Seminario Nazionale Rivelatori Innovativi

TRIESTE 18-22/10/2010

INTRODUCTION TO THE THGEM LABORATORY

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THGEM R&D is work in progress

please, keep in mind that

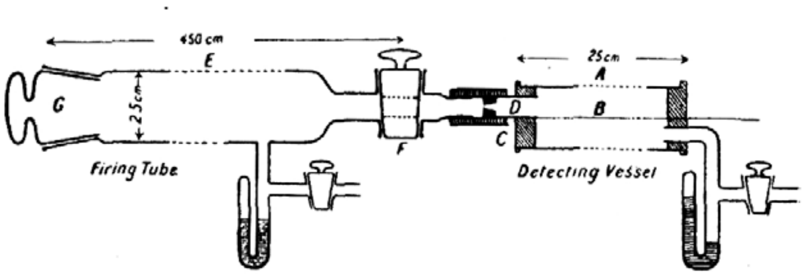
in particular our goal, namely

THGEM-based photon detectors

are not yet there

100 years of gaseous detector developments

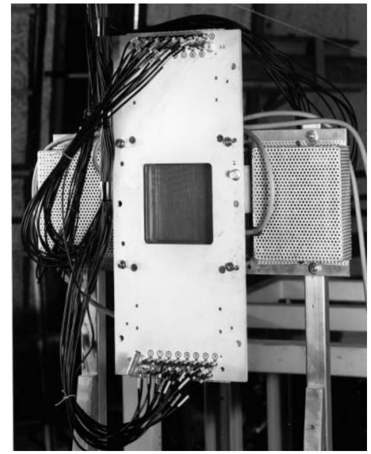
1908: FIRST WIRE COUNTER
USED BY RUTHERFORD IN THE STUDY OF NATURAL RADIOACTIVITY

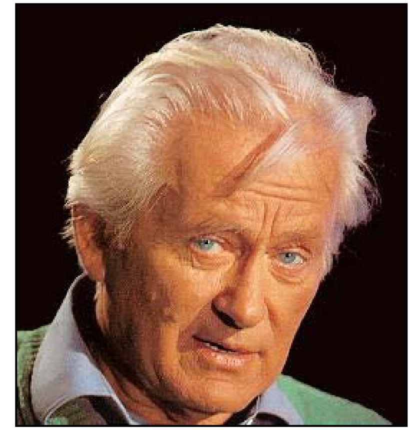


E. Rutherford and H. Geiger ,
Proc. Royal Soc. A81 (1908) 141

Nobel Prize in Chemistry in 1908

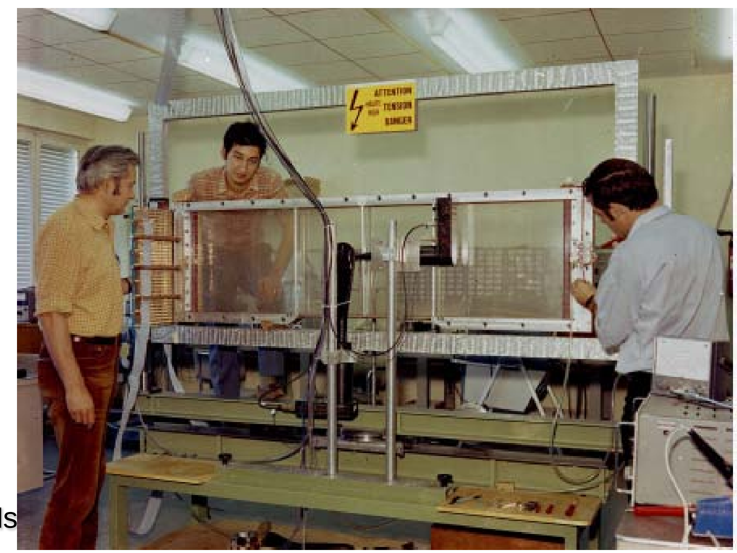
1968: MULTIWIRE PROPORTIONAL CHAMBER



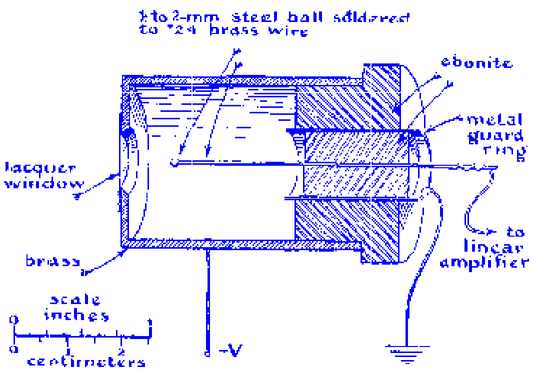


Nobel Prize in 1992

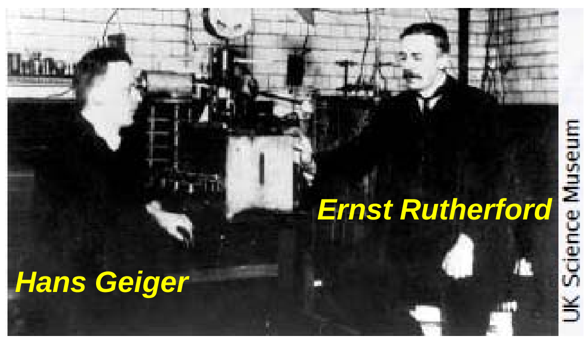
G. Charpak, Proc. Int. Symp. Nuclear Electronics
(Versailles 10-13 Sept 1968)

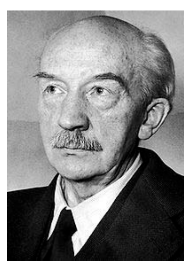


1928: GEIGER COUNTER
SINGLE ELECTRON SENSITIVITY



H. Geiger and W. Müller,
Phys. Zeits. 29 (1928) 839

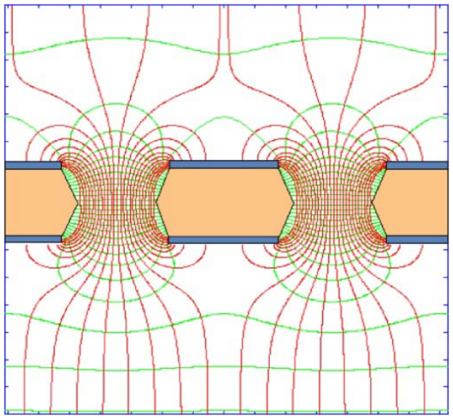




Walther Bothe
Nobel Prize in
1954 for the
"coincidence
method"

Recent gaseous detector development: GEM

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

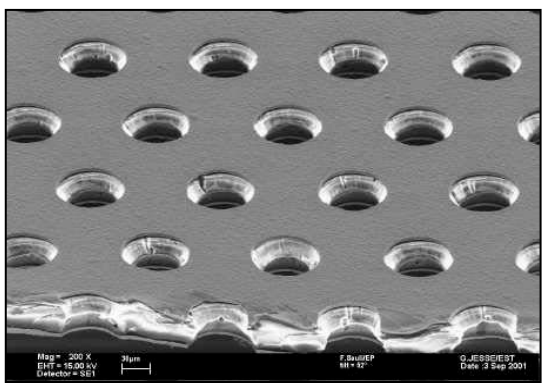


Many advantages:

high rate capability,

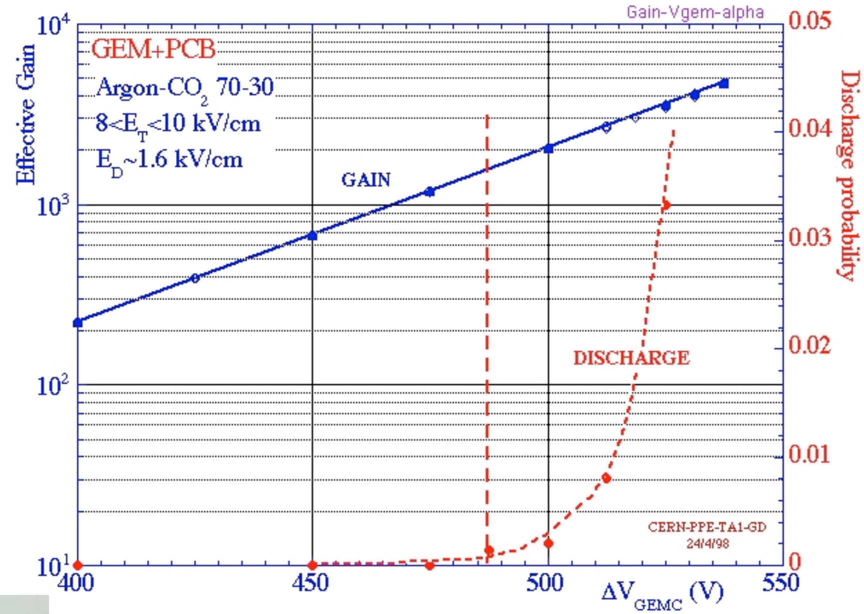
good space resolution,

good time resolution

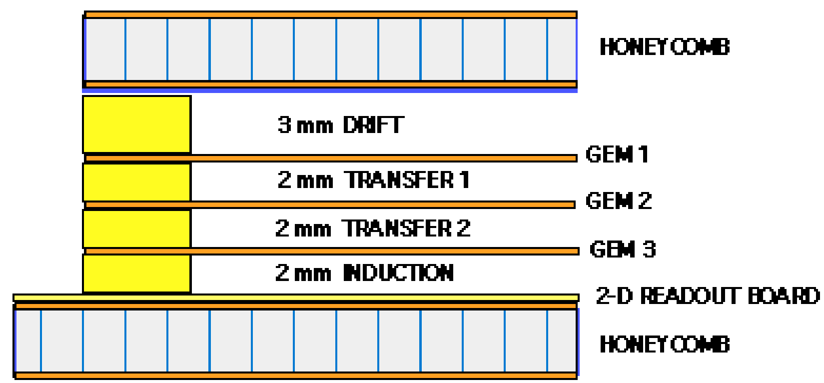


F. Sauli, Nucl. Instr. Meth. A 386(1997)531

COMPASS TRIPLE THGEM:



A. Bressan et al, Nucl. Instr. and Meth. A424(1999)321



B. Ketzer et al, Nucl. Instr. and Meth. A535(2004)314

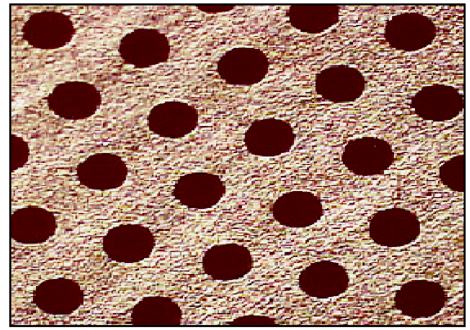
THGEM R&D

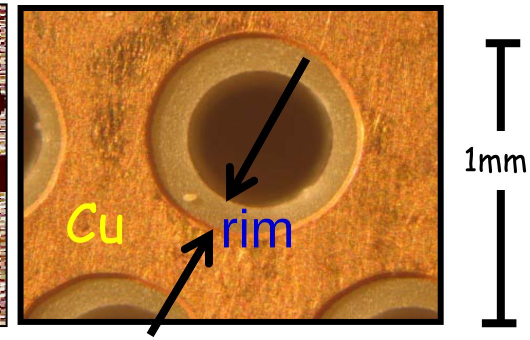
THGEMs (Thick GEM)
are elctron multipliers derived from GEM concept changing the production technology

manufactured through standard PCB techniques

drilling holes **in G-10 and applying** Cu etching

GEM	THGEM
Max 10^3 gain in single GEM	Max 10^5 gain in single-THGEM





FROM LITERATURE:

Gain 10^4-10^5 (single electrons)
Rise time < 10ns
Rate capability: 10MHz/mm^2

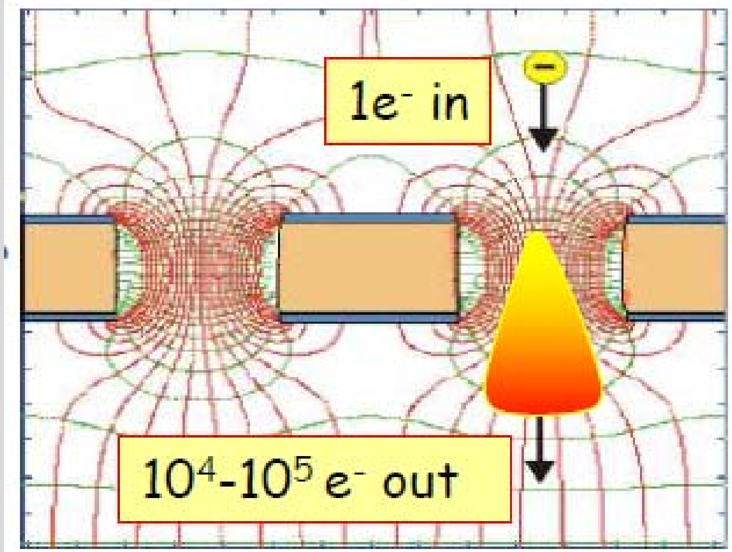
Insensitive to magnetic fields

Invented by:
- Weizmann group: A. Breskin et al.

and also by:
- V. Peskov,

L. Periale et al., NIM A478 (2002) 377

P. Jeanneret, PhD thesis, 2001



THGEM APPLICATION FIELDS

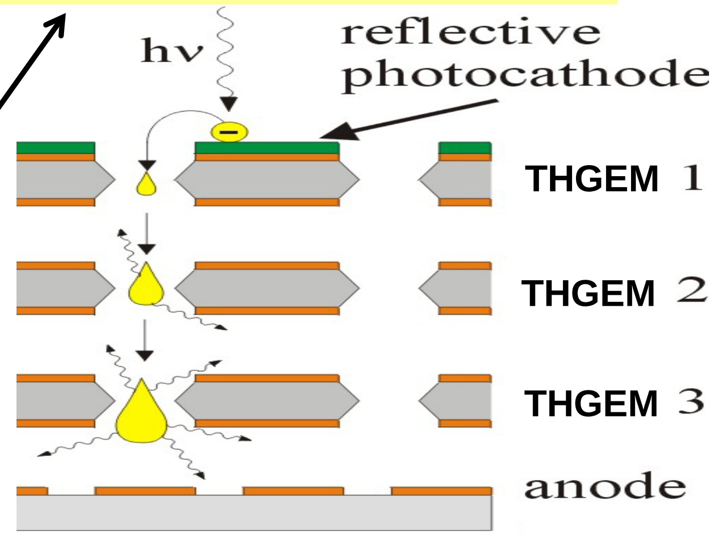
Some features

- Space resolution ~ 1mm
- Time resolution ~ 10 ns
- Non negligible material budget (a THGEM is a PCB, thickness 0.4-0.6 mm)

What is appealing

- Industrial production
- Moderate cost
- Robustness
- Large size availability
- Insensitivity to magnetic field

OUR APPLICATION: DETECTION OF SINGLE CHERENKOV PHOTON



Applications:

- Sampling calorimetry
- Muon tracking
- Photon detection (in Cherenkov imaging counters)

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)

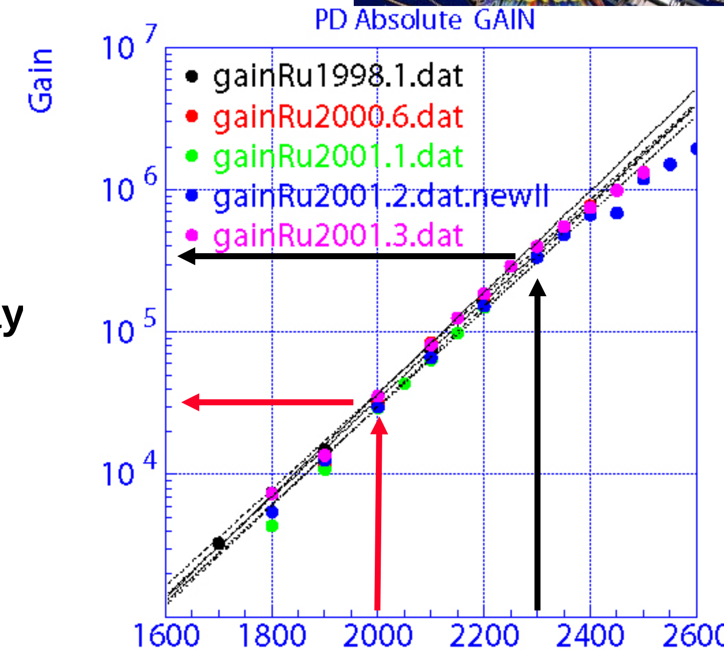
Whenever a severe discharge happens, recovery takes ~1 day

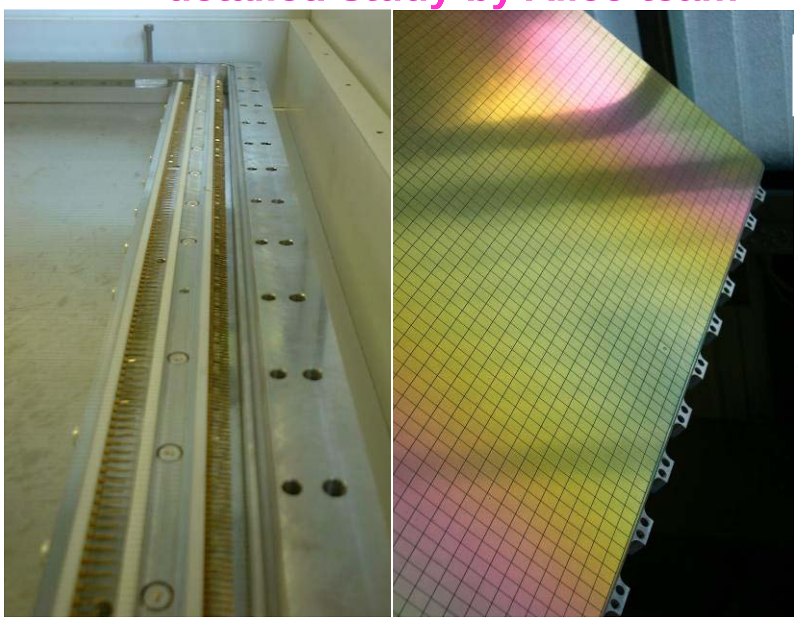
Similar behavior reported from JLAB Hall-A

2) Photocathode aging:

- our information from accidental contamination

- detailed study by Alice team

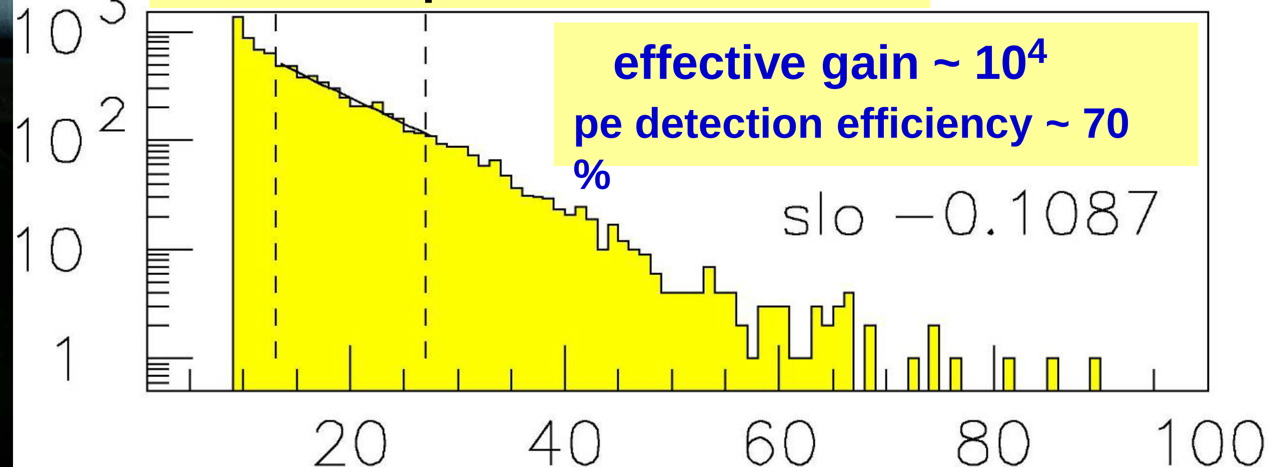




cluster amplitude distribution:

effective gain ~ 10^4

pe detection efficiency ~ 70 %



Our path towards THGEM-based PDs

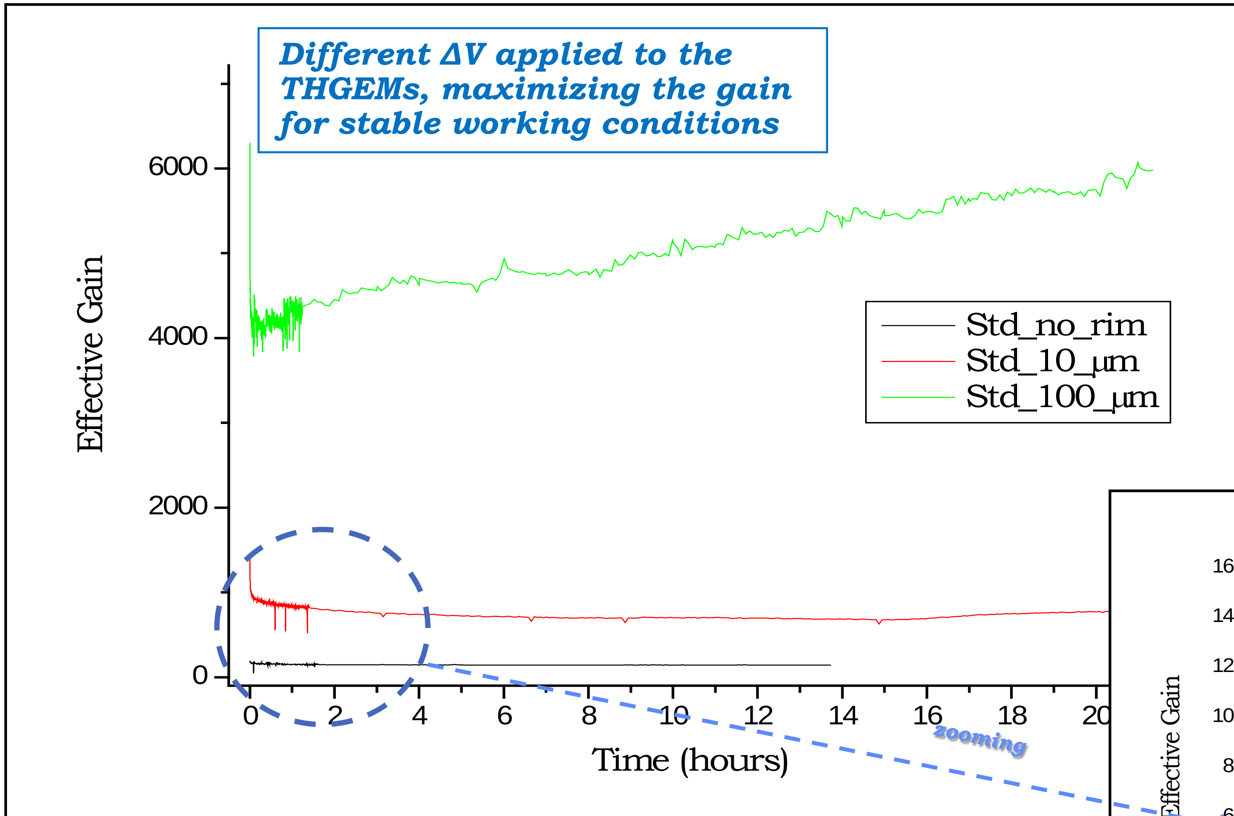
Characterization

Gain stability and geometrical parameters	completed, OK
THGEM production techniques	completed, OK
Effective QE in THGEM-based PDs	well advanced, ~OK
Photon detection and gain request	well advanced, ~OK
Time properties	well advanced, ~OK
Ion feed-back	in progress

Engineering

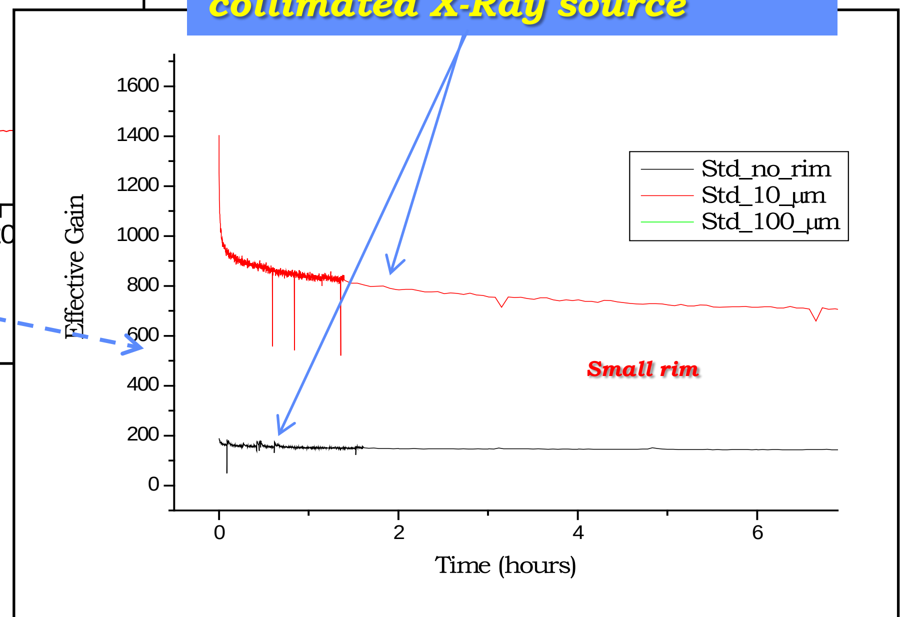
Construction and test of small prototype detectors	completed, OK
THGEM segmentation and discharges control	in progress
High voltage supply and distribution	in progress
Large surface THGEM boards	in progress
Large surface THGEM-based detectors	in progress

GAIN (IN)STABILITY STUDY



- A factor >>2 in gain variation between the initial drop and the stabilization;
- Different behaviour for THGEMs with and without (or small) rim.

