



Progress report (FY13) / Proposal (FY14)
Fast and lightweight tracking systems
Barrel MicroMegas
&
Forward Triple-GEM

Maxence Vandembroucke
Bernd Surrow (PI)



Doug Hasell



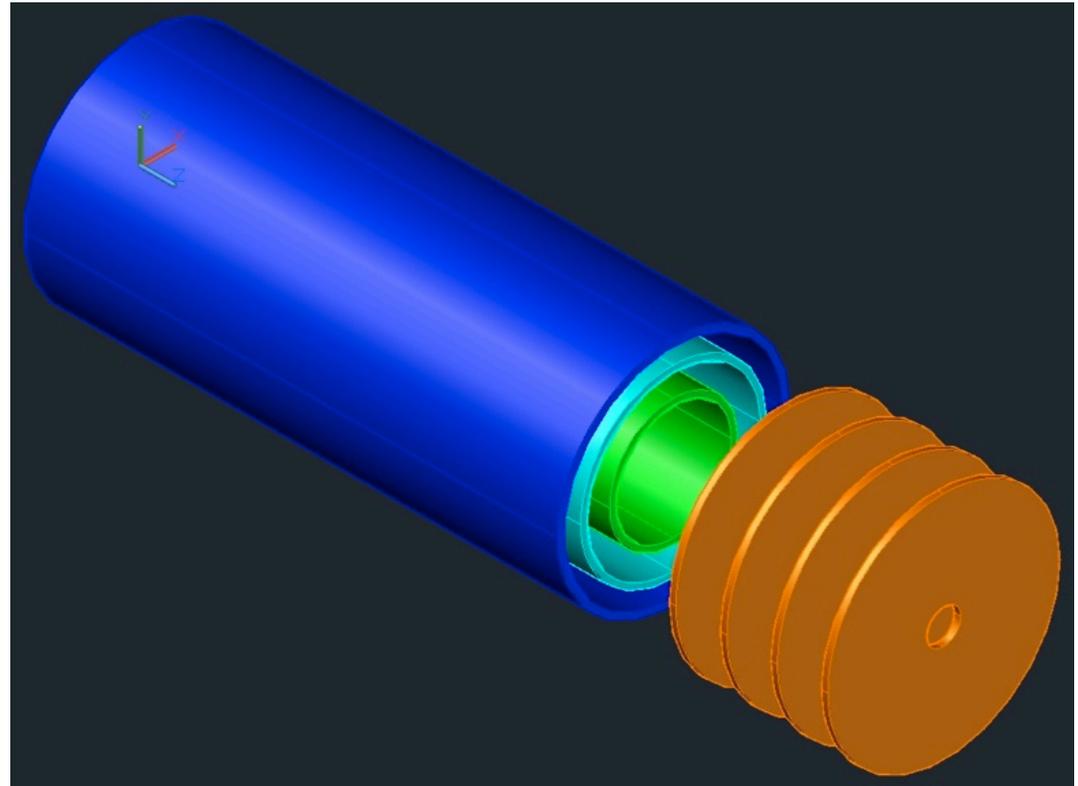
Franck Sabatie (PI)





Outline

- Project overview
- Progress report - FY13
 - Forward GEM tracking
 - Barrel MicroMegas tracking
- Proposal - FY14
 - Forward GEM tracking
 - Barrel MicroMegas tracking
 - Simulations
- Budget and Schedule
- Summary



Project overview

□ 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, MIT and Temple University**)

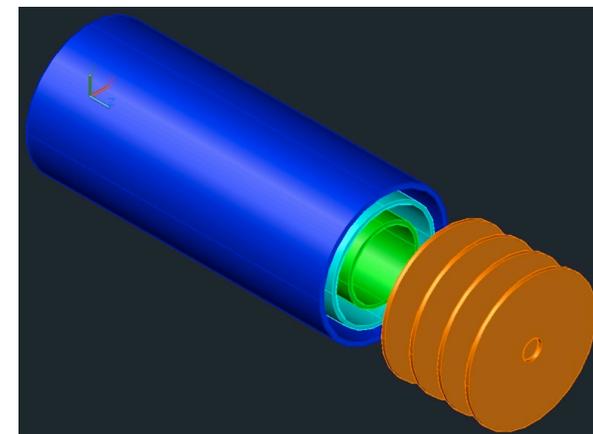
Design and assembly
of
fast and light-weight
barrel and forward tracking prototype systems
for an EIC

Progress report (FY13) and Proposal (FY14)

S. Aune, E. Delagnes, M. Garçon, I. Mandjavidze, S. Procureur, F. Sabatié¹
CEA Saclay

P. Bull, A. Dumont, B. Elman, C. Harris, R. Harris, D. S. Gunarathne,
E. Kaczanowicz, A. F. Kraishan, X. Li, M. McCormick, G. Miller, D. L. Olivitt,
J. Roemer, B. Surrow², K. Tawhid-Al-Islam, M. Vandenbroucke and G. Zangakis
Temple University, College of Science and Technology

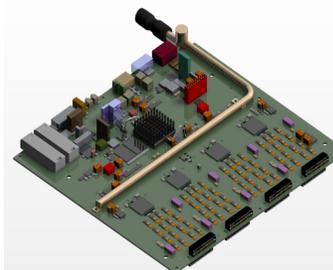
J. Bessuille, B. Buck, D. Hasell
MIT, Laboratory for Nuclear Science



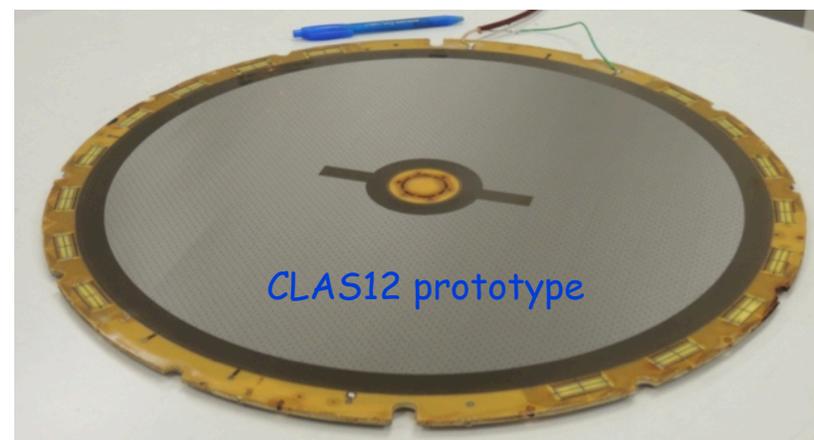
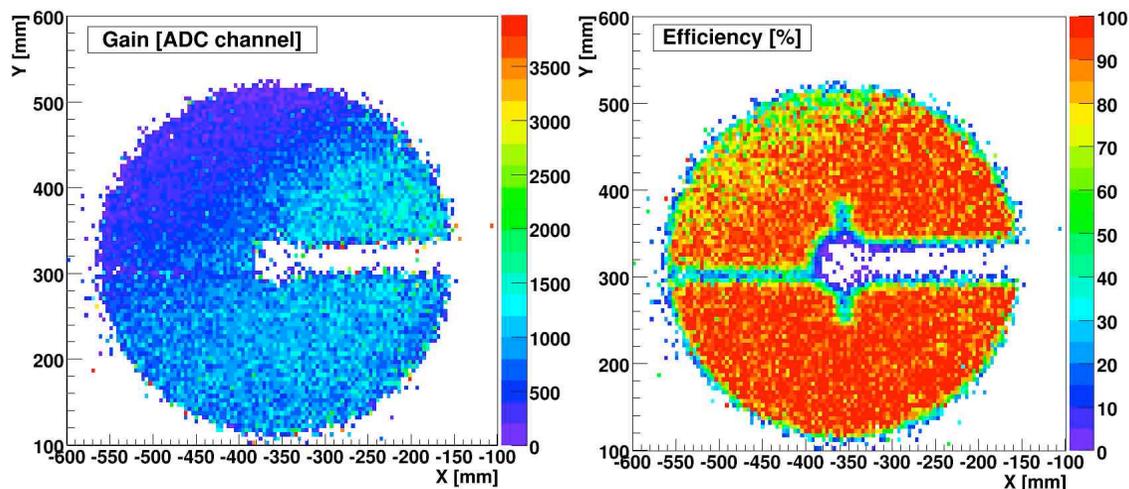
Project overview

Executive Summary of Barrel MicroMegas

- Successful assembly of two flat CLAS12 MicroMegas detectors
- Successful test of two flat CLAS12 MicroMegas detectors in cosmic-ray test stand
- Successful test of light-weight, low capacitance flex cables
- Test of first DREAM chip production version v0



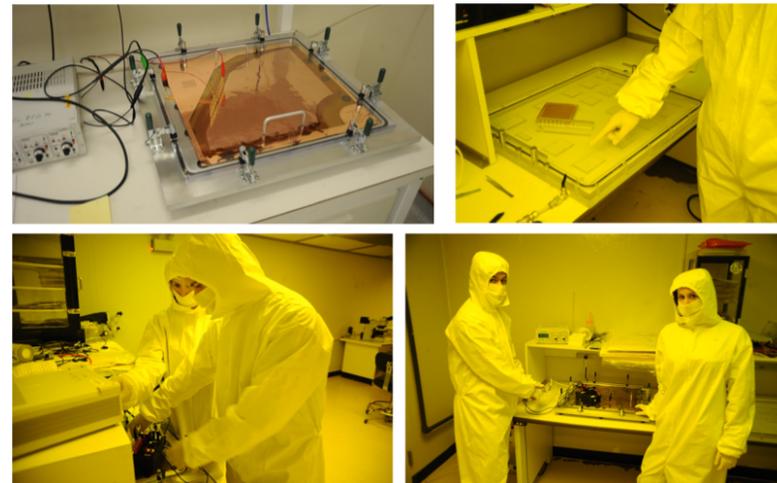
DREAM v0



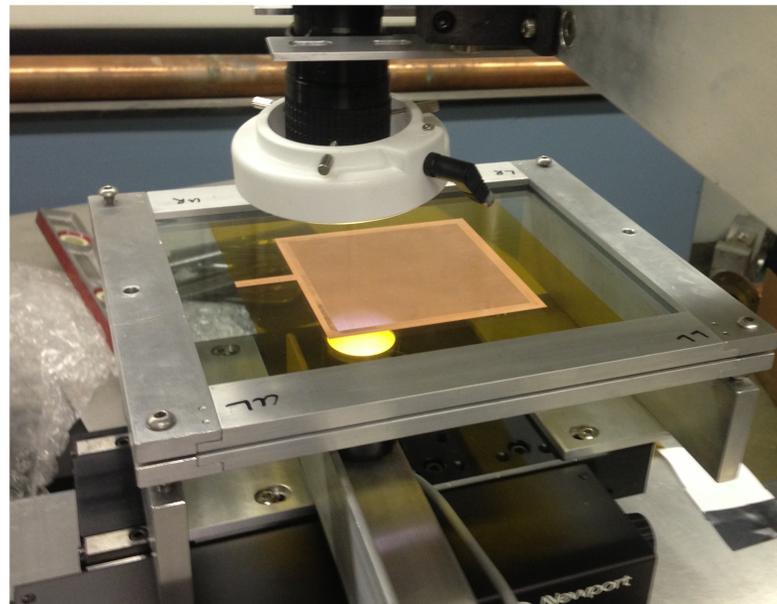
Project overview

- Executive Summary of Forward triple-GEM
 - Setup of **two labs**, a **detector lab** and **dedicated clean room** in the current Department of Physics at Temple University (New Science Education and Research Center ready by summer 2014) in addition to existing resources at MIT Bates
 - **Characterization of GEM foils** in terms of **leakage current** and **optical uniformity**
 - **Assembly of small** ($10 \times 10 \text{ cm}^2$) **triple-GEM test detectors**
 - Setup of **cosmic-ray test** and **^{55}Fe source scanner**
 - Setup of **DAQ** and **HV** system
 - **Mechanical design studies** on large triple-GEM detector segment and support structure
 - **Commercialization** of large GEM foil production using single-mask manufacturing techniques

