Lycoris: Large Area Telescope

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

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HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

SLAC NATIONAL ACCELERATOR LABORATORY

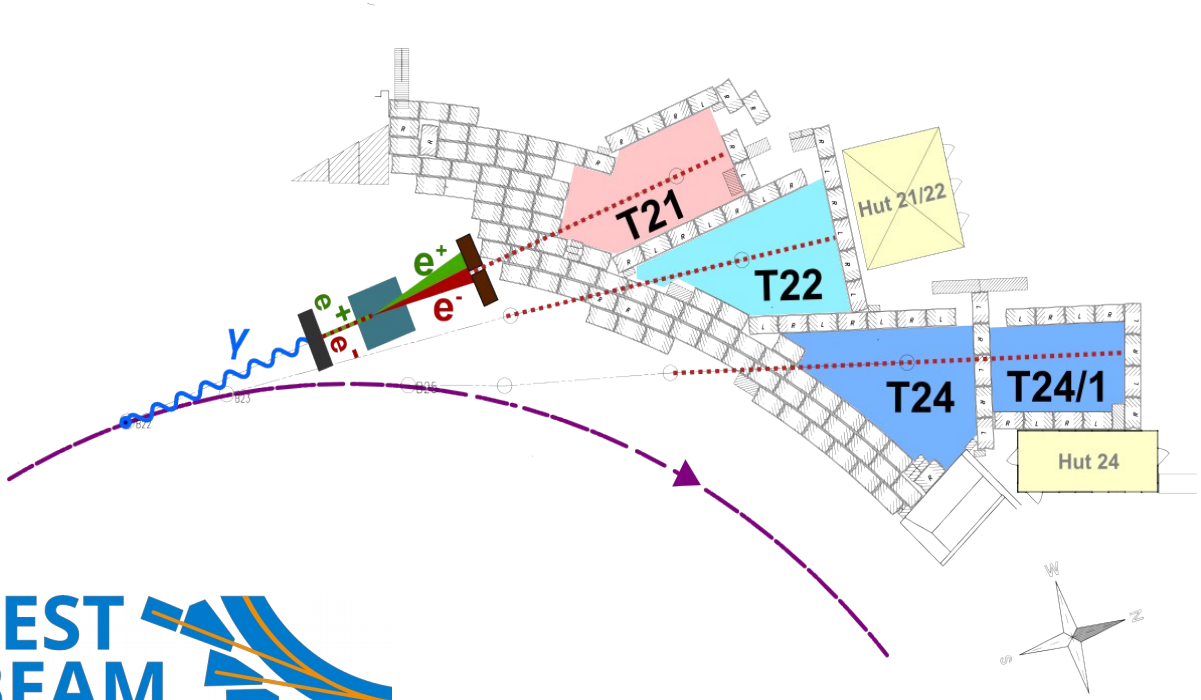
AIDA 2020

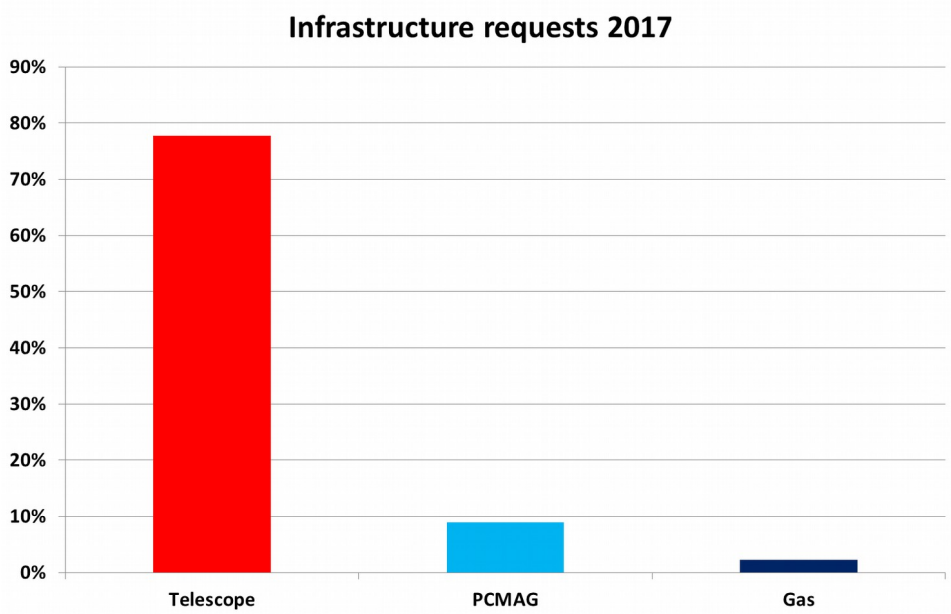
DESY TEST BEAM.

DESY.

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



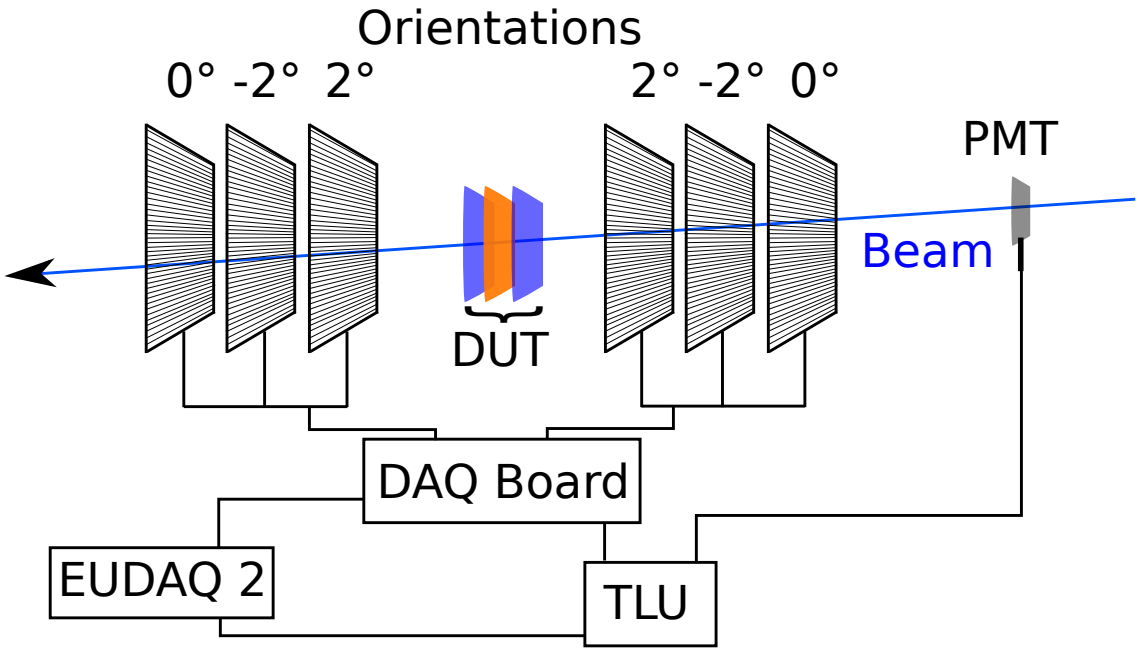


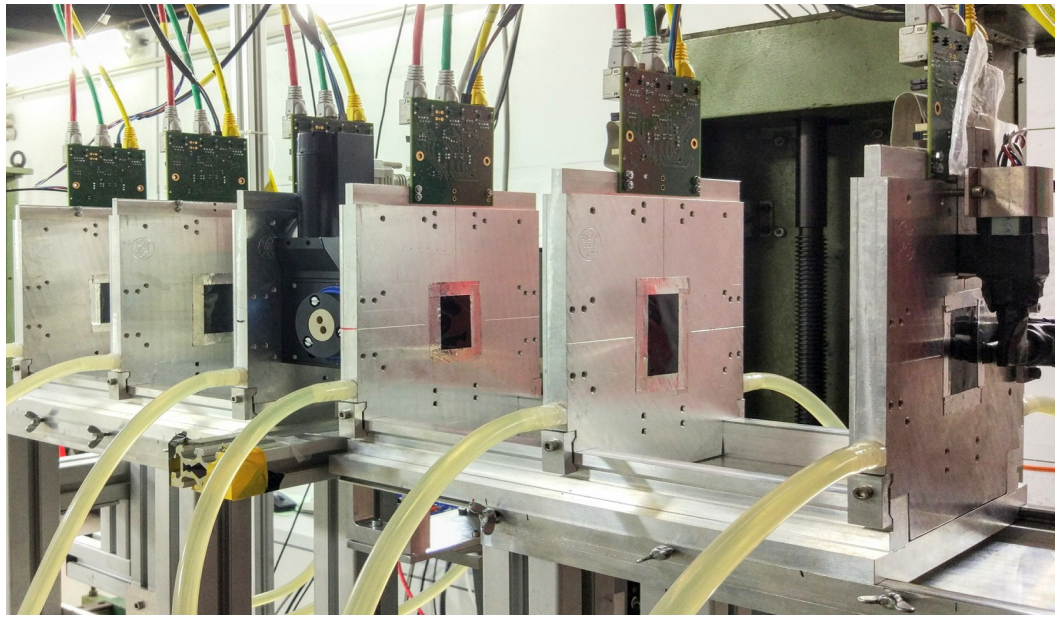
DESY TEST BEAM.
DESY.

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

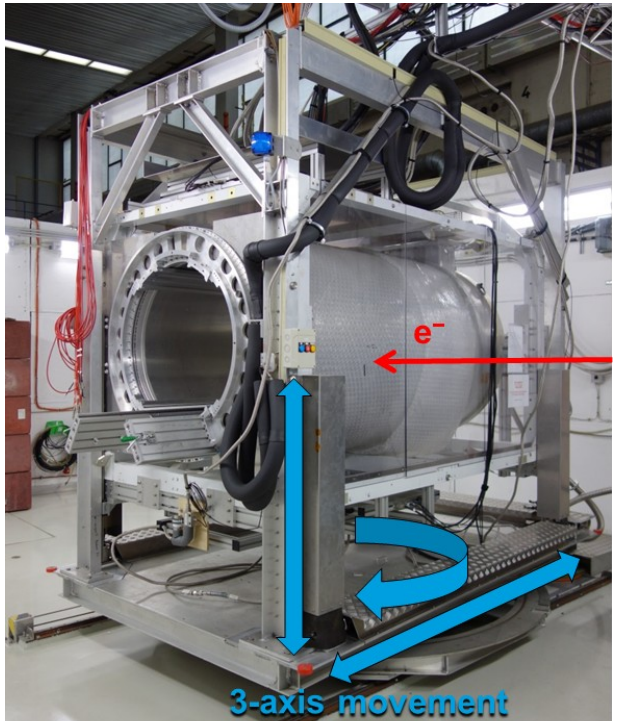




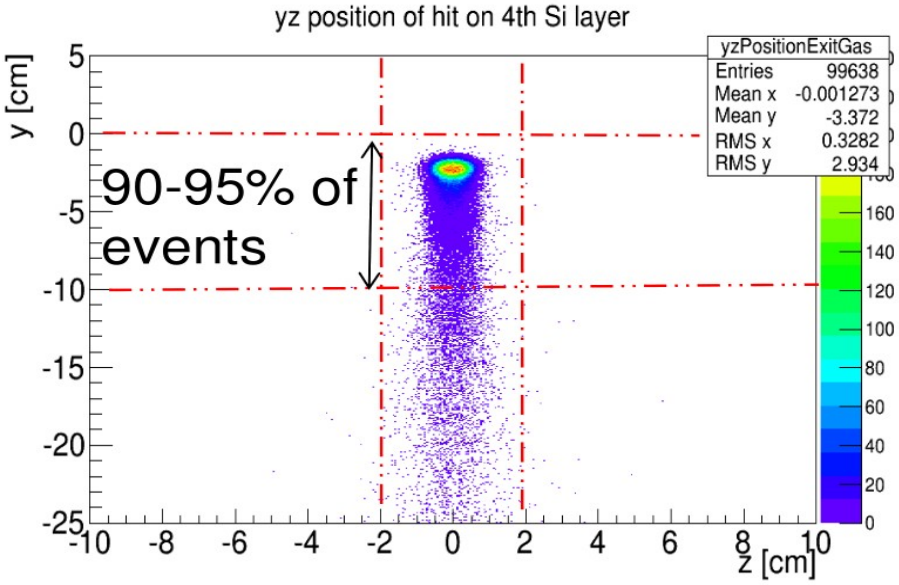
The Lycoris Telescope

An AIDA 2020 project

- A new large area strip telescope within the Test Beam Area 24/1 solenoid
- The solenoid has:
  - ~75 cm usable inner diameter
  - 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
  - Less than 3.5 cm of space per telescope module.
  - Spatial resolution requirements better than:
    - σ_y = ~10 µm
    - σ_z = ~1 mm

