Small Project Quarterly Report

DOE Office of Nuclear Physics (NP)
Facilities and Project Management Division

Proposal Name:
New Approach for 2D Readout of GEM Detectors

Report Date:
29 November, 2011

Principal Investigator:
Douglas Hasell

Work-scope Highlights:

This is the final report for this project. We will continue to test the various 2D readout concepts created through this project but the primary goals of the project have been achieved.

1. We have produced a number of different 2D readout boards for our test GEM detectors. The first boards had a simple cartesian (i.e. XY geometries) with different pitches (2000 micron, 800 micron, 600 micron, and 400 micron). Afterwards different geometries were produced: a stereo geometry with 22° stereo angle and a three layer XUV design with a 45° angle between the readout lines. Several figures are appended to the end of this article detailing the various readout geometries.
2. We have determined that the charge sharing between the different readout geometries is very simply determined by the ratio of line width to pad width. This can thus be tuned to the needs of the experiment or application. The charge sharing ratio is important in resolving events where there is more than one hit in the detector for an event.
3. We have shown that the coarser geometries (e.g. 2000 micron pitch) can be produced by almost any PCB manufacturer but that the finest pitches require a high technology company capable of laser drilling vias down to 25 micron in diameter and of producing lines down to 100 microns in width.
4. Pitches down to 300 microns have been achieved however, this is currently a practical limit. At this pitch lines and pads are 100 micron wide with a gap of only 50 microns. These fine lines require 25 or 50 micron vias which are difficult. Also the ENIG plating has a tendency to jump the small gaps producing shorts unless carefully controlled.
5. The stereo geometry allows a coarser pitch to be used thus easing manufacturing. In one direction the effective pitch is quite small and in the other direction it is larger so this is only applicable in situations where the different resolutions are acceptable.

6. The XUV readout design requires a three-layer readout board but again allows a coarser pitch to be used easing production and in this case a reasonable resolution is obtained in all directions. Also, the ambiguity of more than one hit in the detector per event is more easily handled with the added redundancy of the hit information.

We are also investigating using the charge collected on the back of the last GEM foil to trigger the GEM detector. This would be very useful as then the GEM detectors could be self triggering without the need for an external scintillator or similar detector to provide a trigger when an event occurs.

Further studies with different HV configurations and gas mixtures will be pursued to quantify and optimize the GEM detector performance.

Brief summary of activity issues, concerns, successes:

There was a period with production issues. Material that our preferred manufacturer obtained was delaminating and caused significant delays. This was to some extent related to difficulties in obtaining material from Japan after the earthquake and tsunami. New material was found and production completed but it should be noted that these foils are quite delicate and care must be maintained in processing, handling, and testing.

Milestones

The results of this project have been extremely useful. Developing the technology for this simple approach to 2D readout of GEM detectors allows readout designs to be tailored to the experiment and application. Production is considerably easier and cheaper than the previous techniques of laser or chemical etching. Also this approach allows 2D readout boards which are considerably thinner than those from the other approaches which require a backing layer for support. This further benefits the GEM detector in reducing the material budget in the active area.

This approach for producing 2D readout boards has already been successfully applied to the construction of the STAR Forward GEM Tracker upgrade at Brookhaven National Laboratories which was installed last month. This is an excellent example of applying the line and pad technology (see Figure 7) as the RΦ geometry had pitches varying from 400 to 800 micron as a function of radius and of course the line widths and gap widths also varied with radius to maintain a constant charge sharing ratio of 1:1. This geometry is ideal for this particular experimental application and would have been almost impossible and very expensive with laser or chemical etching.

The stereo readout design is being used in the OLYMPUS GEM tracking detector which will be constructed early in 2012. In this design it is useful to have a good resolution in one direction while the requirements on resolution in the other direction are not crucial. Thus a fairly coarse pitch, 1300 microns, can be used, easing production and cost while satisfying the physics requirements.

