Lycoris: Large Area Telescope

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

Ties Behnke, Ralf Diener, **Uwe Krämer**, Marcel Stanitzki, Mengqing Wu

in Collaboration with, M. Breidenbach, D. R. Freytag, B. A. Reese and R. Herbst from SLAC

LCTPC Collaboration meeting , 9-11th of January 2019

Case for an External Reference Tracker

- **Challenge:** Distortion of particle trajectory as a result of multiple scattering or inhomogeneous electric fields
- **Solution:** Reference measurement of the particle position before and after the DUT

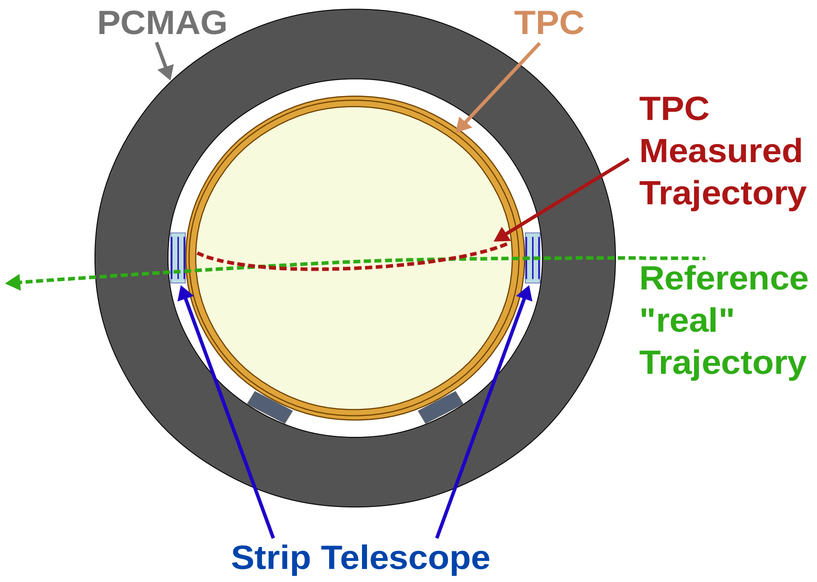

Fig.: Sketch explanation for the need of a reference trajectory

- **Challenge:** Smearing of particle momentum as a result of interactions with the magnet wall
- **Solution:** Accurate measurement of the momentum after magnet wall

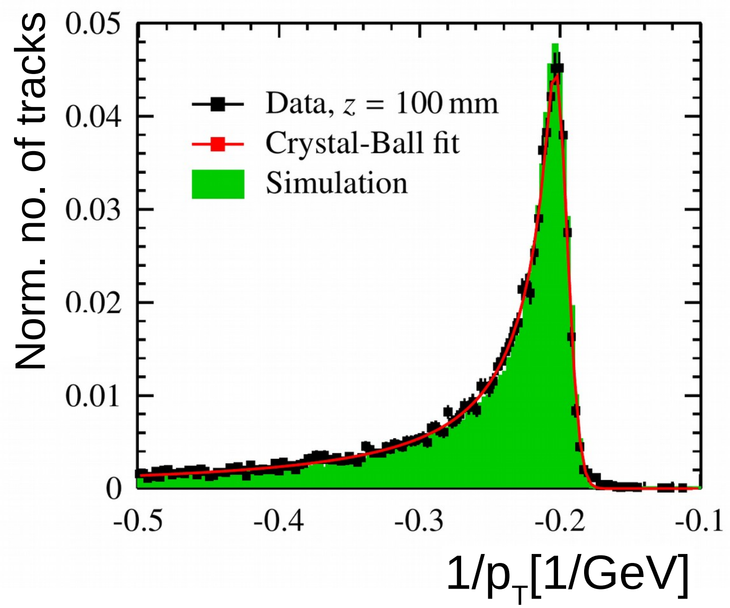

Fig.: Momentum distribution after interaction with the PCMAG wall
(Felix Müller | DOI: 10.3204/PUBDB-2016-02659)

The Lycoris Telescope

An AIDA[2020] project

- A new large area strip telescope within the Test Beam Area 24/1 solenoid
- The solenoid has:
  - Wall thickness of 20% X_0
  - Mounted on a stage to be able to move/rotate along 3 axes
  - Magnetic field strength of up to 1T

- Telescope demands defined by use case:
  - Coverage area of ~10x10 cm^2
  - ~3.5 cm of space per telescope module.
  - Spatial resolution requirements better than:
    - σ_y= ~10 µm
    - σ_z= ~1 mm

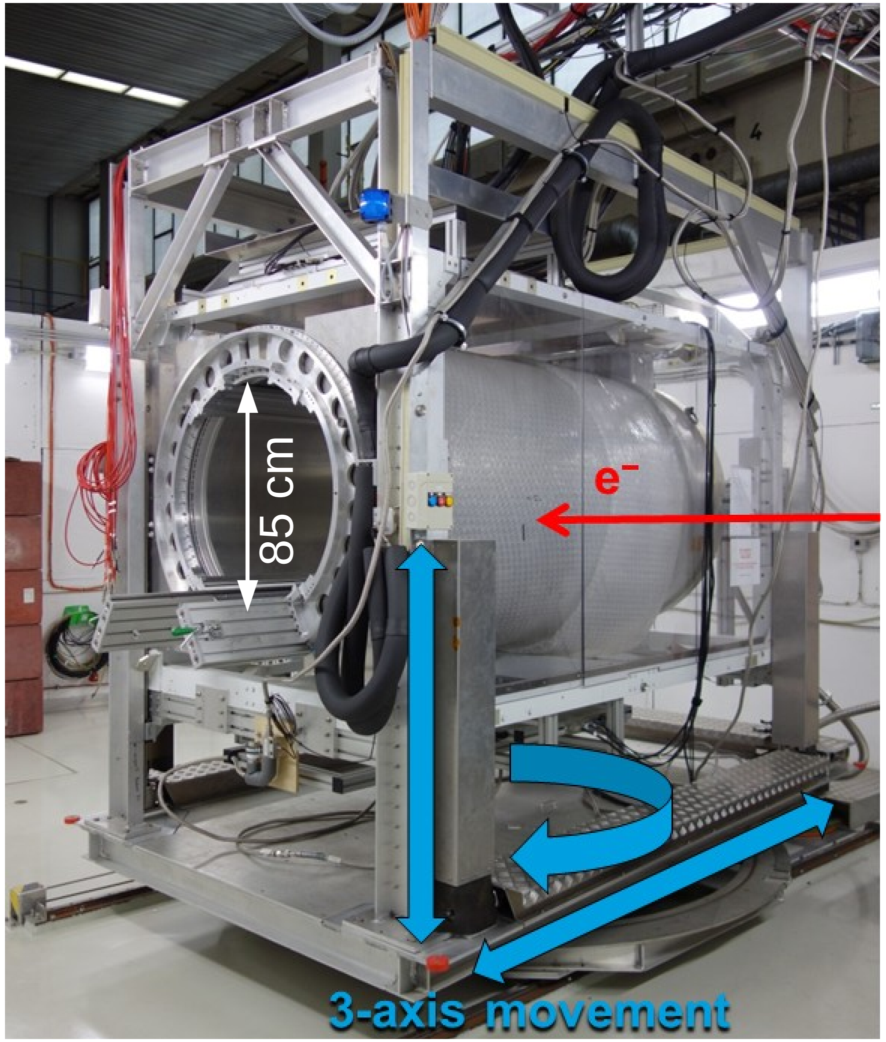

Fig.: PCMAG Stage

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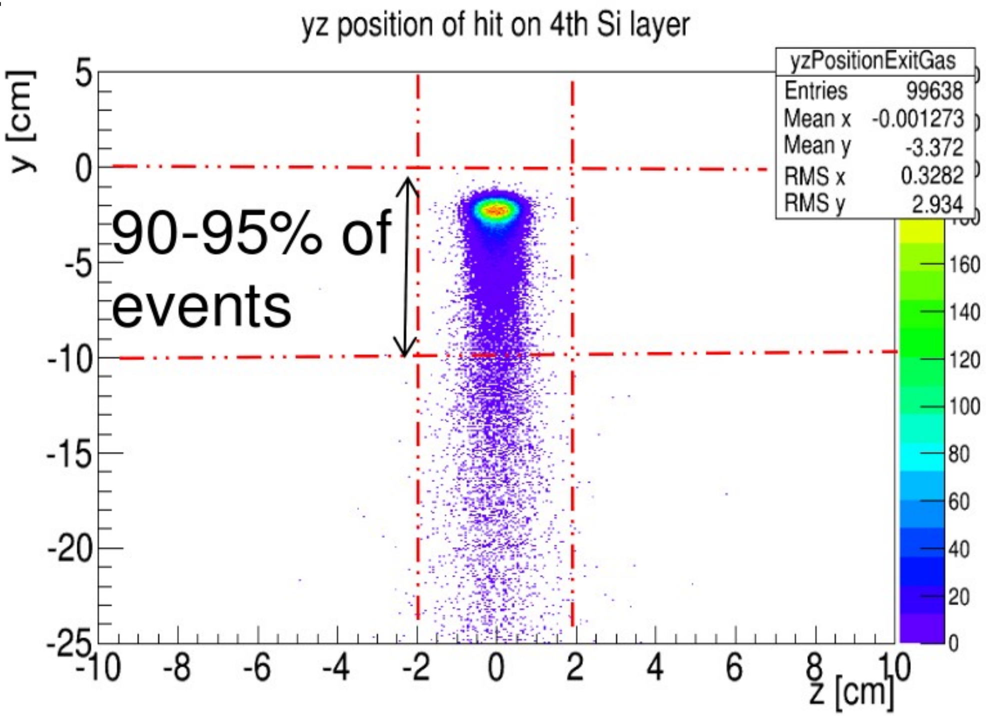

Fig.: Simulated particle spread at last silicon layer

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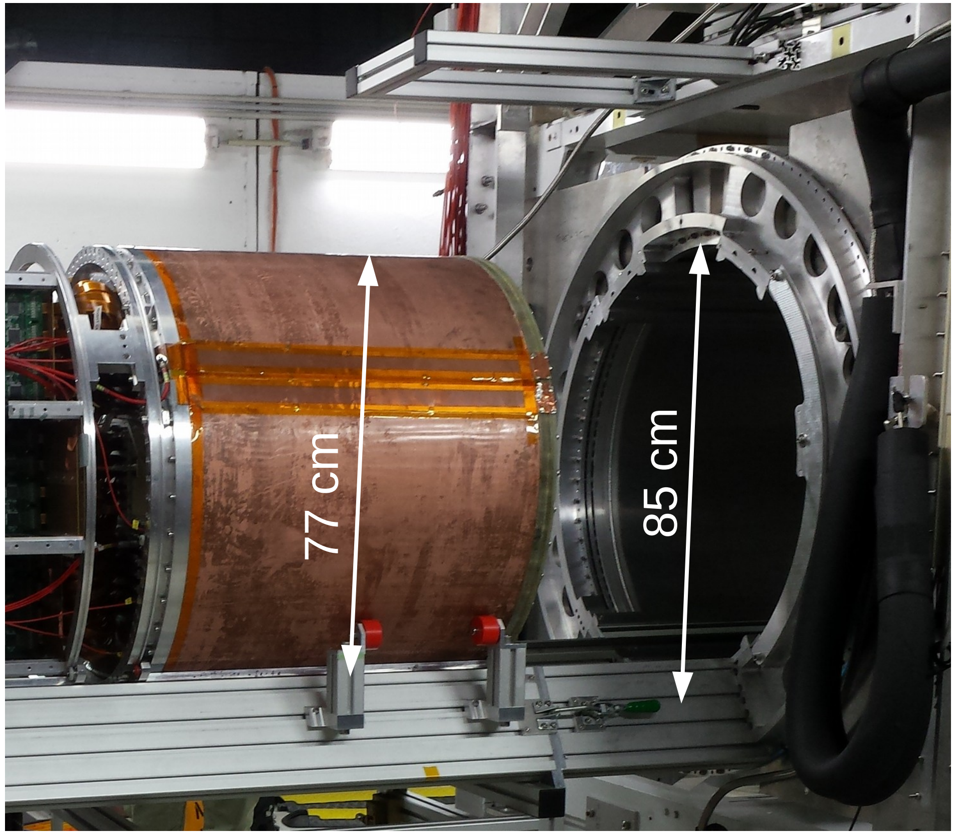

Fig.: PCMAG Stage with LCTPC Field Cage

The Lycoris Telescope

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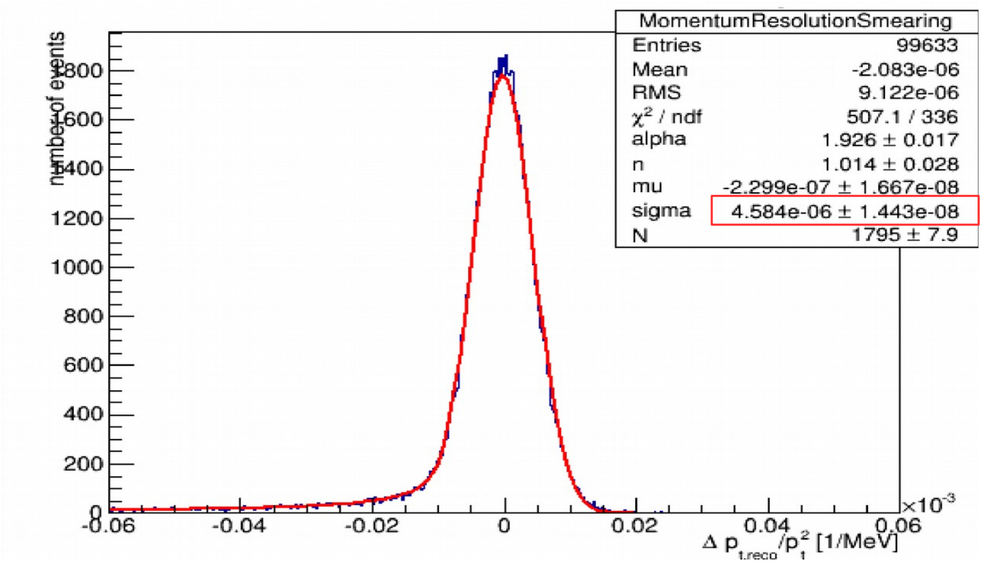


Fig.: Simulated TPC momentum resolution

- Telescope demands defined by use case:
  - Coverage area of ~10x10 cm^2
  - ~3.5 cm of space per telescope module.
  - **Spatial resolution requirements better than:**
    - **σ_y= ~10 μm**
    - **σ_z= ~1 mm**

Tab.: Simulated achievable momentum resolution for different layer distance and sensor resolution (in 1E-6 MeV^{-1})

		Distance between inner and outer Si layer			
		4 cm	3 cm	2 cm	1 cm
Sensor spatial resolution	2.5 μm	2.85	2.90	3.00	3.68
	5 μm	3.05	3.21	3.63	5.52
	7.5 μm	3.37	3.65	4.43	7.92
	10 μm	3.68	4.16	5.33	9.90
	15 μm	4.49	5.36	7.53	14.3

The SiD Silicon Strip Sensor

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

- A strip pitch of 25 µm
- ~7 micron tracking resolution
- Alternate strips will be read out
- 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

