GEM Detectors for Proton Charge Radius (PRad) Experiment

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for PRad Collaboration

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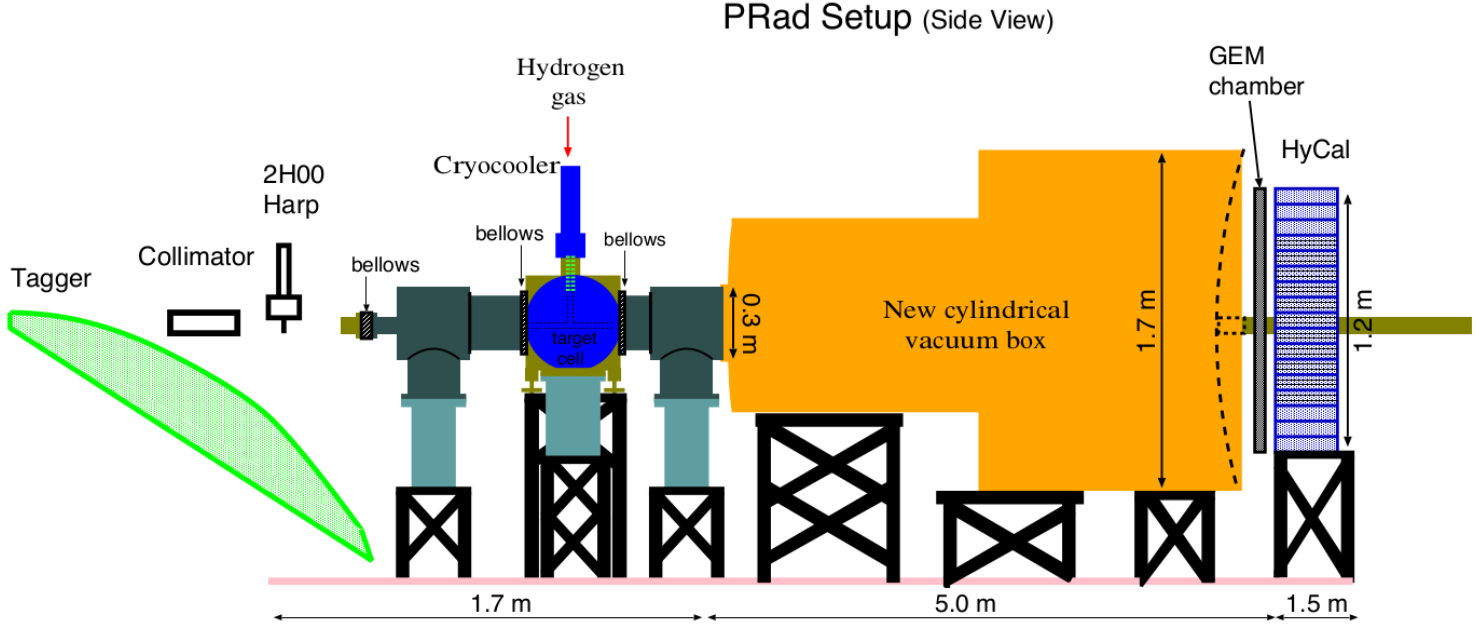
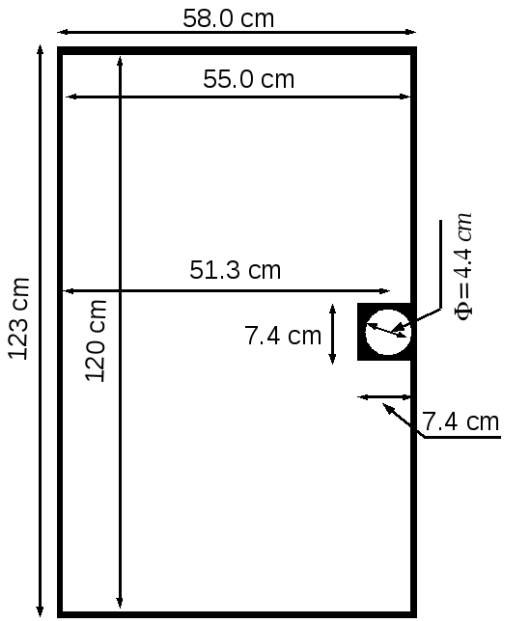
PRad Experimental Setup



- PRad Experiment designed to measure proton charge radius with sub-percent precision, to address 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

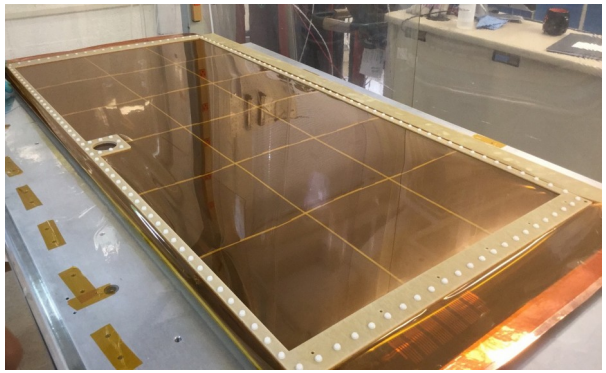
- Desired Sensitive Area: 116.4 x 116.4 cm^2
- Central Hole: diameter 4.4cm, including the frame max allowed
- Maximum allowable non-sensitive region 7.8 x 7.8 cm^2



