Lycoris: Large Area Telescope

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

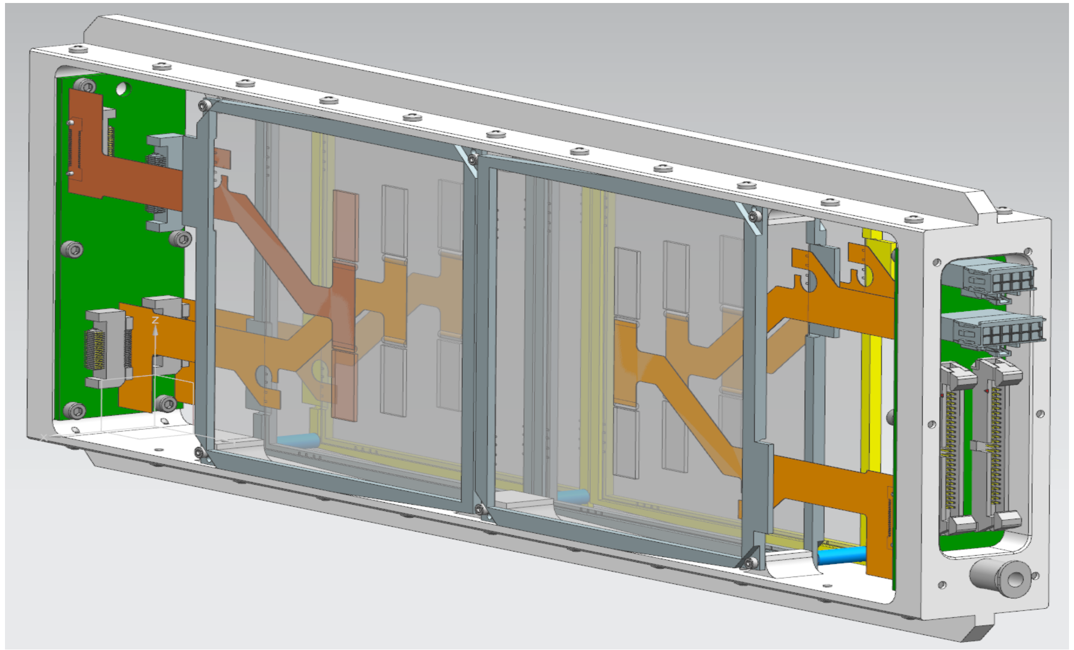


Fig.: Lycoris Tēlescopia

Fig.: Lycoris Radiata

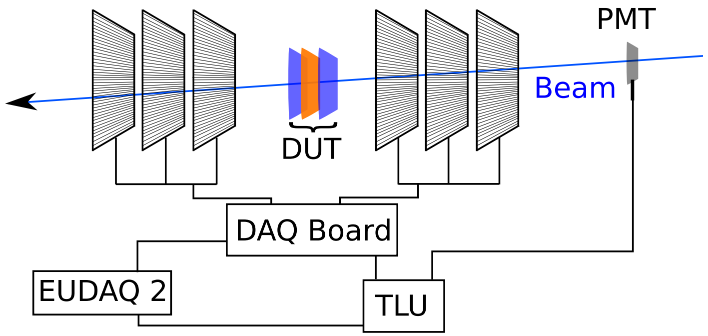
Uwe Krämer, Mengqing Wu

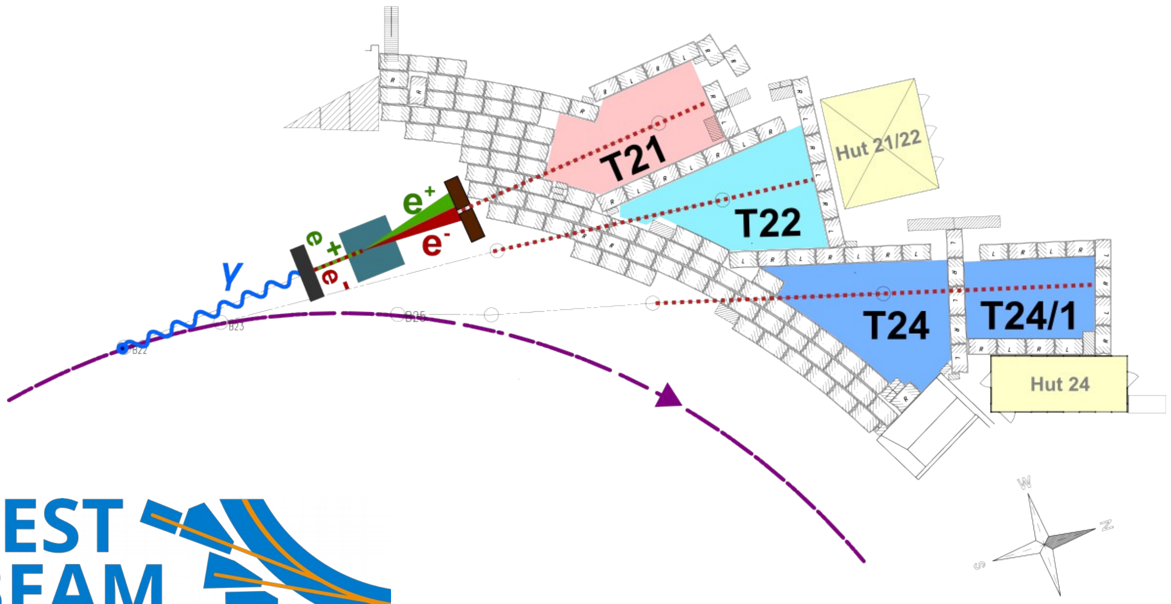
LCTPC Collaboration Meeting 13th of January 2020

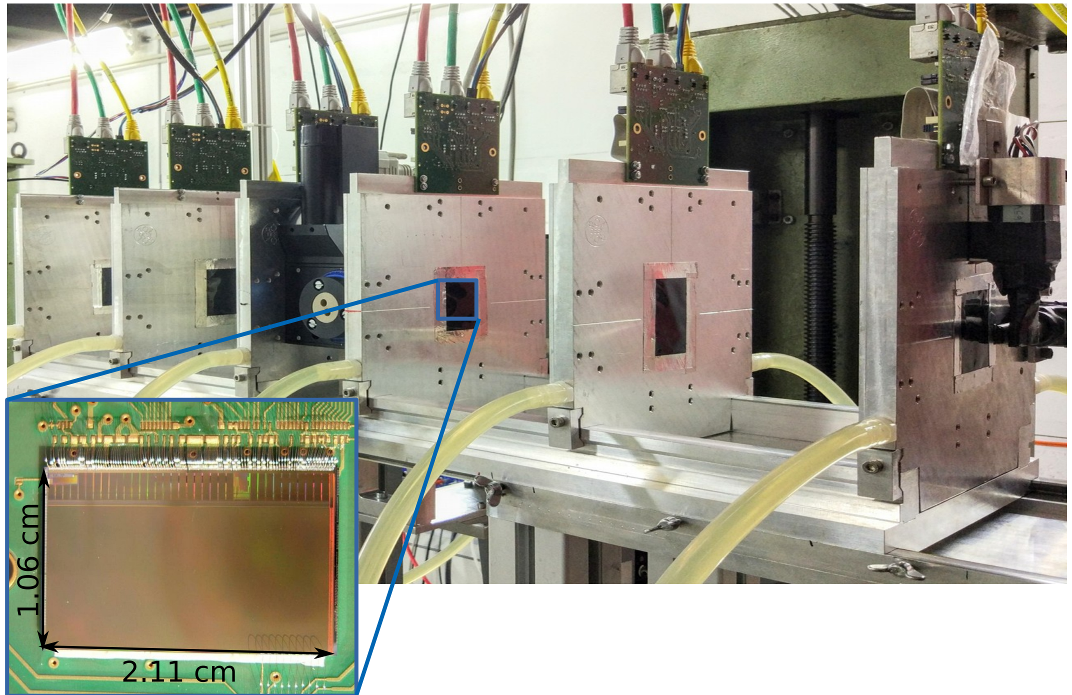
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES
AIDA 2020
LCTPC
DESY TEST BEAM.
DESY.

Telescopes at the DESY II Testbeam Facility

- Three EUDET silicon pixel Telescopes (Datura/Duranta/Azalea).
- Based on Mimosa 26, in T21, T22 and T24.
  - 3-4 µm tracking resolution .
  - Water cooled.
  - Large Aluminum Frames for holding.







DESY TEST BEAM.
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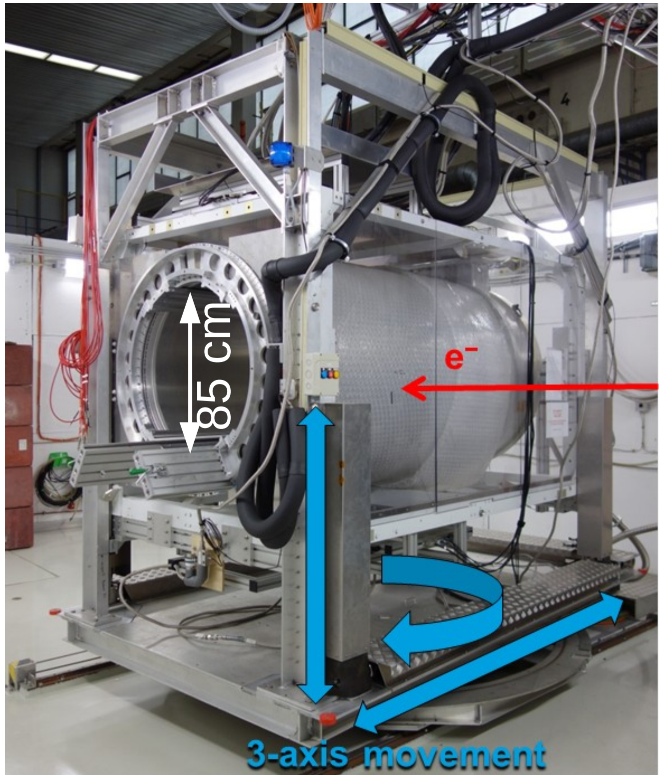
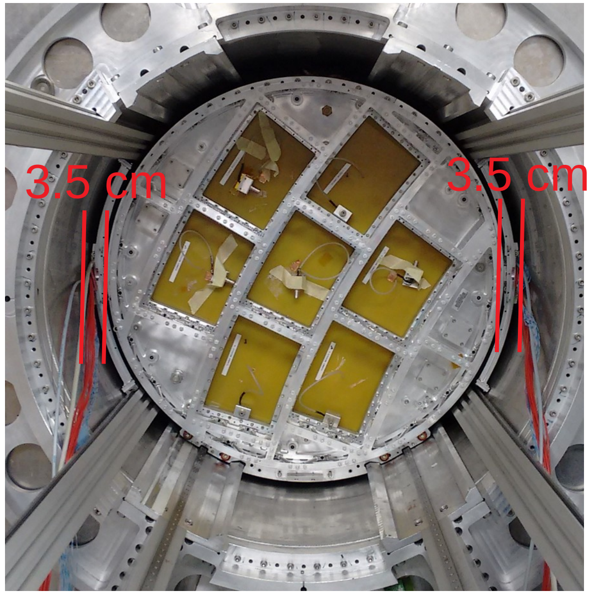
A New Telescope

