GridPix: Production and Applications of Integrated Pixel Readouts

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University of Twente/MESA+: Juriaan Schmitz . . .
Fraunhofer IZM: Oswin Ehrmann, Thomas Fritzsch, Stefan Mayer, Michael Töpper . . .

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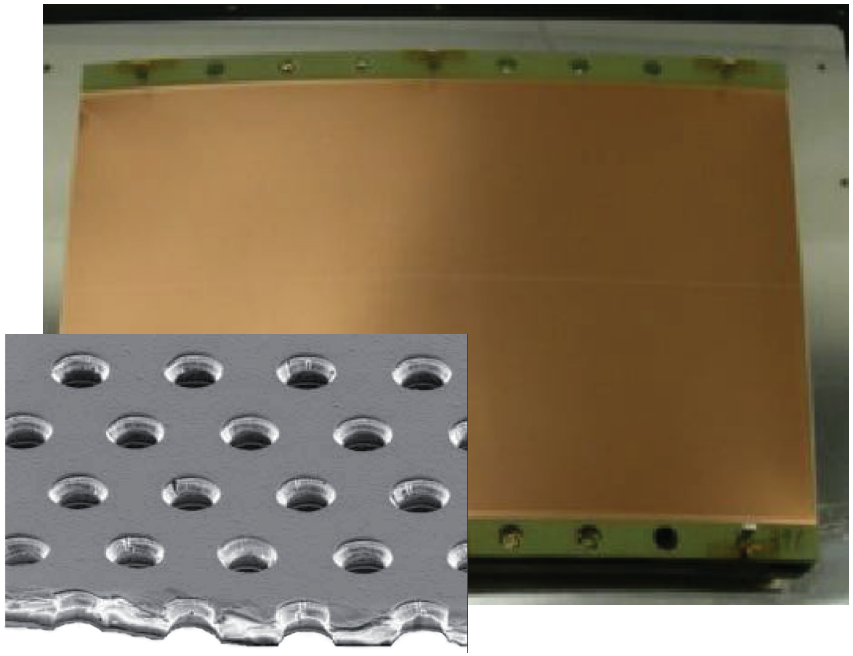
Outline

1. Introduction
2. GridPix in CAST
3. GridPix in a prototype TPC
4. Wafer scale production
5. Conclusions & Outlook

Introduction



MPGDs

- Pad sizes: $\mathcal{O}(\mathrm{mm}^2)$
- Strips (pitch): $\mathcal{O}$(100-200 µm)

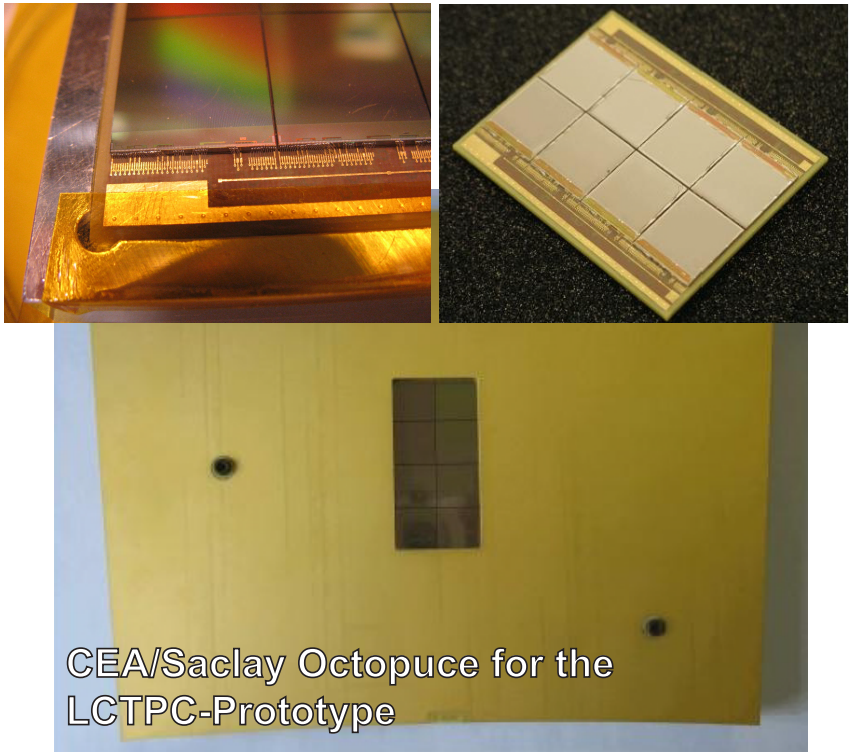
⇒ This does not fully exploit the resolution of MPGDs

⇒ Smaller pads: $\mathcal{O}$(50-100 µm)

⇒ Pixelized readouts

Possible applications

- Rare event searches:
  - Axions (CAST)
  - Dark matter (DARWIN)
    (see *"Operating the GridPix detector in dark matter search experiments"* - by Rolf Schön)
- Tracking (ILD)



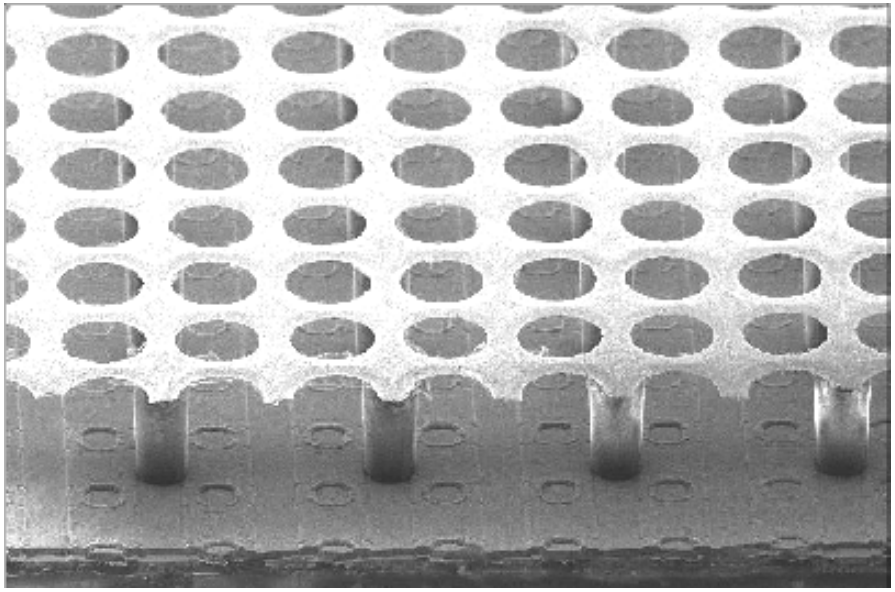
(see *"A TPC for the Linear Collider"* - by Paul Colas)

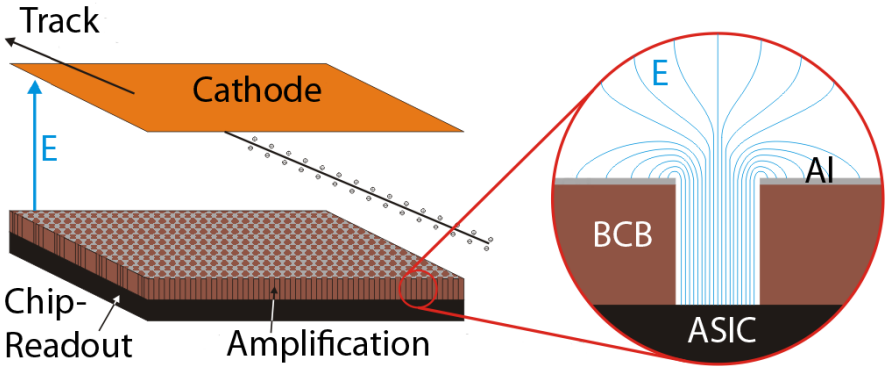
GridPix - Integrated Pixel Readout

GridPix

GEMs / Micromegas on a pixelchip

- Insulator between grid and pixelchip
- One hole above each pixel
- Amplification directly above the pixelchip





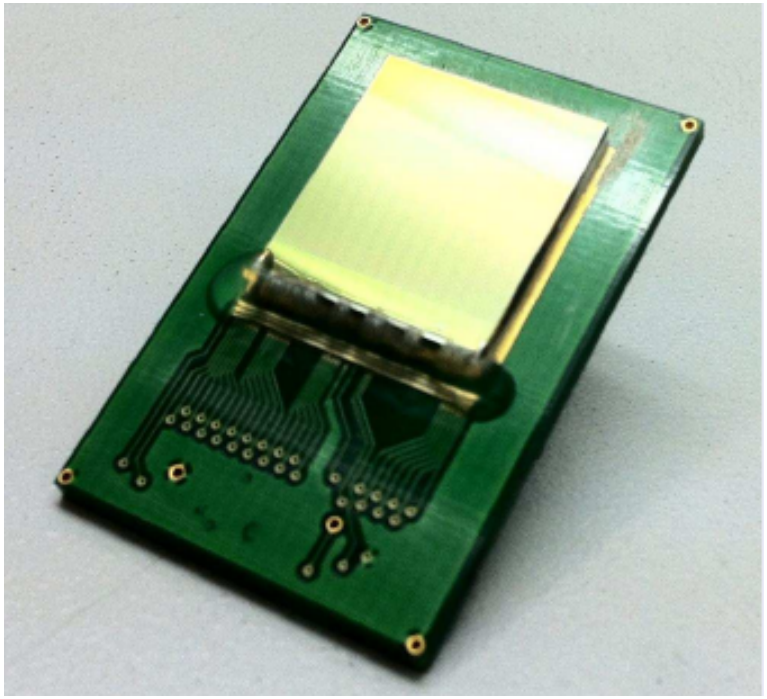
Advantages

- Ultimate single point resolution
- Perfect alignment
  - Each primary e^- is detected on <u>one</u> pixel
  - Nearly 100 % single e^- efficiency
  - Low occupancy

Timepix Pixel Chip

Characteristics

- Derived from Medipix-2
- 256×256 pixel
  $\Rightarrow$ 55 µm pixel pitch
  $\Rightarrow$ 2 cm^2 active area
- Charge sensitive amplifier and discriminator in each pixel
- ENC $\approx$ 100 electrons
- Threshold $\approx$ 700 electrons
- 30 - 100 MHz clock frequency
- Two modes of measurement (per pixel):
  $\Rightarrow$ Time or charge
- No multiple hit capability

