High-granularity charge readout of MPGDs with the Timepix4

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On behalf of CERN EP-DT-DD GDD team
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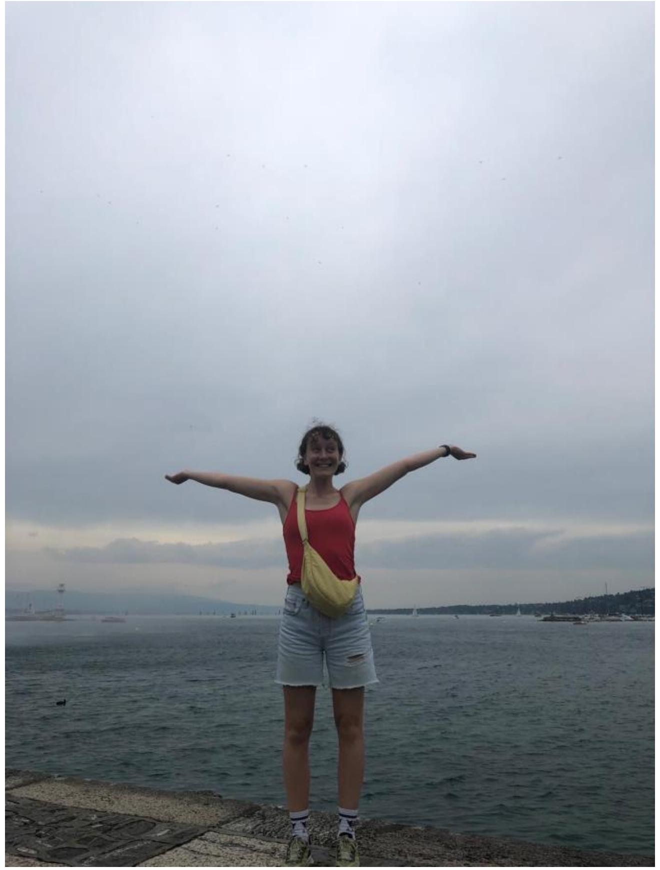
About me

- From London, UK
- Physics undergraduate student at the University of Oxford
- Studying biological and particle physics for my masters
- Interested in medical physics



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General motivation

- High-granularity charge readout of Micro-Pattern Gaseous Detectors (MPGDs) with the Timepix4
- Explore the possibility of integrating pixelated readout Application-Specific Integrated Circuits (ASICs) in gaseous detectors, using standard Printed Circuit Board (PCB) technologies
- Utilise the benefits of both systems

- Gaseous detectors
  - Low material budget
  - Large area coverage
  - High gain
  - High dynamic range

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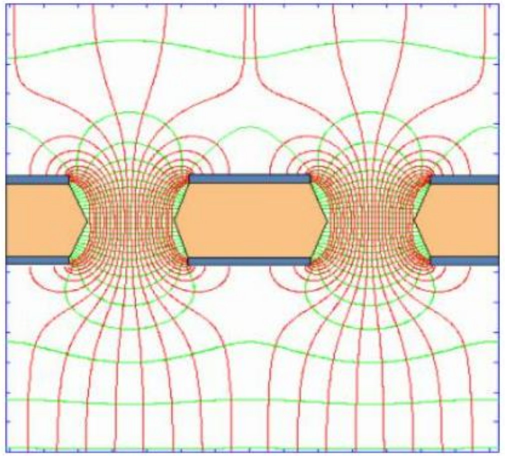
- Pixel ASICs
  - High spatial accuracy

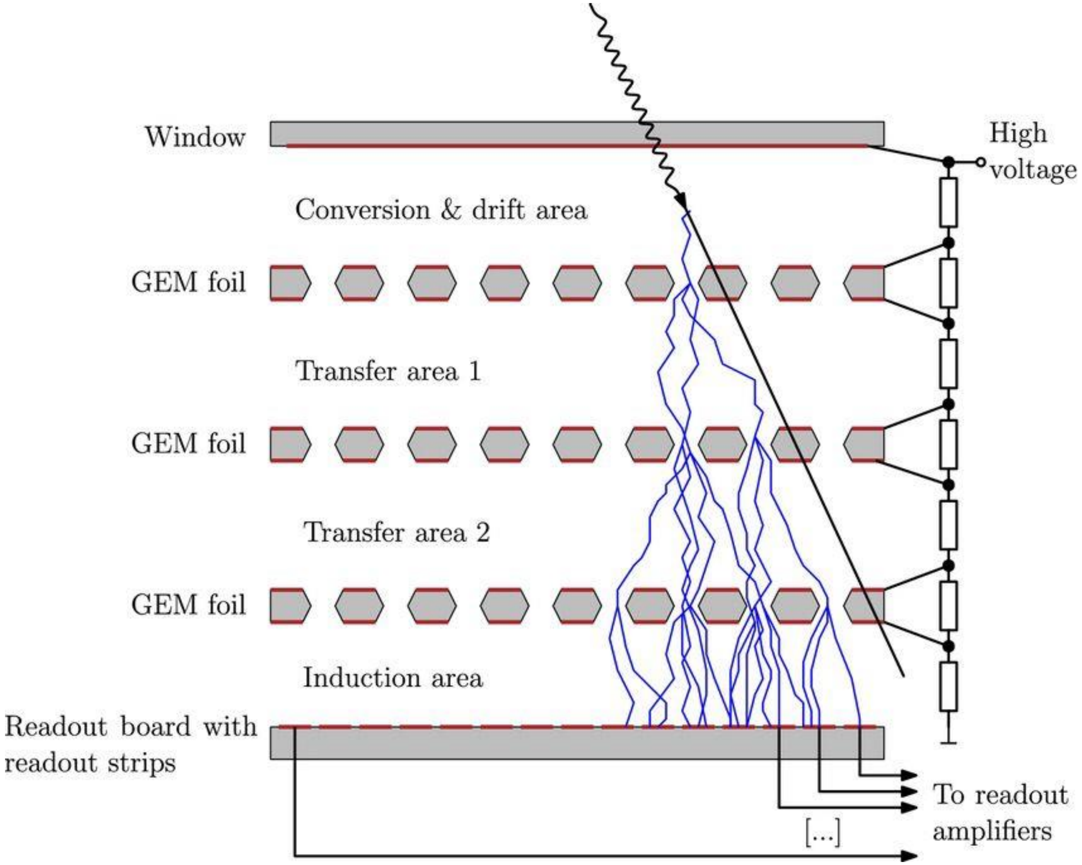
Event selection based purely on geometry, e.g. in rare-event searches

Gaseous detectors – General overview

Gaseous detectors work by amplifying the primary electrons from an event to be read out through current induction



