

# The LHCb Mighty Tracker pixel sensor characterisation and multi-module serial powering prototyping

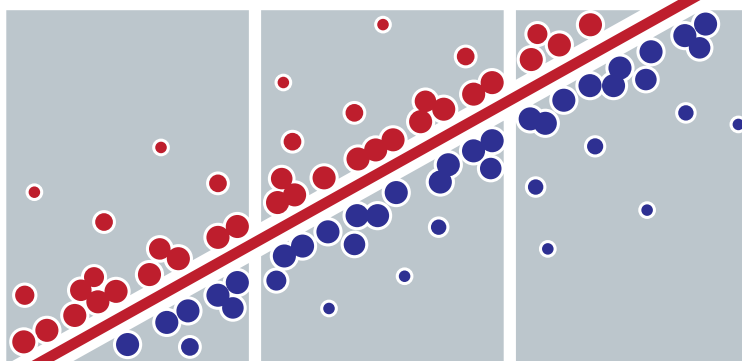
Daniel Foulds-Holt on behalf of the Mighty Tracker Sensor Community

IOP Joint APP and HEPP Annual Conference

9th April 2026

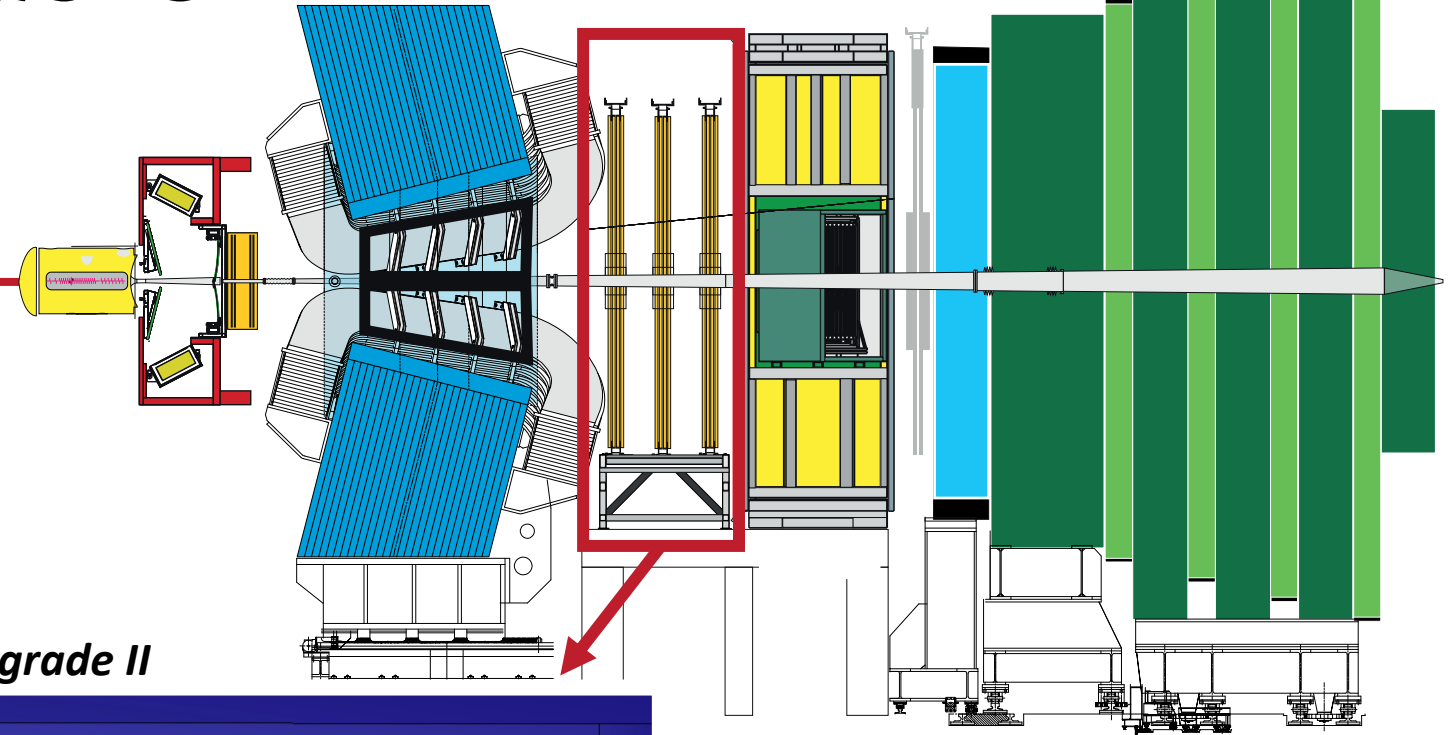


THE UNIVERSITY  
*of* EDINBURGH



# The LHCb Mighty Tracker

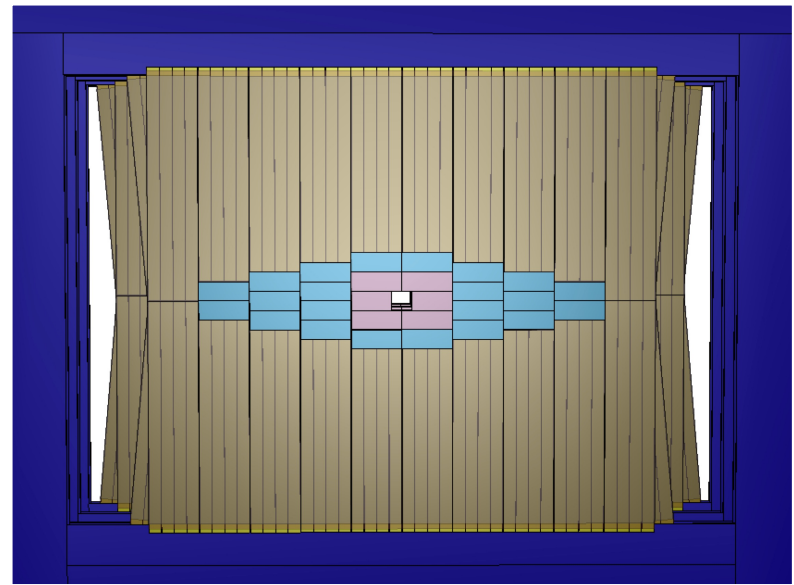
The **Mighty Tracker** is a proposed upgrade to the existing Scintillating Fiber (*SciFi*) tracker.



*Currently...*



*In Upgrade II*

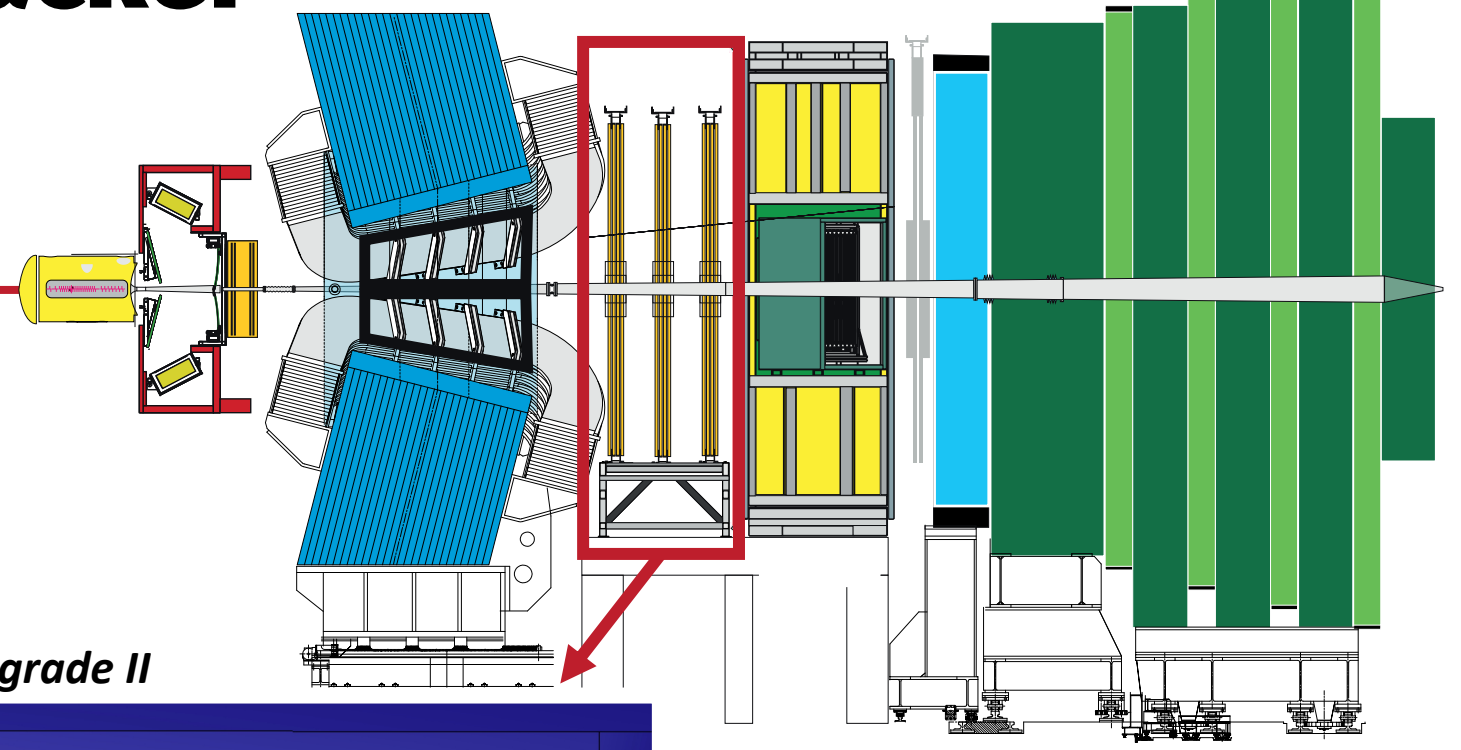


# The LHCb Mighty Tracker

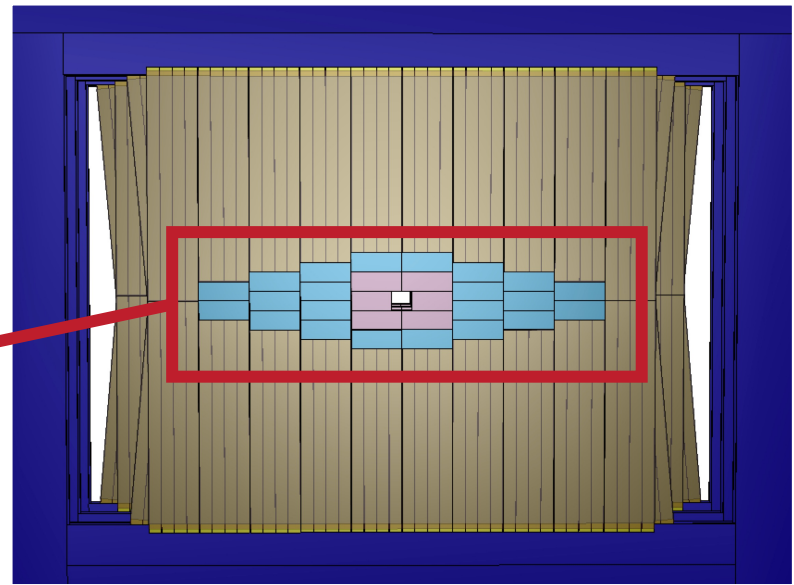
The **Mighty Tracker** is a proposed upgrade to the existing Scintillating Fiber (*SciFi*) tracker.

