



Progress report (Q4 FY13 / Q1 FY14)
Fast and lightweight tracking systems
Barrel MicroMegas
&
Forward Triple-GEM

Maxence Vandembroucke
Bernd Surov (PI)



Doug Hasell



Franck Sabatie (PI)





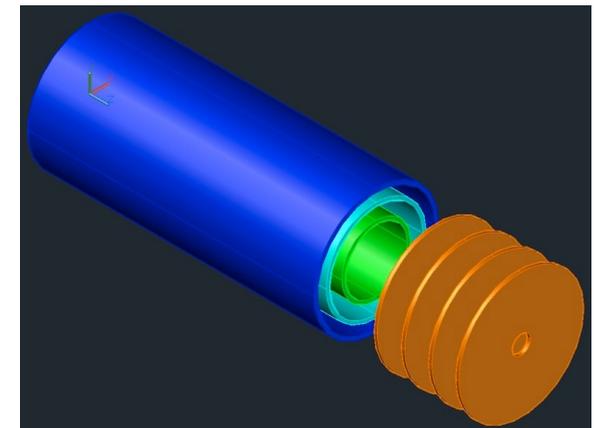
Project overview

- Progress report: Q4 FY13 / Q1 FY14
 - 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 (Q4 FY13 / Q1 FY14)

S. Aune, E. Delagnes, M. Garçon, I. Mandjavidze, S. Procureur, F. Sabatié¹
CEA Saclay
P. Bull, A. Dumont, C. Harris, R. Harris, D. S. Gunarathne,
E. Kaczanowicz, A. F. Kraishan, X. Li, M. McCormick, G. Miller, D. L. Olivitt,
B. Surrøw², M. Vandenbroucke and G. Zangakis
Temple University, College of Science and Technology
J. Bessuille, B. Buck, D. Hasell
MIT, Laboratory for Nuclear Science





Progress report - Q4 FY13 / Q1 FY14

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)
- Design of dedicated **large-size N2 storage shelves** for GEMS
- Design and preparation of **large assembly tools** will start in spring 2014 by a new mechanical engineer

Detector lab at Temple University
(Current Department of Physics)



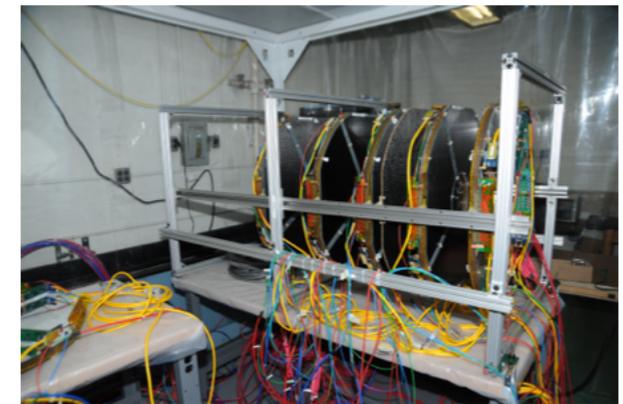
(a)



(b)



(c)



(d)

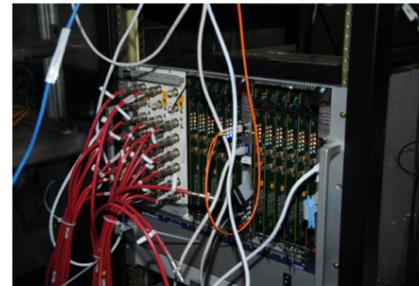


Progress report - Q4 FY13 / Q1 FY14

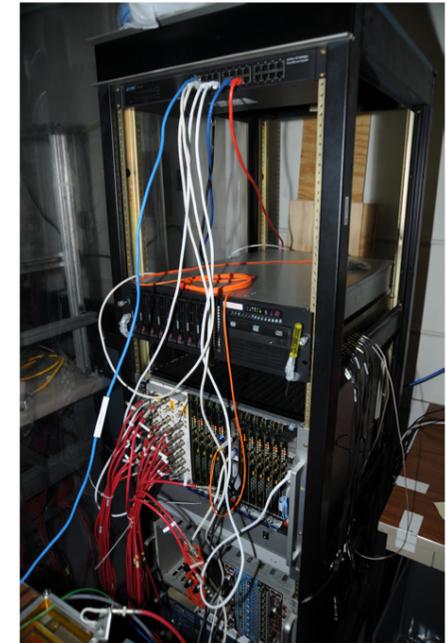
- Forward GEM tracking - DAQ system
 - Setup of DAQ system profits enormously from synergy with STAR FGT DAQ system
 - In place: Special Wiener crate (3 HV modules, 2 control modules and 2 X 6 readout modules (ARC))
 - Completed DAQ system:
 - DAQ computer
 - Run control / Slow control computer
 - HV modules (3)
 - Readout modules (2 X 6)
 - Control modules (2) and
 - Run control and slow control operational / Copy of STAR DAQ setup



(a)



(b)

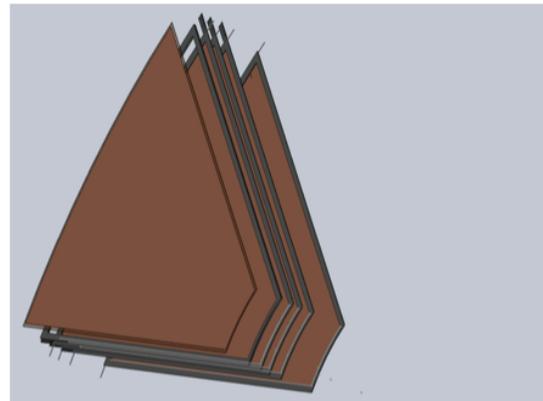


(c)

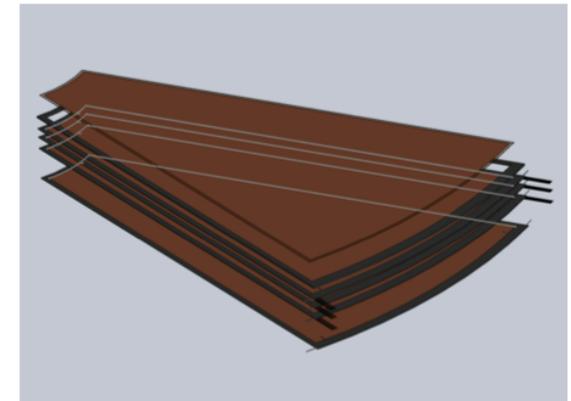


Progress report - Q4 FY13 / Q1 FY14

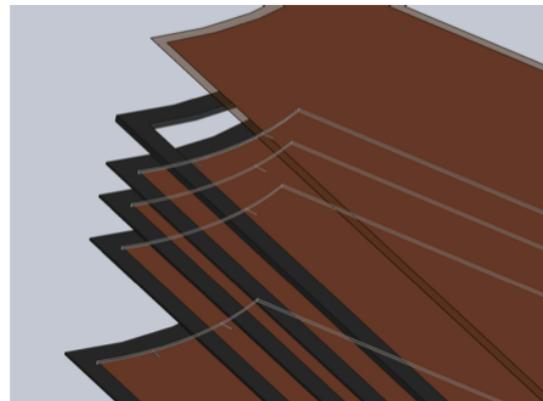
- Forward GEM tracking - Design of large triple-GEM segment
 - **Commercial fabrication** of single-mask process started
 - GEM frames based on **Carbon** material for self-support
 - **No spacers** (Kapton ring)
 - Gas piping in each CC frame
 - **HV routing** realized through **Kapton PCB** extended by flaps for connection to HV distribution
 - Design review by MIT Bates engineering team followed by procurement of large foils, initially at CERN



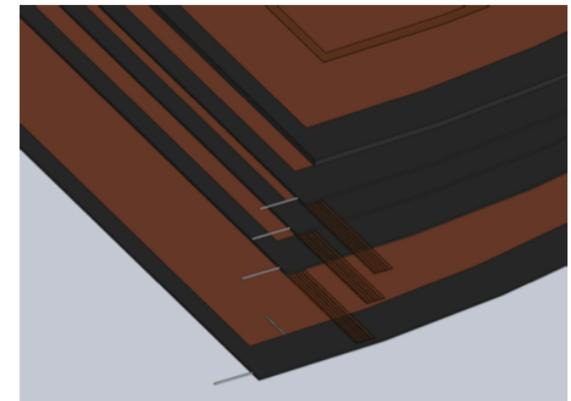
(a)



(b)



(c)



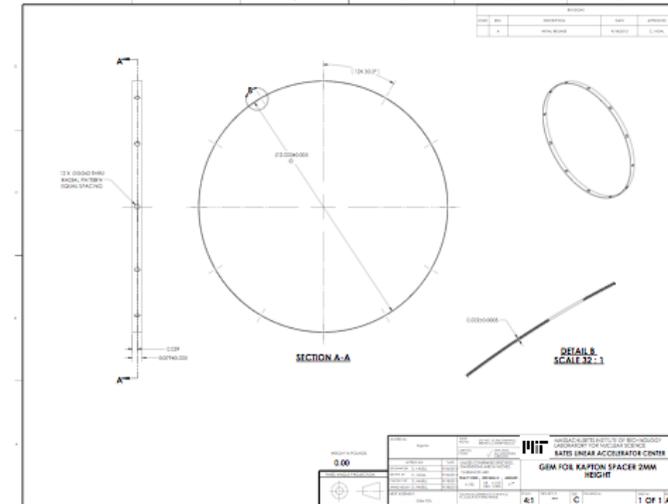
(d)



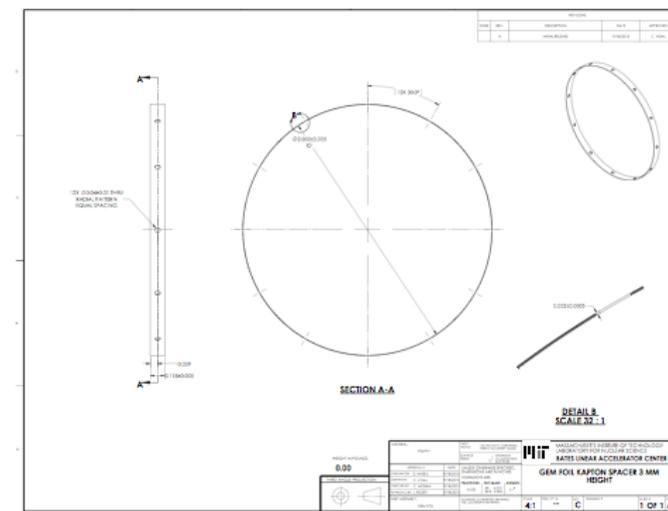
Progress report - Q4 FY13 / Q1 FY14

Forward GEM tracking - Kapton ring details

- Kapton ring design finalized.
- Commercial source for fabrication identified (POTOMAC, Lanham, MD)
- 2 or 3 mm in height:
 - 2 mm for GEM gap
 - 3 mm for HV (and PV) gap
 - Tolerance on height ± 0.3 mm
- Expect to start with assembly of Kapton-ring based triple-GEM detector in spring 2014 after delivery of Kapton rings



(a)

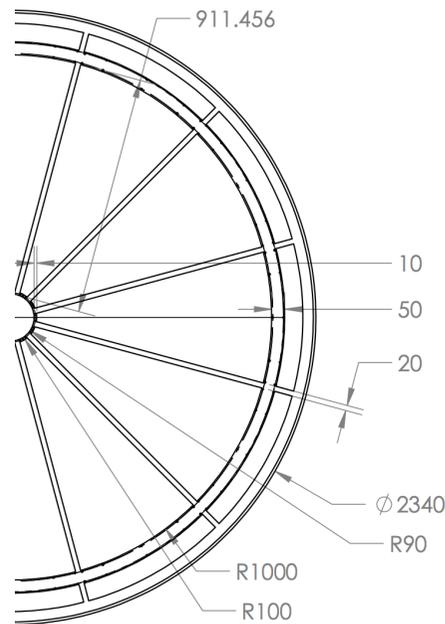


(b)

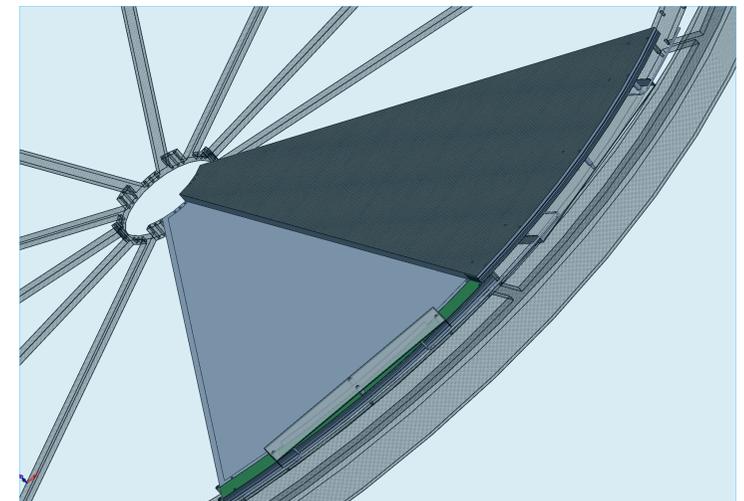
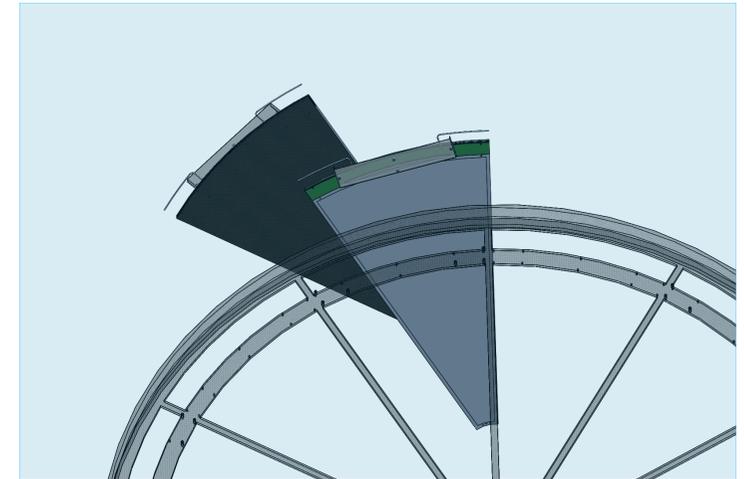


Progress report - Q4 FY13 / Q1 FY14

- Forward GEM tracking - Mechanical design
 - Light weight design allows **minimal support structure**
 - Initial discussion with E. Anderson (CC shop, LBL) very encouraging / Plan to prototype part of support structure after MIT Bates design review



