Exploring VMM3a and SRS Features using GEMs and X-Rays

Lucian Scharenberg *on Behalf of the CERN EP-DT-DD GDD Team*
CERN, University of Bonn

RD51 Collaboration Meeting, CERN
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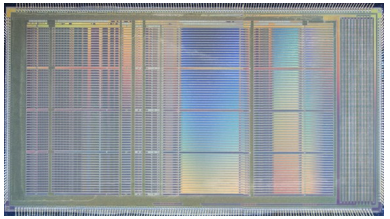
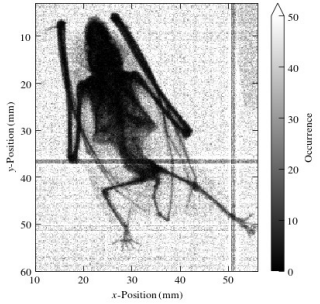
Outline

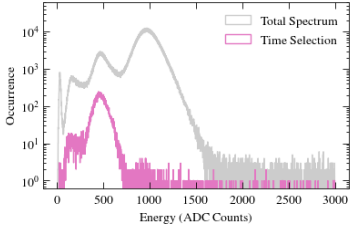
1. VMM specs in the SRS



2. Different types of measurements



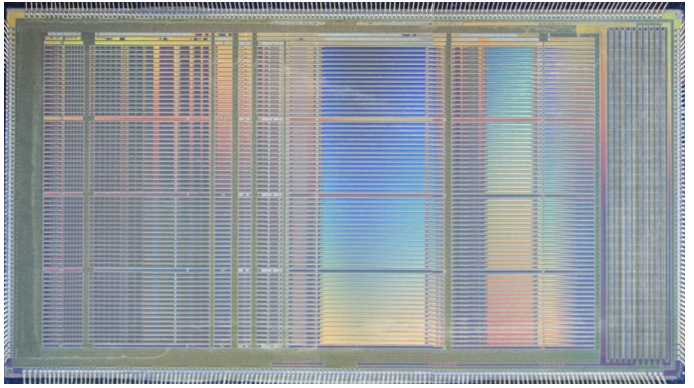
a) Imaging



b) Gaseous detector physics

3. Future perspectives

VMM3a Specifications

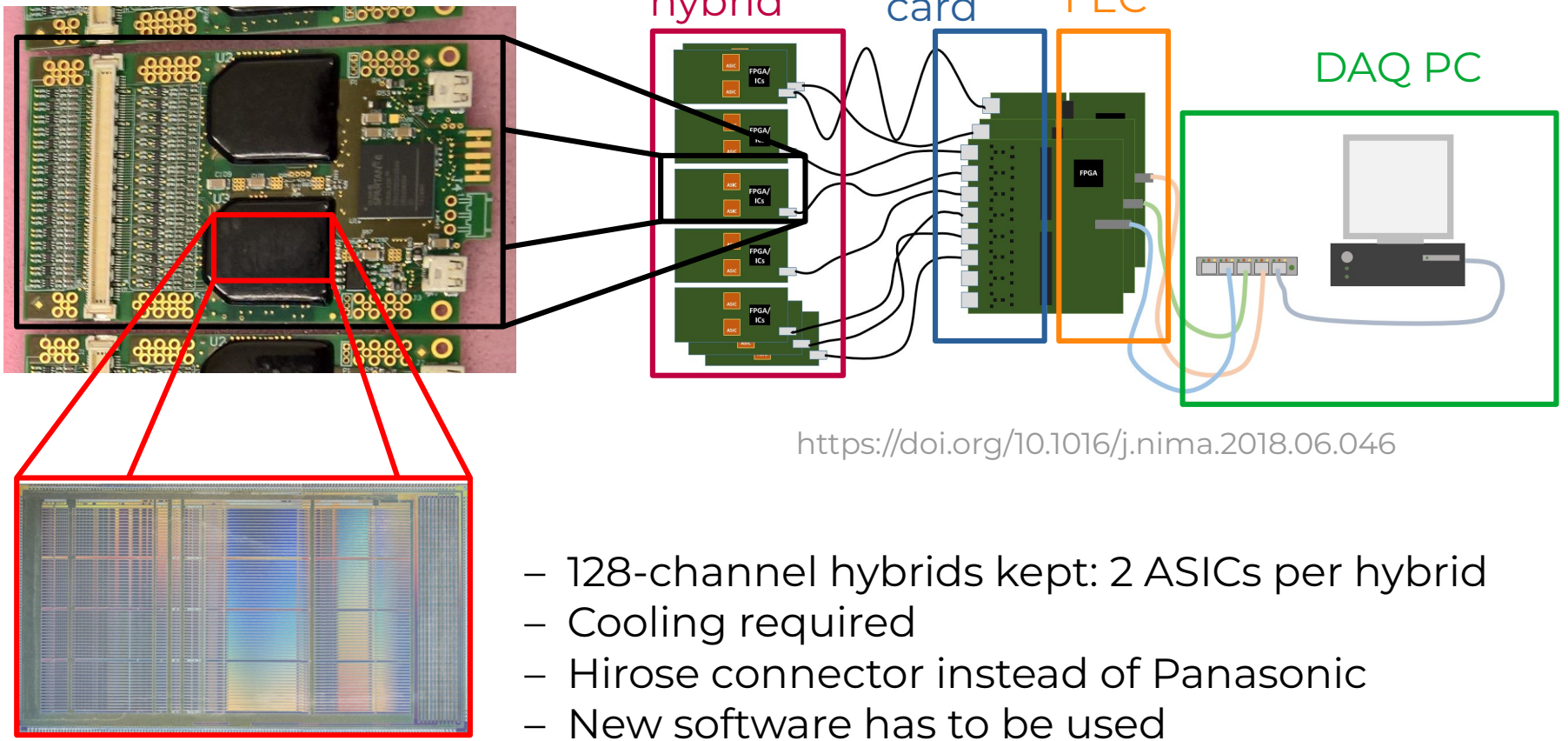


https://indico.cern.ch/event/757322/contributions/3394528/attachments/1838914/3014049/2019_05_06_Iakovidis_VMM.pdf

- 64 channels
- **High rate capability** → up to 4 MHz/channel
- **Self triggered, continuous read-out**
- Integrated zero suppression
- 10-bit **charge information**
- 12+8-bit **time information** → O(ns) time resolution
- **Neighbouring logic** and **subhysteresis discrimination**
- …

VMM3a in the SRS

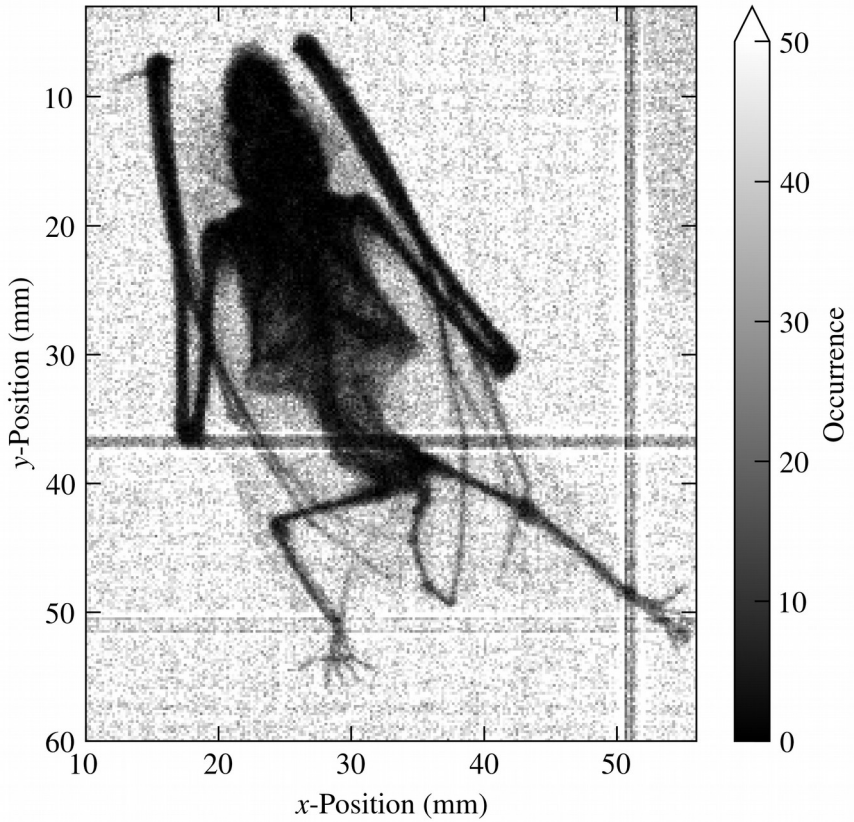
See esp. talk from H. Muller



https://doi.org/10.1016/j.nima.2018.06.046

- 128-channel hybrids kept: 2 ASICs per hybrid
- Cooling required
- Hirose connector instead of Panasonic
- New software has to be used

High Rate Capability: Radiography



High Rate Capability: Radiography

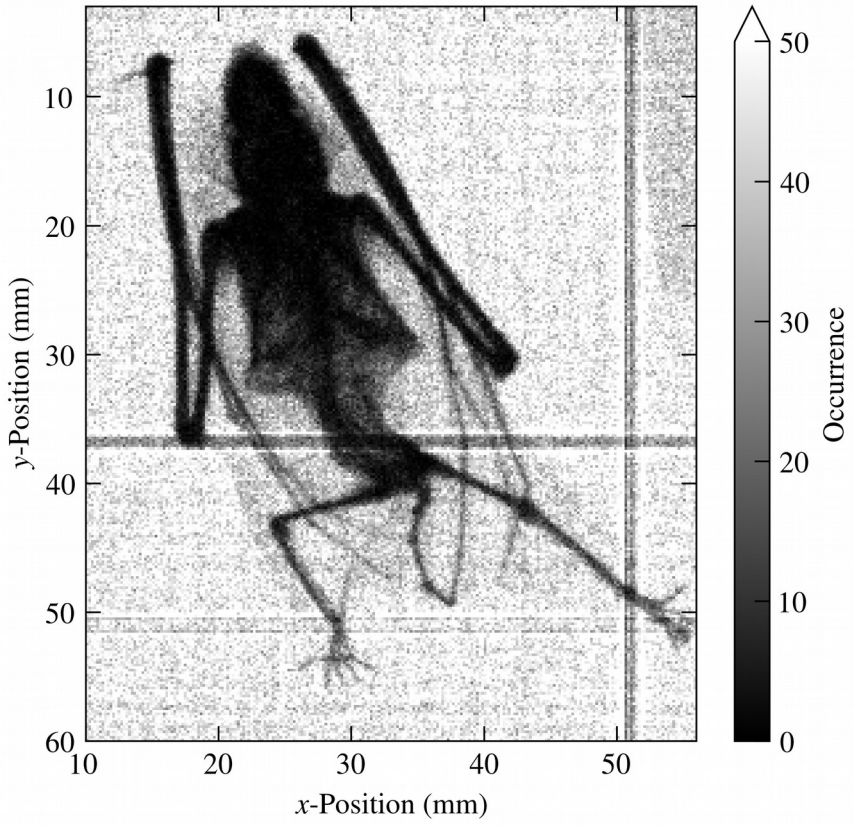


Image made out of 4 million clusters

APV25 (assuming 100 Hz trigger rate):
2.7 hours

VMM3a:
2 minutes acquisition @ 40 kHz
1 GB of raw data
2 minutes processing/reconstruction

