Test and characterization of commercially produced GEM foils using single-mask techniques

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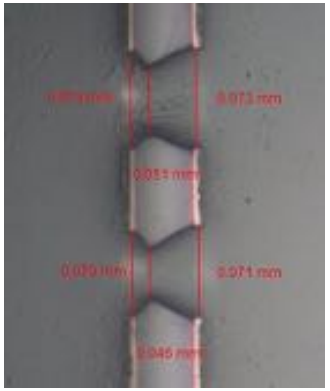

Outline

- Overview and Goals of EIC R&D program
- Commercial fabrication of single-mask GEM foil
- Electrical and optical characterizations
- Summary

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Overview and Goals of EIC R&D program

Introduction

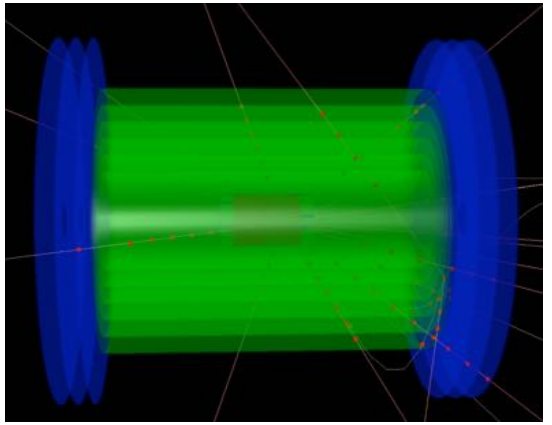
- R&D effort focuses on intermediate tracking system:
  - Barrel tracking system based on MicroMegas detectors manufactured as cylindrical shell elements and
  - Forward tracking system based on triple-GEM detectors manufactured as planar segments.
- R&D effort - Main strategy:
  - Design and assembly of large cylindrical MicroMegas detector elements and planar triple-GEM detectors
  - Test and characterization of MicroMegas and triple-GEM prototype detectors
  - Design and test of new chip readout system employing CLAS12 'DREAM' chip development
  - Utilization of light-weight materials
  - Development and commercial fabrication of various critical detector elements
  - European/US collaborative effort on EIC detector development (CEA Saclay, and Temple University)

Design and assembly
of
fast and light-weight
barrel and forward tracking prototype systems
for an EIC

S. Aune, E. Delagnes, M. Garçon, I. Mandjavidze, S. Procureur, F. Sabatié[1]
CEA Saclay

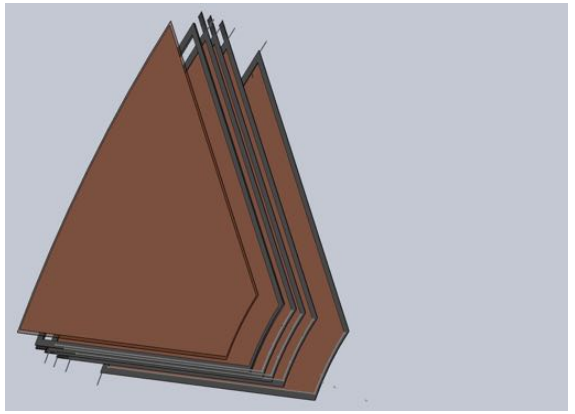
P. Bull, J. Fitzgerald, R. Harris, D. S. Gunarathne, E. Kaczanowicz,
A. F. Kraishan, X. Li, M. McCormick, Z. Meziani, G. Miller, D. L. Olvitt, J. Napolitano,
M. Posik, B. Surrow[2], M. Vandenbroucke and J. Wilhelmi
Temple University, College of Science and Technology

J. Bessuille, B. Buck, D. Hasell
MIT, Laboratory for Nuclear Science



Overview and Goals of EIC R&D program

- Design of large triple-GEM segment
  - Commercial fabrication using single-mask process of GEM foils and commercial fabrication of 2D foils: Weekly coordination meetings between Tech-Etch, CERN, FIT, Yale and Temple University
  - No spacers (Kapton ring)
  - Gas piping in frame
  - HV routing realized through Kapton PCB



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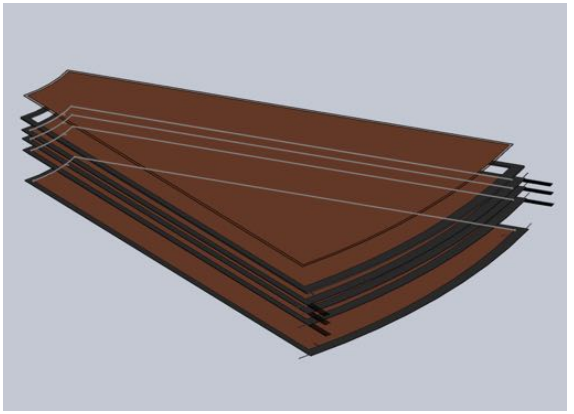

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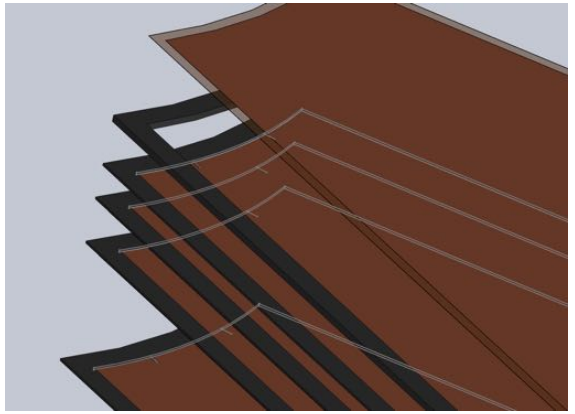

