Status of the PRad Experiment (E12-11-106)

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for the PRad collaboration

Outline

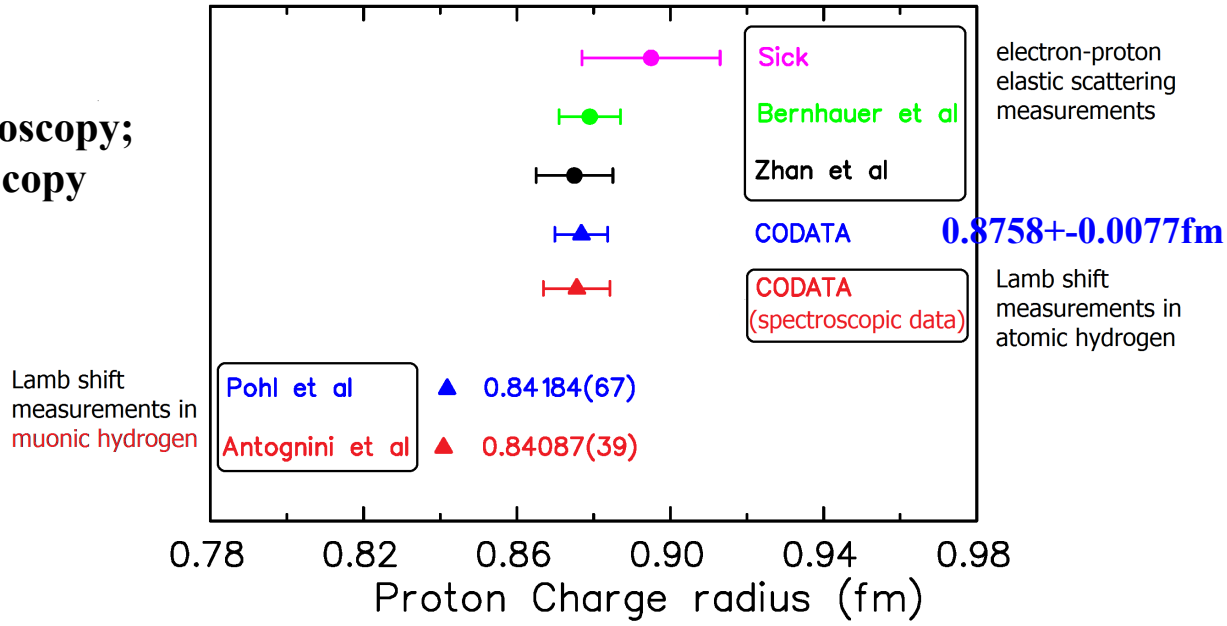
- ***PRad Physics goals***
- ***Experimental setup***
- ***Current status***
- ***Summary***

CLAS col. meeting, June. 2016

The Proton Charge Radius Puzzle

Existing data :

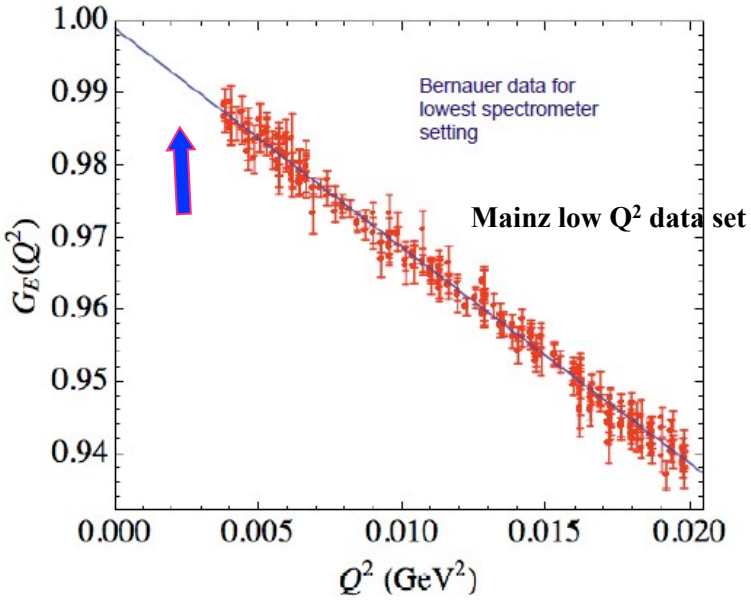
1) **e-p elastic scattering**
2) **Ordinary hydrogen spectroscopy;**
3) **Muonic hydrogen spectroscopy**



- Muonic hydrogen Lamb shift experiment at PSI (2010,2013)
- **r_p = 0.84184(67) fm ➡ Unprecedented less than 0.1% precision**
- **7σ discrepancy from most of previous experimental results and analyses**

The PRad Experiment (E12-11-106)

- Experimental goals:
  - reach very low Q^2 range (~ 10 times less than the Mainz experiment)
  - reach sub-percent precision in r_p extraction



- Suggested solutions:
  1) Non-magnetic-spectrometer method:
     use high resolution high acceptance calorimeter and high position resolution GEM detector
     - reach smaller scattering angles: ($\Theta = 0.8^0 – 7.0^0$)
       ($Q^2 = 2x10^{-4} – 1x10^{-1}$) GeV/c^2
       essentially, model independent r_p extraction

  2) Simultaneous detection of *ee* → *ee* Moller scattering
     - (best known control of systematics)

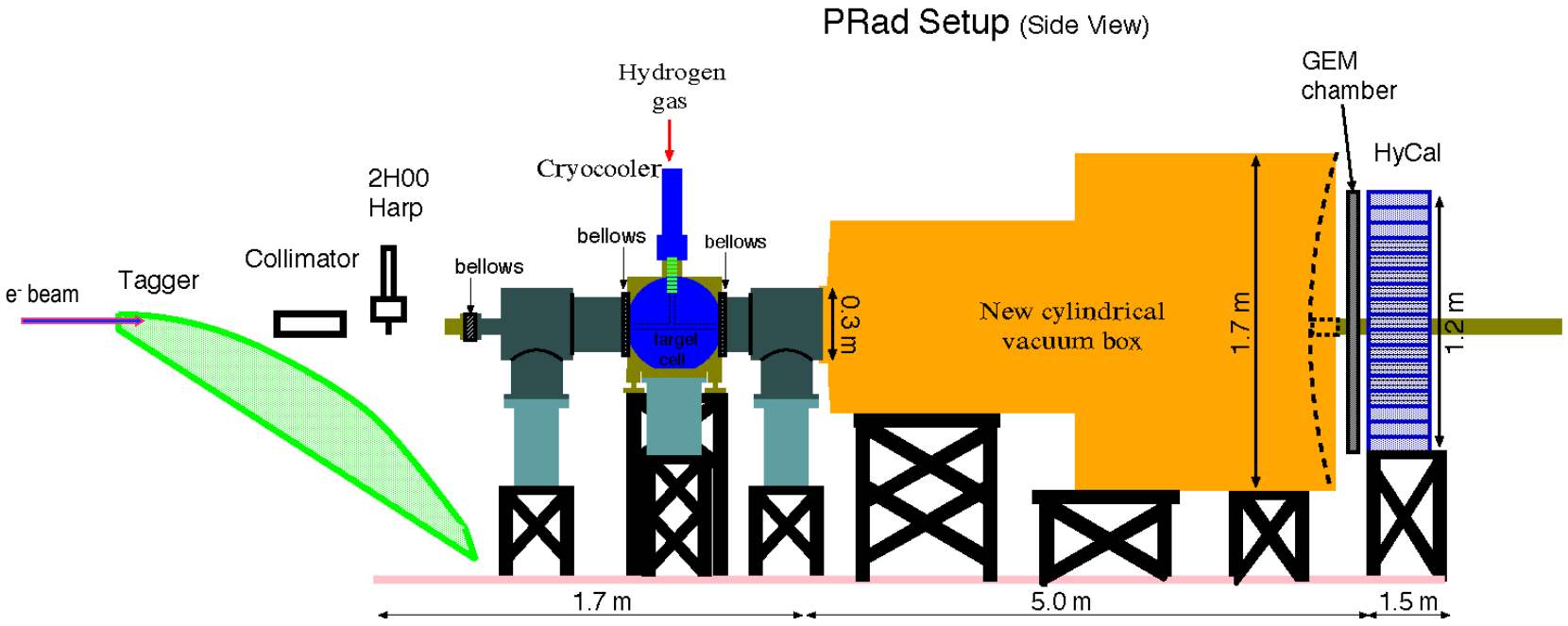
  3) Use high density windowless H2 gas flow target:
     - beam background fully under control with high quality CEBAF beam
     - minimize experimental background

