Status Report (Q4FY14 & Q1FY15)

Fast and lightweight EIC integrated tracking system

Barrel MicroMegas

&

Forward Triple-GEM

Franck Sabatie (PI),
Maxence Vandenbroucke

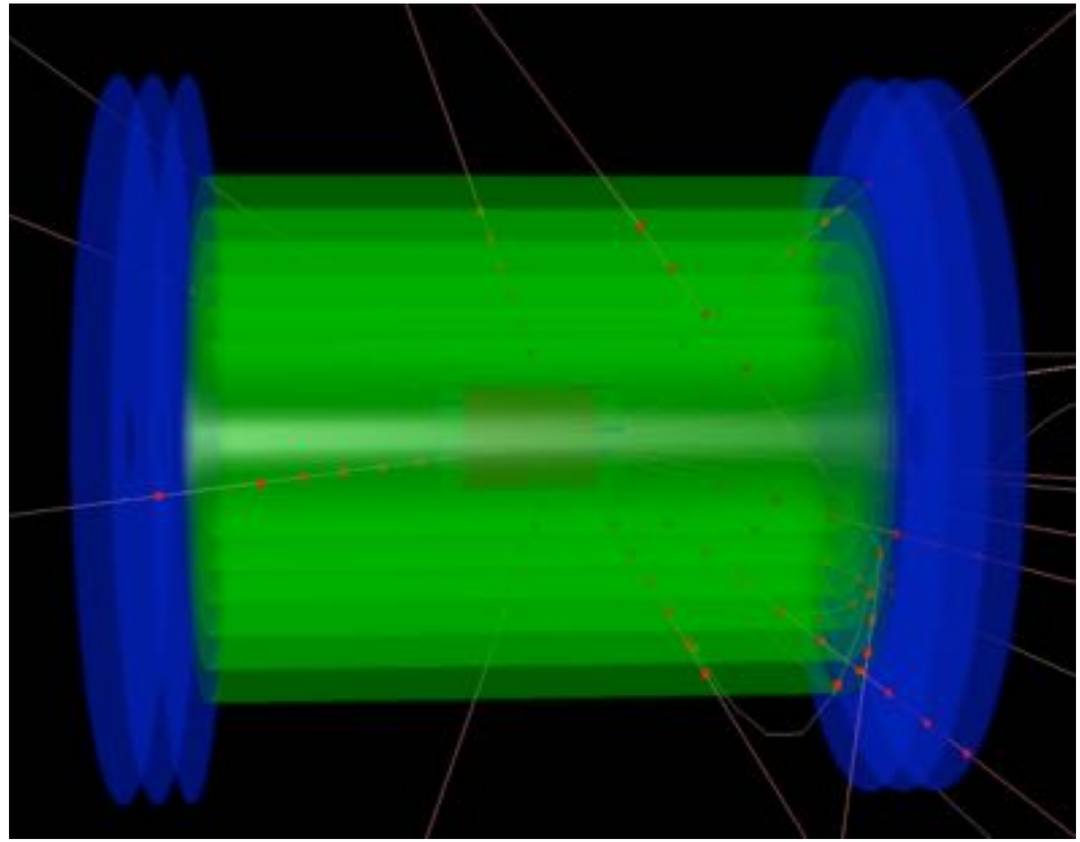
CEA Saclay

Matt Posik,
Bernd Surrow (PI)

Temple University

Outline

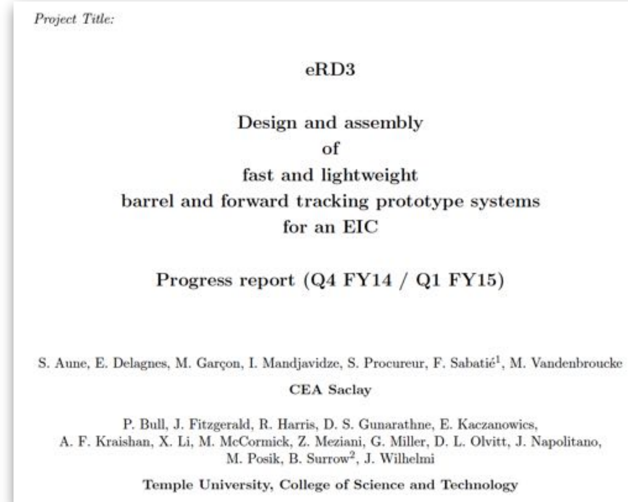
- Introduction
- R&D program: Status
  - (1) Forward GEM tracking
  - (2) Barrel MicroMegas tracking
  - (3) Front-End Readout System
  - (4) Simulations
- Summary



Introduction

Overview of eRD3 effort

- R&D effort focuses on intermediate tracking system:
  - Barrel tracking system based on MicroMegas detectors (Sole MM EIC R&D program) manufactured as cylindrical shell elements and
  - Rear / 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, common chip readout system employing CLAS12 'DREAM' chip development, ideally suited for micro-pattern detectors
  - 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)



Project Title:

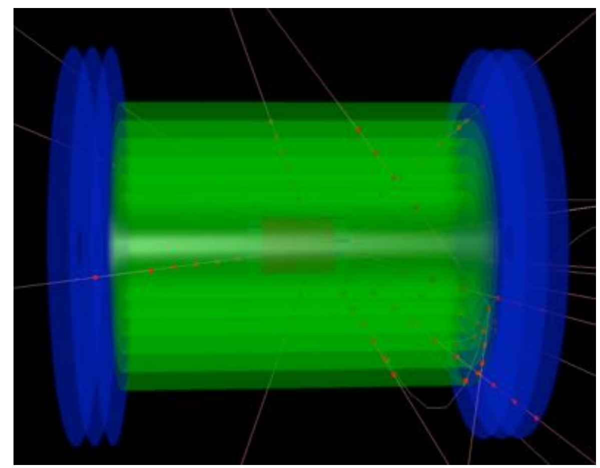
eRD3

Design and assembly
of
fast and lightweight
barrel and forward tracking prototype systems
for an EIC

Progress report (Q4 FY14 / Q1 FY15)

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

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



Introduction

Highlights of triple-GEM R&D program (1)

- Established reliable commercial source for single-mask produced GEM foils now up to 50 X 50 cm^2
- Extensive characterization of single-mask GEM foils
- Presentation and publication of single-mask result by IEEE
- Completion of all testing and tooling stations
- Completion of common large GEM foil design
- Relocation of three labs at Temple University to the new Science Education and Research Center

Single-Mask GEM foil (40cm X 40cm) Single-Mask GEM foil (50cm X 50cm)

Matt Posik, Maxence Vandenbroucke,
Bernd Surrow (PI) and Franck Sabatie (PI)

Introduction

- Highlights of triple-GEM R&D program (2)
  - IEEE paper

Research and Development of Commercially Manufactured Large GEM Foils

M. Posik and B. Surrow

***Abstract*—The recently completed Forward GEM Tracker (FGT) of the STAR experiment at RHIC took advantage of commercially produced GEM foils based on double-mask chemical etching techniques. With future experiments proposing detectors that utilize very large-area GEM foils, there is a need for commercially available GEM foils. Double-mask etching techniques pose a clear limitation in the maximum size. In contrast, single-mask techniques developed at CERN would allow one to overcome those limitations. We report on results obtained using 10 × 10 cm^2 and 40×40 cm^2 GEM foils produced by Tech-Etch Inc. of Plymouth, MA, USA using single-mask techniques and thus the beginning for large GEM foil production on a commercial basis. A quality assurance procedure has been established through electrical and optical analyses via leakage current measurements and an automated high-resolution CCD scanner. The Tech-Etch foils show excellent electrical properties with leakage currents typically measured below 1 nA. The geometrical properties of the Tech-Etch single-mask foils were found to be consistent with one another, and were in line with geometrical specifications from previously measured double-mask foils. The single-mask foils displayed good inner and outer hole diameter uniformities over the entire active area.**

I. Introduction

TECHNOLOGY based on gas electron multipliers (GEMs) have been establishing their presence in the nuclear and particle physics communities since their invention in 1997 [1]. They have several attractive features including the ability to perform in a high rate environment (> 10^5 Hz/mm^2 [2]), excellent spatial resolution (40 μm rms [2]), and the ability to cover a large acceptance. Several experiments: STAR [3], COMPASS [2], and others are already employing the use of GEM technology in their detectors. With GEM technology maturing and based on successful runs from experiments already using GEM technology, many future experiments and experiment upgrades are either planning on or looking into using GEM technology, such as ALICE [4], JLab's Super Big-Bite Spectrometer [5], CMS [6] and dedicated EIC detectors.

The main distributor of GEMs to the scientific community is CERN. In the past CERN has been able to adequately provide GEMs to experiments that needed them. However, given the newly generated interest in GEMs and the fact that CERN is not a dedicated production facility, one can not expect CERN to be able to provide all experiments with the GEMs that they need. As a result the commercialization of GEMs has been successfully established at Tech-Etch Inc [7], which will help to alleviate the high demand for GEMs. Tech-Etch Inc. is a company based in Plymouth, Massachusetts who have commercialized large area (up to ~50×50 cm^2) GEMs using single-mask and double-mask etching processes [3], [8], [9], [10].

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M. Posik is with Temple University, Philadelphia, PA 19122 USA (e-mail: posik@temple.edu).
B. Surrow is with Temple University, Philadelphia, PA 19122 USA (e-mail: surrow@temple.edu).

II. Single-Mask Etching Process

Tech-Etch employs the single-mask etching technique to produce their GEM foils. This has the advantage of allowing for the production of larger GEMs, up to about 1 m long. Figure 1 highlights the GEM foil production steps used by Tech-Etch to produce their single-mask GEMs. A GEM is produced starting from a standard foil which has a polyimide layer made of Apical, that is about 50 μm thick, which is sandwiched between two layers of copper (~ 5 μm thick). The foil is then coated with a layer of photoresist, and laser direct imaging is used to apply the micro hole pattern to the front side of the foil (fig. 1 (a)). The unexposed photoresist is developed away and the front side copper is etched via an acid bath (fig. 1 (b)). Ethylenediamine (EDA) chemistry is then used to etch the polyimide layer on the front side of the foil (fig. 1 (c)) and the back side copper layer is then etched using an electrolytic process (fig. 1 (d)). This now leaves the micro pattern holes on the GEM foil having a conical structure. In order to obtain the desired double conical hole geometry, the back side polyimide layer is etched using EDA chemistry (fig. 1 (e)). The resulting double conical structure can clearly be seen in the cross-sectional image of a Tech-Etch 40×40 cm^2 GEM foil shown in fig. 2.

III. Tech-Etch GEM Production

Following the GEM production process discussed in the previous section, Tech-Etch has successfully produced 10×10 and 40×40 cm^2 GEM foils. Three 10×10 cm^2 manufacturing lots consisting of 6,12, and 6 foils respectively, have been sent to Temple University for analysis of their electrical performance and geometrical properties. Additionally one 40×40 cm^2 manufacturing lot consisting of 3 foils was also sent to Temple University for analysis. Section IV will discuss the means by which the electrical performance and geometrical properties of the foils were determined. Sections V and VI will present the electrical and geometrical results, respectively.