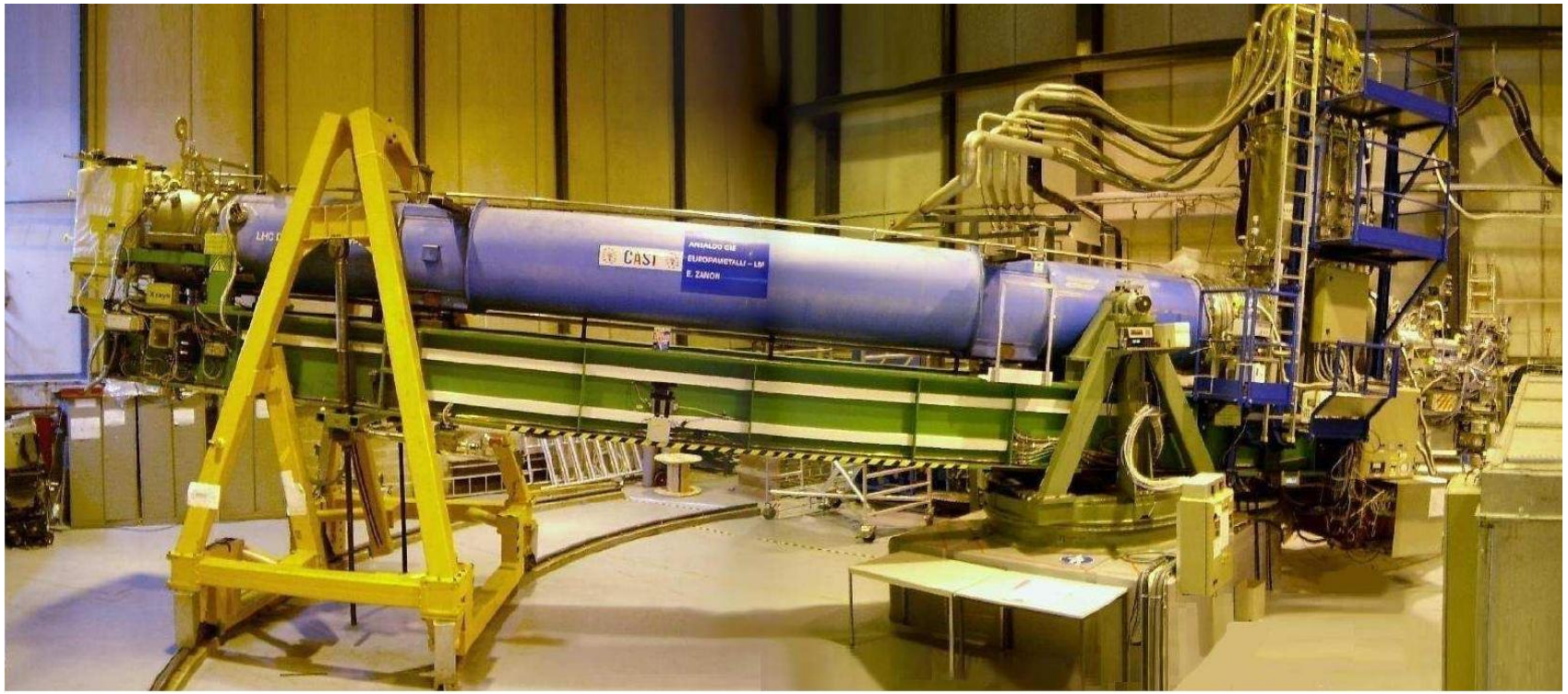


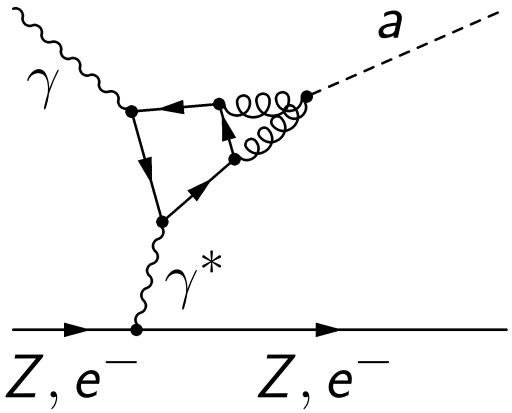
Successor: Timepix-3

In preparation

- Simultaneous charge and time measurement
- Multiple hit capability
- Higher clock frequency

A Detector for CAST

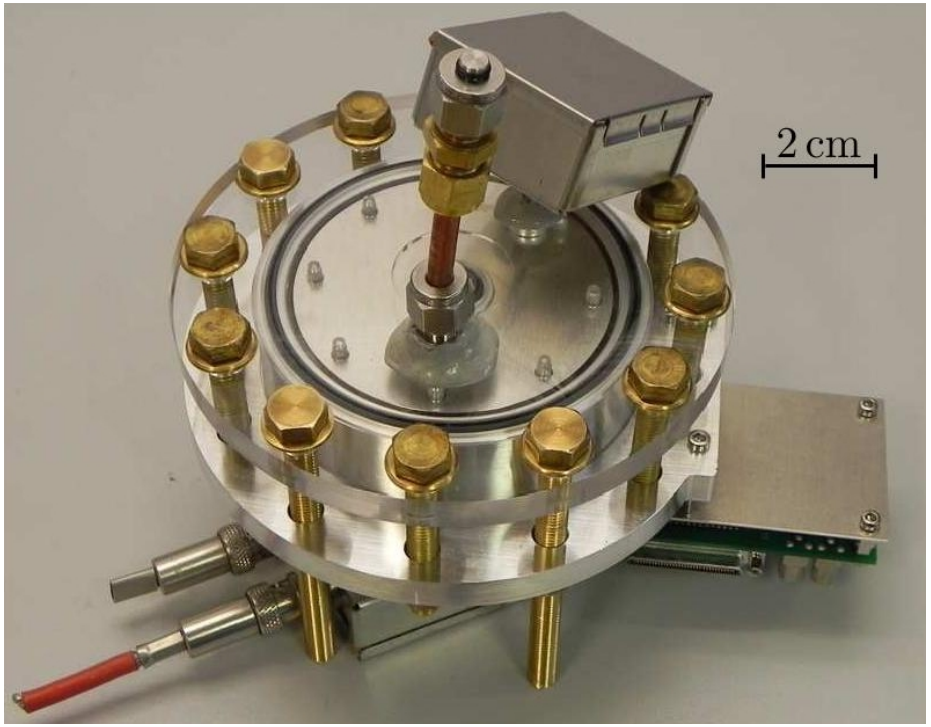




CERN Solar Axion Telescope

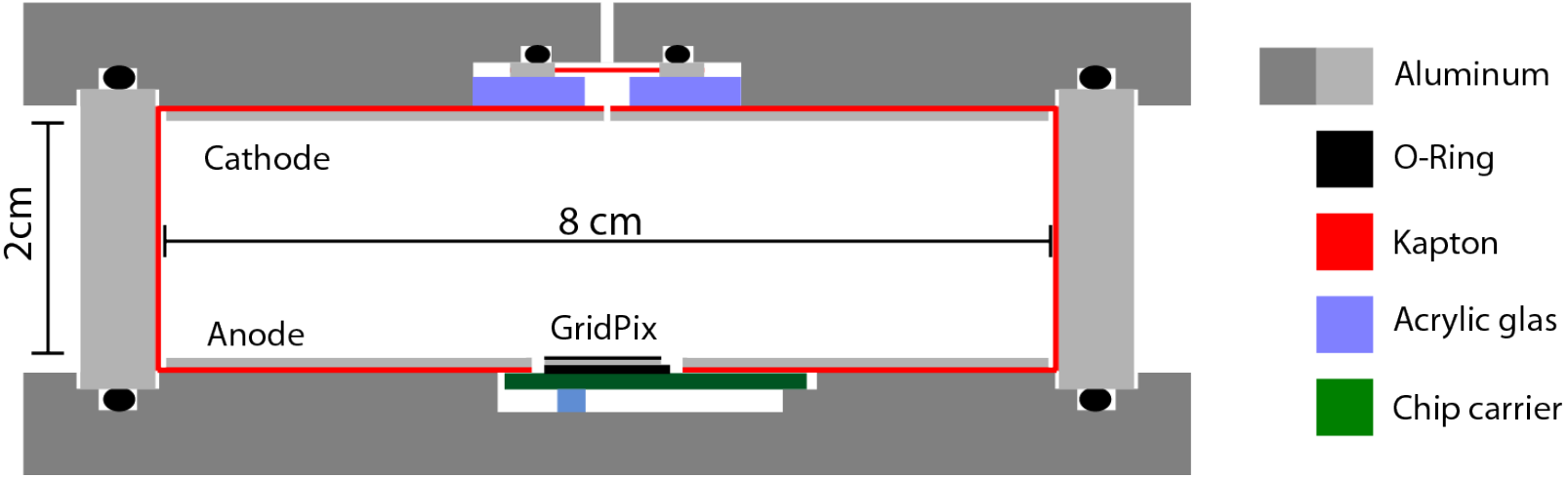
- Axion production in sun
- Axions can convert to photons in strong $\vec{B}$-Fields
- Solar axions: 0 to 12 keV

A Detector for CAST



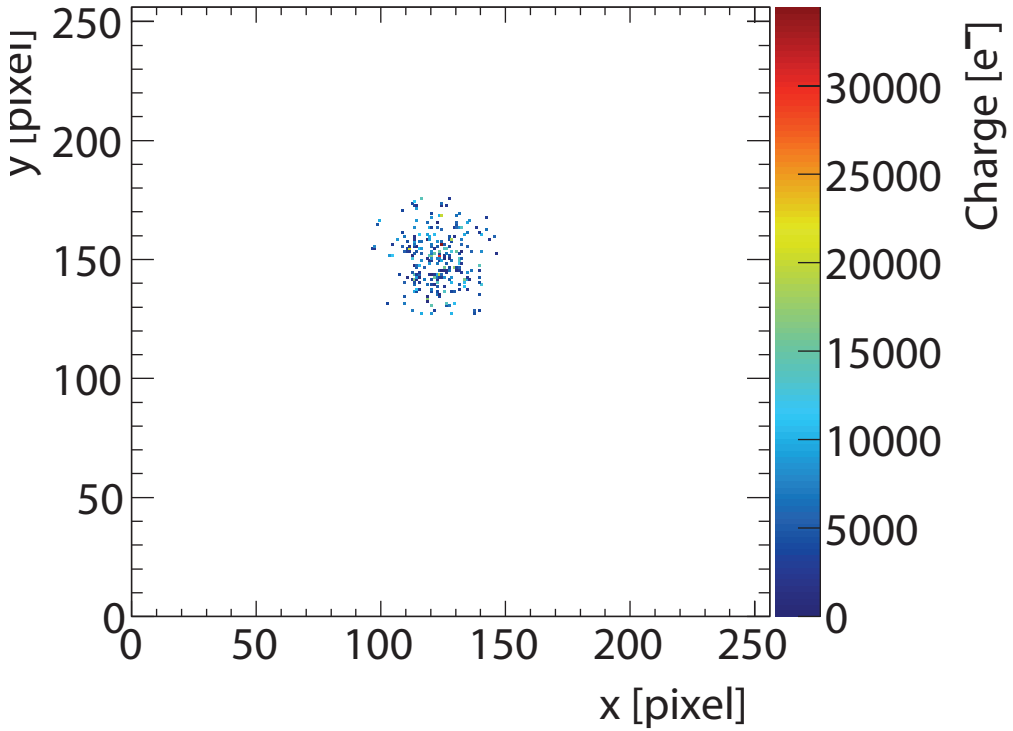
Detector requirements

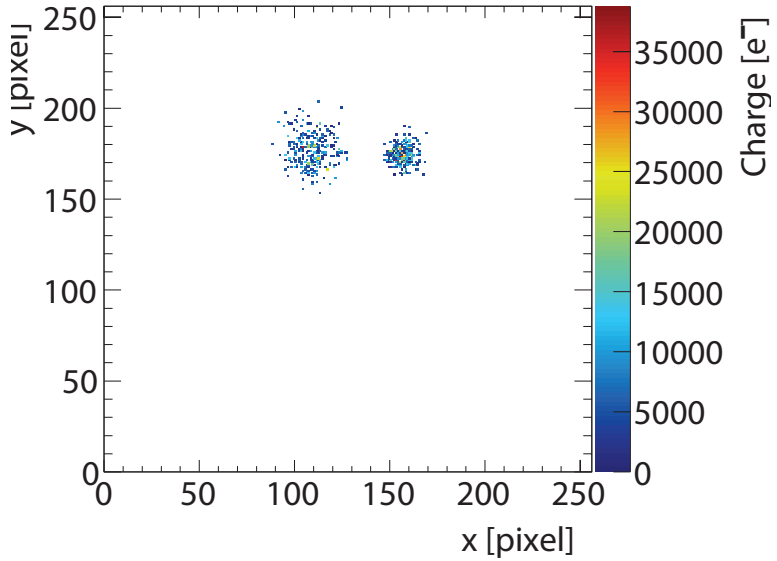
- High radioactive purity
- No materials with X-Ray fluorescence lines
- High conversion probability
  ⇒ Argon or Xenon at 1.5 to 2 bar
- Good energy resolution
  ⇒ Timepix GridPix

