GridPix detector with Timepix3 ASIC

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Introduction

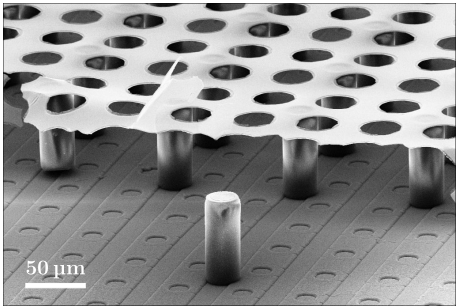
What is GridPix?

- GridPix is a type of micro-pattern gaseous detector (MPGD)
- Other well known types of MPGDs use GEM foils and Micromegas

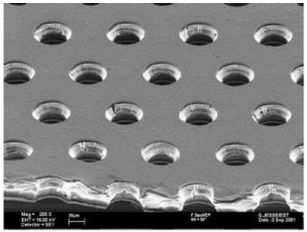
What sets GridPix apart from the others?

- The grid is produced directly on top of ASIC
- Good alignment of grid holes and pixels
- Primary electron counting instead of charge integration improves the energy resolution

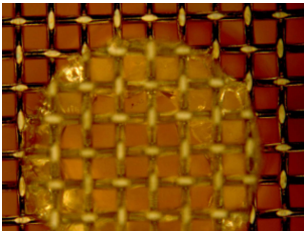
GridPix



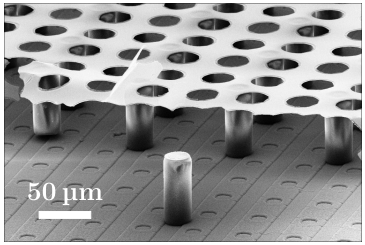
GEM foil



Micromegas



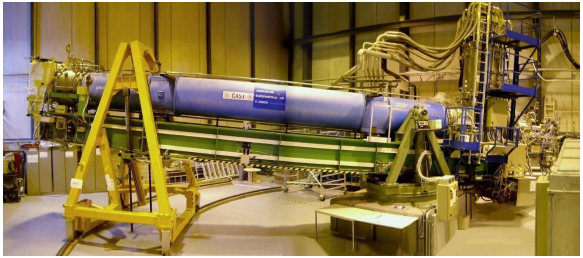
Introduction



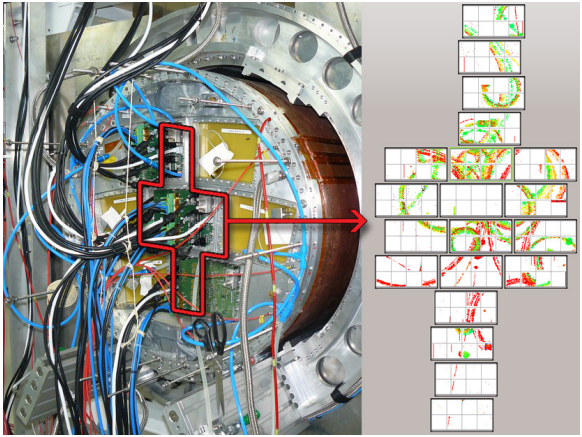
Application

- Potential of GridPix has been demonstrated in several environments

CAST at CERN



Linear Collider TPC with 160 GridPixes
Test e-beam at DESY



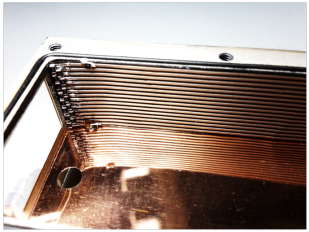
First Timepix3-based GridPix

New ASIC (Timepix3) overcomes its predecessor's limitations:

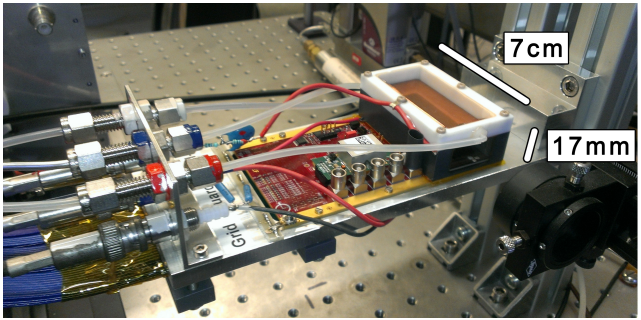
- Multihit readout
- Simultaneous charge and time measurement of each pixel
- Improved time resolution: ~ 1.56 ns

