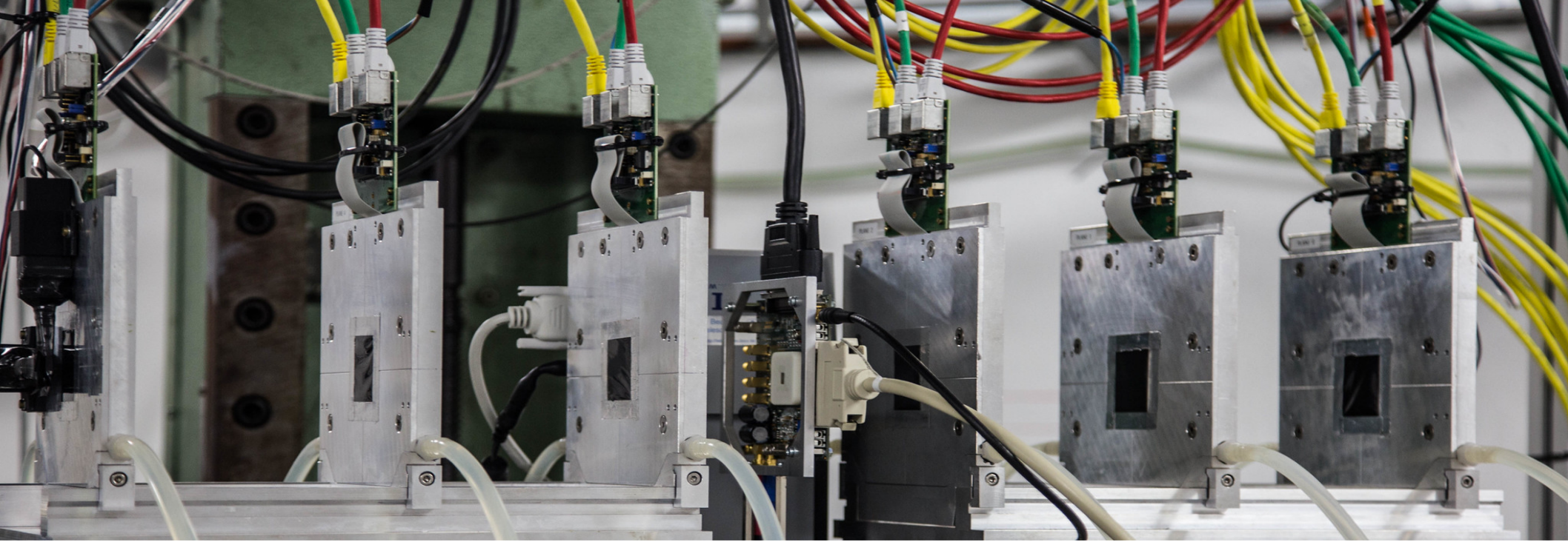


Beam Telescopes at the DESY II Test Beam Facility

Adrian Herkert on behalf of the DESY test beam crew

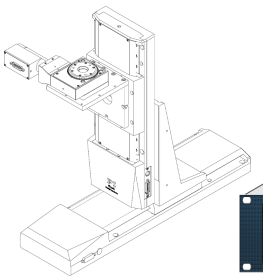
BTTB12, 17 April 2024, Edinburgh

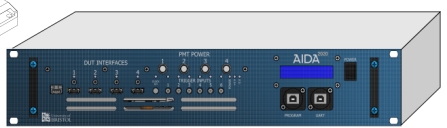
HELMHOLTZ AIDA innova DESY.

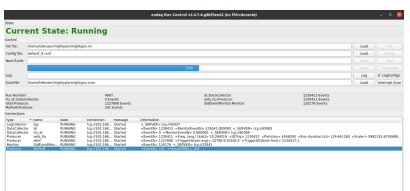
Beam telescopes at the DESY test beams

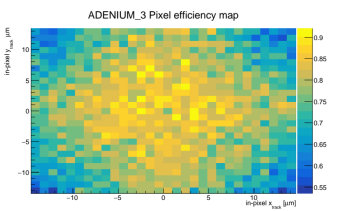
Outline of this talk

- Quick reminder of the DESY II Test Beam facility
- Overview of our current beam telescopes
  - EUDET-type (MIMOSA26)
  - Adenium (ALPIDE)
- Status of telescope upgrades
- Using our beam telescopes
  - DUT integration
    - Mechanical
    - DAQ synchronization (AIDA TLU)
    - Control software (EUDAQ2)
  - Data analysis





