UNIVERSITÄT BONN

SI LAB
Silizium Labor Bonn

BTTB13 VALENCIA

BEAM TESTS FOR THE BELLE II VTX UPGRADE AT HIGH TEMPERATURES WITH A PELTIER-BASED HEATING AND COOLING DEVICE

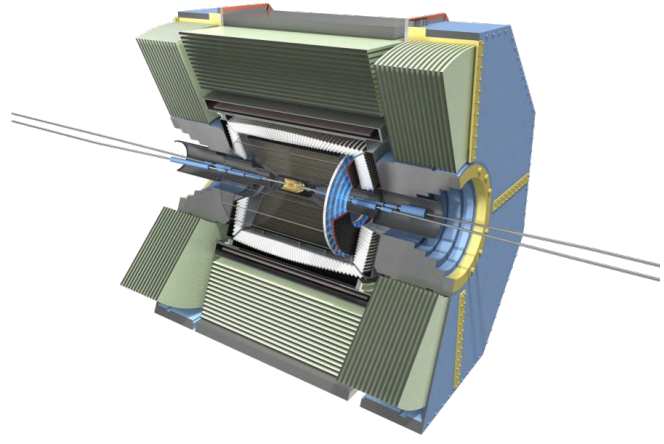
Rasmus Partzsch - on behalf of the Belle II VTX collaboration

rasmus.partzsch@uni-bonn.de

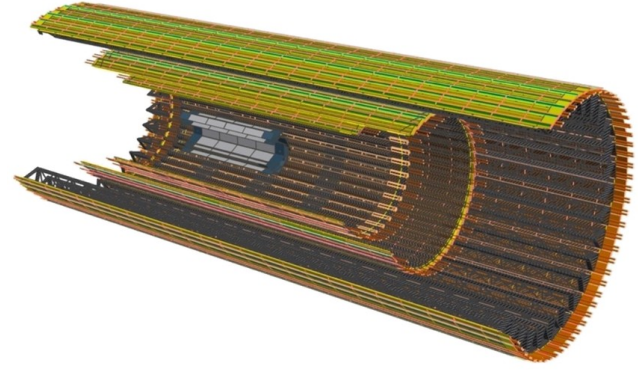
Outline

- Introduction and Motivation
- Test Beam Setup
- DUT Event Synchronization
  - AIDA-Mode
- Heating and Cooling Device
- Slow Control and Data Acquisition
- Conclusion and Outlook

VTX Upgrade



- Belle II experiment at the SuperKEKB collider
  - Asymmetric e^-e^+ collider
  - Vertex detector (VXD):
    - DEPFET pixels (PXD)
    - Double-sided strip detectors (SVD)
- Peak Luminosity upgrade during long shutdown (LS2)
  - Increases background levels and therefore impairs tracking capabilities of existing inner detector (VXD)
- Solution: upgrade VXD utilizing fully pixelated detector
  - iVTX and oVTX
- TJ-Monopix2 is the baseline for a new detector
  - Optimised BELle II monolithic pIXel (OBELIX)
    - Utilizing low material budget

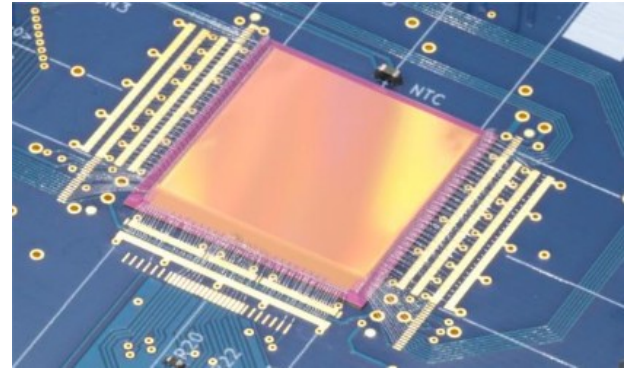


Toru Tsuboyama., et al.
https://hal.science/hal-04631585v1

Device Under Test: TJ-Monopix2

- Depleted Monolithic Active Pixel (DMAPS)
  - 180nm TowerSemi CMOS
- Large scale 2x2 cm^2 chip with 33x33 μm^2 pixel pitch
- Four different irradiated DUT
  - 3 proton irradiated
    - 1e14 neq/cm^2 – 5e14 neq/cm^2
  - 1 electron irradiated
    - 5e14 neq/cm^2
- VTX designed to operate at room temperature

