Recent advances in Gridpix detectors

(reading out gas detectors with pixel ASICs)

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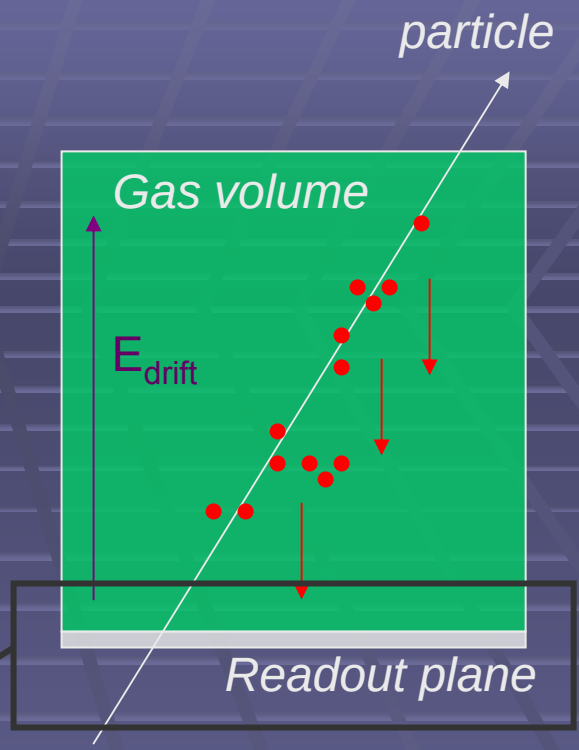
IWORID, Erlangen 2007

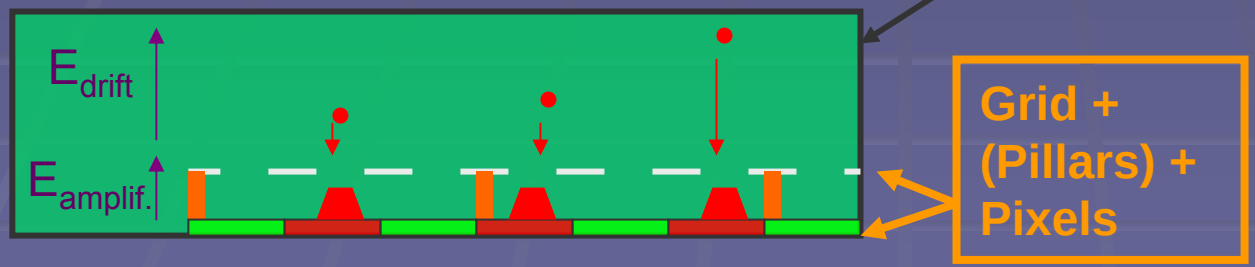
Overview

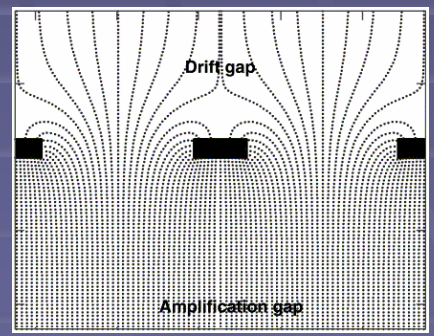
- The pixel readout of gaseous detectors
- Adding functionalities to pixel readout chips by wafer post-processing
  - Gas amplifying grids
  - Gas discharge protection
  - Post-processed Medipix2 chip
- The Timepix chamber, a 64k channel μTPC

The Gridpix detector

- Readout gas volume by means of pixels
  - Small input capacitance
  - High granularity
- Micromegas-based amplification
  - High electric field faced by the chip
  - Single electron sensitivity
- Broad range of application from HEP (TPC, VTX) to Rare events detection and X-ray polarimetry

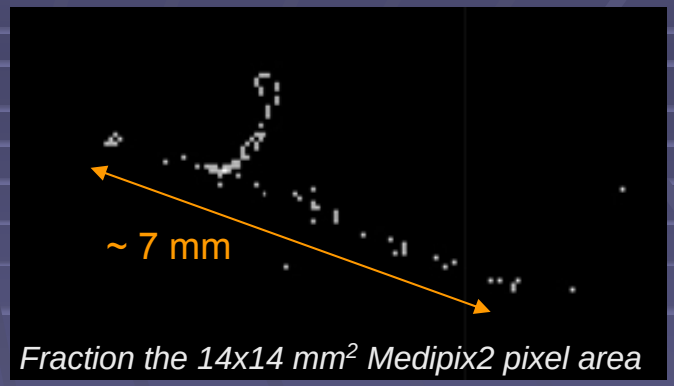






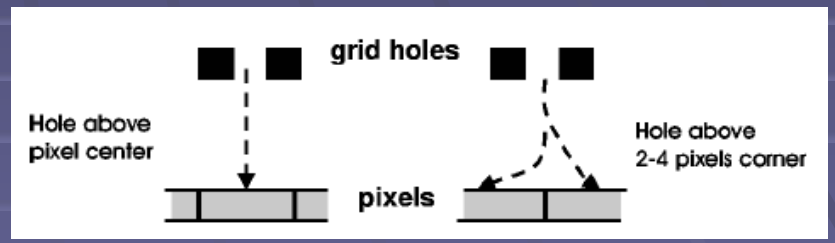
Typical events and issues

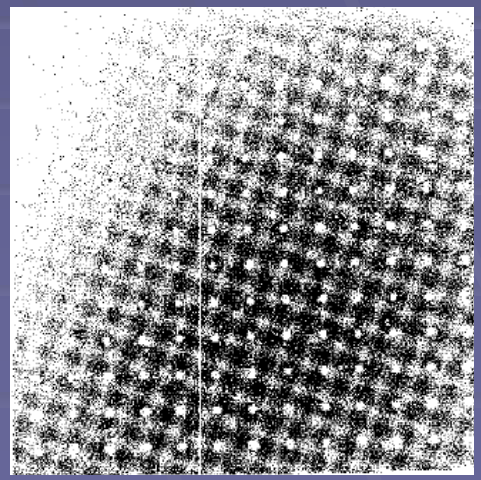
- Micromegas + Medipix2
  - 2D projection of the track ionization



Fraction the 14x14 mm² Medipix2 pixel area

- Issues
  - Gas detectors do spark
    sensitive to gas discharges
  - Large Micromegas pillar Ø
    detection area loss
  - Pixel pads and grid holes misaligned
    efficiency loss
  - Grid hole and pixel pitches ≠
    periodic variation of efficiency
    Moiré pattern