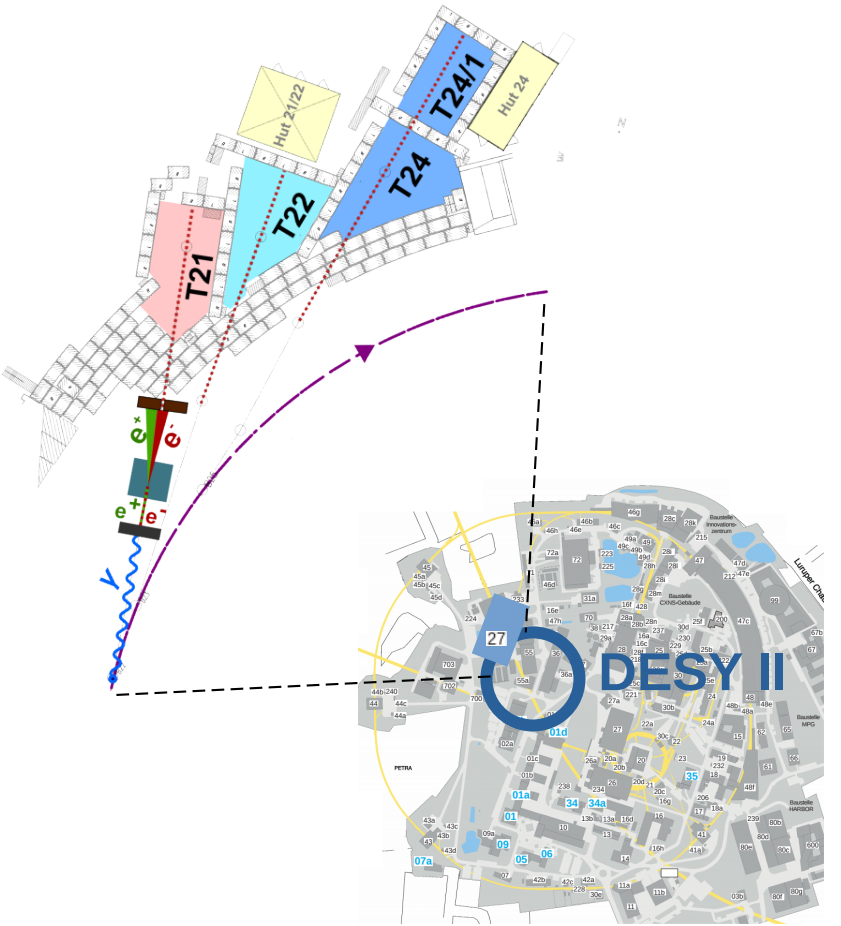




The DESY II Test Beam Facility

Quick reminder

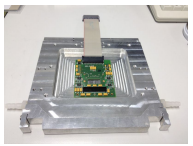
- There was a dedicated talk on Monday
- Test beam user facility
  - Located at DESY Hamburg
  - User operations ~ 40 weeks per year
- 3 independent beam lines
- $e^{+/-}$, $O(10{,}000\ s^{-1})$
- Energy between 1 and 6 GeV
  - ➔ Crucial that for “in-beam part” of beam telescope, amount material needs to be minimal



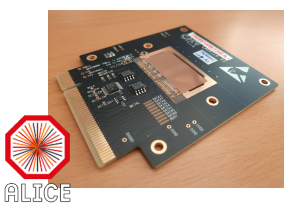
Currently available beam telescopes

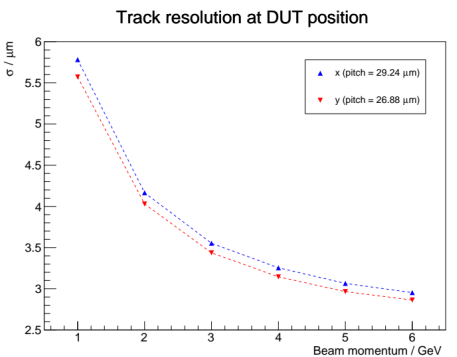
One at each beam line

- 2 x EUDET-type (TB21, TB24):
  - 6 layers of MIMOSA26 MAPS thinned to 50 µm
  - Pitch: 18.4 µm x 18.4 µm, active area: ~ 2 cm x 1 cm
  - Best possible track resolution on DUT: 2 µm
  - Readout frame length: 230 µs
  - Several legacy components



