DESY Test Beam Facilities and CMS Pixel Studies

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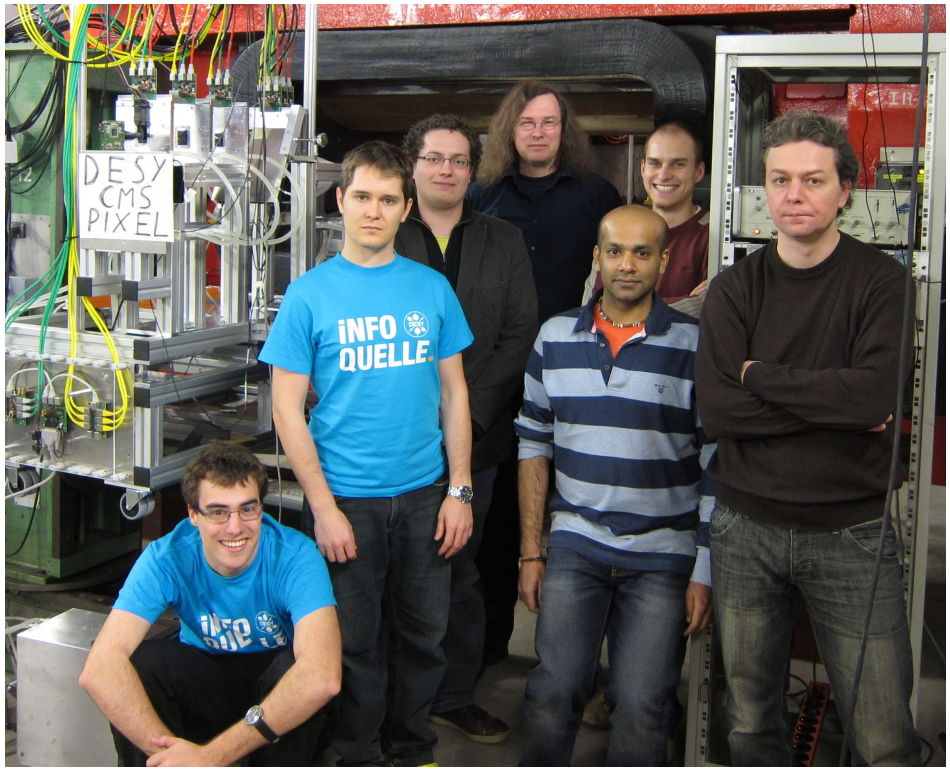
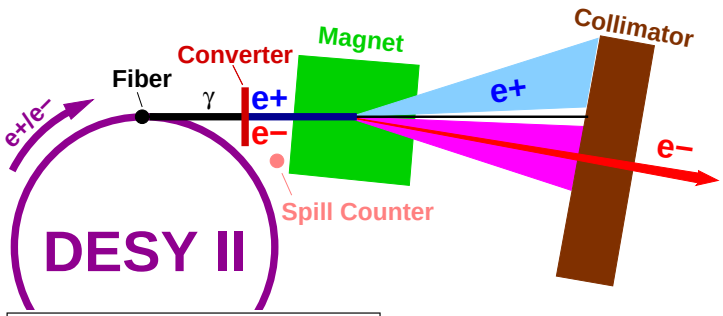
