Status of GEM R&D @ UVa

Kondo Gnanvo

University of Virginia, Charlottesville,

EIC Tracking R&D Workshop @ Temple University

05/09/2015

GEM Detectors @ UVa: The group members

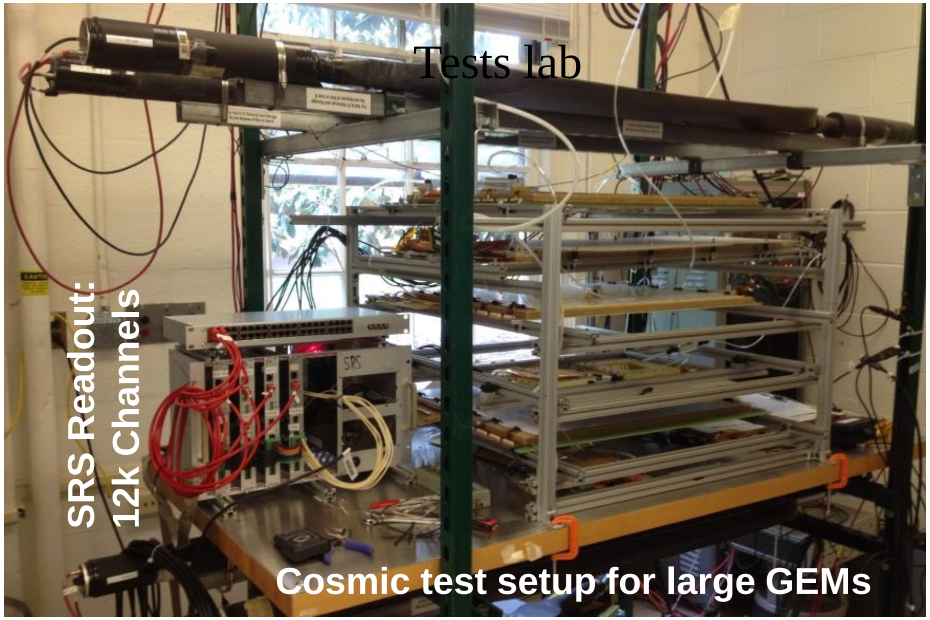
Faculty: Nilanga Liyanage (Associate Professor)

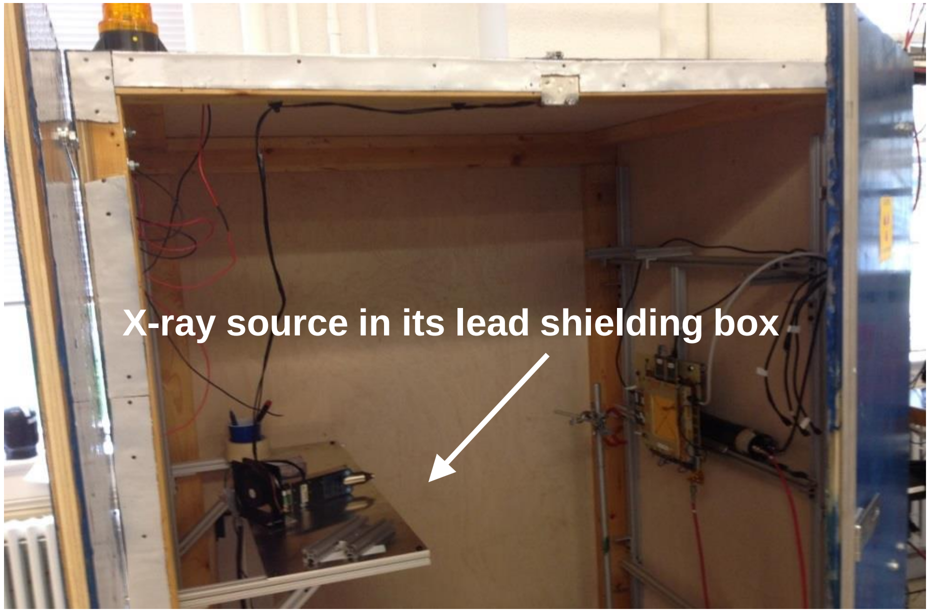
Research Scientists: Vladimir Neliyubin, Kondo Gnanvo

Post Docs: Huong Nguyen

Graduate Students: Xinzhan Bai, Danning Di

GEM Detectors @ UVa: The Lab

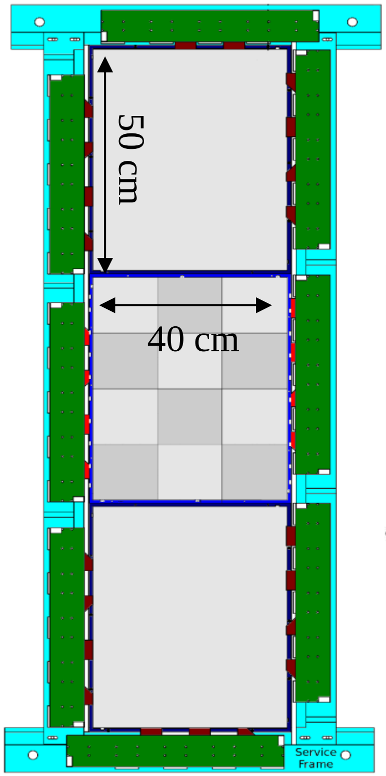


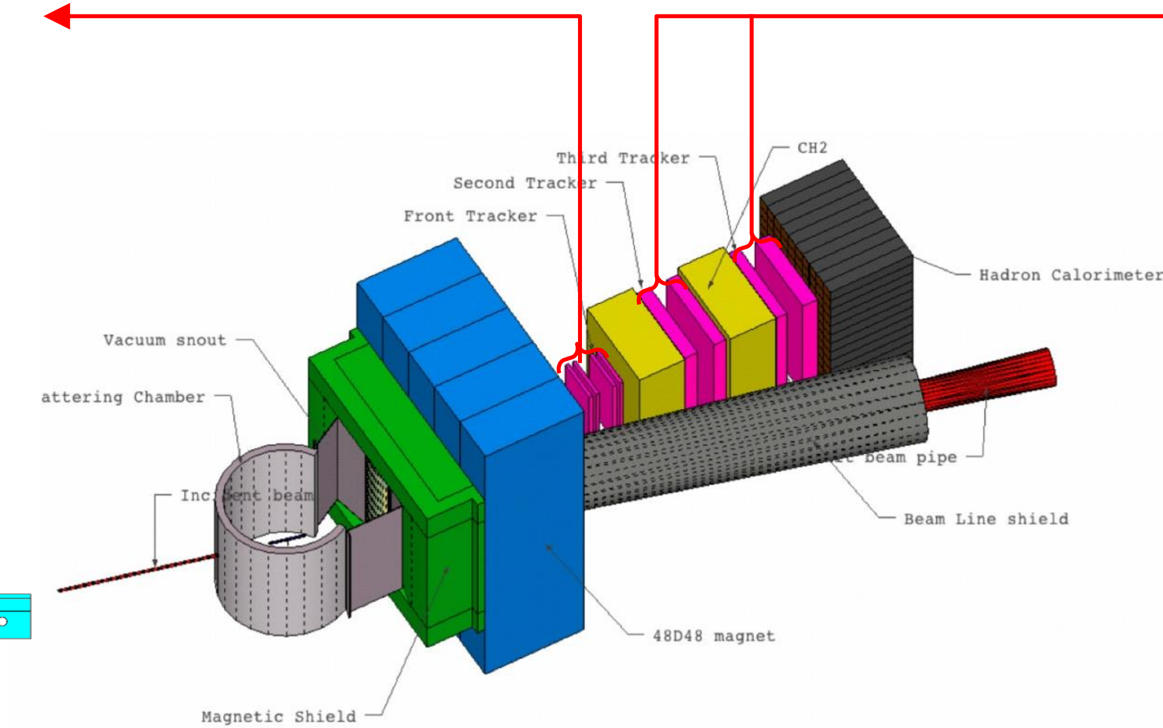


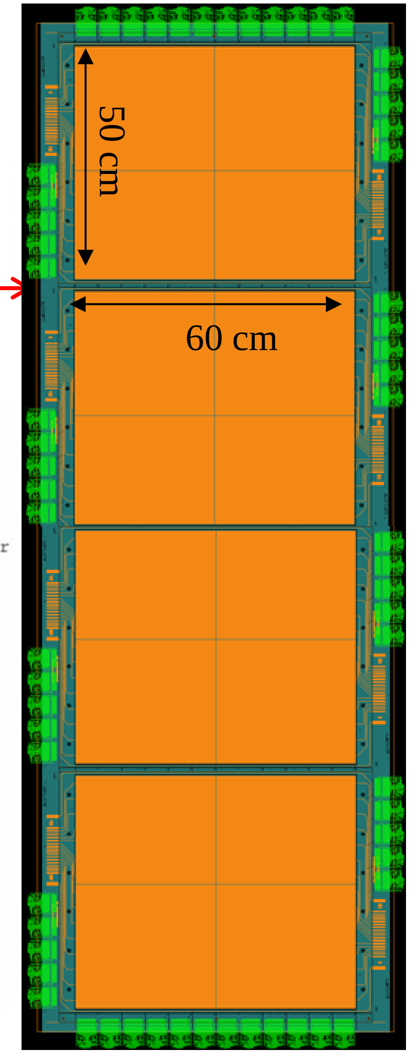
GEMs for Super Bigbite Spectrometer (SBS) in Hall A @ JLab

