R&D for the next generation of gaseous photon detectors for Imaging Cherenkov Counters

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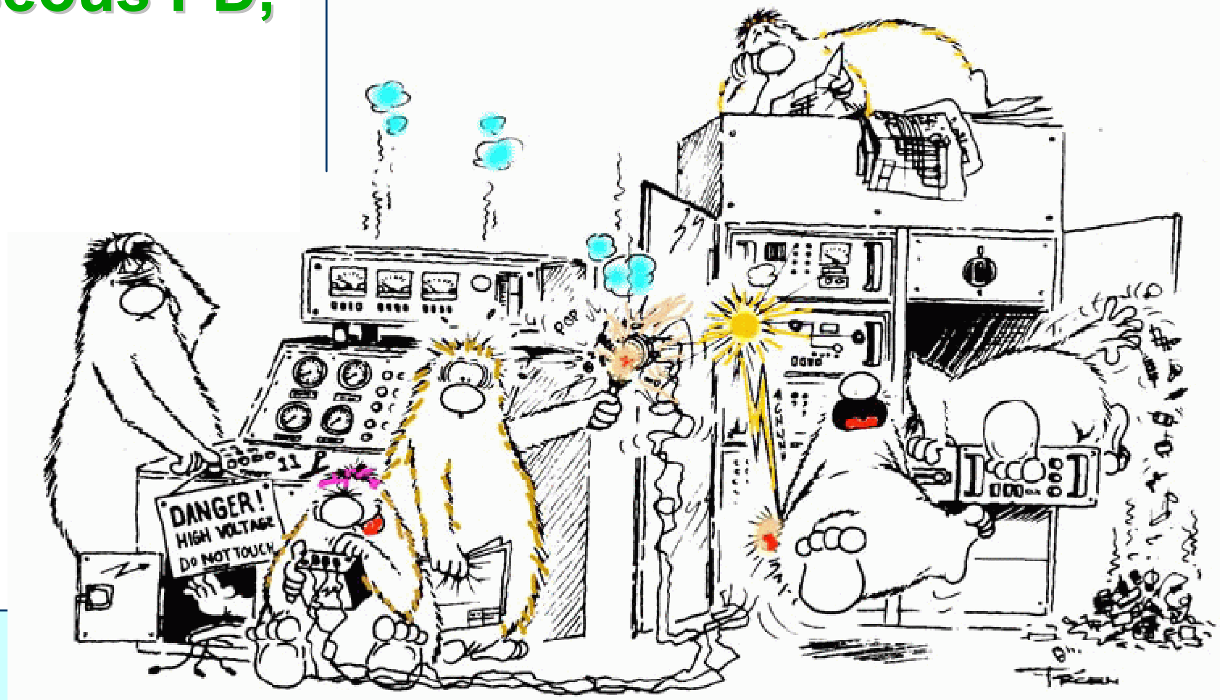
Today's generation of gaseous PD, their limitations and the way out

The R&D lab studies

Our plans for future



Photon Detectors used for RICHs belong to three categories:

Vacuum based PDs

- PMTS (SELEX, HERMES, BaBar)
- MAPMTs (HERA-B, COMPASS)
- Flat panels (various test beams, proposed for CBM)
- Hybride PMTs (LHCb)
- MCP-PMT (all the studies for the high time resolution applications)

Gaseous PDs

- Organic vapours: TMAE and TEA (DELPHI, OMEGA, SLD CRID, CLEO III)
- Solid photocathodes: CsI (HADES, COMPASS, ALICE, JLAB-HALL A, PHENIX)

Si PDs

- Silicon PMs (first tests only recently)

Large sensitive areas -> gaseous PD (the only cost affordable solution)

- photoconverting vapours are no longer in use, a part CLEO III (rates ! time resolution !)

PAST

- **the present is represented by MWPC (open geometry!) with CsI**
  - the first prove (in experiments !) that coupling solid photocathodes and gaseous detectors works
  - Severe recovery time (~ 1 d) after detector trips
  - Moderate gain: effective gain ~ 10^4
  - Aging

  } CsI ion feedback → bombardment (see below)

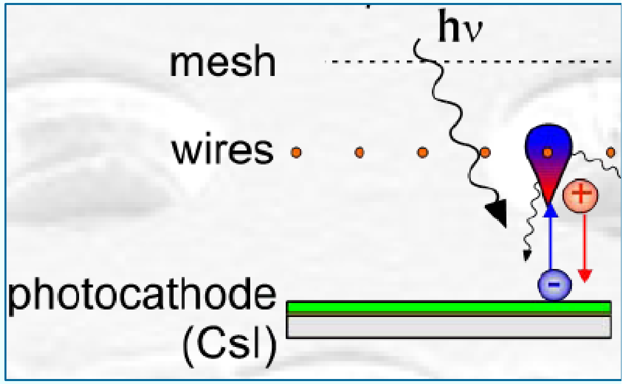
PRESENT

- **The way to the future: ion blocking geometries**
  - GEM/THGEM allow for multistage detectors
    - With THGEMs: High overall gain ↔ pe det. efficiency!
    - Good ion blocking (up to IFB at a few % level)
    - MHSP: IFB at 10^{-4} level
  - opening the way to:
    - Gaseous detectors with solid photocathodes for visible light
  - First step in this direction: PHENIX HBD

FUTURE

Limitations of recent generation - MWPC

The MWPC



Source of the problem:
ion bombardment of photo-converting layer

1) Moderate gain

MWPCs with CsI photocathodes in COMPASS:

beam off: stable operation up to > 2300 V

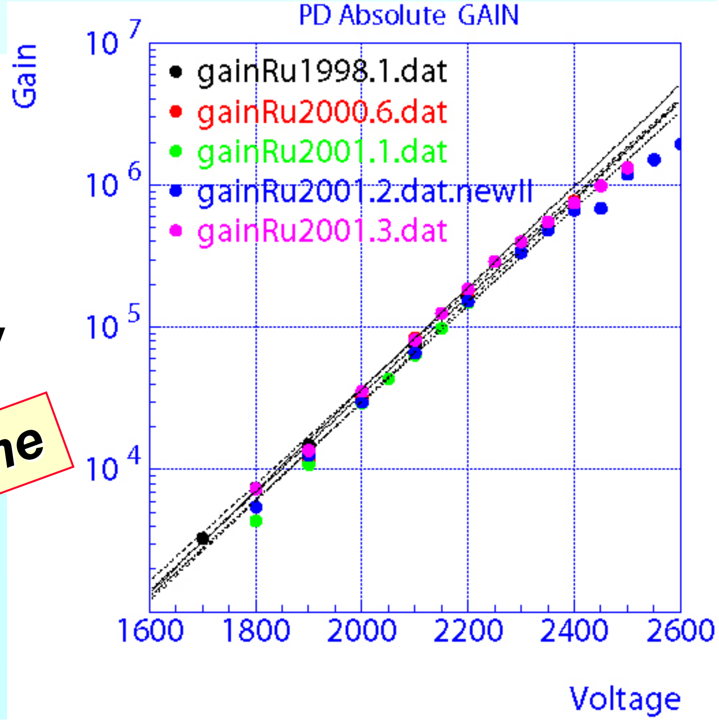
beam on: stable operation only up to ~2000 V

(in spill→ ph. flux: 0 - 50 kHz/cm^2 , mip flux: ~1 kHz/cm^2)

Whenever a severe discharge happens, recovery takes ~1 day

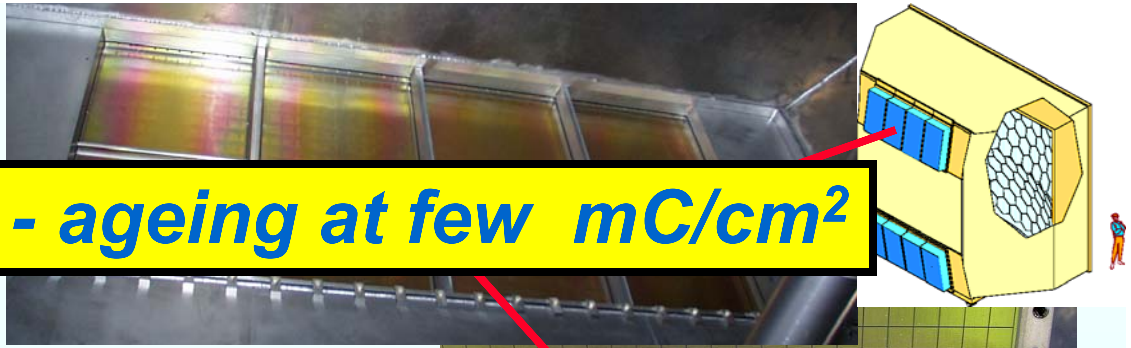
Similar behavior reported from JLAB Hall-A

this limits the time

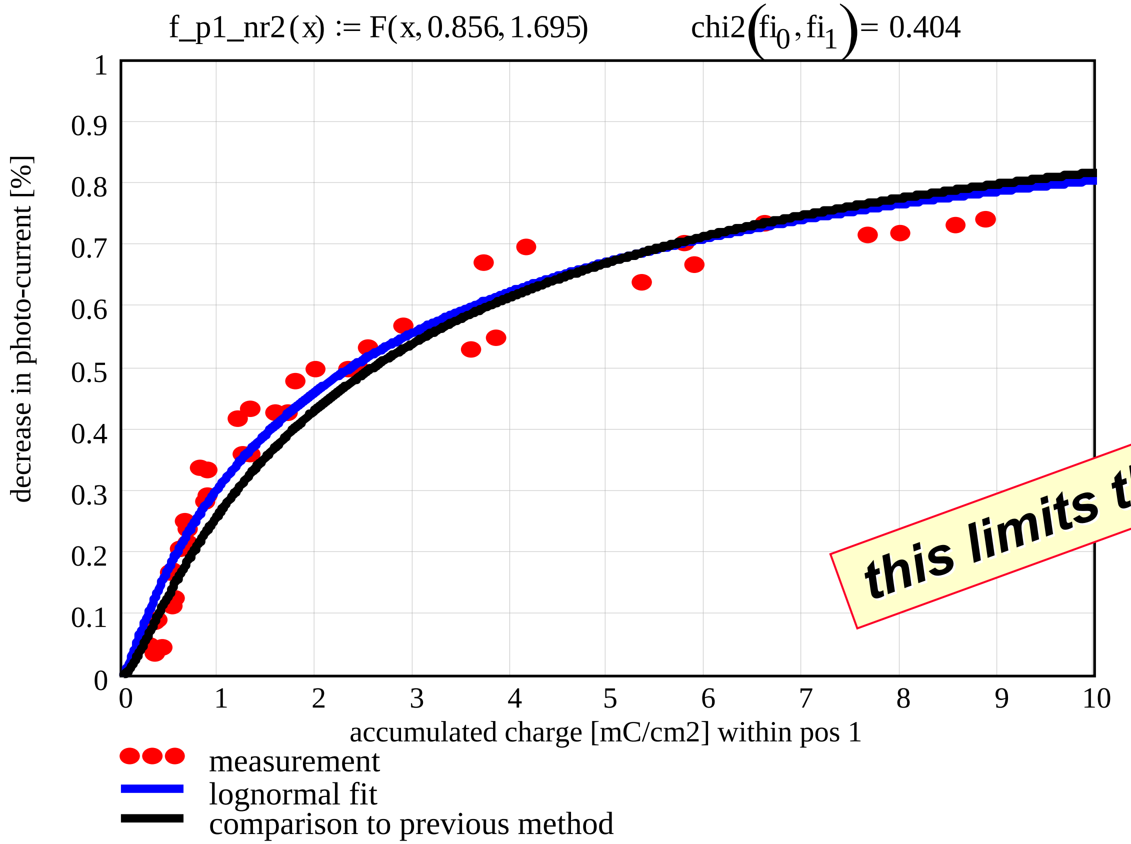


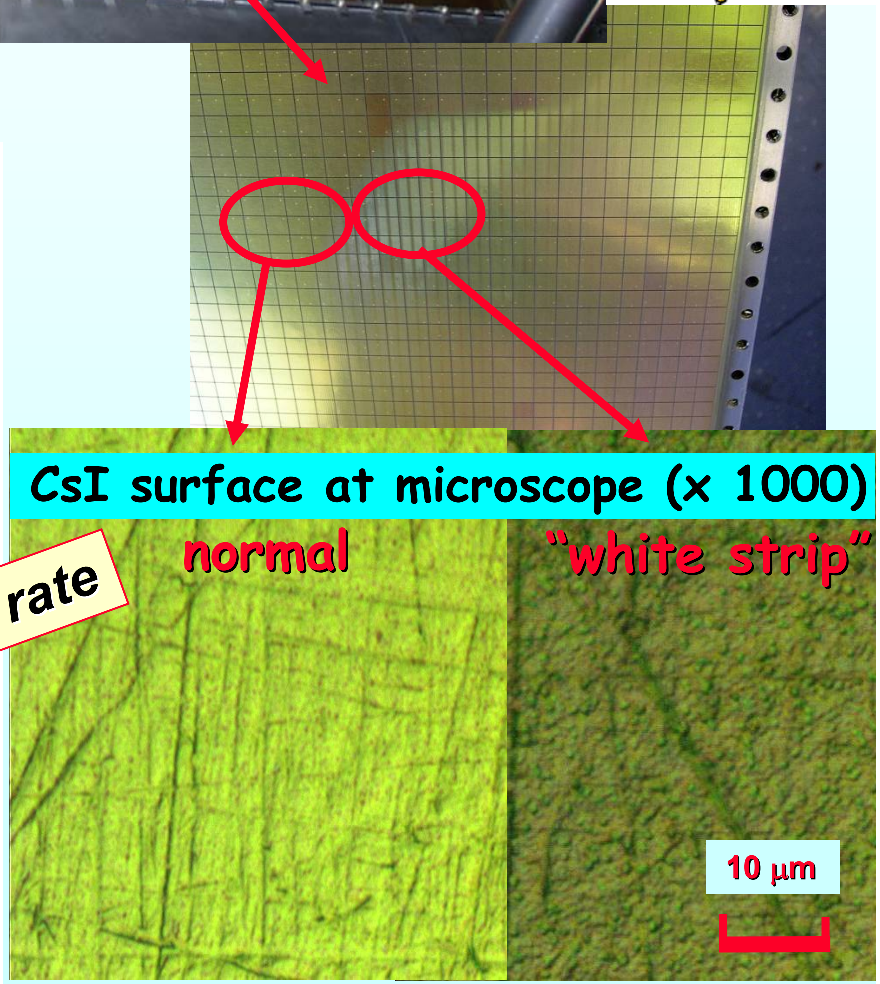
2) Ageing

due to ion bombardment - ageing at few mC/cm^2



Q.E. degradation vs charge





H. Hoedlmoser et al., NIM A 574 (2007)28; H. Hoedlmoser, CERN-THESIS-2006-004

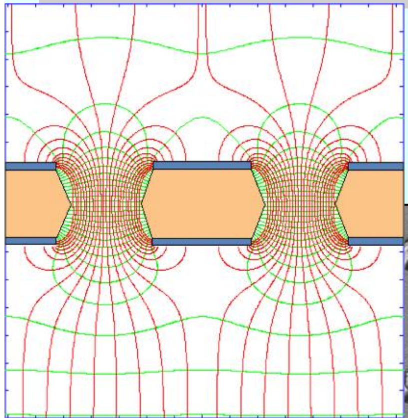
There is need of new technology

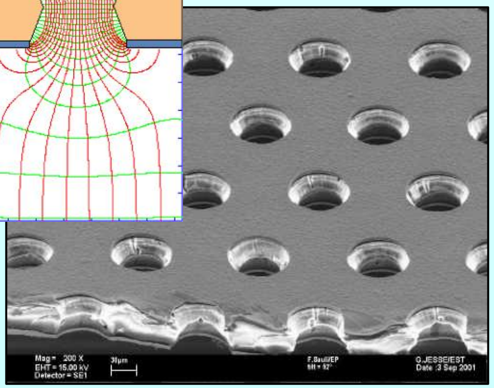
to overcome recent limits – fight ion bombardment and photon feedback

