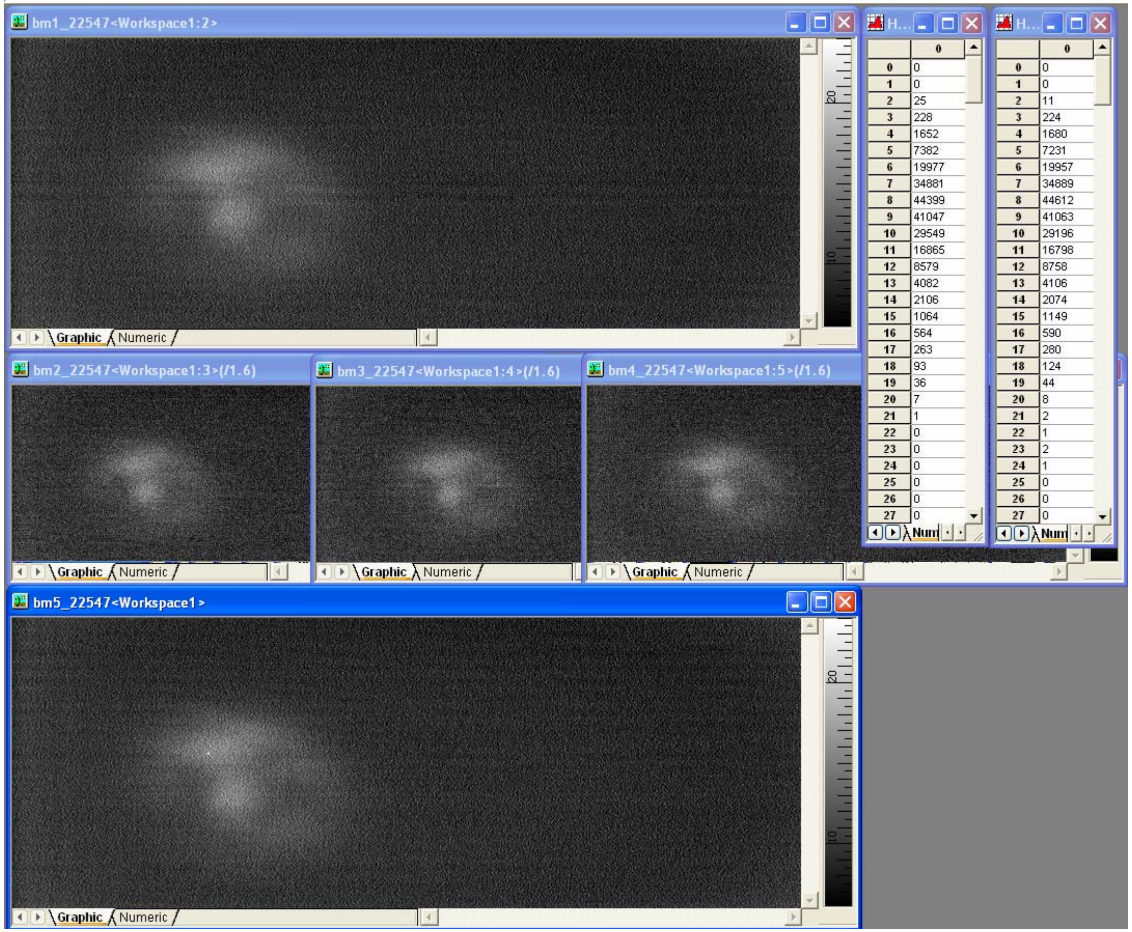

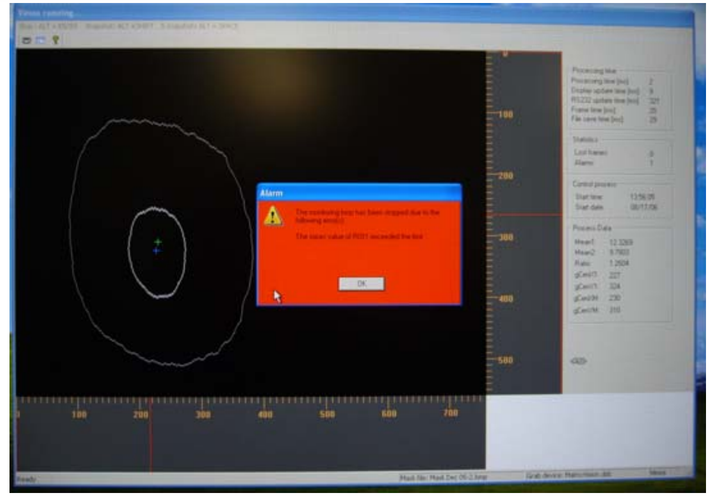

Proof of Functionality and Sensitivity at Very Low Signal Level
(frames enhanced)

VIMOS Alarm on 15 September

BSR-SINQ-6

```
Fri Sep 15 00:49:15 2006

Lost frames: 18
bm1_22551: Mean1:49.777452, Mean2:22.104875, Ratio:2.251877,X-Center of ROI1:232, Y-Center of ROI1:160,X-Center of ROI2 and ROI1 :226, Y-Center of ROI2 and ROI1 :155
bm2_22551: Mean1:49.958113, Mean2:22.138196, Ratio:2.256648,X-Center of ROI1:232, Y-Center of ROI1:160,X-Center of ROI2 and ROI1 :226, Y-Center of ROI2 and ROI1 :155
bm3_22551: Mean1:49.846350, Mean2:22.138268, Ratio:2.251592,X-Center of ROI1:232, Y-Center of ROI1:160,X-Center of ROI2 and ROI1 :226, Y-Center of ROI2 and ROI1 :155
