



GEM Detectors for Proton Charge Radius (pRad) Experiment

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for PRad Collaboration

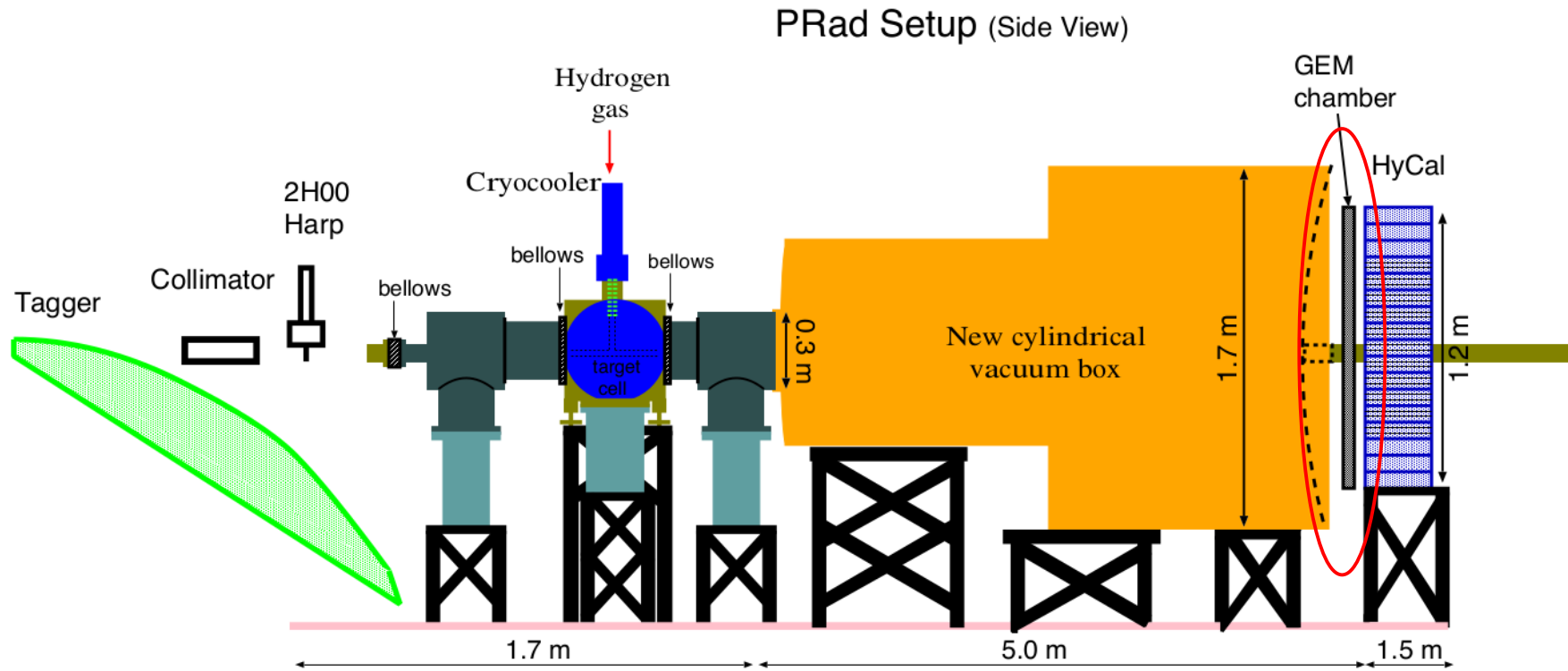
Oct. 15, 2016

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PRad Experimental Setup

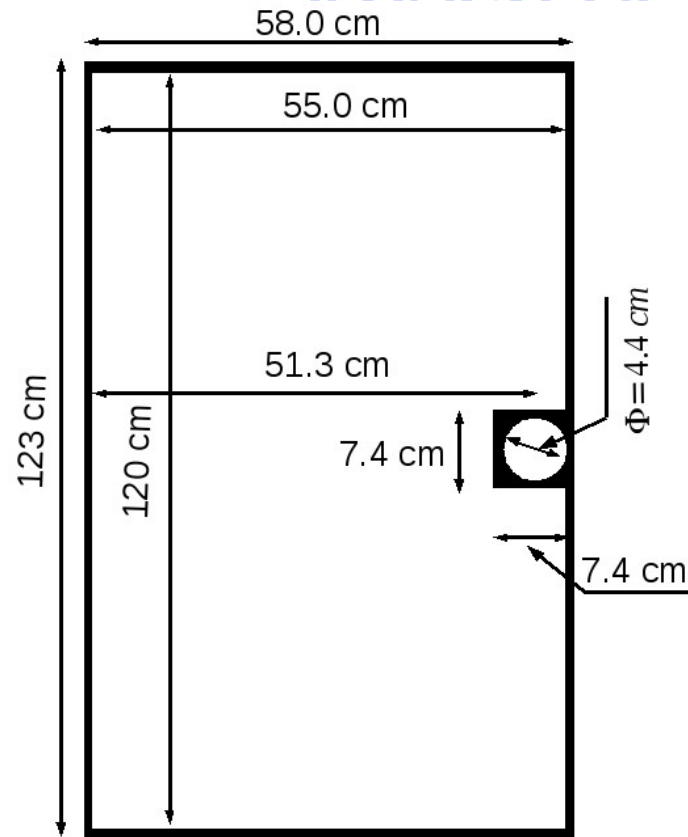


PRad Detector Setup

- PRad Experiment designed to measure proton charge radius with sub-percent precision, to solve the Proton Radius Puzzle.
- Using GEM detector improves position resolution by a factor of 20 – 40.
- The combination of HyCal and GEM delivers powerful performance.

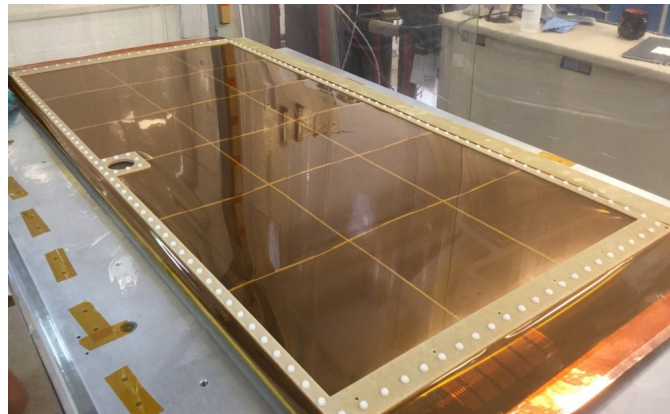
PRad GEM Design

- Desired Sensitive Area: $116.4 \times 116.4 \text{ cm}^2$
- Central Hole: diameter 4.4cm, including the frame max allowed
- Maximum allowable non-sensitive region $7.8 \times 7.8 \text{ cm}^2$



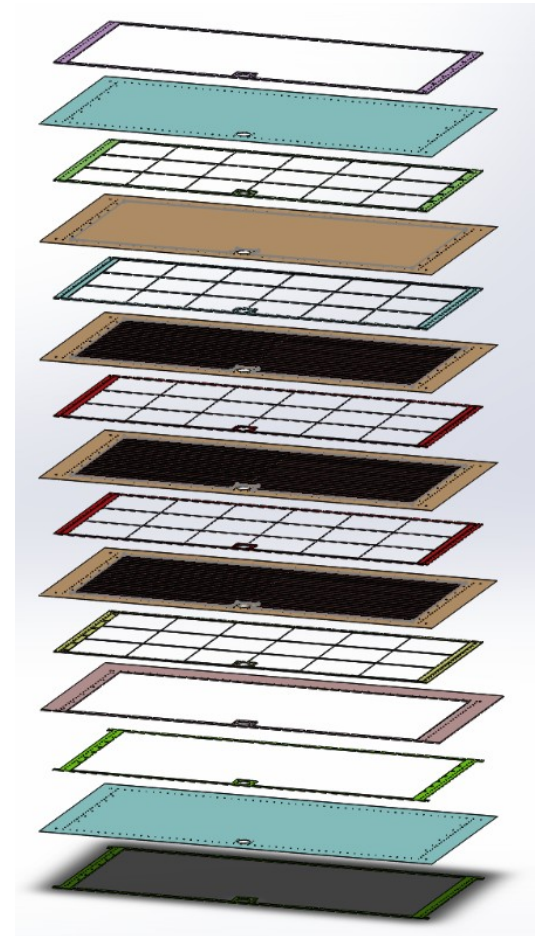
- Actual sensitive area: $120 \times 102.6 \text{ cm}^2$
- Actual non-sensitive area: $7.4 \times 7.4 \text{ cm}^2$

