Recent progress in large THGEM production

On behalf of
Trieste group
and
Rui de Oliveira (CERN)

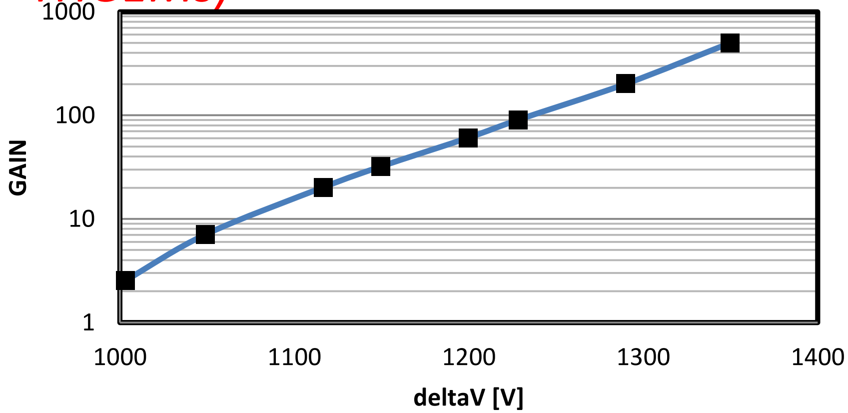
Large THGEM (300x300 mm²) performances: considerations

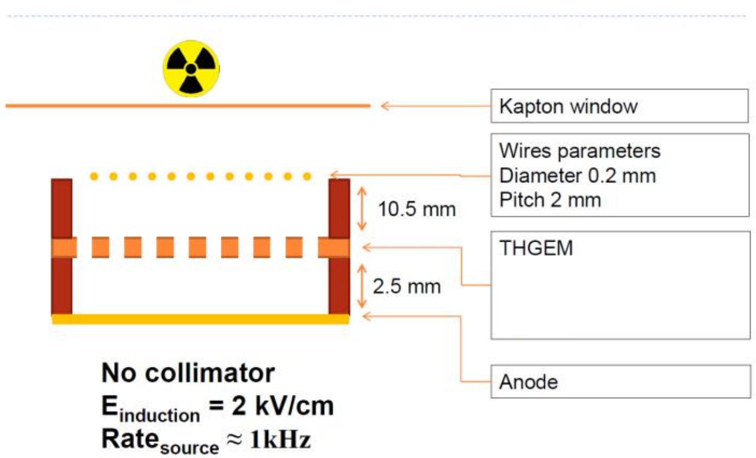
Small THGEM prototypes *30x30 mm²* have superior performances than our large prototypes:

→ *stopping point to cover large surfaces ?*

→ *Stick to one geometry 0.4 mm thickness 0.4 mm holes diameter 0.4 mm pitch*

For small prototypes max stable gain achievable with ^{55}Fe source (single THGEM) Ar/CO2 70-30 mixture ~ 1K (Pieces received from Eltos) (no rim THGEMs)





Same setup but with large prototypes

Gain ranging 20-50

(Pieces received from Eltos)

Large THGEM (300x300 mm^2) performance: Quality check

Asked help of Rui,

→ elaborated a chain of mechanical and chemical treatments + conditioning that improved the THGEM performances

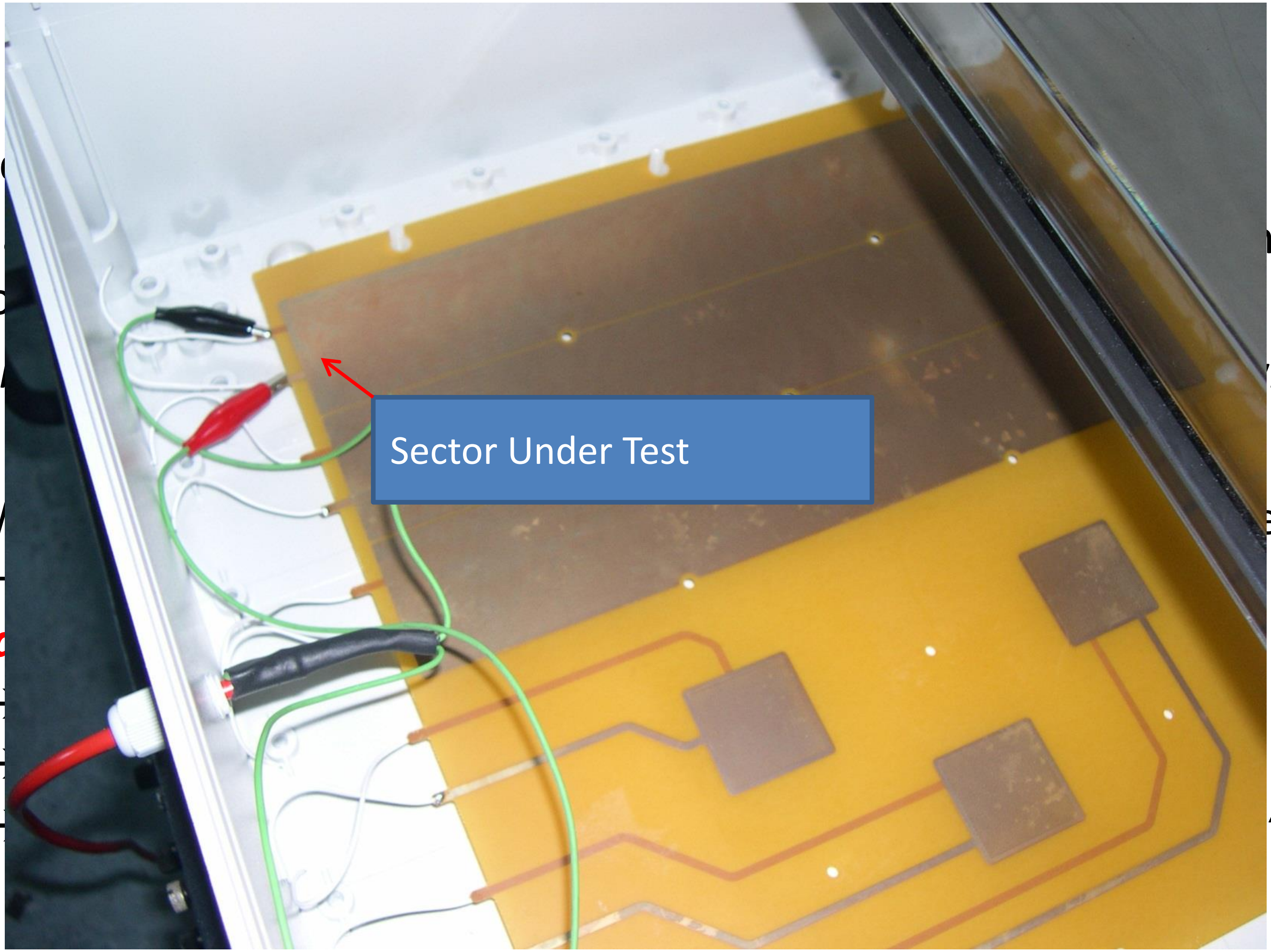
High pressure water cleaning, desmearing, etching, polishing, drying, PU coating…

how to judge on the piece quality

→ We adopted the same "reference" test used by Rui to judge the THGEM quality: discharge voltage value compared with the ***Paschen*** limit, our sequence:

- → The test is performed in air, in a dedicated box
- → Biasing of the electrode: using a CAEN N471A I_{max}=100nA
- → the maximum delta V : maximum voltage at which the sector doesn't trip for at least 30s.