Leakage current measurement



CCD scans





Progress report - FY13

□ Forward GEM tracking - Manpower

□ Temple University:

□ Technical staff

- Supervisor / Designer (center): Ed Kaczanowics
- Machinist (left): Matt McCormick
- Electronics technician (right): Richard Harris

□ Students

- **Undergraduate students (7):** Alexander Dumont, Caley Harris, Gabriel Zangakis, Garrett Miller, Phoebe Bull, Brandon Elman and Jake Roemer
- **Graduate students (4):** Kazi Tawhid-Al-Islam, Amani Kraishan, Daniel Olivitt and Devika Gunarathne

□ Postdocs

- Xuan Li
- Maxence Vandenbroucke (EIC R&D grant)

□ Faculty

- Bernd Surrow (PI)

□ MIT:

□ Technical staff:

- Ben Buck
- Jason Bessuille

□ Scientific staff:

- Doug Hasell



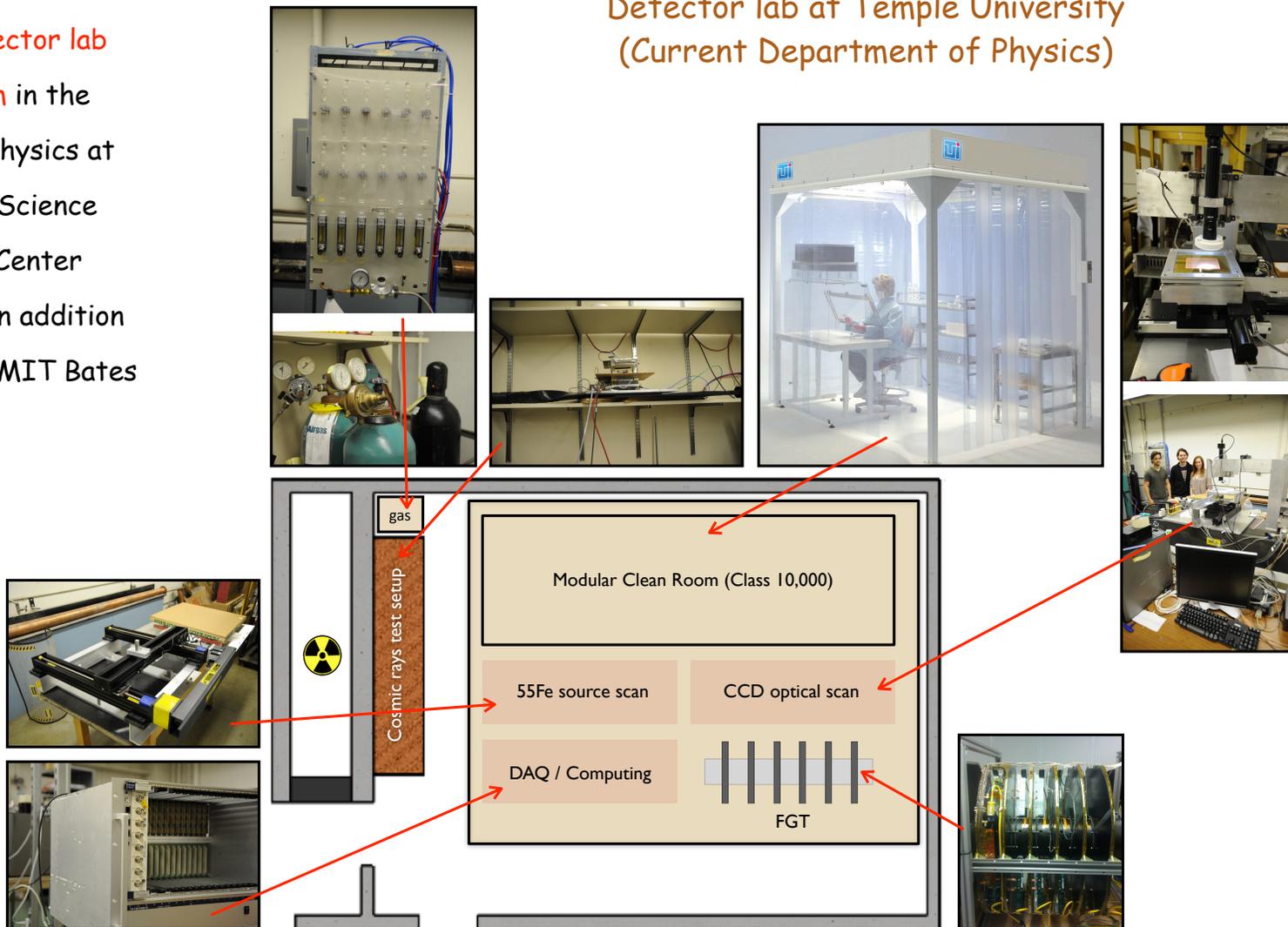
Maxence Vandenbroucke, Bernd Surrow (PI), Doug Hasell and Franck Sabatie (PI)

Progress report - FY13

□ Forward GEM tracking - Laboratory setup

- Setup of **two labs**, a **detector lab** and **dedicated clean room** in the current Department of Physics at Temple University (New Science Education and Research Center ready by summer 2014) in addition to existing resources at MIT Bates
- **Engineering resources** at **TU** with Ed Kaczanowics (Mechanical engineer) and at **MIT Bates** with Ben Buck (Electrical engineer) and Jason Bessuille (Mechanical engineer)

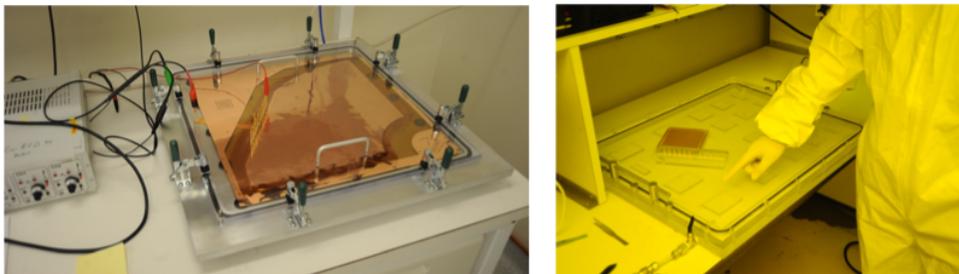
Detector lab at Temple University
(Current Department of Physics)



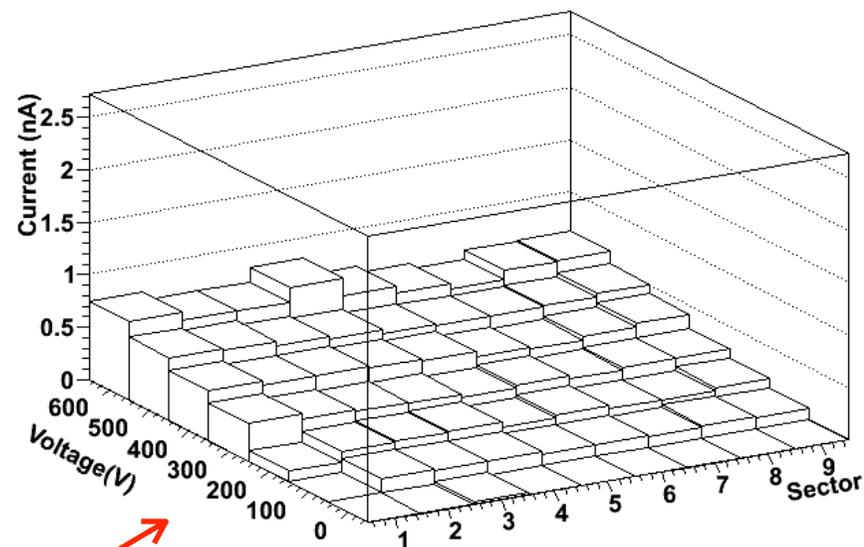
Progress report - FY13

□ Forward GEM tracking - Leakage current

- Setup of leakage current measurement at TU / First foils tested by undergraduate students



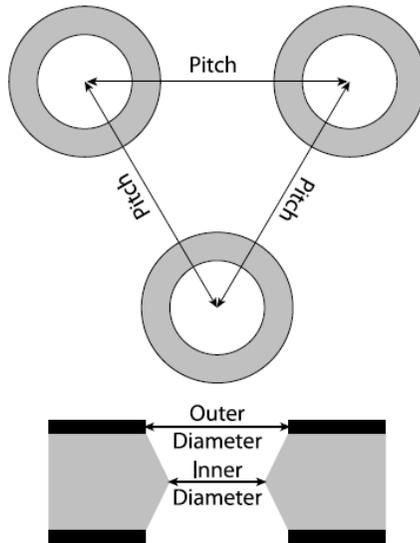
- Setup including **nitrogen box** with **HV connections**
- **ISEG power supply** and **nA current measurement**
- Example of **measured leakage current performance**
(STAR FGT foil)



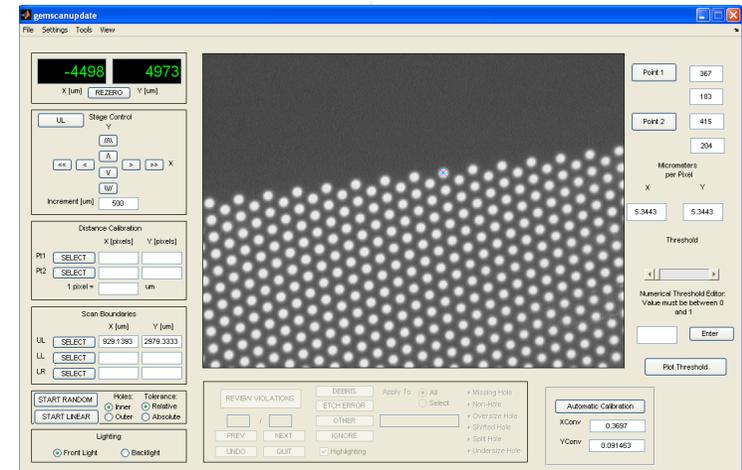
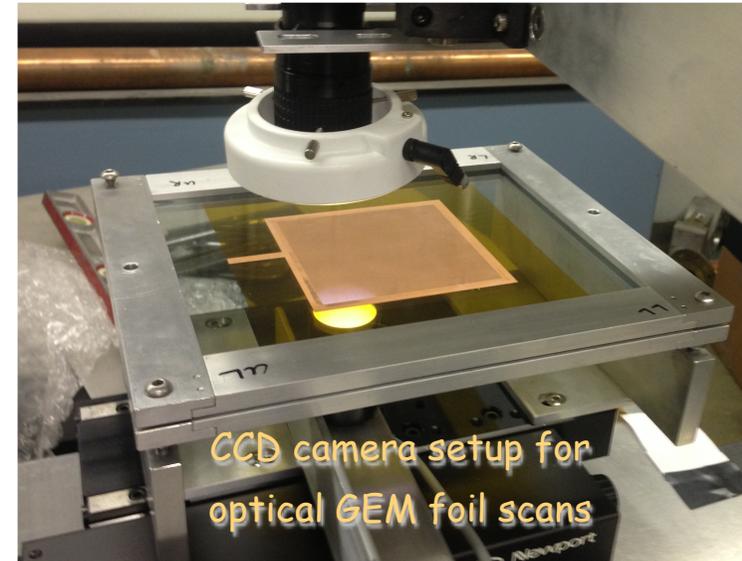
Progress report - FY13