The center of Mighty Tracker will be instrumented with silicon pixel tracking sensors.

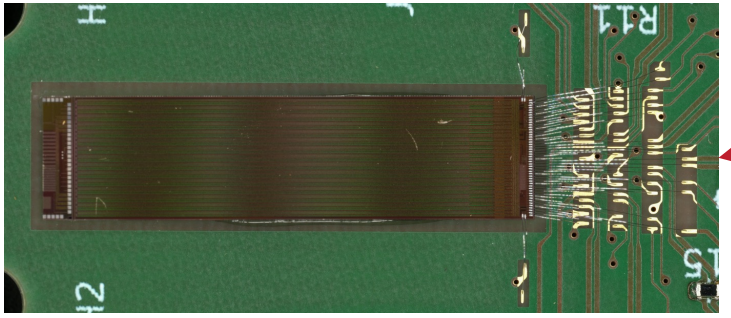
The characterization of these sensors is the object of my talk!



*In Upgrade II*



*A prototype pixel sensor*



*This is an international effort with multiple institutes contributing to these results.*

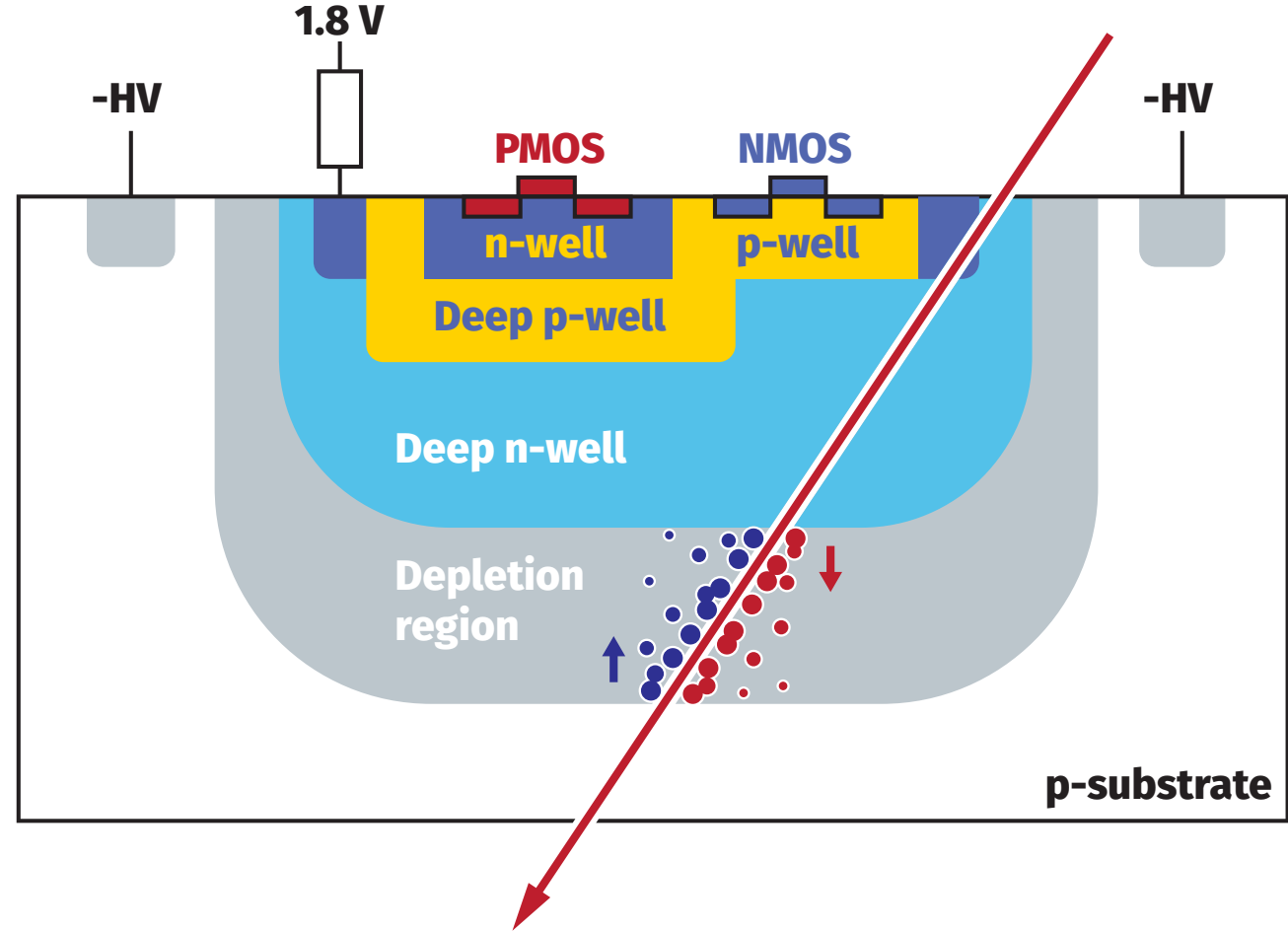
**In the UK:** Cambridge, Edinburgh, Glasgow, Liverpool, RAL

# HV-CMOS

The silicon sensor technology used is High-Voltage Complementary Metal Oxide Sensor (HV-CMOS).

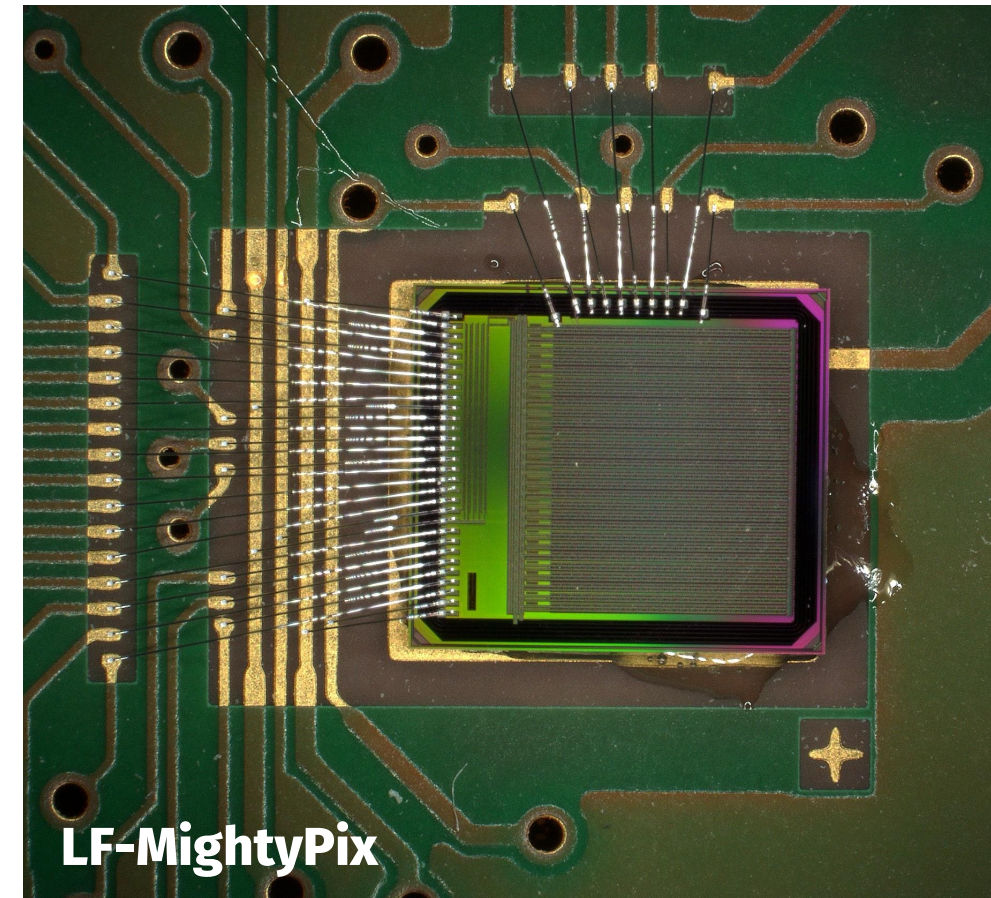
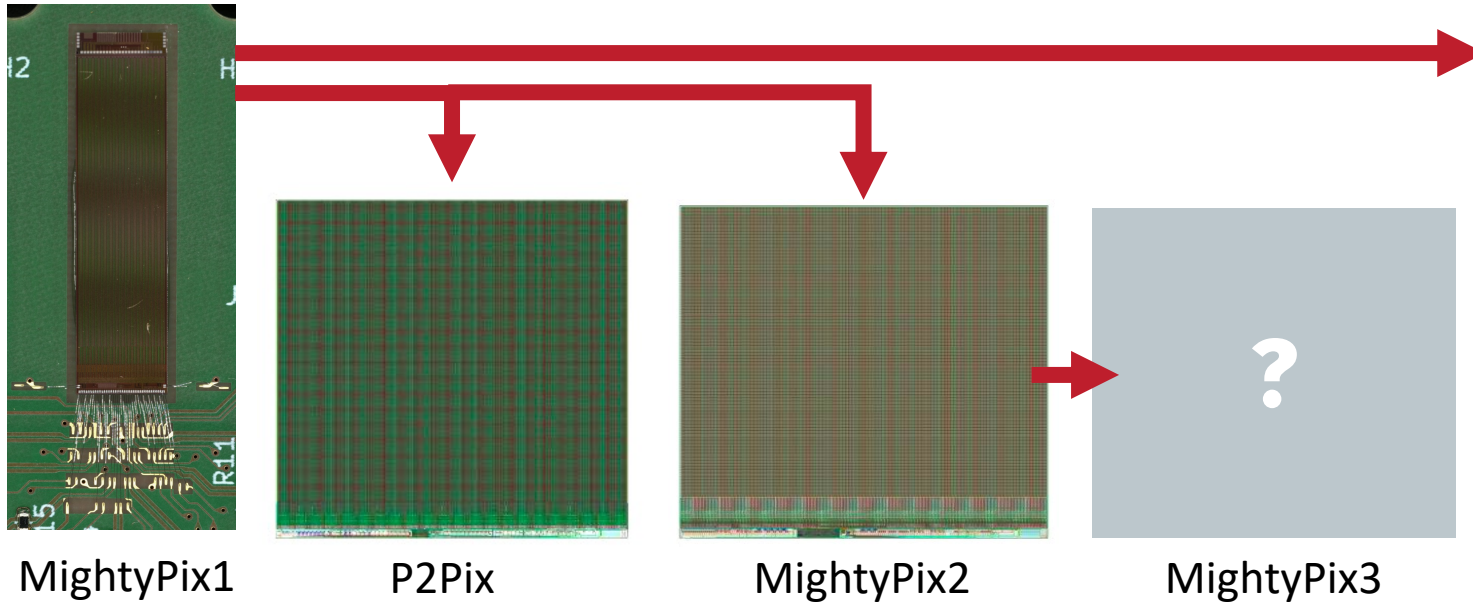
When a particle traverses the sensor, charge carriers are liberated. Under high e-fields, the charge drifts and towards, and is collected by, the readout electronics.

The HV-CMOS technology provides a monolithic sensor, where the electronics are integrated into the sensor silicon, removing the complexity introduced by external readout electronics.