Large THGEM (300x300 mm^2) performance: Quality check



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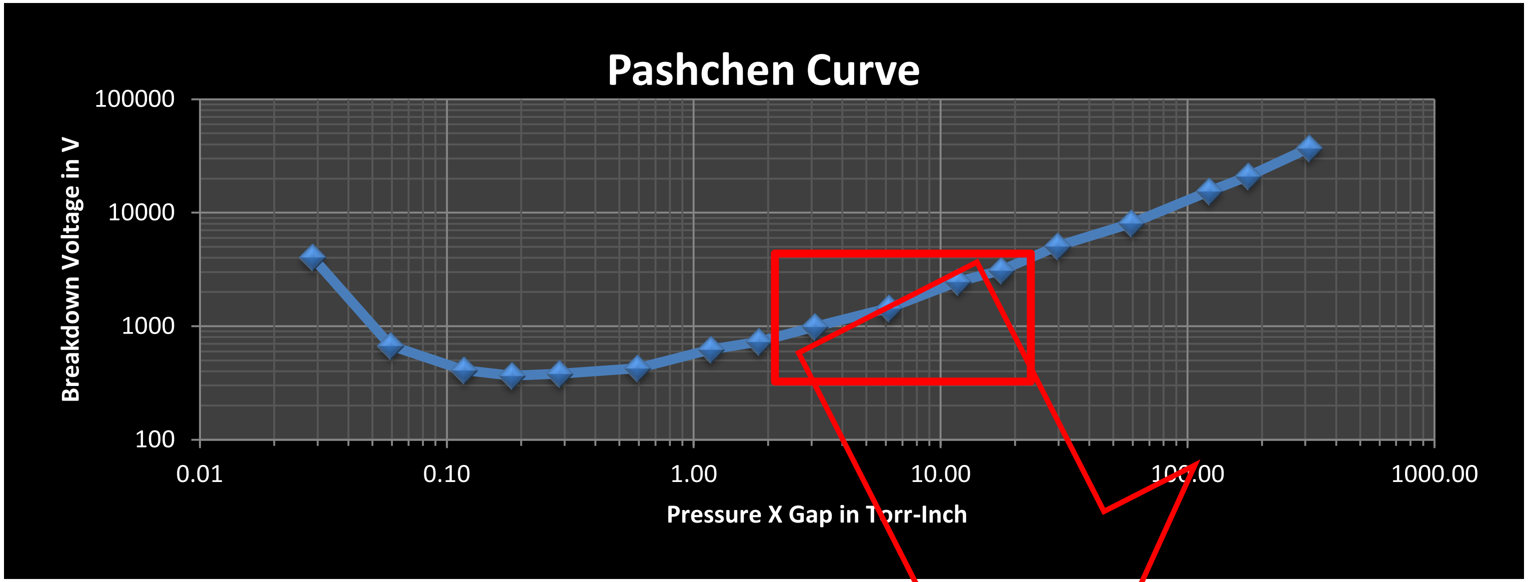
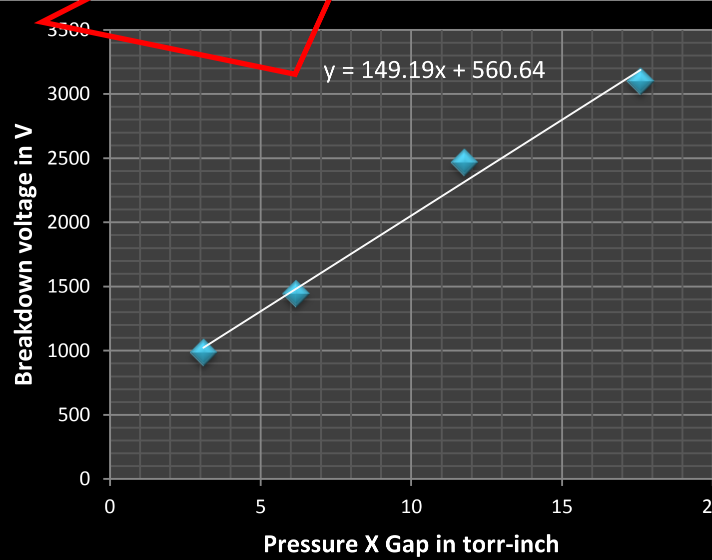
Large THGEM (300x300 mm^2) performance: Paschen



- According to Paschen relation the breakdown voltage between two electrode is given by $V = \frac{apd}{(\ln(pd)+b)}$ where p is the pressure, d is the distance between two electrodes. a and b are constants depend on the gas used. For air $a = 4.36 \times 10^7\ V/atm{-}m$, considering 101 kPa of atmospheric pressure, and $b = 12.8$. the curve shown at the side is $\boldsymbol{pd}$ **vs.** $\boldsymbol{V}$ and is called Paschen Curve. This curve has been taken from Google.
- To have the quick reference of voltage we fit the portion of the curve boxed in orange (in our case pd belongs to this range) and calculate the voltage from the fit.
- $\boldsymbol{V \sim 2268V}$



For our case pressure ~ 970mbar = 727.56torr, gap ~ 0.4mm = 0.01575m. So Pressure X Gap = 11.45 torr-inch

Large THGEM (300x300 mm^2) performance: Quality check

Paschen limit is related to thickness:

→ if it varies along one sector (see Fulvio's presentation at last miniweek): i.e. it is less than the nominal value, the Pashen voltage value is decreased : 20μm variation in thickness ~ 100 V difference !