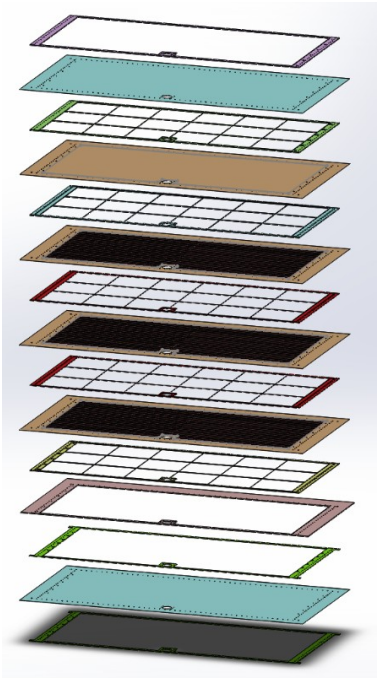
The World's largest GEM chambers

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

PRad GEM Detector in UVa clean room



Triple GEM Detector

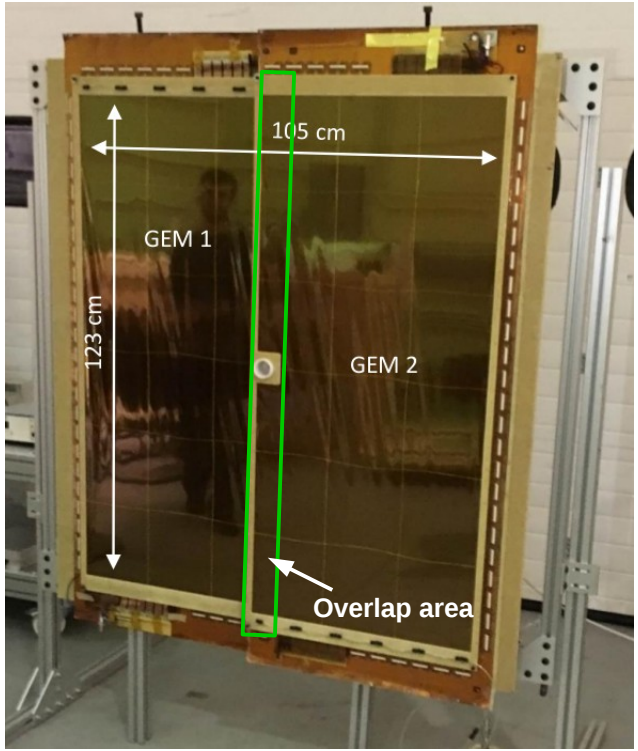


Challenges encountered:

- 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

- Designed and constructed at UVa in 2015.
- Installed in Hall B beam line at JLab in 2016.



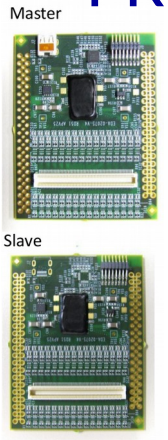
Two chambers, overlap in the central part. with a central opening hole for beam.

Chamber mounted on HyCal in Hall B

PRad GEM DAQ

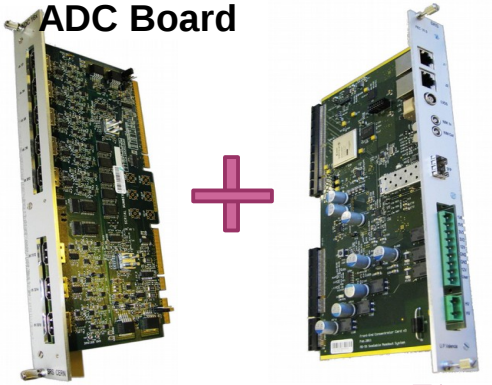
GEM

Panasonic Connector



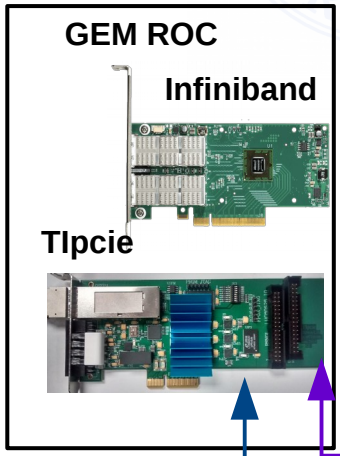
HDMI Connection

Data Flow



- Normal event rate: ~ 4kHz
- 2 SRUs for 2 GEM chambers
- 8 FEC + ADC's
- 72 APVs (a total of 9216 channels)
- 3 time sample
- Normal data transfer rate per ROC: 150~250MB/s

- DAQ software: Hall B CODA.
- Electronics: APV25 based Scalable Readout System (SRS).