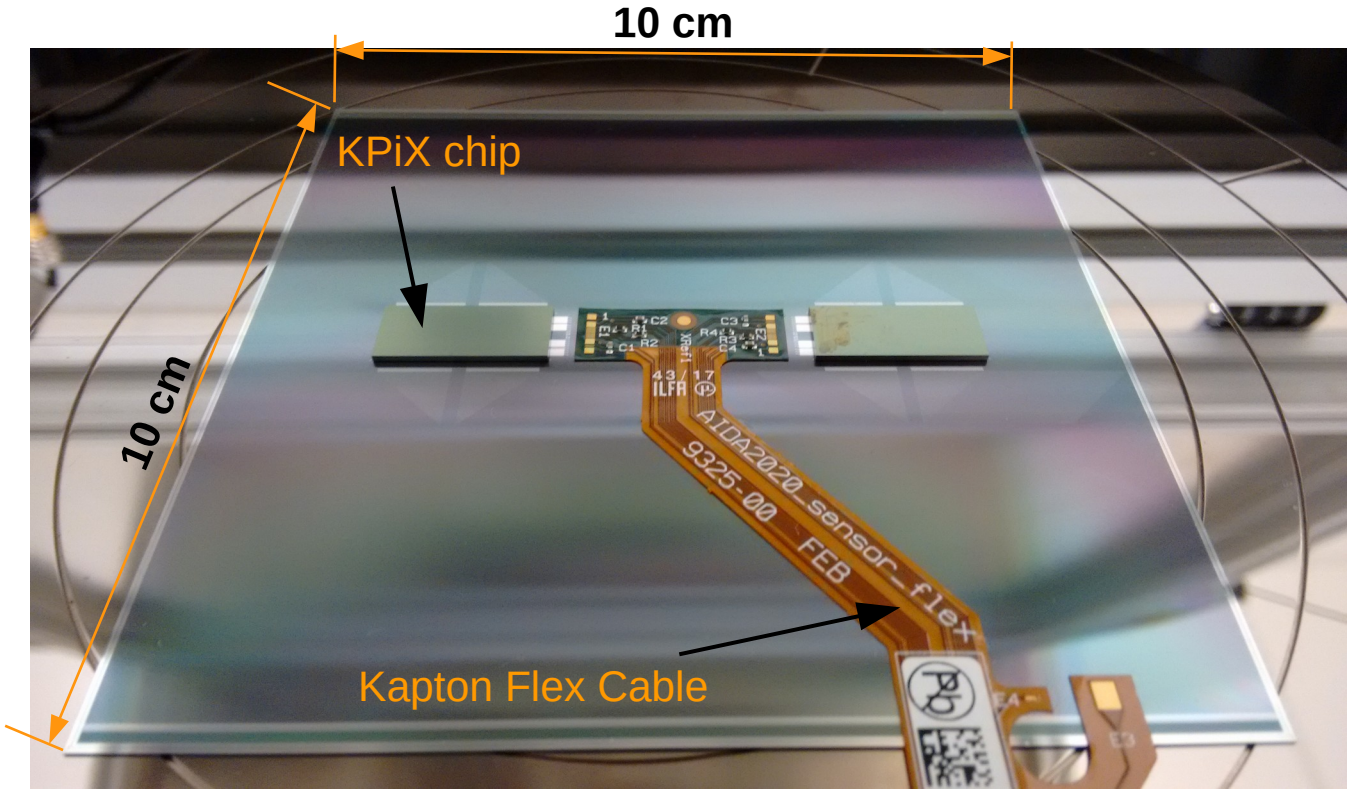


The SiD Silicon Strip Sensor

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

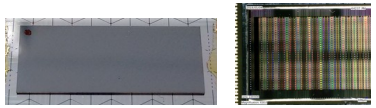
- A strip pitch of 25 µm
- ~7 micron tracking resolution
- Alternate strips will be read out
- An integrated pitch adapter and digital readout (KPiX)

  → Directly bump bonded to sensor surface
- Thickness of 320 µm
- Material budget of 0.3% X_0



First sensor was fully assembled earlier this year.

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

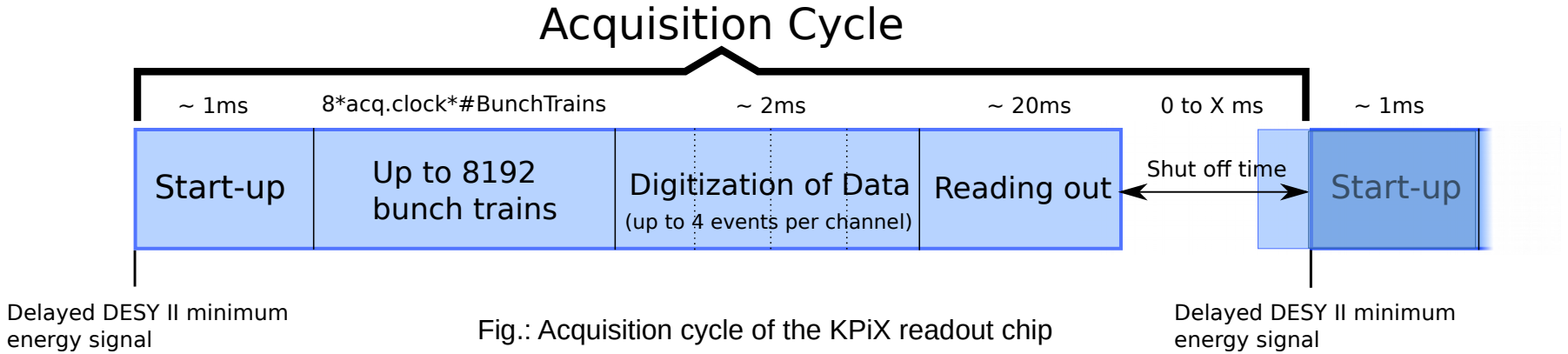


Fig.: Acquisition cycle of the KPiX readout chip

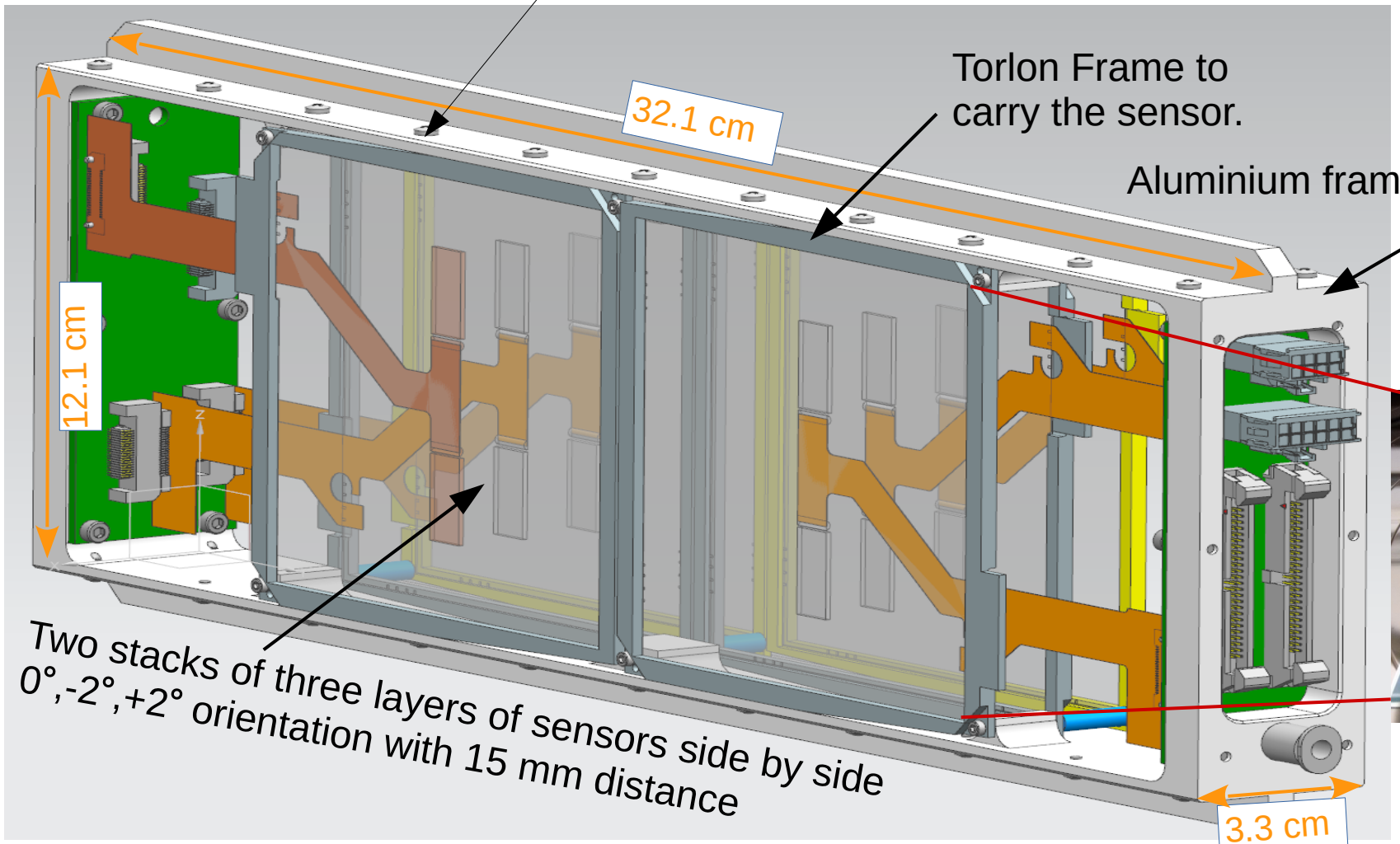
- Only open for a maximum time of 8192*8*acq.clock
  → For example with a 320 ns acq.clock = 20.97 ms

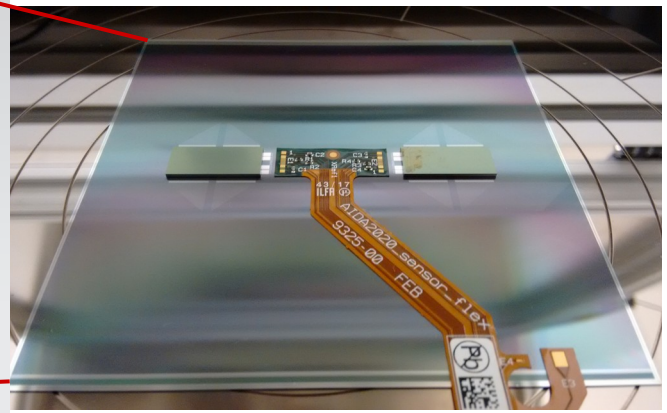
The Final System: The Cassette

Carbon fiber window for protection + grounding shield

Torlon Frame to carry the sensor.

