LMU test-beam performance of 20x20 triple GEM and XYUV triple GEM

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6TH DRD1 COLLABORATION MEETING, WARSAW – 09.10.25

LMU telescope setup

List of investigated detectors:

- 3-layer charge sharing MM (pixel-strip hybrid readout, see next talk)
- 5-layer charge sharing MM (pixel readout, see next talk)
- 2x 20x20 cm^2 triple GEM
- XYUV triple GEM
- Inverted RICH MM with different crystals (not presented here)
- XYUV GEM-MM hybrid (not presented here)

Trigger, tracking and readout:

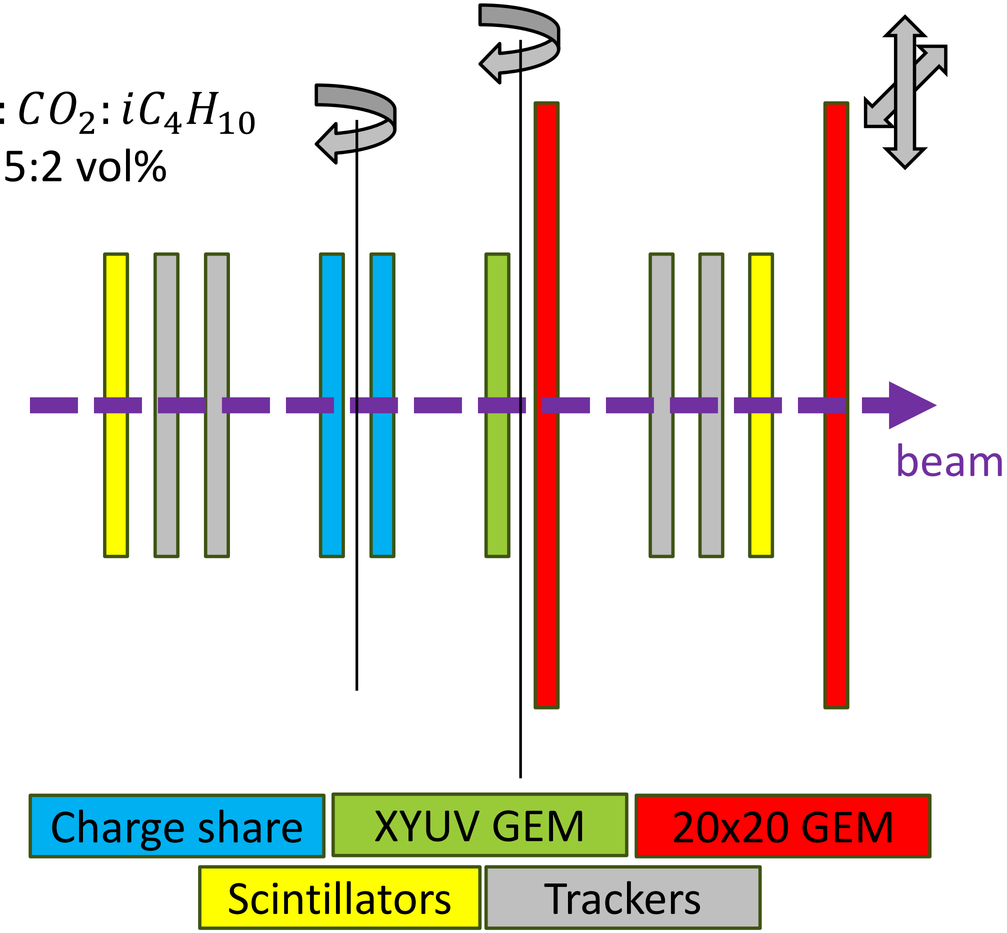
- 2 scintillators for coincident triggers
- 4 XY, DLC, Bulk MM as trackers
- Readout by APV25
- Due to high number of channels, rate limited by data transfer/processing speed (max. ~500 Hz during spill)

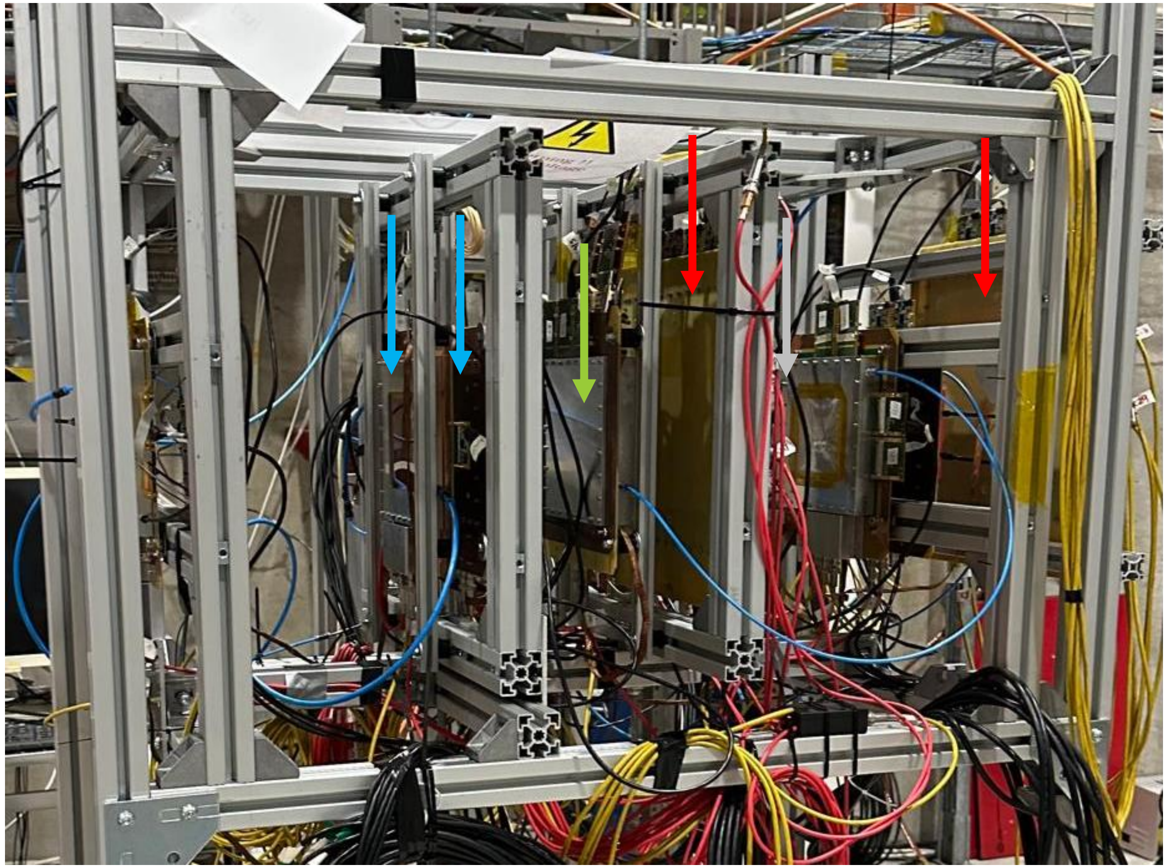
Other Specs:

- Ability to rotate and move detectors in beam
- Gas: $Ar: CO_2: iC_4H_{10}$ 93:5:2 vol%

LMU telescope setup

$Ar:CO_2:iC_4H_{10}$
93:5:2 vol%

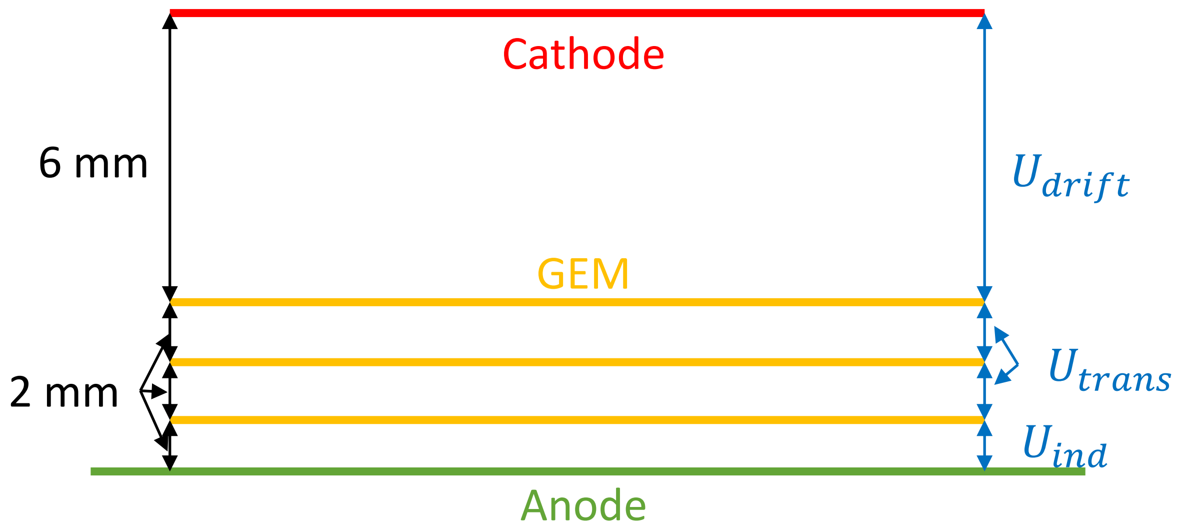




20x20 triple GEM

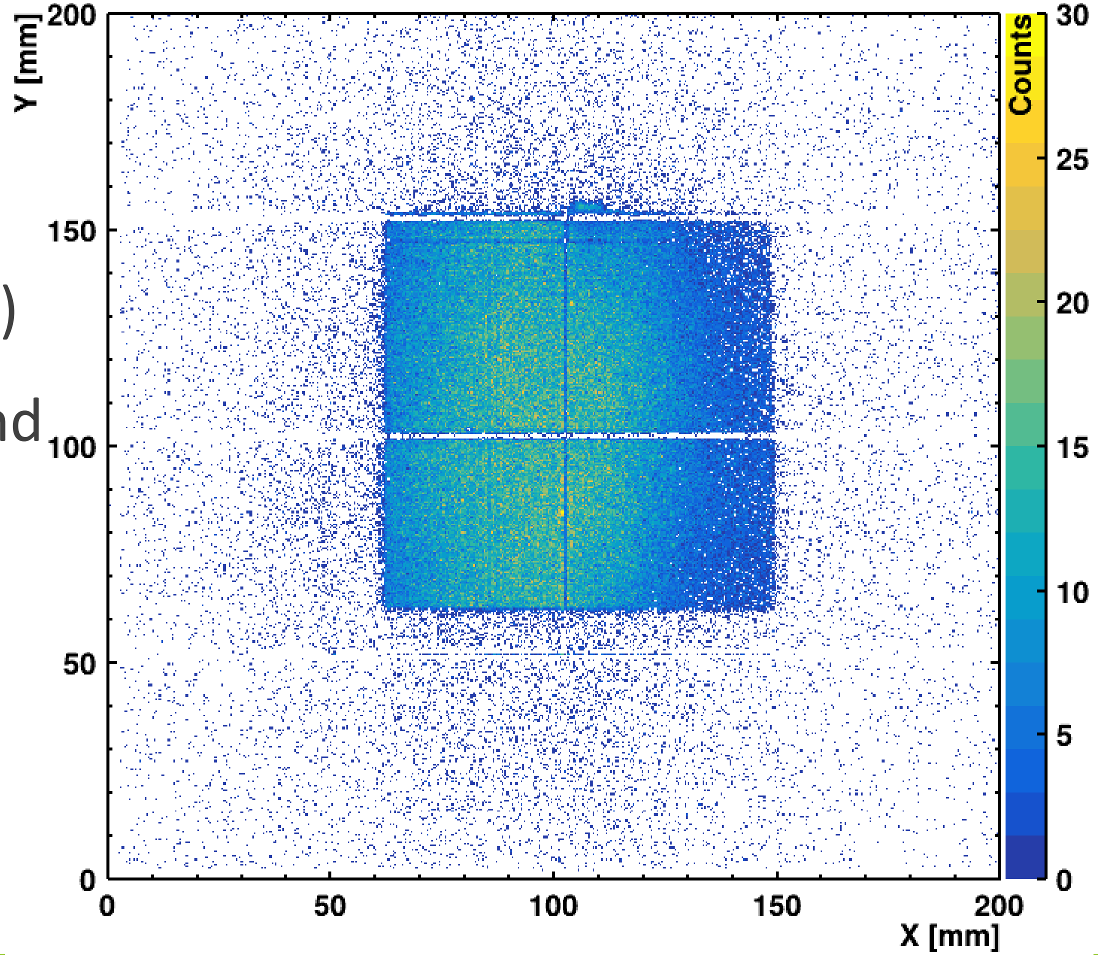
20x20 triple GEM setup

- Segmented in 4 sections each 5x20 cm^2
  - Only top side of the GEM foil
  - Gap of 500 µm
- To investigate segmentation effects =>a different orientation setup for each detector
- Local charge-up effects observed in tests with Fe-55
- If not stated otherwise: U_{drift} = 360 V, U_{trans} = 310 V, U_{ind}= 390 V



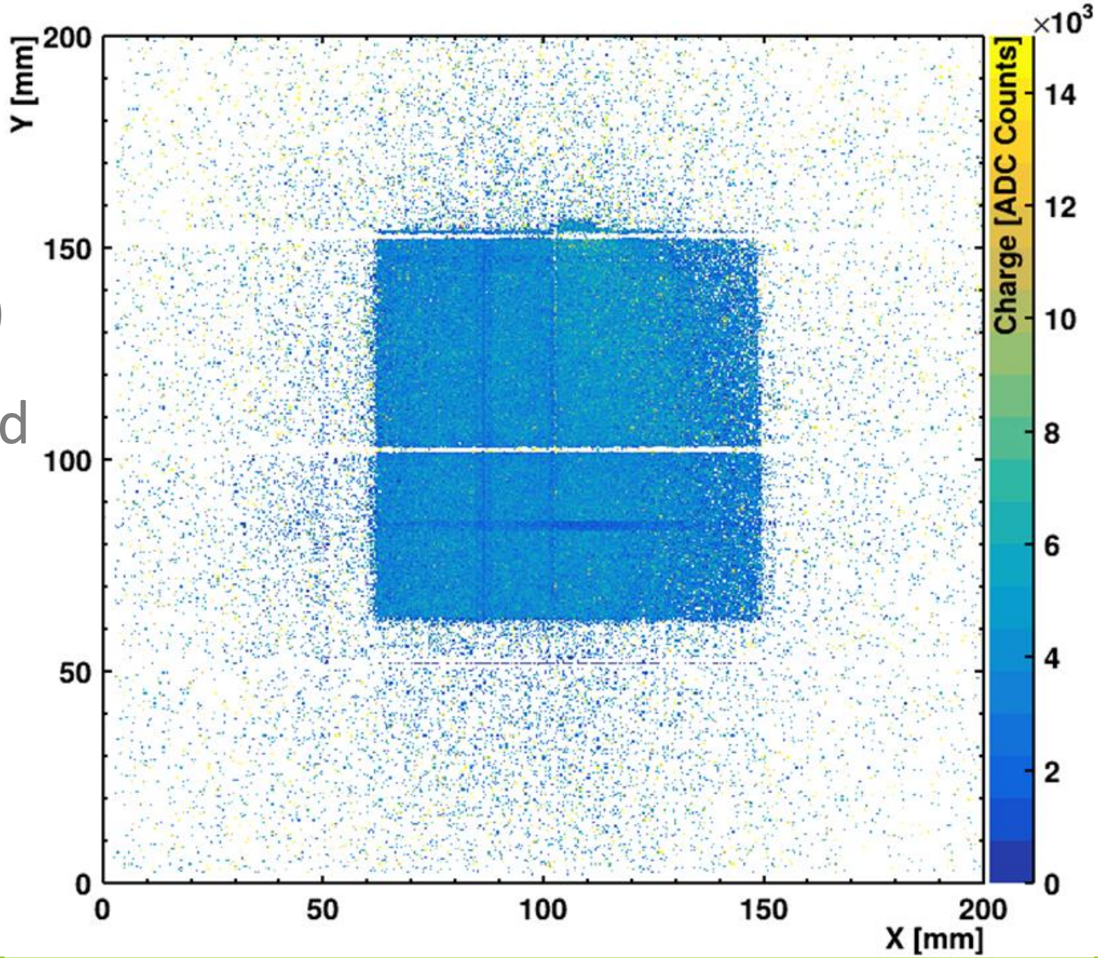
20x20 triple GEM hit map

- Nice beam profile
- Segmentations clearly visible
  - Different widths depending on direction (overlapping segmentations)
- Limited by active area of scintillators and trackers
  - Coincident hits outside of active area



