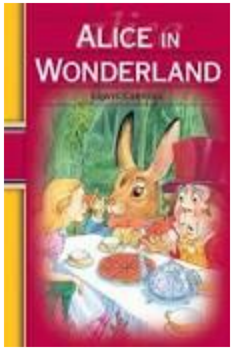
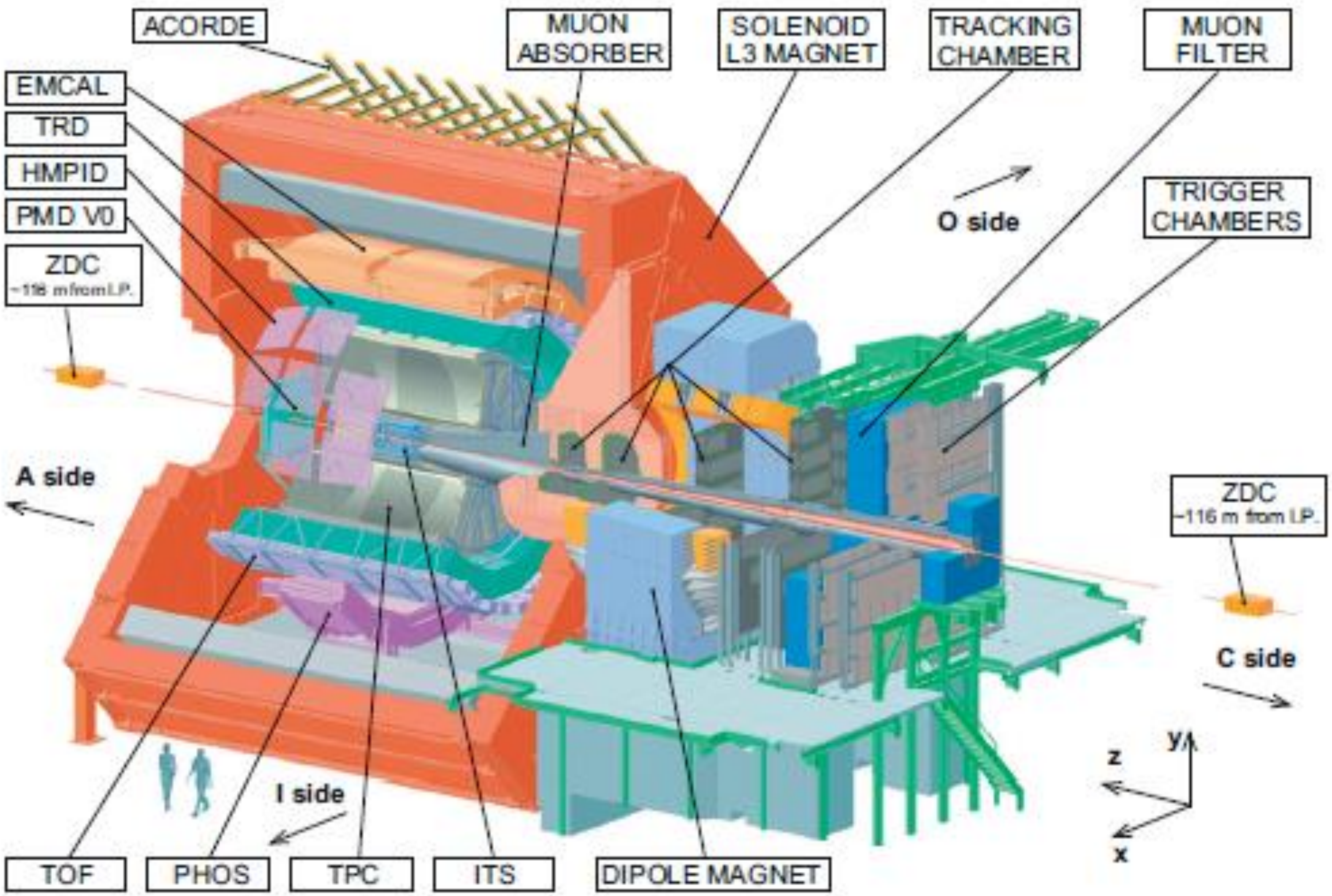


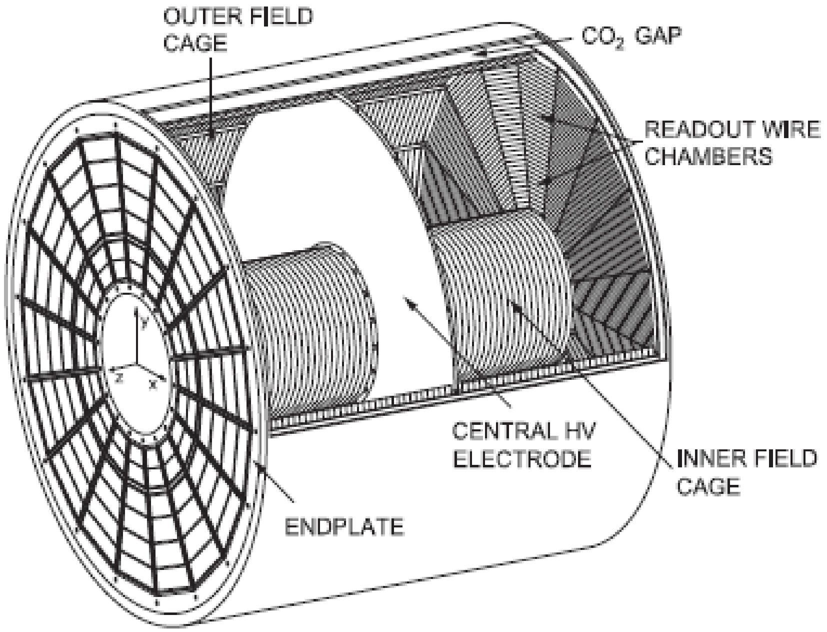
Stability tests of GEMs with cylindrical holes for ALICE upgrade

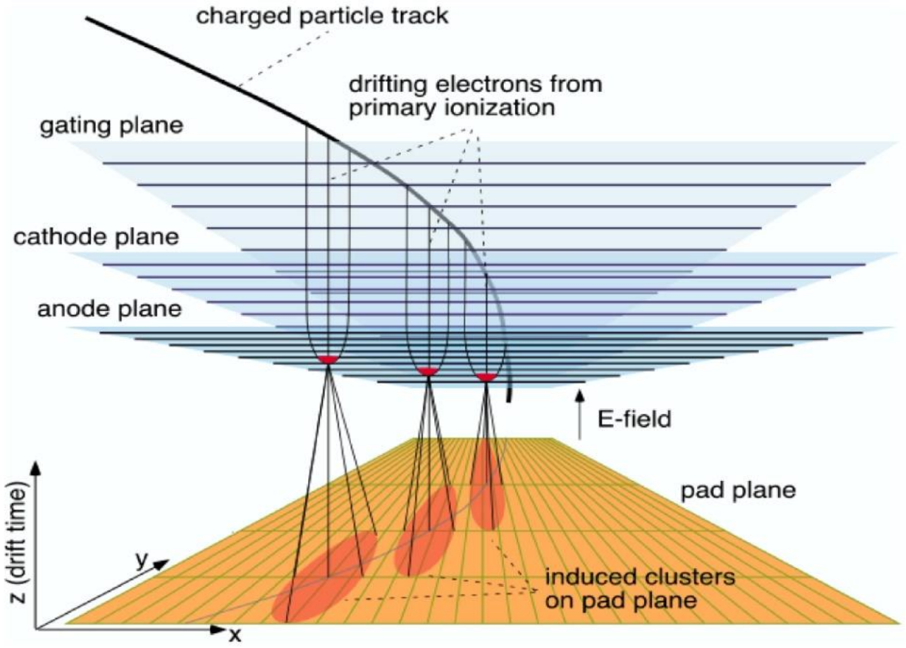
Behalf of the ALICE TPC upgrade collaboration

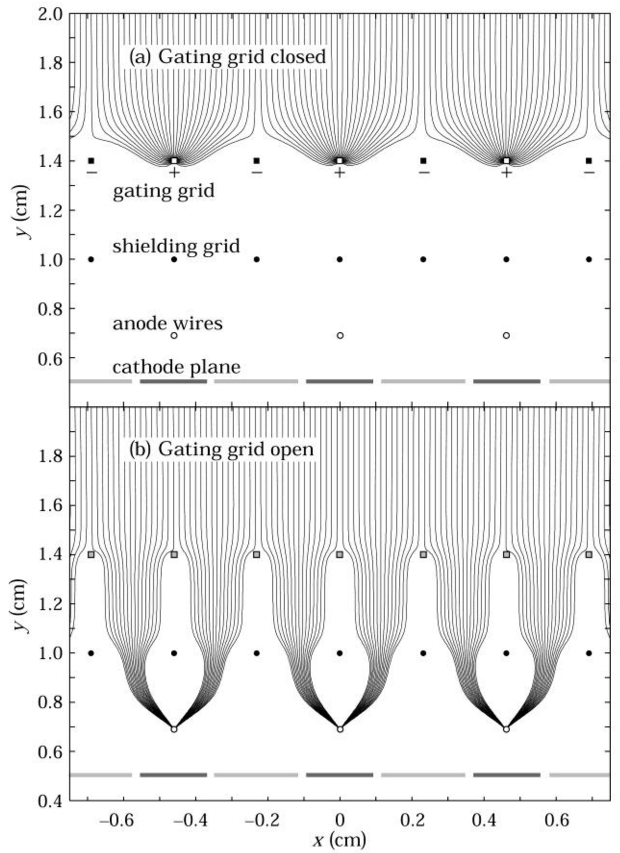


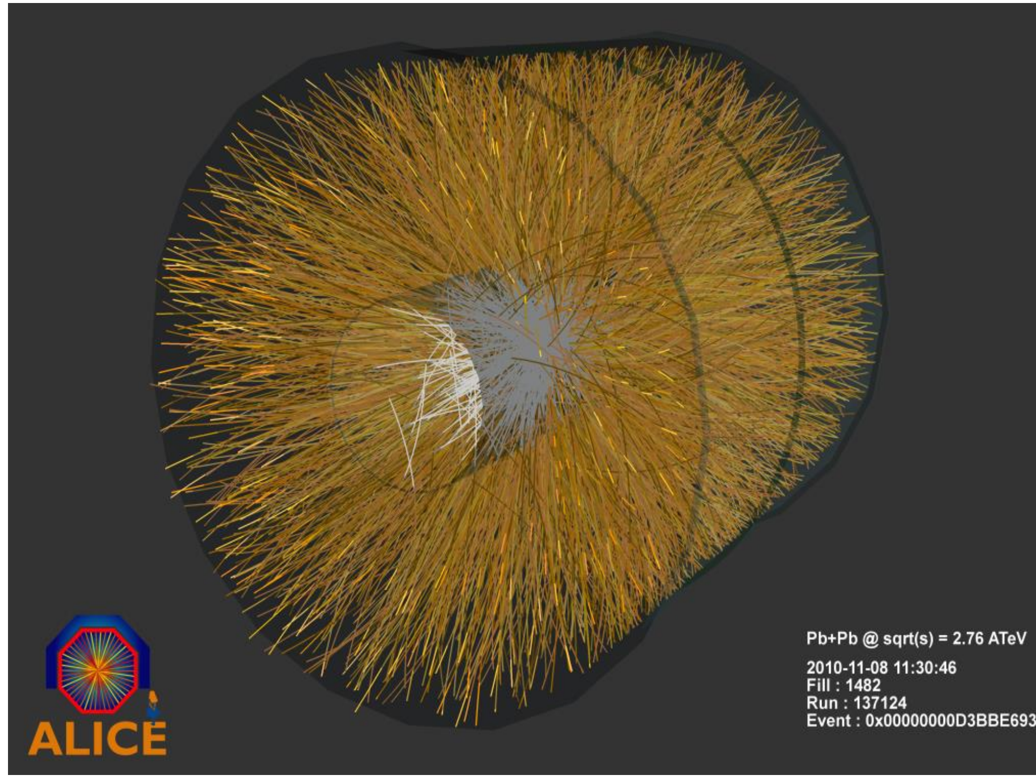
The ALICE TPC is the main device in the ALICE central barrel for tracking of charged particles and particle identification

Design of the present ALICE TPC





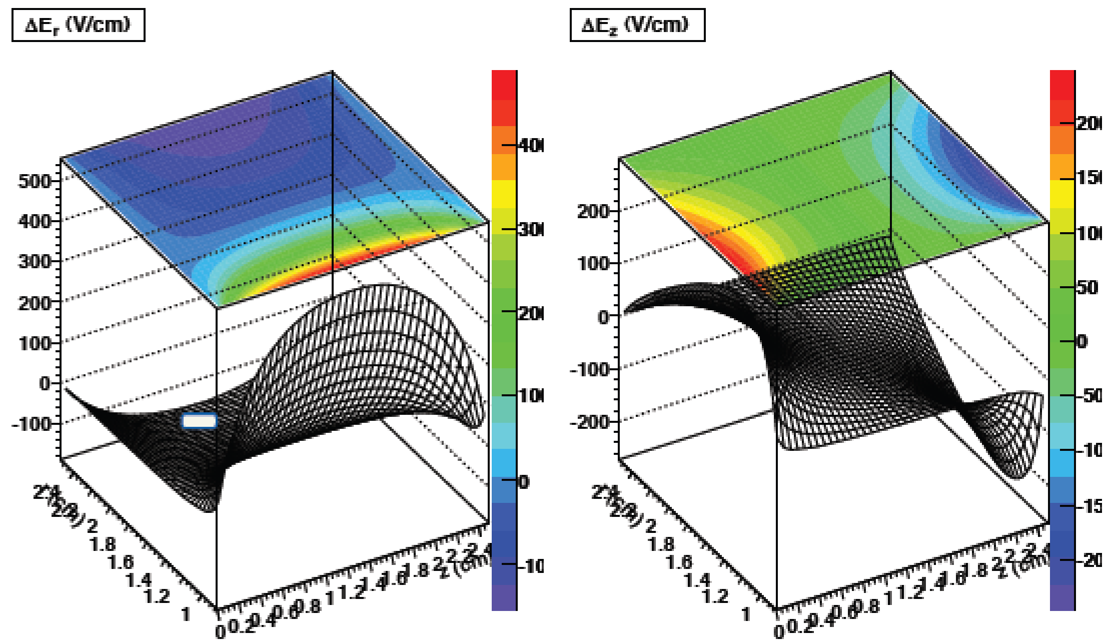




Requirement to gating grids: ion back flow is below 10^{-4}

Running at 50 kHz Pb-Pb after LS2

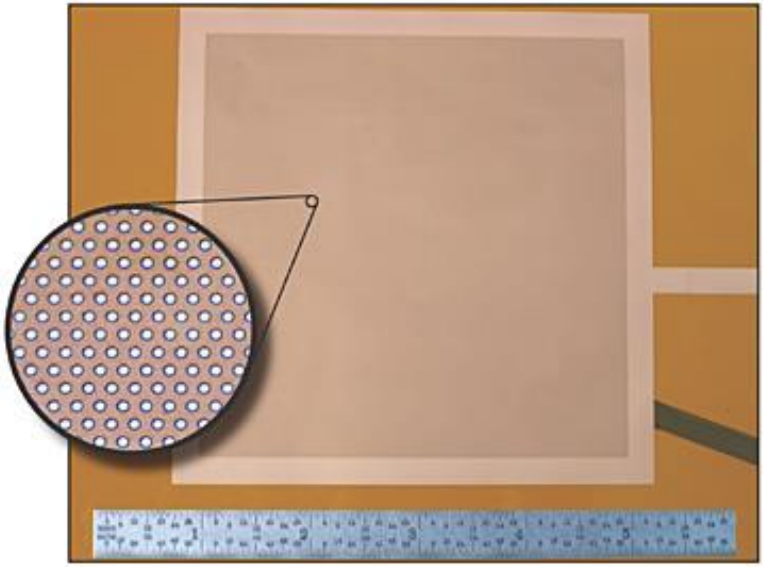
- No GG triggering, continuous readout
- This leads to electric field distortions of the order of the electric field → space point distortions of order 1 m
- MWPC are not an option