- Two beam energies: E_0 = 1.1 GeV and 2.2 GeV to increase Q^2 range: ($2x10^{-4} – 1x10^{-1}$) GeV/c^2
- Will reach sub-percent precision in r_p extraction
- Approved by PAC39 (June, 2012) with high "A" scientific rating

PRad Experimental Setup (schematics)

- Main detectors and elements:
  - windowless H_2 gas flow target
  - PrimEx HyCal calorimeter
  - vacuum box with one thin window at HyCal end
  - X,Y – GEM detector in front of HyCal

- Beam line equipment:
  - standard beam line elements (0.1 – 10 nA)
  - photon tagger for HyCal calibration
  - collimator box (6.4 mm collimator for photon beam, 12.7 mm for e^- beam halo “clean-up”)
  - Harp 2H00
  - pipe connecting Vacuum Window through HyCal



Windowless H_2 Gas Flow Target

- Target chamber is differentially pumped with four high speed turbos.
- Kapton orifices up- and downstream from the cell reduce the beam line vacuum.
- A four-axis motion mechanism positions the target cell, with approximately ±10 μm accuracy.

Target specs:

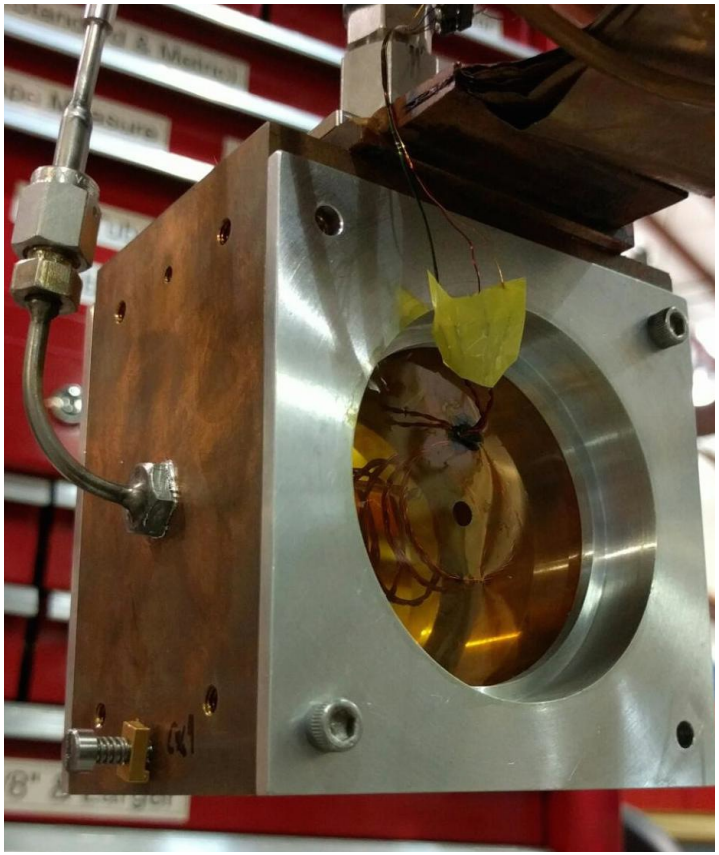
Cell: 30 μm thick Kapton, length 4 cm

- diameter 8 cm with 2 mm diameter holes for the beam to pass through
- Cell pressure 0.5 torr

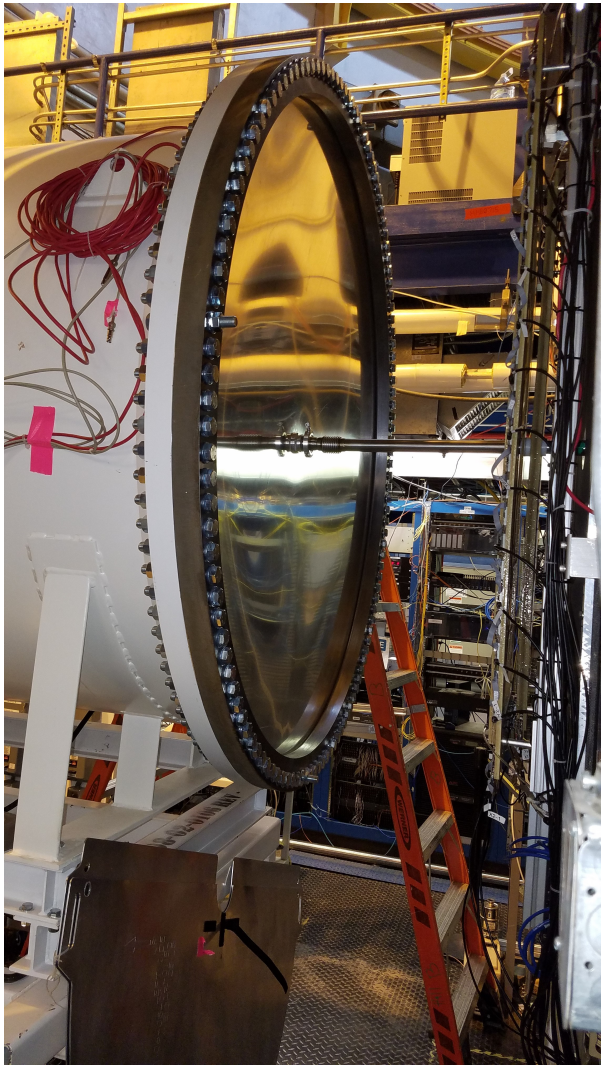
Target: H_2 input gas temp. 19.5 K

- thickness 2×10^{18} **(atoms)** / cm^2
- density 2.75×10^{17} **(molecules)** / cm^3
- Vacuum in target chamber ~5×10^{-3} torr

