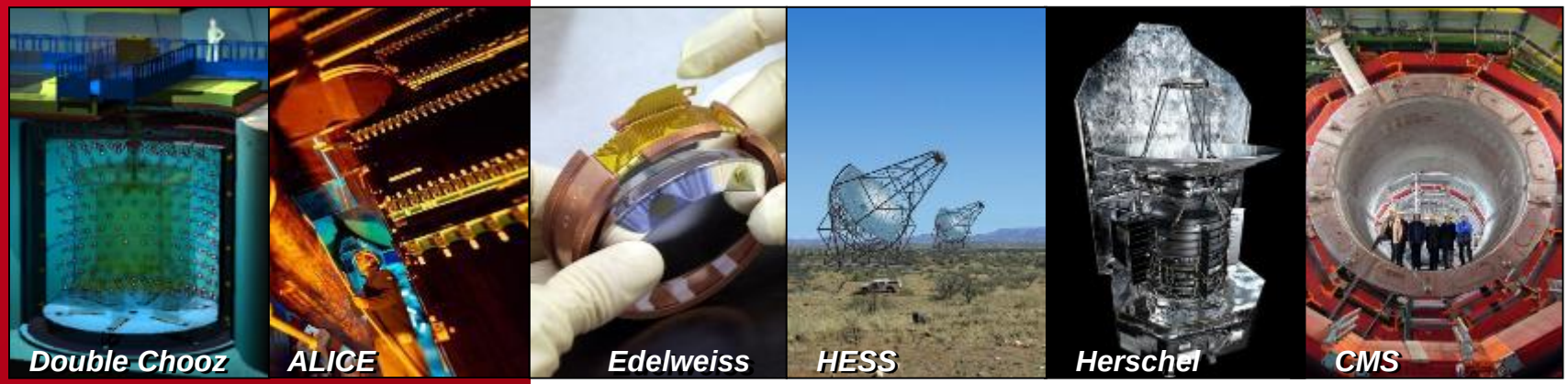
DE LA RECHERCHE À L'INDUSTRIE

RD51 Collaboration meeting

Laser ablation technics for Micromegas : laser zigzag readout and laser mesh



Déchiffrer les rayons de l'Univers

S. Aune for the MPGD4EIC collaboration

22/10/19

CONTEXT OF THIS ZIGZAG SITUATION

The idea of laser ablation for zigzag pattern is brought by **Alexander Kiselev** from Brookhaven National Laboratory (BNL).

In June 2017 at MPGD 2017 meeting we meet Alexander and decide to try for a LDRD funding (~10 pages of proposal) focused on zigzag pattern for future Electron-Ion Collider (EIC) tracker with the knowhow from:

- BNL (GEM, zigzag),
- Saclay IRFU (micromegas, bulk, clas12 tracker)
- Stony Brook University (GEM, sPhenix TPC)

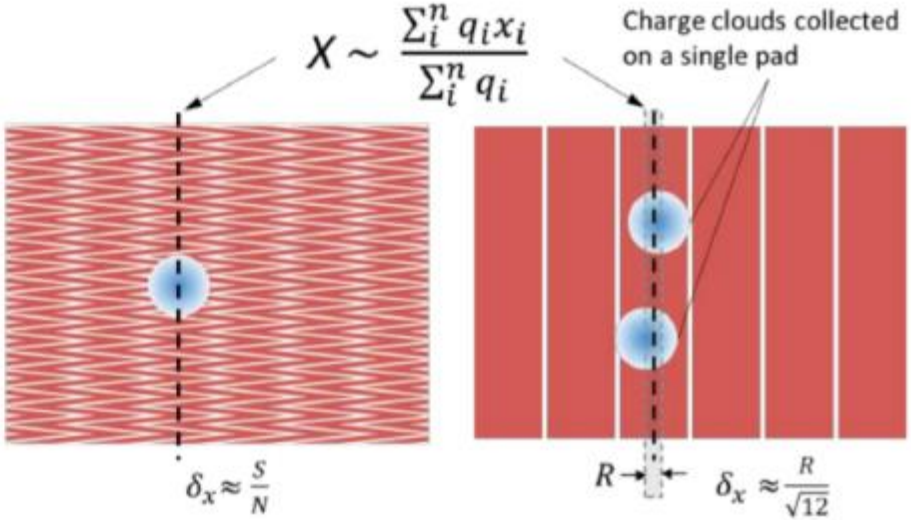
In October 2017: LDRD "MPGD-4-IEC" is selected ☺

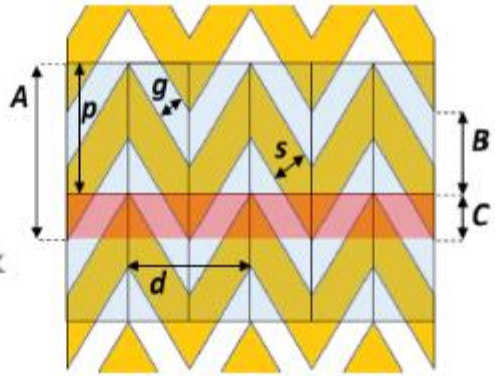
1.2 M$ is obtain on 3 years (FY18-FY20)

ZIGZAG STRIP VS STRAIT STRIP

- Minimal number of instrumented channels without loss of performance (spatial resolution)
- Resolution limit: single-strip/ pad cluster
- Zigzag pattern: avoid single-strip cluster and increase the charge sharing with the same pitch as rectangular strips
- Geometry parameters can be tuned to have a optimal performance: best resolution & linear response

IEEE 2018, Bob Azmoun





Legend
p: pad pitch
d: zigzag period
s: trace width
g: gap width
A: full pad width
B: region with no overlap of neighboring pads
C: region where neighboring pads overlap

NEEDS OF THIN INTER STRIP AREA

The idea is to decrease the seize of gap between strips on a MPGD readout, in order to have zigzag patterns with copper…

- Actual inter gap by chemical process:
  - ~70 µm to ~120 µm (depends on: surface, cost, manufacturer)
- Could we by laser ablation of copper lower this gap ?

- The need of high density pattern is to have zigzag pattern in order for a **same spatial resolution** the **lower the number of strip** (elec. channels)

First try at Elvia PCB manufacturer

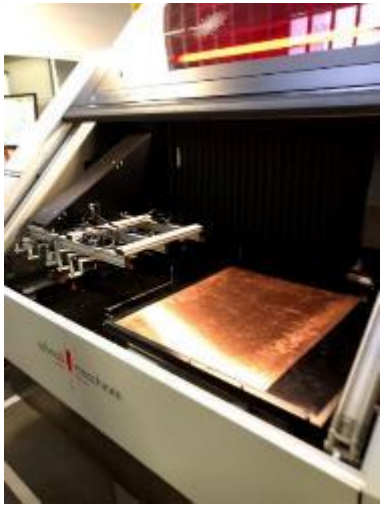
In October 2017 we go two days at Elvia to try laser ablation of thin copper (9 µm) PCB.

Elvia possess a UV laser machine used to cut thin PCB and to make thin via.

R&D on site is possible thanks to close relation with them.

R&D AT ELVIA (10/18 AND 02/19)

- We laser etched many ZZ patterns into sample substrates (50um FR4 with 5um Cu), and varied a number of parameters like the laser power, the number of passes of the laser over the pattern, etc.
- Laser can generate pattern on an area of about 500mm x 600mm
- Surprisingly it only takes a few minutes (depending on the number of passes) to generate a ZZ pattern on a ~10cm x ~10cm area
- We made our gap width equal to the laser profile, but needed to make several (4-8) passes to fully cut through the copper (the precision of the XY translation is at the level of a few um so that the laser retraces over its path very accurately

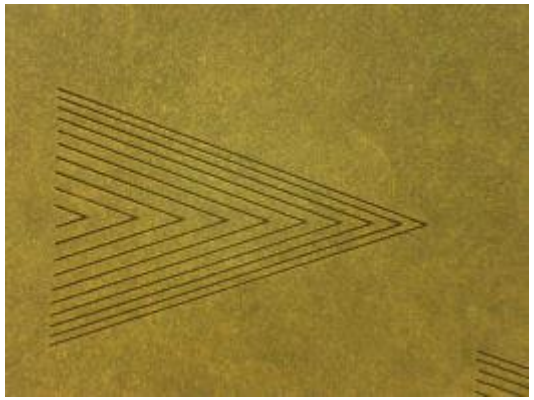


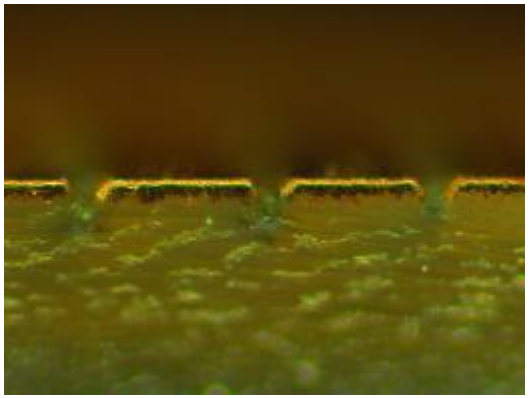
First try at Elvia 2

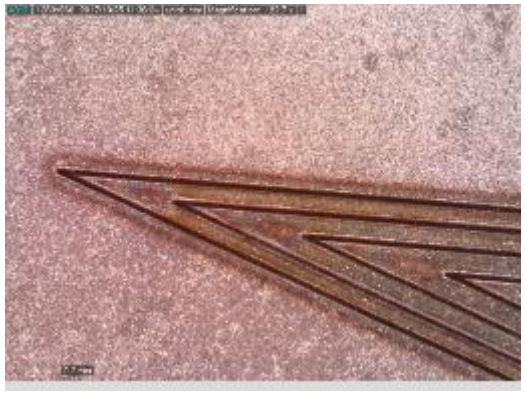
With Picoflex laser several parameter are tested:

- UV power (1 W to 20 W) we take ~5 W
- Number of path on same pattern: ~ 8 loops
- Recovery on close angle stips
- Diameter of laser is ~ 25 µm (fixed)
- We try different pattern (~10) to have an idea of possibilities.