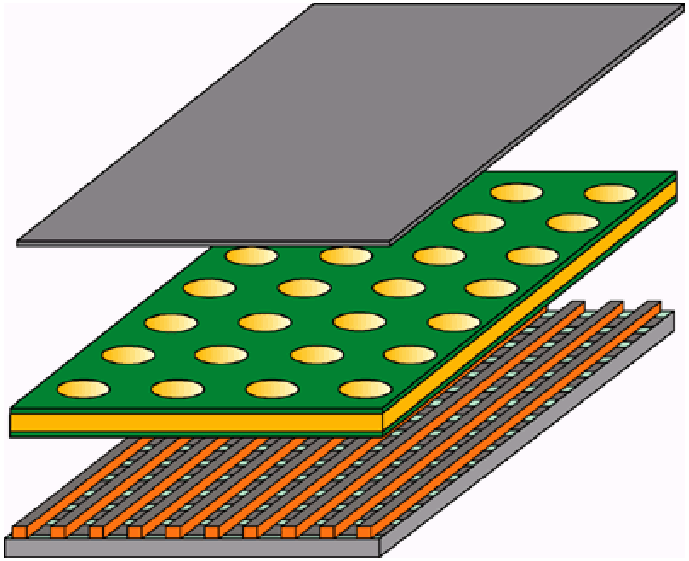


S. Rossegger

Counting rate will be increased 100 times!

A very attractive option is GEM…



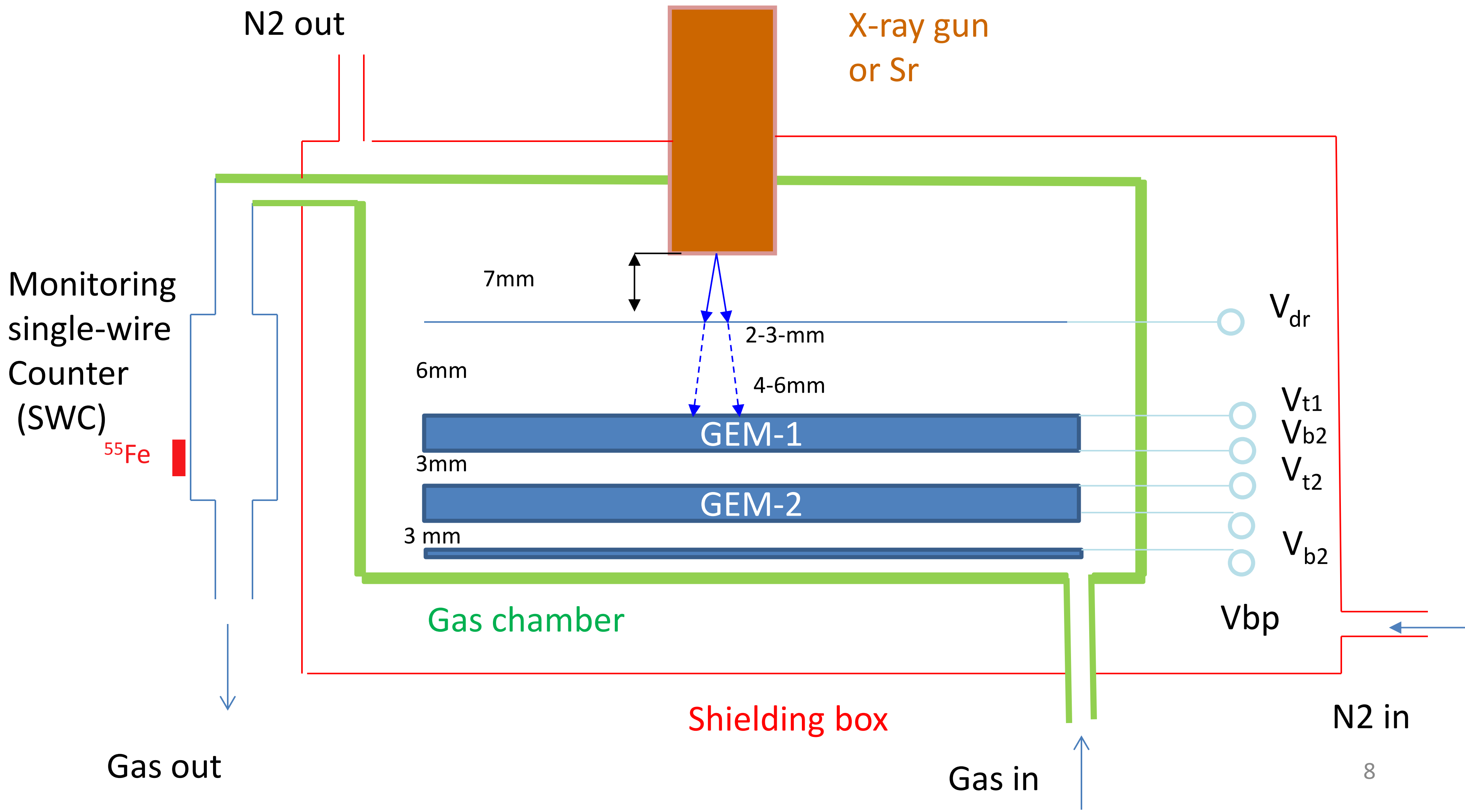


However

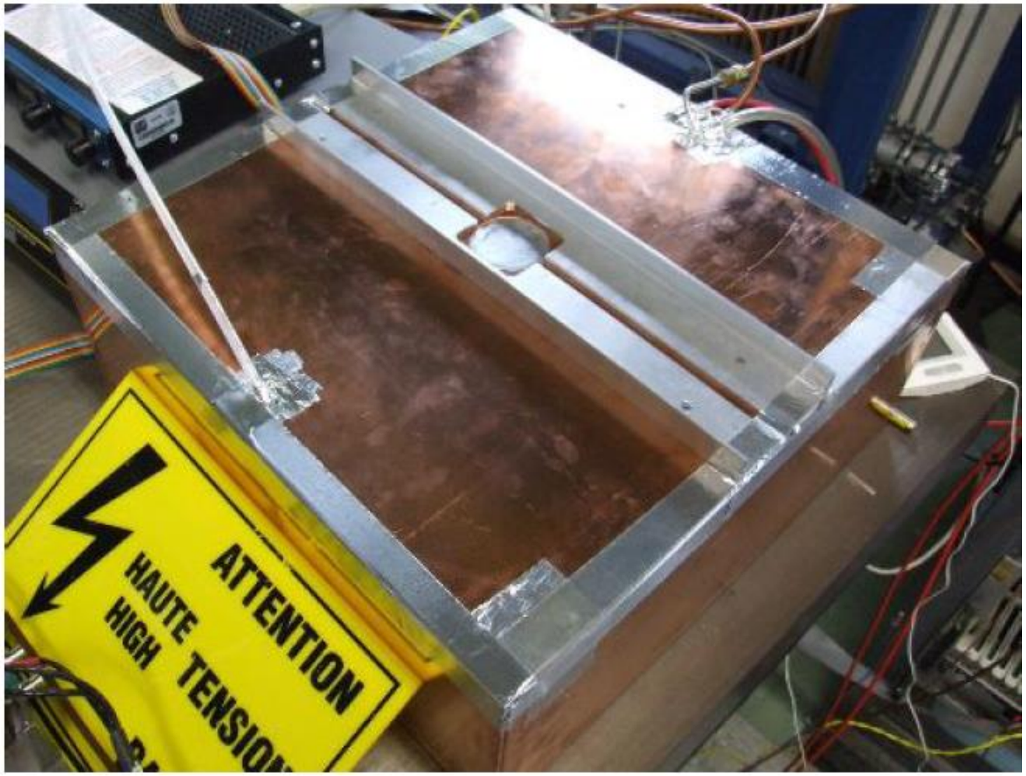
- R&D is needed to settle a few issues with GEMs
  - Ion back-flow – typically few % (usually no need for a better figure)
  - V Gain stability – charging up processes, rate dependence…
  - Position and momentum resolution – not a show stopper
  - Stability under LHC conditions – to be tested
  - New electronics needed (speed, signal polarity) – profit from a common ALICE effort and existing prototypes

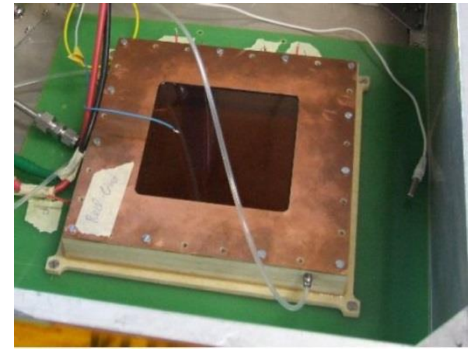
Chilo Garabatos

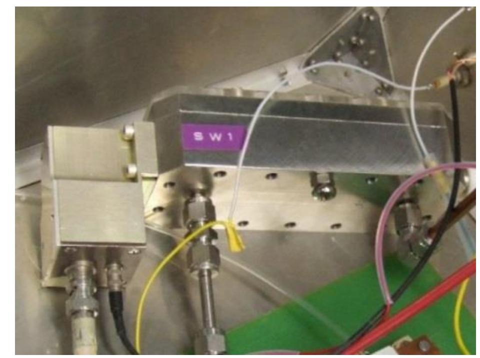
Experimental setup



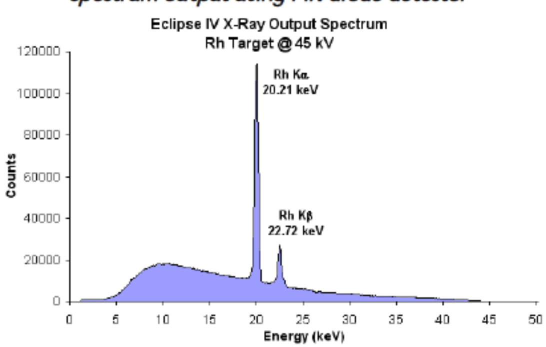
Some related images…

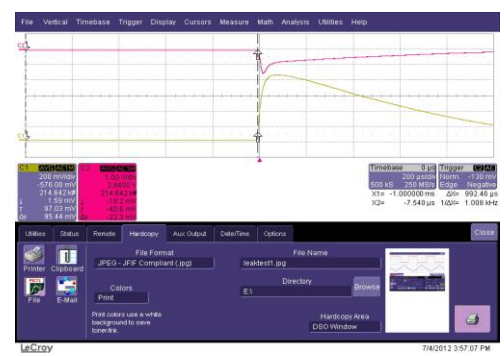






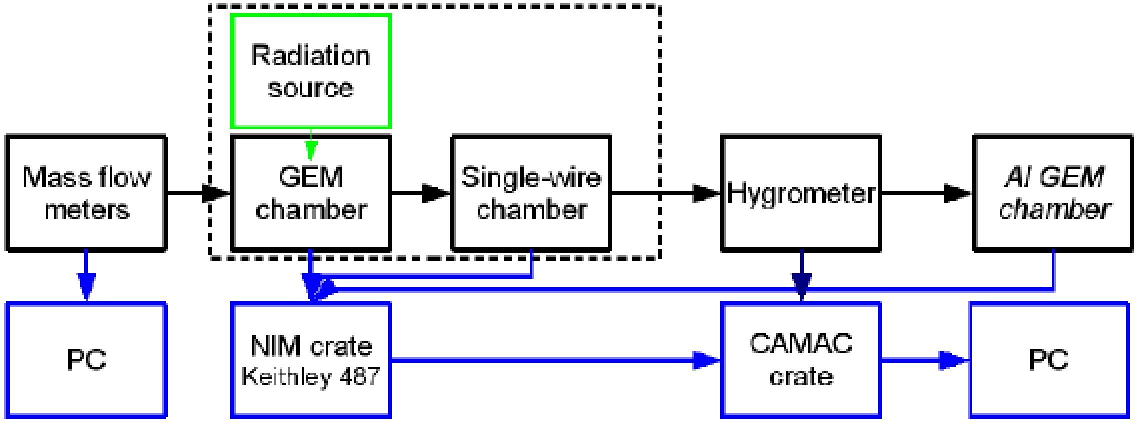
Spectrum output using PiN diode detector