- 1 x ALPIDE-based (called Adenium, TB22):
  - 6 layers of ALPIDE (M. Mager, NIMA 824, 2016.)
  - Active area: ~ 3 cm x 1.5 cm
  - Readout frame length: 10 µs





Upgrade of the EUDET-type telescopes (1/2)

… with ALPIDE sensors

- DESY has committed in AIDAinnova (WP3.2) to deliver upgrades of the EUDET-type beam telescopes
- ALPIDE was chosen as the best available sensor option
- Adenium is first prototype from this project (Developed in collaboration with USTC)
- Performs very well, but issues with production
  - Several components' prices increased drastically
  - Didn't get full design access, nor guarantee for long-term support

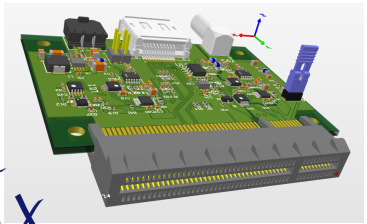
➔ Had to start over

- Second prototype being developed by DESY
  - Design for the system's two types of custom PCBs finished → Production for one prototype will start any day now
- DESY bought 60 ALPIDE sensors on chip boards
- Plan to have new telescopes come with fully integrated timing layer
  - Additional tracking layer that provides timestamps on individual hits
  - Often being used with EUDET-type telescopes already

TelePix2 poster, A. Wintle

Upgrade of the EUDET-type telescopes (2/2)