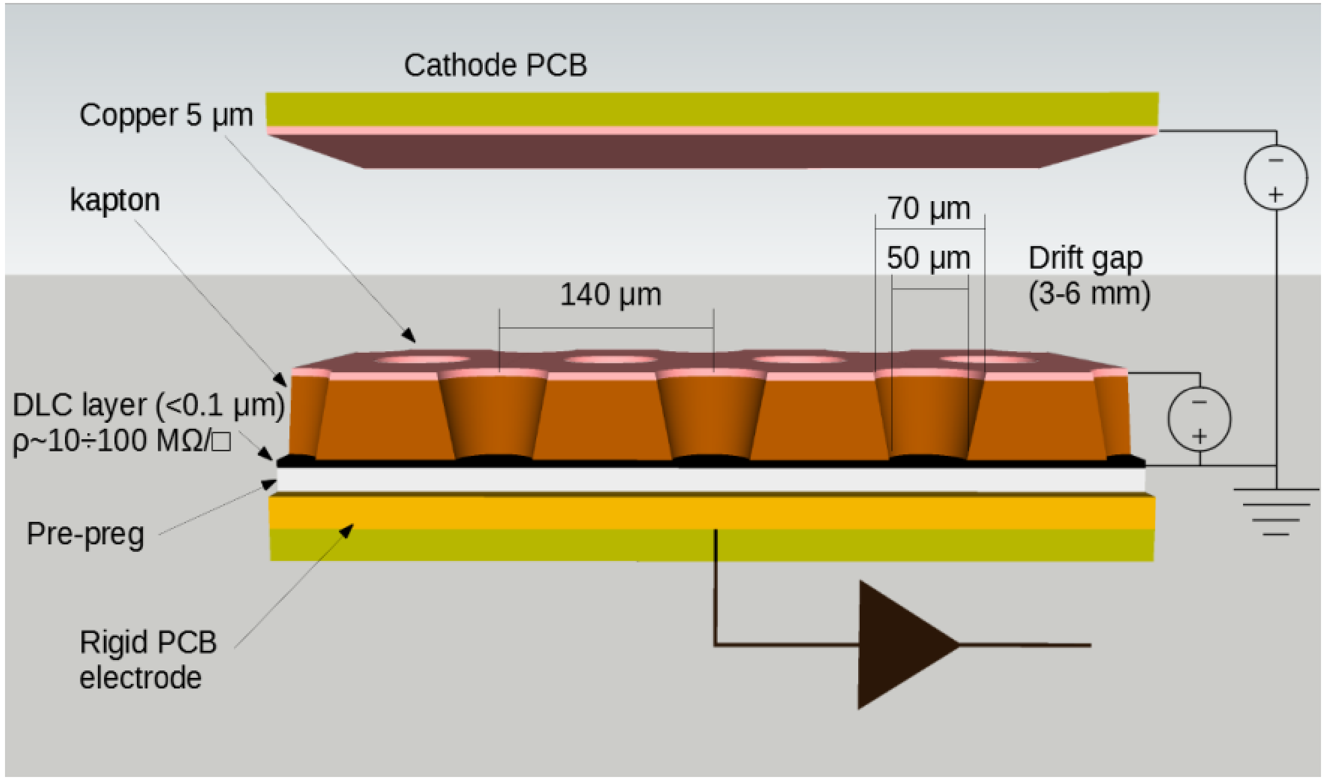
https://gdd.web.cern.ch/gem



https://doi.org/10.1007/s10894-018-0181-2

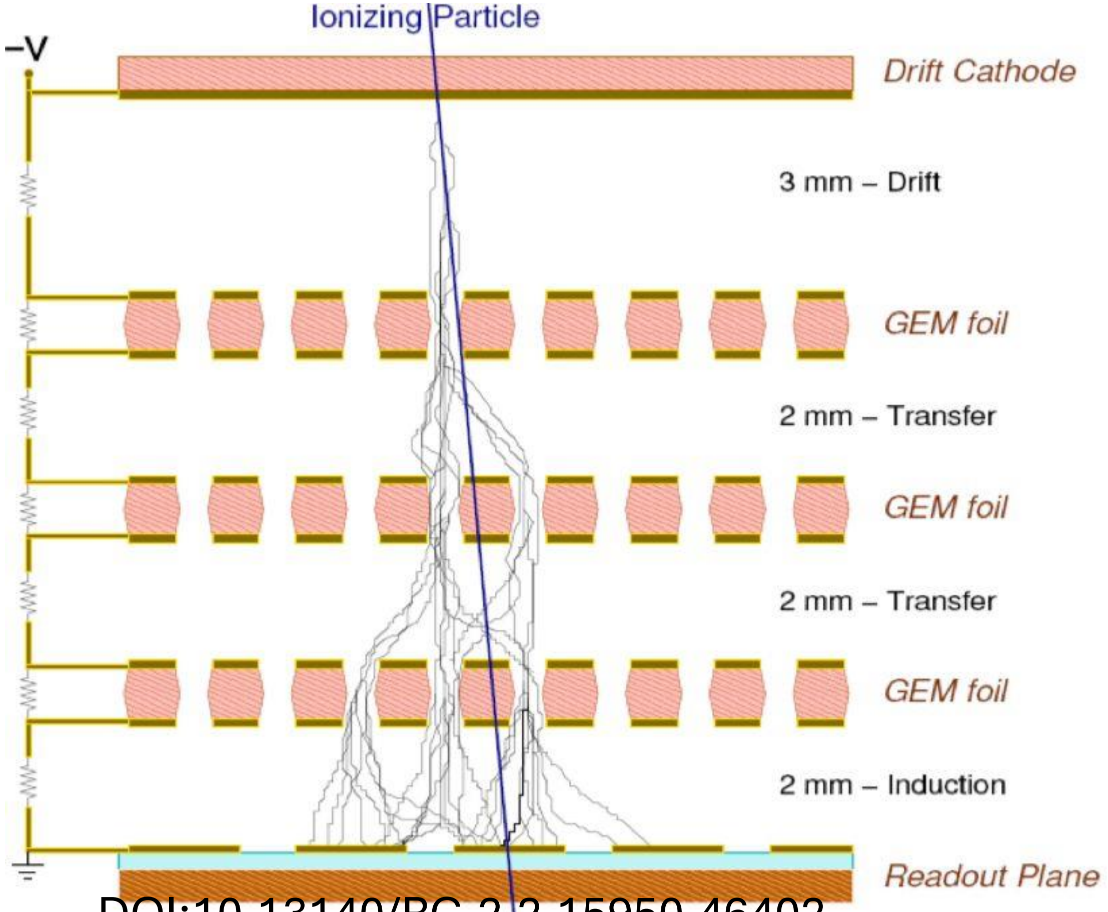
Gaseous detector technologies of interest

Micro-resistive well (µRWELL)



https://dx.doi.org/10.1016/j.nima.2022.167993

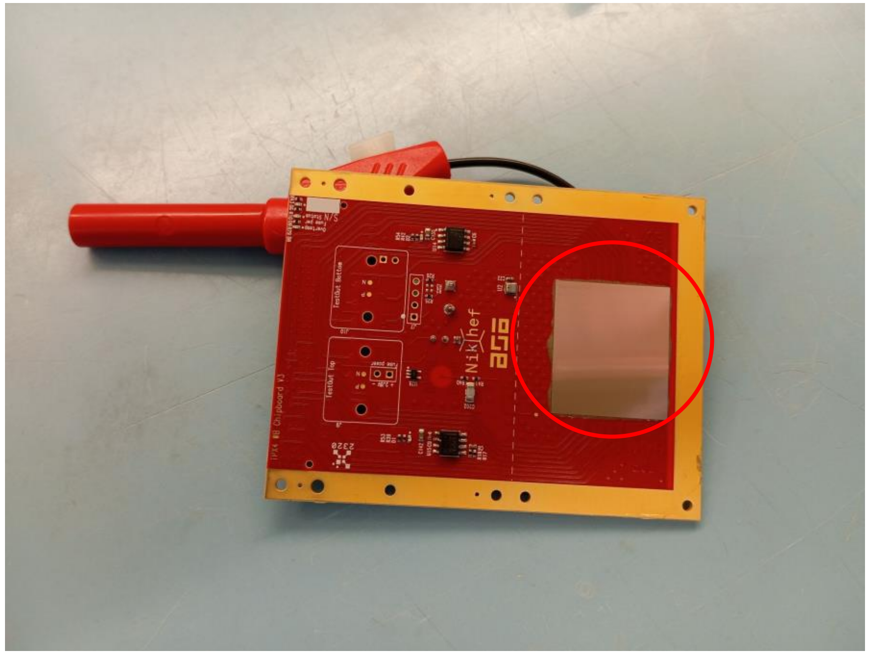
Triple gas electron multiplier (triple-GEM)



