GEM Analysis & Detector Status

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What is gemControl?

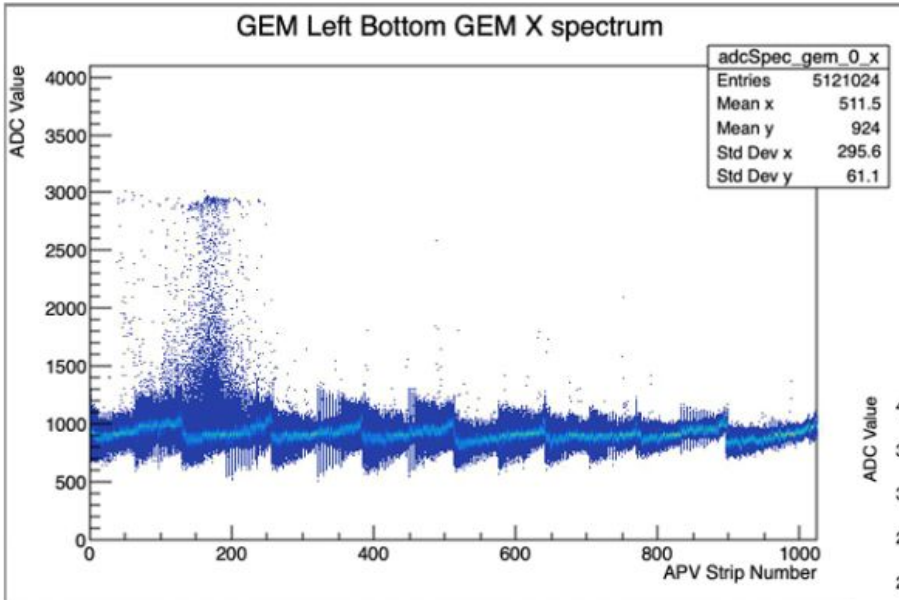
- Plugin inherited from MUSE that performs low level GEM analysis.
- Decoding of gem data, common mode + pedestal determination, clustering is done here.
- Plotting of raw data, pedestal+common mode subtracted data at both the GEM level (i.e. axis) and APV level done here.
- Finding clusters and fill a branch with the cluster information. No plotting of histograms with cluster information (done separately in gemDiagnostics plugin)

Slide from Ryan Richards

gemControl Configuration

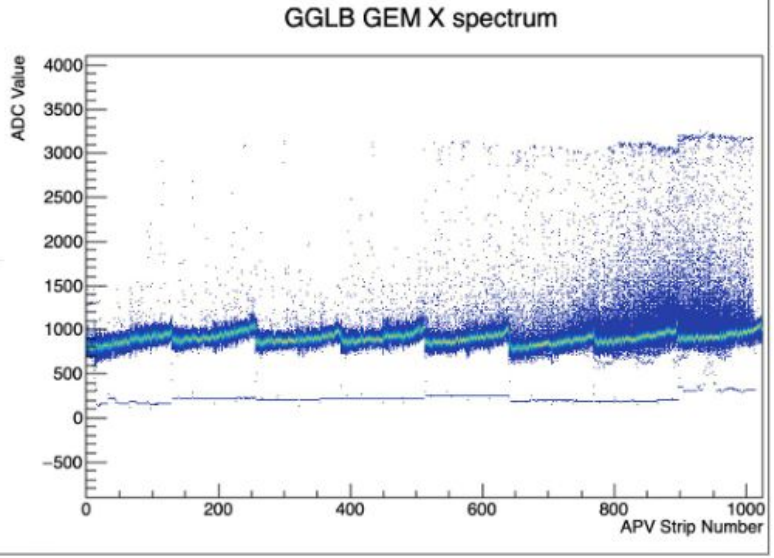
```
#Plugin in name
[gemControl]

[config]
  gemnum=initNumberOfGems
  apv=associateApvToGem
  cmode=selectCmode
  sample=initNumberOfSamples
  allwords=initAllWords
  format=setDataFormat
  activeGEM=setActiveGEM
  readmode=setReadMode
  deadchannels=Maskdeadchannels

[run:0]
  gemnum=1,4
  cmode=2
  allwords=0
  format=2
  sample=6
  activeGEM=1,1,1,1

# save event N to event N+1 due to DAQ from GE
  readmode="AHEAD"

  apv:0=0,0,"X",0
  apv:1=0,1,"X",0
  apv:2=0,2,"X",0
  apv:3=0,3,"X",0
  apv:4=0,4,"X",0
  apv:5=0,5,"X",0
  apv:6=0,6,"X",0
  apv:7=0,7,"X",0
  apv:8=0,8,"Y",0
```

- Work by Ryan Richards has made gemControl flexible enough to be able to decode different data structures, handle single vs multi sample, turn on/off GEMs.
- Current Formats are:
  - = 2 (Current data structure, in e-Hall)
  - = 1 (TRIUMF test lab data structure)
  - = 0 (EEL data structure)
- Sample = 6 (6 Sample Readout)
- activeGEM = 1, 1, 0, 0 (Left arm only)
- activeGEM = 0, 0, 1, 1 (Right arm only)
- activeGEM = 1, 1, 1, 1 (Both arms)



TRIUMF Test Lab
Two GEM, single sample run.

Data structure is different here.



