Preliminary results from Quad test beam

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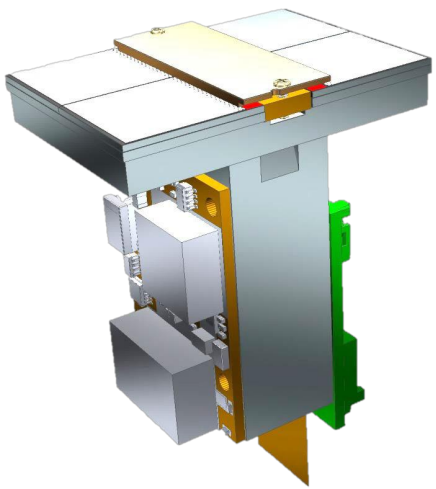
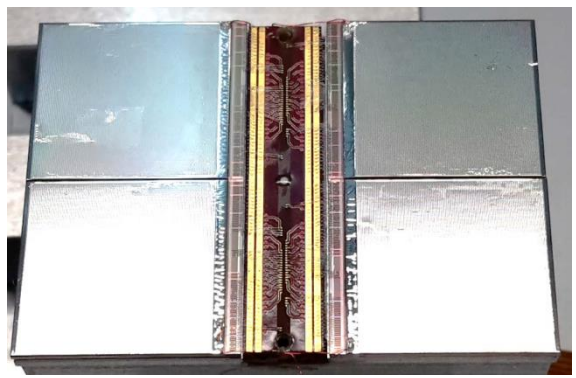
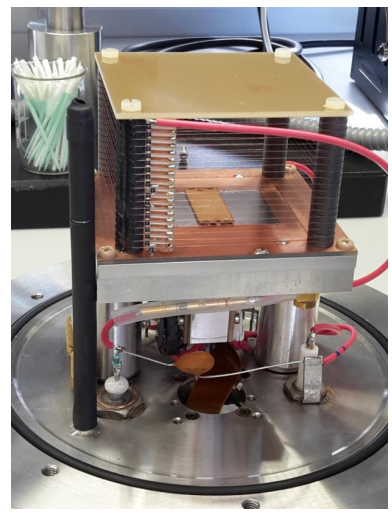
Introduction

- Quad is a module consisting of 4 Timepix3 chips, with all services under the active area
- Quad detector is put inside a test box with guards and field shaping, filled with T2K gas
- 2 Quads were tested one by one



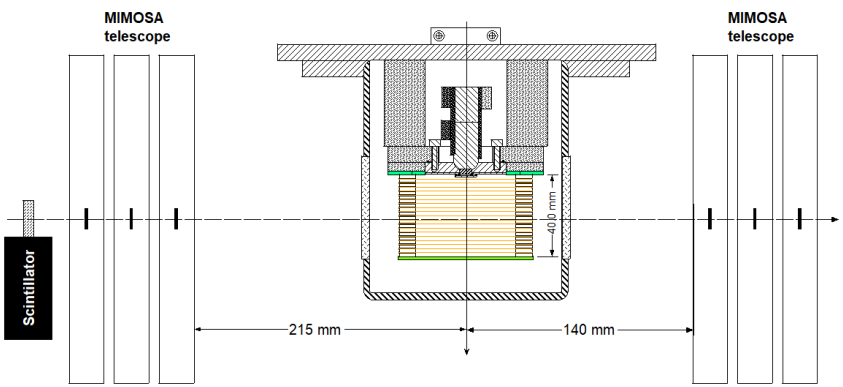


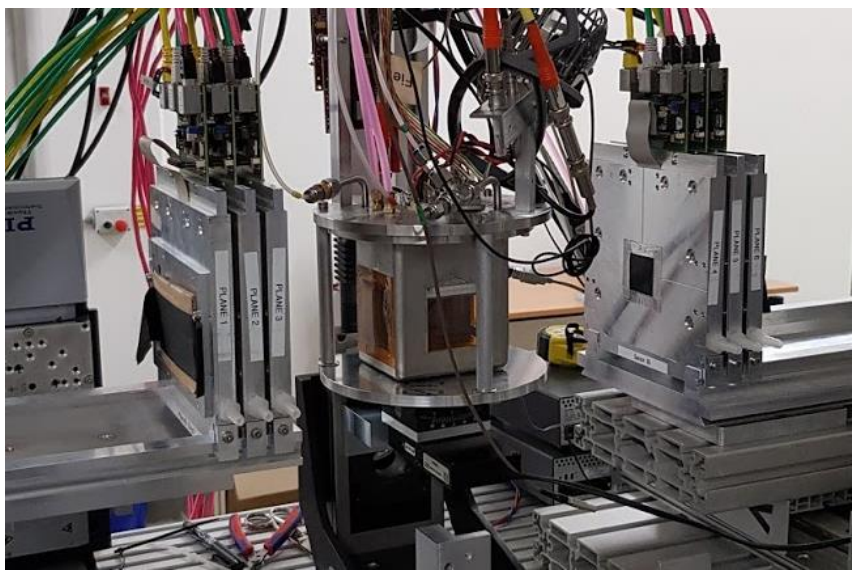


See also introduction talk by Peter Kluit

Test beam setup

- 2.5 GeV electrons provided by the ELSA facility (Bonn) at a 10 kHz rate
- Events are triggered by a scintillating plane
- The telescope consist of 6 mimosa planes with 18.4 µm × 18.4 µm sized pixels