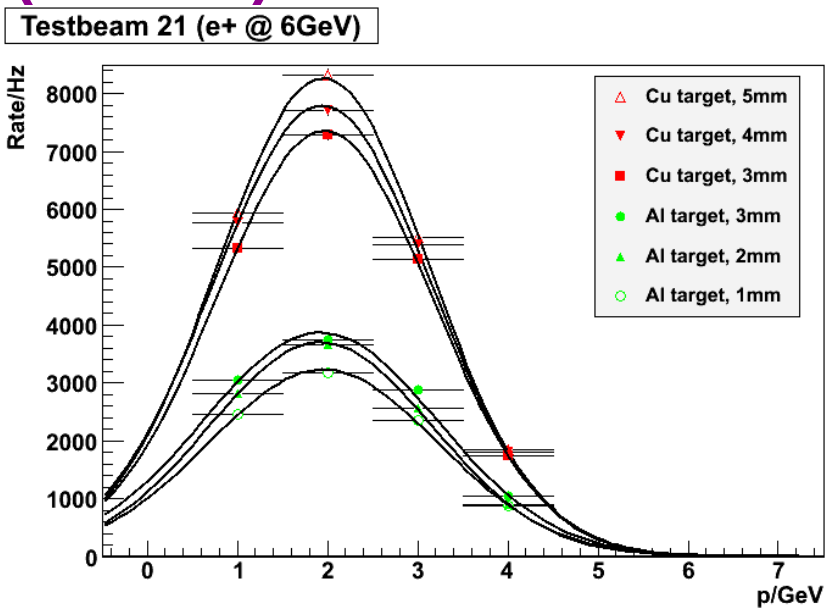
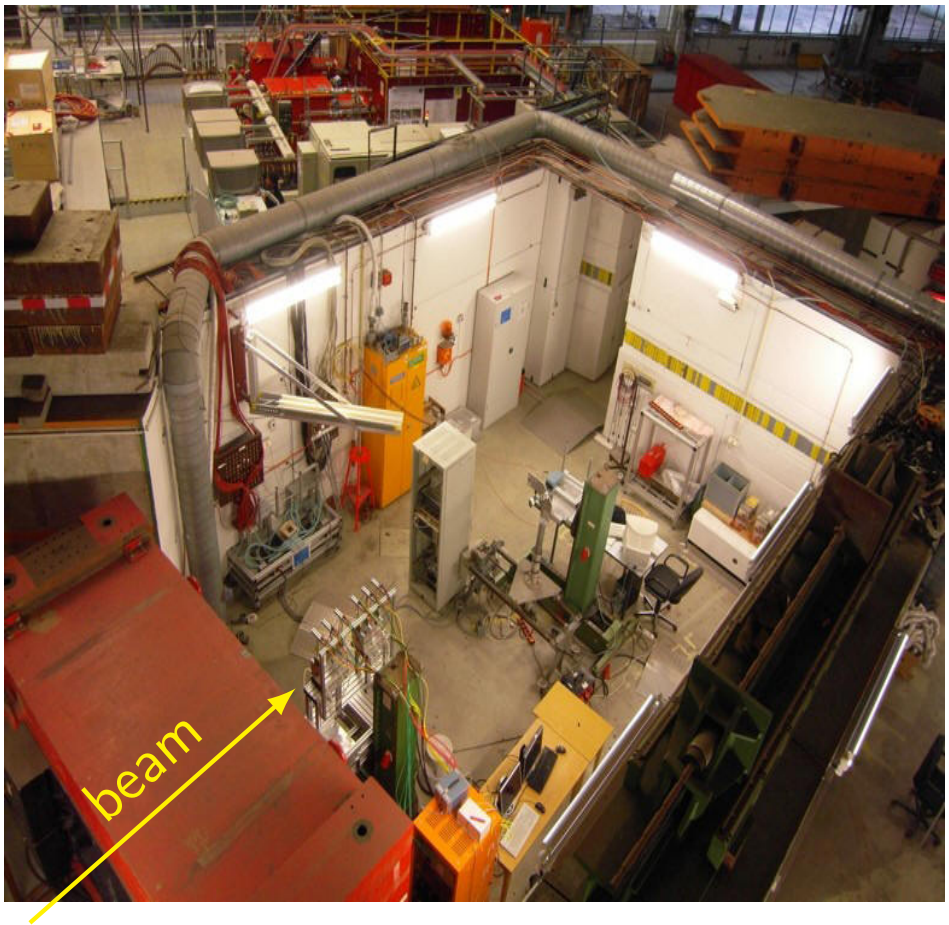
1. Test Beams at DESY
2. EUDET/AIDA Pixel Telescope
3. CMS Pixel Test Beam Campaign