Funded by a NSF MRI grant
PHY-1229153



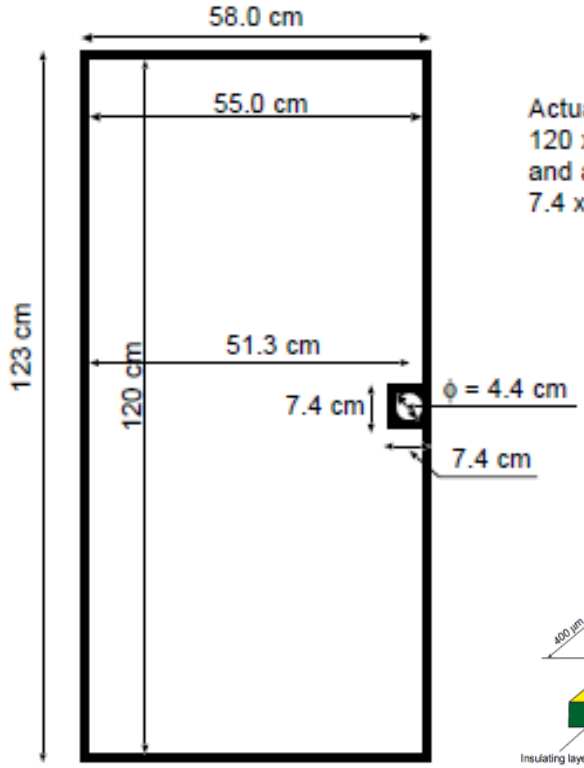
Vacuum Box



- Engineering design is done by Duke/Jlab
- Construction is done (March 2015)
- Tested with window by vendor (March 2015)
- Delivered to JLab (March 2015)
- Preassembled at JLab
- Installed: May, 2016

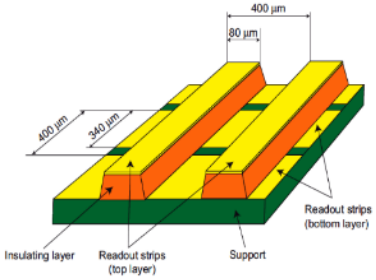
PRad GEMs: Design & Specifications

Desired Sensitive area: 116.4 x 116.4 cm^2
central hole: diameter 4.4 cm, including the frame max allowed
maximum allowable non-sensitive region 7.8 x 7.8 cm^2

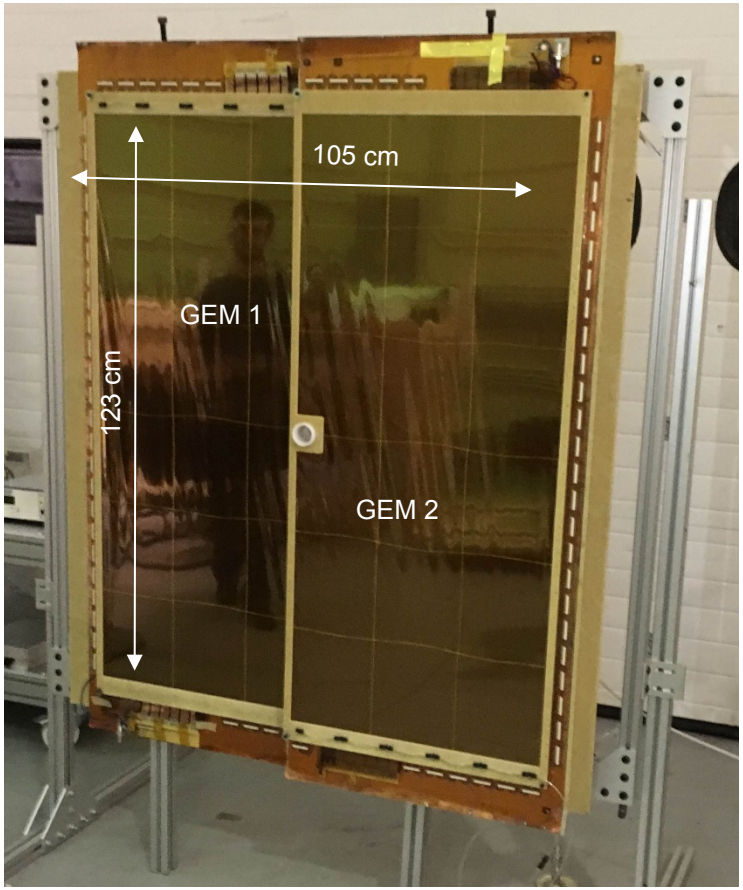


Actual sensitive area:
120 x 102.6 cm^2
and actual non-sensitive area:
7.4 x 7.4 cm^2

2D strips readout
spatial resolution < 70 μm



Two modules mounted on the holding frame in PRad GEM configuration before the cosmic run in EEL (March 2016)



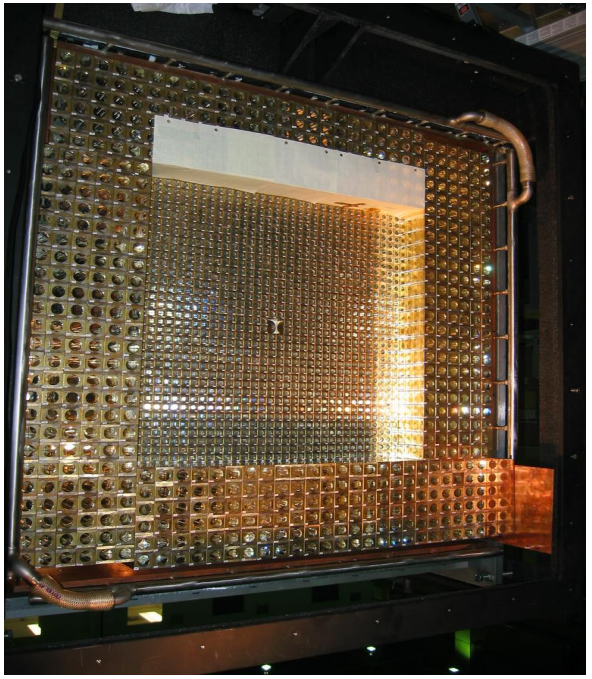
- Largest GEM detector ever built in the world
  - Each module(123 cm x 55 cm) is twice the size of SBS Back Tracker GEMs
  - The two modules overlap in the central part for the alignment of the beam pipe hole
- COMPASS-like strip readout (1.3 m long strips in the vertical direction ⇨ capacitance noise still OK)

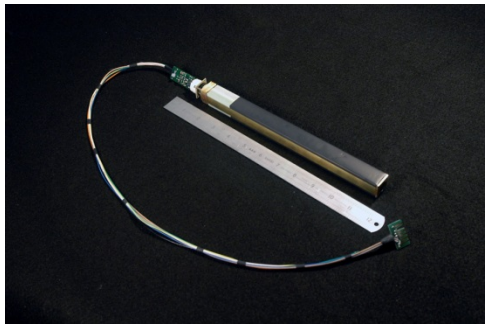
Electromagnetic Calorimeter (PrimEx HyCal)

- Combination of $PbWO_4$ and Pb-glass detectors (118x118 cm^2)
- 34 x 34 matrix of 2.05 x 2.05 x 18 cm^3 $PbWO_4$ shower detectors
- 576 Pb-glass shower detectors (3.82x3.82x45.0 cm^3)
- 2 x 2 $PbWO_4$ modules removed in middle for beam passage
- 5.5 m from H_2 target (~0.5 sr acceptance)