Possible solution – closed geometries

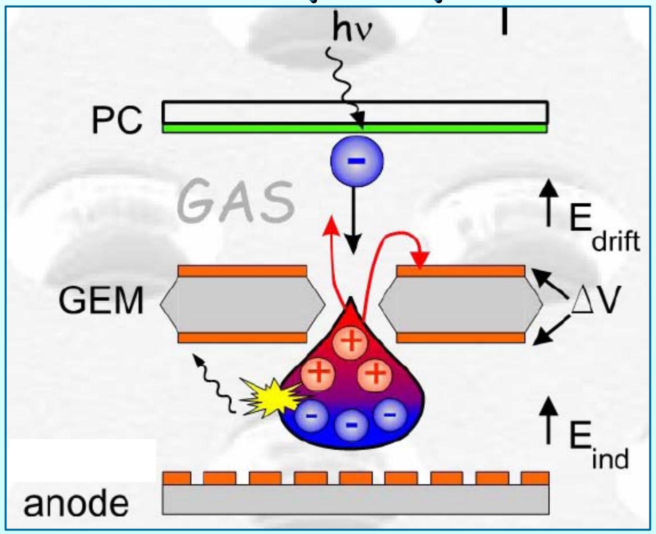
GEMs and THGEMs

GAS ELECTRON MULTIPLIER (GEM)
Thin metal-coated polymer foils
70 µm holes at 140 µm pitch





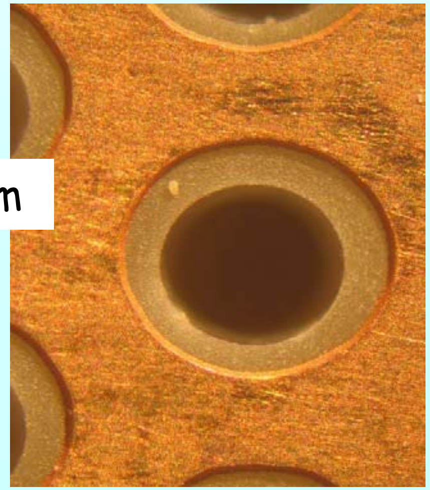
GEM's principle



ECONOMIC & ROBUST

Manufactured by **standard PCB techniques** of precise drilling and Cu etching.

1mm



F. Sauli, NIM A386(1997)531

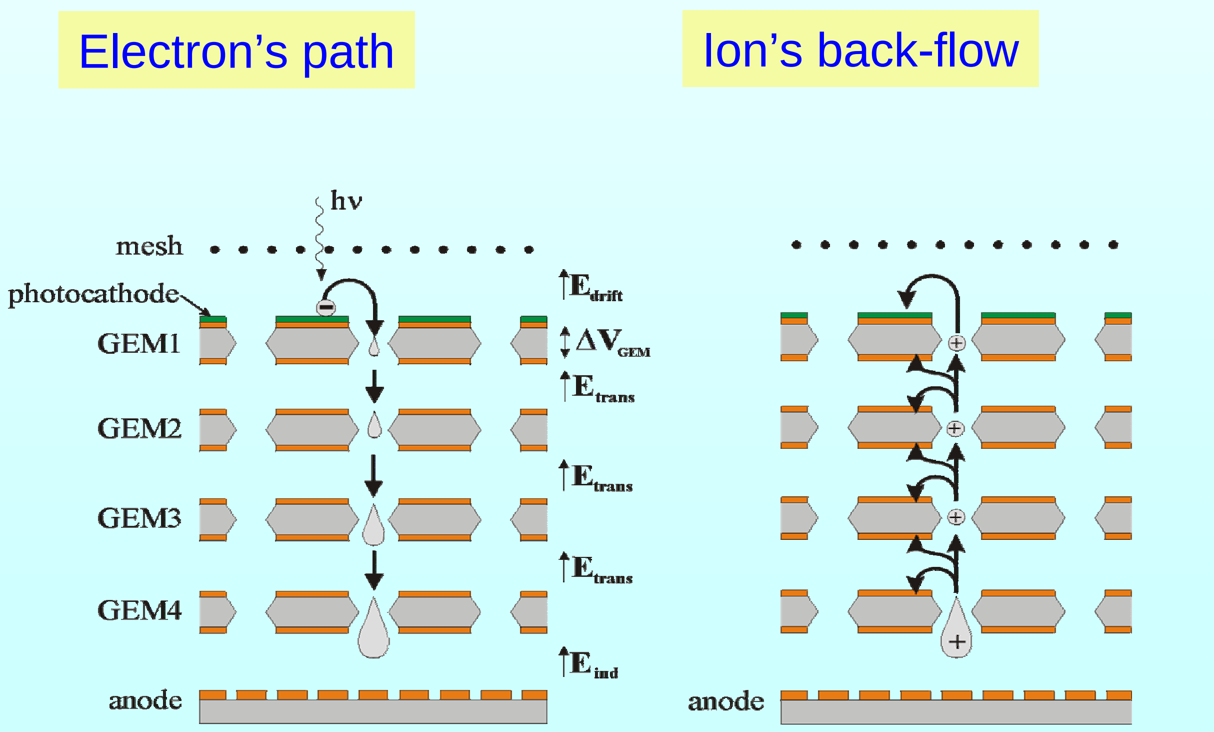
Chechik et al. NIM A535 (2004) 303
C. Shalem et al. NIM A558 (2006) 475
& NIM A558 (2006) 468

MultiGEM's:
ion blocking + high GAIN

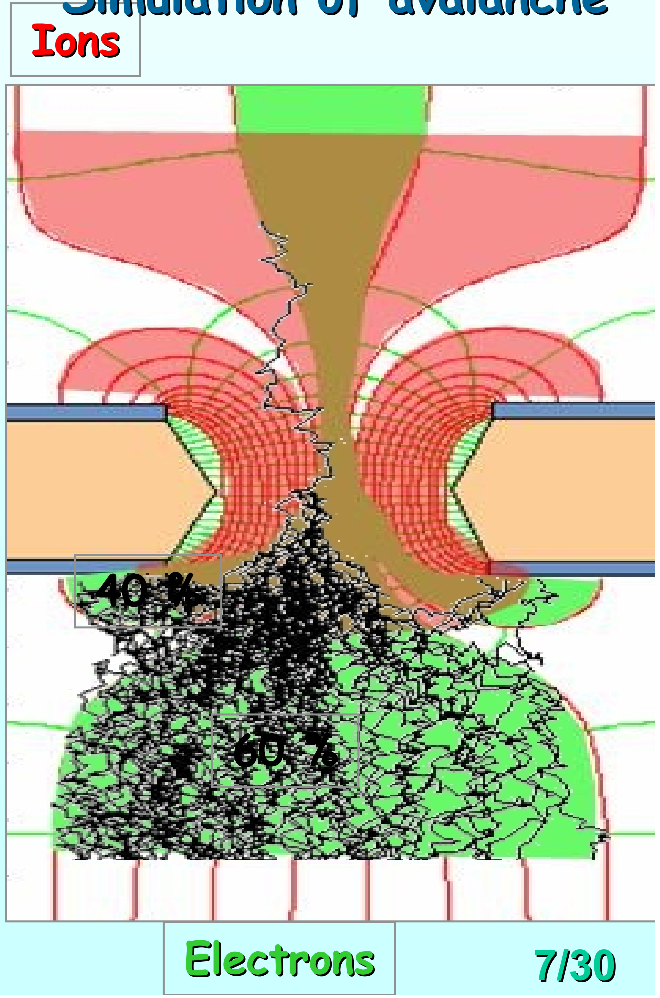
Examples of ion blocking schemes from literature

- Similar schemes can be adopted with THGEM

multiGEM with
Reflective photocathode

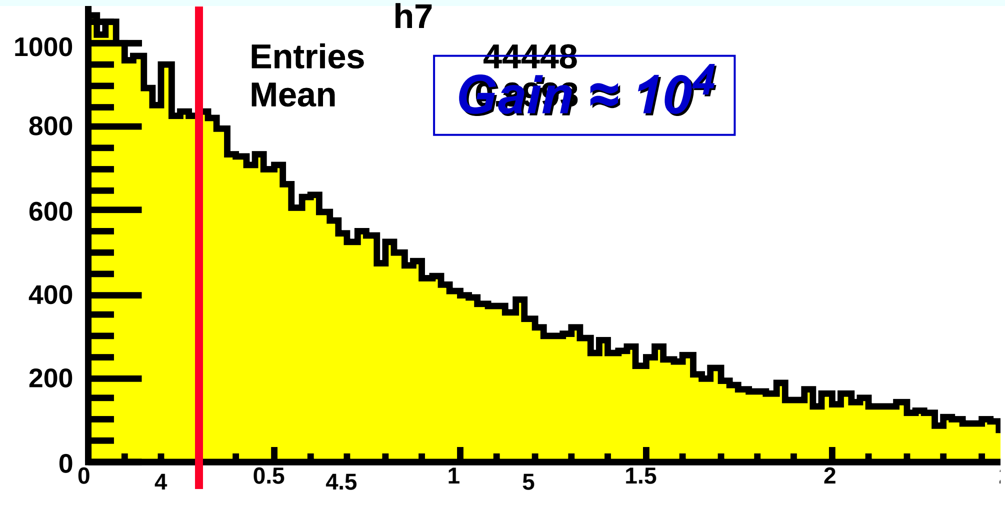


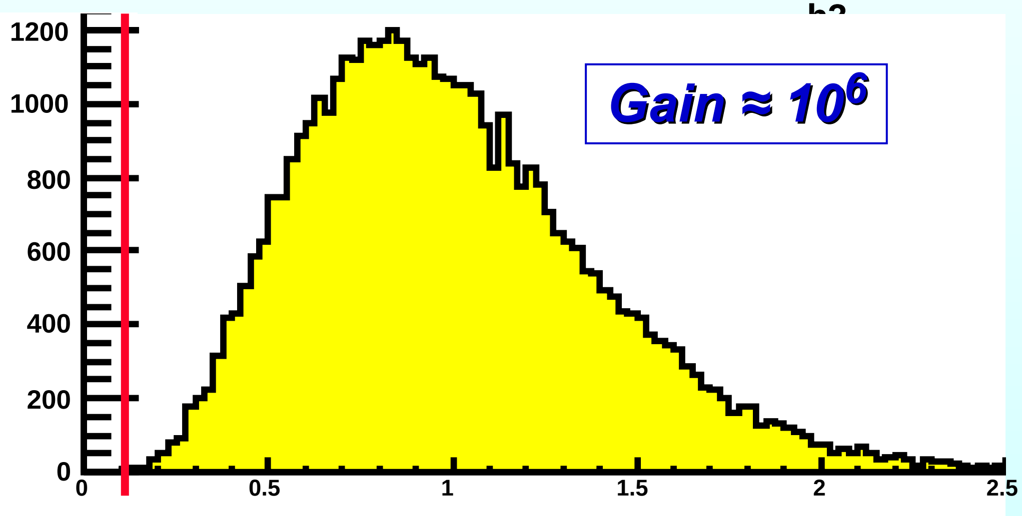
Simulation of avalanche



The relevance of high GAIN

- Signal amplitude follows Polya distribution:





Threshold always critical !

Limited pe detection efficiency,

performance instabilities

With good electronics:

threshold no longer critical,

good pe detection efficiency

stable behaviour

Why do we try with THGEMs and reflective photocathode?

No need of high space resolution (> 1 mm)

Large area coverage (5.5 m^2 for COMPASS RICH)

- **industrial production**
- **stiffness**
- **robust against discharge damages**

For reflective photocathodes,

- **no need to keep the window at a fixed potential (2nm Cr → -20%)**
- **possibility of windowless geometry**
- **higher effective QE (larger pe extraction probability)**

→small photoconversion dead zones (<20%; GEM ~ 40%)

Large gain

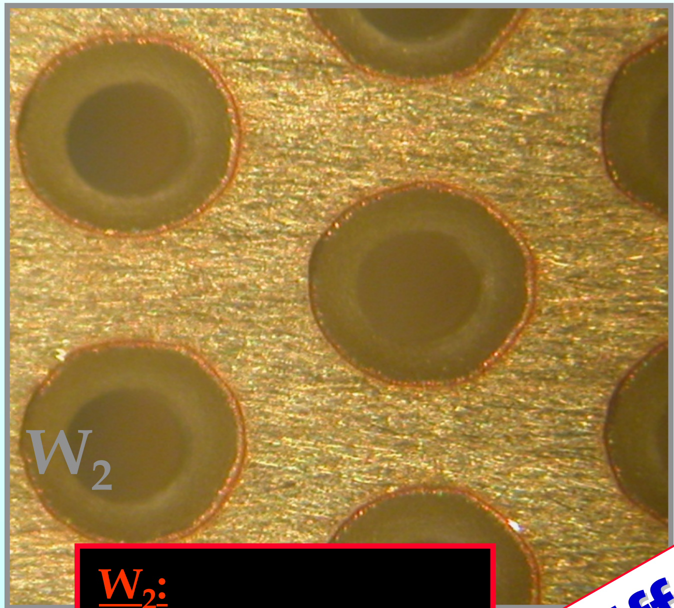
goal: SINGLE PHOTON detection

EXAMPLES OF THGEMS

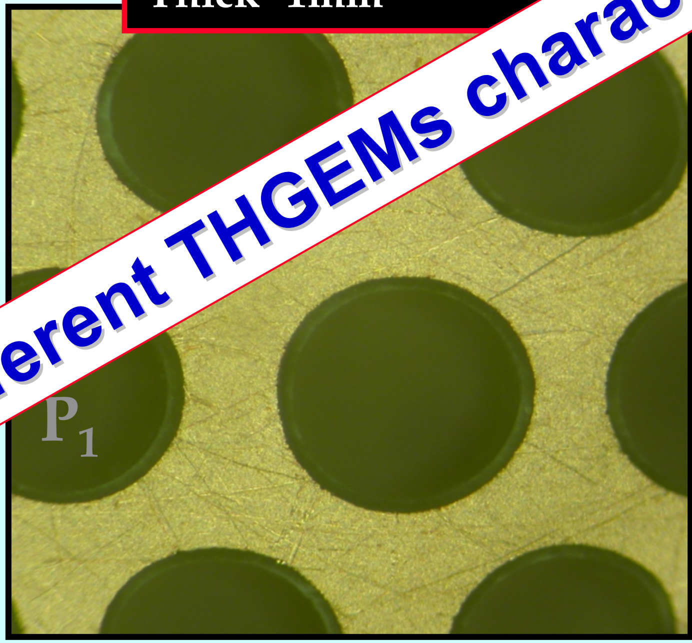
A MULTIPARAMETER SPACE TO EXPLORE !