DOI:10.13140/RG.2.2.15950.46402

The pixelated readout system

- **Timepix4** - hybrid pixel detector readout ASIC
- Readout system – SPIDR4
- Control software
  - tpx4tools, Nikhef
  - Timepix4 control scripts from chip designers here at CERN



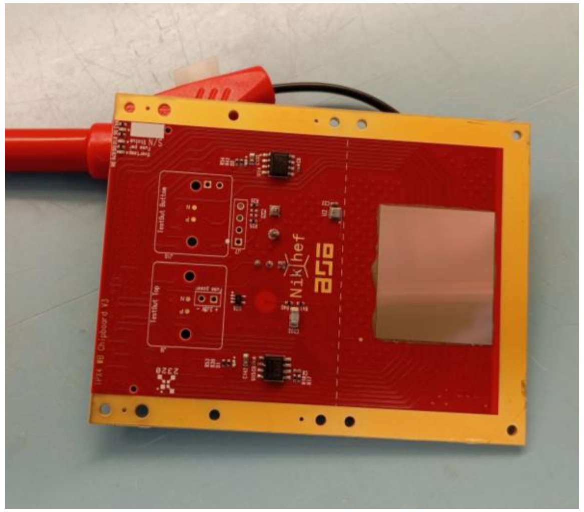
- Can be embedded (**TSV** – Through Silicon Via)
- Large area coverage
- High performance (55 µm, 200ps, 5Ghz/mm^2)
- Works on existing technologies

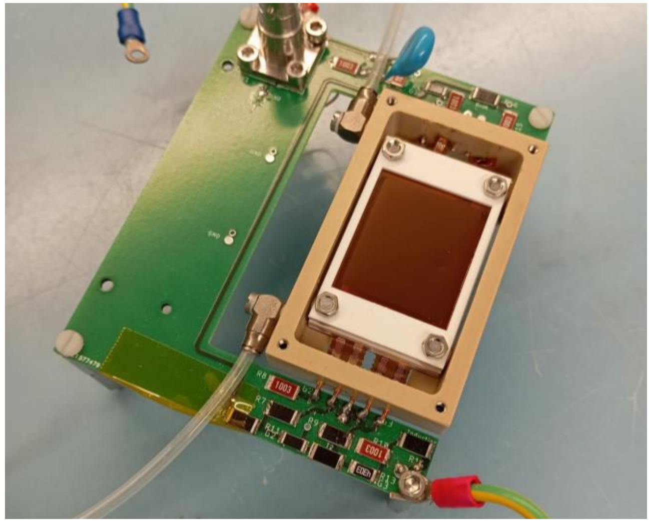
Motivation for these specific technologies

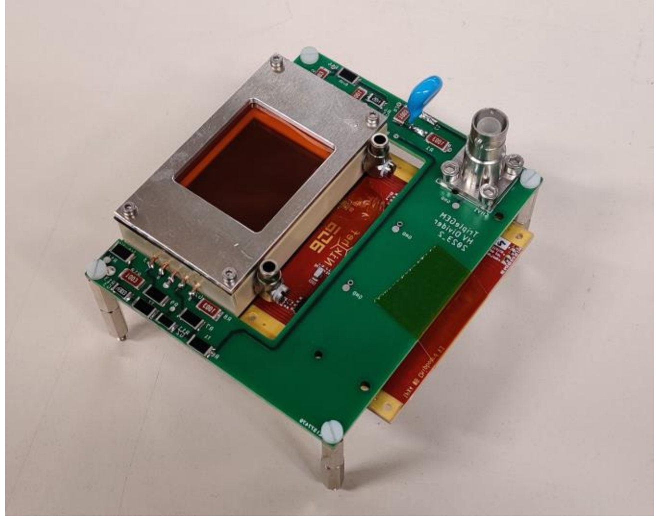
- Through silicon via (TSV) as a new technology allows us to embed the μRWELL
- Eventually we want to be able to make a gas-based amplification stage with a directly embedded readout
- μRWELL
  - Low material budget
  - Standard PCB techniques
  - Protects from discharge
- Timepix4
  - Large area coverage
  - High performance
  - Works on existing technologies
- Easier to produce than the existing technologies (GridPix)

Integration process

Timepix4 underneath, with the triple-GEM housing on top



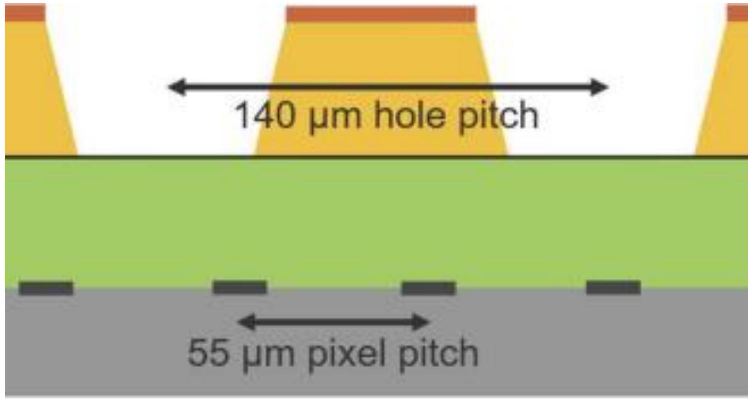




DOI 10.1088/1748-0221/9/01/C01058 – GEMPix

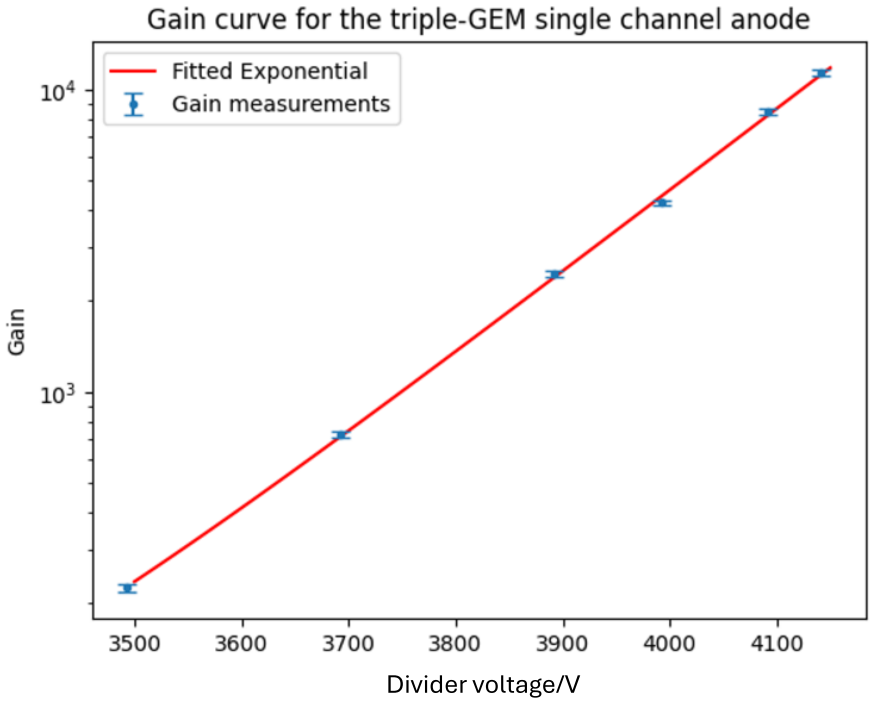
Integration process – Steps to be taken

- Detector characterisation and assembly – can we assemble the Timepix4 TSV with familiar technologies as a test of operation?
- Operation and analysis – does the existing reconstruction software work with gaseous detector signals?
- Simulation of microRWELL – How well is the signal from gaseous detectors coupled, given the pitch of the holes and readout pads is different?



