Status Summary of the AIDA WP9.3 Activities

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28th of March 2012,
1st Annual AIDA Meeting

Reminder: WP9.3 Objectives

- Development of a versatile beam telescope able to characterize detector prototypes, satisfying the demanding requirements in terms of cooling infrastructure, read-out speed and precision
- Development of an off-beam infrastructure for the evaluation of thermo-mechanical properties of Vertex Detector prototypes

Outline

WP9.3 Objectives in More Detail

Task 9.3.1 Telescope

... builds on the telescope infrastructure developed as part of EUDET:

- A versatile and modular pixel telescope is to be built using state-of-the-art pixel devices (TimePix, ATLAS FE-I4 and MIMOSA) to meet the requirements of a broad user community. The telescope must provide a precise set of reference measurements and must be capable of LHC-speed response and time-stamping.
- CO_2 cooling plant
- Common analysis software

Deliverable 9.4 in month 37
Milestone with design in 13

Task 9.3.2 Thermo-mechanical infrastructure

- Development of an infrastructure that allows to evaluate the thermo-mechanical performance of fully integrated detector prototypes under a realistic power load.

Deliverable 9.1 in month 33
Milestone with design in 13

The EUDET Telescope

- EUDET telescope used by many groups in 2011
- Telescope was running extremely smoothly
- Running here at DESY until May
- Users scheduled for May till November at SPS-H6B
- Most user are planning to request transnational access (TA)

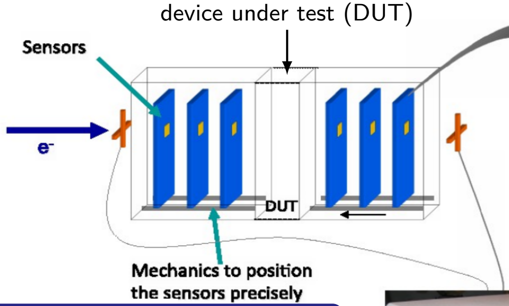
ANEMONE 100%

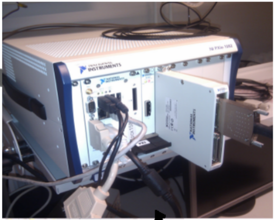
ACONITE 80%

DATURA 60%

- commercial DAQ hardware → "easy" copies:
  - Bonn copy (ANEMONE)
  - ATLAS copy (ACONITE)
  - DESY test beam (DATURA)
  - ...
- Goal: same infrastructure at DESY TB and CERN SPS TB

Components of the EUDET Telescope





Trigger Logic Unit (TLU)

EUDAQ

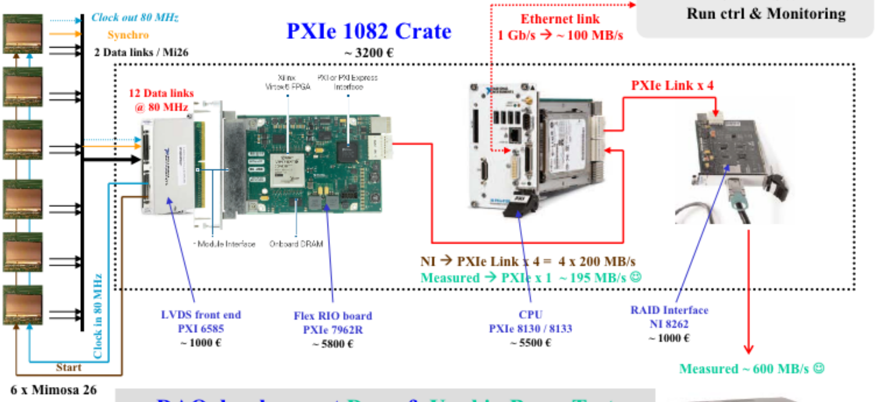
Hardware Ingredients

- Mechanics
- Sensors
- Trigger Logic Unit (TLU)
- DAQ

Upgrade of the DAQ in 2011

Much faster
⇒ ready for the future

DAQ (15,5 k€) → Crate + Flex RIO + CPU + RAID (Option)

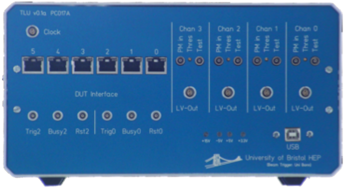


DAQ development Done & Used in Beam Test

- Telescope 6 x Mimosa 26 = 12 links @ 80 MHz = 120 MB/s
- Telescope 6 x Ultimate = 12 links @ 160 MHz = 240 MB/s