IV. Measurement Techniques

The production quality a GEM foil can be quantified through its electrical and geometrical properties. The electrical performance of the GEM is determined through its leakage

Introduction

Highlights of MicroMegas R&D program

- Design and assembly of barrel MicroMegas large radius 1D (Z) MM detector with restive readout
- Design of MicroMegas large radius 1D (Phi) MM detector with restive readout
- Characterization of MicroMegas detectors in cosmic-ray test stand
- Usage of DREAM chip production versions
- Test of DREAM-chip based DAQ system

Matt Posik, Maxence Vandenbroucke,
Bernd Surrow (PI) and Franck Sabatie (PI)

Status - Forward GEM Tracking

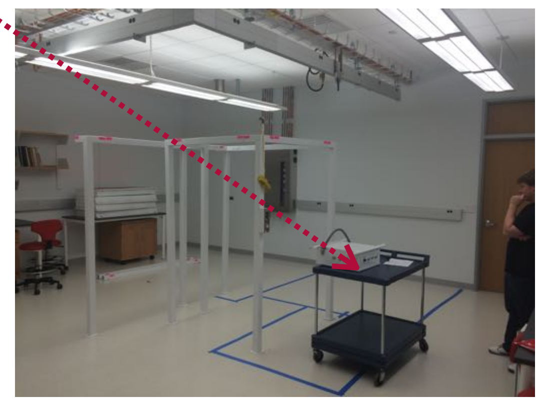
- New Laboratory facilities at Temple University (New Department of Physics)

Note: GEM Clean Room (a/b) is ready (Move-in soon) / GEM detector (c/d/e) lab move-in completed. Both labs will be equipped with new Newport Optical tables (6' X 4') provided by Temple University, CST (Total cost: $25k)

Science Education and Research Center (SERC)

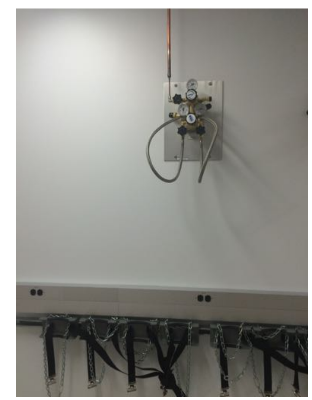
(a)

(b)



(c)

(d)



(e)

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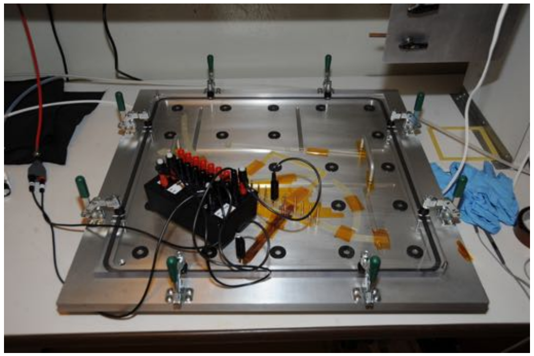
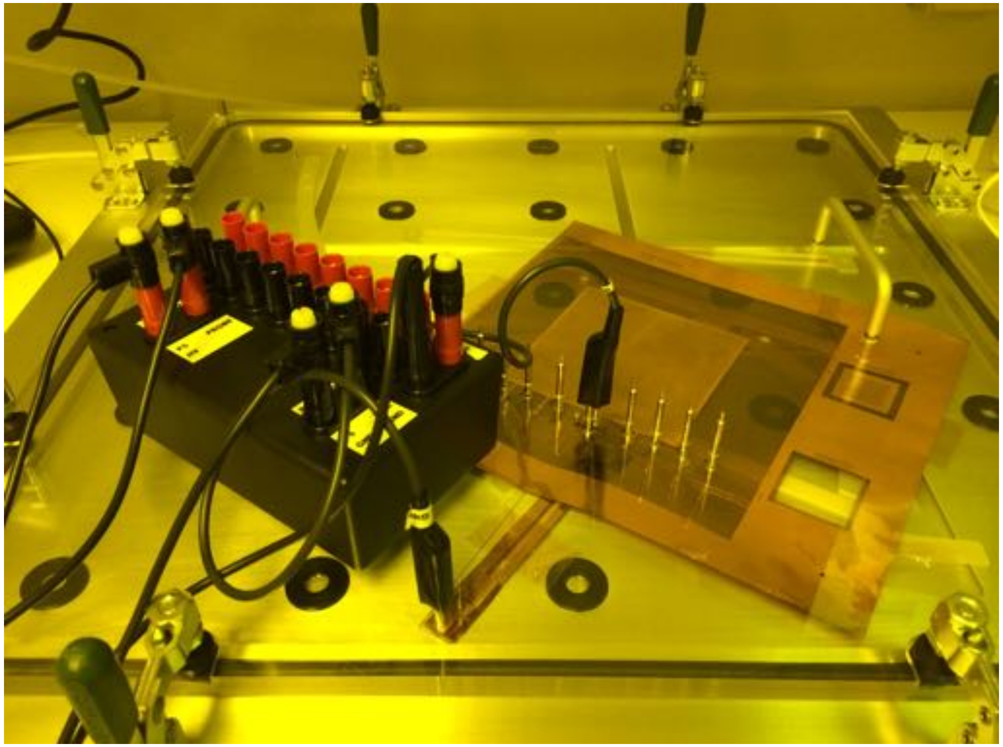
Status - Forward GEM Tracking

- 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

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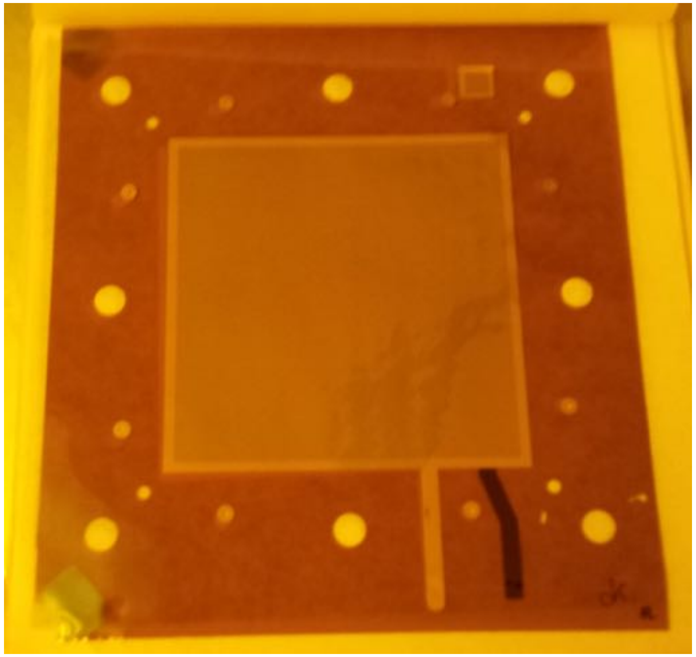
Bernd Surrow (PI) and Franck Sabatie (PI)

Status - Forward GEM Tracking

Single mask GEM Foil: Electrical tests at Temple University / Leakage current (2)

- Setup of leakage current measurement at Temple University
- All Tech-Etch GEM foil leakage currents have been measured consisting of:
  - 3 manufacturing lots of 10 x 10 cm^2 consisting of 6/12/6 foils
  - 3 40 x 40 cm^2 foils
- All foils were found to display consistent leakage currents with typical values < 1 nA.
- Tech-Etch found same results when measuring the leakage current prior to shipping.

- Critical step for achieving low leakage current was changing polymide material from Kapton to Apical.
- Leakage currents from 3 10 x 10 cm^2 single mask GEM foils produced by CERN have also been measured.
- CERN foils use same polymide material (Apical) as Tech-Etch.
- CERN foils were also found to have typical leakage current < 1 nA.

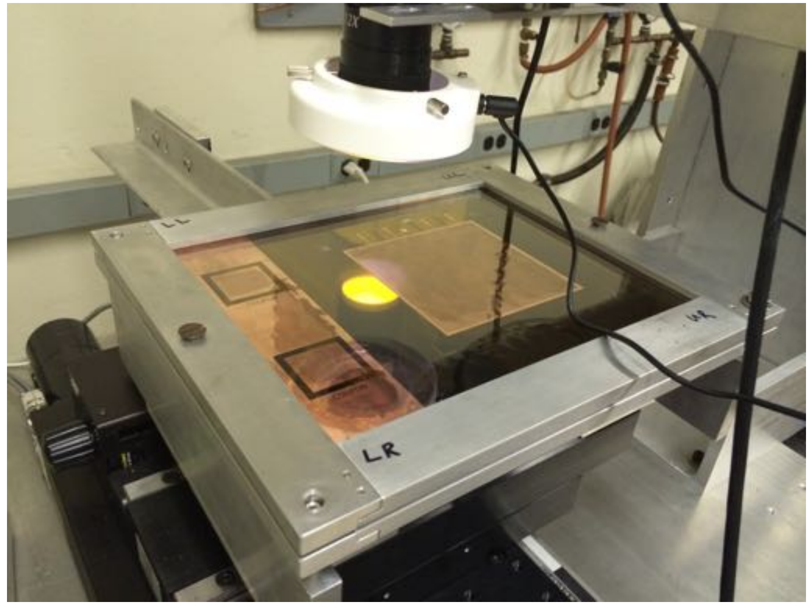


CERN 10 X 10 cm^2 single mask GEM foil

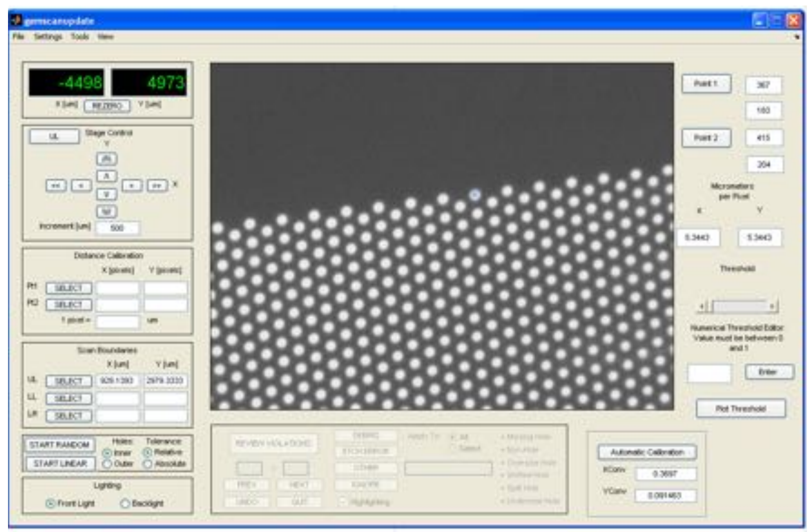
Matt Posik, Maxence Vandenbroucke,
Bernd Surrow (PI) and Franck Sabatie (PI)

Status - Forward GEM Tracking

- 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!



