Gaseous Detector Studies with the VMM3a ASIC and the SRS

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INSTR20, Novosibirsk
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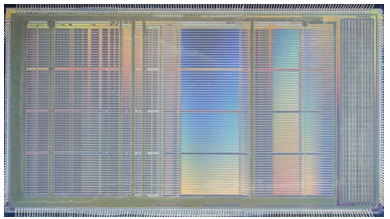
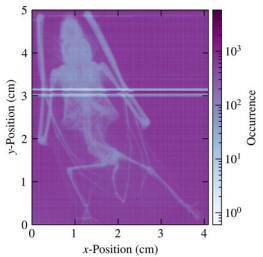
Outline

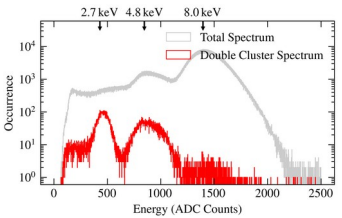
1. VMM in the SRS



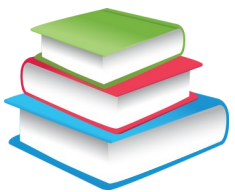
2. X-Ray Imaging



3. X-Ray Fluorescence



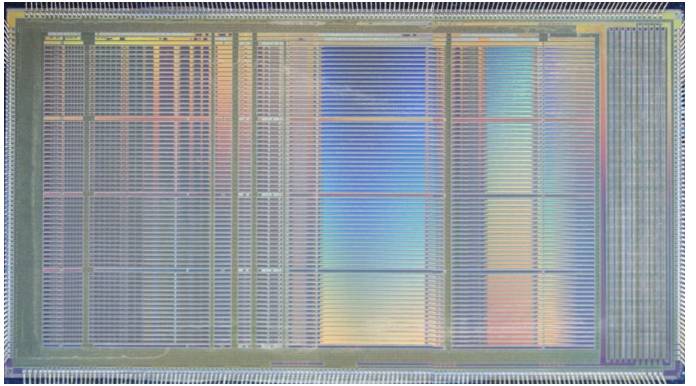
4. Summary



VMM3a and SRS: A Short Overview

VMM3a Specifications

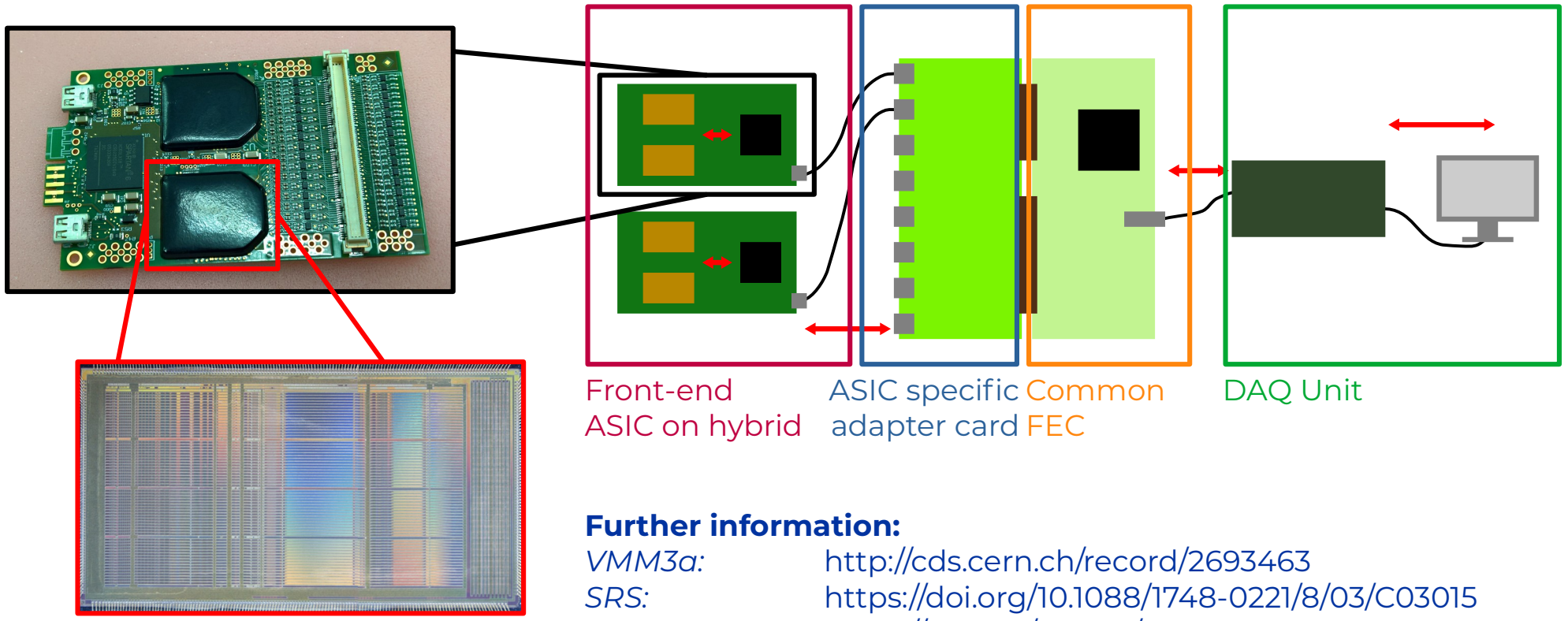
- 64 channels
- Developed by BNL for ATLAS New Small Wheel Upgrade
- **High rate capability** → about 4 MHz/channel
- **Self triggered, continuous read-out**
- Integrated zero suppression
- 10-bit **charge information**
- 12+8-bit **time information** → O(ns) time resolution
- **Neighbouring logic**
- …



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

VMM3a in the Scalable Readout System

Scalable Readout System (**SRS**) developed by the **RD51** collaboration for the readout of Micro-Pattern Gaseous Detectors (**MPGDs**)



Further information:

VMM3a: http://cds.cern.ch/record/2693463
SRS: https://doi.org/10.1088/1748-0221/8/03/C03015
VMM3a in SRS: https://doi.org/10.1016/j.nima.2018.06.046