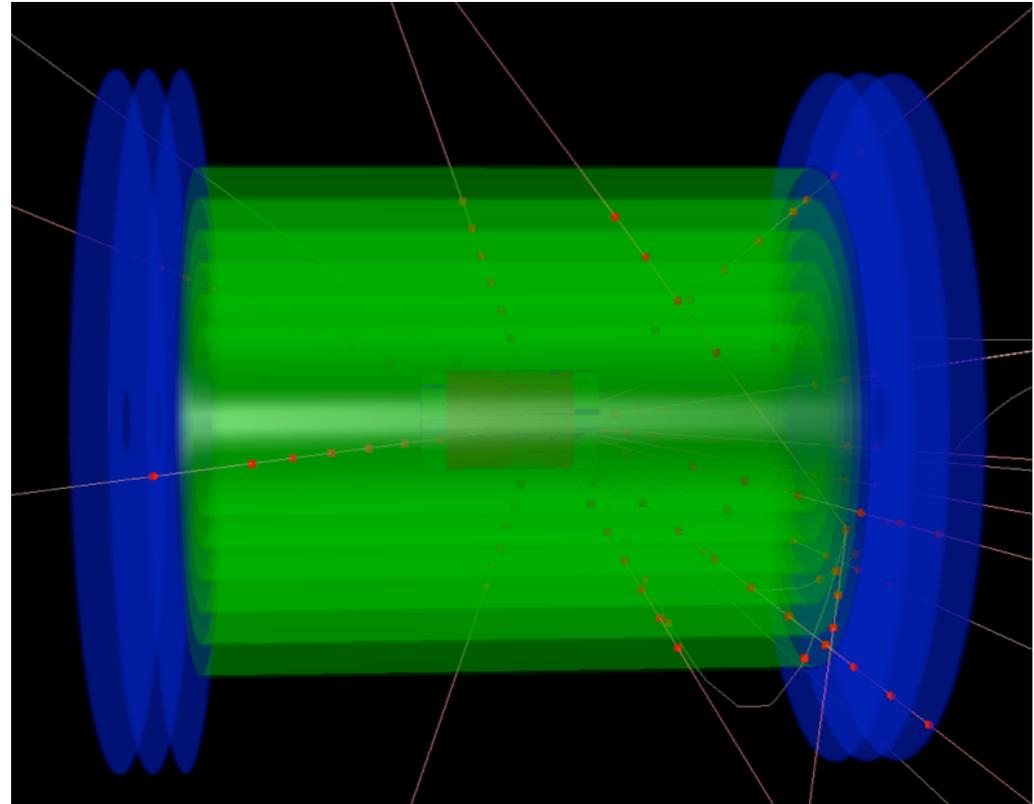
Wheel dimensions (cm)





Progress report - Q4 FY13 / Q1 FY14

- EICROOT Simulations
 - EICROOT package + Smearing
 - Focus on Tracking and the Energy resolution
 - Geometry implementation started
 - **Forward GEM**: 3 FGT-type disks with $r_{in} = 10\text{cm}$ and $r_{out} = 100\text{cm}$
 - **Barrel MicroMegas**: 6 cylindrical barrel layers
 - Simulations include the Barrel Silicon Tracker and Forward Silicon Tracker



Objectives

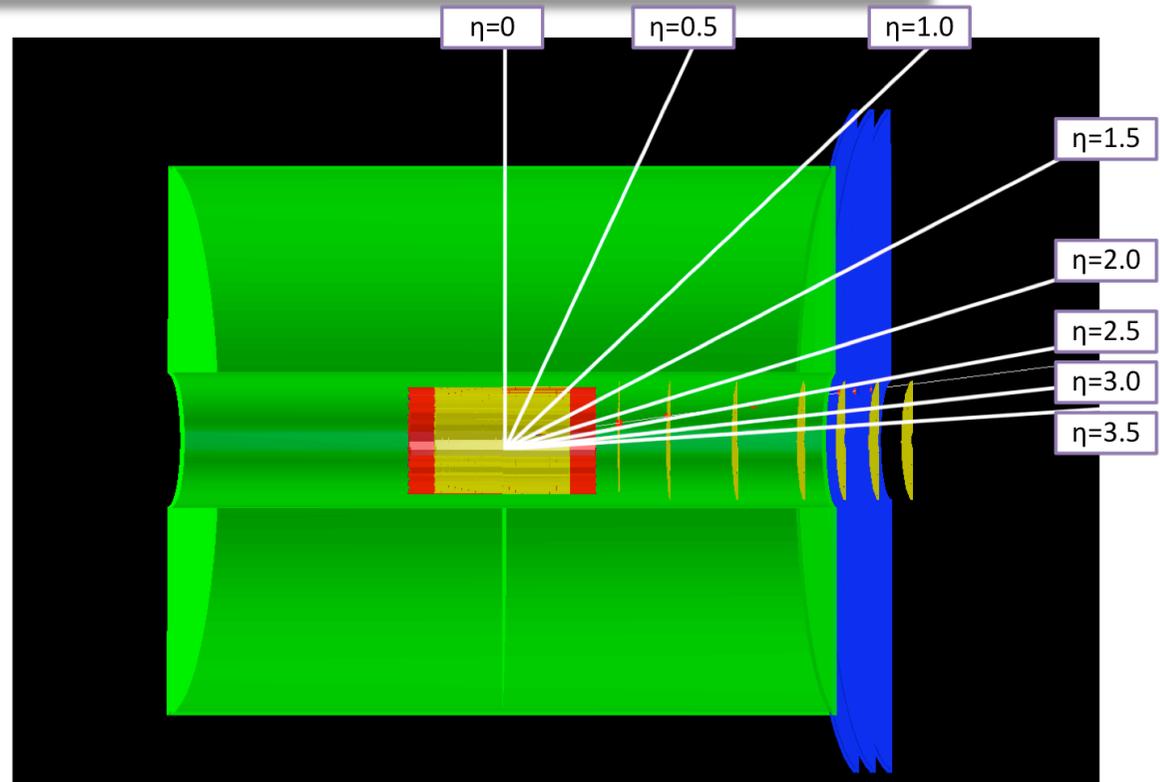
- => Good definition of the general FGT geometry
- => Comparison of the Micromegas barrel with a TPC



Progress report - Q4 FY13 / Q1 FY14

9

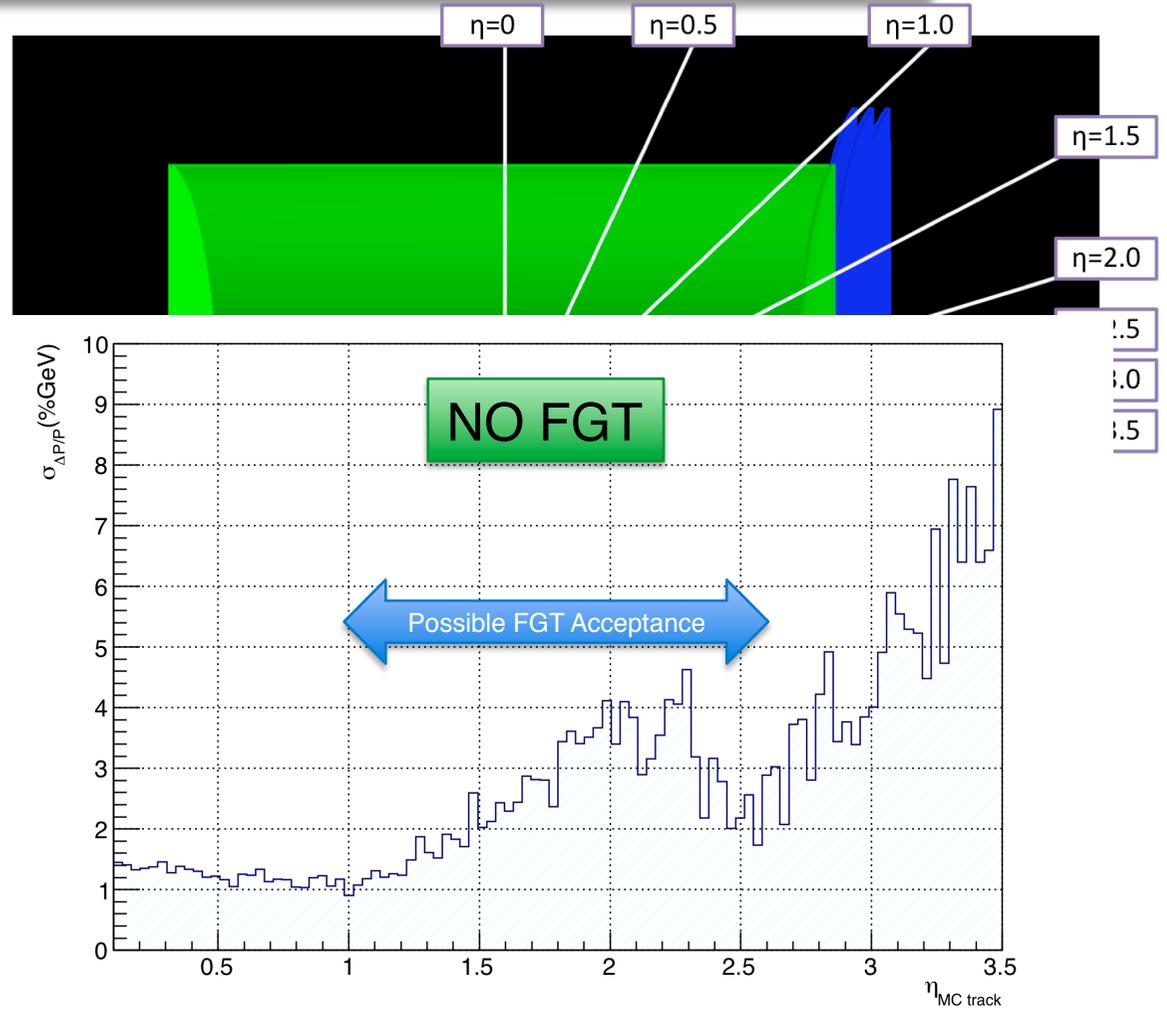
- Simulations - FGT Size Studies
 - Studies aiming to **constrain the size of a forward GEM system** (Studies based on TPC barrel system)
 - Box generator : π^- @ 10 GeV/c, 10k events





Progress report - Q4 FY13 / Q1 FY14

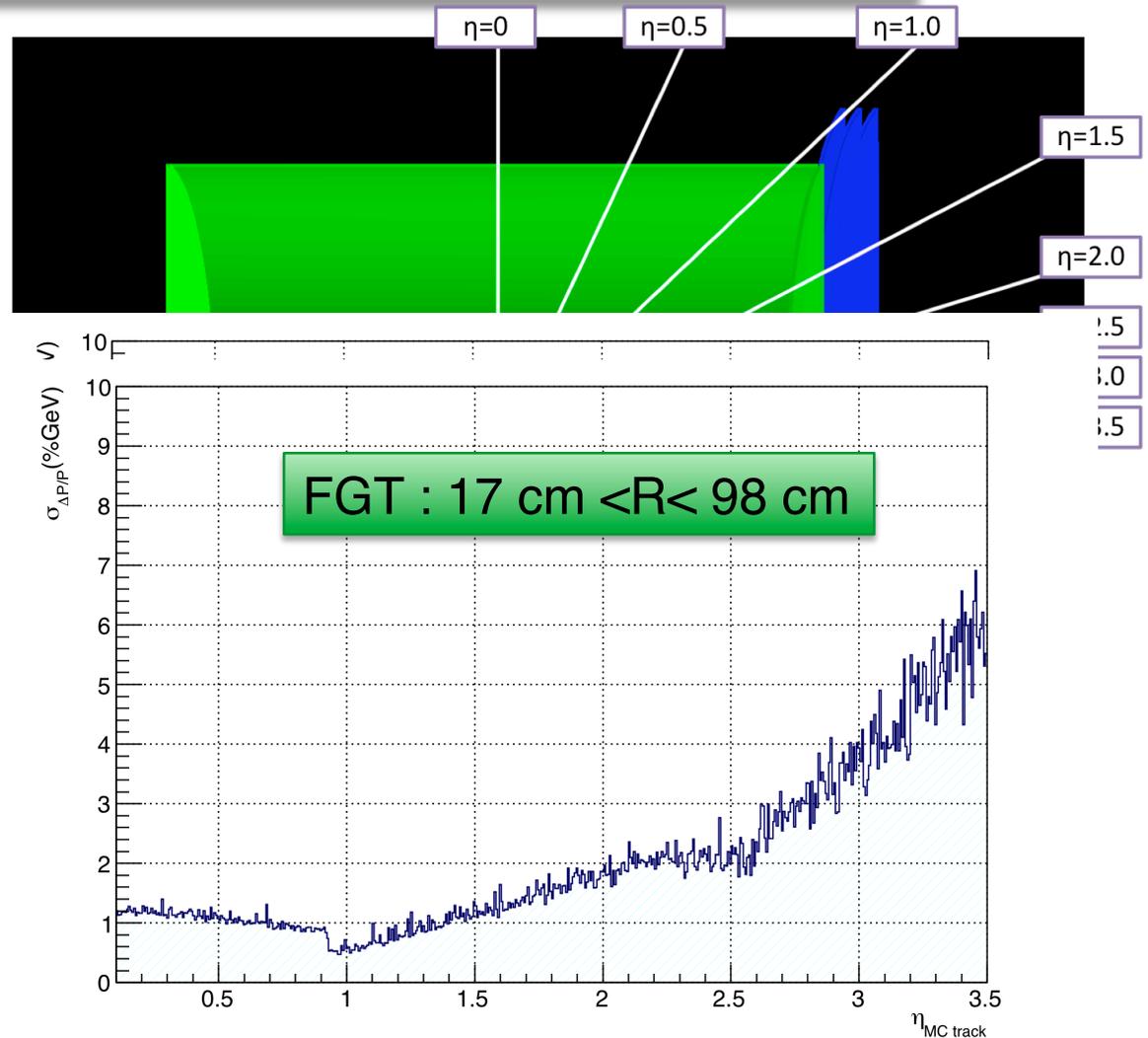
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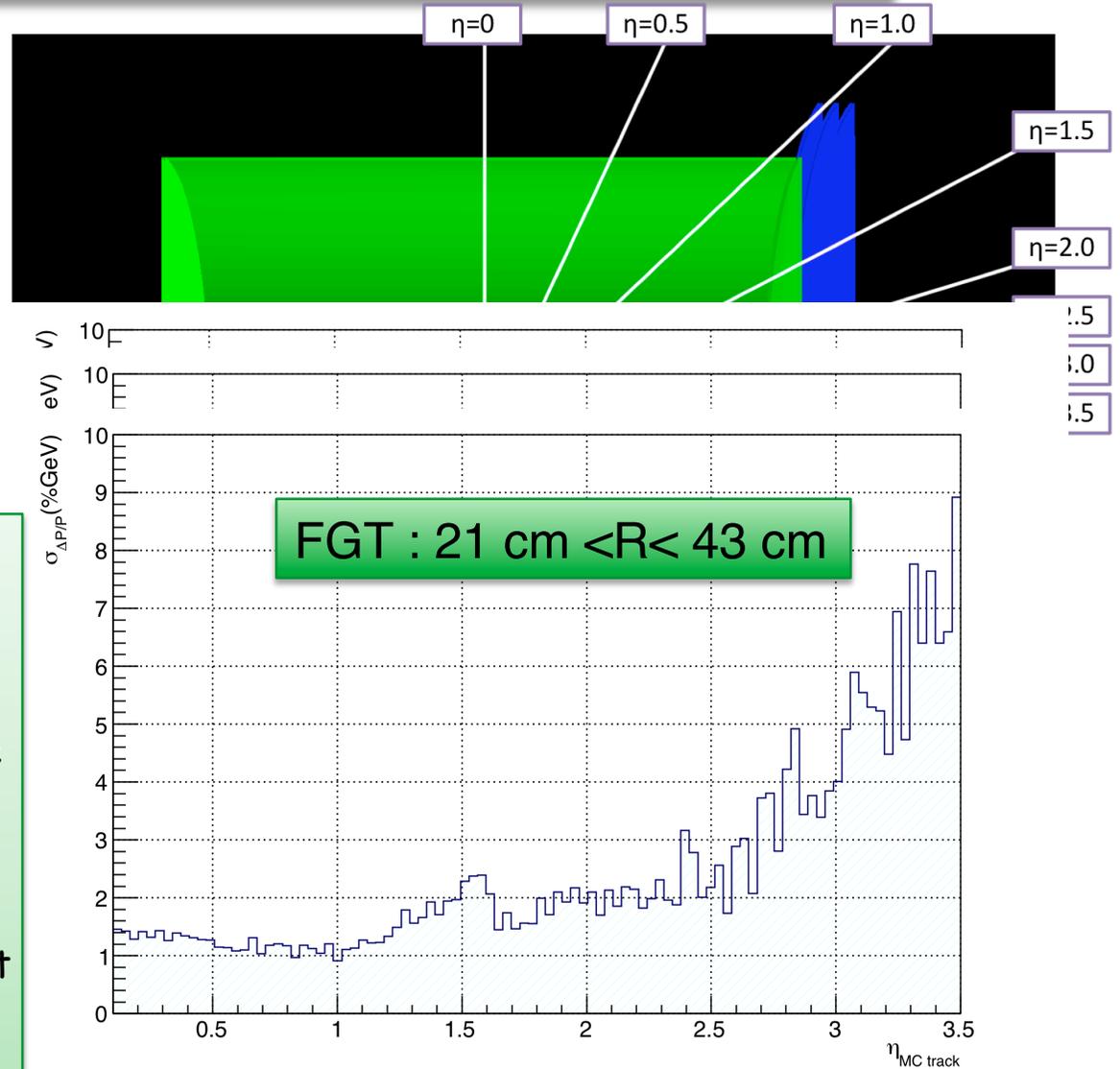