(a)



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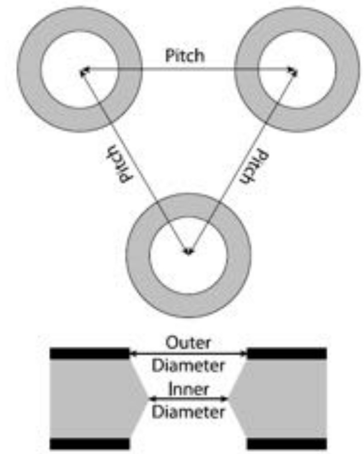

(c)

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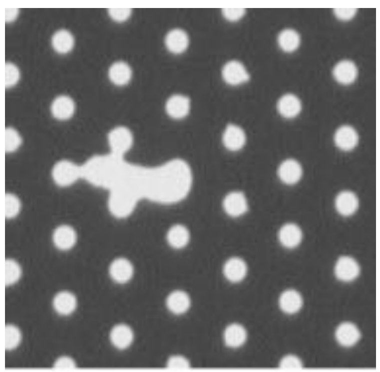
Status - Forward GEM Tracking

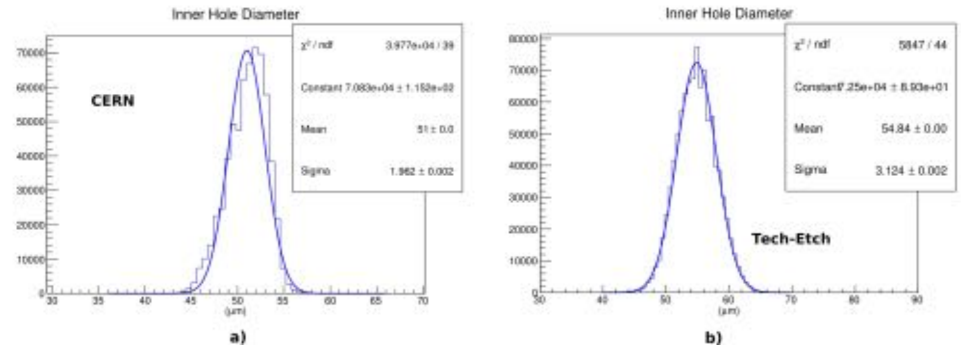
Single mask GEM Foil: CCD scan results / CERN vs. Tech-Etch (1)

- Inner hole diameter and pitch are compared between a representative Tech-Etch and CERN (Only 1 CERN foil has been optically scanned) single-mask 10 X 10 cm^2 foil.
- Mean inner hole diameters between the two foils are similar size.
- The mean pitch between the two foils is also have similar values.
- However a double peak structure is present in the CERN pitch distribution. Maybe due to etching defects seen in the foil.

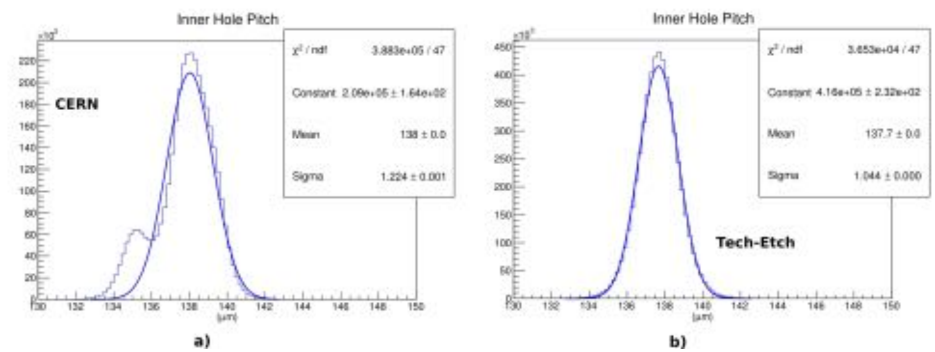


CERN CCD image showing etching defects

Inner Hole Diameter



Pitch



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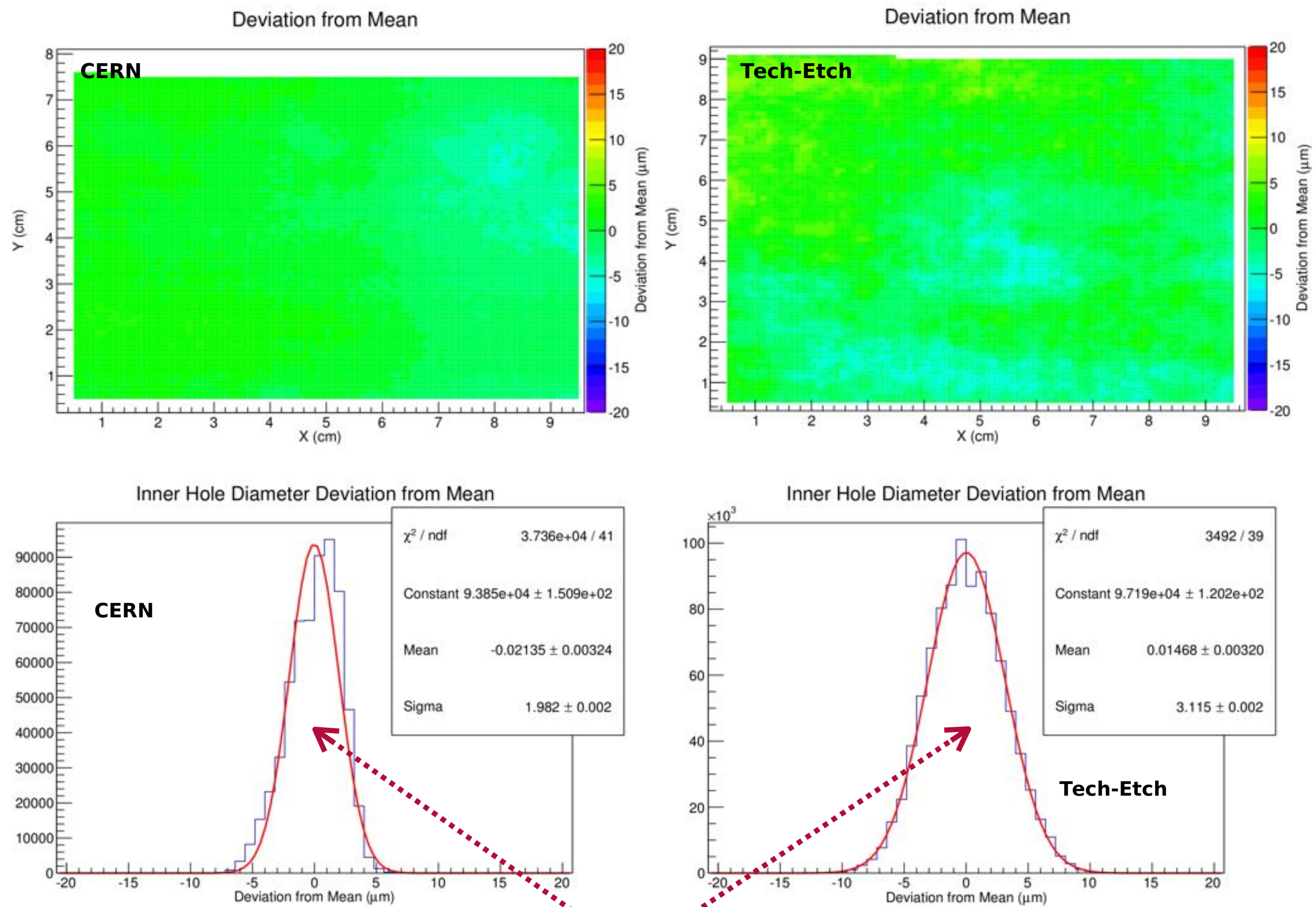
Status - Forward GEM Tracking

- Single mask GEM Foil: CCD scan results / CERN vs. Tech-Etch (2)

Inner Hole Diameter Uniformity



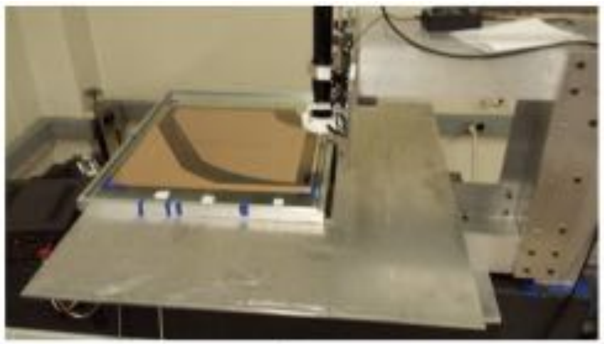
a) b)

The **CERN** foil (1) show a slight improvement in inner hole uniformity

Status - Forward GEM Tracking

Single mask GEM Foil: Large foil scan setup (40 X 40cm^2)

- Modification to perform large foil scans requires manual repositioning after each automated CCD scan.
- To cover entire active area of the GEM foil, the CCD scans are divided into 6 regions.
- Manual repositioning due to small x-y travel of the linear stage results in very long scan times.



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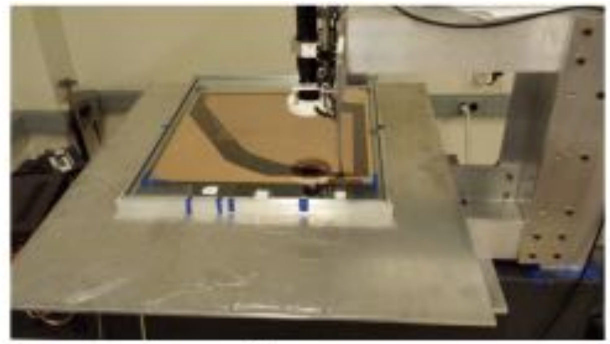

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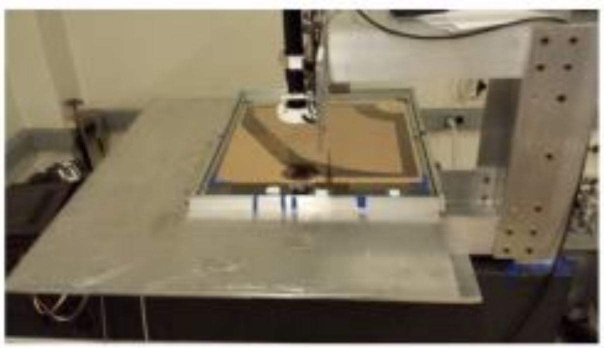

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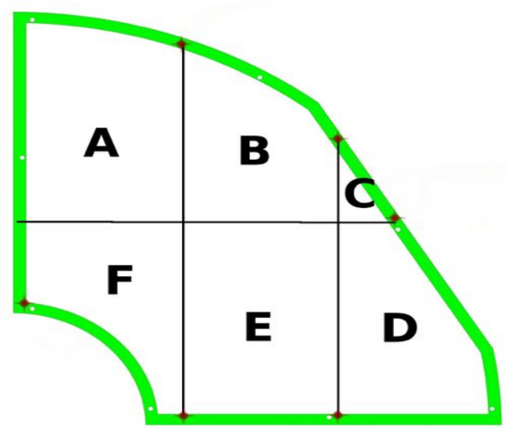