Continuously irradiated with collimated X-Ray source



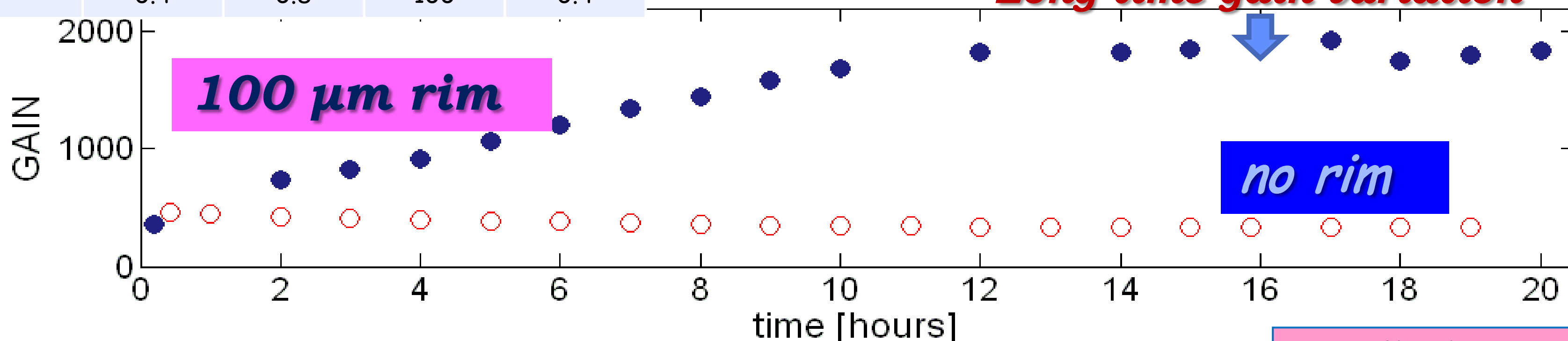
Name	Diam (mm)	Pitch (mm)	Rim (μm)	Thick (mm)
Std_no_rim	0.3	0.7	0	0.4
Std_10_μm	0.3	0.7	10	0.4
Std_100_μm	0.3	0.7	100	0.4

THE ROLE OF THE RIM

Name	Diam (mm)	Pitch (mm)	Rim (µm)	Thick (mm)
M1	0.4	0.8	0	0.4
C4	0.4	0.8	100	0.4

^{55}Fe source; uniform irradiation

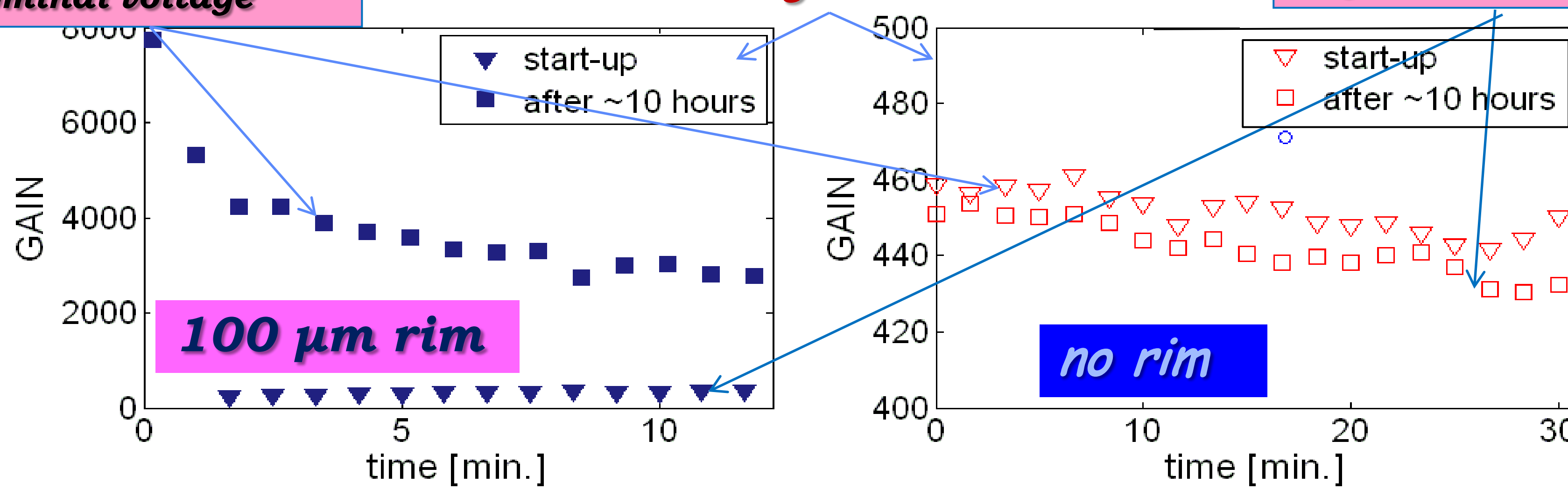
Long time gain variation



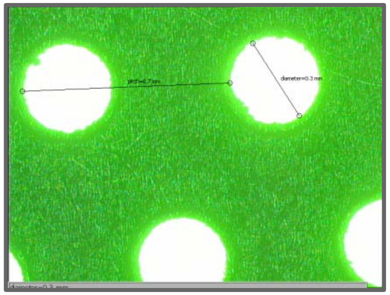
START IRRADIATING after ~10 hours at nominal voltage

Short time gain variation

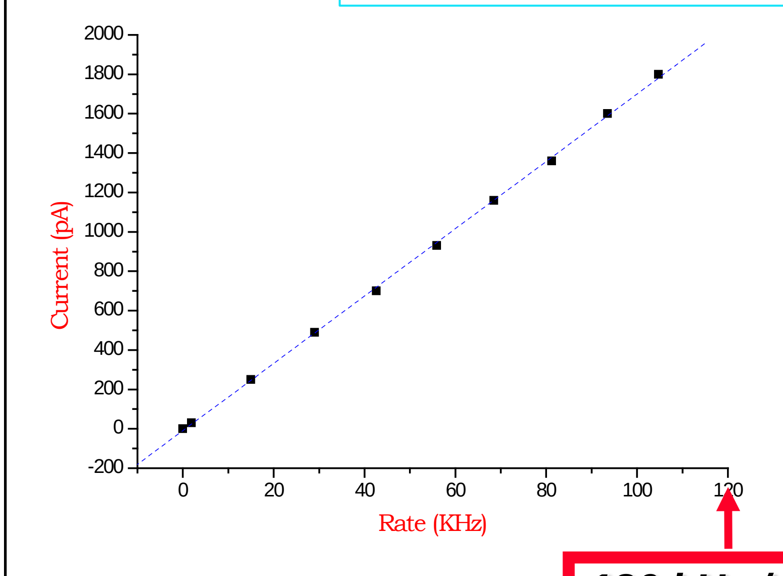
Irradiation at HV switch on, after ~1 day with no voltage



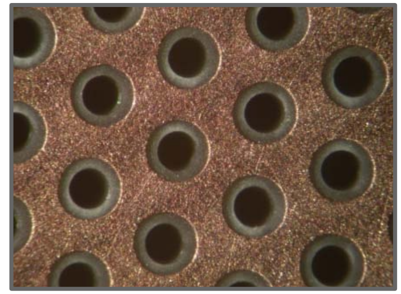
RATE CAPABILITY



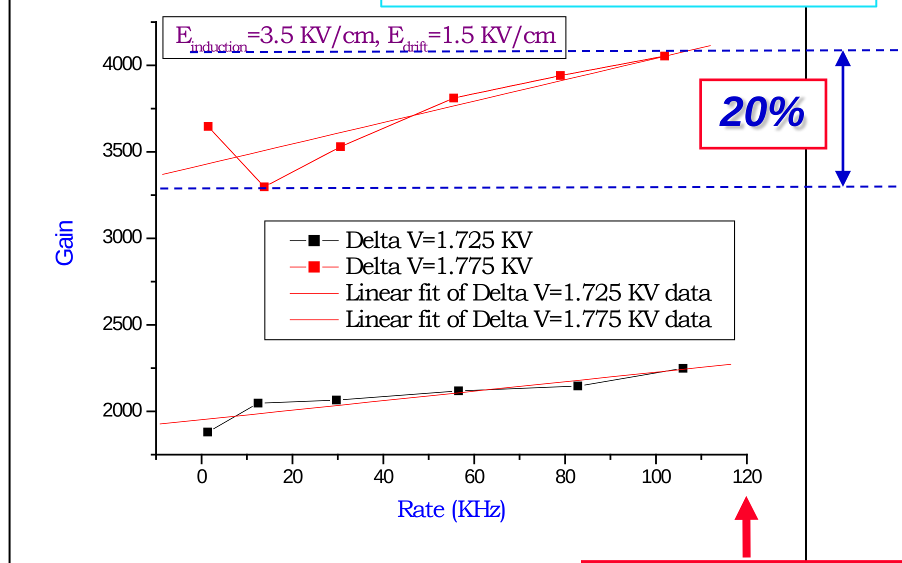
PARAMETERS:
- *Diameter = 0.3 mm*
- *Pitch= 0.7 mm*
- *Thickness = 0.4 mm*
- *Rim = 0 mm*
- *Gas: Ar/CO_2 – 70/30*



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*

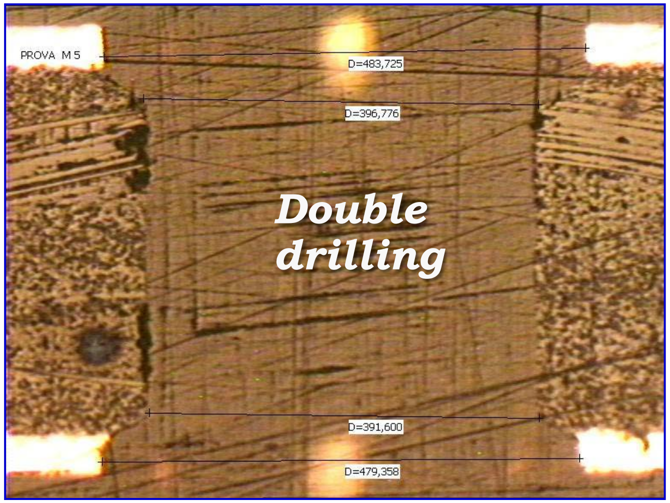


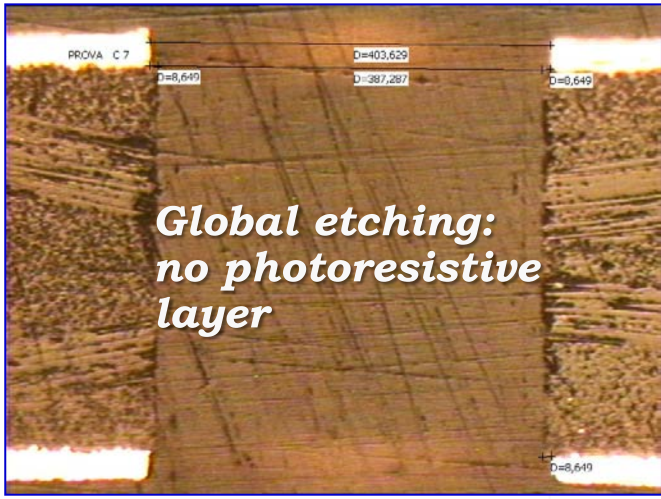
120 kHz / mm²

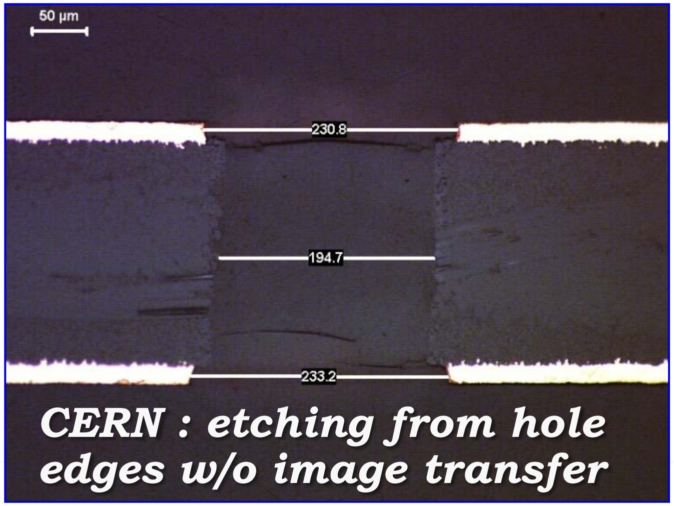
RECALL:
120 kHz/ mm², 300 e- → single photoelectron rates of ~35 MHz/ mm²

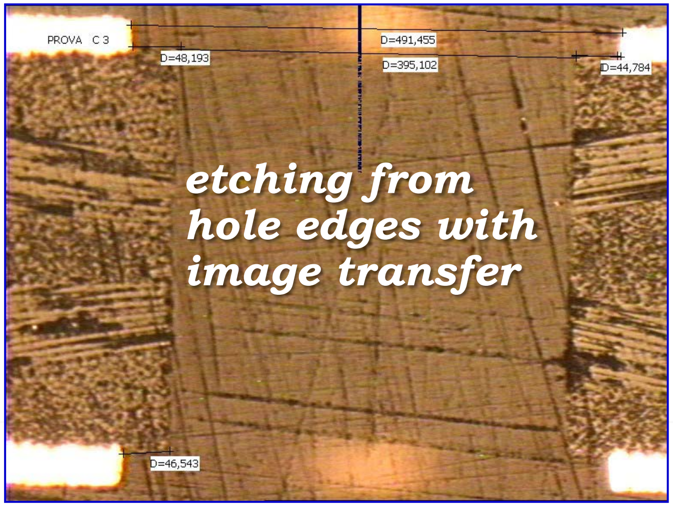
THGEM PRODUCTION STUDIES

RIM production techniques – 5 approaches tested



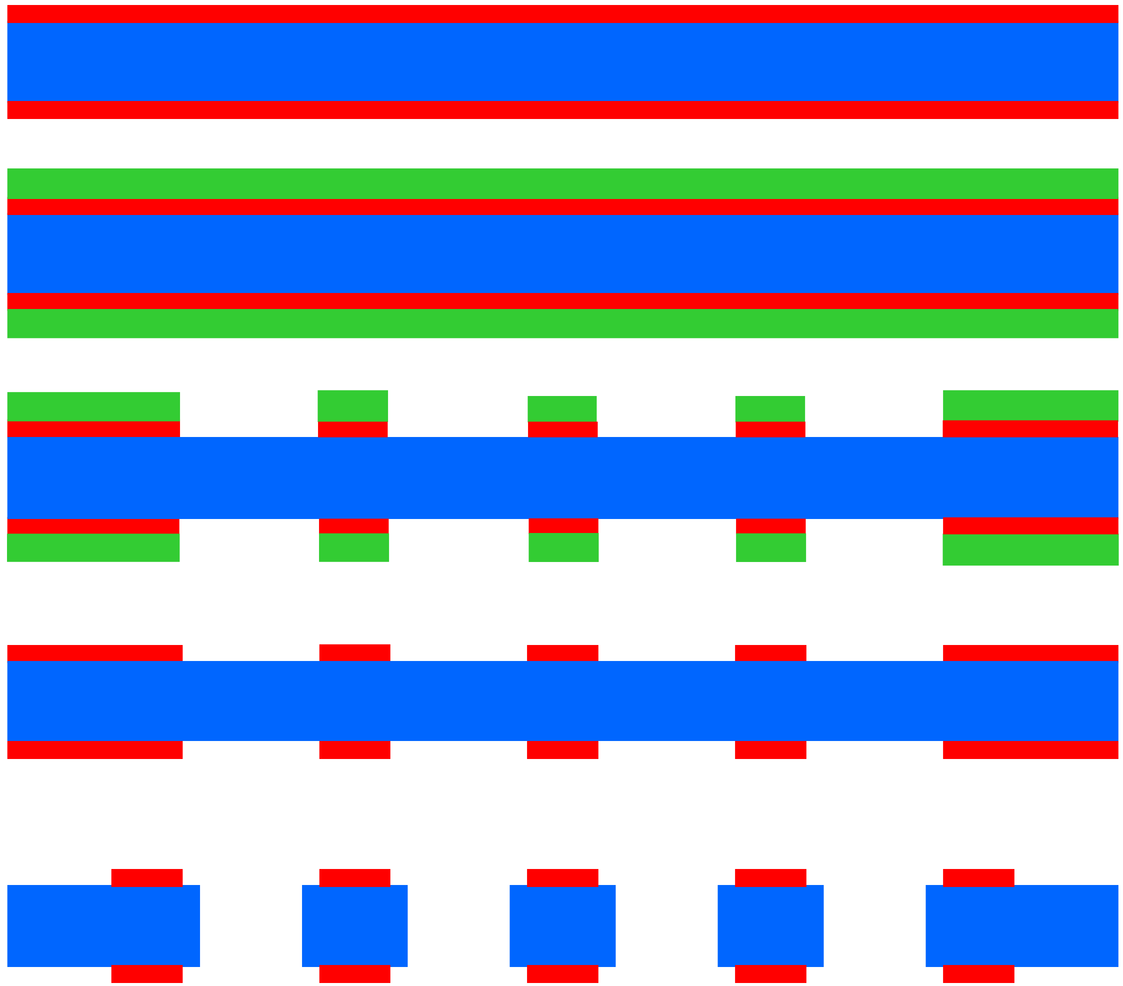






Industrial production of THGEMs at ELTOS S.p.A. (Arezzo)