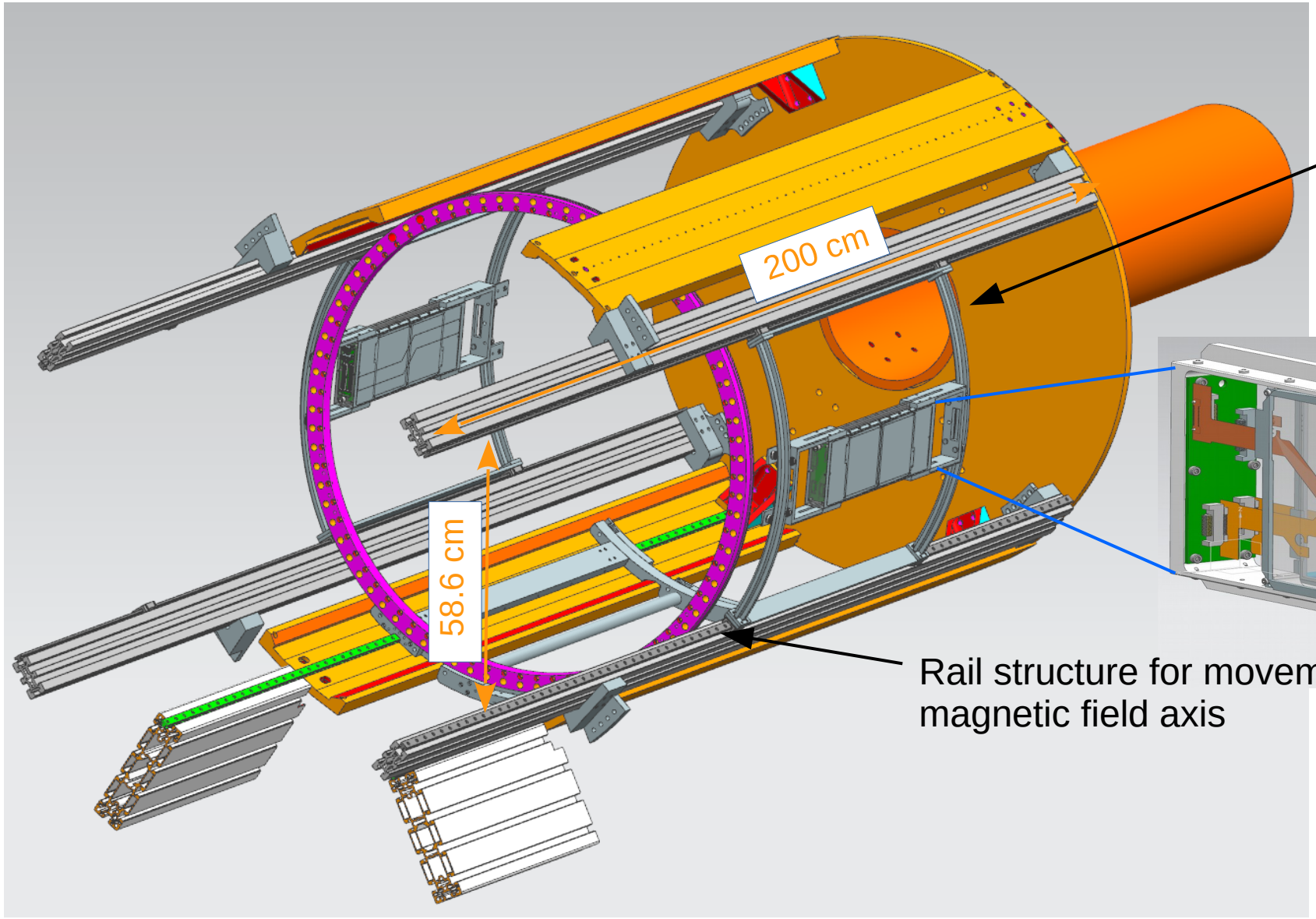
Aluminium frame for mechanical stability



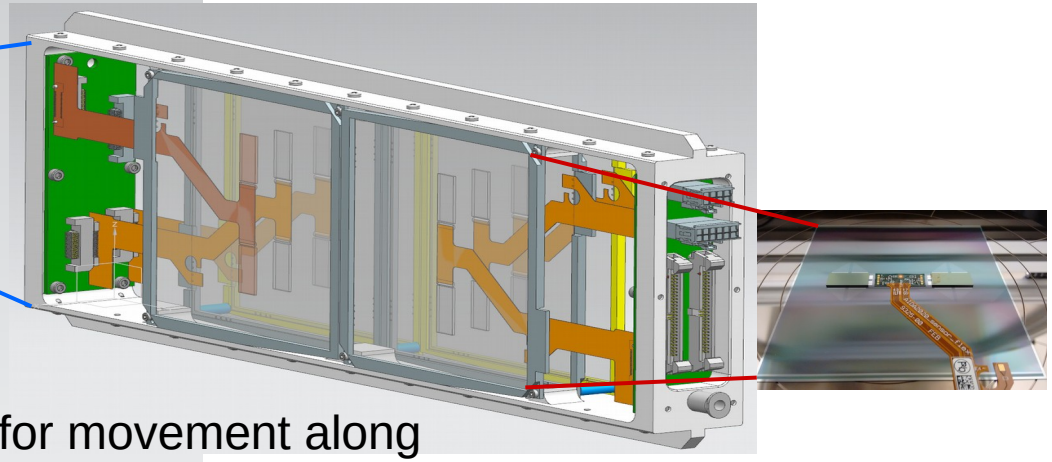


Final system has an active area of 10x20 cm²

The Final System: The rail system



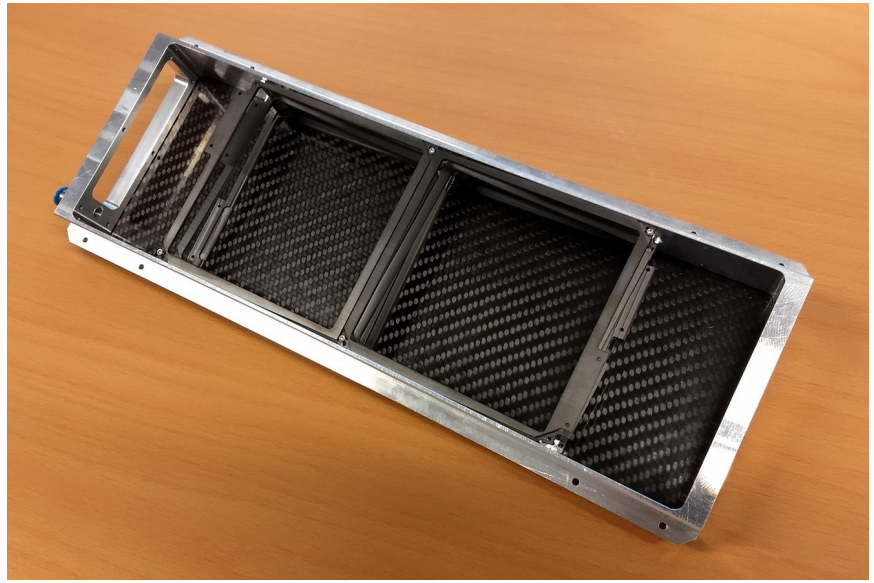
Rail structure for movement along magnet angle

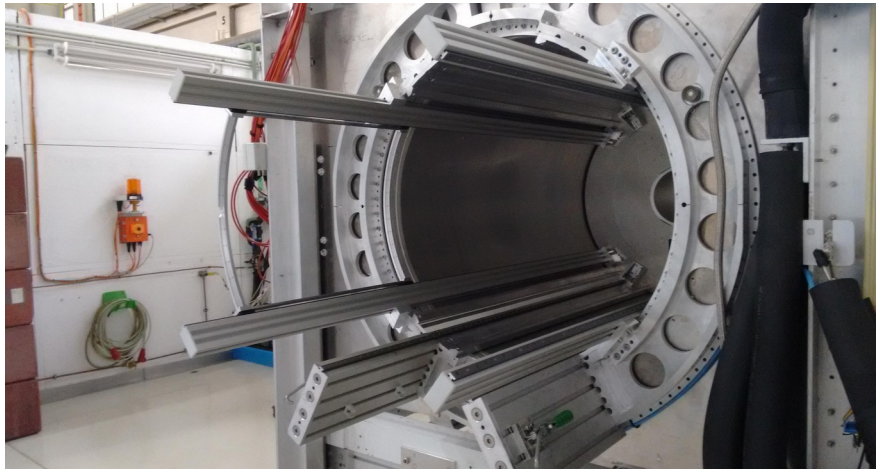


Rail structure for movement along magnetic field axis

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
- Only need to assemble further sensors and install them in the Torlon frames.