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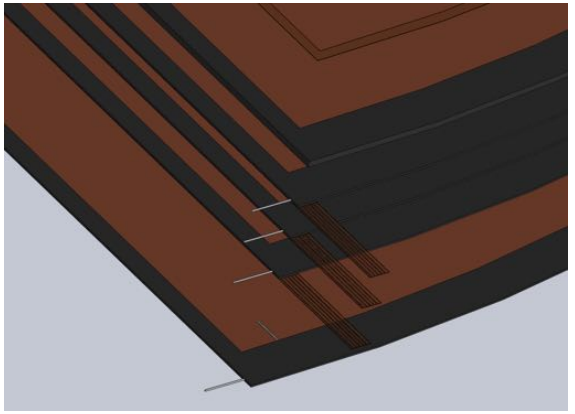
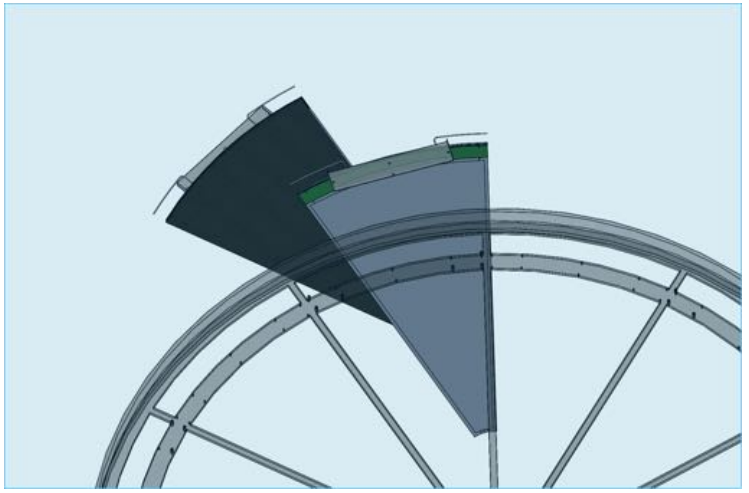
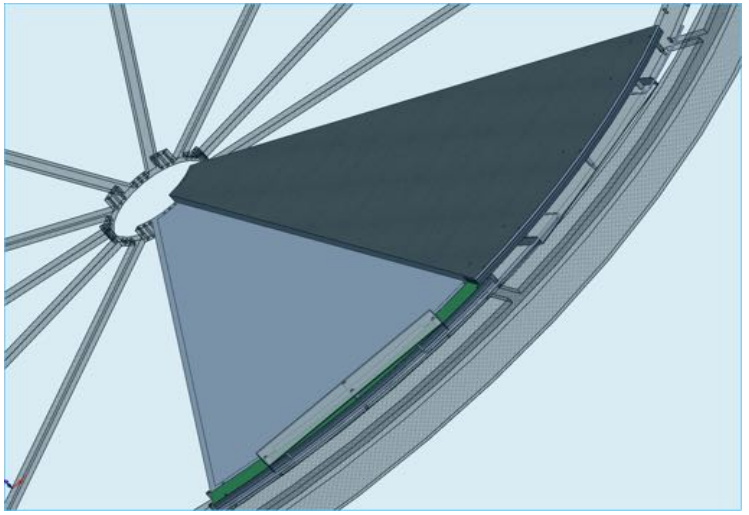


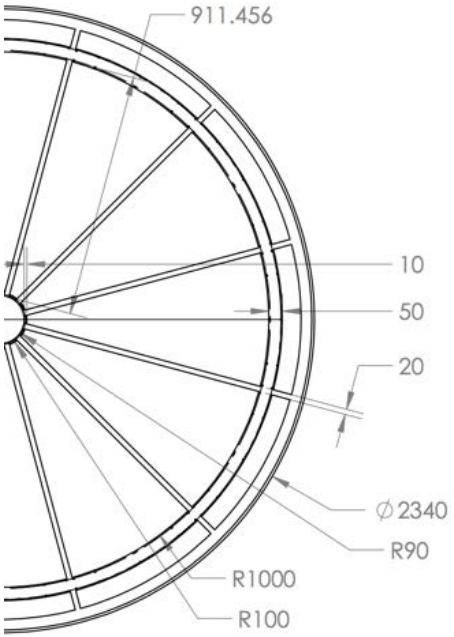
(d)

Overview and Goals of EIC R&D program

- Forward GEM tracking - Mechanical design
  - Light weight design allows minimal support structure
  - Initial discussion with CC shop at LBL very encouraging / Plan to prototype part of support structure







Wheel dimensions (cm)

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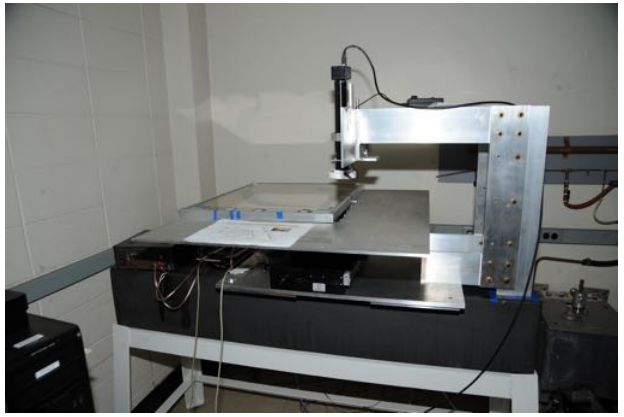
Overview and Goals of EIC R&D program

- Laboratory facilities at Temple University (Current Department of Physics)
  - Setup of three labs concerning CCD scans, assembly and testing
  - Characterization of GEM foils in terms of leakage current and optical uniformity routinely performed
  - Assembly of triple-GEM test detectors
  - Setup of cosmic-ray test and 55Fe source scanner
  - DAQ and HV system
  - Mechanical design studies on large triple-GEM detector segment
  - Commercialization of large GEM foil production using single-mask manufacturing

(a)



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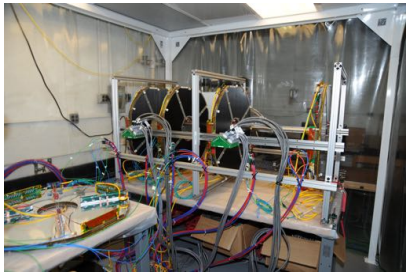