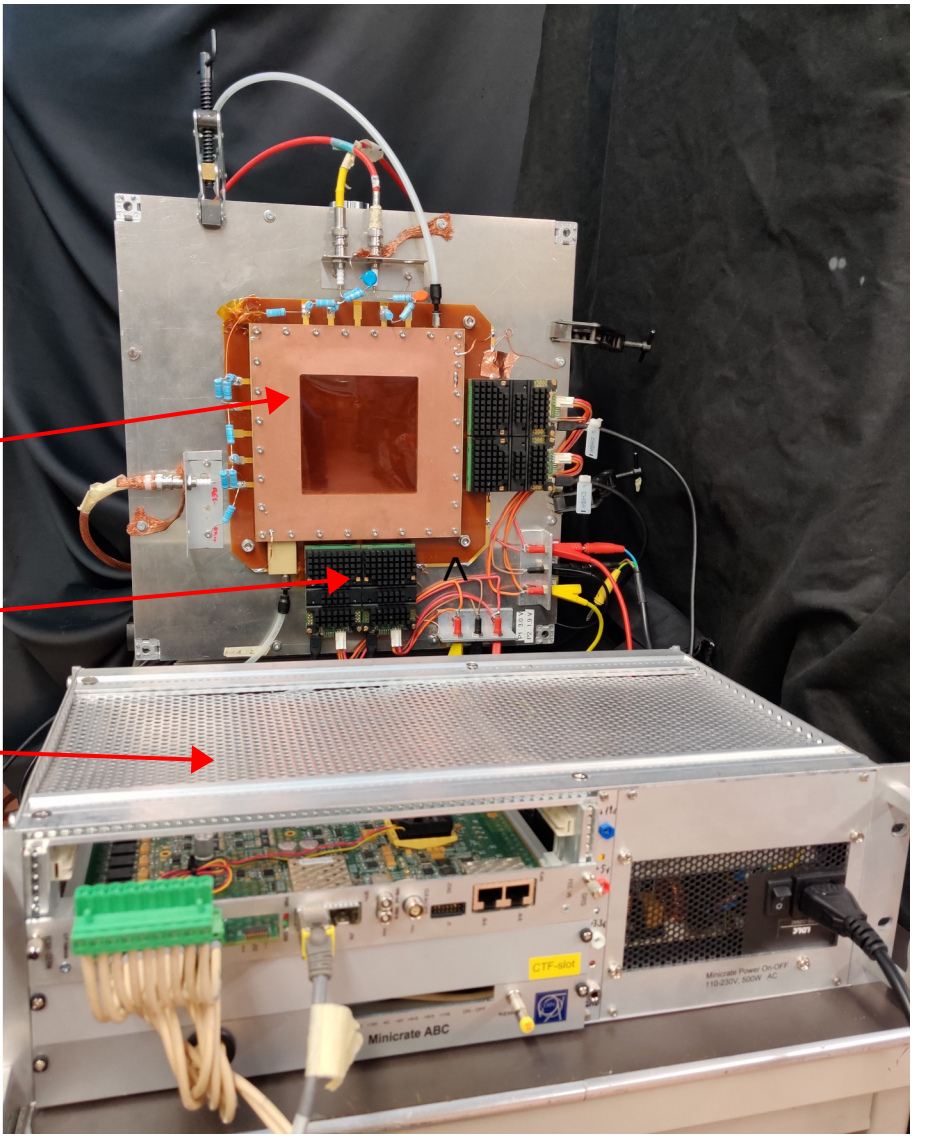
VMM3a/SRS + Detector

Experimental setup used for the measurements: COMPASS-like **triple-GEM** detector read out with **VMM3a hybrids** implemented into the **SRS**

10 x 10 cm^2 COMPASS-like Triple-GEM detector
3 mm drift gap
2 mm transfer/induction gap
gas mixture: Ar/CO_2 (70/30%)

VMM3a hybrids

SRS mini-crate with one FEC and D-Card sufficient for an R&D detector

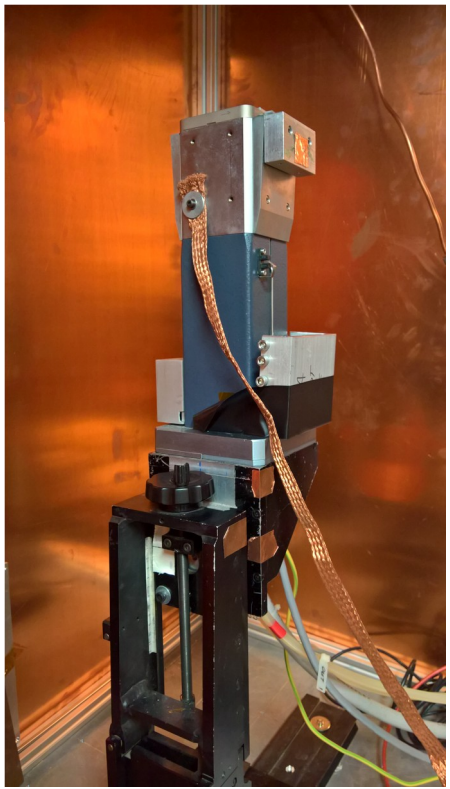


Similar setups, but with APV25, have been used by ATLAS and CMS for testing their MPGD upgrades