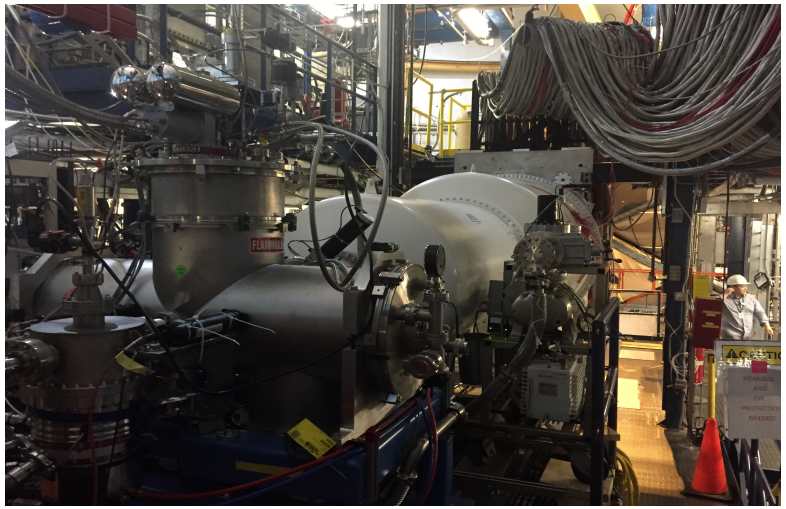
- Moved back to Hall B in June, 2014:

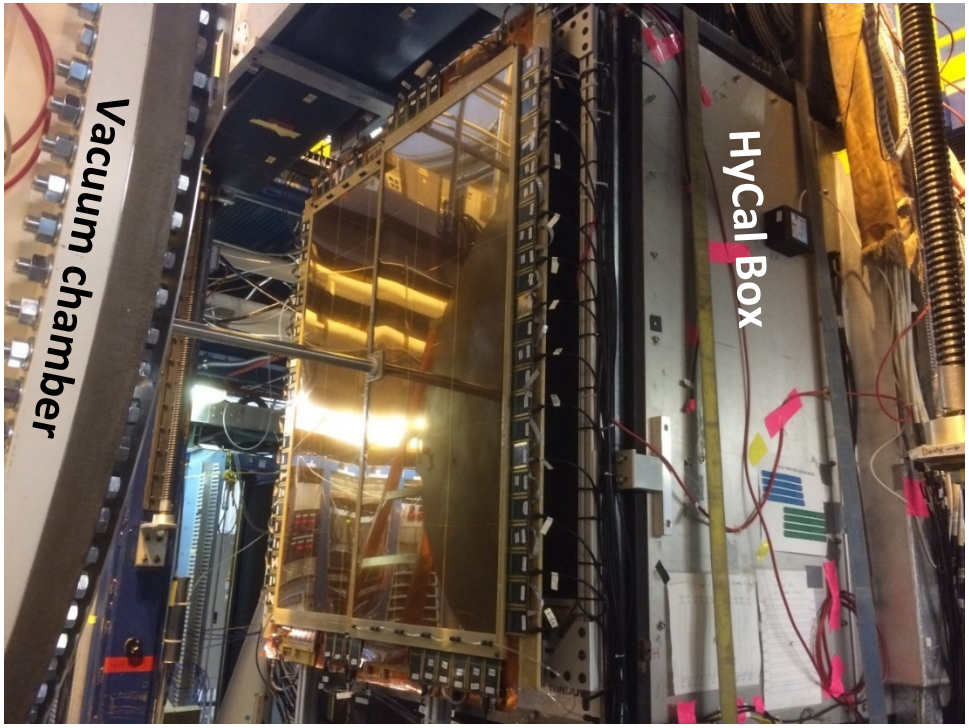
  (thanks to Technical Group (D. Tilles and All)
  - Cabling system with infrastructure reassembled
  - Trigger, analog and HV electronics are reinstalled
  - Cooling system is operational
  - LMS checked and repaired
  - All individual detectors checked and repaired
  - DAQ is operational (HyCal readout part)
  - Transporter is reinstalled/repaired and operational