→ New set of RAW FR4 pieces sent to ELTOS after selection from Rui's LAB: thickness variation is ~2% (± 10 μm) over 400 μm

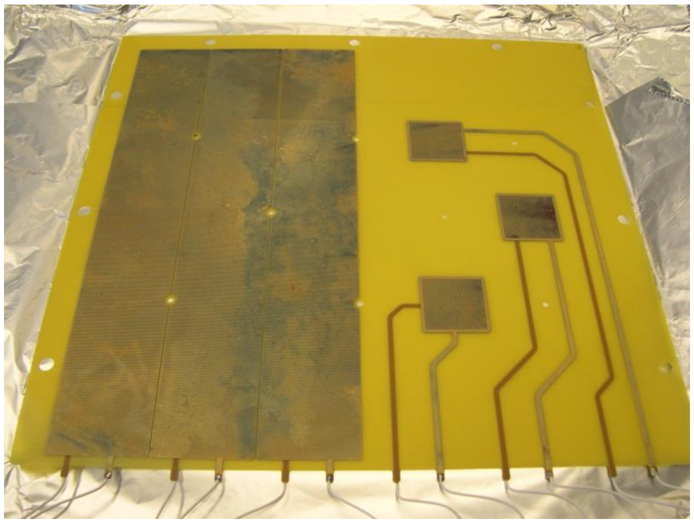
→ After production at Eltos sent to RUI for cleaning procedure but for this last batch the max standing voltage measured by Rui after his treatment resulted in 1.6kV,

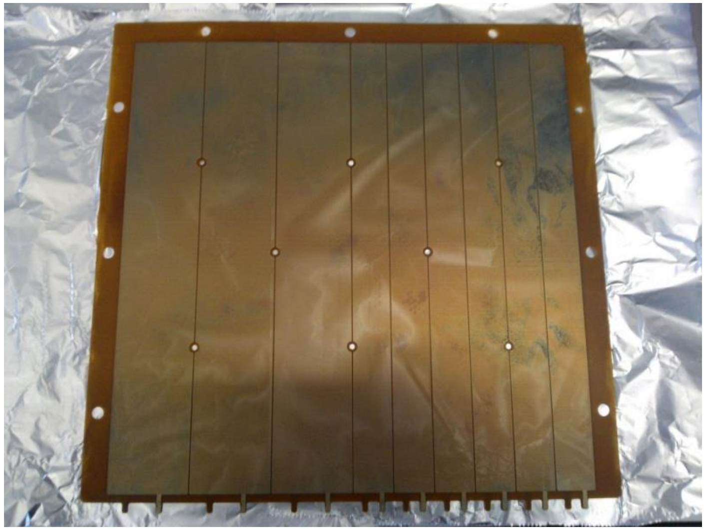
We repeated the measurement in Trieste to check the consistency of our method obtaining 1.6kV (identical result) well below the Paschen limit..

WHY?

Large THGEM (300x300 mm^2) performance: Quality check

We asked ELTOS several pieces:



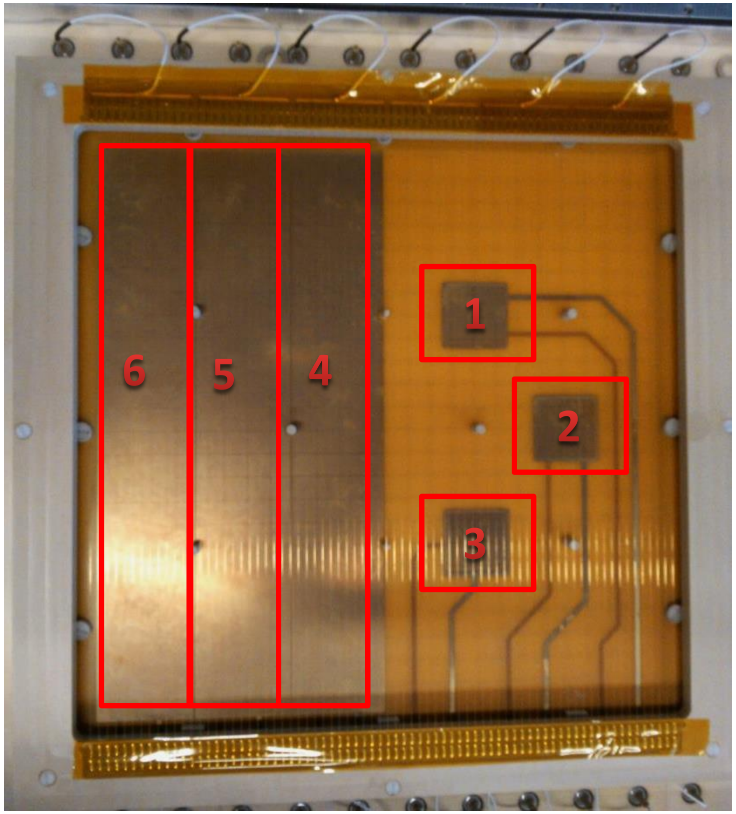


3 standard sector (50mm x300mm) of 300x300mm^2
3 standard 30x30mm^2
On ISOLA FR4 instead of Panasonic
material effect / surface effect
Reference with our small prototypes

3 standard sector of 300x300mm^2 +
6 half sectors of 300x300mm^2
On ISOLA FR4 instead of Panasonic
Material effect / surface effect

Large THGEM (300x300 mm^2) performance: Quality check

After testing with the Vmax Test -> Check the maximum gain with 55Fe source and try to correlate Vmax results (faster) with Max gain result



Just take out from the package

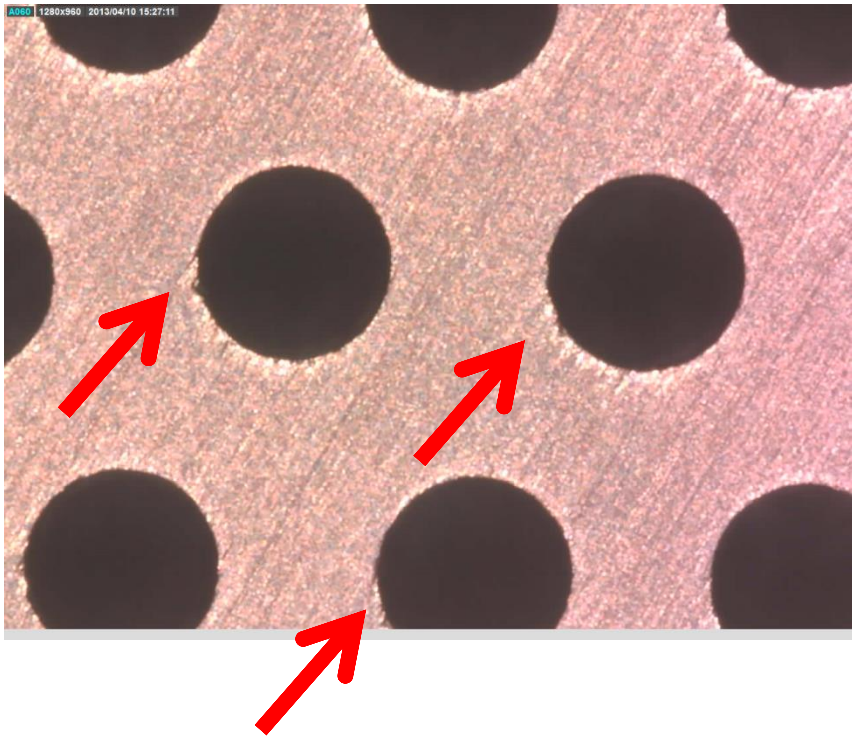
Sec 1	Sec 2	Sec 3	Sec 4	Sec 5	Sec 6
1820	**1650**	**1660**	**1630**	**1570**	**1330**