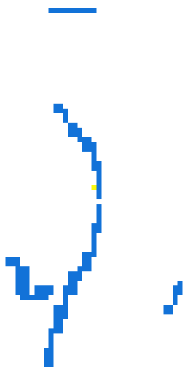
Detector characterisation and assembly

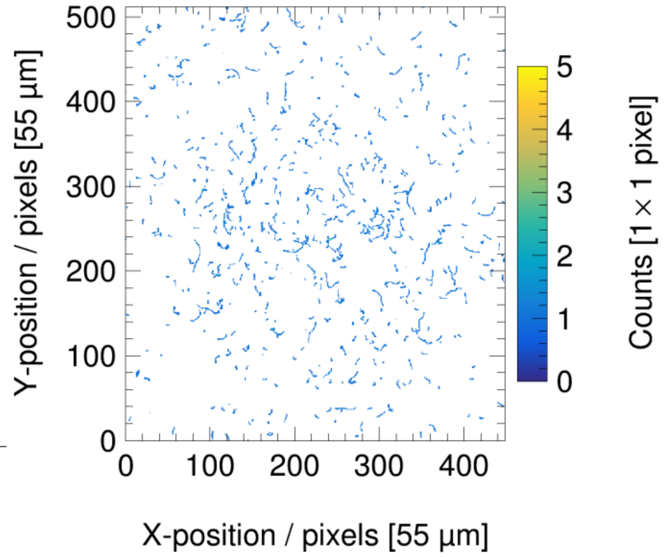
Taking gain measurements on the triple-GEM with **single-channel readout** to prepare for the attachment of the Timepix4