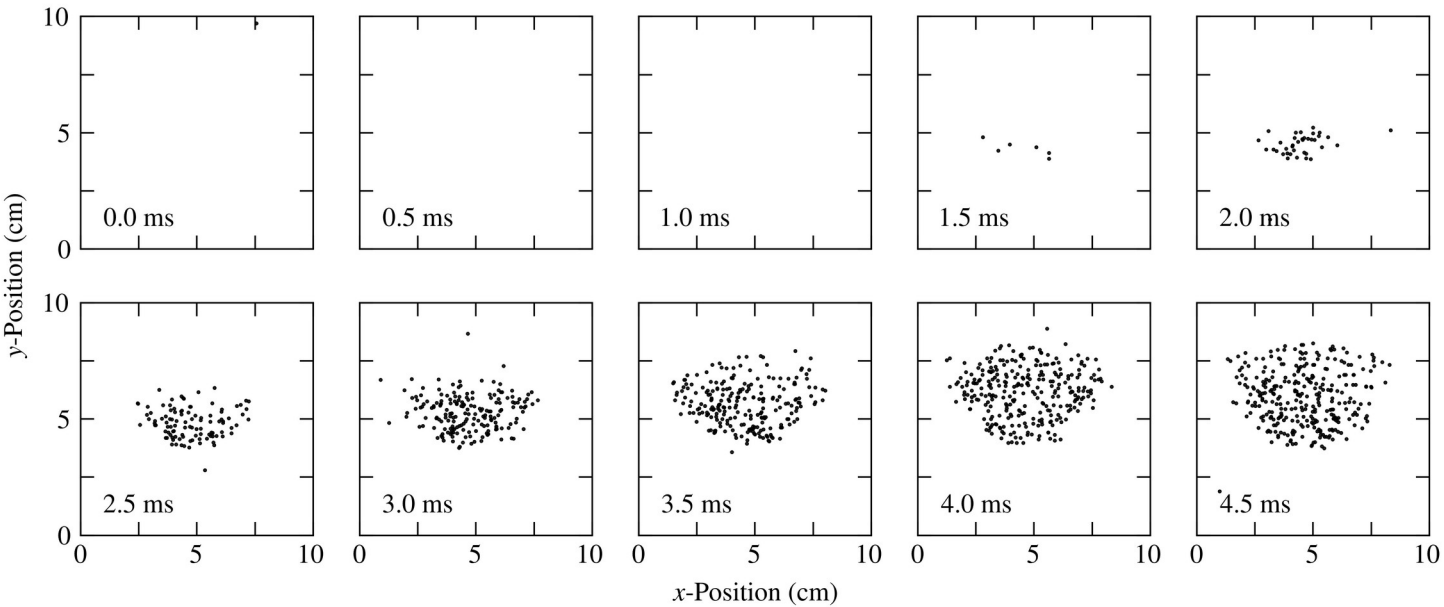
X-Ray Imaging with VMM3a/SRS

Fast Continuous Processes

HIGH RATE CAPABILITY
CONTINUOUS READOUT



Opening of X-ray tube shutter, sliced in 500 µs long frames



High-Rate X-Ray Imaging

HIGH RATE CAPABILITY

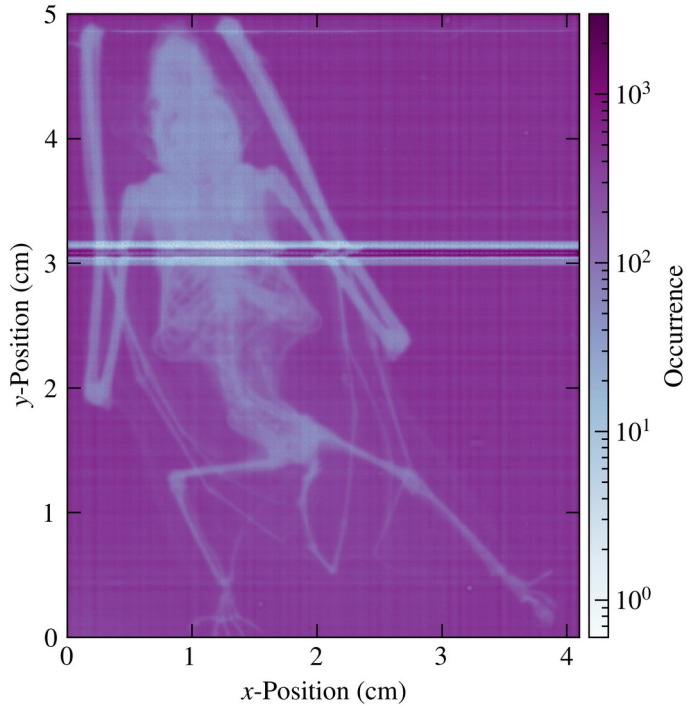
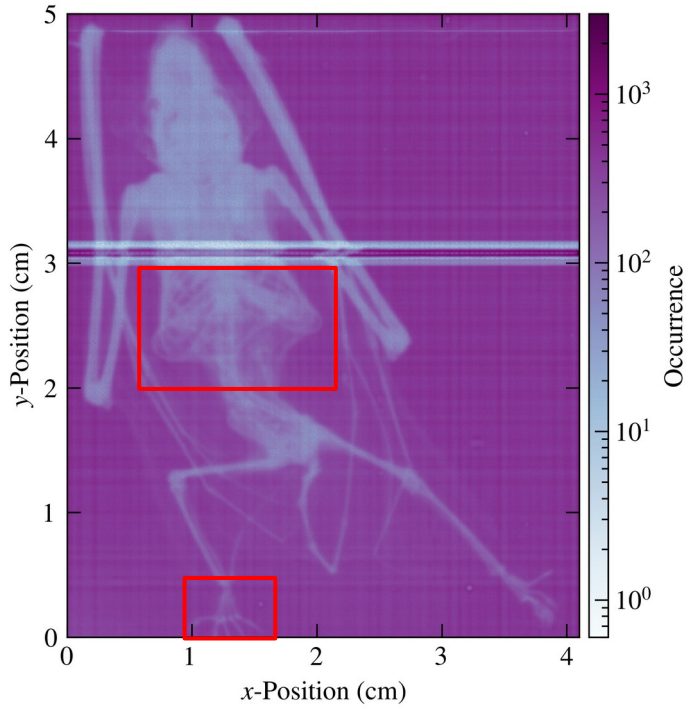


Image contains **421 x 10^6 X-ray interactions**
Acquisition time: **35 minutes**
Corresponds to 90 GB of raw data

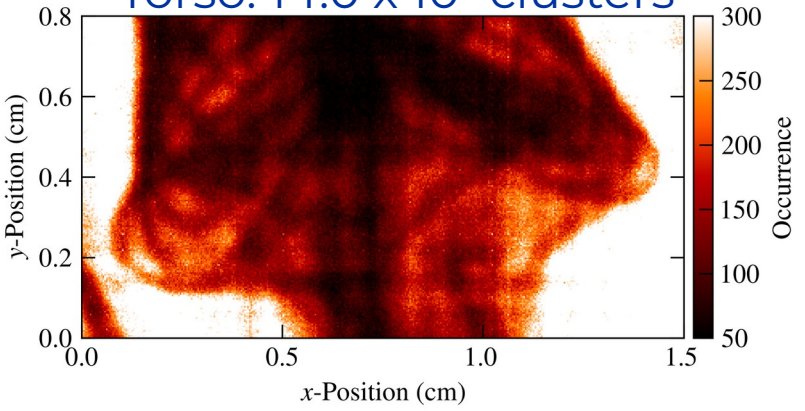
Comparison with predecessor (APV25),
assuming 500 Hz trigger rate: 10 days

