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Large-area GEM Detector with Zigzag Strip Readout

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Florida Institute of Technology

Experience with MPGD Readout Production in US Industry,
WG6, RD 51 Workshop, 2013-10-17

Outline

- Zigzag concept
- Previous experience with zigzag readout
- Zigzag readout board design with Altium
- Large-area zigzag board production in PCB factories in the US
- Beam test of CMS GEM GE1/1 with a zigzag readout board
- Summary & Future plan

Zigzag concept

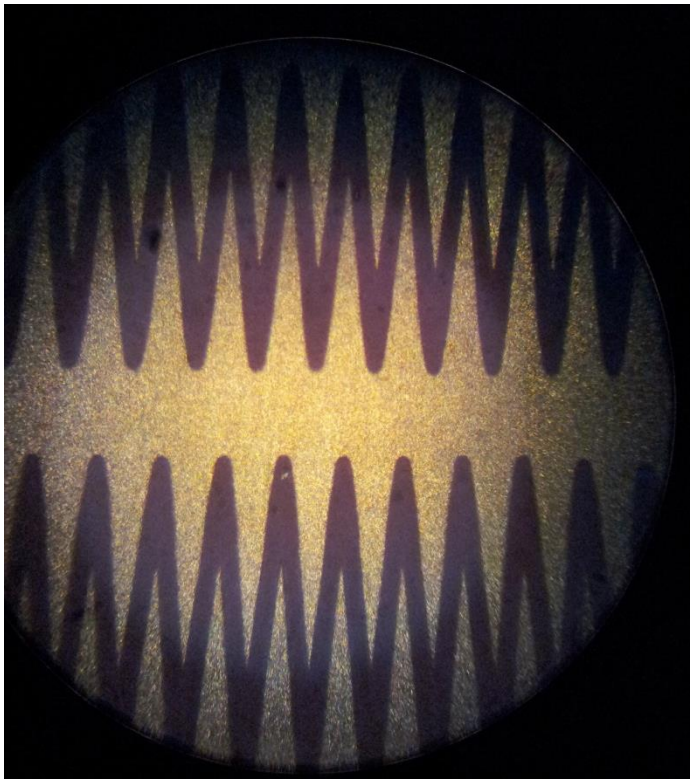
❑ Structure:

- 1-D zigzag strips,
- With sharp tips
- Tip to tip width: 2-4mm, zigzag pitch along strip: 0.5mm;
- Gap between strips: ~0.1mm

❑ Advantage:

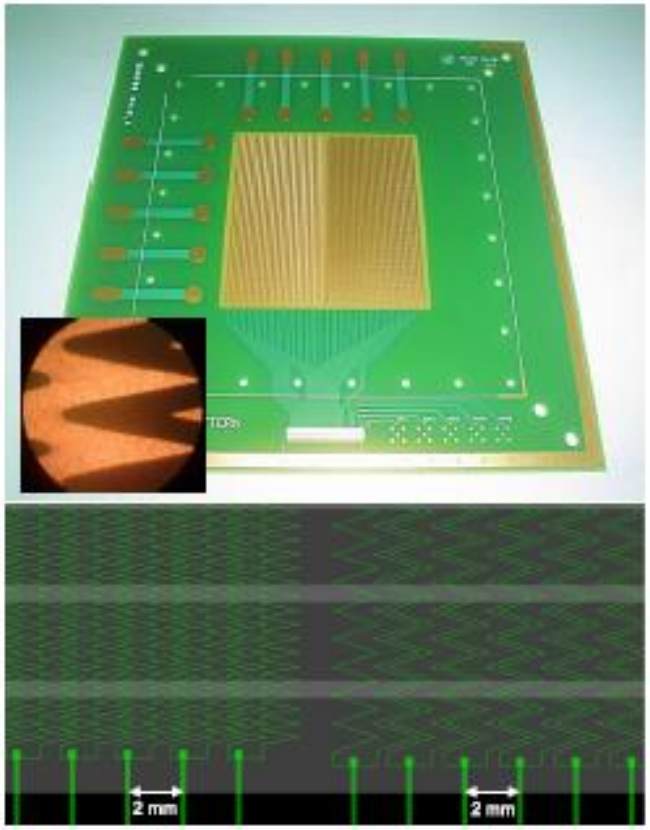
- Reduce readout channel numbers dramatically, potential for dramatic cost reduction of readout electronics
- Conserve/improve spatial resolution compare with normal

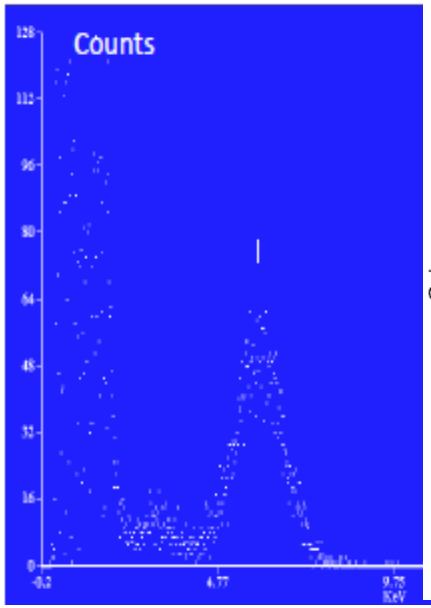
❖ Applicable only to 1-D readouts

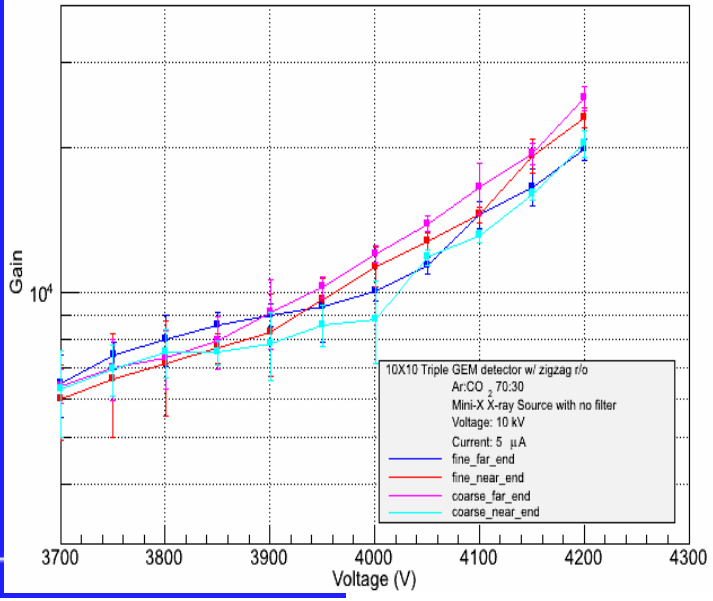


A microscopic view of a zigzag manufactured by American Circuit Technology, for 30cm GEM detector.

Previous experience with Zigzags







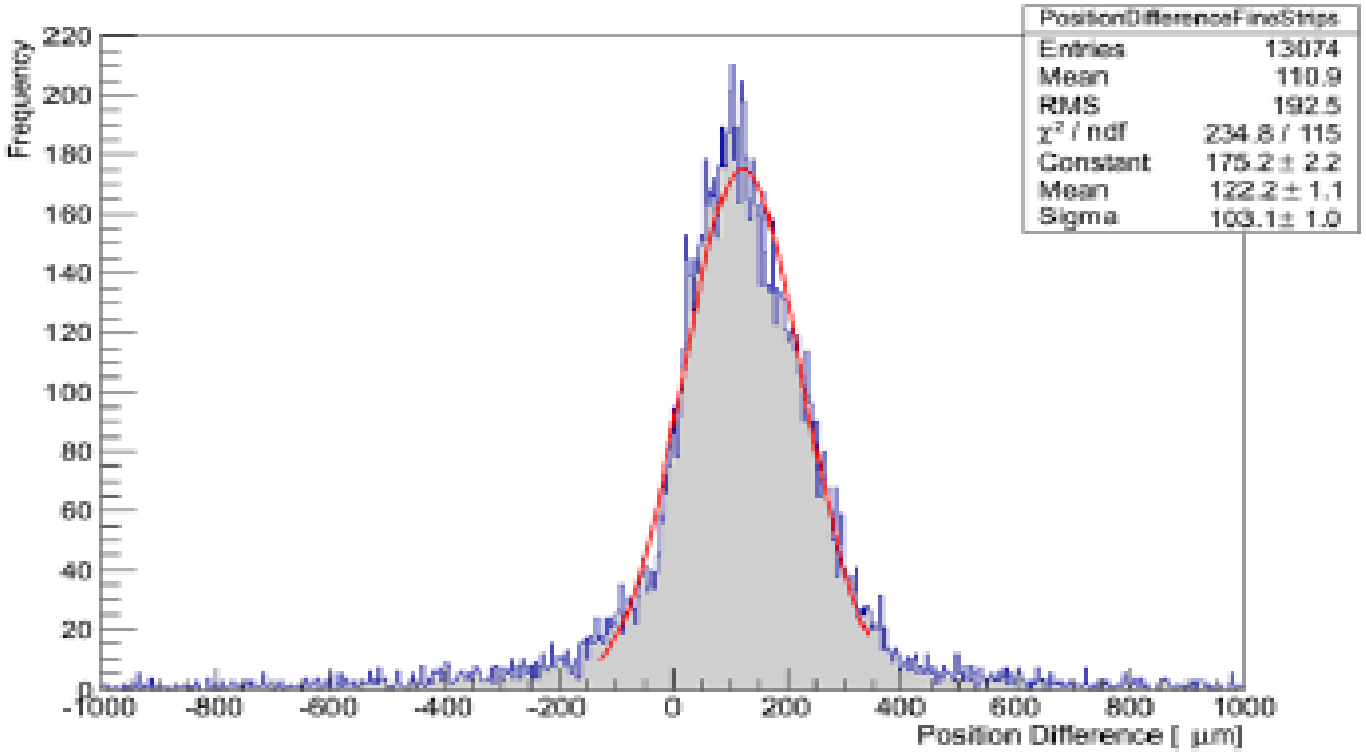
Fe55 spectrum

Gas gain in Ar:CO2(70:30) larger than 10^4

Ref: Proc. of IEEE Nucl. Sci. Symp. 2012, N14-137, Anaheim, CA, Oct 29-Nov 3, 2012, arXiv:1211.3939.

