eRD6 & eRD3/eRD6

TK Hemmick

Collaboration Status

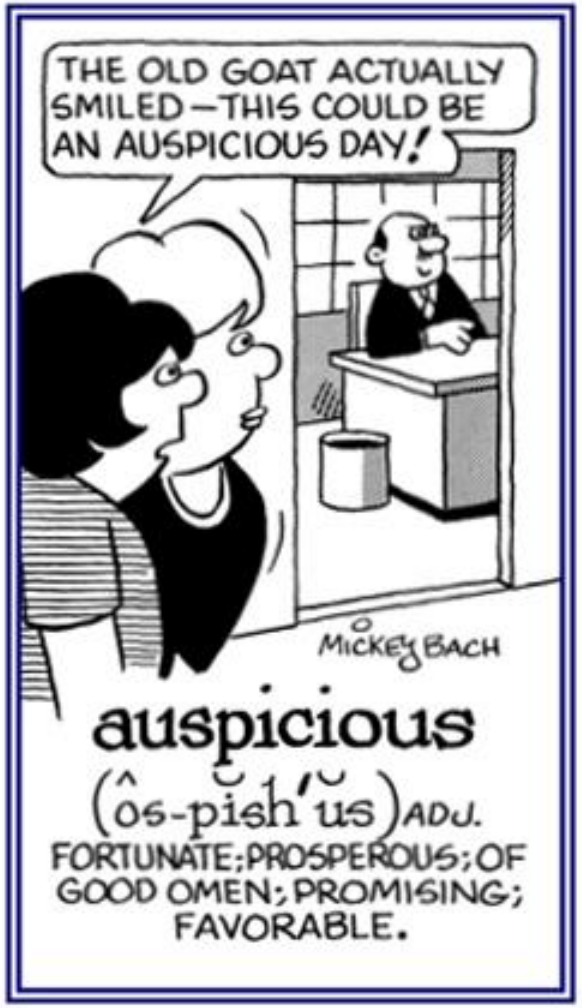
It is about time they got hitched!

Now is an Auspicious Time

- The EIC R&D Program is celebrating its 5th year of generic R&D.
- Much of the initially-proposed work has been completed or nearly so.
- The EIC is featured prominently in the Long-Range Plan.
- Several detector designs have achieved an advanced stage.

- It is really time to respond to the changed landscape:
  - Efforts with commonality should merge.
  - Research should move from generic to targeted
    - We define targeted R&D as addressing an identifiable component of a leading detector design(s).

- Scheme:
  - eRD3 and eRD6 will complete already-promised generic R&D under their original bannerheads.
  - Targeted R&D will be the complete focus of the merged group.
  - I will attempt to make a clear distinction between remaining generic work and targeted.



Initial eRD6 Program

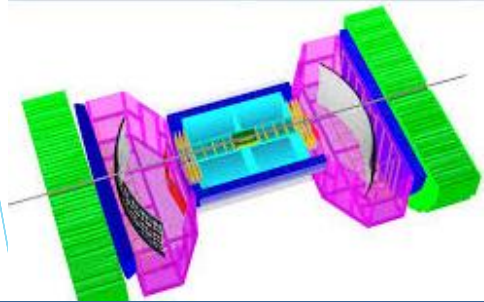
- BNL
  - Minidrift GEM detector to overcome resolution degradation common to all planar trackers for highly inclined tracks.
  - TPC-Cherenkov detector to provide enhanced eID via threshold Cherenkov detected from the main TPC gas volume.
- Florida Institute of Tech
  - Development of large planar GEM trackers using Zig-Zag charge division.
- University of Virginia
  - Development of large planar GEM trackers using “stereo-compass-style” readout.
- Stony Brook University
  - Compact RICH Detector (CF_4 – 1 meter)
  - TPC-Cherenkov (the Cherenkov part)
- Yale University
  - 3-Coordinate (XYU) readout to disambiguate coordinate associations over large areas.
  - Hybrid Gain Stages for decreased Ion Back Flow (IBF) in gateless TPCs.
  - Weiman-mesh studies for high live time gated TPCs.

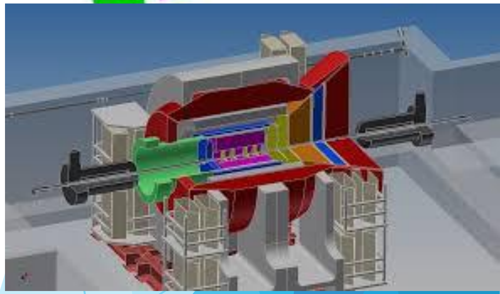
13 published or submitted papers as of today

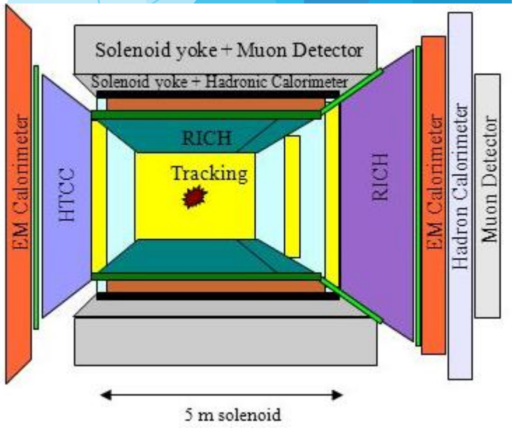
eRD3/eRD6 Targeted Program

- BNL
  - Move exclusively to gate-less TPC development work (w/o Cherenkov stage)
- Stony Brook University
  - Move exclusively to gateless TPC development work (w/o Cherenkov Stage).
- Florida Institute of Tech
  - Development of large planar GEM trackers.
- University of Virginia
  - Development of large planar GEM trackers.
- Temple/Saclay
  - Development of large scalar GEM trackers.
- Yale University
  - Hybrid Gain Stages for decreased Ion Back Flow (IBF) in gateless TPCs.
  - Weiman-mesh studies for high live time gated TPCs.

- INFN Trieste
  - Development of dual-radiator RICH w/ hybrid readout plane (also TPC-appropriate!)
- Weizmann Institute of Science
  - IBF studies for gateless TPC.

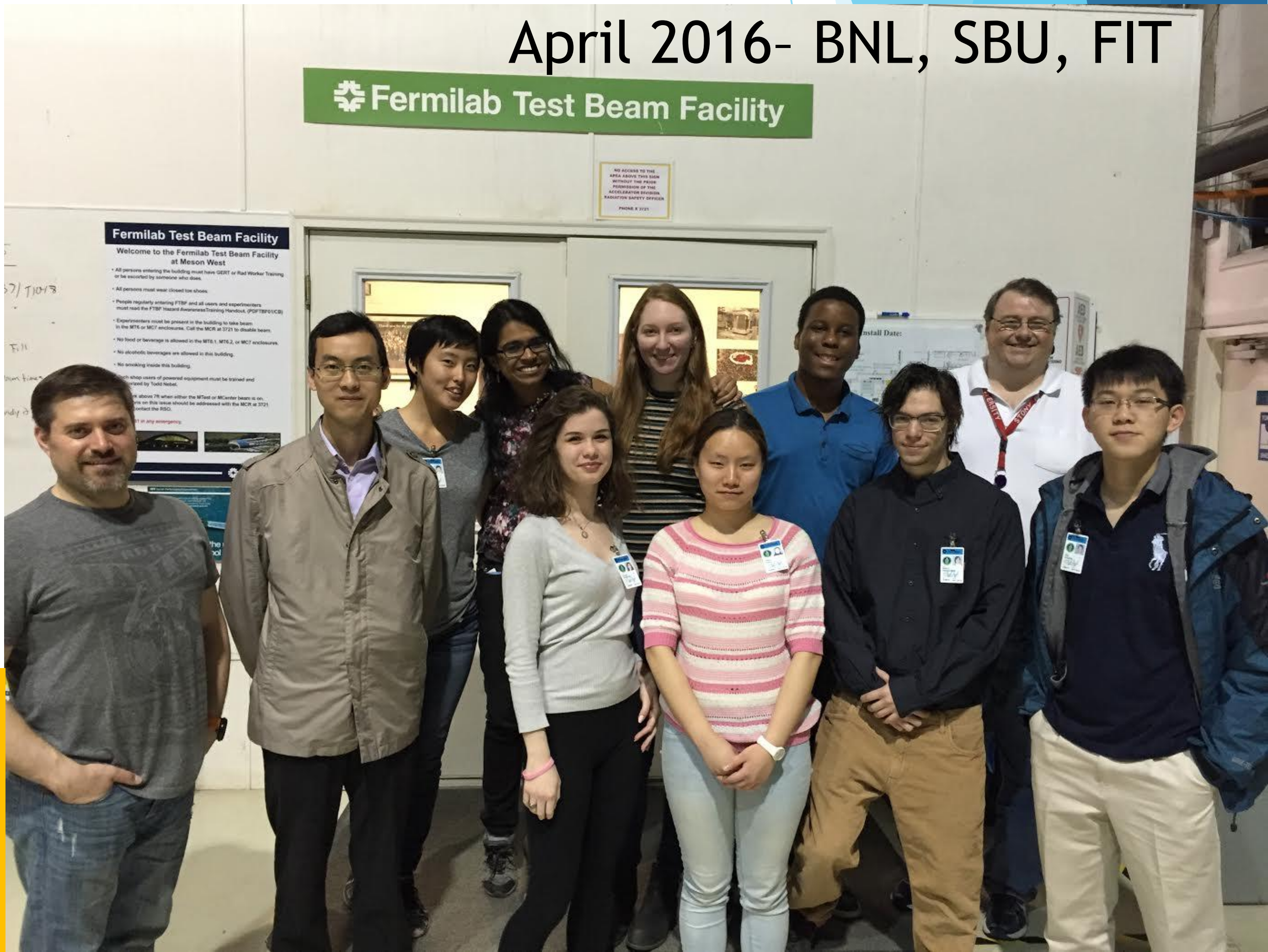






Planned Progress in the past 6 months:

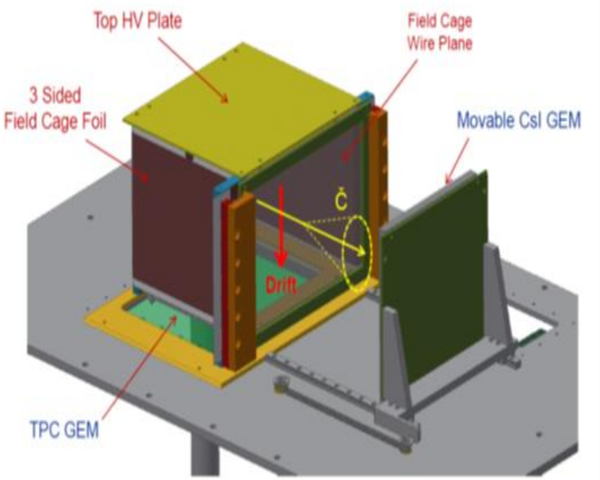
- BNL / (SBU too!)
  - ✓ TPC commissioning/studies: field cage stability; cosmics; $v_{drift}(E)$; gain; diffusion; attachment
  - ✓ TPC complete → SBU
  - ✓ Make photocathode
  - ✓ TPCC complete drive it (under gas flow) → FNAL
  - ✓ Gather and Analyze Test Beam Data
  - ✓ TPC Resolution & Cherenkov yield measured
  - ✗ Try improved pad plane design in test beam
    - Pad plane not delivered in time for test beam.

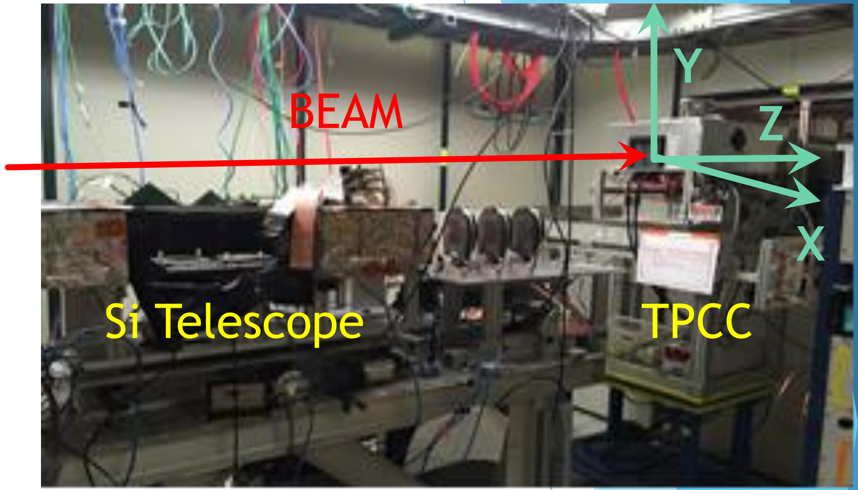


April 2016– BNL, SBU, FIT

BNL:	1 scientist
FIT:	1 postdoc
SBU:	1 prof,
	1 grad stu
	8 UG's

TPC/Cherenkov Prototype Beam Test at FTBF





- Overall objective was to demonstrate proof of principle behind the concept of eID and tracking within a common detector volume
- TPC: quantify some performance specs like position and angular resolution for ~horizontal tracks
- Cherenkov: Light yield and eID performance
- Look for hit correlations between Cherenkov and TPC detectors

Detector Specs:

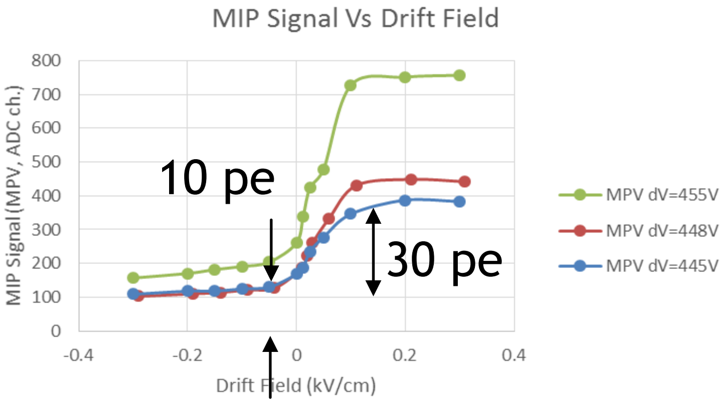
- TPC: 10cm drift + 10cmx10cm 4GEM
- Cherenkov: 3.3x3.3cm^2 pad array + 10cmx10cm 4GEM
- Common Gas: CF4

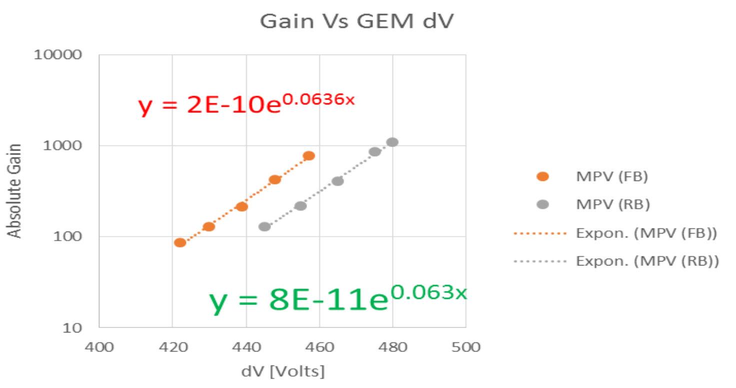
(drift vel = 7.5cm/us & large N0)

BTW---This is SBU and BNL working jointly.