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Timepix readout procedure

Timepix readout procedure

- The Timepix3 registers the fine time of a hit and stores it near the pixel to be read out.
- 4 Timepix3 chips are connected with one 160 Mb/s link to the SPIDR each
  - 12 links with a maximum speed of 640 Mb/s per link are available
- The SPIDR boards adds a course time stamp (409.6µs per tick) to each hit and transmits it to the DAQ PC.

Because the link speed was not fast enough for the rates, a maximum of 1.3 MHits/s was read out per chip
Some hits arrived too late at the SPIDR board and received the wrong course time

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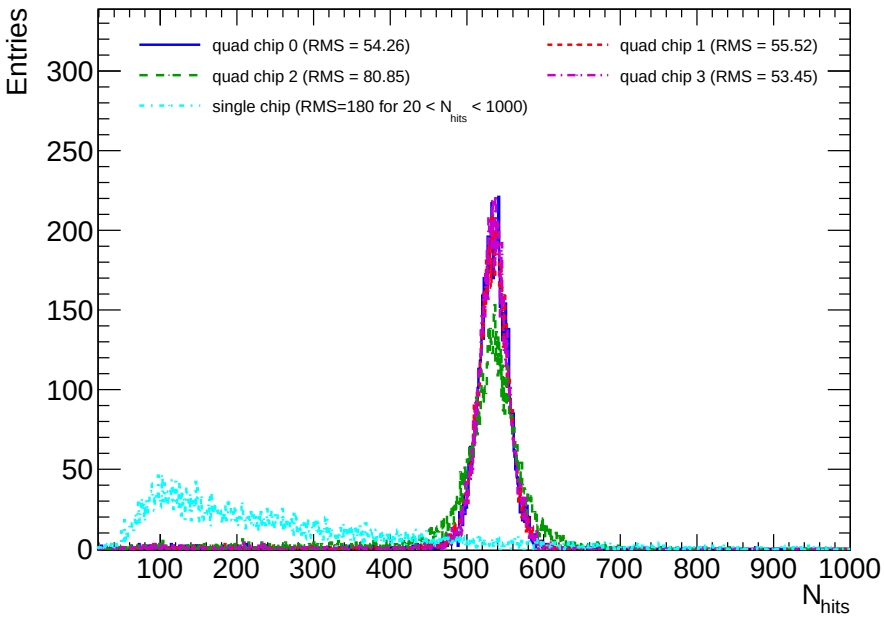
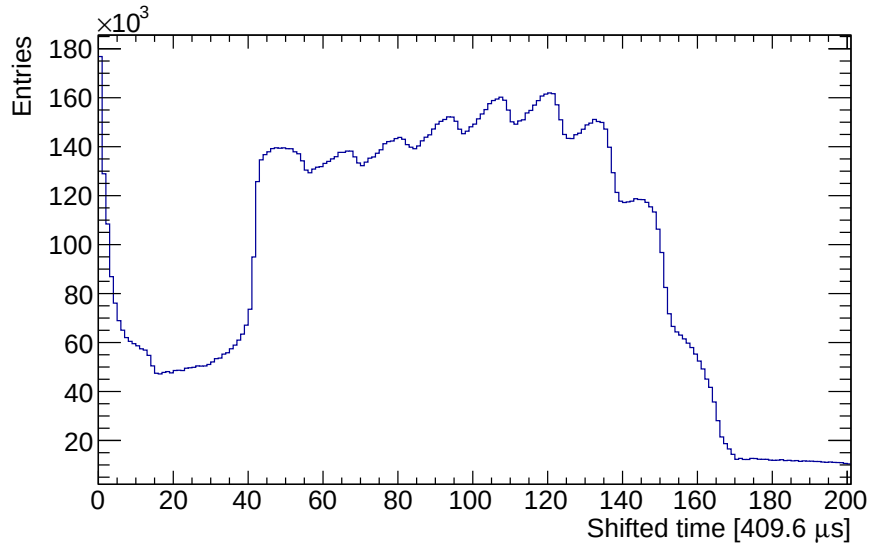
Synchronization issues



The number of hits per 409.6 µs does hardly fluctuate
(Teal represents the 2017 single chip)



