Large Area Detectors of single photons based on THGEM and hybrid MPGD architectures

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on behalf of the COMPASS THGEM group:

Alessandria, Aveiro, Calcutta, Freiburg, Liberec, Prague, Torino, Trieste

History of large area gaseous PDs

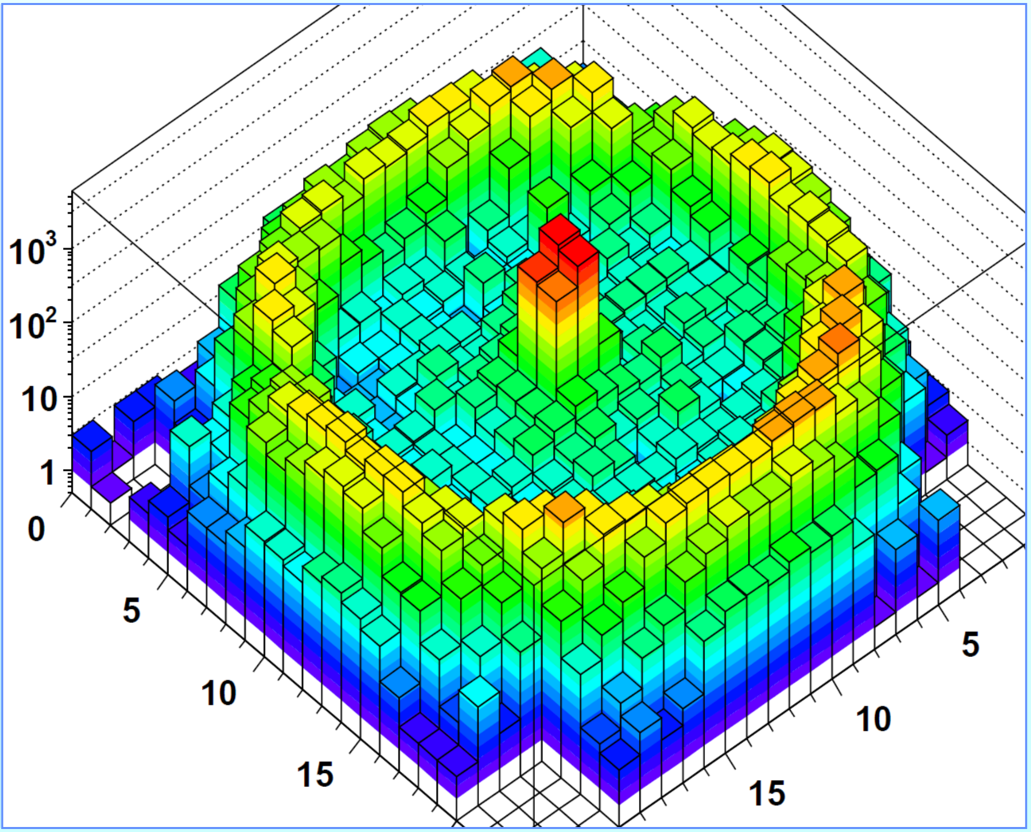
THGEM-based PD’s

Production issues for large THGEMs

The ion backflow reduction

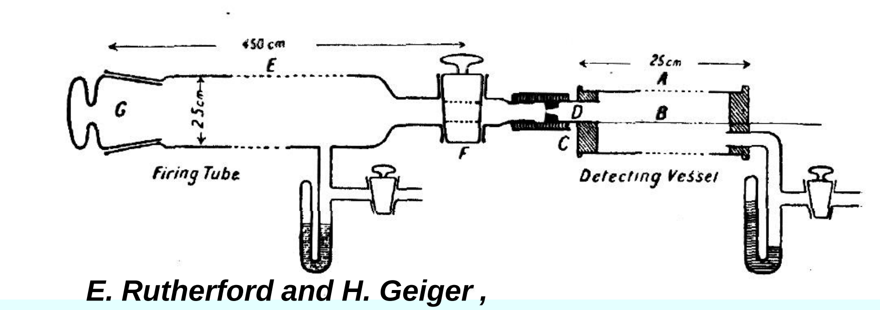
Hybrid THGEM + Micromegas PD’s

The 600 mm x 600 mm PD’s for RICH-1



100 years of gaseous detector developments

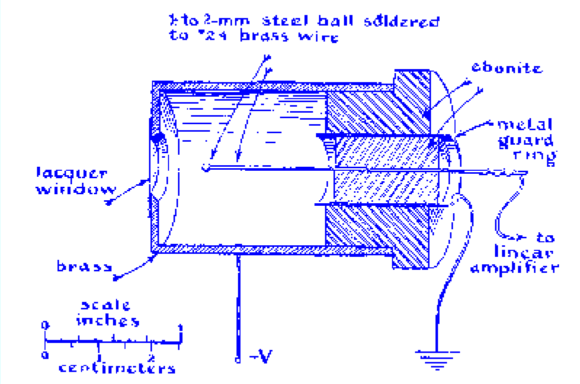
1908: FIRST WIRE COUNTER USED BY RUTHERFORD IN THE STUDY OF NATURAL RADIOACTIVITY



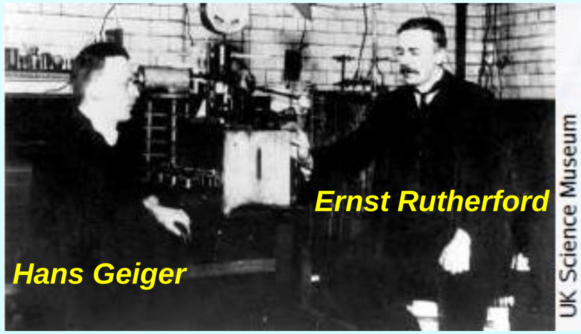
E. Rutherford and H. Geiger , Proc. Royal Soc. A81 (1908) 141

Nobel Prize in Chemistry in 1908

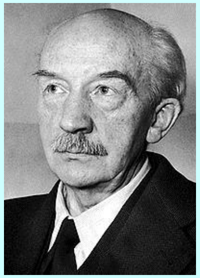
1928: GEIGER COUNTER SINGLE ELECTRON SENSITIVITY



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

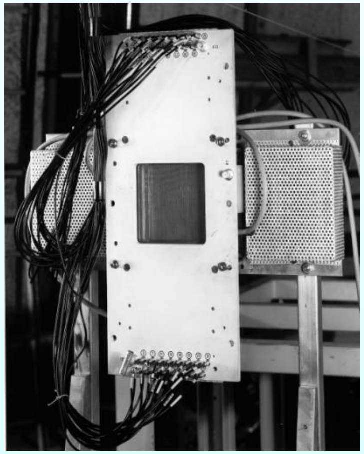


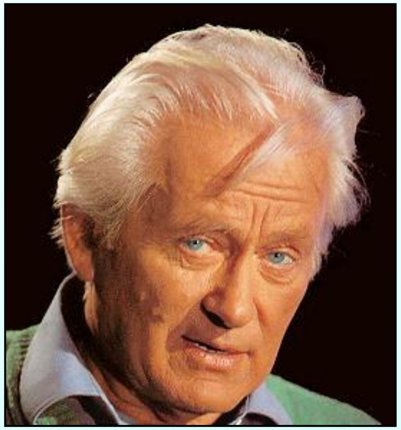
UK Science Museum



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

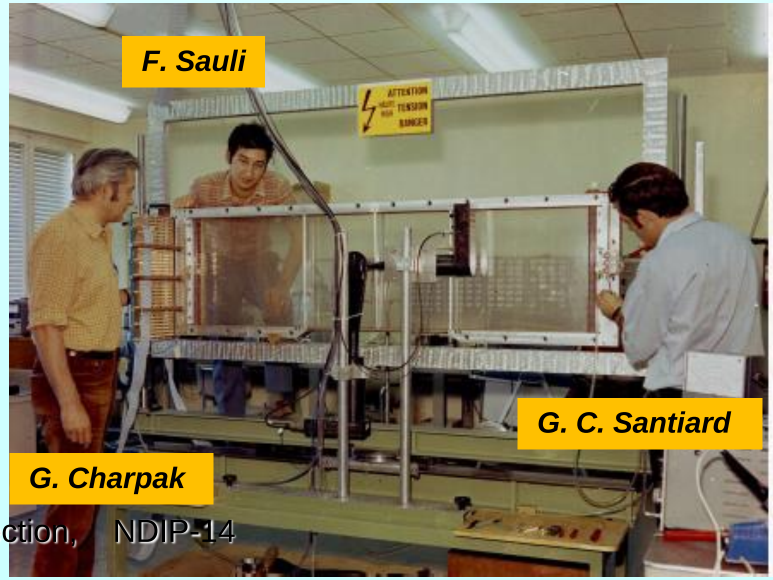
1968: MULTIWIRE PROPORTIONAL CHAMBER





Nobel Prize in 1992

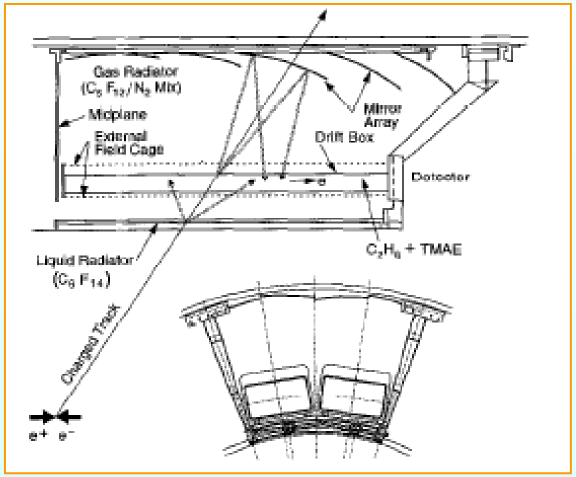
G. Charpak, Proc. Int. Symp. Nuclear Electronics (Versailles 10-13 Sept 1968)

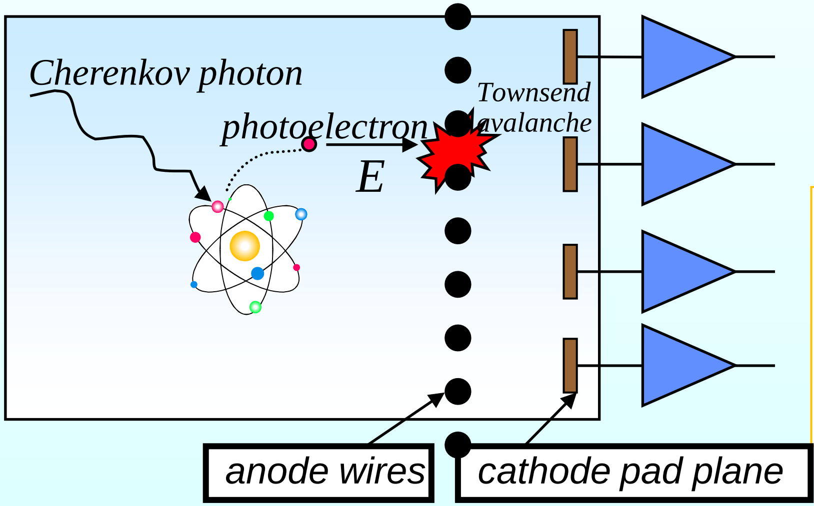


RICH with large area gaseous PD's
1st generation: photoconverting vapours


A. Einstein, Nobel Prize in 1921

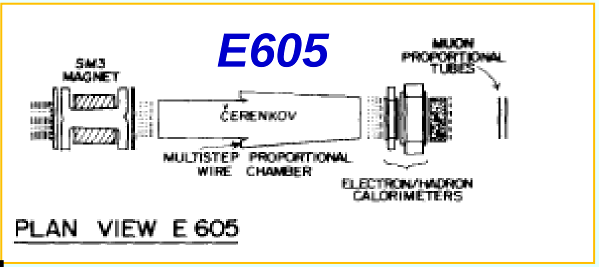
SLD - CRID

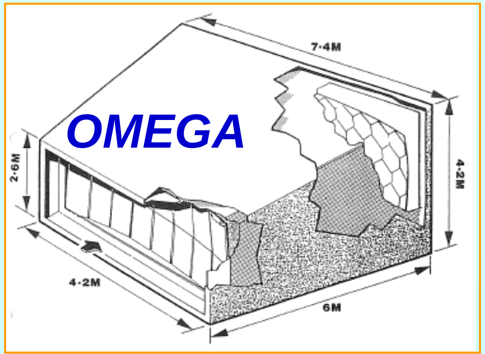


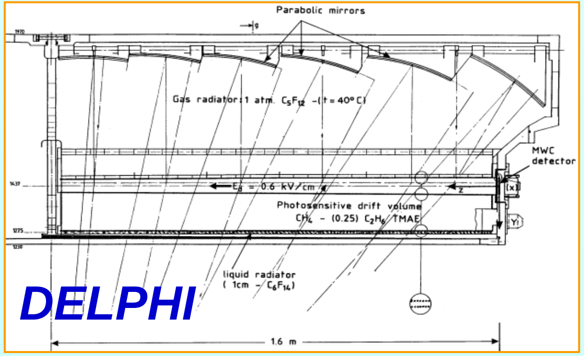


anode wires

cathode pad plane

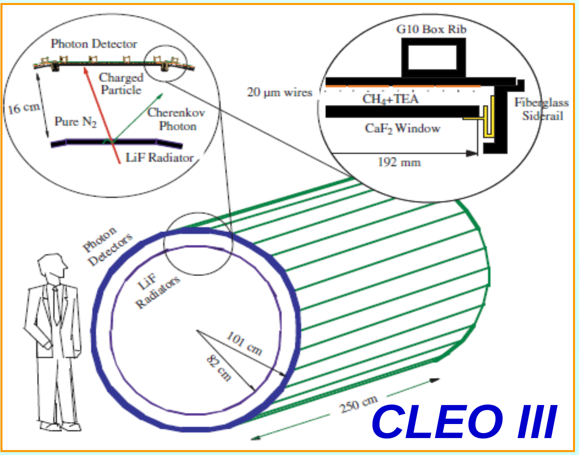






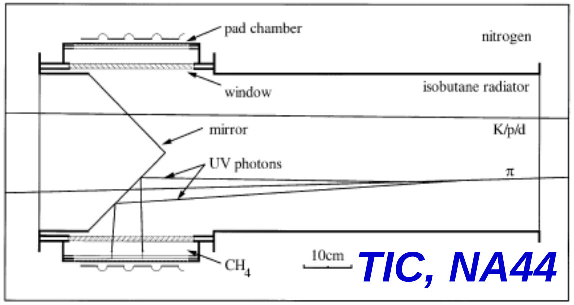
TMAE(Tetrakis-Dimethylamine-Ethylene)


Tom Ypsilantis



TEA (Tri-Ethyl-Amine)

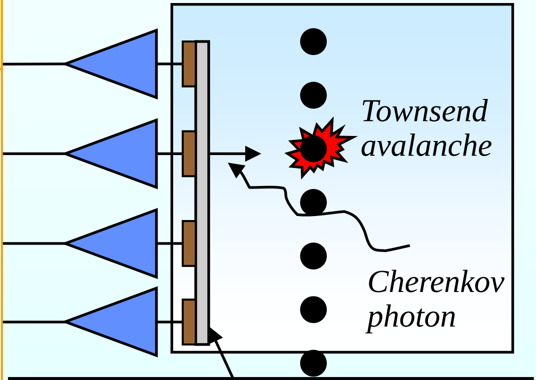
RICH with large area gaseous PD's
2nd generation: MWPC's + CsI



TIC, NA44

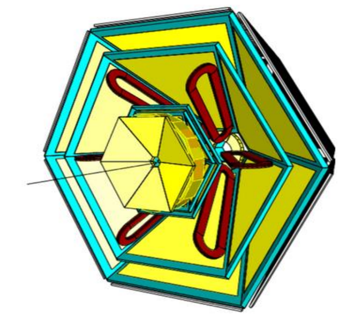
RD26

1992, F. Piuz et al. Development of large area advanced fast-RICH detector for particle identification at LHC operated with heavy ions



thin layer (300 - 500 nm) of CsI on the cathode pad plane

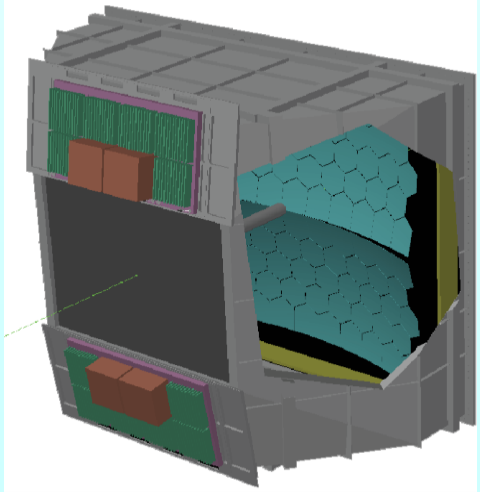
François Piuz



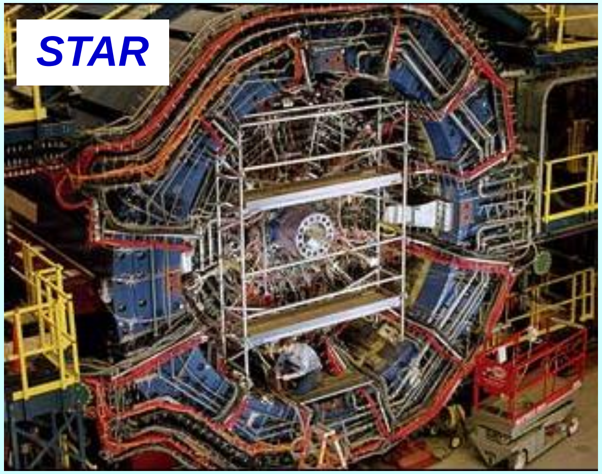
HADES

JLAB-HALL A

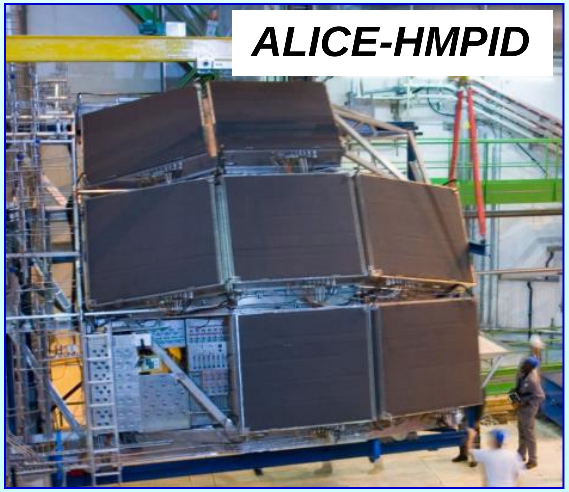
COMPASS RICH-1



STAR

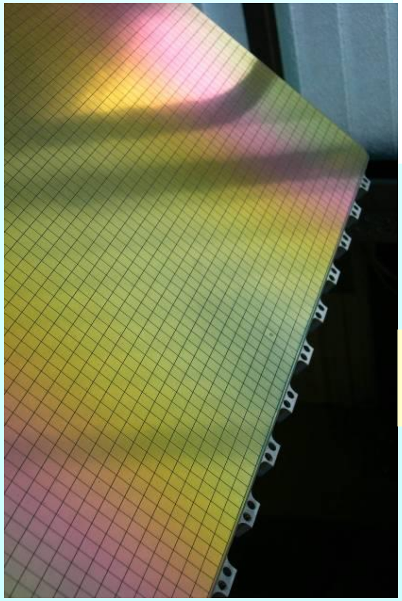


ALICE-HMPID



An effective PD with solid state photocathode in a gaseous atmosphere: a success !

MWPCs + CsI have some limits:



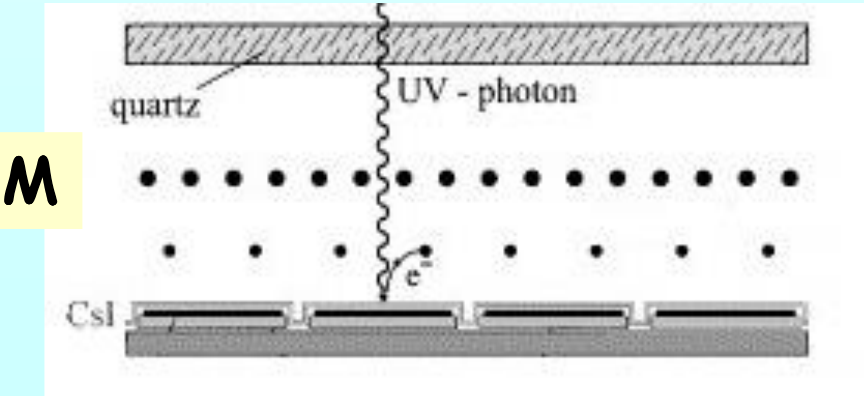
- *the effective gain is moderate (~10,000 → p.e. detection eff. ~70%)*
- *the quantum efficiency is challenged by aging (~1 mC/cm^2)*
- *the signal is slow, coming from the ions drift (~100 ns)*
- *for larger gains the electrical stability in the experimental environment is limited and the recovery time after a detector trip is long (~1 d)*

__Performances in terms of rate capability and noise rejection cannot be increased without a change of technology__.

The new photon detectors should:

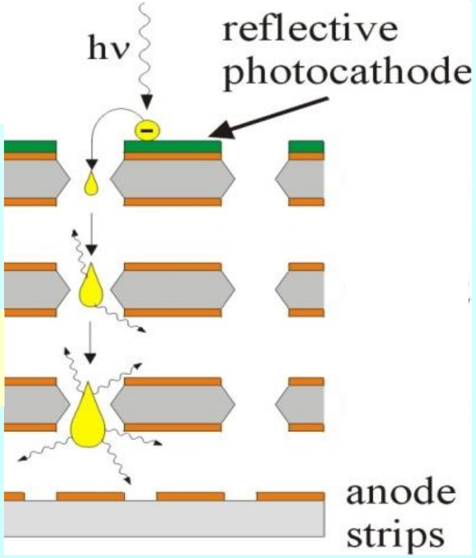
- *use a closed geometry to avoid photon feedback*
- *reduce the ion backflow to the CsI layer*
- *detect signals from electron drift (few ns)*
- *use simple and robust components*

FROM



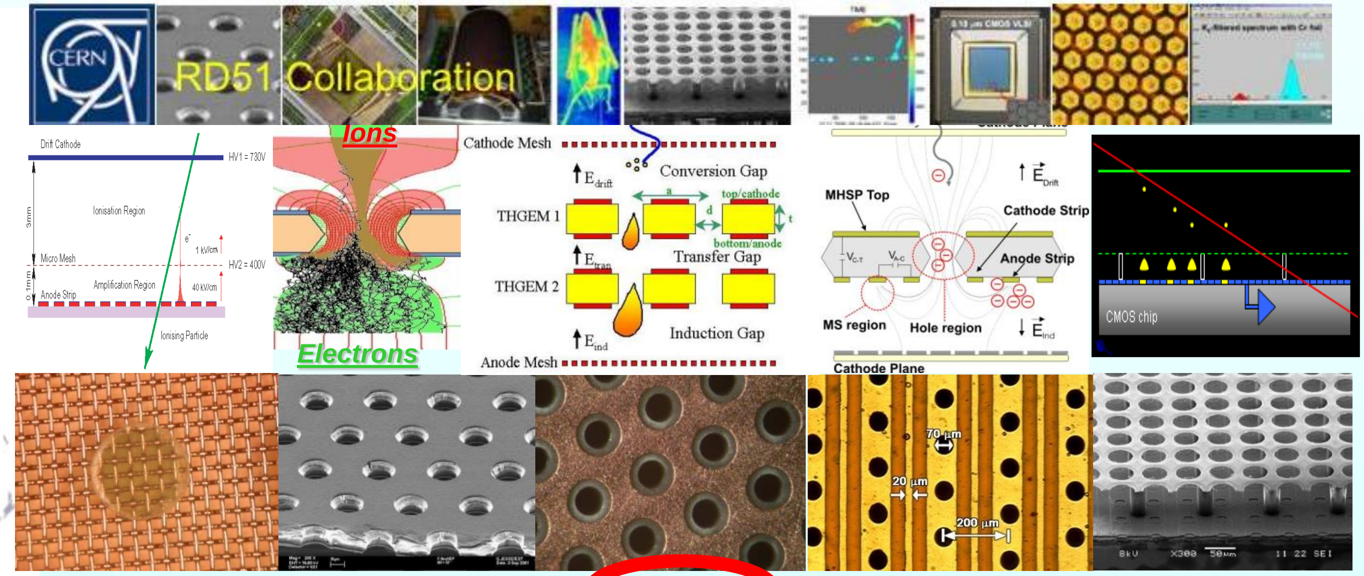
TO

A. Breskin and R. Chechik,
NIM A 595 (2008) 116



the large area gaseous PD's for next generation RICH's will use MPGDs

~ 90 Institutes from 4 continents
~ 500 physicists
"serves as an access point to MPGD know-how for the world-wide community"

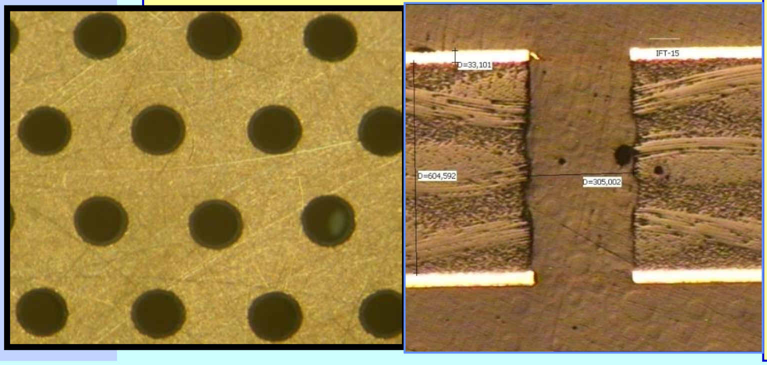


Micromegas **GEM** **THGEM** *MHSP* *Ingrid*

MPGD characteristics:

- *Able to work and cope with high rate detection*
- *High gain achievable: gas gain*
- *Good time/space/E resolution*
- *Robust: ageing robustness*
- *Natural Ion Backflow/Photon feedback reduction*
- *Low cost large size detector production possible*
- *Intrinsically fast: signal is induced by electrons…!*

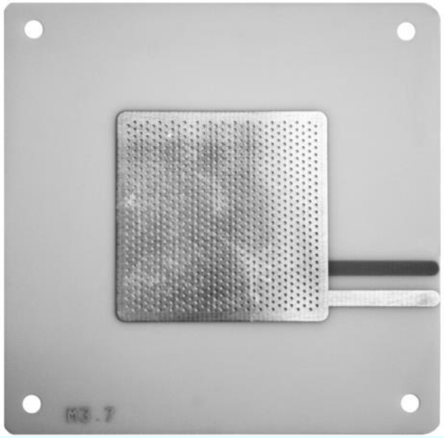
THGEMs are Electron Multipliers derived from the GEM concept with larger geometrical dimensions and produced by standard PCB technology.



Electrical robustness: no damages induced by discharges
- Mechanical properties: robust and self supporting (no stretching is needed)
- Possible industrial production of large size @ low cost (PCB)
- Economic material

The COMPASS THGEM R&D project

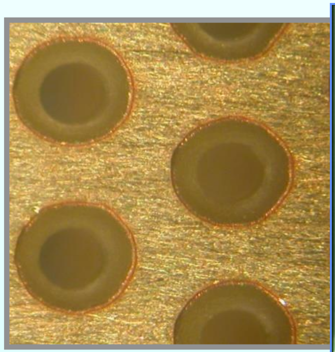
Seven years ago we started an R&D program to develop a large size, cheap, robust, fast, high gain, high rate, magnetic insensitive single photon detector for RICH applications, based on THGEM and reflective CsI photocathode, to be used for the upgrade of COMPASS RICH-1

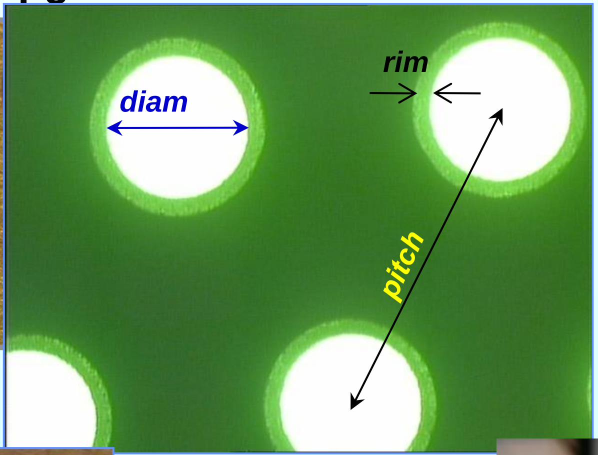


small THGEM's have 30 x 30 mm^2 active area

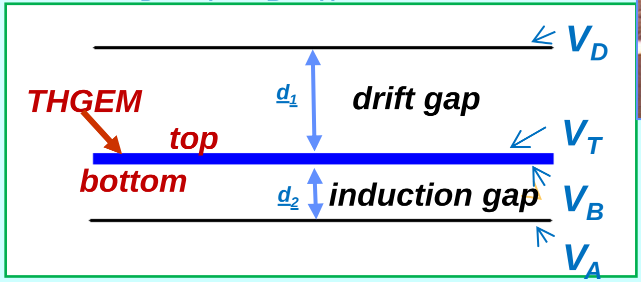
MULTI-DIMENSIONAL SPACE:

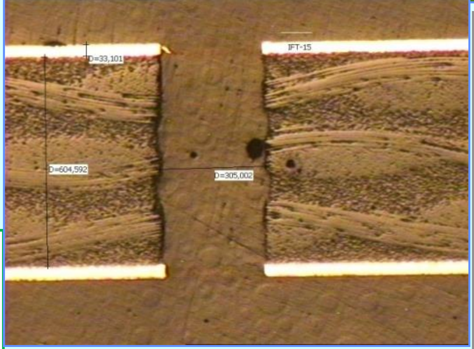
- **Isolating substrate material**
- **Thickness**
- **Hole diameter**
- **Pitch**
- **Rim size**
- **Holes and rim production procedure**
- **Induction field**
- **Drift field**
- **Geometrical arrangement**
- **Gas mixture**





To detect ionizing particle :
$V_D < V_T < V_B < V_A$

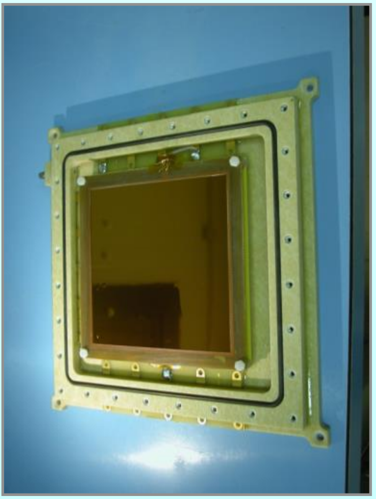


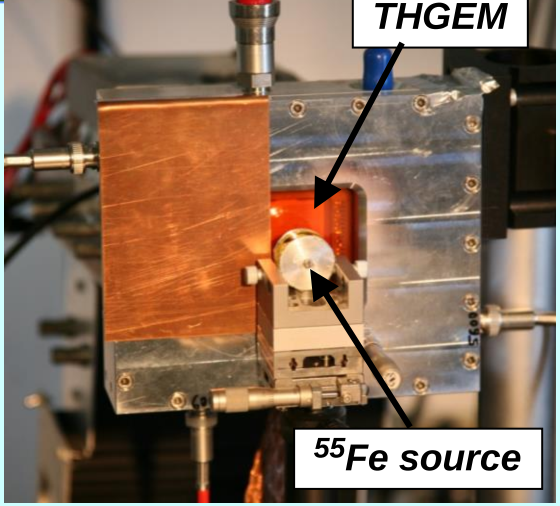


$E_{drift} = (V_D - V_T) / d_1$

$E_{induction} = (V_B - V_A) / d_2$

$\Delta V = V_T - V_B$





Characterization and tests of small THGEMs

More than 50 different THGEM types have been characterized using X-ray:

- optimized drift field (specific for each type)

- large rim → large gain but good gain stability guaranteed for small rim or no rim

- production procedure details are very important

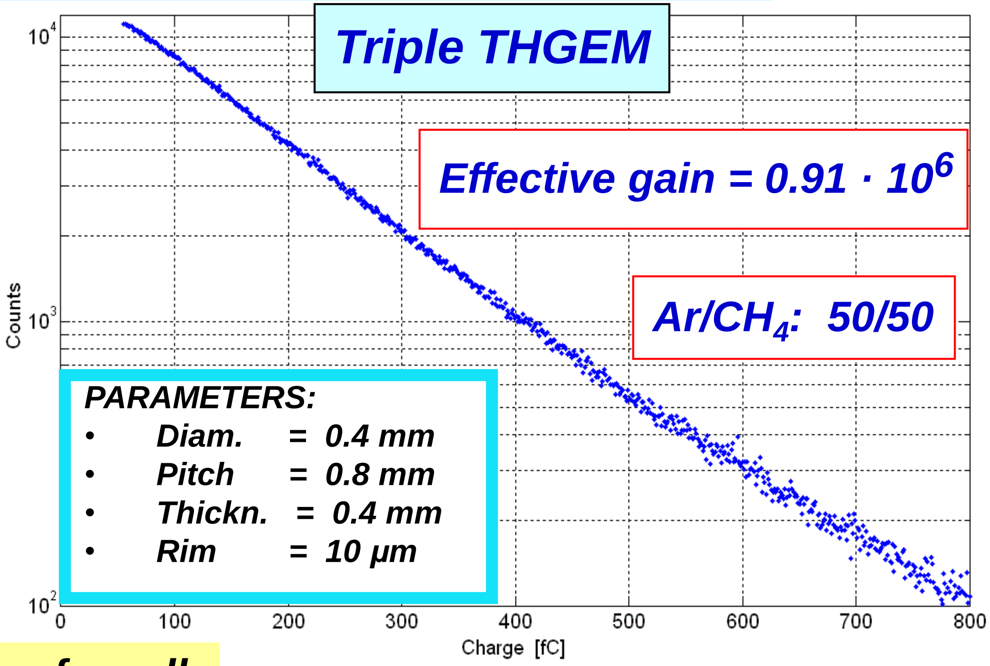
- good rate capability

Using UV light sources we investigated:

- photoelectron extraction and collection efficiency,

- timing properties of the signal (using 600 ps long light pulses)

- photoelectron detection efficiency with digital r/o



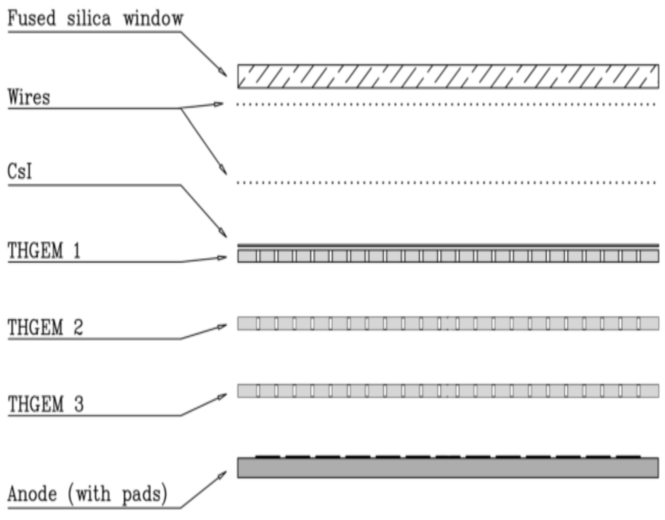
Triple THGEM

Effective gain = 0.91 · 10^6

Ar/CH$_4$: 50/50

PARAMETERS:

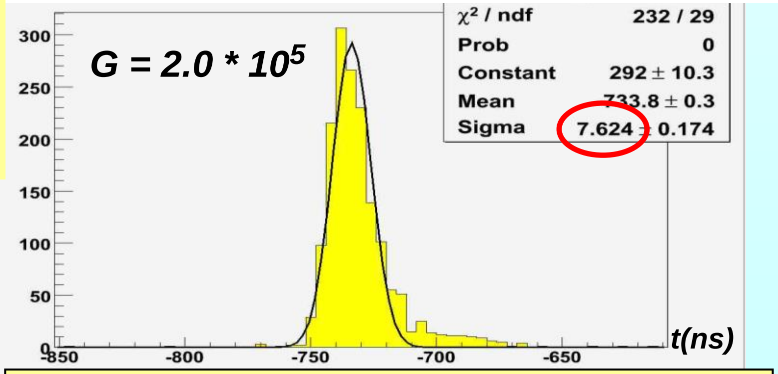
- ***Diam. = 0.4 mm***
- ***Pitch = 0.8 mm***
- ***Thickn. = 0.4 mm***
- ***Rim = 10 µm***



Several prototypes of small THGEM-based PD's have been built and tested in the lab and at test beams

Small size PD's
(active area = 30x30 mm^2)

typical max. stable gain:
with UV light in lab: 1 M
during test beam: 0.2 M



efficient detection of single photons
signal formation time ≈ 100 ns,
time resolution ≈ 8 ns

Operating THGEM-based PDs we realized:

In order to achieve a good photoelectron extraction efficiency we need:

- ***high value of the electric field at the CsI surface (>1 kV/cm)***
- ***a methane-rich gas mixture to reduce backscattering (> 30% CH_4)***

Reasonable geometrical parameters for our application are:

- ***THGEM_1 (with CsI): thickn. = 0.4 mm, hole diam. = 0.4 mm, pitch = 0.8 mm***
- ***THGEM_2 and THGEM_3: thickn. = 0.8 mm, hole diam. = 0.4 mm, pitch = 0.8 mm***

Predictable detector response is provided by choosing rim size < 10 µm

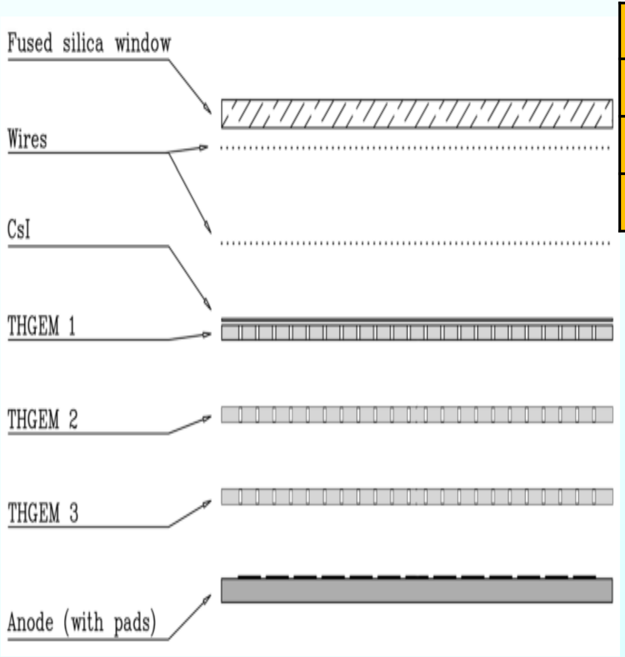
Practical issues:

- ***THGEMs can be produced by industry (ELTOS Company in Italy, for instance)***
- ***The price is moderate: 1000 holes/Euro.***

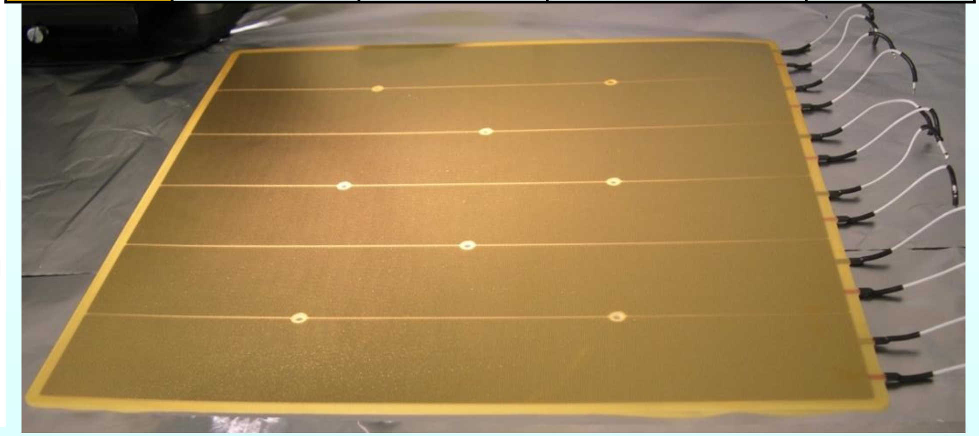
The response may vary a bit from piece to piece, but is stable and reproducible.

