2D Interleaved Readouts for MPGDs

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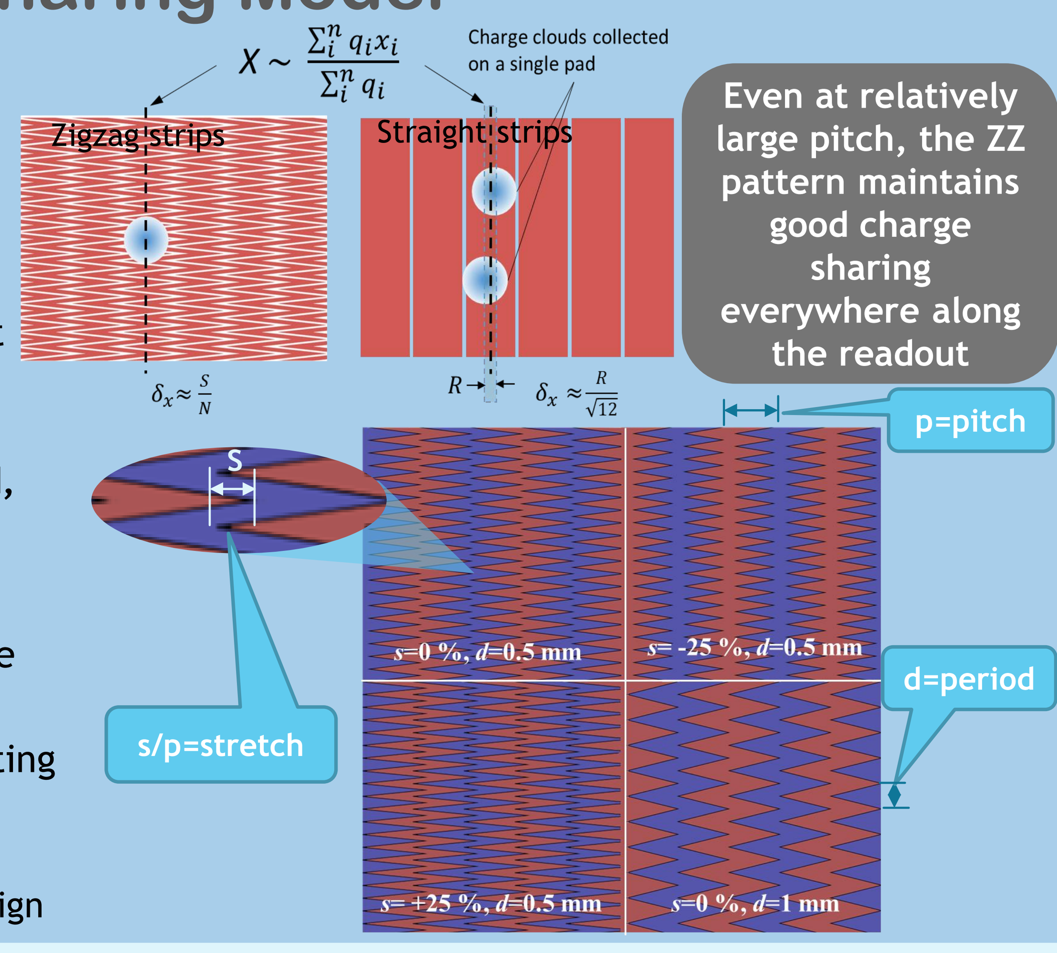
Introduction