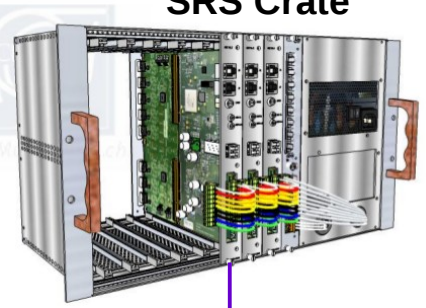


10Gbps Fibre

SRU

TCP/UDP CAT6

SRS Crate



Trigger

Trigger

Busy

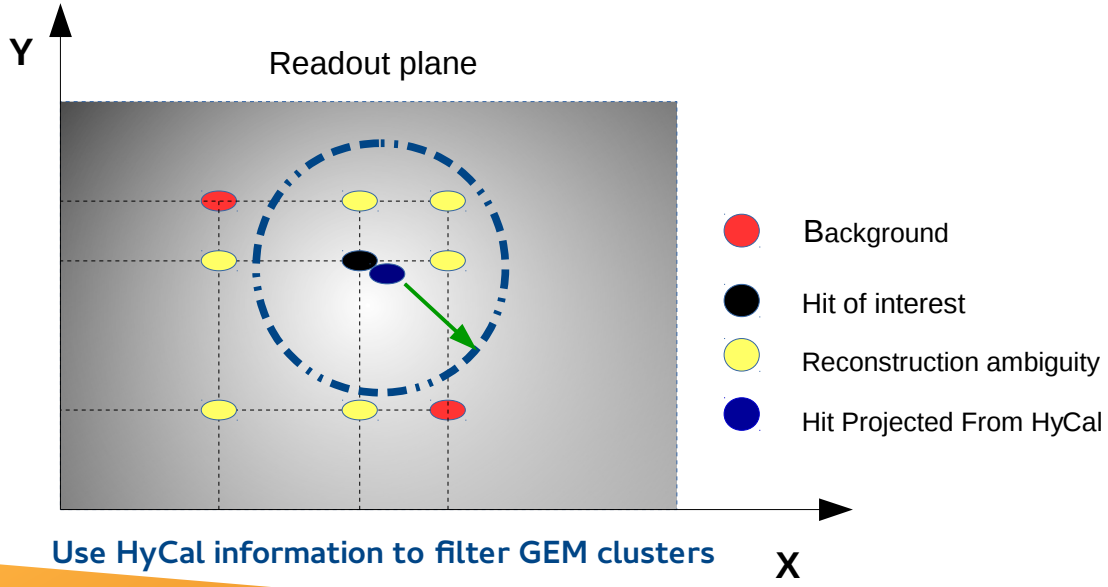
Busy Signal

Trigger From Master TI

Logic & Translator

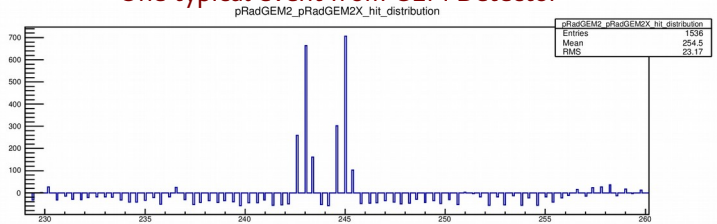
Cluster Reconstruction

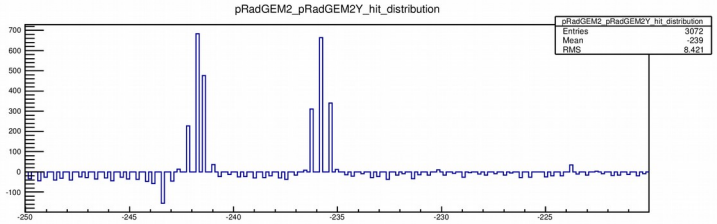
- Mostly relativistic electrons.
- Minimum Ionization Particles (MIP).
- Only one layer of GEM detectors, no tracking.
- No timing information.
- Challenge to match X-Y clusters.
- An experiment-dependent clustering method.