Here test results will be shown for a single chip detector with a source and in a laser setup

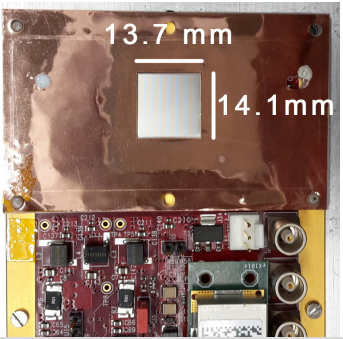
Field shaping inside



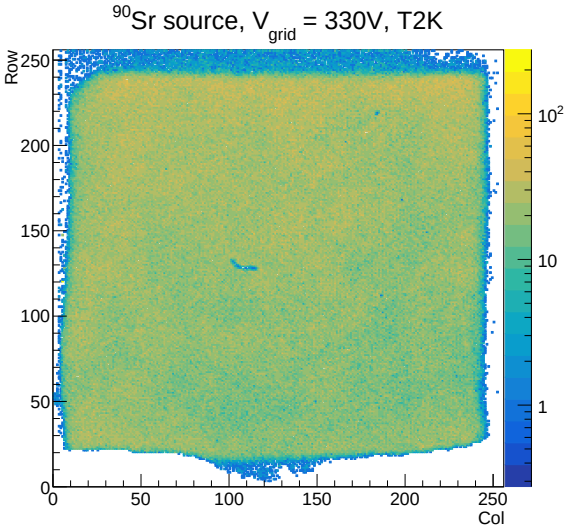
Detector

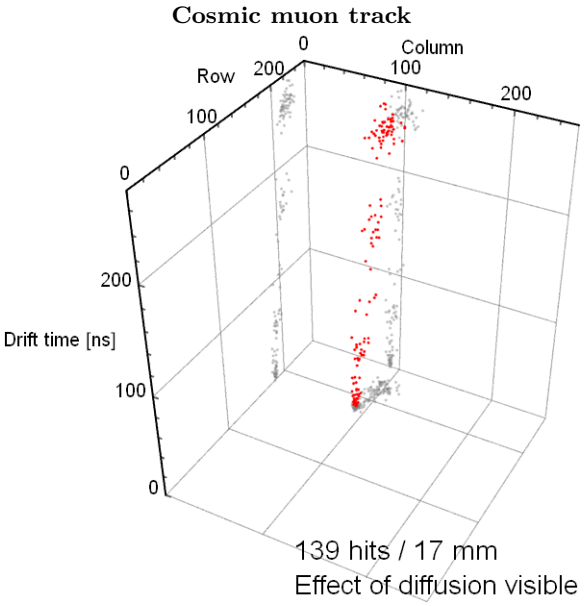


Guard electrode and GridPix



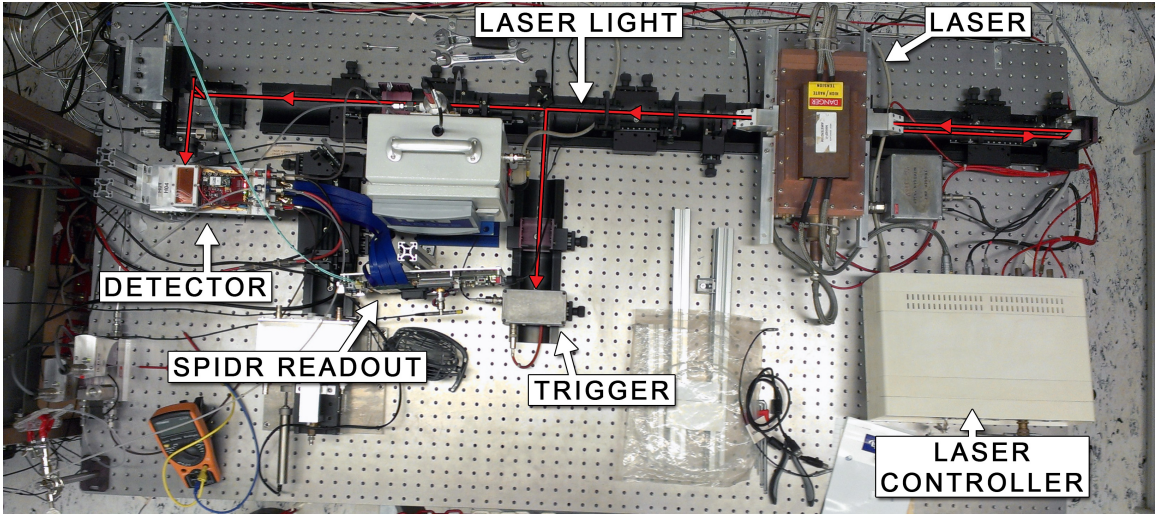
First Timepix3-based GridPix—It works!