PRad Installation in Hall B Beam Line

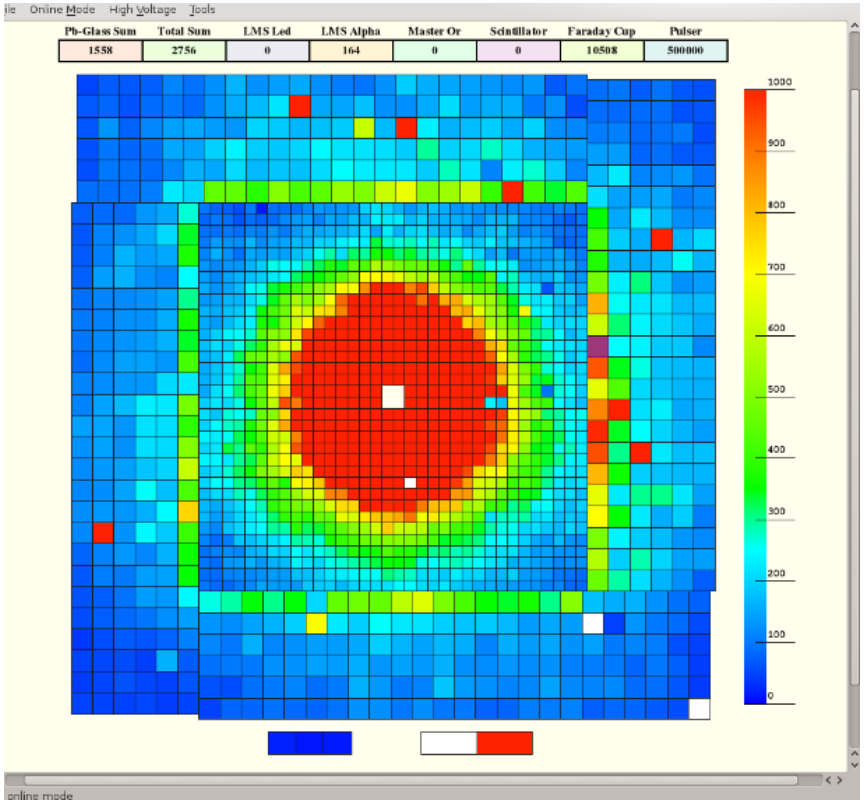


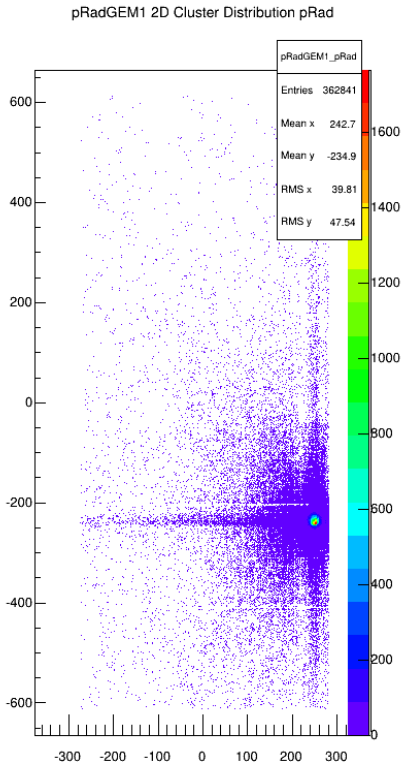


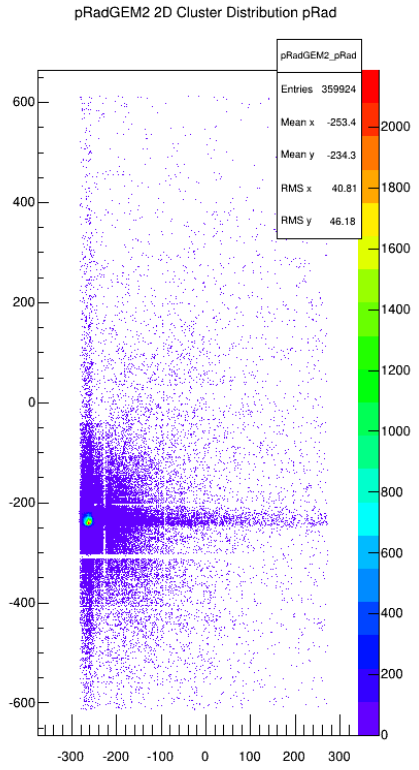
Gain Equalizing and Calibration

a) Gain equalizing and calibration data taking completed (May 25 - May 31)

b) 1.1GeV production completed (June 04 - June 12)