“Weizmann” THGEM production process



Raw material

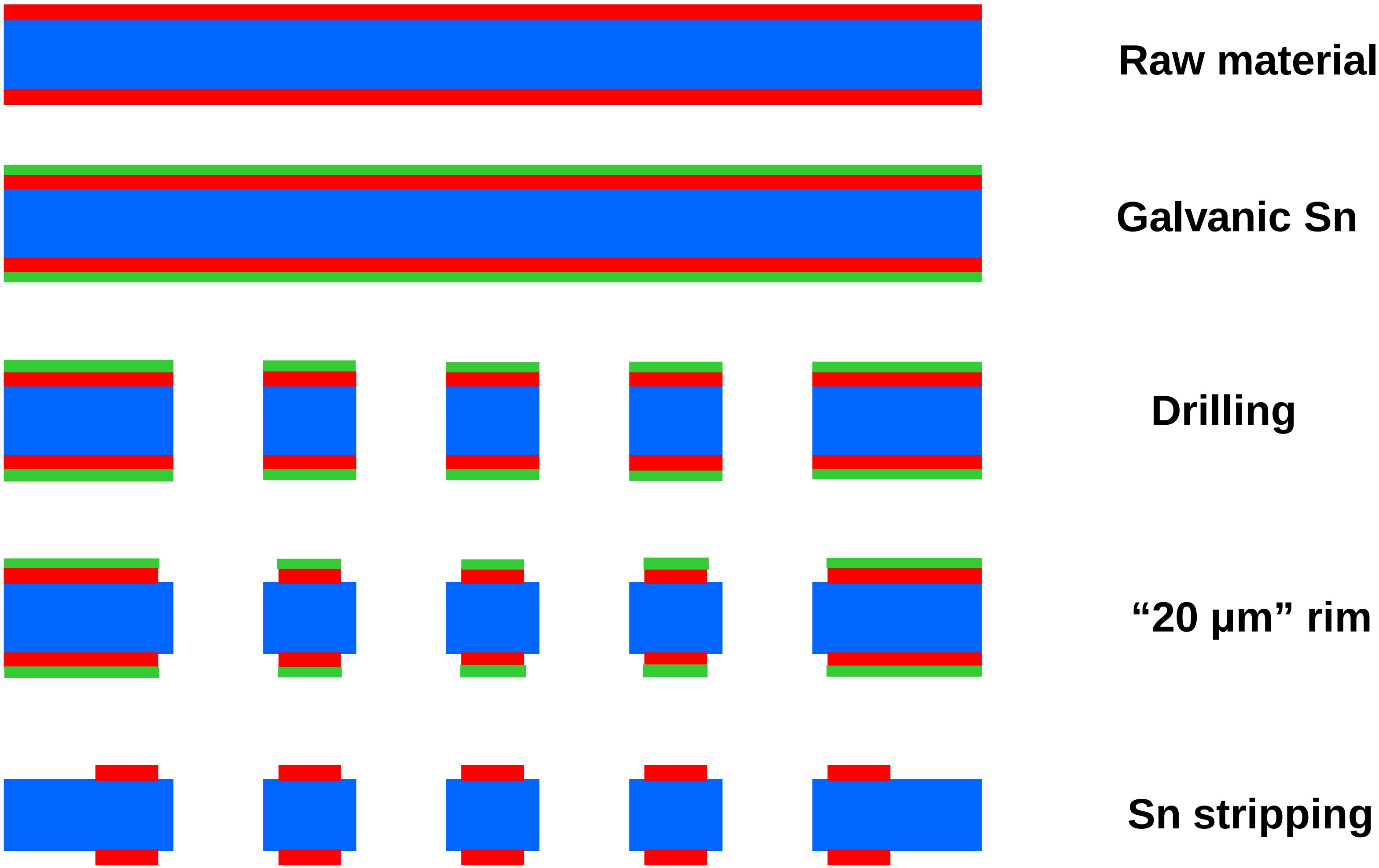
Resist covering

Image transfer and etching

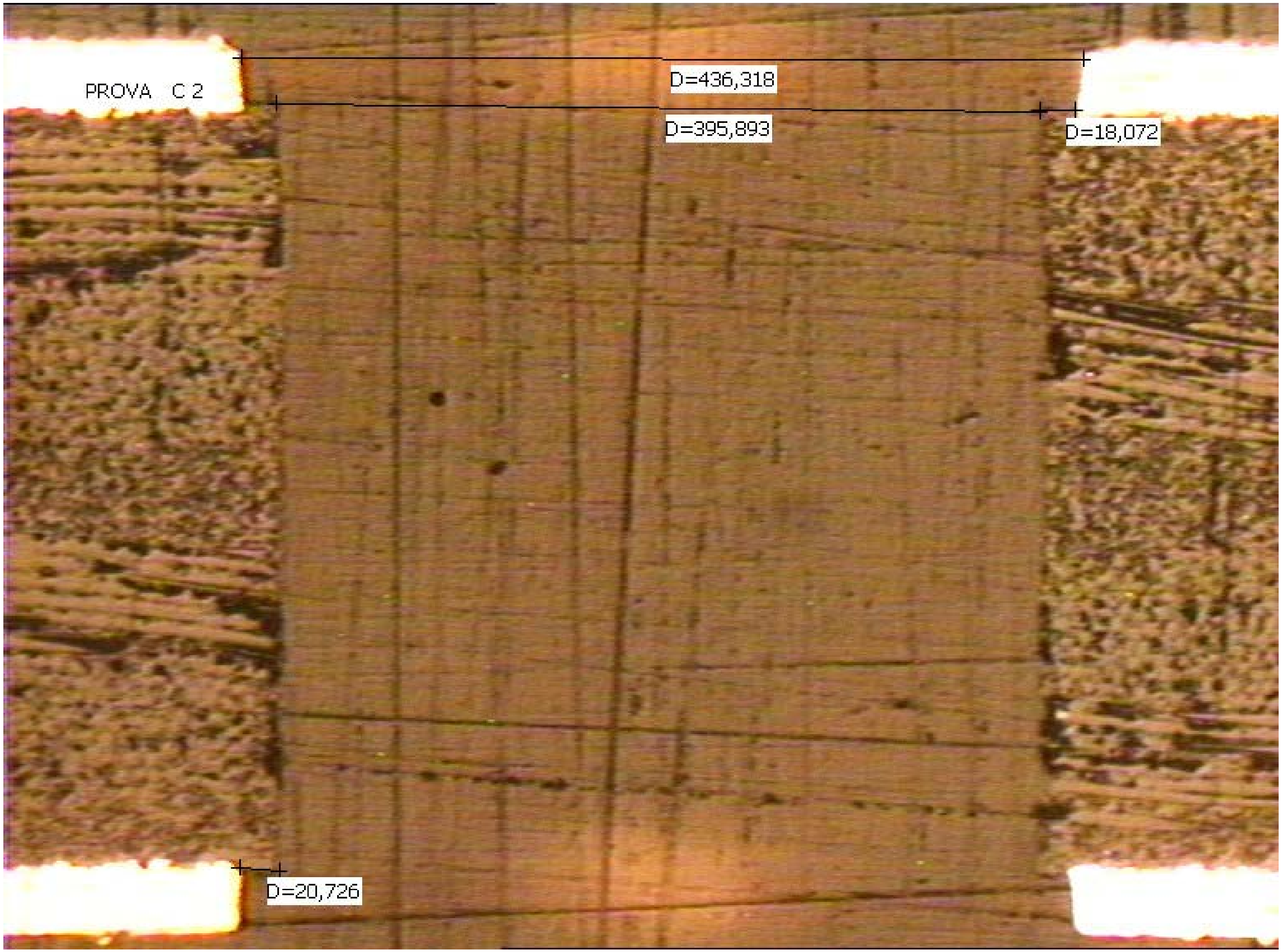
Stripping

Drilling

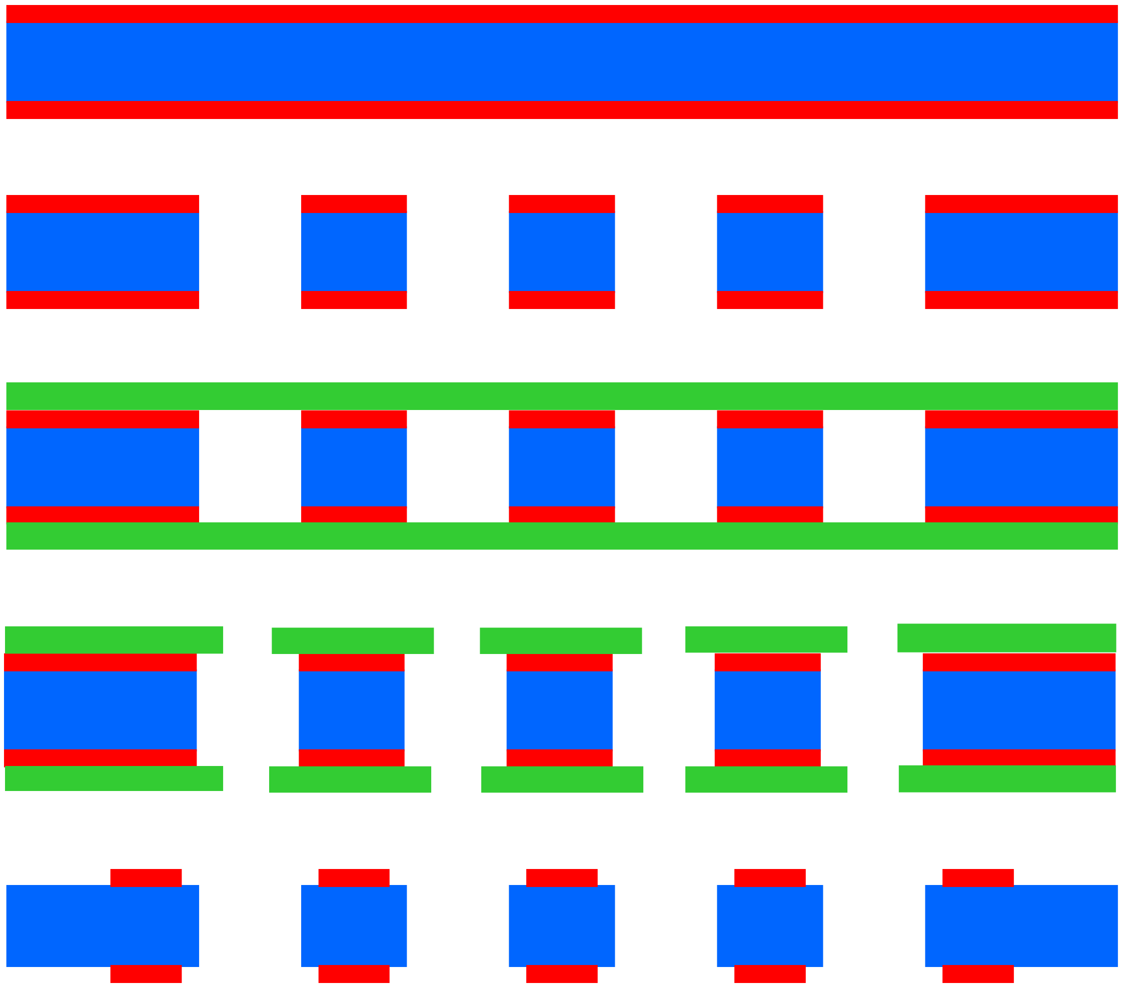
“small rim” production process



example of “small rim” (25μm)



"large rim" production process



Raw material

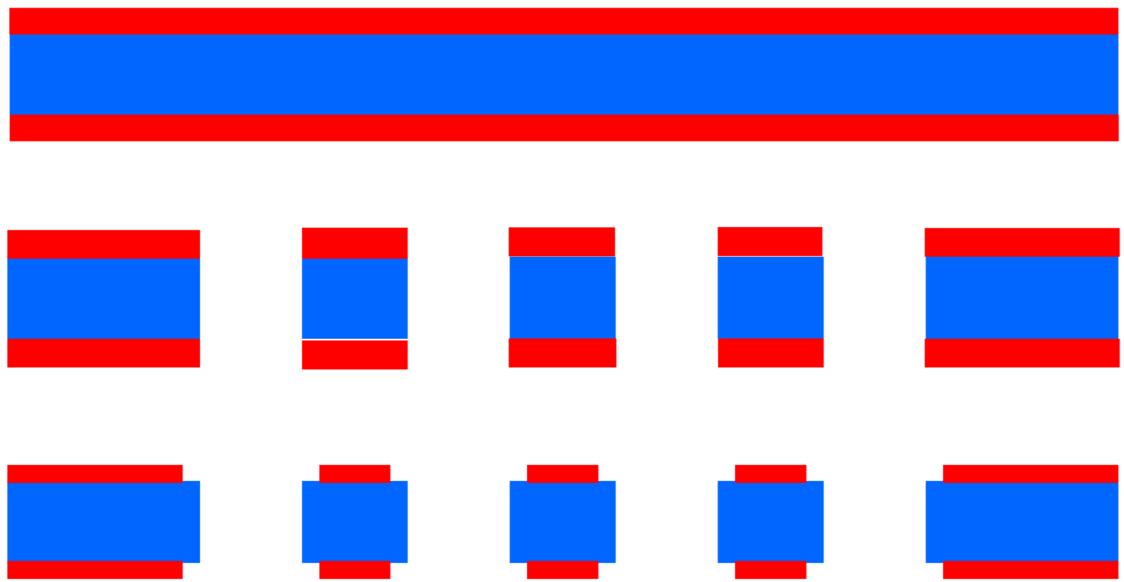
Drilling

Photo-resist

Image transfer

"100 µm" etching

“global etching” production process

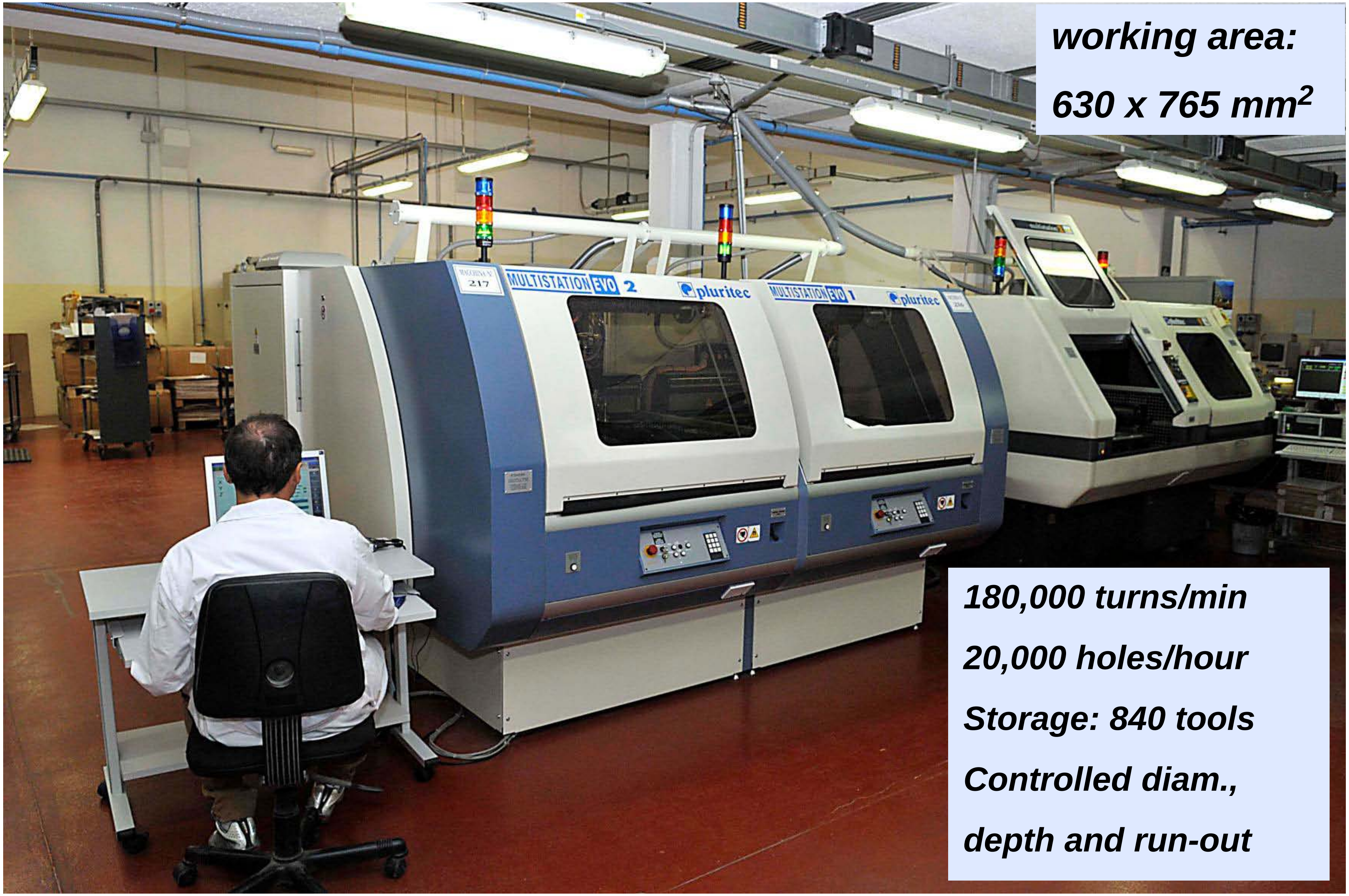


Raw material

Drilling

Global etching
(no protection)

Pluritec Multistation Evolution (ELTOS)



working area:

630 x 765 mm^2

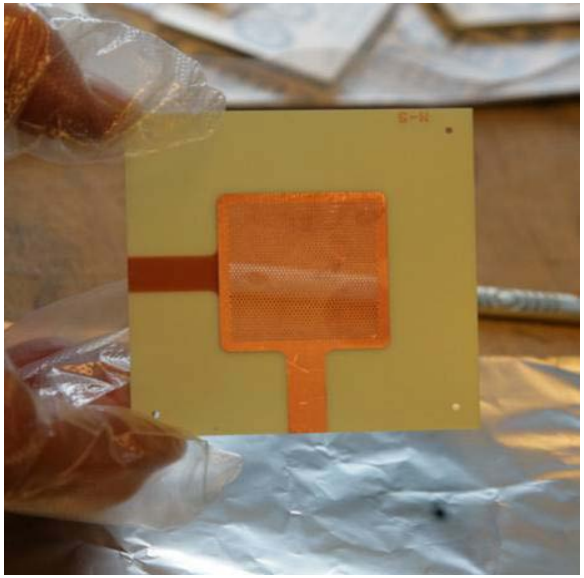
180,000 turns/min

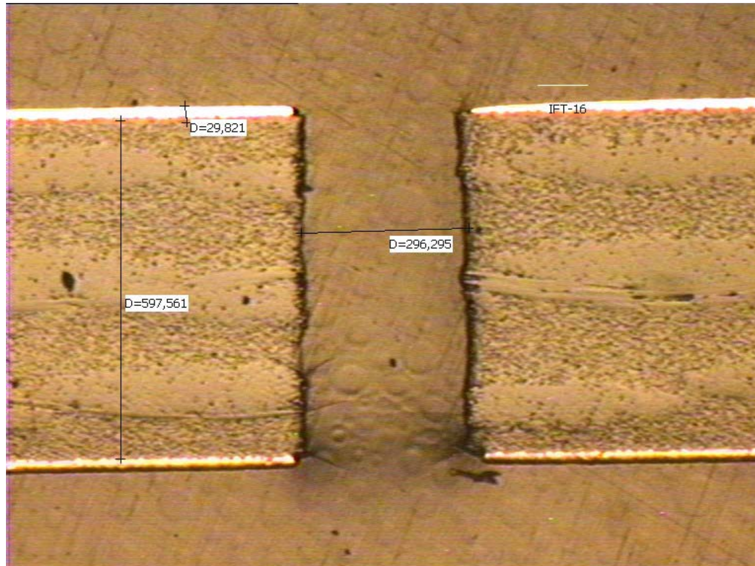
20,000 holes/hour

Storage: 840 tools

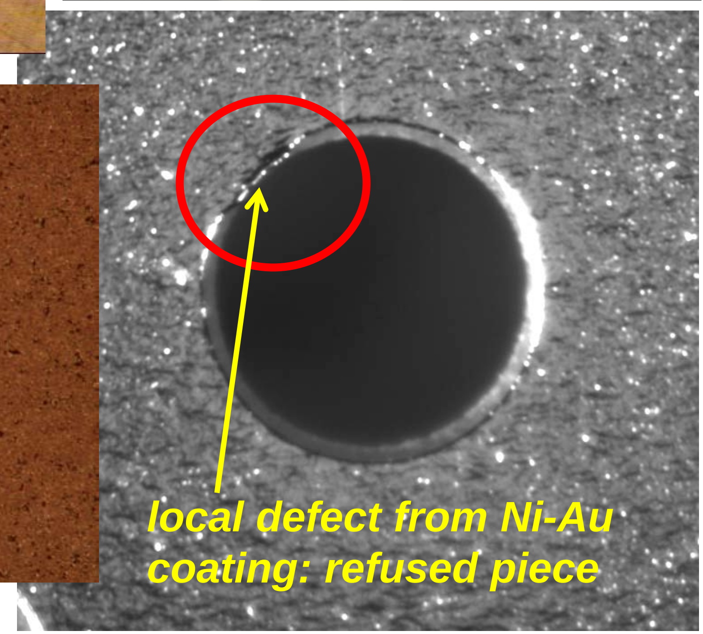
Controlled diam., depth and run-out

THGEM quality test

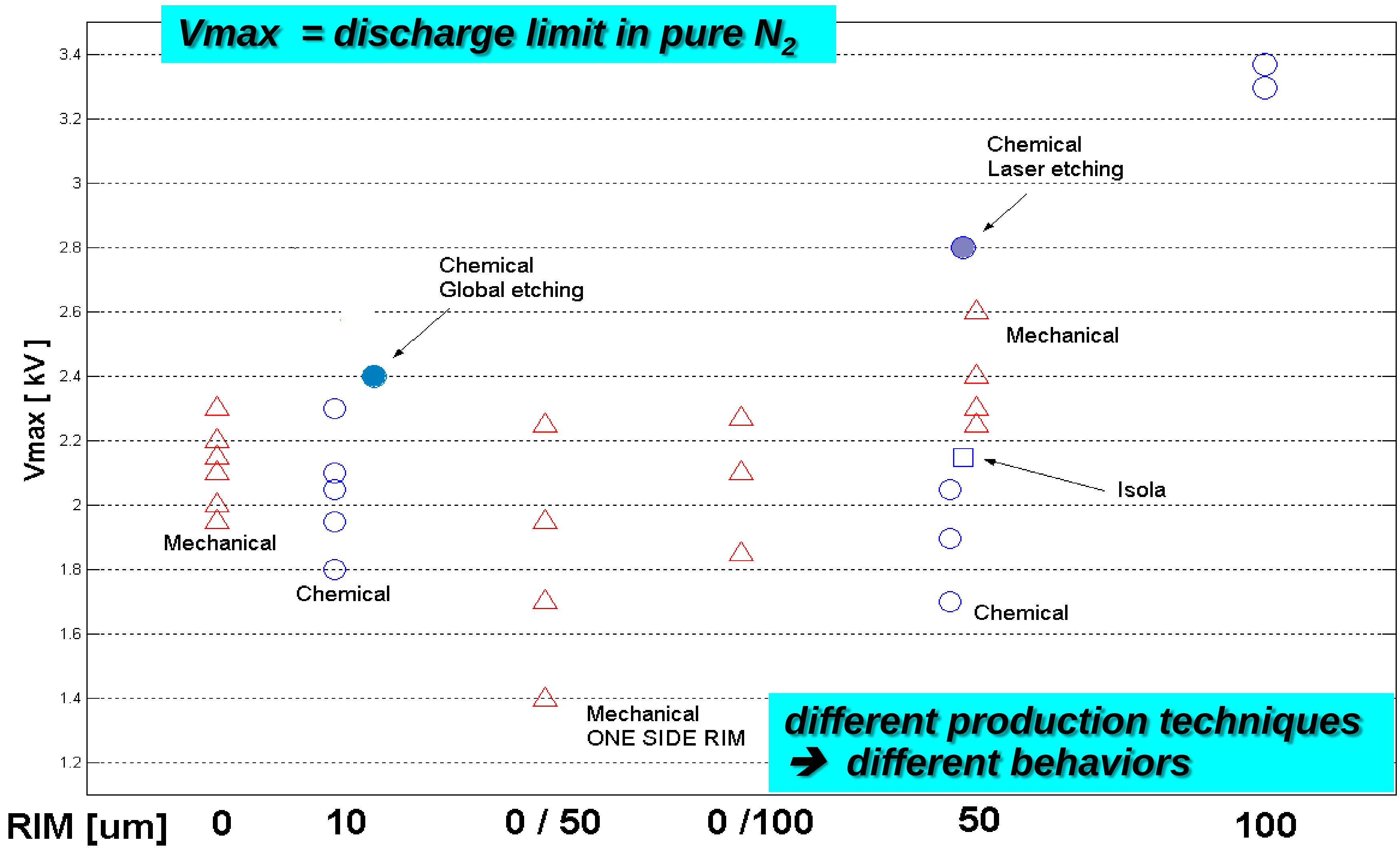




Defects are detected by a quality check procedure when THGEMs are received



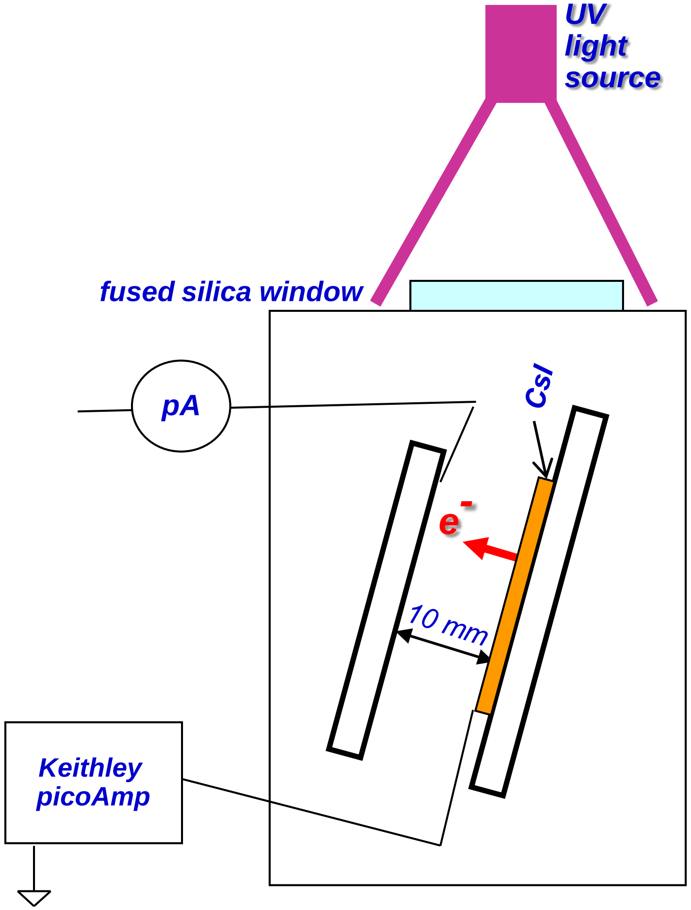
Comparison of production techniques

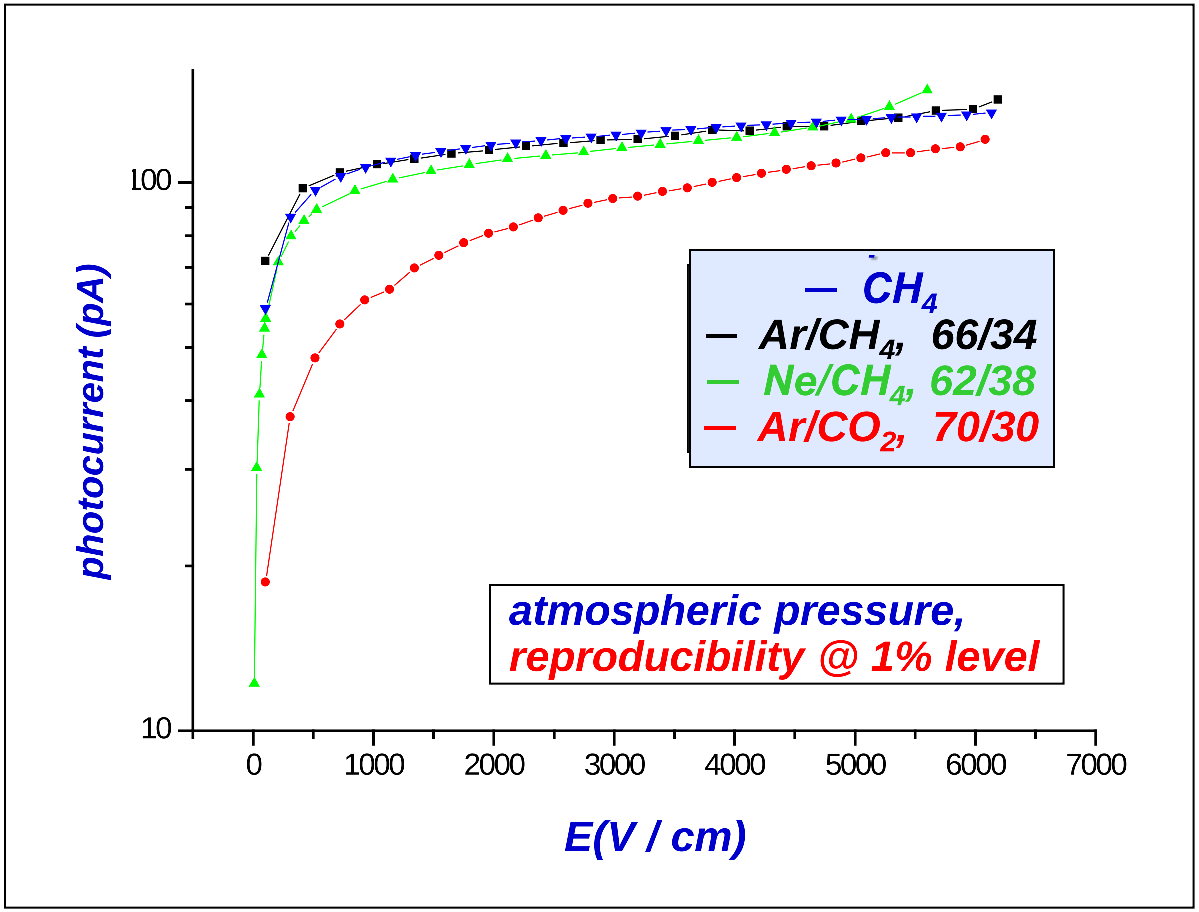


different production techniques
➔ different behaviors

PHOTOELECTRON EXTRACTION

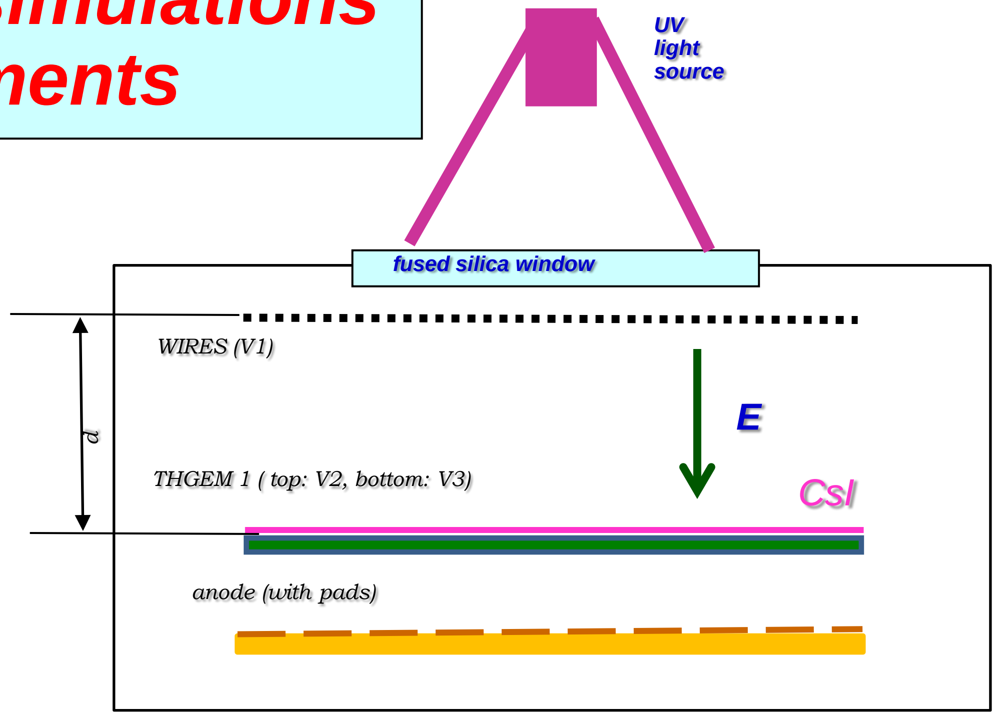
Photocurrent measurements in various gas atmospheres

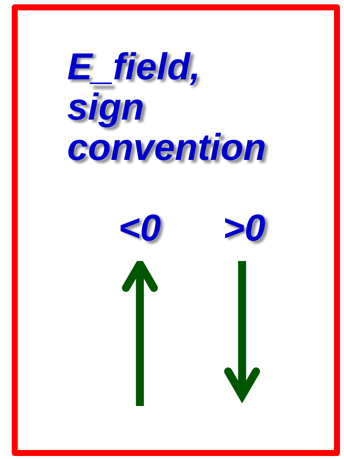




PHOTOELECTRON EXTRACTION

Photoelectron extraction vs ΔV and E, simulations and measurements



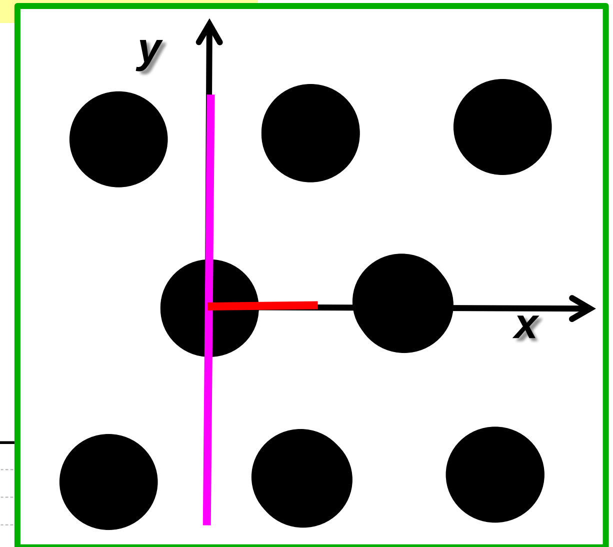


$$E = (V2 - V1) / d$$
$$\Delta V = V3 - V2$$

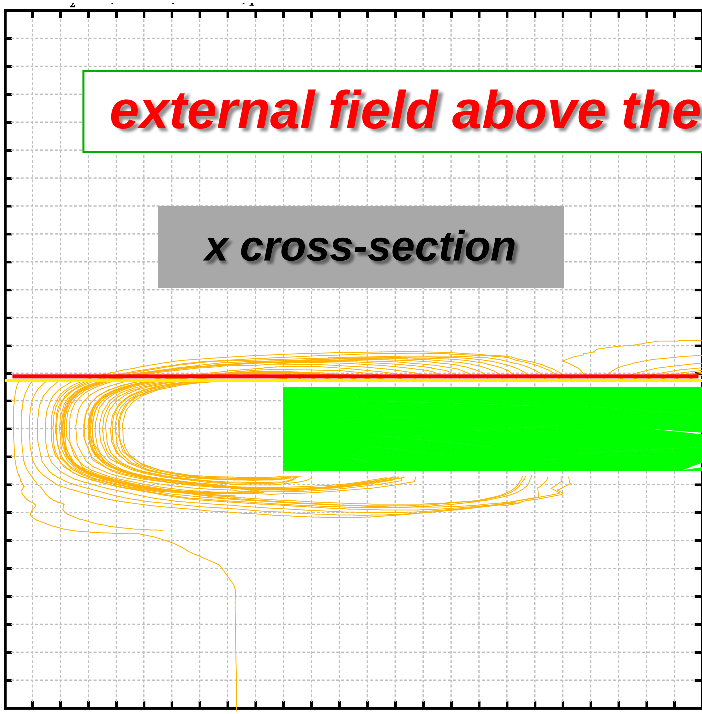
Photoelectron extraction: simulation study

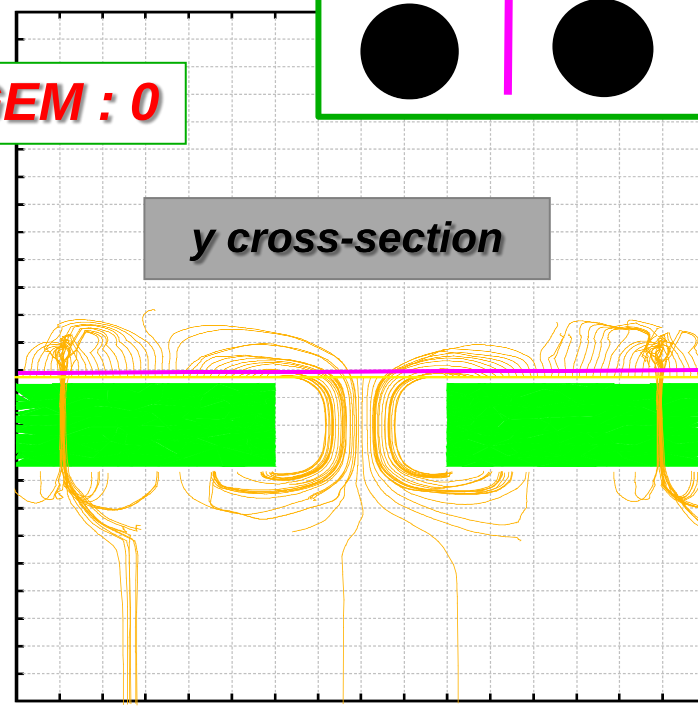
photoelectron trajectories from a THGEM photocathode, <u>simulation,</u> multiplication switched off

thickness 0.6 mm, diam. 0.4 mm, pitch: 0.8 mm, ΔV = 1500 V



external field above the THGEM : 0





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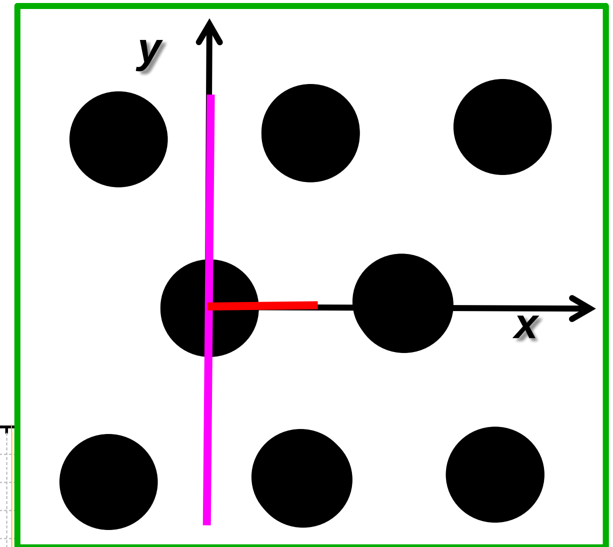
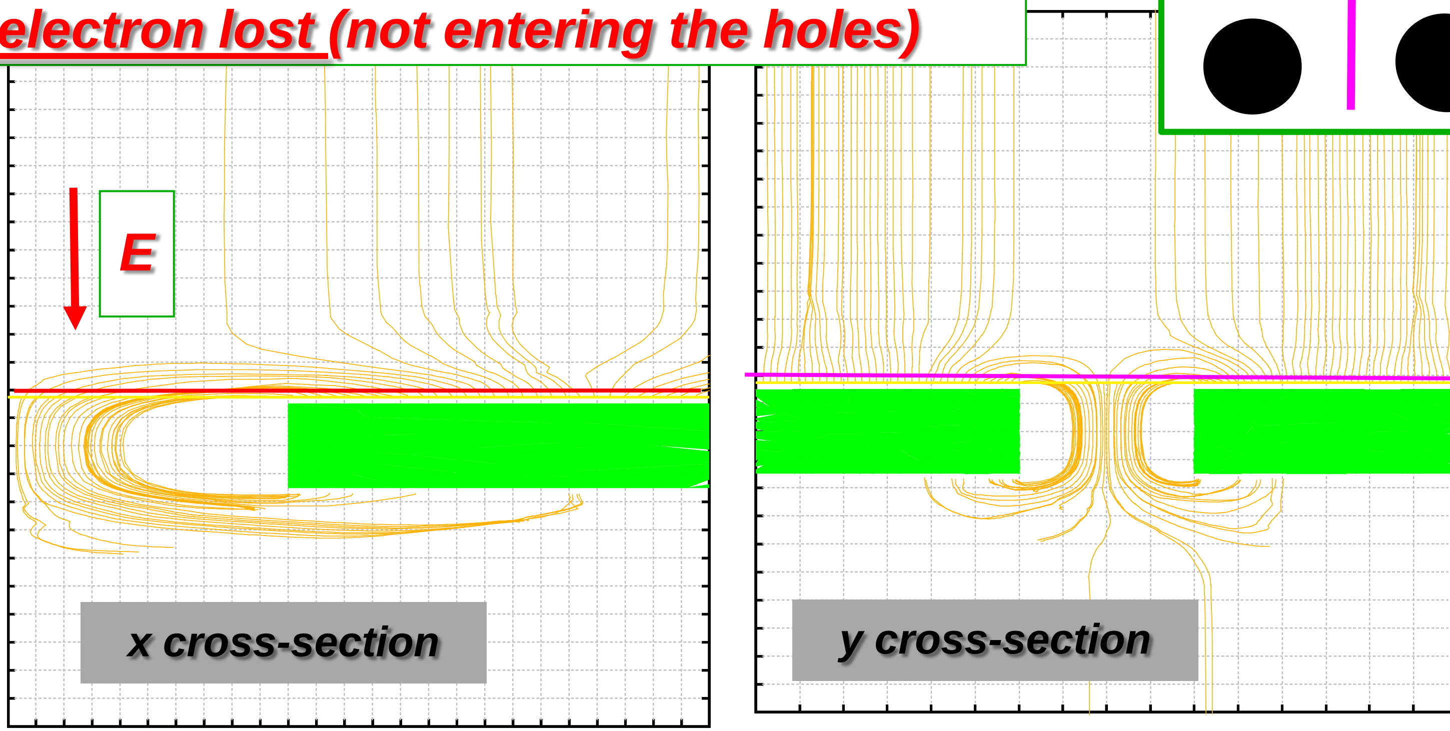


external field above the THGEM : - 500 V /cm: <u>photoelectron lost</u> (not entering the holes)

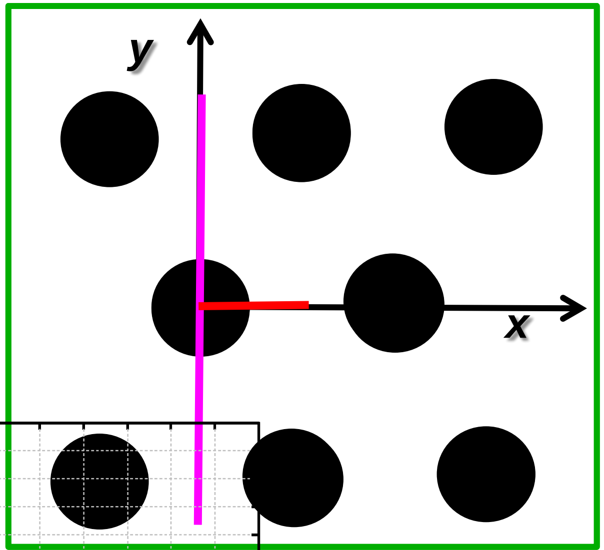


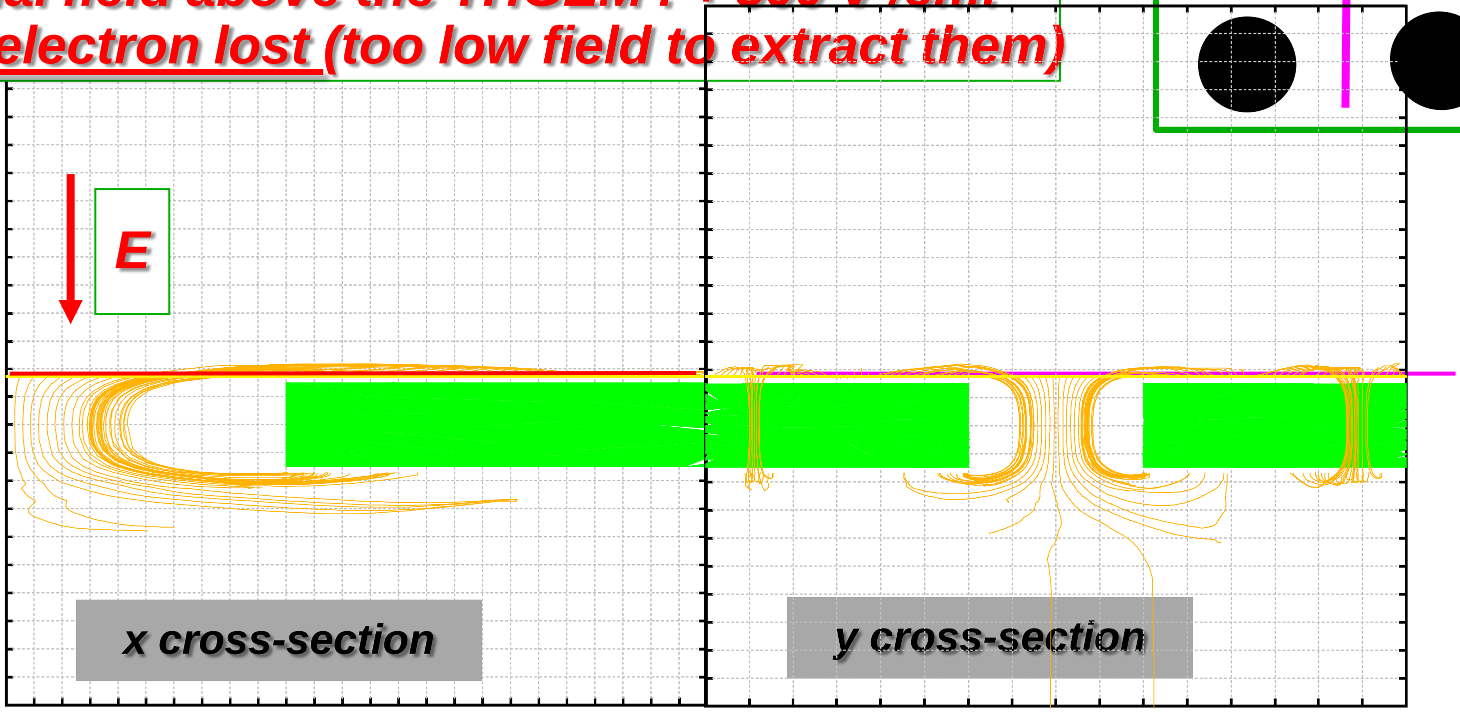
Photoelectron extraction: simulation study

photoelectron trajectories from a THGEM photocathode, simulation , multiplication switched off

thickness 0.6 mm, diam. 0.4 mm, pitch: 0.8 mm, ΔV = 1500 V

external field above the THGEM : + 500 V /cm: photoelectron lost (too low field to extract them)