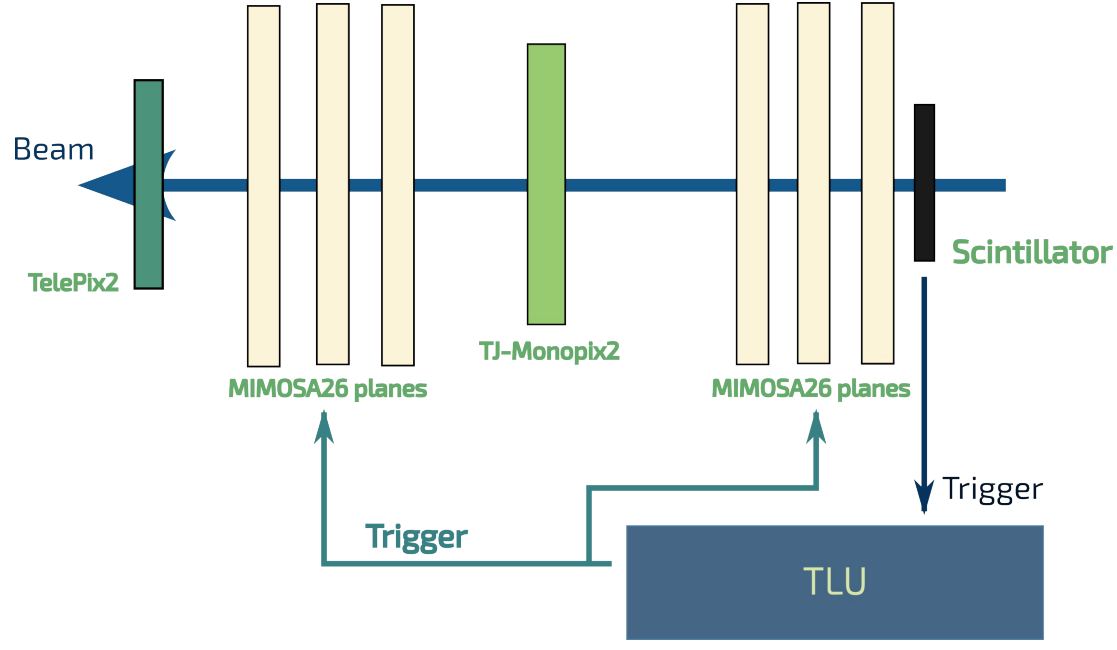
→ Evaluate temperature dependence performance of irradiated TJ-Monopix2



Ivan Caicedo., et al.
https://doi.org/10.7566/JPSCP.42.011021

Test Beam Setup

- EUDET-type Beam telescope DATURA
  - MIMOSA26 planes for particle tracking
  - Time reference plane
- Trigger logic unit (AIDA-TLU)
- TJ-Monopix2 as DUT
- TelePix2 time reference plane
  - Fine time stamping of particle tracks