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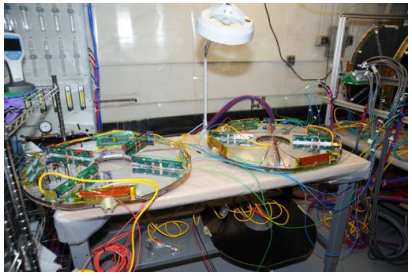

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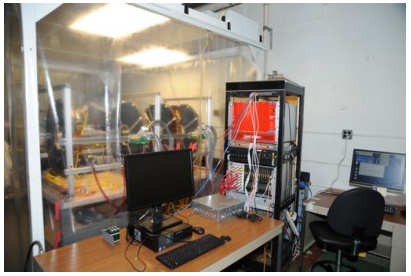


(e)

Overview and Goals of EIC R&D program

- New Laboratory facilities at Temple University (New Department of Physics)

(a)

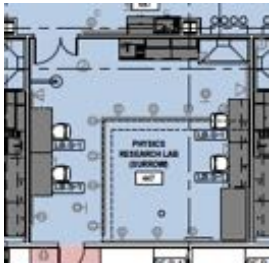
Class 1,000 Clean Room
GEM Assembly Lab

(d) Science Education and Research Center

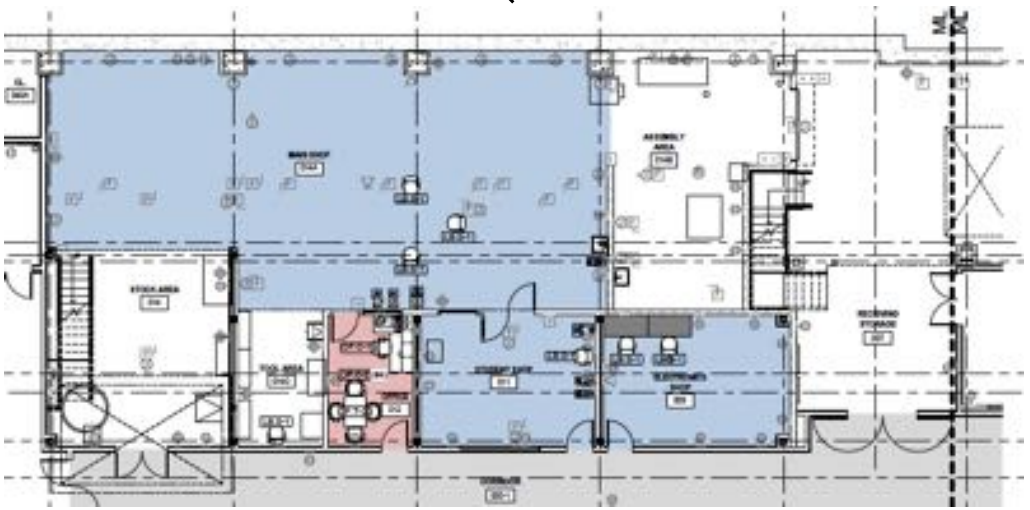
4th floor

Basement

(b)



GEM testing lab

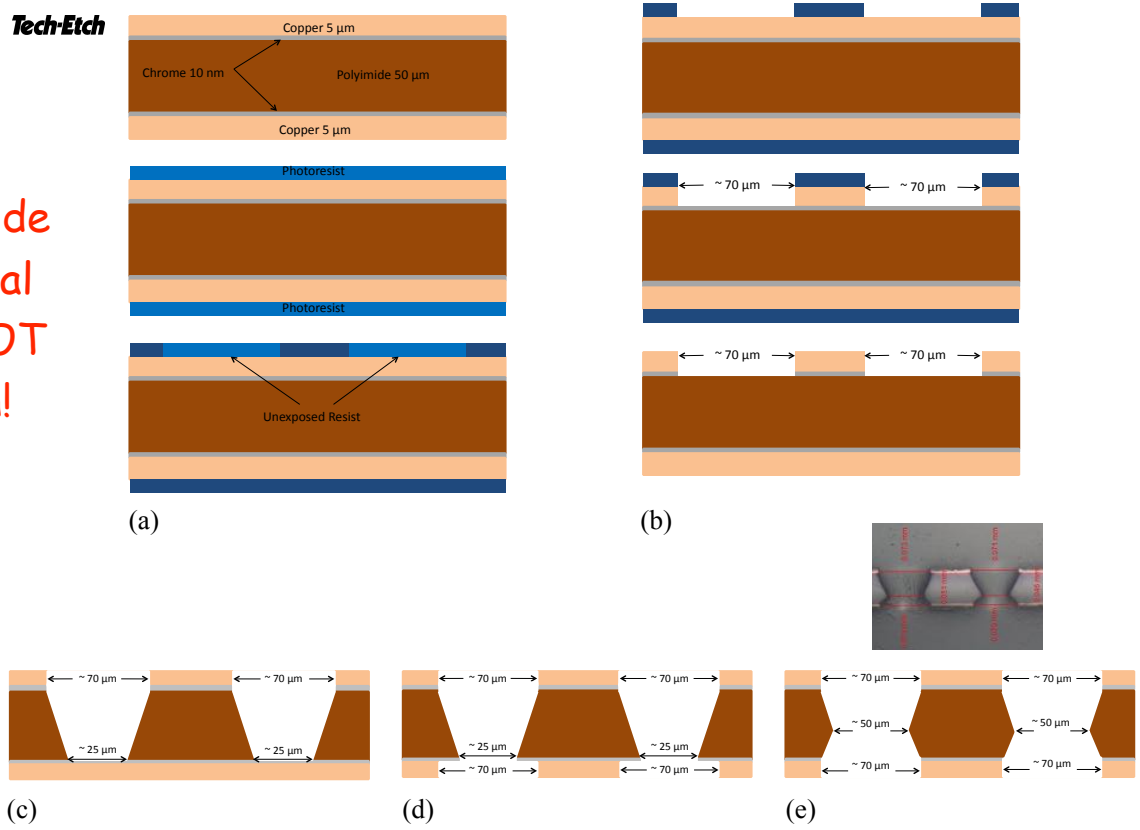


(c) Basement - Machine Shop

Commercial fabrication of single-mask GEM foils

- Highlight: Commercial fabrication of single-mask produced GEM foils
  - Successful fabrication of single-mask produced GEM foils at Tech-Etch Inc. in collaboration with Temple University & Yale University
  - Processing steps:

Note: Polyimide is Apical and NOT Kapton!