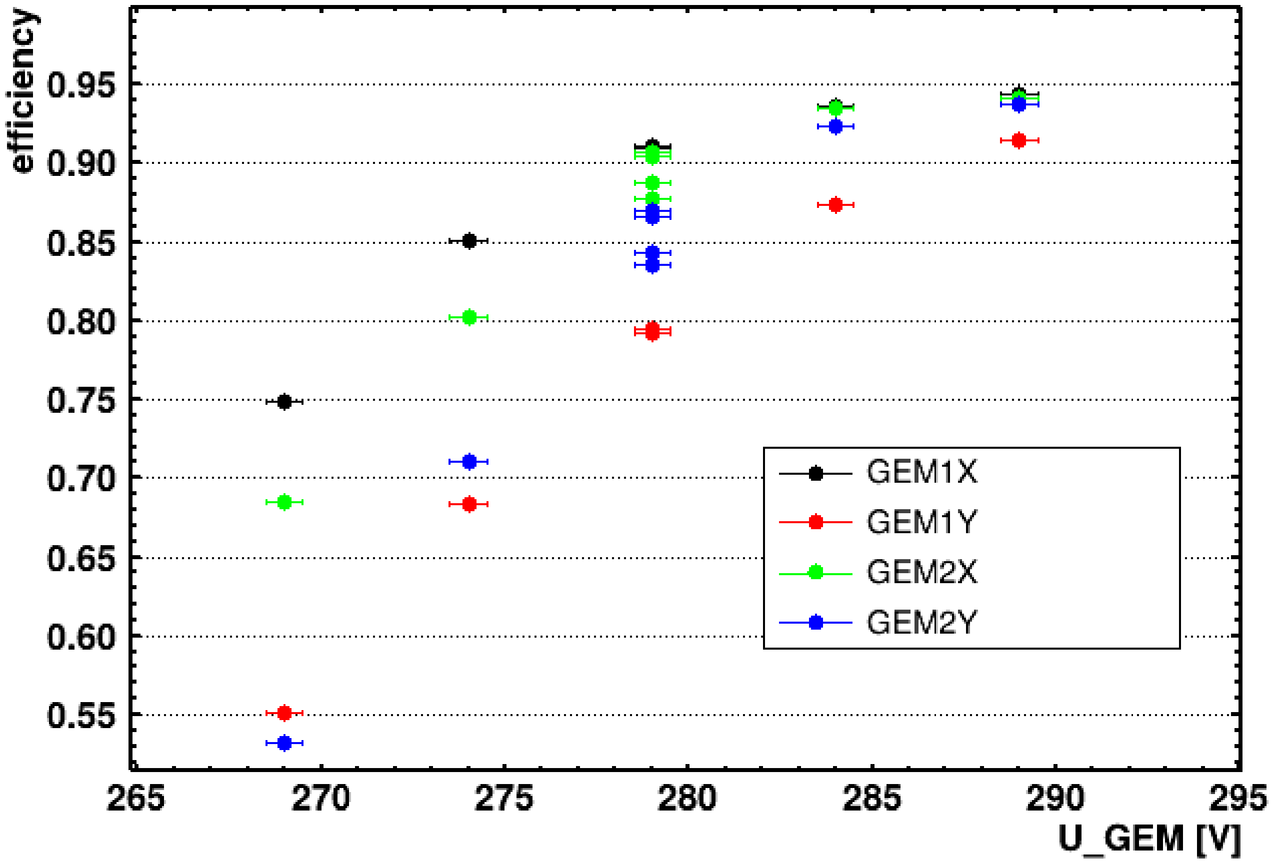
20x20 triple GEM hit map

- Nice beam profile
- Segmentations clearly visible
  - Different widths depending on direction (overlapping segmentations)
- Limited by active area of scintillators and trackers
  - Coincident hits outside of active area
- No charge-up effects visible in the per event charge distribution
  - Only some inefficient strips



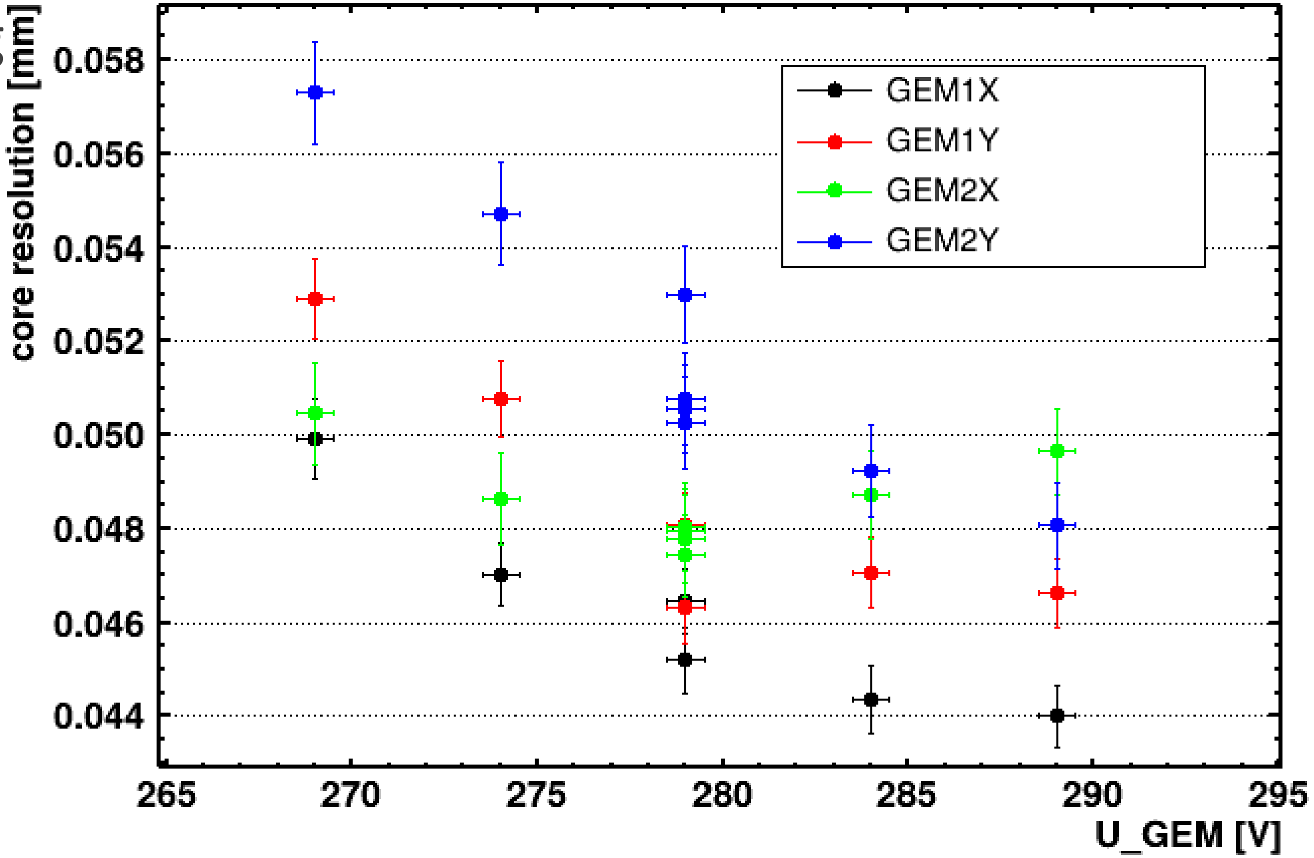
20x20 triple GEM efficiency

- Efficiency defined as hits within +-1 mm of the reference track
- Increase to higher voltages reaching > 90%
- Could get even better at higher voltages
- X-layers more efficient than Y-layers



20x20 triple GEM resolution

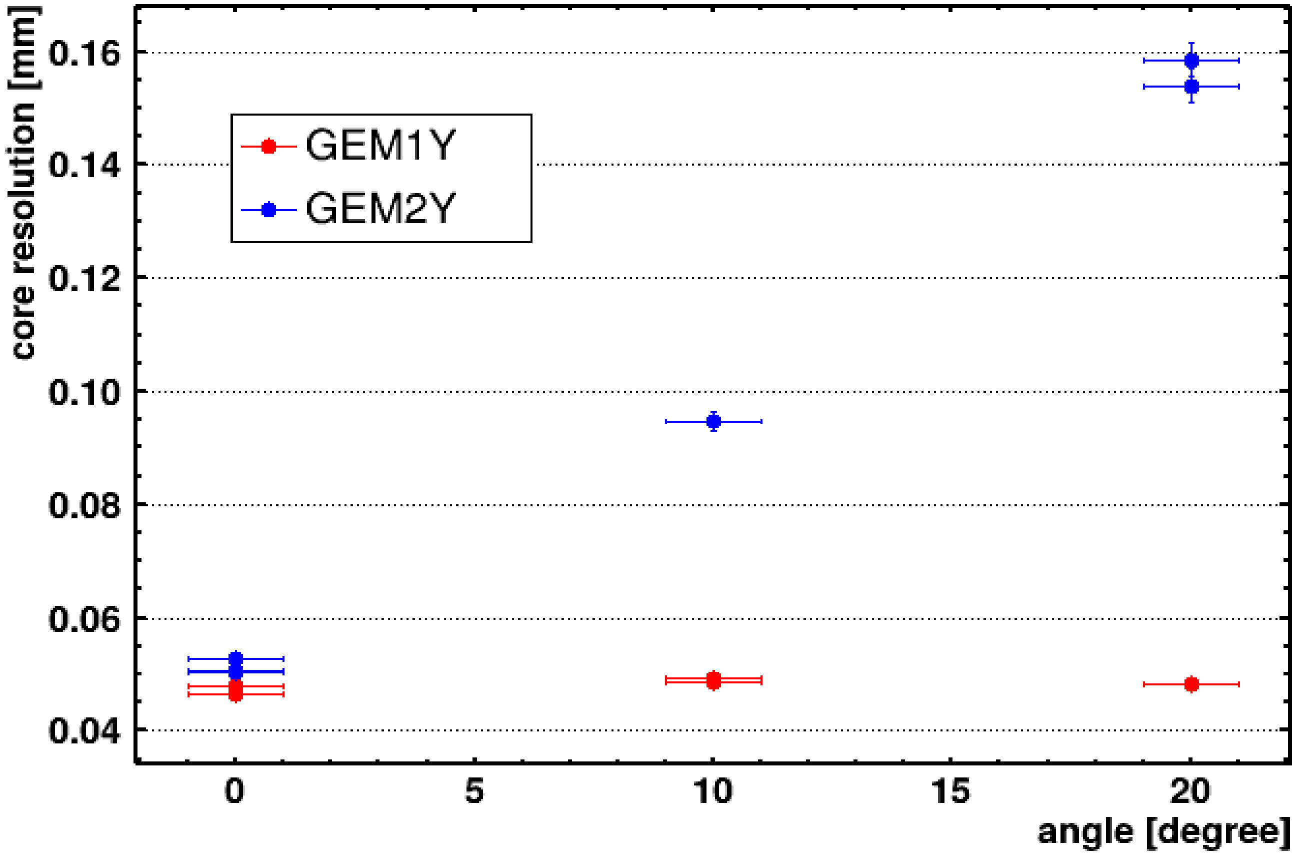
- Triple gauss function is used for fitting
- Using time-corrected centroid [1]
- A charge scaled centroid $x = \frac{\sum i \ x_i q_i^s}{\sum i \ q_i^s}$ is used to improve signal/noise ratio
- Improving resolutions for higher voltages
- At 279 V minimum of GEM2X (covering a GEM1Y point)
- 68% resolutions reach ~ 70 µm



[1] B.Flierl, PhD Thesis: *Particle Tracking with Micro-Pattern Gaseous Detectors*; Mar 2018