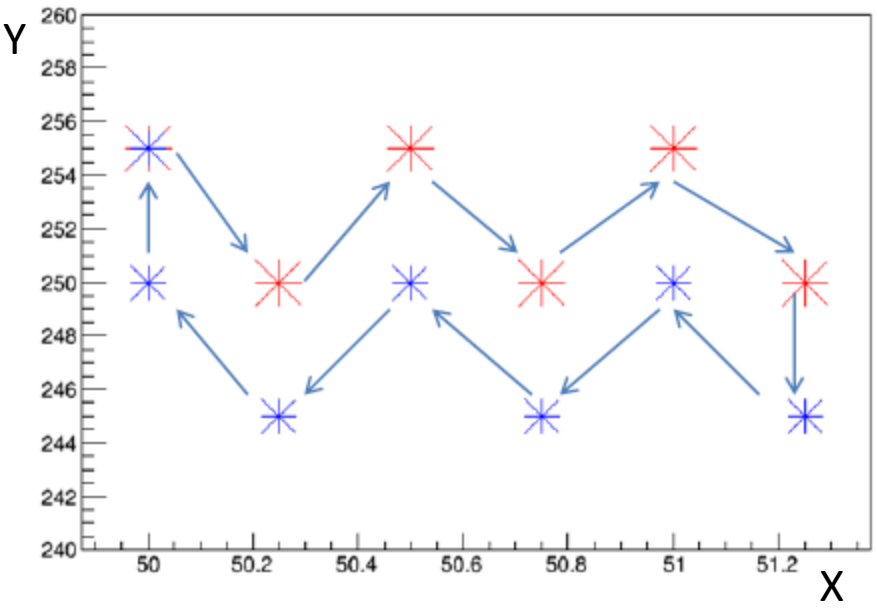
First results of a zigzag board tested with a 10cm GEM detector at FIT

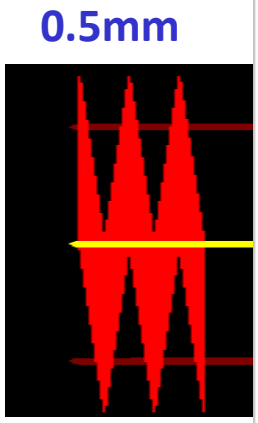
Previous experience with Zigzags

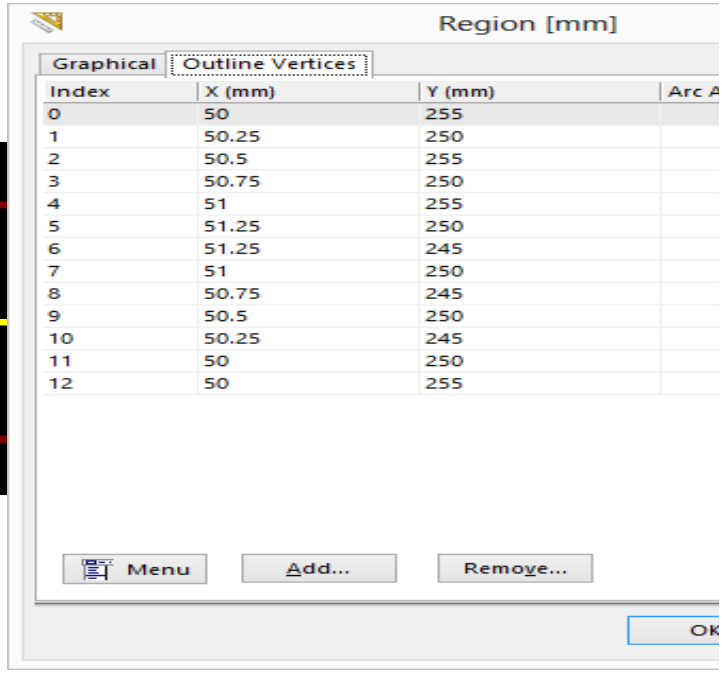


The spatial resolution of GEM detector with this zigzag readout was tested to be ~73µm, (Ref: Proc. of IEEE Nucl. Sci. Symp. 2012, N14-137, Anaheim, CA, Oct 29-Nov 3, 2012, arXiv:1211.3939)

Zigzag board design with Altium

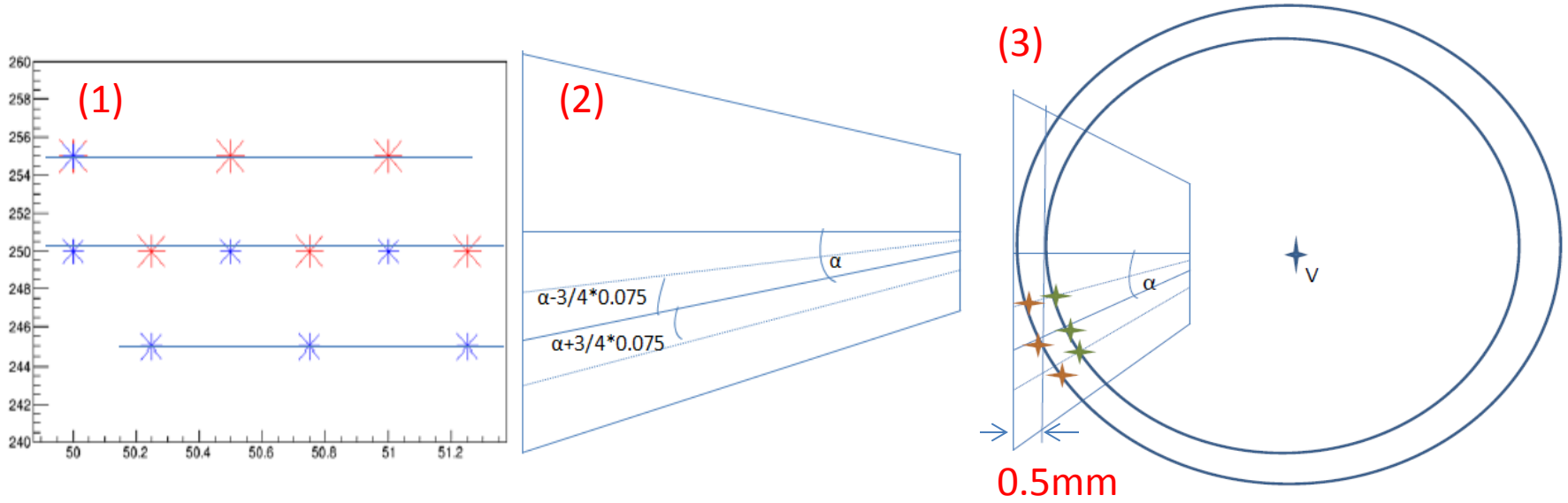






- Software: Altium Designer, http://www.altium.com/
- For drawing **straight Zigzag (Parallel)** strips: (1) Use '**Region**' in Altium, (2) Put the vertex coordinate values in proper order. The vertices can be saved in a **.csv** format file, which can be imported into Altium

Zigzag board design with Altium



- For drawing **Radial Zigzag** strips:

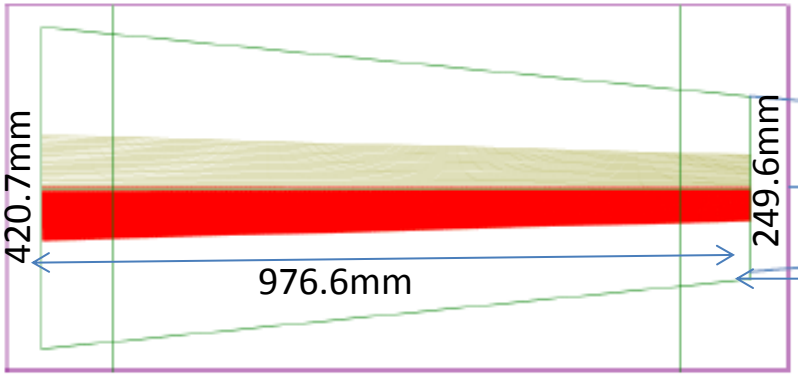
(1) First notice that all vertices are located along three lines, there is a 'center' line;

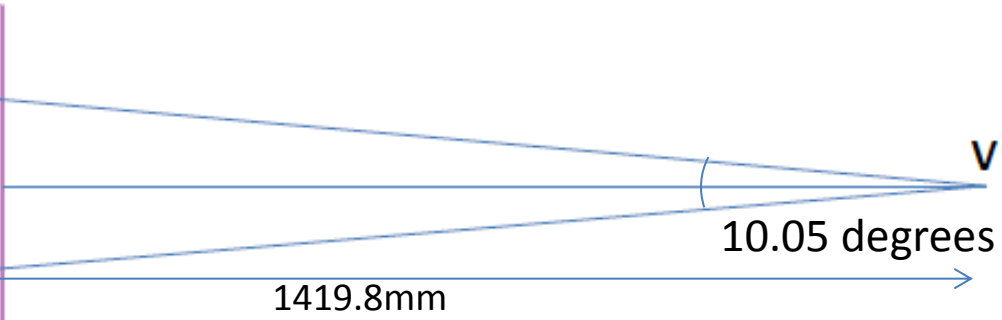
(2) Figure out which lines are the vertices, according to the given angle (of the 'center' line), call it the 'main angle'. Then add a fixed angle to the main angle;

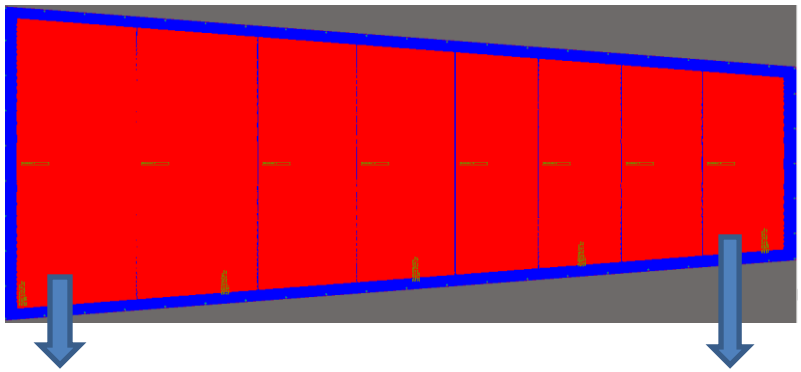
(3) Use many concentric circles to find vertices, the center of the circles is the intersection point of the three lines, and the circle space can be selected, e.g., 0.5mm;

(4) Finally put the vertices in proper order and save as a .cvs format file.