Budget

Summary of total expenditures:

ID #	Item/Task	Baseline Total Cost (AY$)	Costed & Committed (AY$)	Estimate To Complete (AY$)	Estimated Total Cost (AY$)
1.1	GEM foil design	$ 0	$ 0	$ 0	$ 0
1.2	GEM foil procurement	$ 15,392	$22,955	$ 0	$ 22,955
2.1	2D readout design	$ 0	$ 0	$ 0	$ 0
2.2	2D readout procurement	$ 32,028	$ 23,722	$ 0	$ 23,722
3.1	Test assembly design	$ 13,294	$ 21,436	$ 0	$ 21,436
3.2	Test assembly procurement	$ 19,573	$ 26,928	$ 0	$ 26,928
4.1	APV and R/O design	$ 13,294	$ 16,709	$ 0	$ 16,709
4.2	APV and R/O procurement	$ 49,744	$ 30,756	$ 0	$ 30,756
5.1	Assembly	$ 14,896	$ 5,630	$ 0	$ 5,630
6.1	Test	$ 1,779	$ 11,864	$ 0	$ 11,864
	Totals:	$ 160,000	$ 160,000	$ 0	$ 160,000

Summary of expenditures by fiscal year (FY):

	FY 2010	FY 2011	Cumulative
a) Funds allocated	160,000	0	160,000
b) Actual costs to date	51,022	108,978	160,000
c) Uncosted commitments	37,404	0	0
d) Uncommitted funds (d=a-b-c)	71,574	0	0

Details on, or further, issues/concerns

At this moment there are no outstanding issues or concerns with the project. We requested and received a no-cost extension until 8/31/2011 that allowed us to complete the fabrication of the readout boards we wished to test.

We will continue to use these readout boards and test setup to continue out studies of 2D readout of GEM detectors. Specific plans for the future are:

1. Use the backside of the last GEM foil as a trigger of a valid event.
2. Study resolution, cluster size, etc. as a function of different HV configurations and gas mixtures.