PRad GEM Detector



The World's Largest GEM Chambers

Triple GEM Detector

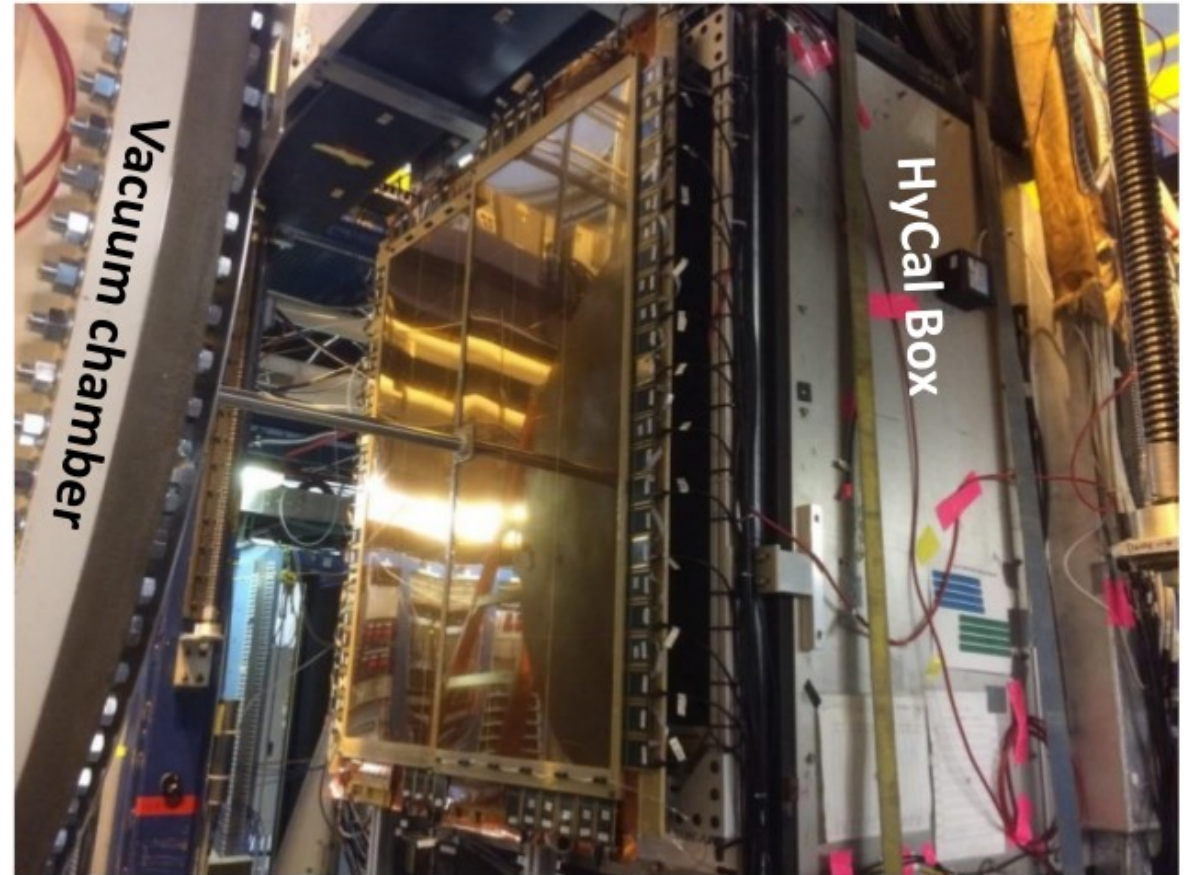
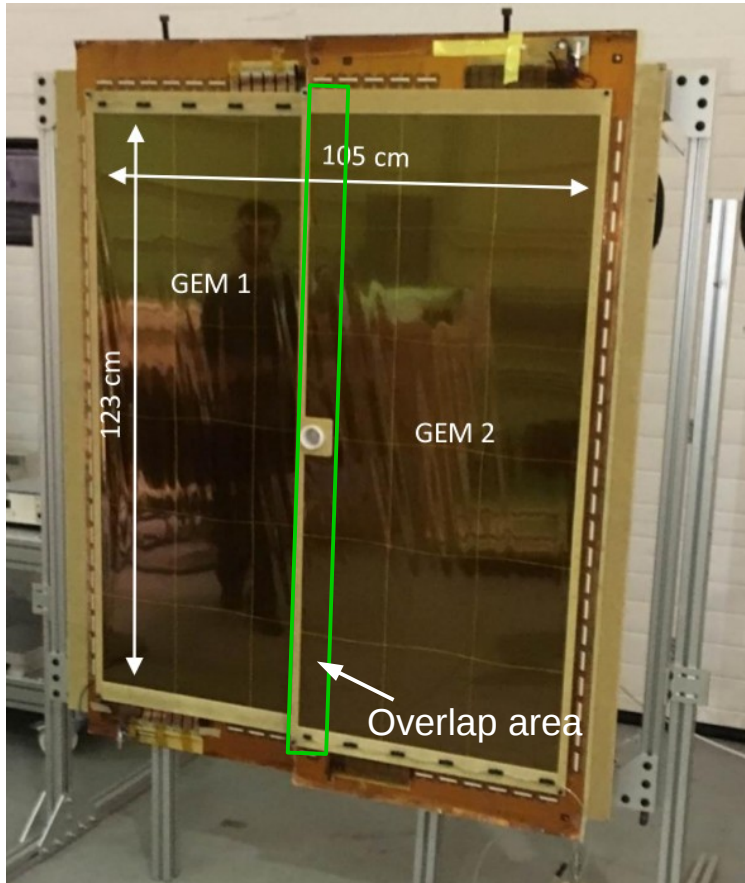


Challenges encountered:

- Large area, difficult to keep the space between each gem foil to be 2mm.
- Longer Strips, higher noise level.
- Biggest foil ever made.

PRad GEM Construction

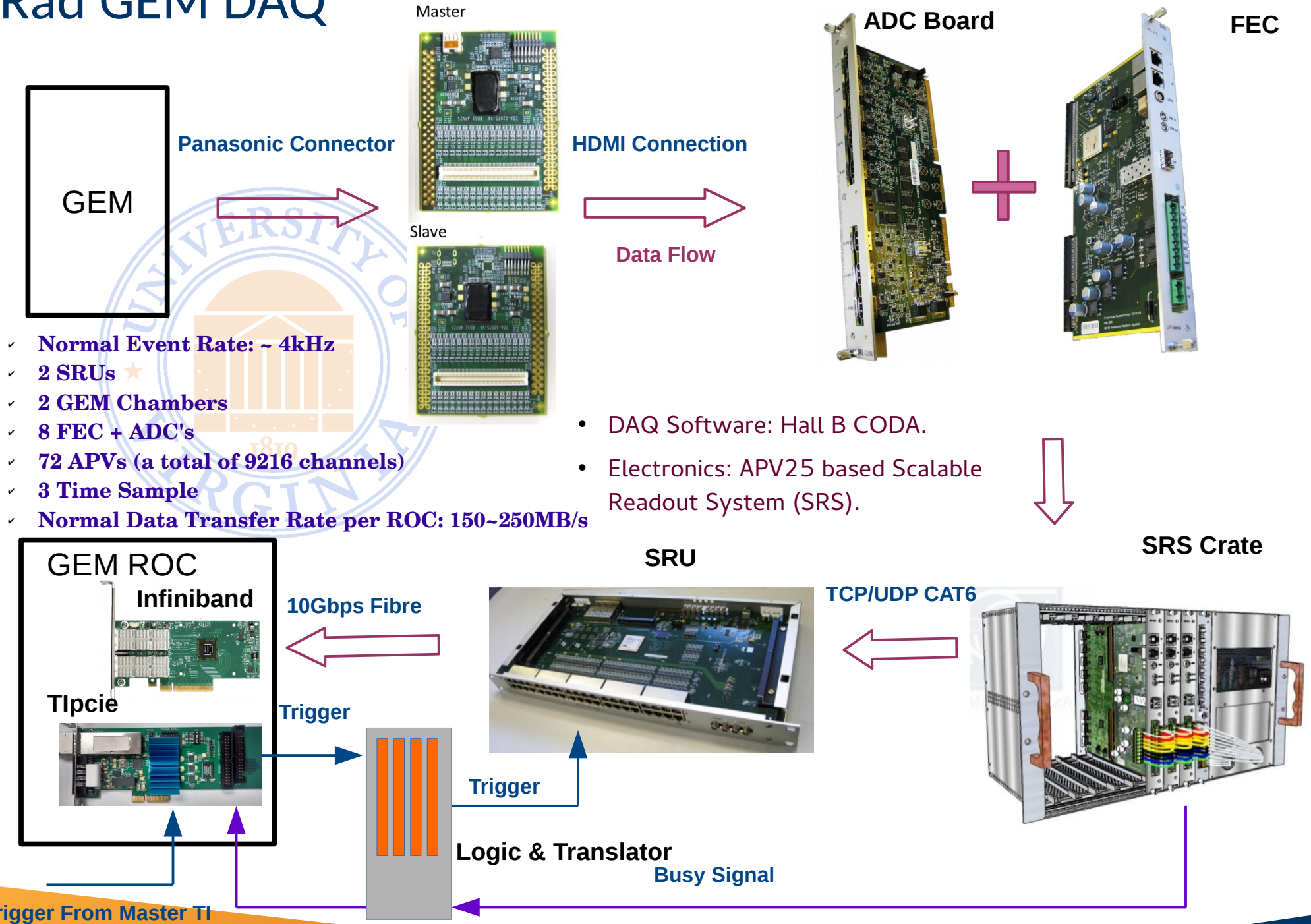
- Design and Constructed at UVa in 2015.
- Installed in Hall B beam line at JLab in 2016.