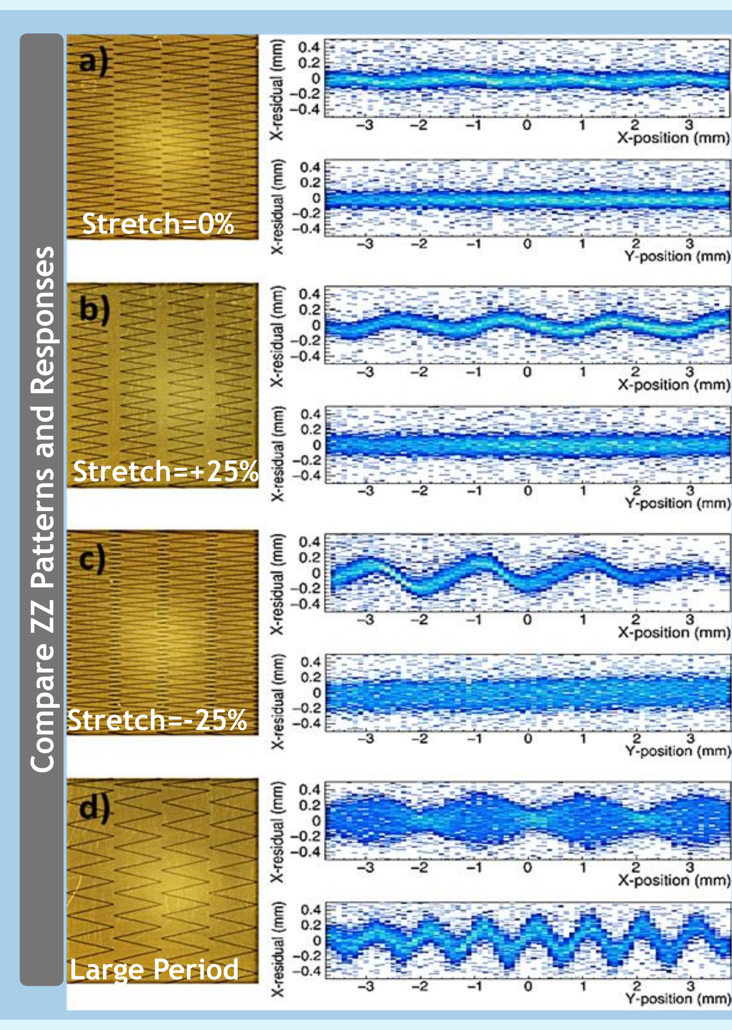
Coarsely segmented (pitch > 1 mm) zigzag-shaped anode strip arrays have been shown to have considerable advantages over similarly pitched straight strip arrays for standard planar MPGDs, including GEM, Micromegas, and μRWELL detectors. Once the geometric parameters of the zigzag are precisely tuned for a specific detector application, the spatial resolution remains high and approximately flat for very large pitches, up to 3.3 mm or more. Additionally, the response of the optimized zigzags along the measured coordinate and in the orthogonal direction are highly uniform without the need for differential non-linearity corrections. We extend the enhanced charge sharing characteristic of the zigzags to the case of a 2D readout by employing anode structures that are interleaved along two distinct directions. This allows for the possibility to choose arbitrary coordinate axes suitable for particular detector applications. As in the 1D case, the segmentation of the 2D anodes can also be large to minimize the channel count and save considerably on the readout electronics.

Motivation: Linear Charge Sharing Model

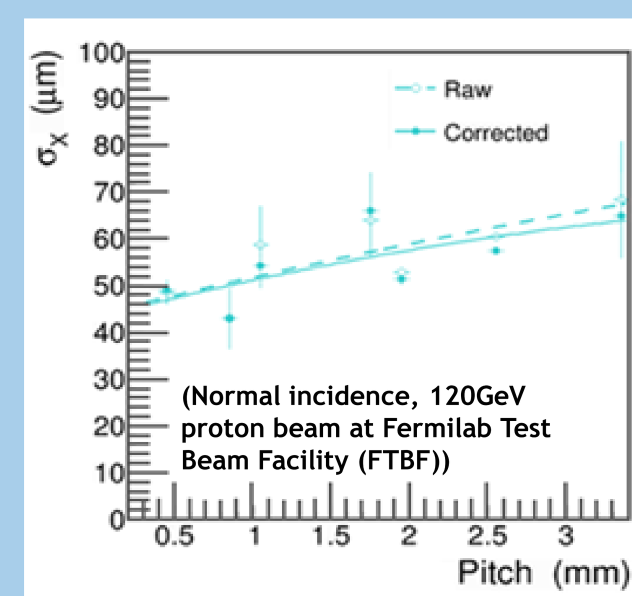
Design Philosophy

- Interleaved anode geometries substantially improve charge sharing
- Coarse segmentations maintain excellent position resolution with fewer frontend electronics channels
- The design of the anode structure may be tuned so that the reconstructed position varies linearly with charge sampling everywhere across the readout
  - Geometric parameters to be optimized: **pitch, period, stretch**
  - Achieve uniform detector response with no needed correction functions
- The segmentation of the anodes into strips/pads may be customized to achieve a given occupancy requirement
- Coarsely segmented anodes allow for simpler trace routing on fewer layers in the board stack-up
  - 2-layer flex-circuit boards are possible, offering tremendous flexibility for the detector backplane design