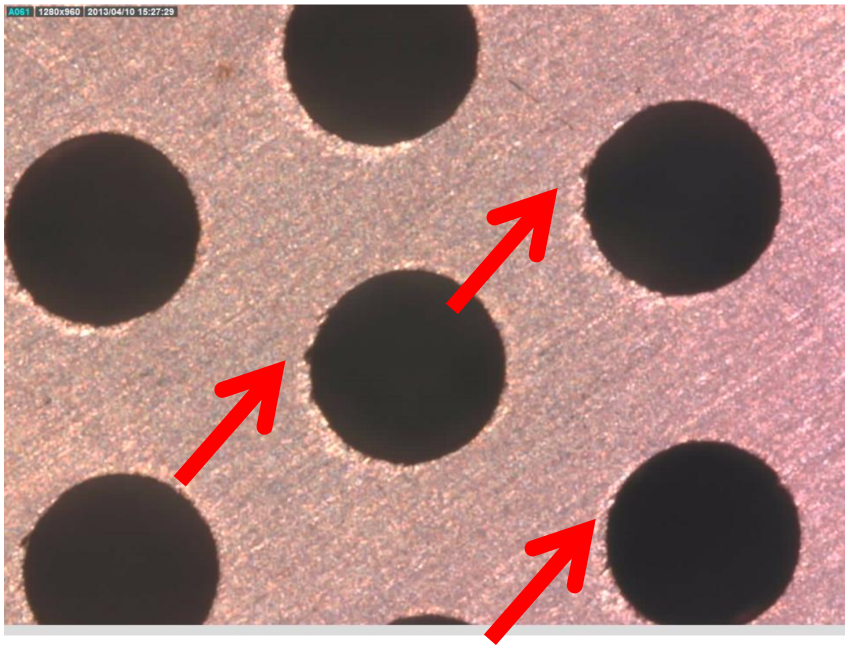
THGEM #12, Thickness = 0.4mm, ϕ = 0.4 mm, Pitch = 0.8 mm

Remider
for small 30x30 mm prototypes isola
Vmax ~ 2200-2300 V

We decided to inspect the THGEM surface

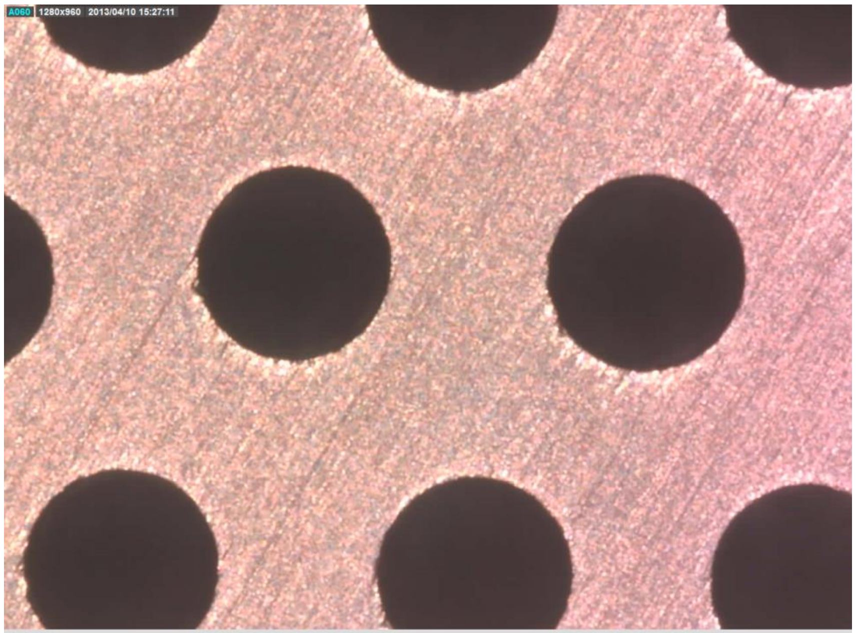
Large THGEM (300x300 mm^2) performance: Quality check

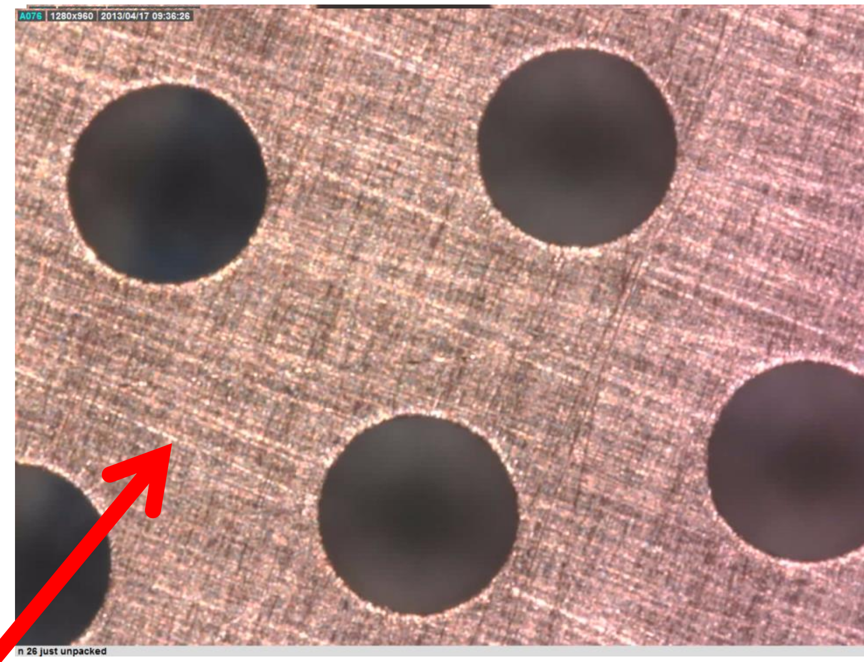




Irregularities are located on one side of the hole, irregular hole edge, correlated with brushing by Eltos (too strong ?)
These “problems” are not there for small prototypes (30mmx30mm)