Components of the second prototype



Custom chip board interface PCB

6x

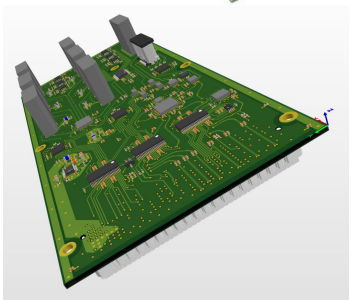
ALPIDE

Bonded to chip board by ALICE

Enclustra System on module (SoM), e.g. ME-XU1-15EG-2I-D12E

Enclustra base board

Convenient solution for connecting SoM

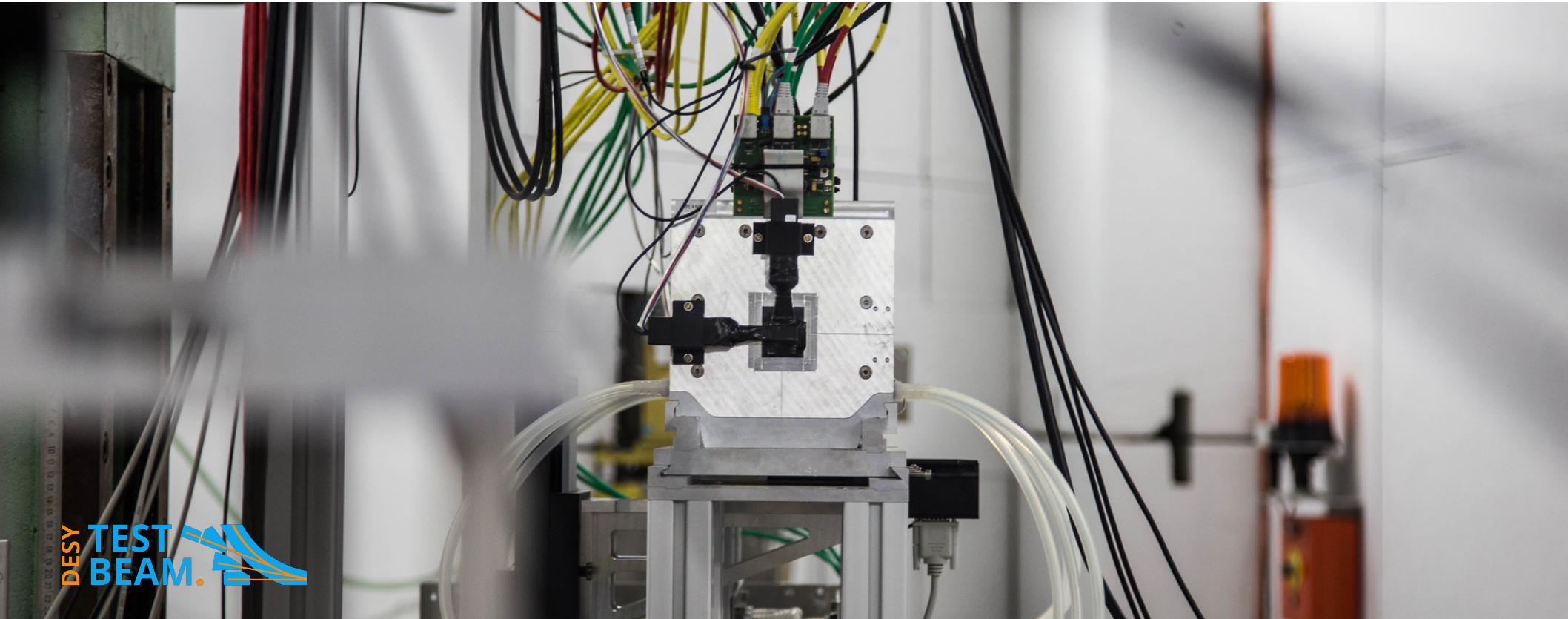


Custom hub PCB Interface between SoM and sensor layers/TLU

PC running EUDAQ2

TLU sending clock and triggers

Using a beam telescope at DESY



A word on documentation

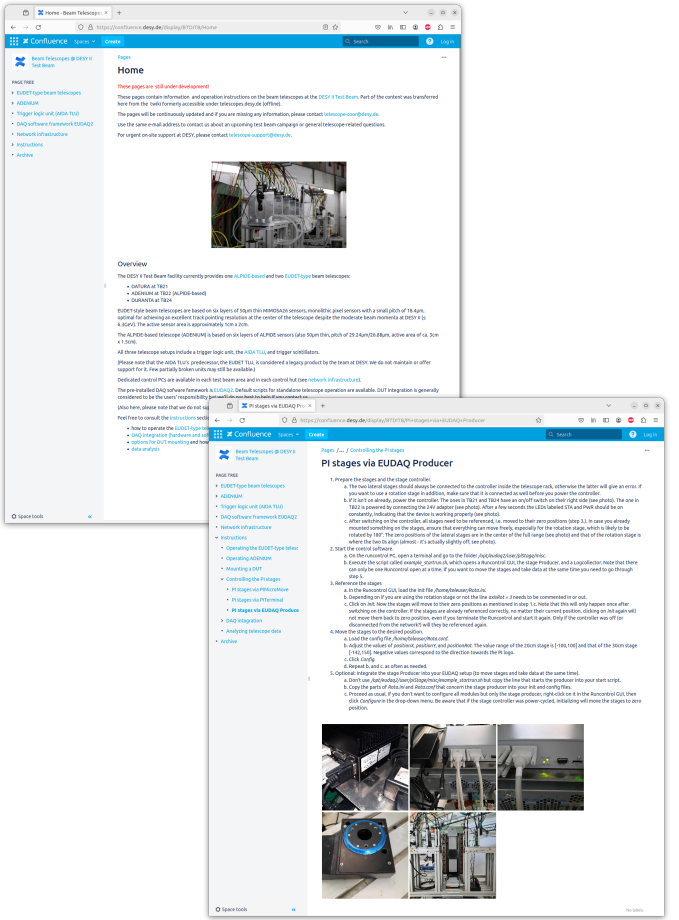
Always work in progress ...

- Situation hasn't been ideal lately
- Since twiki went down there has been a confluence space that has never been fully comprehensive/complete:

  https://confluence.desy.de/display/BTDITB

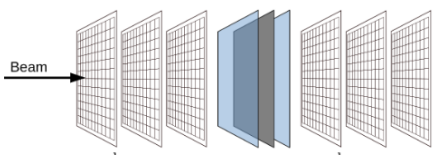
  - Since recently, DESY is phasing out the use of confluence
    → no longer reachable from outside DESY network
  - To be moved to new public space
    (by DESY IT, not known when this will be finished)
  - Until then, if you're on site, you can still find instructions there on:
    operating the telescopes, operating the PI stages, …
- If you have any questions before or after beam time:

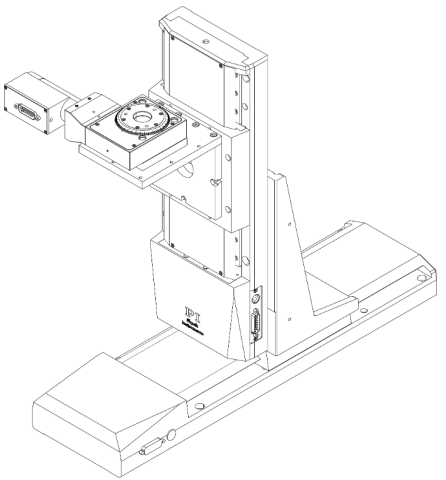
  telescope-coor@desy.de

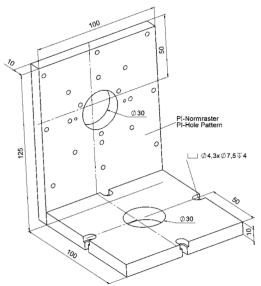


Mechanical DUT integration

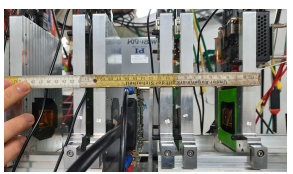
… and positioning of telescope layers

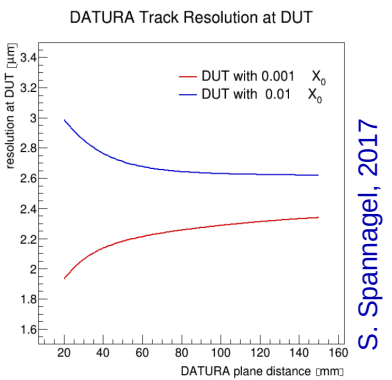






- Intended to place DUT in center
- XY- and rotation tables provided by DESY with different mounting options (max. load: 8kg)
- z-positions of the telescope layers can and should be adjusted
  - Optimal geometry depends on material budget of DUT
- GBL track resolution calculator:
  https://github.com/simonspa/resolution-simulator
- **Don’t forget to measure z-positions!**





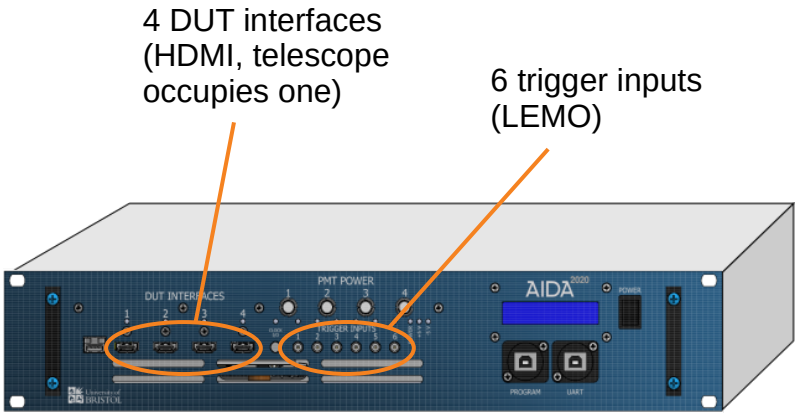
S. Spannagel, 2017

DAQ “synchronization”

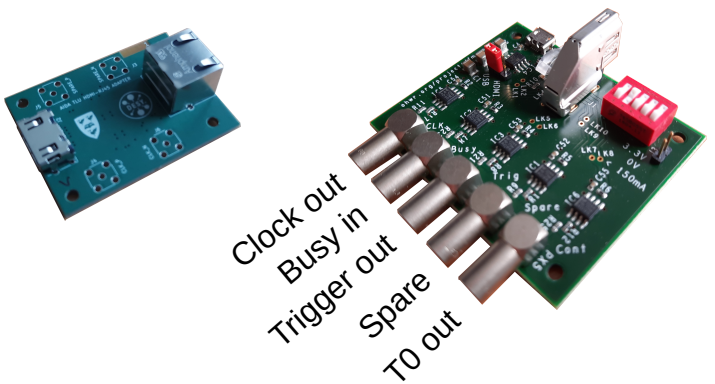
The other crucial thing to fix before data taking!