High-Rate X-Ray Imaging

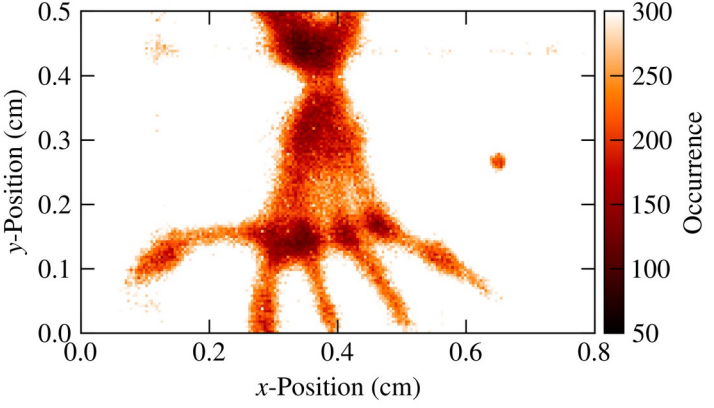
HIGH RATE CAPABILITY



Torso: 14.0 x 10^6 clusters



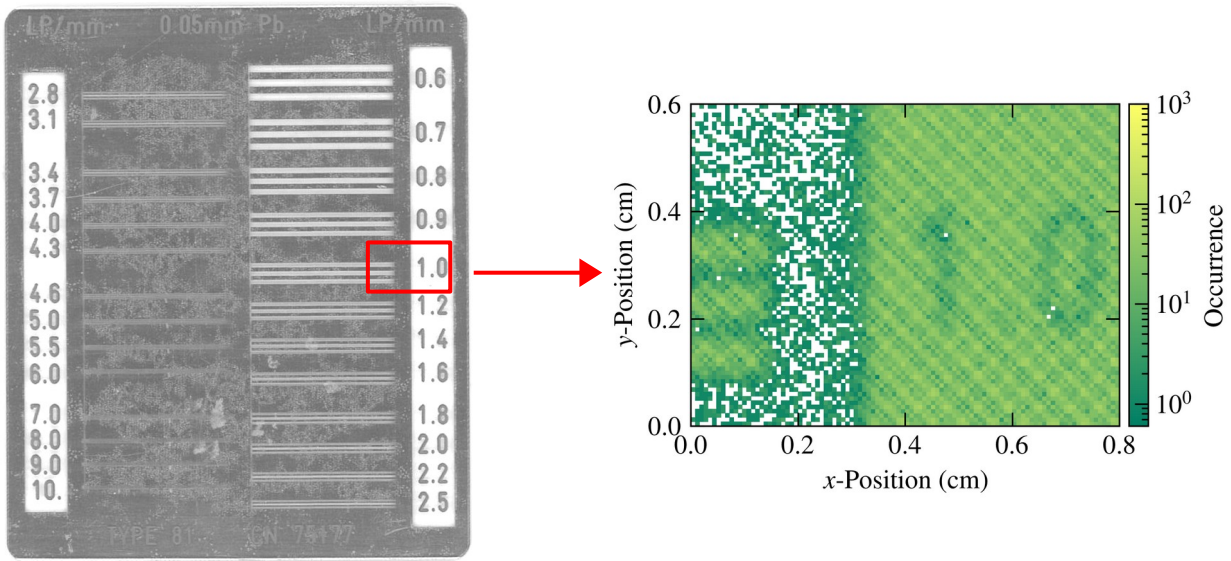
Claw: 8.5 x 10^6 clusters



Periodic Pattern in Image…

Goal for Imaging:
image with (very) good quality

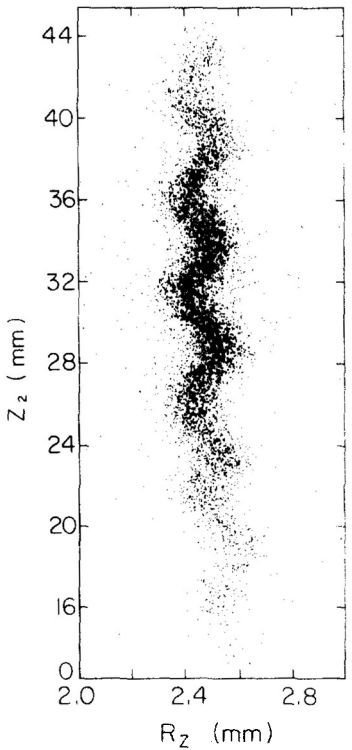
Advantage of VMM:
Speed



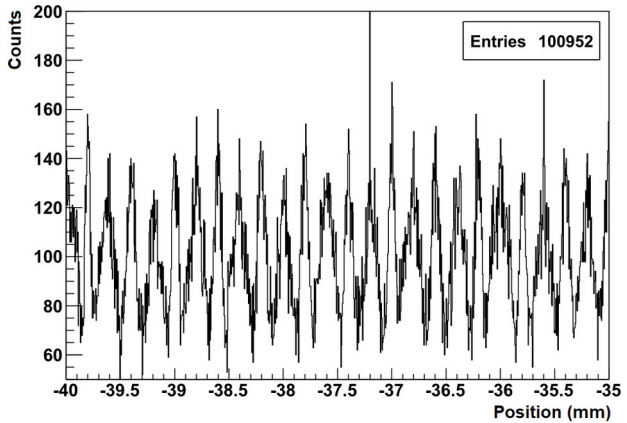
‘Problem’: a periodic pattern appears in the reconstructed image…

...Result of Segmented Readout with THL

Observed in **MWPC** with strip cathodes

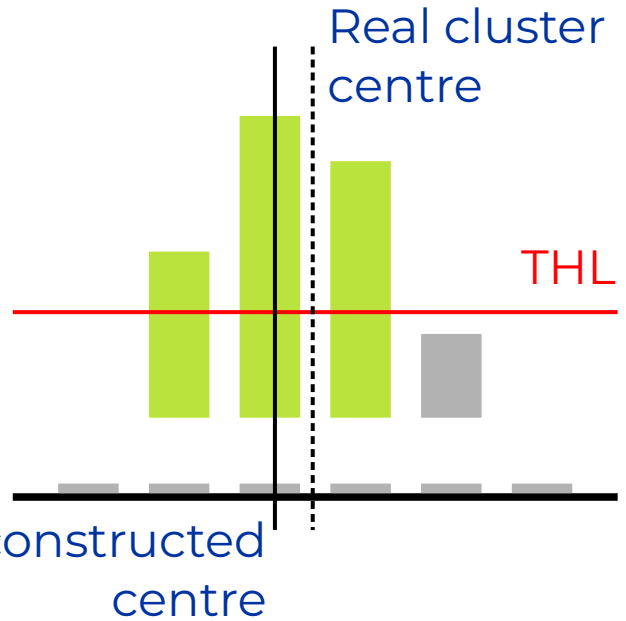


https://doi.org/10.1016/0029-554X(82)90113-6



Observed with **APV25**

measurement performed by H. Pulkkinen in 2013



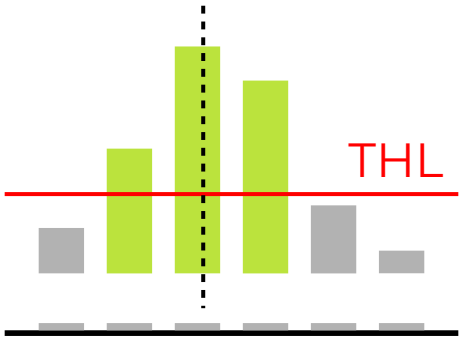
Result of **centre-of-gravity** method:
fast and straight forward position reconstruction, but fluctuations introduced due to threshold

