Proposal for Very Forward tracking in STAR
(up to eta=5)

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INTRODUCTION

There is a gap in the forward rapidity coverage for tracks in the present version of the STAR experiment, and there is likely to be the same issue in EIC detectors because of the structure of detectors such as the FGT disks and the flanges on beam pipes. The rapidity region from roughly 4.5 to 5 is important for two body diffractive physics in p-p running, for polarimetry at RHIC and EIC, and for very low x studies in e-p running.

We propose to develop a type of tracking detector, a Thick GEM, specifically to cover this kinematic region, and to test it in STAR. The primary reason that the detector we propose could get to higher eta than any other detector is that it would be very close to the beam pipe, less than 1 cm, at a region where the beam pipe is 3 inch diameter, not 5 inch, and it would be closer to the interaction region than a flange with a massive amount of material.

The most practical detection scheme in STAR for high rapidity is to put tracking around the beam pipe near the BBC, closer to the interaction point than the large vacuum flanges near the small BBC counters. This can cover up to eta=5, as measured from the nominal interaction point.

PROPOSAL

The original motivation was to follow up on our Data Analysis and Monte-Carlo of events with correlated BBC and ZDC hits, presented at the 2010 RHIC Spin meeting in Ames Iowa. [1] These have kinematics consistent with diffraction dissociation, and show enhanced spin asymmetries compared to single detector asymmetries. We hypothesize that they are neutron into the ZDC and a single (or a few) charged pions into the BBC. A both MC and data show all the events of interest to be in very close to the beam pipe, covered by the inner 6 BBC counters. The MC indicates that the pions of interest in diffraction dissociation are actually in the inner half of the inner BBC tiles.

Local polarimetry will become more important in STAR as the proton beam intensity increases, particularly at 250 GeV. The gas jet target measurement is typically done at most once per year. The p-Carbon polarimeters have always had rate issues, and this will get worse in the future. Additionally, when the P-Carbon polarimeter electronics is changed, they must be recalibrated. Local polarimetry is essential for tuning the spin precession snakes for longitudinal spin running. It is known that the BBC asymmetry alone is essentially unmeasurable at 250 GeV, but there is a measurable spin asymmetry when using combined BBC and ZDC information , event by event. The ZDC sensitivity has changed several times over the years because of HV changes and cabling changes. It would be good to have another constraint for cross-checking year to year.

There is a fairly simple way to improve the situation with better spatial resolution in the area of the present small BBC counters. Thick GEM chambers which can be made using PC board technology can give resolution of 1 mm to a few mm at minimal cost. In addition, the readout electronics can be copied from the current FGT electronics, with major savings in development cost.

The FGT disks which are being installed in STAR have an inner radius of 11.5 cm so that for them to cover to eta=5, they would have to be at 8.5 meters distance, where particles would traverse the thick stainless steel flange and both the 3 inch and 5 inch pipes at a grazing angle of 13.5 mr. For that case, the total material would be about 20 radiation lengths or 5 interaction lengths. Fig[1], Fig[2]

We designed, and had produced, printed circuit boards for a prototype detector to use Large GEMs for very forward particles in STAR (eta 4 to 5). These consisted of the 9 cm hexagonal GEM foil,(7000 holes), Fig[3], the readout plane with 150 pad rows and 150 stripes on 1 mm centers, Fig[4], Fig[5], and a coupling plane from the readout plane to the APV chip which would eliminate the expense of 4 layers with 7000 blind vias if the scheme of Zebra rubber connectors on the edge works. Fig[6], Fig[7] These were designed and produced for minimum cost in small quantities, roughly $400 per board. These have not yet been tested due to a lack of funding and effort.

We are in the process of setting up a test stand.