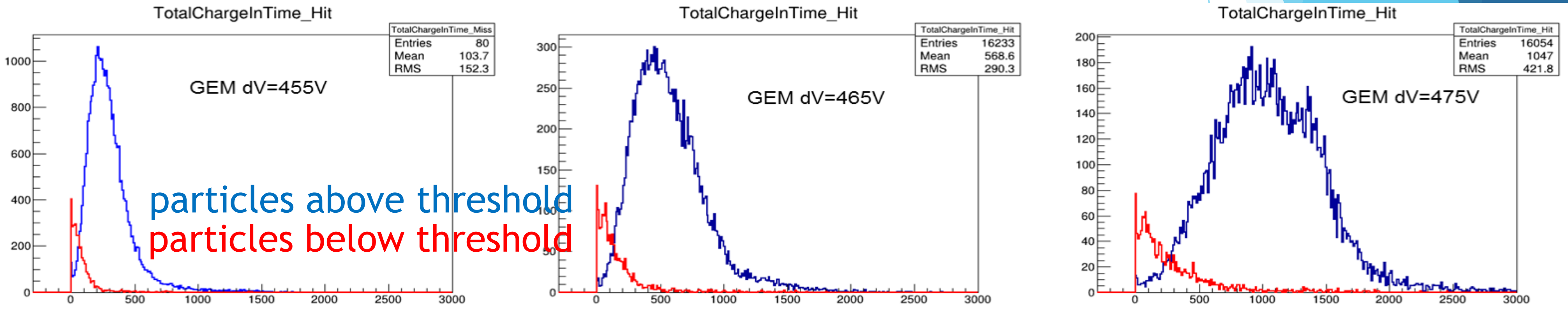
Cherenkov Hits

- Optimum drift field: -0.05kV/cm
- Npe ~10, in line with expectations
- NOTE: Radiator length less than ½ of the full-sized TPC.

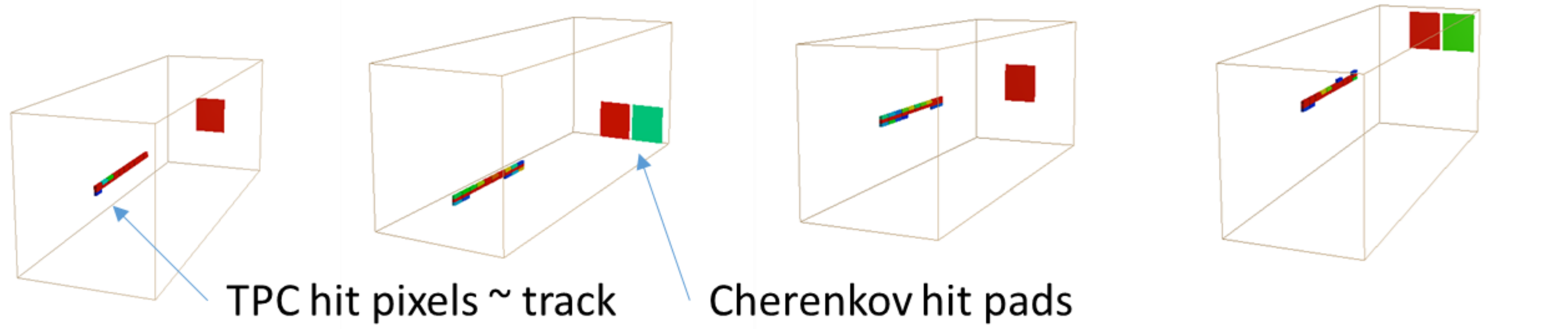




eID performance

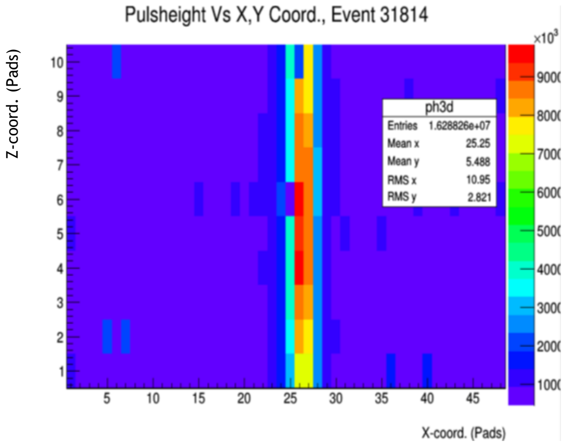


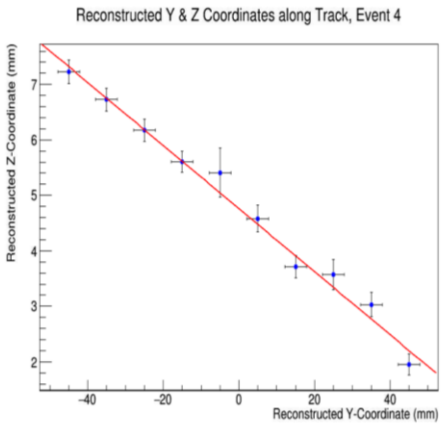
Cherenkov/TPC Track correlations

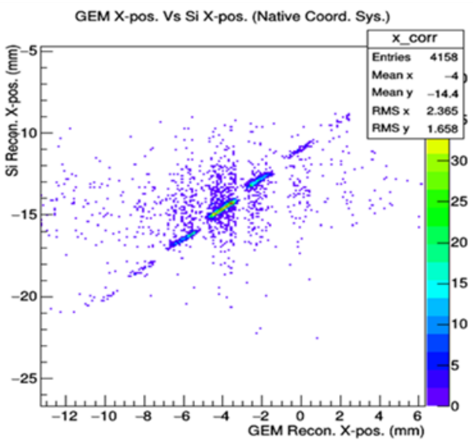


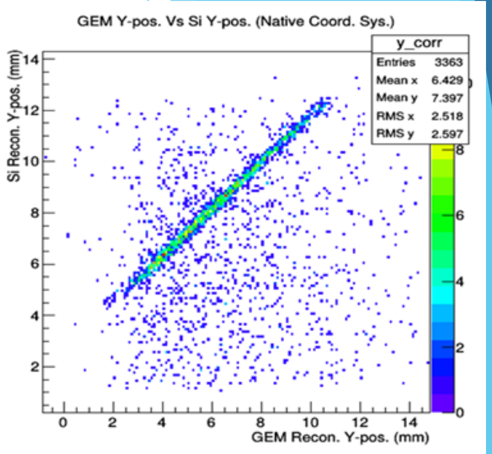
TPC Tracks

Works exactly as expected…publish this fall.



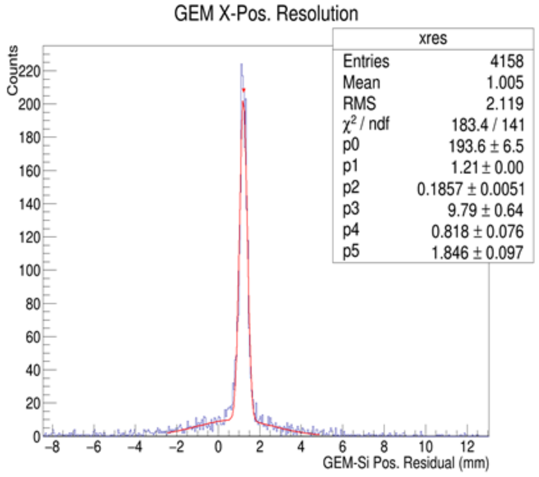


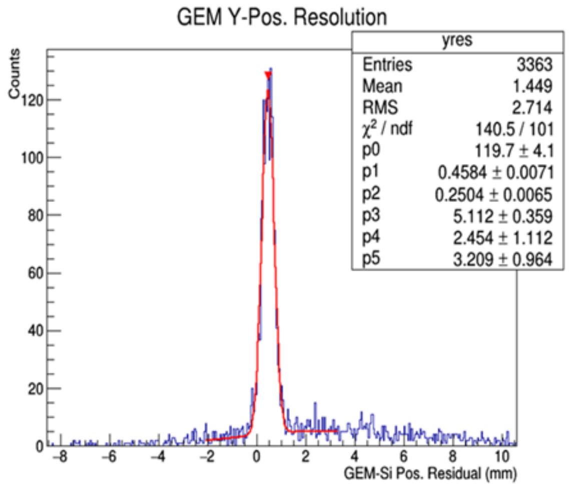


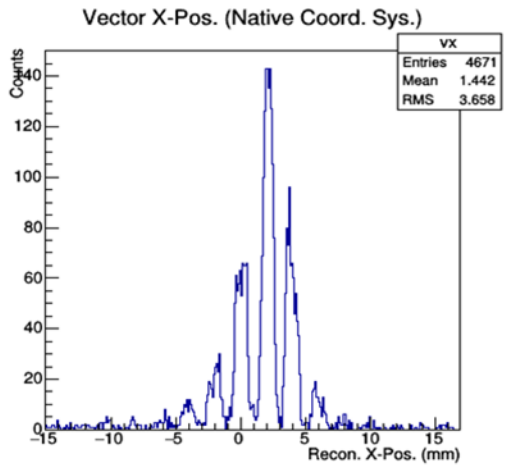


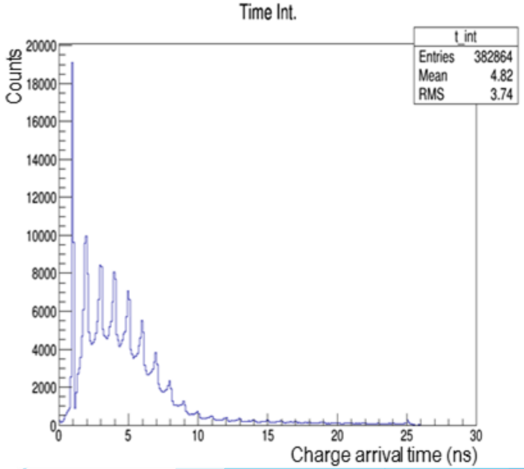
X-Z tracks: charge weighted centroid along 2mm pads x10
Y-Z tracks: use timing info. to reconstruct y-coord.

TPC – Si Correlation
Background hits due to unsynchronized events in TPC-Si DAQ









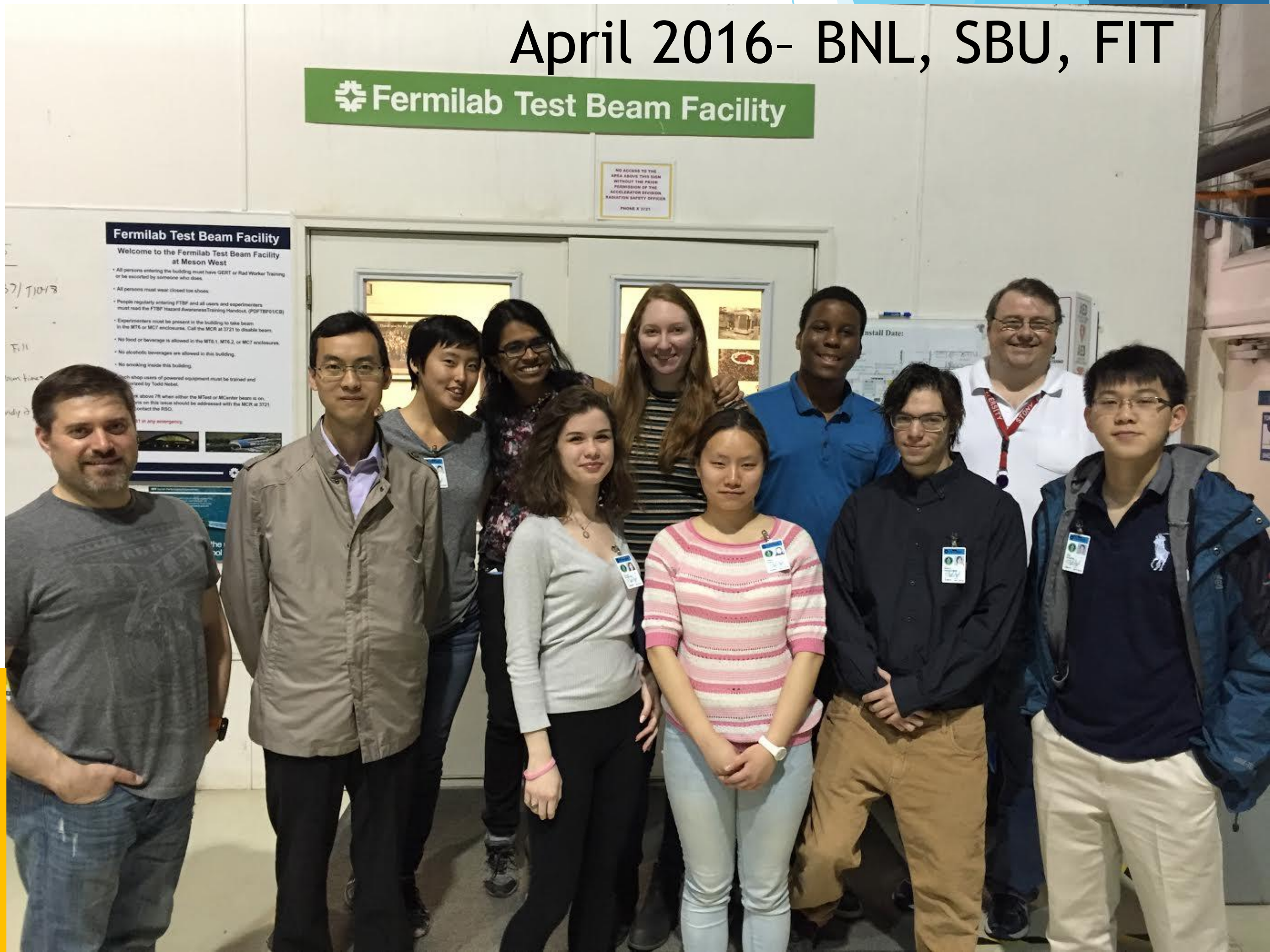
TPC position resolution
X~186um, Y~570um

Position resolution is limited by current track reco.
X: DNL & poor charge sharing; Y: limited timing resolution

Planned Progress in the past 6 months:

- SBU
  - ✓ Make photocathode
  - ✓ TPCC complete drive it (under gas flow) → FNAL
  - ✓ Gather and Analyze Test Beam Data
  - ✓ TPC Resolution & Cherenkov yield measured
  - ✗ Equip evaporator for mirror evaporation
    - Evaporator occupied by TPCC
  - ✗ Test SBU-made Al/MgF_2 mirrors
    - Evaporator occupied by TPCC