# MightyPix

The MightyPix sensor series are a series of HV-CMOS sensors developed by KIT specifically for the MightyTracker requirements. The final MightyPix design is a candidate for installation in MightyTracker.



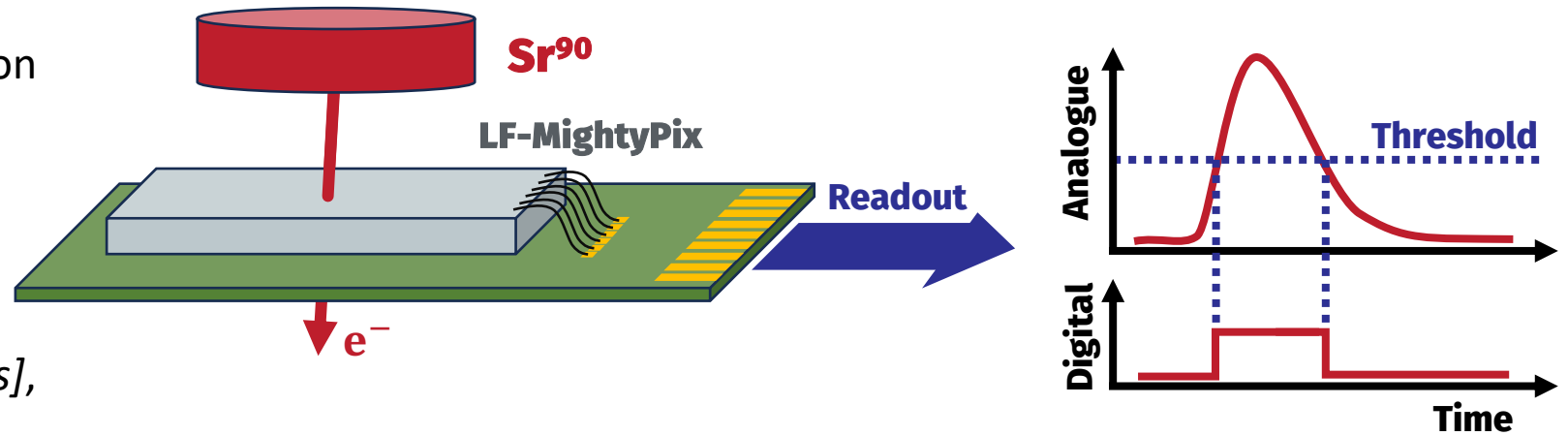
The latest version is that of the LF-MightyPix, which, while a very small prototype, contains many of the readout and sensor features that will be implemented in later chips. All results presented are from LF-MightyPix.

*MightyPix is only one of the candidate HV-CMOS chip designs for MightyTracker. See [Karol's talk](#) later this session for details on the RadPix, another one of them.*

Parameter	LF-MightyPix
Process	150 nm CMOS
Dimensions	3 mm x 4 mm
Number of pixels	28 x 23
Pixel pitch (X & Y)	100 $\mu$ m

# First sensor characterisation

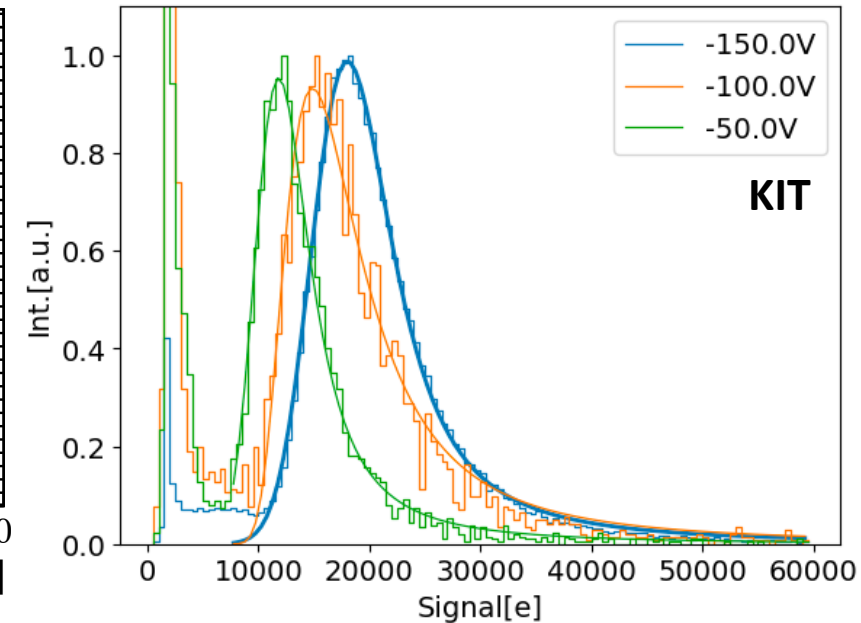
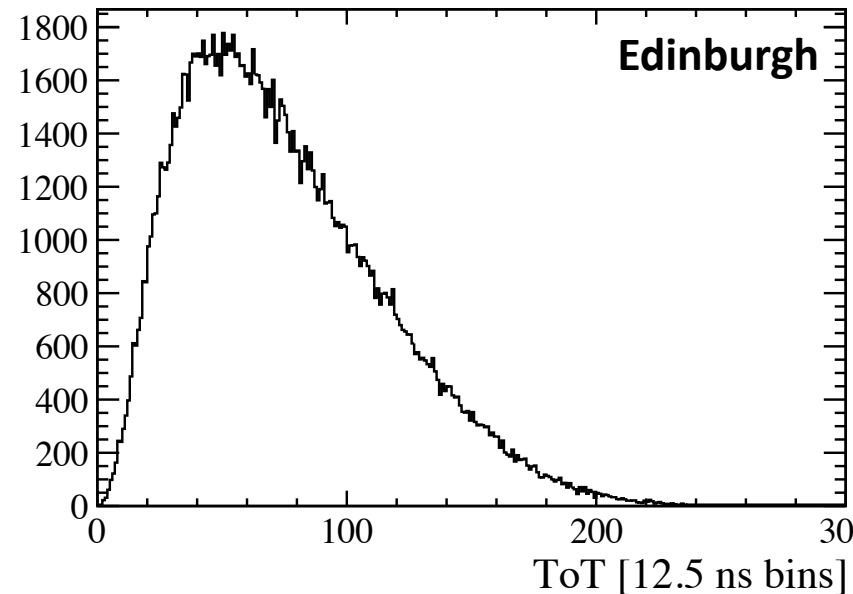
The easiest and first sensor characterisation that can be done is to record energy deposition from a radioactive source e.g. Strontium-90.



The signal time of arrival (ToA) [6.25ns bins], time over threshold (ToT) [12.5ns bins], and Pixel position are provided by the LF-MightyPix readout.

## What do we want to measure:

- Time resolution
- Cross-talk
- In-time efficiency
- etc.

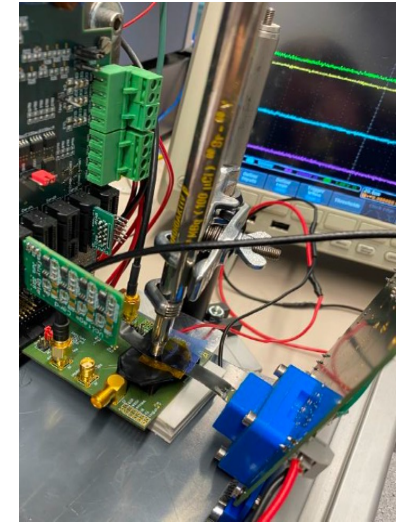
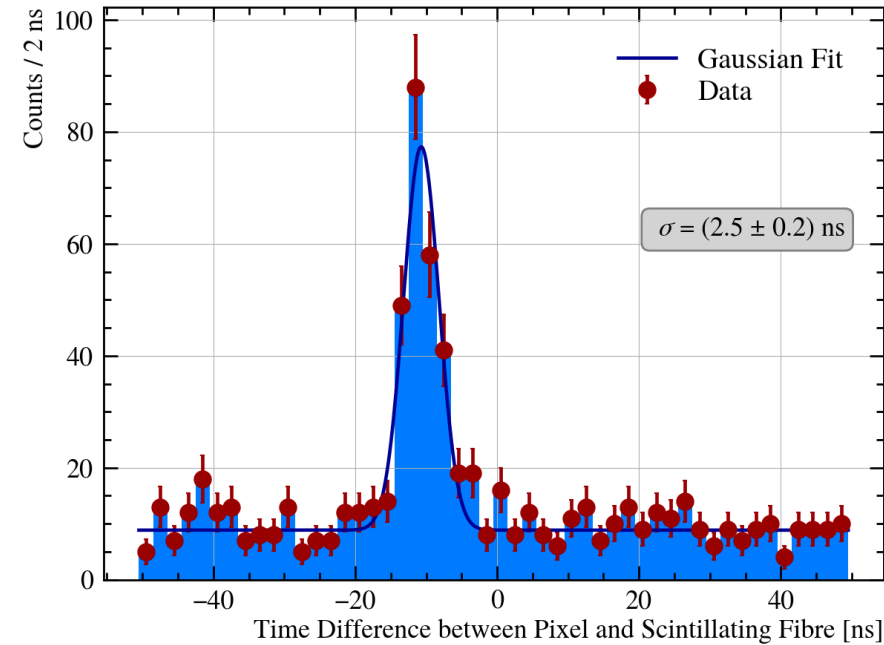


# Scintillator based time resolution

A scintillator placed between the source and sensor can provide an excellent time reference for timing analysis.

This has been done by [Celina Welschoff](#) in Heidelberg using a SciFi + SiPM module. The timestamps are obtained by digitising the analogue signal.

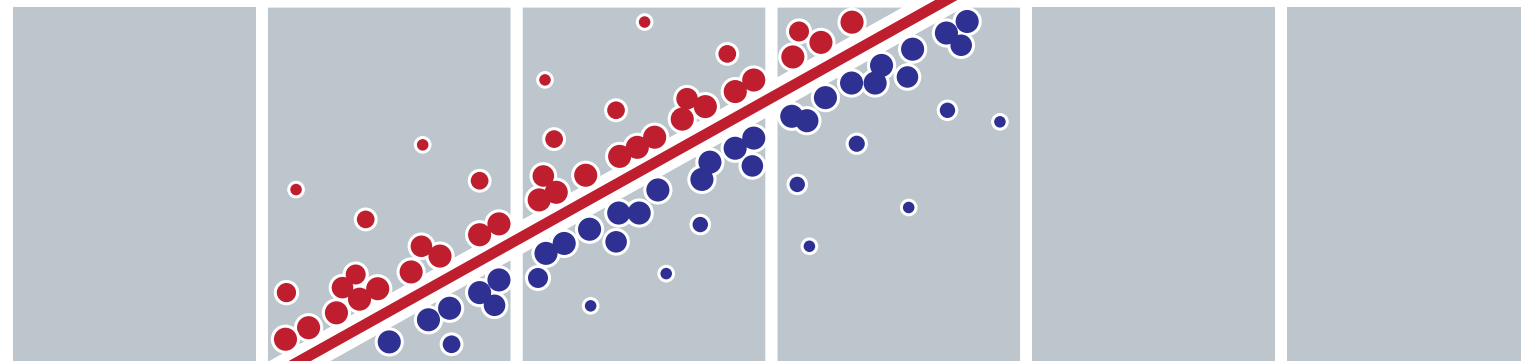
This allows for optimisation of the sensor configuration for performance.



