AIDA-2020-SLIDE-2019-007

AIDA-2020

Advanced European Infrastructures for Detectors at Accelerators

Presentation

Lycoris: Large Area Telescope

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23 October 2018

The AIDA-2020 Advanced European Infrastructures for Detectors at Accelerators project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement no. 654168.

This work is part of AIDA-2020 Work Package **15: Upgrade of beam and irradiation test infrastructure**.

Lycoris: Large Area Telescope

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

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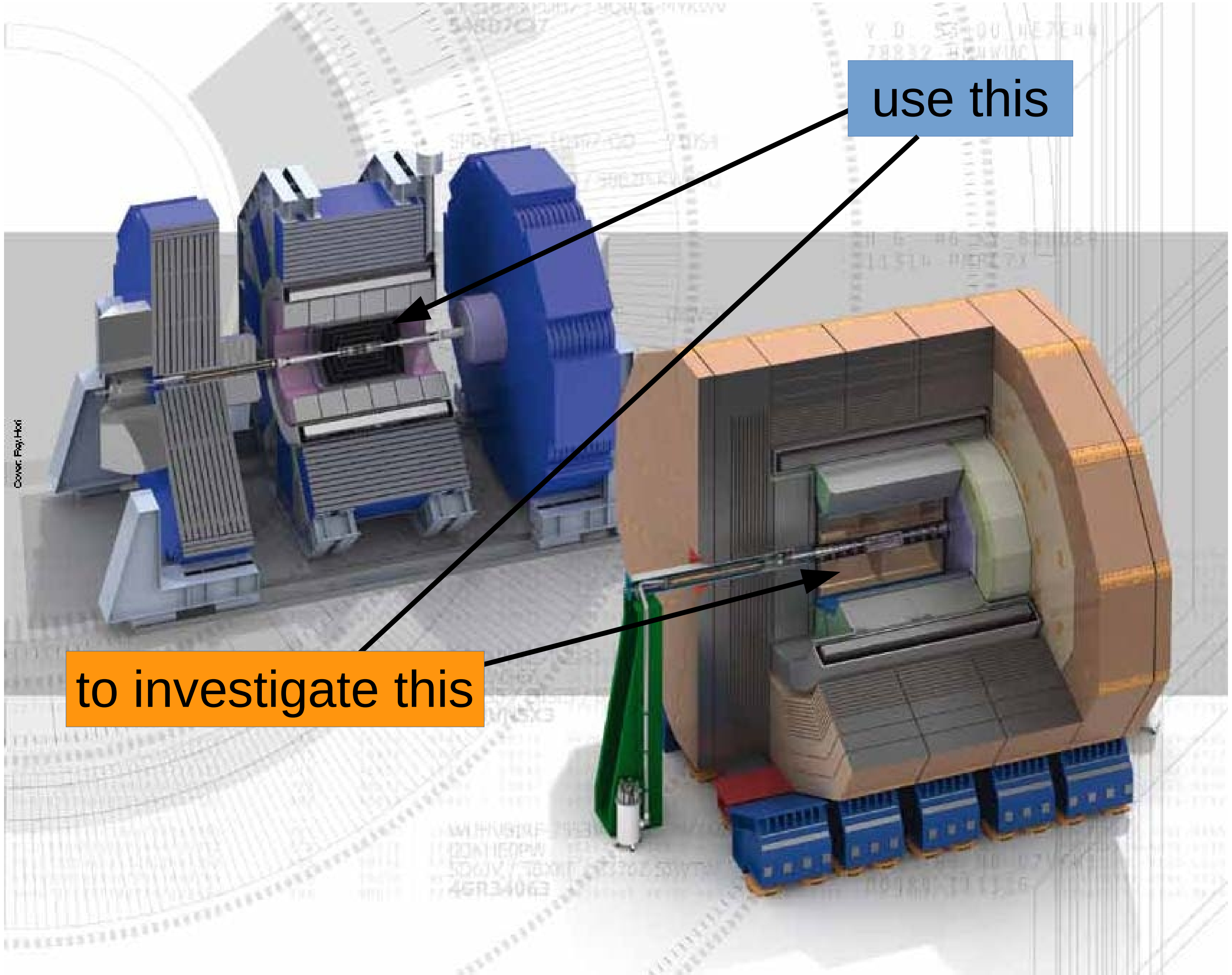
in Collaboration with, M. Breidenbach, D. R. Freytag, B. A. Reese and R. Herbst from SLAC

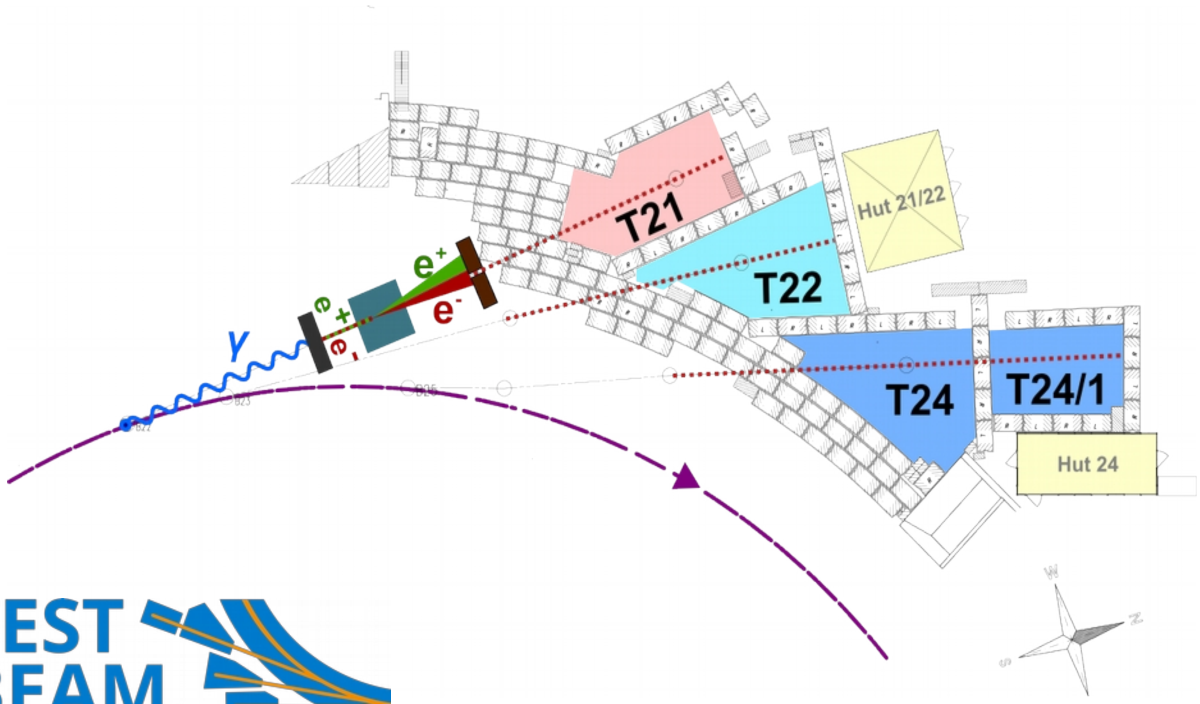
LCWS 2018, 23rd of October 2018

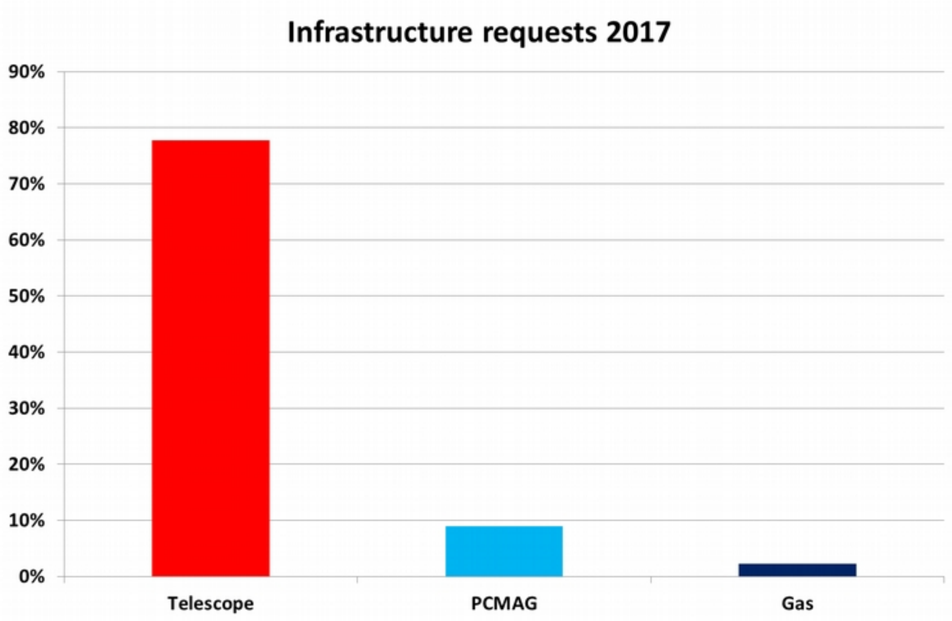
The LYCORIS Project In the Context of ILC



