The quest for a third generation of gaseous Photon Detectors for Imaging Cherenkov Counters

Fulvio Tessarotto

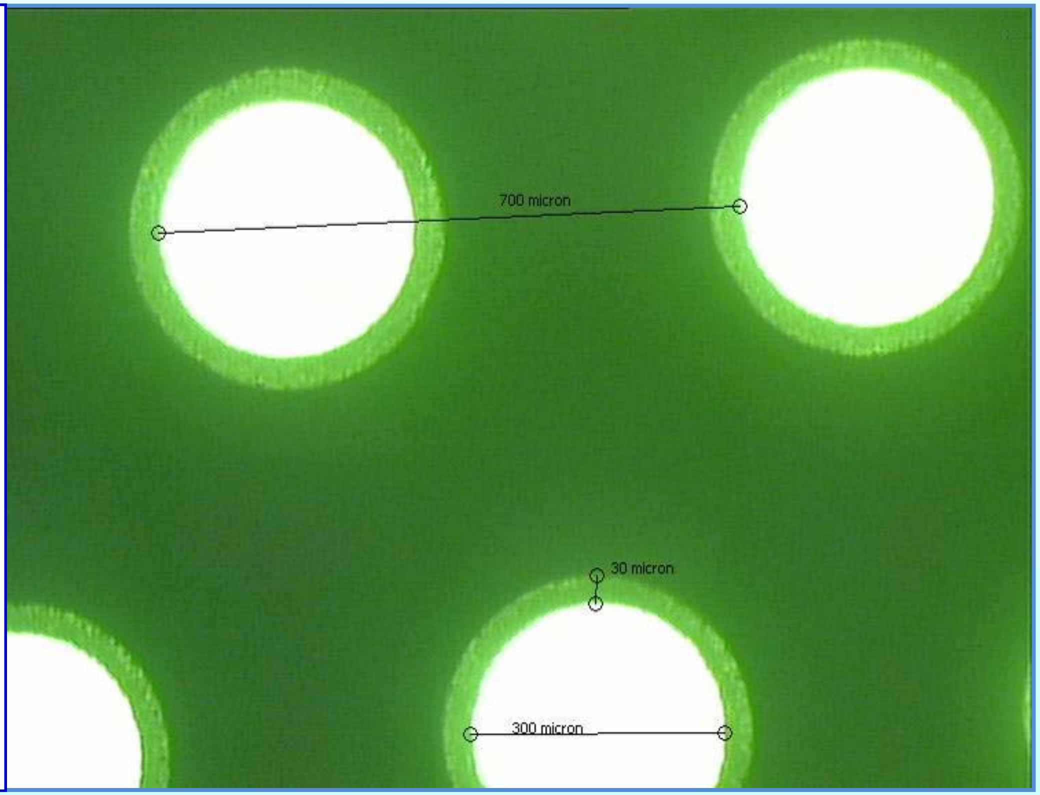
Introduction

Limitations of MWPC's with CsI

The choice of THGEM detectors

Characterization and optimization

Large area THGEM based PD's



Cherenkov Imaging Detectors presently in use or construction in particle and nuclear physics

Concluded experiments are not listed

field of Physics	experiment	where	status
heavy and light quark spectroscopy	BABAR	SLAC	active
	superBELLE	KEK	proposal
	CLEO III	CORNELL	active
	COMPASS	CERN	active
	COMPASS2	CERN	proposal
	future superB		
	PANDA	GSI	preparation
	MIPP	FERMILAB	active
	GlueX	Jlab	preparation
K physics	P326	CERN	proposal
B physics	BABAR	SLAC	active
	superBELLE	KEK	proposal
	future superB		
	LHCb	CERN	starting
Longitudinal and transverse spin structure of the nucleon, generalized parton distribution function	COMPASS	CERN	active
	COMPASS2	CERN	proposal
	HERMES	DESY	just concluded
	PANDA	GSI	preparation
	PHENIX	BNL	active
	Hall A	JLAB	active
quark-gluon fusion	ALICE	CERN	starting
	ALICE upgrade	CERN	proposal
heavy ion physics	BRAMHMS	RHIC	active
	PHENIX	RHIC	active
	ALICE	CERN	starting
hadron properties in normal and heigh density nuclear matter	CBM	GSI	preparation
	HADES	GSI	active
hypernuclei	PANDA	GSI	preparation

Photon Detectors used for RICHs belong to three chategories:

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)

PID FOR HIGH MOMENTA AND WIDE ANGULAR ACCEPTANCE NEEDS

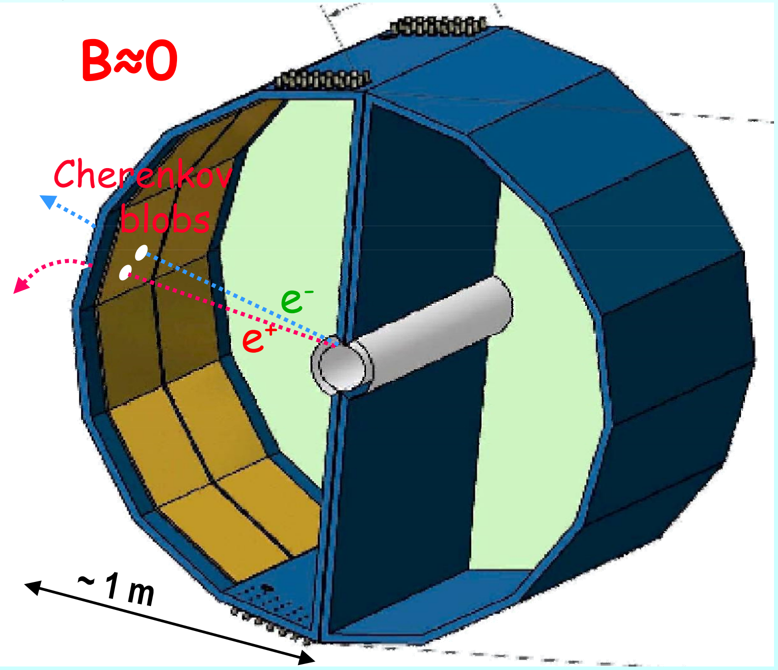
LARGE SENSITIVE AREAS ↔ GASEOUS PDs

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

- **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
  - Aging
  - Moderate gain: < 10^5 (effective gain: <1/2)

  } ion feedback → CsI ion bombardment (see below)

- **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



Performance limitations of MWPC with CsI

1) 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)

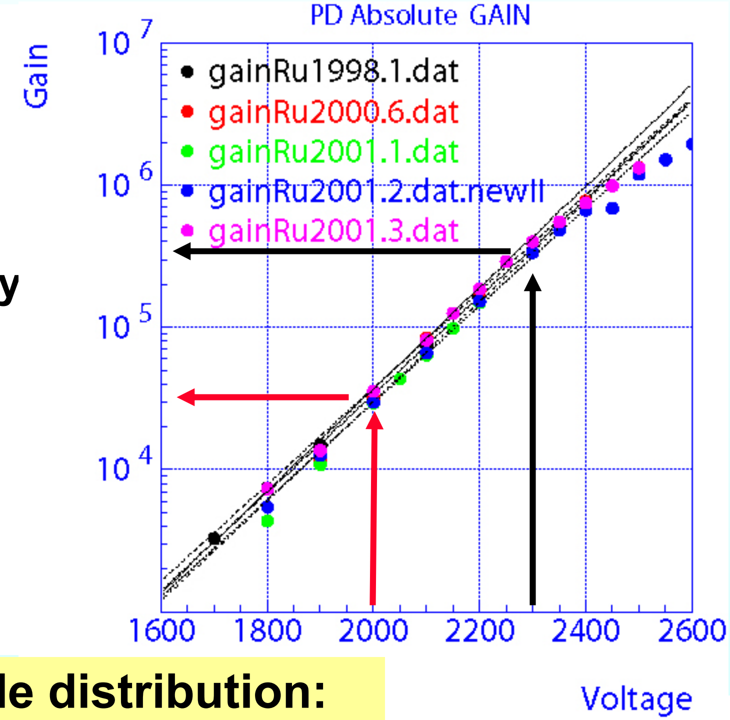
Whenever a severe discharge happens, recovery takes ~1 day

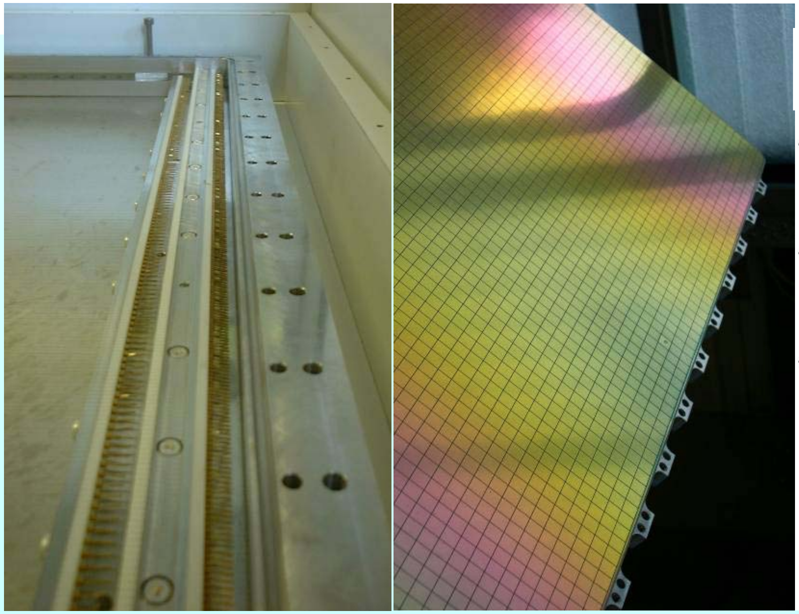
Similar behavior reported from JLAB Hall-A

2) Photocathode aging:

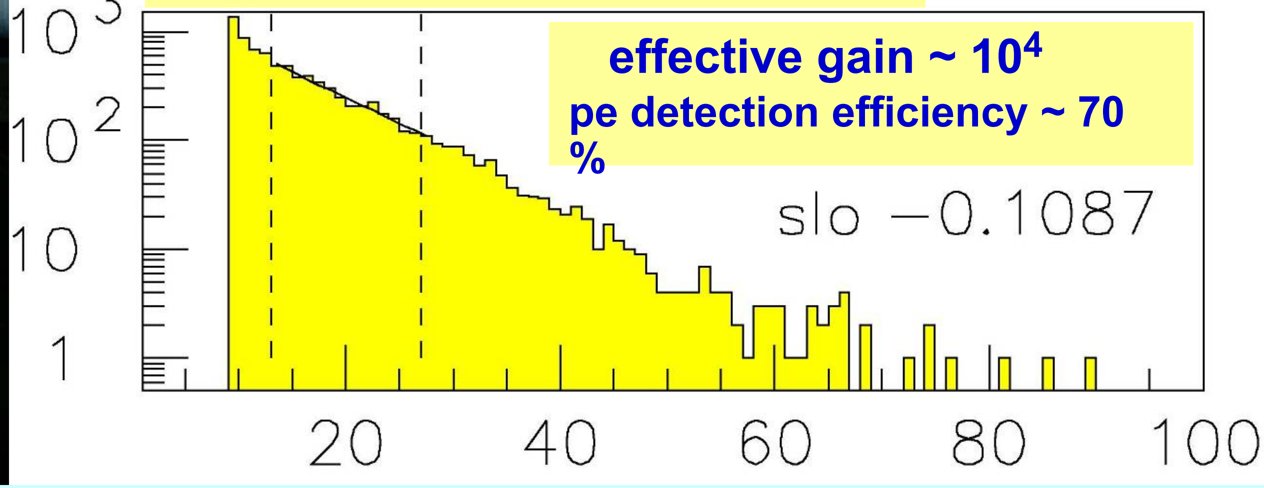
- our information from accidental contamination

- detailed study by Alice team

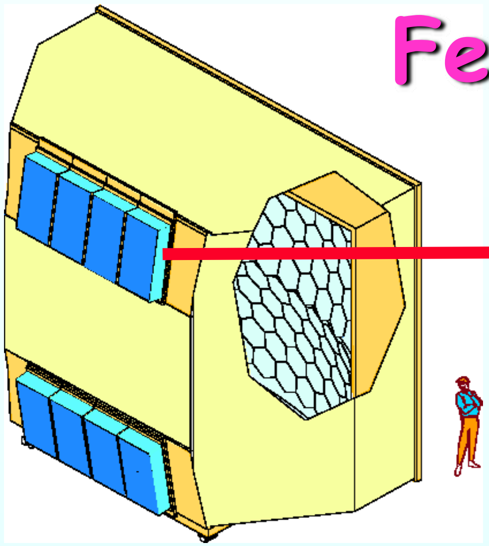


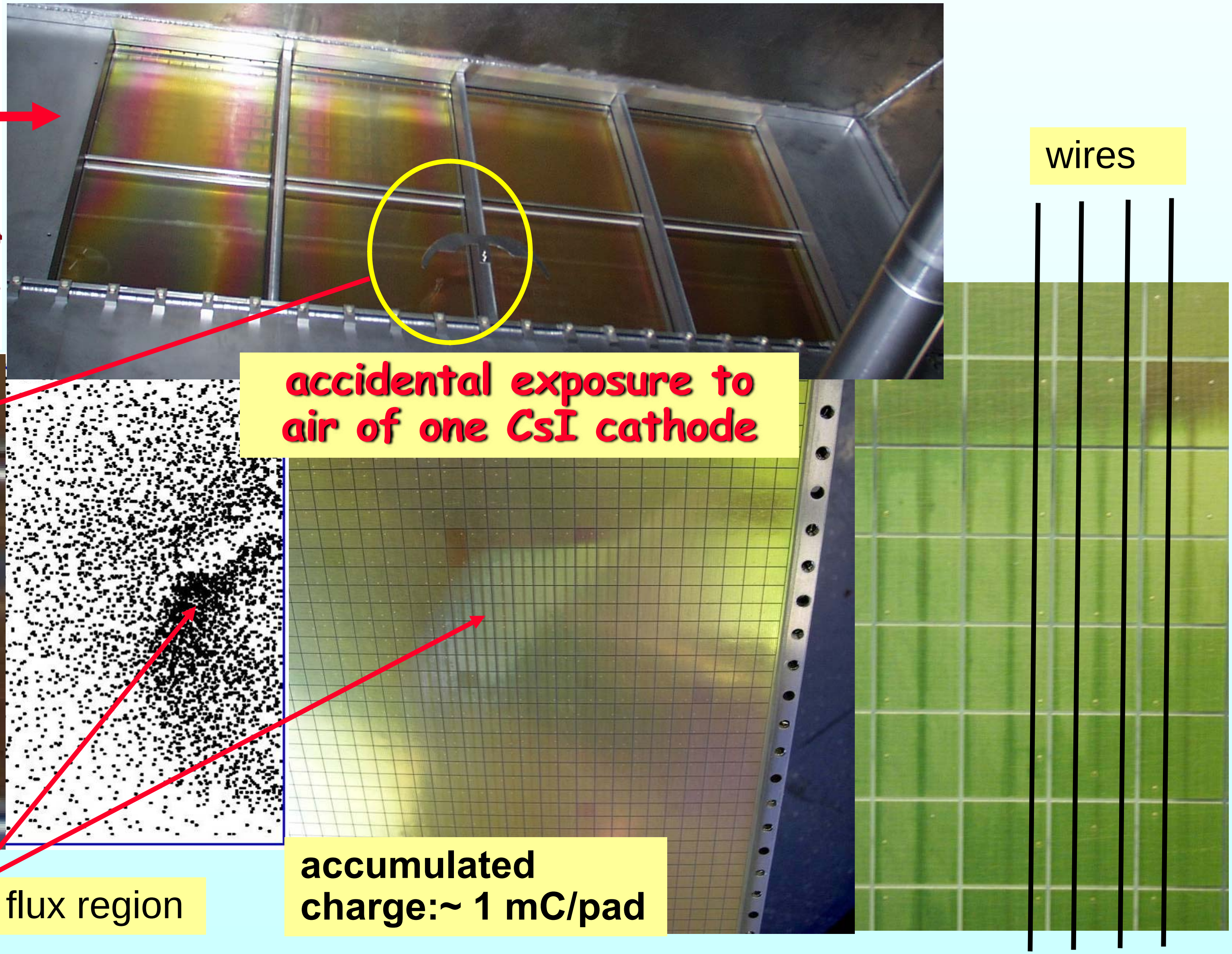


cluster amplitude distribution:

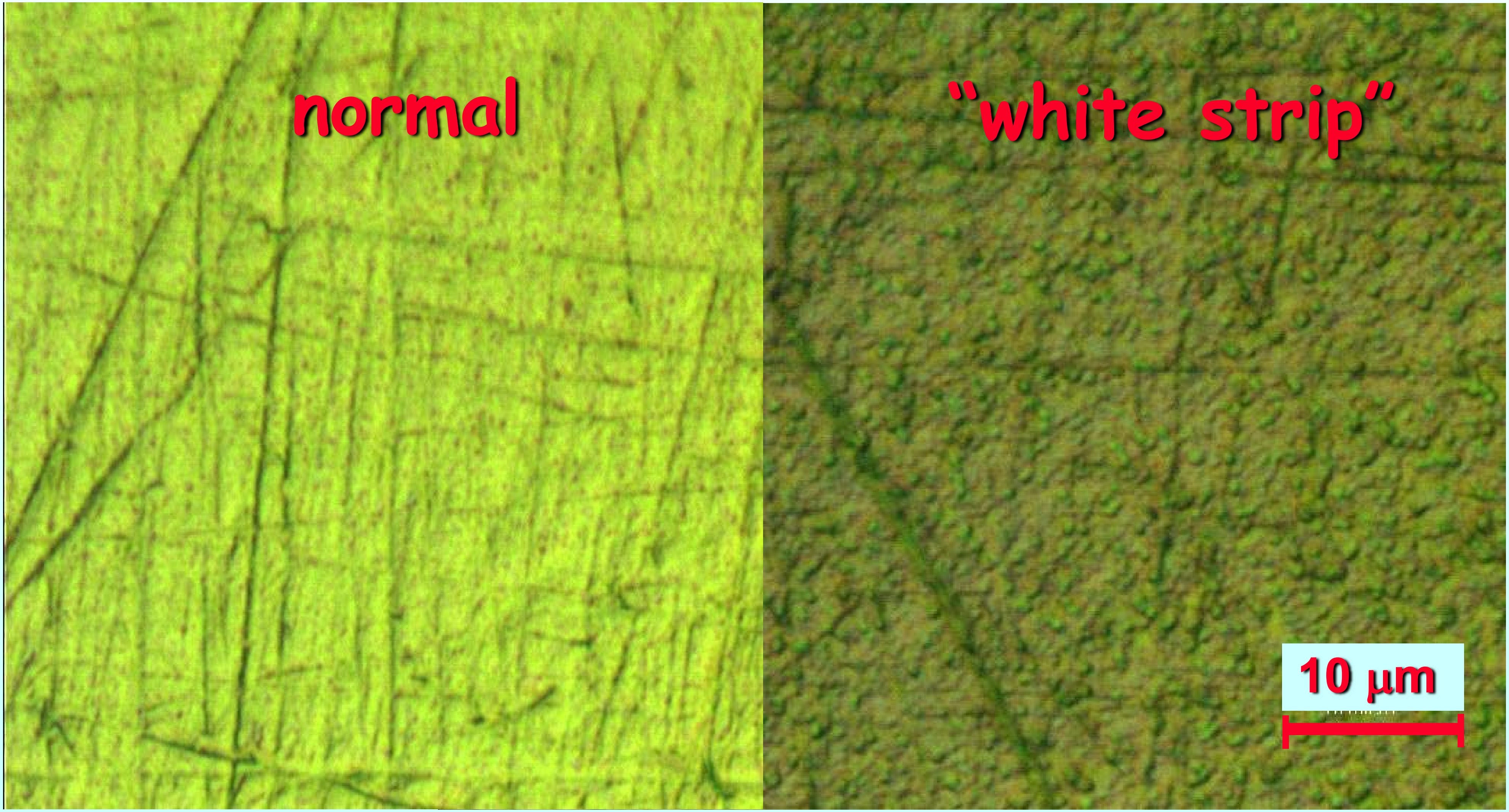


Few months after the end of the run

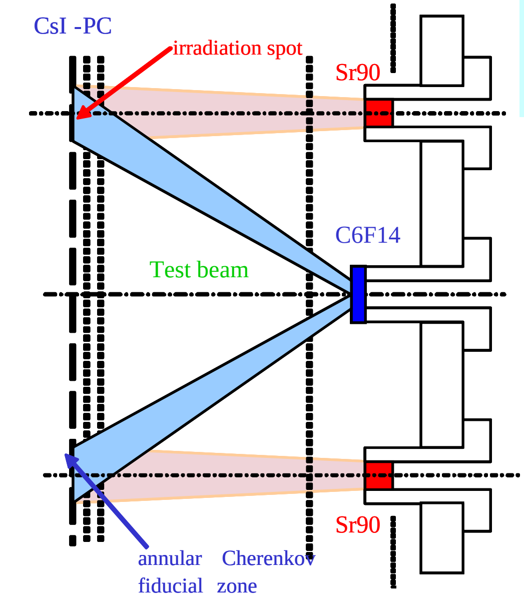




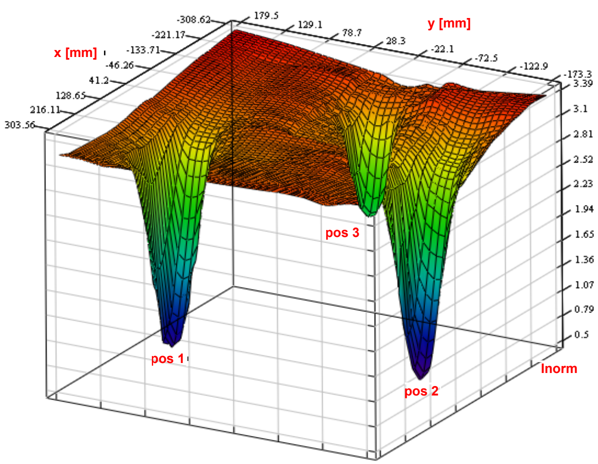
CsI surface at microscope (x 1000)

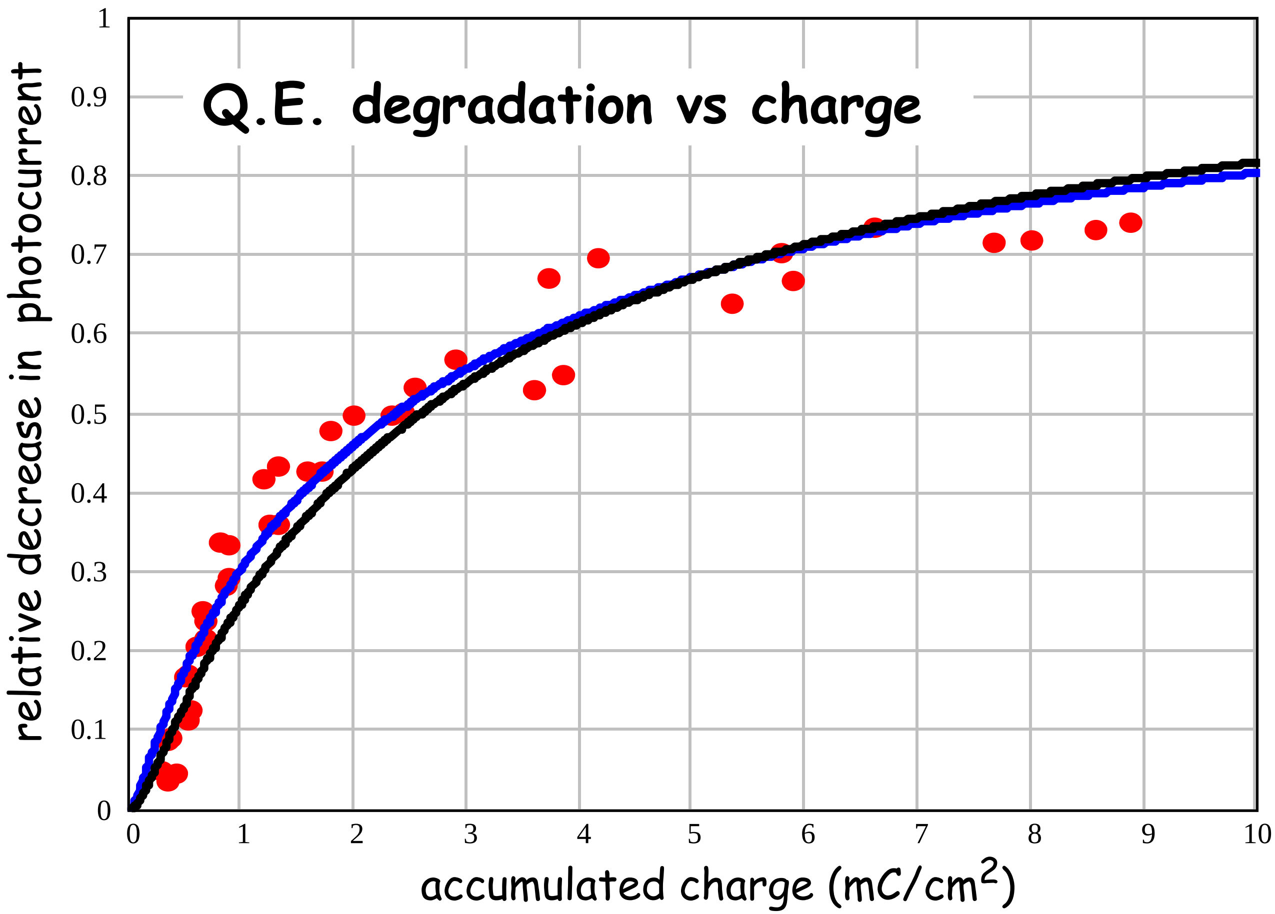


Aging effect from ion bombardment (Alice HMPID)



Irradiation with ^{90}Sr source of 3 positions located on the Cherenkov ring, subsequent test beam analysis and 2-d scan of cathode photocurrent



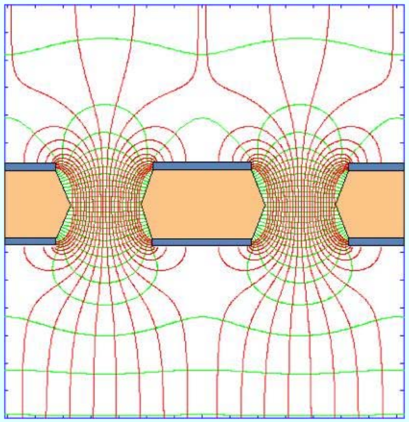


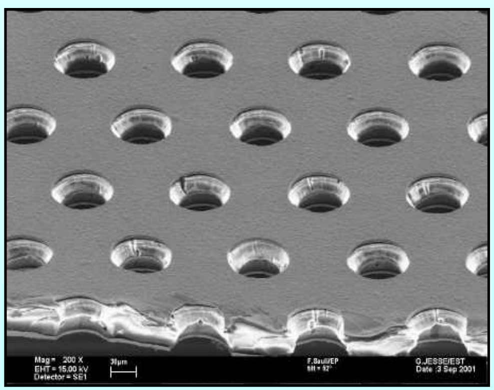
H. Hoedlmoser et al., NIM A 574 (2007)28; H. Hoedlmoser, CERN-THESIS-2006-004

GEMs and THGEMs

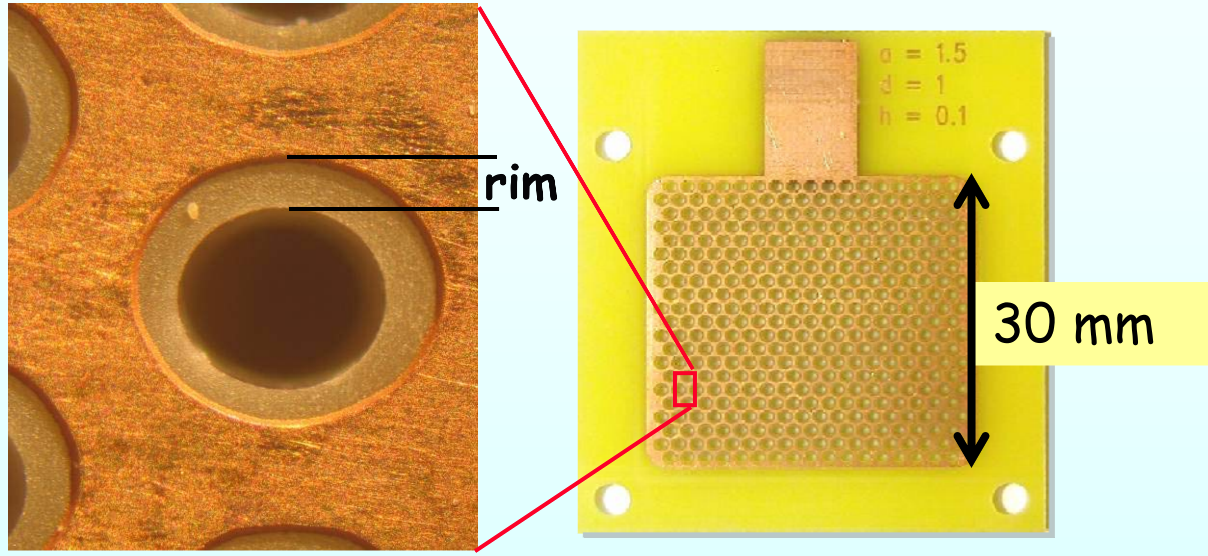
Hole diameter d = 0.3 - 1 mm
Pitch a = 0.7- 7 mm
Thickness t = 0.4 - 3 mm

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



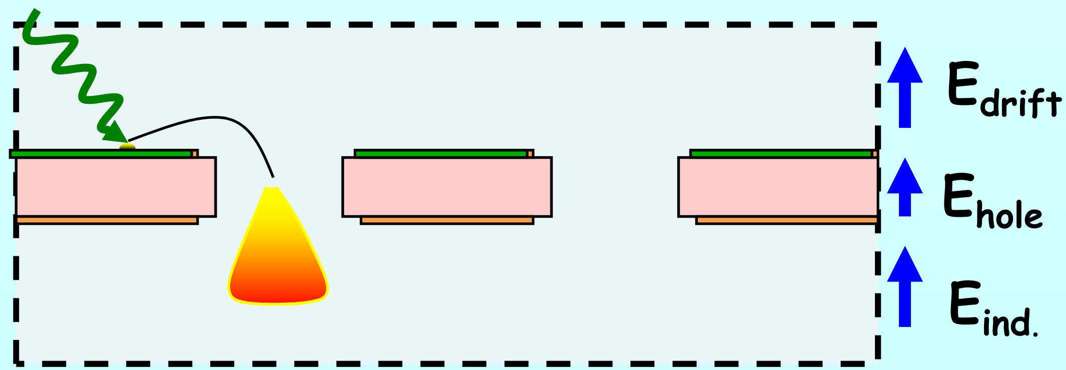


F. Sauli, Nucl. Instr. and Methods A386(1997)531



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

ECONOMIC & ROBUST



C. Shalem et al. NIM A558 (2006) 475

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,

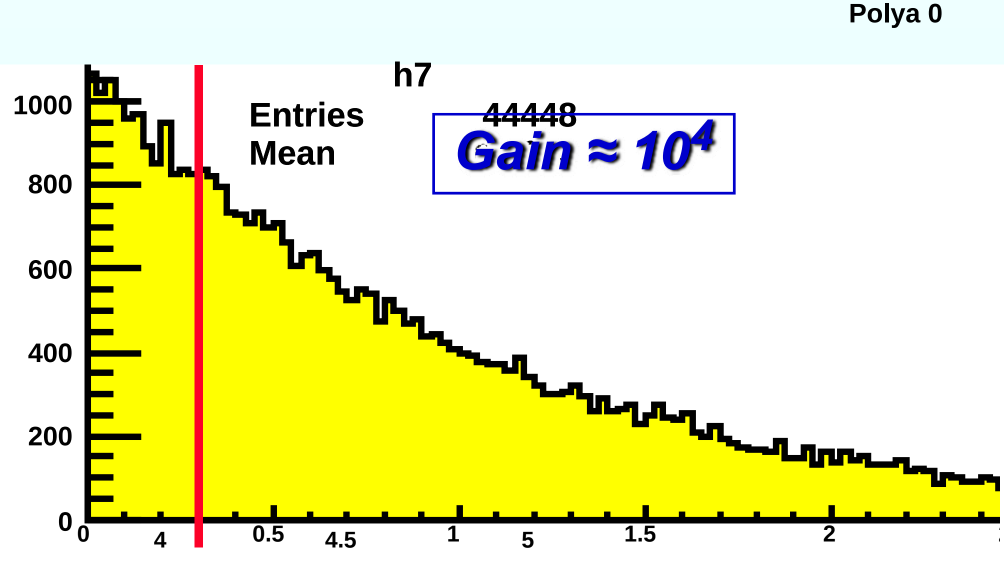
- no need to keep the window at a fixed potential (2nm Cr →-20%)
- possibility of windowless geometry
- higher effective QE (larger pe extraction probability)

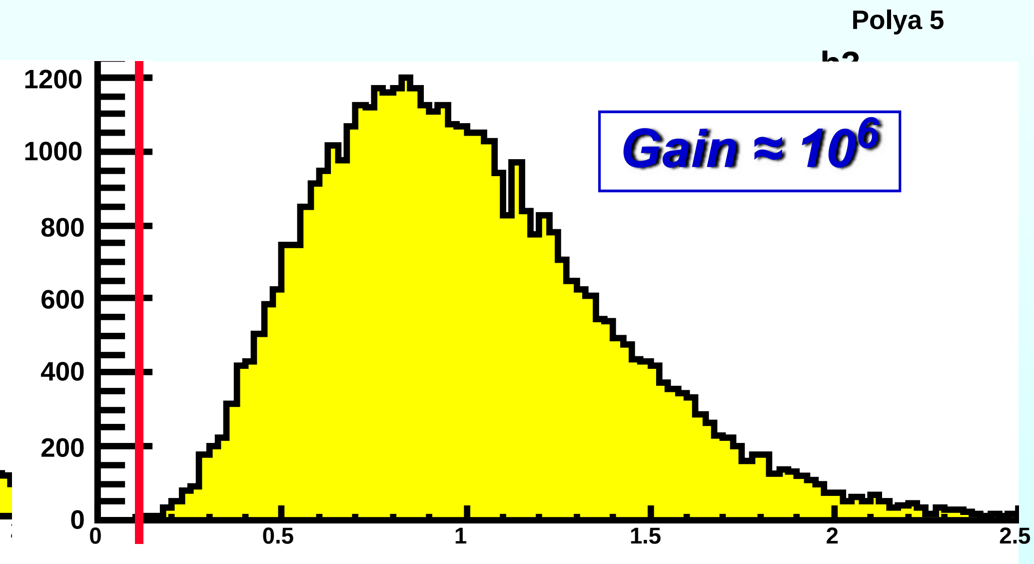
→small photoconversion dead zones (<20%; GEM ~ 40%)

Large gain

THE RELEVANCE OF HIGH GAINS

- **Signal amplitude follows Polya distribution:**





threshold ***threshold***

Threshold always critical !