Single sample, single GEM configuration

Run from JLab

Slide from Ryan Richards

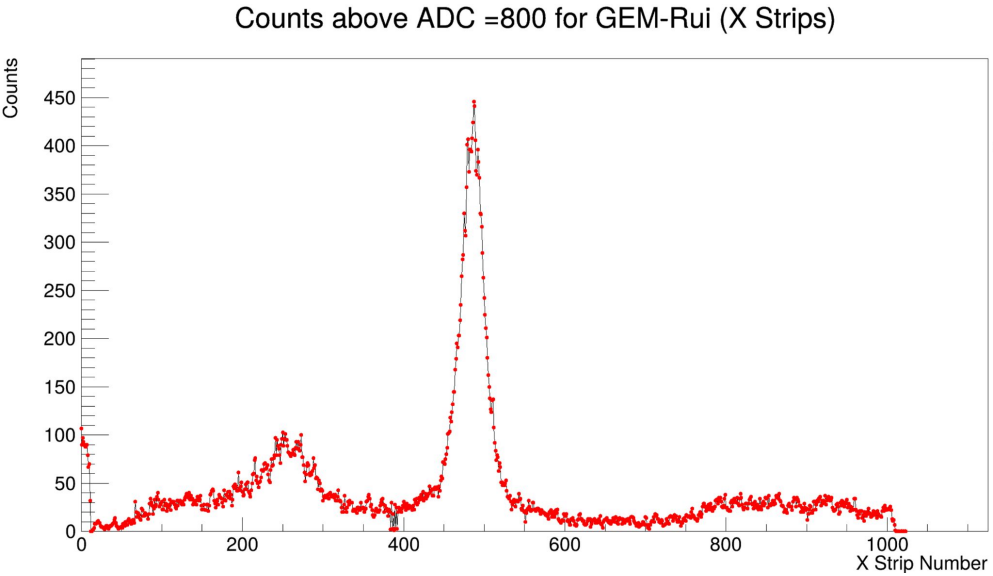
Implement Channel Masking: Step 1

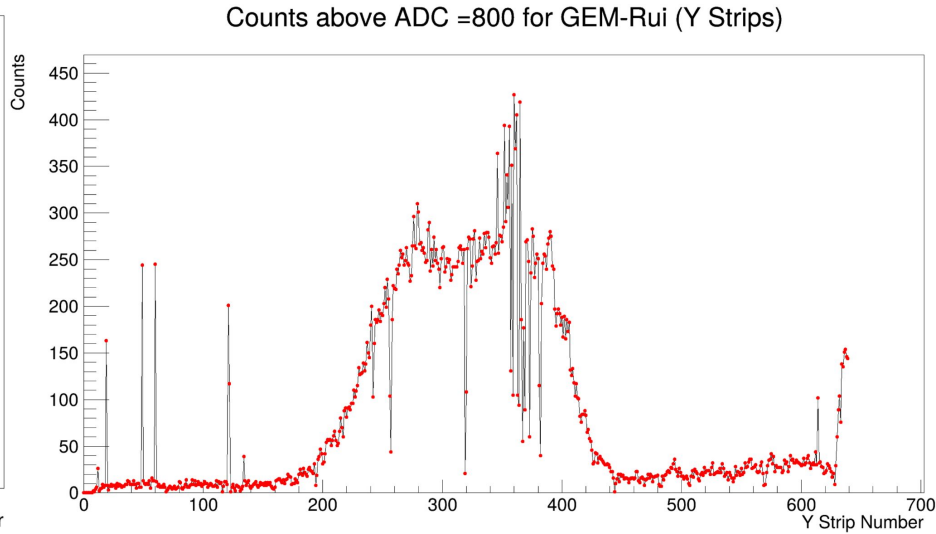
- Perform an ADC scan for chosen run
- Using MIN_PEAK_ADC to set ADC threshold
- MIN_PEAK_ADC identifies peaks that become clusters
- Counts = # of times a strip fires above the set ADC threshold
- Plotting Counts as a function of Strip Numbers
- “Probability Heatmap”, a 2D histogram gives Strip Number (X axis), ADC (Y axis) and how often each strip fires at a certain ADC, normalized (color in Z axis)
- Probability of strip firing = ((# Counts above threshold / Total # of events) * 100)

Chosen Run Conditions:

- Run 3237 (a GEM HV scan run), Dec 14, 2025
- Right Arm Only, Both GEMs at 3950V
- Beam ON, 50k events

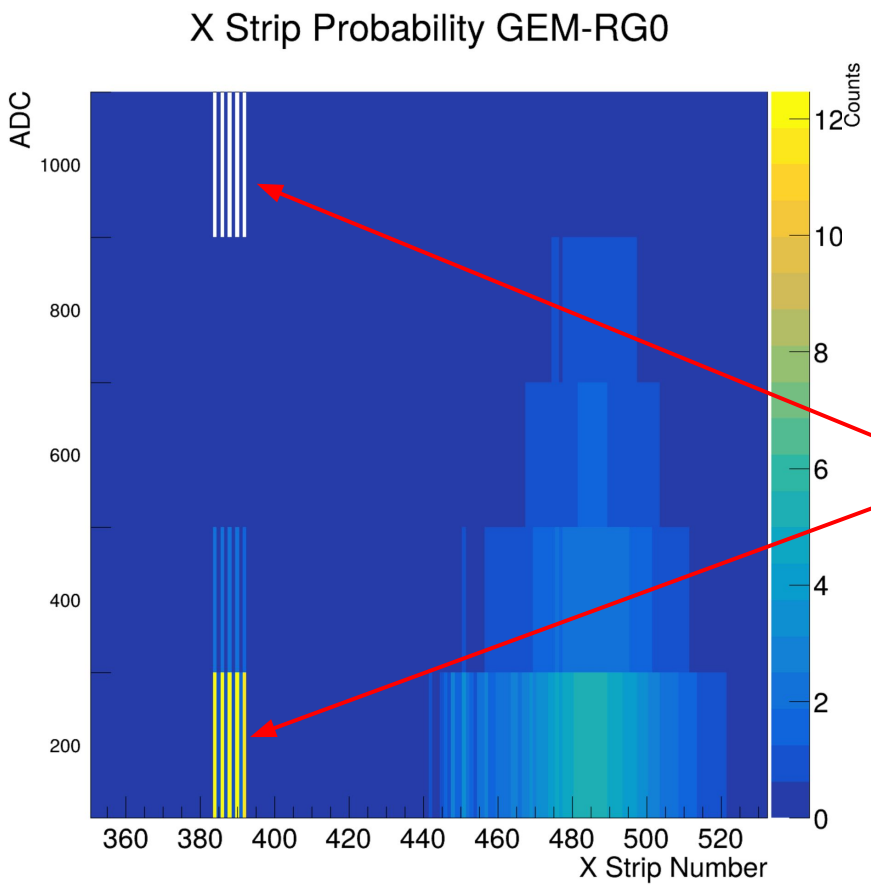
Counts vs Strip Numbers

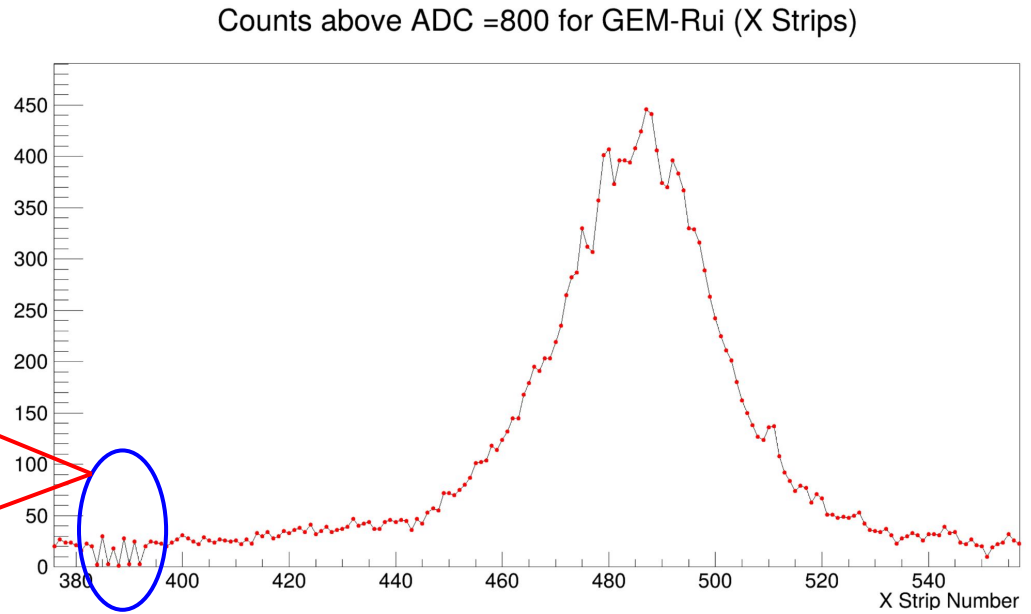




- GEM Rui = **Right Bottom GEM (RG0)**
- Installed on June 25, 2025
- Only GEM not replaced in e-Hall after initial installation

