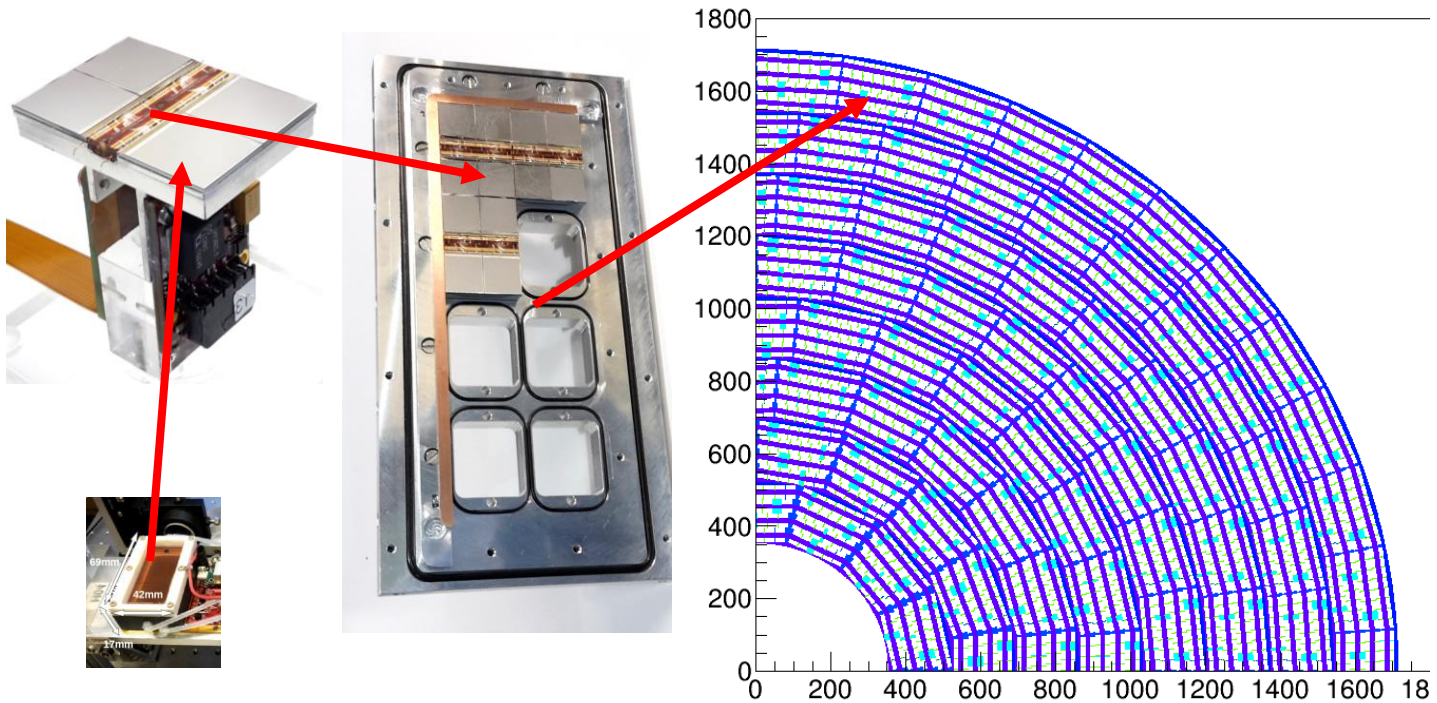
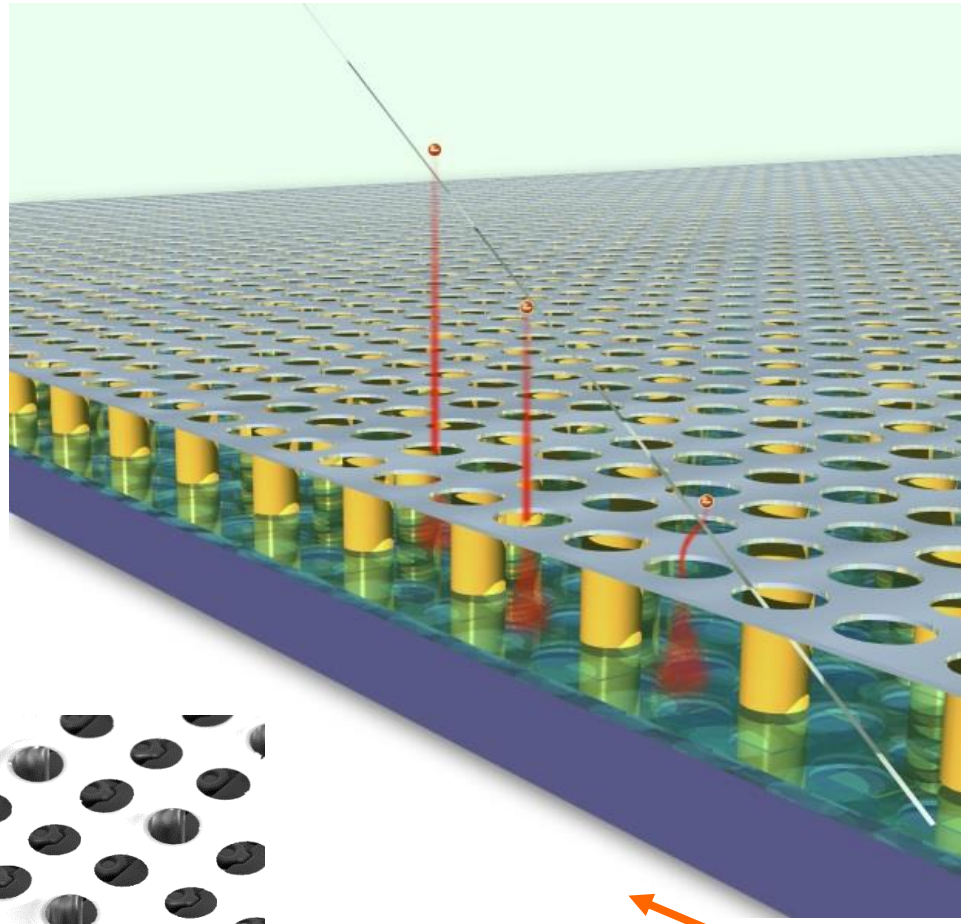
Pixel TPC

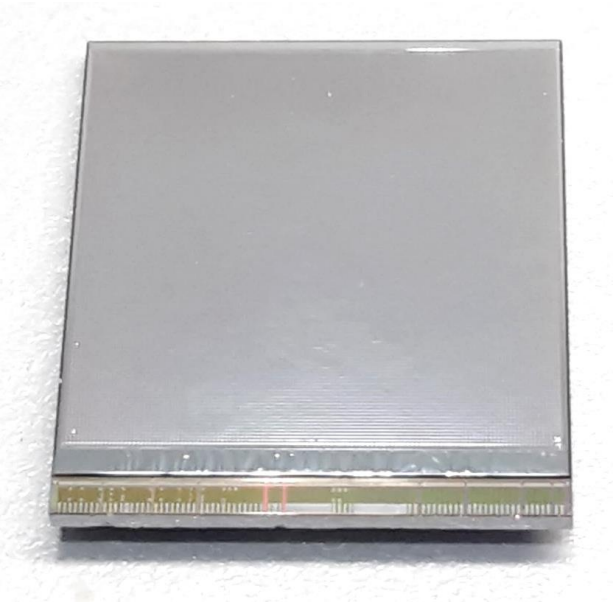
Yevgen Bilevych, Klaus Desch, Jean-Paul Fransen, Harry van der Graaf, Markus Gruber, Fred Hartjes, Bas van der Heijden, Kevin Heijhof, Charles Ietswaard, Dimitri John, Jochen Kaminski, Peter Kluit, Naomi van der Kolk, Auke Korporaal, Cornelis Ligtenberg, Oscar van Petten, Gerhard Raven, Joop Rövekamp, Lucian Scharenberg, Tobias Schiffer, Sebastian Schmidt and Jan Timmermans