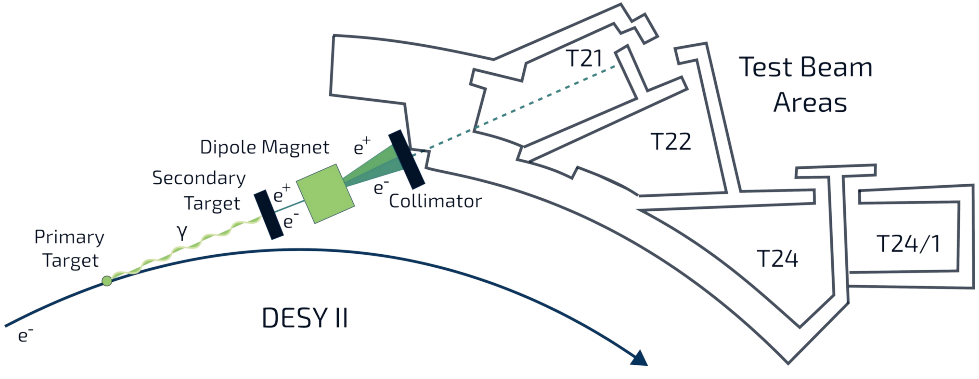


Jansen, H., et al.
https://doi.org/10.1140/epjti/s40485-016-0033-2

DESY Test Beam Area

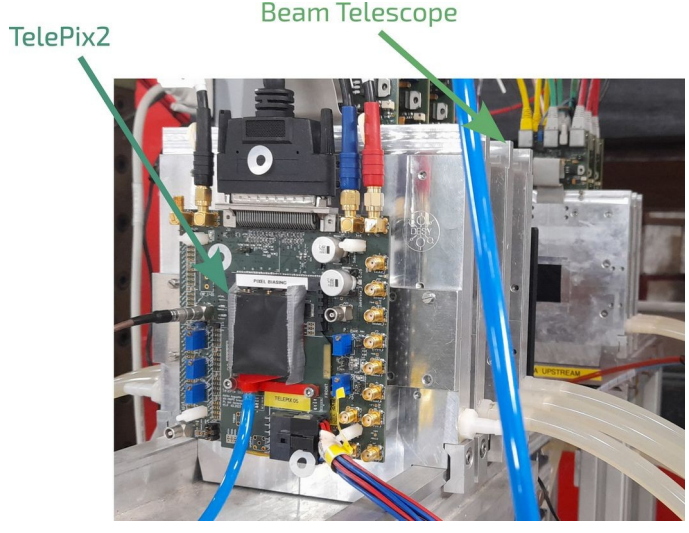
DESY test beam areas:

- Tertiary beam
- Full control over tertiary beam
- Energy and particle rate variable (1 GeV – 6 GeV)



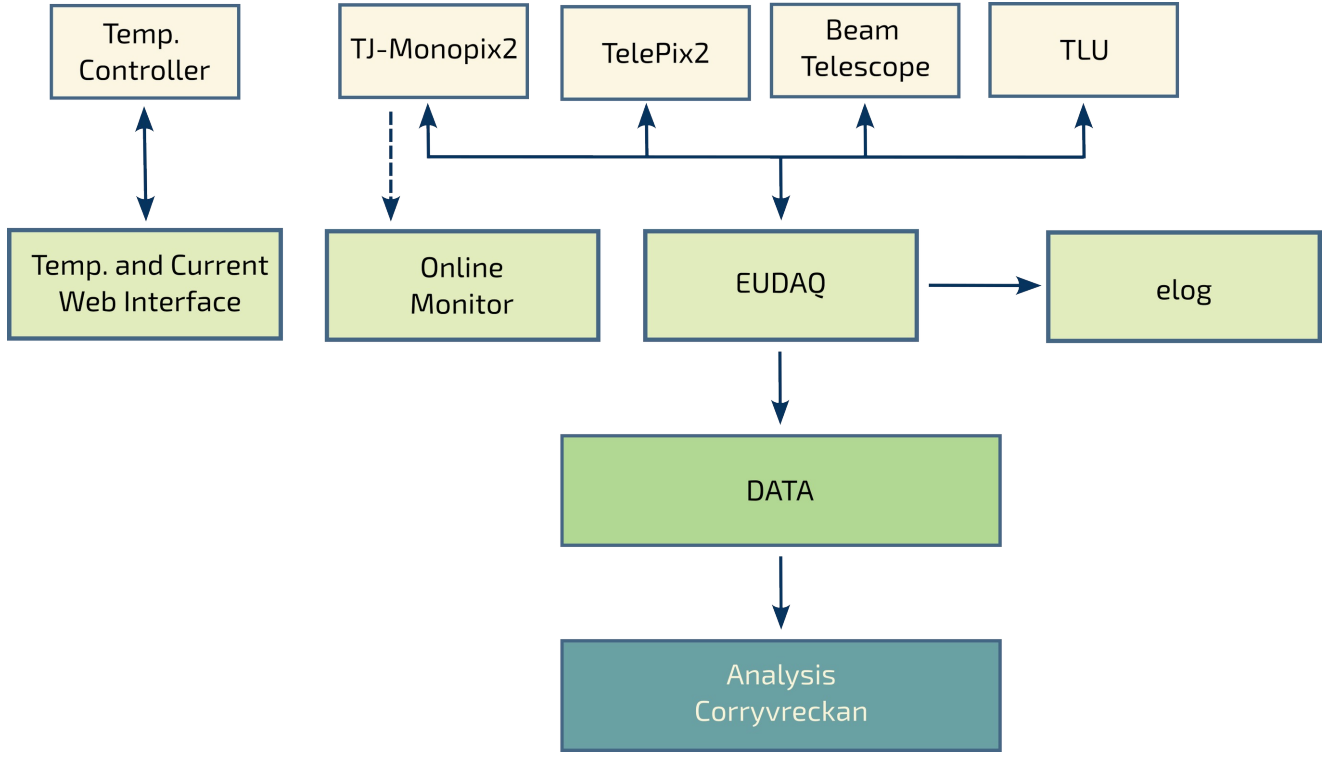
R. Diener et al.
https://doi.org/10.1016/j.nima.2018.11.133