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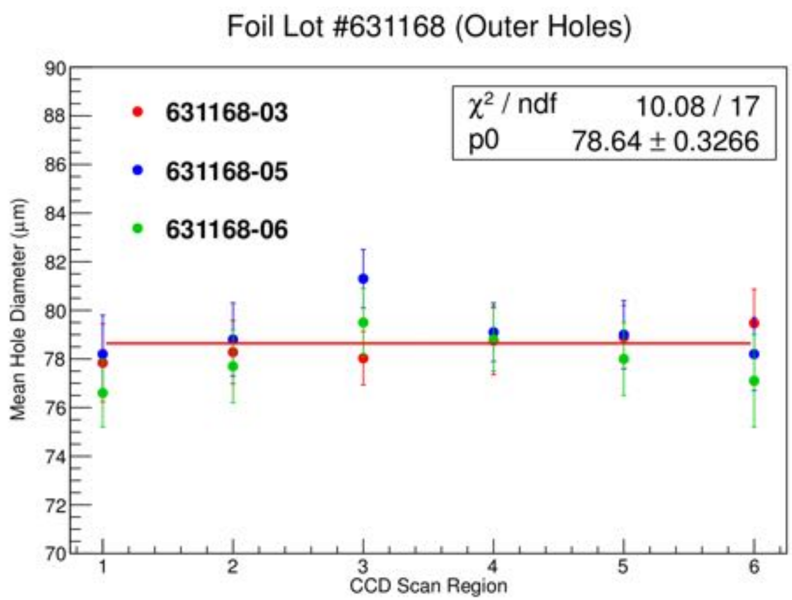
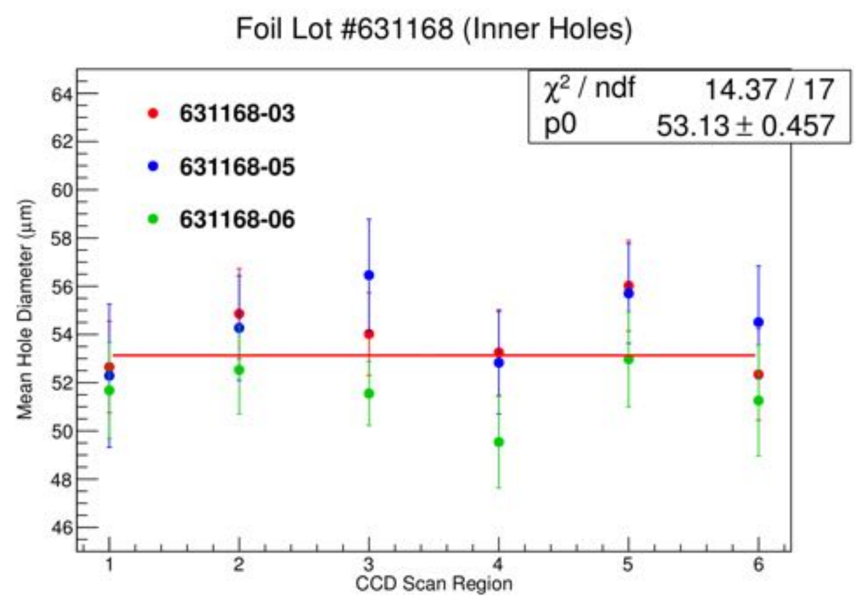
Status - Forward GEM Tracking

- Single mask GEM Foil: Large foil scan results (40 X 40cm^2)
  - All 3 40x40 cm^2 foils from Tech-Etch have been optically analyzed.
  - A flat pitch of ~ 138μm was found in all CCD scan regions across all 3 foils.
  - The outer and inner hole diameters were found to be consistent across each of the 3 foils.
  - The average values of the pitch (~138μm), outer (~78μm), and inner (~53μm) hole diameters were found to be similar to those of the previously measured single-mask 10x10 cm^2 Tech-Etch foils (pitch ~ 138μm, outer diameter ~71μm, and inner diameter of ~ 58μm).





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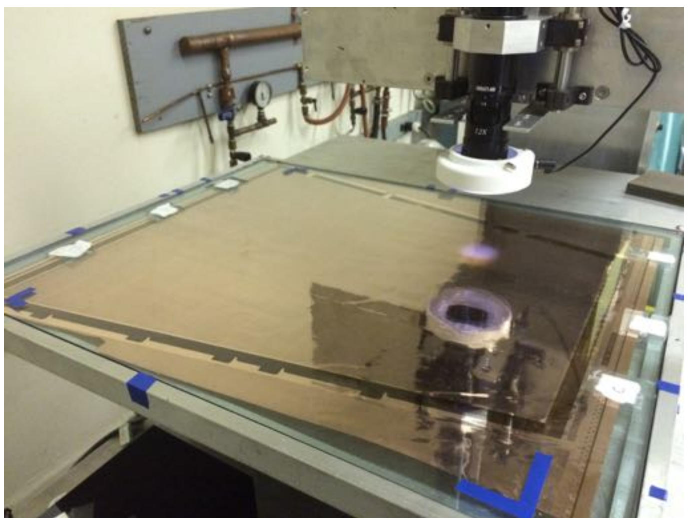
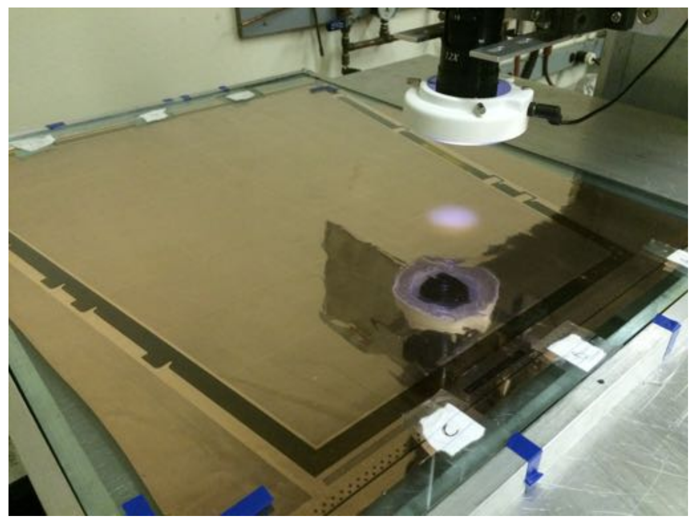
Status - Forward GEM Tracking

Single mask GEM Foil: Large foil scan setup (50 X 50cm^2)

- First samples of 50 X 50cm^2 single-mask GEM foils were received and scan setup has been prepared
- Scans started, but very time consuming : Urgently need upgrade of CCD scan setup (Funding required!)
- Initial results seem to be consistent with previous single-mask results
- Tech-Etch is working with CERN on improving uniformity of large 50 X 50cm^2 single-mask GEM foils / Final foils delivered soon!





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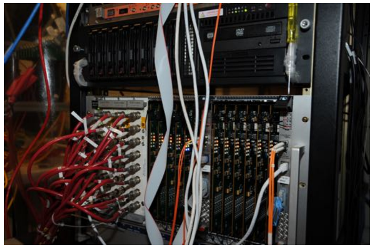
Status - Forward GEM Tracking

- Assembly of 40 X 40cm^2 detectors
  - Complete FEE (APV25-S1) / DAQ system operational
  - Spacer ring material changed from Kapton to Apical / Delivery expected soon
  - Order of FGT material requires FY15 funding

(a)



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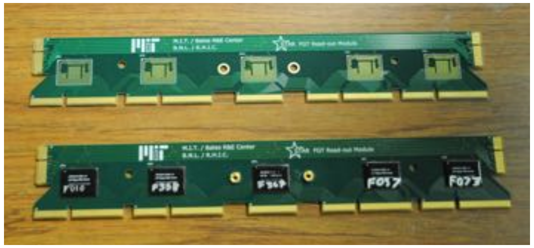

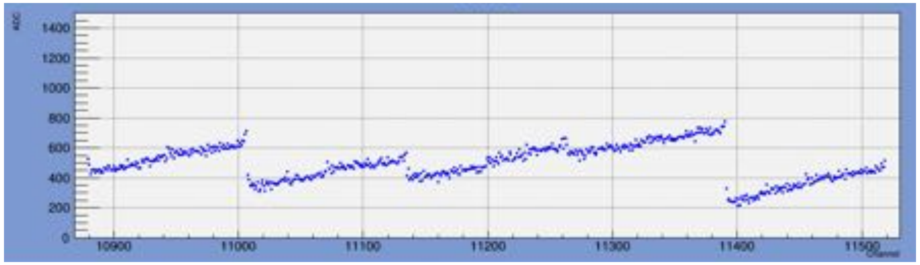

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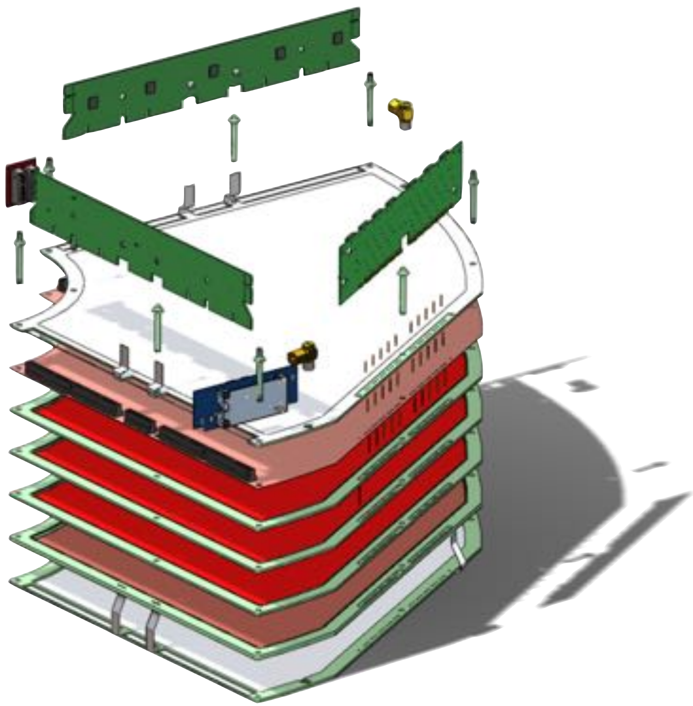

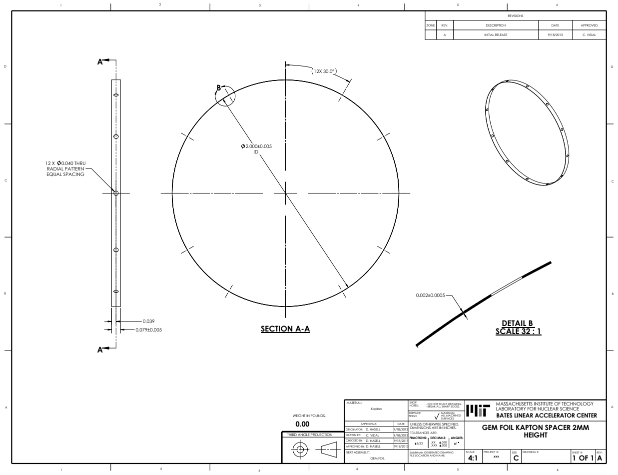

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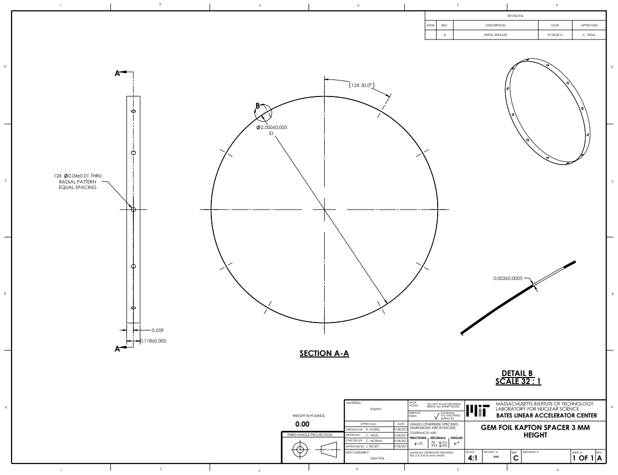