Large THGEM (300x300 mm^2) performance: Quality check

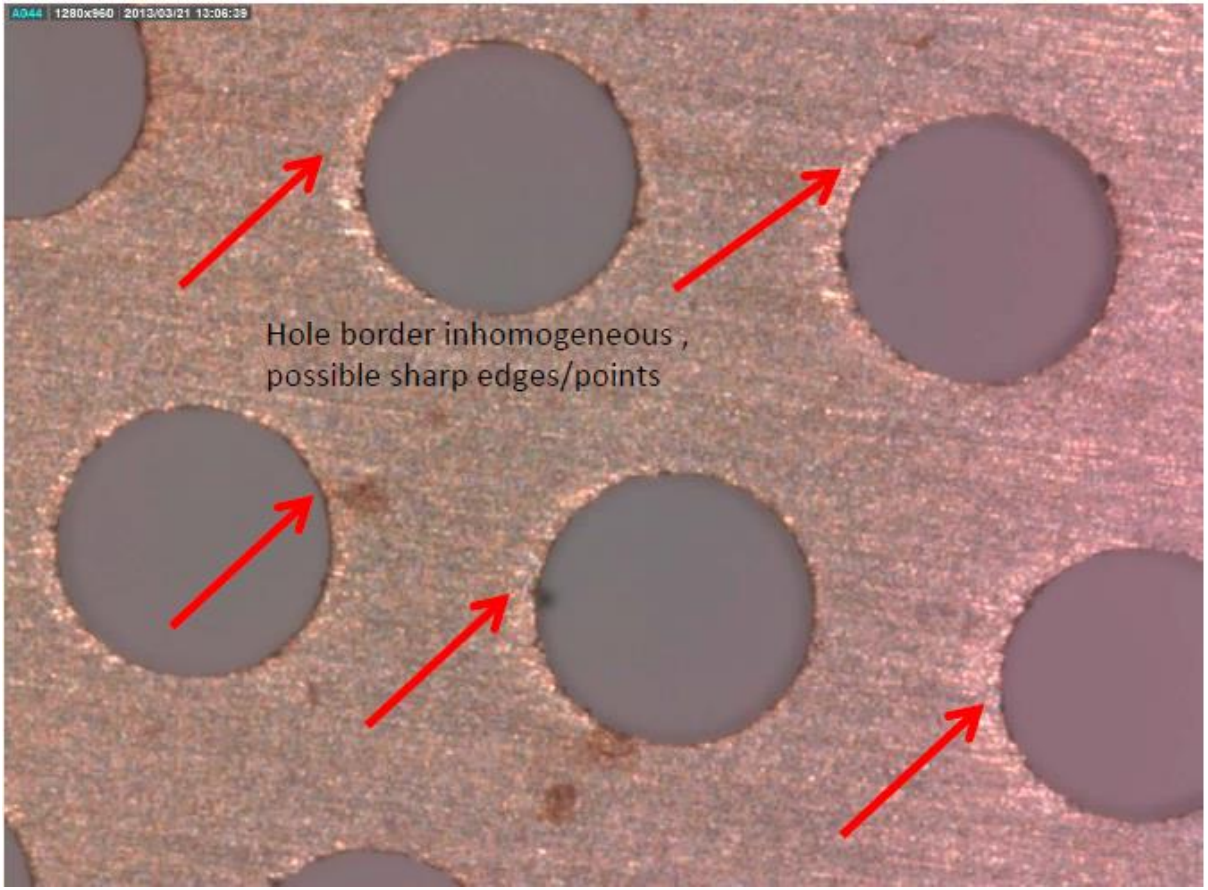




Irregularities are gone after Rui treatment but still the THGEM can not stand more than 1600 V
Can its electrical properties improved?

Taking inspiration from Rui's procedure
A similar procedure was elaborated on the simple idea
better shaped edges, better field uniformity, and no high field values for sharp edges

Large THGEM (300x300 mm^2) performance: Quality procedure

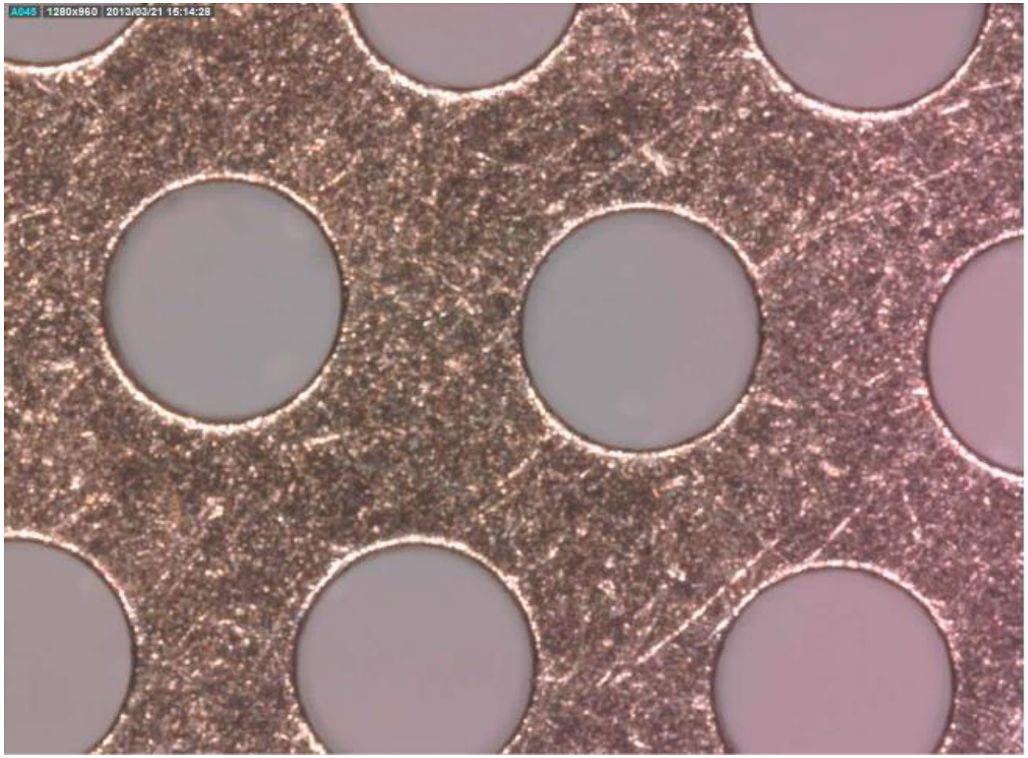


First step mechanical brushing using pumice stone plus water
3 types are used I 0-40 μm II 90-300 μm III (coarse)
Hinrichs Pumice Powder, Coarse