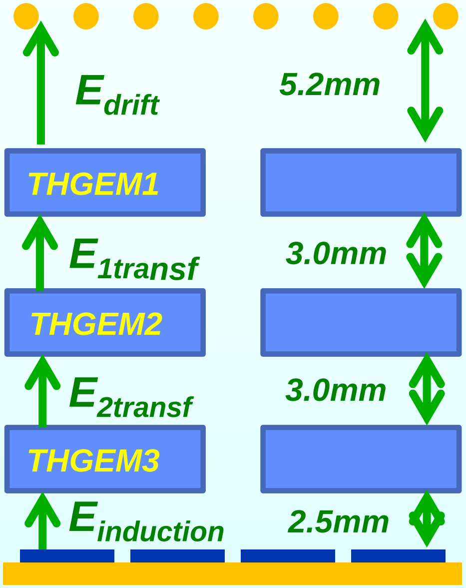
<u>The ion backflow to the CsI is an important item</u>

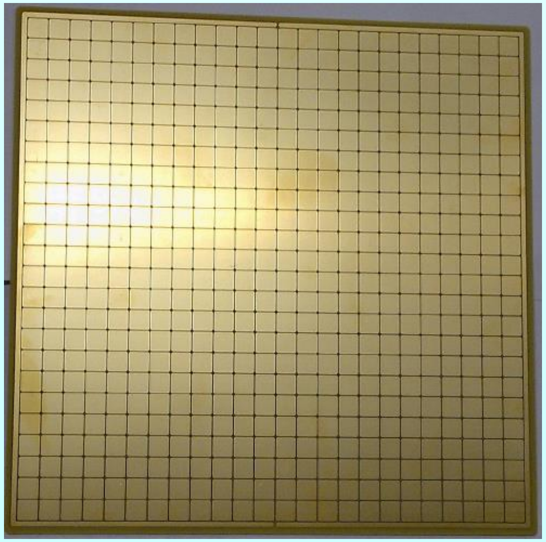
A THGEM-based PD with 300 mm x 300 mm active area has been built

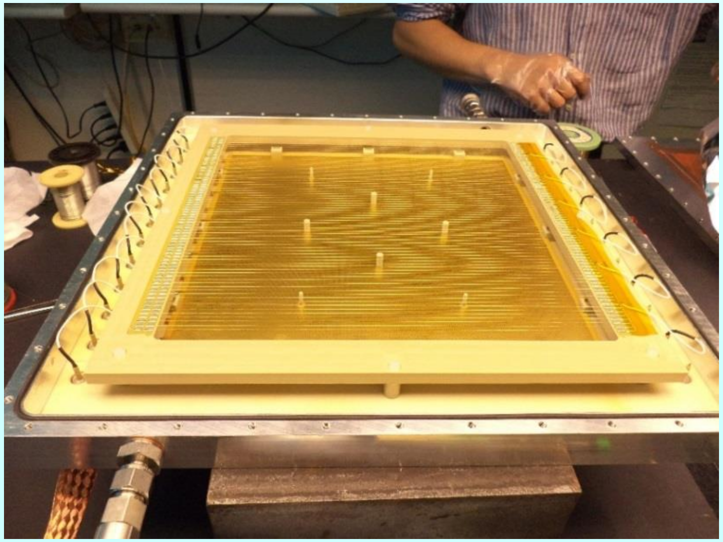


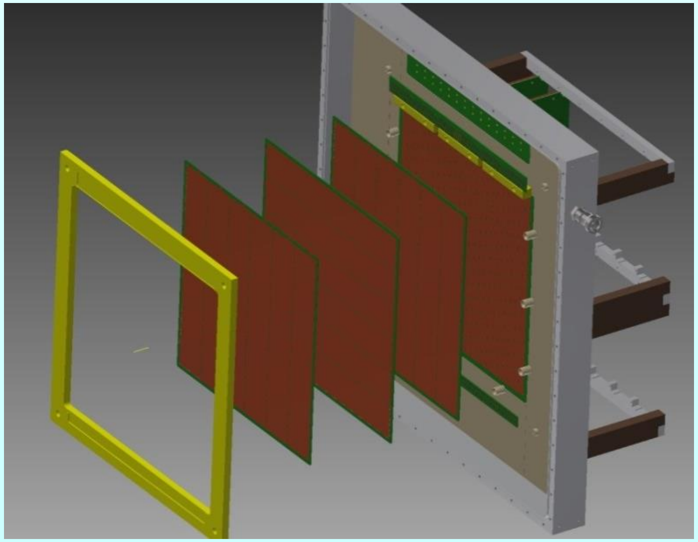
layer	pitch(mm)	Ø$_{hole}$ (mm)	thickness (mm)	rim (μm)
THGEM1	0.8	0.4	0.4	< 5
THGEM2	0.8	0.4	0.8	< 5
THGEM3	0.8	0.4	0.8	< 5





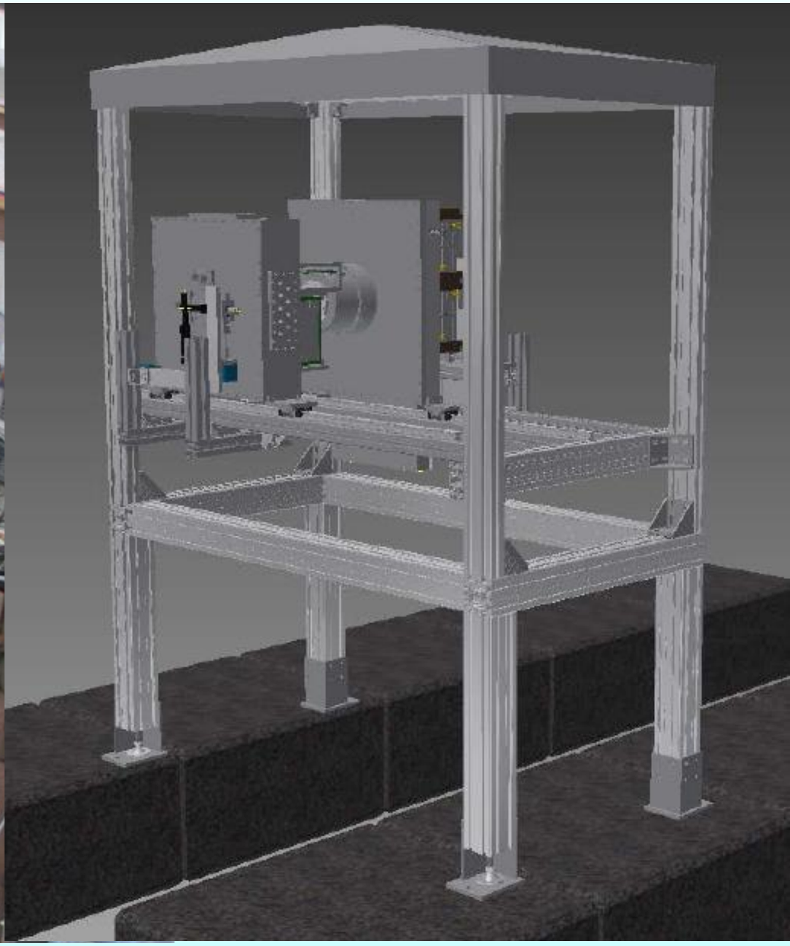




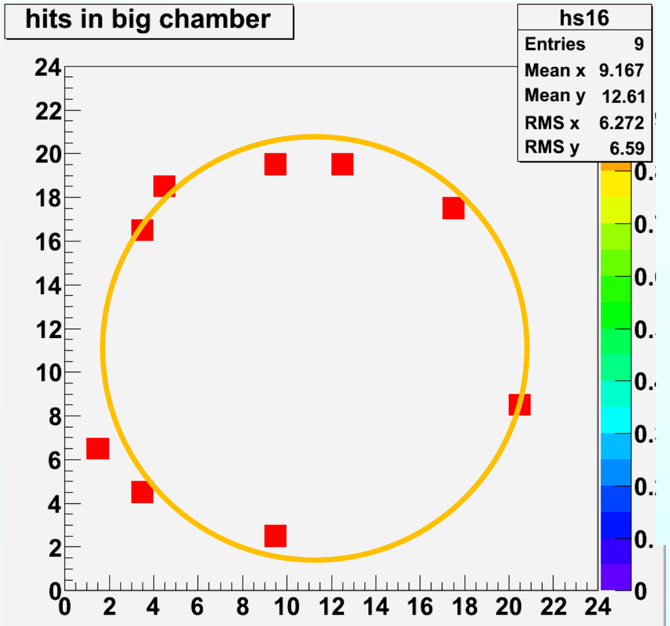


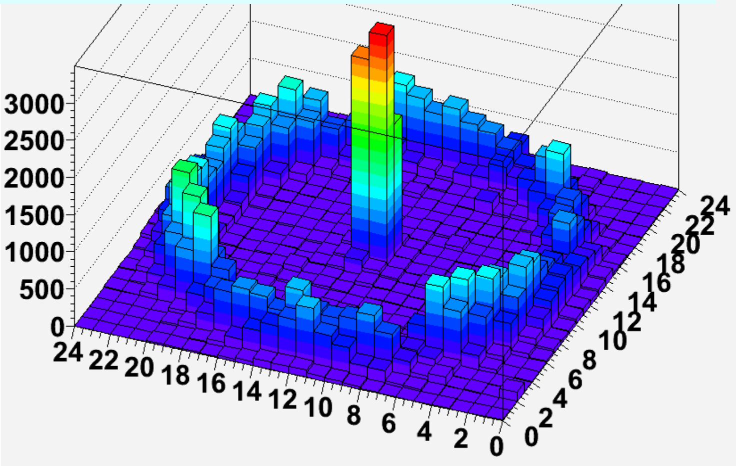
and tested at the PS T10 beam line at CERN

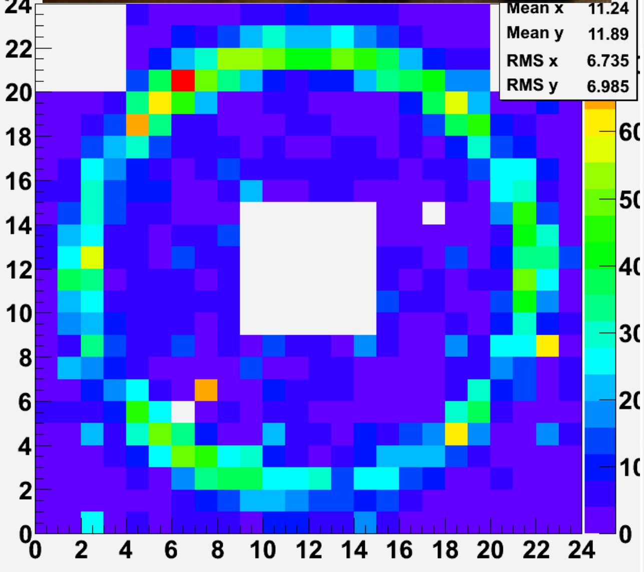
Triple THGEM 300x300 (576 pads); 2 Triple 30x30, 1 MWPC, 1 MAPMT trigger system, Č radiators, analog & digital r/o, COMPASS-like DAQ, …

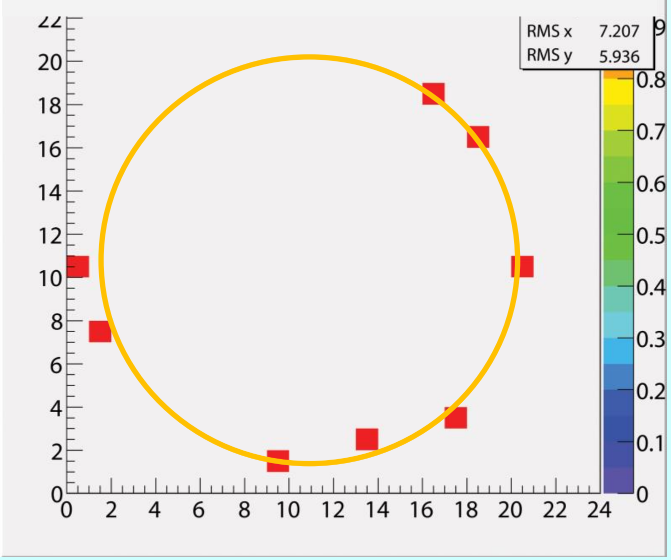


Cherenkov photon signals have been obtained

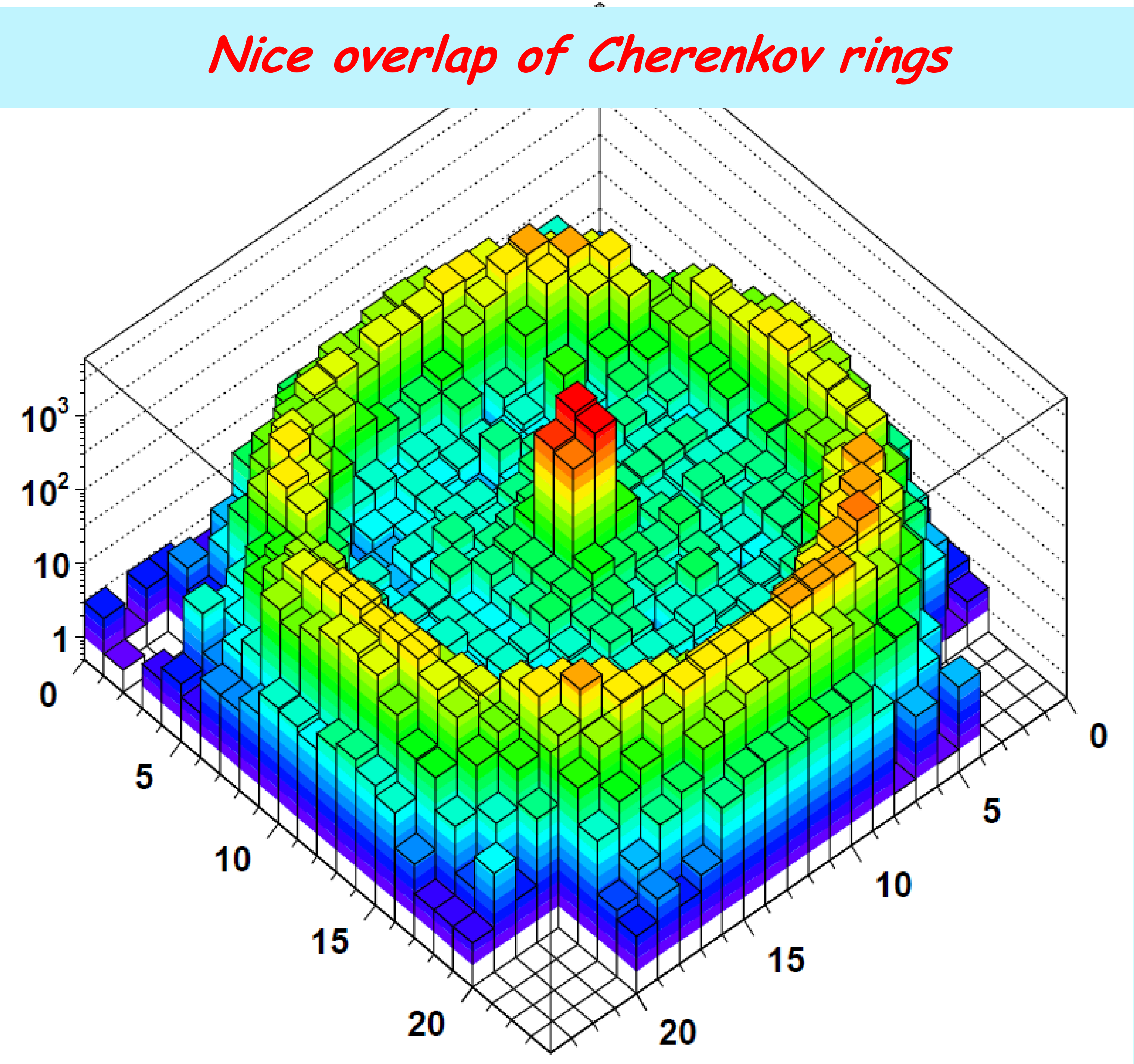






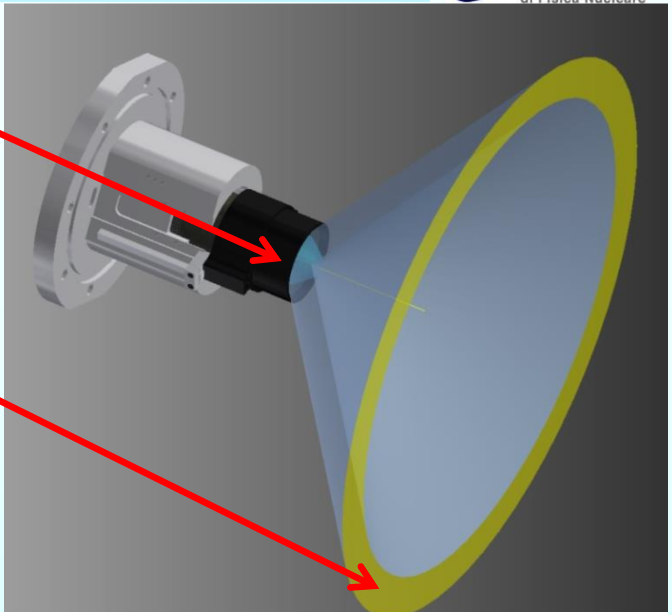


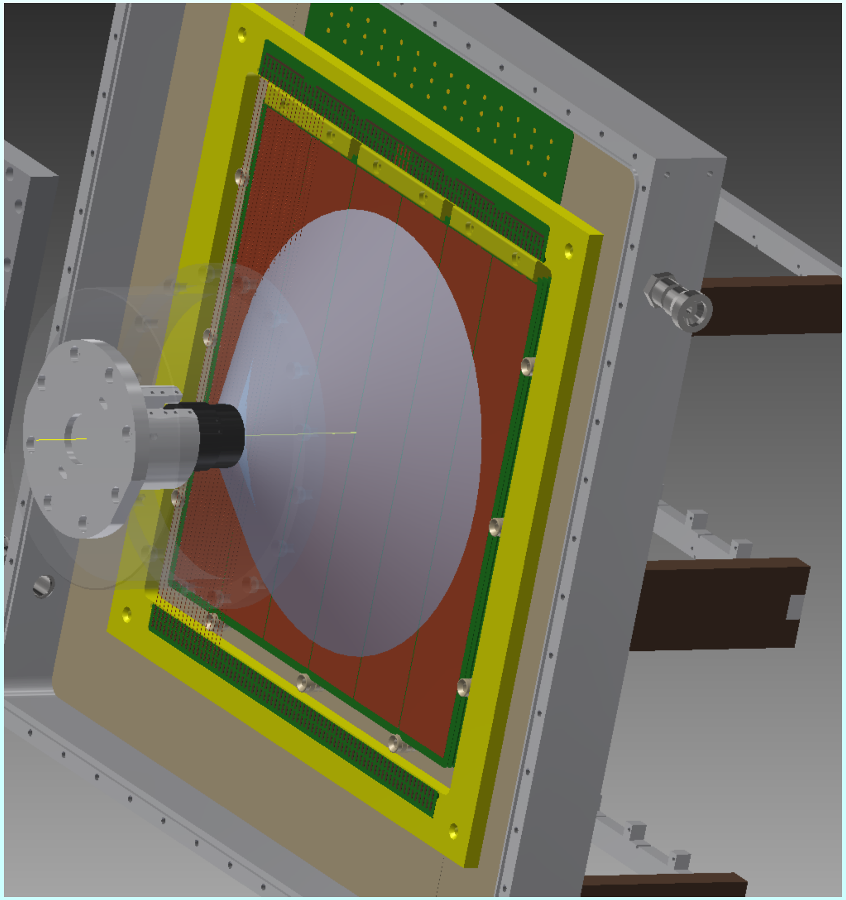
Nice overlap of Cherenkov rings

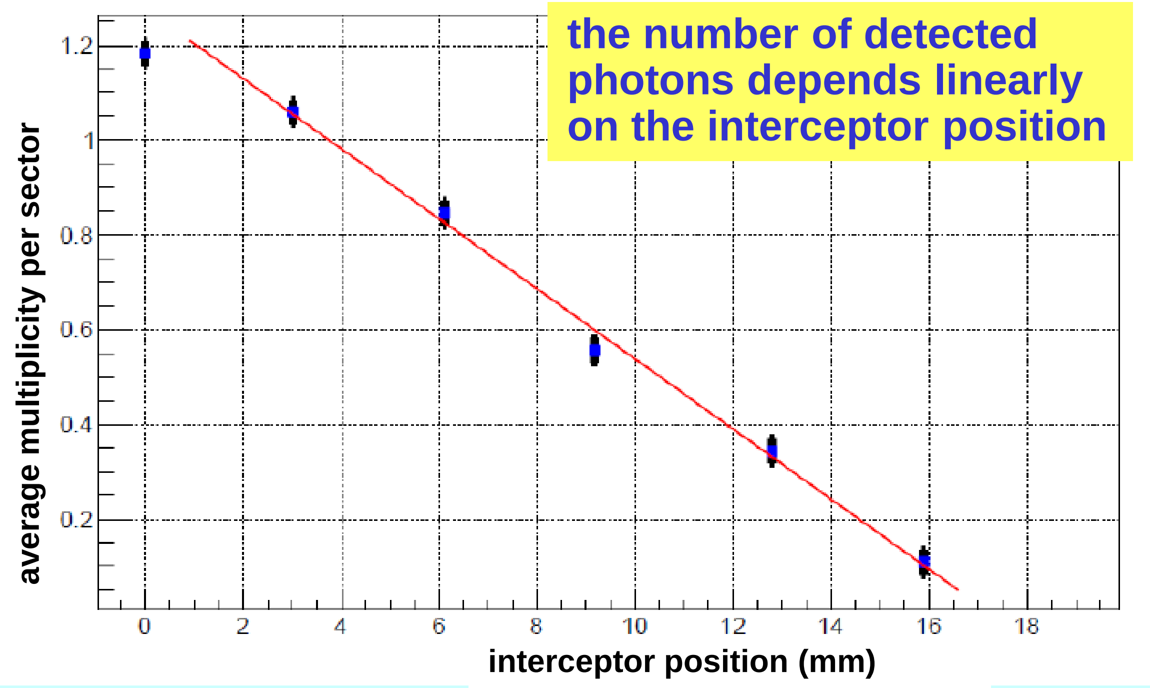


Conical fused silica radiator

A remotely controlled movable interceptor allows for changing the number of photons in the corona



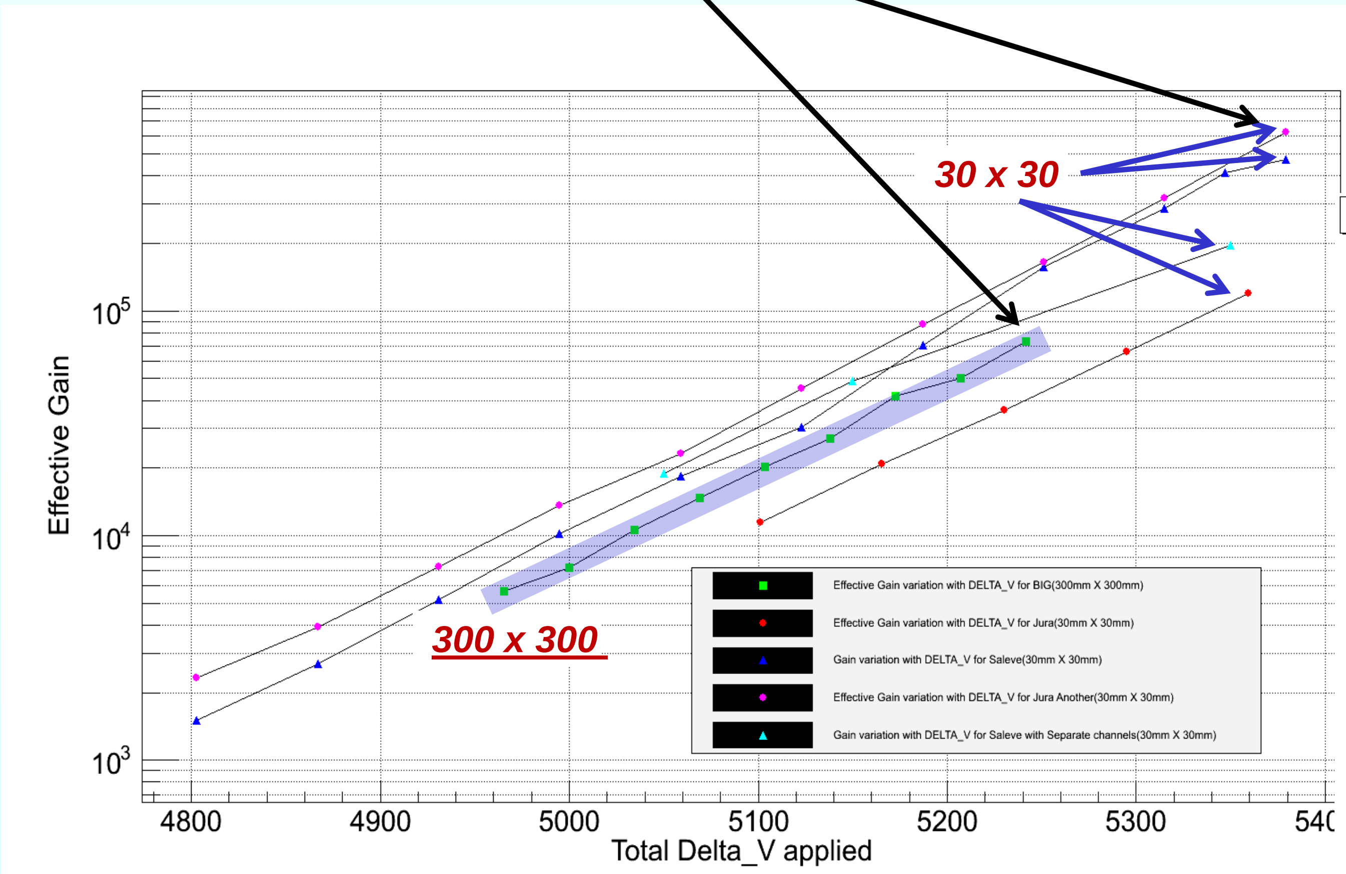




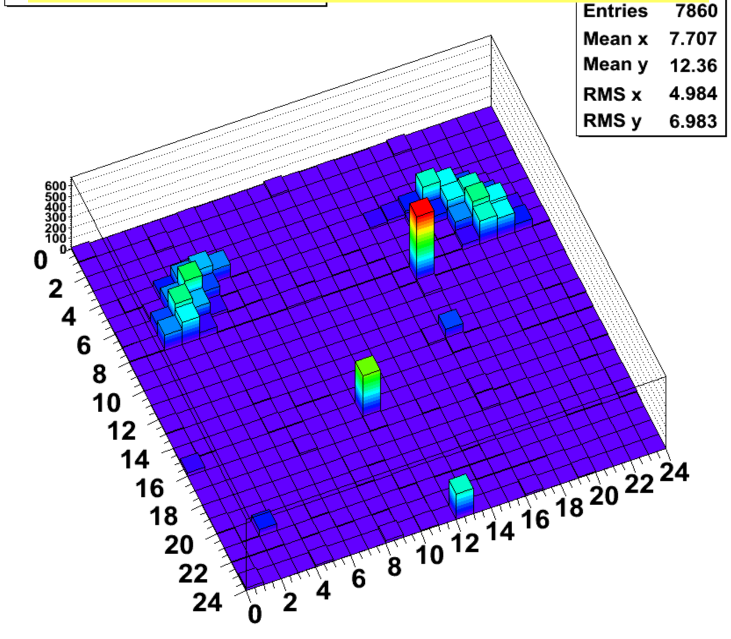
the number of detected photons depends linearly on the interceptor position

The 300 mm x 300 mm chamber had low gain

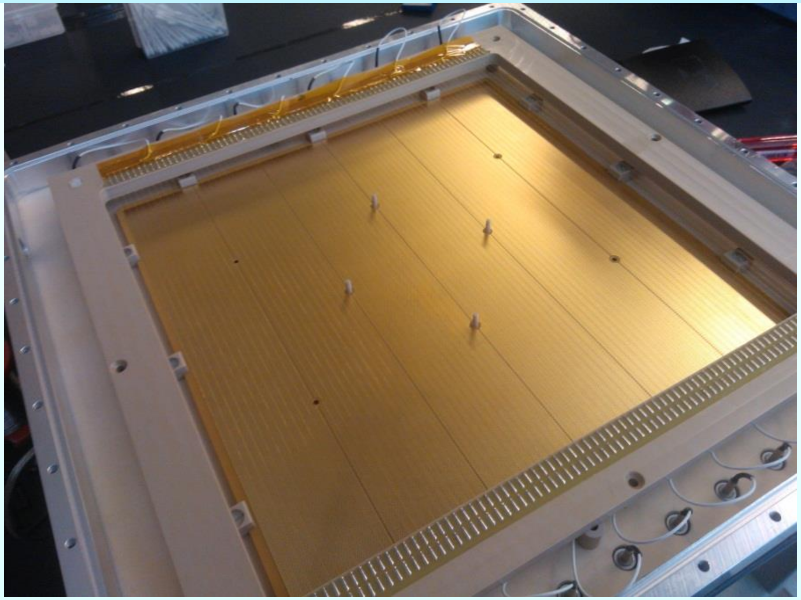
The 300 x 300 mm^2 chamber provided the <u>same response</u> of the small ones (30 x 30 mm^2), but <u>it could not reach the same maximum gain</u> (almost a factor 10 lower than the best one):

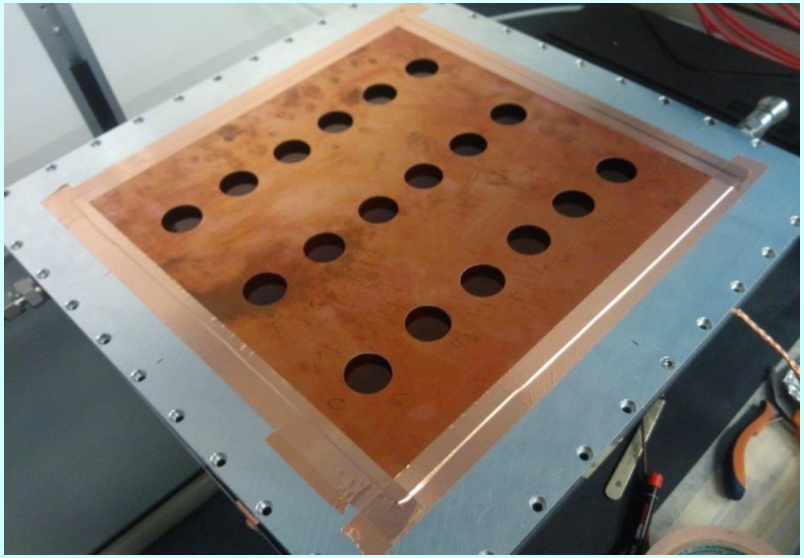


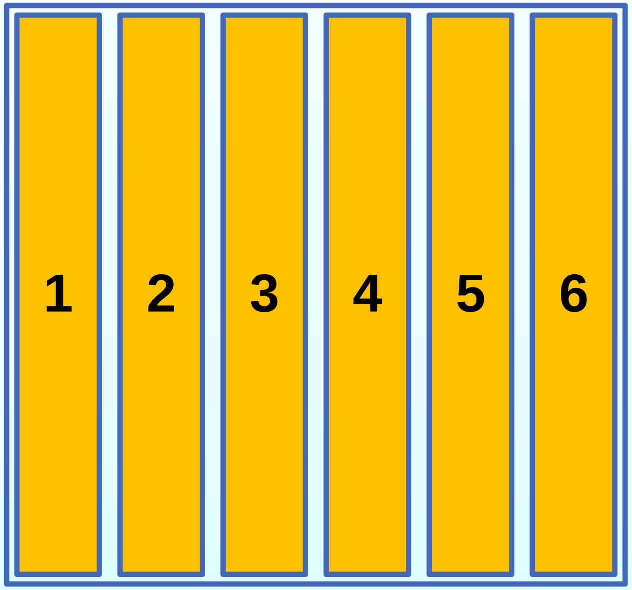
but when operating a single sector we could achieve a gain of ~0.2 M