High Rate Continuous Readout

Record fast processes continuously → Movie

e.g. mechanical movements

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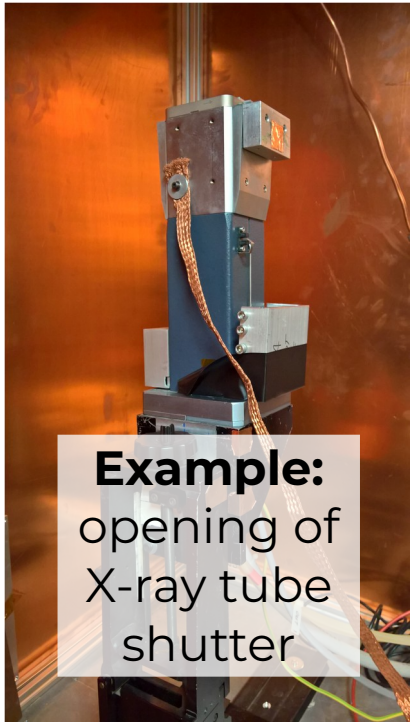
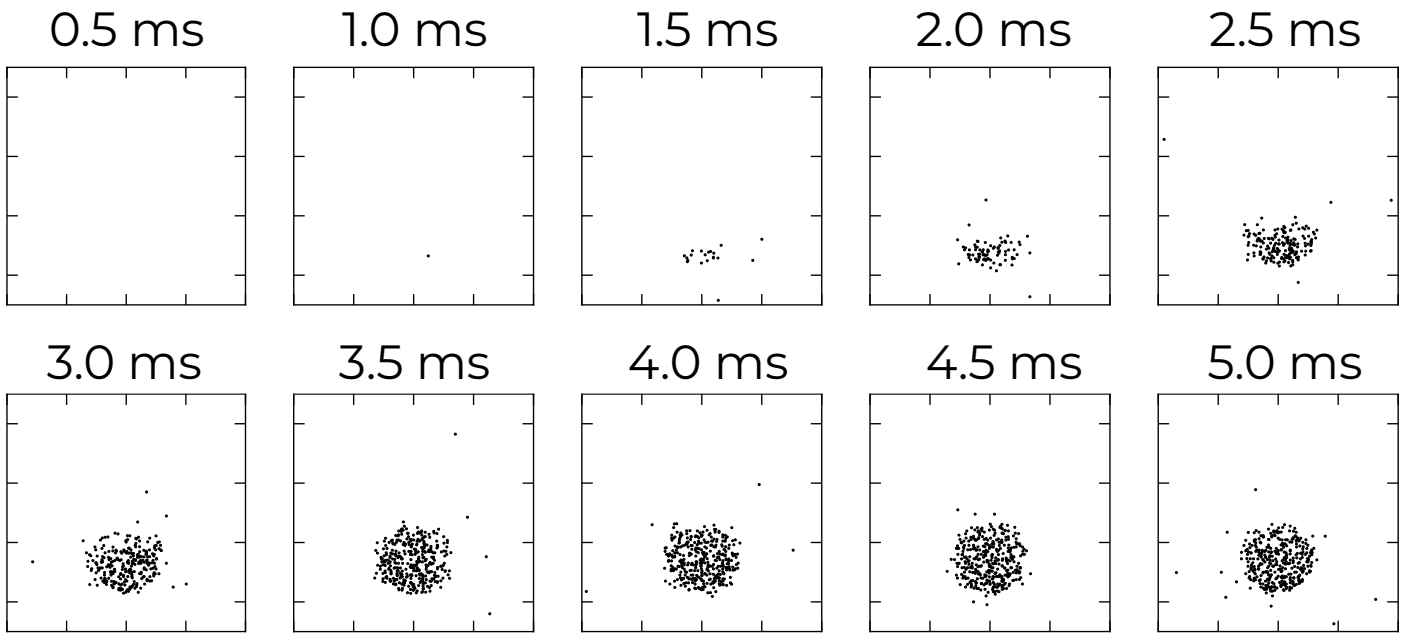
e.g. mechanical movements

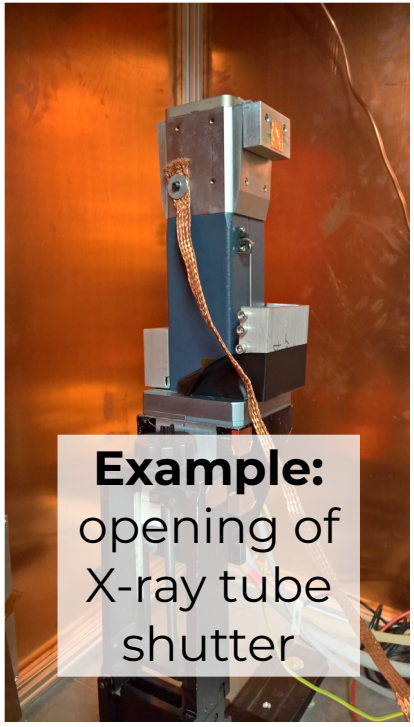


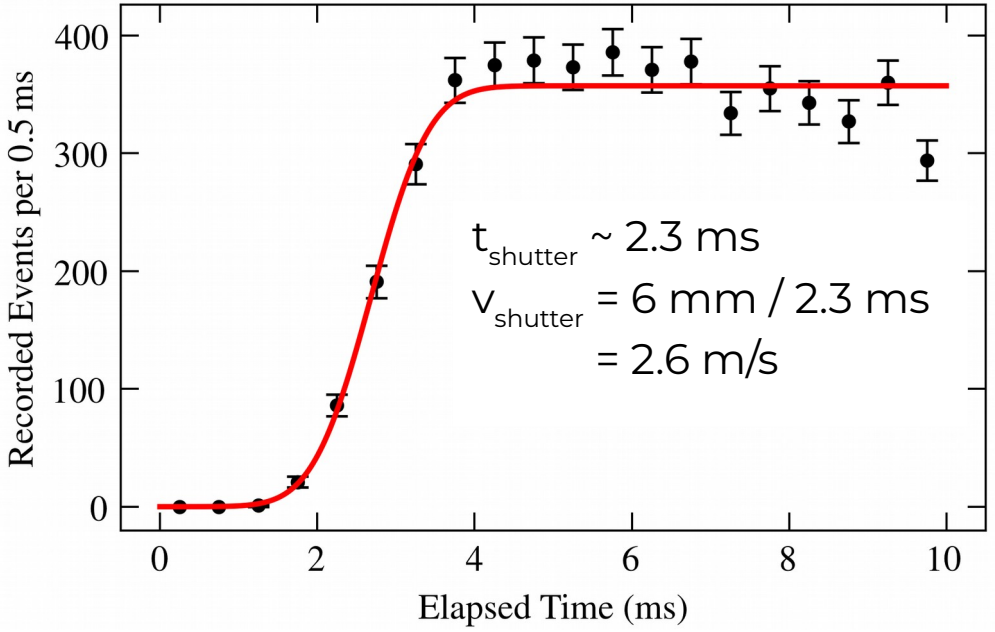


High Rate Continuous Readout

Record fast processes continuously → Movie

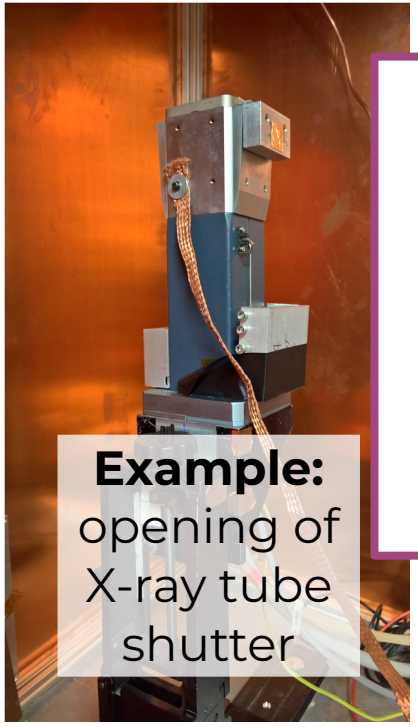
e.g. mechanical movements





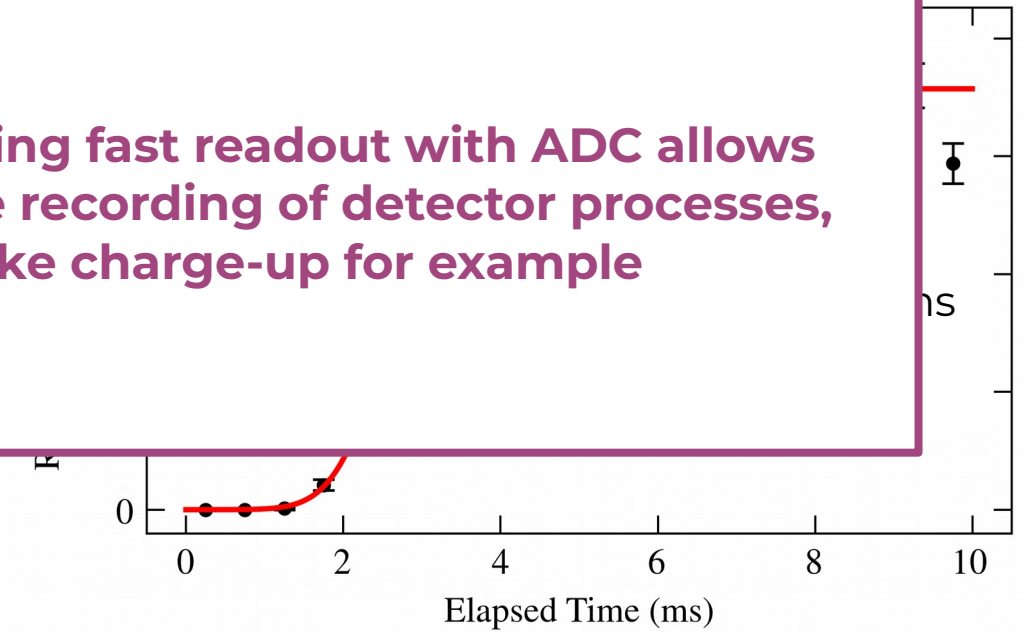
High Rate Continuous Readout

Record fast processes continuously → Movie
e.g. mechanical movements



Example: opening of X-ray tube shutter

Combining fast readout with ADC allows real-time recording of detector processes, like charge-up for example

