AIDA-2020-SLIDE-2020-026

AIDA-2020

Advanced European Infrastructures for Detectors at Accelerators

Presentation

First performance results of the Lycoris large area strip telescope

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30 January 2020

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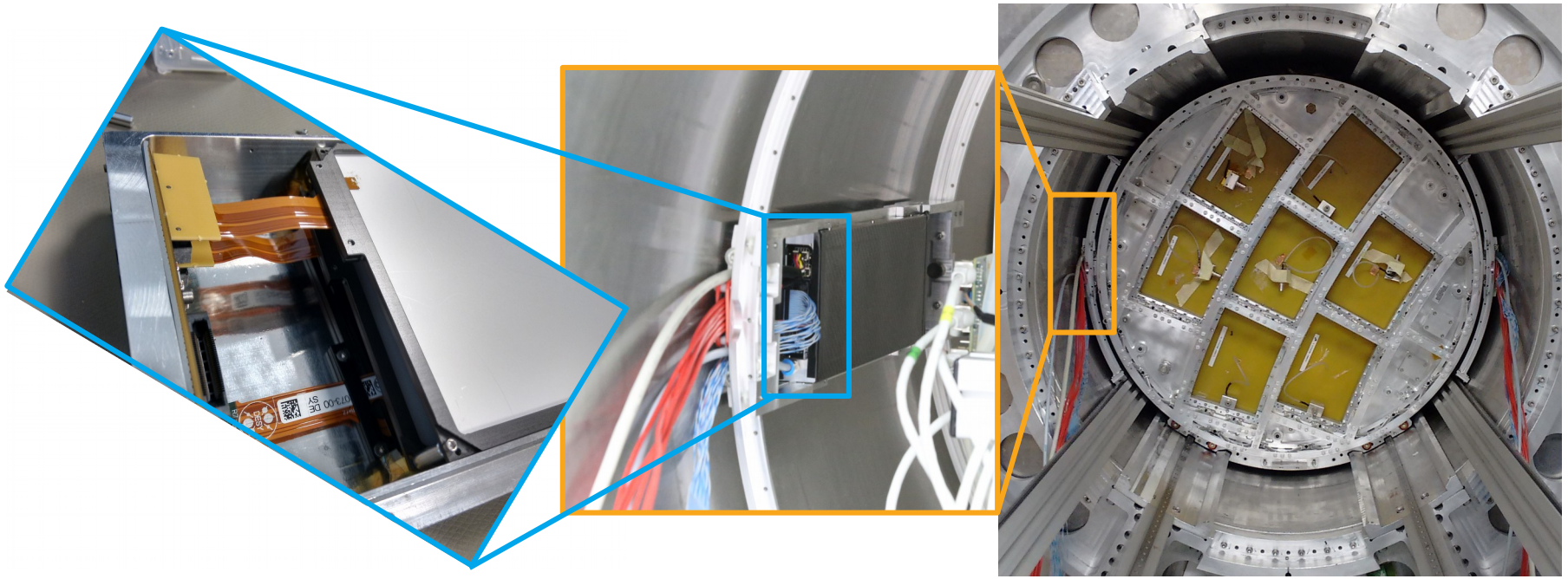
Lycoris: Large Area Telescope

LYCORIS Telescope: Large Area x-Y Coverage Readout Integrated Strip Telescope



Uwe Krämer, Mengqing Wu

BTTB 2020, 30th of January 2020

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

AIDA 2020

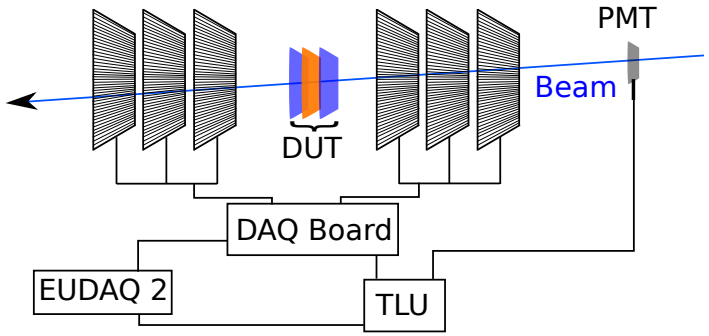
LC TPC

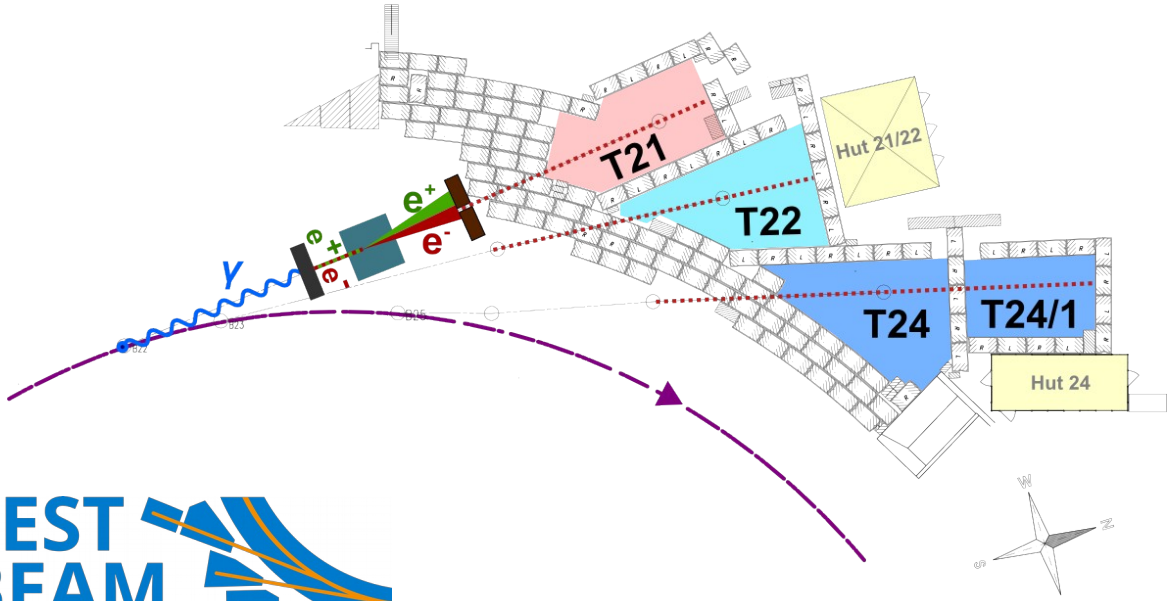
DESY TEST BEAM.

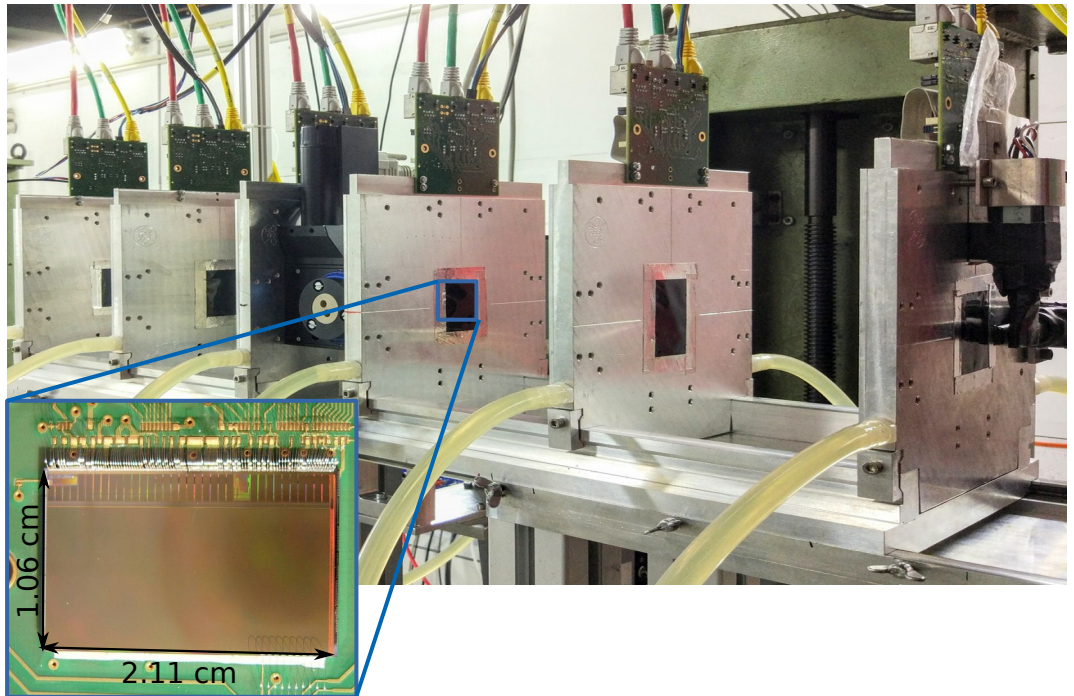
DESY.

Telescopes at the DESY II Testbeam Facility

- Three EUDET silicon pixel Telescopes (Datura/Duranta/Azalea).
- Based on Mimosa 26, in T21, T22 and T24.
  - Very good tracking performance.
  - Long frame readout time O(100 us) via rolling shutter
  - Small active area
  - Large support structure



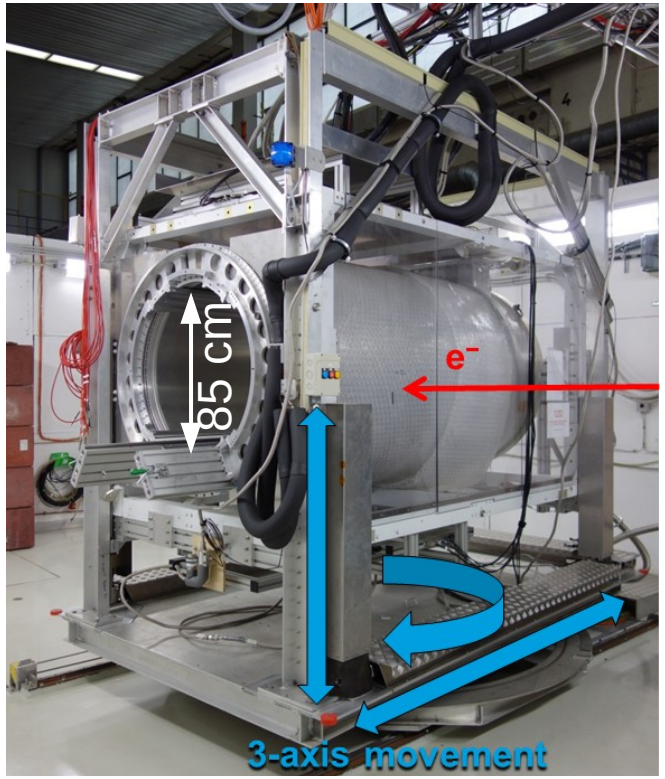




DESY TEST BEAM. DESY.