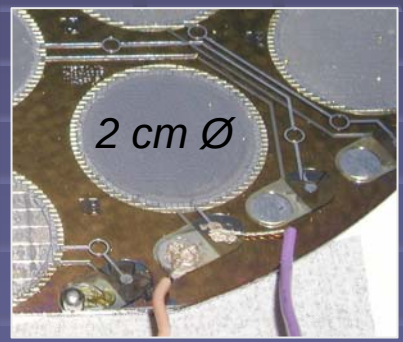


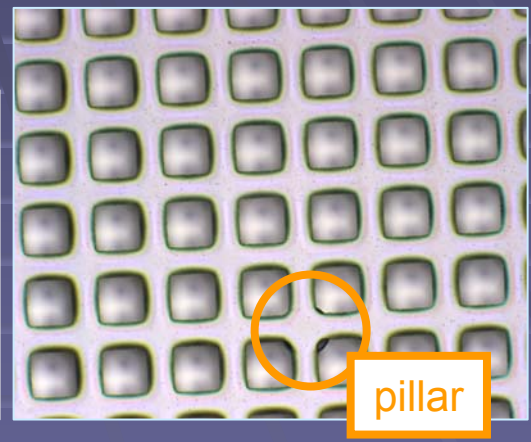
InGrid, an integrated Micromegas

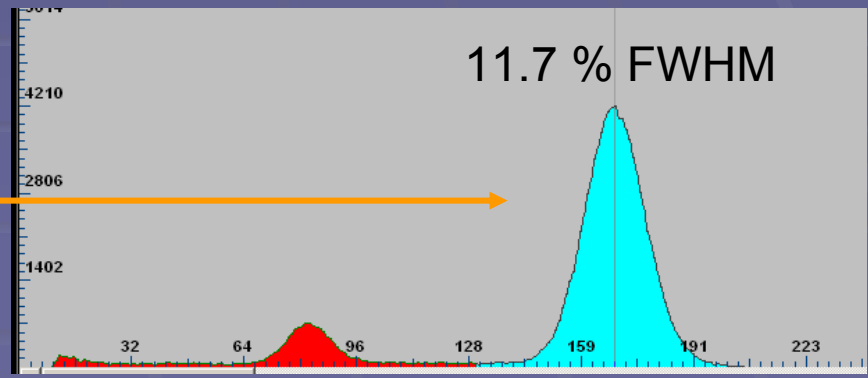
- Solve the alignment / pillar Ø / pitch issues by integrating the Micromegas onto the chip

- Wafer post-processing
  - Grid geometry fits the chip
  - Pillar Ø ~ 30 µm

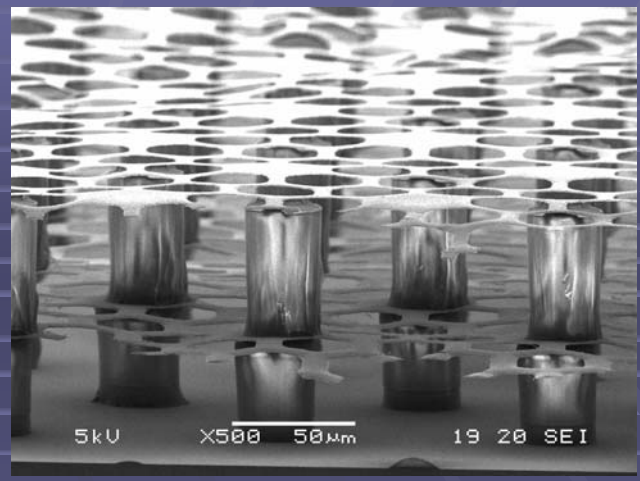
- Very good grid flatness
  - Minimum gain fluctuations
  - Extremely good resolution of 690 keV FWHM @ 5.9 keV in Ar 10% CH_4



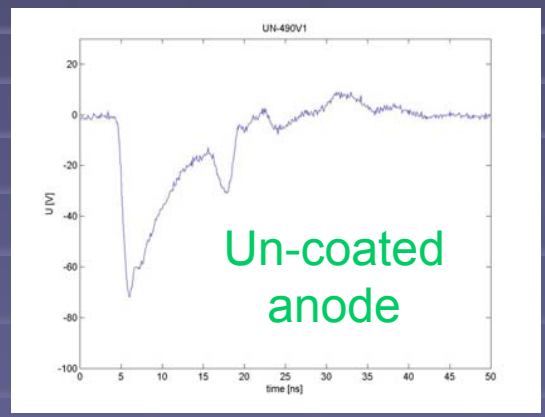




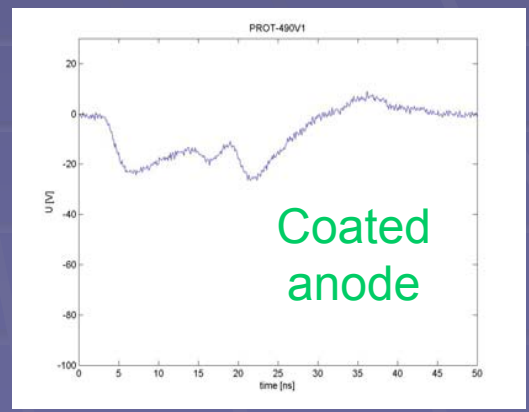
Solutions against sparking



- Multi-stage amplification
  - less gain (E field) per stage
  - first trial: TwinGrid worked!
    systematic study to come

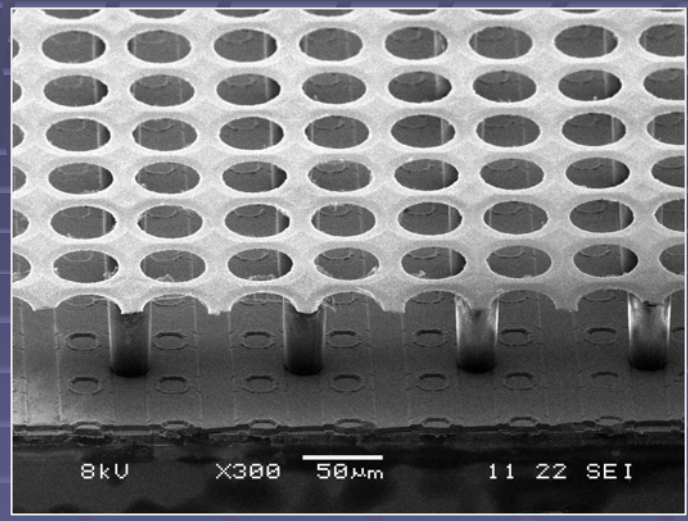


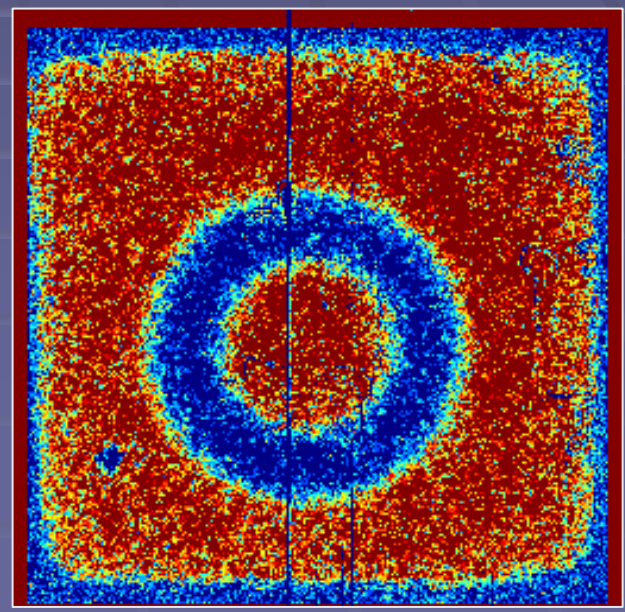
- aSi layer on top of the pixel matrix: Silicon Protection
  - 10^{11} Ω.cm, few µm thin
  - deposited at ~ 250 °C
  - Attenuate discharge current