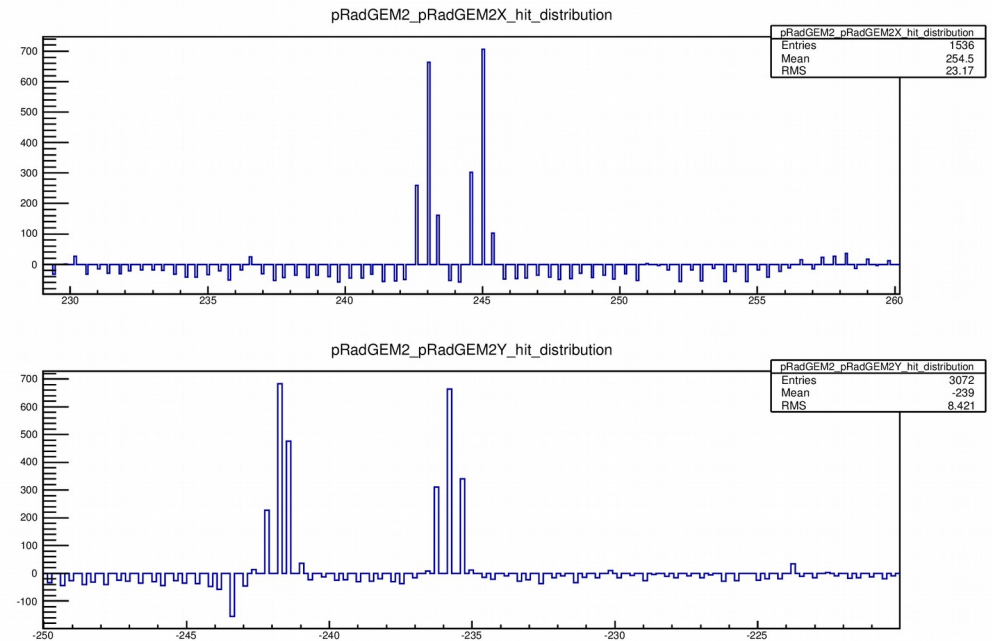
Two chambers, Overlap in the central part.
With a Central opening hole for beam.

Chamber mounted on HyCal in Hall B

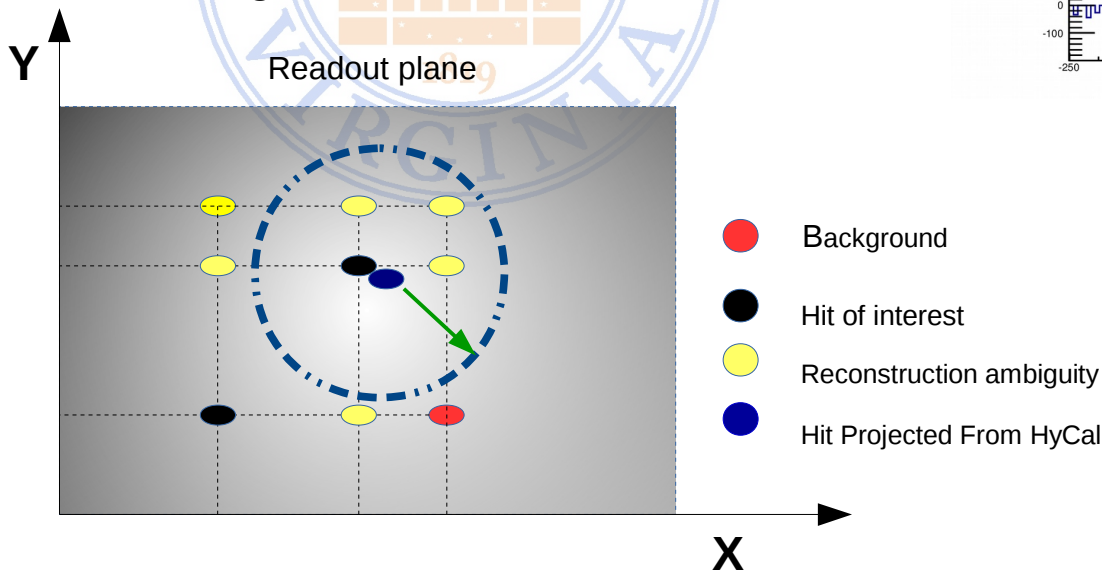
PRad GEM DAQ



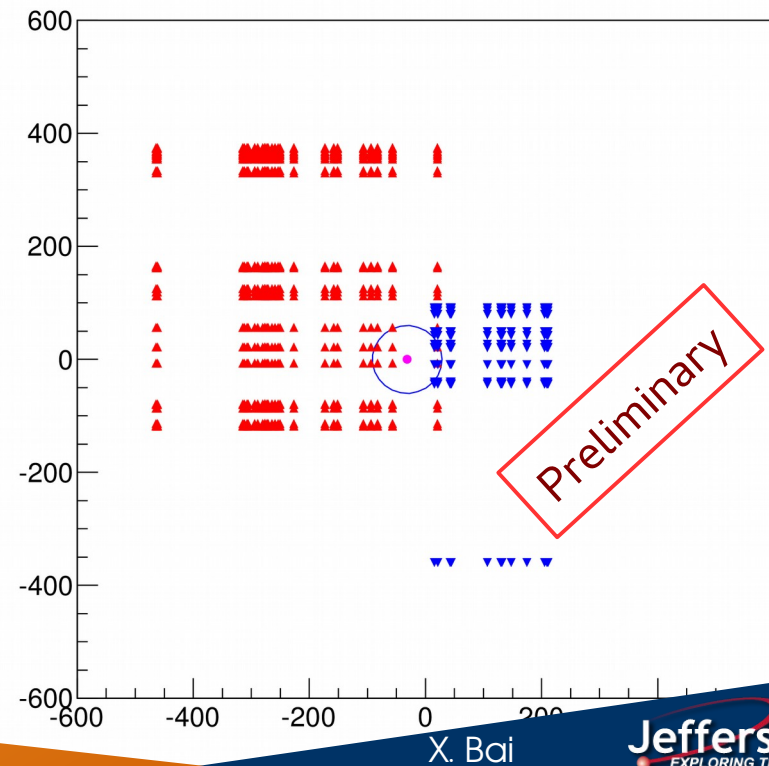
One typical event from GEM Detector



- Mostly Relativistic Electrons.
- Minimum Ionization Particles (MIP).
- Only one layer of GEM detectors, no tracking
- No timing information.
- Challenge to match X-Y clusters.
- A totally new, experiment-dependent clustering method.



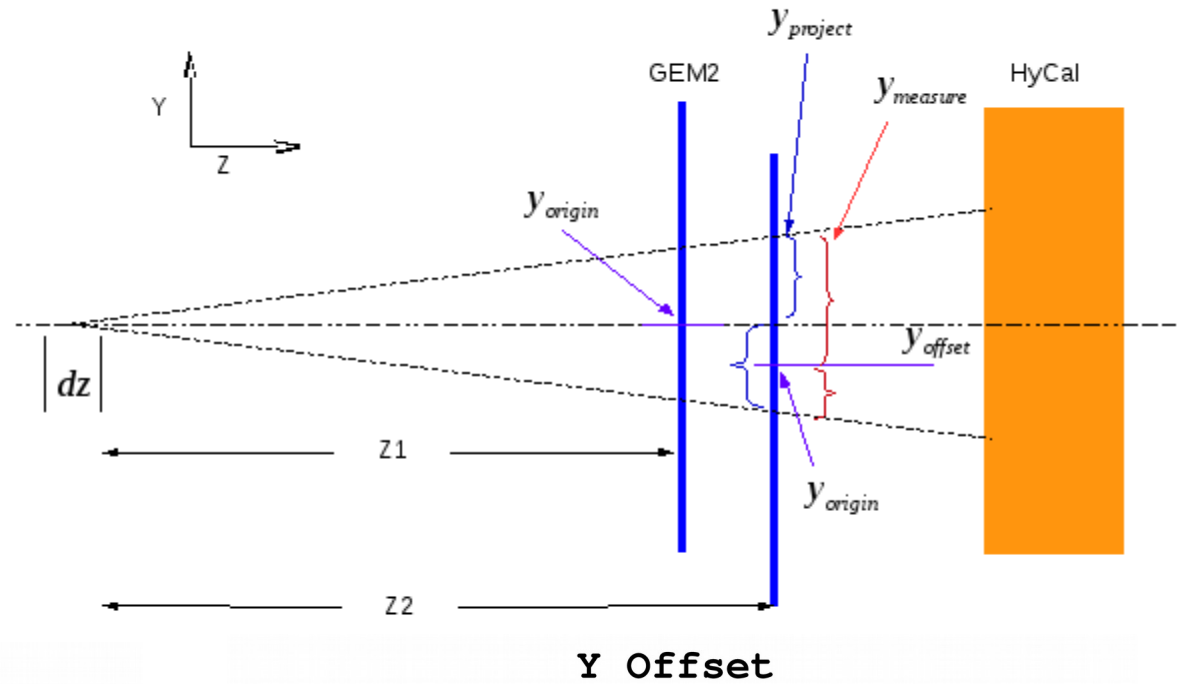
Use HyCal Information to Filter GEM Clusters



Detector Alignment

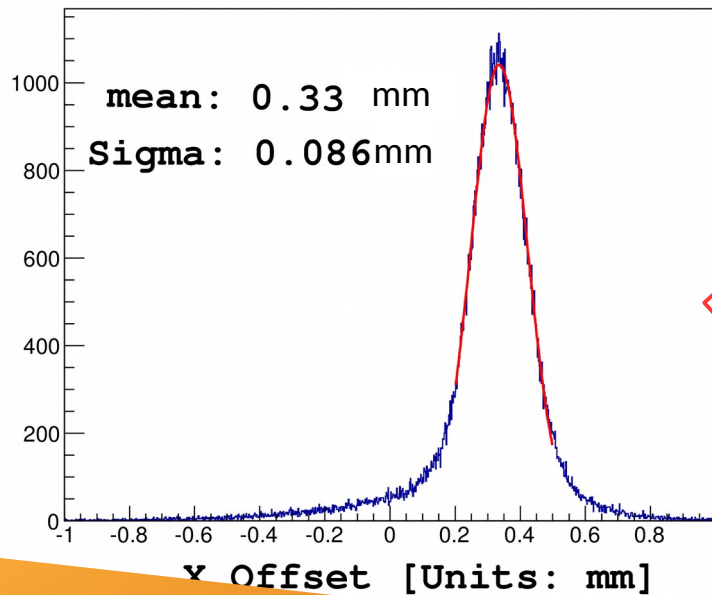
X-Y Offset:

- Using overlapping area events.
- Project GEM1 Coordinates to GEM2.
- Take the difference of projected value and measured value.