Large THGEM (300x300 mm^2) performance: Quality procedure

Large THGEM (300x300 mm^2) performance: Quality procedure

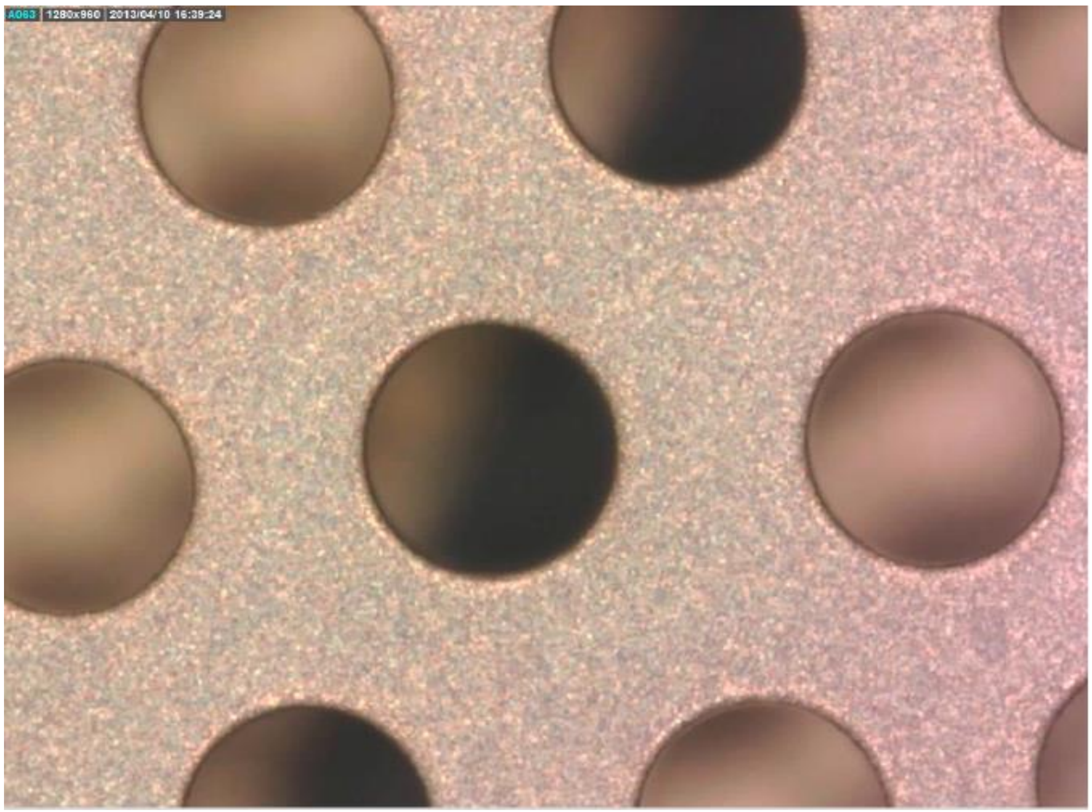
Cleaning with high pressure water to remove all pumice residuals a/o other materials,
Result after first polishing, reduced irregularities, smoothened borders, still scratches



Ultrasonic bath @ 50-60 C in Sonica pcb solution, long bath ~1h or more (check every 20 min) extremely mild chemical attack
Sonica PCB is alkaline pH11 ultrasonic cleaning solution

Large THGEM (300x300 mm^2) performance: Quality procedure

After washing with demineralized water plus oven at 180 C for 24 h



Large THGEM (300x300 mm^2) performance: Quality procedure

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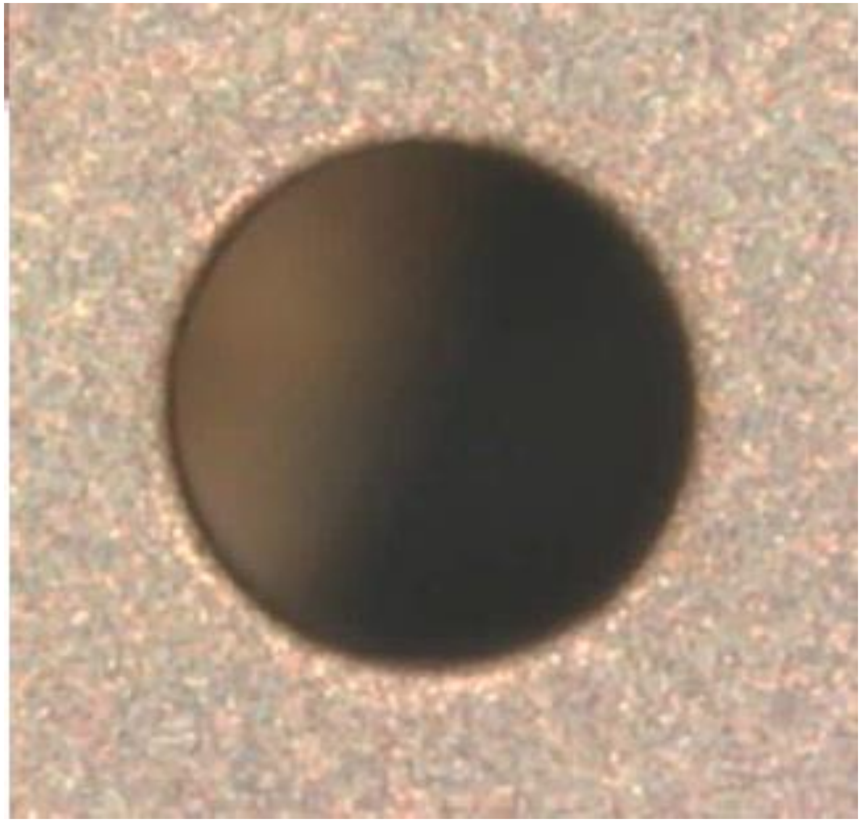
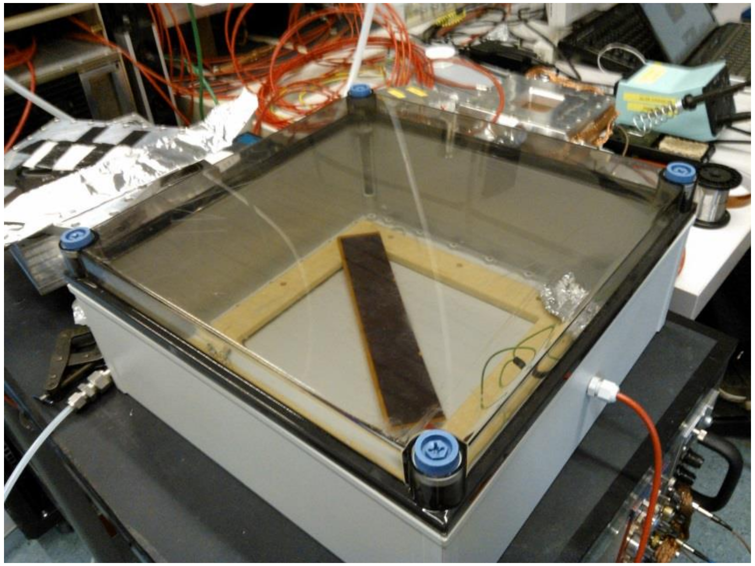


- THGEM bottom connected to ground.
- HV applied to the top face of the THGEM
- Tests done in air.
- Max ΔV defined as the highest voltage at which the sample stayed for at least 30 seconds without discharges.
- We used CAEN N471A HV Power Supply, $I_{SET} = 100nA$.
- As shown in Picture the contact via crocodile clips .