- 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





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

- 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

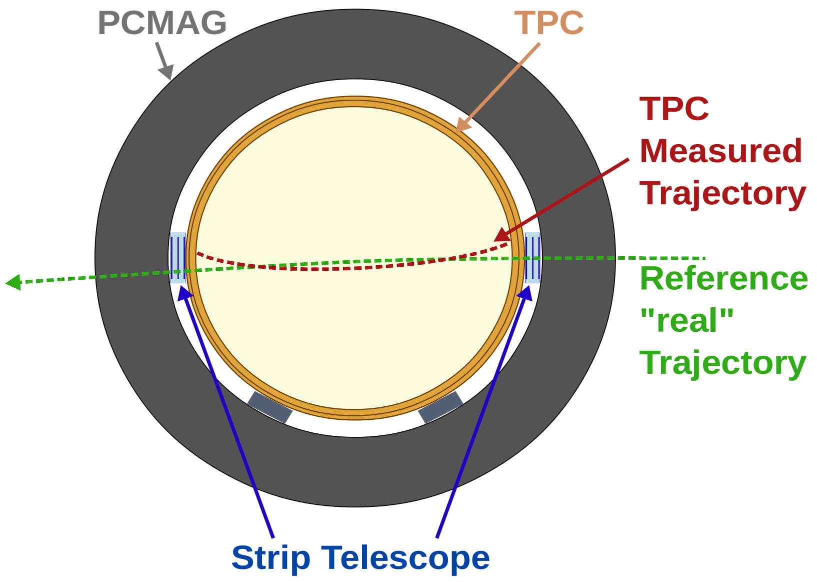


Fig.: Sketch explanation for the need of a reference trajectory

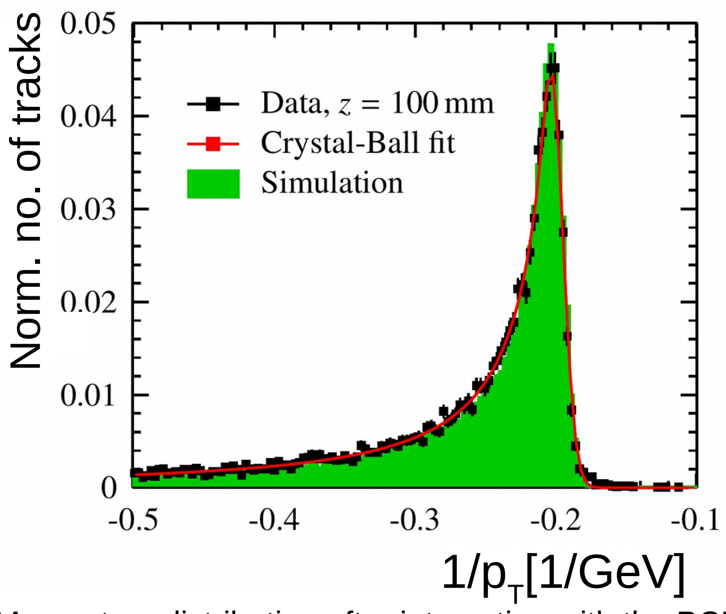
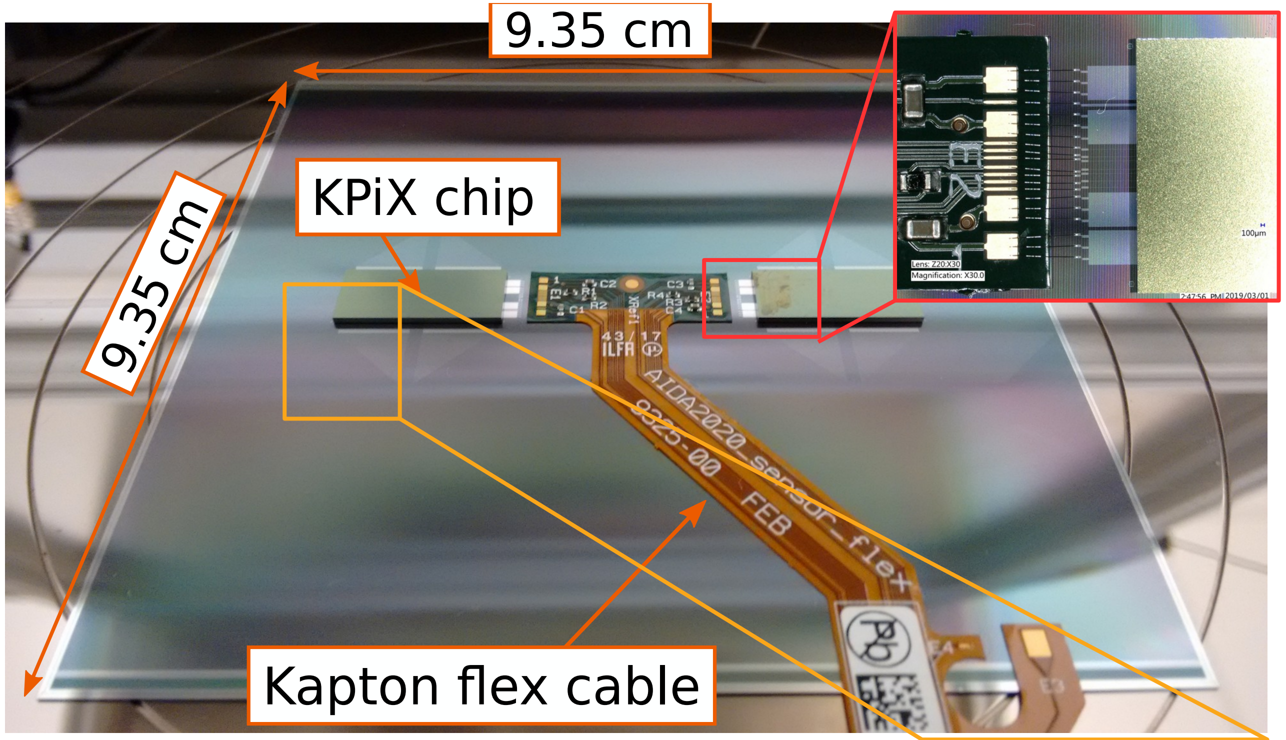


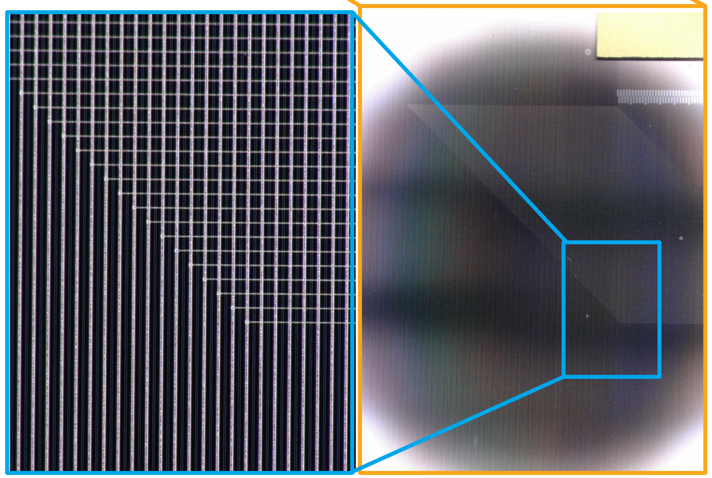
Fig.: Momentum distribution after interaction with the PCMAG wall (Felix Müller | DOI: 10.3204/PUBDB-2016-02659)

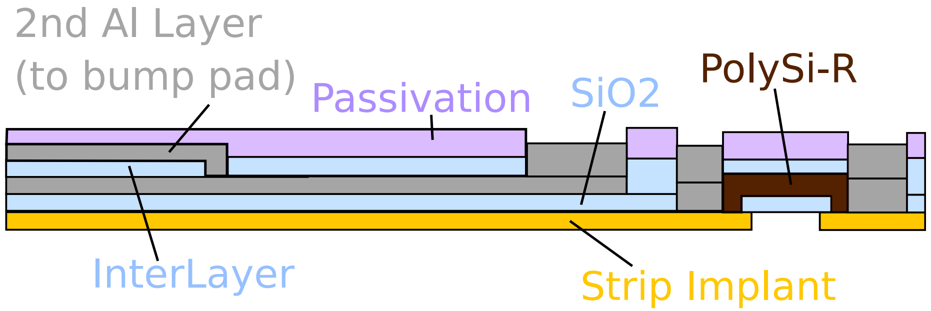
The SiD Silicon Strip Sensor

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

- A readout/floating strip pitch of 50/25 µm.
  - ~7 micron tracking resolution with charge sharing.
- An integrated pitch adapter and digital readout (KPiX).
  - Directly bump bonded to sensor surface.
- Thickness of 320 µm.
- Material budget of 0.3% X_0.