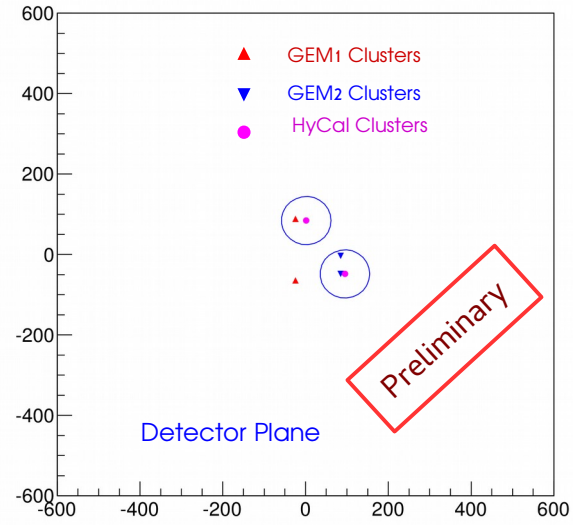


Use HyCal information to filter GEM clusters

One typical event from GEM Detector



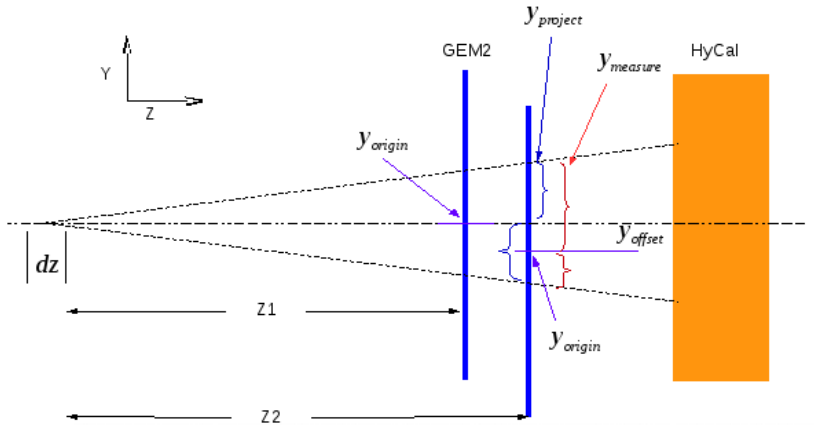


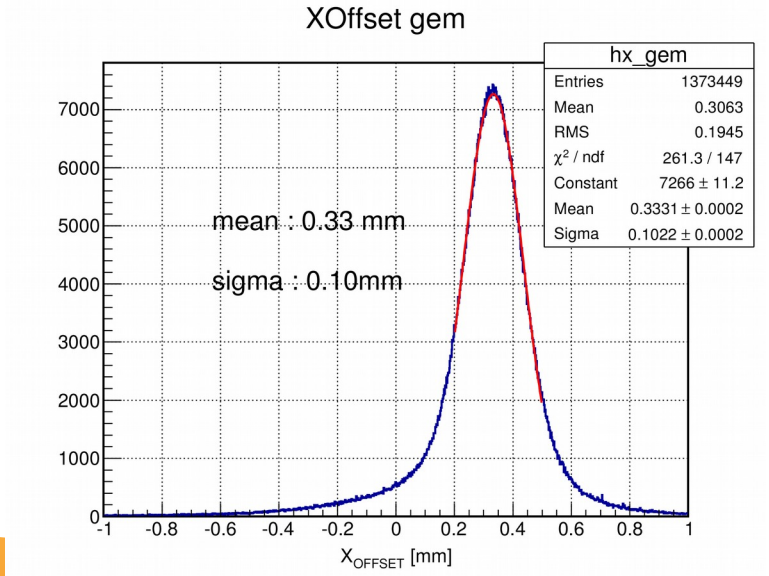


Detector Alignment

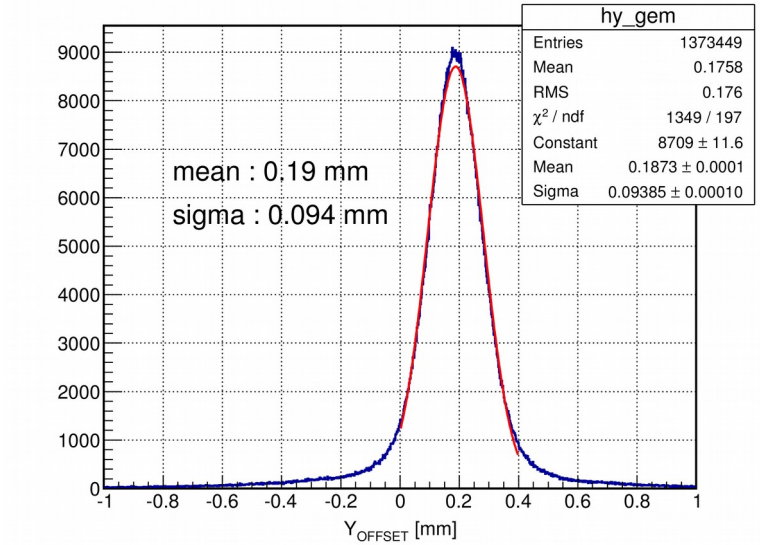
X-Y Offset:

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

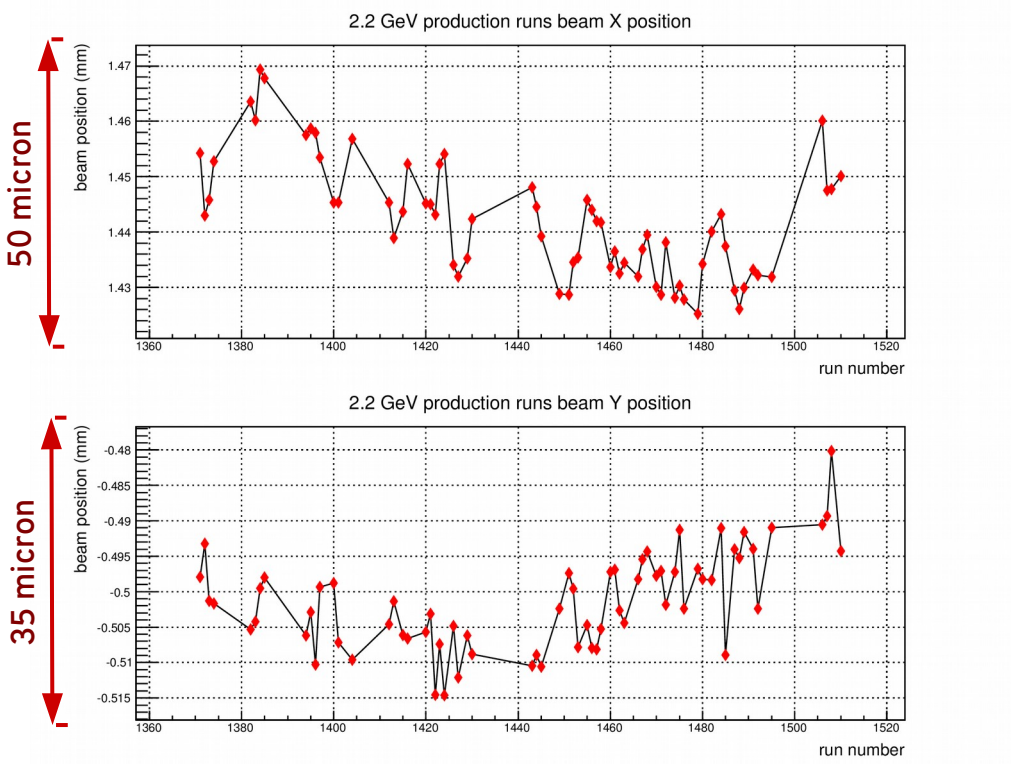




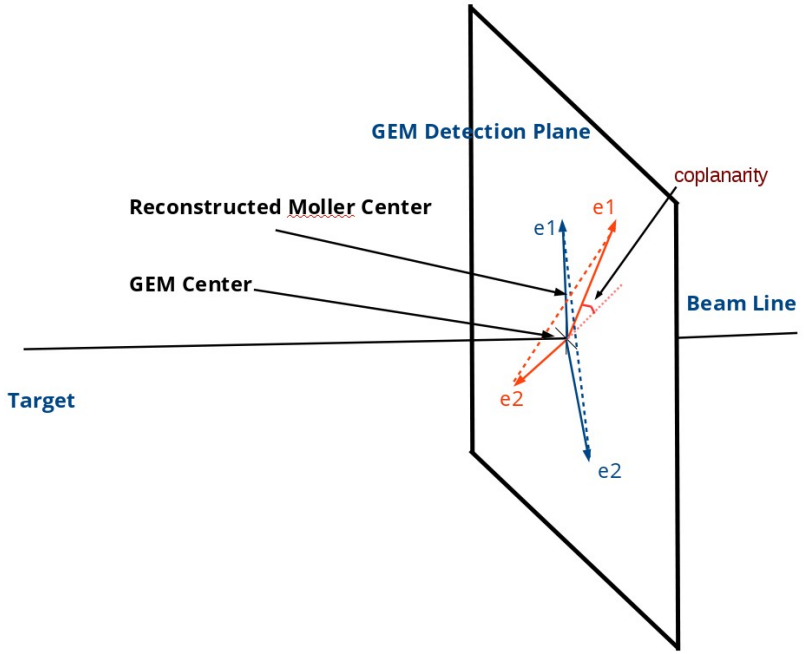
Preliminary



Beam position monitoring by GEM



Beam position monitored by GEM detectors in different runs



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

Detector Resolution

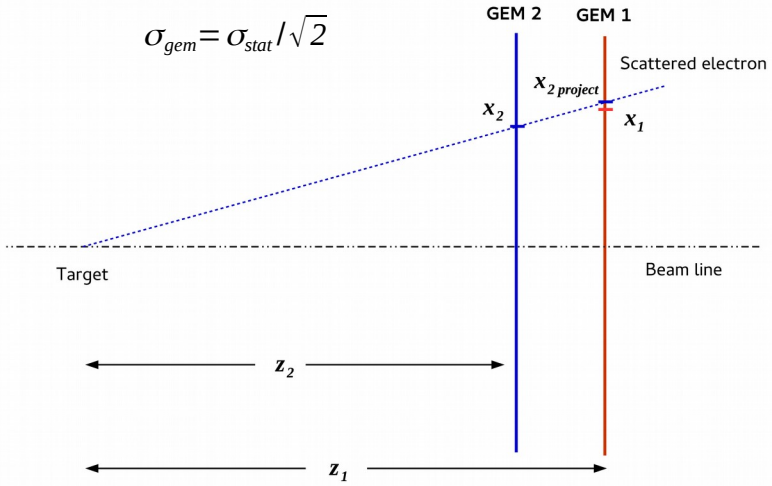
Using overlapping area e-p events to check resolution.