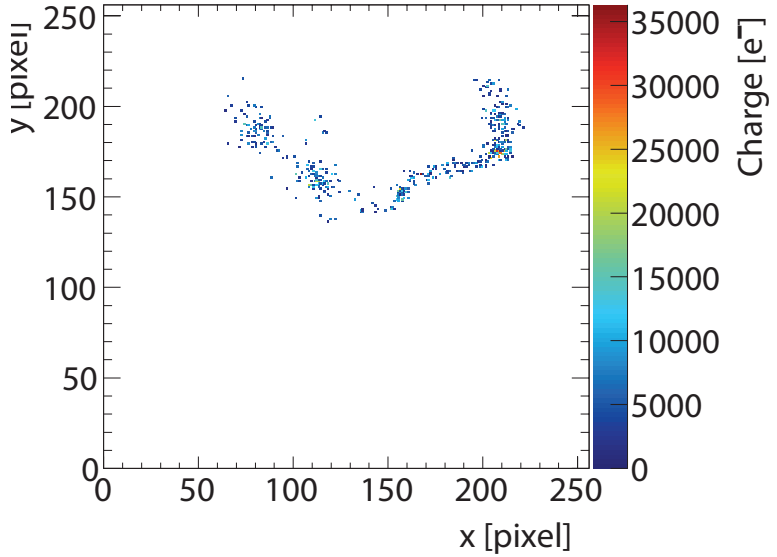


Example Events

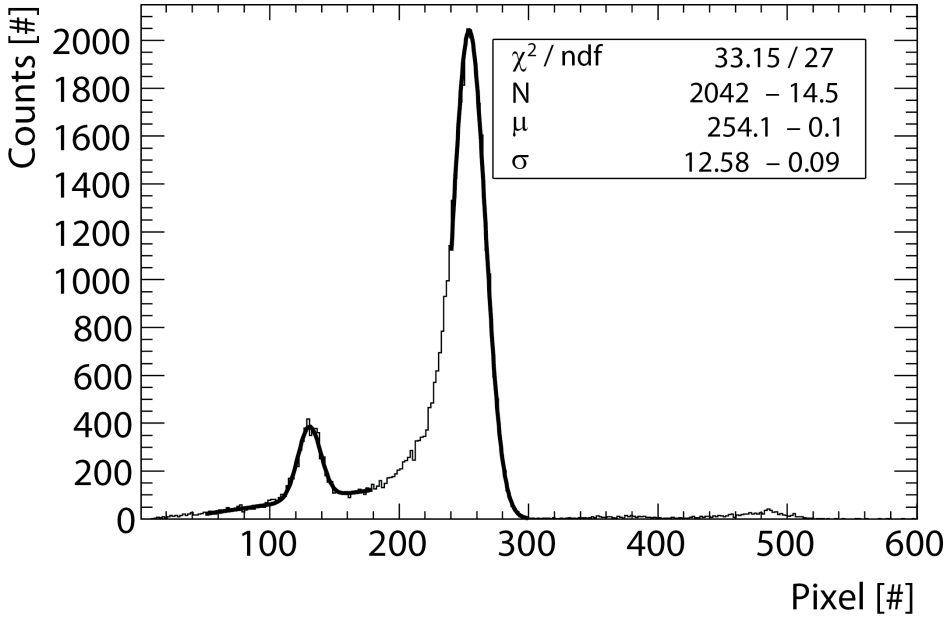
^{55}Fe - Source

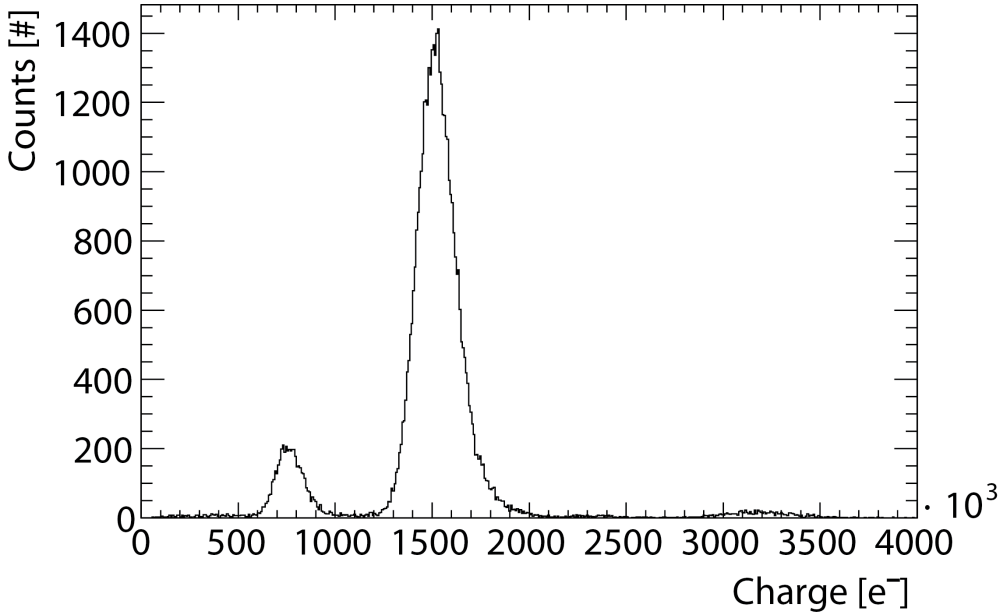






Spectra of ^{55}Fe





Measurement parameters

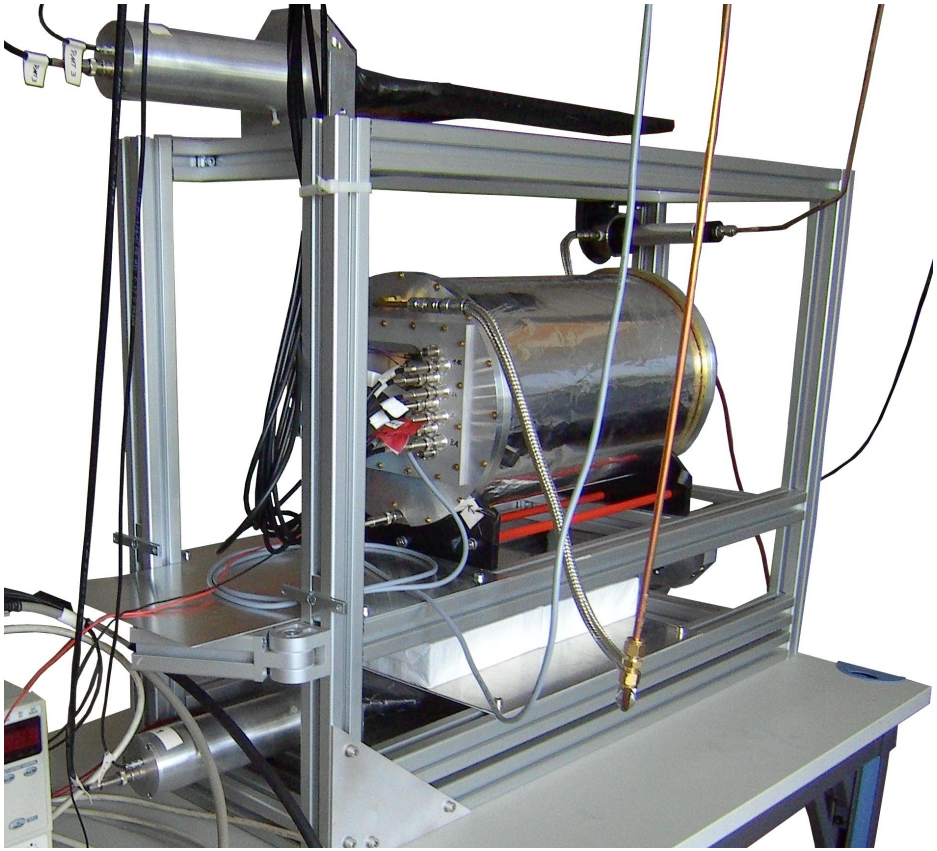
- Max. drift distance: 2 cm
- Drift field: 225 V/cm
- Gas: Ar/iButane (95/5)
- Grid voltage: 350 V
- Source: ^{55}Fe

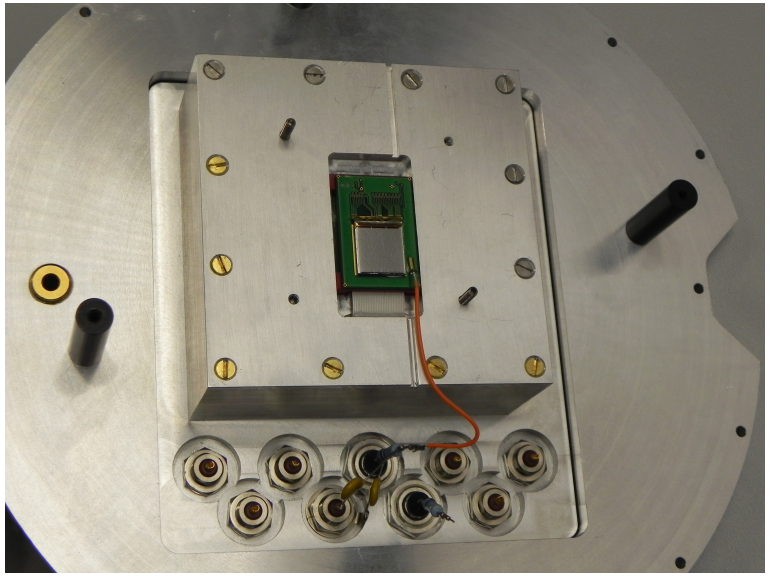
Energy resolution

For 5.9 keV photons of ^{55}Fe (6.5 keV photons suppressed by chromium foil)

- Pixel spectrum: $\frac{\sigma_N}{N} \approx 5\ \%$
- Charge spectrum: $\frac{\sigma_N}{N} \approx 6.6\ \%$