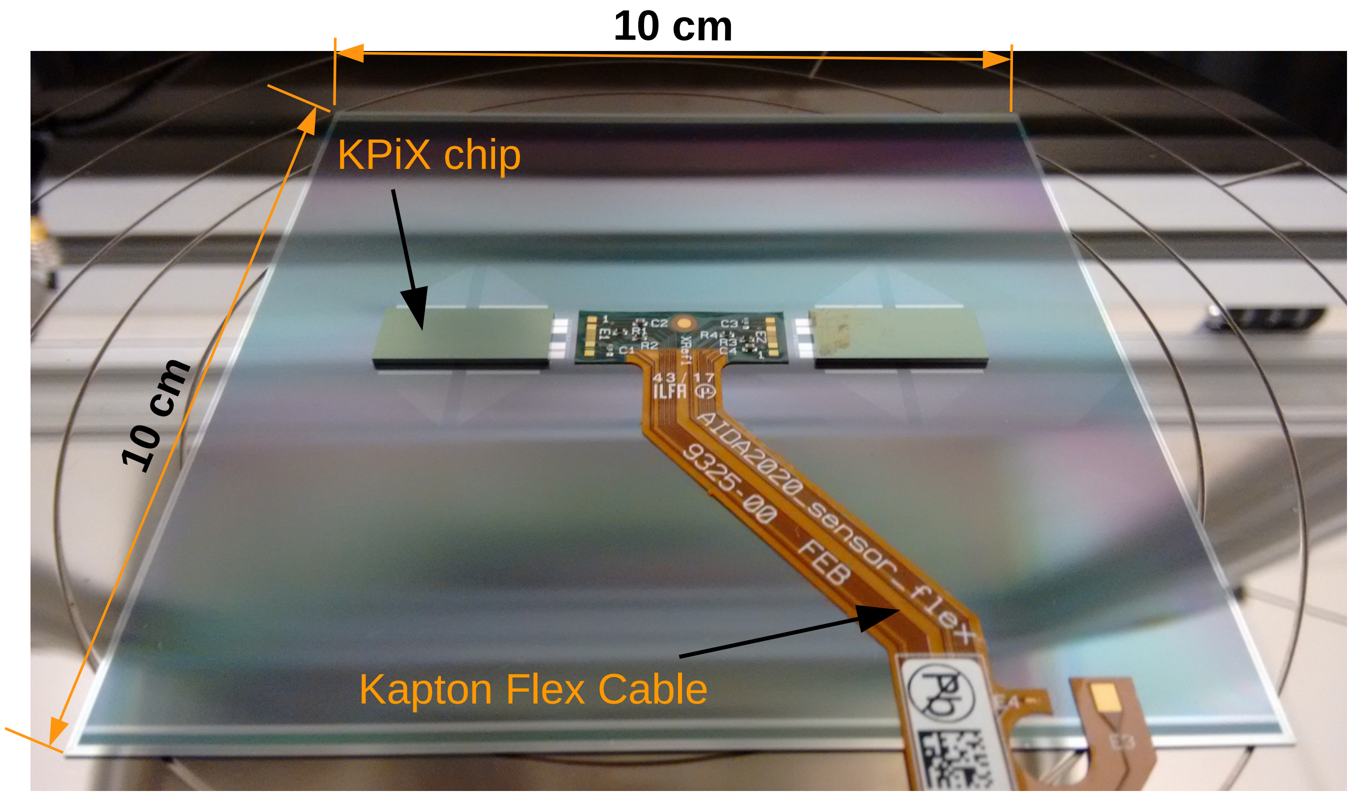


Fig.: Assembled Tracker Module

The Final System: The Cassette

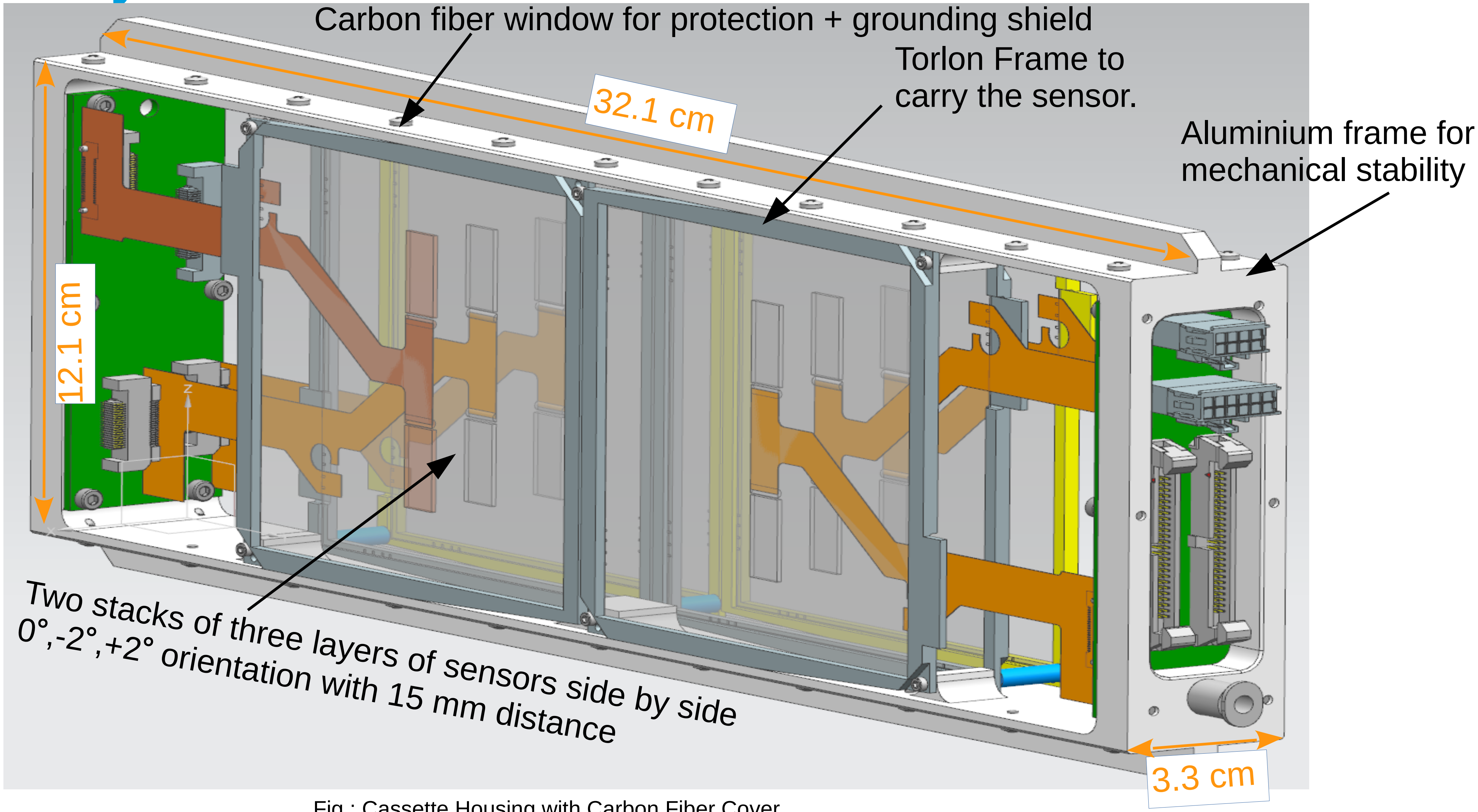


Fig.: Cassette Housing with Carbon Fiber Cover

Final system has an active area of 10x20 cm²

The Final System: The rail system

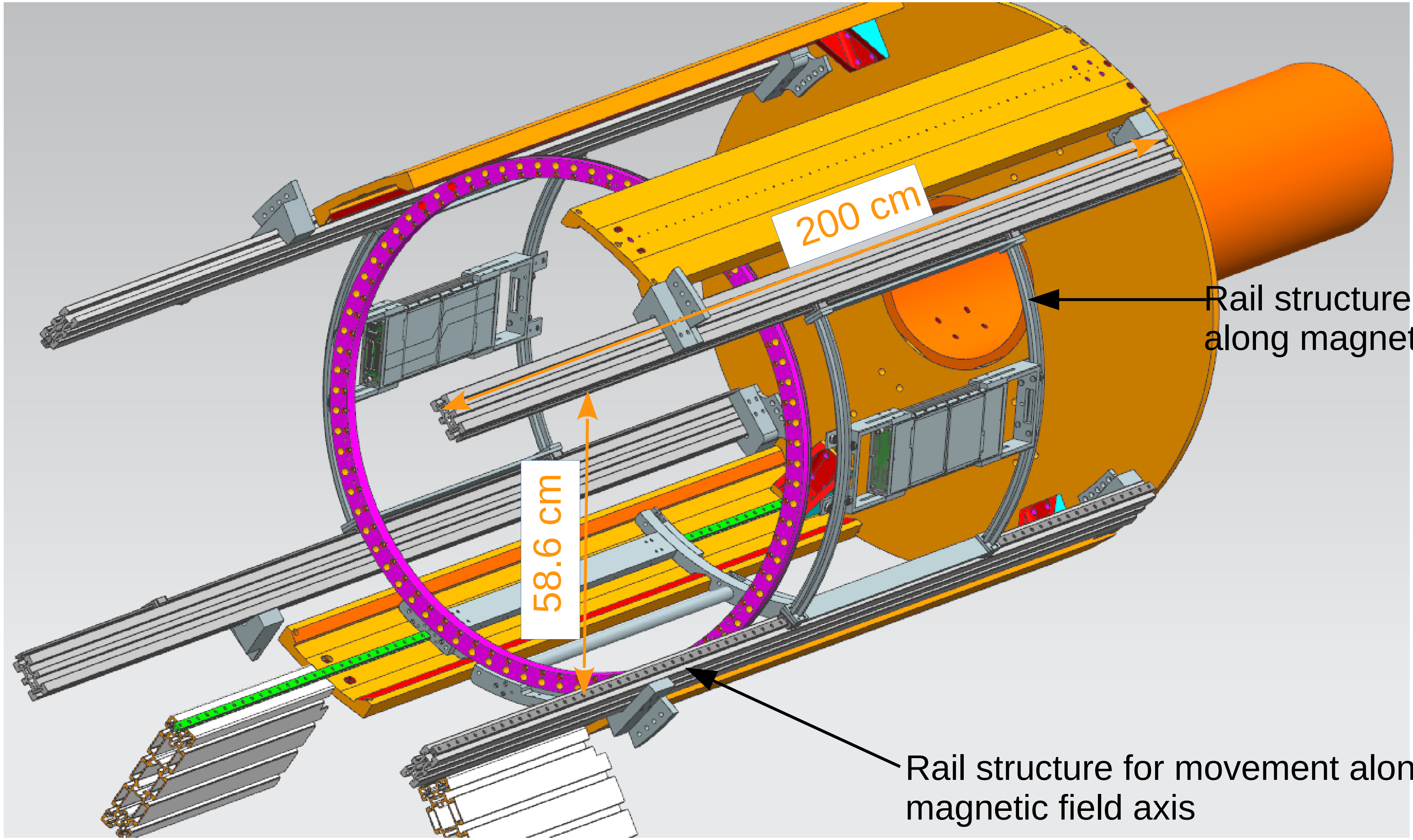


Fig.: PCMAG with cassette rails

The expected resolution

- Analytical calculations using GeneralBrokenLines (GBL) by Claus Kleinwort with a 25 µm pitch strip sensor.
- Depending on the orientations, correlations between planes severely limit the resolution
- The right orientation means the Telescope can easily achieve the curvature resolution needed for the LP TPC

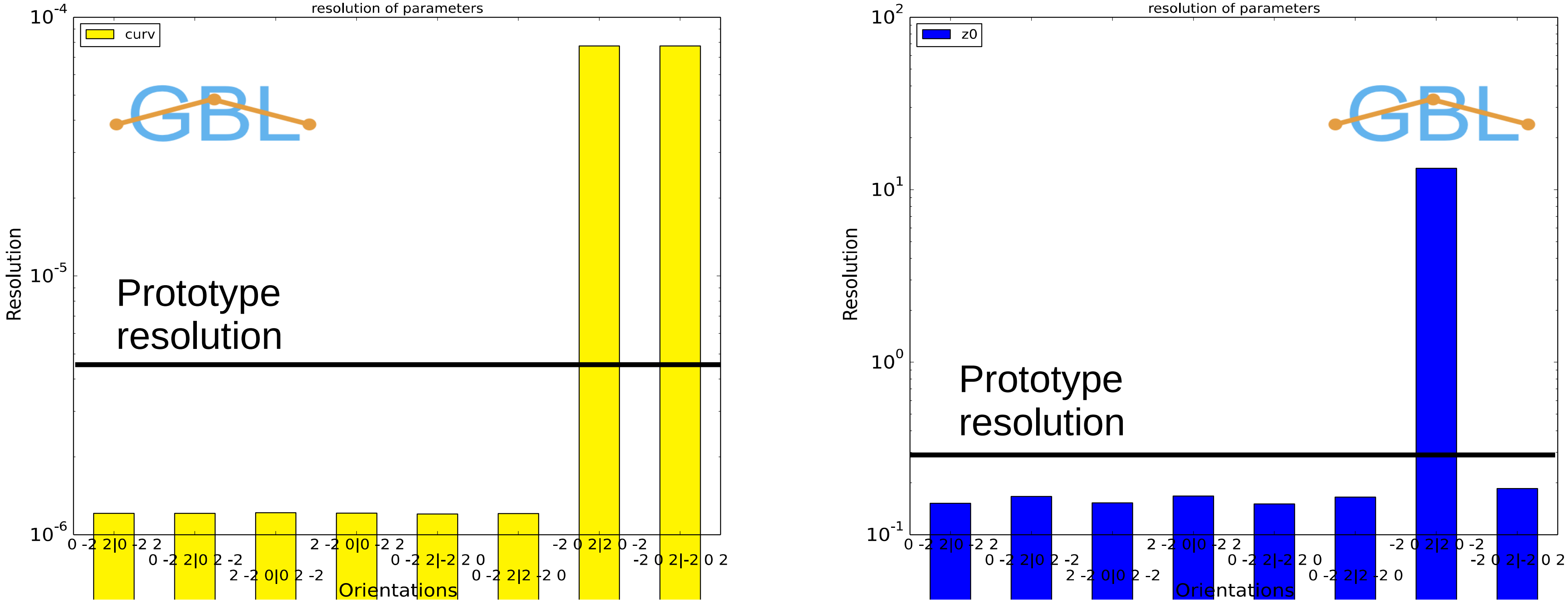
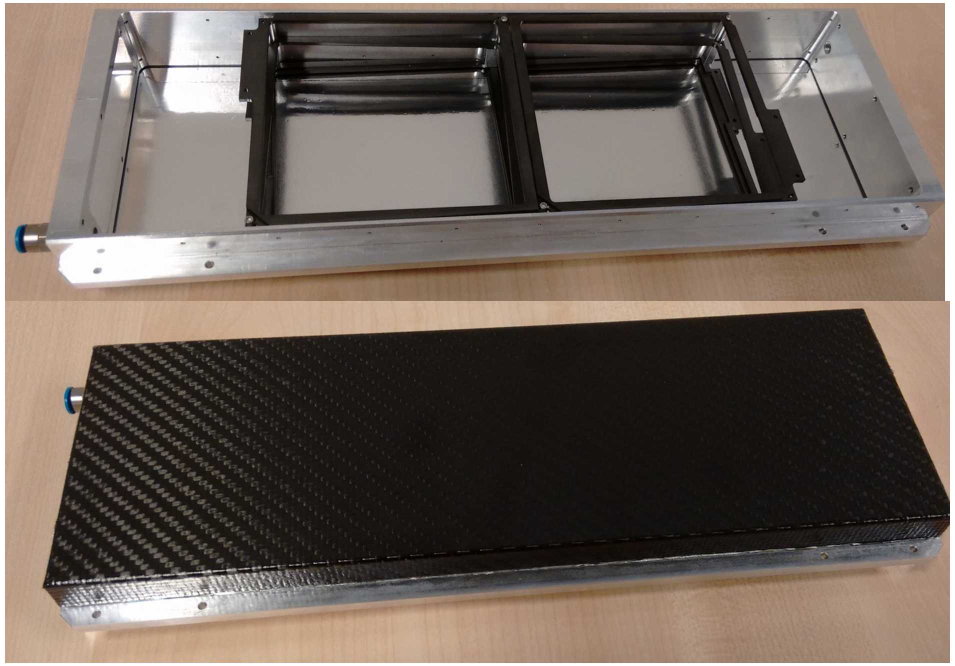


Fig.: Achievable curvature and z resolution of the telescope, with multiple scattering, depending on angular orientation

System Status: Mechanics

- All mechanical components have been produced
- A first test of the rail system shows the overall functionality
- Dummies and one sensor were already installed in the Cassette for first test beam
- Radiation length in beam path per cassette ~ 1% X_0