Progress report - Q4 FY13 / Q1 FY14

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 - Box generator : π^- @10GeV/c, 10k events

- FGT acceptance should match the central tracker size
- No material in the acceptance of the silicon tracker disks (BST/FST)
- Impact of material budget not clear, depends on the physics

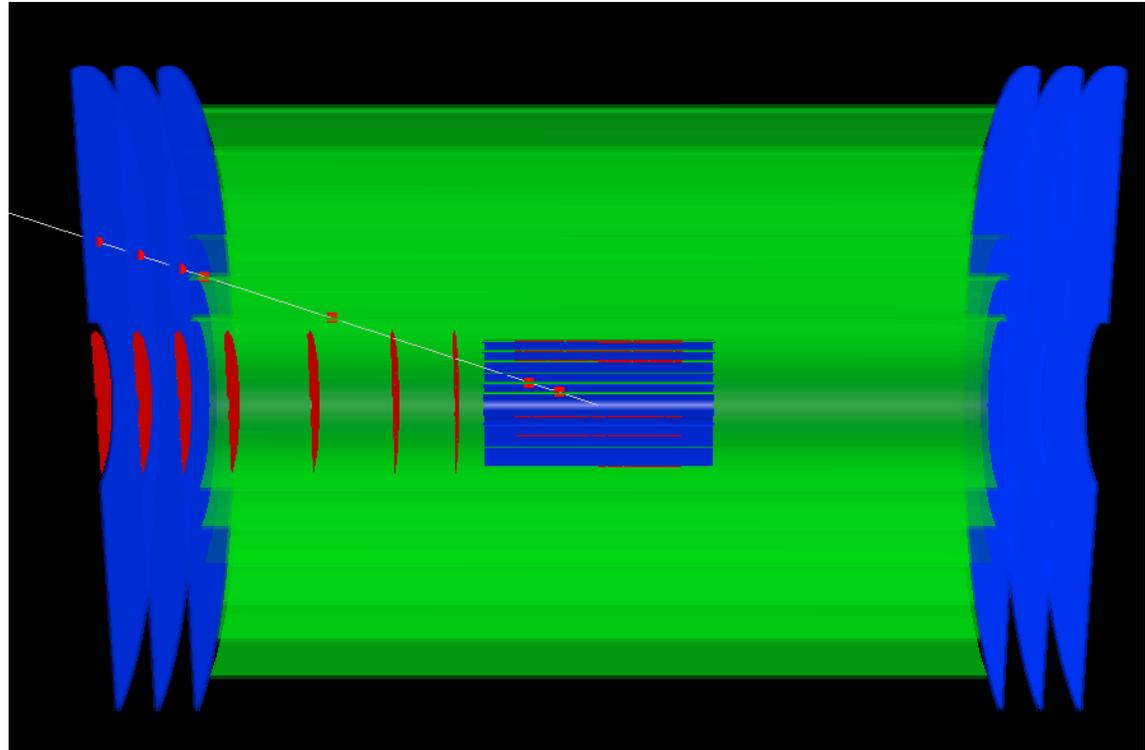




Progress report - Q4 FY13 / Q1 FY14

13

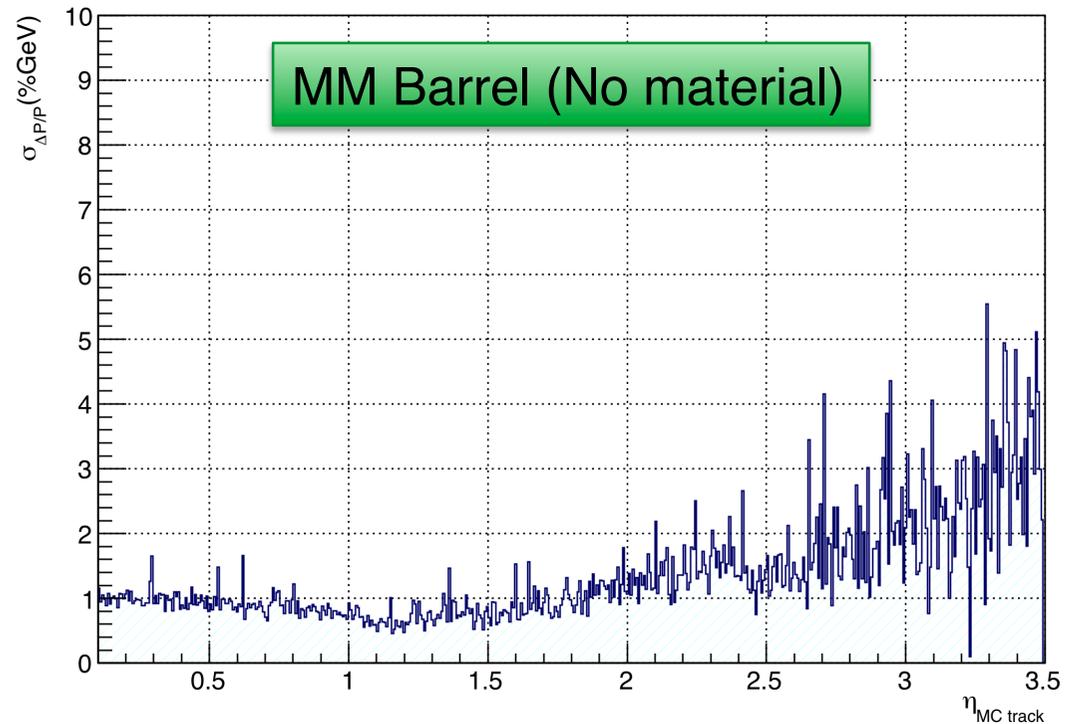
- Simulations - Micromegas Barrel
 - Same software environment
 - 6 barrels from 20cm to 80cm radii
 - 2 chambers per barrels for 2 dimension readout
 - 200 μ m spatial resolution (using smearing package)





Progress report - Q4 FY13 / Q1 FY14

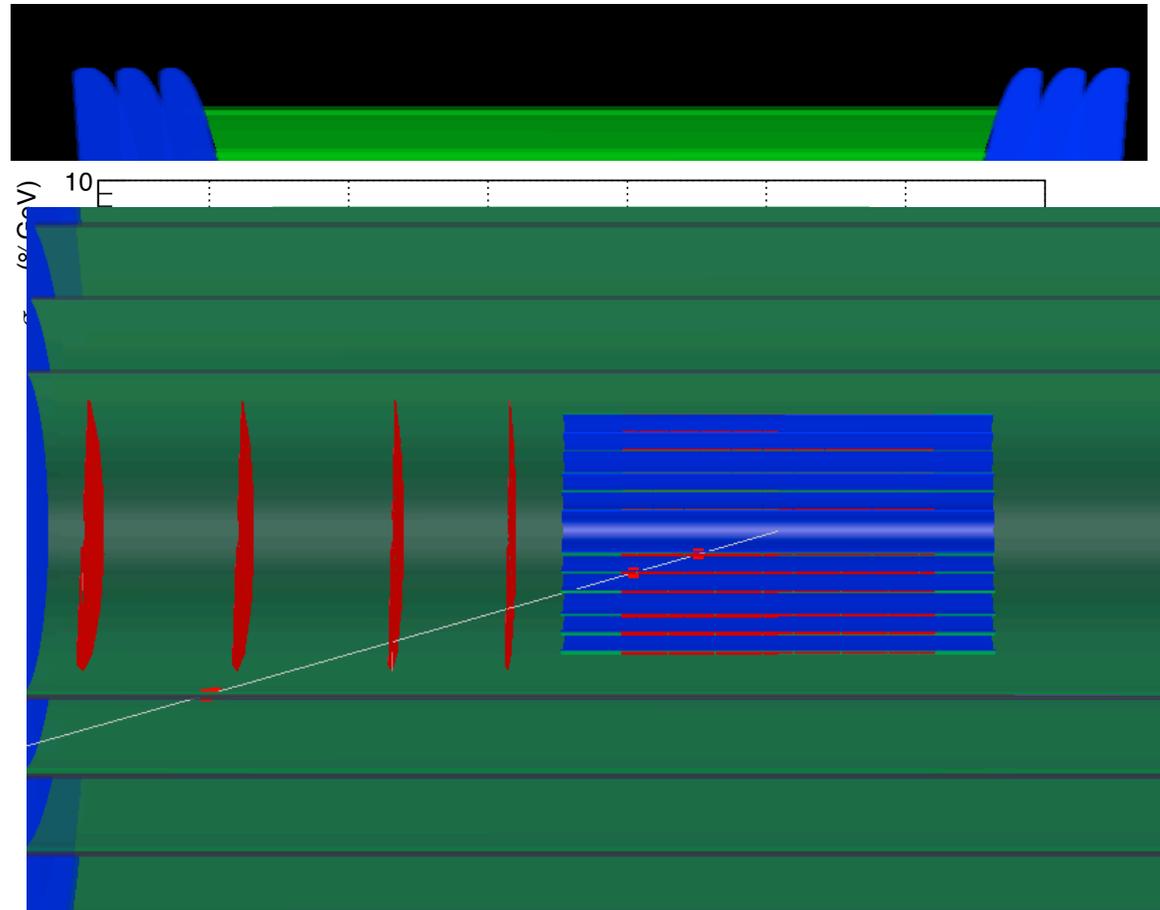
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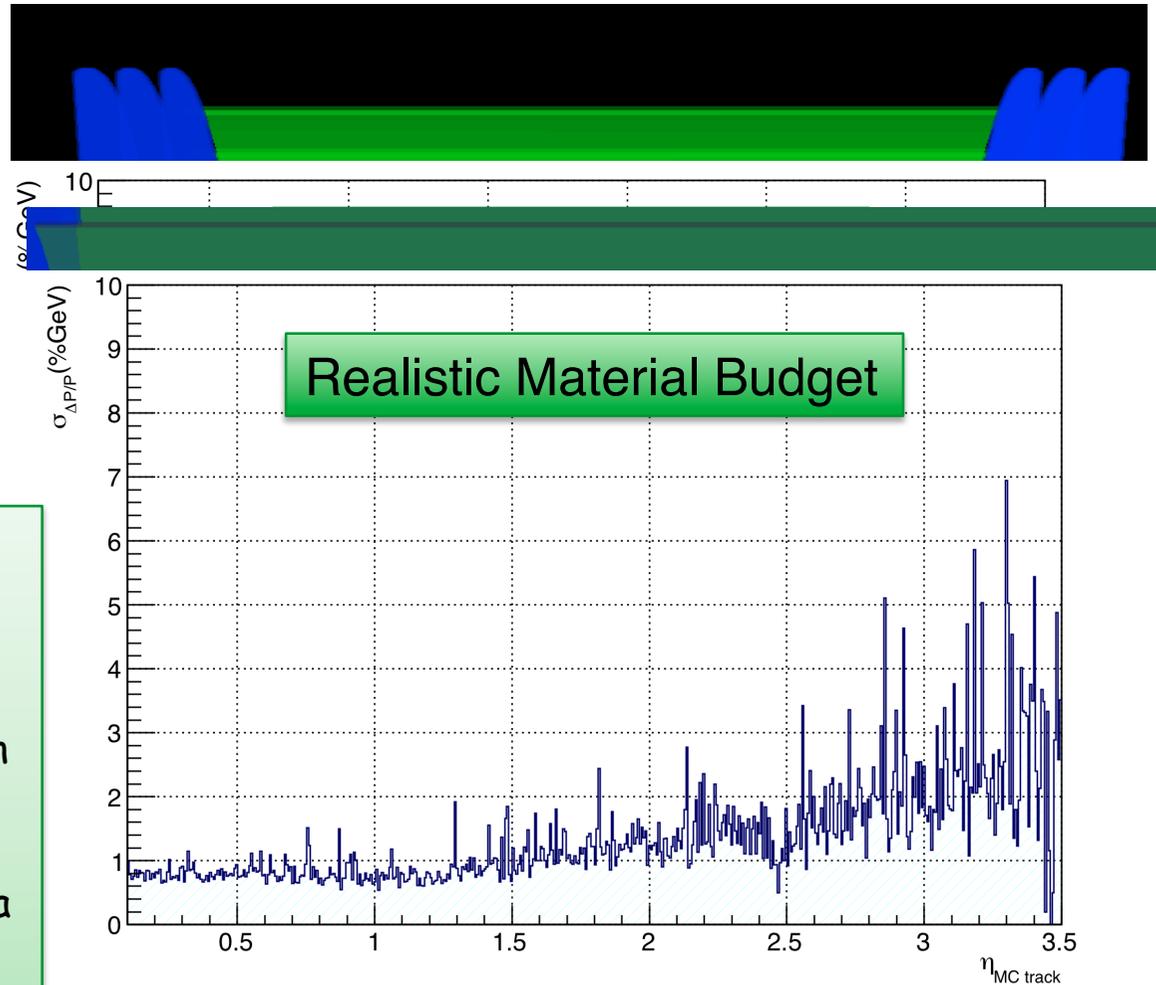