Limited pe detection efficiency,

performance instabilities

With good electronics:

threshold no longer critical

good pe detection efficiency

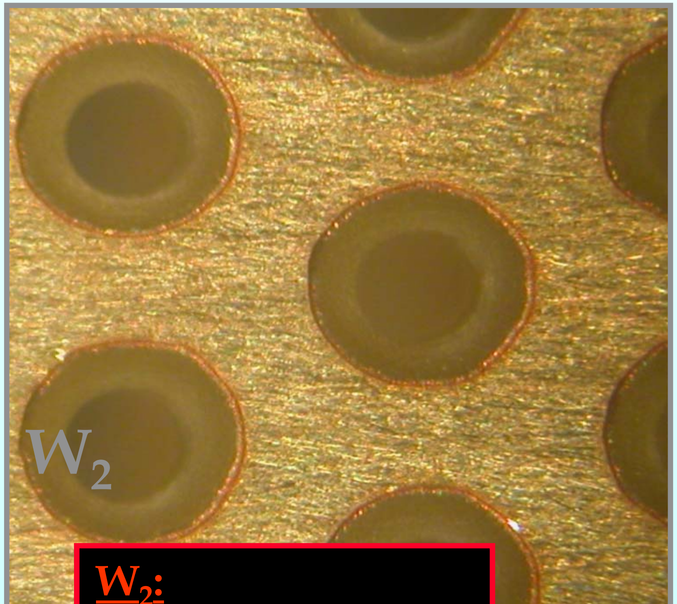
stable behaviour

EXAMPLES OF THGEMS

A MULTIPARAMETER SPACE TO EXPLORE !

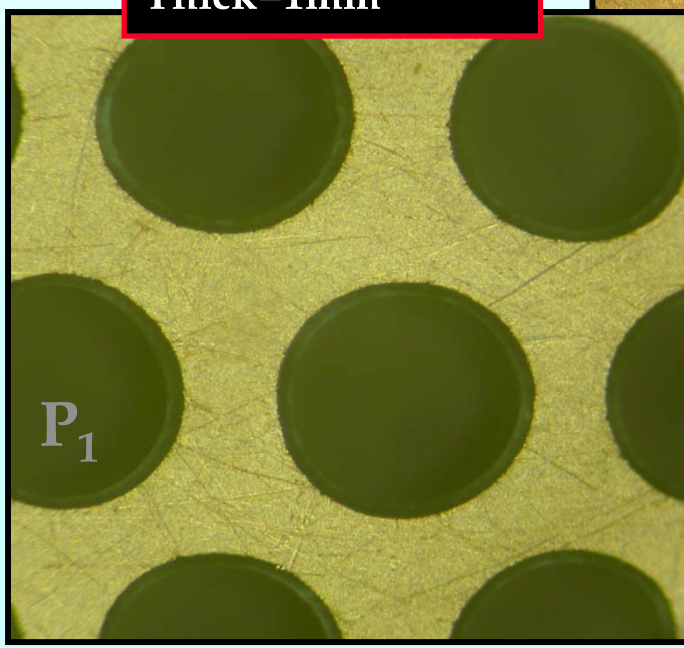
4 geometrical parameters: diameter pitch rim thickness

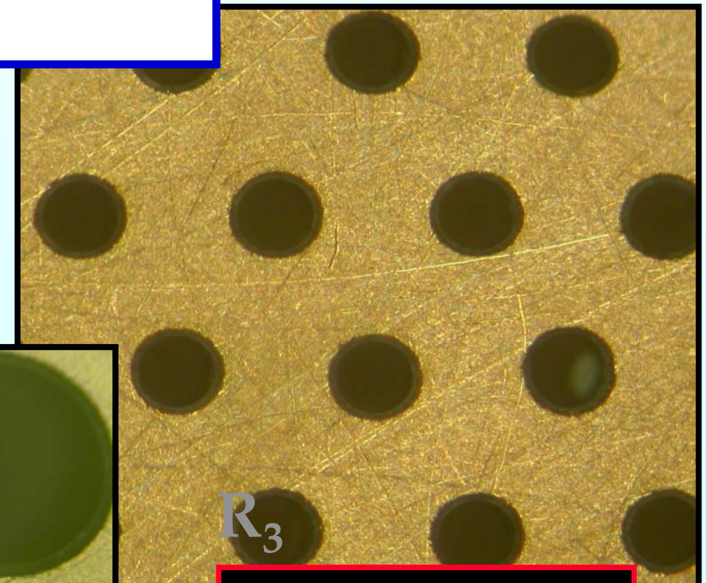
\+ material + production procedure



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

EXAMPLES OF THGEMS

A MULTIPARAMETER SPACE TO EXPLORE !

4 geometrical parameters: diameter pitch rim thickness

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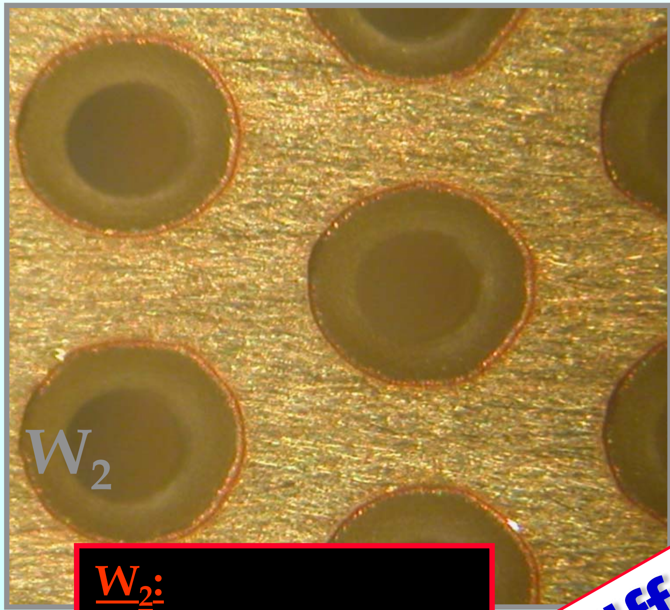

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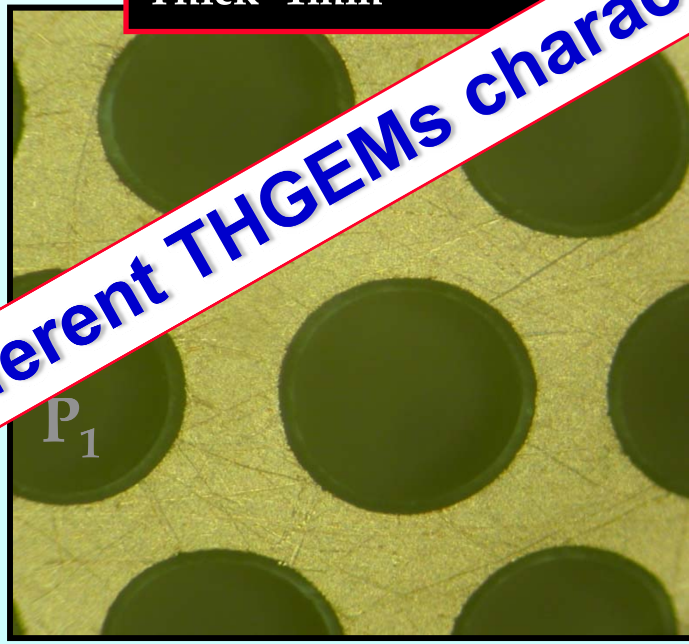
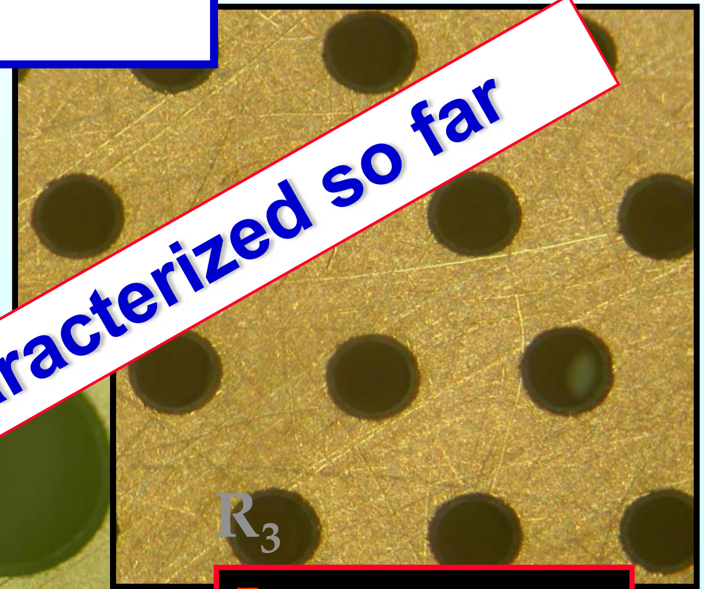




R_3:
D=0.2 mm
Pitch=0.5 mm
Rim=0.01 mm
Thick=0.2mm

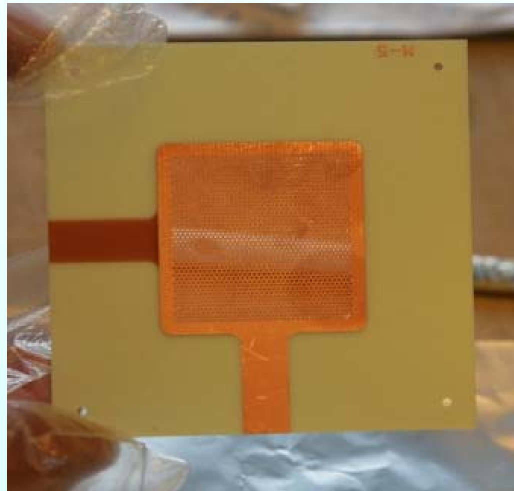
24 different THGEMs characterized so far

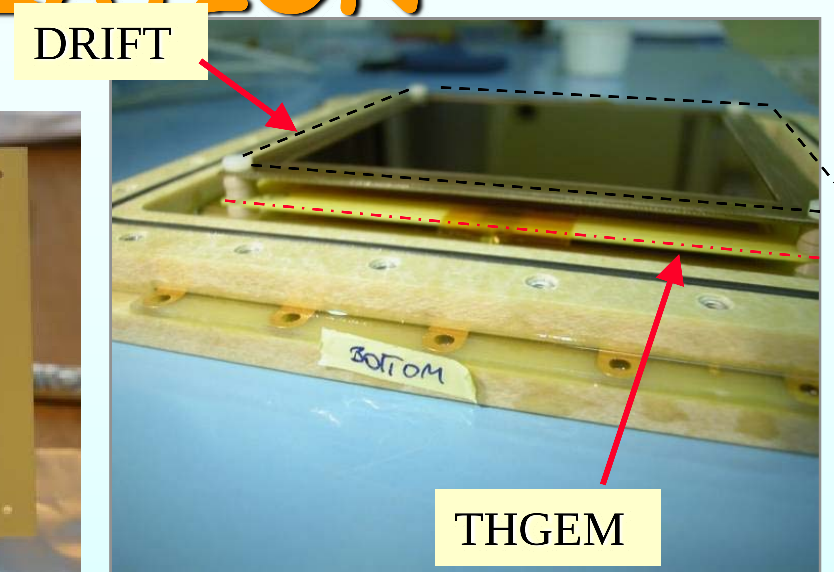
CHARACTERIZATION

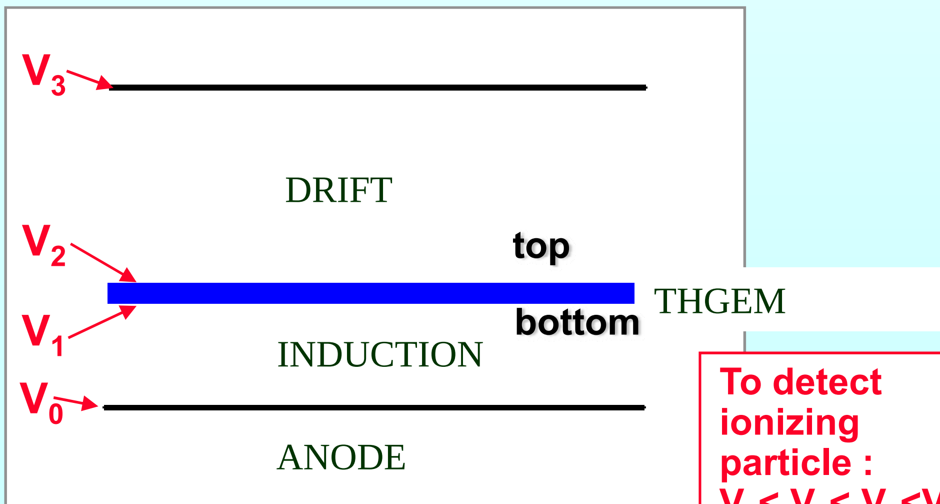
small prototypes – active surface (30 x 30) mm²