Zigzag board design with Altium

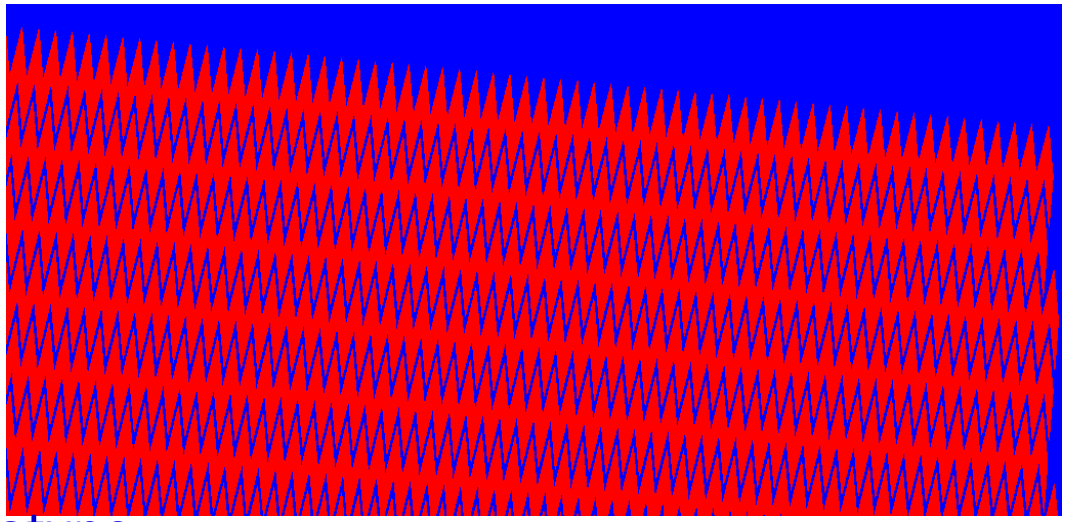






Larger End

Smaller End

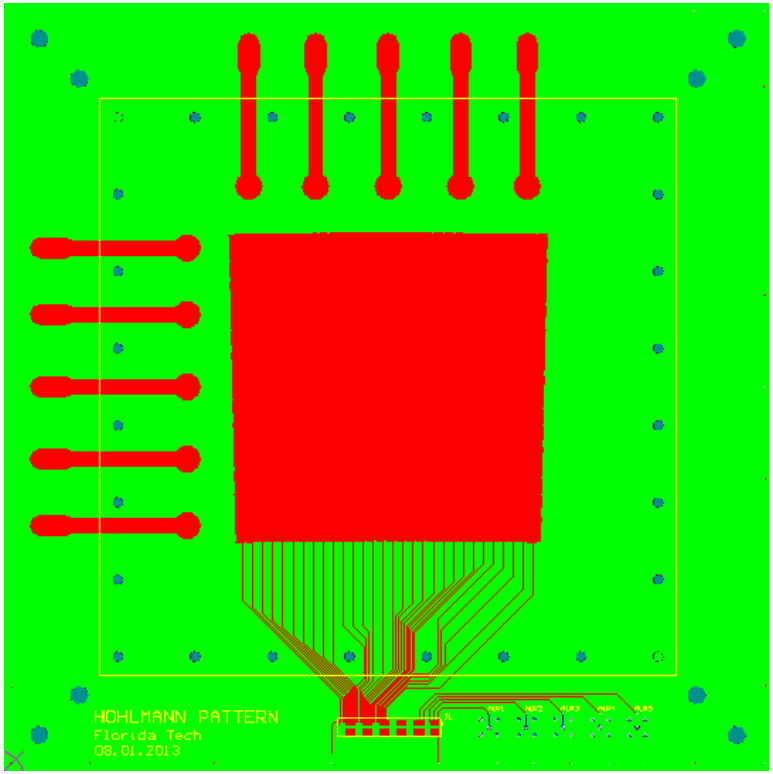


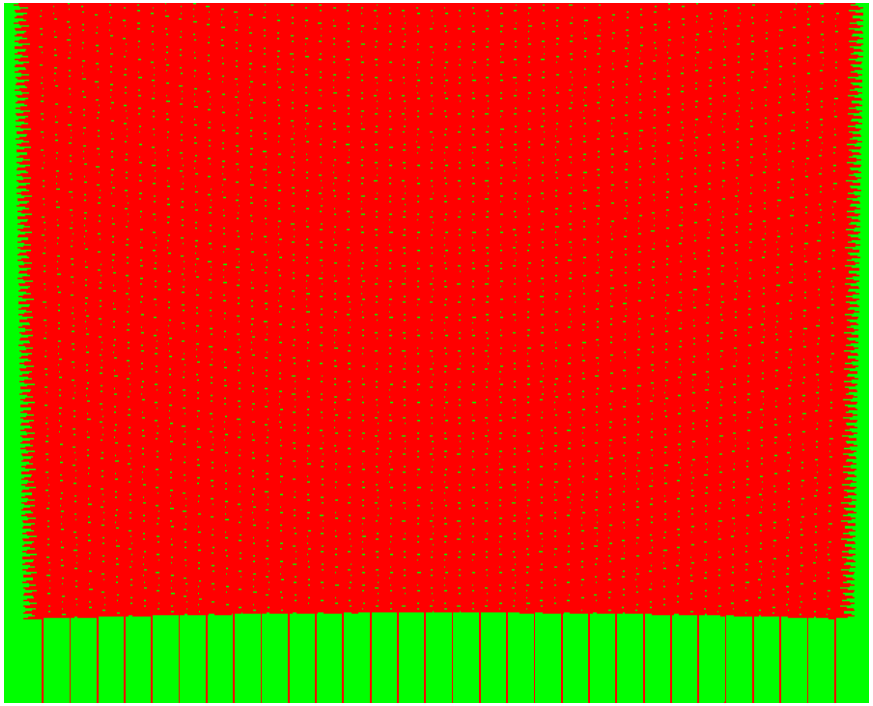
Zigzag design of CMS GE 1/1 prototype.

It has 8 sectors, each sector has 128 zz strips, neighbouring strips intersection angle: 13.8mradian (0.079 degrees).

Only 1/3 of straight strips readout board.

Zigzag board design with Altium





Also designed zigzag boards for 10cm GEM detectors, to simulate larger and smaller ends of CMS GEM detector.

Above picture shows the larger end, which has 30 zz strips.

(48 channels for the smaller end.)

Zigzag board production

Contacted **20 PCB factories** in the US, selected three that we thought were most capable for the job: San Francisco Circuits, American Circuit Technology and Precision Technologies

Our requirements:

- **Flatness**: bending ~0.1% of the length of the board. This aspect is especially important for larger area board.
- Prefer **Halogen Free PCB** materials. (less potential for aging problem due to halogen release).
- **Gold** plated.

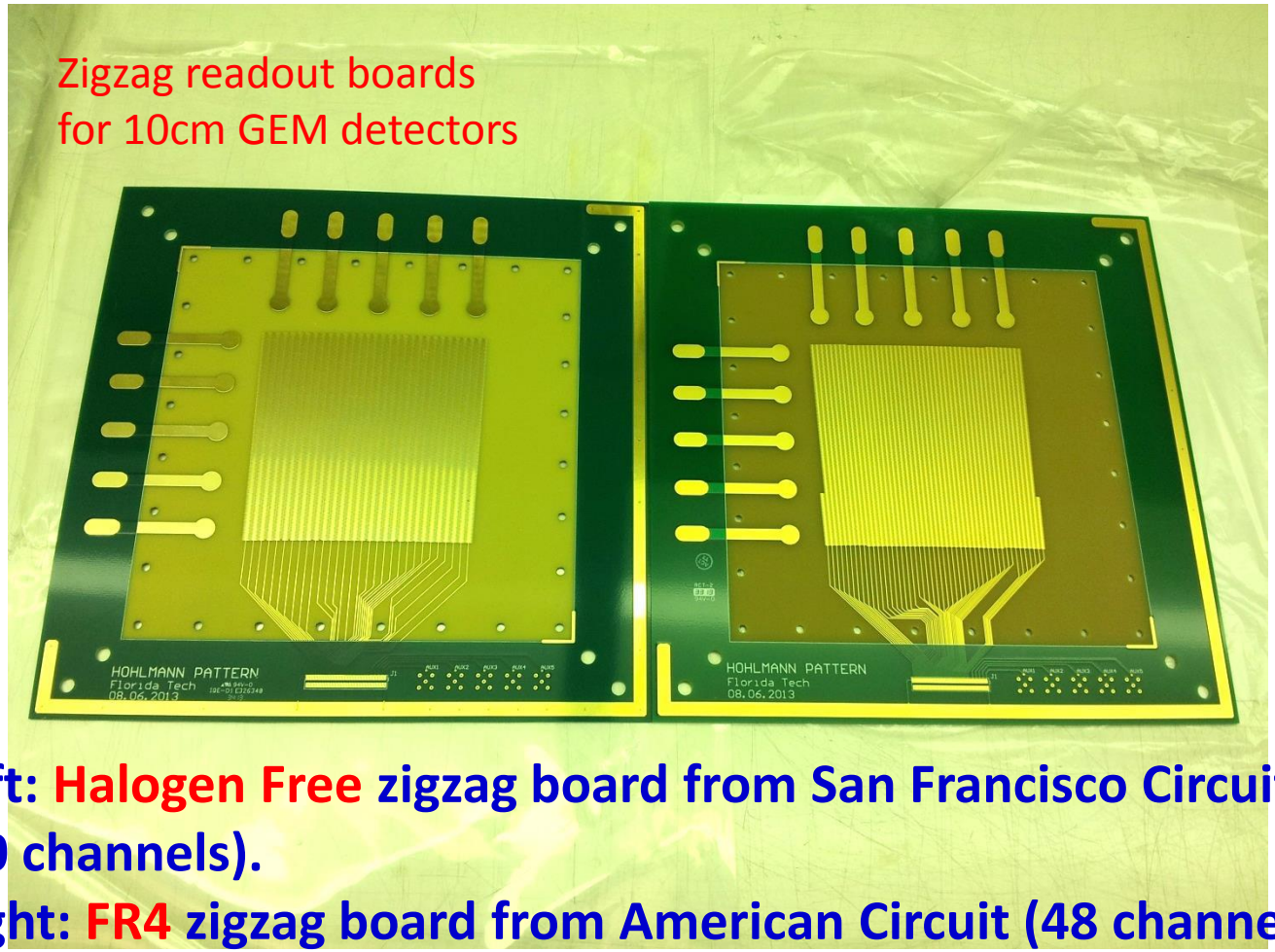
Feedback of PCB factories:

- American Circuit: NO Halogen Free Material; flatness better than 0.75% (IPC standard); cost reasonable (cheapest).
- San Francisco Circuits: HAVE Halogen Free Material but could NOT provide large area like 1 meter; flatness better than 1.5%(IPC standard); very expensive.
- Precision Technologies Inc.: Willing to purchase Halogen Free Material, need more time; flatness better than 1.5% and not too expensive (a little higher than American Circuit).

Halogen Free Materials survey:

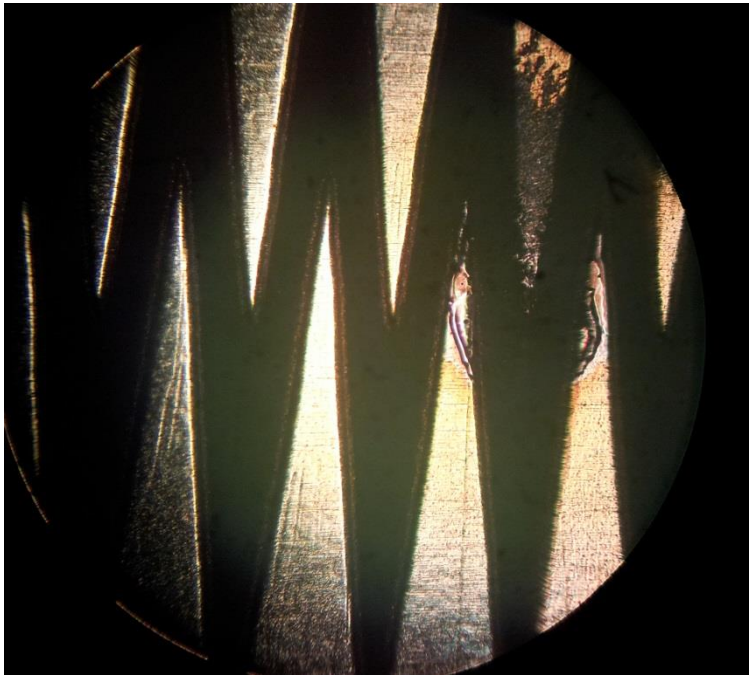
- Nelco N4000-7 EF
- Ventec Group 447 TDS
- Hard to get large area in the US.