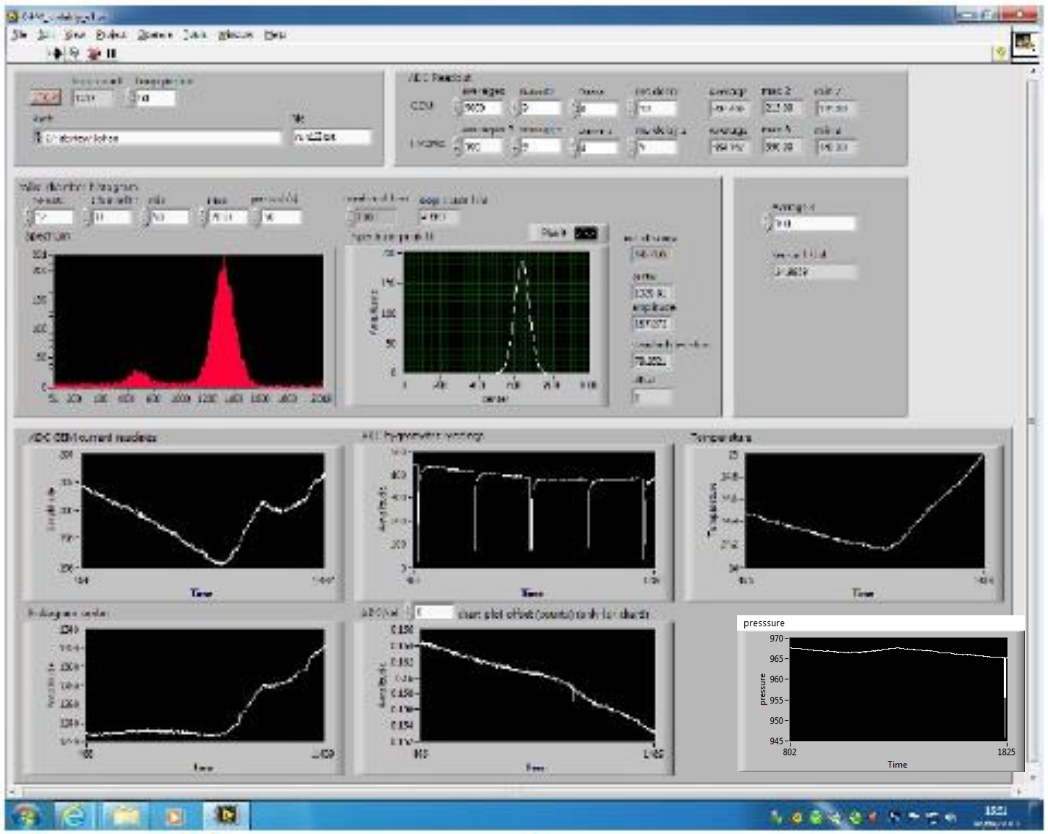




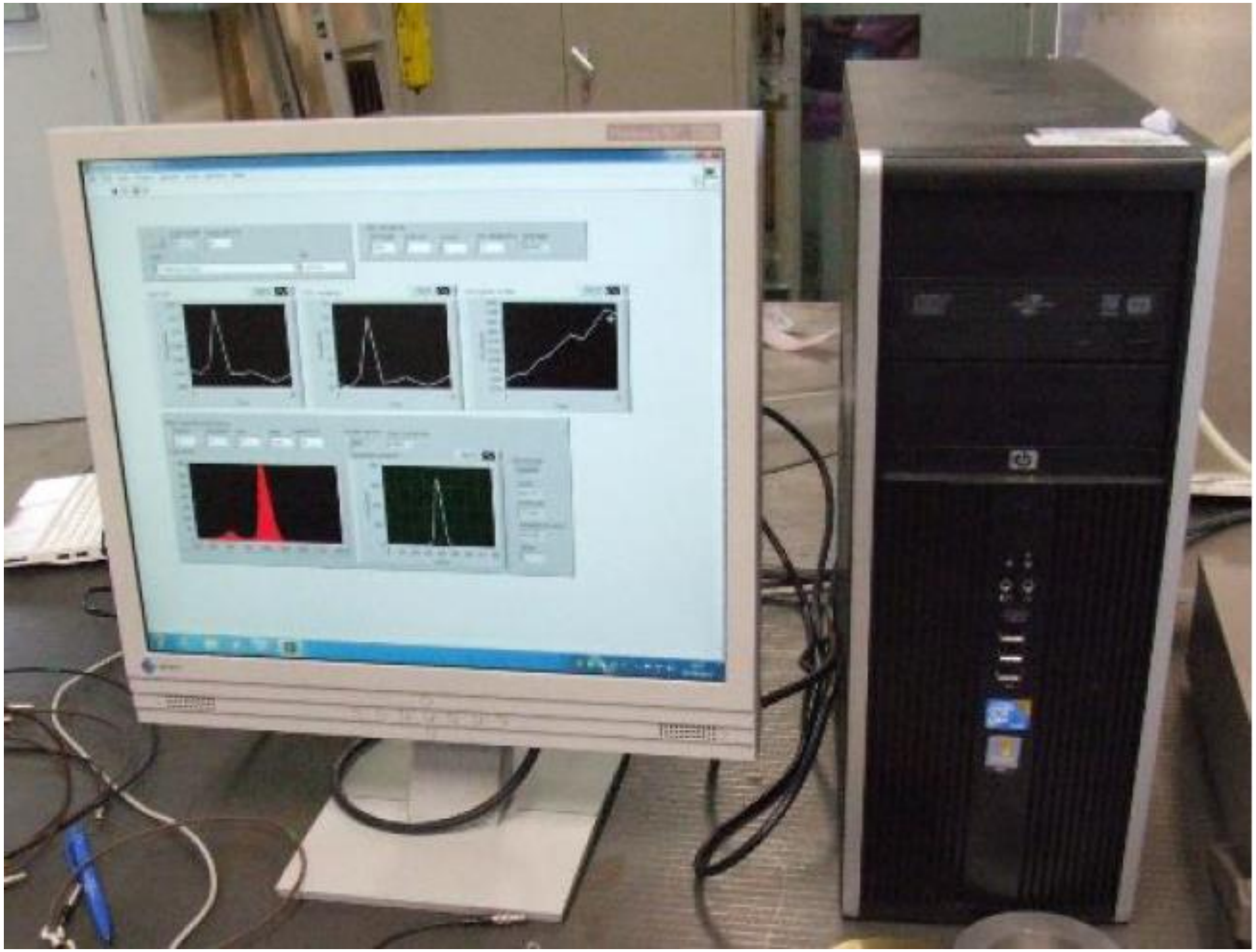
Data acquisition

(J. Reinink)





Labview presentation



At what conditions the test should be done?

…"this is an important question. I ill try to answer it in terms of expected current per cm2 expected in Pb-Pb at 50 kHz at GEM gain of 1000. I put alice-tpc-upgrade in cc to make sure everybody agrees.
I start with the charge expected in the TDR era (dN/dy=8000) per central collisions event in the innermost region: 2.3 10^-13 mC/cm
I correct for the expected true multiplicity (2200 per CC at 14 TeV) and convert into charge per Minimum Bias (not central collision) event: 1.2x10-12 mC/cm
At 50 kHz event rate this results in: 6.2x10^-10 mA/cm
This was for readout chamber with 2.5 mm pitch anode wires, so I divide by this and multiply by gain of 1000: 2.5x10^-6 mA/cm2 = 2.5 nA/cm2…"

Chilo

Results:

Measurements were performed with single and double and triple GEMs in $Ne+10\%CO_2$ and $Ar+10\%CO_2$ at p=1atm and humidity range 1000-50 ppm

A few examples are given below:

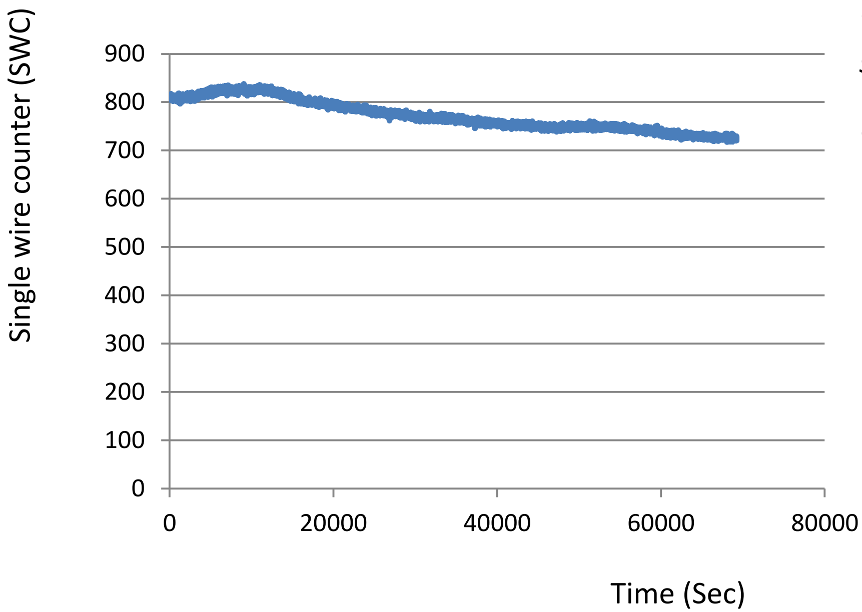
1. Single GEM

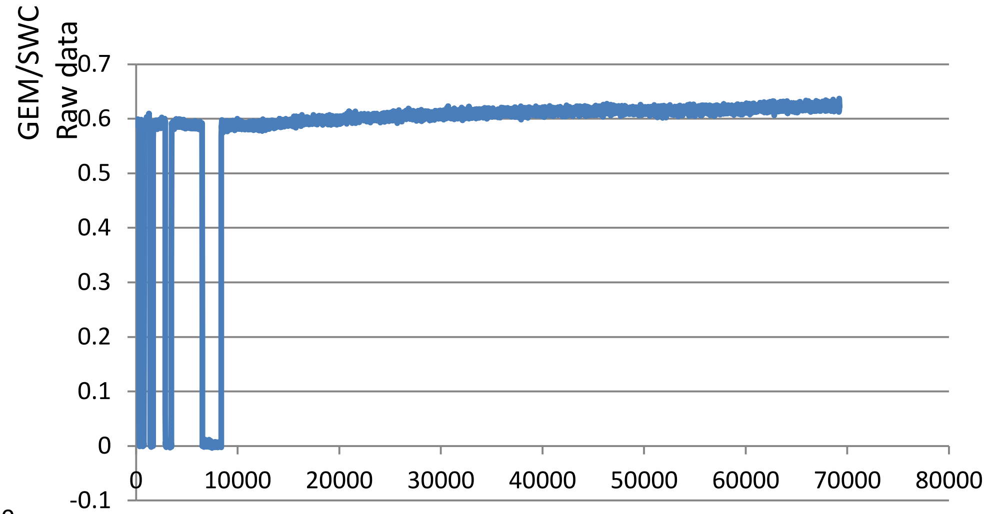
Gas gain 200

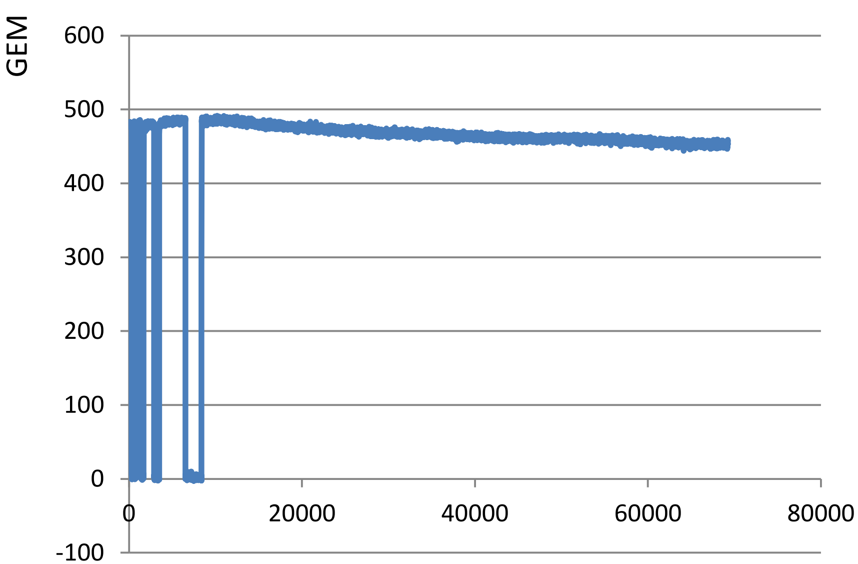
Current ≈2nA/cm2

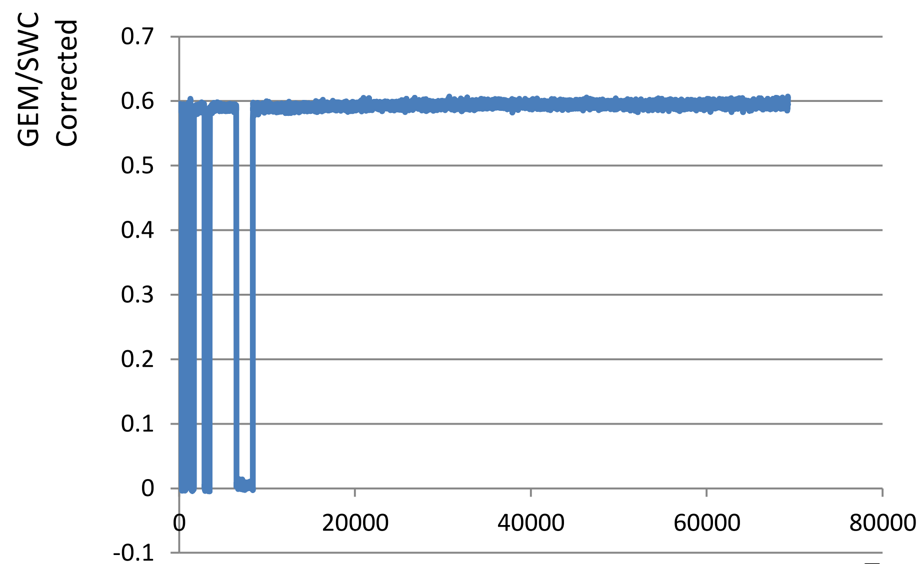
Long-term runs as well as intensity and voltage variations were done