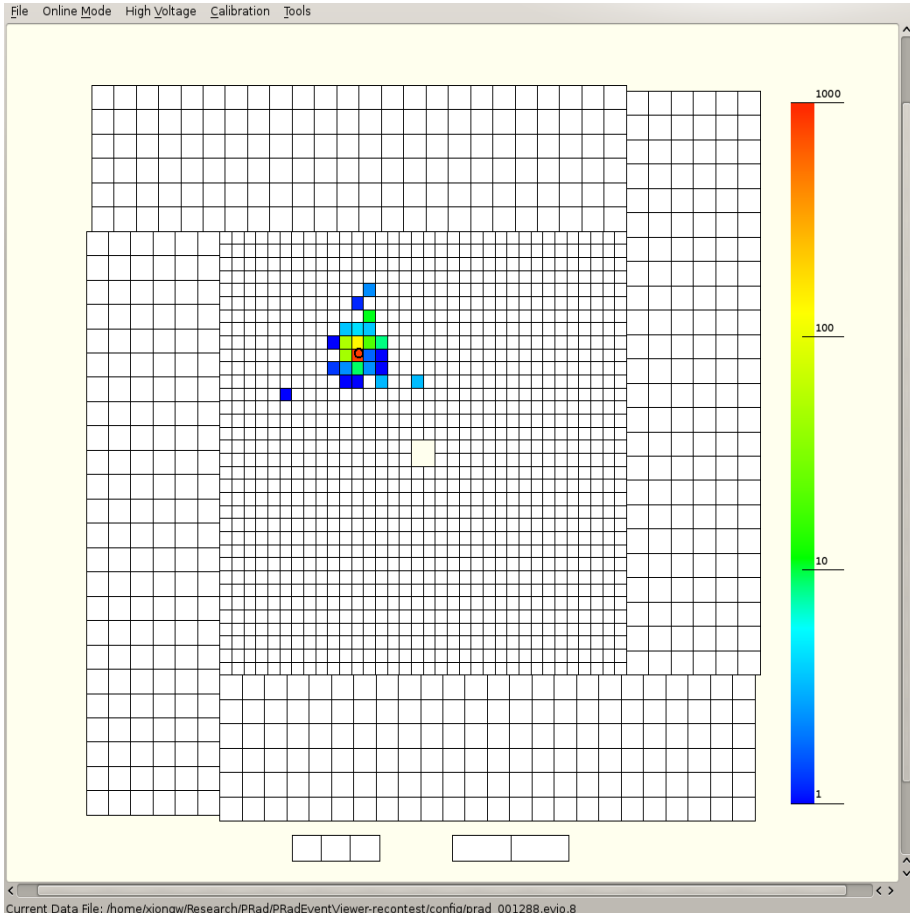


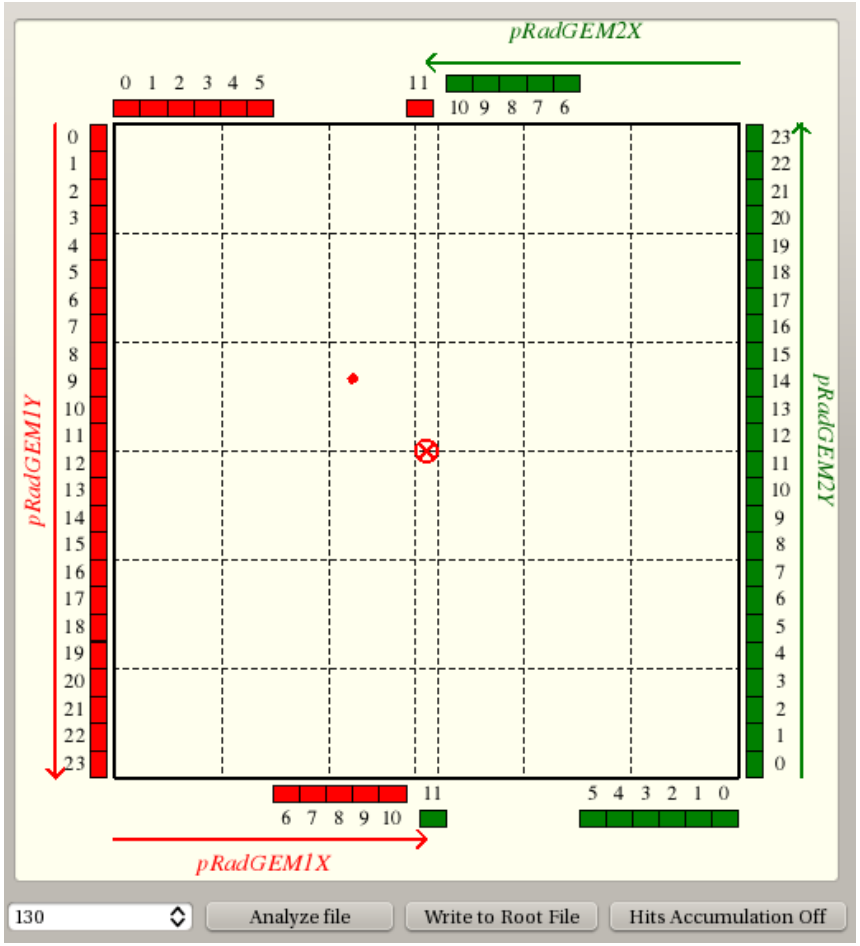




Event Matching Between GEM and HyCal Hits

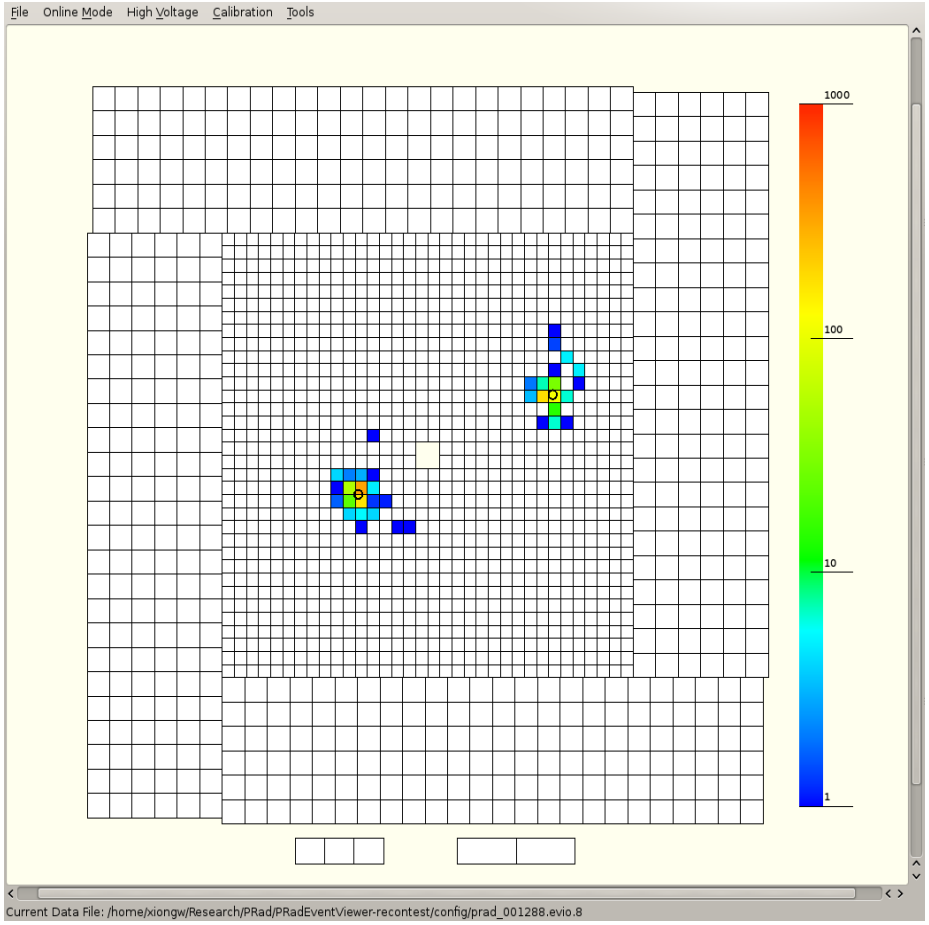
(an e-p elastic scattering event candidate)

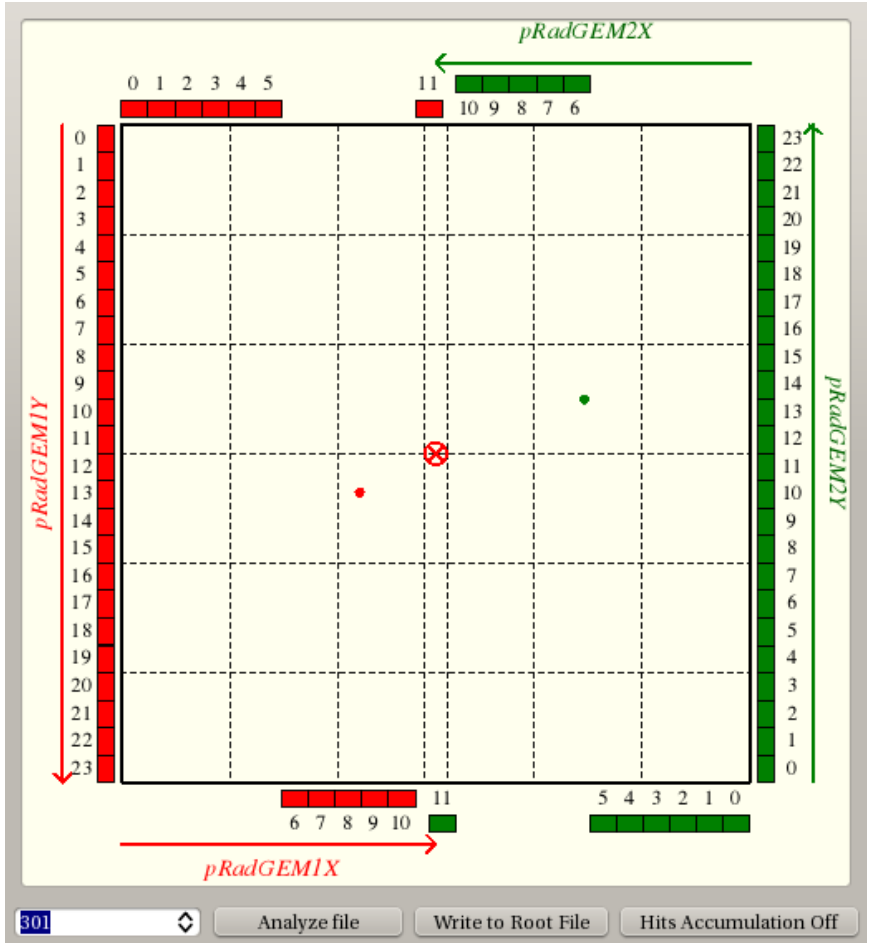




Event Matching Between GEM and HyCal

(an e-e Moller event candidate)





Data taking status

By June 12th

ran with 10 nA beam current @ events rate 1.8KHz and 65% live-time for 5 days (busy signal issue)

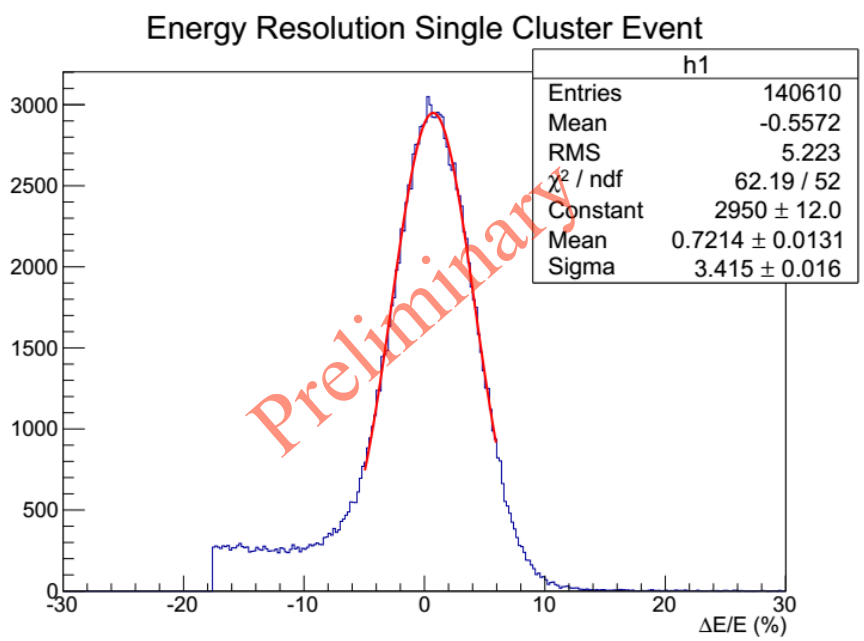
ran with 15 nA beam current @ events rate 4.0KHz and 87% live-time (data rate 400MB/sec) for 3 days