- DATURA in TB21
- TelePix2 time reference plane



L. Huth. et al.
https://arxiv.org/abs/2503.08177

Test Beam Setup Overview



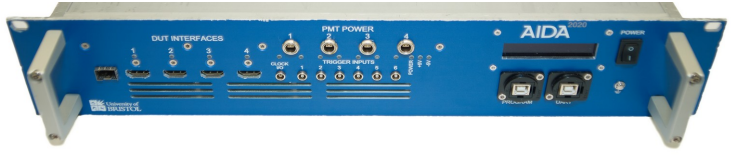
DUT Event Synchronization

Previously: EUDET-Mode

- Synchronization via trigger number, originating from TLU
- Devices run on own clock
- Handshake, TLU awaits accepted signal from DUT

Now: AIDA-Mode

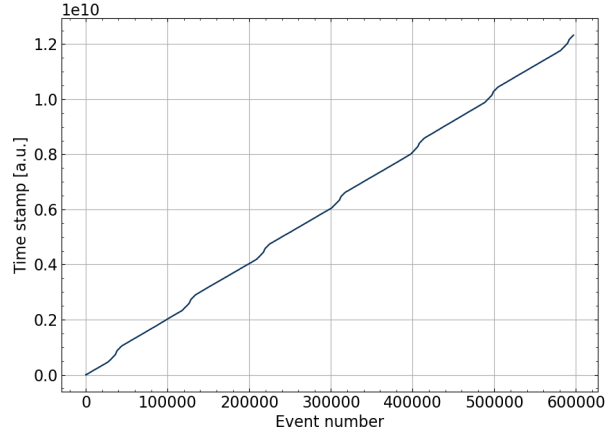
- Synchronization via time stamp originating from TLU
- Devices run on synchronous clock from TLU
- No handshake, trigger are sent out continuously (if no veto from DUT)
- Time stamp reset at the start of measurement