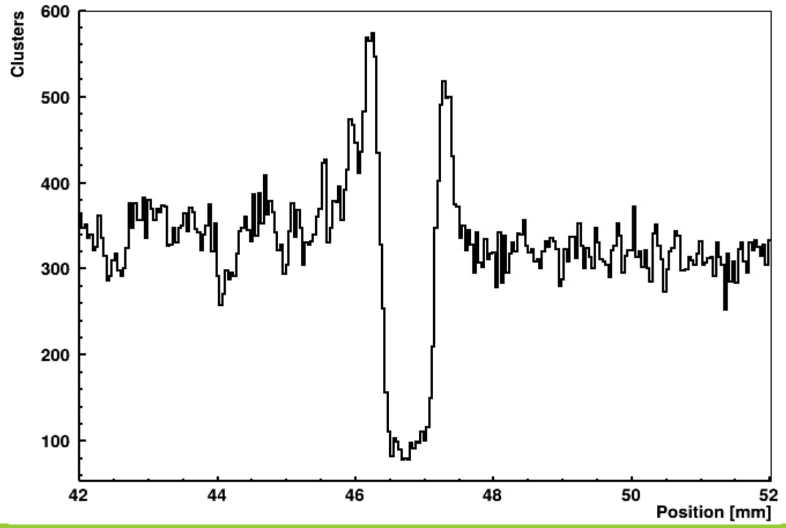
20x20 triple GEM resolution

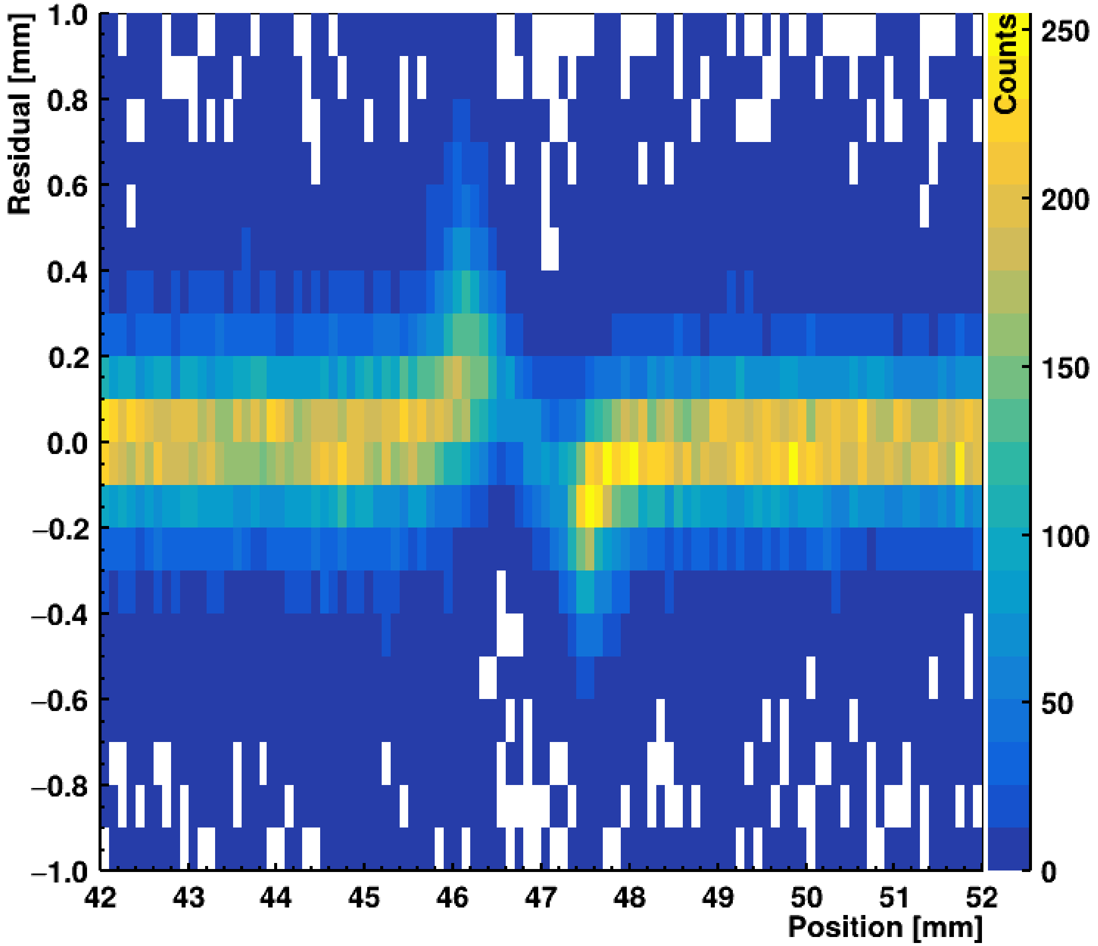
- GEM1Y is the not rotated detector in the same measurement
- Degrading resolution for increasing angles as expected
- Strong improvement compared with no time correction (~400 µm @ 20°)



20x20 triple GEM segmentation effects

- Clusters get wrongly reconstructed to the sides of the segmentation gaps
- Has local effect on the residuals
- Effect overlapping with end of APVs
- Variance in actual shape and effect on residuals





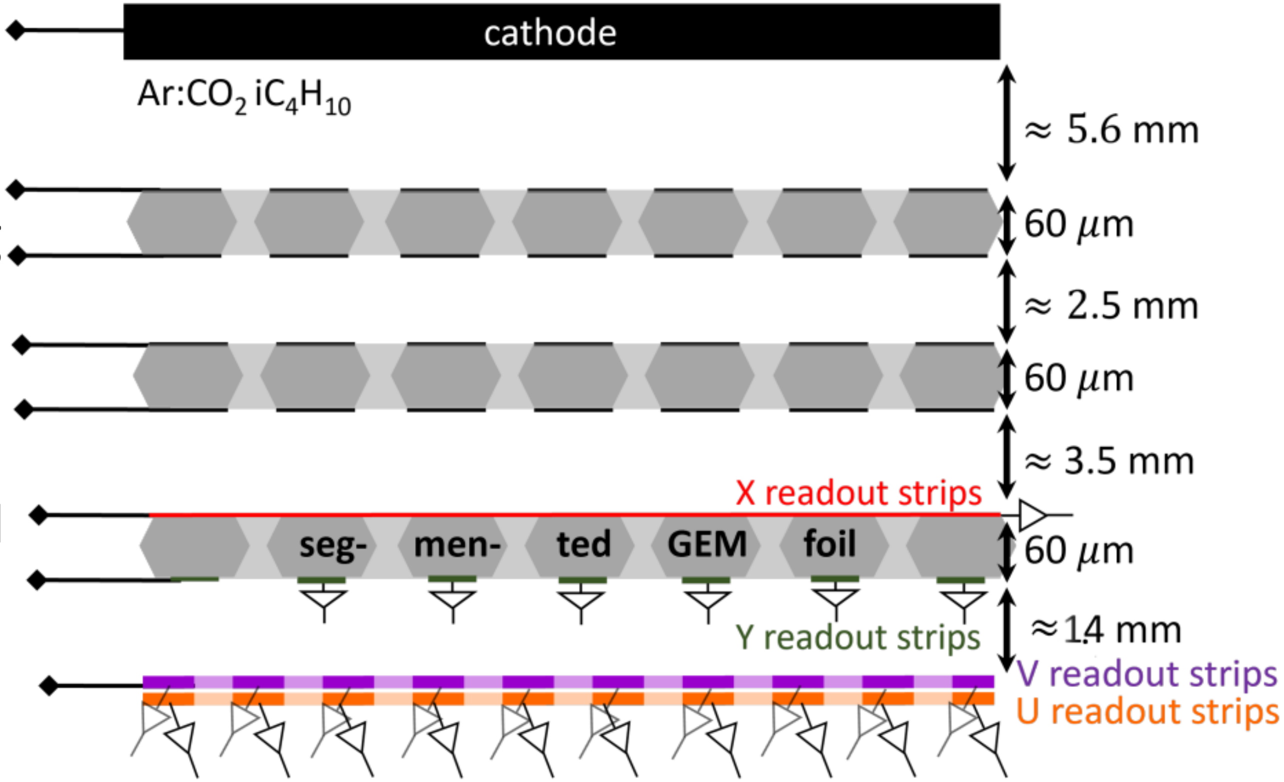
XYUV triple GEM

RESULTS OBTAINED BY DANIEL GREWE [2]

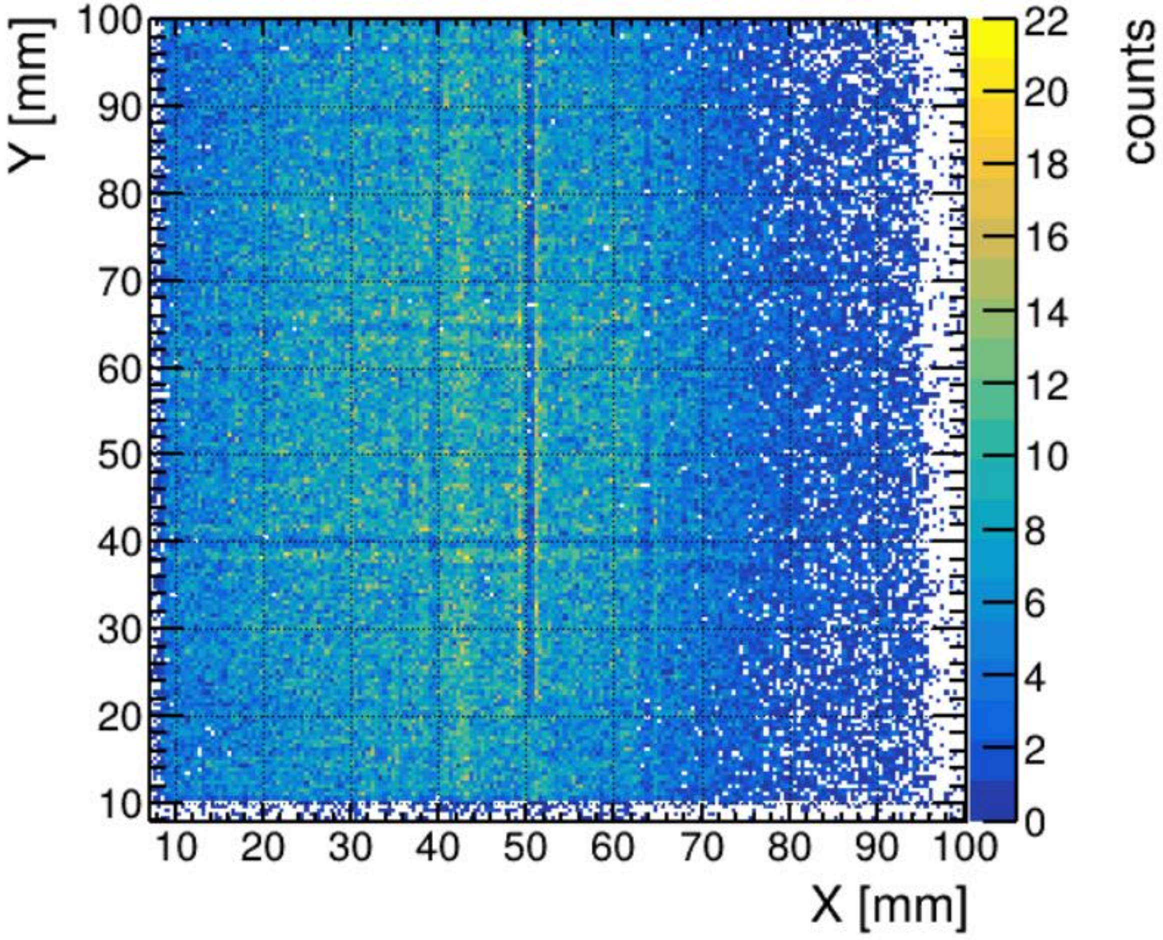
[2] Master-Thesis: https://www.etp.physik.uni-muenchen.de/publications/theses/download/master_dgrewe.pdf

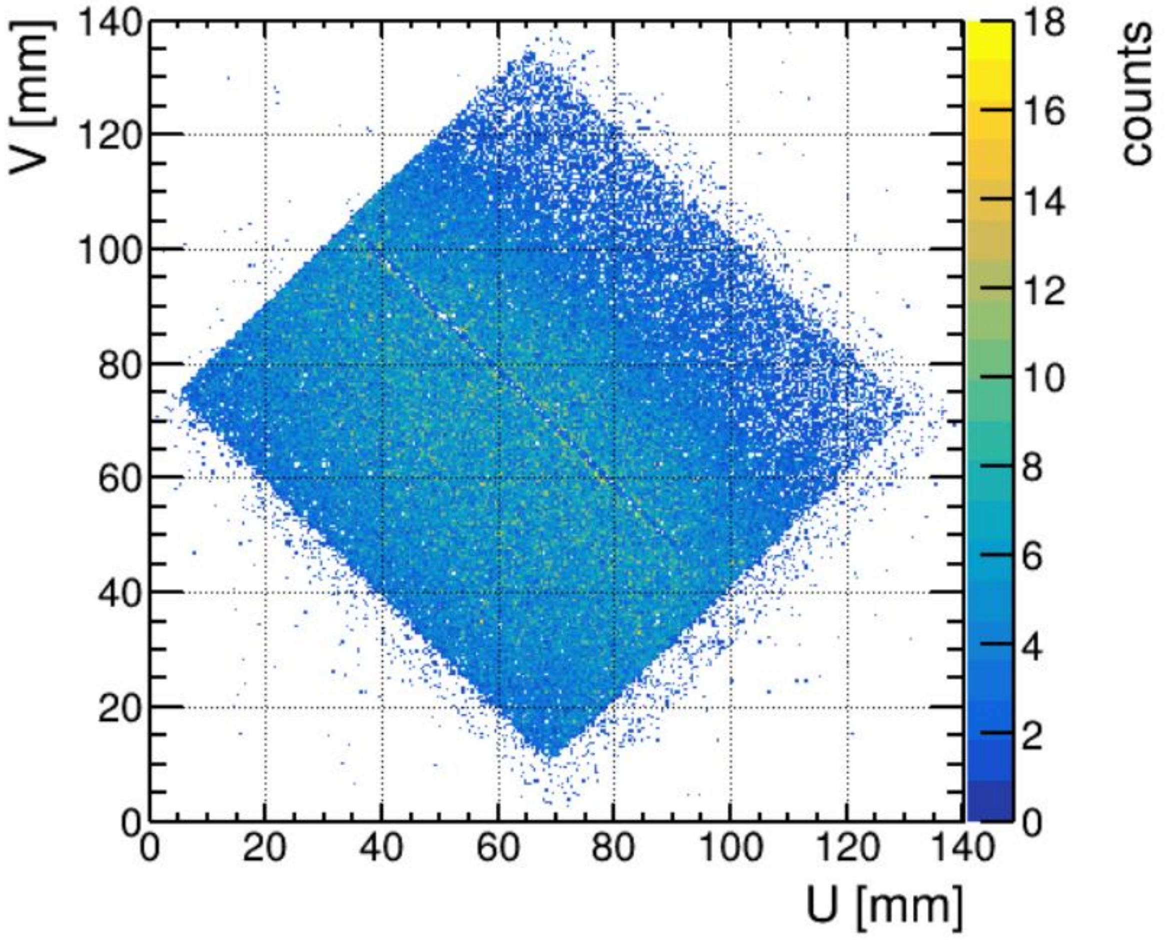
XYUV triple GEM setup

- Last GEM foil is segmented into strips with pitch of 470 µm on either side
  - HV and readout connected via custom adapter boards also reducing noise
- Anode with strips in UV directions
- GEM voltages decrease by 5V per GEM from top to bottom (i.e. 300-295-290)
- If not stated otherwise: U_{drift} = 350 V, U_{ind}= 390 V, $U_{trans}^{1,2}$= (350, 500) V