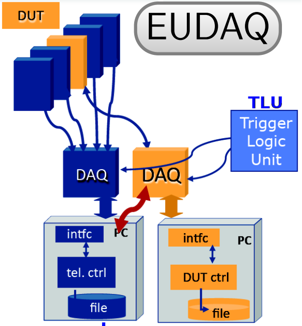
System set up by Strasbourg, connection to EUDAQ done by DESY

The Trigger Logic Unit (TLU)



- Existing TLU designed to give a simple but flexible interface to trigger/timing signals at EUDET JRA1 beam-telescope
- Produces triggers from beam scintillators (→ EUDET-Memo-2009-4)
- Low cost
- Used by many ILC, LHC and "non-aligned" groups.
- Many copies build by Uni Göttingen to fulfill growing demand

- Existing TLU works. Why a new one?
- Want to move to one-trigger-per-particle (not one trigger per telescope frame) needed for LHC detectors.
- Cheaper to produce TLUs for integration in home labs.
- Decided that a AIDA high speed TLU is needed and defined the details.
- Mini TLU prototype in preparation



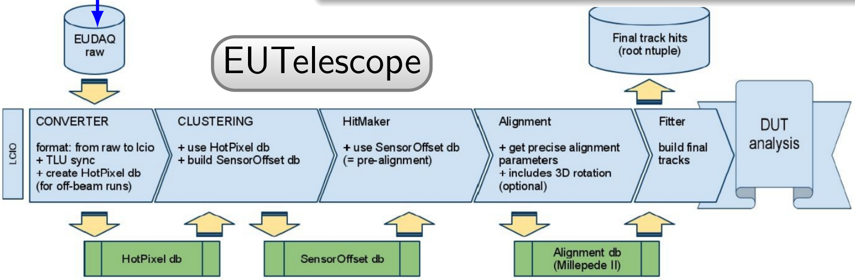
EUDAQ (Data Acquisition Software)

- Allows full integration of *device under test* (DUT) independent of its technology including pre-existing DAQ systems
- Modular and flexible design

⇒ in usage by many groups already!

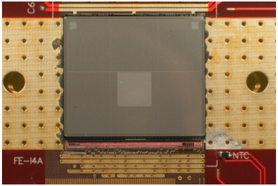
EUTelescope (Track Reconstruction & Analysis)

- stepwise transition from single pixel array to 3D coordinates of fitted tracks in global frame
- based on Marlin (ILCSoft)

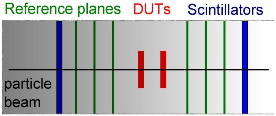


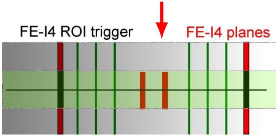
One Technology: ATLAS FE-I4

- FE-I4 properties:
  - $50\,\mu m \times 250\,\mu m$ pixel size
  - array size: $80\,\mathrm{col} \times 336\,\mathrm{rows}$
  - large area: $4\,\mathrm{cm}^2$
  - max. trigger rate: $200\,\mathrm{kHz}$
  - HitOr signal for self-trigger



- FE-I4 module-based reference planes offer. . .
  - high rate and high occupancy capability
  - large area $\sim 4\,\mathrm{cm}^2$
  - fast self-triggering in defined region of interest





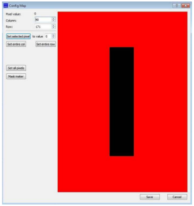
- R/O fully integrated in common infrastructure of the "AIDA telescope" framework:
  - mechanics: cold operation (DESY/Wuppertal)
  - DAQ-software based on the EUDAQ package
  - reacts to TLU signal
  - can send trigger signal to TLU (see next slide)

ATLAS FE-I4 as Telescope Trigger

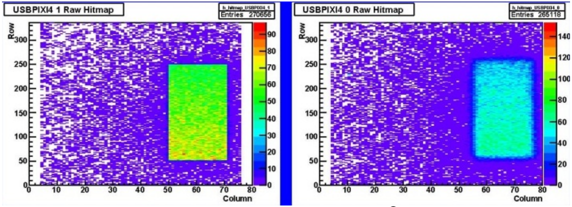
- FE-I4 features fast HitOr:
  a wired `OR` over all pixels
- each pixels HitOr can be switched on/off