IT work ! After tuning we obtain ~25 µm gap







LASER ABLATION ON RD3 READOUT FOR FNAL TEST

A first beam test for spatial resolution on Bulk and GEM detector is done in Marsh 2018 at Fermilab test beam

The 10x10 cm² active area is divided in 100 zigzag different patterns. (change in pitch and density on zigzag)

BNL try to have laser ablation at TTM in the US, very difficult to obtain good results with a collaboration based only on quotation with few (~no) information exchanges: all board are made at Elvia.

~ 8 boards are done: 4 micromegas and 4 GEM are done = a fully MPGD beam test ☺

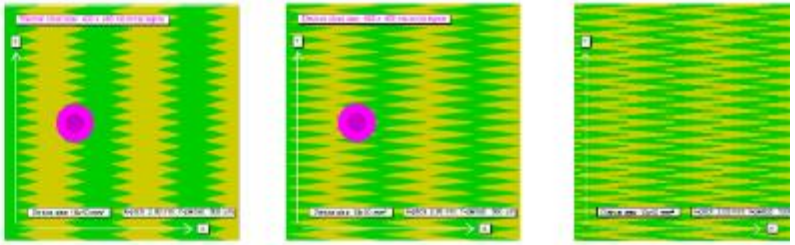
TYPE DE PARAMÈTRES ZIGZAG

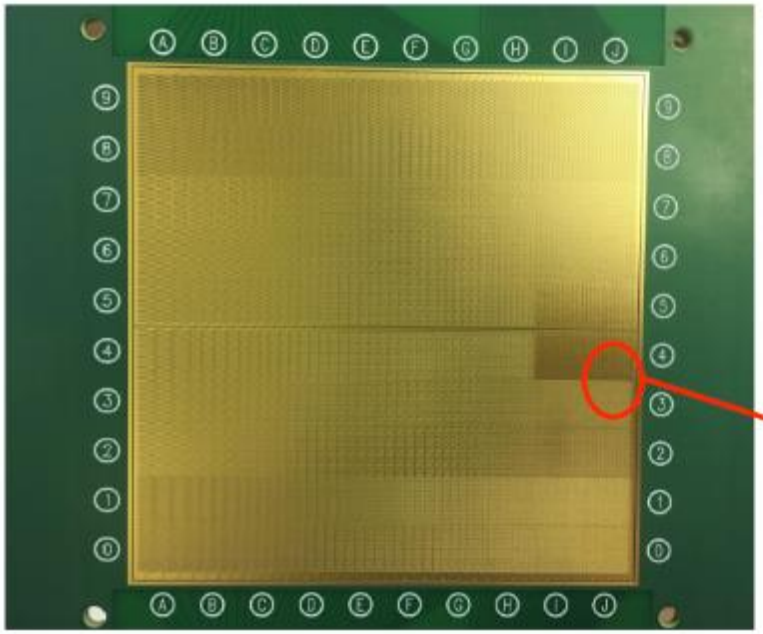
- Tuning zigzag geometry parameters:
  - Pitch p (same for rectangular strip)
  - Period d
  - Gap g
  - Stretch (L/P-1)x100%