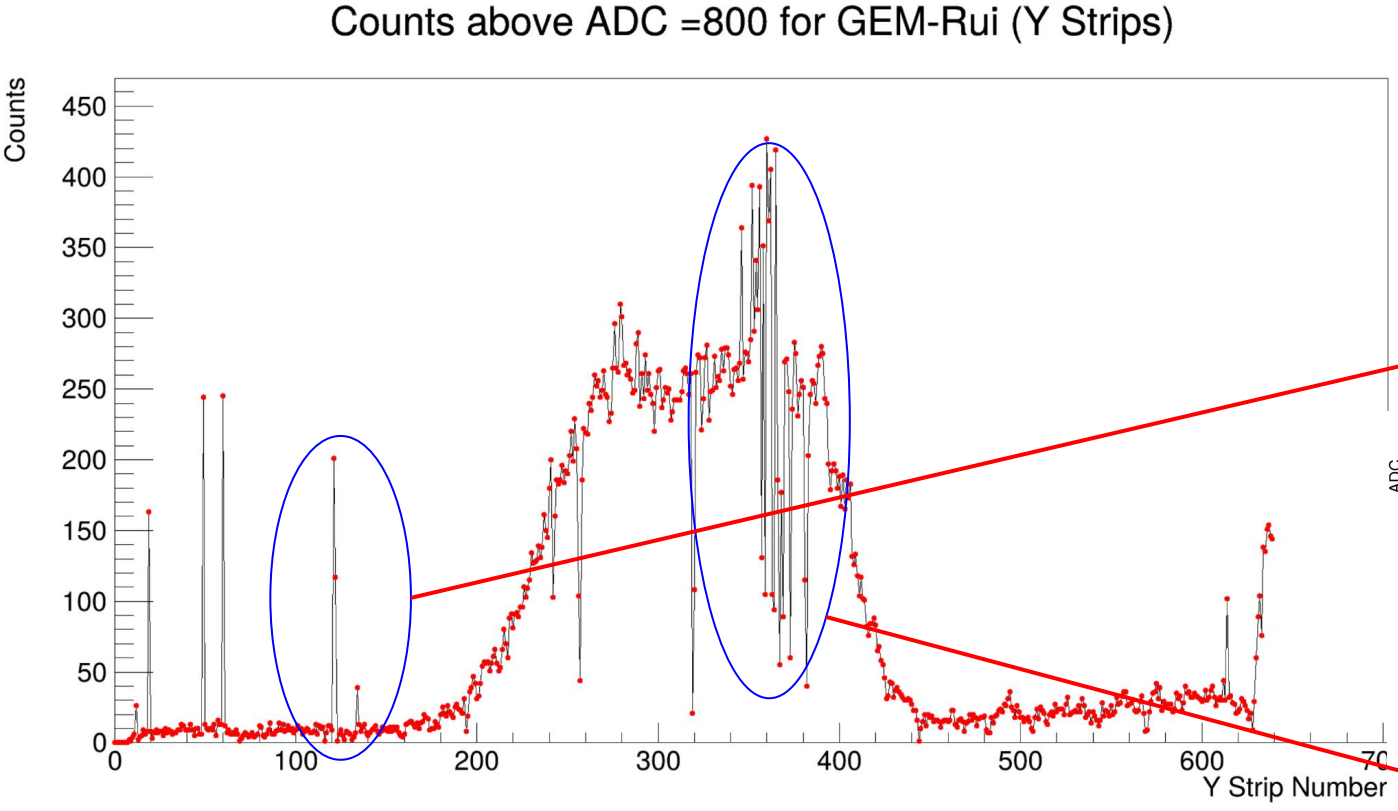
Identifying Bad X Strips

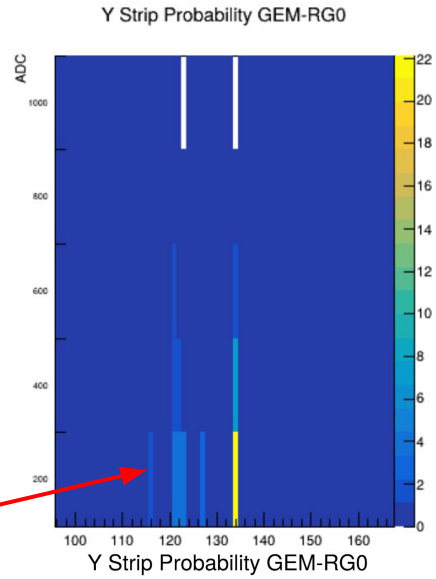


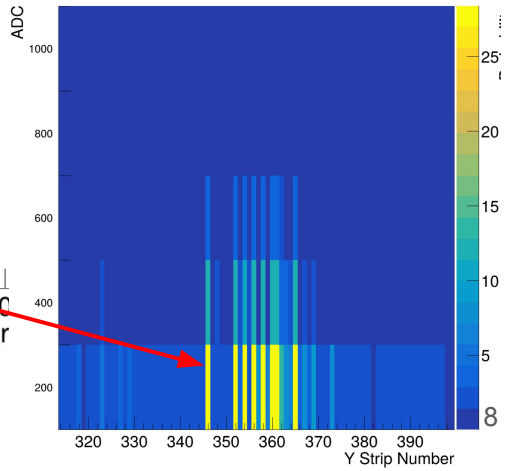


Bad strips have high count probability at low ADCs & very low to no counts as ADCs increase