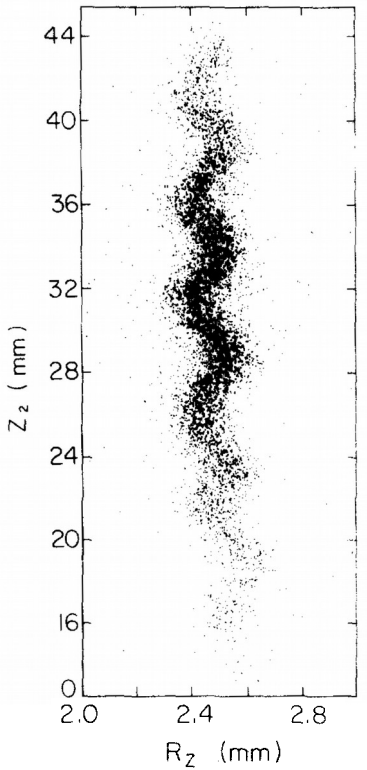


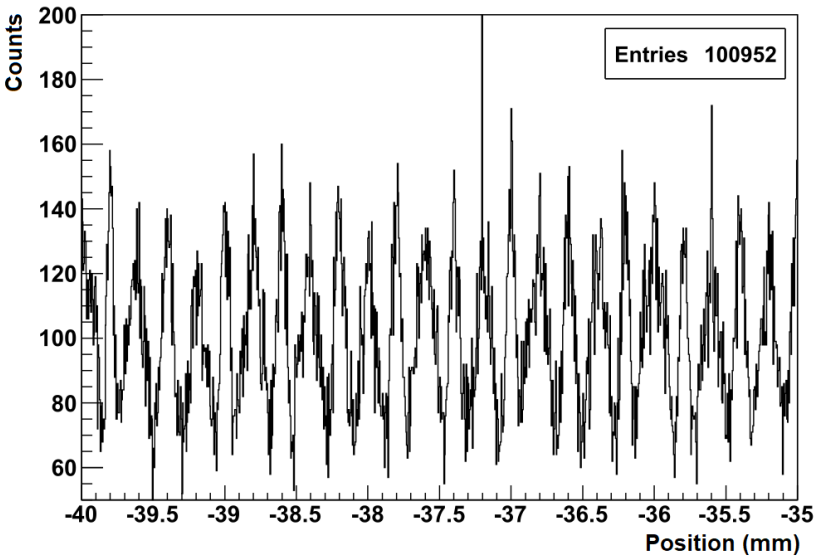
Readout Modulation

Goal:
combine fast imaging with good image quality

Centre-of-gravity method: fast and good position reconstruction, but fluctuations in exact position

Observed in **MWPC** with strip cathods





Also observed with **APV25**

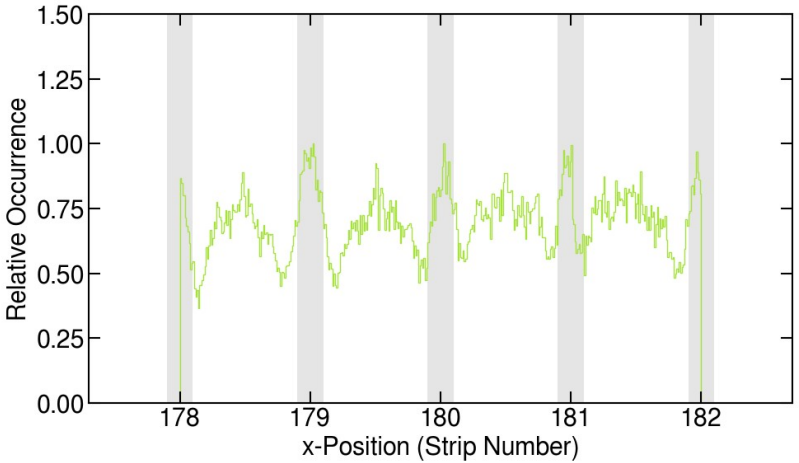
measurement performed by H. Pulkkinen in 2013

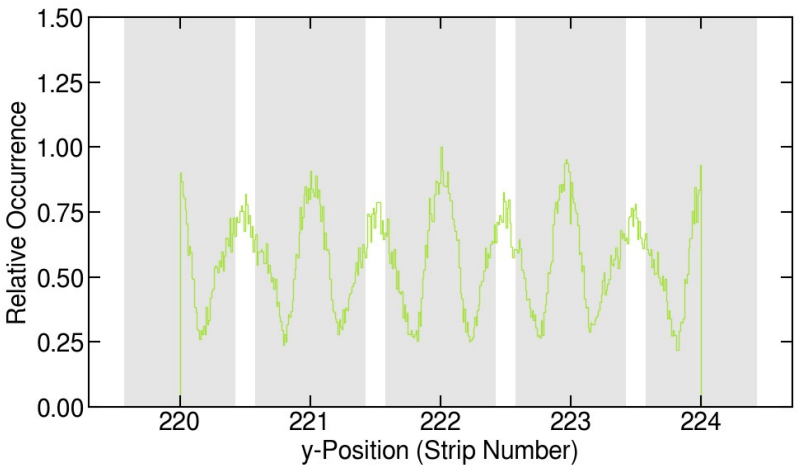
DOI: 10.1016/0029-554X(82)90113-6

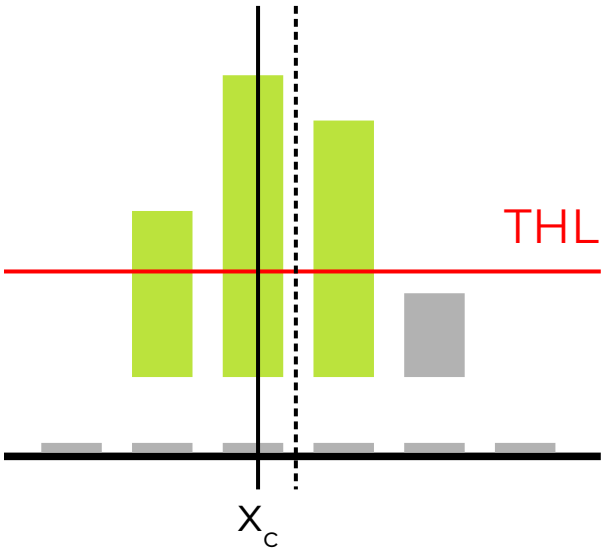
Readout Modulation with the VMM

Uniform irradiation: similar **non-uniform** response observed with the VMM.

Can be related to lack of information due to threshold level + discrete readout

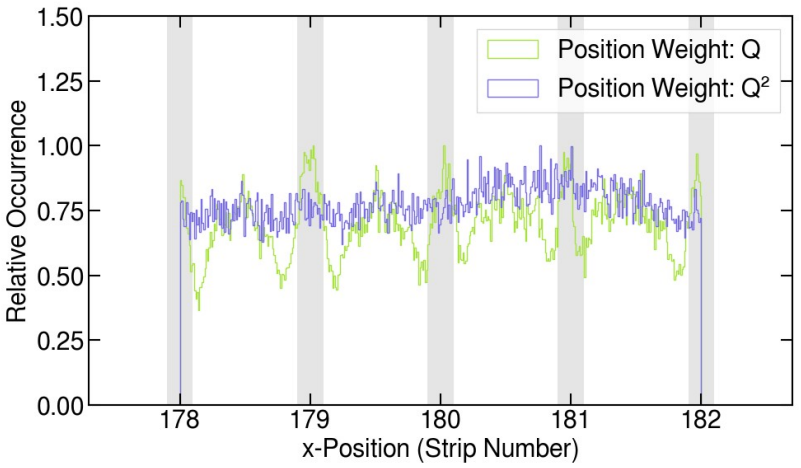


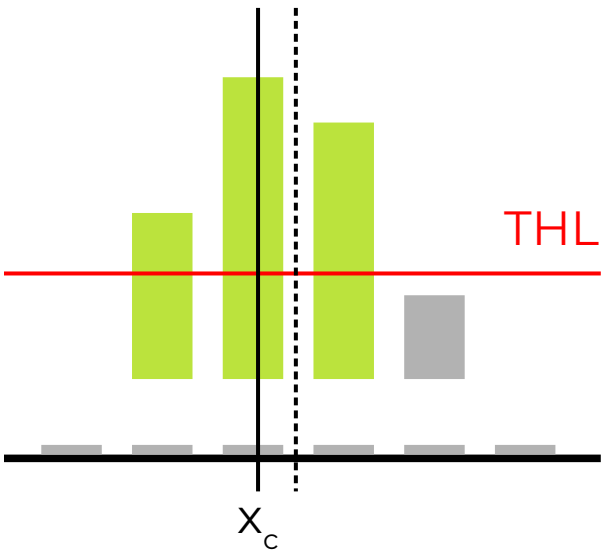




Readout Modulation with the VMM

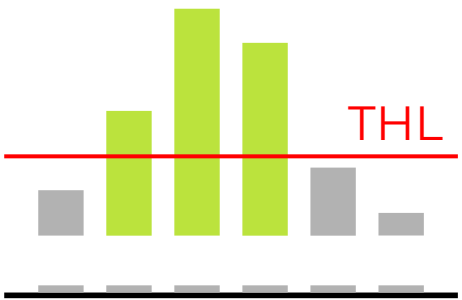
$$x_c = \frac{\sum Q_i^2 x_i}{\sum Q_i^2}$$



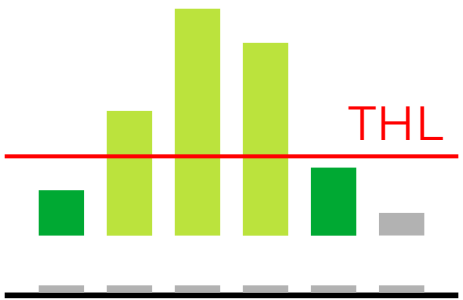


Neighbouring Logic & Subhysteresis Discrimination

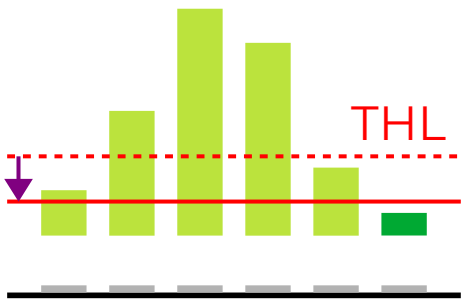
Two of the many hardware features of the VMM:
neighbouring logic and **subhysteresis discrimination**
→ different way of dealing with the threshold level