Progress report - Q4 FY13 / Q1 FY14

- Simulations - Micromegas Barrel
 - Same software environment
 - **6 barrels** from 20cm to 80cm radii
 - **2 chambers per barrels** for 2 dimension readout
 - **200 μ m spatial resolution** (using smearing package)

- Micromegas Barrel is a realistic solution
- Realistic material description
- Initial studies point to an improved p_T resolution with a MicroMegas barrel system

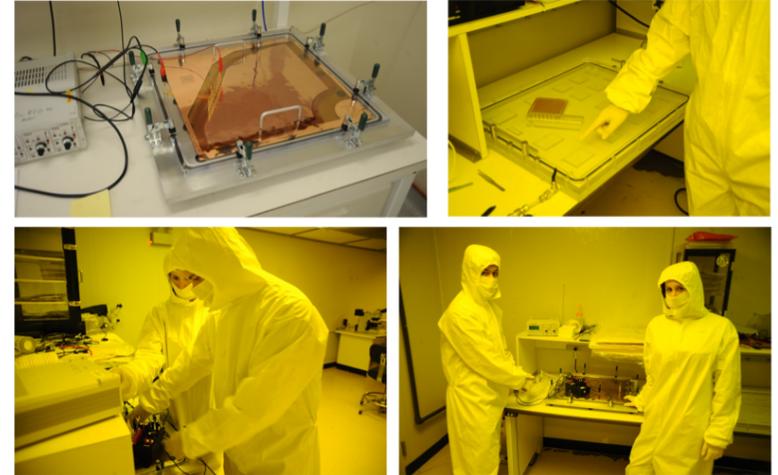




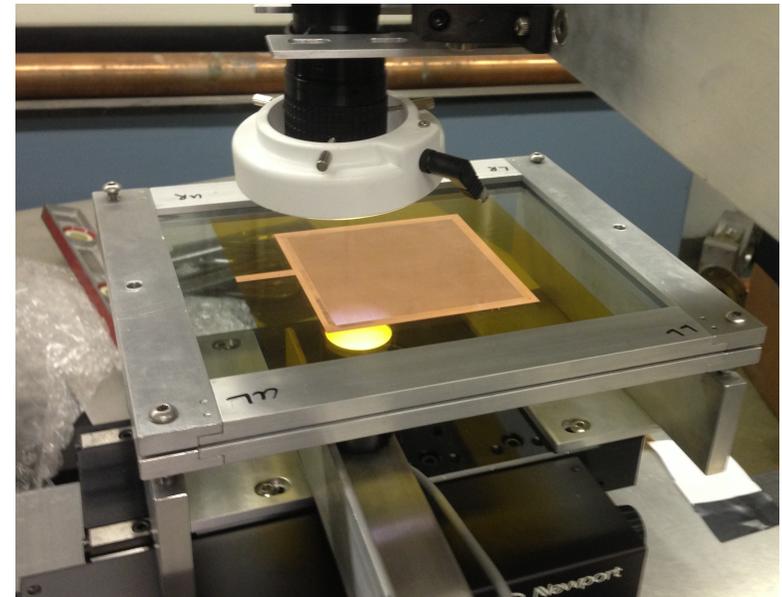
Project overview

- 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 completed (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** routinely performed
 - Assembly of small (10 X 10 cm²) triple-GEM test detectors**
 - Setup of **cosmic-ray test** and **⁵⁵Fe source scanner**
 - Setup of **DAQ** and **HV** system completed
 - Mechanical design studies** on large triple-GEM detector segment and initial discussion with LBL CC shop
 - Commercialization** of large GEM foil production using single-mask manufacturing techniques started
 - Simulations** within the EICROOT framework of the FGT

Leakage current measurement



CCD scans

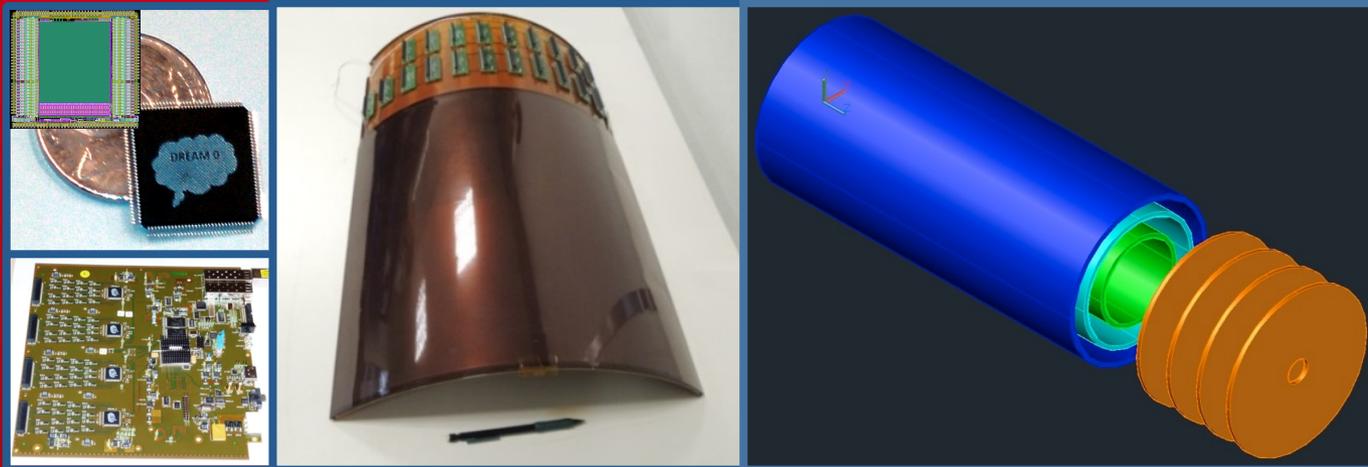




FROM RESEARCH TO INDUSTRY



Micromegas EIC R&D project



F. Sabatié – Irfu/SPhN
Jan. 13th 2014

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. Moudde, S. Procureur, F. Sabatié (PI)

+ M. Vandembroucke (since 11/2013)

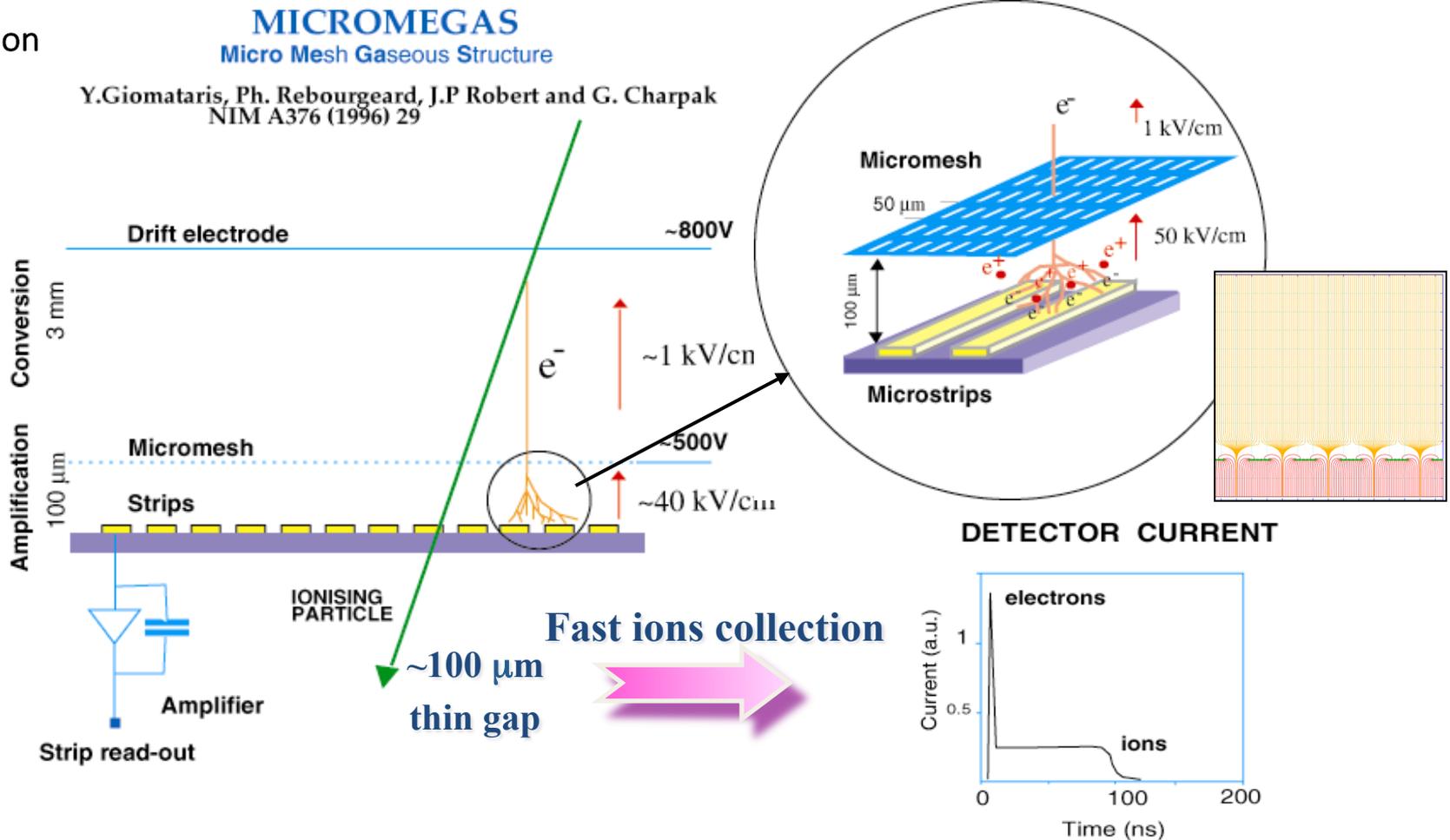


A brief history of Micromegas technology

1996



invention



A brief history of Micromegas technology

1996



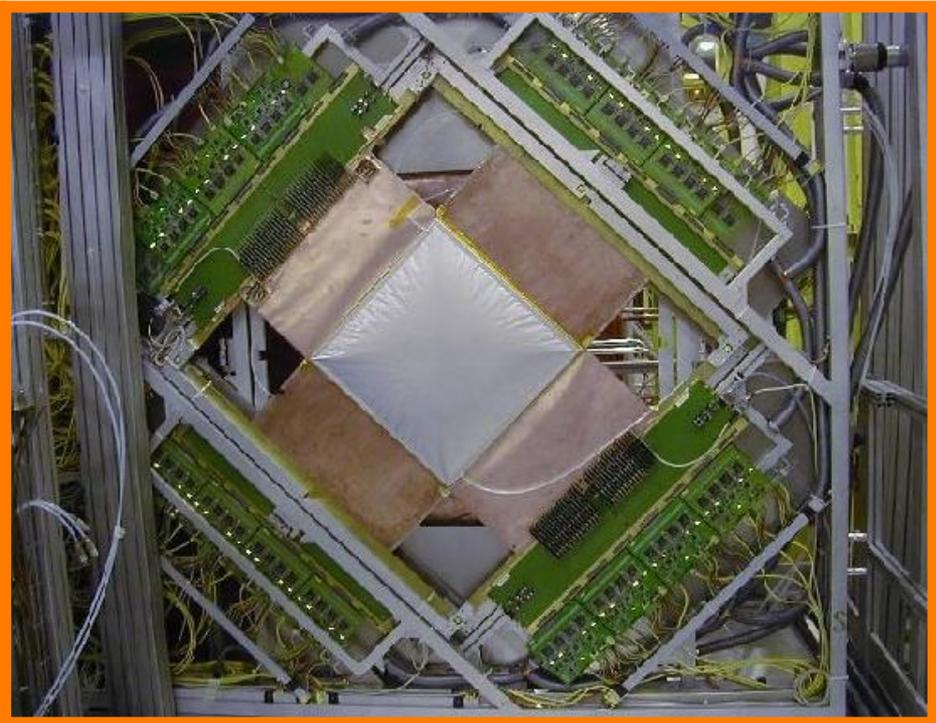
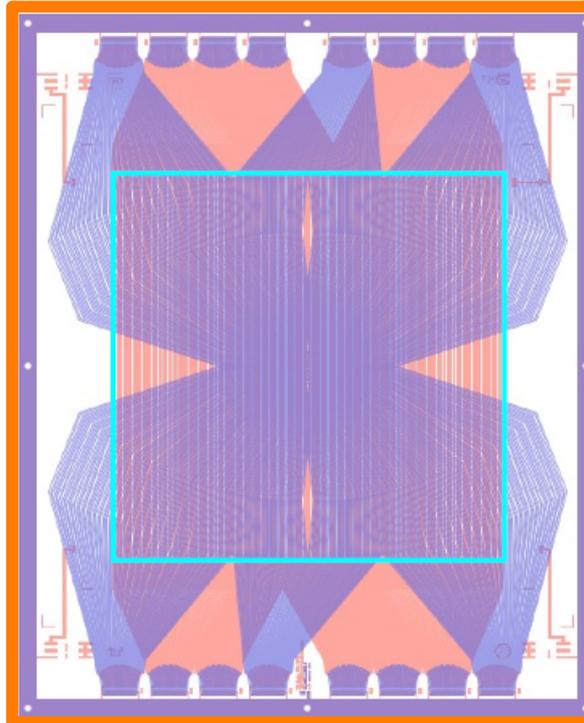
invention