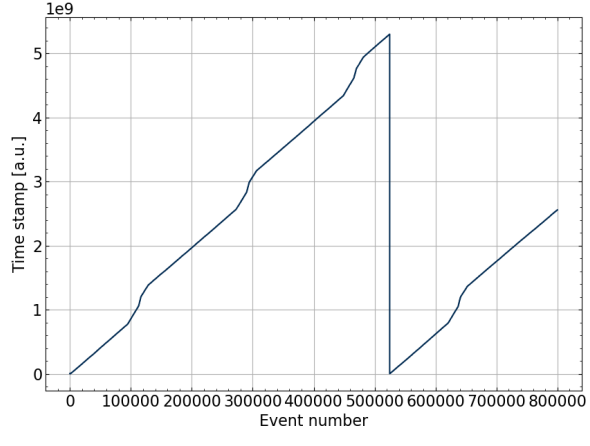


P. Baesso, D. Cussans, J. Goldstein
https://doi.org/10.48550/arXiv.2005.00310

AIDA-Mode

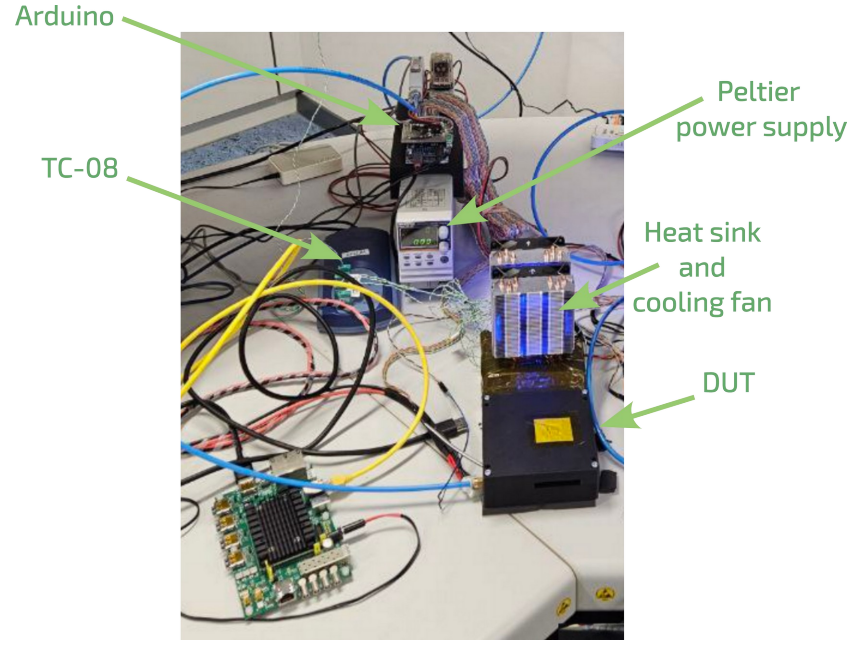
- Firmware update for readout board (BDAQ)
  - Accept external clock
  - Reset time stamp
- HDMI adapter to RJ45 adapter
  - Important: ensure signal integrity
    - Terminate open ends