4 geometrical parameters: diameter pitch rim thickness

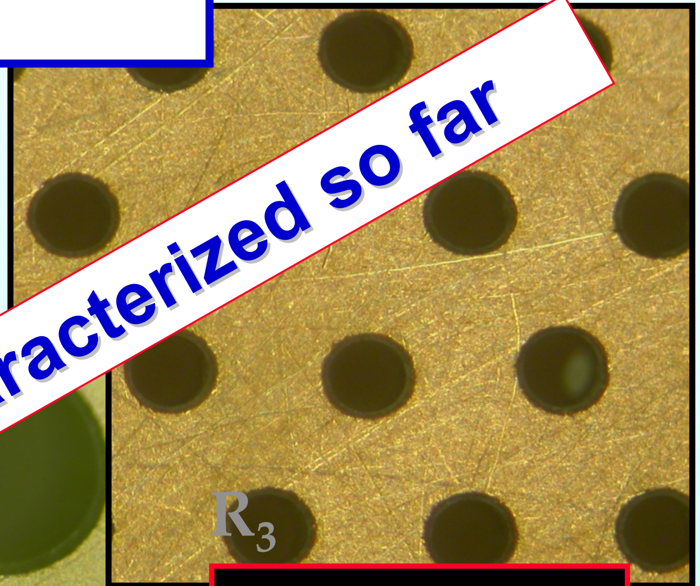
\+ material + production procedure



W_2:
D=0.3 mm
Pitch=0.7 mm
Rim=0.1 mm
Thick=0.4mm



P_1:
D=0.8 mm
Pitch=2 mm
Rim=0.04 mm
Thick=1mm



R_3:
D=0.2 mm
Pitch=0.5 mm
Rim=0.01 mm
Thick=0.2mm

24 different THGEMs characterized so far

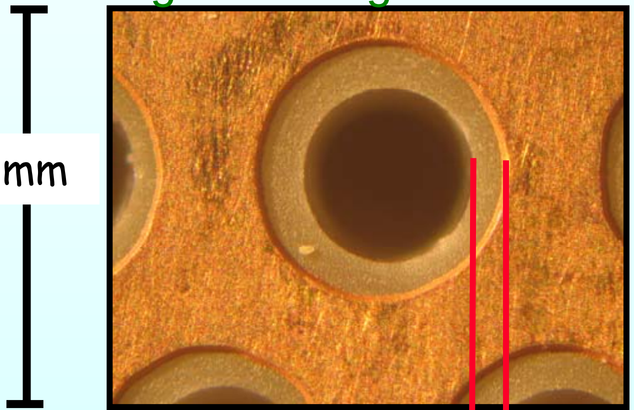
THGEM multipliers

= GEM like structure with expanded dimensions

Manufactured by **standard PCB techniques** of precise drilling (different materials) and Cu etching.

Example of THGEM

10^5 gain in single-THGEM



0.1mm RIM: prevents discharges → high gains!

cross section of one hole

Example of production..

ELTOS S.p.A. (Arezzo, Tuscany)

http://www.eltos.it/en/main/en-main.htm

POSALUX ULTRASPEED 6000LZ
6-spindle-roboter

Small diameter holes → high rotation speed of the driller. Multi-spindle machines at ELTOS reach 180000 turns/min → hole diam. down to 150 µm.

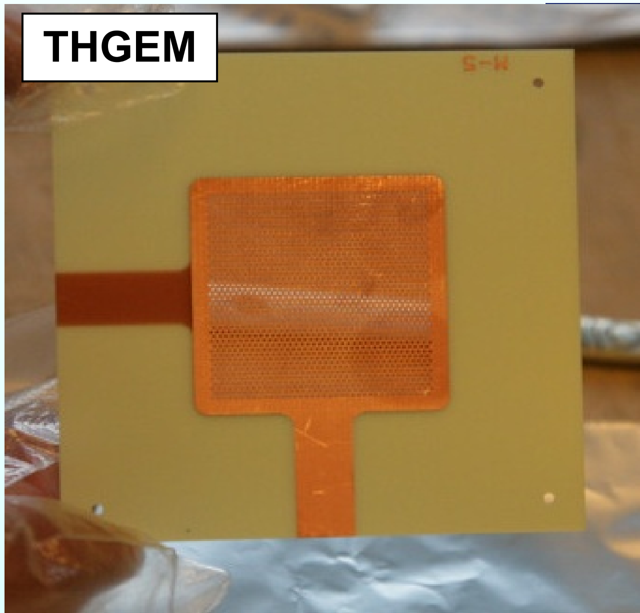
Nominal drilling tolerance: +- 10 µm

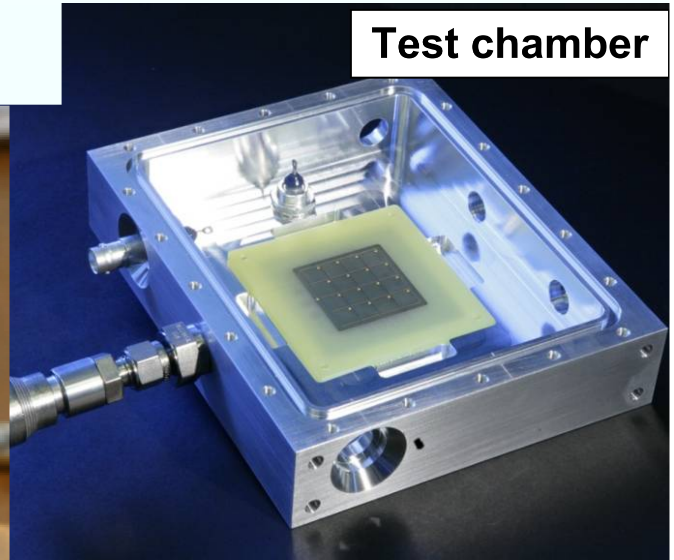
CHARACTERIZATION

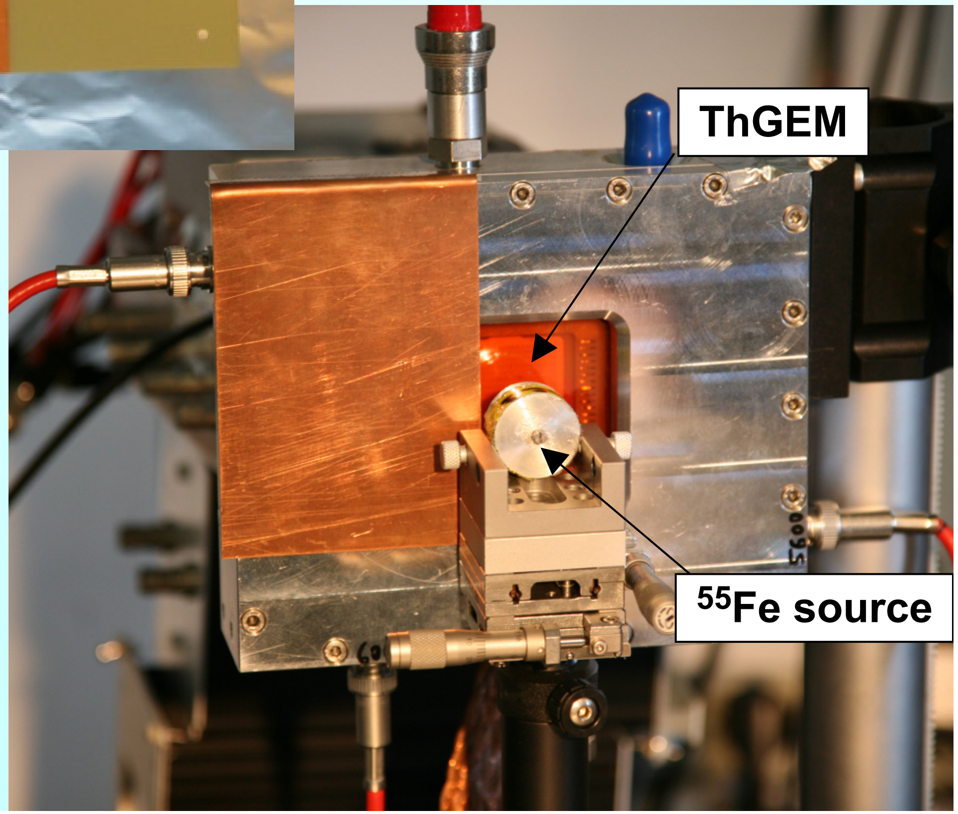
small prototypes – active surface (30 x 30) mm^2

1 THGEM layer for this activity

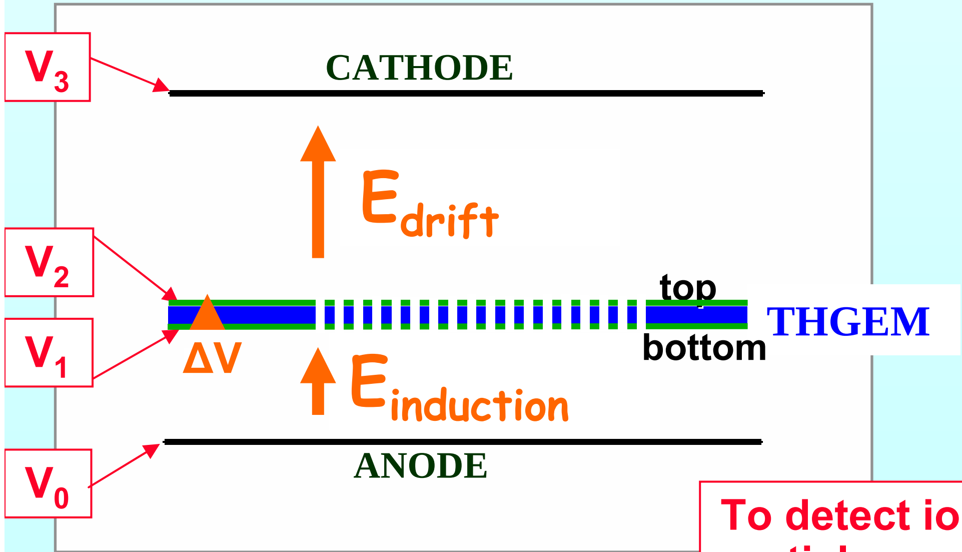
Used Gas: Ar/CO_2 70/30 %







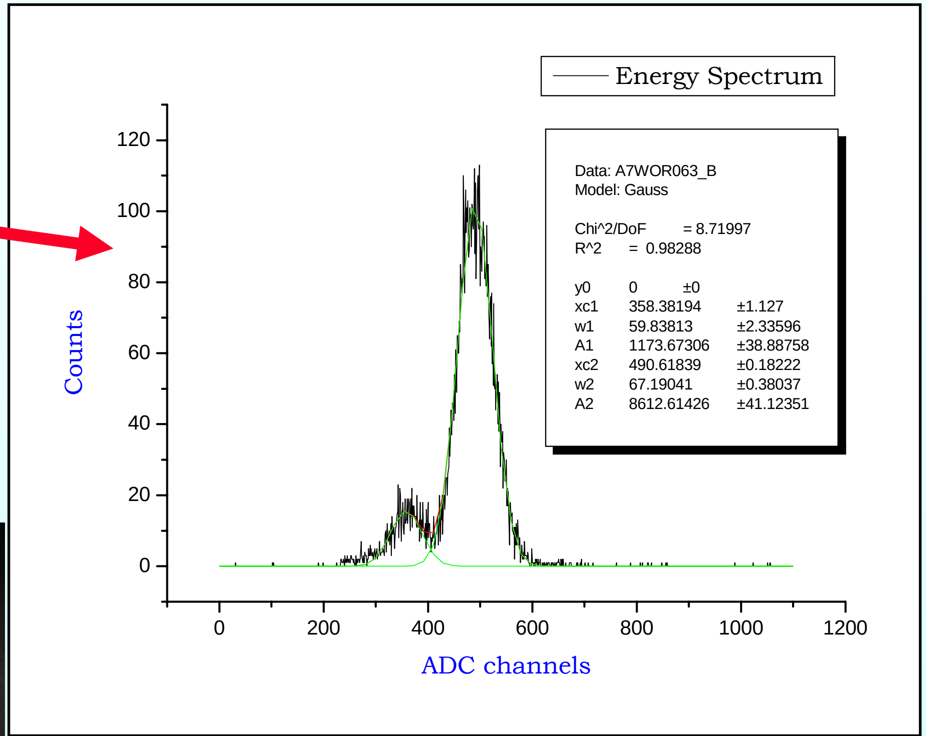
Configuration inside the chamber

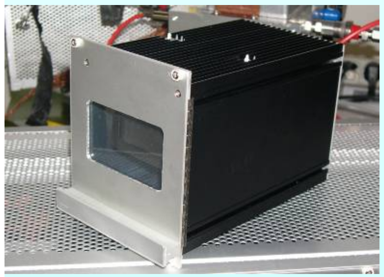


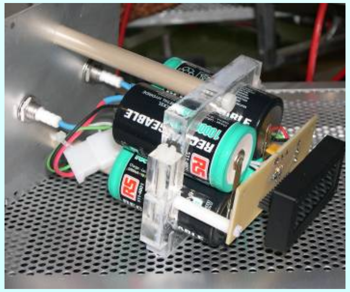
To detect ionizing particle :
$V_3 < V_2 < V_1 < V_0$