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

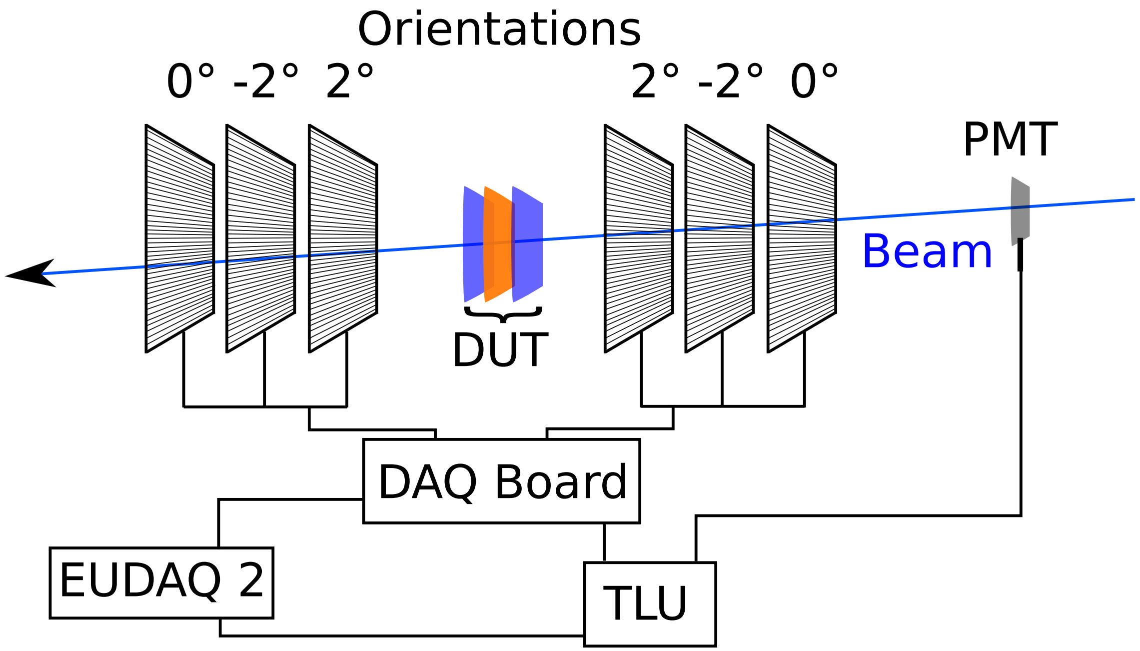


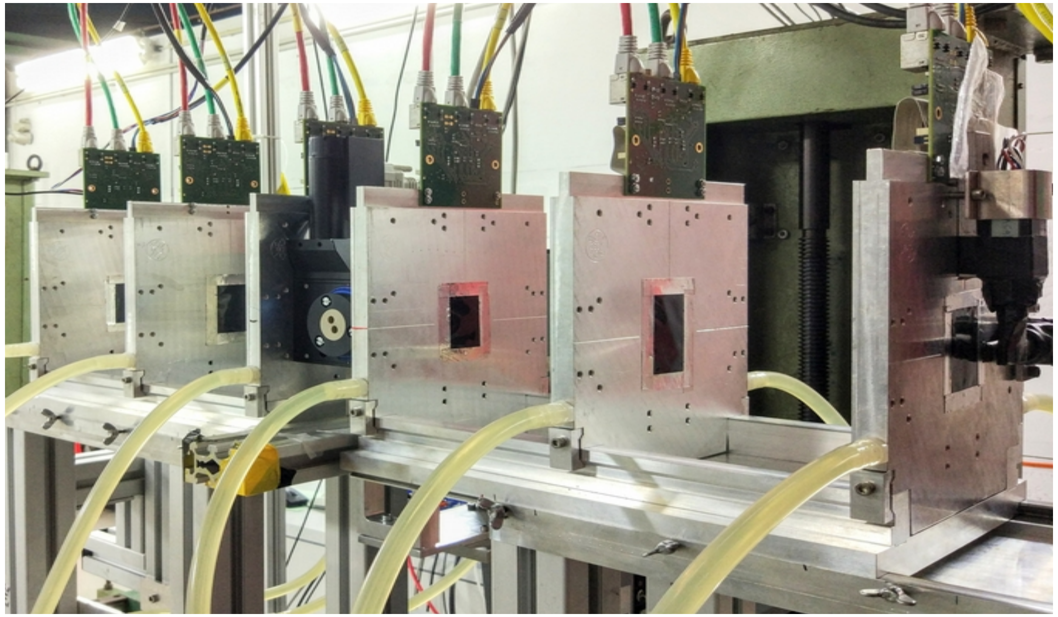


Silicon Telescopes

- 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

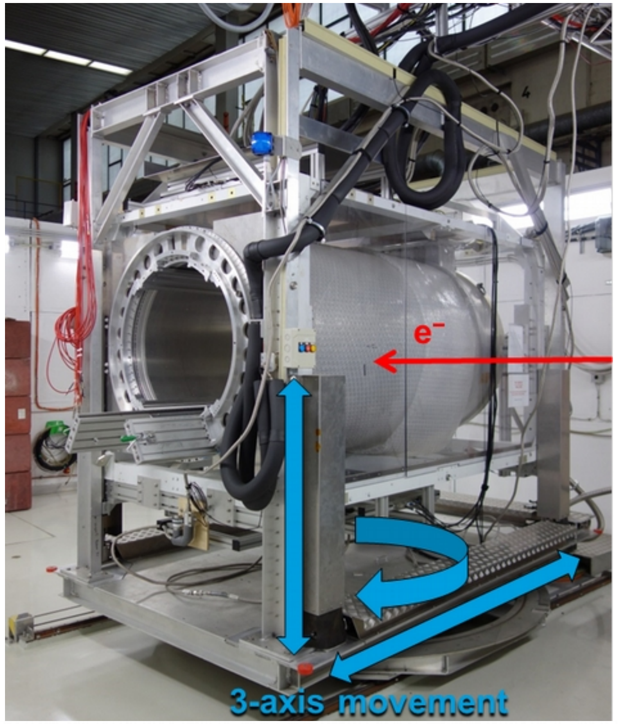




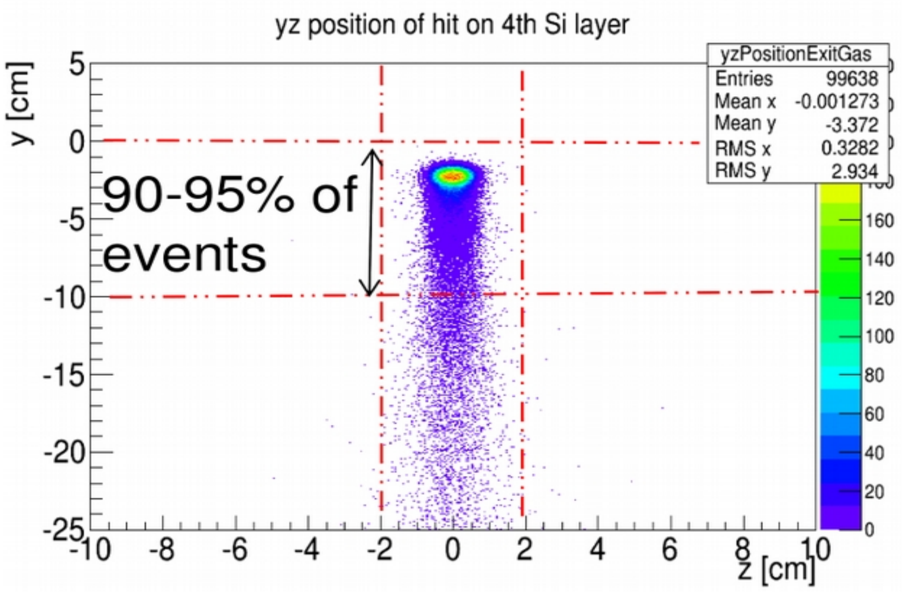
The Lycoris Telescope

An AIDA[2020] project

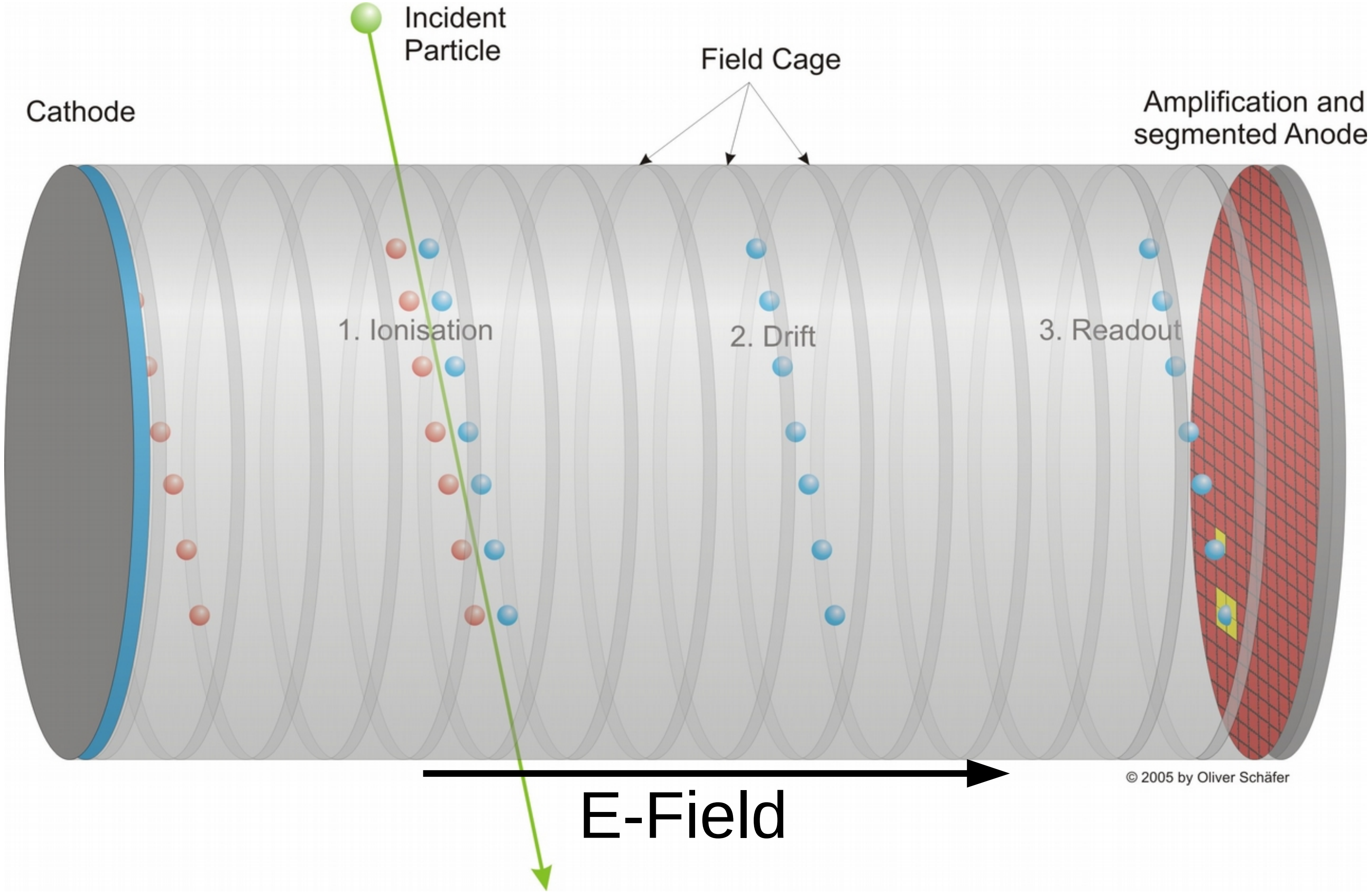
- A new large area strip telescope within the Test Beam Area 24/1 solenoid
- The solenoid has:
  - ~75 cm usable inner diameter
  - Wall thickness of 20% X_0
  - Mounted on a stage to be able to move/rotate along 3 axes
  - Magnetic field strength of up to 1T