The 1st post-processed Medipix2

- InGrid coverage of a 4” wafer successful!
  - SiProt + InGrid equipped
  - Diced to individual chips
- Handling critical
- SU8 photo-resist dike around the pixel matrix
- Perfect alignment pads/holes
- Pillars in between pads

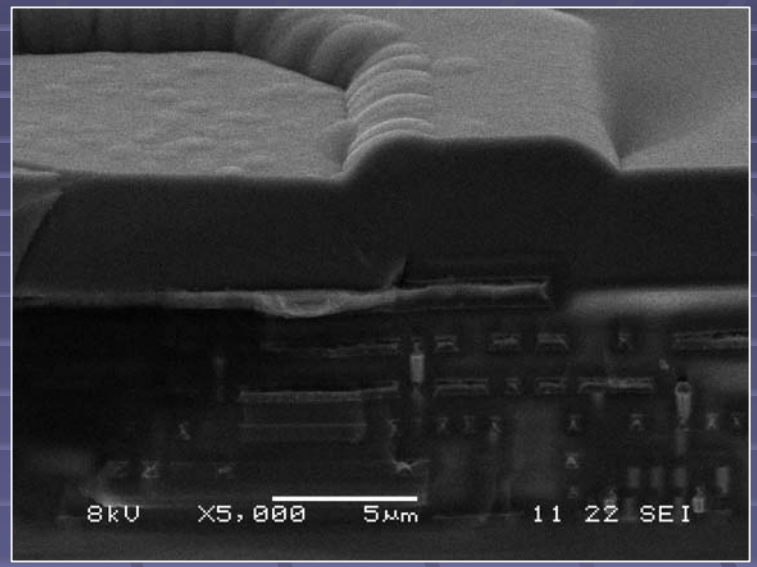




(Almost) full homogeneous response

The Timepix chamber

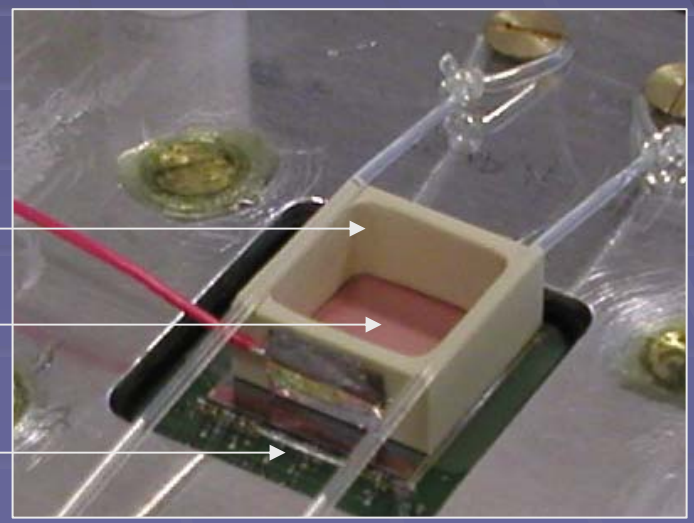
- Timepix chip used
  - covered with a 3 µm thick SiProt
  - Micromegas glued on a frame
  - Function continuously since 3 months



- Electric field homogeneity
  - Extend the grid potential around the chip
  - Guard electrode

- Gas mixture: He 20% iC_4H_{10}
  E_{drift} = 660 V/cm $Drift_{gap}$ = 15 mm
  Gain ~ 8.10^3

- Reduced sensitive area
  - 200 µm Ø pillars
  - Moiré effect
  - Mylar window



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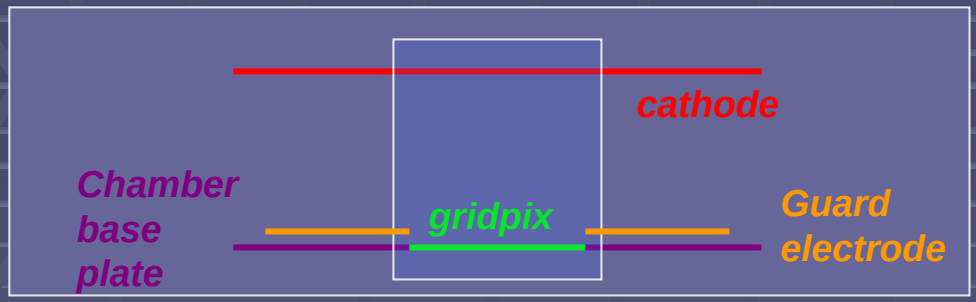

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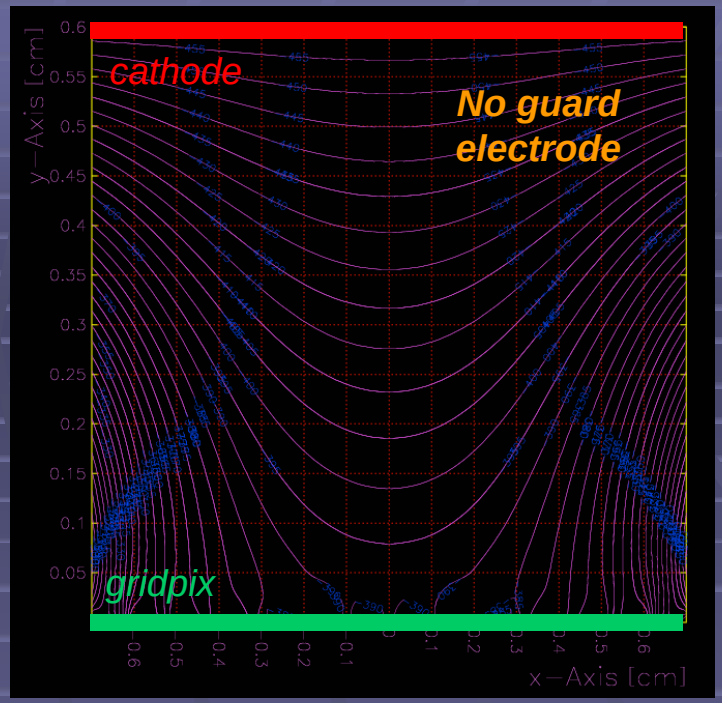