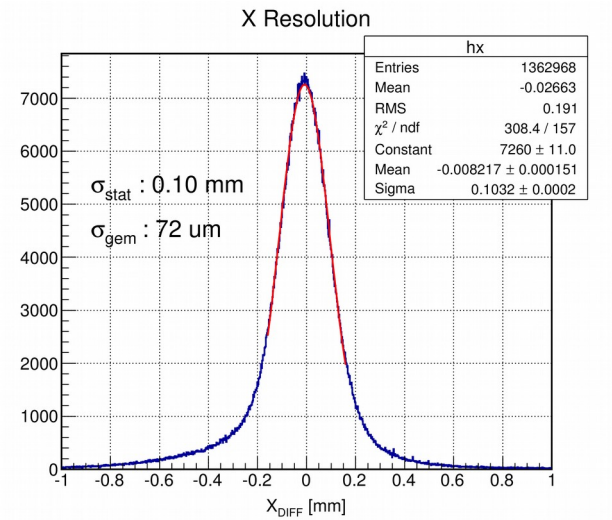
Procedures to check spatial resolution:

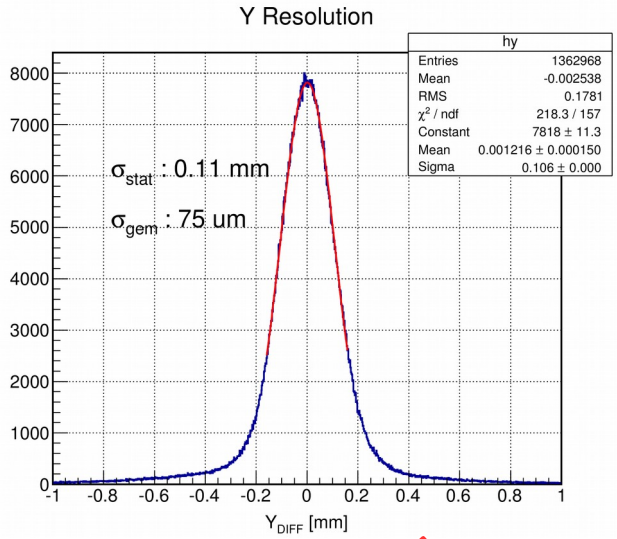
- Correct offsets.
- Project GEM1 coordinates to GEM2.
- Find statistical width.
- Assume two chambers have the same resolution:

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

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







GEM resolution

Preliminary

Detection Efficiency

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:

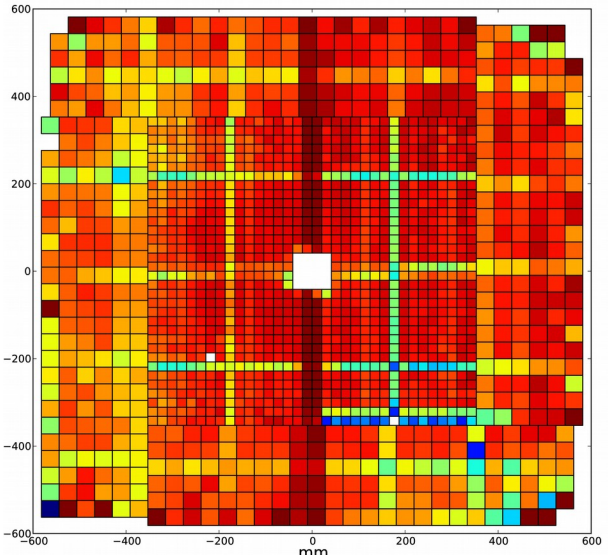
1), Select moller events from HyCal.
2), Match gem clusters.
3), # GEM cluster / # HyCal cluster.

Preliminary average efficiency:

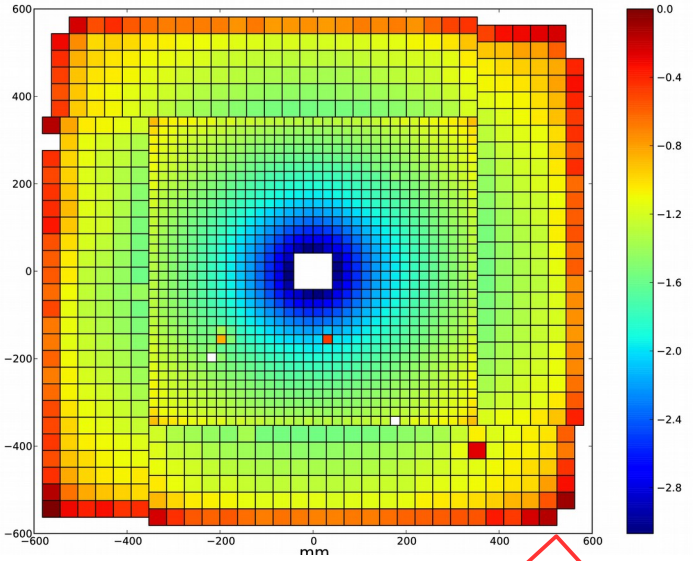
E-p: 92.4% +/- 0.03%

- Dead area not excluded.
- Expected to be even better after finer calibration from both HyCal and GEM.