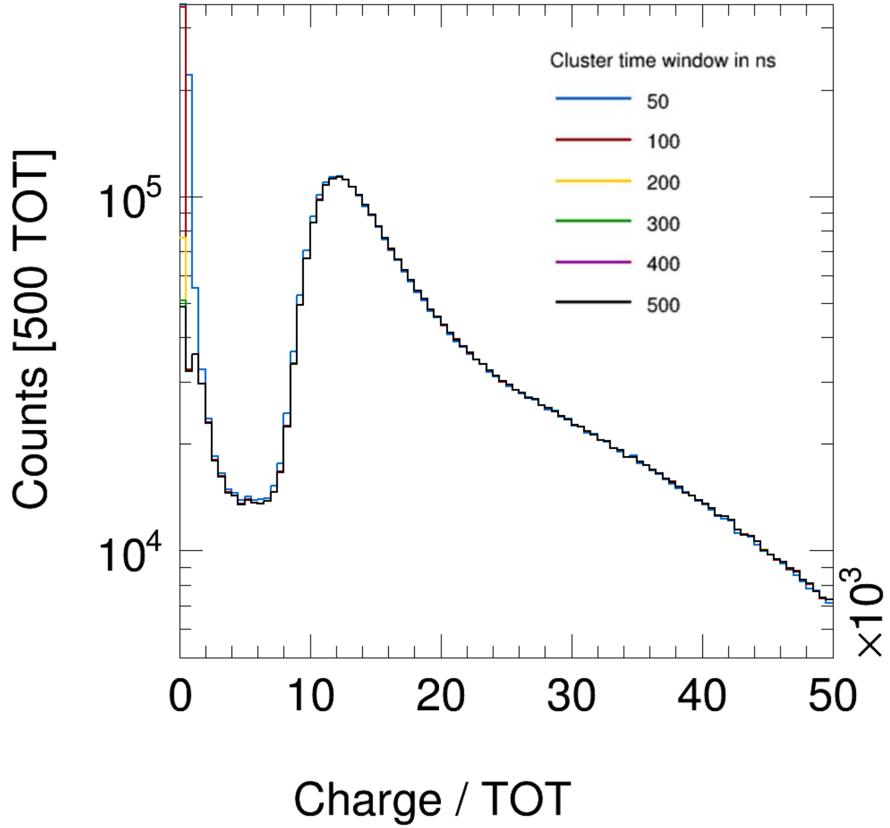


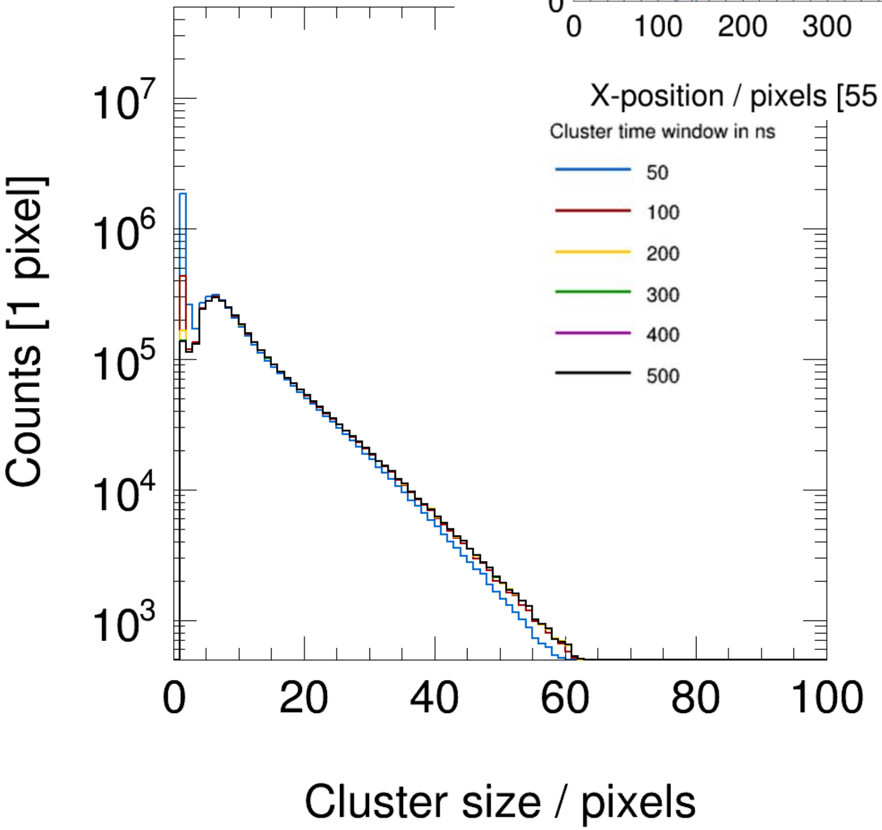
Operation and analysis

Cluster time window



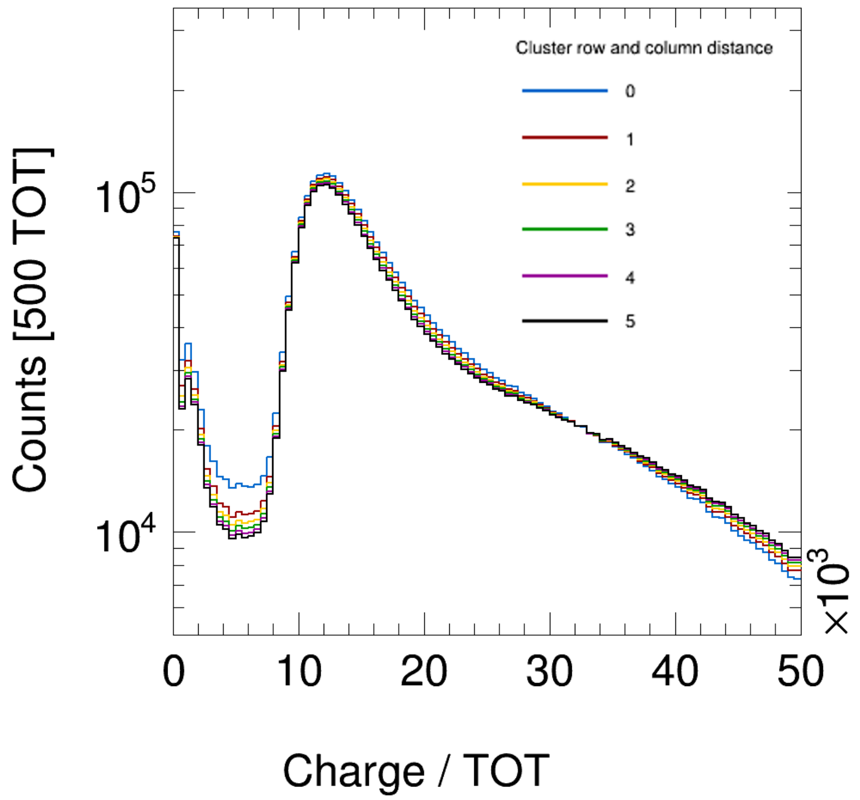


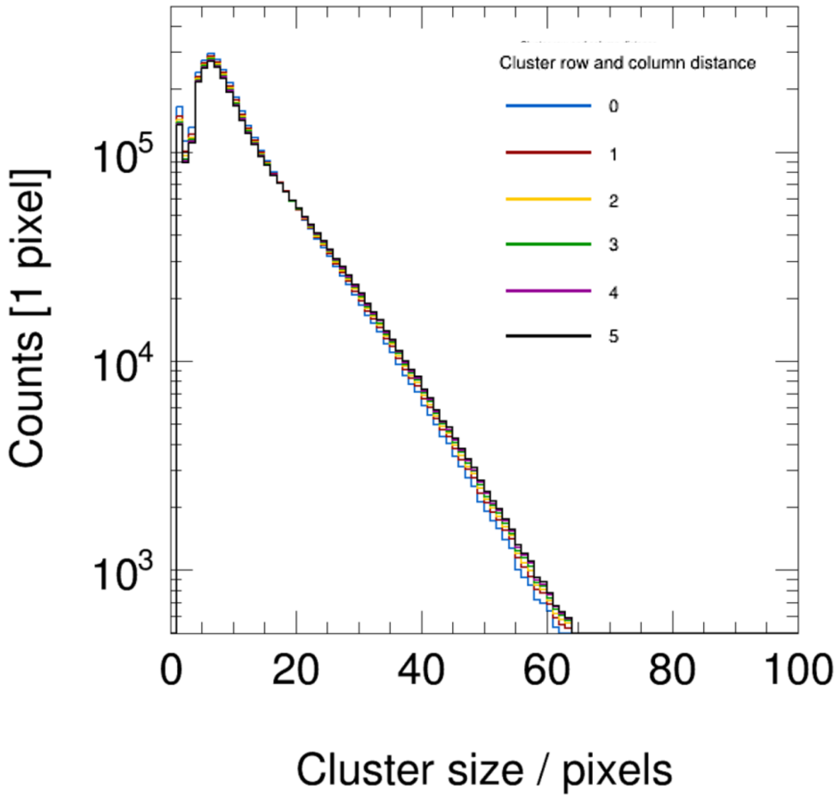




Operation and analysis

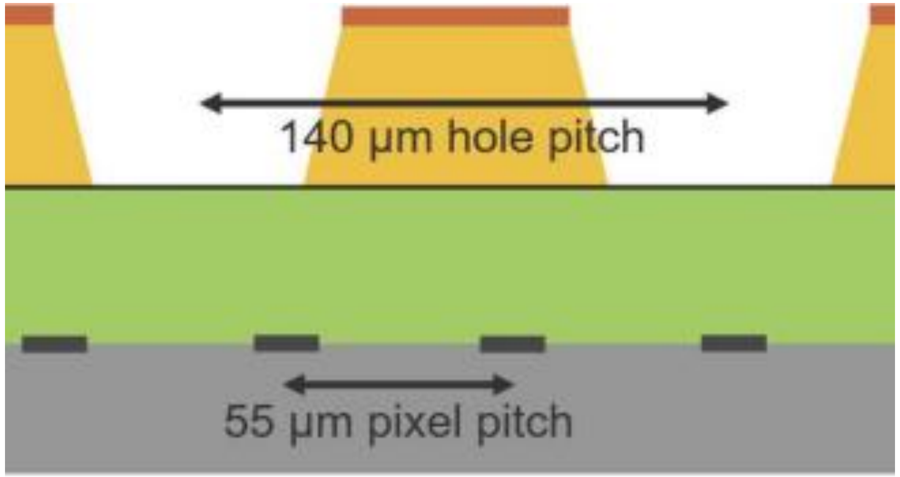
Cluster distance (pixels)