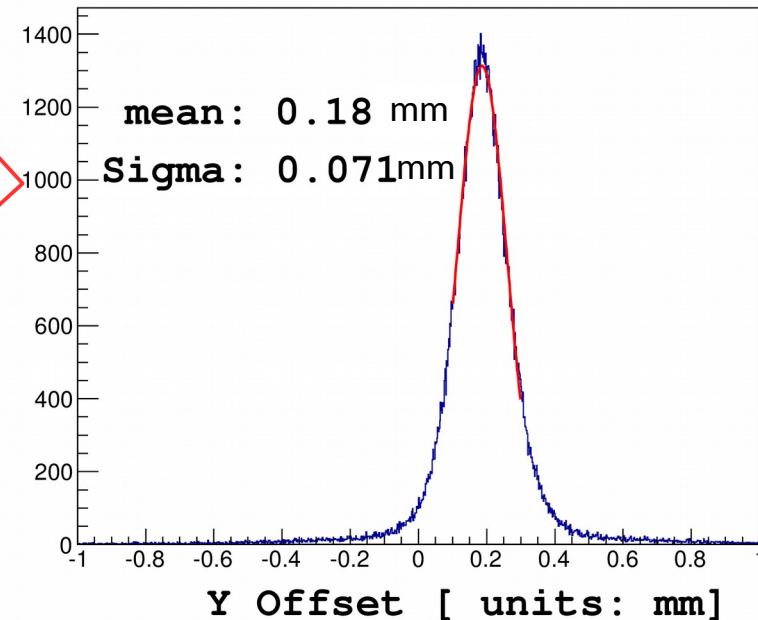


X Offset

Y Offset

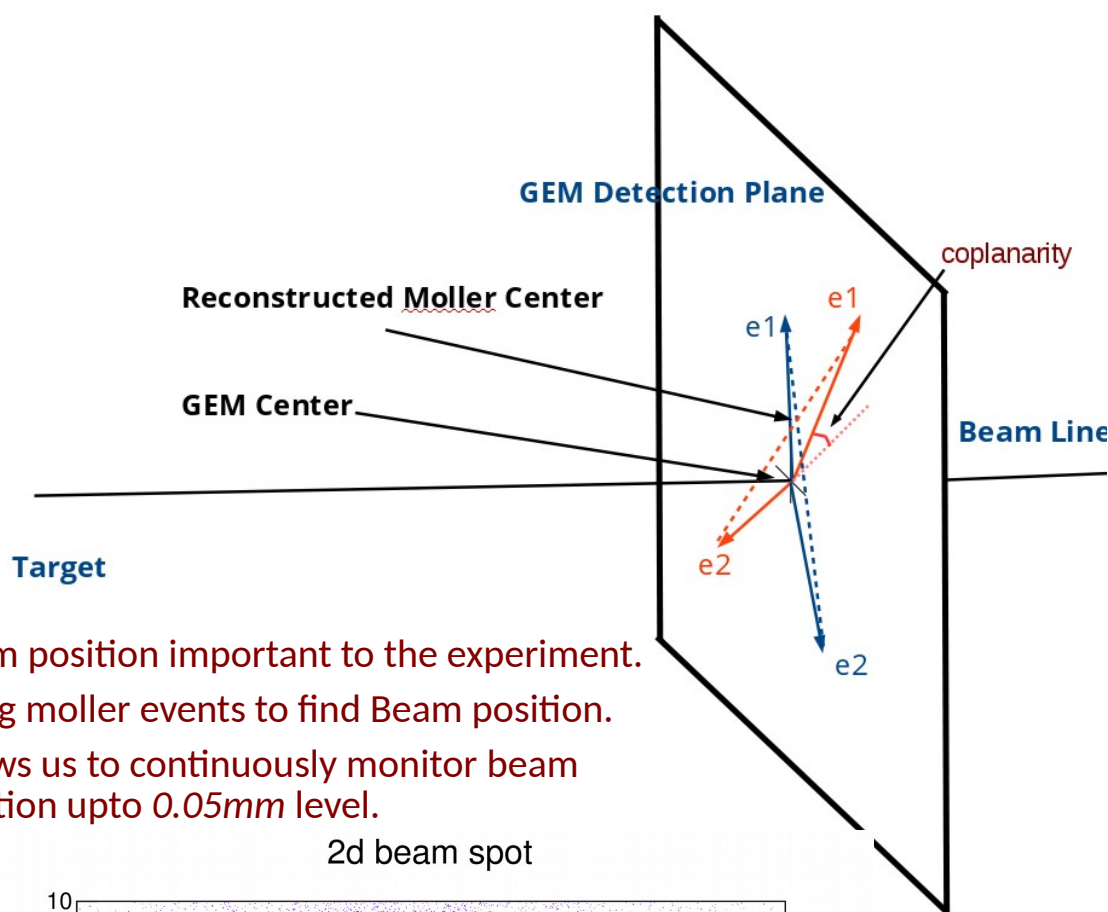
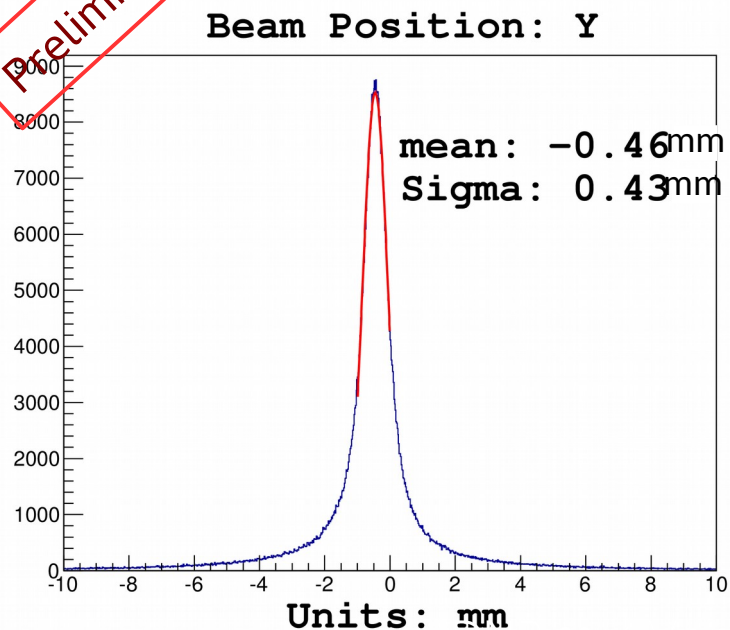
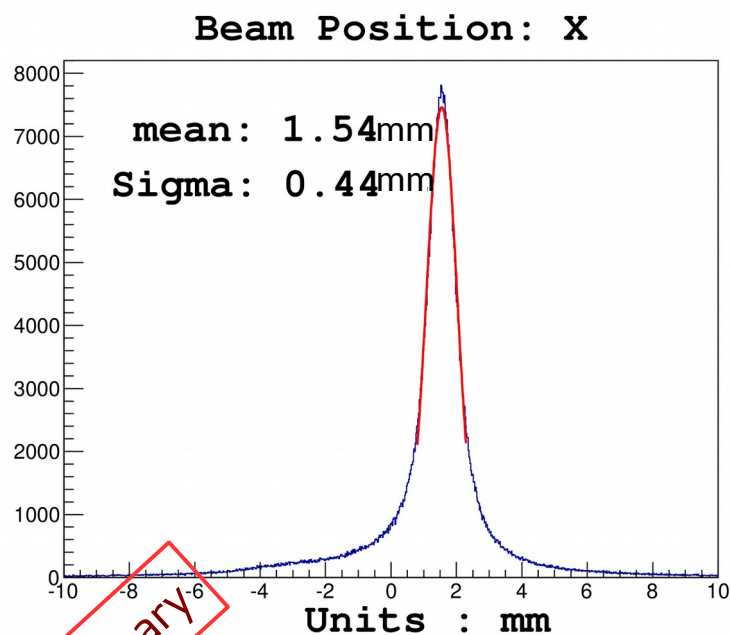