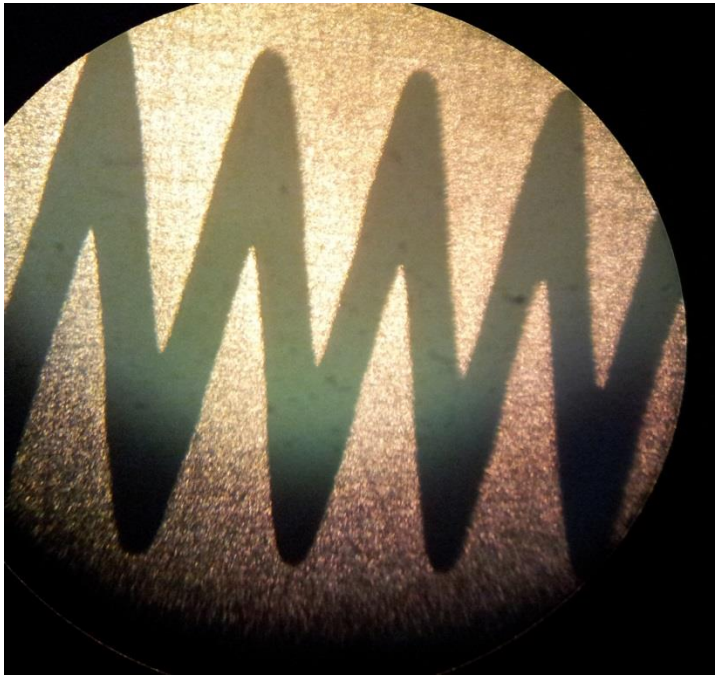
Zigzag board production



Left: Halogen Free zigzag board from San Francisco Circuits (30 channels).
Right: FR4 zigzag board from American Circuit (48 channels).

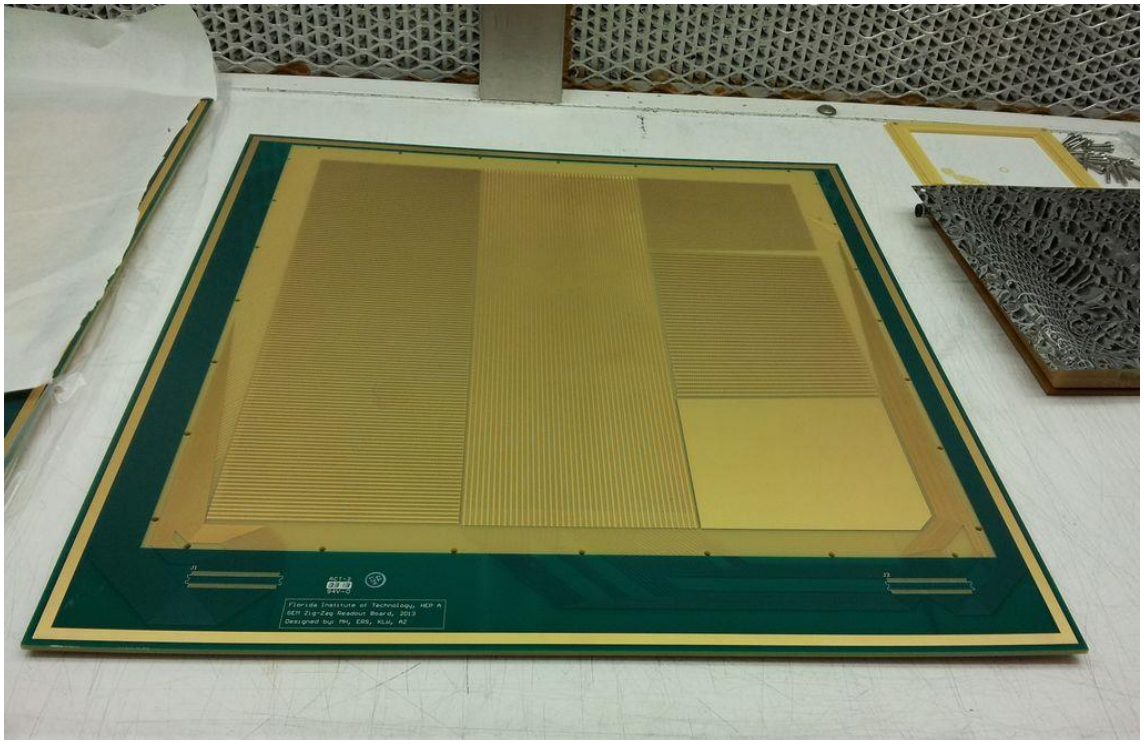
Zigzag board production





Left: San Francisco Circuits makes very sharp tips
Right: there are round corners from American Circuit boards

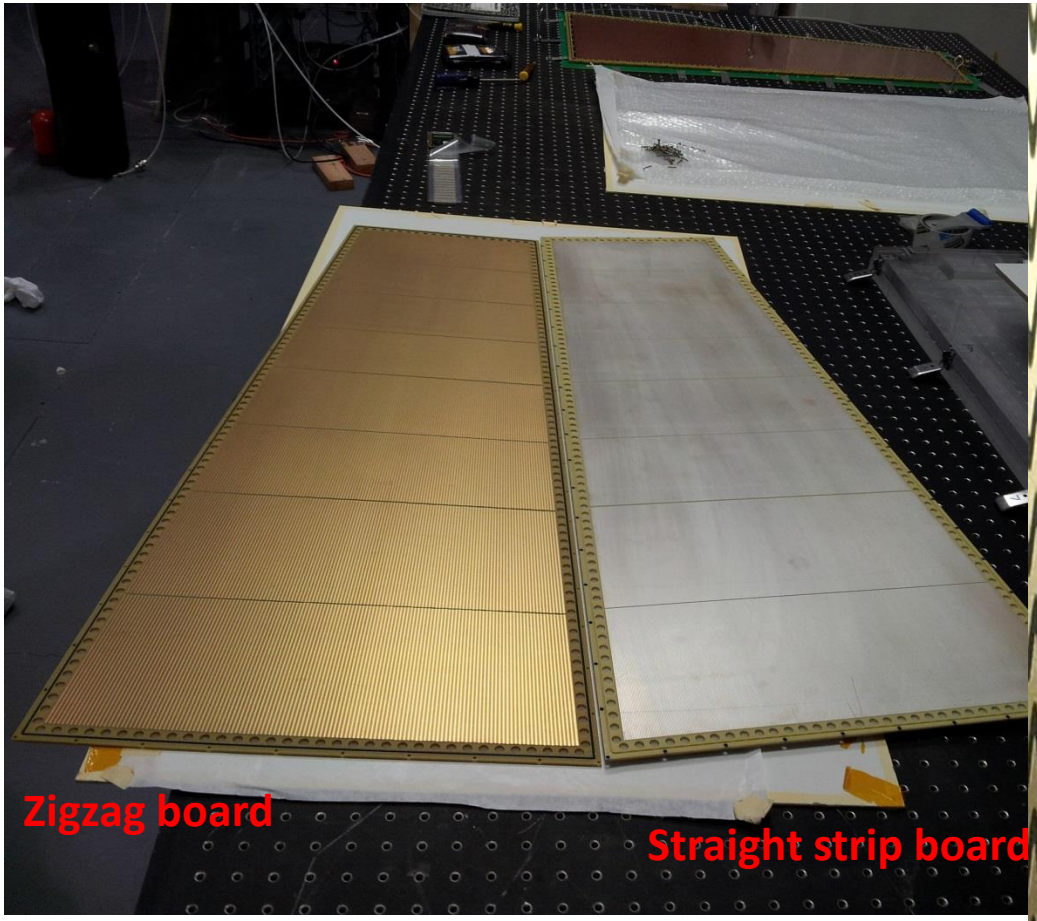
Zigzag board production

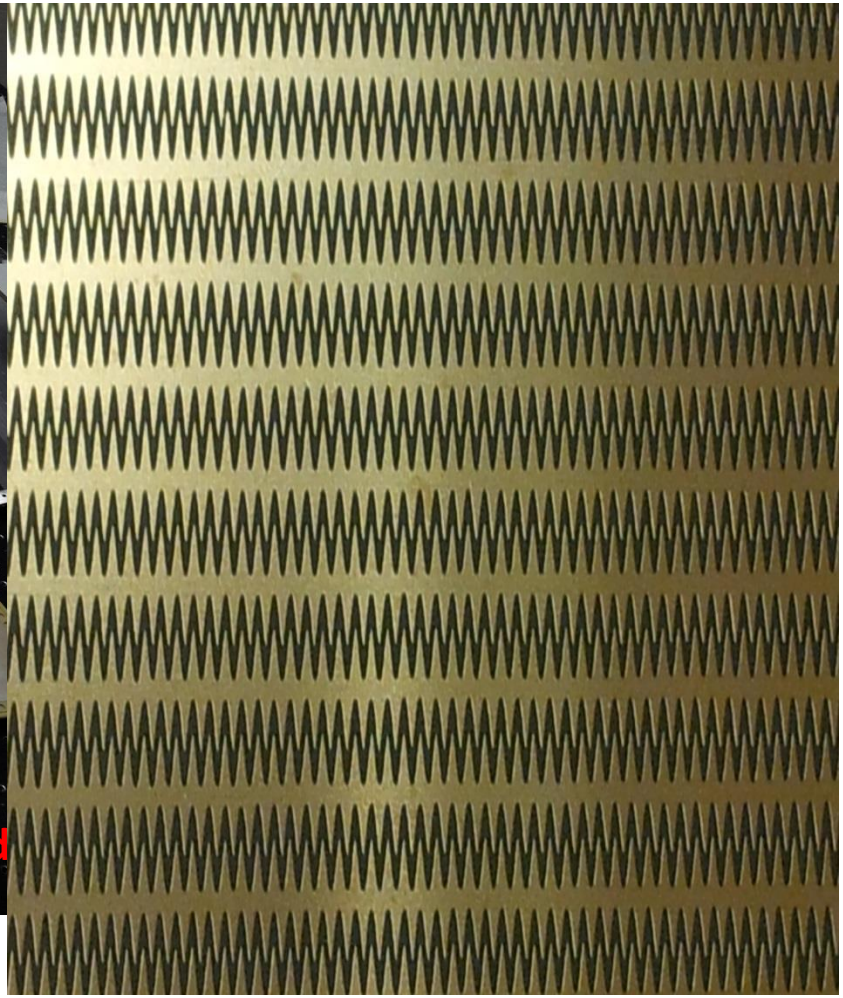


First version for 30cm GEM detectors from American Circuit, bending maximum 1.2% of board length.

The factory rebuilt one new board which reached a bending level of 0.26%, much better!!

