LYCORIS: A large area strip telescope and its use for the LP TPC

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LCTPC Collaboration Meeting 2017

AIDA2020 project:

A new large area strip telescope within the T24 solenoid

- The T24/1 solenoid has:
  - ~75 cm usable inner diameter
  - ~68 cm is taken by the TPC → only 3.5 cm available for the telescope on each side

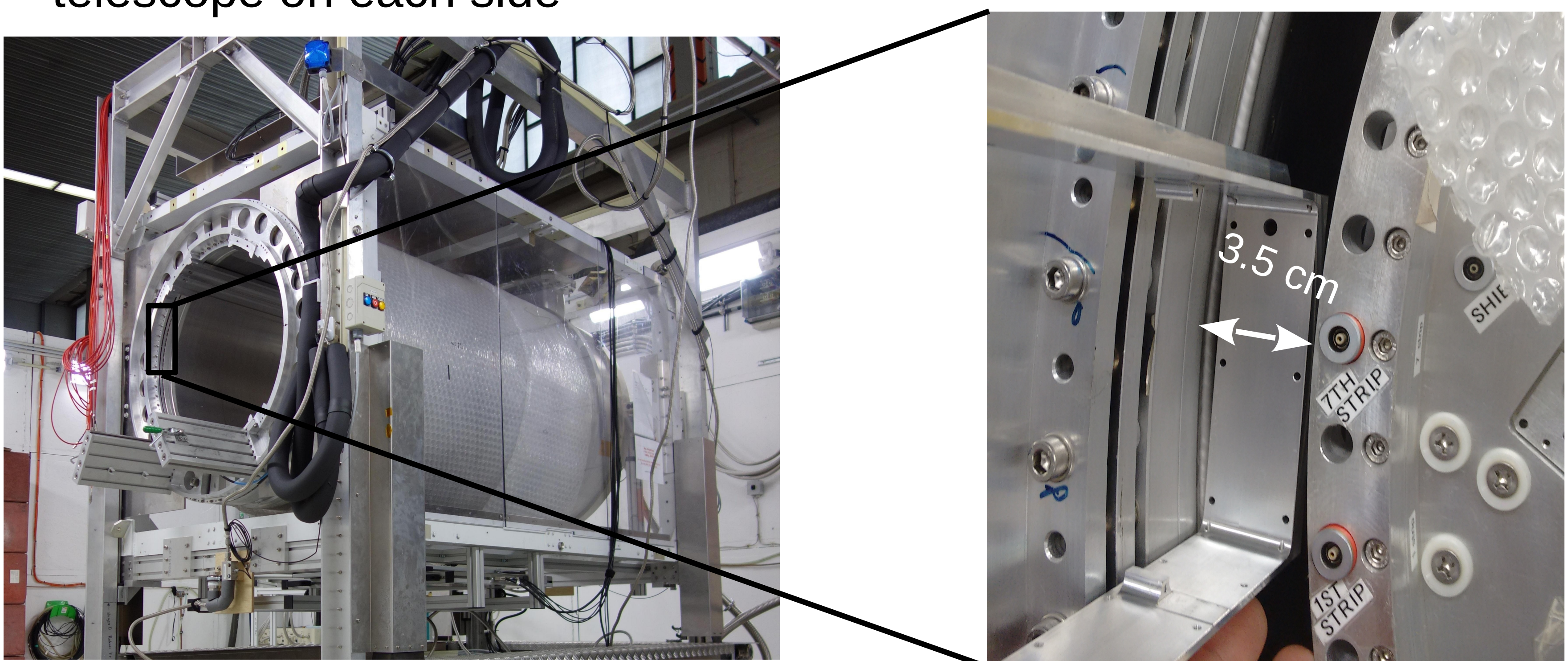
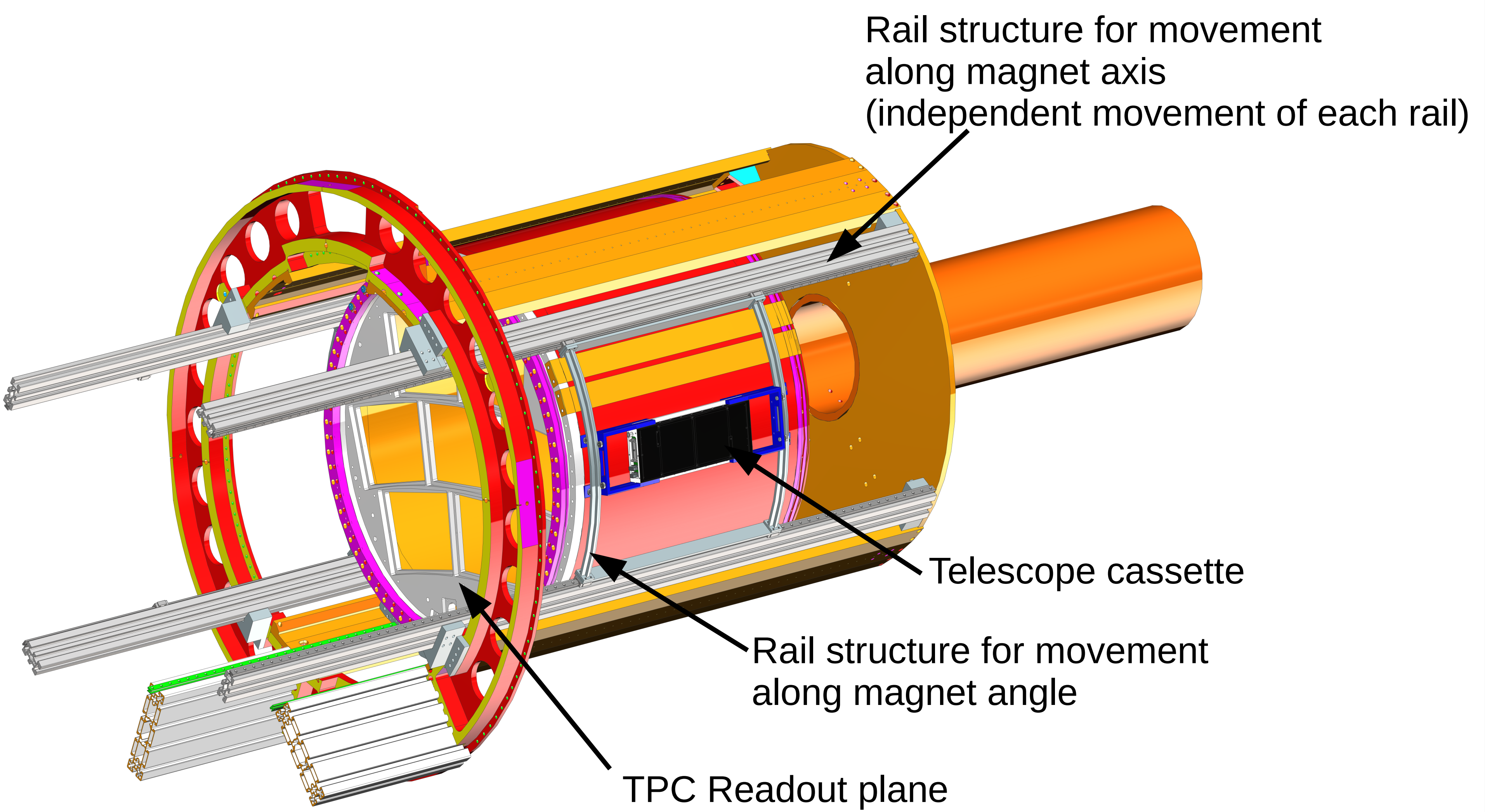


