LYCORIS: A large area strip telescope for the DESY Test Beam

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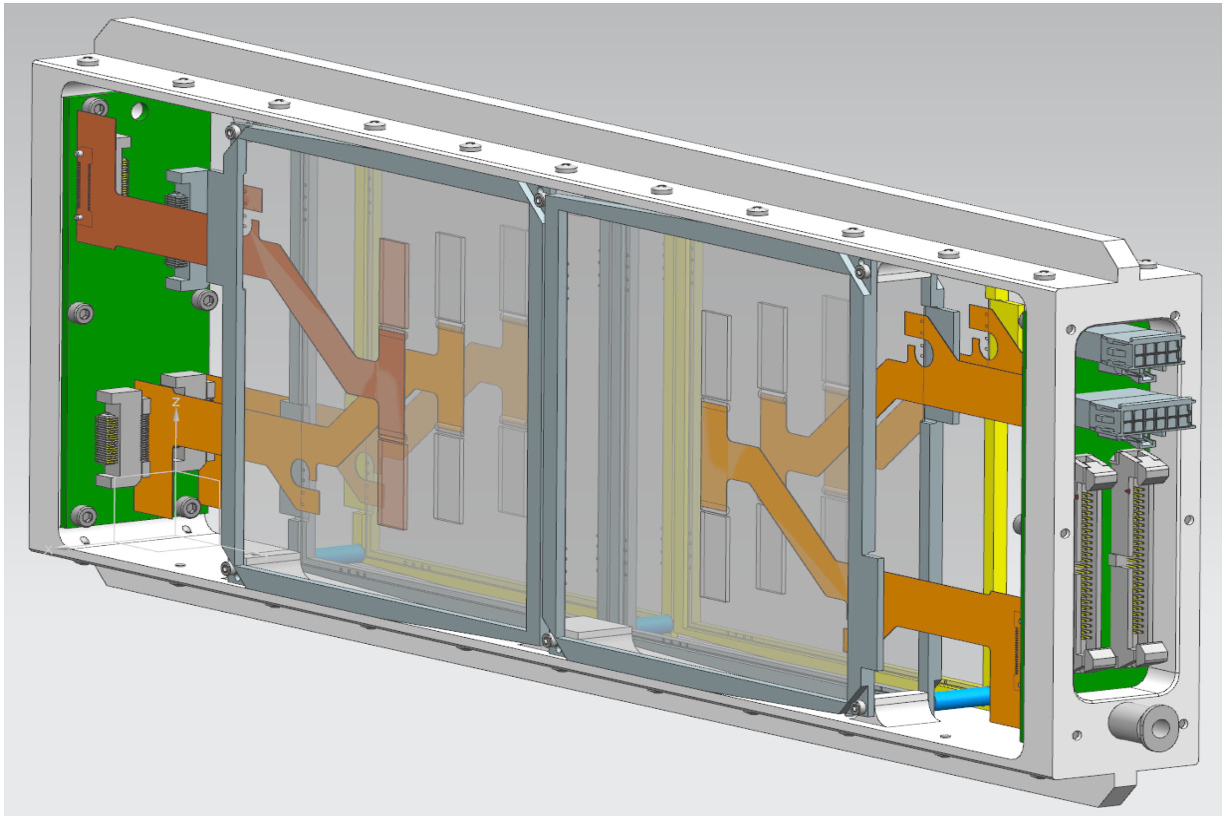
LC Forum 2017



HELMHOLTZ ASSOCIATION

AIDA 2020

DESY

The DESY Testbeam Facility

- Electron beam provided by DESY II synchrotron
- e^+/e^- particles with energy up to 6 GeV
- Silicon telescopes in T21 and T22
- Superconducting solenoid in T24/1

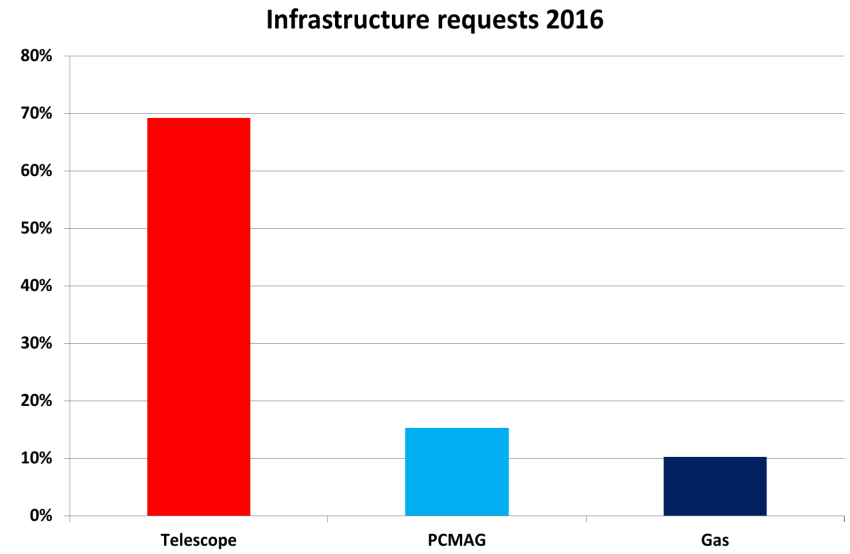


Fig: 2016 infrastructure requests

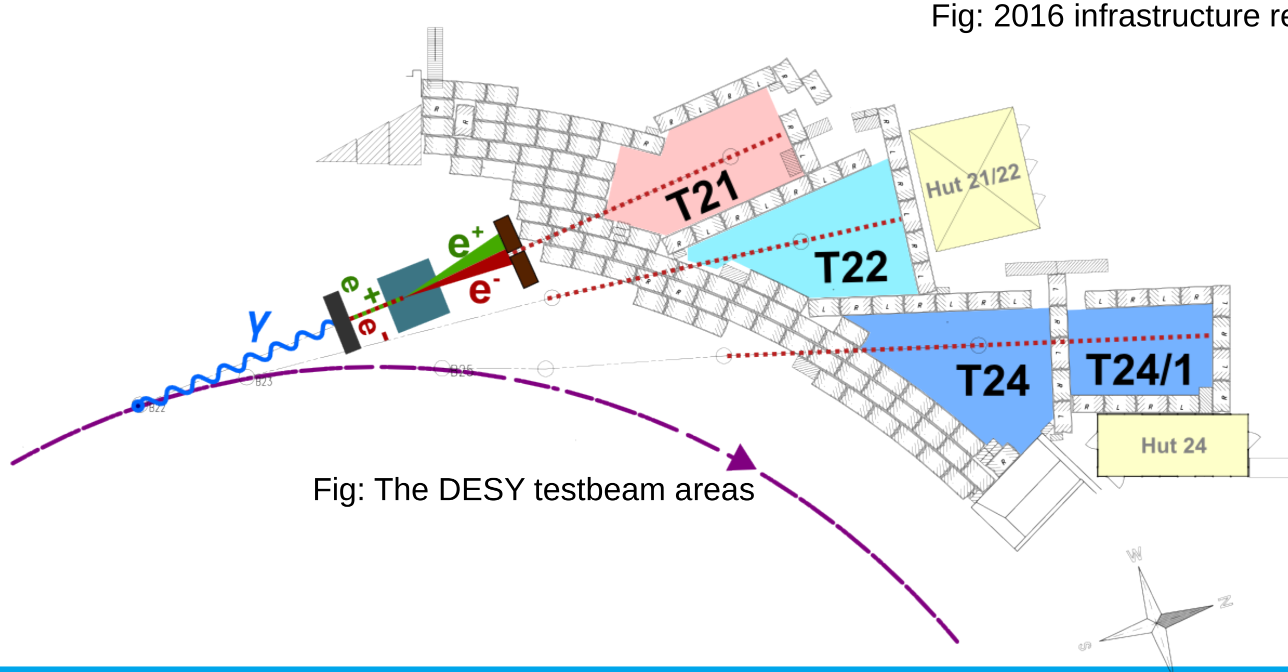
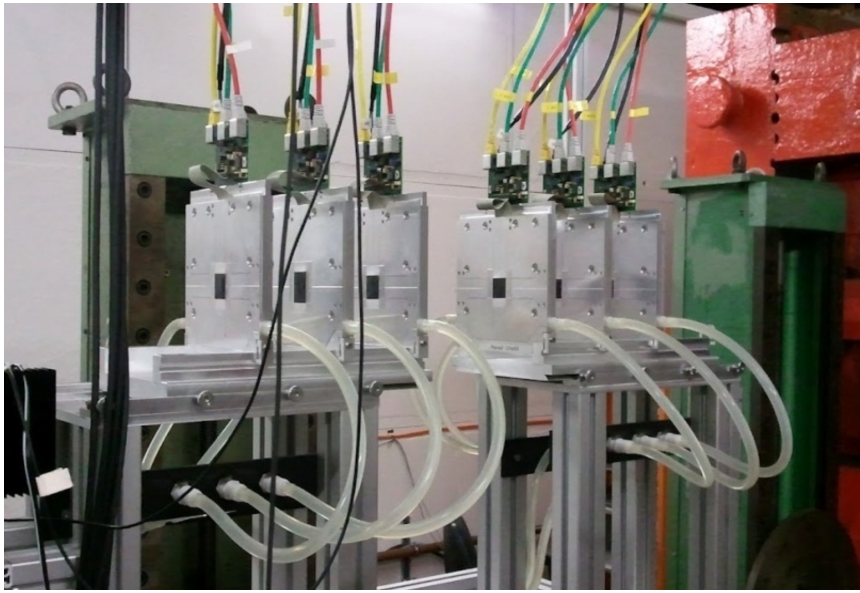