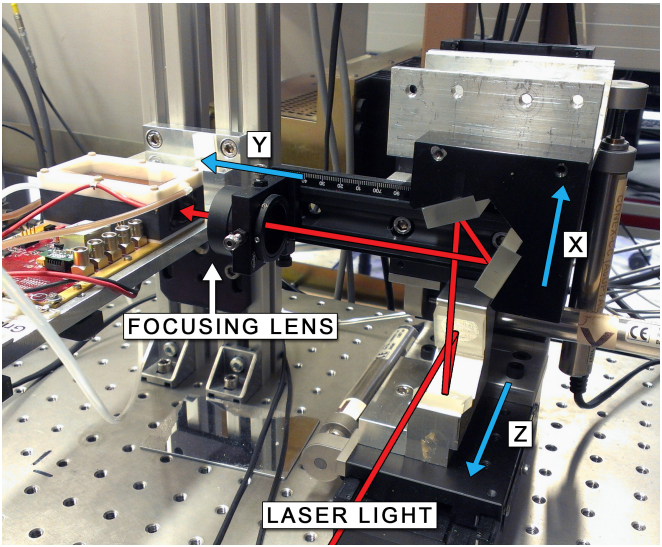
Laser setup

- Pulsed UV nitrogen laser (Nikhef)
- Wavelength: 337 nm
- Pulse duration: 1 ns
- Energy: few µJ
- Divergence near diffraction limit



Laser setup

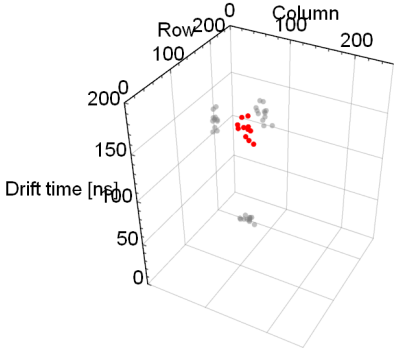
- Ionisation enhanced by traces of TMPD (tetra-methyl-phenylene-diamine)
- Ionisation confined to focal point by double photon absorption
- Laser intensity adjusted such that only single electron hits per pixel occur
- Focus point inside detector



Laser measurements—Examples

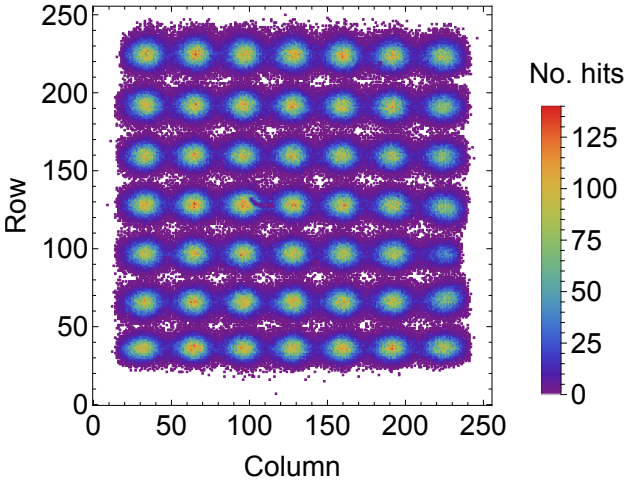
- About 10 hits per laser pulse
- 960 laser pulses per spot
- Measured spot size dominated by diffusion. About 5 pixels (standard deviation) in the example on the right.