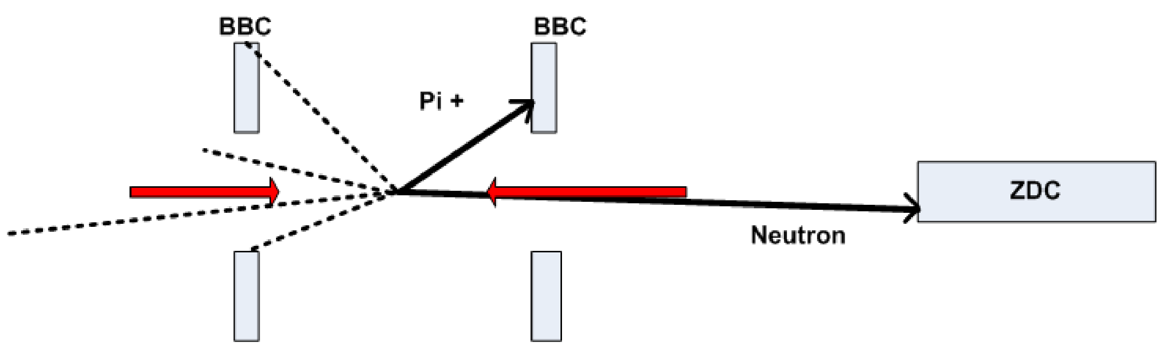

Figure 1) Example of 2-body event with correlated hits in ZDC and BBC. The innermost BBC counters are at approximately rapidity of 4 to 5 , and are around 9 cm wide. The effective (n pi+) mass resolution with this BBC-size position resolution on the pion is several GeV/c^2. A resolution of around 2 mm at the BBC would be commensurate with the 1 cm resolution on particles in the ZDC which is further away.

Proposed Work, Costs, and Deliverables

While we have been able to produce prototype PC boards of all the types needed for a detector, further work is needed in the following areas:

1) A combination ZEBRA connector positioning, and compression system has been partially designed, but not produced. In current plans, this system will also be a ground plane between the readout board and the routing board.
2) Testing of the GEM foils at High Voltage in Argon-CO2 gas is needed. The boards were designed and produced with the copper recessed away from the actual holes in the board, which tests in Israel and at CERN indicated was the correct approach to insure stability, but we have not tested it yet.
3) A better High Voltage divider system is needed. Our current test chamber has some resistors on a PC board and rather long wires (10 to 15 cm) to each plane of the chamber.
4) A way to control the shape of the electrostatic field at the edges of the chamber is needed in order to increase the efficiency near the edges. A study with an electrostatic simulation program would be a good project for a student.
5) Beam tests to determine the maximum particle flux which can be tolerated are needed. We note that the TOTUM detector at the LHC has GEM foils operating in the very forward direction, and there are references quoting high rate capability in Thick Gems.

Proposed R&D funding	
Electronics (Extra ARC and ARM boards from FGT, cables,)	$12K
RORC and SIU	$ 4K
More APV carriers (including wire bonding)	$10K
M&S	$20K
(mechanical parts, backplane, electronic parts, second version of PC boards, Gas, HV cables, etc)	
Labor	$60K
(1/5 of postdoc, EE time for development, etc, Mech. tech)	
Travel to BNL	$18K
Sum R&D	$124K

Estimated Eventual Project construction cost (after R&D)
To produce 24 chambers plus spares, to cover e.g. the 12 small BBC counters on each end of STAR with 1 layer of tracking.

Fabricate 24 detectors	
PC boards	$12K
APV carriers	$10K

Gas and Cable	$12K
M&S	$10K
ANL Labor	$40K
BNL Labor	$40K
Travel	$24K

Sum Construction	$148K

References
(Many more are in our more extensive documentation)

[1] "Looking for Diffraction Dissociation at RHIC"
http://drupal.star.bnl.gov/STAR/blog/dgu/2010/may/06/rough-draft-iowa-diffraction

[2] "Advances in Thick GEM-like gaseous electron multipliers. Part I" C. Shalem, et al, NIM A558: 468-474, 2006

[3] "Measurement of basic features of Thick-GEM and Resistive-GEM" R. Akimoto, et al, 2010 JINST 5 P03002