(b)

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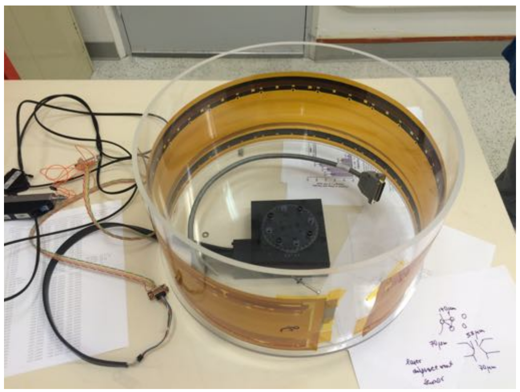
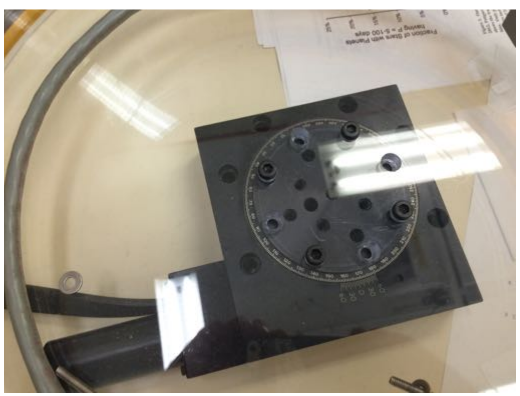
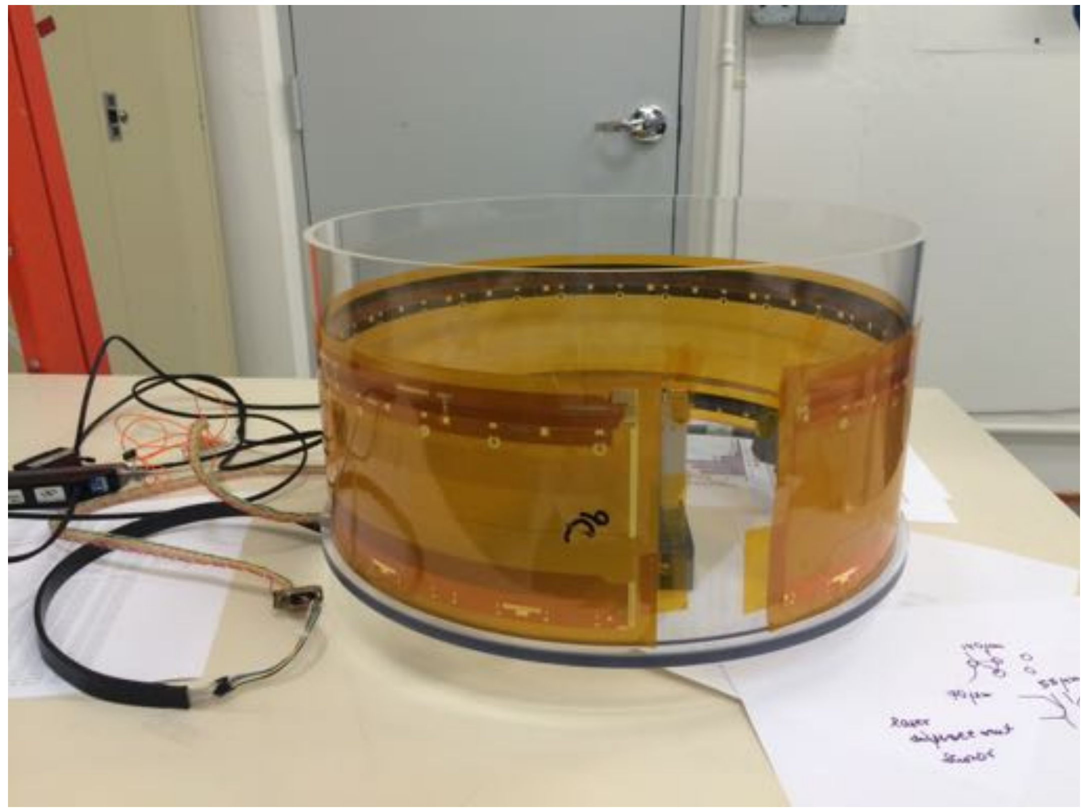
Status - Forward GEM Tracking

- Upgrade of CCD scanner
  - Urgently needed: Upgrade of CCD scanner at Temple University to accommodate large GEM foils
  - Visit at LBNL in September 2014 using tube scanner idea (C. Haber et al.)
  - Completion requires availability of FY15 funding







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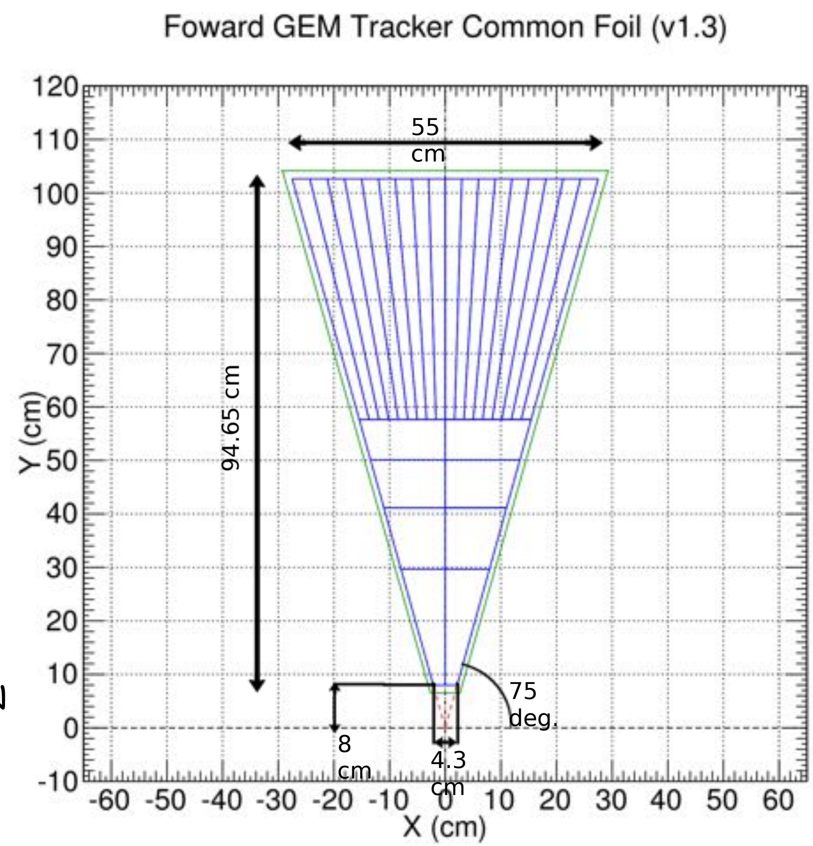
Status - Forward GEM Tracking

- Large EIC segment design
  - Finalized design of large, **dedicated EIC triple-GEM segment** of ~50 X 120cm^2 in collaboration with Florida Institute of Technology and University of Virginia
  - Commercial production of very large GEM foils and 2D readout foils of ~50 X 120cm^2
    - Bi-weekly coordination meetings with Tech-Etch Inc. incl. CERN (GEM foils / 2D readout foils)
    - Tech-Etch strongly motivated to investiate into facility upgrade
    - Last step profiting from EIC R&D program ➜ Enormous benefit to wider nuclear and particle physics community!



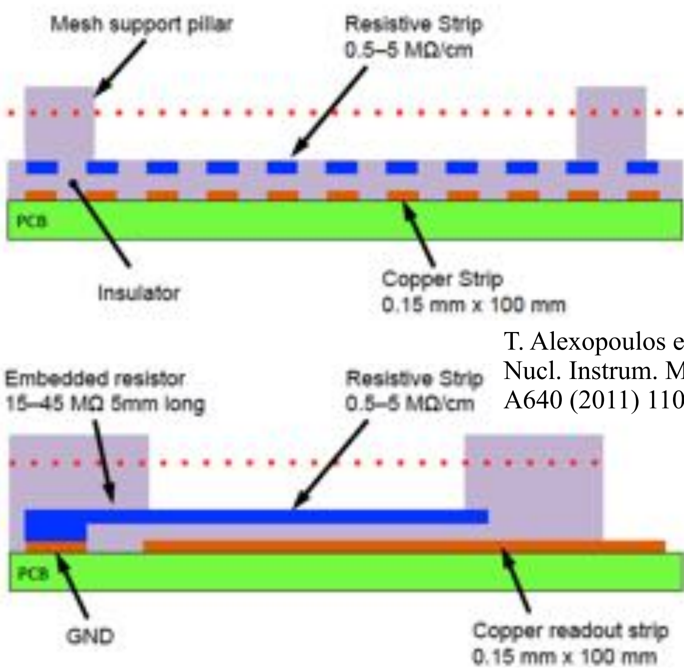
Preliminary Gerber foil layout completed

Matt Posik, Maxence Vandenbroucke, Bernd Surrow (PI) and Franck Sabatie (PI)

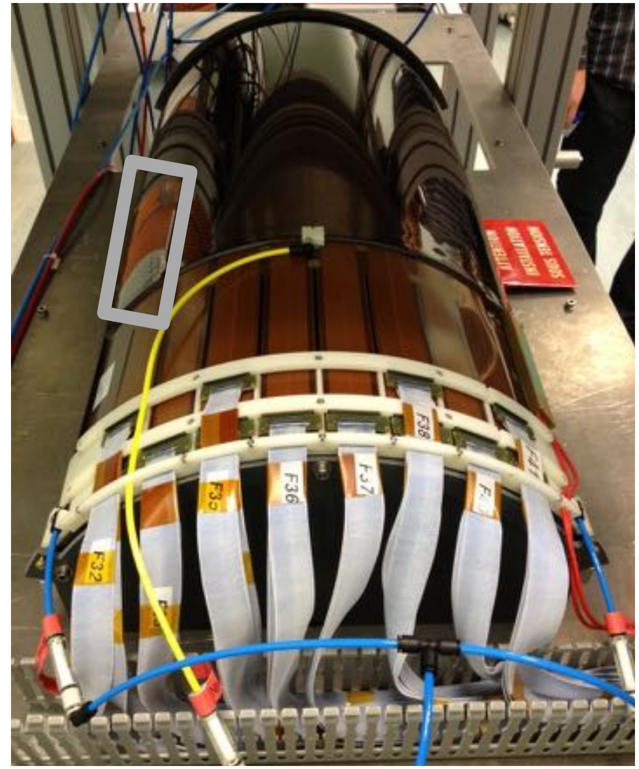
Status - Barrel MicroMegas tracking

Introduction

- Curved MicroMegas for barrel based on carbon structure glued on thin PCB
- Idea validated for CLAS12 tracker
- Need to increase size: PCB size, mesh tension, capacitance and gain homogeneity
- Transition to resistive technology for MicroMegas detectors / No measurable sparking