- Front Tracker: *E. Cisbani (INFN Roma, Italy)*
  6 GEM Layers (150 × 40 cm^2)
  Each layer = 3 GEM modules (50 × 40 cm^2)

- **Back Tracker : *N. Liyanage, (Uva, Virginia, USA)***
- **10 GEM Layers (200 × 50 cm^2)**
- **Each Layer = 4 GEM modules (50 × 60 cm^2)**

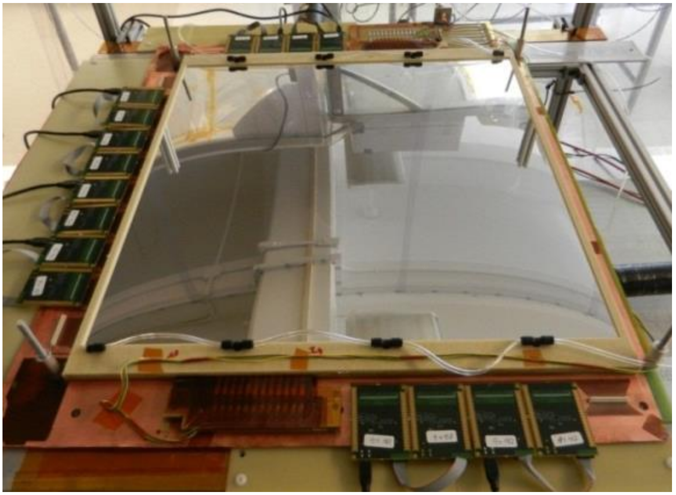


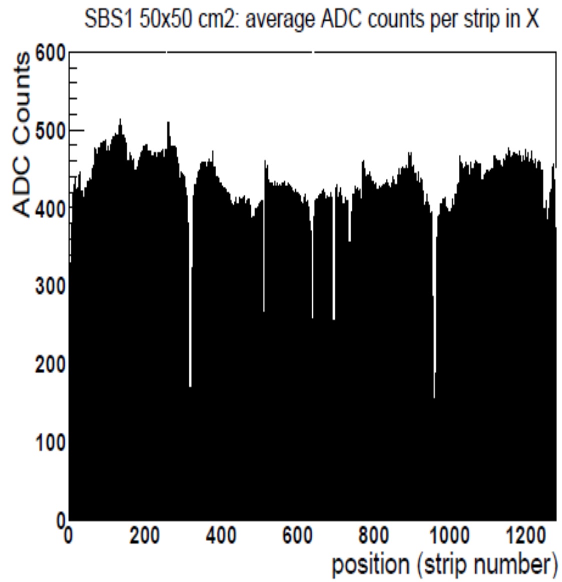


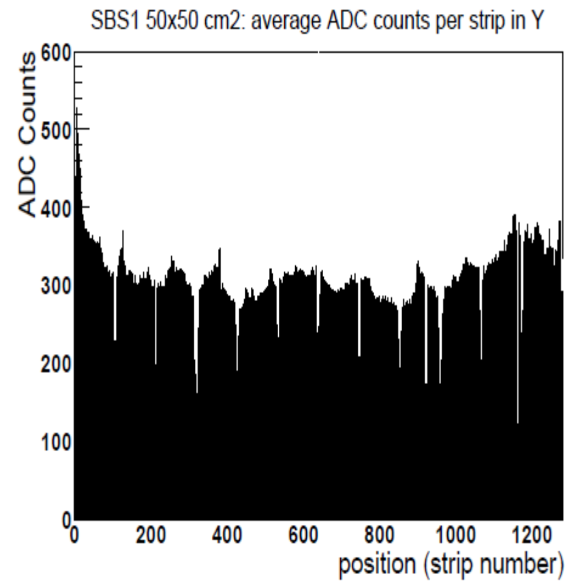


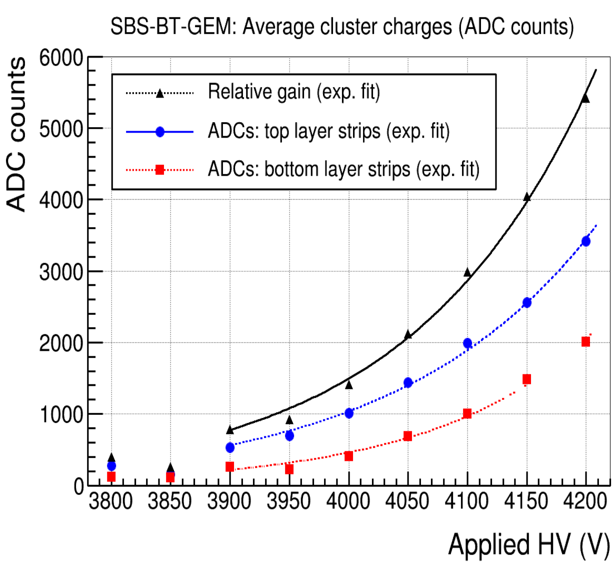
Proton arm layout for GEp (5) experiment