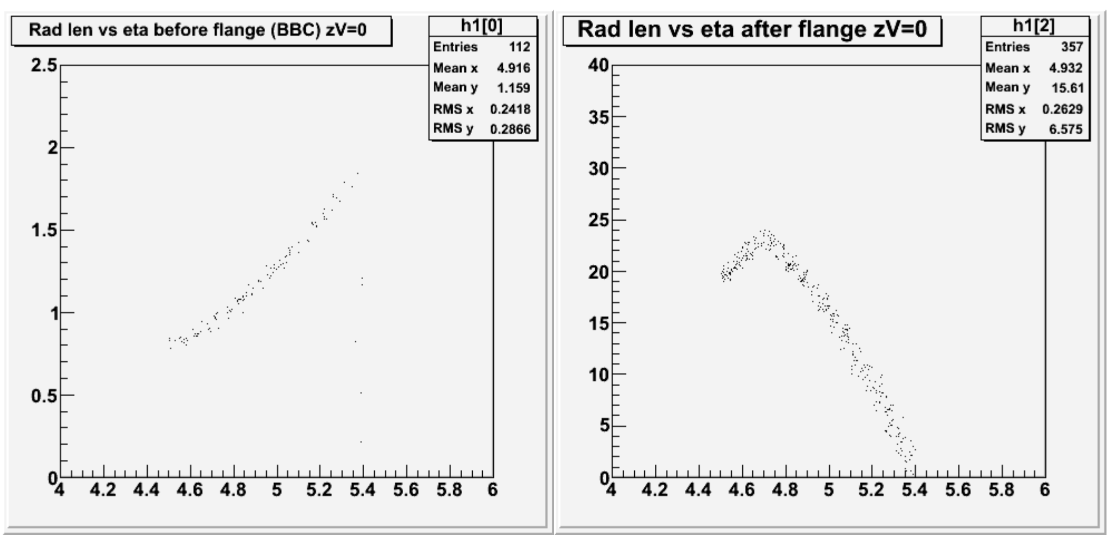

Figure 1 Radiation length before and after the vacuum flange between 3 inch and 5 inch pipes just downstream lf the BBC. The flange is half aluminum and half stainless steel, explosion welded.

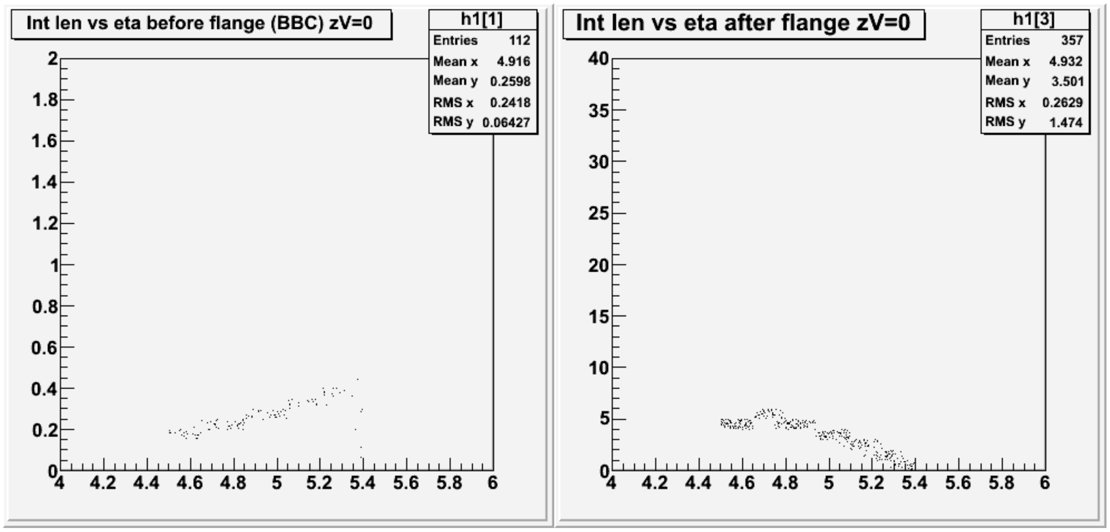

Figure 2 Radiation length before and after the vacuum flange between 3 inch and 5 inch pipes just downstream lf the BBC. The flange is half aluminum and half stainless steel, explosion welded.