Hits after selection: some hits are not read out until after 160 cycles of 409.6 µs

The solution is to stack hits from up to 200 cycles after the original trigger

Selections and some run parameters

Use runs 668, 672, and 676 (center, right, left respectively):

- $E_{\text{drift}} = 400\,\text{V/cm}$, which is closer the maximum drift velocity because of water vapor
- $V_{\text{Grid}} = 330\,\text{V}$
- Threshold at ∼550 e (55 DAC counts above noise)

Selection
$-500\,\text{ns} < t_{\text{hit}} - t_{\text{trigger}} < 500\,\text{ns}$
Hit ToT $> 0.10\,\mu\text{s}$
Reject outliers ($r_x < 1.5\,\text{mm}, r_z < 3\,\text{mm}$)
$N_{\text{hits}} > 20$
$(N_{r_x<1.5\text{mm}} \;/\; N_{r_x<5\text{mm}}) > 0.8$
$\overline{x_{\text{hit}}} - x_{\text{track}} < 0.3\,\text{mm}$

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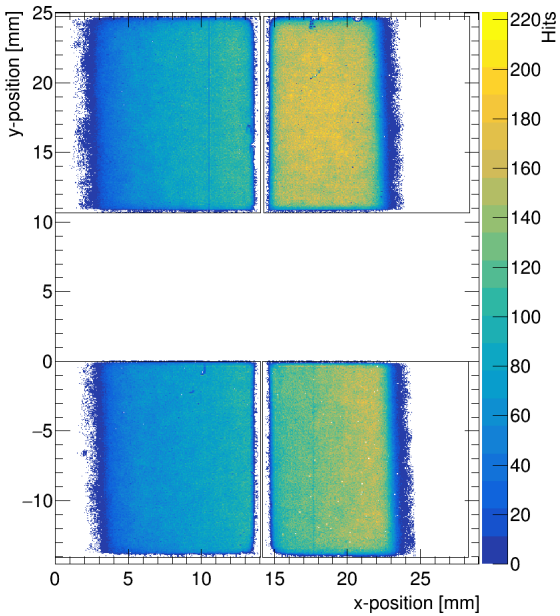
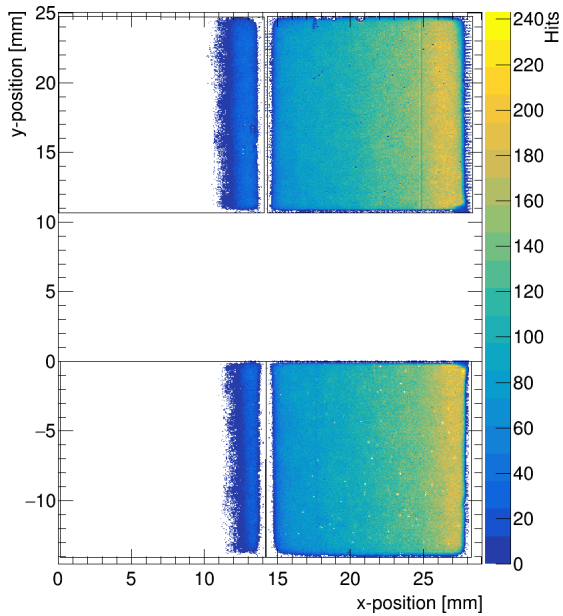
Hit maps