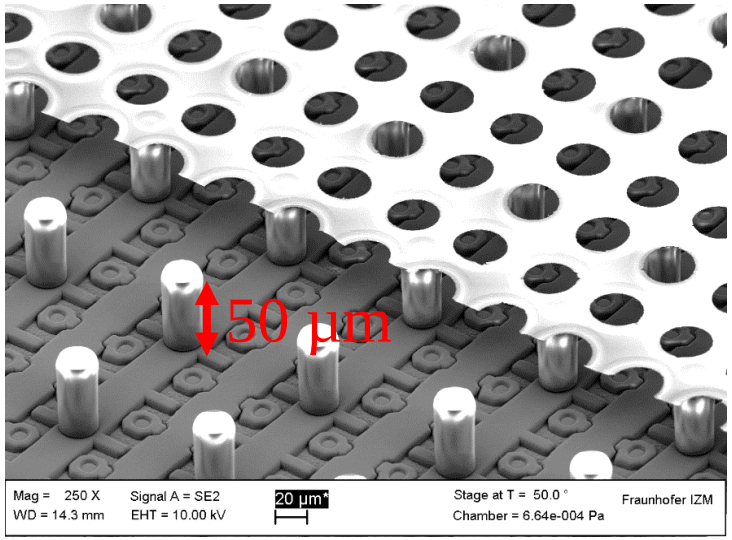


Reminder: GridPix technology

- Pixel chip with integrated Micromegas
- InGrid
- Grid set at negative voltage (300 – 600 V) to provide gas amplification
- Very small pixel size (55 μm)
- mostly detecting individual electrons





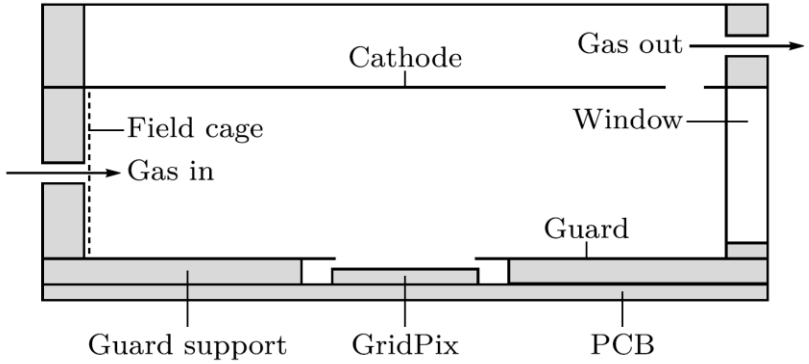


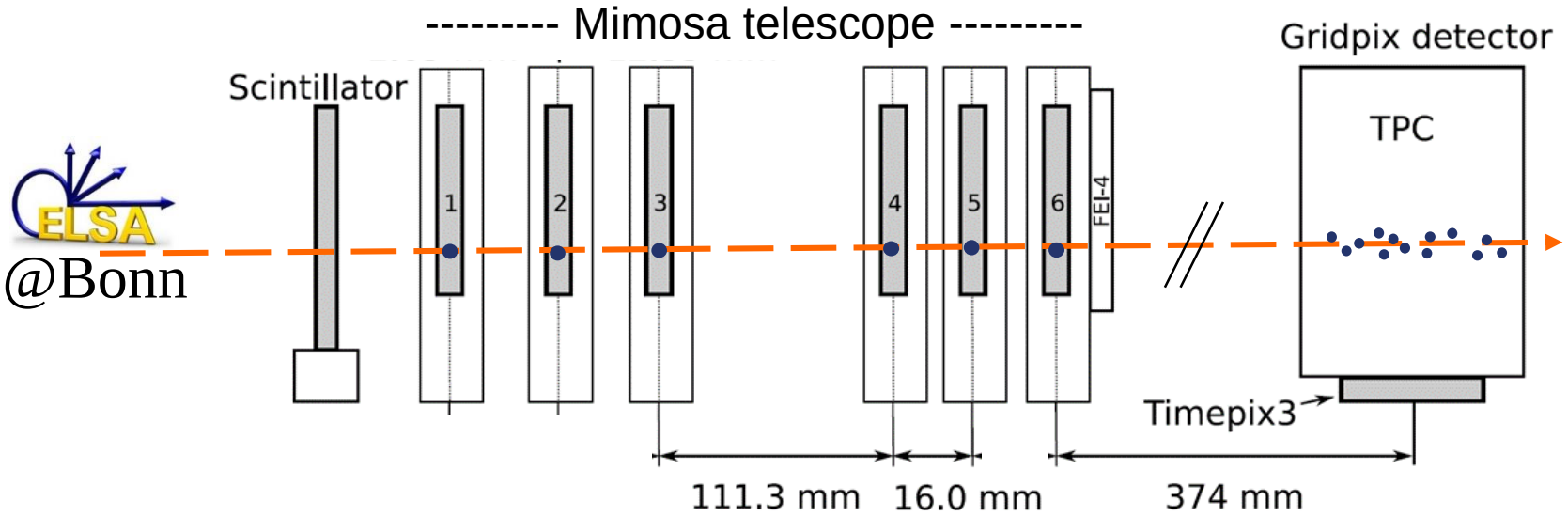
Outlook: where are we and where do we go?

- A single chip detector was made and tested in a test beam at Bonn (2017)
- Results have been analysed and published in NIM https://doi.org/10.1016/j.nima.2018.08.012
  - a summary of the main results will be given below
- A new set of GridPixes – very high quality - has been produced at IZM by Yevgen May 2018
- A quad was designed and several realized
- Two quads have been tested in a test beam at Bonn (2018)
  - Preliminary results will be shown by Kees Ligtenberg
- The next step using several quads to build part of a module will be presented by Fred Hartjes
- In 2019 we want to learn from the 2018 quad test beam and test a part of a module in the test beam at Bonn and eventually at DESY.