Preliminary

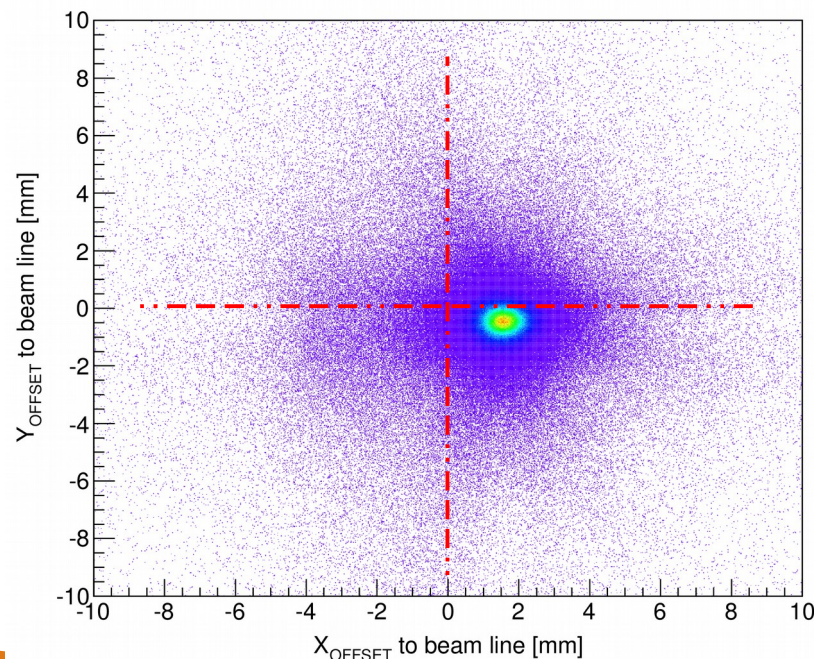


Detector Alignment

Reconstructed Beam Spot:



- Beam position important to the experiment.
- Using moller events to find Beam position.
- Allows us to continuously monitor beam position upto 0.05mm level.



Resolution

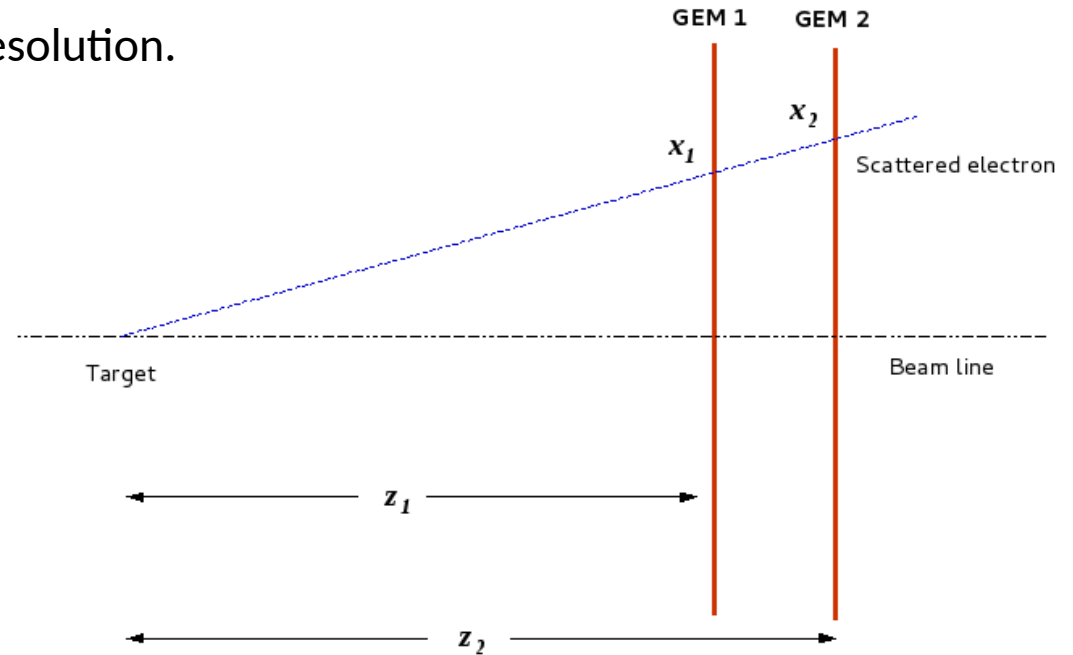
Using overlapping area e-p events to check resolution.

Procedures to Check Spatial Resolution:

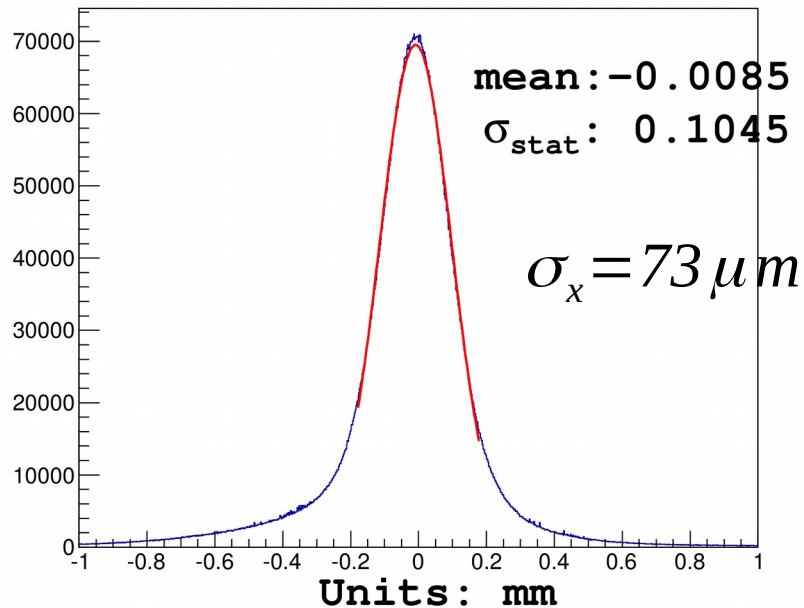
- Correct offsets.
- Project GEM1 coordinates to GEM2.
- Find statistical width.
- Assume two chambers have the same resolution:

$$\sqrt{\sigma_{gem1}^2 + \sigma_{gem2}^2} = \sigma_{stat}$$

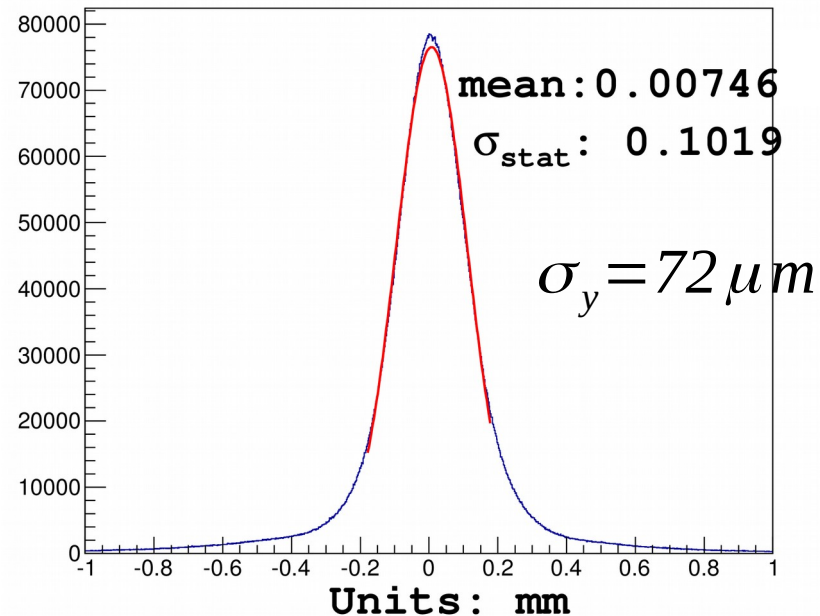
$$\sigma_{gem} = \sigma_{stat} / \sqrt{2}$$



Resolution: X



Resolution: Y



Efficiency From Production Data

Efficiency from e-p events:

- 1), Select e-p events from HyCal.
- 2), Match gem Clusters.
- 3), # GEM cluster / # HyCal cluster.

Efficiency from Moller events:

- 1), Select moller events from HyCal.
- 2), Match gem Clusters.
- 3), # GEM cluster / # HyCal cluster.