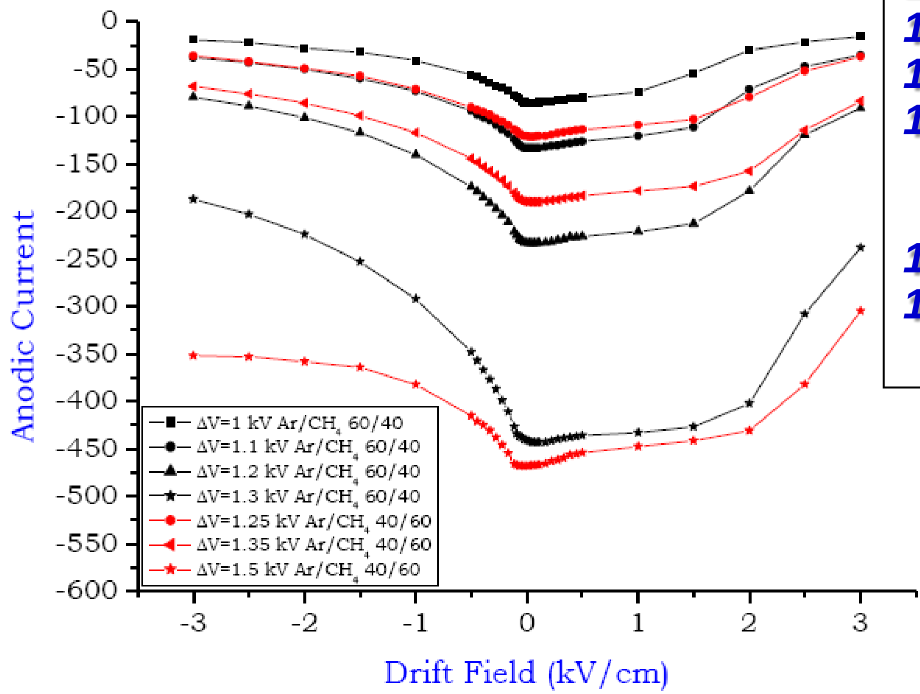
Photoelectron extraction: measurement

Anodic current in a THGEM detector versus the external electric field applied , a measurement

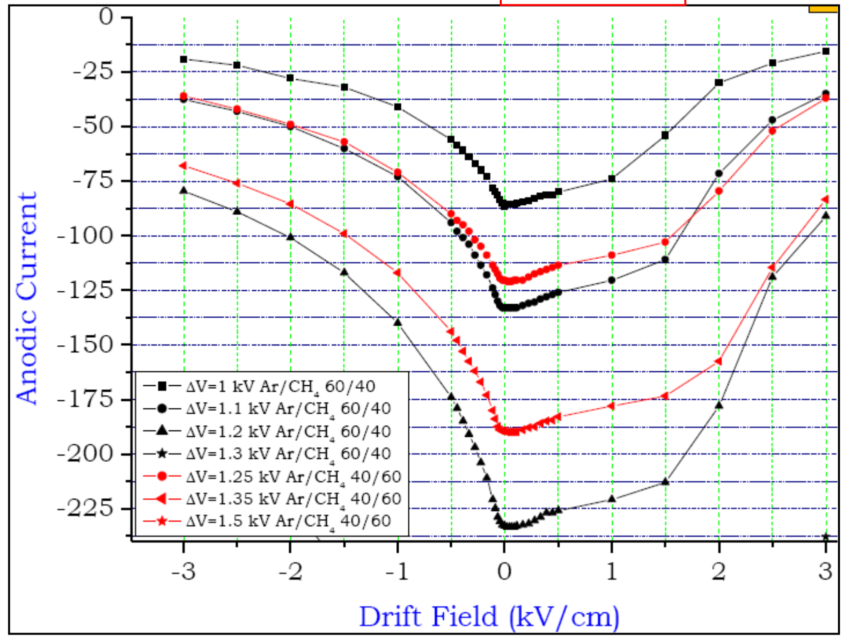
Ar/CH_4: 40/60; 60/40

ΔV = 1kV 1.1, 1.2 1.25, 1.3

1.35 1.5



ZOOM



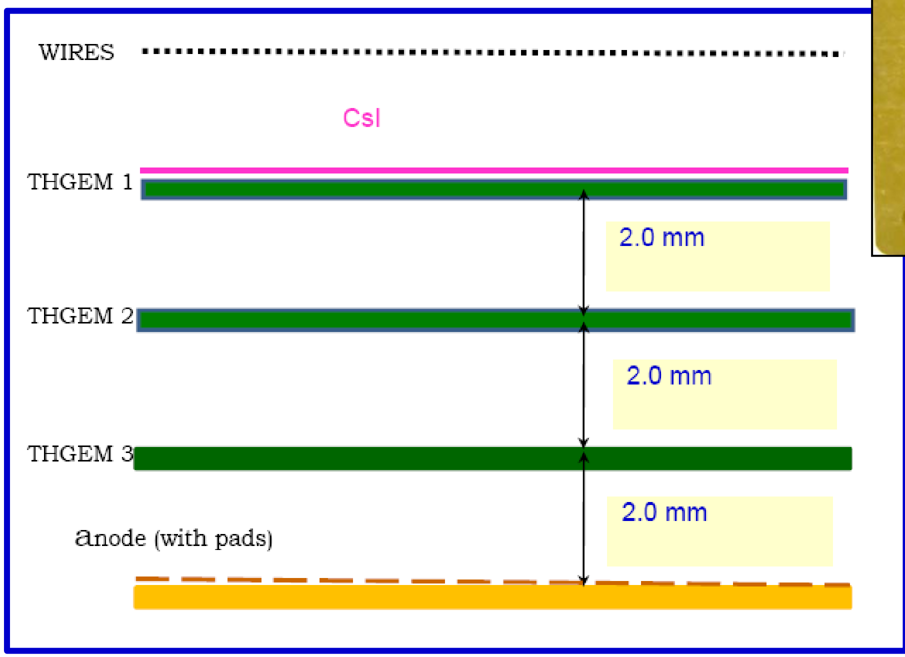
The behaviour predicted by the simulation is confirmed!
→A clear suggestion to optimise the detector design