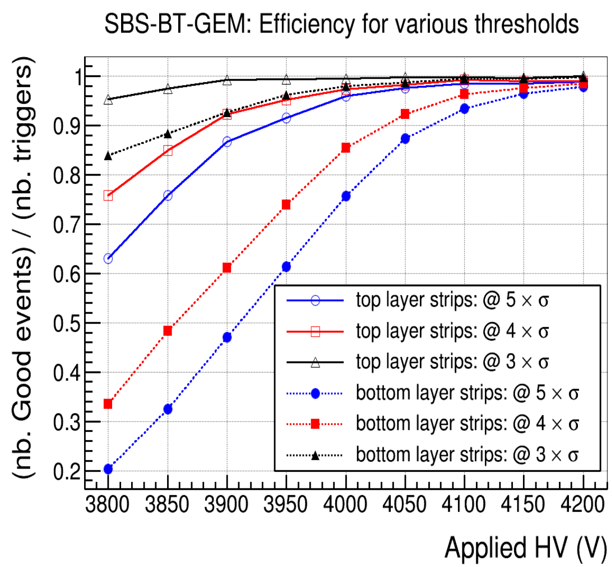
SBS-BT-GEM: R&D

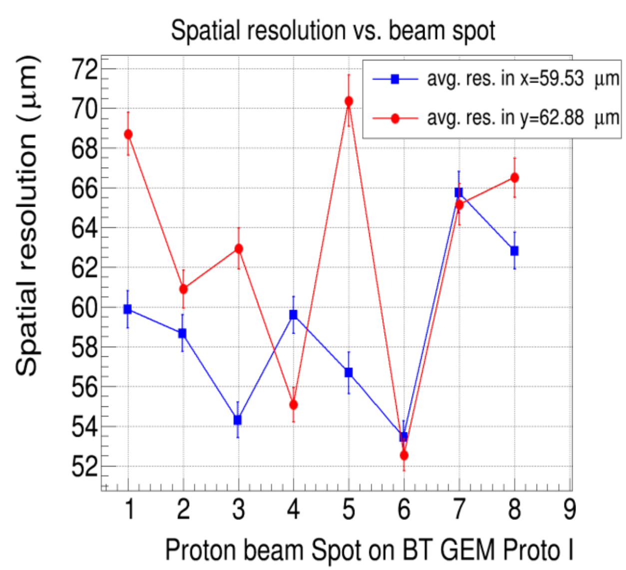












K. Gnanvo *et al.*, Nucl. Inst. and Meth. **A782**, 77-86 (2015), http://dx.doi.org/10.1016/j.nima.2015.02.017

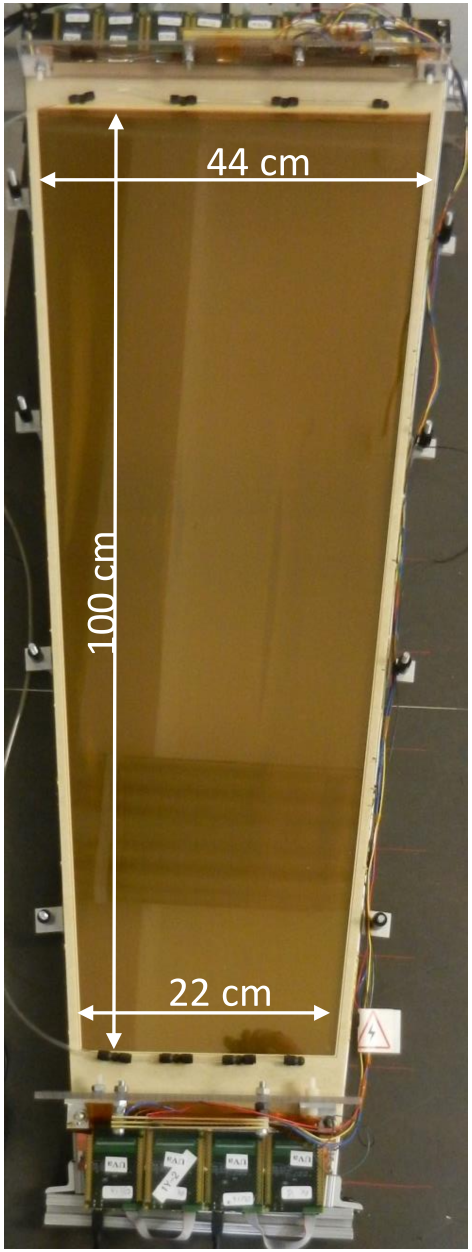
SBS-BT-GEM: Production

Production of the SBS-BT-GEM Modules

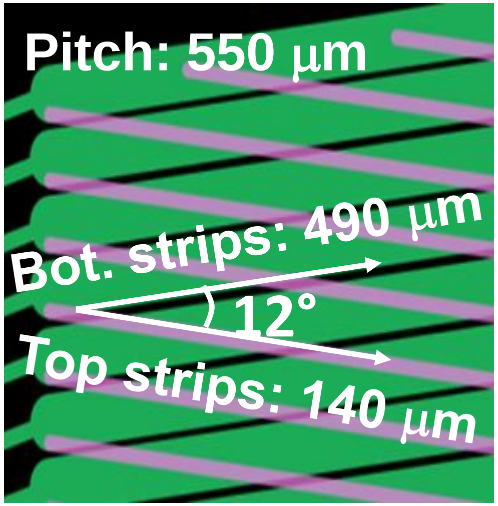
- 40 modules to be built by July 2017
- 13 modules already built as of May 09, 2015
- 11 successfully passes the ultimate test with cosmics
  - 1 HV sector out of 1080 ($12 \times 3 \times 30$) was shorted and disabled
- Last 2 modules just out of the clean room and will be tested in the coming days
- Construction rate of 2 SBS modules / month

R&D for EIC Forward Tracker: Design of EIC-FT-GEM proto I

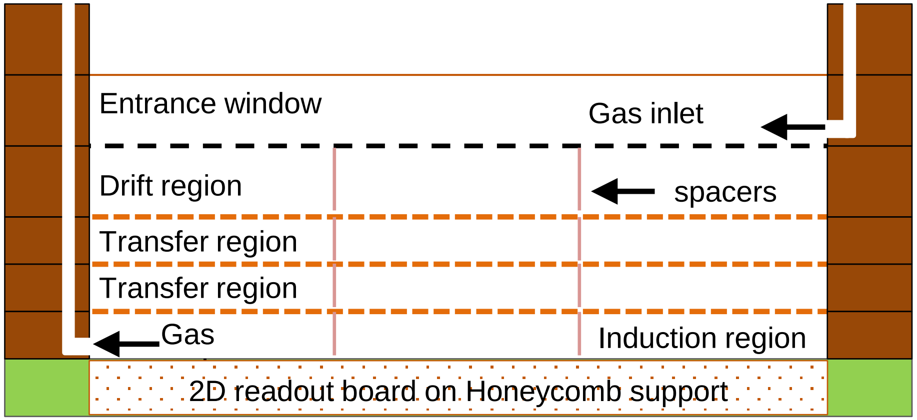
- **Key characteristics**
- Largest 2D GEM detector ever built: 100 cm × (44 cm – 22 cm)
- Low mass and small dead area full disk chamber
  - Narrow edge GEM frame support and honeycomb for the readout
  - All electronics on inner and outer radius side of the chamber
- Fine strips 2-d small stereo angle u/v readout on flexible board
  - Good position resolution and low capacitance noise