(a) Coating of photoresist and laser direct imaging

(b) Removal of unexposed photoresist and etching of copper and removal of Chrome adhesive layer

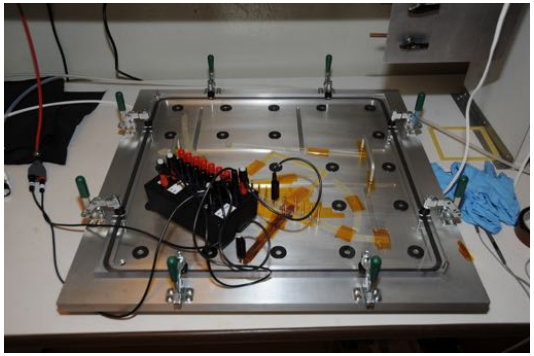
(c) 1st polyimide etching in EDA chemistry

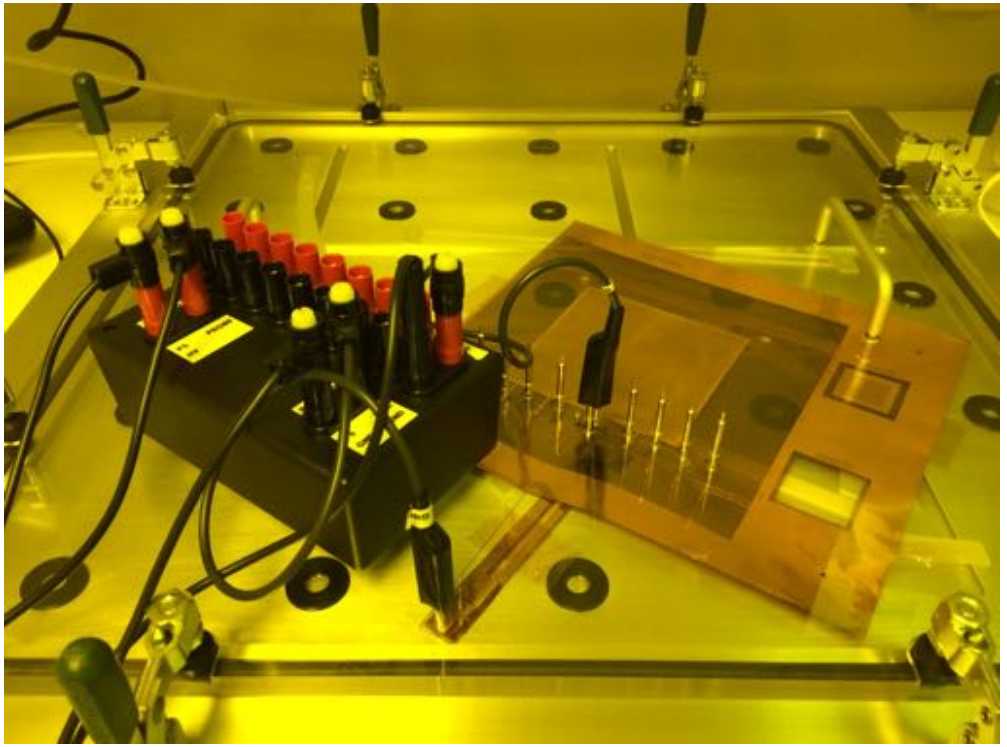
(d) Electrolyte etching and removal of backside copper

(e) 2nd polyimide etching in EDA chemistry

Electrical and optical characterization

- Single mask GEM Foil: Electrical tests at Temple University / Leakage current (1)
  - Setup of leakage current measurement at Temple University





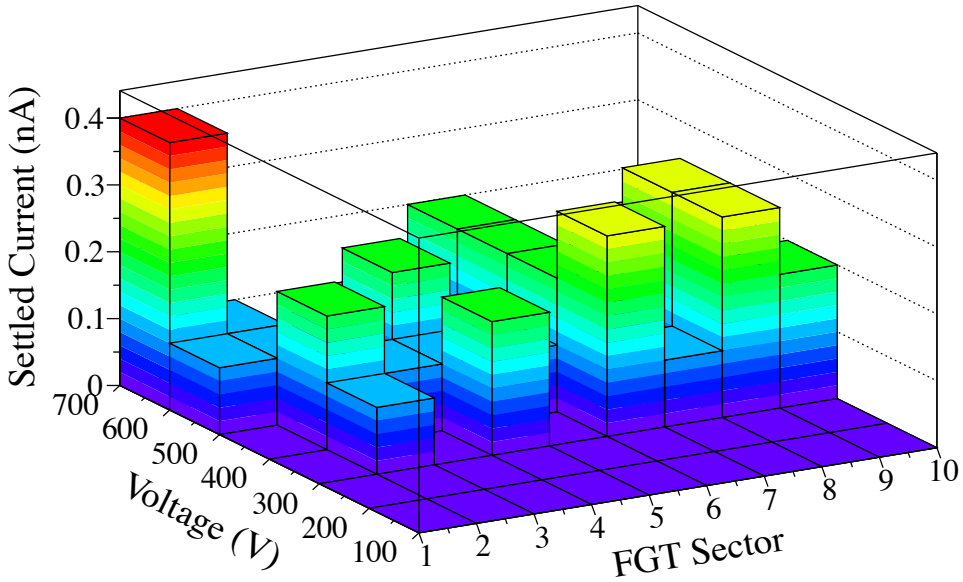
- Setup including nitrogen box with HV connections
- Power supply and nA current measurement