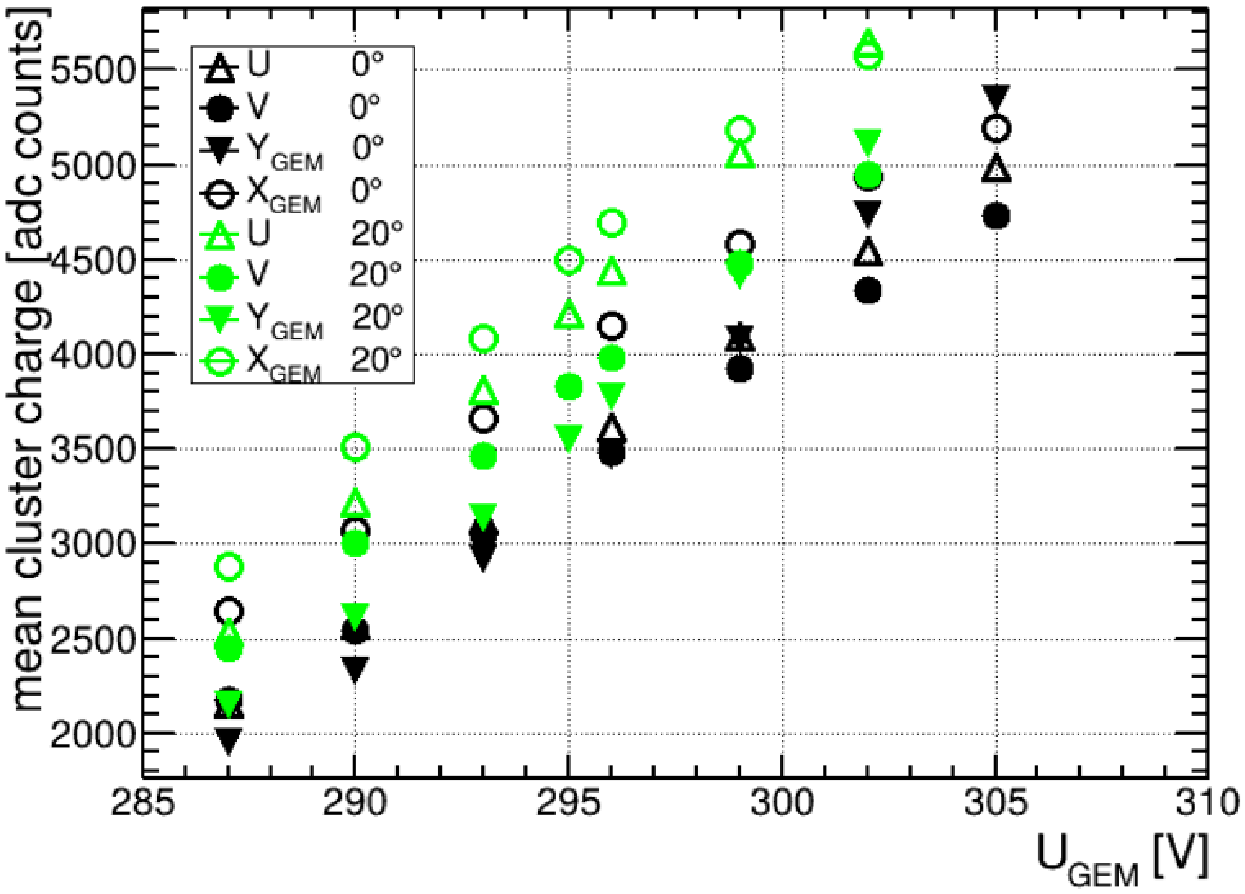
XYUV triple GEM 2D hit maps





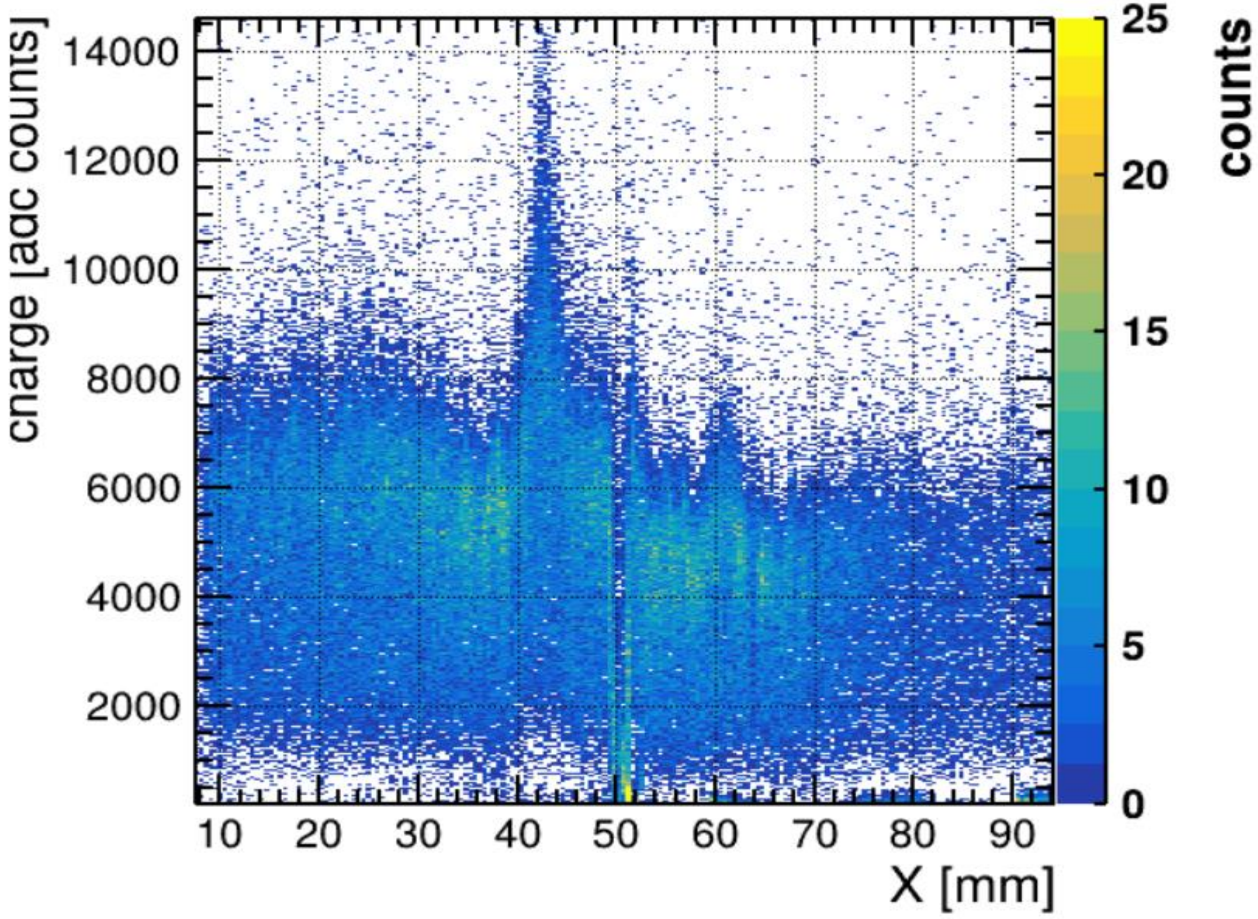
XYUV triple GEM cluster charge

- Mean cluster charge increases rather linear due to saturation of the APV25
- Charges measured by the GEM foil readout are comparable to the anode readout
  - X layer (top of GEM) is dominant for most voltages
- Slight increase for inclined tracks due to longer effective drift gap



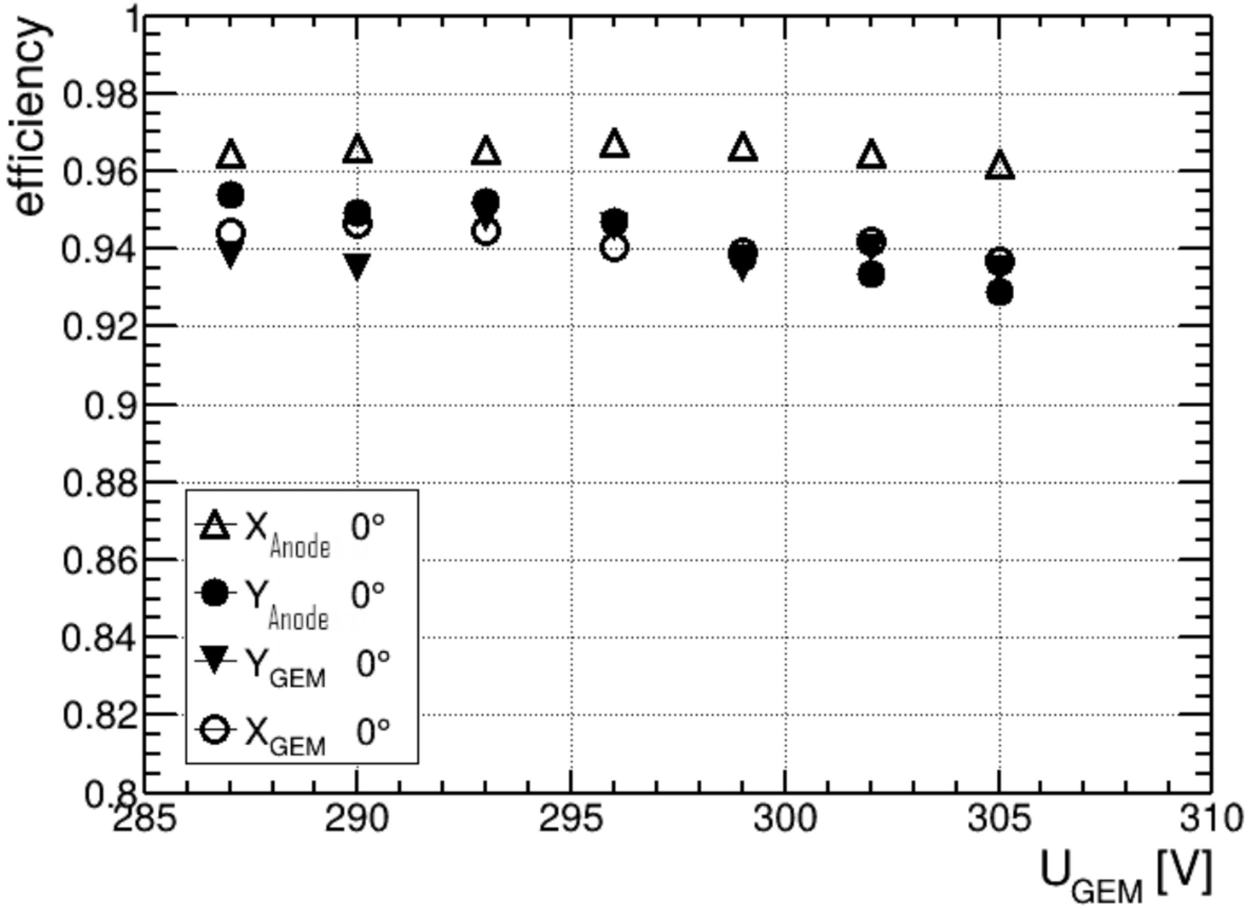
XYUV triple GEM cluster charge

- Cluster charges show strong fluctuations along the position in X direction (top of GEM)
- This is also observed in the other layers but weaker
- Has a negative effect on resolution
- Strip at x=50 mm has a malfunction
- Apart from malfunctioning strips, the inhomogeneity might result from problems of the adapter boards or imperfections in the GEM foils



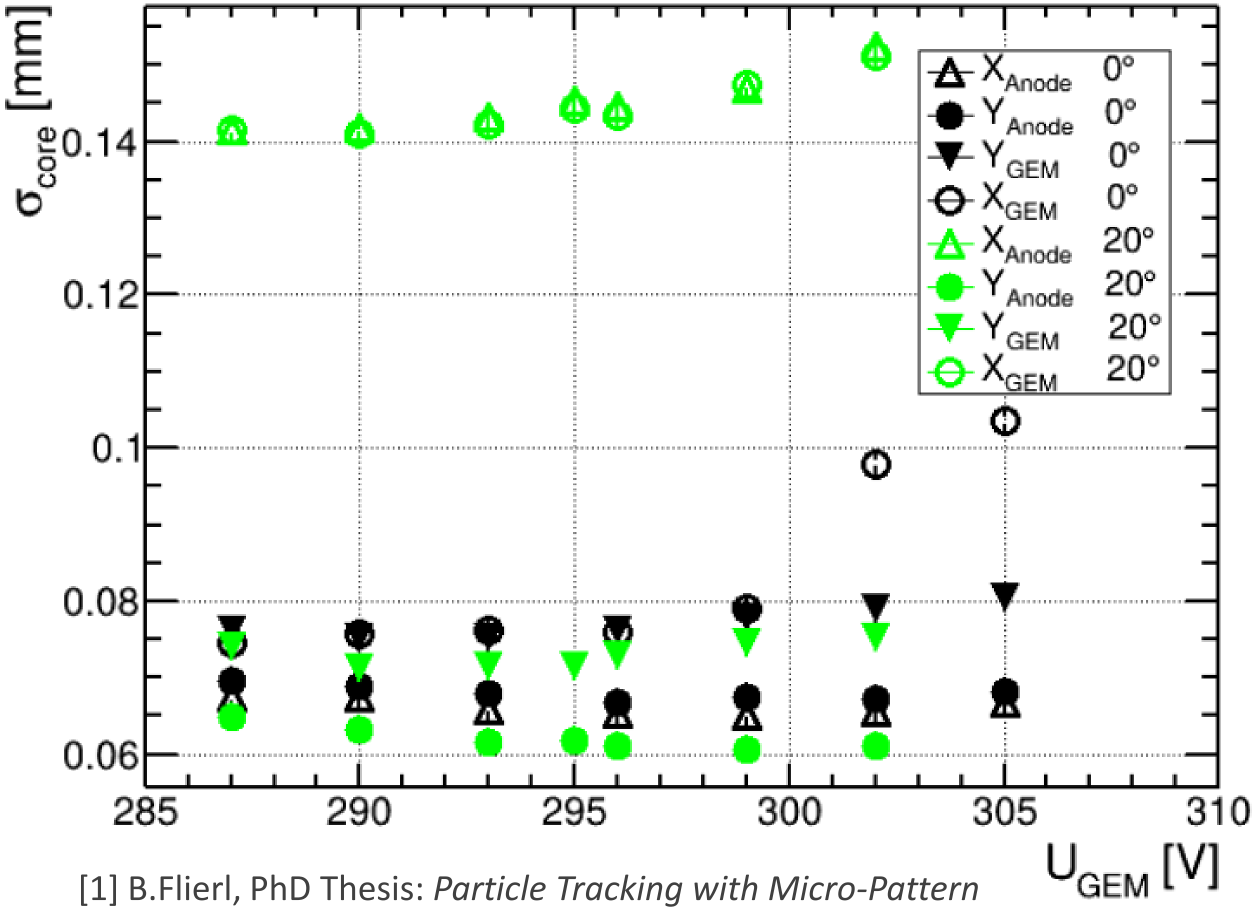
XYUV triple GEM efficiency

- All layers can achieve efficiencies (+- 3 mm) > 94%
- The malfunctioning strip at x=50 mm results in a loss of efficiency of ~2% for all layers
- X and Y position of the anode are reconstructed from the U and V readout layer
- Differences between layers most likely due to inhomogeneous gain over the active area (see previous slide)



XYUV triple GEM resolution

- Using time-corrected centroid [1]
- Resolutions of < 80 µm can be achieved, going below 65 µm for some layers
- For inclined tracks resolutions of ~140 µm are reached
- Loss of resolution due to saturation at high GEM voltages (especially for X_{GEM})
- Weighted resolutions ~85 µm