1 THGEM layer for this activity

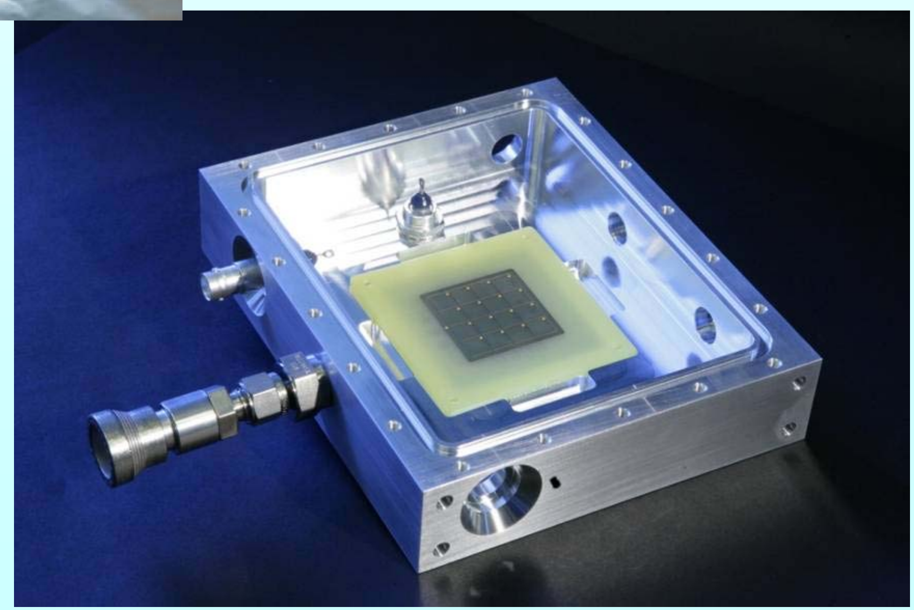
Ar/CO_2 70/30





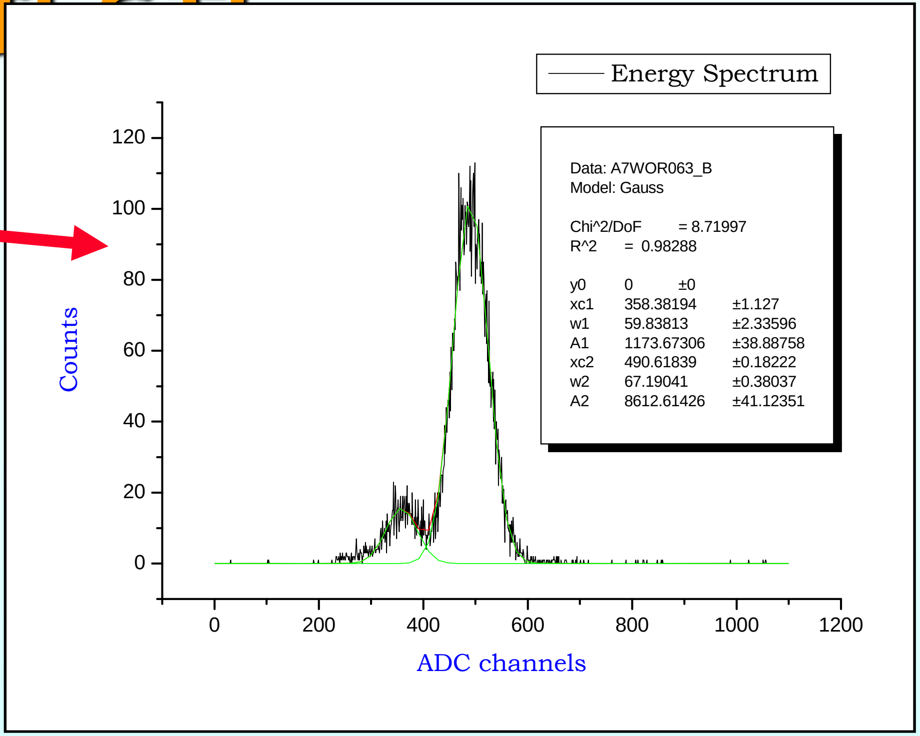


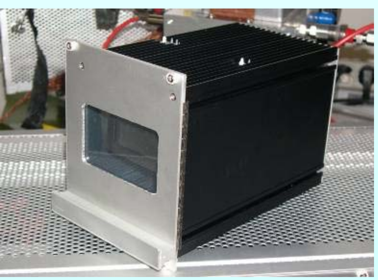
To detect ionizing particle : $V_3 < V_2 < V_1 < V_0$

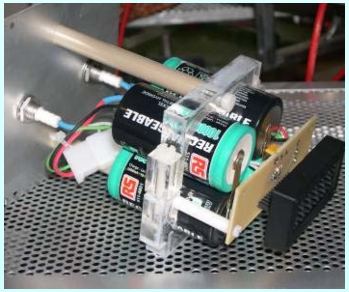


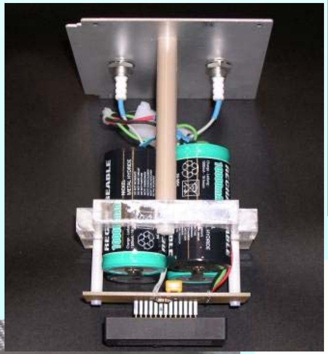
LAB STUDIES AT CERN AND TRI

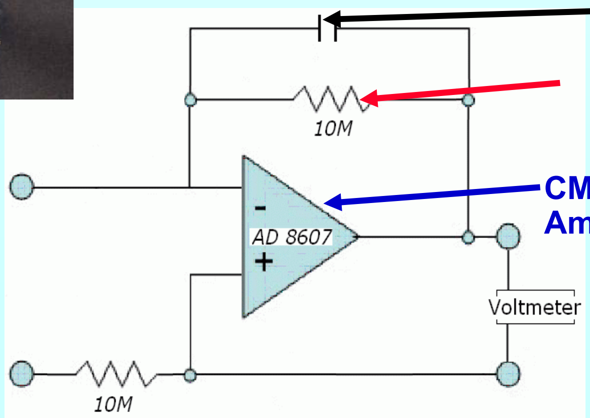
- so far using Cu X-ray
- spectra are collected
- currents are measured at HV
  - homemade instruments (~100 €) with ~1 pA resolution
  - data collection via pictures and image recognition











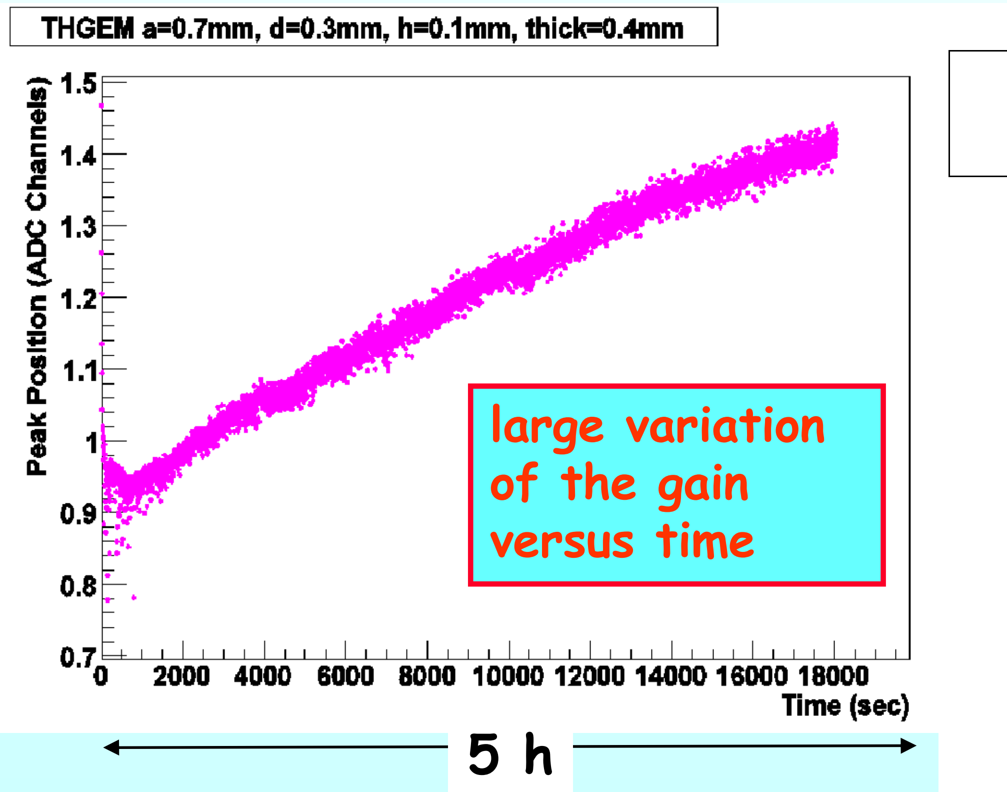
1 nF to 100 nF feedback capacitor

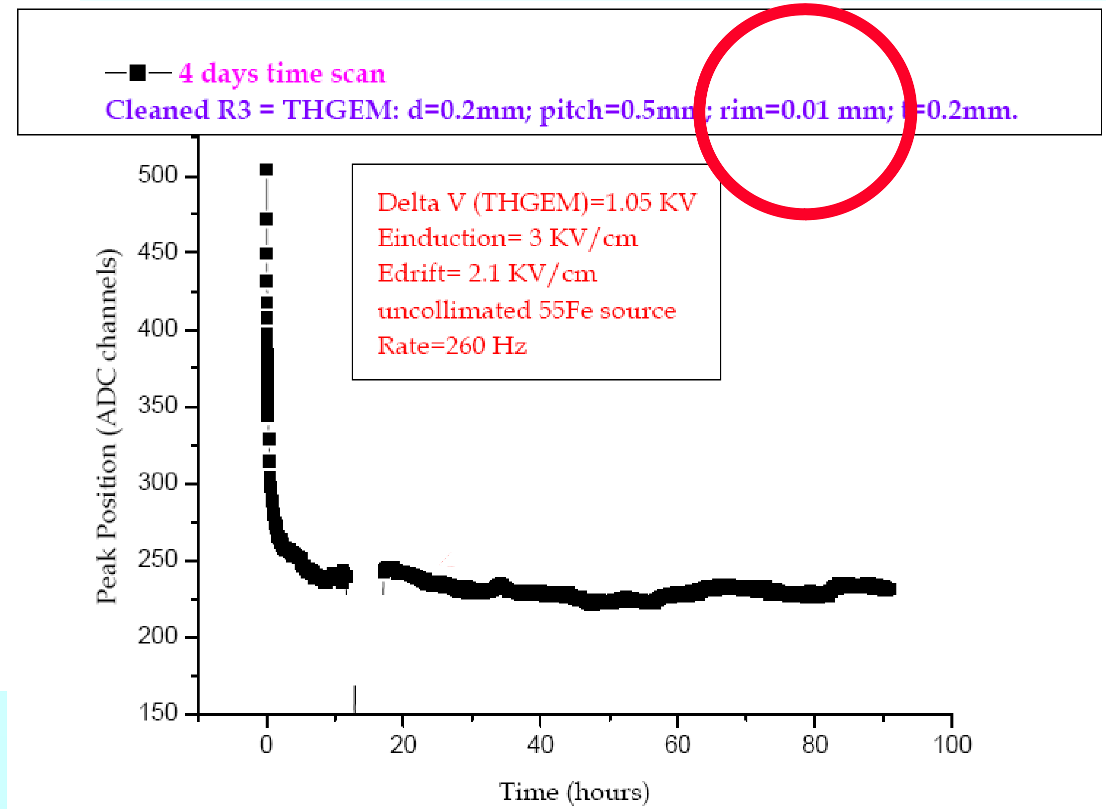
10 MΩ feedback resistor: VISHAY CNS020(+- 0.02%, +- 10 ppm/ºC)

CMOS Operational Amplifier: AD 8607

GAIN STABILITY

THGEM	Diameter (mm)	Pitch (mm)	Rim (mm)	Thick (mm)
W_2	0.3	0.7	0.1	0.4

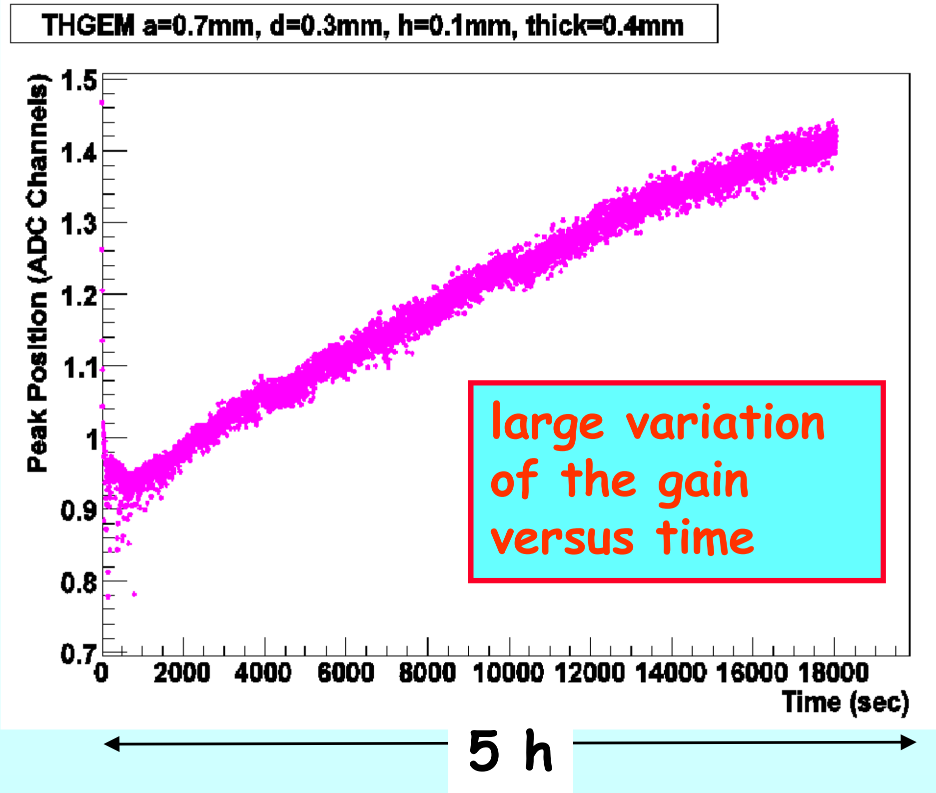


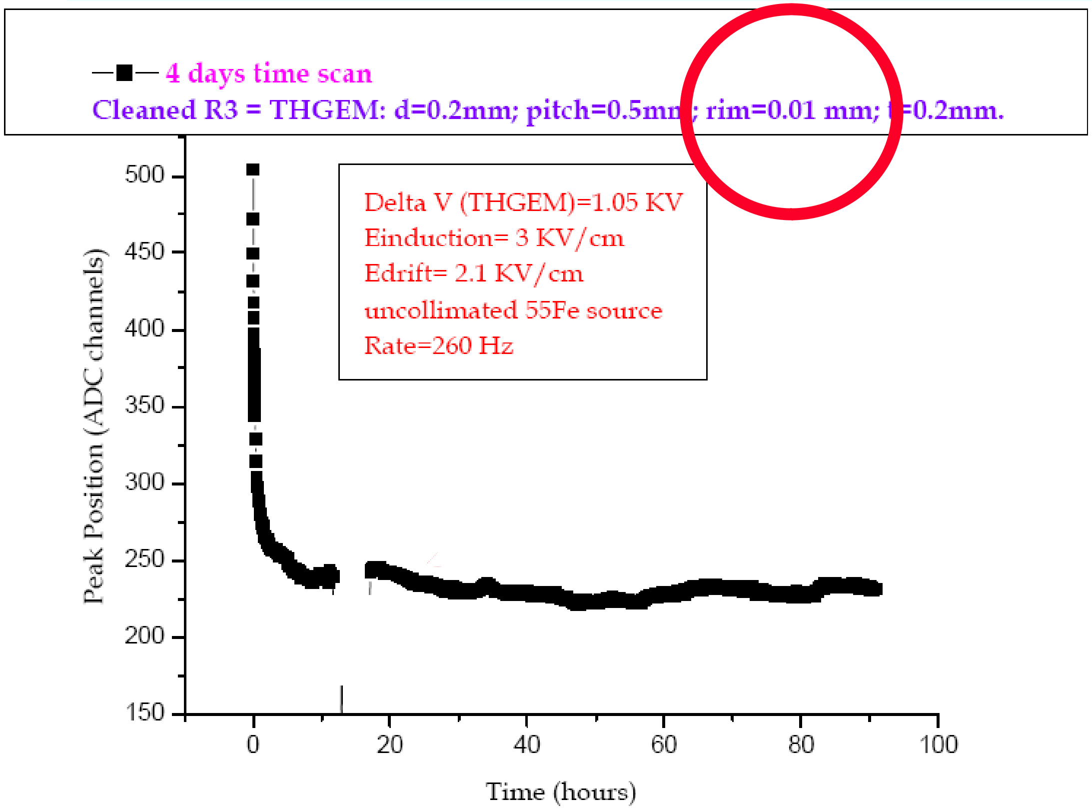


GAIN STABILITY

THGEM	Diameter (mm)	Pitch (mm)	Rim (mm)	Thick (mm)
W_2	0.3	0.7	0.1	0.4

It is now clarified that the good stability (within ~20-30%) is obtained with small rim (< 20 μm)





this effect is seen in GEM's:

2007 IEEE Nuclear Science Symposium Conference Record MP5-3

gain variations are related to the dielectric surface

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

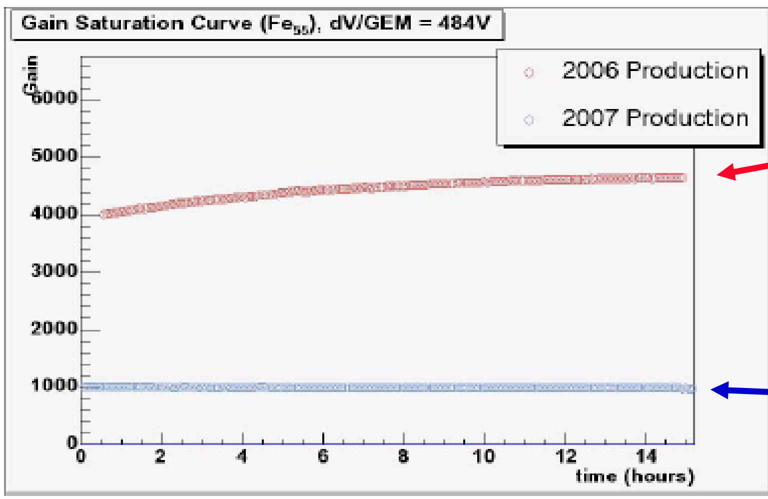


Fig. 11. Gain as a function of time after HV was on for 3 days. Red points are for a GEM stack comprised of GEMs produced in 2006; blue points are for a stack of 2007 GEMs.