bm4_22551: Mean1:50.199256, Mean2:22.143562, Ratio:2.266991,X-Center of ROI1:232, Y-Center of ROI1:160,X-Center of ROI2 and ROI1 :226, Y-Center of ROI2 and ROI1 :155
bm5_22551: Mean1:50.009395, Mean2:22.140735, Ratio:2.258705,X-Center of ROI1:232, Y-Center of ROI1:160,X-Center of ROI2 and ROI1 :226, Y-Center of ROI2 and ROI1 :155
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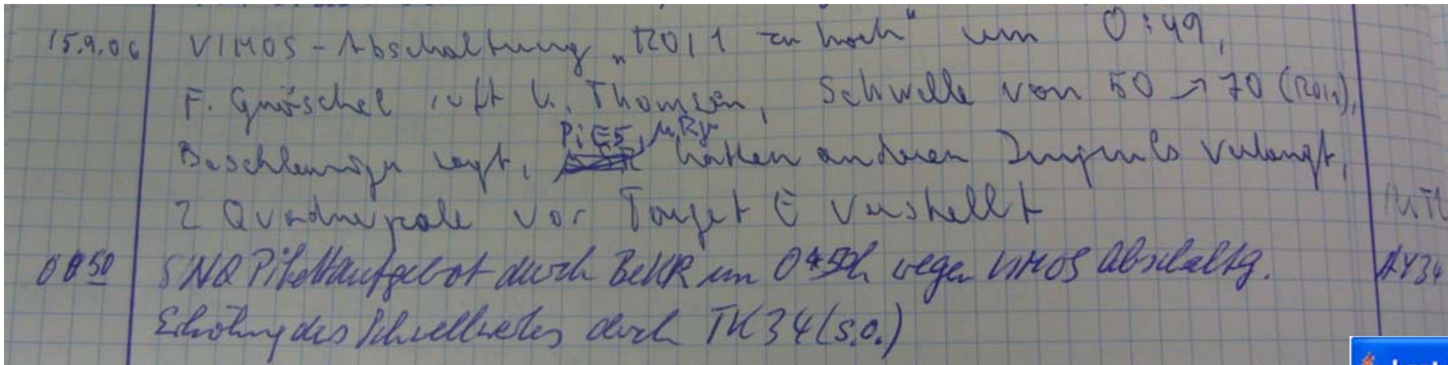
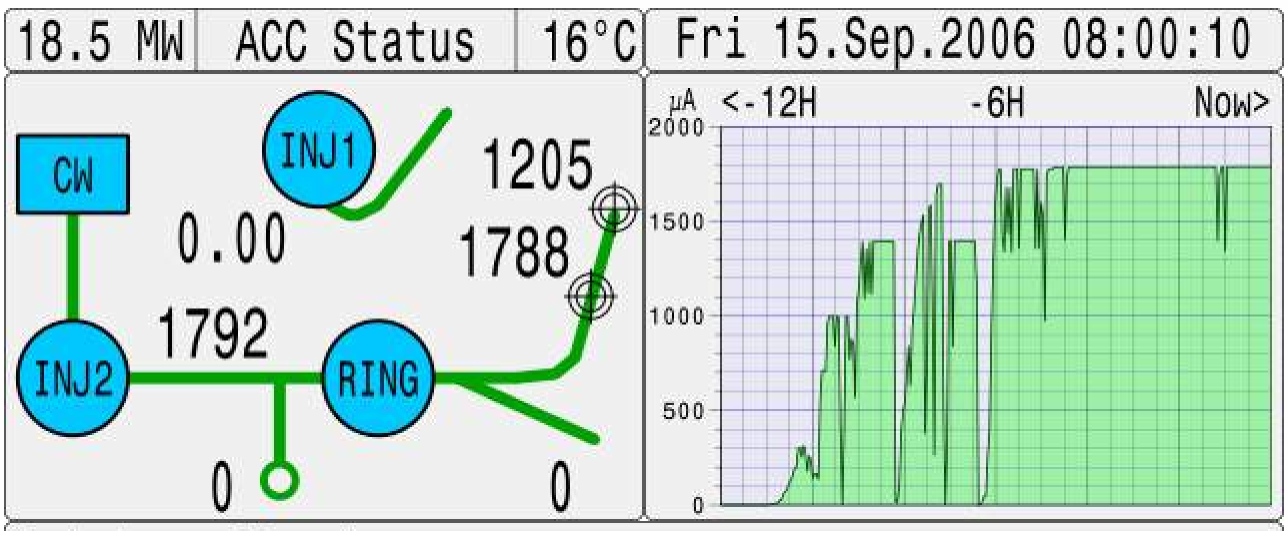
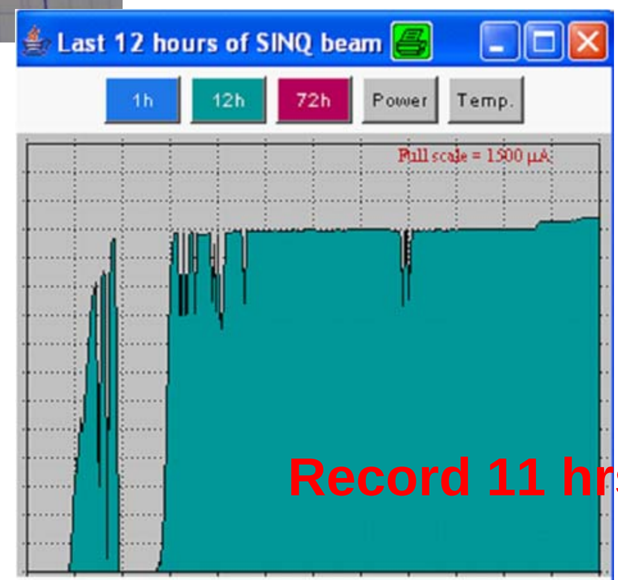
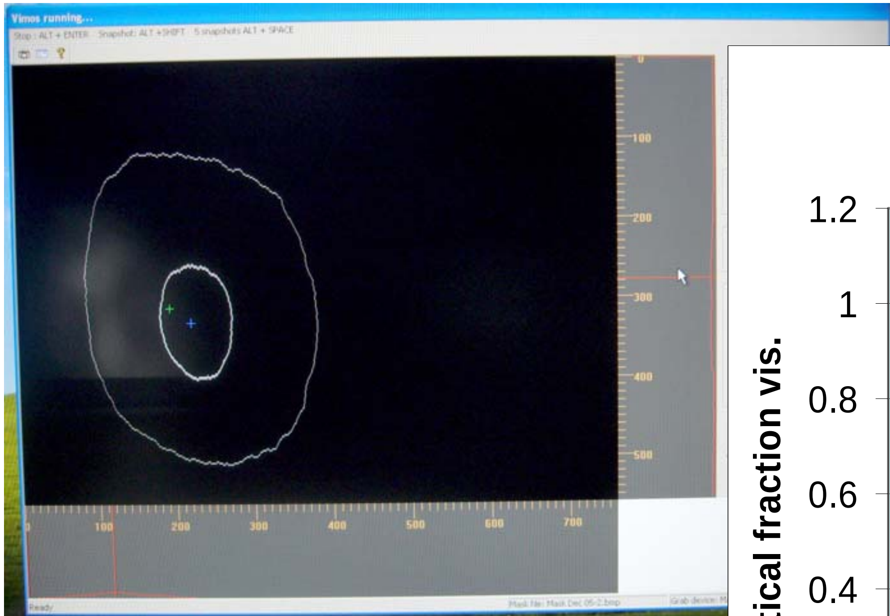
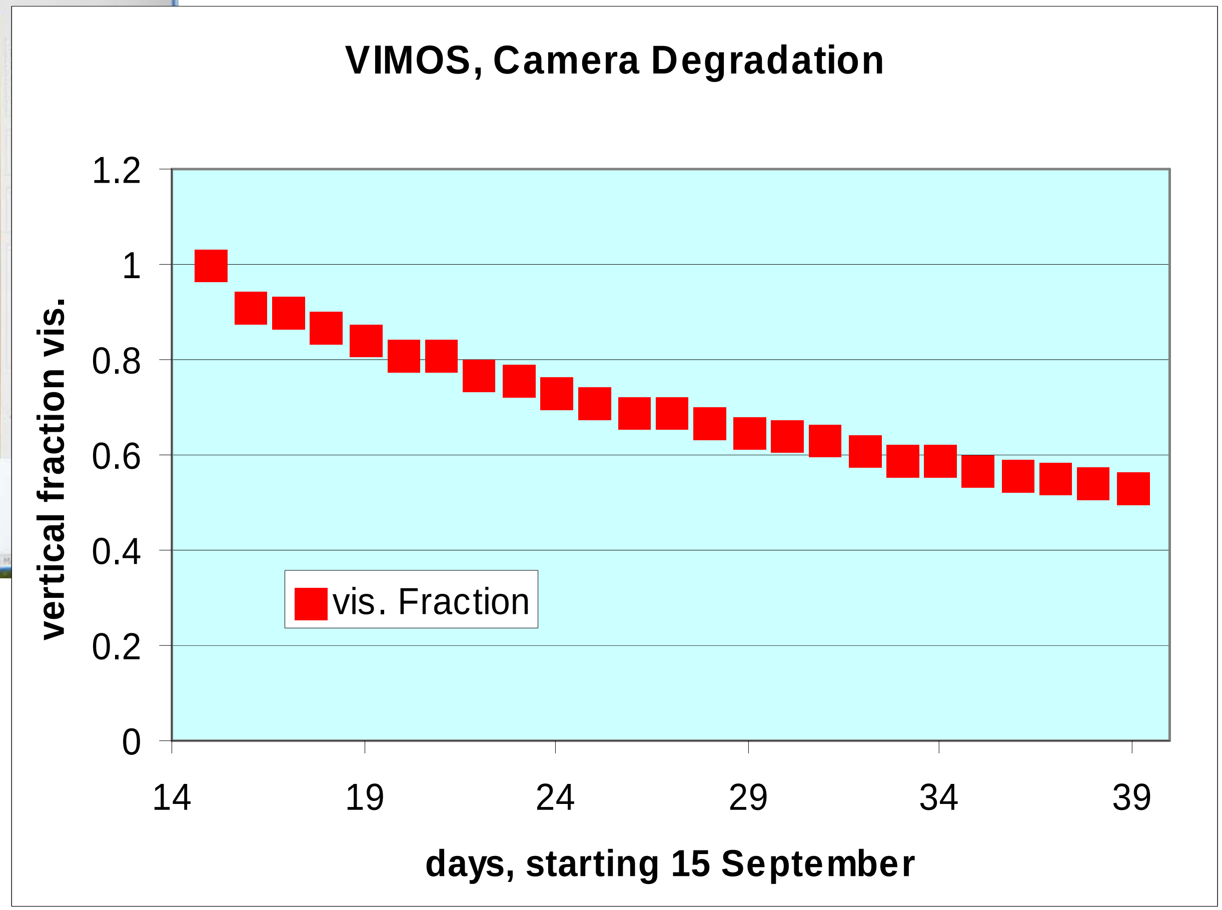