2002



1st use in expt

- *COMPASS @ CERN*
- *A decade of smooth operation*
- *No ageing seen*



A brief history of Micromegas technology

1996



invention

2002



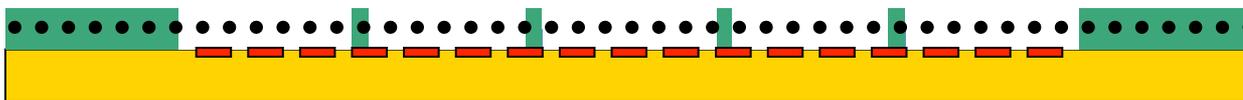
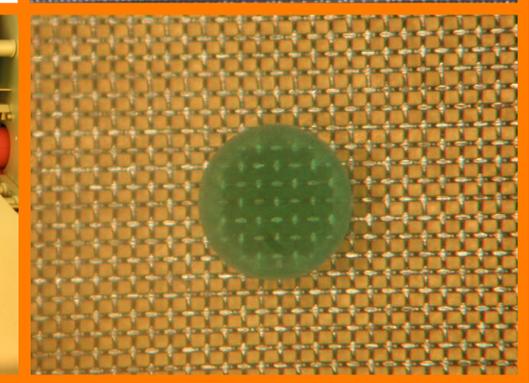
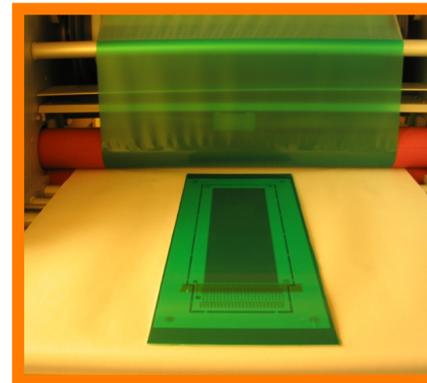
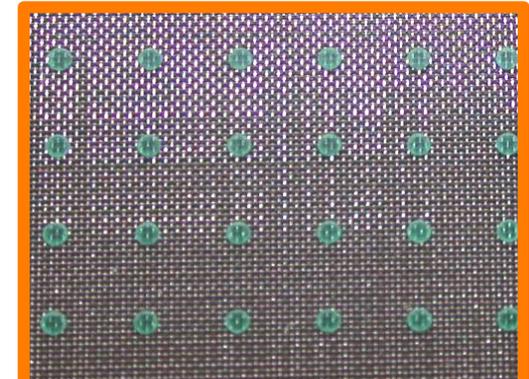
1st use in expt

2006



bulk process

- *More robust (mesh is embedded in photoresist)*
- *Simplified mechanical structure*
- *Ability to use thin PCBs and produce different shapes (cylindrical detectors !)*
- *Ability to industrialize the process*
- ***Cheap !!!***



A brief history of Micromegas technology

1996



invention

2002



1st use in expt

2006 2007

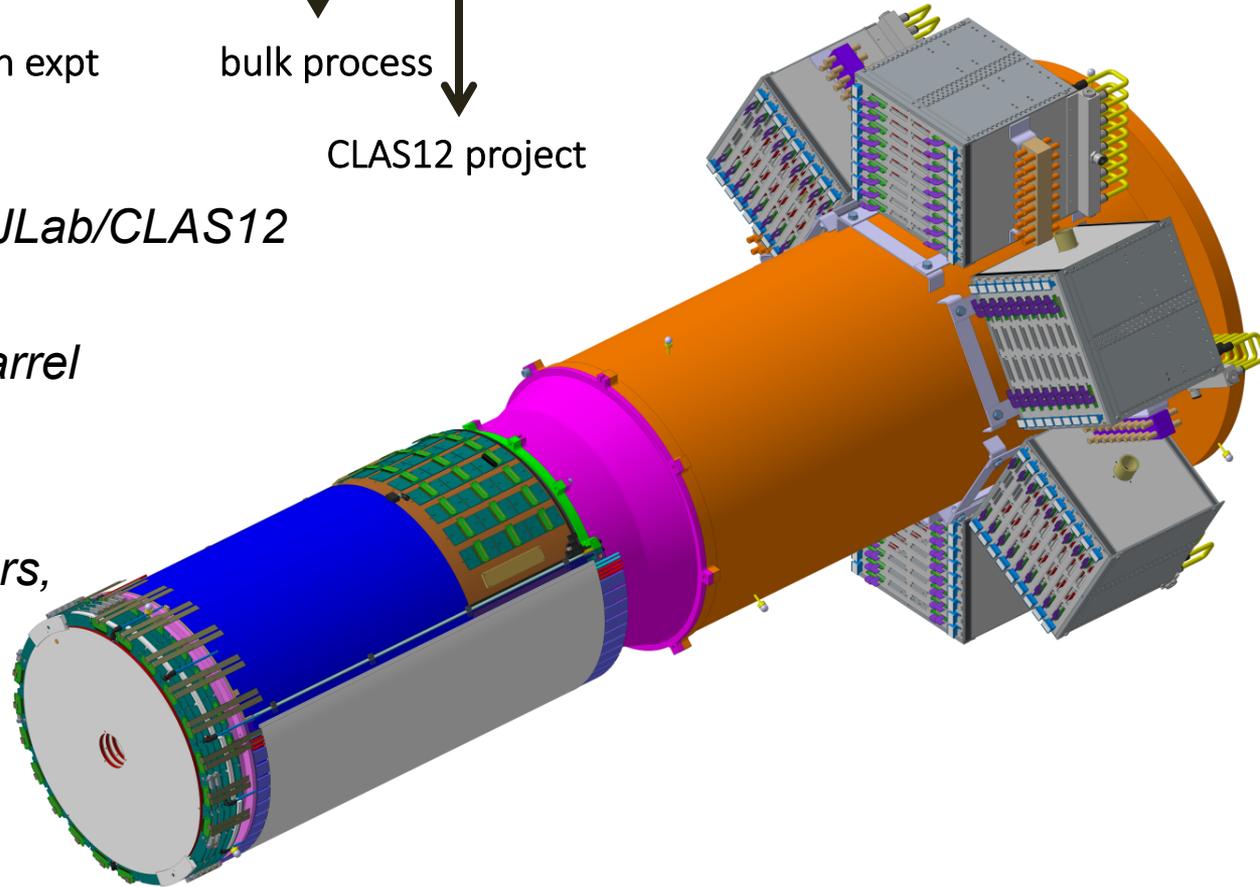


bulk process



CLAS12 project

- *Micromegas tracker for JLab/CLAS12*
- *Forward + Cylindrical Barrel*
- *Triggered a lot of R&D
(new ASIC, flexible detectors,
long flex cables, etc)*



A brief history of Micromegas technology

1996

invention

2002

1st use in expt

2006

bulk process

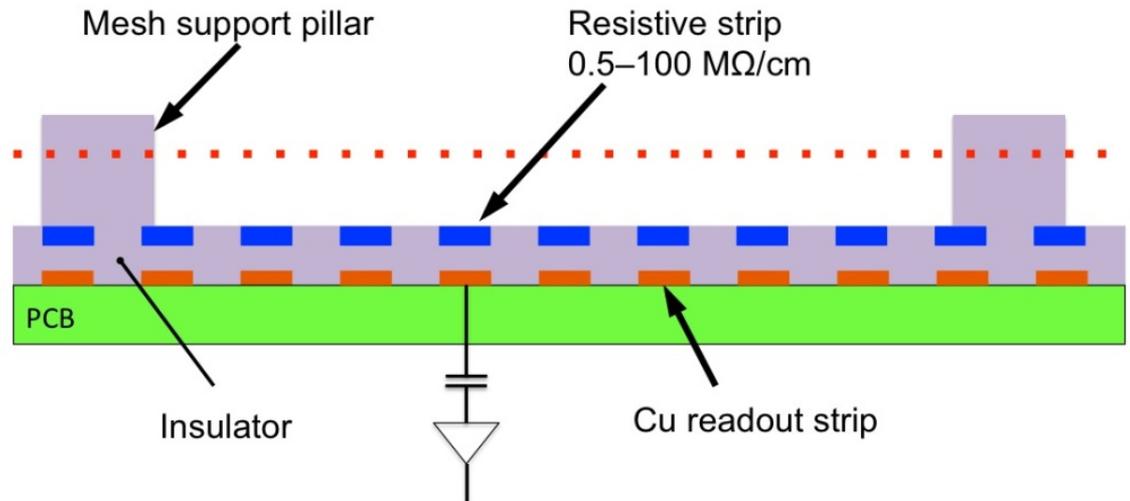
2007

CLAS12 project

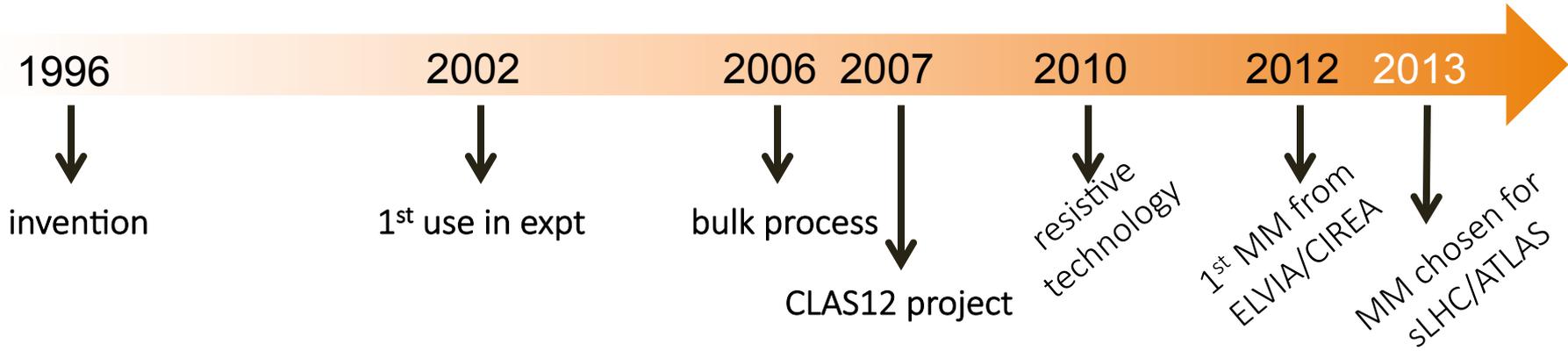
2010

resistive technology

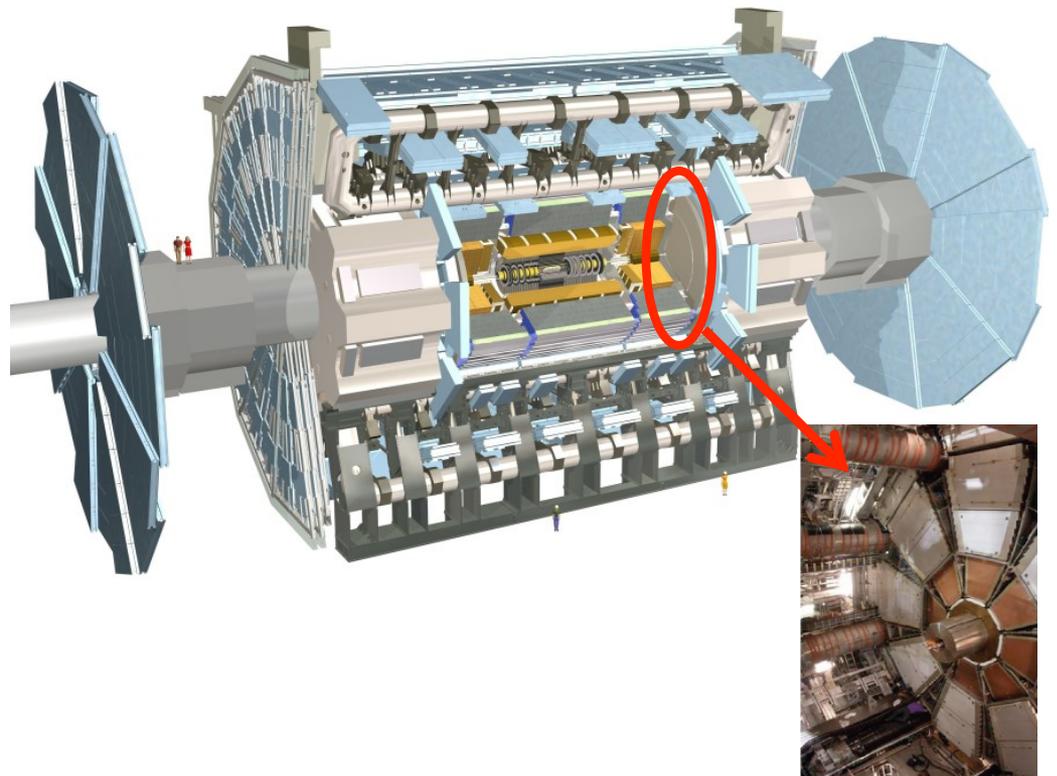
- *Capacitive readout*
- *Quenches sparks (max 1V HV drop)*
- *No ageing seen*
- *Higher flux capability*



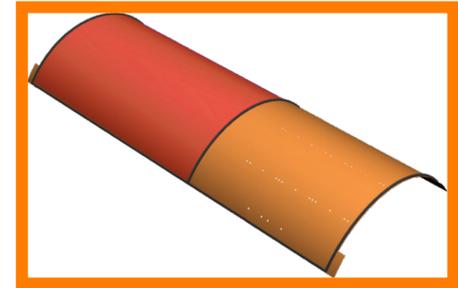
A brief history of Micromegas technology



- *ATLAS small wheel*
- *1200 m² of Micromegas detectors to build !*
- *Industrialization process intensified*



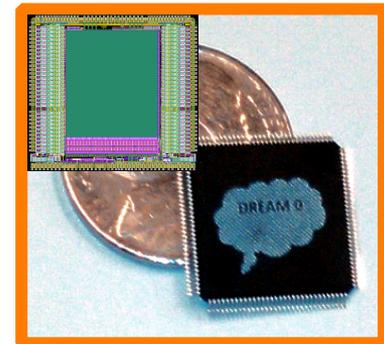
Large detectors manufacturing process



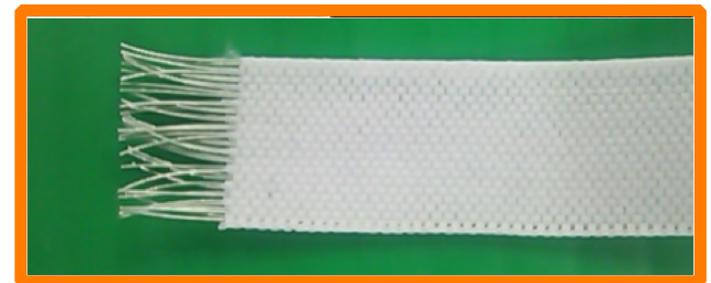
Lightweight mechanical structure



Next-gen dedicated ASIC tailored for large capacitance detectors



Low-capacitance micro-coax cables



Lightweight mechanical structure, cylindrical detectors

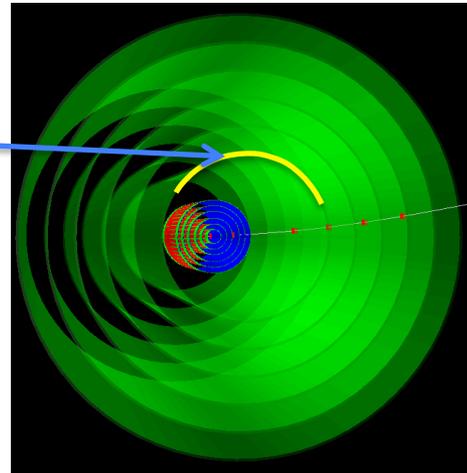
1st fully functional prototype



Specifications :