Local characterization of the sectors of each THGEM using an ^{55}Fe source



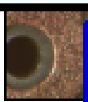




1	2	3	4	5	6

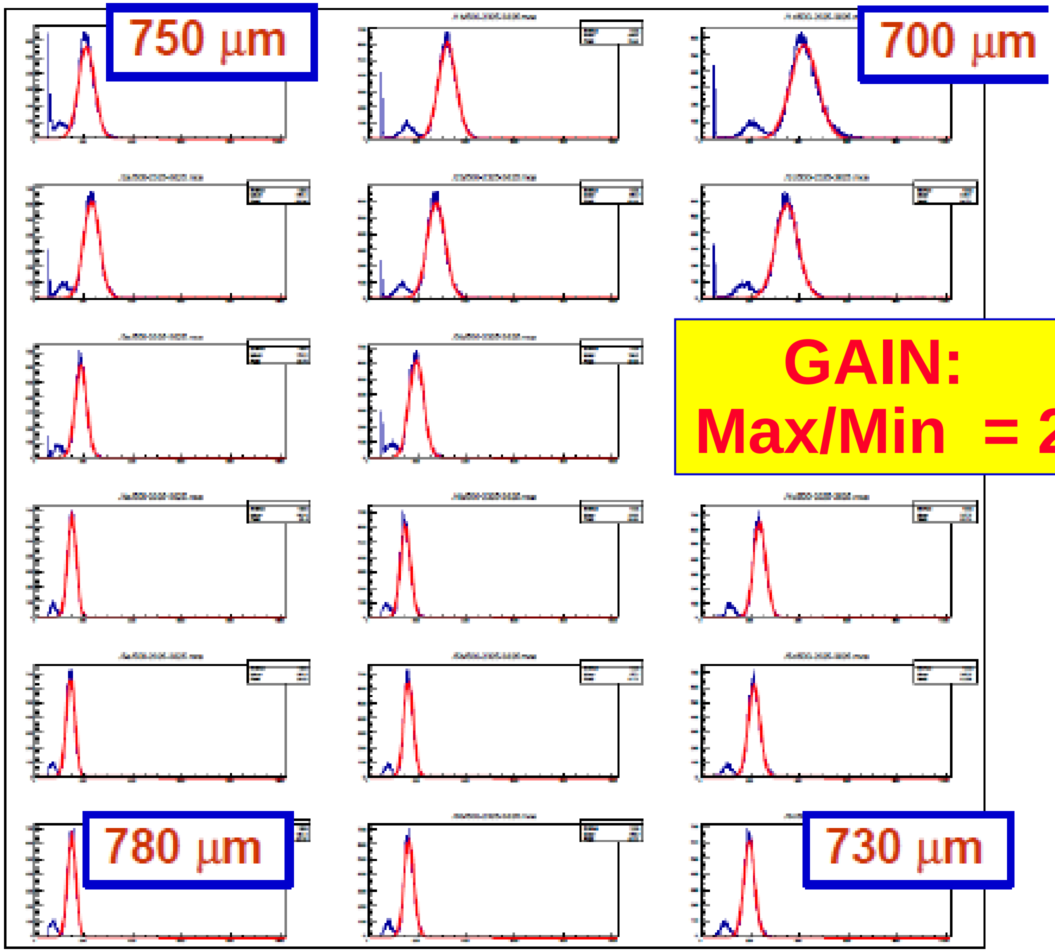
1A	2A	3A	4A	5A	6A
1B	2B	3B	4B	5B	6B
1C	2C	3C	4C	5C	6C

Gain uniformity and thickness uniformity

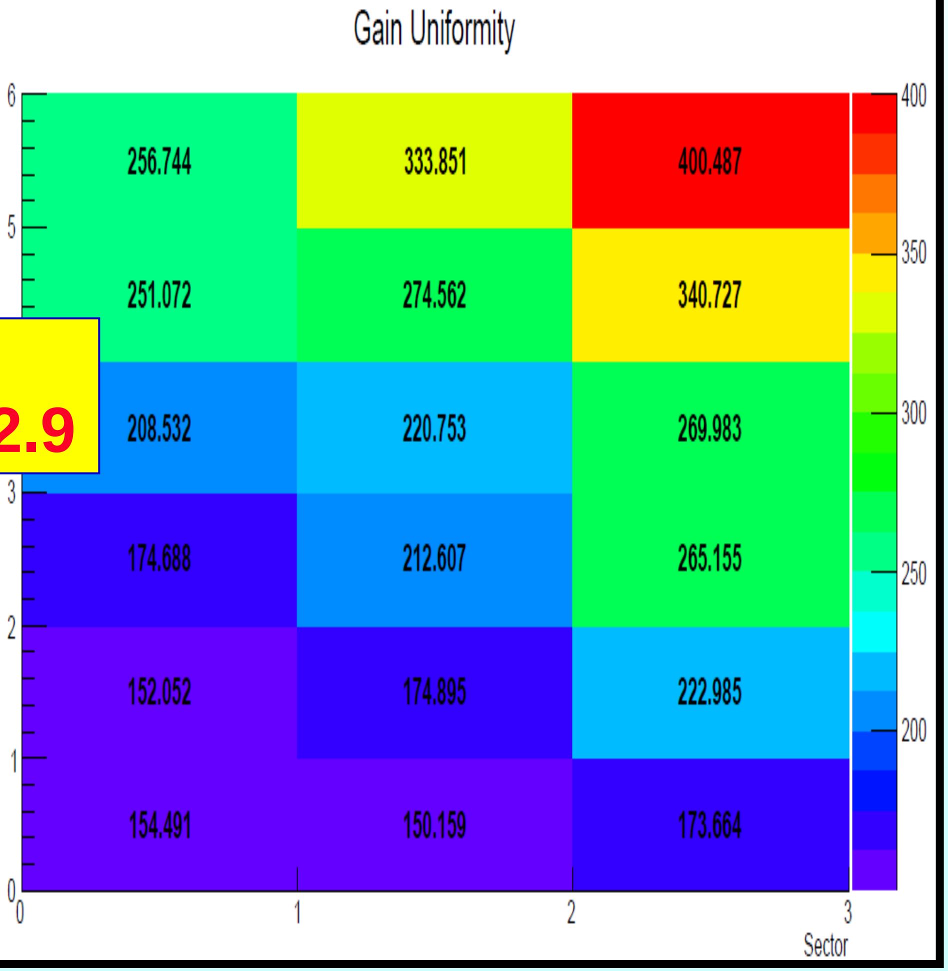


Systematic measurements of 300 x 300 mm² THGEMs (source: ^{55}Fe) :

Gain variations correlated with the thickness

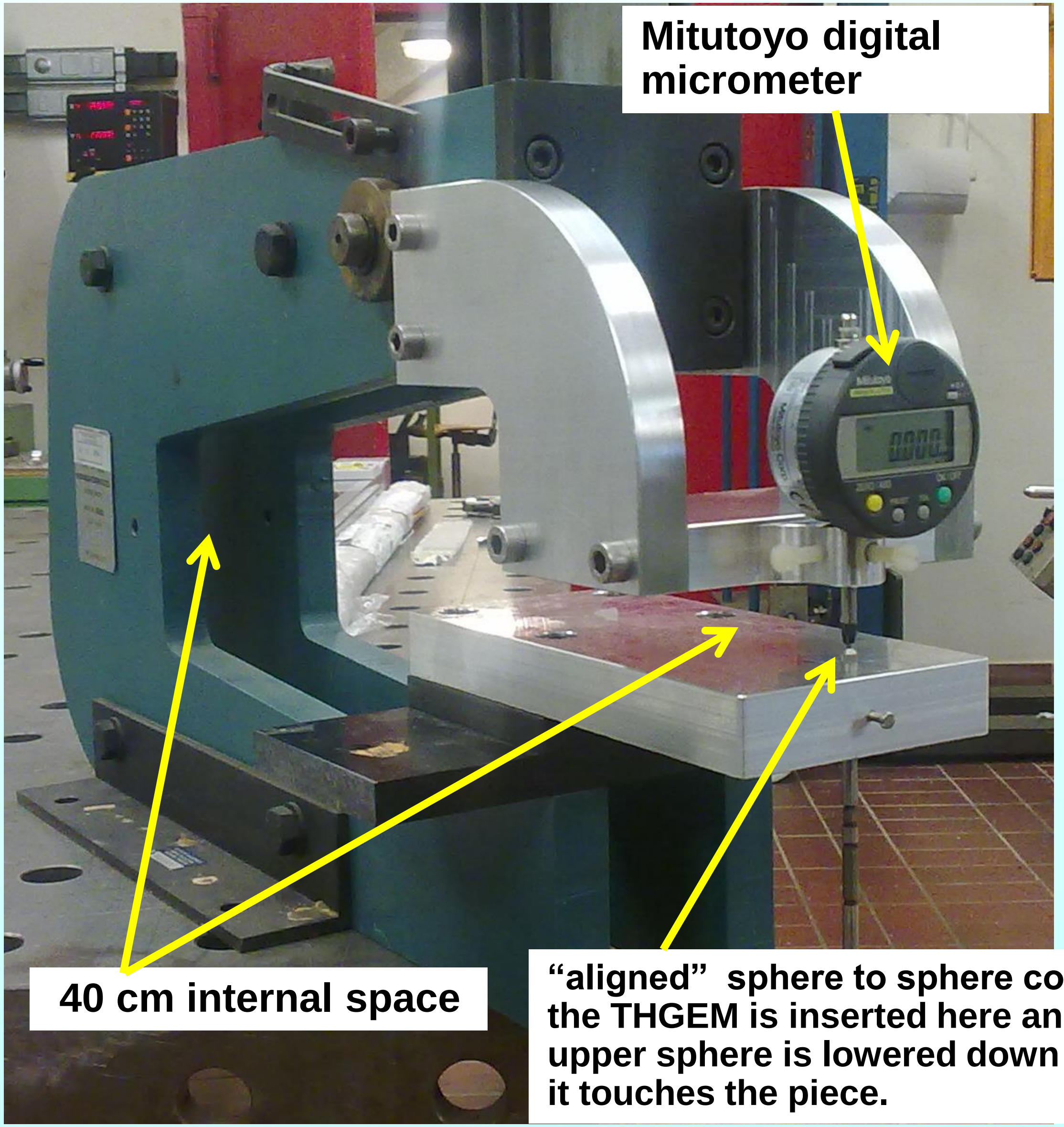


GAIN:
Max/Min = 2.9



256.744	333.851	400.487
251.072	274.562	340.727
208.532	220.753	269.983
174.688	212.607	265.155
152.052	174.895	222.985
154.491	150.159	173.664

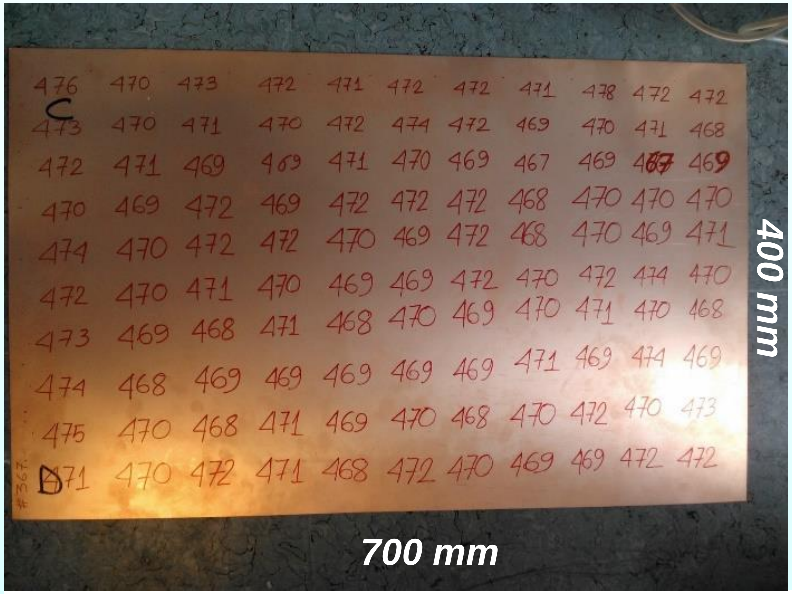
PCB thickness measurement for the selection of the good samples

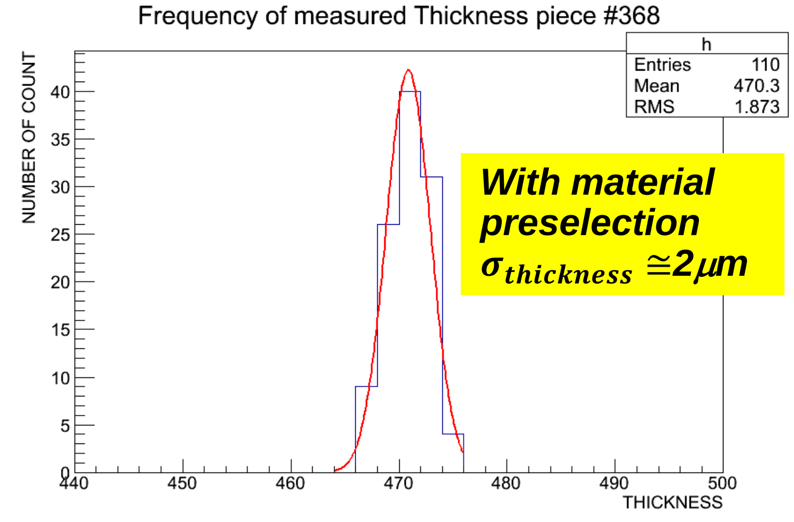


Mitutoyo digital micrometer

40 cm internal space

"aligned" sphere to sphere contact: the THGEM is inserted here and the upper sphere is lowered down until it touches the piece.

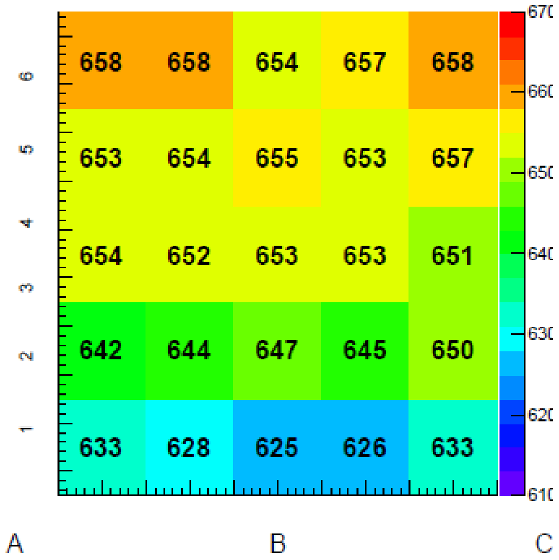




With material preselection $\sigma_{thickness} \cong 2\mu m$

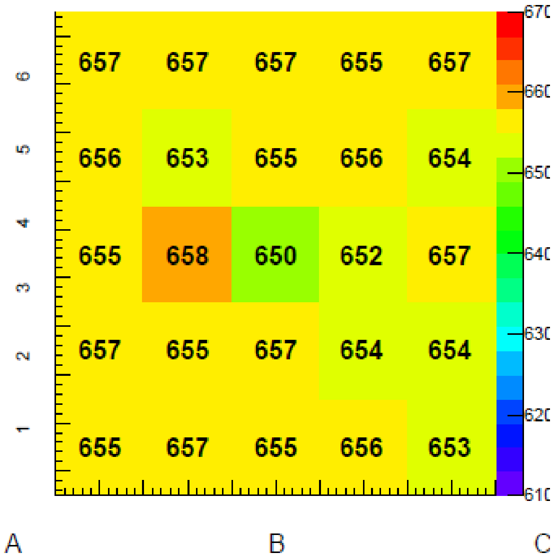
Thickness reading (in μm)

THICKNESS VARIATION



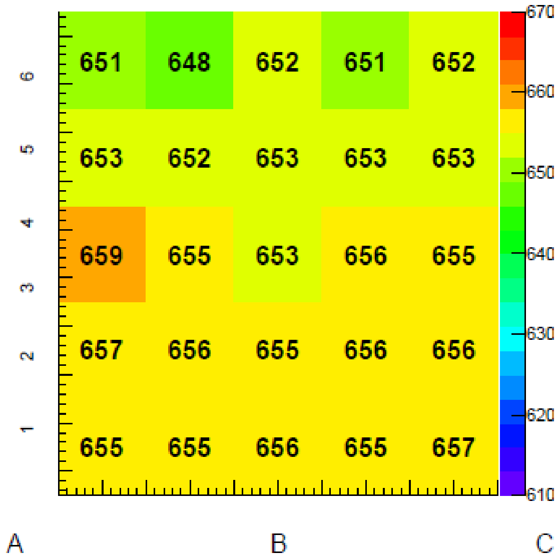
6	658	658	654	657	658
5	653	654	655	653	657
4	654	652	653	653	651
2	642	644	647	645	650
1	633	628	625	626	633

THICKNESS VARIATION



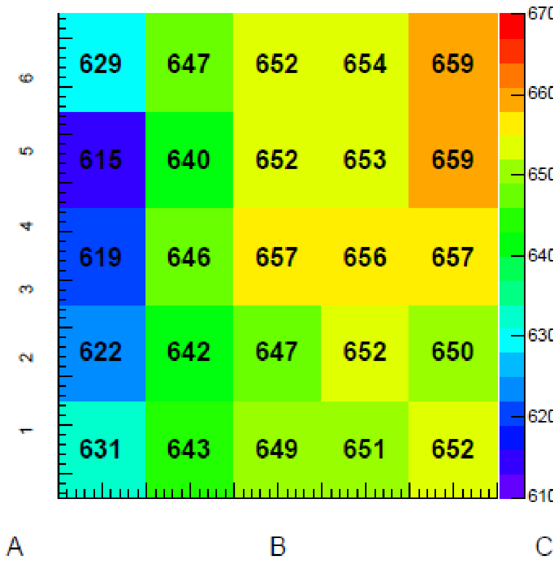
6	657	657	657	655	657
5	656	653	655	656	654
4	655	658	650	652	657
2	657	655	657	654	654
1	655	657	655	656	653

THICKNESS VARIATION



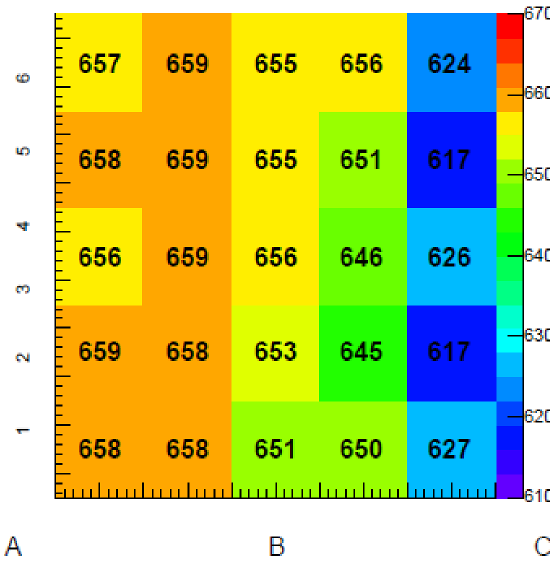
6	651	648	652	651	652
5	653	652	653	653	653
4	659	655	653	656	655
2	657	656	655	656	656
1	655	655	656	655	657

THICKNESS VARIATION



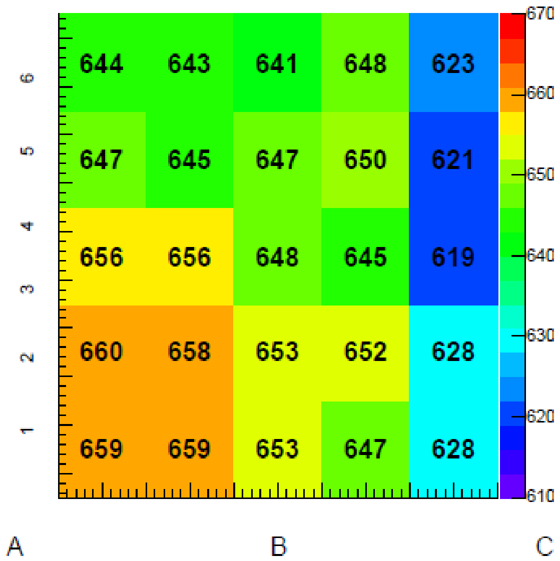
6	629	647	652	654	659
5	615	640	652	653	659
4	619	646	657	656	657
2	622	642	647	652	650
1	631	643	649	651	652

THICKNESS VARIATION



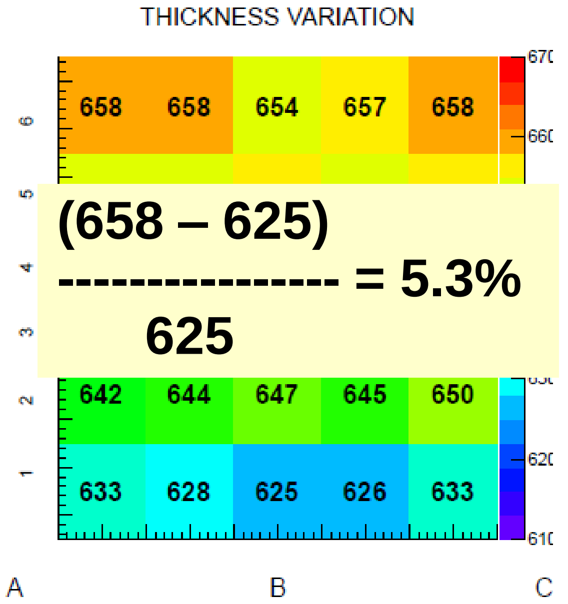
6	657	659	655	656	624
5	658	659	655	651	617
4	656	659	656	646	626
2	659	658	653	645	617
1	658	658	651	650	627

THICKNESS VARIATION

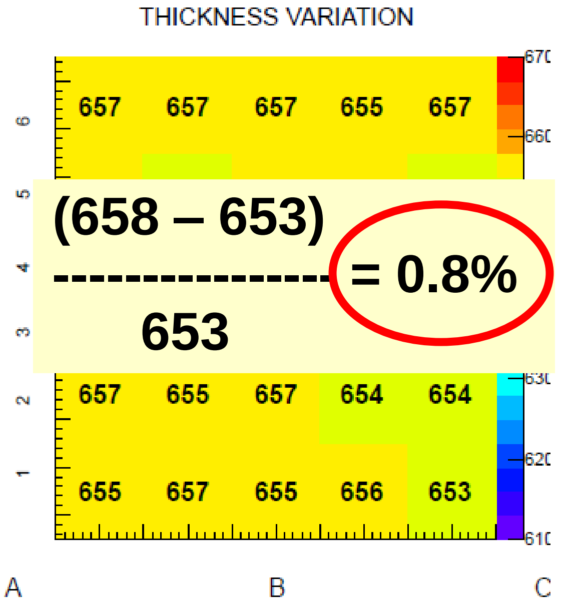


6	644	643	641	648	623
5	647	645	647	650	621
4	656	656	648	645	619
2	660	658	653	652	628
1	659	659	653	647	628

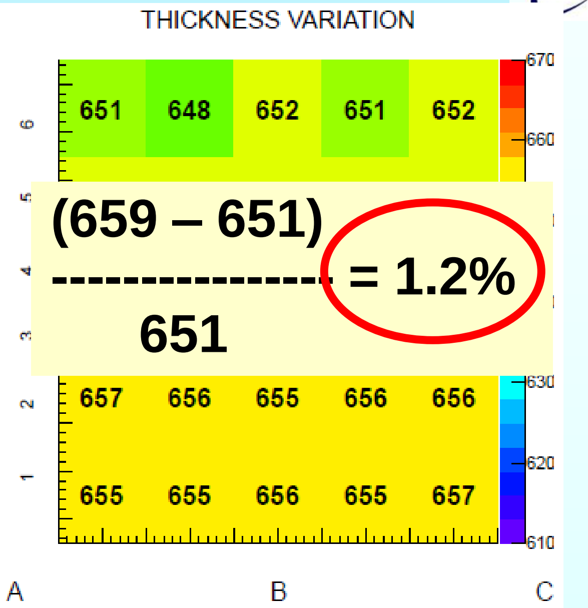
Thickness reading (in μm)



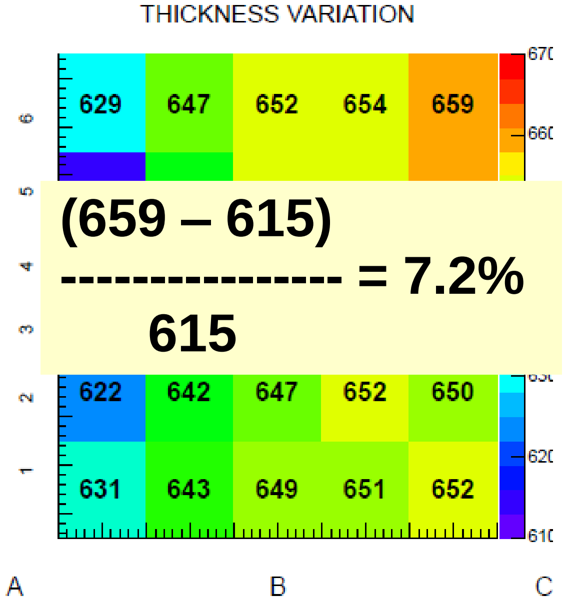
$$\frac{(658 - 625)}{625} = 5.3\%$$



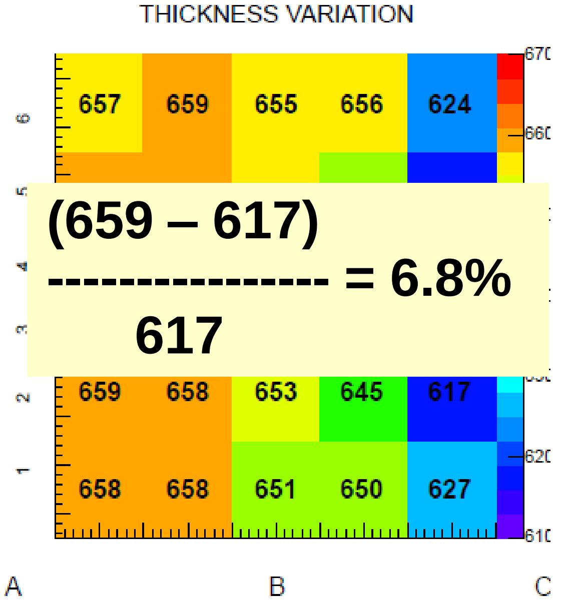
$$\frac{(658 - 653)}{653} = 0.8\%$$



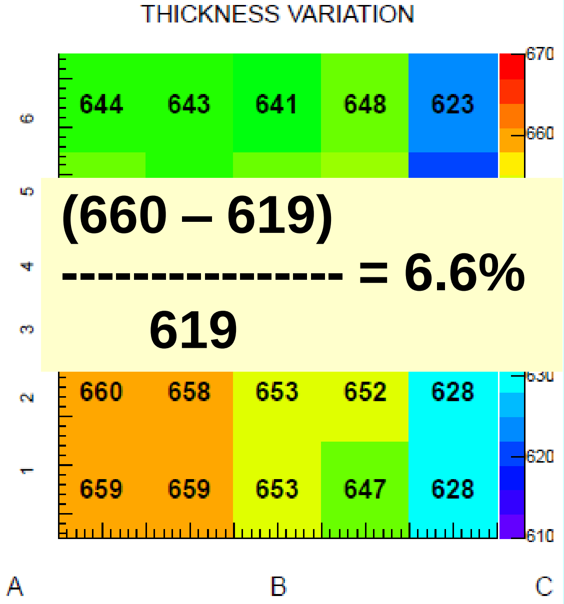
$$\frac{(659 - 651)}{651} = 1.2\%$$



$$\frac{(659 - 615)}{615} = 7.2\%$$



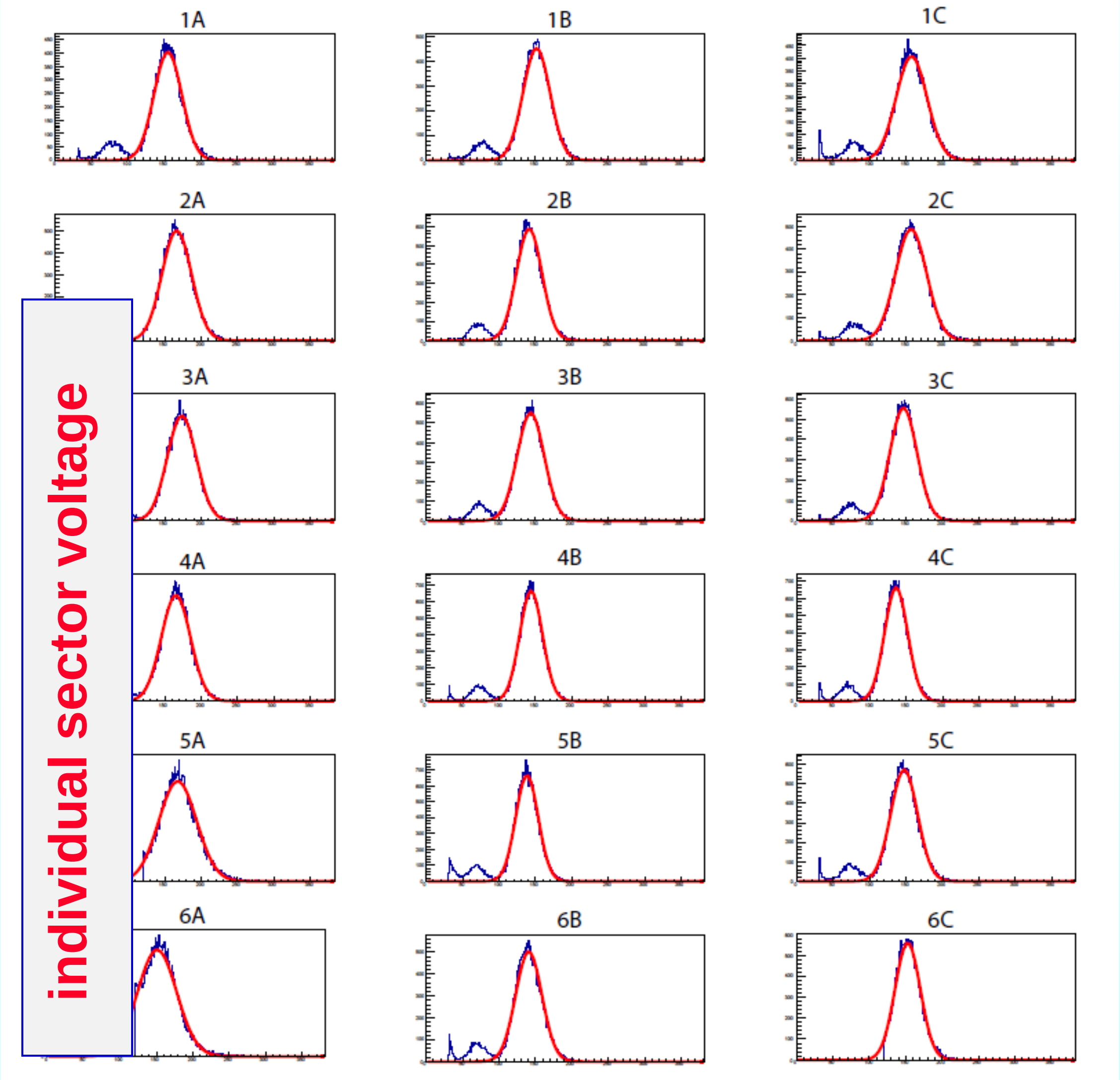
$$\frac{(659 - 617)}{617} = 6.8\%$$



$$\frac{(660 - 619)}{619} = 6.6\%$$

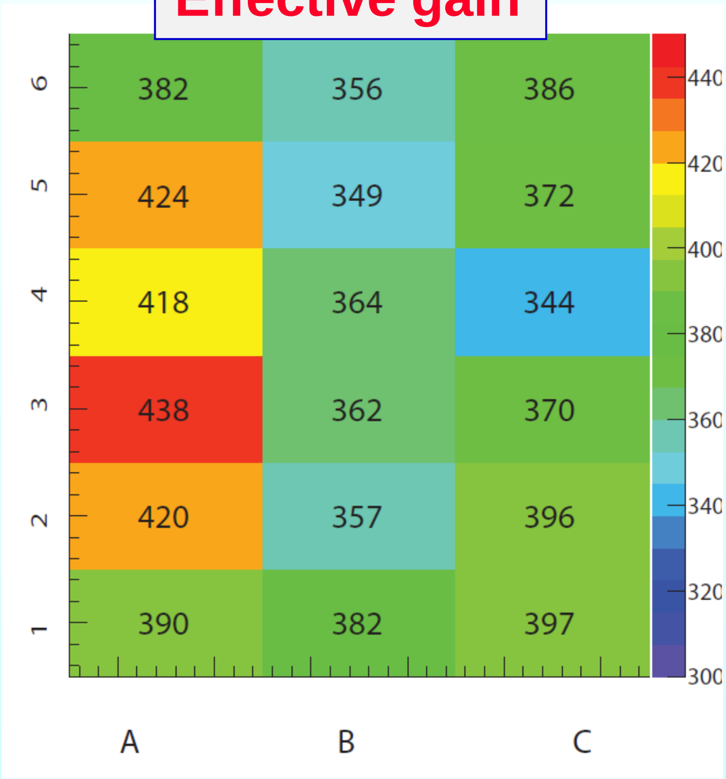
Gain uniformity of a selected piece

Same voltage on all sectors: GAIN Max/Min = 1.6

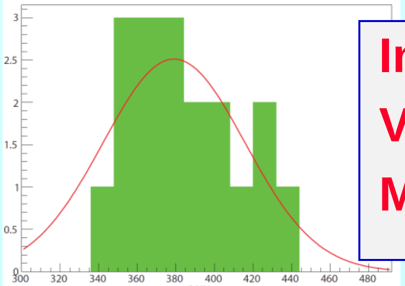


individual sector voltage

Effective gain

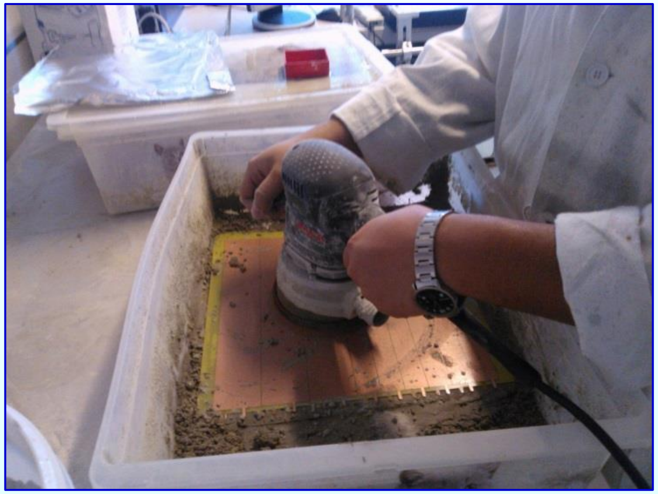


	A	B	C
6	382	356	386
5	424	349	372
4	418	364	344
3	438	362	370
2	420	357	396
1	390	382	397



Individual Voltages: GAIN Max/Min = 1.25

THGEM treatment after production



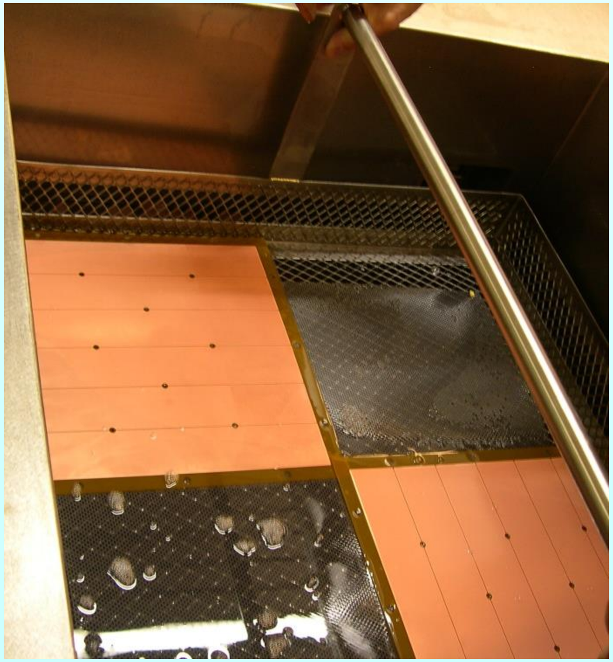
polishing (Hinrichs Pumice Powder)