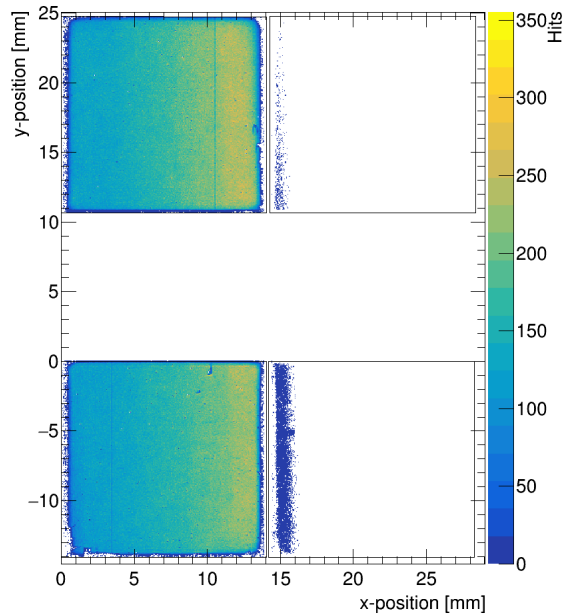
After selection with telescope



Run 668



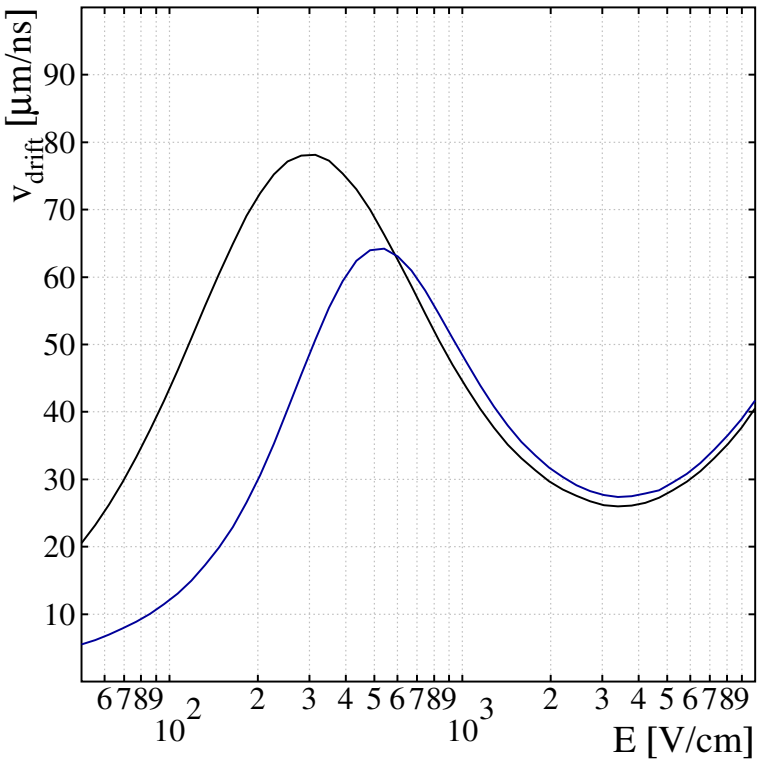
Run 672

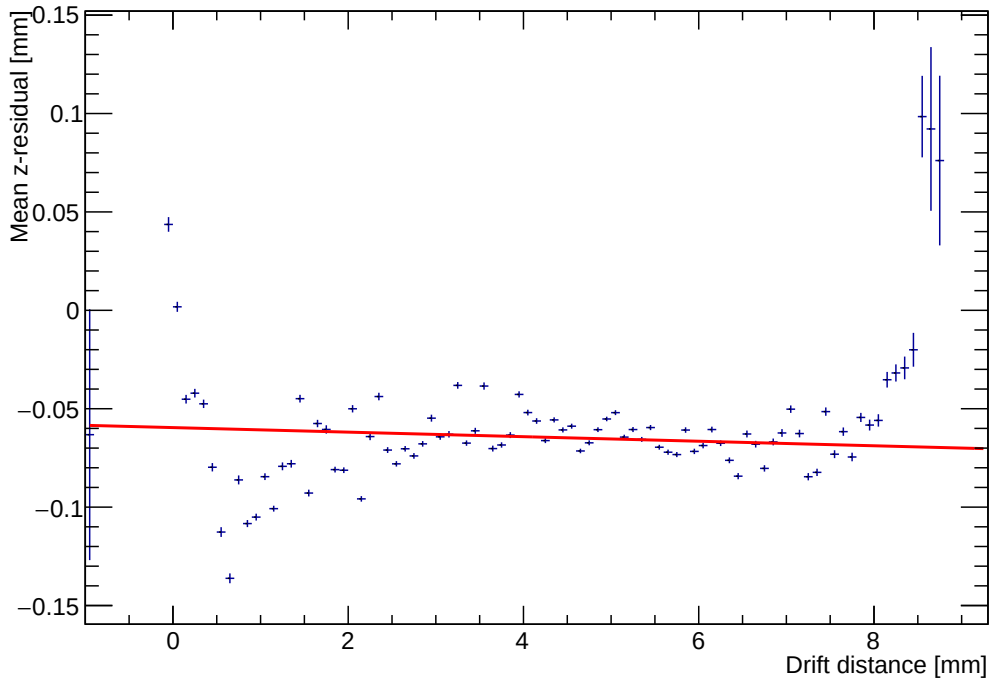


Run 676

Drift velocity

- Because of water vapor content (0.6%), the drift velocity is expected to be slower than normally for a T2K gas
- The measured drift speed (55 µm/ns) is slightly smaller than expected for this water vapor concentration (60 µm/ns)





