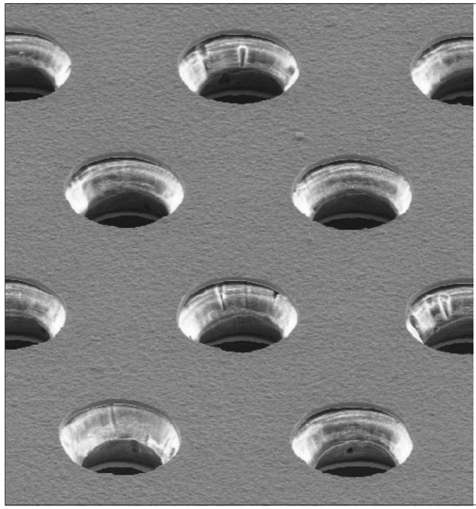


Aging Measurements with the Gas Electron Multiplier (GEM)

International Workshop on
Aging Phenomena in Gaseous Detectors
DESY Hamburg - October 2-5, 2001

Invesitgation of a $31x31cm^2$ Triple-GEM Detector operated in Ar:CO_2 (70:30)

M.C. Altunbas[3], K. Dehmelt[4], **S. Kappler[1,2]*, **
B. Ketzer[1], L. Ropelewski[1], and F. Sauli[1]

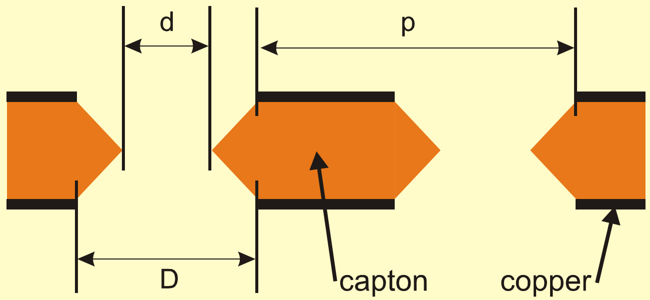
[1] *CERN, EP Division, Geneva (Switzerland)*
[2] *Inst. f. Exp.. Kernphysik, Karlsruhe University (Germany)*
[3] *State University of New York, Buffalo (U.S.A.)*
[4] *Inst. f. Kernphysik, Mainz University (Germany)*

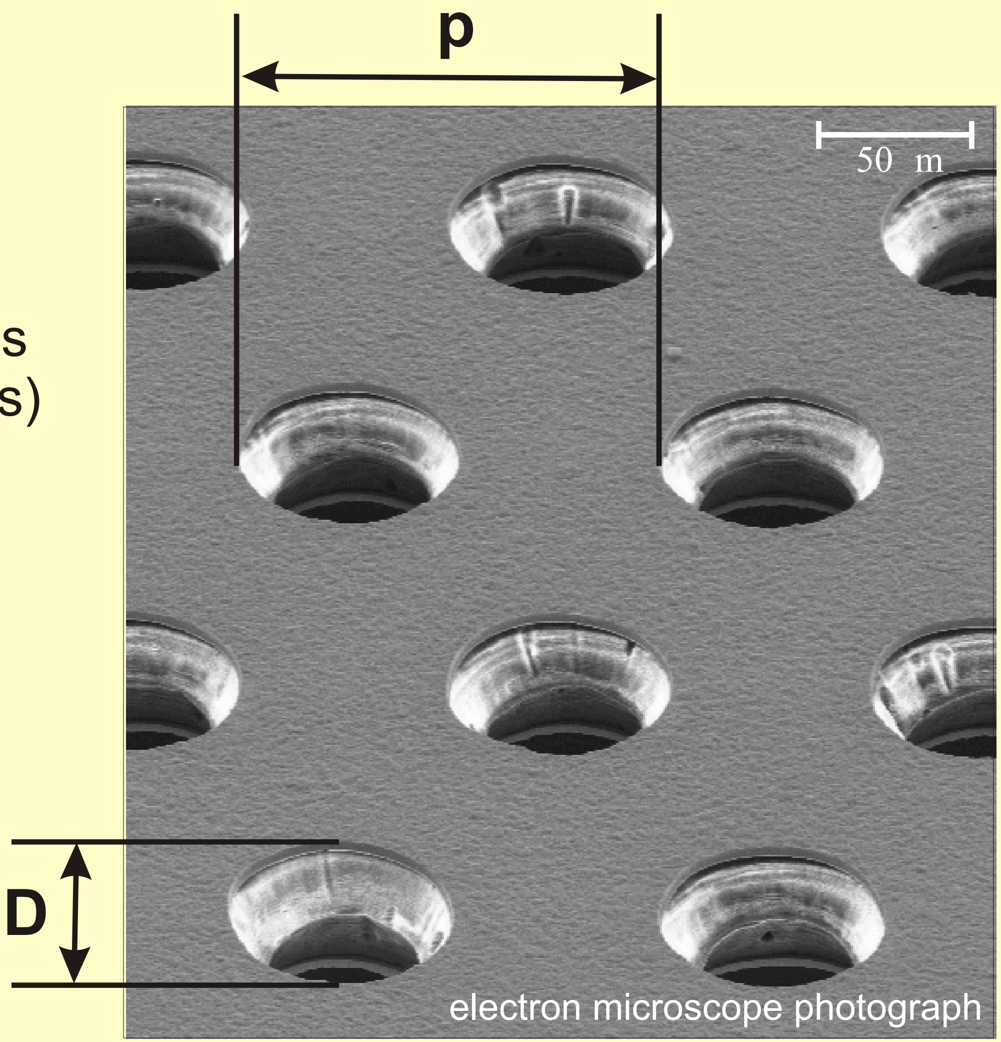
The GEM foil

+ Kapton foil of 50 m,
  two-side copper-clad (5 m each)

+ Perforated with a high density of holes
  (etched in a photolithographic process)

+ Typically *p=140 m, D=70 m, d=60 m*





The Gas Electron Multiplier
as a Charge Amplification Stage

The GEM Principle:

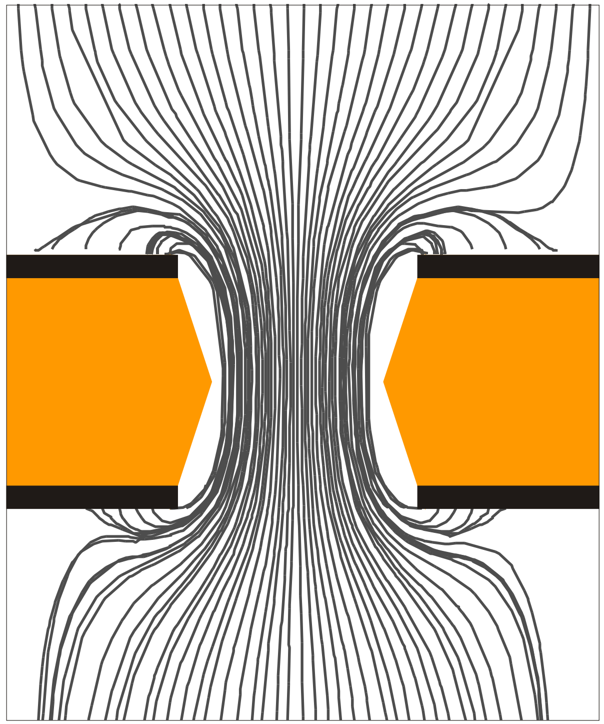
+ High voltage on electrodes (0.3-0.5kV)

+ Fieldlines from the volume above the GEM are strongly compressed into the holes:

  -> High fields inside the holes
  -> ***Proportional Gas Amplification***

+ A big part of the fieldlines are decompressed into the volume below the GEM,

  -> High electric transparency
  -> Effective gains up to 10^3



Electron drift lines through a GEM

The Multi-GEM Detector

General Design

Principle:

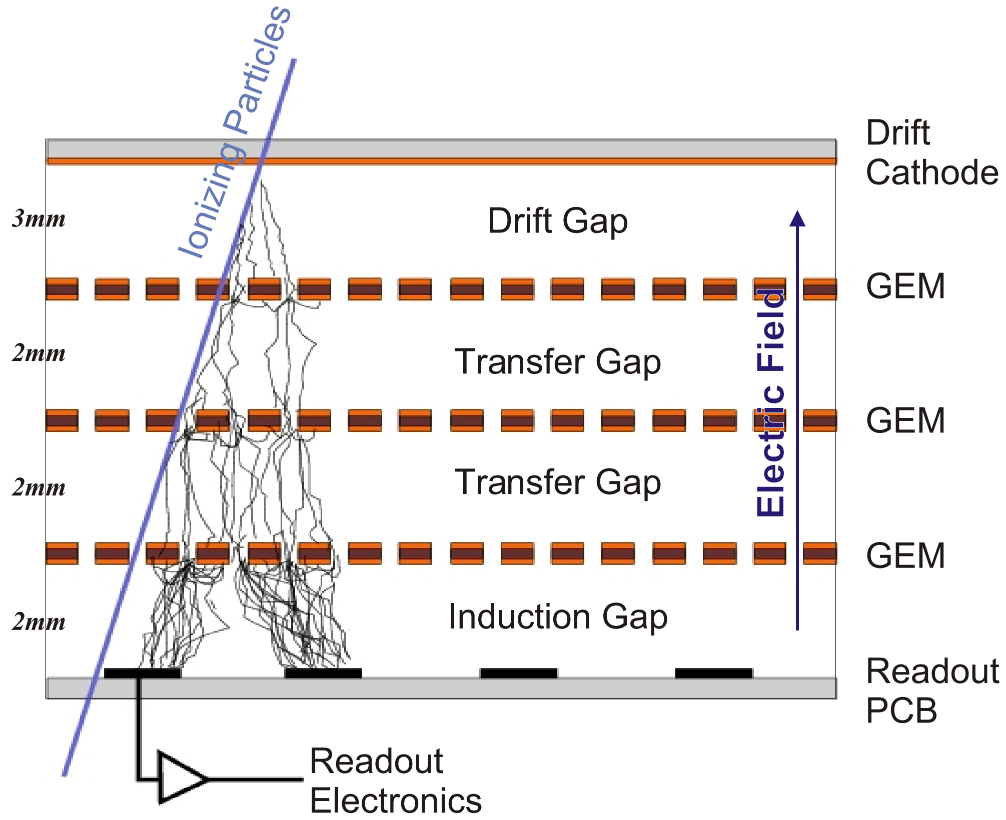
+ Parallel electrode gas detector with one or more GEMs inserted

Features:

+ Adaptable eff. gain (# of GEMs, GEM-voltage)

+ Separation of gas amplification and readout stage allows high flexibility in the readout design

+ 2D readout easily realizable



Previous Aging Measurements
with a Double-GEM Detector

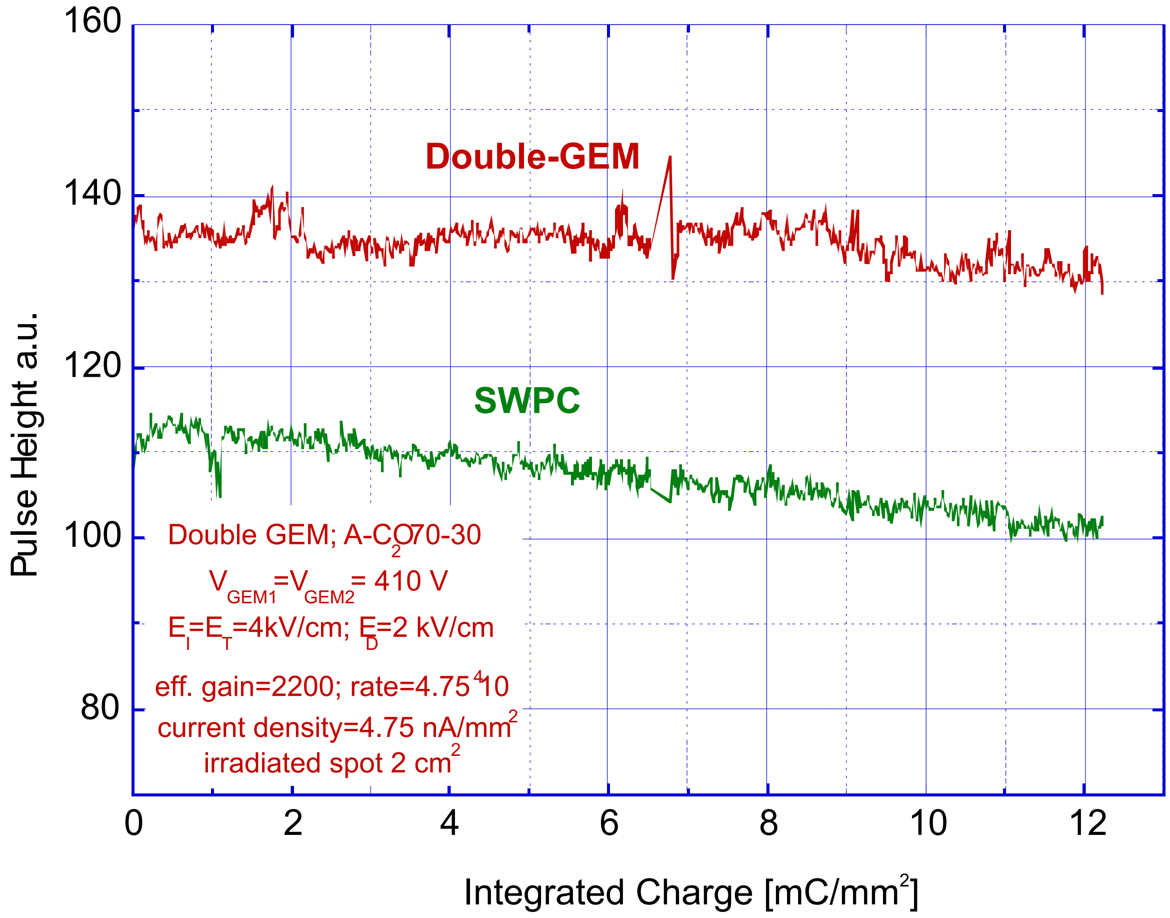
Former Studies:

+ Double-GEM detector, standard GEMs & PCB readout

+ Detector operated with
  - Ar:CO_2 (70:30)
  - Effective gain $G = (2.2 \pm 0.4) \cdot 10^3$
    - $E_D = 2.0kV/cm$,
    - $E_T = E_I = 4kV/cm$
    - GEM voltage: $410/410V$

+ $6keV$ X-ray tube, $2cm^2$ irradiated

+ SWPC for reference, installed in the same gas line



Triple-GEM detectors
for COMPASS

Final Design:

+Triple-GEM detector
- Minimization of probability and energy in spark discharges

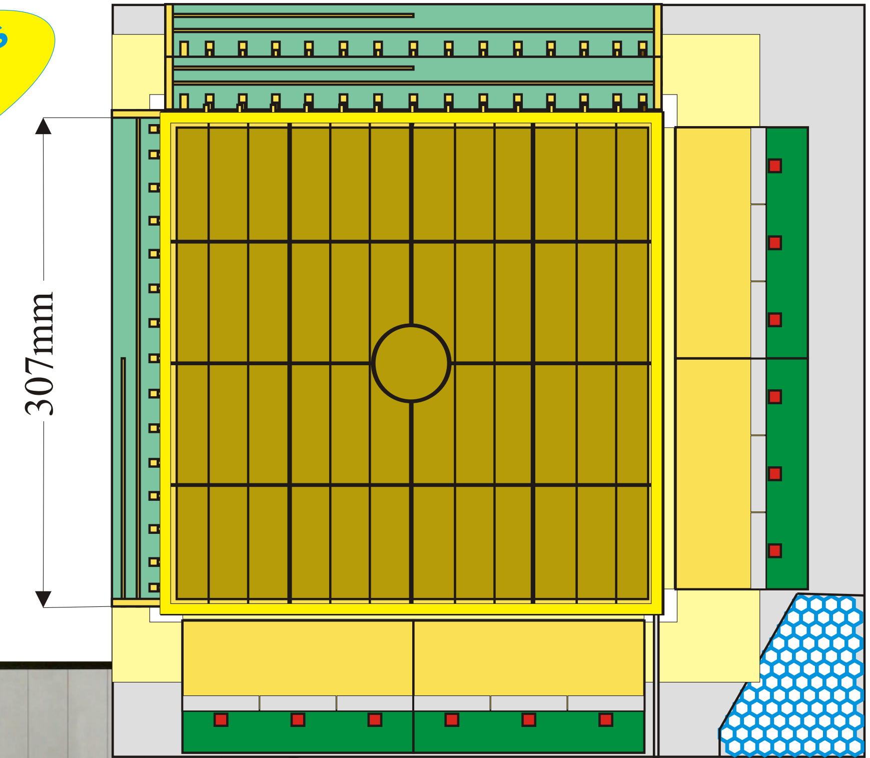
$\sigma_x = 45\,\mu m$ for MIPs
$\sigma_t = 15ns$