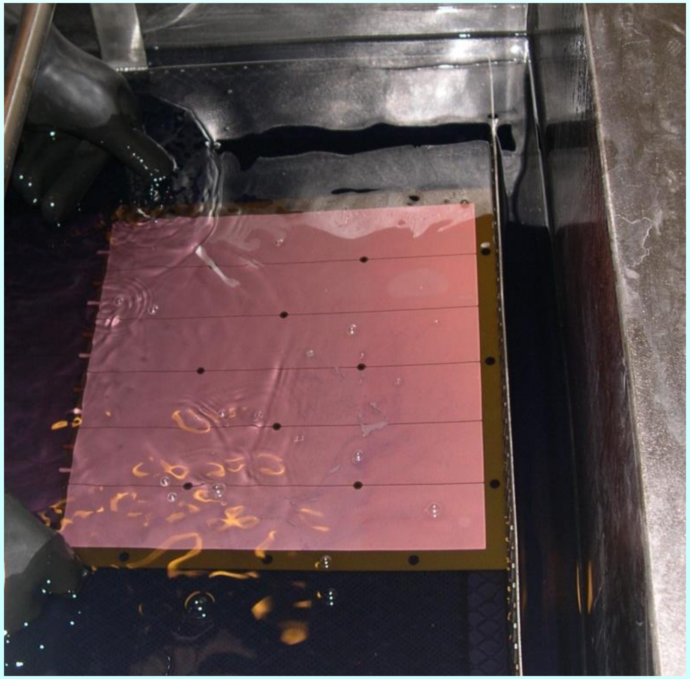
cleaning with high pressure water to remove all pumice residuals

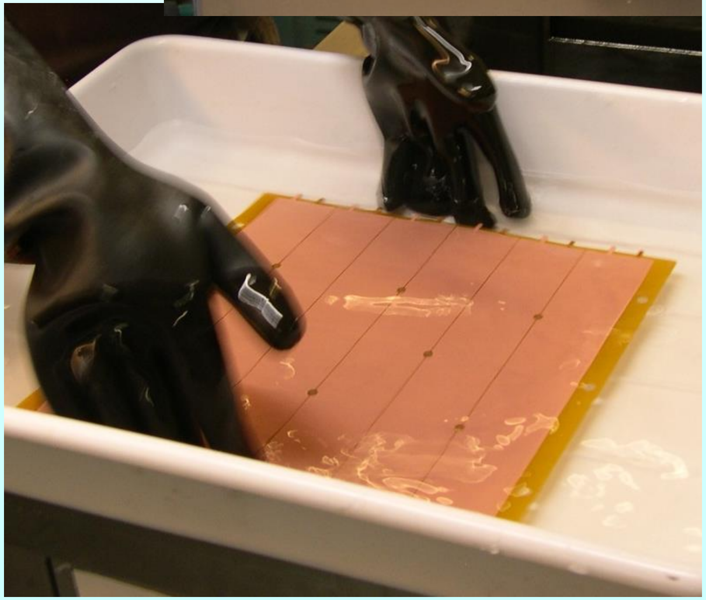
ultrasonic bath (~1 h) @ 50-60 °C in Sonica PCB solution (pH11)

washing with demineralized water plus

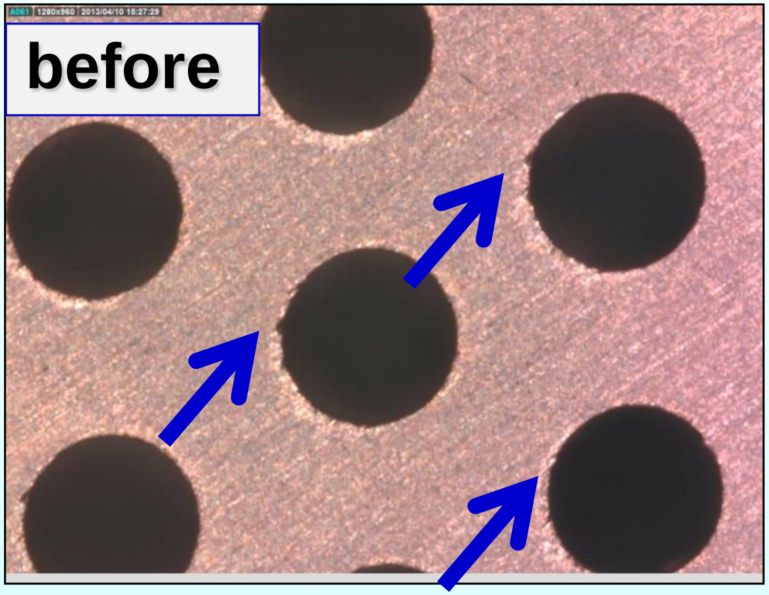
oven at 180 °C for 24 h

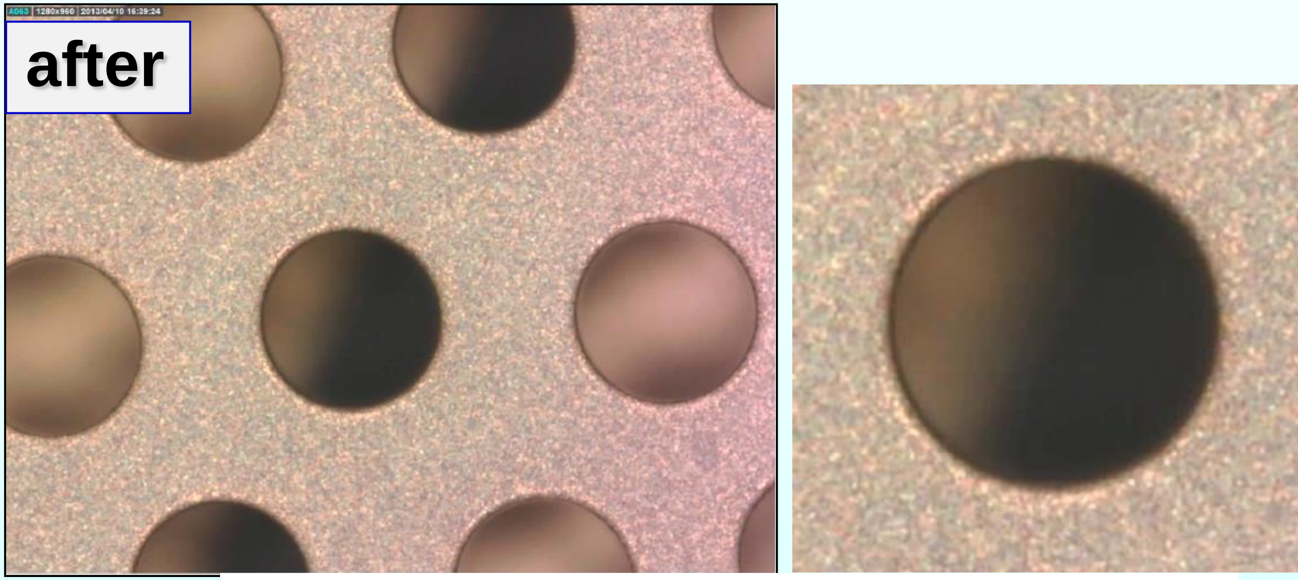






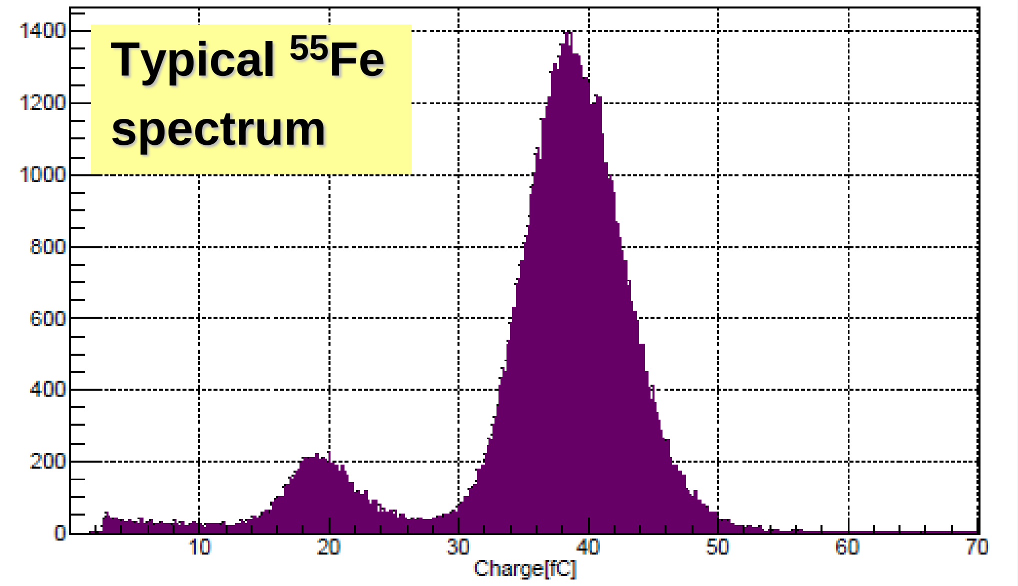
Smoother surface and better prformance



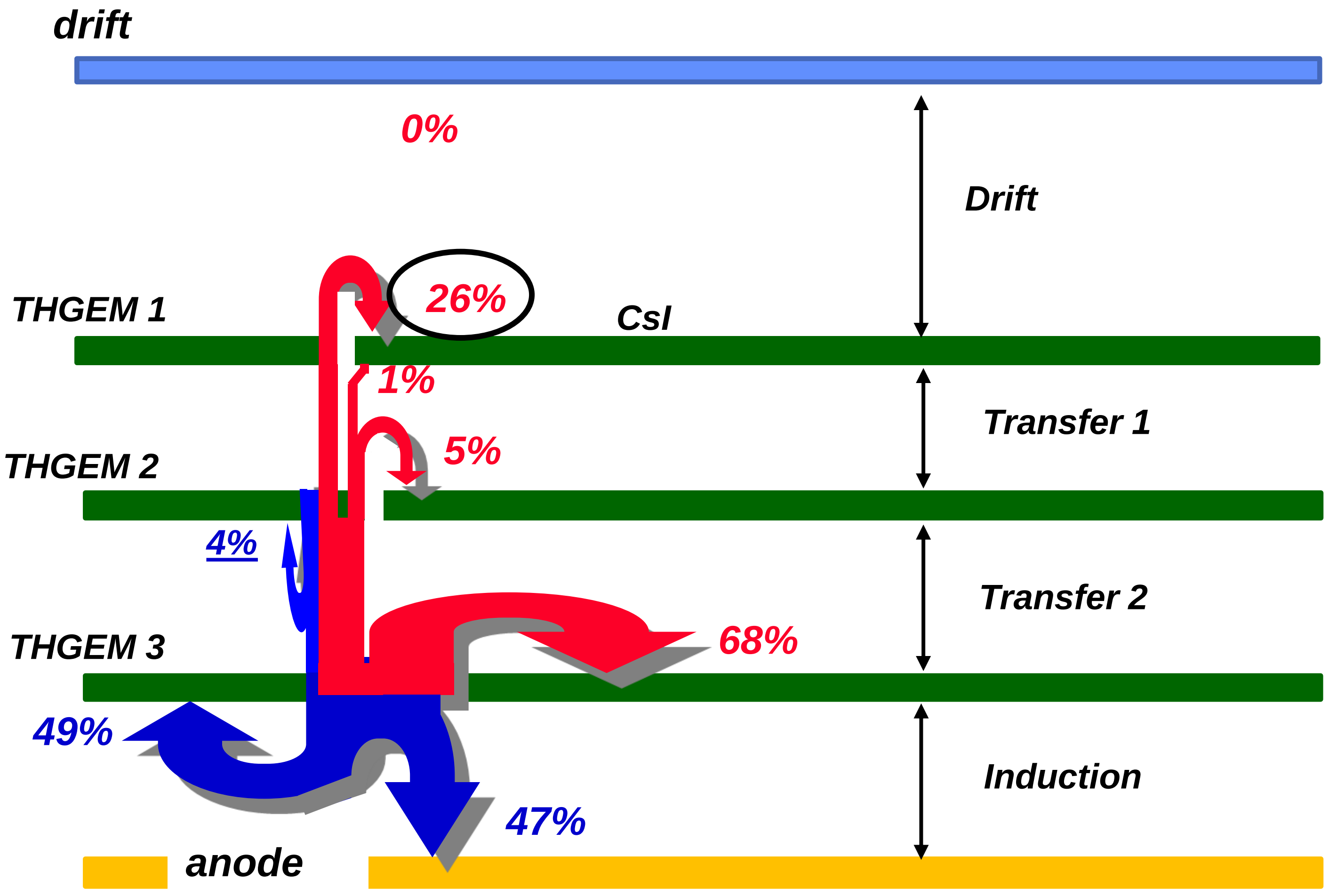


After the treatment the response of the 300 mm x 300 mm THGEM is the same as for small THGEMs

measured breakdown voltage for all sectors results to be at least 95% of the Paschen voltage.


Typical ^{55}Fe spectrum

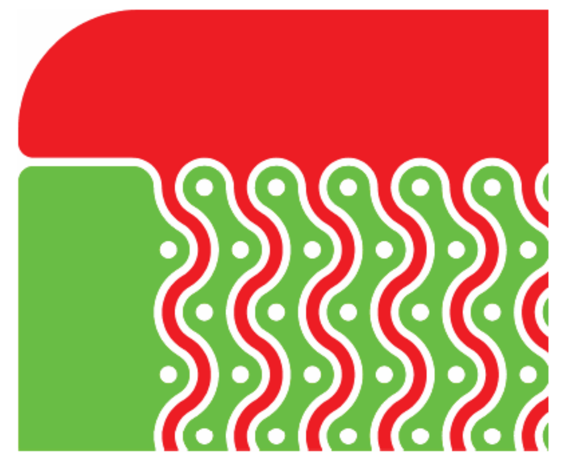
The Ion Backflow problem

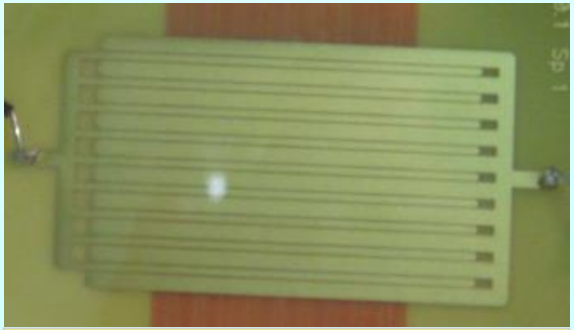


field values optimization could reduce IBF by a factor 2

Attempts to solve the problem

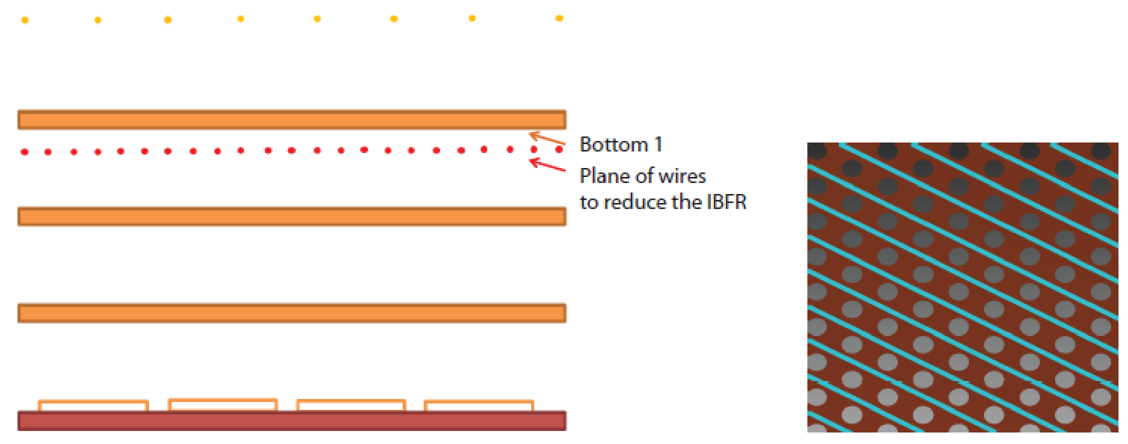
THCOBRA

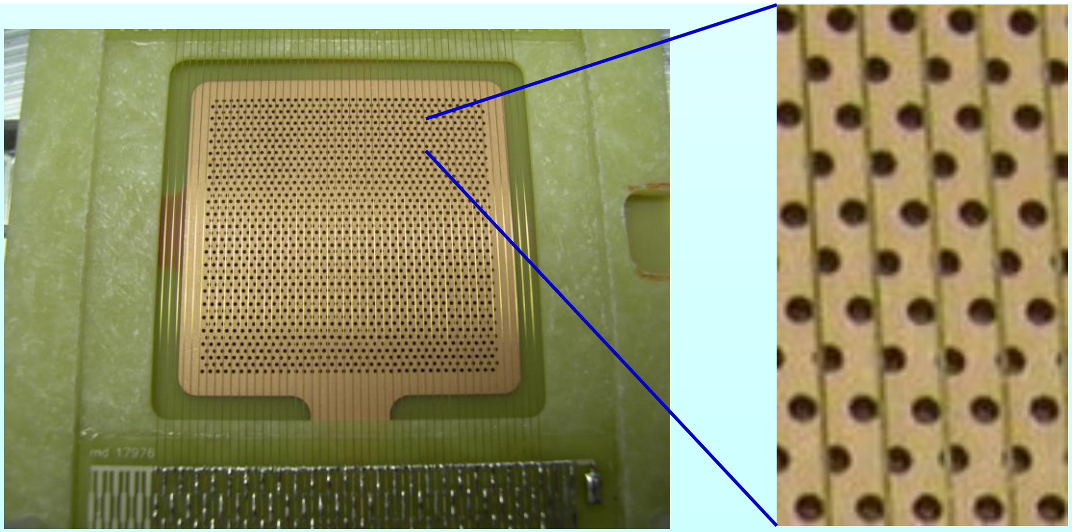




path width < 0.1 mm: may get damaged by sparks

dedicated extra electrode

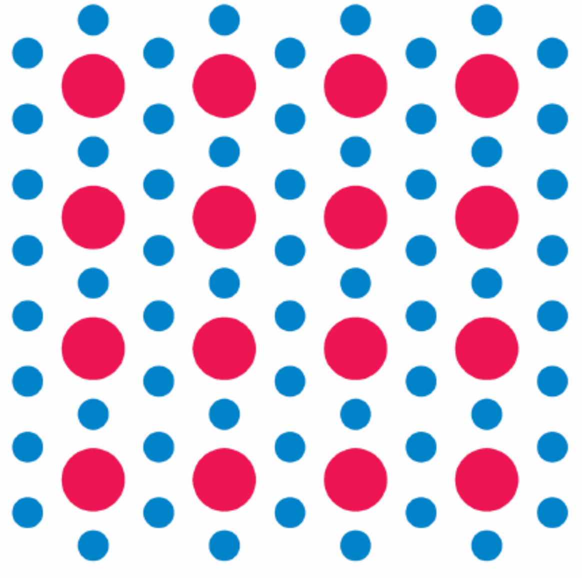




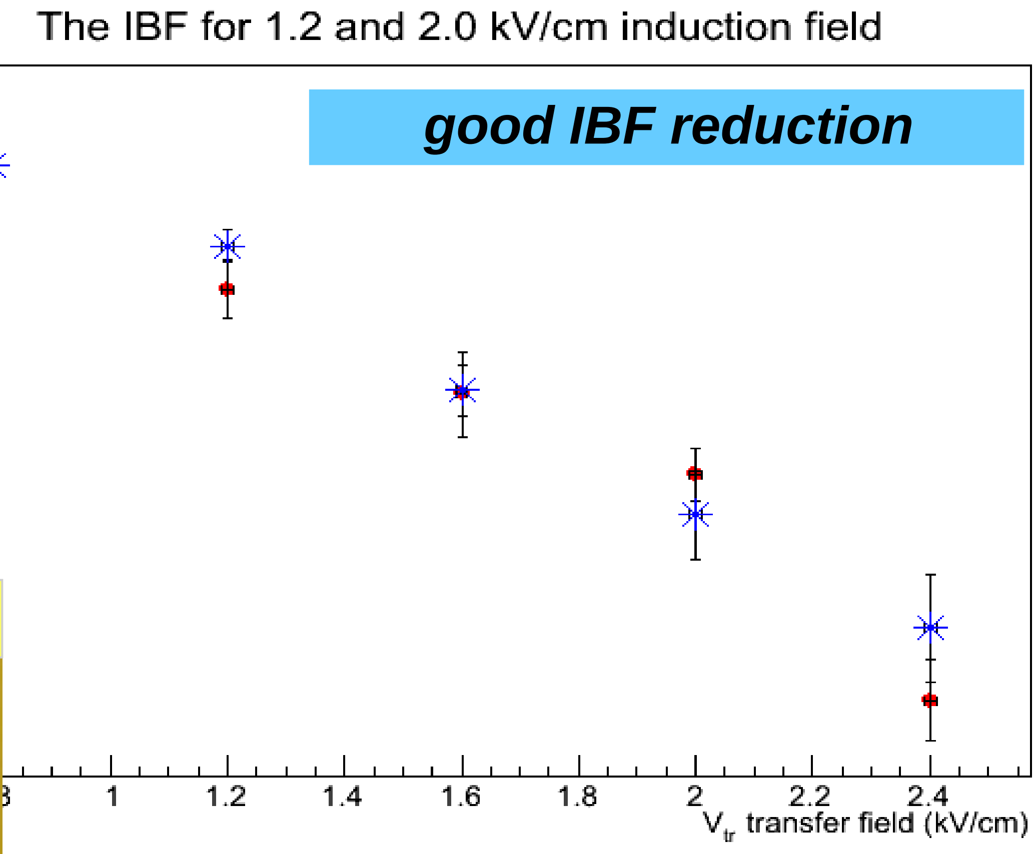
unpractical for large surfaces

The "Flower" THGEM

Coupling different geometries: THGEM-1 (red holes) and THGEM-2 (blue holes)

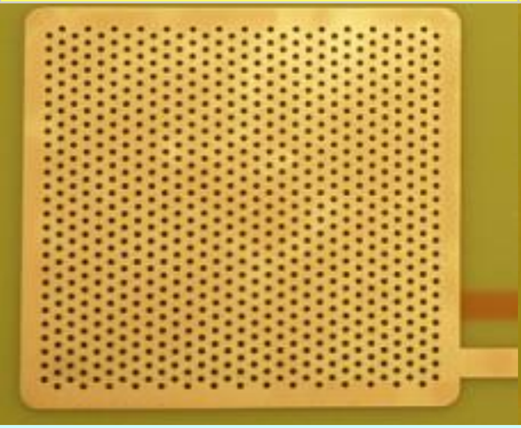


The IBF for 1.2 and 2.0 kV/cm induction field



good IBF reduction

THGEM-1 (CsI)



Flower

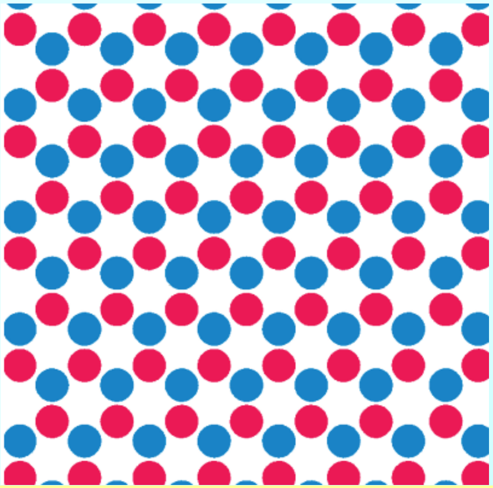
Identical THGEMs: aligned and staggered

Inspired by:

NIM A 260 (2006) 269

we studied the effect of THGEM hole alignment on IBF.

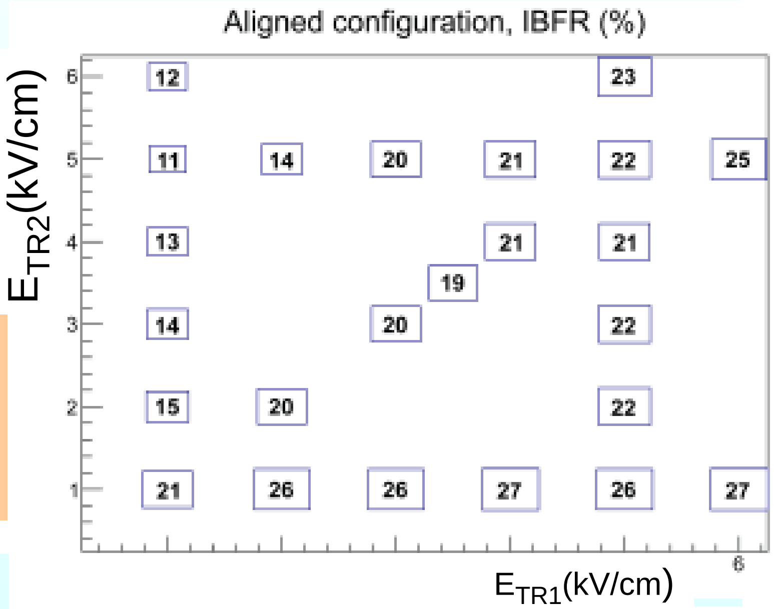
efficient IBF reduction with moderate impact on the effective gain

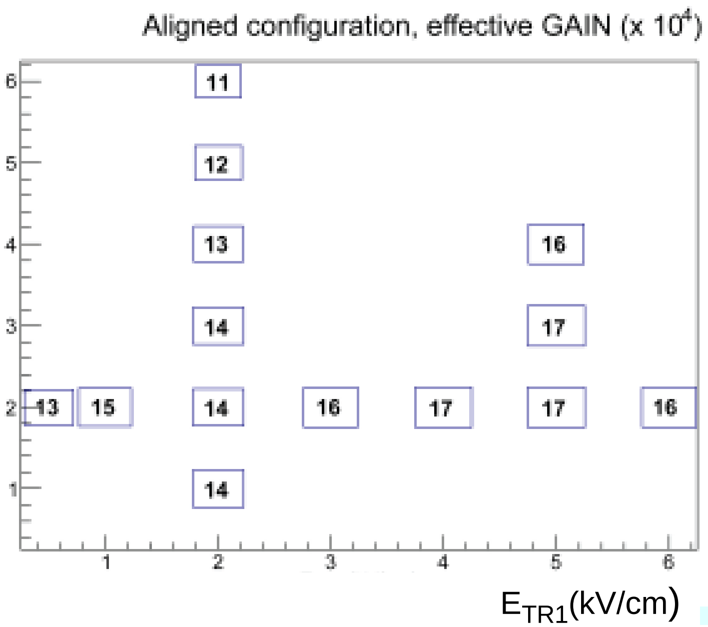


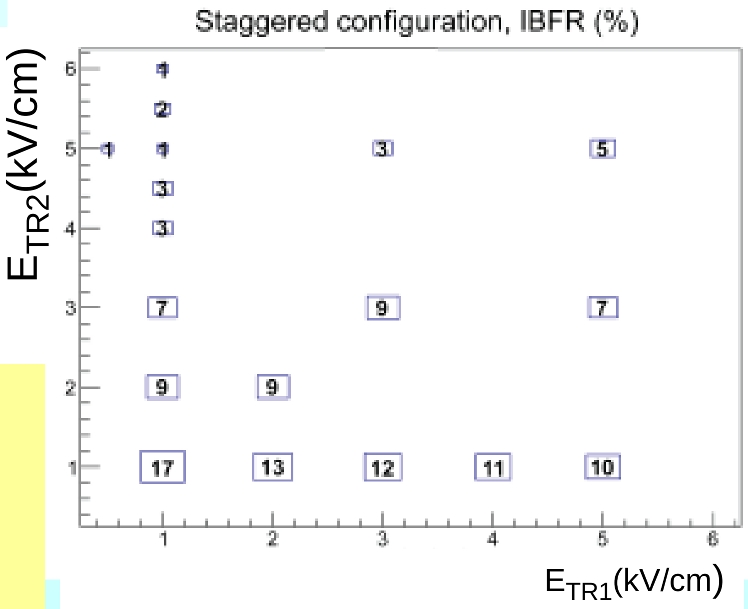
M. Alexeev et al.

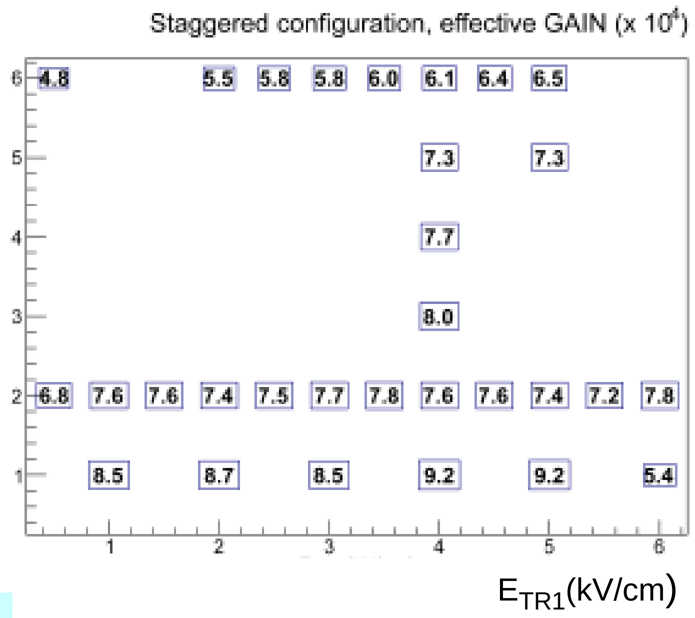
JINST 8 P01021 (2013)

"Ion backflow in thick GEM-based detectors of single photons"


Aligned configuration, IBFR (%)


Aligned configuration, effective GAIN (x 10^4)

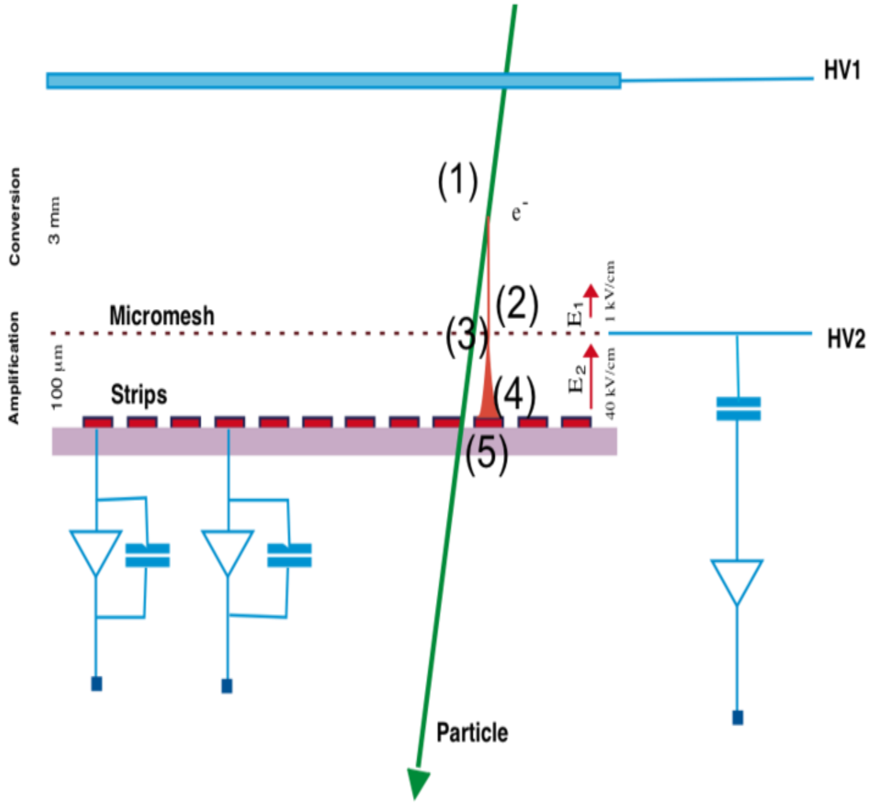

Staggered configuration, IBFR (%)


Staggered configuration, effective GAIN (x 10^4)

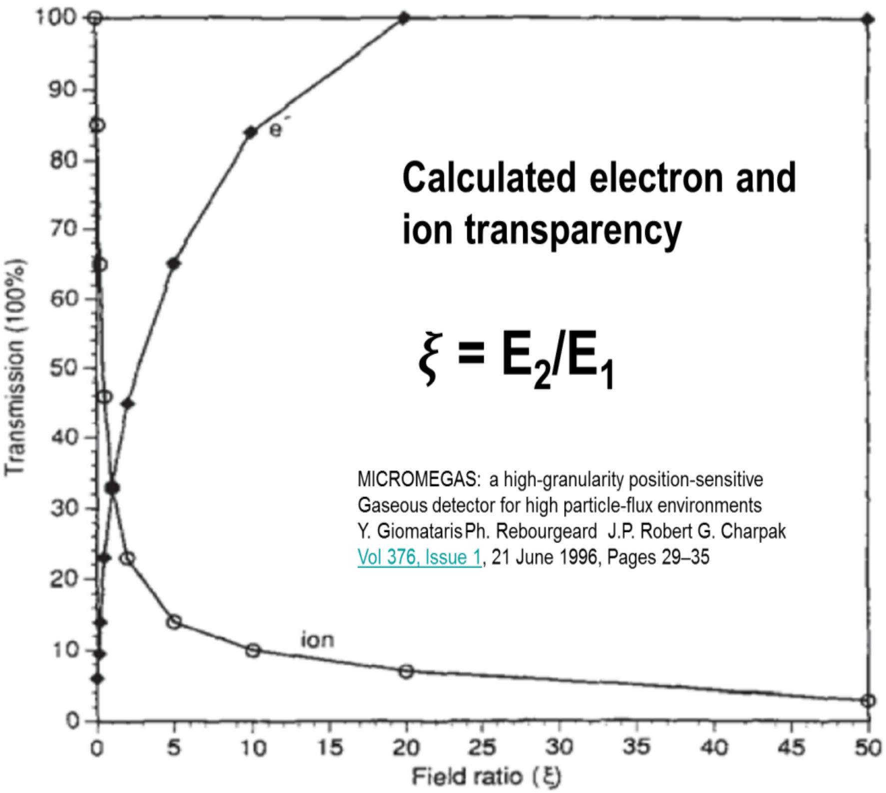
Micromegas, the natural way to suppress IBF

A Micromegas detector consists in an ionization stage + a parallel plate avalanche chamber with a very narrow amplification gap (~100 μm) defined by the anode plane and by a micromesh.

It offers a natural suppression of the Ion Back Flow: the large majority of the ions are collected by the mesh.



1: Ionizing track, 2: Primary ionization, 3: Micromesh, 4 Charge Avalanche, 5: Readout Pad



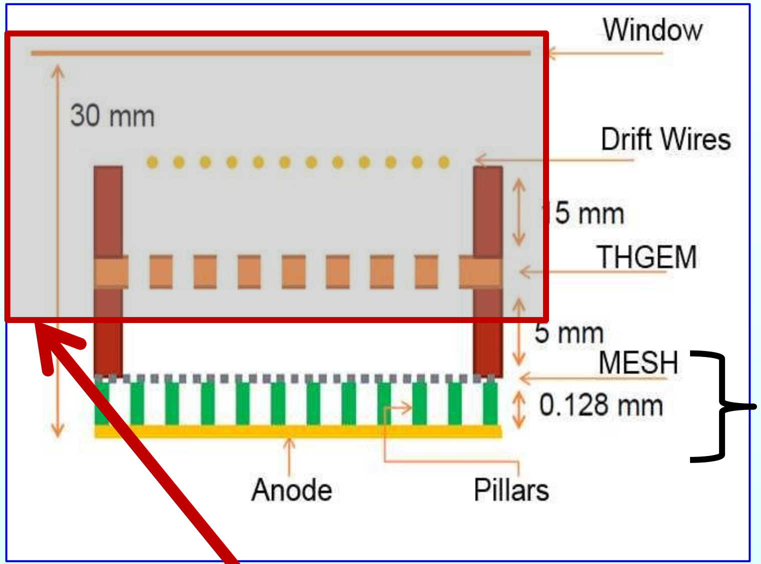
Calculated electron and ion transparency

$$\xi = E_2/E_1$$

MICROMEGAS: a high-granularity position-sensitive Gaseous detector for high particle-flux environments
Y. Giomataris Ph. Rebourgeard J.P. Robert G. Charpak
Vol 376, Issue 1, 21 June 1996, Pages 29–35

Fig. 5. Calculated electron and ion transparency.