- 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

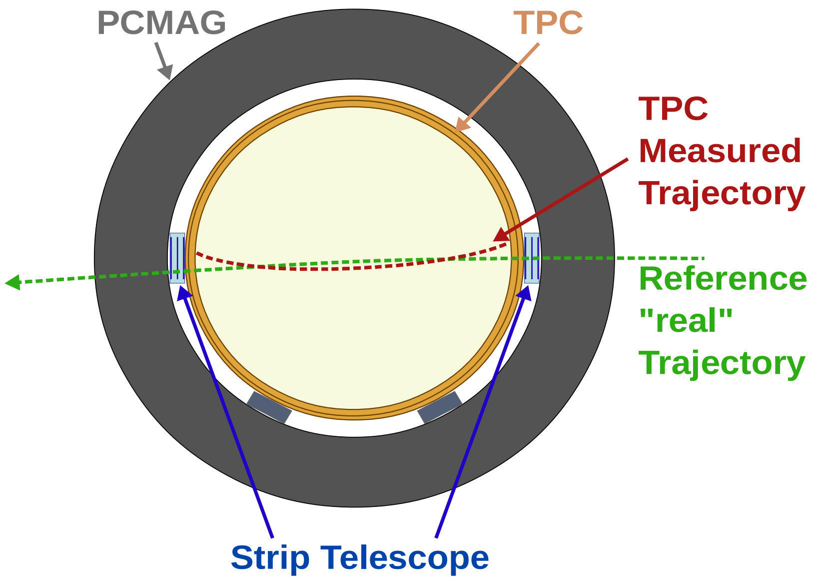


The TPC Use Case

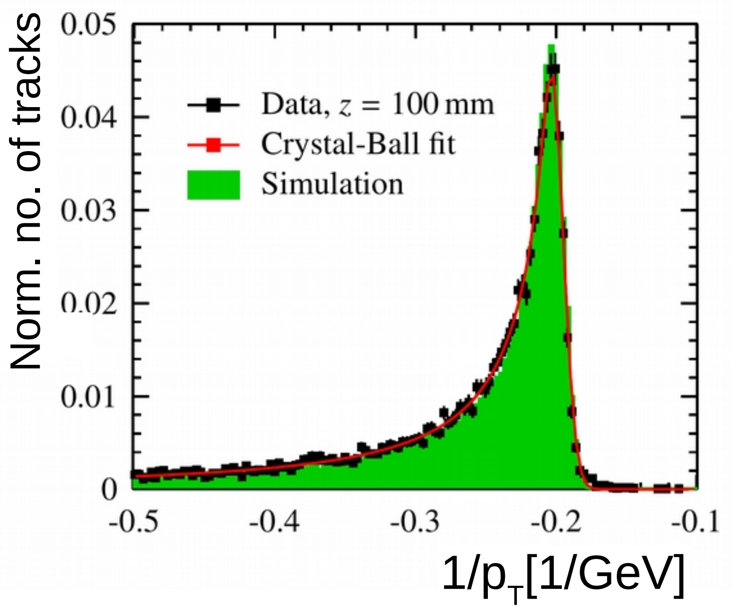


The TPC Use Case

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



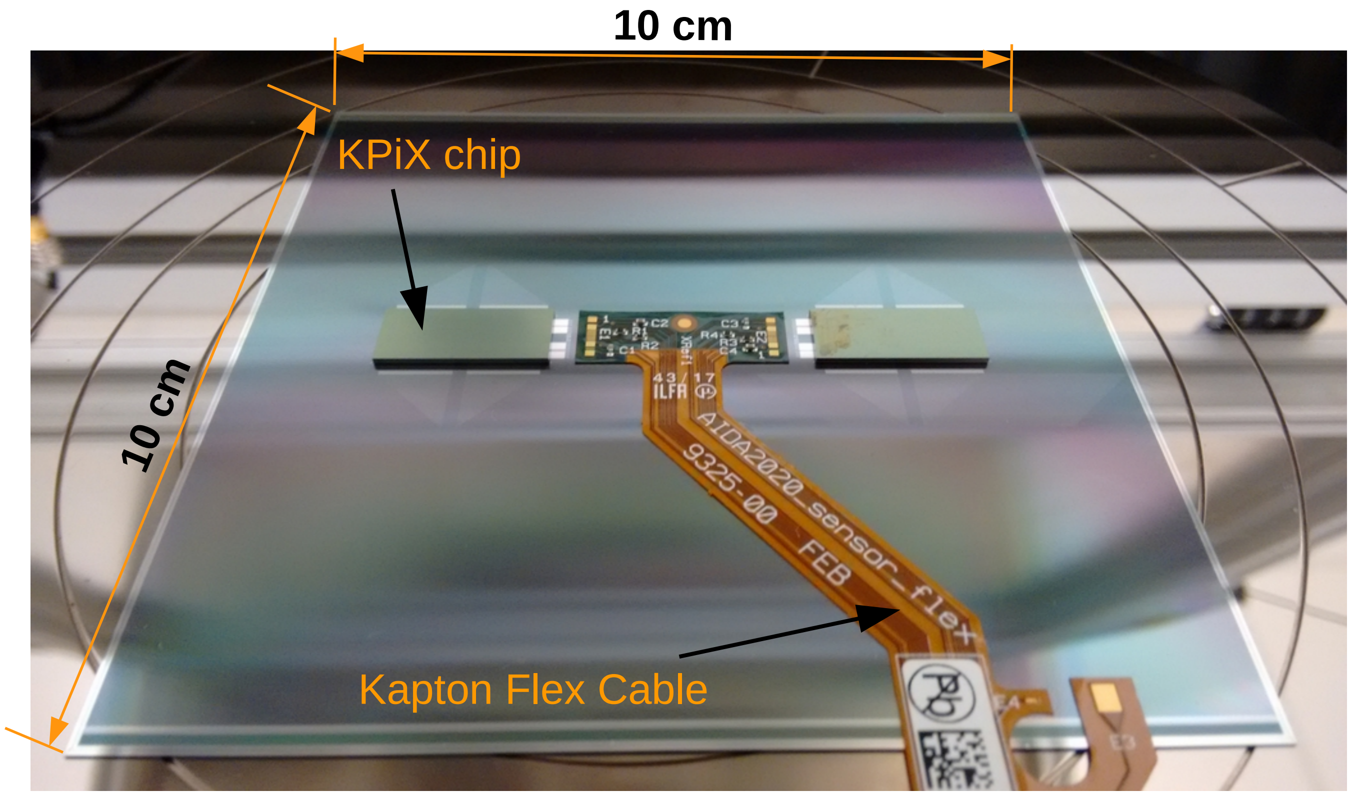
- **<u>Challenge:</u>** Smearing of particle momentum as a result of interactions with the magnet wall
- **<u>Solution:</u>** Accurate measurement of the momentum after magnet wall



The SiD Silicon Strip Sensor

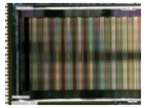
Hybrid-Less silicon strip sensor designed by SLAC NATIONAL ACCELERATOR LABORATORY for the ILC :

- 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

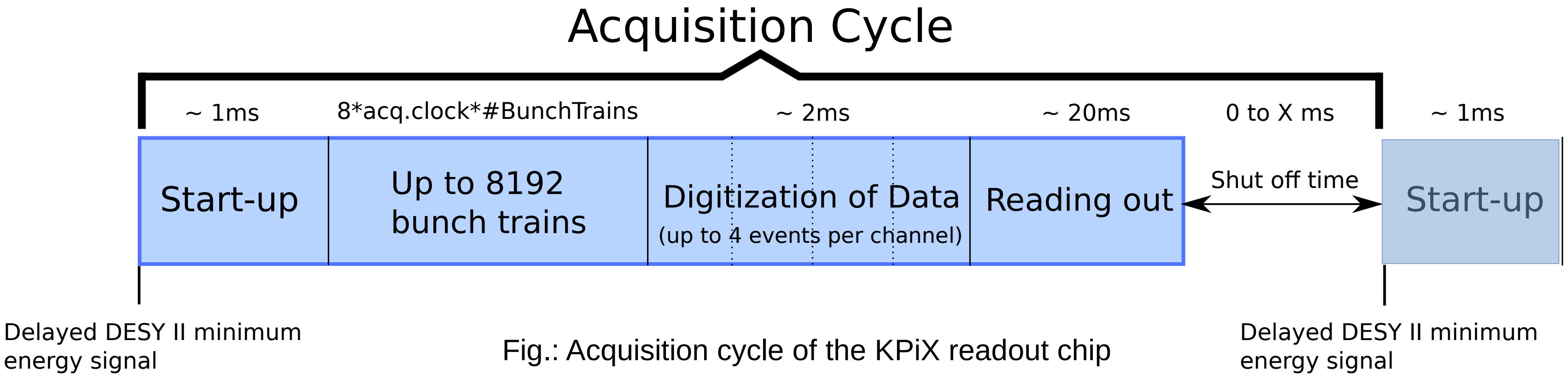
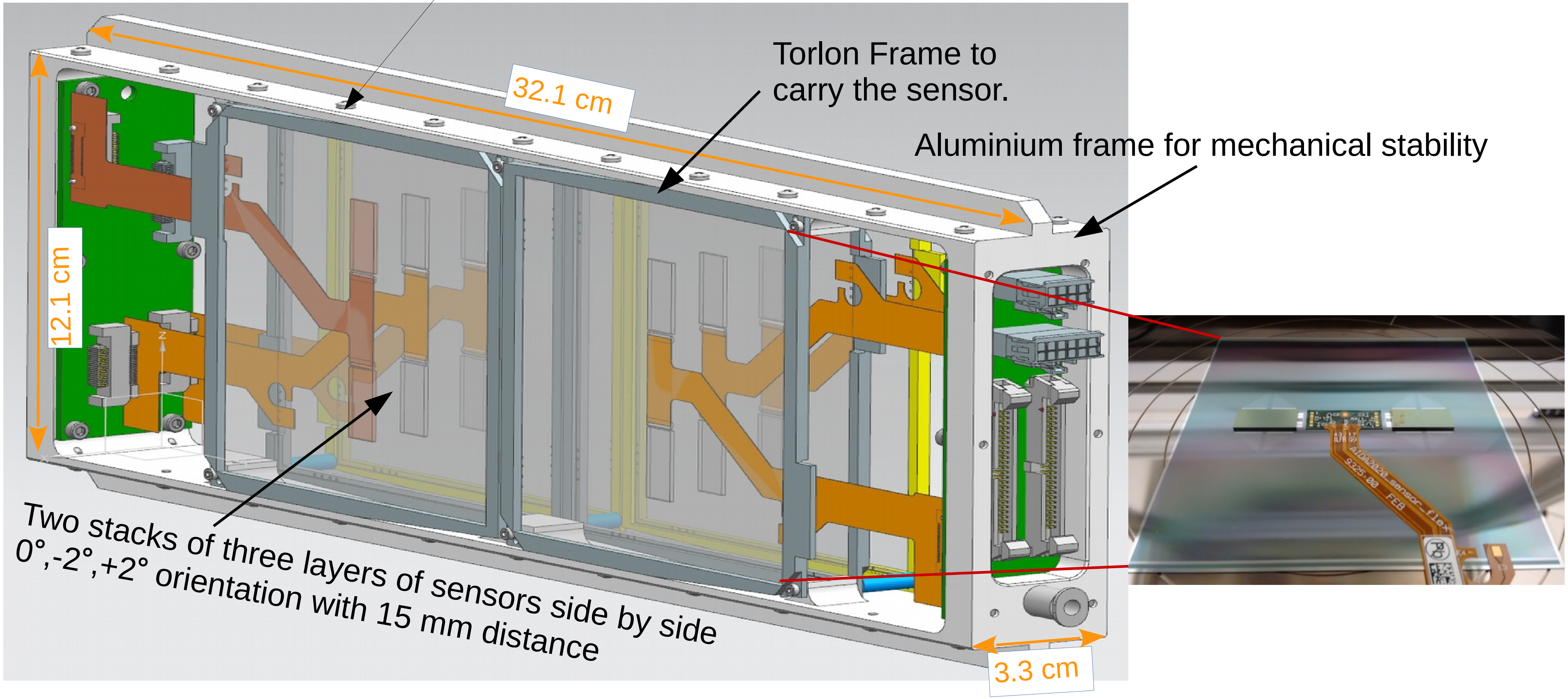


Fig.: Acquisition cycle of the KPiX readout chip

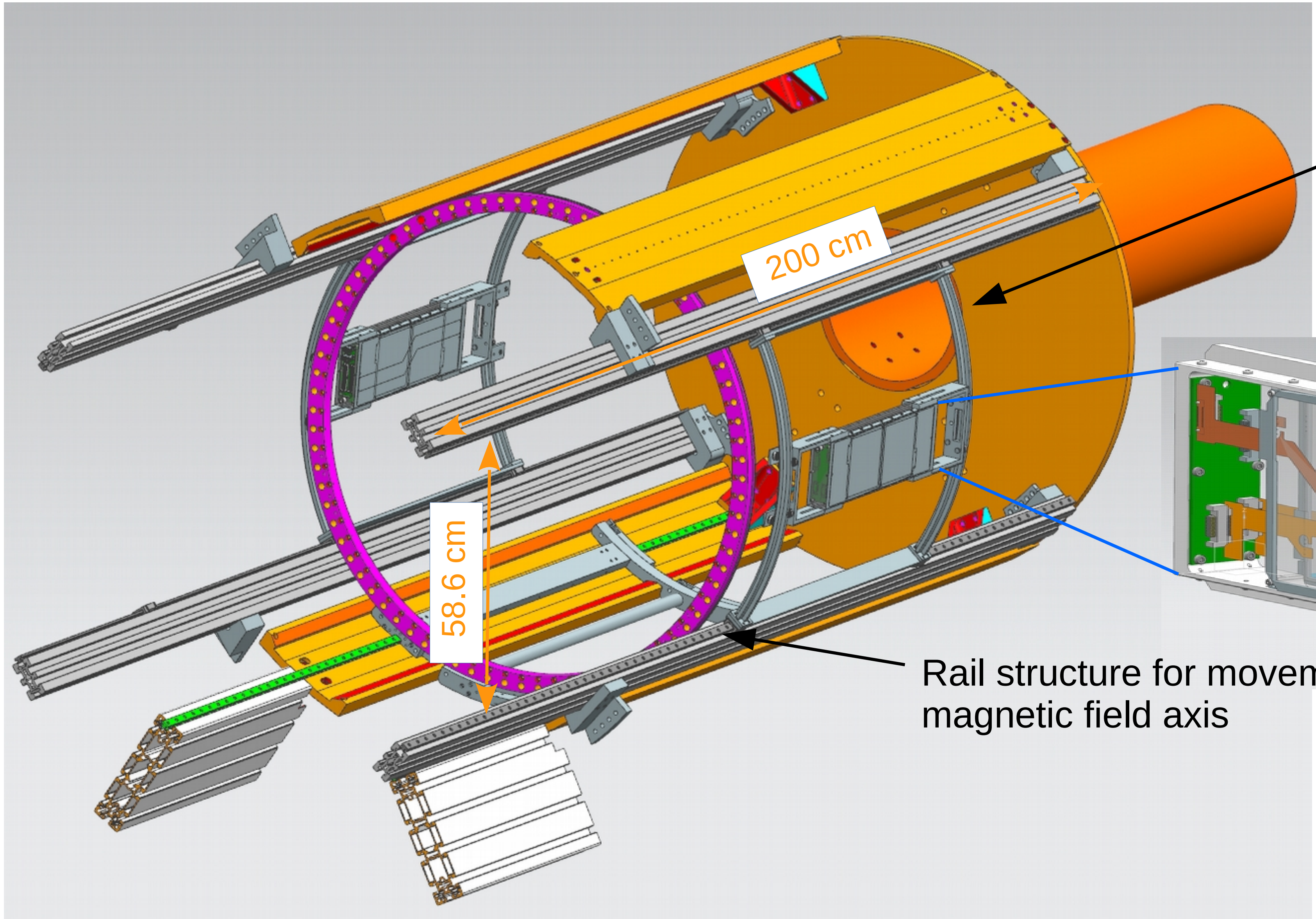
- Only open for a maximum time of 8192*8*acq.clock
  →For example with a 320 ns acq.clock = 20.97 ms