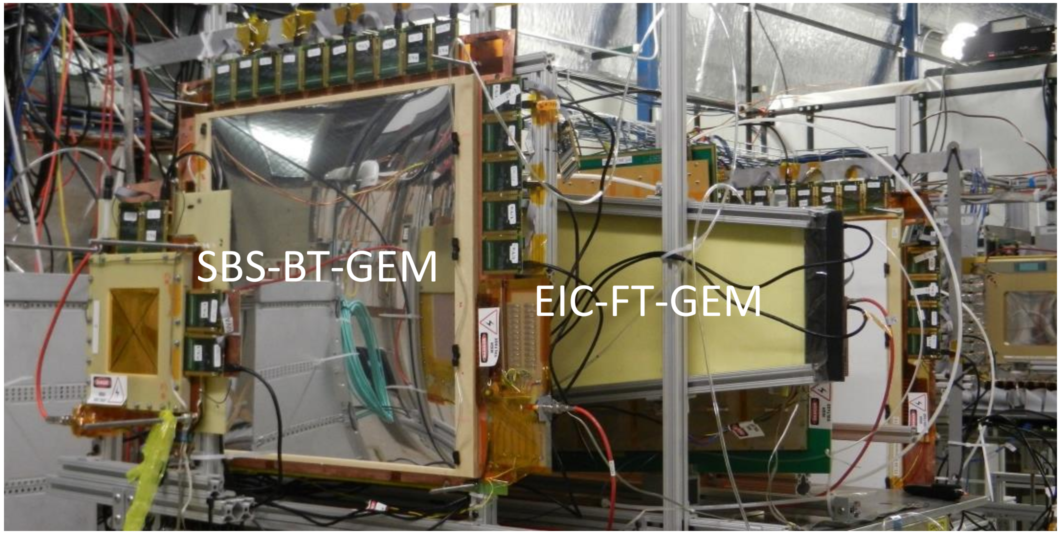
2D u/v readout strips

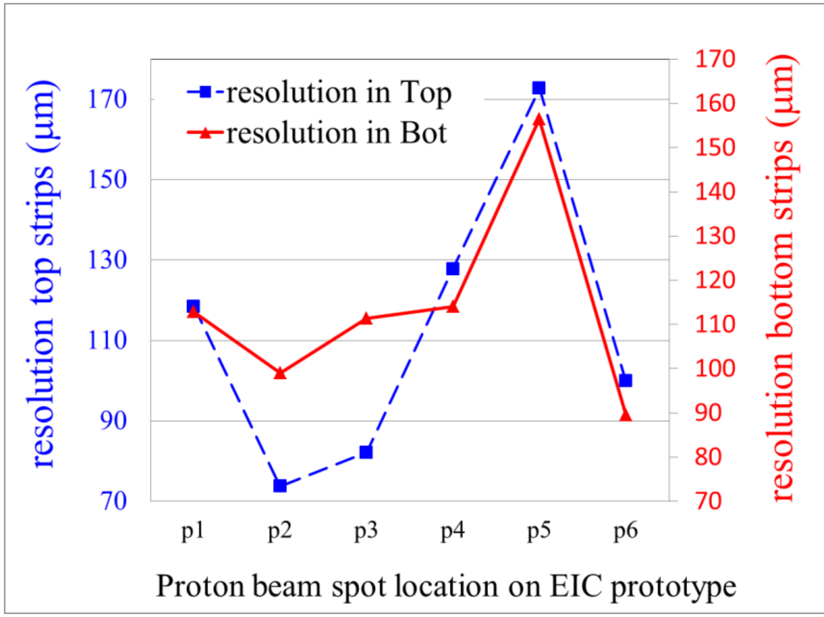


Cross section of low mass triple GEM



EIC-FT-GEM @ FTBF: Spatial resolution

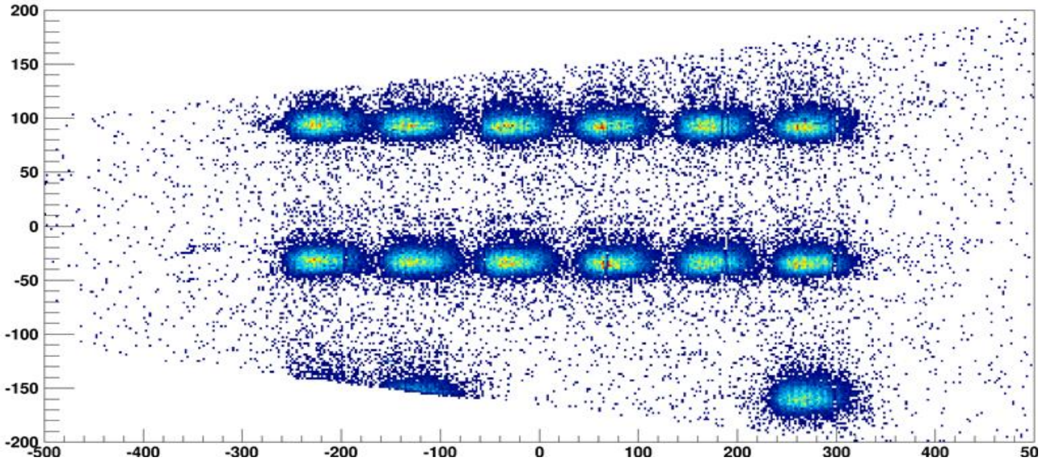


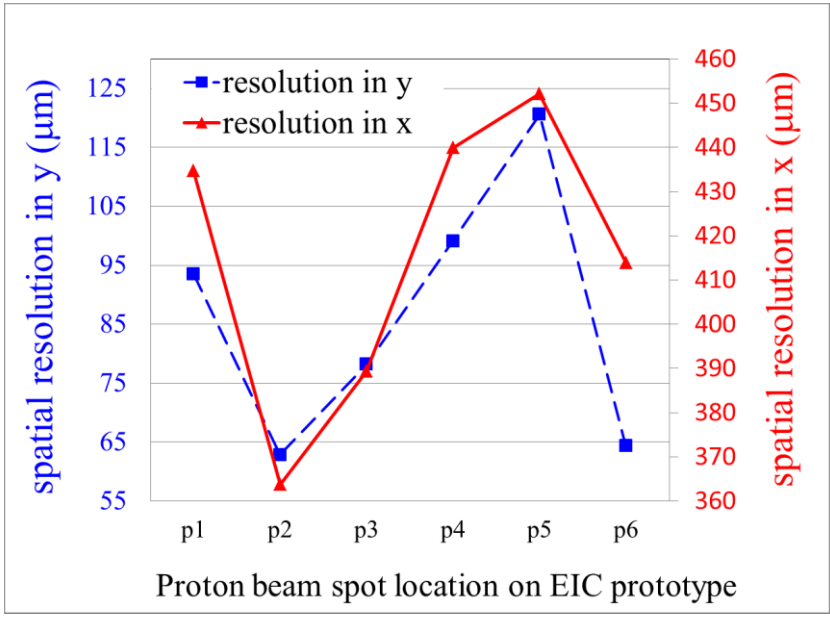


Good spatial resolution

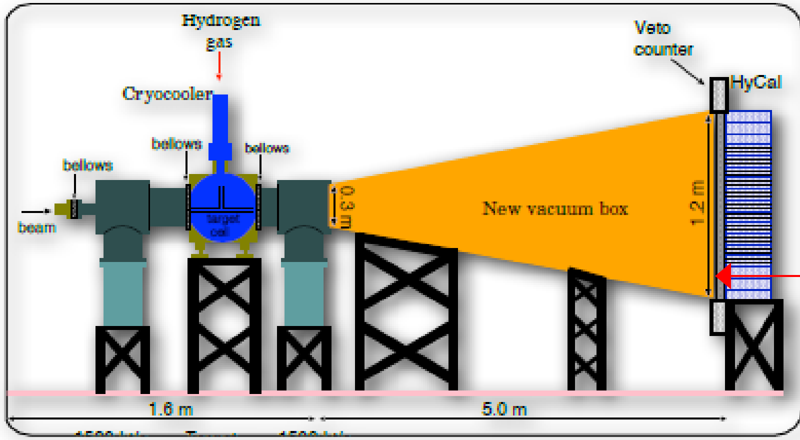
- Better than 130 μm for the top and bottom strips
- Better than 100 μm for y and 450 μm for x

Hadron bean reconstruction from position scan





pRad GEM: Proton Radius Experiment pRad @ JLab

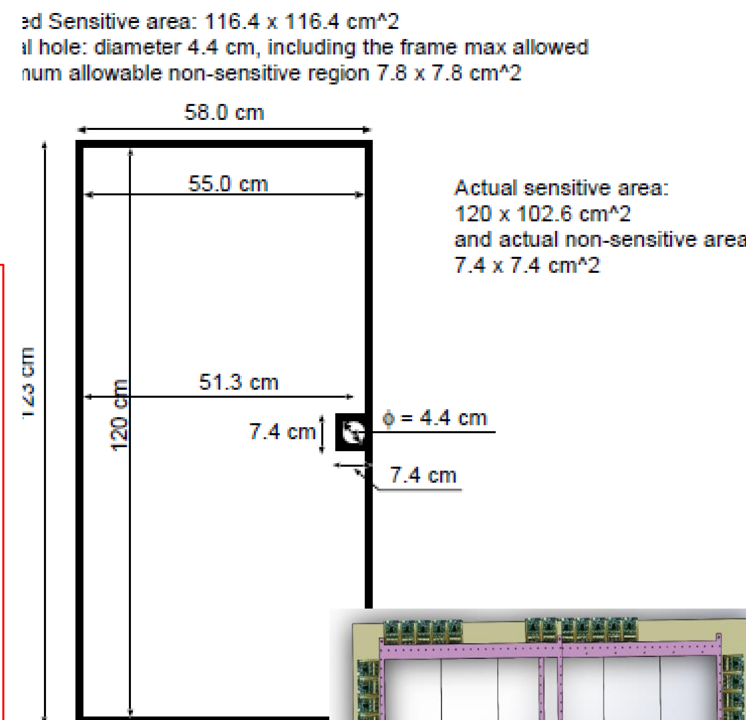


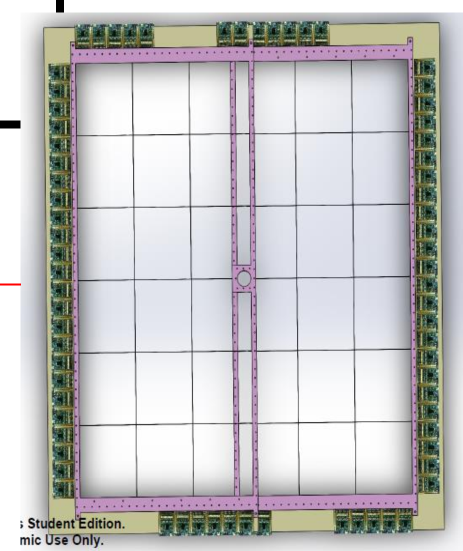
Spokesperson: A. Gasparian,
Co-spokespersons: M. Khandaker, H. Gao and D. Dutta

The PRad experiment in JLab Hall-B

Approved with A rating

GEM chambers: X-Y veto counter





- High resolution, Hybrid calorimeter (Magnetic Spectrometer Free)
- Windowless H_2 gas flow target
- Simultaneous detection of elastic and Moller electrons
- Vacuum box, one thin window
- Q^2 range of $2\times10^{-4} - 2.0\times10^{-2}$ GeV^2 (lower than all previous electron scattering expts.)
  (using a 1.1 and 2.2 GeV electron beam)

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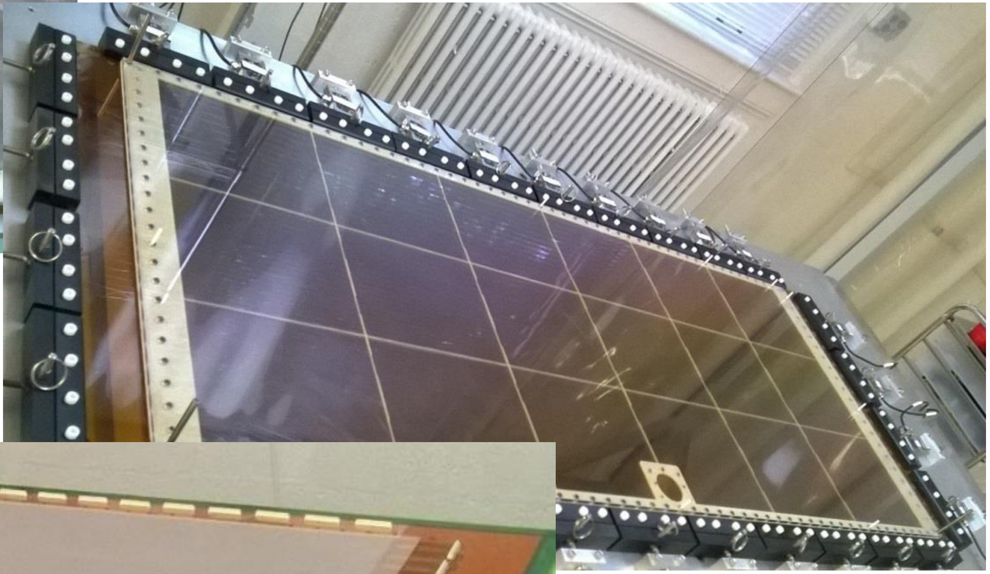
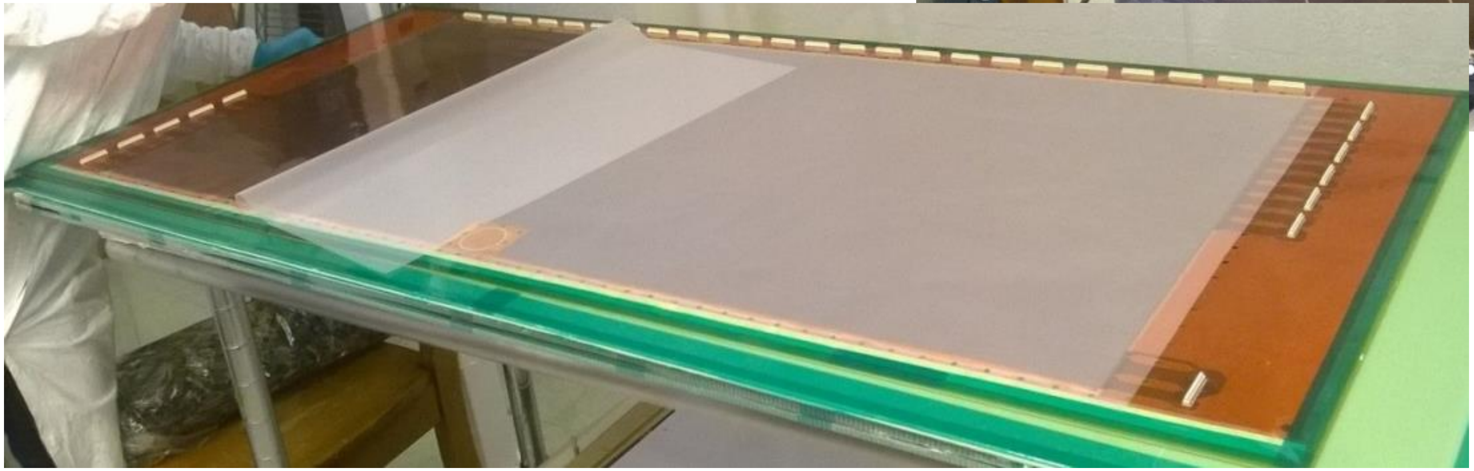
Slide from D. Dutta, PasSpin, Ji'nan, China, Oct. 30, 2013

pRad GEM: Assembly of the first chamber is ongoing

New assembly technique used for pRad chambers (See next slide)