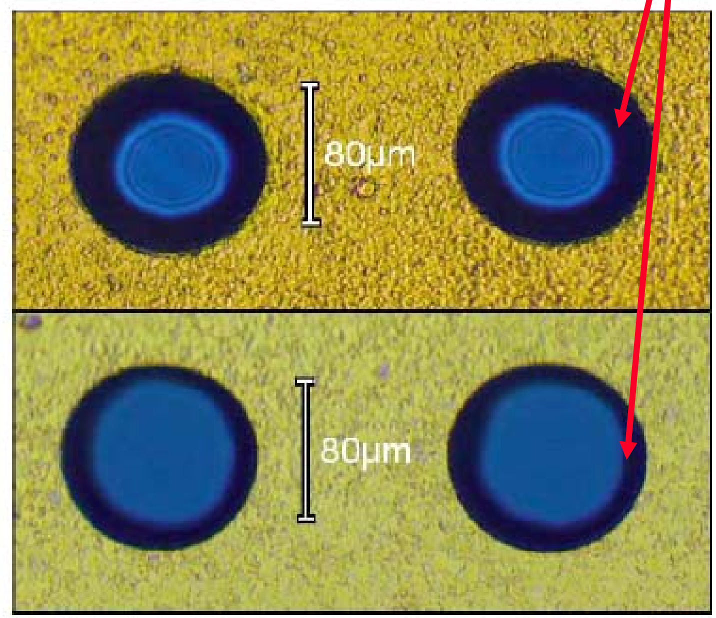
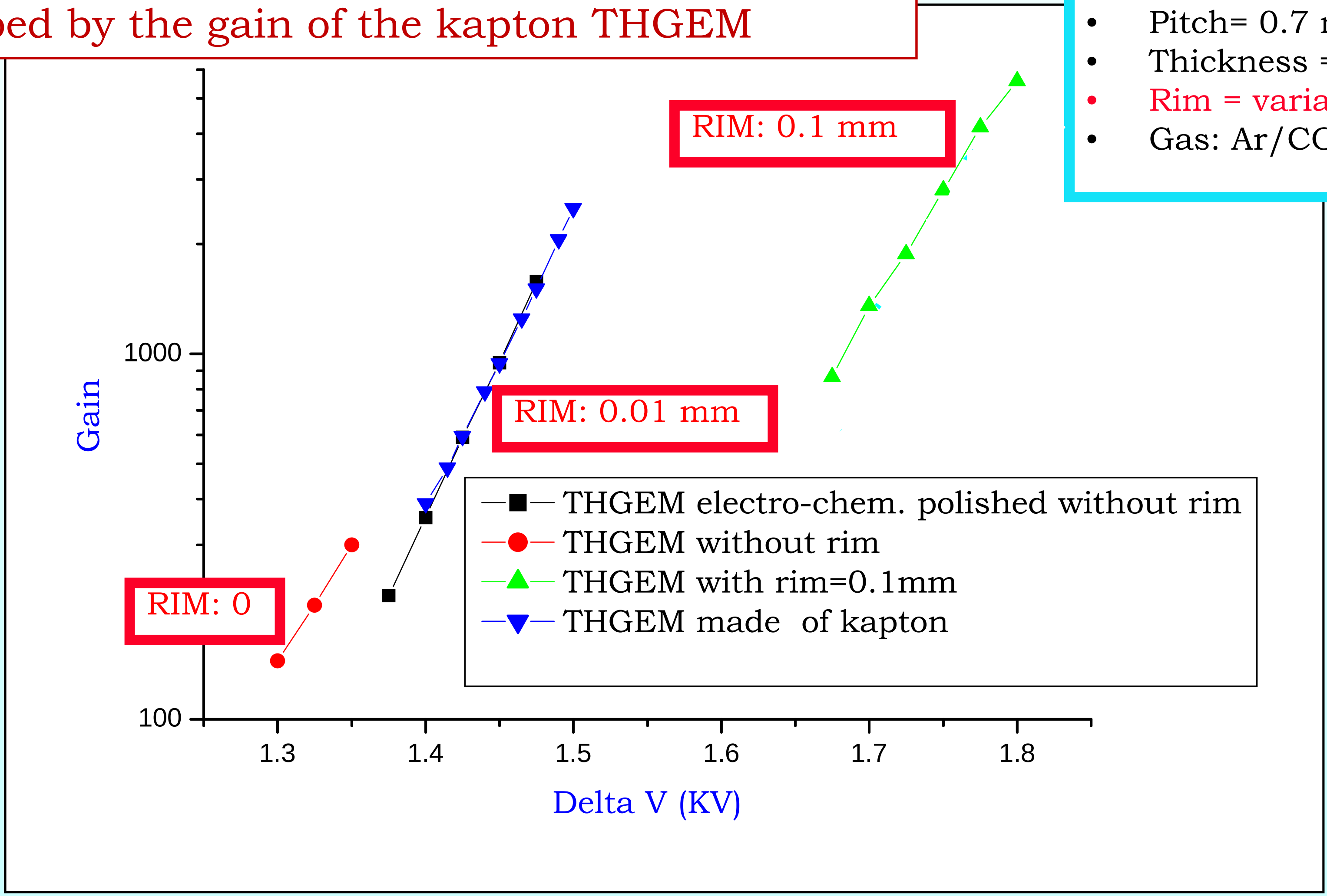


Fig. 12. GEM holes viewed under a microscope. 2006 production GEMs are shown above; 2007 production GEMs are below.

LARGER RIMS ALLOW HIGHER GAINS …

The gain of the electro-chem. polished THGEM is overlapped by the gain of the kapton THGEM

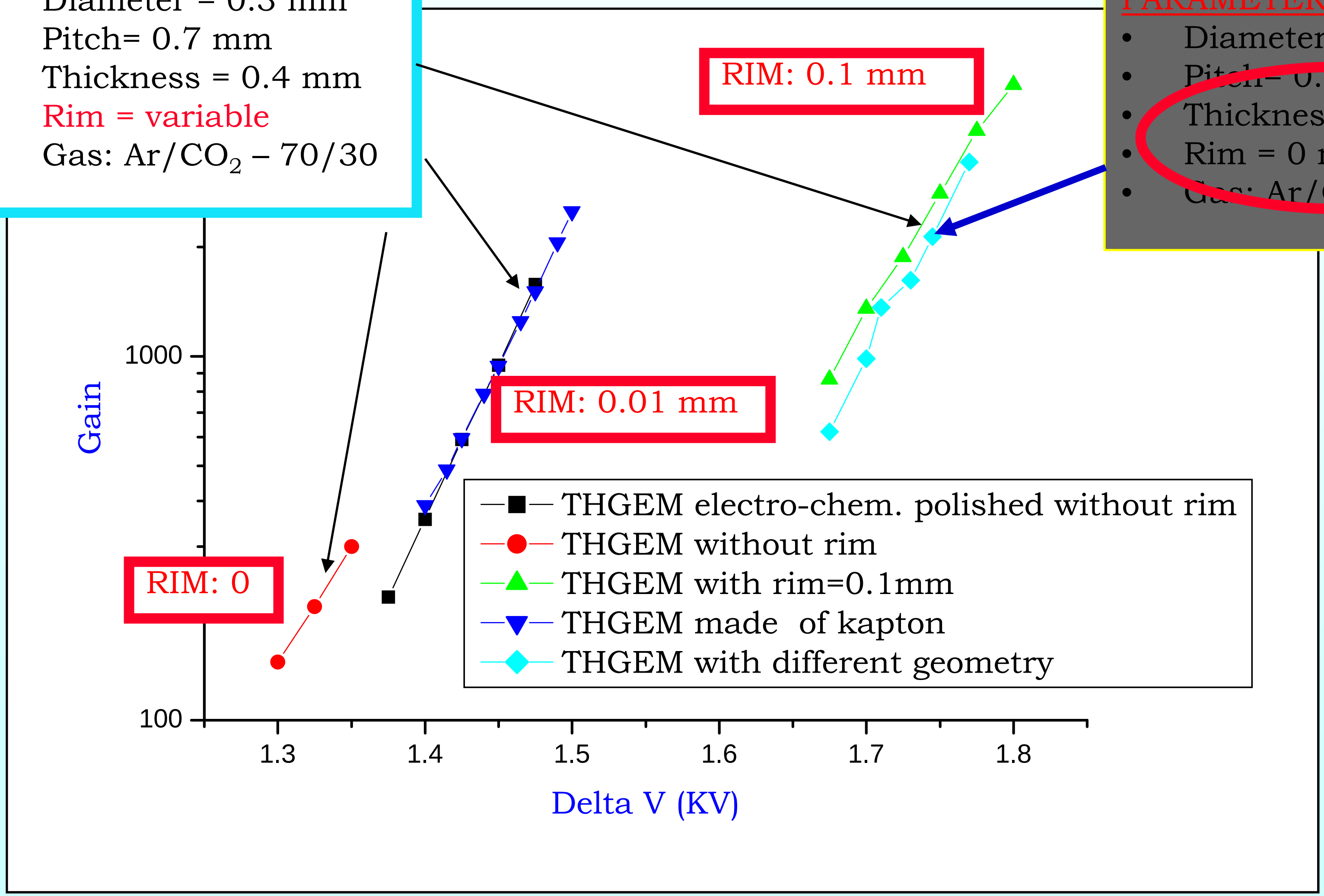
PARAMETERS:
- Diameter = 0.3 mm
- Pitch= 0.7 mm
- Thickness = 0.4 mm
- Rim = variable
- Gas: Ar/CO_2 – 70/30



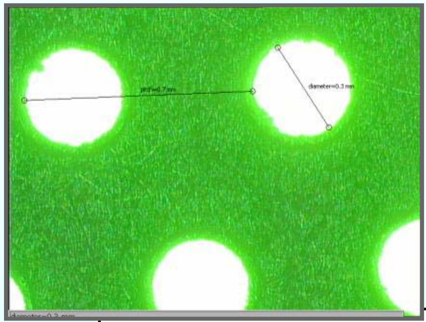
BUT INCREASING THICKNESS DOES IT TOO

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

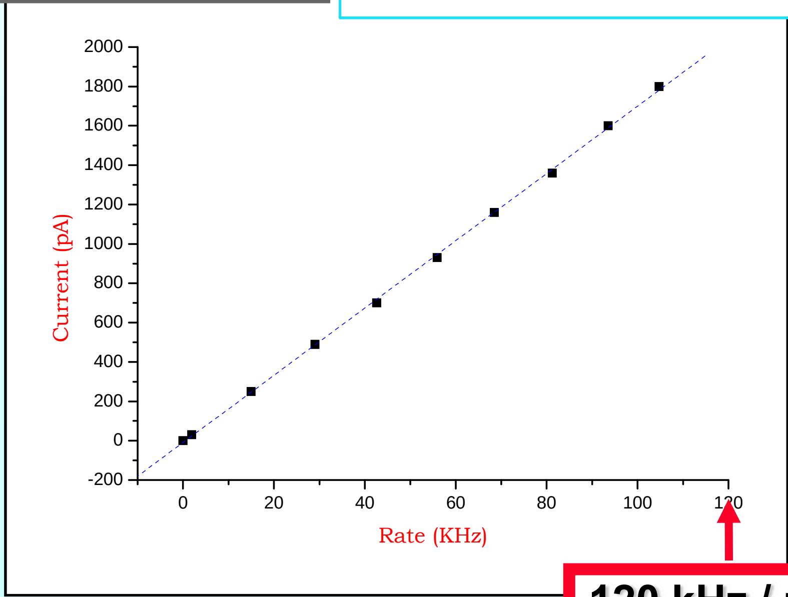
PARAMETERS:
- Diameter = 0.3 mm
- Pitch= 0.6 mm
- Thickness = 0.6 mm
- Rim = 0 mm
- Gas: Ar/CO_2 – 70/30



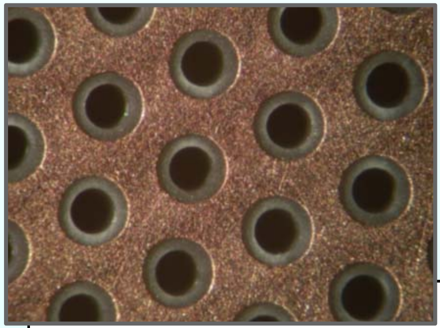
ARE THGEM DEVICES FOR HIGH RATERS ?



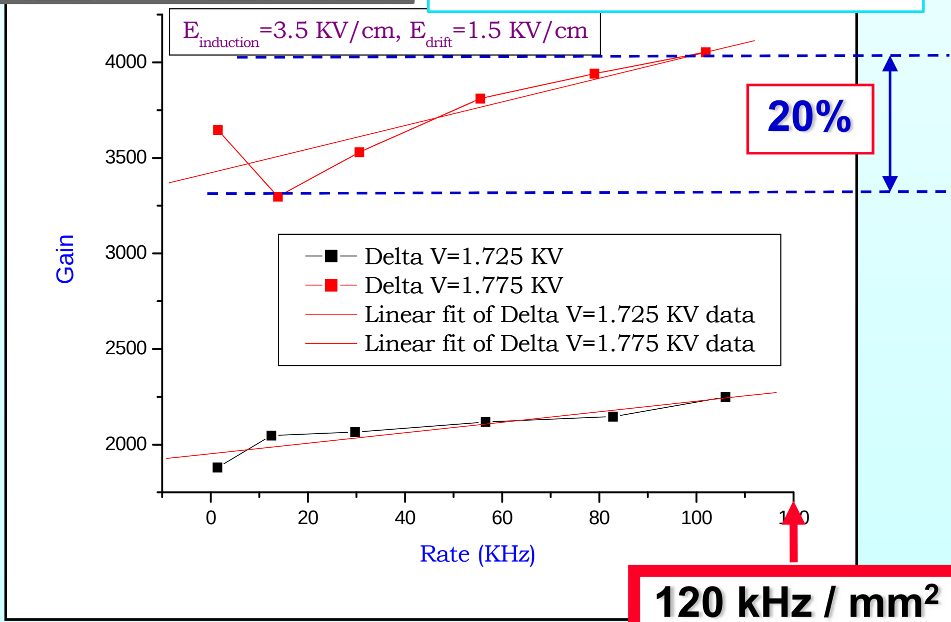
PARAMETERS:
- Diameter = 0.3 mm
- Pitch= 0.7 mm
- Thickness = 0.4 mm
- Rim = 0 mm
- Gas: Ar/CO_2 = 70/30