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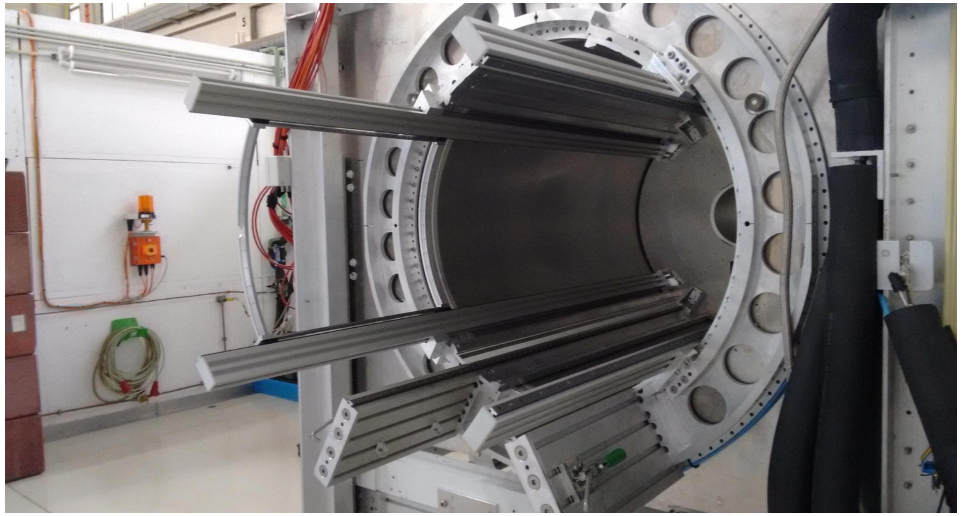

Fig.: PCMAG with cassette rails

System Status: Electronics

- AIDA TLU
  - Needed for Synchronized data readout of DUT and telescope
  - At DESY

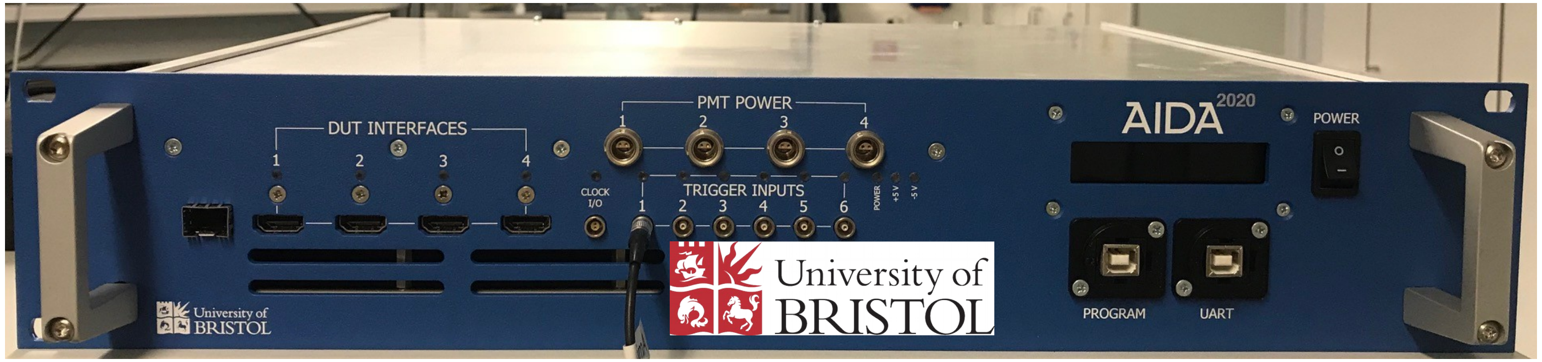

Fig.: AIDA TLU

- New DAQ board
  - Provide necessary connections
  - Hardware/Firmware improvement compared to old sytem
  - At DESY

- Cassette boards
  - connecting electronics within the cassette to outside world.
  - In transit to DESY

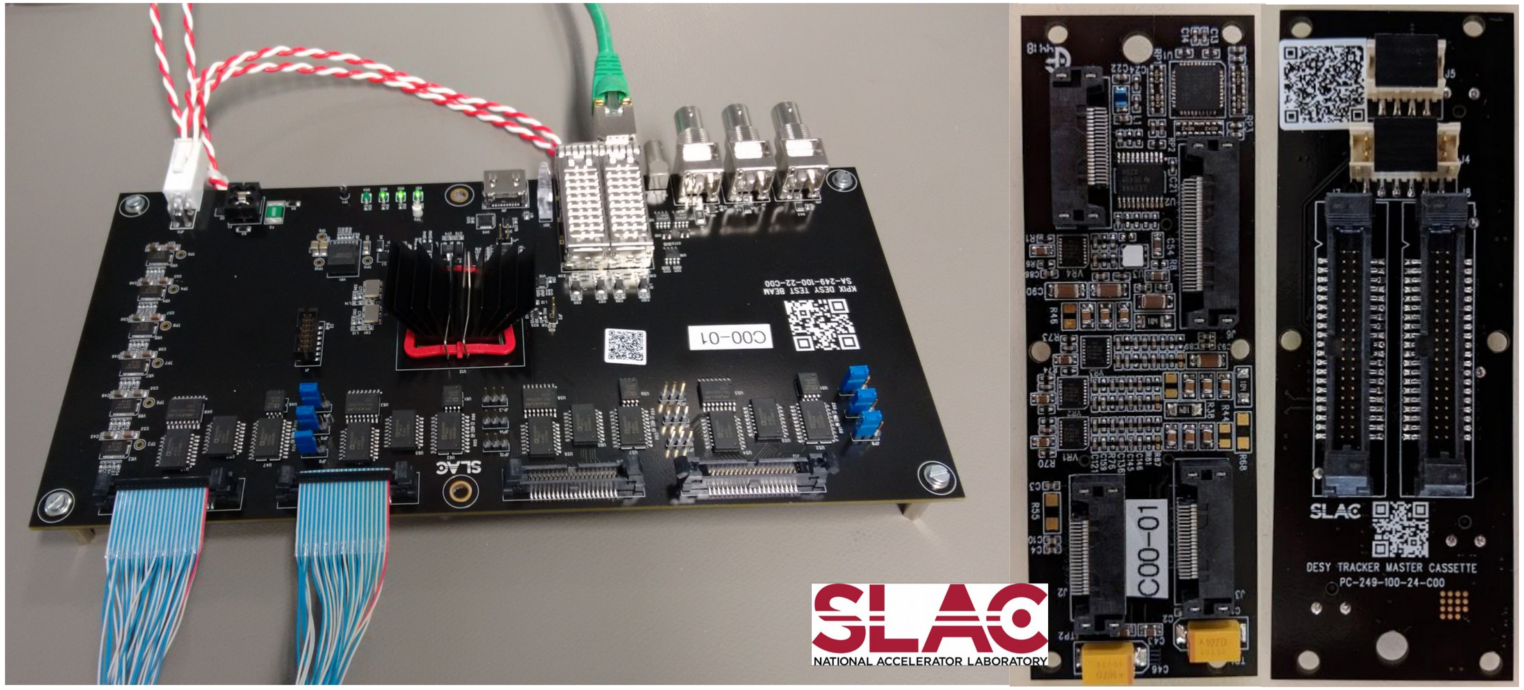

Fig.: New DAQ board with front and backside of cassette board.

System Status: Sensors

- 27 Bump Bonded sensors tested:
  - Good behaviour:
    - ~ 100 nA currents, stable up to 300 V
    - Depletion voltage for all sensors at ~50 V
  - Two sensors show breakdown beginning at 280 V

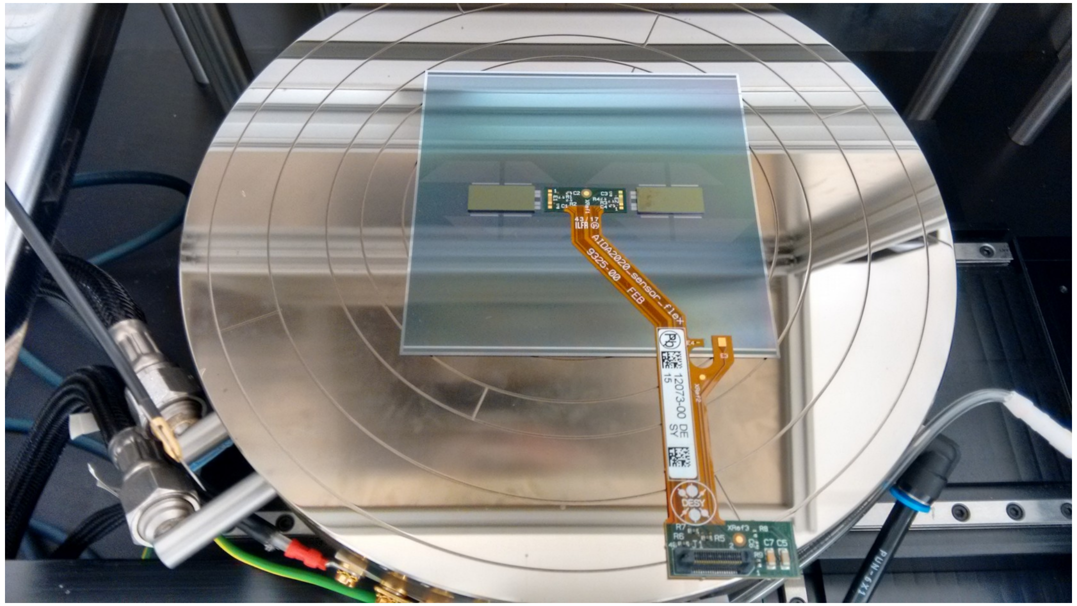

Fig.: Bump Bonded Sensor with flex cable on the probe station

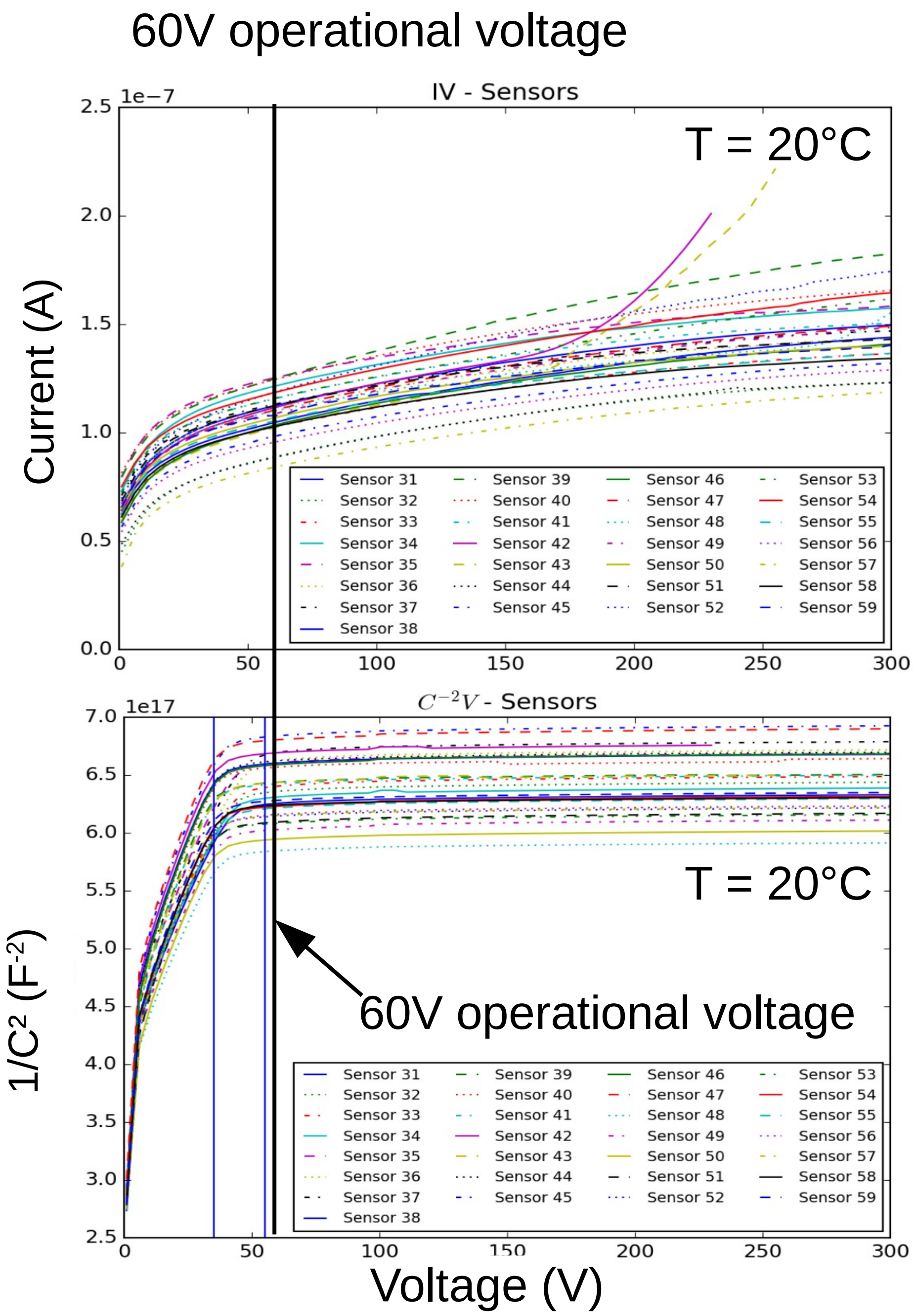

Fig.: IV (top) and CV (bottom) of the sensors

System Status: Sensors

- Assembled 5 Sensor Modules (S59, S58, S52, S57 and S56):
  - S59:
    - good performance,
    - full depletion,
    - Sensitive to radiation.
    - Able to talk to and record data from both chips
  - S58 and S52:
    - Damaged during assembly, gluing of the Kapton Flex
    - Micro cracks in the silicon make the sensor impossible to deplete
  - S56 and S57:
    - Assembled with new tool, assembly without any major complications
    - Wirebonding to Kapton Flex was not possible.
    - Too old to be wirebonded

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- While sensor S59 shows overall good performance, the need for intermediate adapter electronics and newly encountered challenges delayed the project.

System Status: Sensors

Self triggering operation

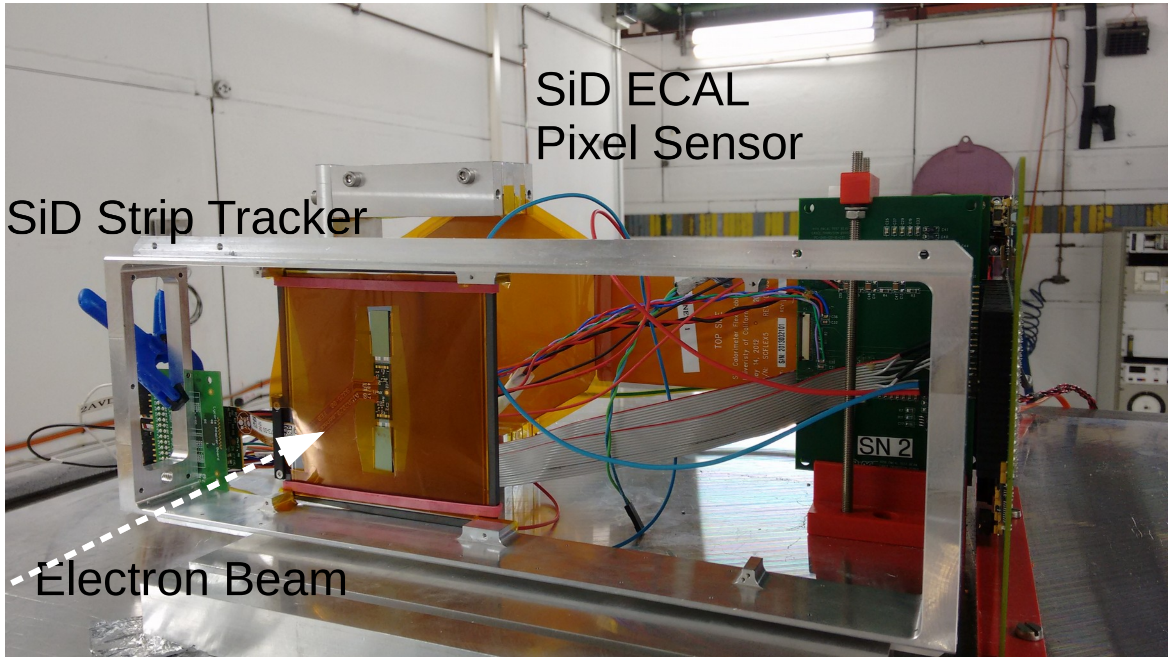

Fig.: Testbeam setup with the tracker in front and ECAL in the back.