GEM R&D: New assembly technique for large GEM

Idea:

- GEM foil stretched and glued to support frames
- Individual framed GEM stacked together in the assembled chamber
- O-ring and screws used to close the chamber and ensure the gas tighness

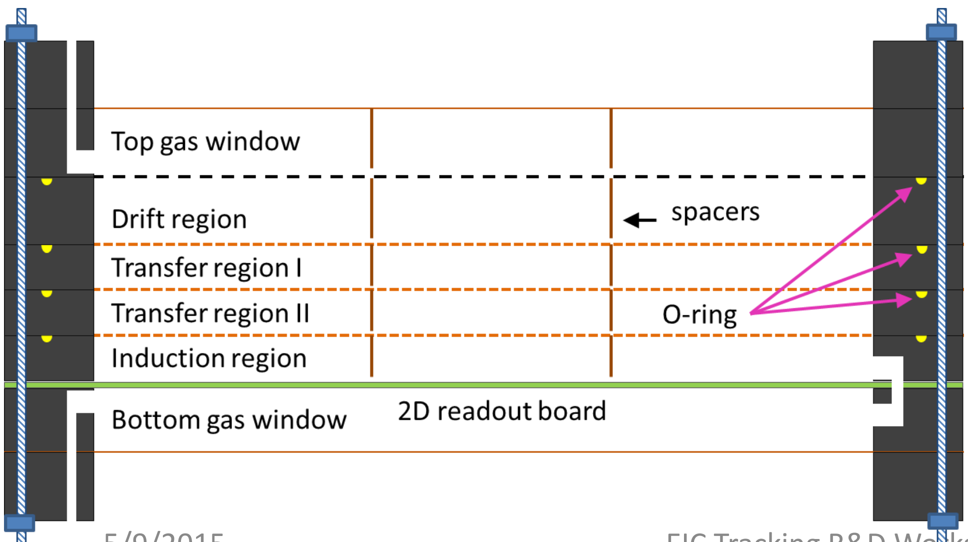
Pros:

- Possibility of easy replacement of GEM foils or readout board after assembly
- Work for light detector: plastic screw and narrow support frames, no rigid support needed
- Idea already being tested on the pRad GEM chamber

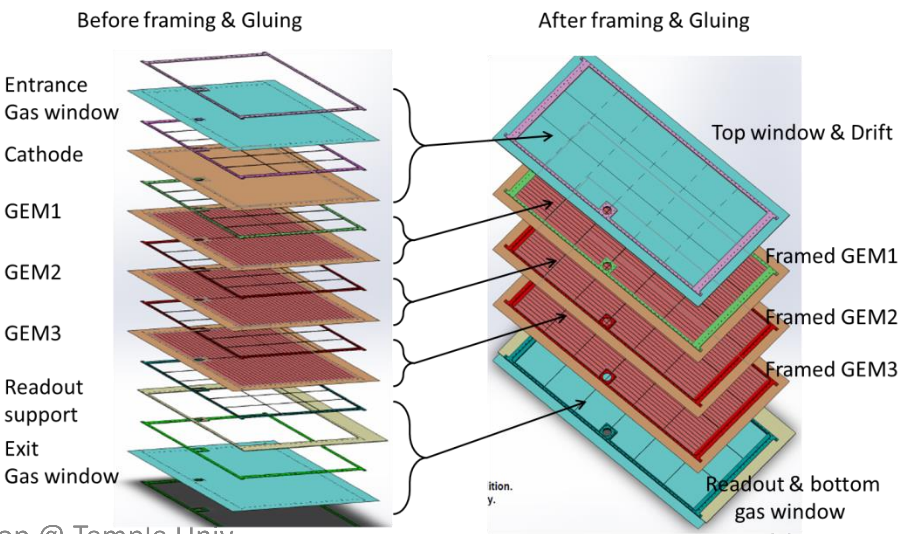
Cons:

- Need to evaluate gas tightness with O-ring + screw system
- Would still need spacers inside the active area

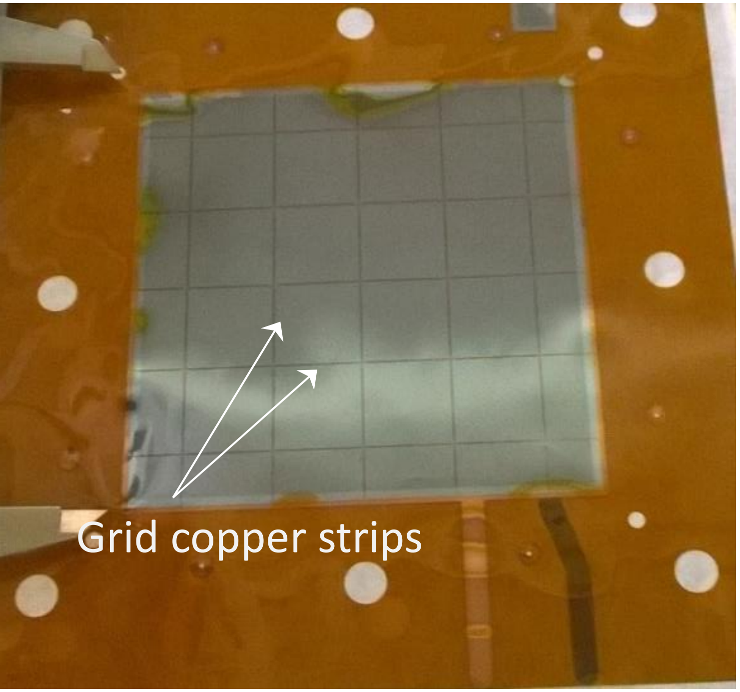
Cross section of triple GEM with new assembly



Exploded view of pRad GEM: 100 cm × 55 cm

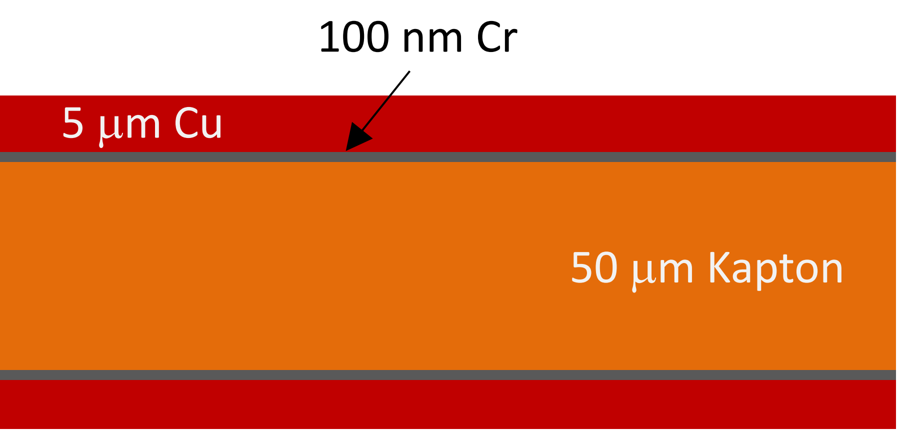


GEM R&D: Copper Free GEM foil

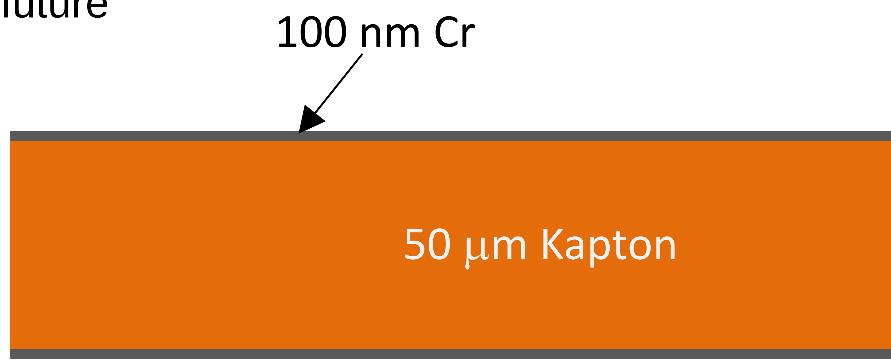


Cu-Free GEM foil

- Standard GEM foil with the copper layer removed
- Copper clad Kapton based material comes with 100 nm Chromium (Cr) layer between Cu and Kapton
- 100 nm Cr layer replace Cu as top and bottom GEM electrode
- Cu-Free GEM Samples from Rui with a grid of Cu strips
  - Ensure electrical contact to be removed in the future