Settings	Time resolution	Power consumption
Default	$4.1 \pm 0.3 \text{ ns}$	19.9 $\mu\text{W}/\text{Pixel}$
<b>Best timing</b>	<b><math>2.5 \pm 0.2 \text{ ns}</math></b>	29.7 $\mu\text{W}/\text{Pixel}$
Current Optimisation	$3.4 \pm 0.1 \text{ ns}$	21.0 $\mu\text{W}/\text{Pixel}$

*From Celina*

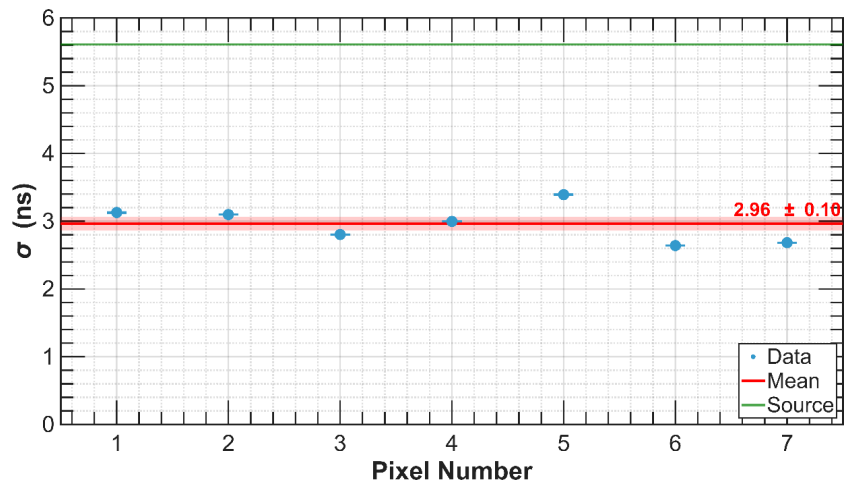
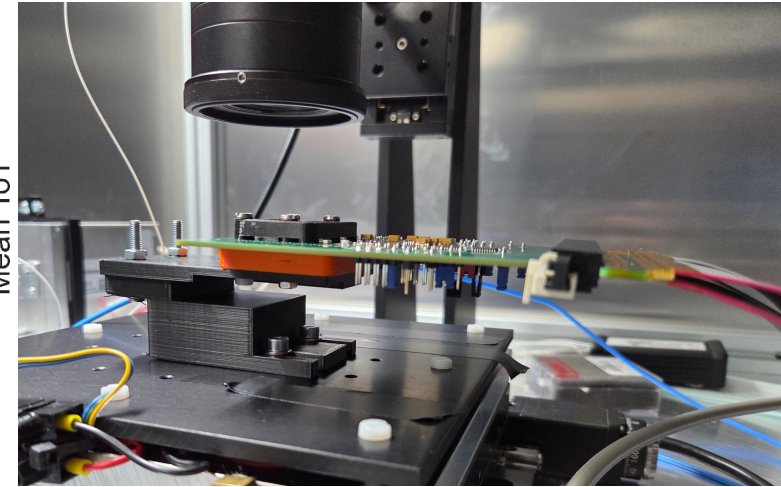
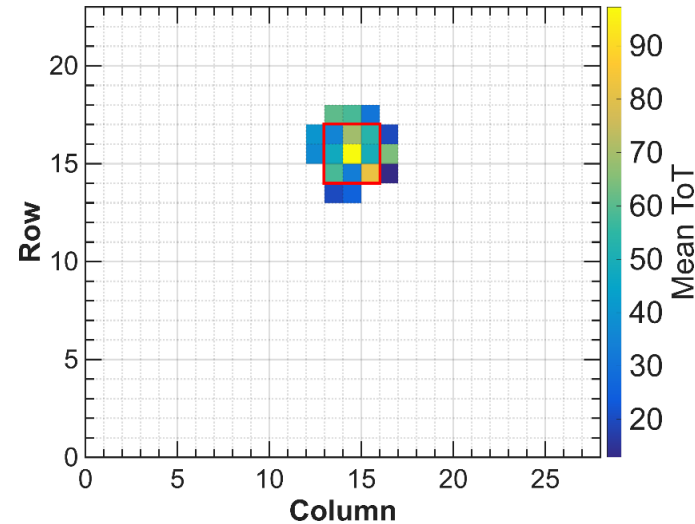
Scintillator



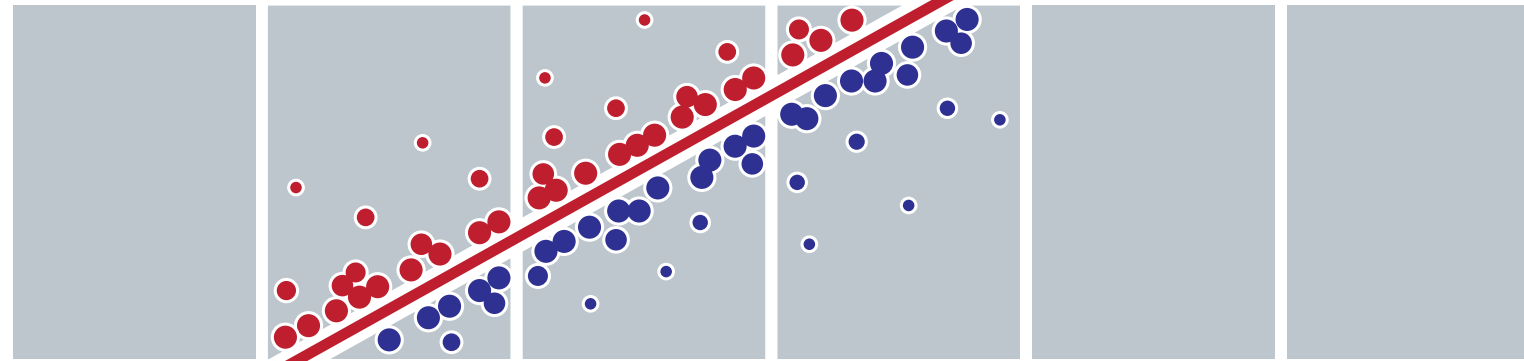
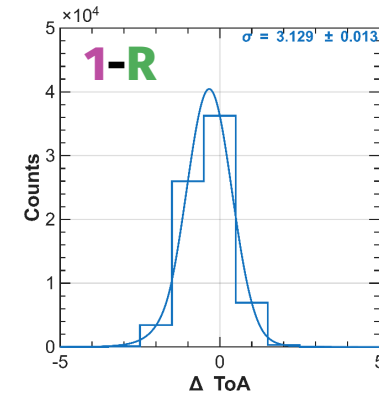
# Laser based time resolution

A near-infrared (1064 nm) laser is able to penetrate a few mm into silicon and deposit a column of charge, resembling a particle track.

In Edinburgh, tests with a defocused laser spot allows for simultaneous charge injection across multiple channels and therefore a precise measurement of the time resolution using the MightyPix readout electronics.



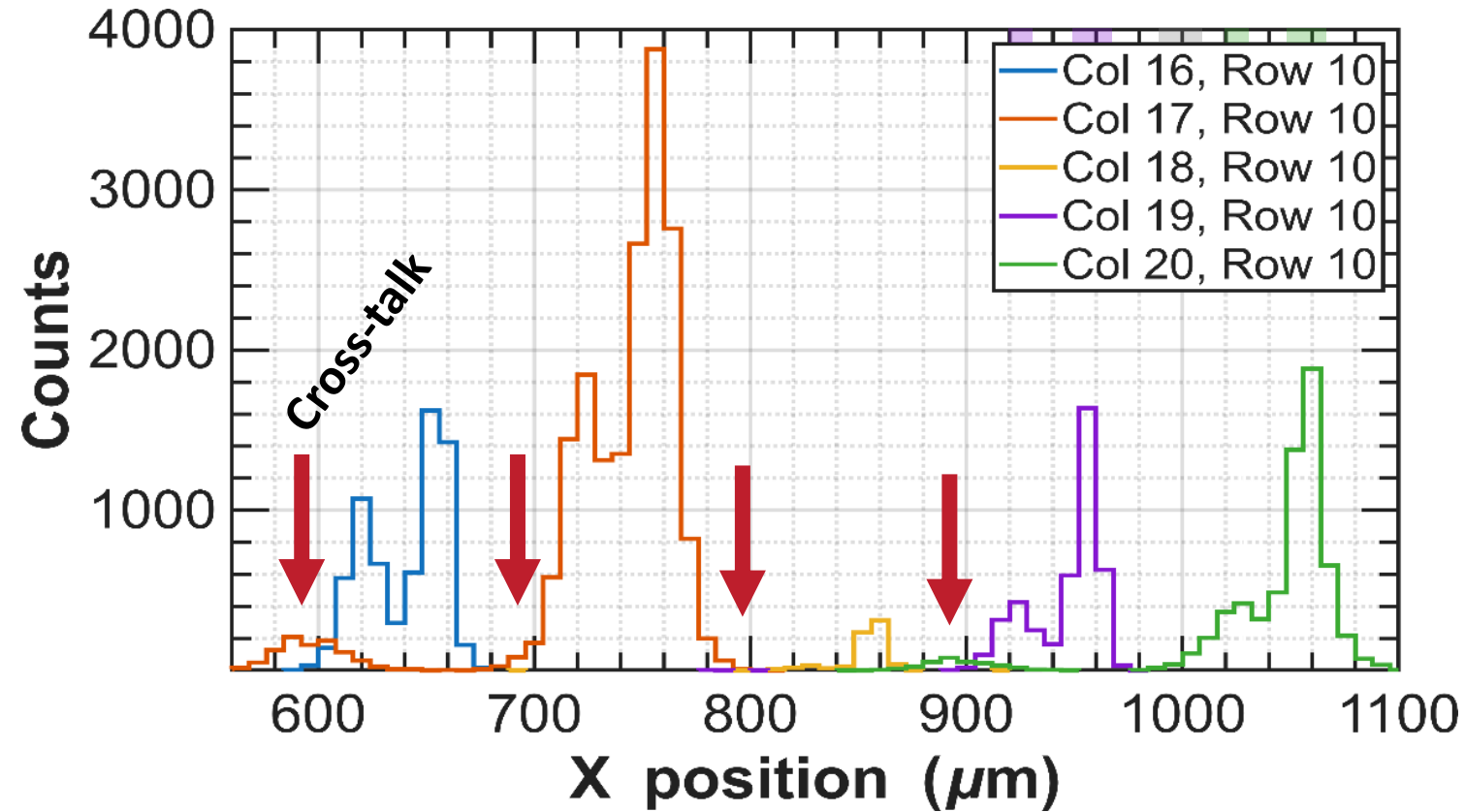
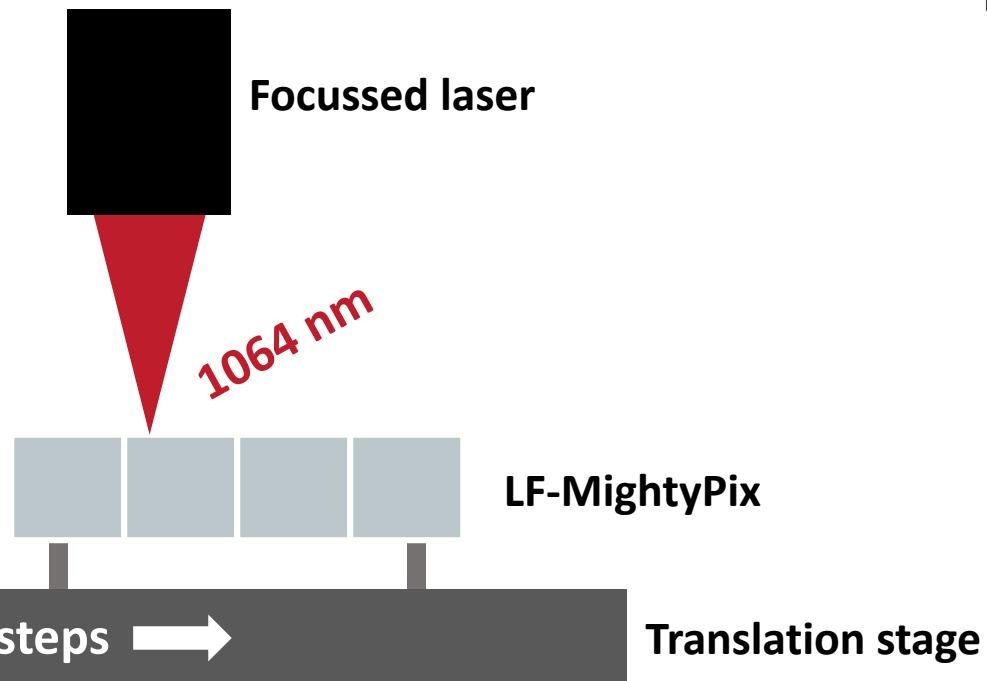
$$\sigma_{ToA} = 2.96 \pm 0.10 \text{ ns}$$