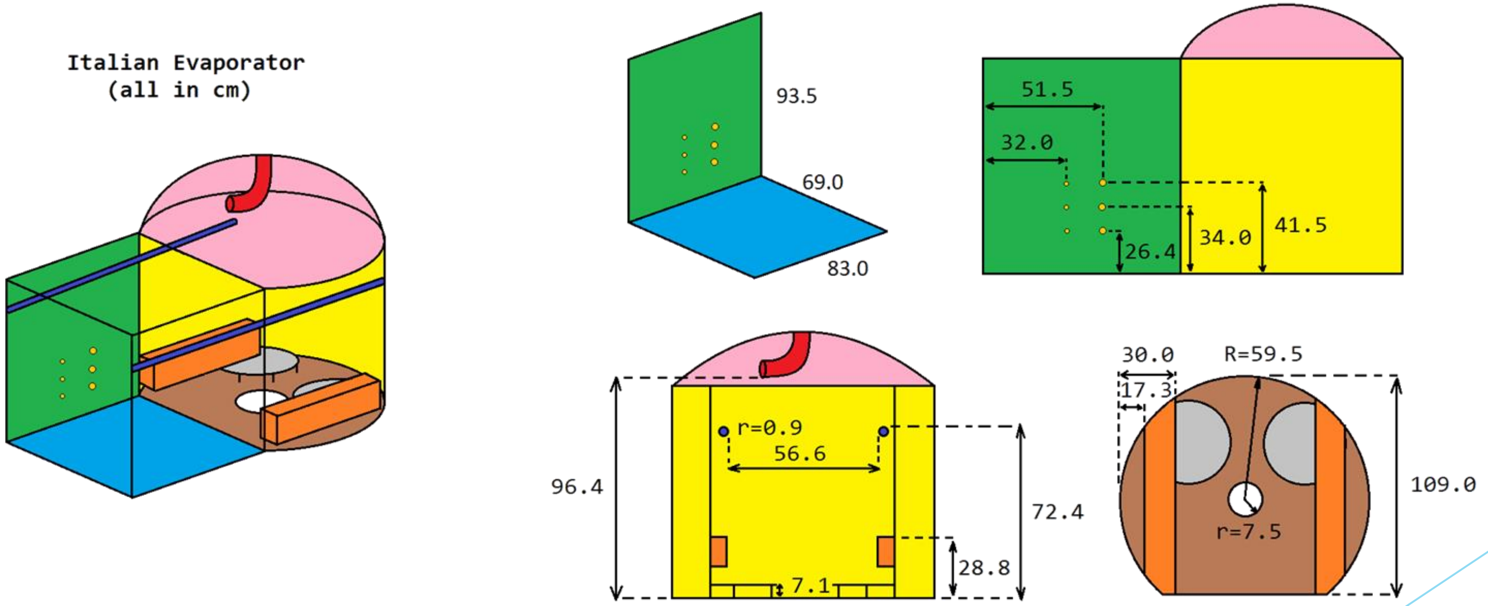
April 2016– BNL, SBU, FIT



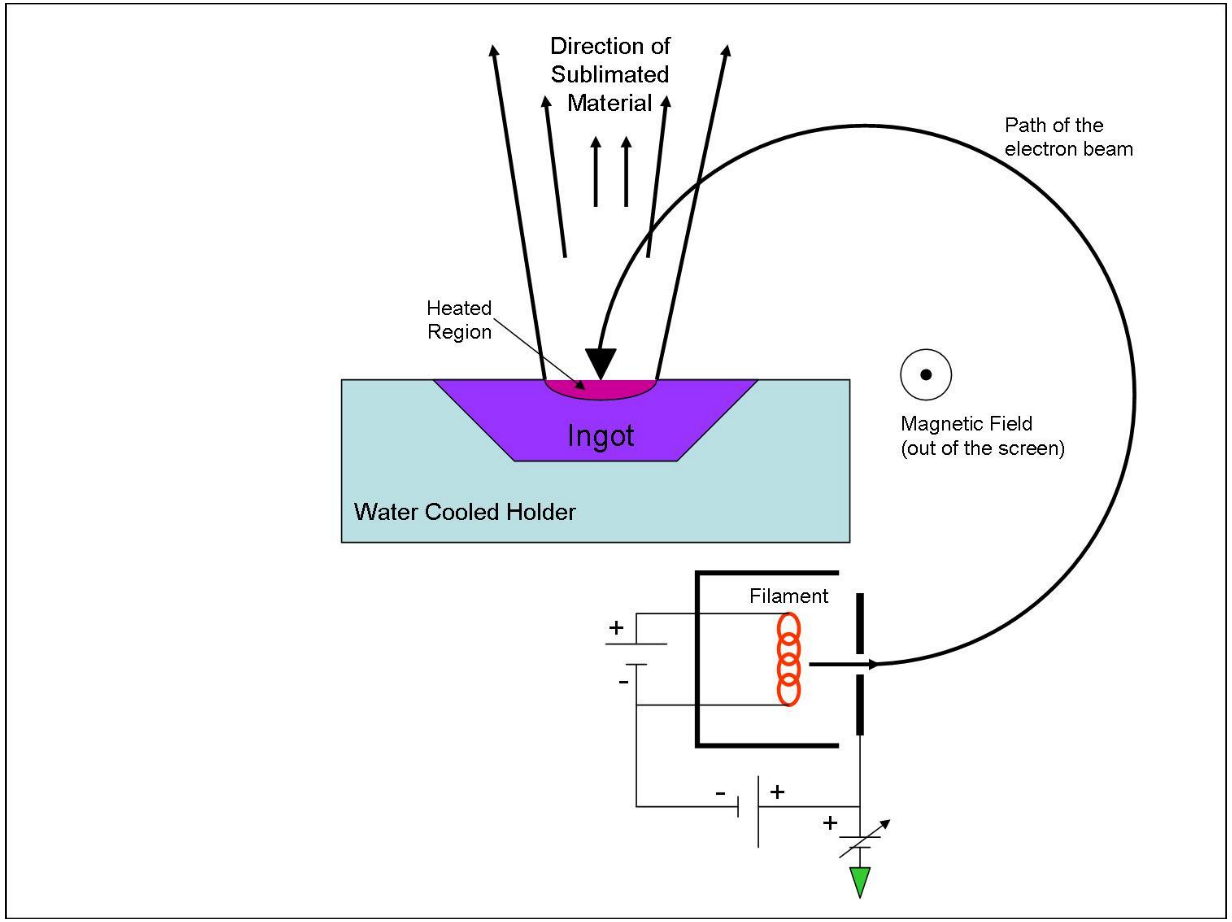
BNL: 1 scientist
FIT: 1 postdoc
SBU: 1 prof,
1 grad stu
8 UG's

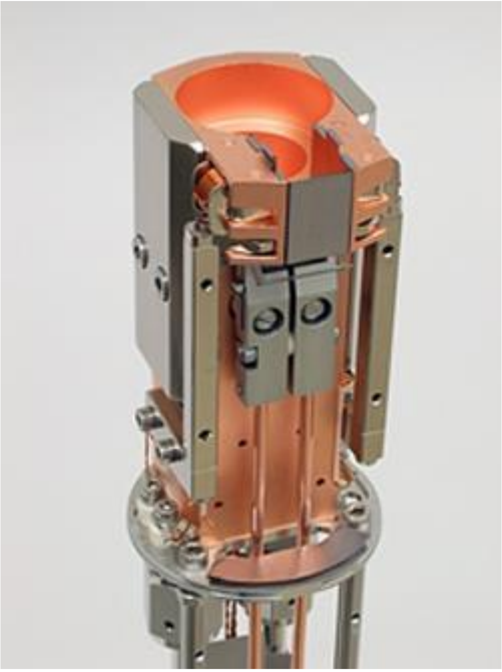
INFN Roma Evaporator

- Big enough to make the mirror size we require.
- MUCH MUCH better vacuum
  - Big Mac $3x10^{-6}$ torr
  - INFN $7x10^{-8}$ torr



Electron Gun



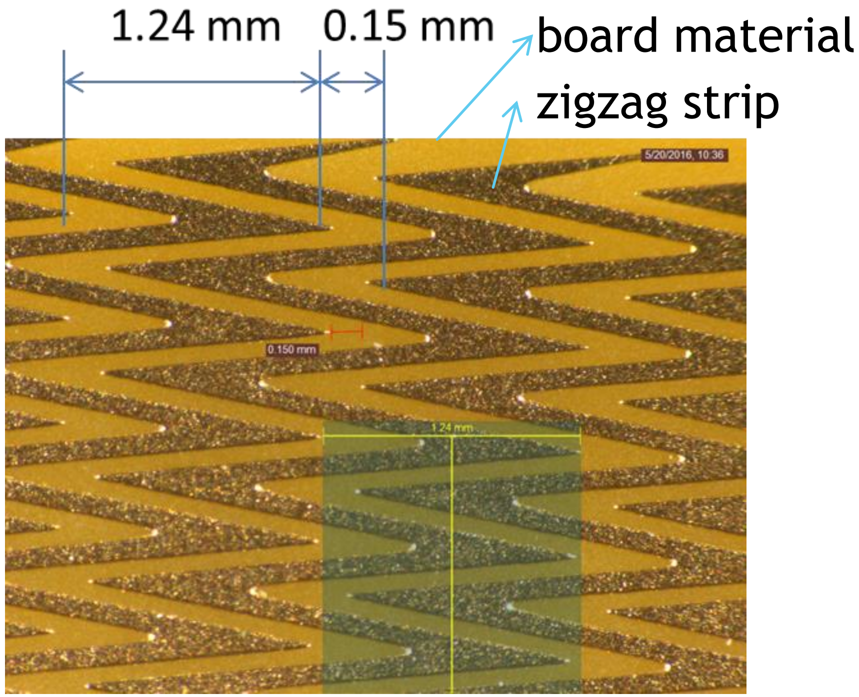


Electron gun MUCH MUCH cleaner than thermal boat.

Progress in 6 months

- FIT
  - ✓ Finish second paper from test beam
  - ✓ Submit & publish.
  - ✓ Analyze data from X-ray scans of new Zig-Zig shapes
  - ✓ Demonstrate improved linearity with new shapes.
  - ✓ Produce the “common GEM” foils
  - ✗ Test C-fiber options for frame stiffener
    - Finite element analysis results complete; actual parts not yet arrived.

Topic 1: X-ray scans of PCBs with improved zigzag strip design

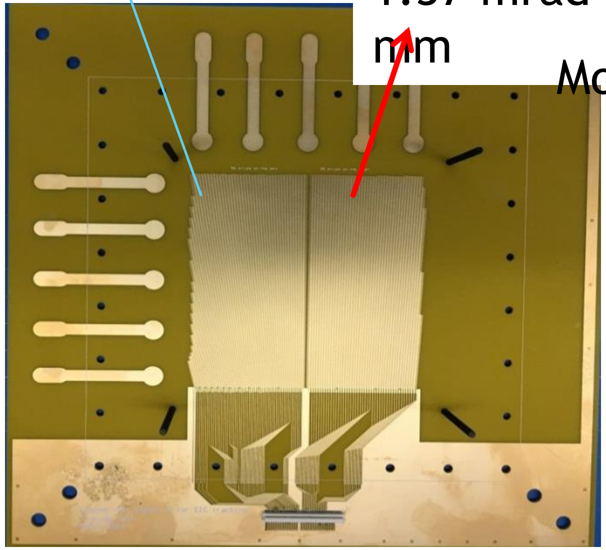


Interleaving of zigs and zags:
1-(0.15/2)/1.24=94%

Left part: angle pitch 4.14 mrad @ R = 206-306 mm

Right part: angle pitch 1.37 mrad @ R = 761-861 mm

More in next slide!

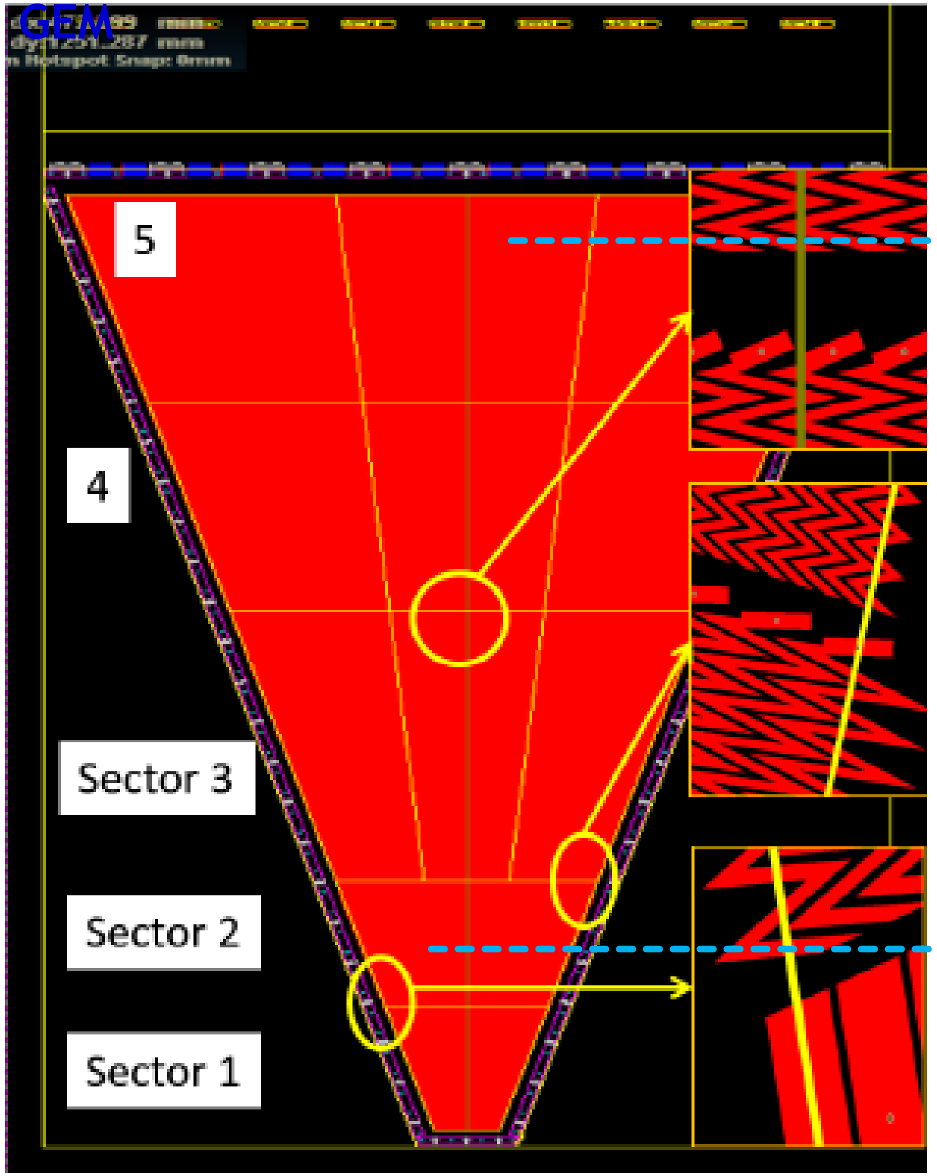


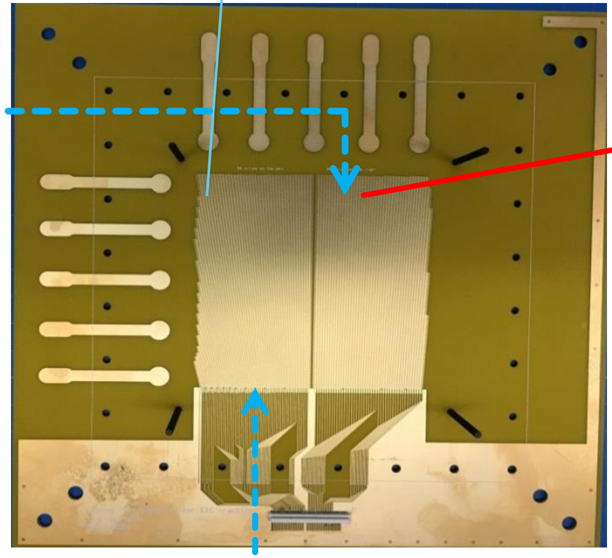
- We have designed improved zigzag structures with better interleaving of zigs and zags; **the goal is to reduce non-linear response and achieve <100 μm spatial resolution.**

- **Four small test boards were made and tested at BNL.** Due to small trace width and space (<3 mil) in the design, it took some efforts for the PCB company (Acurrate Circuit Engineering) to produce a board that is 94% close to what has been designed. For comparison, we also produced a board from CERN (it is also because CERN will be very likely producing 1-m long zigzag r/o for us, a test board will work as a proof of the ability of producing zigzag strips).