Test Beams at DESY

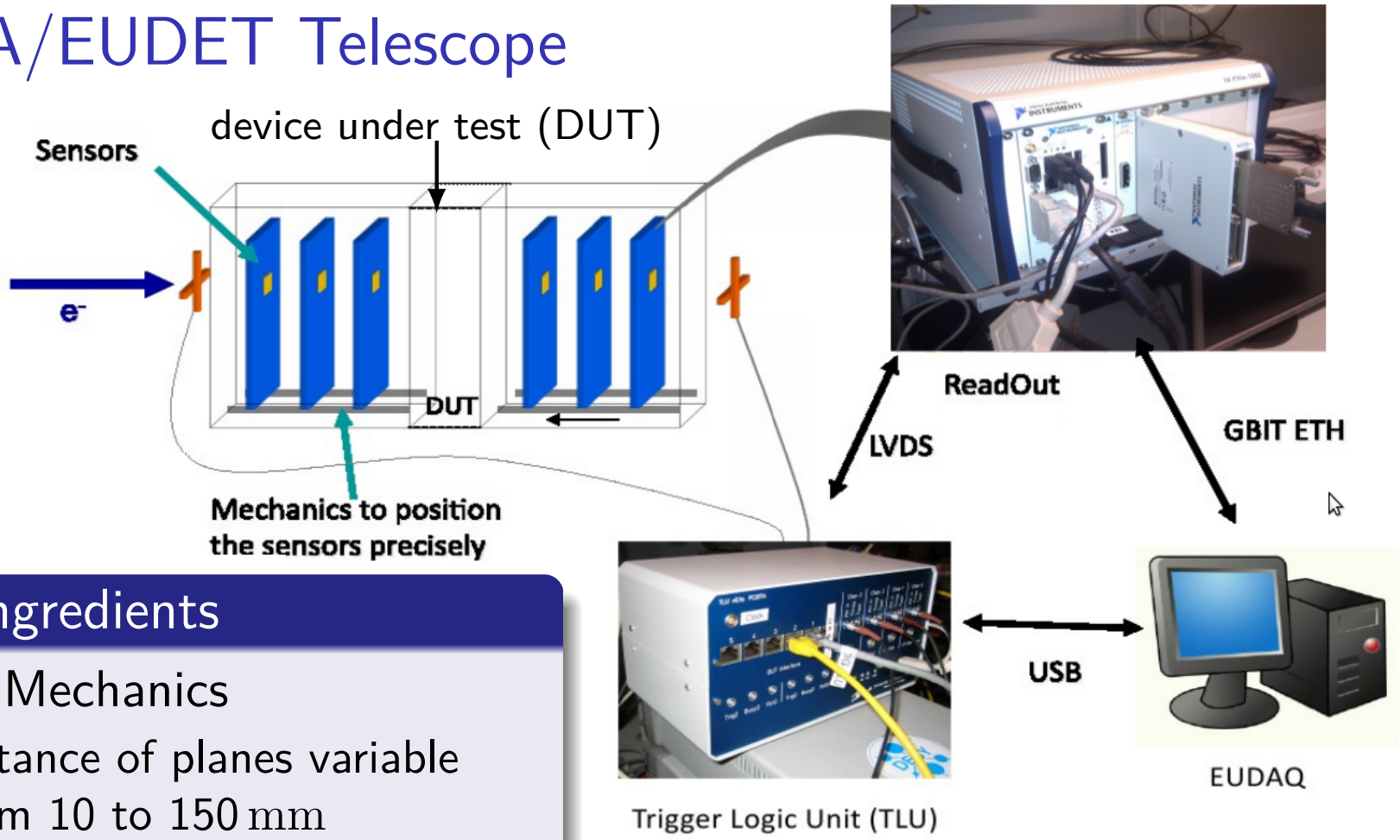






- three test beam lines available at DESY (TB 21, 22, 24)
- beam energy variable by setting magnet current
- rates in the order of kHz for energies 1 – 4 GeV
- test beam typically available to us over long periods of time