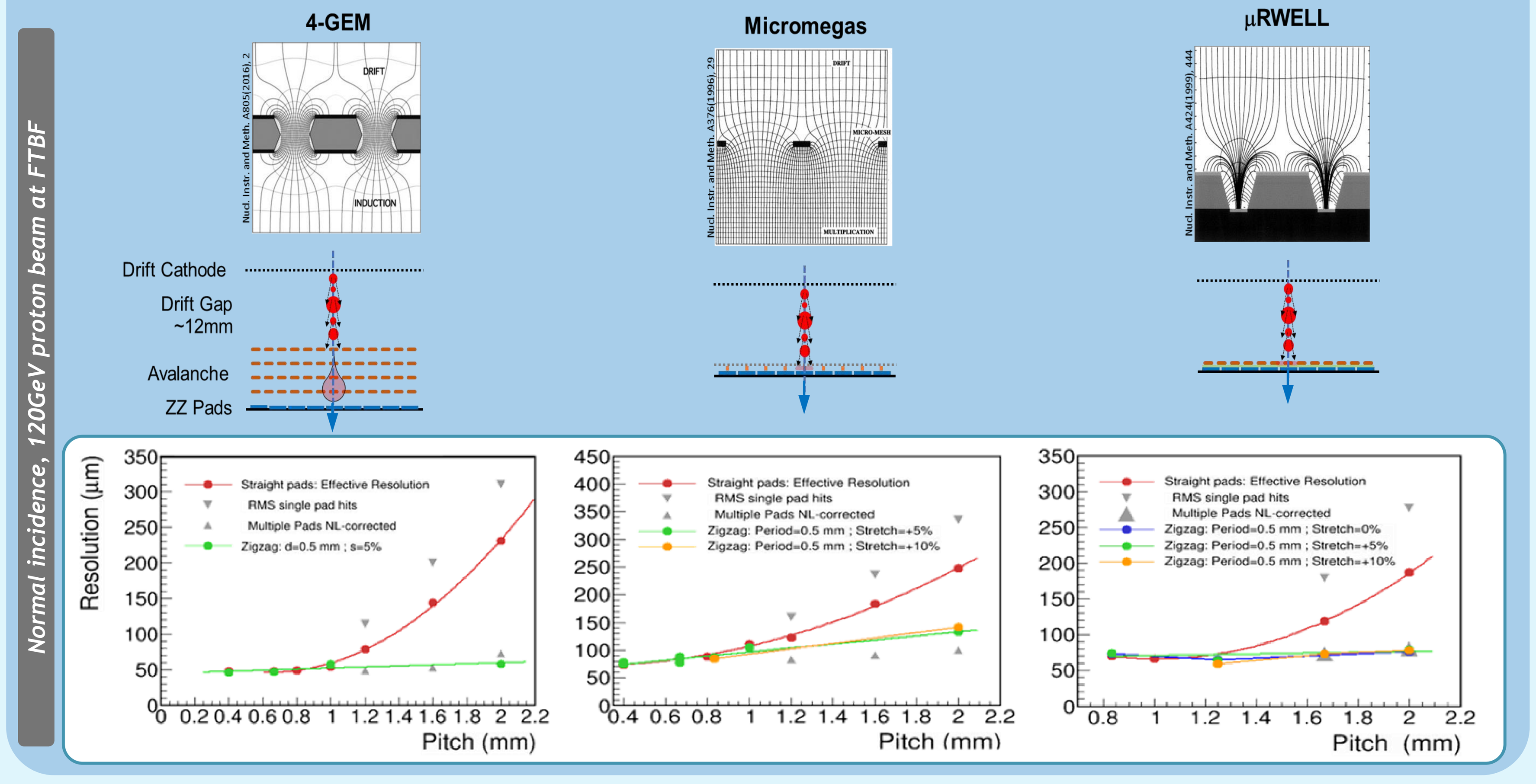


Position resolution of optimized ZZ patterns (beam test results w/ 4GEM)