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

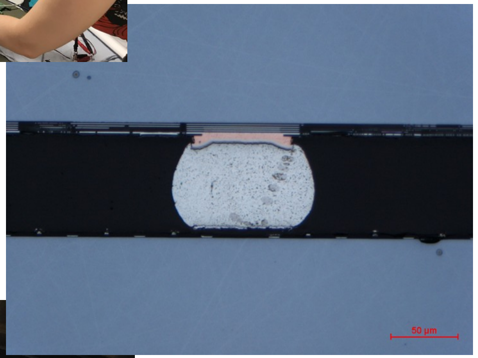
→ 2 Sensors were not assembled

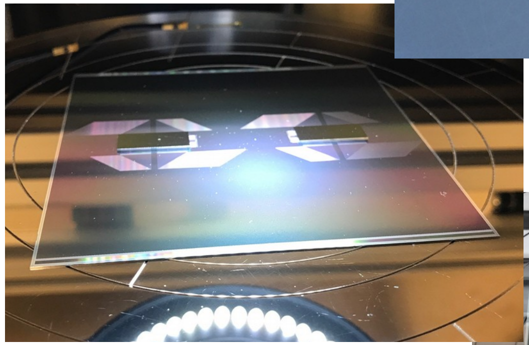
17 sensors fully assembled sensors at DESY

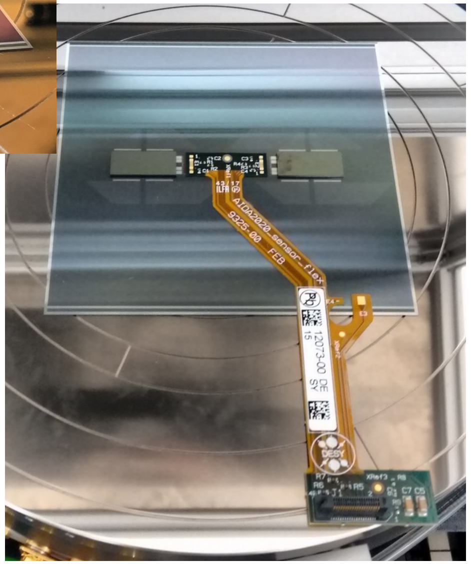
- E-Lab tests on sensor performance

→ 8 sensors showed mediocre performance

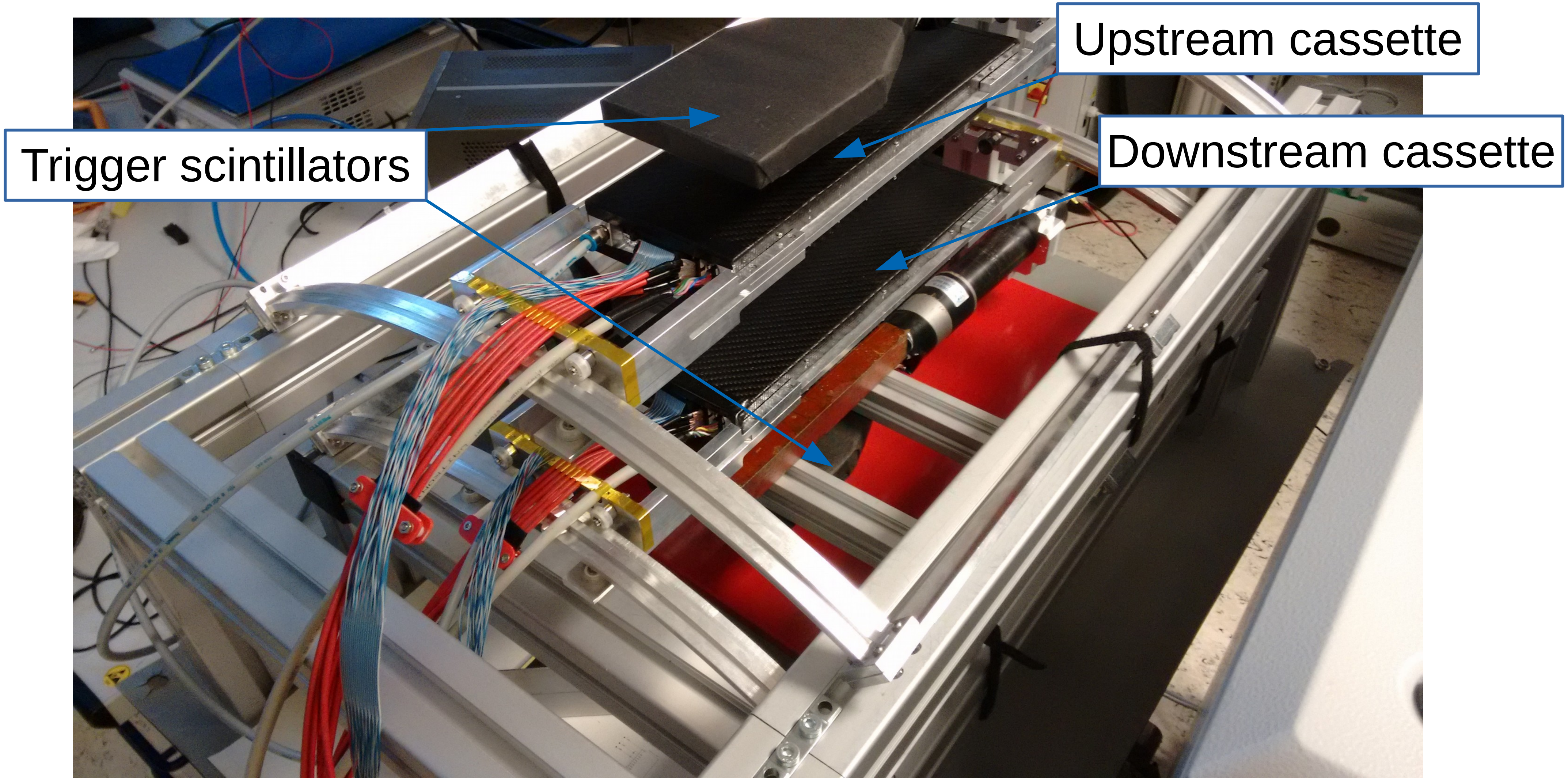
<u>9 Sensors were used during test beam campaigns</u>