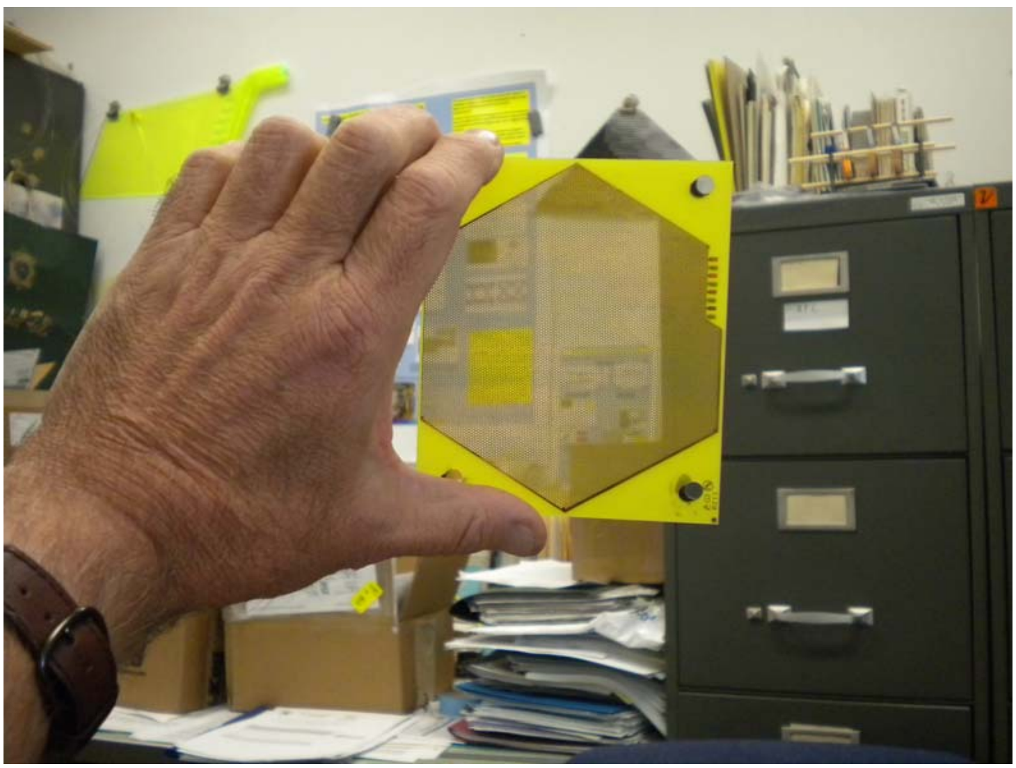

Figure X2 Thick GEM foil to match small BBC counter size. Holes are on 1 mm centers, almost equilateral triangular mesh.