300 X 300 Single Sector #1 (before treatment)	300 X 300 Single Sector #1 (After treatment)
1390	**2180**

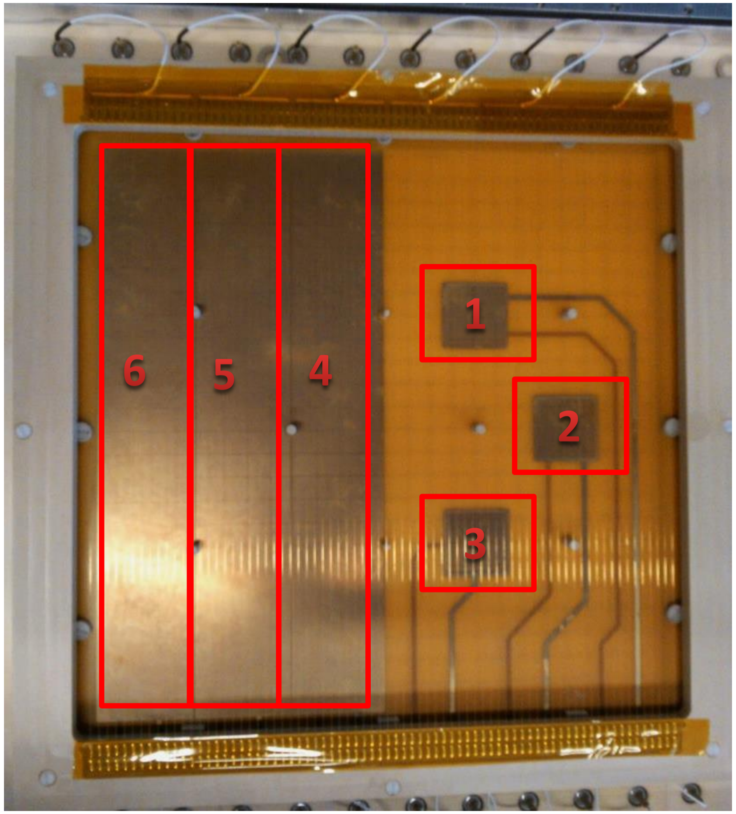
Paschen limit expected = 2190.76V

300 X 300 Single Sector #1 (before treatment)	300 X 300 Single Sector #1 (After treatment)
63	**99**

% of Calculated breakdown voltage obtained

Large THGEM (300x300 mm^2) performance: Results Vmax

For the THGEM #12, Thickness = 0.4mm, ϕ = 0.4 mm, Pitch = 0.8 mm



Just take out from the package

Sec 1	Sec 2	Sec 3	Sec 4	Sec 5	Sec 6
1820	1650	1660	1630	1570	1330

After first full Treatment

Sec 1	Sec 2	Sec 3	Sec 4	Sec 5	Sec 6
2270	2380	2370	2080	2050	1970

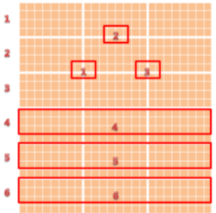
After second full Treatment

Sec 1	Sec 2	Sec 3	Sec 4	Sec 5	Sec 6
2400	2360	2300	2130	2030	2100

NO PU coating is applied here

Large THGEM (300x300 mm^2) performance: Gain max Ar/CO2 70-30%

Turn on the Chamber with 500V bottom (over 2.5 mm), 1050V top, and 3500 volt for drift (~10mm).
Rising one sector at a time keeping all the others at 1050V.
Maximum delta V as the maximum voltage where the sector doesn't trip for at least 30s.
Then we go down 100V and put the source on the sector and repeat the procedure.
At the maximum standing voltage with source we collect spectra.



Large THGEM (300x300 mm^2) performance: Gain max results Ar/CO2 70-30%

TABLE I:
Maximum ΔV scan with & without source

	A	B	C
1		1690 (1540)	
2		1810 (1610)	
3		1660 (1570)	
4	1470 (1410)	1470 (1410)	1470 (1410)
5	1510 (1490)	1510 (1500)	1510 (1500)
6	1590 (1580)	1590 (1550)	1590 (1500)

Without source
(With Source)

TABLE II:
Gain measurement @ highest ΔV of the sectors

	A	B	C
1			
2		1137	
3			
4			
5	312	335	350
6	581	474	

Large THGEM (300x300 mm^2) performance: Gain max results Ar/CO2 70-30%

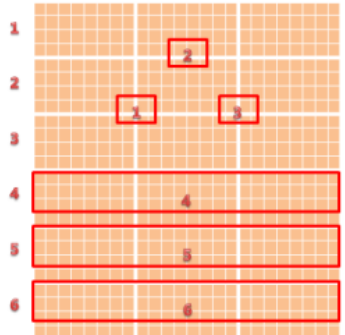
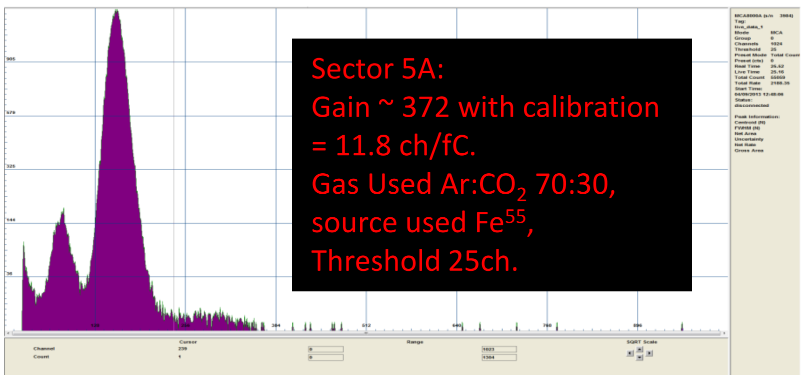
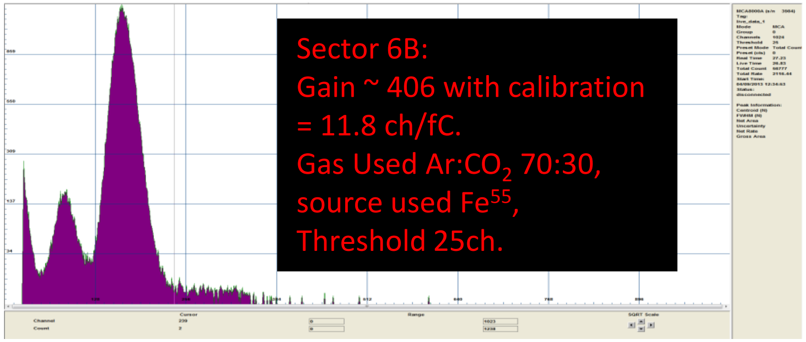


TABLE III:
Gain measurement @ highest ΔV which all sector stand

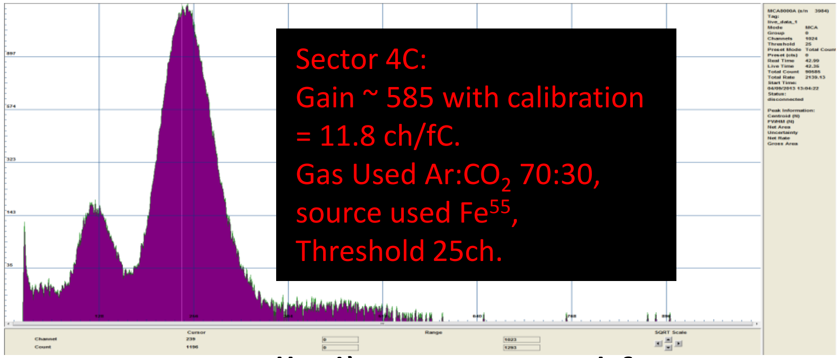
	A	B	C
1		502	
2			488
3	469		
4	516	429	585
5	372	420	428
6	423	406	402



Sector 5A:
Gain ~ 372 with calibration = 11.8 ch/fC.
Gas Used Ar:CO_2 70:30,
source used Fe^{55},
Threshold 25ch.