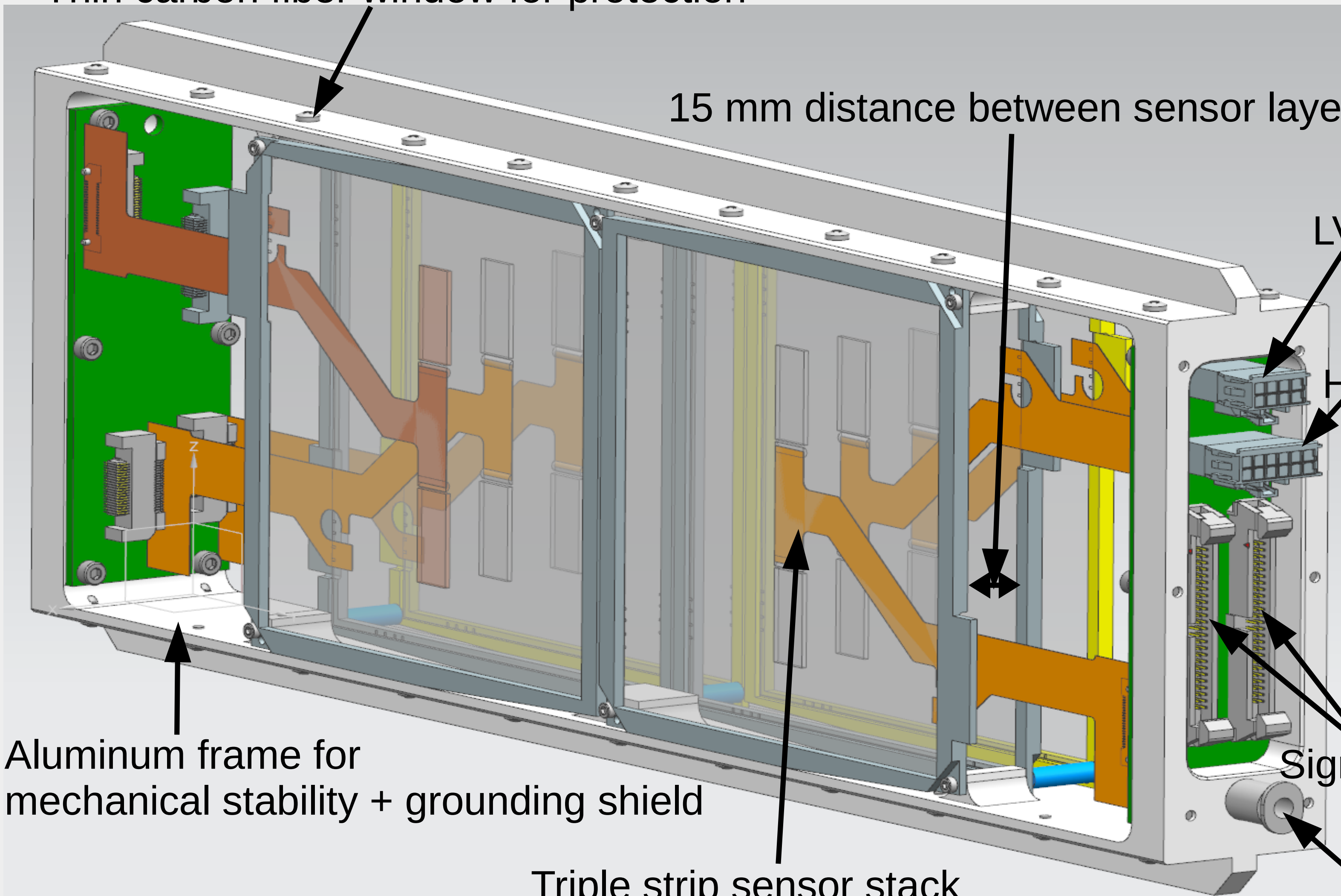
Fig: T24/1 solenoid



Final dimension of the active area is 10x20 cm²

- **System currently under final review before send off to production**

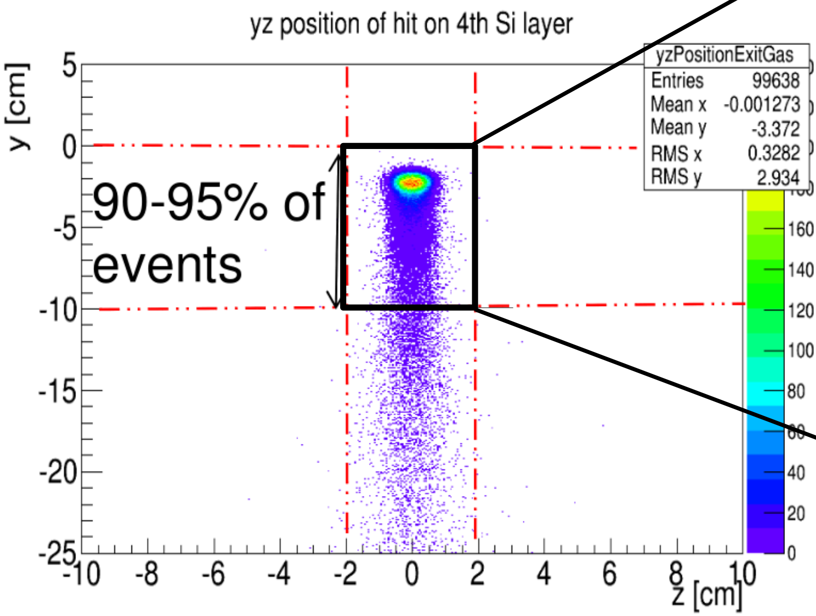
Sensor Cassette



- **Currently in production**

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

- 10x10 cm^2 active area



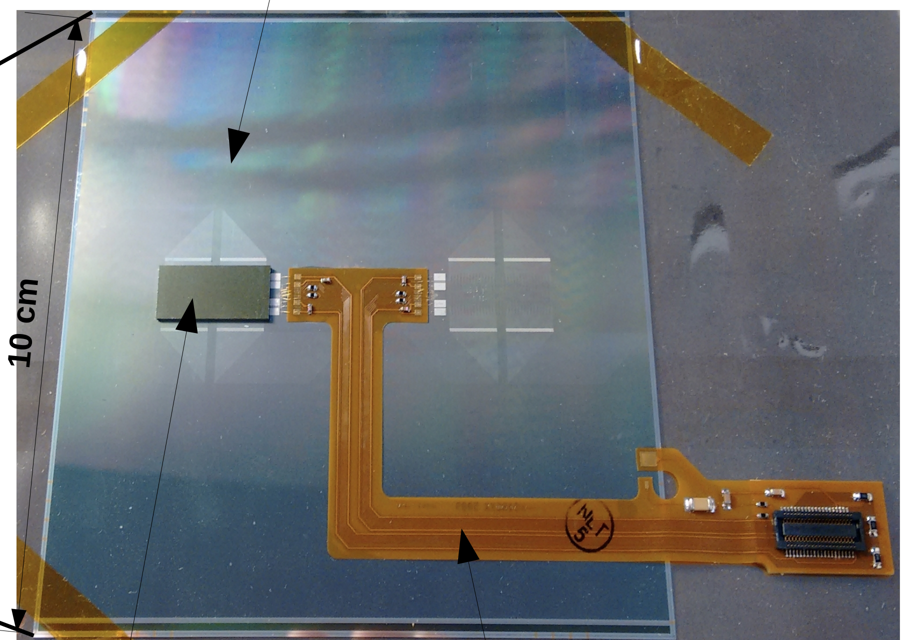


Fig: SiD silicon strip sensor with one bump bonded KPiX

Delivered in July by Hamamatsu

The SiD Silicon Strip Sensor

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

- $10 \times 10\ cm^2$ active area
- A strip pitch of 25 µm to fulfill TPC momentum resolution requirement
- 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)