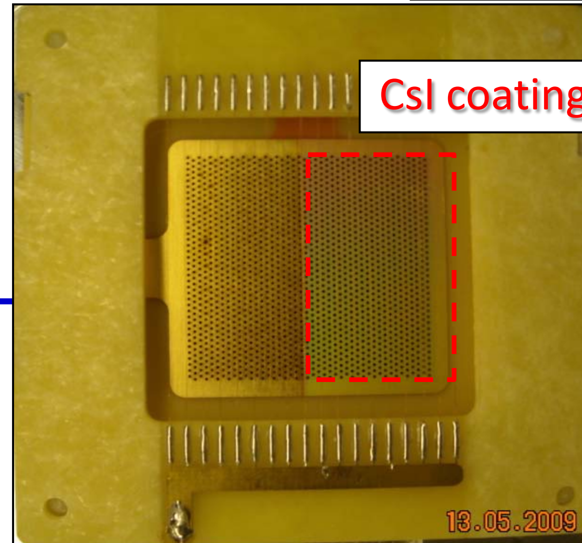
OUR FIRST THGEM-BASED PDs

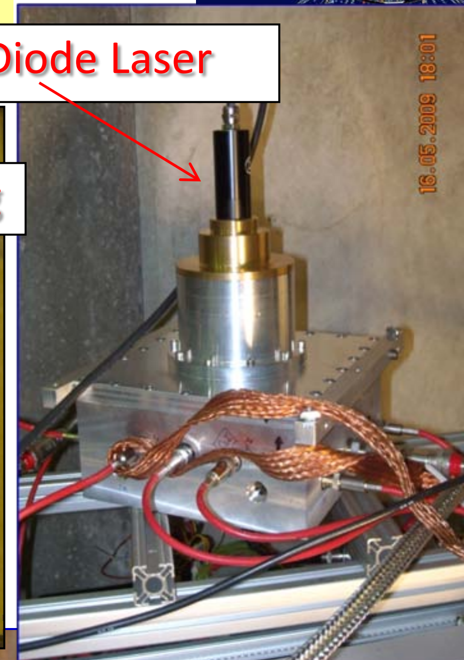
Triple THGEM (CsI) Ar/CH_4

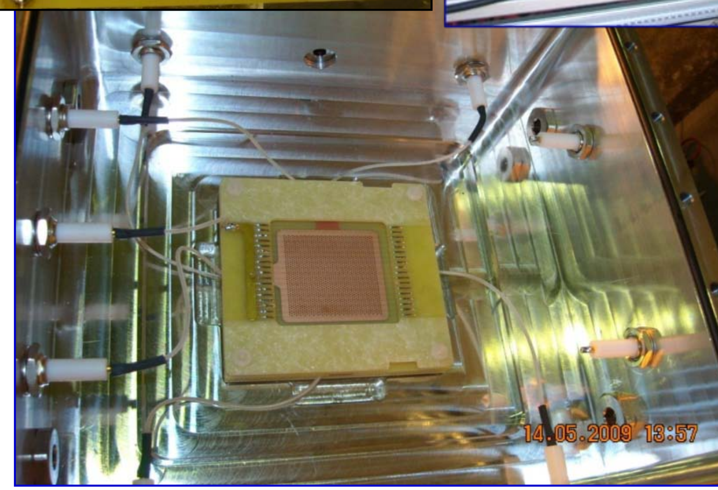
Active area = 30 mm x 30 mm

Diam=0.4 mm, pitch =0.8, Thick=0.4, rim ≤10 μm

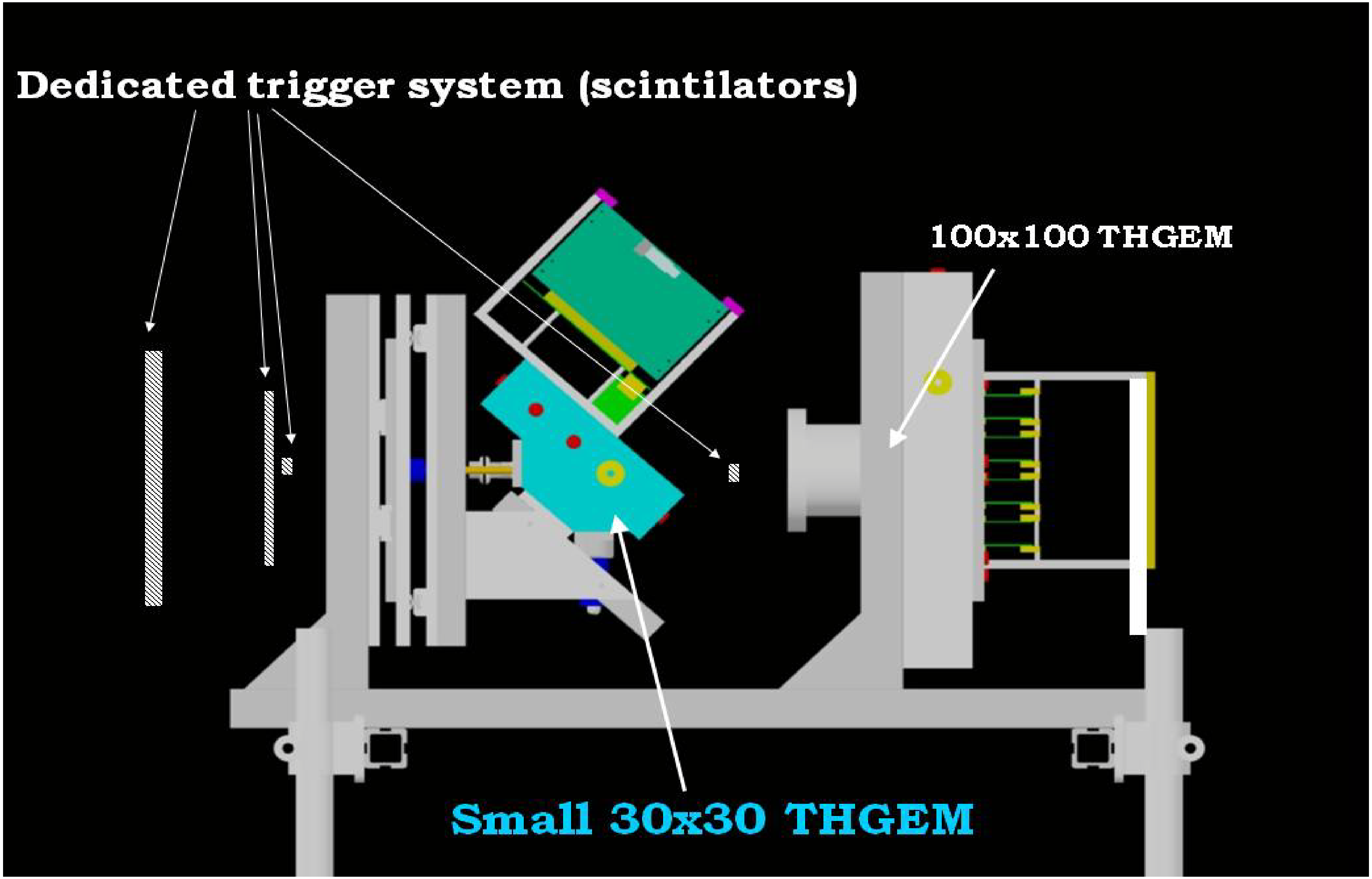




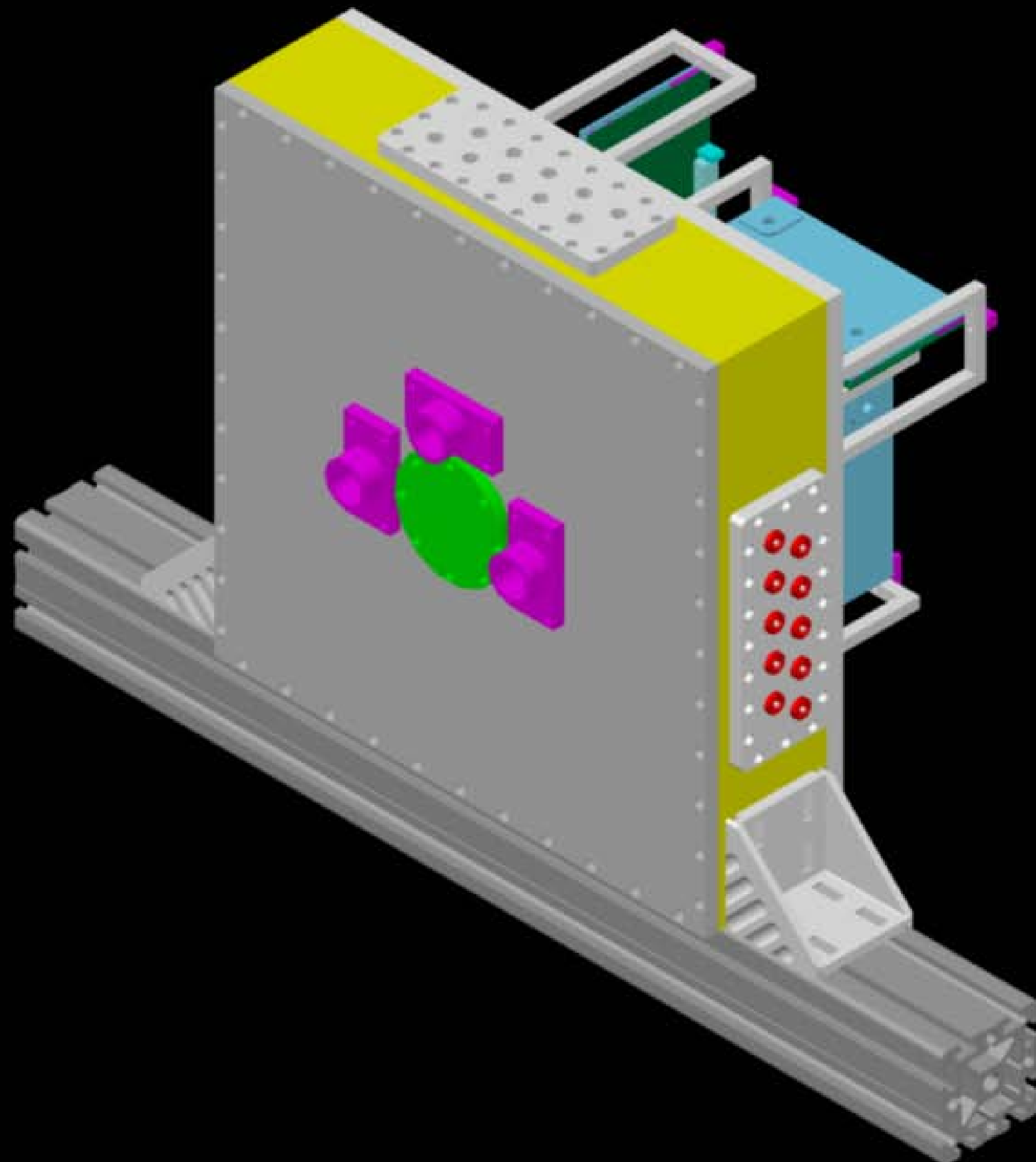




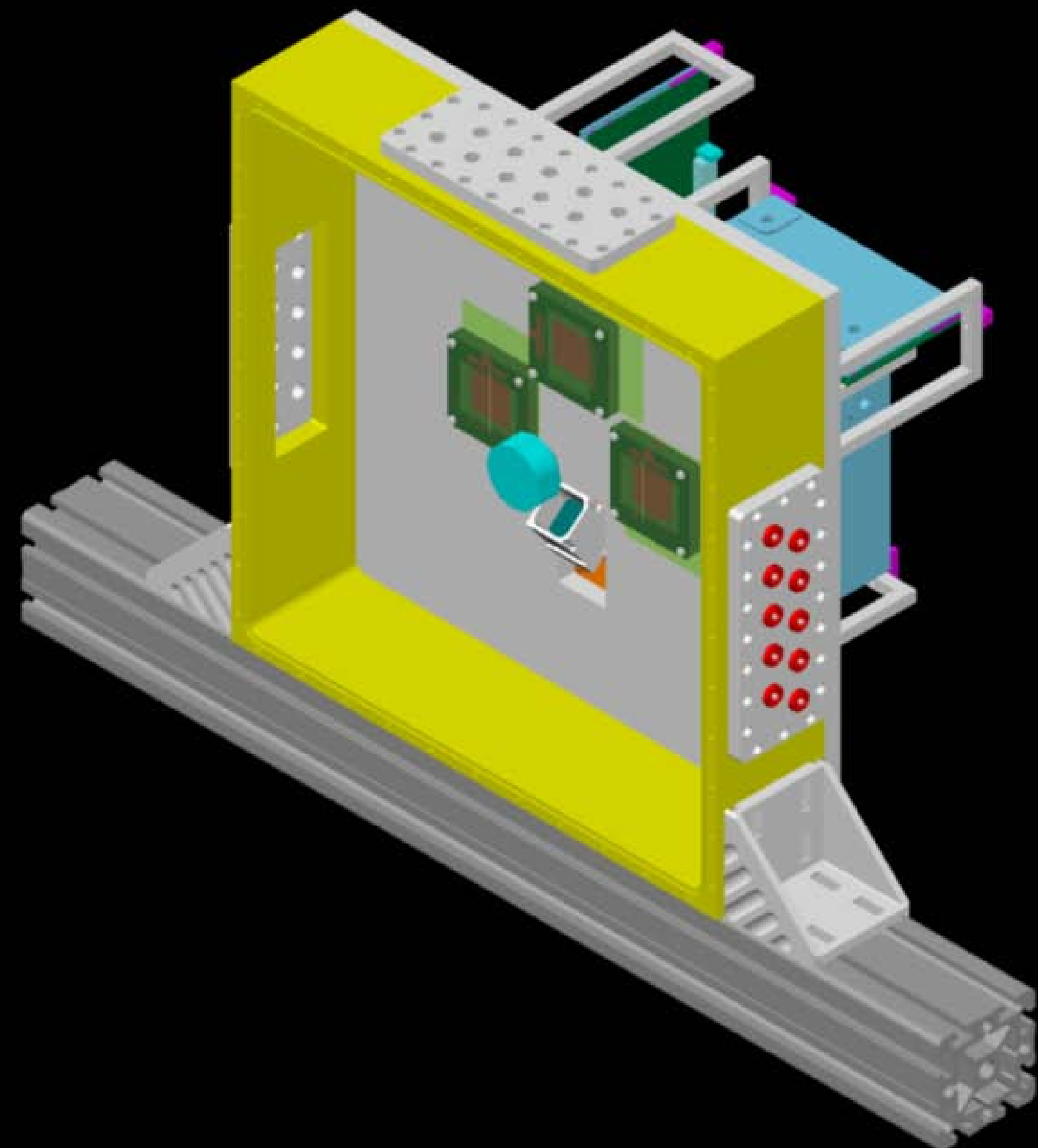
Test beam: oct. 2009, aug. 2010

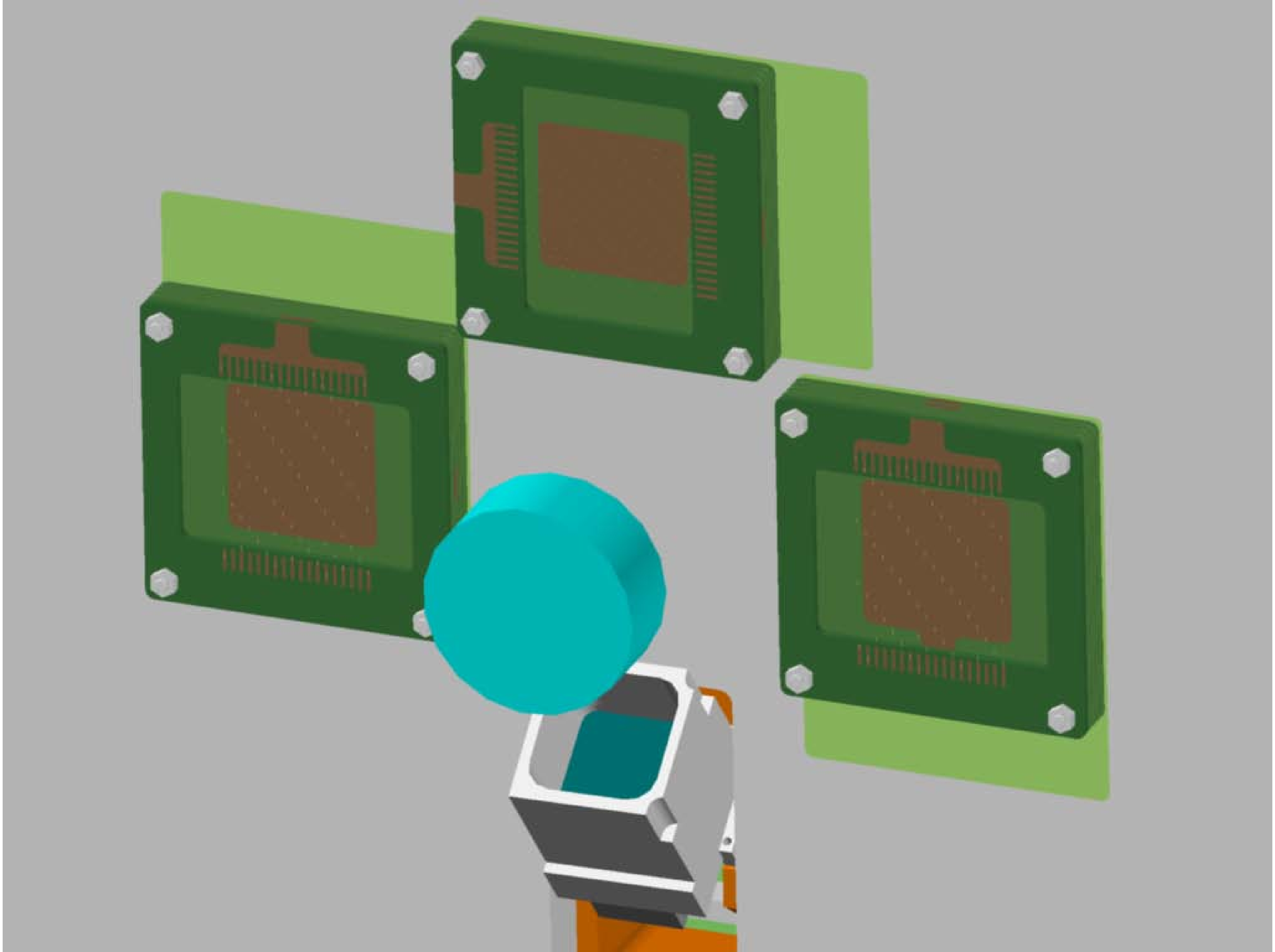


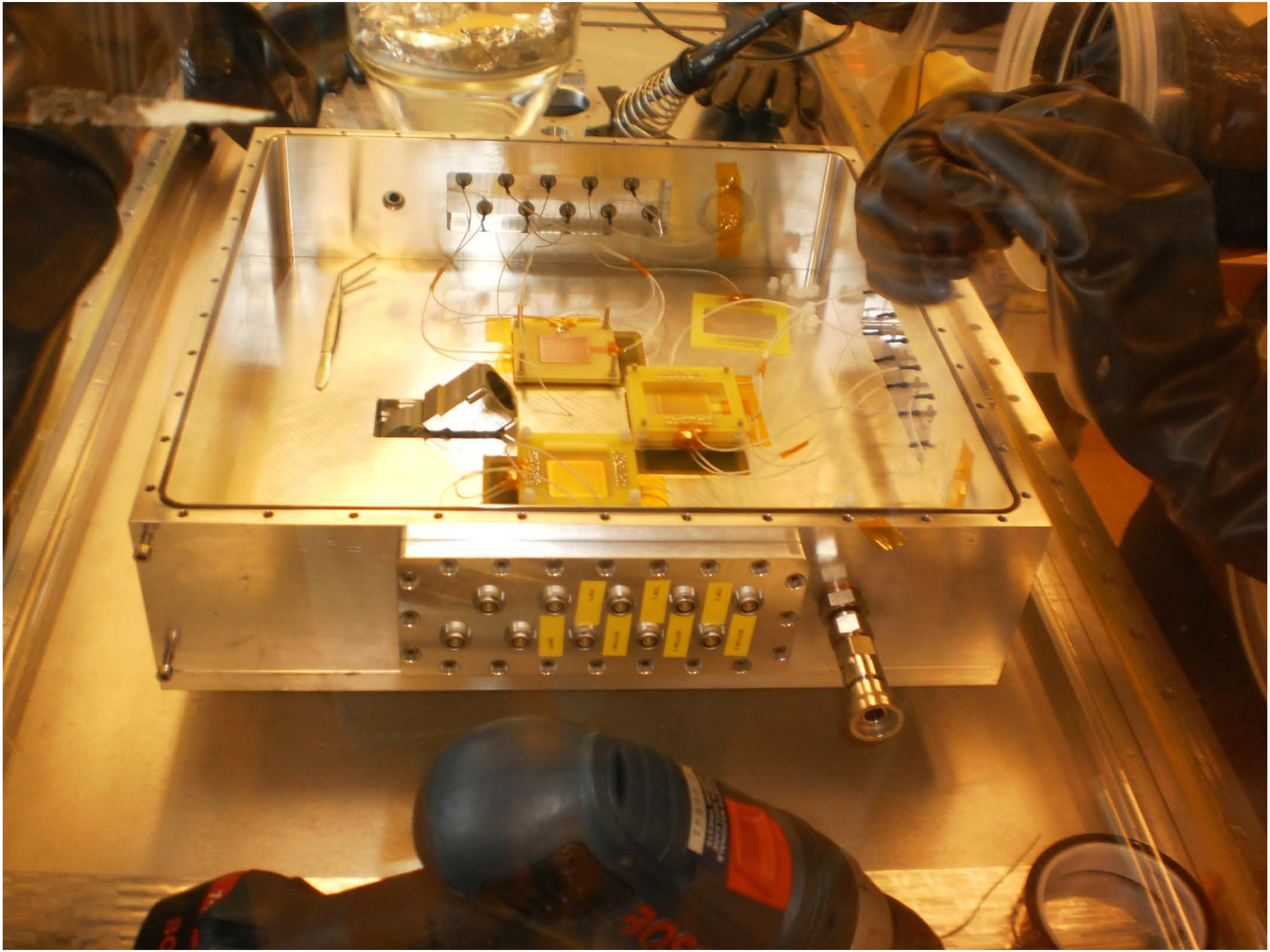
Test beam: aug. 2010

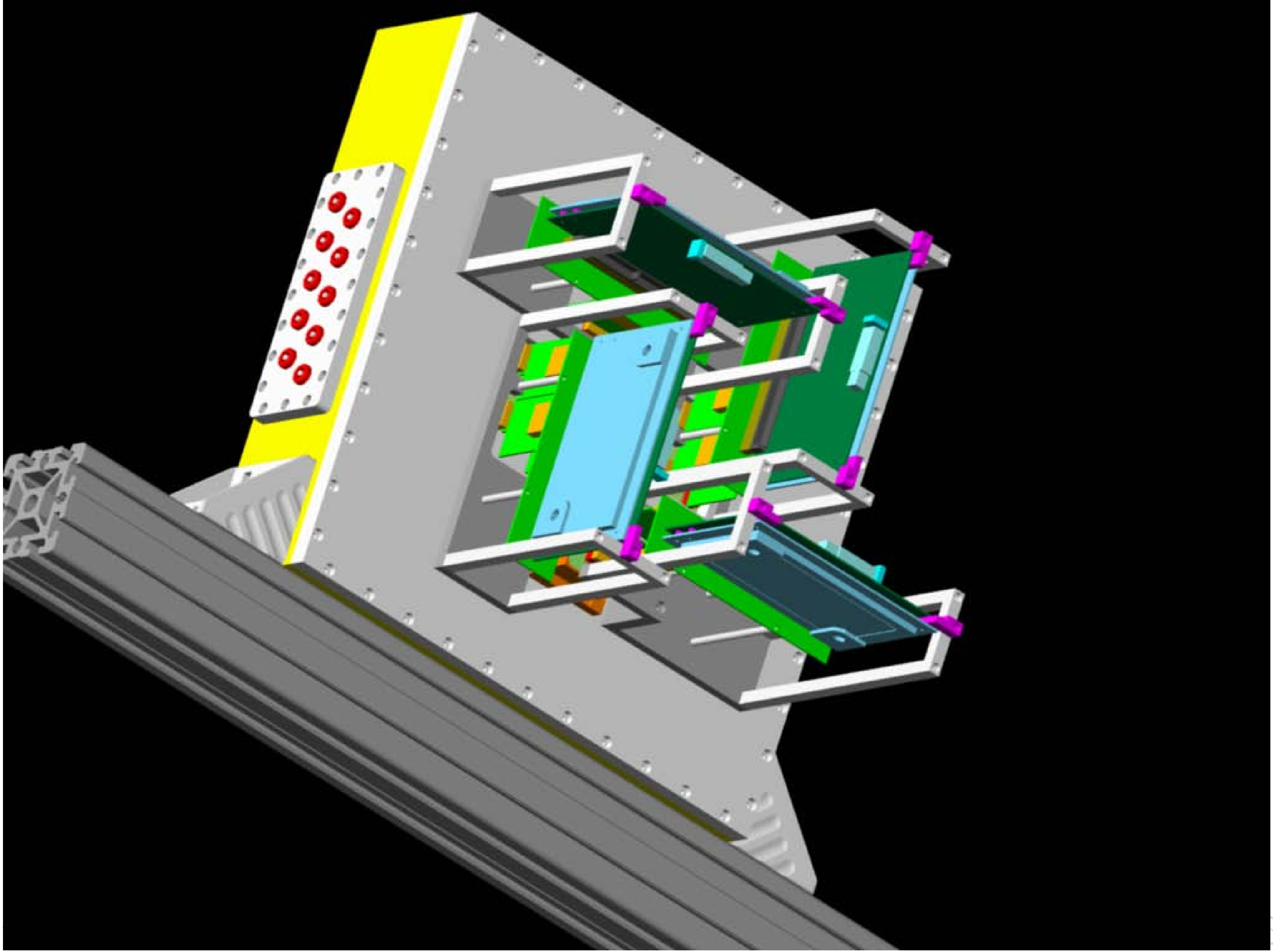


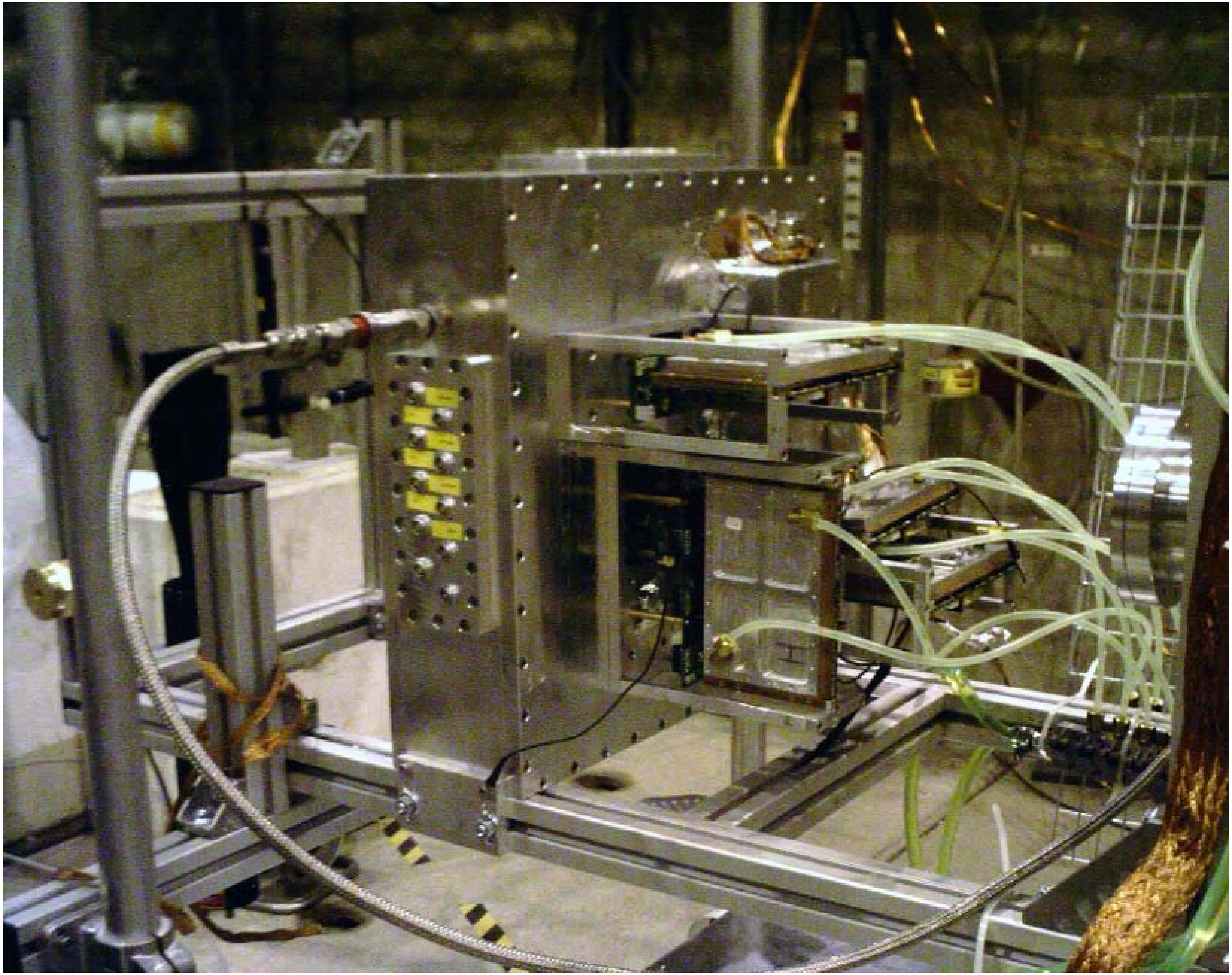
Test beam: aug. 2010





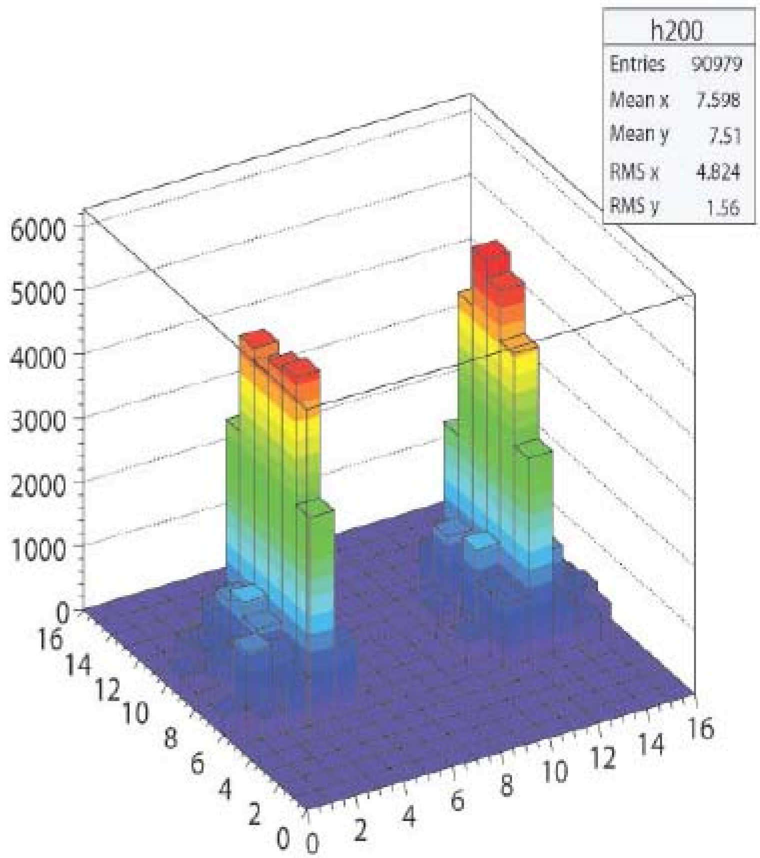


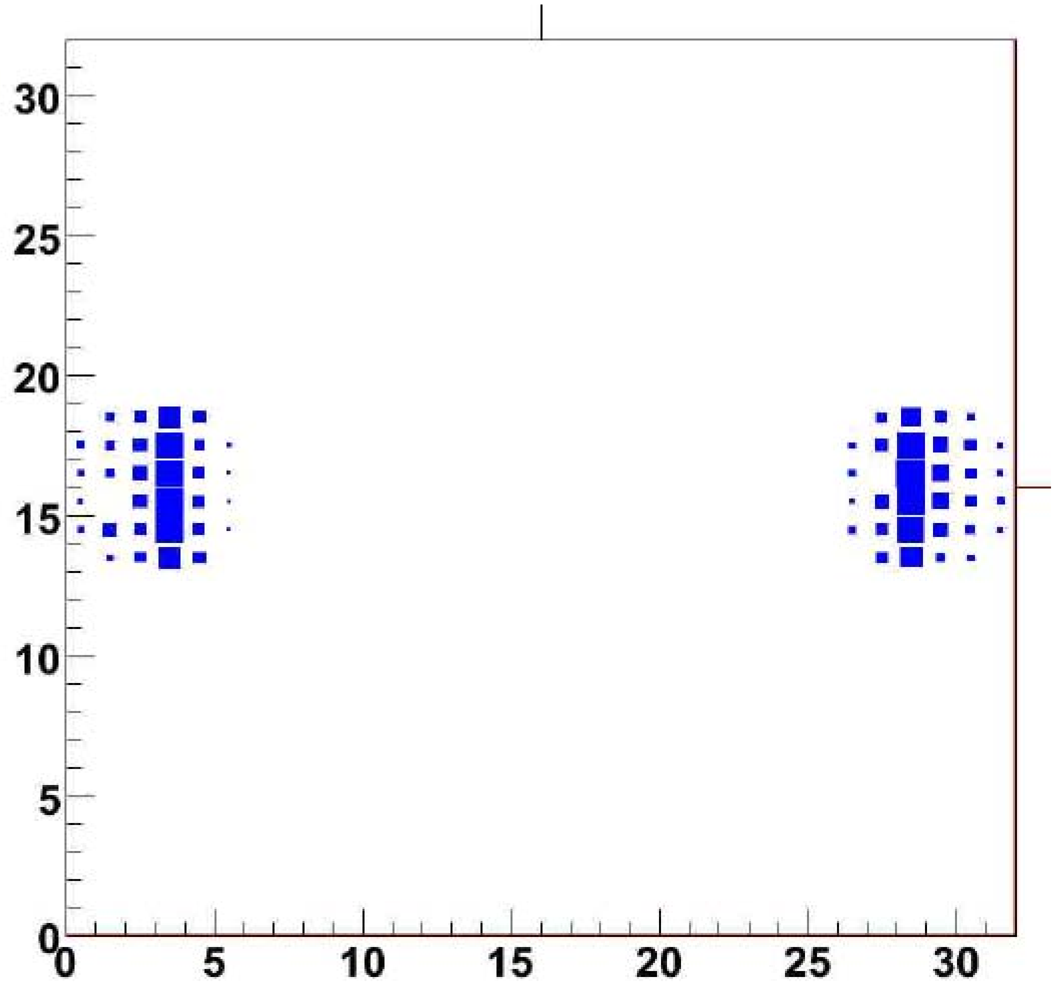




AUGUST 2010 TEST BEAM EXERCISE

Overlap of events   digital r/o threshold = 3 fC   gain: ~ 120,000

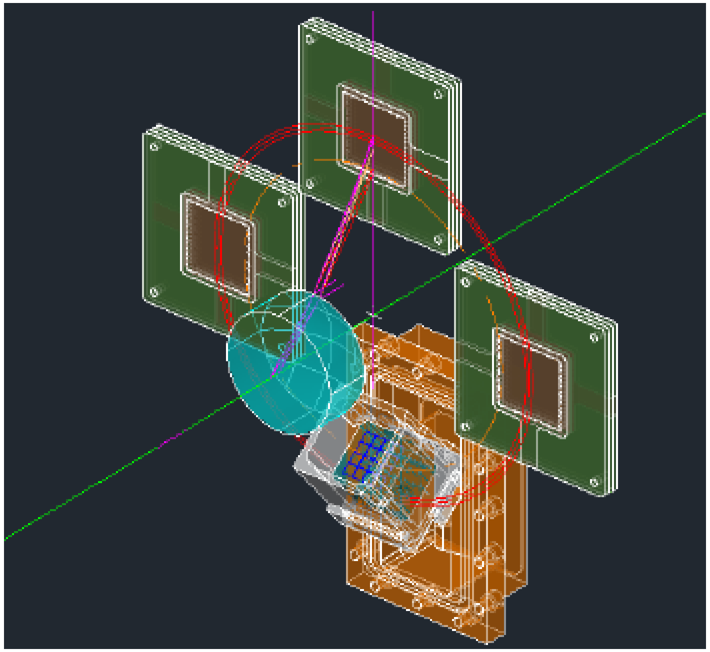


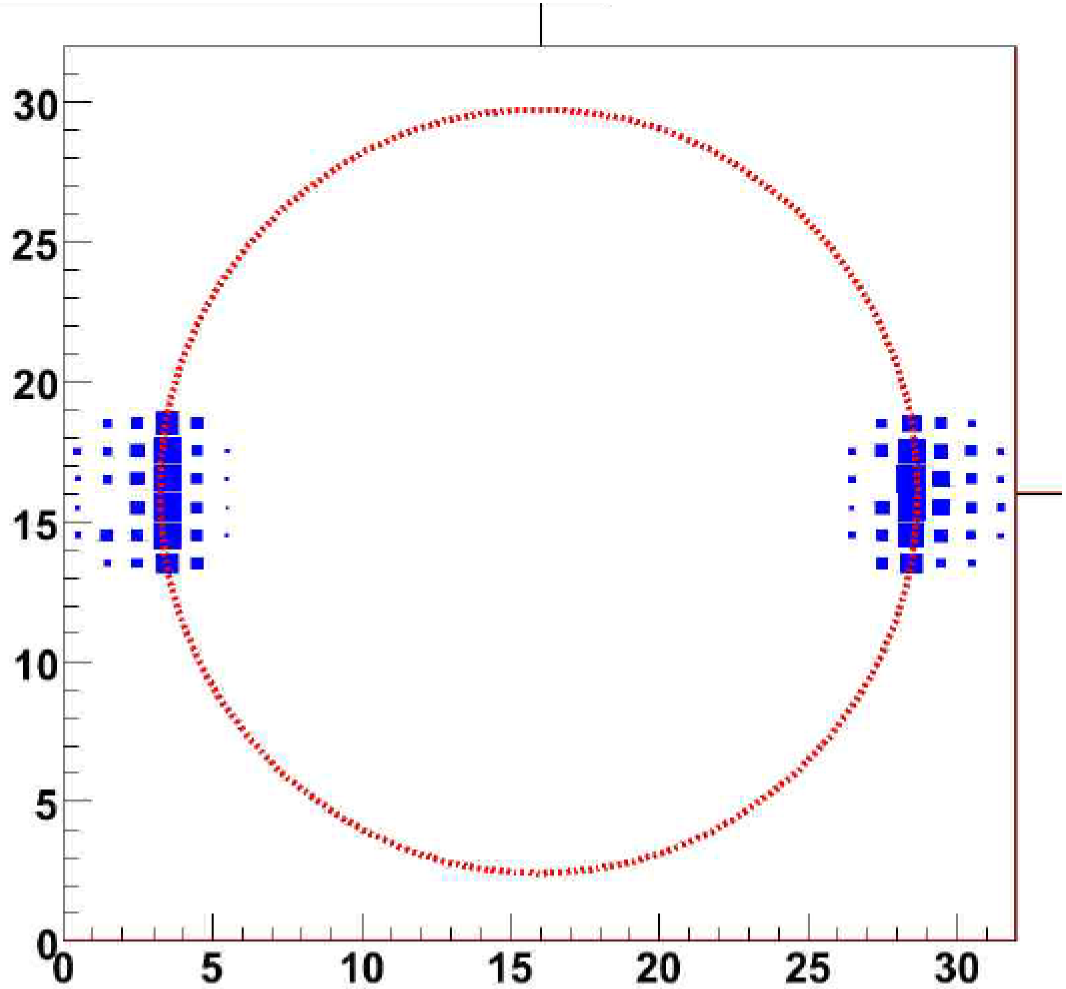


AUGUST 2010 TEST BEAM EXERCISE

Overlap of events digital r/o threshold = 3 fC gain: ~ 120,000

The circle is the expected corona on the THGEM surface

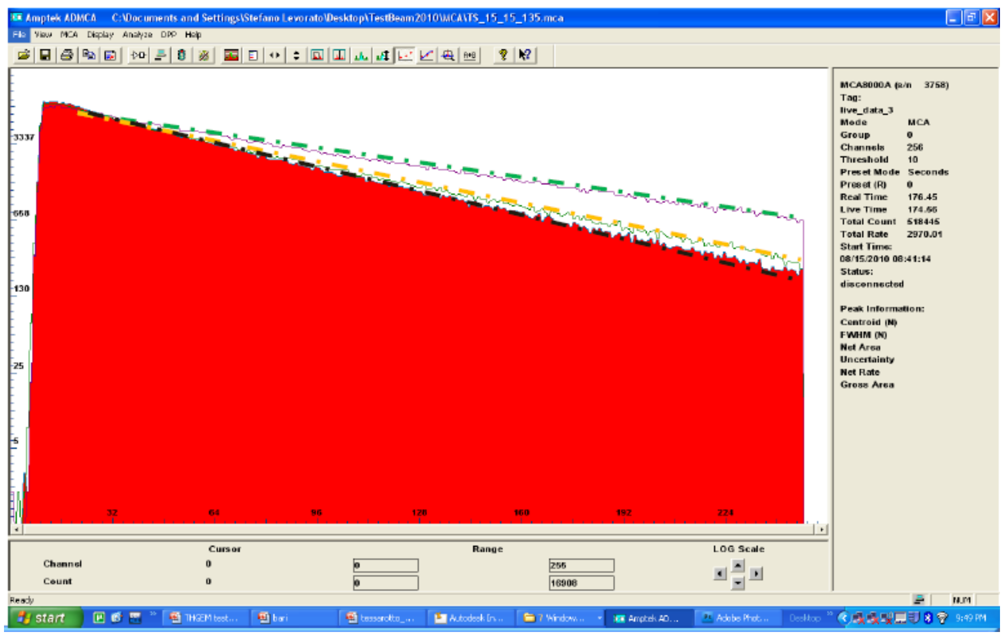


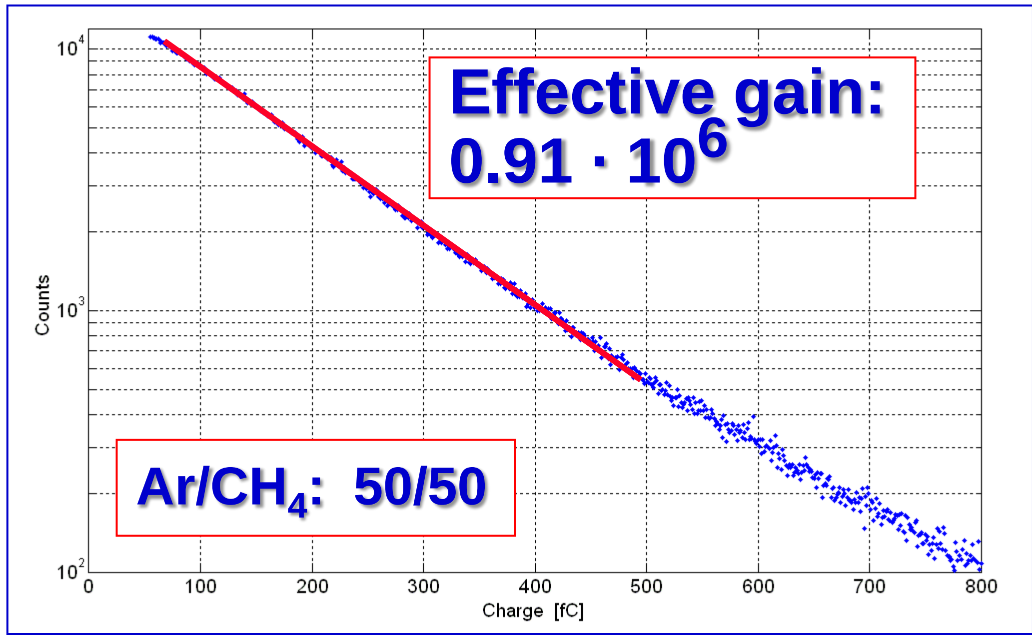


Large gain for single photoelectron

stable detector behaviour at gains up to ~200 000 during test beam exercises

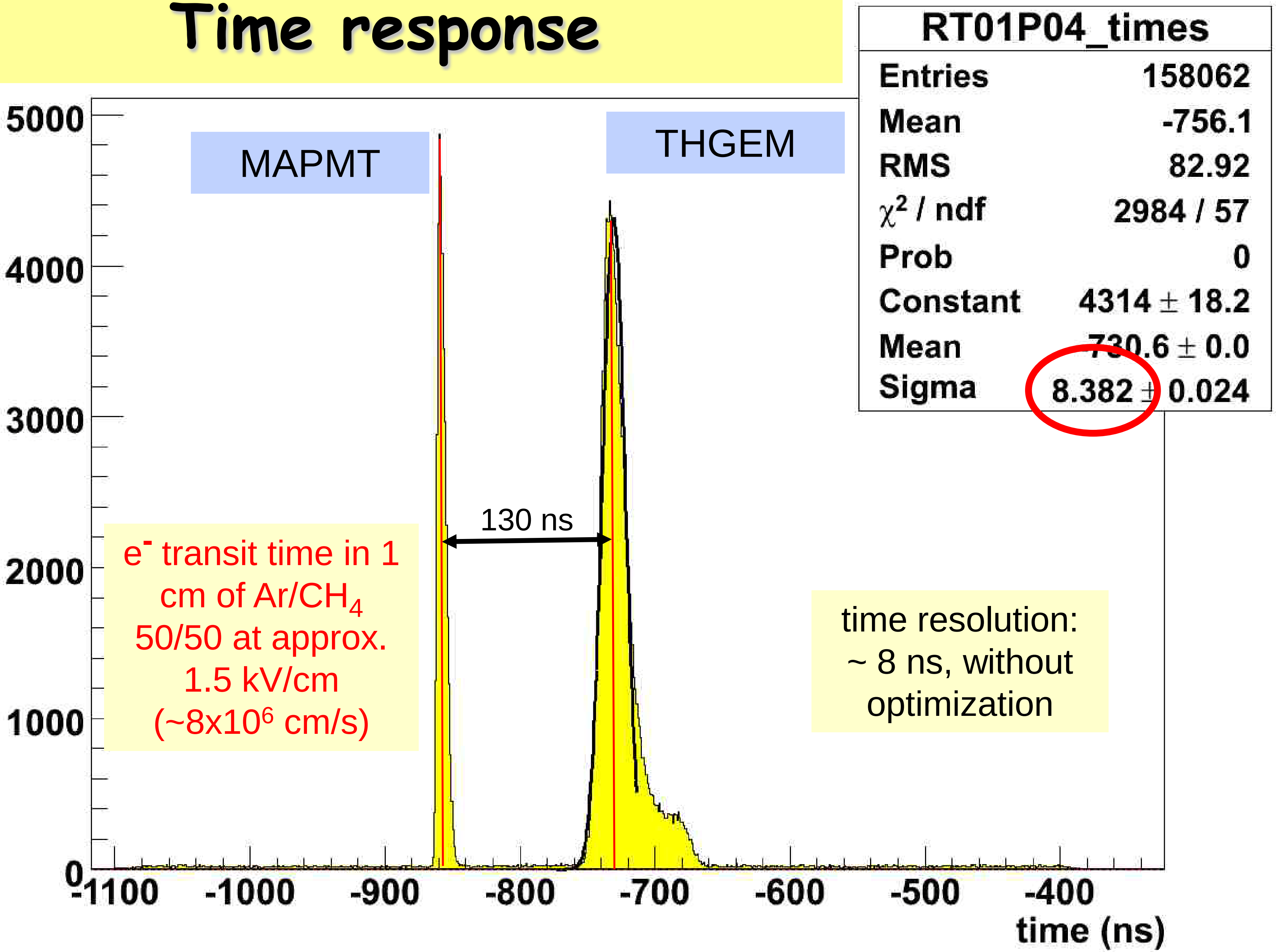