Efficiency Preliminary Results:

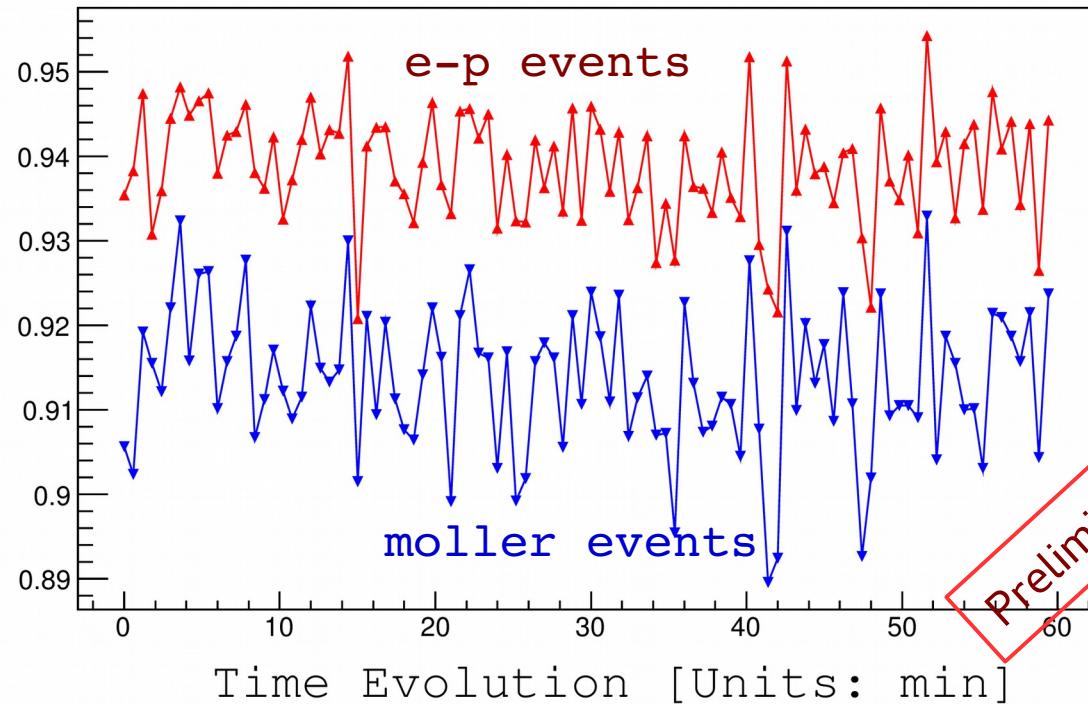
E-p: 92.0% $\pm 0.03\%$

Moller: 91.4% $\pm 0.03\%$

Moller events covering a larger detection area, includes more dead area. Has slightly lower efficiency.

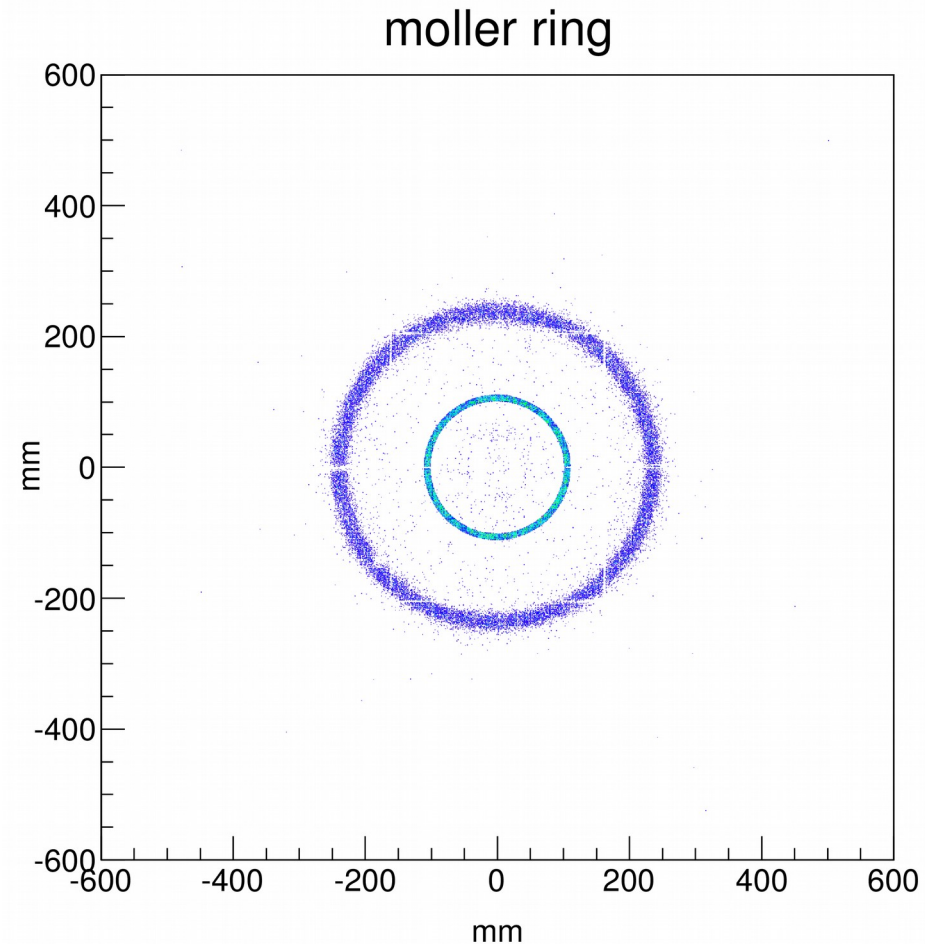
Dead Area Not yet Excluded, Efficiency can be higher.

Efficiency Stability



Performance

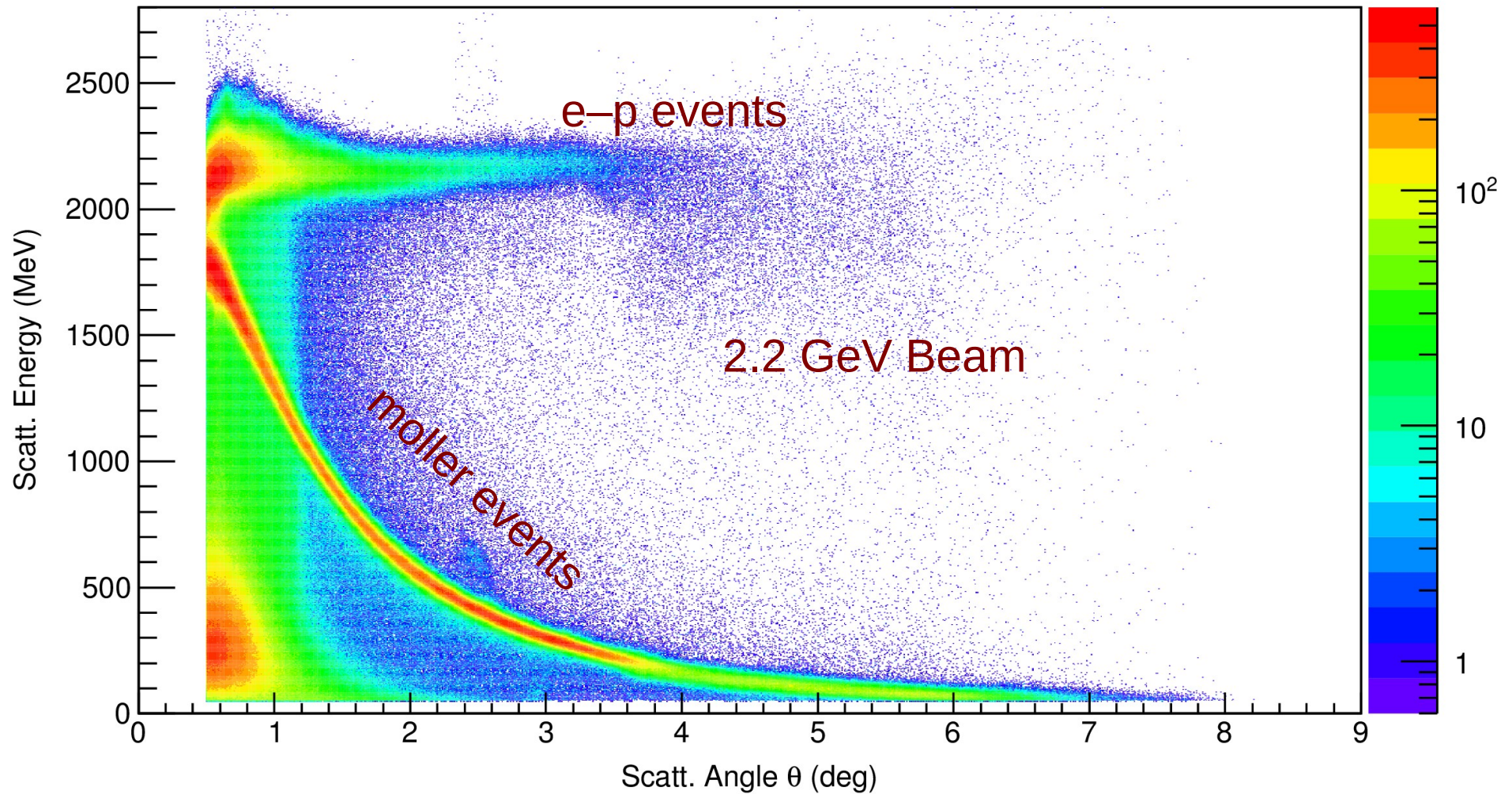
- Use two-cluster Events (Moller Events).
- Inner scattering angle cut: $1.0\text{deg} \sim 1.1\text{ deg}$



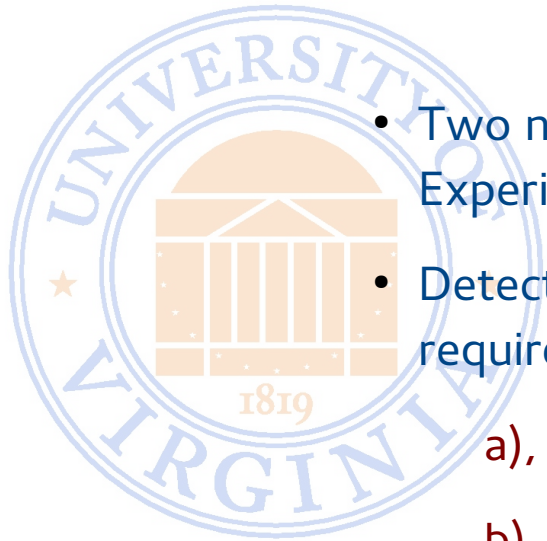
Moller Ring From GEMs

Performance

Scatt. Energy vs Scatt. Angle



Summary



- Two new large GEM detectors built for PRad Experiment to improve space resolution.
- Detector performed well, delivered designed requirements
 - a), High Position Resolution achieved.
 - b), very stable, and uniformly distributed efficiency.
- World's largest GEM detectors.
- Data Analysis in Progress

This work was supported in part by NSF MRI award PHY-1229153, the U.S. Department of Energy Under Contract No. DE-FG02-03ER41231, No. DE-FG02-03ER41240 and Thomas Jefferson National Laboratory.