Single laser pulse



- "T2K TPC gas" Ar : CF_4 : iC_4H_{10} (95 : 3 : 2)
- $V_{\text{grid}} = -330\,\text{V}$, $E_{\text{drift}} = 200\,\text{V}\,\text{cm}^{-1}$

Scanning a grid of points

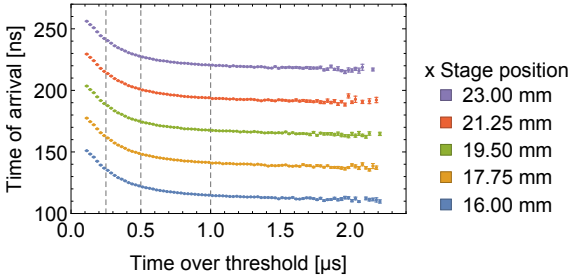


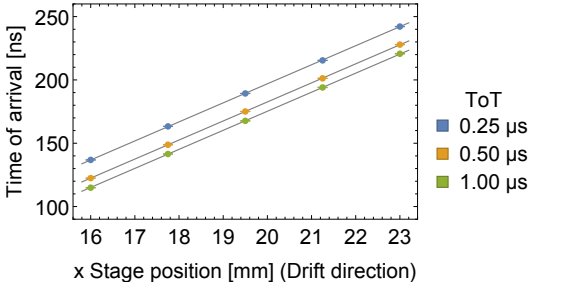
Drift velocity

- Measure time of arrival for different laser heights
- We do not know the absolute trigger time-offset, but we only need time differences
- Small detail: arrival time depends on charge. Solution: Different offset for each time-over-threshold (ToT) bin.[1]

$$\chi^2 = \sum_{ToT} \sum_{n} \left(\frac{t[ToT,\, n] - (t_0[ToT] + x[n]\,/v_{\text{drift}})}{\sigma[ToT,\, n]} \right)^2$$

- Minimising gives $v_{\text{drift}} = 66.480(7)\,\mu\text{m}\,\text{ns}^{-1}$
- Magboltz: $v_{\text{drift}} = 72.819(7)\,\mu\text{m}\,\text{ns}^{-1}$





[1] Time-over-threshold is linearly related to charge

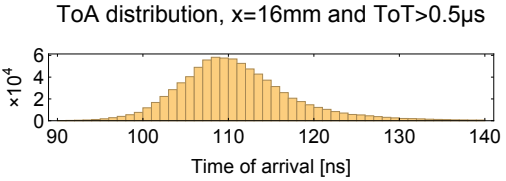
Diffusion coefficients

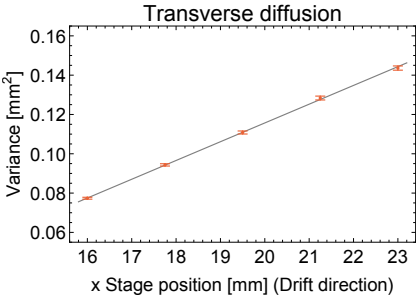
- Measure laser spot variance for different laser heights (dominated by diffusion)
- 3.5×10^5 laser pulses per point

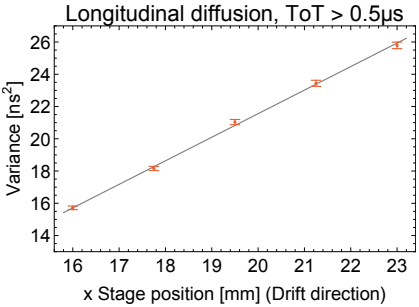
$$\sigma_{\mathrm{T}}^2 = D_{\mathrm{T}}\,(x - x_{\mathrm{grid}}) + \tfrac{1}{12}\,(55\,\mu\mathrm{m})^2$$

$$\sigma_{\mathrm{L}}^2 = D_{\mathrm{L}}\,(x - x_{\mathrm{grid}}) + \sigma_{\mathrm{L},0}^2$$

- Grid at $x_{\mathrm{grid}} = 7.886(22)\,\mathrm{mm}$
- Transverse-diffusion coefficient $\sqrt{D_{\mathrm{T}}} = 309.0(22)\,\mu\mathrm{m}/\sqrt{\mathrm{cm}}$ (Magboltz: $316(4)\,\mu\mathrm{m}/\sqrt{\mathrm{cm}}$)
- Longitudinal-diffusion coefficient $\sqrt{D_{\mathrm{L}}} = 254.1(27)\,\mu\mathrm{m}/\sqrt{\mathrm{cm}}$ (Magboltz: $245(3)\,\mu\mathrm{m}/\sqrt{\mathrm{cm}}$)
- Small additional contribution to the time resolution of $\sigma_{\mathrm{L},0} \approx 2\,\mathrm{ns}$