Electrical and optical characterization

- Single mask GEM Foil: Electrical tests at Temple University / Leakage current (2)
  - Results for small GEM foils (10 X 10cm^2)

    Three manufacturing lots of 6 / 12 / 6 foils each were obtained which ALL showed consistent behavior, i.e. < 1nA for 0…600V

    Tech-Etch independently measured leakage current prior to packaging and shipment with same results!
  - Results for large GEM foils (40 X 40cm^2)



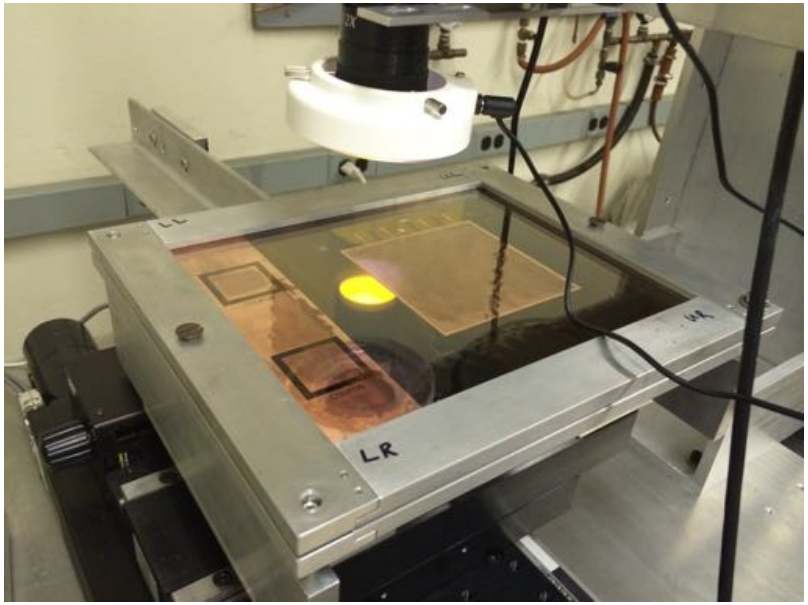
  - Very small currents < 1nA repeatedly measured for 3 large GEM foils (40 X 40cm^2)
  - **Critical step**: Switch from Kapton polyimide base material to Apical base material as suggested by CERN / Previous base material by Tech-Etch was Kapton with typically X 10 larger leakage current

Electrical and optical characterization

- Single mask GEM Foil:

  CCD scan setup

  - 2D scanning table with CCD camera fully automated
  - Scan GEM foils to measure hole diameter (inner and outer) and pitch
  - Unique world-wide setup in micro-pattern detector community
  - Critical for feedback in development and QA stage!



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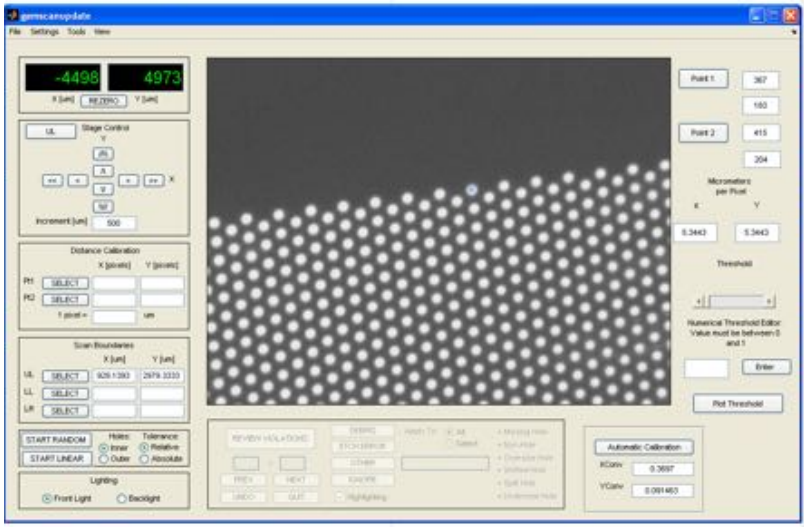

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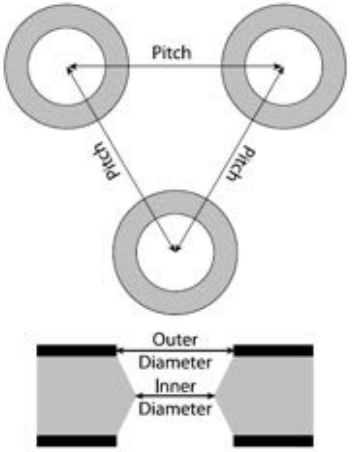

(c)