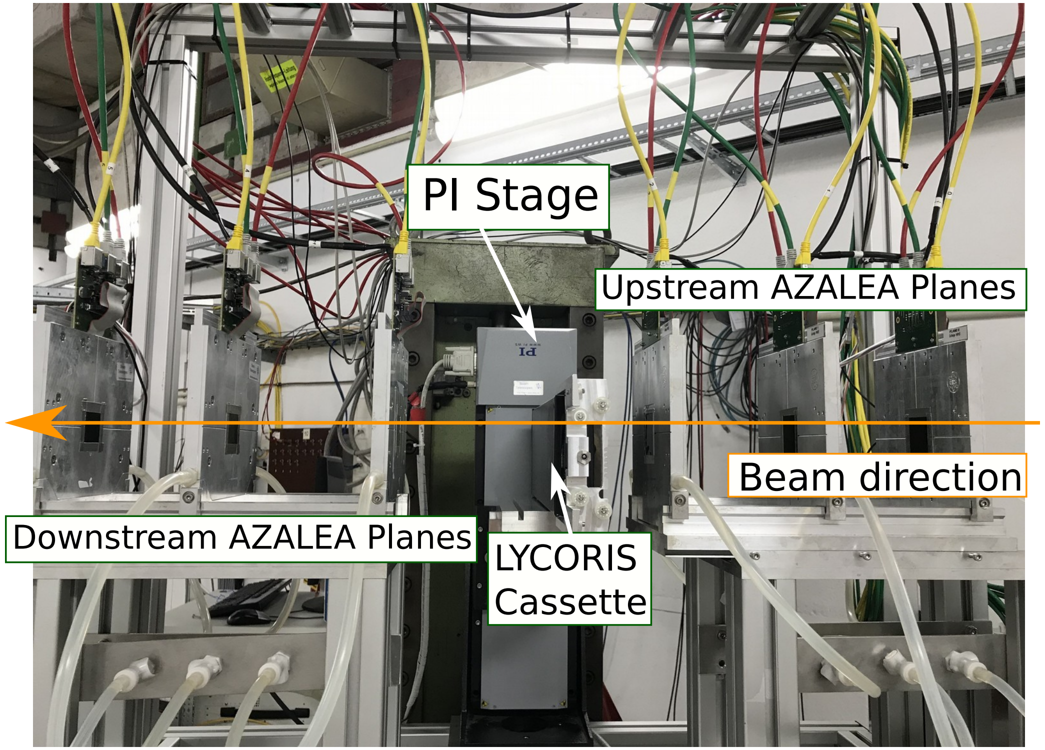
Cosmic Setup



Test Beam Setup

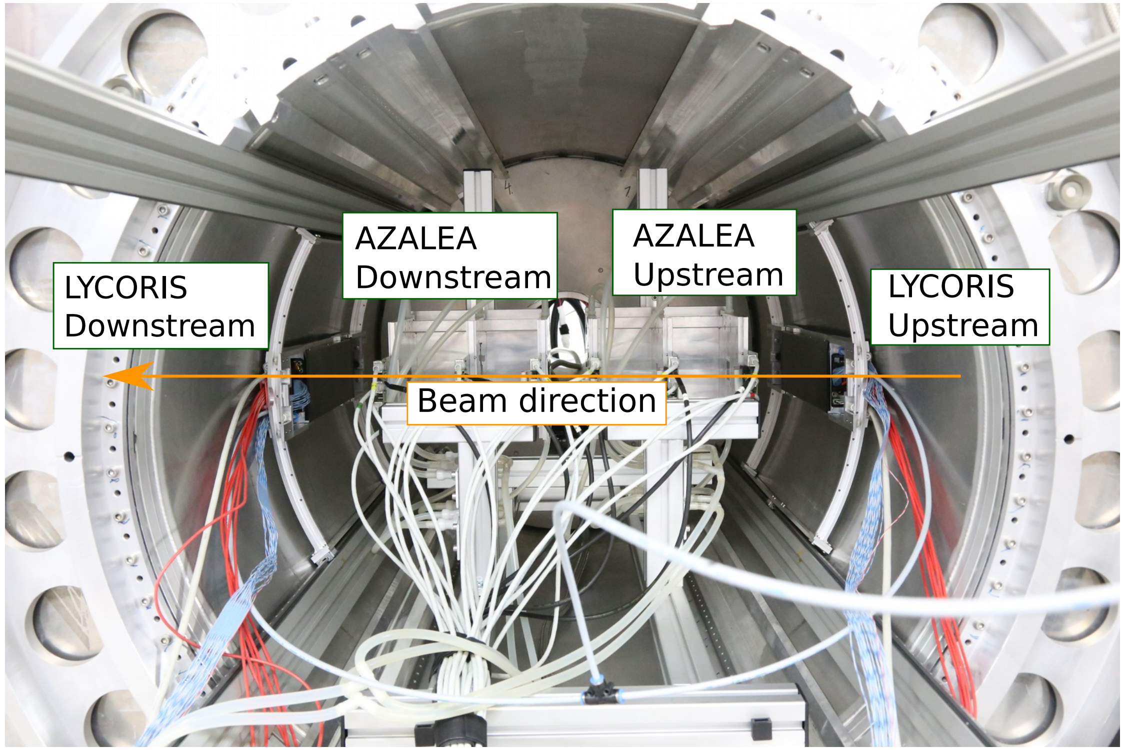
T24 setup

- One LYCORIS cassette placed between both AZALEA planes

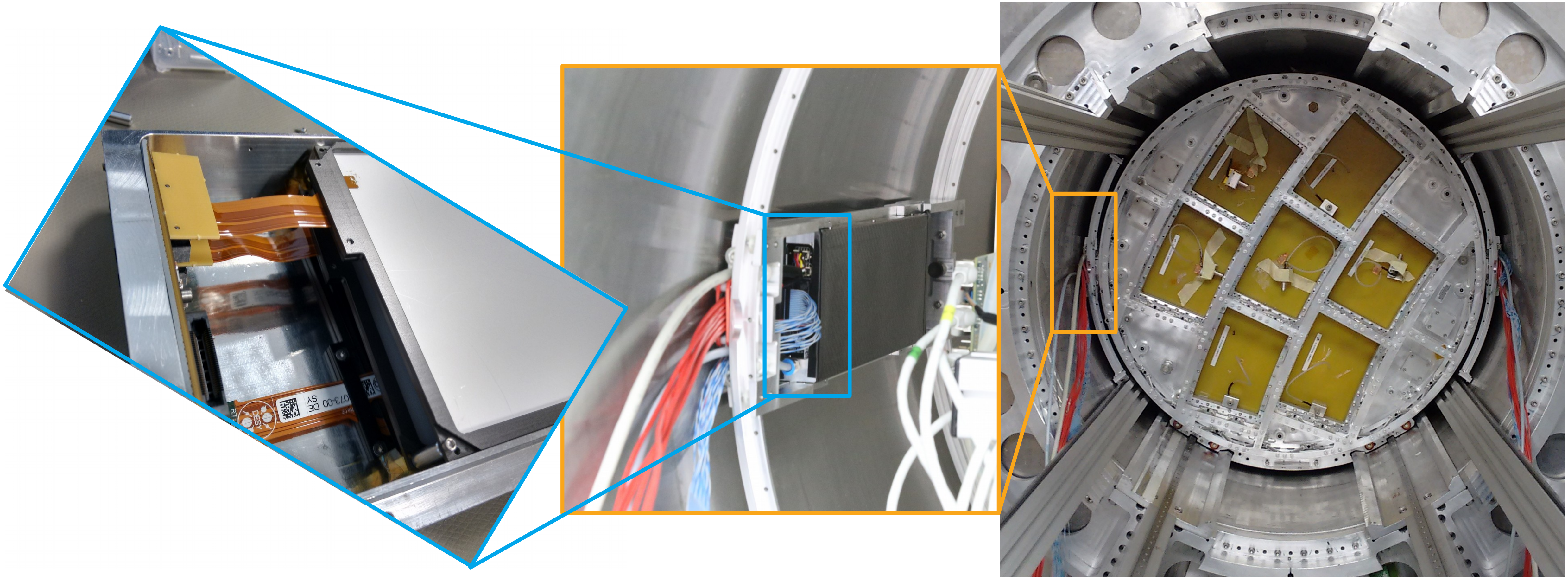


T24/1 setup

- Both AZALEA planes are placed between two LYCORIS cassettes

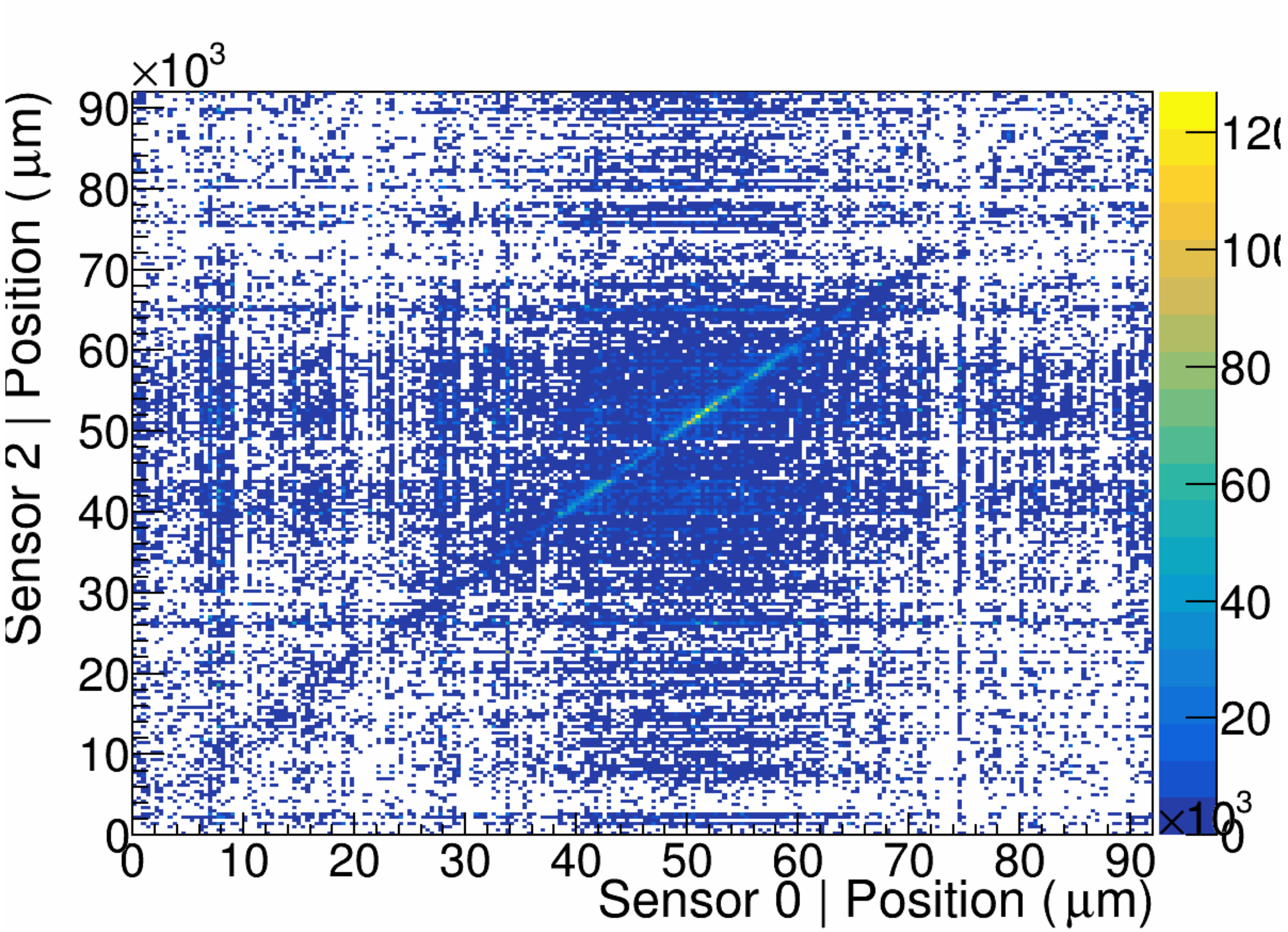


Final System

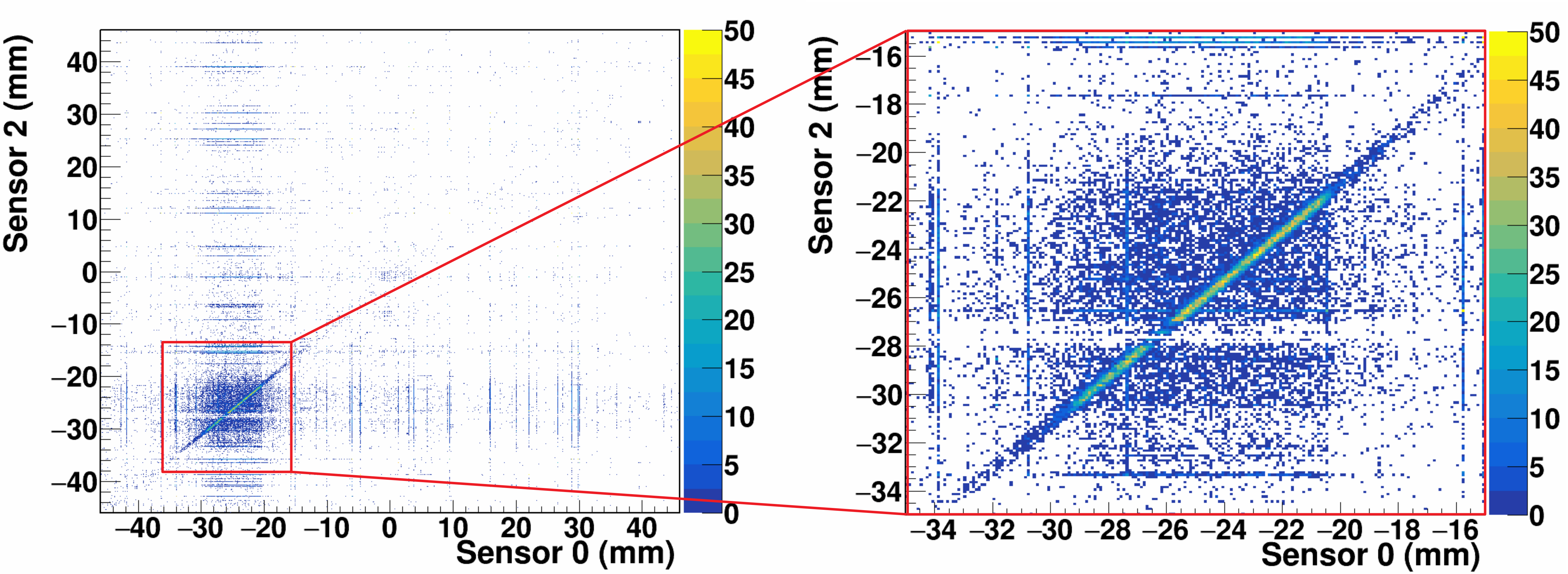


First testbeam results

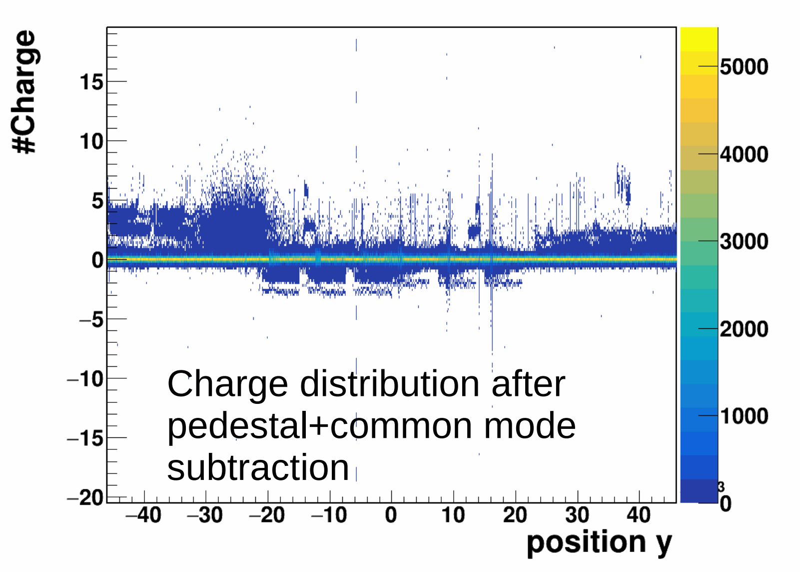
- General useabality of the system was shown in first data
- Overall quality of data seemed fairly bad
- Result of taking raw hits before any layer correlations.