=0: 100% overlap
>0: over-stretch
<0: under-stretch

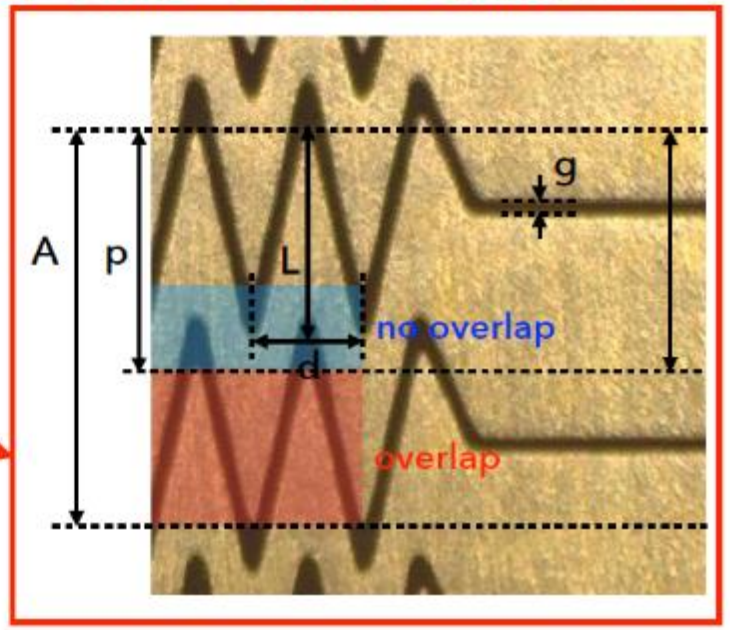
Simulation

Under-stretched | Stretch=0 | Over-stretched



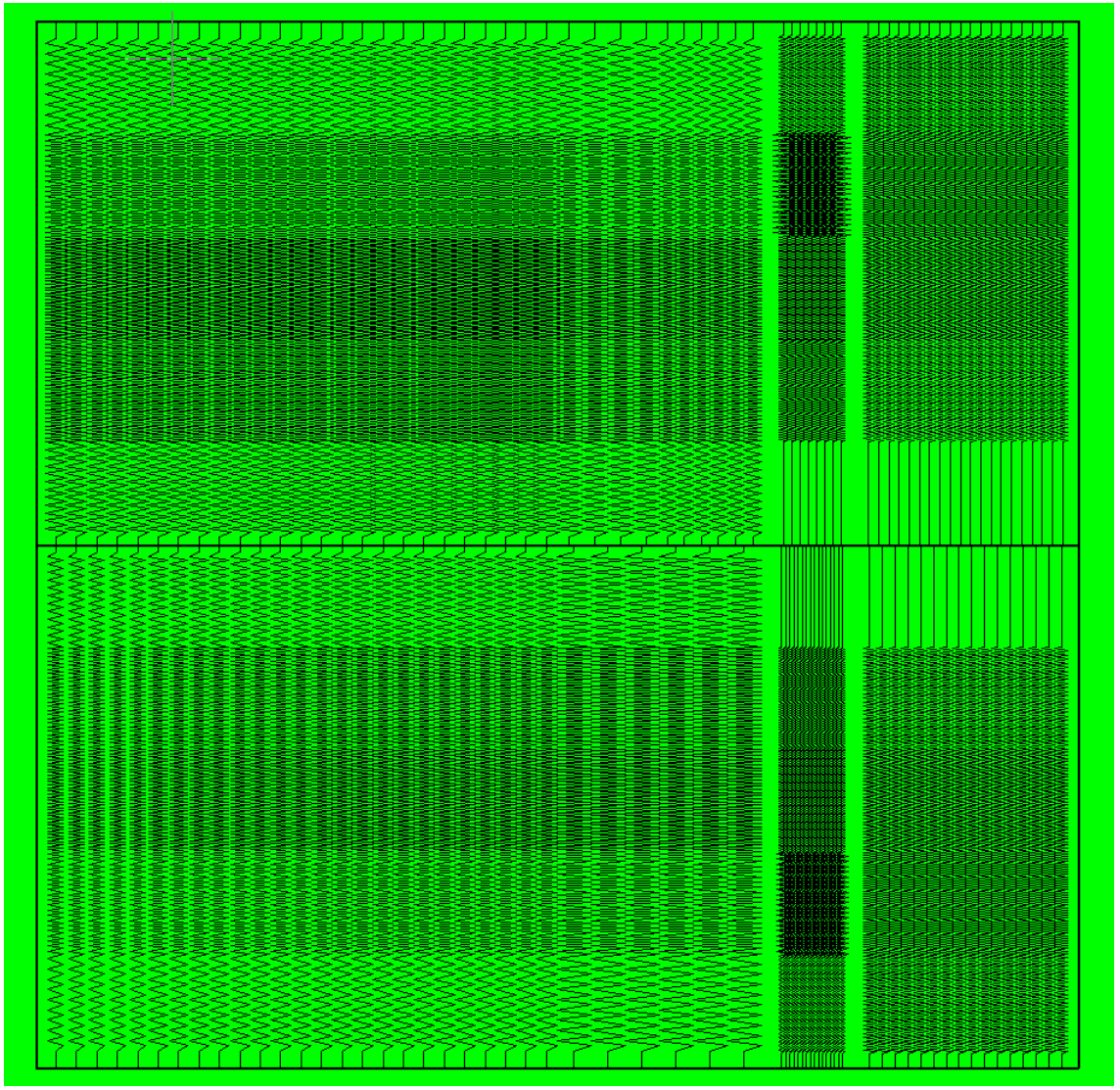


E.g. p=2mm, d=500µm, g=75µm, stretch = -10%



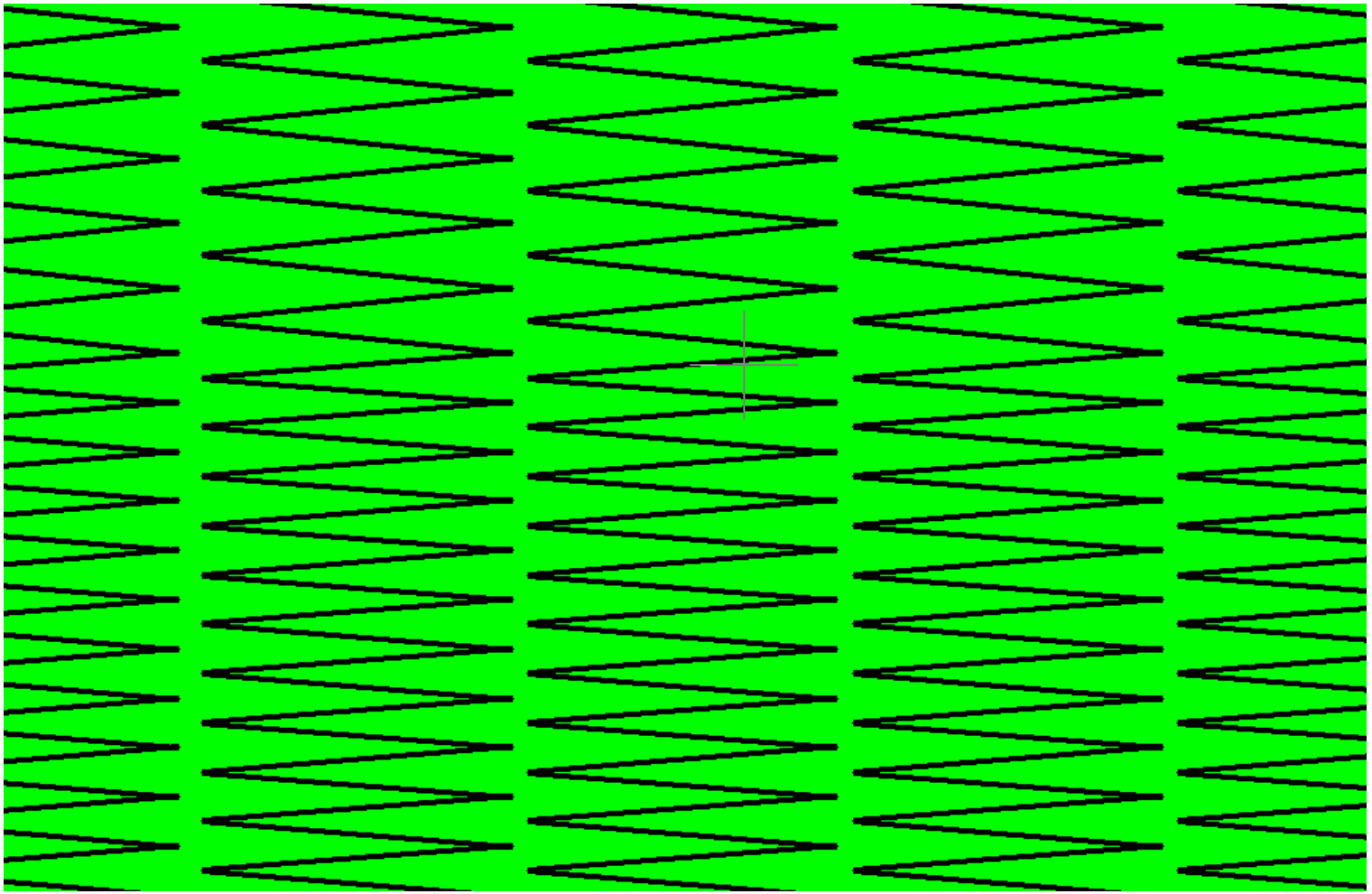
RD3 ZIGZAG FOR FNAL18 TEST

RD3 active area



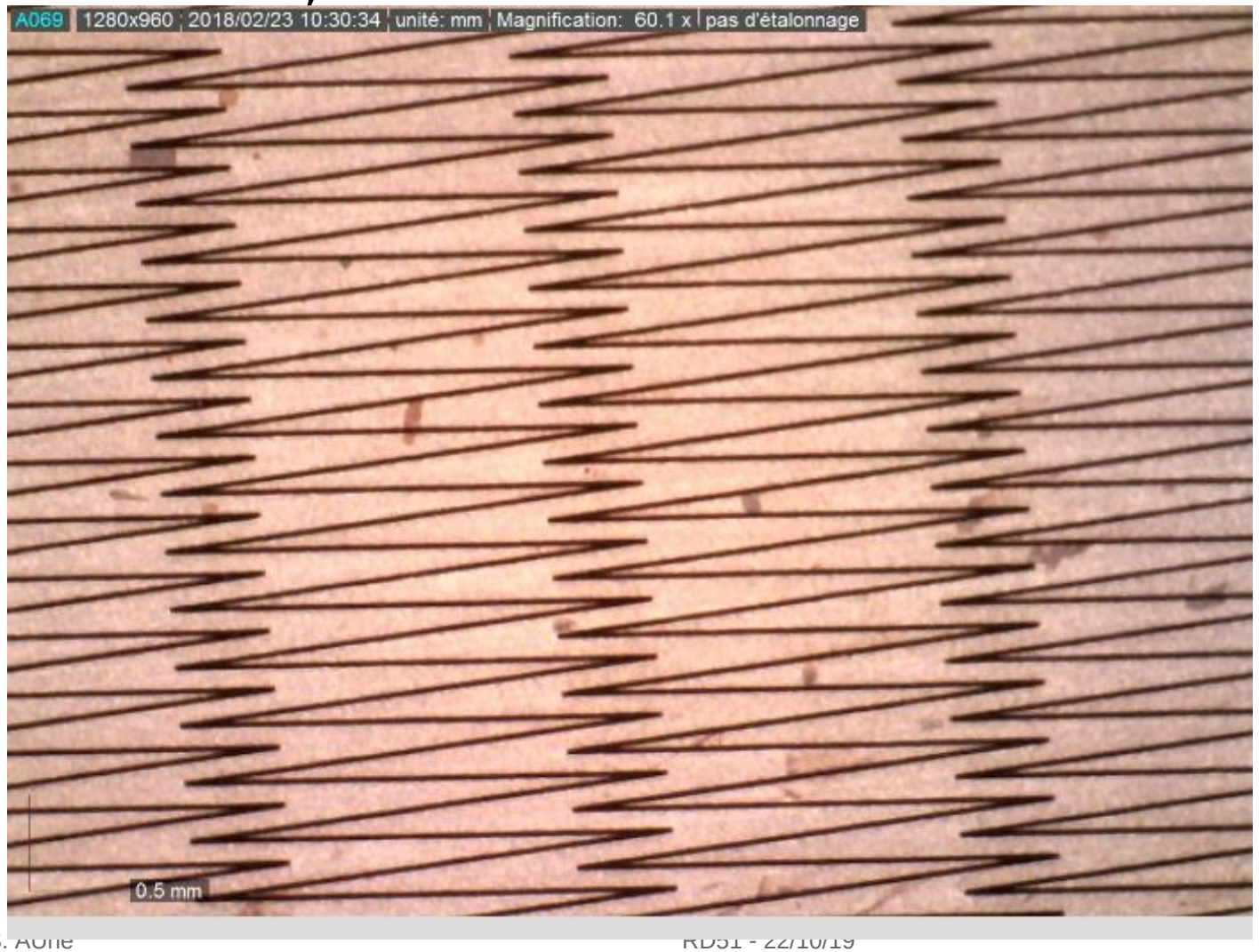
RD3 ZIGZAG FOR FNAL18 TEST

RD3 active area, zoom



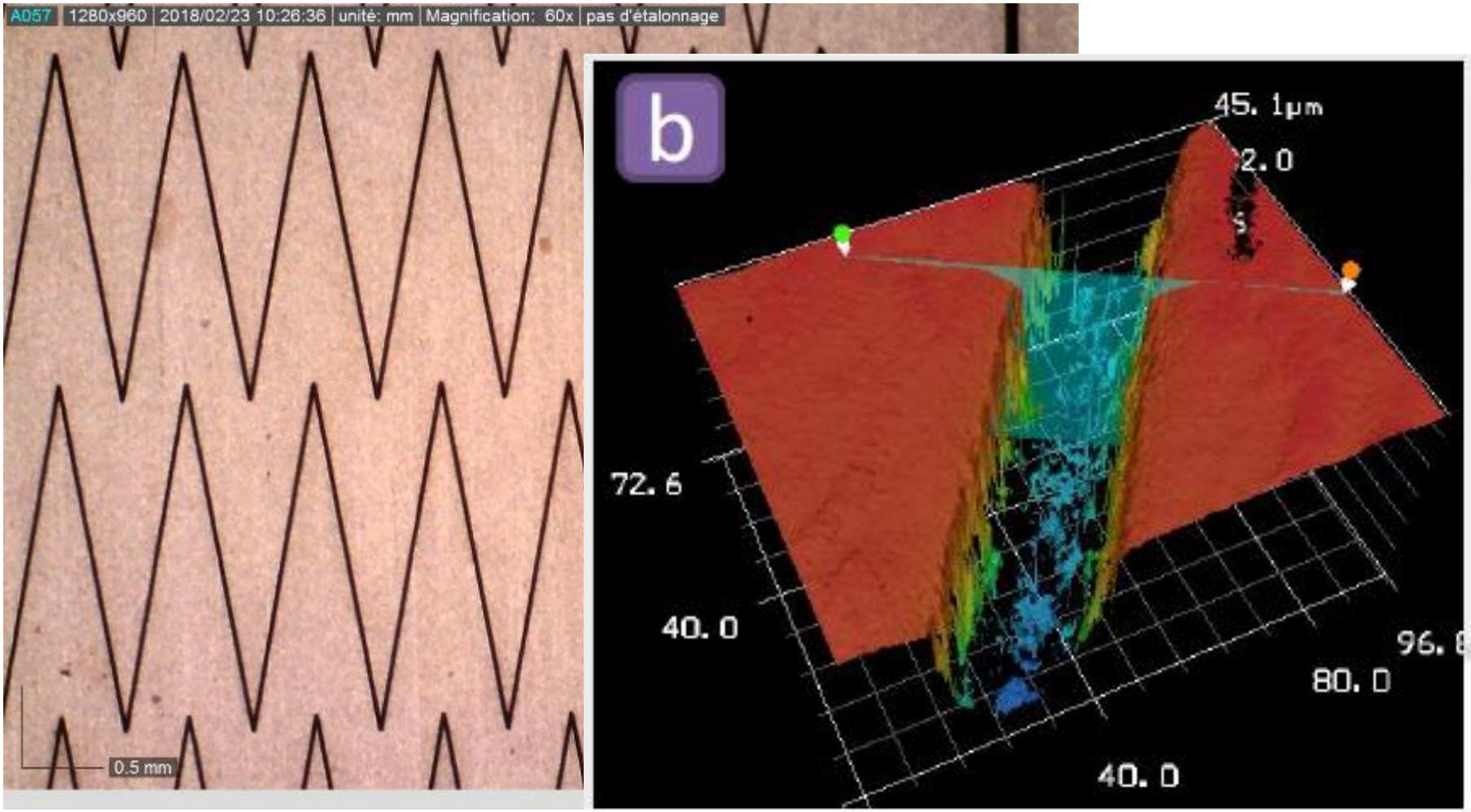
RD3 ZIGZAG FOR FNAL18 TEST

RD3 active area, zoom



RD3 ZIGZAG FOR FNAL18 TEST

RD3 active area, zoom

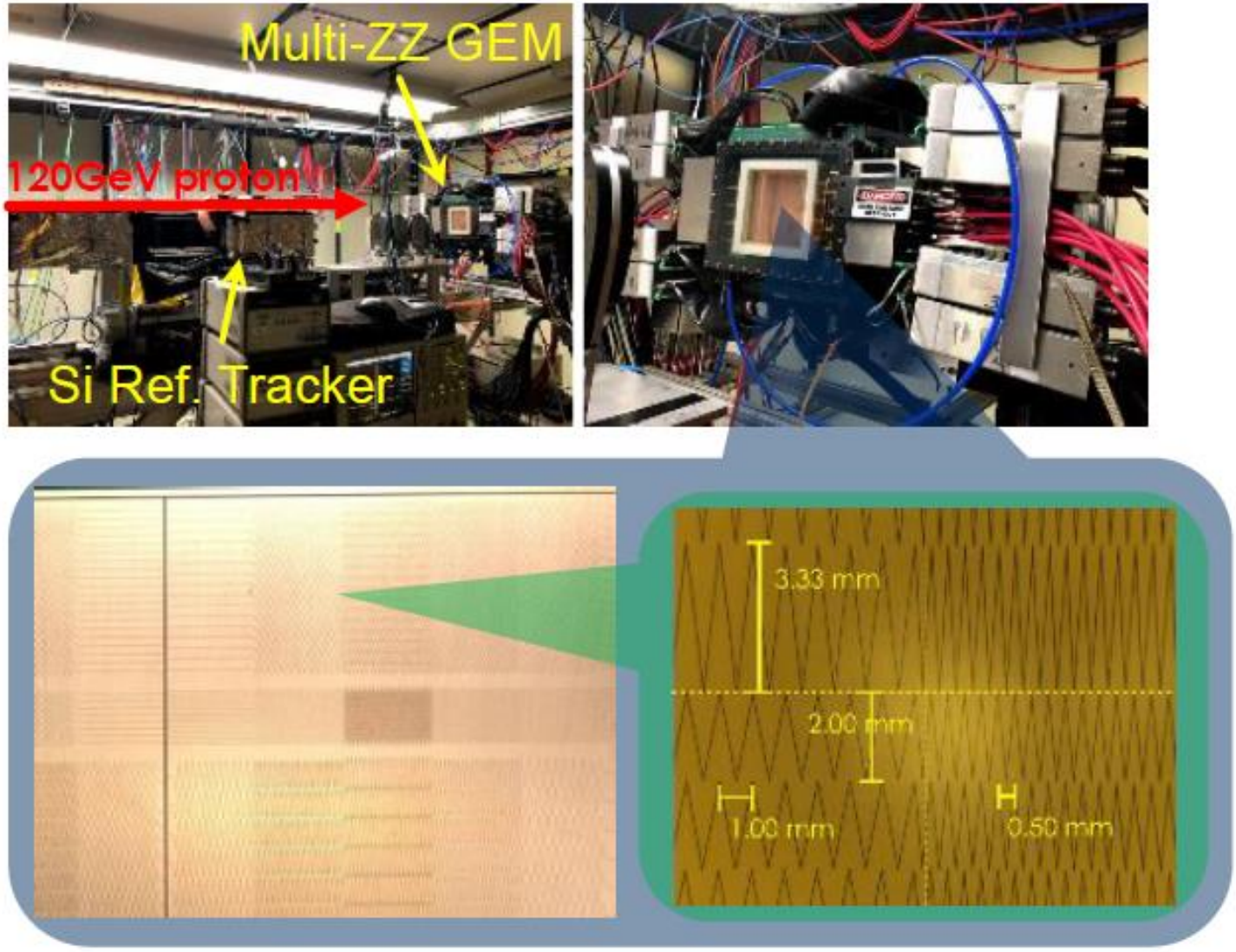


RD3 ZIGZAG FOR FNAL18 TEST

For beam test we are late….

The board are transformed into bulk at Saclay the week before the travel to FNAL !