T. Alexopoulos et al., Nucl. Instrum. Meth. A640 (2011) 110.



- First dedicated EIC large radius resistive 1D (Z) MM prototype (EIC-MM-V1) with 37x45cm^2
- 120 degree section, R=22.5cm, L=45cm

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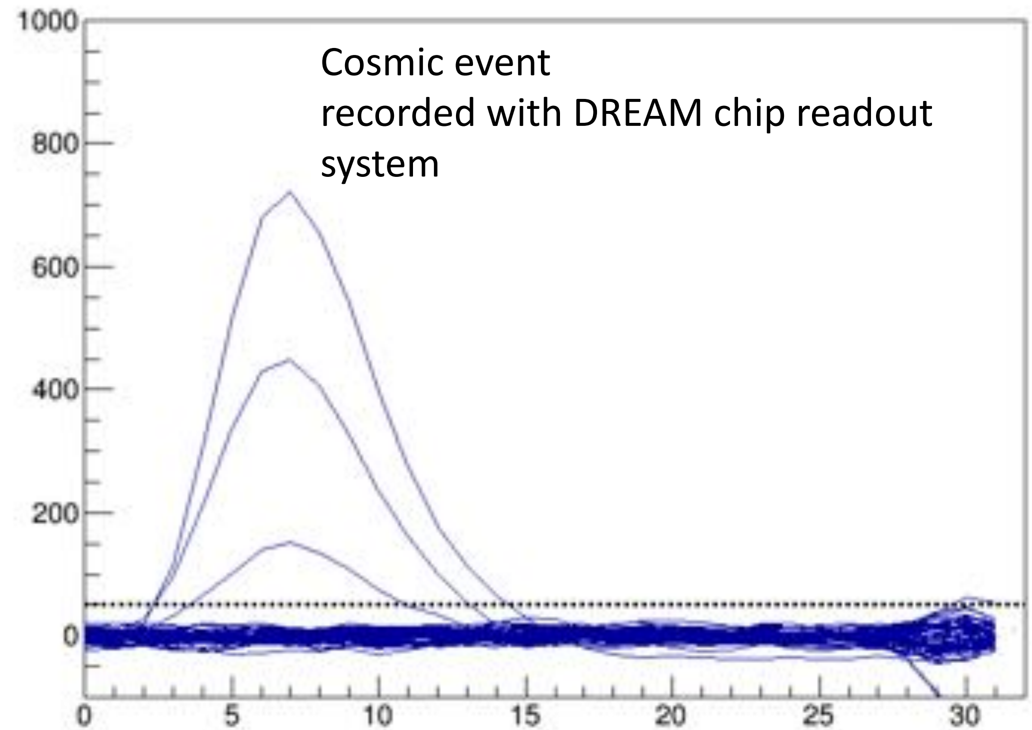
Status - Barrel MicroMegas tracking

- Highlight: 1st Z-layer resitive prottotype and cosmic-ray testing (1)



Status - Barrel MicroMegas tracking

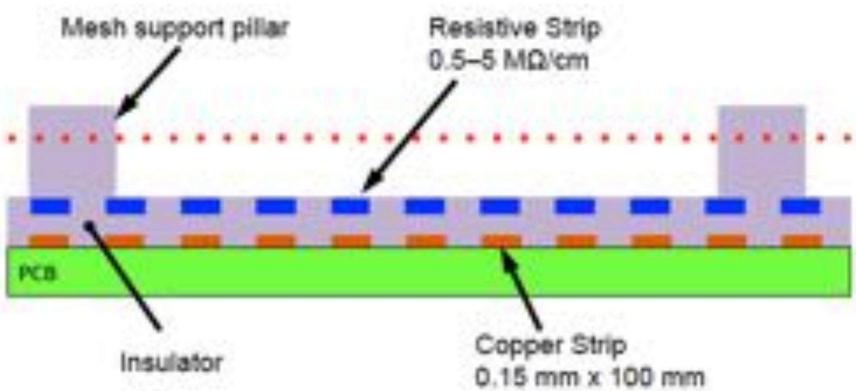
Barrel MM resistive technology (1)

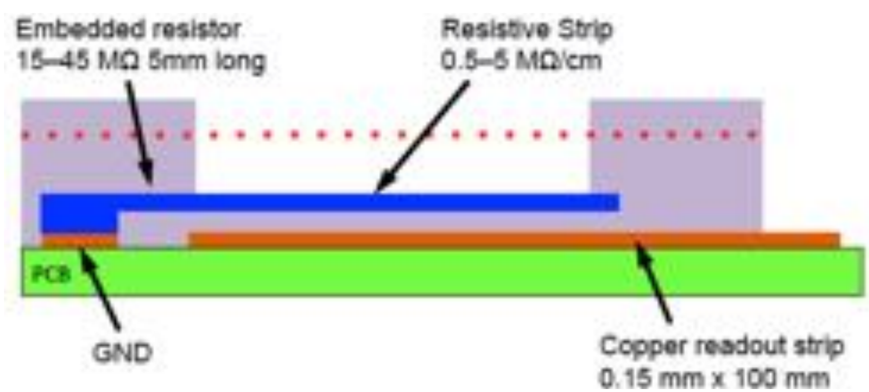
Why Resistive technology?

- To avoid discharges and obtain a higher gain in a safe and stable fashion

How ?

- Resistive strips are laid on top of the copper strips above an insulator (Kapton foil)
- Kapton foil with resistive strips is produced using resistive ink / screen printing (Commercial process!)
- Connection to ground is made using vias and silver paste
- The micro-mesh is placed on top of the resistive layer using bulk technology





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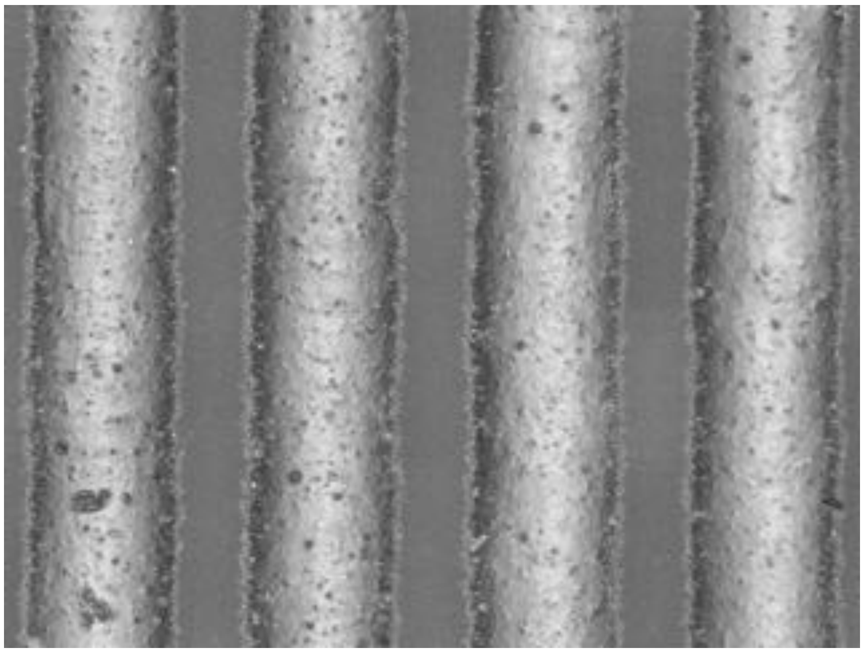
Status - Barrel MicroMegas tracking

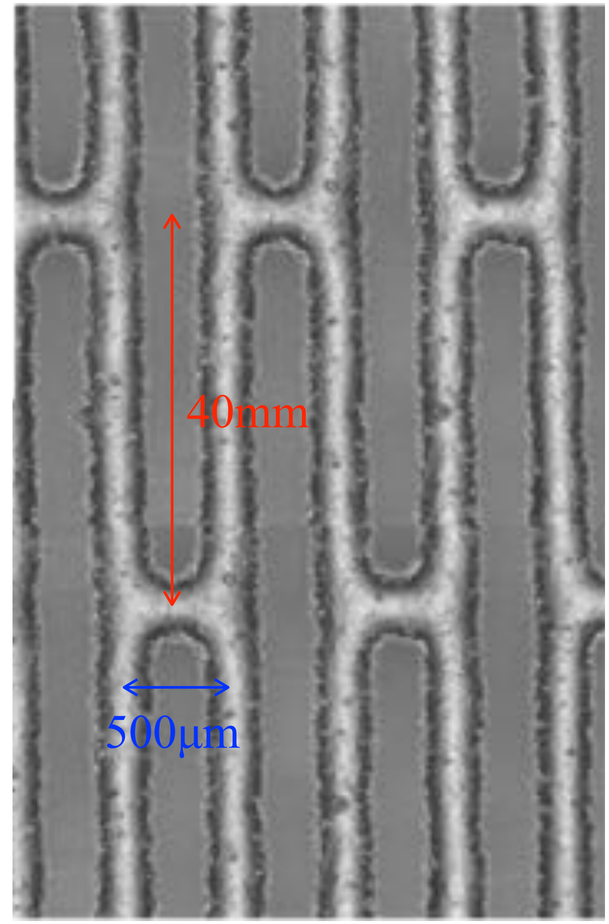
Barrel MM resistive technology (2)

Ladders :

- Connections between resistive strips every 4cm
- Goal: Improve resistive uniformity



Resistive strips with no ladders



Resistive strips with ladders

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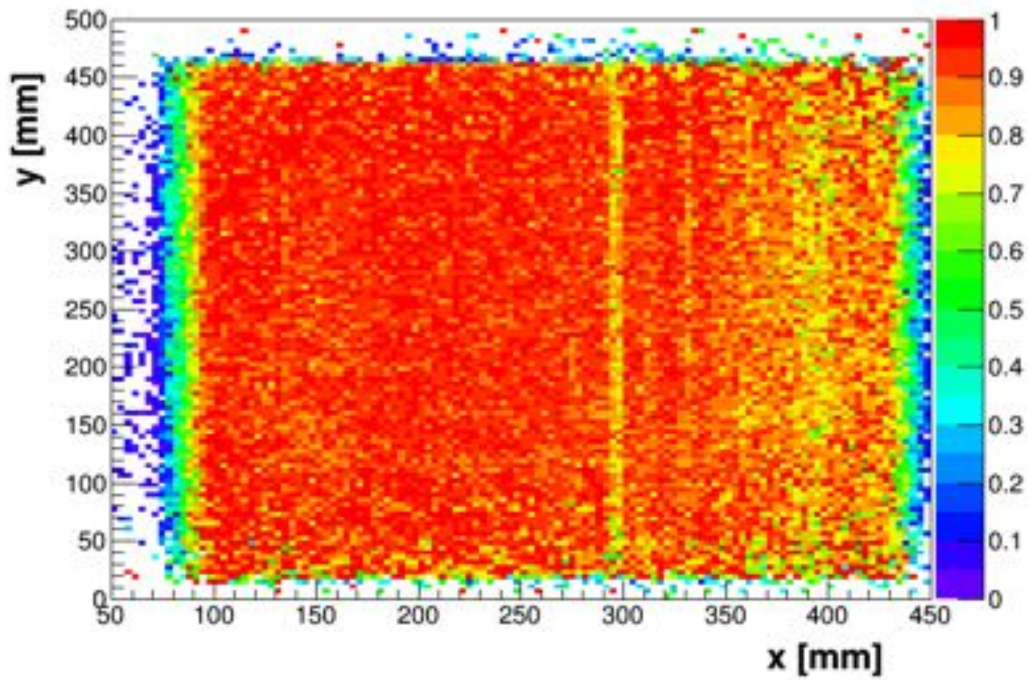
Status - Barrel MicroMegas tracking

Barrel MM test with cosmic-rays (1)

- 2D efficiency measured with cosmic rays just after construction
- 94% efficiency for the first prototype
- 45x37 cm^2 active area, manufactured at CERN
- Resistive technology with ladders

94% overall efficiency !