Identifying Bad Y Strips







Implementing Channel Masking

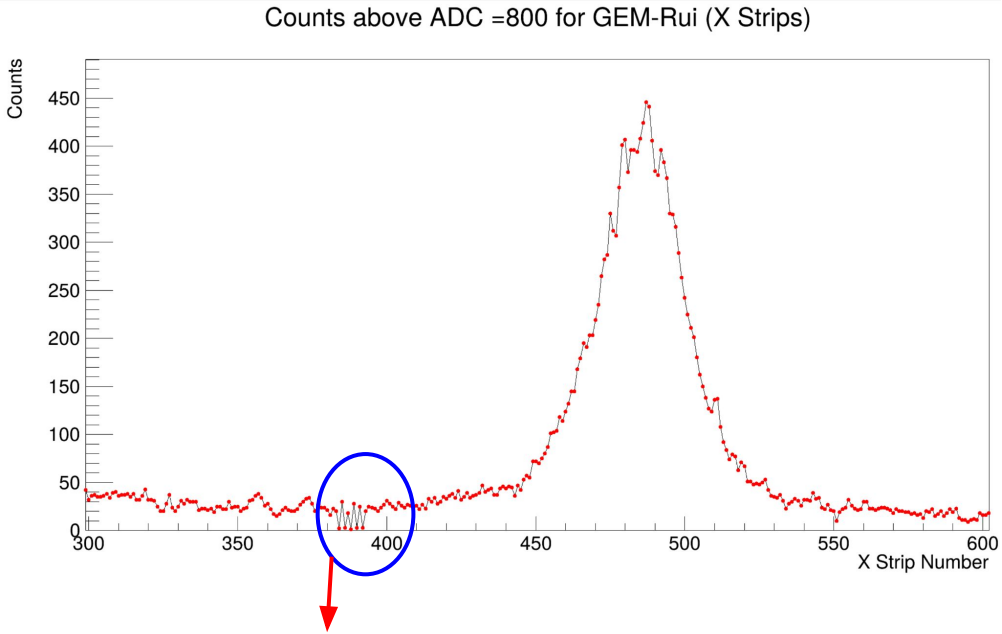
```
#Plugin in name
[gemControl]

[config]
  gemnum=initNumberOfGems
  apv=associateApvToGem
  cmode=selectCmode
  sample=initNumberOfSamples
  allwords=initAllWords
  format=setDataFormat
  activeGEM=setActiveGEM
  readmode=setReadMode
  deadchannels=Maskdeadchannels
```

- Add deadchannels in the gemControl.ini
- Requires to be run tagged to account for the changing GEMs in the e-Hall

```
# ID, GEM ID, Dead channel number, Axis id, value
deadchannels:0=2,384,"X",384
deadchannels:1=2,386,"X",386
deadchannels:2=2,388,"X",388
deadchannels:3=2,390,"X",390
deadchannels:4=2,392,"X",392

deadchannels:5=2,19,"Y",19
deadchannels:6=2,49,"Y",49
deadchannels:7=2,134,"Y",134
deadchannels:8=2,242,"Y",242
deadchannels:9=2,257,"Y",257
deadchannels:10=2,346,"Y",346
deadchannels:11=2,352,"Y",352
deadchannels:12=2,354,"Y",354
deadchannels:13=2,356,"Y",356
deadchannels:14=2,358,"Y",358
deadchannels:15=2,365,"Y",365
deadchannels:15=2,367,"Y",367
deadchannels:16=2,369,"Y",369
deadchannels:17=2,373,"Y",373
deadchannels:18=2,382,"Y",382
deadchannels:19=2,612,"Y",612
deadchannels:20=2,614,"Y",614
deadchannels:21=2,629,"Y",629
```