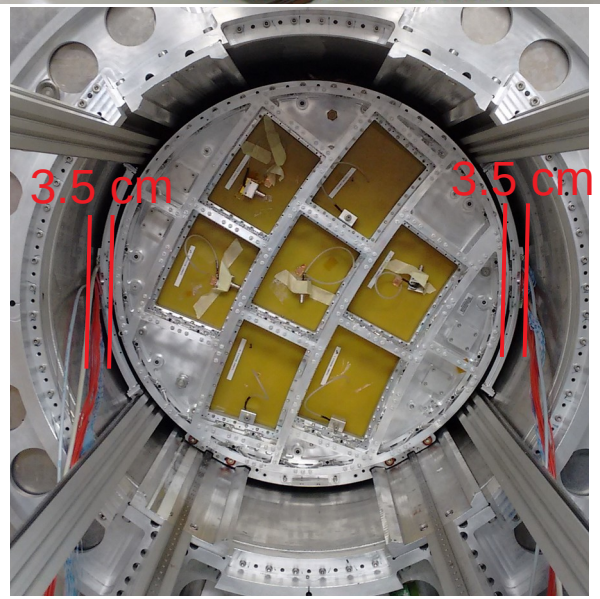
A New Telescope

- A new large area strip telescope within the Test Beam Area 24/1 solenoid:
  - Wall thickness of 20% X_0.
  - Magnetic field strength of up to 1T.



- Telescope demands complementary to existing EUDET Telescopes and user demands:
  - Larger area ~10x10 cm².
  - Spatial resolution requirements better than:
    - σ_{Bend} = ~10 µm.
    - $\sigma_{opening}$ = ~1 mm.

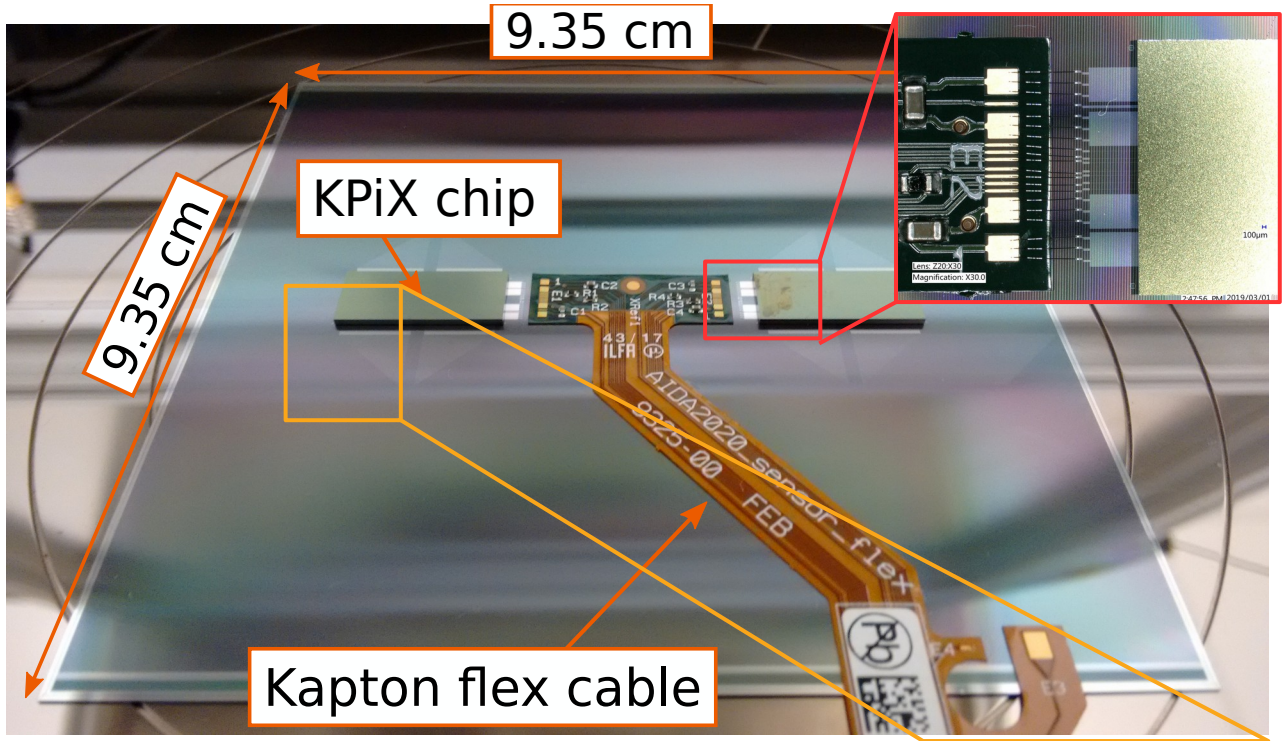
      → No standard ATLAS and CMS tracker sensors

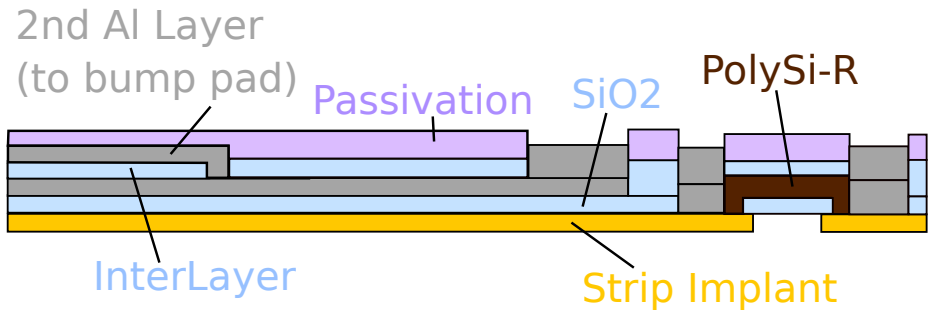


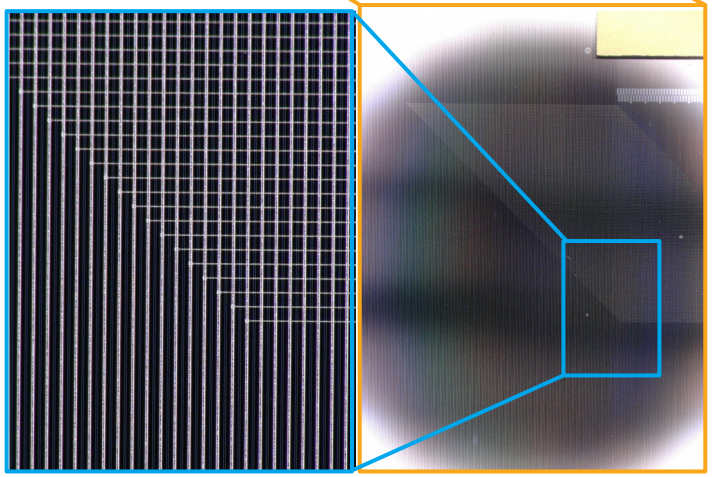
The SiD Silicon Strip Sensor

Hybrid-Less silicon strip sensor designed by SLAC NATIONAL ACCELERATOR LABORATORY for the ILC :

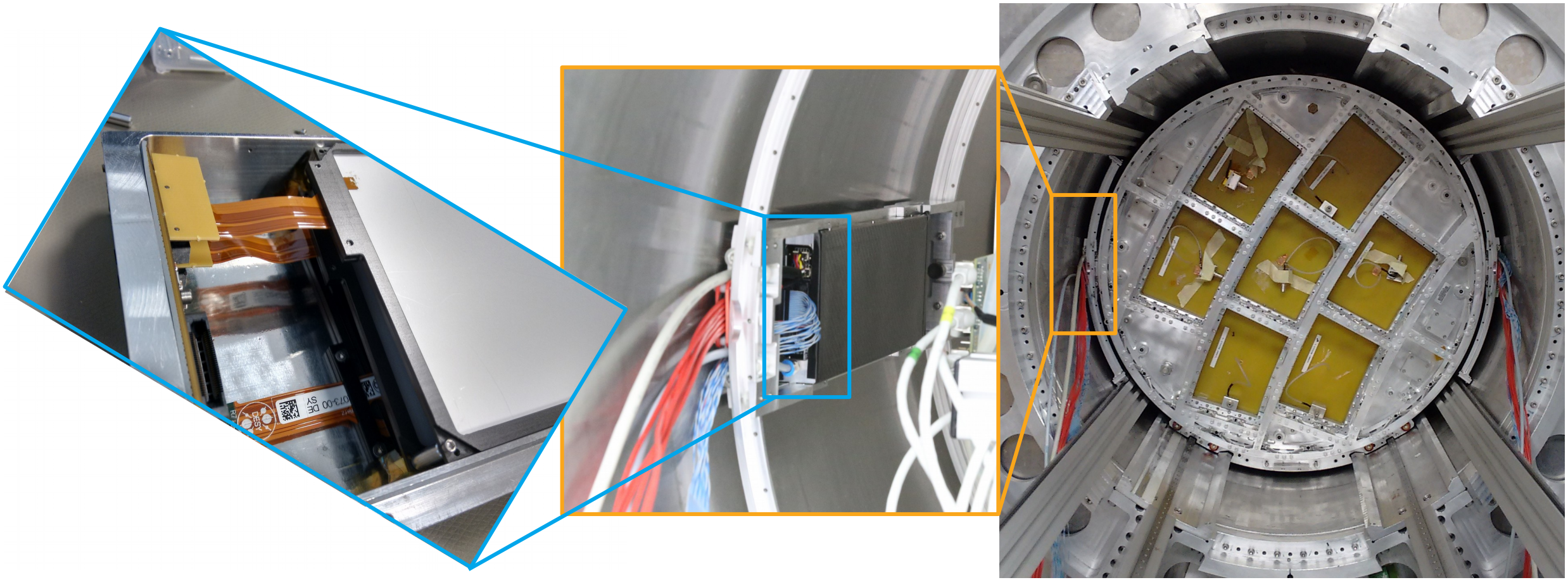
- A readout/floating strip pitch of 50/25 micron
  - ~7 micron tracking resolution with charge sharing
- Thickness of 320 micron
- An integrated pitch adapter and digital readout (KpiX)
  - Dicretly bump bonded to sensor surface
  - Power pulsed operation
  - 13 bit ADC readout