Fig: The DESY testbeam areas

- 6 Layer pixel planes, 1x2 cm^2, 18 µm pitch
- Based on Mimosa26
- Trigger rates up to 3 kHz
- 3 micron tracking resolution
- Provides full tracking and analysis package
- High demand: requested by ~ 70 % of users in 2016
- Uses EUDAQ and EUDET / AIDA mini-TLU



Why design a new telescope?

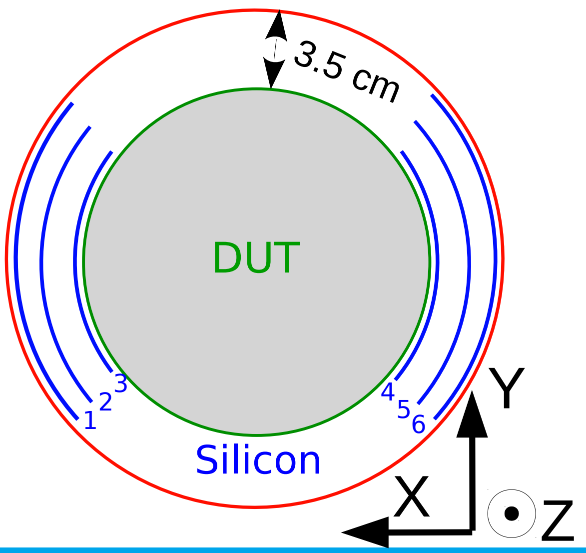
- Mimosa, while extremely good is not without faults:
  - Small active area
  - Support structure demands a lot of space
  - High amount of channels = Large power consumption → Dedicated water cooling
  - Slow readout with an integration time of about 100 µs

AIDA2020 project:

A new large area strip telescope within the T24 solenoid

- The T24/1 solenoid has:
  - ~75 cm usable inner diameter
  - A wall with a radiation length of 0.2 X_0
  - Is mounted on a stage that can be moved/rotated around 3 axes
  - A magnetic field up to 1T
- Telescope demands defined by use case:
  - A large coverage area (~10x10 cm^2)
  - Minimal needed space to allow large DUT inside the magnet (e.g. a TPC)
  - Spatial resolution better than σ_y= ~10 μm along bending direction of particles in the magnet
  - Resolution along field axis of the magnet less important σ_z= ~1 mm

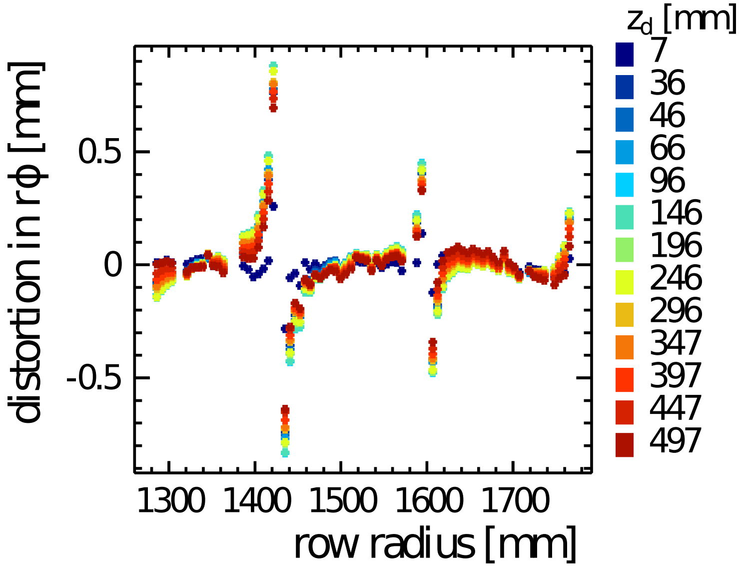
Fig: T24/1 solenoid



- Non perfect electric fields within TPC, especially close to the readout plane

  Reference measurement of the position

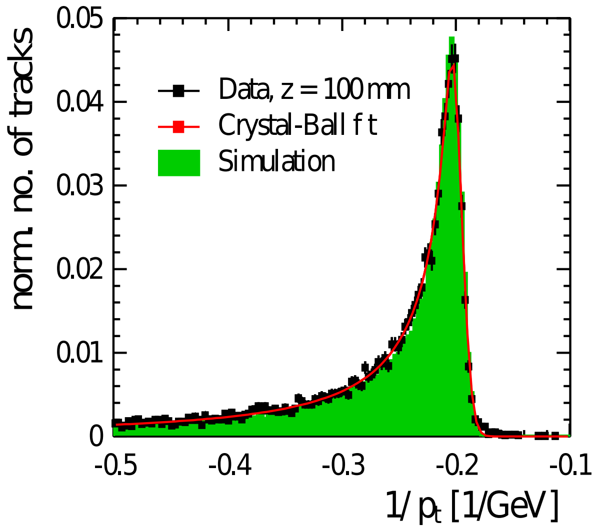
  → Studies of and corrections for field distortions in the TPC possible



- Broad distribution of particle momentum after interactions with magnet wall material limits momentum resolution studies

  Reference measurement of the momentum

  → allows for studies of the achievable momentum resolution of the TPC readout.



(1)Mueller, Felix Johannes ; doi:10.3204/PUBDB-2016-02659

The sensor is a silicon strip sensor designed by SLAC for an ILC environment:

- A strip pitch of 25 µm
- Alternate strips will be read out
- Thickness of 320 µm
- Material budget of 0.3% X_0
- An integrated pitch adapter and digital readout (KPiX)

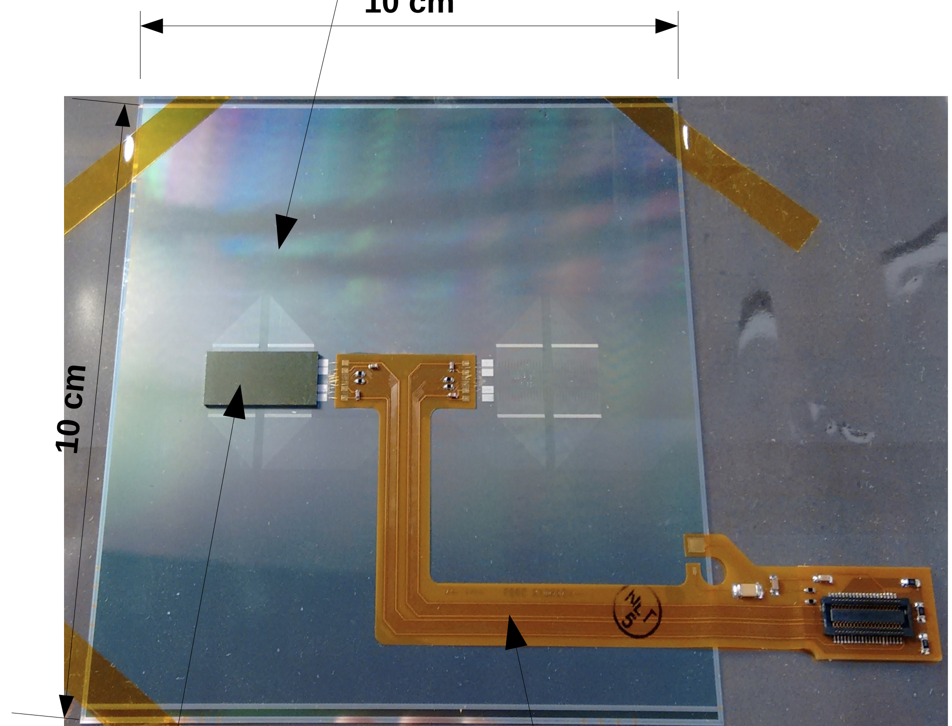


Fig: SiD silicon strip sensor with one bump bonded KPiX

Delivered in July by Hamamatsu

SLAC NATIONAL ACCELERATOR LABORATORY

IV measurement

- Good behaviour and expected performance of all sensors (~100 nA currents and stable up to 300V)
- Two sensors show the beginning of a breakdown around 280V
  - Depletion voltage for all sensors around 50V
- No significant differences before and after bump bonding