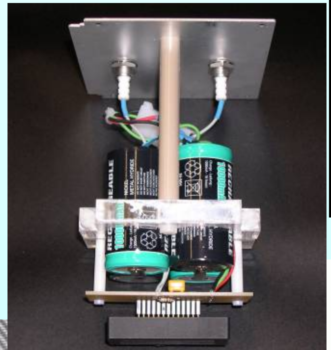
LAB STUDIES AT CERN AND TRIESTE

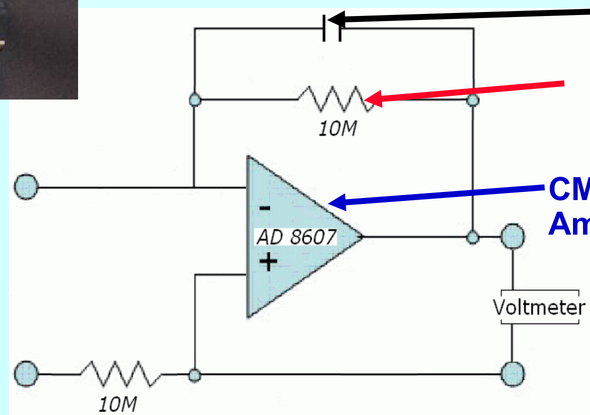
- so far using Cu X-ray
- spectra are collected
- currents are measured at HV
  - homemade instruments (~200 €) with ~1 pA resolution
  - data collection via pictures and image recognition











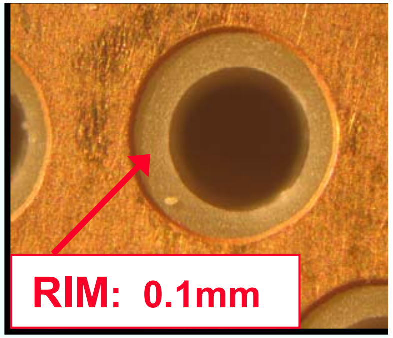
1 nF to 100 nF feedback capacitor

10 MΩ feedback resistor: VISHAY CNS020(+- 0.02%, +- 10 ppm/ºC)

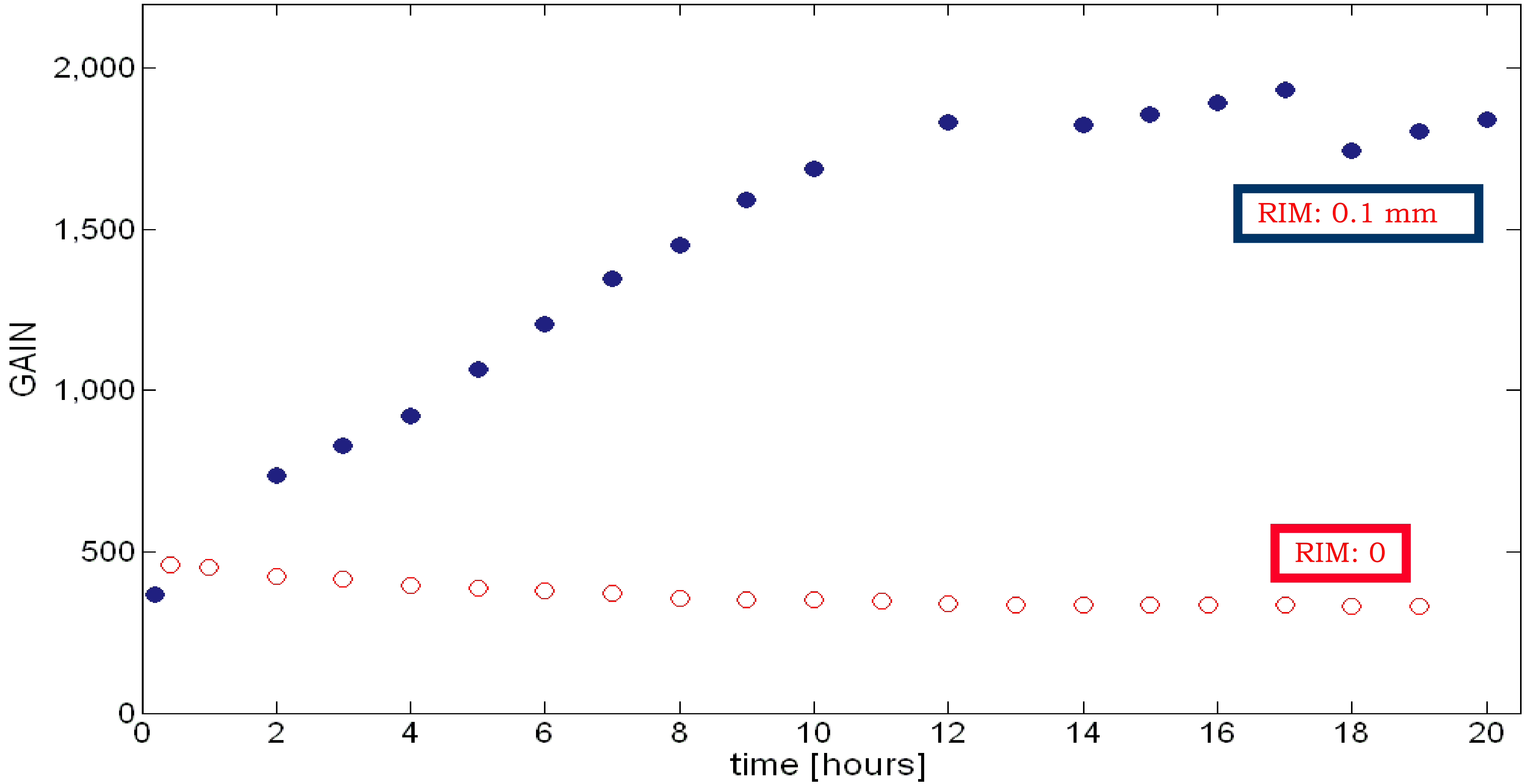
CMOS Operational Amplifier: AD 8607

What we have learned so far

1) Gain stability vs. RIM

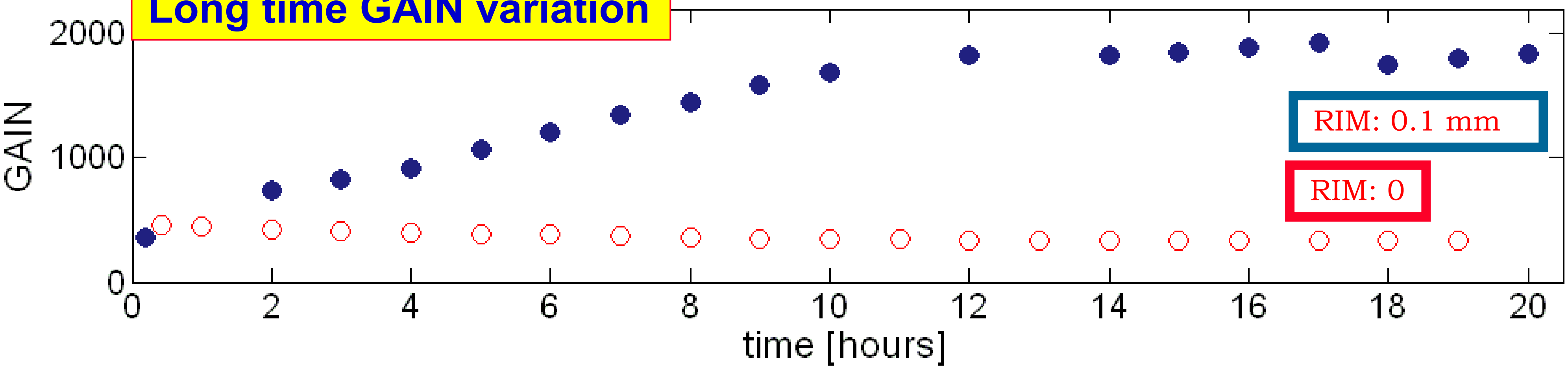


Long time GAIN variation

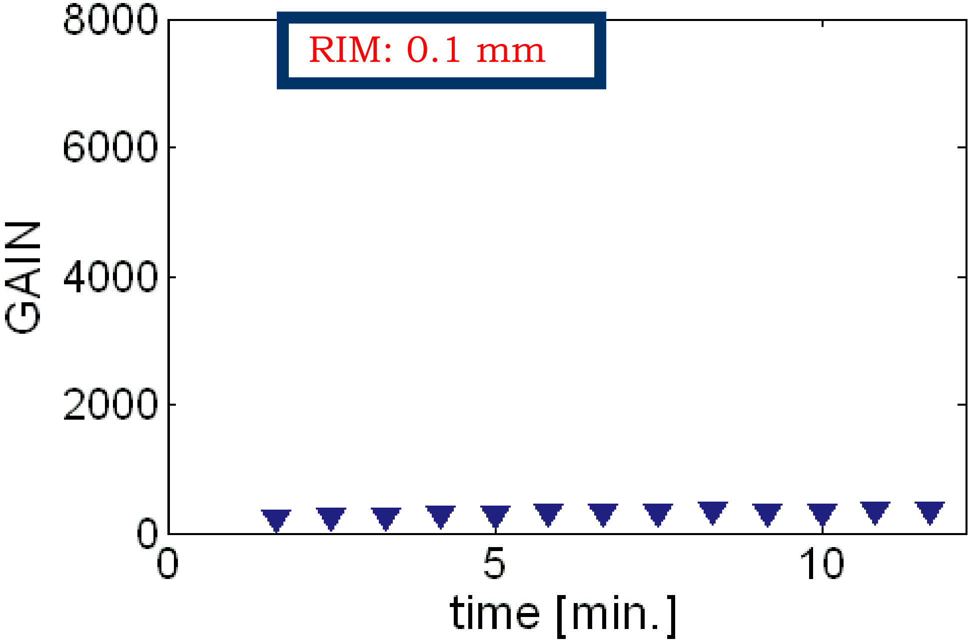


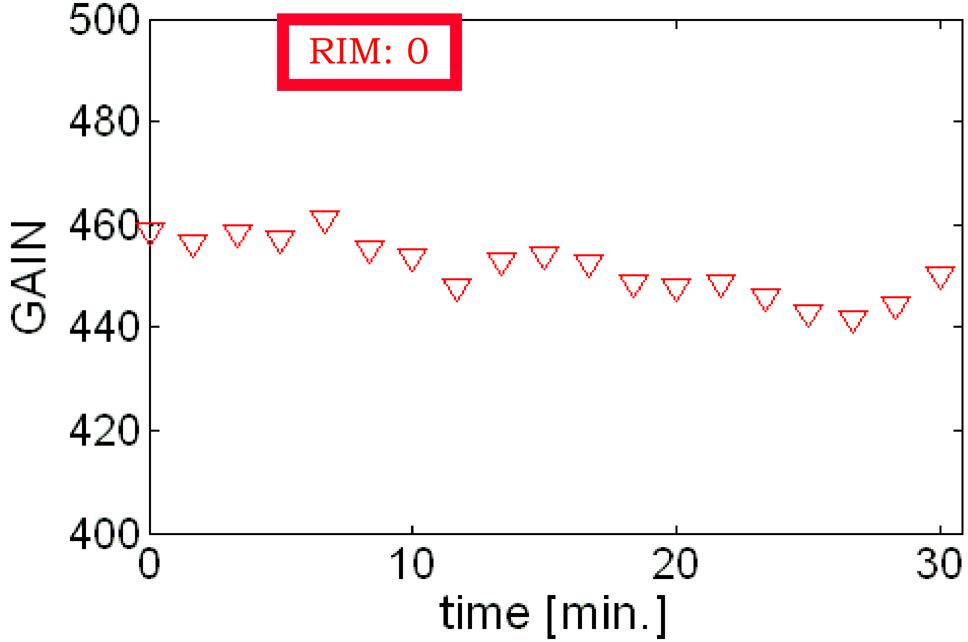
1) Gain stability vs. RIM

Long time GAIN variation



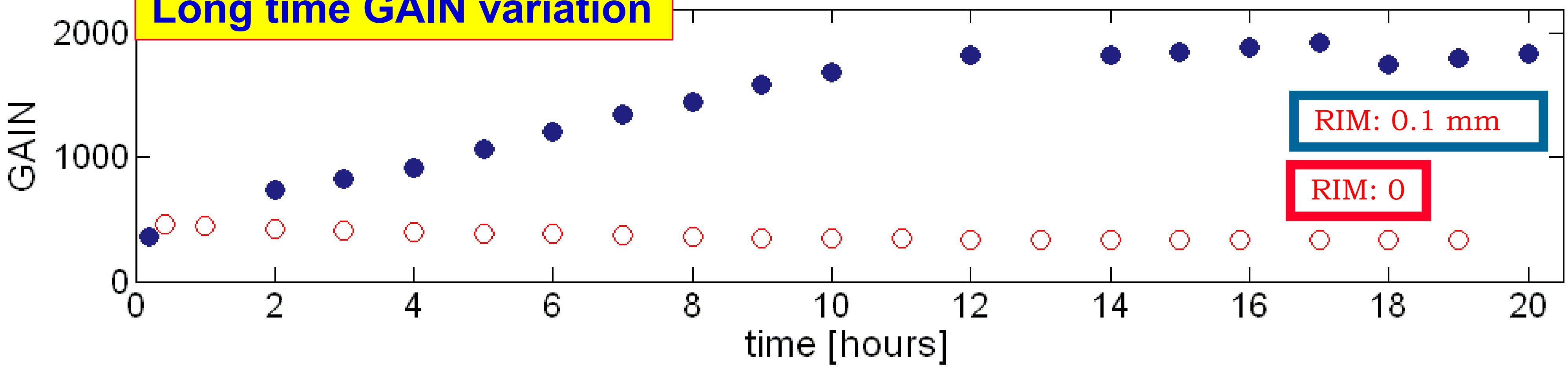
Short time GAIN variation
– irradiation at HV switch ON (after ~1 day with NO voltage)