- active area : $40 \times 45 \text{ cm}^2$ $r=225 \text{ mm}$
- $575 \mu\text{m}$ pitch
- resistive strips
- kapton drift
- $200 \mu\text{m}$ PCB, **total 0.25% X_0 /layer**

120° tile

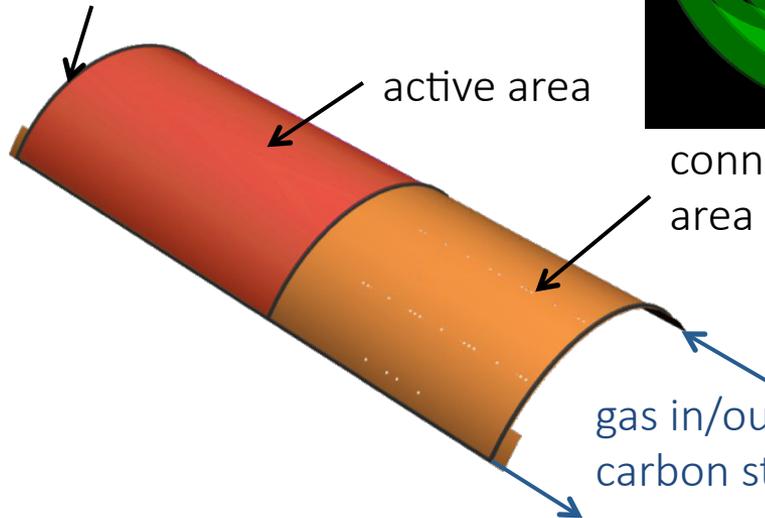


connectors area

gas in/out through carbon structure

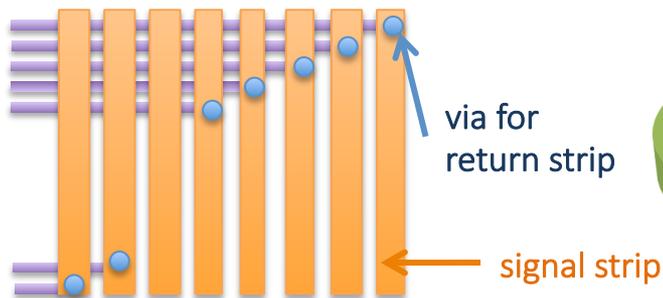
Self-sustaining carbon structure

active area

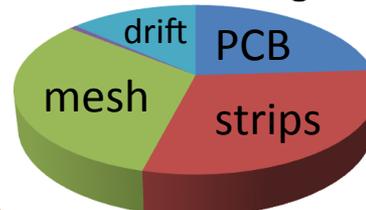


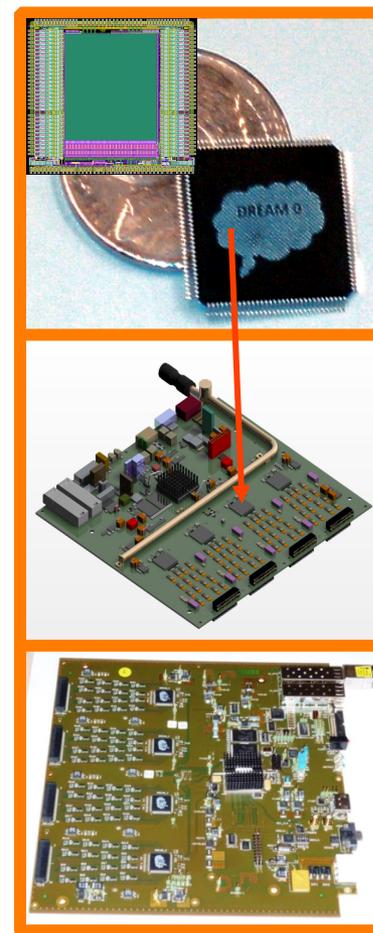
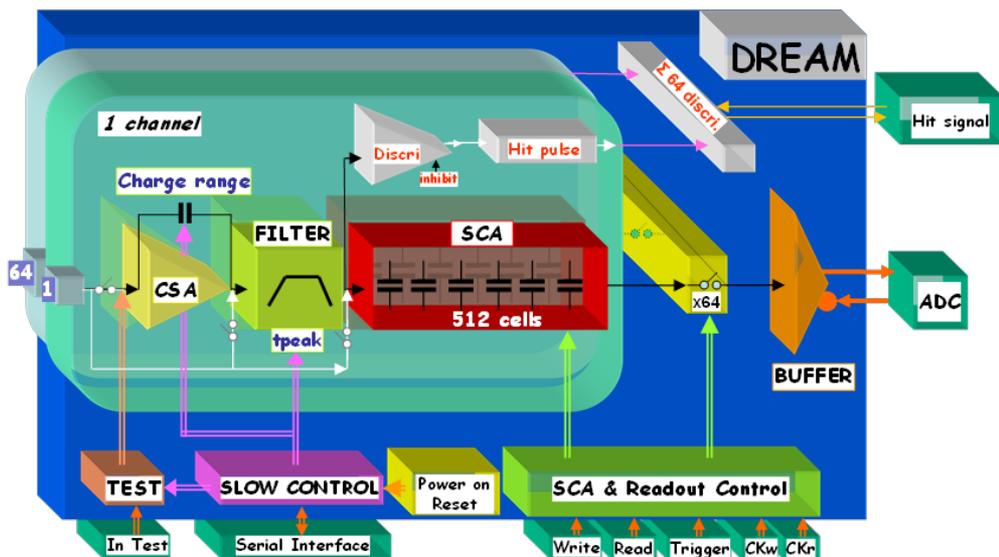
Return strips for « C » detectors

beam direction →



material budget





First front-end prototype

- ◆ Evolution of AFTER and APV25 chips
- ◆ Tailored for high capacitance detectors (MPGDs)
- ◆ Dead-time free
- ◆ Low noise : 2100e-

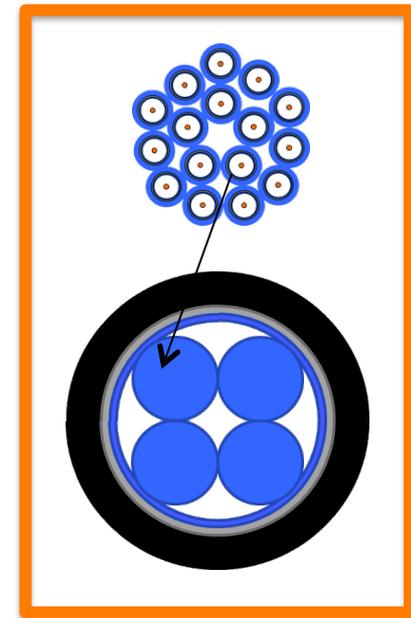
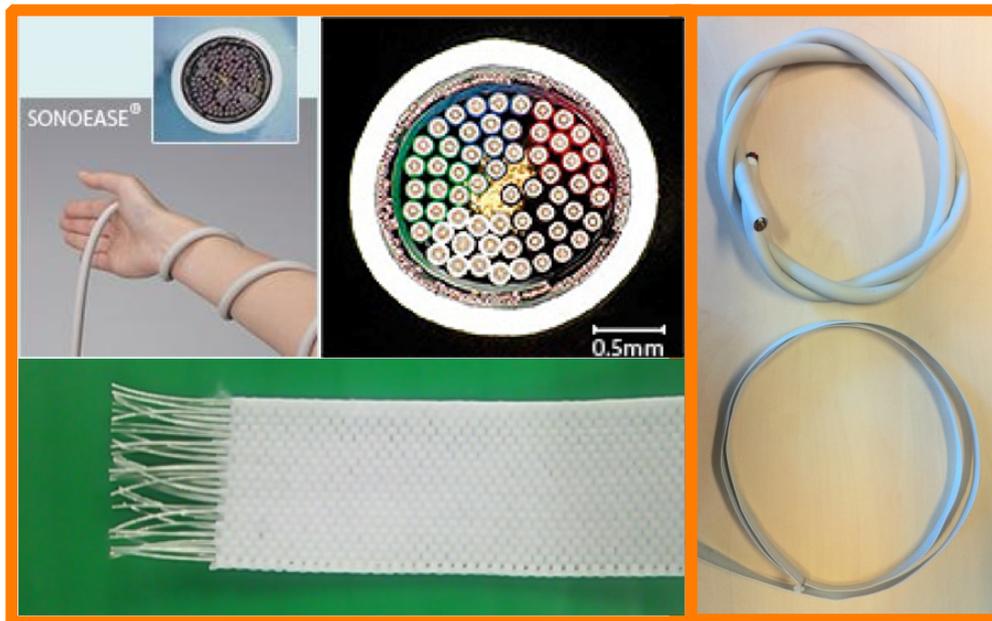
- ◆ v0 chip validated in 2012
- ◆ Sample of v1 chip received summer 2013
- ◆ Full production of final revision in March 2014

- ◆ Gain in S/N up to 25% wrt previous chip generation
- ◆ Self-triggering capabilities (part of EIC R&D, **successfully tested !**)

- ◆ Front-end unit prototype received, tested, validated. 12 boards ordered (6000 channels)
- ◆ Production of 70 units for 2014 (part of which is for this proposal)

Low capacitance micro-coax signal cables

- R&D started for CLAS12
- Goal : reduce capacitance of signal cables, keep good S/N
- First cables had a capacitance of 240 pF/m, triggered further R&D
- Now micro-coaxial cables made by Hitachi have a capacitance of about 45 pF/m



- 100 units of 2m-long cables expected in January 2014

Micromegas R&D next year

- M. Vandembroucke arrived at Saclay in November 2013
- Early 2014 : design and fabrication of 2 “EIC” prototypes
- Spring 2014 : Characterization and tests with the Dream ASIC
- Simulation/tracking work in 2014



- Forward GEM tracker
 - 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
 - Simulation within EICROOT ongoing
- Barrel Micromegas tracker
 - Design of two 120° Micromegas tiles ongoing
 - Last revision of Dream ASIC submitted for production
 - First version of Front-End Electronics card tested and validated
 - Prototypes of light-weight, low capacitance flex cables tested and validated
- Successful undergraduate student recruitment with strong support from TU College of Science and Technology
- Outlook for 2014
 - Expect to order large GEM foils in FY14
 - Order of two 120° Micromegas tiles, test, characterization with final Dream chip + Front-End
 - More simulation work



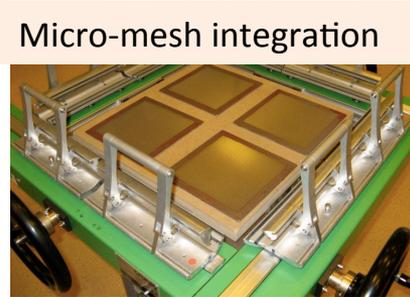
Backup slides

Bulk Micromegas : Fabrication scheme

- First prototypes in 2004. Collaboration CERN/Irfu.
- The woven micro-mesh is laminated between two photo-sensitive layers → **reduction of dead zones**
- Large areas
- Robust, industrial process (printed circuit)



Lamination



Micro-mesh integration



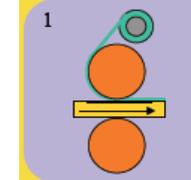
Insolation



Development



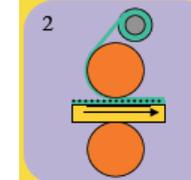
PCB nu équipé avec ses pistes ou pixel



Lamination



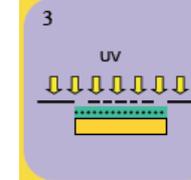
PCB avec une couche de photoresist



Lamination



PCB avec la micro-grille entre deux couches de photoresist



Insolation



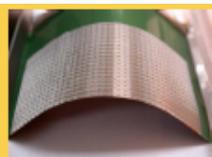
Une partie du photoresist est insolée



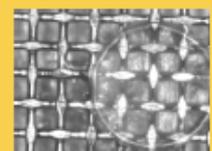
Le bulk !!!

du PCB.