The Final System: The Cassette



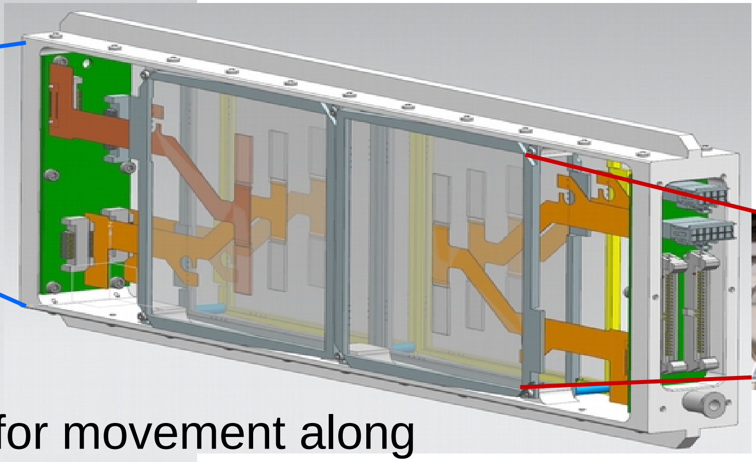
Final system has an active area of 10x20 cm²

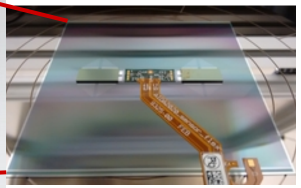
The Final System: The rail system



Rail structure for movement along magnet angle

Rail structure for movement along magnetic field axis

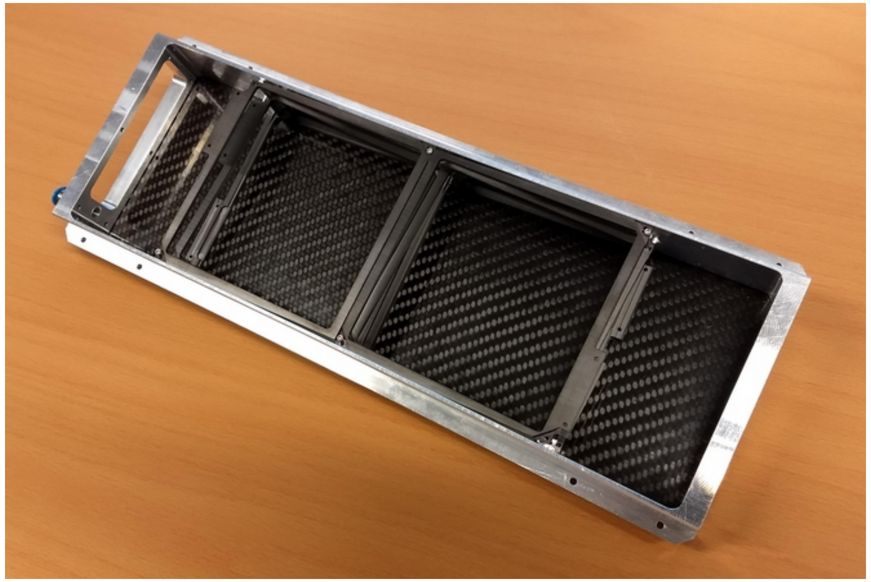


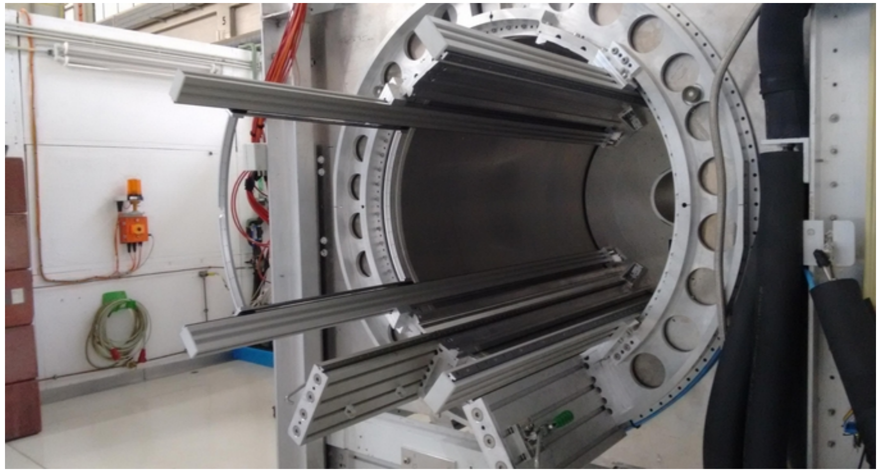


System Status: Mechanics

- 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.

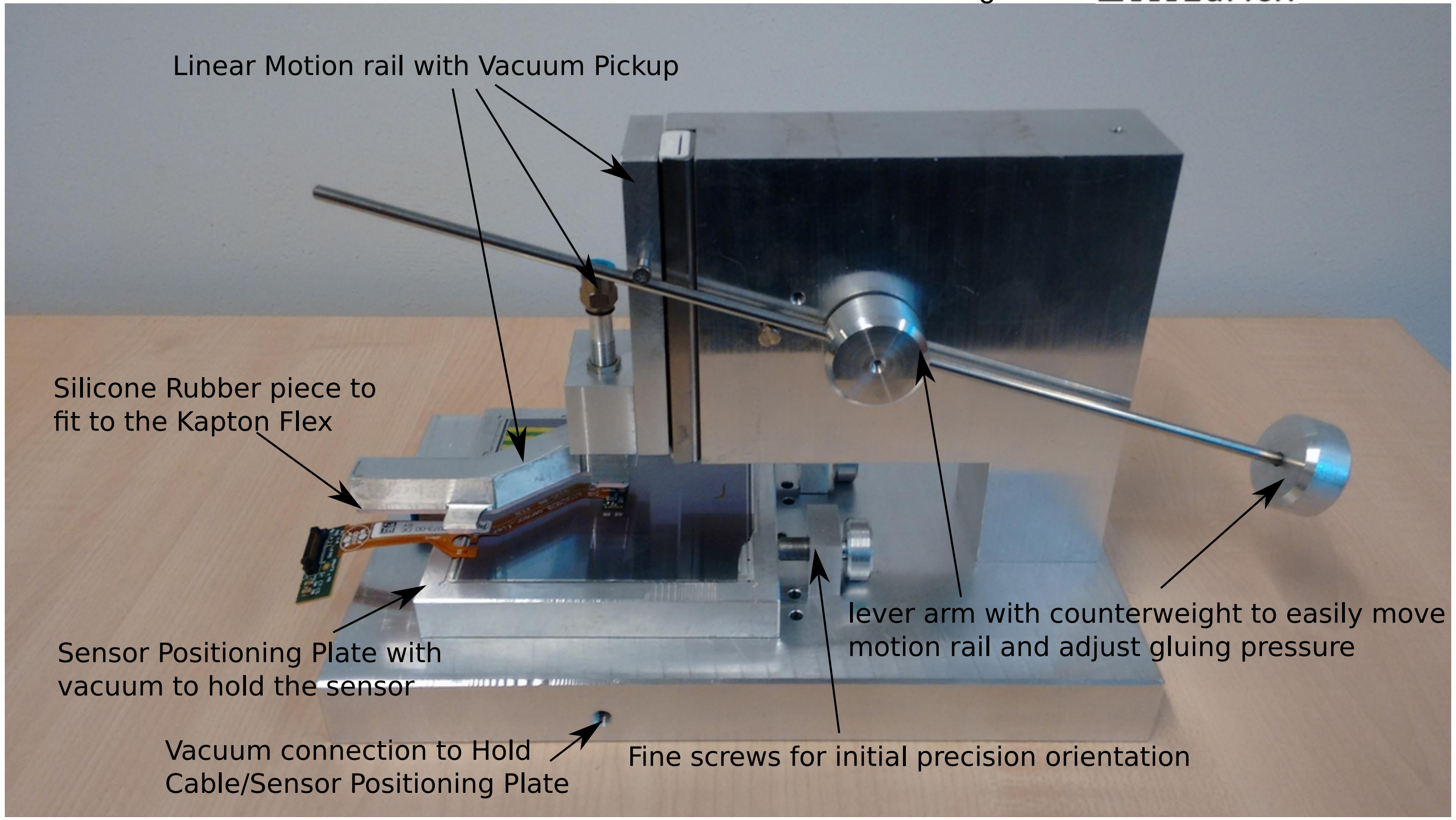




System Status: Mechanics

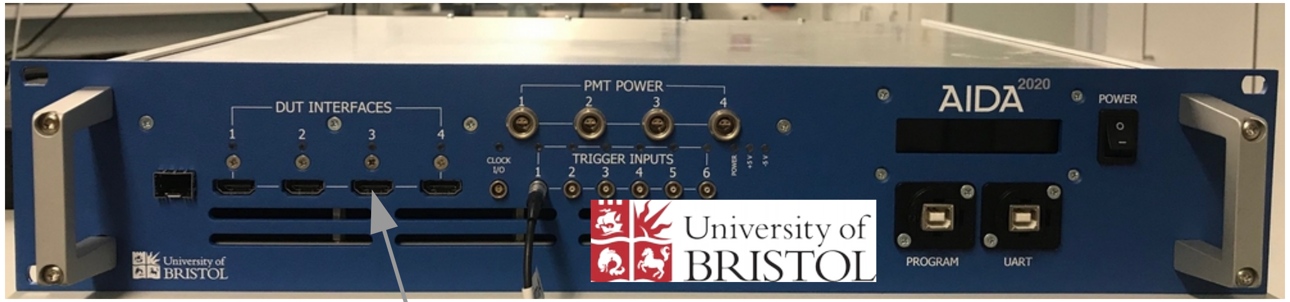
- After first manual assemblies, a new tool was designed and built to provide reproducible results through:
  - Controlled glue application
  - Fine adjustable gluing pressure
  - Precise cable positioning
- Able to be used for further assembly of sensors into Torlon frames

Based on a design from ETH zürich



First assembly with new tool expected to start next week.