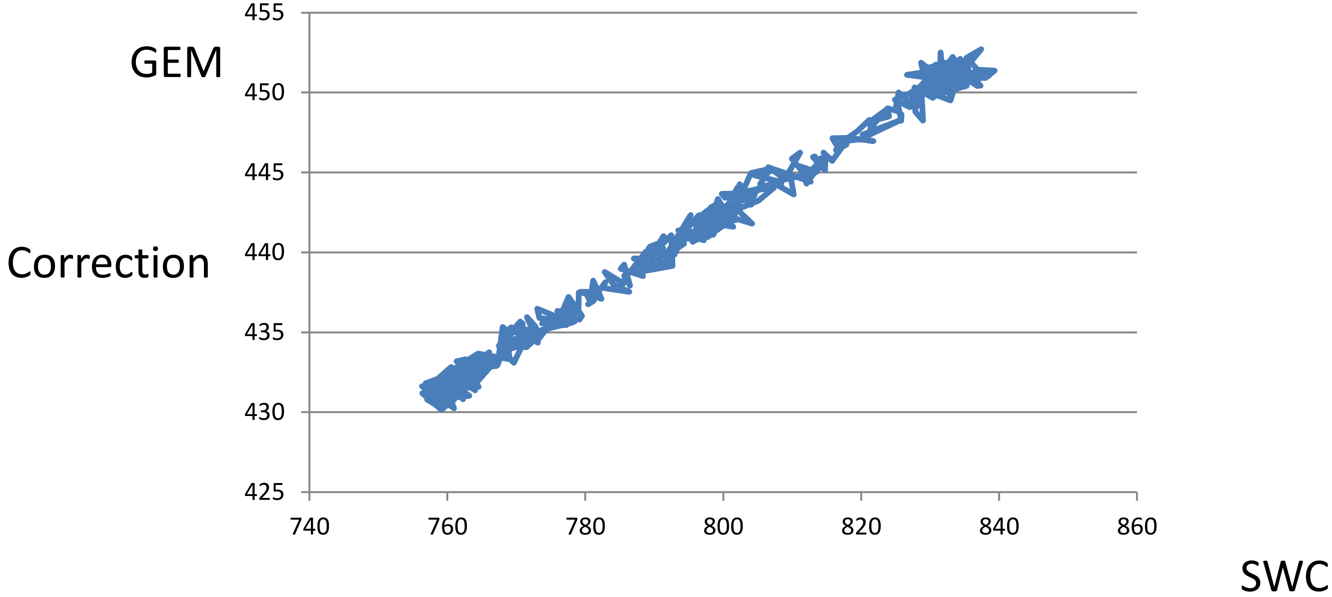
Intensity variations



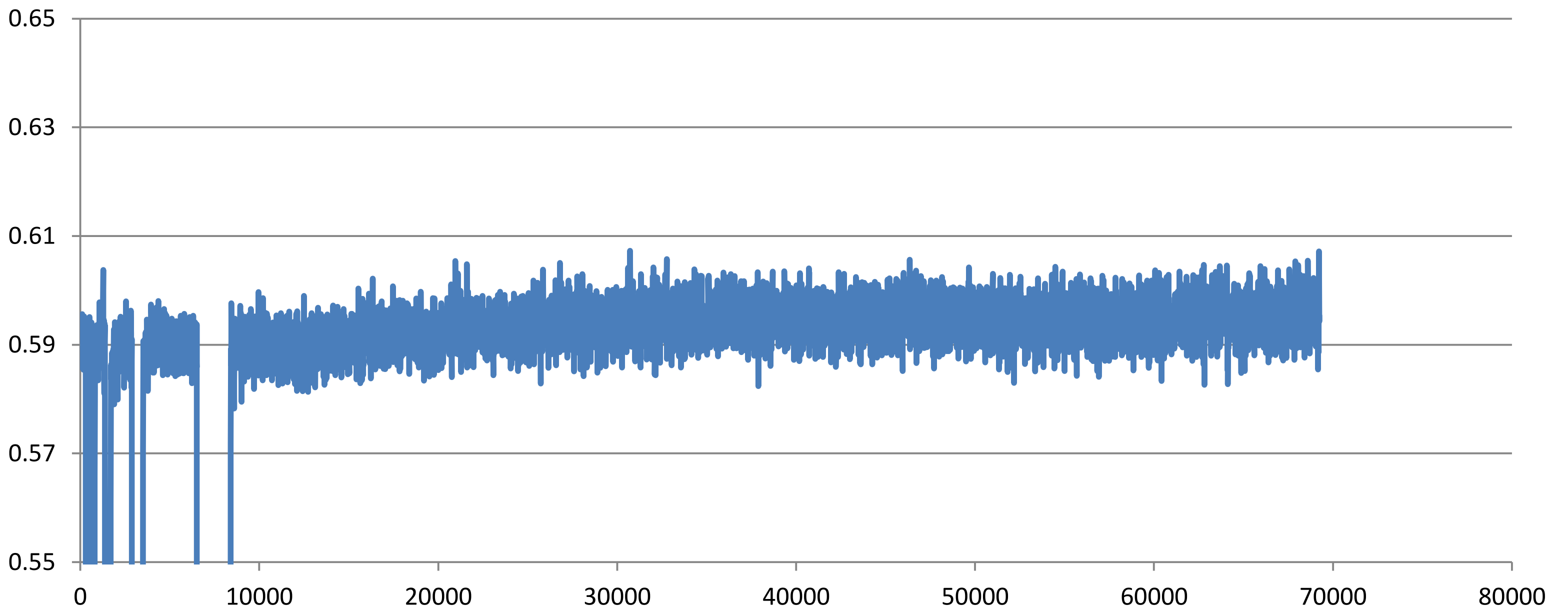




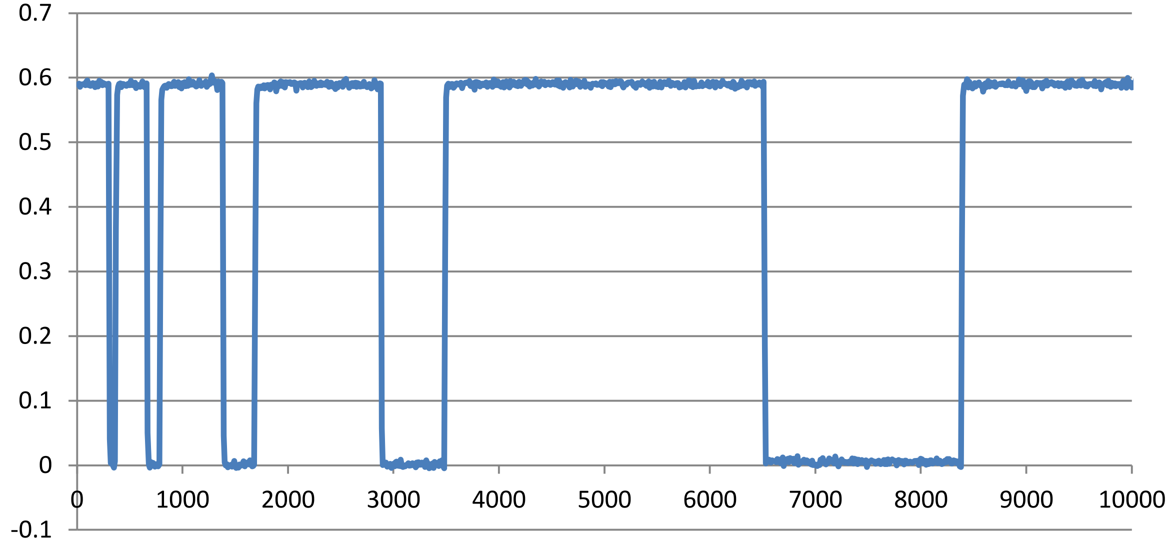




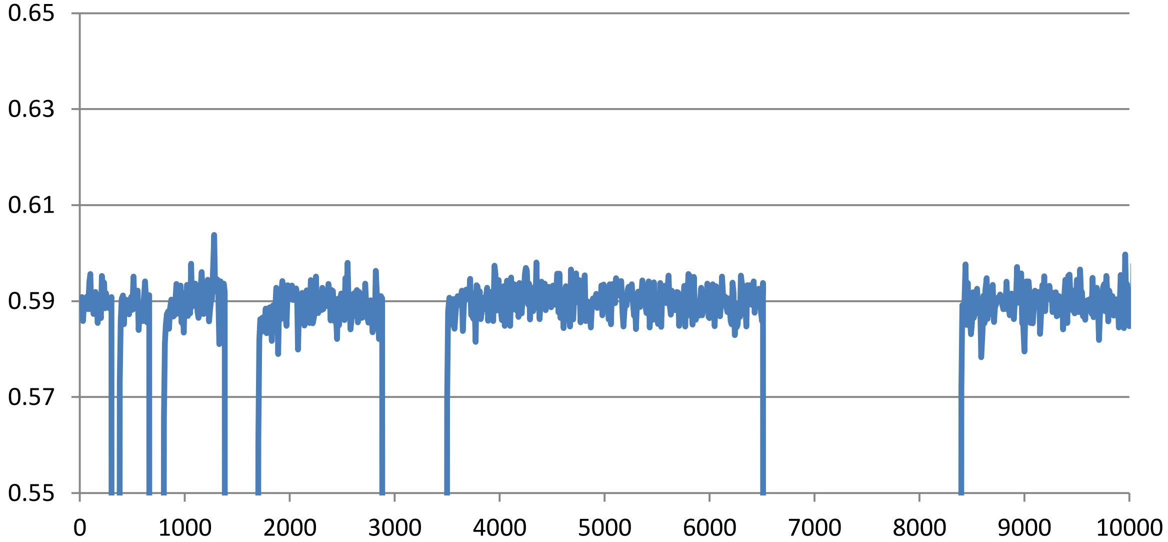
Zoomed area of the corrected data



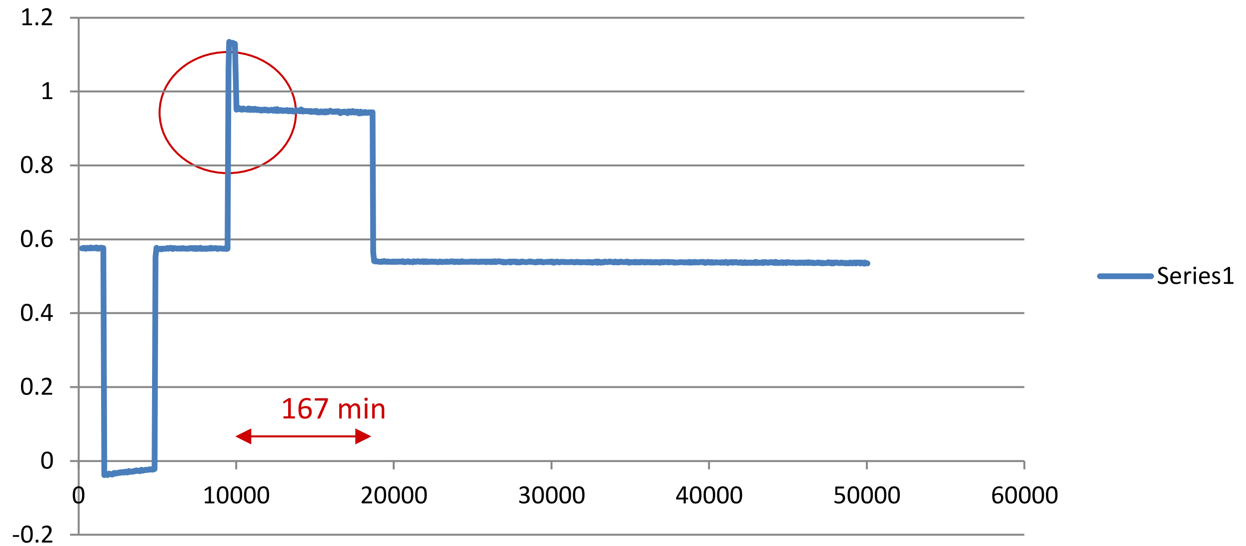
Various tests with intensity variations

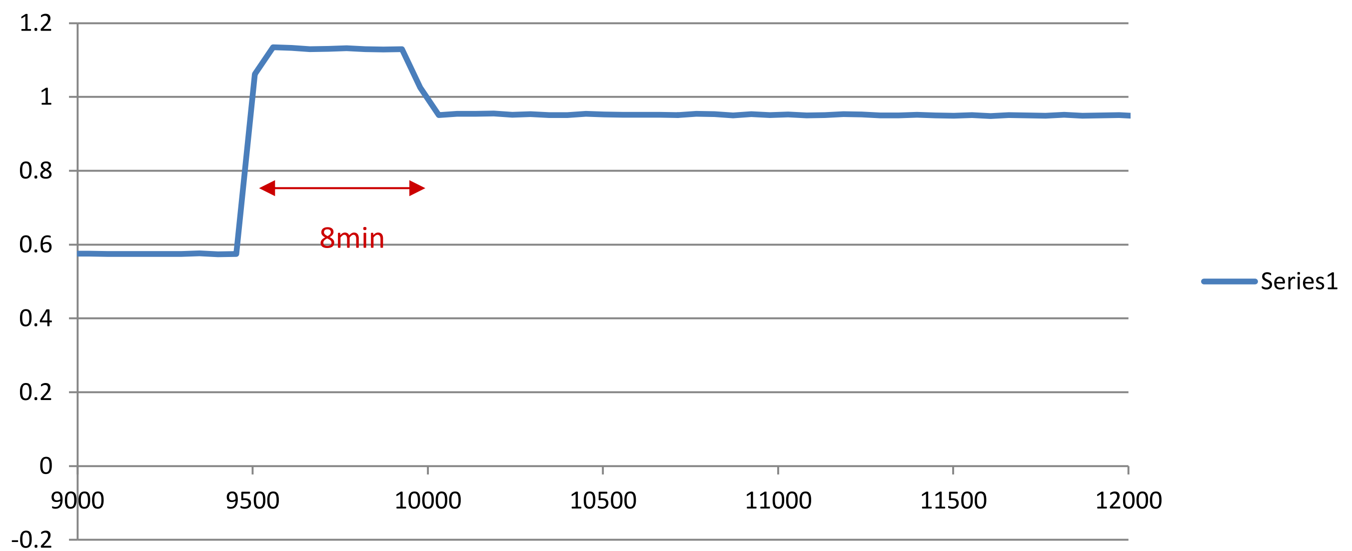


Zoomed

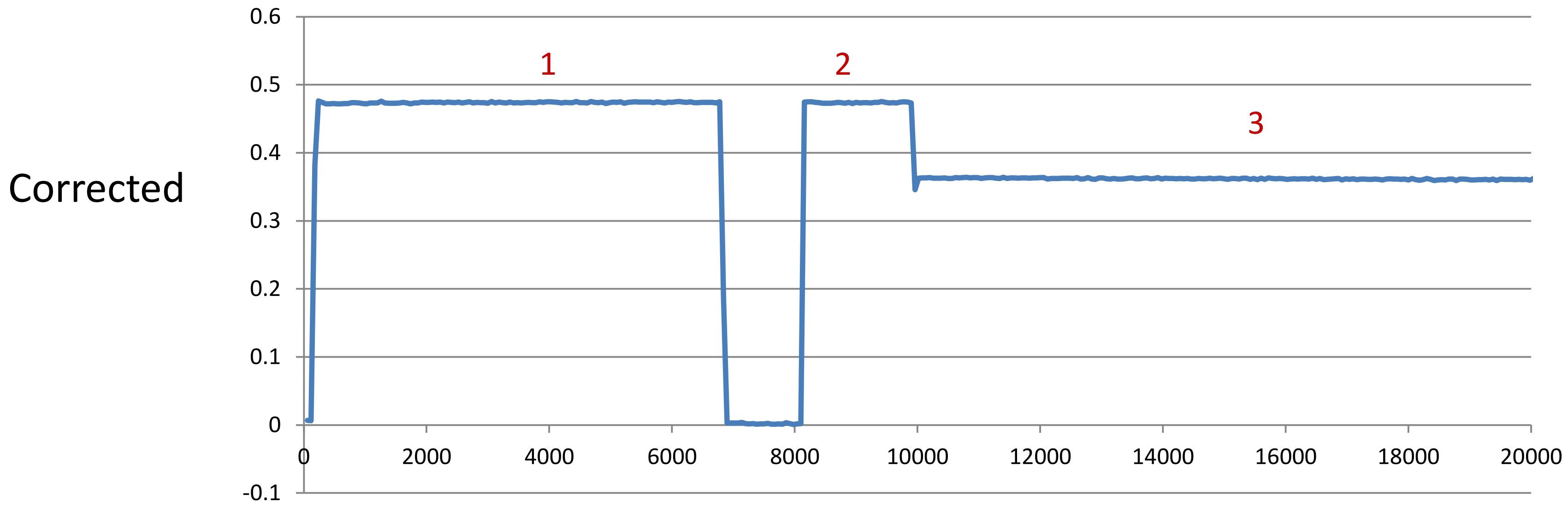


GEM/SWC corrected

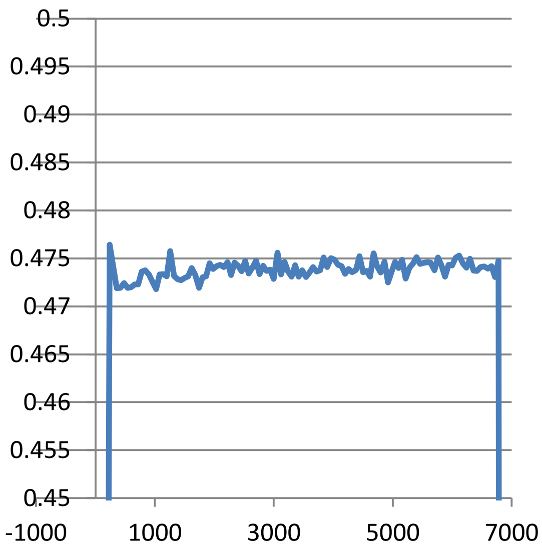


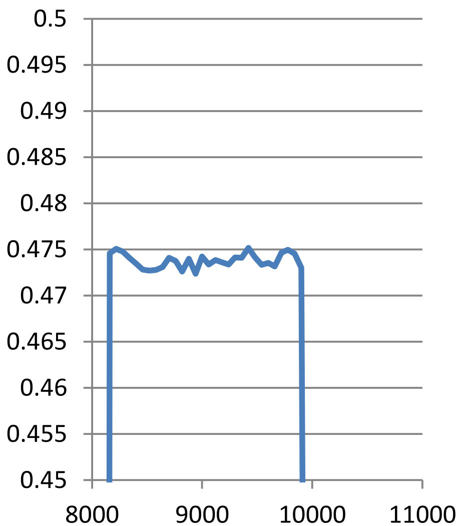


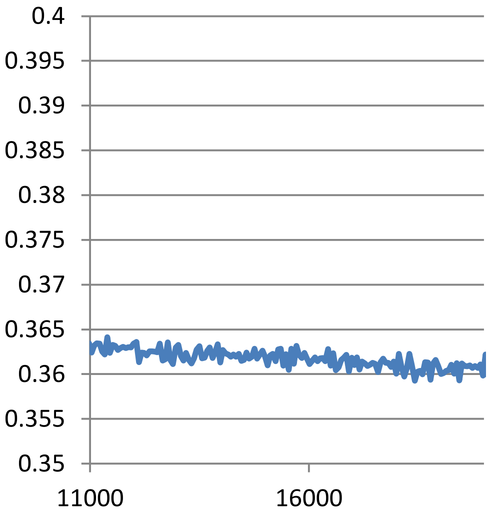
X-ray intensity modulations



Zoomed areas

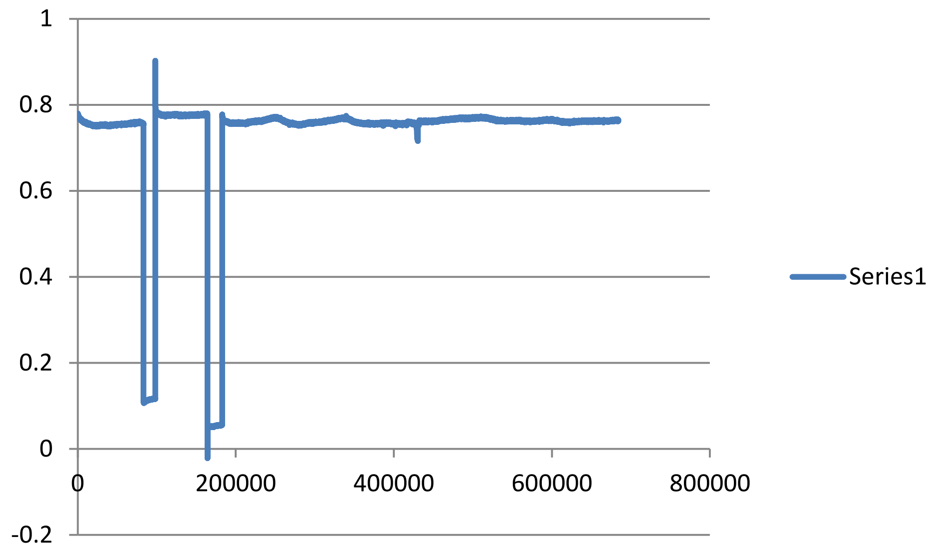




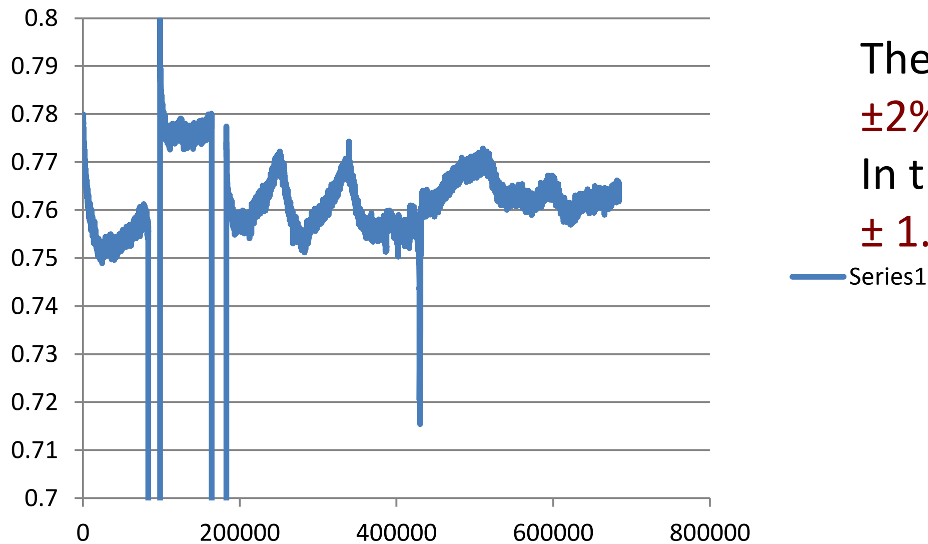


GEM voltage variations

GEM/SWC corrected on offset



The same, but zoomed
±2%!
In the plateau region
± 1.3%



Summary of measurements with a singe GEM:

GEM stable within ±1-2% (continuous test time was 7 weeks)

Humidity level was 500-50ppm