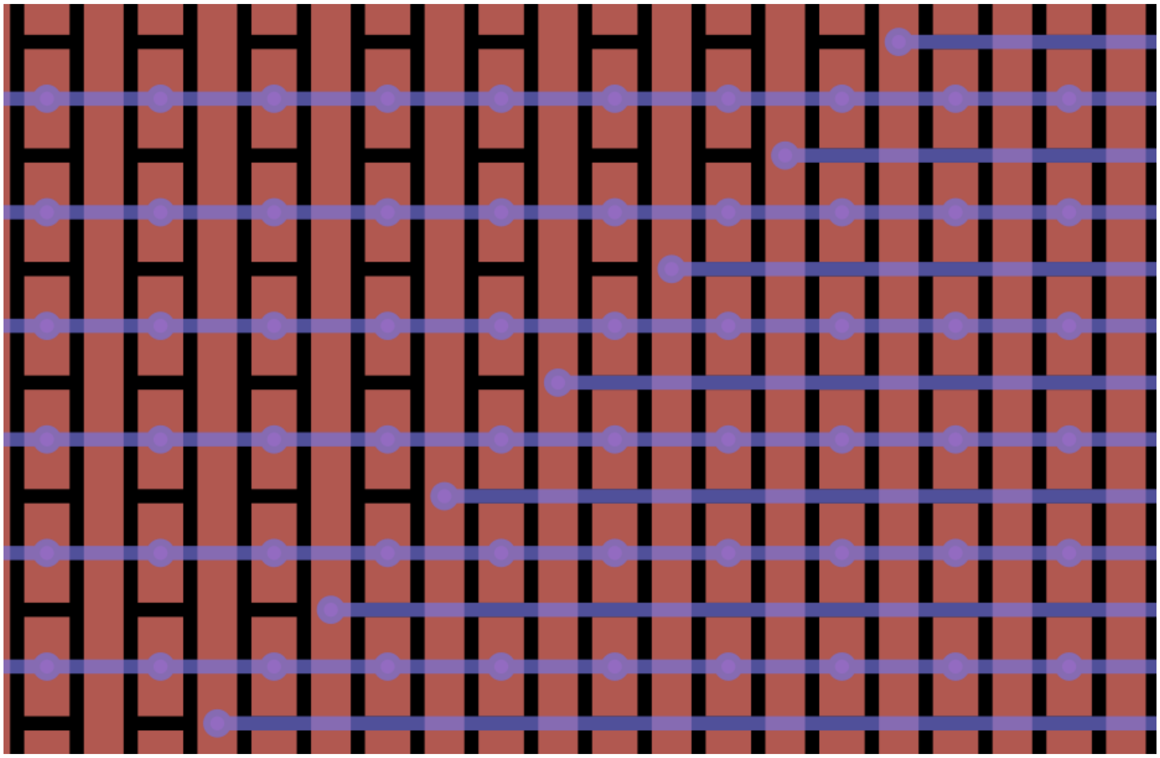

Figure 1 2D readout board with cartesian geometry and 2000 micron pitch between lines and pads. Lines are 700 microns wide. Pads are 800x1750 microns. There is a 250 micron gap between lines and pads and between pads and pads. The vias are 250 microns in diameters with 500 micron diameter landing pads. Both lines and pads are connected through vias to the bottom layer of the readout board and routed to connectors along one edge of the readout board.

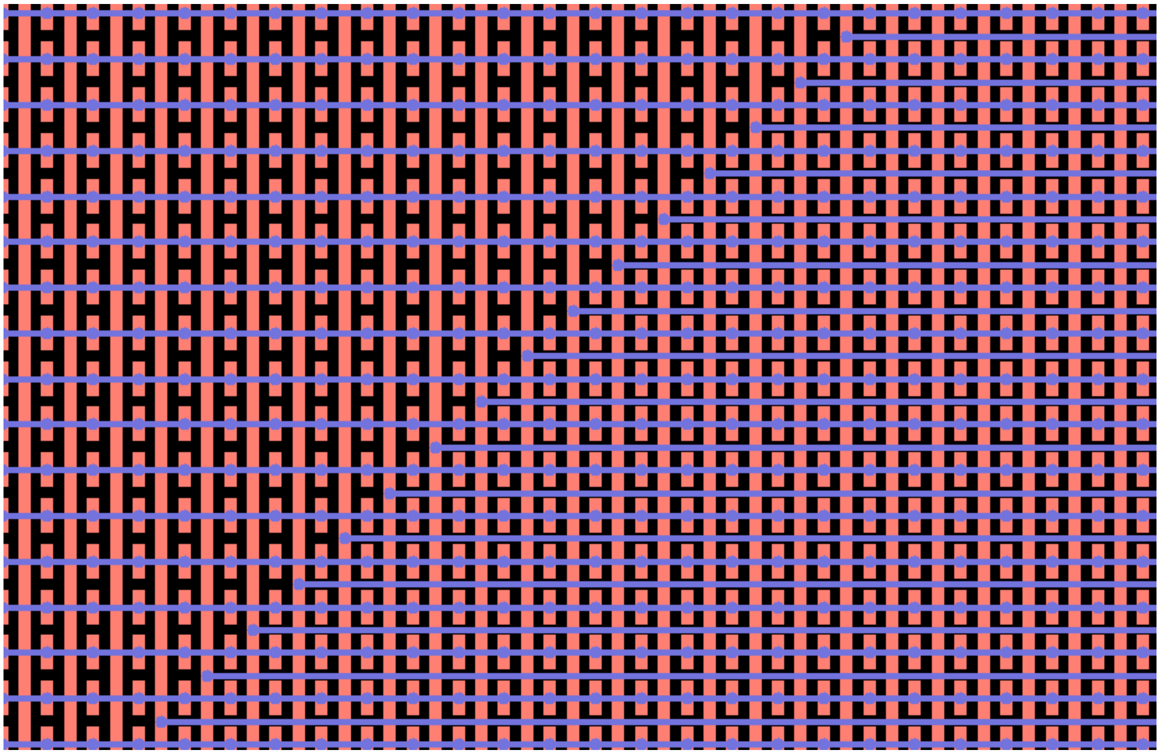

Figure 2 2D readout board with cartesian geometry and 800 micron pitch between lines and pads. Lines are 200 microns wide. Pads are 200x600 microns. There is a 200 micron gap between lines and pads and between pads and pads. The vias are 100 microns in diameters with 200 micron diameter landing pads. Both lines and pads are connected through vias to the bottom layer of the readout board and routed to connectors along one edge of the readout board.