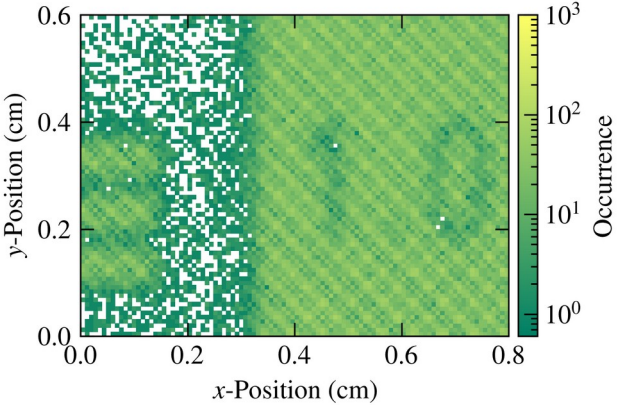
Can the VMM Help Us?

NEIGHBOURING LOGIC

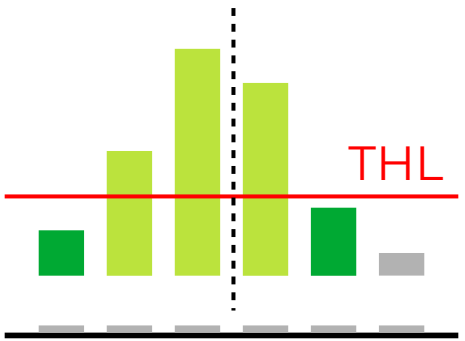
VMM offers different way of dealing with the threshold level

Standard approach





Neighbouring logic enabled



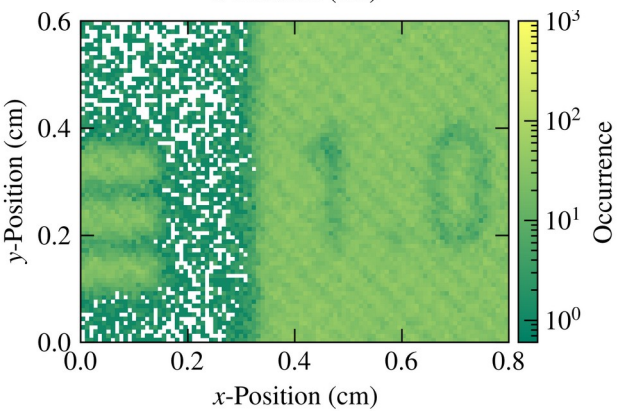


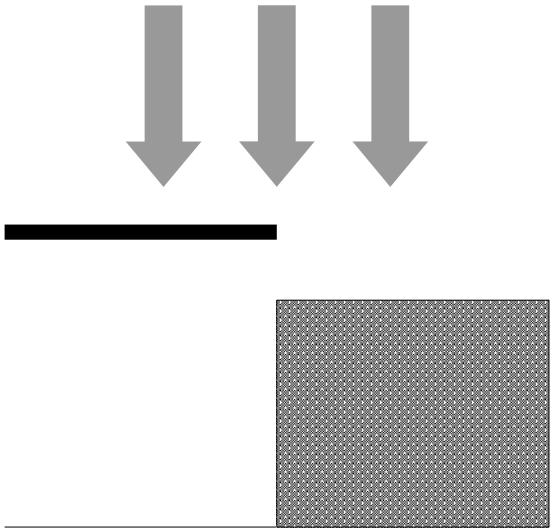
Image quality improves!

Can we find a quantitative expression or is this just some smoothing?

Spatial Resolution via ESF

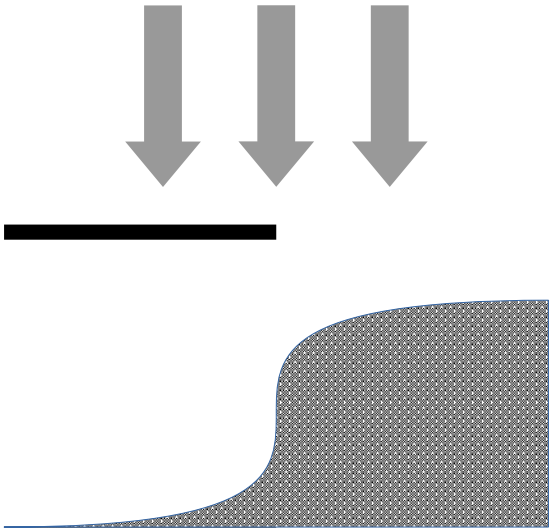
Use edge spread function (ESF) for quantitative investigation:
What is the effect of the neighbouring logic on the spatial resolution?