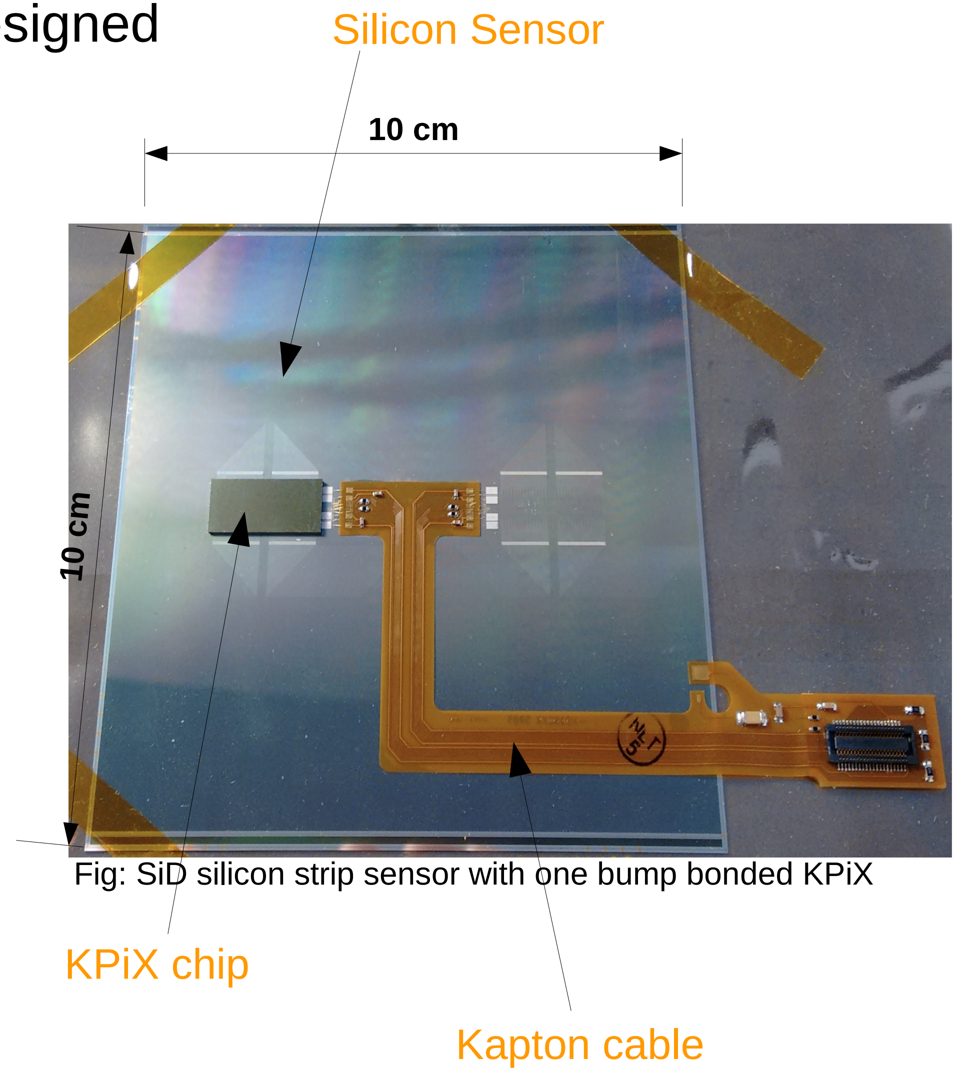


Fig: SiD silicon strip sensor with one bump bonded KPiX

Delivered in July by Hamamatsu

SLAC NATIONAL ACCELERATOR LABORATORY

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

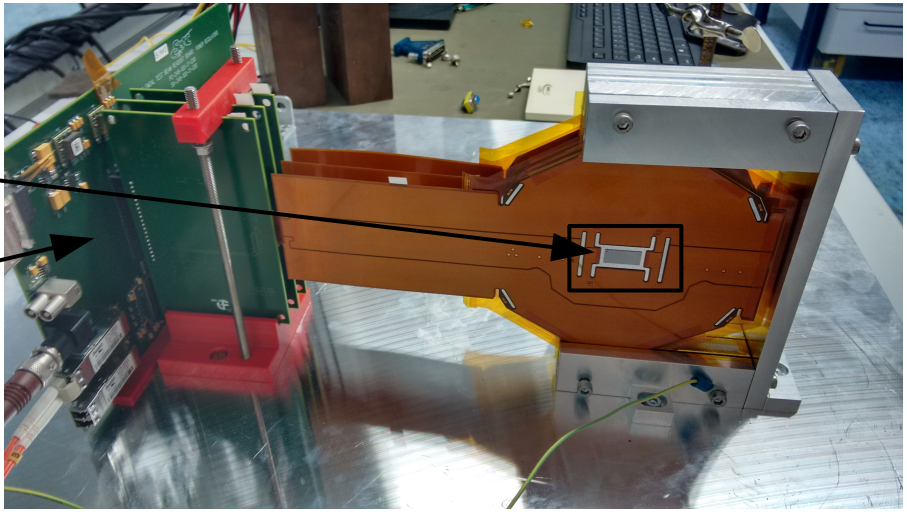


Fig.: ECAL sensor in holding structure

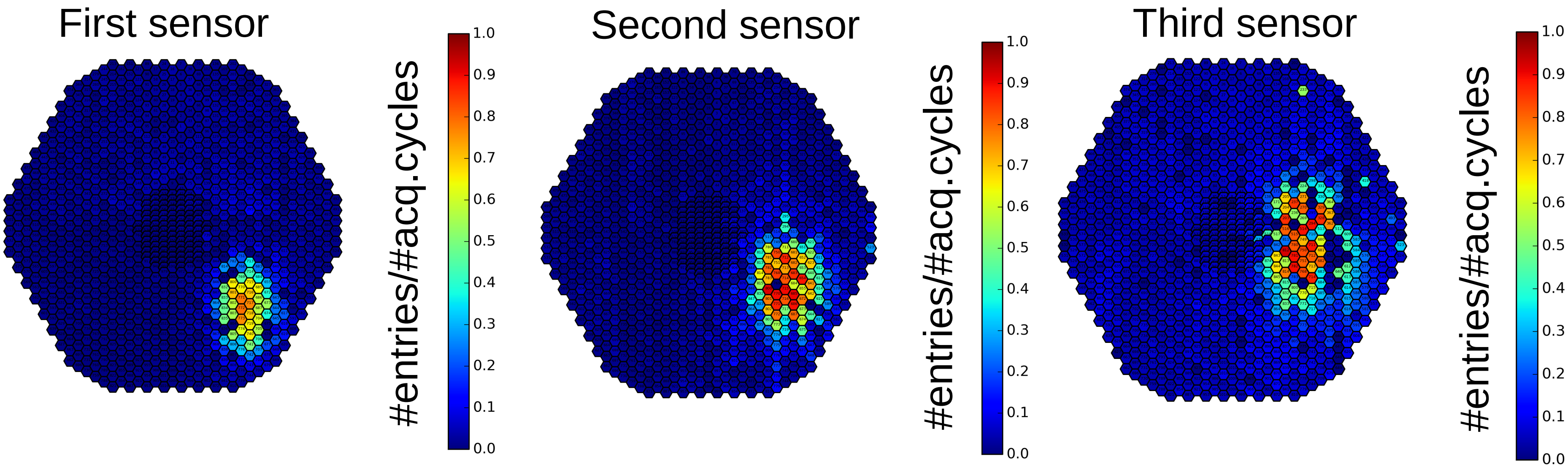


Fig.: Beam spot with angled sensors to the beam mapped onto the ECAL sensor

- 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
- Performing power pulsing
- Length of the opening period depends on timing resolution

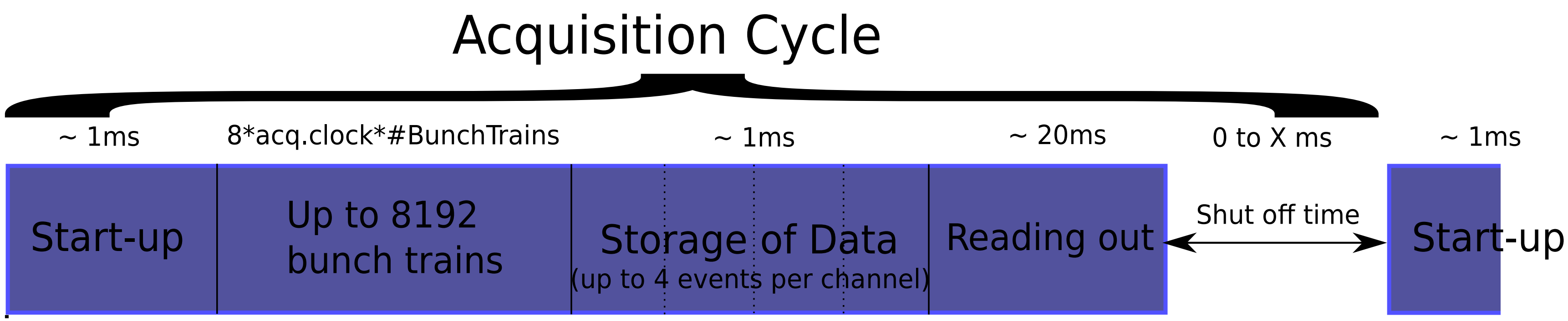


Fig.: Activation/Acquisition cycle of the KPiX readout chip

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

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

- 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

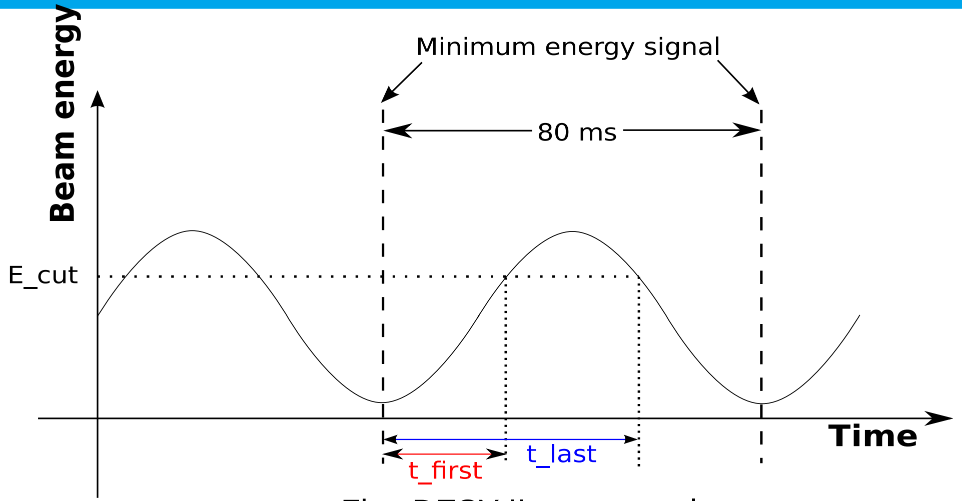


Fig.: DESY II energy cycle

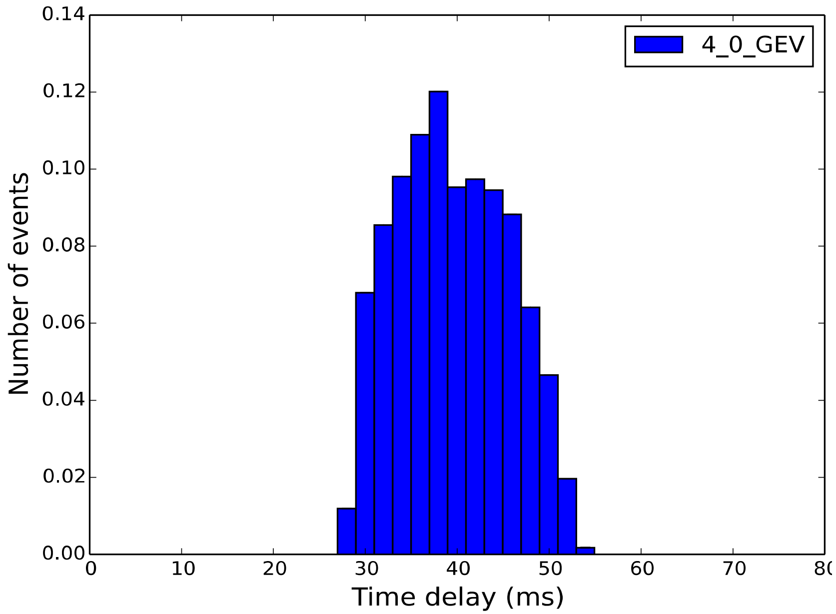


Fig.: Time difference from min. energy to trigger signal

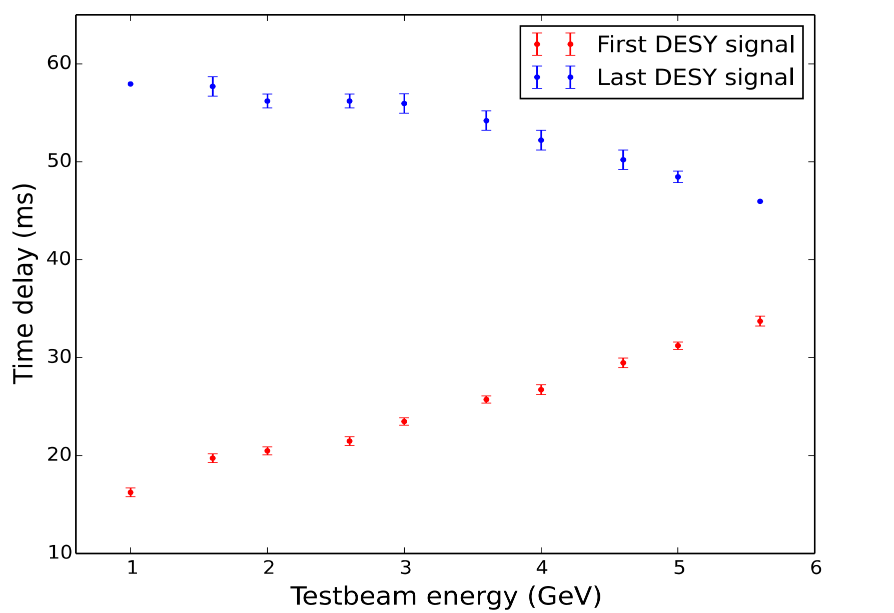
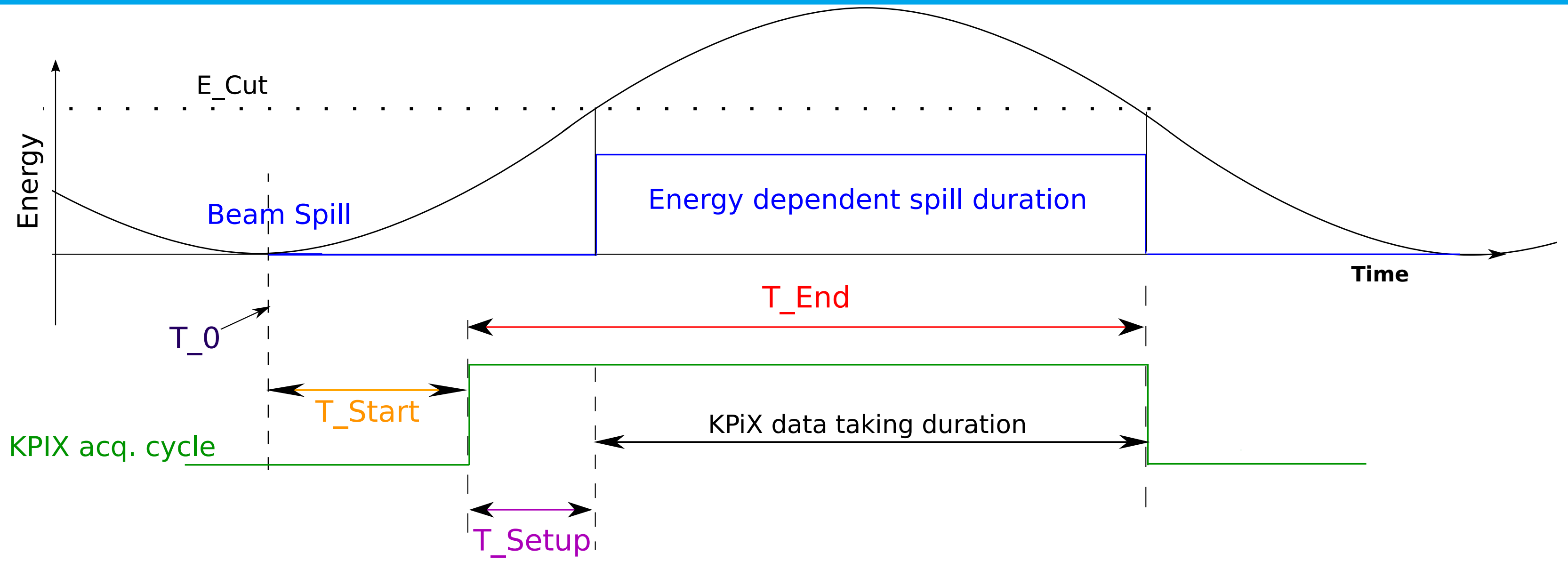