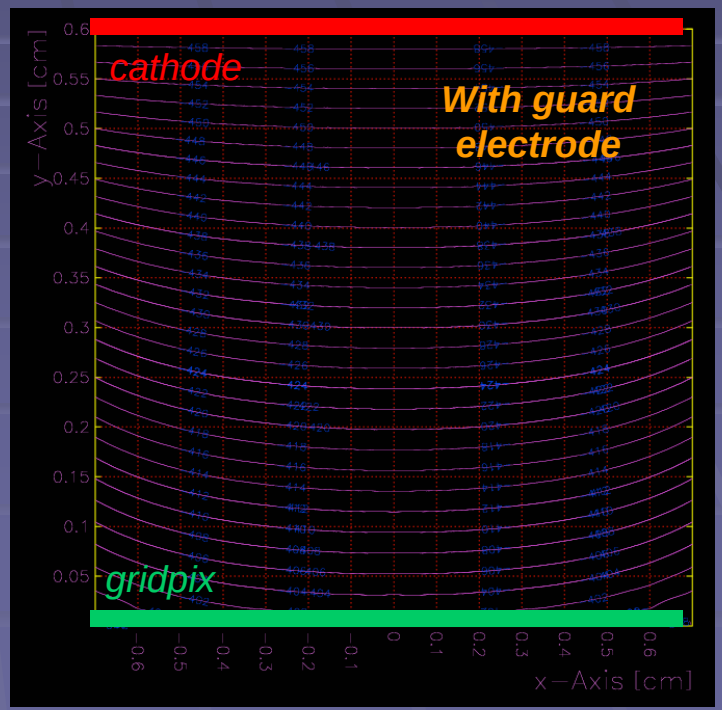

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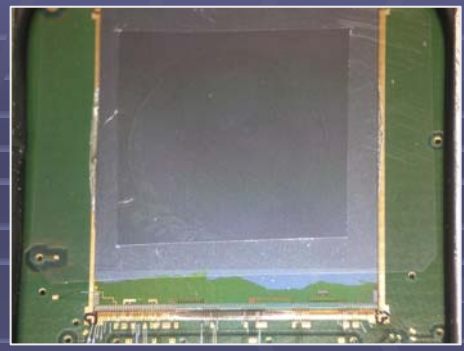

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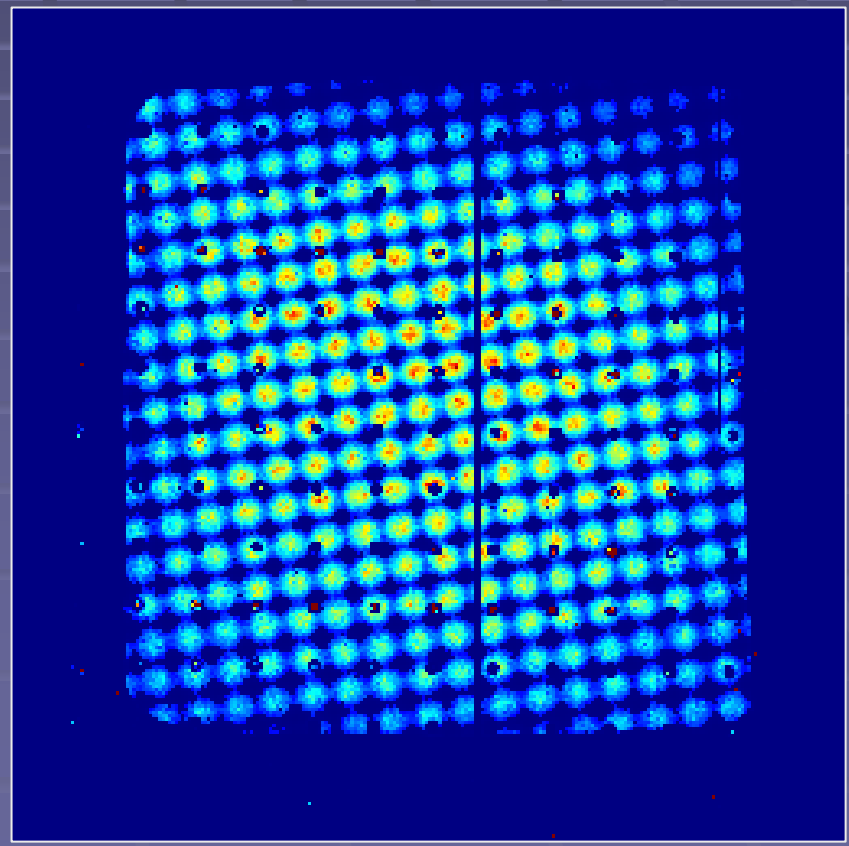
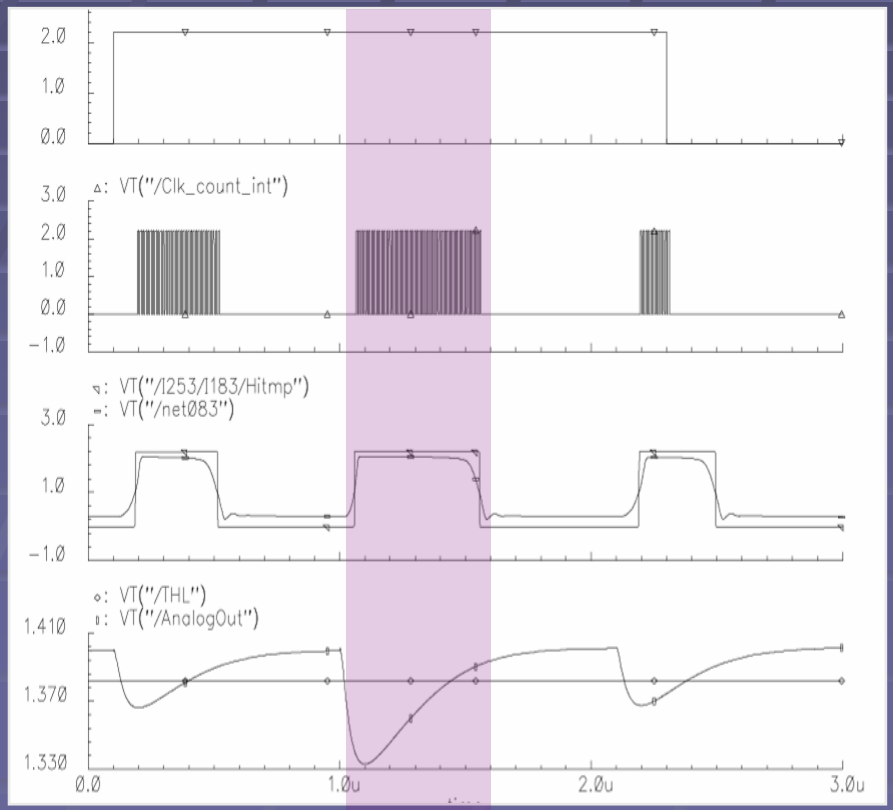