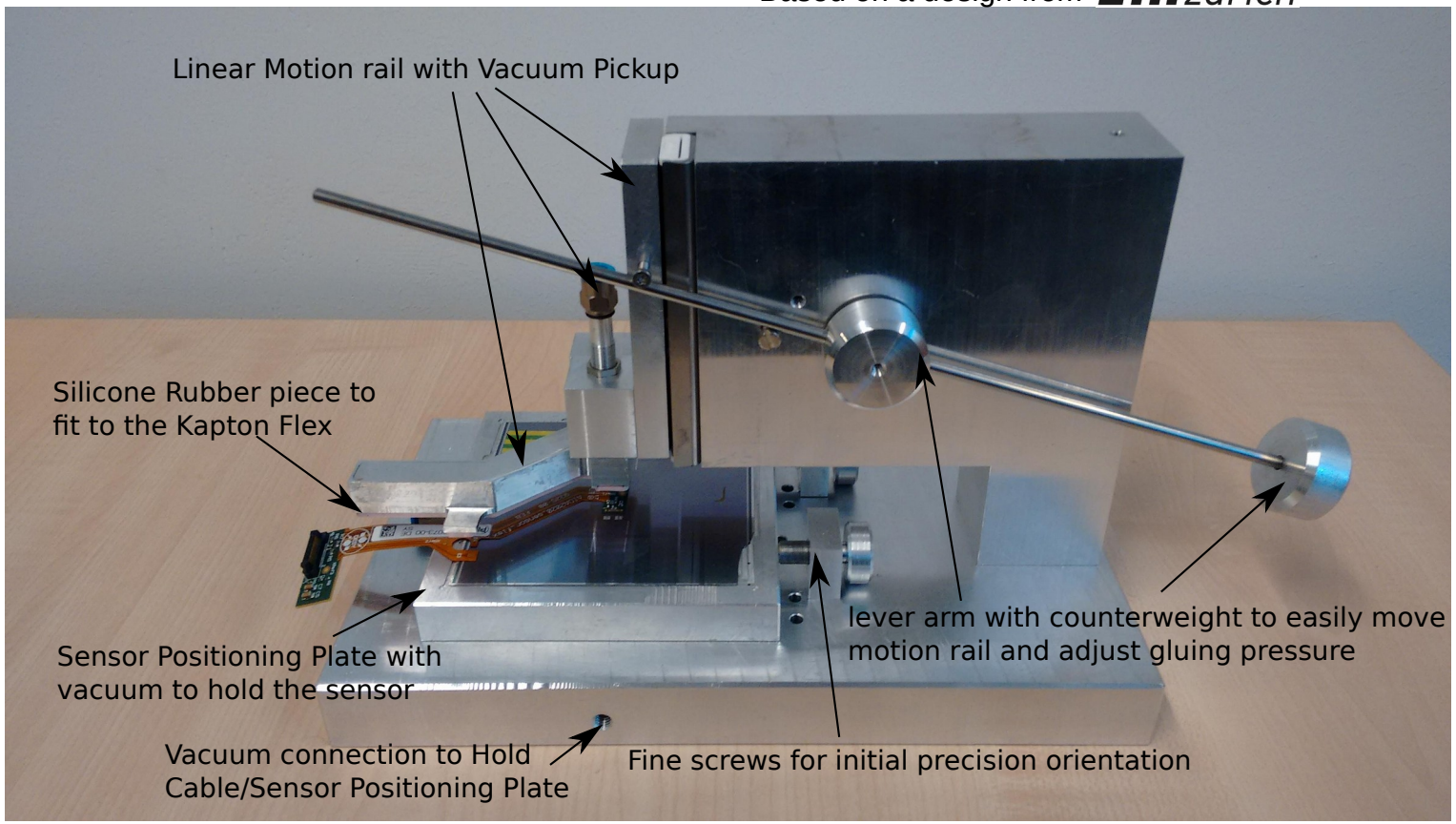




System Status: Mechanics

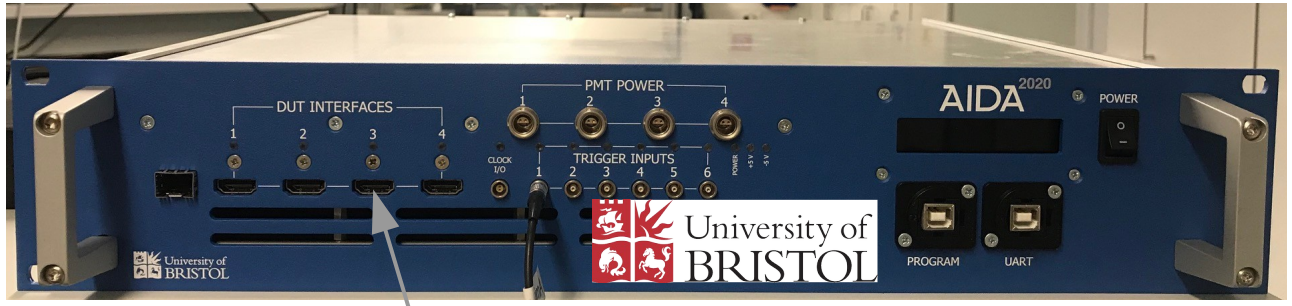
- After first manual assemblies, a new tool was designed and built to provide reproducible results through:
  - Controlled glue application
  - Fine adjustable gluing pressure
  - Precise cable positioning
- Able to be used for further assembly of sensors into Torlon frames

Based on a design from ETH zürich



First assembly with new tool expected to start next week.

System Status: Electronics

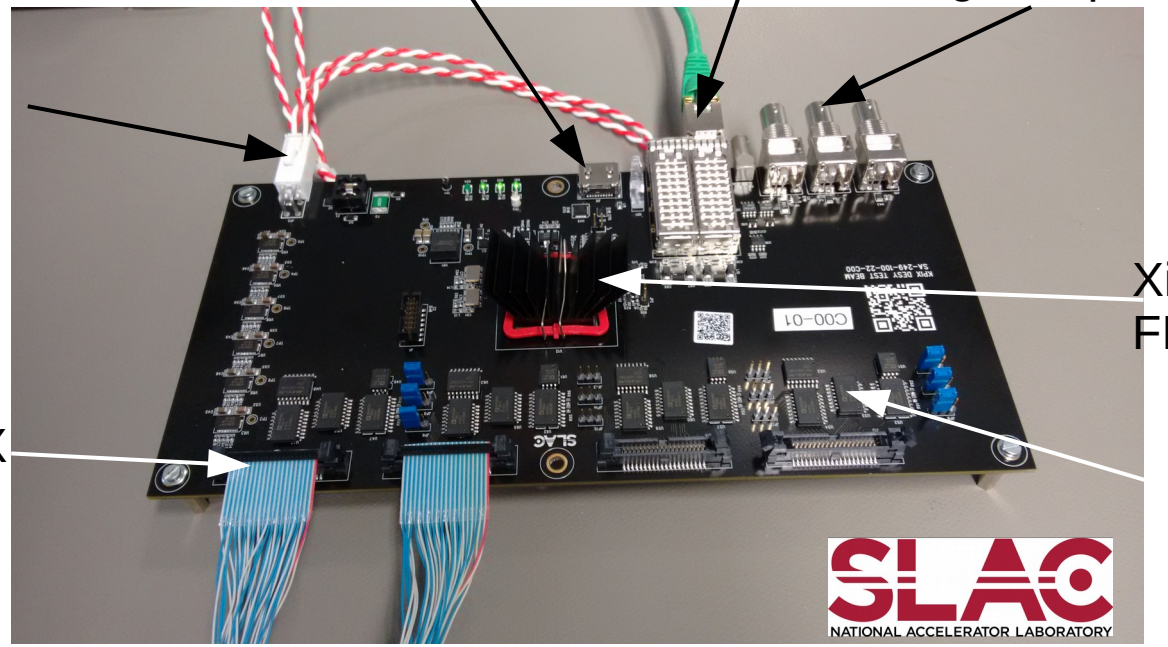


HDMI connector to AIDA TLU

Optical cable output connector

Digital input/output

FPGA Power



Xilinx Kintek 7 FPGA

Signal connectors to KPiX (6 KPiX per cable)

Isolation Buffers

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

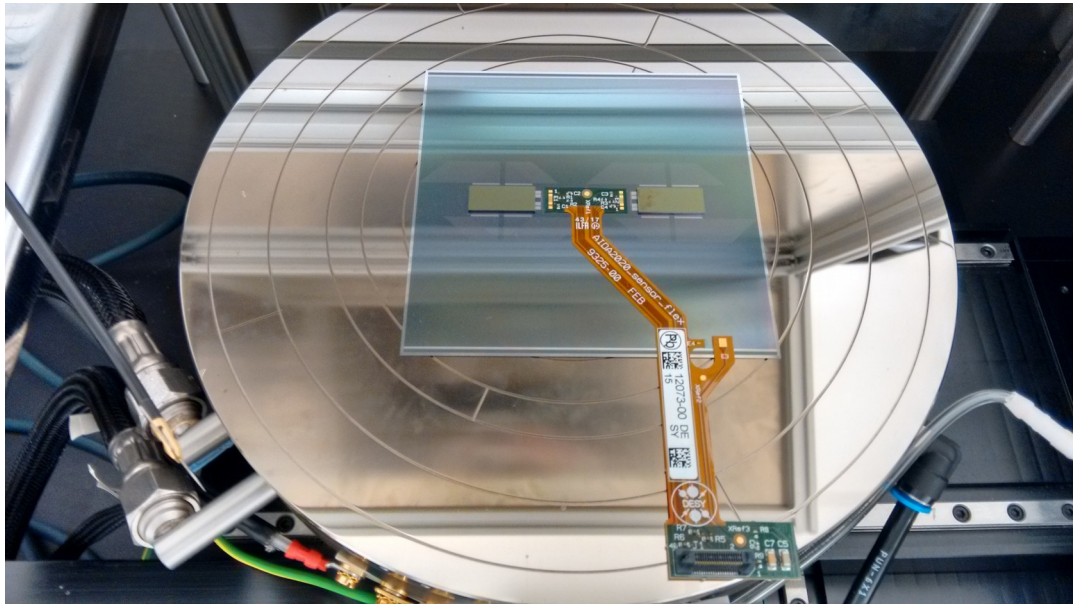
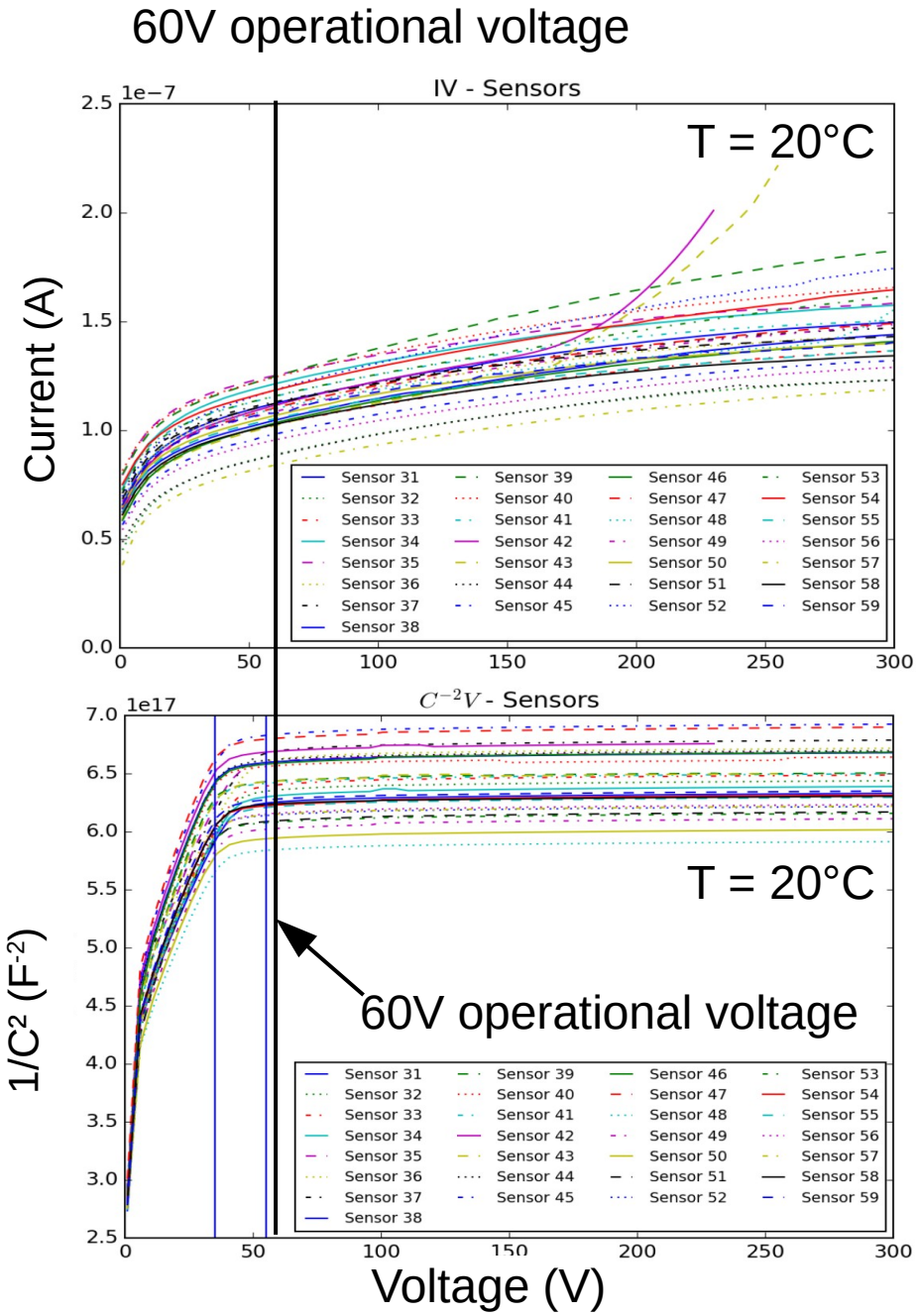
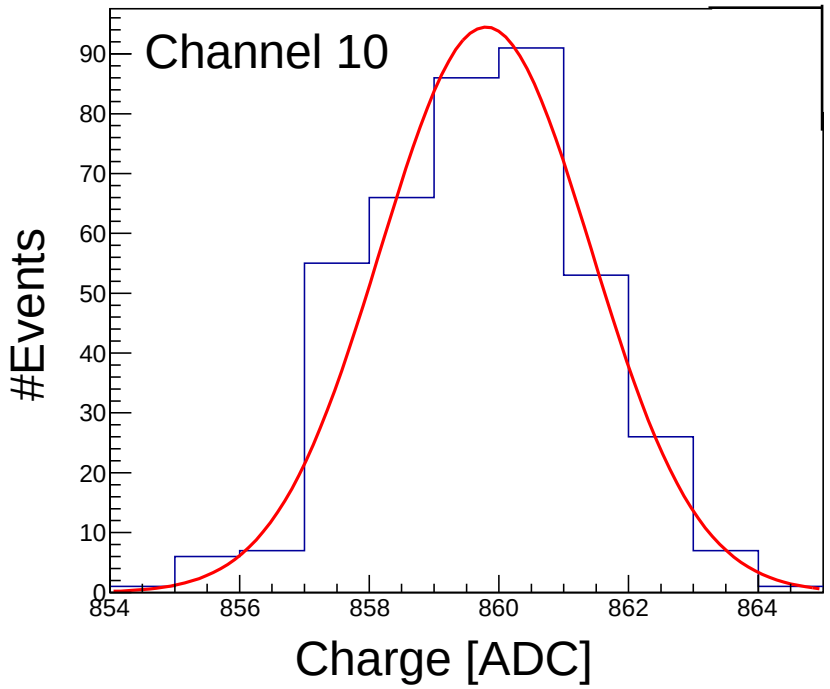