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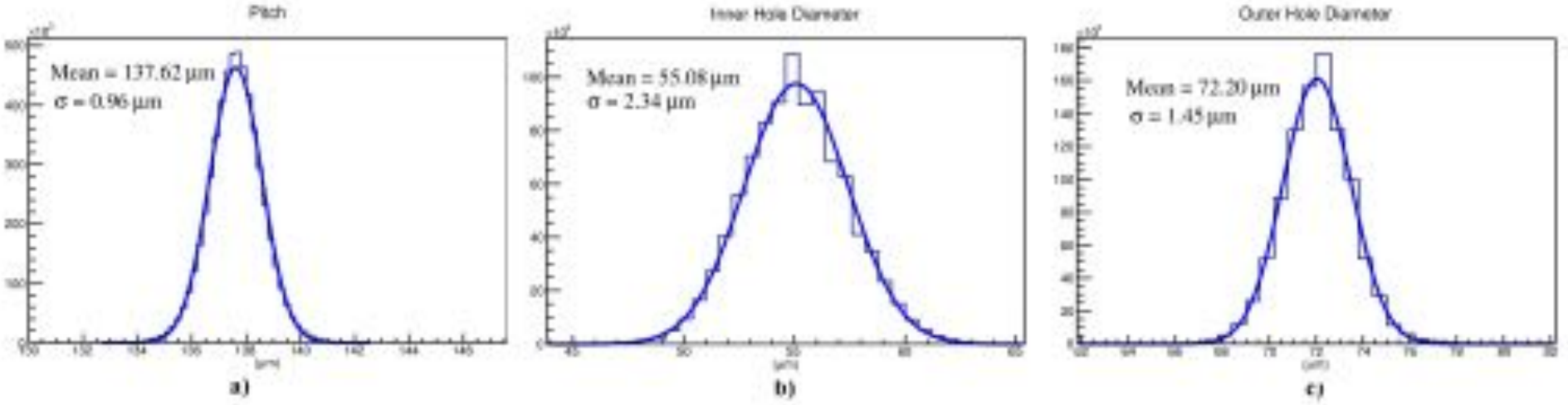
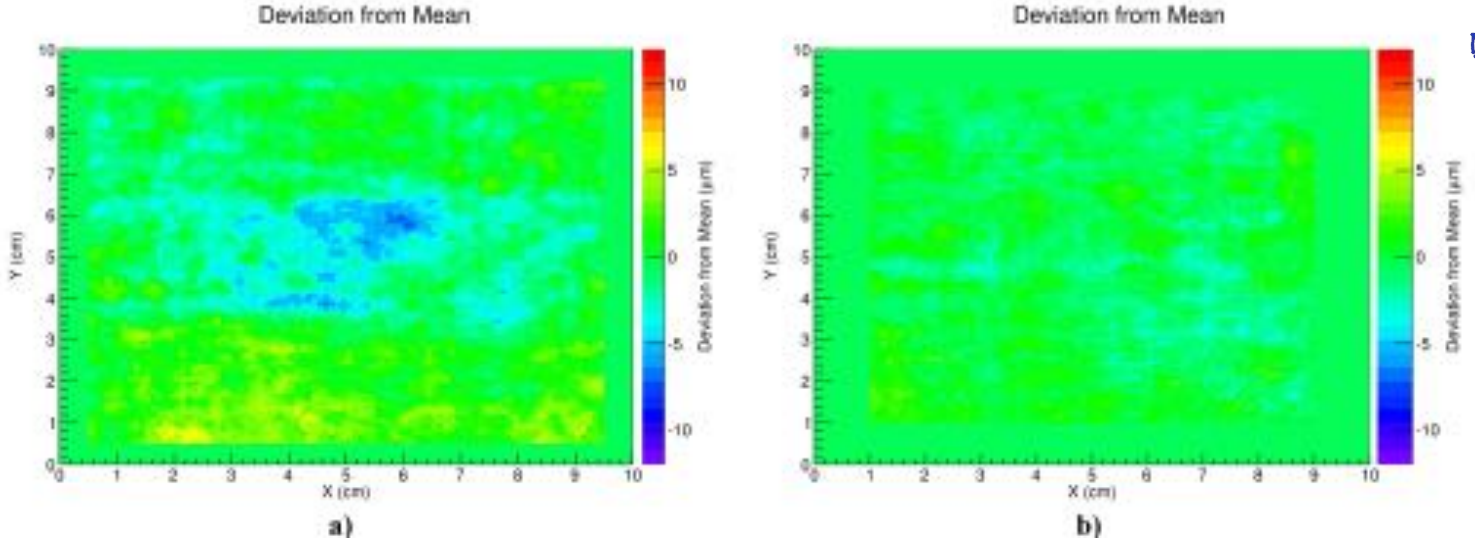
Electrical and optical characterization