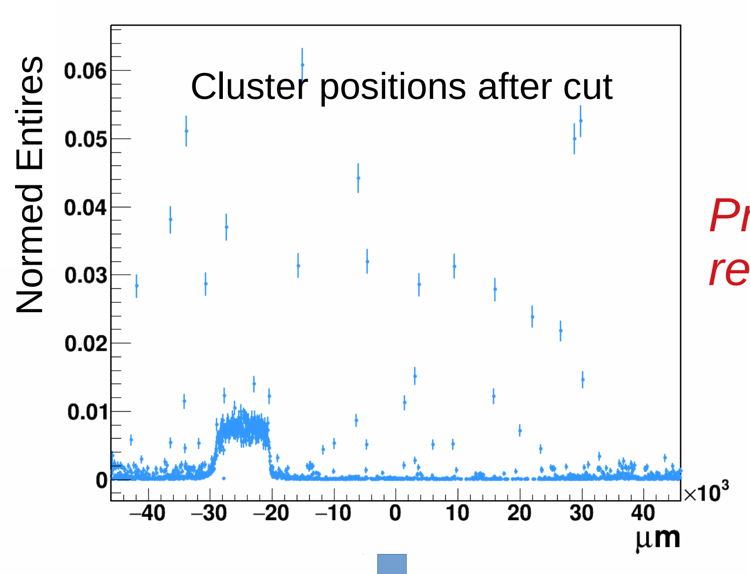
Recent test beam results



A small step by step

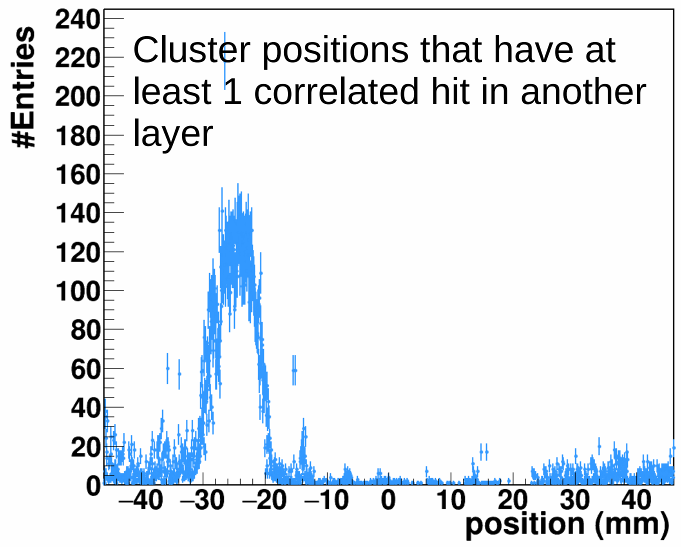


S/N cut + clustering

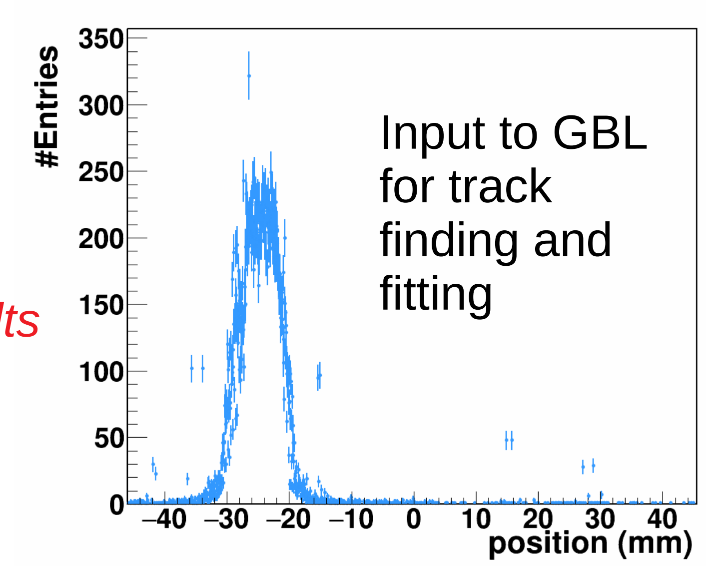


Previous results

Correlations between layers

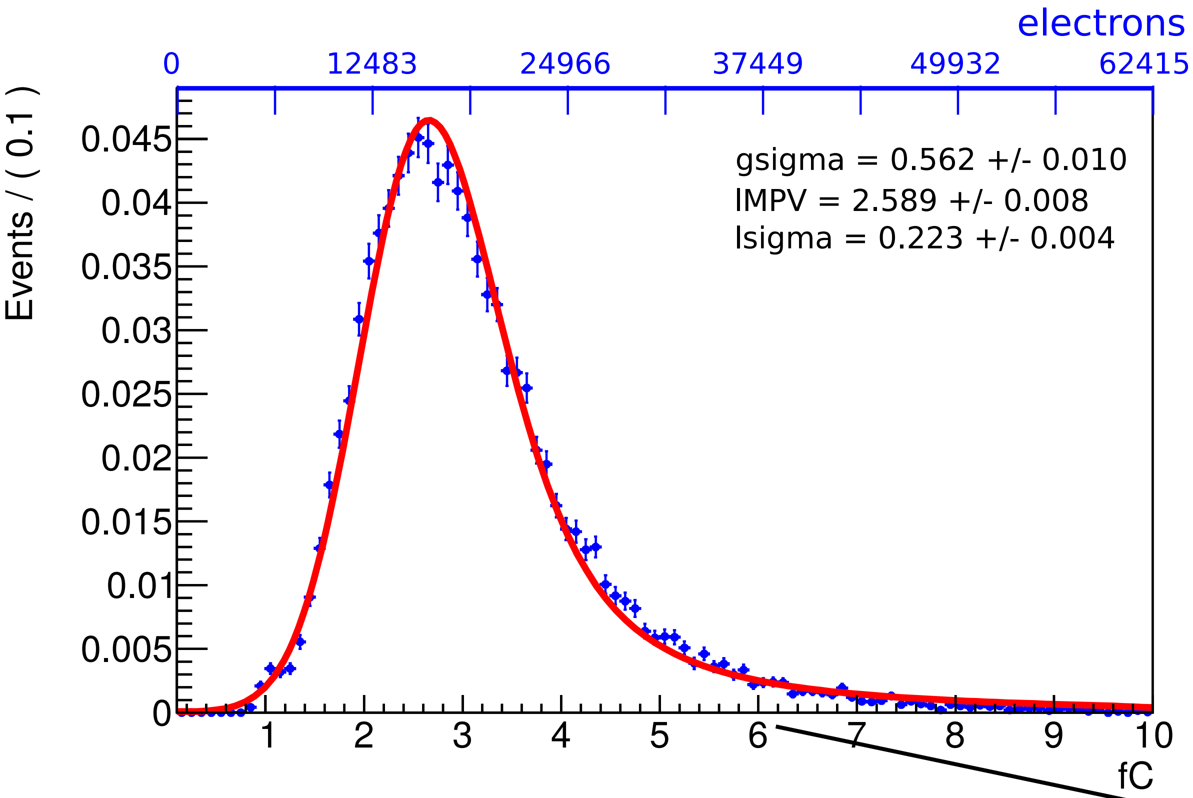


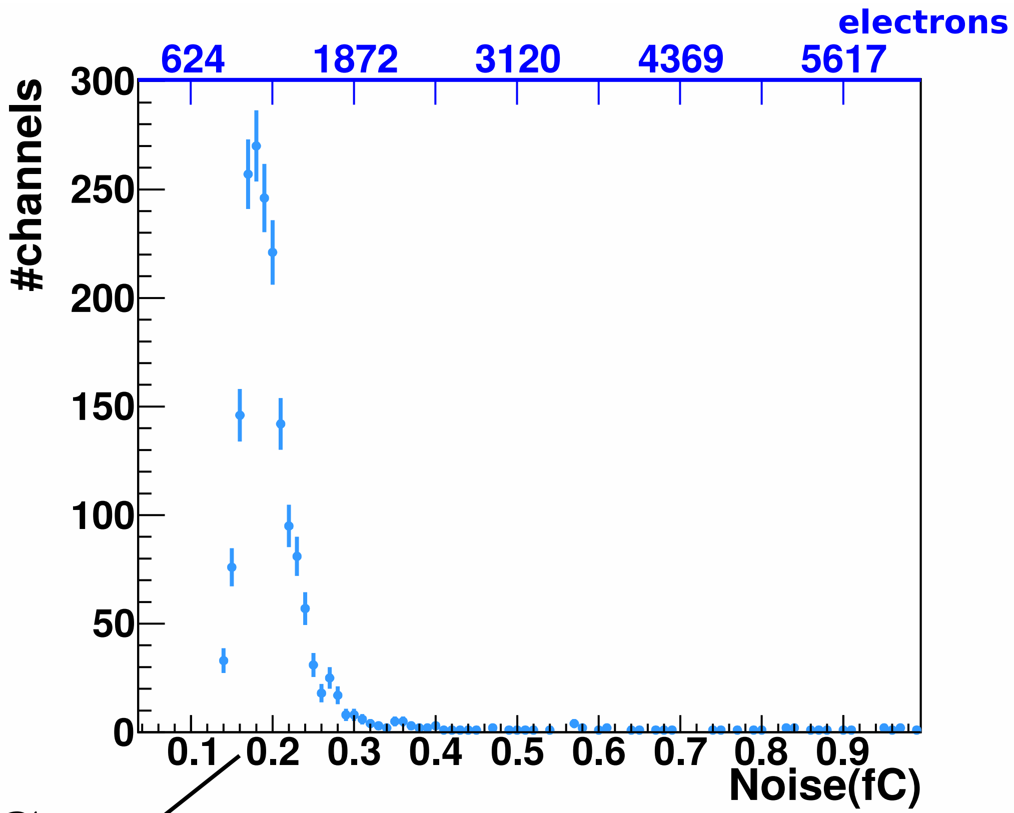
Trigger filter



New 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

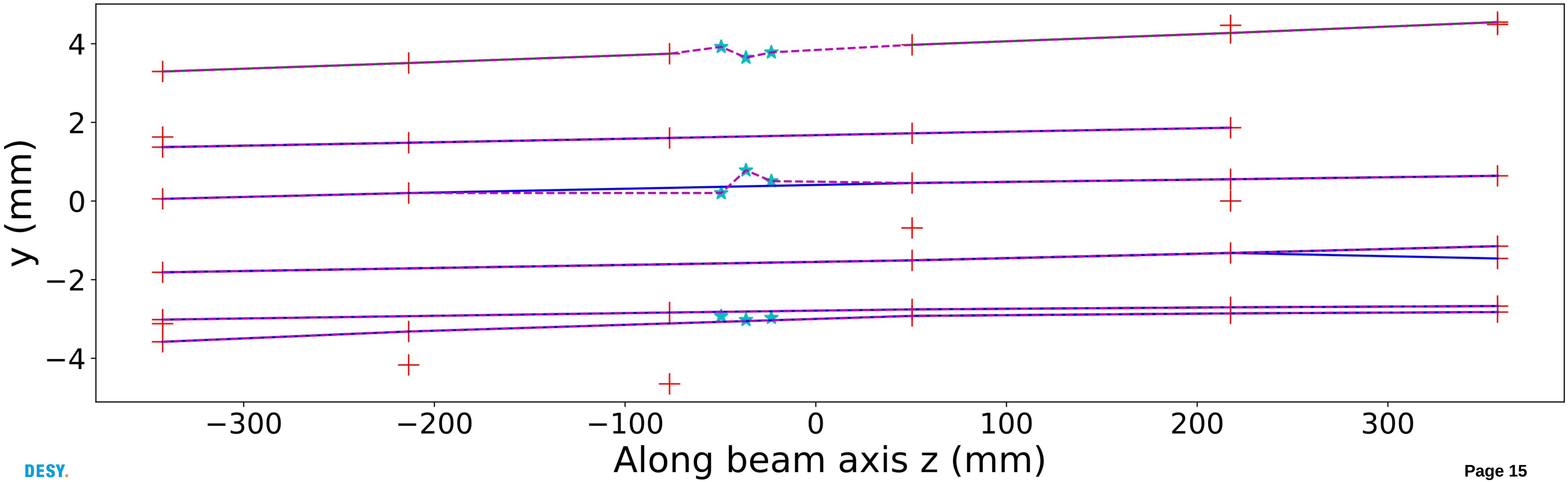
Comparing apples and oranges

- To perform track finding and fitting we want to use the AZALEA telescope as reference to see our achievable resolution with LYCORIS.
- Unfortunately: The two systems are extremely different.
  - Mimosa: Continuous rolling shutter readout and extremely slow
  - 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