System Status: Electronics

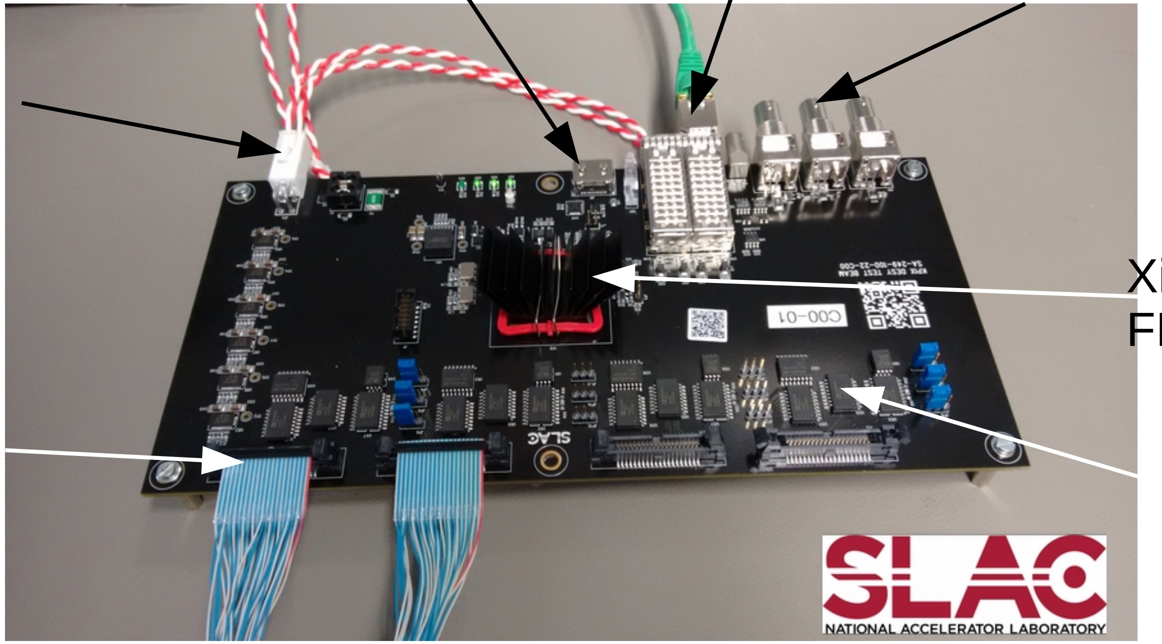


HDMI connector to AIDA TLU

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

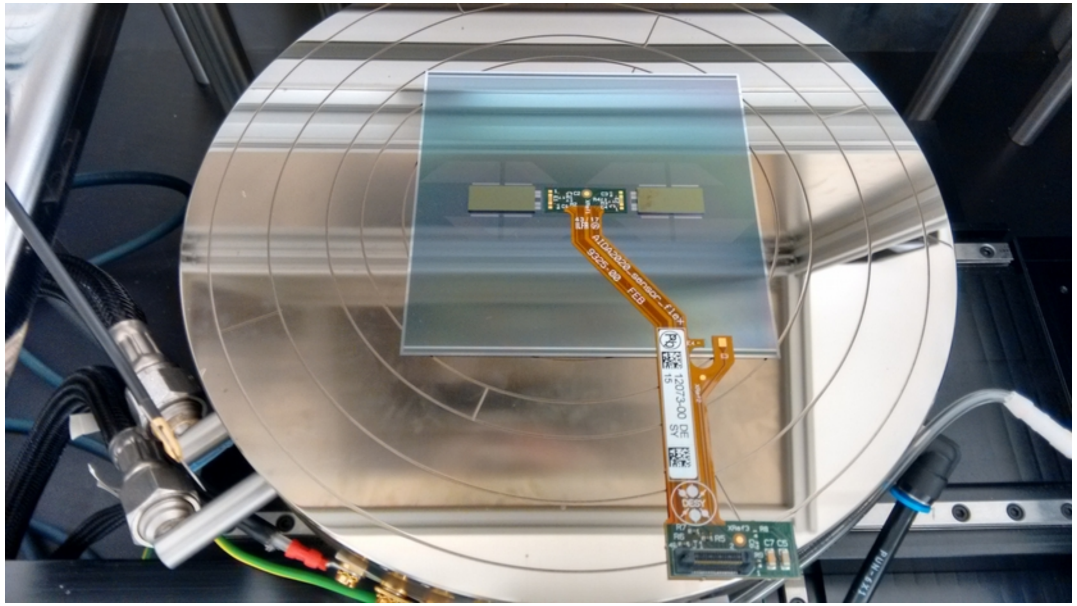
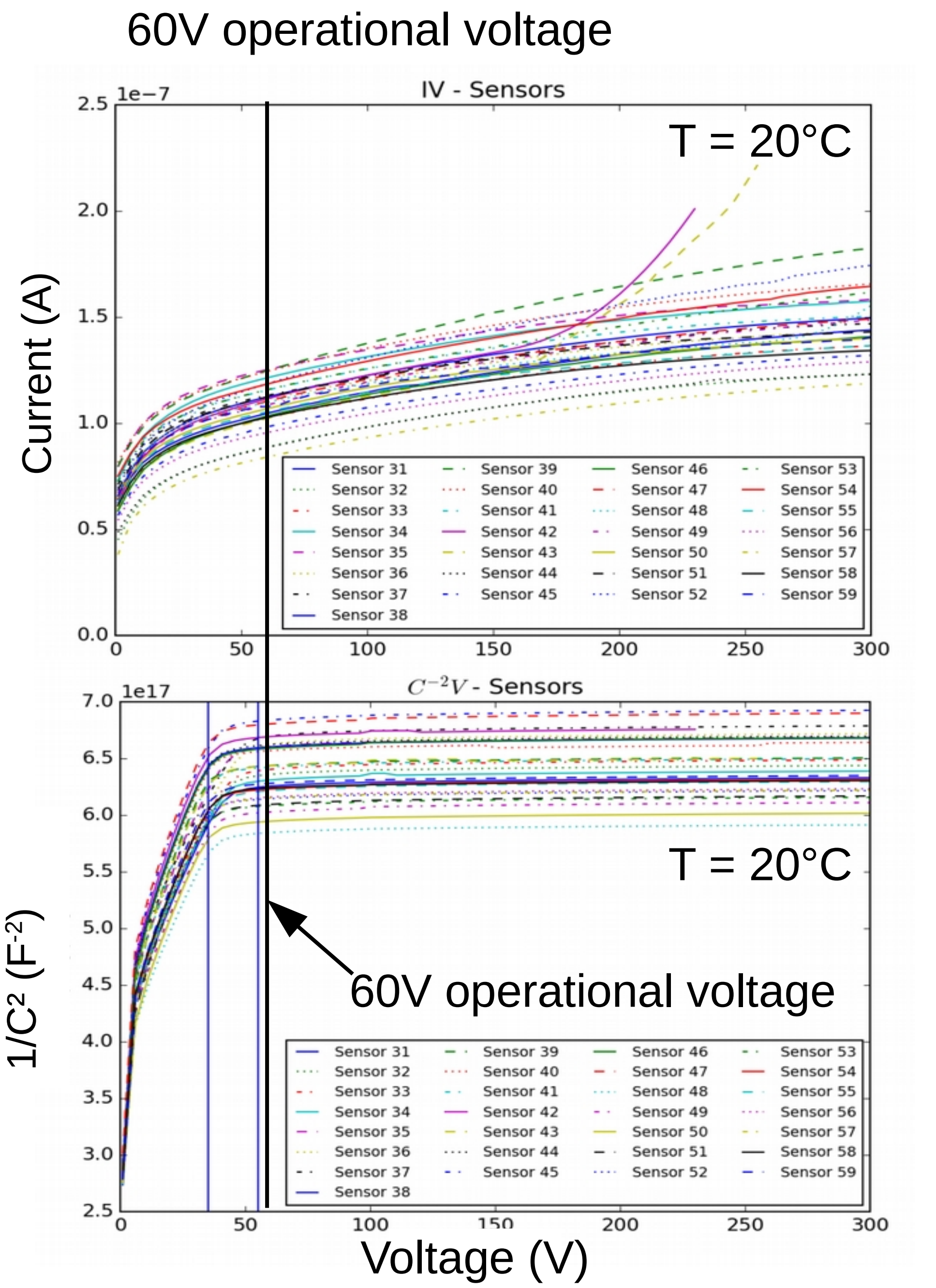
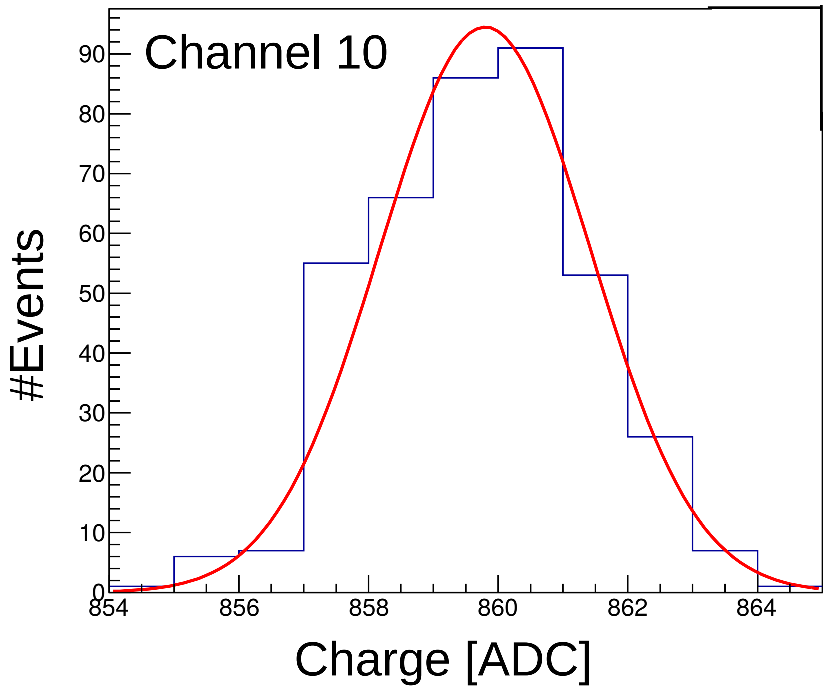


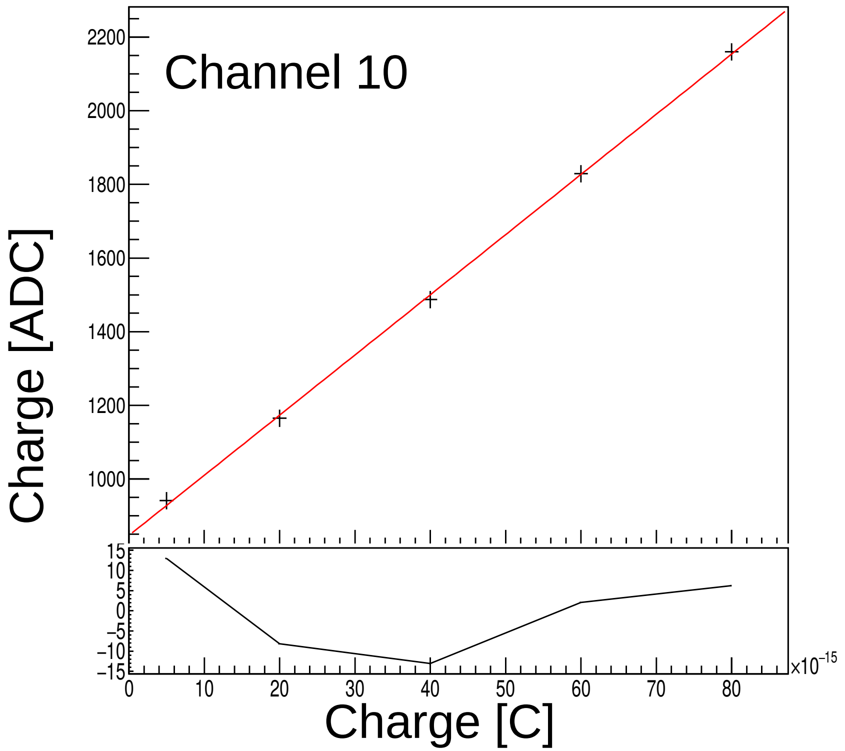
Fig.: Bump Bonded Sensor with flex cable on the probe station