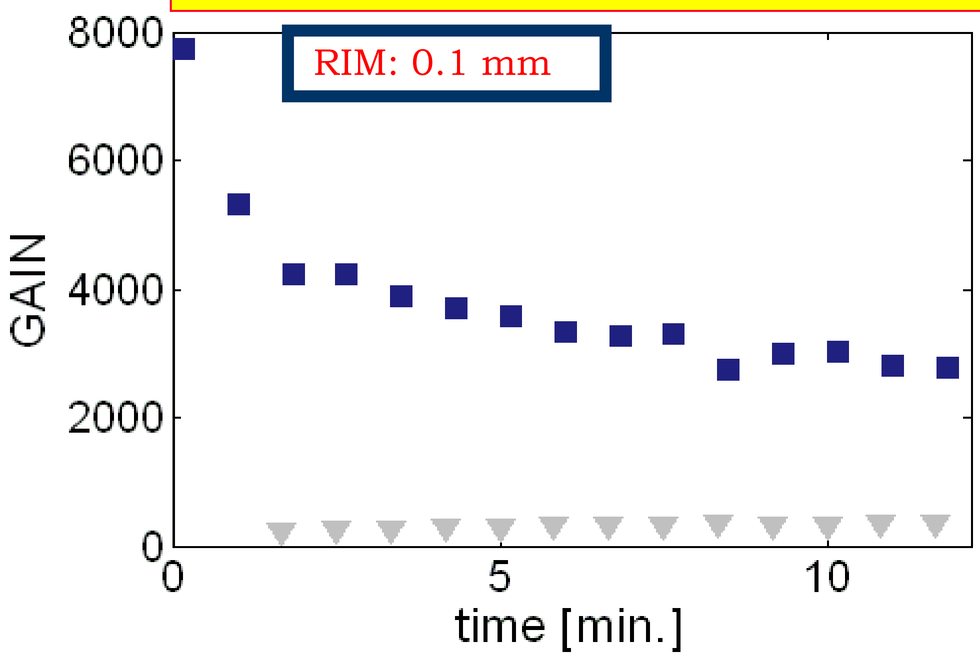


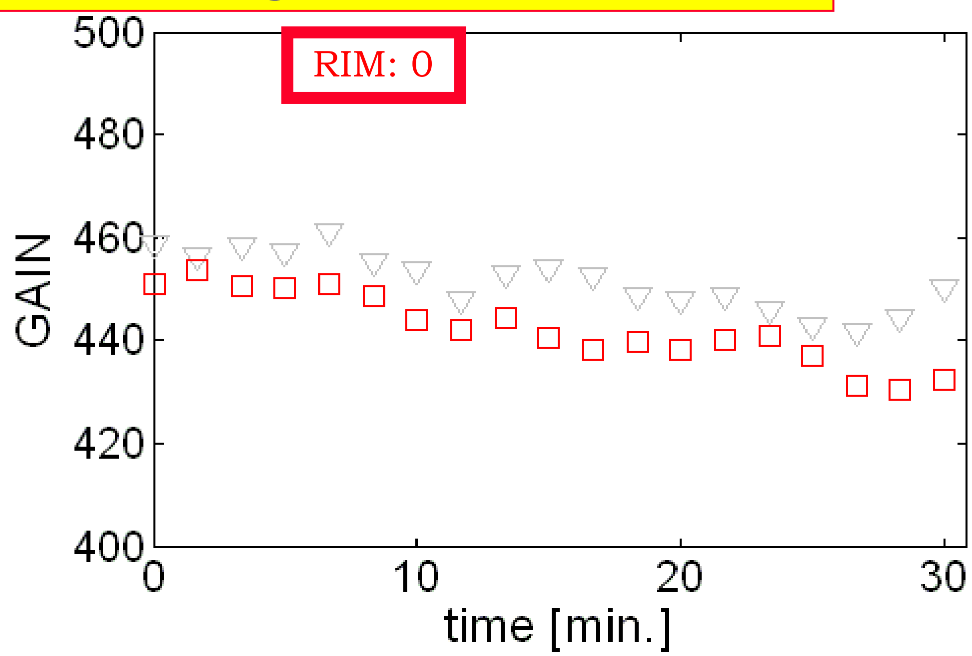
1) Gain stability vs. RIM

Long time GAIN variation

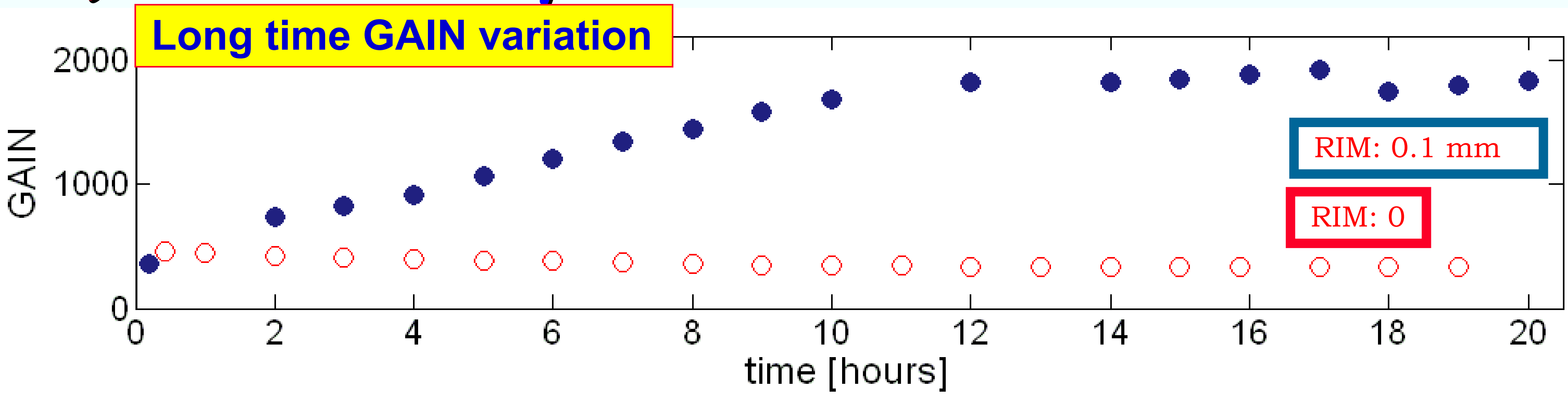


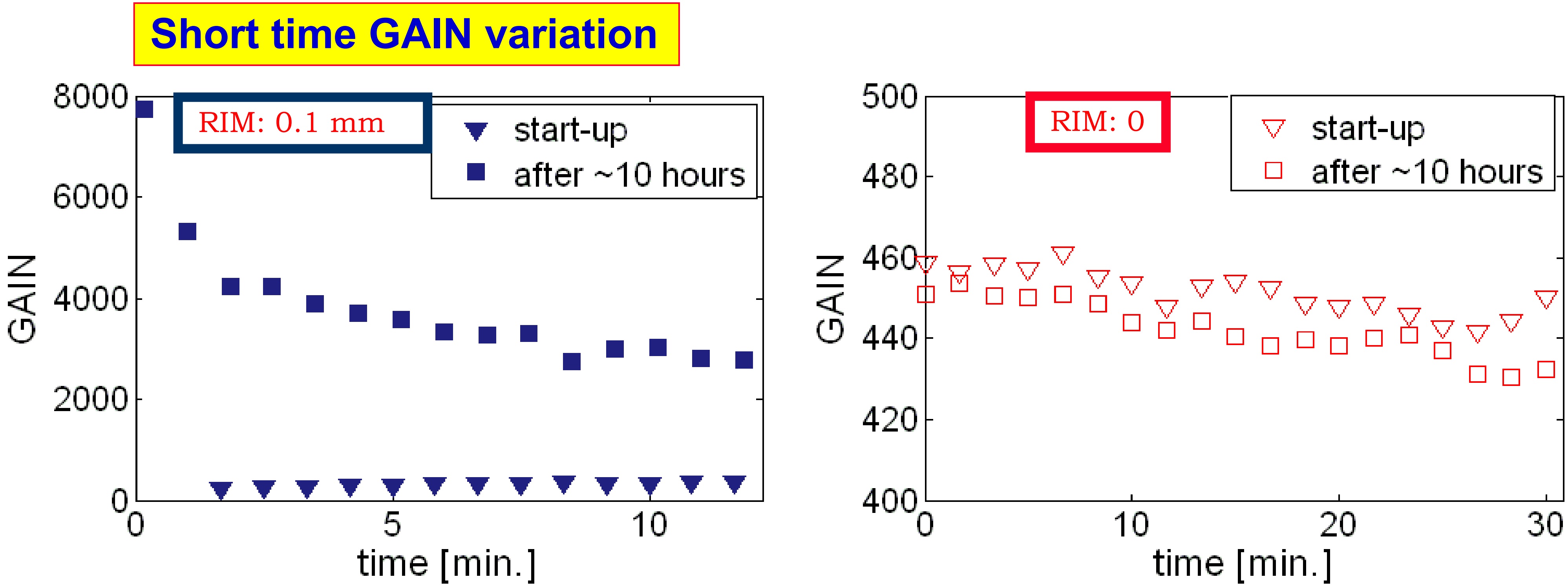
Short time GAIN variation
– irradiation after ~10 hour at nominal voltage without irradiation





1) Gain stability vs. RIM





… also GEM's are not so stable …

2007 IEEE Nuclear Science Symposium Conference Record MP5-3

Understanding the gain characteristics of GEMs inside the Hadron Blind Detector in PHENIX.

W. Anderson, B. Azmoun, C.-Y. Chi, Z. Citron, A. Dubey, J. M. Durham, Z. Fraenkel, T.Hemmick, J. Kamin, A. Kozlov, A.Milov, M. Naglis, R. Pisani, I. Ravinovich, T. Sakaguchi , D. Sharma, A. Sickles, I. Tserruya, C. Woody

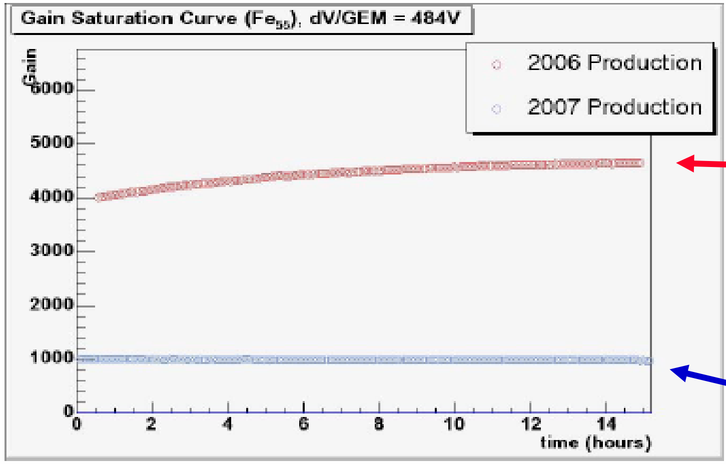


Fig. 11. Gain as a function of time after HV was on for 3 days. Red points are for a GEM stack comprised of GEMs produced in 2006; blue points are for a stack of 2007 GEMs.

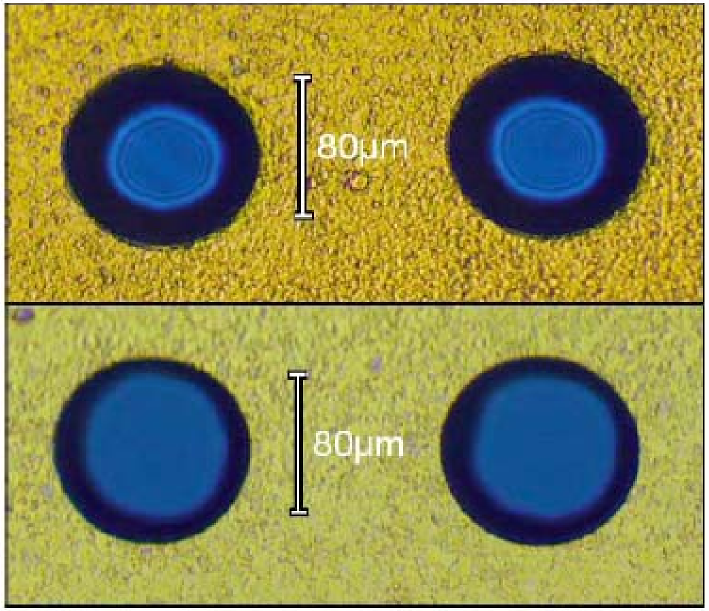
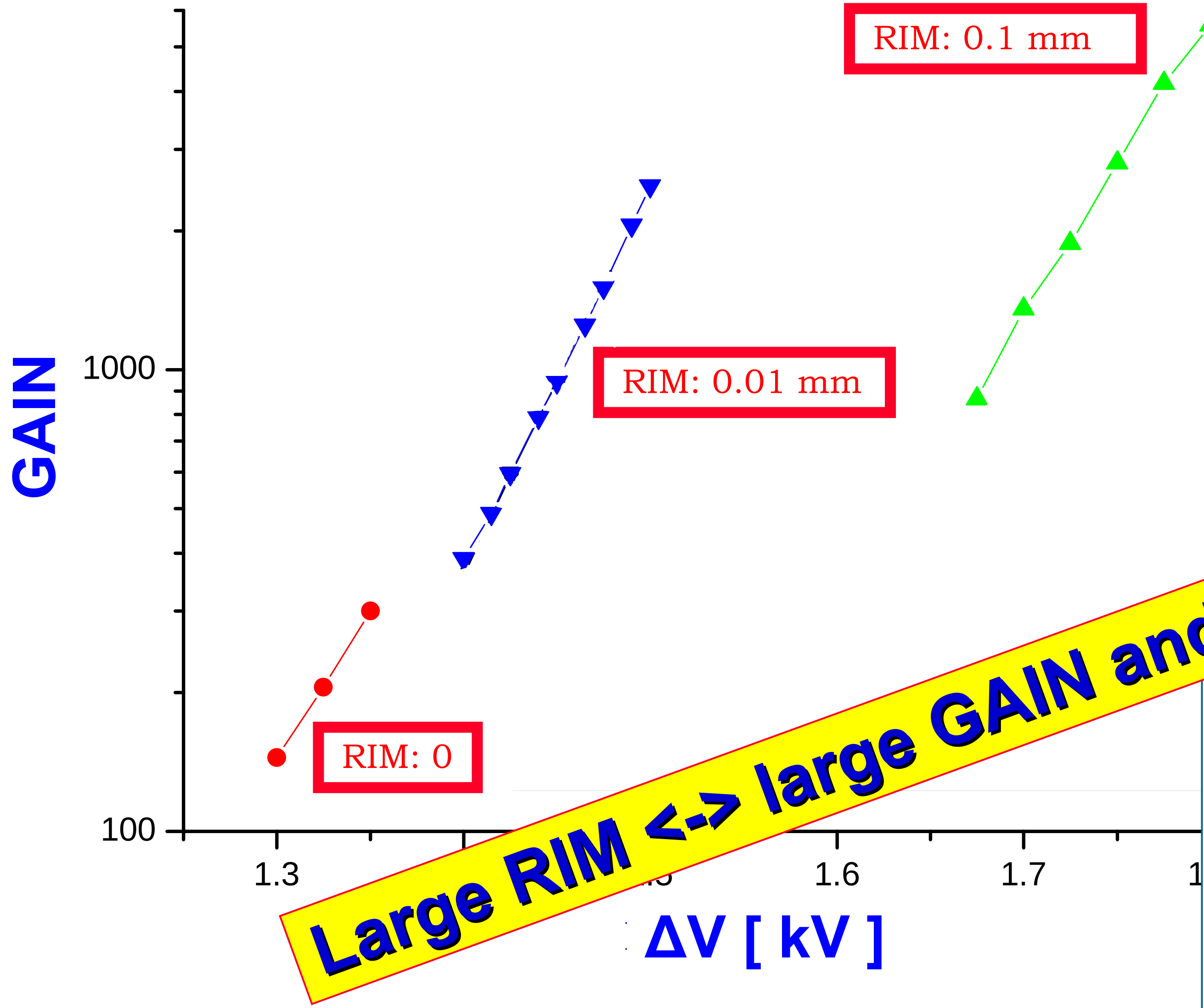


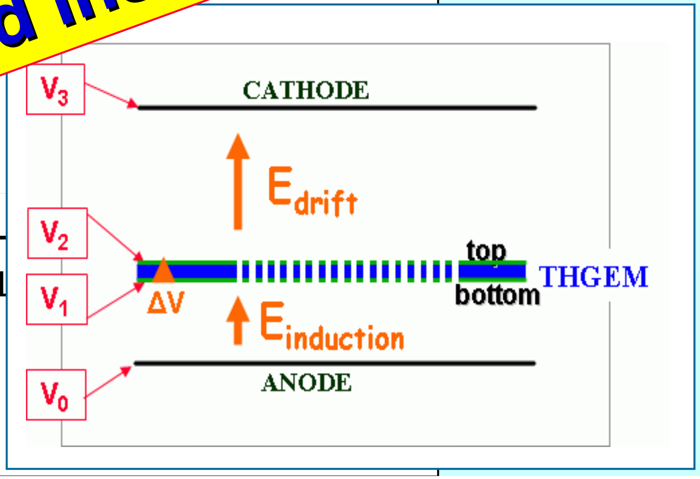
Fig. 12. GEM holes viewed under a microscope. 2006 production GEMs are shown above; 2007 production GEMs are below.