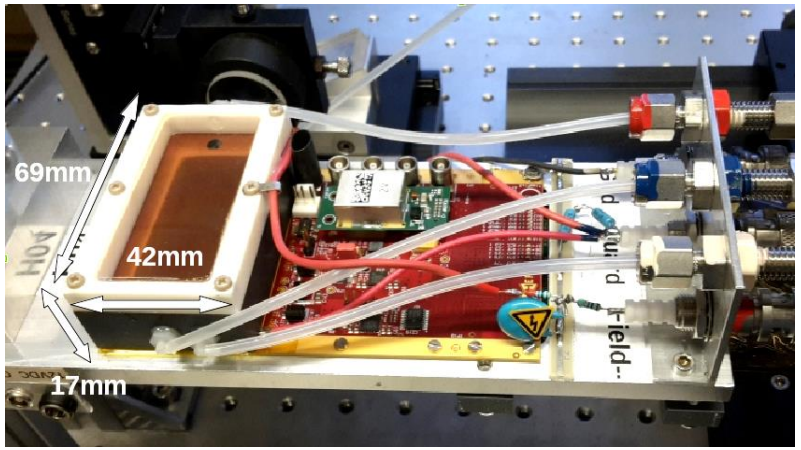
Single chip test in test beam Bonn (June 2017)

- ELSA: 2.5 GeV electrons
- Tracks referenced by Mimosa telescope
- Gas: $Ar/CF_4/iC_4H_{10}$ 95/3/2 (T2K)
- E_d = 280 V/cm, V_{grid} = - 350 V



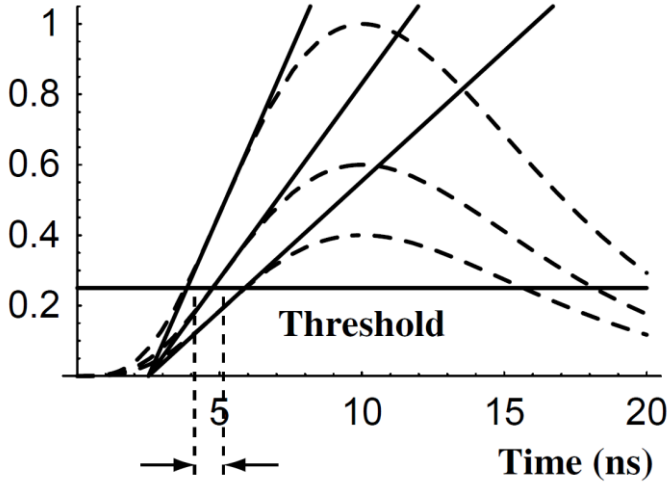


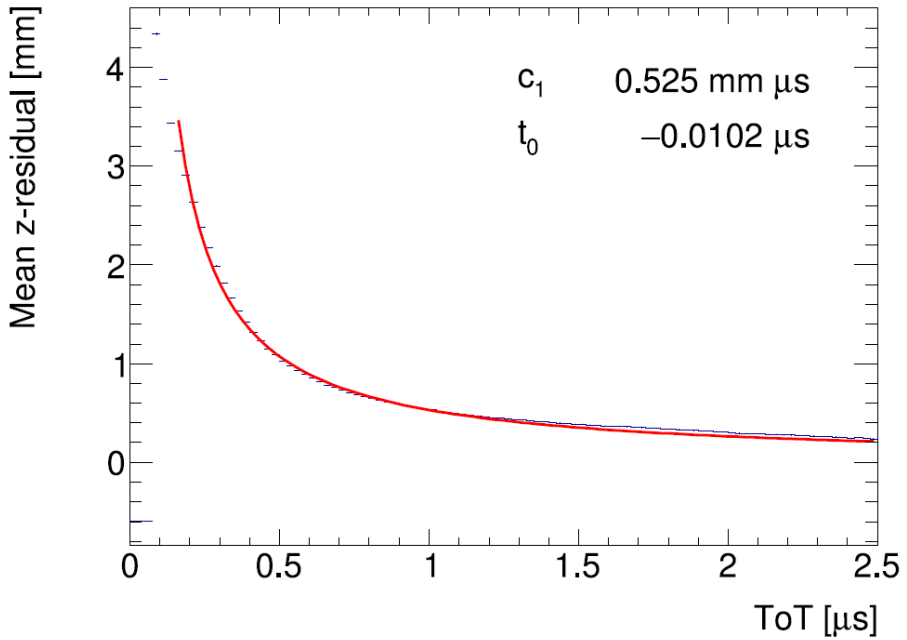
Detector with guard and field shaper

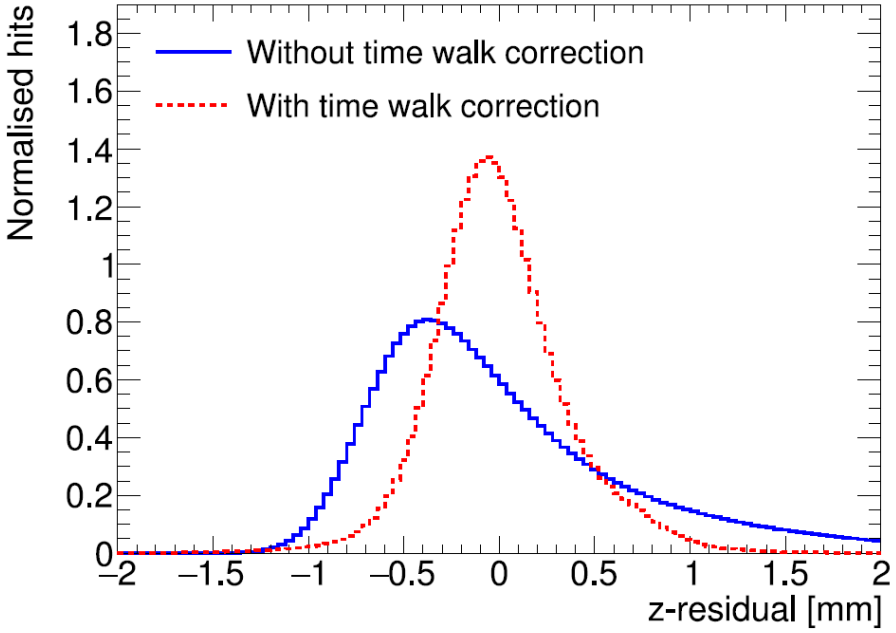


Published paper on 2017 testbeam: https://doi.org/10.1016/j.nima.2018.08.012

TimePix3 time walk correction







Time walk error: time of arrival depends on signal amplitude

(Blum, Particle detection 2008)