run 672, with hits outside fiducial area

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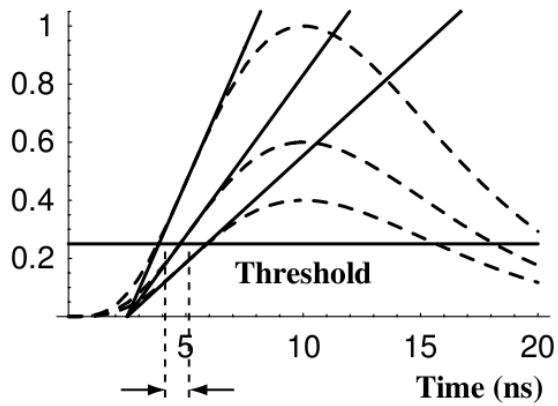
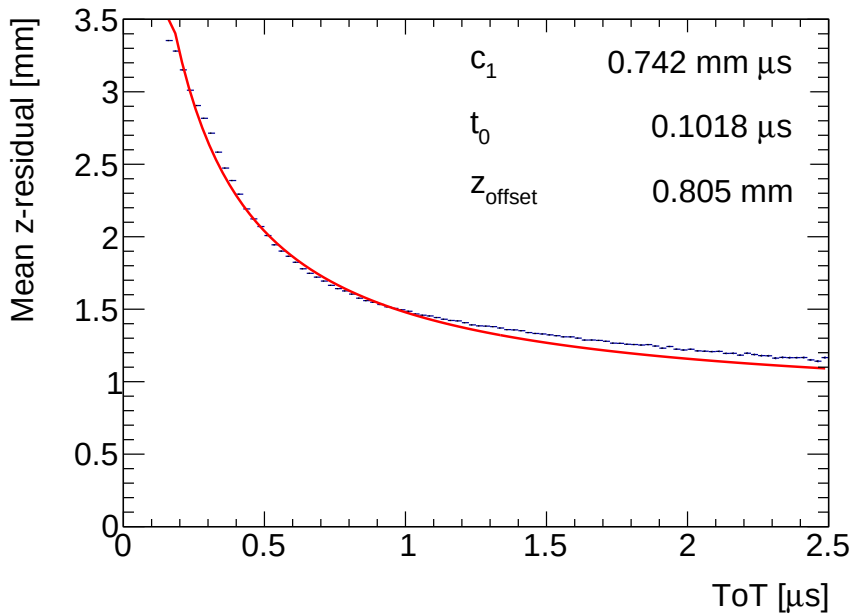
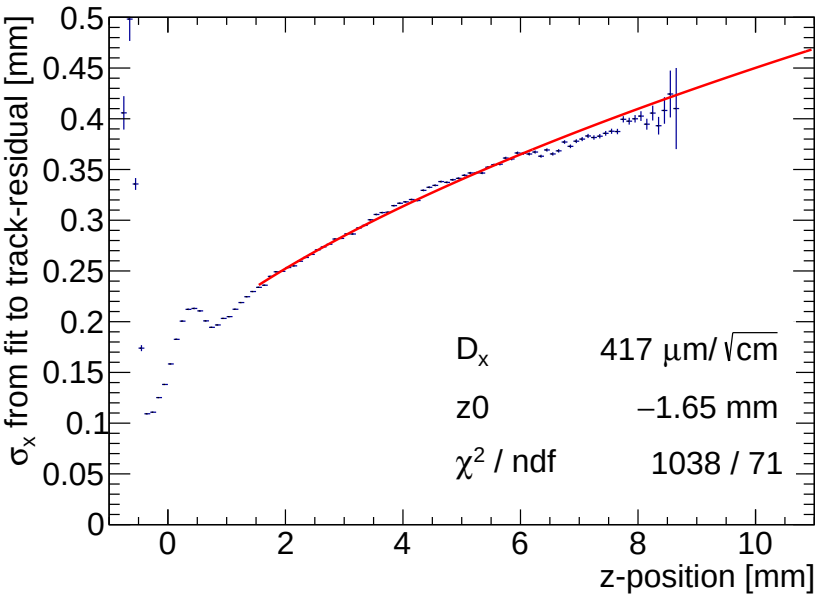
Time walk correction

- Time walk occurs when the apparent time of arrival depends on the signal amplitude
- With Timepix3 the time walk can be corrected for using the Time over Threshold (ToT) as measure of signal strength:
  $\delta z_{\text{timewalk}} = \frac{c_1}{t_{\text{ToT}} + t_0} + z_0$