Standard GEM foil



Cu-Free GEM foil

GEM R&D: radiation length of Cu-Free GEM

Triple-GEM detector with standard GEM foil

	Quantity	Thickness µm	Density g/cm3	X0 mm	Area Fraction	X0 %	S-Density g/cm2
Window							
Kapton	2	25	1.42	286	1	0.0175	0.0071
Drift							
Copper	1	5	8.96	14.3	1	0.0350	0.0045
Kapton	1	50	1.42	286	1	0.0175	0.0071
GEM Foil							
Copper	6	5	8.96	14.3	0.8	0.1678	0.0215
Kapton	3	50	1.42	286	0.8	0.0420	0.0170
Grid Spacer							
G10	3	2000	1.7	194	0.008	0.0247	0.0082
Readout							
Copper-80	1	5	8.96	14.3	0.2	0.0070	0.0009
Copper-350	1	5	8.96	14.3	0.75	0.0262	0.0034
Kapton	1	50	1.42	286	0.2	0.0035	0.0014
Kapton	1	50	1.42	286	1	0.0175	0.0071
NoFlu glue	1	60	1.5	200	1	0.0300	0.0090
Gas							
(CO2)	1	15000	1.84E-03	18310	1	0.0819	0.0028
					Total	**0.471**	**0.090**

Triple-GEM detector with Cu-Free GEM foil

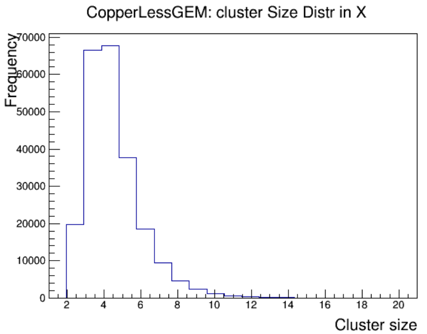
	Quantity	Thickness µm	Density g/cm3	X0 mm	Area Fraction	X0 %	S-Density g/cm2
Window							
Kapton	2	25	1.42	286	1	0.0175	0.0071
Drift							
Copper	1	0	8.96	14.3	1	0.0000	0.0000
Kapton	1	50	1.42	286	1	0.0175	0.0071
GEM Foil							
Copper	6	0	8.96	14.3	0.8	0.0000	0.0000
Kapton	3	50	1.42	286	0.8	0.0420	0.0170
Grid Spacer							
G10	3	2000	1.7	194	0.008	0.0247	0.0082
Readout							
Copper-80	1	0	8.96	14.3	0.2	0.0000	0.0000
Copper-350	1	0	8.96	14.3	0.75	0.0000	0.0000
Kapton	1	50	1.42	286	0.2	0.0035	0.0014
Kapton	1	50	1.42	286	1	0.0175	0.0071
NoFlu glue	1	60	1.5	200	1	0.0300	0.0090
Gas							
(CO2)	1	15000	1.84E-03	18310	1	0.0819	0.0028
					Total	**0.235**	**0.060**

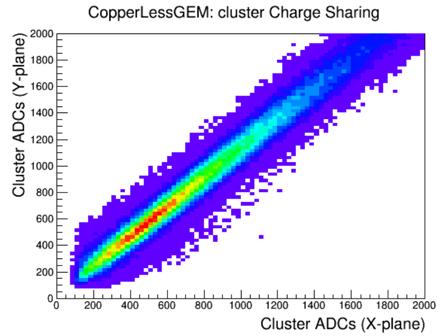
- Based on the data for the SBS-BT-GEM modules
- The contribution of the Cr layer has not been added but is negligible to the first order

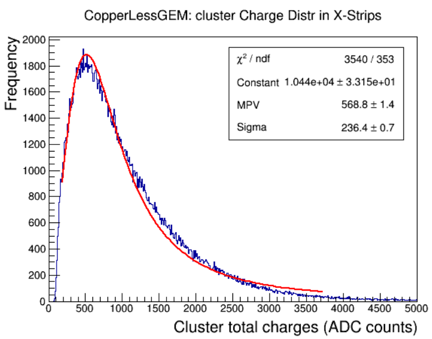
About 50% reduction in the material in a EIC-like chamber with Copperless GEM

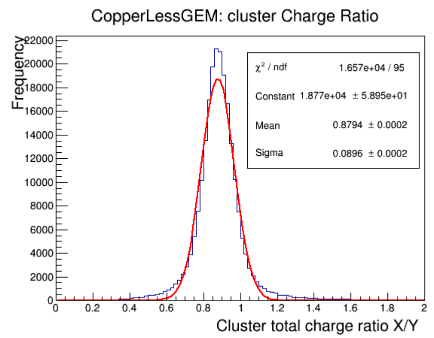
GEM R&D: Preliminary tests of Cu-Free GEM

Tests with Cosmics



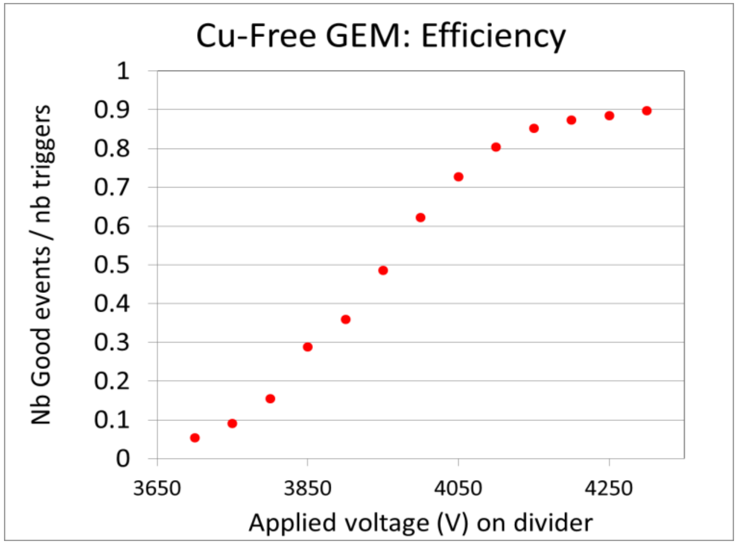


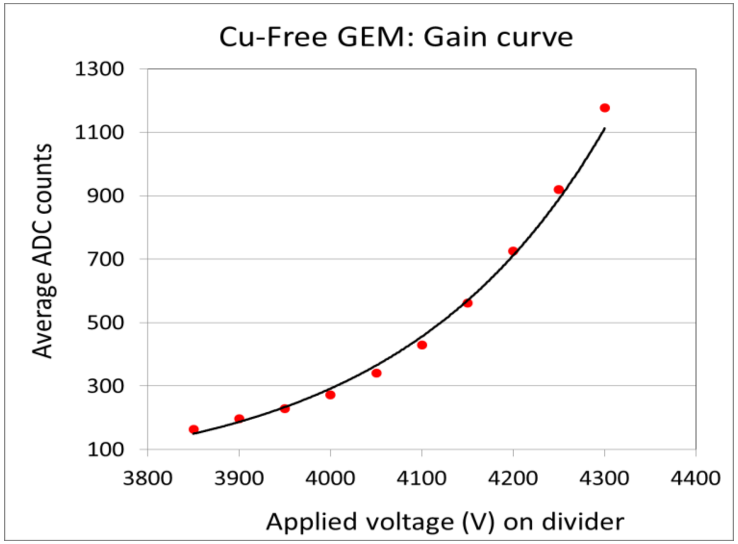




- Good performances of the Cu-free GEM
- Need to study spark rate and ageing of the foil
- High rate and long term performance study will be done with our x-ray source
- Investigate Cu-less COMPASS-like readout board

