The novel XYU-Readout for ambiguity-reduced tracking

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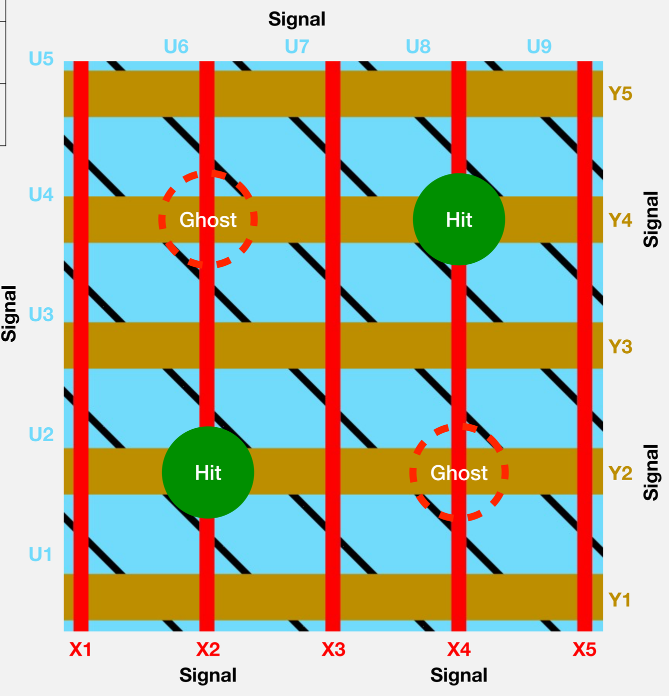
Reducing ambiguities for strip-readout

- In HEP we need high rate capabilities of tracking detectors and a way to cope with multiplicities

Signal	Combinations
X2,X4,Y2,Y4	X2/Y2,X2/Y4, X4/Y2,X4/Y4
X2,X4,Y2,Y4, U3,U7	X2/Y2/U3, X4/Y4/U7



- Removing ambiguities within one detector becomes crucial when one can not use multiple detectors behind each other to resolve them. One example would be RICH detectors. Due to the Cherenkov-rings, one obtains multiple hits at the same time. In addition, because the signals are originated from photons, one can not simply use another detector to resolve these ambiguities

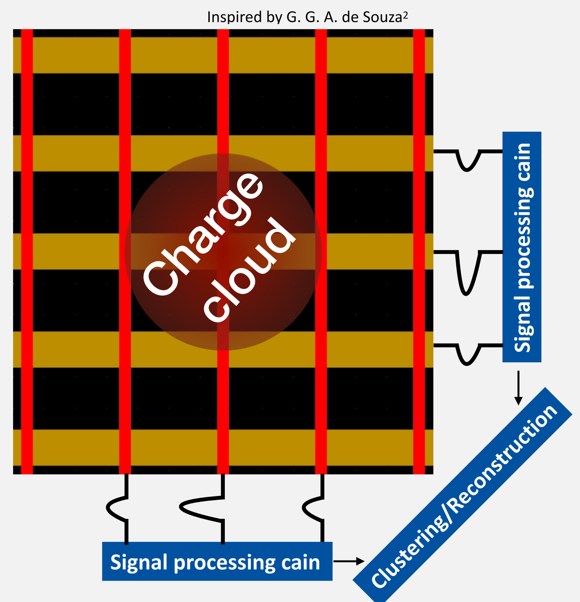
- Within limits, this can also be obtained by improving time resolution and/or additional information about signal amplitude. Solutions for this problem can be found at detector level[8,9], regardless of used electronics. One can use pixilated readout, this causes a huge increase in quantity of channels and does not scale well. Therefore, the XYU-R/O was proposed as a three coordinate strip-readout.