- Recently completed first Testbeam with the new tracker sensor
- ~ 2 Million Events recorded, split between different running modes.
- Test of both internal triggering and external triggering functionality.

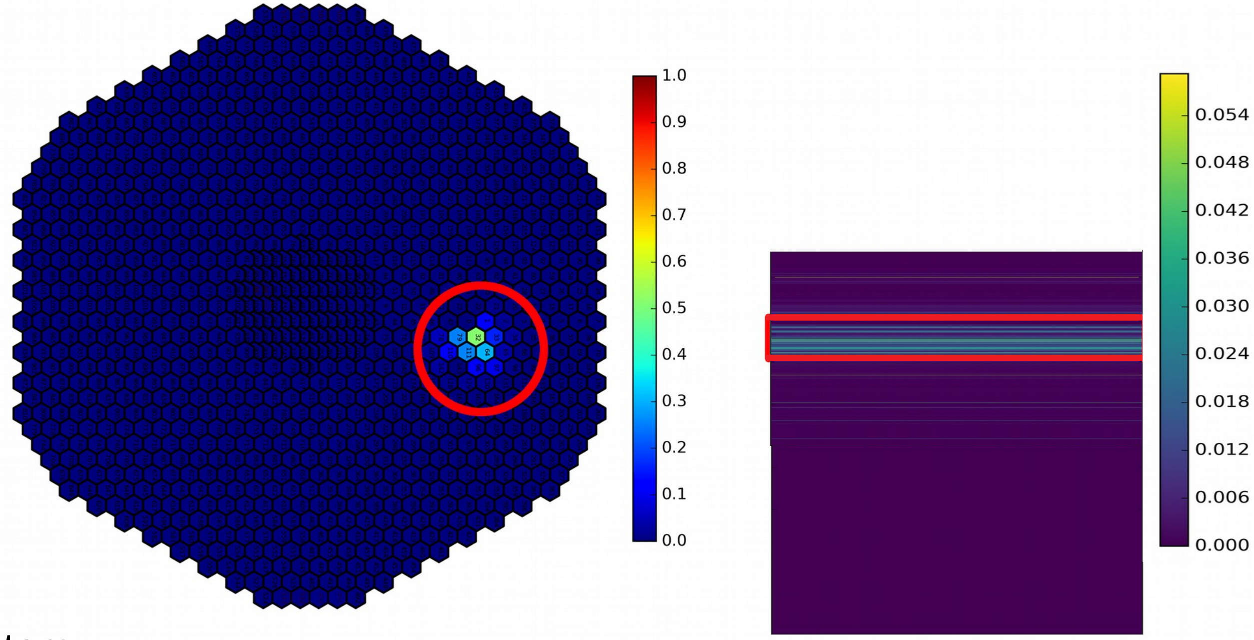

Fig.: Mapping of trigger hits to ECAL (left) and tracker (right)

- Full coincidence:
  - SiD Strip Tracker ↔ SiD ECAL Pixel Sensor ↔ Beam Scintillators.

System Status: Sensors

Self triggering operation

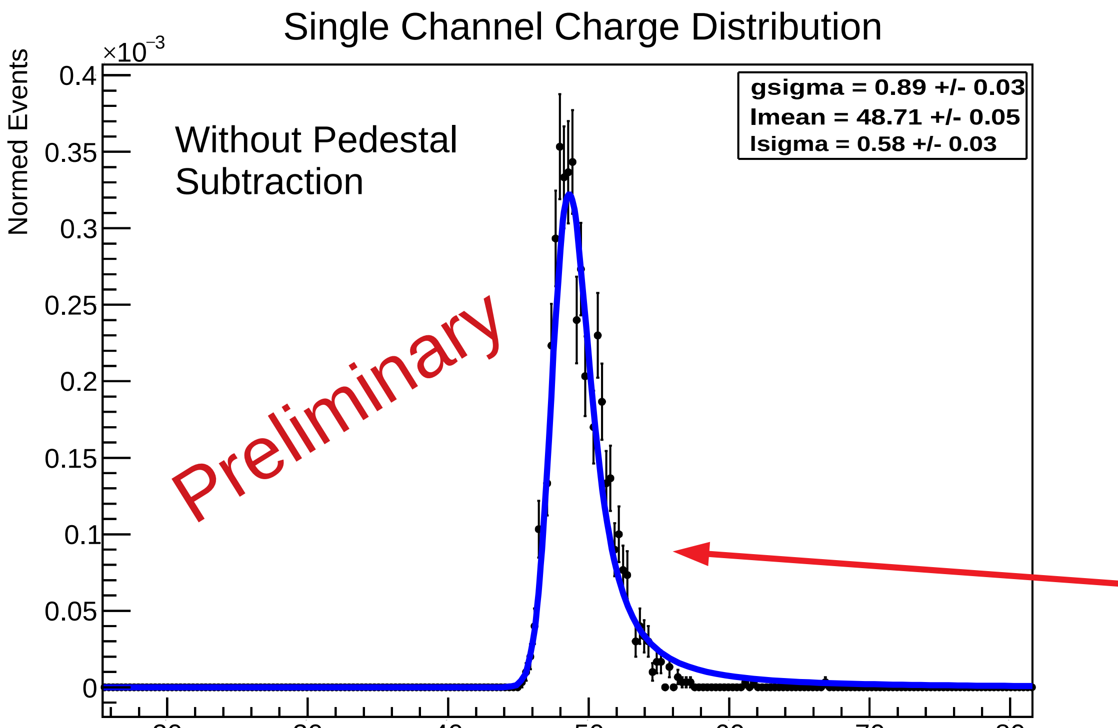

Fig.: High threshold charge distribution for the tracker with landau gauss convolution fit

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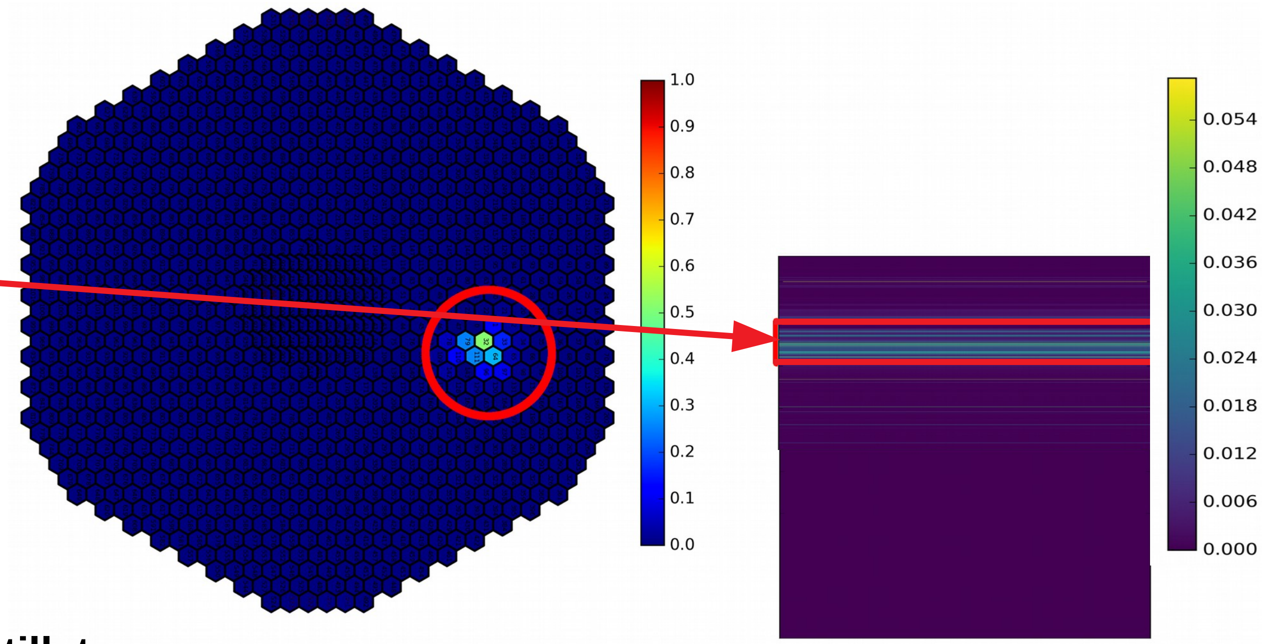


Fig.: Mapping of trigger hits to ECAL (left) and tracker (right)

- **Full coincidence:**
  - **SiD Strip Tracker ↔ SiD ECAL Pixel Sensor ↔ Beam Scintillators.**

System Status: Sensors

External triggering operation

- Final running operation with TPC is going to be in external triggering
  - System noise was pushed to 0.28 fC (Tracker) and 0.32 fc (ECAL)
  - ~3 fC excpected signal charge in 320 micron silicon

    → S/N = ~10

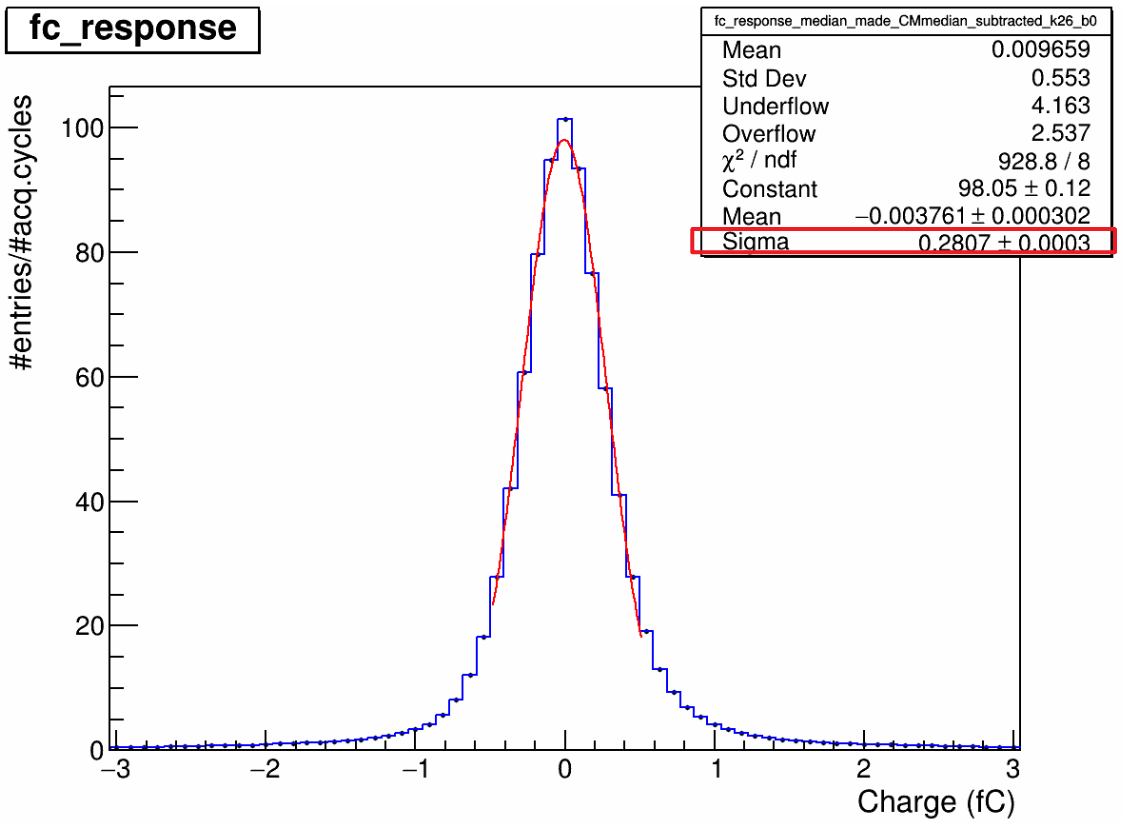


Fig.: Pedestal distribution for Tracker sensor

System Status: Sensors

External triggering operation

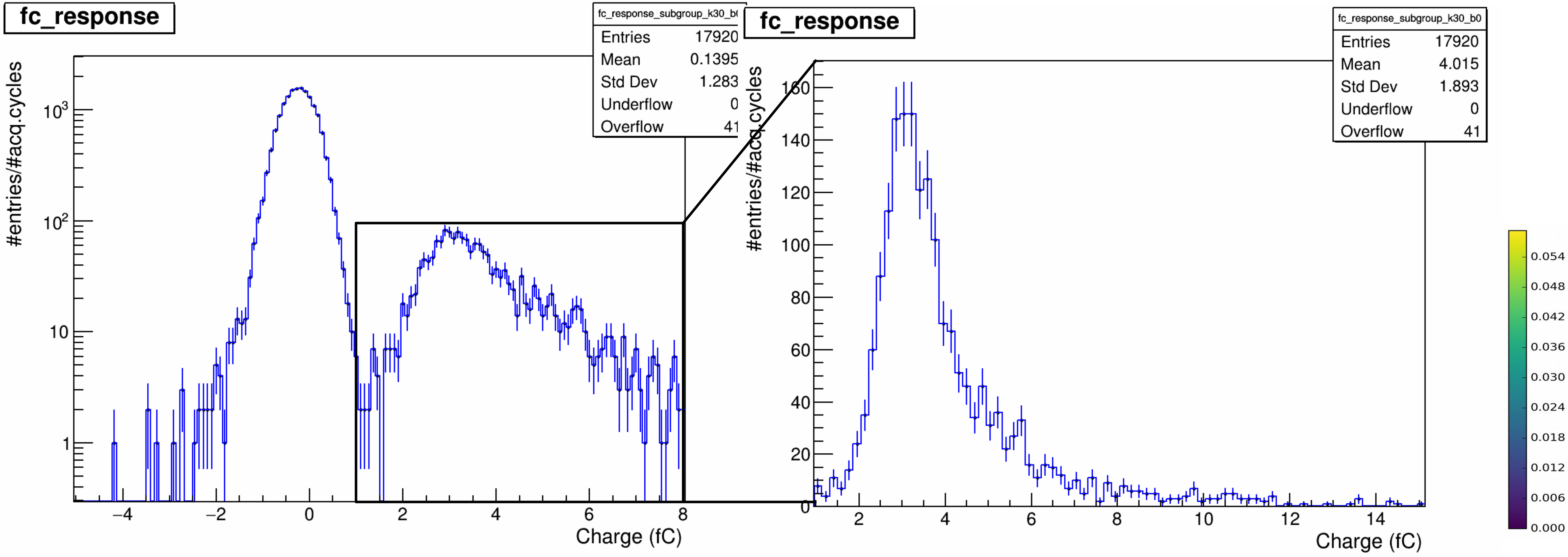


Fig.: Signal charge distribution for ECAL sensor with channel preselection

- Operation works quite well for the ECAL

System Status: Sensors

External triggering operation

- Same analysis is not able to show the signal within the tracker.
- Differences are clear
  - ECAL:
    - ~4x4 mm² pads
      → ~10 pads in beam
      → effectively no charge sharing
  - Tracker:
    - 25 µm strip pitch + alternating readout and floating strips
      → ~ 400 strips in beam (200 readout strips)
      → significant charge sharing and multiple different hit profiles