Will be interesting to compare with simulation

Discussion with Rob Veenhof:

His calculations show:

With real conical holes 70μm in diameter no charging up effect. Some short-term (10-30min) variation with time are predicted:

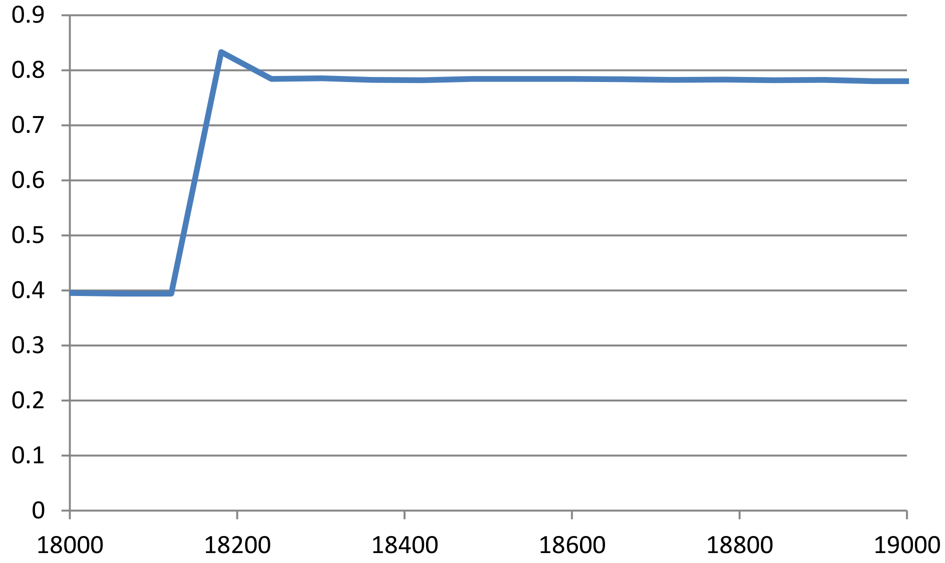
with 70 μm holes having and inner diameter 60 μm some initial gain loss is predicted,

with inner diameters less than 60 μm gain may increases with time

2. Double GEM

The same type of measurements:
long-term runs, intensity and voltage variations

An example of double GEM reaction on intensity variation



Conclusion from double GEM stability studies

double GEM, irradiated in its middle area (current ~1.8nA/cm2, gain 900) is stable within ~±2%.

After the voltage variation it is still not so bad: ±2.6%

When the gain was increase 2 times (from 900 to ~ 2000) and intensity 4 times, so that the current range ~ 7-15nA/cm2, stability is ±3%

(which is inside the expected √2 degradation)