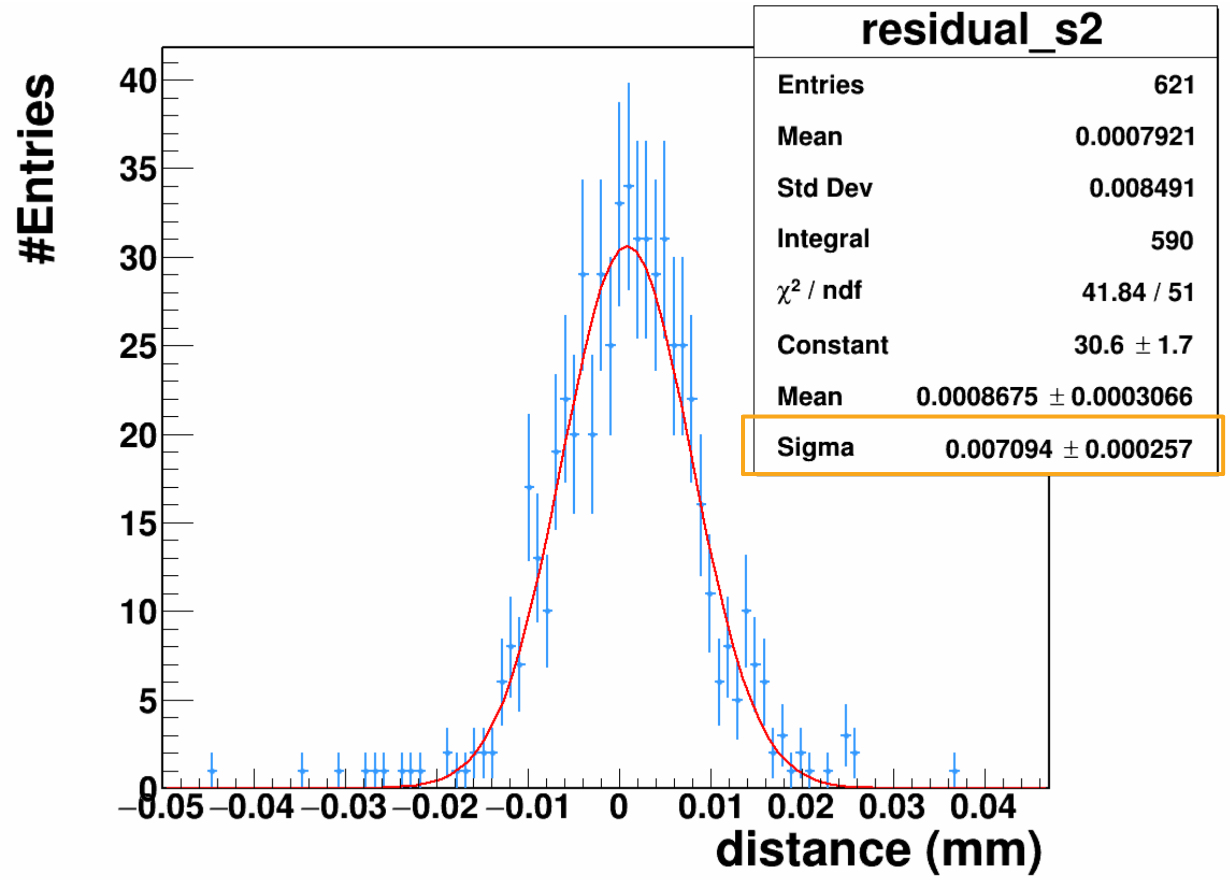
Making things fit

- The fact that only a fraction of all events are compatible with each other severely limits statistics.
- ~5% of all recorded Mimosa events have LYCORIS events
- We perform two different track finding algorithms.
  - For purity: Triplet Finder
  - For efficiency: Road Search



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

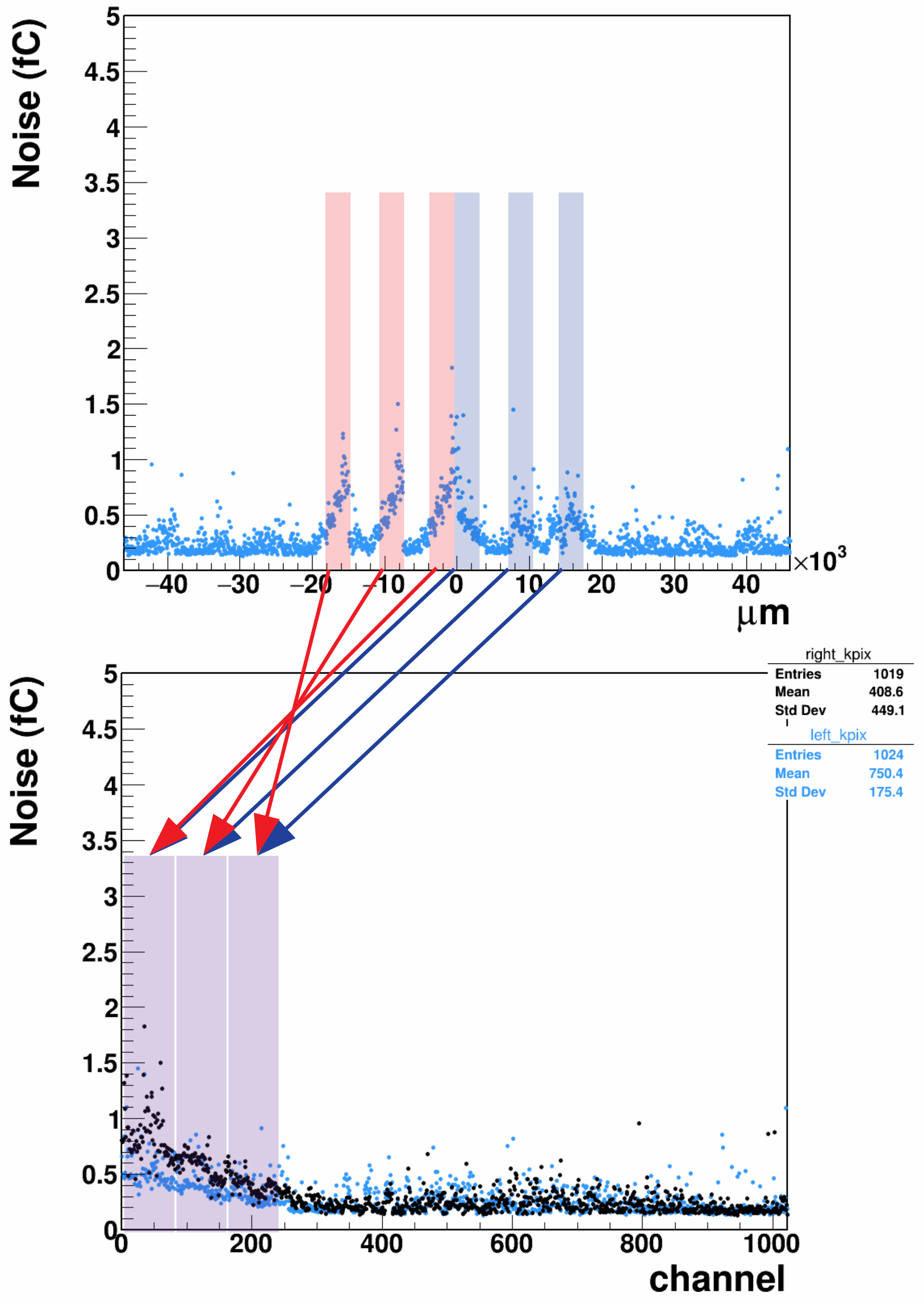


An open question

- While on average the S/N is ~13 the center region strips have much higher noise than the average

  → Lower S/N → Efficiency

- Unclear noise source that is mirrored between KpiX that can be referenced to power connection to the chip
  - Leakage of power into pixels?
  - Induced noise because of insufficient shielding from adjacent power/signal lines?