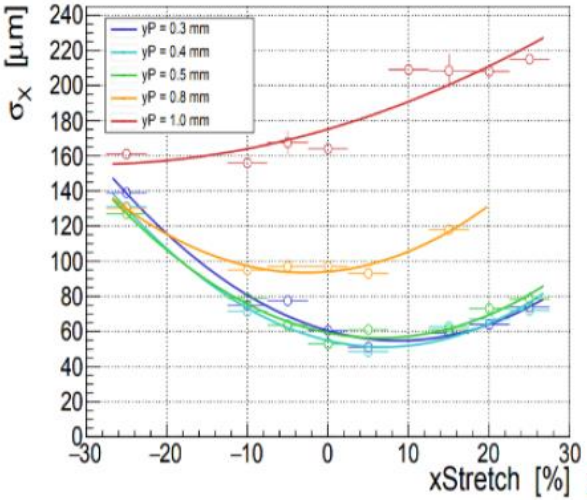
FNAL ZIGZAG TEST 2018 GEM AND MICROMEGAS



BEAM GEM RESULT PRESENTED AT IEEE 2018

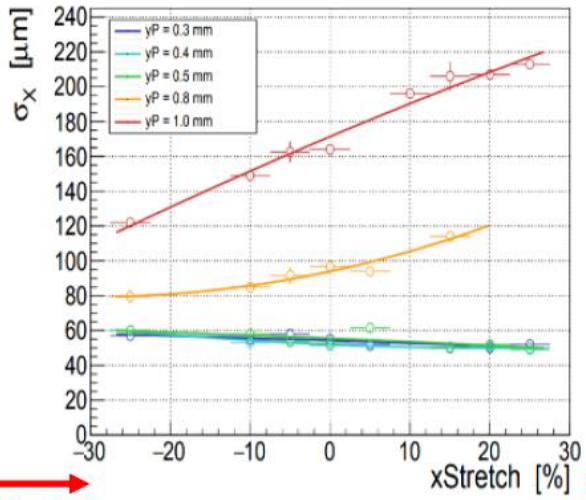
BEAM TEST RESULTS: PERFORMANCE TRENDS

Pitch = 2mm, No DNL correction



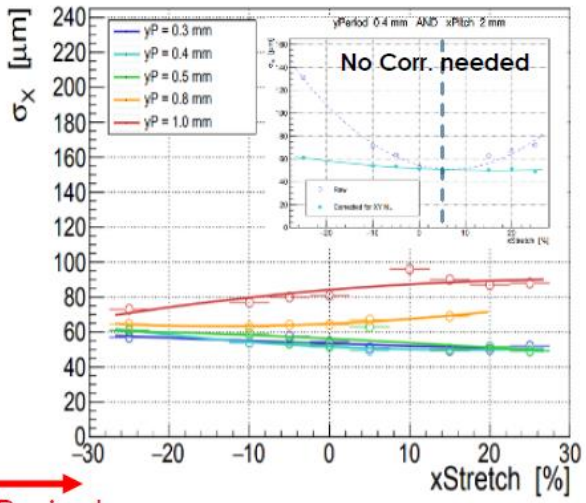
xStretch Correction

Pitch = 2mm, DNL-x correction



yPeriod Correction

Pitch = 2mm, DNL-xy correction



- Recover systematic offset in residuals using DNL-y correction followed by DNL-x correction
- Use centroid for correction, so process is limited by resolution of centroid itself
- At small periods, the impact of this parameter on performance becomes saturated
- **Inset plot identifies the point where no correction is required and 50μm resolution is obtained**