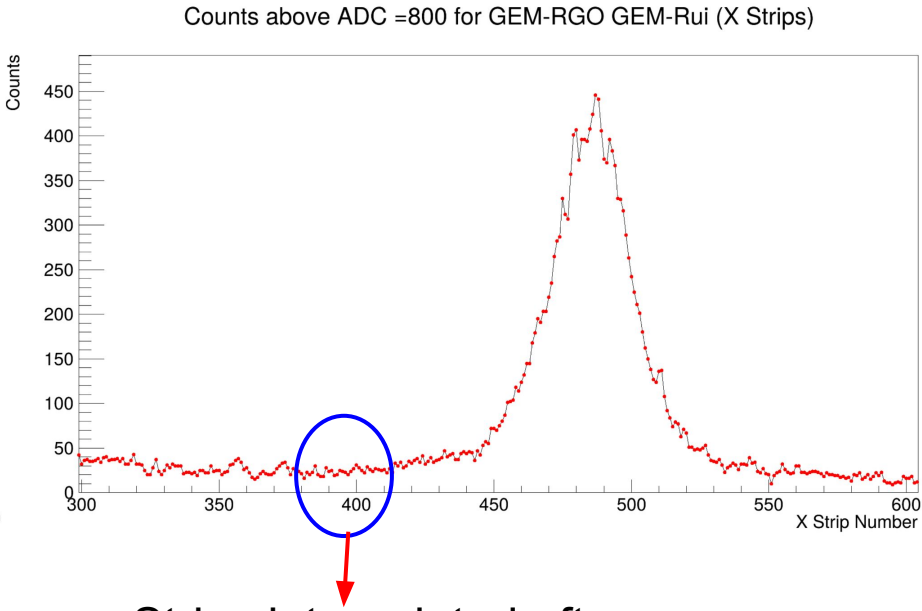
Comparisons After Channel Masking

Before Channel Masking



Visible bad channels

After Channel Masking

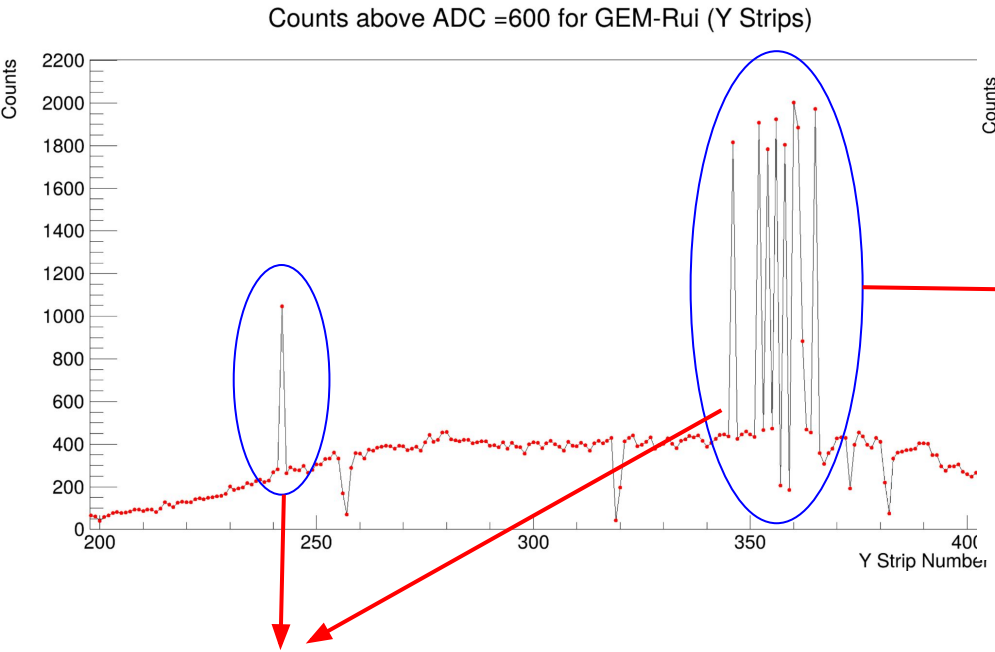


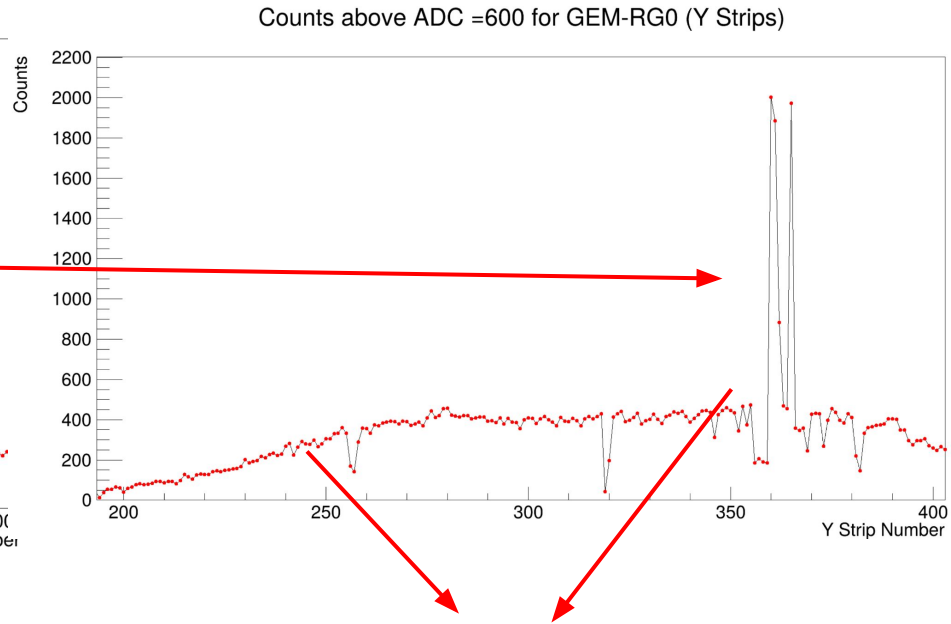
Strips interpolated after masking

Comparisons after Bad Channel Masking

Before Channel Masking

After Channel Masking



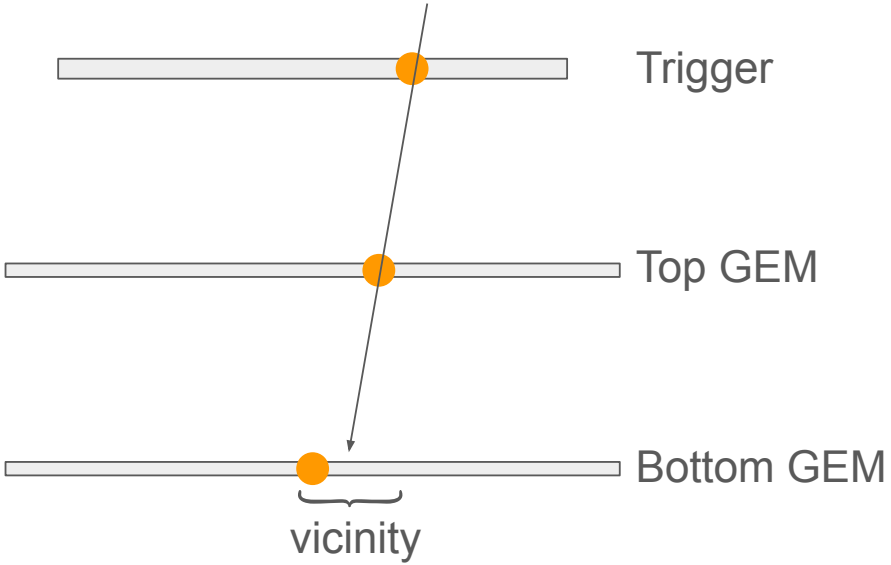


Visible bad channels

Many strips interpolated after masking

GEM Efficiency Framework

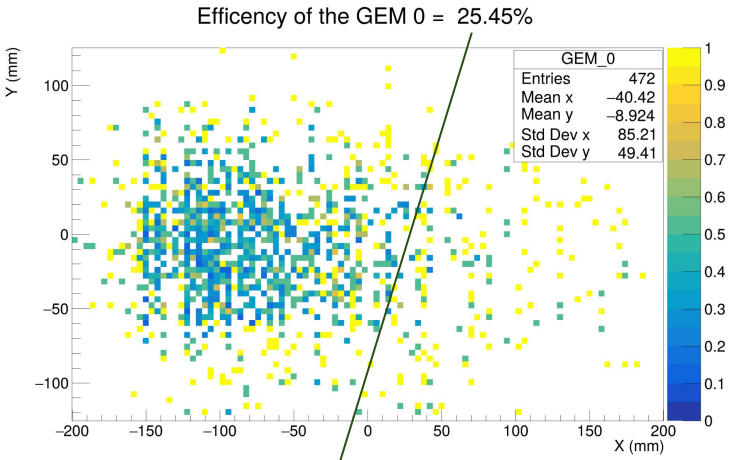
- Tracks using the other GEM and the Trigger
- Project the track on the probing GEM
- Look for a hit in the vicinity of projection

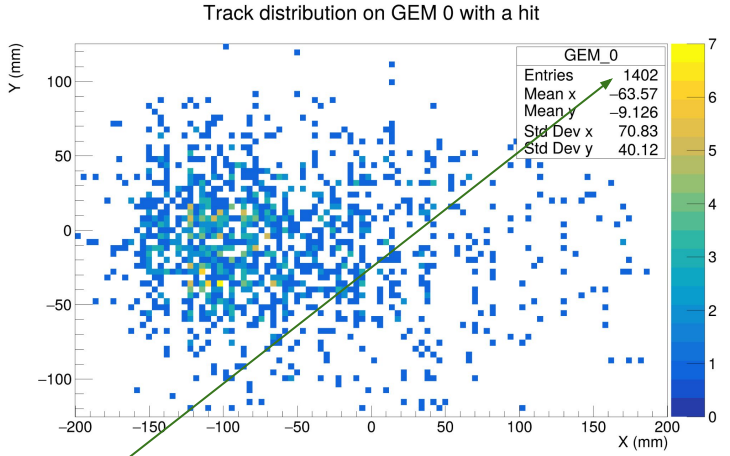


$$\text{Efficiency} = \frac{\#\ \text{proj. tracks on GEM with a hit in vicinity}}{\#\ \text{proj. tracks on GEM}}$$

Slide from Dulitha Jayakodige

GEM Efficiency Framework





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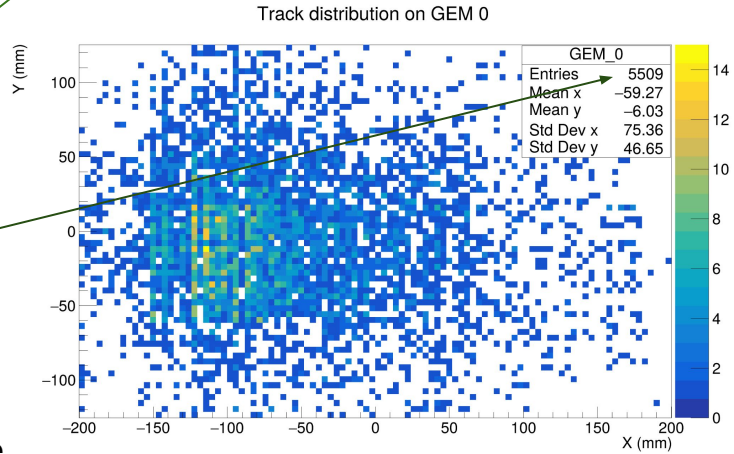


$$\text{Efficiency} = \frac{\text{GetEntries}(\quad)}{\text{GetEntries}(\quad)}$$