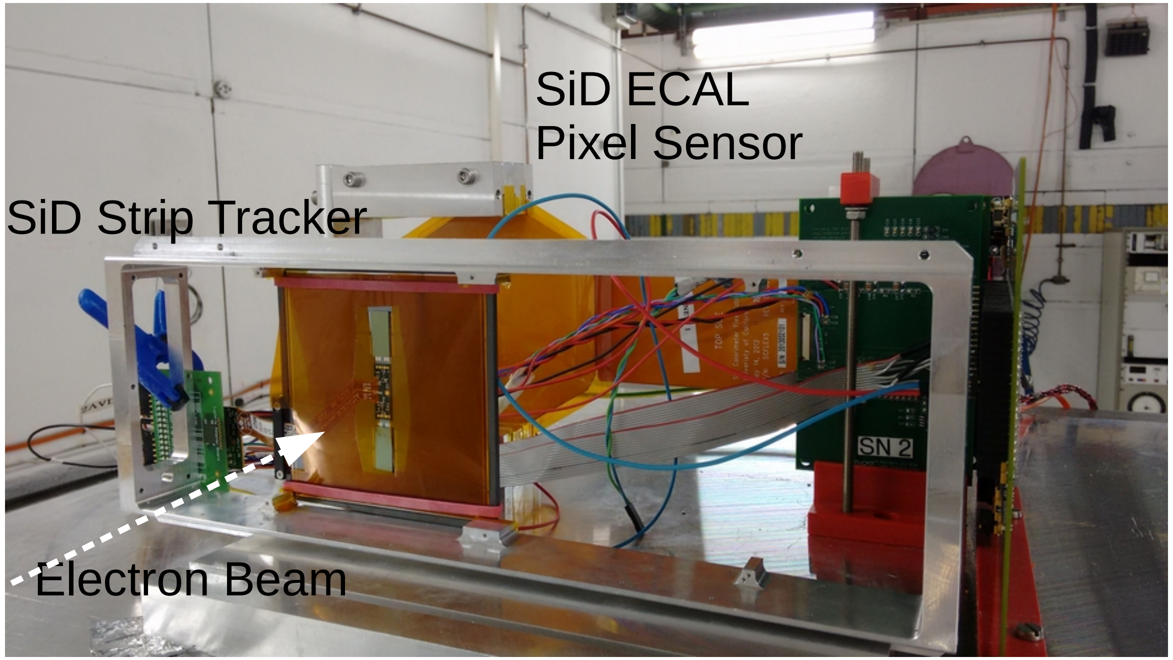
System Status: Sensors

- 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**

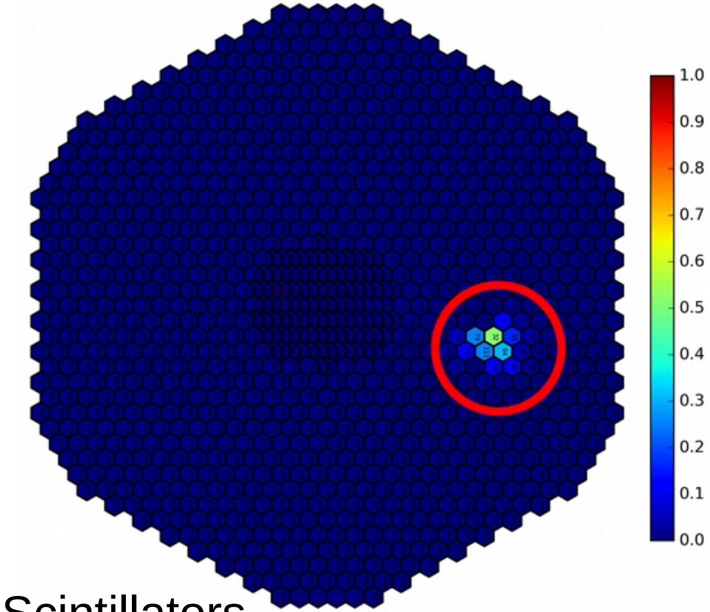


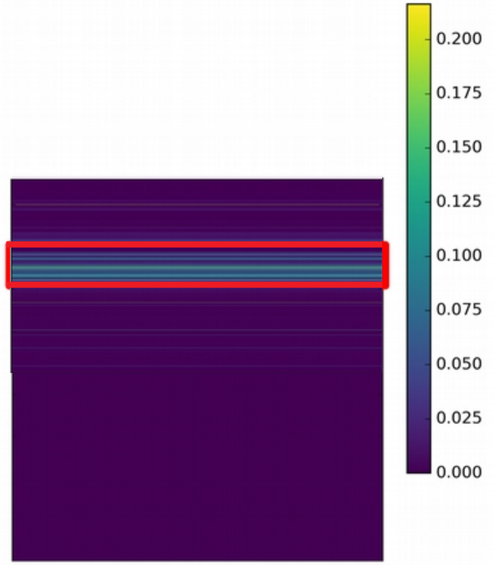


System Status: Sensors



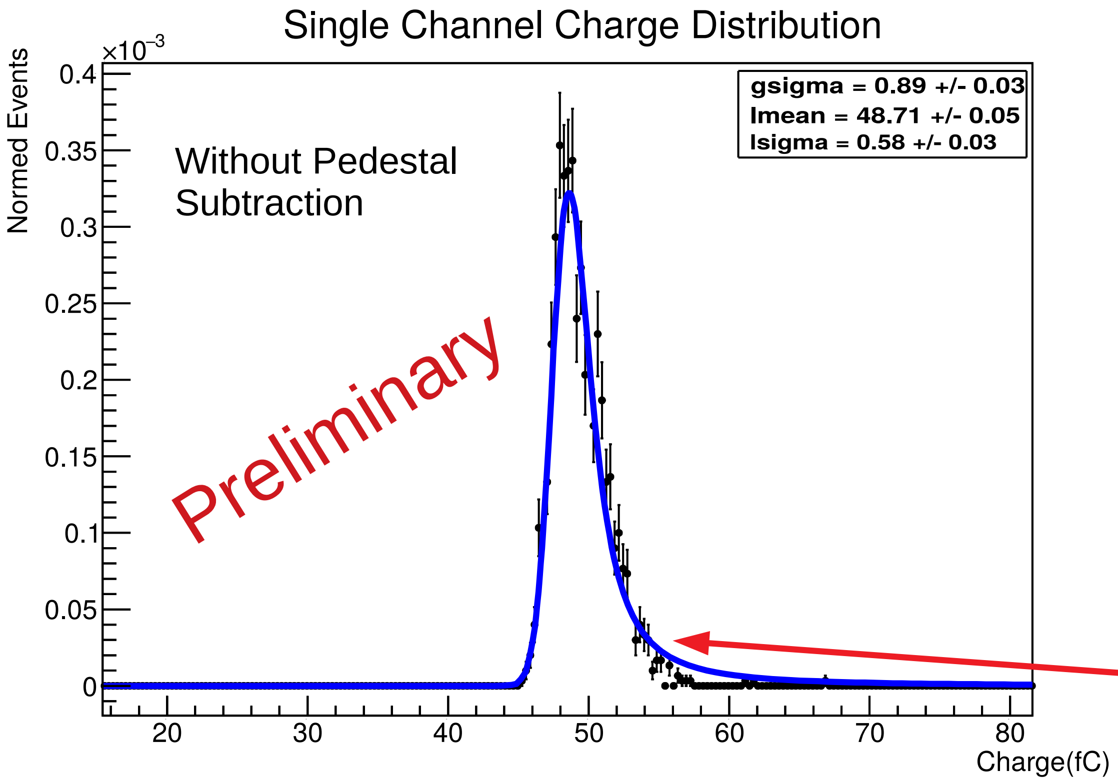
- Recently completed first Testbeam with the new tracker sensor
- ~ 2 Million Events recorded, split between different running modes.
- Test of both internal triggering and external triggering functionality.





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

System Status: Sensors



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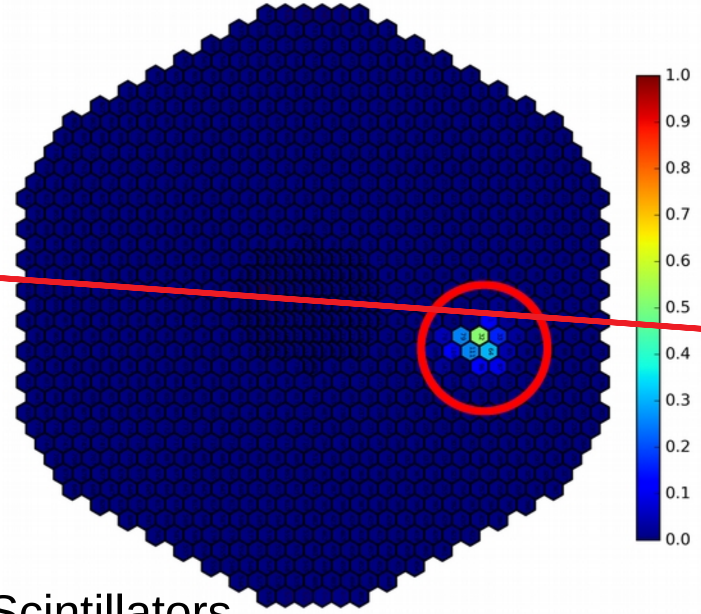
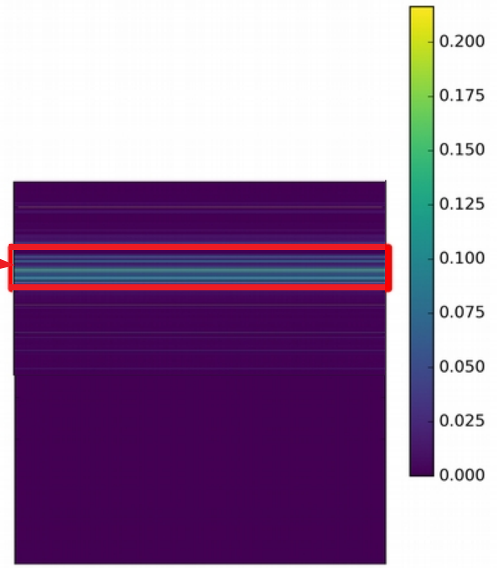




- Full coincidence:
  - SiD Strip Tracker ↔ SiD ECAL Pixel Sensor ↔ Beam Scintillators.