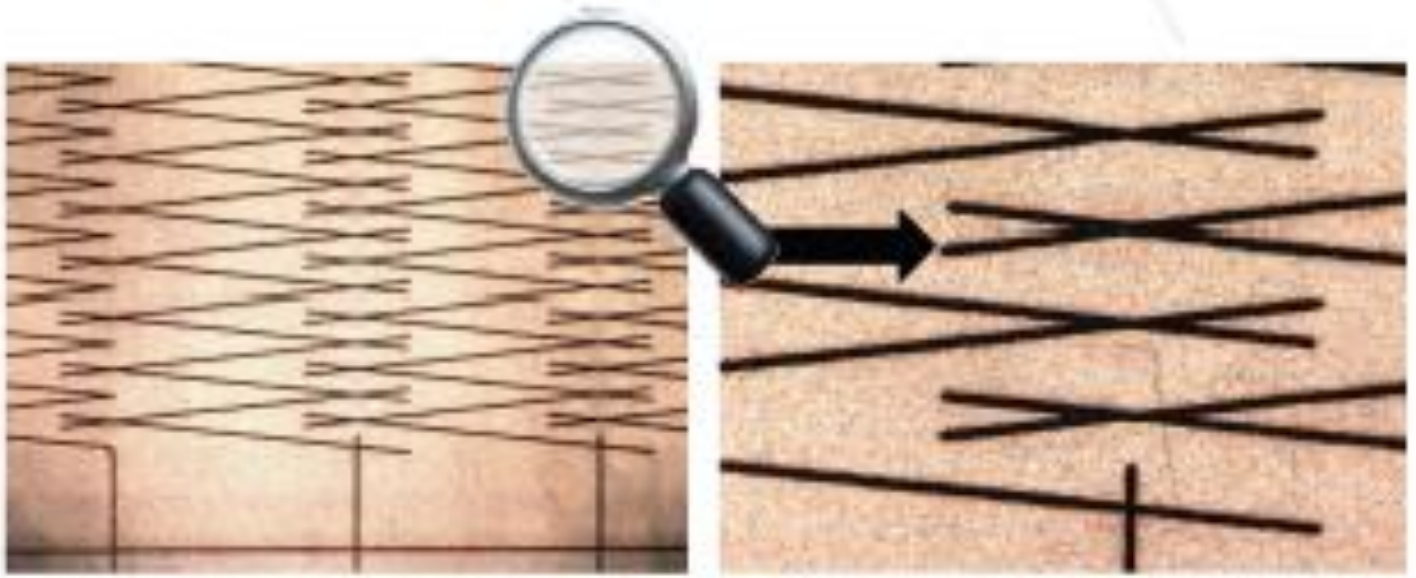
B.Azmoun, BNL 11/16/2018

For Micromegas spatial resolution of ~140 μm for 2 mm pitch

NEXT BEAM TEST FNAL19 WITH 1D AND 2D ZIGZAG

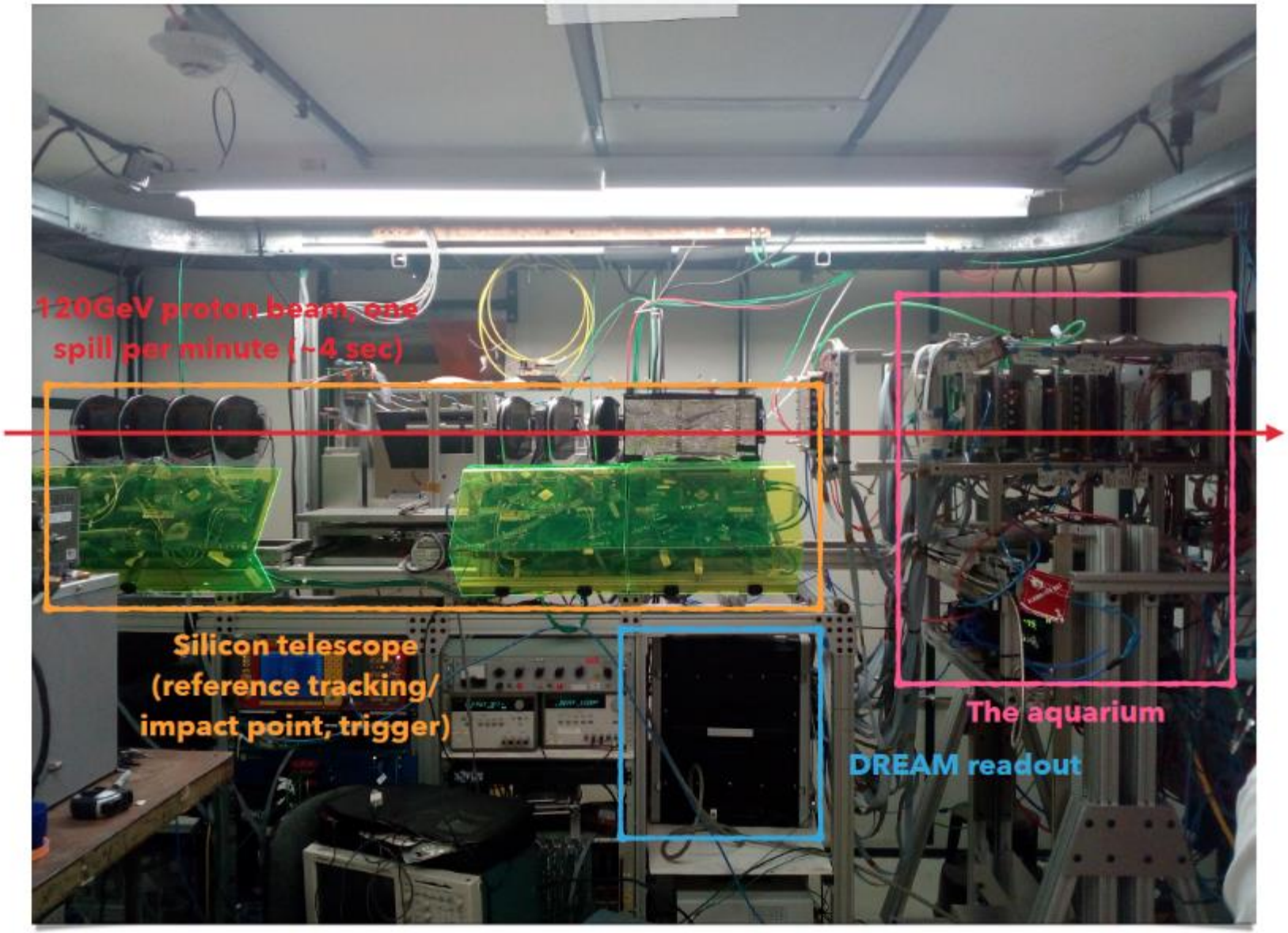
1D improvement for short:

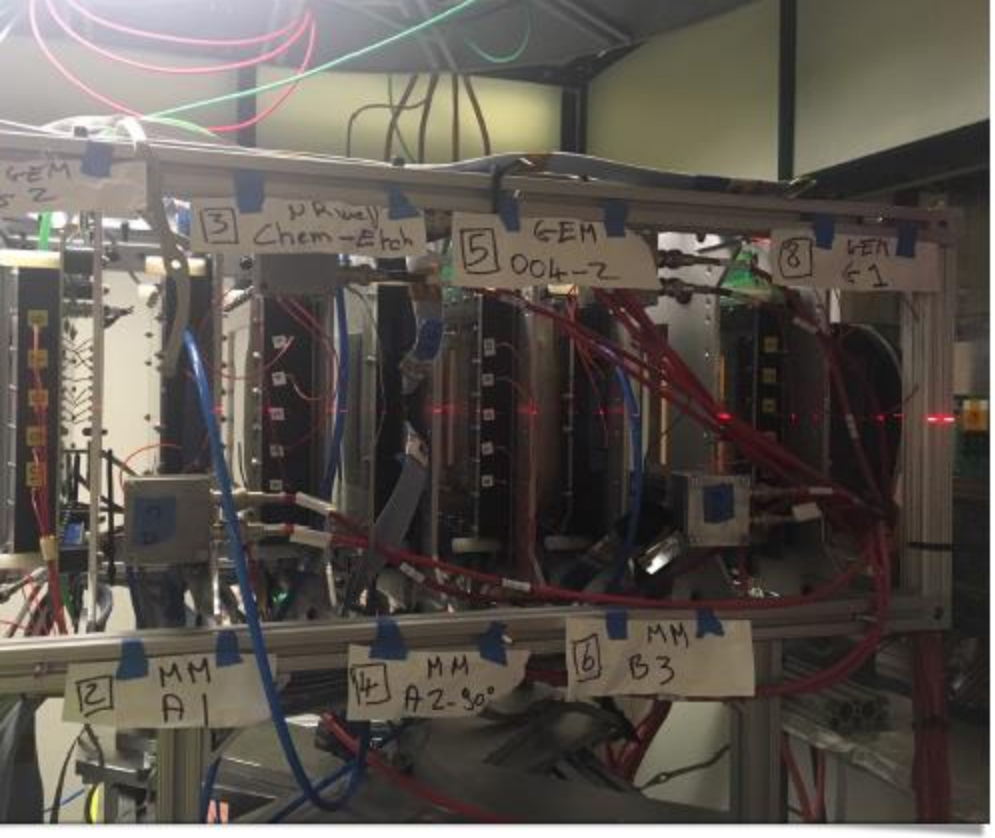
We have idea to avoid short between strip at low angle crossing: it work !



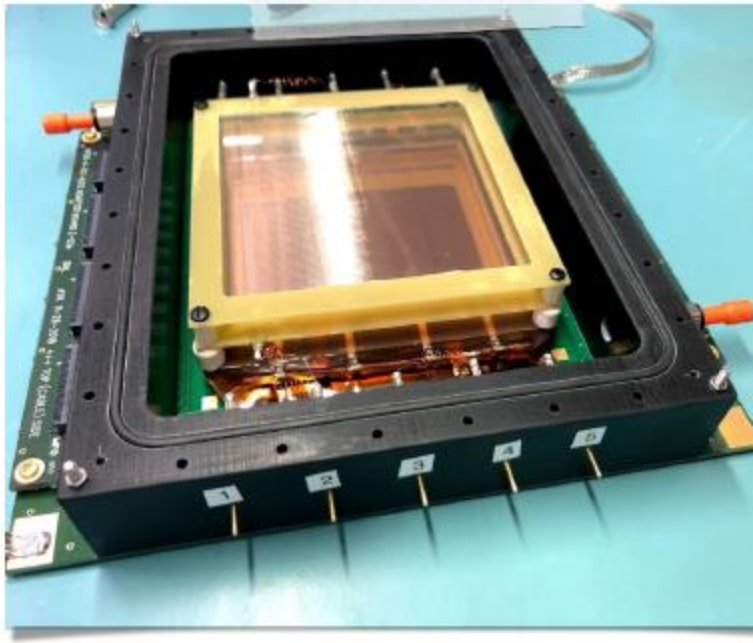
Over shooting the laser path improve greatly electrical insulation between zigzag strips