Fig.: First and last DESY signal in a cycle for different energies

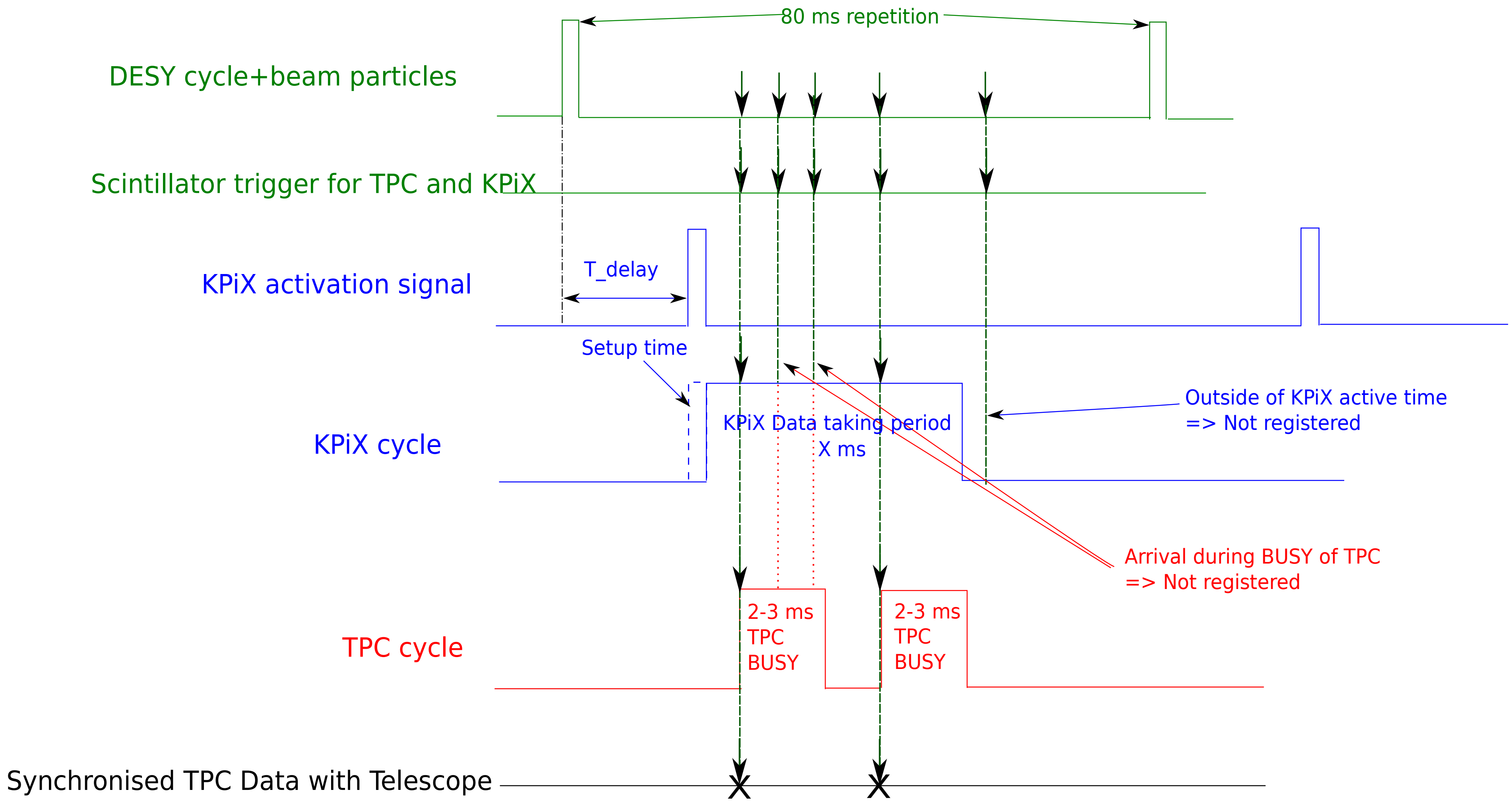
KPiX synchronisation, DUT and Beam



- 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.

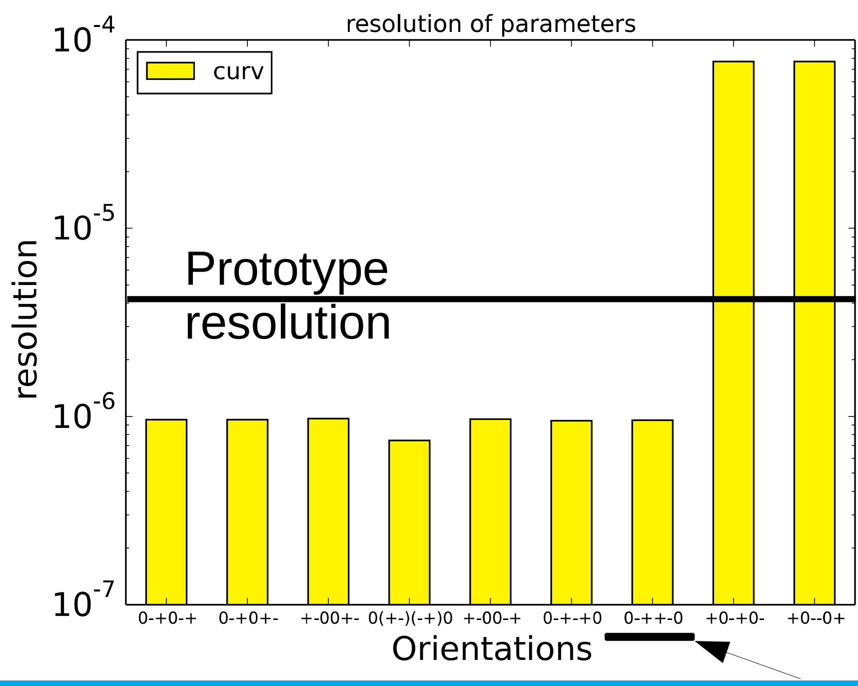
KPiX synchronisation, ALTRO Electronics

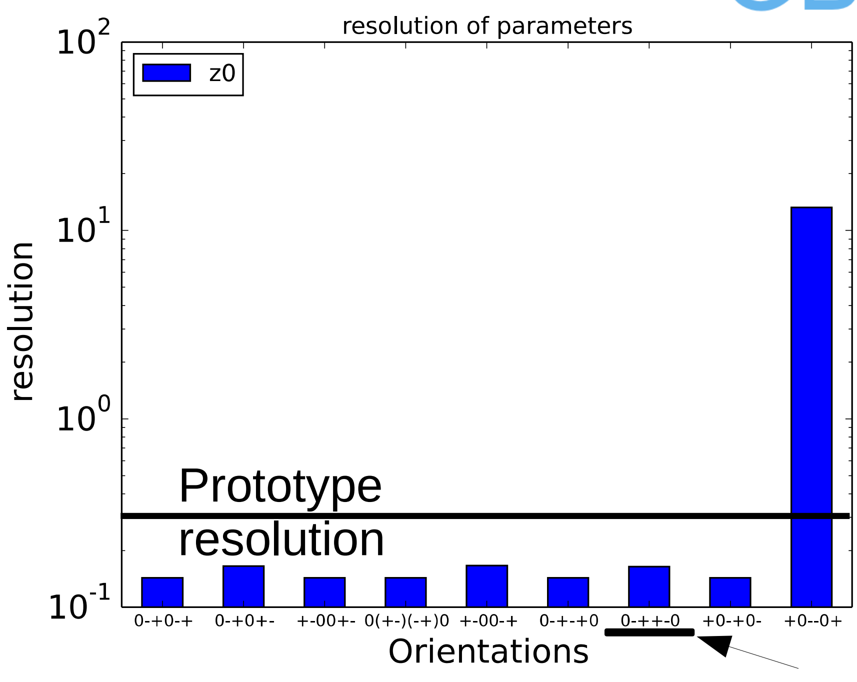
- ALTRO electronics run independently of other devices without sending any time information.
- Matching will be done by exclusion of unmatched events using busy signals