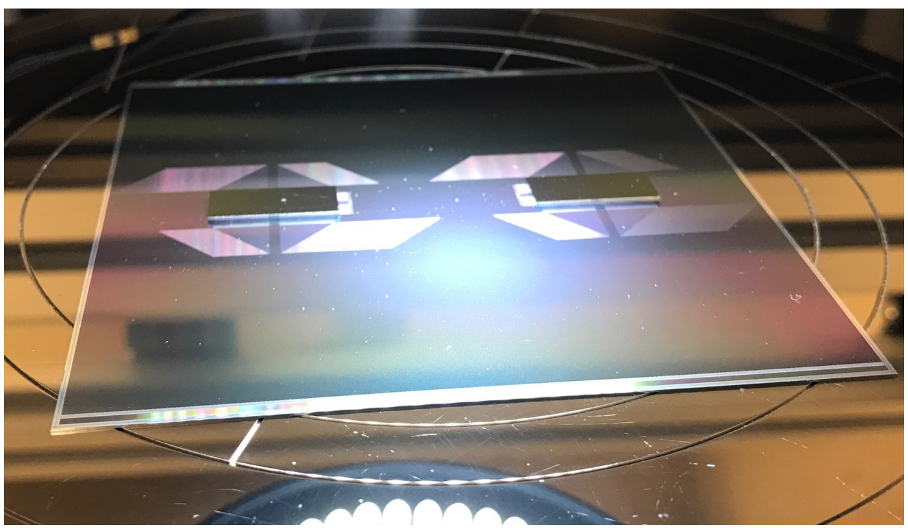
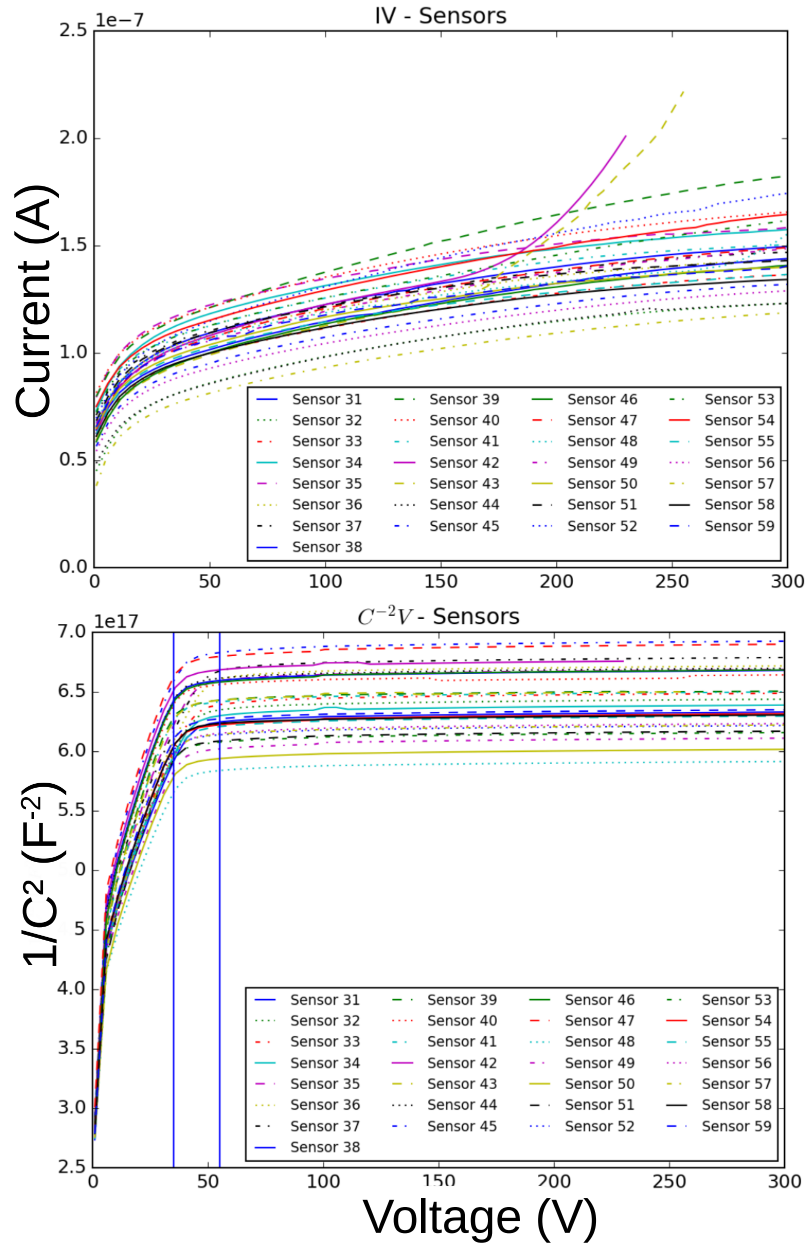


Fig.: Bump Bonded Sensor on the probe station



The KPiX Test Setup

- KPiX readout system set up at DESY
  - 3 Pixel sensors with large pixel size and bump bonded KPiX
  - Readout board with FPGA
  - Dark box cover to reduce light induced noise

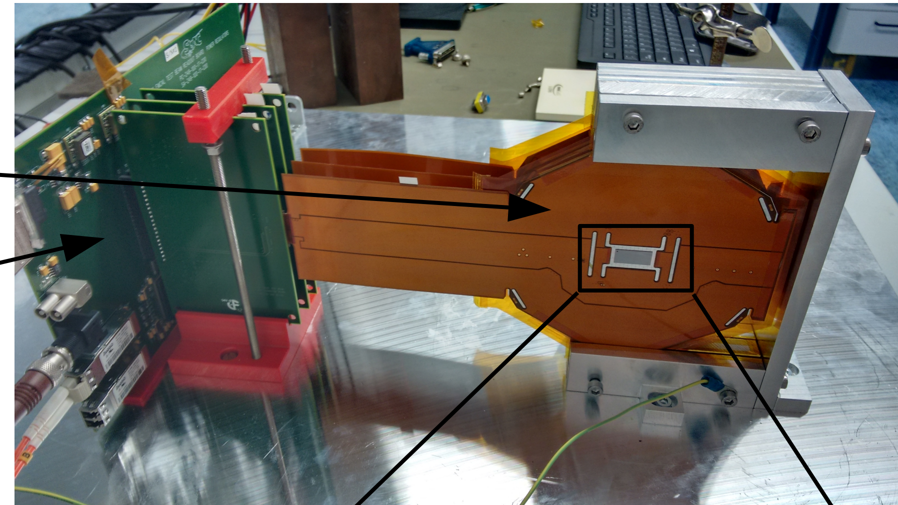


Fig.: ECAL sensor in holding structure

- Preparation of readout for tracker sensor:
  - Measurement of heat generation of readout chip
  - Test of the chip with pedestals and calibration
  - Measurements with a radioactive source
  - Testbeam measurements with testbeam DAQ synchronisation