Forward GEM tracking - Optical scan

- 2D scanning table with CCD camera fully automated
- Scan GEM foils to measure hole diameter (inner and outer) and pitch

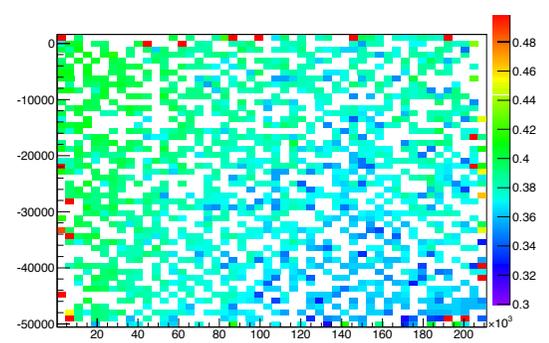
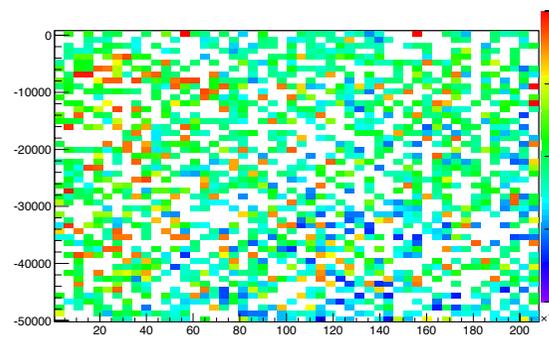
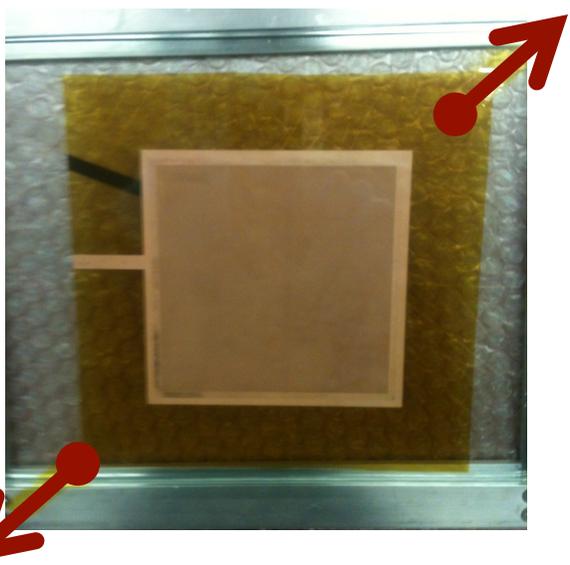
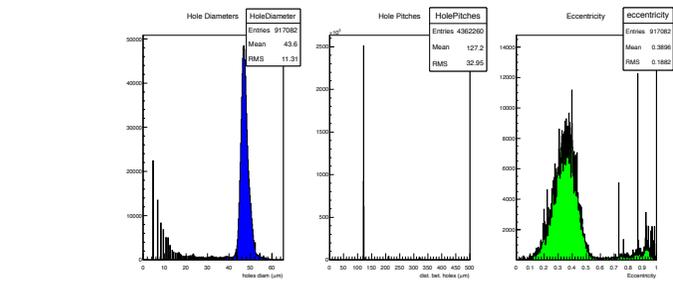
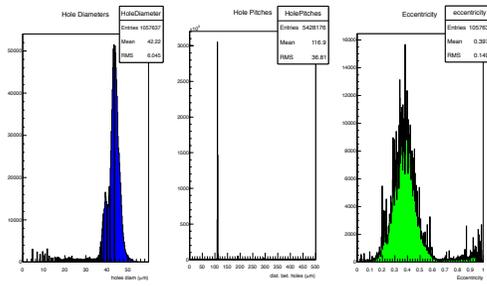
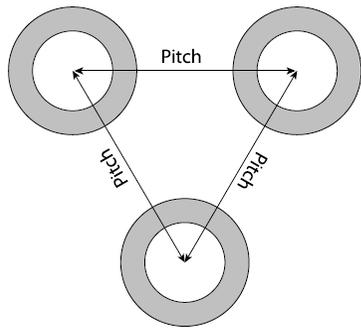


- Check for defects such as missing holes, enlarged holes, hole geometry due to over-stretching, dirt in holes and etching defects
- Setup routinely operated by undergraduate students



Progress report - FY13

- Forward GEM tracking - Optical scan characterization
 - Optical scan measurement - First results on stretching impact

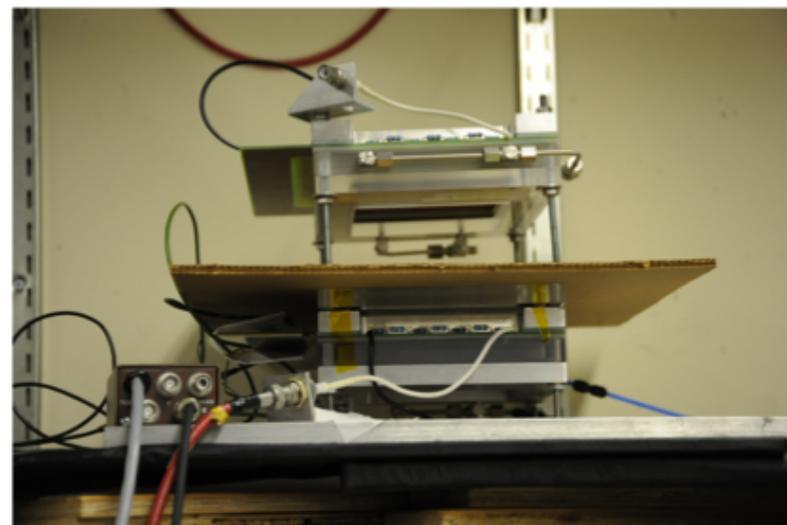
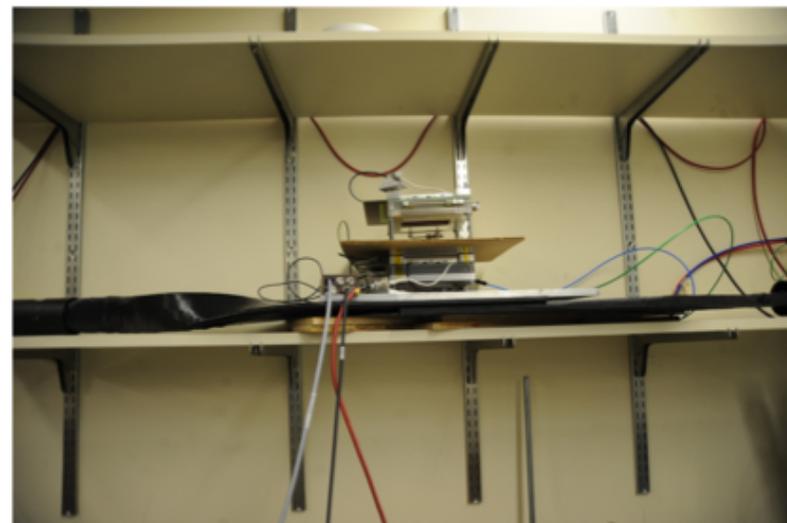


Not stretched

Stretched

Progress report - FY13

□ Forward GEM tracking - Test chamber / Cosmic-ray and ^{55}Fe source setup



- Assembly of $10 \times 10 \text{ cm}^2$ prototypes by undergraduate students
- Setup of cosmic-ray test stand consisting of two plastic scintillator plates
- Established signal coincidence between detectors - DAQ system in preparation!

Progress report - FY13

□ Forward GEM tracking - DAQ system

- **Setup of DAQ system** profits enormously from synergy with STAR FGT DAQ system

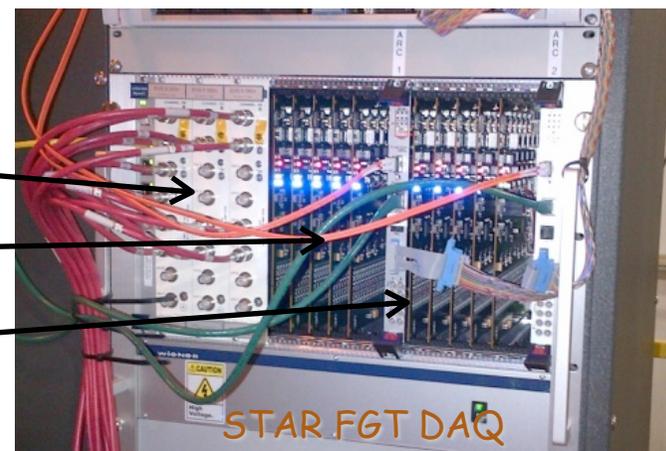
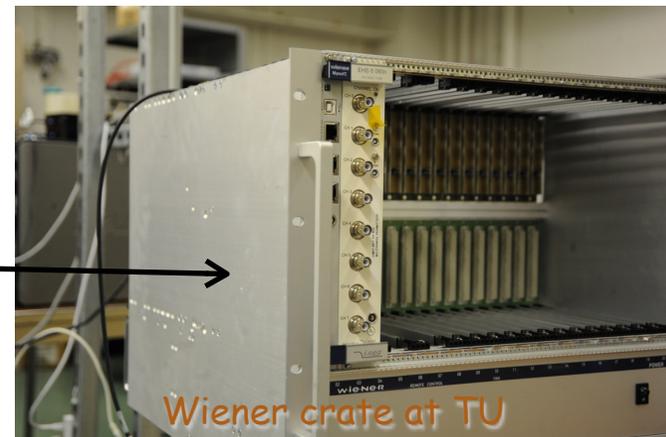
- **In place:** Special Wiener crate (3 HV modules, 2 control modules and 2 X 6 readout modules (ARC))

- **In preparation:**

- DAQ computer
- Run control / Slow control computer
- HV modules (3)
- Readout modules (2 X 6)
- Control modules (2) and

- **Run control** and **slow control** operational / Copy of STAR

DAQ setup





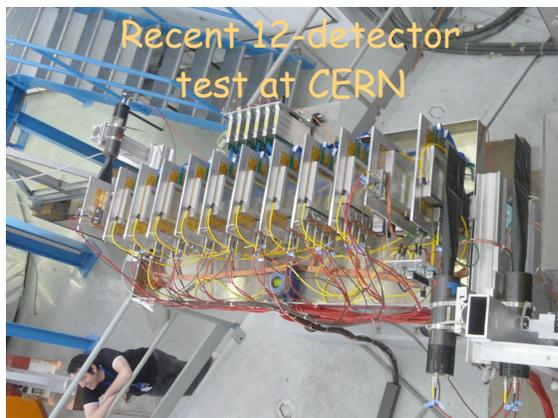
Progress report - FY13

- Barrel MicroMegas tracking - Manpower
 - CEA Saclay / IRFU
 - A. Acker, D. Attie, S. Aune, J. Ball, M. Boyer, G. Charles, E. Delagnes, M. Garçon, A. Giganon, J. Giraud, R. Granelli, N. Grouas, I. Mandjavidze, C. Lahonde, O. Meunier, Y. Mouddeu, S. Procureur, F. Sabatié (PI)
 - Maxence Vandenbroucke will be at Saclay from 11/01/13 - 04/30/14 (6 months)



Progress report - FY13

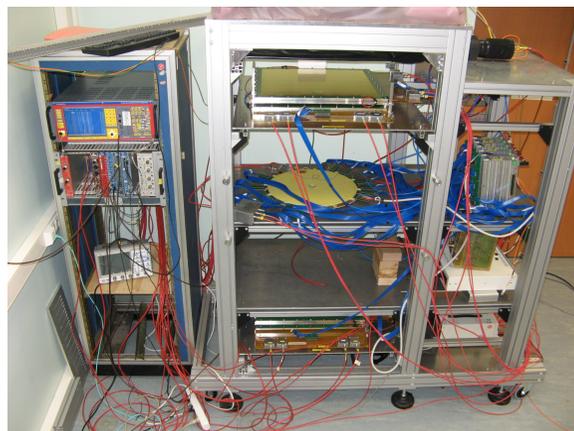
Barrel Micromegas tracking - Laboratory setup