Position reconstruction in MPGD using strip-readout

- To obtain the position information the induced signal of the amplified and diffused electron charge cloud[1] is used

- A geometrical resolution for the position can be given by (1). If multiple strips are included it is possible to use algorithms (e.g. COG (2)) to improve

- The third coordinate might be a possibility to further improve by combining the position informations (3)



$$(1)\ \frac{pitch}{\sqrt{12}} \qquad (2)\ x = \frac{\sum x_i q_i}{\sum q_i} \qquad (3)\ \frac{X + X(U,Y)}{2}$$

XYU-GEM simulation and design

- Simulations[3] of the charge sharing have been performed to obtain the parameters for the first prototype, shown in d). The simulation was done using Garfield++ and COMSOL. However, Production limitations led to a set of manufactured parameters, which vary from the optimized set of the parameters (a). In (e) the simulation results for the manufactured parameter show a good agreement with the measurement.

- Naturally, the design does not require vias in the active area. This should help to ease production and upscaling. The manufacturing procedure was developed by CERN's Micro Pattern Technology (MPT) workshop[4].

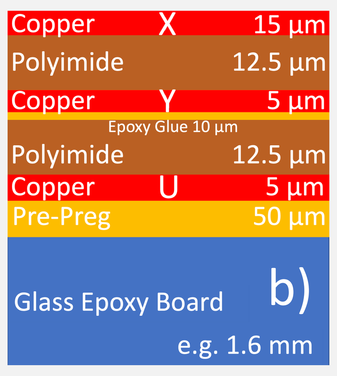
- The detector is based on the standard COMPASS-like triple-GEM detector[5] using Ar/CO_2 (70/30)

Parameter sets

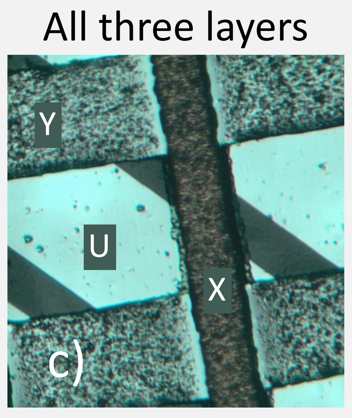
a)

Strips	X	Y	U	X	Y	U
	Optimized			Manufactured		
Pitch (µm)	400	400	400	400	400	283
Width (µm)	50	150	350	80	180	220
Insulator thickness (µm)	25	12.5		12.5	22.5	