2) Larger RIMs allow higher gains …

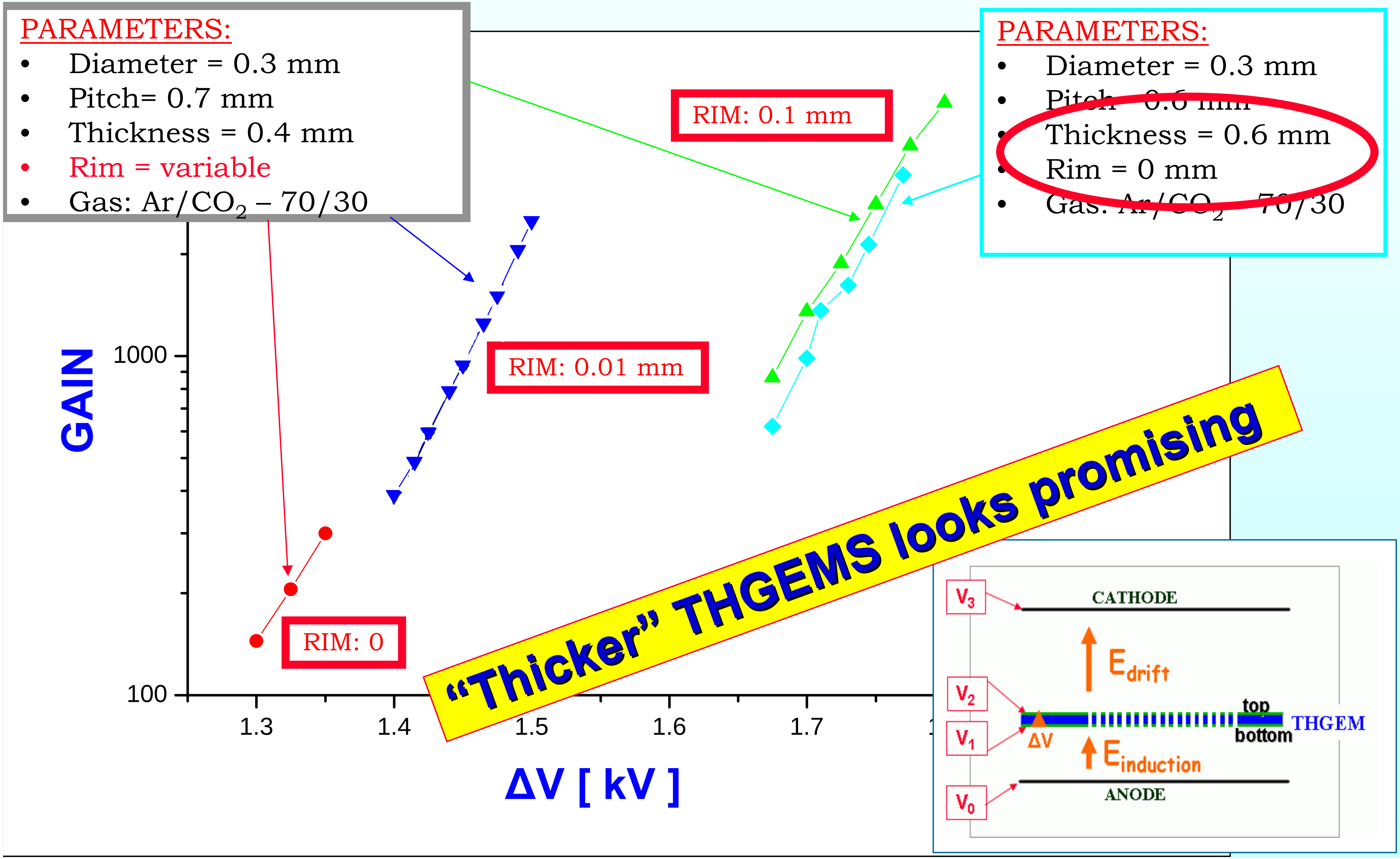


PARAMETERS:

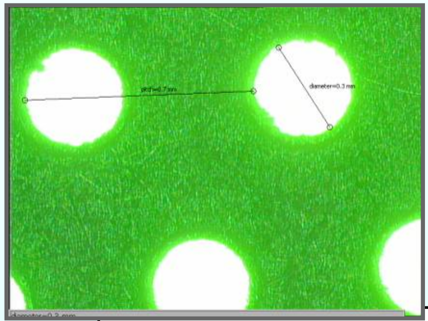
- Diameter = 0.3 mm
- Pitch= 0.7 mm
- Thickness = 0.4 mm
- Rim = variable
- Gas: Ar/CO_2 – 70/30



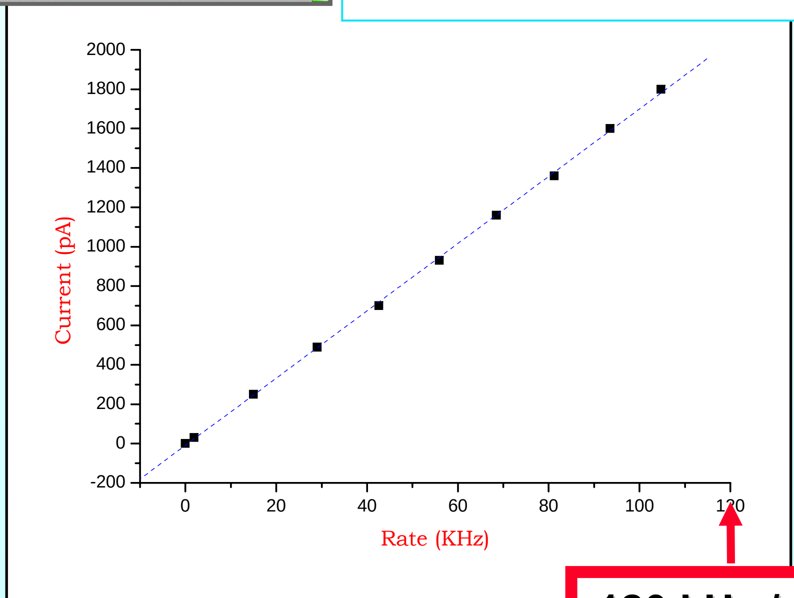
2) but increasing THICKNESS does it too



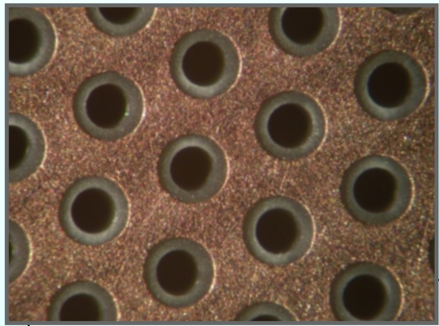
3) Are THGEM devices for HIGH RATES ?



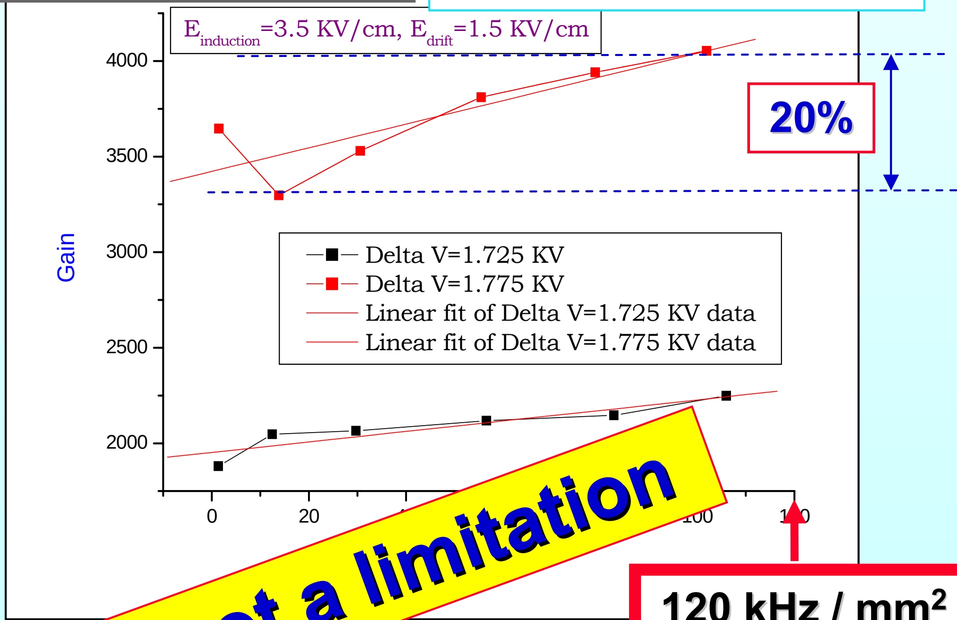
PARAMETERS:
- Diameter = 0.3 mm
- Pitch= 0.7 mm
- Thickness = 0.4 mm
- Rim = 0 mm
- Gas: Ar/CO_2 – 70/30



120 kHz / mm^2



PARAMETERS:
- Diameter = 0.3 mm
- Pitch= 0.7 mm
- Thickness = 0.4 mm
- Rim = 0.1 mm
- Gas: Ar/CO_2 – 70/30



120 kHz / mm^2

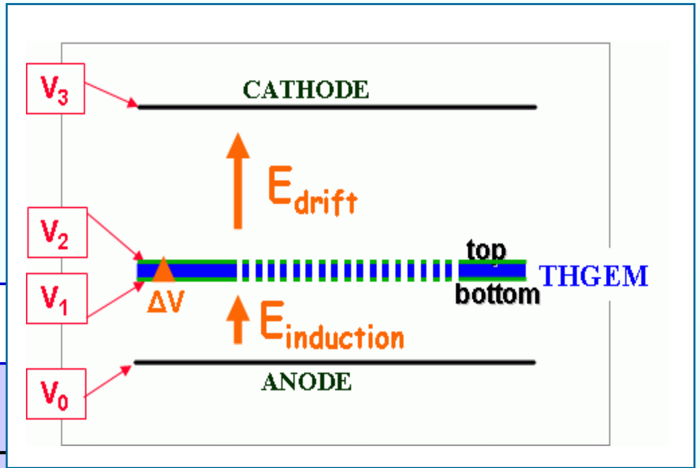
Rate is not a limitation

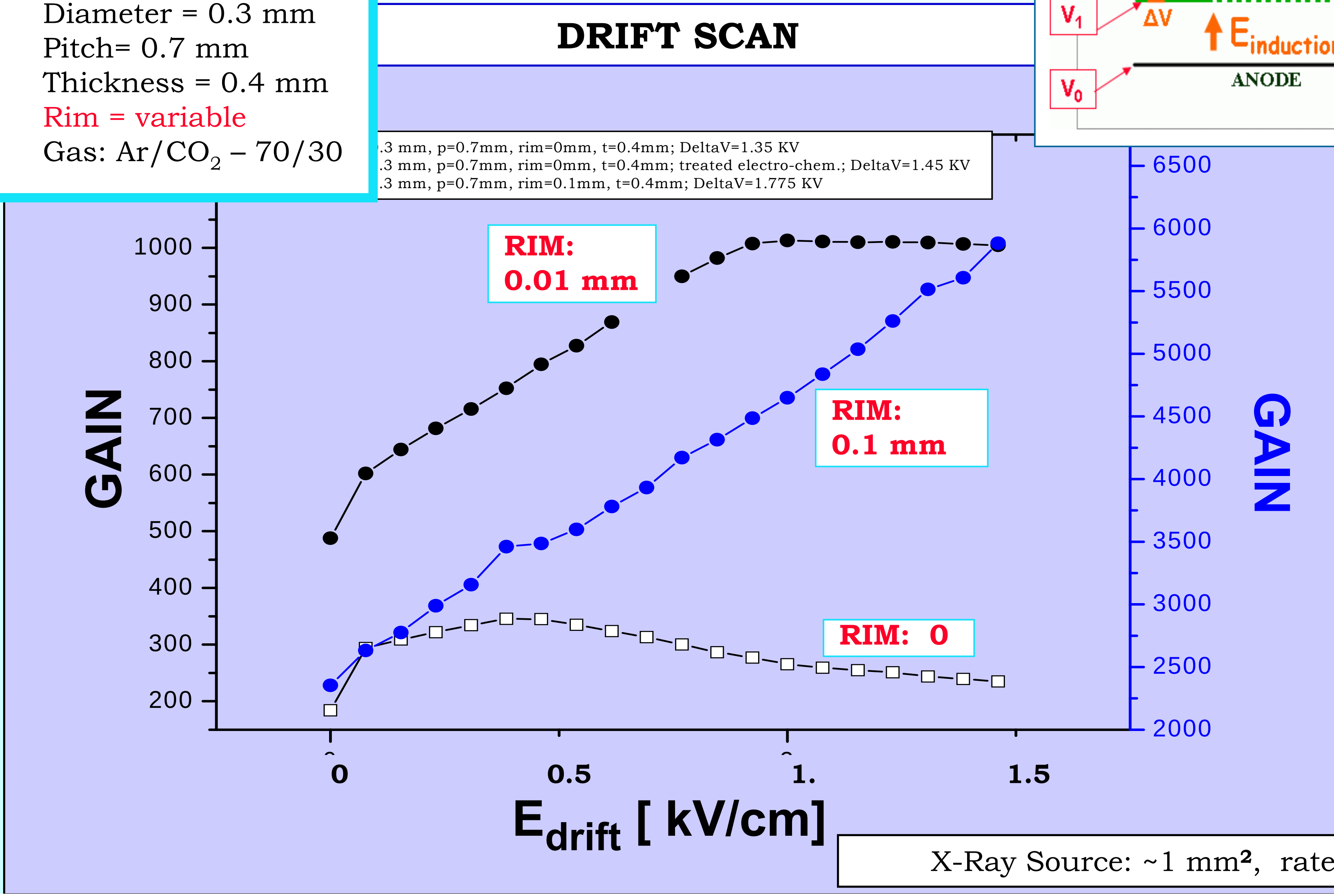
RECALL:
120 kHz/ mm^2, 300 e- → single photoelectron rates of ~35 MHz/ mm^2