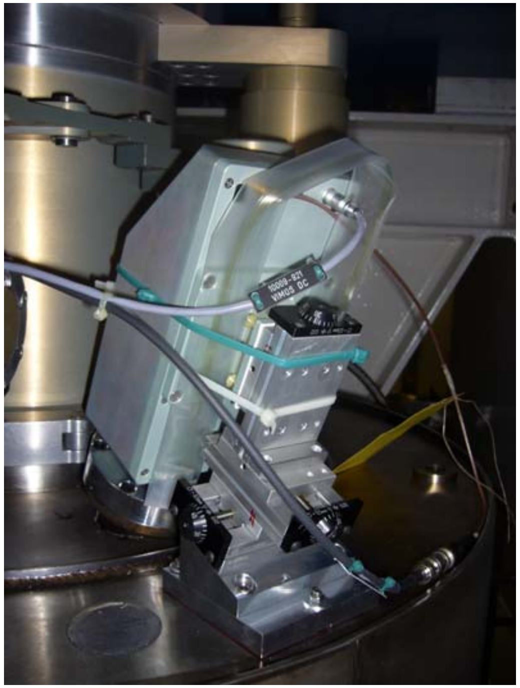
Record 11 hrs

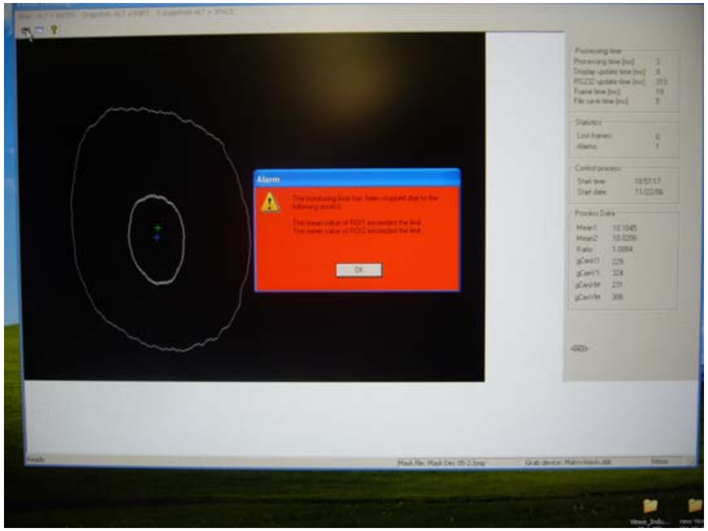


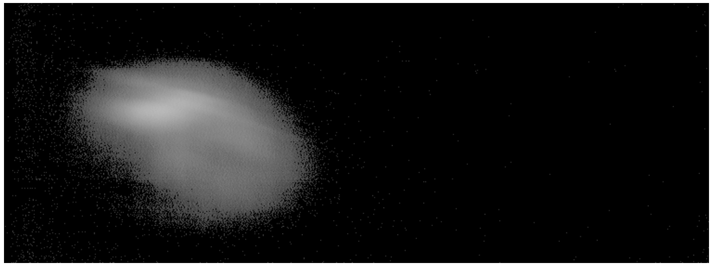


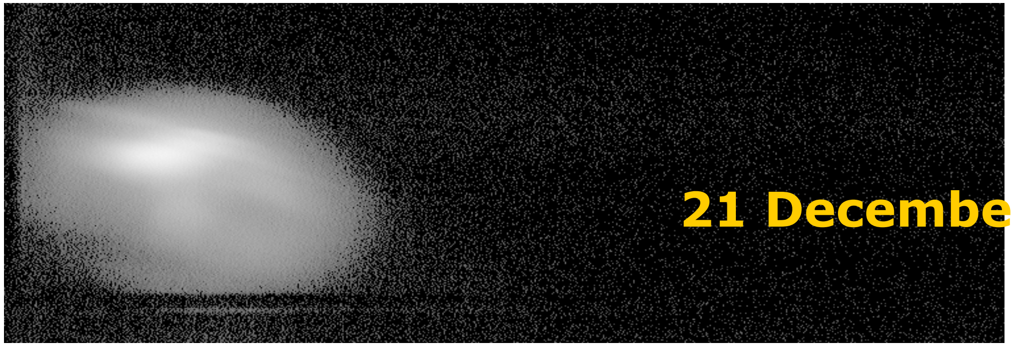
1. New Mask, 2. New Camera

Third Camera: 22 November

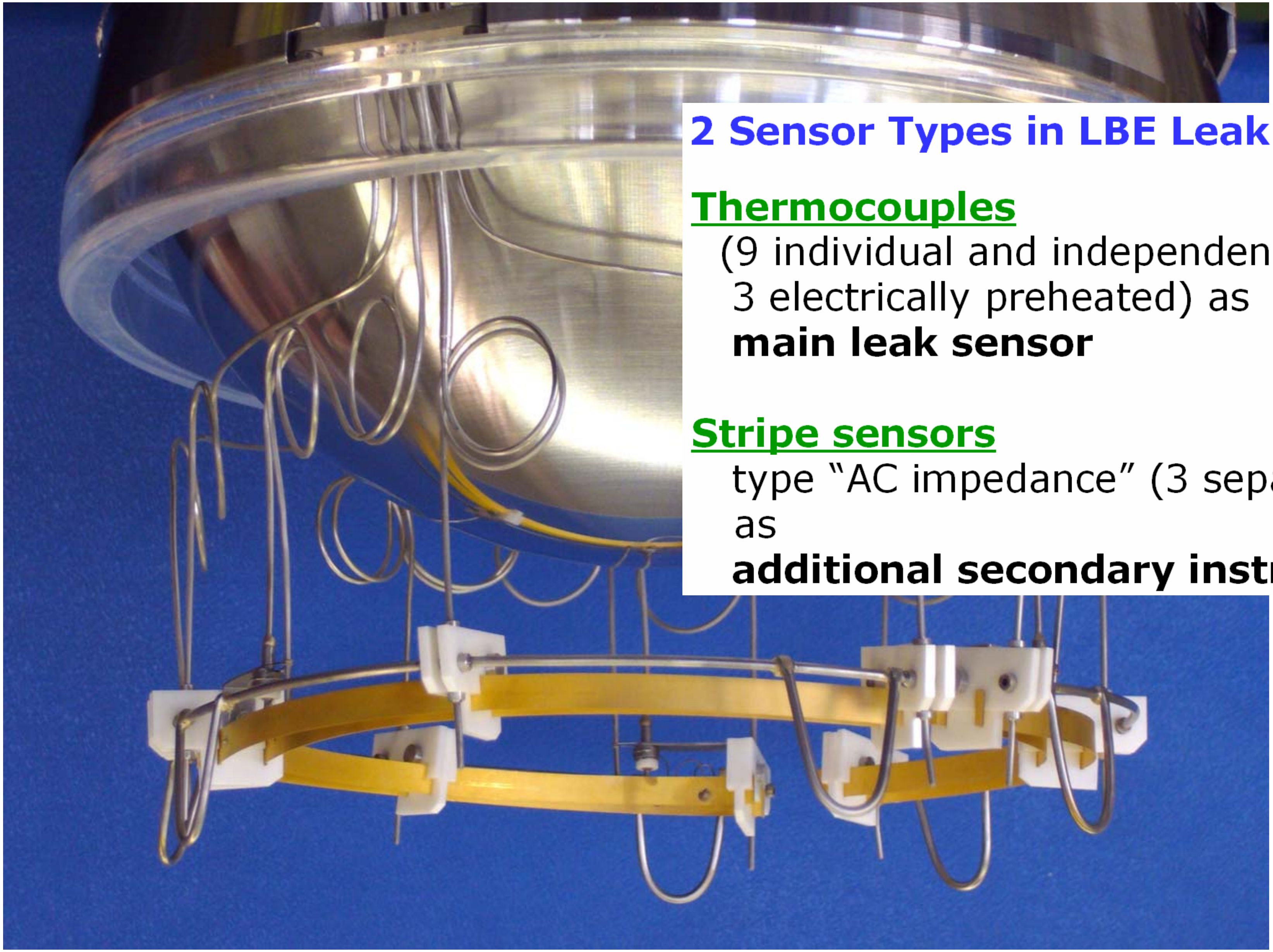








21 December 2006

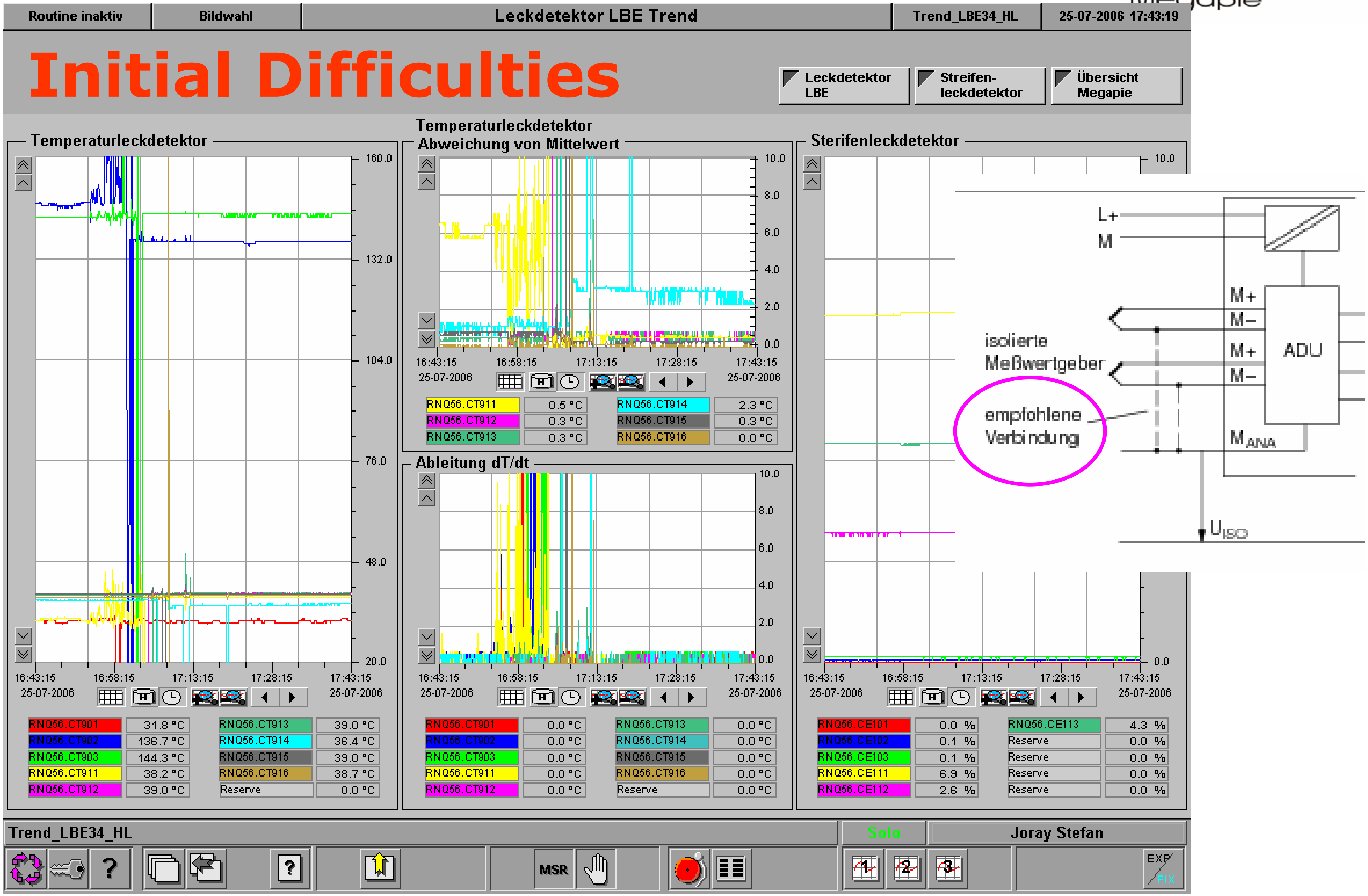


2 Sensor Types in LBE Leak Detector:

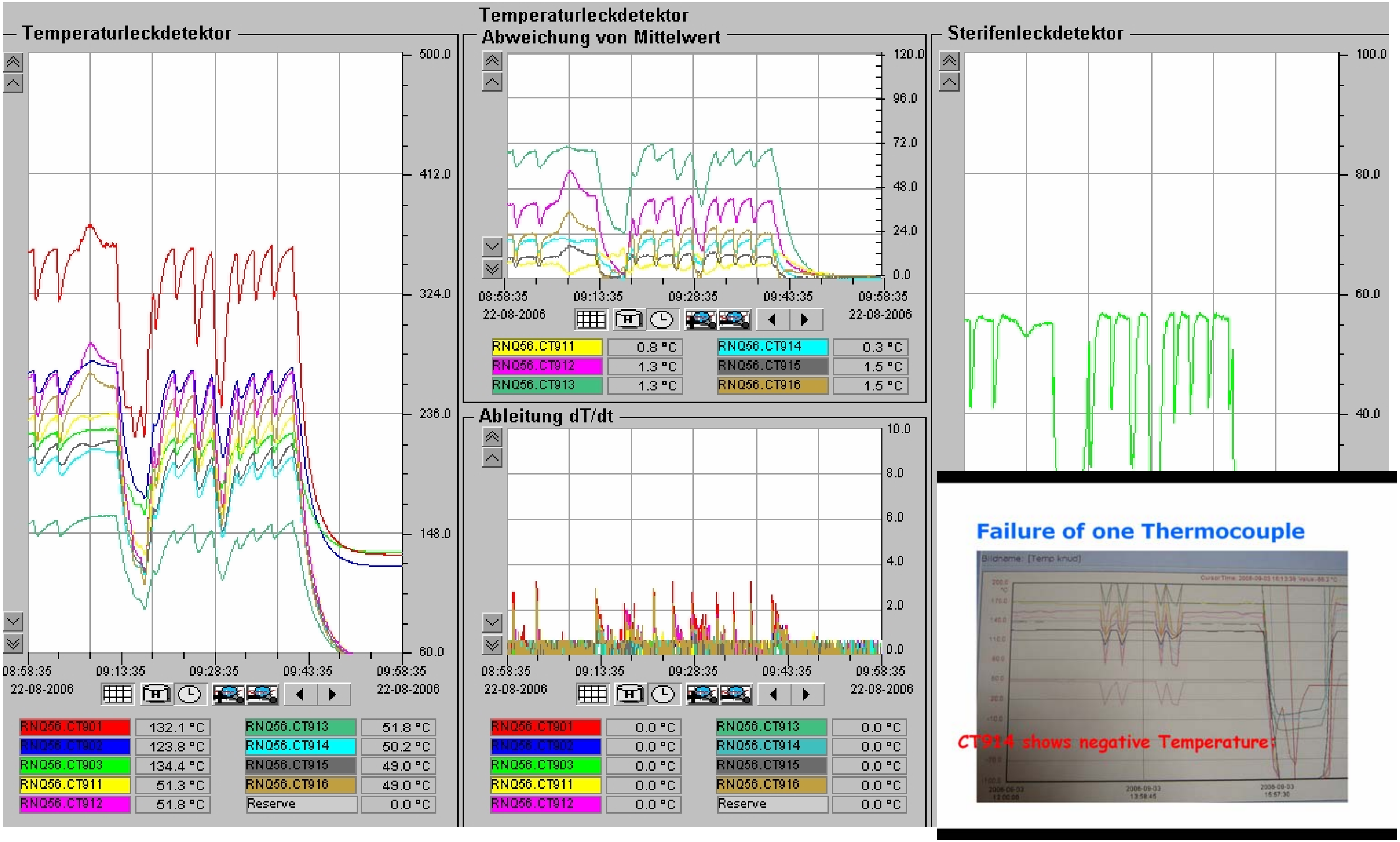
Thermocouples
(9 individual and independent sensors, 3 electrically preheated) as
main leak sensor

Stripe sensors
type “AC impedance” (3 separate units) as
additional secondary instruments

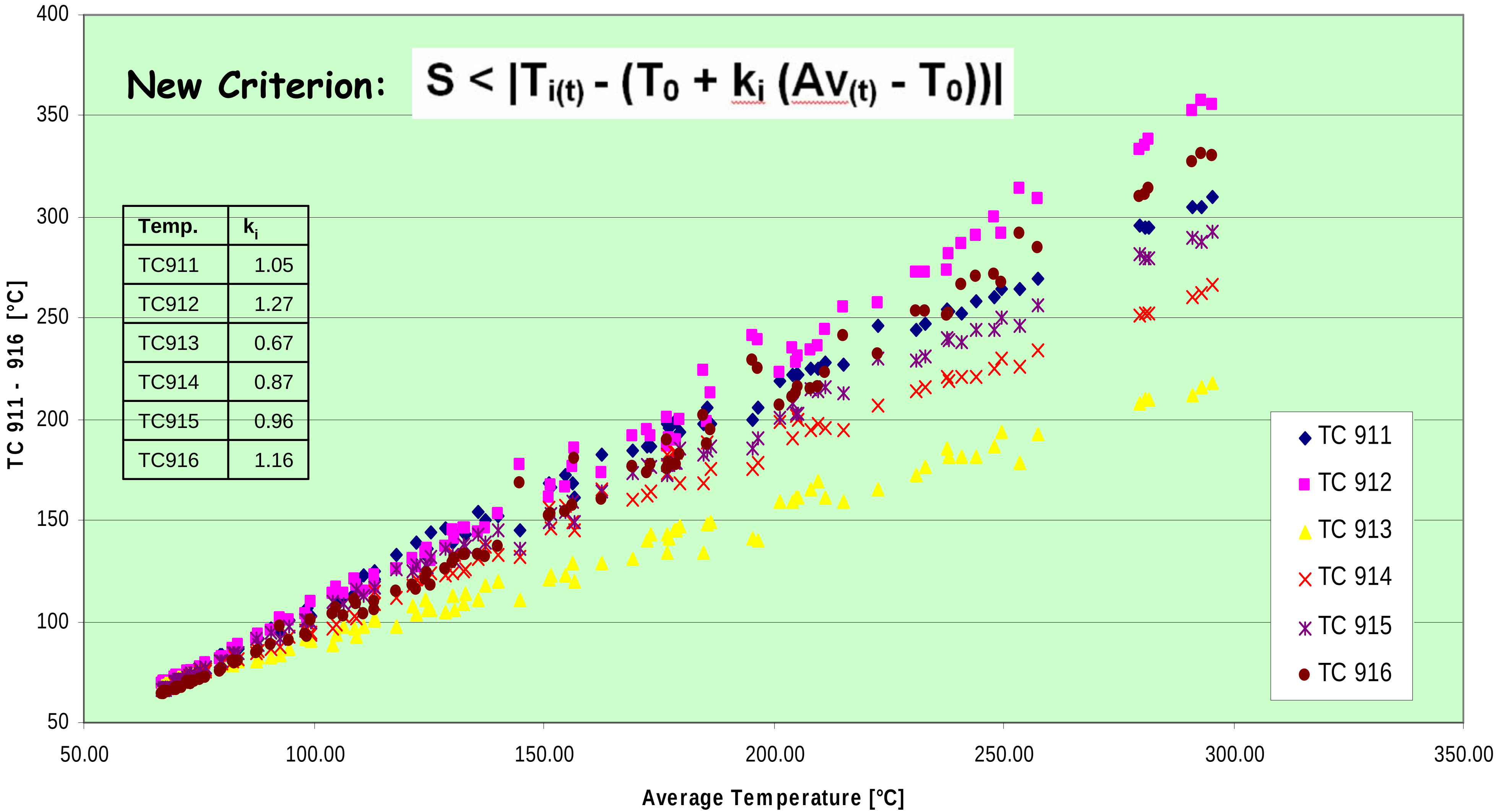
Initial Difficulties