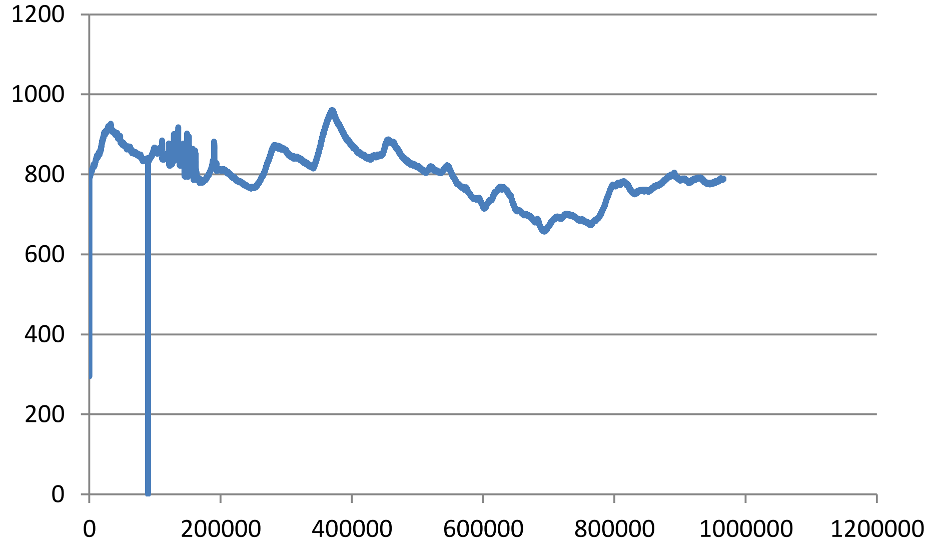
Triple GEM-
the most important case

Measurements were done at 180 and 70ppm

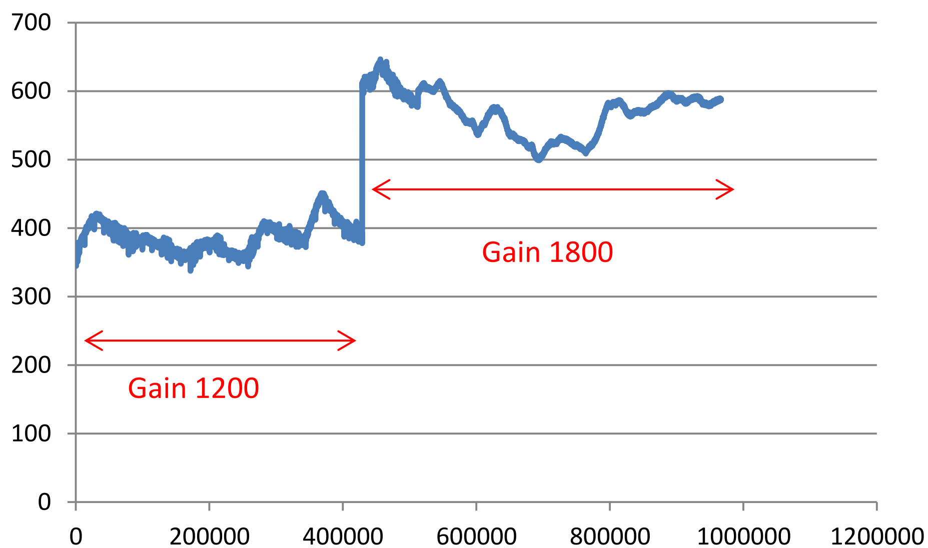
Results at humidity 180 ppm

Overview of raw data

Single-wire, raw data

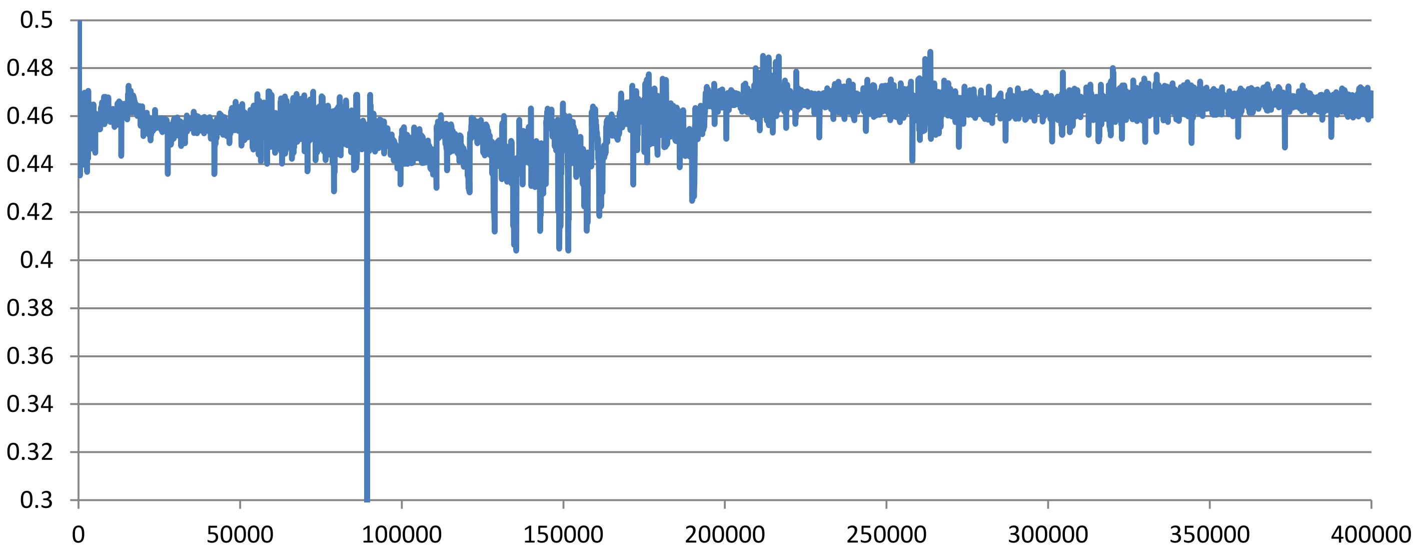


GEM, raw data



180ppm

Corrected GEM data at gain 1200



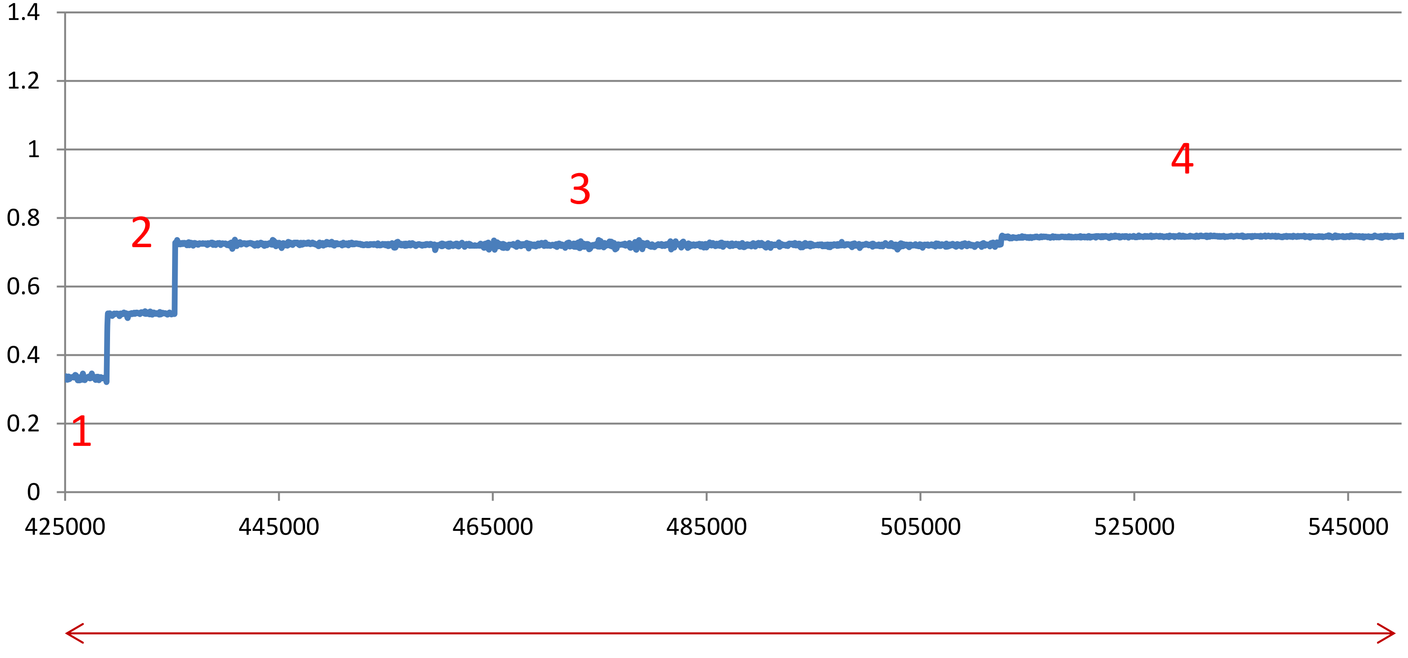
Noise
came for humidity
monitor
Then it was
switched off

±3%,

If pikes excluded ± 2%

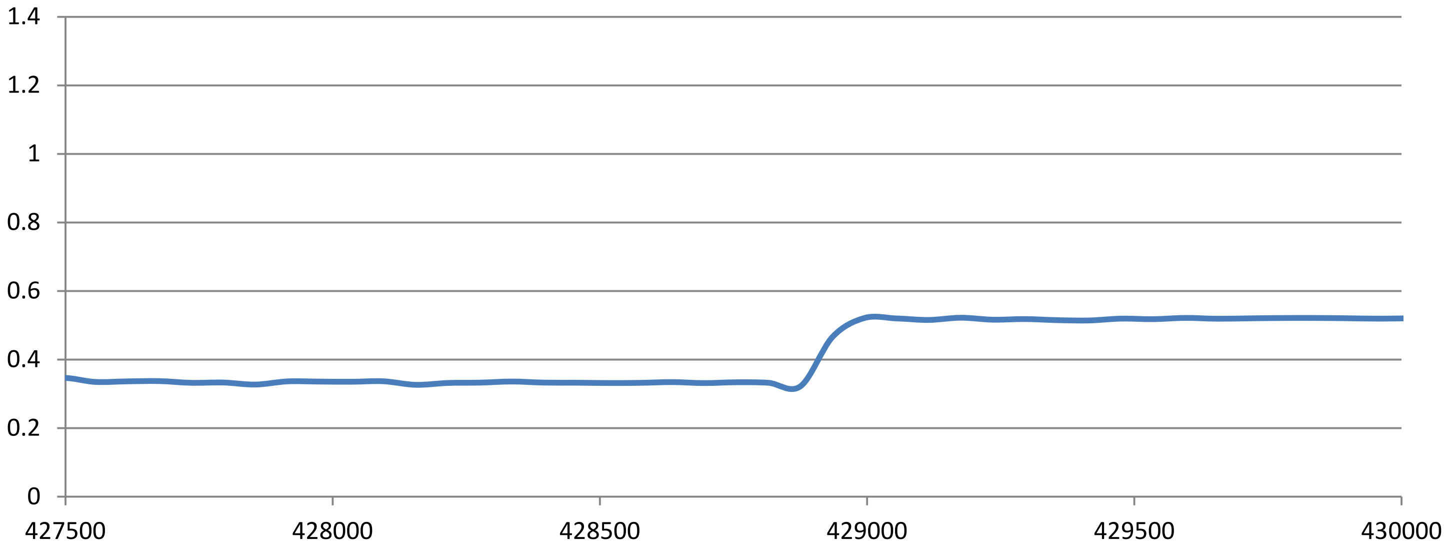
-both are consistent with old measurements

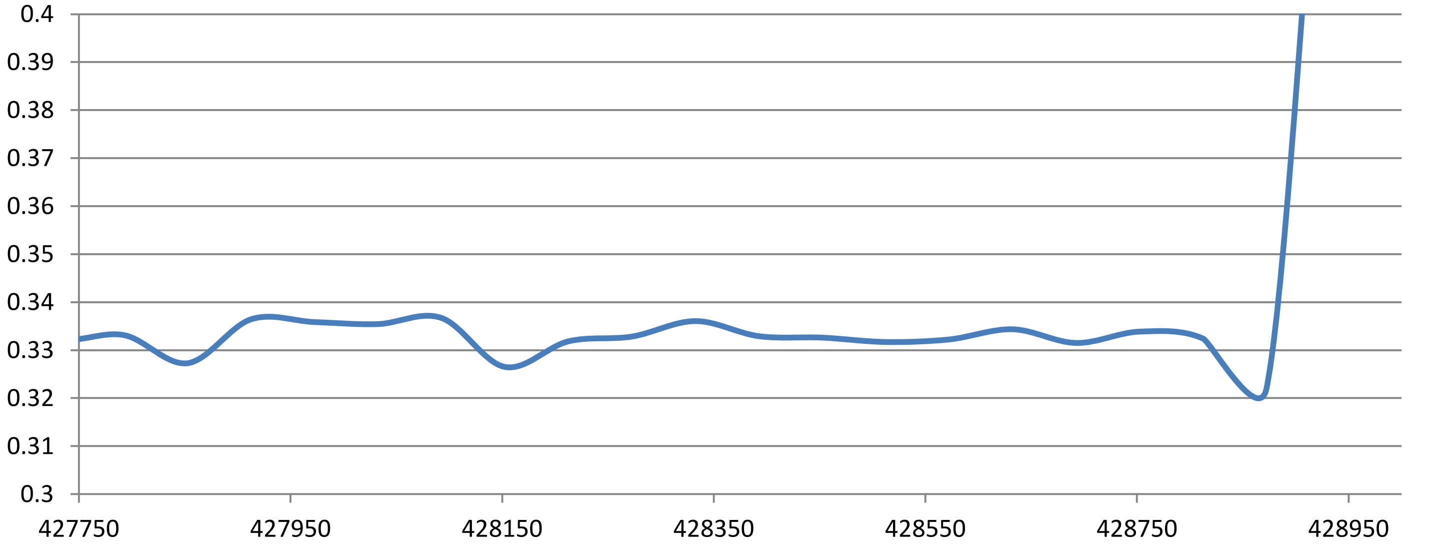
Step by step gain increase from 1200 to 1800



27 hours

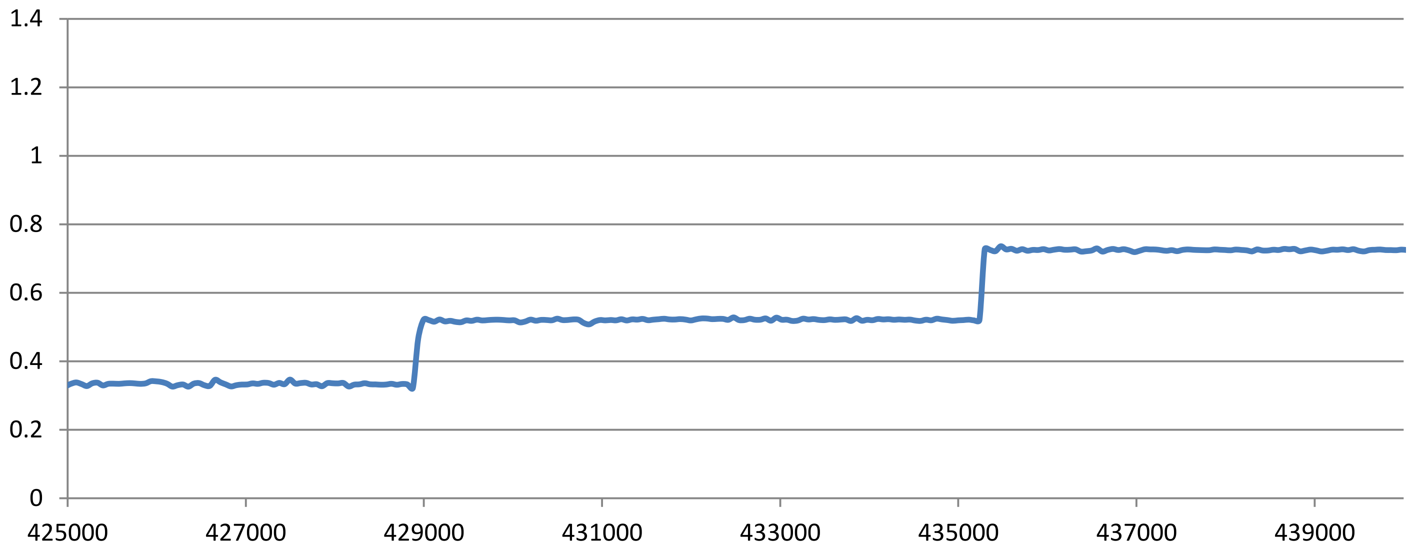
Region 1

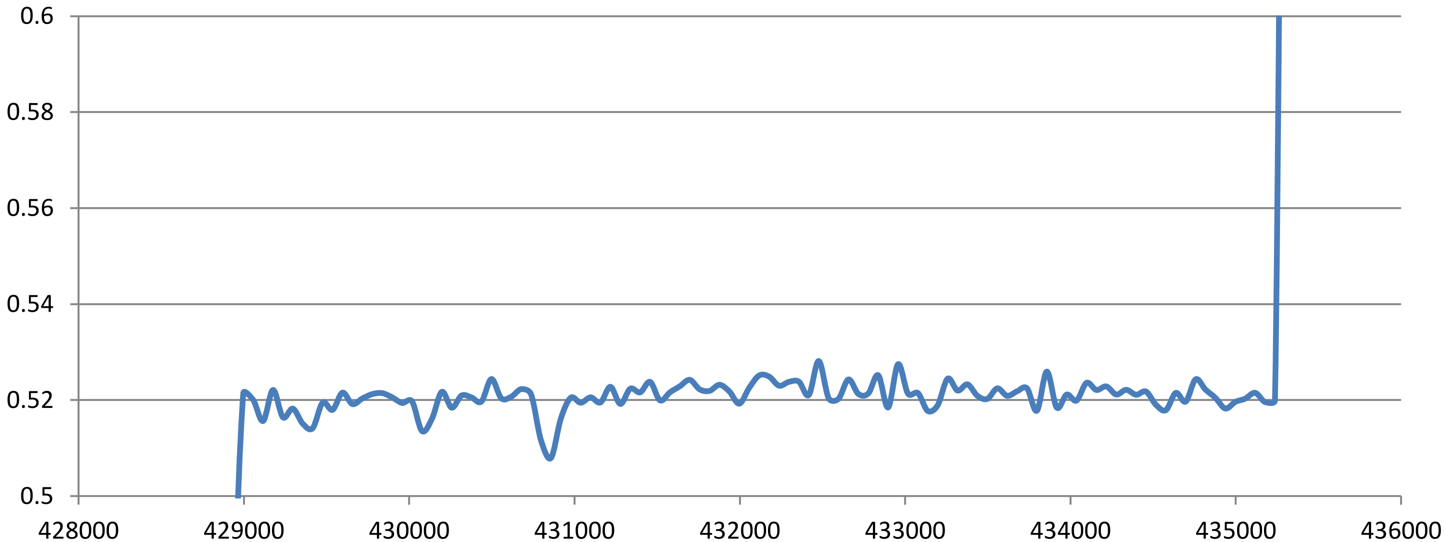

1.4
1.2
1
0.8
0.6
0.4
0.2
0
427500
428000
428500
429000
429500
430000


0.4
0.39
0.38
0.37
0.36
0.35
0.34
0.33
0.32
0.31
0.3
427750
427950
428150
428350
428550
428750
428950