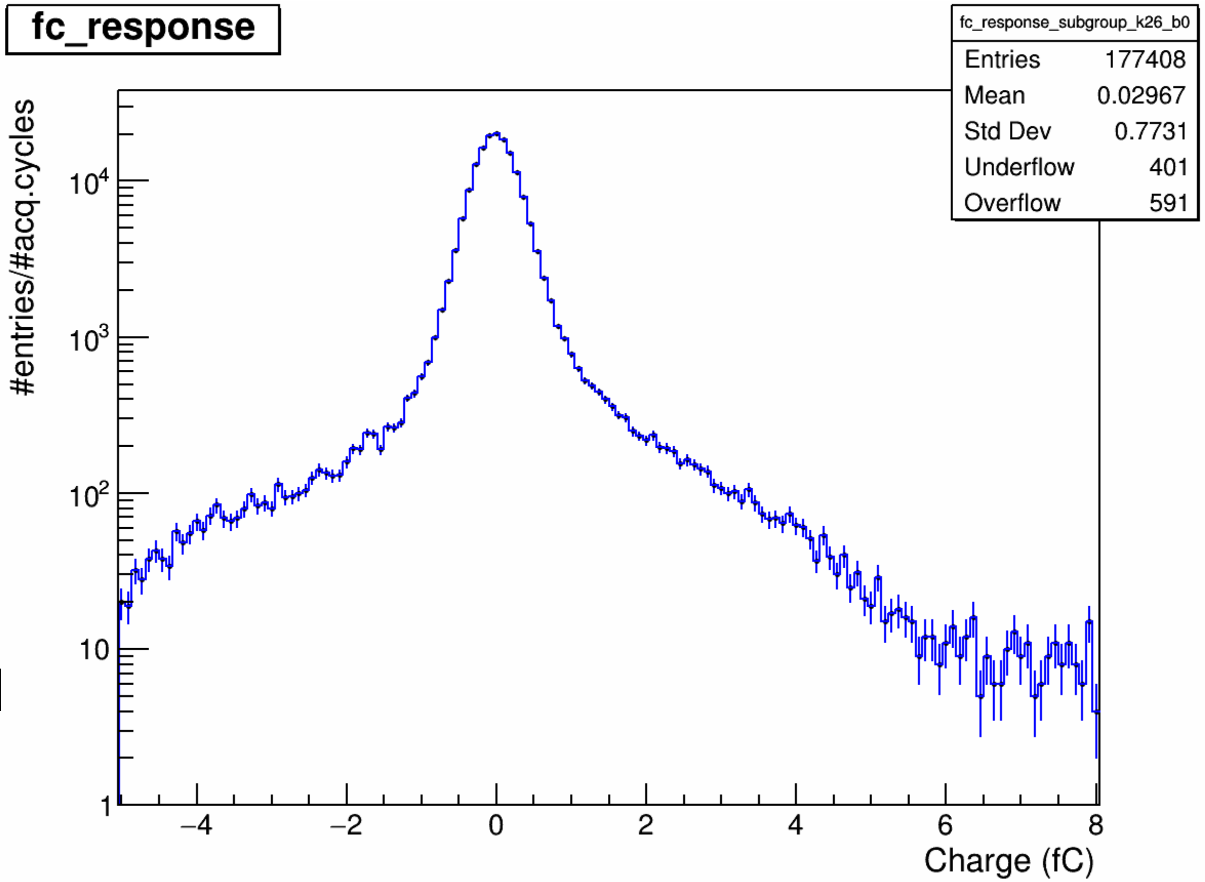


Fig.: Signal charge distribution for Tracker sensor with channel preselection

System Status: Sensors

External triggering operation

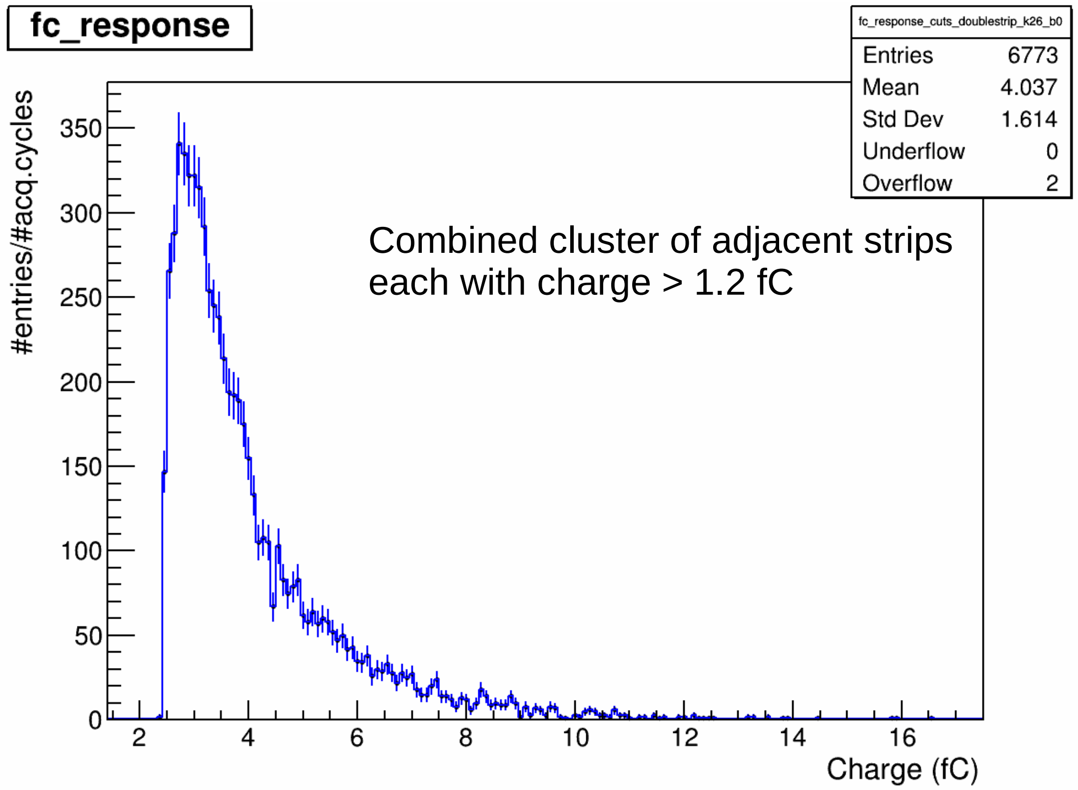


Fig.: Charge distribution after floating strip hit candidate filtering

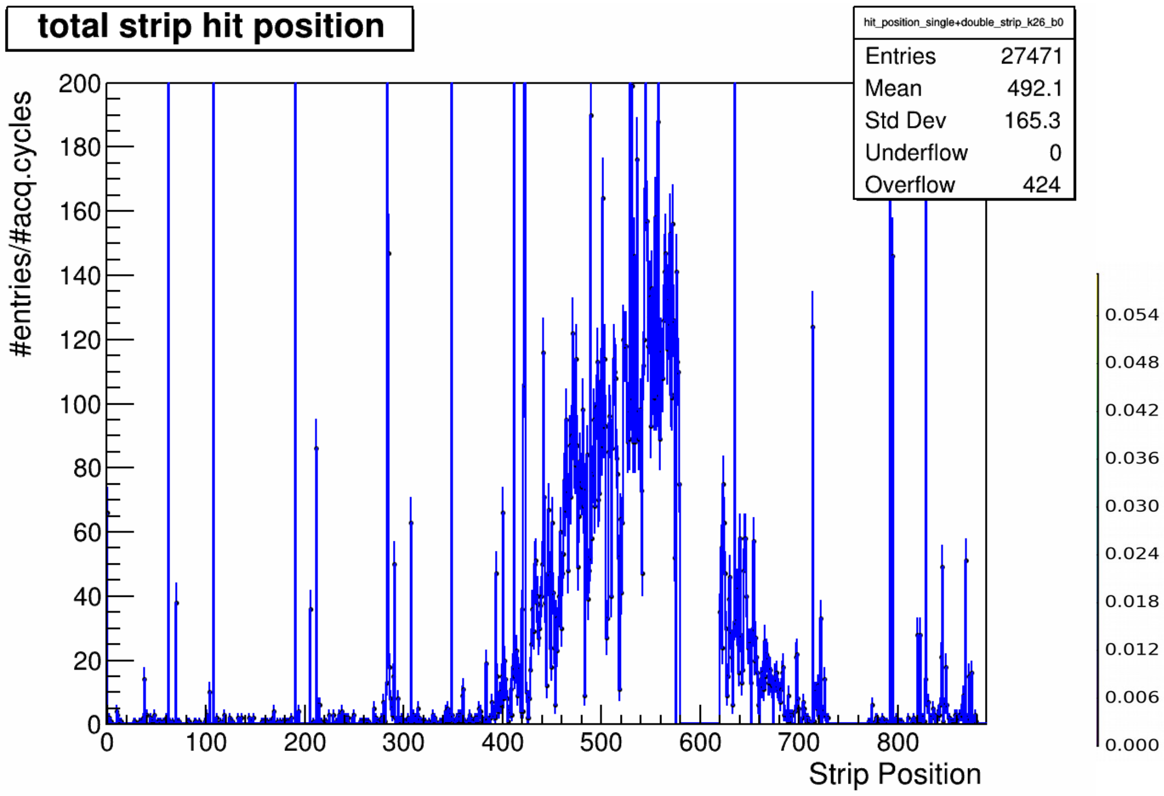


Fig.: Hit position after floating strip + single strip hit candidate filtering.

Summary and Outlook

- Receiving last missing components for the system.
  - Mechanical structure fully assembled and sensor+dummies tested within the structure
  - New DAQ board recently finished
    → First tests of the new firmware and hardware successful.
  - Cassette electronics in transit

- Assembled the first telescope module.
  - Successful communication and calibration with both chips
  - Completed multiple tests of the sensor in the lab and at the DESY II Test Beam Facility
  - Moving to assembly of remaining sensors with new tool.
  - Challenges from the assembly and component lifetime going to be conquered within a few weeks.
    → Assembly of the sensors in the coming week(s)

- Work is ongoing on the analysis of the data including clustering algorithms and tracking.
- Testbeam with multiple modules in the cassette and a mimosa telescope scheduled for **02/2019**
- Testbeam of LYCORIS within PCMAG, potentially with a DUT, scheduled for **04/2019**

Thank you for your attention

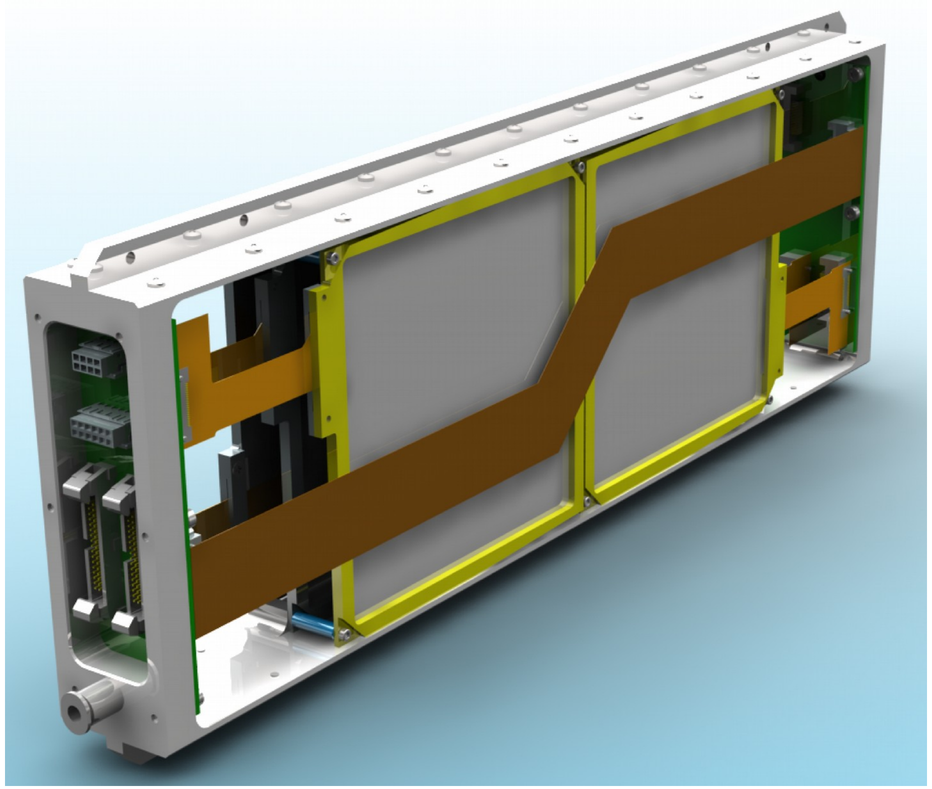
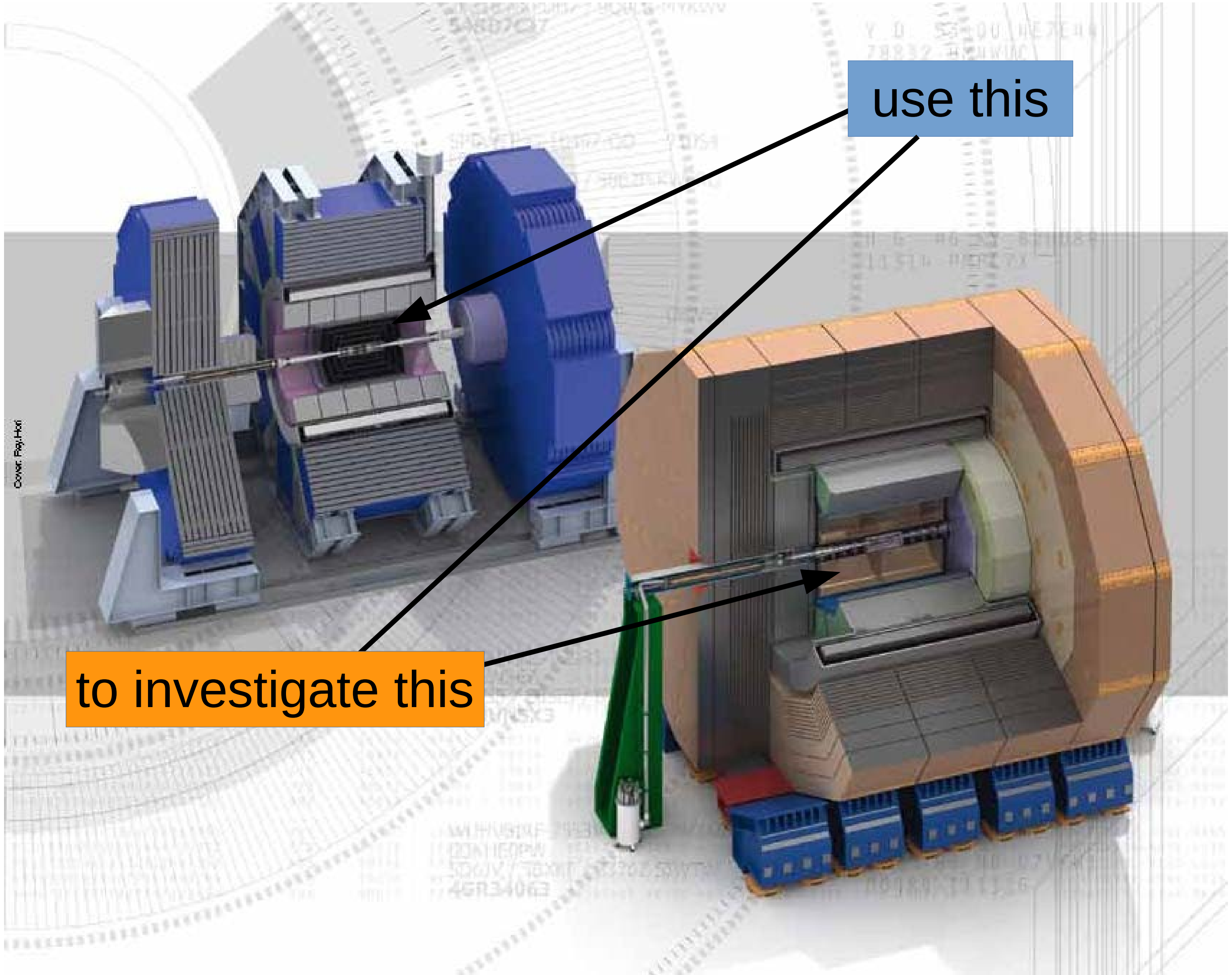


Fig.: LYCORIS Tēlescopia

Fig.: Lycoris Radiata

BACKUP

The LYCORIS Project In the Context of ILC



Silicon Telescopes

- High precision silicon trackers
- Used to provide reference measurements of particle track
- Multiple layers placed before and after the Device Under Test (DUT)