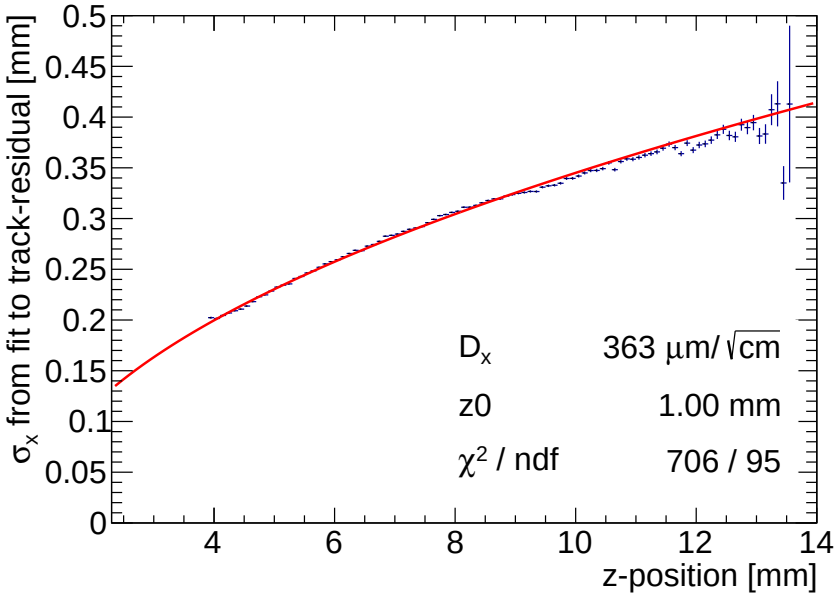




Resolution in the transverse direction (pixel plane)



Run 668 with newer Quad

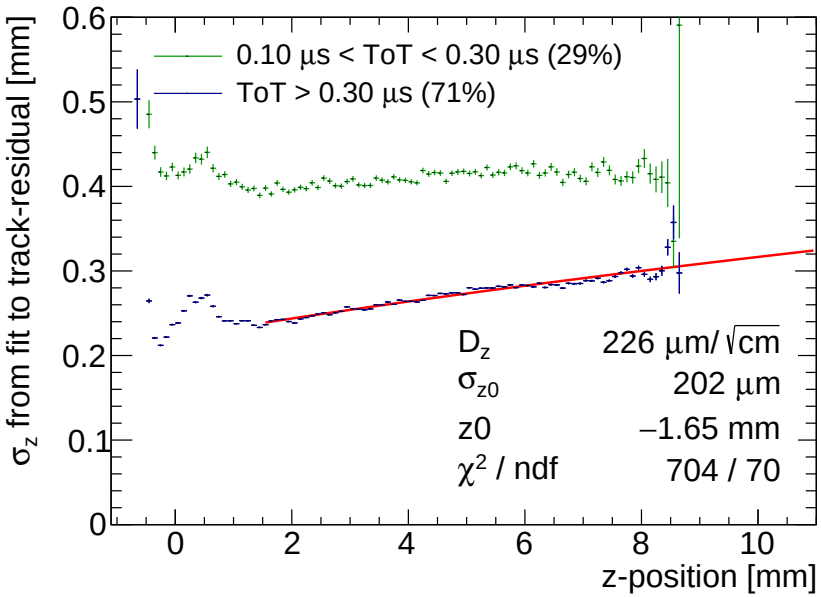


Older quad, tested in the same test beam

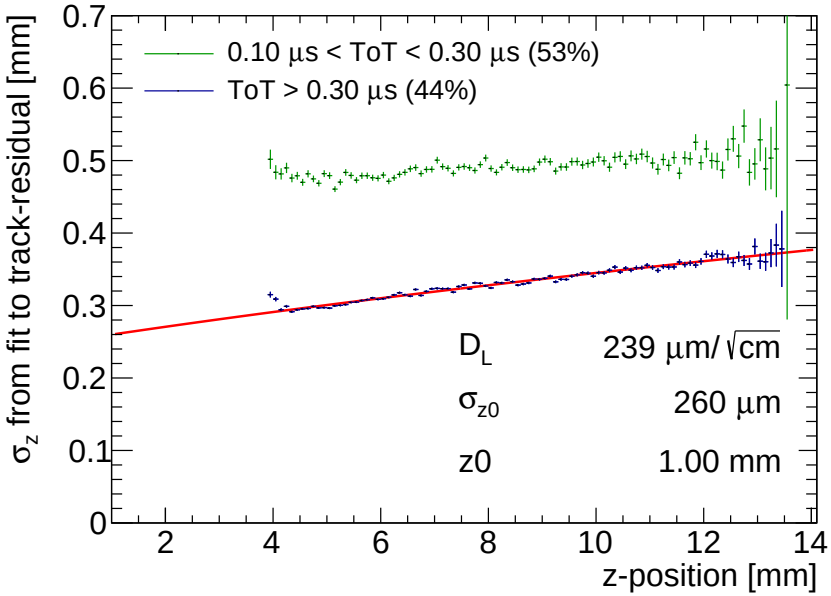
Residual as function of drift distance is fitted with