Topic 1: X-ray scans of PCBs with improved zigzag strip design

The readout design for our next EIC FT GEM





Left part: angle pitch 4.14 mrad @ R = 206-306 mm

Right part: angle pitch 1.37 mrad @ R = 761-861 mm

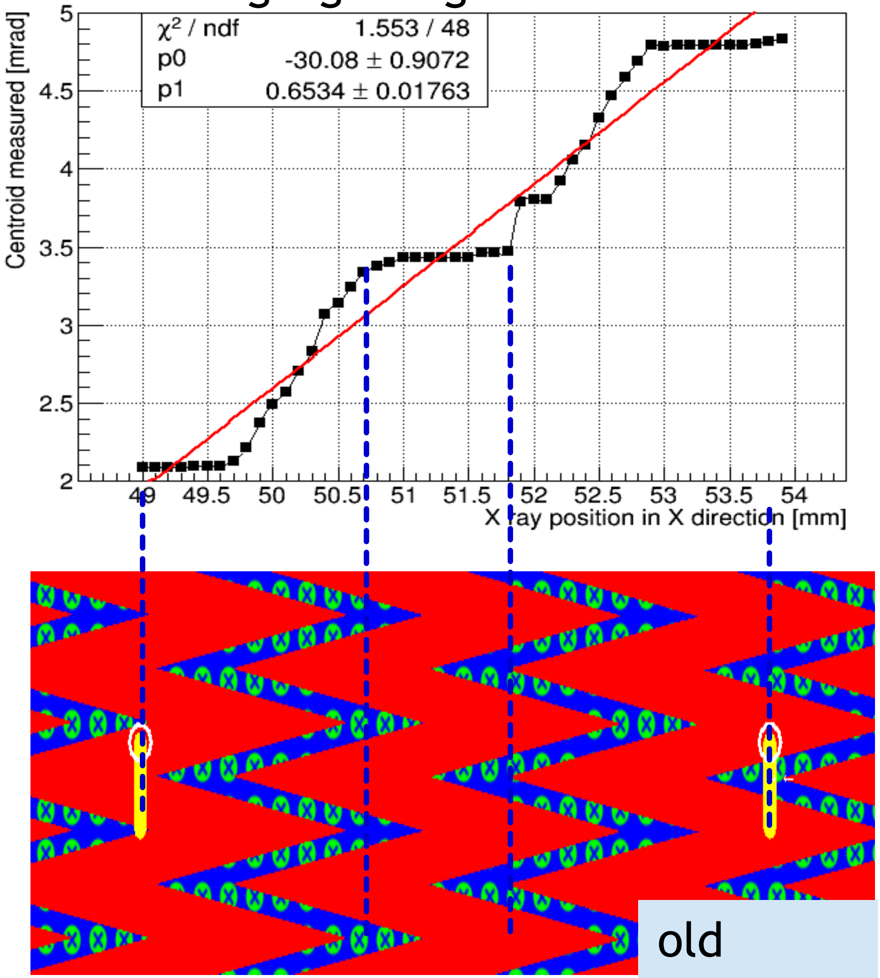
The strips in the right part of the small test board are from sector 5

The strips in the left part of the small test board are from sector 2

Topic 1: X-ray scans of PCBs with improved zigzag strip design

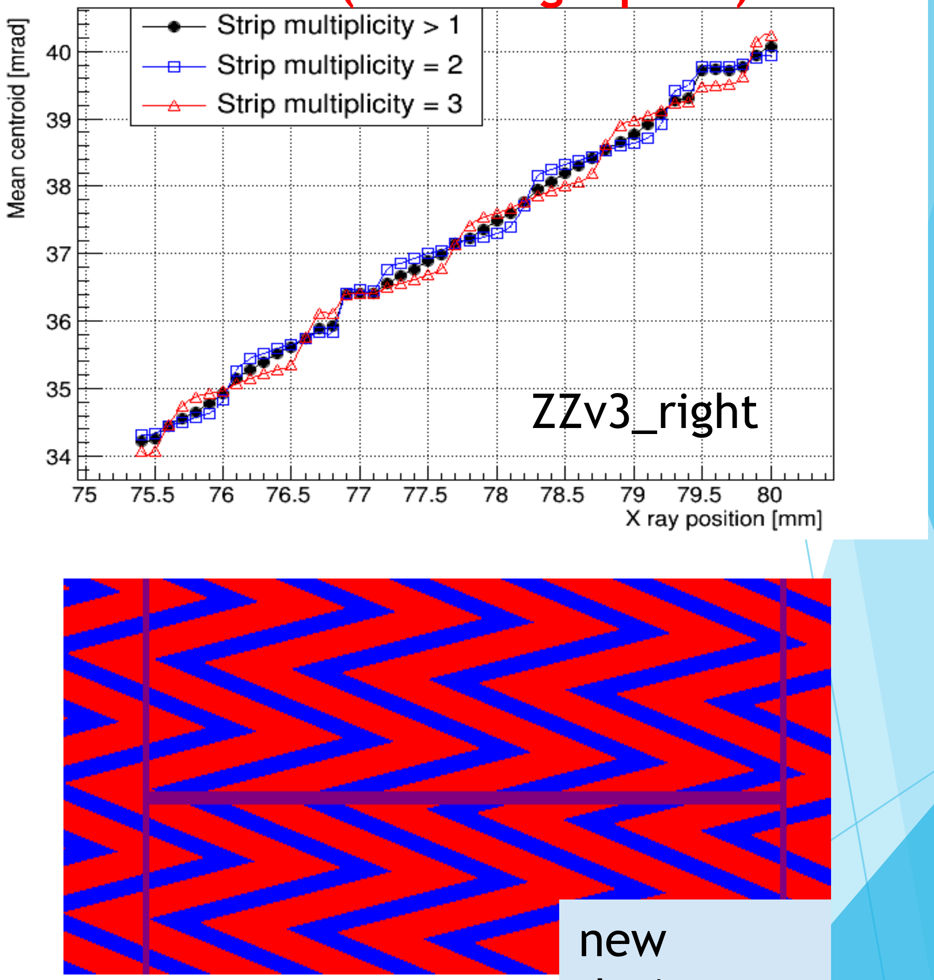
Mean centroid vs. X ray position (scan across strips)

Previous zigzag design ZZ48



(1) Flat regions are insensitive to hit positions.
(2) Too many events fire only 1 strip, some have 2 strips, few events fire ≥ 3 strips.

New board (same angle pitch) results:



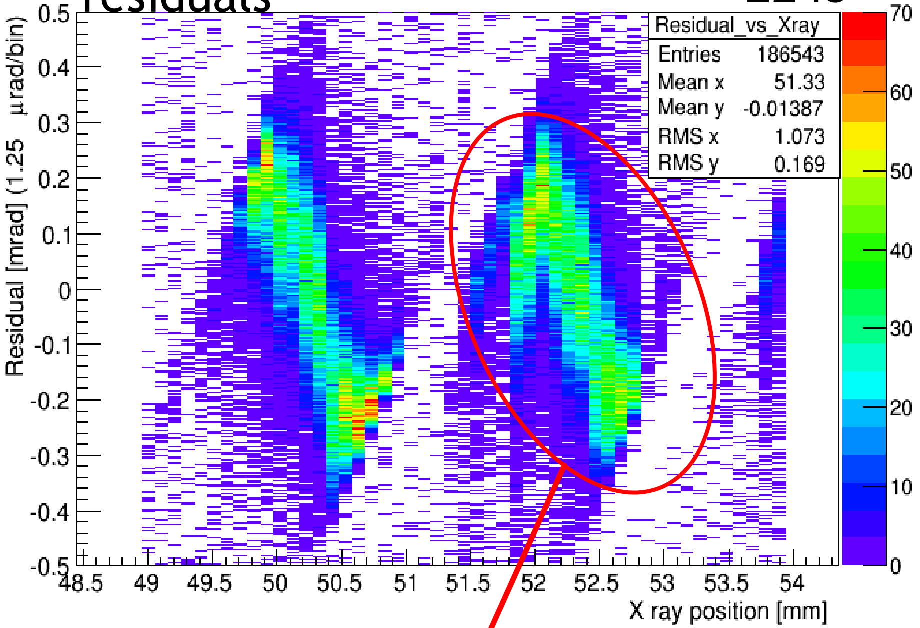
(1) Clearly linear response over whole range.
(2) > 95% events fire 2 or 3 strips.

Topic 1: X-ray scans of PCBs with improved zigzag strip design

Residuals (events with 2 firing strips)

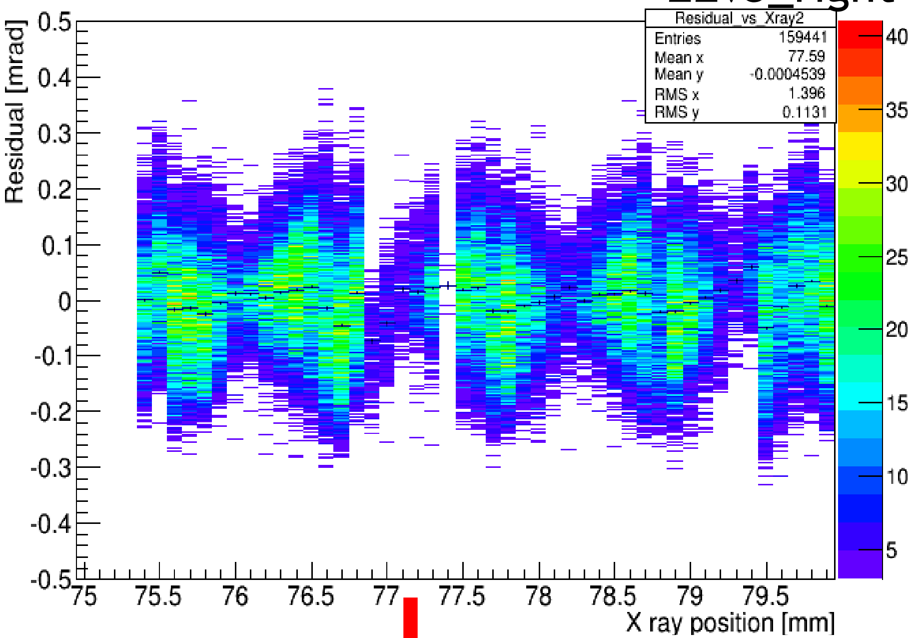
Previous board, non-flat residuals

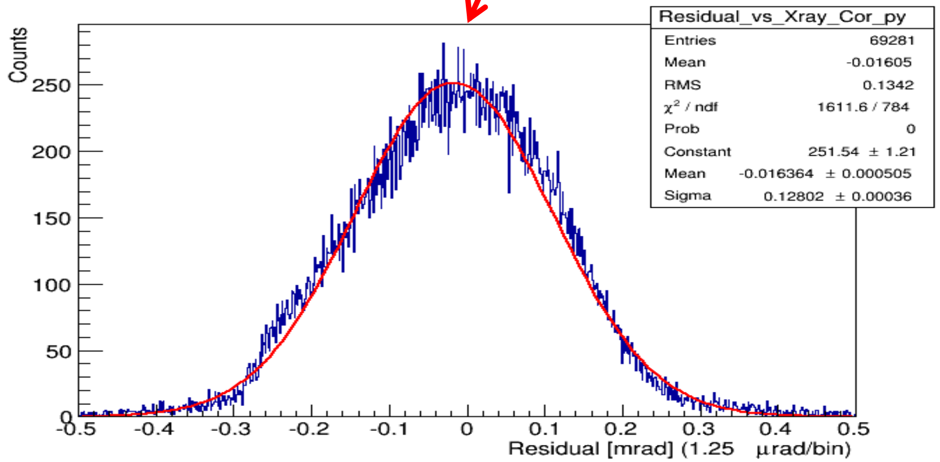
ZZ48

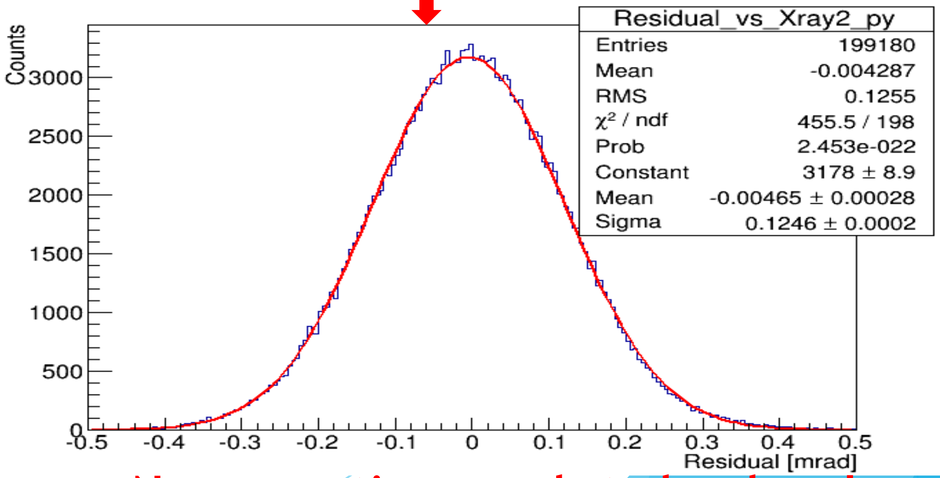


New board, residuals are flatter

ZZv3_right







Need corrections to get this

No correction needs to be done!