Prototype TPC

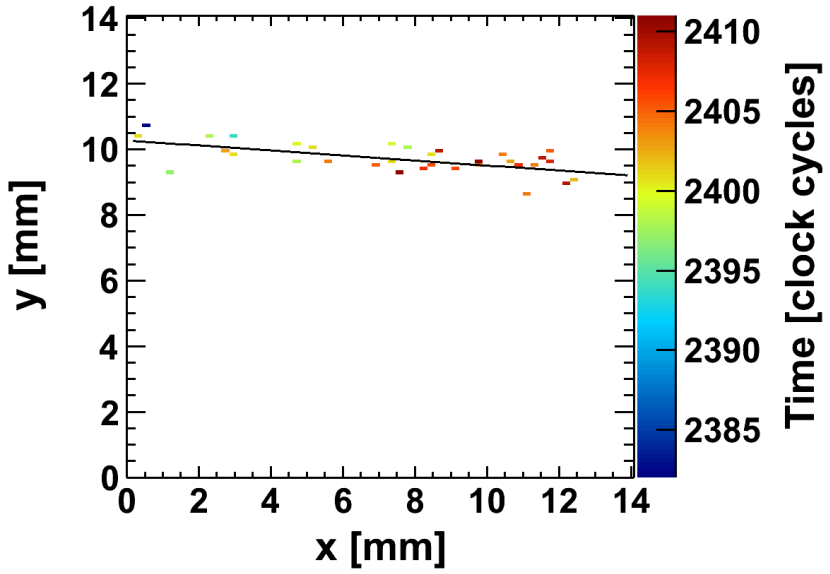


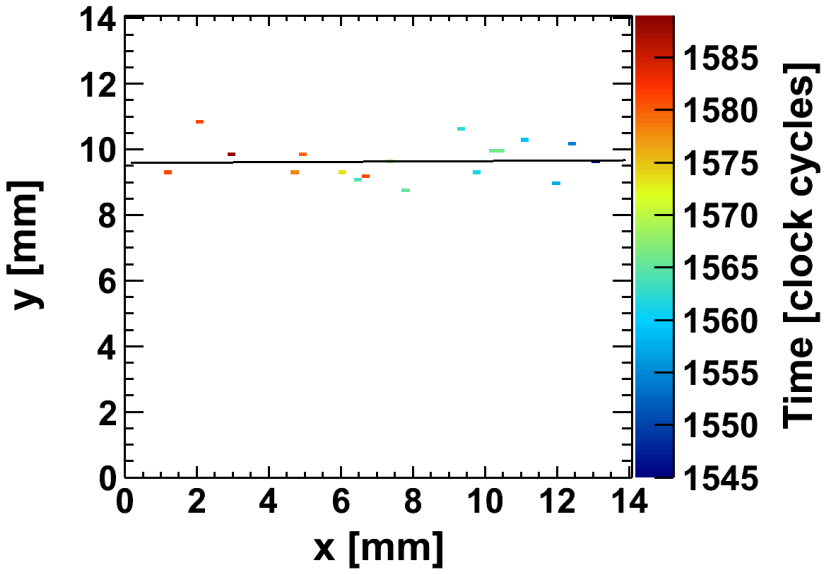


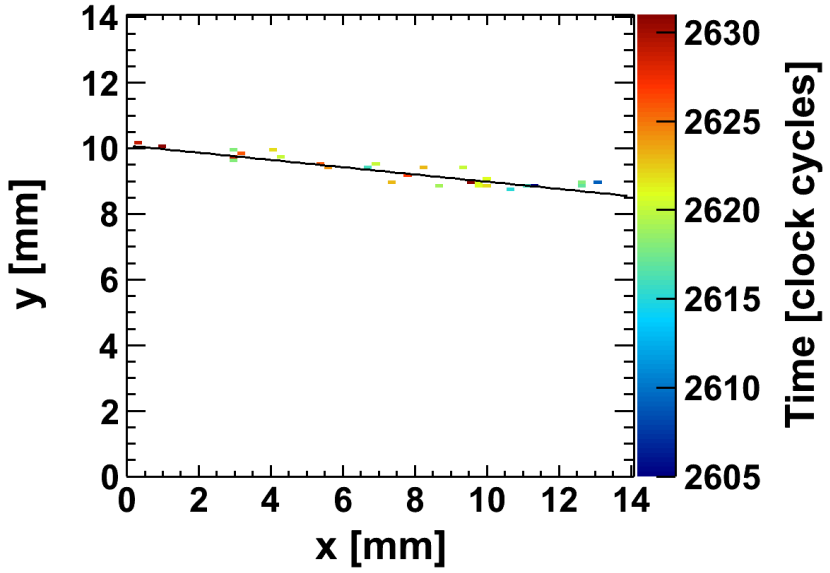
TPC Setup

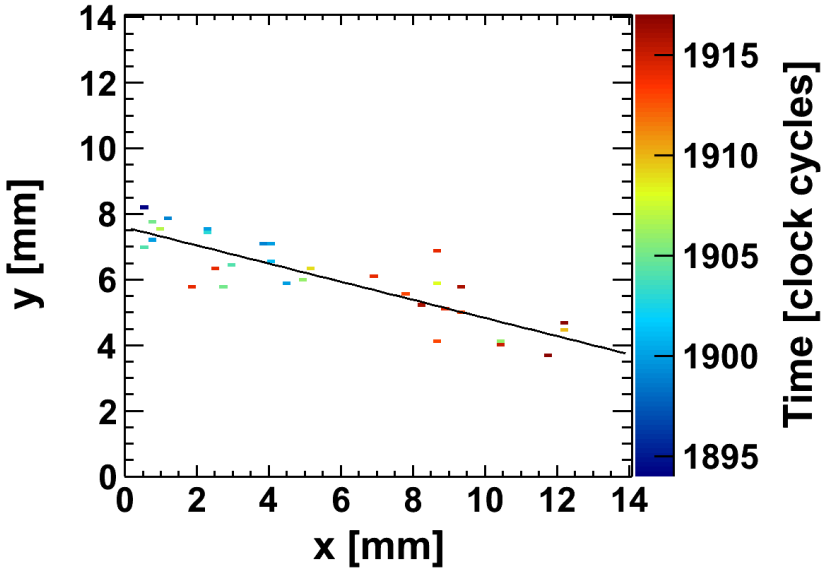
- 26 cm drift length
- Cosmic muons triggered by 2 scintillators
- Timepix + MUROS

Example Tracks

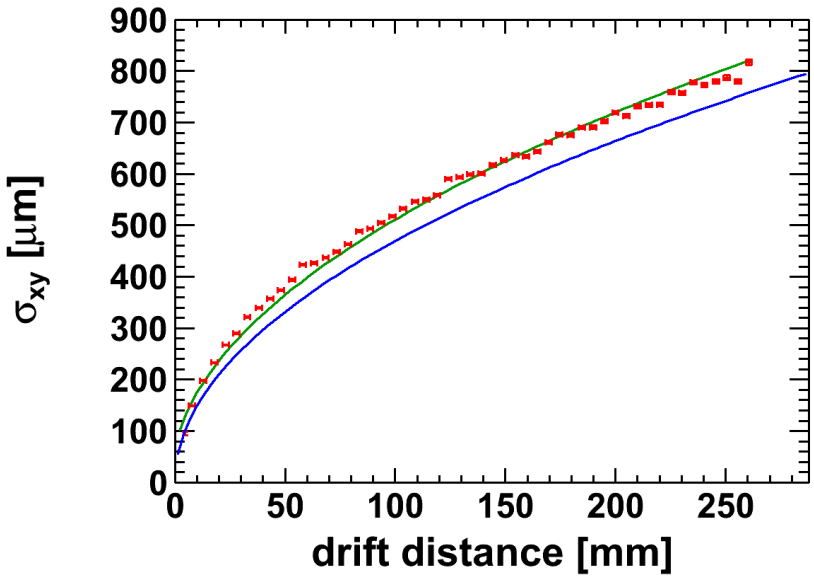


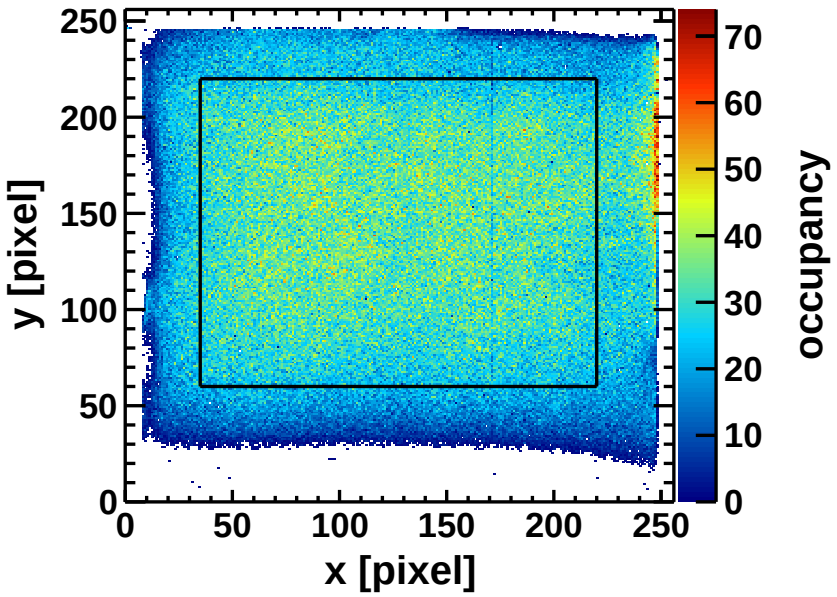


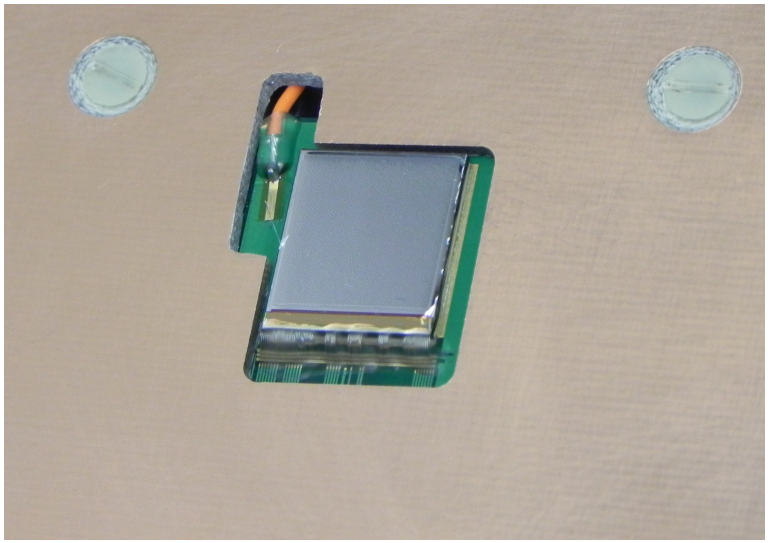




Single Point Resolution



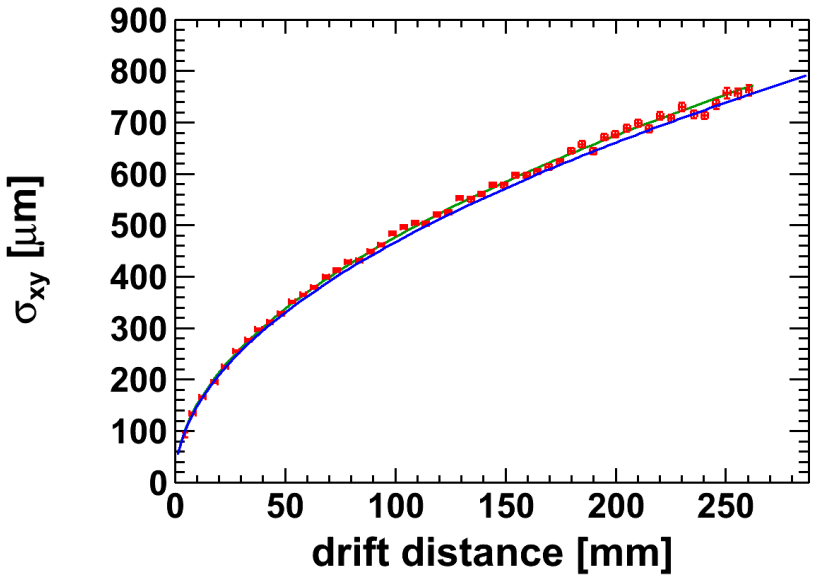


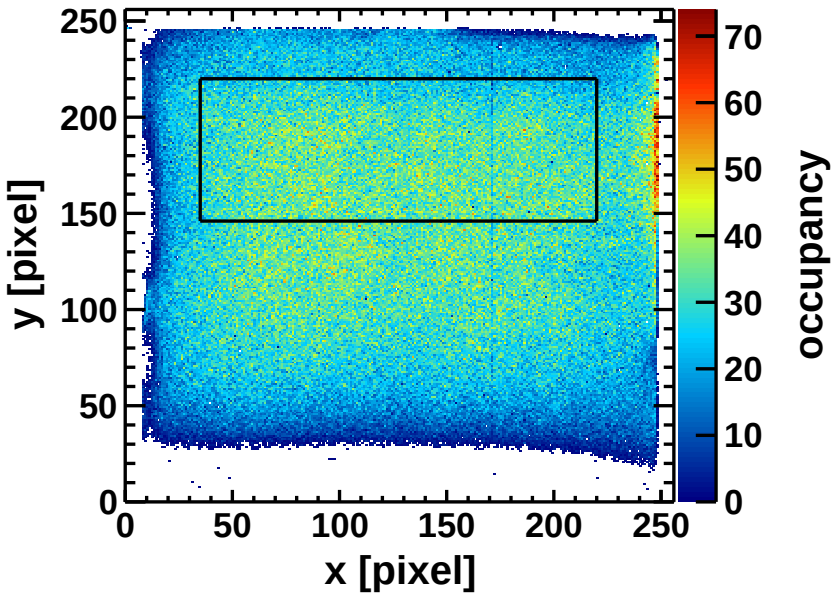


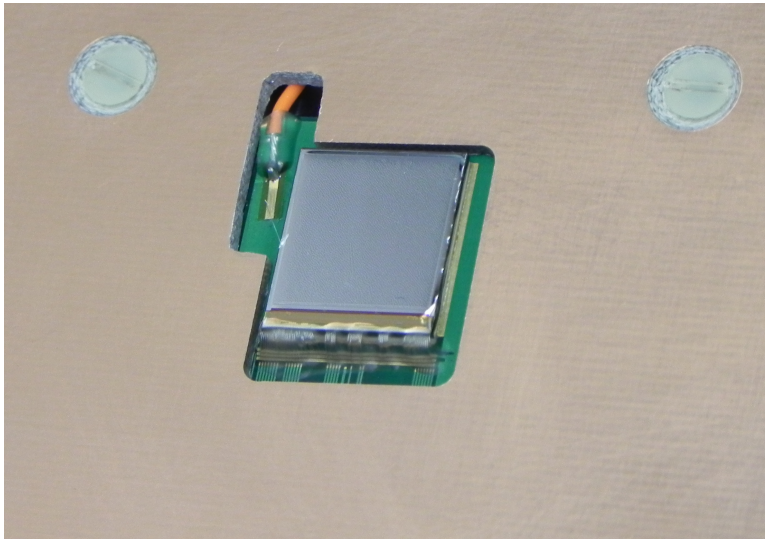
Transverse single point resolution

- Fit function: $\sigma = \sqrt{\sigma_0^2 + D^2 z}$ in green
- Theoretical limit from single e⁻ diffusion in blue
- Spatial resolution close to the theoretical limit