Sensor orientations

- Demand of good spatial resolution in y and less importance in z in combination with limited space results in low stereo angles between sensors (+2, -2 and 0 degree)
- Analytical calculations using GeneralBrokenLines (GBL) by Claus Kleinwort with a 25 µm pitch strip sensor and realistic parameters show:
  - Strong correlations between planes depending on orientations
  - Right orientation means the telescope can achieve the demand in curvature resolution





The state of: Sensors

- 25 sensors have been bump bonded by IZM
- Boards and cables have either arrived, or are in production
- Currently in the middle of testing electrical properties of sensors after bump bonding

- **To follow:**
- Gluing of Cables onto the sensor
- Test of fully assembled sensors
- Installation within Cassette
- Installation within Holding Structure
- Final tests within PCMAG

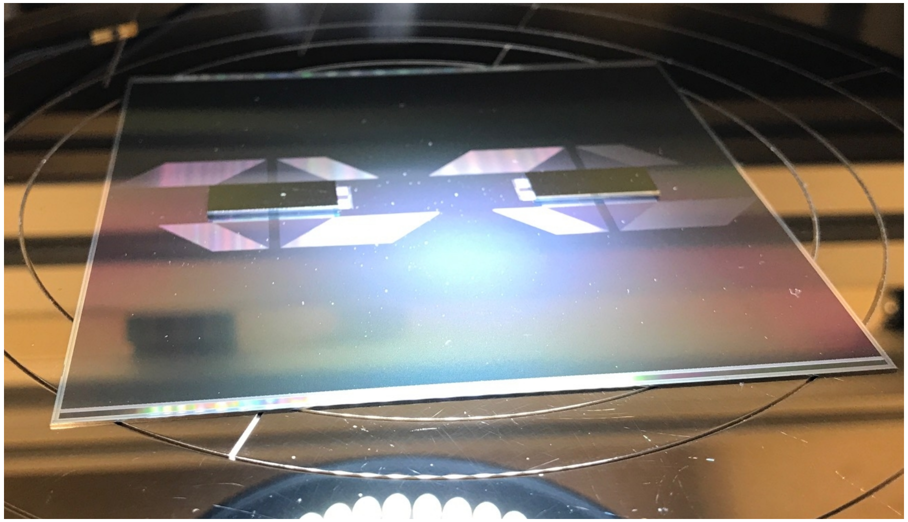


Fig.: Sensor with bump bonded KPiX on the probe station

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 late december

- Synchronisation of the TPC depends largely on the used readout system. As the ALTRO electronics do not communicate their time information, synchronization can only be done by exclusion of all other events.
- If one wishes to use the Telescope with the TPC one needs to think about some of the aspects of the synchronization.
- The telescope is being integrated into the EUDAQ framework to provide basic data taking and analysis.

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

Thank you for your Attention

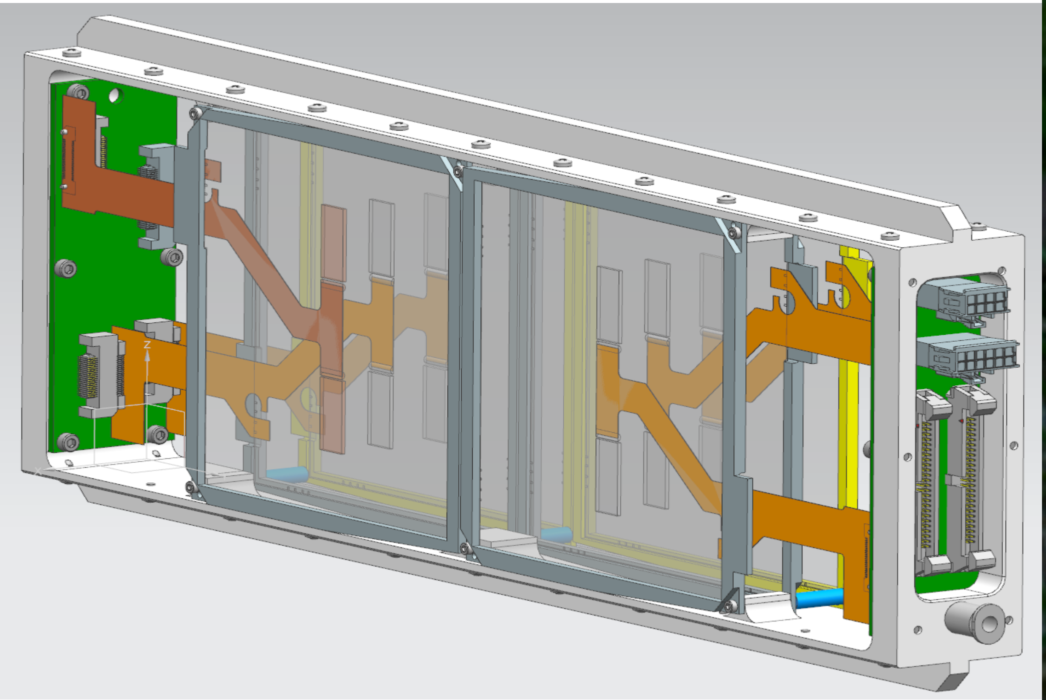


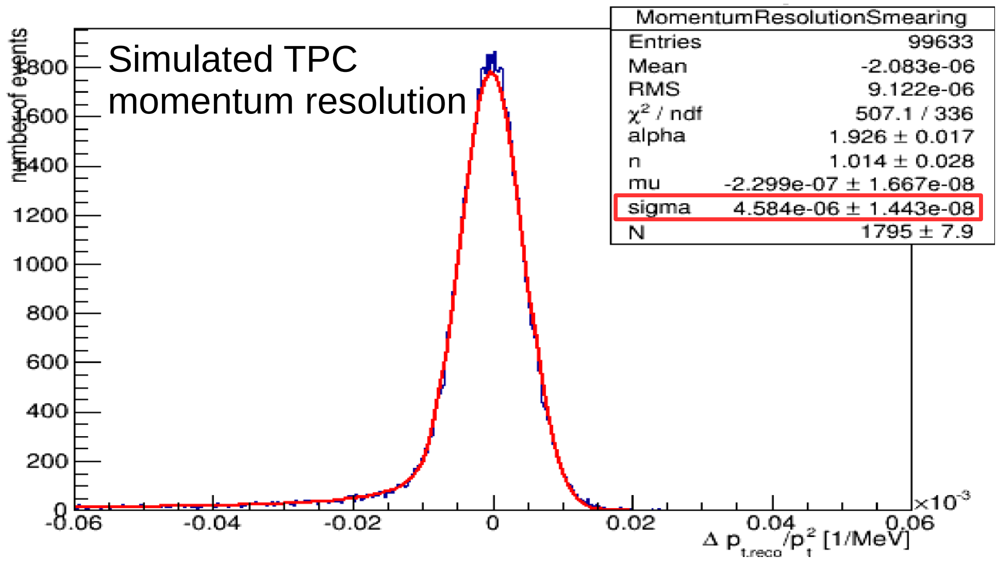
Fig.: LYCORIS Telescopium

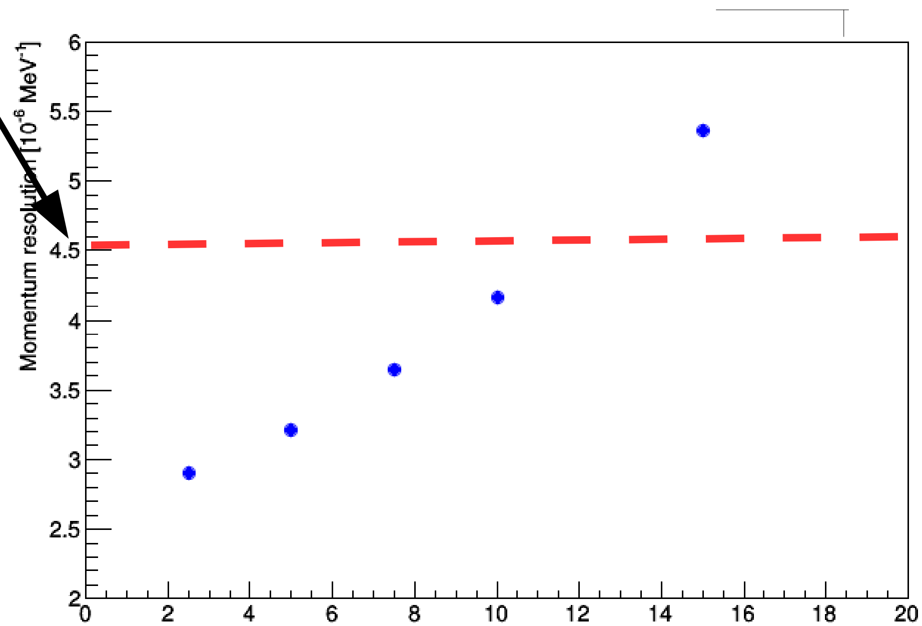
Fig.: Lycoris Radiata

BACKUP

- Requirement on telescope is that the momentum resolution is better than the TPC
  - Taken ILD requirements
  - Scaled down to LP size

  → 4.584e-6 MeV^{-1} momentum resolution



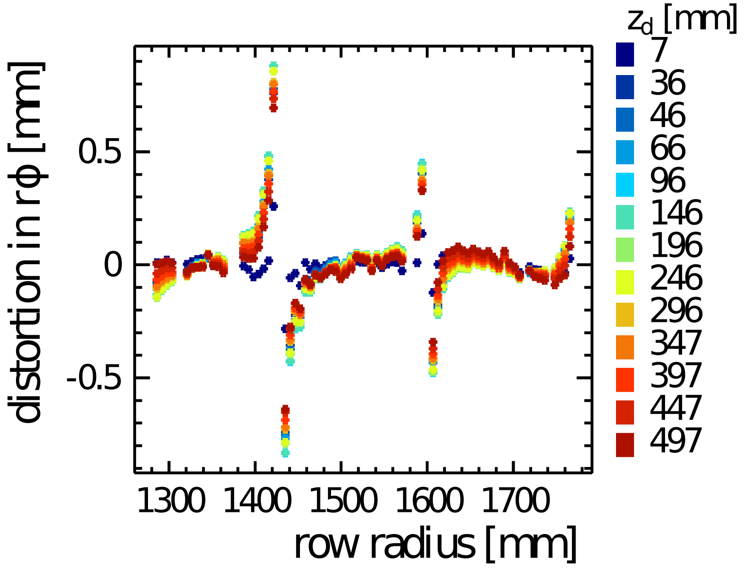


- For a maximum available space of 3 cm
- We need sensors with a spatial resolution better than 10 µm
- Not achievable with standard LHC silicon sensors