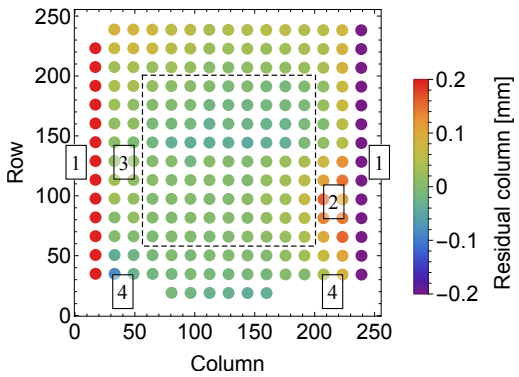


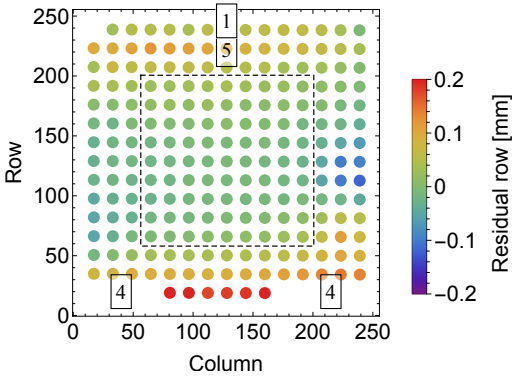




Scanning a grid of points

Drift distance: 7.114(22) mm, Dashed rectangle indicates points used in fit



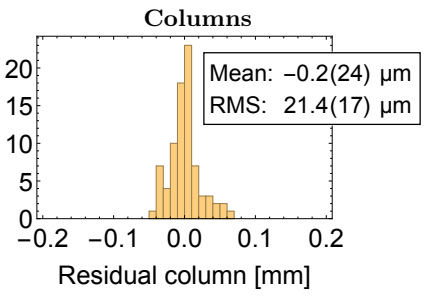


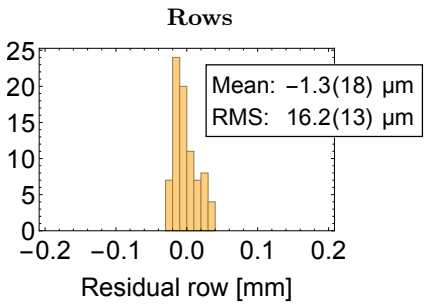
1. Laser spots on edge have cut outs
2. Pixels have low yield
3. Field cage is not uniform at level 100–200 µm
4. Grid not well attached
5. E-field not uniform due to guard-chip distance

*residual column = measured column − expected column

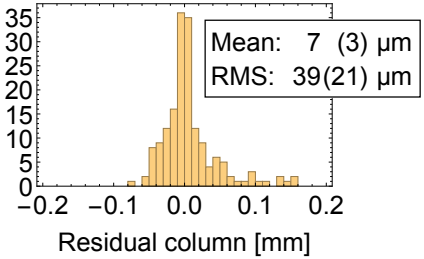
Scanning a grid of points—Residuals

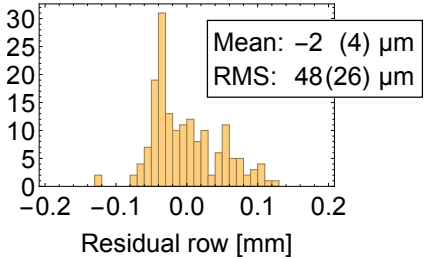
Points in selected region:





All points that are not cut off:





Conclusions

- Realised GridPix detector with Timepix3 ASIC
- We operated it using T2K TPC gas and $V_{\text{grid}} = -330\,\text{V}$, $E_{\text{drift}} = 200\,\text{V}\,\text{cm}^{-1}$
- We used a laser to perform measurements
  - Transverse resolution dominated by diffusion, $\sqrt{D_{\text{T}}} = 309.0(22)\,\mu\text{m}/\sqrt{\text{cm}}$ (Magboltz: $316(4)\,\mu\text{m}/\sqrt{\text{cm}}$)
  - Longitudinal resolution possibly also affected by timewalk, $\sqrt{D_{\text{L}}} = 254.1(27)\,\mu\text{m}/\sqrt{\text{cm}}$ (Magboltz: $245(3)\,\mu\text{m}/\sqrt{\text{cm}}$)
  - $v_{\text{drift}} = 66.480(7)\,\mu\text{m}\,\text{ns}^{-1}$ (Magboltz: $72.819(7)\,\mu\text{m}\,\text{ns}^{-1}$)
  - Precision in column×row plane better than 25 µm in central area
- Test beam with electrons planned at ELSA in Bonn
- Next detector: Quad (4 chips)