Topic 1: X-ray scans of PCBs with improved zigzag strip design

Summary of resolutions – we find that new zigzag boards reach < 100 μm resolution

Board		HV (kV)	Width in polar coordinate (μrad)			Width in Cartesian coordinate (μm)			X ray collimator width subtracted (μm)		
			Strip Multi = 2	Strip Multi = 3	Strip Multi = 4	Strip Multi = 2	Strip Multi = 3	Strip Multi = 4	Strip Multi = 2	Strip Multi = 3	Strip Multi = 4
Left section, Angle pitch 4.14 mrad, R: 229 mm	ZZv2	3.38	339.1	437.1	-	77.6	100.1	-	60.5	85.0	-
	ZZv3	3.20	472.8	323	-	108.3	74	-	94.0	56.6	-
	ZZv3	**3.38**	**400.6**	**225.8**	**-**	**91.7**	**51.7**	**-**	**75.9**	**32.3**	**-**
	ZZv3	3.48	388.8	514.2	394.3	89	117.8	90.3	72.9	104.3	74.3
	ZZv4	3.25	151.6	622.8	317.9	34.7	142.6	72.8	13.8	131.3	55.3
Right section, Angle pitch 1.37 mrad, R: 784 mm	ZZv2	3.38	79.2	90.9	-	62.1	71.3	-	43.6	53.6	-
	ZZv3	**3.38**	**124.6**	**98.03**	**-**	**97.7**	**76.9**	**-**	**82.4**	**59.7**	**-**
	ZZv3	3.48	110.2	134.8	-	86.4	105.7	-	70.1	91.1	-
	ZZv4	3.25	39.49	157.3	-	31	123.3	-	9.7	110.3	-
1.37 mrad, R 1420-1520 mm, ZZ48, **old board**		3.38	128	-	-	188.2	-	-	181	-	-

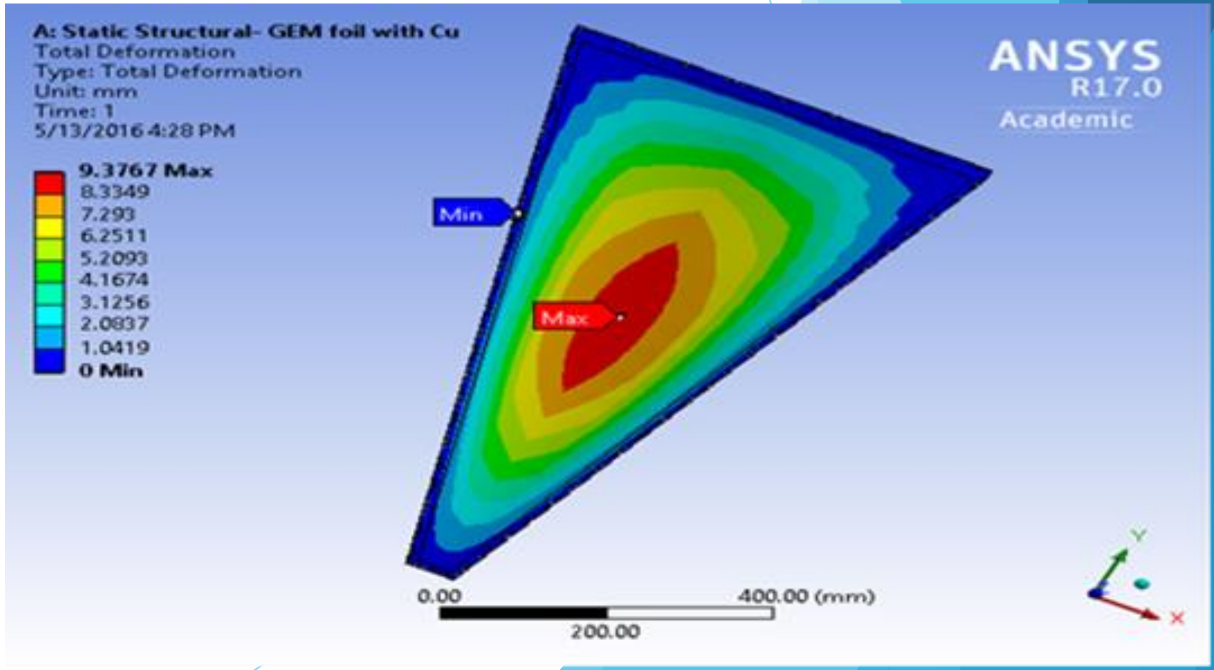
Topic 2: Status of 2^{nd} EIC FT GEM prototyping

1. **Common GEM foils**: Being shipped from CERN; plan to do QC on foils at Fl. Tech in July.

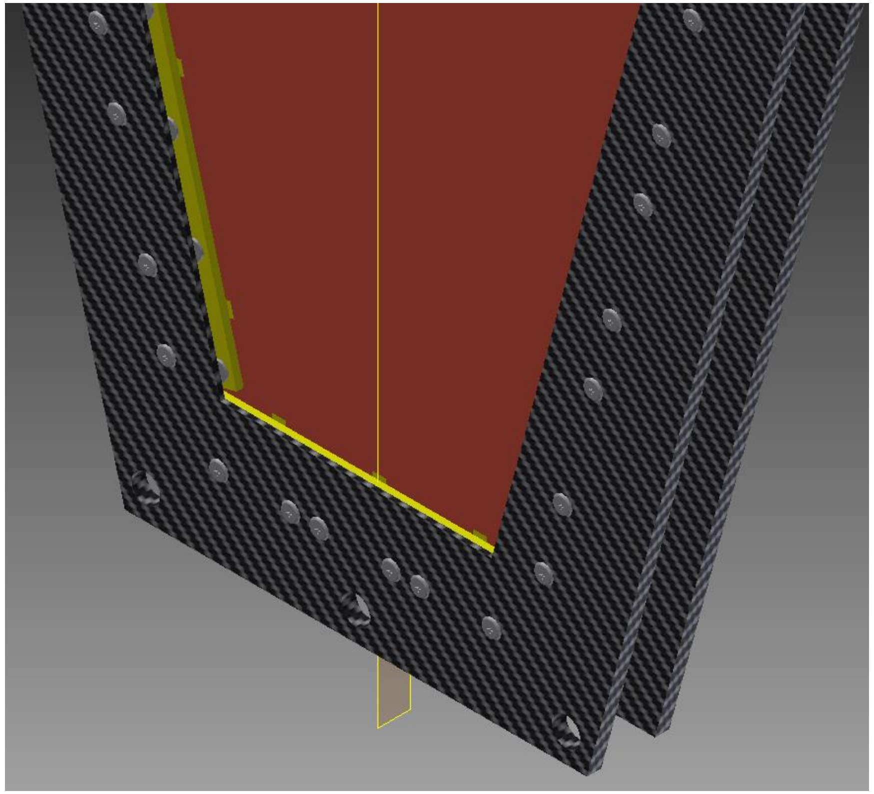
2. **Large zigzag r/o**:
(1) We will produce r/o strips on a foil in order to reduce material in the detection area. We have produced one 10 cm by 10 cm foil r/o for testing.
(2) We tried to contact some US flex PCB companies and it turned out that they were not able to produce large zigzag strip foil with < 3 mil traces & spaces.
(3) Our plan is for CERN to produce large zigzag foil. CERN has already demonstrated the ability of producing high precision zigzag strips by providing a small test foil mounted on a honeycomb board with same zz design.

3. **Mechanical design for chamber assembly**: We have completed the CAD design of all main components. We have done some structural stress analysis with Autodesk Inventor and Ansys workbench.

Total deformation of a GEM foil due to gravity with the four corners fixed (constraint applied)



Topic 2: Status of our 2nd EIC FT GEM prototyping

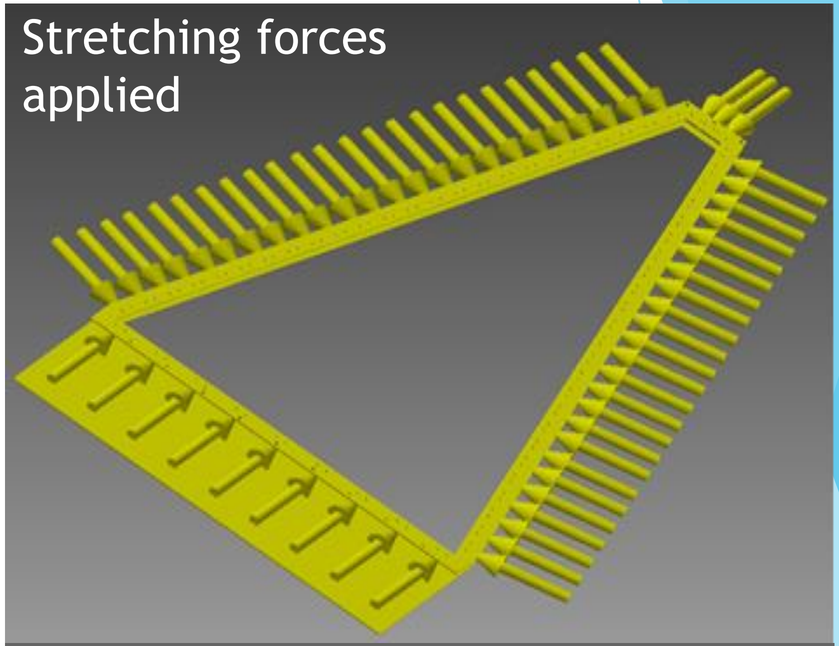


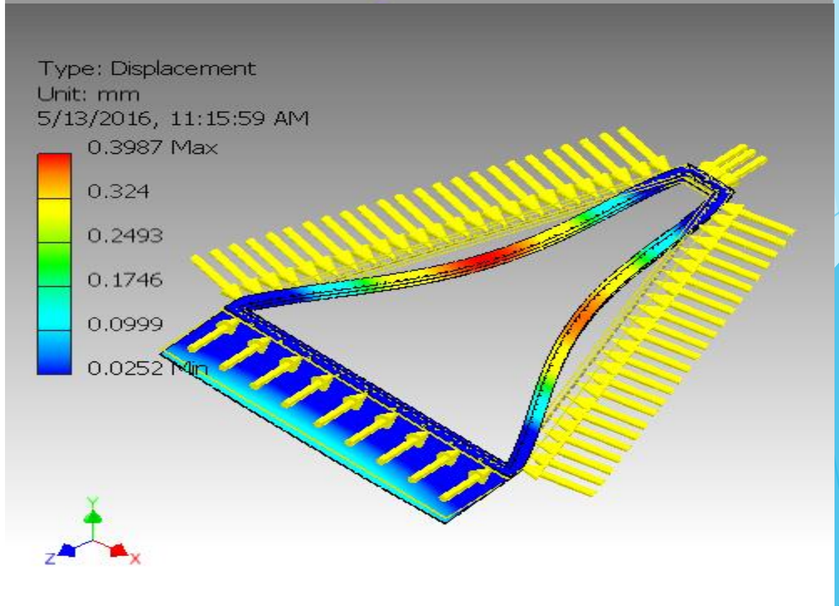
(Drift foil, 3 GEM foils, r/o foil; carbon fiber frames)

Model for stress analysis in Inventor: -->

- Applying an opposite force to each post (mimicking GEM foils being stretched against the posts)
- Observing the displacement of the frames. (see also next page)

Simulated deformation for 10N force applied to each stretching screw



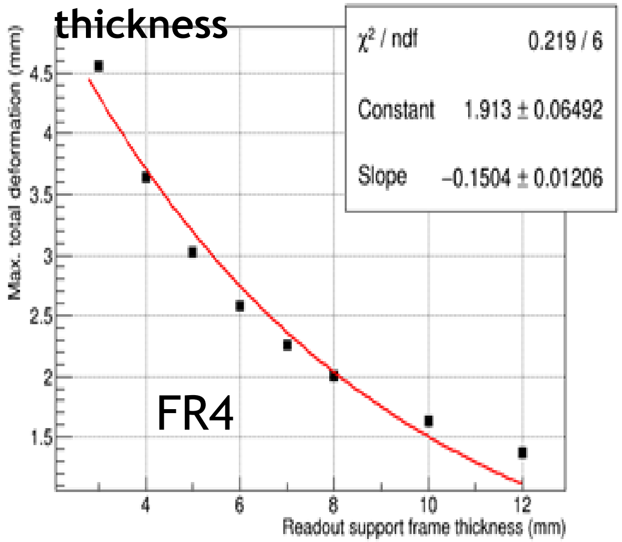


Topic 2: Status of our 2nd EIC FT GEM prototyping

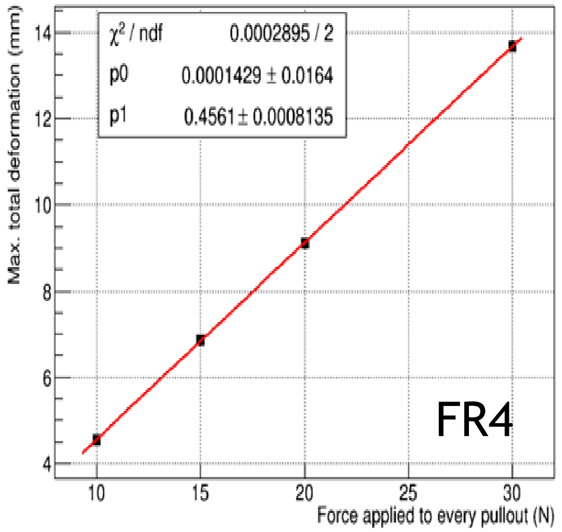
The **max. deformation** for different frame materials (10 N force, 3 mm frame thickness). Carbon fiber and ceramic materials gives small displacement. Plan to go with carbon fiber.

Frame material	Carbon fiber (M55UD)	Carbon fiber (UD std.)	Ceramic (Silicon Nitride)	FR4
Max. deformation (mm)	0.399	1.068	0.282	4.565

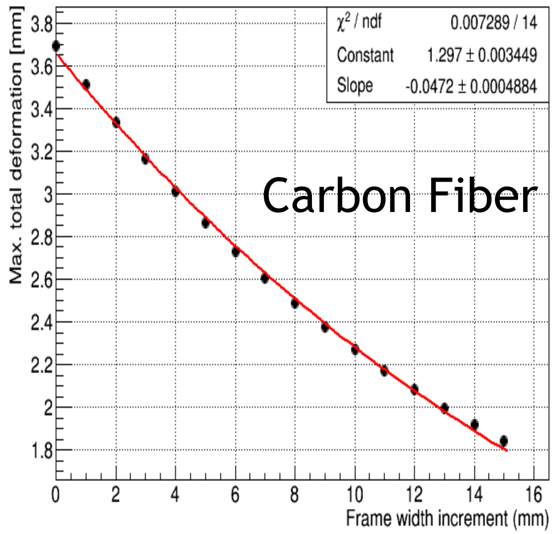
Deformation vs. frame thickness

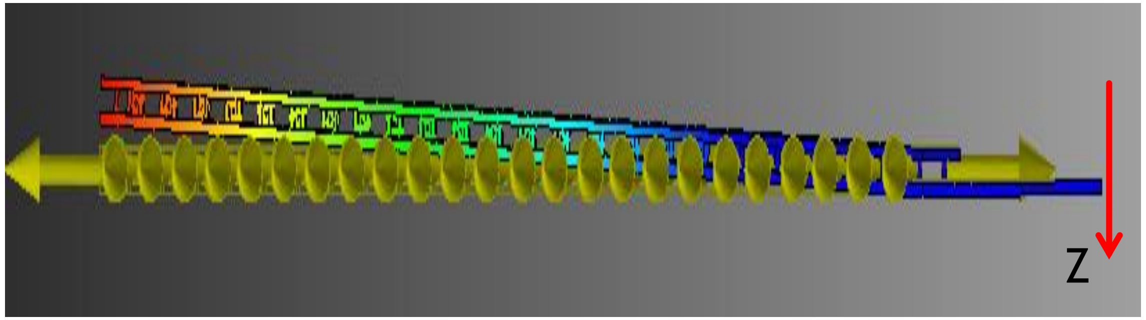


Deformation vs. force



Deformation vs. frame width





Frame buckling (displacement in Z direction) under stretching force (50 N each) while fixed at one end.