Timepix counting modes

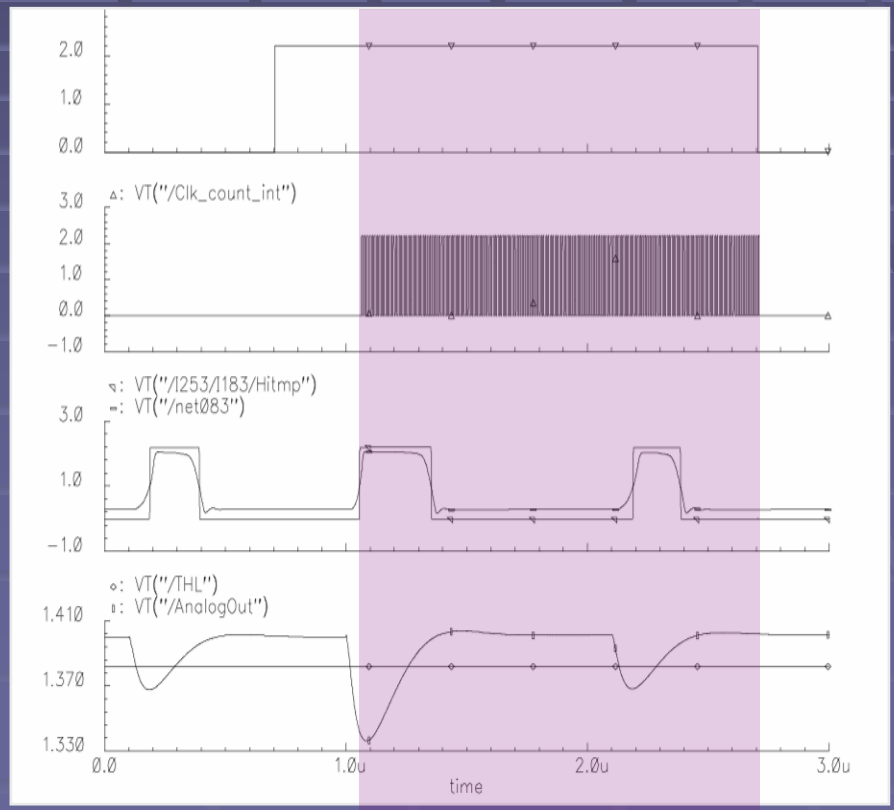
TOT mode

N_{counts} related to Q_{tot}



Time mode

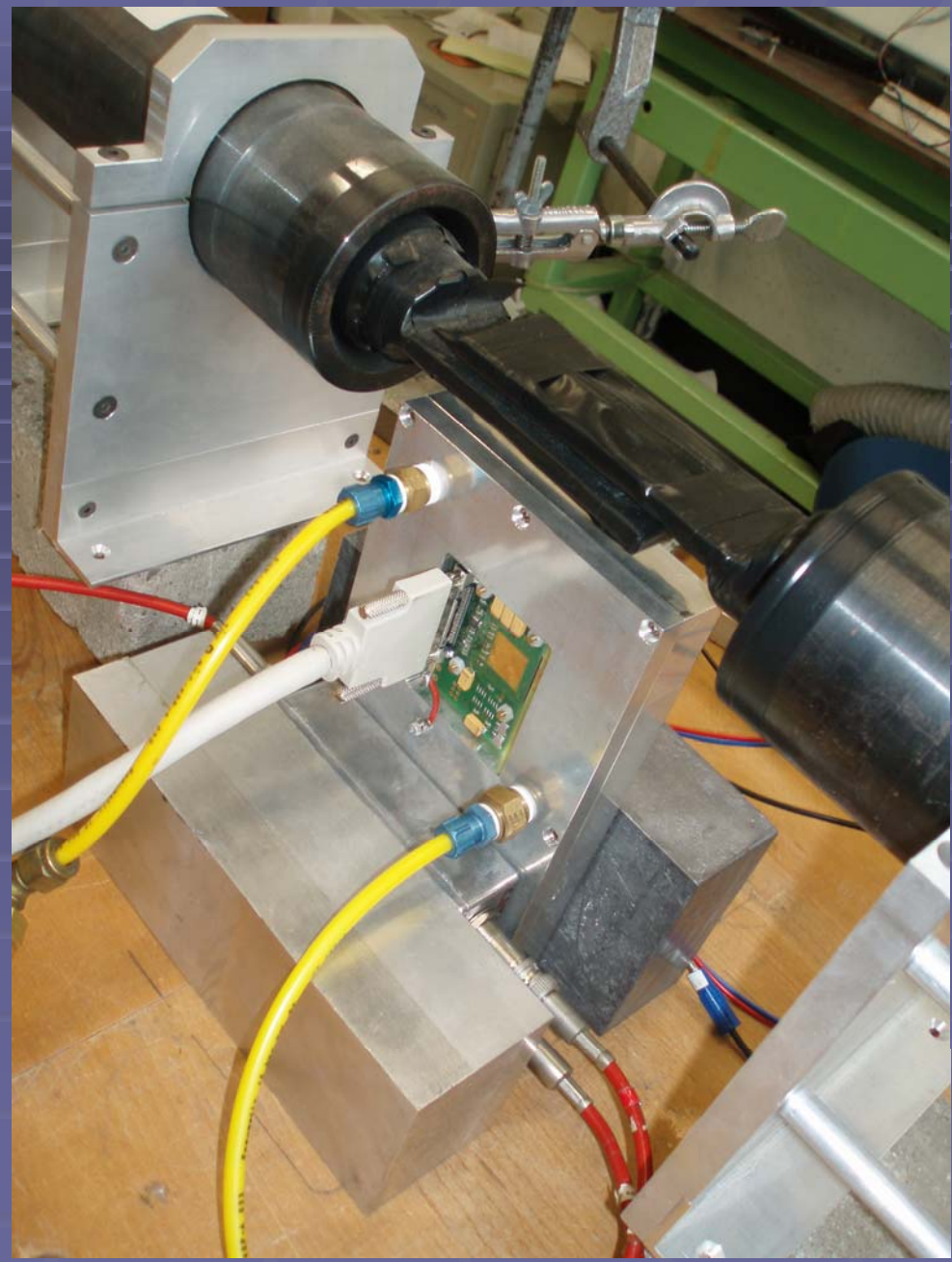
N_{counts} related to "drift time"