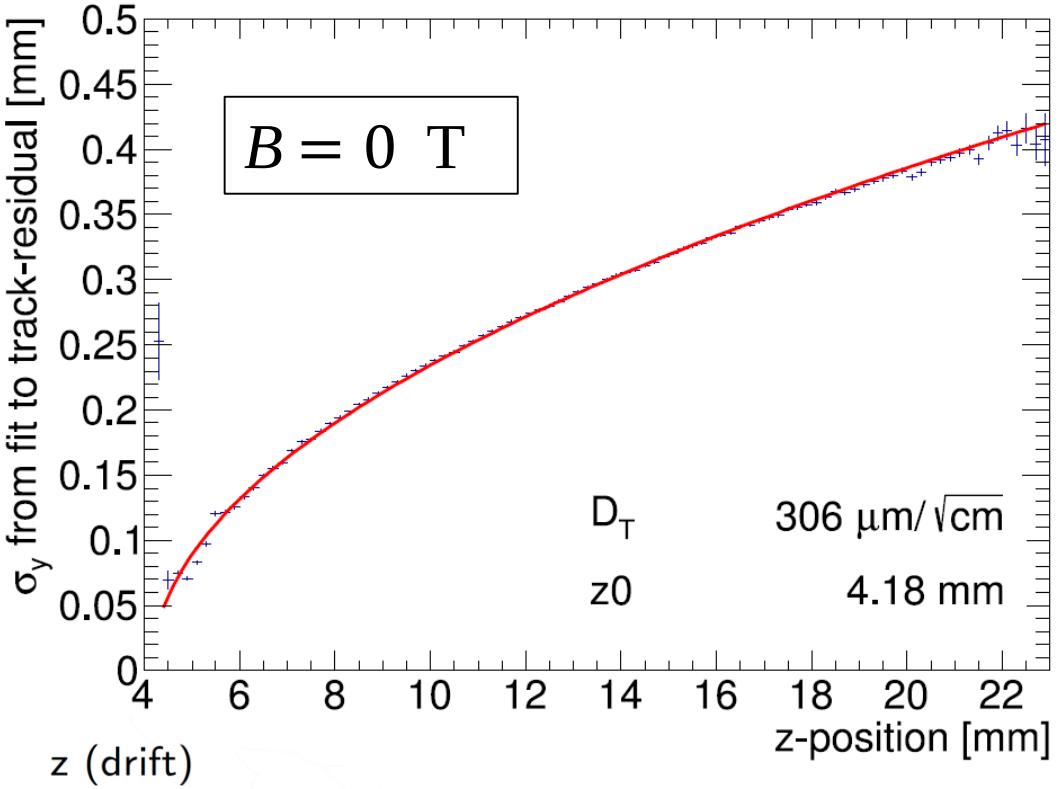
Correction using Time over Threshold (ToT) as a measure of signal strength

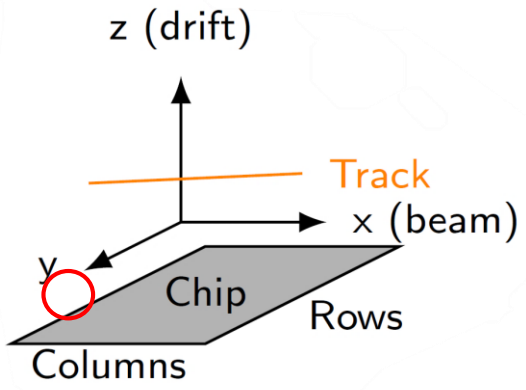
$$\delta z_{\text{timewalk}} = \frac{c_1}{t_{ToT} + t_0} + z_0$$

Residual distribution improved

Higher order corrections did not yield further improvements

Single hit resolution in transverse direction





$D_T = 306\ \mu m/\sqrt{cm}$

$(318 \pm 7\ \mu m/\sqrt{cm}$ expected)

Single hit resolution in pixel plane:

$$\sigma_y^2 = \sigma_{y0}^2 + D_T^2(z - z_0)$$

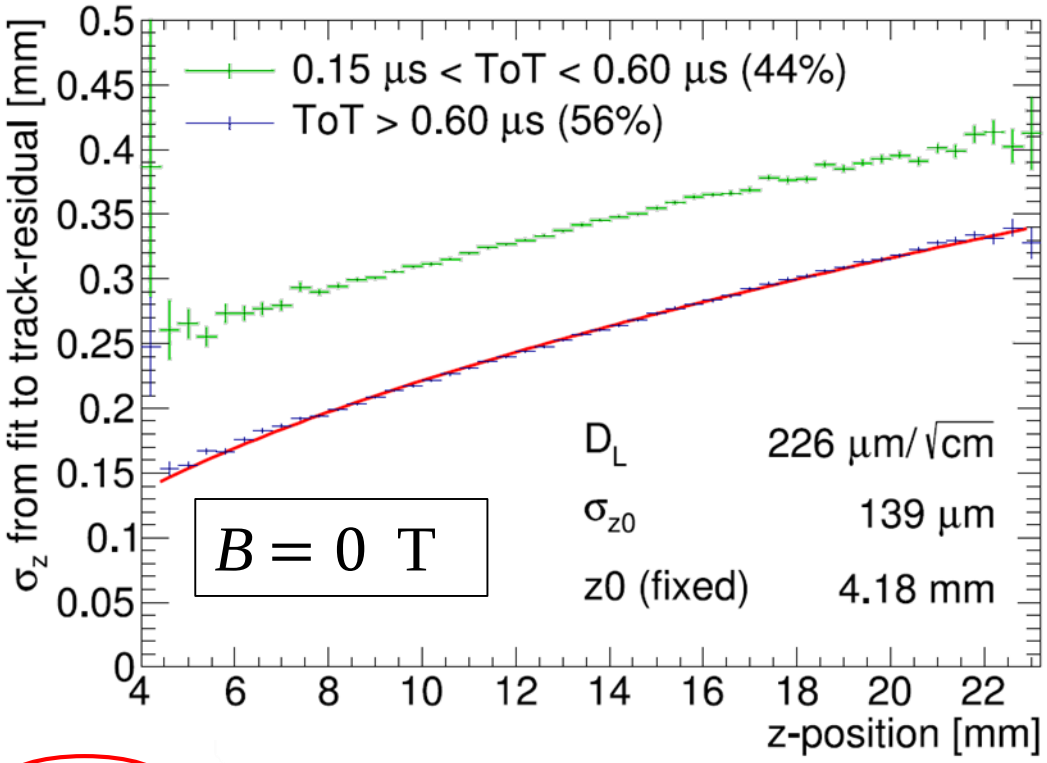
Depends on:

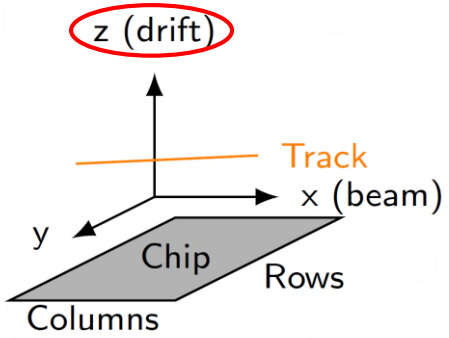
- σ_{y0} = pixel size $/\sqrt{12}$
- Diffusion D_T from fit

Note that:

- A hit resolution of ~250 µm is ~25 µm for a 100-hit track (~ 1 cm track length)
- At $B = 4$ T , $D_T = 25\ \mu m/\sqrt{cm}$

Single hit resolution in longitudinal direction





$D_L = 226\ \mu\text{m}/\sqrt{\text{cm}}$

$(201 \pm 5\ \mu\text{m}/\sqrt{\text{cm}}$ expected)