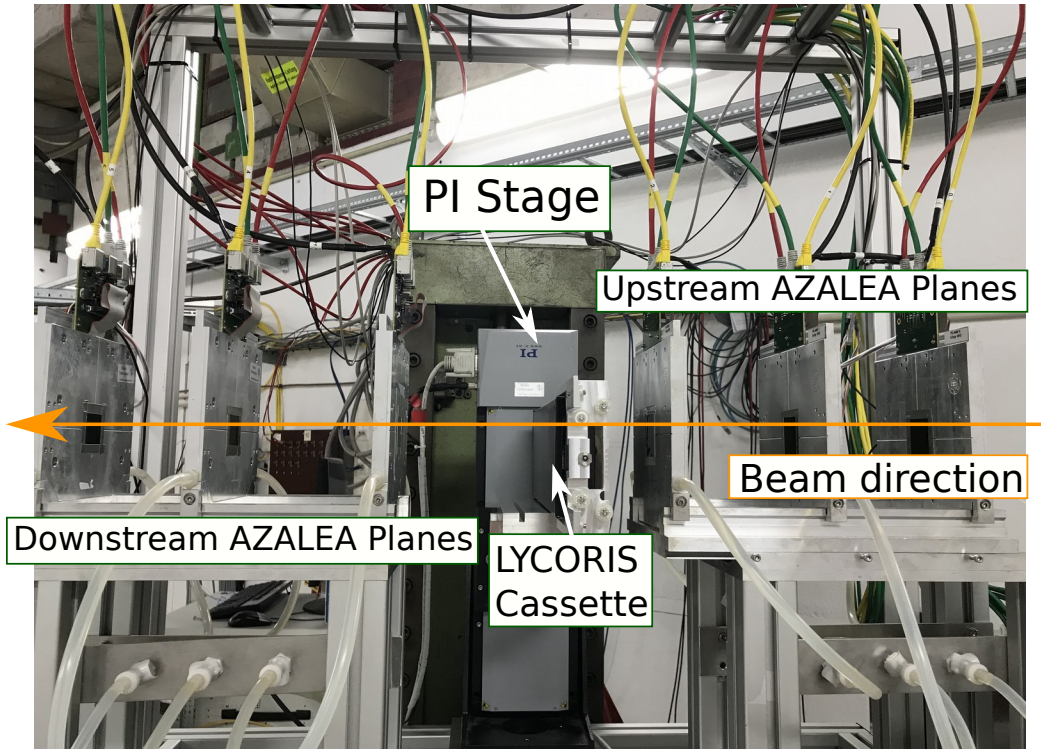
Final System



Telescopes within telescopes

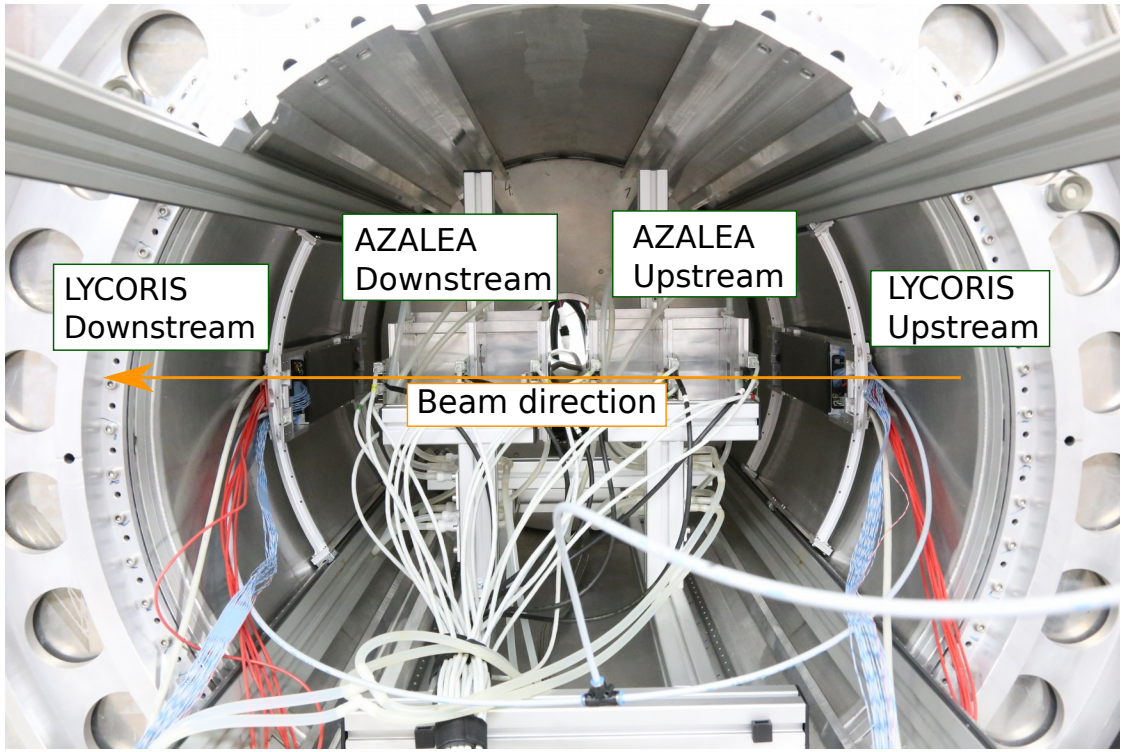
T24 setup

- One LYCORIS cassette placed between both AZALEA planes

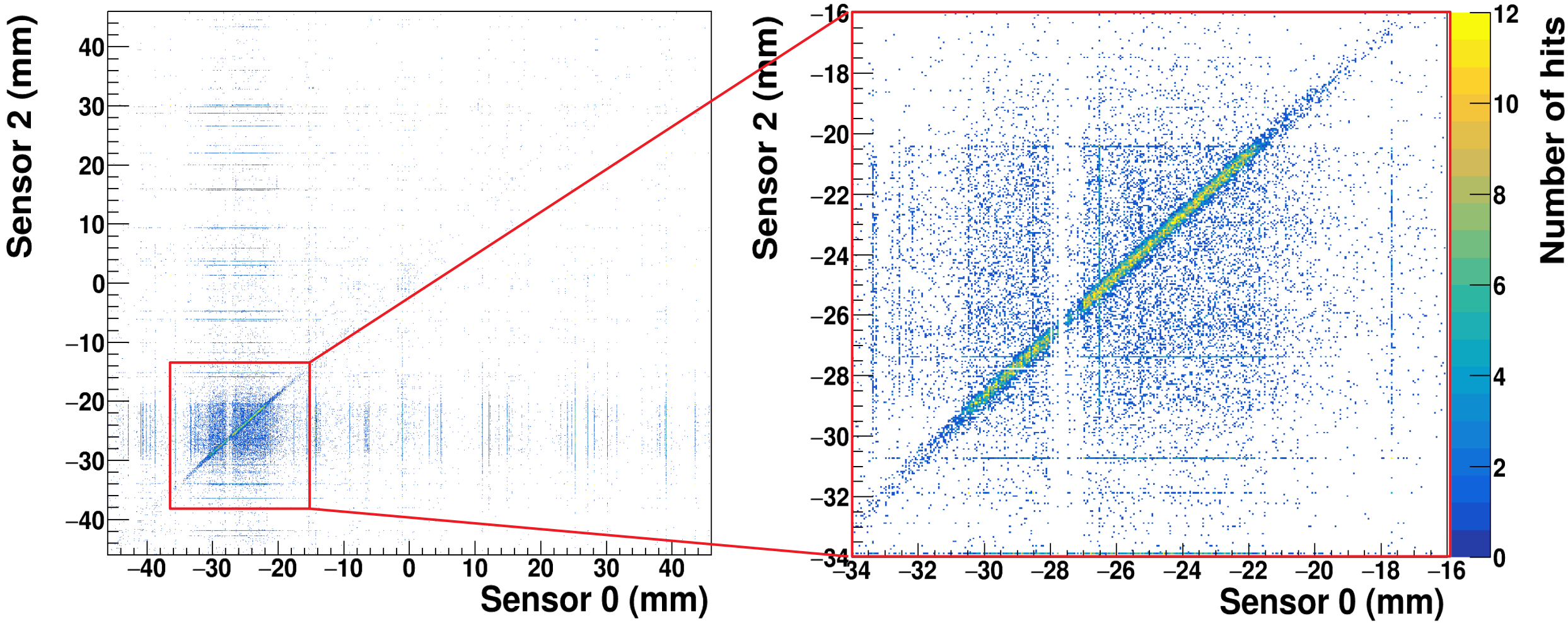


T24/1 setup

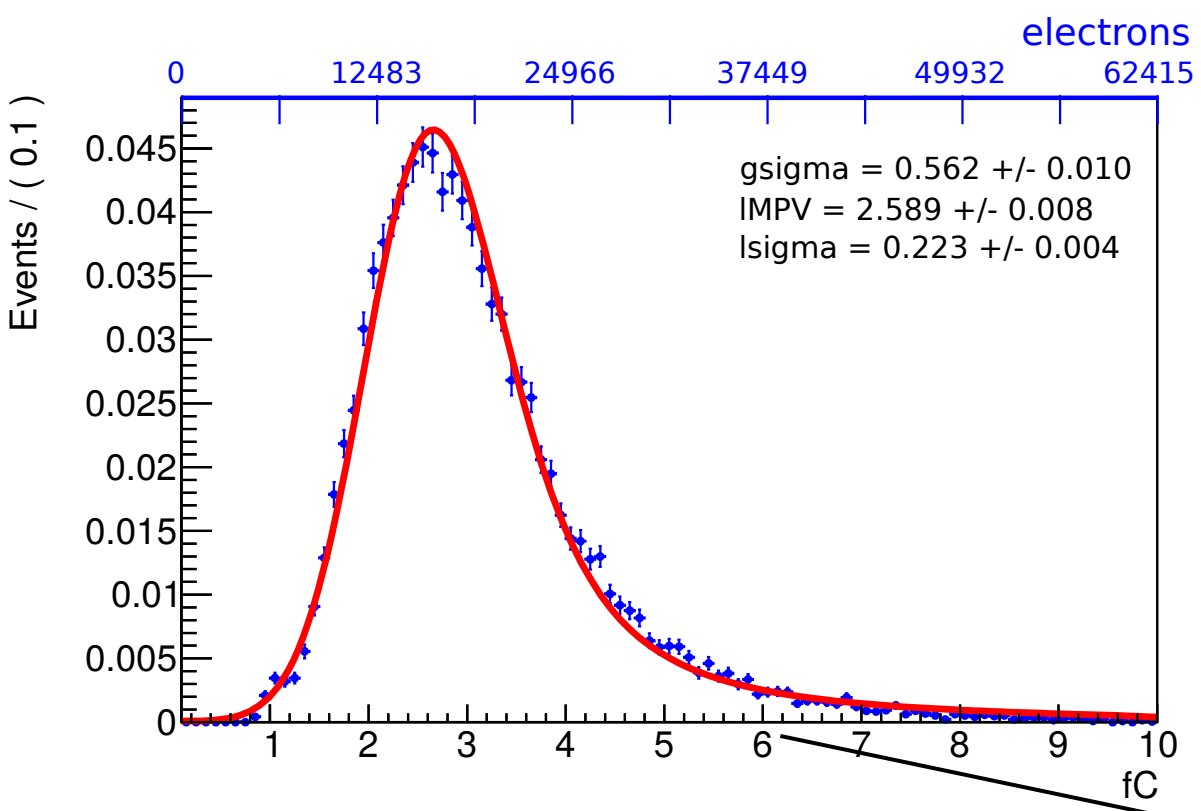
- Both AZALEA planes are placed between two LYCORIS cassettes

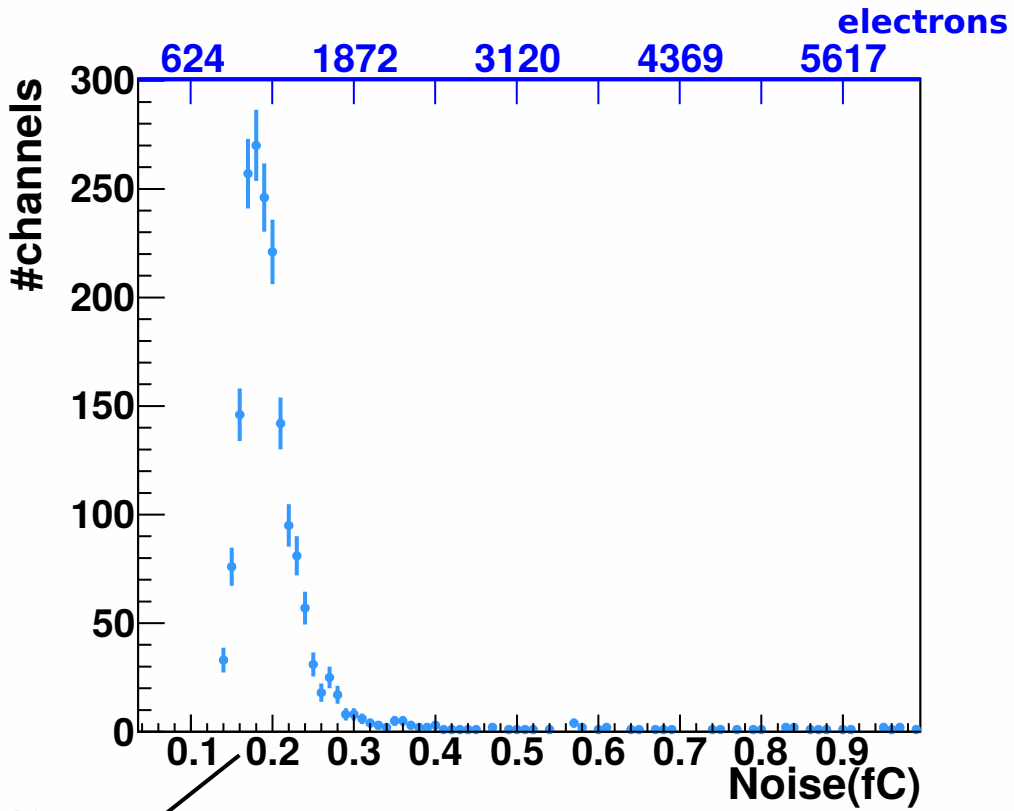


Recent test beam results



Charge and Noise distribution for correlated hits





$$S/N \approx \frac{2.6\,\mathrm{fC}}{0.2\,\mathrm{fC}} = 13$$

- Un-/Fortunately we already know that a problem with late triggers reduced the recorded charge by ~30% meaning our expected S/N should be higher

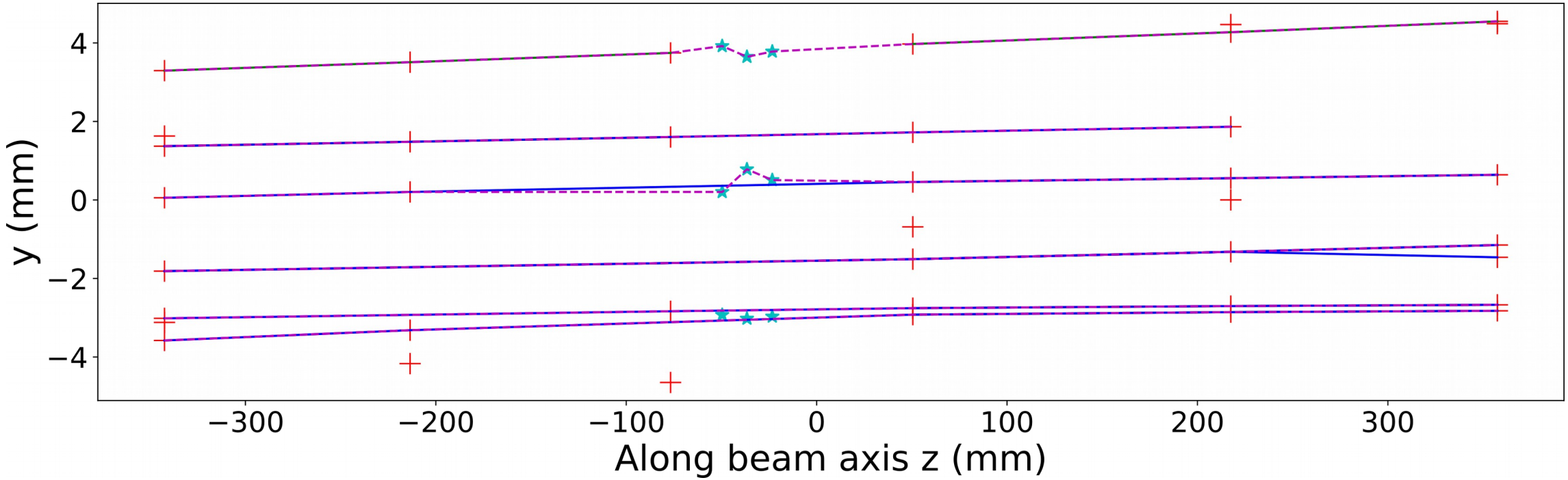
Making things fit

- To perform track finding and fitting we want to use the Azalea telescope as reference to see our achievable resolution with Lycoris.