Carbon fiber frame bends < 2 mm.

Progress in 6 months

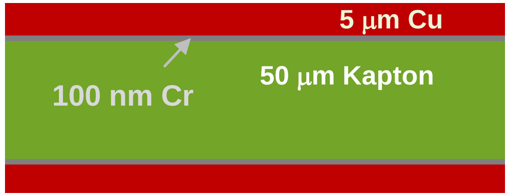
- UVA
  - ✓ Severe irradiation of Cr-GEMs
  - ✓ Zebra-Panasonic adapter board design
  - ✓ Delivery of first “common GEM” foil
  - ✗ Test of zebra concept board.
    - Order delayed by funds delivery

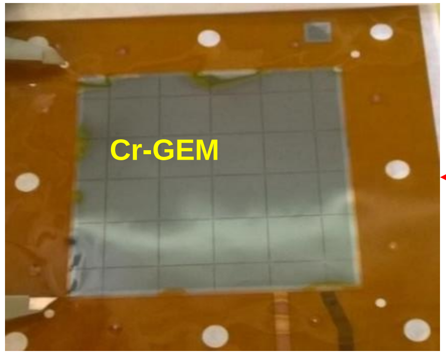
R&D on Chromium GEM foil (Cr-GEM): Low mass detector

Characteristic of Cr-GEM foil:

- ✓ Copper (Cu) clad raw material comes with 100 nm Chromium (Cr) layer between Cu and Kapton, 5μm Cu layers removed, leave only 100 nm residual Cr layers as electrodes, **Cr-GEM foils provided CERN PCB workshop**
- ✓ Using Cr-GEM foil lead to almost 50% reduction of the material of an EIC light weight **triple-GEM detector**: this is because the material in a lightweight triple-GEM is dominated by GEM foils

Standard GEM





Triple-GEM with standard GEM foil

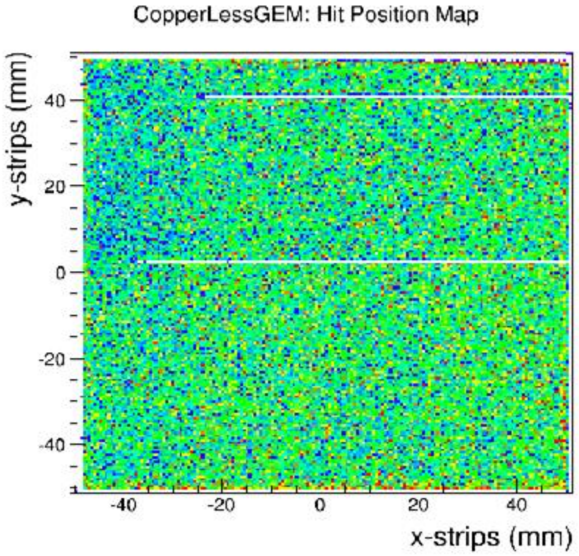
	Quantity	Thickness µm	Density g/cm3	X0 mm	Area Fraction	X0 %	S-Density g/cm2
Window							
Kapton	2	25	1.42	286	1	0.0175	0.0071
Drift							
Copper	1	5	8.96	14.3	1	0.0350	0.0045
Kapton	1	50	1.42	286	1	0.0175	0.0071
GEM Foil							
Copper	6	5	8.96	14.3	0.8	0.1678	0.0215
Kapton	3	50	1.42	286	0.8	0.0420	0.0170
Grid Spacer							
G10	3	2000	1.7	194	0.008	0.0247	0.0082
Readout							
Copper-80	1	5	8.96	14.3	0.2	0.0070	0.0009
Copper-350	1	5	8.96	14.3	0.75	0.0262	0.0034
Kapton	1	50	1.42	286	0.2	0.0035	0.0014
Kapton	1	50	1.42	286	1	0.0175	0.0071
NoFlu glue	1	60	1.5	200	1	0.0300	0.0090
Gas							
(CO_2)	1	15000	1.84E-03	18310	1	0.0819	0.0028
					Total	0.471	0.090

Triple-GEM with Cr-GEM foil

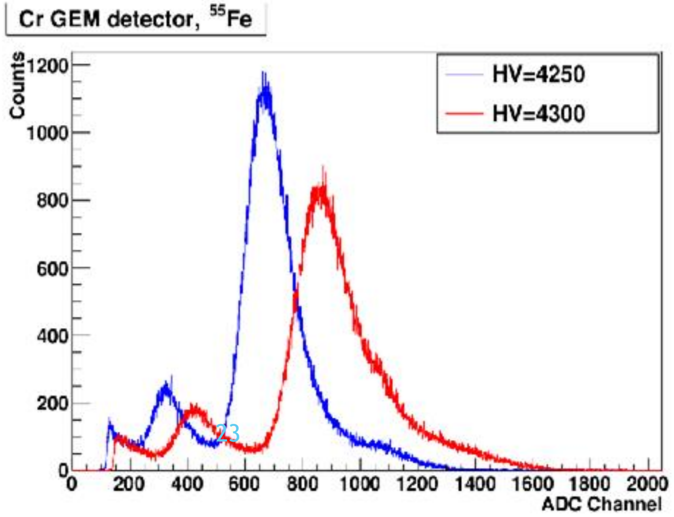
	Quantity	Thickness µm	Density g/cm3	X0 mm	Area Fraction	X0 %	S-Density g/cm2
Window							
Kapton	2	25	1.42	286	1	0.0175	0.0071
Drift							
Copper	1	0	8.96	14.3	1	0.0000	0.0000
Kapton	1	50	1.42	286	1	0.0175	0.0071
GEM Foil							
Copper	6	0	8.96	14.3	0.8	0.0000	0.0000
Kapton	3	50	1.42	286	0.8	0.0420	0.0170
Grid Spacer							
G10	3	2000	1.7	194	0.008	0.0247	0.0082
Readout							
Copper-80	1	0	8.96	14.3	0.2	0.0000	0.0000
Copper-350	1	0	8.96	14.3	0.75	0.0000	0.0000
Kapton	1	50	1.42	286	0.2	0.0035	0.0014
Kapton	1	50	1.42	286	1	0.0175	0.0071
NoFlu glue	1	60	1.5	200	1	0.0300	0.0090
Gas							
(CO_2)	1	15000	1.84E-03	18310	1	0.0819	0.0028
					Total	0.235	0.060

About 50% reduction in the amount of material in a EIC-FT-GEM with Cr-GEM

Uniformity test with Cosmic



ADC Spectrum with Fe55



R&D on Chromium GEM (Cr-GEM): High particle rate studies

***High particle rate study of the Cr-GEM*:**

- ✓ uniform exposure of the Cr-GEM in the high intensity x-ray source to analyze the response of the chamber with particle rate.
- ✓ For each measurement: rate the total charge (Coulombs) over 24
- ✓ The top left hit map plot shows no degradation at 0.17 C.
- ✓ @ 0.35 C ⇨ appearance of small dead area (**top right Fig1**).
- ✓ The dead area size increases with increasing rate (**bottom 2 plots Fig1**) ⇨ almost half of the active area is dead @ 0.7 C

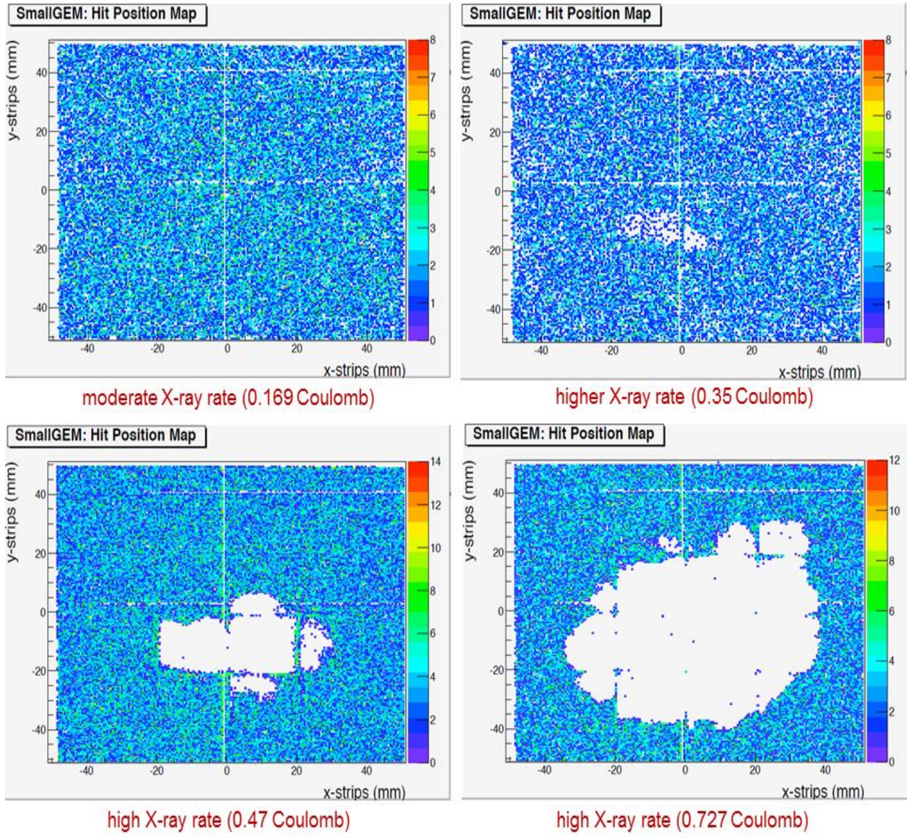


Fig1:Degradation of Cr-GEM in high particle rate environment with X-ray.

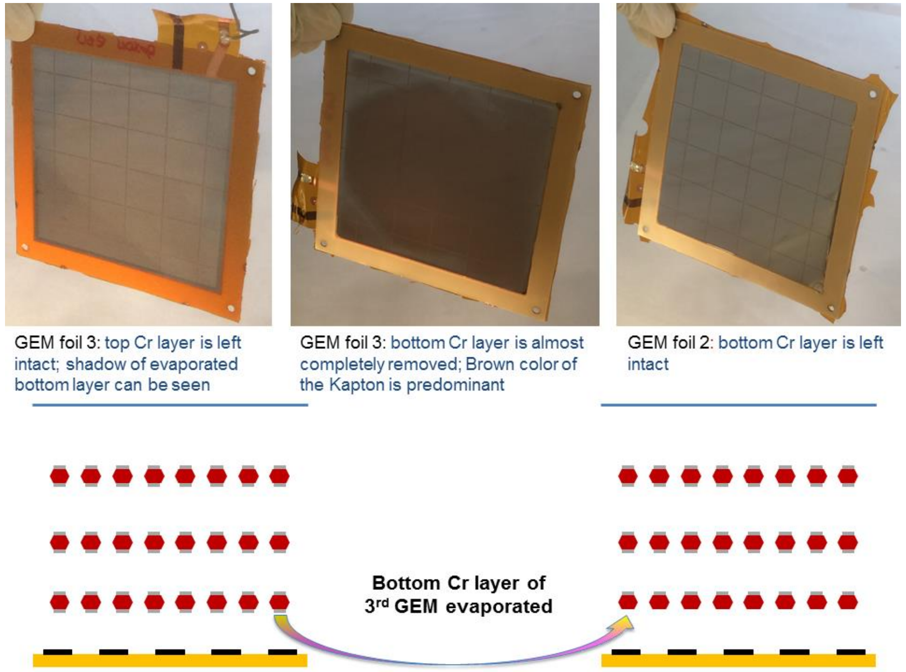


Fig2:Degradation of Cr-GEM in high particle rate environment with X-ray.