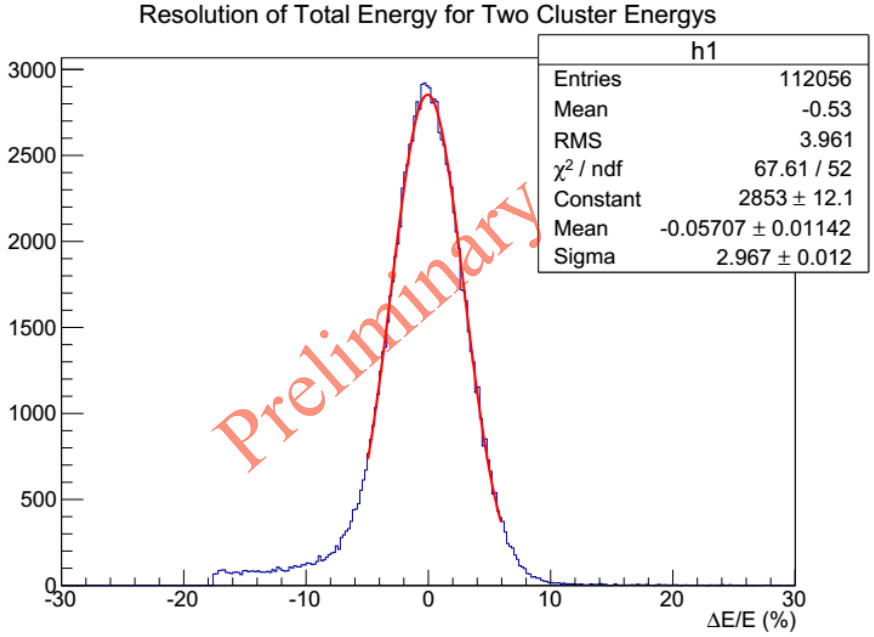
Reached production goal for 1.1GeV beam on Hydrogen

(600M events collected)

(50M events collected with empty target)