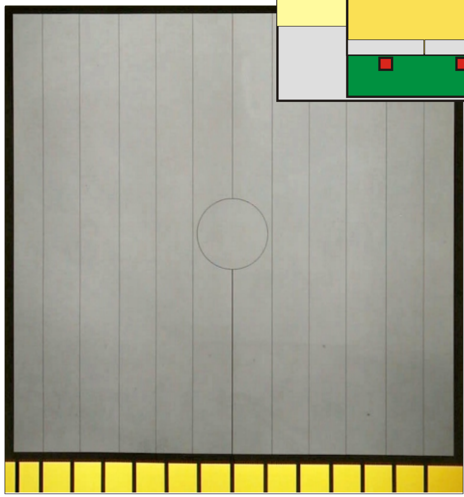
+ GEM-foils segmented into 12 sectors plus central disk

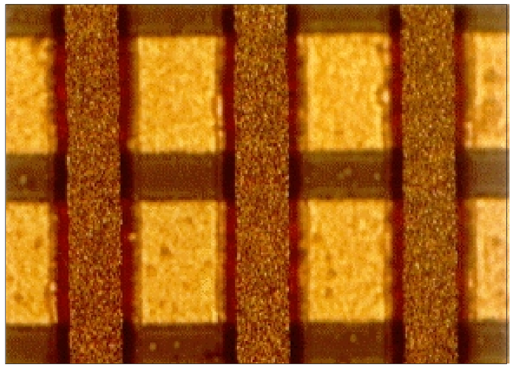
+ 2D Readout, *2x768* strips
400 μm pitch, *70* & *350 μm* width

+ Active area $31x31cm^2$
+ Gaps: *3/2/2/2mm*
+ Total thickness *15mm*

+ Rigid support with *Nomex* honeycomb and *Vetronite* skin





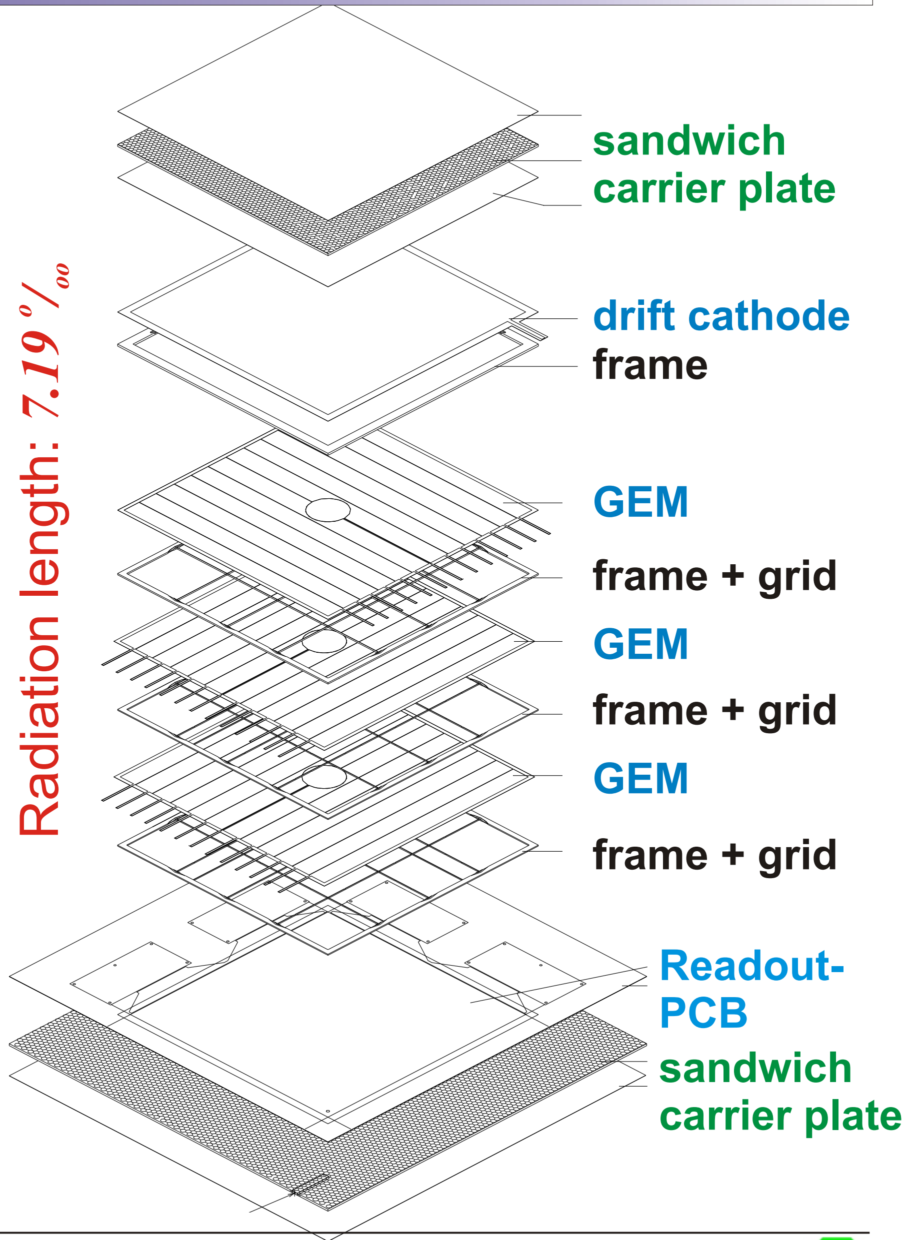


Detector Components

Overview of the Materials used

Material	Details	Supplied or manufactured by
Assembly Glue	ARALDIT AY103 + HD991 (ratio 10:4)	CERN store
Frame & grid spacer conditioning	Polyurethane (2 component)	Nuvovern LW Walter Mader AG CH-8956 Killwangen
Sandwich structure (external)	Sandwich Stesalit (125μm)- Honeycomb Nomex (3mm)- Stesalit (125μm)	Nomex: Socol 24 Rue du Lac, CH-1020 Renens Stesalit: Stesalit AG, CH-4234 ZULLWIL SO
Shielding	Aluminium (10μm)	GDD
GEM foils (50μm)	50μm thick Kapton, 5μm Cu, 70μm hole diam., 140μm pitch	CERN/EST
Drift	5μm Cu on 50μm Kapton	CERN/EST
Frame	3mm thick Stesalit	CERN/EP/TA1
Spacers	Vetronite grids 2mm thick	CERN/EST
Gas pipes	PP tube (3mm diam.)	Angst-Pfister Thurgauer Str. 66 CH-8052 Zürich
Gas outlet	F-glass + fitting	CERN/EP/TA1
PCB	Active area 30.7 x 30.7 cm^2, 2-dim. 2x 768 strips, 400μm pitch	CERN/EST
HV boards	Custom made	CERN/EST