120 kHz / mm²



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



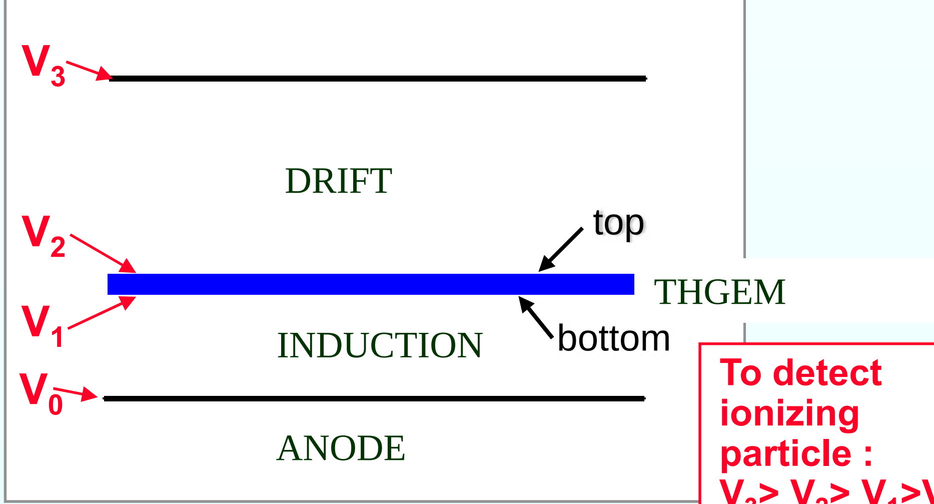
120 kHz / mm²

RECALL:
120 kHz/ mm², 300 e- → single photoelectron rates of ~35 MHz/ mm²

TUNING CHAMBER PARAMETERS

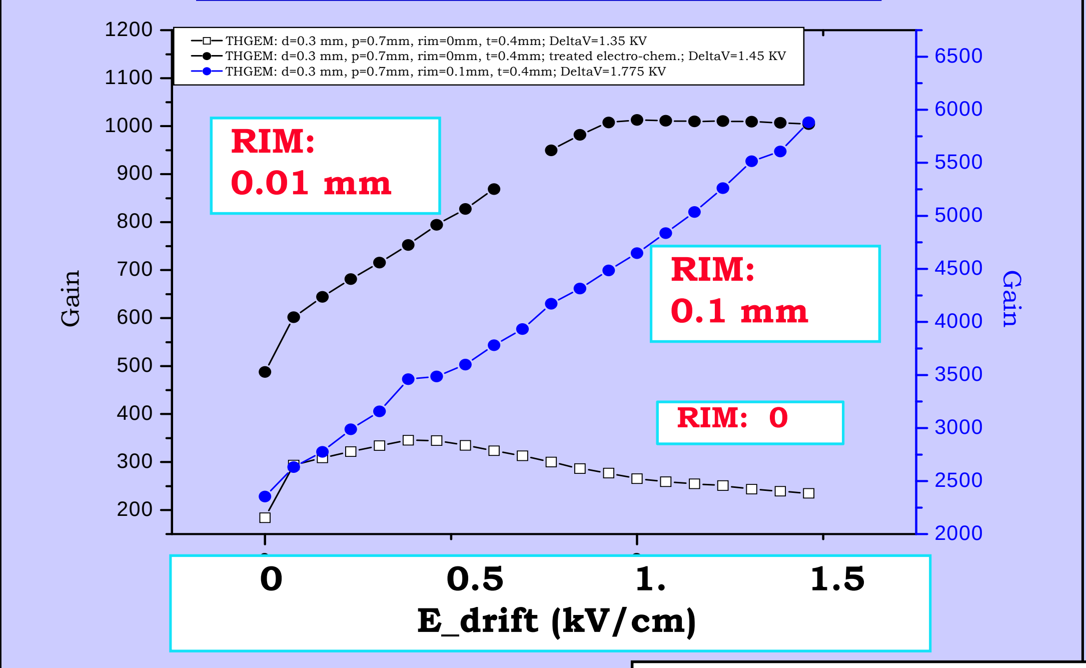
PARAMETERS:

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

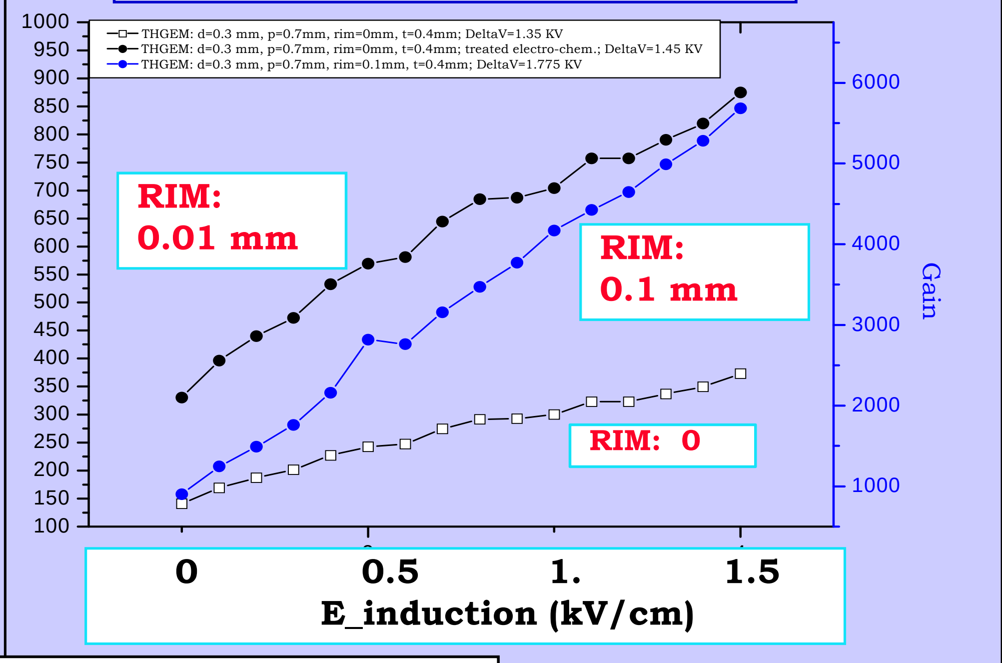


To detect ionizing particle : $V_3 > V_2 > V_1 > V_0$

DRIFT SCAN

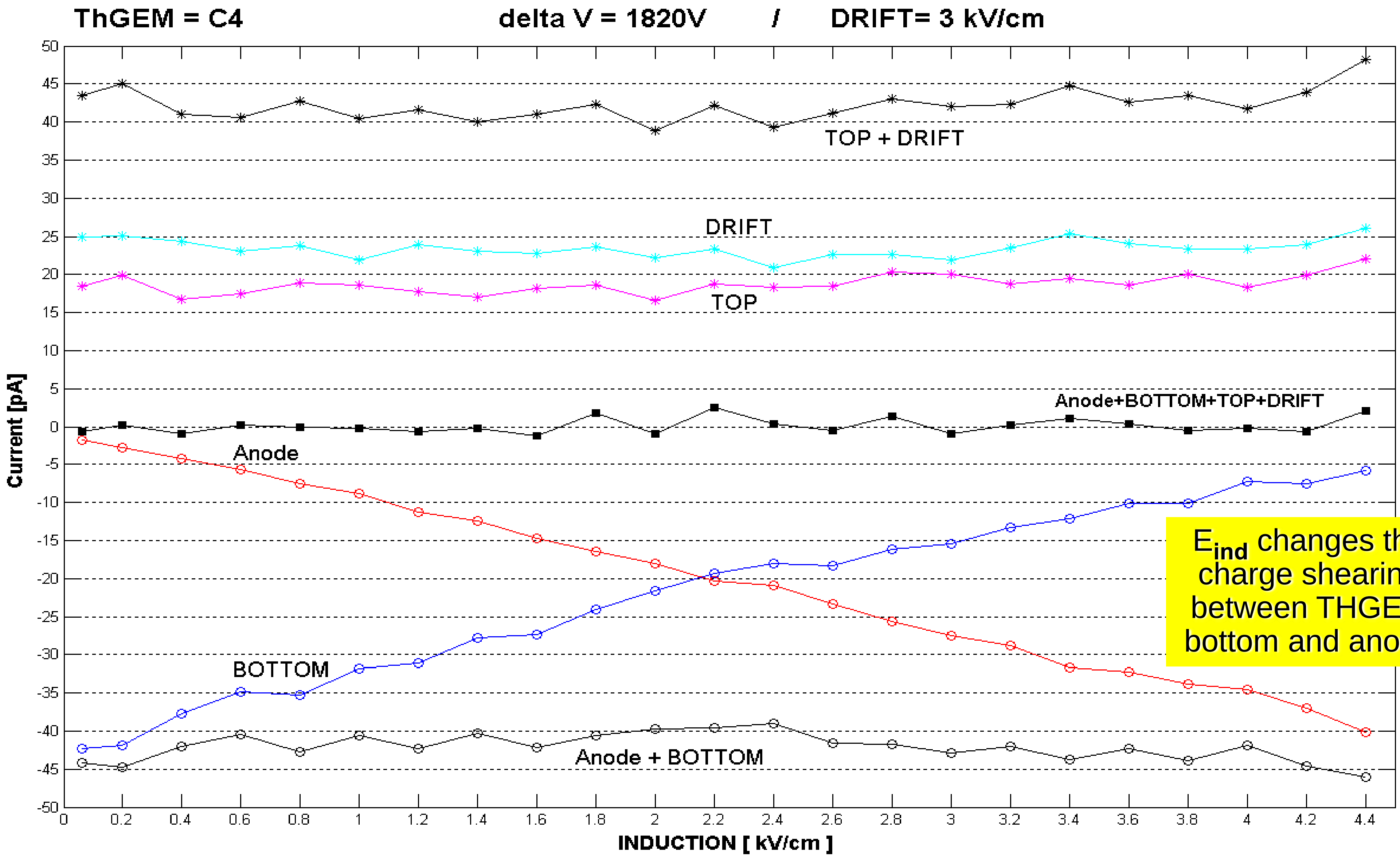


INDUCTION SCAN



X-Ray Source: ~1 mm^2, rate ~1.7KHz.

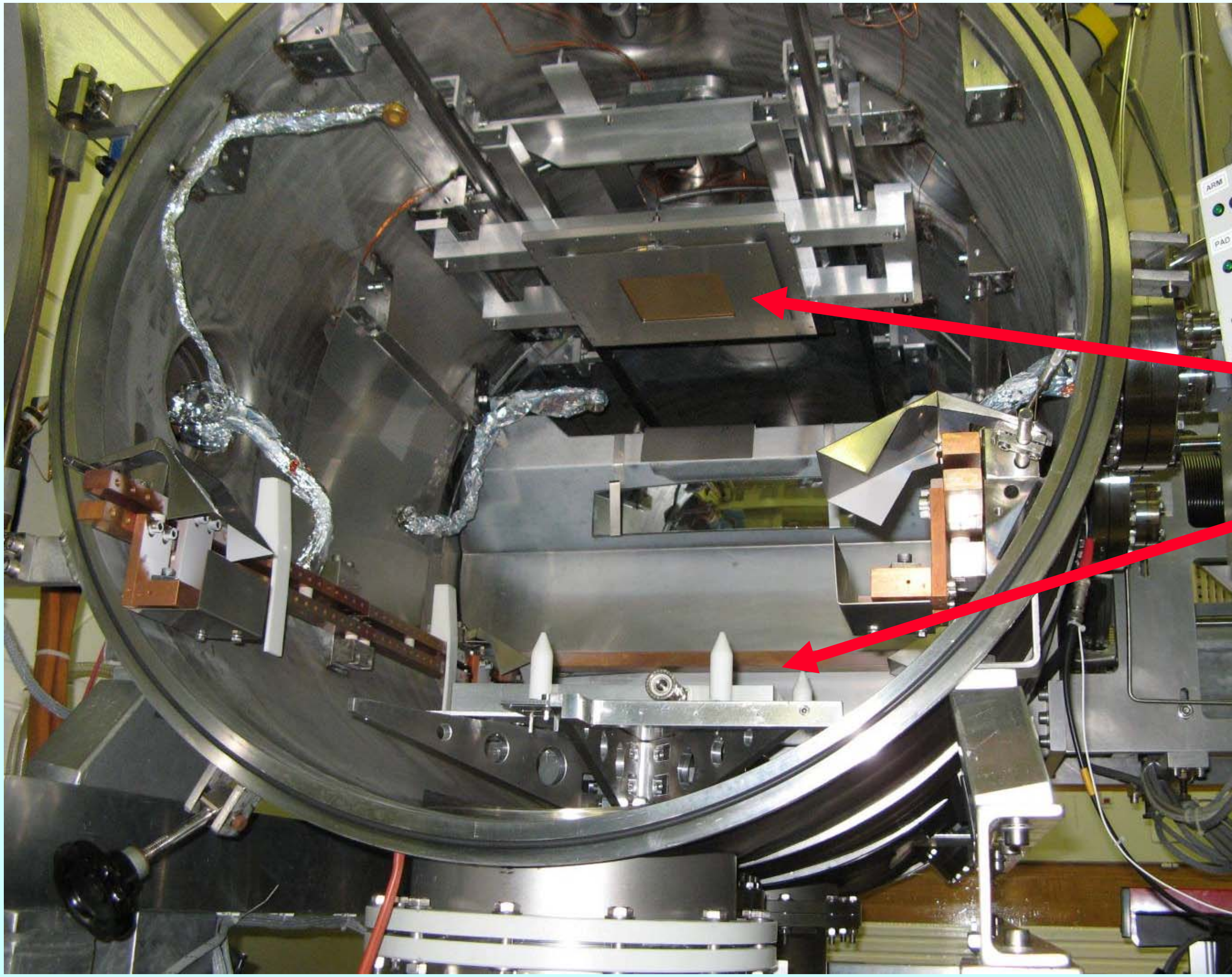
Monitoring currents during an "induction scan"

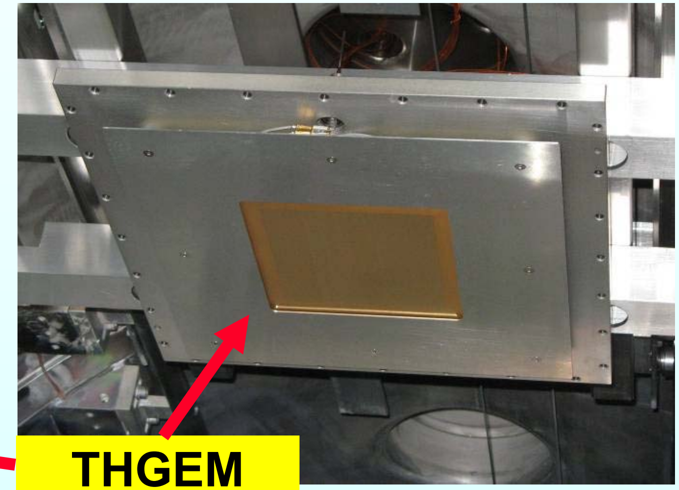


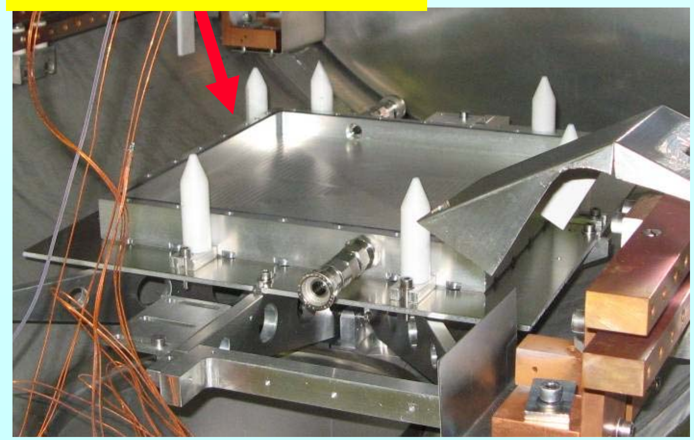
E_{ind} changes the charge shearing between THGEM bottom and anode

CsI evaporation at CERN

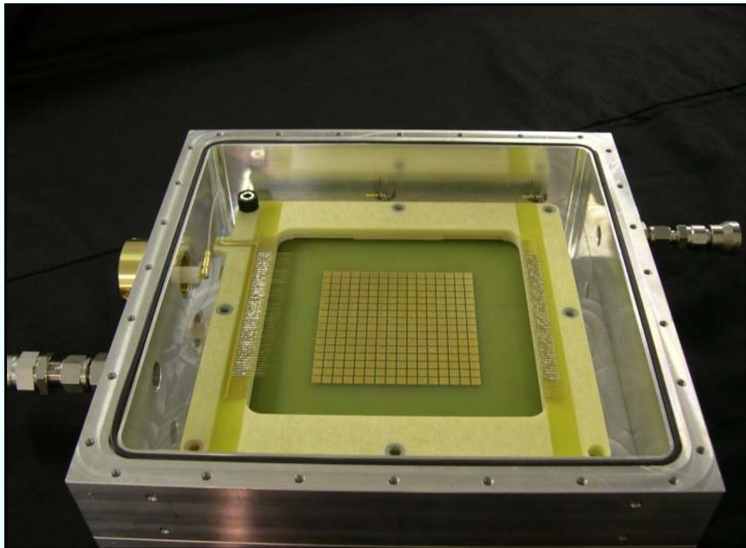
(A. Braem, C. David, M. van Stenis)