Single hit resolution in drift direction

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

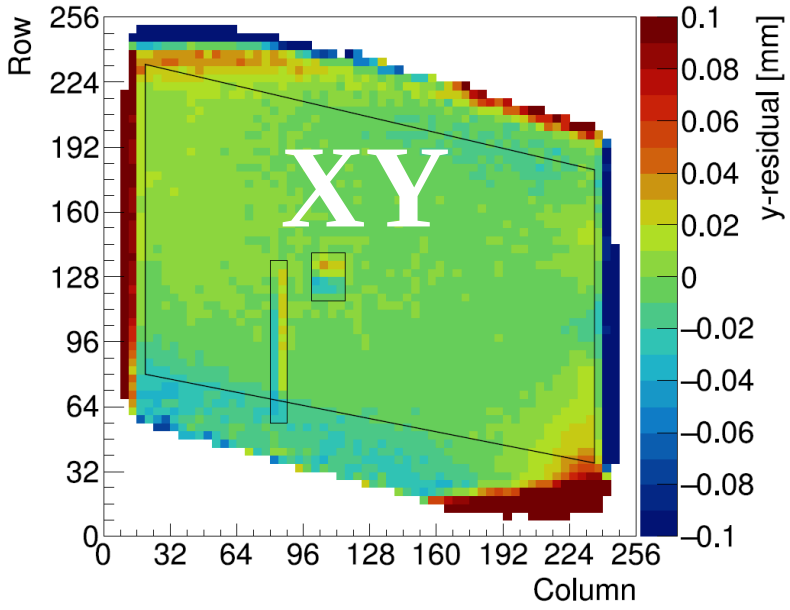
Depends on

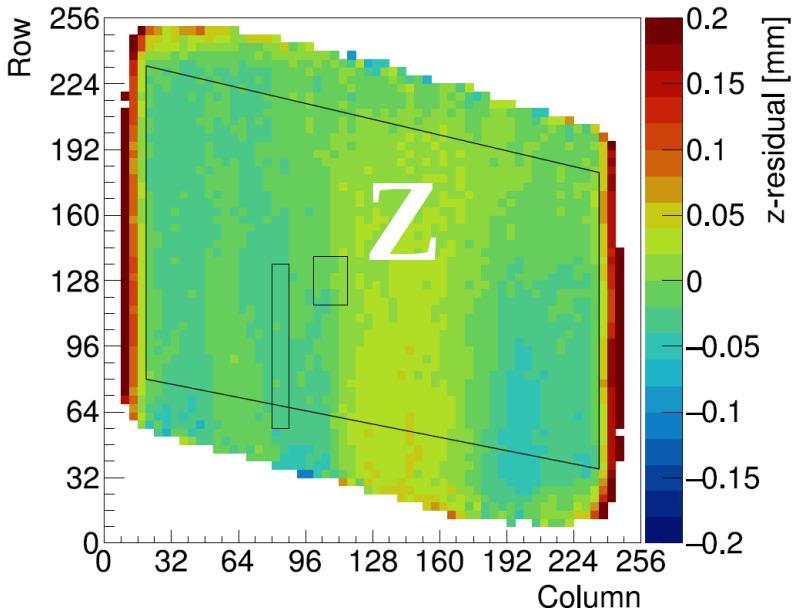
- σ_{z0} from fit
- Diffusion D_L from fit

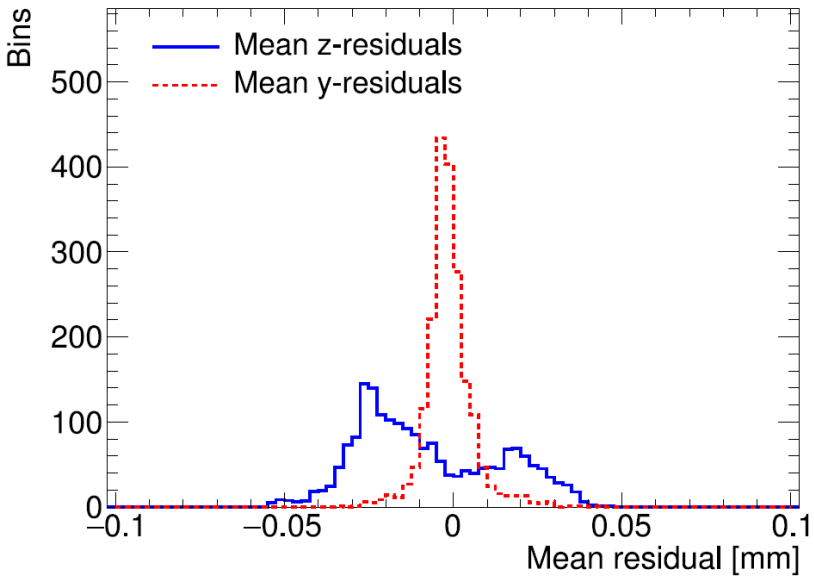
The additional ToT cut (>0.60 µs) was applied to avoid large time walk errors

Deformations in pixel plane (XY) and drift direction (Z)

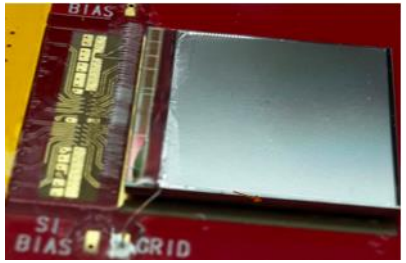
- The RMS of the mean residuals is 7 µm in the pixel plane and 21 µm (0.3 ns) in the drift direction