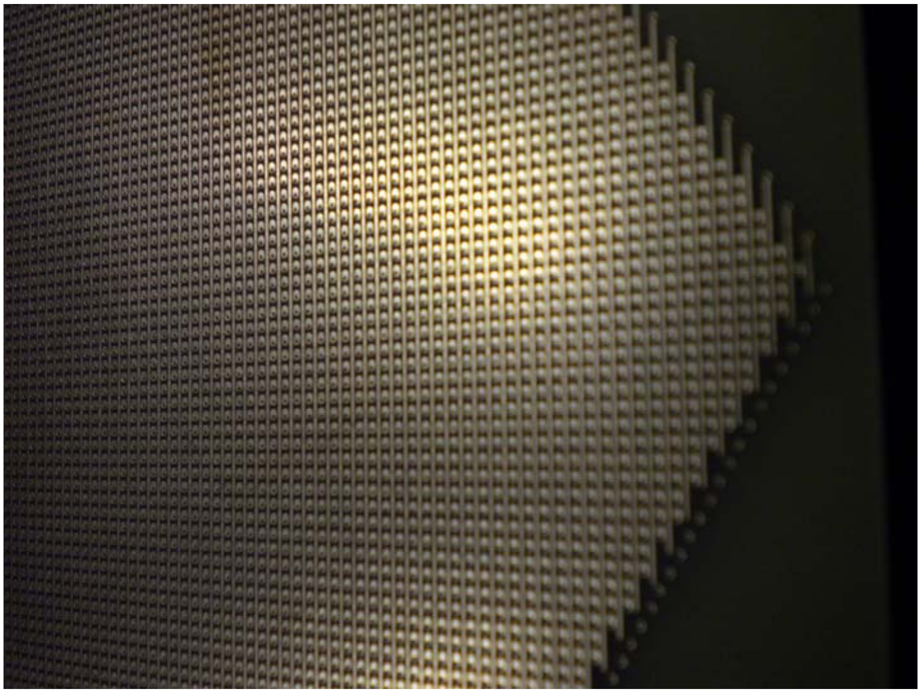

Figure X3 Front of readout plane, which is a 2D board,   showing pad and strip structure. The strips are 1 mm apart.   The pads are on 1 mm centers and are elliptical. The pads in each row are connected on the back of the board. The signals are routed on the back to pads around the edges for readout connections.

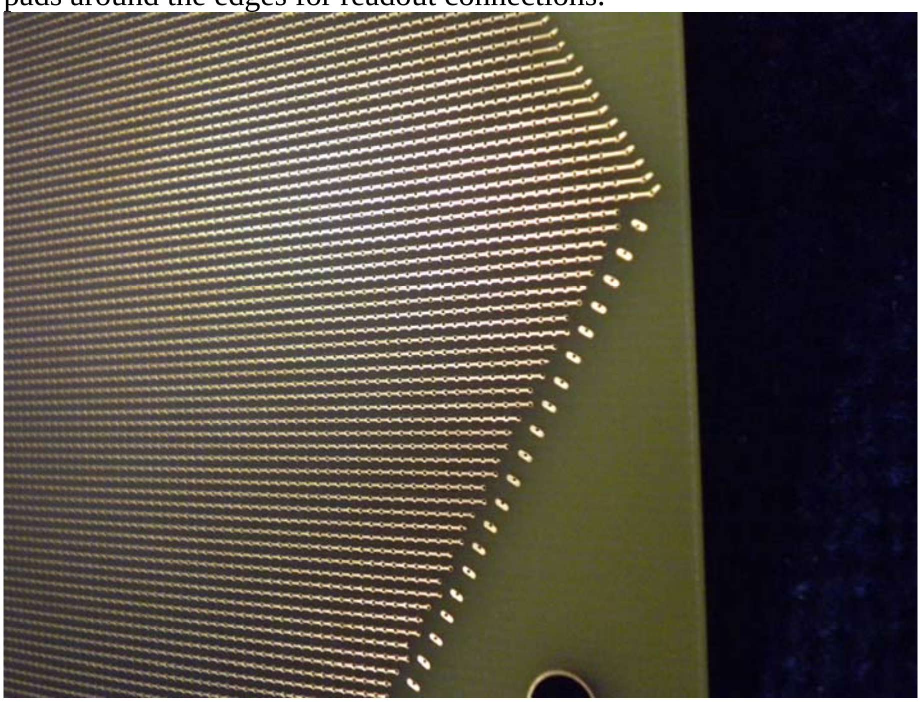

Fig X3   Back of 2D readout board, showing routing of sensor pads, and also the connection pads for the ZEBRA connectors for signal readout.