Small hybrid THGEM + Micromegas PD



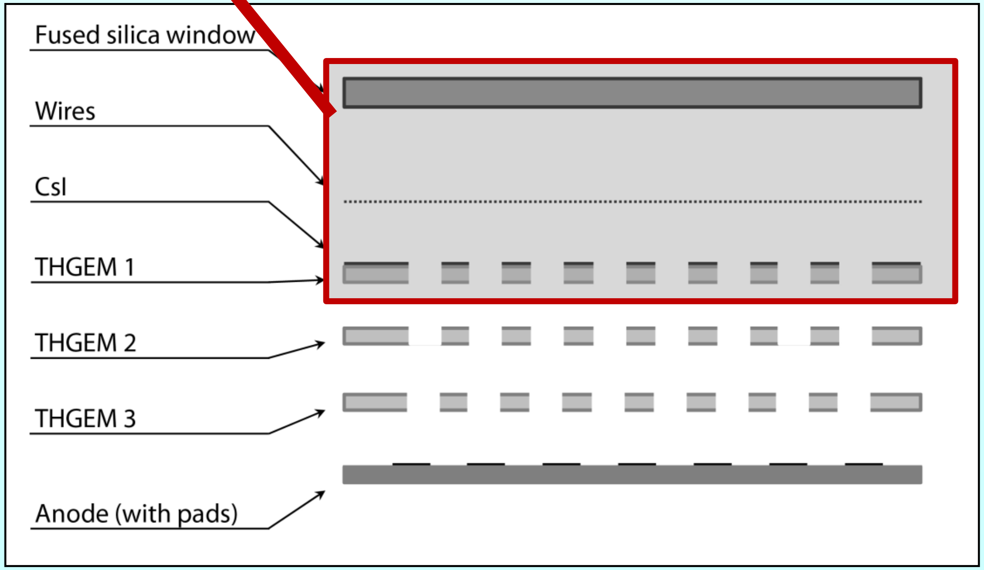
Hybrid detector

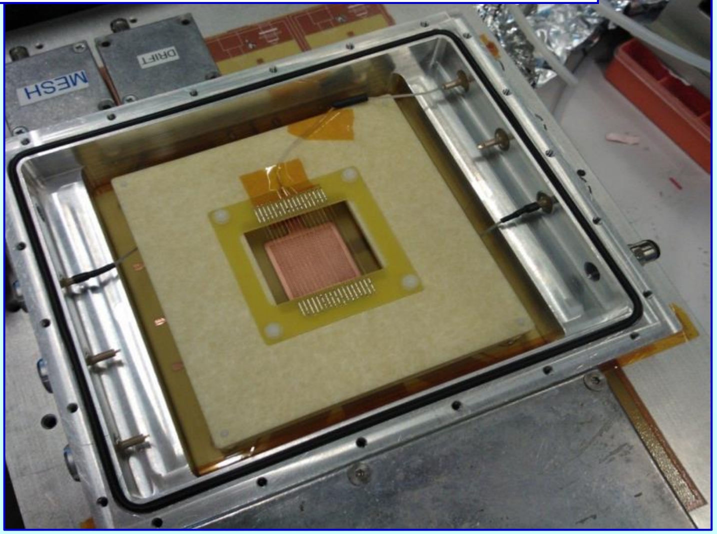
MICROMEGAS stage

Bulk Micromegas: courtesy of Saclay COMPASS colleagues

PRELIMINARY

PROTOTYPE



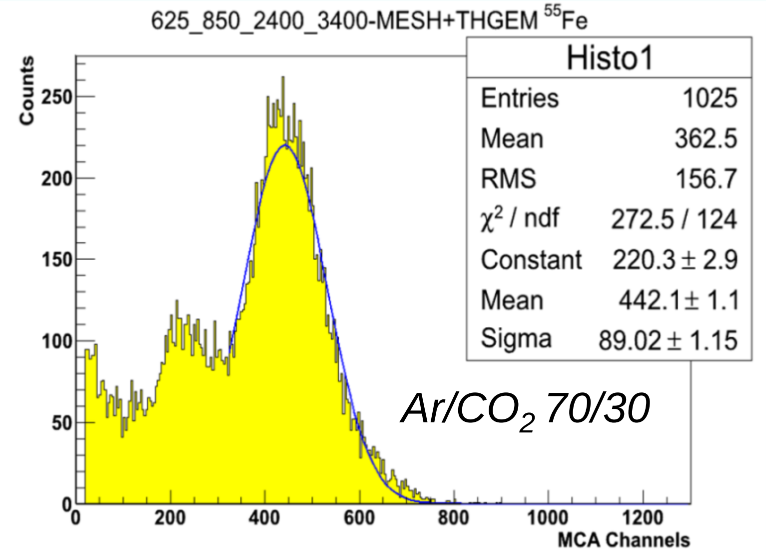


Very promising first results

^{55}Fe source,

Micromegas +

single THGEM



Ar/CO$_2$ 70/30

V_{mesh} = 625 V

E_{trans} = 450 V/cm

ΔV = 1550 V

E_{drift} = 666 V/cm

ER = 47%

Gain = 250 k

Pulsed UV source

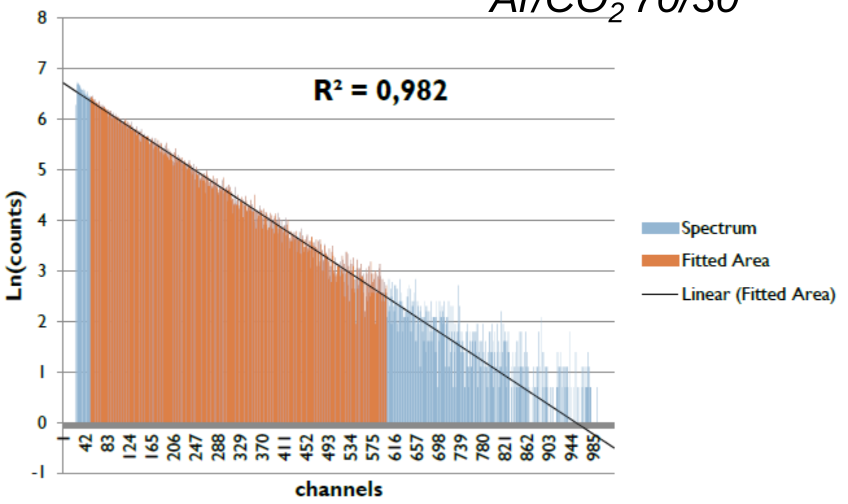
(single photoelectron mode)

Micromegas +

double THGEM

IBF: ~ 4%

Ar/CO$_2$ 70/30

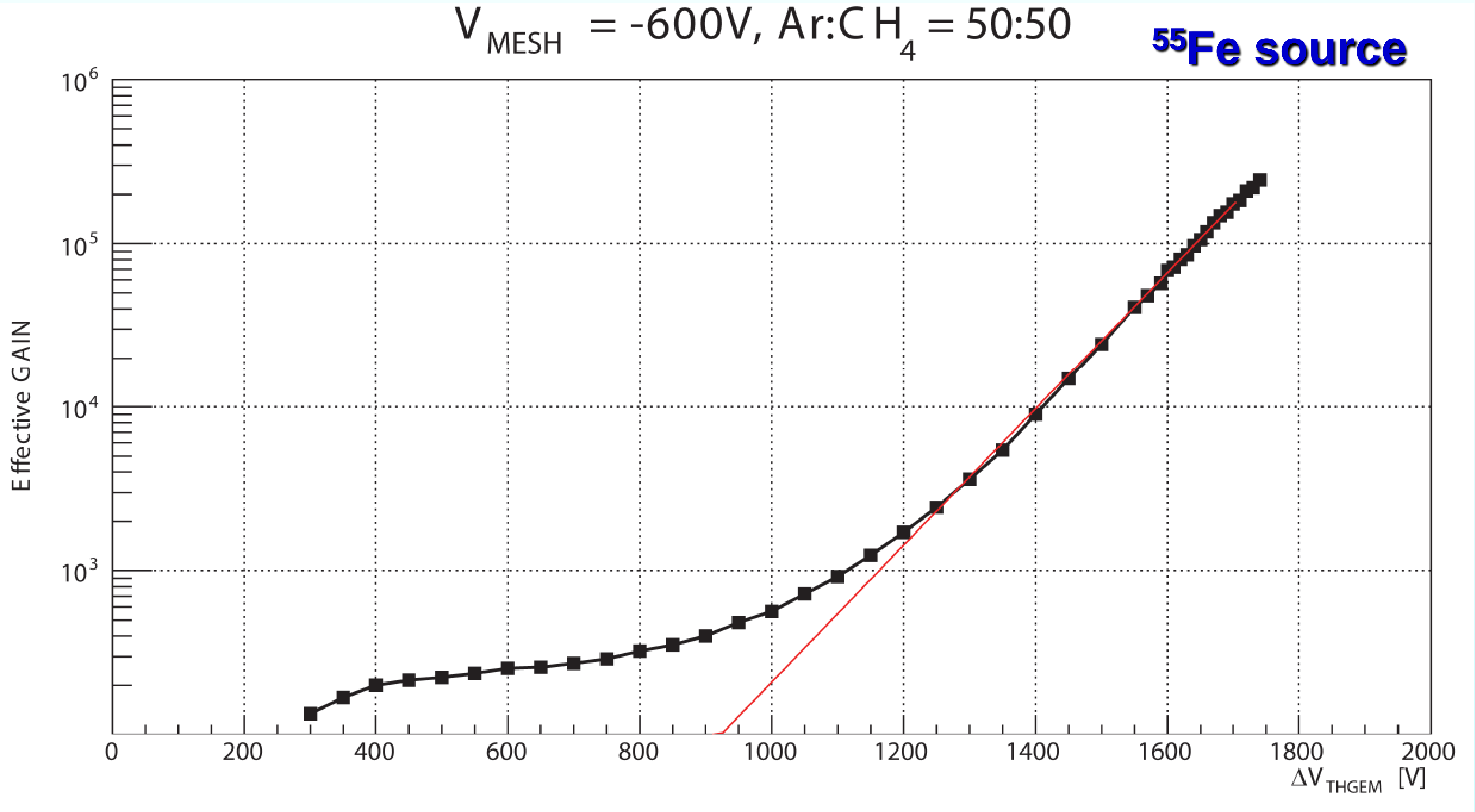


Gain ≈ 1.7E6

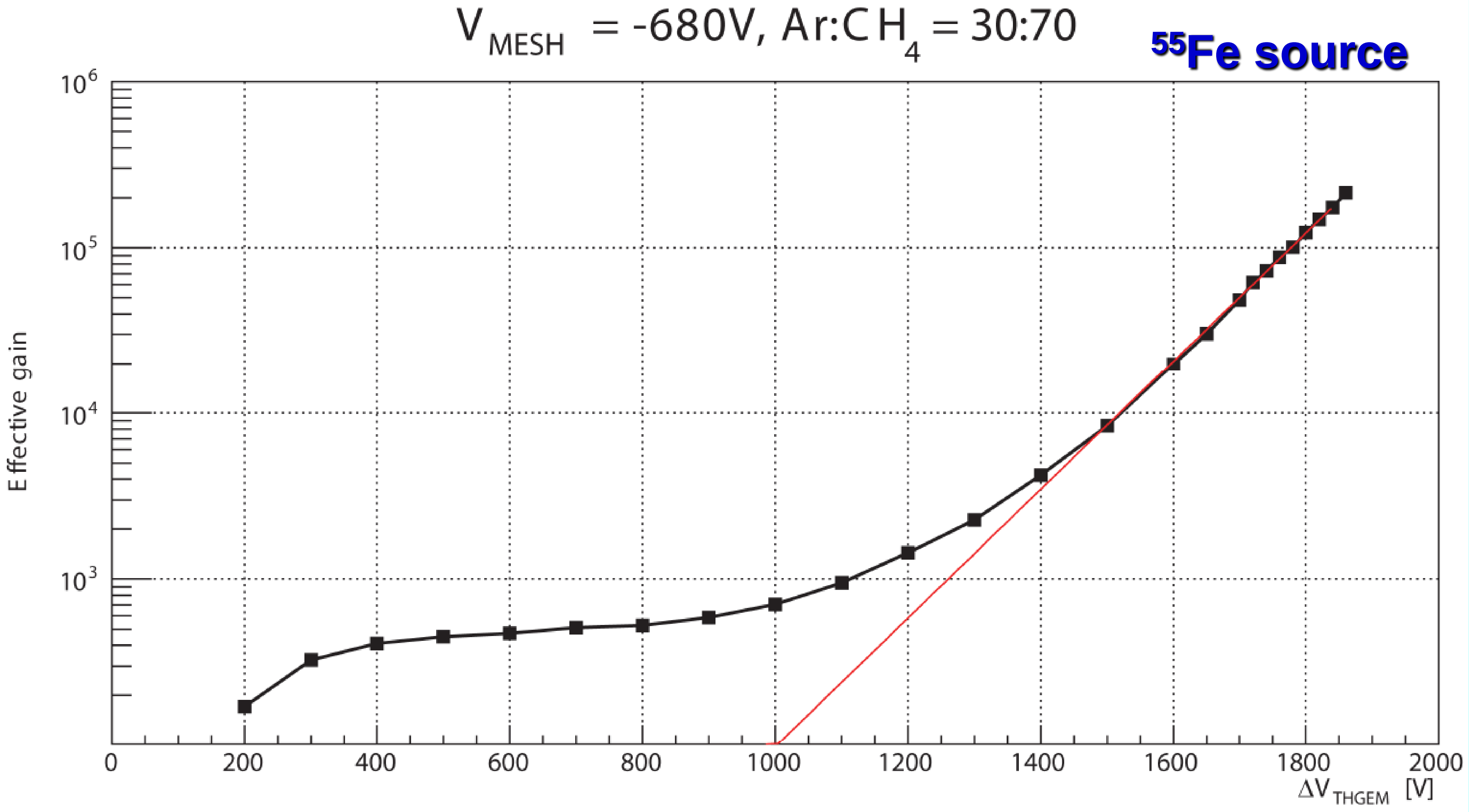
V_{mesh} = 600 V
E_{trans2} = 625 V/cm
ΔV_2 = 1450 V
E_{trans1} = 967 V/cm
ΔV_1 = 1410 V
E_{drift} = 0 V/cm

Rate ≈ 771 Hz

Effective gain versus THGEM bias

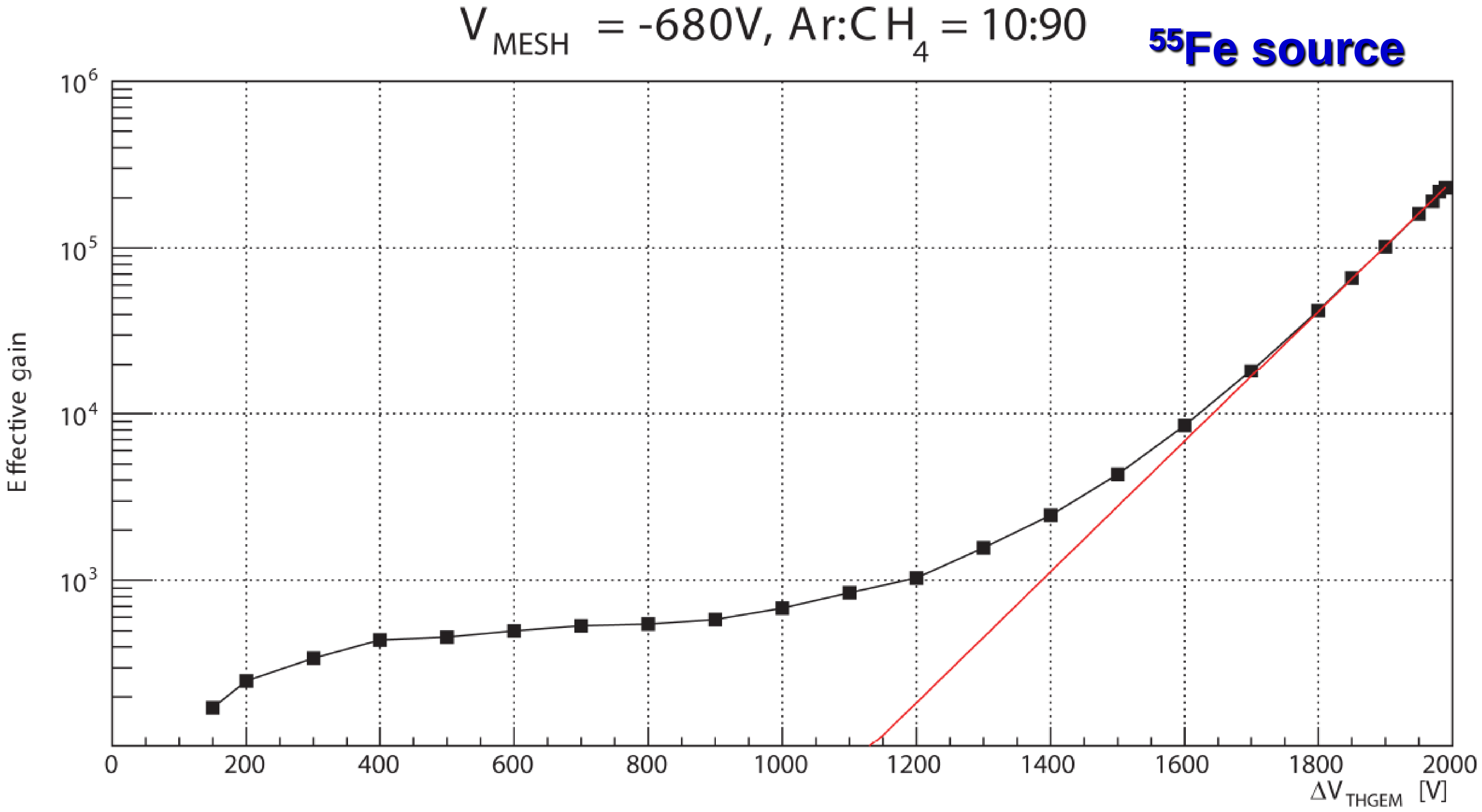


Effective gain versus THGEM bias



Effective gain versus THGEM bias

^{55}Fe source

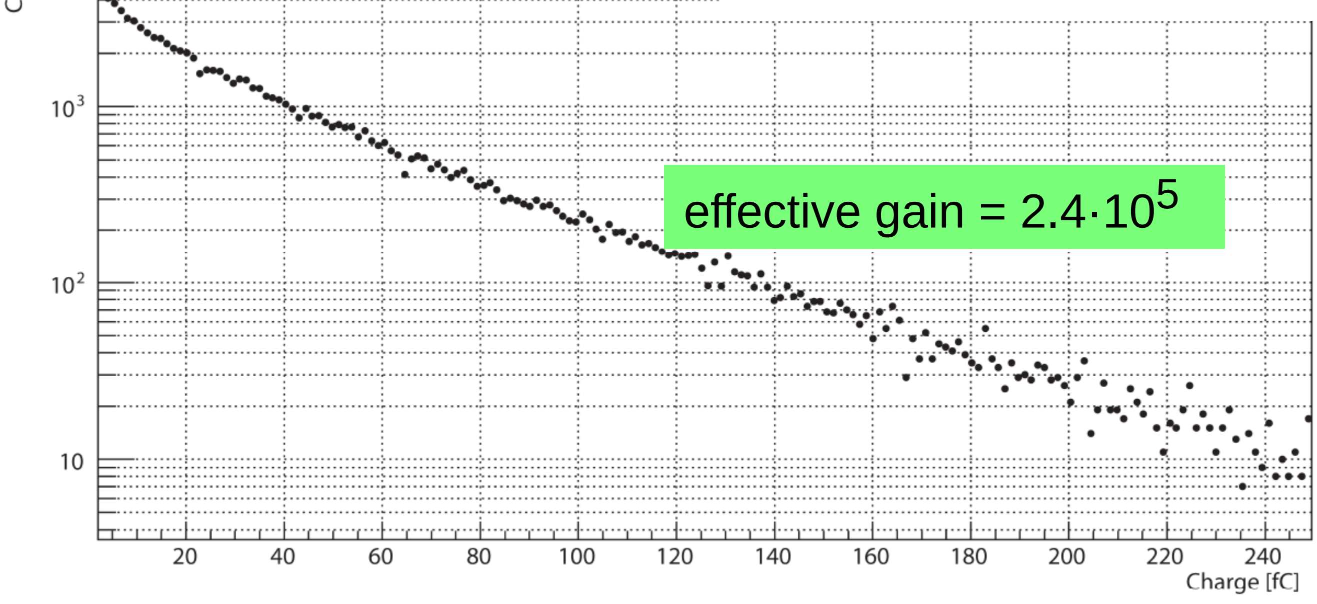


operating with pure CH_4 is not a problem

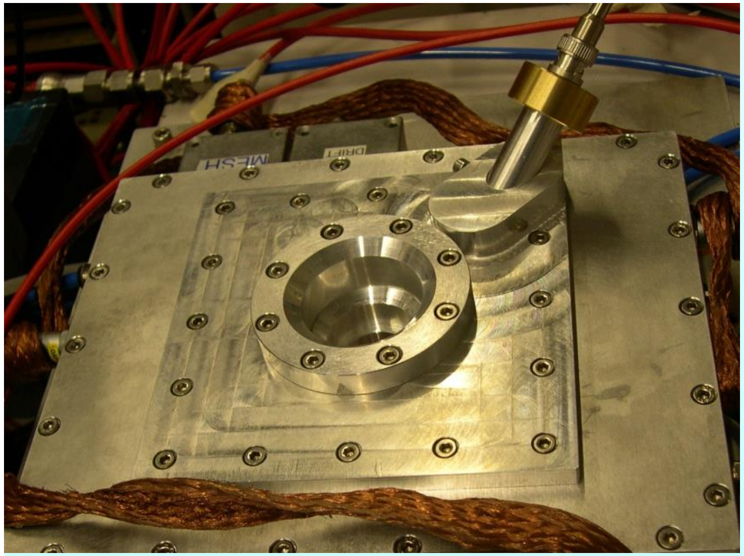
UV LED source

(single photoelectron mode)

Can be used at the same time as ^{55}Fe X-ray source

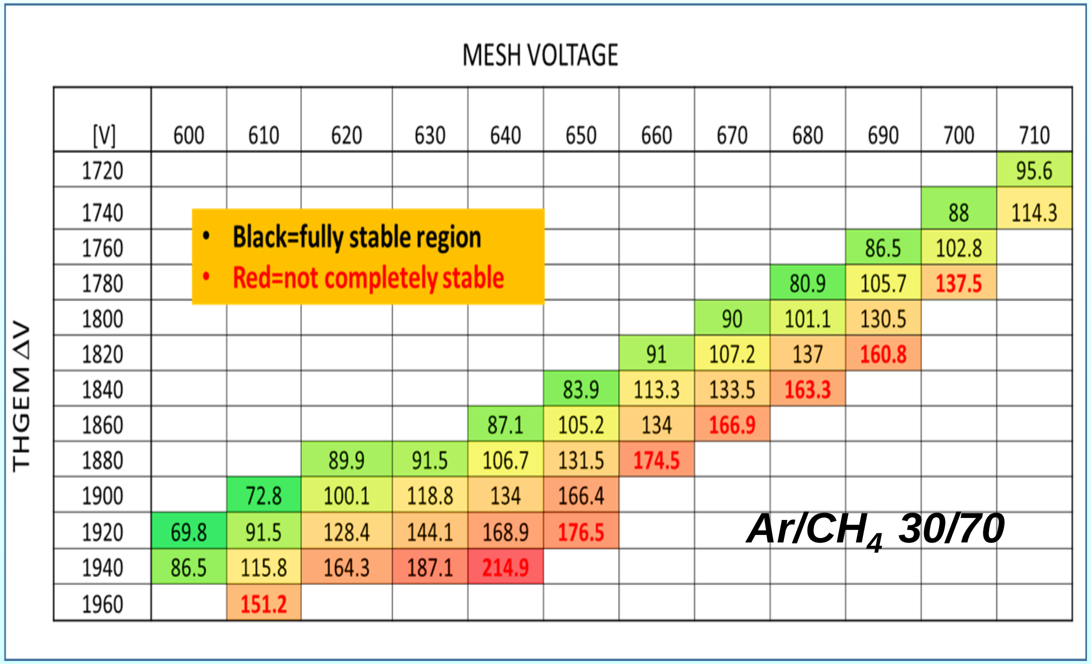


effective gain = $2.4 \cdot 10^5$



Study of the stability conditions

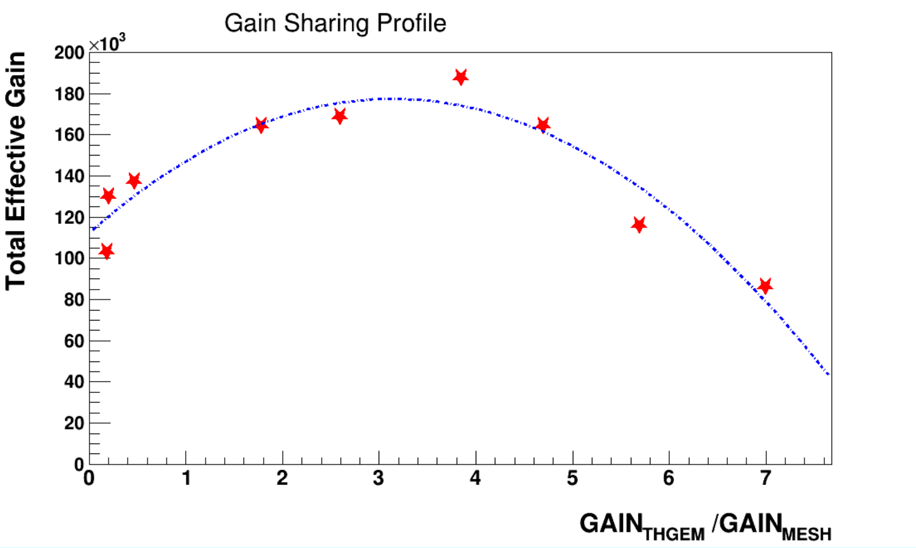
^{55}Fe source



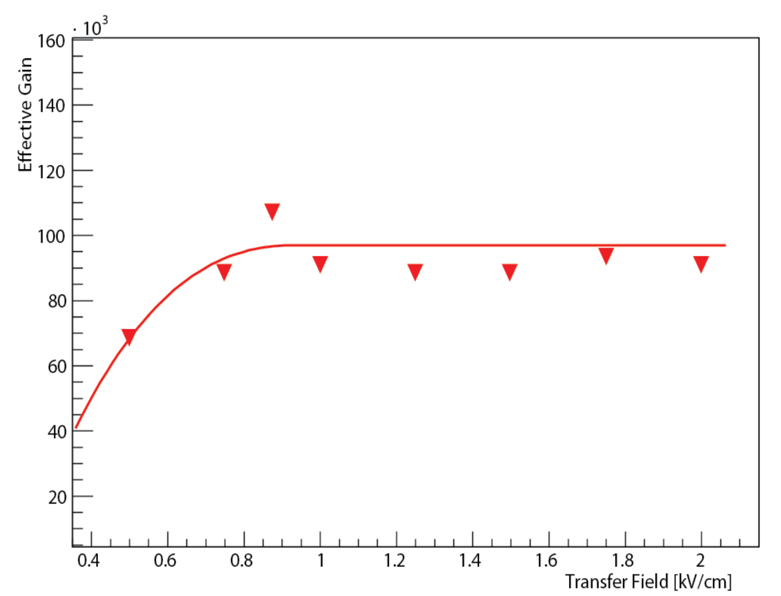
THGEM ΔV	MESH VOLTAGE											
[V]	600	610	620	630	640	650	660	670	680	690	700	710
1720												95.6
1740											88	114.3
1760										86.5	102.8	
1780									80.9	105.7	137.5	
1800								90	101.1	130.5		
1820							91	107.2	137	160.8		
1840						83.9	113.3	133.5	163.3			
1860					87.1	105.2	134	166.9				
1880			89.9	91.5	106.7	131.5	174.5					
1900		72.8	100.1	118.8	134	166.4						
1920	69.8	91.5	128.4	144.1	168.9	176.5						
1940	86.5	115.8	164.3	187.1	214.9							
1960		151.2										