- The two systems are extremely different.
  - Mimosa: Continuous rolling shutter readout and extremely slow frame readout time.
  - KPiX: Power pulsed readout with limited buffer capacity.
- Solution: Offline synchronization of the two data stream using the TLU.

	TriggerID (TLU)	TriggerID (AZALEA)	Timestamp (TLU)	Timestamp (KPiX)
	0	0	A	
	1	1	B	
	2		C	C
	3	3	D	
	4	4	E	
Match	5	5	F	F
	6		G	G
	7		H	H
Match	8	8	I	I
Match	9	9	J	J
	10		K	K
Match	11	11	L	L
	12	12	M	
	13		N	N
Match	14	14	P	P

Making things fit

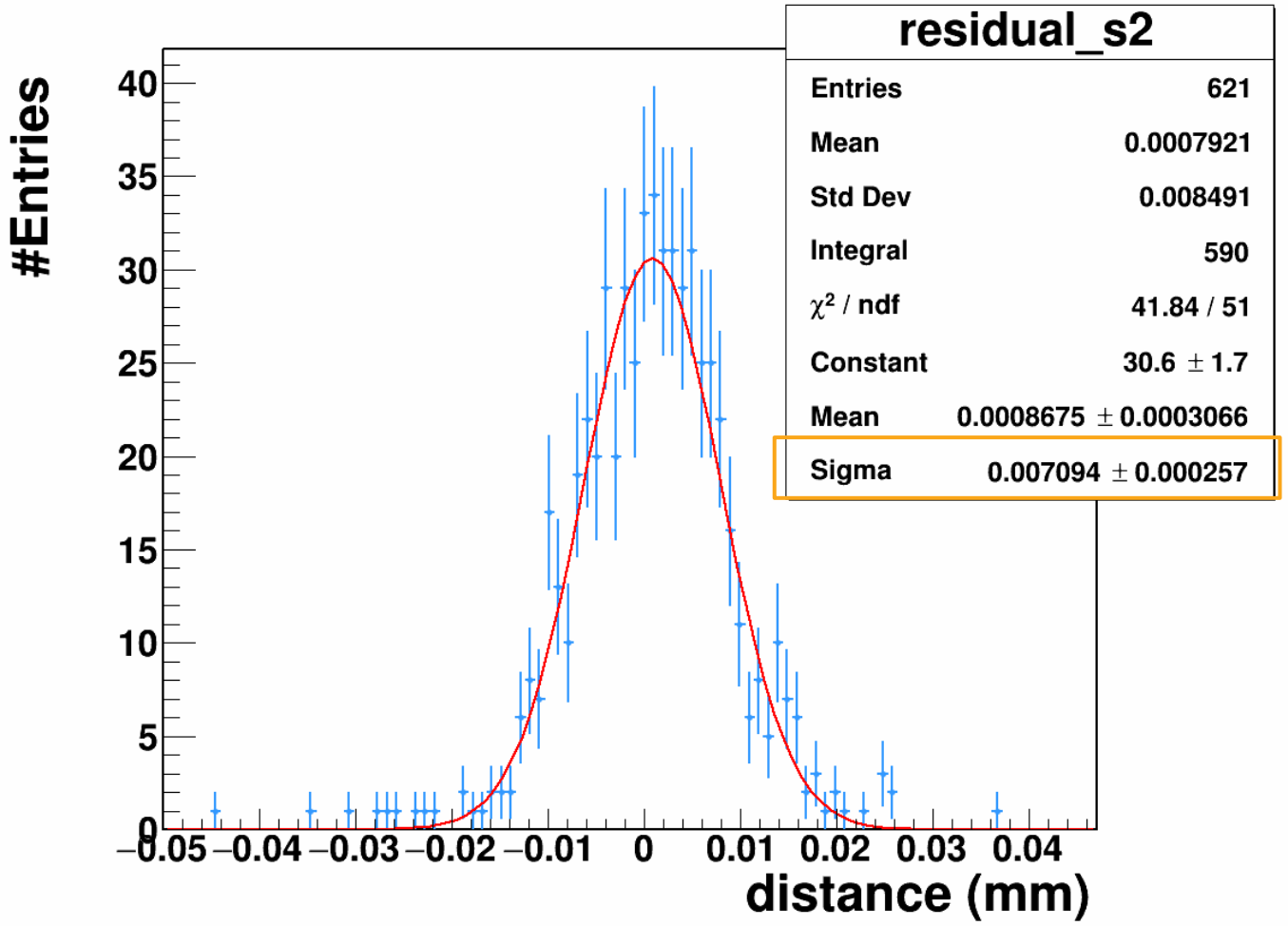
- Only a fraction of all events are compatible as a result of the different operating methods of Azalea and Lycoris.
  - ~5% of all recorded Mimosa events have Lycoris events
- Track finding and fitting using General Broken Lines GBL and subsequent alignment using Millepede II MPII