HV scan with Sr90 source



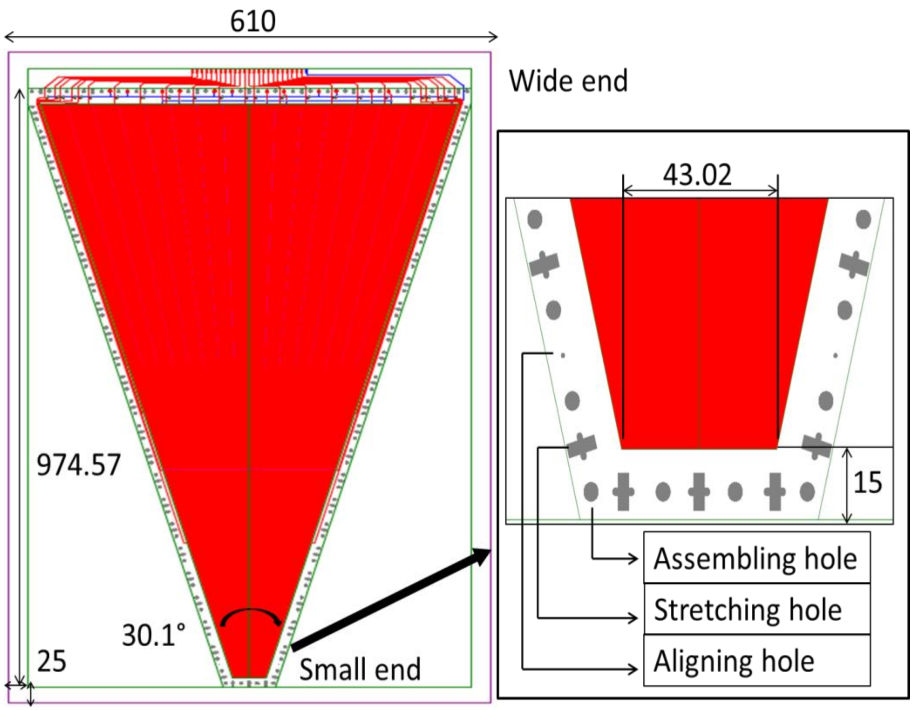


GEM R&D: EIC-FT-GEM prototype II

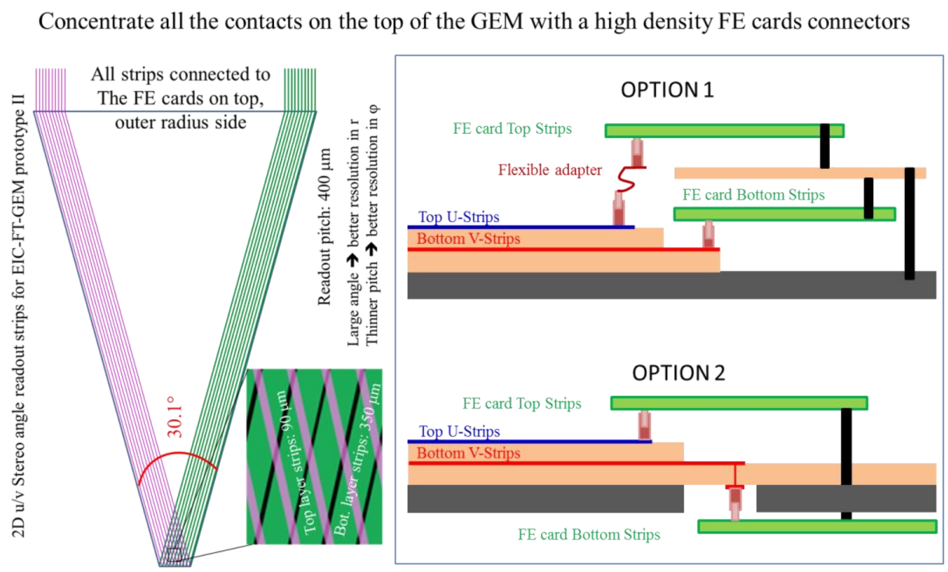
EIC GEM prototype II:

- Common GEM foil design between UVa, Florida Tech (FIT) and Temple Univ. (TU) (Aiwu's talk)
  - Satisfy the requirements and constraints from 3 different assembly assembly
- Low mass and light detector
  - Reduce overall the material budget, Investigate copper less GEM
- New detector construction technique
  - Possibility to re open the detector to replace parts
- New u/v strips readout design
  - Finer pitch to improve spatial resolution, all connectors for FE electronics at the outer radius

Common GEM foil UVa, FIT and TU (Aiwu's talk)



u/v strips readout board

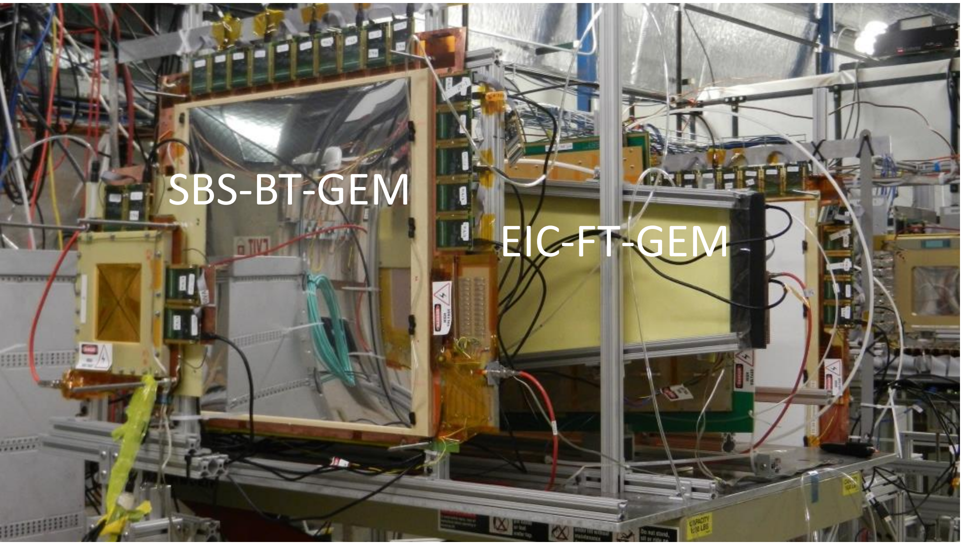


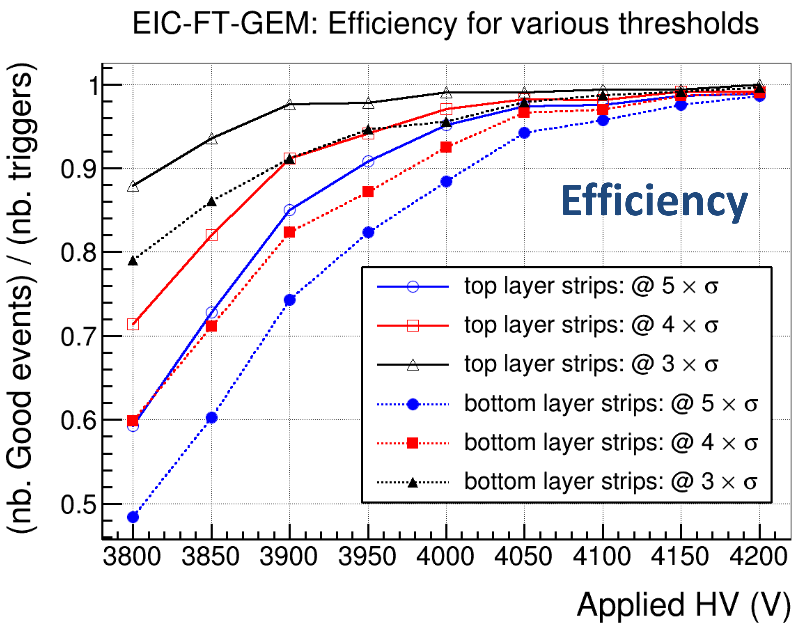
Summary

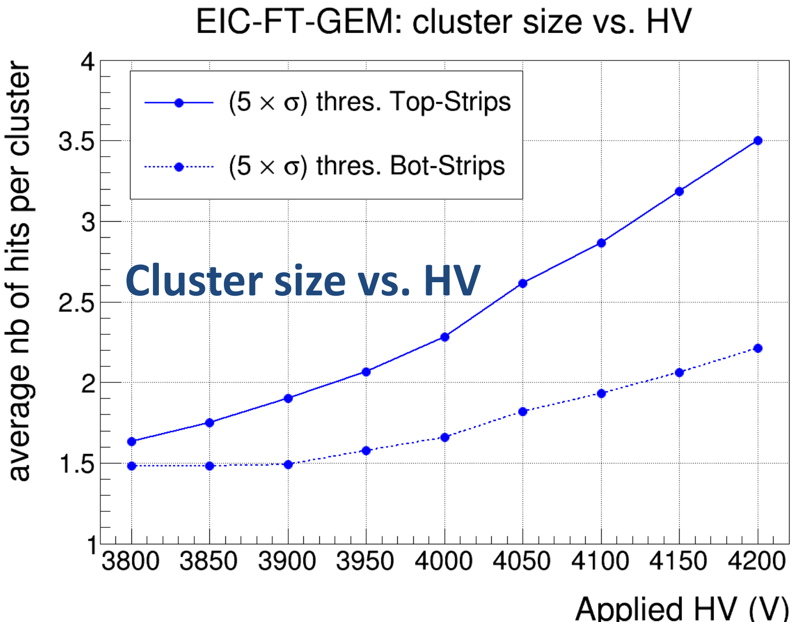
- Large GEM R&D and Production Activities at UVa
  - Production of the SBS Back Trackers GEM modules
  - First pre-R&D prototype for EIC forward tracker GEM (successfully tested @ FTBF)
  - Assembly of the largest GEM for pRad experiment is ongoing
- New ideas for on large GEMs
  - New assembly technique been tested ➔ possibility to re-open large size triple-GEM chamber
  - Reduce overall the material budget, Investigate copper free GEM foils
- EIC-FT-GEM prototype II
  - Common GEM foil design shared with FIT and TU
  - Upgrade of the U/V readout design with finer pitch to improve spatial resolution and all connectors for FE electronics at the outer radius