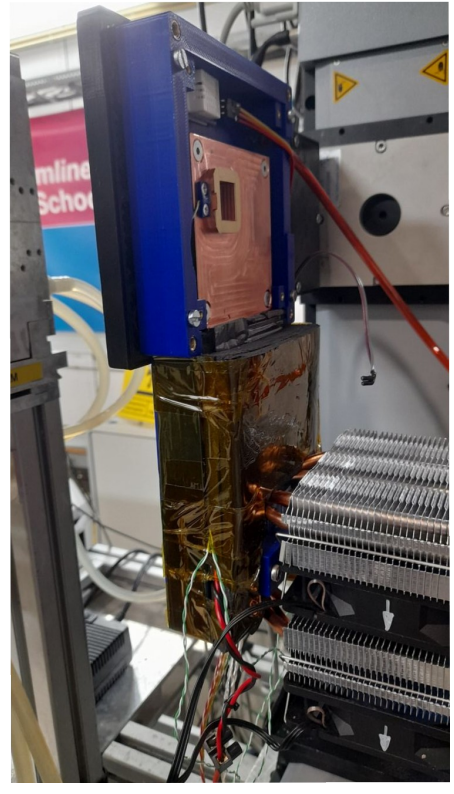
Heating and Cooling Device

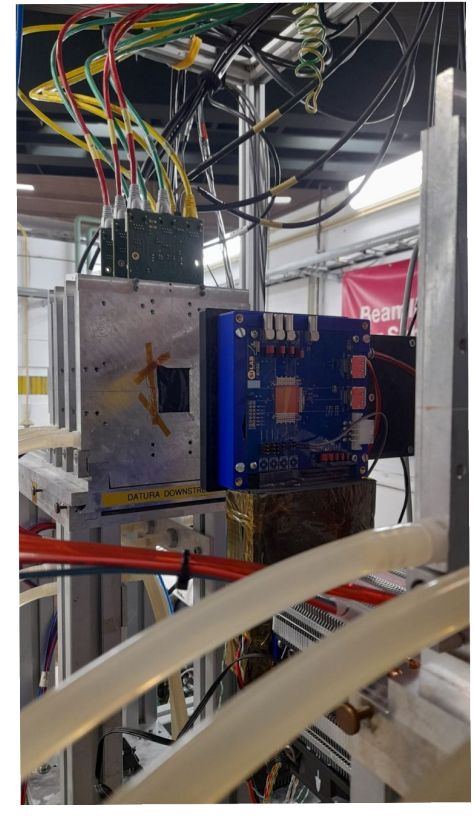
- System developed by HEPHY for the VTX test beam setup
  - Similar system already used by RD50
- Peltier element for heating and cooling setup
- Relay switches polarity for heating and cooling
- Pico Technology TC-08 for temperature measurements
- Arduino for readout of NTC, humidity sensors
- PID controller
  - Adjusts current
- PC controls Peltier power supply
- Temperature readings logged to file

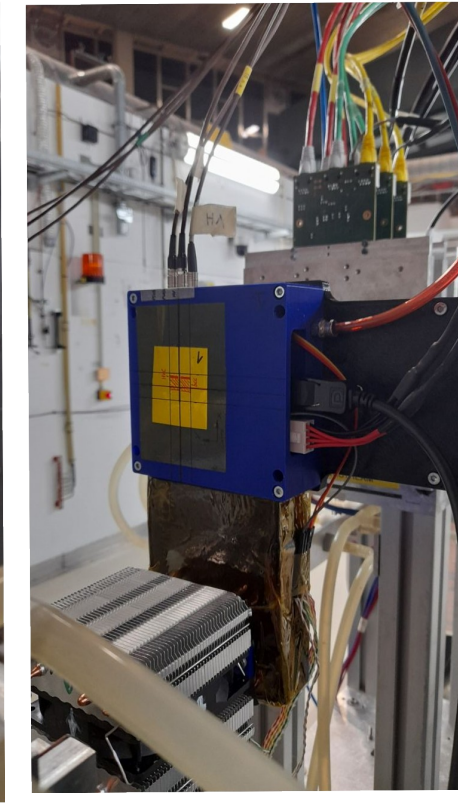


Heating and Cooling Device

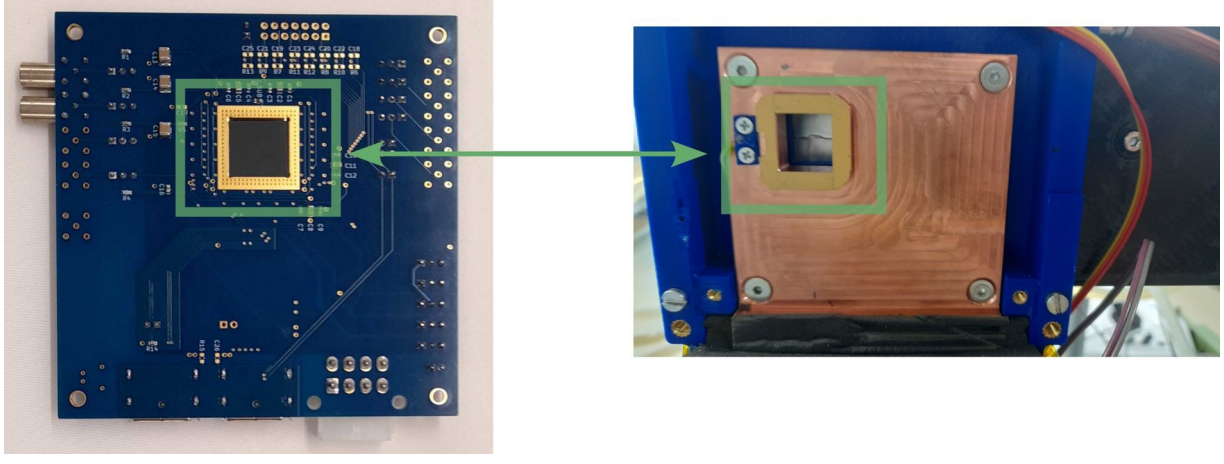
- Stable operation in large temperature range (5 °C – 50 °C)
- Large cooper frame
- Heat sink + cooling fans