The AIDA/EUDET Telescope



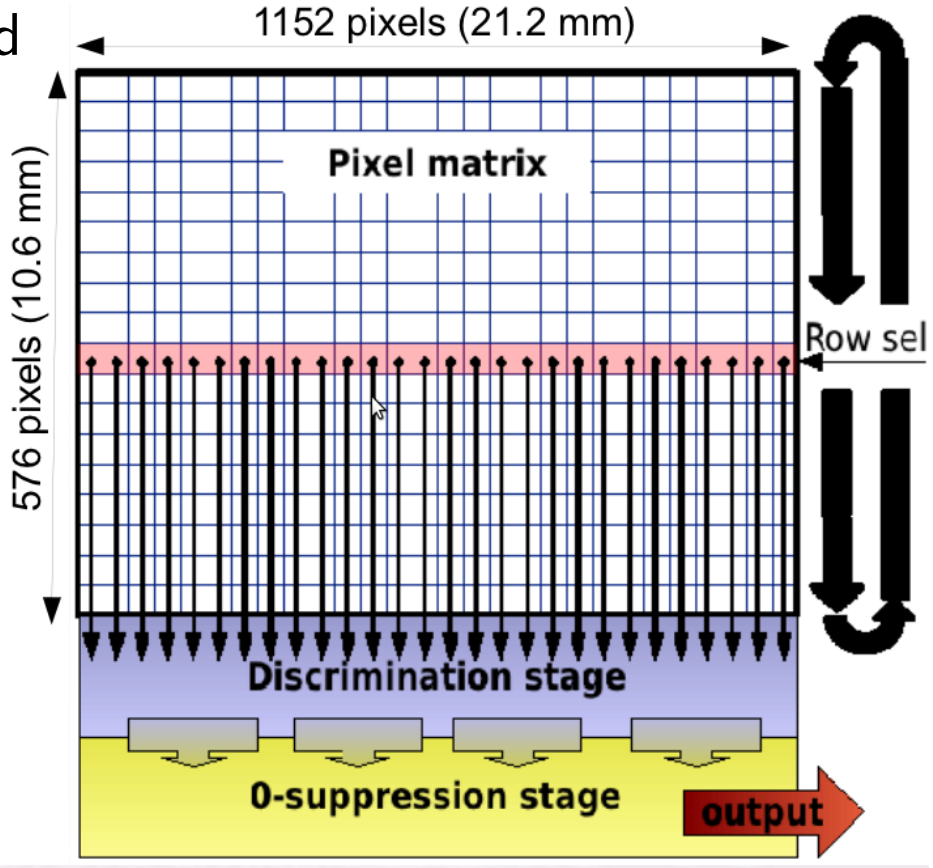
Hardware Ingredients

- flexible Mechanics
  - distance of planes variable from 10 to 150 mm
  - up to 35 cm available for DUT
- very thin Sensors: Mimosa26
- Trigger Logic Unit (TLU)
- fast DAQ

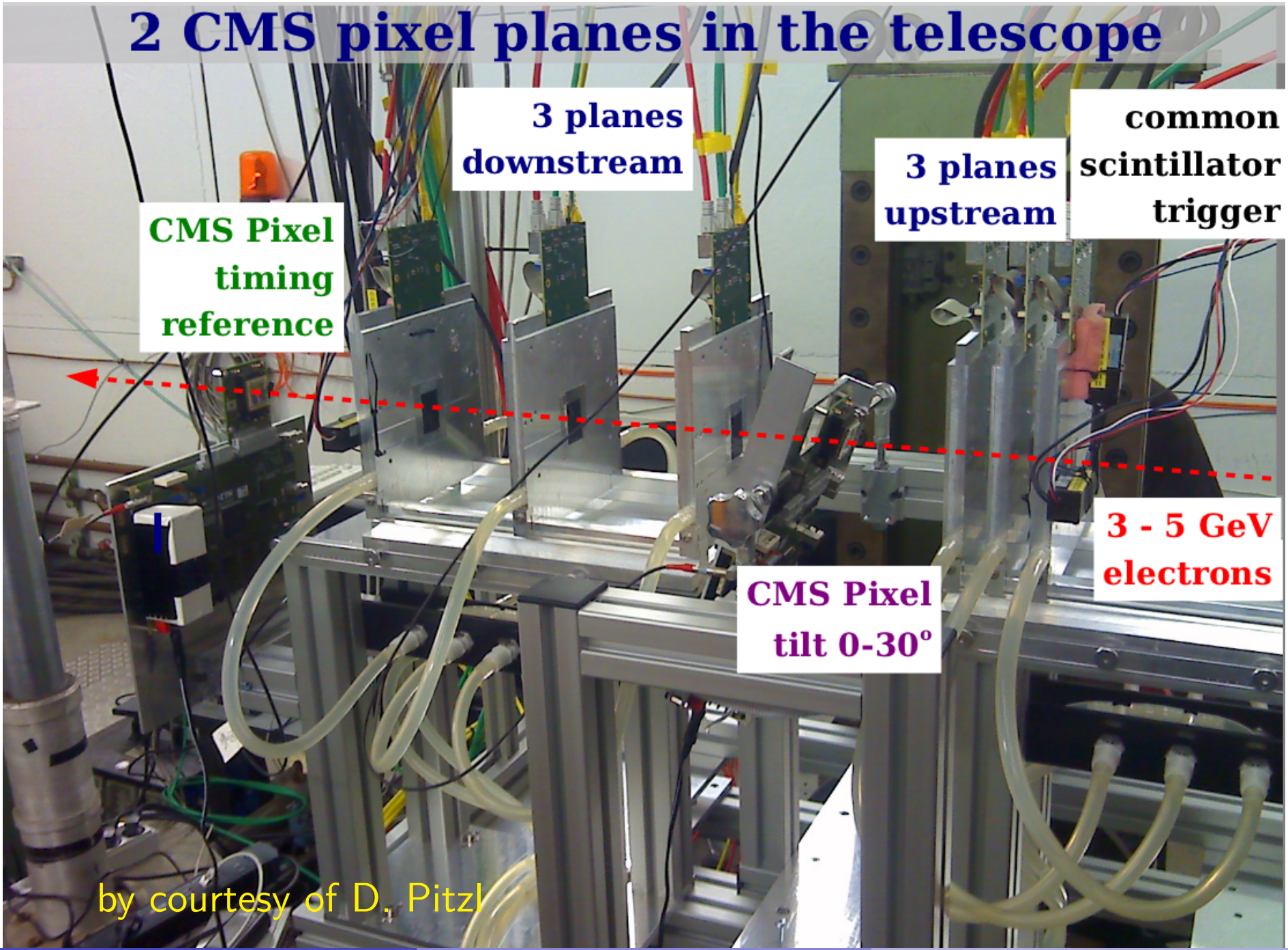
pointing resolution @ DUT:
$\sigma_i \sim 3\,\mu\mathrm{m}$

