Upgrading the Beam Telescopes at the DESY II Test Beam Facility

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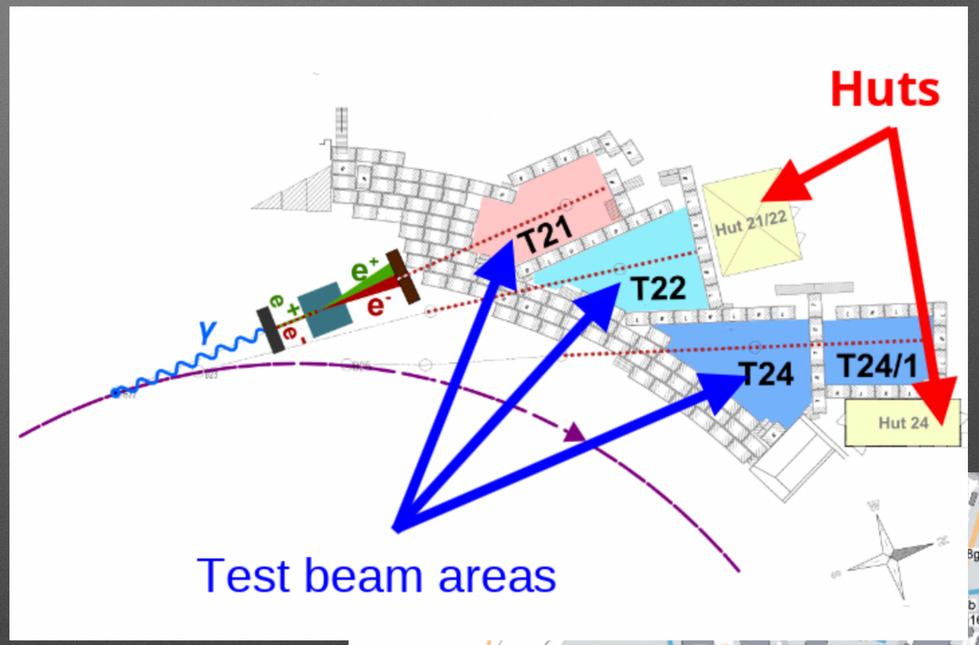
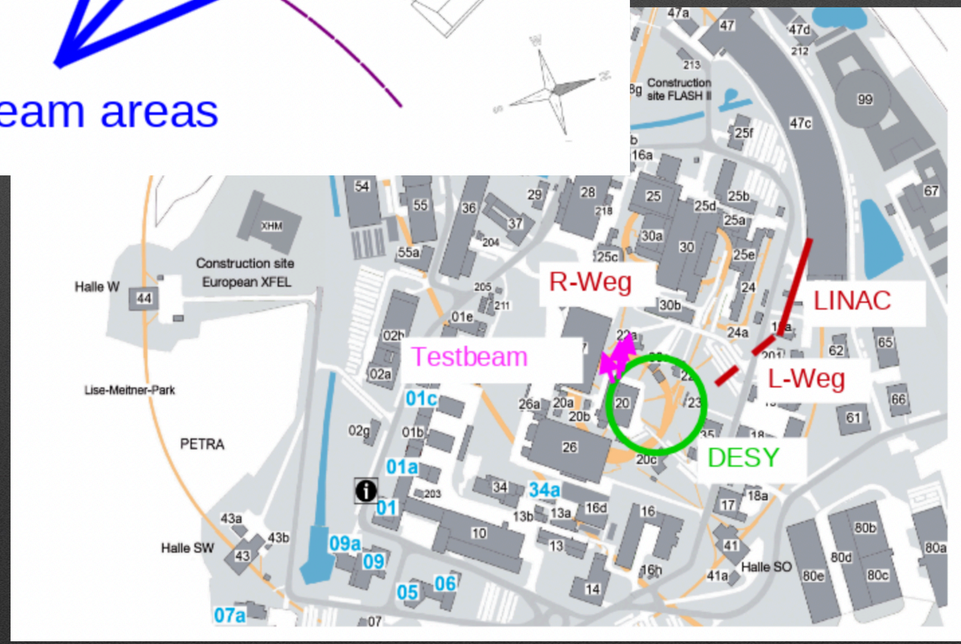
The DESY II Test Beam