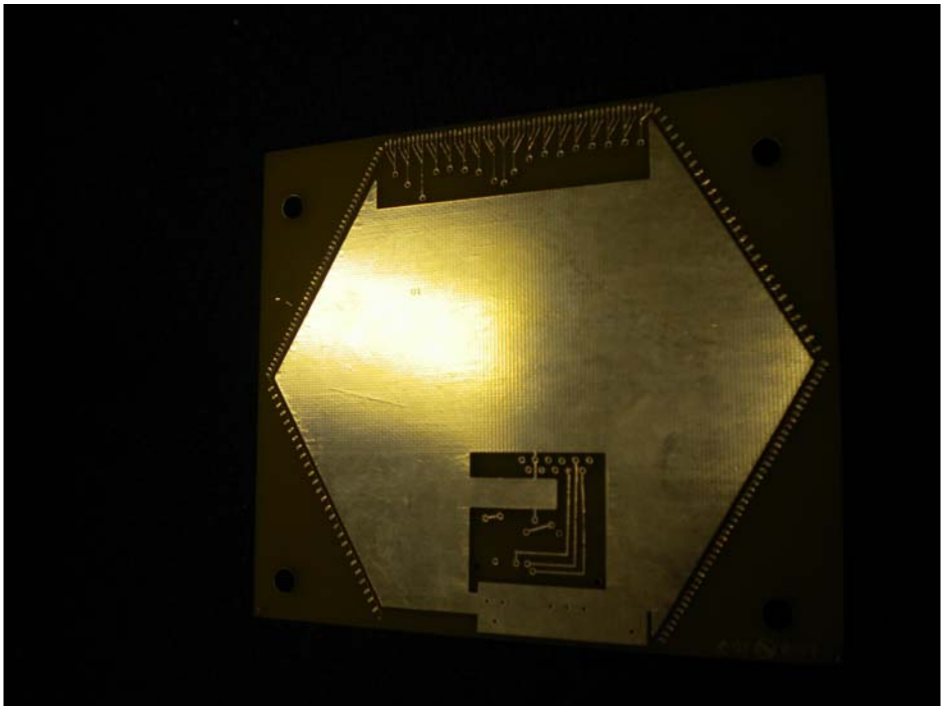

Fig X4   Back of 2D routing board. This connects to the readout plane around the edges, using rubber ZEBRA connectors.   This two-board scheme eliminates about 7000 blind vias, and uses about 150 connections between boards around the edge.

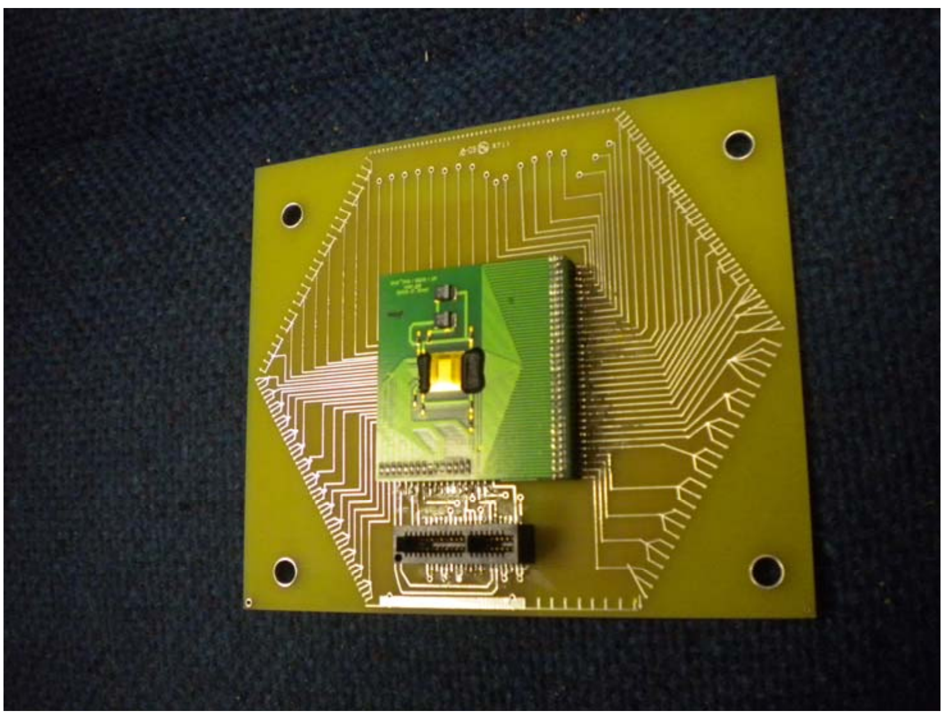

Fig X5   Back of routing plane, showing APV chip and connector.   Also, one can see that readout sensor rows are ganged together, typically in groups of 3. This will make the resolution only 3 mm/ root(12) but allows the use of only 1 APV chip per detector patch.