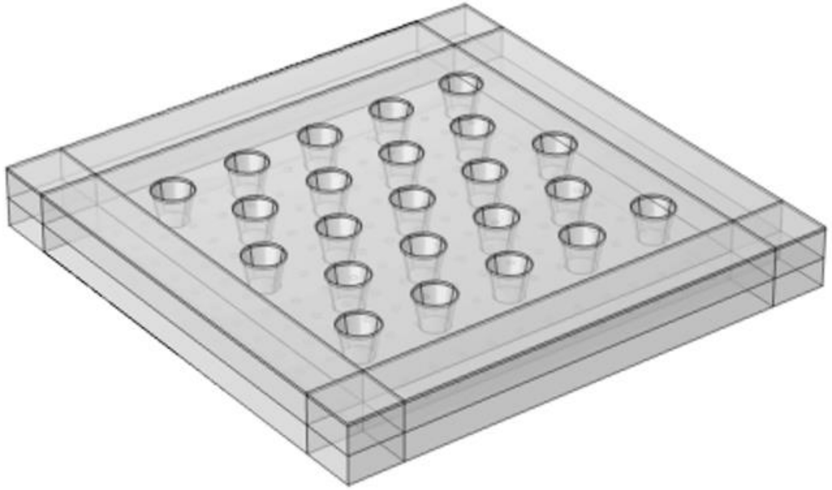




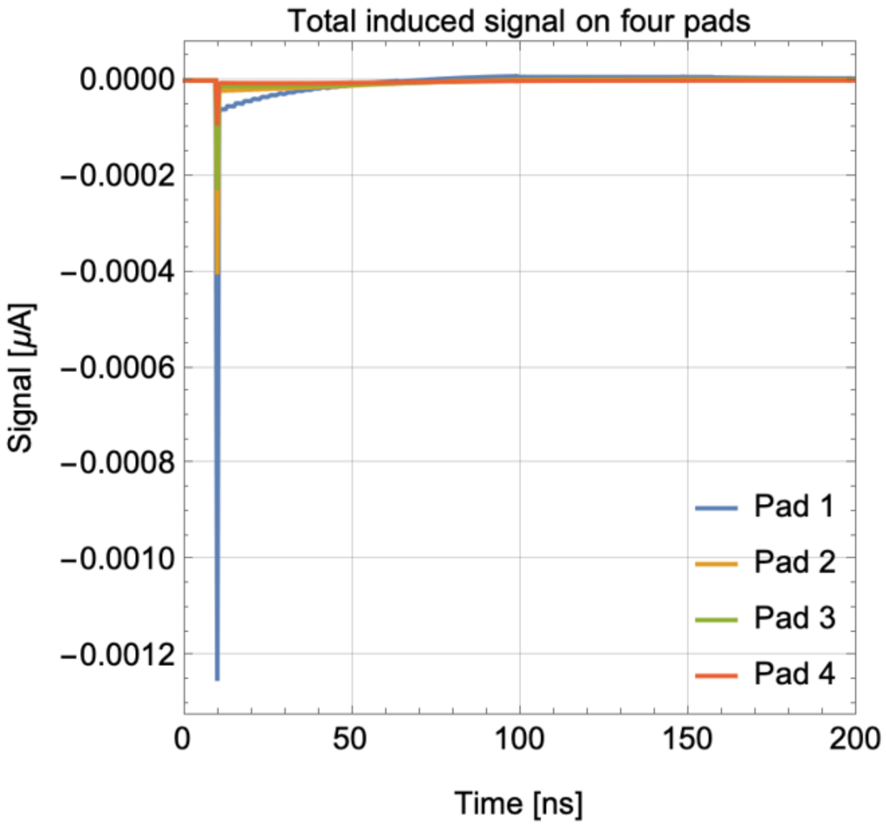
Simulation

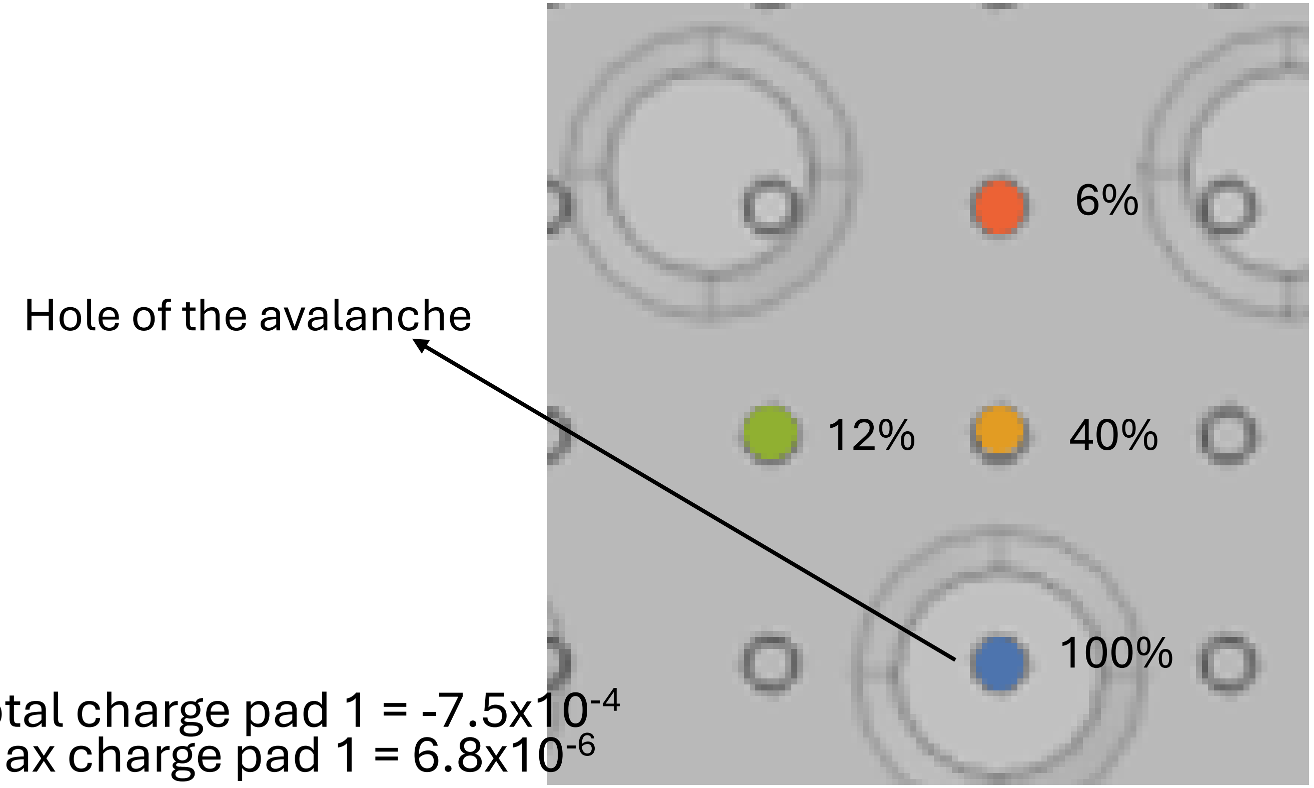
- Single readout in different pads based on the geometry of the holes
- Thank you Djunes Janssens!





Simulation





total charge pad 1 = -7.5×10^{-4}
max charge pad 1 = 6.8×10^{-6}

total charge pad 2 = -7.0×10^{-4}
max charge pad 2 = 2.7×10^{-6}

total charge pad 3 = -6.3×10^{-4}
max charge pad 3 = 1.0×10^{-6}

total charge pad 4 = -5.2×10^{-4}
max charge pad 4 = 3.9×10^{-7}

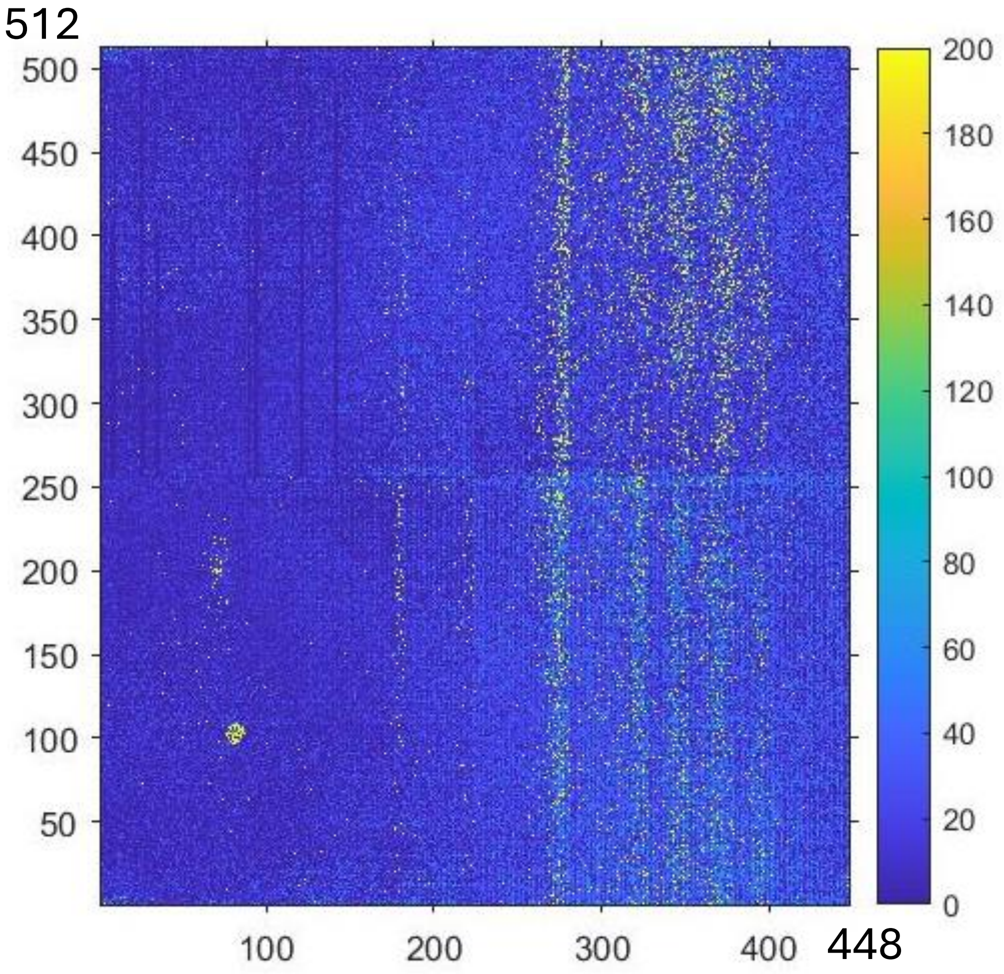
From preparation to operation

- So far the goal has been to prepare to operate
- We have been able to communicate with the chip for a week
- Thanks to Xavi Llopart and Jerome Alozy
- Thanks to Pierre Carbonez and Tristan Genetay