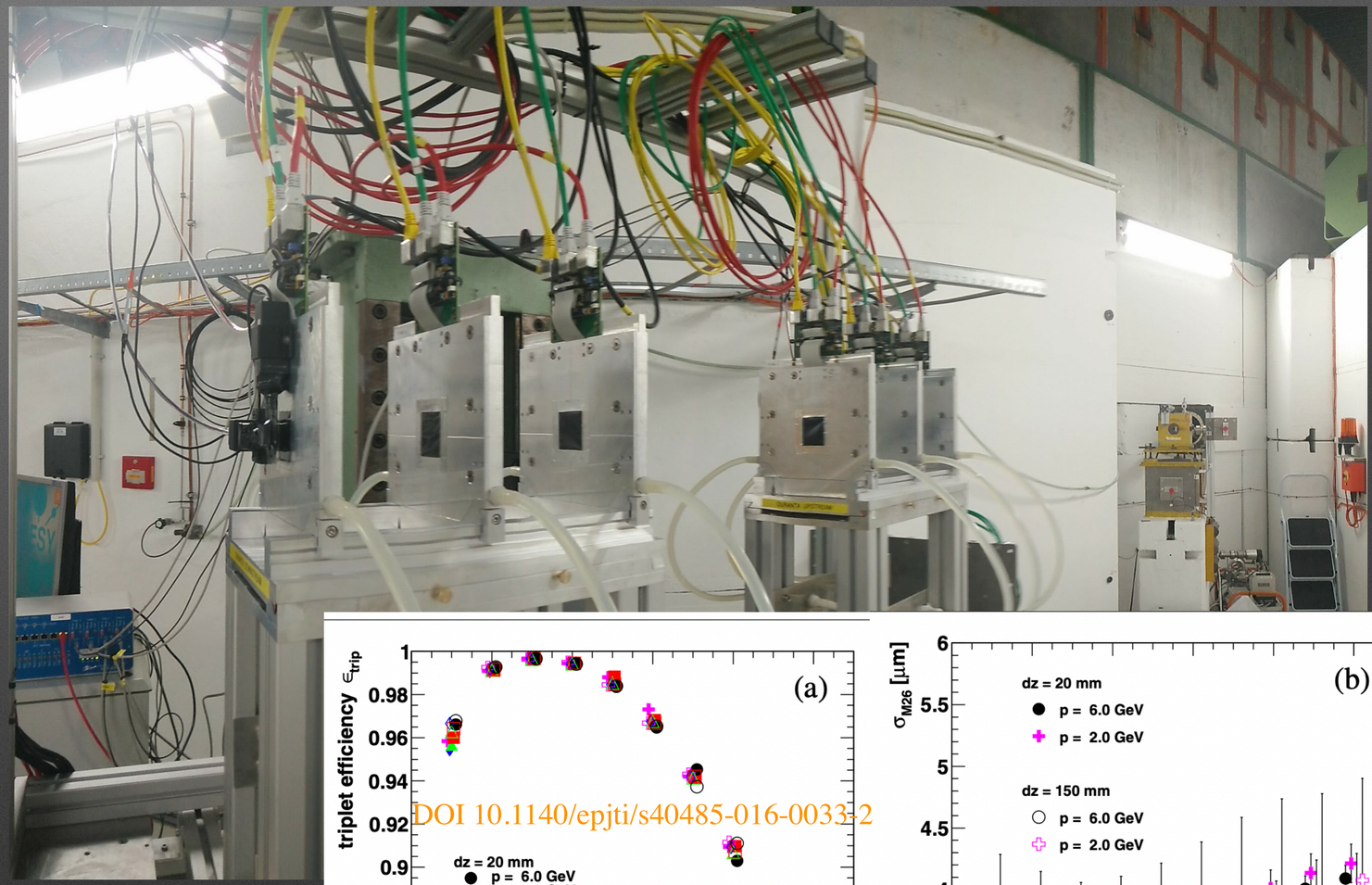
- Facility parasitically fed by DESY II synchrotron (Petra III injector): 1 bunch per fill, 30ps long, 1 MHz repetition rate
- Beam is generated via 7um thick carbon fibres creating Bremsstrahlung photons, that are converted to electron positron pairs on a copper target
- Momentum range from 1-6.3 GeV/c, magnet to select either e+ or e-
- Particle rates of up to a few 10kHz, momentum dependent
- Essentially single particle events
- Significant effort to provide excellent user experience: Huts, Network/BNC/optical patch panels, stages, cooling, gas connections,…
- Maximum user control: Rate, Collimation, Area Interlock, momentum, particle type





The EUDET Style Reference Telescopes

- 6 Layers of MIMOSA26 sensors
  - 18um pitch
  - 1x2cm active area
  - 115us rolling shutter readout, no timestamps
  - >10 years in operation
  - Active cooling
- Spatial resolution on DUT down to below 2um
- Mounted on xy-table
- DUT mount on xy/rotation stages
- Fully integrated into EUDAQ/AIDA-TLU



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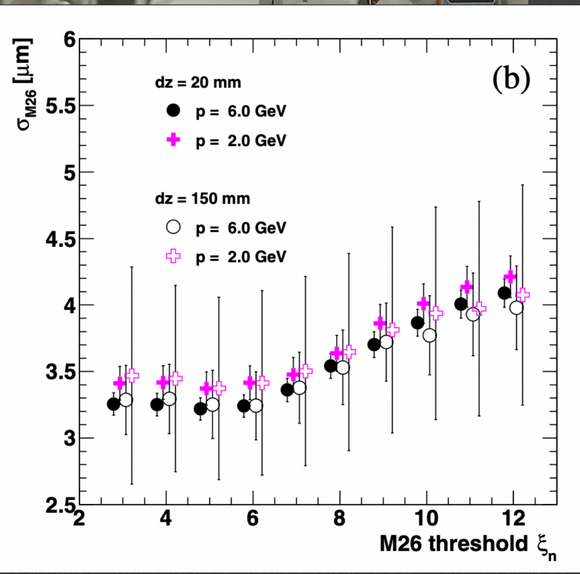
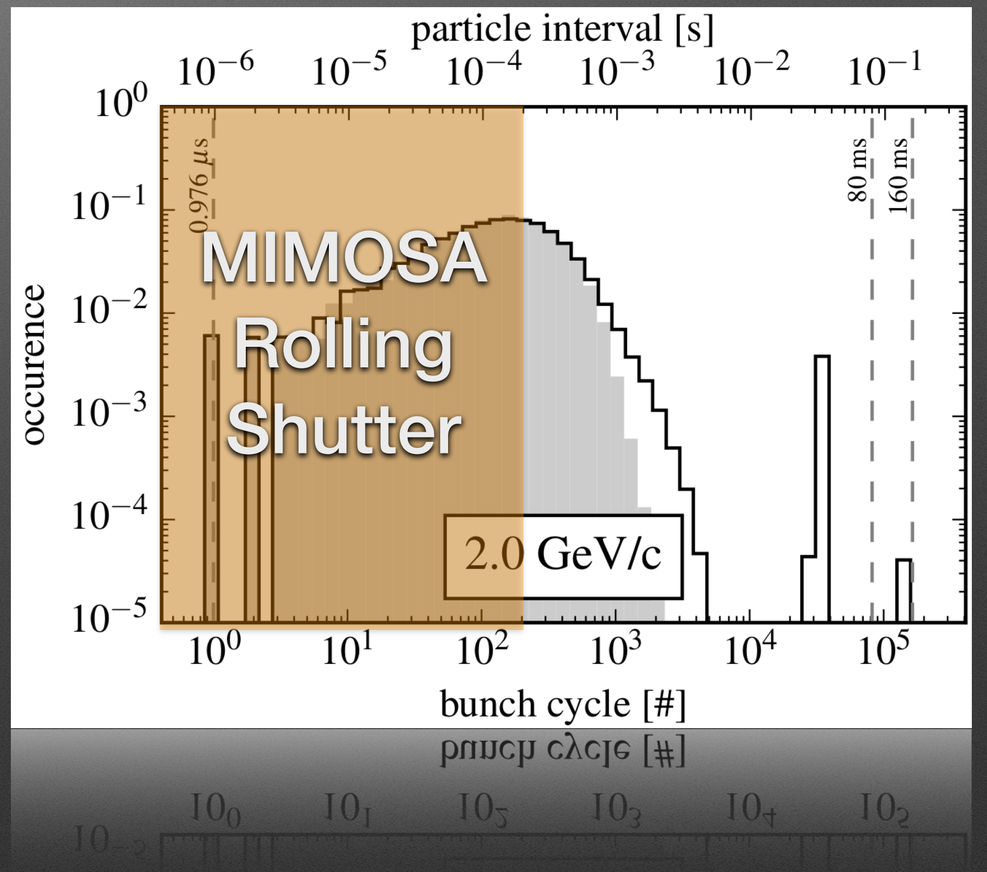