No hardware features enabled



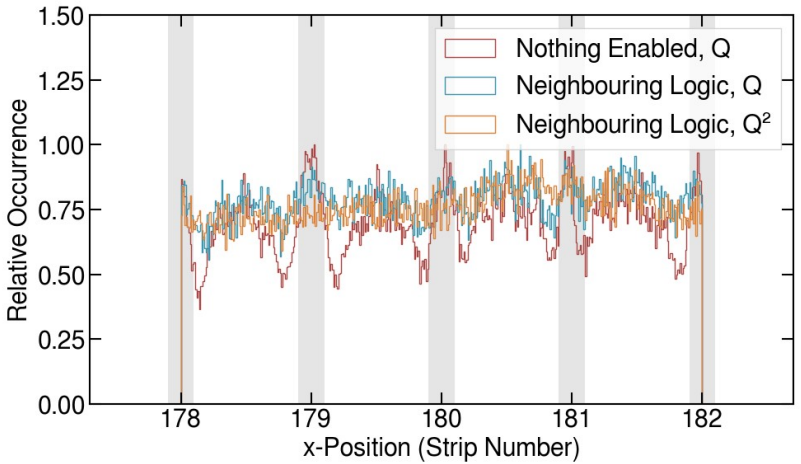
Neighbouring logic

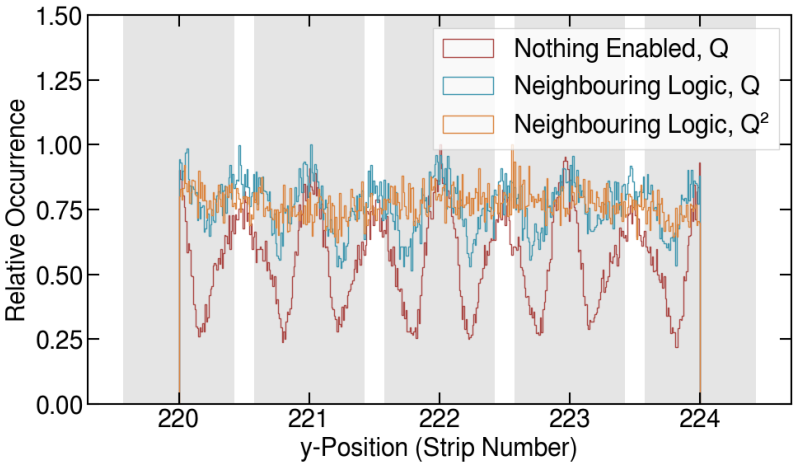


Neighbouring + subhysteresis

Hardware features instead of software to increase uniformity?
Effect of **smoothing** on spatial resolution?

Neighbouring Logic & Subhysteresis Discrimination



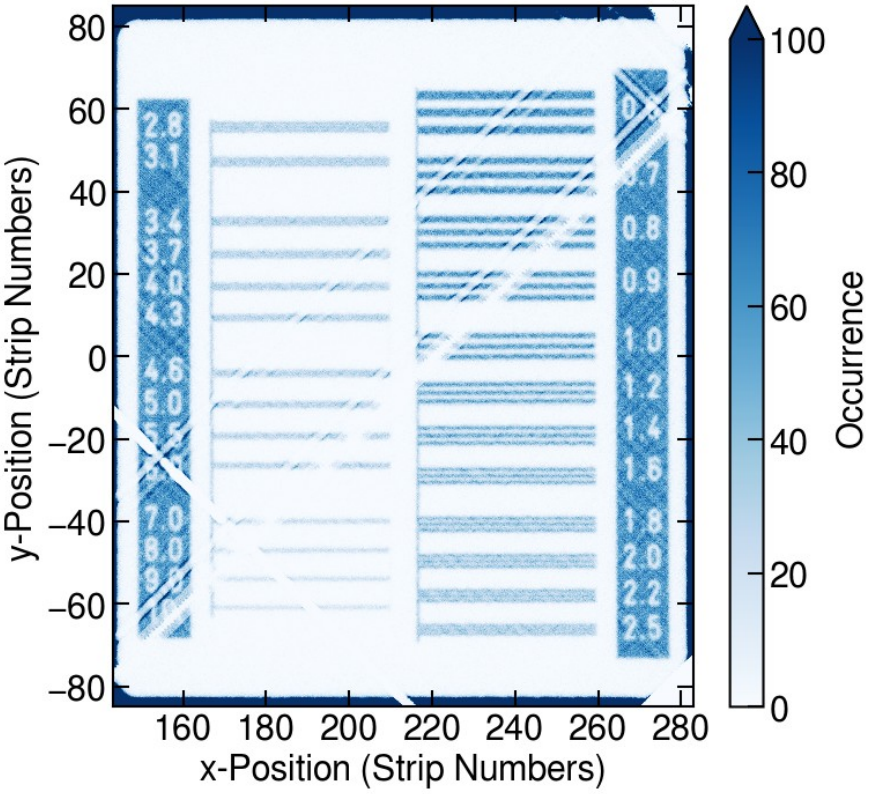


Hardware features lead to smoothing
Combined with software even more uniform
Neighbouring logic has large impact on smoothing, subhysteresis discrimination not

Neighbouring Logic & Subhysteresis Discrimination

PRELIMINARY

Investigate effect on spatial resolution:
MTF and **ESF** are used



Neighbouring Logic & Subhysteresis Discrimination

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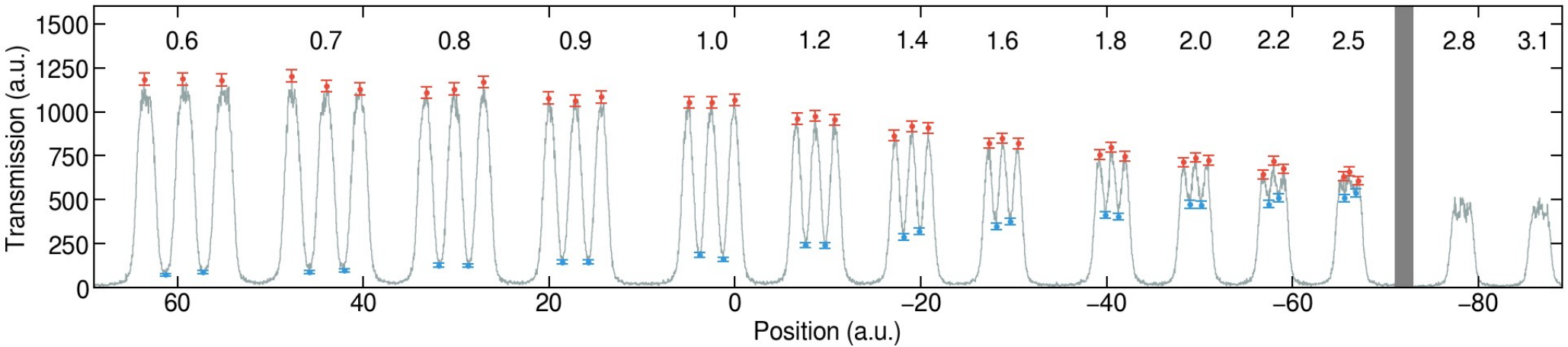

$$C = \frac{I_{\max} - I_{\min}}{I_{\max} - I_{\min}}$$

$$\mathrm{MTF}(f) = \frac{C(f)}{C_{\max}}$$

Neighbouring Logic & Subhysteresis Discrimination

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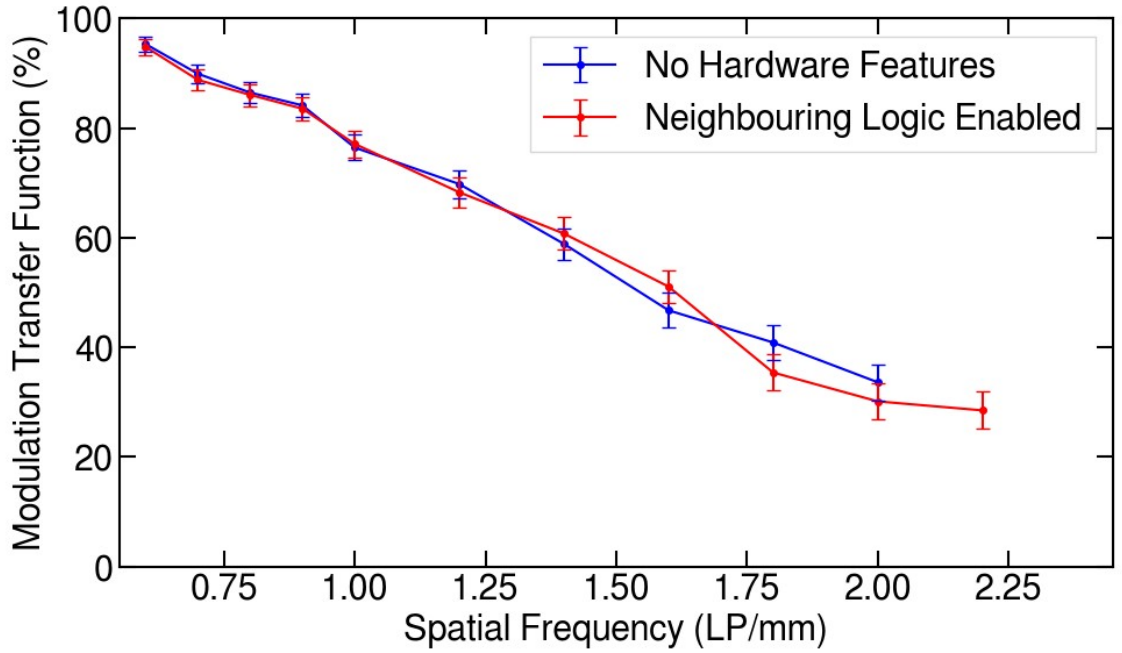

Within the errors no improvement of spatial resolution observed

Neighbouring Logic & Subhysteresis Discrimination

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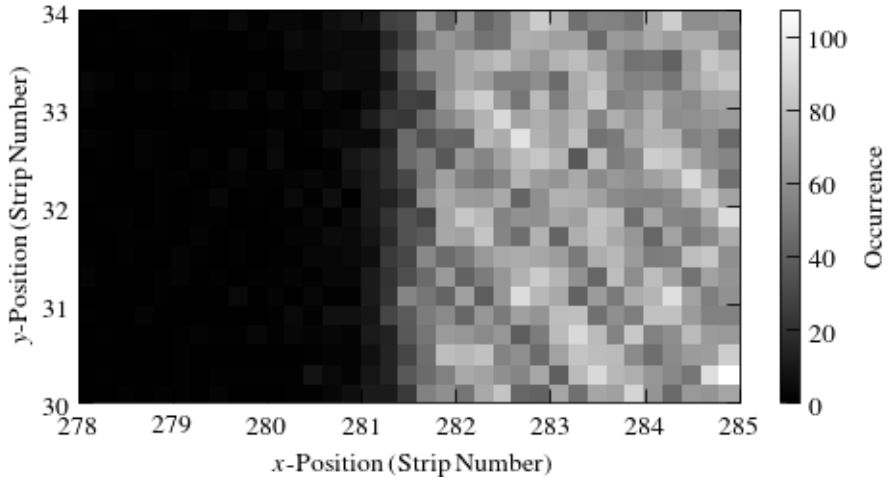