  → Provide tracking through the DUT even in the case of multiple scattering

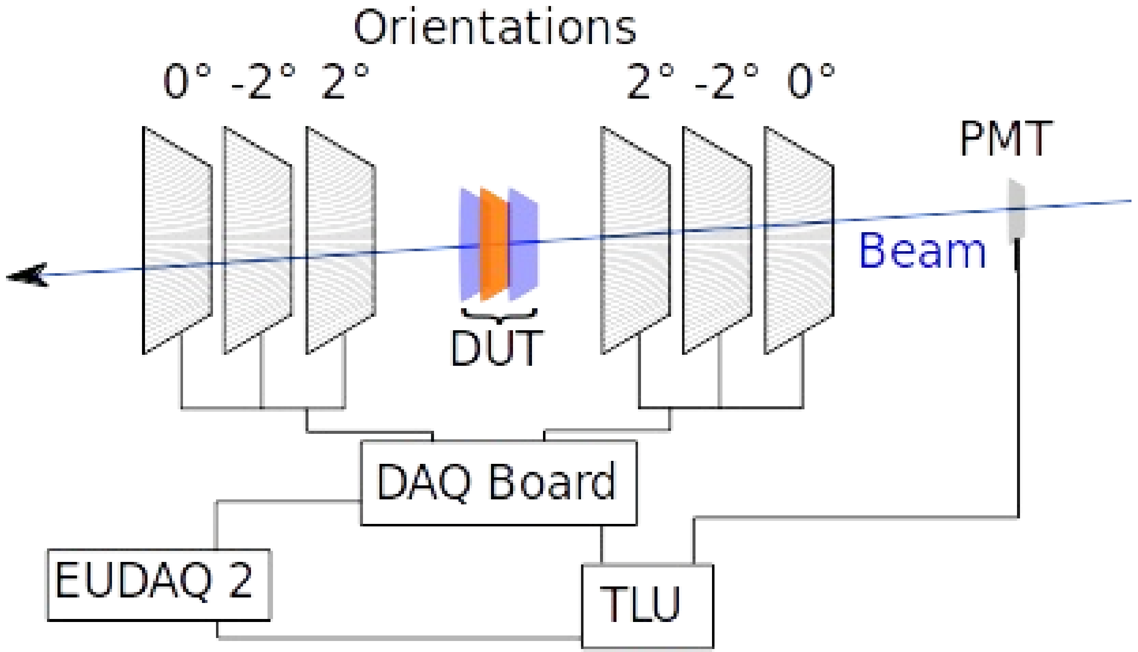


Fig.: External strip tracker sketch

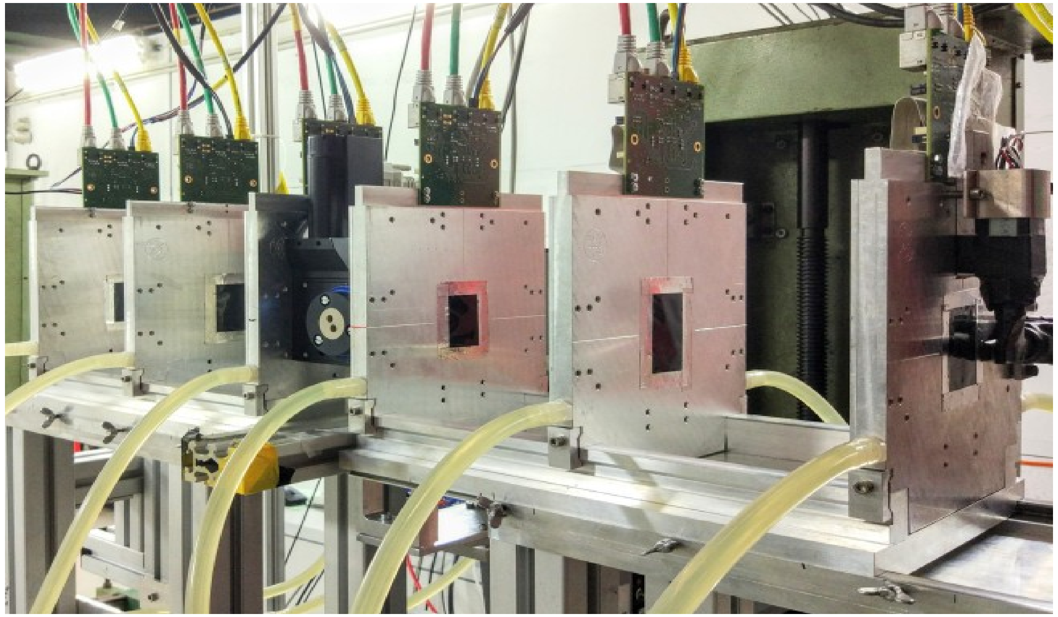
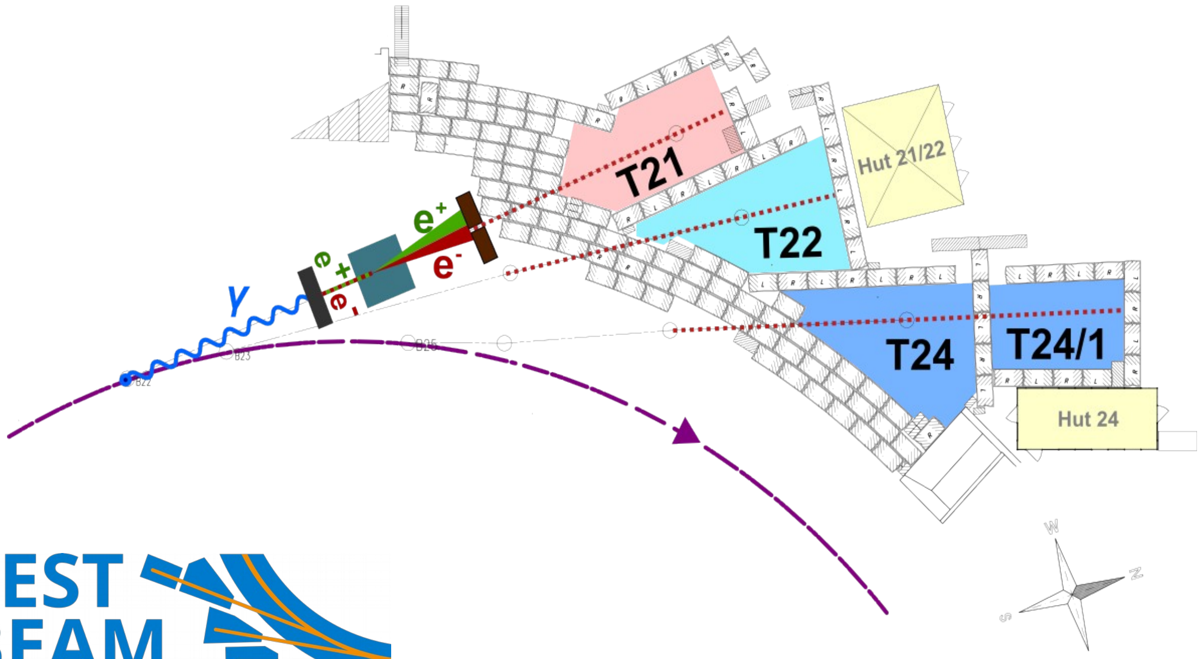
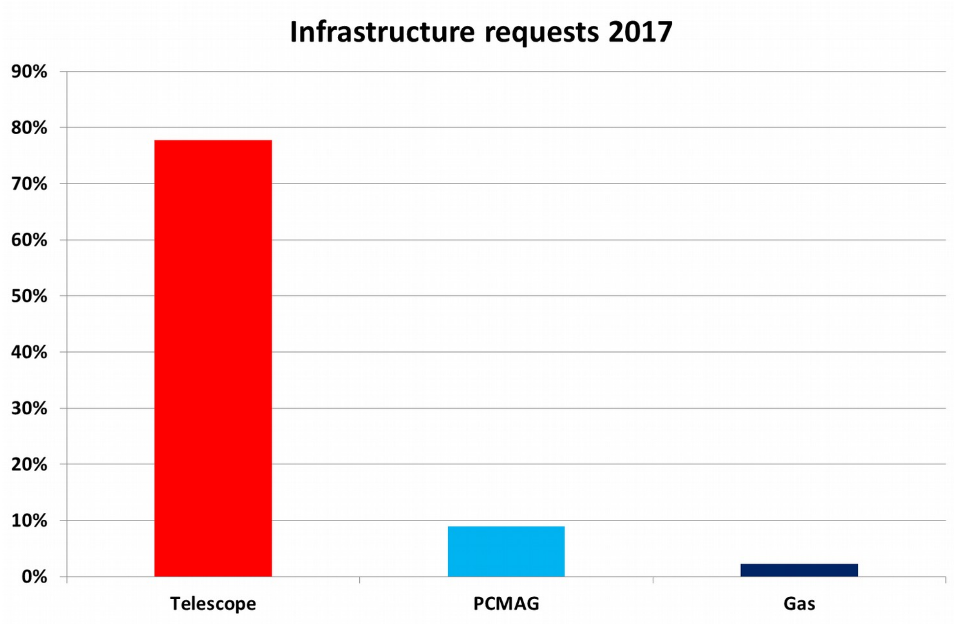


Fig.: EUDET Type Telescopes at DESY II Test Beam Facility

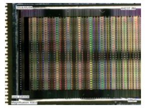
The DESY II Test Beam Facility

- Electron beam provided by DESY II synchrotron
- e^+/e^- particles with energy up to 6 GeV
- 1.2 T Dipole magnet in T21
- Two silicon pixel Telescopes (Datura/Duranta), based on Mimosa 26, in T21 and T22
- 1 T Superconducting solenoid (PCMAG) in T24/1





KPiX readout chip



- 1024 channel fully digital readout with 13 bit resolution (8192 ADC)
- 100 MHz clock → 10 ns flexible acq. Clock period
- Can work in two modes:
  - Self/Internal trigger = 4 events per channel per cycle stored
  - External trigger = 4 events per cycle stored
- Power pulsing operation → Only open for a short timeframe
- Length of the opening period depends on timing resolution

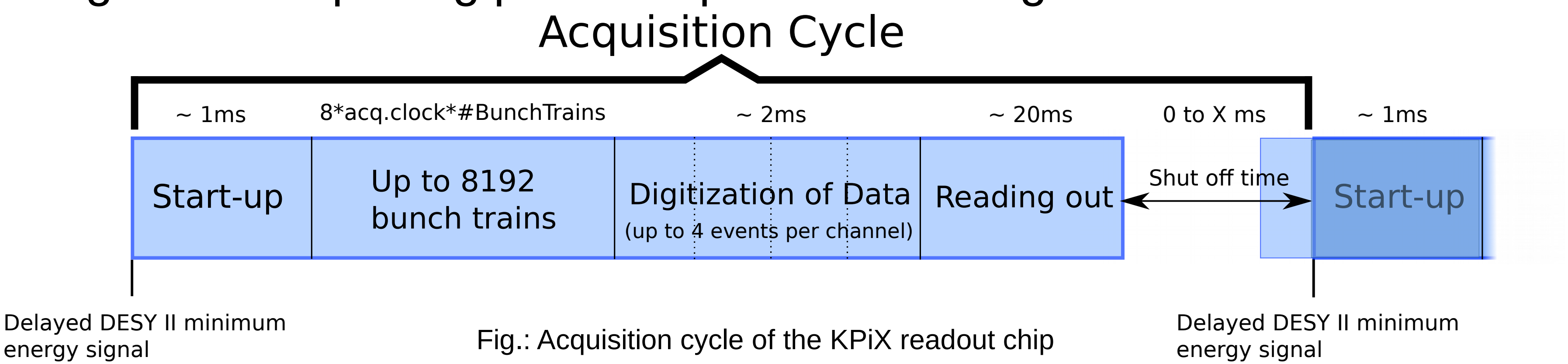


Fig.: Acquisition cycle of the KPiX readout chip

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

The DESY II Energy Cycle

- DESY II energy cycle follows a sinoidal curve
- Time difference between minimal energy signal and signal in the test area is measured using scintillator triggers in the area