Mimosa26 Sensors

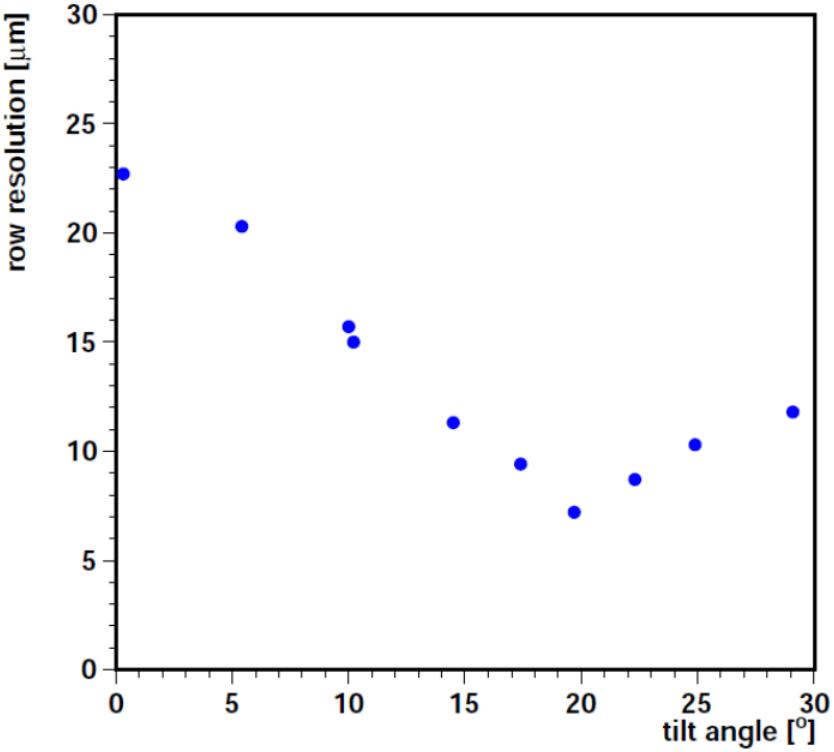
- by IPHC Strasbourg
- MAPS – Monolithic Active Pixel Sensor
- signal processing µ-circuits integrated on sensor substrate
- Pixel size: $18.4 \times 18.4\,\mu\mathrm{m}^2$
- Excellent ($\approx 4\,\mu\mathrm{m}$) spatial resolution
- Readout in rolling shutter mode
- At $80\,\mathrm{MHz} \rightarrow 112.5\,\mu\mathrm{s}$ 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 $50\,\mu\mathrm{m}$

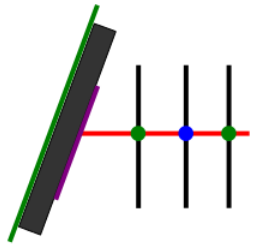


2 CMS pixel planes in the telescope



CMS pixel row resolution vs tilt angle





- Chip 10, 5.6 GeV, telescope extrapolation uncertainty subtracted.
- row pixels = 100 µm.
- Binary:
  - $\sigma = 100 / \sqrt{12} = 29$ µm
- Optimal angle 19.5°:
  - $\sigma = 7$ µm.

D. Pitzl et al.: April 2012 beam test results 30 DESY CMS Pixel Upgrade, 18.5.2012

In April 2012:
measured efficiency and resolution . . .