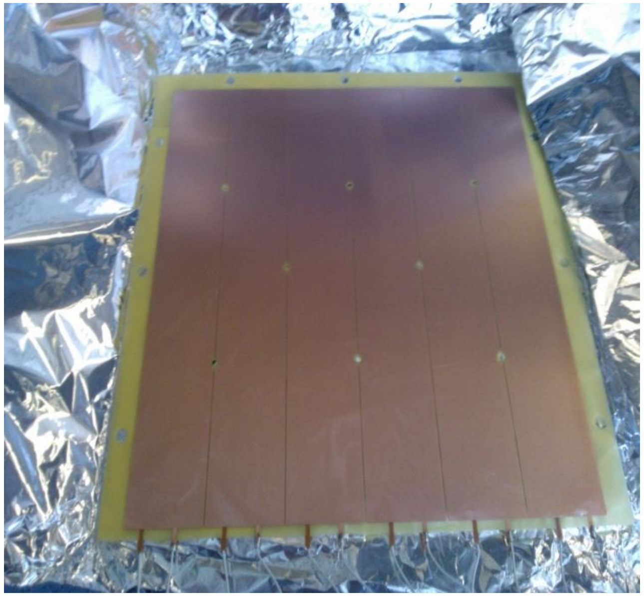
Sector 6B:
Gain ~ 406 with calibration = 11.8 ch/fC.
Gas Used Ar:CO_2 70:30,
source used Fe^{55},
Threshold 25ch.

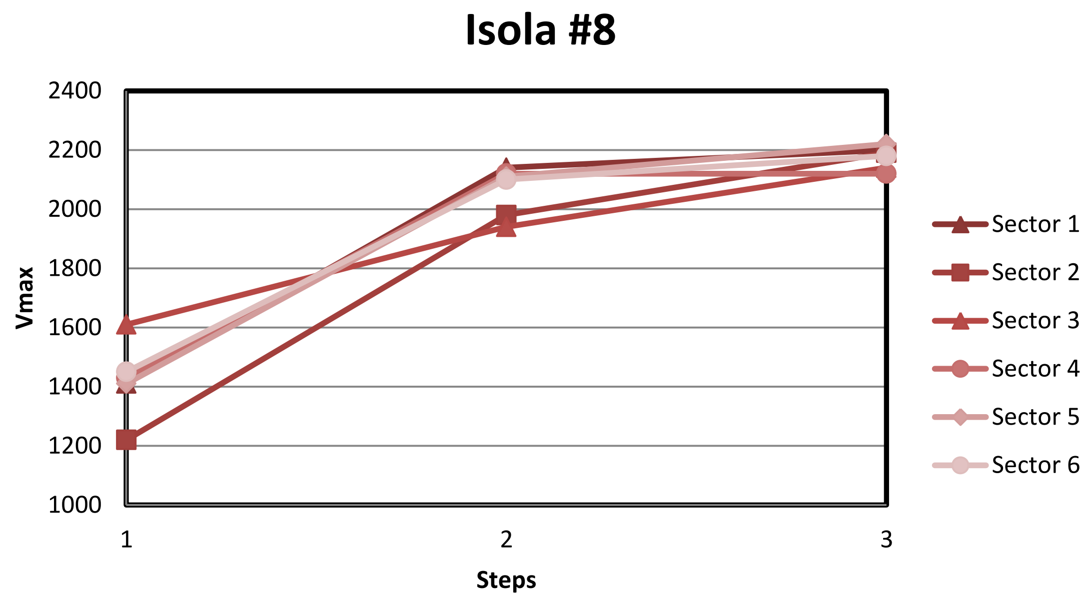


Sector 4C:
Gain ~ 585 with calibration = 11.8 ch/fC.
Gas Used Ar:CO_2 70:30,
source used Fe^{55},
Threshold 25ch.

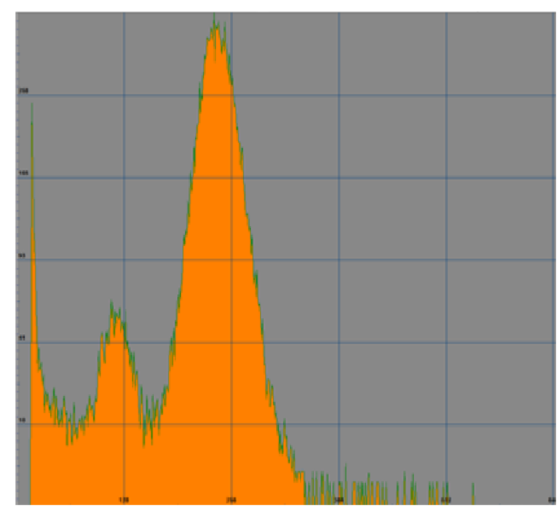
Pre-Amplifier stage Cremat CR110 (spark protection circuit installed)+Ortec Amplifier + MCA

Large THGEM (300x300 mm^2) performance: V max





Sectror 6 ΔV = 1550; EFFECTIVE GAIN = 579;



out of the box	**1410**	**1220**	**1610**	**1430**	**1410**	**1450**
After first treatment	**2140**	**1980**	**1940**	**2120**	**2110**	**2100**
After second treatment 24/4	**2200**	**2190**	**2140**	**2120**	**2220**	**2180**

Large THGEM (300x300 mm^2) Preliminary conclusion:

At first sight no difference between ISOLA and PANASONIC material concerning electrical behavior

Selection of PCB with uniform thickness → good gain uniformity

Cleaning Procedure on the tested pieces improves the electrical characteristics of the Large THGEMs, the max gain is a factor 2-3 less than the small prototypes and no longer a factor 20-30

The rounding of the hole edges: important aspect for THGEM behavior

The Delta V max tests in air shows a discrete correlation with Gain max results

No PU coating has been applied yet, there is maybe still room for improvement for the large prototypes

Thanks!