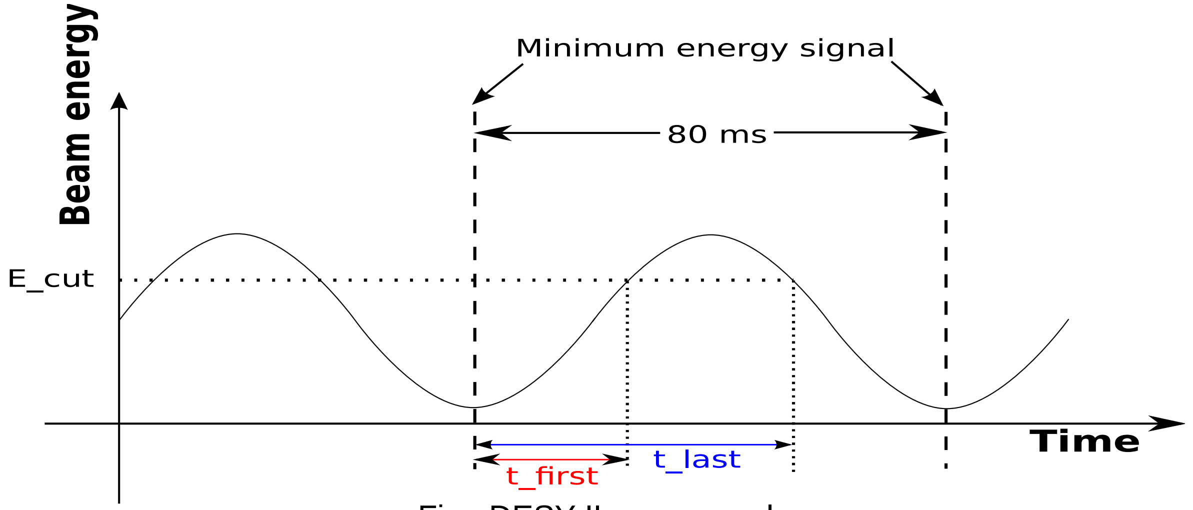


Fig.: DESY II energy cycle

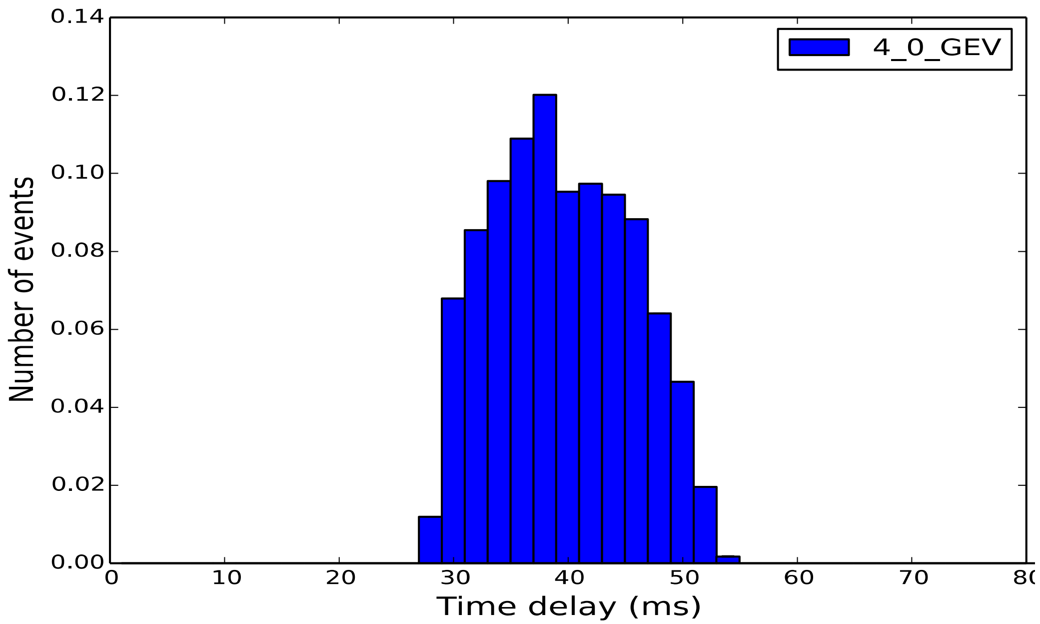


Fig.: Time difference from min. energy to trigger signal

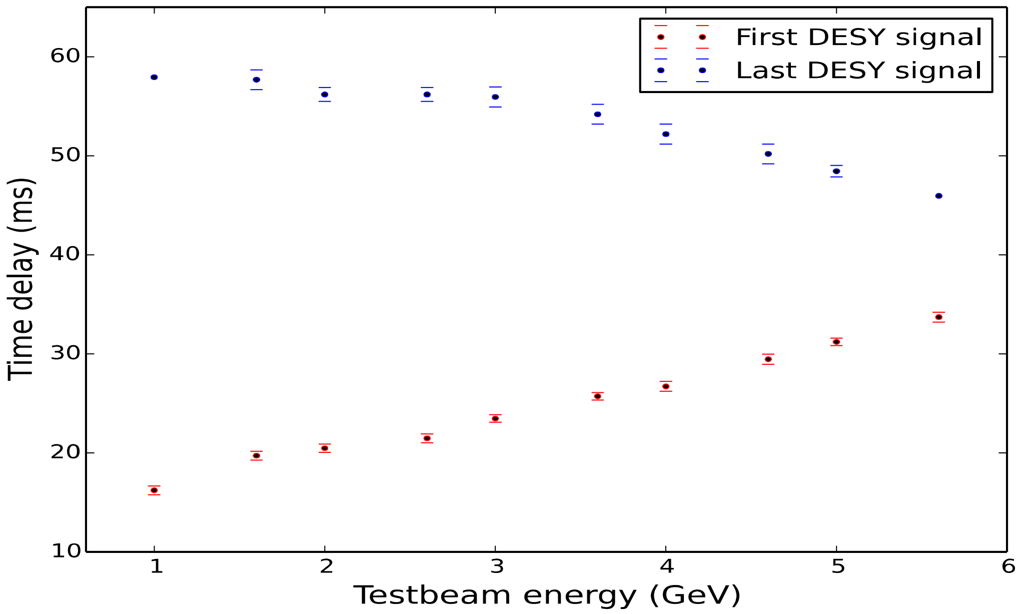
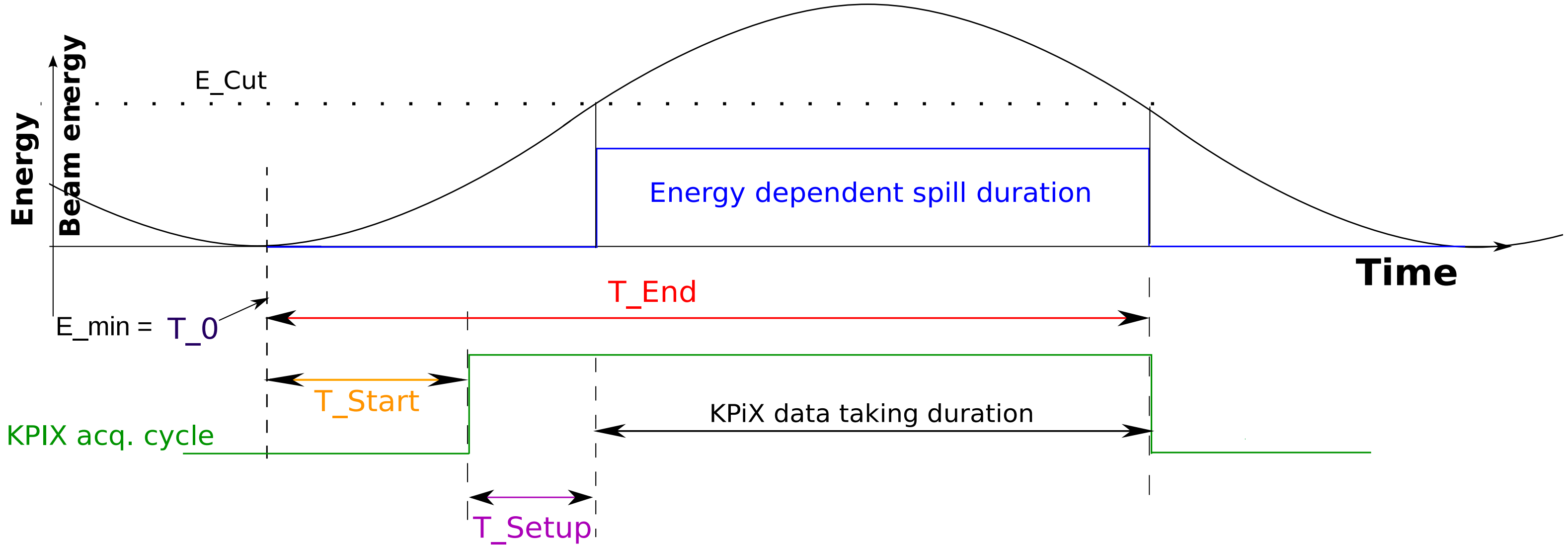


Fig.: First and last DESY signal in a cycle for different energies

DESY.

KPiX synchronisation, DUT and Beam



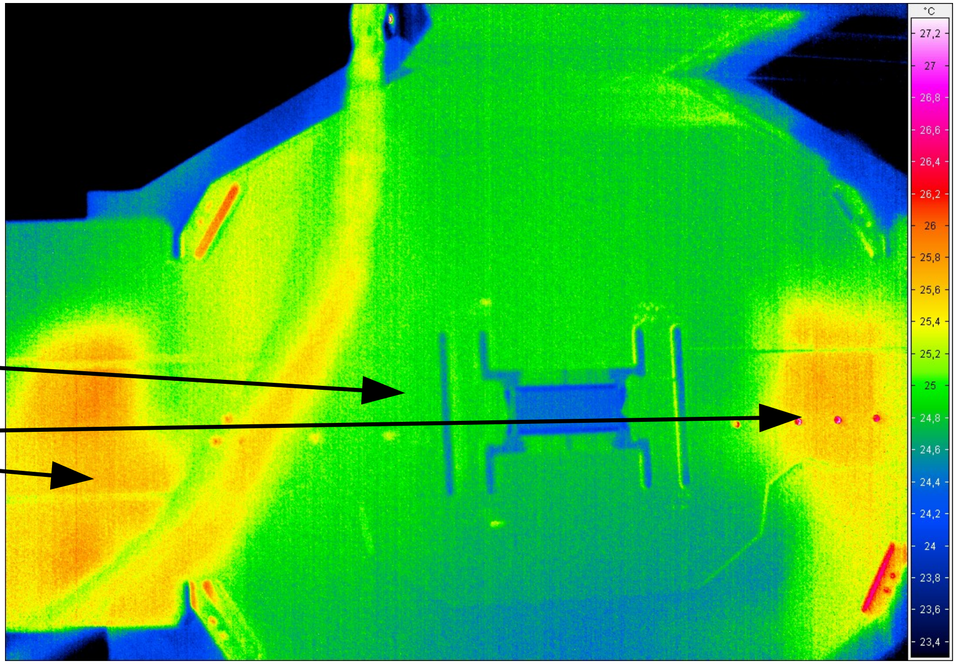
- KpiX needs to be synchronised to beam spill of the acceleerator and the DUT
  - T_0: Accelerator signal for synchronisation with beam spiull
  - T_Start: User adjustable delay between T_0 and KpiX switch on.
  - T_Setup: Setup time of KpiX. At the end of which KpiX can start the data taking
  - T_End: User adjustable signal telling all devices that KpiX has stopped data taking
- New AIDA TLU (Trigger Logic Unit) will be able to provide these signals and distribute a common clock

Heat production

- As a result of power pulsing and only 1024 channels, a low power Consumption is expected (40 mW in total)
- Measurement of heat production done via infrared camera

KPiX Chip

Reflection of heat sources



- Overall power consumption and heat generation is negligible

  → No active cooling needed

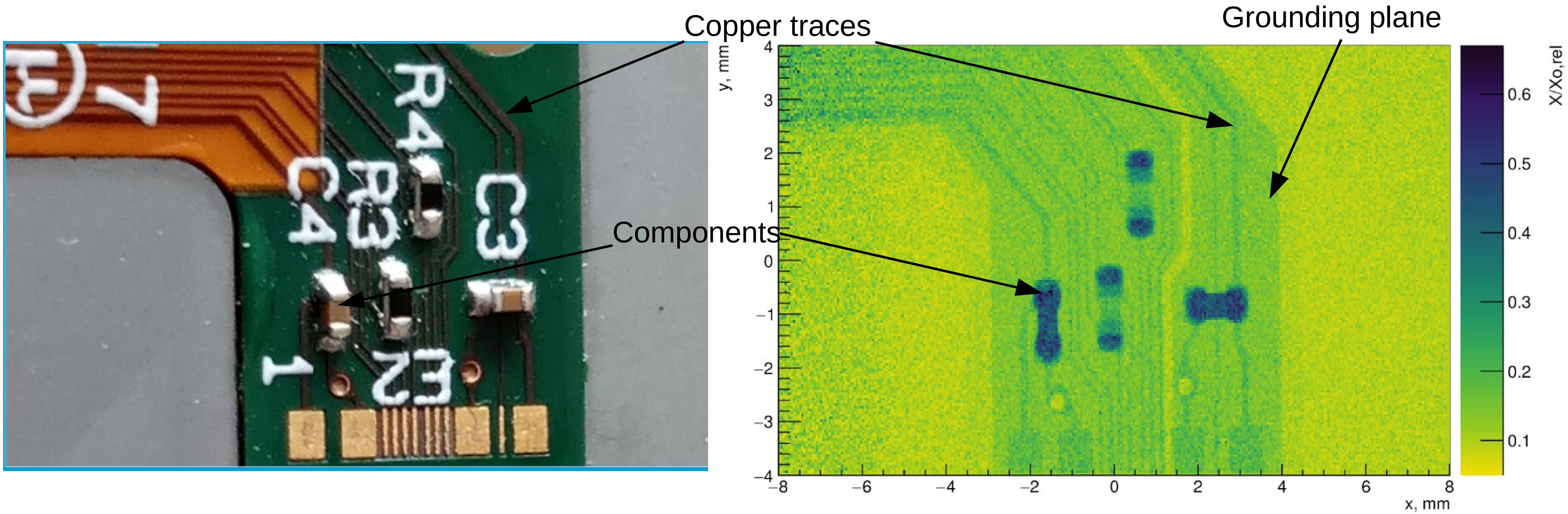
Radiation Length

Material	Thickness	General Radiation Length (= 1 X0)	Final Radiation length (as multiples of X0)
Carbon Fiber Window	0.03 cm	~29 cm	0.103%
Aluminium Foil (Al)	0.0013 cm	8.897 cm	0.015%
Silicon Sensor (Si)	0.032 cm	9.37 cm	0.342%
Kapton Cable (Cu)	maximum 0.025 cm	1.436 cm	1.74% (maximum)
Kapton Cable (Kapton)	maximum 0.025 cm	57.6 cm	0.043% (maximum)
KPiX (Si)	0.032 cm	9.37 cm	0.342%
Araldite (2011) by ATLAS	~0.01 cm	33.5 cm	0.030%
Araldite (2011) by calculation (C6 H6 O)	~0.01 cm	46.24 cm	0.022%

The materials in question are the following:

1. Carbon Fiber Window + Aluminium Sheet + Stycast
2. Master ↔ Slave Interboard Kapton Flex
3. **Sensor 1 (+Kapton Flex && Araldite2011 || +KPiX)**
4. **Sensor 2 (+Kapton Flex && Araldite2011 || +KPiX)**
5. **Sensor 3 (+Kapton Flex && Araldite2011 || +KPiX)**
6. **Carbon Fiber Window + Aluminium Sheet + Stycast**
7. DUT
8. **Carbon Fiber Window + Aluminium Sheet + Stycast**
9. **Sensor 4 (+Kapton Flex && Araldite2011 || +KPiX)**
10. **Sensor 5 (+Kapton Flex && Araldite2011 || +KPiX)**
11. **Sensor 6 (+Kapton Flex && Araldite2011 || +KPiX)**
12. Master ↔ Slave Interboard Kapton Flex
13. Carbon Fiber Window + Aluminium Sheet + Stycast

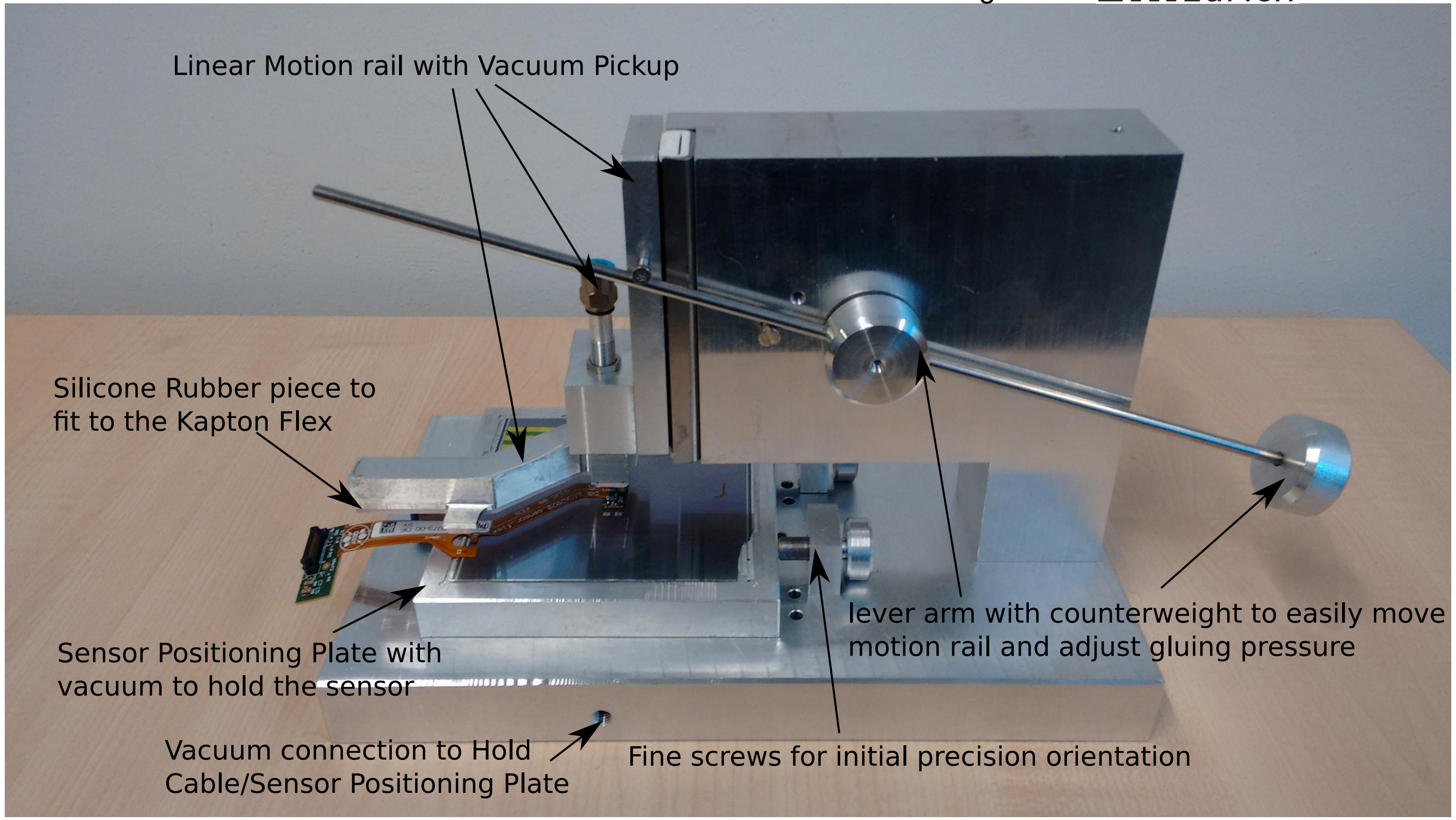
Radiation Length



System Status: Mechanics

- After first manual assemblies, a new tool was designed and built to provide reproducible results through:
  - Controlled glue application
  - Fine adjustable gluing pressure
  - Precise cable positioning
- Able to be used for further assembly of sensors into Torlon frames