Radiation length: 7.19 ‰



The Setup I

Detector, SWPC & X-Ray Tube

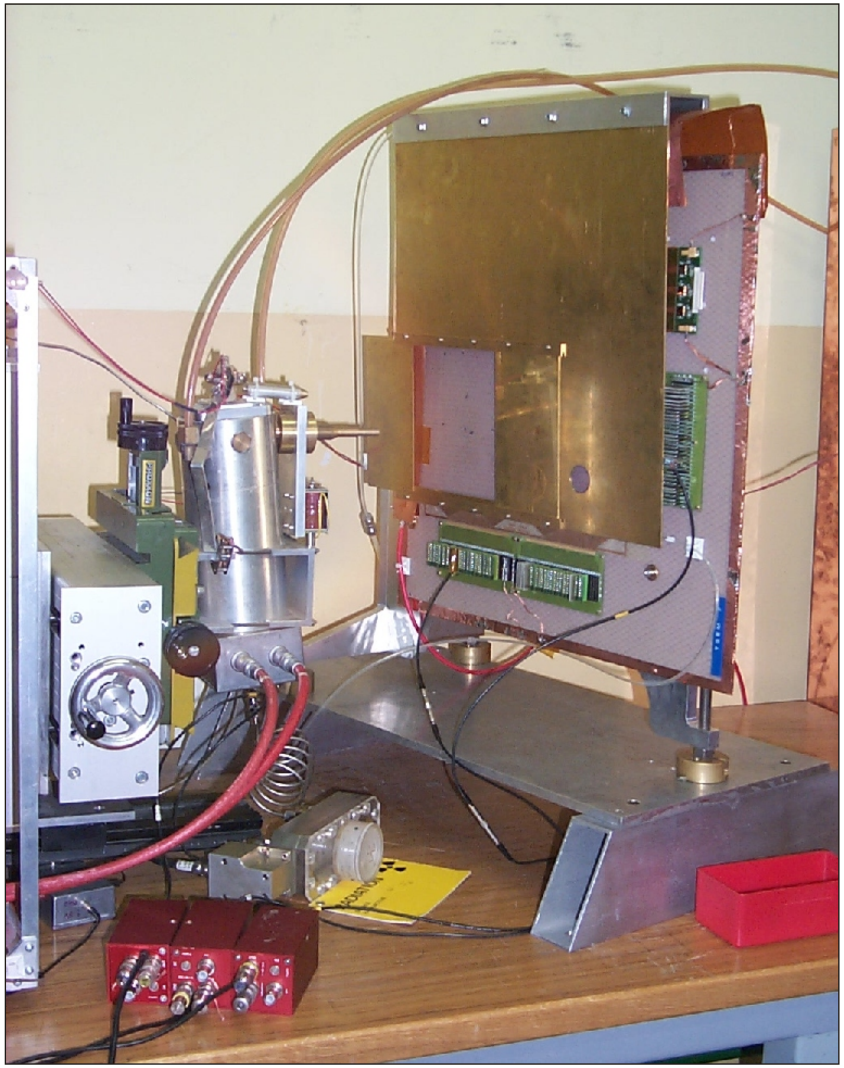
Aging Setup:

+ $8.9keV$ X-ray tube, $38.5cm$ distance
  to the detector

+¼ of the detector (15x$15cm^2$) irradiated
  with a Gaussian X-ray beam profile

+ Detector operated with
  - Ar:CO_2 (70:30)
  - Effective gain of $G = (8.5 \pm 1.3) \cdot 10^3$
    during the irradiation phases,
    thus:
    - $E_D = 2.5kV/cm$, $E_{T1} = E_{T2} = E_I = 3.7kV/cm$
    - GEM voltage: $425/380/340V$

+ SWPC for reference,
  installed in the same gas line



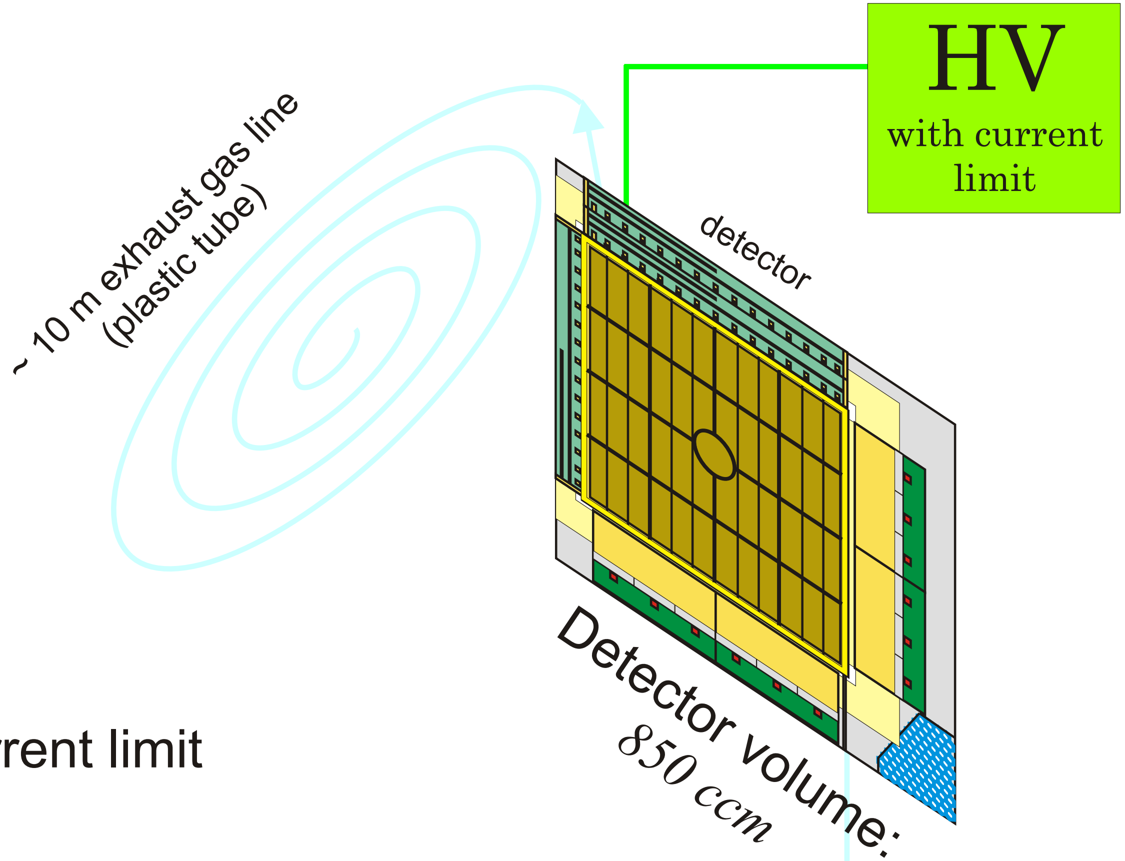
The Setup II
Gas System & HV Supply

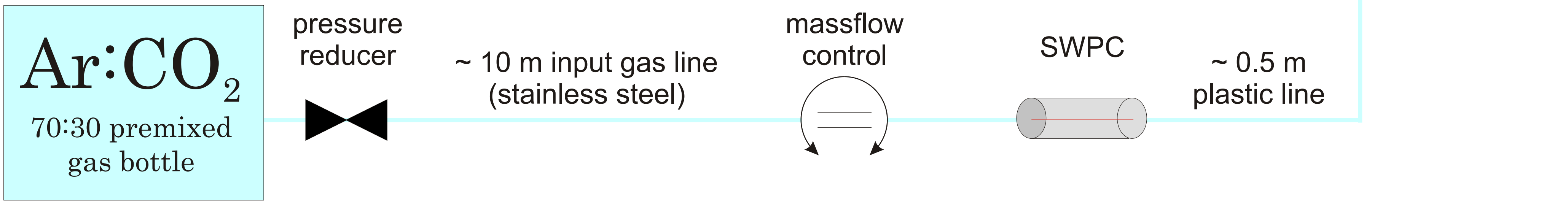
+ Open Gas System:

  - Premixed gas bottle
    Ar:CO_2 (70:30)
  - Mass flow control
    80±0.5 ccm/min
  - Exhaust gas line of ~10m

+ HV Supply:

  - CAEN high voltage supply with current limit
  - Resistive voltage divider

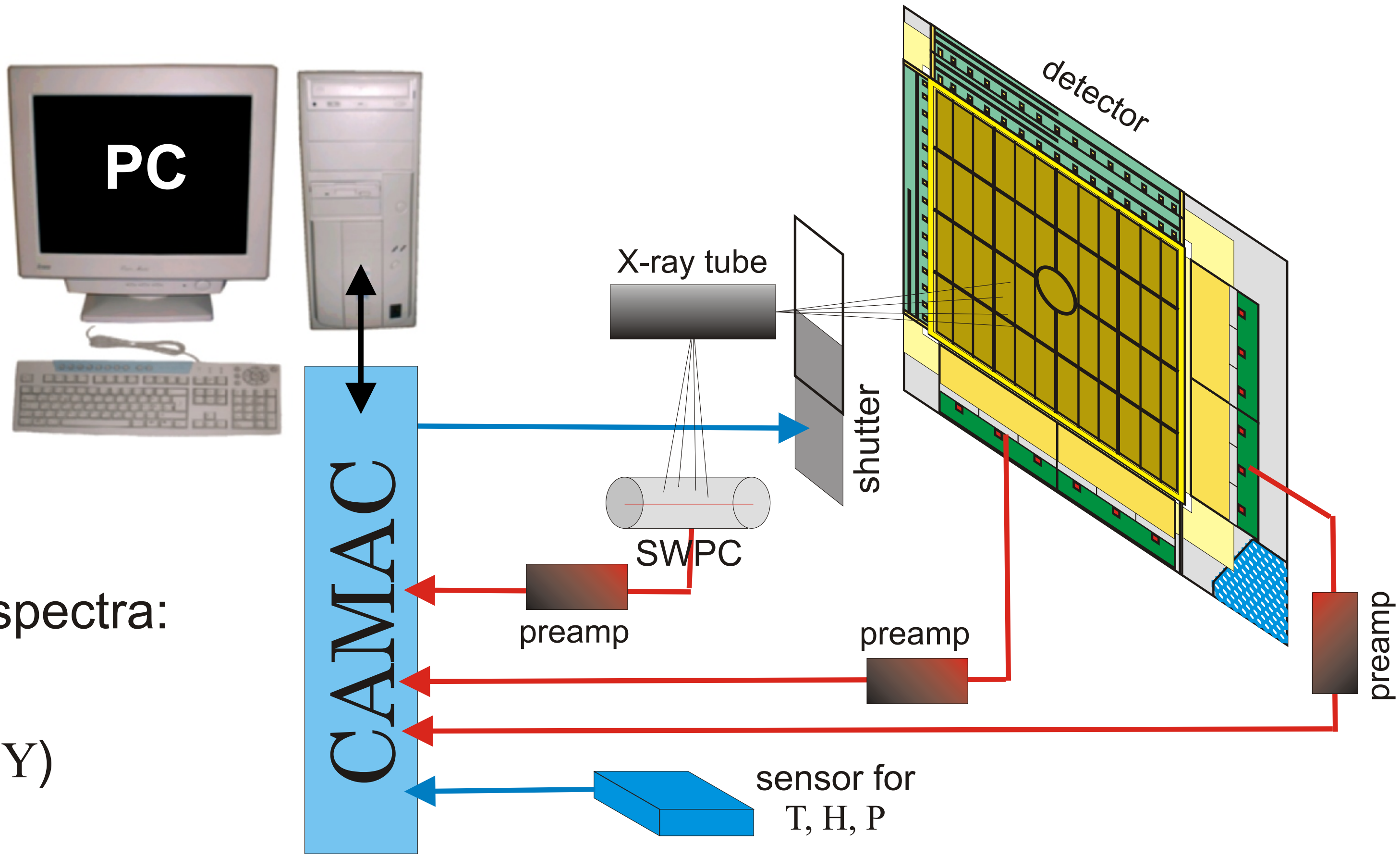




The Setup III
Monitoring System for Environment & Spectra

+ Measurement cycle:

- 10 min irradiation
- Measurement of:
  Temperature
  Relative humidity
  Pressure
  Currents
- Recording of PH spectra:
  (with shutter closed)
  SWPC
  Triple-GEM (X & Y)

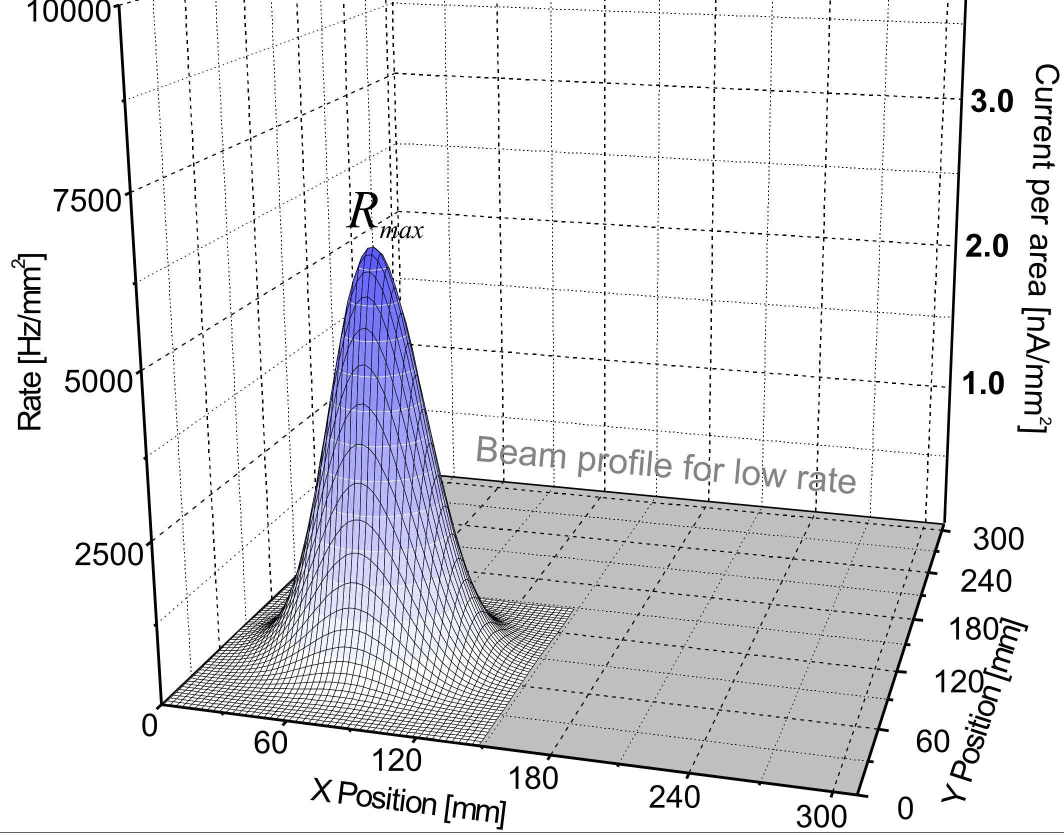


Irradiation Phases, X-Ray Beam Profile
Cu-Anode, 8.9keV X-rays

Irradiation in 2 phases:

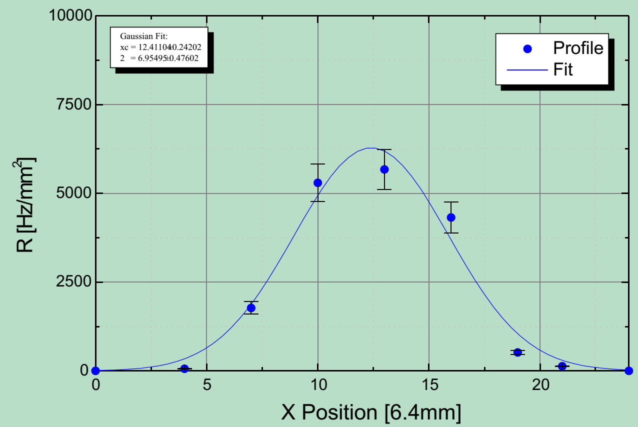
I. 10 days at *"low rate"*
$R_{max}=6.3 \cdot 10^3 Hz/mm^2$ or $2.5nA/mm^2$

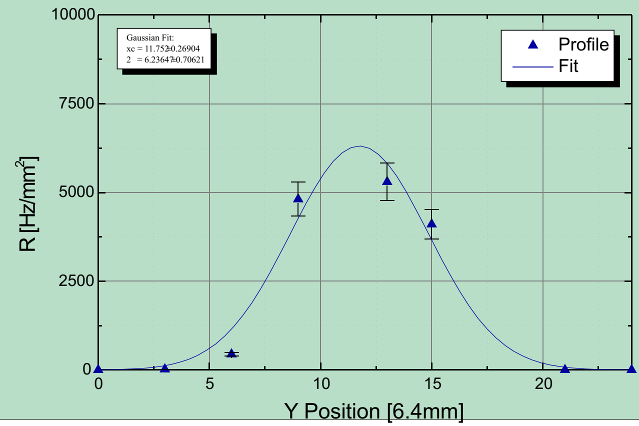
II. 10 days at *"high rate"*
$R_{max}=2.5 \cdot 10^4 Hz/mm^2$ or $10nA/mm^2$