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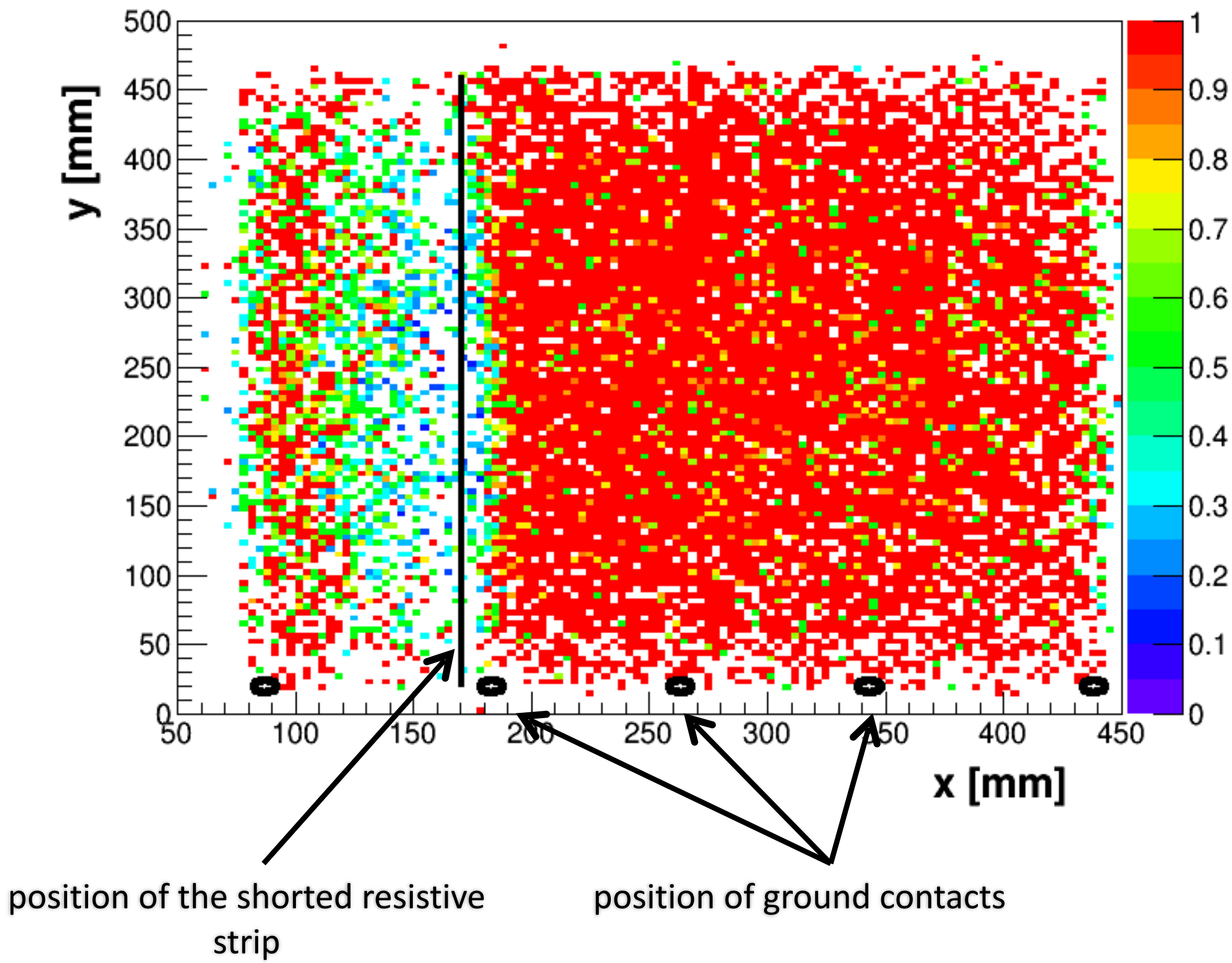
Status - Barrel MicroMegas tracking

Barrel MM test with cosmic-rays (2)

- Several days after the start of operation, a short developed between the micro-mesh and a resistive strip
- The short induced a large current on a resistive strip
- This current propagates via the ladders toward the ground of the resistive strips creating an inefficiency pattern measured with cosmic rays



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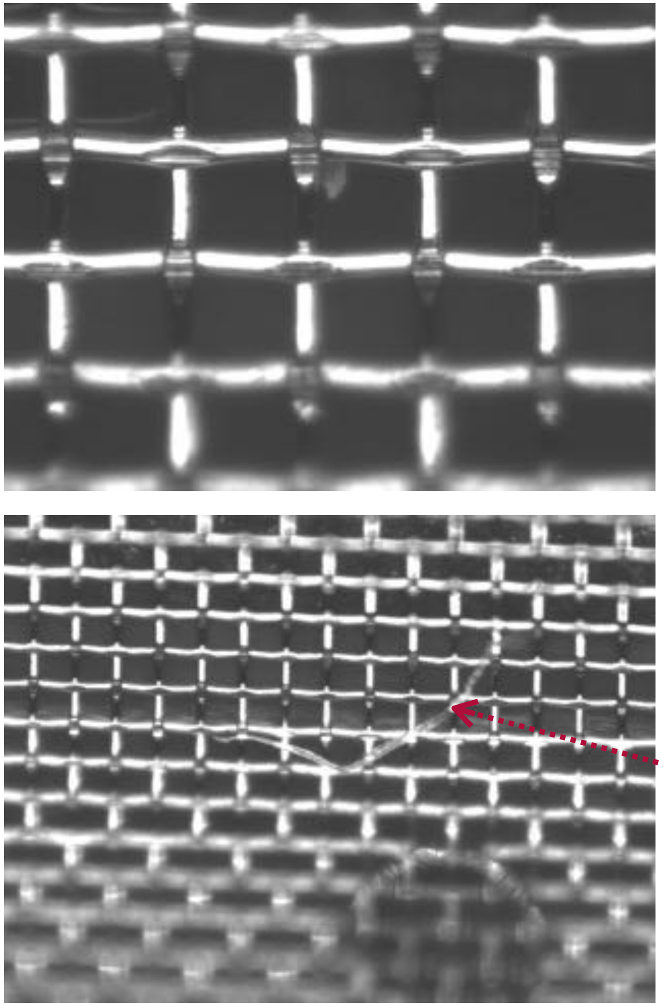
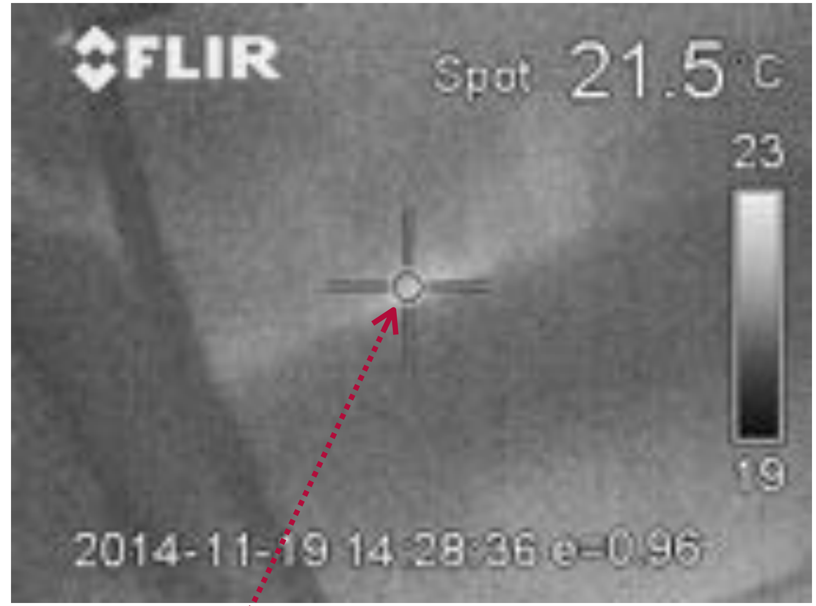
Status - Barrel MicroMegas tracking

Barrel MM test with cosmic-rays (3)



Some defects observed with the microscope along a noisy resistive strip

- Dust residues on micro-mesh / Clean handling required!
- Observation of high current (high T) with infra-red camera made



Zoom on a part of the prototype with thermal cam, with HV on and current of about 300 μA

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Status - Barrel MicroMegas tracking

- Barrel MM test with cosmic-rays (3)
  - The first EIC barrel prototype has been build at CERN and assembled at Saclay
  - This is a 1D resistive Micromegas detector with an active area of 37x45cm^2 (120 degree section, R=22.5cm, L=45cm)
  - A good 94% efficiency as been measured using cosmic rays
  - A large current appeared later and caused a localized inefficiency zone via the ladders of the resistive layer caused by dust residues

Next steps:

- Improvements in handling / Clean room
- Identify the source of dust residues making the short between the micro-mesh and the resistive strips (carbon frame fiber?)
- Increase the number of contacts in the resistive strips
- Change carbon frames for peek or Aluminum
- For now: Avoid using resistive layer ladder connections!