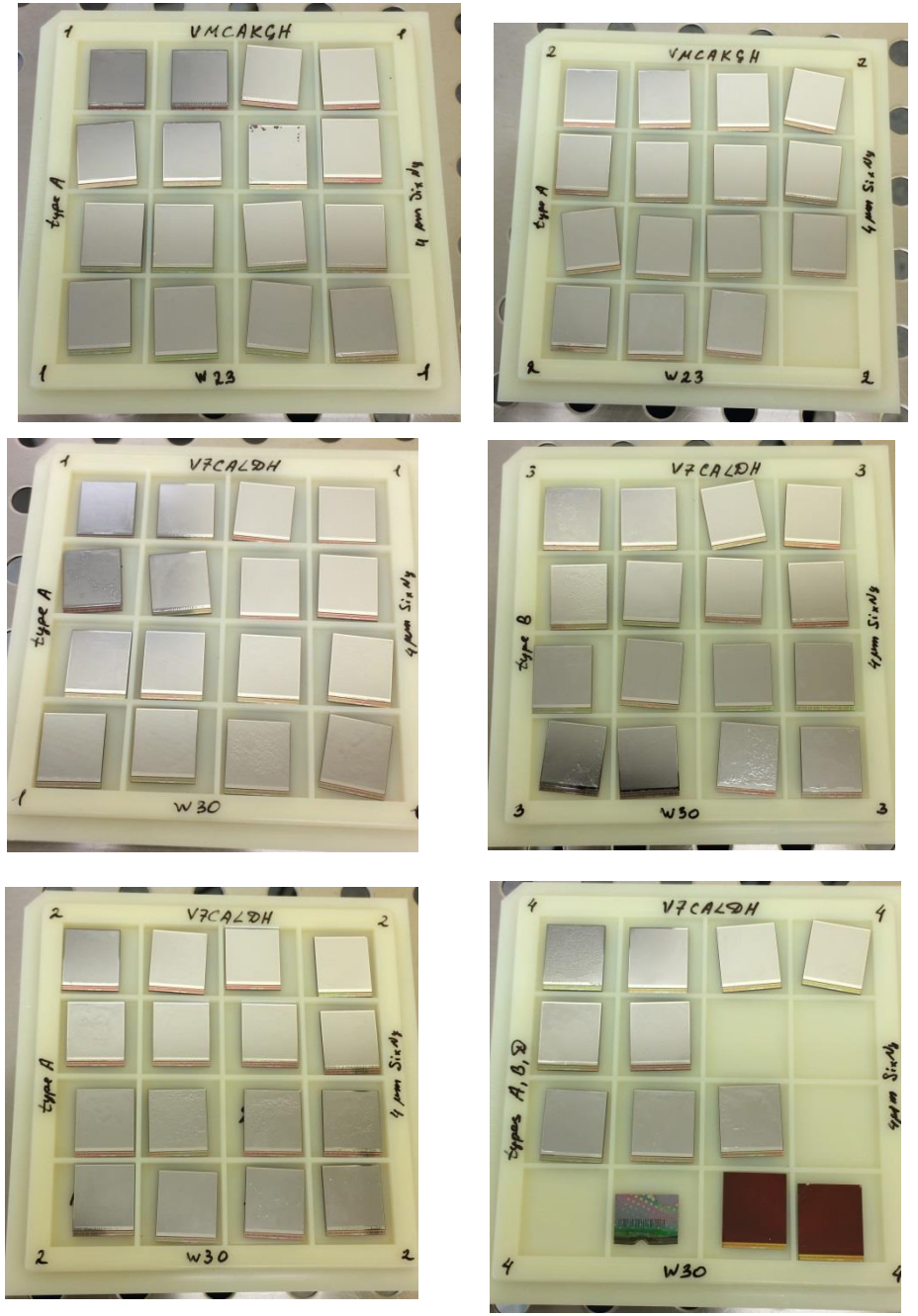


- How can we make an even better detector?
  - Improve the quality (homogenity) of the InGrid; redesign the dike and edges
  - Test beam: put the detector between the two silicon telescope planes
  - Go to a large areas keeping the field distortions (at edges) minimal -> QUAD



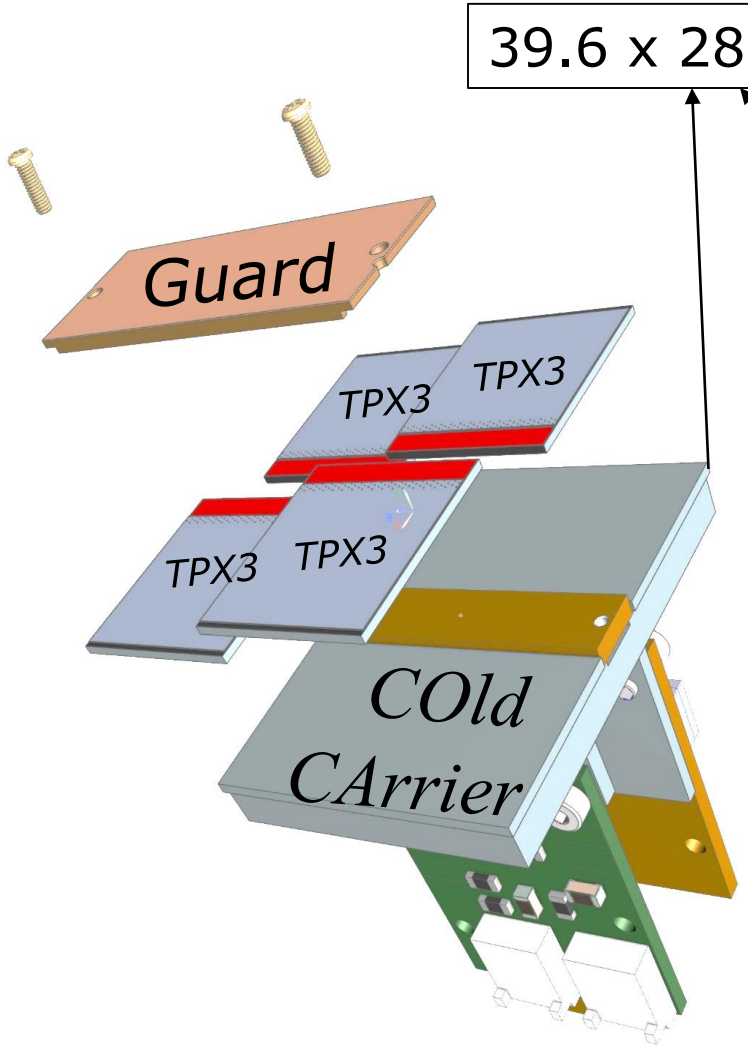
New InGrid production

- Yevgen's latest production has been very successful (May 2018)
- Wafer 23 (VMCAKGH) 31 class A
- 4 class B
  Wafer 30 (V7CALDH)
- 36 class A 18 class B
- 89 chips in total
- Yevgen's yield
  74 good (class A/B)
  13 limited performance 1 bad
- 88 chips in total

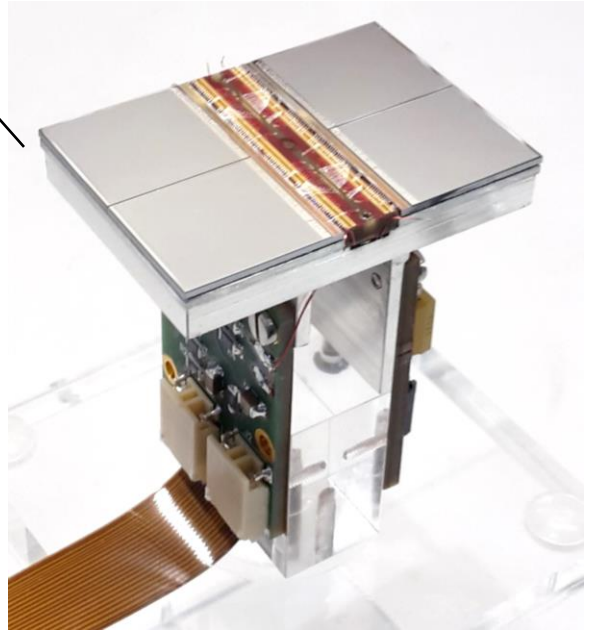


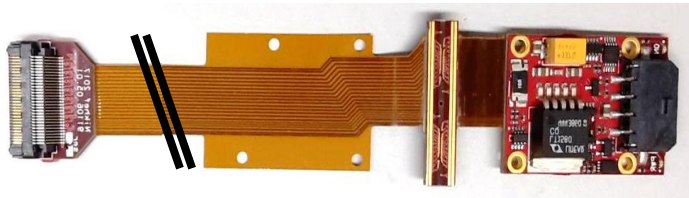
QUAD design and realization

- Four-TimePix3 chips
- All services (signal IO, LV power) are located under the detection surface
- The area for connections was squeezed to the minimum
- Very high precision 10 μm mounting of the chips and guard
- QUAD has an sensitive area of 68.9%
- DAQ by SPIDR