Backup Slides

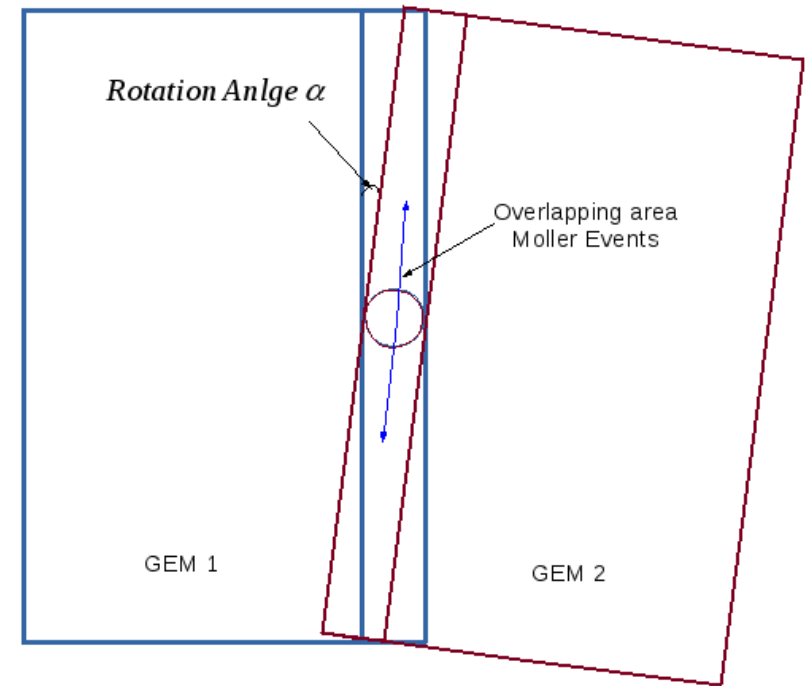
Detector Alignment

Two Offsets:

- 1), Relative Rotation Between Two GEM chambers.
- 2), X-Y Offsets Between Two Chambers.

Angular Offset:

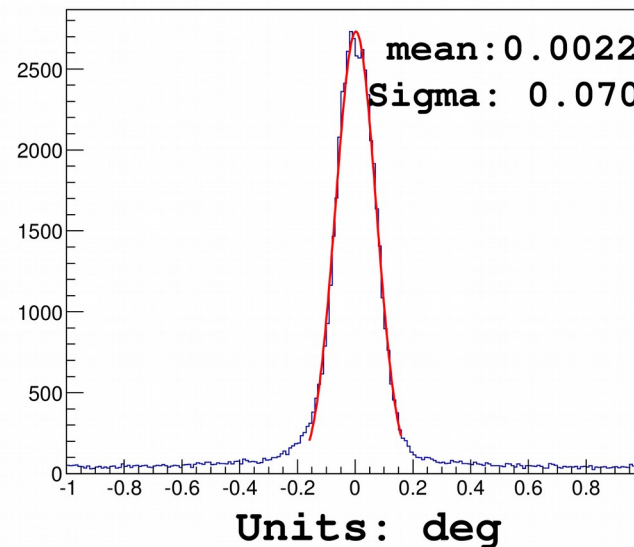
- Select moller events in the overlapping area.
- Connect the two electrons.
- On each chamber find the angle between the electron line and GEM axis.
- Get difference for rotation angle.



Angular Offset

Using overlapping area moller events to find relative rotation between two gems.

Value: ~ 0.0022 deg.
negligible

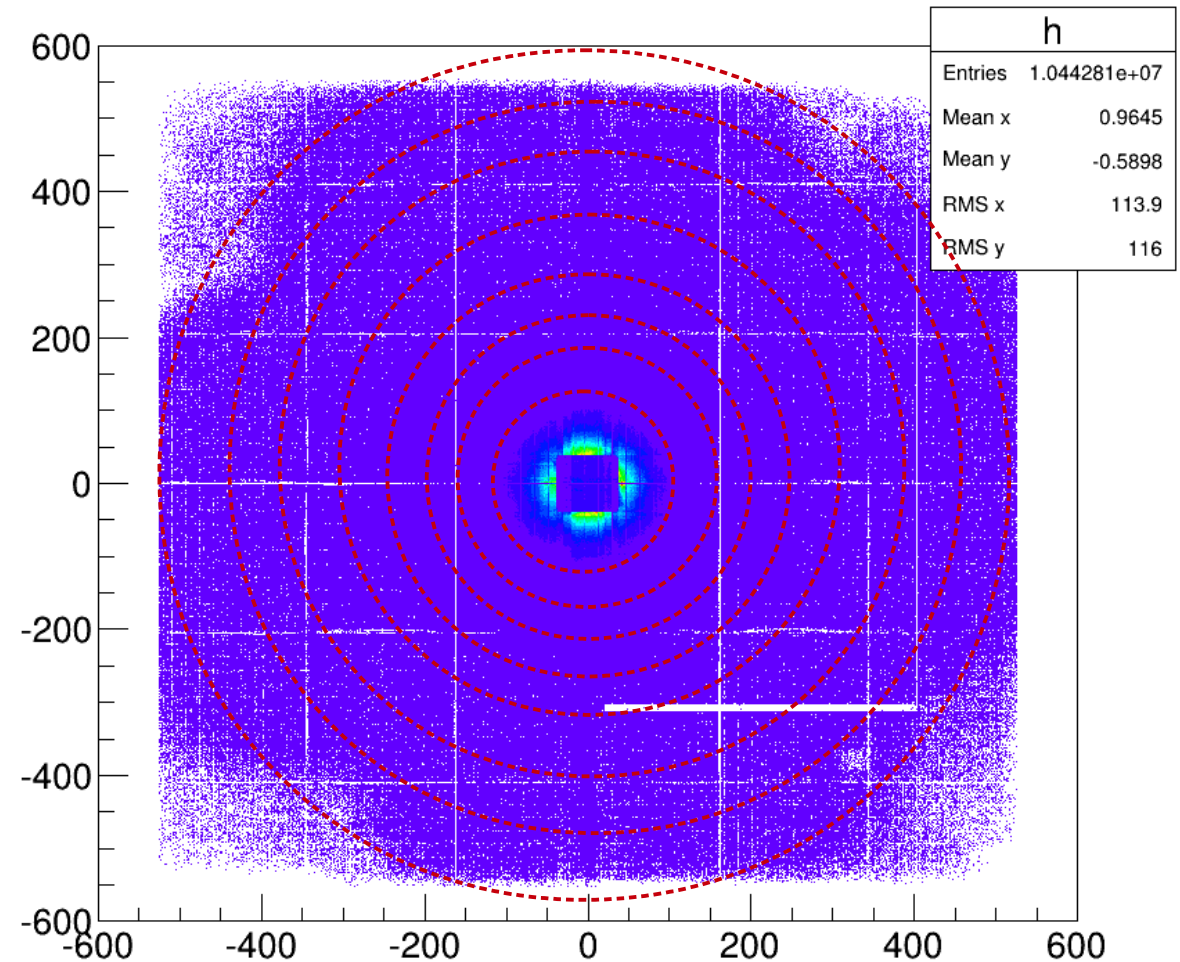


Efficiency

Using preliminary e-p + Moller events. Efficiency relative to hycal. Clusters Filtered by HyCal.

gem_hit_y:gem_hit_x

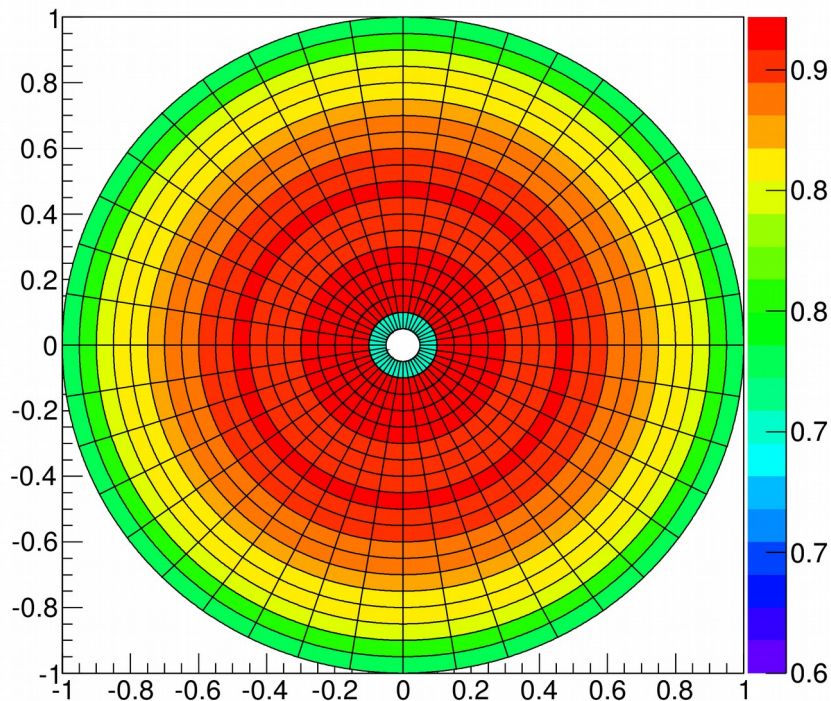
- Divide GEM Plane into 20 rings. (ring radius difference: 30mm).
- Estimate Efficiency for each ring.