- Single mask GEM Foil: CCD scan

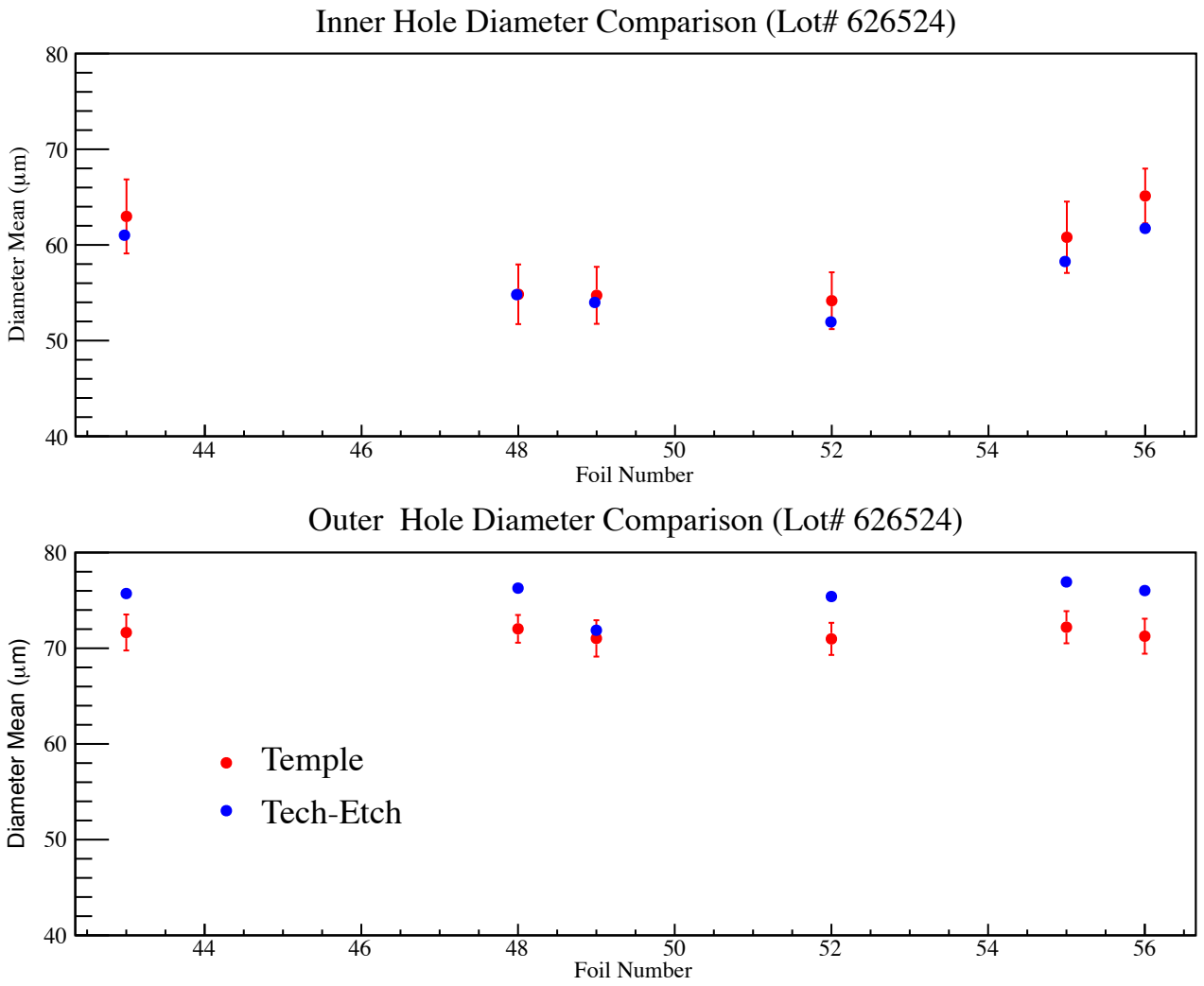




- Simple model calculation yields a completely negligible effect of the established σ (Inner Hole diameter) on the reconstructed hit position and resolution

Electrical and optical characterization

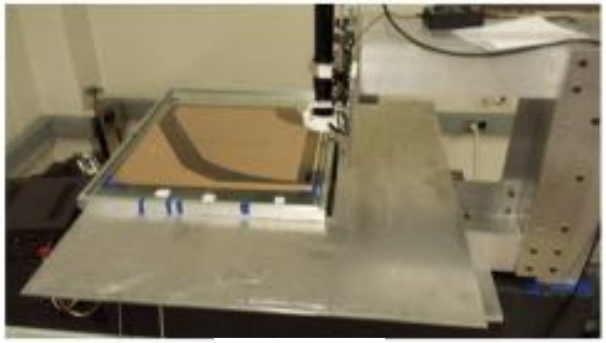
- Single mask GEM Foil: GEM Foil CCD scan results / Small samples



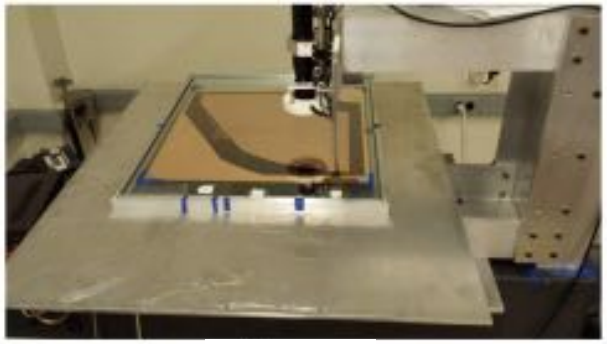
- Feedback from optical and electrical measurements at Temple University during development steps absolutely critical for Tech-Etch
- Tech-Etch has established strict handling and QA procedures based on numerous discussions and site visits

Electrical and optical characterization

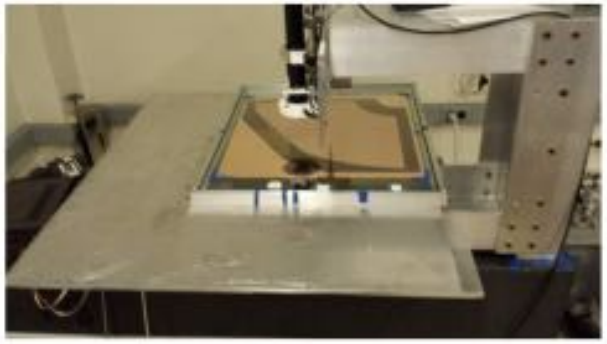
- Single mask GEM Foil: CCD scan results / Large samples (1)



Setup A

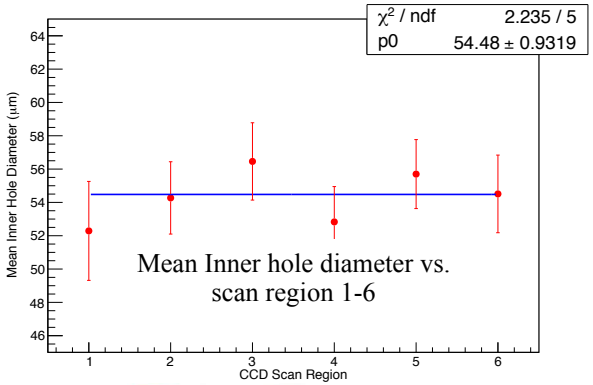


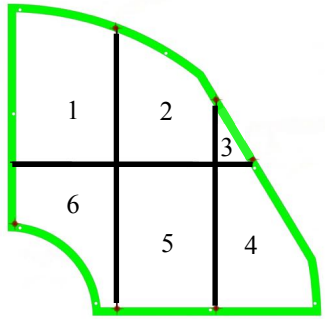
Setup B

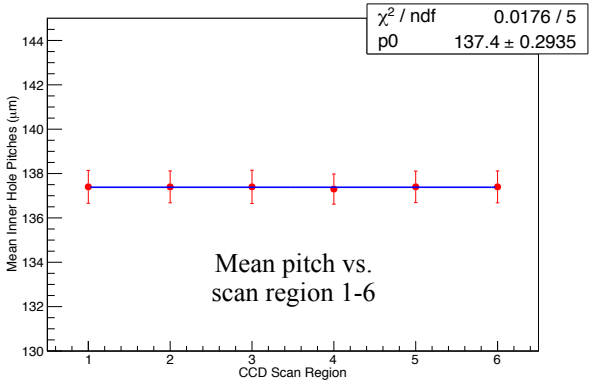


Setup C

- Consistent inner hole diameter of ~55µm for all 6 regions identical to small GEM foils
- Completely flat pitch for all six regions close to ~140µm
- Small X/Y travel of CCD scanner results in very long total scanning time ➜ Upgrade for large foils urgently needed!