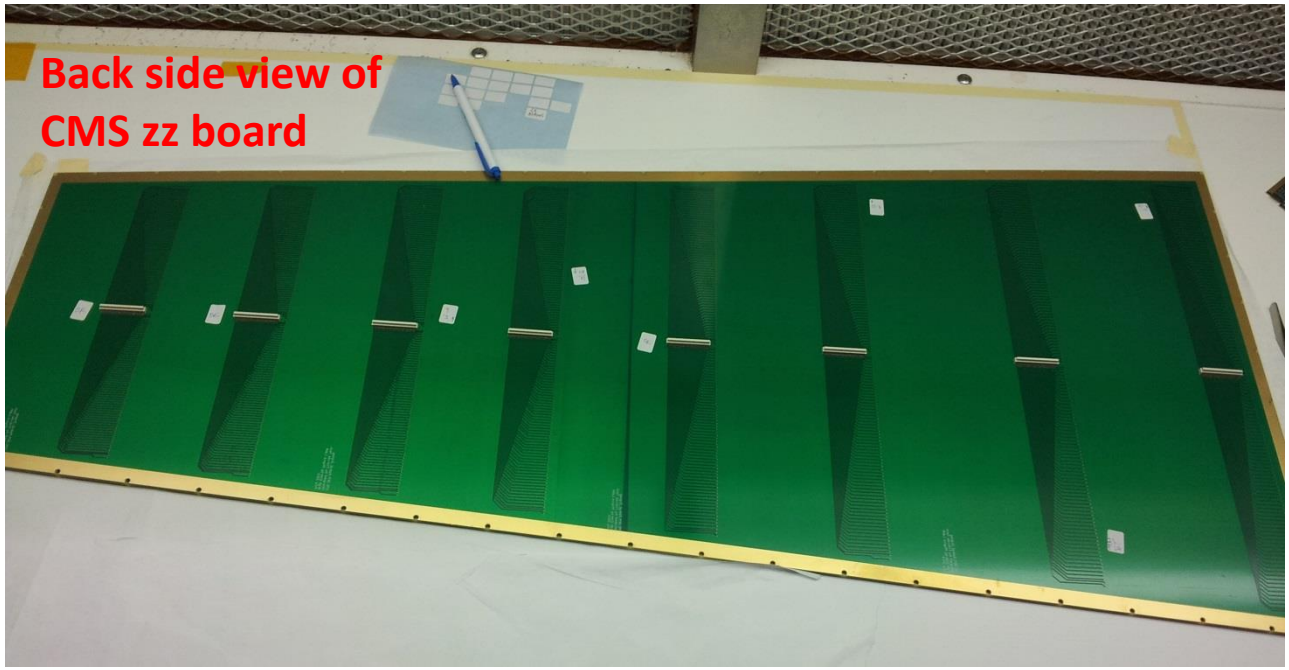
Zigzag board production





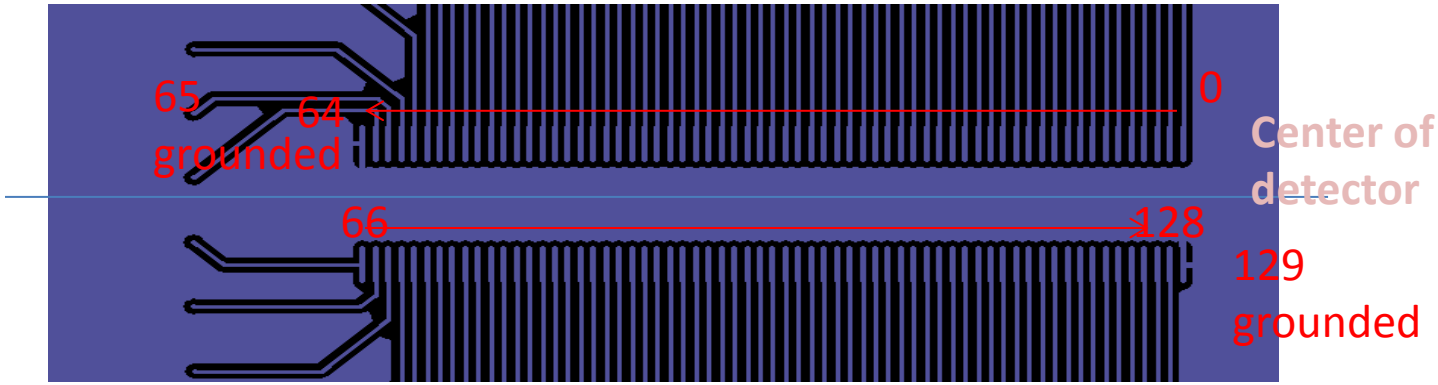
1 meter zigzag board from American Circuit, with FR4 material, bending level is 0.4%!!

Zigzag board production



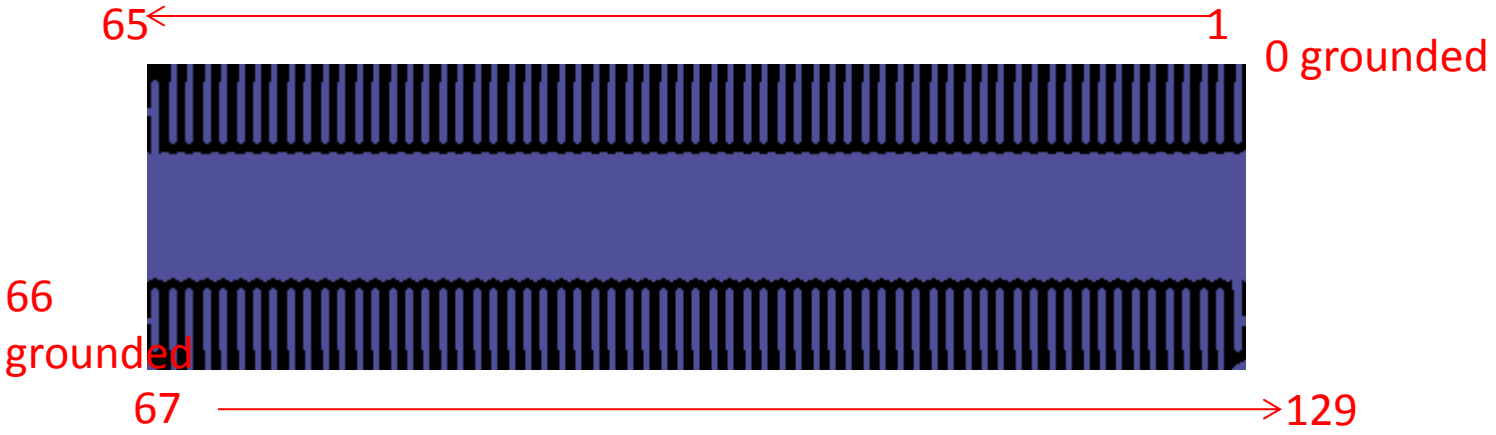
One problem for this board:
Connector side was produced as mirror image. Due to high symmetry mostly OK, but 2 readout strips and 2 ground strips were swapped resulting in the loss of 4 out of 128 channels per eta sector. Also easy to produce shorts when soldering connectors because of less experience on this 'fine' soldering.

Zigzag board production



Original design.

The left up and bottom right pins of Panasonic should be grounded

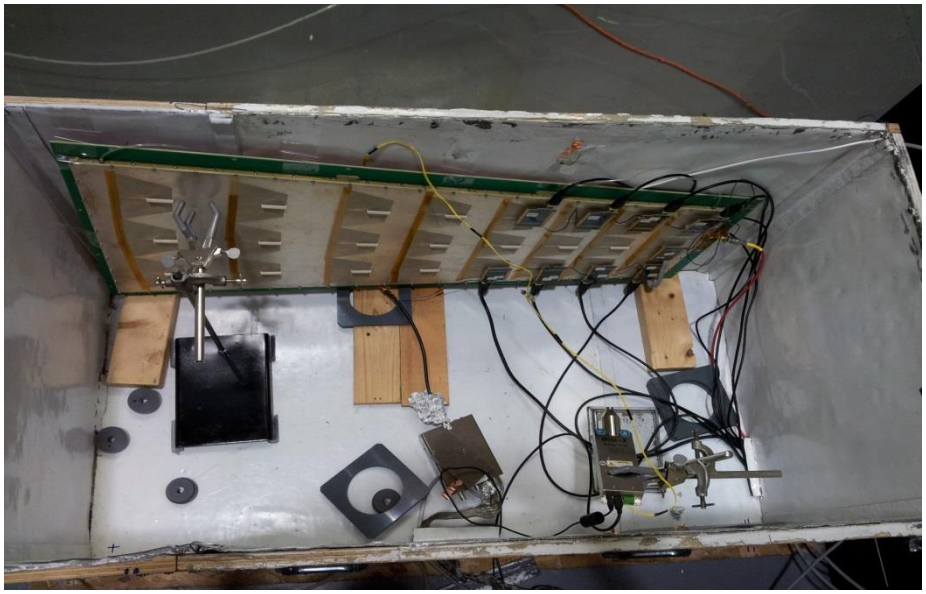


PCB production reversed this, ch0 and ch66 were grounded.

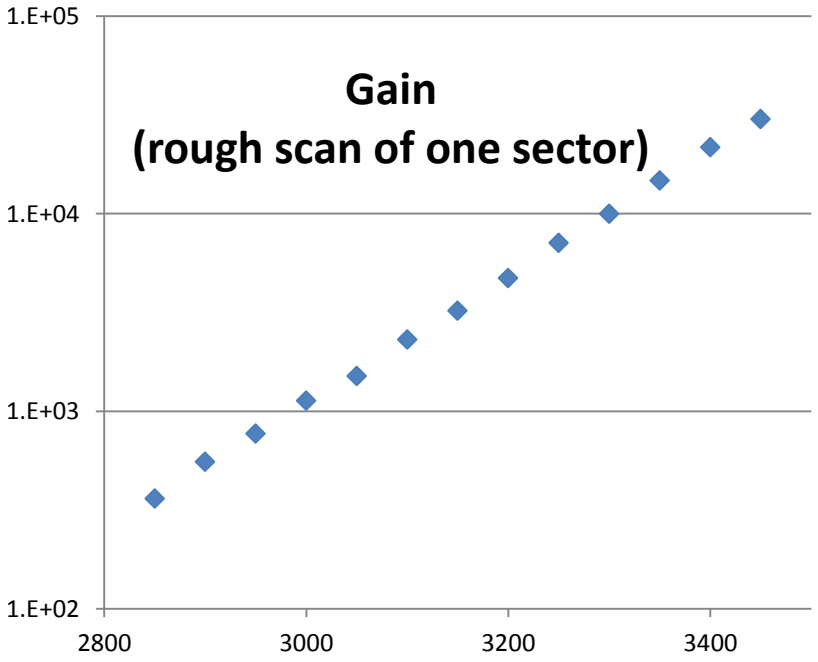
Ch65 and ch129 are also grounded when APV is mounted.

Beam test of CMS GEM GE1/1

- First, we saw very nice signals from CMS detector with straight readout strips. We took some data with X-ray source in our lab, also we did a rough gain measurement.