- Micromegas detectors build either at outside company (CERN/CIREA) or at Saclay workshop

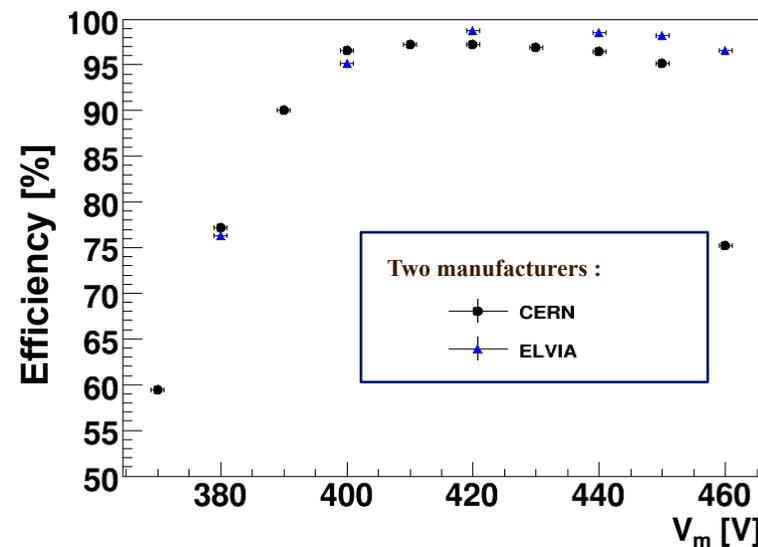
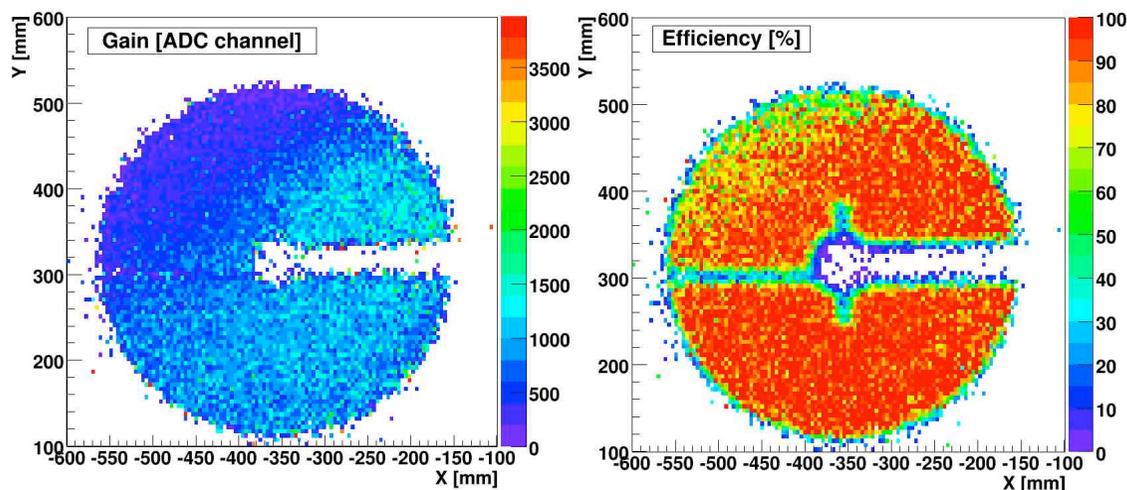
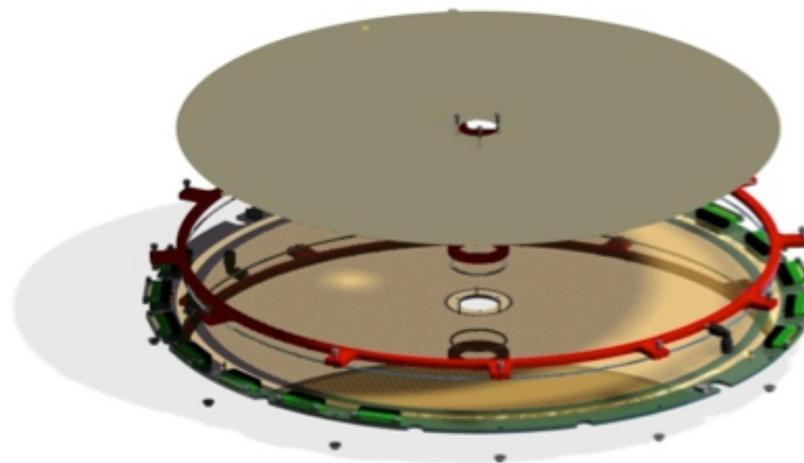
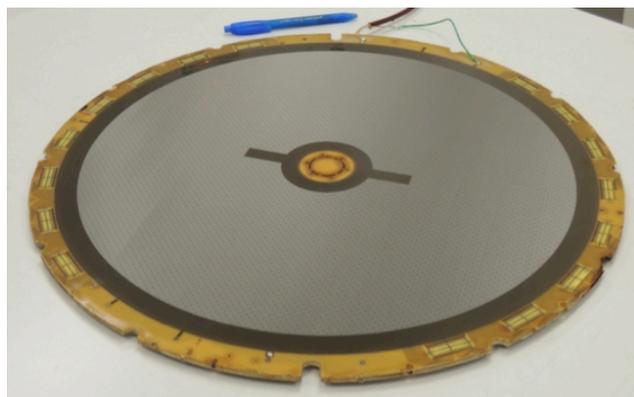


- Tests done in CLAS12 lab with fully-equipped cosmic-test stand incl. reference detector



Progress report - FY13

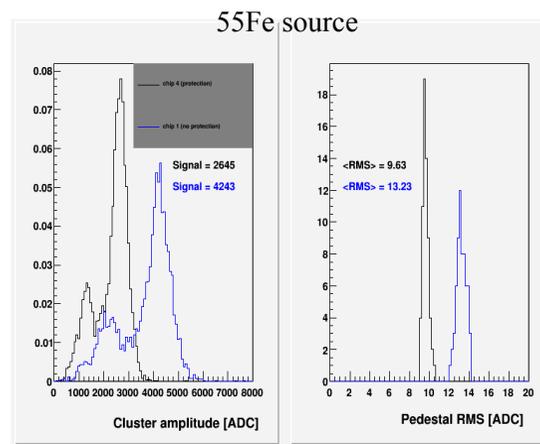
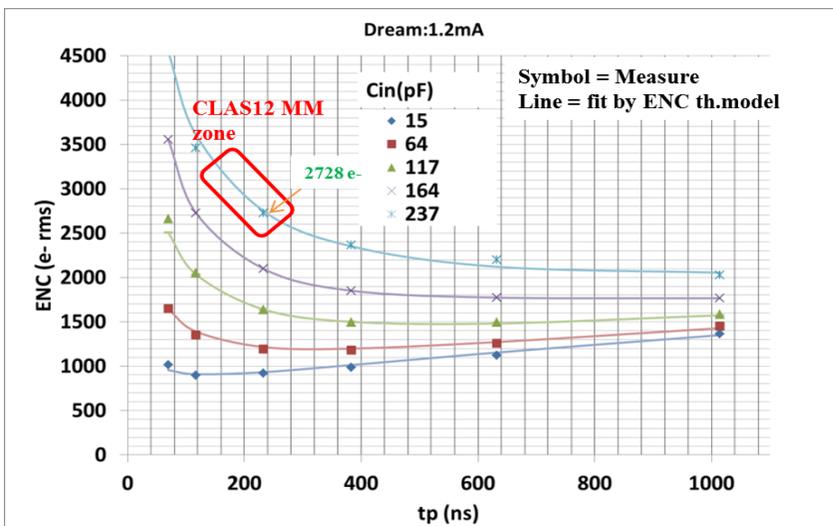
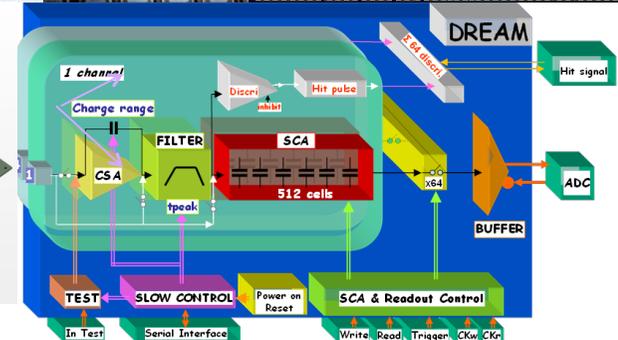
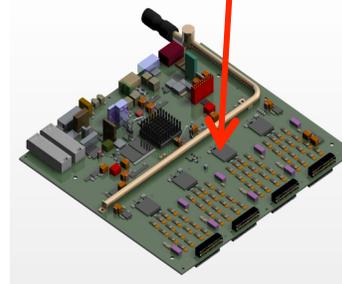
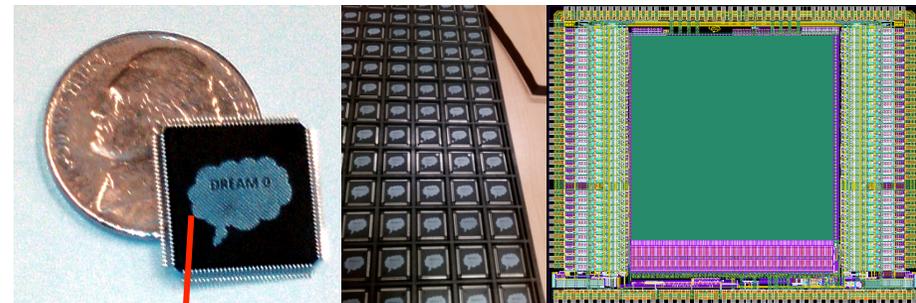
- Barrel Micromegas tracking - Test of flat/resistive CLAS12 detectors
 - **First prototypes** of flat disks with resistive layers arrived and are being tested:
Excellent performance!