- The Trigger Logic Unit (TLU) exists for this purpose
  - Receives trigger signal
    (by default scintillator+PMT assemblies provided by DESY)
  - Sends common trigger to DUTs (and telescope)
- TLU has different operation modes, in which specific additional signals are exchanged with a DUT (see also manual):
  - Handshake (“old” EUDET mode)
  - No-handshake (so-called AIDA mode)
- TLU will also get an upgrade in scope of AIDAinnova

  → **If you are interested in getting one from a potential new production, let us know soon!**



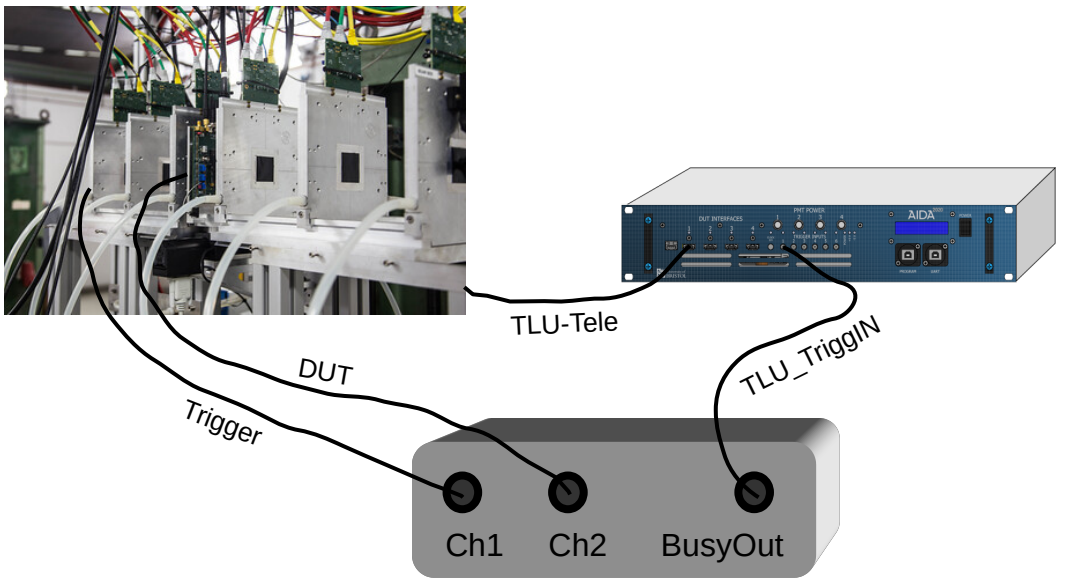
https://ohwr.org/project/fmc-mtlu/blob/master/Documentation/Main_TLU.pdf



Examples of how to utilize the TLU (1/2)

1.: Minimum amount of integration

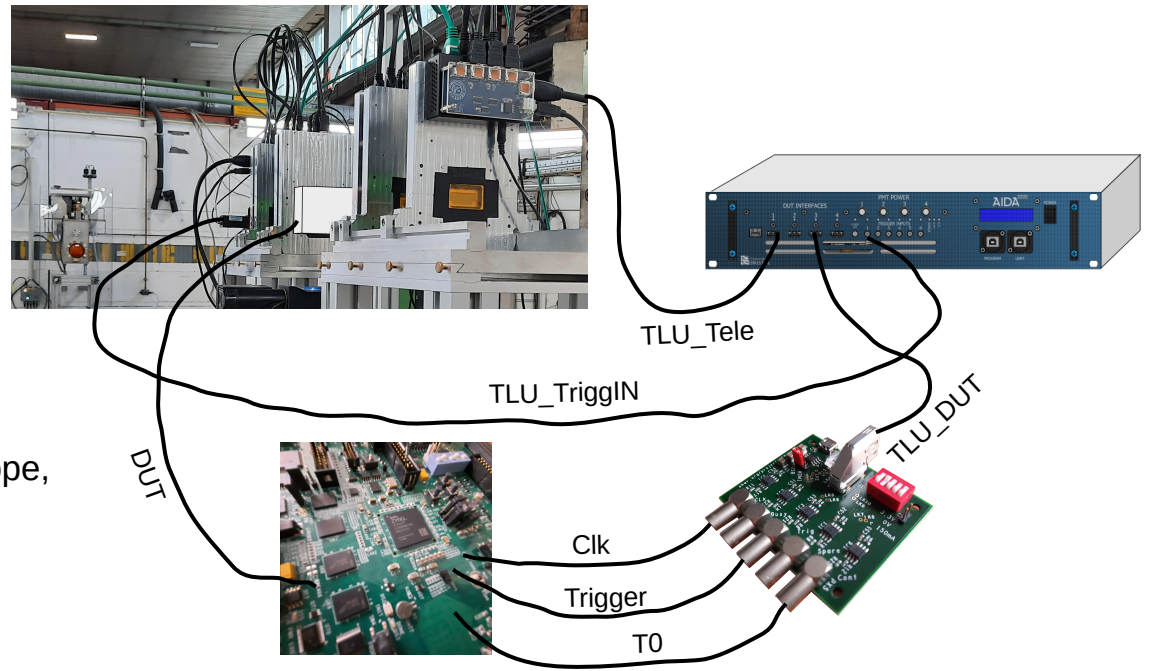
- User DAQ system: Off-the-shelf digitizer
  - 180 µs busy, 100 ns buffer
- Straight-forward approach (triggering DUT by TLU won't work), since **TLU has latency of 150 ns**
  → Do it the other way around
- This introduces another issue to take care of: MIMOSA telescope can be busy up to 230 µs
  → Configure TLU to still register trigger although telescope is still busy
- Still remaining: Possibly multiple or "wrong" telescope tracks per trigger
  → Efficiency measurement not really possible