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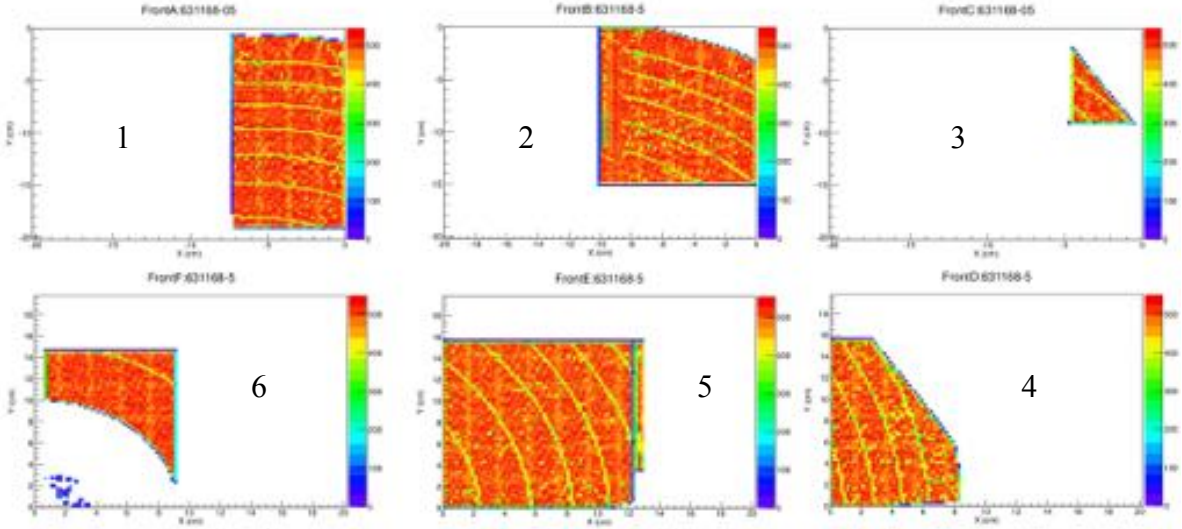
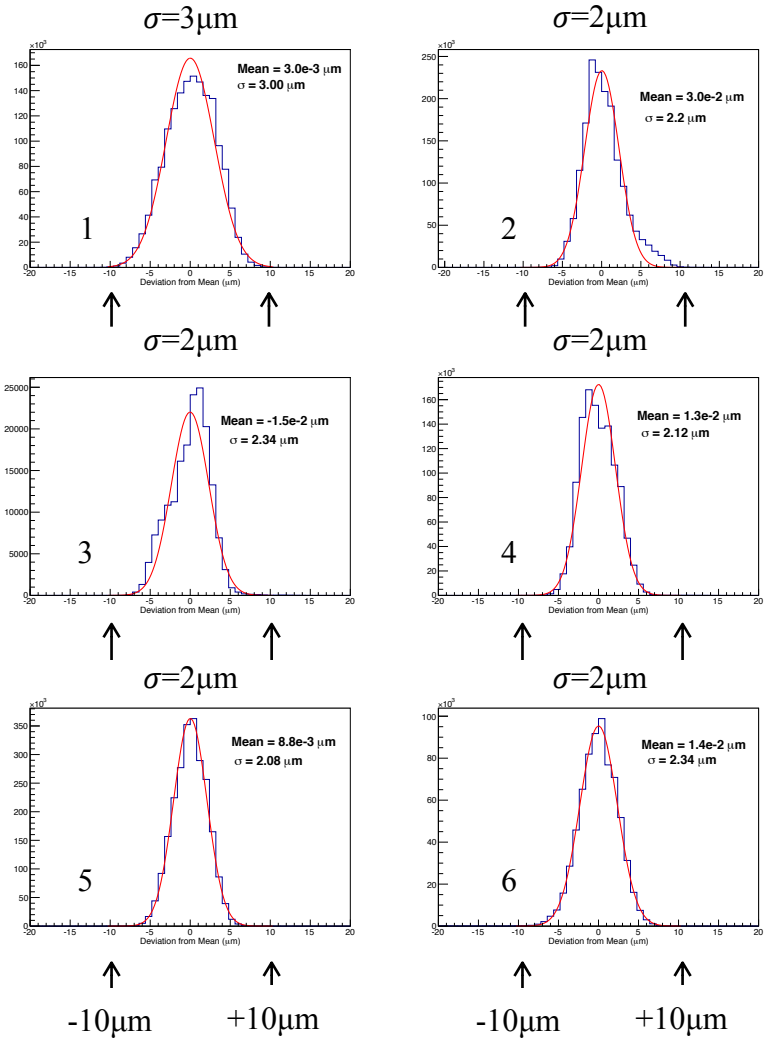
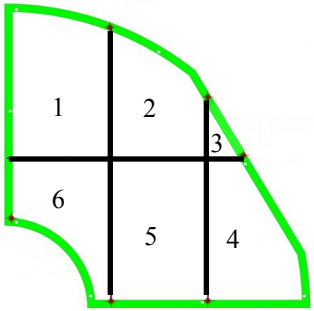
Electrical and optical characterization

- Single mask GEM Foil: CCD scan results / Large samples (2)





- Measurement yield of CCD images for each of the 6 regions
- Boundaries and GEM foil segmentation boundaries are clearly visible



- Simple model calculation yields a completely negligible effect of the established σ (Inner Hole diameter) on the reconstructed hit position and resolution

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Summary

- Successfully established commercial source for small (10cm X 10cm) and large (40cm X 40cm) single-mask produced GEM foils
- Excellent electrical and optical performance
- 50cm X 50cm in progress
- Goal: Expand production facility to larger sizes ~1.2m X ~0.5m between now and next year!

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