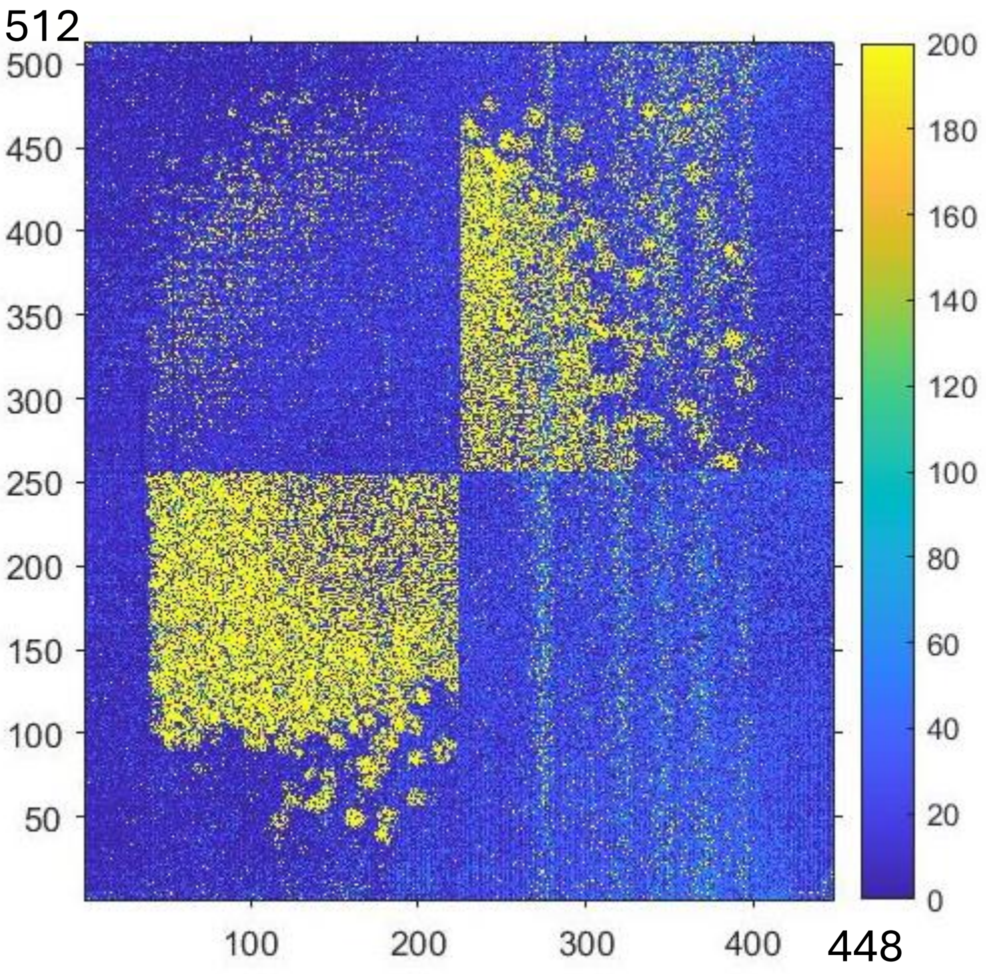
Results

triple-GEM readout with Timepix4
3900 divider voltage, 2500 gain, Sr90 source.