SET UP AT FERMILAB 2019



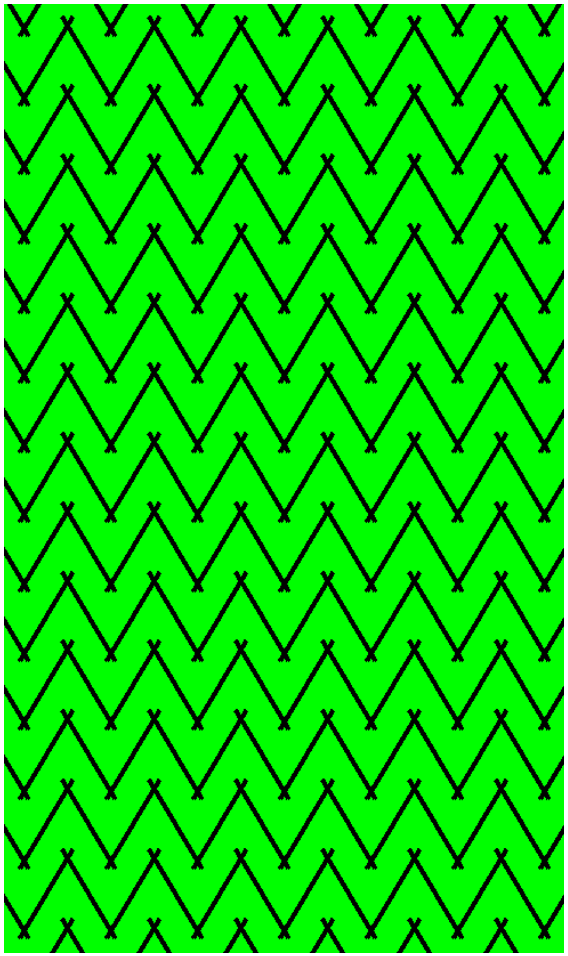


Different GEM/MM/μRwell detec
are mounted on different boards,
into a particular slot of the aquar
filled with a certain kind of ga

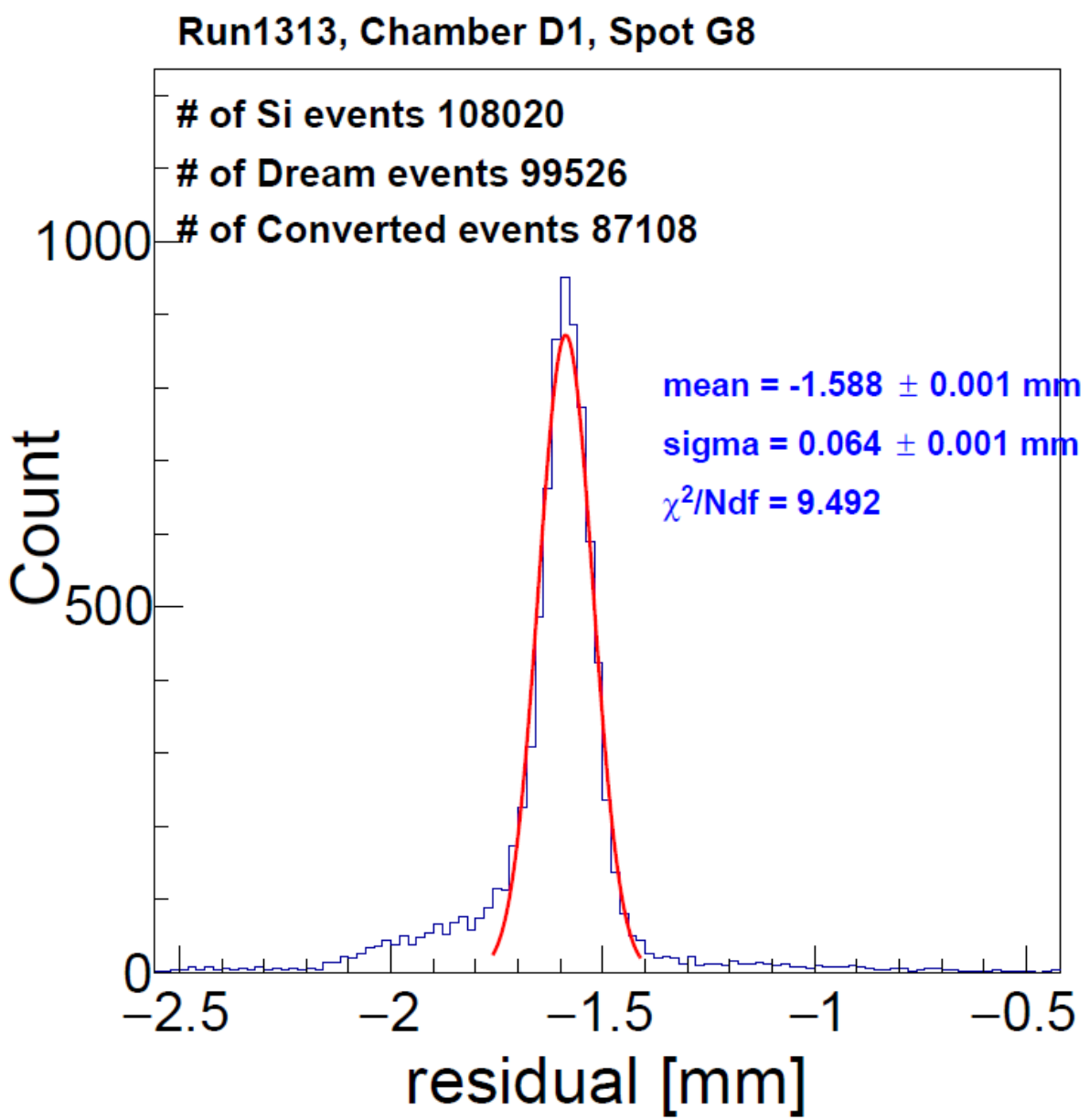


Slot #	Gas	Detector
0	0	
1	0	ArCO2_7030 GEM G2 Elvia 2018
2	0	ArCO2_7030 MM A1 - Flow AS3 - New Gas - Drift change from 5mm to 12.4mm
3	0	ArCO2_7030 uRW #1
4	0	ArISO_9505 MM A2 Elvia 2019 drift 5mm
5	0	ArCO2_7030 GEM C2
6	0	ArISO_9505 MM A5 Elvia 2019 Resit 10 MOmh
7	0	ArISO_9505 MM TTM BNL70-2 Metal drift 5mm

MICROMEGAS RESULT D1 – G8



Pitch 0.4 mm
Over 0.25 mm



FNAL ZIGZAG 2019 RESULTS

Spatial resolution result for different MPGD (2 mm pitch)
~ 50 µm for GEM, ~140 µm for Micromegas

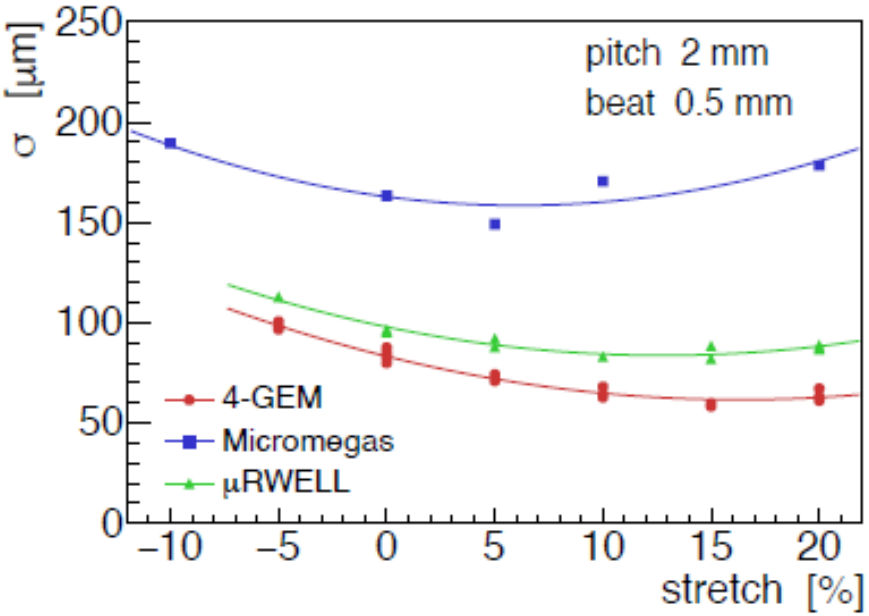


Fig1: Initial residual (Cluster X - Silicon X) width as a function of geometric stretch for a particular zigzag anode pitch (2mm) and beat (0.5mm) showing the response for 4-GEM, Micromegas and uRWELL detectors working under ArCO27030.

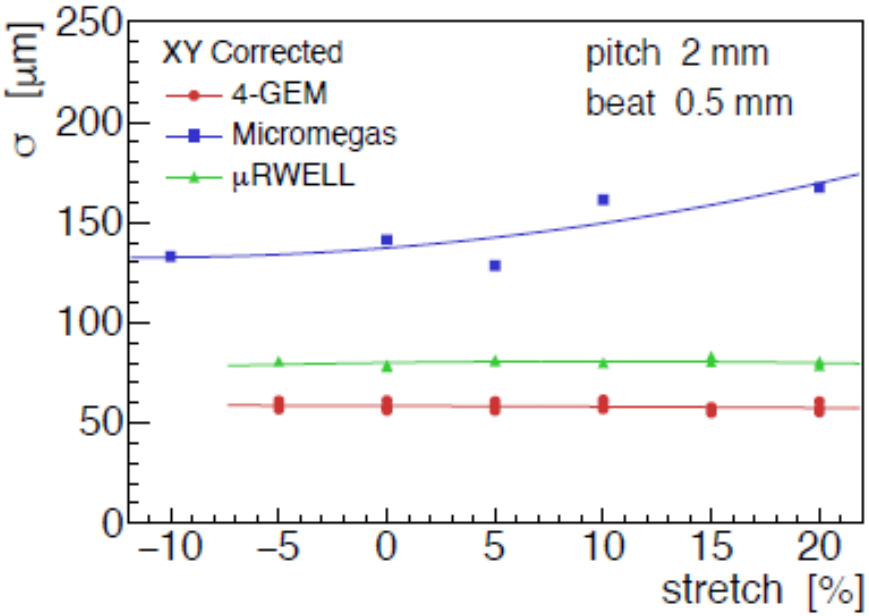


Fig2: Achievable residual width after non-linear corrections as a function of geometric stretch for a particular zigzag anode pitch (2mm) and beat (0.5mm) showing the response for 4-GEM, Micromegas and uRWELL detectors working under ArCO27030.