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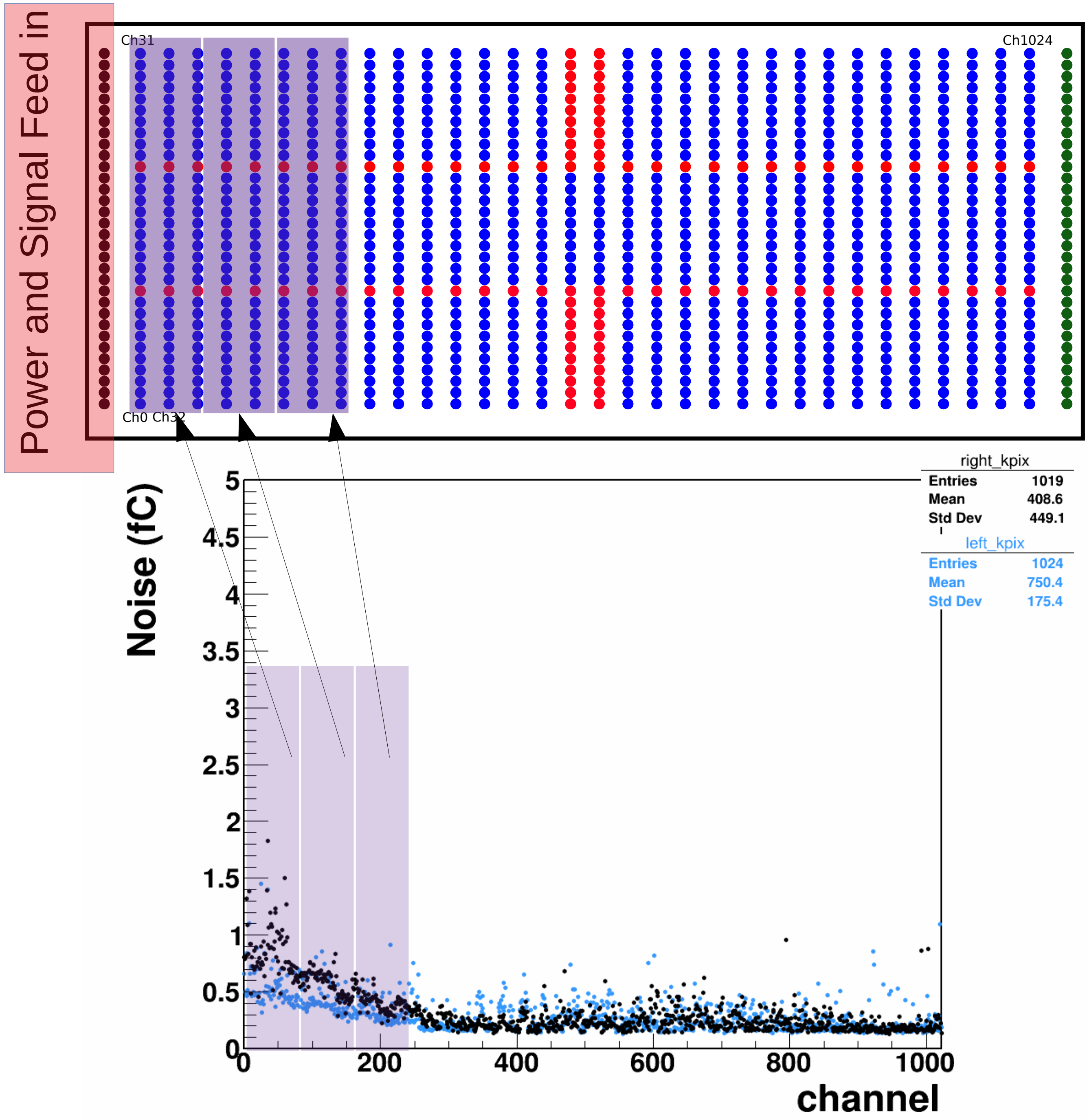


Conclusion and my outlook

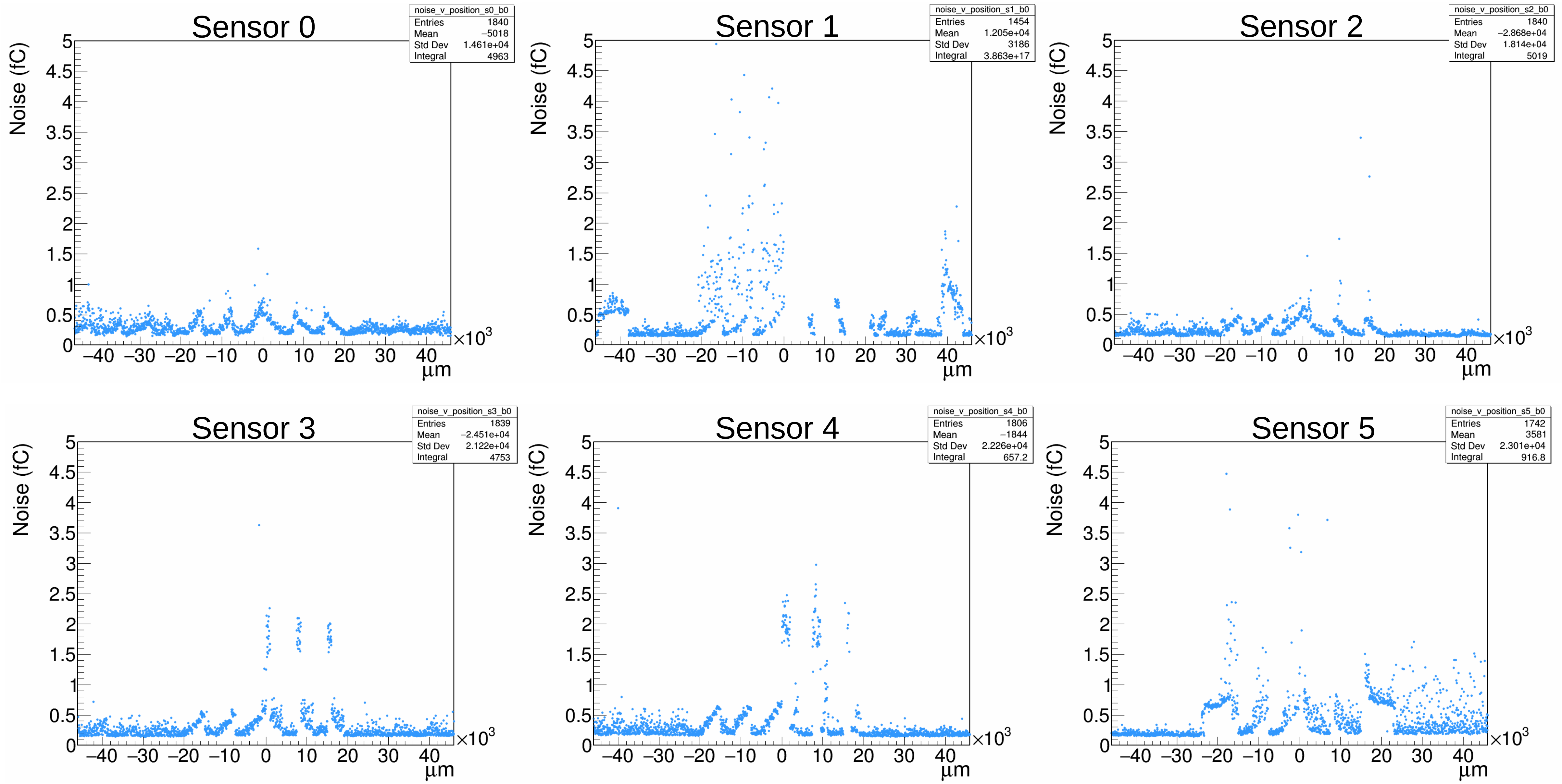
- Showed that an extremely low material budget strip module is feasible and can reach a single point resolution of 7 micron
- System is fully synchronizable to Mimosa → If you can synchronize to Mimosa you can definitely synchronize to Lycoris

- The biggest question that is still open is the large discrepancy between sensors that is not clear yet
  - Is it a problem of the chip or the sensor? Can we adjust our settings to resolve the problem?
- The noise, while annoying, does not prohibit the use of the sensors as a telescope

- The next steps are to look into other data sets including the T24/1 data set to:
  - Crosscheck results
  - Determine momentum resolution