Without source

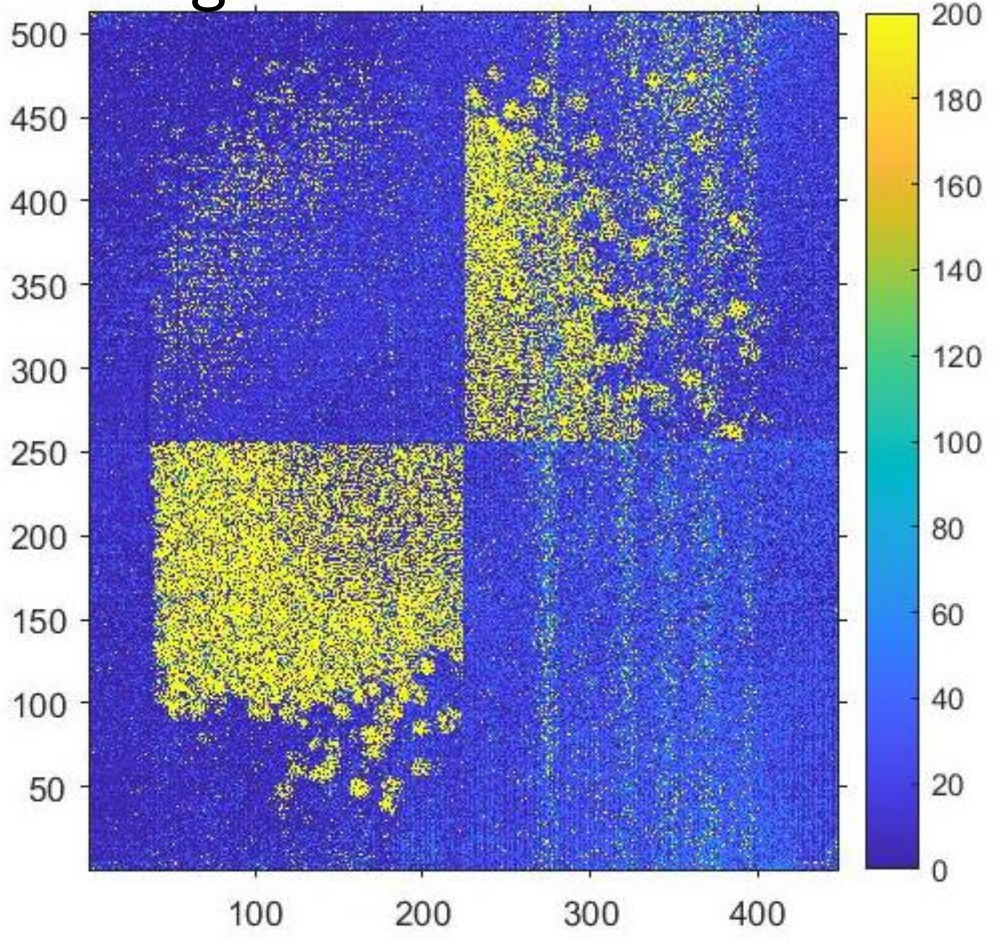


With source

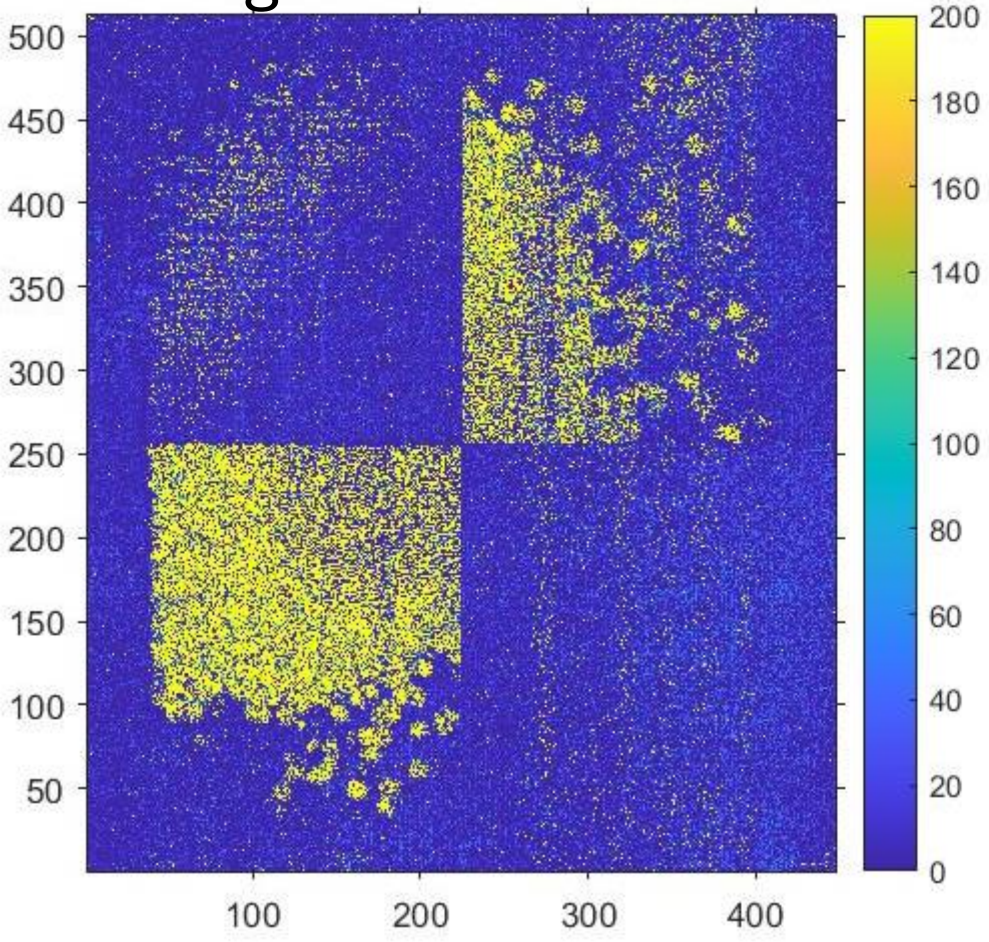


Results – Background subtracted

Original

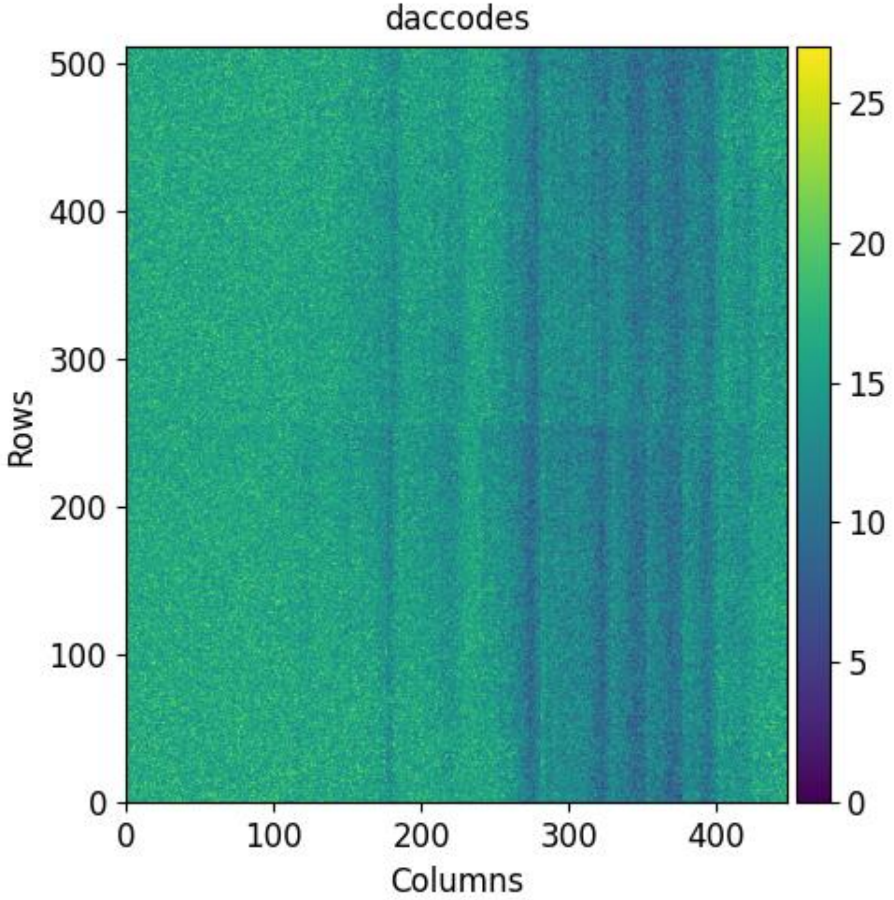


Background subtracted

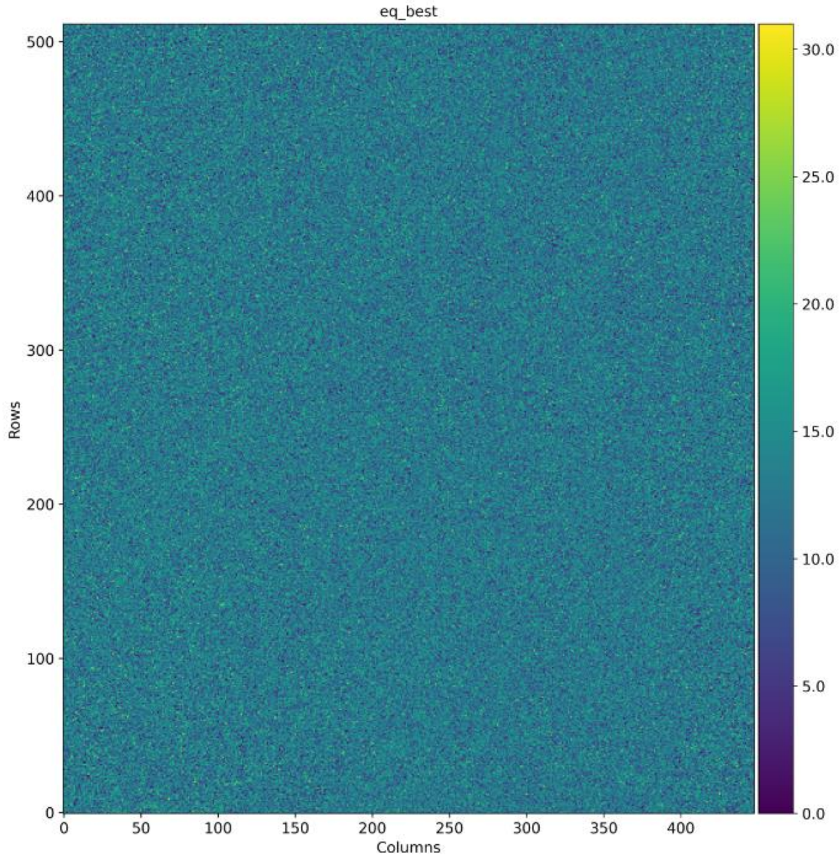


Results – origin of underlying pattern

Used



Ideal



Next steps

- Repeat measurements with improved equalisation
- Test the µRWELL with the chip by placing it on-top
- Improve readout speed for high-rate capabilities. Try to get fast-links (160Gb/s) with Nikhef software running. Currently running at 40Mb/s.

Thank you