Progress report - FY13

Barrel Micromegas tracking - DREAM chip readout development

- Tailored for detectors with high capacitances
 - ~30% less noise compared to the previous generation (after ASIC)
 - Depending on detector type ENC of 2000-2700 is expected
- Version 1 submitted
 - Added intermediate peaking times for more flexibility
 - Minor bugs corrected
 - Packaged chips expected in May-June



Front End Unit : Active comp. on top & bottom sides

- 8 Dream ASICs
- 8-channel 40 MHz ADC
- Virtex-6 FPGA
- SFP cages
 - 2.5 Gbit/s optical link
 - 1Gb Ethernet
- JTAG based system monitor

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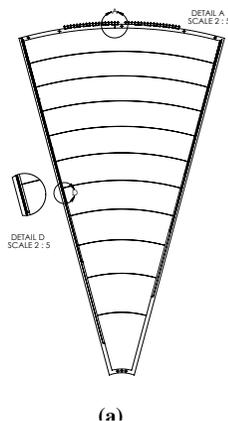


Proposal - FY14

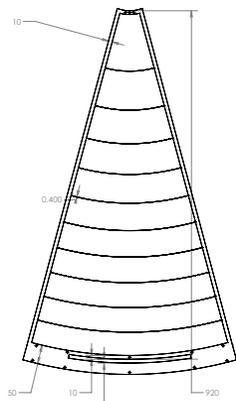
- Forward GEM tracking - Commercialization of GEM foils and 2D readout foils
 - GEM foils:
 - Tech-Etch signed **license agreement** with CERN
 - **Technology transfer** can start at any moment / Details are being worked out
 - Solution for **funding of visit to CERN** by Tech-Etch in sight
 - CERN is fully committed to provide **technical assistance**
 - Tech-Etch committed to invest into **upgrading** their **production facility** (Chemical etching bath / imaging setups) even without SBIR funding which will be sought after by BNL, TU and Yale
 - Agreed to **start with 10X10cm² foils** followed by FGT-type foils around early fall
 - **TU and Yale agreed to provide feedback** on leakage current and optical uniformity besides single-foil gain behavior
 - Important: Effort is a **collaborative effort between CERN, Tech-Etch, BNL, TU, Yale and various CERN experiments** such as ALICE, CMS and RD51
 - 2D readout foils:
 - Tech-Etch **agreed to start development of large 2D structures**

Proposal - FY14

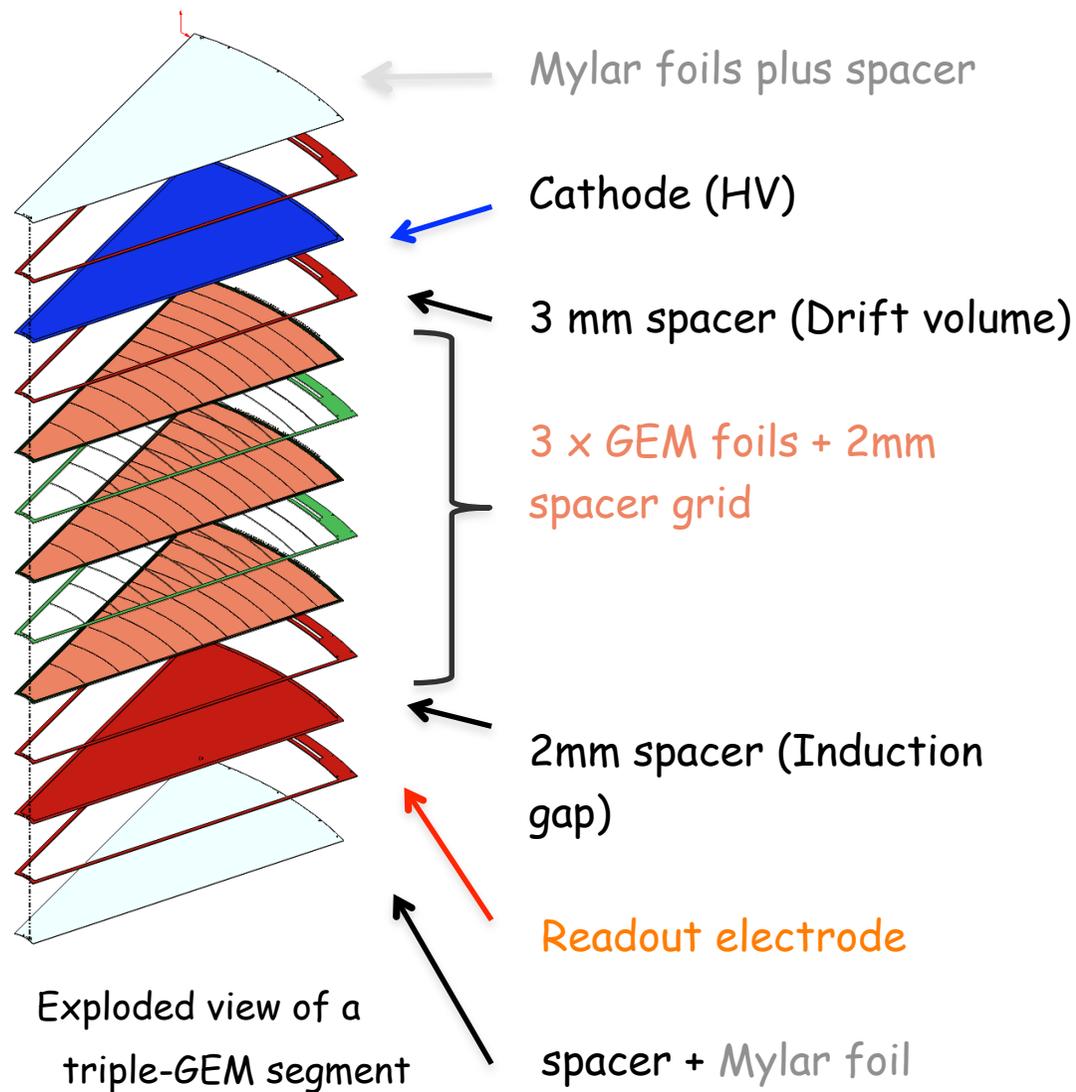
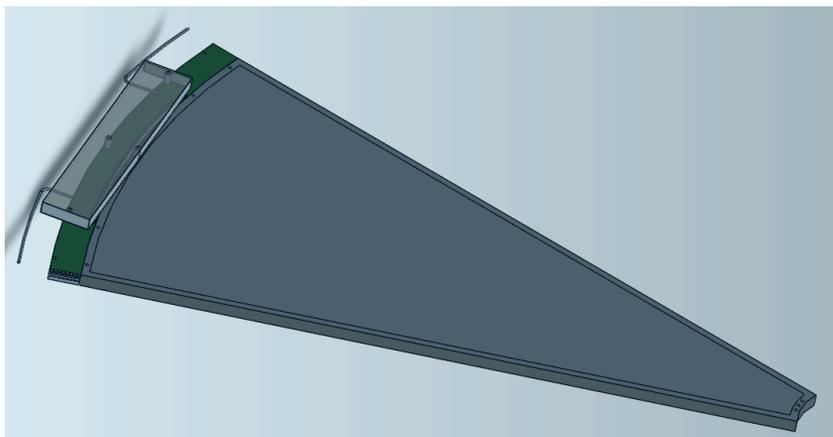
- Forward GEM tracking - Design of large triple-GEM segment
 - 30 degree segments



GEM Foil:
92 cm x 54 cm

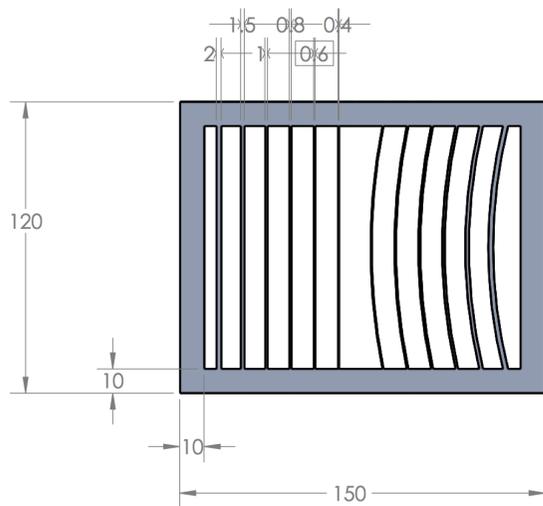


FR4 Frame:
102 cm x 57 cm

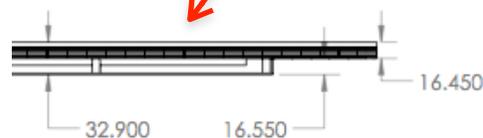
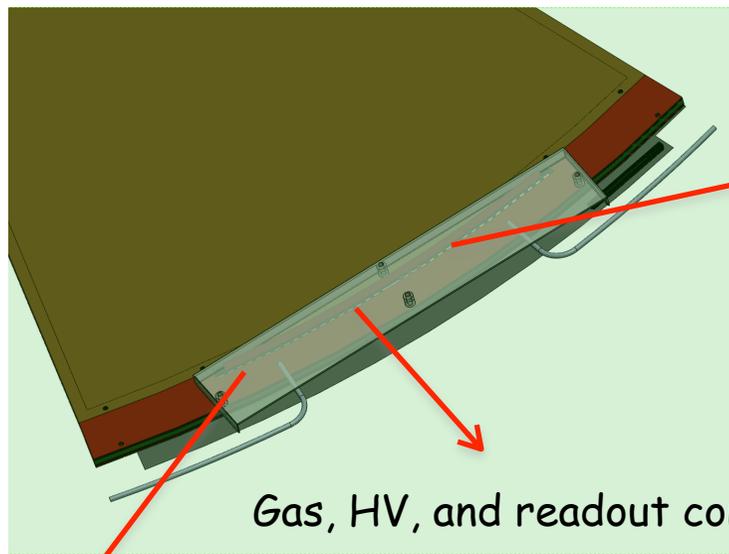


Proposal - FY14

- Forward GEM tracking - Design of large triple-GEM segment
 - Light-weight design concept:
 - Services (electronics / HV / Gas) placed at the outer radial region
 - Minimal stretched foils to avoid bulky frame
 - Spacer grids or Kapton ring spacers

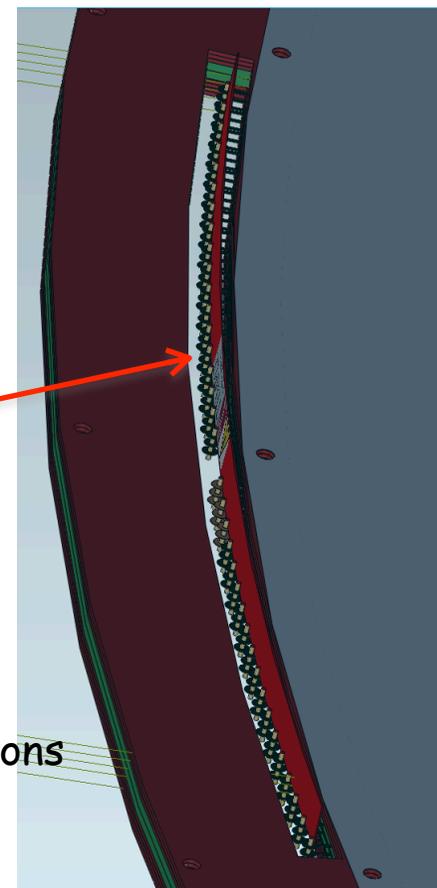


R&D on water-jet cut spacer grid



16.45 mm thick
+ service box

Lightweight (<1% X_0 in active area)

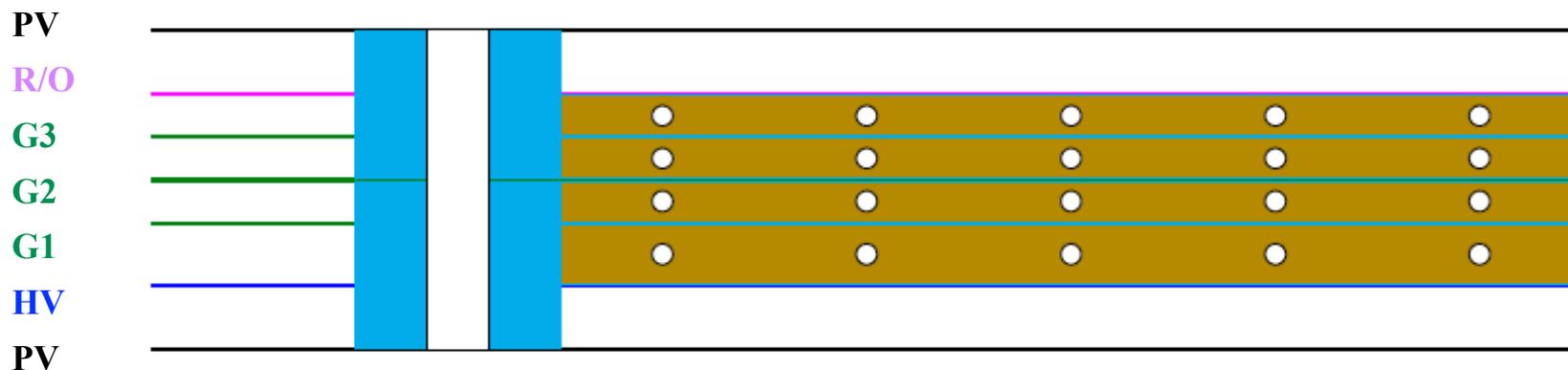
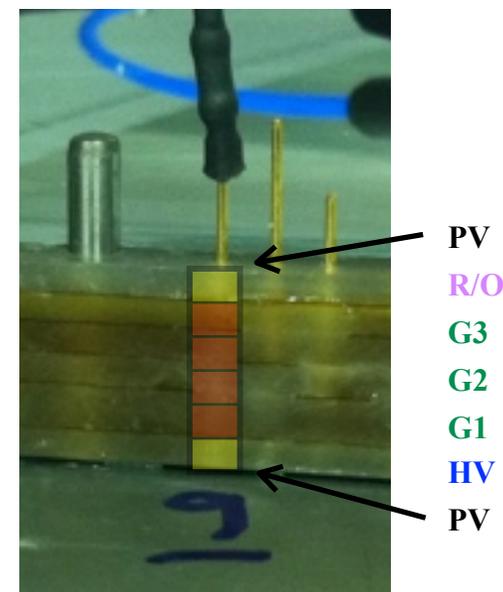