$\Rightarrow$ can define *region of interest*

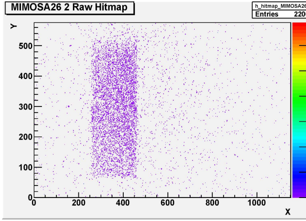
trigger mask
$3 \times 10\,\mathrm{mm}^2$



- successfully tested with EUDET telescope at DESY using Mimosa26 reference planes
- successfully tested two FE-I4 planes at ELSA

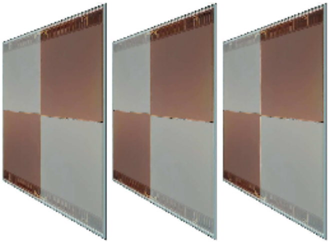


FE-I4 Hitmap, $10 \times 5\,\mathrm{mm}^2$ window



EUDET hitmap

Single Arm Large Area Telescope (SALAT)



- Prominent features of SALAT:
  - very low material budget: $50\,\mu\mathrm{m}$ Si
  - high resolution: $\sim 4\,\mu\mathrm{m}$ in x and y
    $\rightarrow$ beam particle impact position on DUT known within $\sim 2\,\mu\mathrm{m}$
    ($\sim 1\,\mu\mathrm{m}$ on reduced area)
  - large detection area : $4 \times 6\,\mathrm{cm}^2$

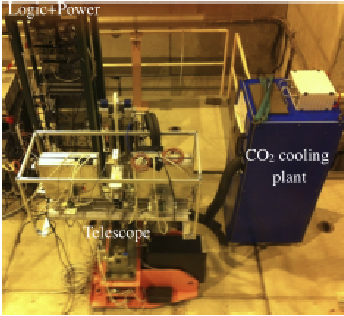
- Production of sensors in two steps:
- Start with demonstrator based on MIMOSA-28 sensors (fabricated for the STAR-PXL)
  - allows setting up the full device and read-out chain
  - provides $39 \times 37\,\mathrm{mm}^2$ active areas for users already in 2013
- Replace demonstrator sensors with final SALAT sensors;
  $\Rightarrow$ available for users by 2015
  - active area $\sim 4 \times 6\,\mathrm{cm}^2$

SALAT Demonstrator & Final Sensors

- SALAT demonstrator:
  - $50\,\mu\mathrm{m}$ thin sensors (MIMOSA-28) fabricated and tested
    $\rightarrow \sigma_{sp} \sim 3.5\,\mu\mathrm{m}$ and fake rate $\ll 10^{-4}$
  - BT plane realization starting (4 sensors on mylar foil $\rightarrow 3.9 \times 3.7\,\mathrm{cm}^2$)
  - testing in lab (IPHC) by end of 2012,
    will be tested on beam at DESY in 2013-Q1
- Final beam telescope plane:
  - nearly twice as large planes ($4 \times 6\,\mathrm{cm}^2$),
    free of insensitive band, faster, etc.
  - relies on new $0.18\,\mu\mathrm{m}$ CMOS process, currently investigated (MIMOSA-32), which provides stitching
  - sensor (MIMAIDA) will be derived from R&D for CBM/FAIR, ALICE/LHC, eRHIC/BNL: Full Scale Basic Block (FSBB)
  - Milestones:
    - ★ Q2/2012: MIMOSA-32 techno validation (lab tests just started)
    - ★ Q2/2013: M22THR validation
    - ★ Q3/2013: SUZE-02 validation
    - ★ Q2-Q3/2014 : FSBB validation

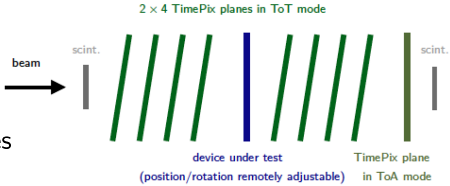
The TimePix Beam Telescope

- Developed in collaboration with VELO upgrade project and AIDA WP9.3
- Infrastructure upgrade in 2011, including
  - Improved DAQ
  - New portable CO_2 cooling system
- "semi-permanent" installation in H8.A area
- Available to LHCb collab. and in the framework of AIDA WP9.3 to external users



Features:

- Spatial resolution $\sim 2\,\mu\mathrm{m}$
- Time tagging with $\sim 1\,\mathrm{ns}$ precision
- $\sim 15\,\mathrm{kHz}$ trigger rate
- (disadvantage: material budget degrades resolution for lower energy beams)

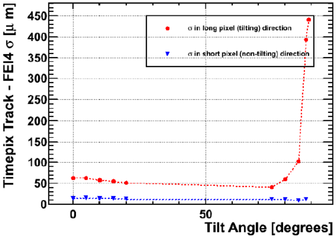


TimePix: Integration with external users

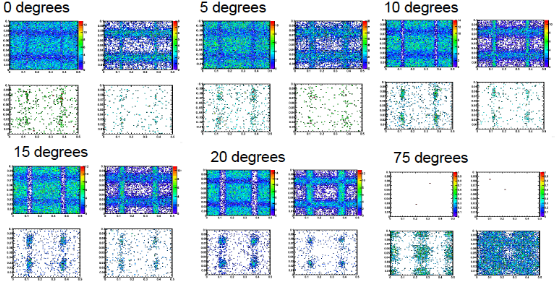
Effort to make external integration as simple as possible:

- DAQ systems run independently, information combined offline
- CO_2 cooling, remote controlled translations and full rotations, large space in z and y directions provided to DUT
- External integration works with 40 MHz style readouts without need for tagging plane.
- Proved with scintillating fibers, FE-I4 with full rotations, strip detectors, etc.
- Excellent quality FE-I4 data:

TimePix/FE-I4 resolution

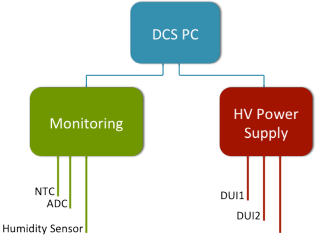


Track positions for 1,2,3,>3 pixel FE-I4 clusters



High-Voltage and Monitoring

- HV system for the use in the test beam ordered
- Individually floating 8 channels per module
- Channels completely independent controllable
- Hardware current and voltage limitation per module
- First modules defined for ATLAS pixels
- Different modules can easily be added
- Environmental monitoring based on ELMB (Embedded Local Monitoring Board)



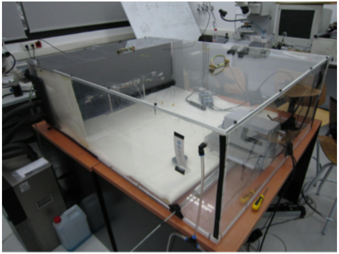
CO_2 Cooling

- WP9.3 includes a CO_2 cooling plant to be used when testing irradiated sensors
- Discussion showed that a system similar to the one used for the TimePix telescope would be perfect.
- Need to define the requirements

Off-Beam Infrastructure

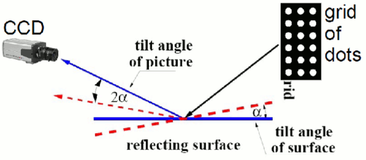
Develop an infrastructure to both ...

- evaluate the thermo-mechanical performance of fully integrated detector prototypes and to
- monitor minute deformations and misalignment of prototypes



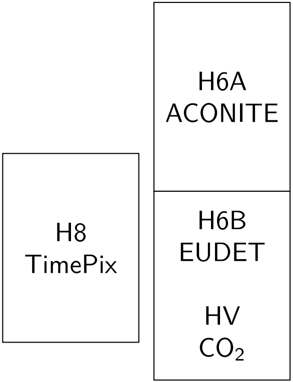
... under realistic environmental and power load conditions.

- Two methods of measurement:
  - using fiber-optical sensor based on strain, temperature, and humidity monitoring (CSIC (IFCA, IFIC))
  - optical measurement of deformation using an optical grid (DESY)
- First measurements using this infrastructure are planed for mid 2012



Plans for Commissioning & Summary

- The telescope will be available in different stages most of the time
- EUDET original version will be transported back to CERN in May
- ATLAS copy will be available at the same time
- TimePix telescope is installed at H8 (and is now a part of AIDA)
- HV and CO_2 will be installed as soon as available
- AIDA will not provide one telescope with a lot of features but a couple of telescopes with different features!