- Black=fully stable region
- Red=not completely stable

Ar/CH$_4$ 30/70



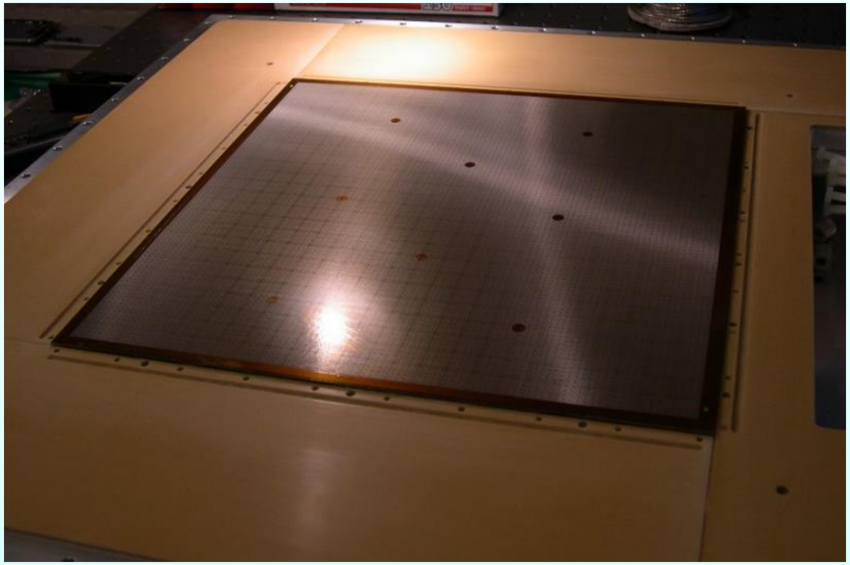
Gain Sharing Profile

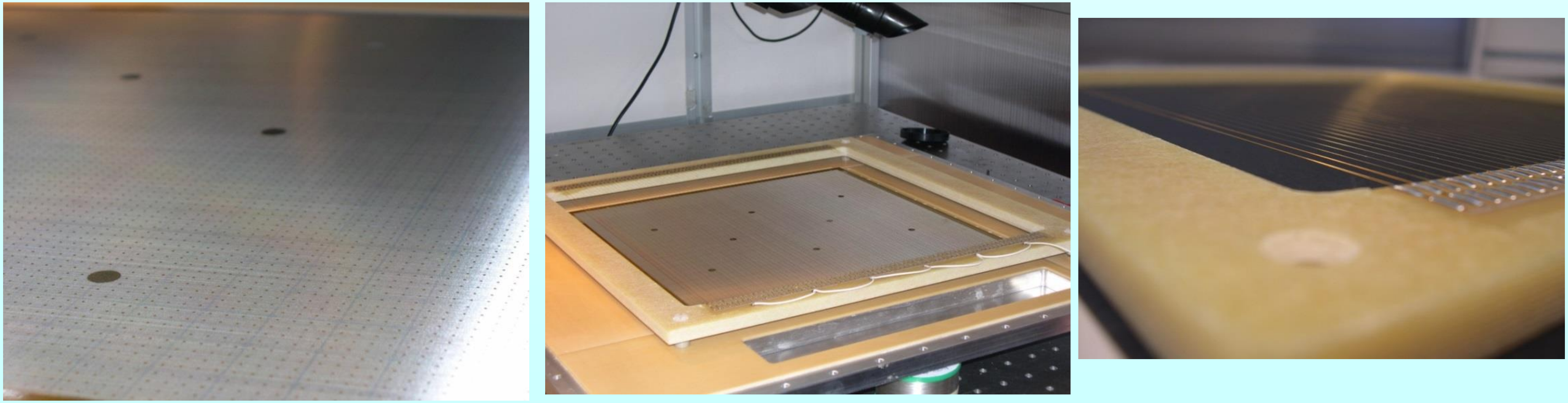


Production of 300 mm x 300 mm hybrid PDs

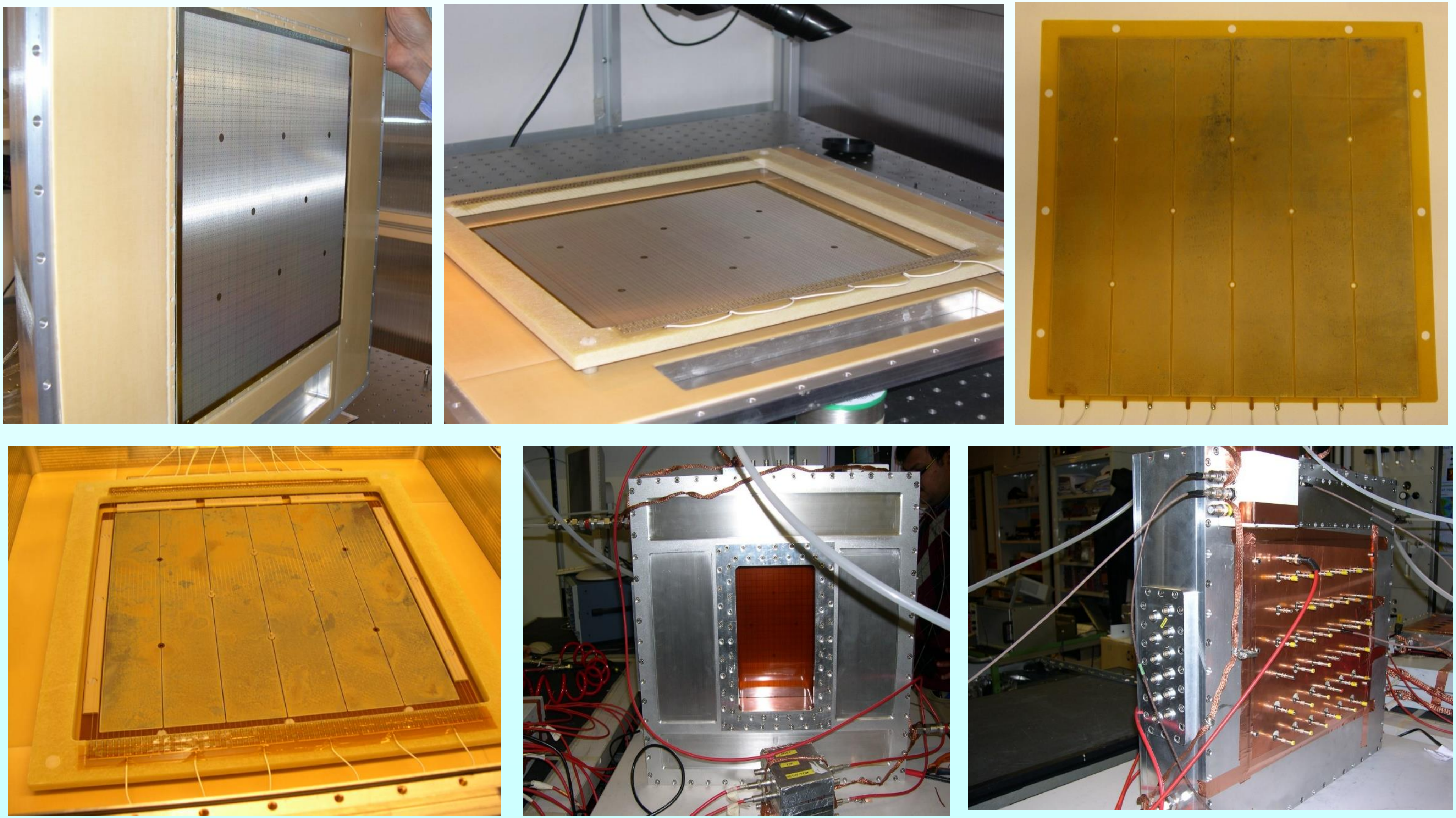
Mesh preparation at Seritech

Bulk Micromegas produced at CERN

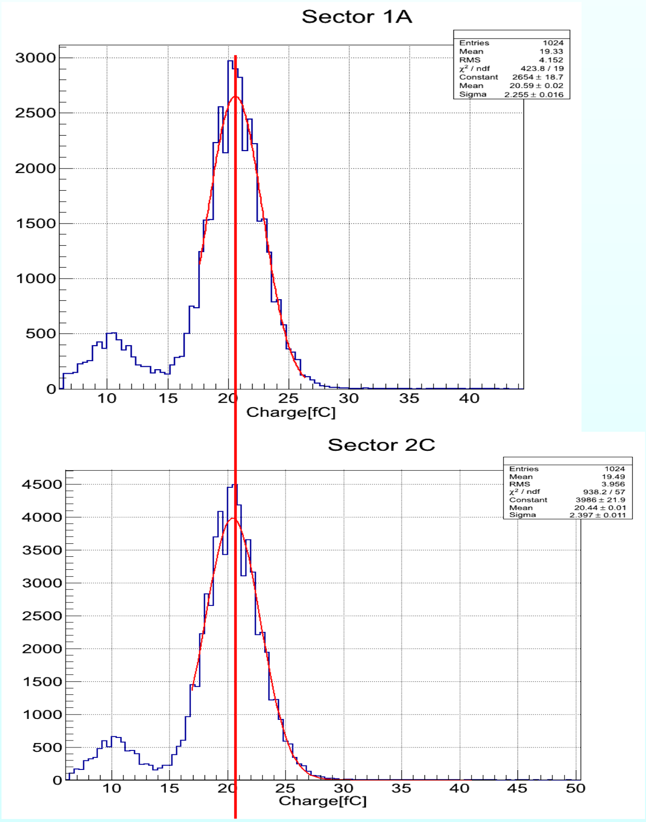


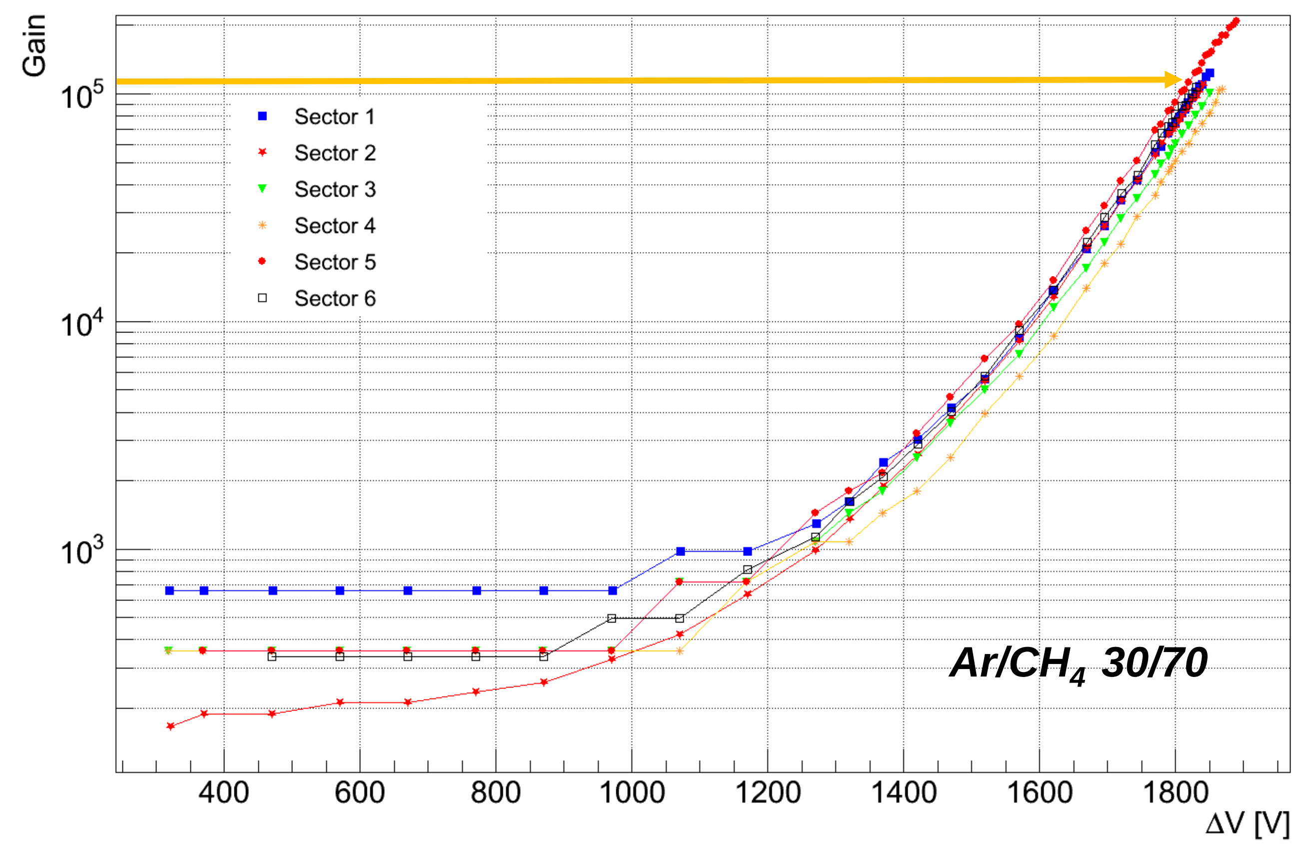


Assembly in Trieste



test with ^{55}Fe source





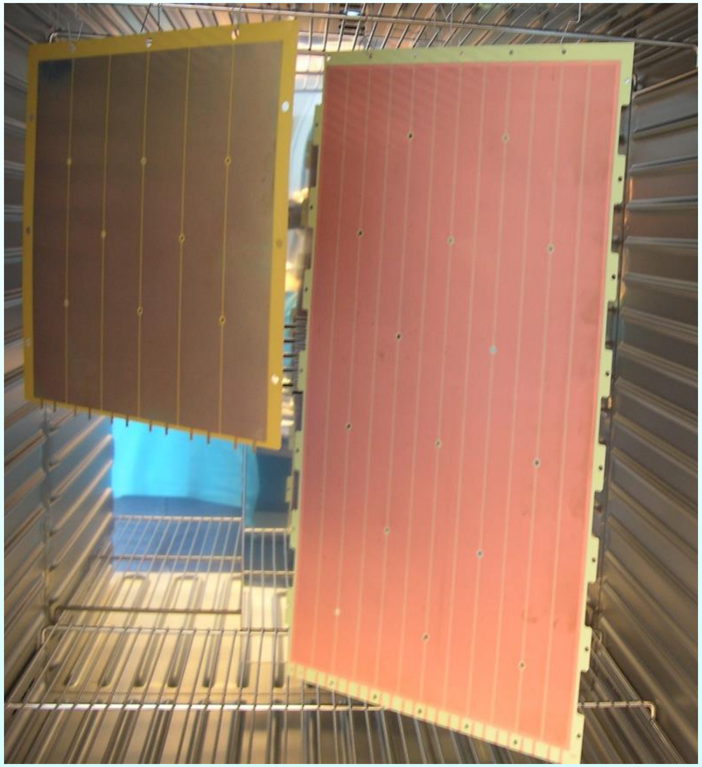
The maximum gain is between $1 \cdot 10^5$ and $2 \cdot 10^5$

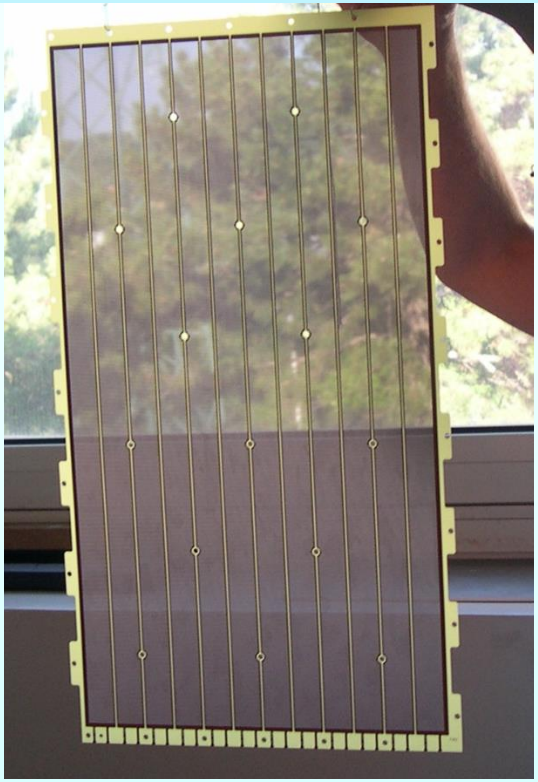
➔ Total charge ~ $3 \cdot 10^7$, close to the Raether limit

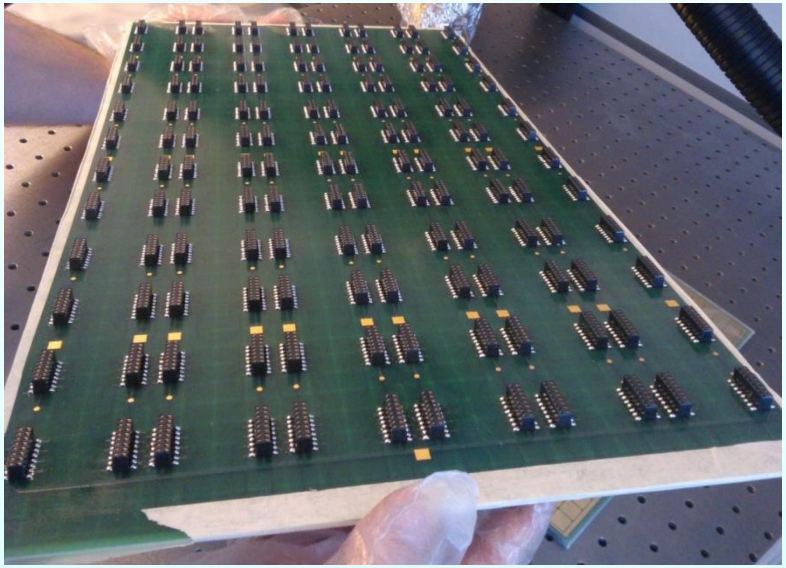
The large prototype shows the same performance as the small one

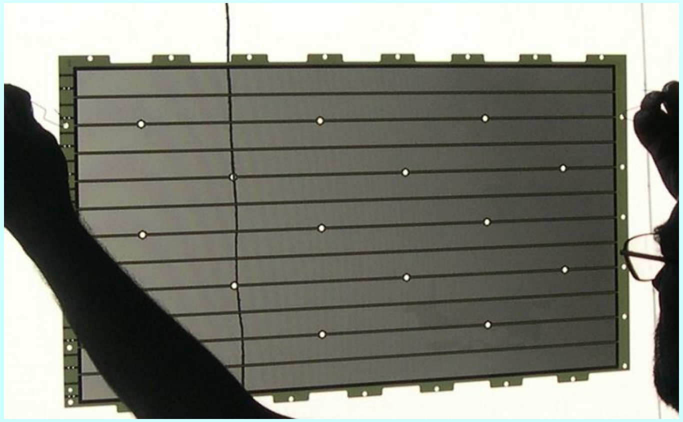
Systematic tests will be performed both in laboratory and at the PS T10 CERN beam line soon (test beam: August 26 - September 16)

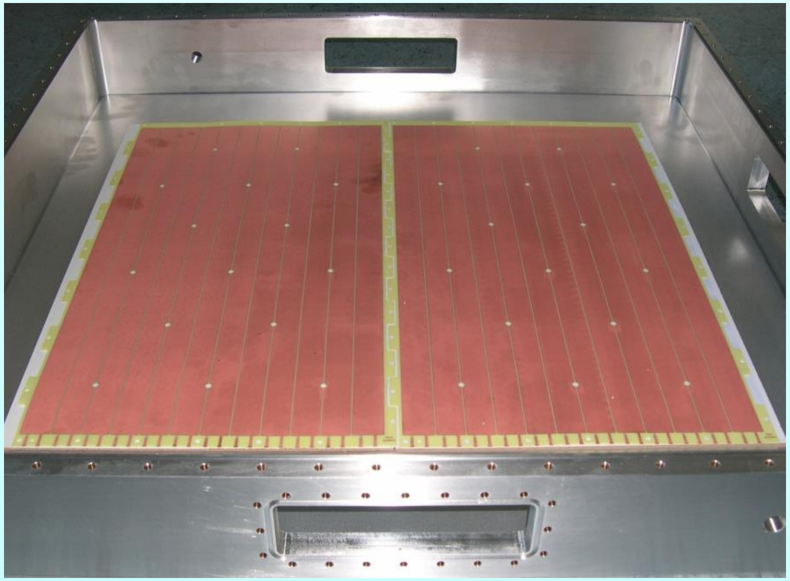
Production of a 600 mm x 600 mm hybrid PD