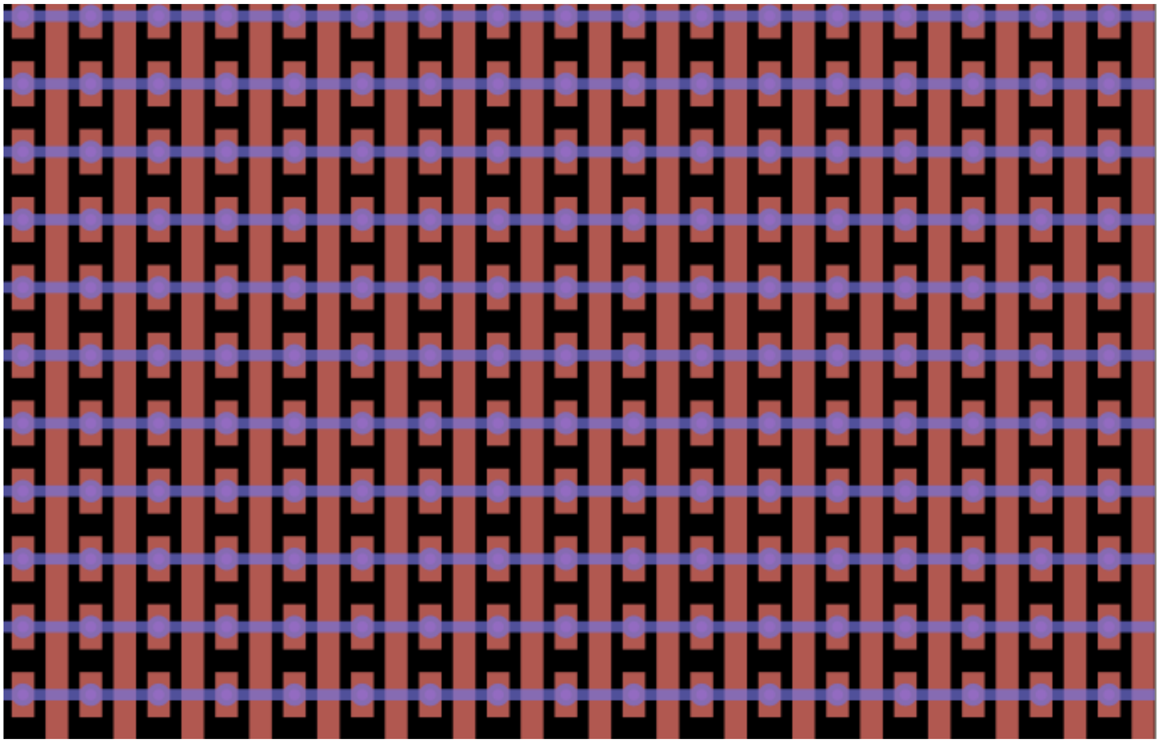

Figure 3 2D readout board with cartesian geometry and 600 micron pitch between lines and pads. Lines are 200 microns wide. Pads are 200x400 microns. There is a 100 micron gap between lines and pads and between pads and pads. The vias are 100 microns in diameters with 200 micron diameter landing pads. The pads are connected through vias to the bottom layer of the readout board and routed to connectors along one edge of the readout board. The lines run to the top and bottom edges of the board and are connected there.