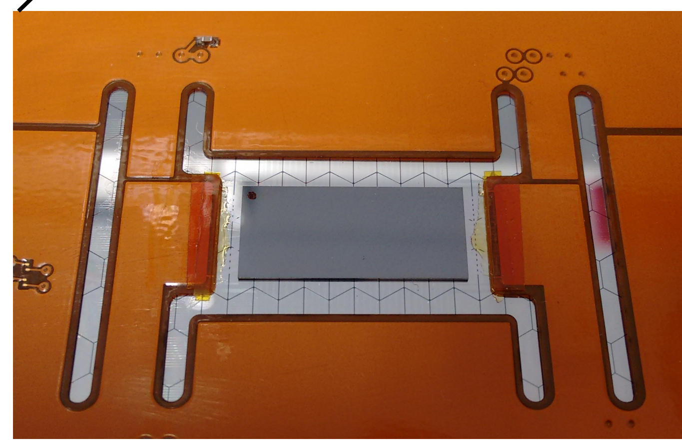
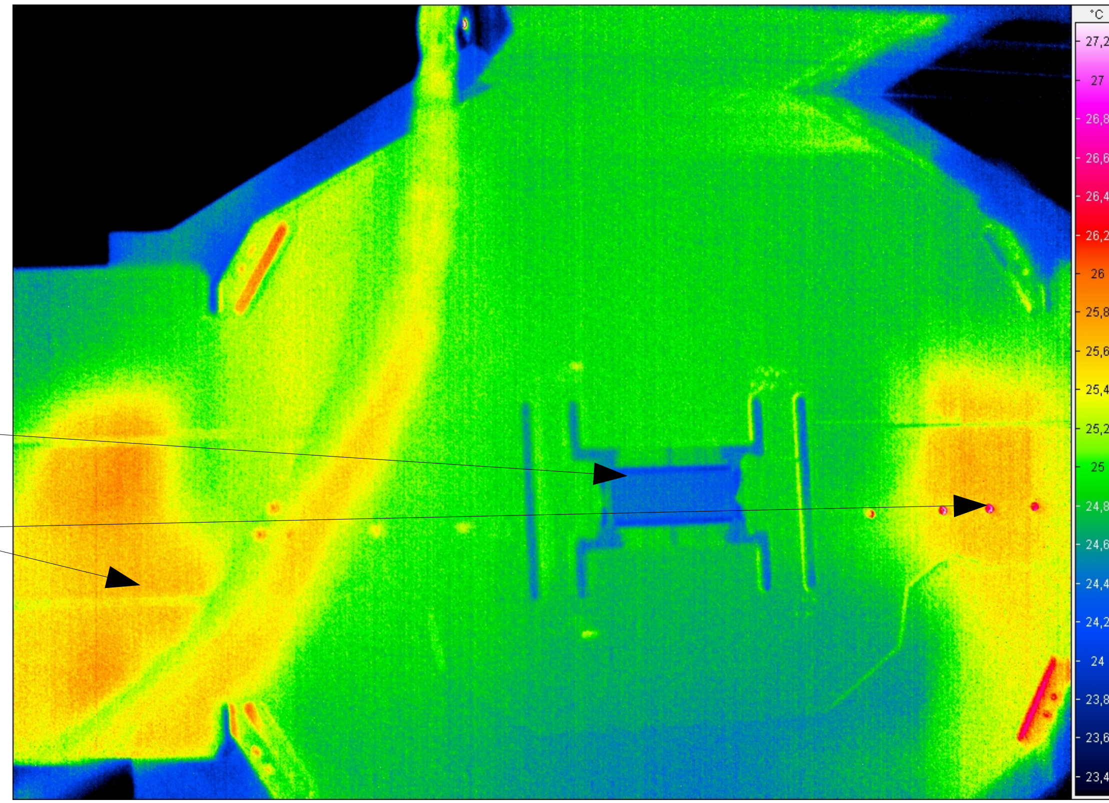


Fig.: Closeup of the bump bonded KPiX

- 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

The KPiX Readout Chip

- Fully digital readout with 13 bit resolution (8192 ADC)
- 100 MHz clock → 10 ns flexible acq. Clock
- Can work in two modes:
  - Self trigger = 4 events per channel per cycle stored
  - External trigger = 4 events per cycle stored
- Capable of power pulsing
- Length of the opening period depends on timing resolution

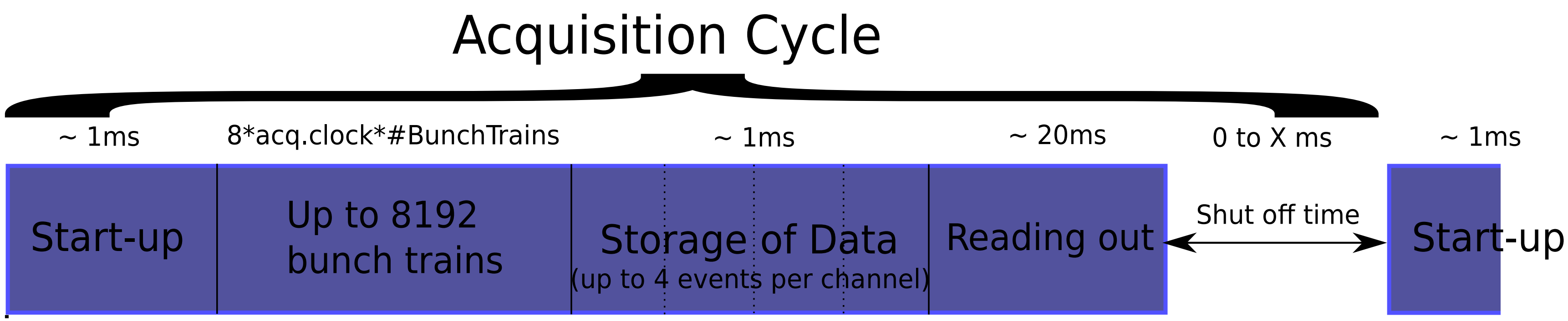
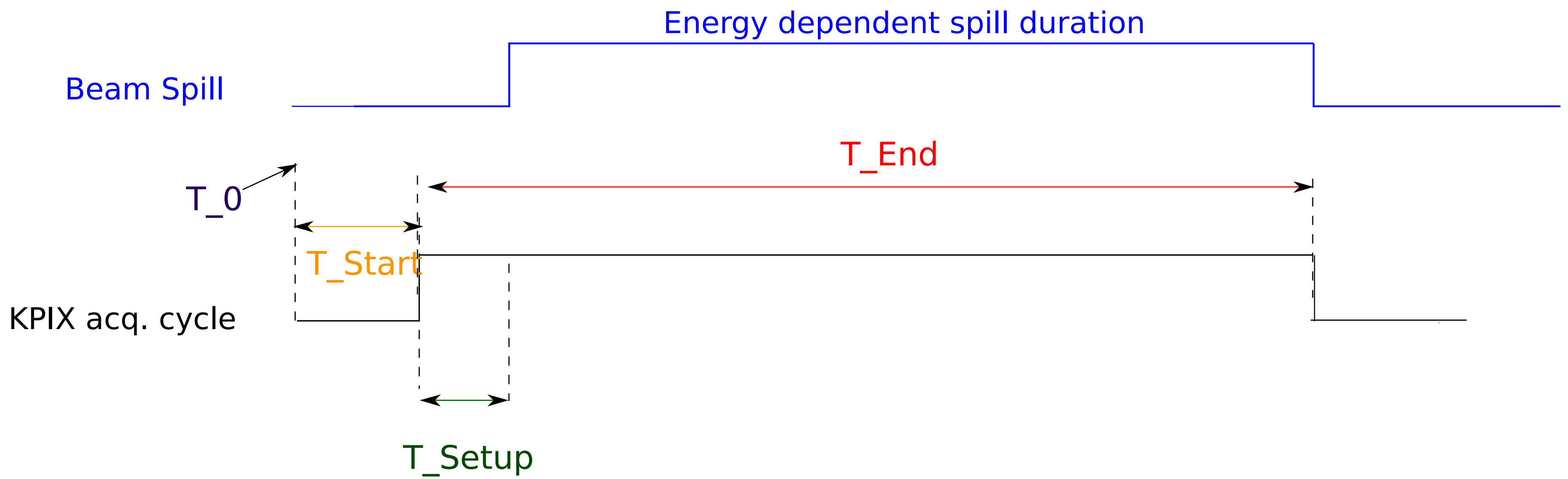


Fig.: Activation/Acquisition cycle of the KPiX readout chip

- Only open for a maximum time of 8192*8*acq.clock

  → For example with a 320 ns acq.clock = 20.97 ms

KPiX synchronization, DUT and Beam



- As a result of the power pulsing KPiX needs to be synchronised to beam spill of the accelerator and the different devices. This will be accomplished via a new EUDAQ TLU.
  - T_0: Accelerator signal for synchronisation with beam spill.
  - T_Start: User adjustable delay between T_0 and the 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.