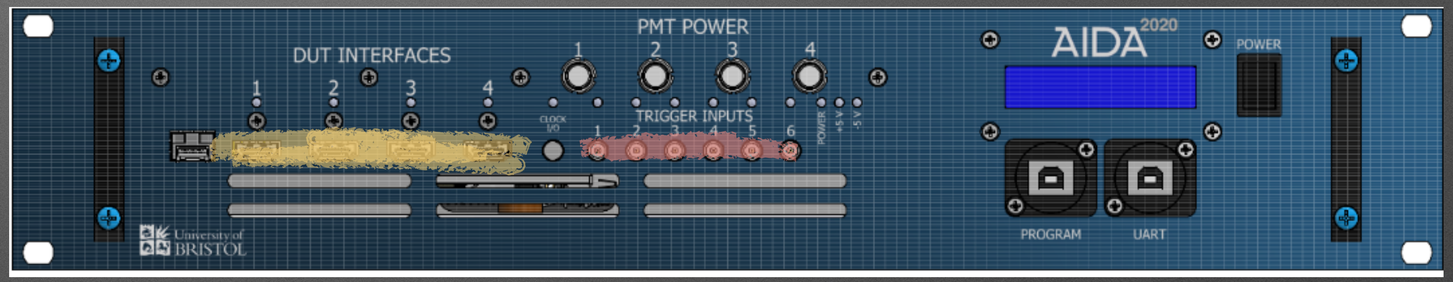
Limitations of the current setup

- No timestamp on MIMOSA sensors -> We need to store the current and next shutter cycle, totalling to up to 230us readout time
- Used to record only one trigger, limits the rate
- If more than one particle per event -> confusion, require additional timing layers.
- AIDA TLU supports higher trigger rates and can ignore the busy from individual channels
- However, high multiplicities take longer to reconstruct and most R&D projects have small size devices to test
  - Region of interest trigger can drastically reduce the amount of data



User Integration: AIDA TLU and EUDAQ2

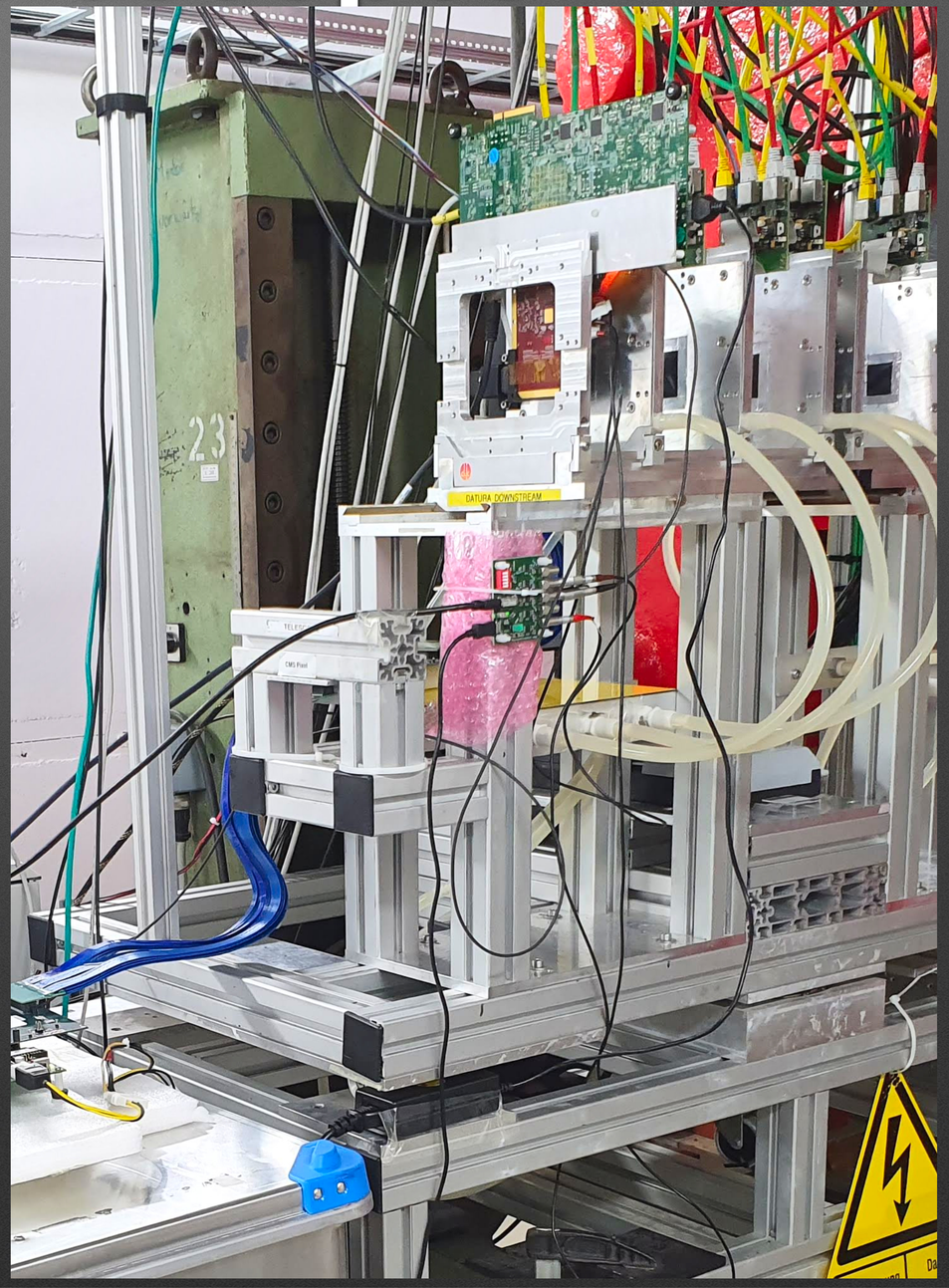
- Supporting up to four devices
- Integrated trigger logic
- Fully integrated into EUDAQ2
- 3 different modes of operation
  - Trigger-ID exchange → Little chance of failure, slow
  - Simple trigger mode → Fast, but desynchronised when one trigger is missed
  - Clock and T_0 distribution → Fast, reliable, modern, requires FPGA/intelligent logic
  - EUDAQ2 as software interface: Automatic run control, data handling and online monitoring