- vs bias voltage
- vs threshold
- vs tilt angle

. . . for present Pixel ROC PSI46 v2.3

$\Rightarrow$ reference data for 2nd beam test with new PSI46xdb in summer

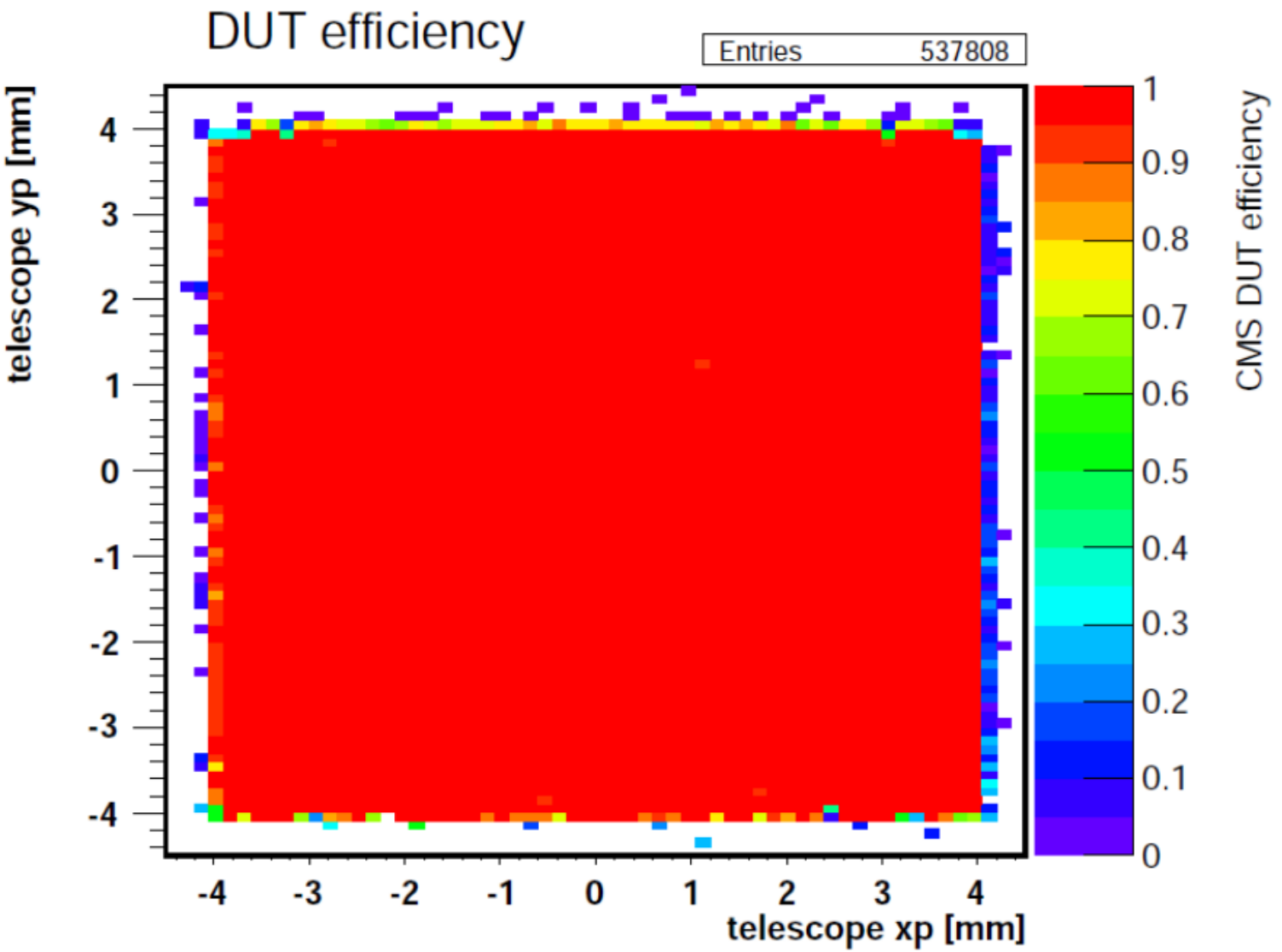
Summary

- The AIDA/EUDET pixel telescope offers a flexible framework to test detectors; low material budget makes it ideal for test beams at DESY
- The CMS pixel was successfully operated together with the pixel telescope using parallel DAQs
- First results: efficiency above 99% for thresholds below $9\,\mathrm{k}e$, and optimal resolution of $7\,\mu\mathrm{m}$ (at $3.3\,\mathrm{k}e$ and 20°tilt)