BULK workshop at Irfu/Sedi



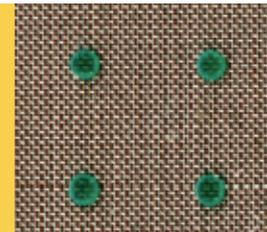
Bulk flexible sur Kapton de 50 microns



Détail: mesh prise entre deux plots



Bulk et PCB nu 120 x 140 mm

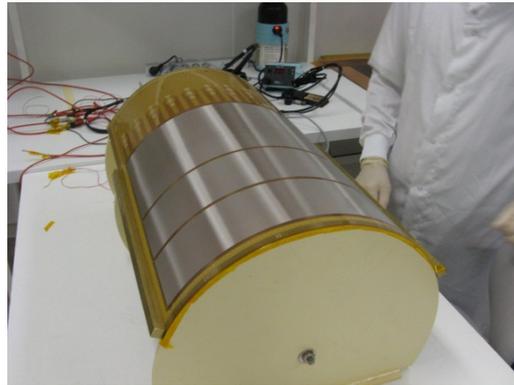


Plots de 400 microns au pas de 2 mm. Mesh inox 500 LPI

Curved Micromegas : Fabrication process



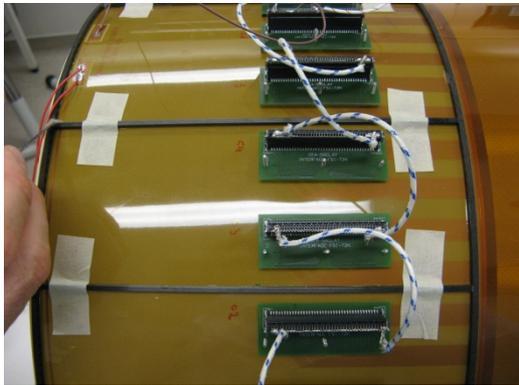
Segmentation and preparation



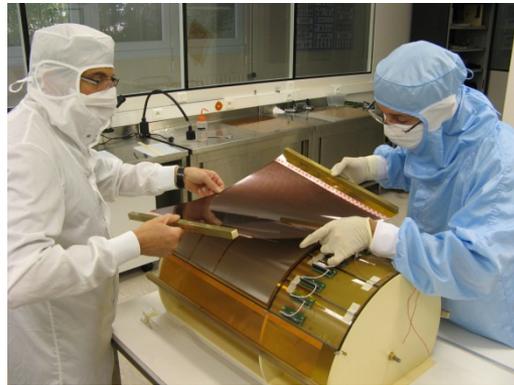
Gluing of the side carbon ribs on circular shape



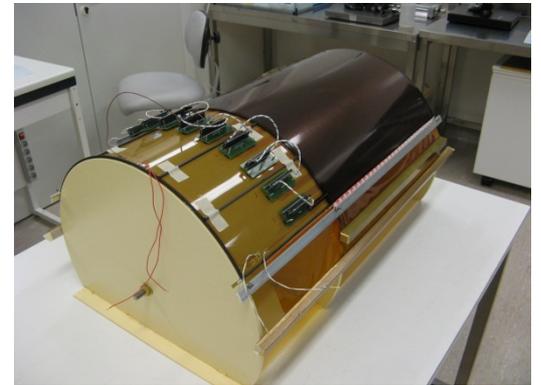
Electric leak test



Gluing of additional ribs



Setting and gluing of drift plane

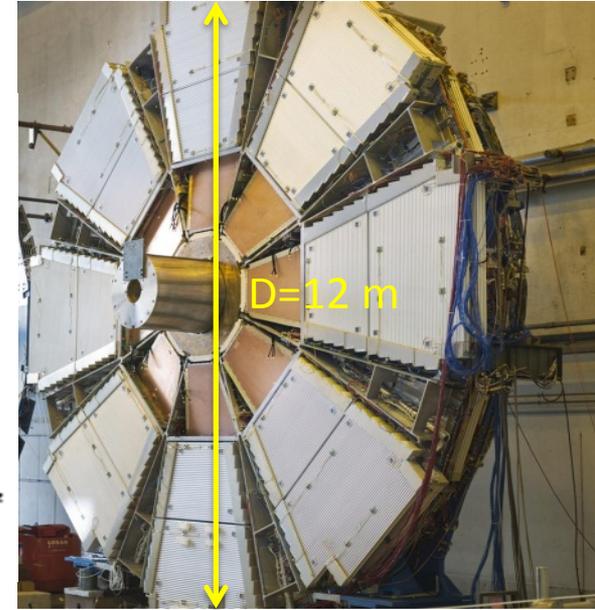
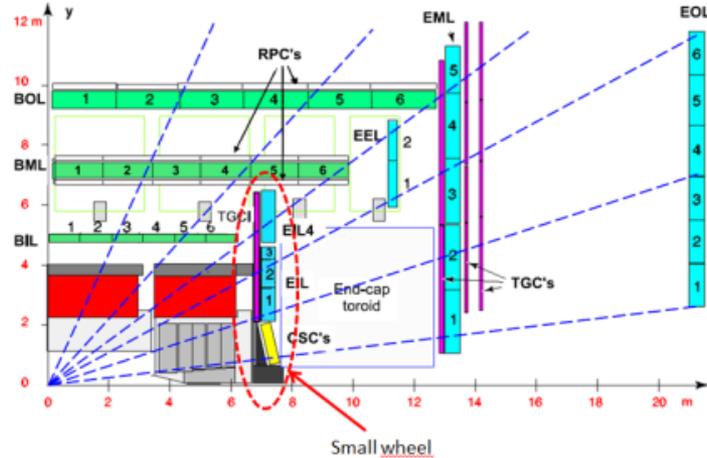


ATLAS Micromegas small wheel project

2 new wheels (NSW):

- 1200 m² of resistive Micromegas
- More than 2M electronics channels

ATLAS/NSW



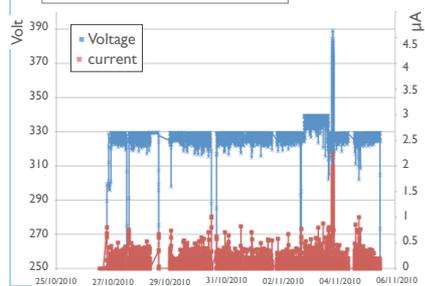
High flux et sparking

Resistive anodes:

- Reduced spark amplitude
- No dead time
- Robustness

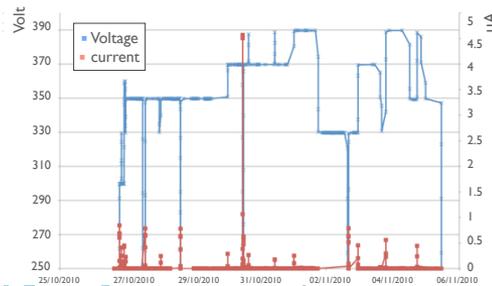
Non resistive

Non resistive telescope 0.5 mm



Resistive

R-strip to ground, 1.0 mm



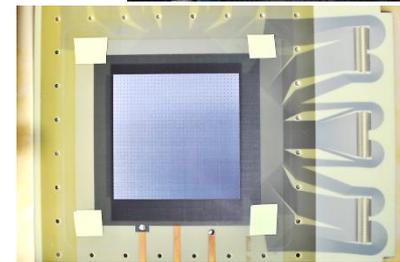
Fabrication

- Maximum area ~ 2 m²
- Production: 1024 planes (2015-16)

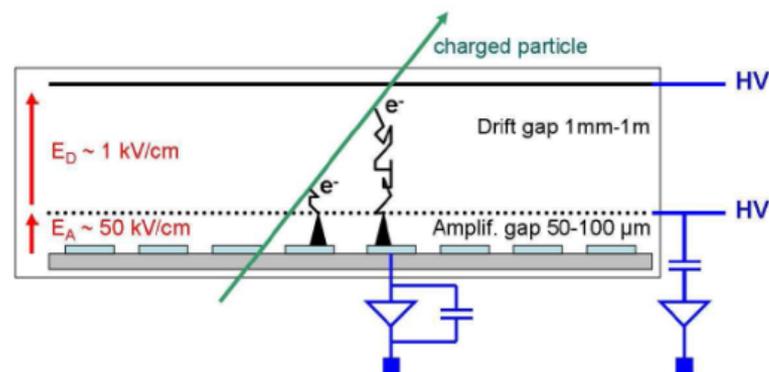
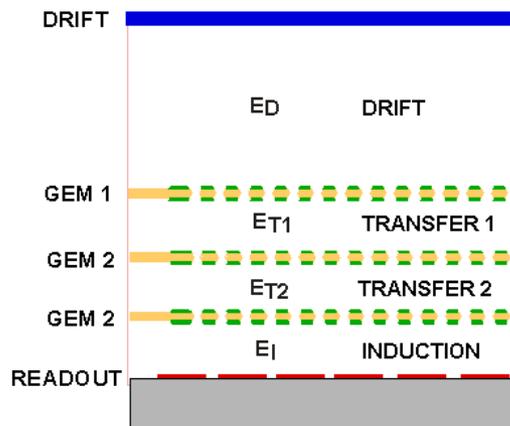


Transfer to industry:

- ELVIA (France)
- ELTOS (Italy)
- Triangle Labs (US)



GEMs vs. Micromegas



- Multiplication in the holes
- ~ 50% of electrons transferred
- Gain per layer a few 10's to 10^3
- Low ion back flow (1%)
- Multistage structure \rightarrow gain 10^5
- More fragile and more integration issues

- Multiplication between mesh and anode
- Stability of gain wrt gap
- Gain 10^4 - 10^5
- Low ion back flow (1%, down to 10^{-6})
- Robust
- Sparking unless resistive or preceded by a GEM foil for preamplification
- Smaller ultimate thickness (both in mm and X_0)
- Slightly more radiation resistant

GEM: Saclay 1997

- COMPASS
- LHCb muon detector
- TOTEM telescope
- HBD (Hadron Blind Detector)
- NA49 (upgrade)
- X-ray polarimeter (XEUS)
- GEM TPC for LEGS, BONUS
- STAR FGT
- KLOE2 vertex detector
- OLYMPUS
- SuperBigBite (JLab/Hall A)
- CMS forward muon chambers
-

and at the proposal/prototyping stage

- EIC R&D
- DarkLight phase-I
-

MM: Giomataris 1996

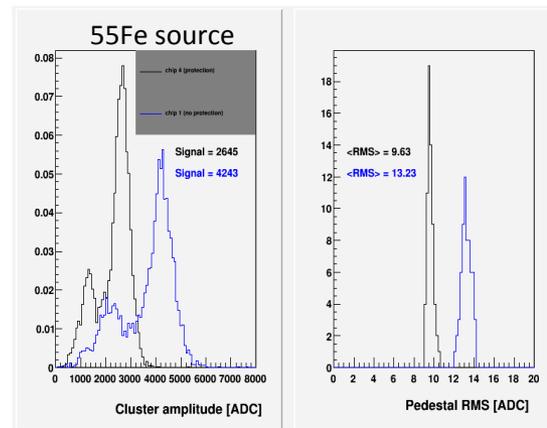
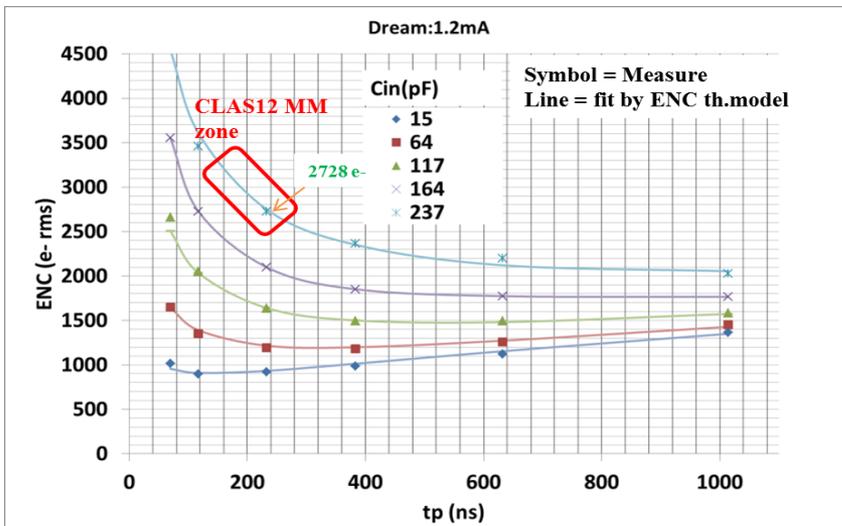
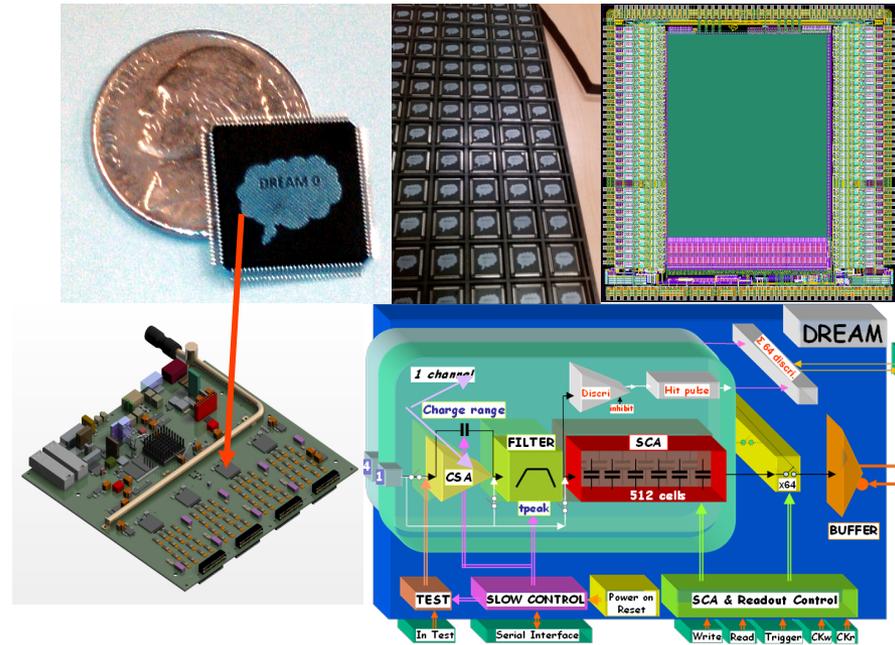
- COMPASS (1 & 2)
- NA48/KABES
- CAST (CERN Axial Solar Telescope)
- nTOF (neutron beam profile)
- Piccolo (in reactor core neutron measurement)
- T2K TPC
- JLab/CLAS12/MVT
- RIKEN/MINOS (exotic nuclei spectroscopy)
- ATLAS muon system upgrade
-

and at the proposal/prototyping stage

- ASACUSA (anti-H)
- HARPO (astrophysics)
- MIMAC (dark matter)
- FIDIAS & ACTAR (low-energy heavy ion)
- EIC R&D