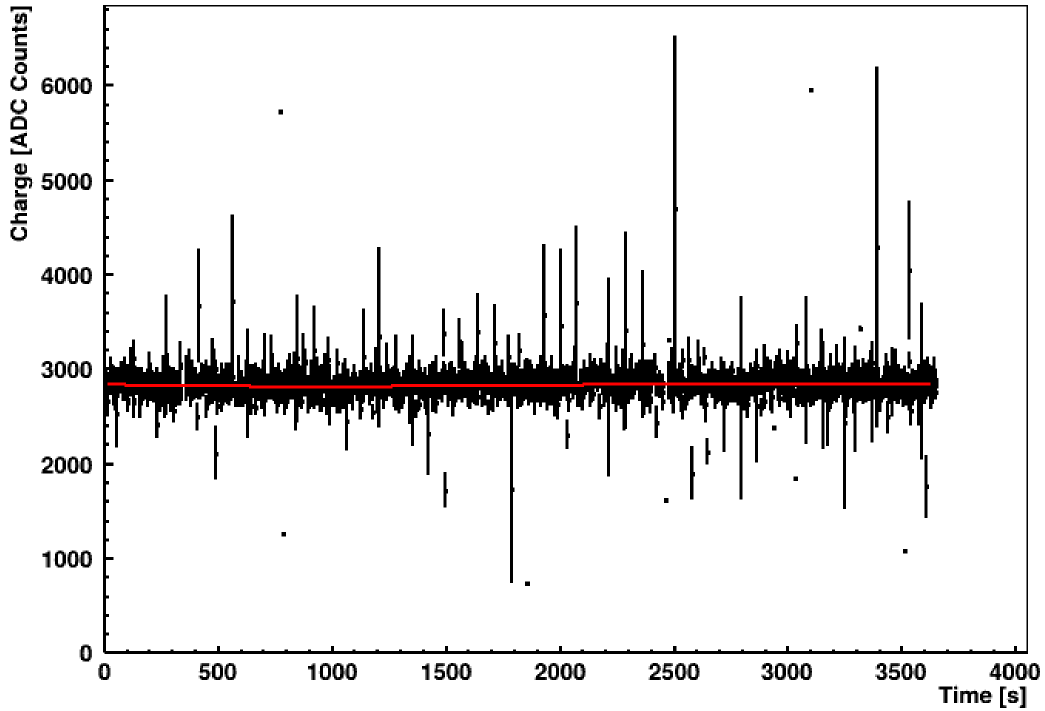


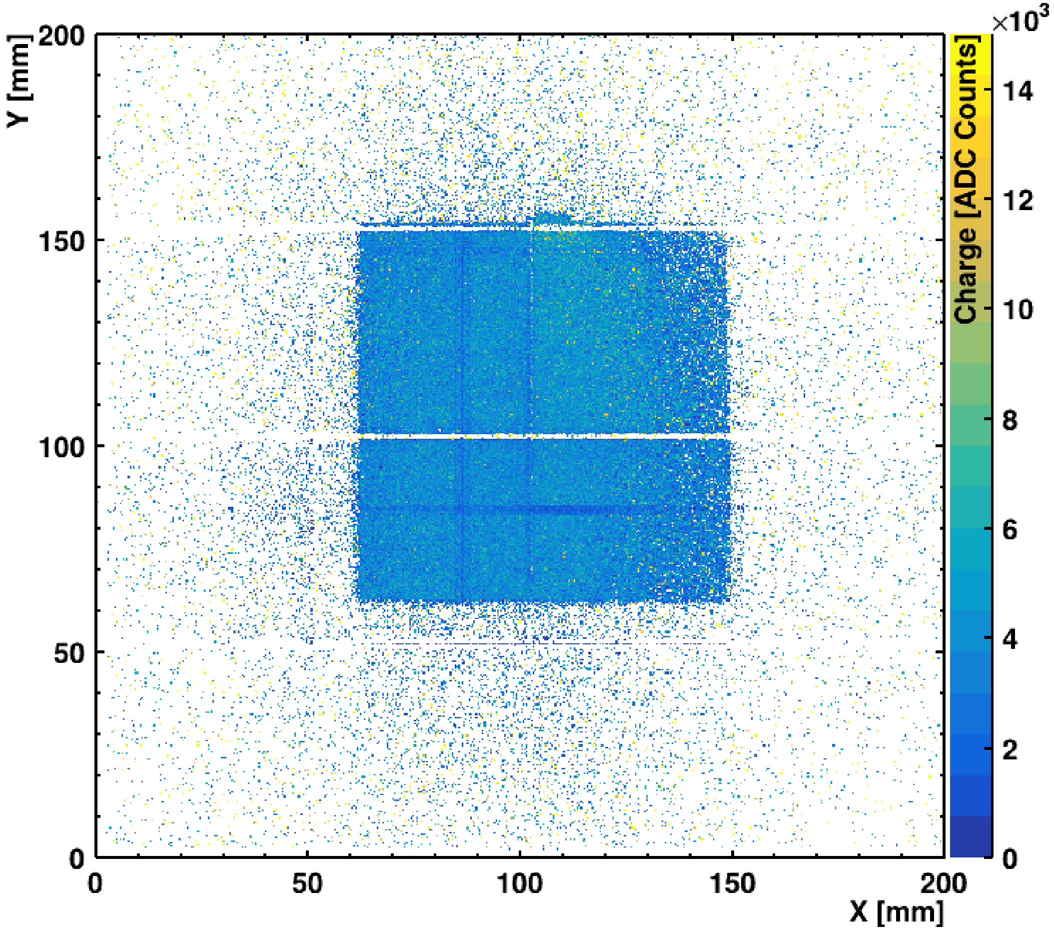
[1] B.Flierl, PhD Thesis: *Particle Tracking with Micro-Pattern Gaseous Detectors*; Mar 2018

Backup

20x20 triple GEM charge-up

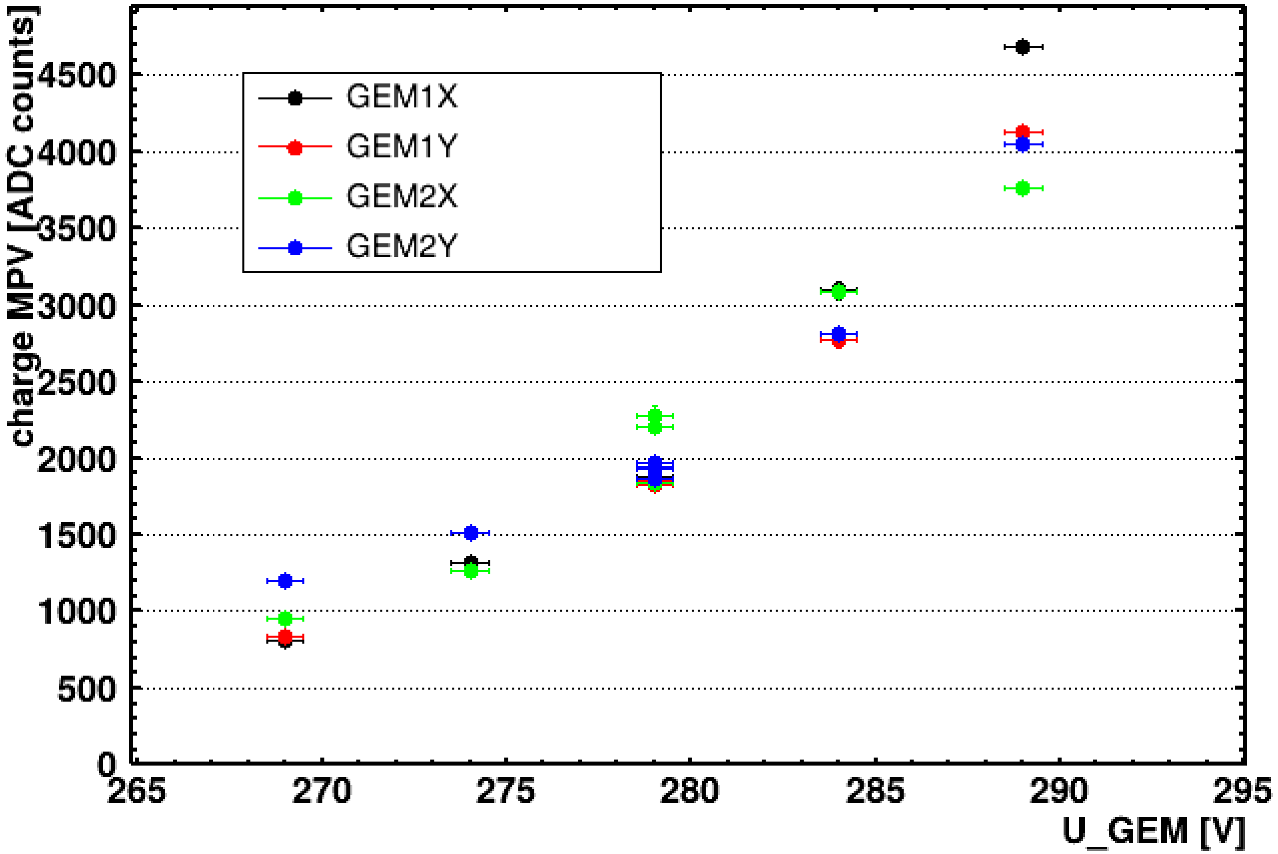
- Only inefficient strips visible
- No charge-up over time





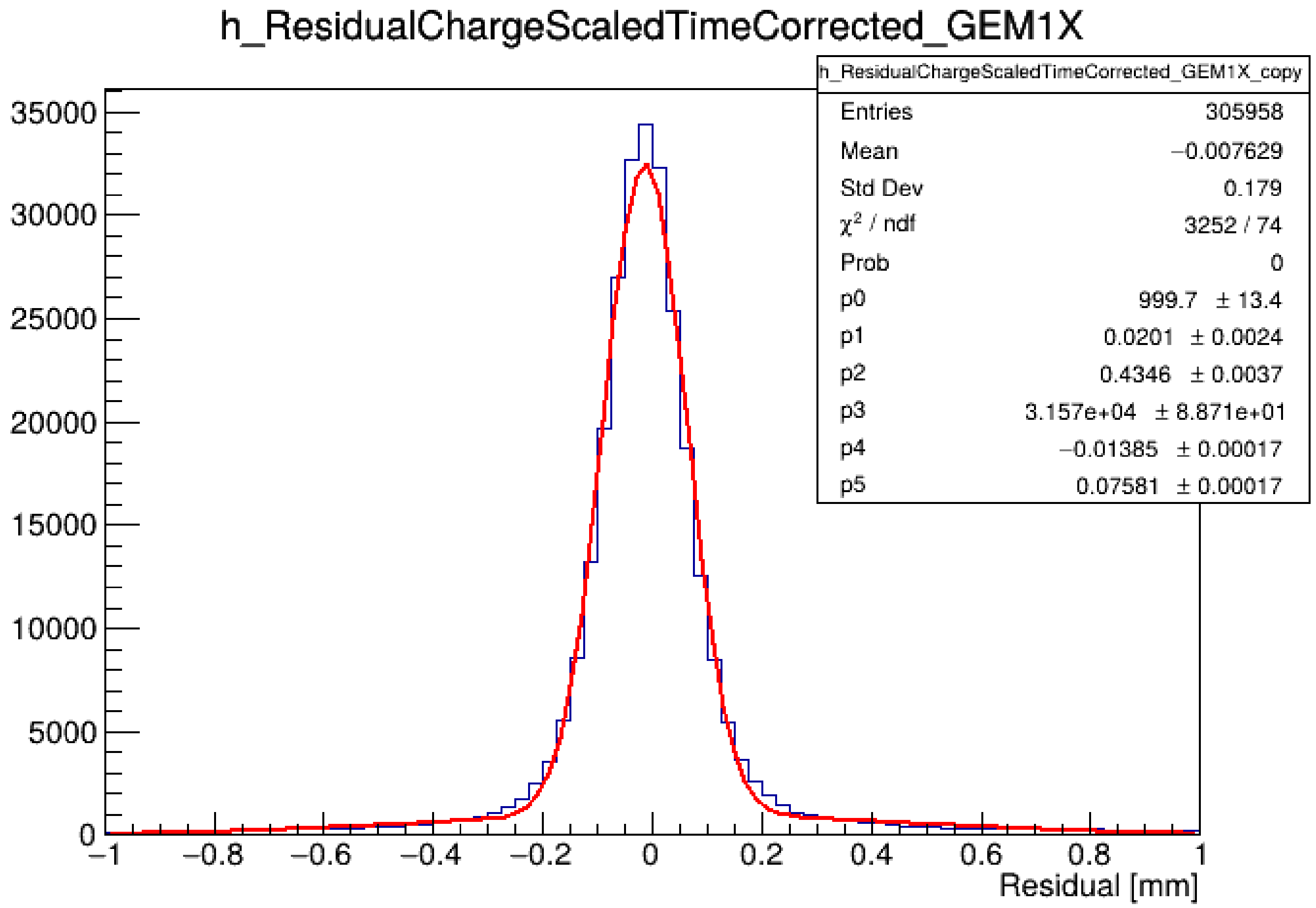
20x20 triple GEM cluster charge

- Exponential rise with increasing GEM voltage
- No strong difference between layers or detectors



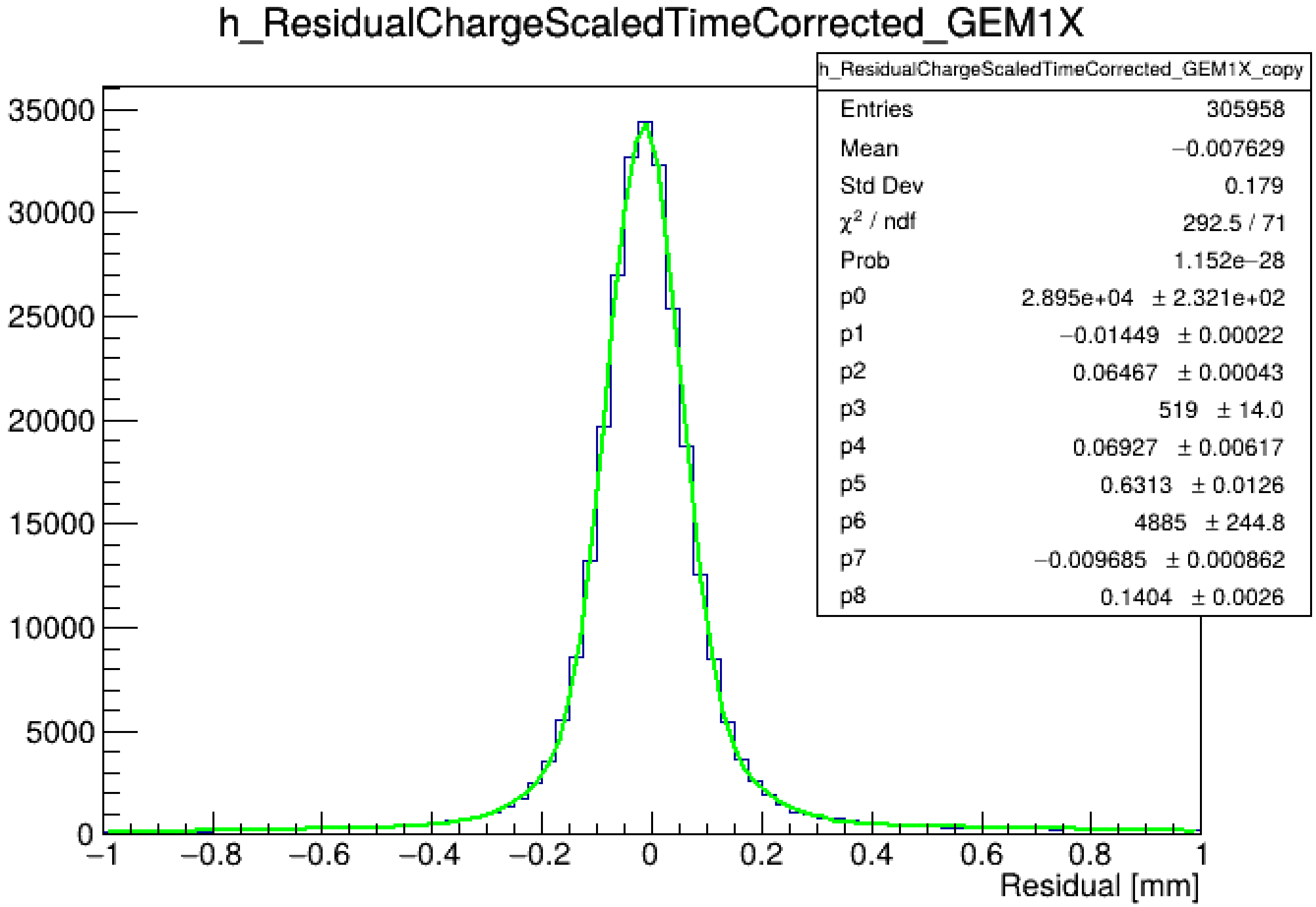
Fitting methods

- Double gaussian fit
- Does not reach peak
- Not good fitting at +-0.2
- Chi2/Ndf = 44