Partly unexpected Results:



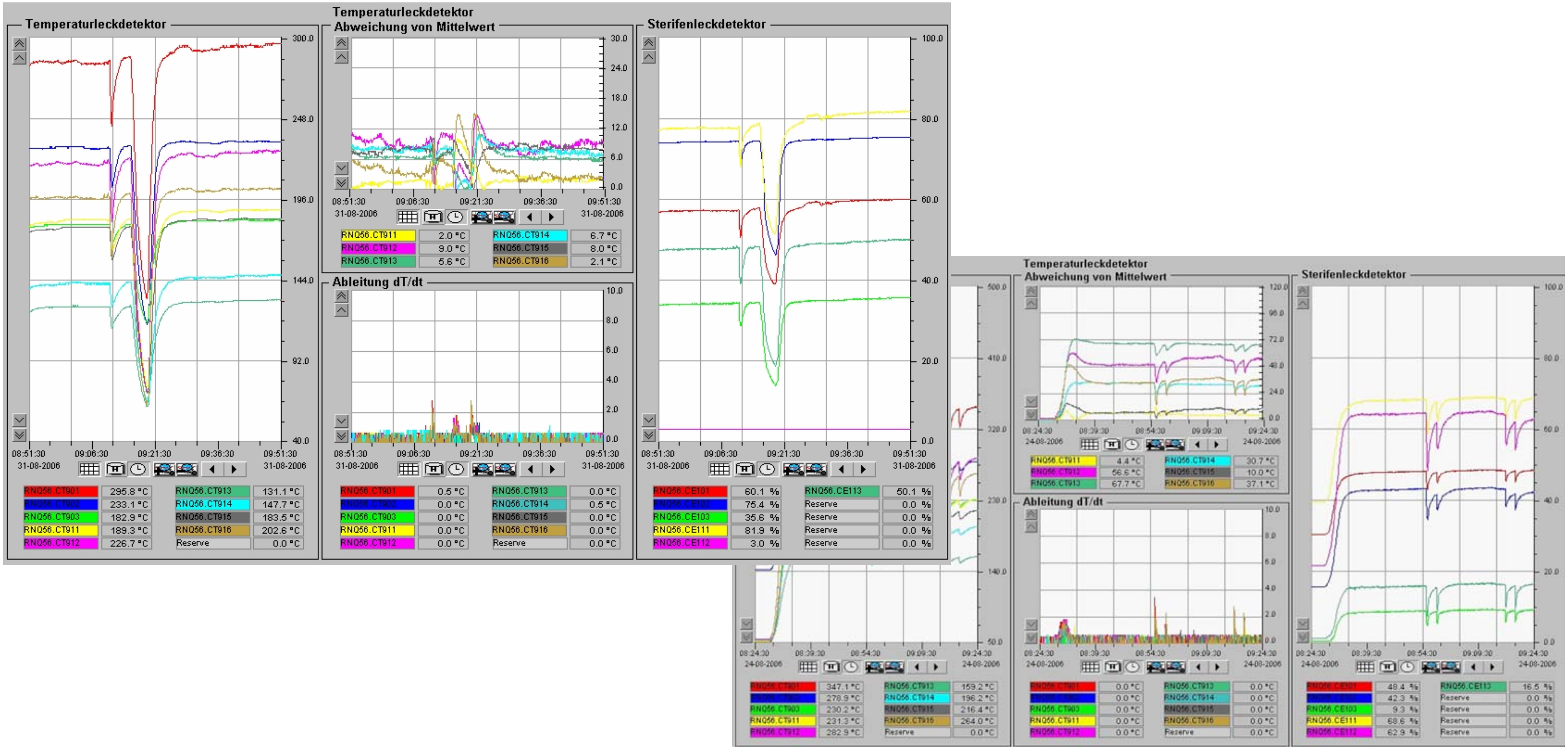
LBE Leak Detector, Temperatures / Average of Unheated TCs



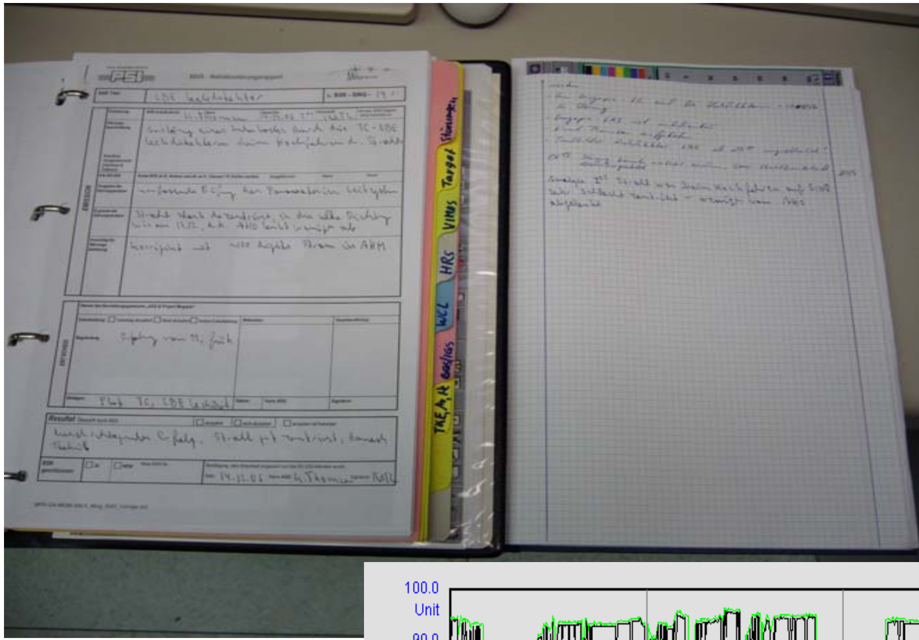
New Criterion: $S < |T_{i(t)} - (T_0 + k_i (Av_{(t)} - T_0))|$

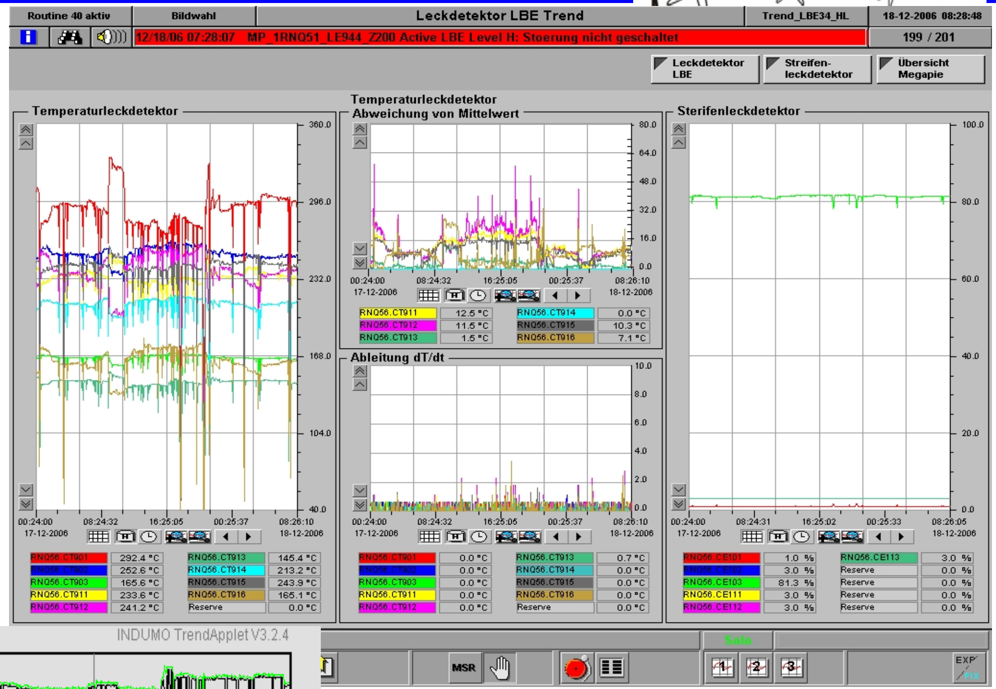
Temp.	k_i
TC911	1.05
TC912	1.27
TC913	0.67
TC914	0.87
TC915	0.96
TC916	1.16

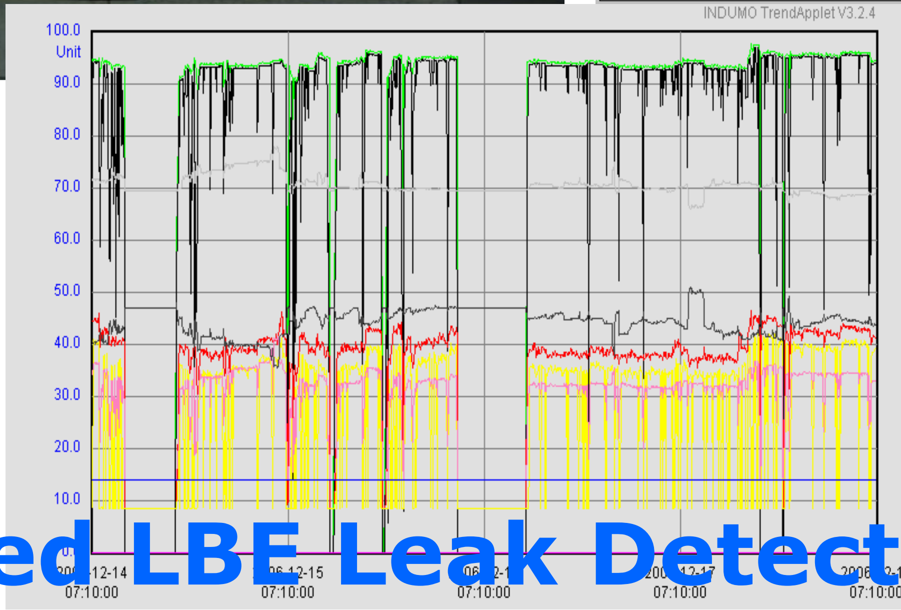
Average-Temperature Algorithm refined



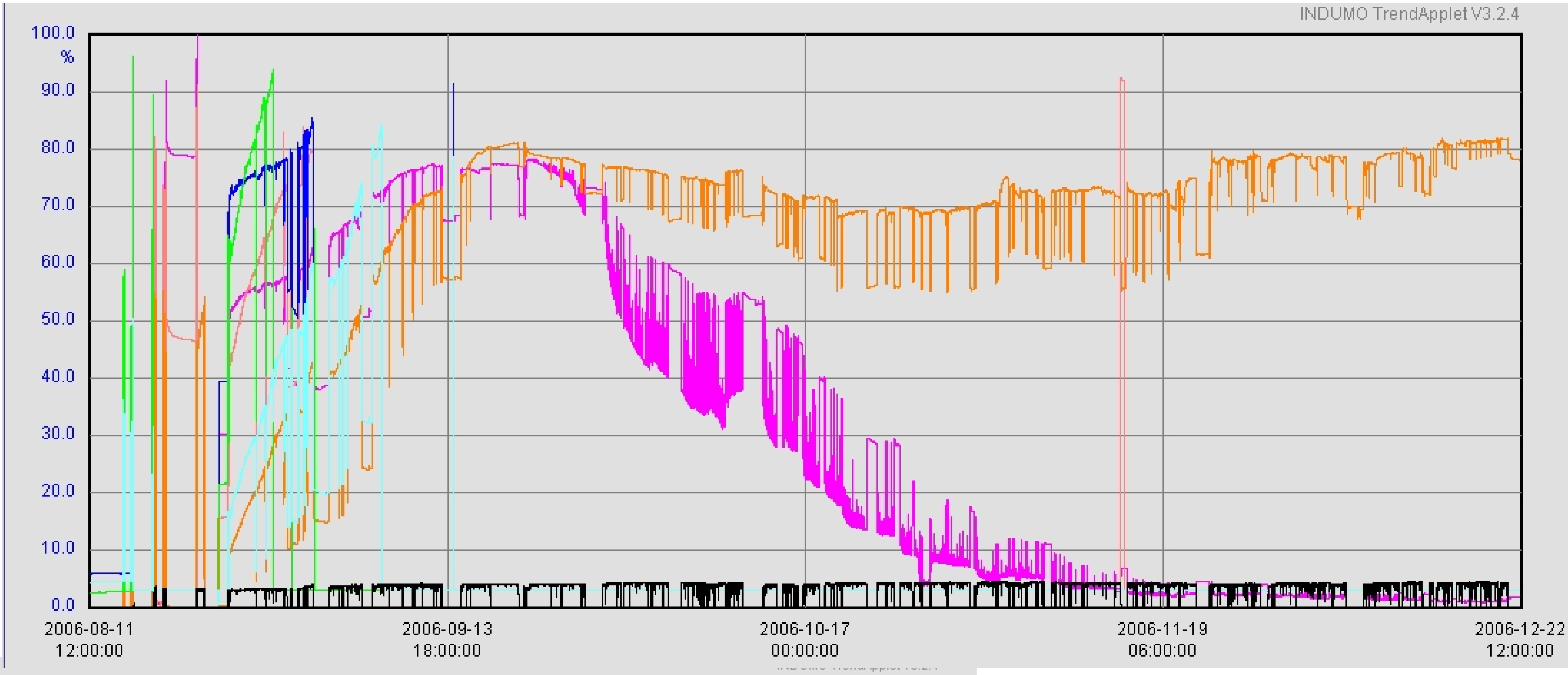
Stripes with reduced sensitivity

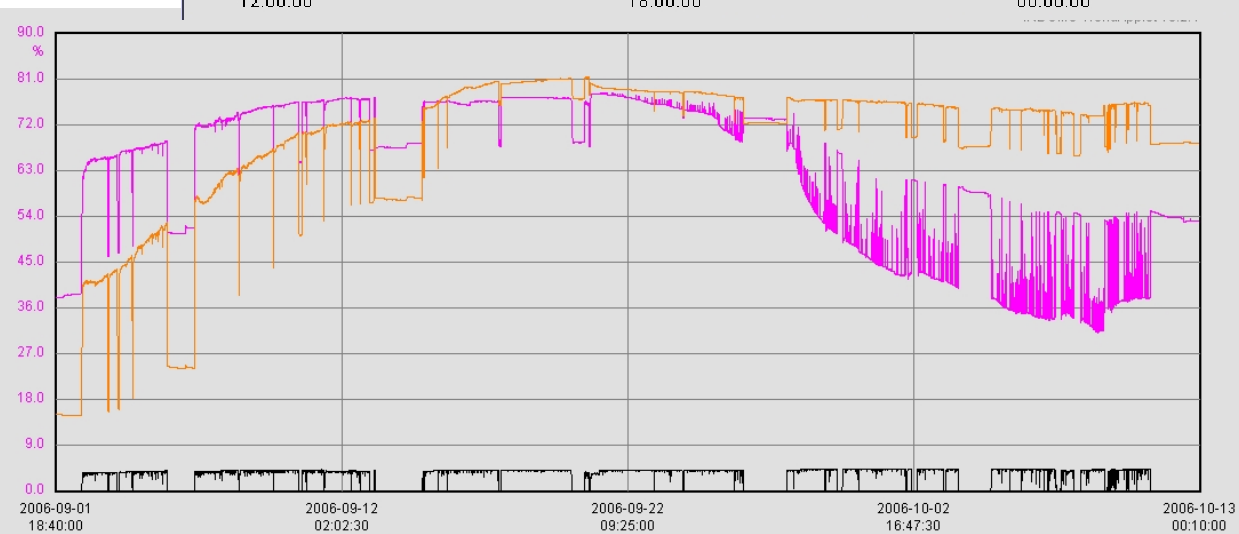






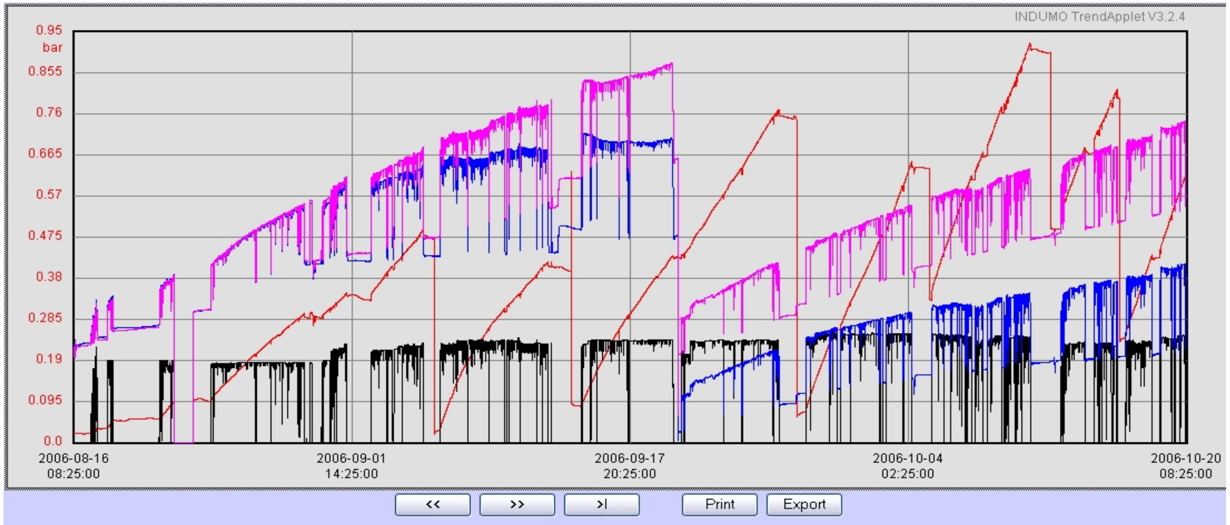
TC based LBE Leak Detectors make the most sensitive Beam Diagnostic