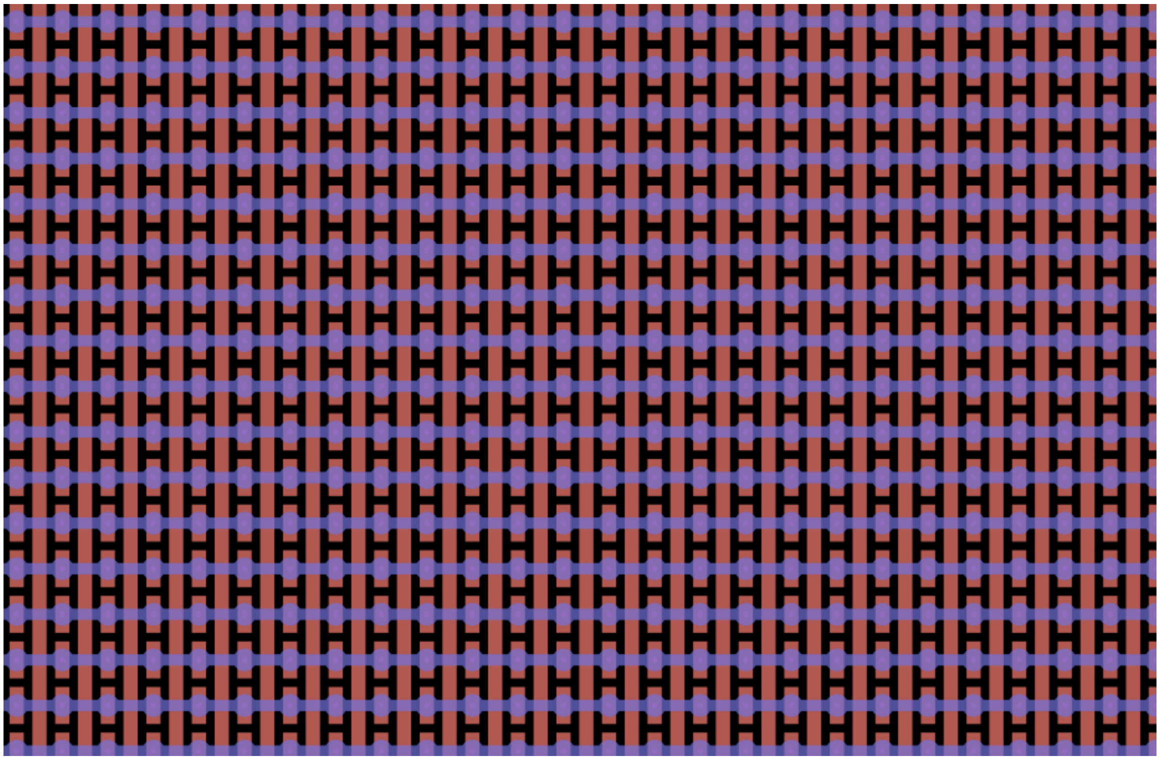

Figure 4 2D readout board with cartesian geometry and 400 micron pitch between lines and pads. Lines are 125 microns wide. Pads are 125x325 microns. There is a 75 micron gap between lines and pads and between pads and pads. The vias are 50 microns in diameters with 200 micron diameter landing pads. The pads are connected through vias to the bottom layer of the readout board and routed to connectors along one edge of the readout board. The lines run to the top and bottom edges of the board and are connected there.