***Inspection of Cr-GEM foils after high rate X-ray exposure*:**

- ✓ Two GEM foils show no noticeable damage ⇨ HV test OK
- ✓ The third GEM foil, closer to the readout board
  - top Cr electrode layer intact with no apparent sign of discharges or spark (**top left Fig2**), however on the
  - bottom Cr electrode almost completely "evaporated" ⇨ dark brown color is the Kapton **(top middle Fig2),** no evidence of short or Kapton melt ⇨ small discharges evaporate Cr layer
- ✓ Unclear if damages are caused by ageing process or small discharges @ high rate
- ✓ Next step: ageing studies ⇨ long exposure at moderate rate

R&D toward EIC Forward Tracker: Ongoing work

Flexible readout board (design is completed)

✓ The readout is a 2D U-V strips readout with angle of 30.1^{o} and 400 µm pitch

⇨ **improvement of spatial resolution**

✓ Electrical contacts between the strips and the FE electronics on the outer radius side of the detector

⇨ **zebra connectors** ⇨ no mounted connectors or metallized holes

⇨ **Lower cost and fabrication risks**

Zebra-Panasonic adapter board (design is ongoing) ⇨ to connect to existing APV-SRS Electronics

✓ Final version for an EIC FT trackers ⇨ the zebra strips directly on the FE cards

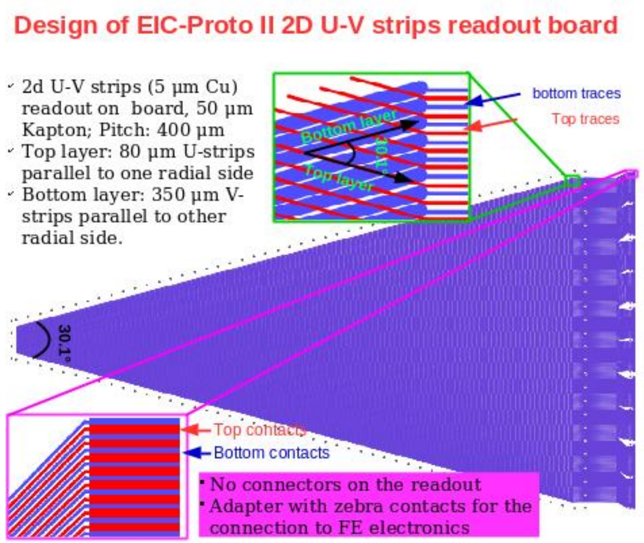
GEM support frames design is ongoing (expected to be completed in a few weeks)

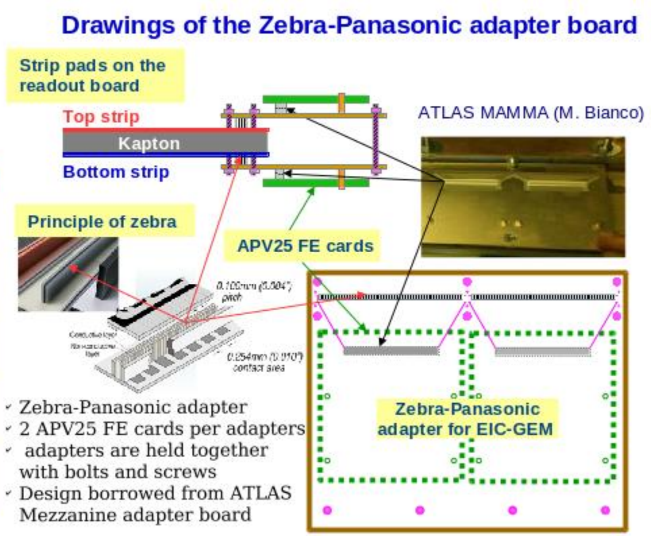
✓ Looking into high strength and light material for the frames

✓ Still considering the O-ring and screws option for the assembling without gluing frames together

⇨ Apply lessons learnt from the PRad GEM detectors

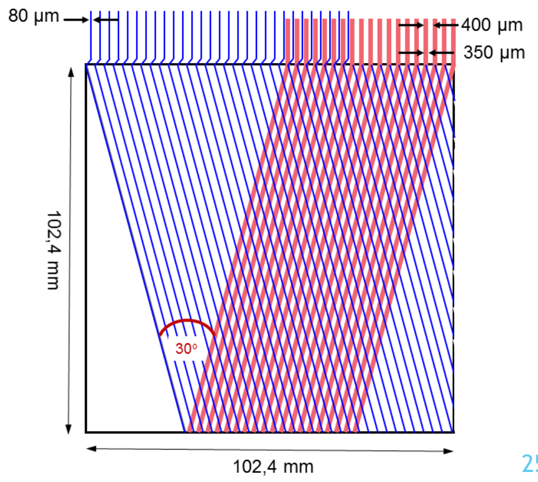
2D U-V strips readout board





Design of small size (10 cm ×10 cm) U-V readout prototype

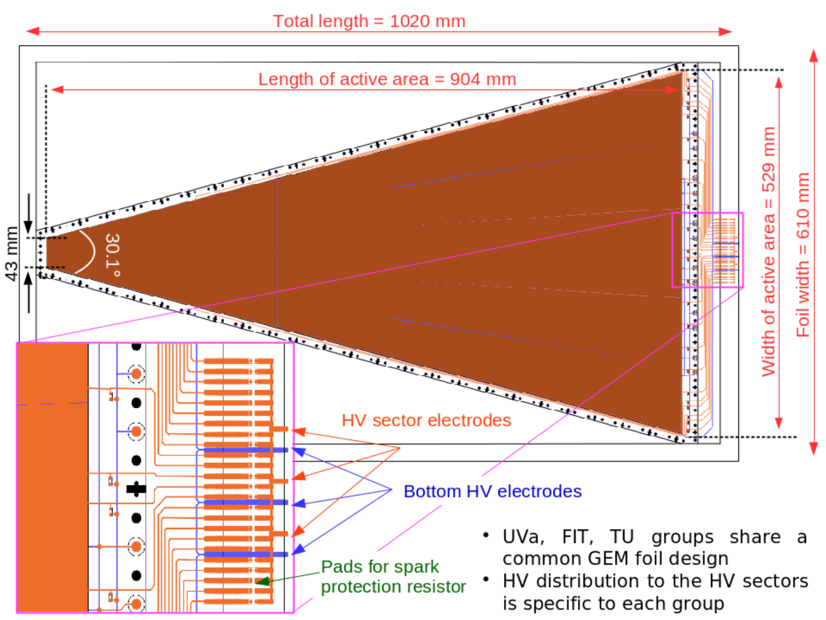
⇨ under production at CERN



R&D toward EIC Forward Tracker: Common GEM foil

Common EIC-FT-GEM foil

- ✓ Common GEM foil designed by 3 groups at UVa, Florida Tech (**M. Hohlmann**), and Temple University (**B. Surrow**).
- ✓ Active area: trapezoid foil with a length of **903.57 mm,** width at both ends equal to **43 mm and 529 mm,** opening angle **30.1º.**
- ✓ All connections (HV, gas flow structure and FE cards) are made on outer radius end.
- ✓ **We just received 4 common GEM foils from CERN ⇨ This is the UVa version**



- UVa, FIT, TU groups share a common GEM foil design
- HV distribution to the HV sectors is specific to each group

Preparation for the clean room setup

- ✓ Nitrogen box setup for electrical test of the GEM HV sectors
- ✓ Small adjustment needed to reuse the existing mechanical stretching device

Progress in 6 months

- Yale
  - ✓ Complete 3-coordinate readout analysis.
  - ✗ Submit 3-coordinate readout paper
    - Draft complete, submission very soon.
  - ✓ Submit hybrid gain stage paper
  - ✓ Understand corona-discharge characteristic of new boards
    - Bad resistive layer.
  - ✗ Test of Weiman multi-grid IBF concept.
    - Assembly nearly complete, tests when HV switch circuitry is functional.
    - Paper on calculations of Weiman grid concept submitted.

Hybrid gain structure for TPC readout

Yale University

Combination of two Gas Electron Multipliers and a Micromegas as gain elements for a time projection chamber

S. Aiola[a], R.J. Ehlers[a], S. Gu[a], J.W. Harris[a], R. Majka[a], J.D. Mulligan[a], M. Oliver[a], J. Schambach[b], N. Smirnov[a]

[a] *Yale University, New Haven, CT, USA*
[b] *University of Texas at Austin, Austin, TX, USA*

Submitted to NIM
http://arxiv.org/abs/1603.08473

Currently working on stacked gated grid scheme*

- Have all wire planes in hand
- Small chamber is built (10 cm x 10 cm)
- Have switchable (fast) ionization source using electrons created by UV LED
- Developing HV switching circuitry

* - H. Wieman, Gating grid concept for ALICE TPC upgrade, private correspondence (04 2014).
https://wiki.bnl.gov/eic/upload/Alice_upgrade_gating_grid_idea.pdf
- J. Mulligan, Simulations of a multi-layer extended gating grid (03 2016).
http://arxiv.org/abs/1603.05648

- Continuing work on 2-GEM+Micromegas gain structure with resistive layer in micromegas – aim is to build a chamber with minimum discharges and same IBF performance and energy resolution as published above (IBF ≤ 0.4% with ^{55}Fe energy resolution ≤ 12%)

3-coordinate Readout GEM Chambers

Analysis of Fermilab test beam data is complete and a paper is in preparation

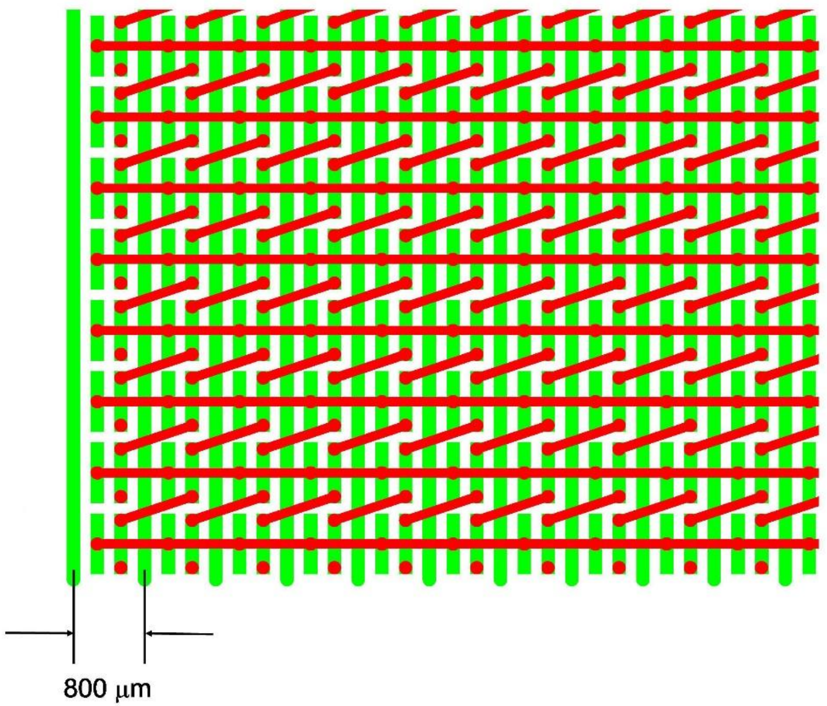
From fitting the test beam data we estimate the resolutions for the various coordinates as:

X (pads) = 66 μm

Y(strips) = 85 μm

U(pads with 45^o connection) = 73 μm

This is quite good for 800 μm pitch readout.



Closing out eRD6 generic R&D efforts

- BNL
  - Test of next generation chevron pattern.
  - $10k (plus overhead) for board production
- FIT
  - N/A Planar GEM trackers are targeted.
- SBU
  - Finish evaporator upgrade.
  - Make test samples.
  - Measure by vacuum photo spectrometer.
  - NO FUNDS REQUESTED.
- UVA
  - N/A Planar GEM trackers are targeted.
- Yale
  - Publish 3-coordinate
  - Grid studies
  - NO FUNDS REQUESTED.

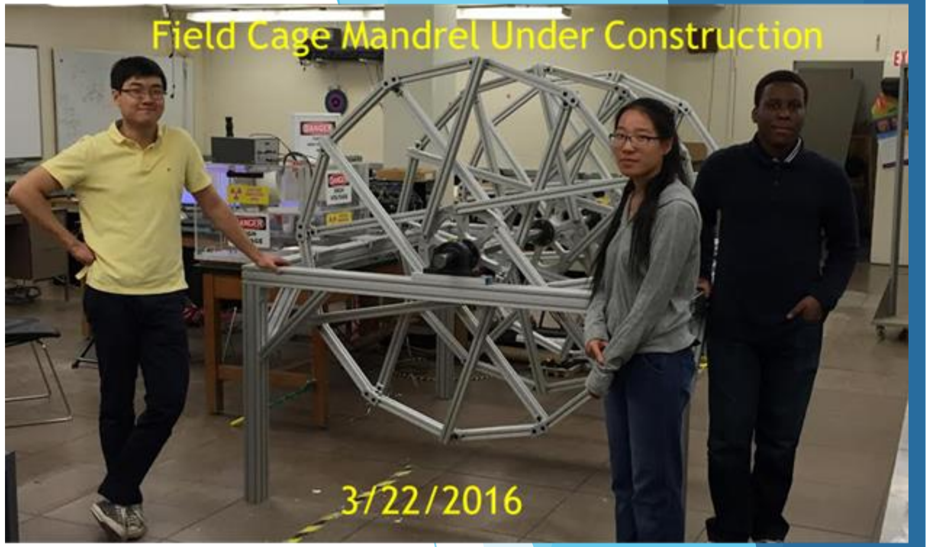
Very close to closing out the era of generic R&D.

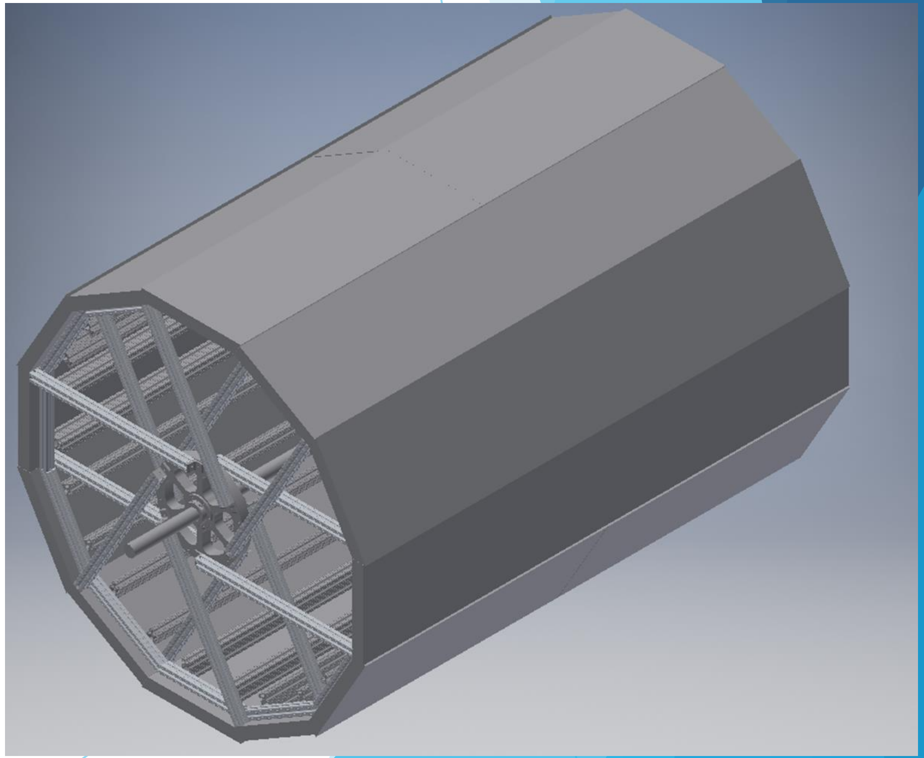
This enables us to focus efforts on Targeted R&D

Targeted R&D on TPC

- BNL
  - Move all efforts to TPC
  - Request Funds $52.5k
- SBU
  - Move all efforts to TPC
  - Request funds $40k ONLY for gain stage studies.
  - Field cage worked funded by BNL LDRD.
- WIS
  - All efforts on TPC
  - Excellent facility already in place for IBF studies.
  - Requesting primarily specialized GEM/consumables at $18.5k
- Yale
  - All efforts on TPC
  - No funding request at this time.