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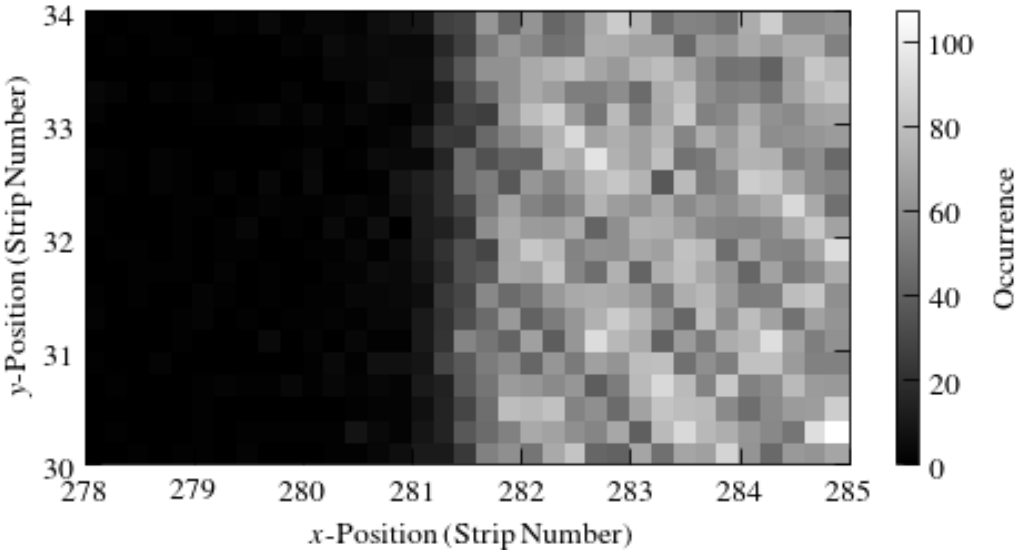

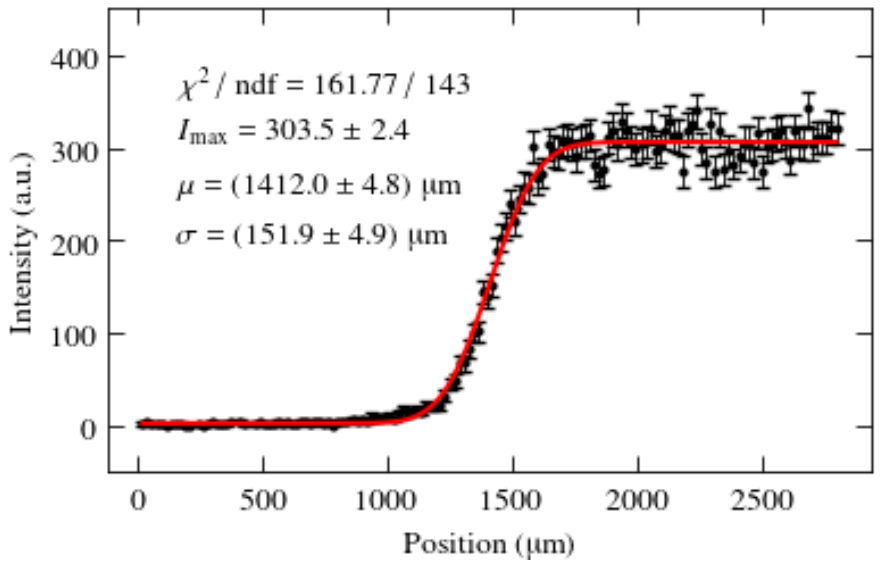

Neighbouring Logic & Subhysteresis Discrimination

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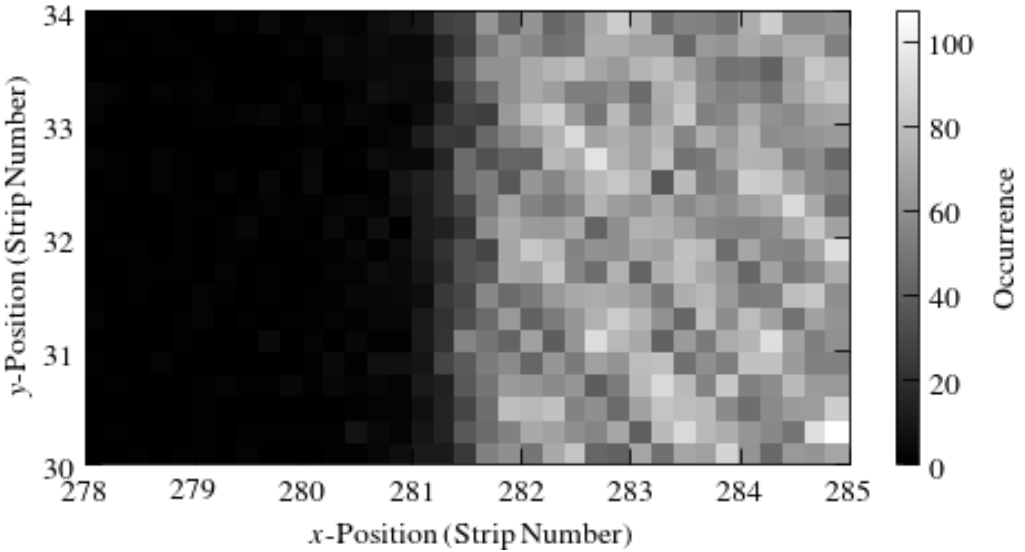