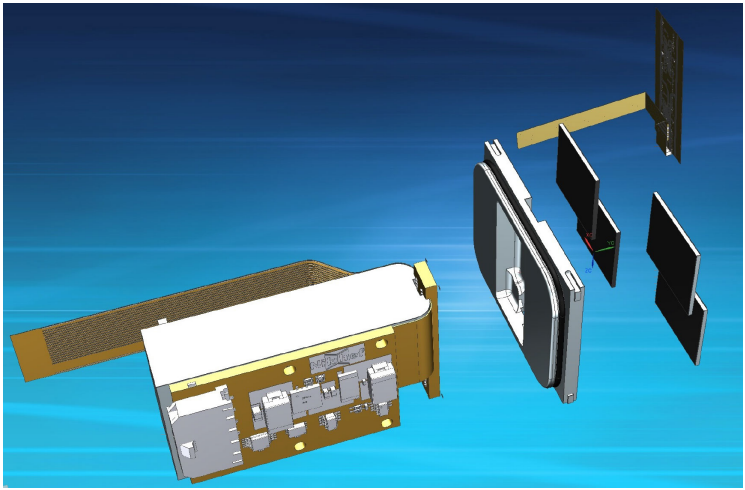
Plans new module

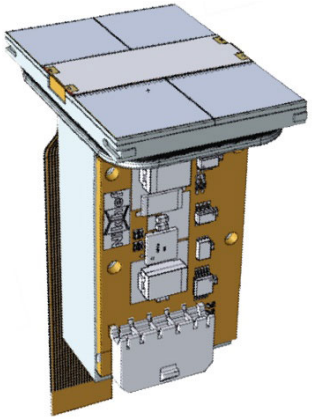
Long term plan:

- Built a LCTPC-module with about 100 GridPixes
- Module size: $22 \times 17\,\mathrm{mm}^2$—keystone shaped

Short term plan:

- Start with a module equipped with 1 or 2 of the small units
- Currently: Quads, designed to minimise the dead area

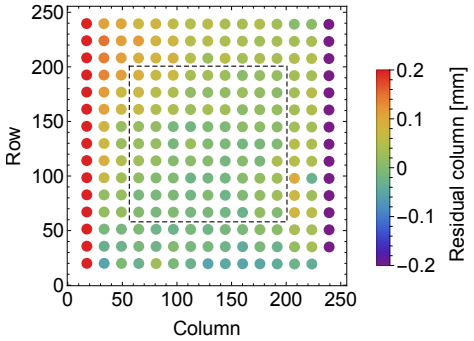


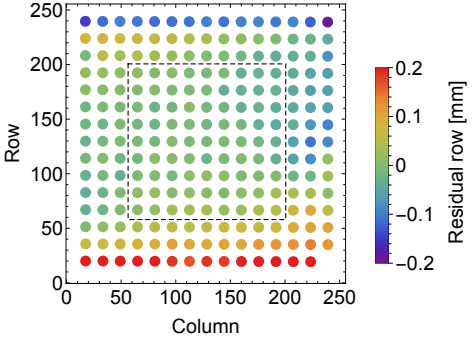


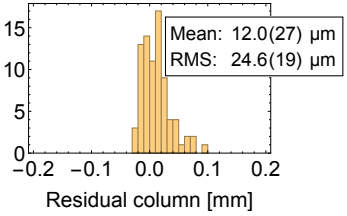
Quad assembly

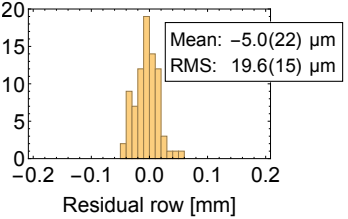
Backup—Scanning a grid of points

- Drift distance: 16.114(22) mm
- Dashed rectangle indicates points used in fit









*residual column = measured column − expected column