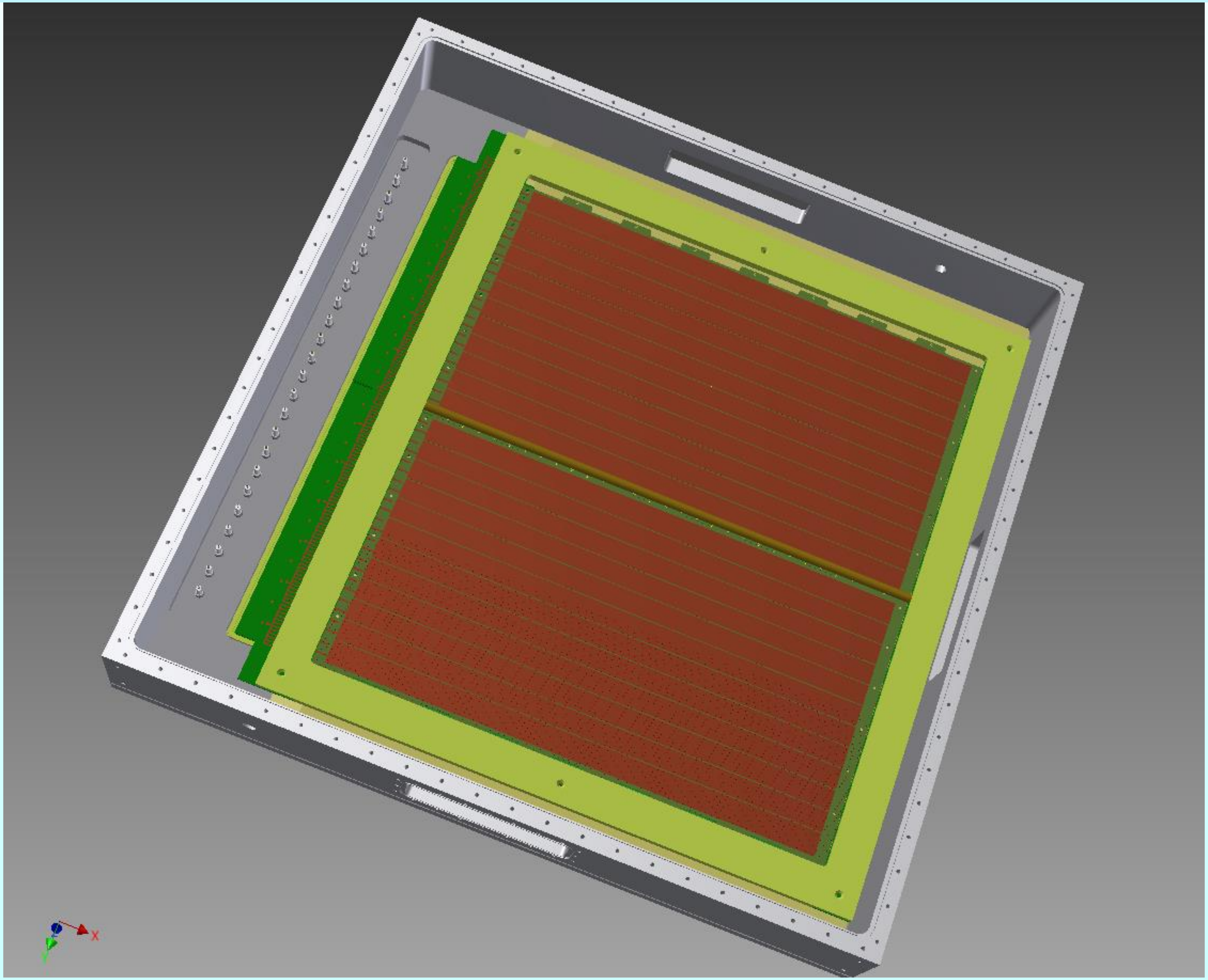




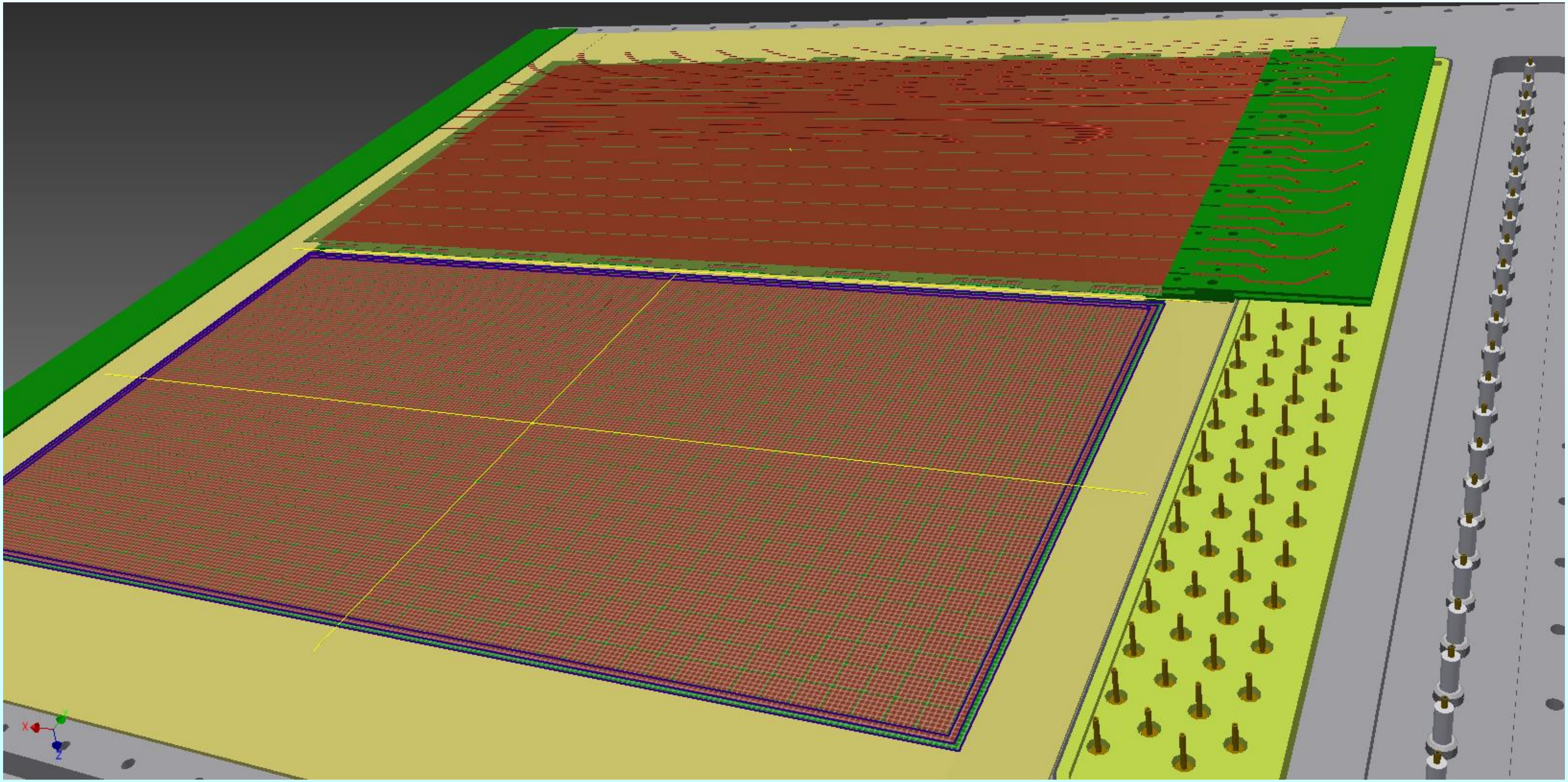




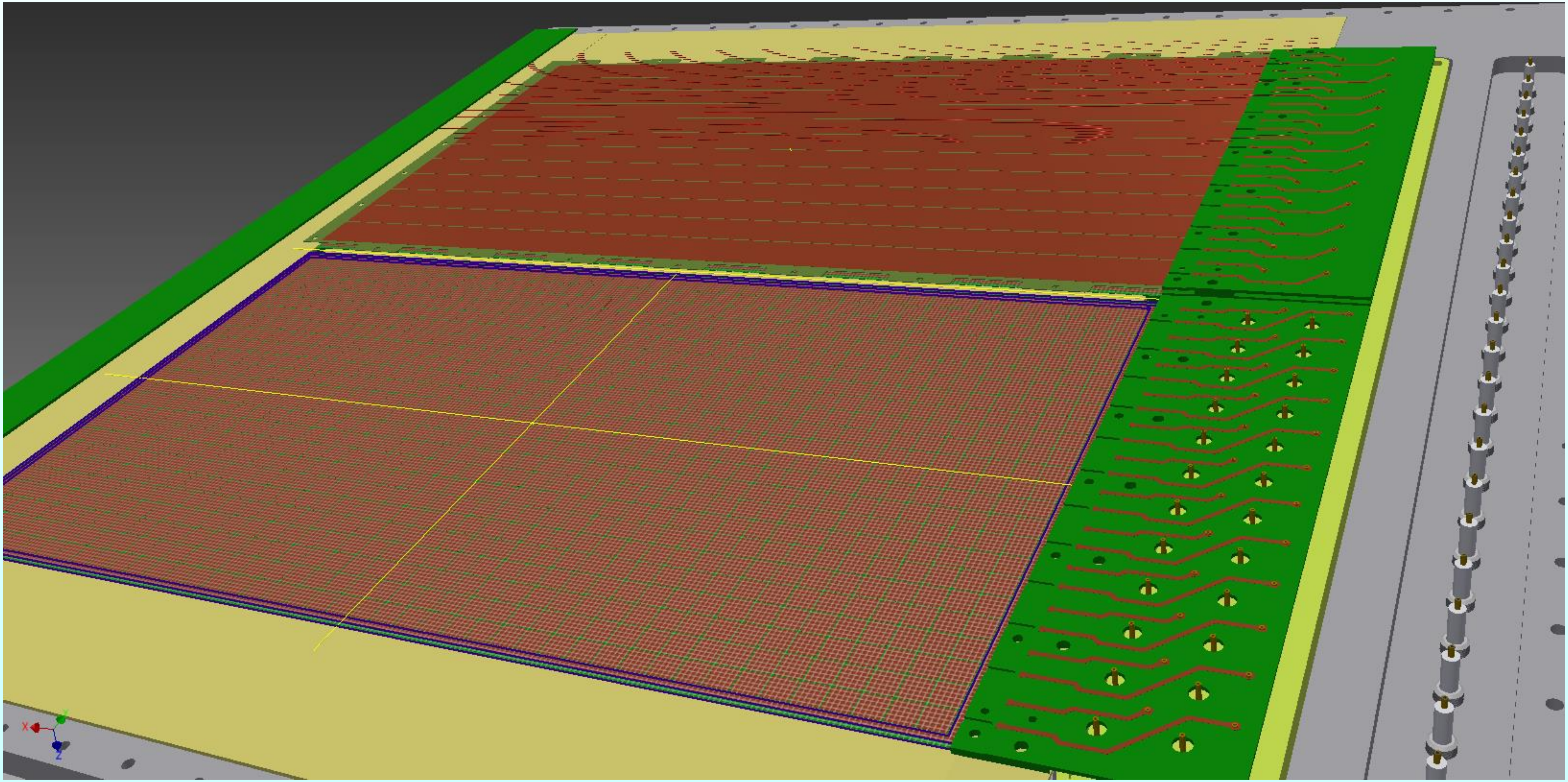
The 600 mm x 600 mm hybrid PD prototype



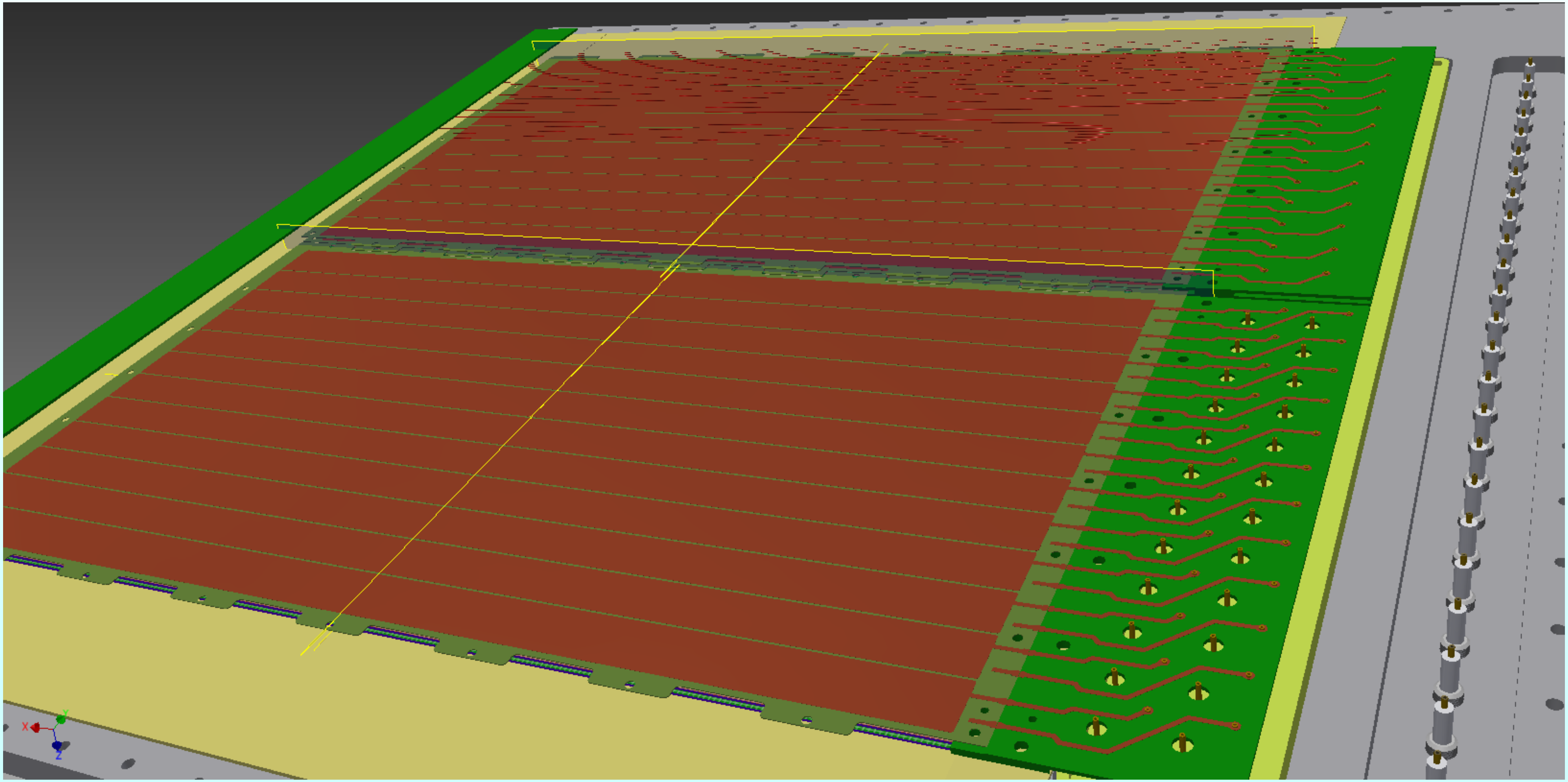
The 600 mm x 600 mm hybrid PD prototype



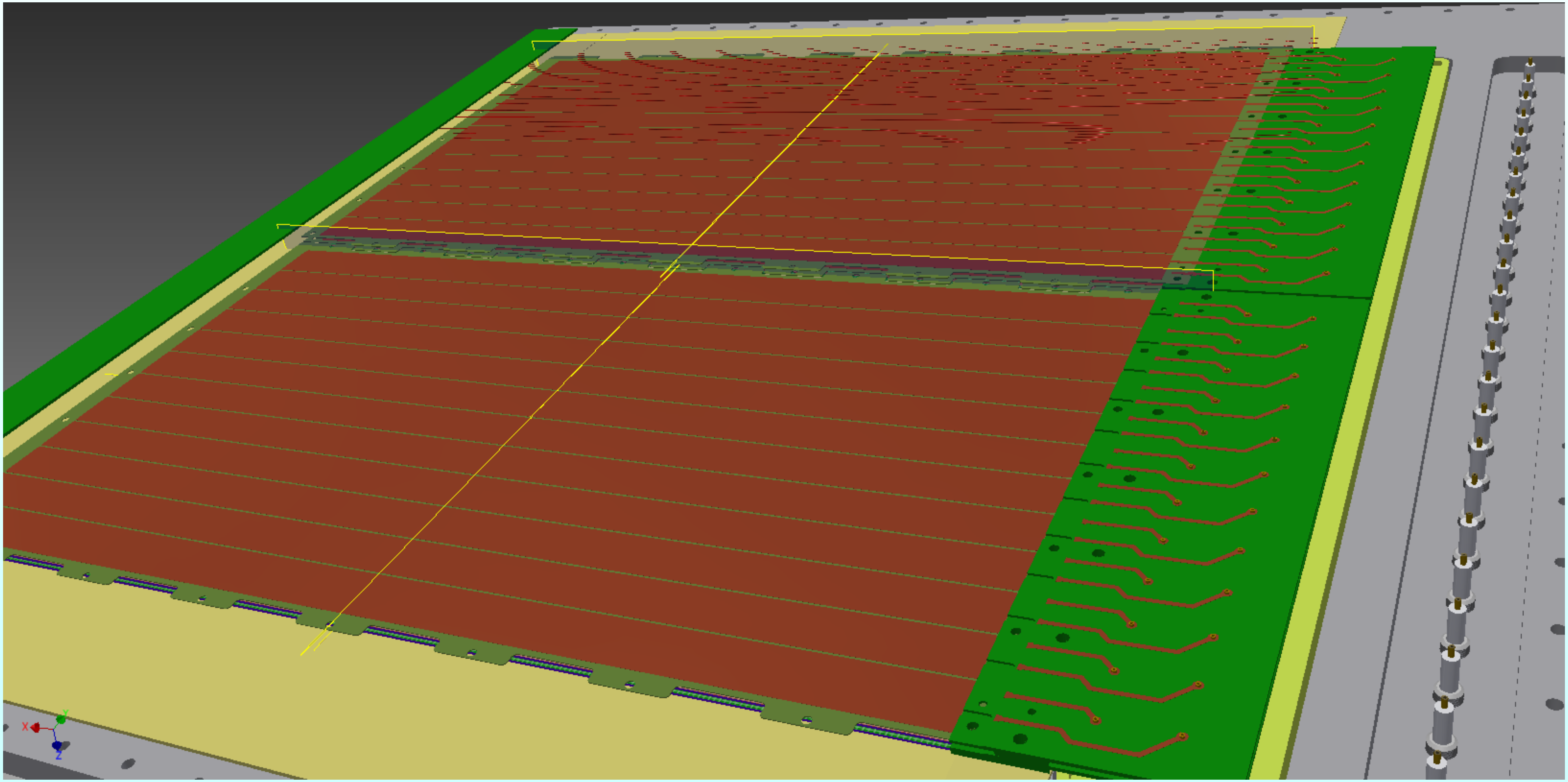
The 600 mm x 600 mm hybrid PD prototype



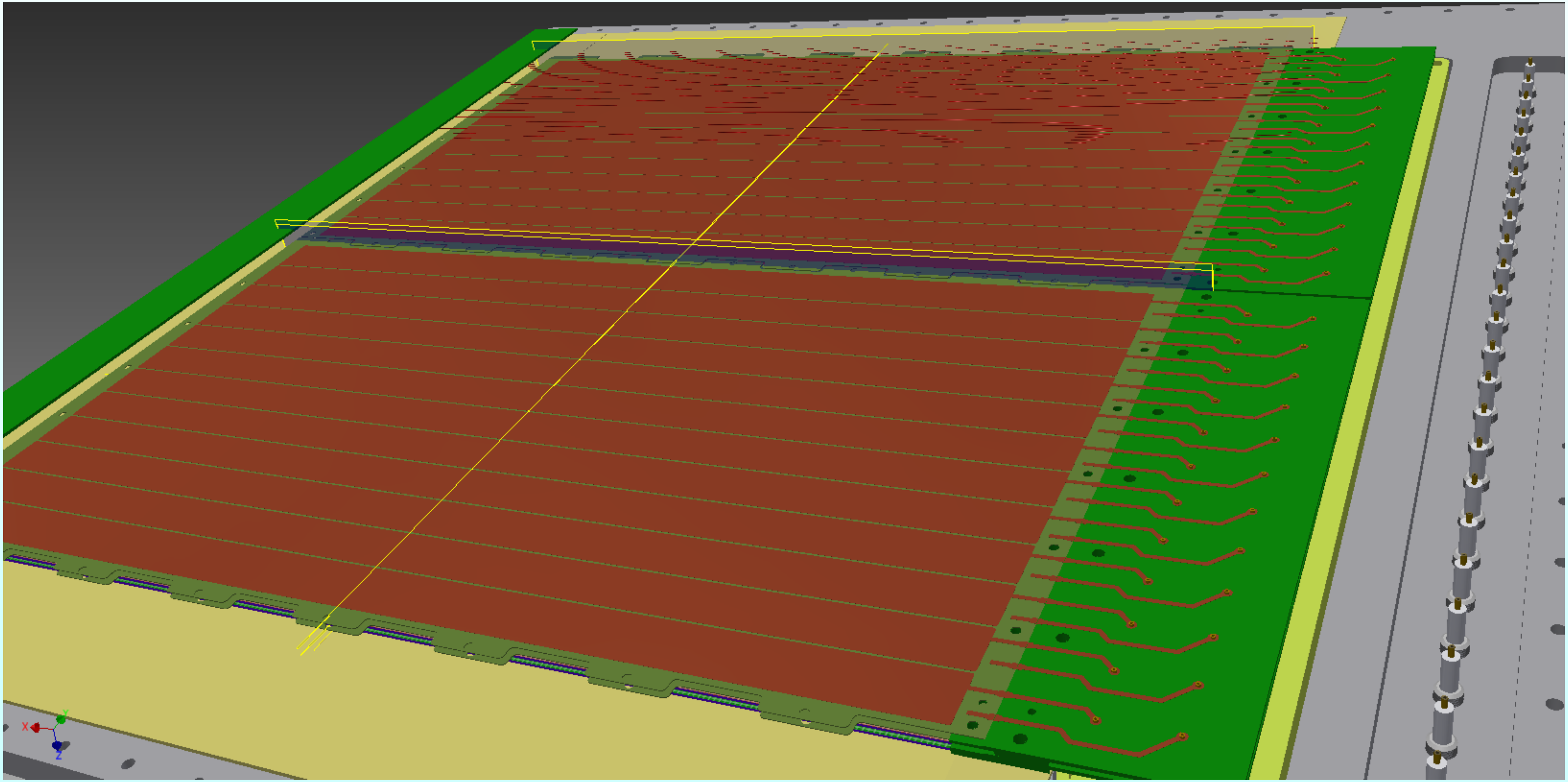
The 600 mm x 600 mm hybrid PD prototype



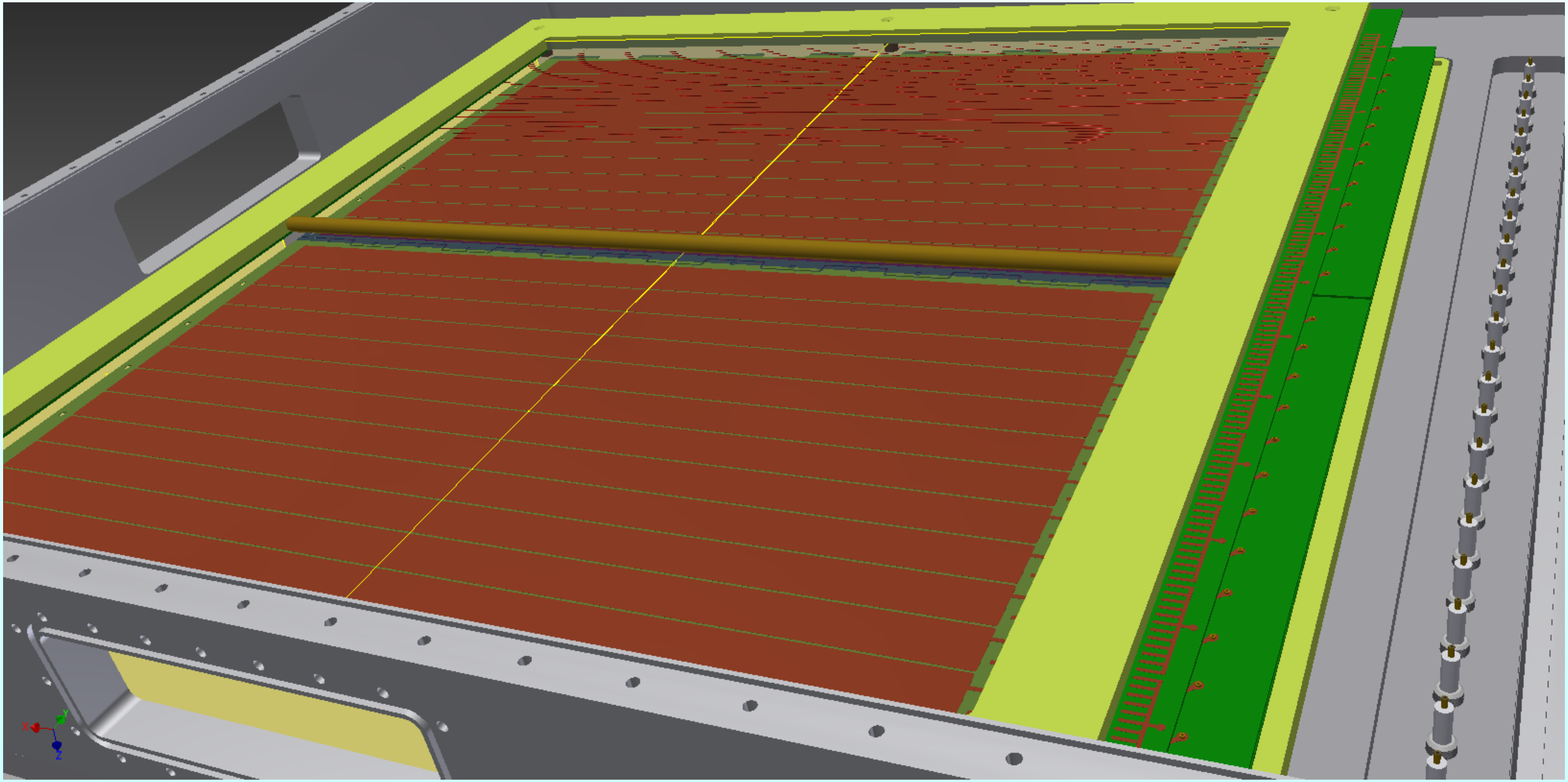
The 600 mm x 600 mm hybrid PD prototype



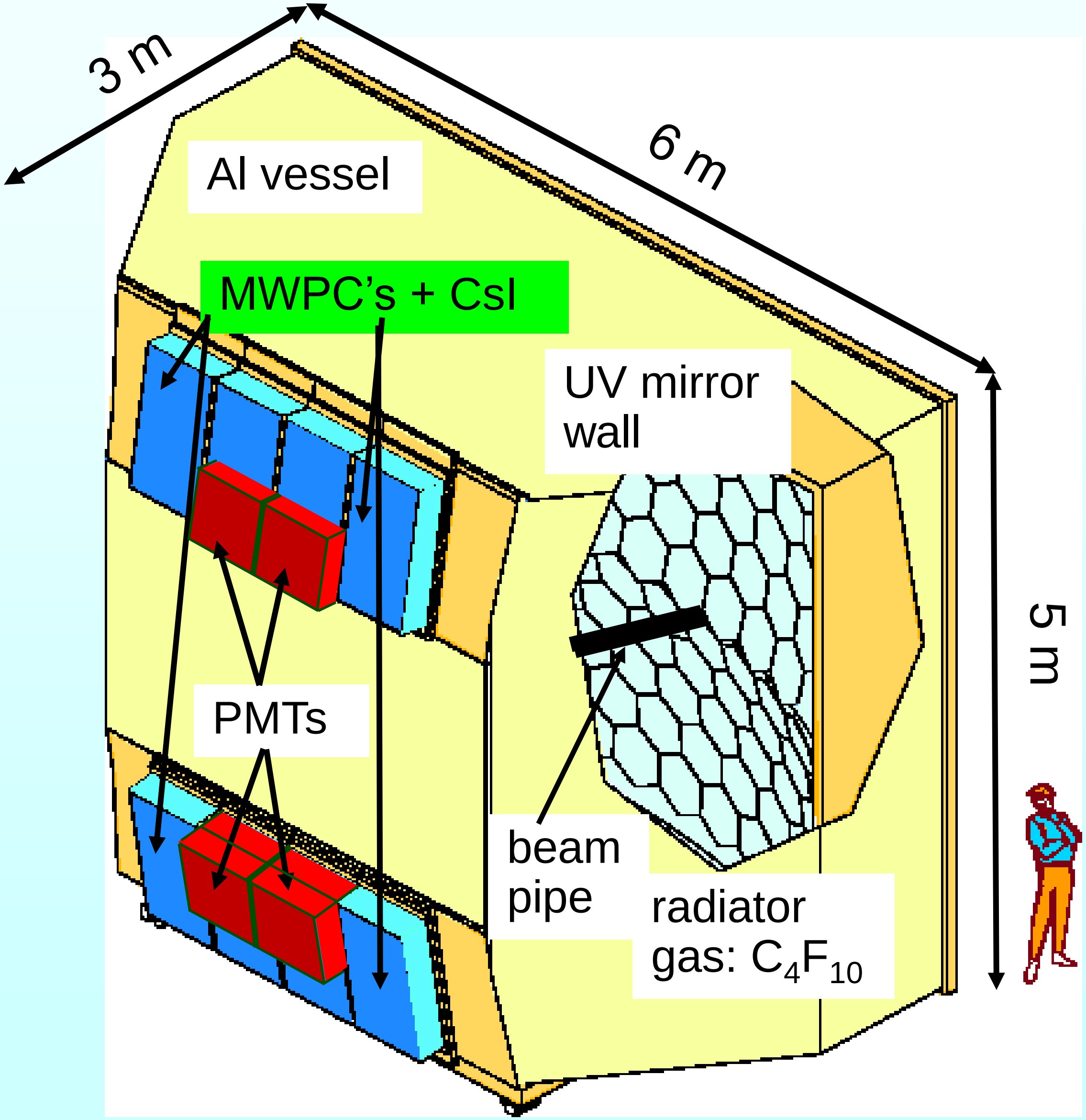
The 600 mm x 600 mm hybrid PD prototype

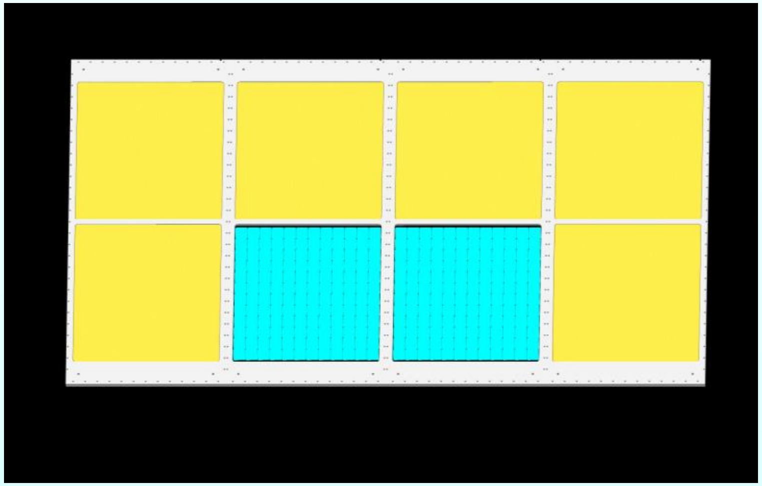


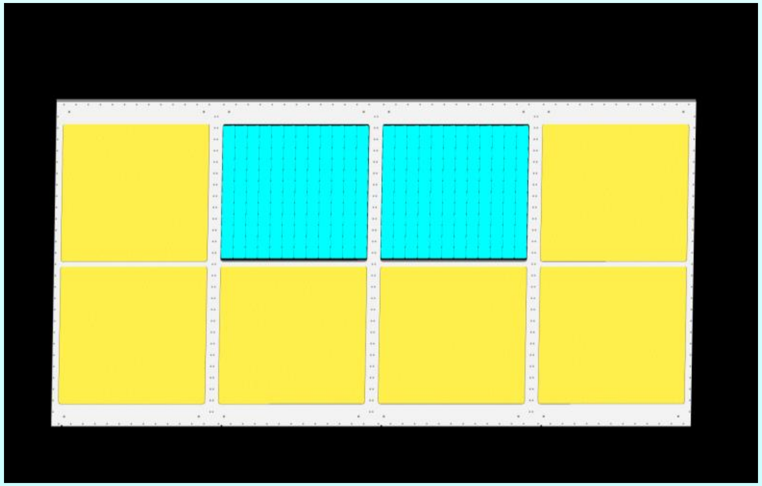
The 600 mm x 600 mm hybrid PD prototype



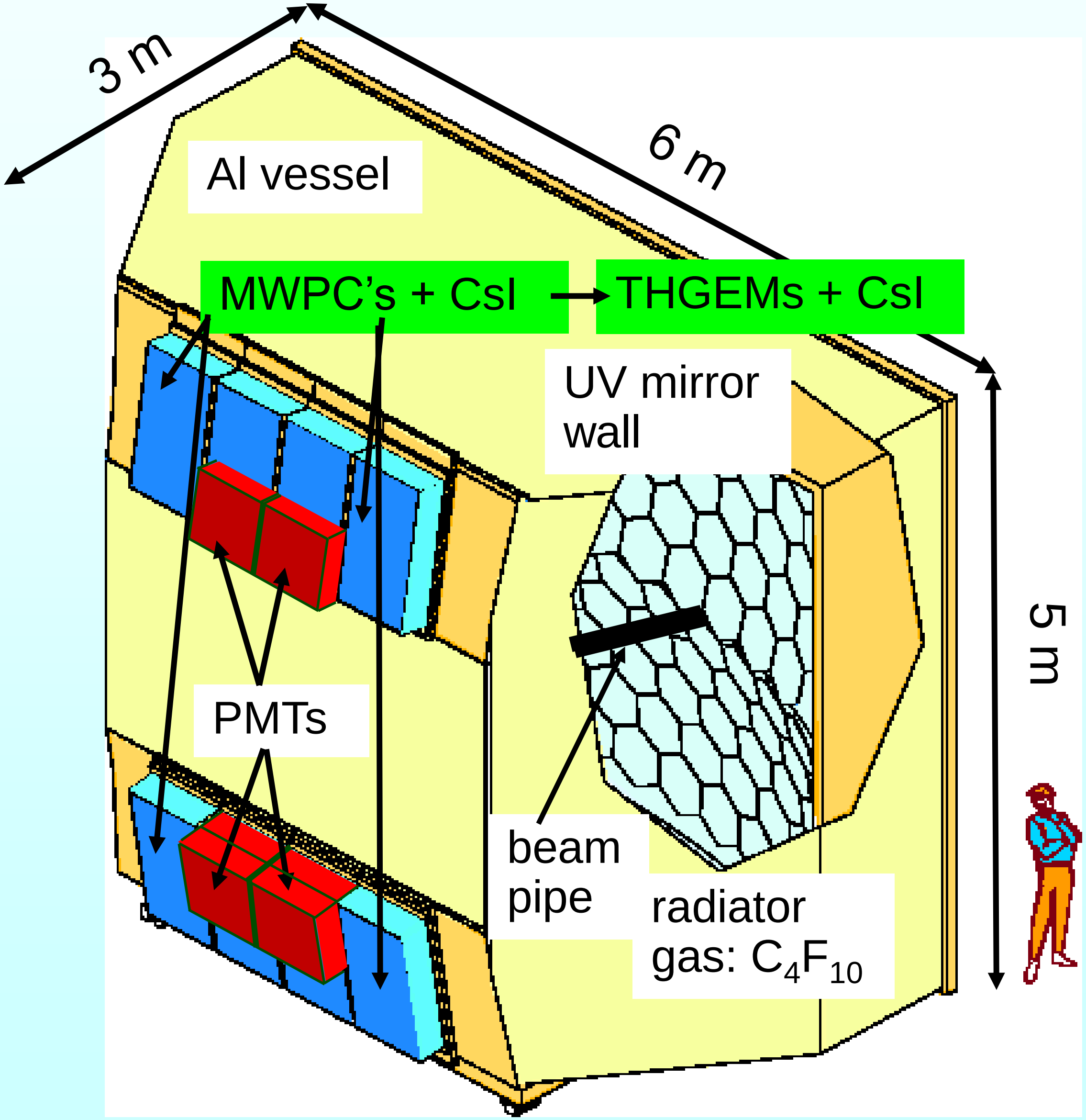
The COMPASS RICH-1 upgrade







The COMPASS RICH-1 upgrade



3 m

6 m

5 m

Al vessel

MWPC's + CsI → THGEMs + CsI

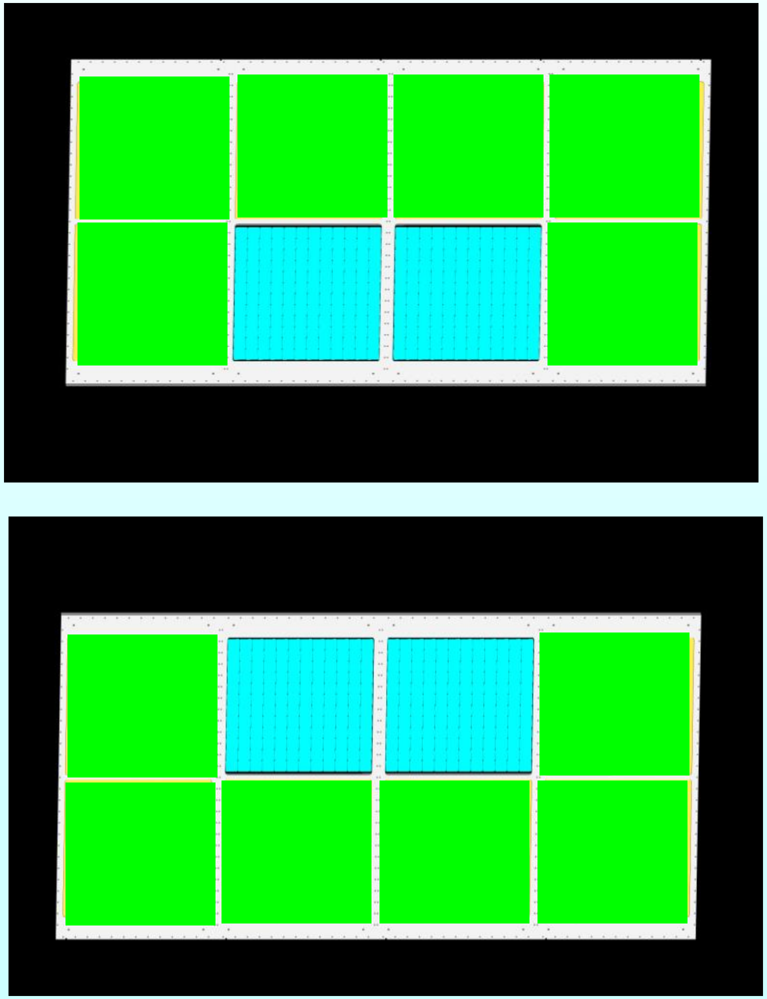
UV mirror wall

PMTs

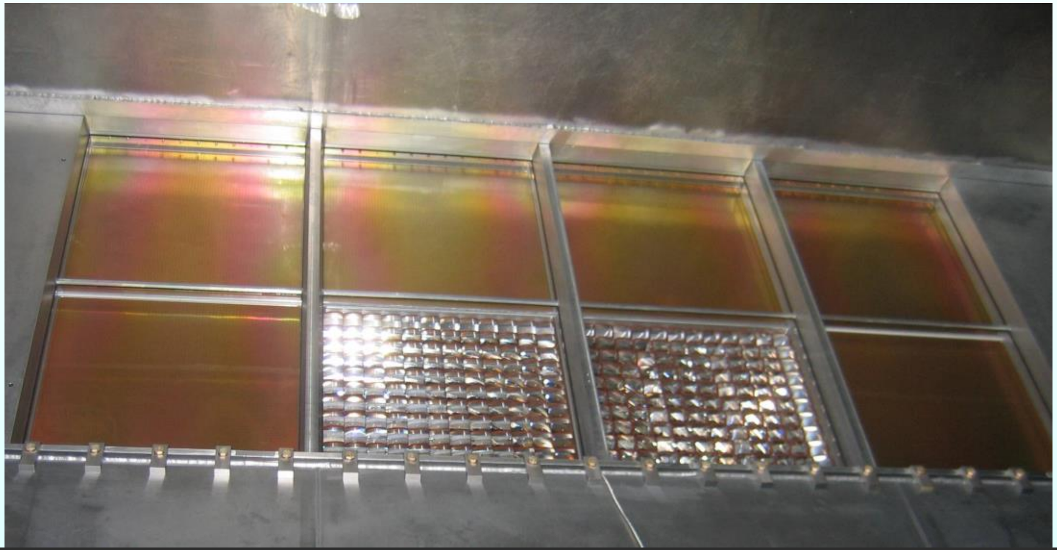
beam pipe

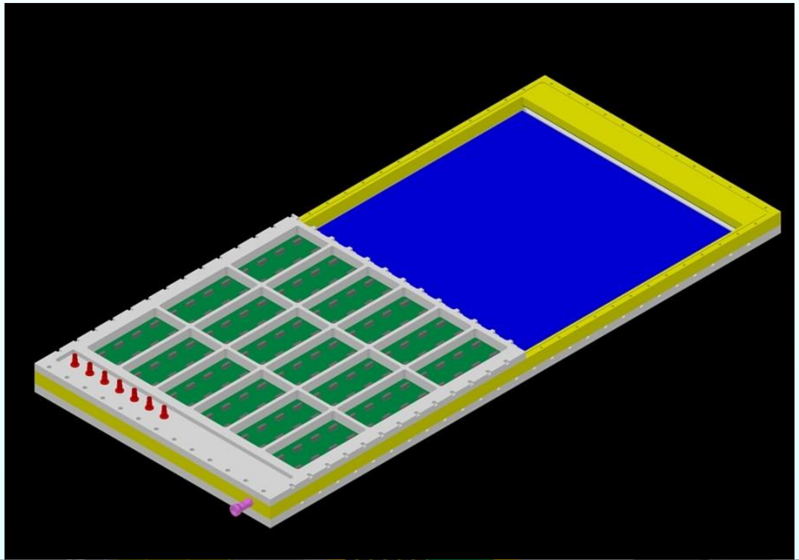
radiator gas: C_4F_{10}

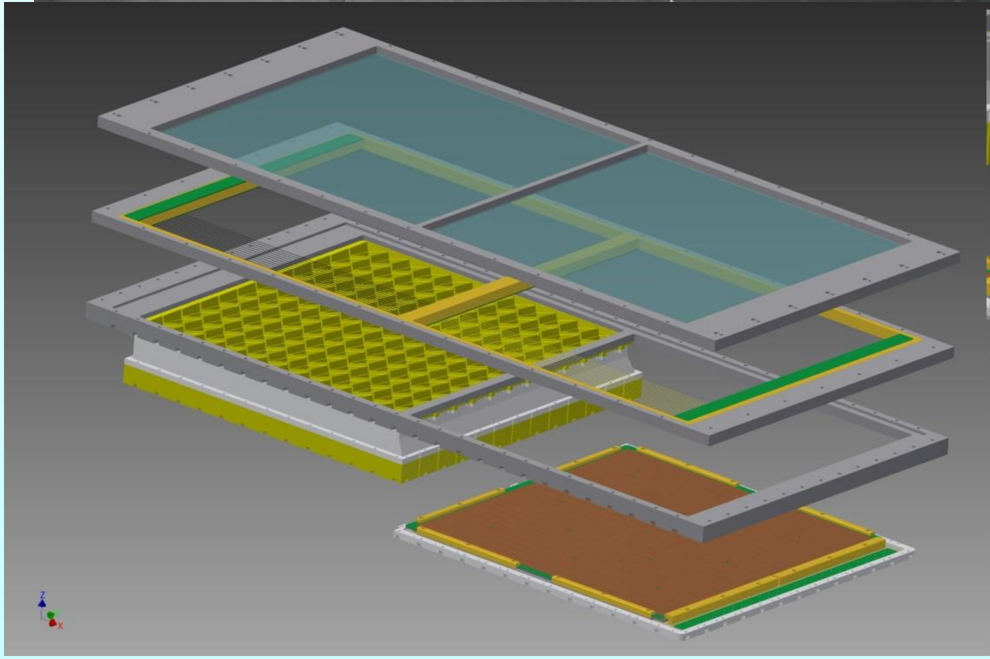
Foreseen for 2016-2017

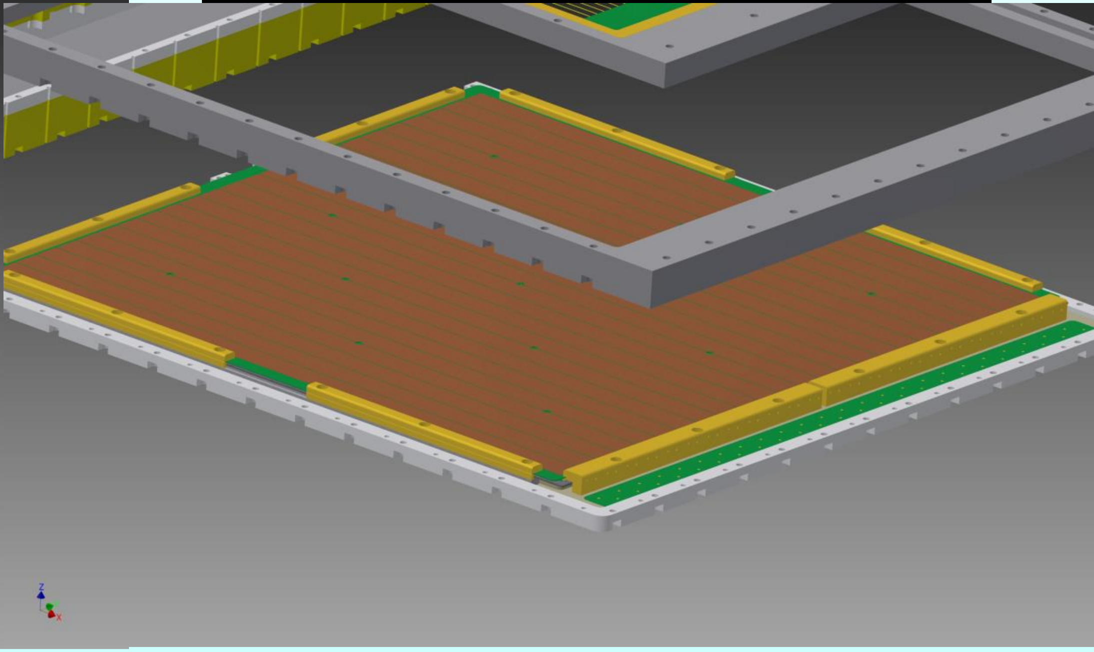


The RICH-1 PDs

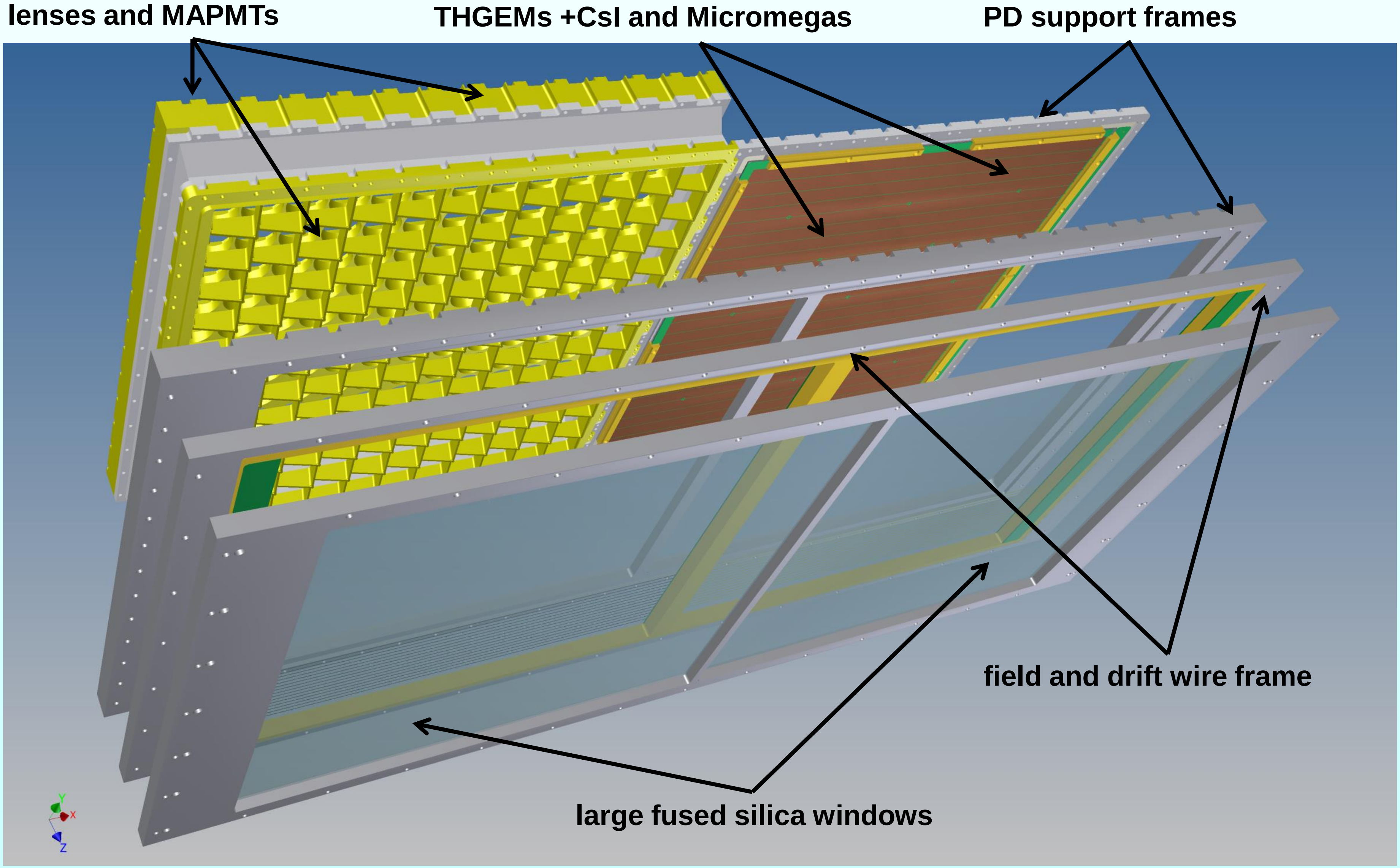








The MAPMT + hybrid PD chamber for RICH-1


lenses and MAPMTs

THGEMs +CsI and Micromegas

PD support frames

field and drift wire frame

large fused silica windows

CONCLUSIONS

THGEMs represent a good choice for large area single photon detectors

Many aspects have been understood using small size prototypes

A 300x300 mm^2 active area Triple THGEM PD has been built and tested

The small hybrid THGEM + Micromegas PD showed excellent results

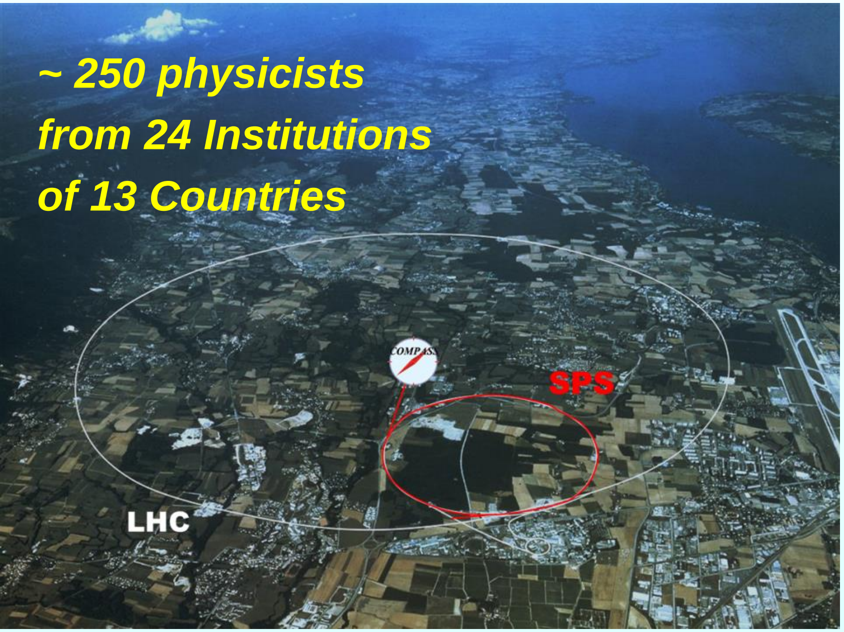
300x300 mm^2 active area hybrid THGEM + Micromegas PDs built and tested

A full scale prototype for COMPASS is under construction

The COMPASS RICH-1 upgrade is progressing on schedule

Spare slides

COMPASS II Collaboration



~ 250 physicists
from 24 Institutions
of 13 Countries

Дубна (LPP and LNP), Москва (INR, LPI, State University), Протвино

Warsawa (NCBJ),
Warsawa (TU)
Warsawa (U)

Praha (CU/CTU)
Liberec (TU)
Brno (ISI-ASCR)

Calcutta (Matriviani)

Taipei (AS)

CERN

Yamagata

Lisboa/Aveiro

Tel Aviv

Bochum, Bonn (ISKP & PI), Erlangen, Freiburg, Mainz, München TU

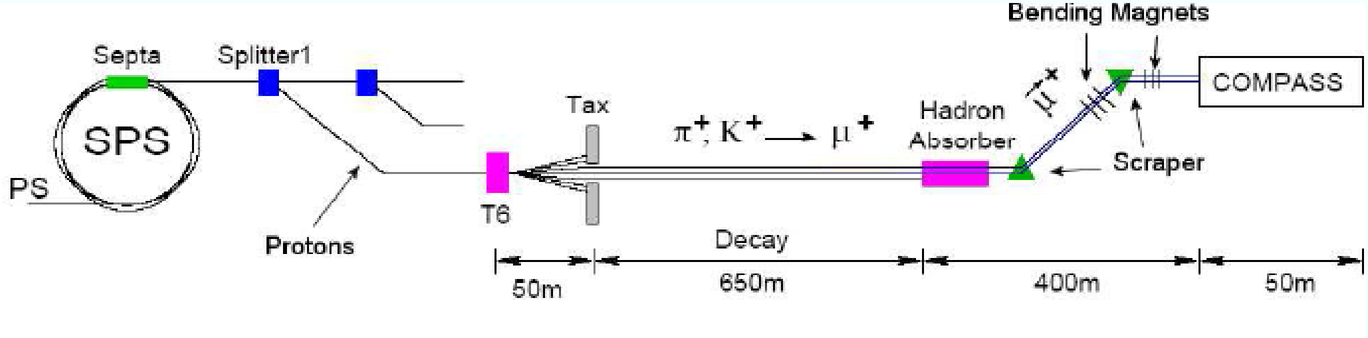
USA (UIUC)

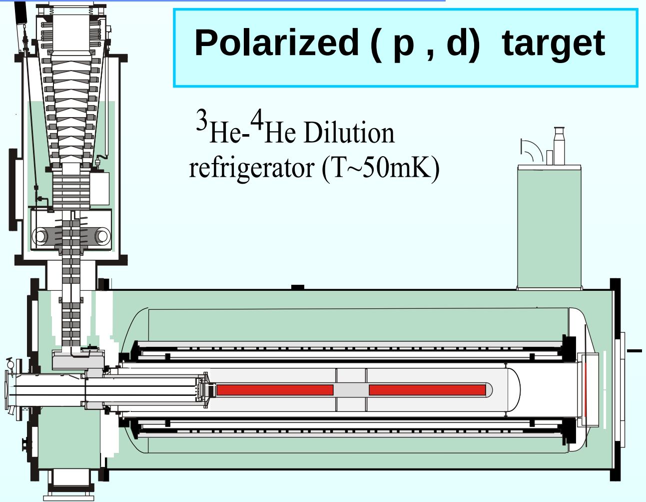
Saclay

Torino (University, INFN),
Trieste (University, INFN)

Experiments with muon beam:	***Experiments with hadron beams:***
COMPASS - I (2002 – 2011)	
Spin structure, Gluon polarization	*Pion polarizability*
Flavor decomposition	*Diffractive and Central production*
Transversity	*Light meson spectroscopy*
Transverse Momentum-dependent PDF	*Baryon spectroscopy*
COMPASS - II (2012 – 2017) …	
DVCS and HEMP	*Pion and Kaon polarizabilities*
Unpolarized SIDIS and TMDs	*Drell-Yan studies*

BEAM, TARGET AND SPECTROMETER





Polarized (p , d) target

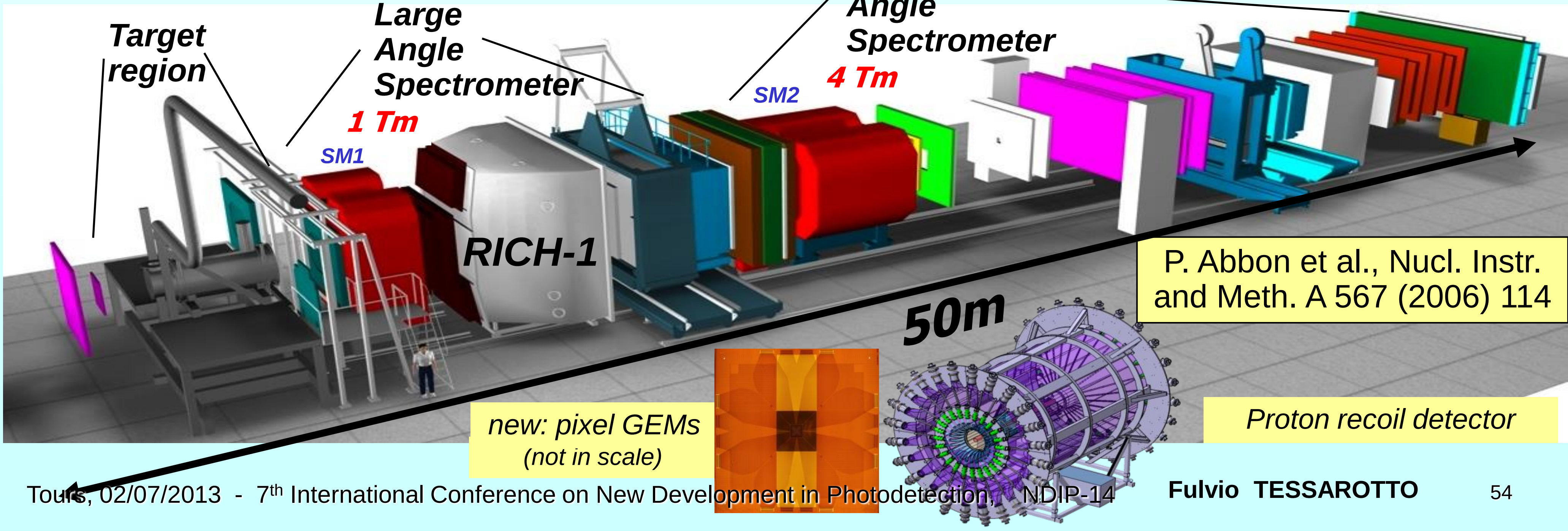
^{3}He-^{4}He Dilution refrigerator (T~50mK)

160 or 190 GeV/c μ^+ (or μ^-), 4 · 10^8 μ/spill, P$_\mu$ ~ 80%
190 GeV/c p, π^+, π^- , K$^+$,K$^-$ beams

Various targets used

first GEMs and Micromegas used in a HEP Experiment

DAQ: 40 kB, 30 kHz, O(PB)



new: pixel GEMs
(not in scale)