$$\sigma_x = \sqrt{\sigma_{x0}^2 + D_T^2(z - z_0)}$$

Resolution in the drift direction



Run 668 with newer Quad



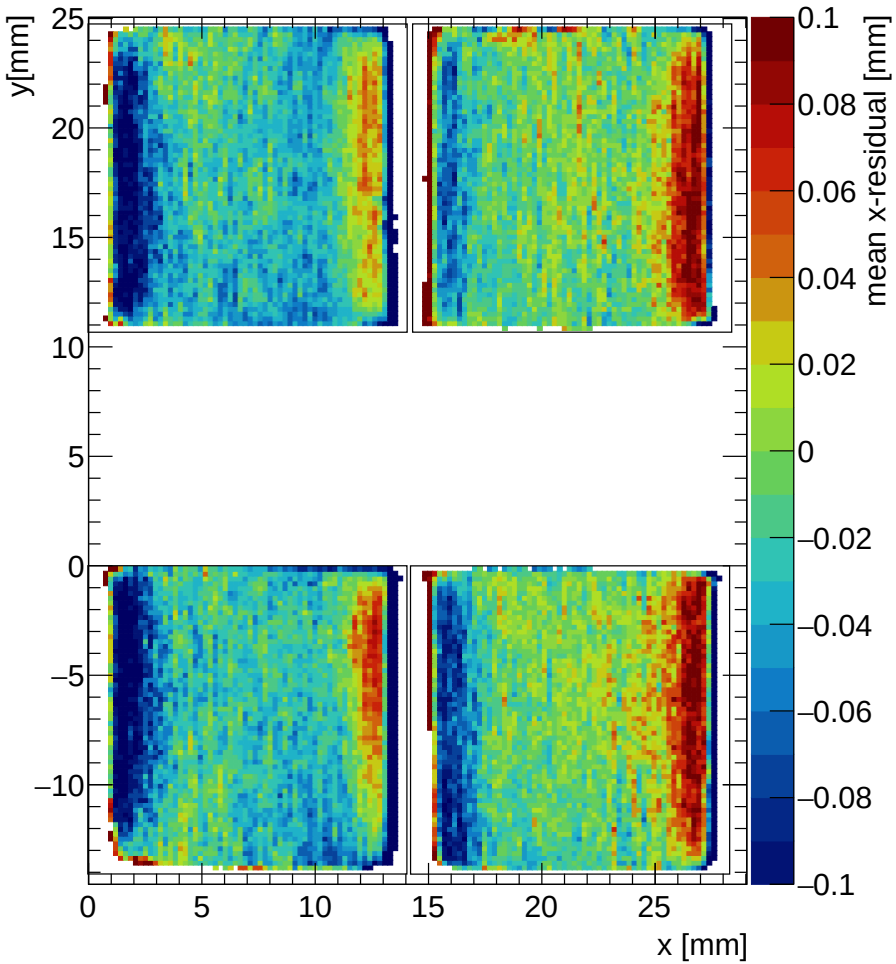
Older quad, tested in the same test beam