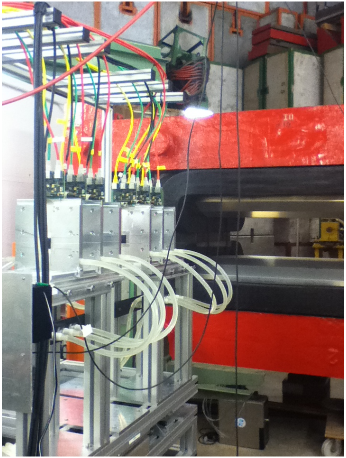


Thank you for your attention!

Overview Backup Slides

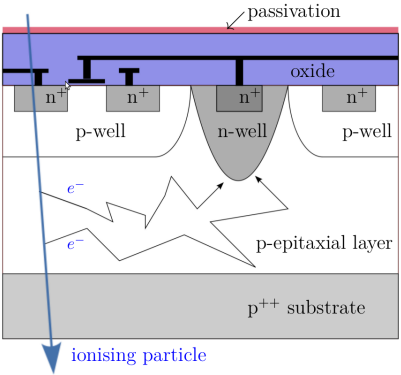
Overview Backup Slides

- A tool to define the exact track of a particle in a beam very precisely
- Used for detailed studies of newly developed detectors
- Pointing resolution should be better than the expected intrinsic resolution of the Device Under Test (DUT)
- DUTs: small pixel sensors to larger detectors
- Flexible design:
  - distances of planes variable from 10 to 150 mm
  - DUT position: gap between arms variable between few cm up to 35 cm
- Low material budget



Mimosa26 Sensors

- by IPHC (Strasbourg) & IRFU (Saclay)
- MAPS – Monolithic Active Pixel Sensor
- signal processing µ-circuits integrated on sensor substrate
- Pixel size: $18.4 \times 18.4\,\mu\mathrm{m}^2$
- Excellent ($\approx 1\,\mu\mathrm{m}$) spatial resolution
- Readout in rolling shutter mode
- At $80\,\mathrm{MHz} \rightarrow 112.5\,\mu\mathrm{s}$ per frame
- No dead-time, continuous readout
- Digital readout
- On-pixel amplification
- 1 discriminator per column width
- Built-in data sparsification
- Current version of Mimosa26:
    - High resistivity epitaxial
    - Back-thinned down to $50\,\mu\mathrm{m}$



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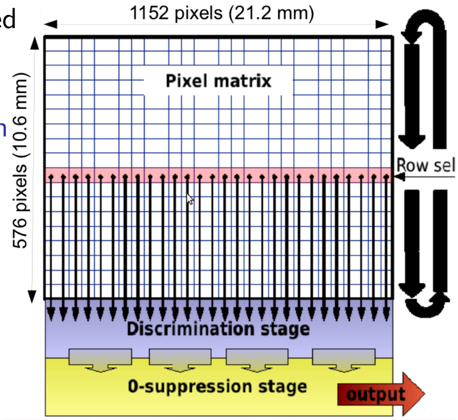
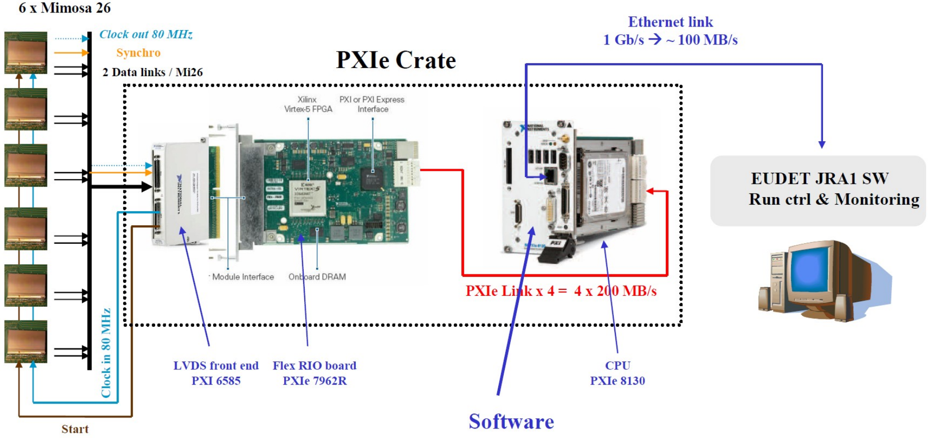