Stable up to gain > 10^6 in laboratroy exercises



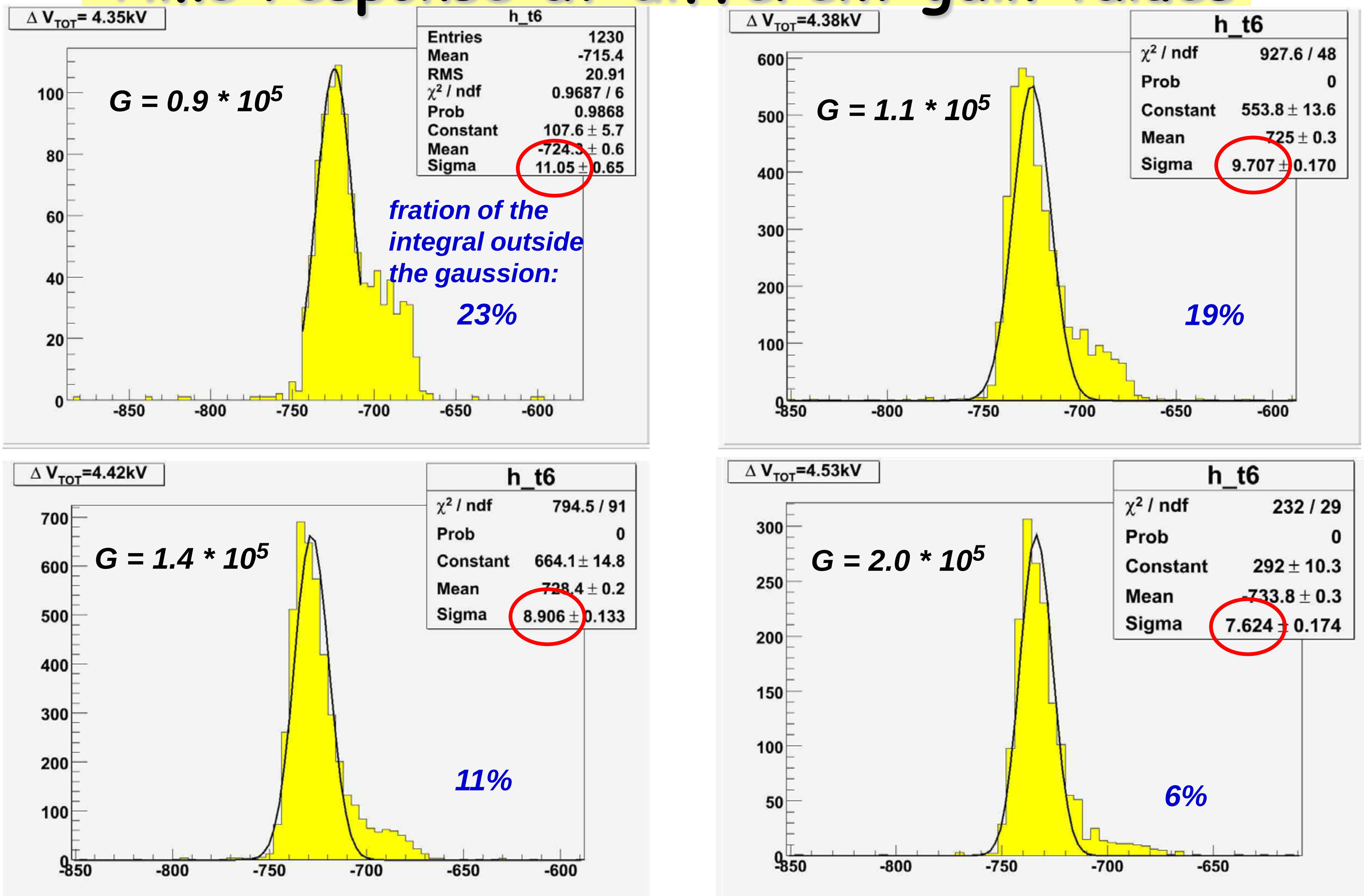


CERN, august 2010

Time response

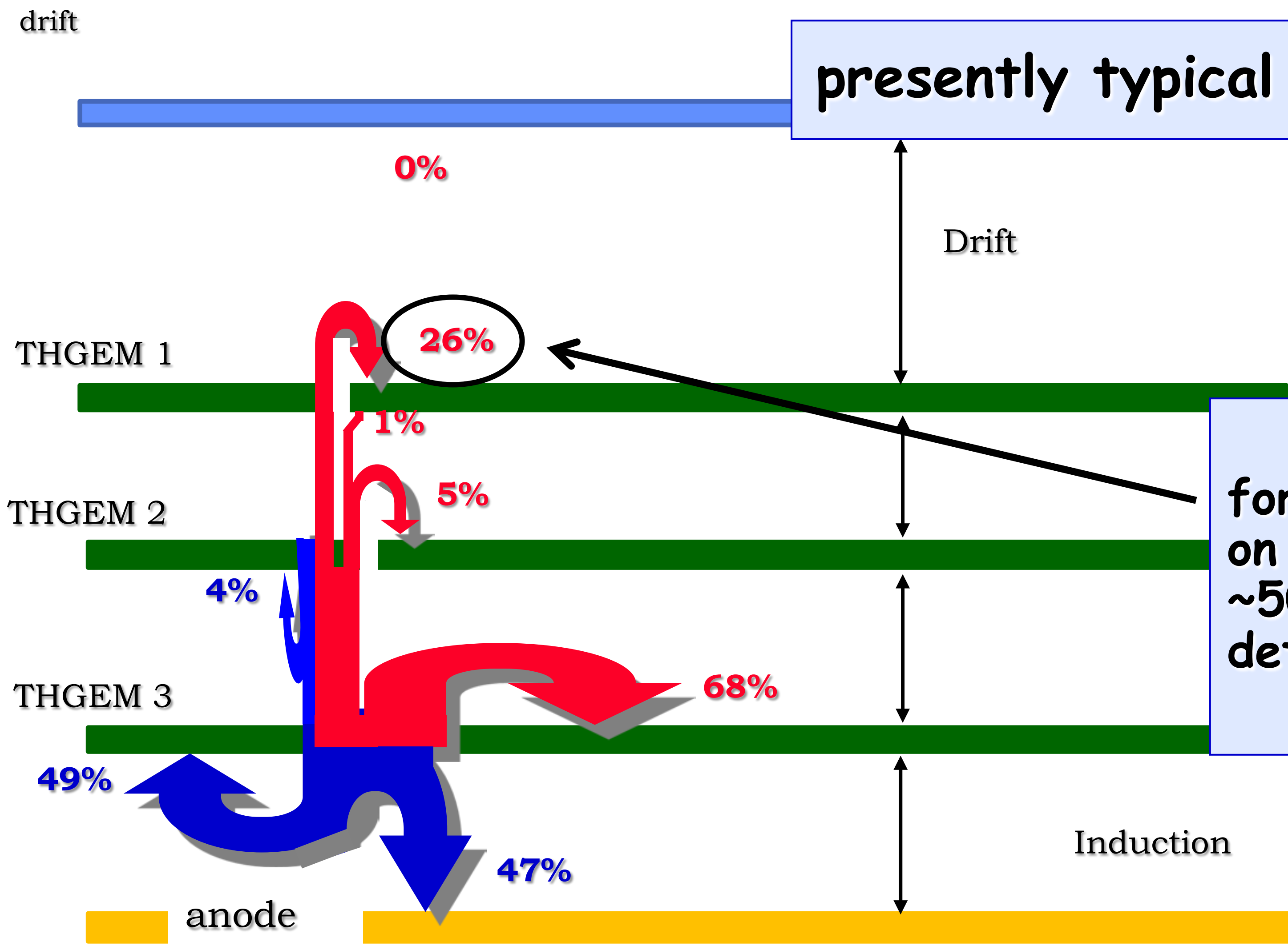


Time response at different gain values



Ion feed-back study: the starting point

presently typical charge sharing



for eff. gain ~ 10^5 → on photocathode ~50000 ions per detected photon

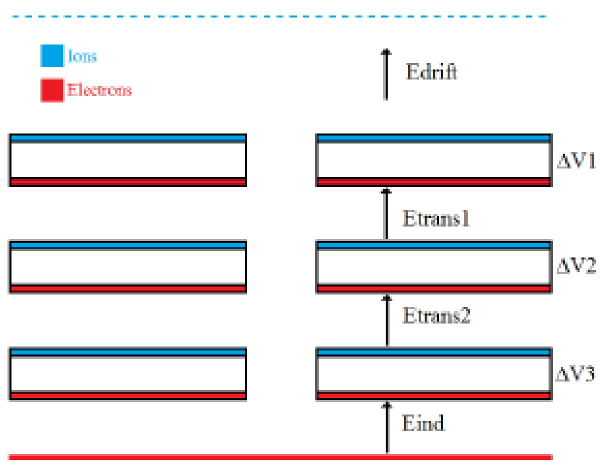
Ion Back Flow

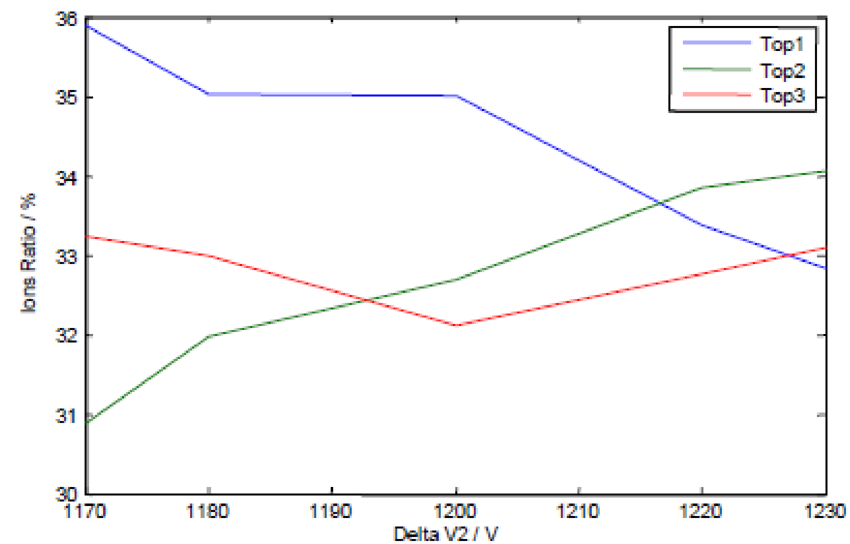
First trial: modify middle THGEM geometry
same pitch 0.8 mm and same thickness but holes from 0.4 to 0.2 mm

Induction Scan, Transfer field scan, ΔV scan and multiple combinations → *reduction possible in the order of few percent only*

E_D = 0 V/cm
E_{T1} = 500 V/cm
E_{T2} = 750 V/cm
E_I = 2500 V/cm

Δ V1 = 1050 V
Δ V2 = 1200 V
ΔV3 = 1000V

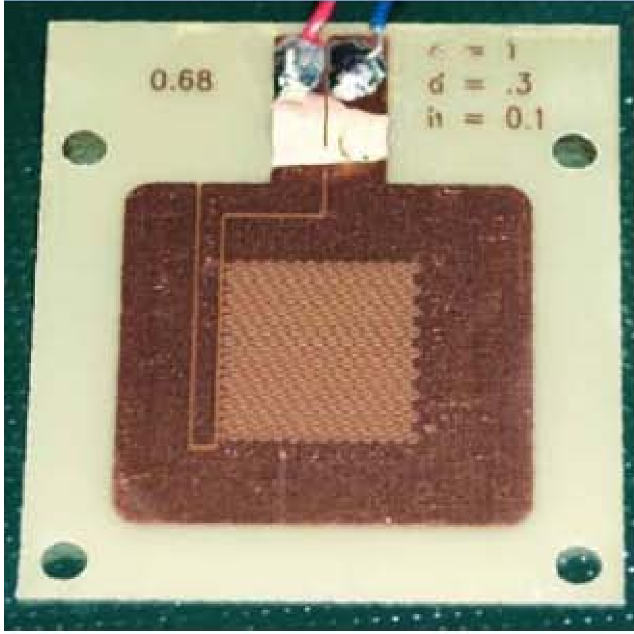


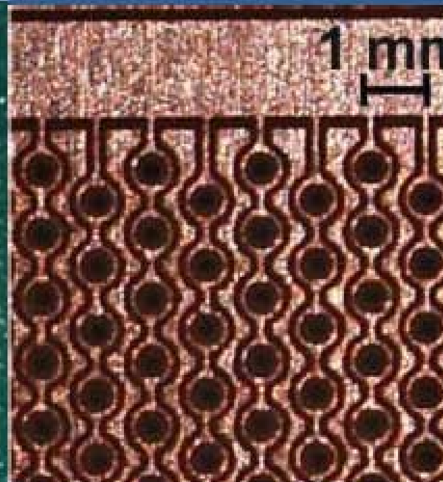


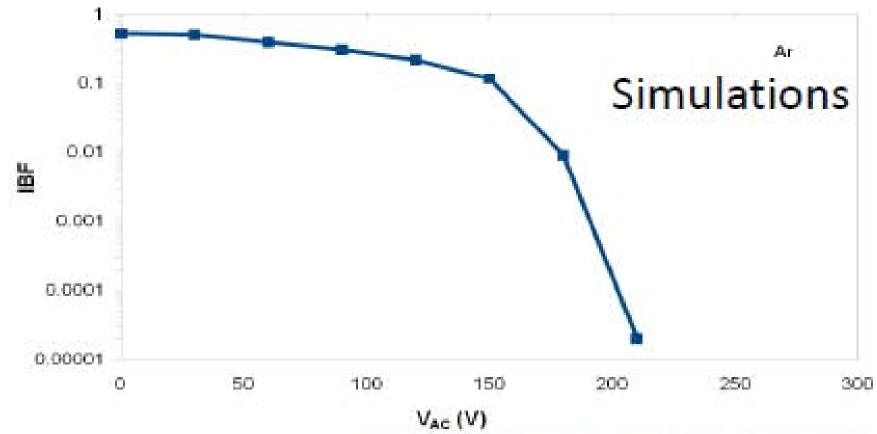
Simple geometrical solutions seem not to be sufficient, different approach needed

Simple geometrical solutions are not effective

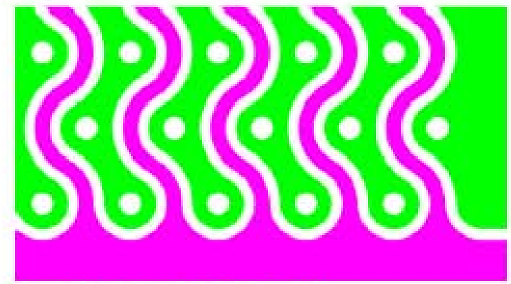
Ion Back Flow reduction







New Thick Hole-Structures for Gaseous Detectors, João Veloso RD51



Single photon detection efficiency strongly affected by

Active area (electrode) / Dead area (holes) → limits on the geometry of 1th THGEM