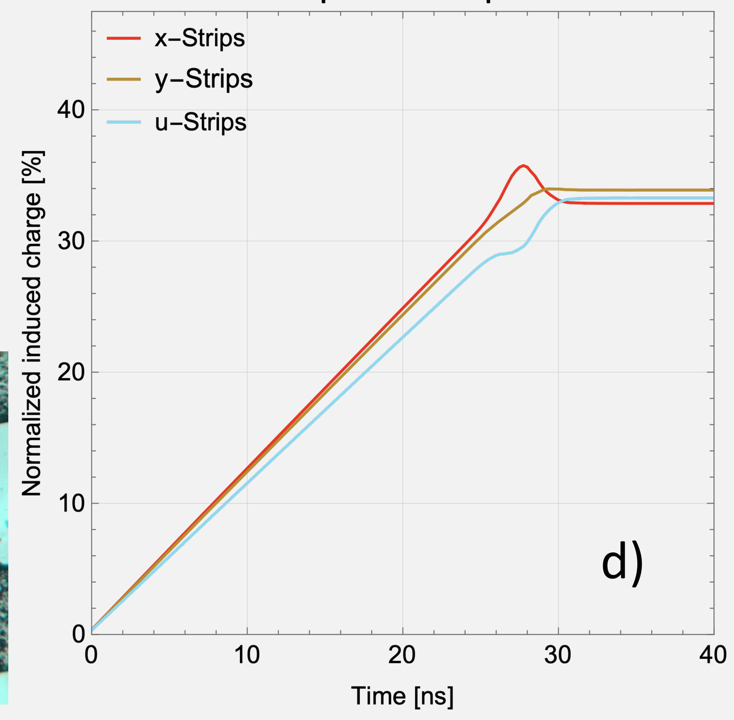
Cross-section XYU



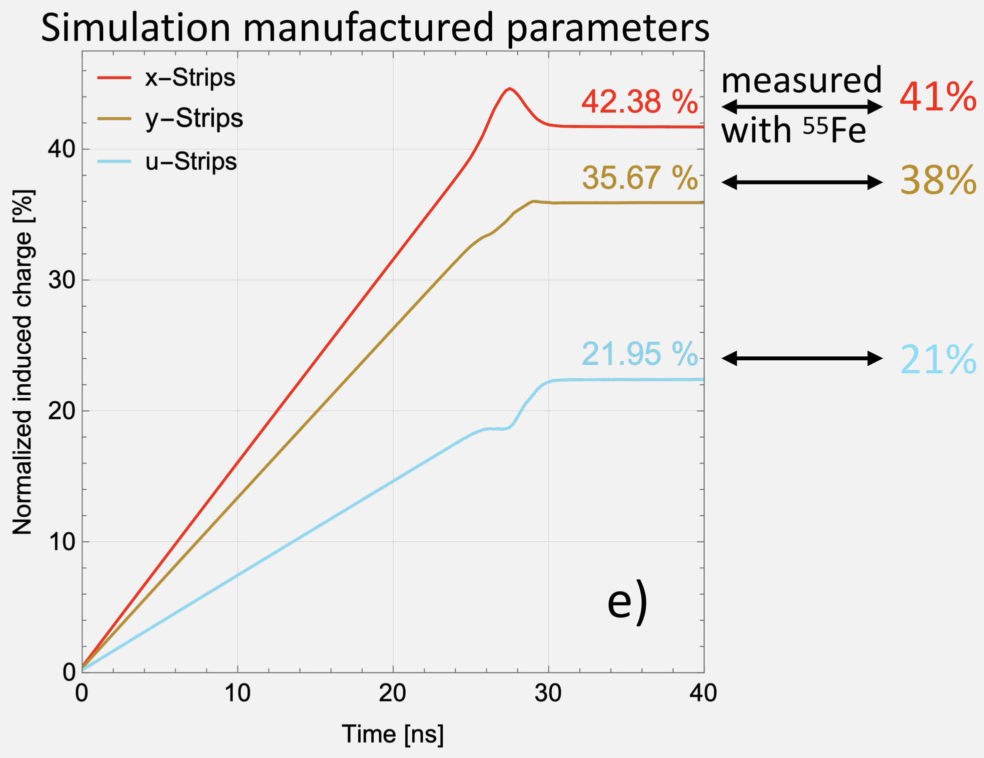
All three layers



Simulation optimized parameters

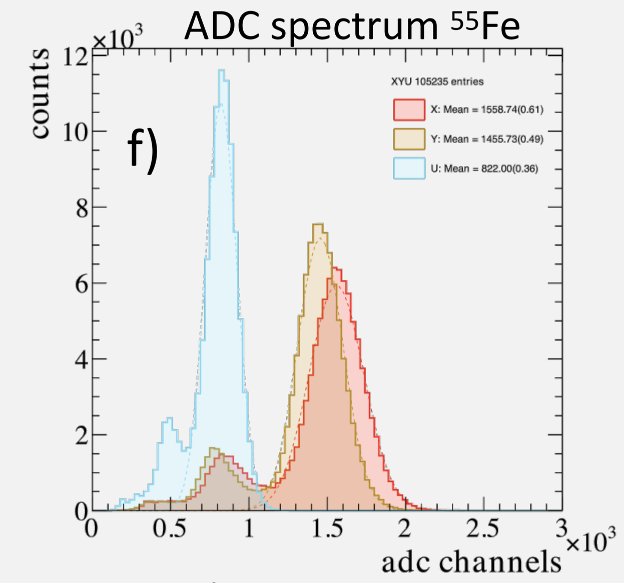


Simulation manufactured parameters

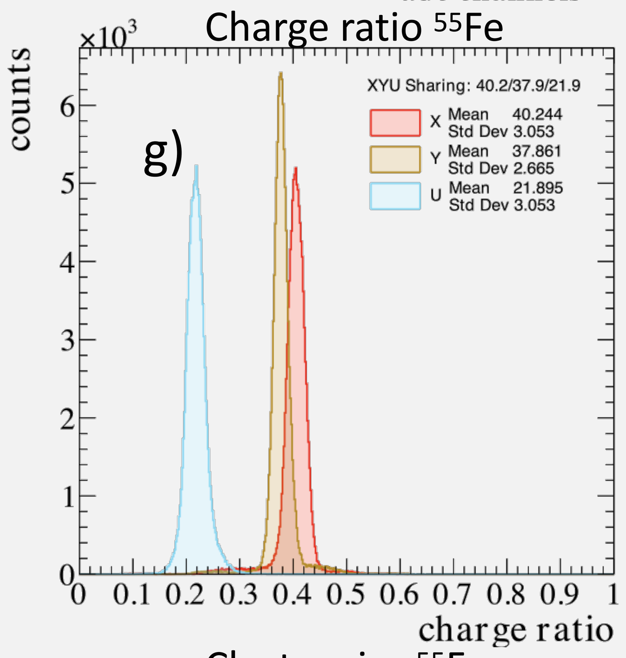


Measurements with ^{55}Fe

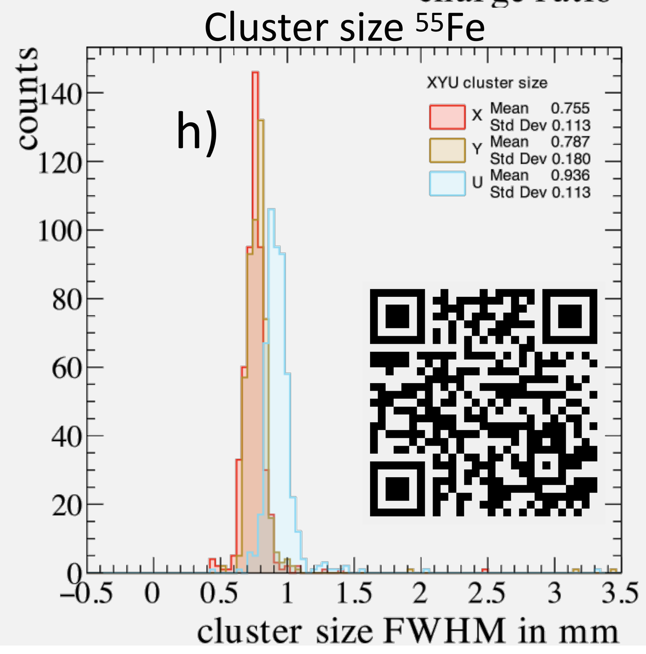
ADC spectrum ^{55}Fe



Charge ratio ^{55}Fe



Cluster size ^{55}Fe



- The measurements where performed using the VMM3a ASIC with the RD51 Scalable Readout System (SRS)[6]

- The beam data has been taken during the RD51 October test-beam at SPS H4 beam-line with 150 GeV/c Muons

- The adc spectra, (f) and (i), show a similar distribution for all three coordinates. The lower charge collection of U is in agreement with laboratory and beam data. Due to the lower initial charge from MIPs, compared to ^{55}Fe, the detector gain for the beam measurements is a factor of three higher

- Extracting the position of the photopeak and the MPV, the charge sharing can be determined. This leads to ~41/38/21 (X/Y/U) for the ^{55}Fe and ~39/36/25 for the beam measurements