Single Point Resolution







Transverse single point resolution

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Production on Wafer Scale

Single chip production

Production of single (few) chips pioneered and optimized at University of Twente and MESA+

Demand

HEP-Detectors (e.g. ILD):

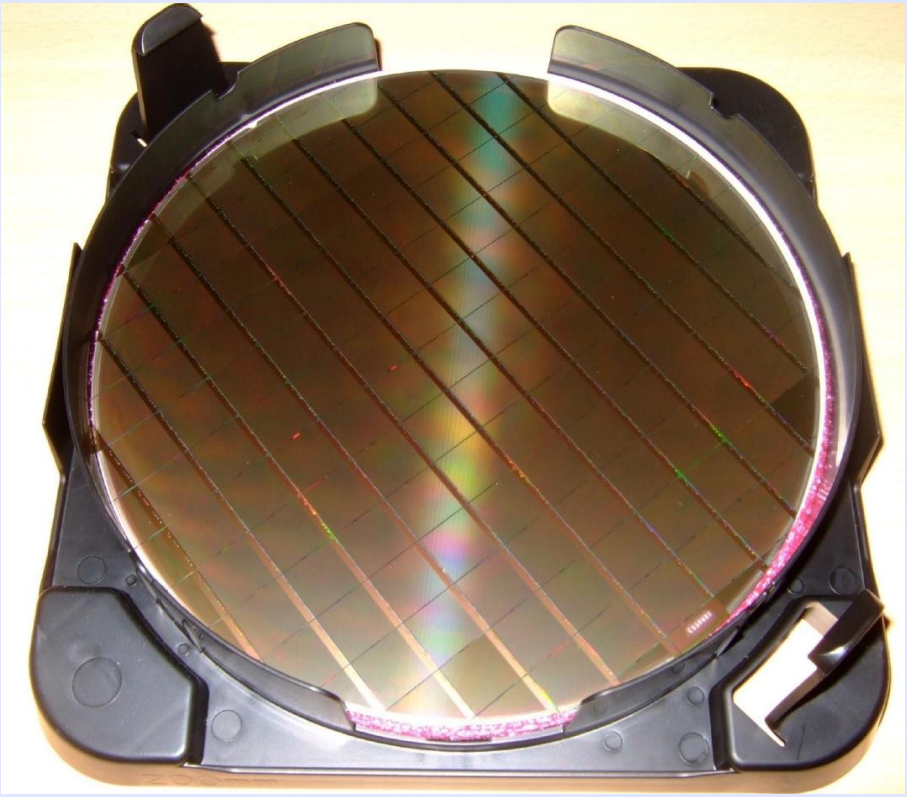
- Readout area of the TPC: $\approx 10\ \mathrm{m}^2$
- Pixelchips ($1.4 \times 1.4\ \mathrm{cm}^2$): $\approx 4 \cdot 10^4$

Research and development:

- Bonn, NIKHEF, Saclay, Twente, Fraunhofer IZM ...