Preliminary Gain Calibrations

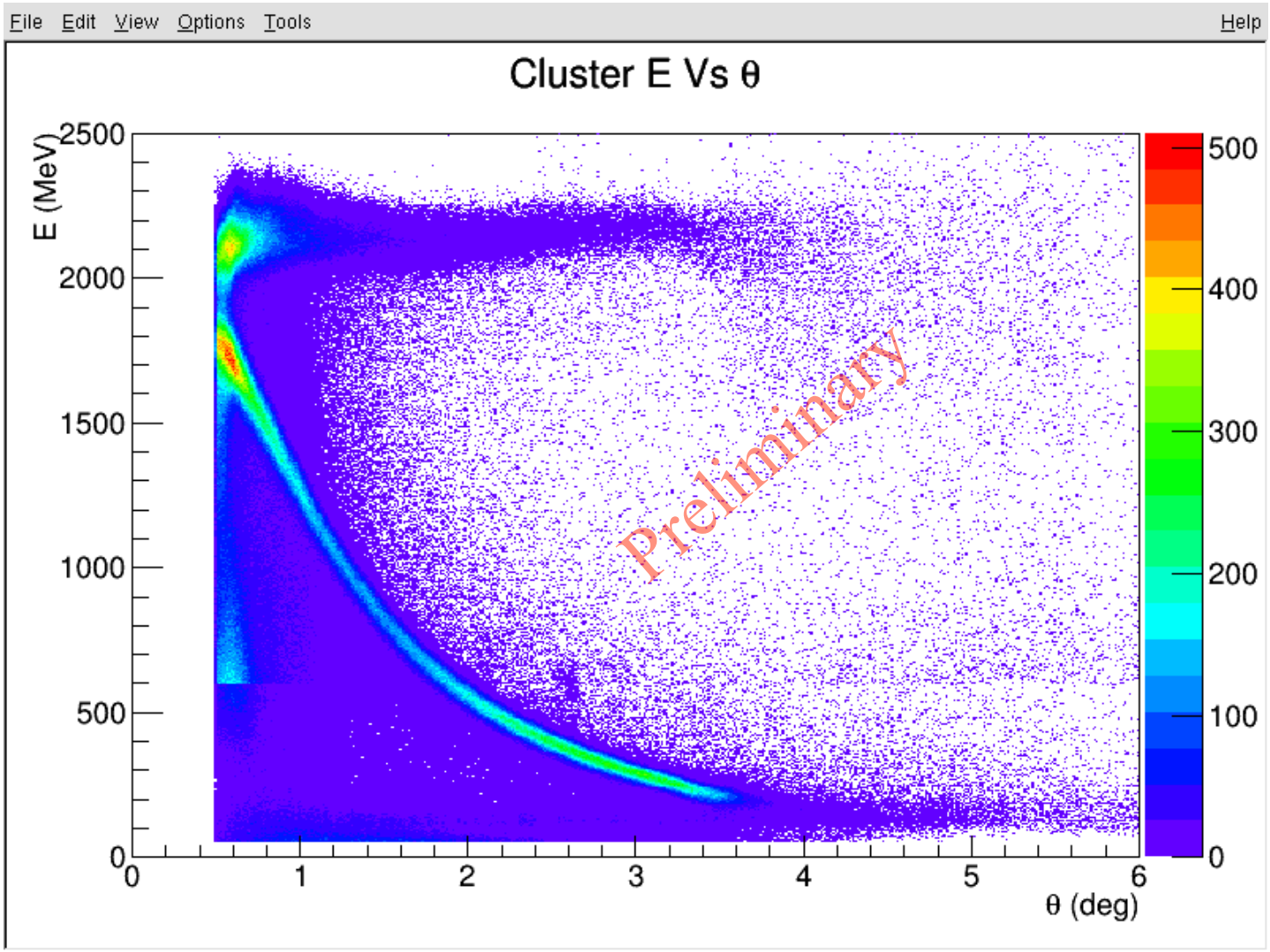


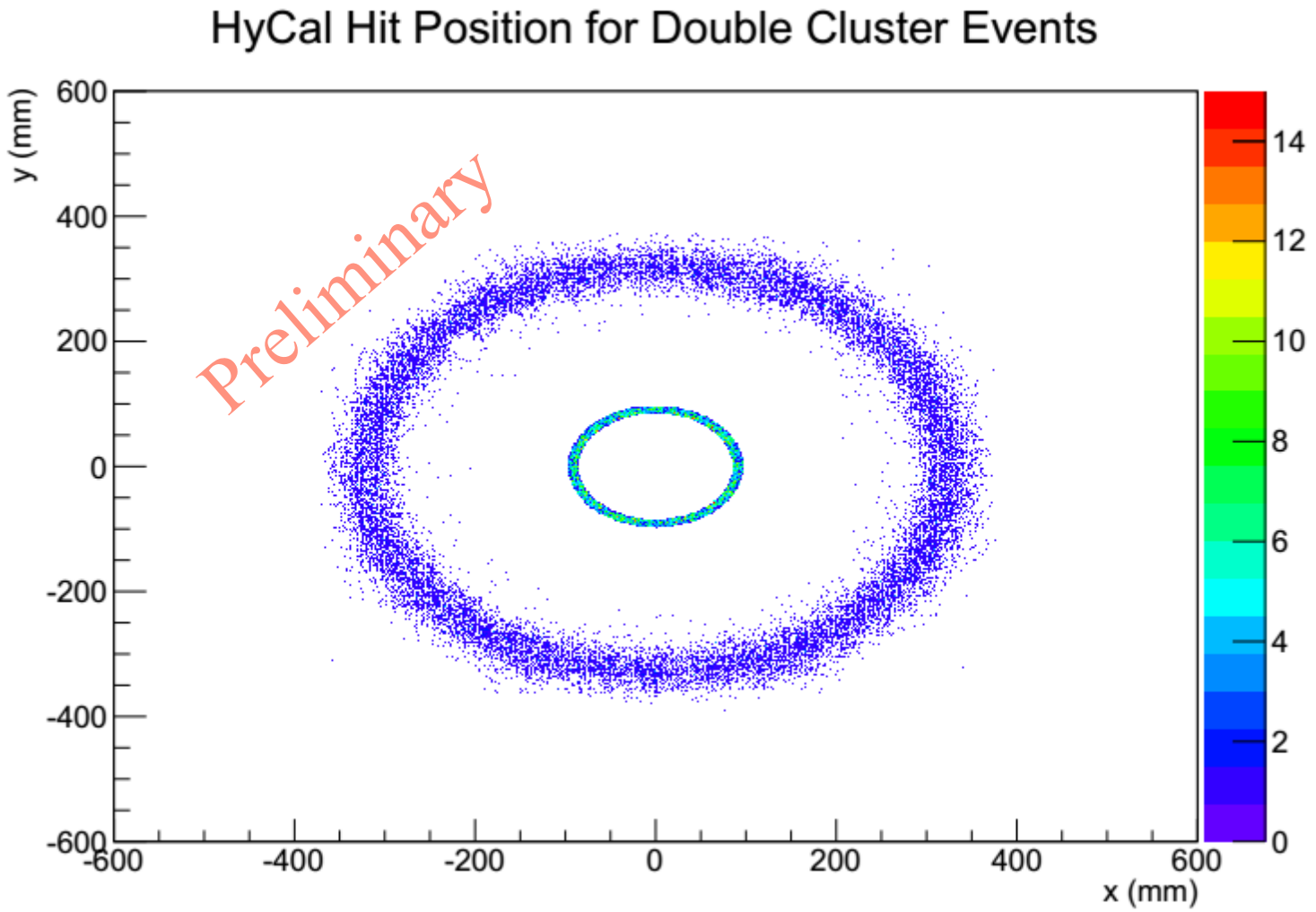


~3.5 % energy resolution on ep

~3.0 % energy resolution on ee

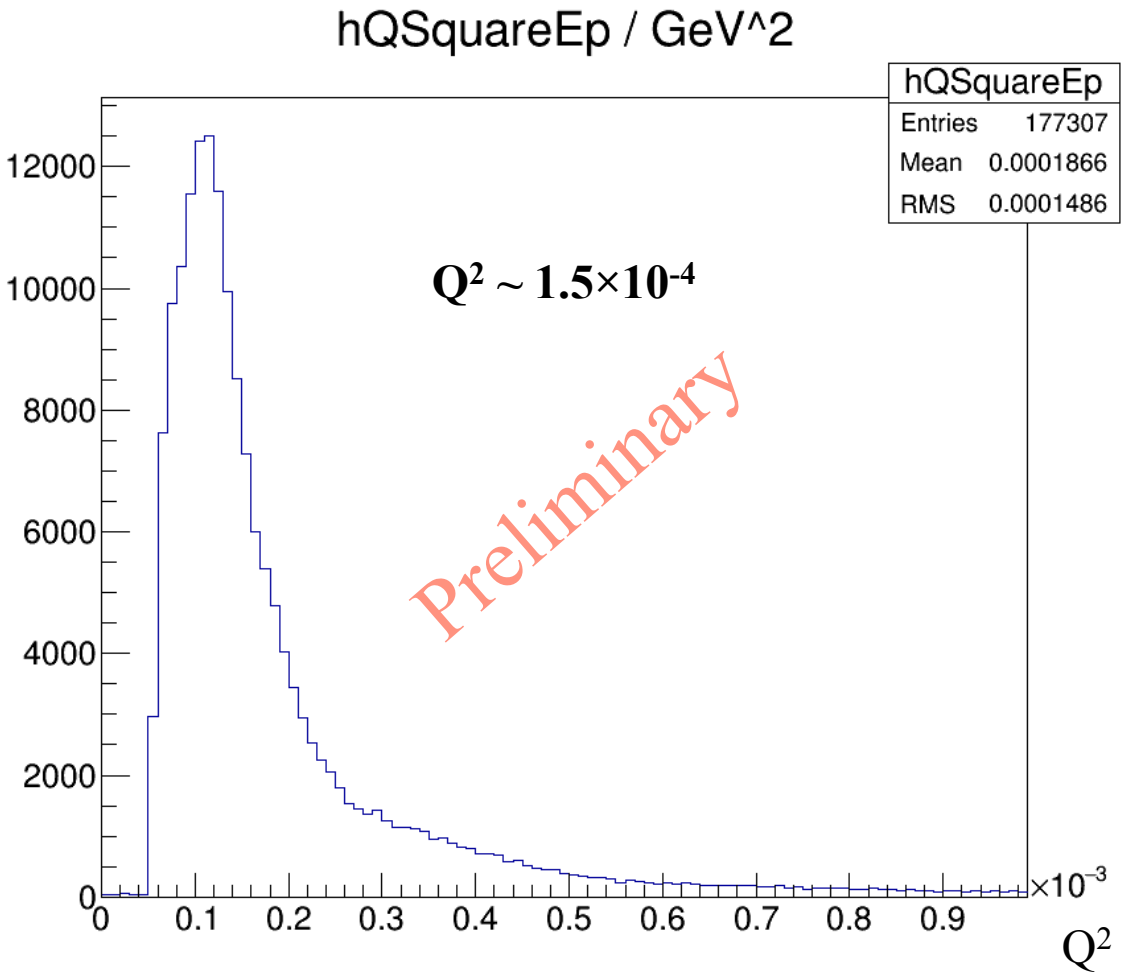
Cluster Energy vs Angle 2D plot




HyCal Hit Position for Double Cluster Events
Preliminary
y (mm)
x (mm)
600
400
200
0
-200
-400
-600
-600
-400
-200
0
200
400
600
14
12
10
8
6
4
2
0

Q2 distribution of single cluster events

With better calibration , back ground subtraction and GEM hits reconstruction, will reach lower Q2



preliminary matching of GEM hits with HyCal clusters
total cluster energy > 700MeV

Summary

- PRad was designed to address the "*Proton Radius Puzzle*"

- PRad installation completed (May 08 - May 11)

- Physics data taking in progress (started from May 25, 2016)
  a) Gain equalizing and calibration completed;
  b) 1.1 GeV production data taking completed;
  c) 2.2 GeV production data taking in progress;

  d) Largest GEM detectors tested in beam with high trigger rate;
  e) DAQ with highest data rate in Hall B achieved (400 MB/sec);
  f) Lowest Q^2 in e-p scattering process recorded ($\sim 10^{-4}$ GeV/c^2);

➢ This project is supported in part by the NSF MRI award: PHY-1229153

Thank you !

- Hall B Engineering and Physics staff
- Target group
- Data acquisition and Fast Electronics groups
- Physics Division
- Accelerator Division
- JLab Administration
- All funding agencies

Proton Charge Radius puzzle ?

NY Times, July 12, 2010