DLrun_003540; vicinity = ±5 cm

Slide from Dulitha Jayakodige

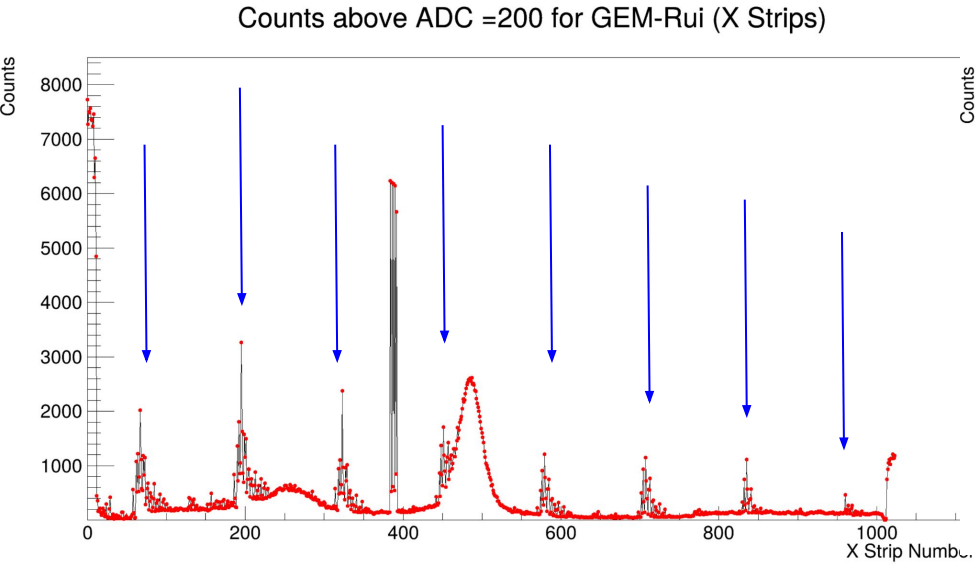
Future work on GEM Efficiency

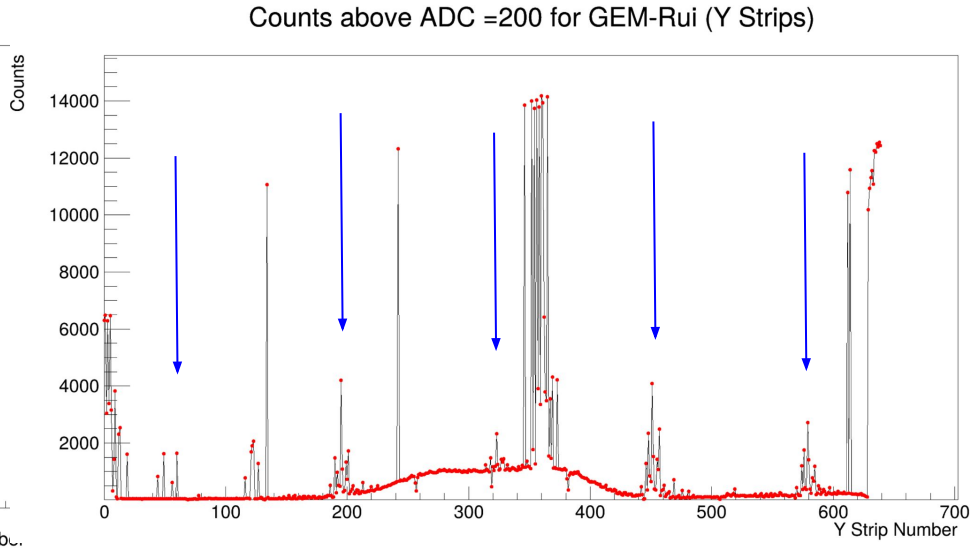
- Identify clean tracks to improve the calculation
- Optimize parameters (vicinity and other cuts)
- Use this as a tool to study GEM performance during:
  - Beam current variations
  - HV variations
  - Channel masking
  - Gain calibration

Slide from Dulitha Jayakodige

Interesting Observations…

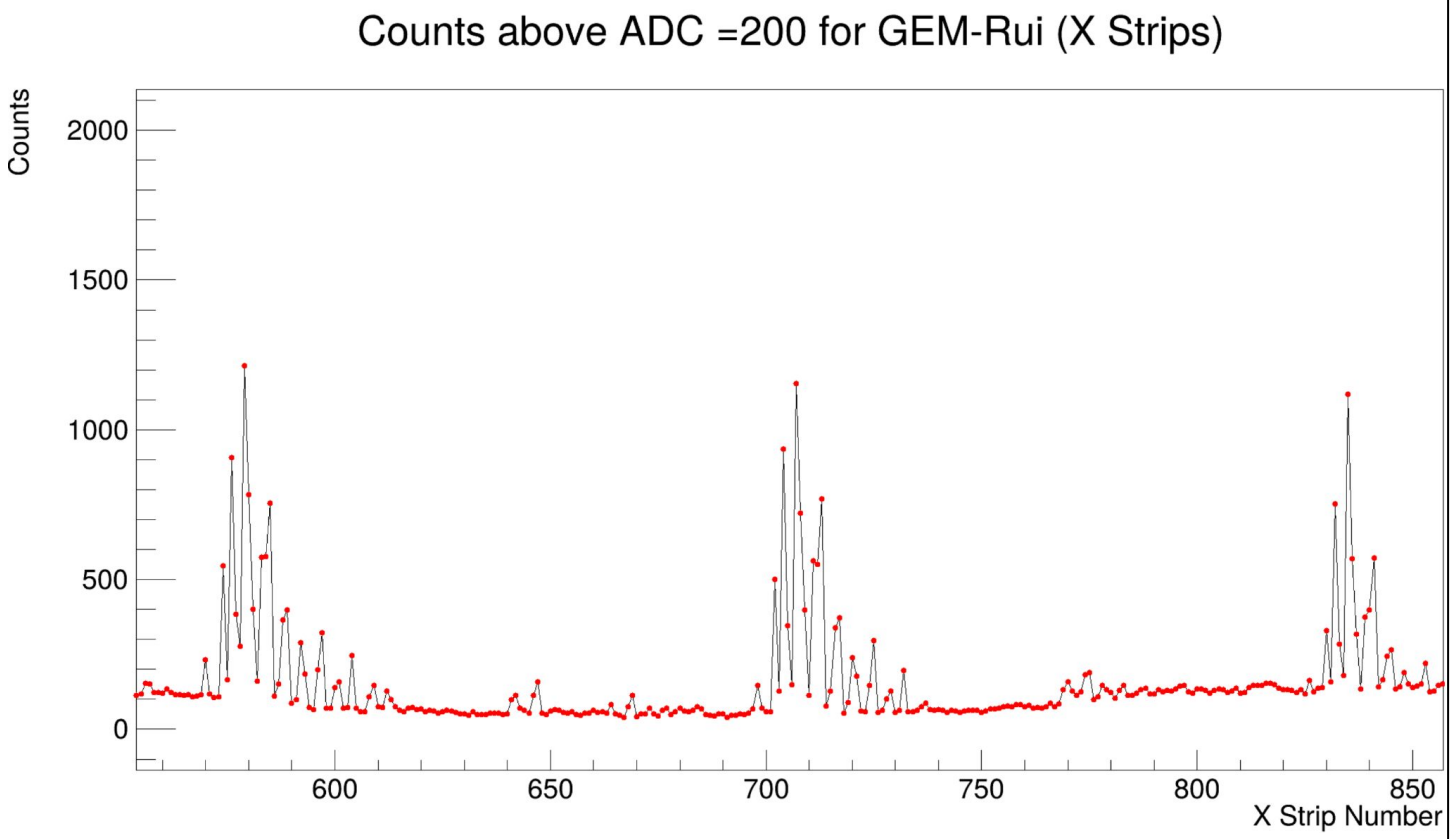
Periodic Pattern..