AIDA 2020

Improving the Telescopes

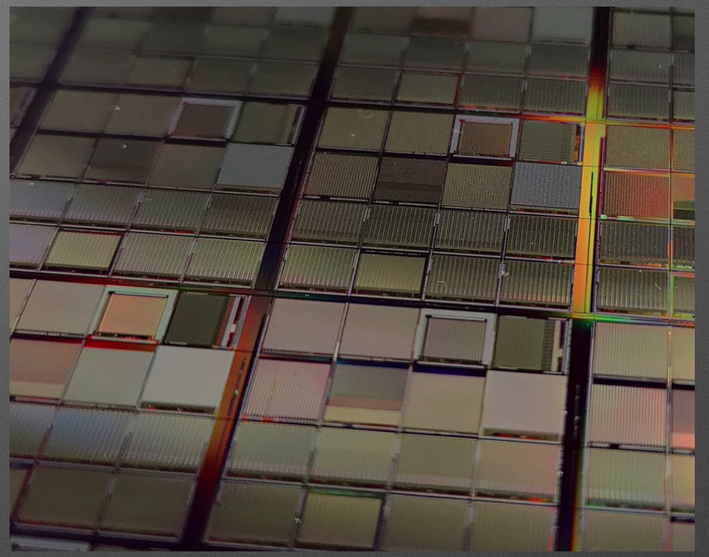
- Long term upgrade: Next generation pixel sensor: 50um thin, comparable spatial resolution, time resolution should be significantly better
- Intermediate upgrade: Adding dedicated timing layers
  - Faster existing sensors (to be defined)
  - Timepix3 (existing, but thick and no trigger capabilities)
  - LGAD for sub nano second timing
  - Telepix HV-CMOS: A few ns timing and region of interest trigger

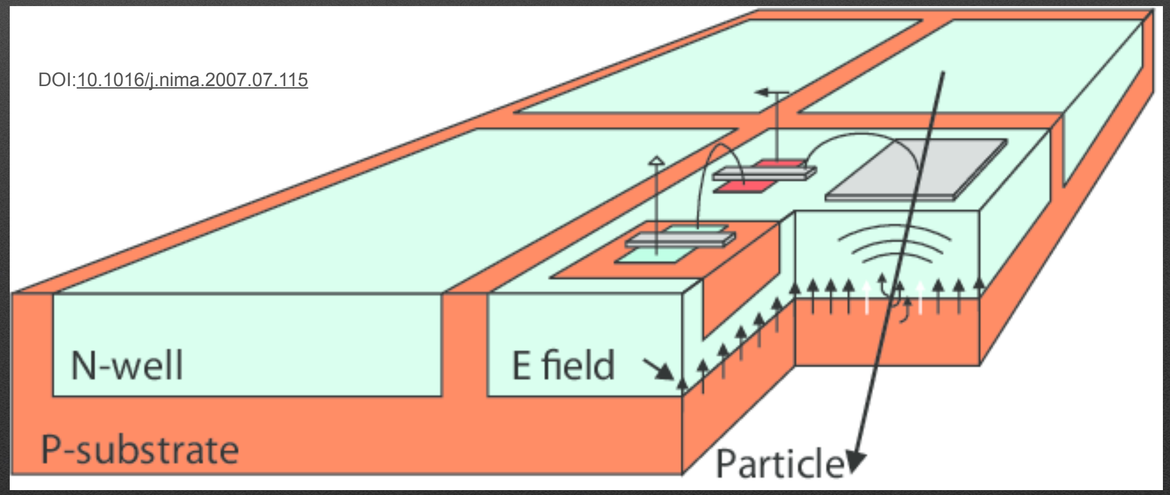


Karlsruher Institut für Technologie

The Telepix Prototype

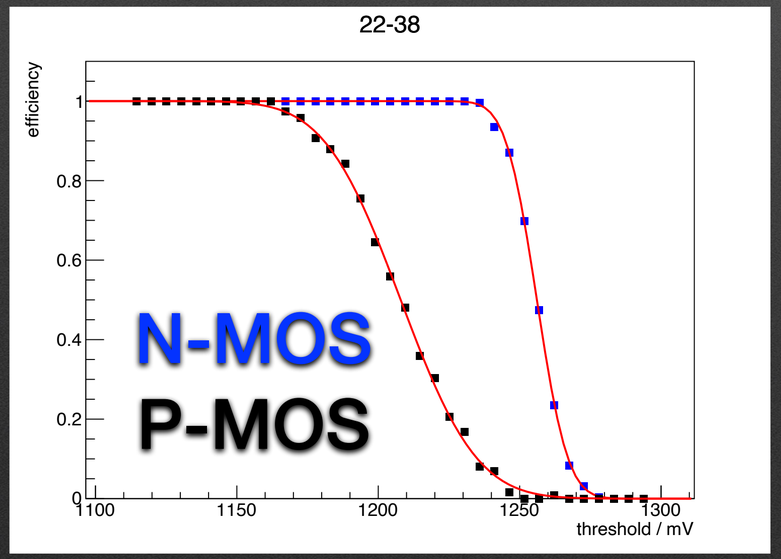
- Joined project between KIT, University of Heidelberg and DESY
- 29x125 pixel with 165x25um pitch
- 2x10 bit time of arrival stamps running at 125MHz (sampled on falling and rising clock egde)
- 10 bit time of falling below threshold (can be combined to a ToT)
- Masking bits/Threshold trin DACs for upper half of sensor
- 2 amplifiers: PMOS/NMOS (left/right part of matrix) based
- In pixel comparator
- Column drain readout logic with digital partner cells in periphery
- Zero surpassed, self triggered, serial data readout
- 180nm TSI HV-CMOS process