# Cross-talk measurement

Inspired by some measurements with MaPMTs by [Callum](#), the laser spot was focussed and translated across one row of the sensor.

This enables us to identify instances of cross-talk - as pixels that are not illuminated by the laser register hits.

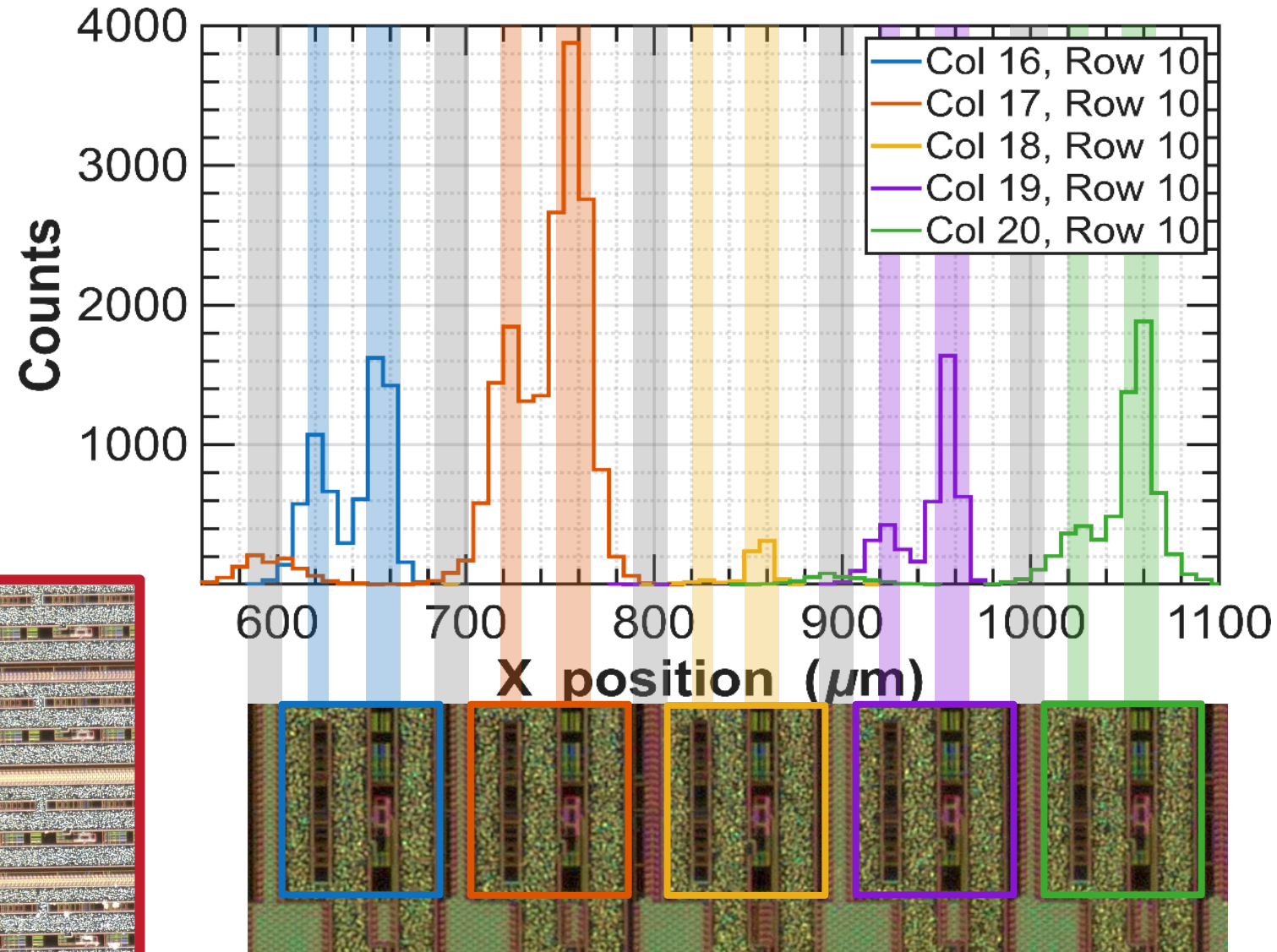
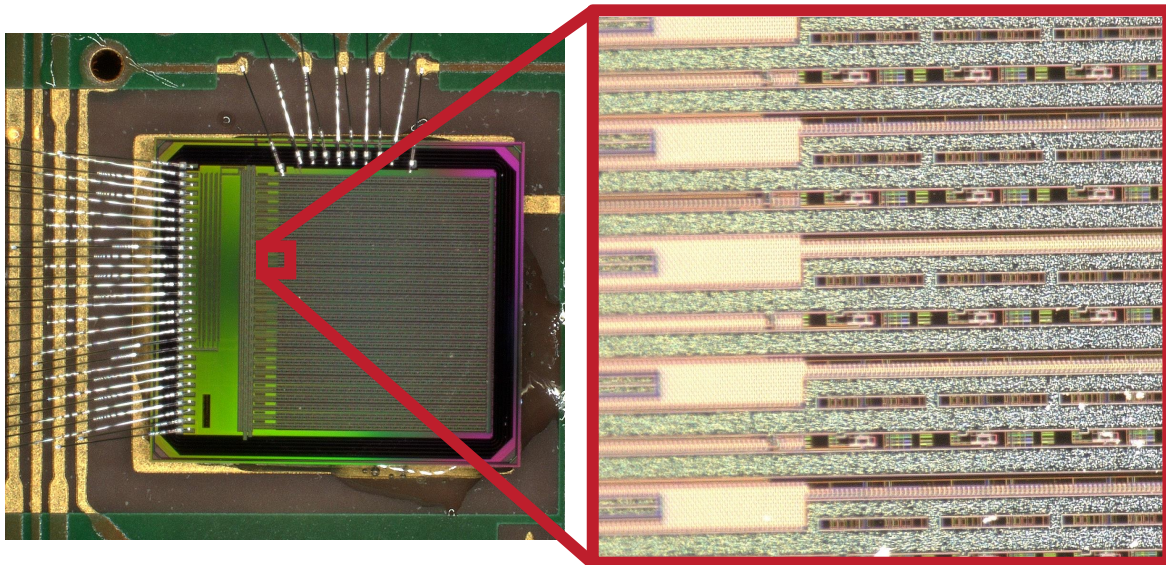


# Cross-talk measurement

Inspired by some measurements with MaPMTs by [Callum](#), the laser spot was focussed and translated across one row of the sensor.

This enables us to identify instances of cross-talk - as pixels that are not illuminated by the laser register hits.

We can observe the aluminium transmission lines reflecting laser light, and start to track down the cause of the cross-talk.



# Test beams

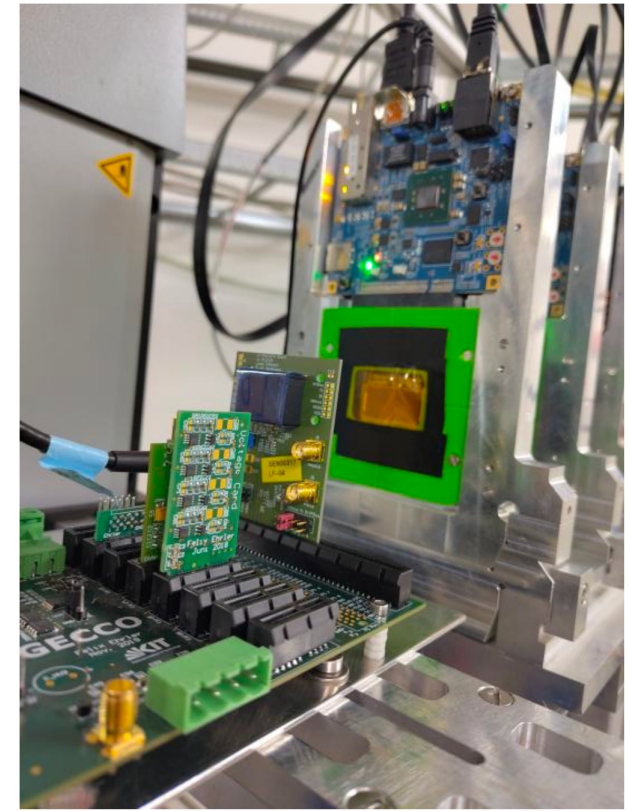
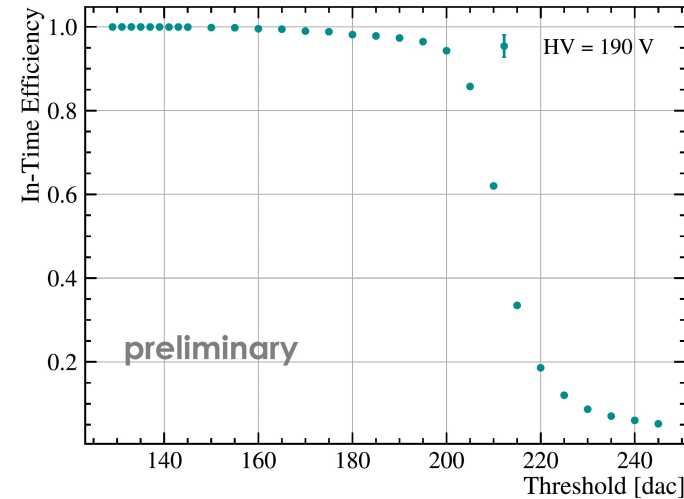
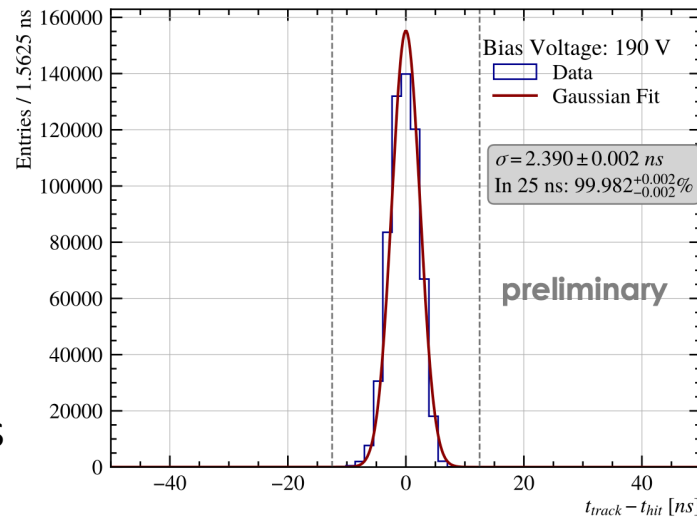
A LF-MightyPix test beam was performed by the Heidelberg group at DESY for 2 weeks in October 2025.