- Different frame readout time → Different number of hits in Lycoris compared to Azalea.

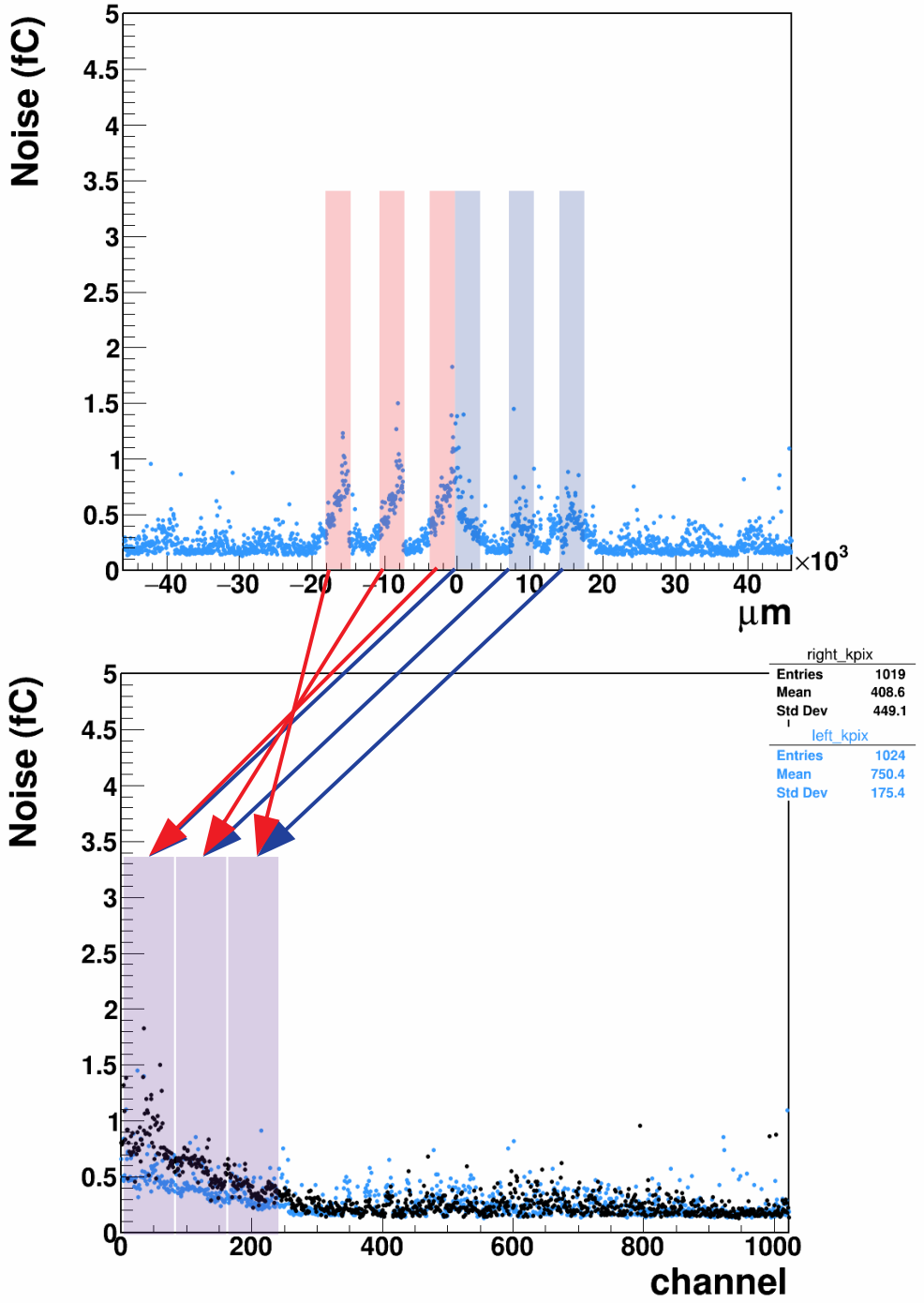
Making things fit

- Looking at residuals of sensor hits to track.
- Sensor in question is not taken into account during fit → Unbiased results
- Sigma of Gaussian fit = Upper limit on single point resolution



An open question

- Average S/N is ~13
- Center region strips have much higher noise than the average
- While shown not to prohibit the use of the system as a telescope, severely limits usable area/efficiency.

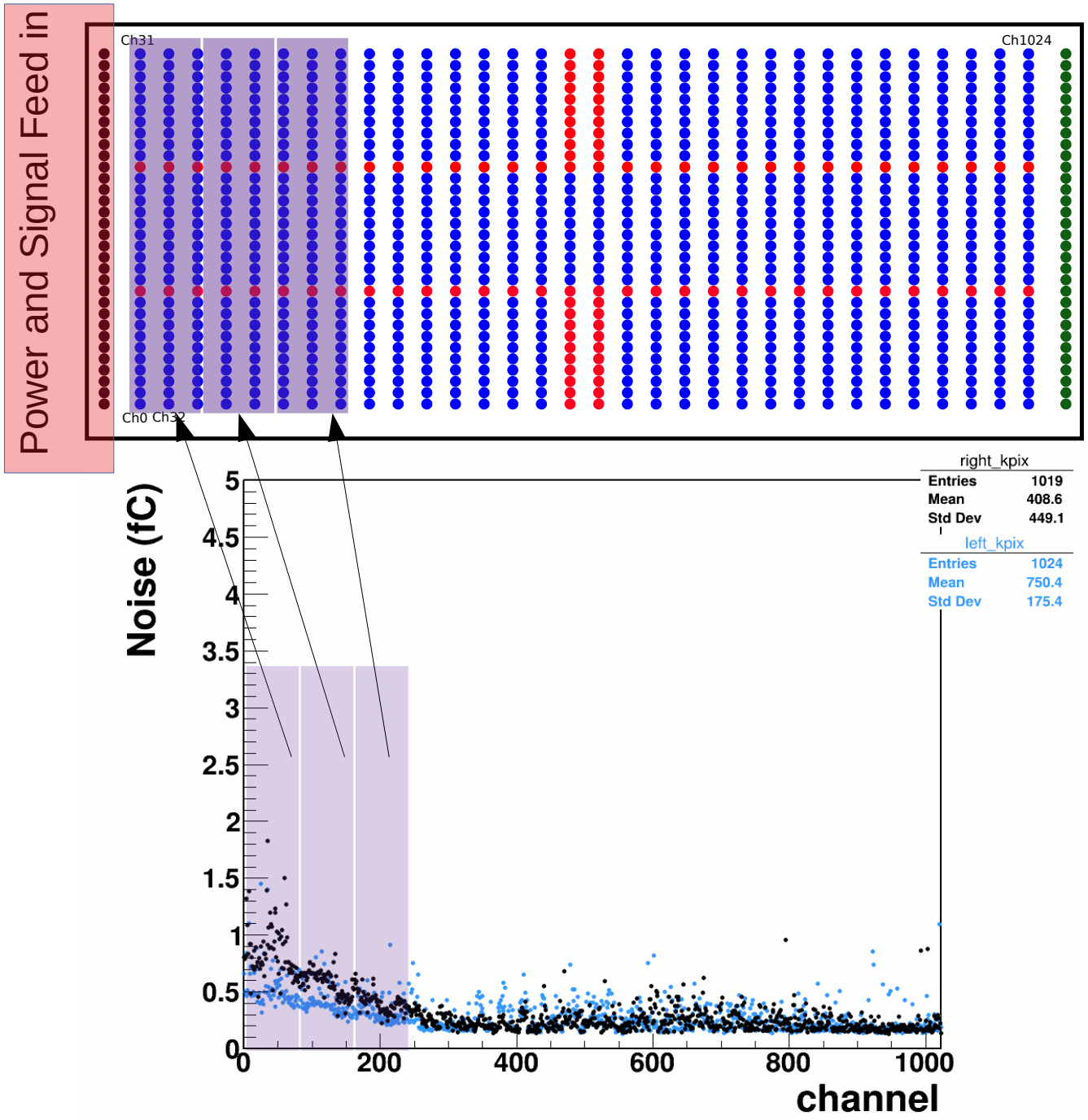


An open question

- Found a correlation between KpiX location and signal feed in.
- Checking input signals for potential noise source revealed clock as potential noise source

  → Clock signals are x10 higher than expected/designed

  → Clock previously induced signal in a different sensor using the same chip
  - Missing resistor in cassette board found to be the reason
  - Currently being added in post.