DREAM chip

- 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



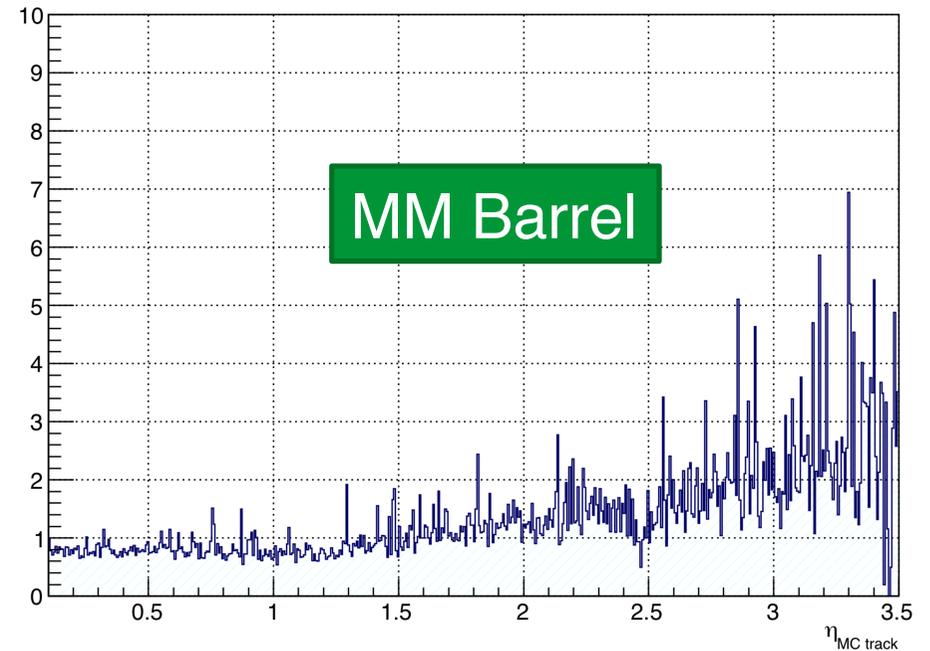
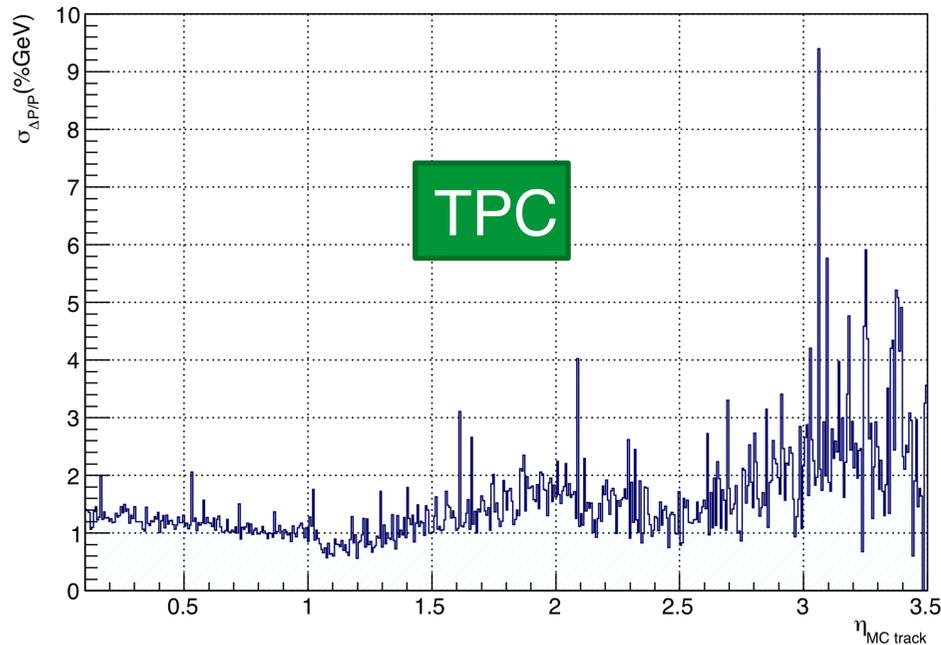
Front End Unit : Active comp. on top & bottom sides

- 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



MM Barrel vs TPC

- TPC MODEL NOT USED
- Spatial resolution simulated with smearing
 - TPC : $\{ \sigma_x = 1\text{mm}, \sigma_y = 1\text{mm}, \sigma_z = 2\text{mm} \}$
 - MM Barrel : $\{ \sigma_R = 0.2\text{mm}, \sigma_C = 0.2\text{mm} \}$
- Material budget not relevant with Pions of 10 GeV/c

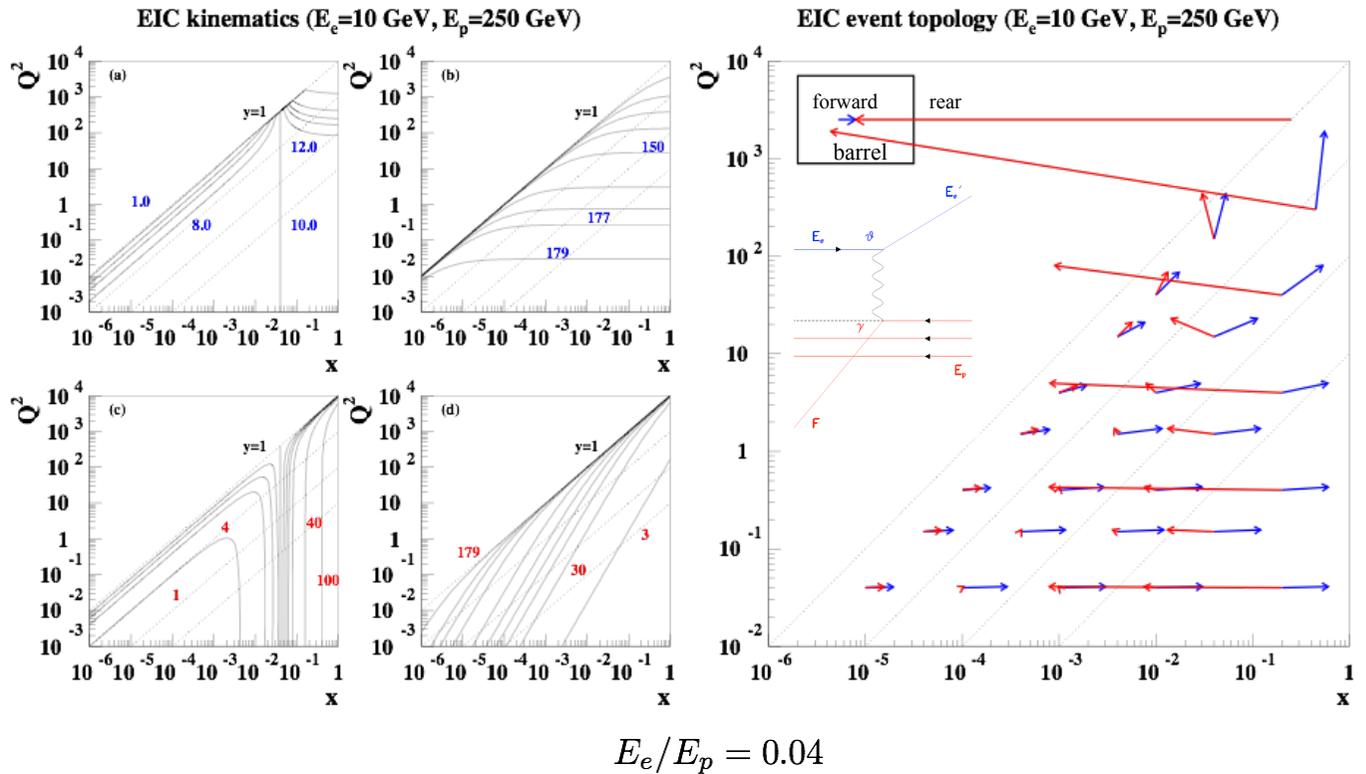




Progress report - Q4 FY13 / Q1 FY14

Simulations - Overview

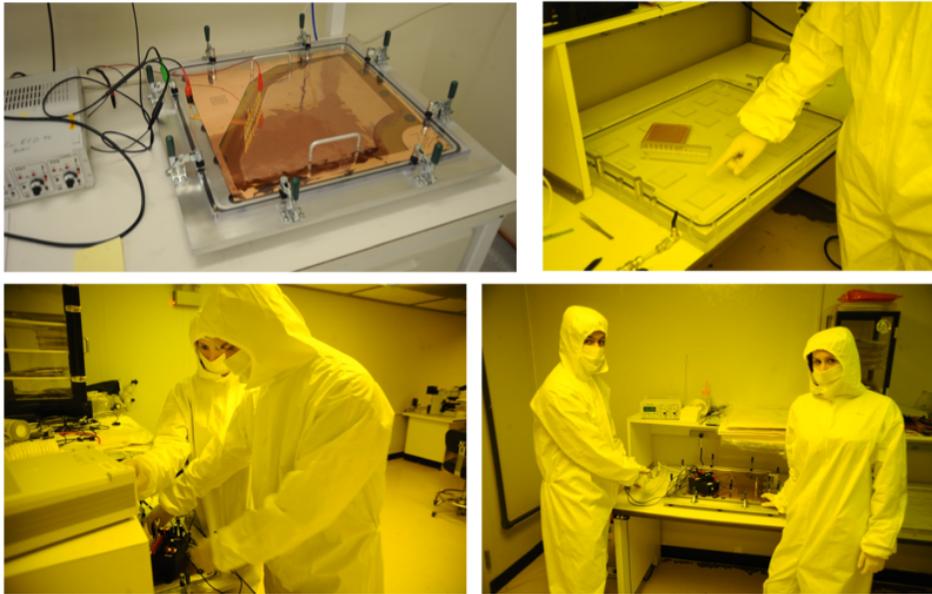
- Analytical acceptance and resolution studies
- Begun with Whitepaper 2012 layout / Started with geometry and material definition focusing on tracking system
- Focus on micro-pattern tracking system



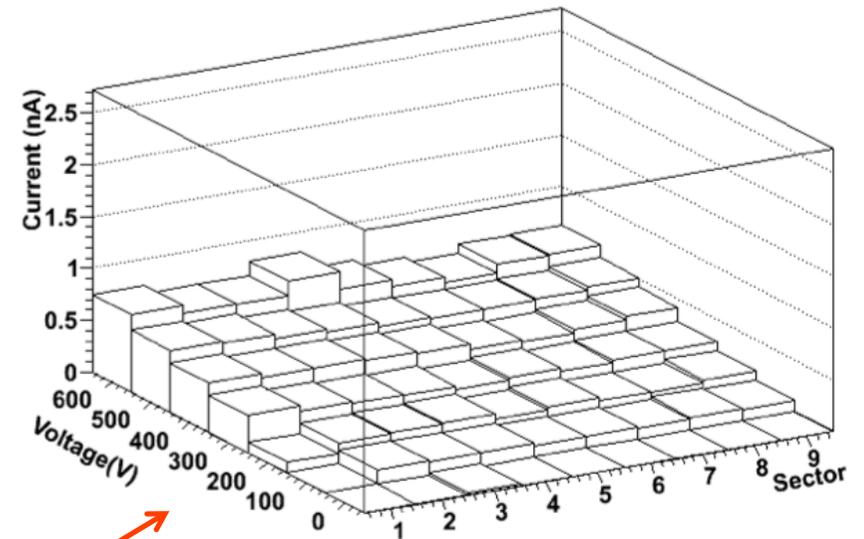


Progress report - Q4 FY13 / Q1 FY14

- Forward GEM tracking - Leakage current
 - Setup of leakage current measurement at TU / First foils tested by undergraduate students



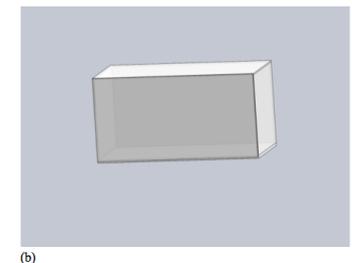
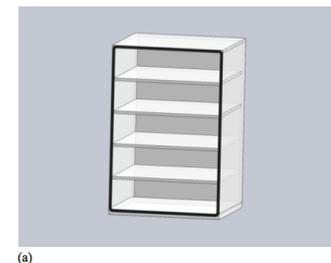
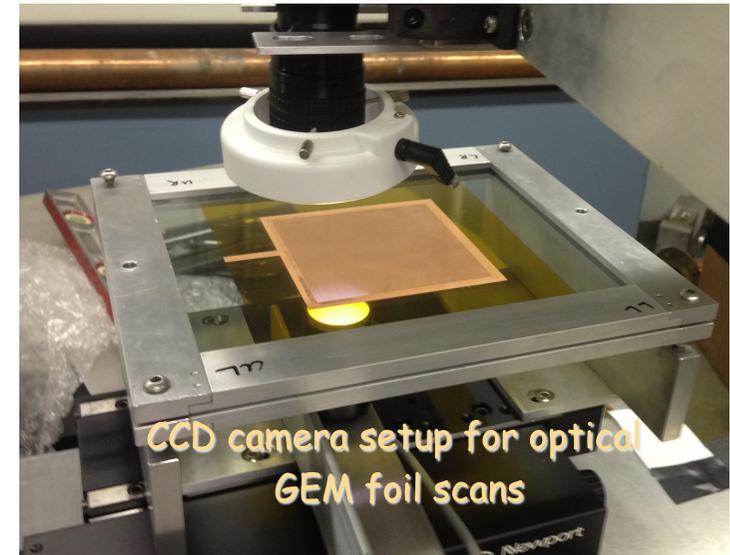
- Setup including nitrogen box with HV connections
- ISEG power supply and nA current measurement
- Example of measured leakage current performance (STAR FGT foil)





Progress report - Q4 FY13 / Q1 FY14

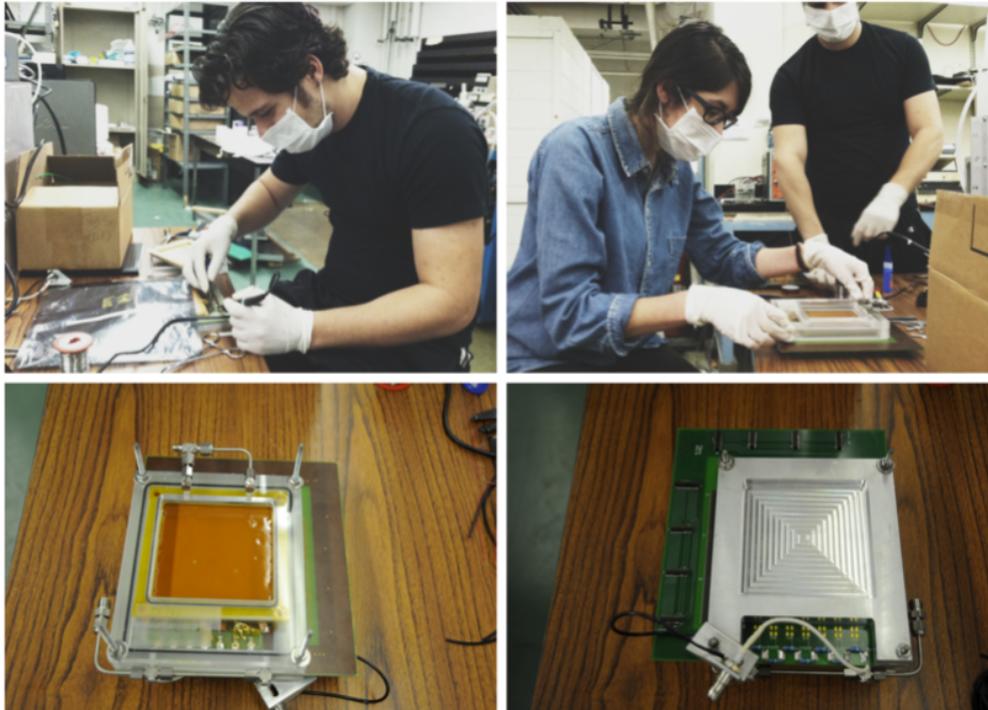
- Forward GEM tracking - Optical scan
 - 2D scanning table with CCD camera fully automated
 - Scan GEM foils to measure hole diameter (inner and outer) and pitch
 - Setup routinely operated by undergraduate students
- Design of dedicated large-size N2 storage shelves
 - SolidWork design completed. Discussion of design with TU CST mechanical engineer in January 2014
- Setup of assembly tools and design of large assembly tools
 - All assembly and stretching tools exists for FGT-type detector segments. The design and preparation of larger assembly tools will start in spring 2014 by a new mechanical engineer





Progress report - Q4 FY13 / Q1 FY14

- 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
- ^{55}Fe scanning system in preparation