Data Acquisition Setup



National Instrument Flex RIO PXIe crate

- fast (max 800 $\mathrm{MB/s}$)
- allows reading Mimosa sensors without dropping frames

Trigger Logic Unit (TLU)

- generates trigger signal from up to four scintillator inputs
- connects up to six DUTs
- handshake with DUTs (optional):
  account for DUT busy signal and read out trigger number

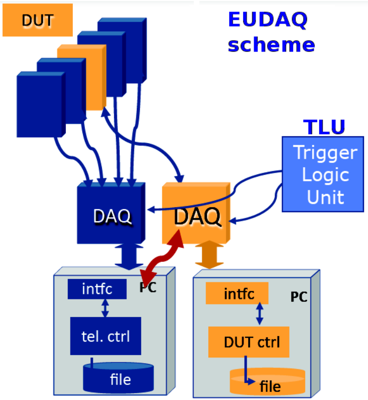
EUDAQ Software Data Acquisition System

- Allows full integration of *device under test* (DUT) independent of its technology including pre-existing DAQ systems
- Modular and flexible design

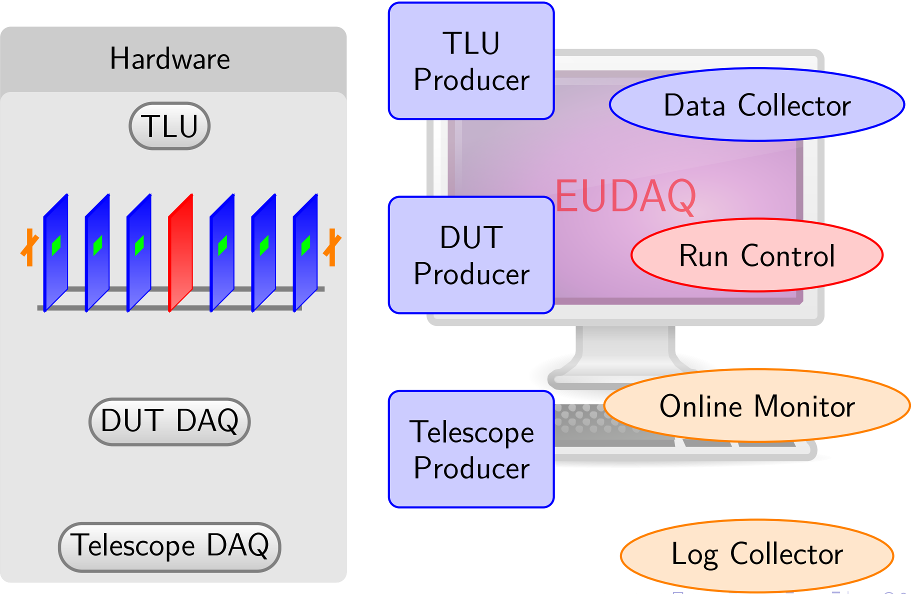
⇒ usable by many groups:

- Altro (Bonn)
- APIX (Atlas Pixels)
- Atlas (TRT)
- CMS Pixel (DESY)
- DEPFET (Bonn)
- FORTIS/SPIDER (Bristol)
- MimoRoma (INFN)
- MVD (DESY)
- PixelMan (Freiburg)
- SITRA (Santander)
- Taki (Mannheim)
- Timepix (Bonn)

... and more (NA62, Alfa, Alice, etc.)



The EUDAQ Architecture



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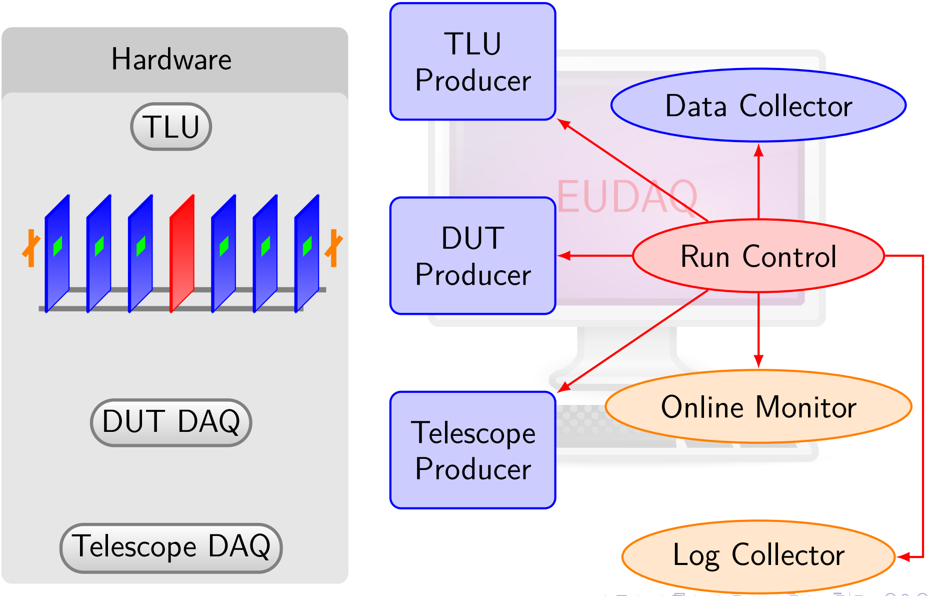