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

  Reference measurement of the position

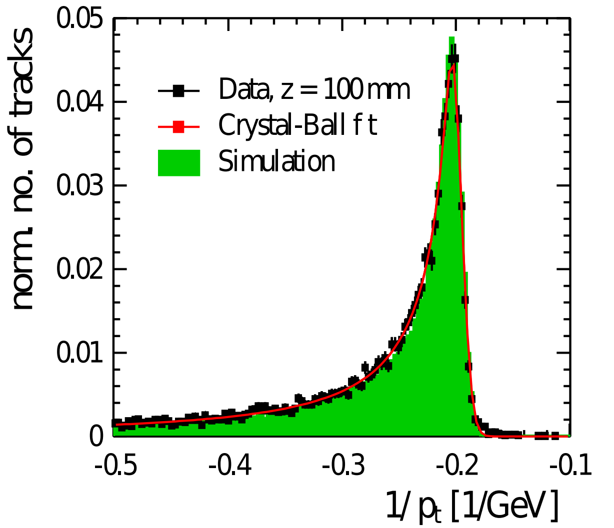
  → Studies of and corrections for field distortions in the TPC possible



- 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

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

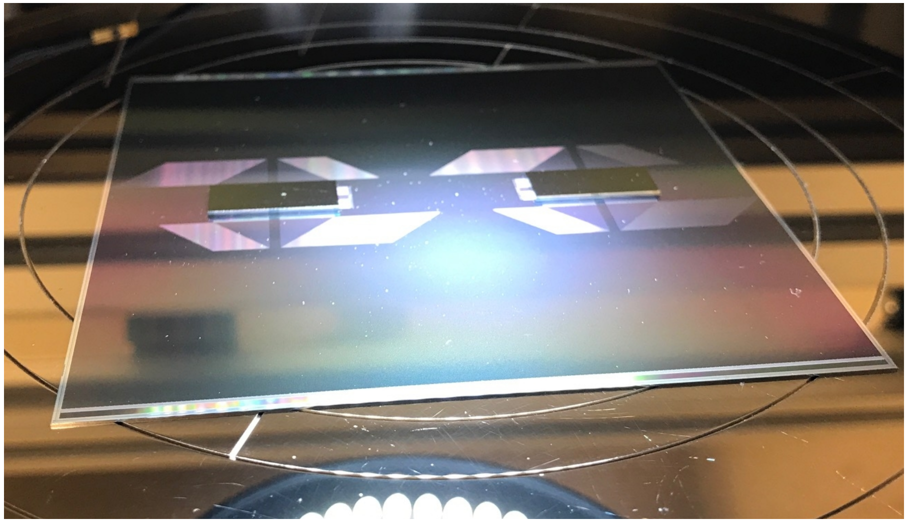
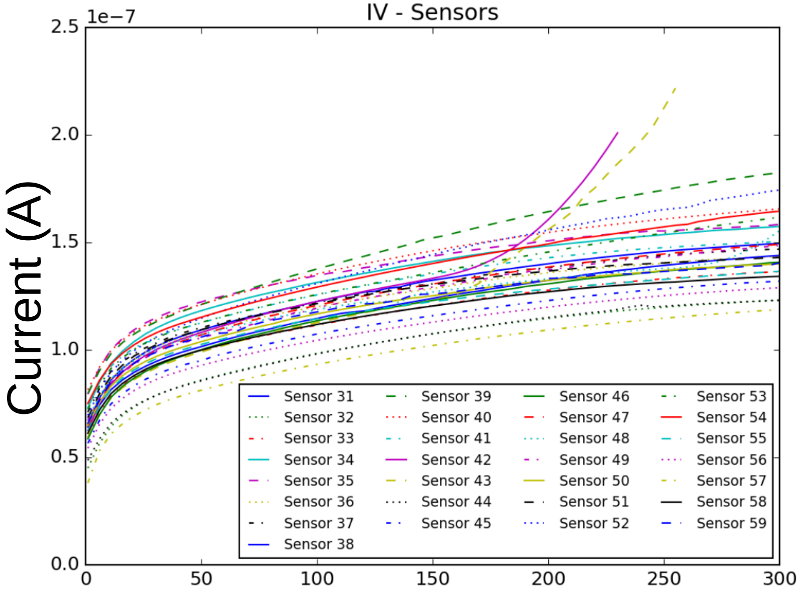
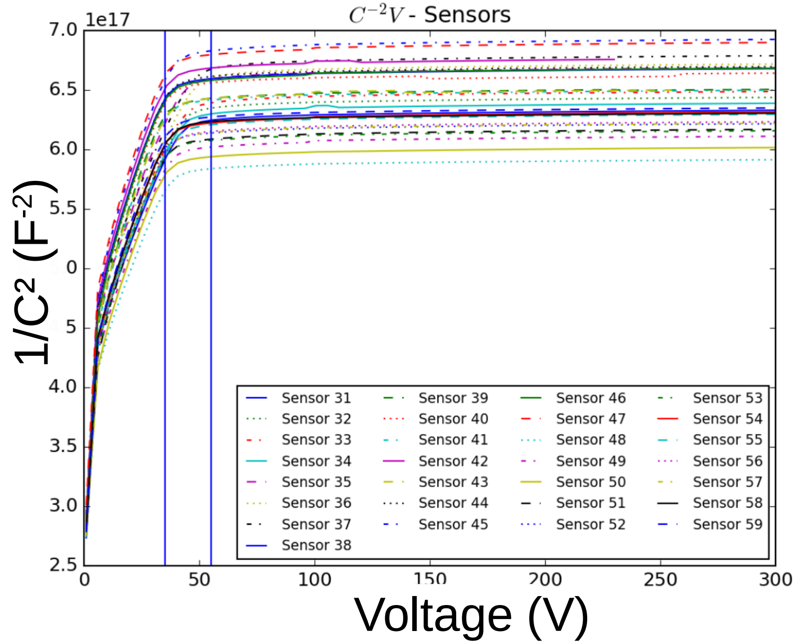
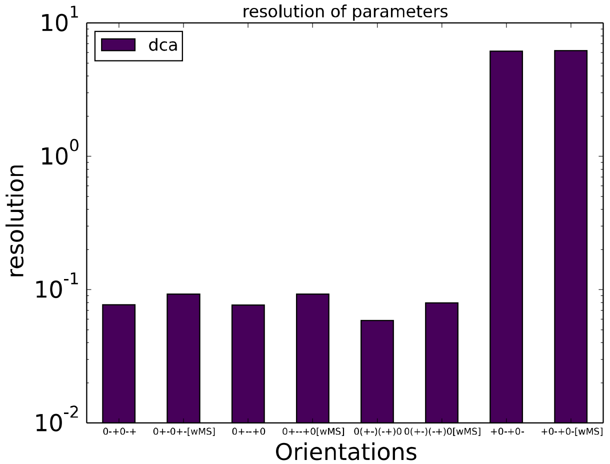


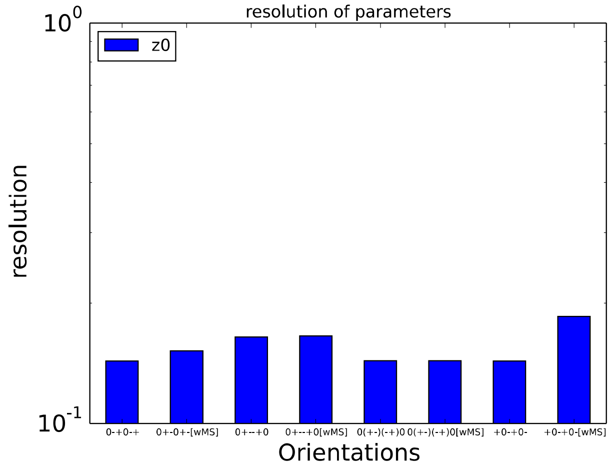
Fig.: Bump Bonded Sensor on the probe station

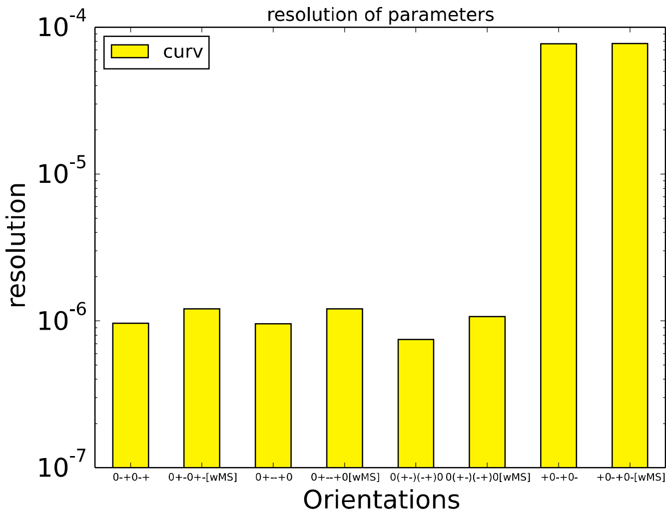


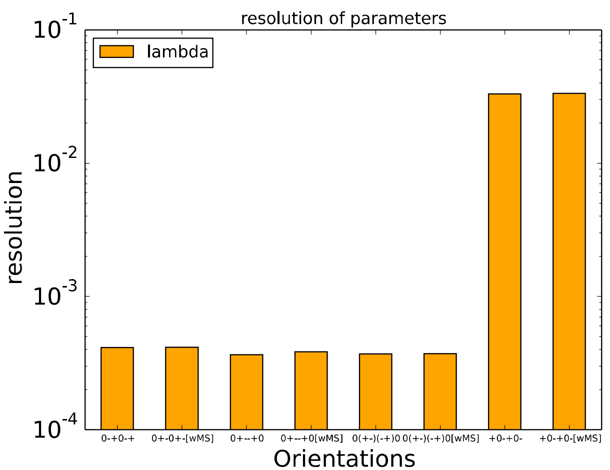


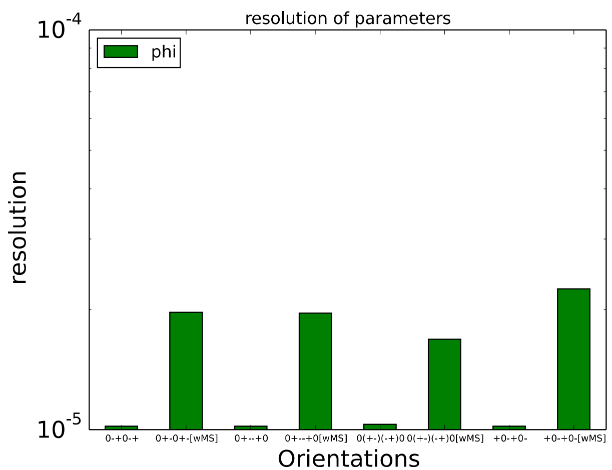
Multiple scattering impact on resolution