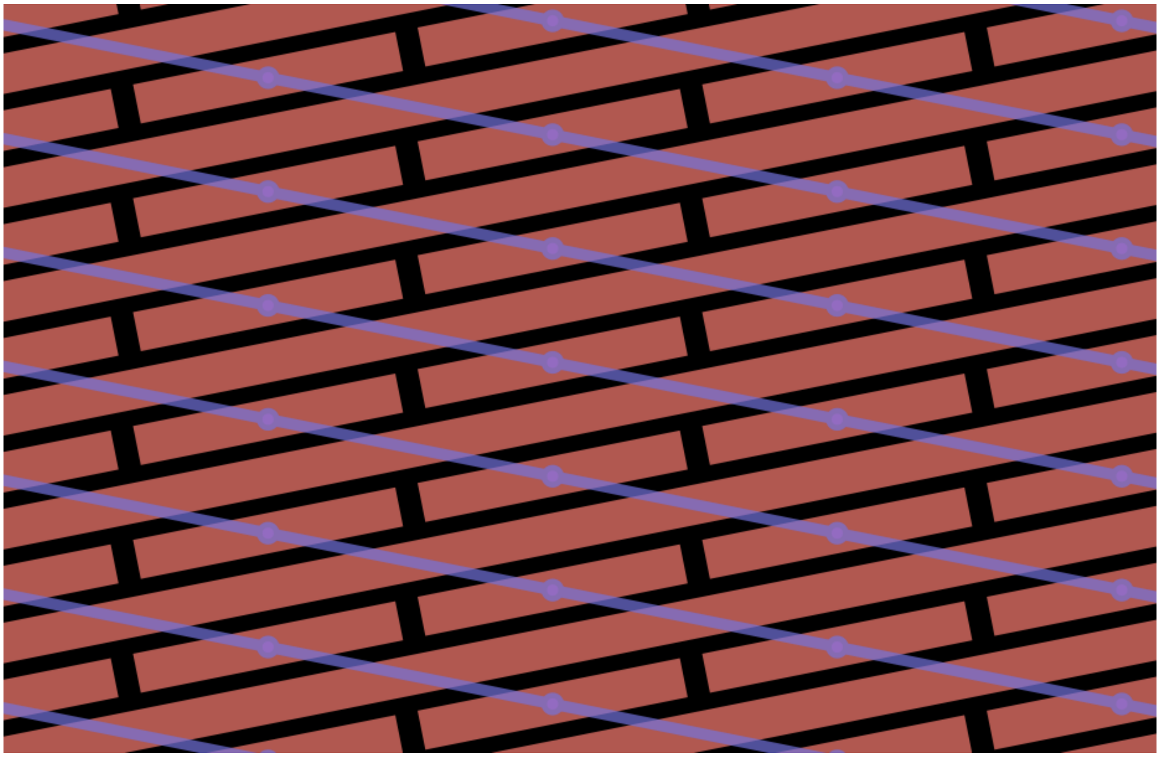

Figure 5 2D readout board with stereo geometry with a 22° angle between readouts. There is a 1000 micron pitch between lines and columns of pads with a pitch of 2500 micron between pads. Lines are 350 microns wide. Pads are 350x2350 microns. There is a 150 micron gap between lines and pads and 200 microns between pads and pads. The vias are 100 microns in diameters with 200 micron diameter landing pads. The pads are connected through vias to the bottom layer of the readout board and routed to connectors along one edge of the readout board. The lines run to the edges of the board and are connected there.