Proposal - FY14

□ Forward GEM tracking - Spacer grid / Motivation for Kapton rings

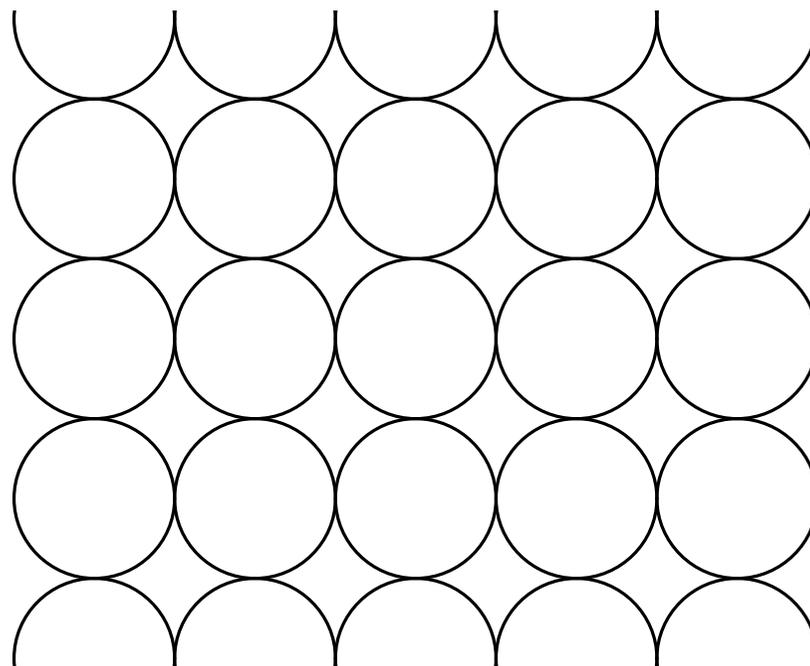
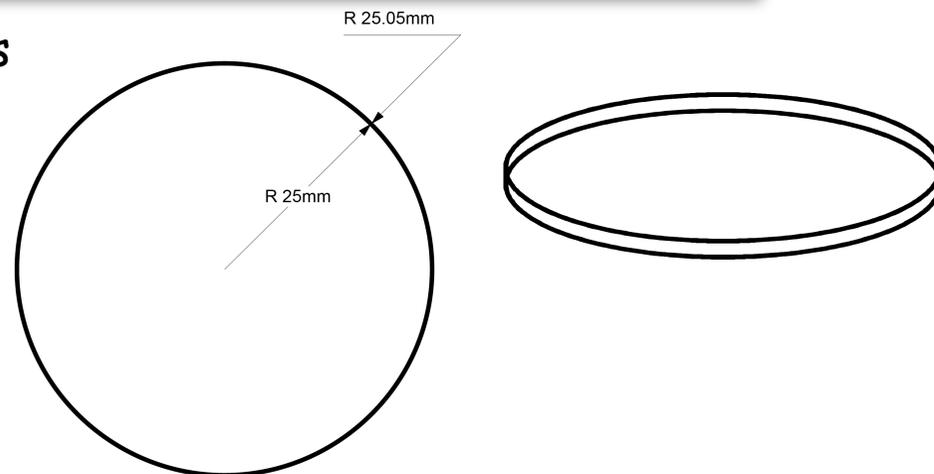
- Gap determines electric field and hence gain
- Foils should be flat, no wrinkles or creases to cause sparks
- Traditionally foils are stretched across frames
 - Frames need to be strong to resist tension: **Dead material**
 - Spacer grids for intermediate support: **Dead area** 2-3 × width
- Propose to use **Kapton rings between foils**:
 - 25-50 mm diameter, 0.05-0.10 mm wall thickness
 - Uniform support on a small grid distance: No need to stretch foils



Proposal - FY14

□ Forward GEM tracking - Kapton ring details

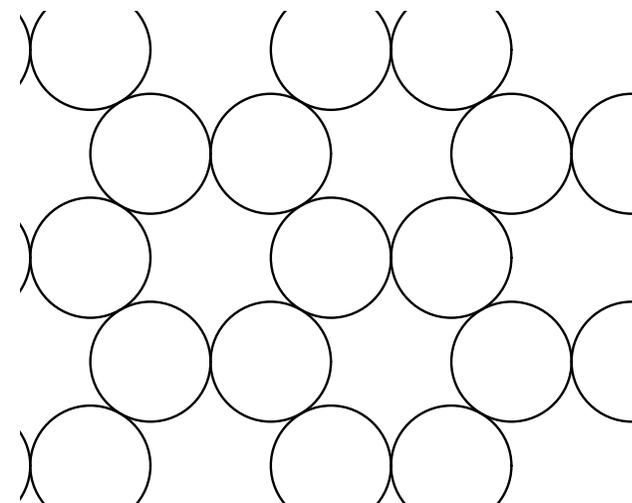
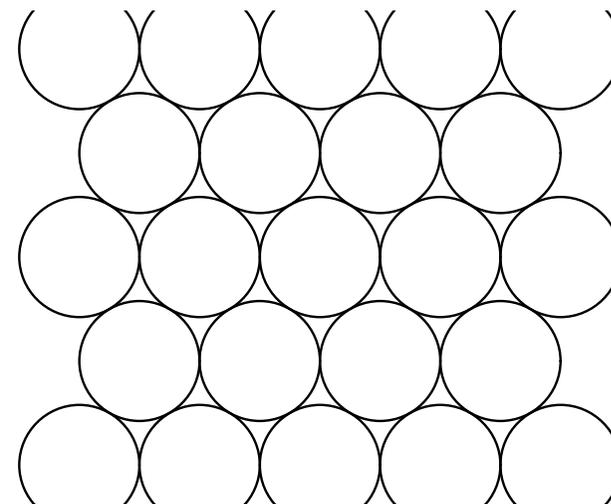
- 25 - 50 mm in diameter:
 - Cut from **Kapton tubes**
 - **0.05 - 0.10 mm wall thickness**
- 2 or 3 mm in height:
 - 2 mm for GEM gap
 - 3 mm for HV (and PV) gap
 - Tolerance on height ± 0.3 mm
- **Support on a small grid size**
- Net effect:
 - Flat foils with a **uniform gap**
 - **No need to stretch foils:** Frames can be narrow
 - **Reduced dead area**





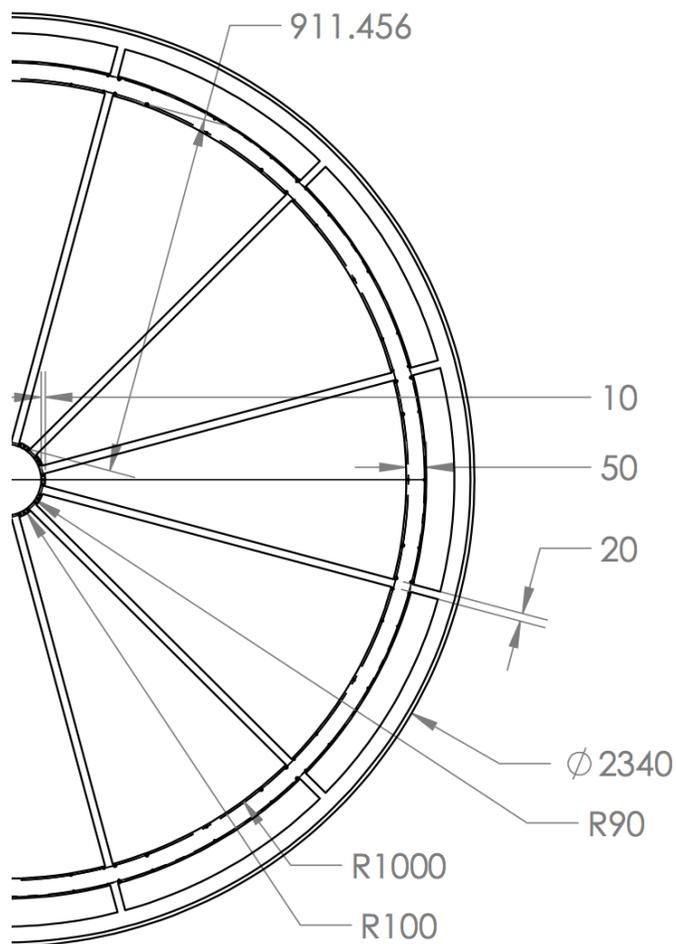
Proposal - FY14

- Forward GEM tracking - Kapton ring layout
 - Different array patterns possible
 - Constrained by narrow frames or pre-assembled glued arrays
 - Gas flow
 - Crucial for GEM operation
 - Design could have gas flow through foils
 - GEM foils porous - 20% holes
 - HV and R/O could also be porous
 - Holes around circumference of rings
 - Production of Kapton rings with holes
 - Kapton tubing readily available
 - Laser cut to length (height) within tolerance
 - Laser cut holes around circumference
 - Cost for R&D order \$2 per ring
 - Including NRE
 - Large production order cheaper

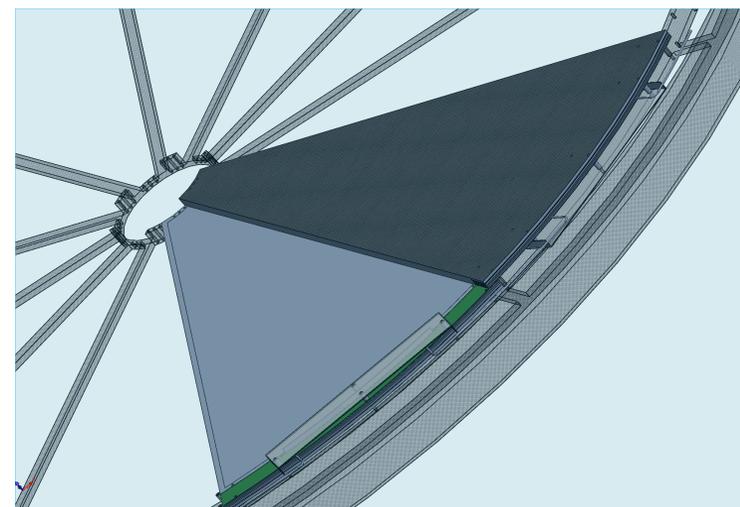
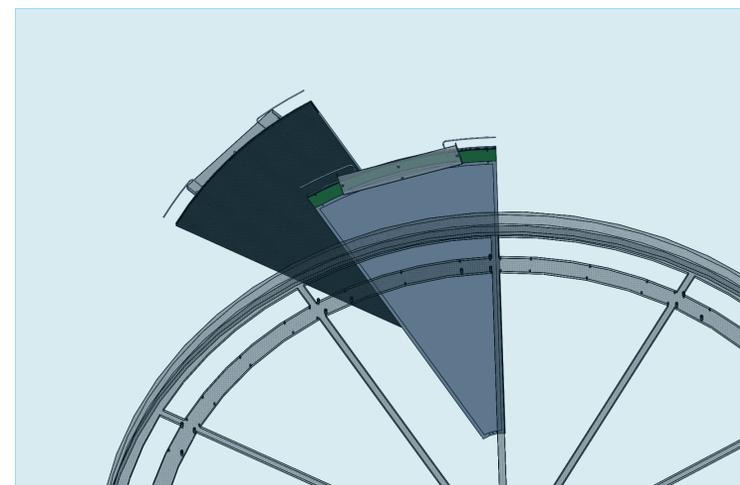