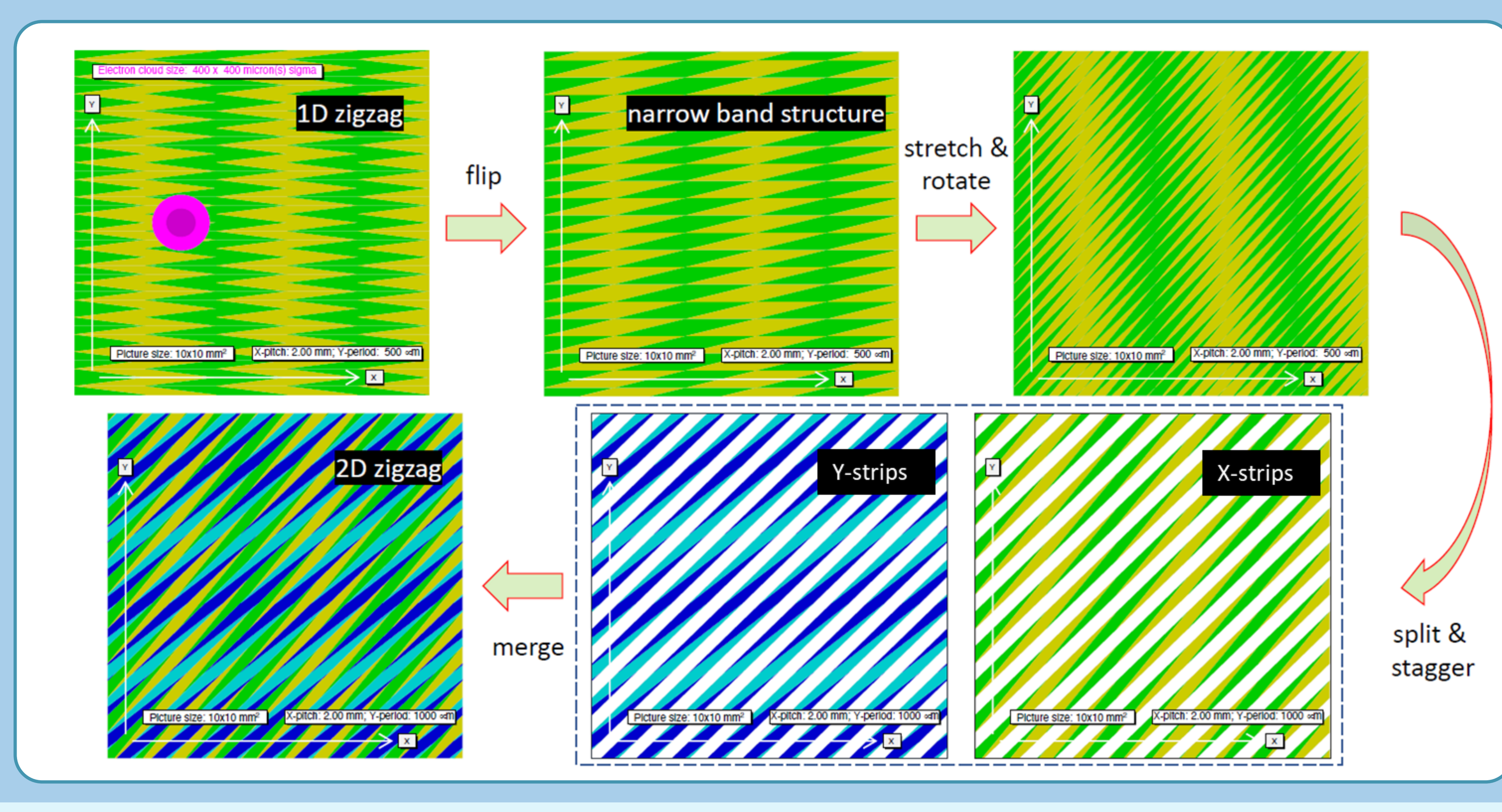


The corrected and raw position resolutions are virtually identical → No corrections needed!