The surrounding DESY Alpile Telescope provides beam tracking with good timing, allowing for an accurate measurement of:

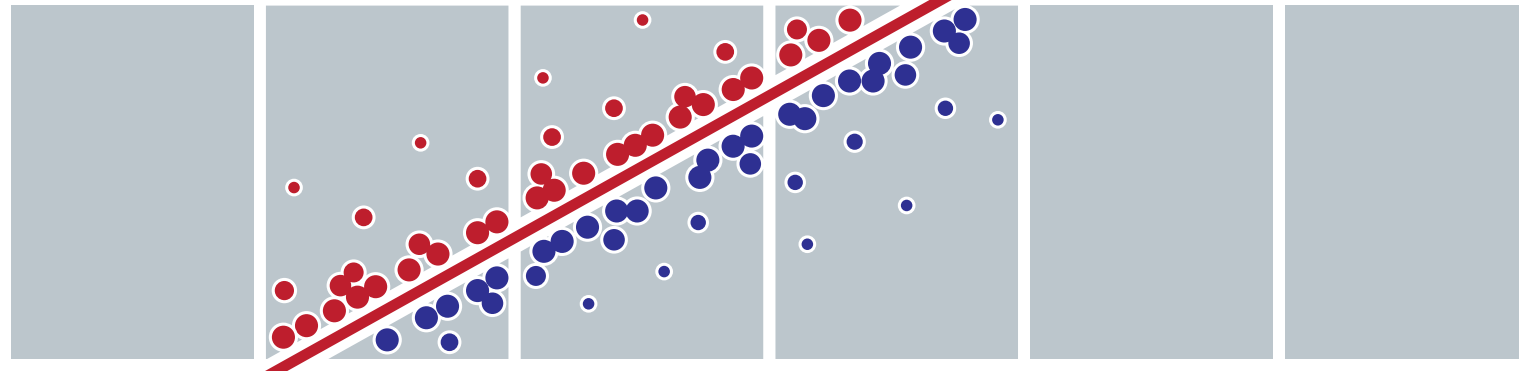
- The time resolution (best  $\sigma_{TOA} = 2.390 \pm 0.002$  ns)
- The in-time efficiency. i.e. How many of the hits register ToAs within 25ns of the track.
- etc.

Test beams allow for extremely detailed characterisation of the sensors in ways that are not possible in the lab.

Two further LF-MightyPix test beams are scheduled for 2026.

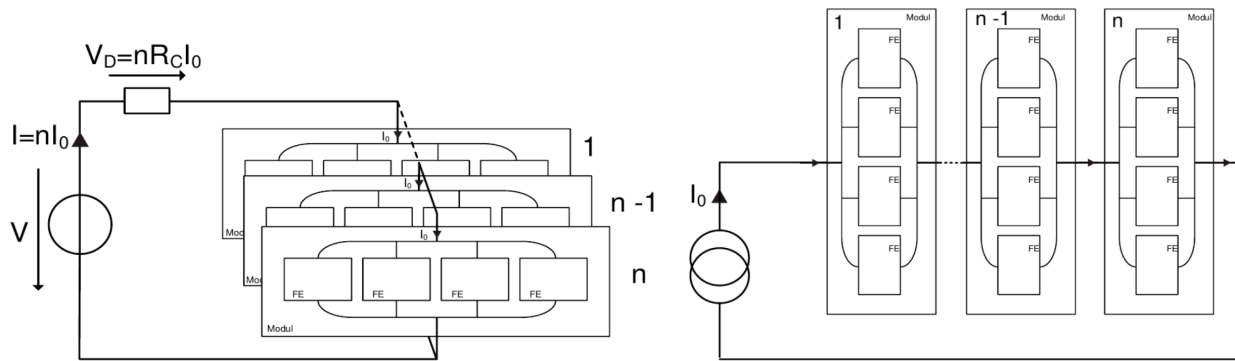


4 GeV  $e^-$  beam

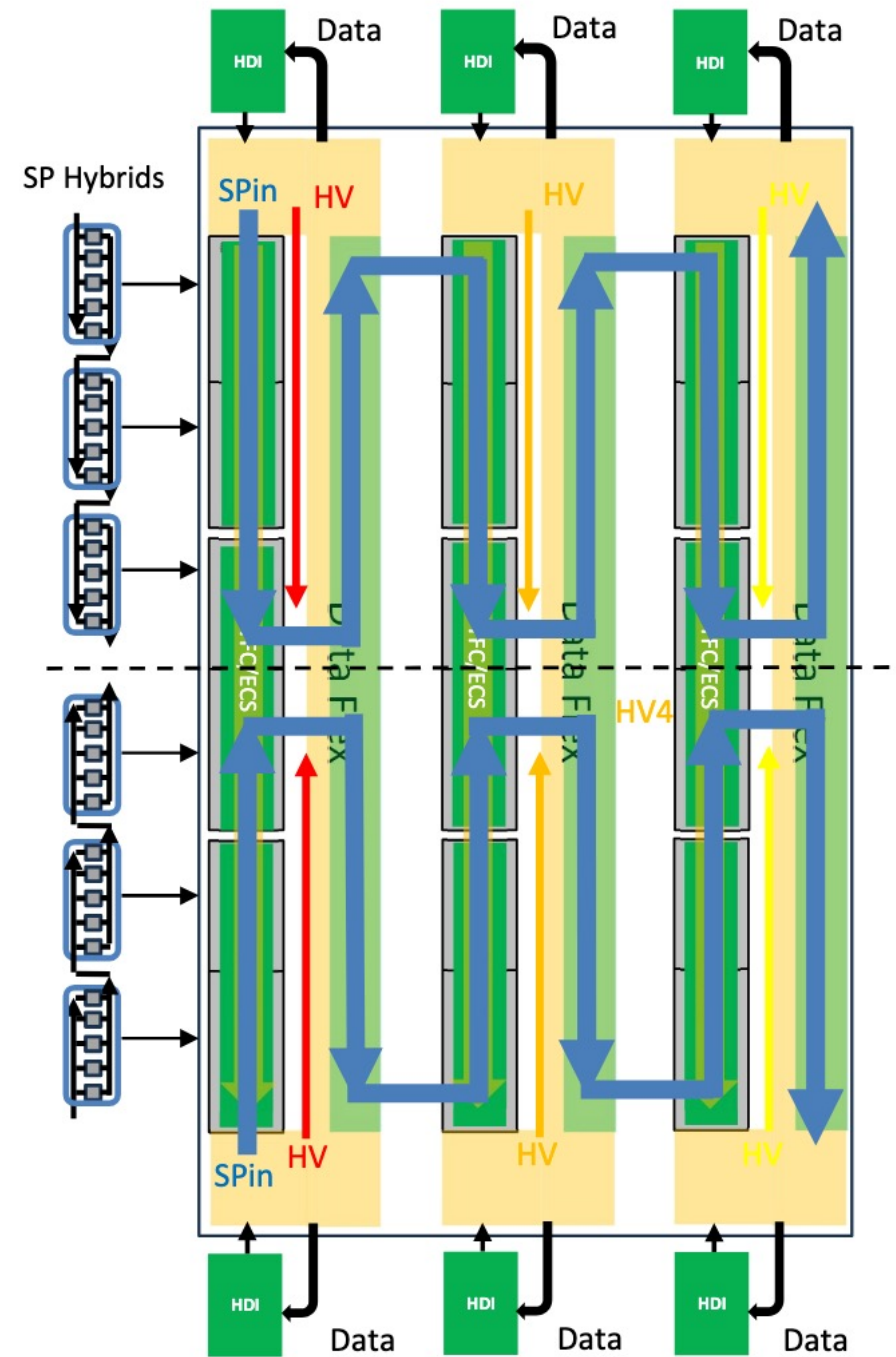
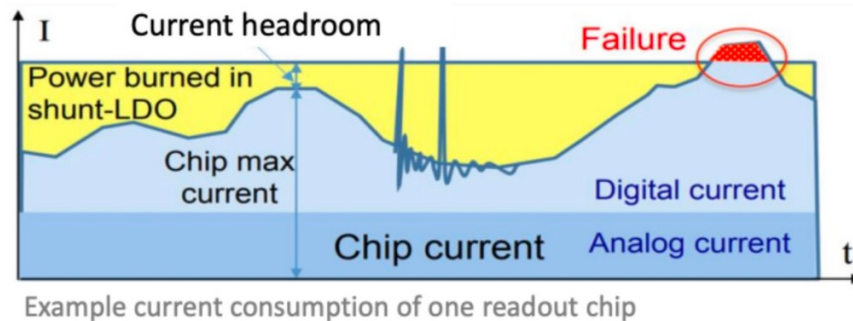
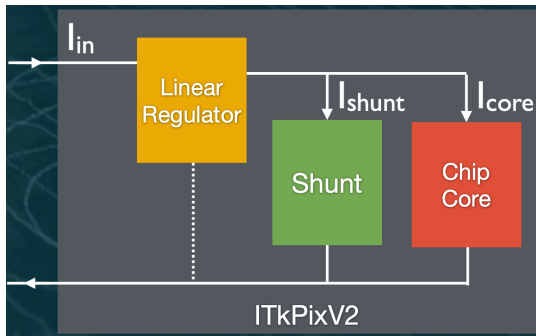


# Serial powering

For the implementation in the MightyTracker, the sensors must be powered in series, limiting cabling (material budget) and power dissipation.