series of QUADs

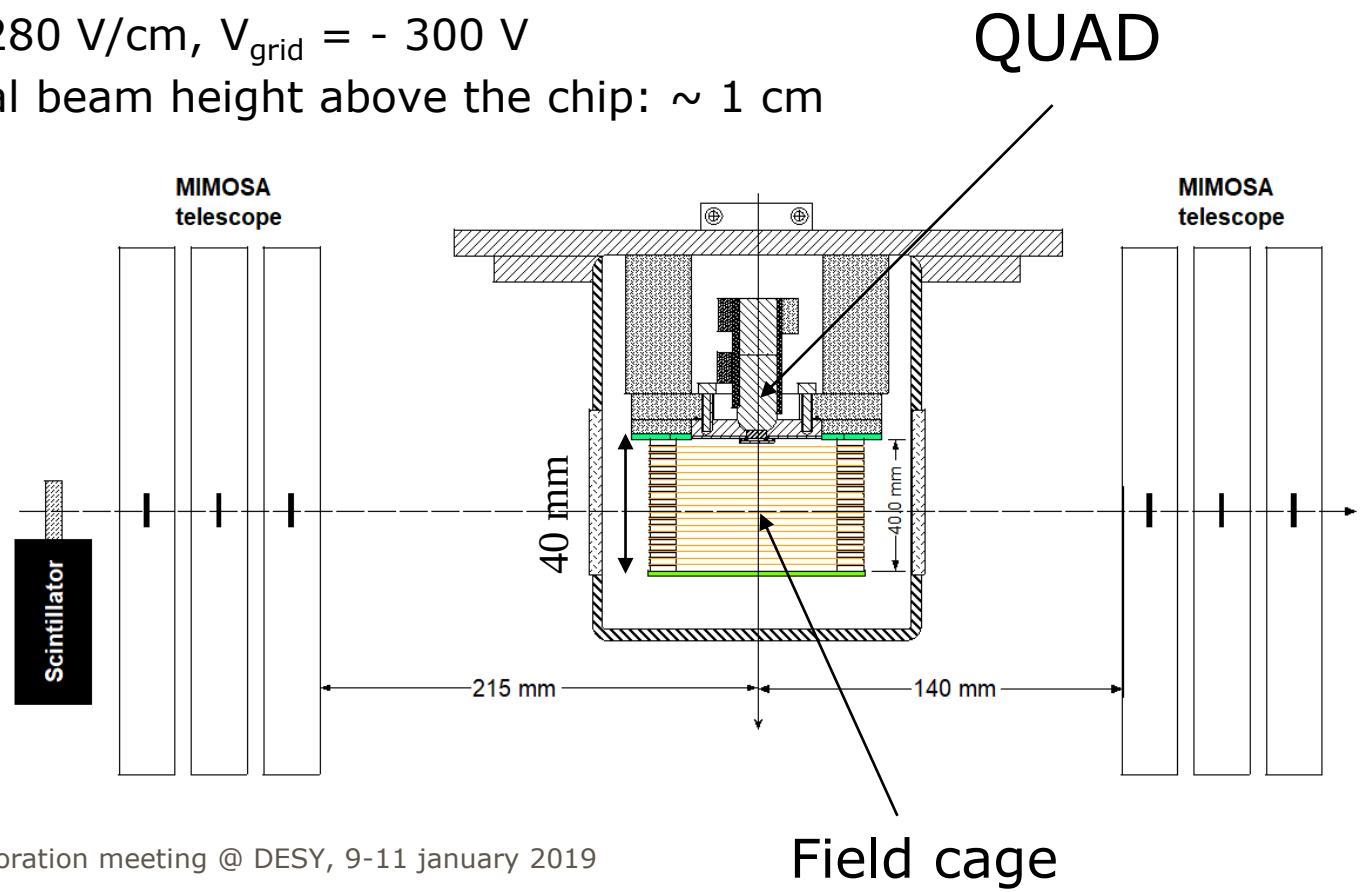




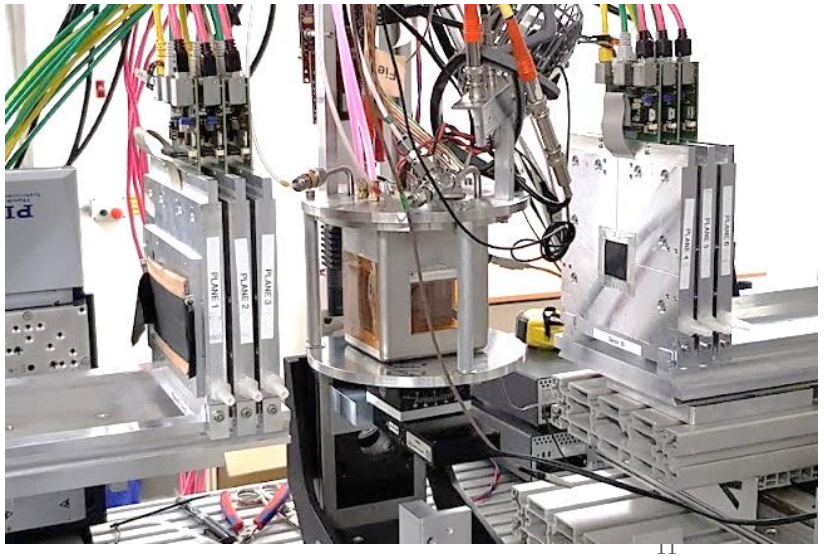
QUAD test beam in Bonn (October 2018)

- ELSA: 2.5 GeV electrons
- Tracks referenced by Mimosa telescope
- QUAD sandwiched between Mimosa halves
  - Largely improved track definition
- Gas: $Ar/CF_4/iC_4H_{10}$ 95/3/2 (T2K)
- E_d = 280 V/cm, V_{grid} = - 300 V
- Typical beam height above the chip: ~ 1 cm

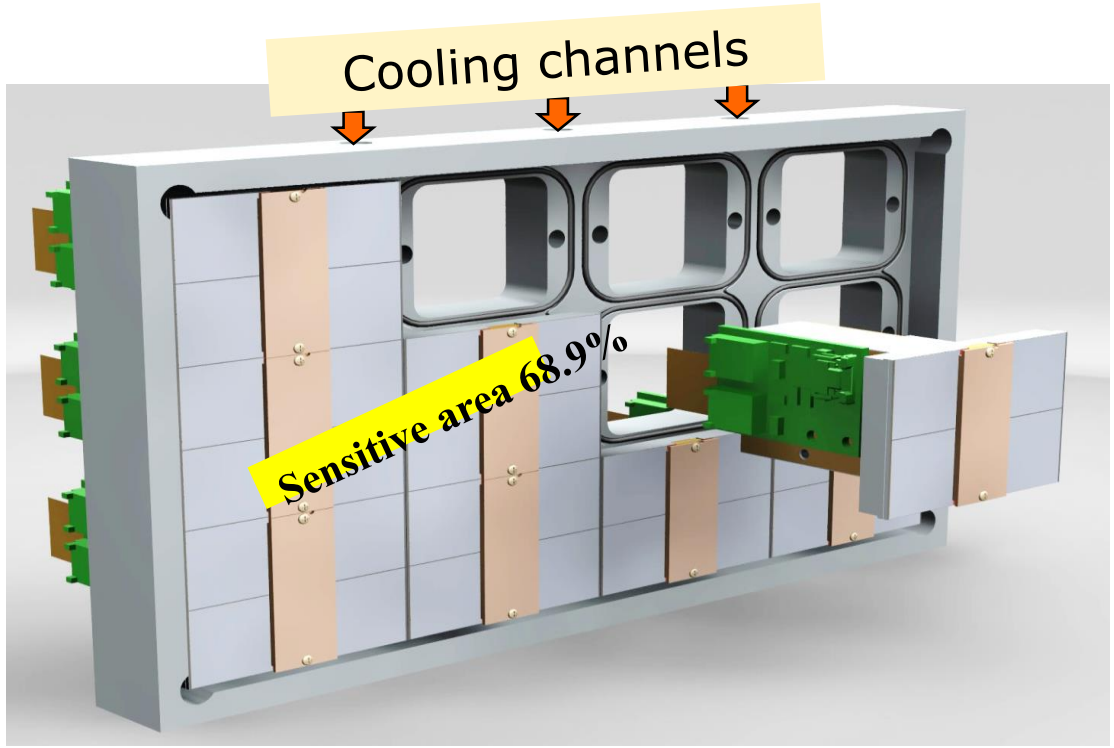
Preliminary results will be presented by Kees Ligtenberg