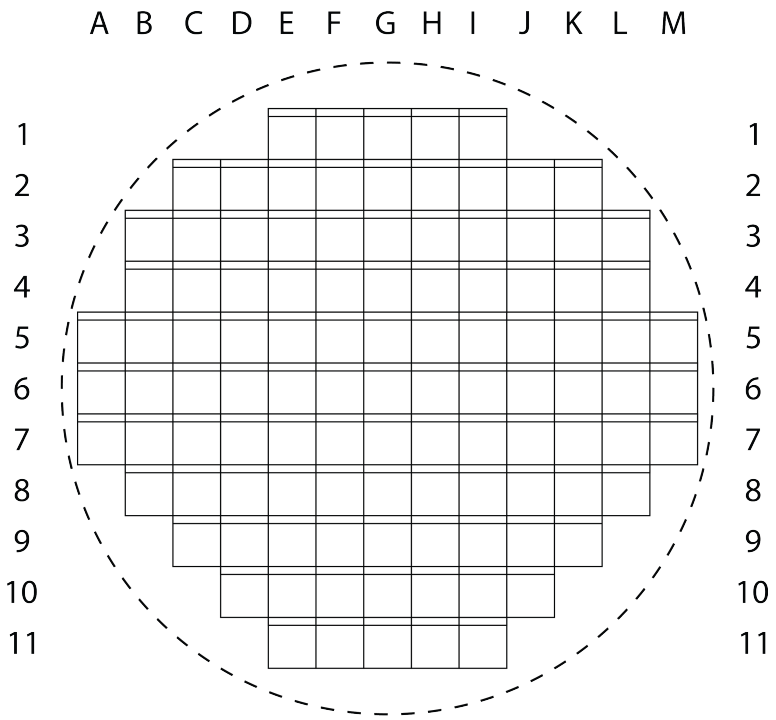
$\Rightarrow$ Production on wafer scale

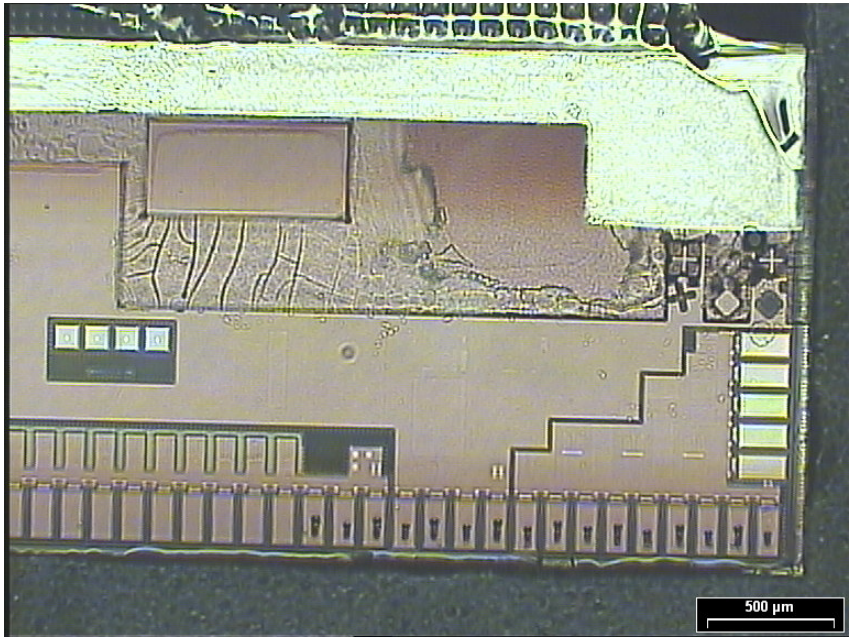
Timepix Wafer

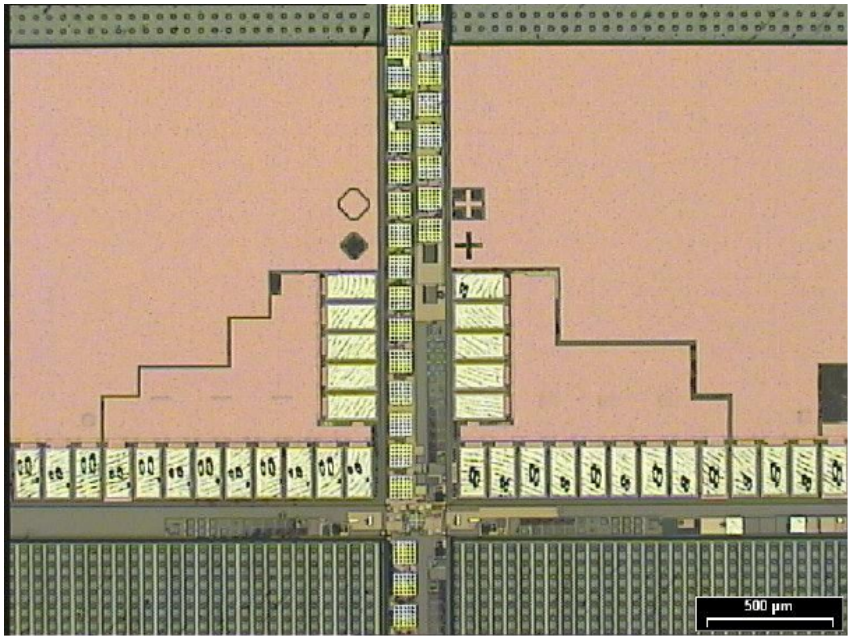


- 8 Inch wafer
- 107 Chips

Bonding Pads



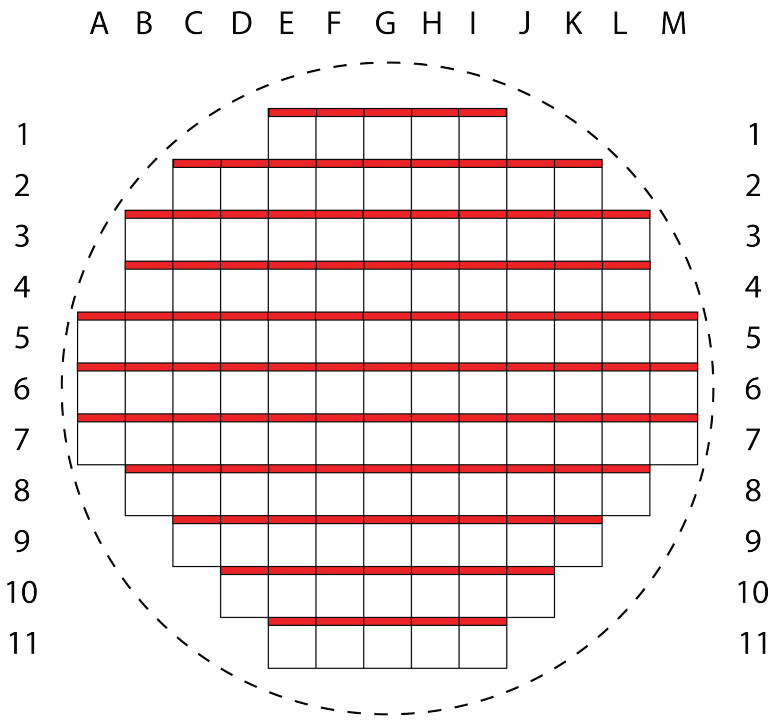


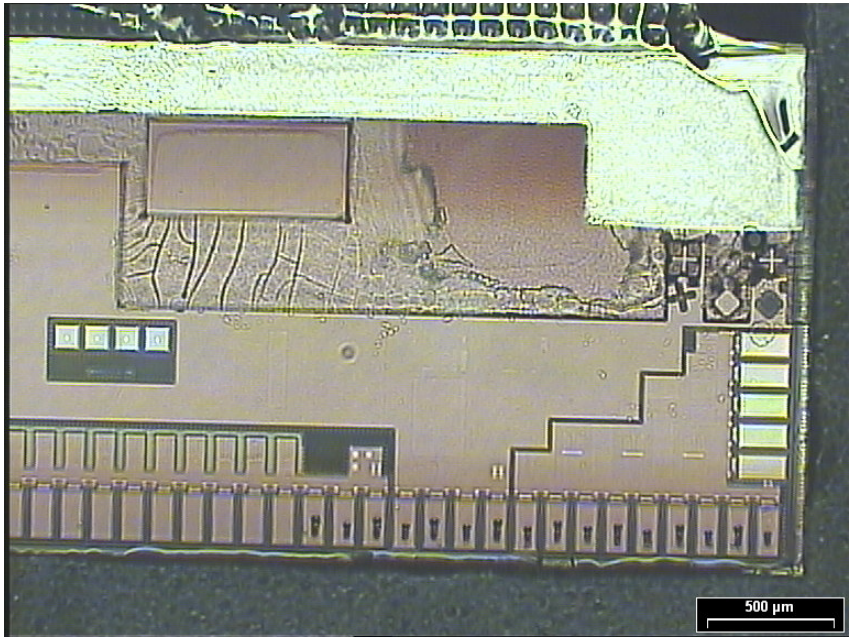


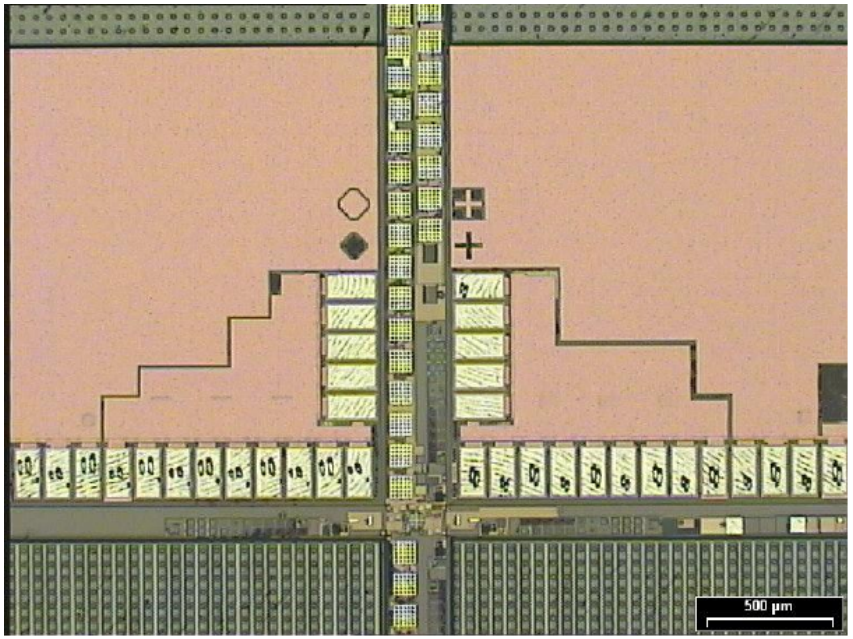
Polyimide

- Negative photoresist
- Precise alignment
- No residuals
- Time-consuming
- Temperature sensitive

Bonding Pads







Polyimide

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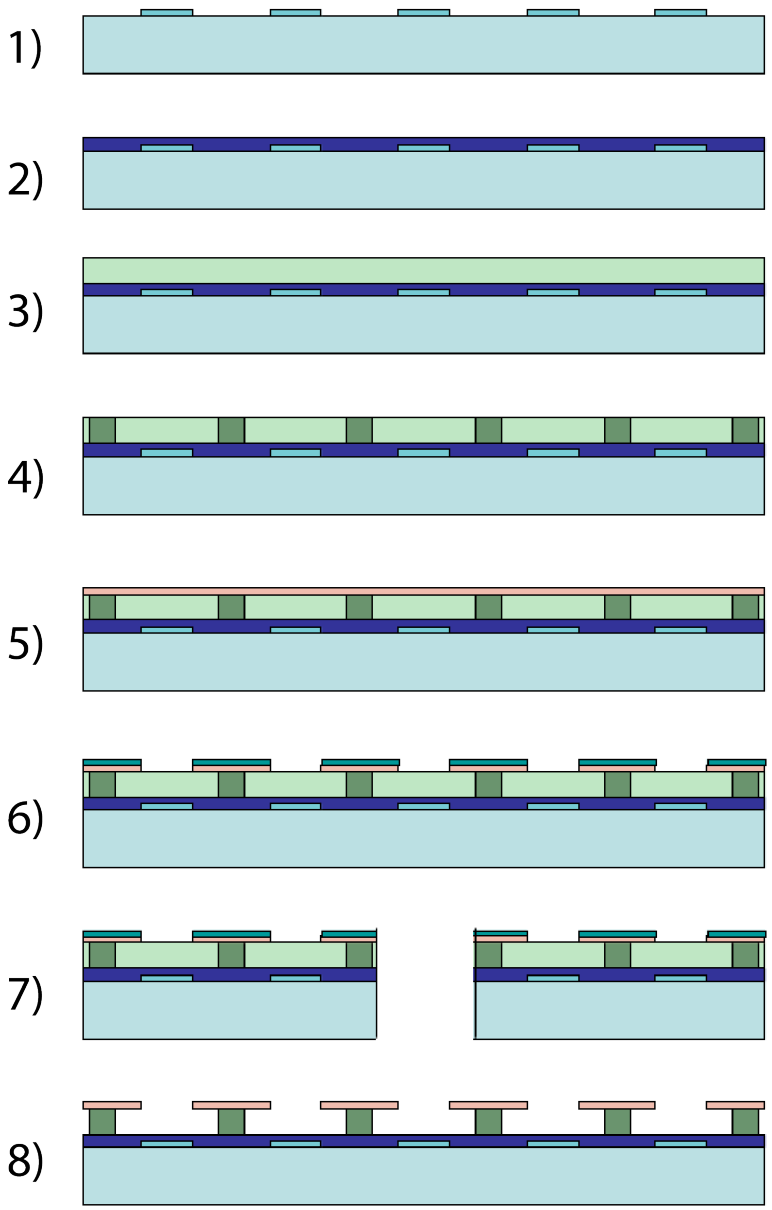
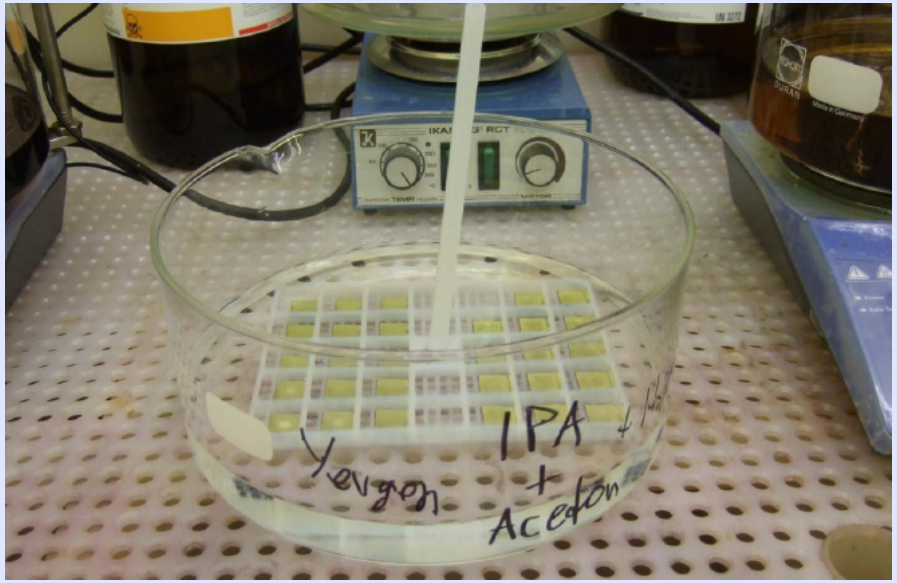
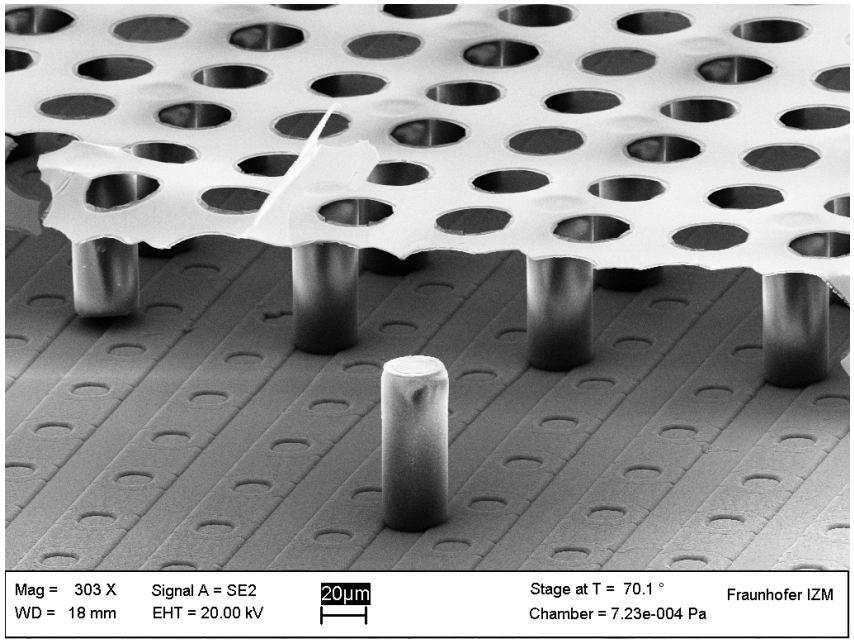
Production on Timepix Wafers

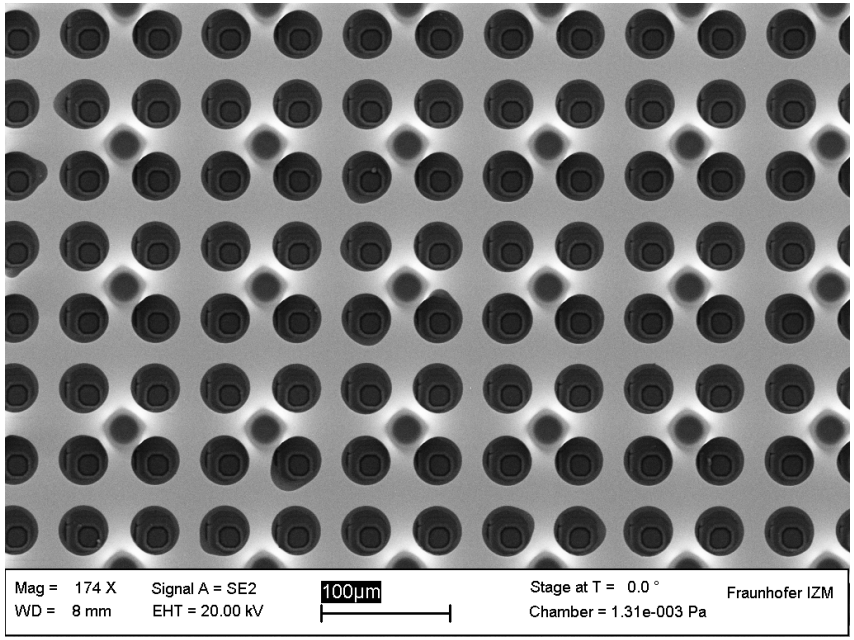


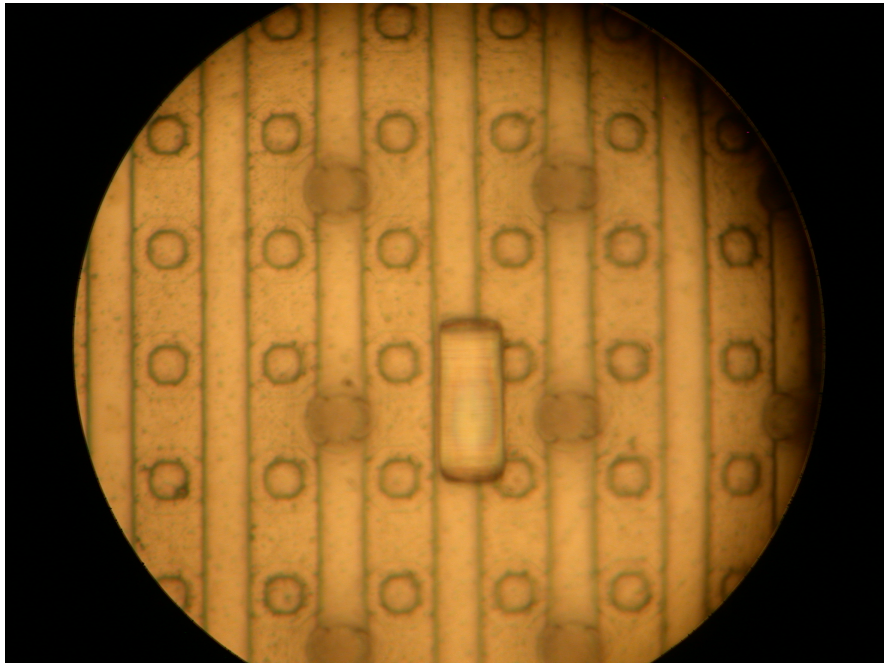
1. Probing and cleaning of the wafer
2. Adding Si_xN_y protection layer
3. Application of the SU-8
4. UV-Exposure of the SU-8
5. Application of the grid
6. Patterning of the grid
7. Dicing of the wafer
8. Development of the SU-8