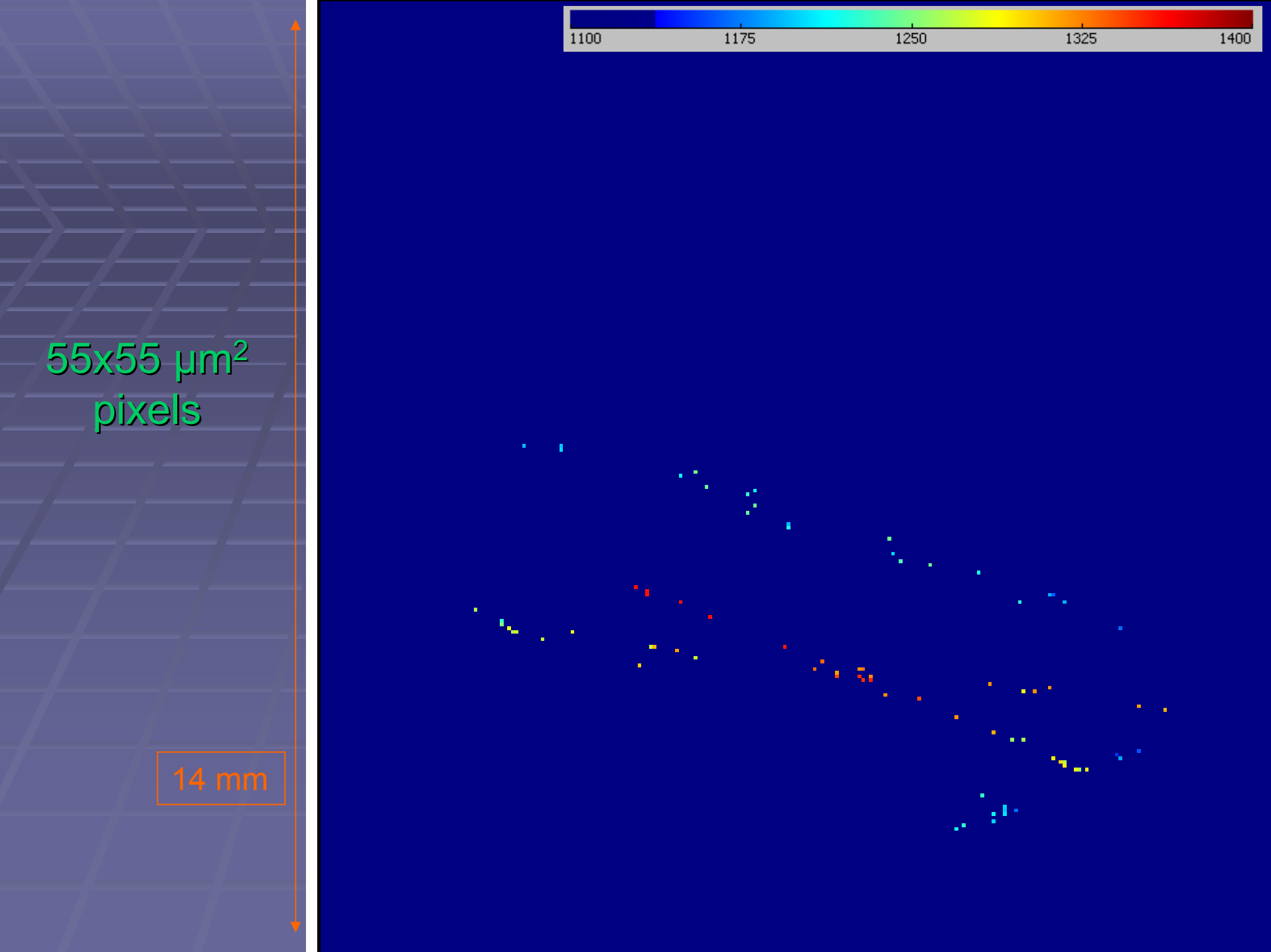


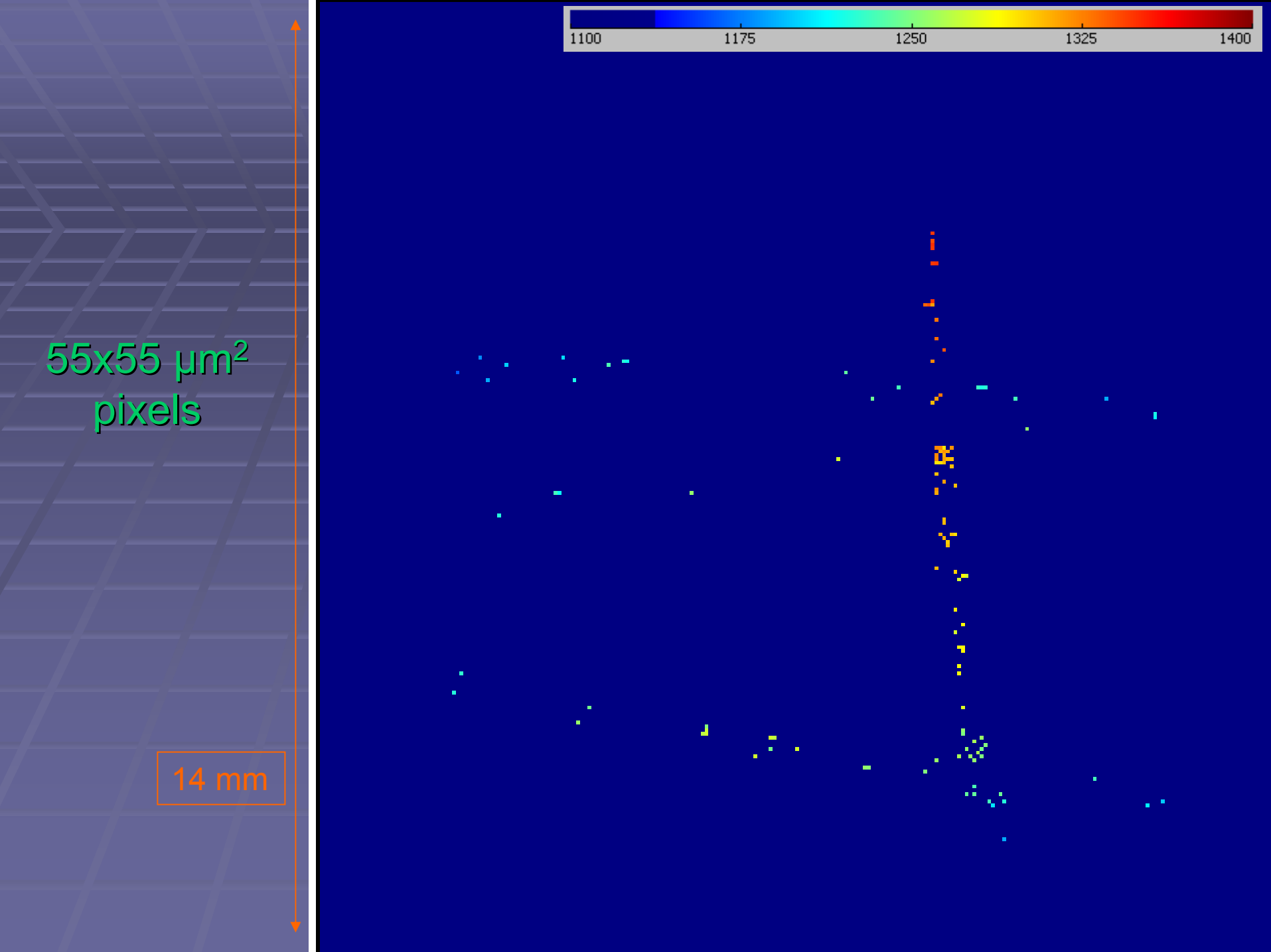
Coincidence set-up

- Coincidence setup
  - 2 scintillators above the chamber
  - lead plates +1 scintillator below
- Time mode:
  - Trigger activates the chip for 15 μs (exposure time)
  - Clock frequency used: 40 & 100 MHz
  - Maximum counts of 600 & 1500

Wait for cosmic particles ….