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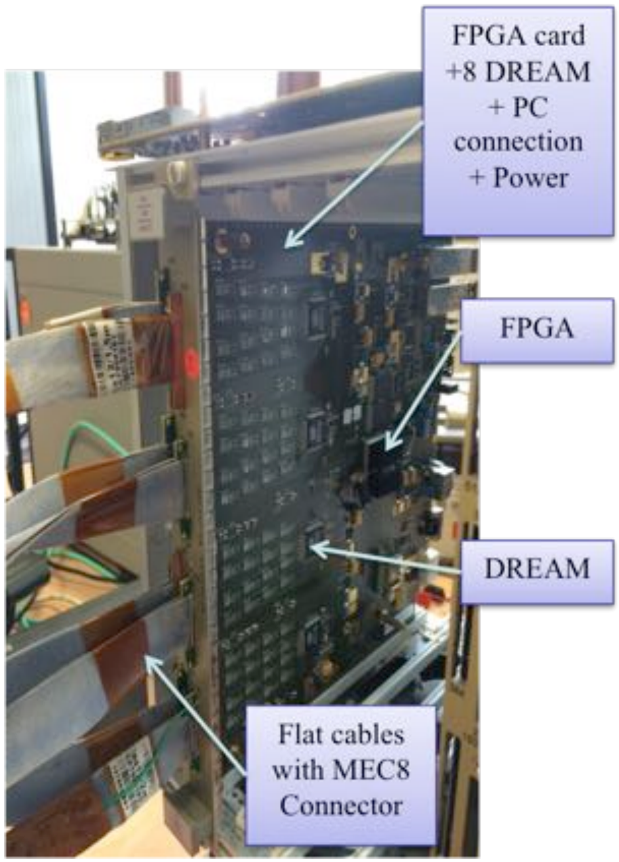
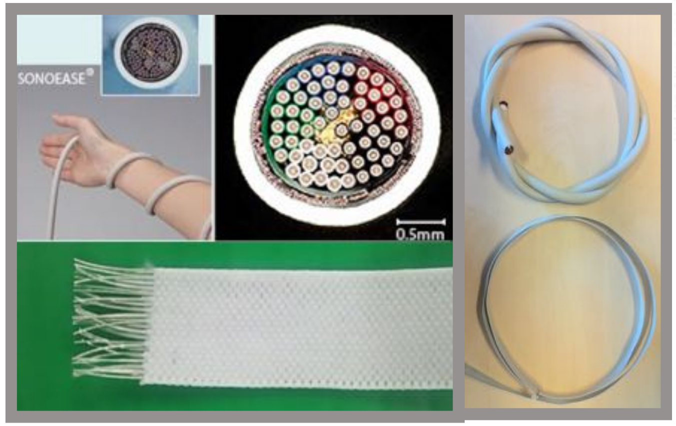
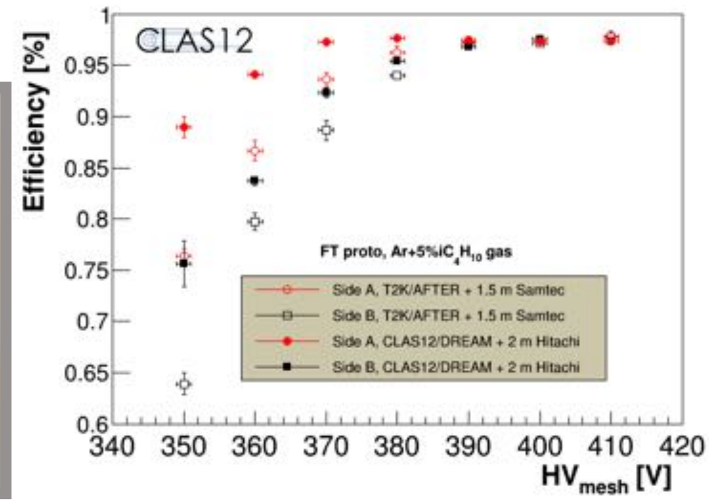
Status - Front-End Readout System

- Front-End Electronics development





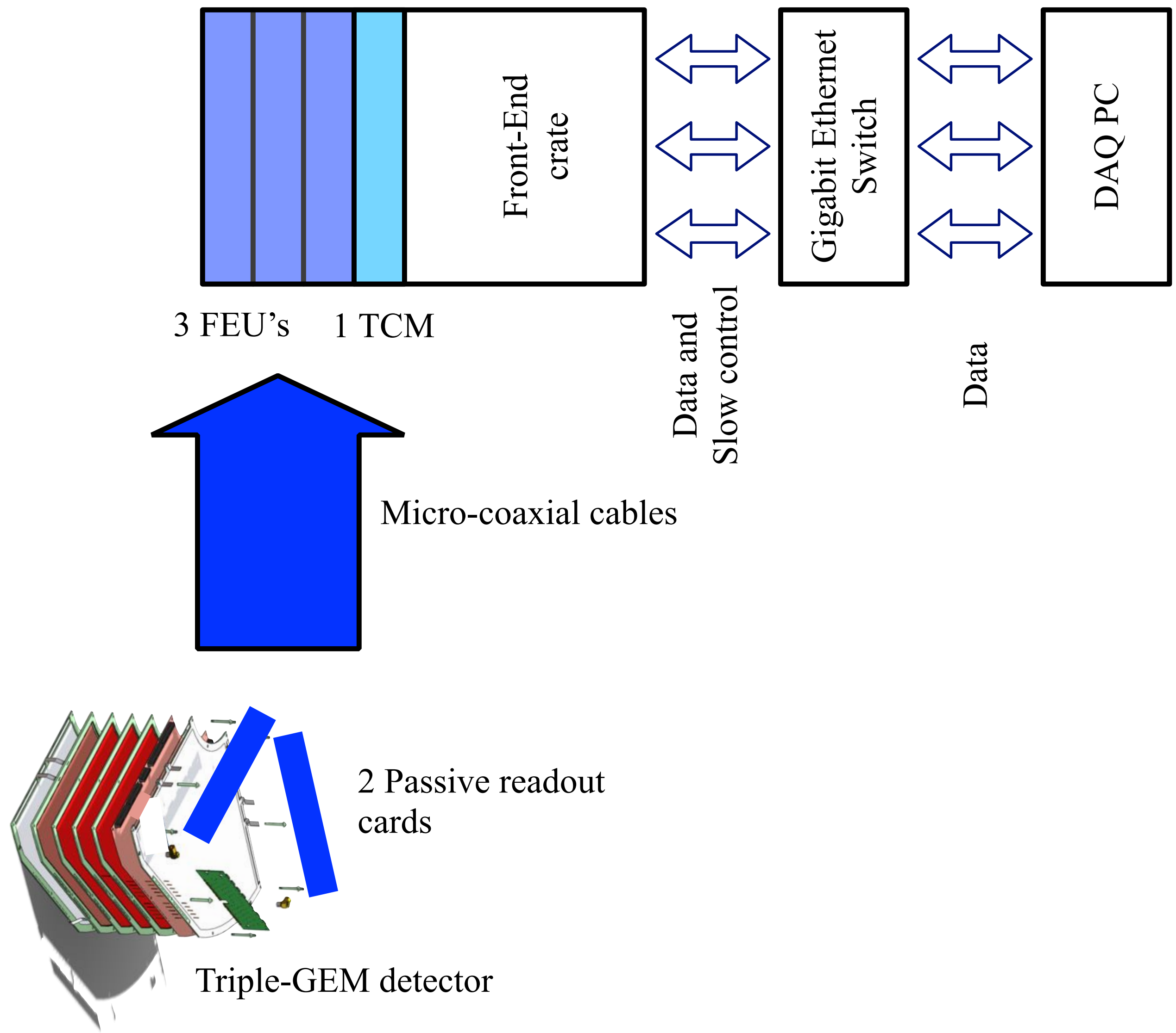


- Successful setup of complete new chip readout system ideally suited for Micropattern detectors
- Successful test with MicroMegas detector
- FEE Cards produced and tested with, and, without spark protection circuit - Noise level with 60cm long cylindrical detectors + 2m flat cables ~3000e-

	Dream Chip	APV25-S1 Chip
Number of channels	64	128
Memory size	512	160
Latency	16μs	8μs
Noise (e-RMS)	2100 (On 180pF)	1200 (On 20pF)
Sampling frequency	1-40MHz	10-50MHz
Dynamic range	50-600fC	150fC
Input capacitance	150pF	18pF
Shaping time	70ns	50ns

Status - Barrel MicroMegas tracking

- Goal: FEE setup for triple-GEM configuration
  - Setup of DREAM chip FEE applied to large triple-GEM detectors
  - Design / Fabrication of Very-Front-End-Board
  - Studies of packaged / bonded DREAM ASIC
  - DREAM ASIC irradiation studies
  - Evaluation of multi-VFEM system



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Status - Simulations

- EICROOT simulation
  - New cluster provided by Temple University for EIC simulation work / Installation of EIC ROOT planned similar to Saclay installation
  - Storage part:
    - Two identical 4824 Intel servers Intel Xeon
    - 64GB Memory
    - SATA Disks 24 X 2TB
    - SSDs 2 X 128GB
  - Computing part:
    - Four identical systems to host VM guests
    - Intel Xeon / 16 X 16GB RAM
  - Strong support for cloud / VM computing applications

Cluster / TU SERC

Summary / Outlook

- Summary
  - Forward GEM tracking
    - Highlight: Successful commercial single-mask production of large GEM foils / Critical characterization of leakage current and optical uniformity at Temple University
    - Upgrade of CCD scanner urgently needed which requires FY15 funding
    - Triple-GEM configuration test with Apical spacer grids and eventual DREAM chip FEE / DAQ requires FY15 funding
    - Large GEM foil design finalized
  - Barrel MicroMegas tracking
    - Highlight: Successful assembly + test of large radius resistive MM detector (1D-Z) using DREAM chip FEE / DAQ
    - Next: Assembly + test of large radius MM cylindrical shell with 1D-Phi and 2D readout using DREAM chip FEE / DAQ requires funding
  - FEE
    - Highlight: Successful test of DREAM chip DAQ ➜ Setup for triple-GEM DREAM DAQ system (Integrated readout!) requires FY15 funding
  - Simulations
    - Dedicated farm at Temple University for computing cluster to be used for EIC simulations

Matt Posik, Maxence Vandenbroucke,
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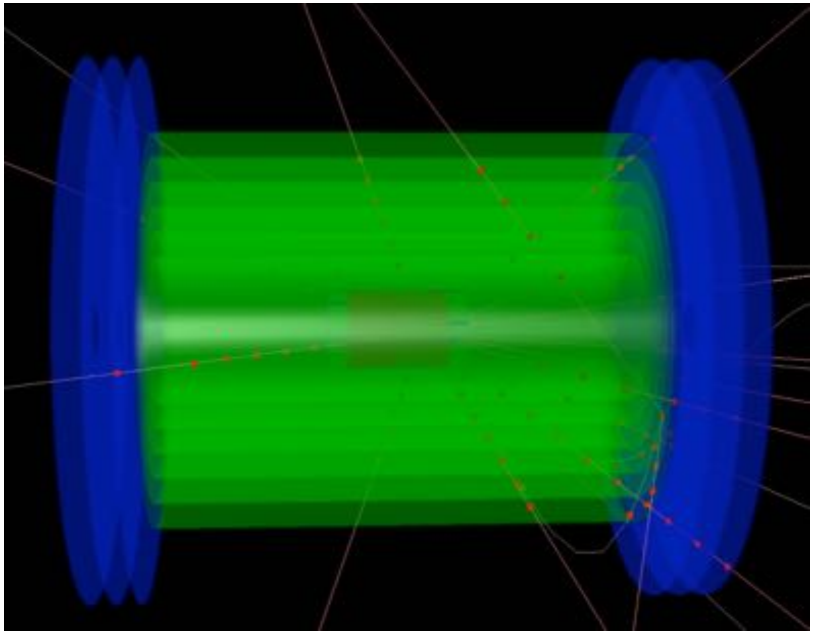
Summary / Outlook

Outlook

- Assembly and test of larger segments ➜ Conclude 'eRD3' program!
- New funding request in summer 2015 focusing on labor (Postdoctoral Fellow), large segment and MM prototype
- MM R&D program is the ONLY MM effort within the EIC R&D program
- Pursue new collaboration with commercial fabrication of MM detectors by Triton Systems (SBIR funding obtained!)
- Plan: Extended summer period at Saclay by B. Surrow / 4 months (May - August 2016)
- Plan: US / EU Ph.D. program between Temple University and Paris 6 / Paris 11 / Saclay



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