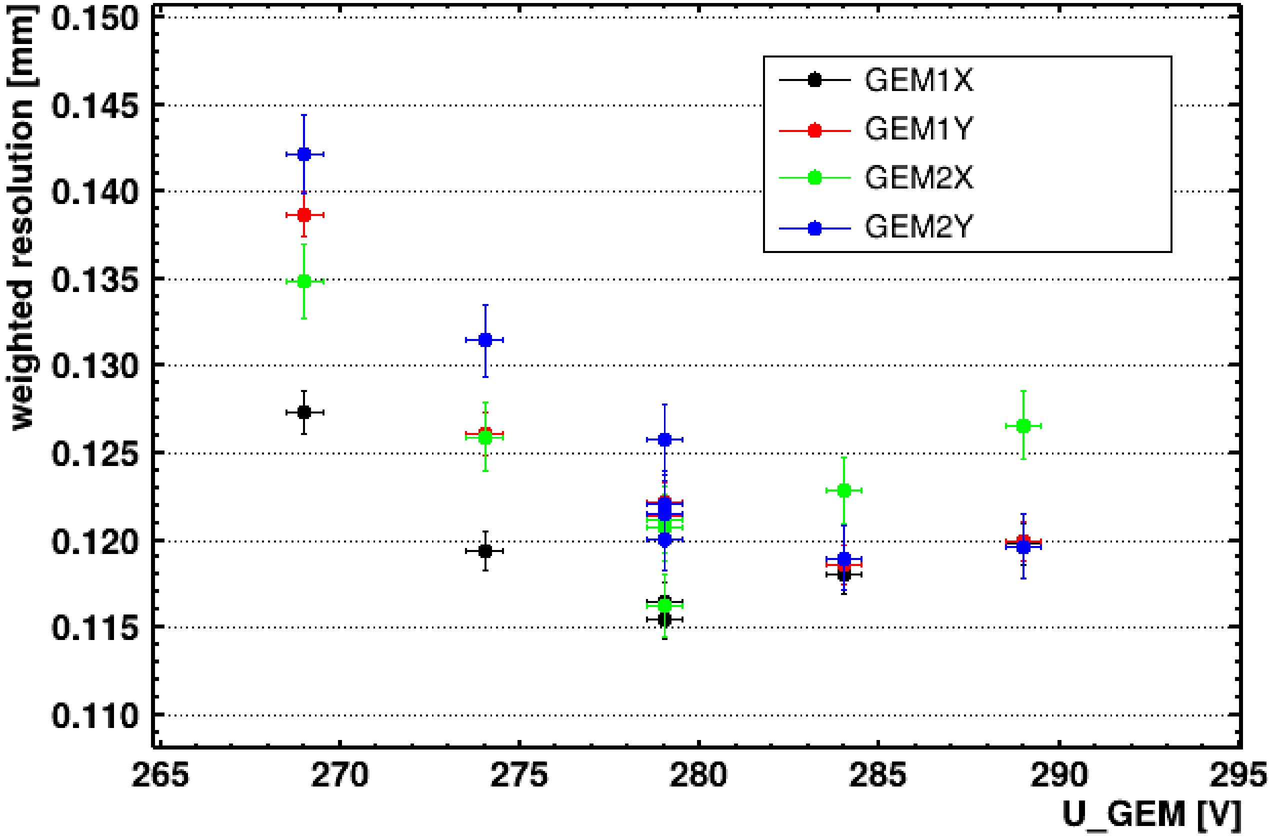


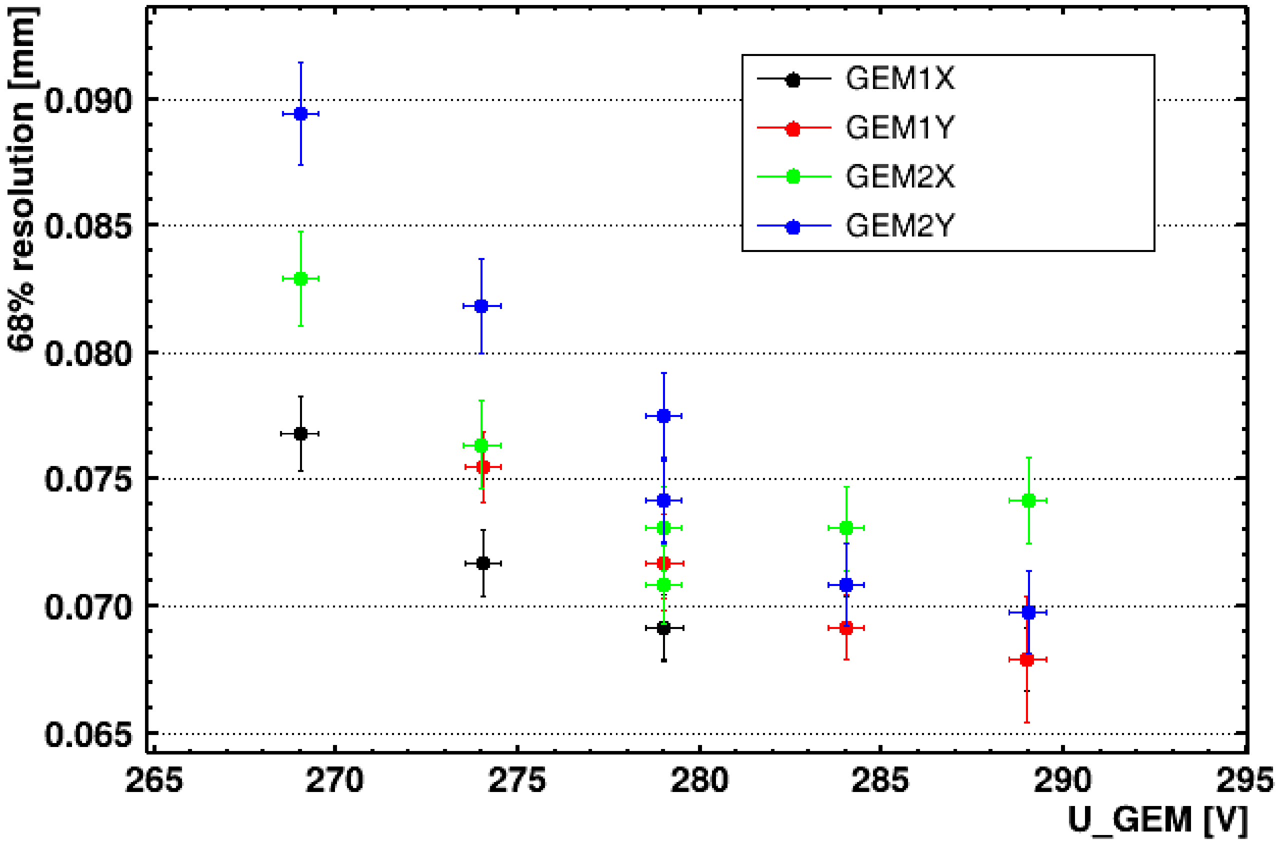
Fitting methods

- Triple gaussian fit
- Fits peak nicely
- Tails are fit well
- Chi2/Ndf = 4.1



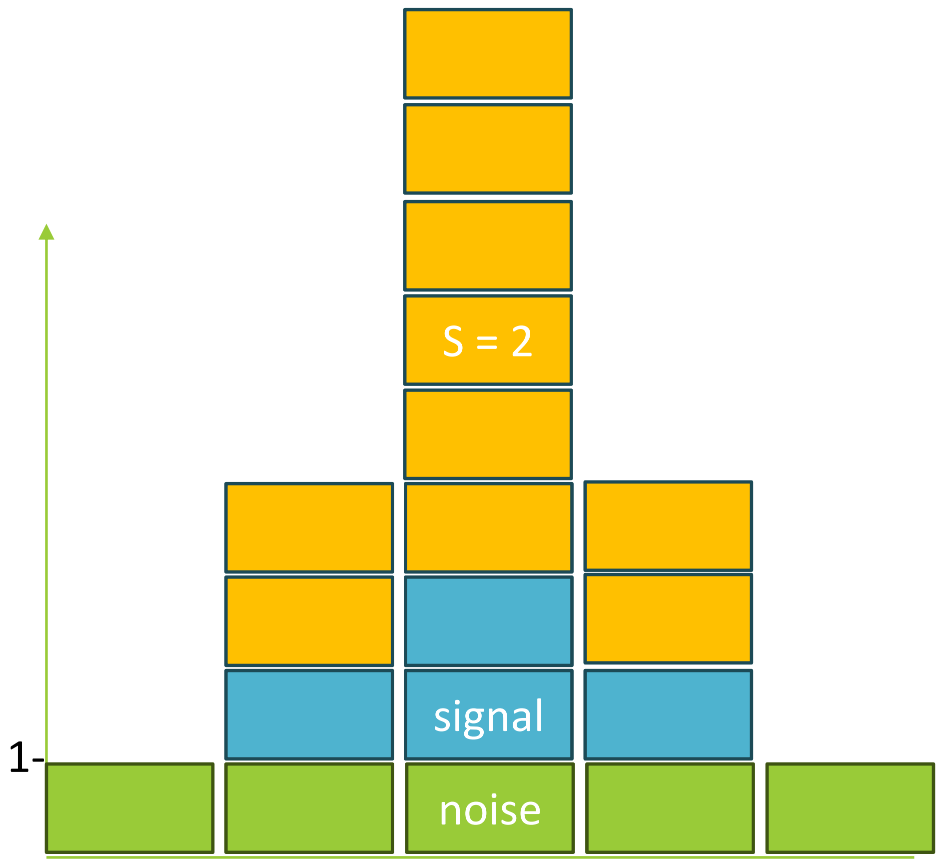
20x20 triple GEM resolution





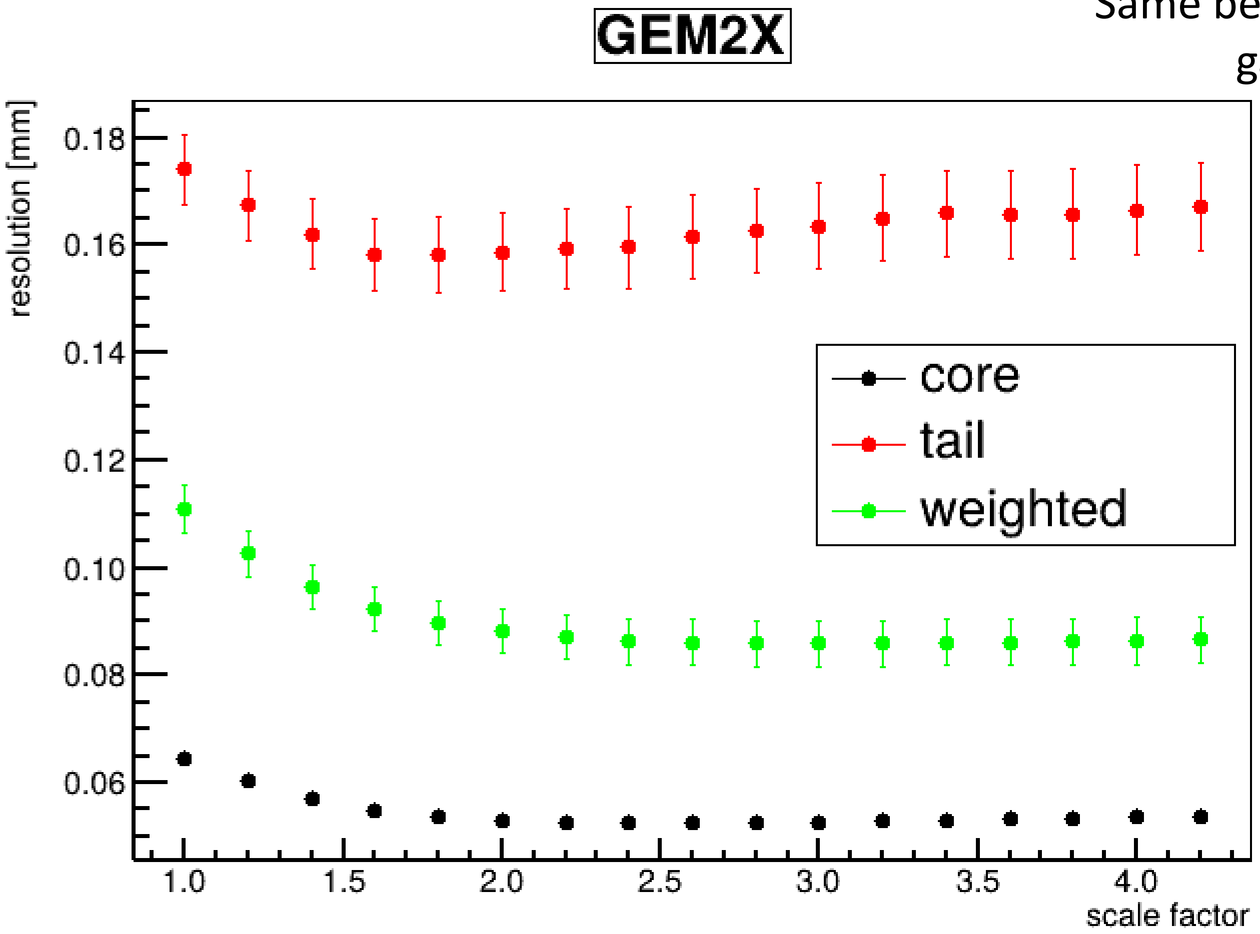
Change in reconstruction

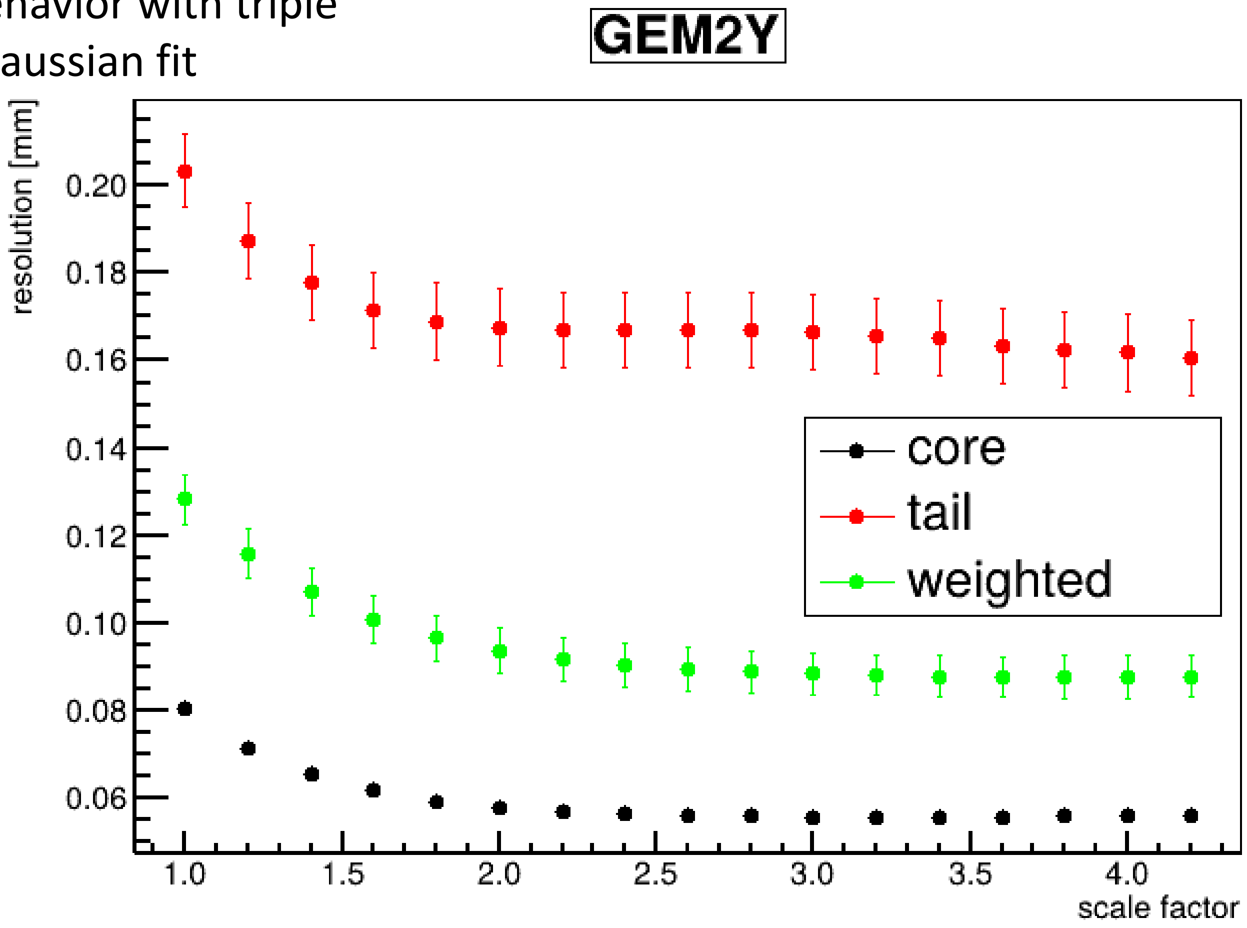
- Centroid: $x = \frac{\sum i \ x_i q_i}{\sum i \ q_i}$
- Charge scaled centroid: $x = \frac{\sum i \ x_i q_i^s}{\sum i \ q_i^s}$
- Increases signal to noise ratio
- Since the detectors were noisy this should increase the resolution
- Optimal value of “s” has to be determined