Visible only at low ADCs

Periodic Pattern Zoomed in…



APV Cards starting at: 1,129,257,385,513,641,769,897, and 1024 the last strip

Midpoint strips of APV cards are: 64,192,320,448,576,704, 832,960

Pattern seen here, spread over a few channels to left and right.

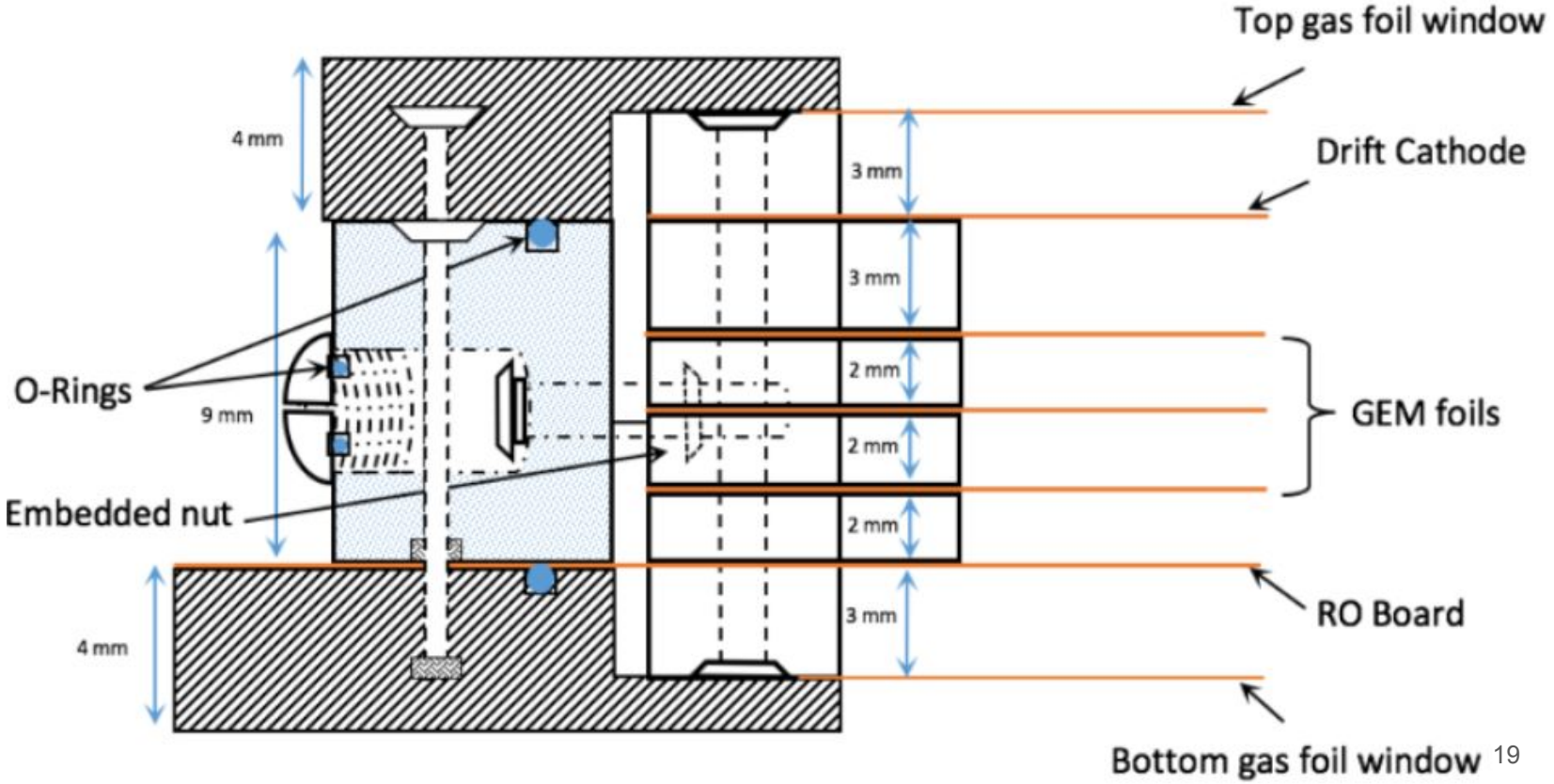
Seen on ALL GEMs but ONLY at low ADC value

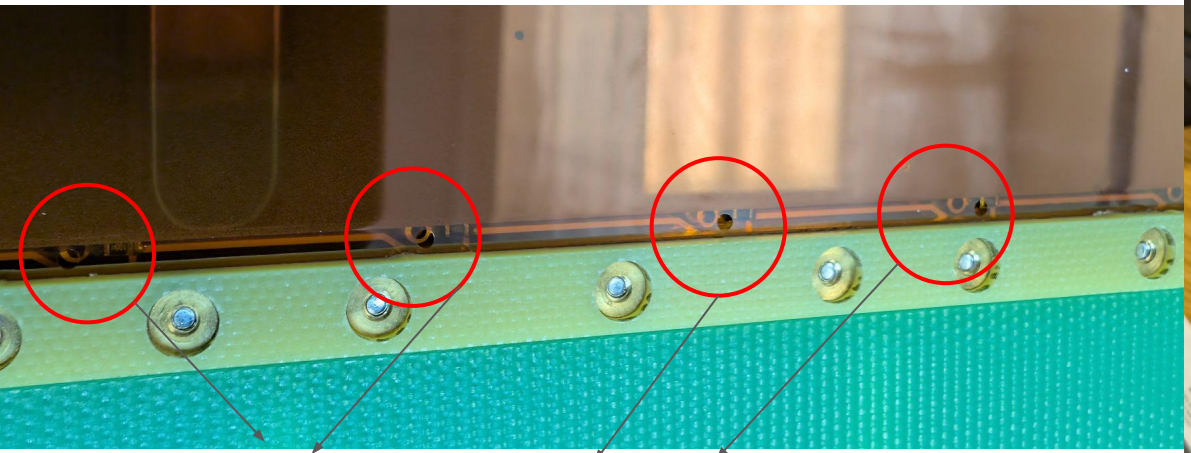
Need to see if this appears/disappears over different runs in the e-Hall

Need to look at data from TRIUMF test lab and JLab to see if this is recurring..