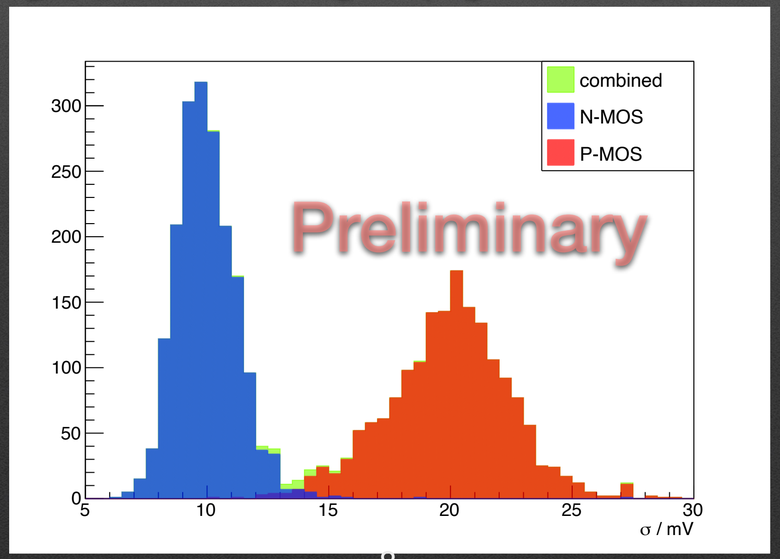


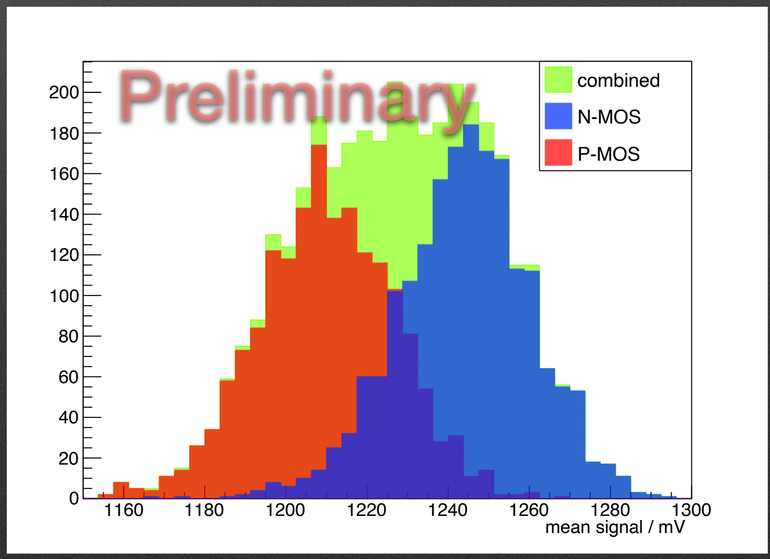


Performance Results I

- To study the difference between the left and right matrix part, injection scans have been performed for each pixel
- Systematic influence from injection capacity fluctuations
- Identical ranges chosen to maximise comparability
- Measurement made with digital hit output and an oscilloscope - 13 minutes measurement time per pixel ->32 days measurement time
- Fitted s-curves to each pixel
- N-MOS performes better: Less noise (smaller sigma) and more signal (higher mean)