4) Tuning the fields

focusing electrons into the holes

PARAMETERS:
- Diameter = 0.3 mm
- Pitch= 0.7 mm
- Thickness = 0.4 mm
- Rim = variable
- Gas: Ar/CO_2 – 70/30

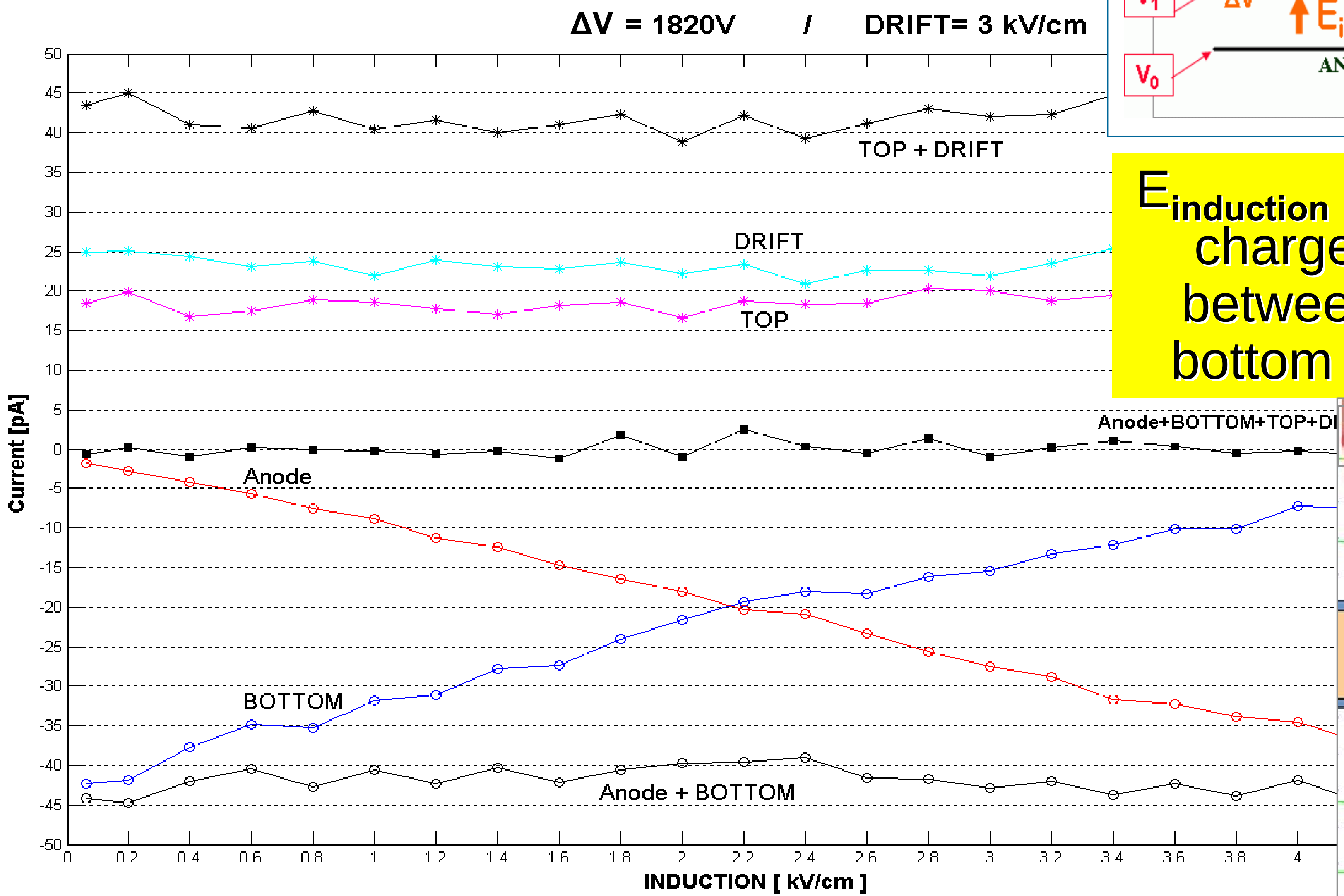


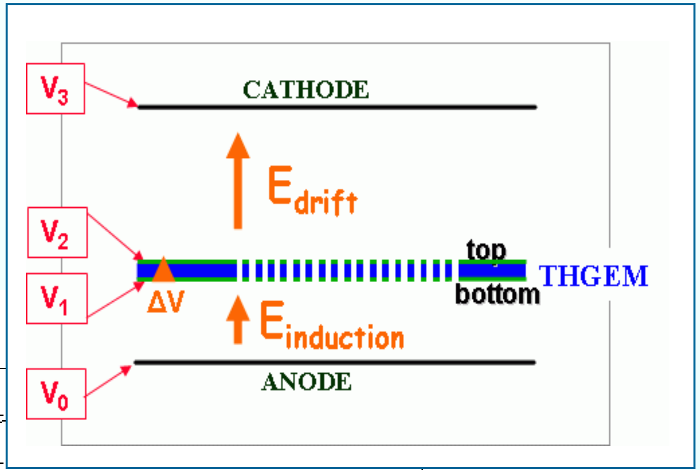


X-Ray Source: ~1 mm², rate ~1.7KHz.

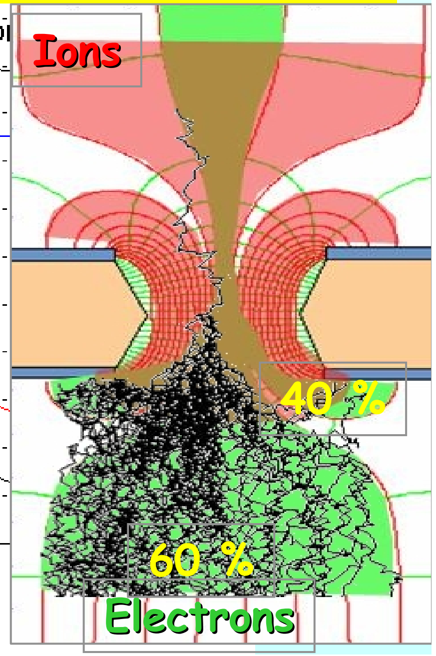
4) Tuning the fields

bottom/anode current sharing



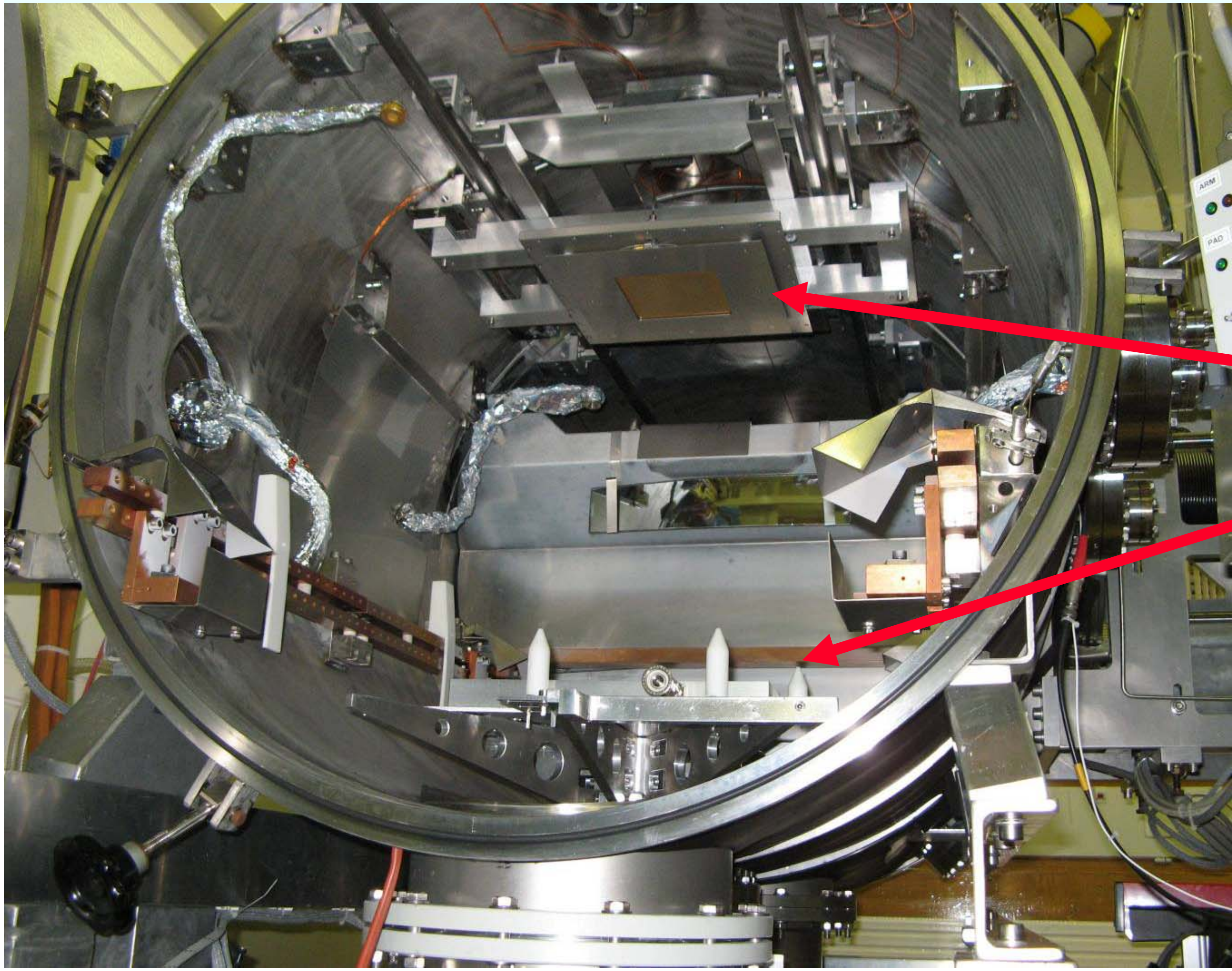


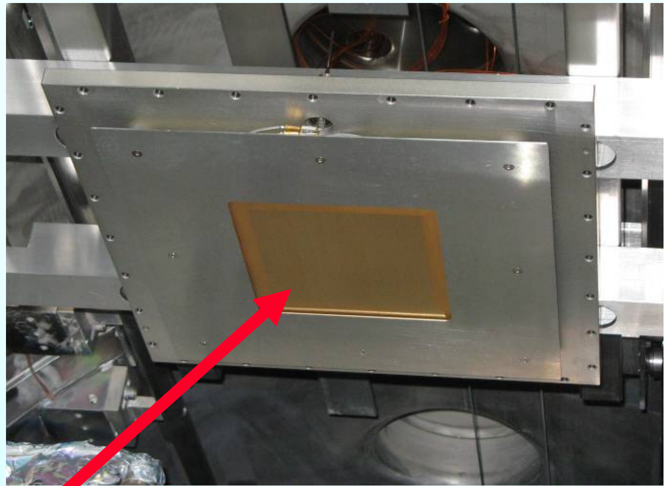
$E_{induction}$ changes the charge shearing between THGEM bottom and anode



Approaching our goal
- detect UV photons…

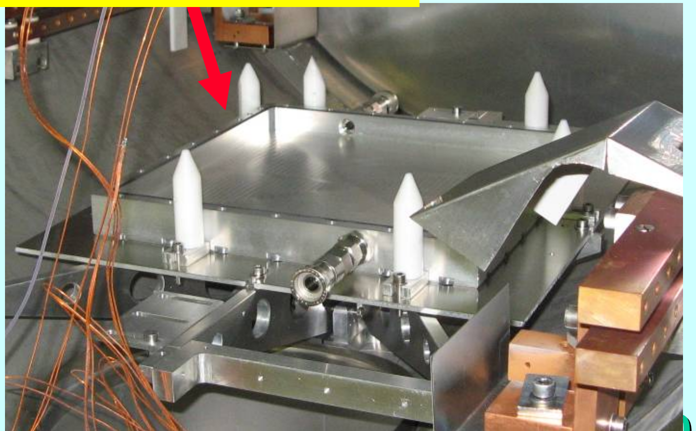
CsI evaporation at CERN
(A. Braem, C. David, M. van Stenis)