- Tests resulted in a good understanding of data taking with KPiX in all aspects
  - Time analysis of events and matching with based on timing with external timestamps
  - ADC response of channels and calibration
  - Mapping of events onto the sensor

<u>Well prepared for tracking sensors</u>

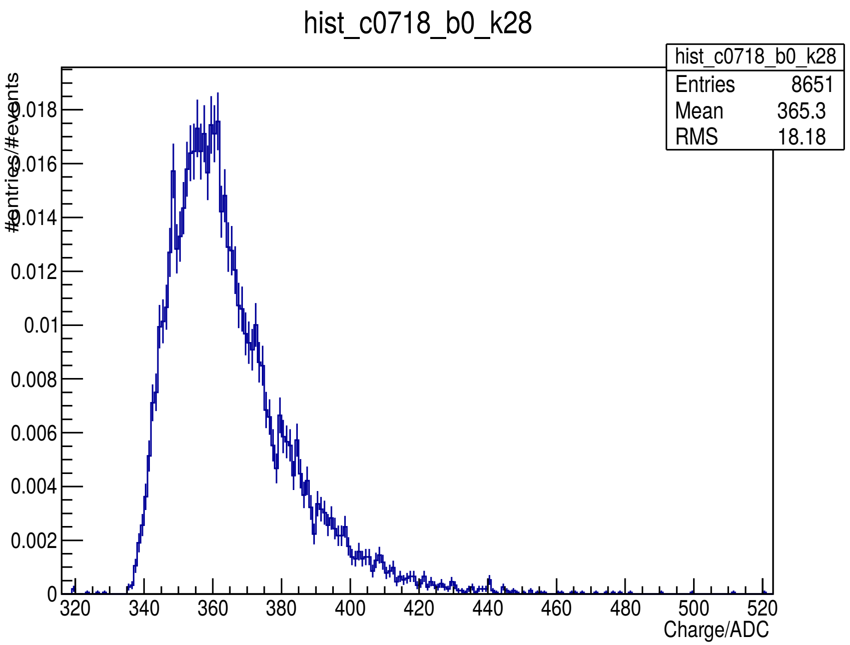


Fig.: ADC response of a channel beneath the beam spot

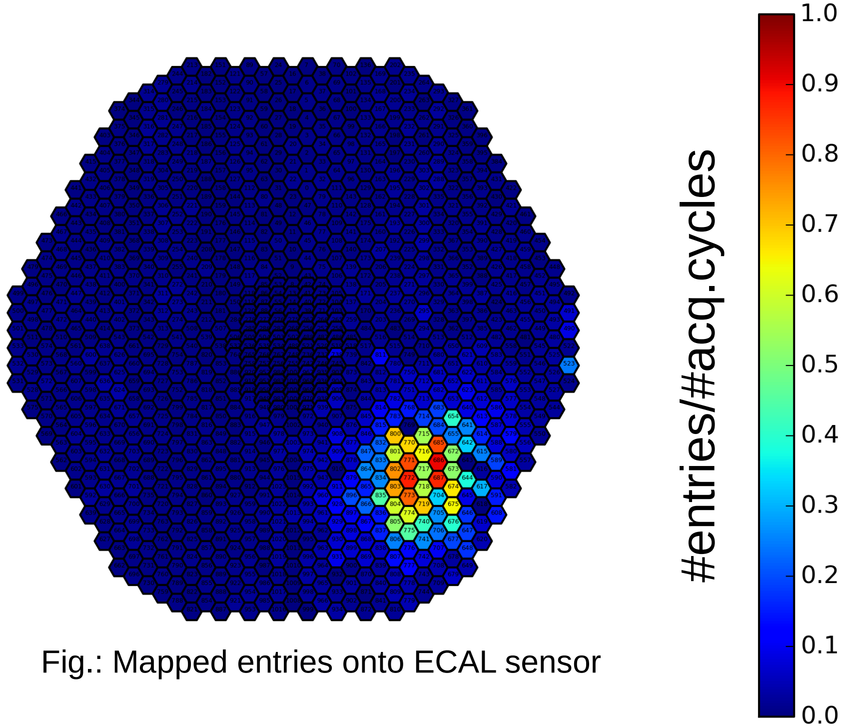
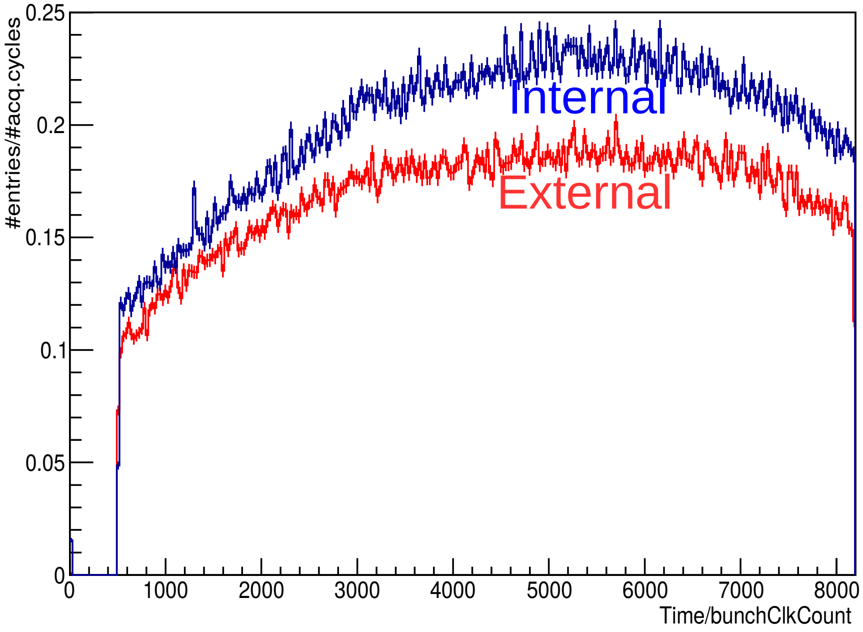


Fig.: Mapped entries onto ECAL sensor

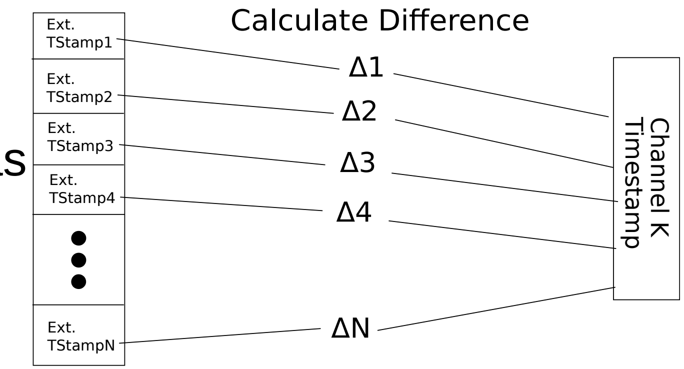
KPiX timing

- KPiX allows for storage of external trigger timestamp and internal timestamp of Data.
  - Fed in either via a NIM or CMOS signal on current DAQ board
- Data is stored in multiples of the BunchClockCount = 8*Acq.Clock
  - For the testbeam Acq.Clock = 320 ns → BunchClockCount ≈ 2.5 µs
- Time data is then used to reduce noise levels and match between sensor layers