Conclusion and outlook

- Assembled for the first time a low material budget hybrid-less silicon strip sensor.
- In general the large area strip module is feasible and can reach a single point resolution of ~7 micron.
- System is fully synchronizable to Mimosa → If you can synchronize to Mimosa you can definitely synchronize to Lycoris.
- System has been integrated into EUDAQ2.

- Central region noise found within system → currently being addressed.
- Sensor yield is not spectacular → not a problem for the telescope but should be addressed

- **<u>Outlook:</u>**
  - Determine momentum resolution within magnetic field.
  - Finish analysis suite to allow external users to use the telescope.

Backup

Case for an External Reference Tracker

- Ongoing effort to build a TPC for the ILC
  - Proven that necessary single point resolution is achievable
  - Not yet experimentally proven whether momentum resolution is achievable

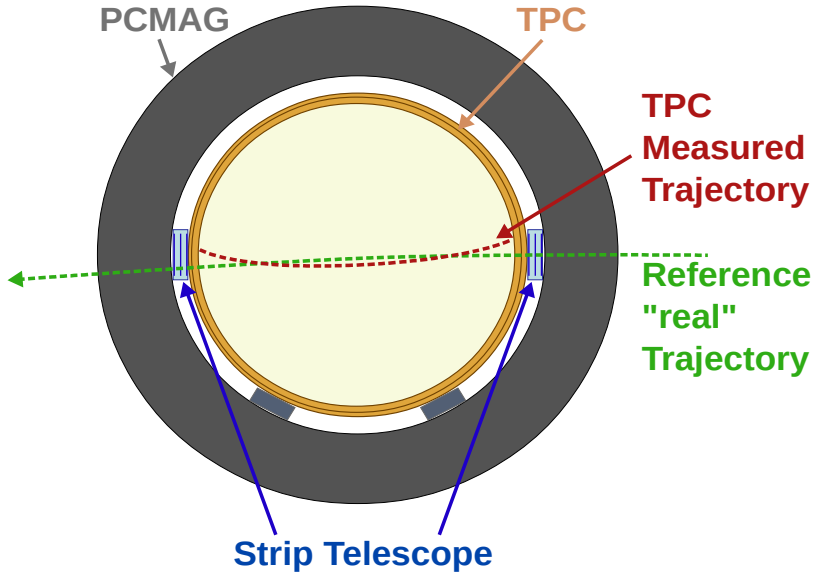


Fig.: Sketch explanation for the need of a reference trajectory

- 1. Field distortions within TPC might distort curvature → Potentially incorrect momentum measurement
- 2. Interactions with the magnet wall smear particle momentum → Particle momentum not known well enough

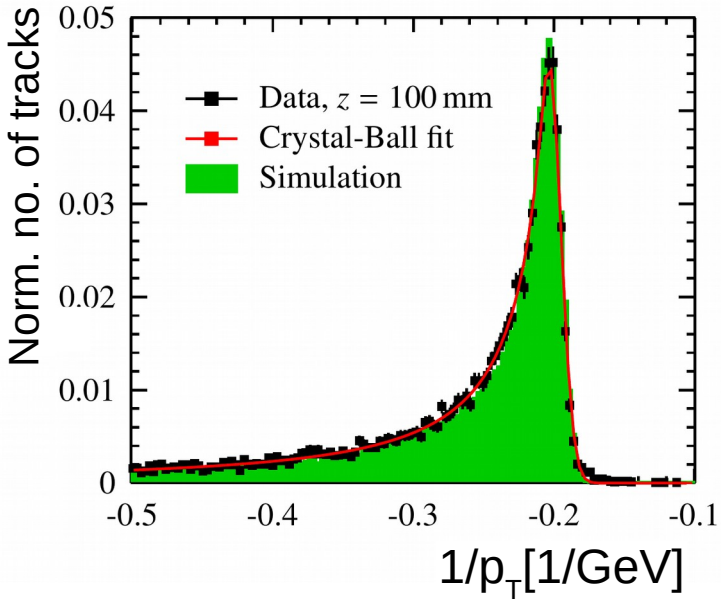


Fig.: Momentum distribution after interaction with the PCMAG wall (Felix Müller | DOI: 10.3204/PUBDB-2016-02659)

KPiX readout chip

- 1024 channel fully digital readout with 13 bit resolution (8192 ADC).
- 100 MHz clock
- Can work in two modes:
  - Self/Internal trigger = 4 events per channel per cycle stored.
  - External trigger = 4 events per cycle stored.
- Power pulsed operation → Only open for a short time frame.
  - Length of the opening period depends on timing resolution.

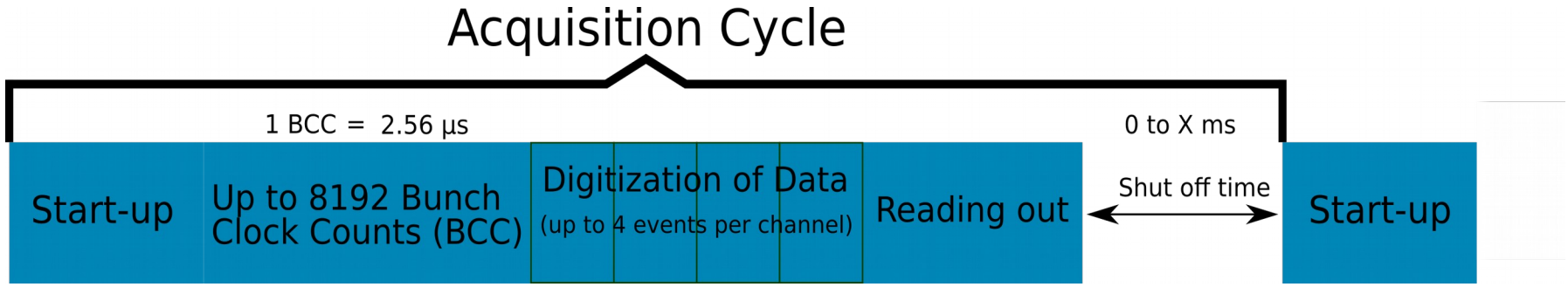


Fig.: Acquisition cycle of the KPiX readout chip

- Only open for a maximum time of 8192*8*acq.clock.
  → For example with a 320 ns acq.clock = 20.97 ms.

Sensor Overview

29 Sensors Produced By Hamamatsu

- Verification of electrical properties
- All sent to IZM for bump bonding

→ 2 Sensors were ground down to verify bump quality

27 bump bonded sensors with KPiX

- Verification of electrical properties
- Gluing of kapton flex and wirebonding

→ 5 sensors sent to SLAC

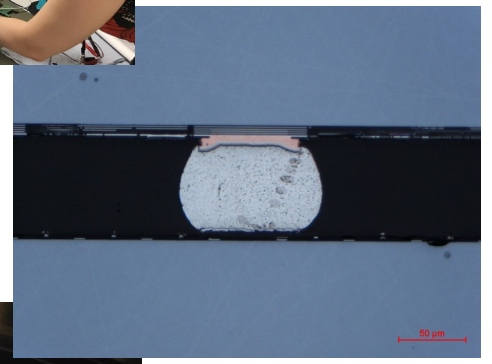
→ 3 sensors were rendered unusable during assembly

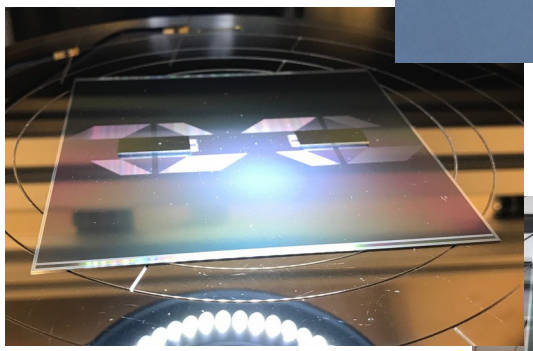
→ 2 Sensors were not assembled

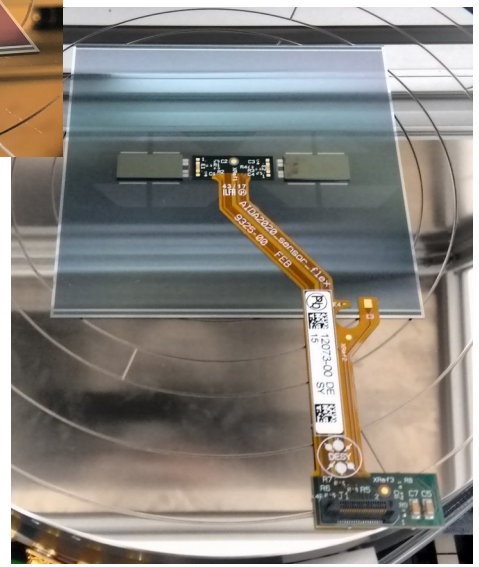
17 sensors fully assembled sensors at DESY