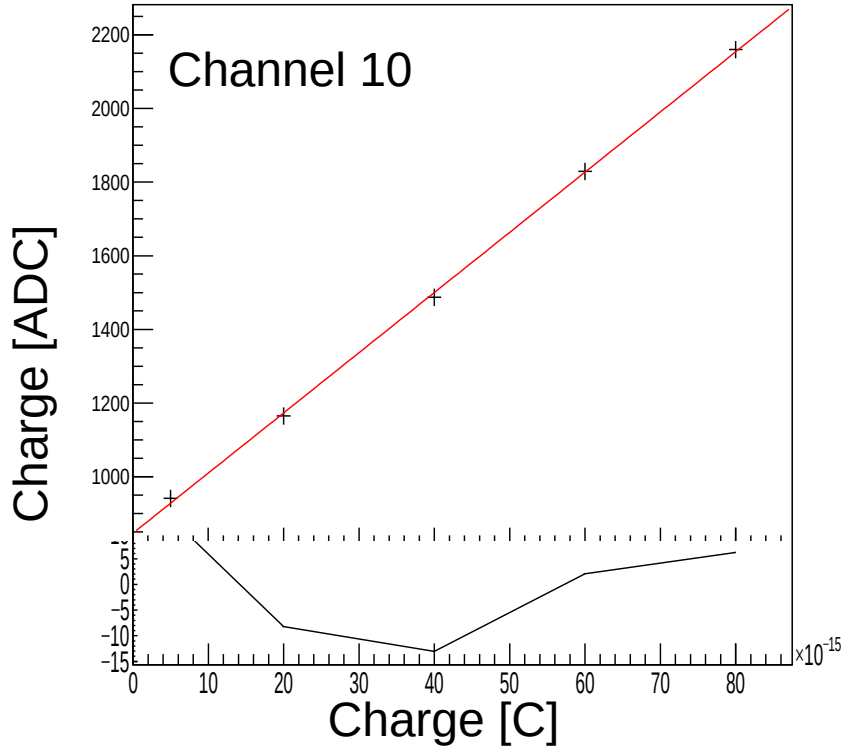
Fig.: Bump Bonded Sensor with flex cable on the probe station



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**





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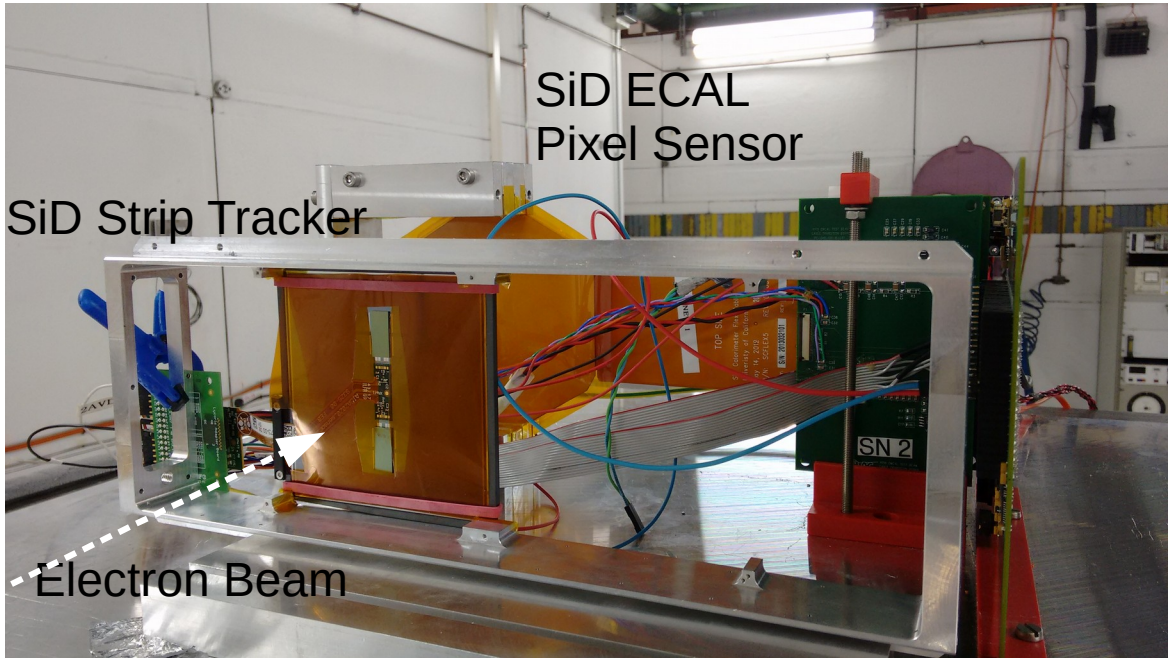
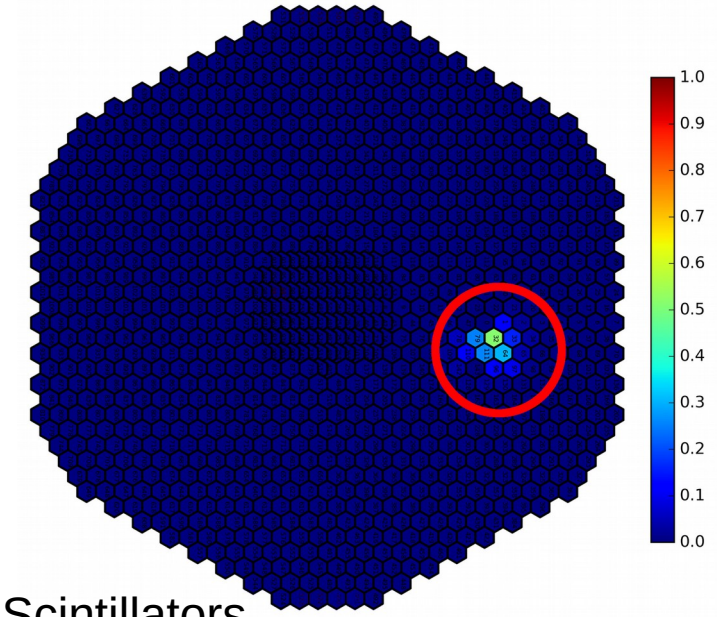
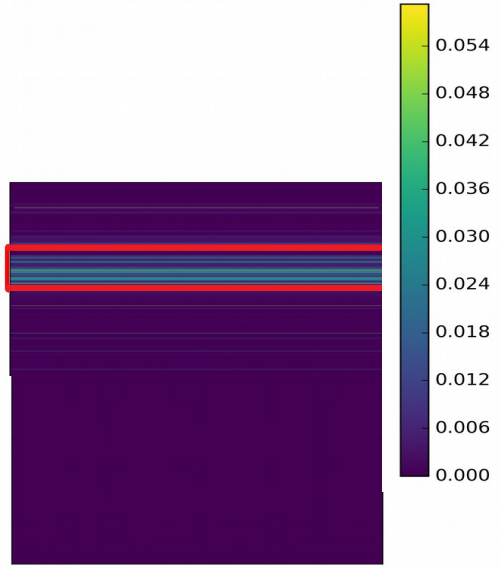


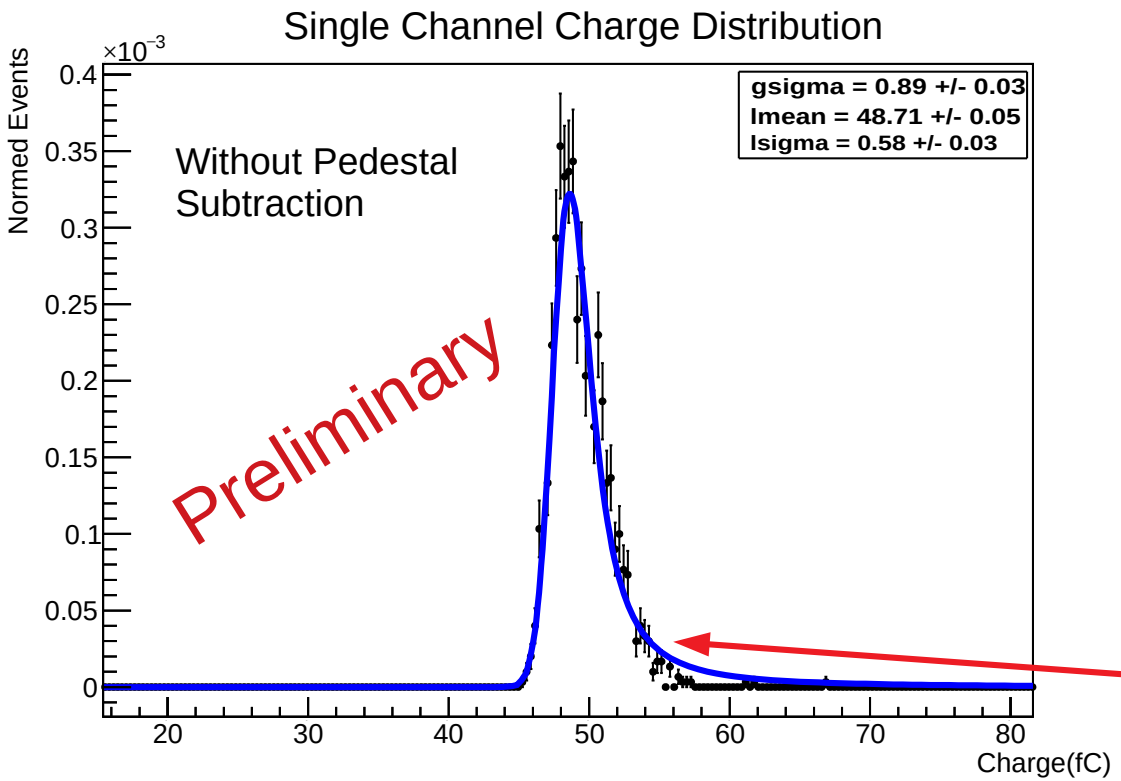
- Recently completed first Testbeam with the new tracker sensor
- ~ 2 Million Events recorded, split between different running modes.
- Test of both internal triggering and external triggering functionality.