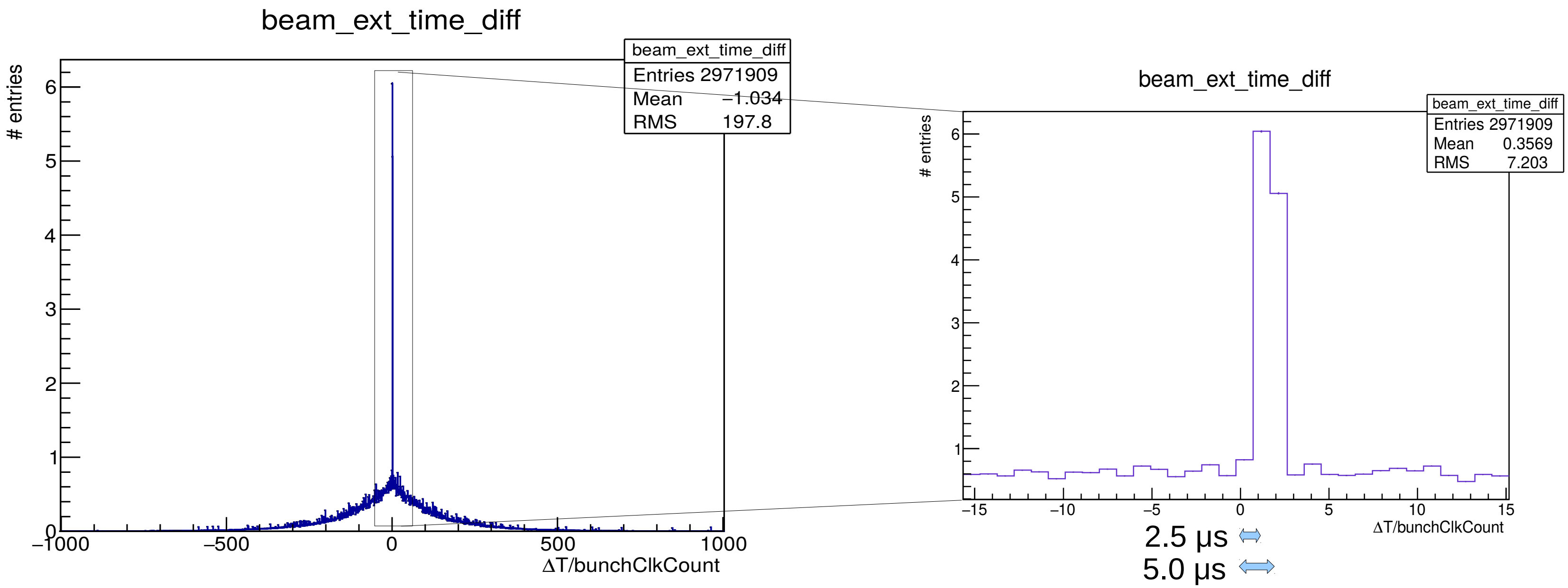
Current Event Matching

List of external timestamp values as recorded by KPiX

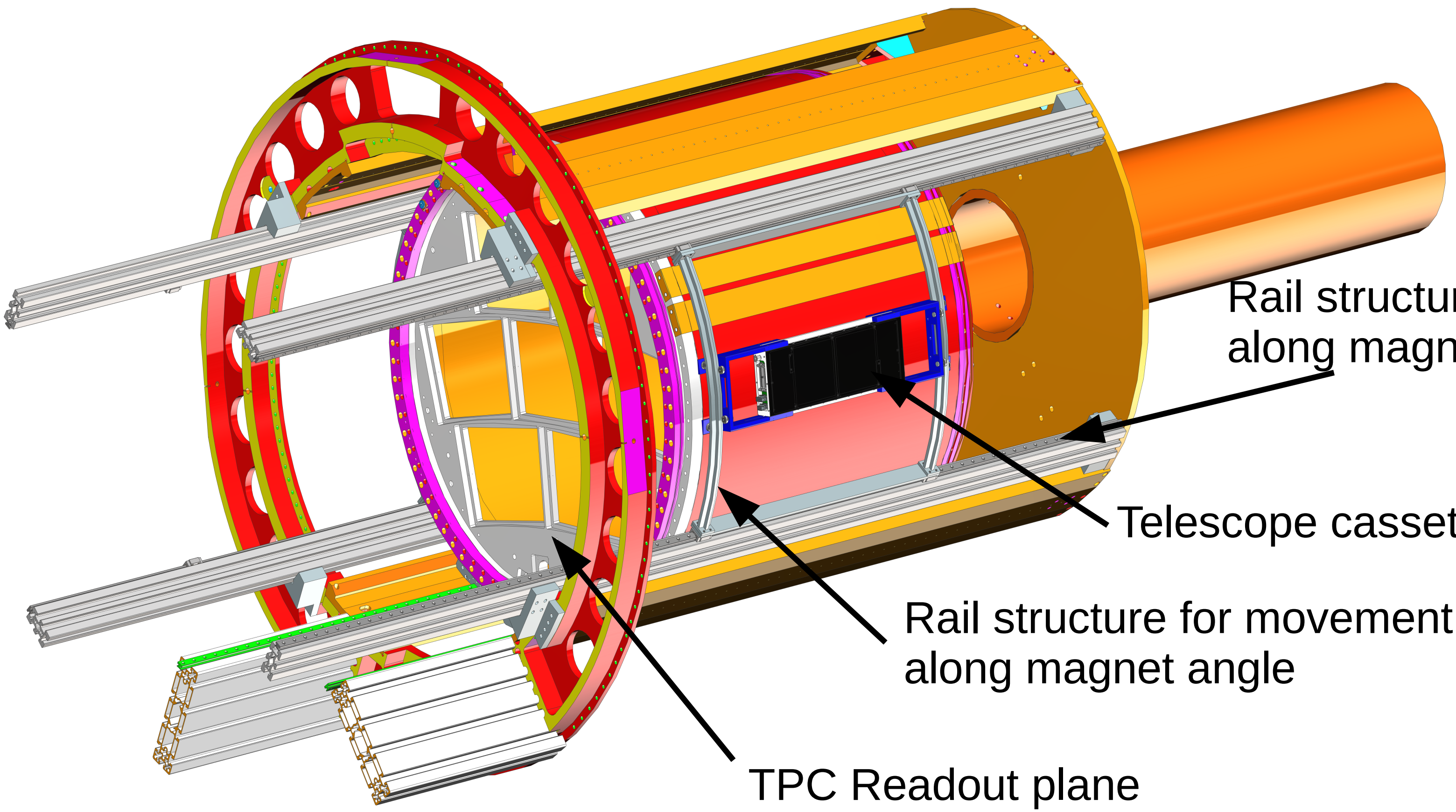


Timestamp for a channel

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

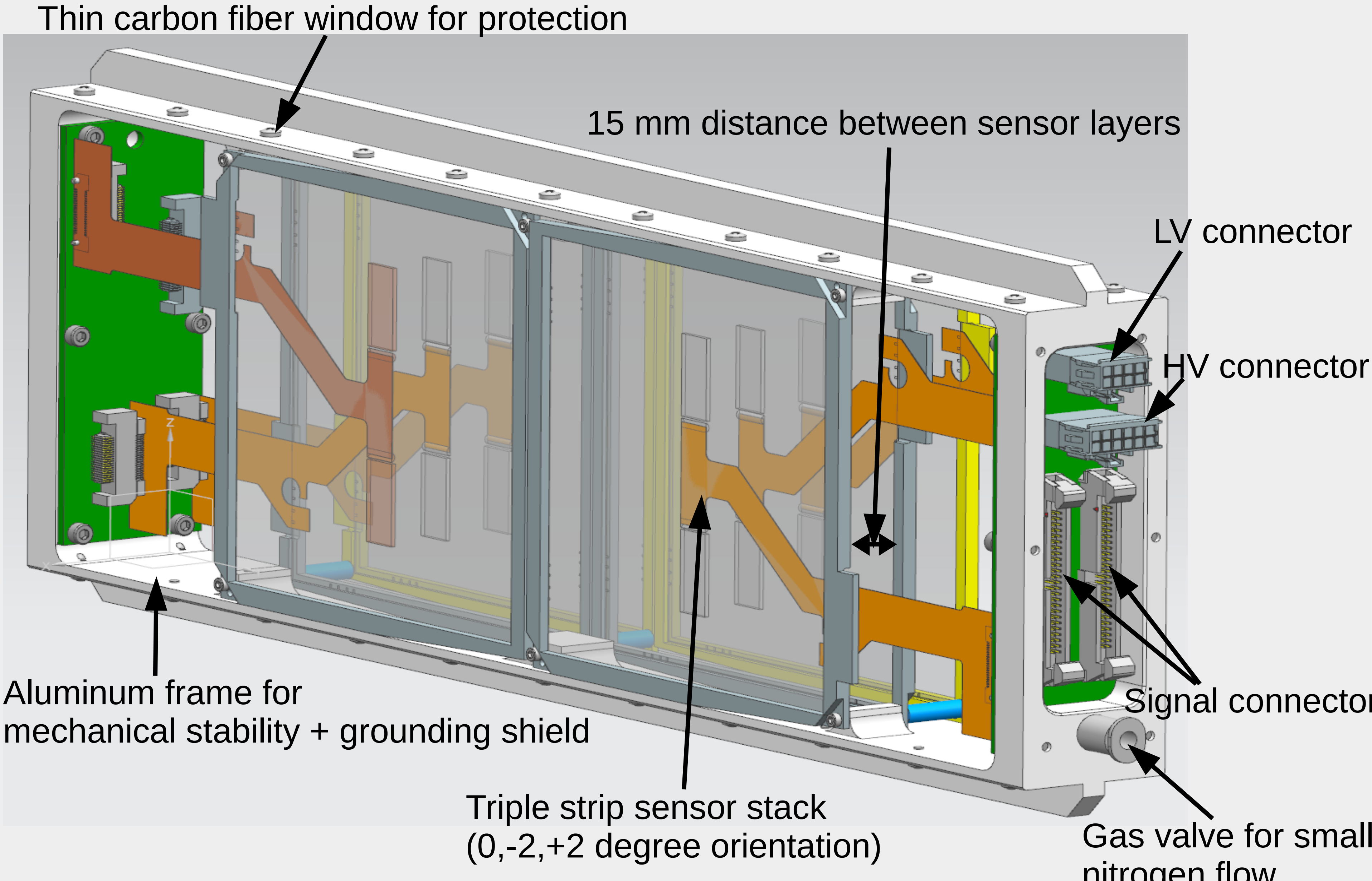


- Matching between external timestamps and internal timestamps shows a small delay between signals.
- Event selection will be done using this information



Final dimension of the active area is 10x20 cm^2

The sensor cassette



Conclusion and Outlook

- Construction of a large area strip telescope is ongoing.
- Multiple tests with KPiX and readout DAQ have been completed.
- Mechanical structure for installation is in production

Expect a fully assembled sensor in late December

- Is being integrated into the EUDAQ framework to provide basic data taking and analysis when using the telescope.
- Combined Testbeam campaign with LP TPC currently in planning.
- Thanks to the cooperation with SLAC the project profits from the expertise and manpower of both DESY and SLAC.
- Fruitful cooperation with Bristol and the AIDA2020 WP5 for the synchronization of the new system with DUT and Accelerators.

AIDA2020 deliverable is in April 2018, the project is currently well on track to fulfill this