Residual as function of drift distance is fitted with

$$\sigma_z = \sqrt{\sigma_{z0}^2 + D_L^2(z - z_0)}$$

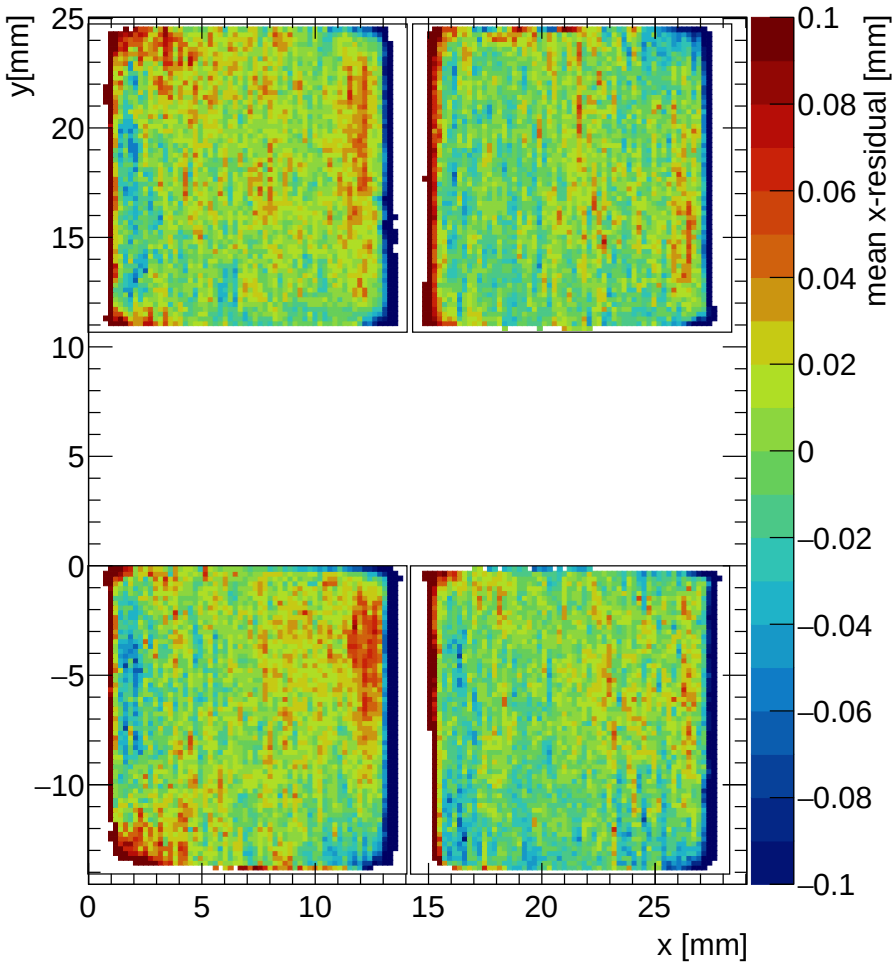
Deformations in the pixel plane

- Calculate the mean x-residual per 4×4 pixels
- Hits are pulled towards the ground potential at the edges of the chips

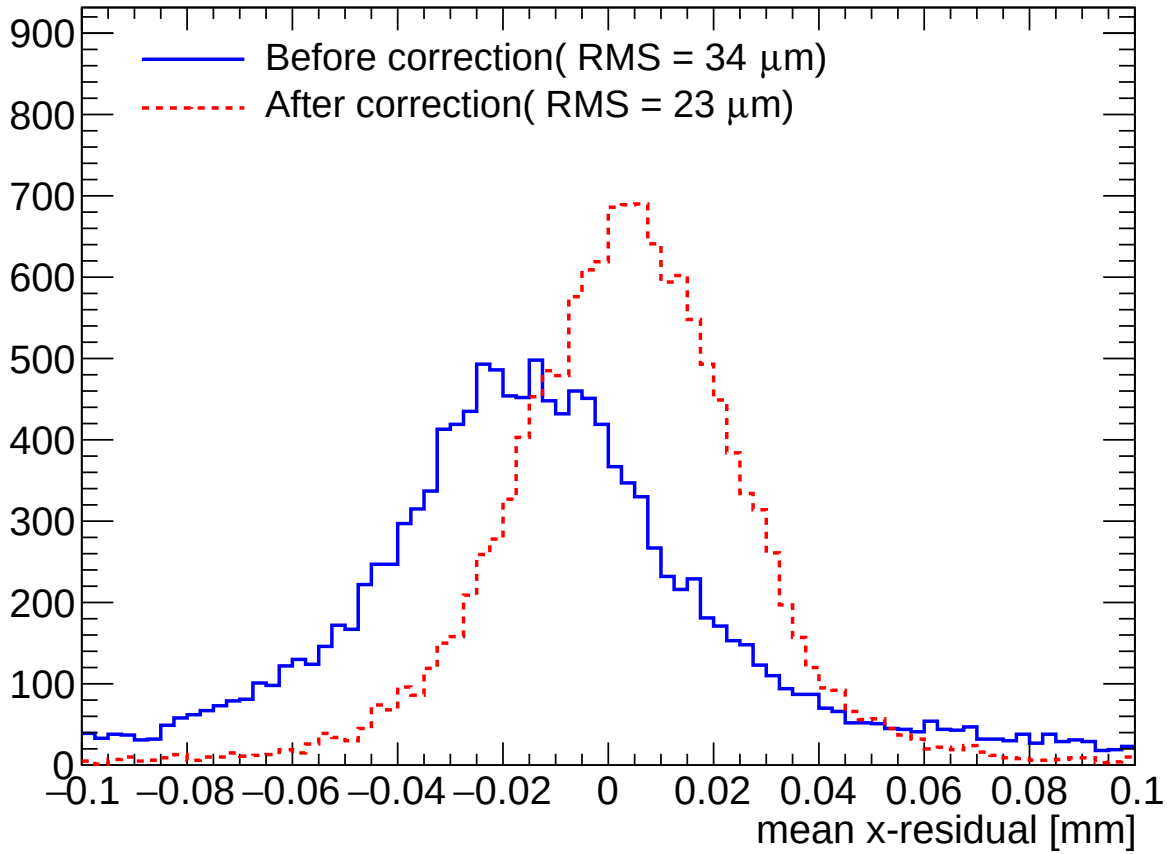


Deformations after correction

- the electric field distortions can be corrected for using the expected track position from e.g. a Telescope
- The applied correction is a single 3rd order polynomial per chip



Frequency histogram of deformations



Each bin (mean residual from 4×4 pixels) is one entry in the histogram

Conclusions

- A good set of data with the Quad was taken using 2.5 GeV electrons
- A synchronization problem was identified, and a work-around is in place
- The hit resolution will be further investigated
- In the first diagrams, systematic deformations are small

The analysis of the quad test beam data is well under way

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Deformations in the drift direction

without per column calibration