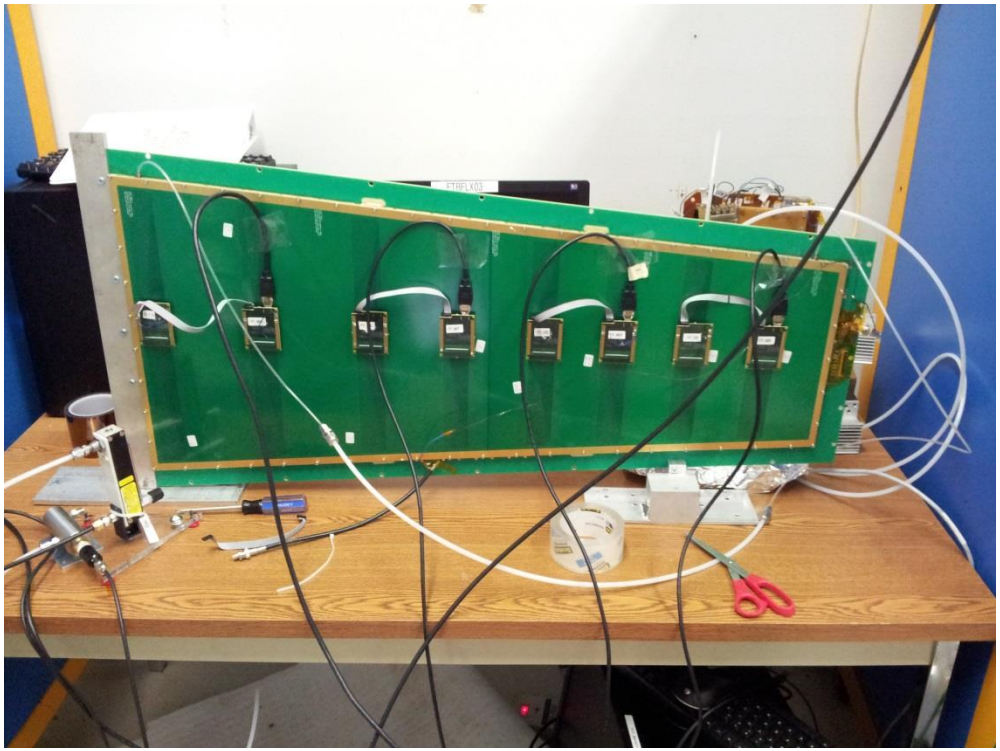


CMS detector vertically in the lead box in our lab



Beam test of CMS GEM GE1/1

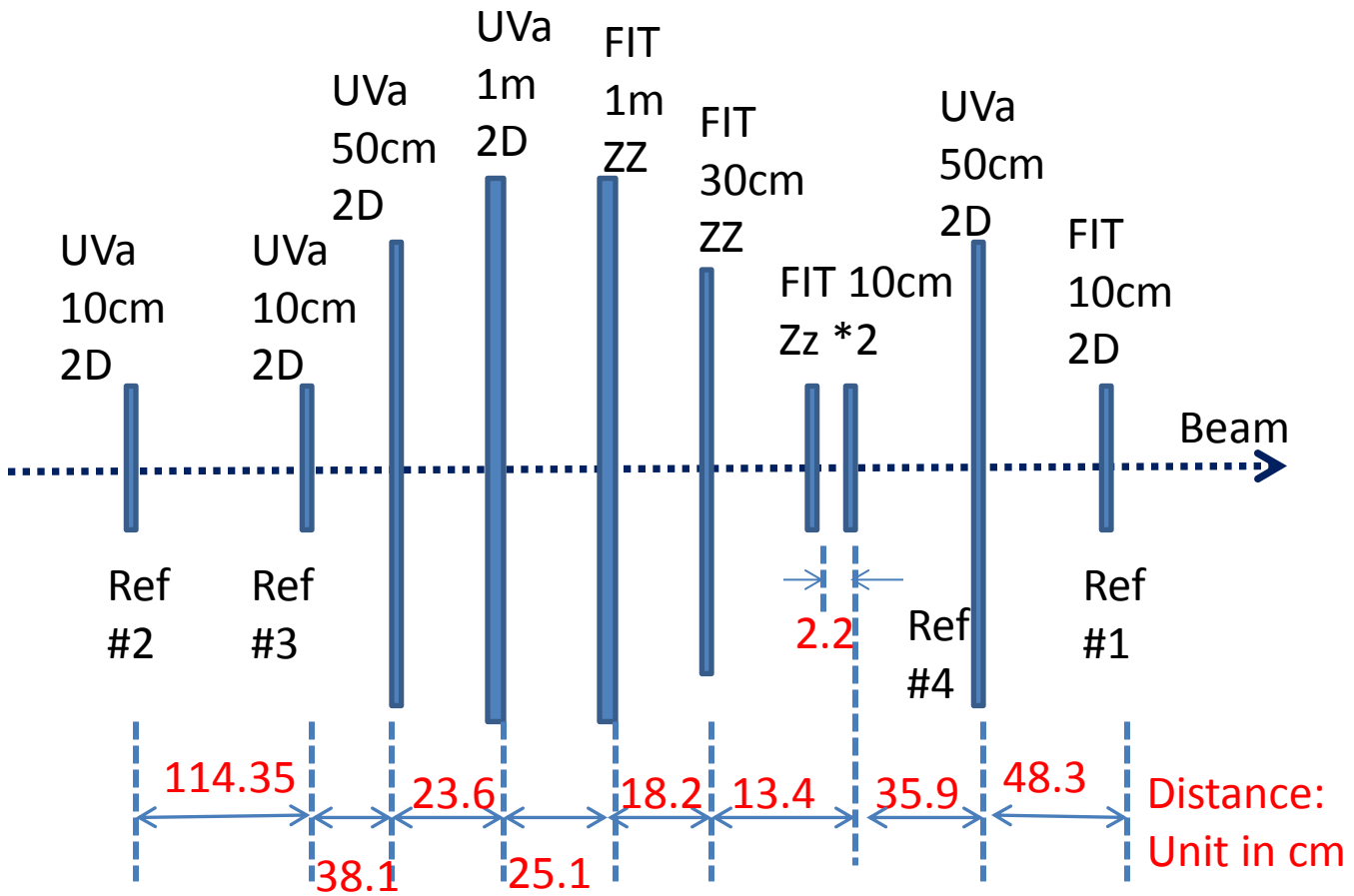
- After we got the zigzag board, we mounted it onto the detector and quickly checked that it was working fine. Then we brought the detector to Fermilab for a beam test (on Sep. 23rd)