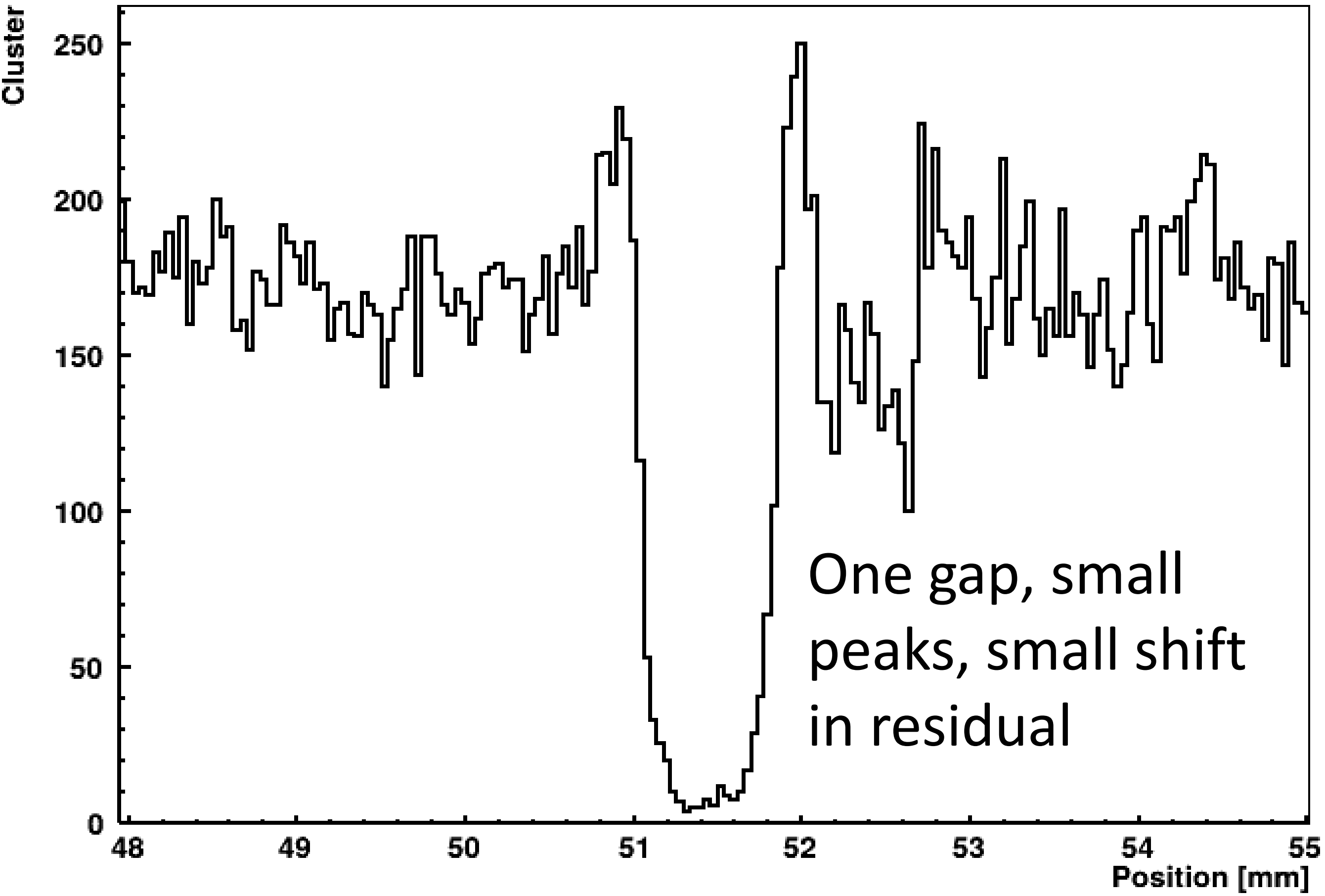
Charge scale centroid

Same behavior with triple gaussian fit

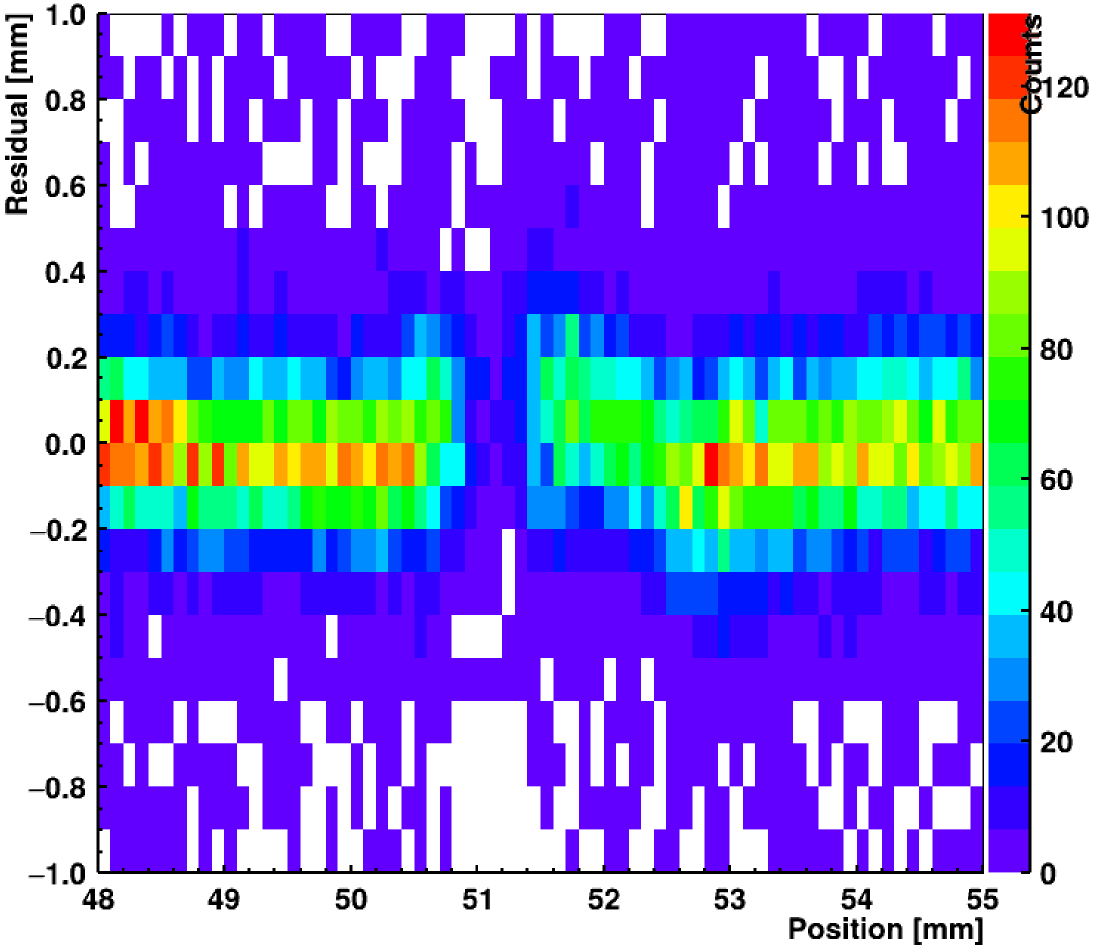




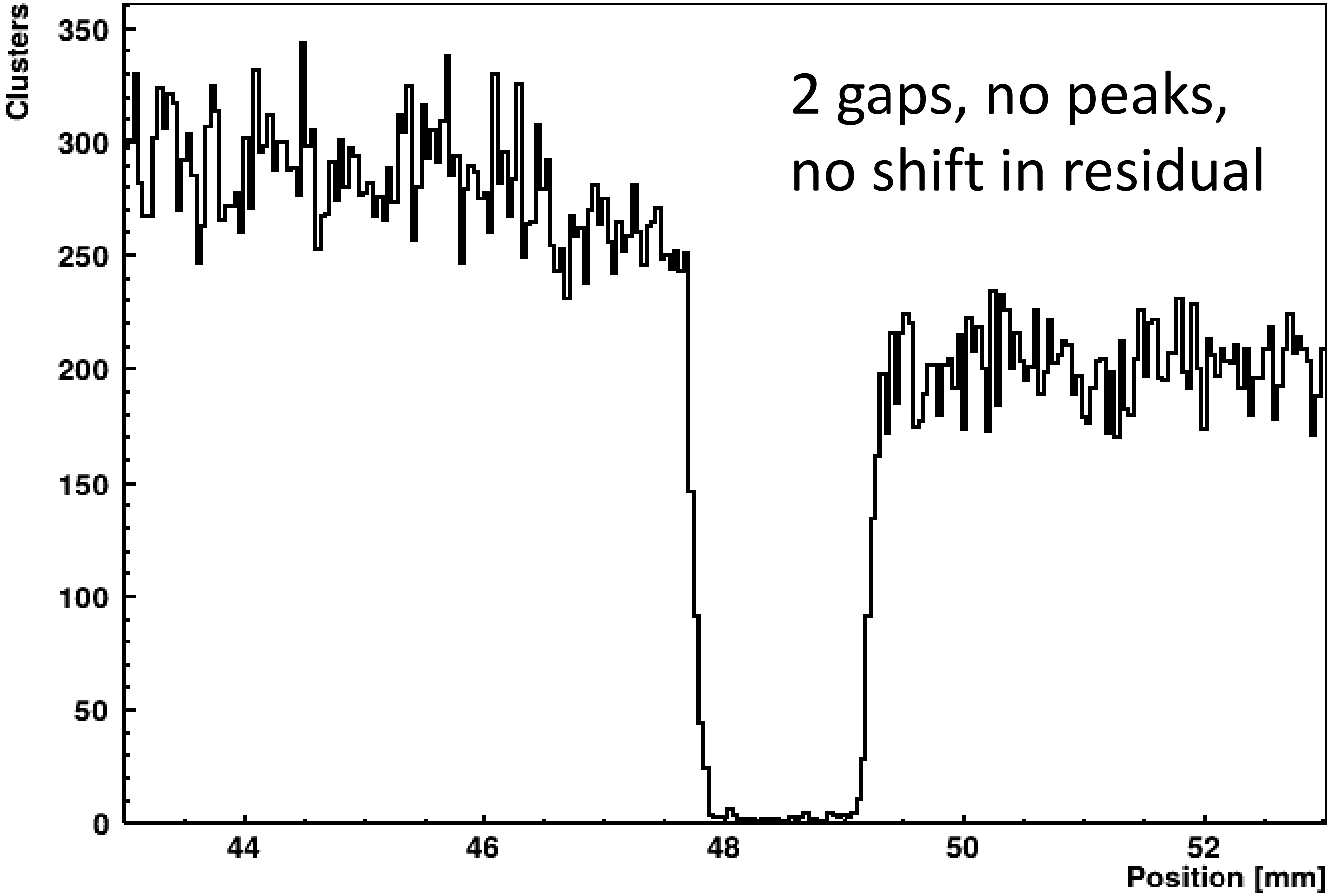
GEM segmentation effects (GEM1X)



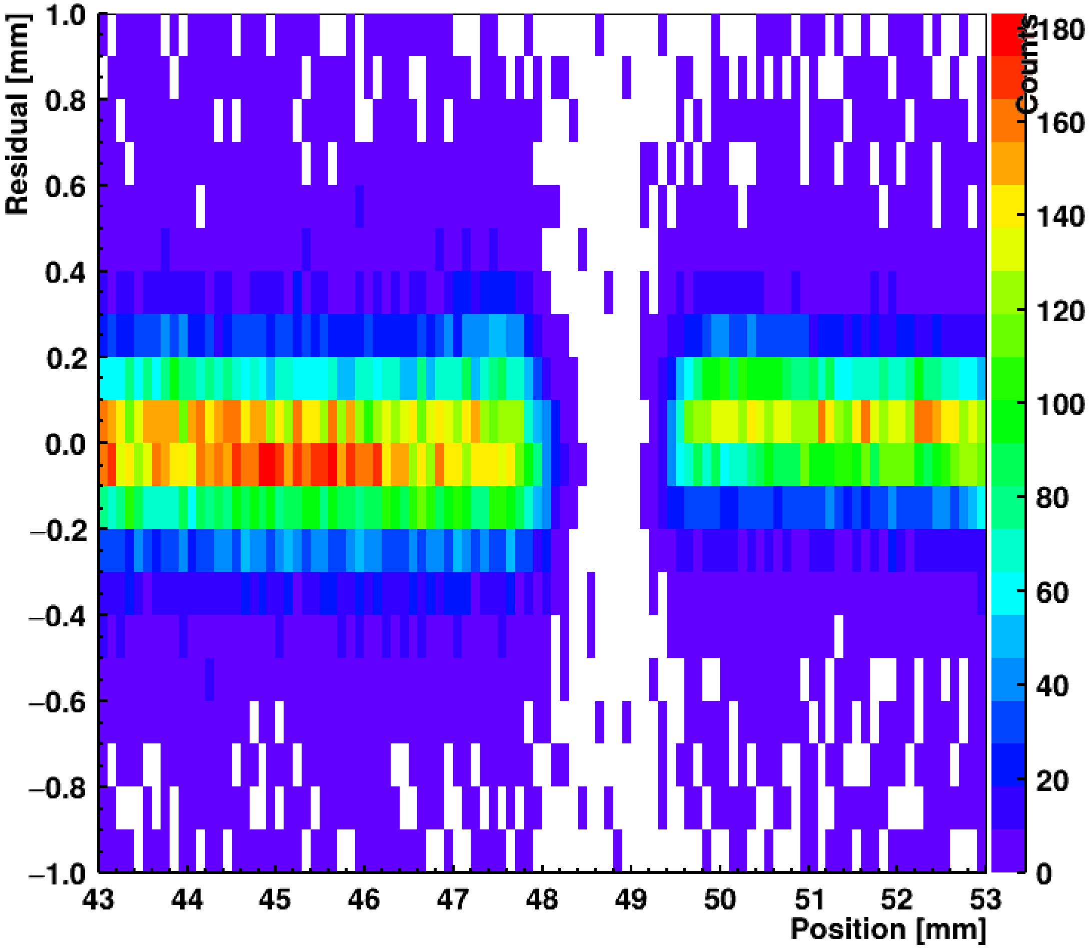
One gap, small peaks, small shift in residual