Proposal - FY14

- Forward GEM tracking - Mechanical design
 - Light weight design allows **minimal support structure**



Wheel dimensions (cm)



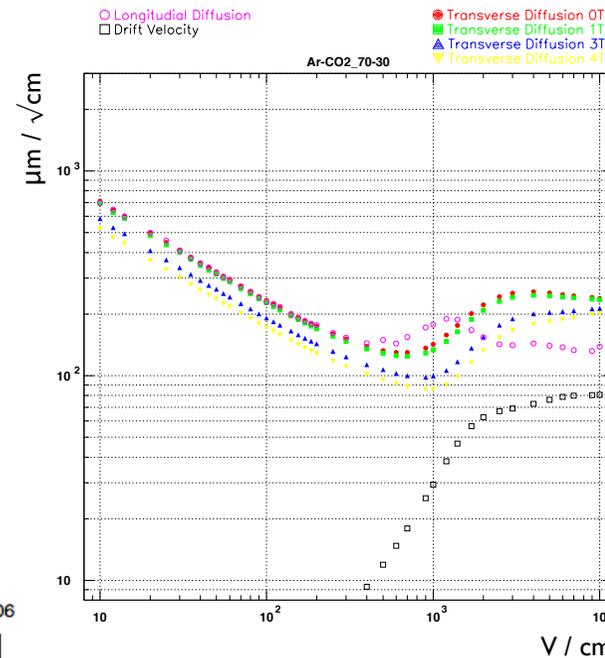
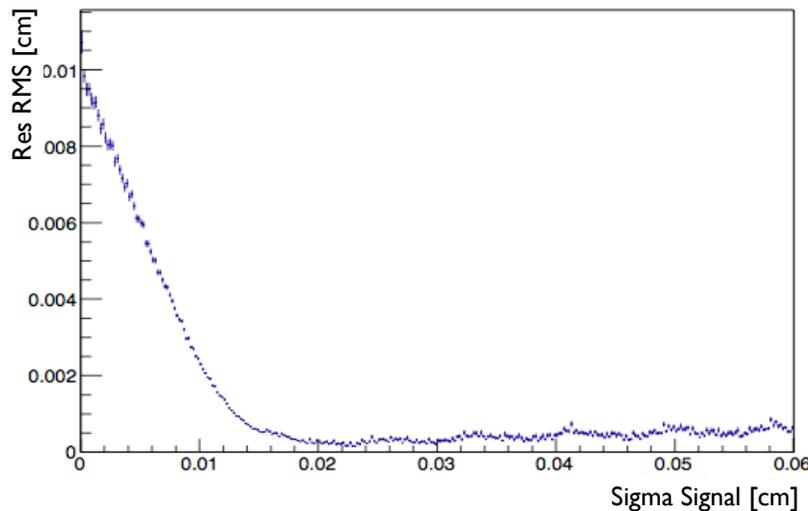
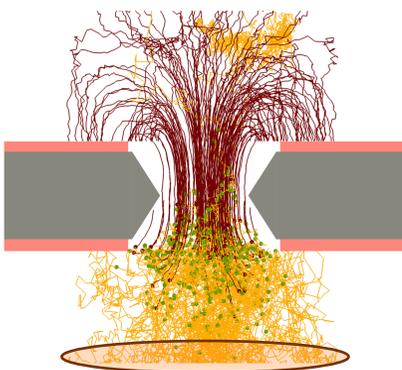
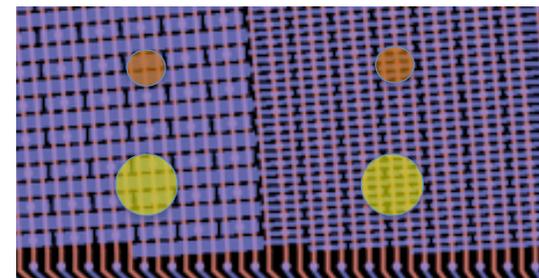
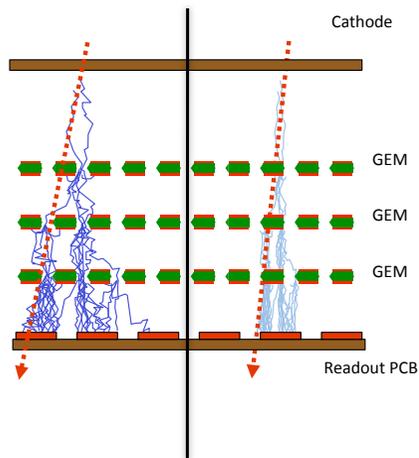
Proposal - FY14

○ Forward GEM tracking - Cluster size studies

○ Equipment needed:

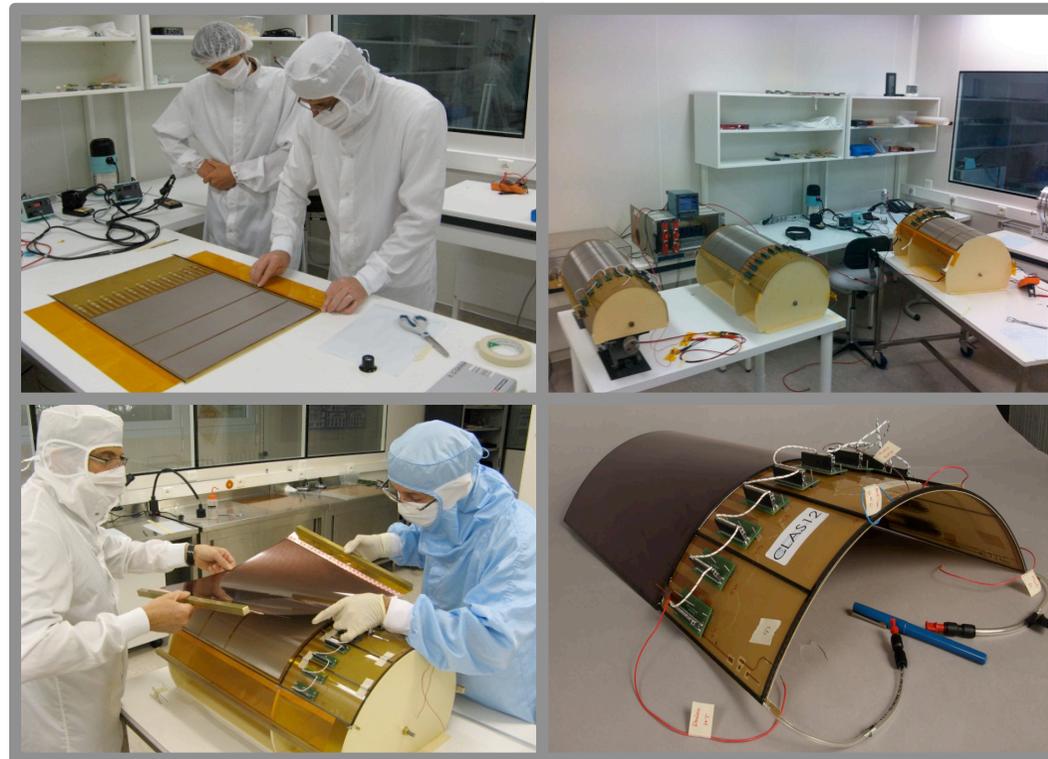
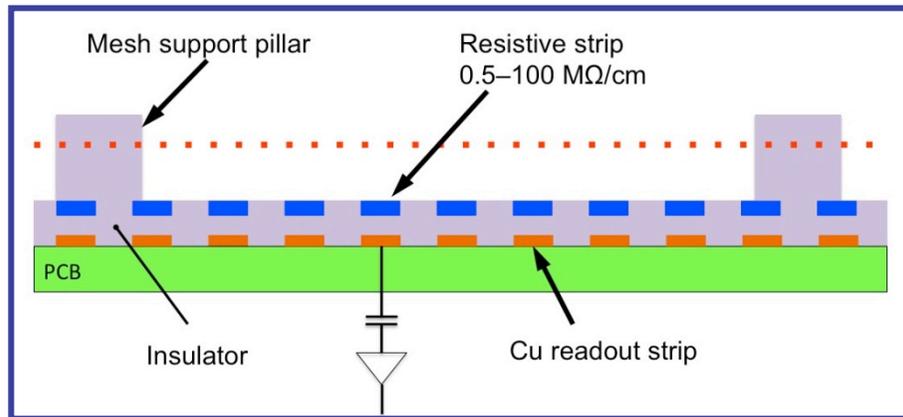
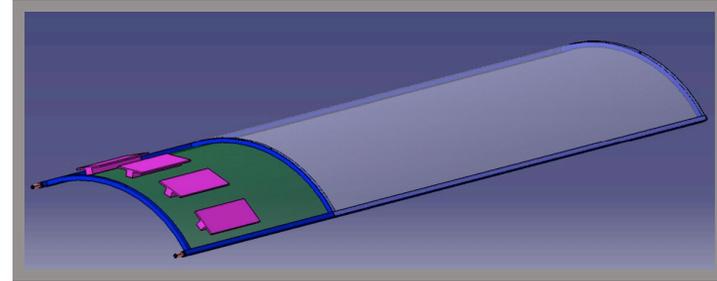
- Working DAQ
- Cosmic-ray setup
- Multi-channel HV system

○ MAGBOLTZ simulation



Proposal - FY14

- Barrel Micromegas tracking - Large prototype development
 - **Curved Micromegas** for barrel based on carbon structure glued on thin PCB
 - **Idea validated for CLAS12 tracker**
 - Need to **increase size**, but studies and simulation are needed : **PCB size, mesh tension, capacitance** and **gain homogeneity**
 - **More R&D needed!**

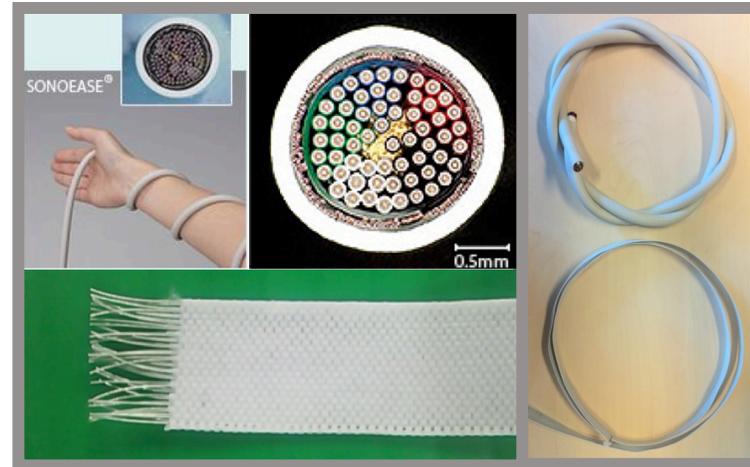


Proposal - FY14

□ Barrel Micromegas tracking - DREAM chip readout system

○ Further developments :

- DREAM v1 tests
- DREAM v1 self-trigger with channel multiplicity
- Long(er) flex cables
- Chip on detector
- Backend firmware development
- Time resolution improvements
- Separation of digitization from readout