GridPix Timepix Wafers





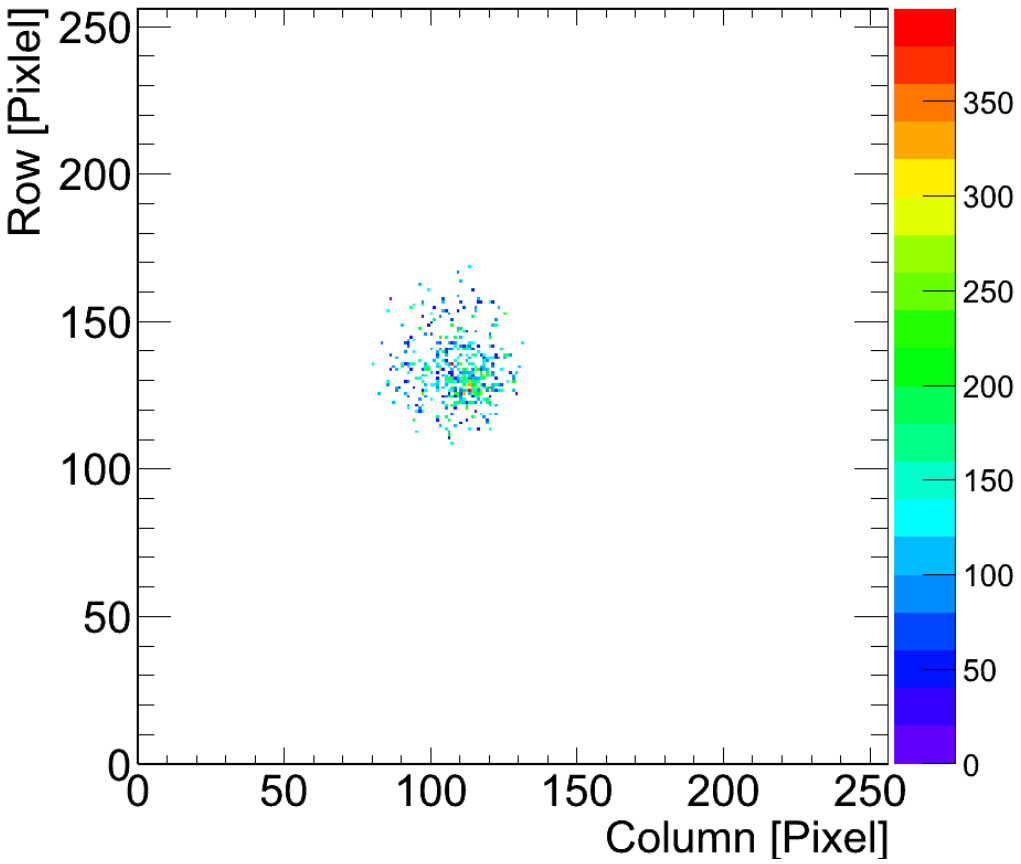


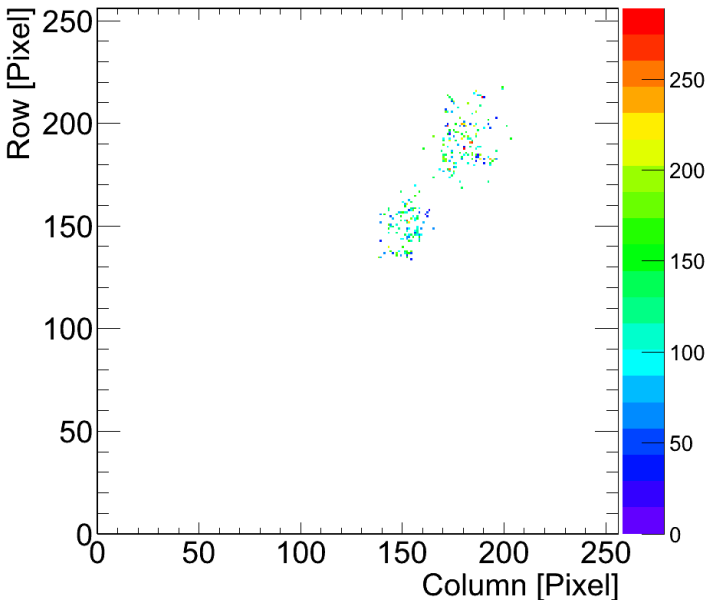
Parameters

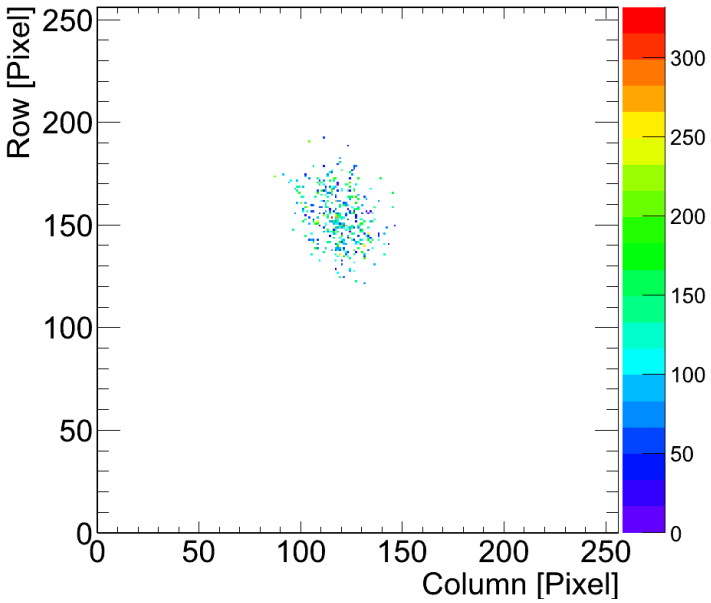
- Hole diameter: $\approx 30 \pm 1$ µm
- Hole pitch: $\approx 55 \pm 1$ µm
- Grid height: ≈ 70 µm $\pm 0,5$ µm
- Pillar pitch: $\approx 110 \pm 1,5$ µm