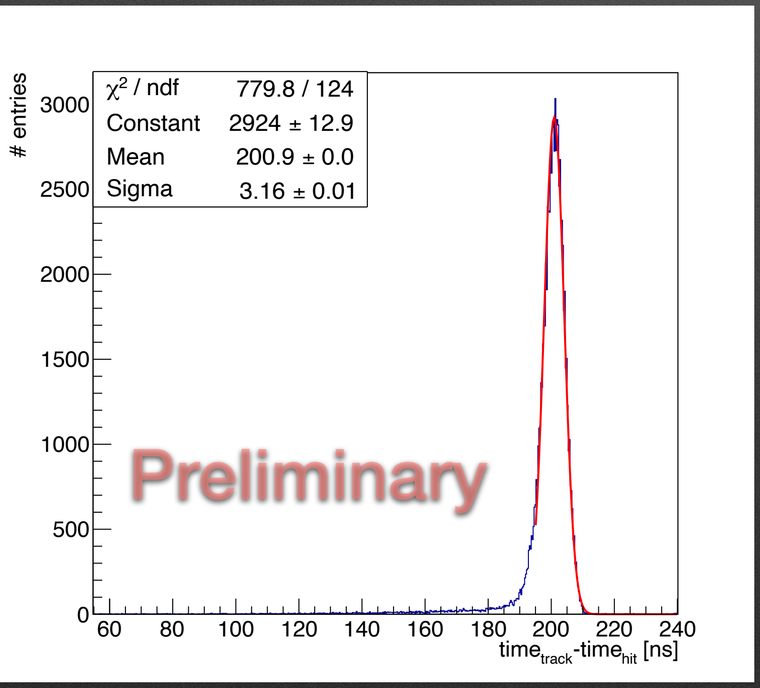




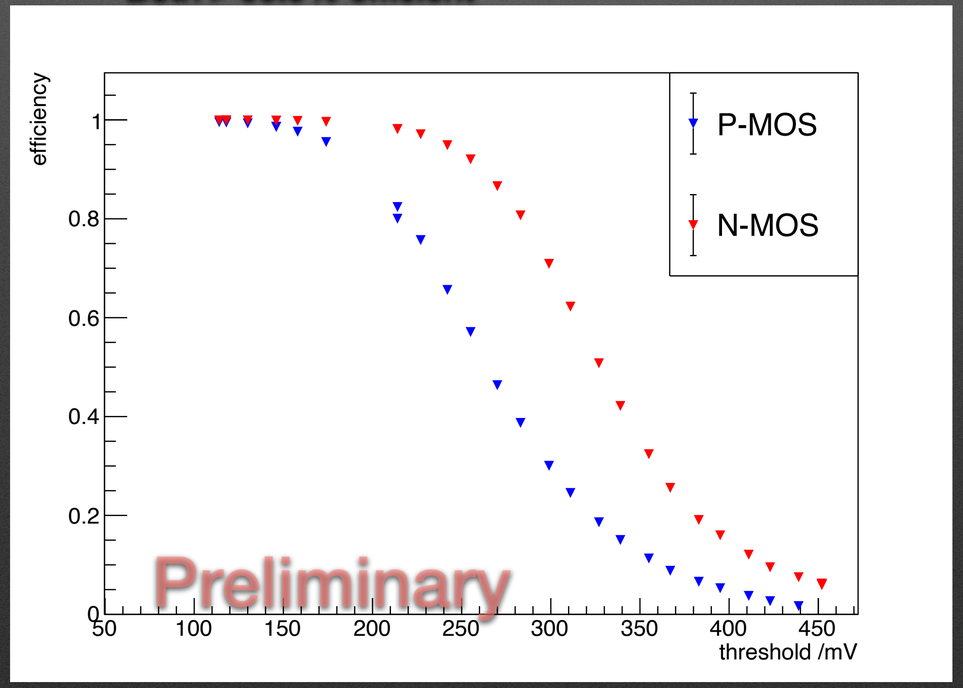


Performance Results II

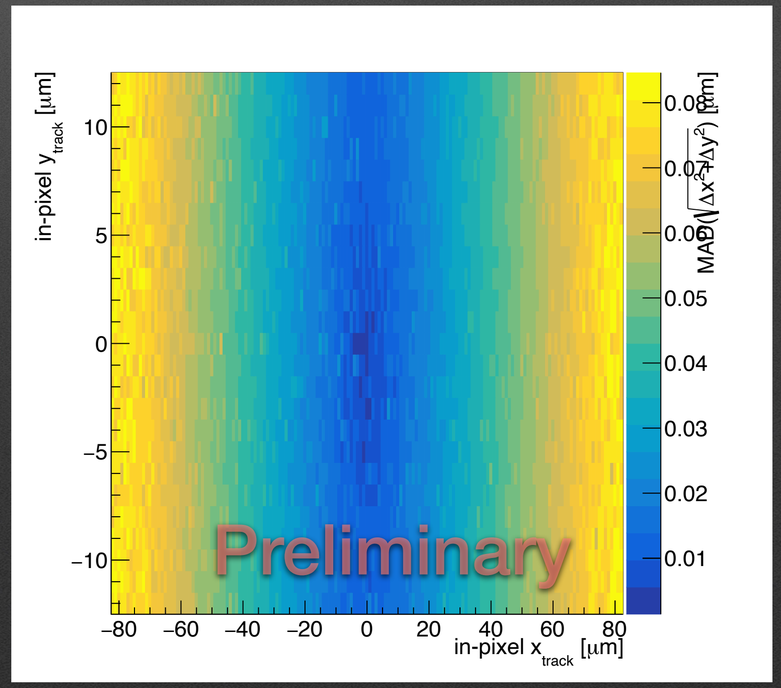
- Time resolution expressed as Gaussian sigma.
- Figure shows N-MOs at 110mV threshold
- Tail to the left steams from double clusters
- Fit to core of the distribution leads to a sigma of 3.16ns



- Efficiency as function of threshold for the two amplifiers
- N-MOS has larger high efficient region -> easier to operate
- Overall large signals obscured
- N(P)- MOS mean signal amplitude 330(260)mV
- Both > 99.9% efficient



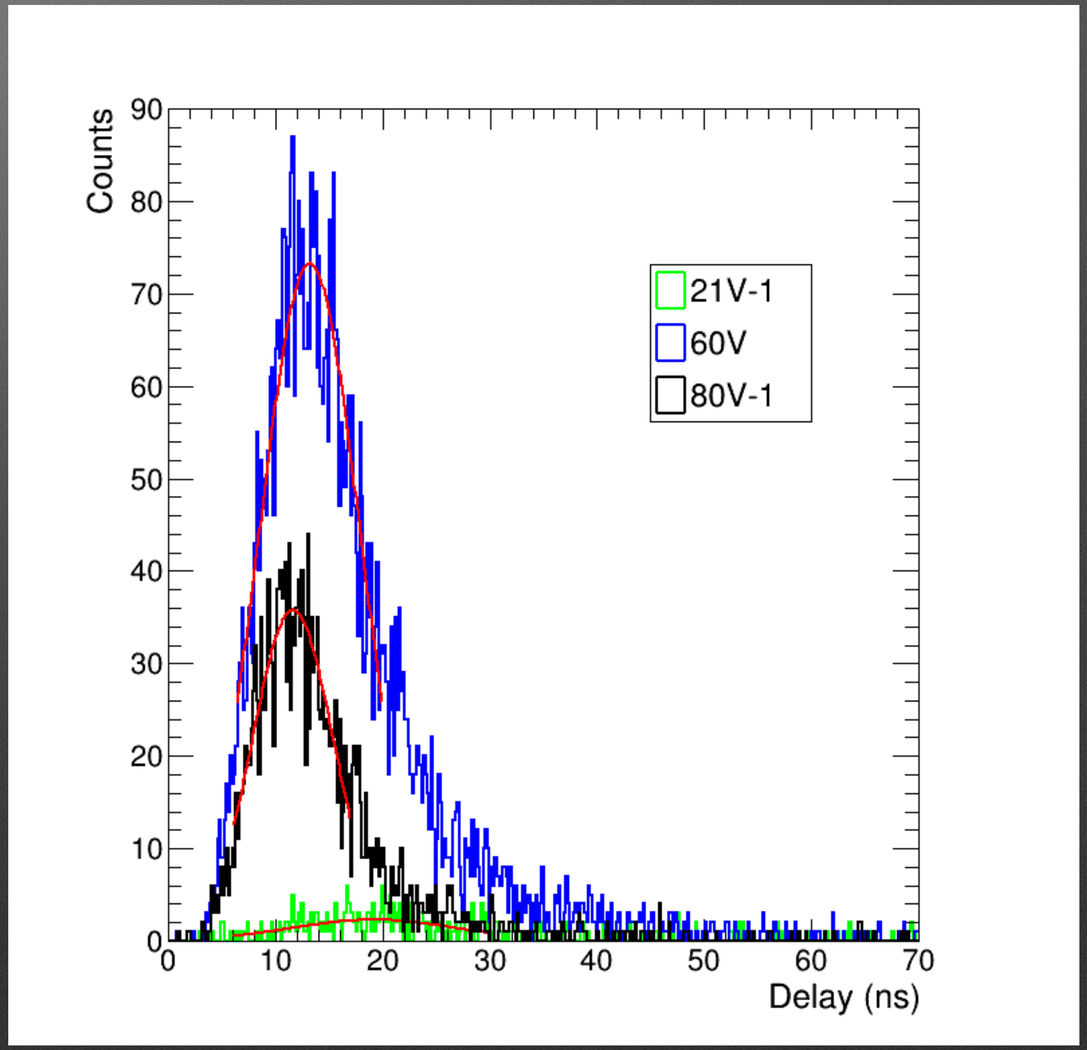
- Spatial resolution within the pixel cell
- In the center 0 per definition
- Reduction towards the edges, little charge sharing
- Along x, the resolution degrades more, since the pixel pitch is larger