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

System Status: Sensors



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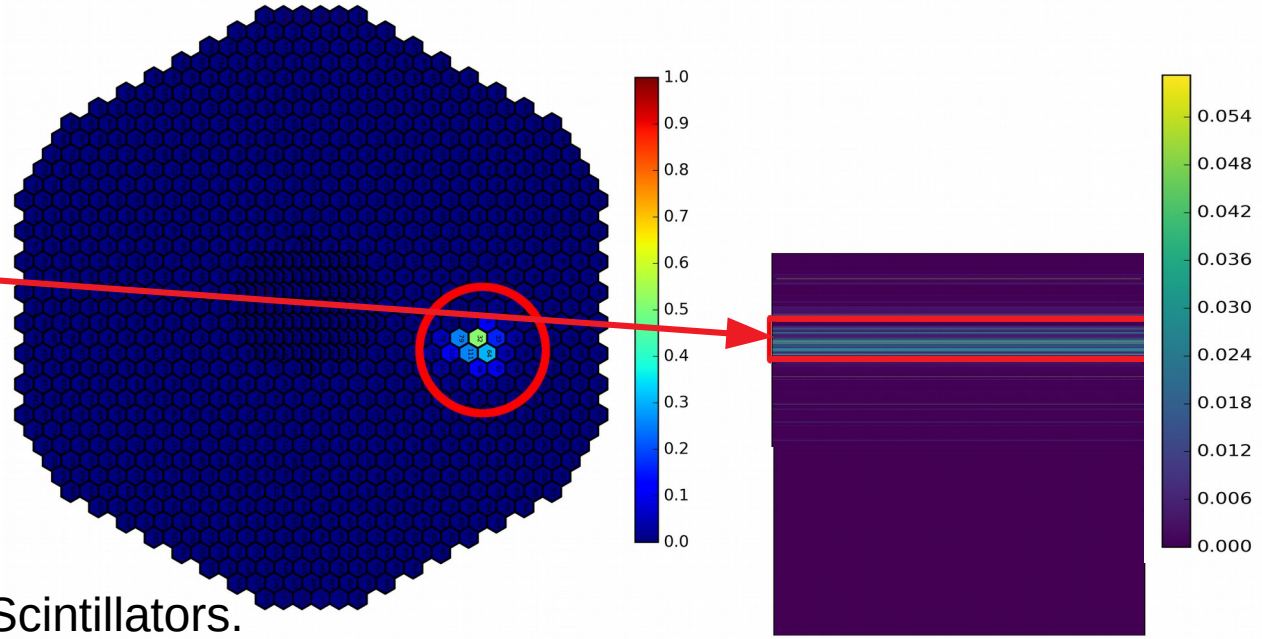
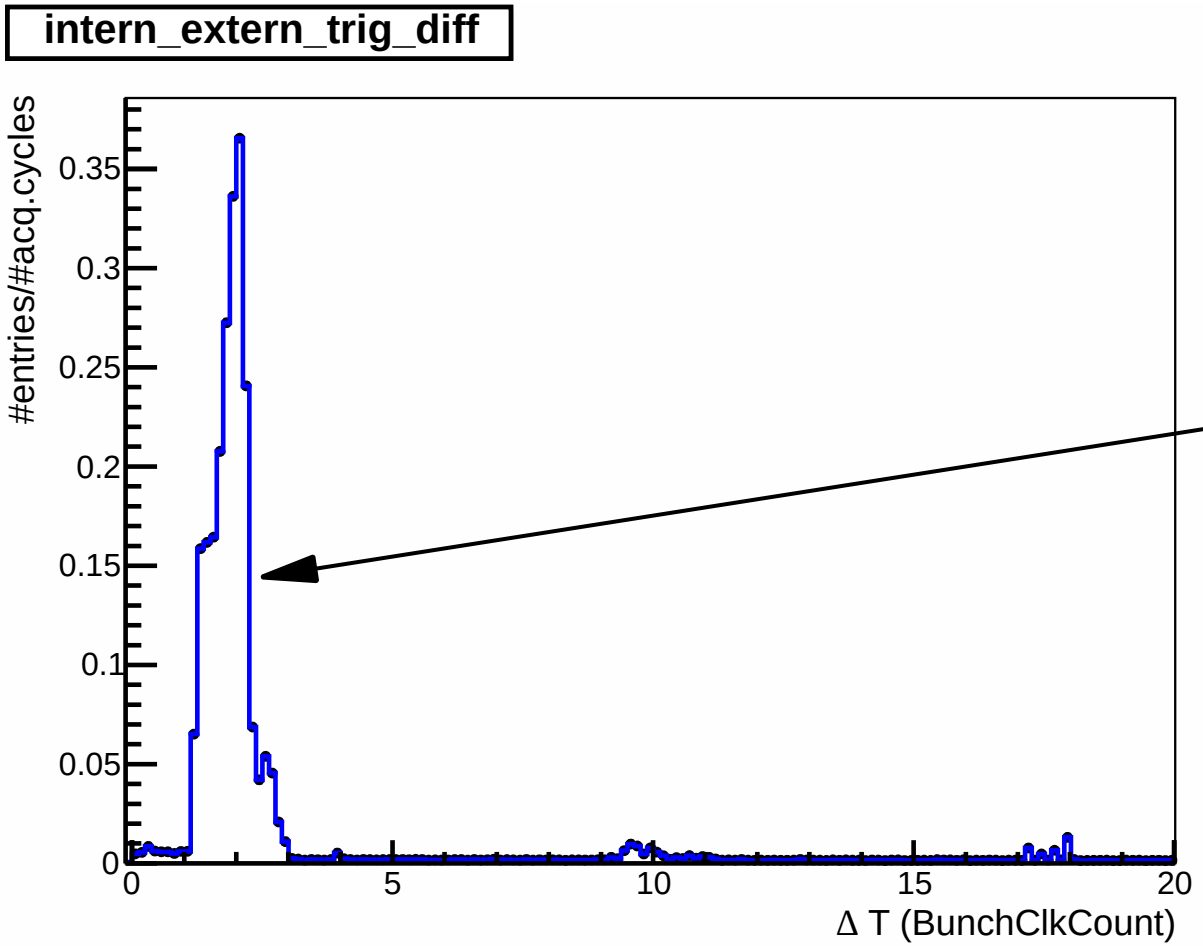
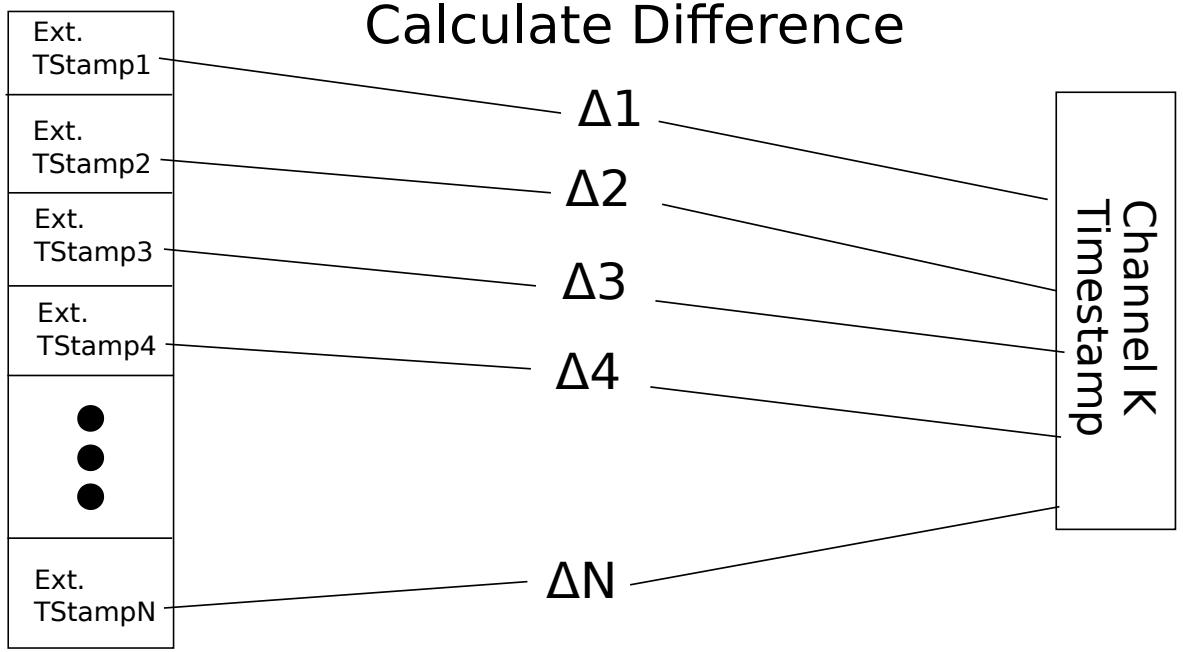


- Full coincidence:
  - SiD Strip Tracker ↔ SiD ECAL Pixel Sensor ↔ Beam Scintillators.

Time Coincidence





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

Summary and Outlook

- Receiving last missing components for the system.
  - Mechanical structure fully assembled
  - New DAQ board recently finished
    → First tests of the new firmware and hardware successful.
  - Cassette electronics close to being finalized

- Assembled the first telescope module based on the SiD tracker design.
  - 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.
    → Assembly of the sensors in the coming week(s)

- Work is ongoing on the analysis of the data including clustering algorithms.
- Testbeam with a fully stacked cassette and mimosa telescope scheduled for **02/2019**
- Testbeam of LYCORIS with LCTPC prototype as DUT scheduled for **04/2019**