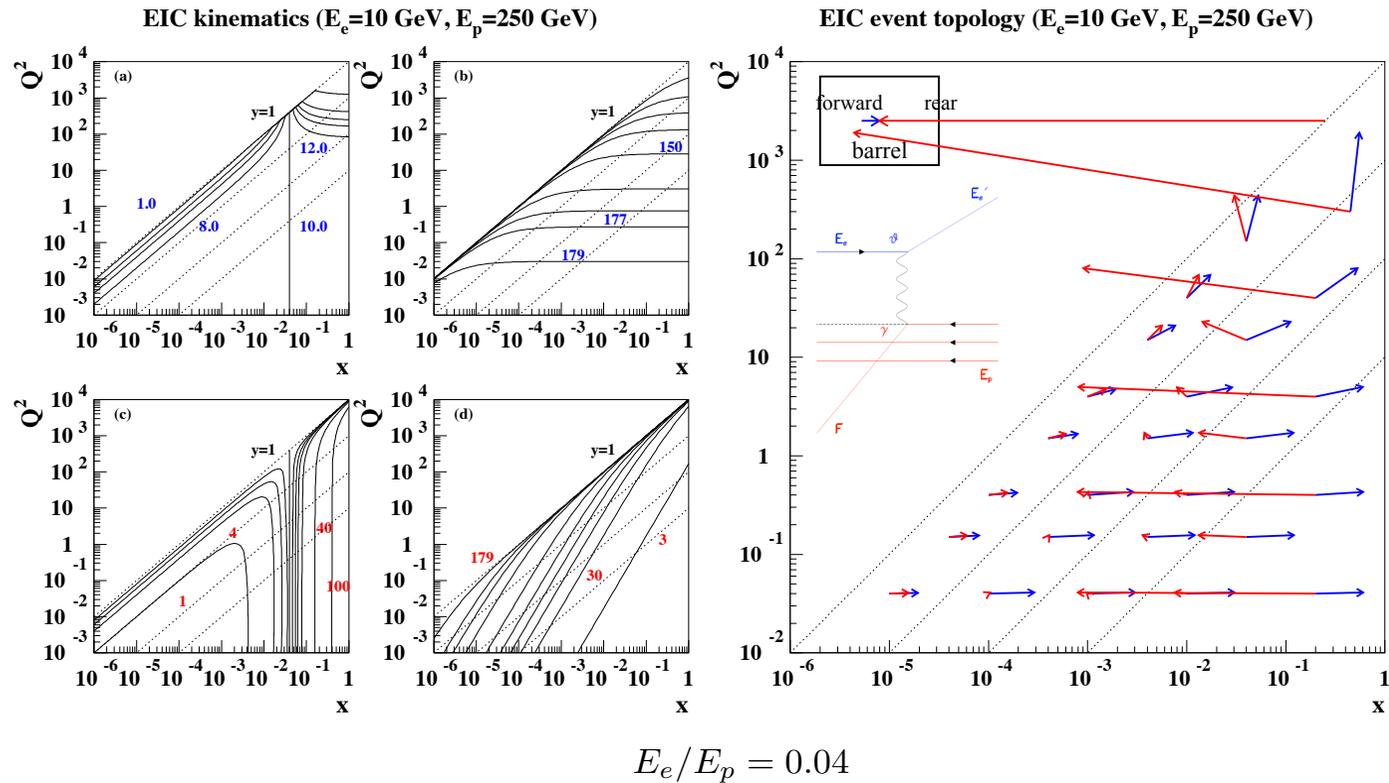


| | Dream Chip | APV25-S1 Chip |
|--------------------|-----------------|----------------|
| Number of channels | 64 | 128 |
| Memory size | 512 | 160 |
| Latency | 16 μ s | 8 μ s |
| Noise (e-RMS) | 2100 (On 180pF) | 1200 (On 20pF) |
| Sampling frequency | 1-40MHz | 10-50MHz |
| Dynamic range | 50-600fC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

Proposal - FY14

□ Simulations

- Two double-major students in physics and computer-science (Brandon and Jake) familiar with C++/Perl and GEANT4
- Begun with Whitepaper 2012 layout / Started with geometry and material definition focusing on tracking system



- Analytical acceptance and resolution studies
- Focus on micro-pattern tracking system

Budget and Schedule

□ Budget accounting - FY13

EIC R&D Items - Sabatie / Surov (PI, Temple University)

Items FY2013 (\$150,000)

Post Doc

Travel - Domestic (BNL / MIT)

Material

Equipment

Technician (TU CST)

EIC R&D Items - Sabatie / Surov (PI, Temple University)

Equipment / Material Items FY2013

1 Oscilloscope

1 Spectroscopy amplifier

1 Pre-amplifier

1 Pulser

1 Multi-Channel Analyser

1 Soldering Iron

1 Clean Room / Portable

300 APV chips

1 DAQ computer

2 ROC DAQ card

2 SIU DAQ cards

Misc. items (Cables / Gas / Gas equipment etc.)

○ Main funding items: FY13

□ Labor

□ Travel

□ Material / Equipment

Budget and Schedule

□ Funding request - FY14

- Funding request for FY14: \$299k (MIT, Saclay, TU)

□ Labor (Post Doc /

Undergraduate

support / Fringe

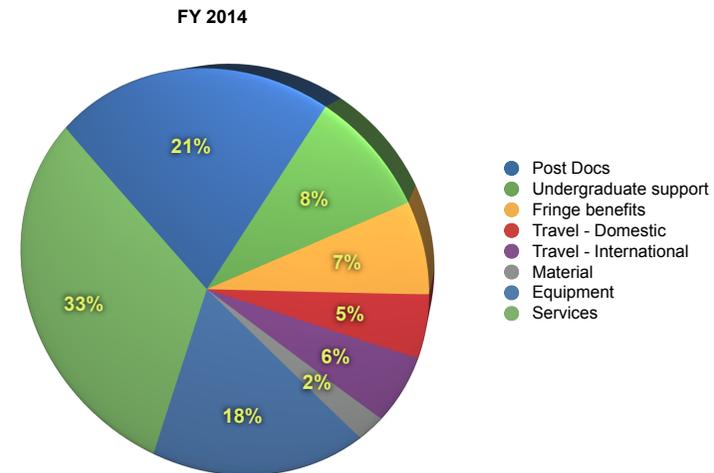
benefits / Services)

almost 2/3

□ Critical equipment

items

| EIC R&D Overview - Sabatie / Surrow (PI, Temple University) FY 2014 | |
|---|-----------|
| | Amount |
| Personnel / Travel | |
| Post Docs | \$51,705 |
| Undergraduate support | \$20,880 |
| Total Salaries | \$72,585 |
| Fringe benefits | \$16,287 |
| Total Personnel | \$88,872 |
| Travel - Domestic | \$12,000 |
| Travel - International | \$14,000 |
| Material / Equipment | |
| Material | \$5,750 |
| Equipment | \$45,550 |
| Other | |
| Services | \$81,320 |
| Total | |
| Total Direct Costs | \$247,492 |
| Modified Total Direct Costs (MTDC) | \$201,942 |
| F&A: 26% | \$52,505 |
| Total Project Costs | \$299,997 |



| EIC R&D Equipment - Sabatie / Surrow (PI, Temple University) FY 2014 | |
|--|----------|
| | Amount |
| Equipment Items | |
| Particle counter | \$500 |
| Gas leak detector | \$750 |
| SolidWorks CPU | \$2,750 |
| Segment HV foils | \$1,500 |
| Segment GEM foils | \$12,000 |
| Segment 2D readout foils | \$5,000 |
| Radioactive source | \$250 |
| HV GEM foil distribution module | \$500 |
| Fume hood | \$2,750 |
| 10 X 10 2D readout board | \$1,250 |
| 10 X 10 APV board | \$1,050 |
| Kapton ring material | \$4,000 |
| Stretching jig | \$4,500 |
| Assembly jig | \$3,250 |
| HV N2 box | \$3,750 |
| Cables | \$1,750 |
| Total Equipment | \$45,550 |

| EIC R&D Services - Sabatie / Surrow (PI, Temple University) FY 2014 | |
|---|----------|
| | Amount |
| Service Type | |
| Technician (TU CST) | \$21,120 |
| Engineering support (MIT Bates) | \$19,200 |
| MicroMegs Production (Saclay) | \$41,000 |
| Total Service | \$81,320 |



Budget and Schedule

□ Schedule

○ General:

- Maxence at TU and Saclay
- Test-beam at FNAL, May 2014

○ Forward triple-GEM R&D:

- Goal: Order large foils at CERN: Nov. 2013
- Single-mask tests: Full FY14

○ Barrel MicroMegas R&D:

- Goal: Order at CERN / CIREA: Jan. 2014

○ Simulations: Full FY14

| EIC R&D Forward and Barrel R&D Schedule | Time in Months for FY 2014 | | | | | | | | | | | |
|---|----------------------------|----|----|---|---|---|---|---|---|---|---|---|
| | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| (1) General: | | | | | | | | | | | | |
| Dr. Maxence Vandenbroucke at Temple University | | | | | | | | | | | | |
| Dr. Maxence Vandenbroucke at CEA Saclay | | | | | | | | | | | | |
| Test beam at FNAL | | | | | | | | | | | | |
| (2) Forward triple-GEM R&D: | | | | | | | | | | | | |
| Spacer grid studies (Frame) at TU | | | | | | | | | | | | |
| Spacer grid studies (Kapton rings) at MIT Bates | | | | | | | | | | | | |
| Complete 55Fe source scanner | | | | | | | | | | | | |
| Finalize mechanical design and verify design at MIT Bates | | | | | | | | | | | | |
| Prepare Gerber files for GEM foil segment | | | | | | | | | | | | |
| Discuss design with CERN photolithographic workshop | | | | | | | | | | | | |
| Order CERN foils | | | | | | | | | | | | |
| Test CERN foils | | | | | | | | | | | | |
| Order frame components | | | | | | | | | | | | |
| Order HV foils | | | | | | | | | | | | |
| Order and complete tooling setup | | | | | | | | | | | | |
| Stretch of foils | | | | | | | | | | | | |
| Design of 2D readout layer | | | | | | | | | | | | |
| Order of 2D readout layer | | | | | | | | | | | | |
| Assembly of segments | | | | | | | | | | | | |
| Test of segments | | | | | | | | | | | | |
| Test of single-mask produced foils at Tech-Etch Inc. | | | | | | | | | | | | |
| (3) Barrel MicroMegas R&D: | | | | | | | | | | | | |
| CAD work for PCB and mechanical structure | | | | | | | | | | | | |
| Order at CERN and CIREA | | | | | | | | | | | | |
| R&D on layout | | | | | | | | | | | | |
| R&D on readout | | | | | | | | | | | | |
| Test of prototype | | | | | | | | | | | | |
| (4) Simulations | | | | | | | | | | | | |
| Analytical resolution studies | | | | | | | | | | | | |
| Fast simulations | | | | | | | | | | | | |
| GEANT4 simulations | | | | | | | | | | | | |





Summary

□ Summary

○ Forward GEM tracking

- Characterization of GEM foils in terms of leakage current and optical uniformity
- Assembly of small (10 X 10 cm²) 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 and support structure
- Commercialization of large GEM foil production using single-mask manufacturing techniques
- Spacer grid studies: Grid and Kapton rings

○ Barrel MicroMegas tracking

- Successful assembly of two flat CLAS12 MicroMegas detectors
- Successful test of two flat CLAS12 MicroMegas detectors in cosmic-ray test stand
- Successful test of light-weight, low capacitance flex cables
- Test of first DREAM chip production version v0

- Successful undergraduate student recruitment with strong support from TU College of Science and Technology

□ Outlook

- Expect to order and test large MicroMegas and GEM foils in FY14