Region of Interest Trigger

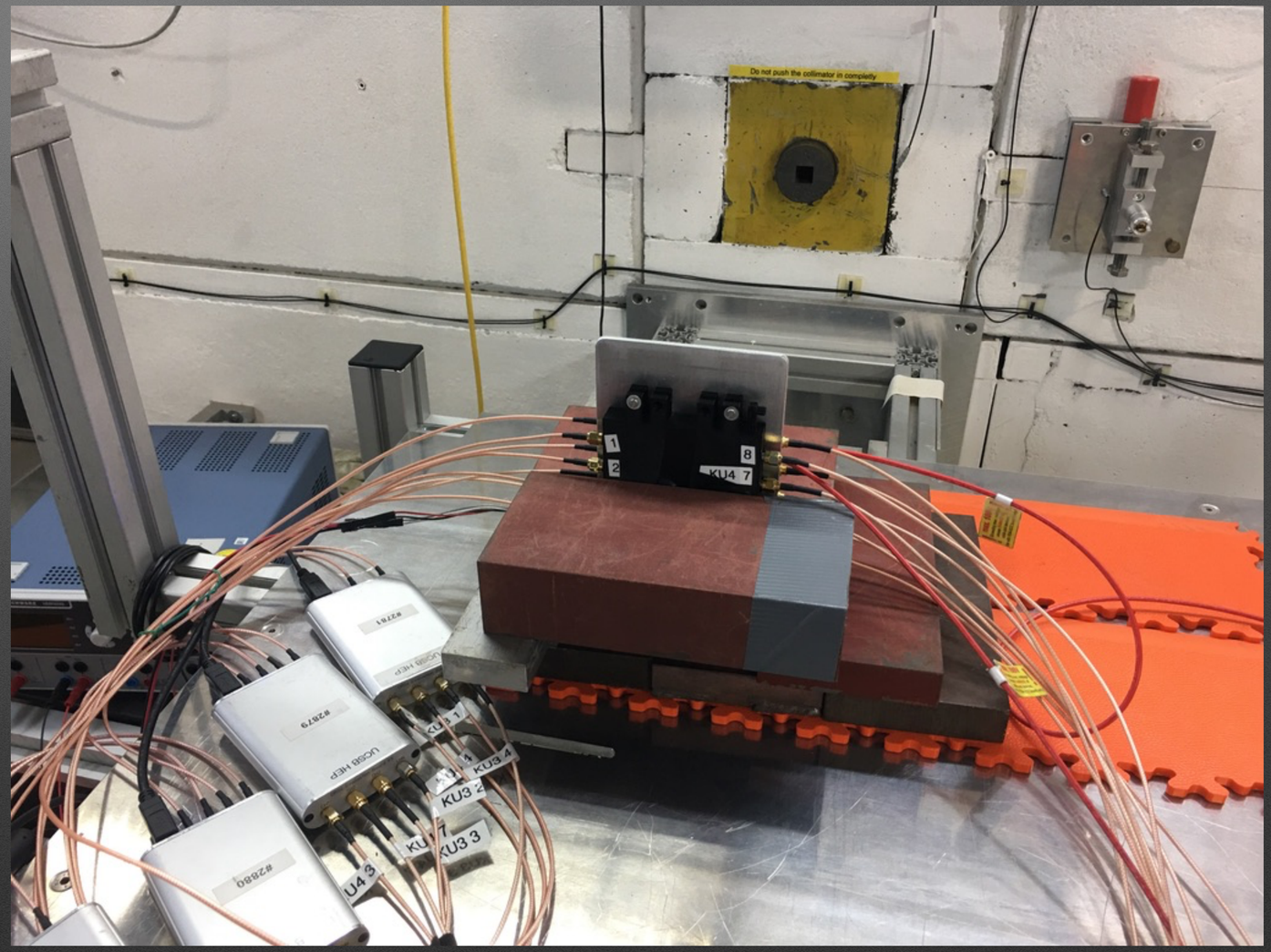
- A fast trigger with a region of interest is a key feature for the developments.
- Telepix can only select full columns to create a trigger from (example plots column 20).
- Measured relative to trigger scintillator with time resolution of approximately 1 ns and equal signal
- Strong (expected) dependence on bias voltage
- Rather high detection threshold to ensure pure sample
- Jitter goes down to below 4ns, with an absolute delay of below 22ns
- Suficient to serve as a trigger plane