GEM efficiency map



GEM efficiency statistical error map (log scale)



Preliminary

GEM efficiency in each sector
from 2.2 GeV ep events

GEM detection plane was divided into small square sectors,
Estimate efficiency for each sector area.

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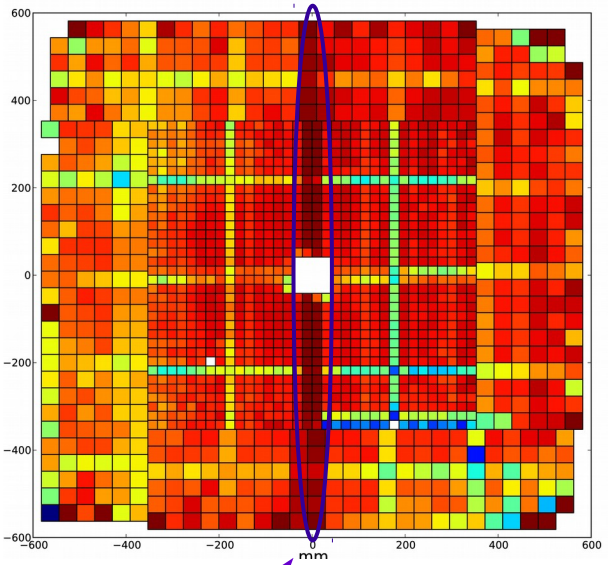
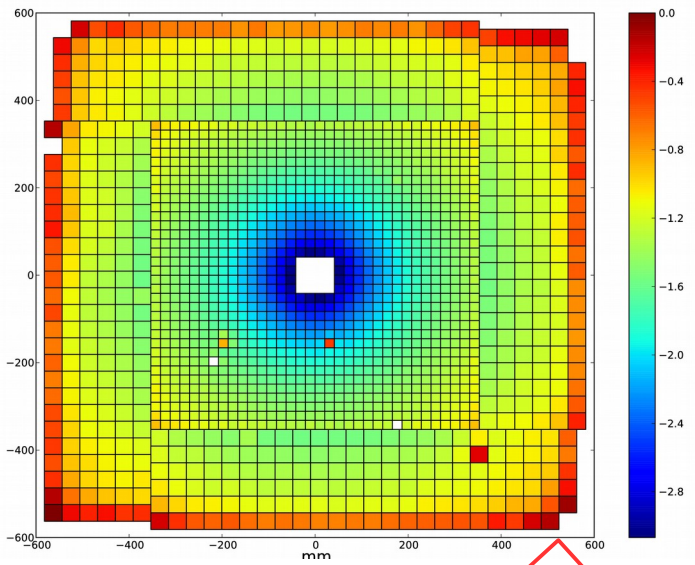


Overlapped area

GEM efficiency statistical error map (log scale)



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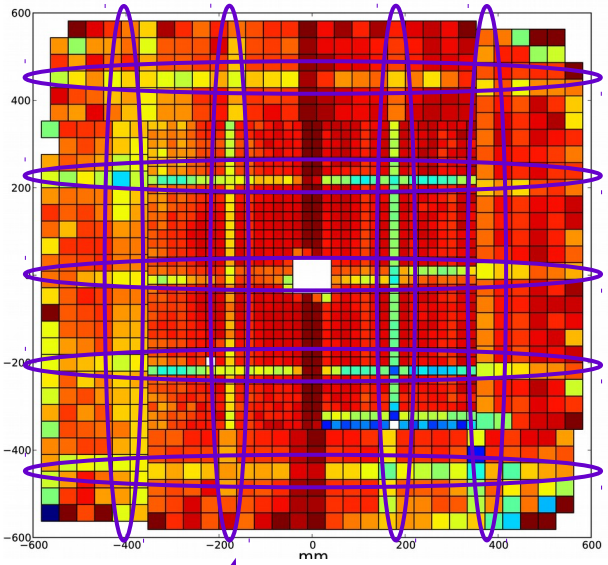
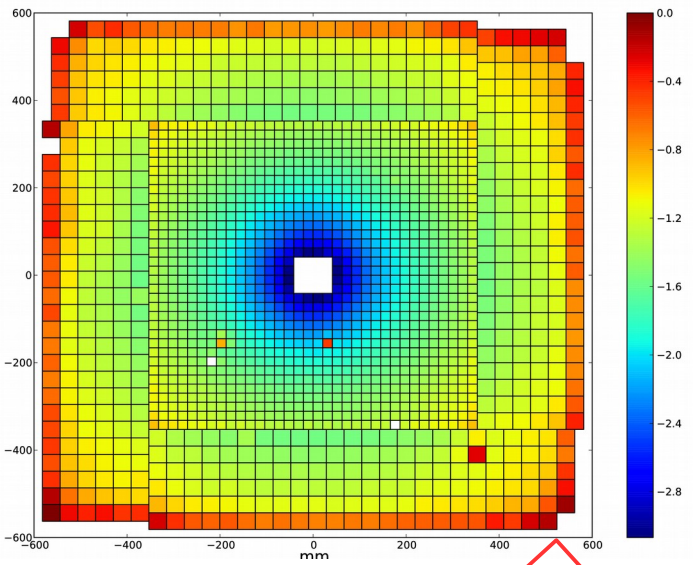