P. Abbon et al., Nucl. Instr. and Meth. A 567 (2006) 114

Proton recoil detector

HADRON PID IS PROVIDED BY RICH-1

COMPASS RICH-1: a large gaseous RICH with two kind of photon detectors providing:

hadron PID from 3 to 60 GeV/c

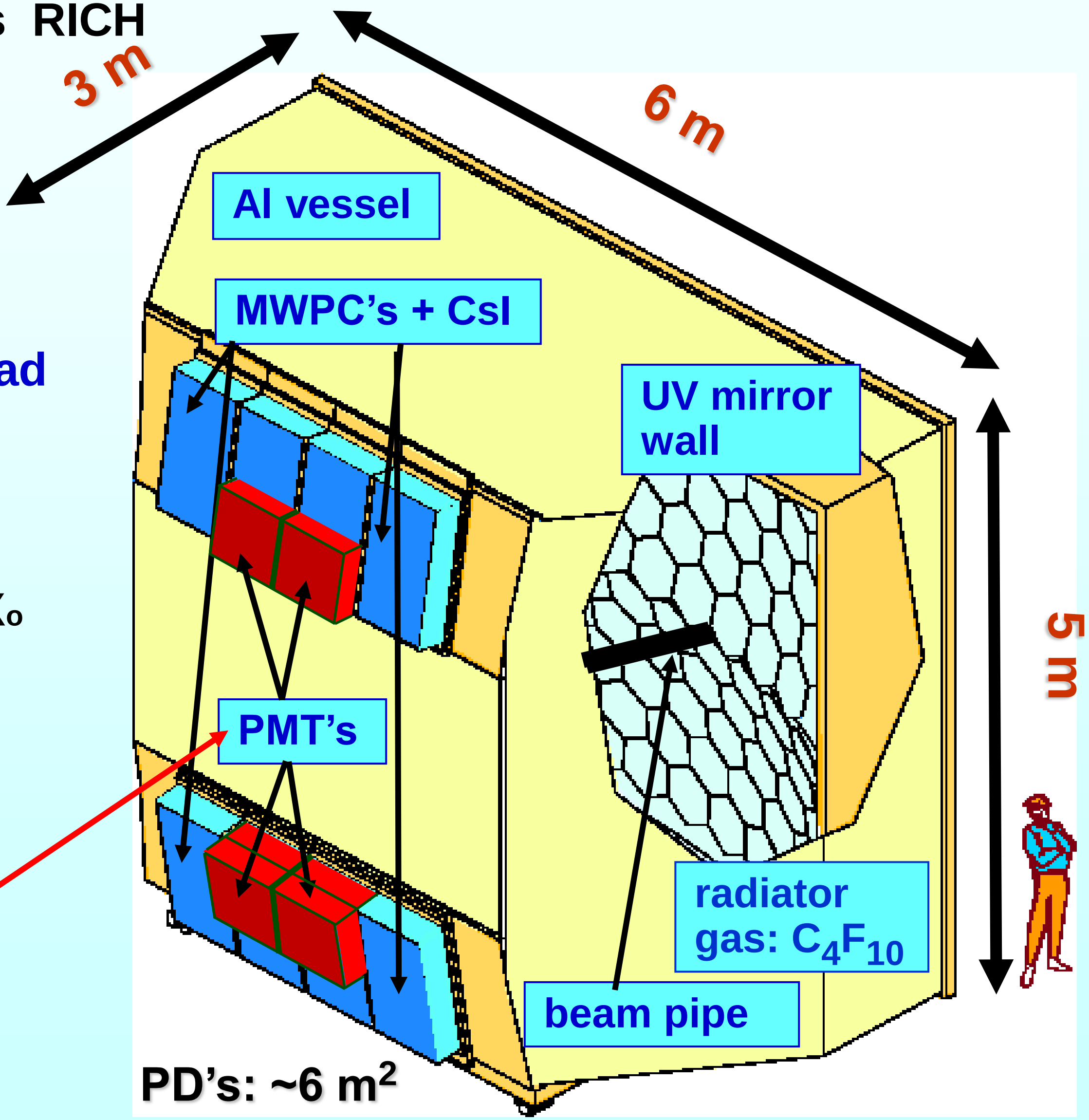
acceptance: H: 500 mrad V: 400 mrad

trigger rates: up to ~100 KHz
beam rates up to ~10^8 Hz

material in the beam region: 2.4% X_o
material in the acceptance: 22% X_o

detector designed in 1996
in operation since 2002
first PD upgrade in 2006

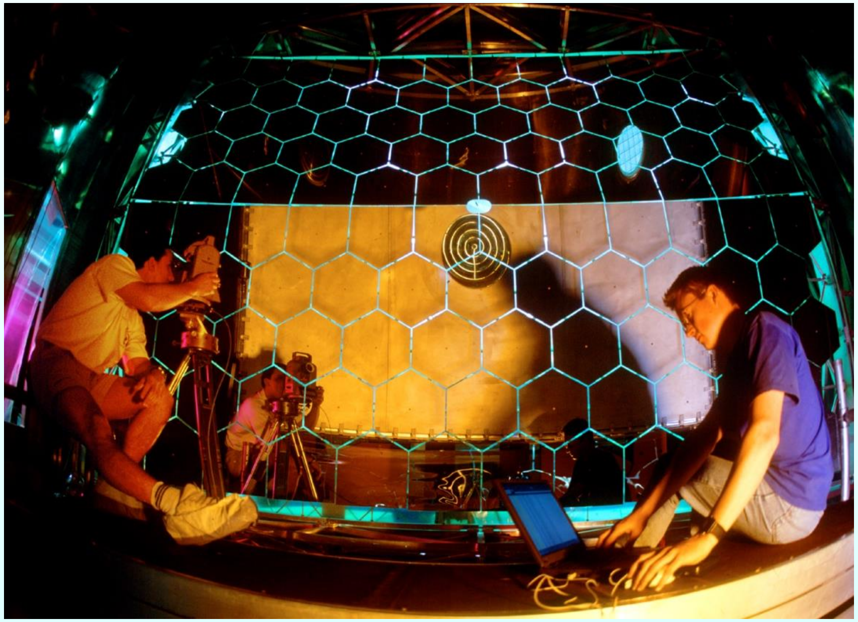
(total investment: ~ 4 M €)

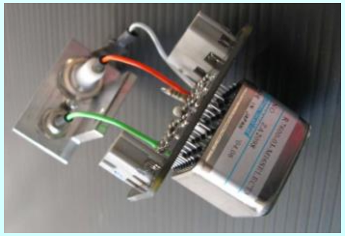


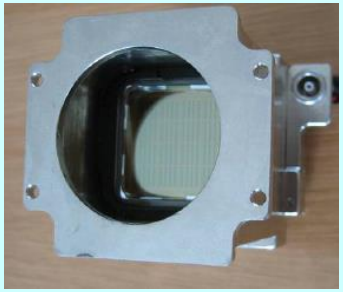
COMPASS

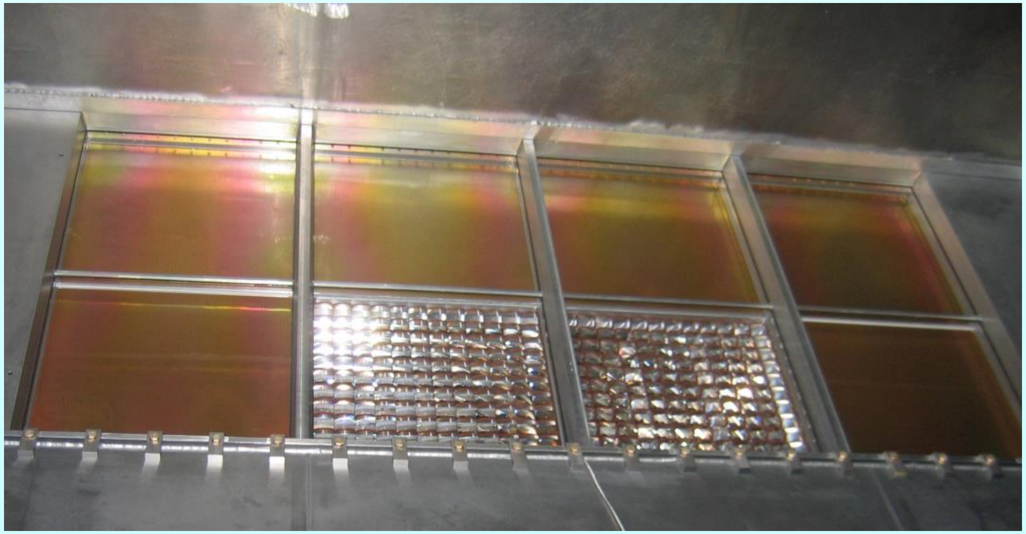
Gas radiator, mirrors, PD's

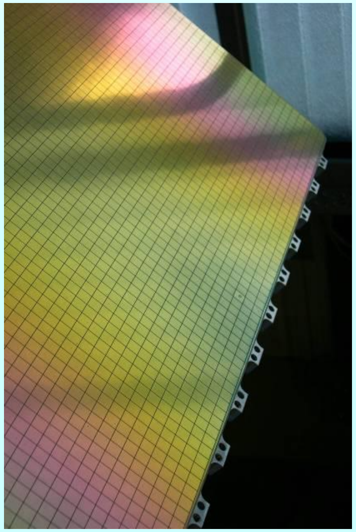
INFN
Istituto Nazionale
di Fisica Nucleare





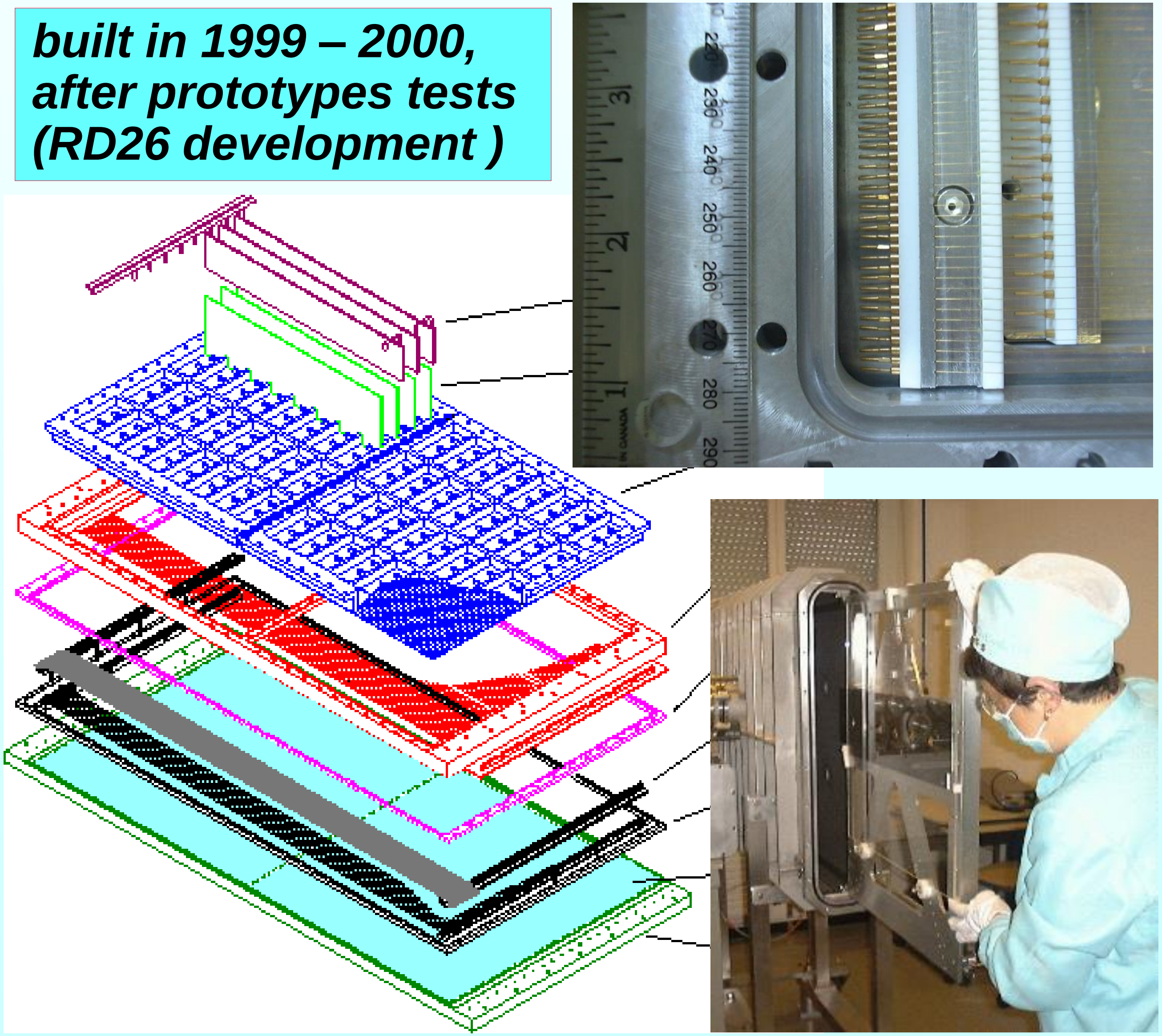




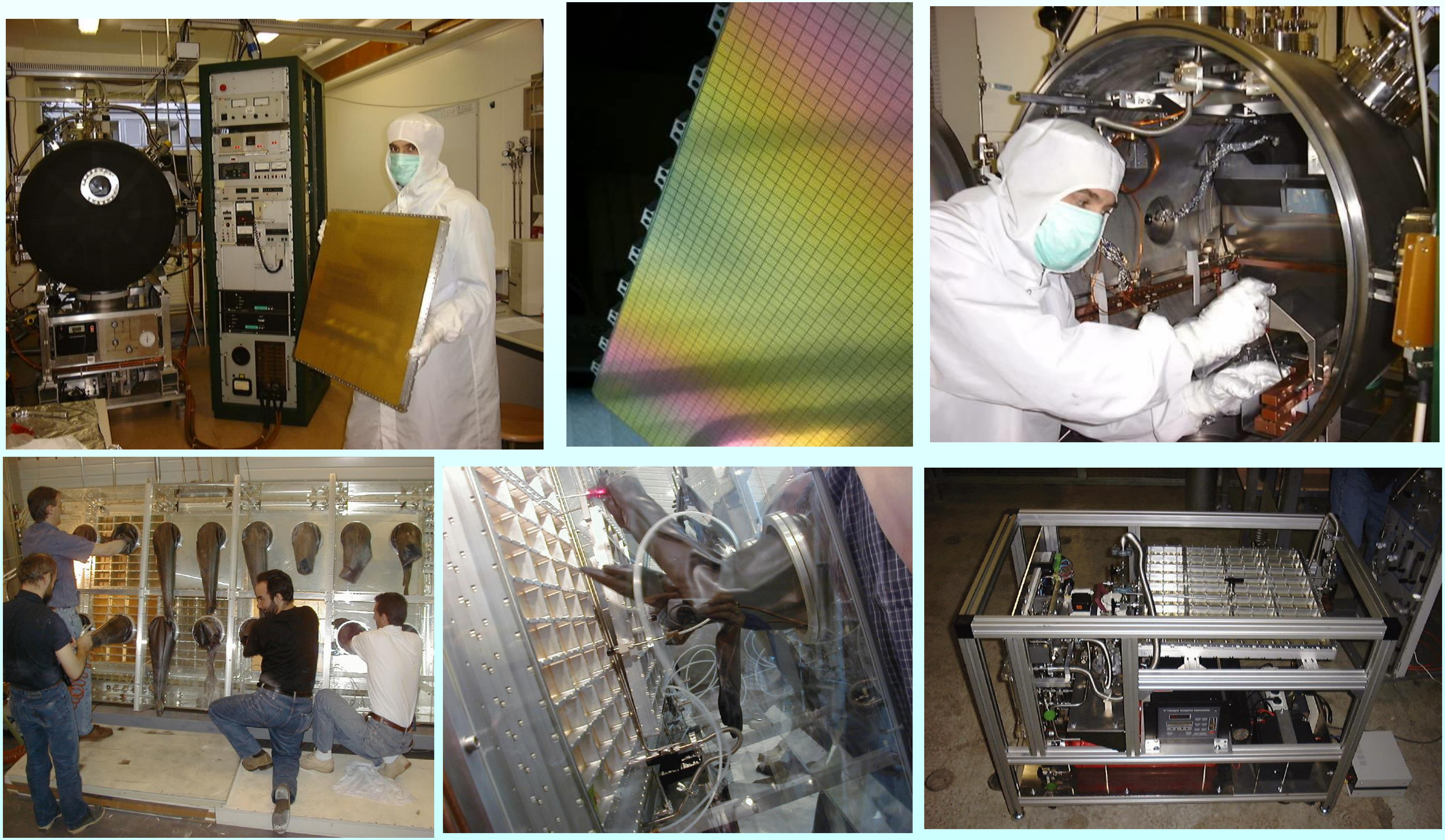


COMPASS MWPC's

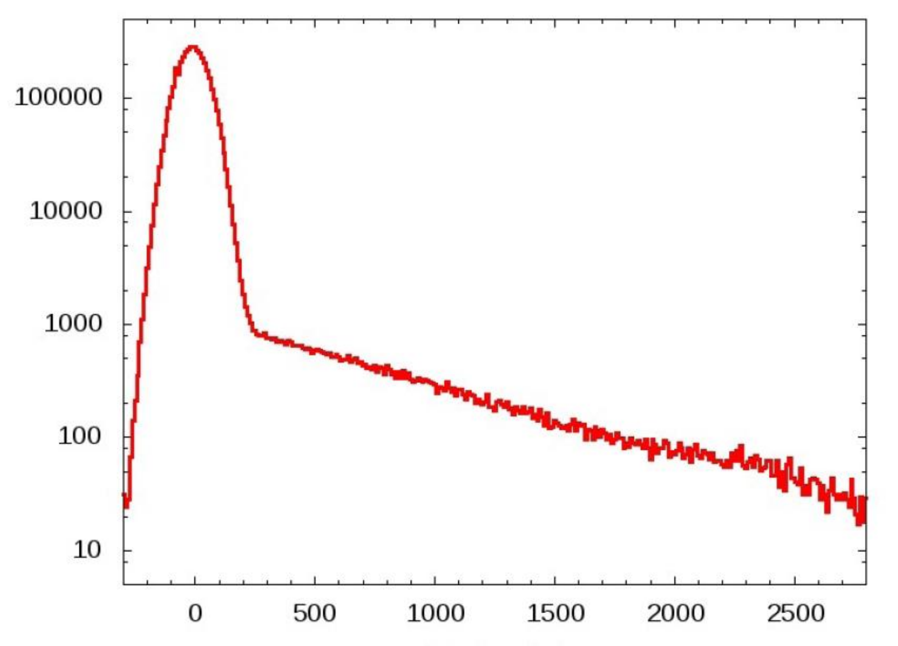
built in 1999 – 2000, after prototypes tests (RD26 development)



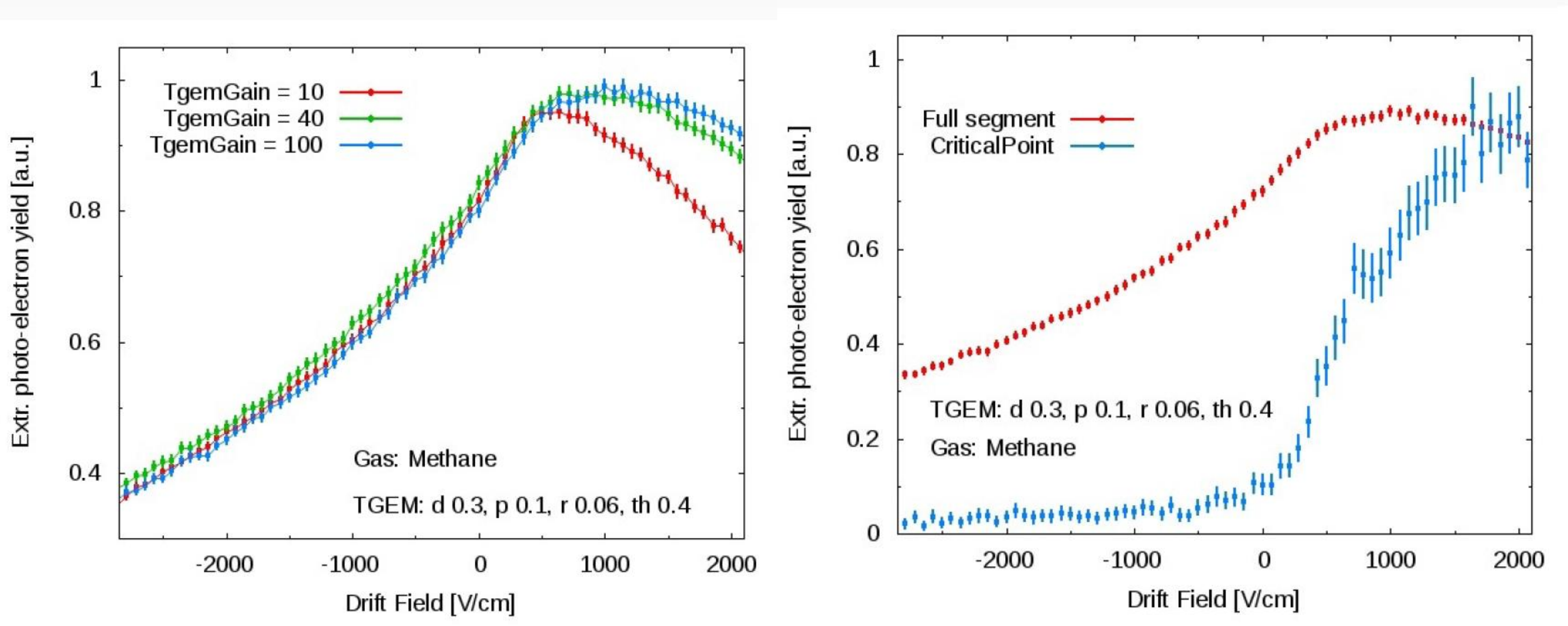
with CsI-coated photocathodes



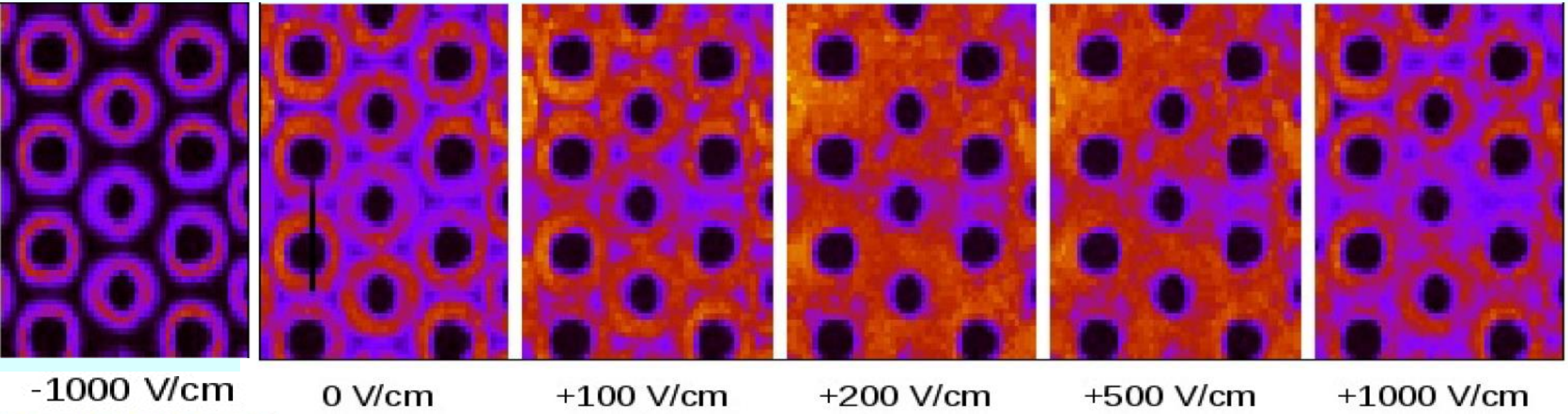
The Leopard system



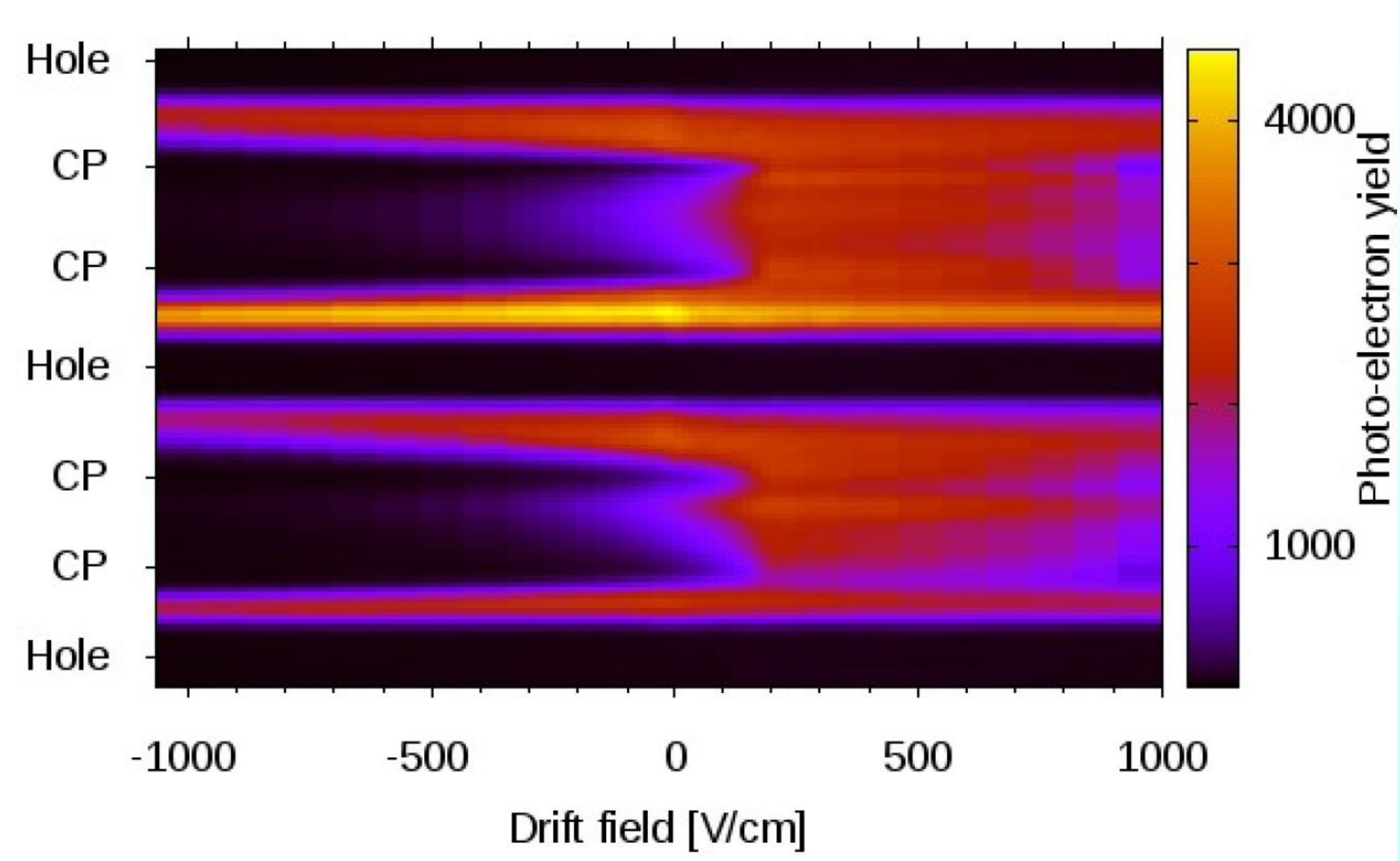
The Leopard system



The Leopard system

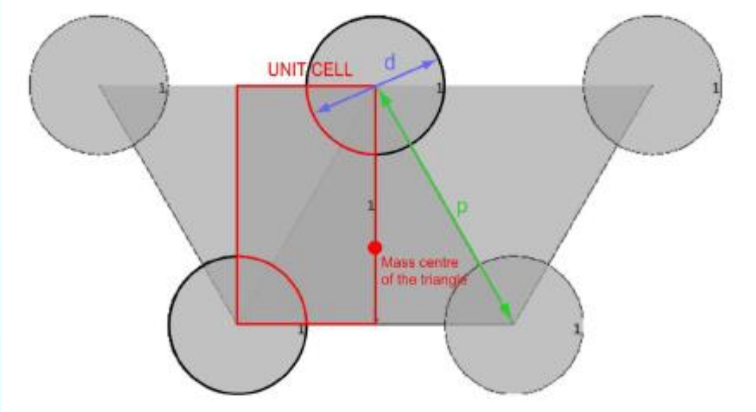


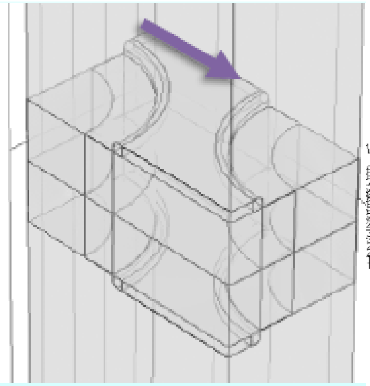
The Leopard system

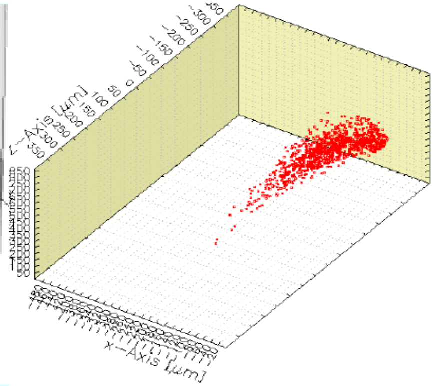


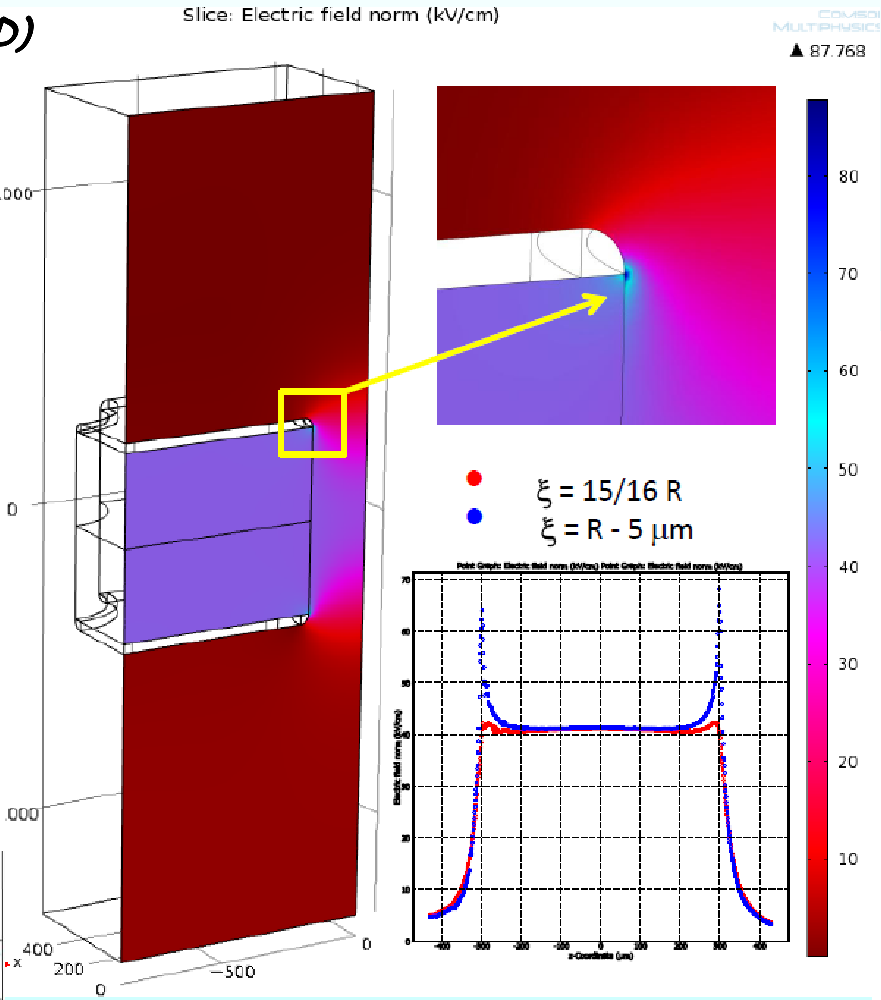
electrostatic calculations (and simulations)

COMSOL and ANSYS (and GARFIELD)

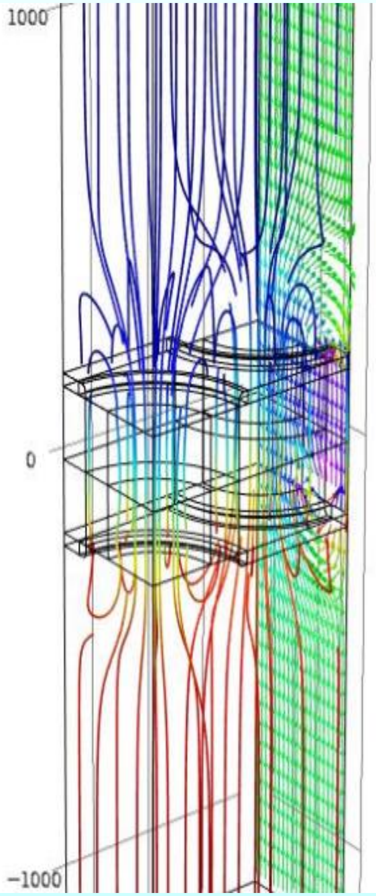


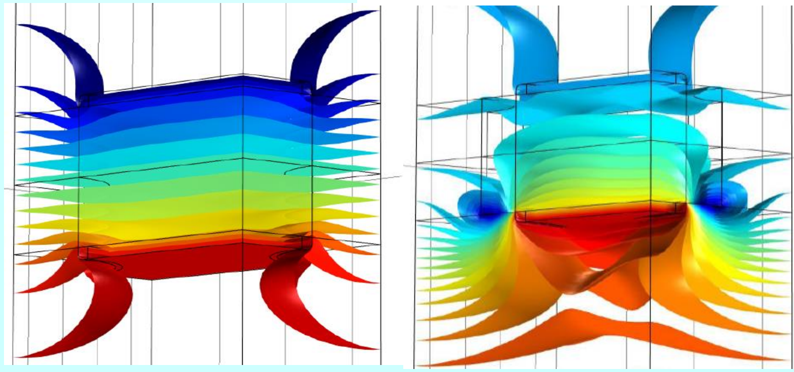






Small "reversed drift bias" provides an inversion of drift field direction: mip suppression.





equipotential surfaces are modified by the presence of a charge on the THGEM rim surface. ***See poster by P.M.M. Correia***

for GEMs, see the nice article by

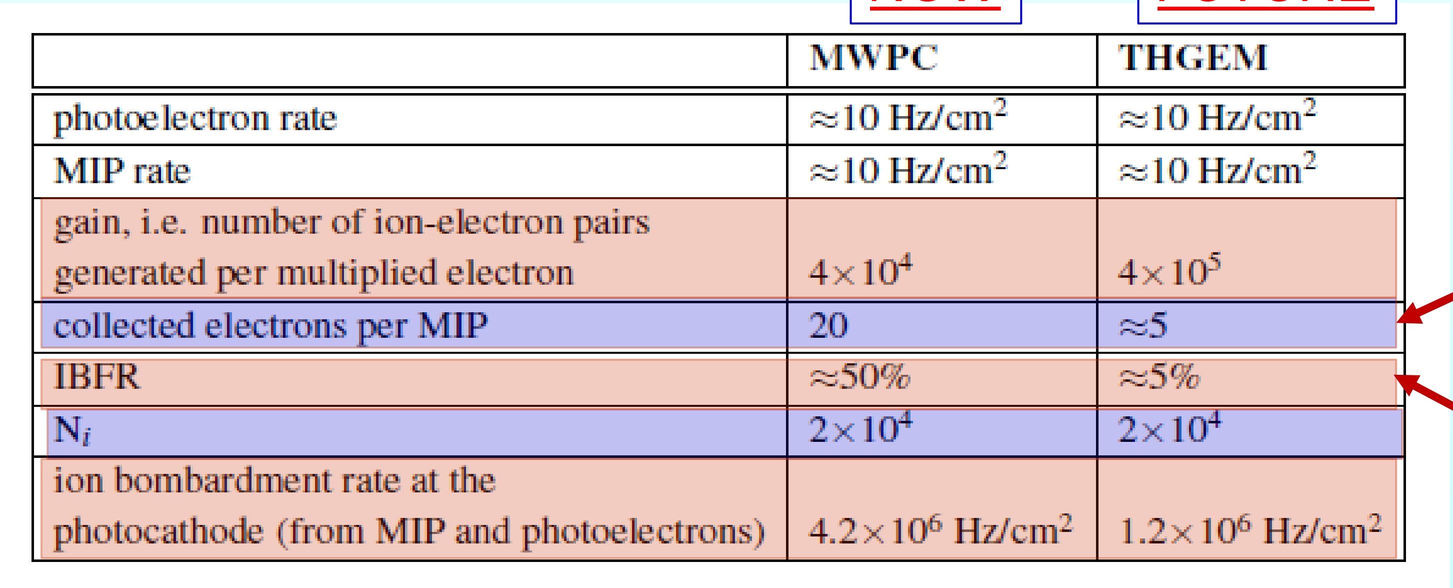
M. Alfonsi et al, NIM A 671 (2012) 6

IBF, needs and goals

in the COMPASS RICH-1 environment:

NOW

FUTURE



	MWPC	THGEM
photoelectron rate	≈ 10 Hz/cm^2	≈ 10 Hz/cm^2
MIP rate	≈ 10 Hz/cm^2	≈ 10 Hz/cm^2
gain, i.e. number of ion-electron pairs generated per multiplied electron	4×10^4	4×10^5
collected electrons per MIP	20	≈ 5
IBFR	$\approx 50\%$	$\approx 5\%$
N_i	2×10^4	2×10^4
ion bombardment rate at the photocathode (from MIP and photoelectrons)	4.2×10^6 Hz/cm^2	1.2×10^6 Hz/cm^2

Reverse Bias !!!

GOAL !!!

NOTE: we normalize to the total ionization