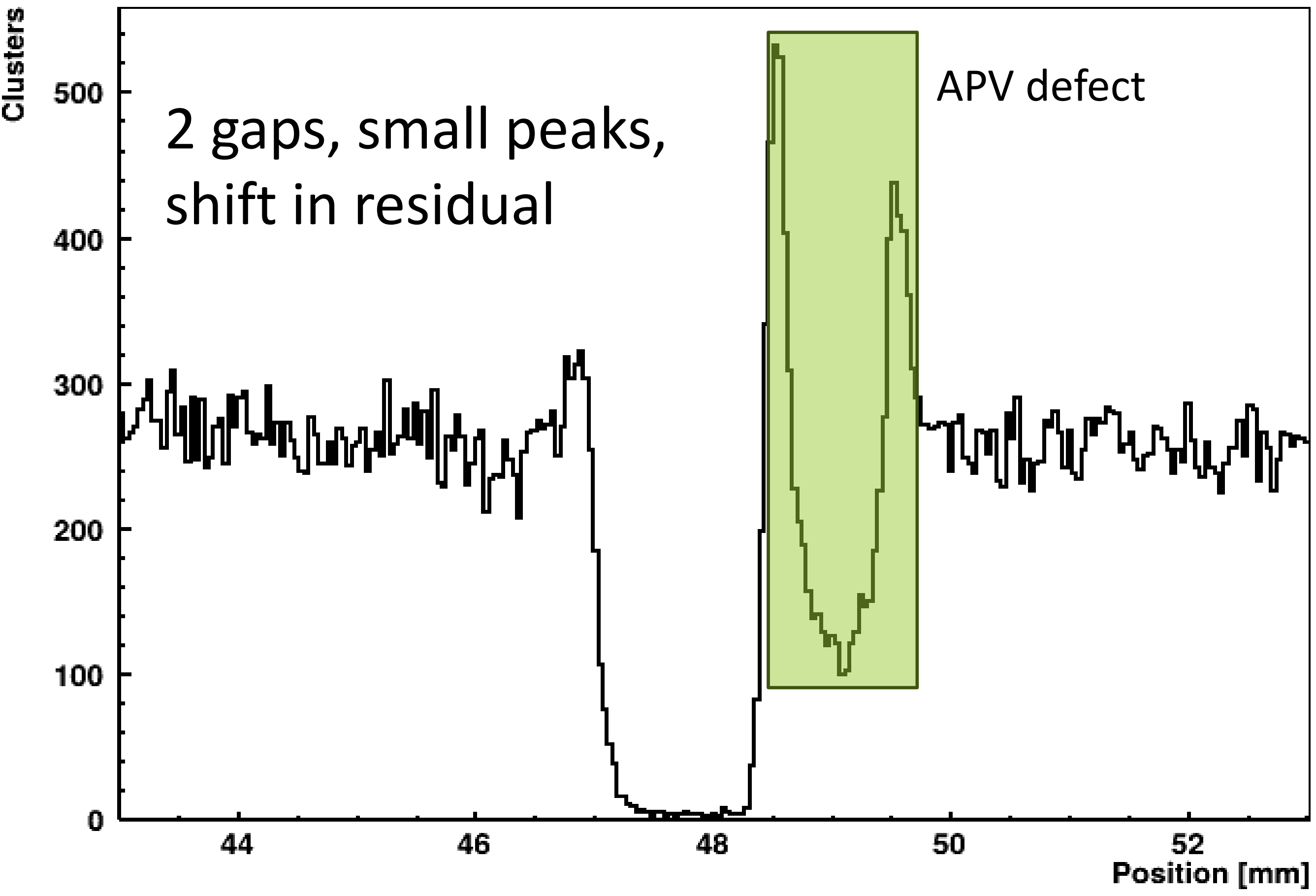
GEM segmentation effects (GEM1Y)

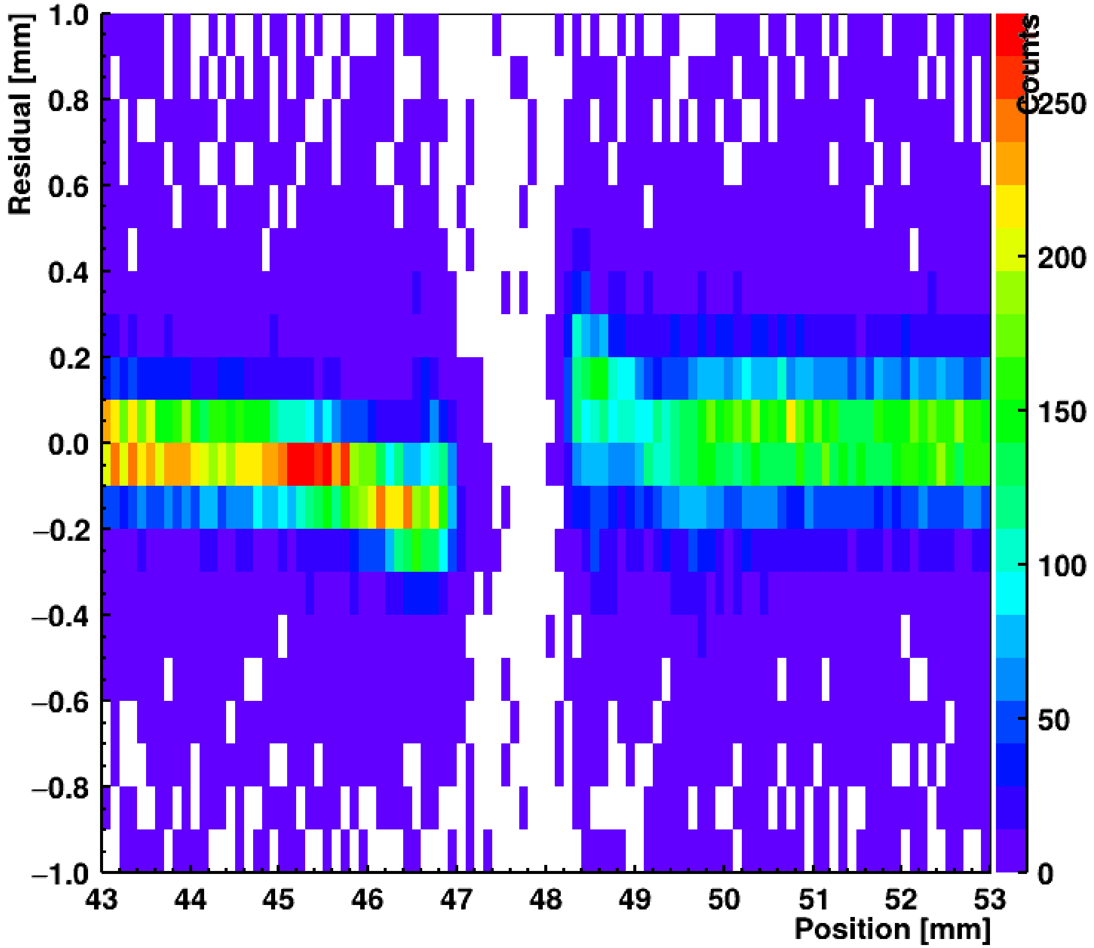


2 gaps, no peaks,
no shift in residual

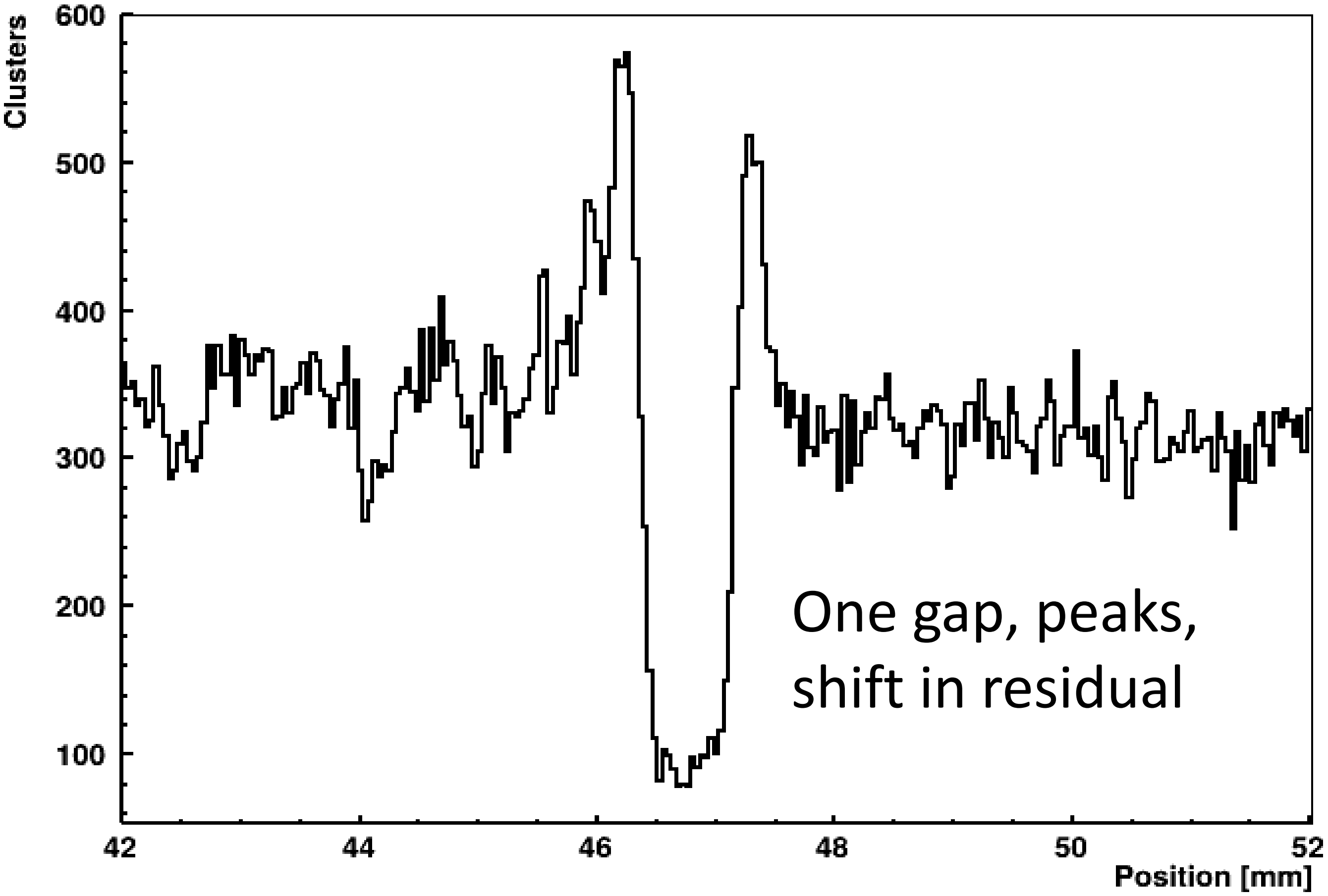


GEM segmentation effects (GEM2X)

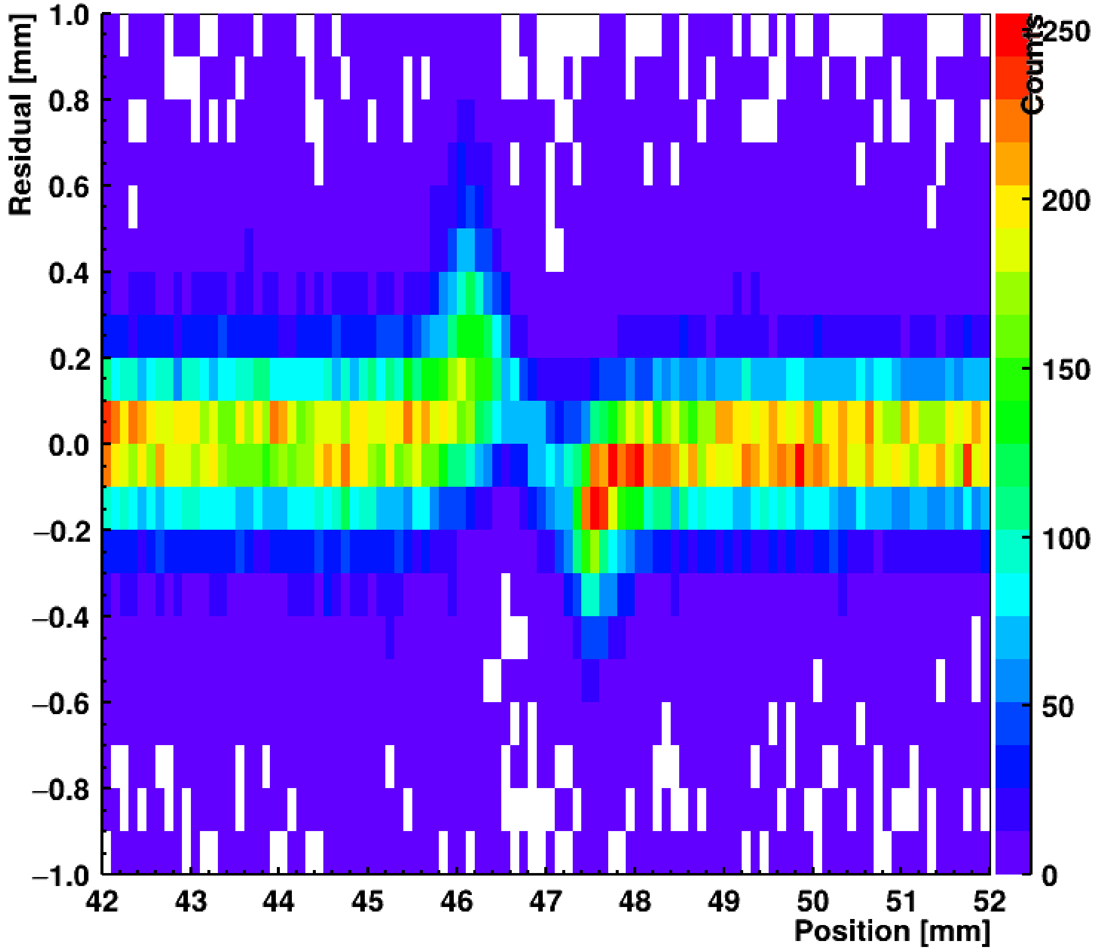




GEM segmentation effects (GEM2Y)



One gap, peaks, shift in residual



XYUV triple GEM results