GEM efficiency statistical error map (log scale)



Spacer areas

GEM efficiency in each sector from 2.2 GeV ep events

Preliminary

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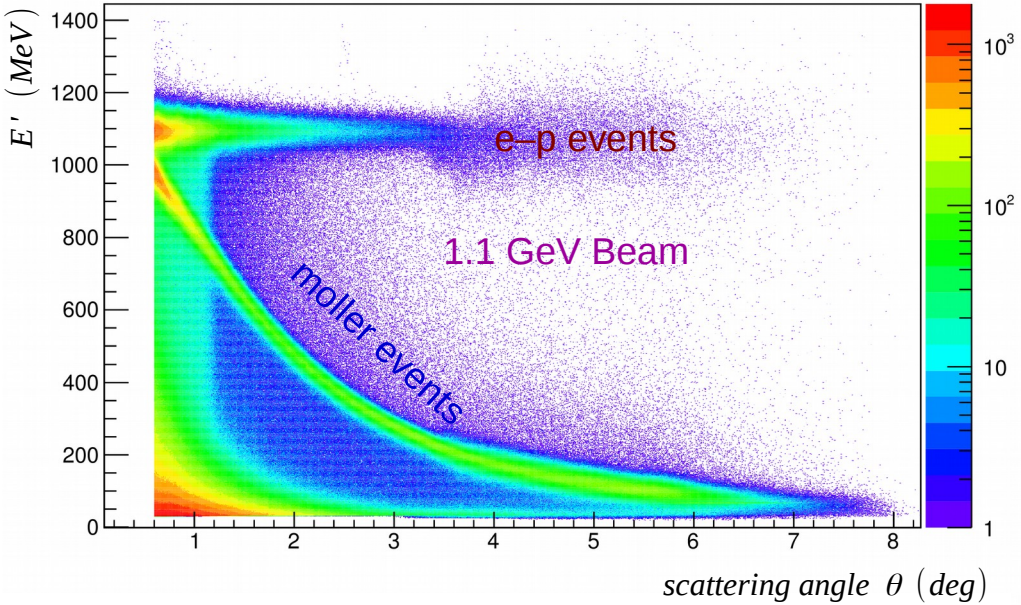
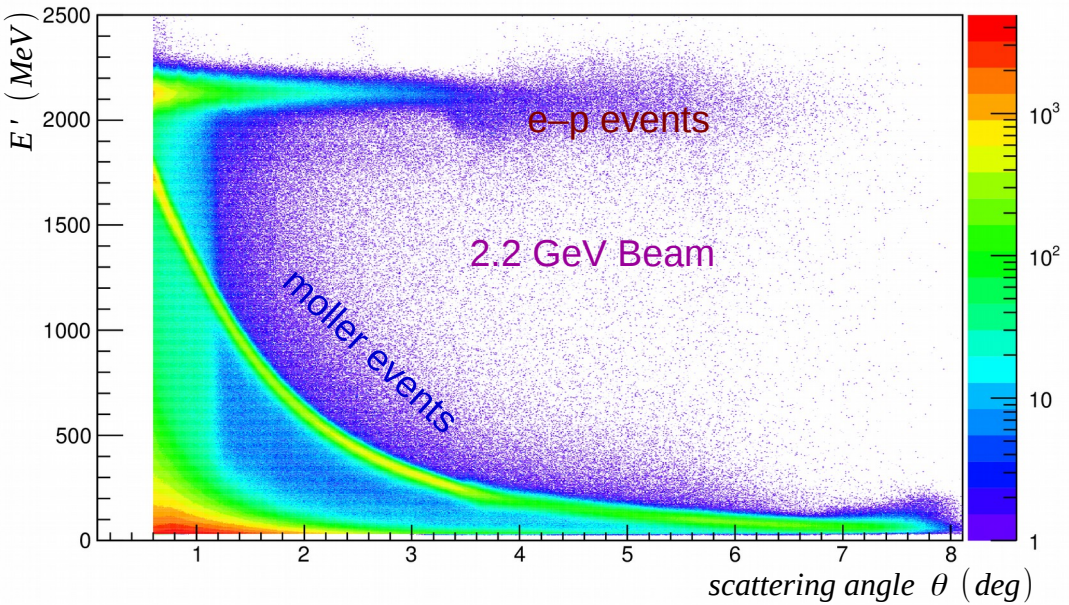
Estimate efficiency for each sector area.

Performance

scattering energy E' vs scattering angle θ





- Coordinates from GEM detectors
- Cluster energy from Calorimeter.

Summary

- Two new large area GEM detectors built for PRad experiment to significantly enhance spatial resolution.
- Detector performed well, delivered designed requirements

  a), High position resolution achieved.

  b), High average efficiency, stable with time.
- World's largest GEM detectors.
- Data analysis in progress .....

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