	$k
BNL	52.5
SBU	40.0
WIS	18.5
TOTAL	111.0





Targeted R&D on FWD Planar GEMs

- FIT
  - All effort dedicated to FWD GEM trackers.
  - Request funds $124k
- UVa
  - All efforts dedicated to FWD GEM trackers.
  - Request funds $30k
- Temple/Saclay
  - All efforts dedicated to FWD GEM Trackers
  - Request funds $43.2k

	$k
FIT	124.0
UVA	30.0
Temple	43.2
TOTAL	197.2

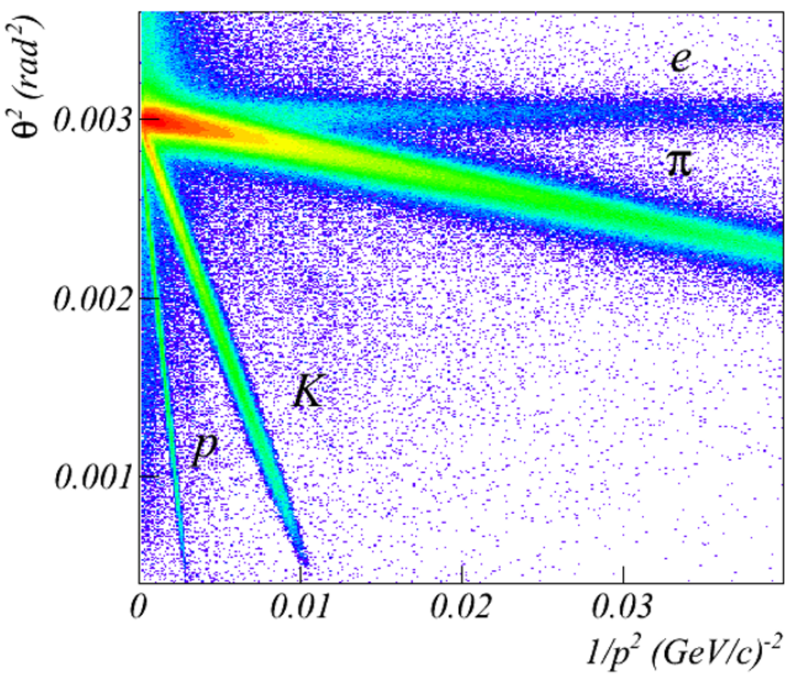
Targeted R&D on Cherenkov

- INFN has world-class expertise and experience on Cherenkov detectors.
- They have just completed an 8-year effort for the new Cherenkov detector system in COMPASS.
- Their concept builds upon this development and surpasses the prior eRD6 effort by being amenable to a dual-radiator design and surpasses the BeAST design by effectively eliminating shot noise (CsI vs SiPM).
- Their pad plane concept in the absence of CsI has compelling interest for use an a gateless TPC.
- I will spend a few slides on this since it is entirely new to the committee.
- Budget is $90k per year.

	$k
INFN	90.0
TOTAL	90.0

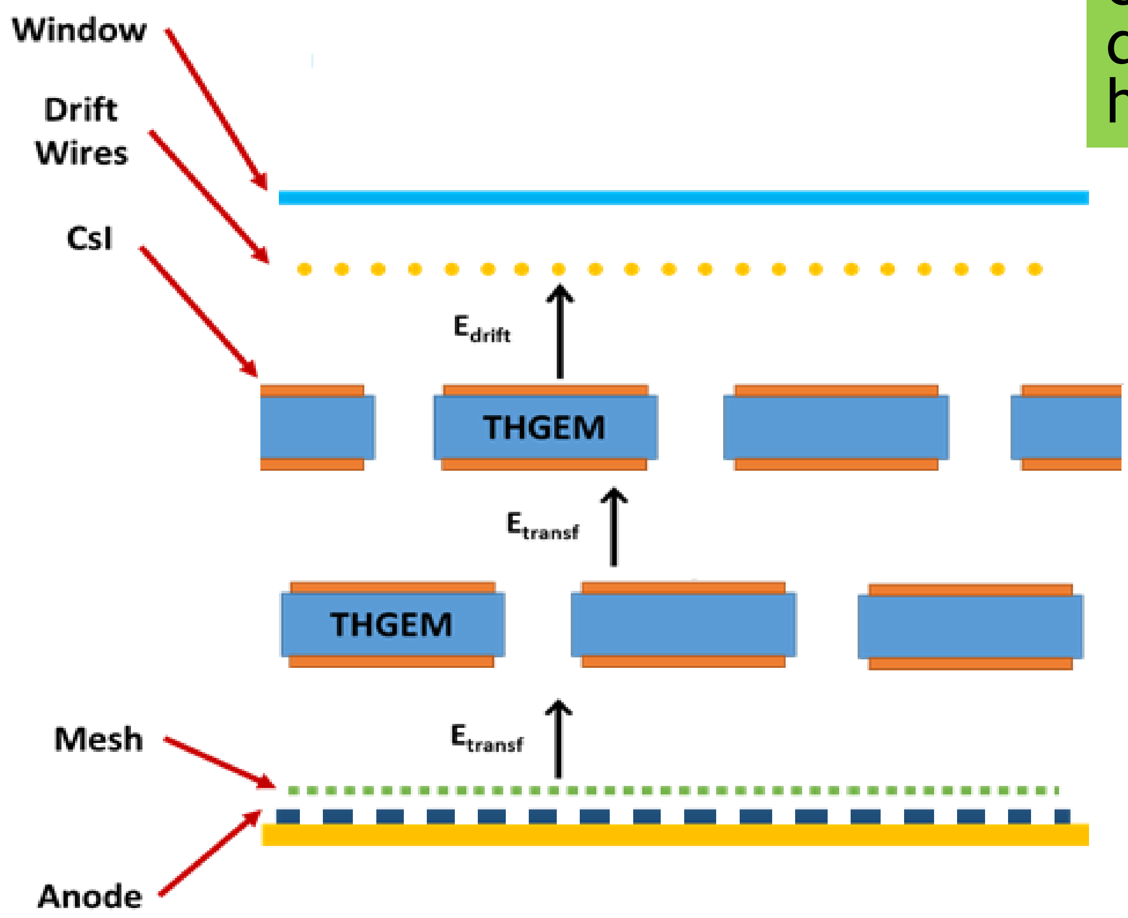
COMPASS RICH-1 Performance

π-K separation, CL > 95% up to 45 GeV/c
π-K separation, CL > 90% up to 60 GeV/c

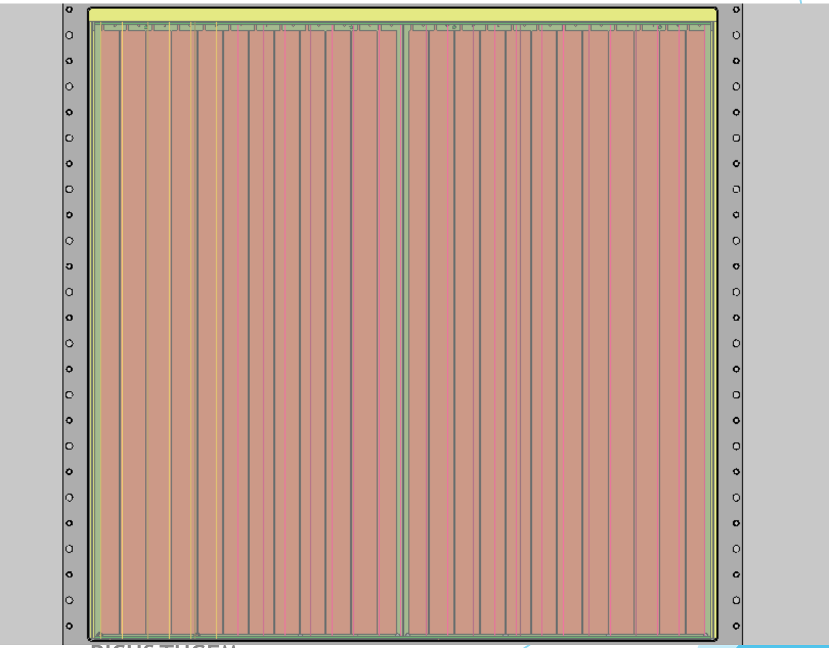


THE ONGOING UPGRADE: MWPCs → hybrid MPGDs

The COMPASS Upgrade Architecture



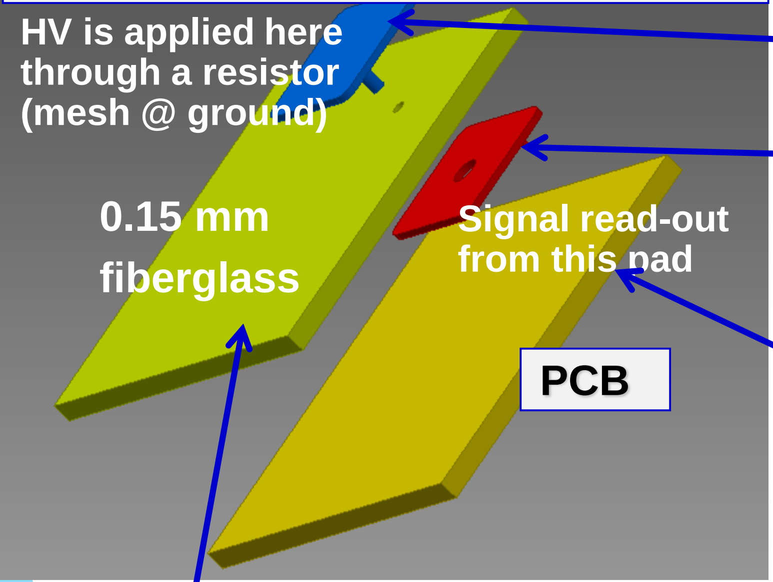
each 600 x 600 mm^2
detector consists of two modules
having 600 x 300 mm^2

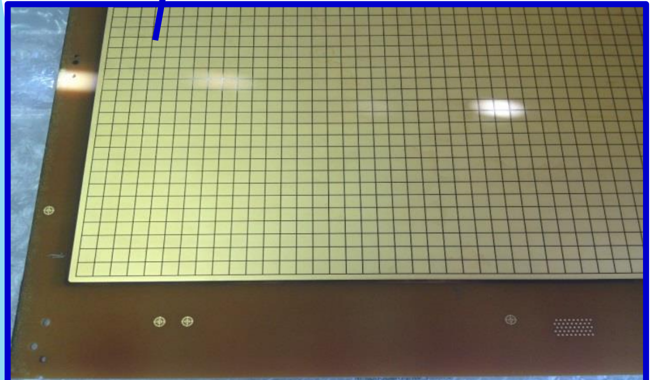


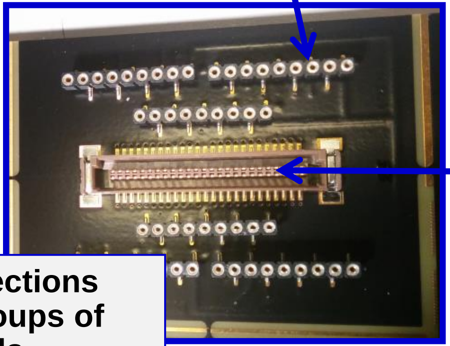
THE ONGOING UPGRADE: MWPCs → hybrid MPGDs

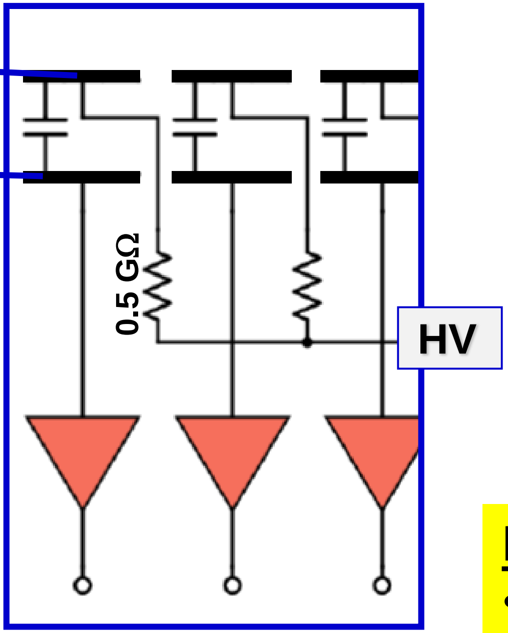
The bulk MICROMEGAS with resistive anode and capacitive coupling R-O

Single pad









Features
- HV→anode = large signal
- Isolate single pad
- No resistive paint
- Good dE/dx for TPC

Future Challenges
- Limit radiator to 1 m
- Fine granularity
- Controlled IBF
- Refine engineering
- THGem vs GEM

Program
- Novel THGEM material
- Miniature Pads
- THGEM vs GEM
- IBF optimization
- Operation w/ Fluorocarbon

Summary of Targeted (only) R&D Request

	$k
BNL	52.5
SBU	40.0
WIS	18.5
FIT	124.0
UVA	30.0
Temple	43.2
INFN	90.0
Yale	0.0
TOTAL	398.2
TOT/inst.	56.9
TOT/pub	30.6

- eRD3 and eRD6 have done the right things.
  - We combined into a new and larger group.
  - We attracted superb international collaborators.
- We recognize that the committee is both wise and human.
- We fear a diminishment of support as a result of combining in the manner that is in the best interest of the field today and will remain in the best interest of the field in the future.
- We request that the committee should both:
  - Calculate all funding requests per institution
  - Calculate all funding requests in light of productivity (publication record seems like an unbiased scaling).
- We also remind the committee that eRD6 has a request of $15k in left-over generic R&D and that eRD3 has generic R&D spelled out clearly in the presentation of Bernd Surrow.

Backups

Per Institution Budget

Stony Brook University:

1. Purchase of IBF-GEM foils - $5k
2. Expendable materials and supplies - $5k
3. Support for beam test - $10k
4. Travel - $5k

Total without overhead - $25k
Total with overhead - $40k

SBU

Brookhaven National Lab:

We anticipate the following funding request for the next round of EIC R&D funding in FY17.

1. Expendable materials and supplies for gas detector lab - $10K
2. Travel - $5K
3. Design and materials for new chevron readout patterns - $10K
4. Parts and materials for investigation of GEM/Micromegas operation - $10K
5. New optics for VUV spectrometer - $10K

Total without overhead - $45K
Total with overhead - $67.5K

BNL

We anticipate the following funding request for the next round of EIC R&D funding in FY17.

1. Materials and Production of (U-V strips) readout board including the Zebra-Panasonic adapter boards - $10K
2. Design and materials and production of GEM support frames - $4K
3. Expendable materials and supplies - $3K
4. Support for undergraduate student $5K
5. Travel - $3K

Total without overhead - $25K
Total with overhead - $30k

UVA

FIT

Forward tracking: large-area GEM with zigzag strip readout		
Personnel (post-doc, Aiwu Zhang)	$100k	12 months, fully loaded
GEM readout foil	$9k	From CERN
GEM assembly parts	$6k	Frames, O-ring, connectors, etc.
Supplies & material	$2k	Gas, T/P monitor, etc.
Travel	$7k	Beam test(s); conference, consortium meetings
Total	$124k	

WIS

Expense	Amount
Design and production of GEM elements and tooling	$10k
Operation of the detector lab (consumables, tooling, IT support, etc…)	$8.4k
Total w/o overhead	$18.4k

INFN	requested founding (k$)	(k$)	(k$)	total (k$)
year	**2017**	**2018**	**2019**	
item				
manpower (1 unit for the 3 years of the project duration)	33	33	33	99
travelling (3 trips to US per year + trips for material procurement and construction)	12	12	12	36
consumables (specific for each year, according to the project time-lines)	30	30	30	90
total	**75**	**75**	**75**	**225**
total adding overhead (at 20% level)	**90**	**90**	**90**	**270**