Thank you for your attention

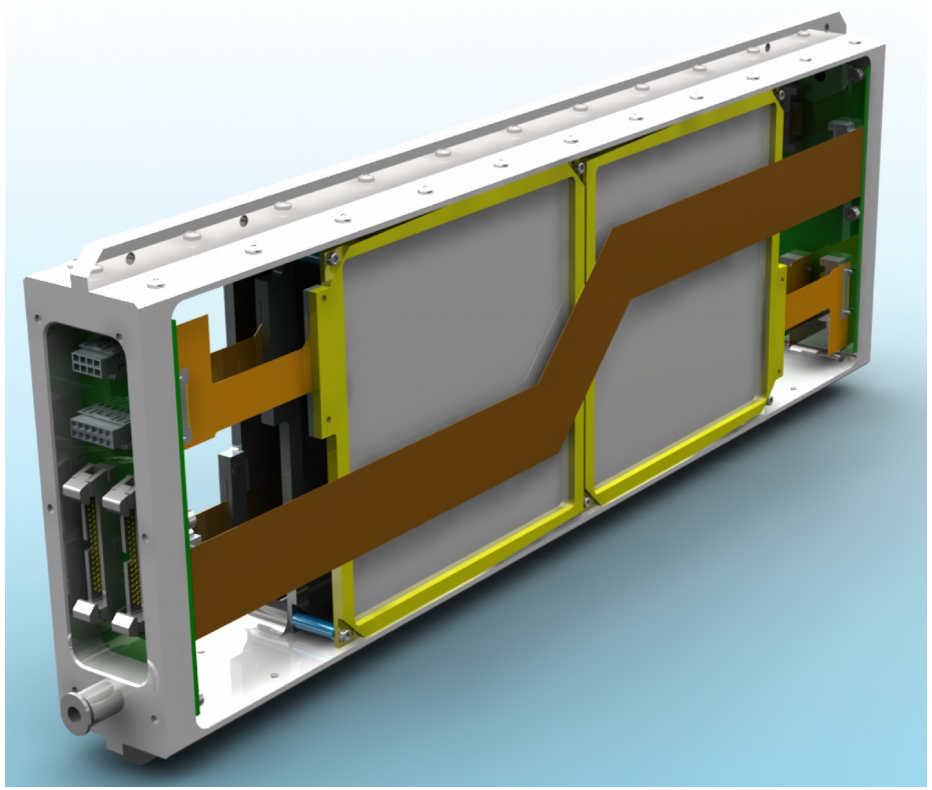


Fig.: LYCORIS Tēlescopia

Fig.: Lycoris Radiata

BACKUP

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

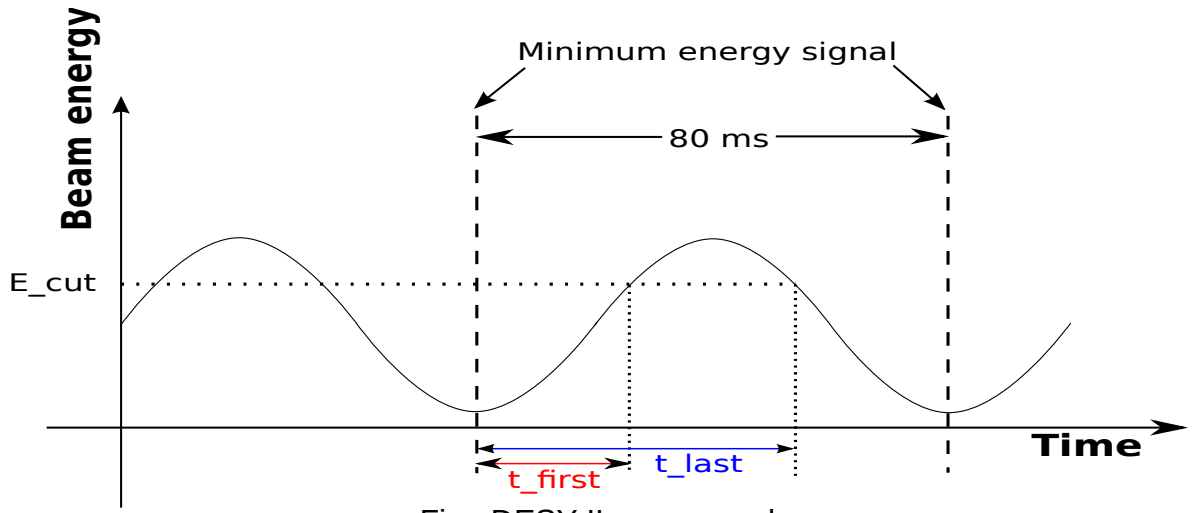


Fig.: DESY II energy cycle

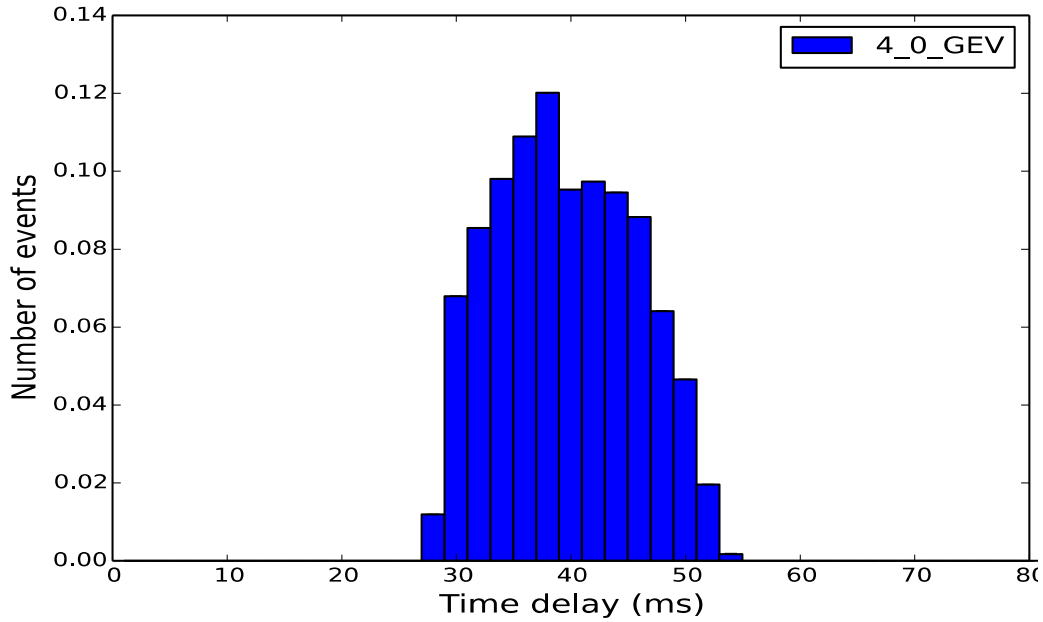


Fig.: Time difference from min. energy to trigger signal

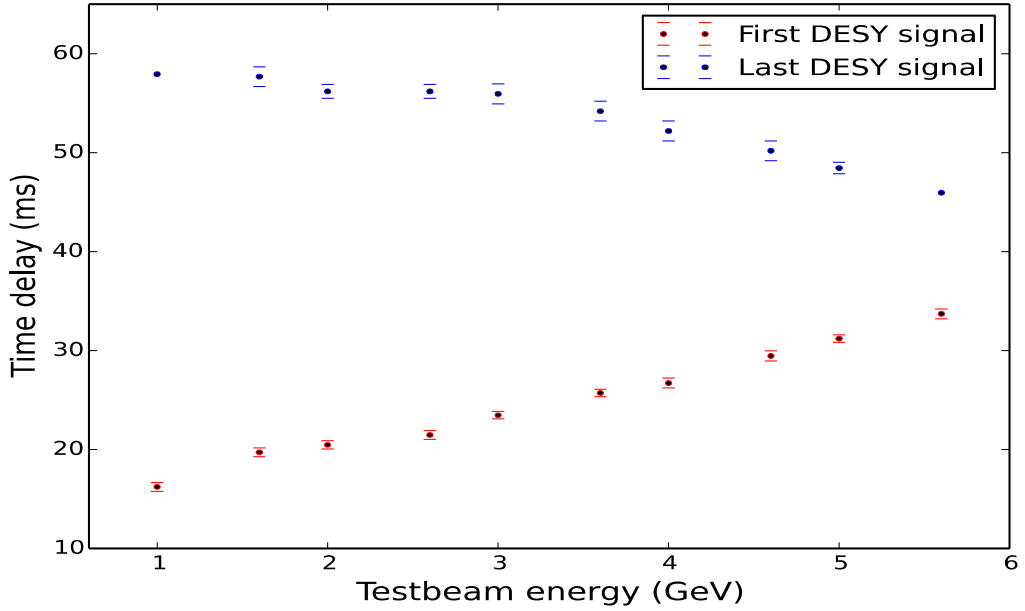
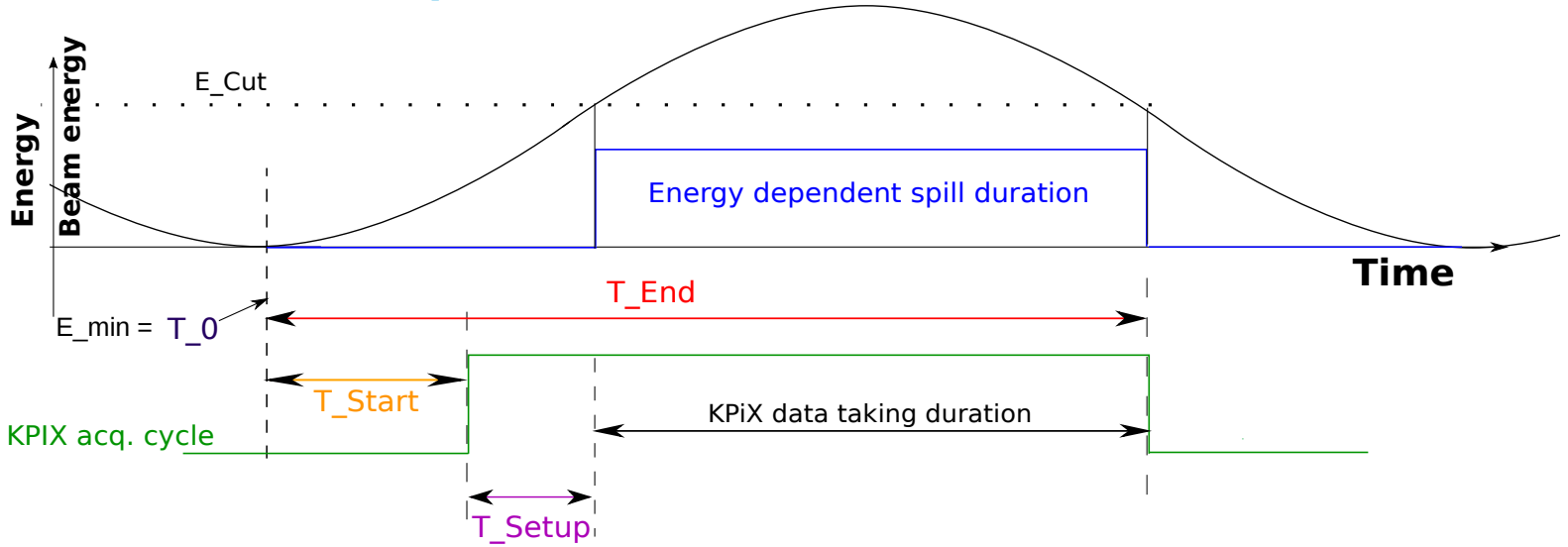


Fig.: First and last DESY signal in a cycle for different energies

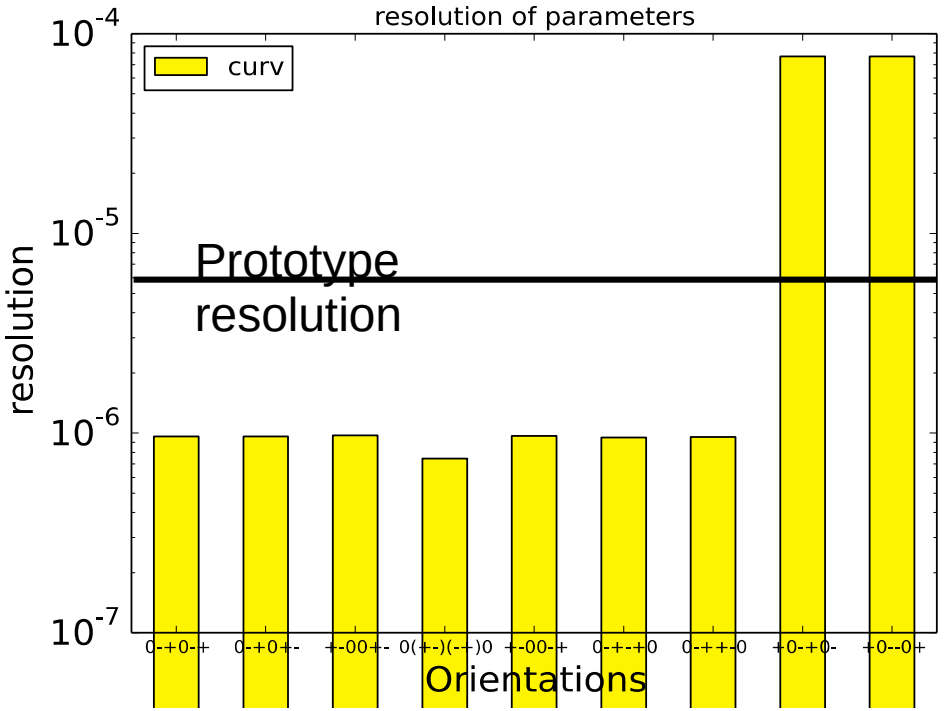
KPiX synchronisation, DUT and Beam

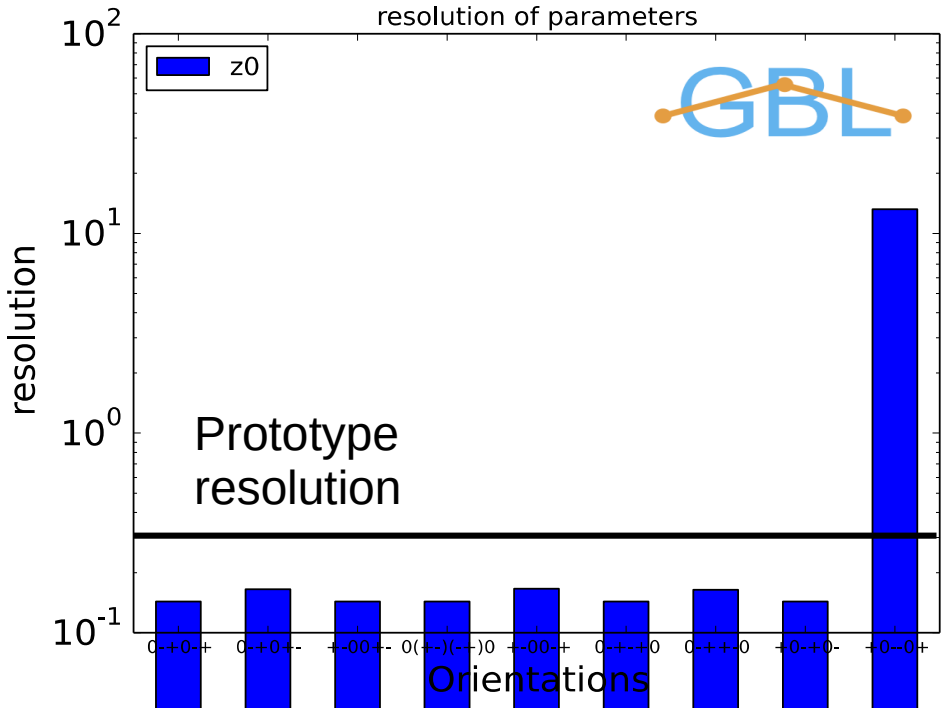


- KpiX needs to be synchronised to beam spill of the acceleerator and the DUT
  - T_0: Accelerator signal for synchronisation with beam spiull
  - T_Start: User adjustable delay between T_0 and KpiX switch on.
  - T_Setup: Setup time of KpiX. At the end of which KpiX can start the data taking
  - T_End: 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

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





Telescope requirements

- Downscaling of ILD TPC to Large Prototype TPC paremeters for simulations.