+ Gaussian beam profile with

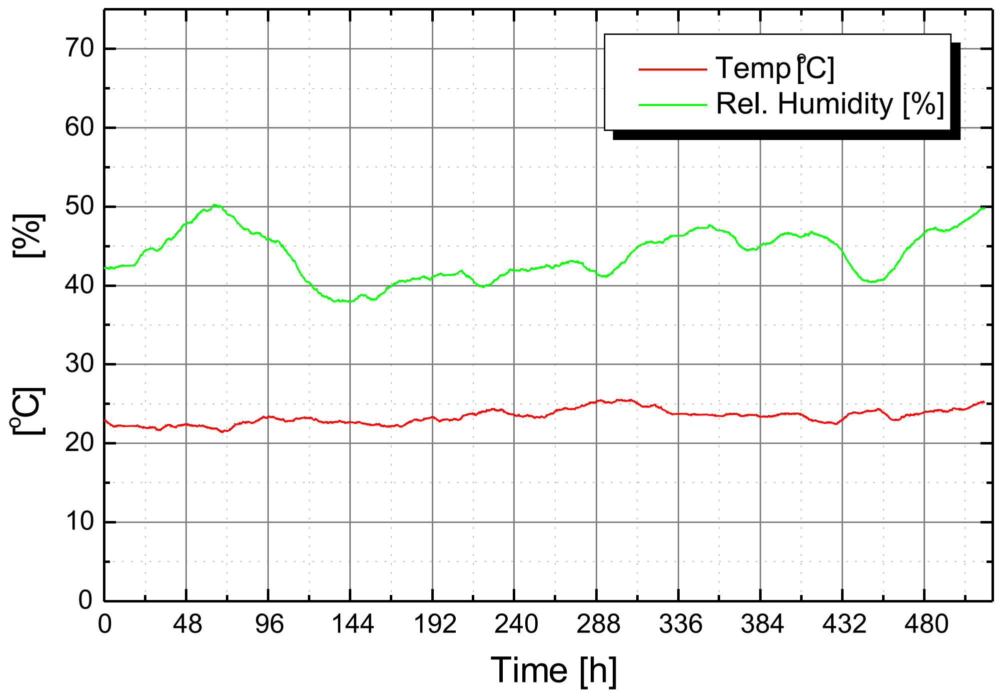
- $= 20\ mm$, and thus
- $12.6\ cm^2$ inside the 1 -line



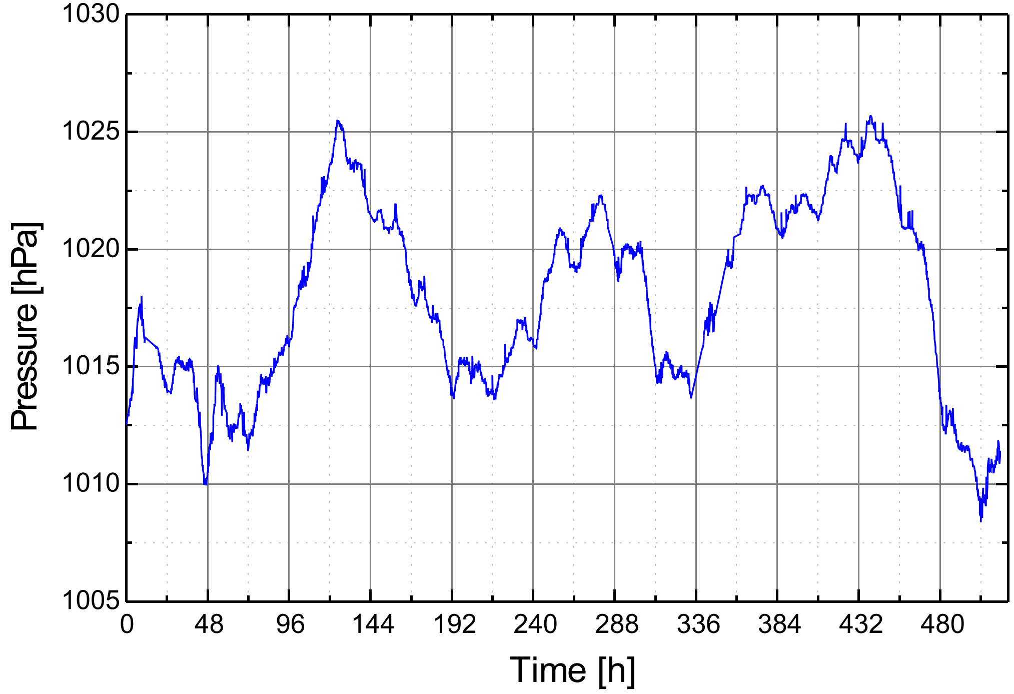


Measurement Results:

+ Temperature (accuracy $\pm 1^{\circ}$)
+ Relative humidity (accuracy $\pm 3\%$)
(outside the detector)



+ Ambient atm. pressure (accuracy $\pm 0.5\%$)
(outside the detector)



+ Gas Line:
- Gas flow: $(80 \pm 0.5)\ ccm/min$
- H_2O content: $(60 \pm 2)\ ppm$
(crucial importance for discharge probability)

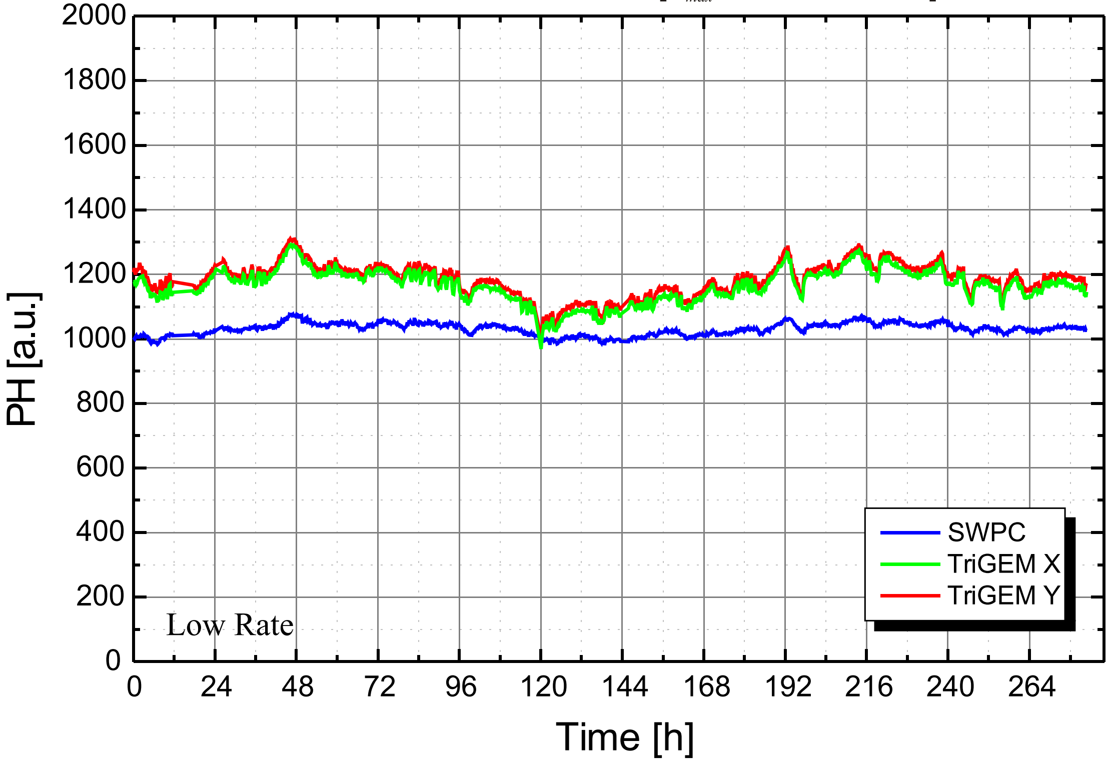
No discharges observed during measurement!