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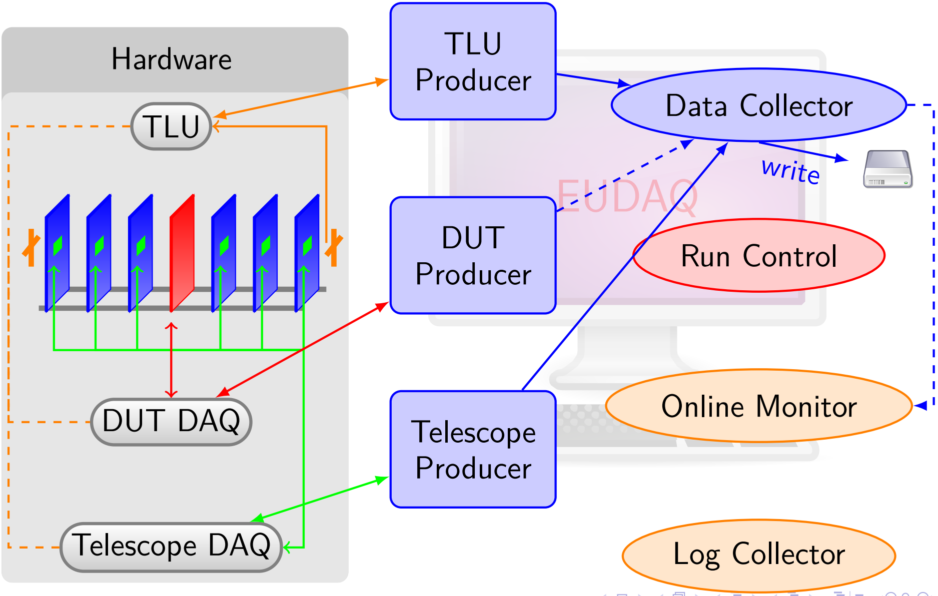