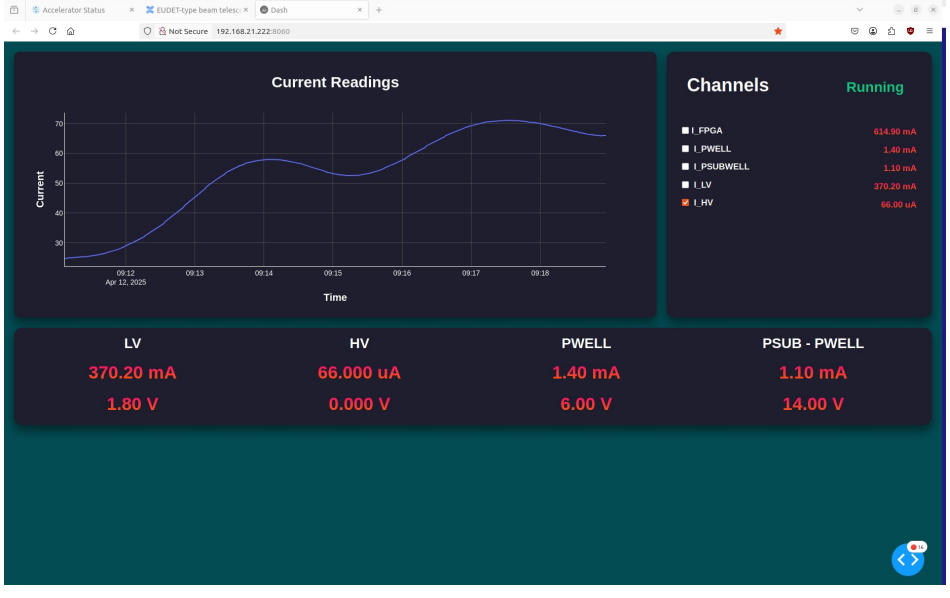


Heating and Cooling Device



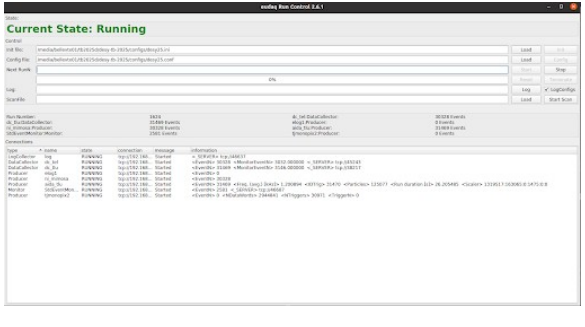
Heating and Cooling Device

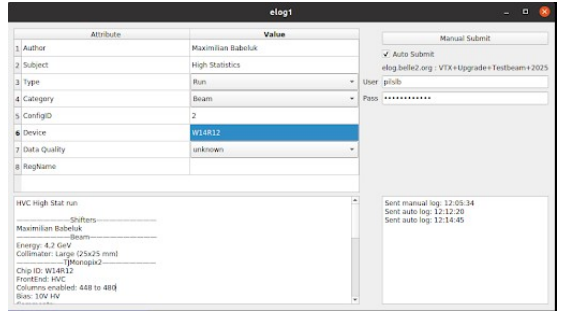
- Web interface
  - Control and monitoring of cooling and heating system
  - TJ-Monopix2 power consumption monitoring