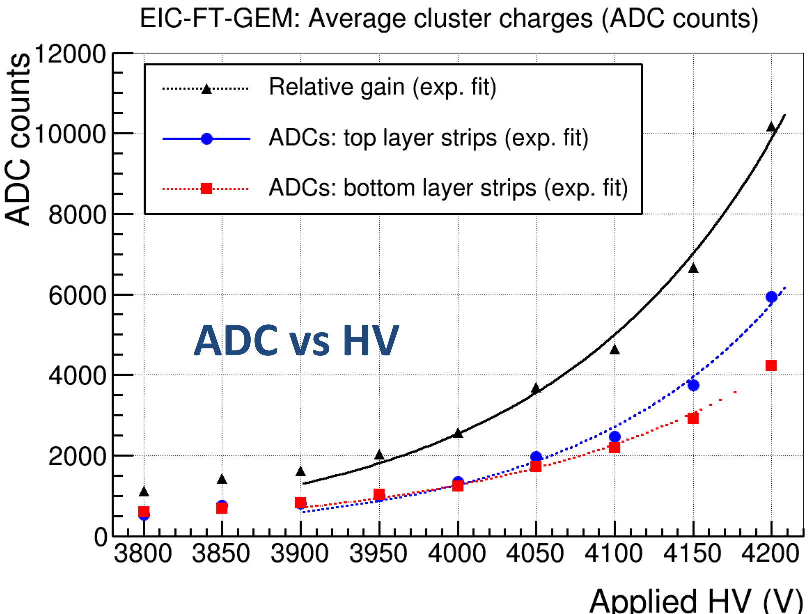
Backup

EIC-FT-GEM @ FTBF: Performances

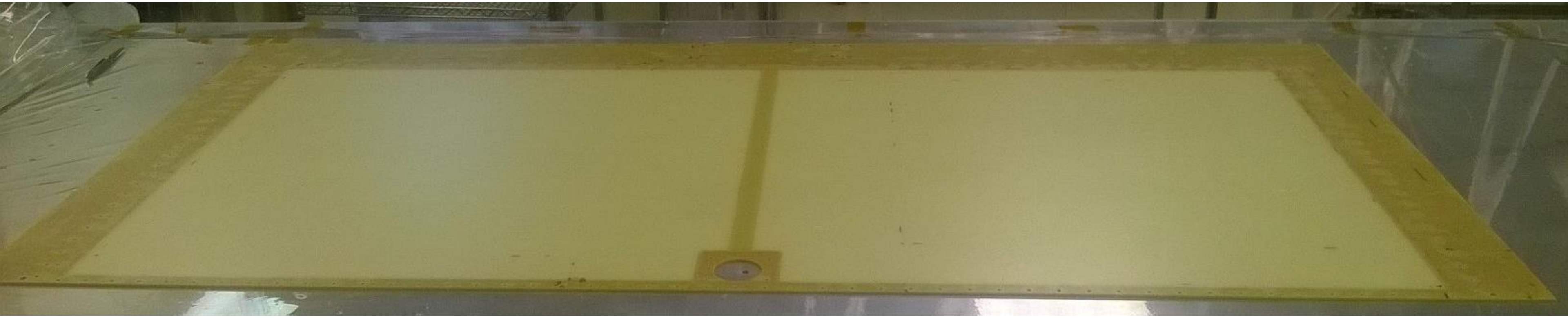








pRad Readout board support



Proton Radius Experiment pRad @ JLab

The proton radius puzzle

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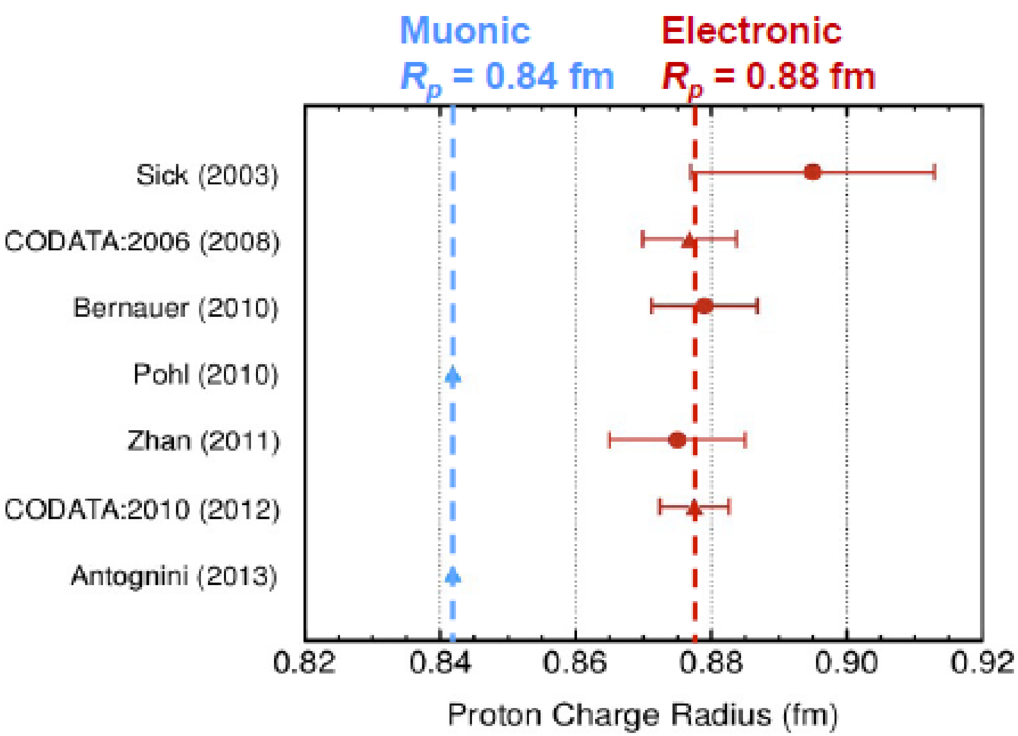
- >7σ discrepancy between **muonic** and **electronic** measurements
- High-profile articles in Nature, NYTimes, etc.
- Puzzle unresolved, possibly New Physics



▲ Spectroscopy

● Scattering

R_p = 0.84184(67) fm

R_p = 0.875(10) fm

R_p = 0.8775(51) fm

R_p = 0.84087(39) fm

Slide from M. Kohl EINN2013, Paphos, Cyprus 2013

Proton Radius Experiment pRad @ JLab

Proton charge radius: ep elastic scattering

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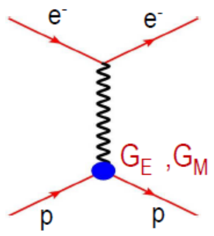
- First Born approximation (one photon exchange):

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott}} \left(\frac{E'}{E}\right) \frac{1}{1+\tau} \left(G_E^{p\,2}(Q^2) + \frac{\tau}{\varepsilon} G_M^{p\,2}(Q^2)\right)$$

$$Q^2 = 4EE' \sin^2\frac{\theta}{2} \qquad \tau = \frac{Q^2}{4M_p^2} \qquad \varepsilon = \left[1 + 2(1+\tau)\tan^2\frac{\theta}{2}\right]^{-1}$$



- Structureless proton:

$$\left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott}} = \frac{\alpha^2\left[1 - \beta^2 \sin^2\frac{\theta}{2}\right]}{4k^2 \sin^4\frac{\theta}{2}}$$

- G_E and G_M from Rosenbluth separation
  Can ignore G_M at extremely low Q^2,
  (assumed in PRad)

- Taylor expansion at low Q^2:

$$G_E^p(Q^2) = 1 - \frac{Q^2}{6}\langle r^2\rangle + \frac{Q^4}{120}\langle r^4\rangle + \ldots$$

→

- Definition of the Proton Radius:
  rms charge radius from slope of G_E

$$\langle r^2\rangle = -6 \left.\frac{dG_E^p(Q^2)}{dQ^2}\right|_{Q^2=0}$$

Slide from M. Kohl
EINN2013, Paphos, Cyprus 2013

The PRad proton radius proposal (JLAB)

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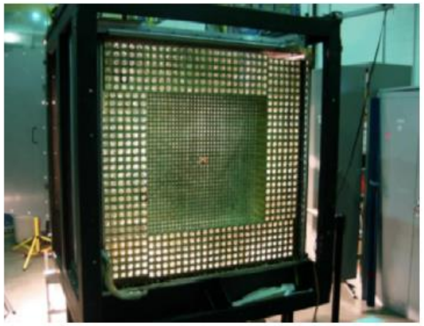

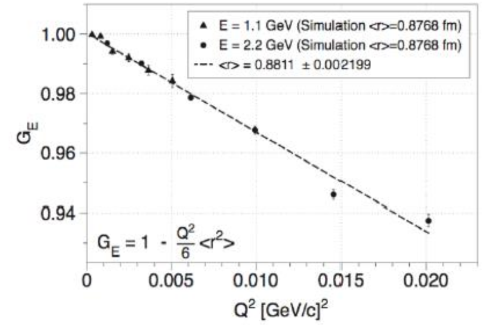

- Low intensity beam in Hall B @ Jlab into windowless gas target
- Scattered ep and Moller electrons into HYCAL at 0^o
- Lower Q^2 than Mainz. Very forward angle, insensitive to 2γ, G_M
- Conditionally approved by PAC38 (Aug 2011): ``Testing of this result is among the most timely and important measurements in physics.''
- Approved by PAC39 (June 2012), graded "A"