Thank you for your Attention

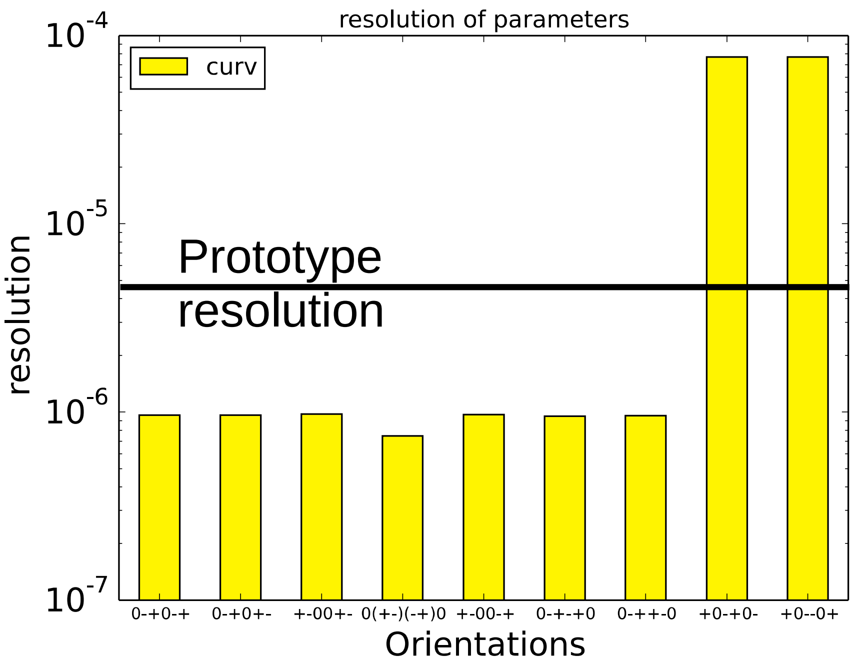
Fig.: Datura

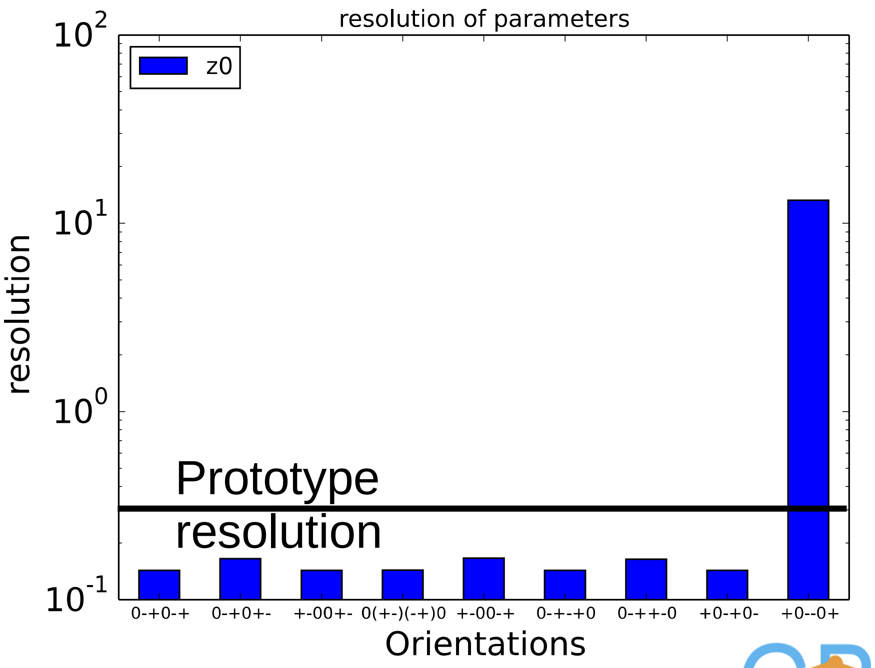
Fig.: Duranta

Fig.: Lycoris

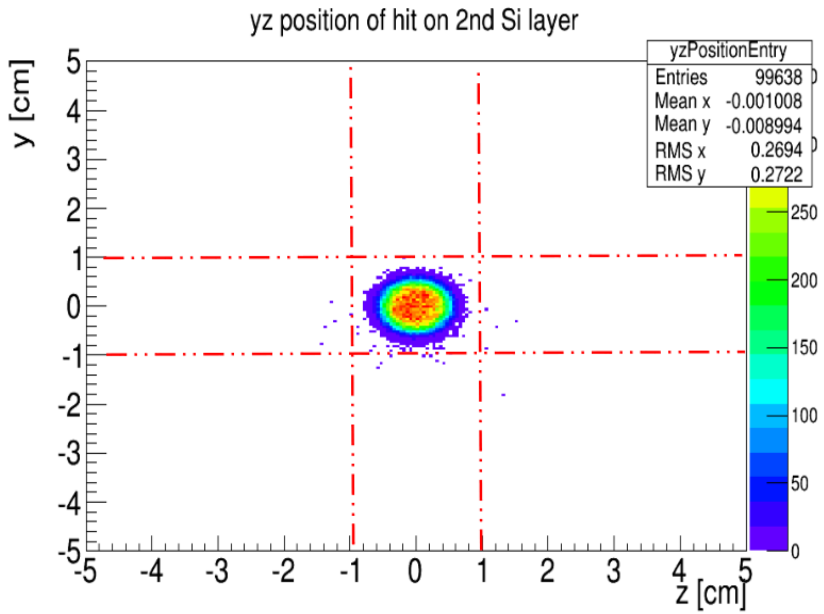
BACKUP

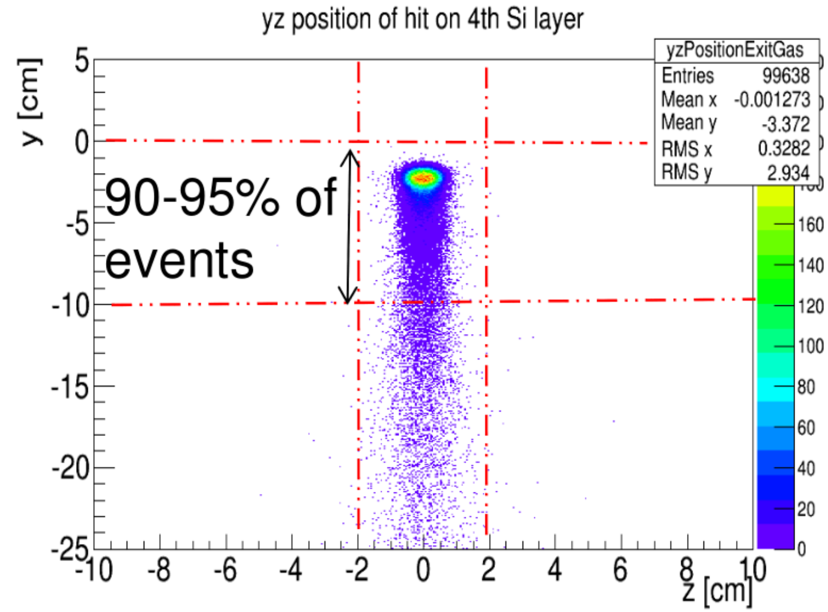
- Analytical calculations using GeneralBrokenLines (GBL) by Claus Kleinwort with a 25 µm pitch strip sensor.
- Depending on the orientations, correlations between planes severely limit the resolution
- The right orientation means the Telescope can easily achieve the curvature resolution needed for the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





Demands for the silicon tracker size





- For lower energy beams, the hit distribution on the back sensors is more spread and shifted to lower y values
- Larger coverage area is beneficial (e.g. less moving and alignment of the system)