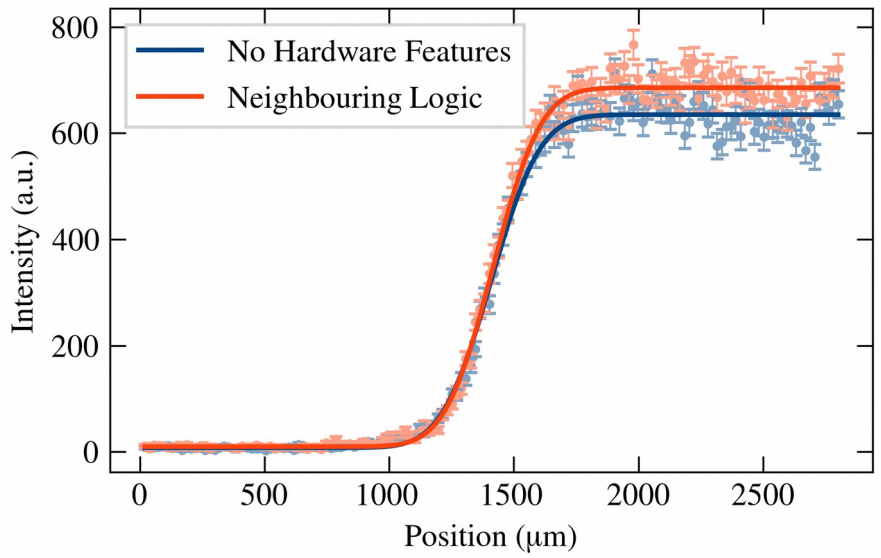

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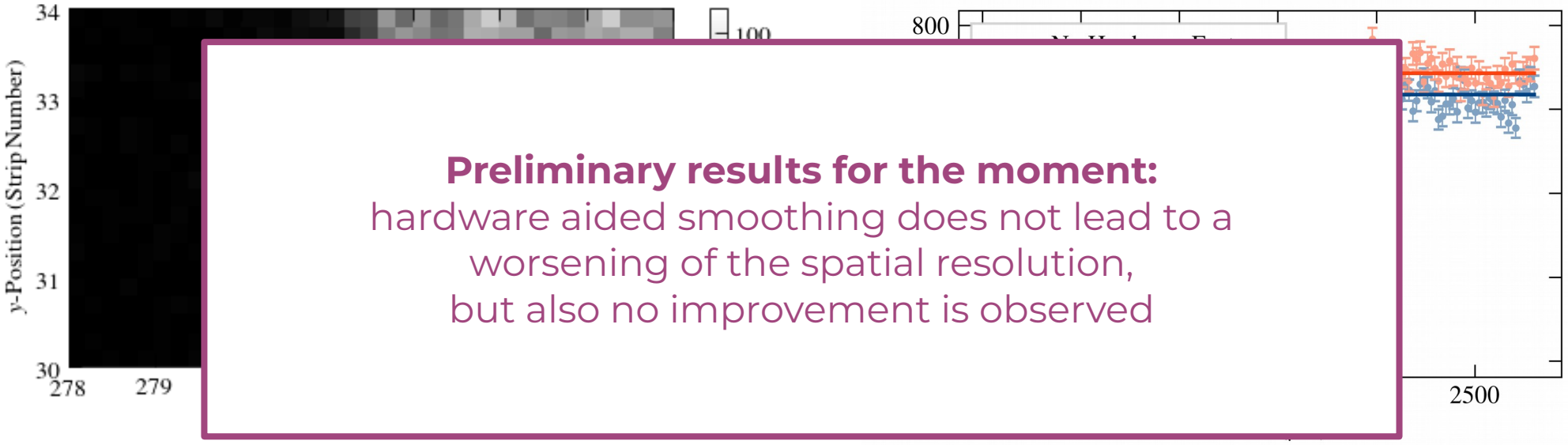
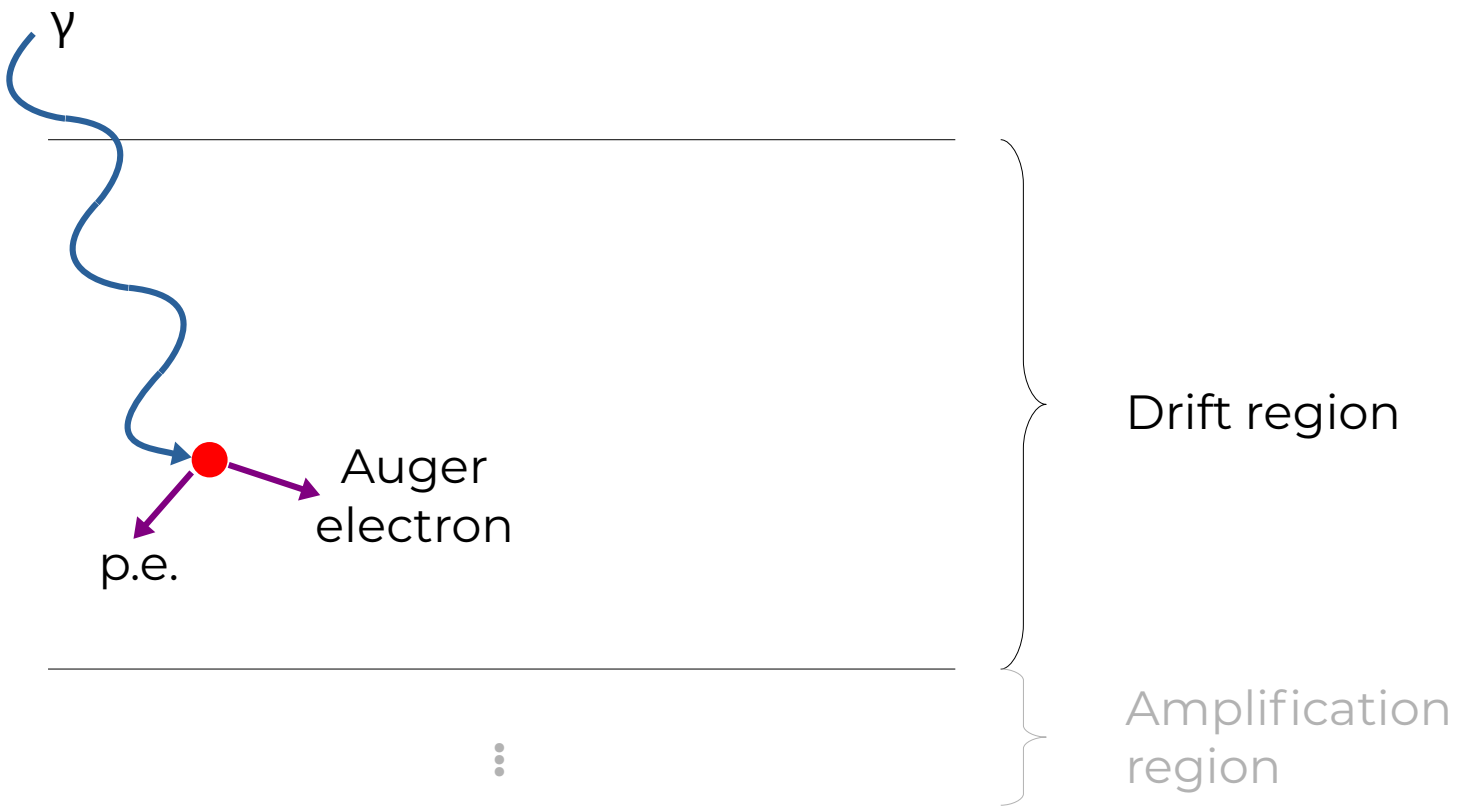
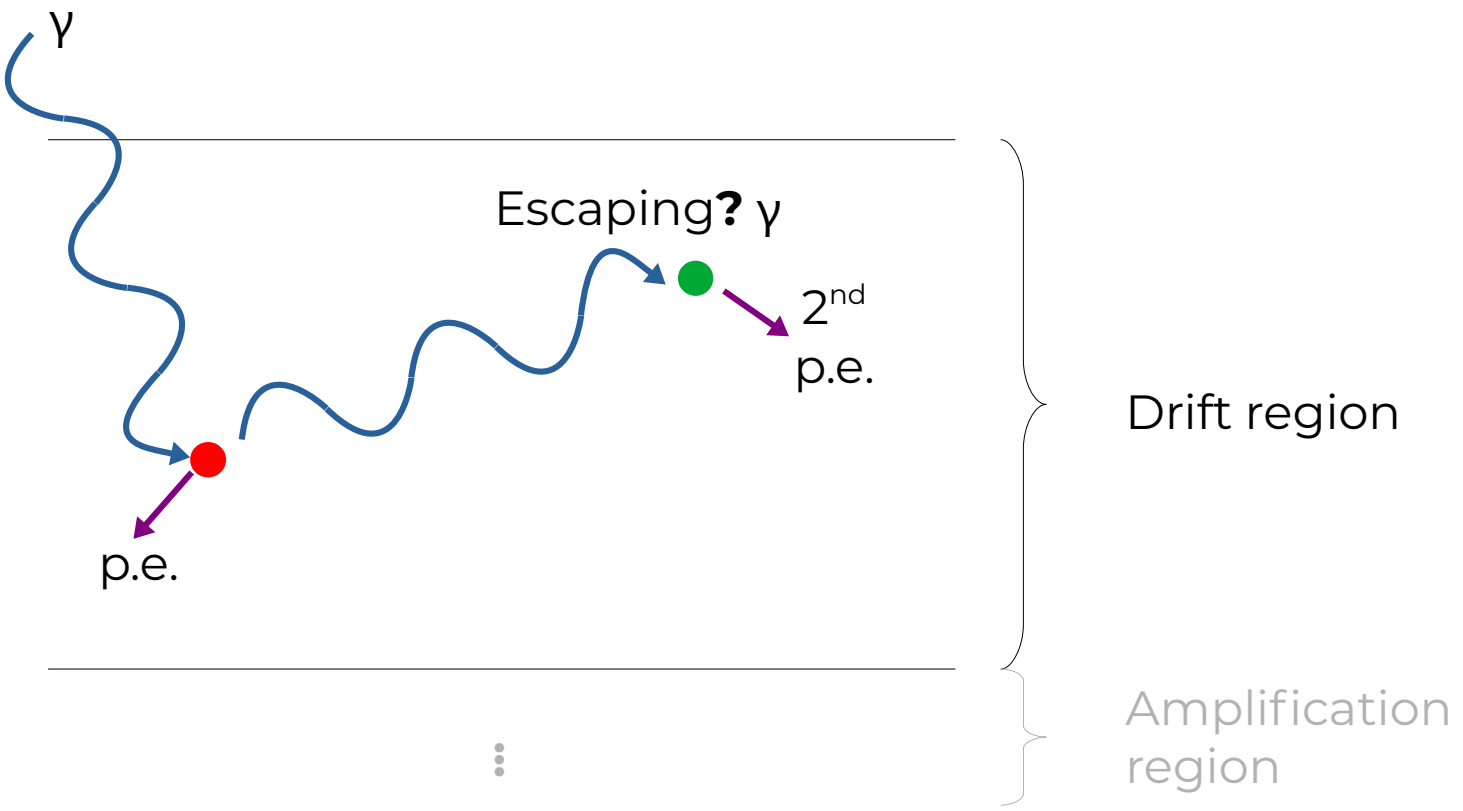


Preliminary results for the moment:
hardware aided smoothing does not lead to a worsening of the spatial resolution,
but also no improvement is observed

Self Triggered, Continuous Readout & Good Time Resolution



Self Triggered, Continuous Readout & Good Time Resolution



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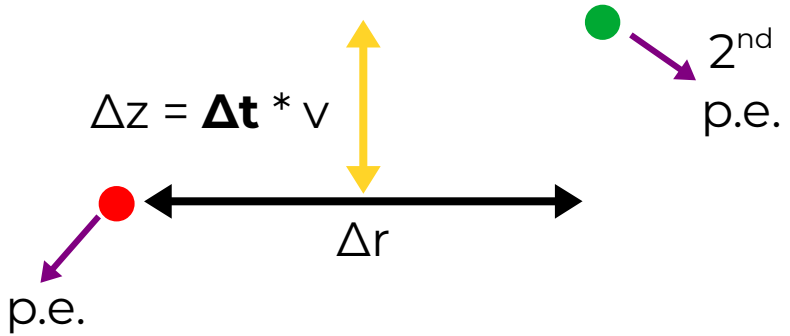


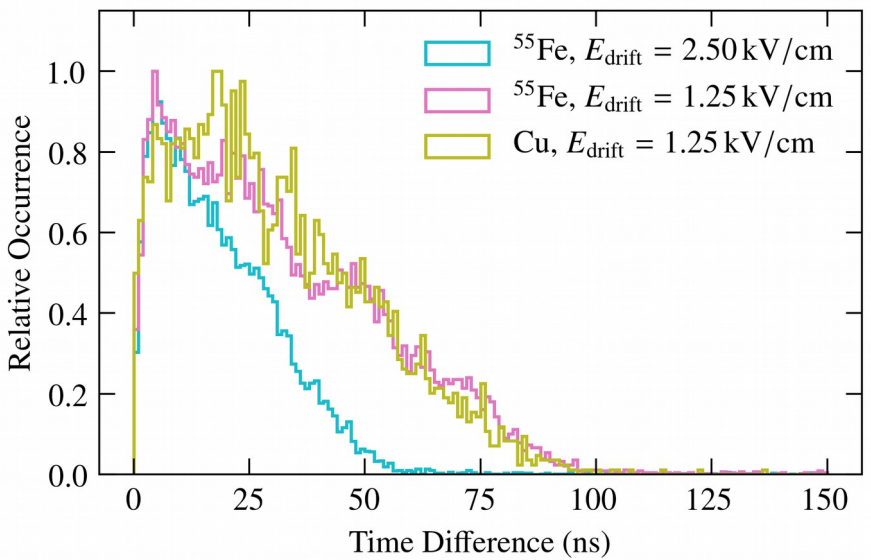
Example:

3 mm drift gap
Ar/CO_2 (70/30)
E = 2.5 kV/cm → v = 6.7 cm/μs

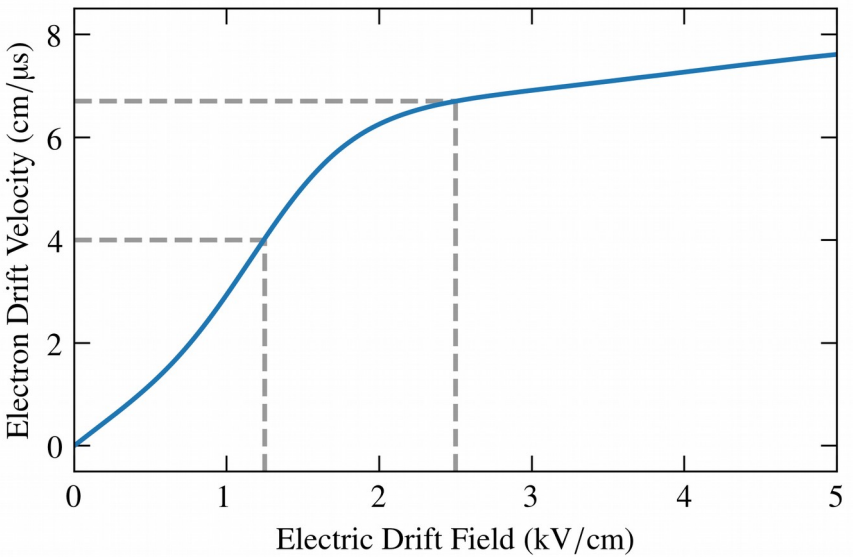
Maximum time difference:
Δt_{max} = 50 ns