Extension to Different MPGDs

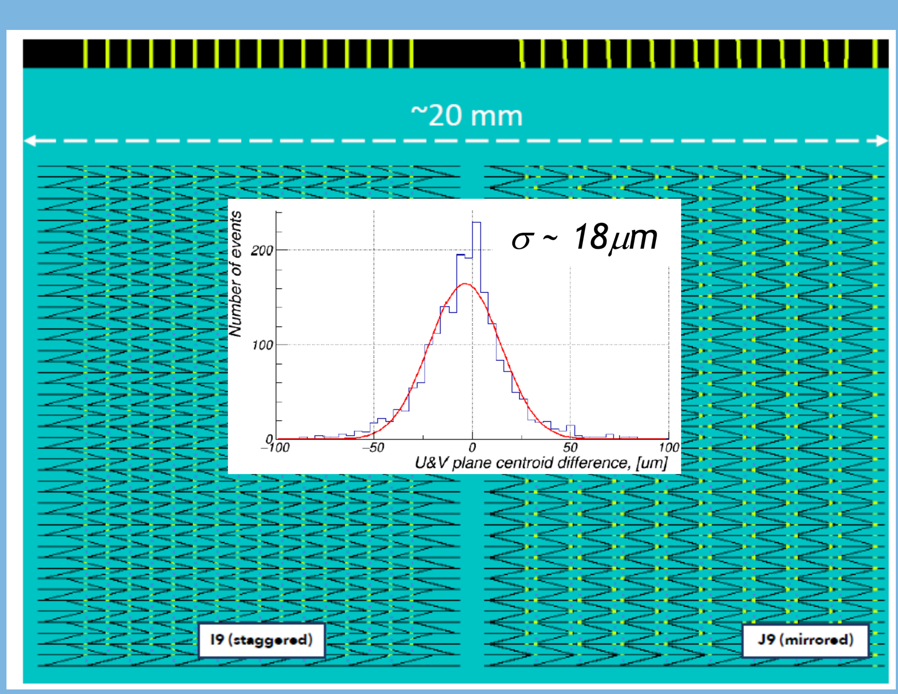


Concept for 2D Interleaved Readout Pads



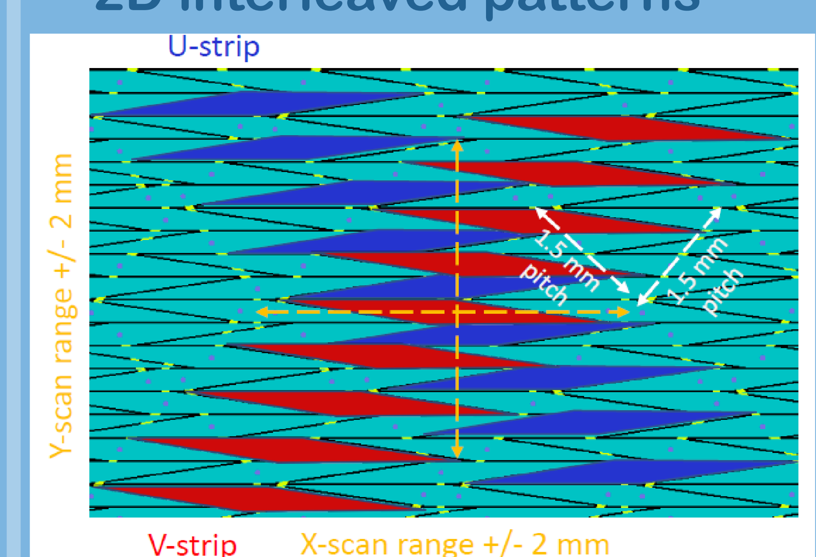
Measurements

2 x 1D (self-testing) patterns

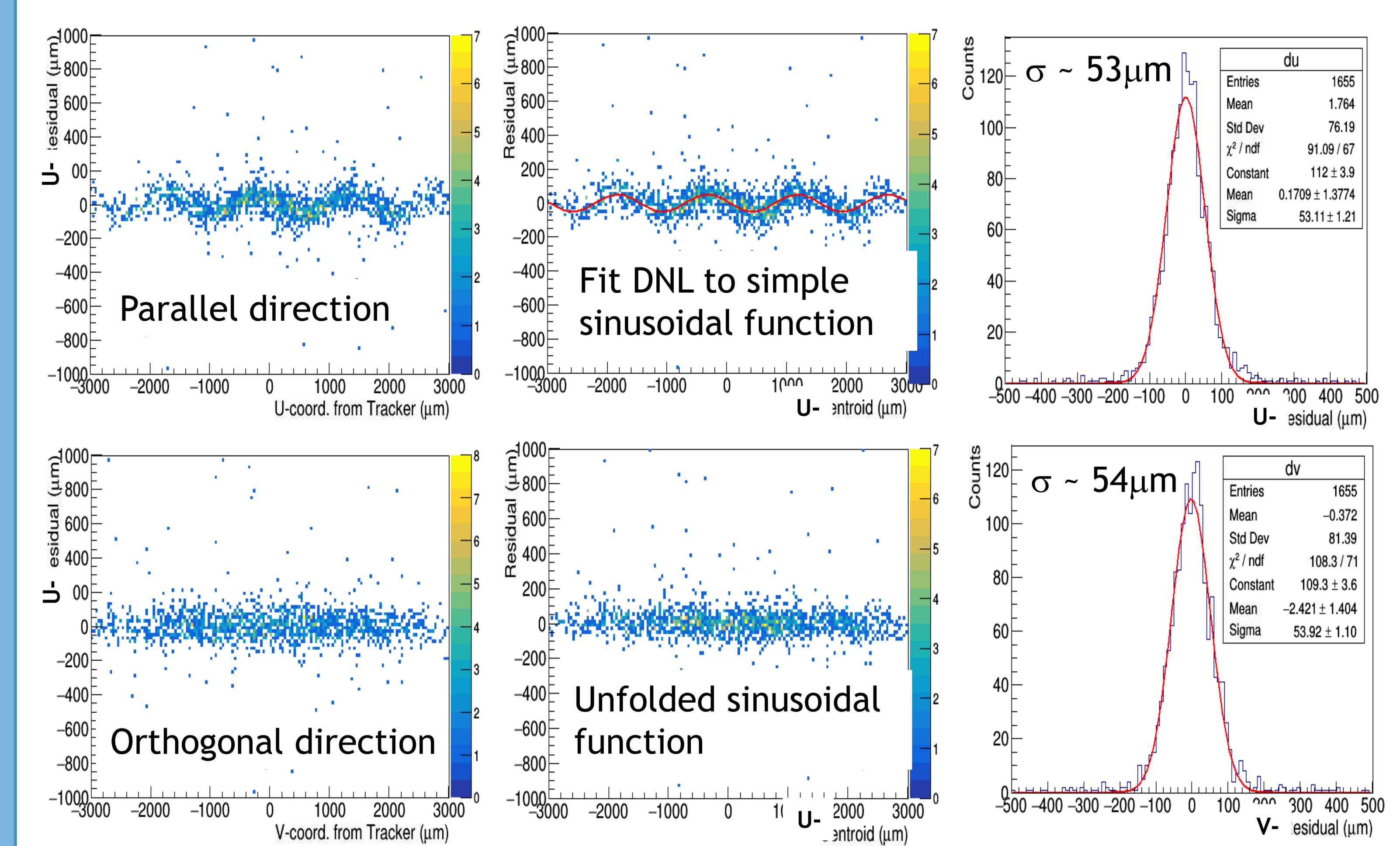


- Effectively, two identical1D readout patterns are superimposed and sample the same cluster along the same direction
- It is thus possible to compute a centroid from both planes and form a position residual with no need for an independent position reference
- The intrinsic resolution may be calculated, free of external factors under the assumption both planes have the same resolution

2D interleaved patterns



- The red and blue strips represent a U-V coordinate system: each strip is composed of inter-connecting sets of specific diamond elements
- To organize strip planes at a given rotation angle, the diamond rows are simply staggered until the bottom green interconnects establish a strip at the desired angle
- Characteristics:
  - The collected charge is divided 50:50 between U-V planes
  - Uniform response in direction orthogonal to strip coord.
  - Slight (<50μm) DNL in parallel direction
  - DNL can be fit to simple sinusoidal function and unfolded



- Normal incidence, 120GeV proton beam at FTBF
- The position resolutions have a differential non-linearity (DNL) correction applied, however the correction only accounts for about 5μm for this pattern.

Summary

- We have shown that 2D interleaved anode structures can be constructed by a relatively simple rearrangement of the 1D zigzag diamond-shaped elements
- The resulting 2D patterns with relatively coarse pitch are capable of producing excellent position resolution and a relatively uniform detector response both in a lab and beam test setting for both GEM and μRWELL (so far)
- While the 2D designs investigated did show a relatively small DNL, we expect this contribution to the overall resolution will be significantly minimized once the anode parameters are optimized, as was demonstrated for the 1D case

Outlook

- Demonstrate scalability to 400mm x 400mm tracking area, suitable for EIC applications
- Produce and measure test patterns with stereo strips to help remove track ambiguities
- Extend 2D anode concept to other technologies such as photosensitive detectors, including Large Area Picosecond Photo-Detectors (LAPPDs) and MCP-PMTs for various RICH applications
- A LAPPD coupled to a 2D interleaved readout may be employed in TOF-PET for improved timing and spatial resolution compared to conventional state of the art readouts

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