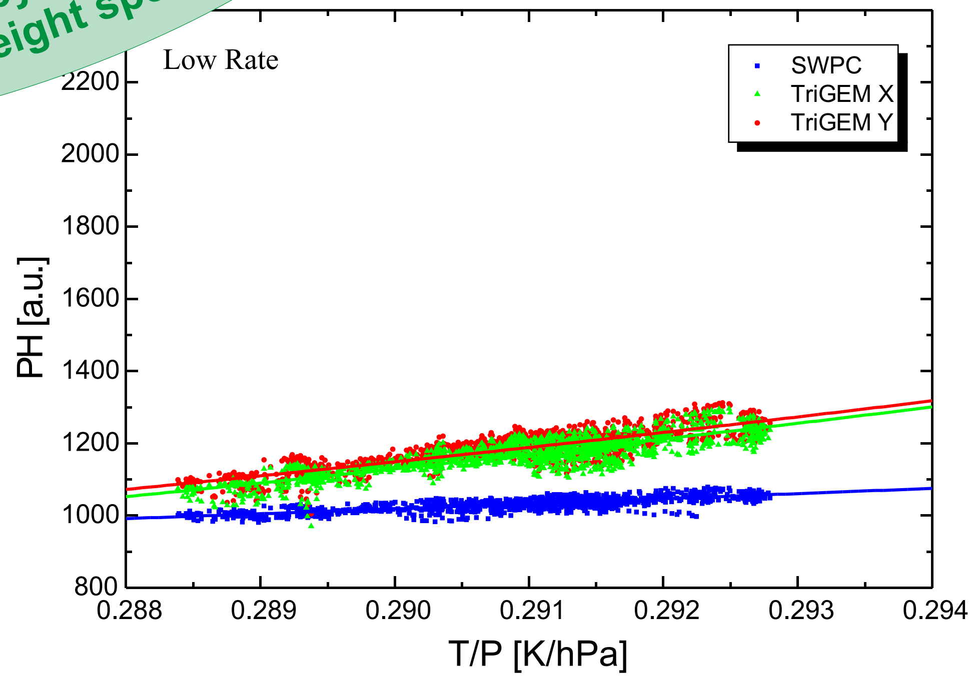
Results
Gain - Temperature - Pressure Correlation

Gain & energy resolution determined by analysis of the pulseheight spectra!

+ Correction for the correlation Gain - Temperature - Pressure

Here: Low Rate Data [$R_{max} = 6.3 \cdot 10^3 Hz/mm^2$]



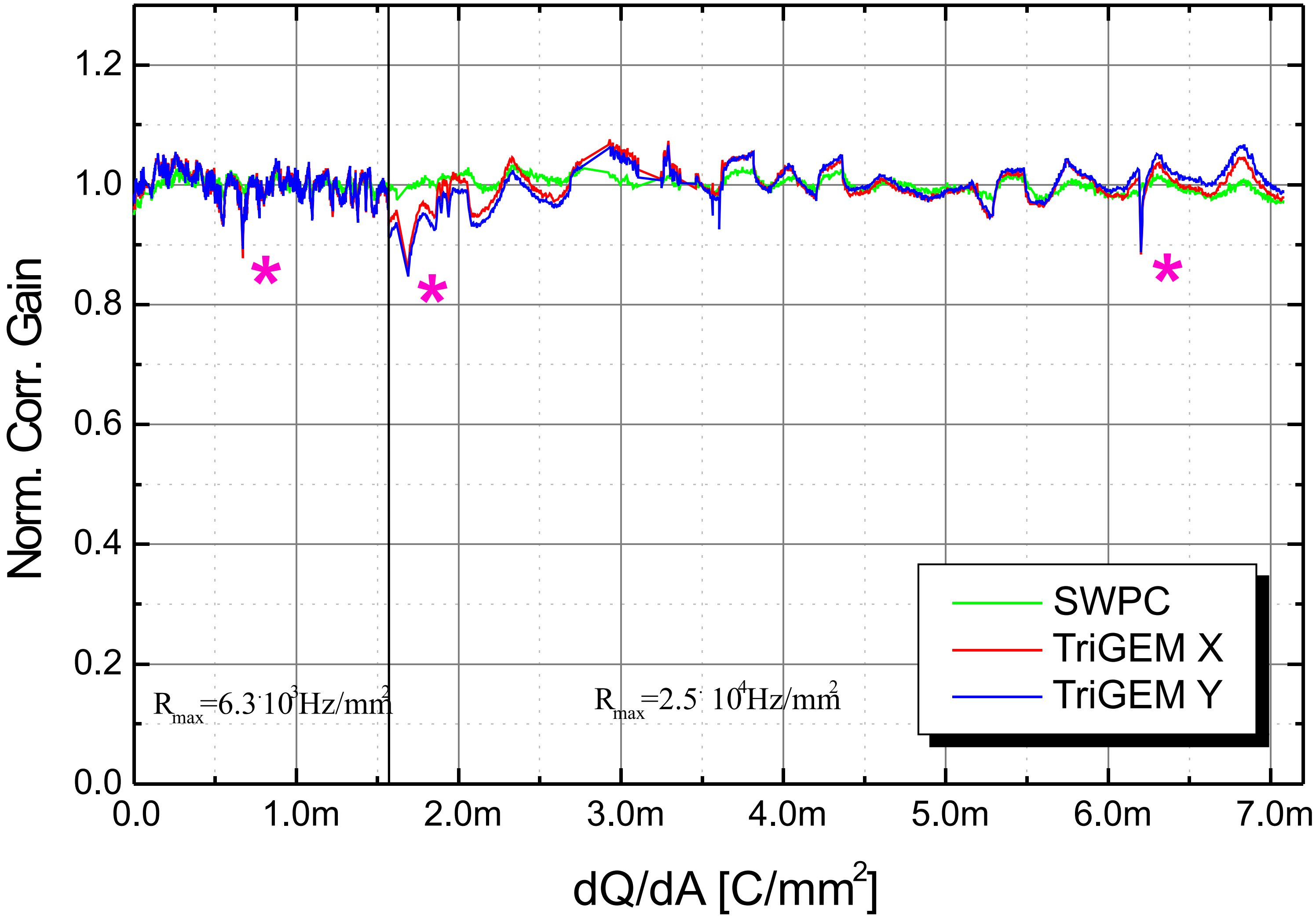


Fit of exponential model for each line:

$$G = A \cdot e^{-B \cdot \frac{T}{P}}$$

G: Eff. Gain T: Temp. P: Press. A, B: Fit parameters

Results
Corrected Gain

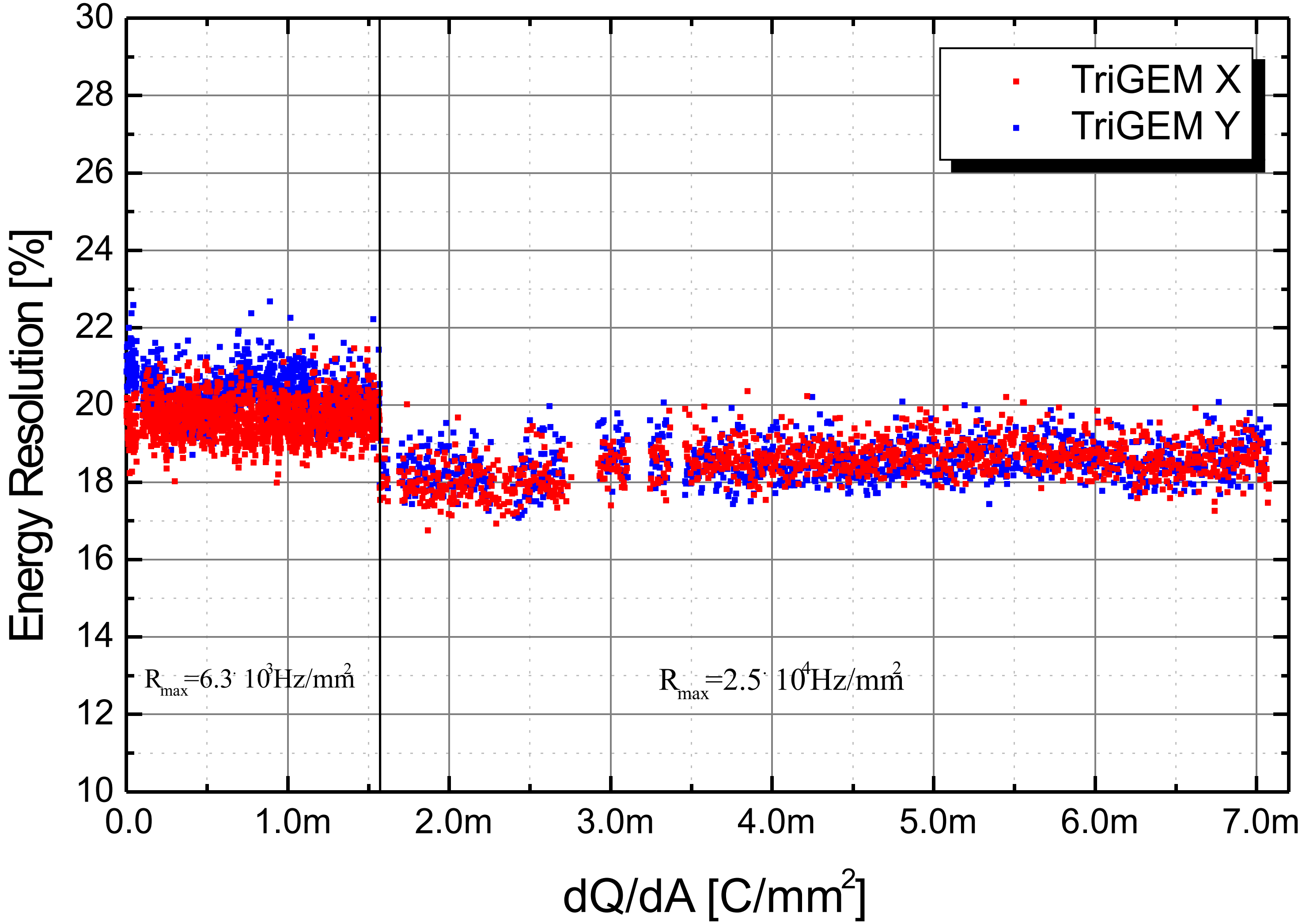


Convention:

We give the quantity dQ/dA as the charge accumulated in the region of the 1 -line of the beam profile.