Self Triggered, Continuous Readout & Good Time Resolution

Measurements for **3 mm drift** at two different fields



v_{drift} (Magboltz 11.7) in Ar/CO_2 (70/30)

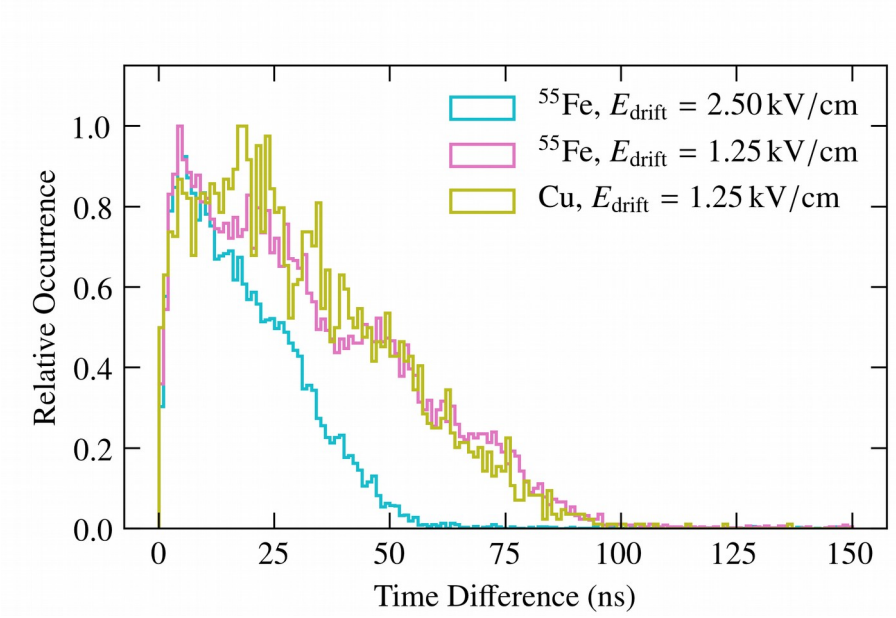


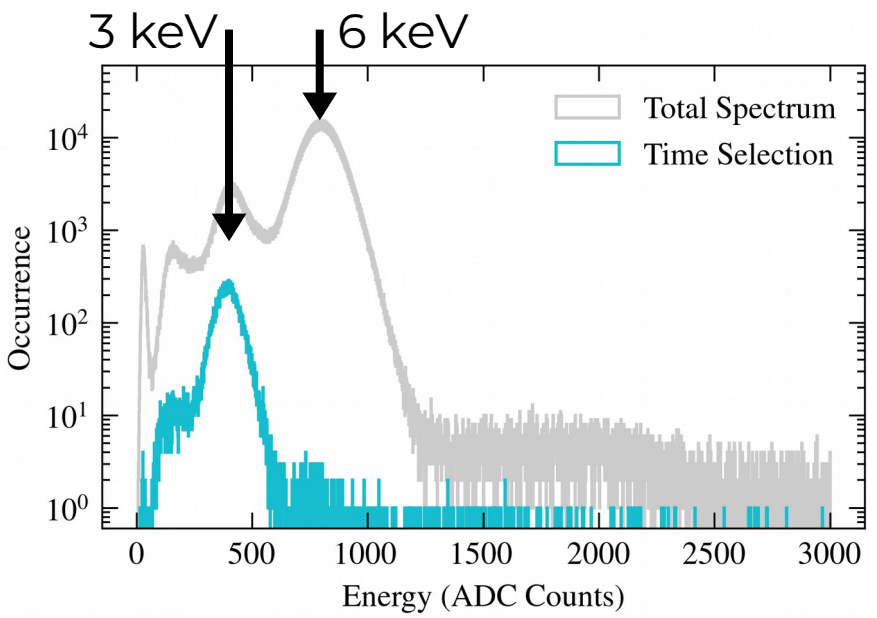
E = 1.25 kV/cm
v = 4 cm/μs
Δt_{max} = 80 ns

E = 2.50 kV/cm
v = 6.7 cm/μs
Δt_{max} = 50 ns

Self Triggered, Continuous Readout & Good Time & Energy Resolution

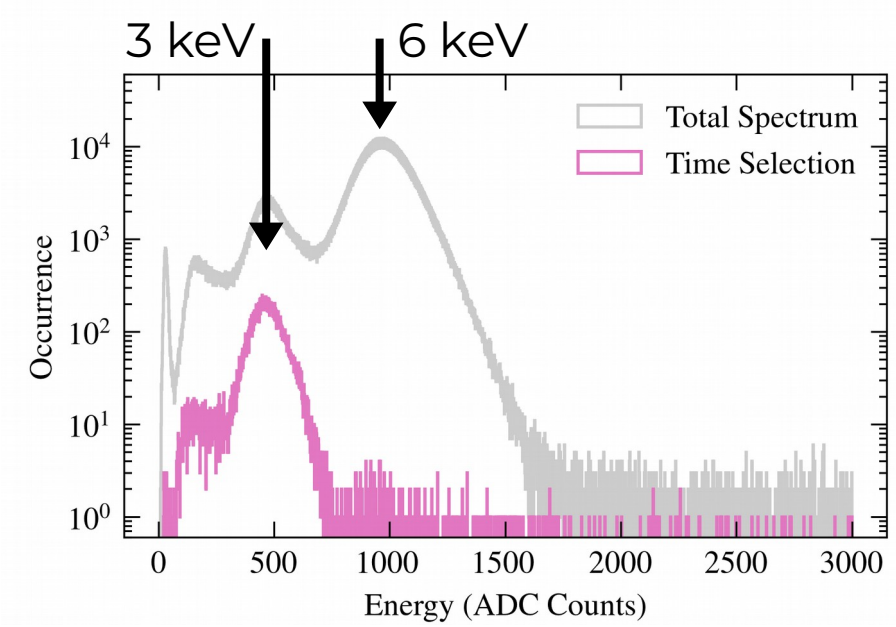
Plot the spectrum of the events with a cut on the time