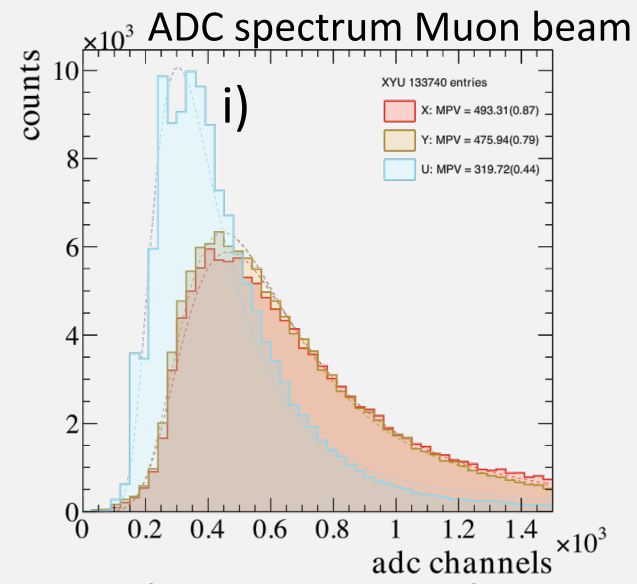
- Calculating the charge ratio directly event by event, it can be seen a similar result. Comparing (g) and (j) the sharing in the beam seems to be moved closer together compared to the laboratory

- To further investigate the detector response, the FWHM for the cluster size of single events was extracted. In (h) and (k) U seems to be shifted to larger cluster sizes. A possible explanation would be that the fit is overestimating for smaller amplitudes

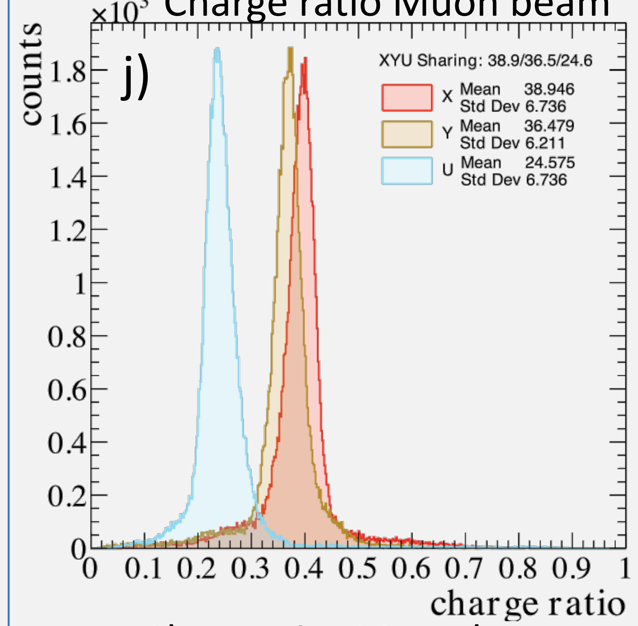
- Using the QR-code it is possible to see some event by event clusters for the different coordinates. Also here the lower amplitude for U can be seen