1100
1175
1250
1325
1400
55x55 µm²
pixels
14 mm


55x55 µm²
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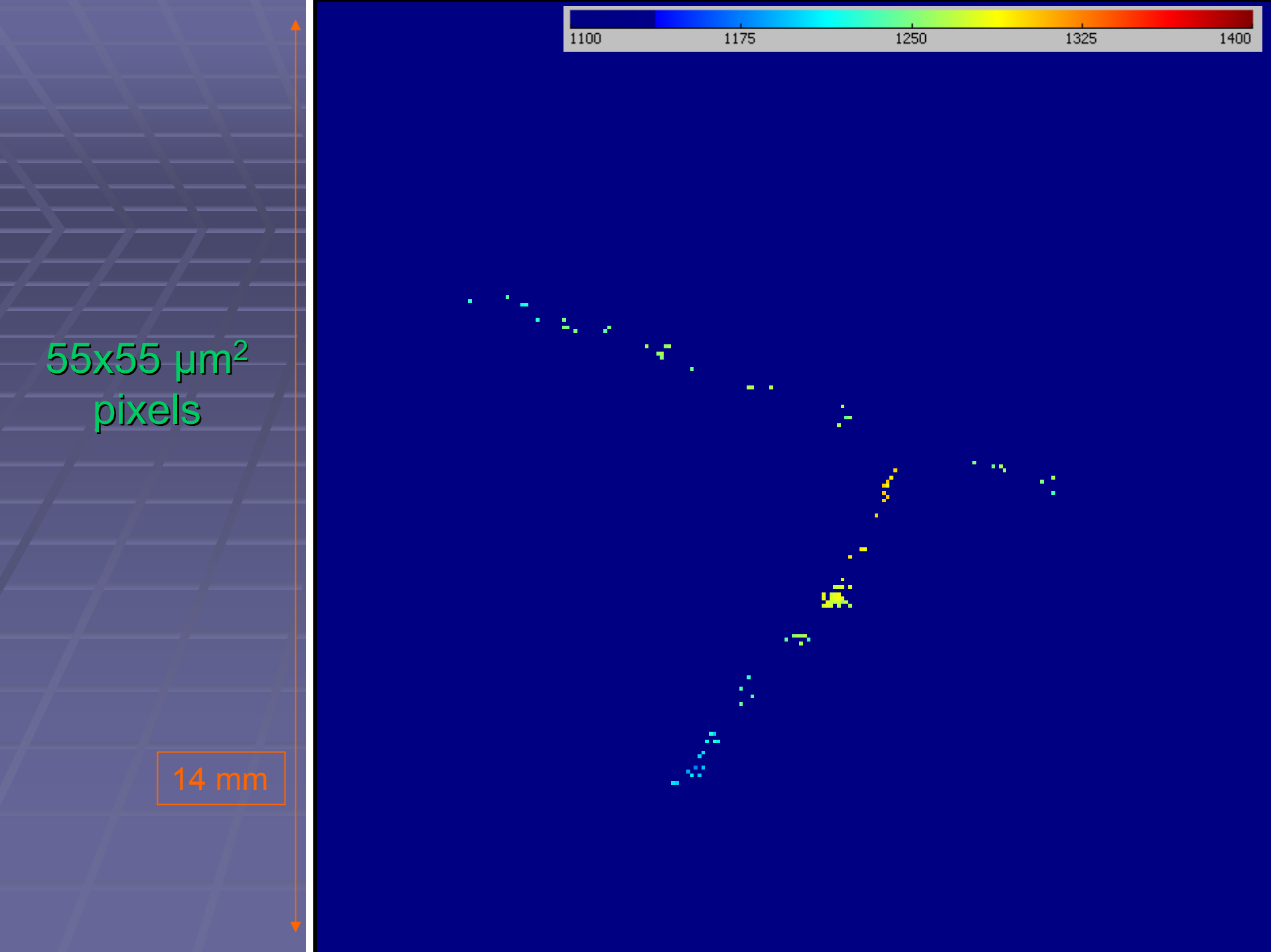
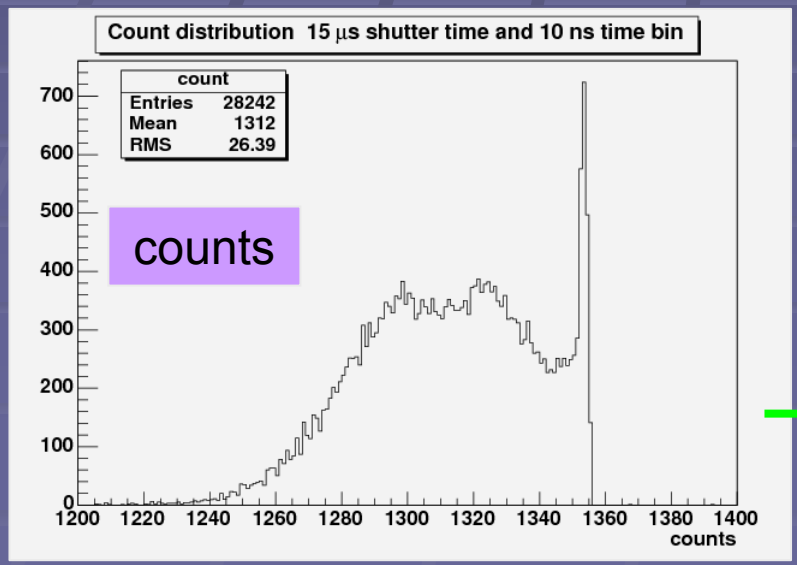
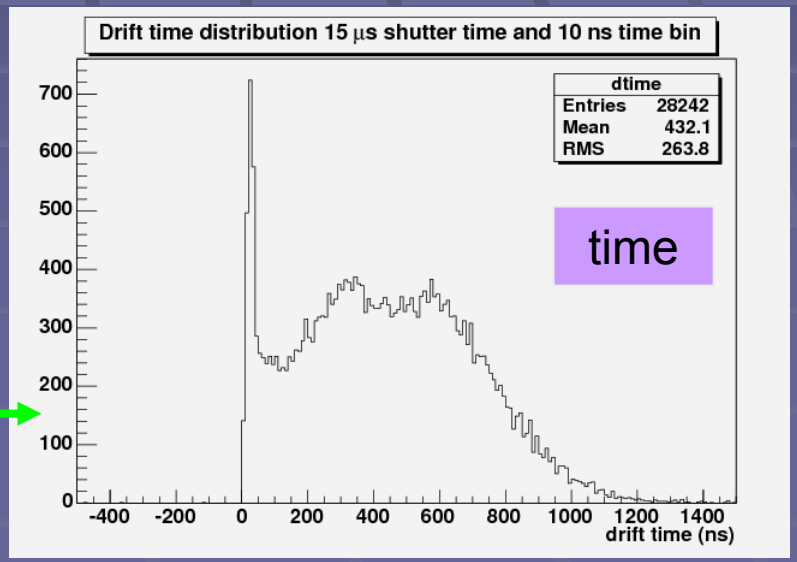

1100
1175
1250
1325
1400
55x55 µm²
pixels
14 mm

Count/Time distribution (I)

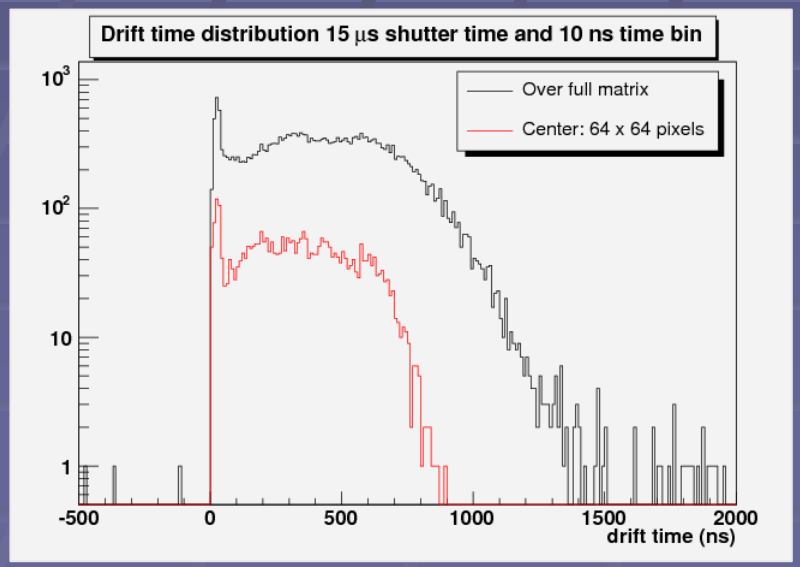
- Sharp peak at short drift times:
  ~ 100 ns from trigger signal to “shutter opening”;
  pixel activated within these 100 ns start counting when the “shutter” comes.
- Tail at larger drift times:
  - Still some field distortions on the sides
- Translate counts in time: $\Delta t = (C_{max} - C) \cdot t_{bin}$