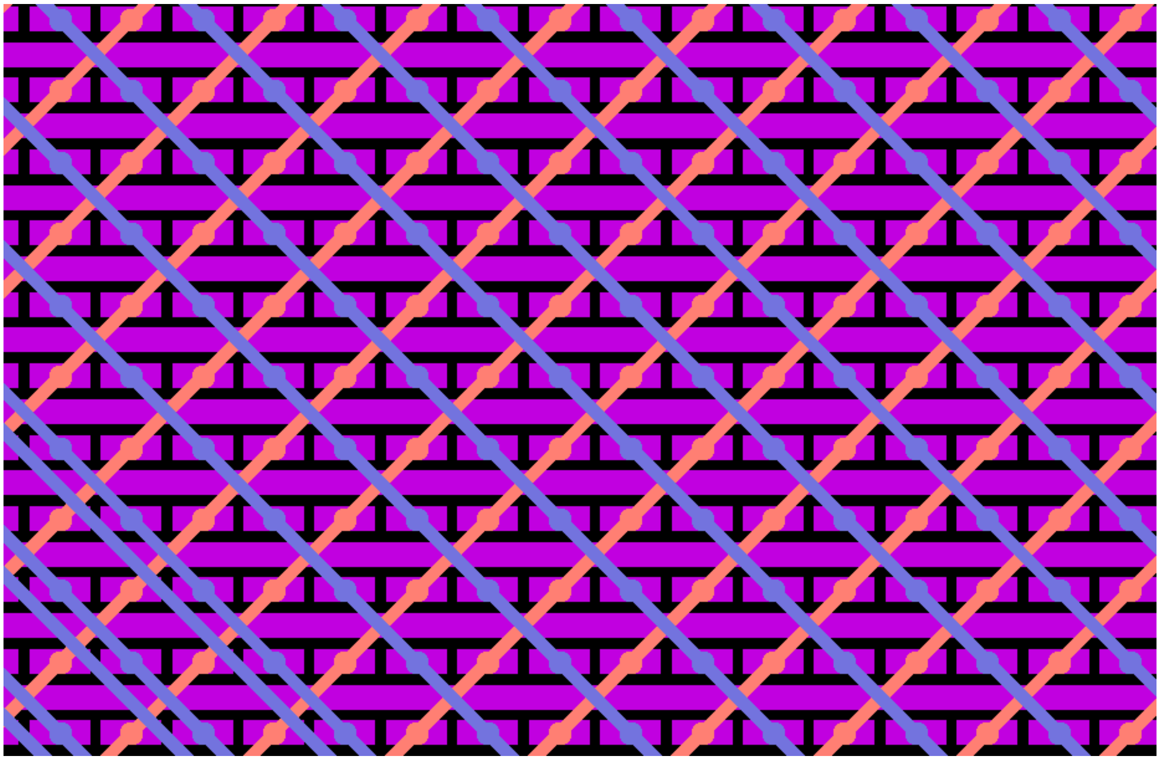

Figure 6 2D readout board with XUV geometry with a 45° angle between readouts. There is a 1250 micron pitch between lines and columns of pads with a pitch of 1250 micron between pads. Lines are 425 microns wide. Pads are 425x1050 microns. There is a 200 micron gap between lines and pads and 200 microns between pads and pads. The vias are 200 microns in diameters with 400 micron diameter landing pads. The pads are connected through vias to the bottom layer of the readout board and routed to connectors along one edge of the readout board. The lines run to the edges of the board and are connected there. Half of the pads are connected together at an angle of 45° relative to the horizontal lines and the other half are connected at an angle of -45°.

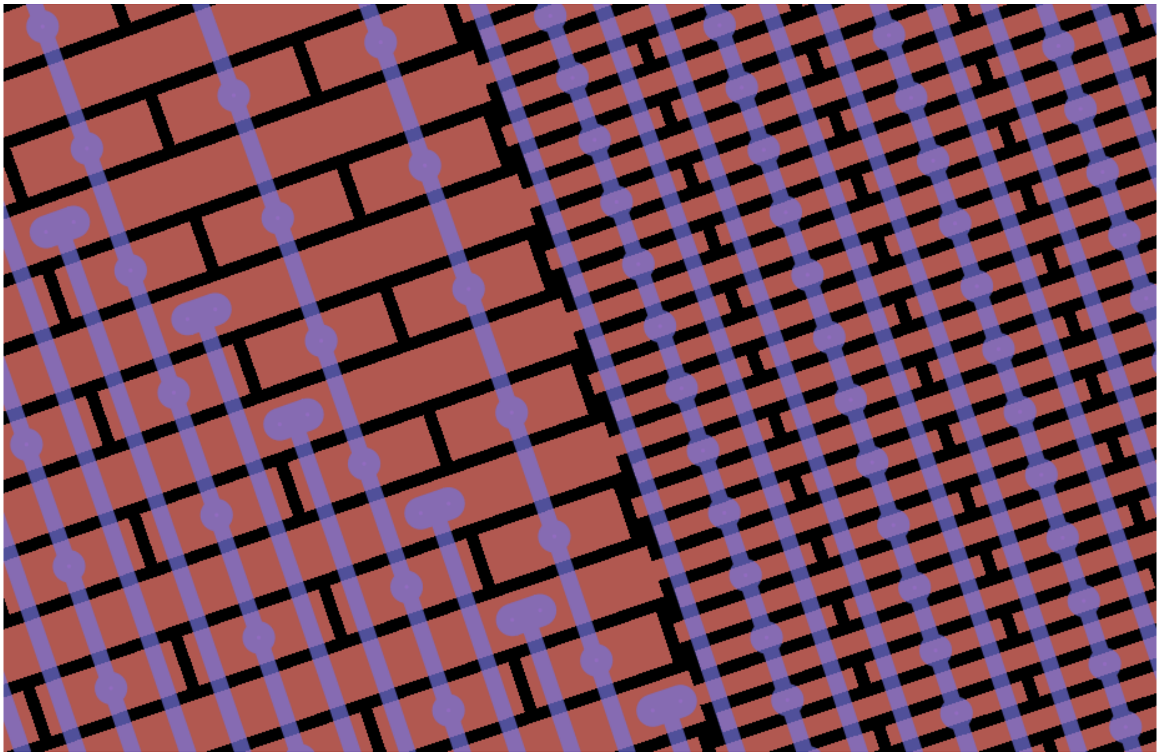

Figure 7 Close-up of the STAR Forward GEM Tracker (FGT) readout board. The readout follows an RΦ or cylindrical geometry. Pads at a constant radius are connected together and routed to connectors along either edge of a quadrant providing a measure of the radial position for an event. Lines running at a constant azimuthal angle measure the Φ coordinate. To maintain equal charge sharing the pitch of the Φ lines varies with radius. Show is the transition region at half of the largest radius where Φ lines from the larger radius (right side of figure) have a pitch of 400 microns and every other line then either ends or transitions to a one with 800 micron pitch. Line and pad widths vary with radius while the gaps are held constant at 75 microns. Each pad is connected by a single via but the lines have two vias for redundancy.