Measurements with MIPs

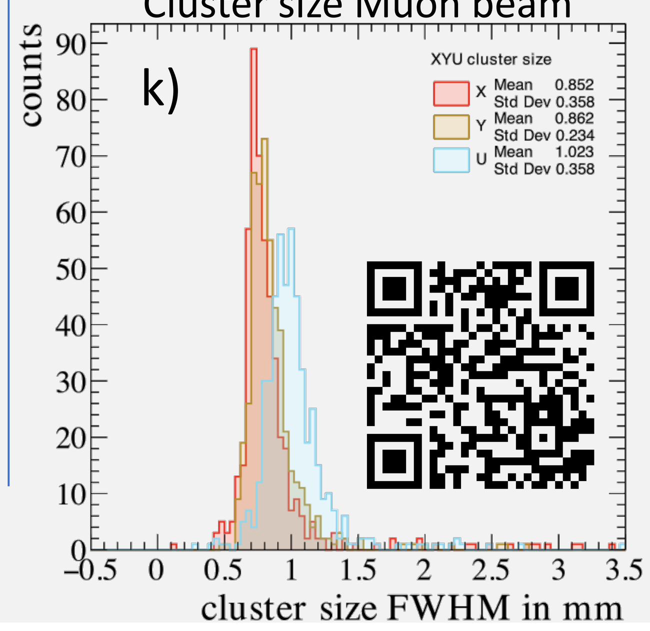
ADC spectrum Muon beam



Charge ratio Muon beam



Cluster size Muon beam

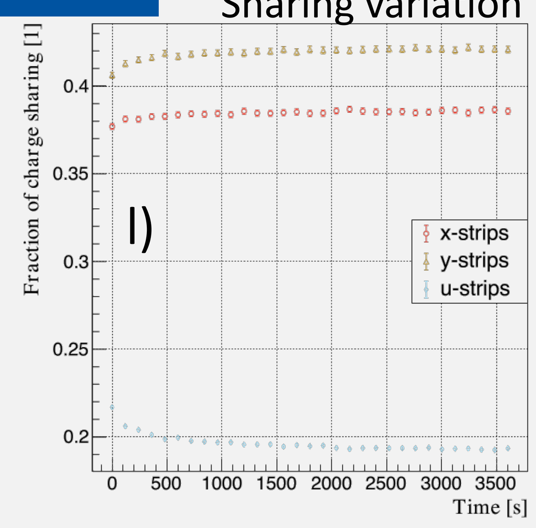


Influence of irradiation

- During irradiation a change in the sharing between the three coordinates was observed

- The assumption: electrons get trapped at the insulator between the strips and thus change the electric field, resulting in a change of the charge collection

Sharing variation



- As visible in (l), the effect is comparably small and an equilibrium can be observed within five minutes with low rate (~2.5 Hz/mm²)

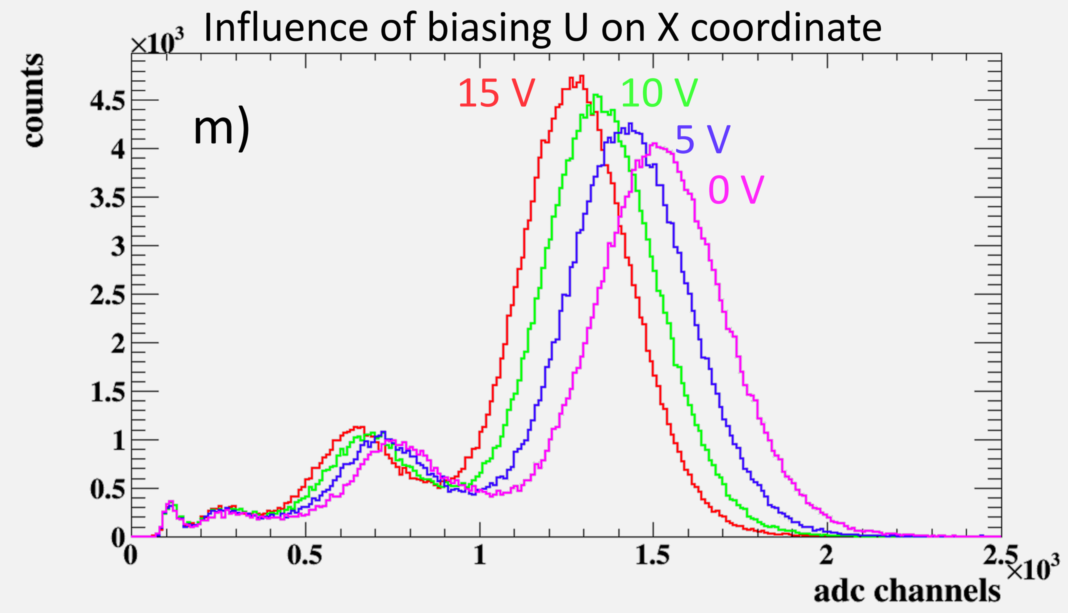
- The charge is mainly shifted from the U layer to the X layer. The intermediate Y layer shows the smallest variation