C. Perez Lara

LASER (25 µM) VS CHIMICAL (~75 µm) ETCHING

Also tested during beam test was classic chemical etching zigzag strip (~75 µm)

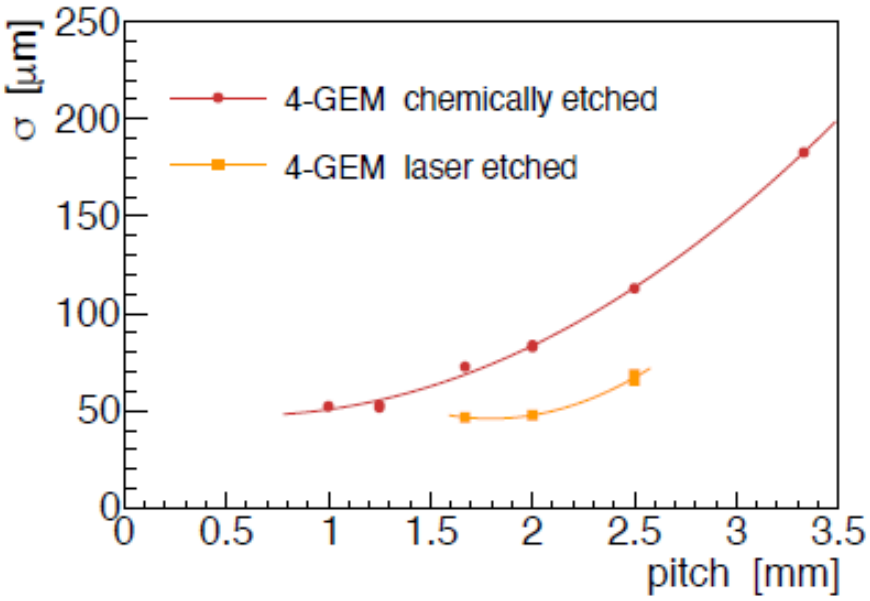


Fig1: Initial residual width as a function of geometric pitch for a particular zigzag anode stretch (0%) and beat (0.5mm) showing the response for two different etching techniques on a 4-GEM detector.

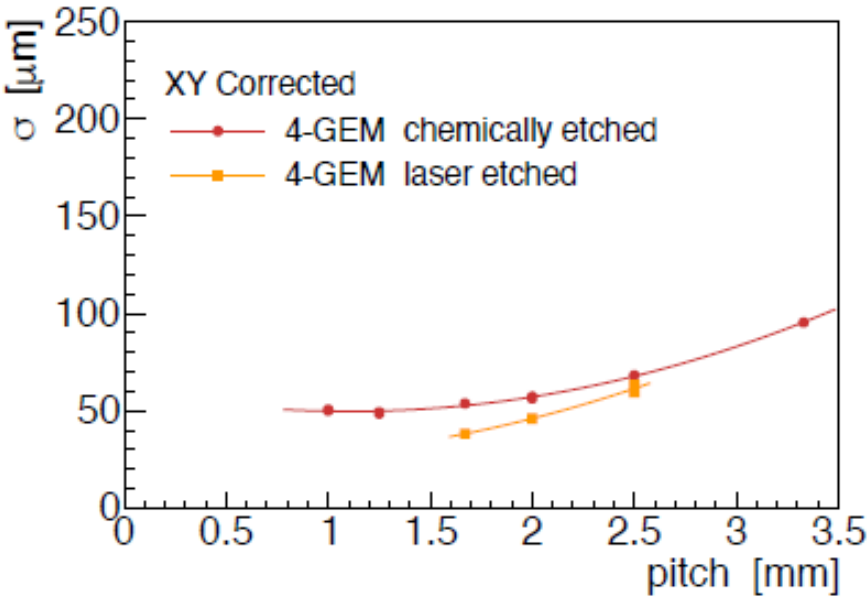
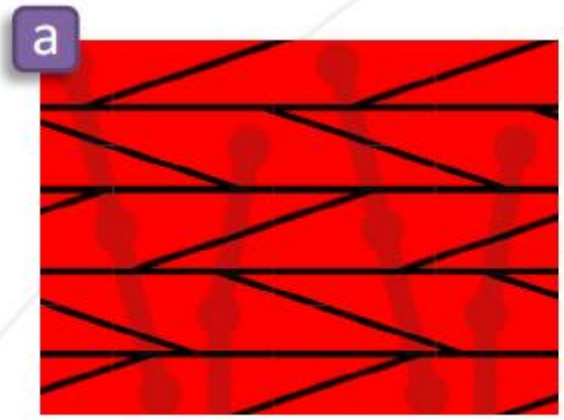
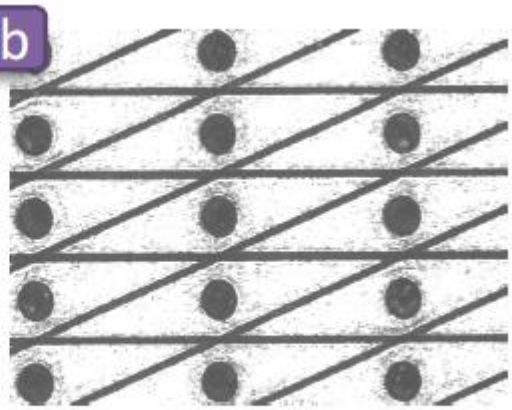


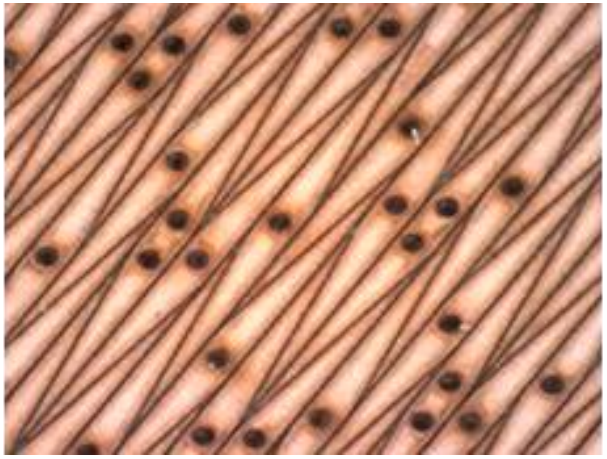
Fig2: Achievable residual width after non-linear corrections as a function of geometric pitch for a particular zigzag anode stretch (0% and beat (0.5mm) showing the response of two different etching techniques on a 4-GEM detector.

NEXT BEAM TEST FNAL19 (2020) WITH 2D ZIGZAG

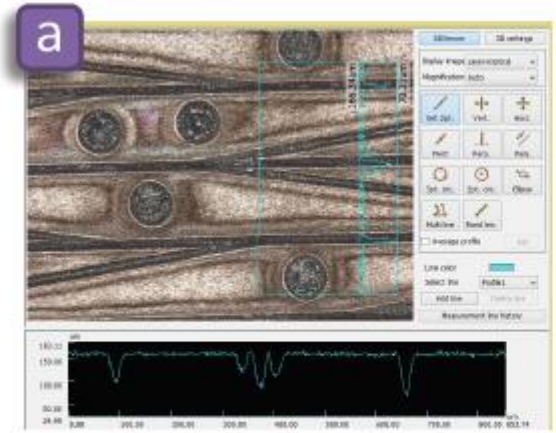
Future is in 2D

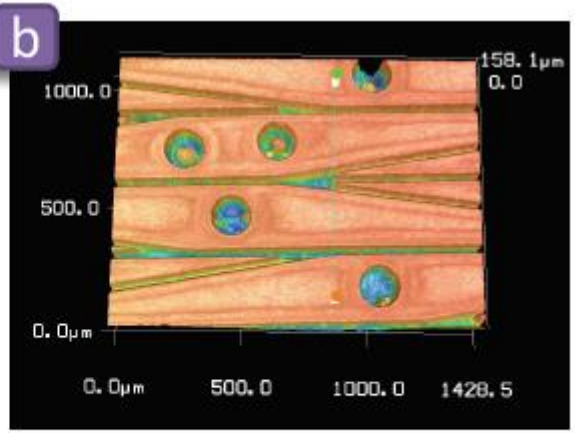






2D Zigzag strips : *Diamond design with Gerber view (a) and prototype board (b)*





Diamond prototype board view and profile using a confocal microscope (a) and 3D reconstruction of the image (b)