E field on the surface → geometrical parameters of the 1th THGEM

$E_z \sim \exp(\text{diam.})$

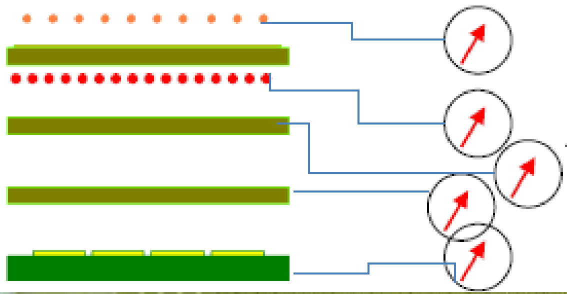
$E_z \sim 1/(\text{pitch})^4$

Impose constrains on the maximum space between electrodes for THCOBRA → pitch and hole size

Hole	Ering	Clearance	Cobra Electrode	Pitch
400	2X80	2X80	80	800

Loosing robustness and constraining too much the geometry

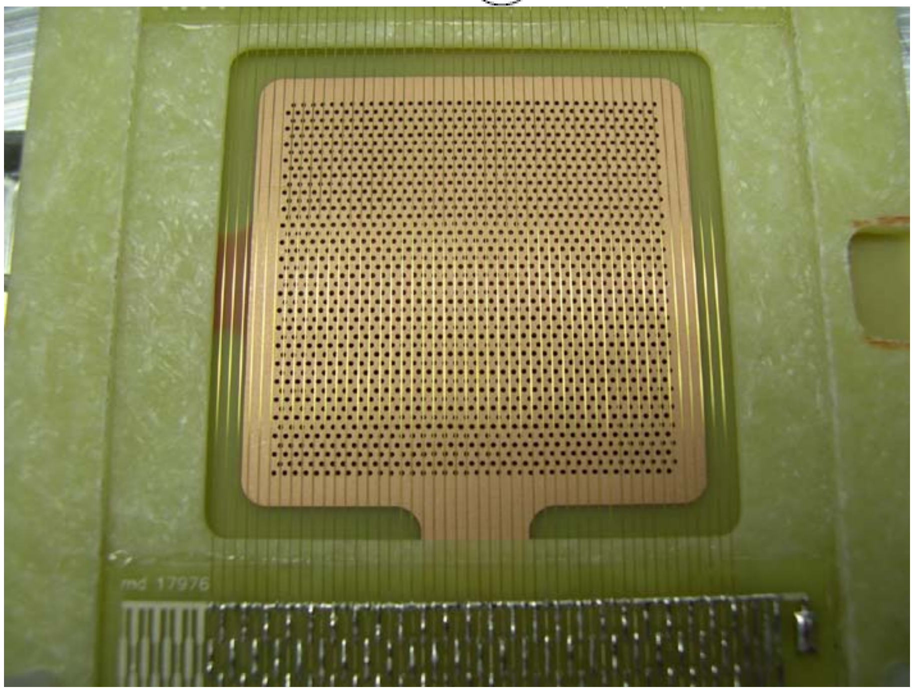
Inserting a dedicated electrode

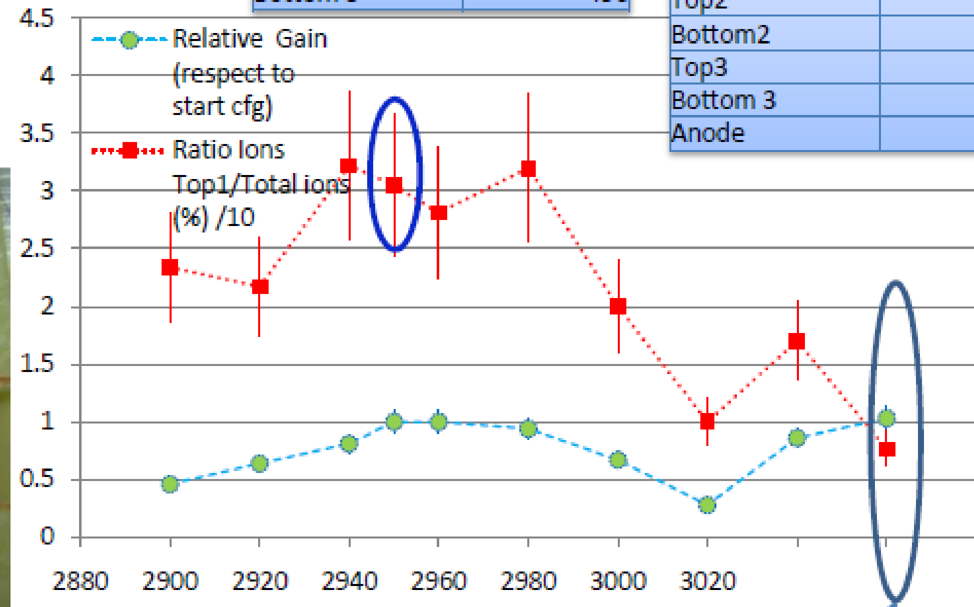


1 pA for each layer, 2mm spacing

HV	Volt
Drift	4100
Top1	4100
Bottom 1	2956
Cobra wires	3020
Top2	2807
Bottom2	1650
Top3	1510
Bottom 3	490

Anode	0
Drift	4100
Top1	4110
Bottom 1	3150
Cobra wires	3220
Top2	3000
Bottom2	1650
Top3	1510
Bottom 3	500
Anode	0





Increasing Second THGEM ΔV (200V)

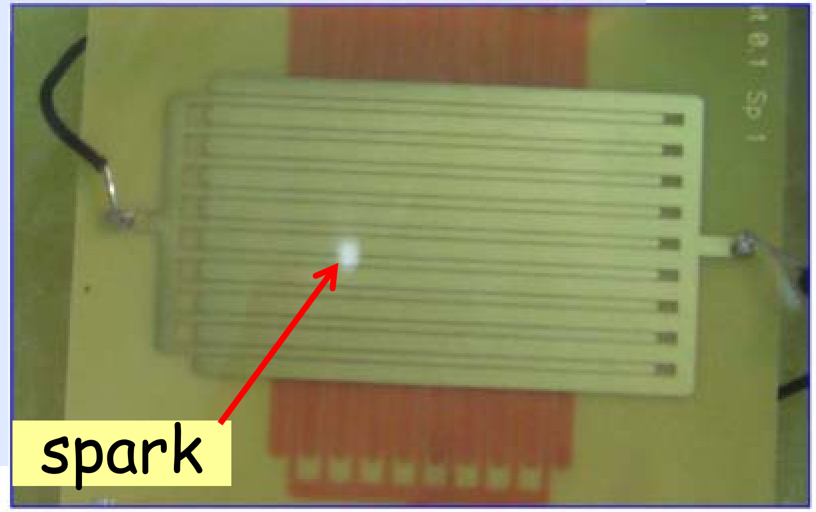
Reduction by a factror 4 of the ion feed-back without gain losses

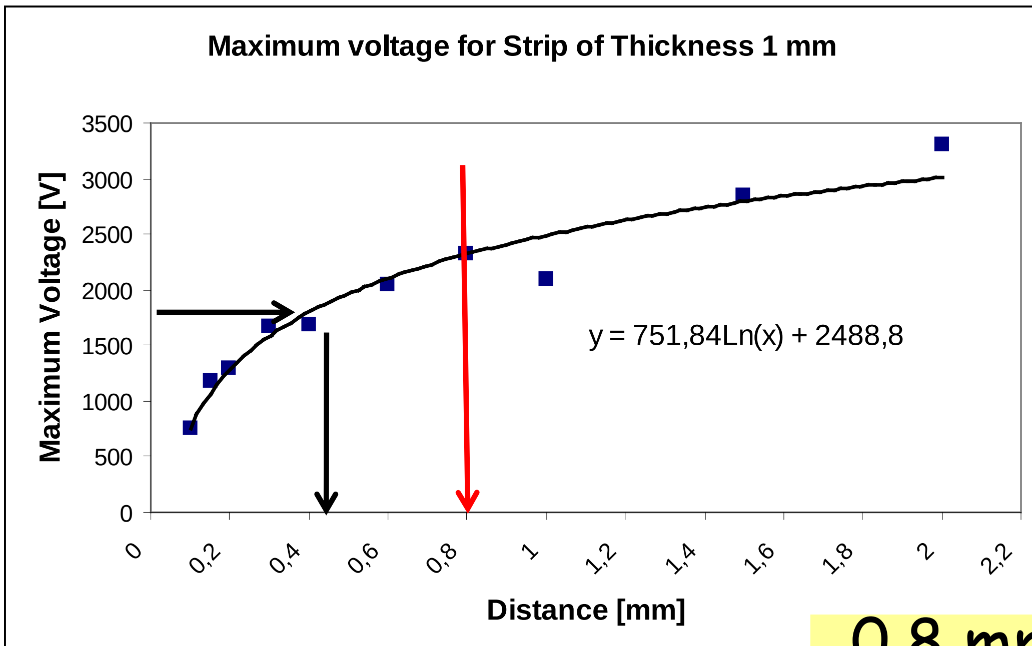
Segmentation studies for the large THGEMs

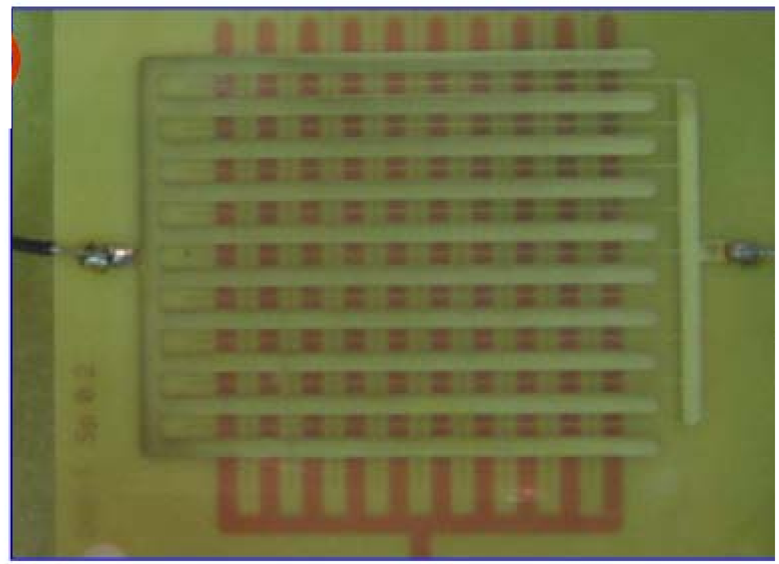
Samples of 20 different types

Determine the breakdown voltage

Use this information to properly design the THGEM segmentation

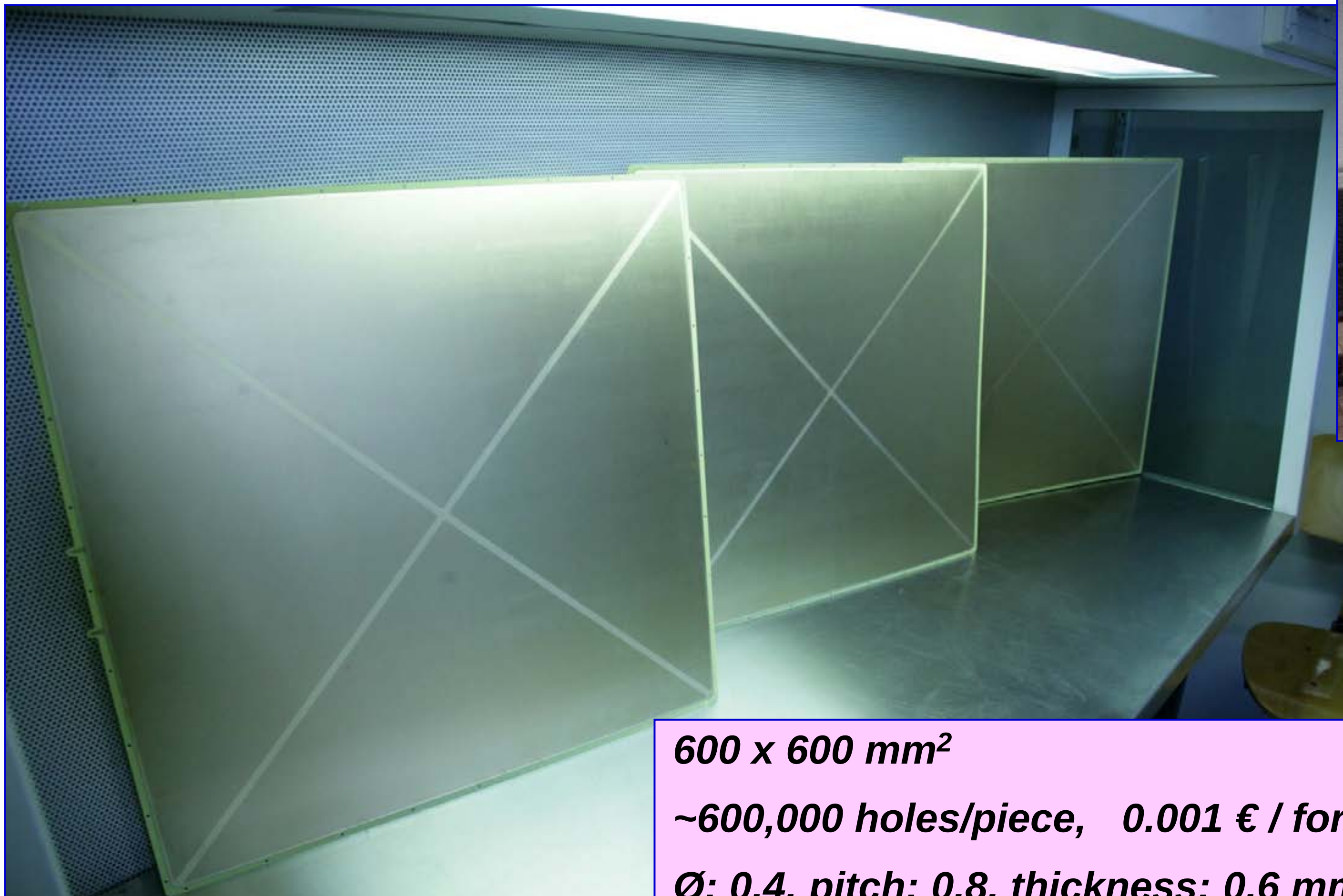






0.8 mm separation between segments → 3% di zona morta

PRODUCING LARGE SIZE THGEMs



600 x 600 mm²

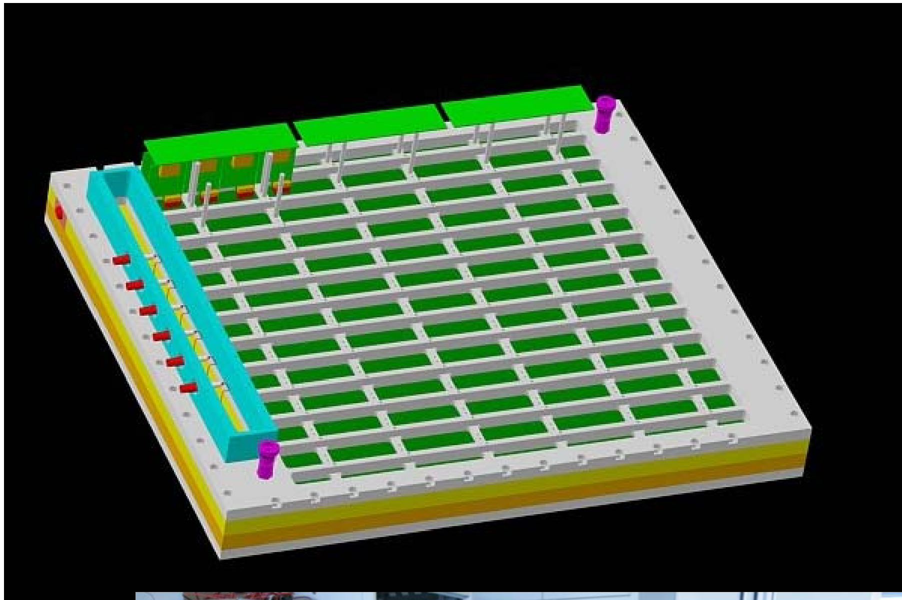
~600,000 holes/piece,   0.001 € / foro

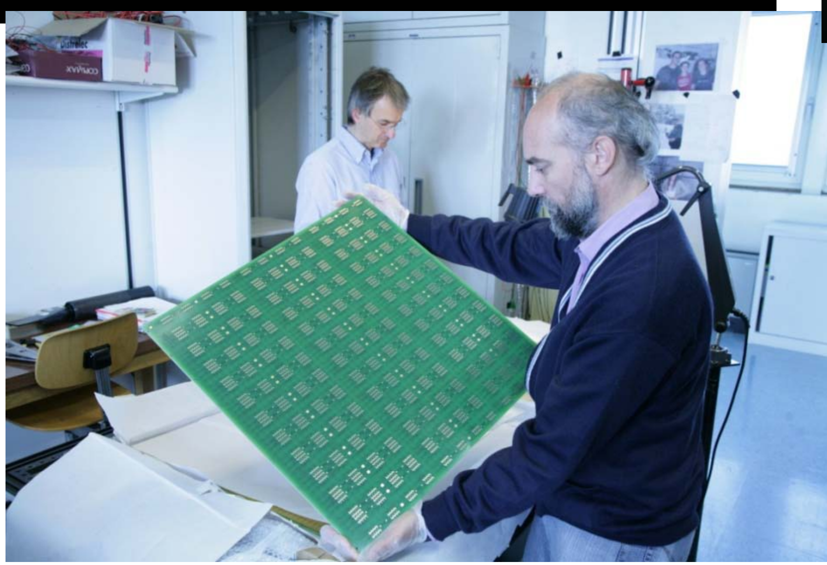
Ø: 0.4, pitch: 0.8, thickness: 0.6 mm

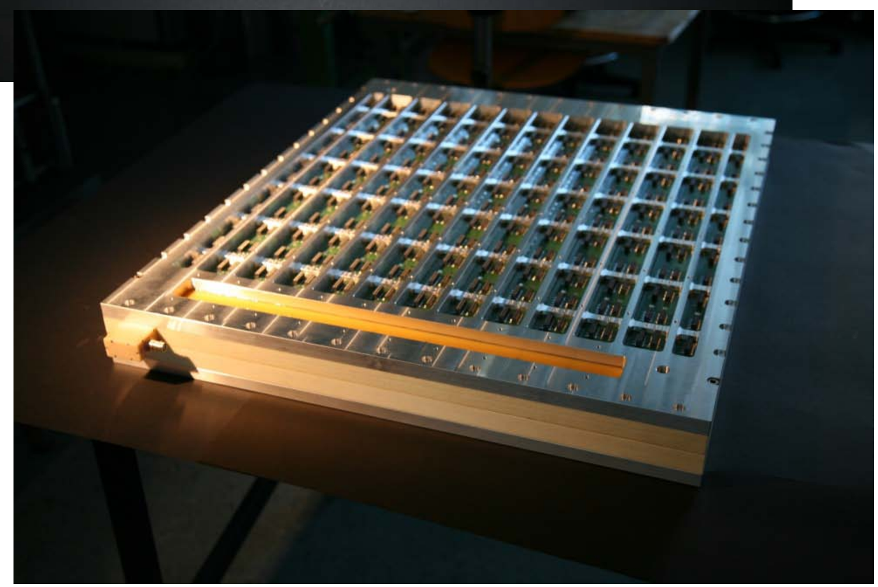
rim: 5 μm (micro-etching)

Ni-Au coating

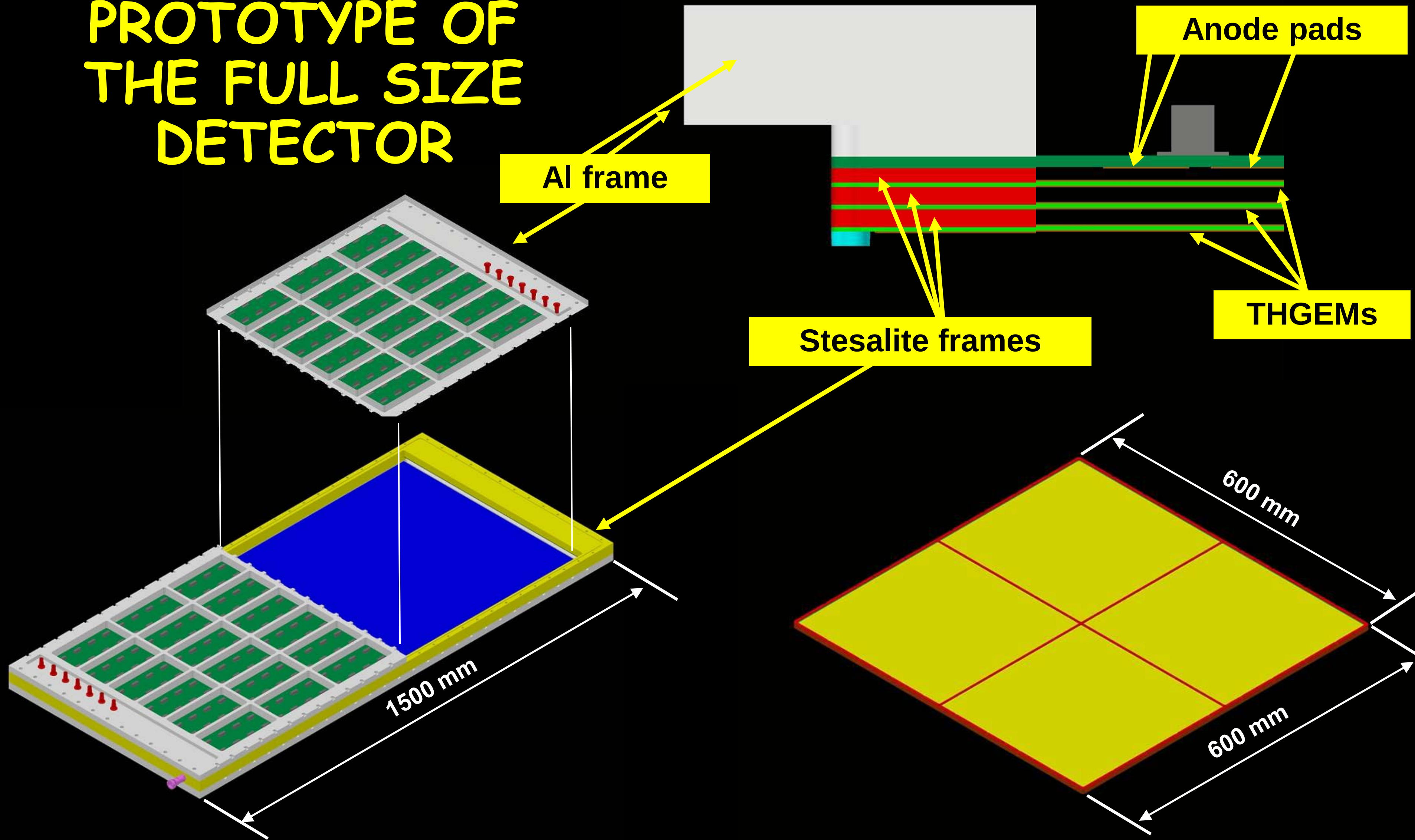
BUILDING LARGE SIZE DETECTORS







DESIGNING THE PROTOTYPE OF THE FULL SIZE DETECTOR



Please,

come and enjoy the lab session !