Examples of how to utilize the TLU (2/2)

2.: Truly synchronous

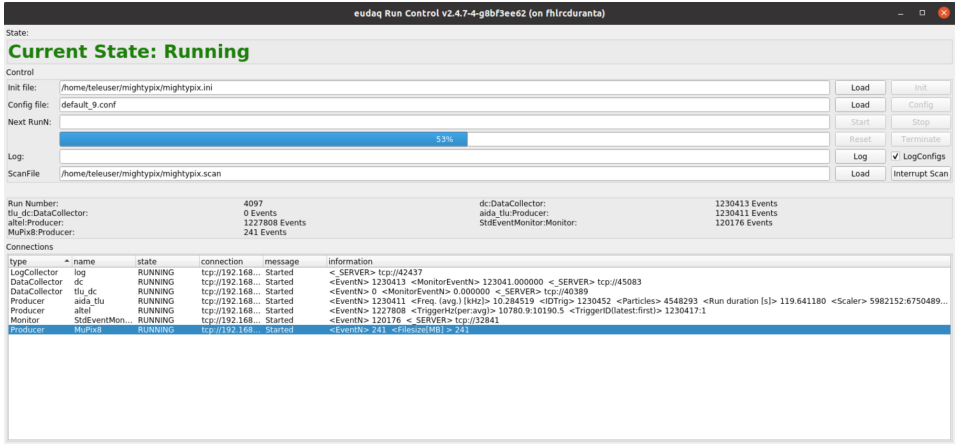
- User DAQ with custom firmware
  - Counter based on external clock provided by TLU
  - Reset on T0
- Synchronization via trigger timestamps
- If DUT has triggered readout
  based on frames shorter than those of telescope,
  same issue as in ex. 1 remains
  → Can be solved with timing layer



The software side (1/2)

EUDAQ2 – A framework to interface multiple DAQ systems

- TLU and the telescopes are integrated in it
- Their operation is steered via Runcontrol GUI
- TLU needs to be configured according to the used setup
  → This requires some adjustment in the TLU part of the EUDAQ2 config file




```
# DUTs
DUTMask = 0x1

# Define mode:
DUTMaskMode = 0xFC # 1st is reading out Trigger ID

# Coincidence of input 0 to 3 (telescope)
#trigMaskHi = 0x00000000
#trigMaskLo = 0x00008000
```

- Example start scripts and and config files in repo: /eudaq/user/eudet/misc/. (https://github.com/eudaq/eudaq)