A Qualitative plot showing Efficiency Along Radius

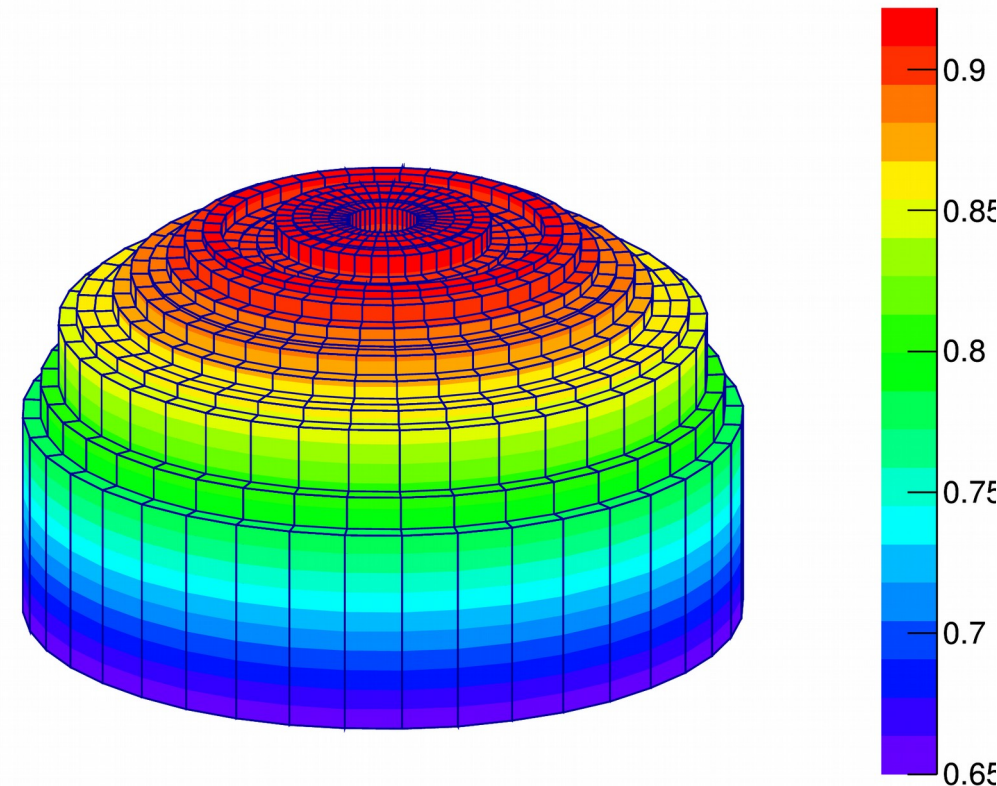
Using preliminary e-p + Moller events. Efficiency relative to hycal. Clusters Filtered by HyCal.

efficiency along radius



Units R/600mm

efficiency along radius



Dead Area Not yet Excluded

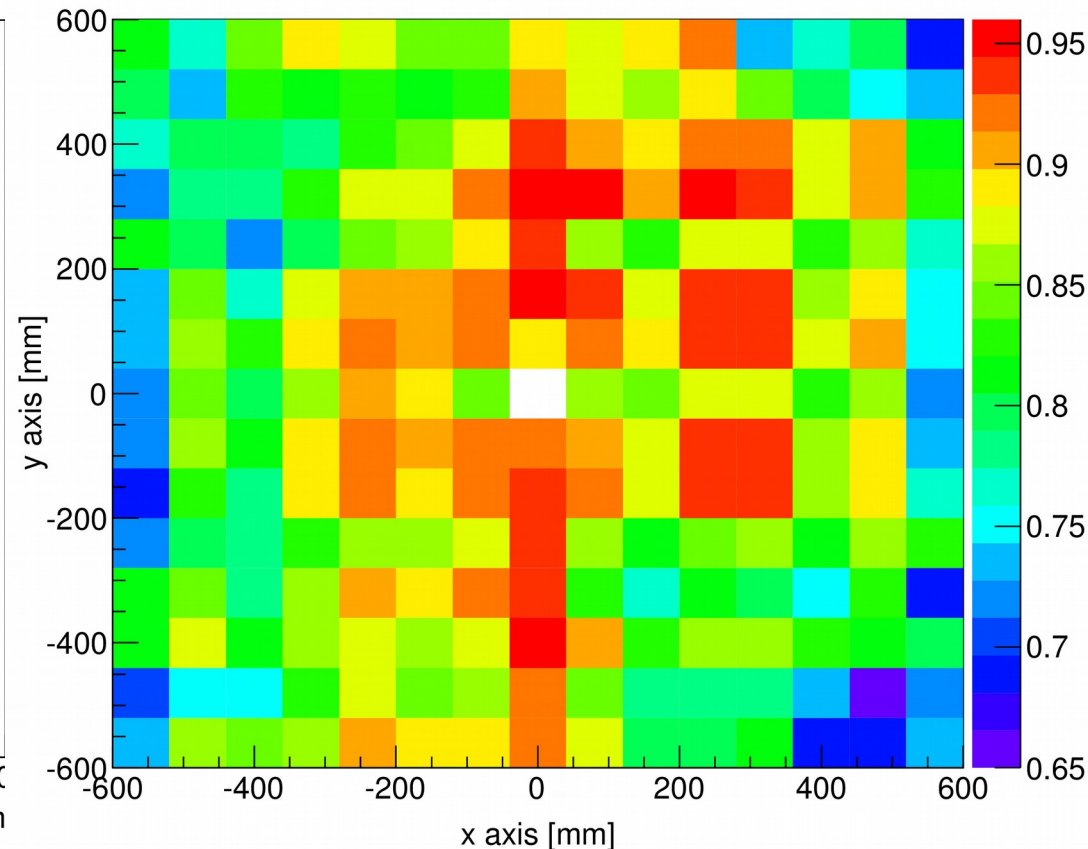
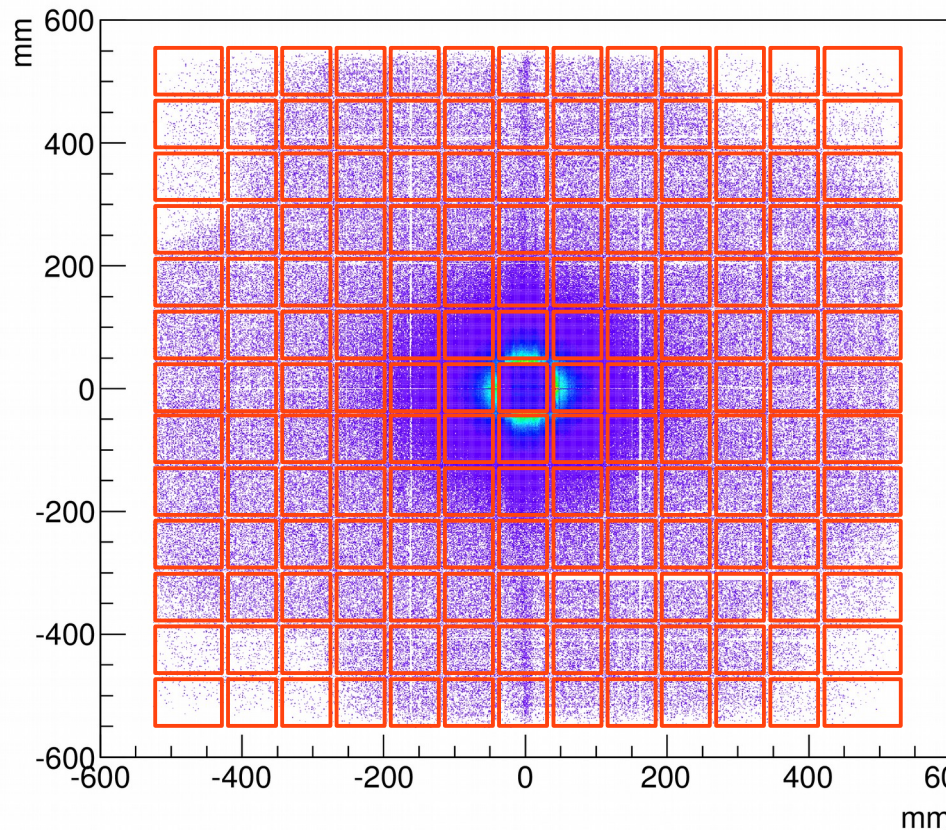
Efficiency by Sectors

Using preliminary e-p + Moller events. Efficiency relative to hycal. Clusters Filtered by HyCal.

- Divide GEM Plane into 225 sectors (sector size: 72mm by 72mm).
- Estimate Efficiency for each sector.

A Qualitative Plot showing efficiency by sectors.

gem efficiency map



Dead Area Not yet Excluded

DNP 2016 Vancouver

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