- E-Lab tests on sensor performance

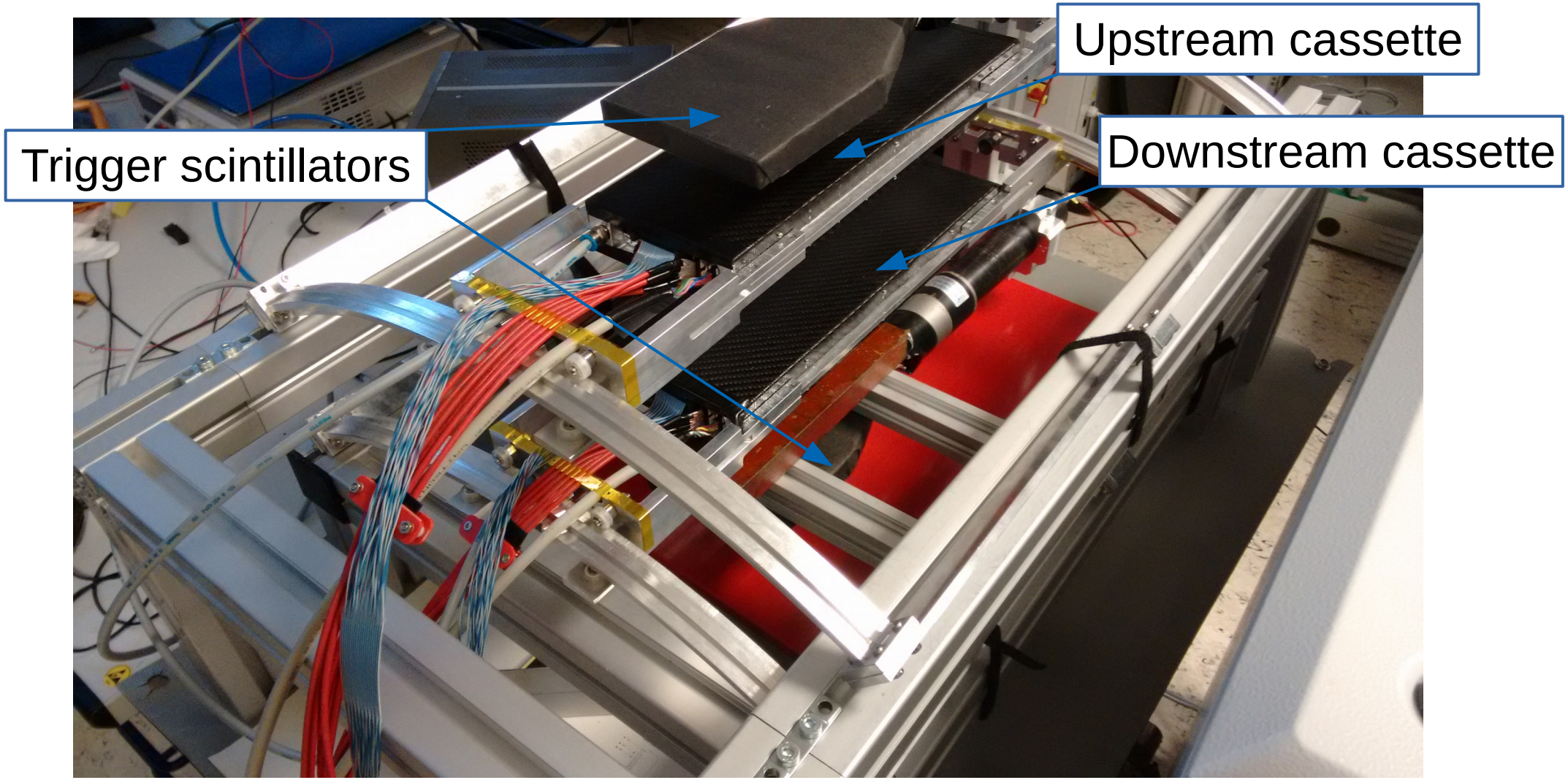
<u>9 Sensors were used during test beam campaigns</u>