X-ray/light source

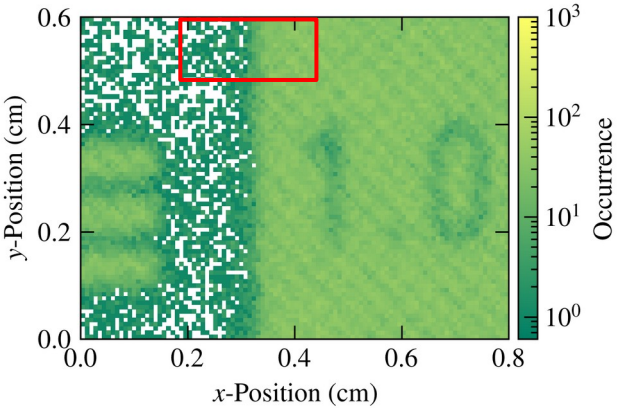


Ideal scenario

X-ray/light source



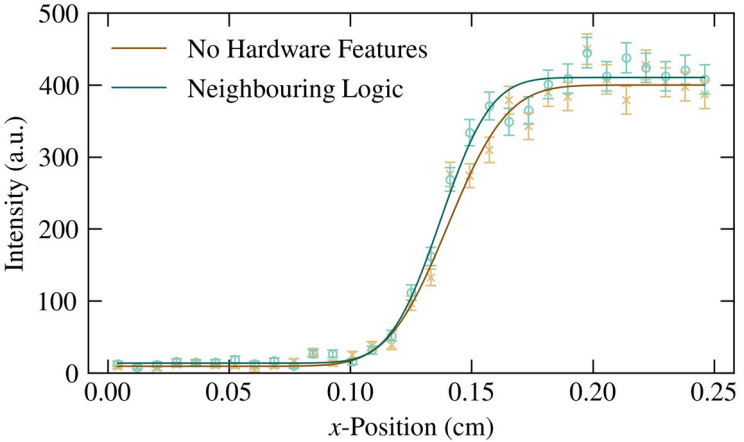
Reality



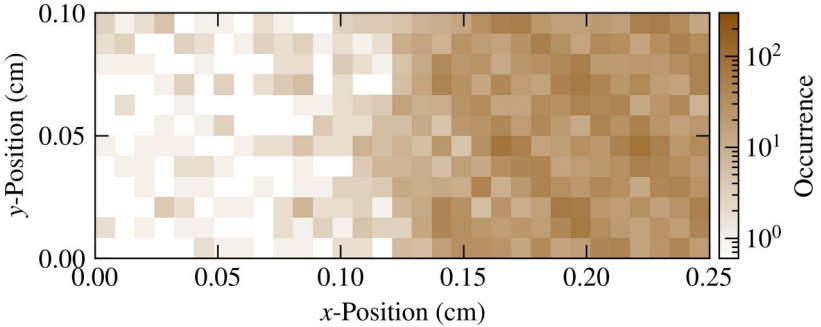
Selection for our analysis

Spatial Resolution via ESF

NEIGHBOURING LOGIC



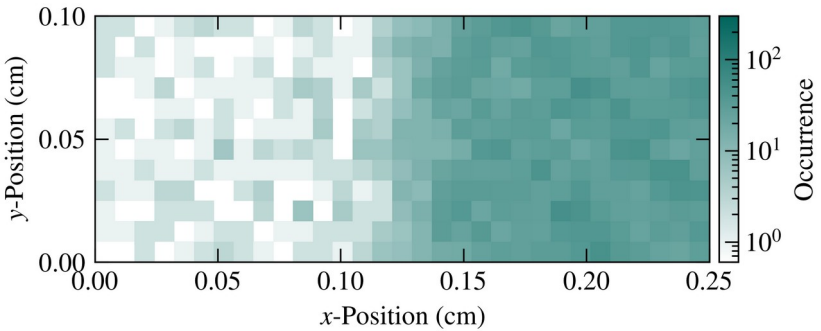
Standard approach



$\sigma_{Standard}$ = 193 µm

$\sigma_{Neighbouring}$ = 164 µm

Neighbouring logic enabled



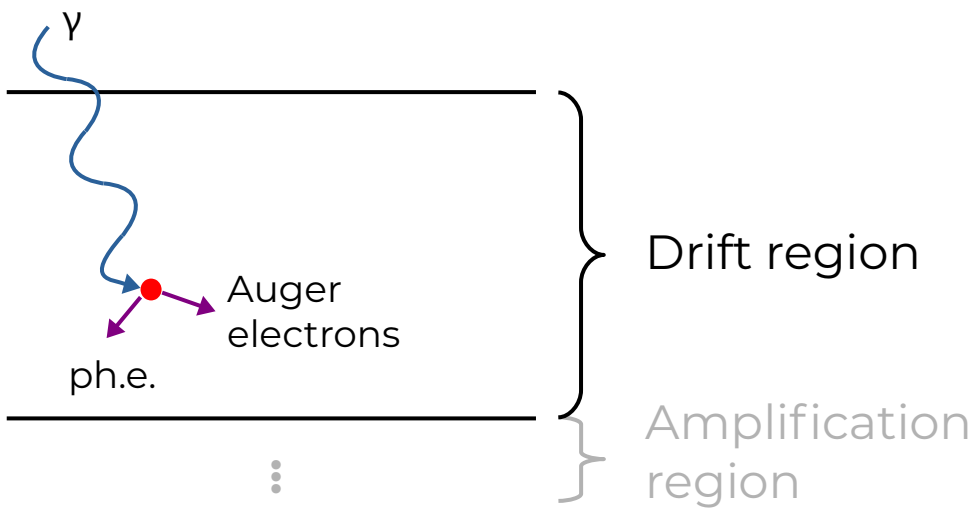
Neighbouring logic **improves** spatial resolution (via ESF method and X-rays) by about **15%**

X-Ray Fluorescence Measurements

X-Ray Fluorescence in Gaseous Detectors

Case A:

- photon-less energy release
- almost full energy deposition
- Single cluster event



X-Ray Fluorescence in Gaseous Detectors

Case A:

- photon-less energy release
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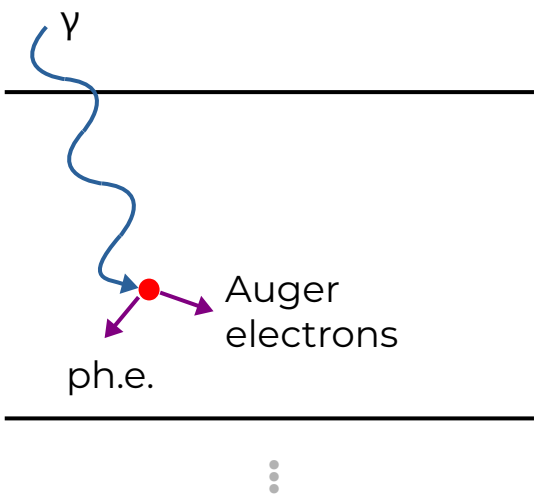
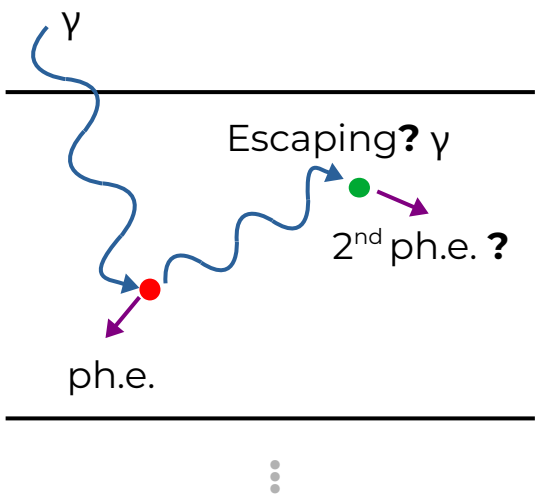


Case B:

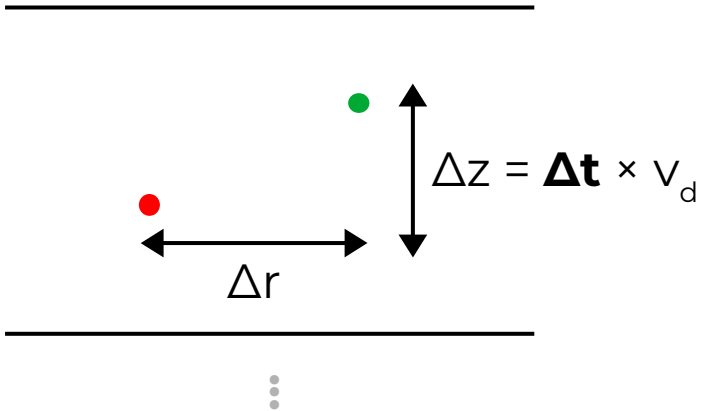
- emission of characteristic X-rays
- most likely: escape of active detector area



Resolving Fluorescence X-Rays

TIME RESOLUTION
SELF-TRIGGERED, CONTINUOUS READOUT

How can we resolve these events?
Separation in z-direction can be related to separation in time



3 mm drift gap with Ar/CO_2 (70/30) @ E_d = 1.25 kV/cm
→ according to Magboltz (11.7) $\mathbf{v_d = 4\ cm/\mu s}$

Maximum time difference: $\mathbf{\Delta t_{max} = 75\ ns}$

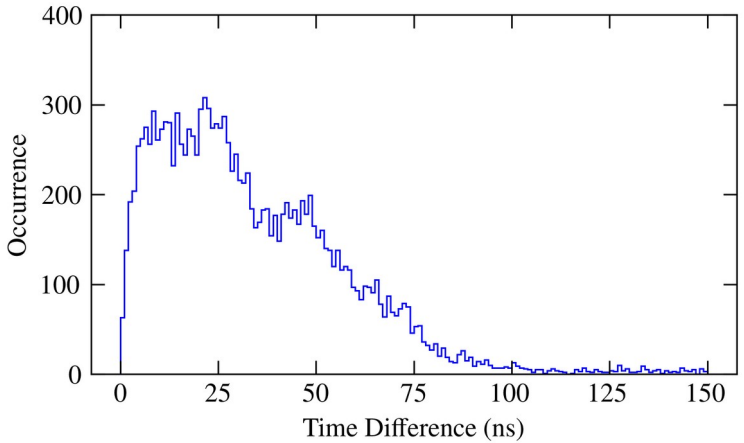
Resolving Fluorescence X-Rays

TIME RESOLUTION
SELF-TRIGGERED, CONTINUOUS READOUT

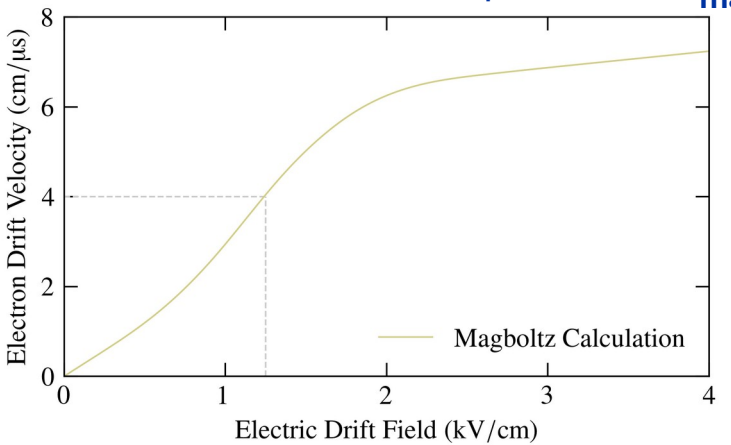
How can we resolve these events?

Separation in z-direction can be related to separation in time

→ Create a distribution of time differences and simply focus on the O(10 ns) region



E = 1.25 kV/cm → v = 4 cm/µs → **Δt_{max} ~ 75 ns**

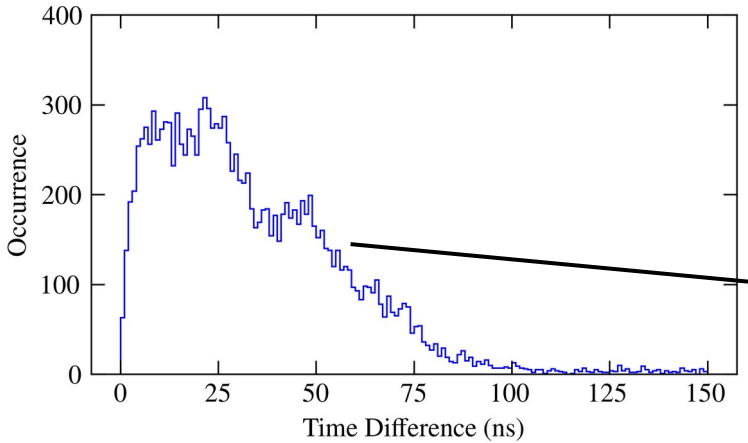


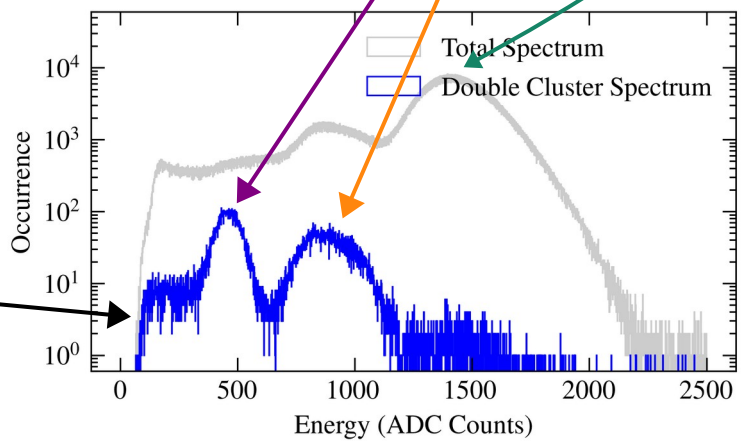
Introducing the Charge Information

TIME RESOLUTION
SELF-TRIGGERED, CONTINUOUS READOUT
CHARGE INFORMATION

Are the resolved events really the ones we are interested in?
→ check the spectrum

8 keV γ's (copper target X-ray tube)
Most probable interaction: ~5 keV ph.e. + ~3 keV Auger
Also possible: ~5 keV ph.e. + ~3 keV fluor. Photon (escaping)
IF fluor. photon interacts: 2nd ph.e. @ ~3 keV