- 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

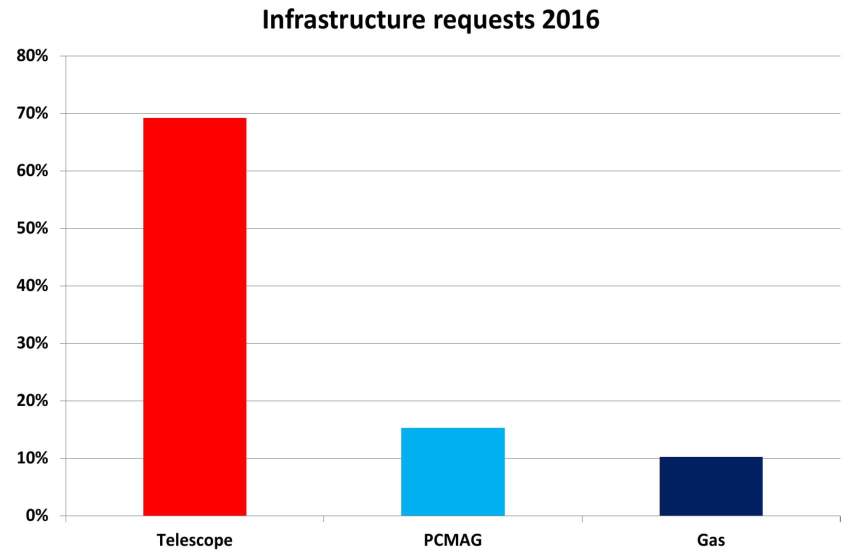


Fig: 2016 infrastructure requests

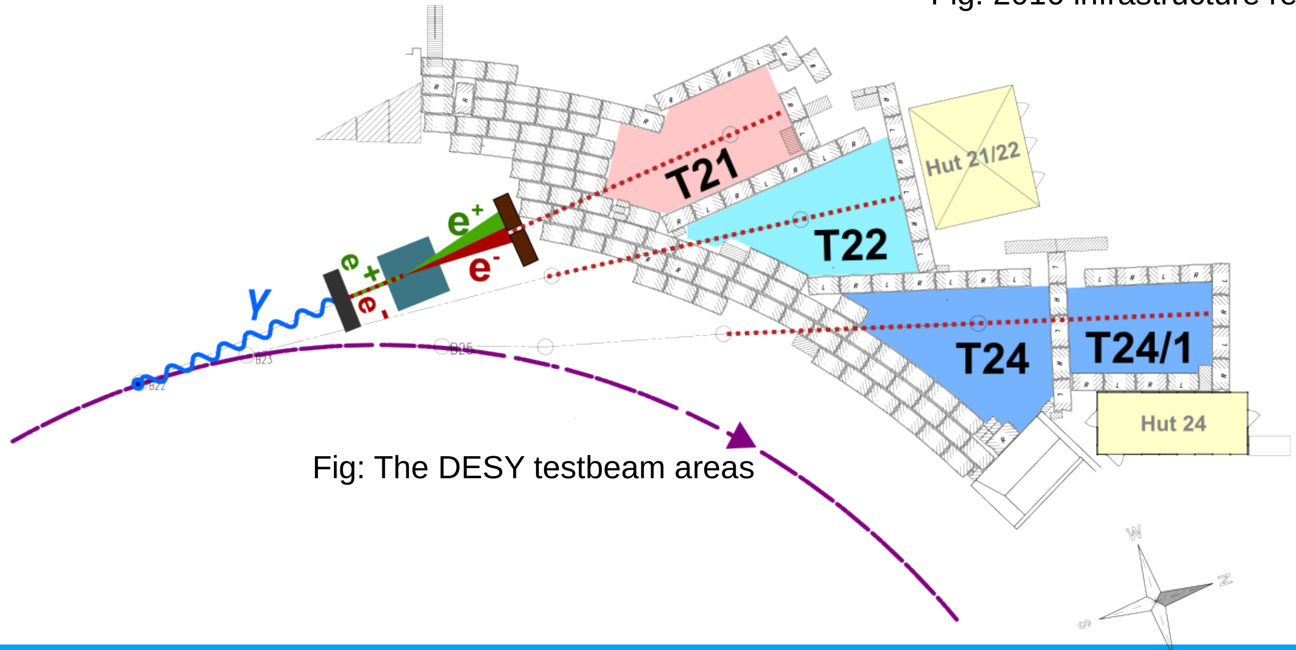
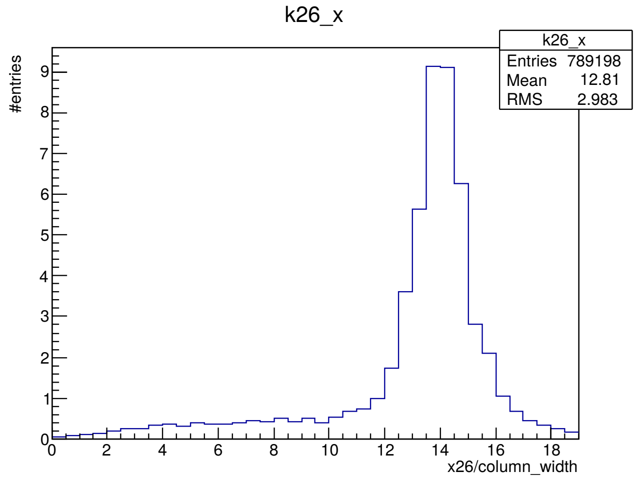
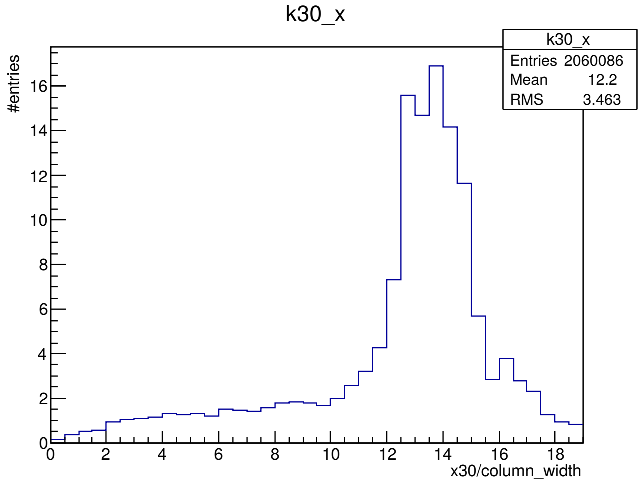
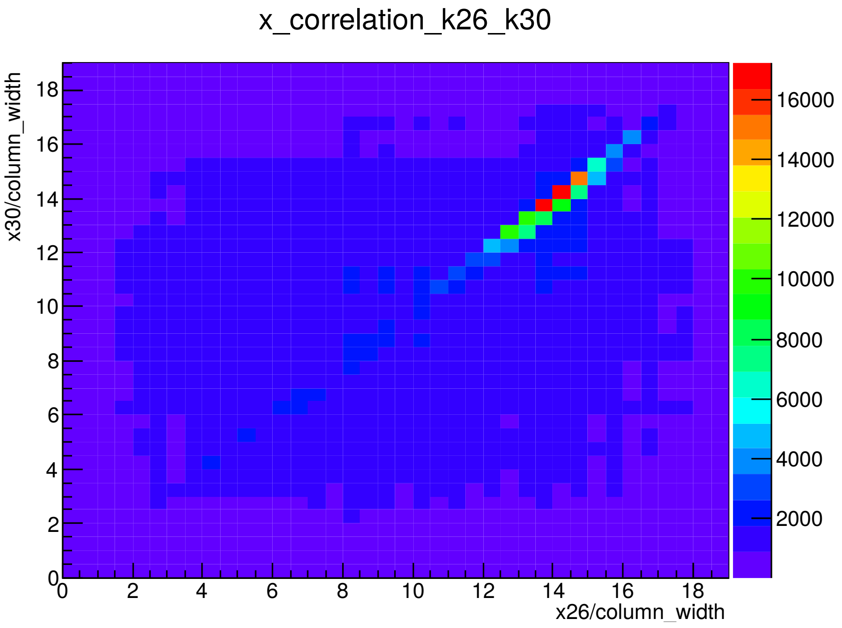