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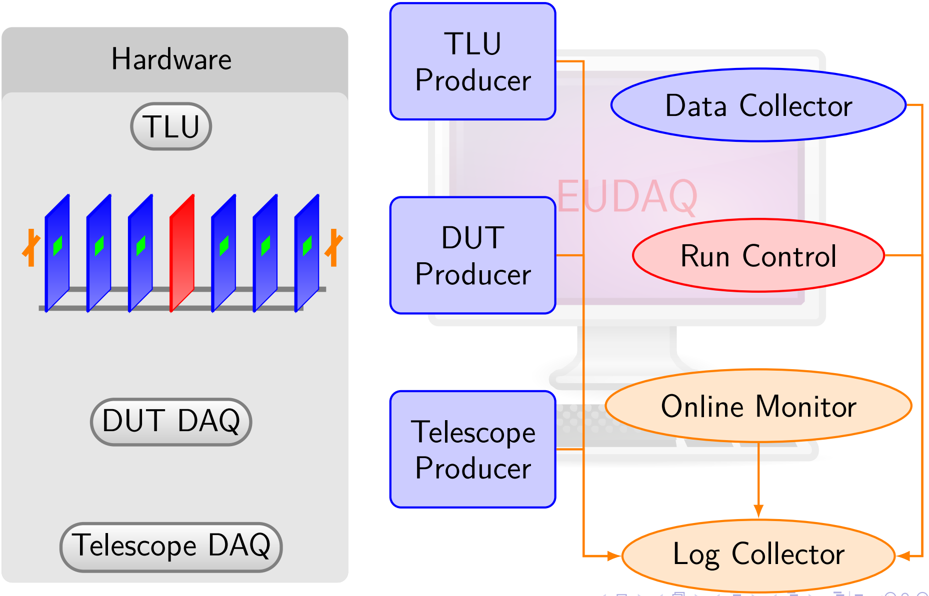
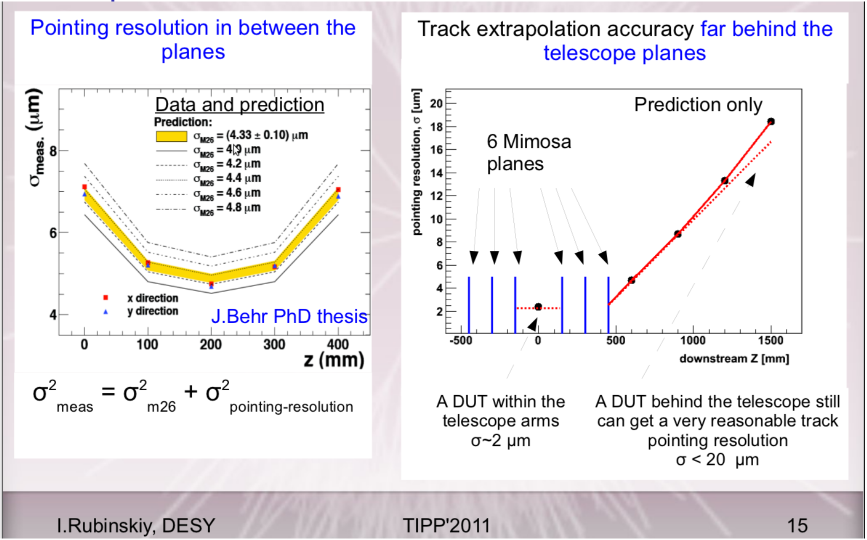
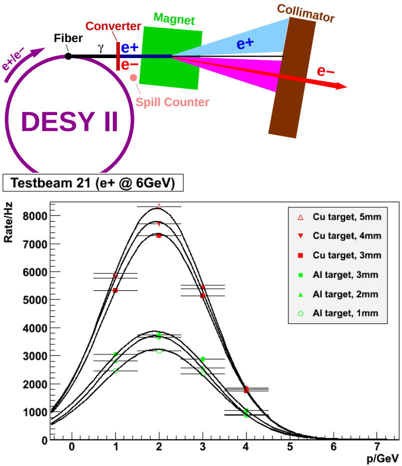


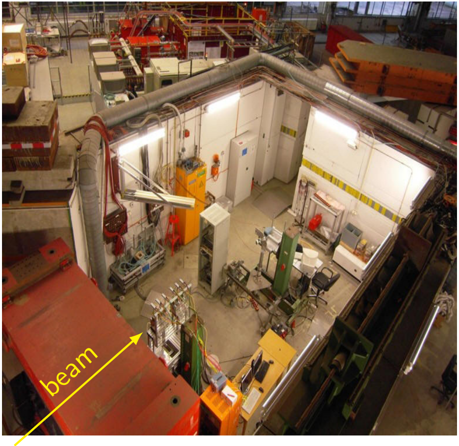
Telescope Performance



- data taken at CERN SPS (120 GeV pions)

Testbeam 21 @ DESY





- magnet current determines beam energy
- rates in the order of kHz for energies 1 – 3 GeV
- testbeam typically available to us over long periods of time

Improving the Trigger Logic Unit (TLU)

- Will start out with mini TLU prototype to test out ideas
- mini-TLU will be cheaper and easier to produce than existing TLU
- From there define the needs for a full AIDA fast TLU
- A solution: Combine LHC pixel detector with MAPS

$\rightarrow$ Good spatial resolution from MAPS, timing e.g. from FE-I4

- Asynchronous Trigger/Busy interface challenging above 100kHz
  - For $>$ 1MHz need signals synchronous with sys clk.
  - Do we want/need a new high-rate interface?
  - Already need to define a new interface for CALICE
  - Likely to be CLOCK/TRIGGER/BUSY
  - Synchronous with system clock
  - Manchester (Phase) Encoded for DC-balance.
  - Verify data integrity using timestamps
- Decided that a AIDA high speed TLU is needed and defined the details.