Overview Backup Slides

4. CMS Pixel Efficiency Map
5. DAQ Software and Analysis Framework
6. Telescope Performance

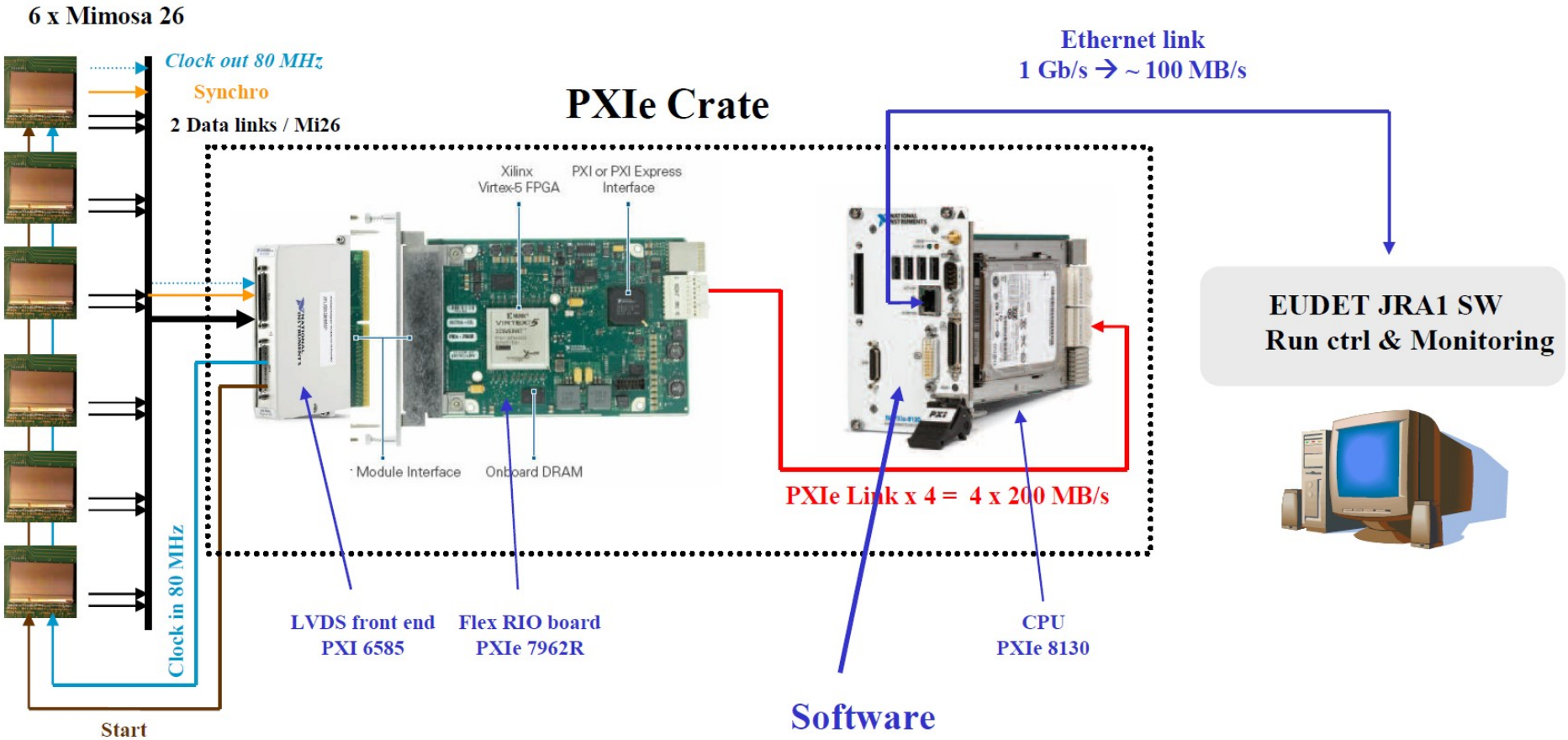
Efficiency map



- run 3096
  - 2800 s
- 5.6 GeV
- chip 10
- tilt 20°

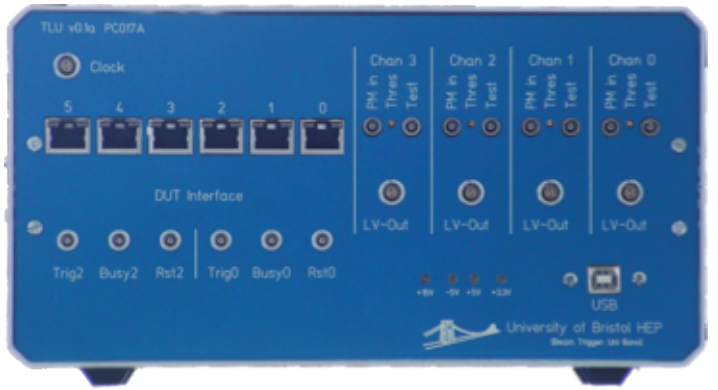
Upgrade of the DAQ in 2011

Much faster
⇒ ready for the future



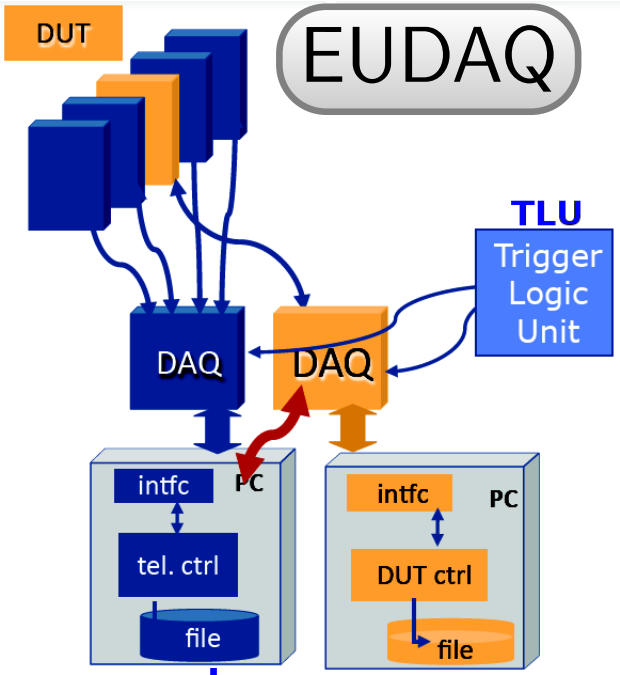
System set up by Strasbourg, connection to EUDAQ done by DESY