  Requirements for minimal momentum resolution of the telescope.

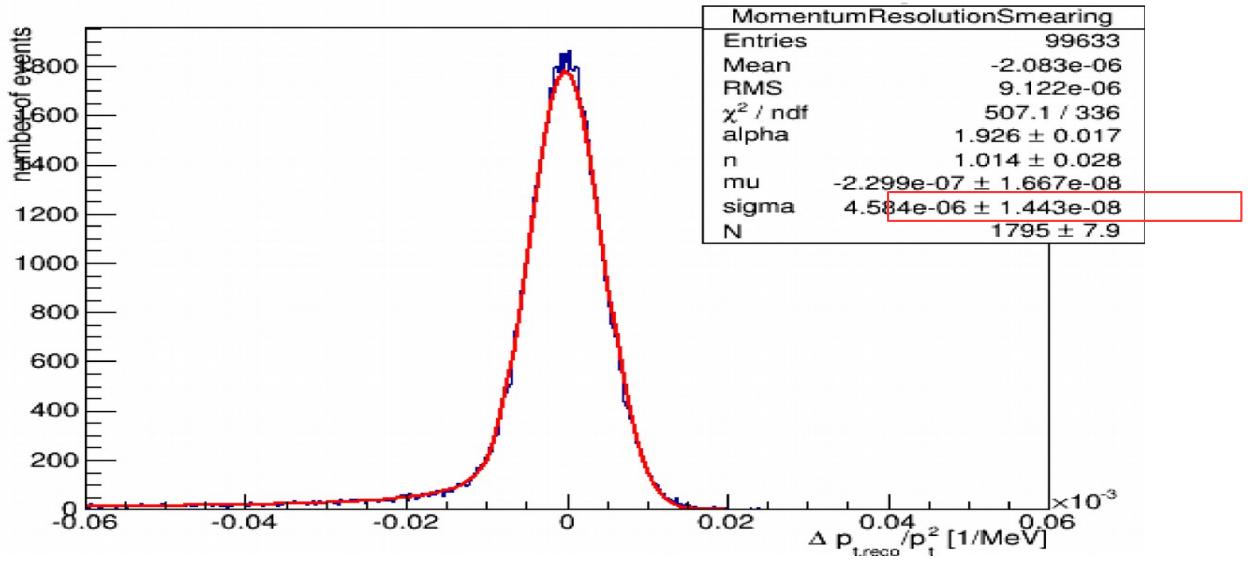


Fig.: Simulated TPC momentum resolution

- This results on further requirements for:
  - Number of layers
  - Distance between layers
  - Material budget
  - Single point resolution
  - Stereo angles
  - ...

Tab.: Momentum resolution for different distance an sensor resolution (in 1E-6 MeV^{-1})

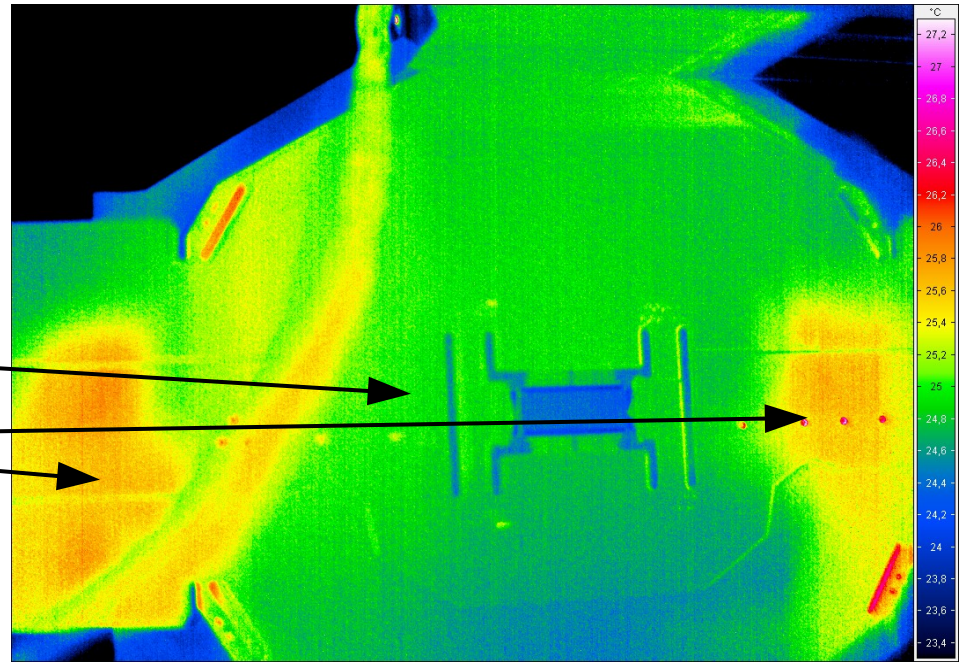
		Distance between inner and outer Si layer			
		4 cm	3 cm	2 cm	1 cm
Sensor spatial resolution	2.5 μm	2.85	2.90	3.00	3.68
	5 μm	3.05	3.21	3.63	5.52
	7.5 μm	3.37	3.65	4.43	7.92
	10 μm	3.68	4.16	5.33	9.90
	15 μm	4.49	5.36	7.53	14.3

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

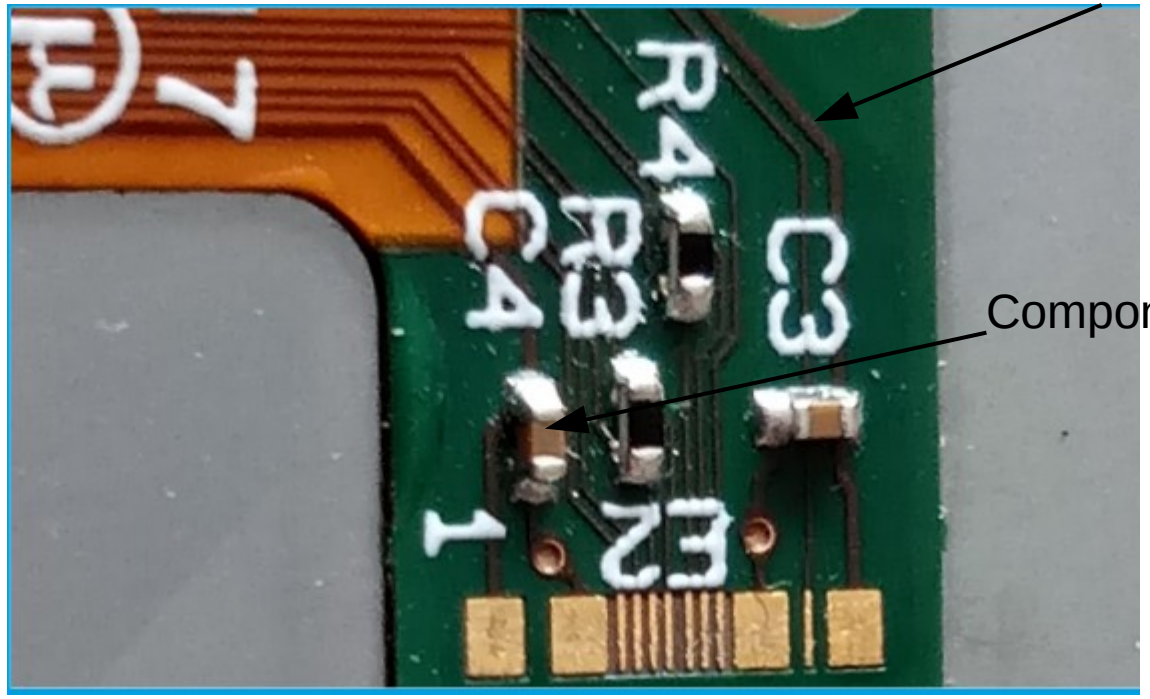
Radiation Length

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%

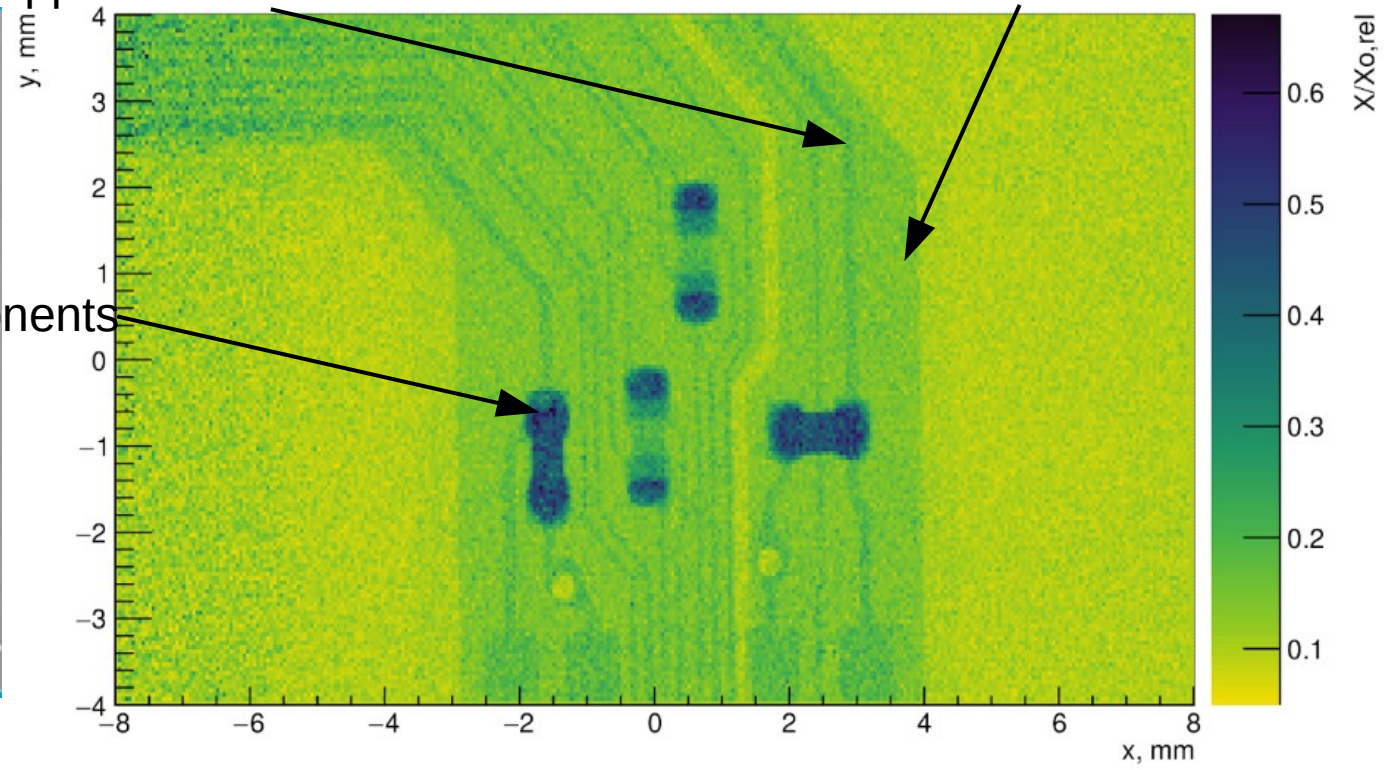
The materials in question are the following:

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



Copper traces

Components

Grounding plane