Example Events

^{55}Fe - Source

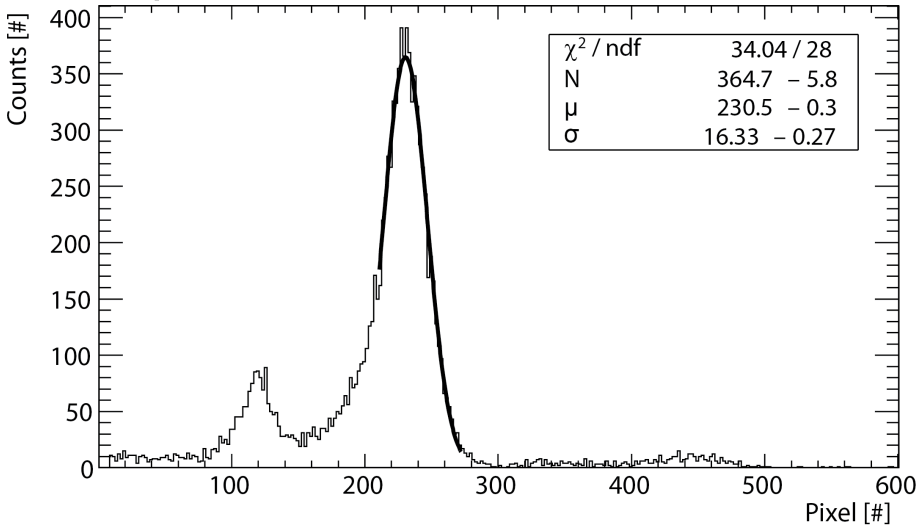




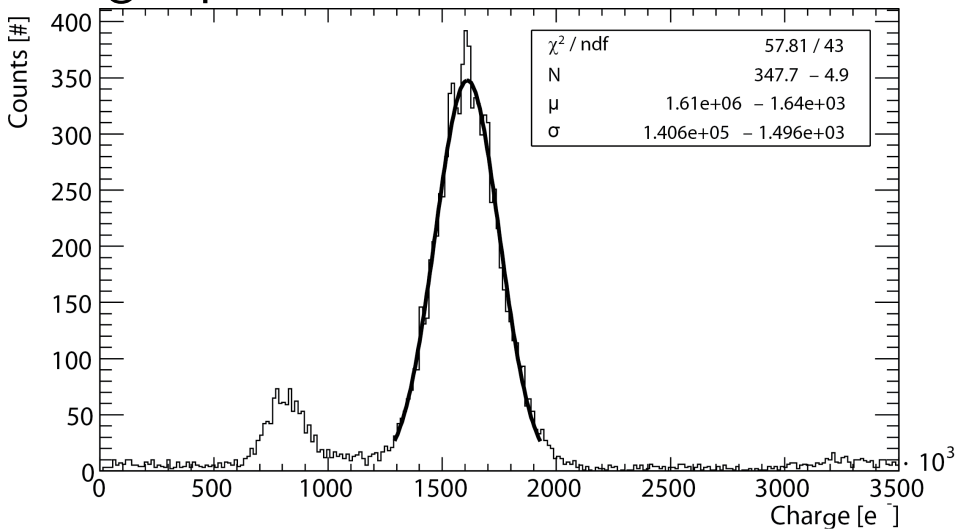


Spectra of ^{55}Fe

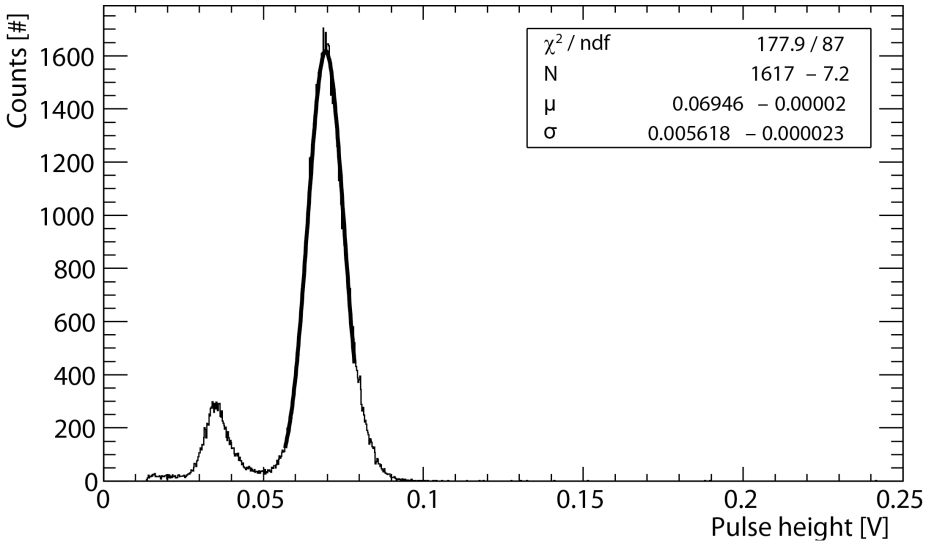
Pixel spectrum



Charge spectrum



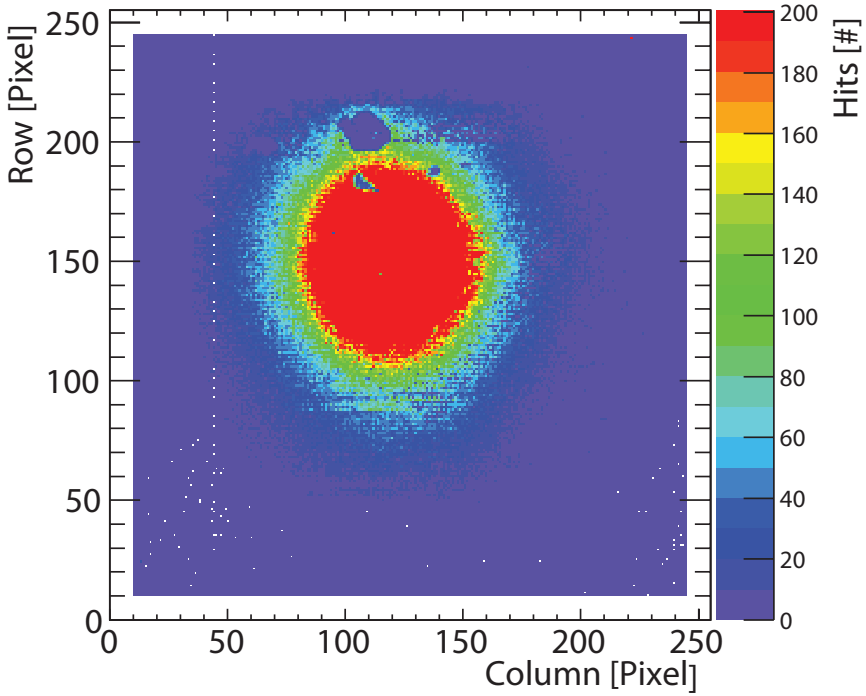
Grid spectrum

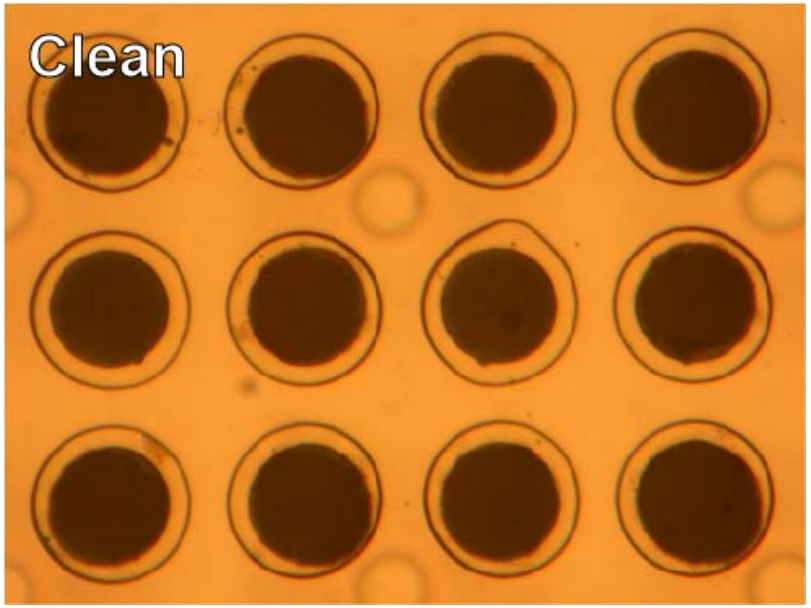


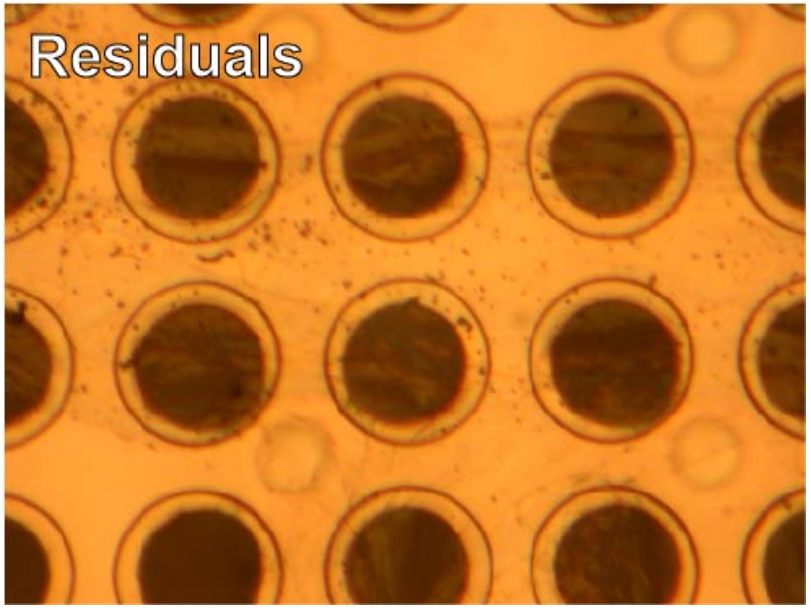
Measurements

- Gas: Ar/iButane (95/5)
- Source: ^{55}Fe
- Grid voltage: 350 V
- Energy resolution ($\frac{\sigma_N}{N}$):
  - Pixel spectrum: $\approx 7.1\%$
  - Charge spectrum: $\approx 7.9\%$
  - Grid spectrum: $\approx 8.1\%$

Production Results



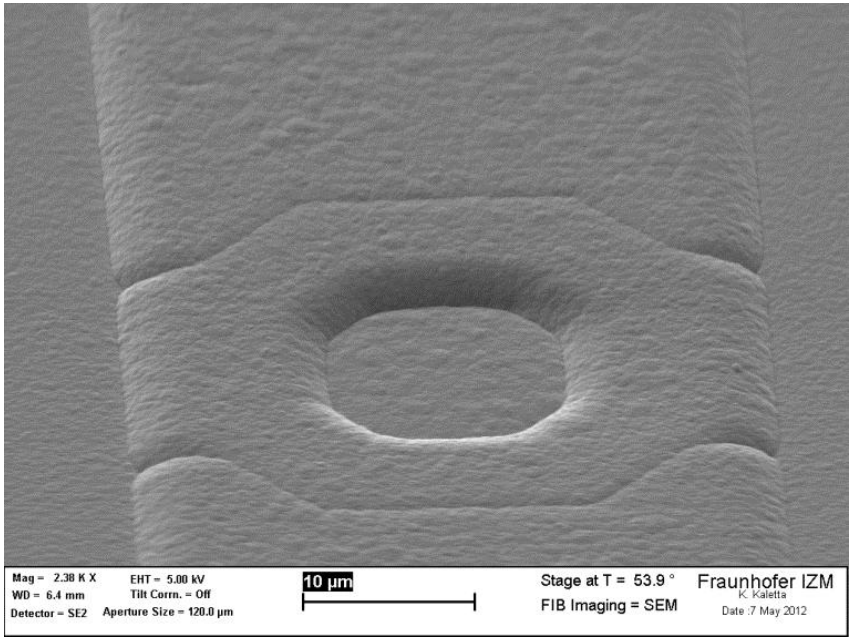


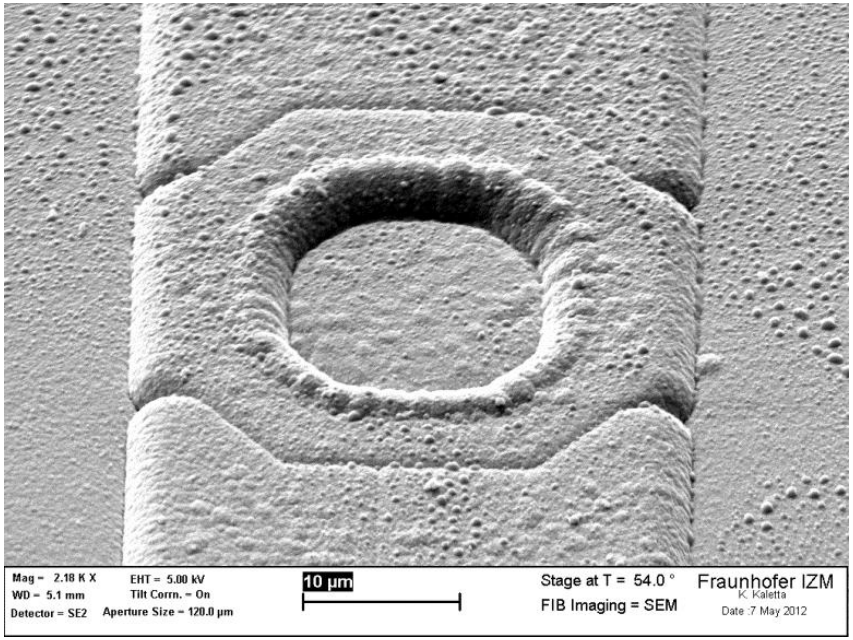


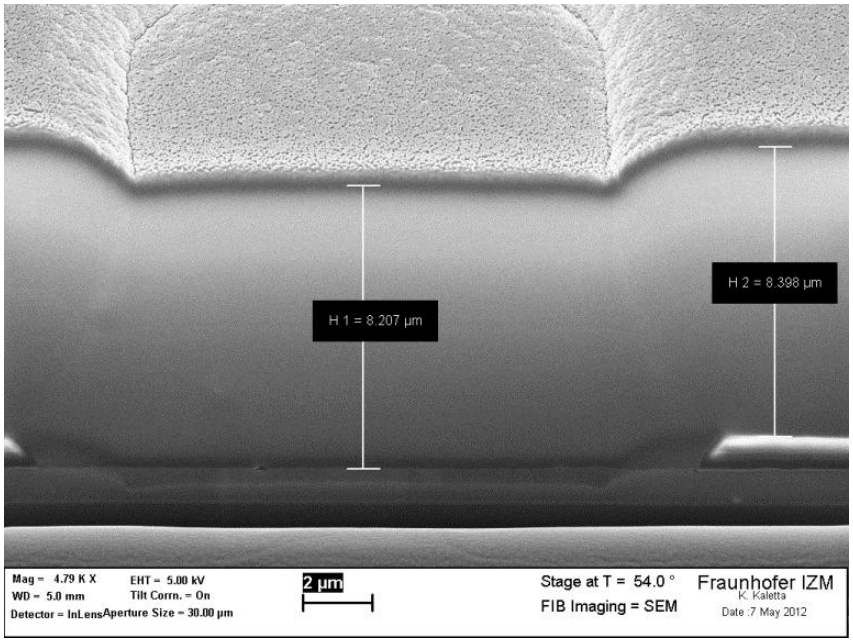
Production problems

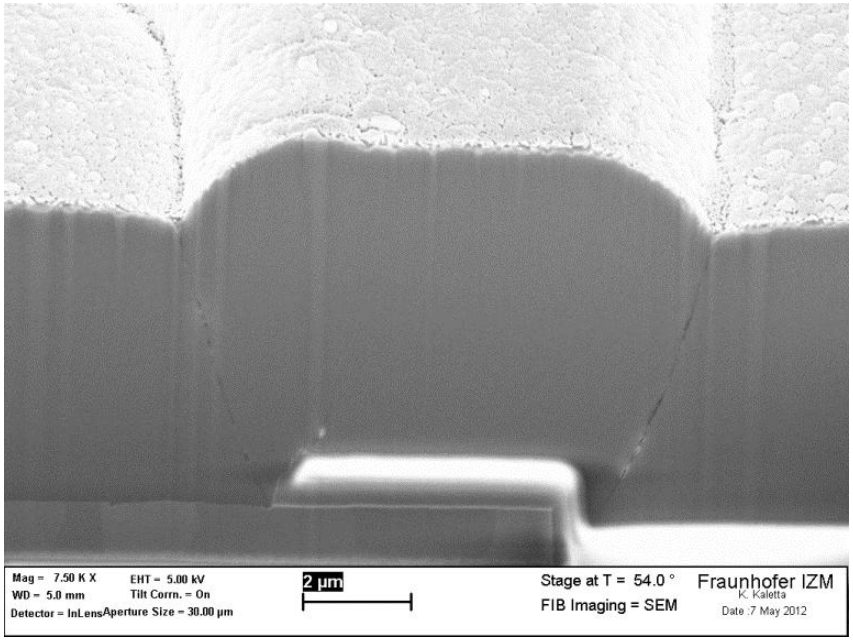
- Dead/unresponsive areas
  ⇒ Residuals on grid
  ⇒ Improve final cleaning
- Chips break at high voltages
  ⇒ Several possible reasons
  ⇒ Investigation ongoing

Si_xN_y Protection Layer









Conclusions & Outlook

Conclusions

- Promising results for X-Ray detection
  - Energy resolution of about 5% for 5.9 keV photons
- High single point resolution
  - Near diffusion limit in transverse direction
- Wafer scale production successful
  - Working structures
  - Some unresolved issues $\Rightarrow$ under investigation

Outlook

- Timepix-3
  - Simultaneous charge and time measurement
  - Multiple hits
  - Higher clock frequency
- Improved robustness (ceramic structures)
- Readout for large areas (SRS)