CMS detector with zigzag r/o, ready for beam test

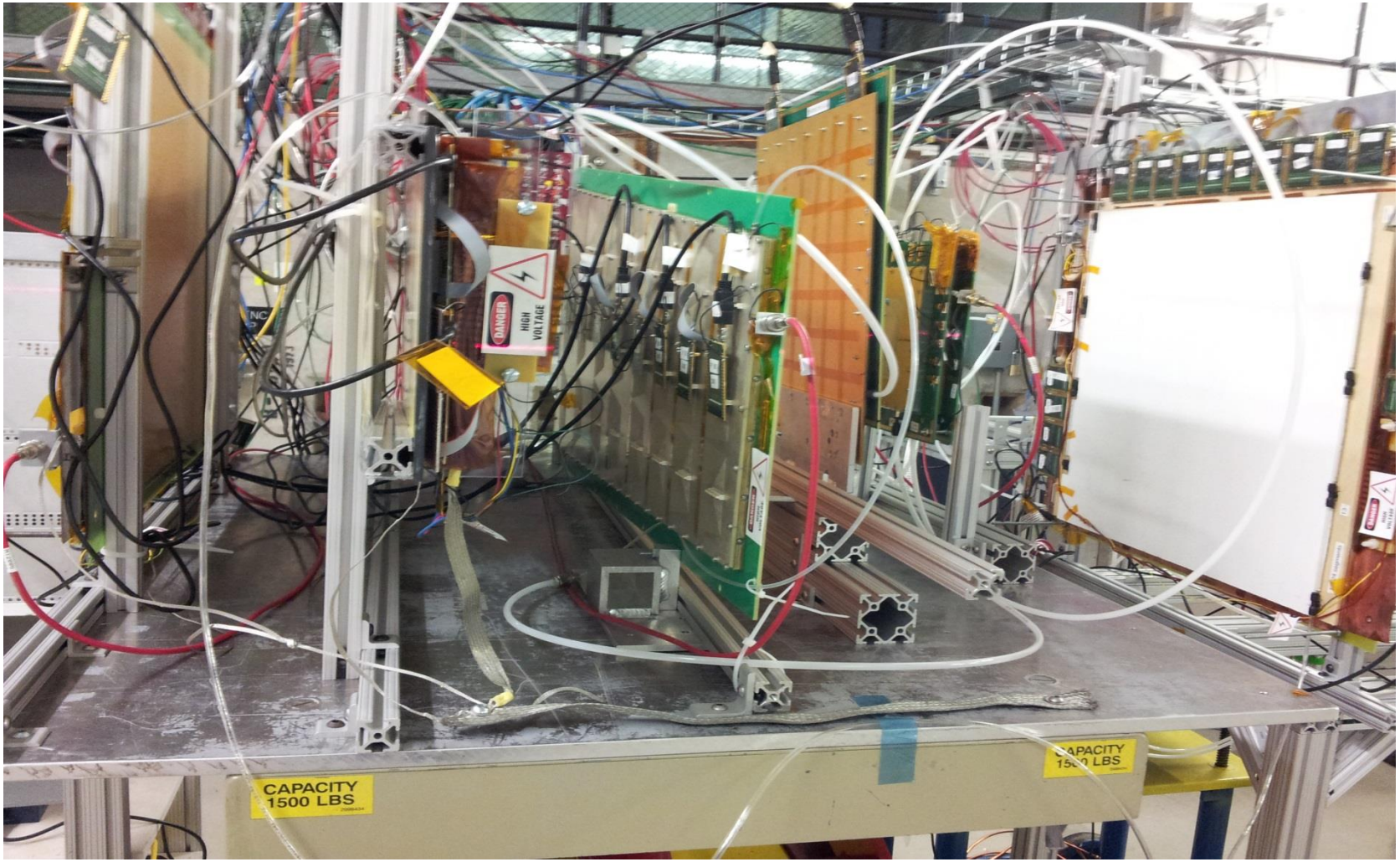
Detector mounted in test beam

Beam test of CMS GEM GE1/1



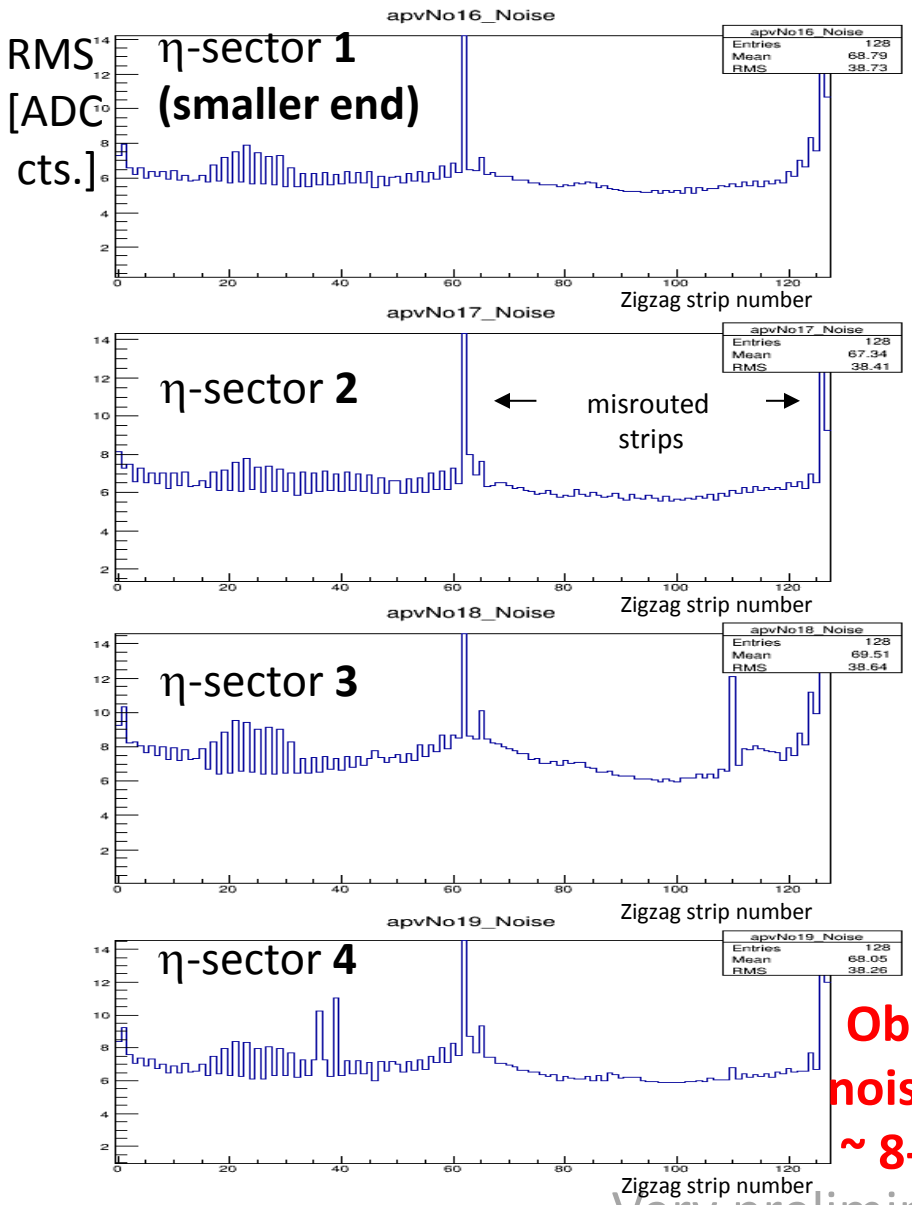
For this beam test, FIT&UVa have brought a total of 10 GEM detectors.
All FIT detectors are read out with Zigzag strip readout boards.
We also have swapped in the CMS straight readout board.

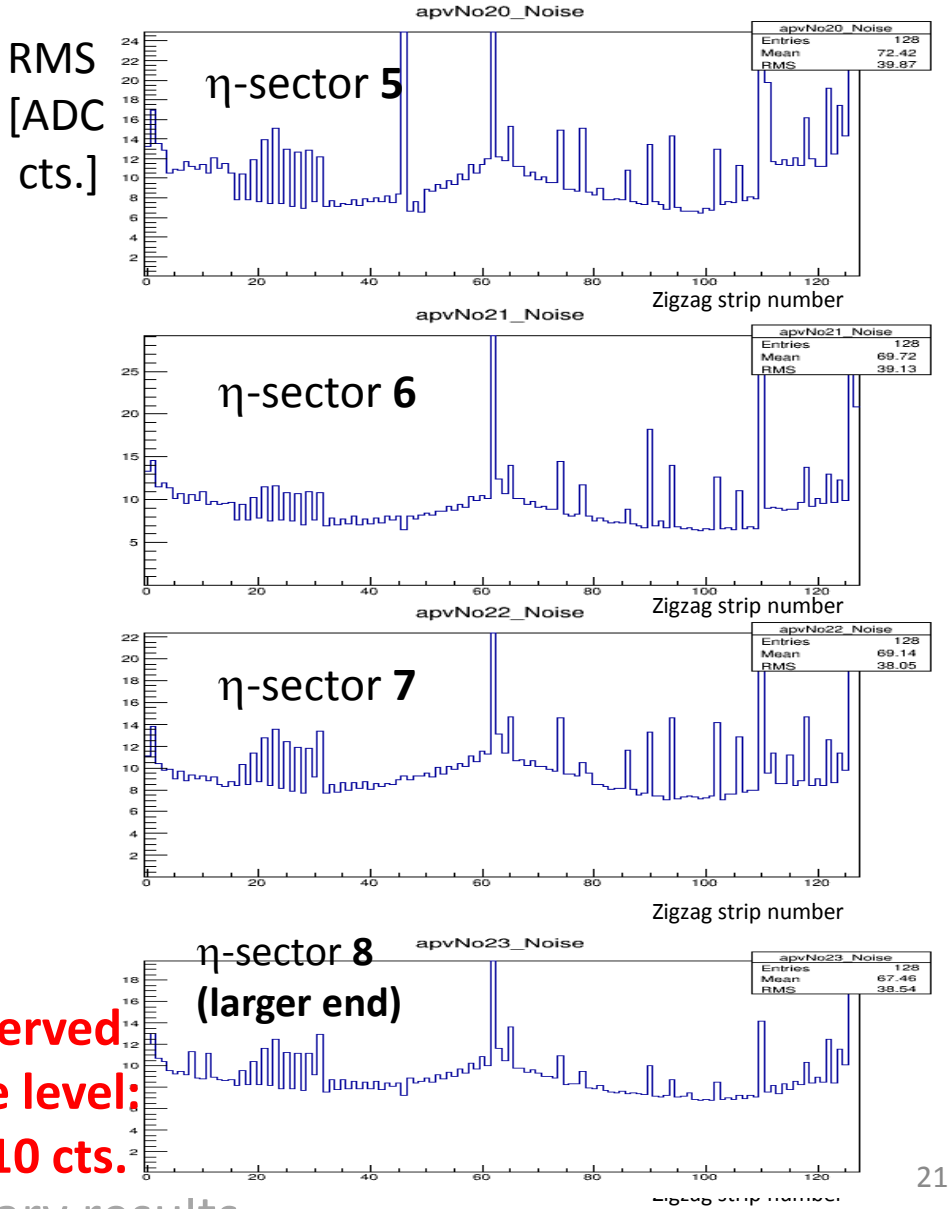
Beam test of CMS GEM GE1/1



CMS GEM GE1/1 detector setup in test beam

Beam test of CMS GEM GE1/1

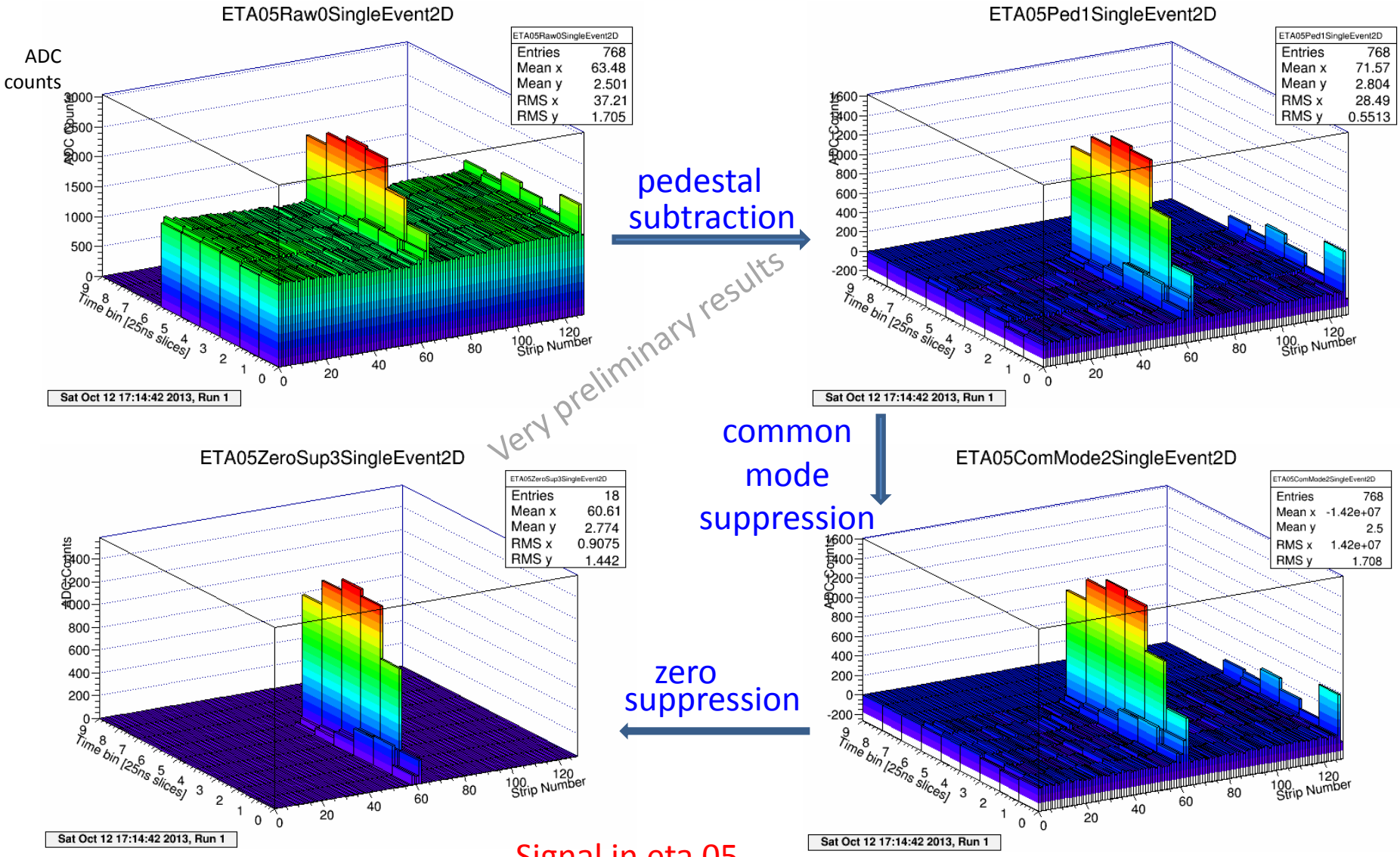




Observed noise level: ~ 8-10 cts.