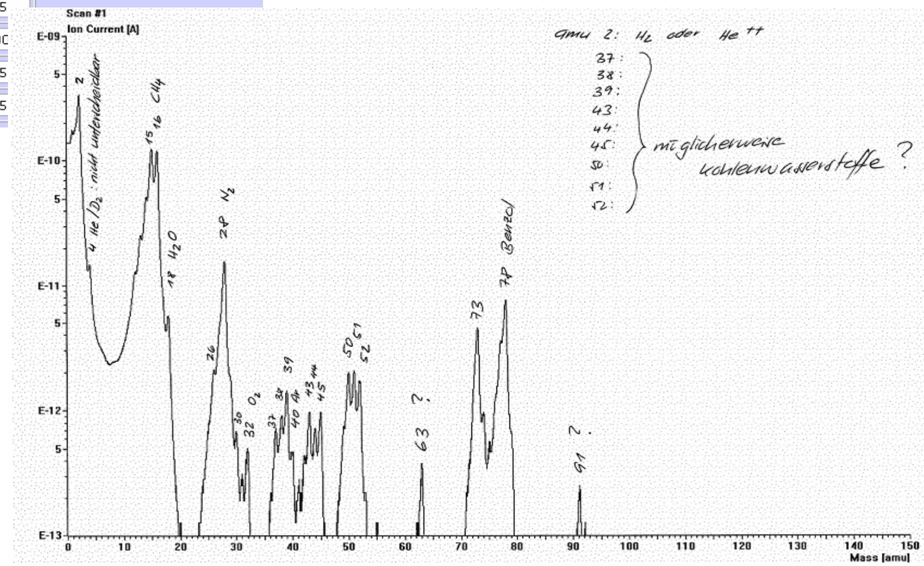
Variable Behavior of Stripe Signals during the MEGAPIE Irradiation Period

IG (and CG) pressure development since start



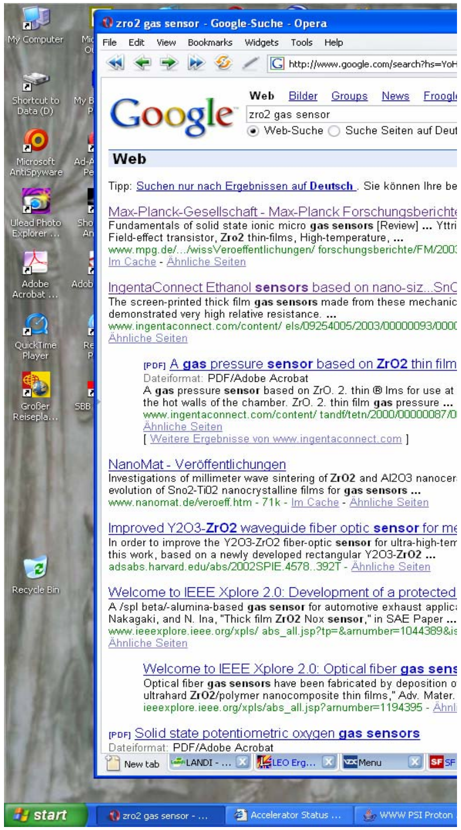
Farbe	Anzeige	Name der Trendlinie	Beschreibung	Skala Min	Skala Max	Cursorwert	Einheit	Min	Max
	☑	MP_1KGH71_CP001_Z400_AVG	Absolutdruck	0	1	0	bar	0	0.95
	☑	_1CFD01_FR001_RZ400_AVG	Protonenstrahlstrom	0	2000	0	mA	0	5000
	☑	MP_1KGA10_CP001_Z400_AVG	Absolutdruck	0	4	0	bar	0	0.95
	☑	MP_1KGA10_CP002_Z400_AVG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

leaking oil into the insulation gap:



Megapie