- Demand on spatial resolution for tracker sensor given by downscaling ILD TPC resolution demand to Large TPC Prototype (LP)
- The LP resolution was simulated by Dimitra by downscaling the momentum resolution demand of the ILD TPC.

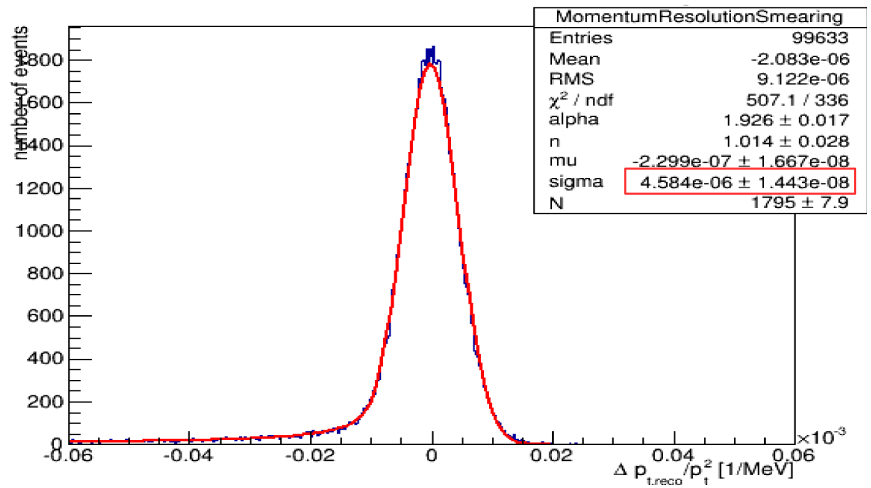


Fig.: Simulated TPC momentum resolution

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

- This then gives a limit on the needed spatial resolution of the sensor, distance between layers, number of layers...

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

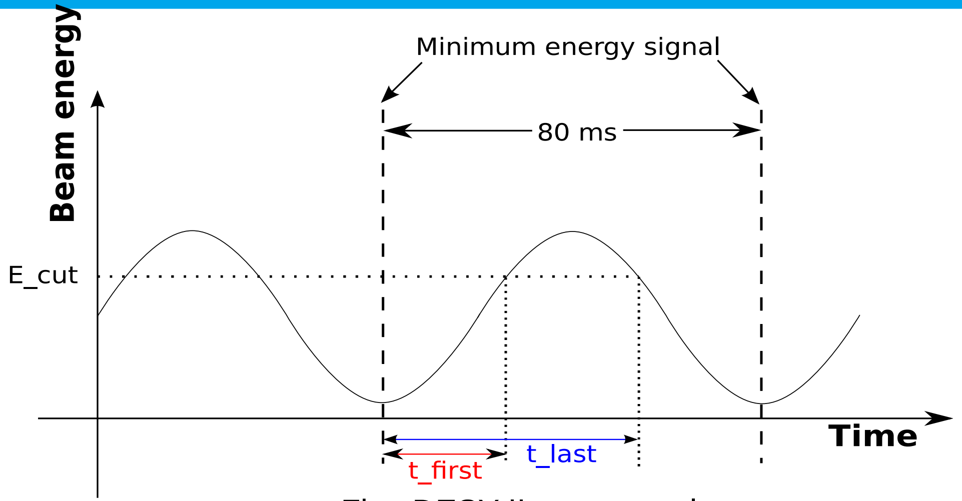


Fig.: DESY II energy cycle

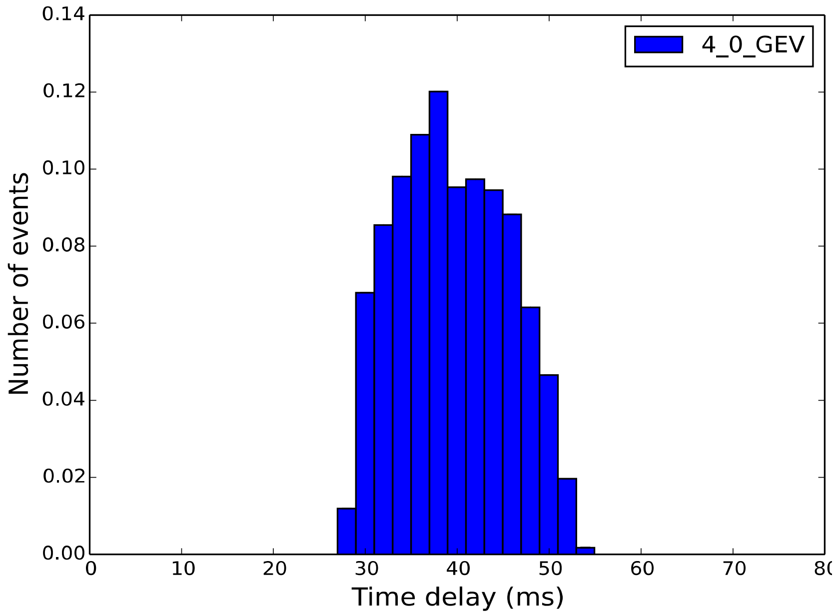


Fig.: Time difference from min. energy to trigger signal

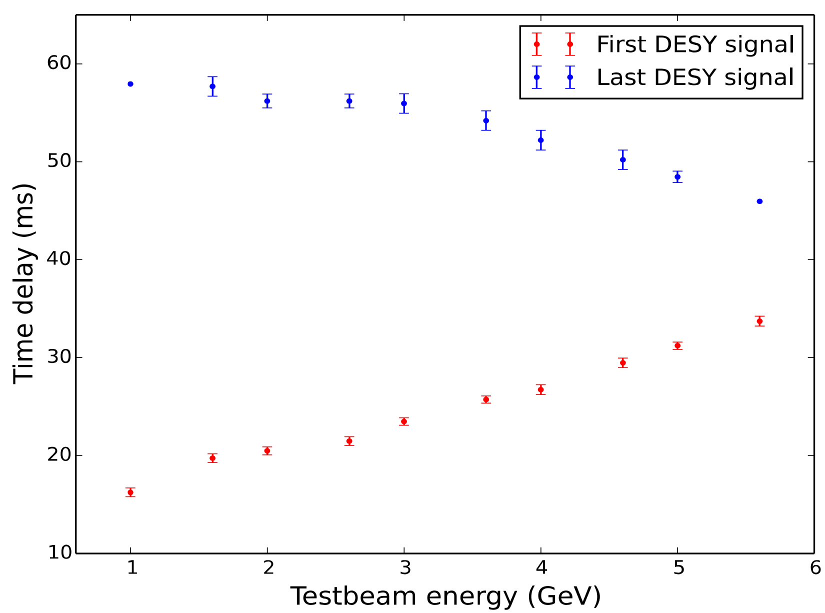


Fig.: First and last DESY signal in a cycle for different energies