± 1.5%

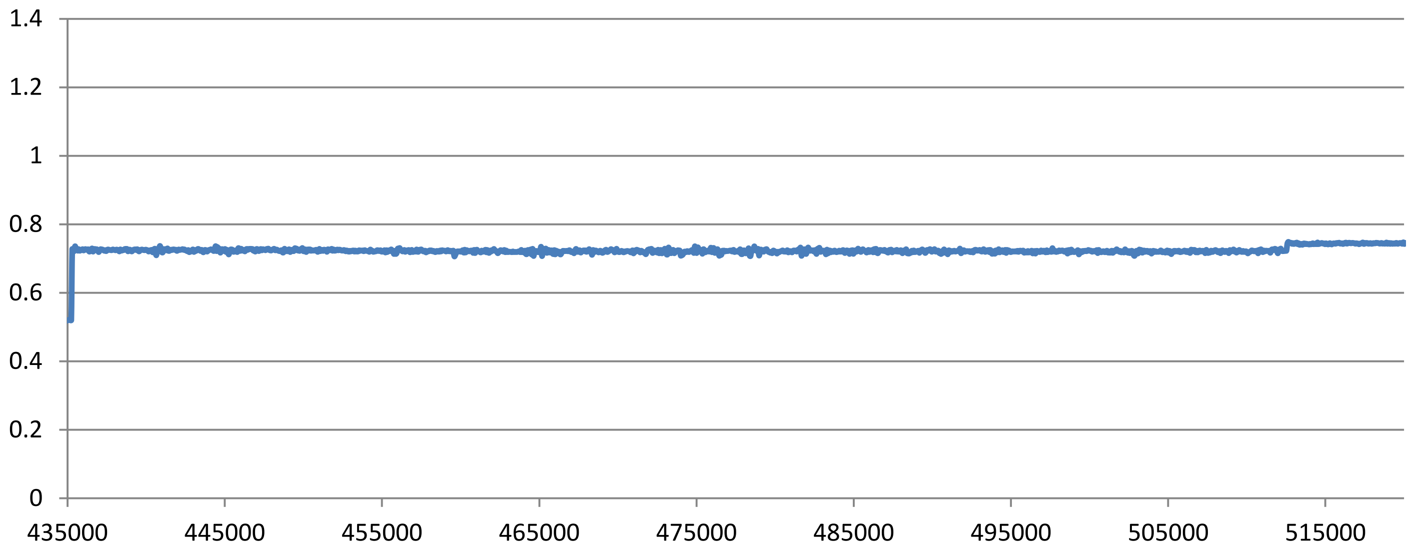
Region 2

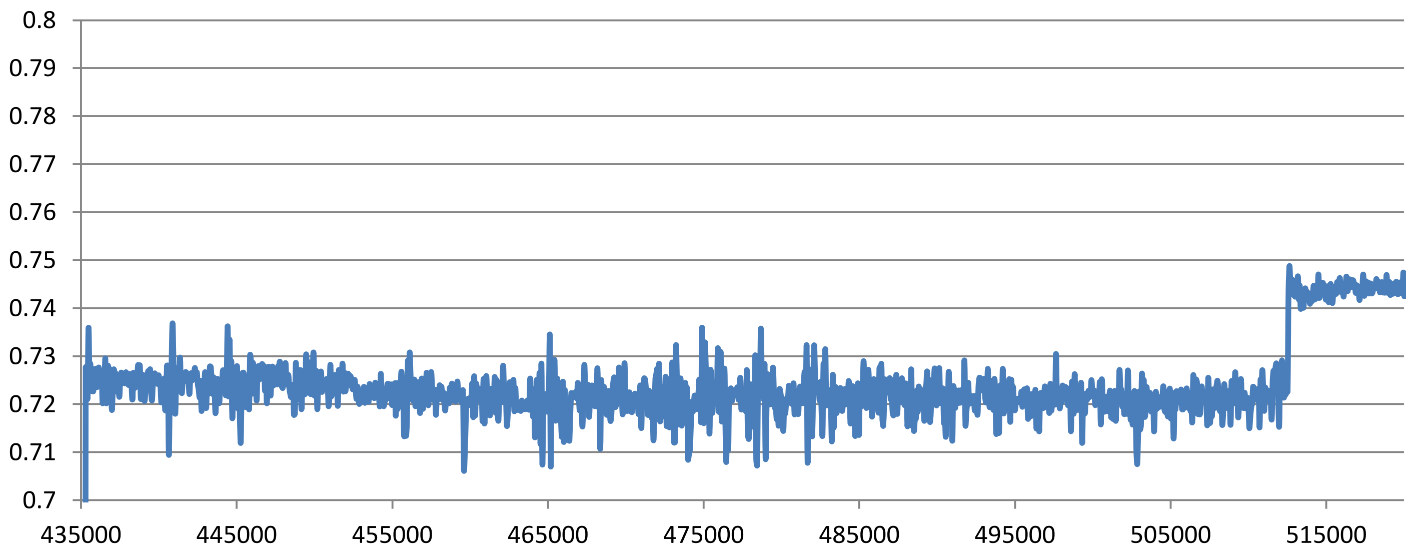

1.4
1.2
1
0.8
0.6
0.4
0.2
0
425000
427000
429000
431000
433000
435000
437000
439000


0.6
0.58
0.56
0.54
0.52
0.5
428000
429000
430000
431000
432000
433000
434000
435000
436000

± 1.4%

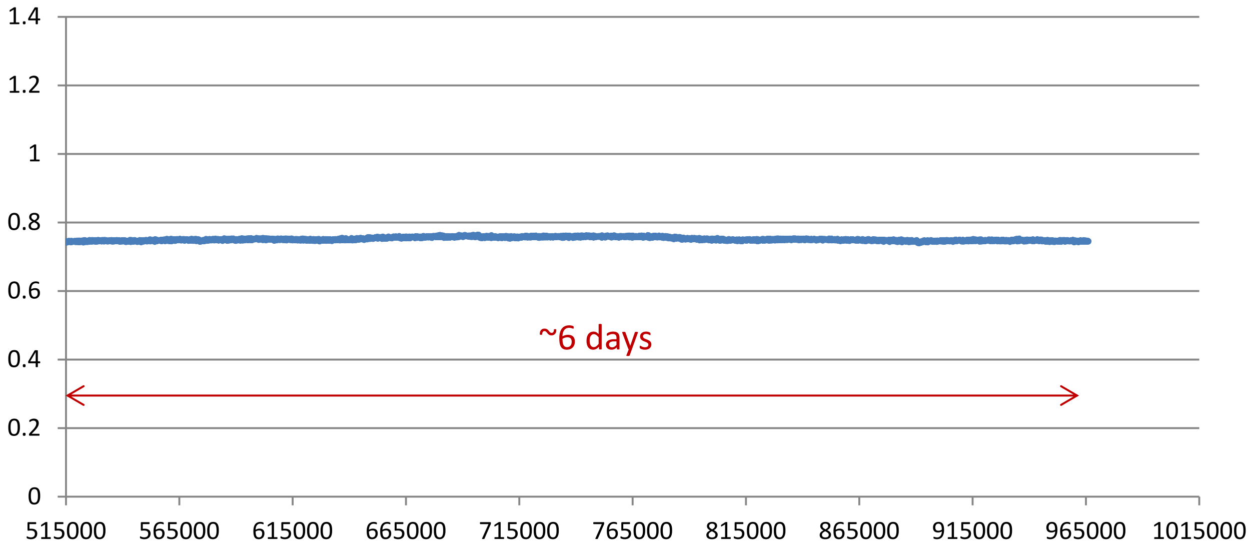
Region 3

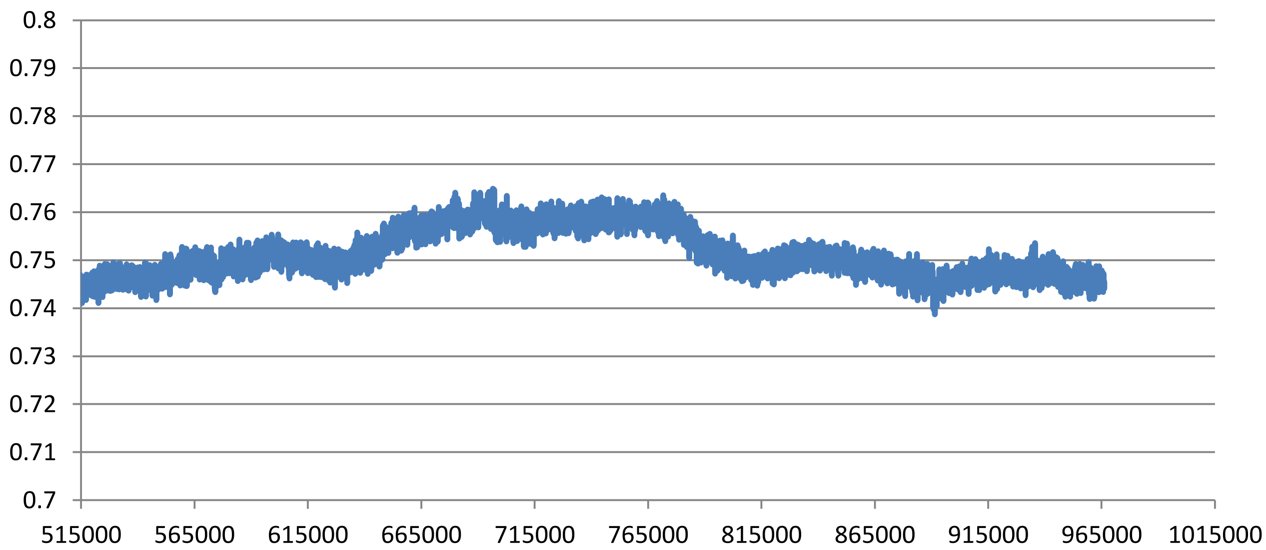

1.4
1.2
1
0.8
0.6
0.4
0.2
0
435000
445000
455000
465000
475000
485000
495000
505000
515000


0.8
0.79
0.78
0.77
0.76
0.75
0.74
0.73
0.72
0.71
0.7
435000
445000
455000
465000
475000
485000
495000
505000
515000

±1.3%

Region 4 (gain 1800)





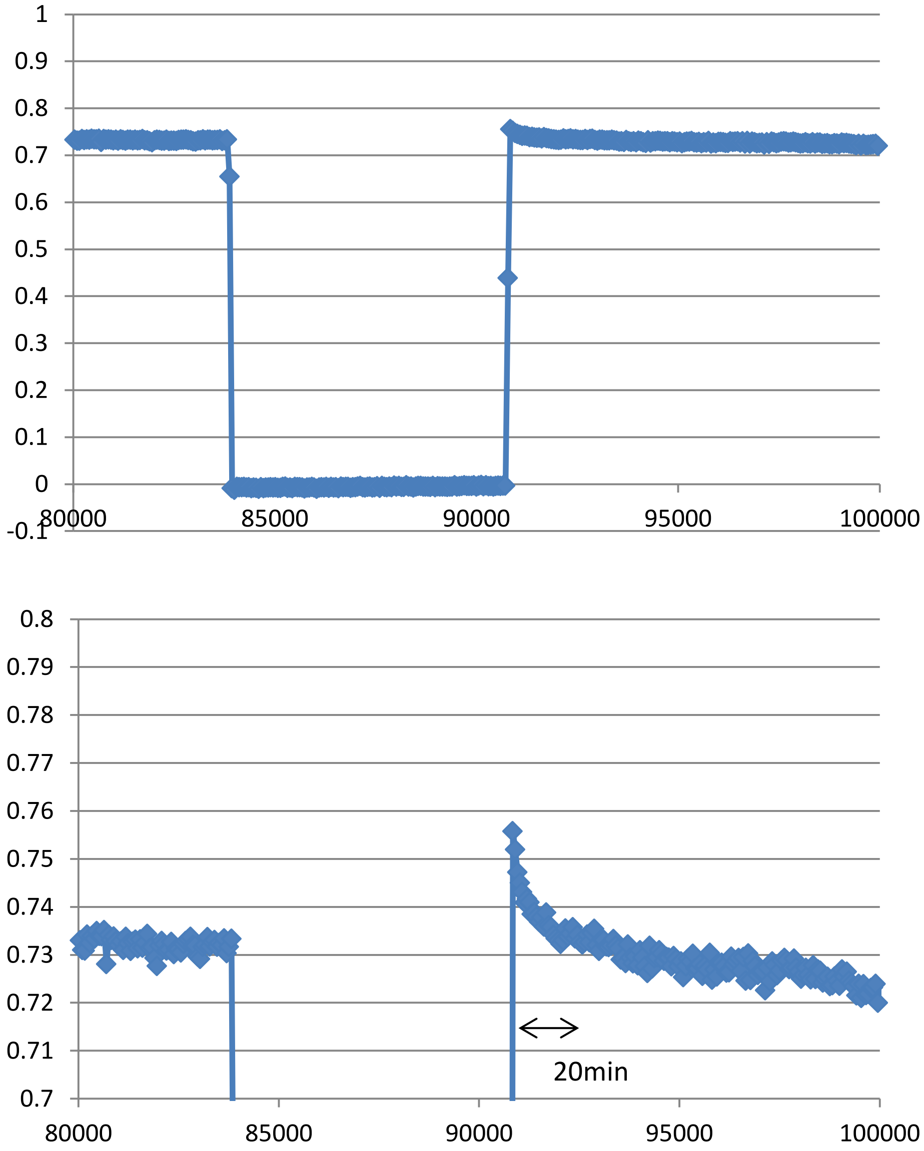
±1.3%

…70 ppm


1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
20000 30000 40000 50000 60000 70000 80000 90000 100000
Sr was removed
0.8
0.79
0.78
0.77
0.76
0.75
0.74
0.73
0.72
0.71
0.7
20000 30000 40000 50000 60000 70000 80000 90000 100000