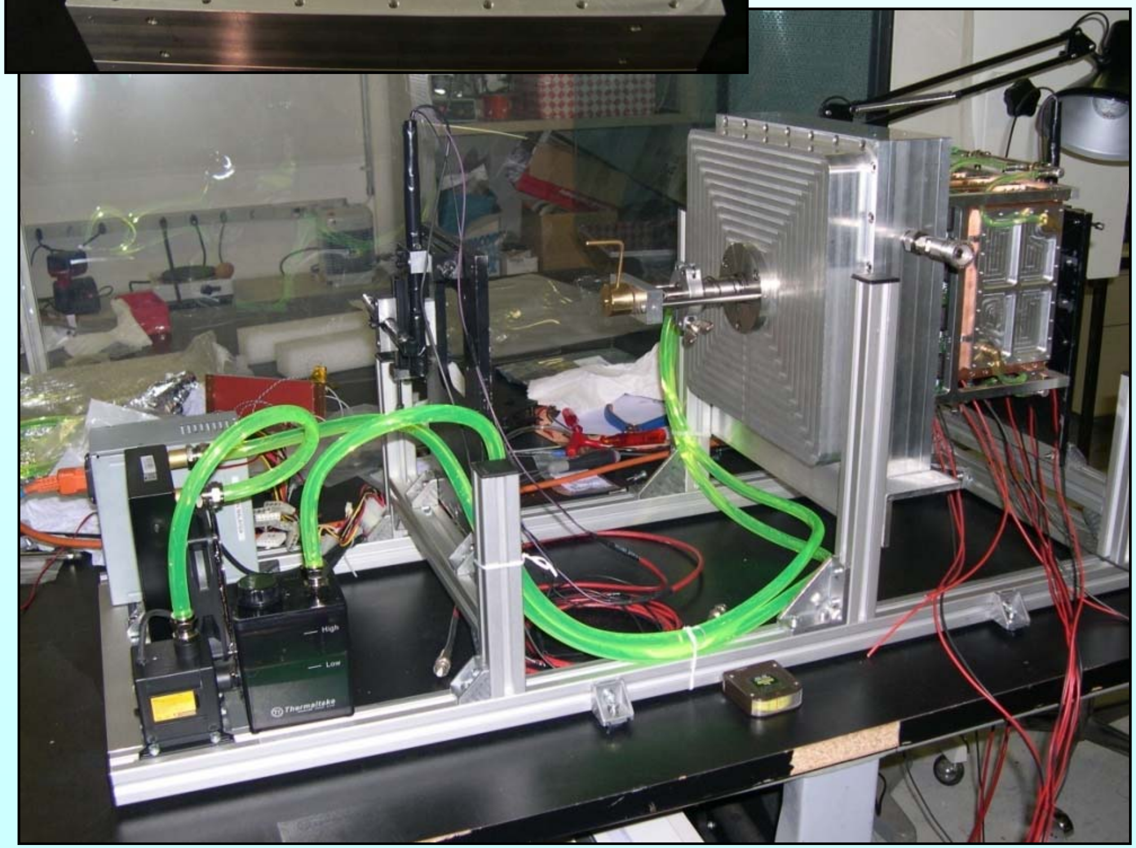


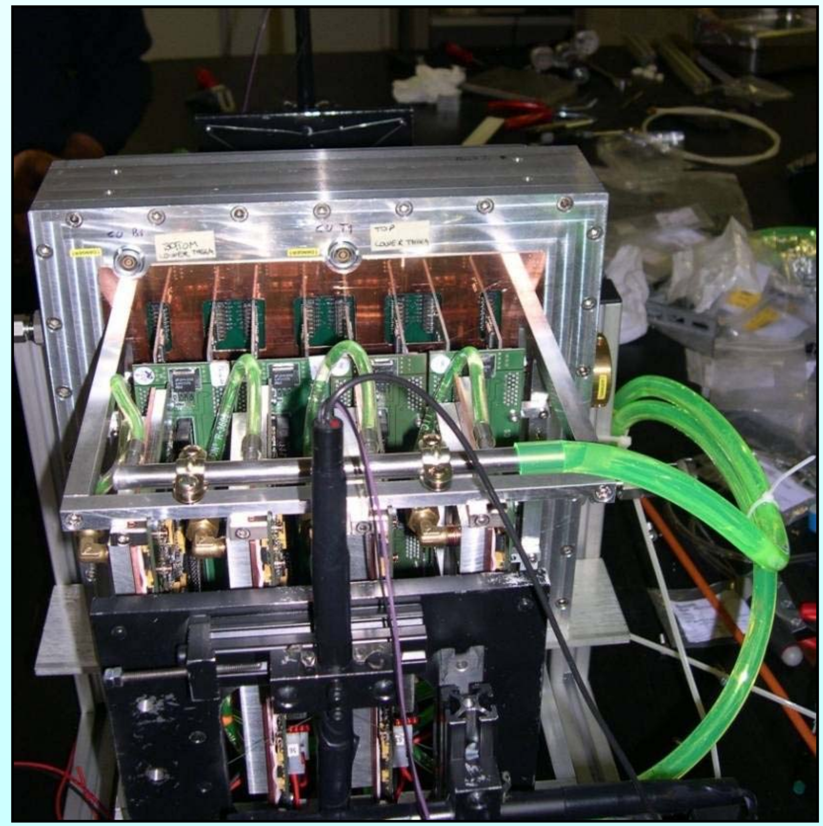




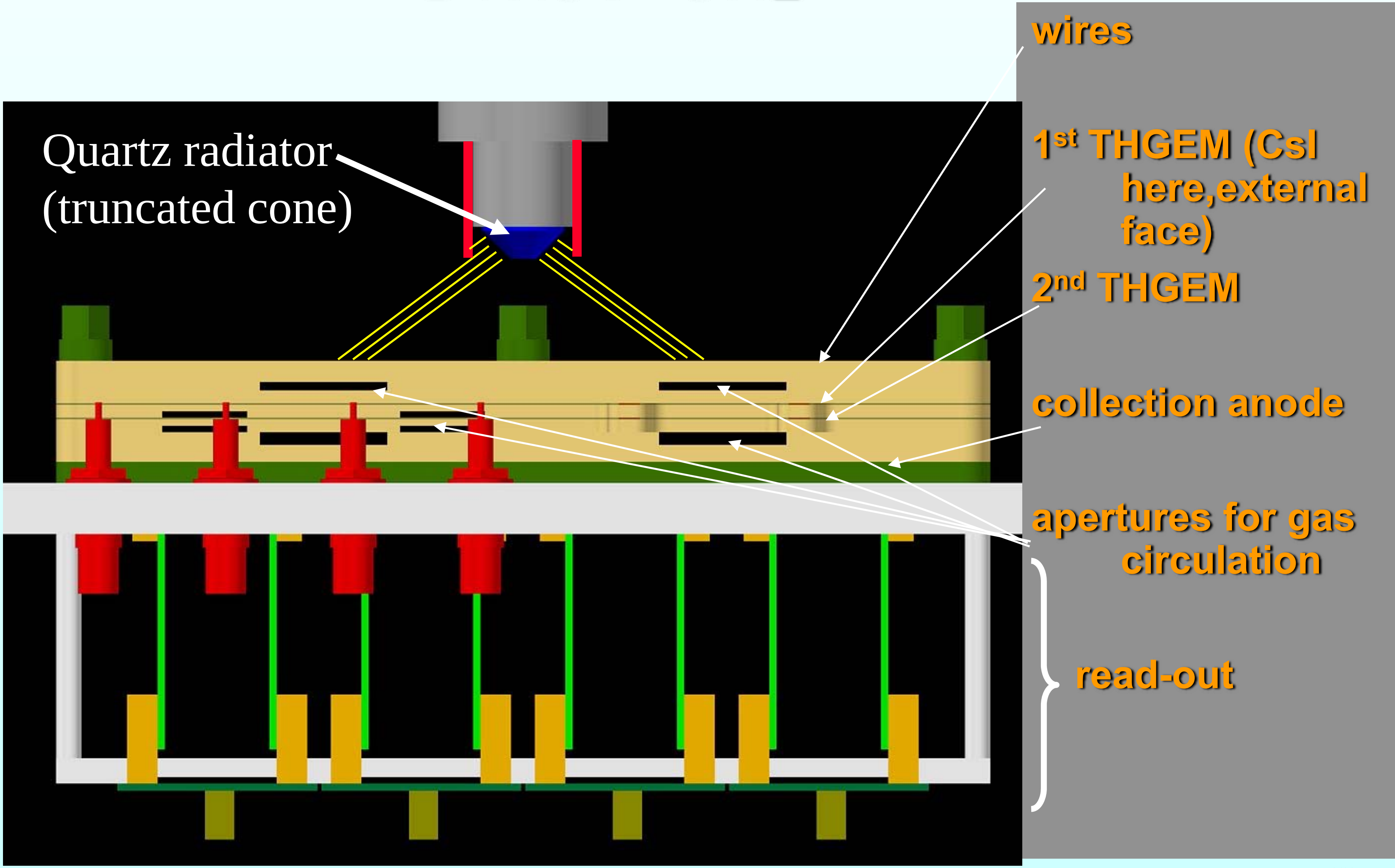
T BEAM SET-UP
MALL PROTOTYPES







THE SMALL PROTOTYPE STRUCTURE



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 of 300 x 300 mm^2 THGEMs to be individually tested, selected and glued on thin 600 x 600 mm^2 (stesalit) frames
- assemble and test a first complete “full size” prototype chamber

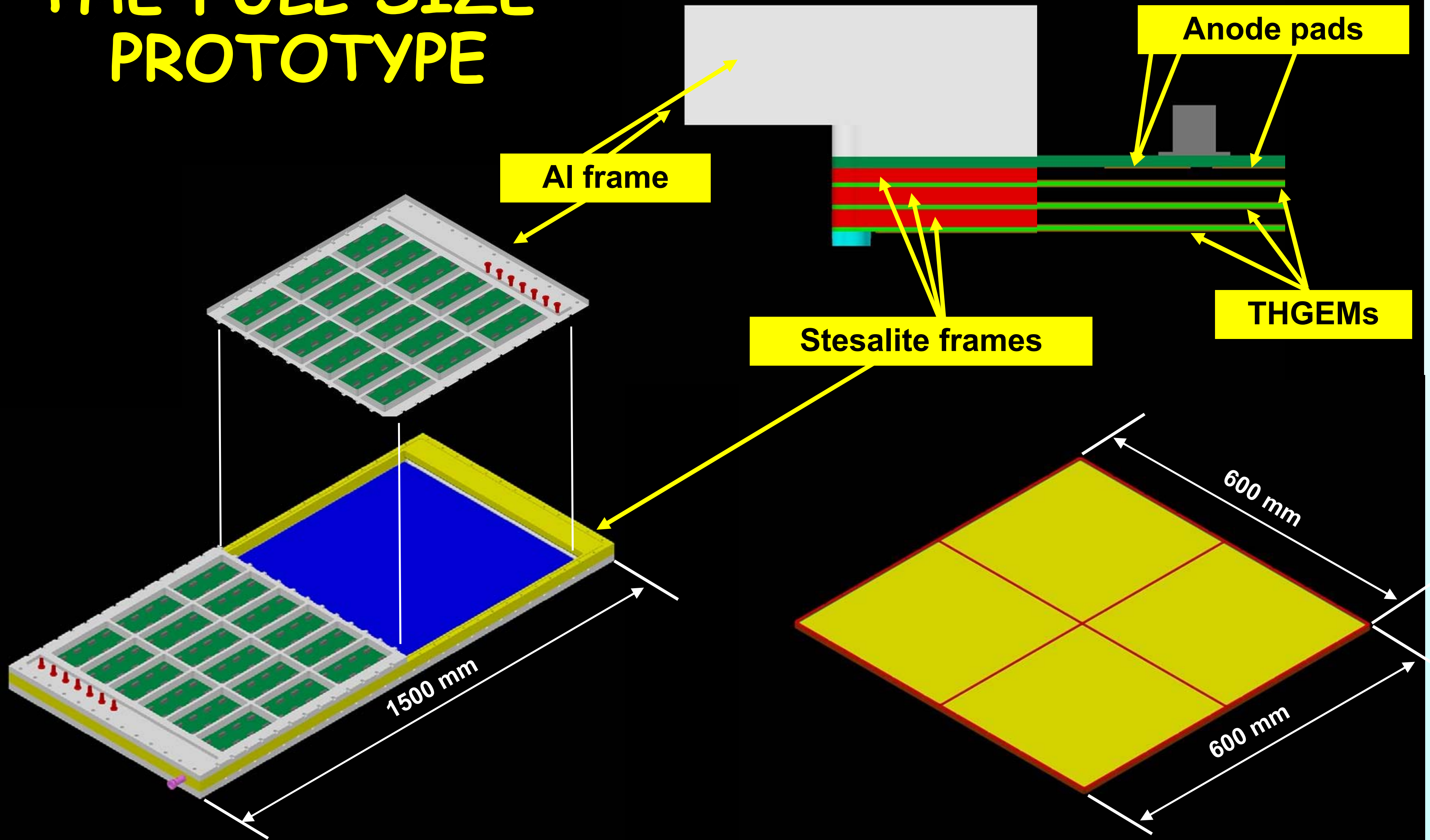
Possible medium term project:

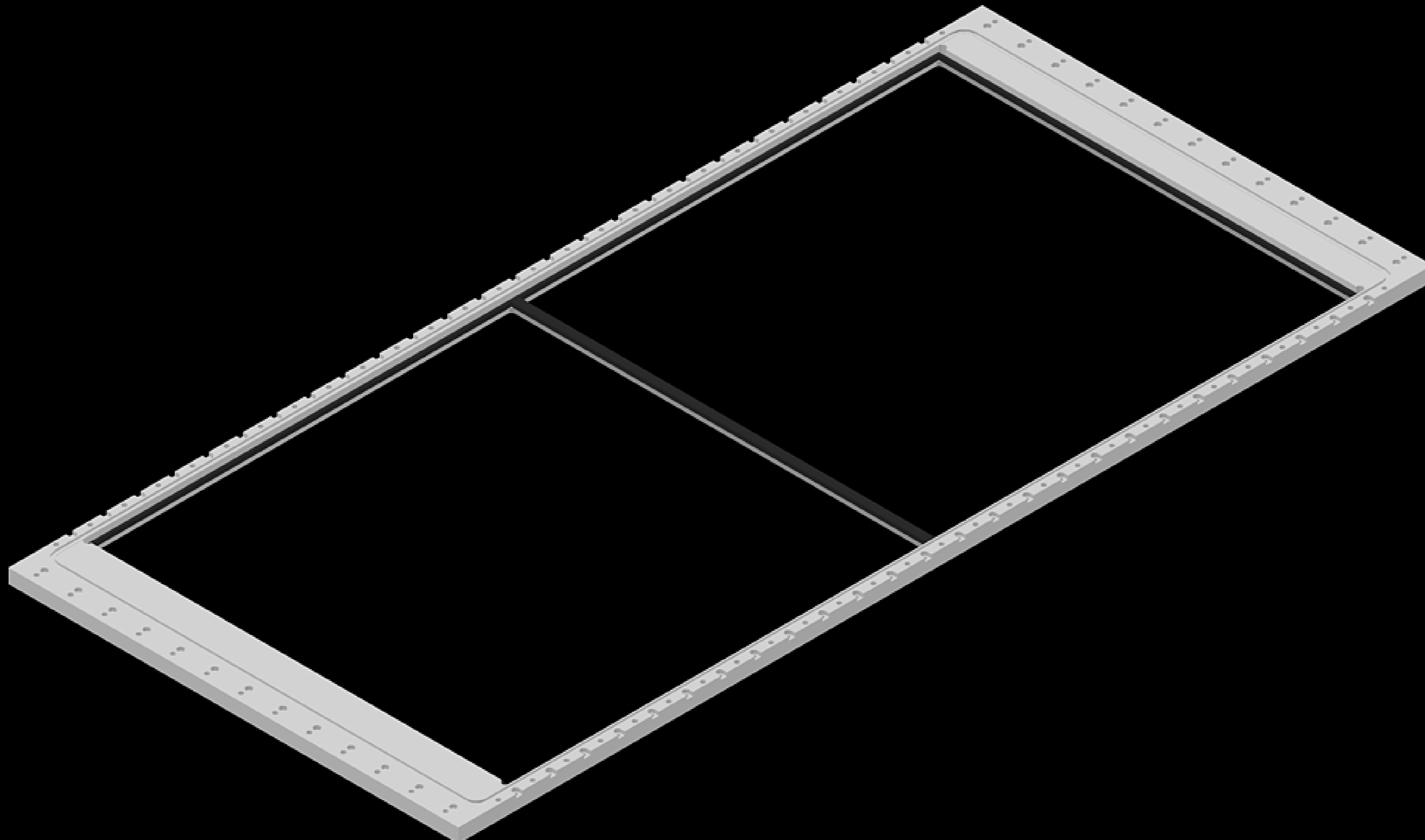
- Upgrade of COMPASS RICH (~4m^2) with the new photon detectors in case the COMPASS Collaboration decides for it.