Biasing coordinates

- Biasing the coordinates by applying a voltage on the strips can be used to tweak the charge collection. Equal charge sharing would be possible without exploiting production limitations

- As shown in (m), a significant change in the signal of the X coordinate can be achieved by biasing the U coordinate

Influence of biasing U on X coordinate



High multiplicities

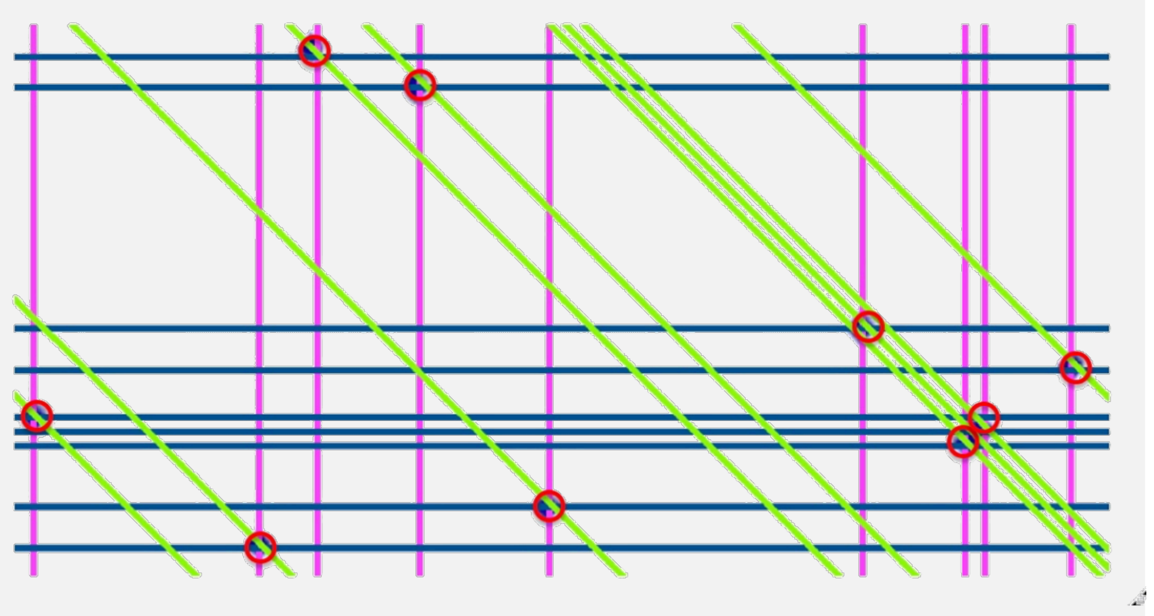
- To emulate high multiplicities, a larger time window was displayed to show nine events

- Correct positions are known (red marks) in this example

- With only two coordinates, it would be impossible to get reliable informations about the real hits

- With the third coordinate one can already resolve most of the ambiguities by simple correlation

- Still present ghosts might be resolved by more complex combination-algorithm, e.g. looping over the multiple possibilities and requiring to use up all signals



Conclusion and outlook

- A first prototype of the XYU-GEM was produced[4] and measurements in the laboratory and with MIPs could be obtained[7]

- The simulation showed good proof with the manufactured parameters and could be used to predict better parameters

- Using the beam data the detector response with actual multi-hit events, caused by showers, is under investigation. As well as the possible influence of the third coordinate on the resolution

- Biasing one of the coordinates to influence the sharing should be further investigated to see the effect simultaneously on all coordinates

- Another aspect worth to investigate would be a different pitch. This can be done using an adapter to merge channels

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References

CERN EP R&D
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