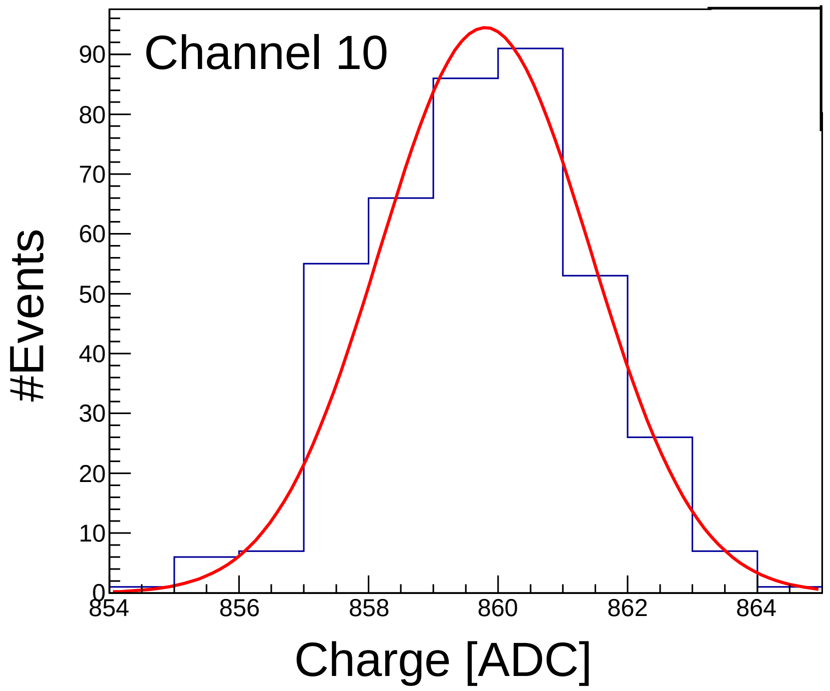
Based on a design from ETH zürich

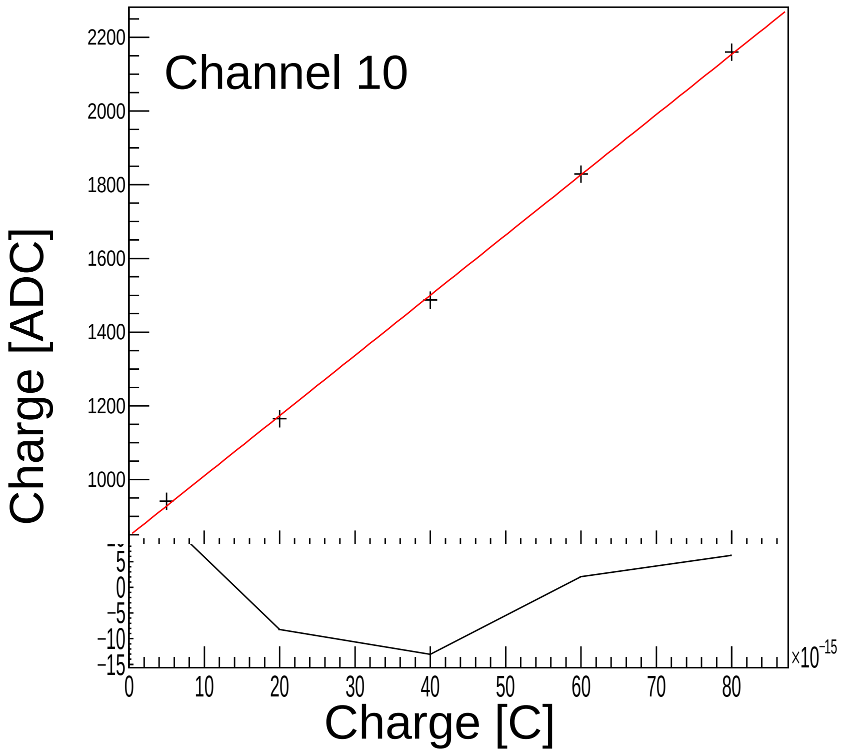


First assembly with new tool expected to start next week.

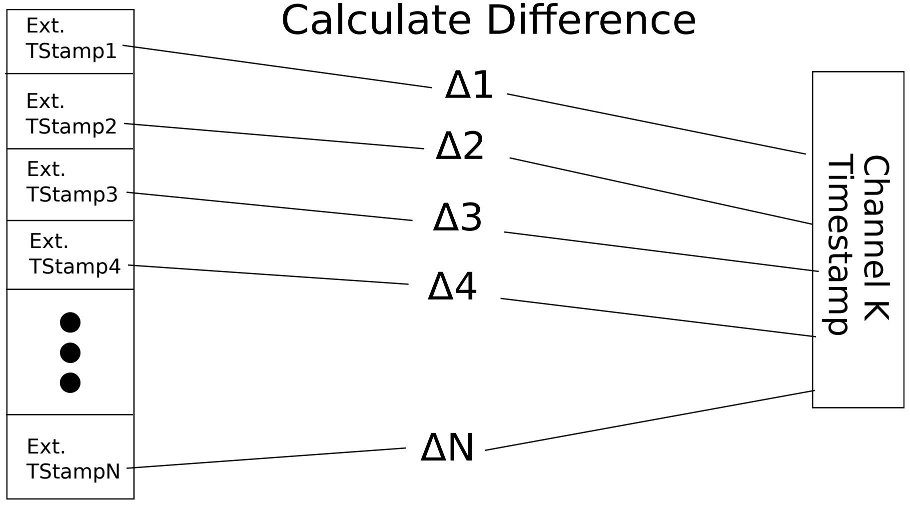
System Status: Sensors

- First sensors assembled and tests on the first sensors are nearing completion:
  - Both readout chips can be talked to.
  - Sensor depletes through wire bonds and shows sensitivity to light
  - First pedestal data taking and calibration measurements **completed**

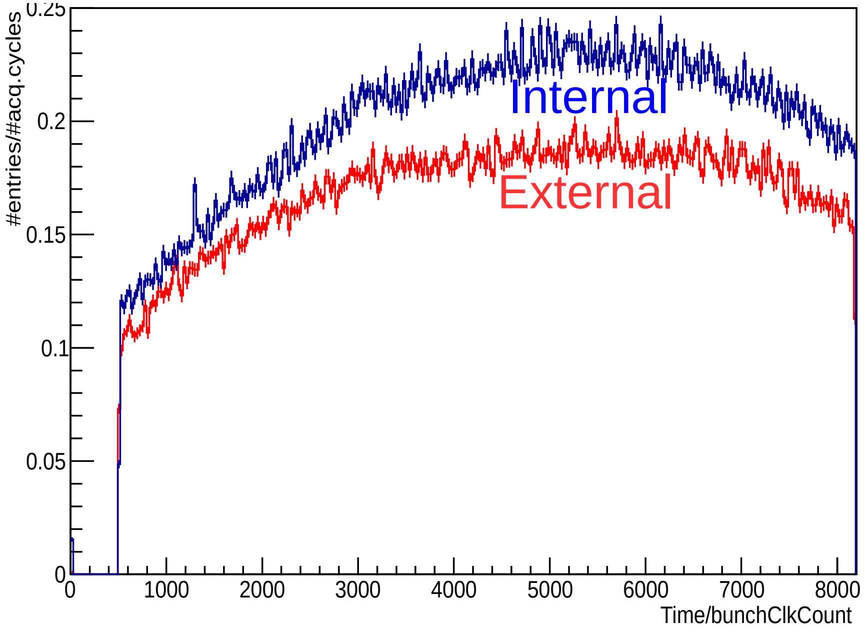


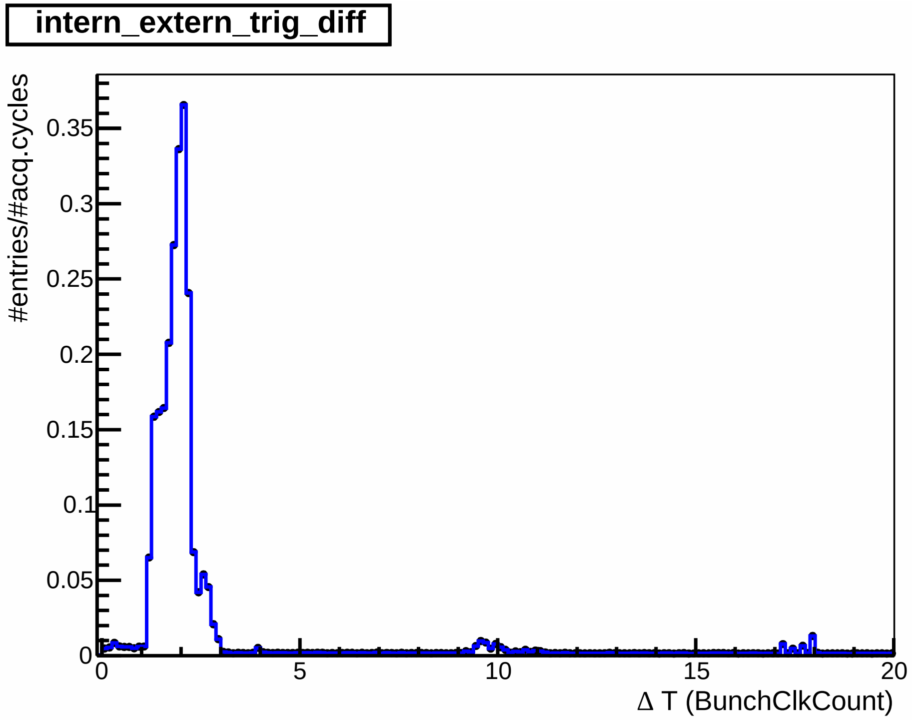


Time Coincidence

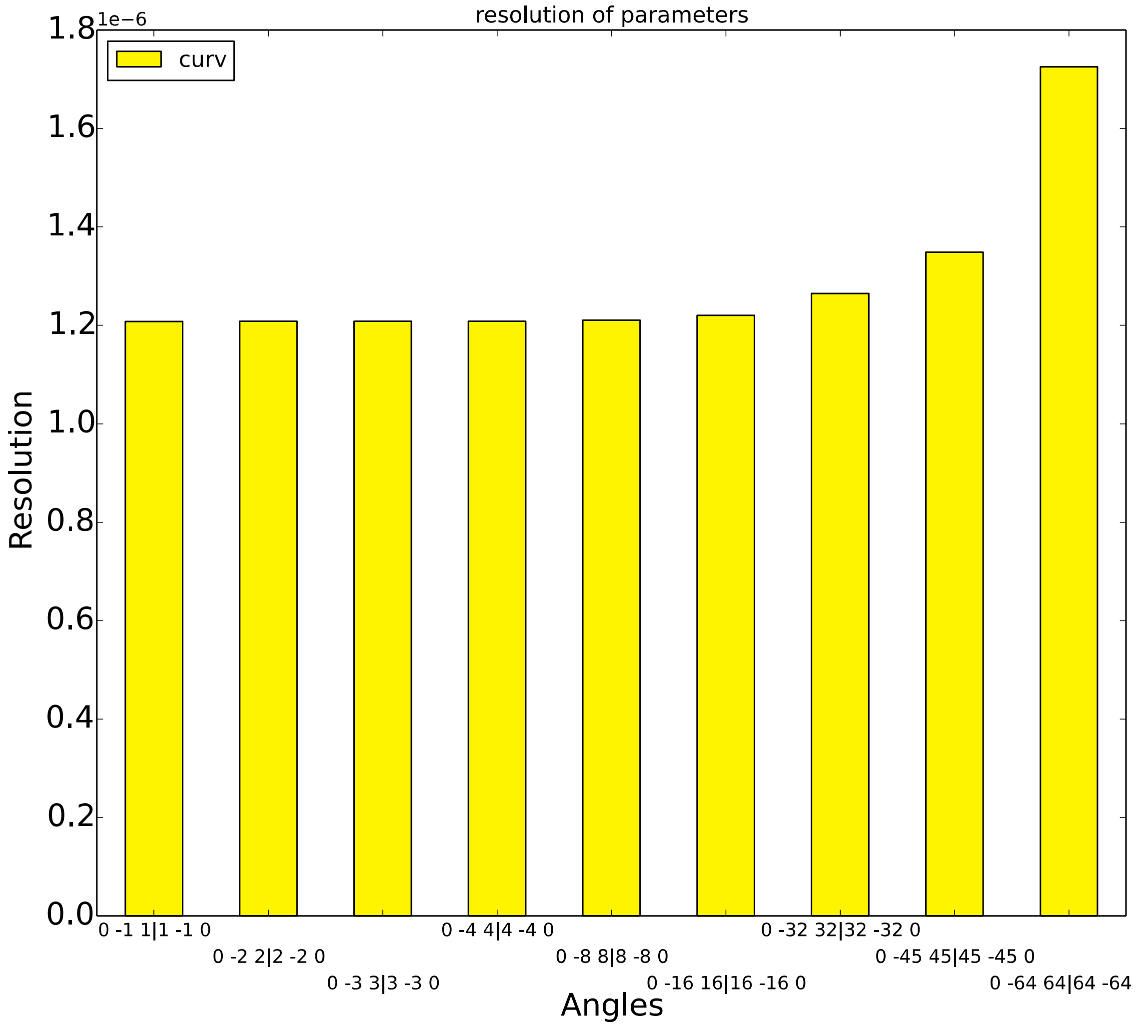


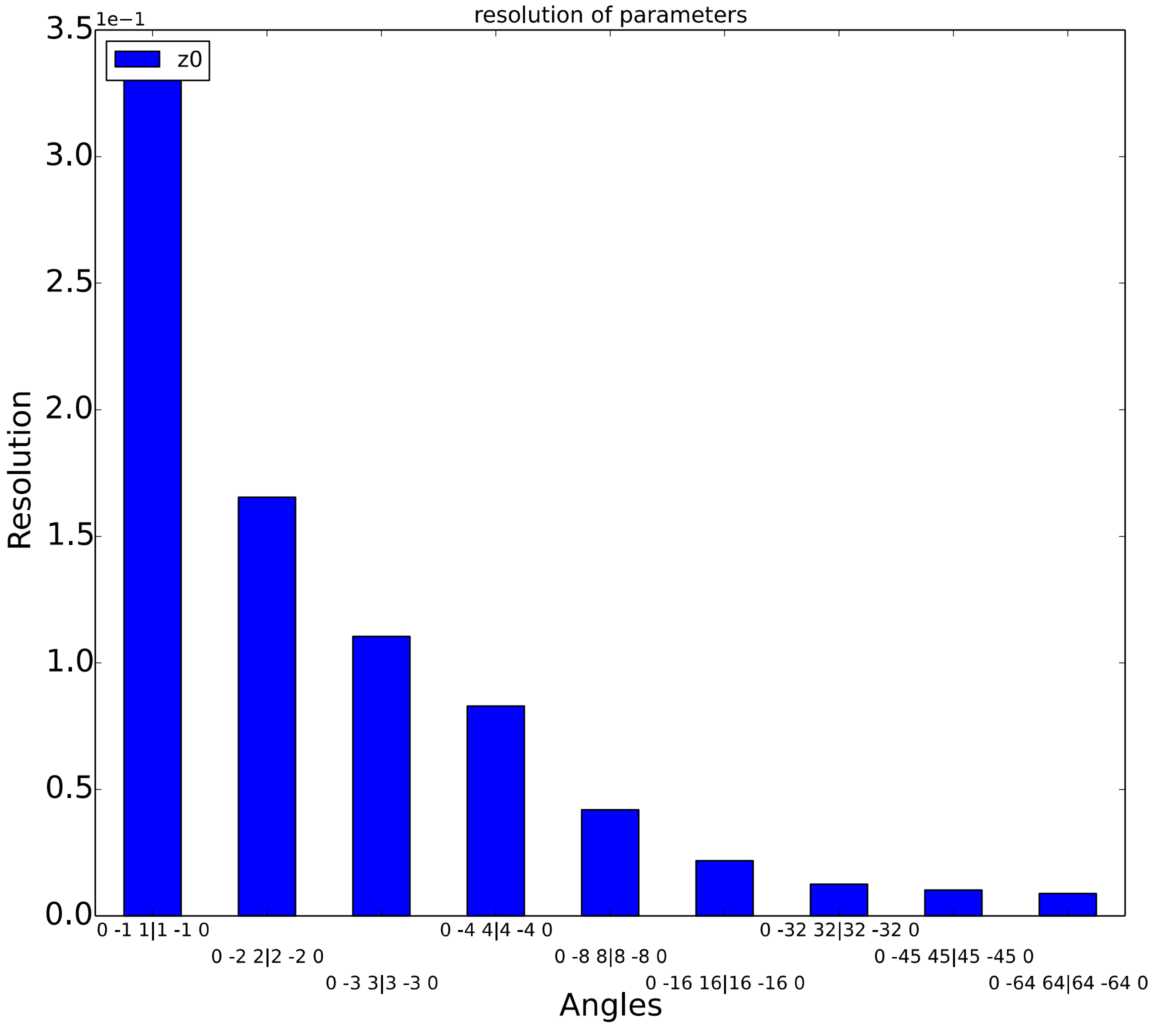
Δ4 < Δ3 < Δ2 < Δ1 < .... < ΔN
=> Δ4 = Time difference for channel K





Stereo angle variation





Parameter correlation