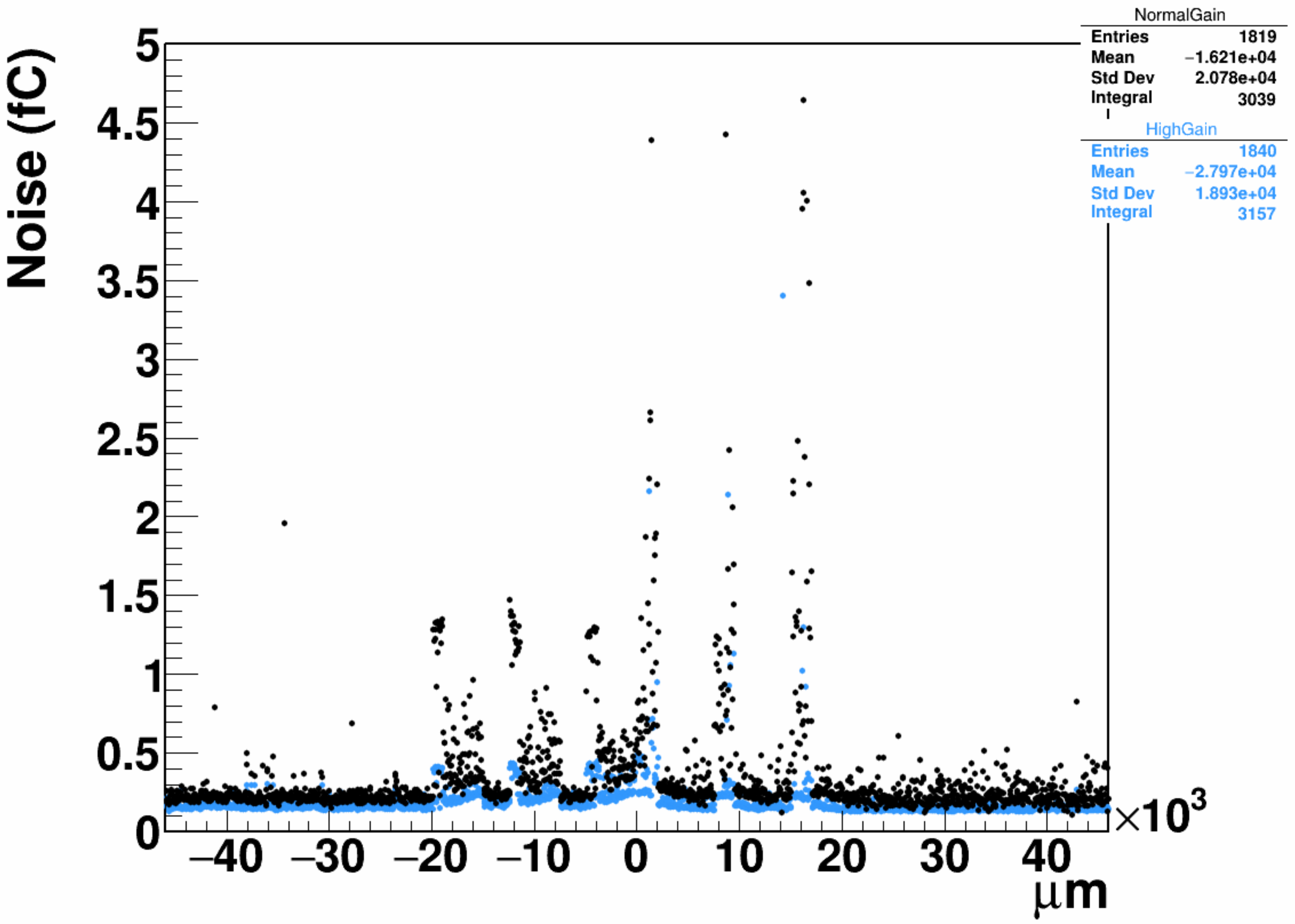
Backup

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

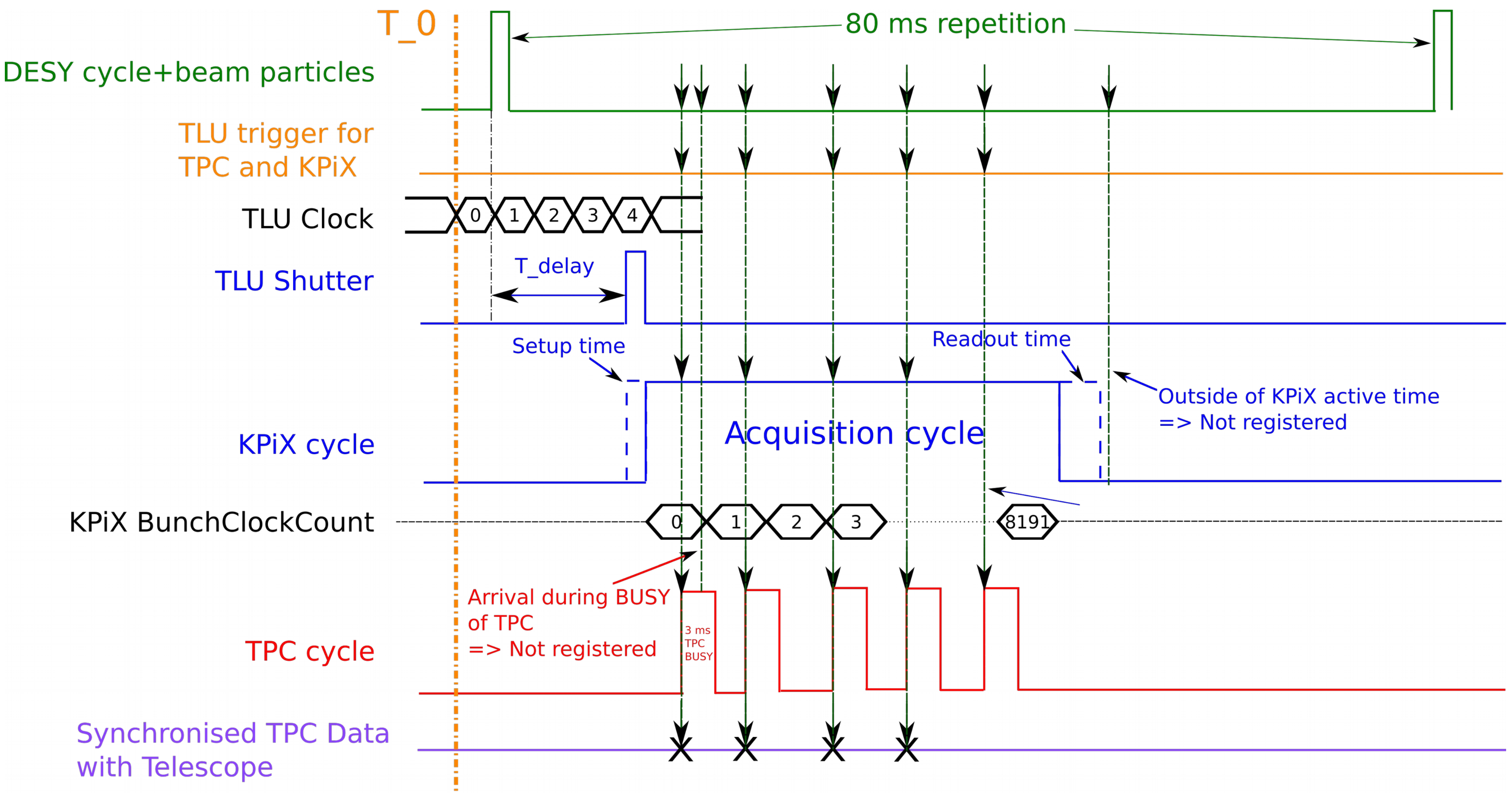


Next steps for use as infrastructure

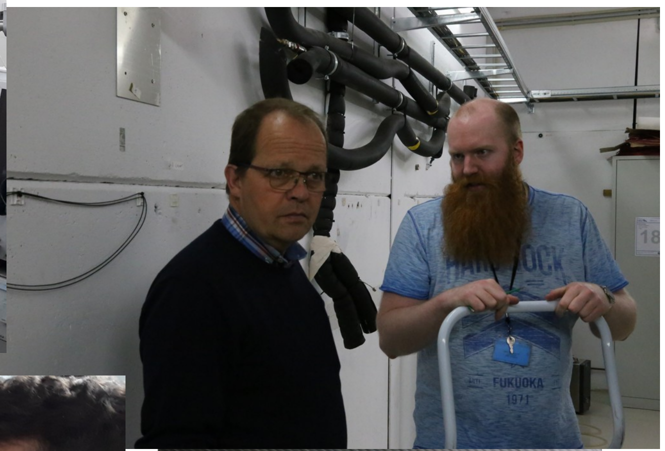
- We have proven that the system works as a telescope and that we can find tracks using the telescope.
- While the sensors show slight problems in their performance, in general the system can reach a 95% plane efficiency.
- The system is fairly easy to use and was integrated into EUDAQ

- Finally we try to provide an analysis suite that can be used to analyze the data.

TPC synchronization in detail




DESY.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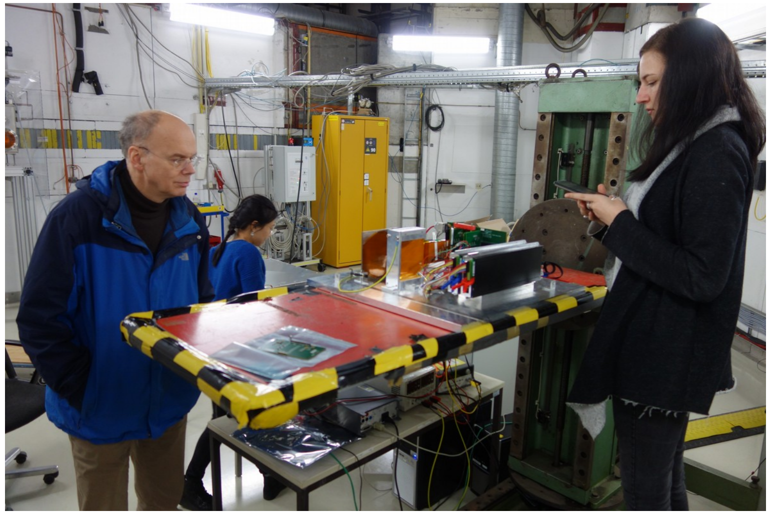

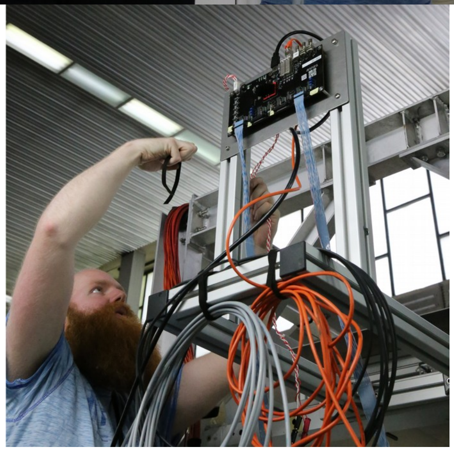

After Test Beam is Before Test Beam

- 3 test beam campaigns. ~ 2 months spent at the DESY II Test Beam Facility and the time in between to prepare for the next

<u>February 2019</u>

- First test beam with 2 tracker sensors in cassettes
- Combined beam with tracker and ECAL
- Help from Amanda Steinhebel from Oregon

<u>May 2019</u>

- First test beam campaign with new electronics within 1T solenoid
- 6 full sensors in two separate cassettes
- Help from Benjamin A. Reese from SLAC

<u>July 2019</u>

- First test beam with a fully stacked cassette between AZALEA in T24
- Another test beam campaign in T24/1 using a different set of sensors
- Help from a lot of FLC people