„Strange“ response of Stripe Sensors from the beginning most likely caused by cracked oil (O_2) in IG: People do make different sensitive gas sensors out of ZrO_2 (!)



? „zro2 gas sensor“
=> 31’700 hits

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Ethanol sensors based on nano-sized α-Fe_2O_3 with SnO_2, ZrO_2, TiO_2 solid solutions

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Abstract

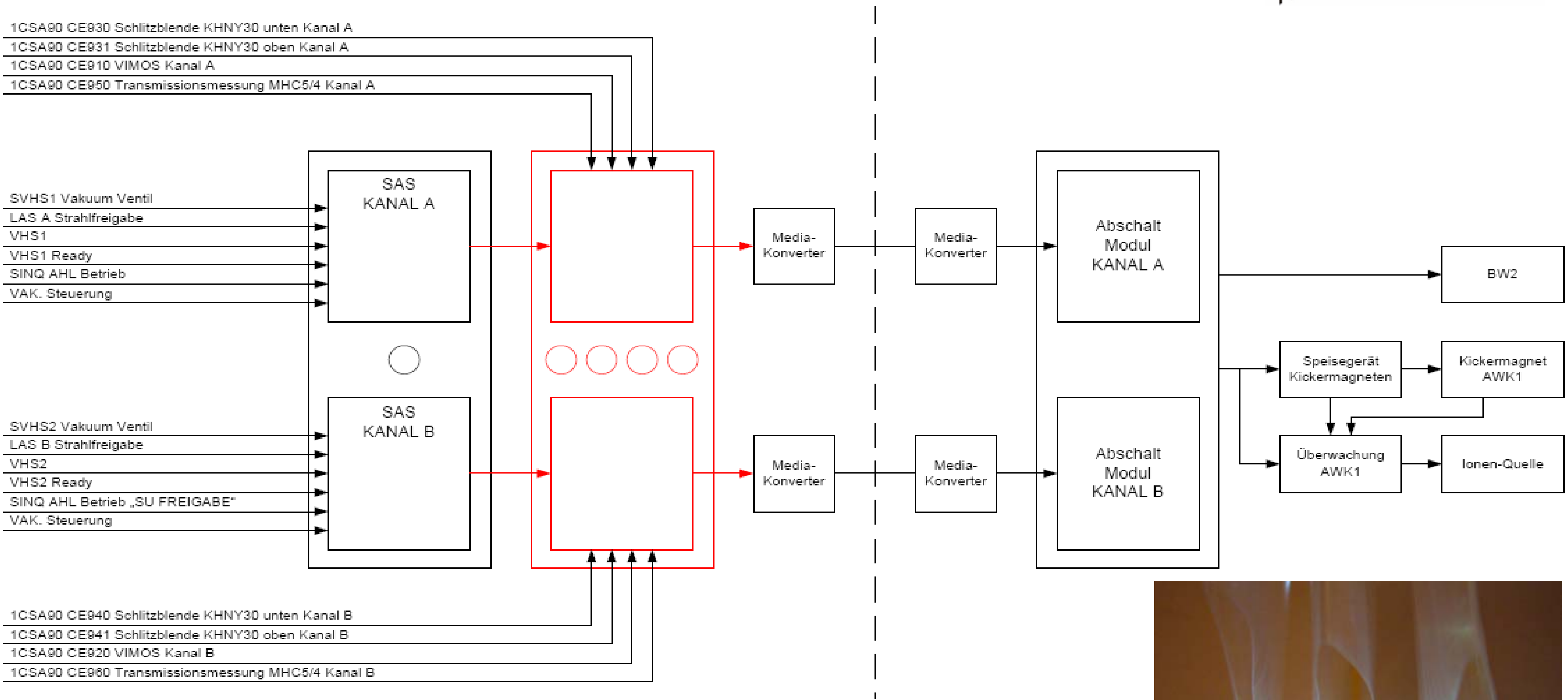
Nano-sized α-Fe_2O_3 based solid solutions with different compositions of SnO_2, ZrO_2 and TiO_2, were prepared using high-energy ball milling technique. Their structural properties and ethanol gas sensing properties were characterized using XRD and gas sensing measurements. The experimental results show that the mechanical alloying processes for these powders are the same. The screen-printed thick film gas sensors made from these mechanically alloyed materials demonstrated very high relative resistance. A non-equilibrium structural model was proposed to explain sensing mechanism. The comparison of gas sensing properties was performed for different α-Fe_2O_3 based solid solutions with optimized compositions of SnO_2, ZrO_2 and TiO_2. Among these three sensors, $x TiO_2$–$(1-x)\alpha$-Fe_2O_3 type of gas sensor has much lower relative resistance value for ethanol. This can be elucidated by the different valence states exhibited by titanium ions.