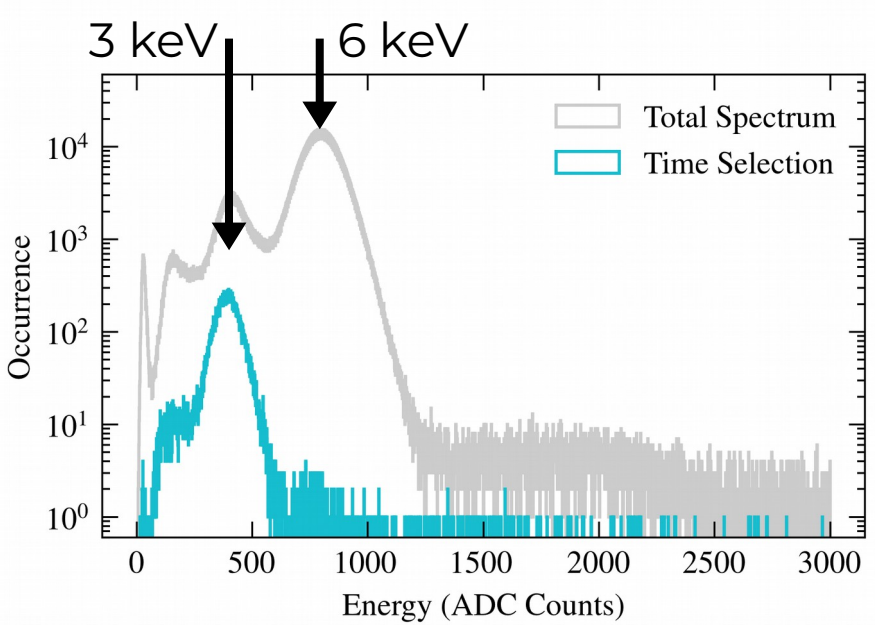


Self Triggered, Continuous Readout & Good Time & Energy Resolution

Should not change for different drift field

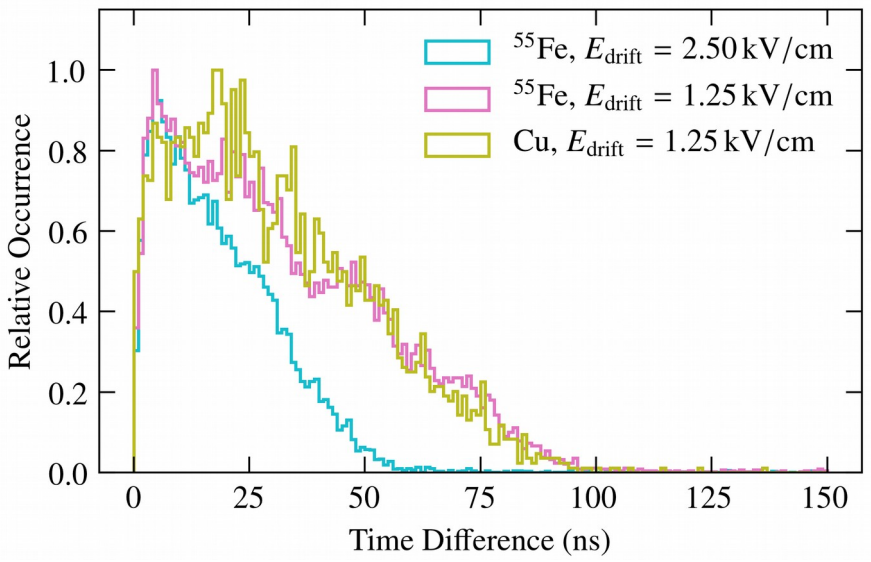


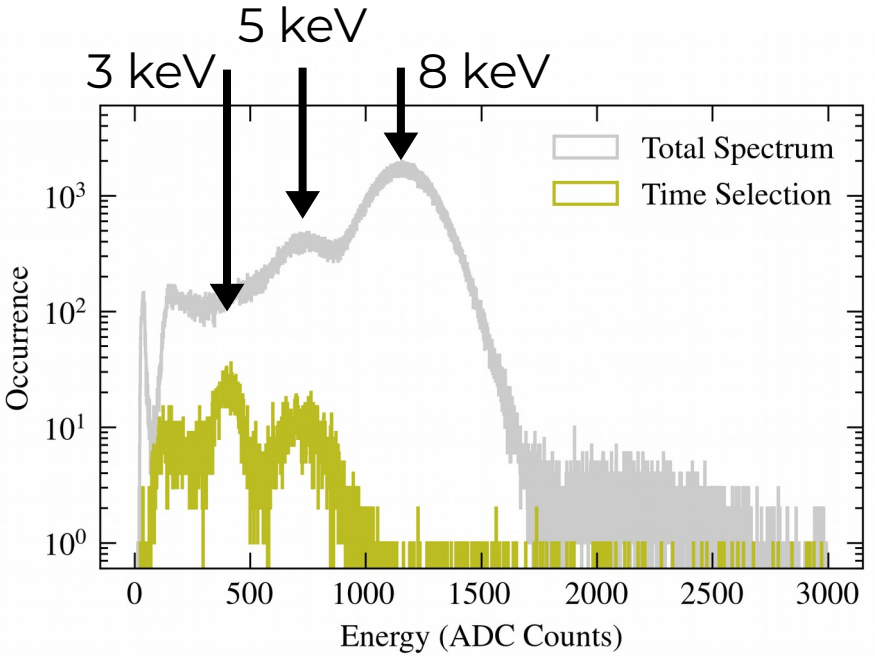
E = 1.25 kV/cm, Δt_{max} = **80 ns**



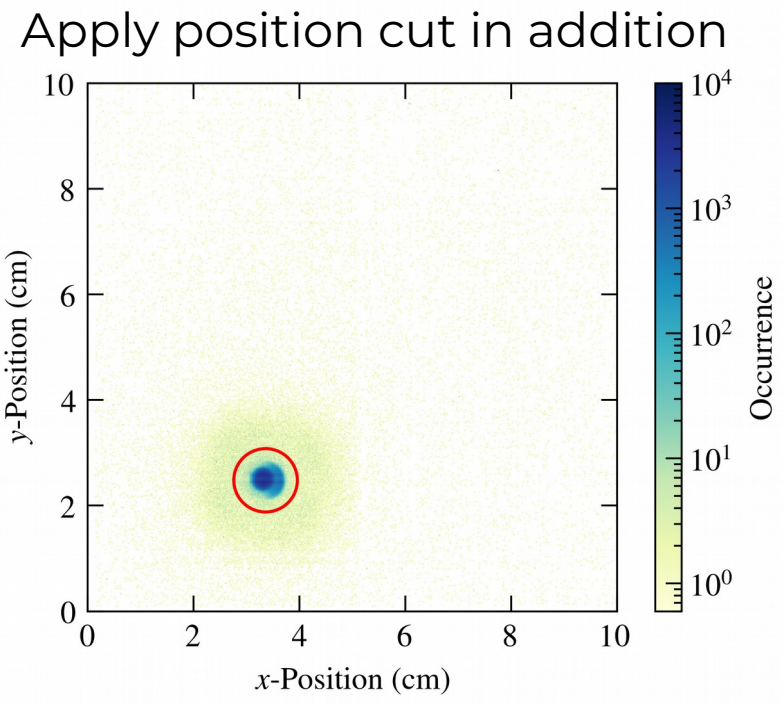
E = 2.50 kV/cm, Δt_{max} = **50 ns**

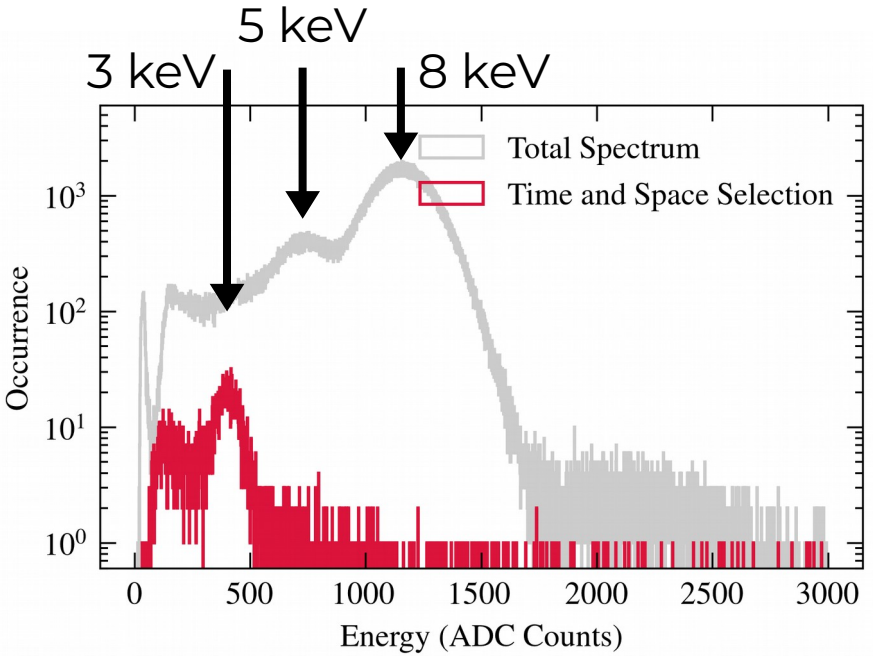
Self Triggered, Continuous Readout & Good Time & Energy Resolution



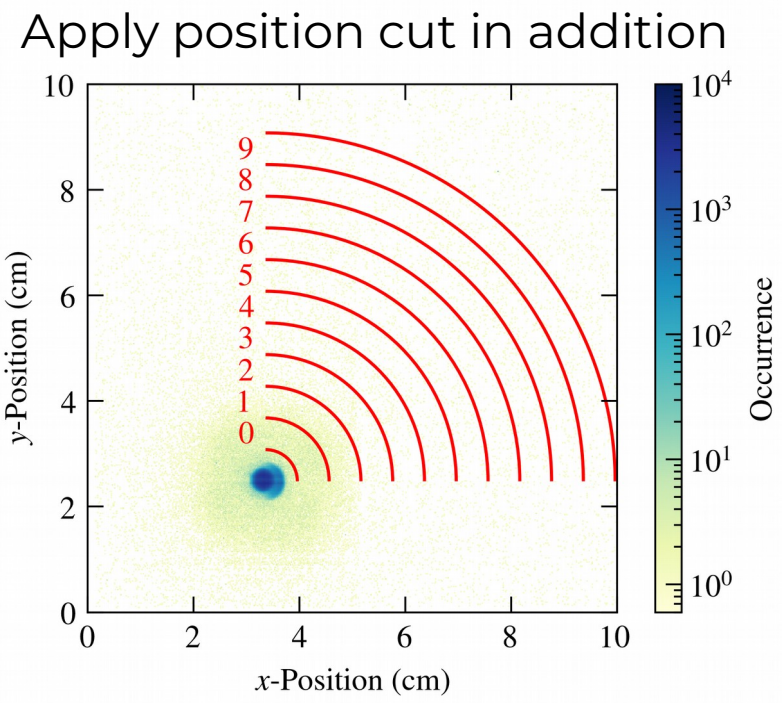


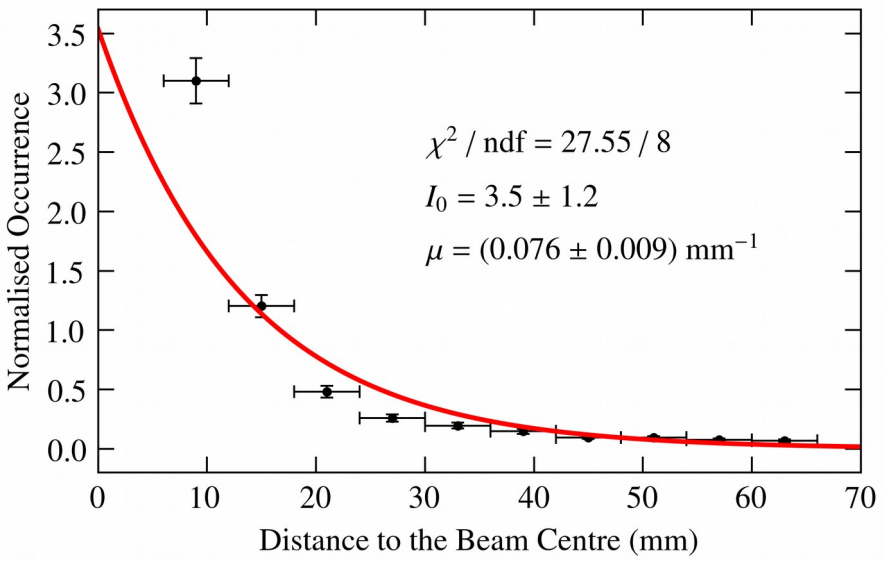
Multichannel Self Triggered, Continuous Readout & Good Time & Energy Resolution





Multichannel Self Triggered, Continuous Readout & Good Time & Energy Resolution





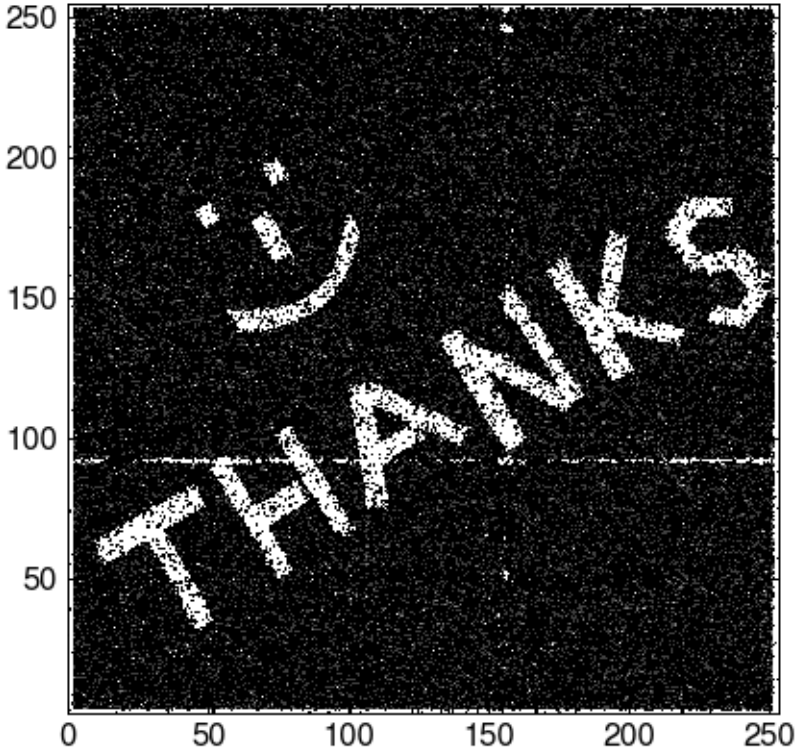
Conclusion and Outlook

- Detector physics results can be obtained

  → Features of the VMM are operational and beneficial

  → Some results could not have been performed without these features
- Start to improve the system based on these results:
  - High rate capability
  - Time resolution and time correction
  - Energy resolution
- System is not (yet) plug and play!

  → A lot of effort was necessary to be able to perform these measurements



for your Attention