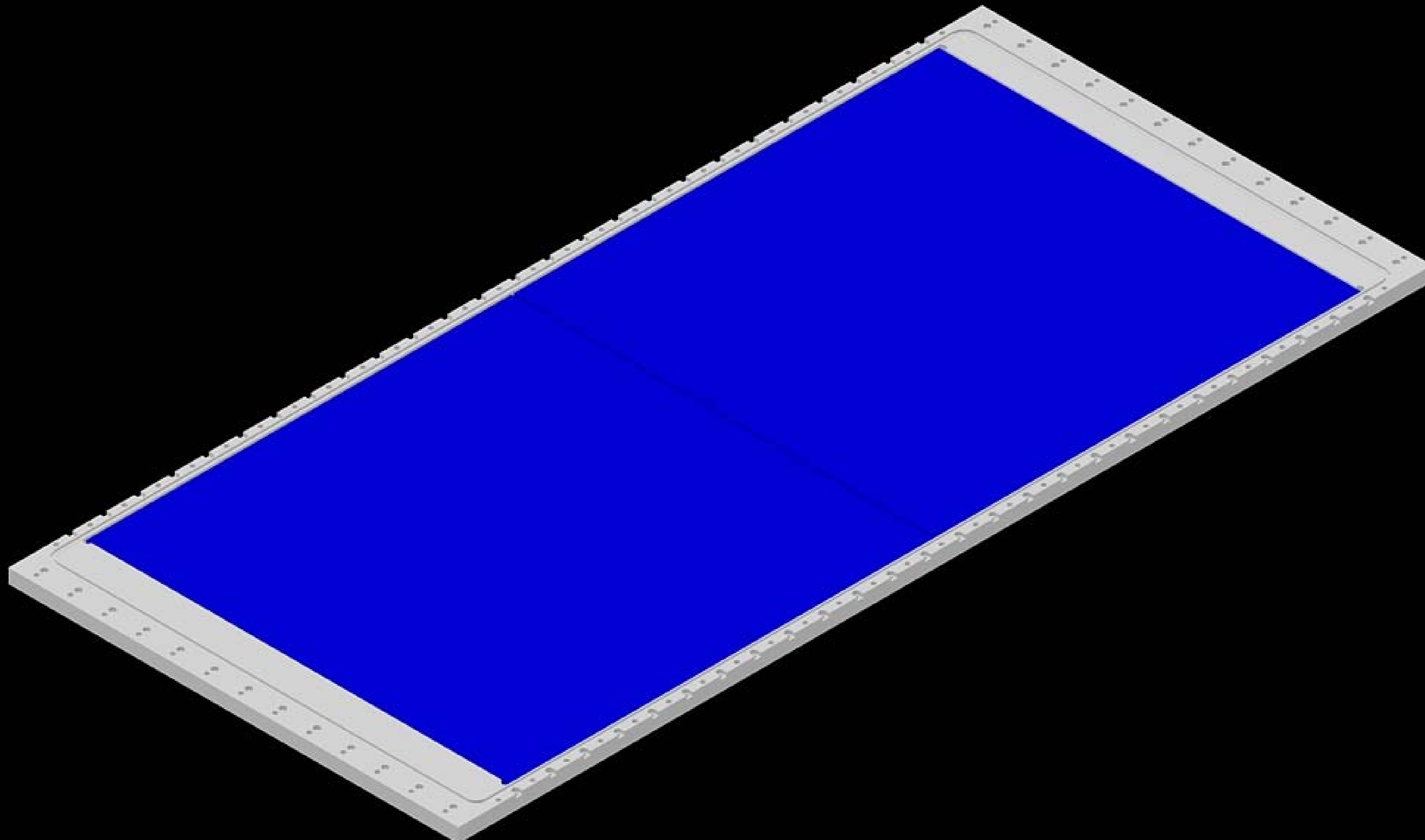
Longer term dream:

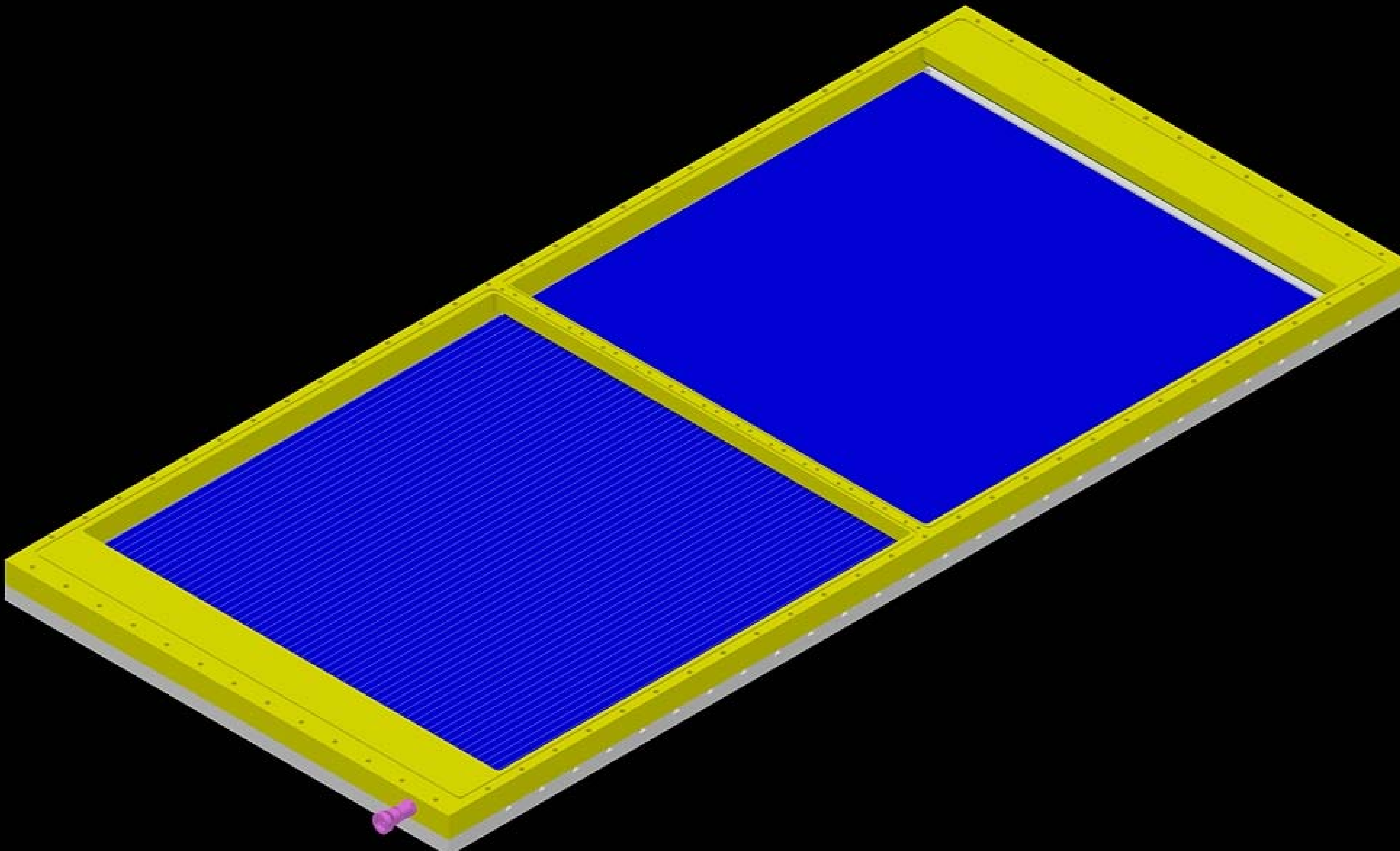
- find a configuration to reduce the ion back-flow down to $<10^{-5}$ and operate this large area detectors with visible photoconverter

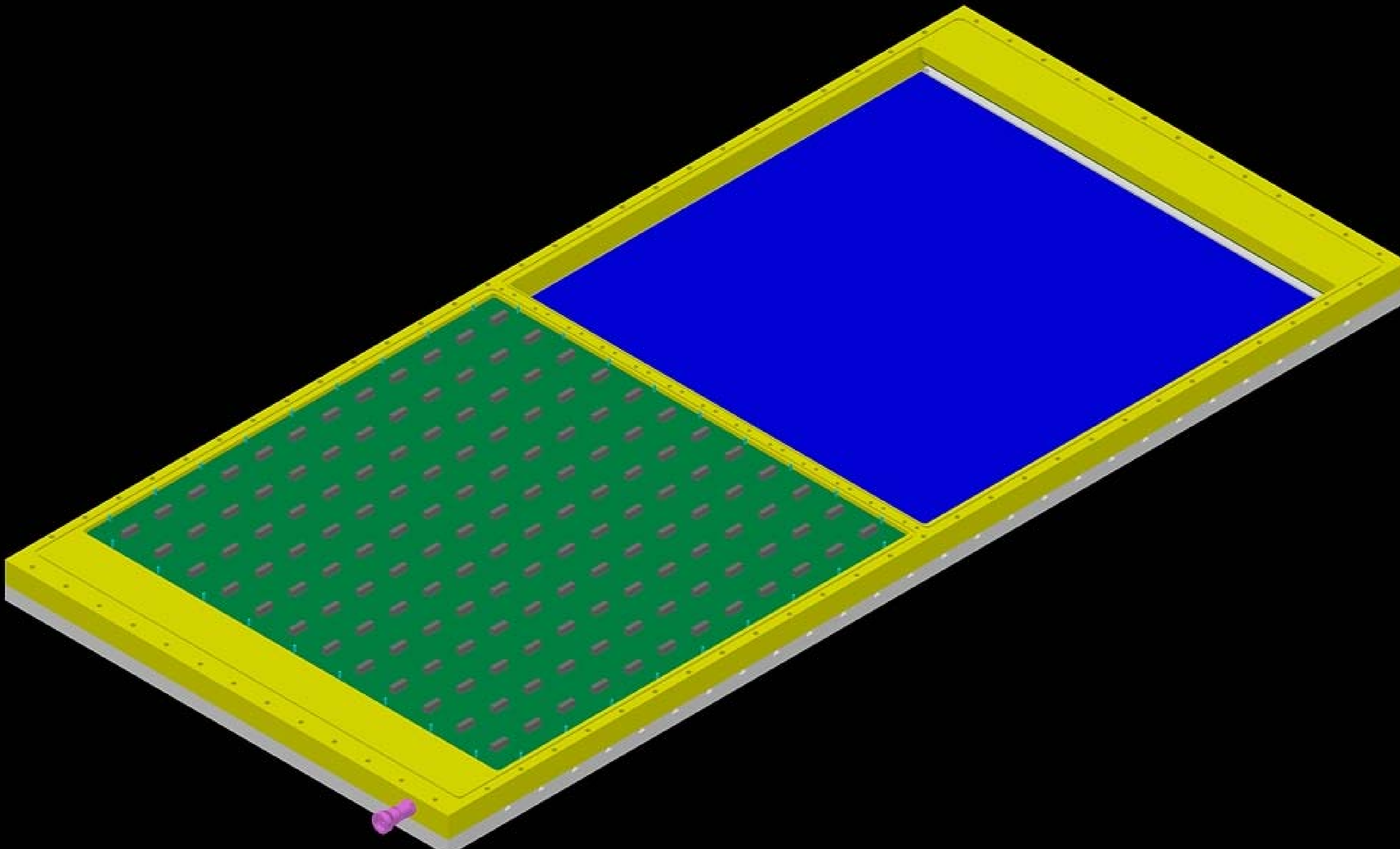
THE FULL SIZE PROTOTYPE

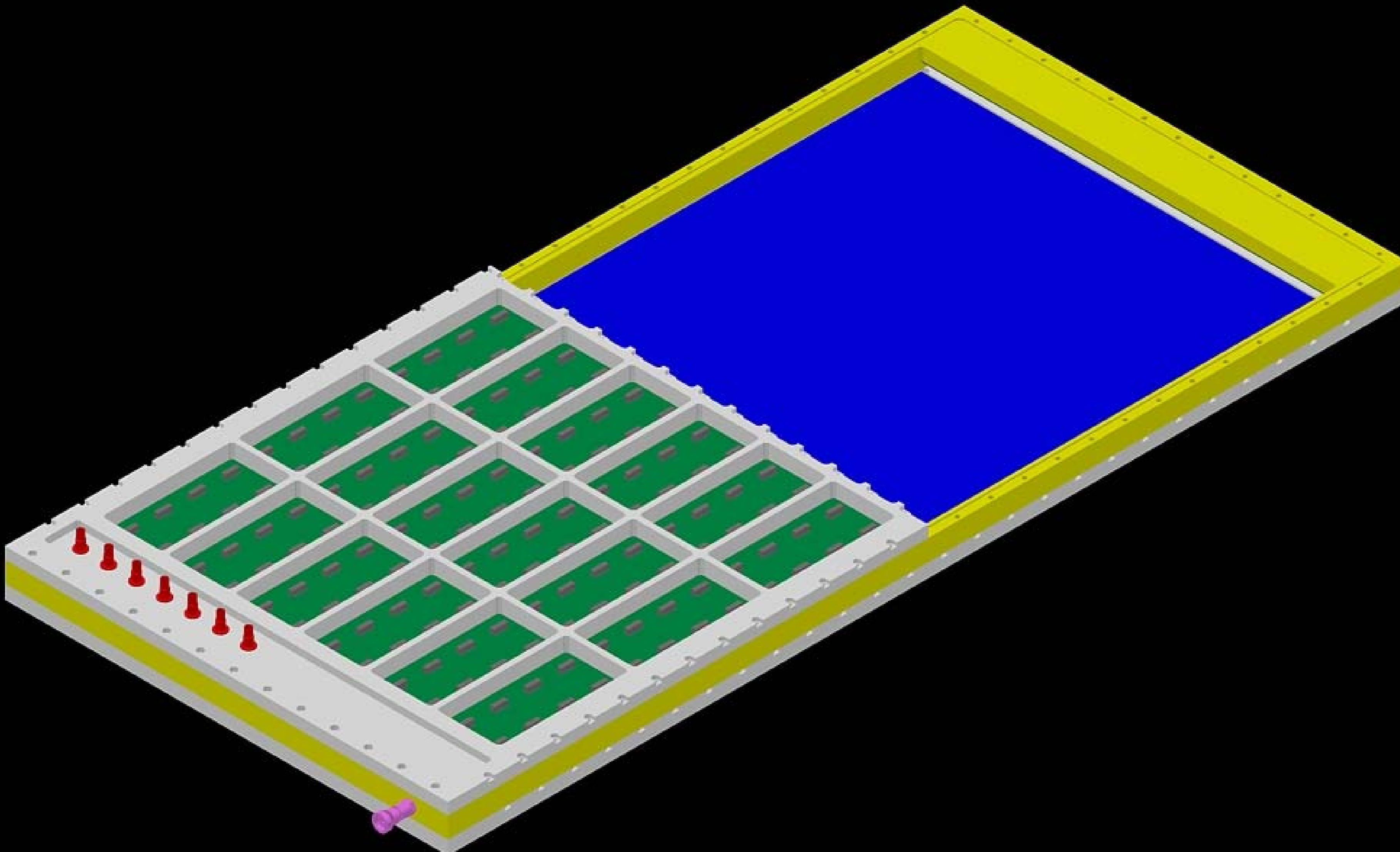












Conclusions

- 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.

Thanks to the help from many colleagues…

M. Alexeev[a], R. Birsa[b], F. Bradamante[c], A. Bressan[c], M. Chiosso[d], P. Ciliberti[c], G. Croci[e], M. Colantoni[f], S. Dalla Torre[b], S. Duarte Pinto[e], O. Denisov[f], V. Diaz[b], N. Dibiase[d], V. Duic[c], A. Ferrero[d], M. Finger[g], M. Finger Jr[g], H. Fischer[h],G. Giacomini[i],b, M. Giorgi[c], B. Gobbo[b], R. Hagemann[h], F. H. Heinsius[h], K. Königsmann[h], D. Kramer[j], S. Levorato[c], A. Maggiora[f], A. Martin[c], G. Menon[b], A. Mutter[h], F. Nerling[h], D. Panzieri[a], G. Pesaro[c], J. Polak[b],j, E. Rocco[d], L. Ropelewski[e], P. Schiavon[c], C. Schill[h], M. Slunecka[j], F. Sozzi[c], L. Steiger[j],M. Sulc[j], M. Svec[j], S. Takekawa[c], F. Tessarotto[b], H. Wollny[h]

a INFN, Sezione di Torino and University of East Piemonte, Alessandria, Italy
b INFN, Sezione di Trieste, Trieste, Italy
c INFN, Sezione di Trieste and University of Trieste, Trieste, Italy
d INFN, Sezione di Torino and University of Torino, Torino, Italy
e CERN, European Organization for Nuclear Research, Geneva, Switzerland
f INFN, Sezione di Torino, Torino, Italy
g Charles University, Prague, Czech Republic and JINR, Dubna, Russia
h Universität Freiburg, Physikalisches Institut, Freiburg, Germany
i University of Bari, Bari, Italy
j Technical University of Liberec, Liberec, Czech Republic