*** = gas bottle exchanged**

Results
Energy Resolution



Energy Resolution:

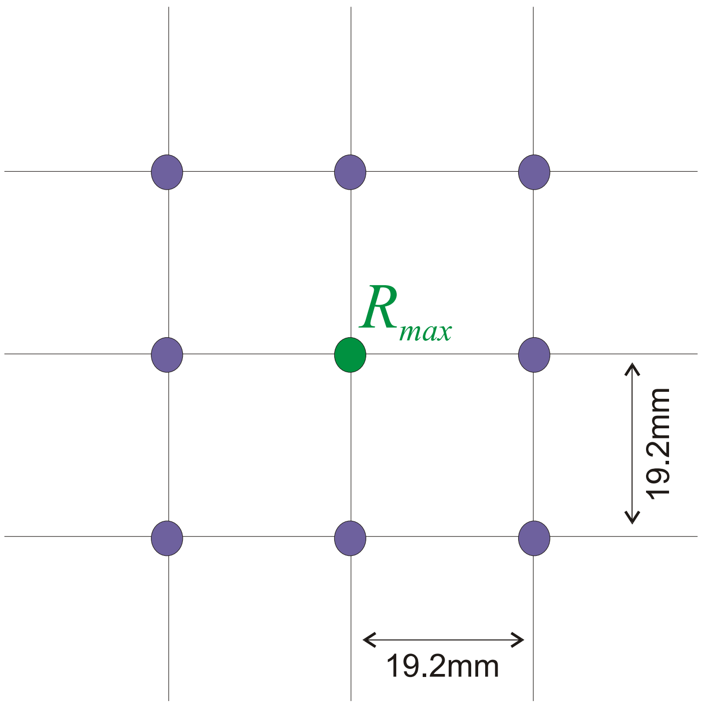
$$E_{fwhm}/8.9keV$$

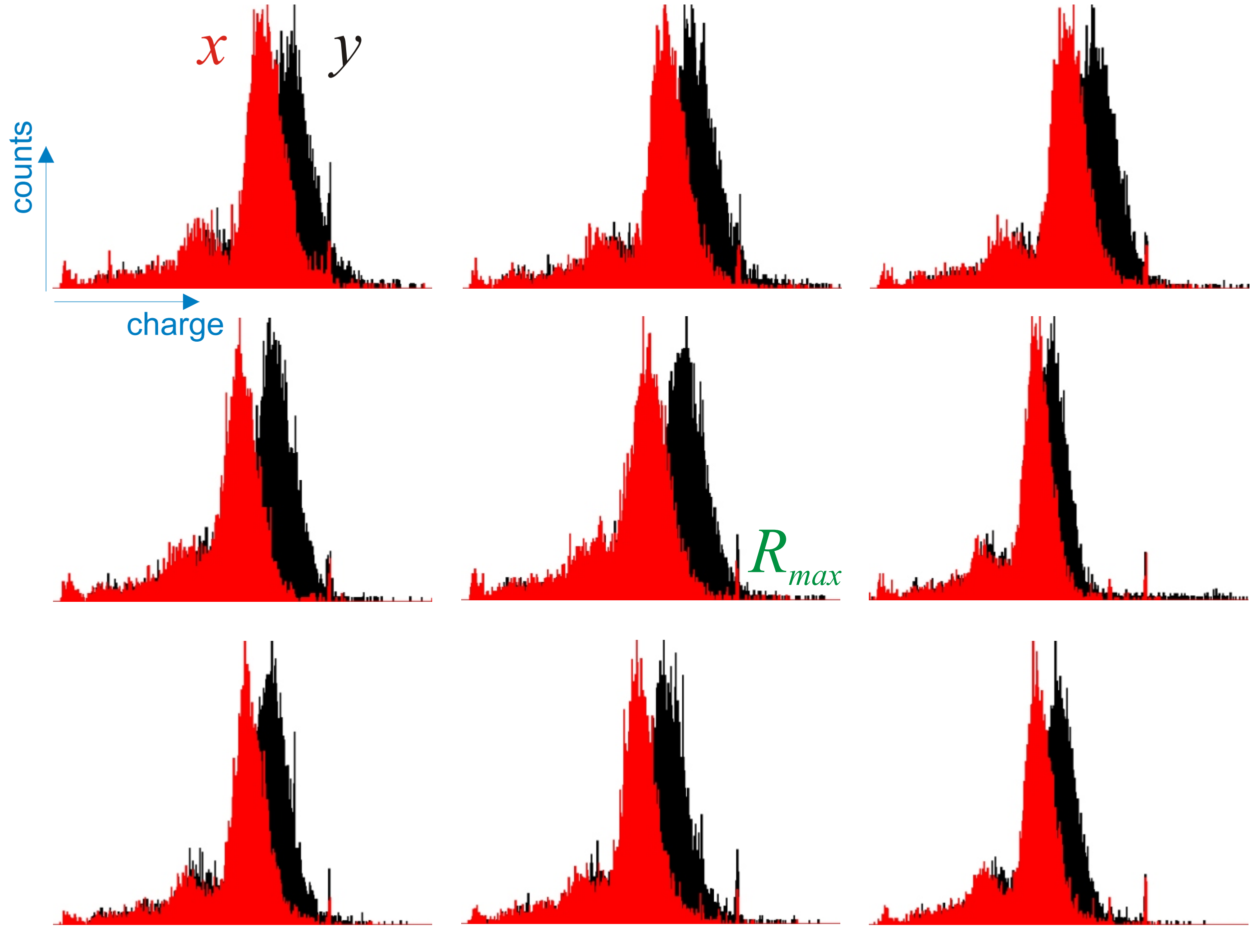
Please notice:

The improvement of the energy resolution at beginning of the high rate phase is due to the increased GEM voltage, resulting in a higher S/N during the recording phase of the spectra.

Results

Final Scan: X-ray spectra of 9 Points in the irradiated region





+ Relative Gain:

$\overline{G} = 100.0\%$ $G^{max} = 116.0\%$

$_{G} = 10.4\%$ $G^{min} = 89.6\%$

+ Energy Resolution:

$E_x = 18.4\%$ $E_y = 18.5\%$

$_{Ex} = 1.0\%$ $_{Ey} = 1.6\%$

No Loss of Gain or Energy Resolution observed !

Summary & Discussion of Results

+ Test of a large-size honeycomb triple-GEM detector ($31x31cm^2$)

+ Production model with a less optimal choice of materials (epoxies, sealants, etc.)

+ Operated in $Ar:CO_2$ (70:30)

+ Effective gain of $G_{eff} = 8500$

+ Aging Measurement performed with an $8.9keV$ X-ray beam on ¼ of the detector area in $2x10$ days

+ More than $7 mC/mm^2$ or $1.7 \cdot 10^{11}$ $MIPs/mm^2$ collected (corresponding to more than 5 yrs. *COMPASS*)

Summary & Discussion of Results

No Loss of Gain or Energy Resolution observed!

+ Gas mixture with good aging properties: $Ar:CO_2$

+ Smaller sensitivity of the GEM to aging due to:

  - Absence of thin anodes

  - Gas amplification is localized inside the holes, rather far from signal electrodes and walls

  - Field shape and strength only little affected by possible polymerisation deposits

12 of 20 detectors already installed and successfully operated in the *COMPASS* experiment...