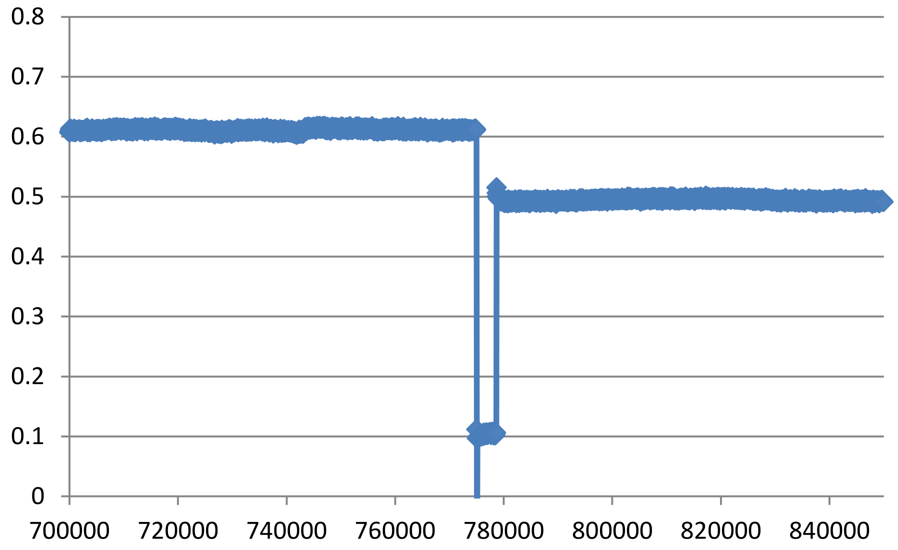
± 1.4%

Zoomed area

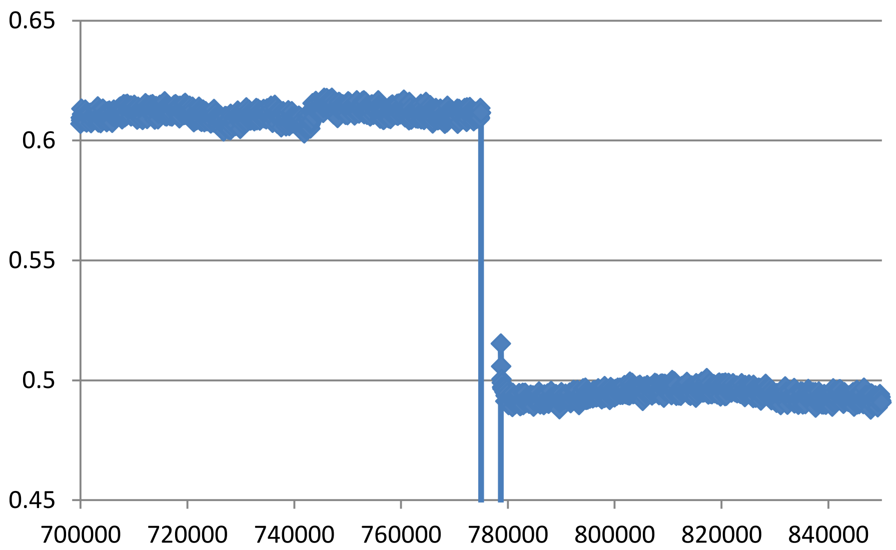


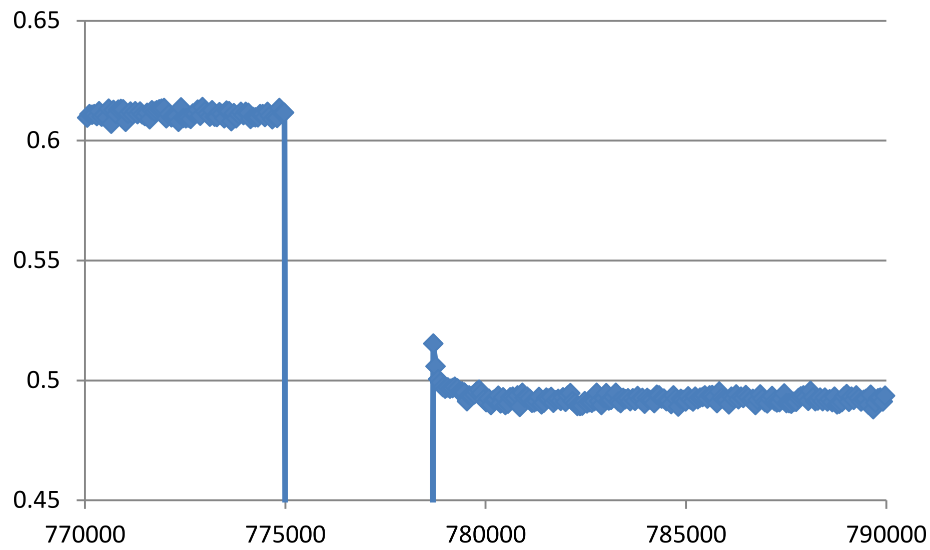
± 1.4%

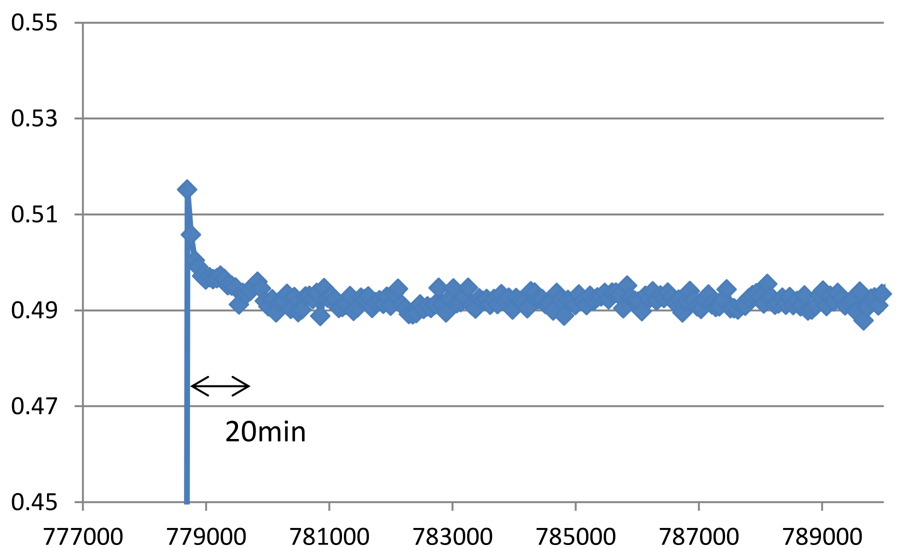
Various voltage variations



± 2%




0.65
0.6
0.55
0.5
0.45
770000
775000
780000
785000
790000


0.55
0.53
0.51
0.49
0.47
0.45
20min
777000
779000
781000
783000
785000
787000
789000

Conclusion for triple GEM:

Stability between ± 2% (gain 1200) and ± 1.4% (gain 1800)was observed with triple GEMs

General conclusions:

1. Long-term measurements (total time more than 6 months) were performed with GEMs having cylindrical holes
2. At expected LHC conditions (corresponding to GEM's current ~2nA a gain of ~ 1000) and humidity 100-50pp the gain variation were (over all tests performed) below ± 3%
3. Probably, better results could be achieved if we implement better compensation on environmental variations

Further plans:

1) Try to compensate on environmental variations even better (using a detector which has a working voltage and a gain vs. voltage close to our GEMs; in the case of the single wire detectors these parameters are very far away)
2) Perform tests very “dry” GEMs (in preparation by Leszek and Eraldo RD-51 Lab)

One of the possibilities is to use as a refernce detector Japanese GEMs:

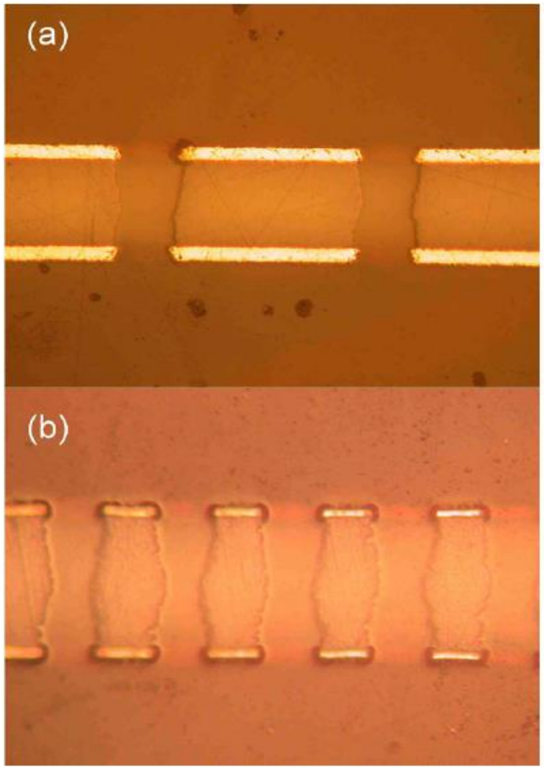


Fig. 1. Cross-section of (a) RIKEN-140T-LCP and (b) RIKEN-80T-LCP obtained with a metallographic microscope.

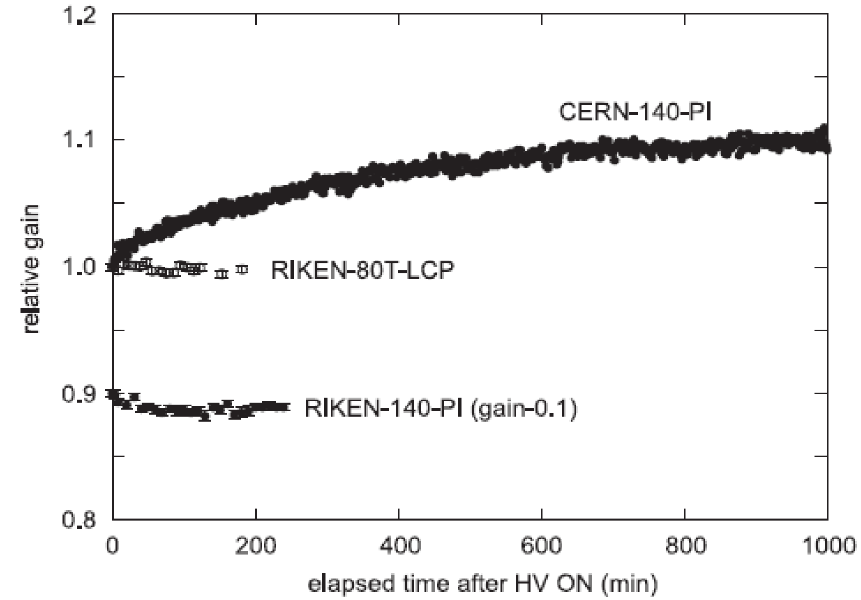
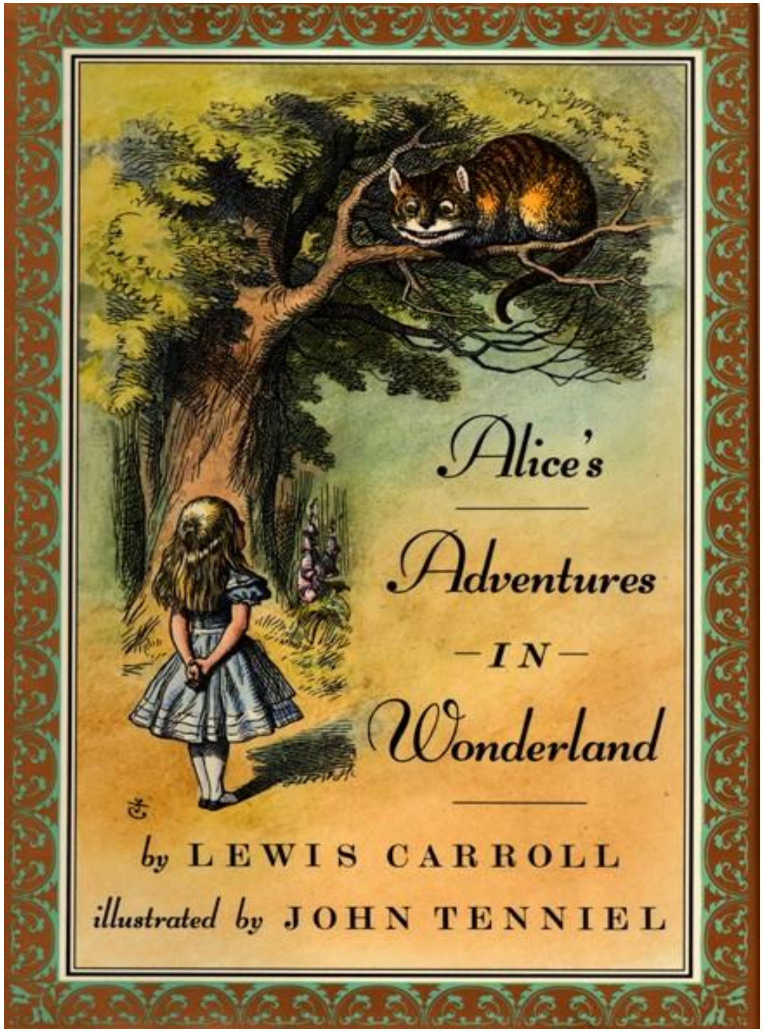


Fig. 5. Relative gain as a function of elapsed time after turning on of high voltage for RIKEN-80T-LCP and RIKEN-140-PI GEMs. The gain was normalized to 1 at the first measurement. For easier visibility, the gain of RIKEN-140-PI was offset by a value of −0.1. A correction for temperature and pressure was applied. The gain evolution of a CERN GEM (which had the same geometry as RIKEN-140-PI), as measured with our test setup, is shown in the figure. The effective gain of the measurements was around 10^3, and the count rate of irradiated 5.9 keV X-rays was about 100 counts cm^{-2} s^{-1}.

Made of liquid crystal (LCP)

The geometry of them is exactly same as the standard CERN-GEM: hole diameter = 70 microns, hole pitch = 140 microns, thickness of LCP = 50 microns, thickness of Cu layers = 5 microns.



…hence,
more adventures
are coming