Hardware Updates

GEM Layout


Top gas foil window
Drift Cathode
GEM foils
RO Board
Bottom gas foil window
4 mm
9 mm
4 mm
3 mm
3 mm
2 mm
2 mm
2 mm
3 mm
O-Rings
Embedded nut

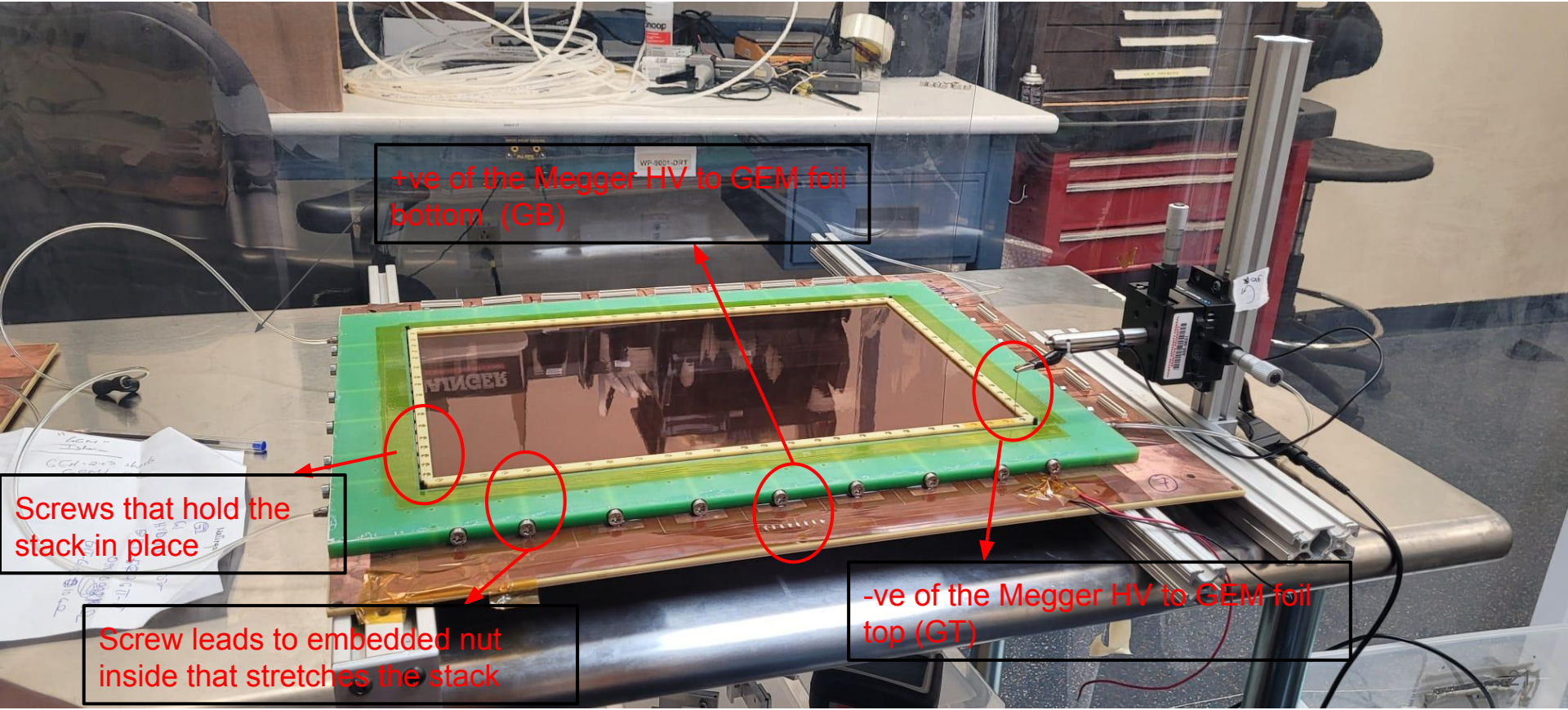


Each access point leads to a separate GEM sector.
Total of 10 sectors

Pin to probe the access points of G1, G2 & G3 top

The stand moves along the Y & Z axis

Complete Setup



Identifying Shorted GEM Foils..

- No short:
  - Measurements made after removing the HV divider
  - “OL” between GEM foil Top (GT) and foil Bottom (GB), measured with a multimeter.
  - 10 GΩ @ 50V, 20 GΩ @100V, 100GΩ @250V, between GT and GB, measured with the Megger.
  - Above measurements made **without** bypassing the protection resistor.
- Short:
  - ~1MΩ between GT & GB measured at the divider, **without** bypassing the protection resistor.
  - >2 MΩ between GT & GB, **after** bypassing the protection resistor, in every non-shorted sector (2 MΩ from 2 protection resistors + kΩ resistance from the short)
  - kΩ resistance between GT & GB in the shorted sector.
  - When bypassing the protection resistor, GB is at the HV divider solder point, and GT at any specific sector out of the 10.

GEM - Malinga / GEM # 7

- Short in Gem Foil 2 (G2). G1 & G3, no short.
  - Applying <500V does not burn off the short. This causes the short to **migrate** to different sectors and even different foils.
  - After locating the shorted sector, apply 500V directly in short bursts to each foil after bypassing the protection resistor
  - Repeat until sparking reduces and eventually stops.
- Current Status
  - Holds 4000V overnight on N2 with CAEN supply
  - Unable to hold voltage with electronics mounted. Trips!

GEM - Ishara / GEM # 1

  - Short in G2 & G3. No short in G1
  - 500V was not sufficient. Briefly apply 600V. Repeat until sparking reduces and eventually stops.
- Current Status
  - No shorts. “OL” between all GT & GB
  - Being flushed with Nitrogen to dry out the GEM.

GEM - Bishoy : Strange inexplicable short

Next Steps…

- Software:
  - Run Tag & Implement Channel Masking for other GEMs
  - GEM Efficiency
  - Gain Matching
  - GEM timing for tracking
- Hardware:
  - Sustain HV longer when bypassing protection resistor, as debris has tended to cause problems again with new shorts after closing GEM
  - Keep HV divider on while supplying shock HV with Megger. Estimated that HV divider stays safe, and majority of power is directed to the short
  - Portable NIM supply for cleanroom (need permission), slowctrl is possible but not readily available, to supply HV through divider while GEM is open. If short reappears, use Megger again. Only close GEM after stable ops are reached