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

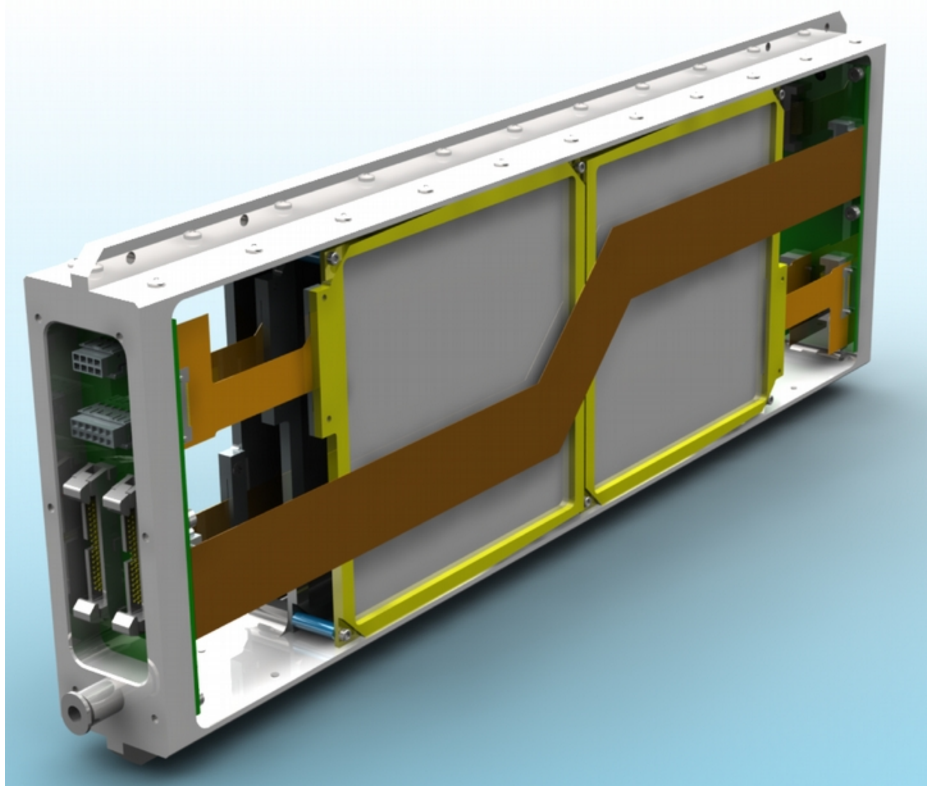


Fig.: LYCORIS Tēlescopia

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

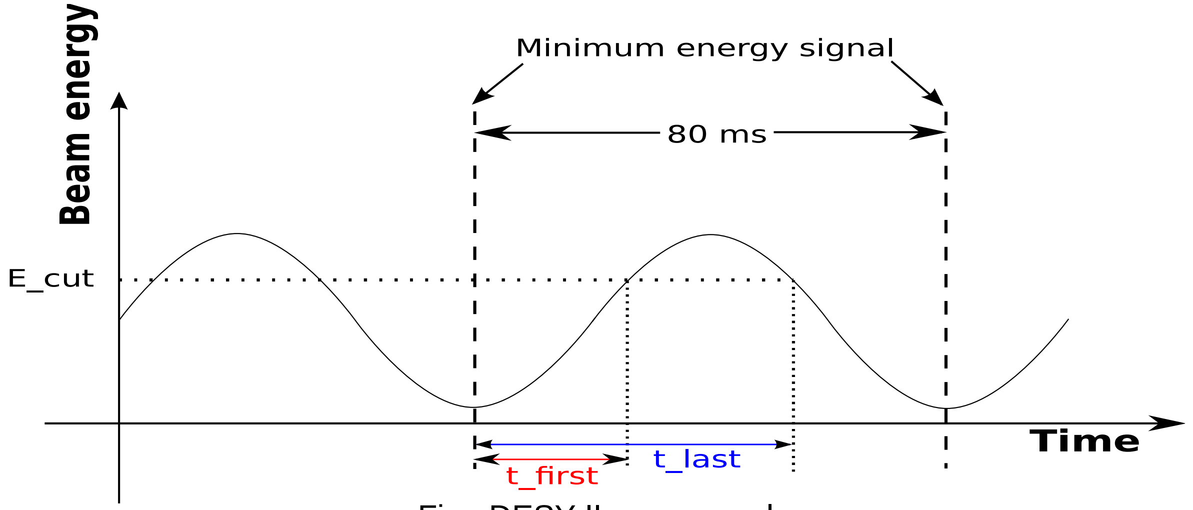


Fig.: DESY II energy cycle

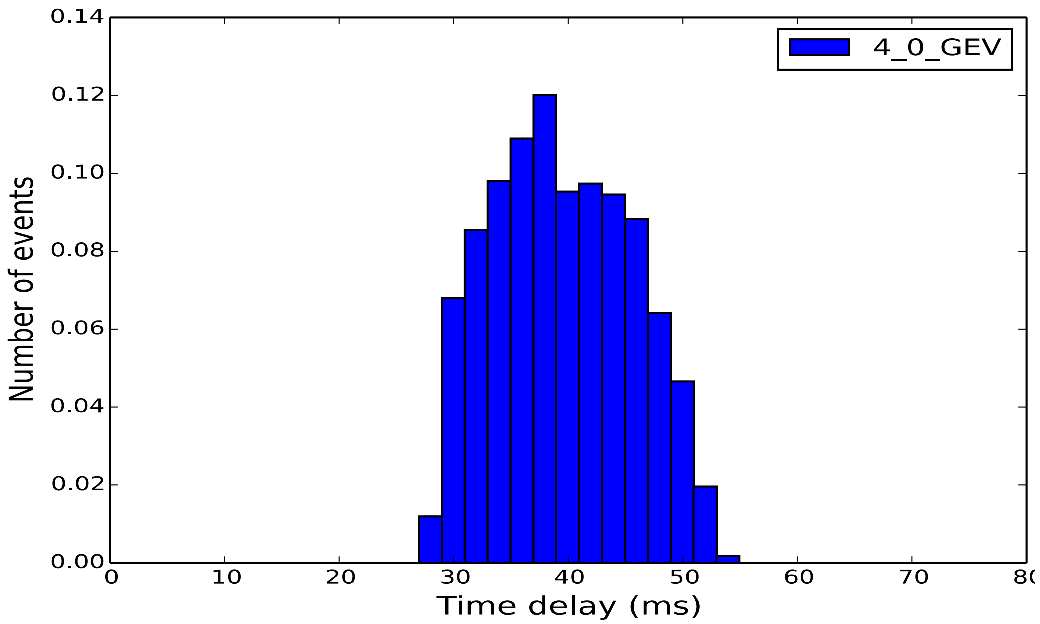


Fig.: Time difference from min. energy to trigger signal

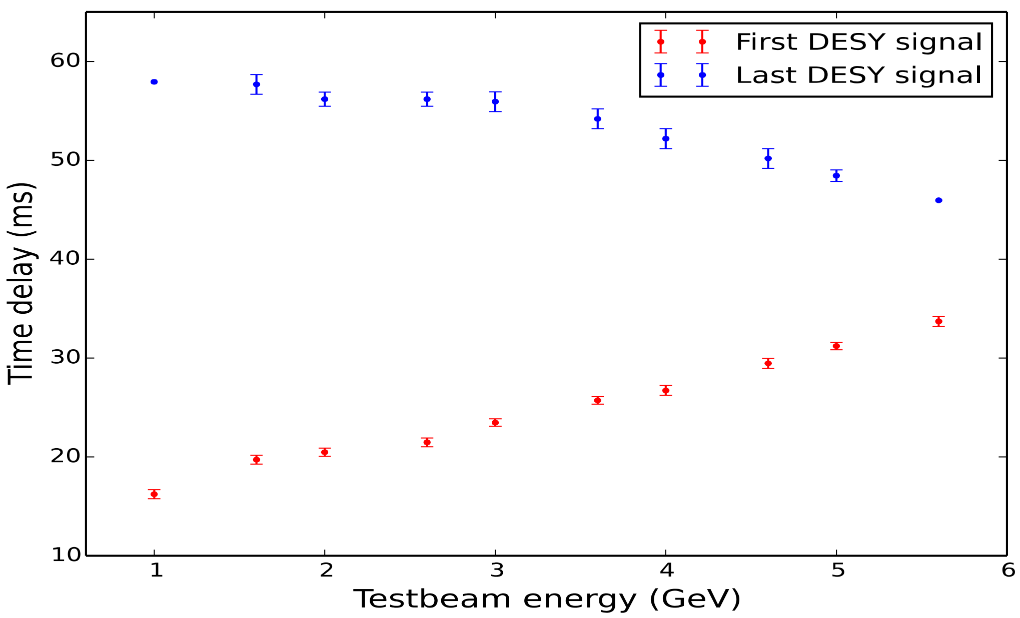
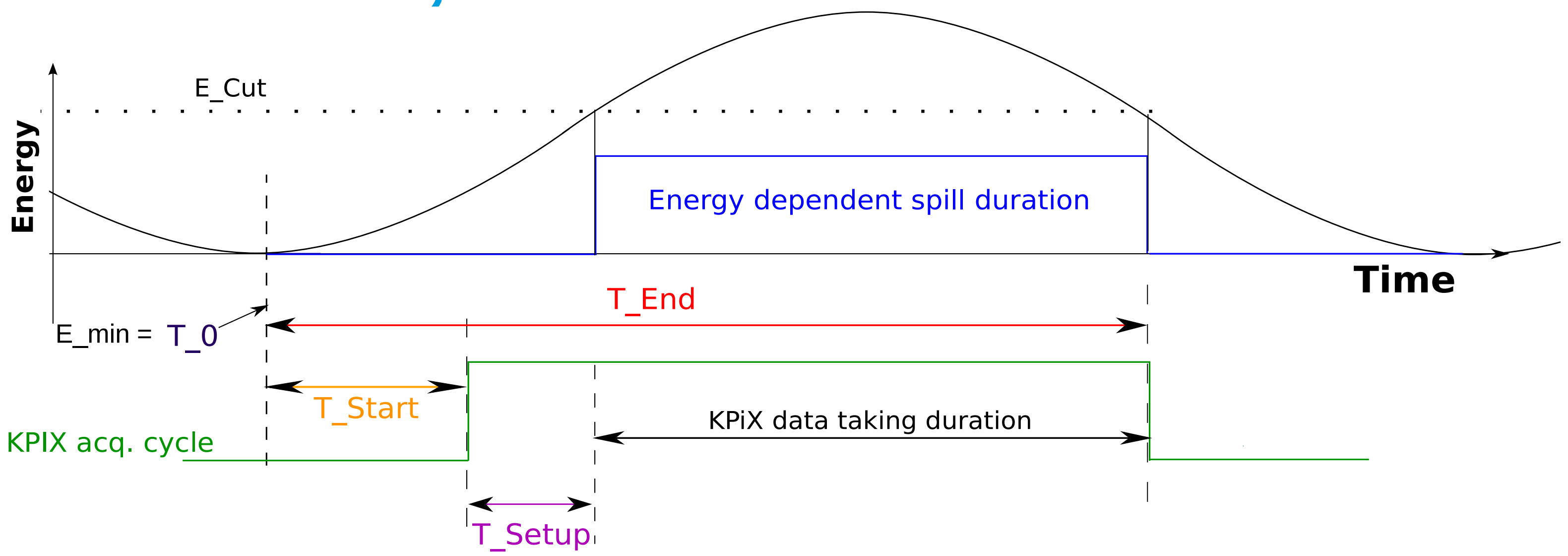