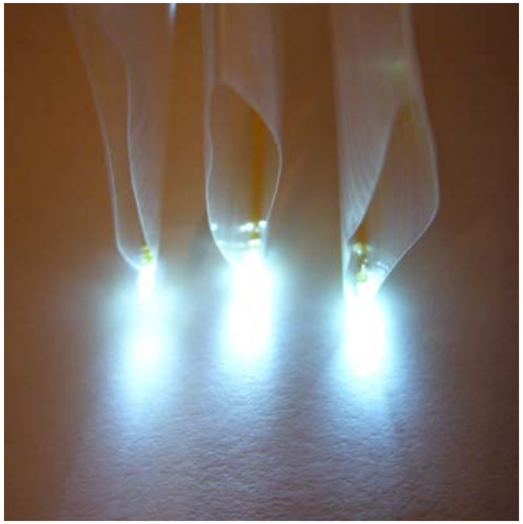
Keywords: Sensors; Ethanol; Non-equilibrium; Nanostructured; XPS

(…highly selective ZnO:Al_2O_3 based thick film hydrogen sensors) !!

Results:

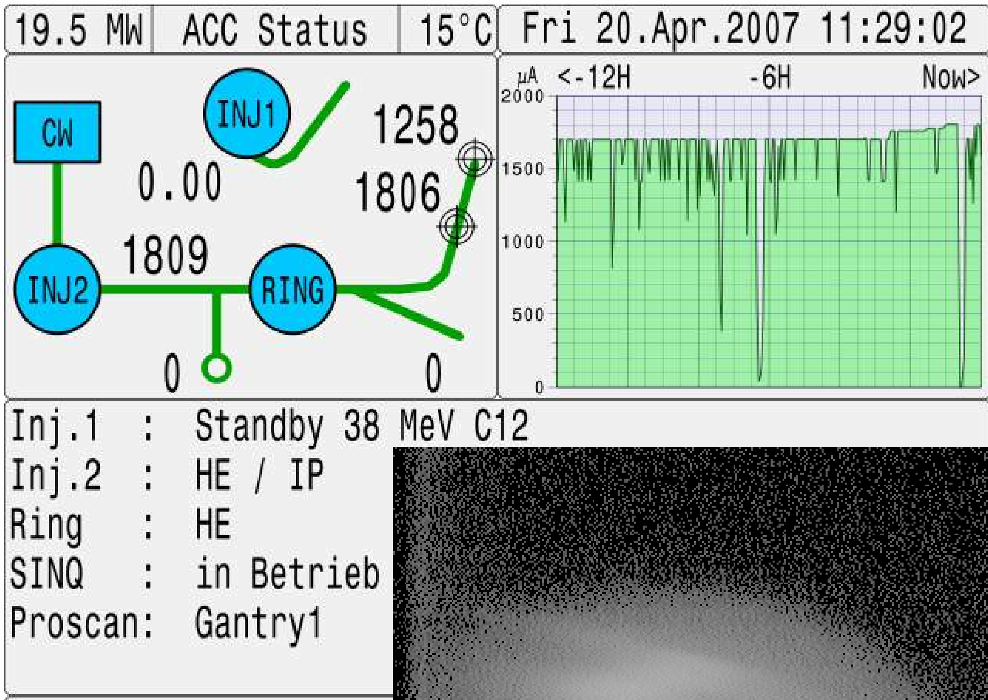
Transmission Monitor	a few interlocks
Slit KHNY30	very few interlocks
VIMOS	2 interlocks, 2 BSRs
Beam Losses	nothing special
EFFECTORS	initial inconvenience
TC LBE Leak Detector	2 interlocks, 1 TC failed
Stripe LBE Leak Detector	2/3 worked all the time

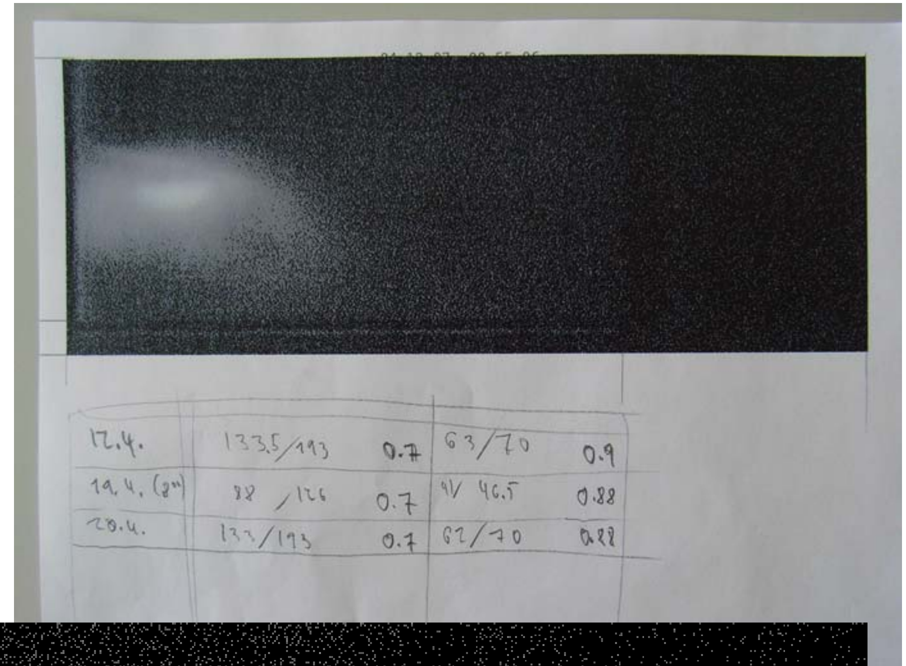


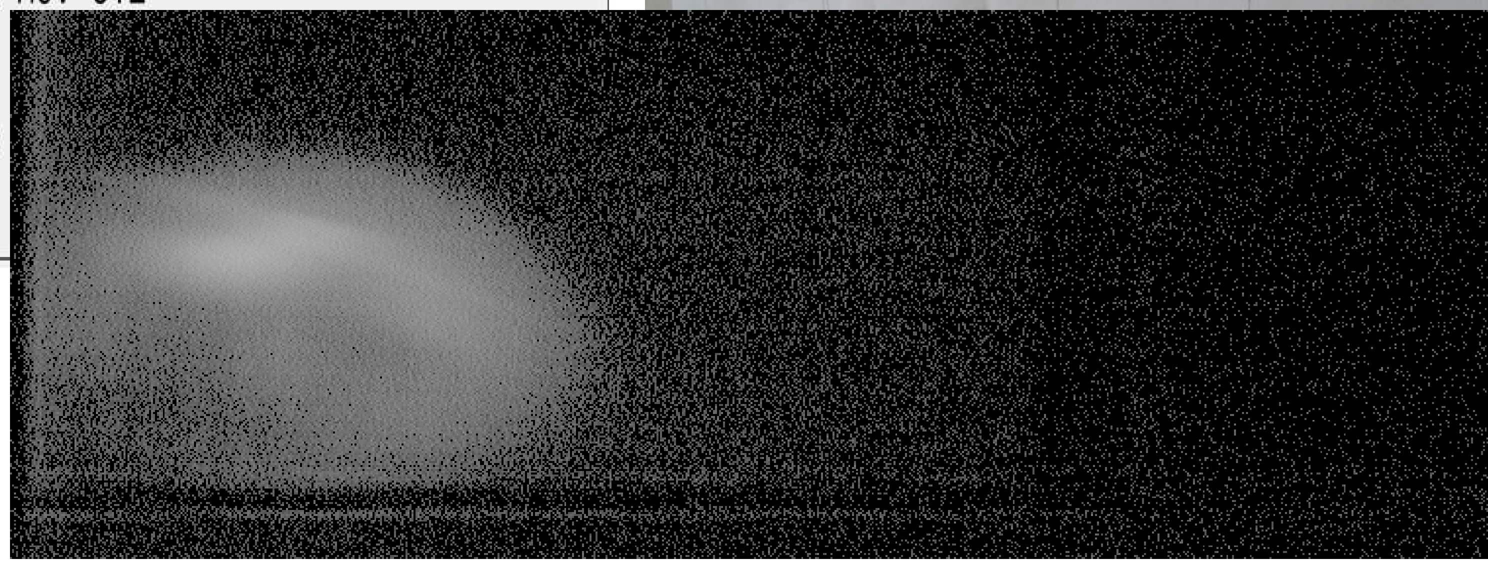


Life for VIMOS et al after MEGAPIE secured

Starting operations 2007







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