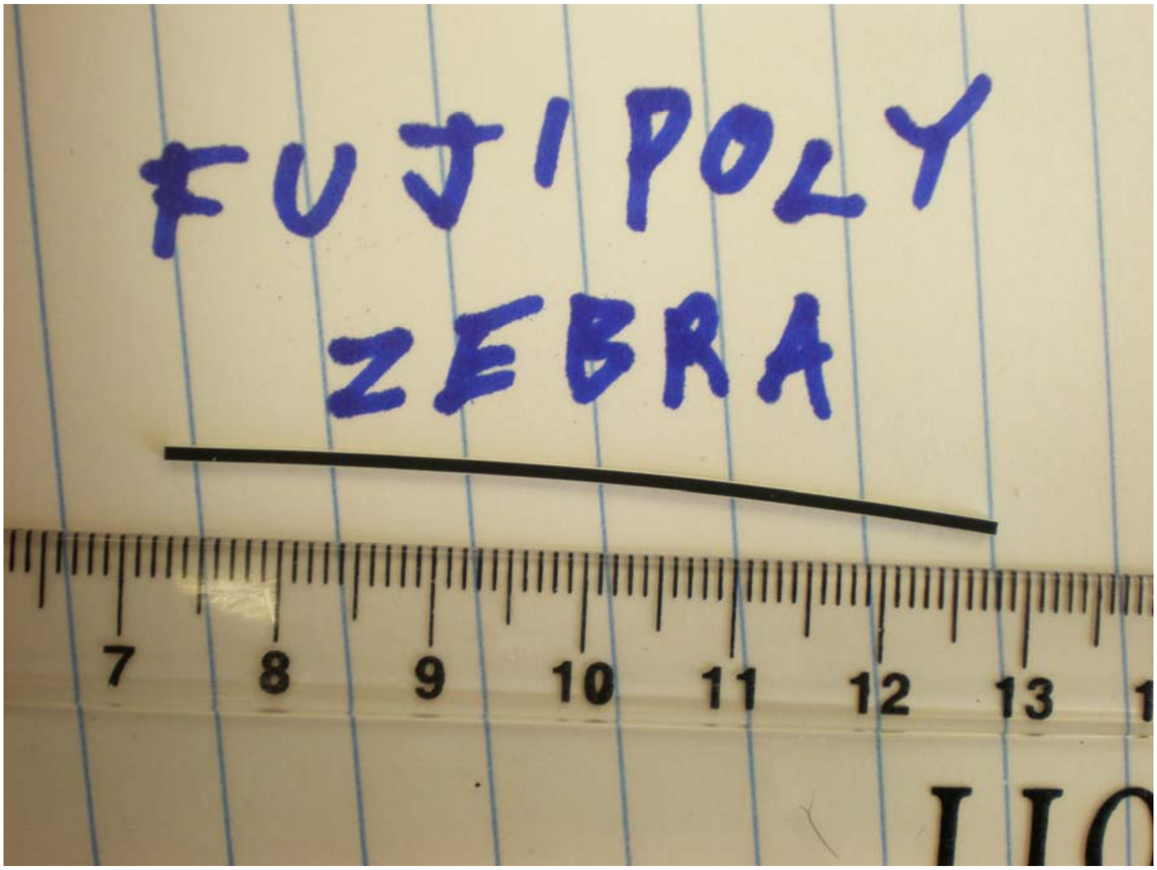

Fig X6 Fujipoly Zebra conducts transverse to the long dimension. There are many isolated conduction paths per mm, so that there are no shorts in the long direction on the scale of interest.