NEXT TEST WITH BIG ZIGZAG

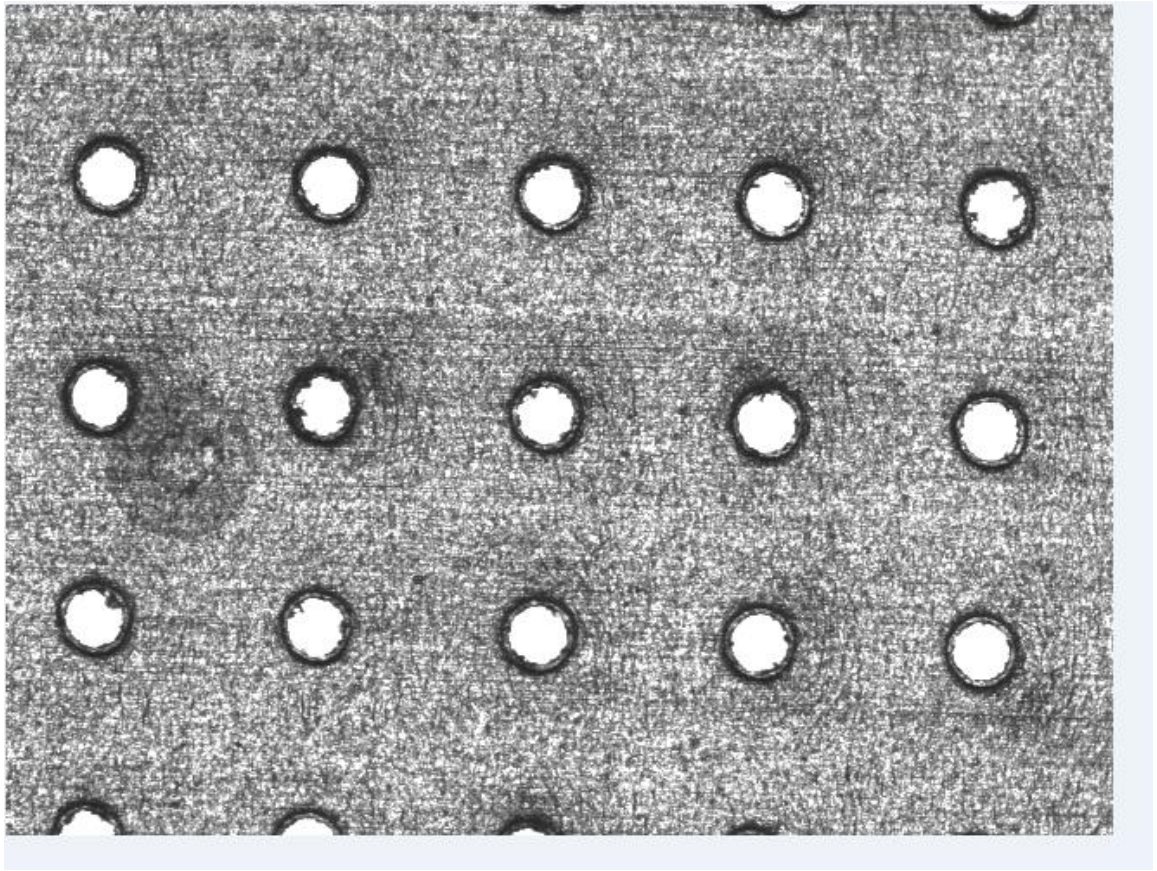
For next test:

- Micromegas zigzag active area: 40 x 40 cm² (256 channels)
  - Laser etched with 25 µm inter
  - Chemical etched with 70 µm inter
  - Resistive area (1 to 10 MOhm/sq)
  - Goal is to curve a micromegas for a tracker prototype.

- 2D zigzag (diamond pixel)
  - GEM (classic and resistive)
  - Micromegas (classic and resistive)

LASER FOR LASER MESH TEST

The laser was used to try holes of thin stretched foil = make your mesh

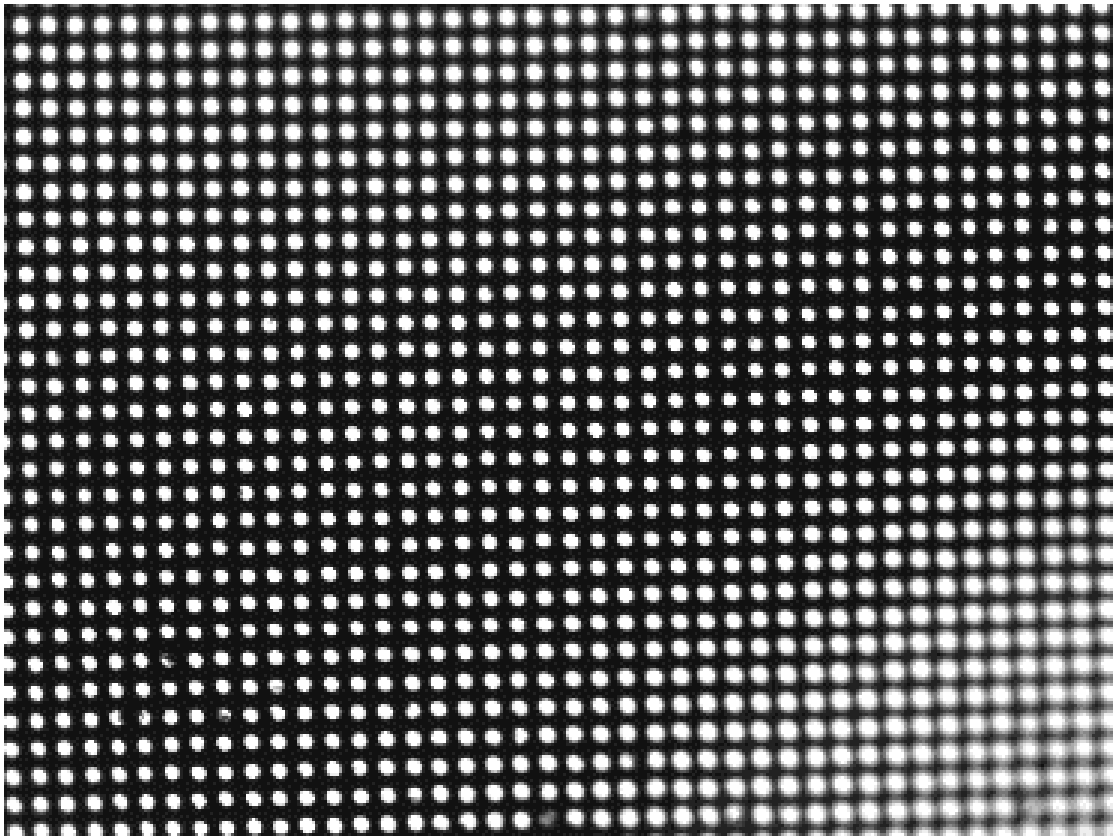


25 µm holes on 10 micron copper foil

LASER MESH TEST

More test should be done with chemical cleaning after laser

Open possibilities for thin mesh or ad hoc mesh for IBF issues



Mesh 45/20 on 10 µm aluminum foil

CONCLUSION: REDUCTION OF CHANNELS

- Laser etching of copper on FR4 is possible
  - If copper thickness low (i.e 9 µm) = easy
  - If Cu with recharge then more delicate
- Laser can be use for other R&D
  - HOLES FOR MESH, MESH SEGMENTATION

- zigzag laser et chemical are almost identical
  - Forget about laser ?

- Zigzag allows a reduction of ~**4** of the number of channels for the same spatial resolution
  - Try it, ask Rui for a zigzag board !

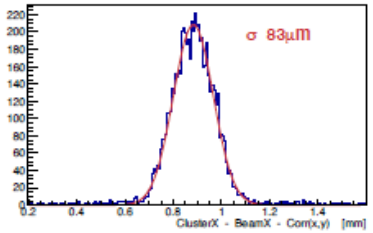
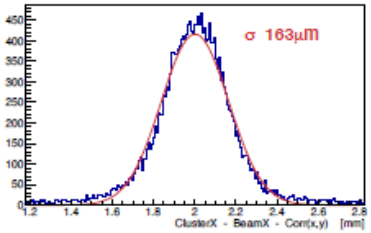
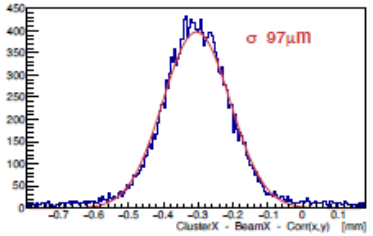
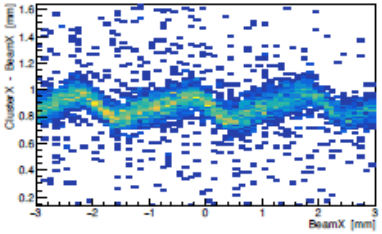
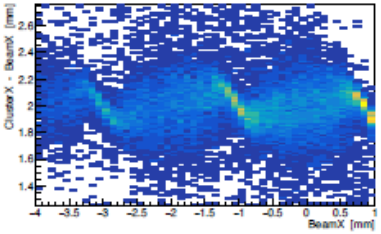
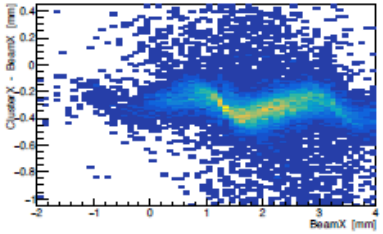
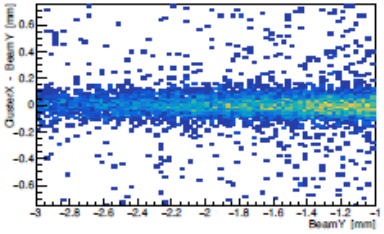
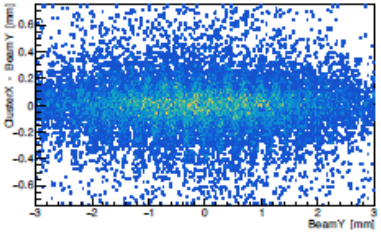
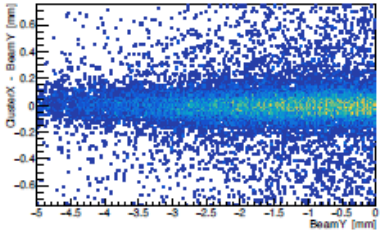
END

Thank you

Be Zigzag ☺

DATA ANALYSIS

Testbench data comparative analysis

	4-GEM	Micromegas	uRWELL
Distribution of initial residuals			
Residual scan in X-direction before corrections			
Residual scan in Y-direction after correction in X			
Distribution of residuals after corrections