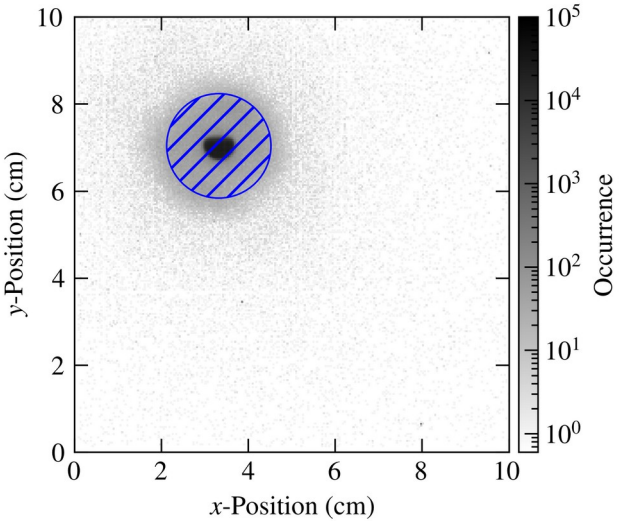


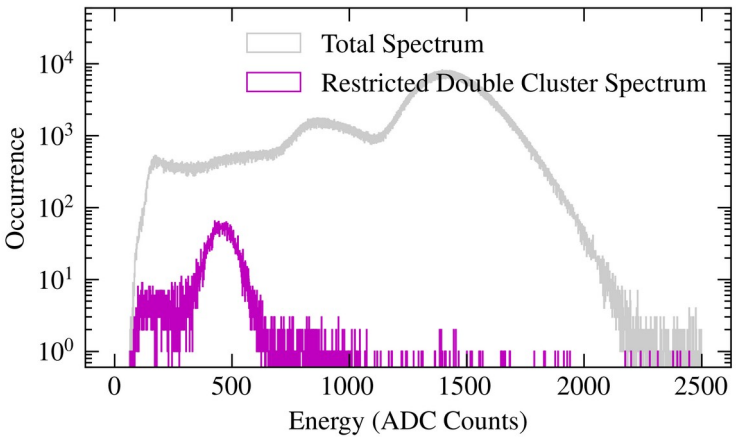


Using the Multichannel Readout

TIME RESOLUTION
SELF-TRIGGERED, CONTINUOUS READOUT
CHARGE INFORMATION

Multichannel = position sensitive readout
→ Exclude the region of the initial interaction, so 5 keV ph.e.



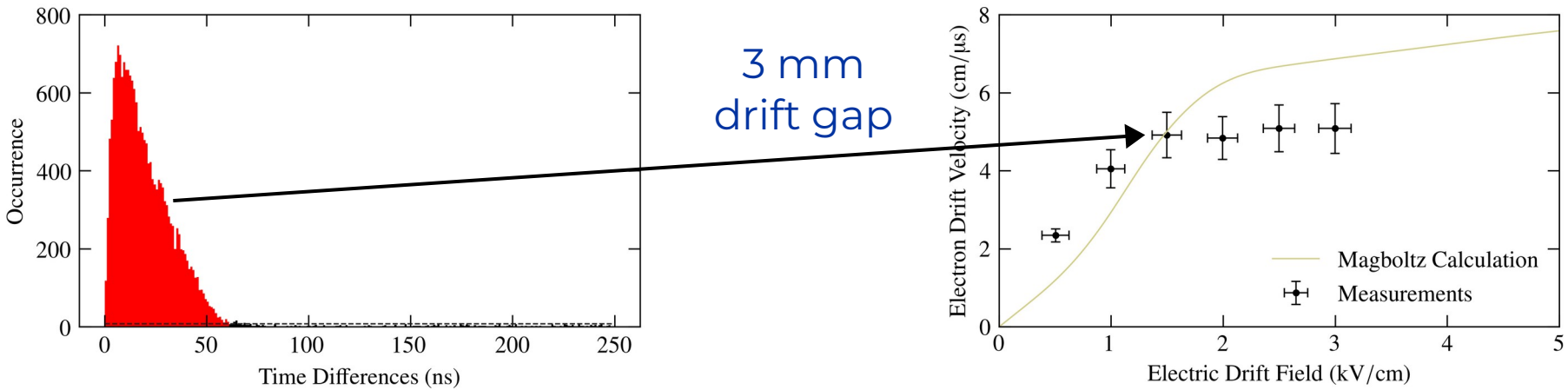


Remaining spectrum shows just the fluorescence interactions

Drift Velocity in Our Detector

Identification procedure: check time difference distribution in the O(10 ns) region

Invert this procedure: get cut-off-value of distribution for different drift fields

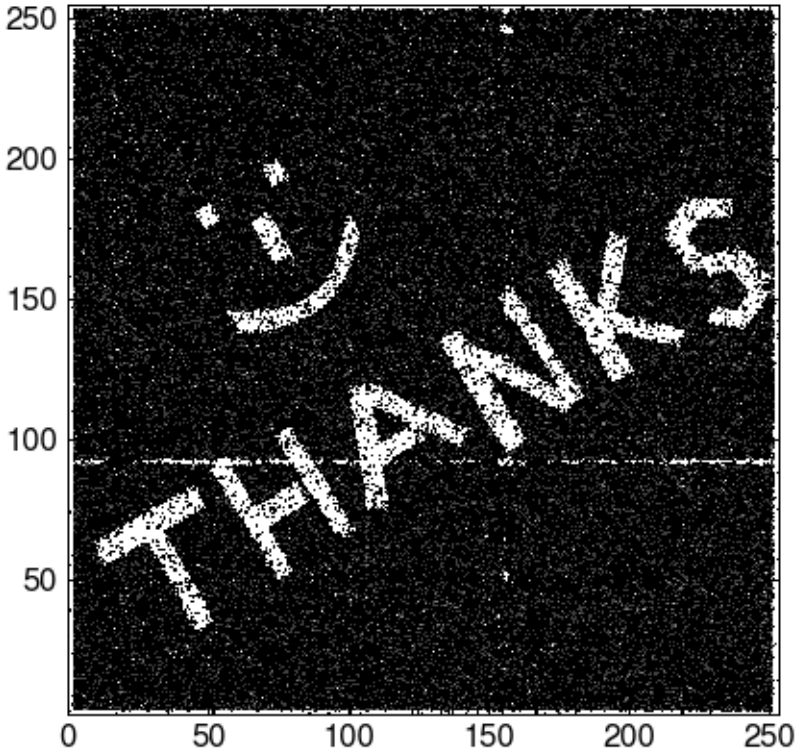


General trend is in agreement with expectation.
Deviation is part of further studies

Summary

Summary

- VMM3a/SRS offers many different features for detector physics and imaging studies
  - O(ns) time resolution
  - Good energy resolution
  - Continuous readout
  - High-rate capability
- All of these features are operational and can be used to get a better understanding of the detector
- VMM3a/SRS is a powerful successor of APV25/SRS



for your Attention