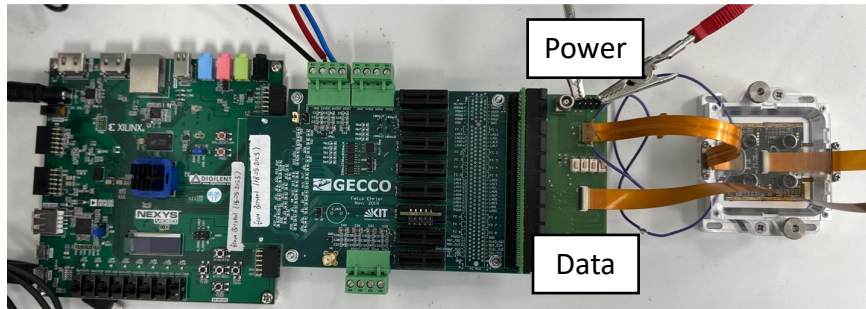
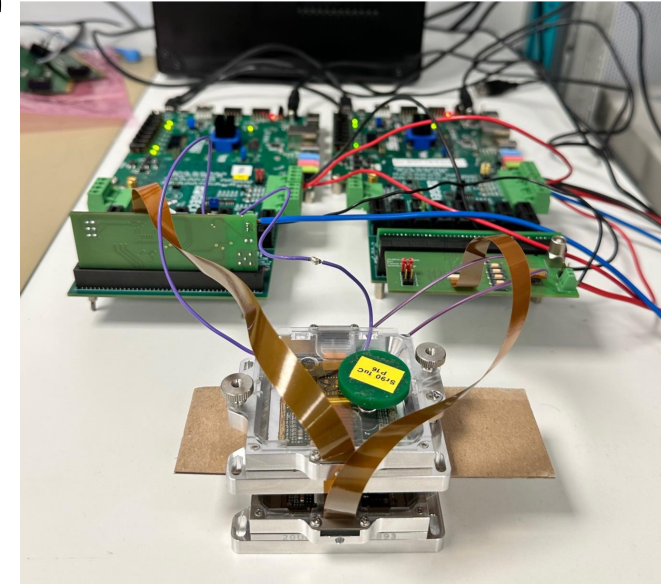
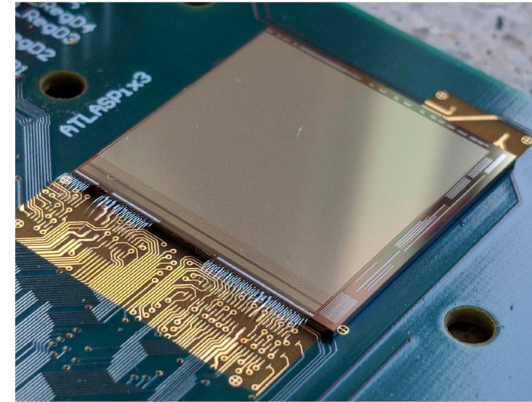


Voltage is regulated locally with a shunt low dropout regulator (SLDO).



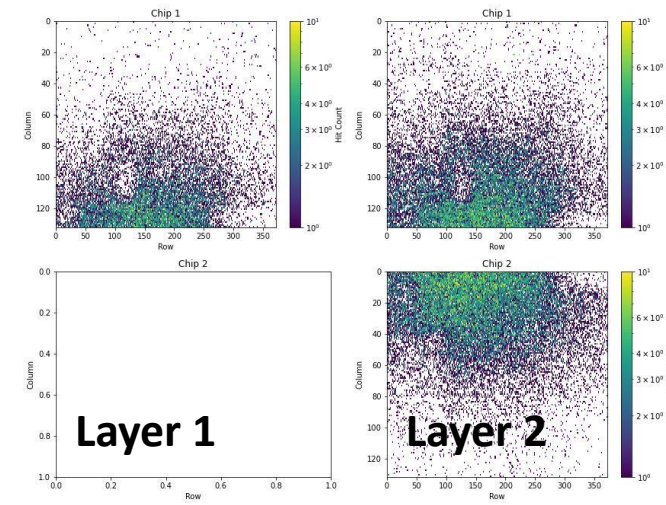
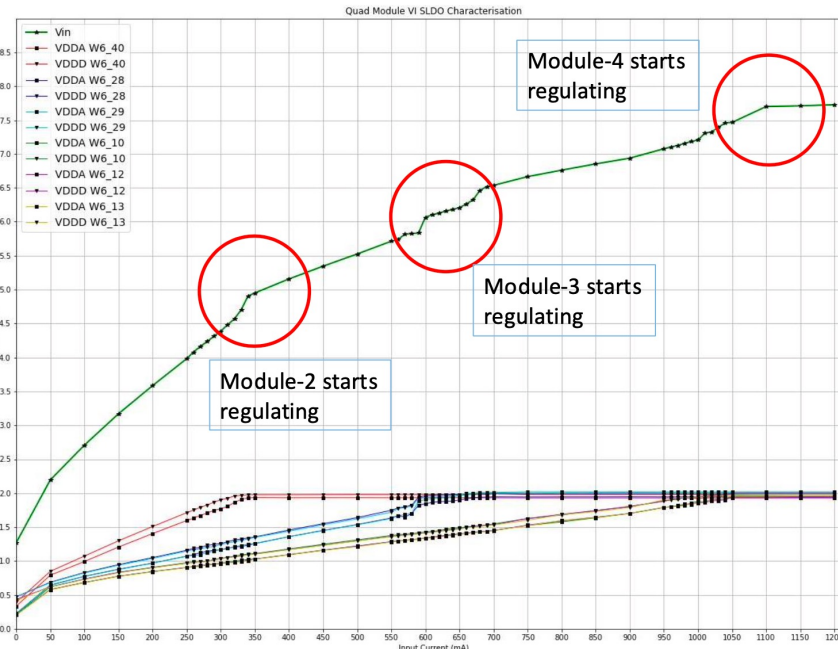
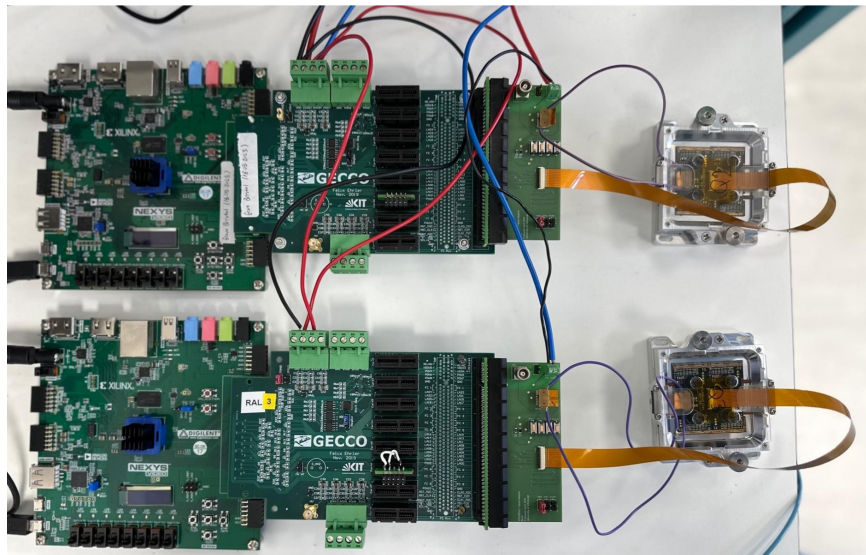
# HV-CMOS serial powering prototype

Extensive testing of this system in ATLASPix3 have been performed in Edinburgh, with successful outcomes with powering and reading out the serial powered prototypes.

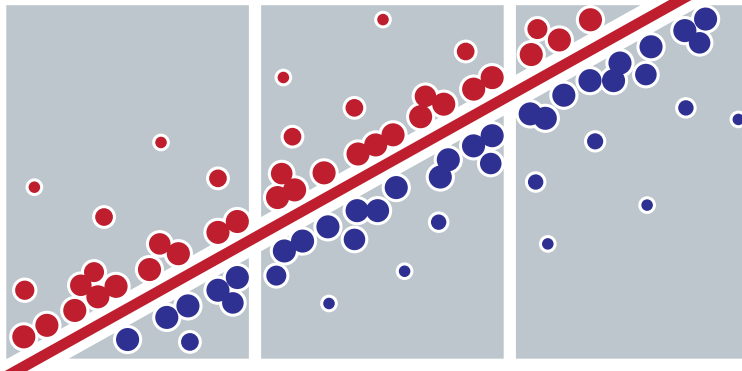


← 1 & 2 (in series) quad module readout  
↓ Verification of voltage regulator

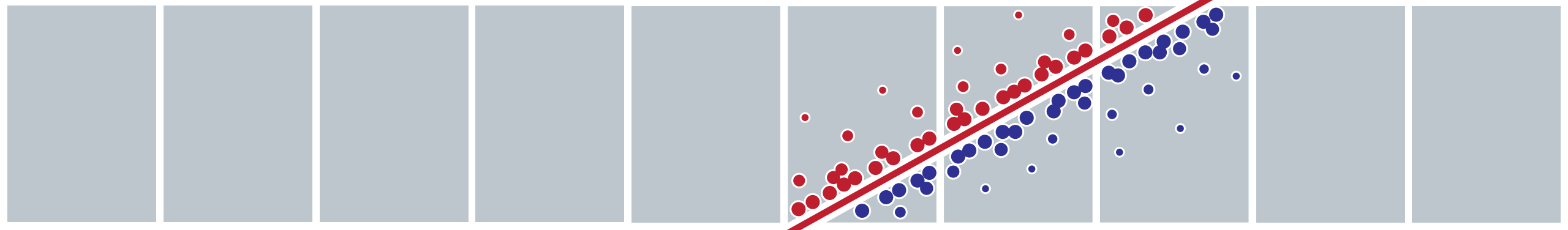
↑ 2 quad modules powered serially read out together  
↓ Hitmaps = **Success!**



**Thank you!**  
**Any Questions?**



# Back-up slides



# Cluster based time resolution

Interestingly, even without a time reference, we can start to study the time resolution of the sensor by leveraging the fact that “hits” within a cluster are in coincidence.