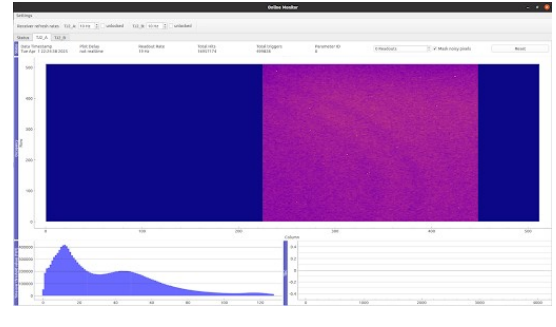


Slow Control and Data Acquisition

- EUDAQ
  - Slow control
  - Configuring, starting stopping measurement runs
- Elog
  - Logs run information (thresholds, bias voltage…)
  - Automatically uploads to Belle II Elog after each run
- Monitoring
  - Web interface for temperature and TJ-Monopix2 power consumption
  - Online monitor for TJ-Monopix2







UNIVERSITÄT BONN

Conclusion

- Updated TJ-Monopix event synchronization to AIDA-Mode
- Developed and characterized cooling and heating setup for BELLE II VTX upgrade
  - Tested DUT performance in large temperature range (5 °C – 50 °C)
- Integration of hardware setups into a slow control and monitoring system

Outlook

- Improvements to the temperature control system
  - Reduction of cooper around chip to reduce multiple scattering
  - Enhanced thermal coupling of cooper to chip PCB
- Setup will be reused for OBELIX testing
- Analysis of large amount of data

UNIVERSITÄT BONN

Thank you for your attention!

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)

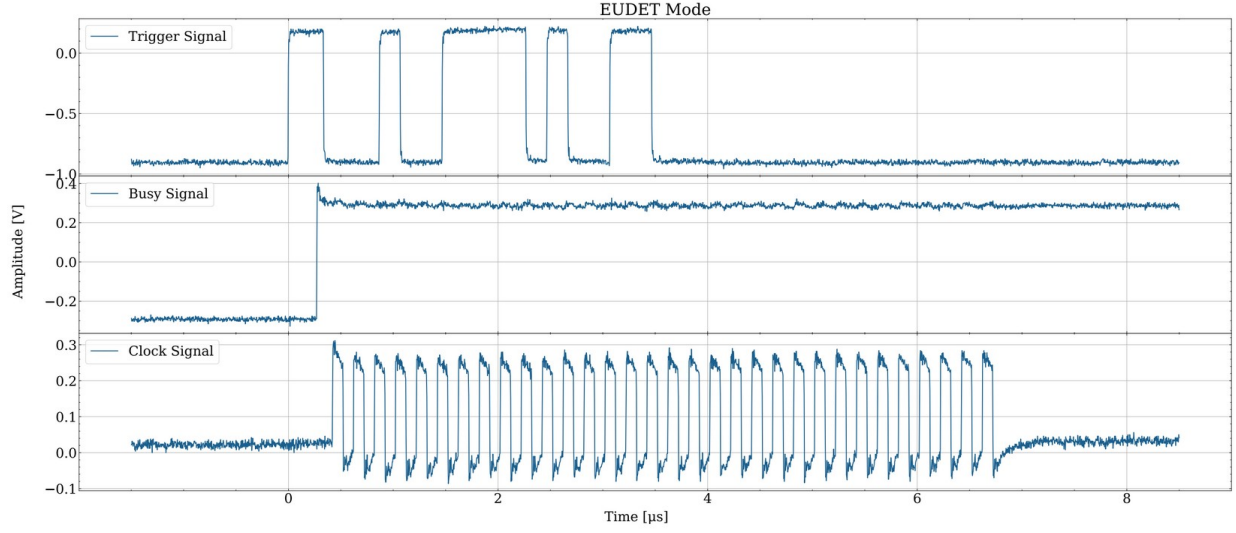
UNIVERSITÄT BONN

Backup

Operating Modes

EUDET Mode (Handshake)

- DUT accepts TRIGGER from TLU and answers by asserting BUSY
- DUT clocks out TLU trigger number (external trigger number)



AIDA Mode (No Handshake)

- TRIGGER are sent continuously
- DUT can veto new trigger by asserting BUSY

The Time Reference Plane

- Readout frame of MIMOSA26 planes: 115.2 µs
- Unambiguous assignment of hits to track is not always possible
- Multiple tracks (trigger) in one readout frame
- Time reference plane for spatial assignment of track to time reference