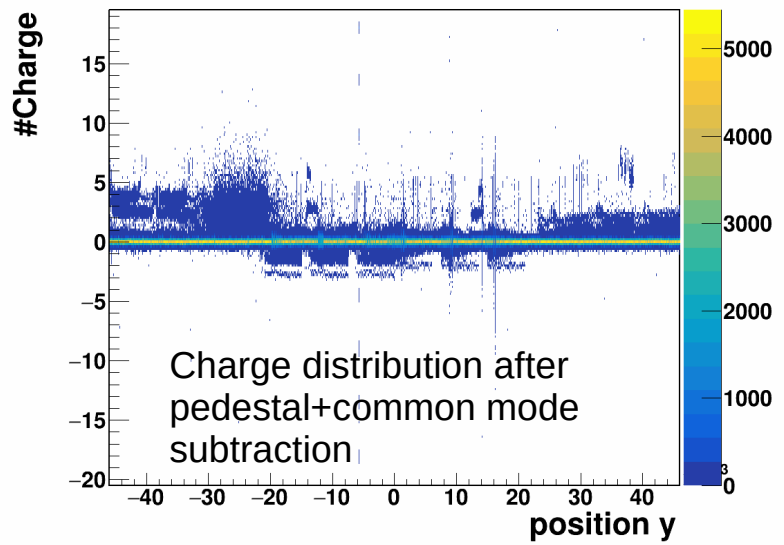




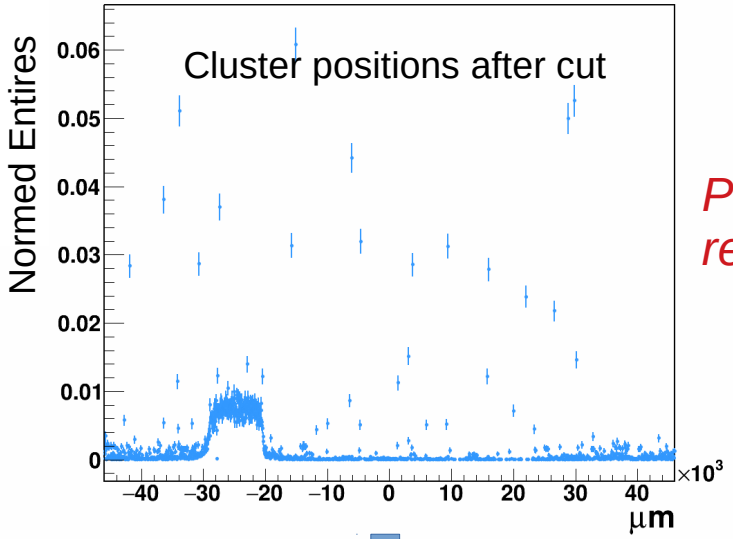
Cosmic Setup



A small step by step

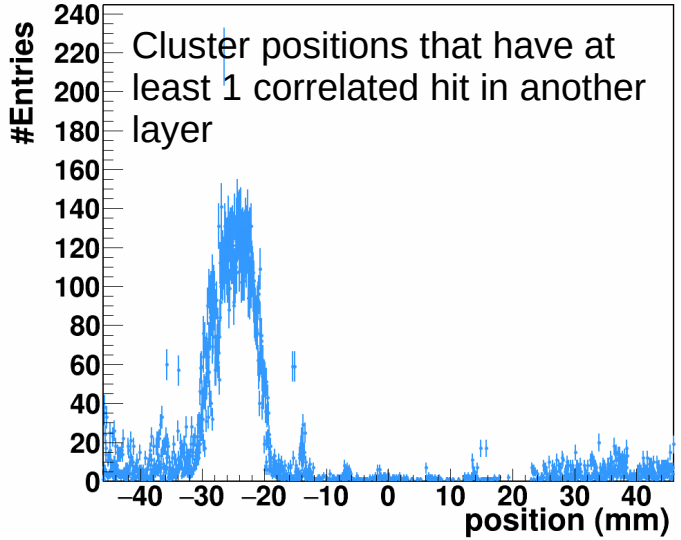


S/N cut + clustering

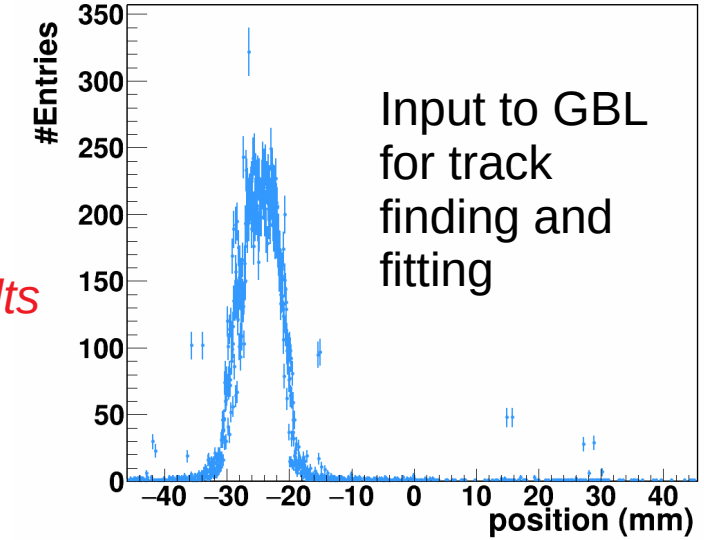


Previous results

Correlations between layers

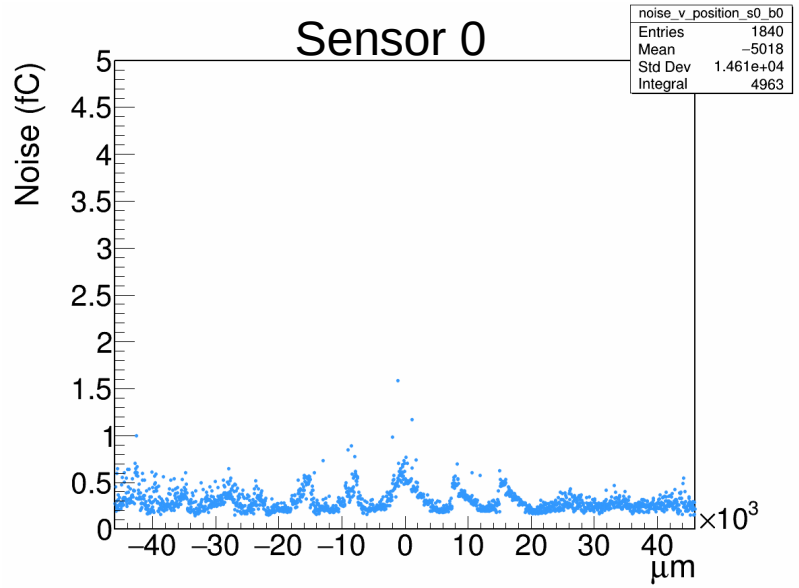


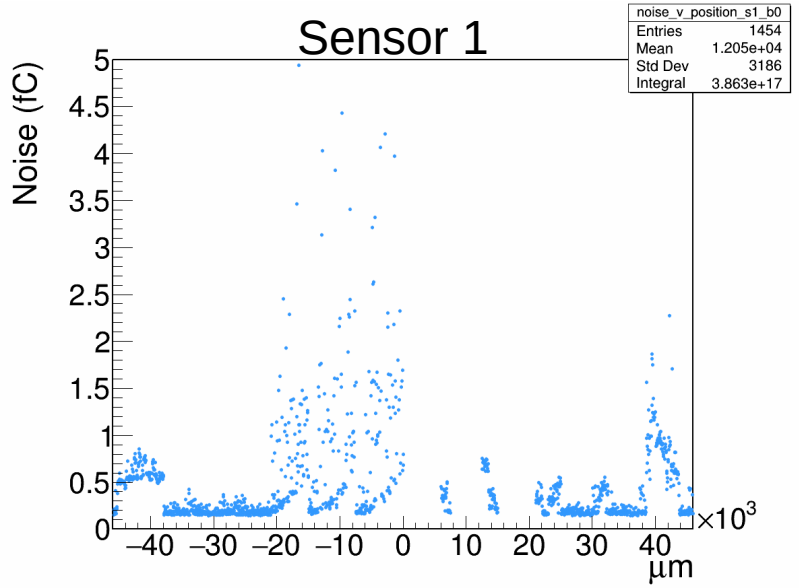
Trigger filter

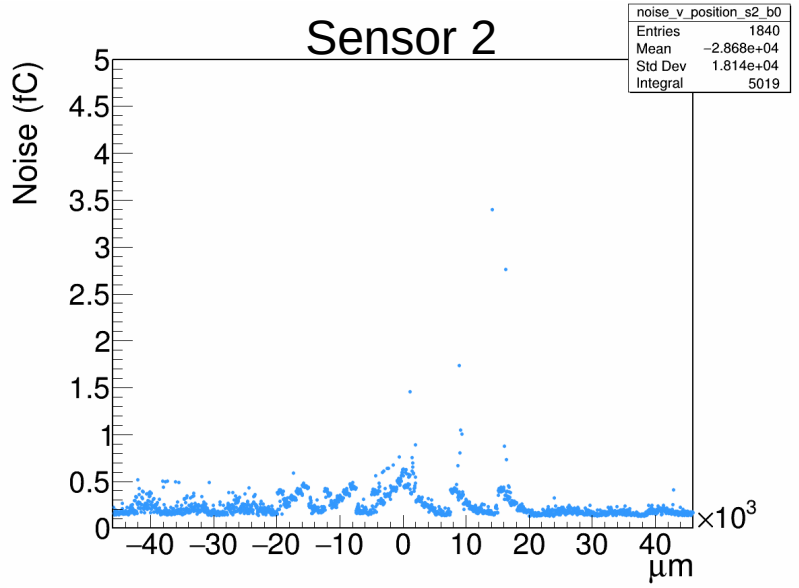


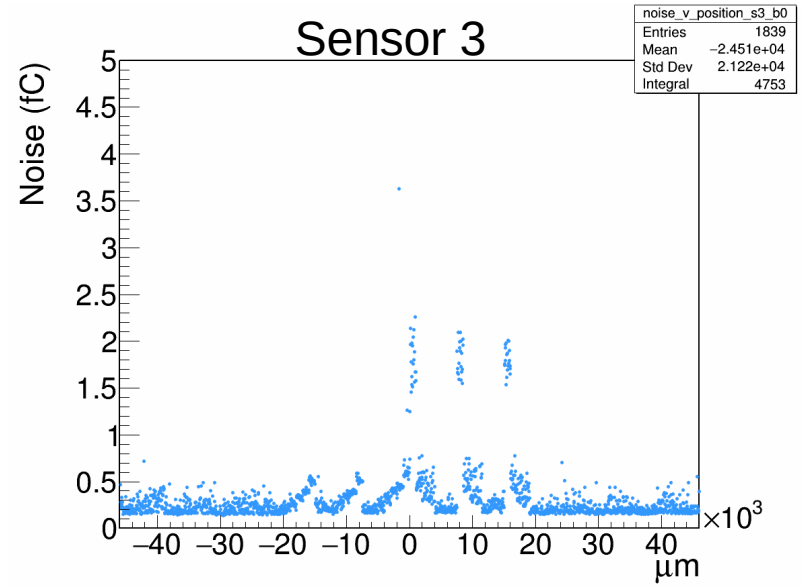
New results

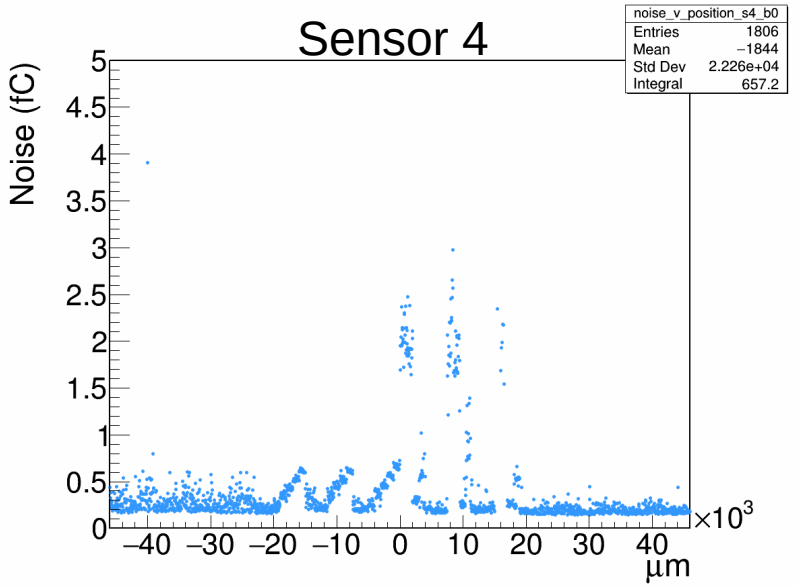
General Sensor performance

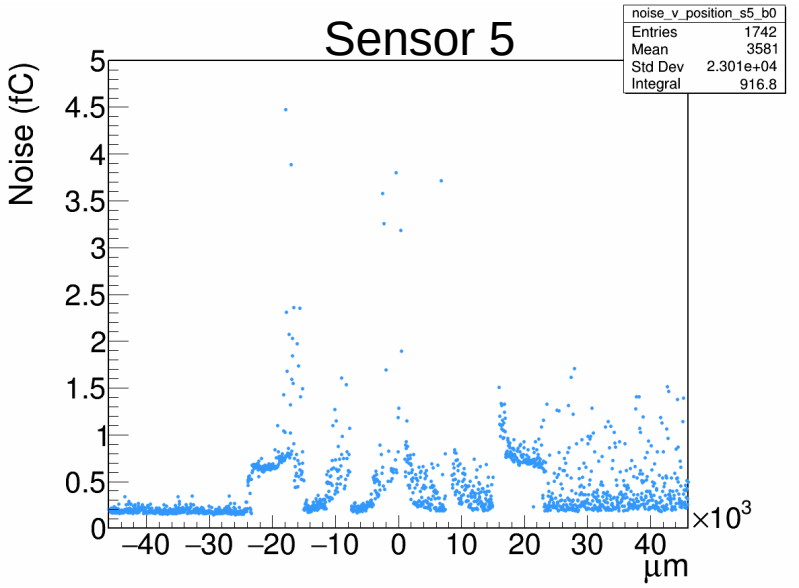






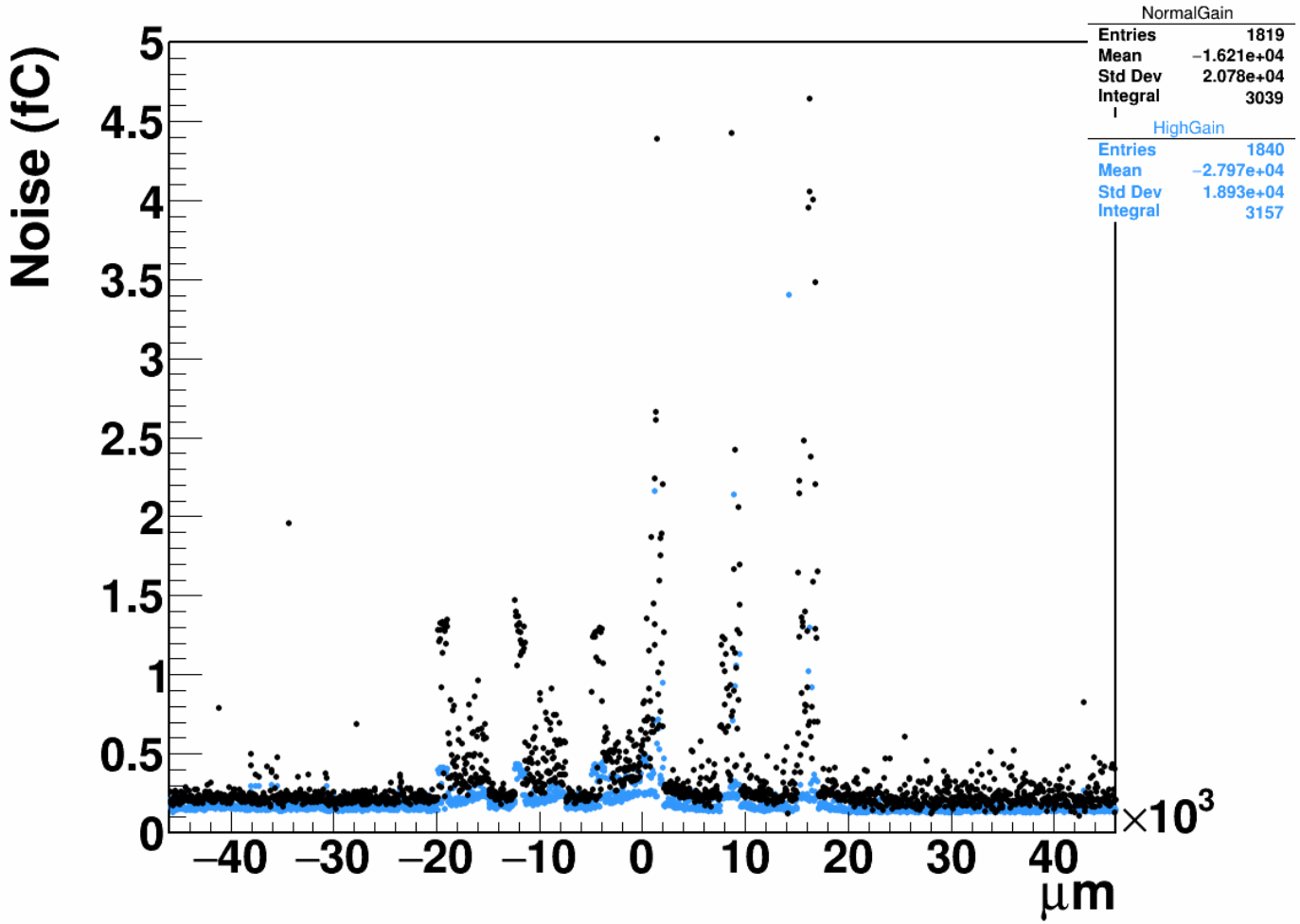






General Sensor performance

- Noise pattern less pronounced in high gain
- General baseline noise after calibration is 30% lower in high gain than in normal gain



TPC synchronization in detail