Very preliminary results

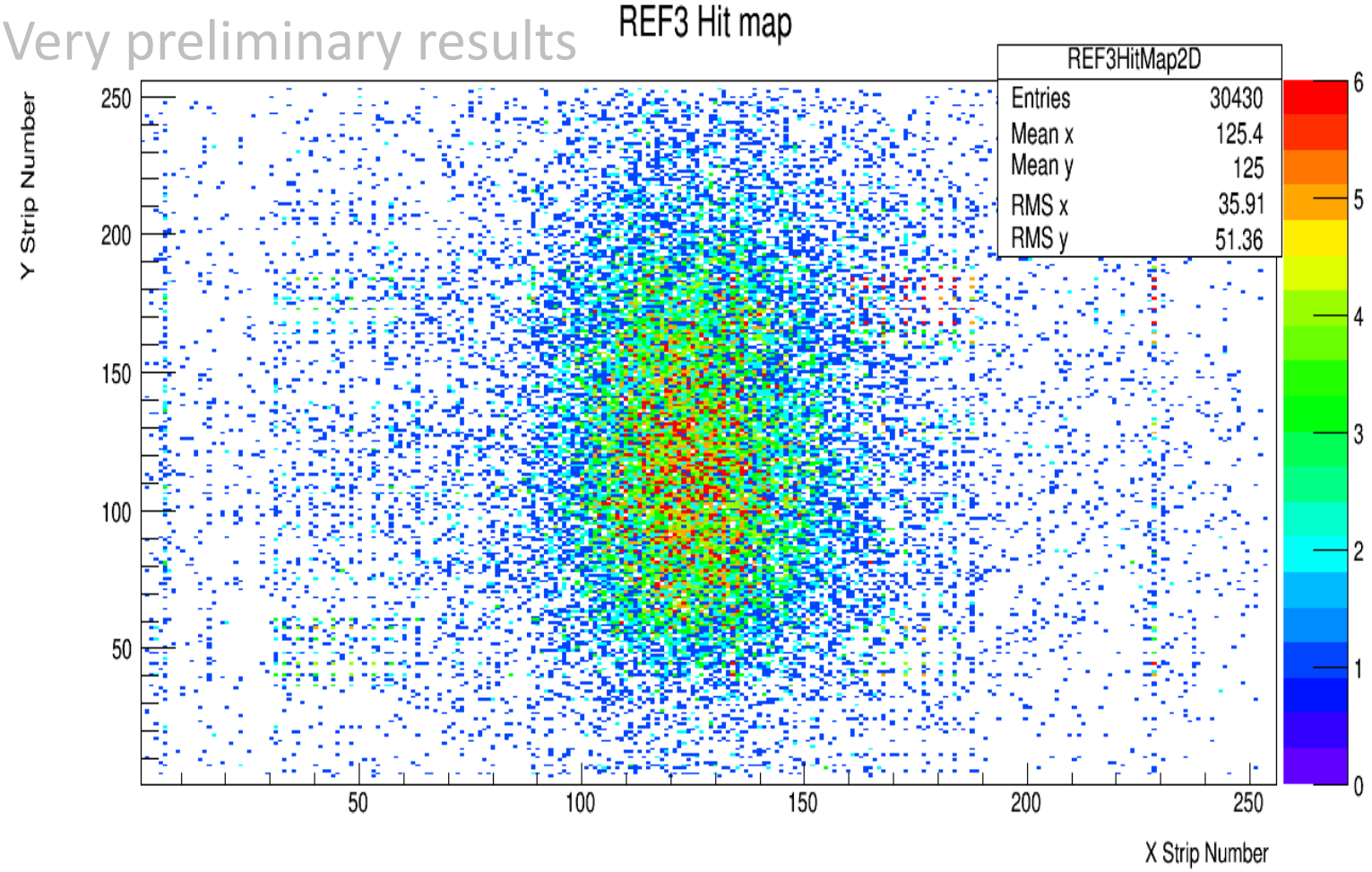
Beam test of CMS GEM GE1/1



Signal in eta 05.

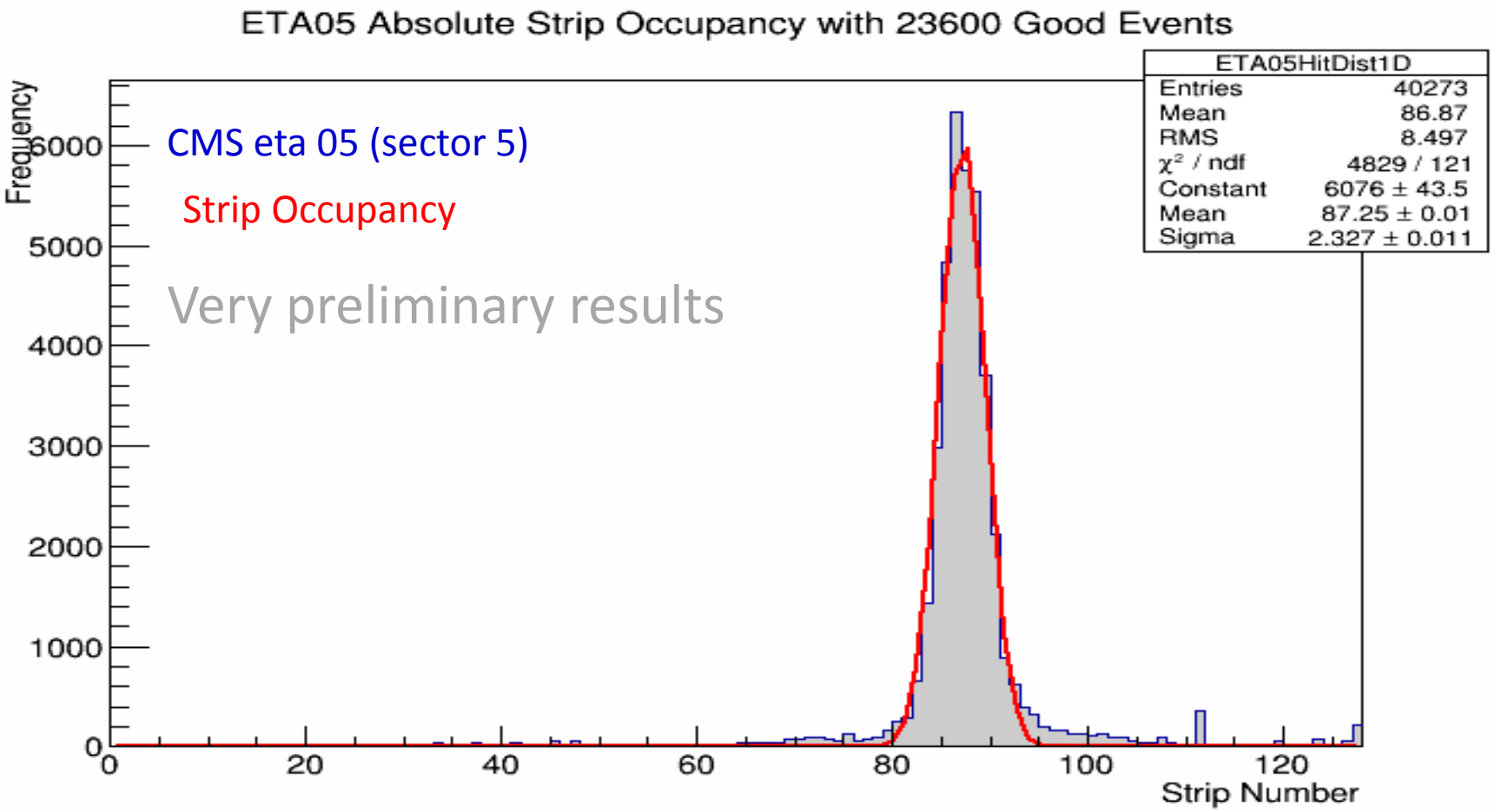
Beam test of CMS GEM GE1/1

Very preliminary results

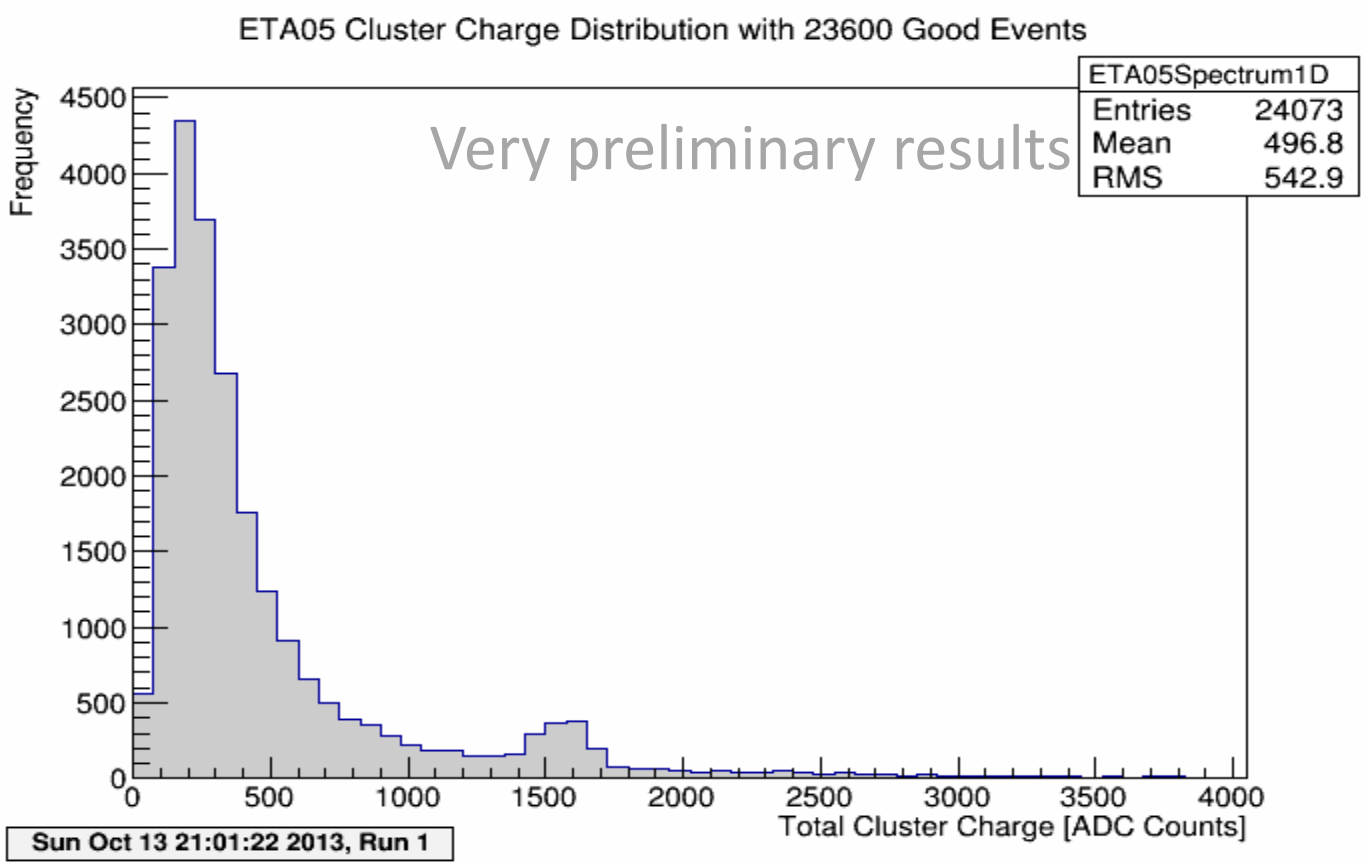


Beam profile from one of the 10cm 2D GEM trackers, showing beam size about 4cm

Beam test of CMS GEM GE1/1



Beam test of CMS GEM GE1/1



CMS zigzag sector 5, Charge distribution

Summary

- Readout with zigzag strips is a new method for MPGD, it helps to reduce the number of required readout channels a lot, e.g., a factor of 3 in the case of the CMS GEM.
- All the GEM detectors with Zigzag are tested to be working well.
- During this beam test effort at Fermilab, we scanned different beam spot positions on the CMS detector, also HV scans.
- CMS GE1/1 GEM with straight strip readout is under testing in the test beam, it is working well!
- Data analysis with AMORE is making progress.

Next to do

- Study other performance parameters of CMS GEM detector in our lab, such as gas gain, uniformity, stability, etc.
- Design a new version of zigzag board, get the reversed connector and shorting problem corrected.
- Build a prototype of the new larger version of the CMS GE1/1 detector (120cm length) with straight-strip and zigzag-strip readout boards.
- Test detector performance in magnetic field.
- Prepare for mass production of CMS GEM detectors at Florida Tech.
- … **Many thanks to the crews from Fermilab and FLYSUB group!**

Thanks!