Fig.: First and last DESY signal in a cycle for different energies

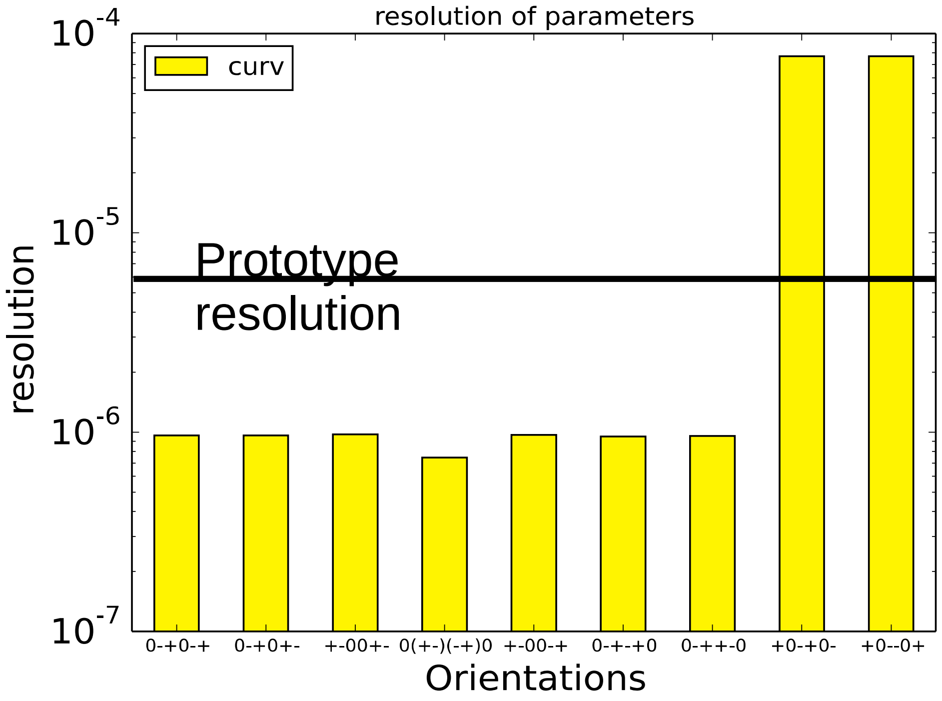
KPiX synchronisation, DUT and Beam

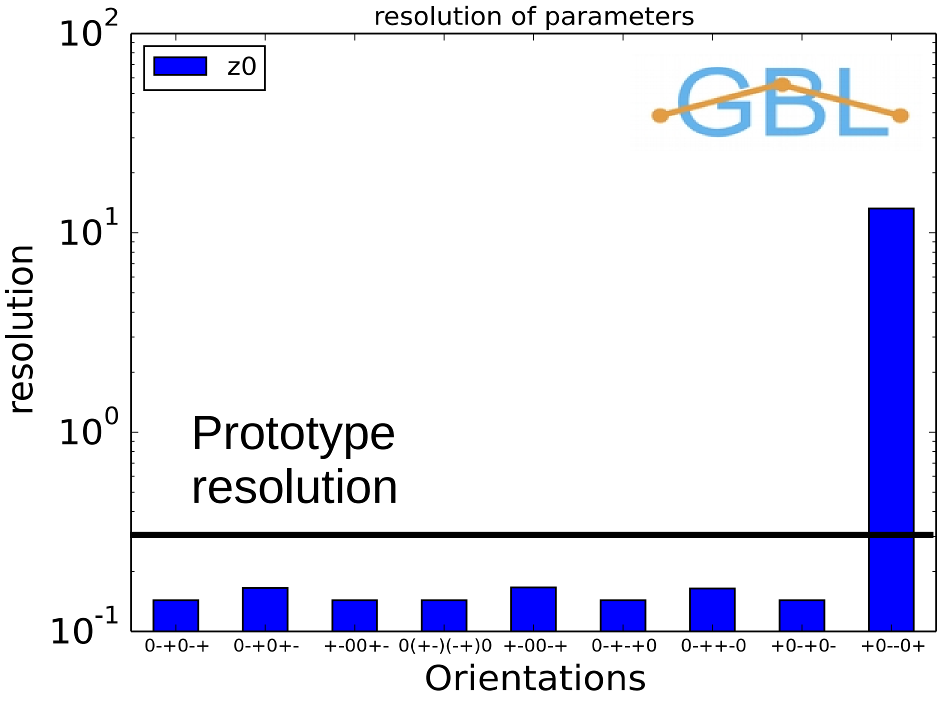


- KpiX needs to be synchronised to beam spill of the acceleerator and the DUT
  - T_0: Accelerator signal for synchronisation with beam spiull
  - T_Start: User adjustable delay between T_0 and KpiX switch on.
  - T_Setup: Setup time of KpiX. At the end of which KpiX can start the data taking
  - T_End: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

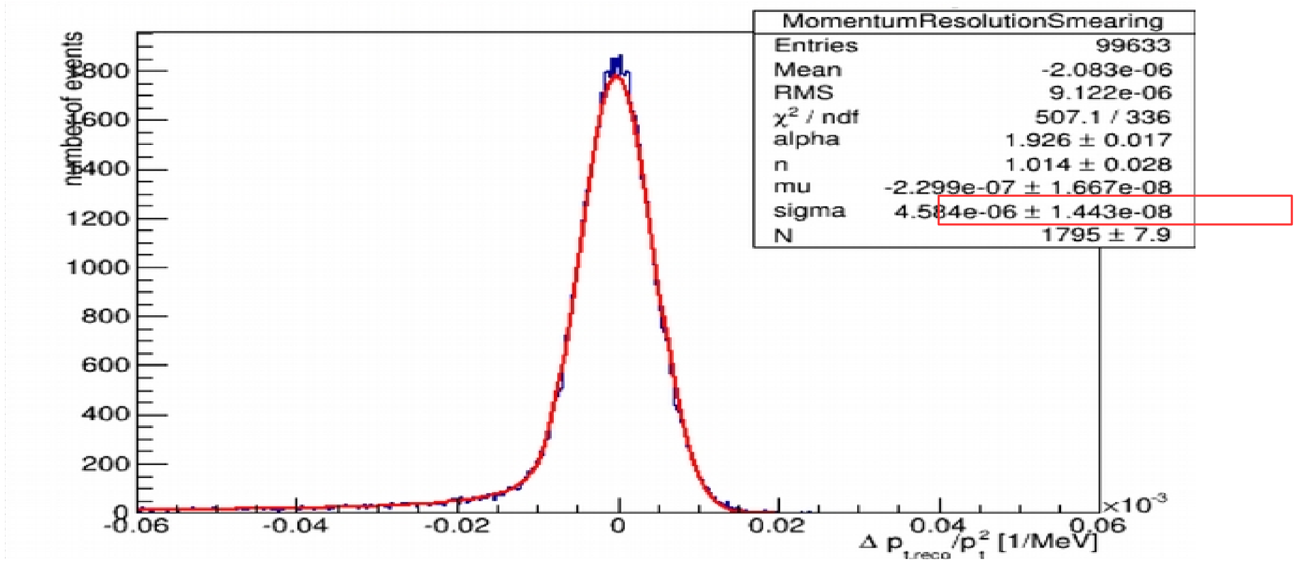


Fig.: Simulated TPC momentum resolution

- 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})

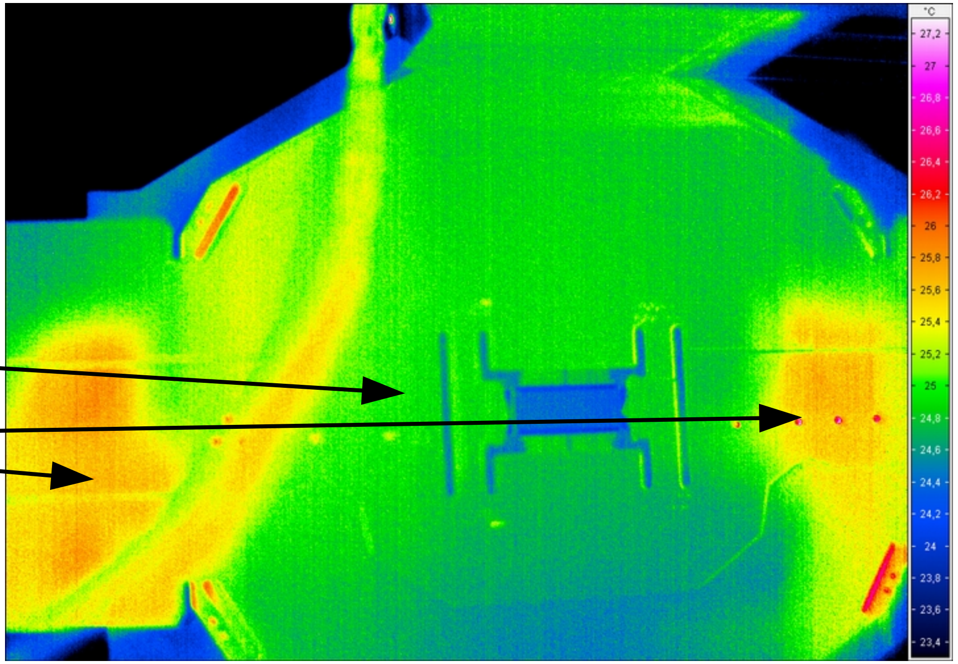
		Distance between inner and outer Si layer			
		4 cm	3 cm	2 cm	1 cm
Sensor spatial resolution	2.5 μm	2.85	2.90	3.00	3.68
	5 μm	3.05	3.21	3.63	5.52
	7.5 μm	3.37	3.65	4.43	7.92
	10 μm	3.68	4.16	5.33	9.90
	15 μm	4.49	5.36	7.53	14.3

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

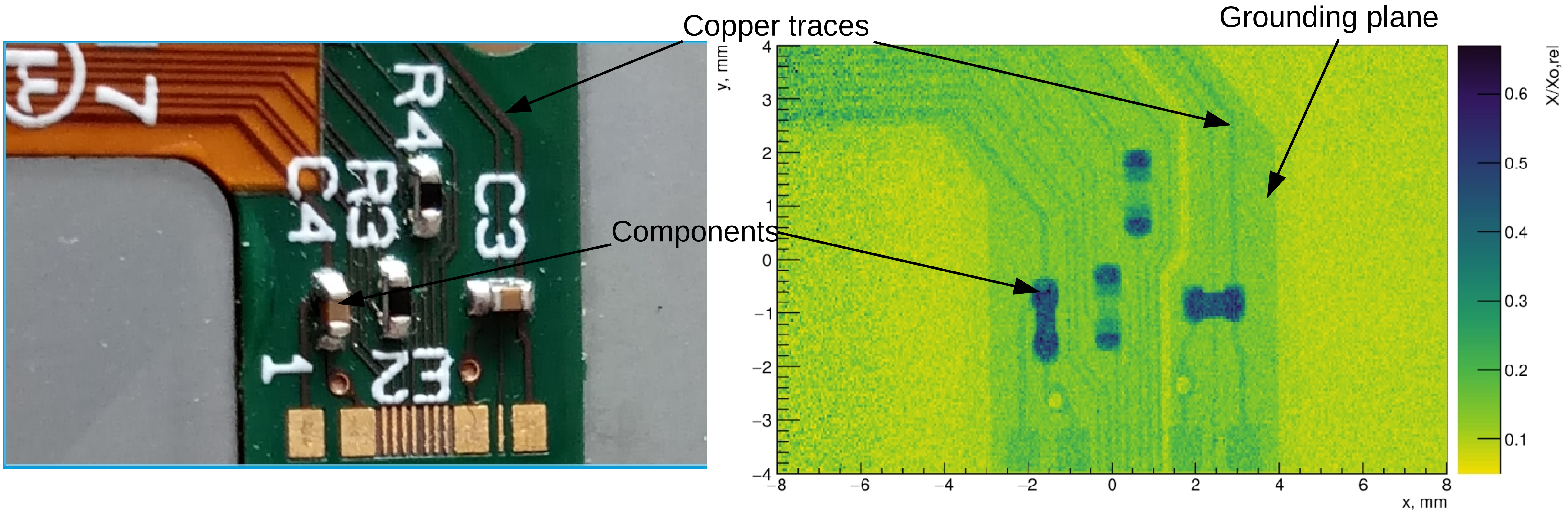
Radiation Length

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%

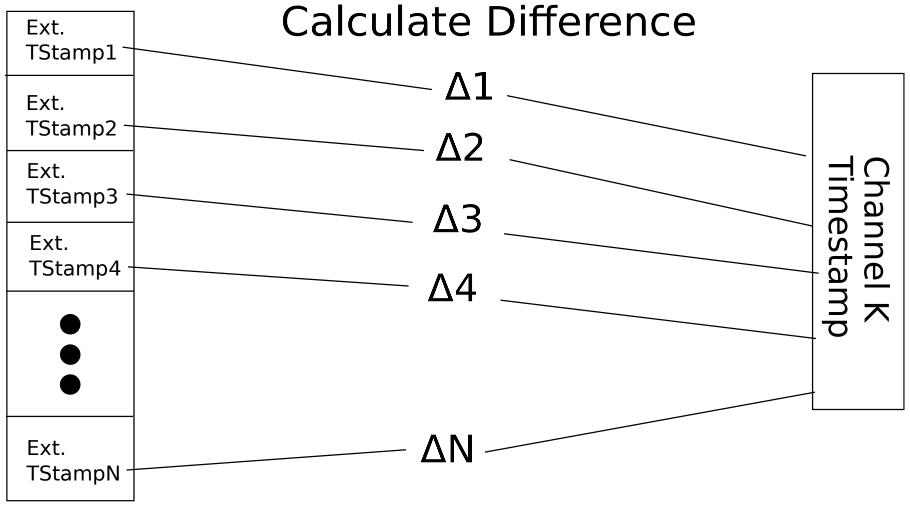
The materials in question are the following:

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



Time Coincidence



$\Delta 4 < \Delta 3 < \Delta 2 < \Delta 1 < .... < \Delta N$

$\Rightarrow \Delta 4$ = Time difference for channel K