$$\Delta ToA = ToA_{hit,i} - \langle ToA_k \rangle_{k \neq i}$$

Pixel under study

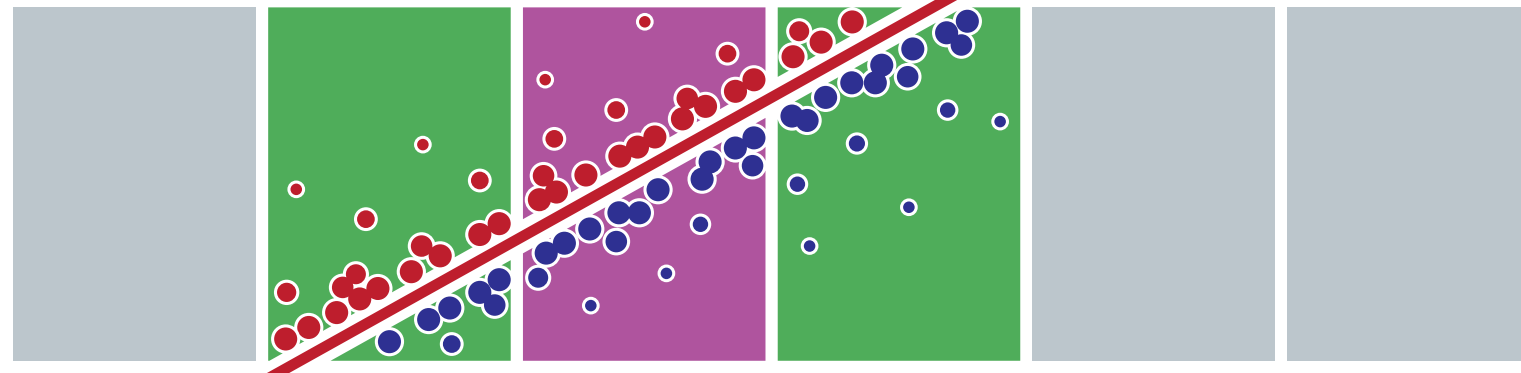
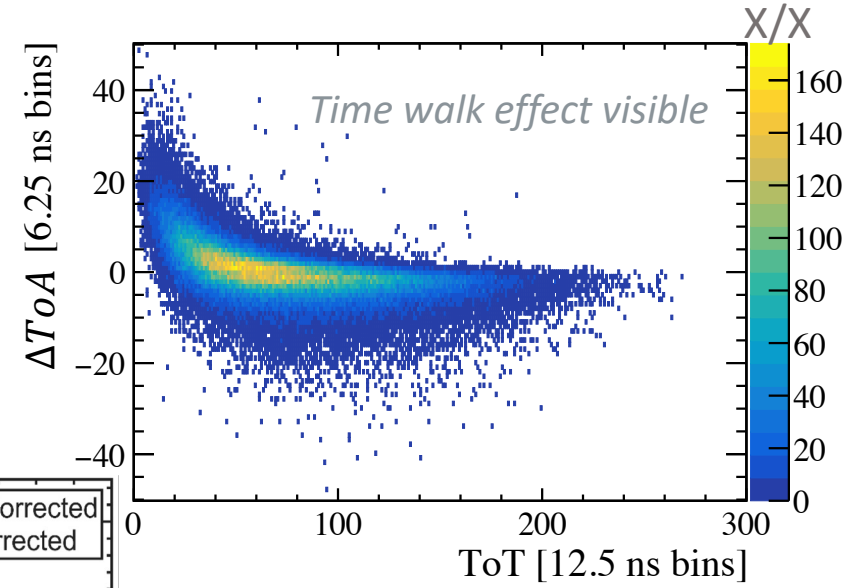
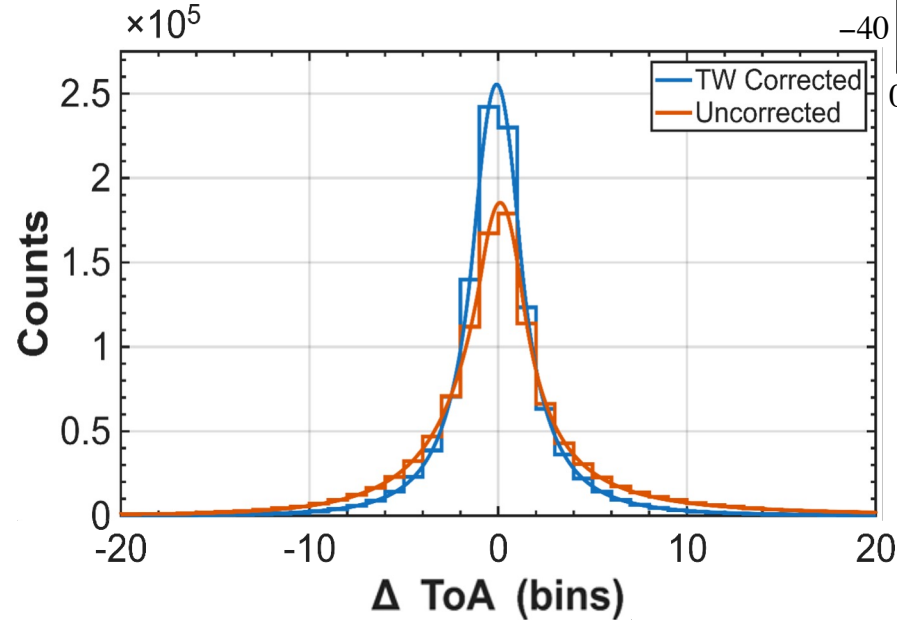
Rest of cluster as time reference

After a time walk correction, we measure the time resolution to be:

$$\sigma_{ToA} > 5.61 \pm 0.04 \text{ ns}$$

**All without a time reference!**

However, there are more accurate measurements available to us...



# Time walk correction

The time walk correction was determined by applying a locally weighted scatterplot smoothing (LOWESS) regression (*moving average*) to the data.

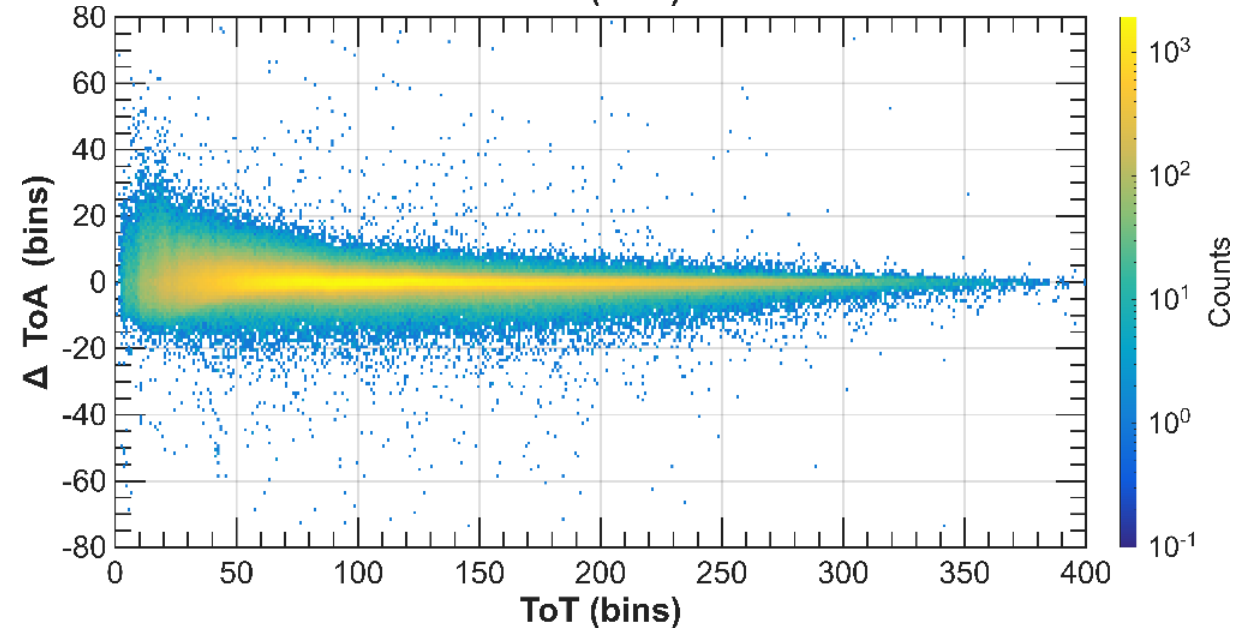
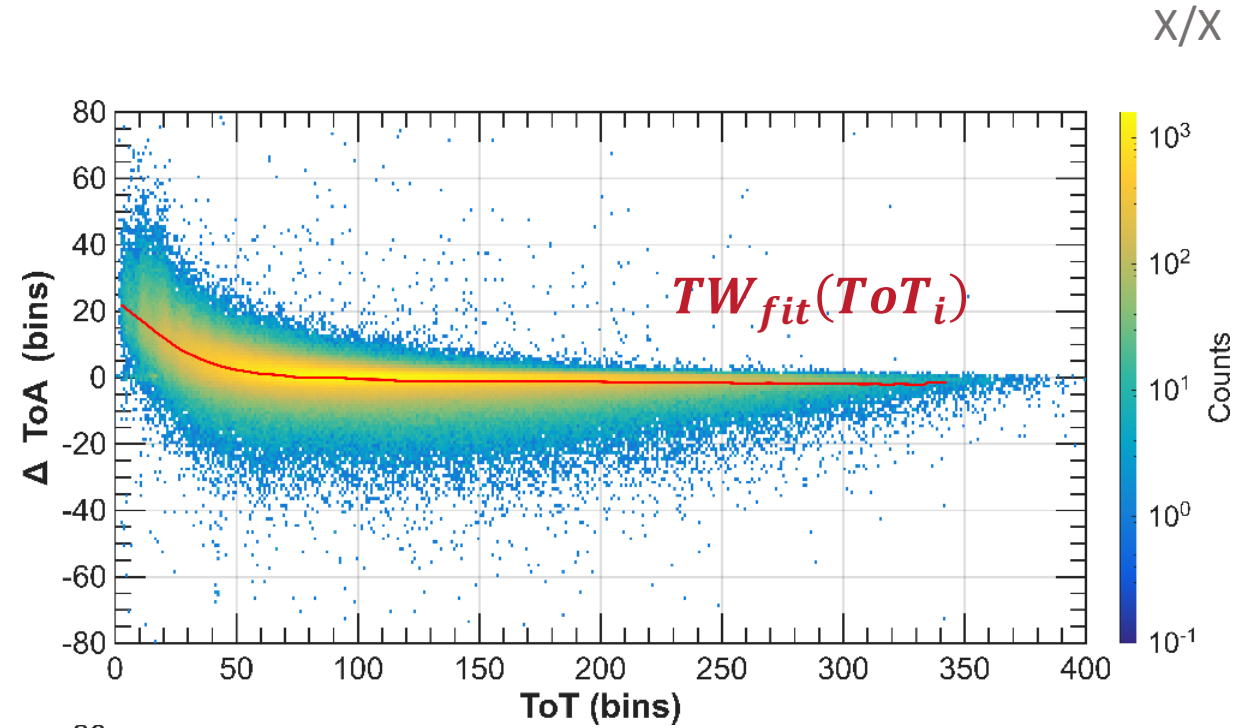
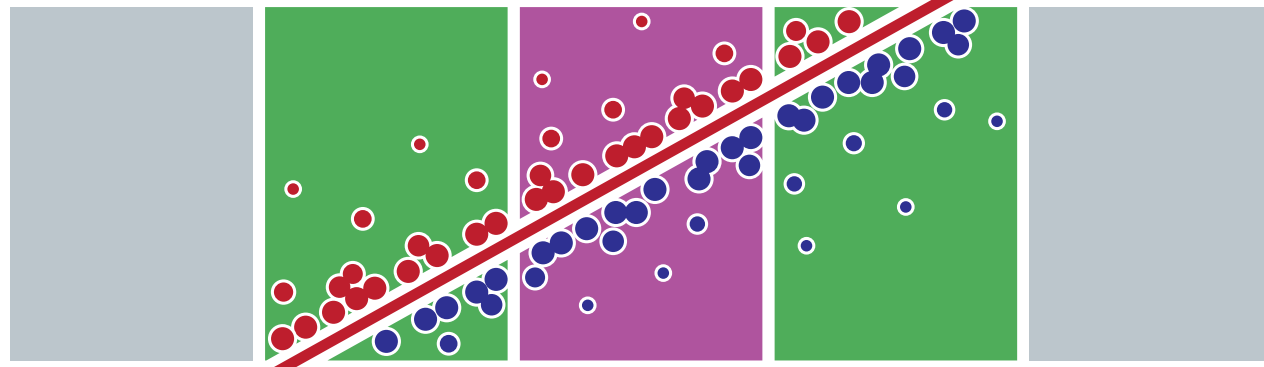
This was then used to correct the time stamps for all hits in the cluster.

$$\Delta ToA = ToA_{hit,i} - \langle ToA_k \rangle_{k \neq i}$$

Pixel under study

Rest of cluster as time reference

$$\Delta ToA_{TW_{cor}} = (ToA_i - TW_{fit}(ToT_i)) - \langle ToA_k - TW_{fit}(ToT_k) \rangle_{k \neq i}$$



# Data acquisition systems

## GECCO

Developed for MightyPix primarily by Lucas Dittmann in Heidelberg. Consists of:

- A carrier board for the MightyPix chip,
- A passive GECCO breakout board
- A commercial FPGA board

This system enables us to configure, control, and read out the LF-MightyPix (and some other HV-CMOS sensors).

## MARS

Developed primarily by Bonn as the the successor to the GECCO system, capable of meeting the demands set by QC & QA checks.



Sensor (+ source) →

GECCO board →

FPGA board →