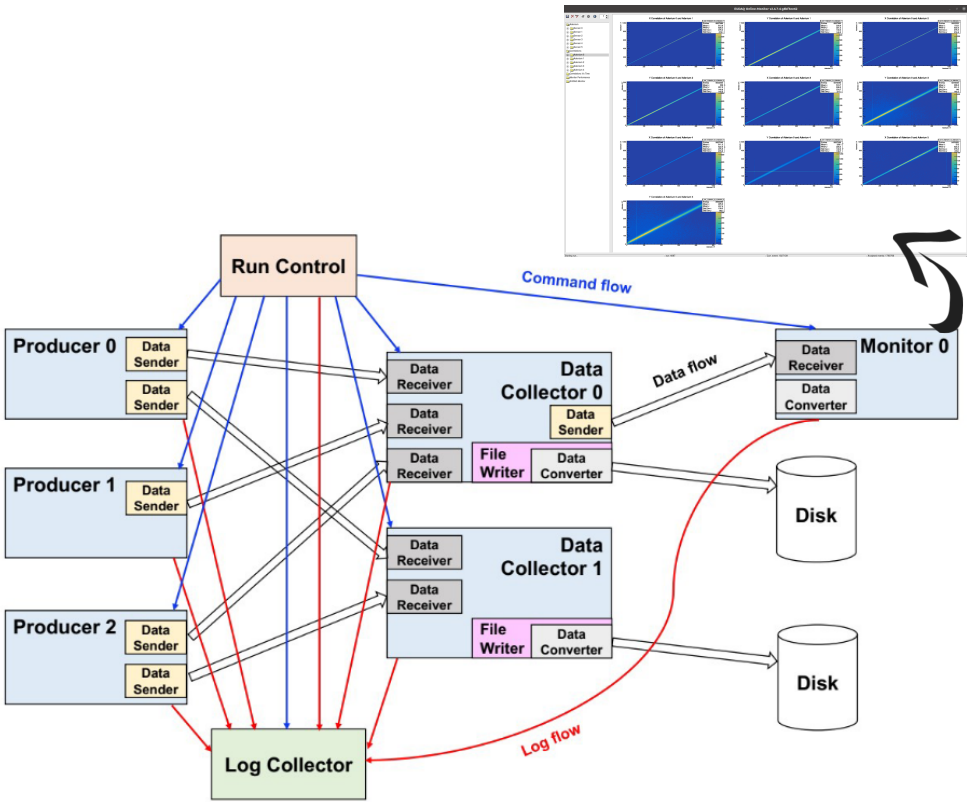
The software side (2/2)

Integration of a DUT in EUDAQ2

- Not a must but makes things more convenient
- Modules most likely to be implemented first:
  - *Producer* represents a device

```
void DoInitialise() override;
void DoConfigure() override;
void DoStartRun() override;
void DoStopRun() override;
void DoReset() override;
void DoTerminate() override;
void RunLoop() override;
```

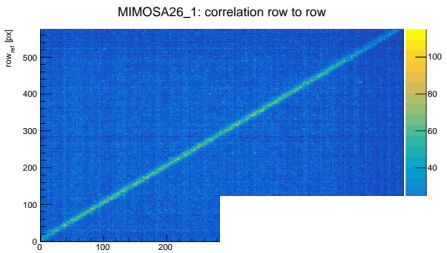
  - *Converter* converts raw data into EUDAQ2 *StdEvent* format
- Examples for user code again in repo: /eudaq/user/.
  Includes also ‘Dummy’ and ‘example’



Data analysis

Just a very rough outline

Corryvreckan Hands-on

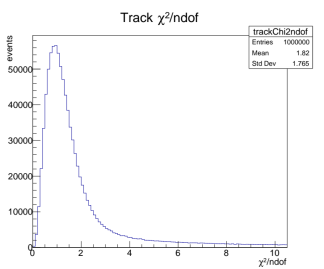


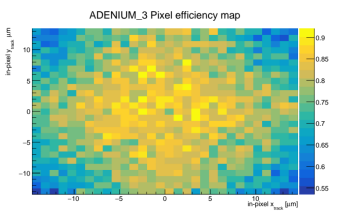
- Telescope data comes in the form of pixel hits in raw data format (sorted by events corresponding to telescope readout frames)
- For any track-based DUT analysis one needs to go through full tracking part of the analysis
- Recommended framework: Corryvreckan
  https://project-corryvreckan.web.cern.ch/project-corryvreckan/
  https://gitlab.cern.ch/corryvreckan/corryvreckan
- To perform also DUT analysis within Corryvreckan (recommended) one has to implement *EventLoader* module or EUDAQ2 *Converter* (to convert DUT data into “Corryvreckan format” and fill it into the right events)
  - Script to produce dummy module in repo: corryvreckan/etc/addModule.sh

```
[Tracking4D]
track_model="gbl"
momentum=4GeV
min_hits_on_track = 6
spatial_cut_abs = 200um, 200um
exclude_dut = true
unique_cluster_usage=true

[AlignmentTrackChi2]
```

```
orientation = -0.0405081deg,0.0308251deg,0.617706deg
position = 404.777um,3.063um,-404mm
```





Closing remarks

Contacts

- For questions before/after beam time:
  telescope-coor@desy.de
- For on-site support:
  telescope-support@desy.de

Call for your support

- If you publish or present results based on data taken at the DESY II Test Beam, please include the following acknowledgement:

  “The measurements leading to these results have been performed at the Test Beam Facility at DESY Hamburg (Germany), a member of the Helmholtz Association (HGF).”

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under GA no 101004761.