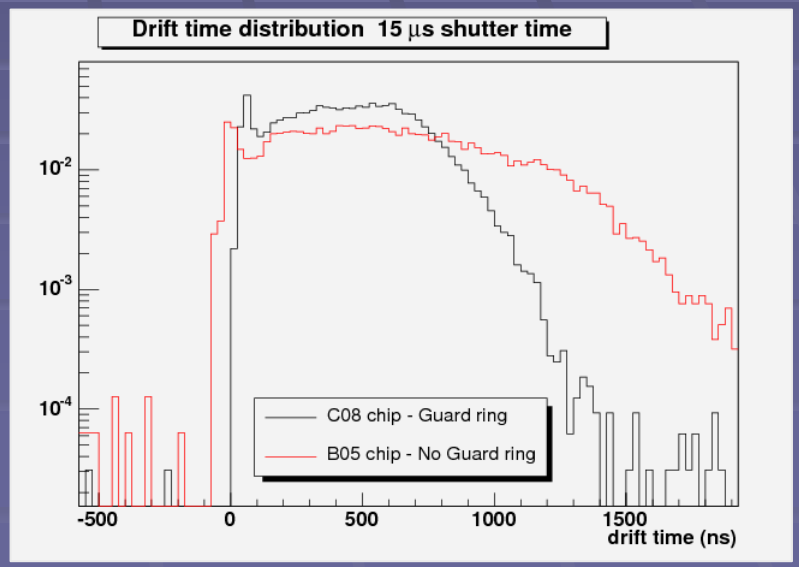




Count/Time distribution (II)

- Tail at larger drift times:
  - Still some field distortions on the sides
- Hits from the pixel matrix center have no tail (longitudinal diffusion only)
- Distribution width ~ 750 ns, 15 mm drift gap yields v_d ~ 2 cm.µs^{-1} @ 660 V.cm^{-1} (2.4 cm.µs^{-1} from Monte Carlo)



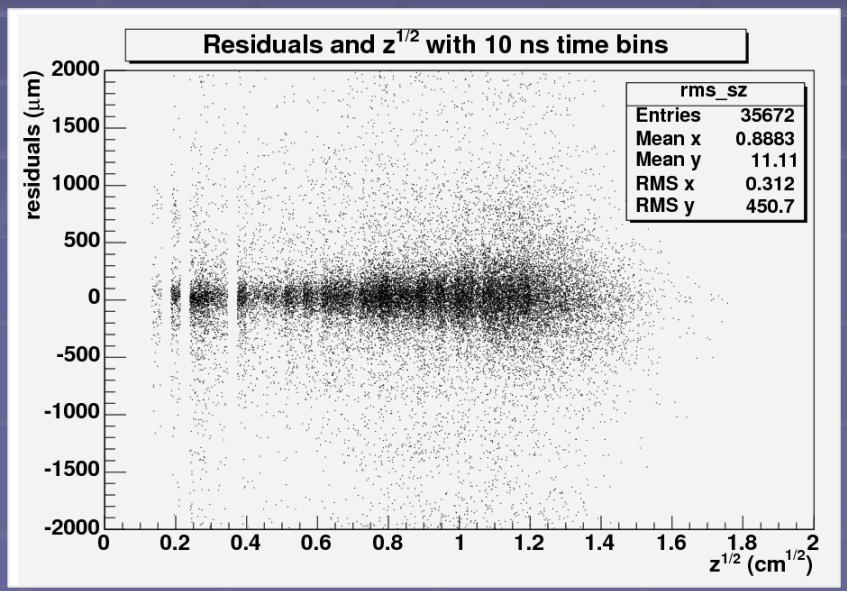


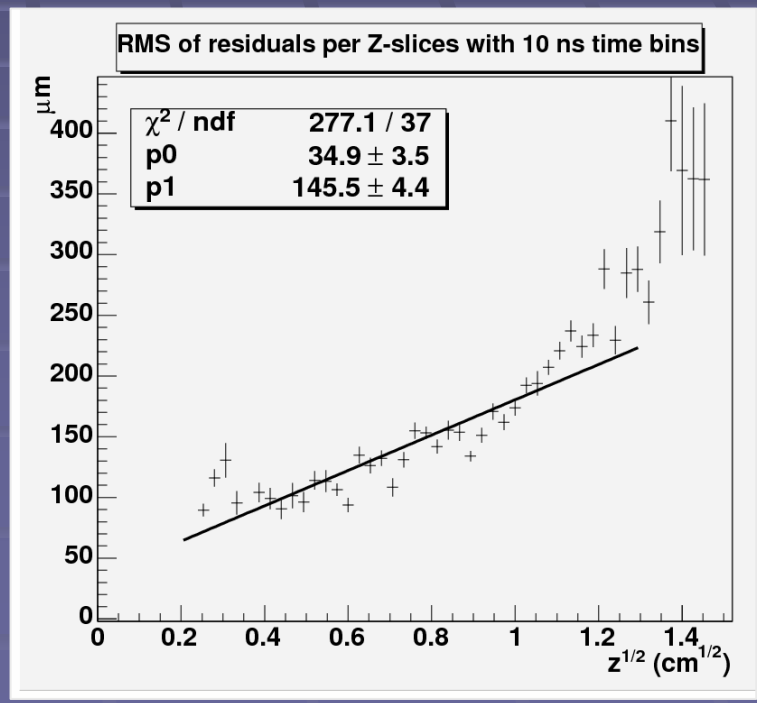
Residuals and drift length

- Standard deviation of residuals follows $\sigma_t^2 = \sigma_0^2 + D_t^2 \cdot z$
  with σ_0 the spatial resolution at "0" drift distance and D_t the diffusion coefficient.

- Fit of $\sigma_t = f(z^{1/2})$ yields:
  D_t = 174 µm.√cm @ 660 V.cm^{-1} for t_{bin} = 25 ns
  D_t = 145 µm.√cm @ 660 V.cm^{-1} for t_{bin} = 10 ns

  D_t = 180 µm.√cm from Monte Carlo





Conclusion and future plans

- Two main steps realized:
  - 3D reconstruction of cosmic MIP tracks;
  - Successful post-processing of a 4” Medipix wafer.
- Post-processing of more Medipix/Timepix chips
- Beam test to come soon:
  - Study of electron ionization statistics
  - Study of spatial resolution
- Timepix setup
  - Make progress on the triggering of the Timepix chamber
  - Pixelman software implementations (plugins for on-line pre-analysis)
- New chamber design for “quad” readout
  Build a small TPC endplate

Acknowledgments

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