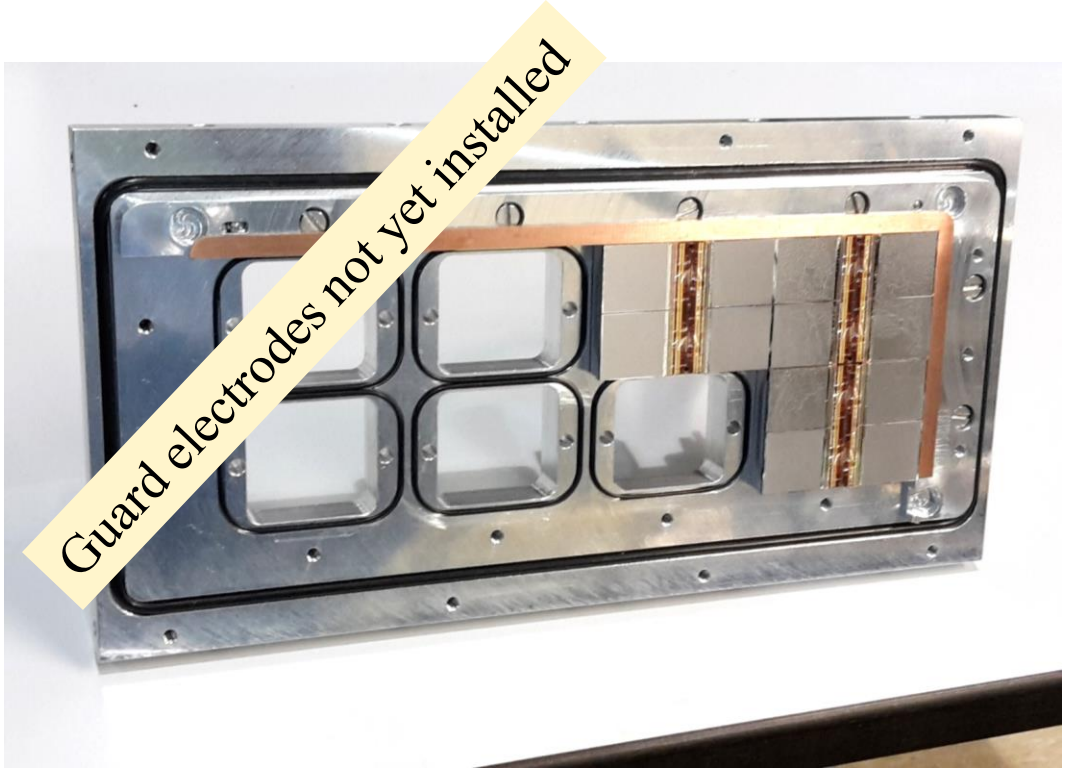


ELSA @Bonn



QUAD module as a building block



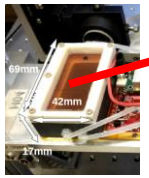


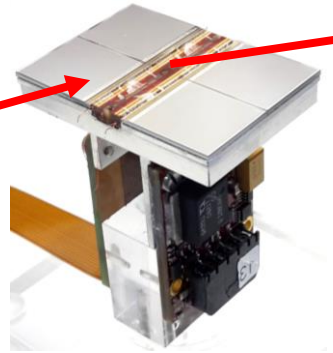
Fred Hartjes will present the next steps towards making a module

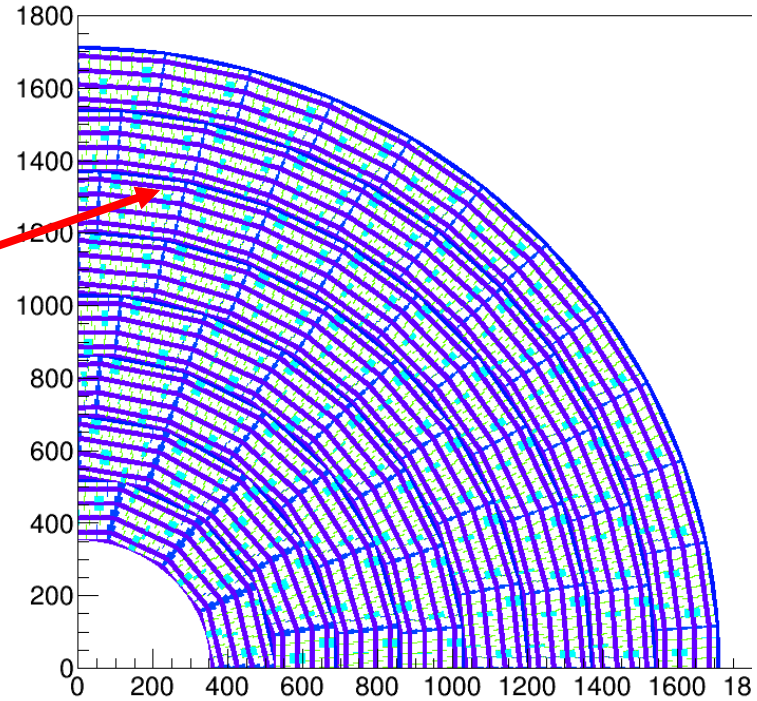
Pixel TPC performance

- Studies to measure the resolution and distortions formations xy and z have been shown here for the single chip test beam results
- Kees Ligtenberg will present the resolutions and distortion results for the QUAD
- The performance of a pixel TPC will be presented by Peter for the topics
  - dEdx using simulation and data
  - Timing resolution will also be addressed
  - Results for the two track resolution based on the 2019 test beam
- The simulation of a pixel TPC for ILD will be summarized by Kees Ligtenberg
  - See also: "Performance of a GridPix TPC readout based on the Timepix3 chip", Proceedings of the International Workshop on Future Linear Colliders (LCWS2018), Arlington, Texas, 22-26 October 2018. C18-10-22. https://agenda.linearcollider.org/event/7889/contributions/42682
- In the analysis meetings pixel results have been presented:
  - First meeting https://agenda.linearcollider.org/event/7909/ on dEdx
  - Second meeting https://agenda.linearcollider.org/event/7950/ on z resolution and timing
  - Third meeting https://agenda.linearcollider.org/event/7982/ distortions (xy) and their mitigation

Pixel TPC







Single chip 2017

Quad 2018

Module 2019

TPC plane