BIAS / V	DELAY / NS	JITTER / NS
21	28+/-0.6	6.56+/-0.65
60	23.2+/-0.1	4.69+/-0.13
80	21.55+/-0.2	3.81+/-0.17



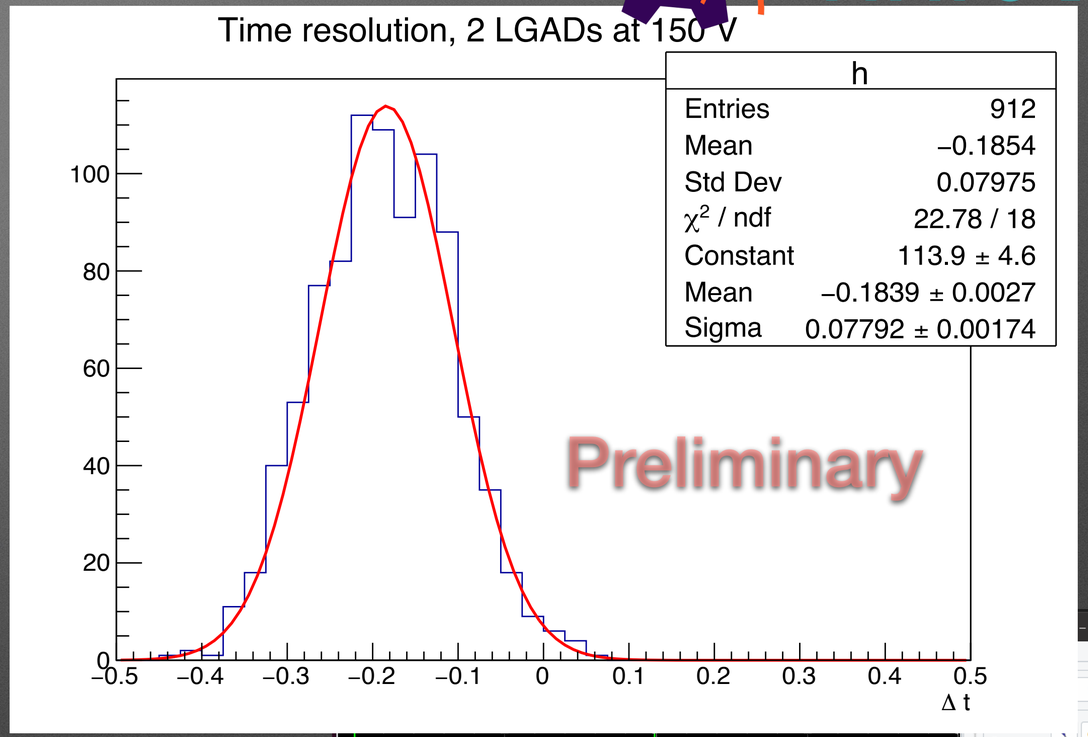
LGAD Upgrade

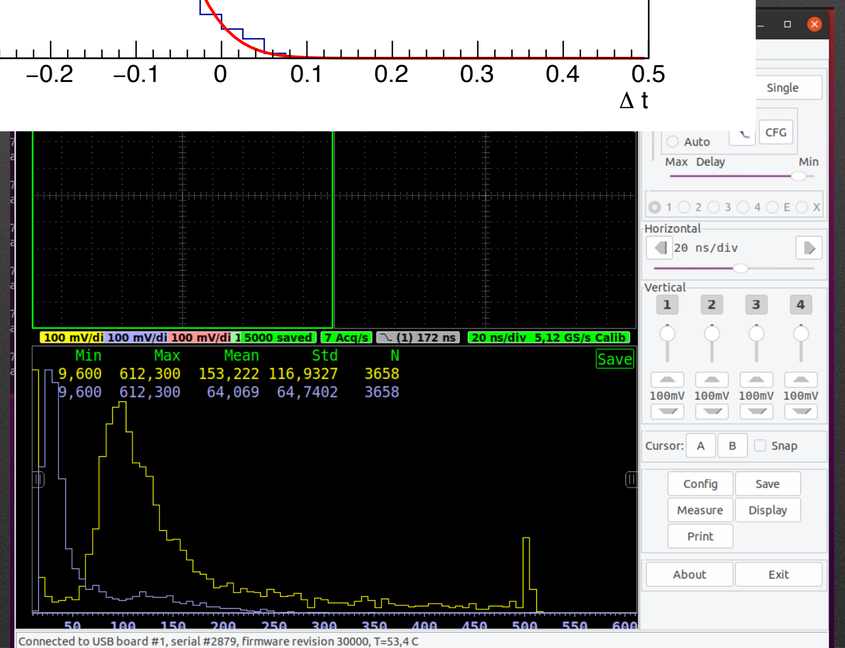
- LGADs provide a few 10 pico second time resolution
- Collaboration with University of California, Santa Barbara
- Prototypes received end of last year
- Set-up at TB24/1
- Planned integrated into telescopes to study efficiency and fill factor
- Read out with 4 synchronised DRS4 Boards
- Part of Aida innova WP3



LGAD Results

- Coincidence setup between two layers on a single DRS4
- Gaussian fit to the distribution leads to time resolution of 78ps
- Readout with DRS GUI fully functional - no showstoppers found
- Improved LGADs and readout in commissioning
- EUDAQ/TLU integration ongoing effort





Summary

- The DESY II Testbeam Facility provides excellent beam to a broad user community
- The EUDET-style telescopes are a popular reference system with excellent spatial, but limited temporal resolution
- Several upgrades are currently being prepared and are likely to go into operation this year
- The Telepix shows promising performance with a digital trigger signal with a jitter below 4ns and a short absolute delay below 22ns
- Efficiencies of above 99.9% and a time resolution of 3.2ns could be determined in a testbeam campaign
- The LGAD planes show a time resolution of 78ps

A glimpse into the Future

- The testbeam will continue being a workhorse for detector R&D and the local crew continuously improves beam/environment and user equipments

- The telescopes are a key infrastructure and undergo continuous upgrades, that are supposed to be transparent to the users:

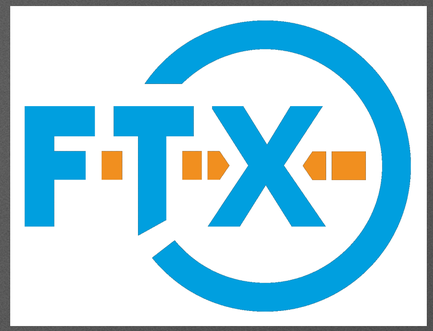
  - Mid term upgrade: Based on existing sensors within the next years

  - Long term upgrade: New sensor development, potentially based on Tangerine developments, see this contribution: https://indi.to/5tHVy

- MIMOSIS integration into EUDAQ2 as part of CREMLIN plus

Connecting Russian and European Measures for Large-scale Research Infrastructures

Closing out



Unfortunately, we cannot meet and discuss in person. If you have any questions/remarks or want to discuss statements please contact me via

- Skype: live:lennhuth
- CERN Mattermost: @lhuth
- Email: lennart.huth@desy.de or lennart.huth@cern.ch

Thanks for reading my slides ;)