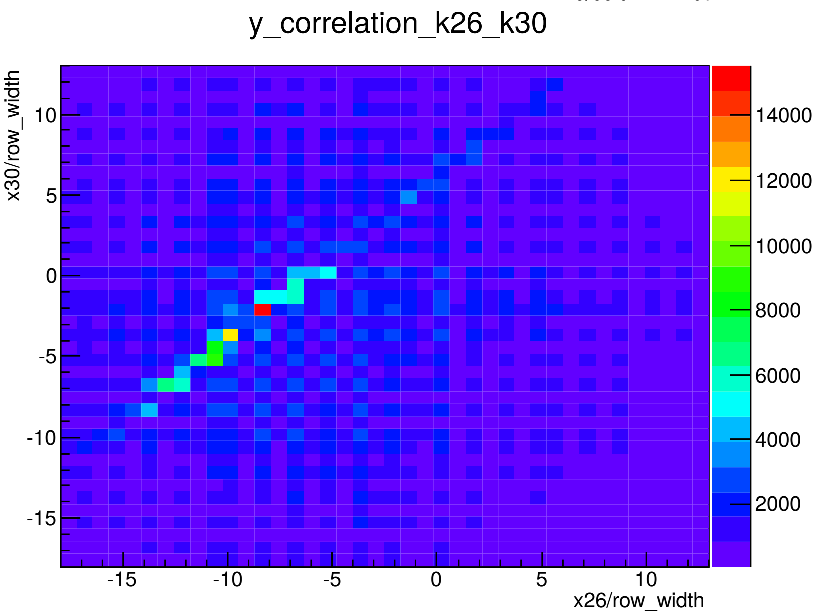
Fig: The DESY testbeam areas

Tracking with macro pixels







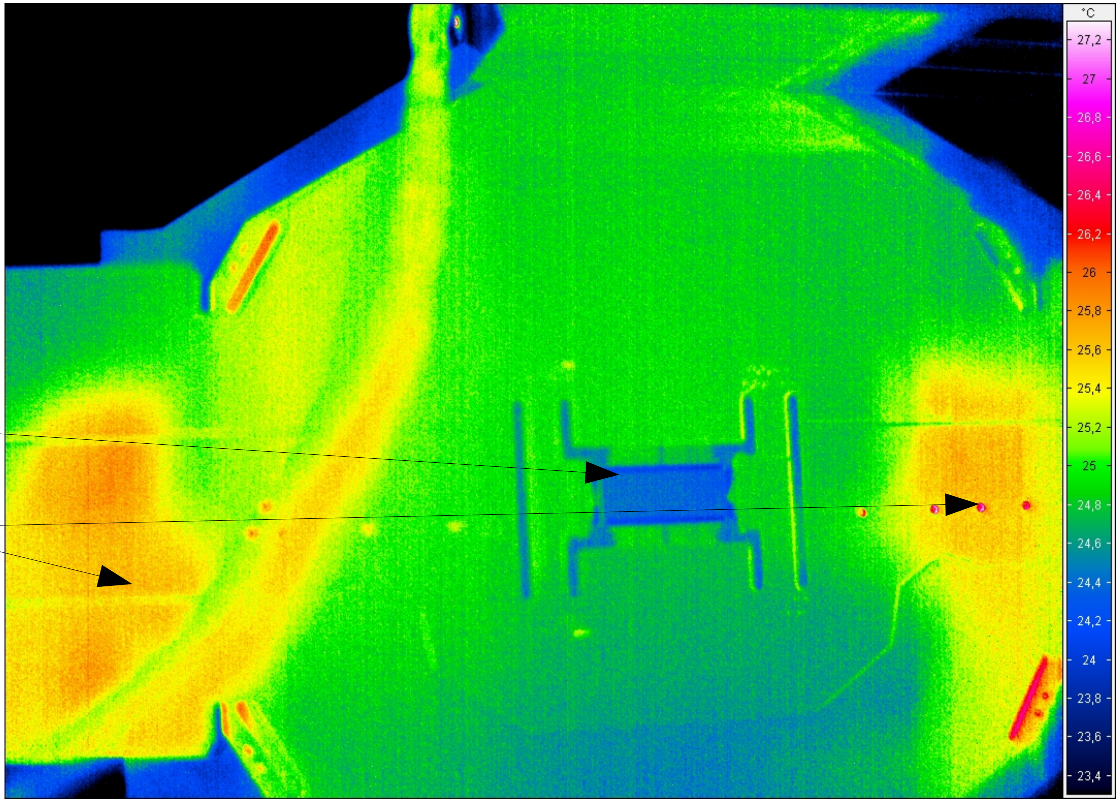


Heat and getting it out

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

KPiX Chip

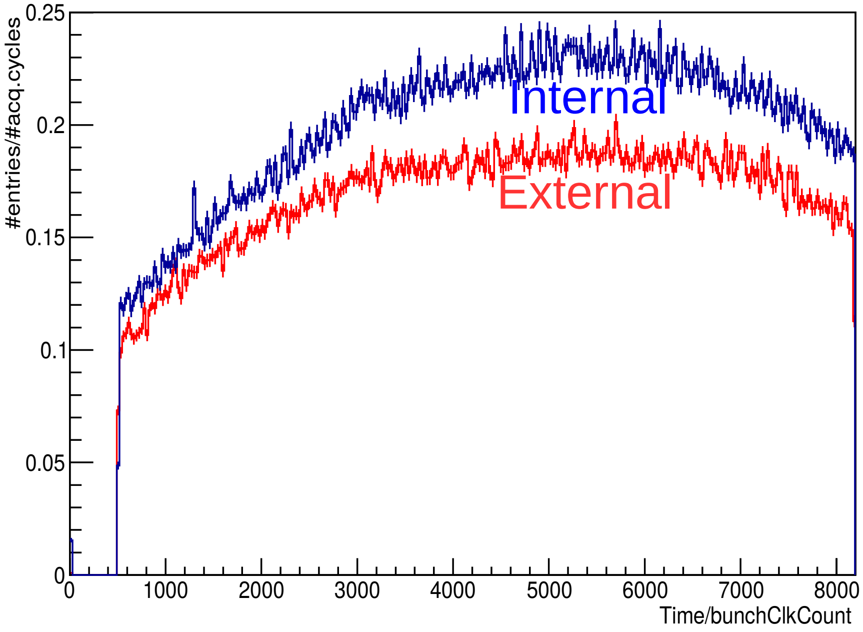
Reflection of heat sources



- Overall power consumption and heat generation is negligable

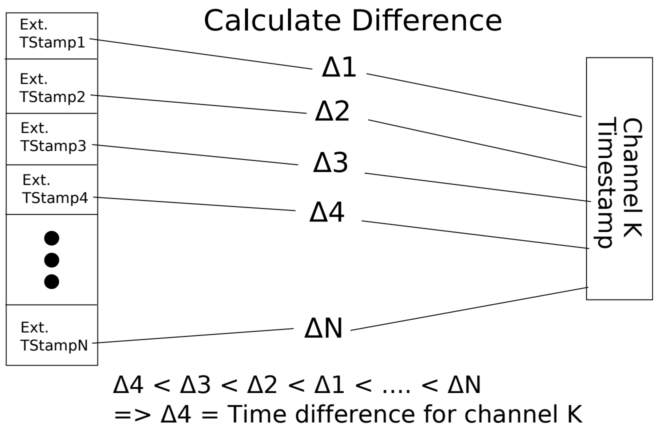
→ No active cooling needed

- 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

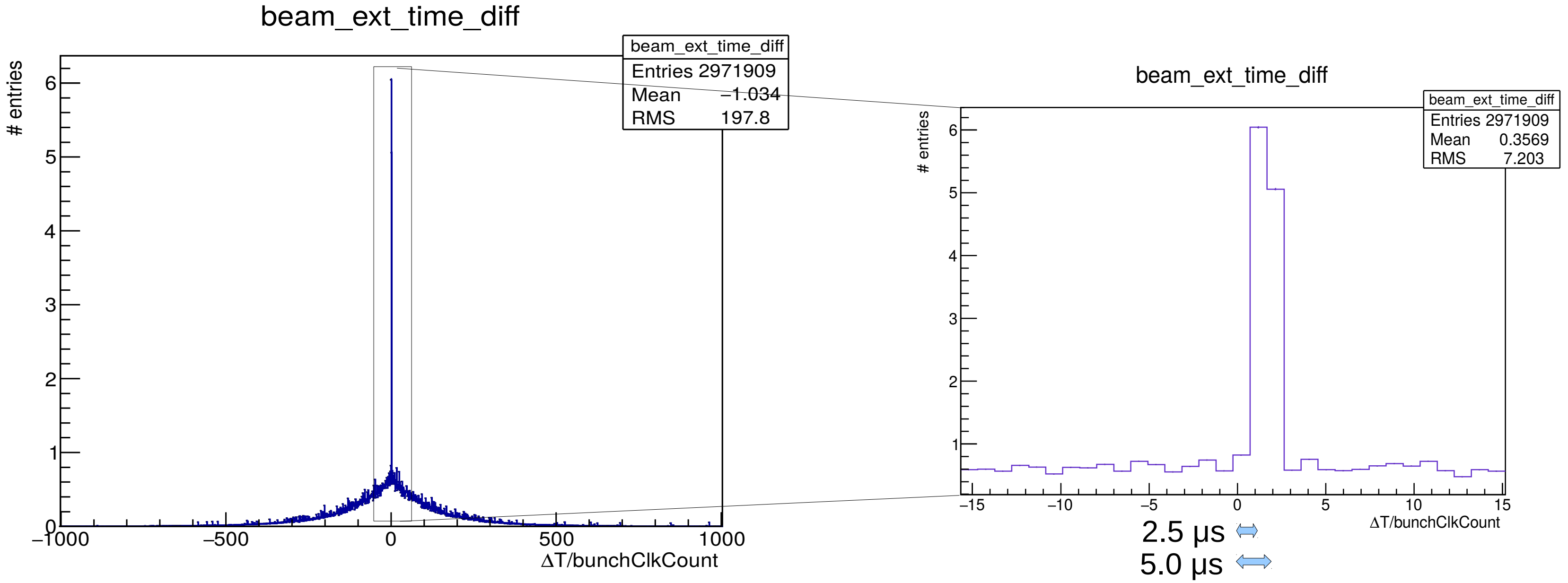


Current Event Matching

List of external timestamp values as recorded by KPiX



Timestamp for a channel



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

Old and new, KPIX and AIDA TLU

- The Old EUDET TLU was able to match events by event counting and provide a TTL/NIM signal.
  - No timestamp for events was provided by the EUDET TLU
    - The AIDA TLU will be able to provide a common clock to the devices

- OLD KPIX DAQ can only receive a start acquisition signal and an external trigger/timestamp.
  - A new board is being designed that can:
    - Receive an external clock for running
    - Send back a busy signal depending on KPIX state
    - Accept trigger and start signals