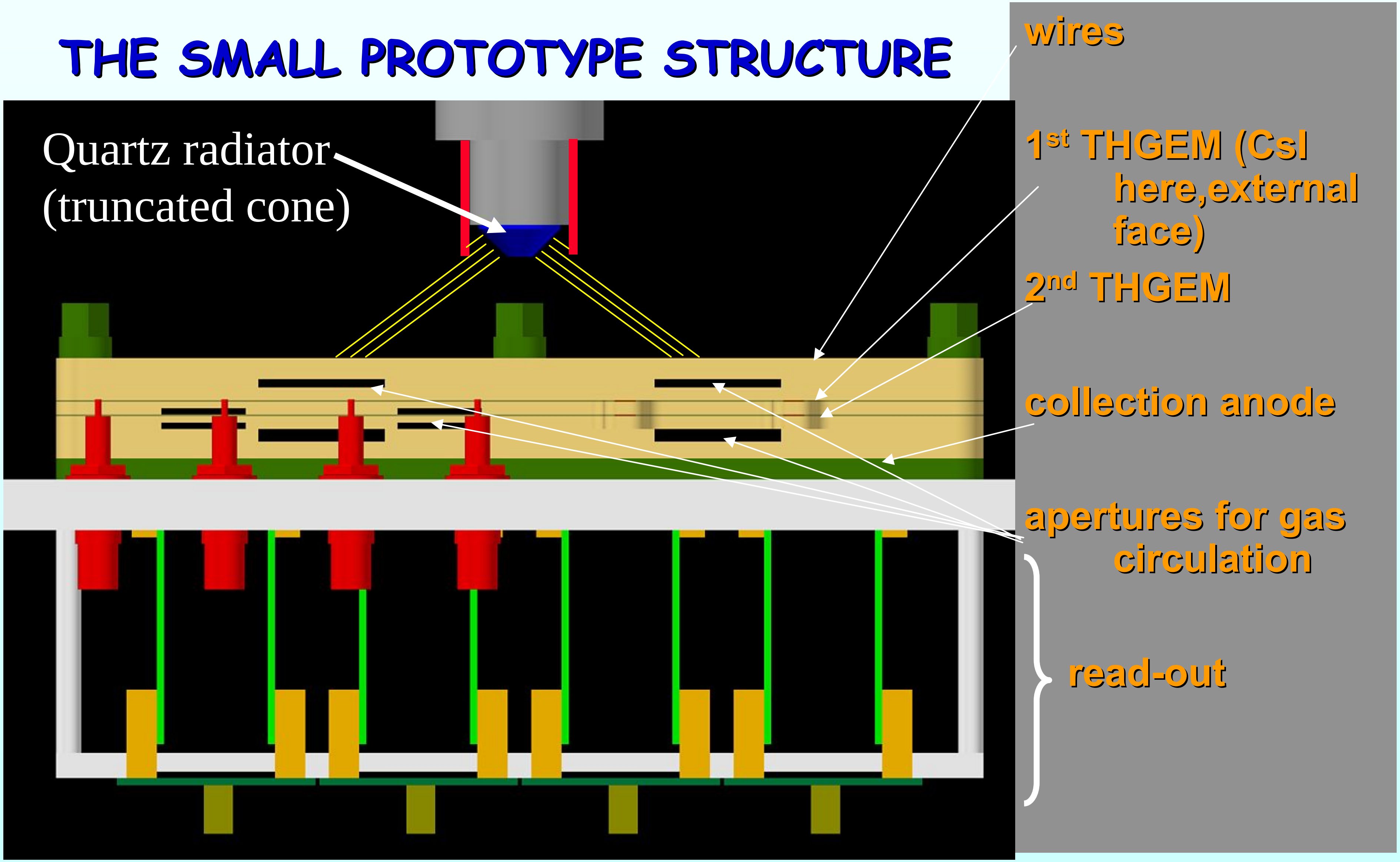
THGEM

protection box

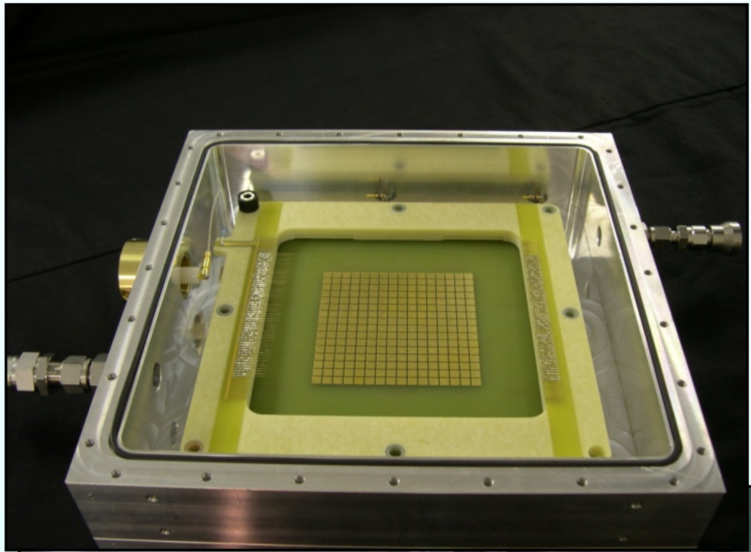


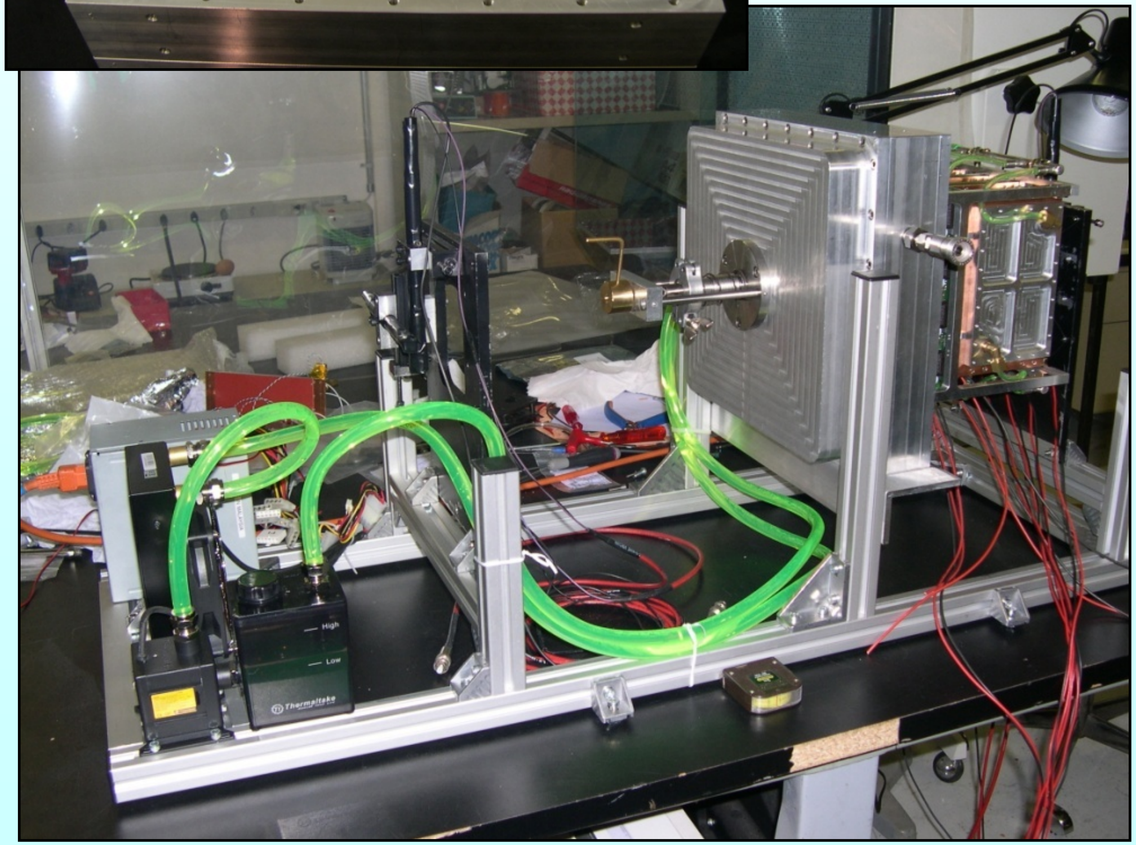
… Cherenkov photons…

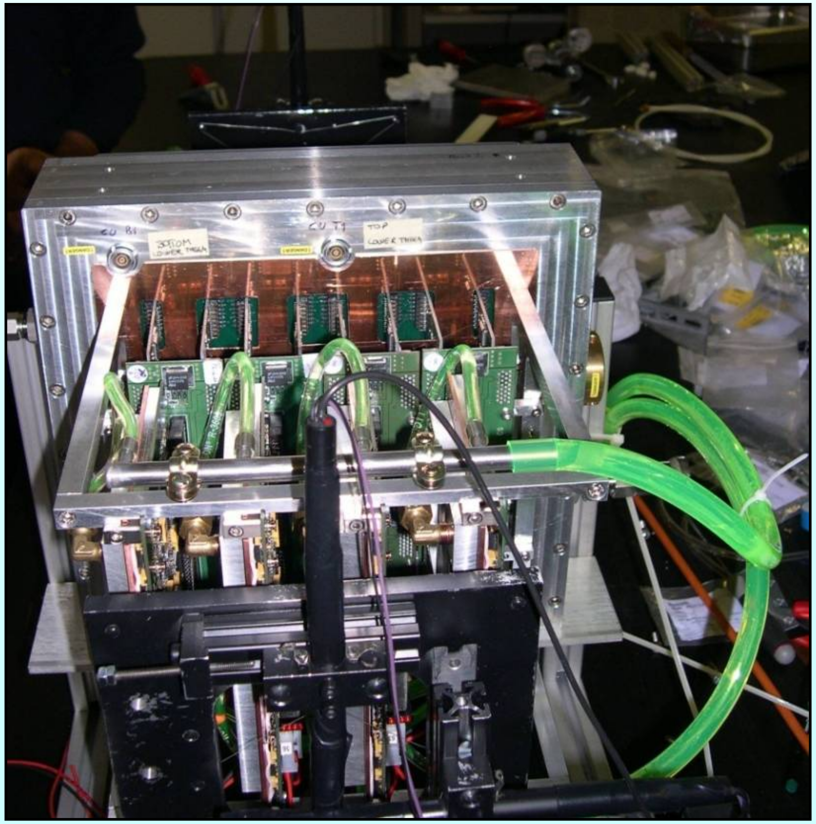
THE SMALL PROTOTYPE STRUCTURE



TEST BEAM SET-UP FOR SMALL PROTOTYPES







Perspectives

Short term plans:

- optimize the parameters of the THGEM with photoconverting CsI layer to achieve maximum photoelectron collection efficiency
- optimize the parameters for the (double) THGEM to be used for the amplification of the signal to provide large and stable gain
- produce a set 600 x 600 mm^2 THGEMs and assemble them with stesalite spacer frames into first complete “full size” prototype chamber

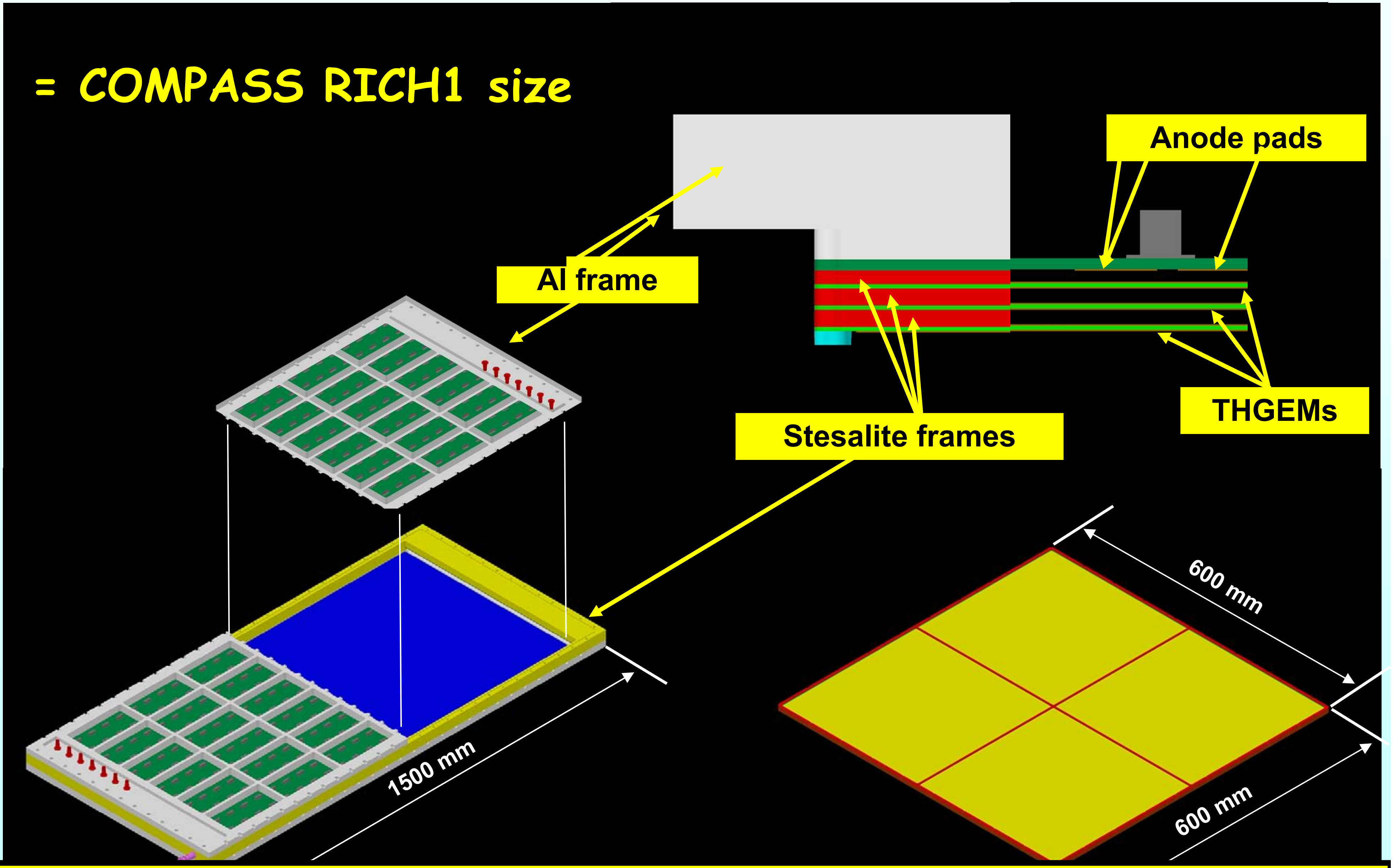
Possible medium term project:

- Upgrade of COMPASS RICH (~4m^2) with the new photon detectors in case the COMPASS Collaboration decides for it.

Longer term dream:

- find a configuration to reduce the ion back-flow down to $<10^{-5}$ and operate this large area detectors with visible photoconverter

…we're building full size prototype



There is hope to use these detectors for detection of visible photons

Conclusions

- A third generation of gaseous Photon Detectors for RICH applications, based on micropattern gas detectors, is expected to overcome the performance limits of MWPC's coupled with CsI photocathodes.
- THGEM seem to be very promising: they are stiff, robust and suitable for industrial production; they are expected to provide high gain, small dead areas and very good photoelectron collection efficiencies.
- An effort to characterize these novel detectors has started with the aim to optimize geometrical parameters, production procedures and working conditions for large area coverage.
- A full size 600 x 600 mm^2 prototype will be produced, assembled and tested in the incoming months.

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Thank you