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 ($\rightarrow$ 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



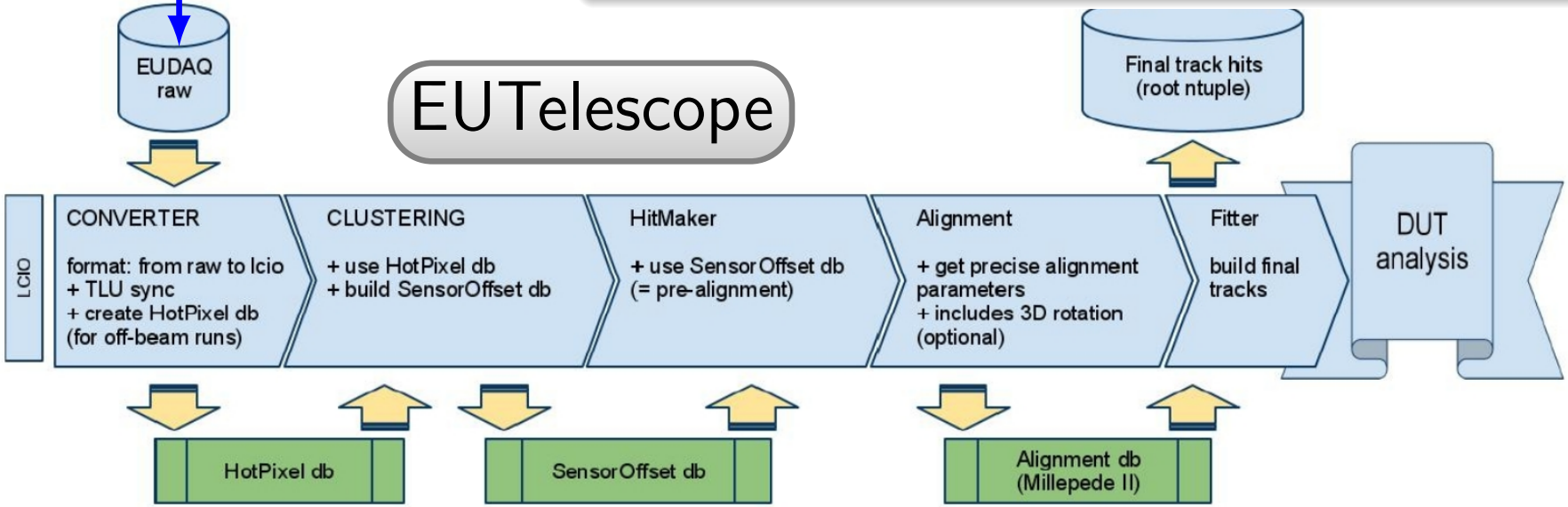
EUDAQ (Data Acquisition Software)

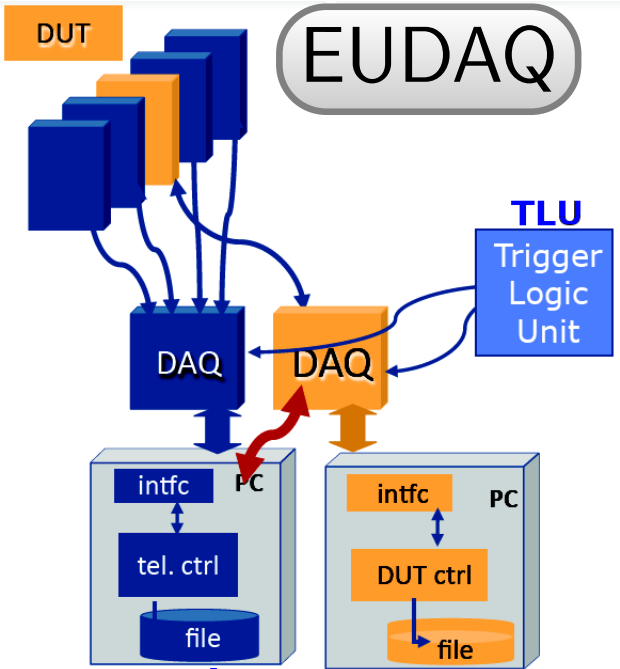
- Allows full integration of *device under test* (DUT) independent of its technology including pre-existing DAQ systems
- Modular and flexible design

$\Rightarrow$ in usage by many groups already!

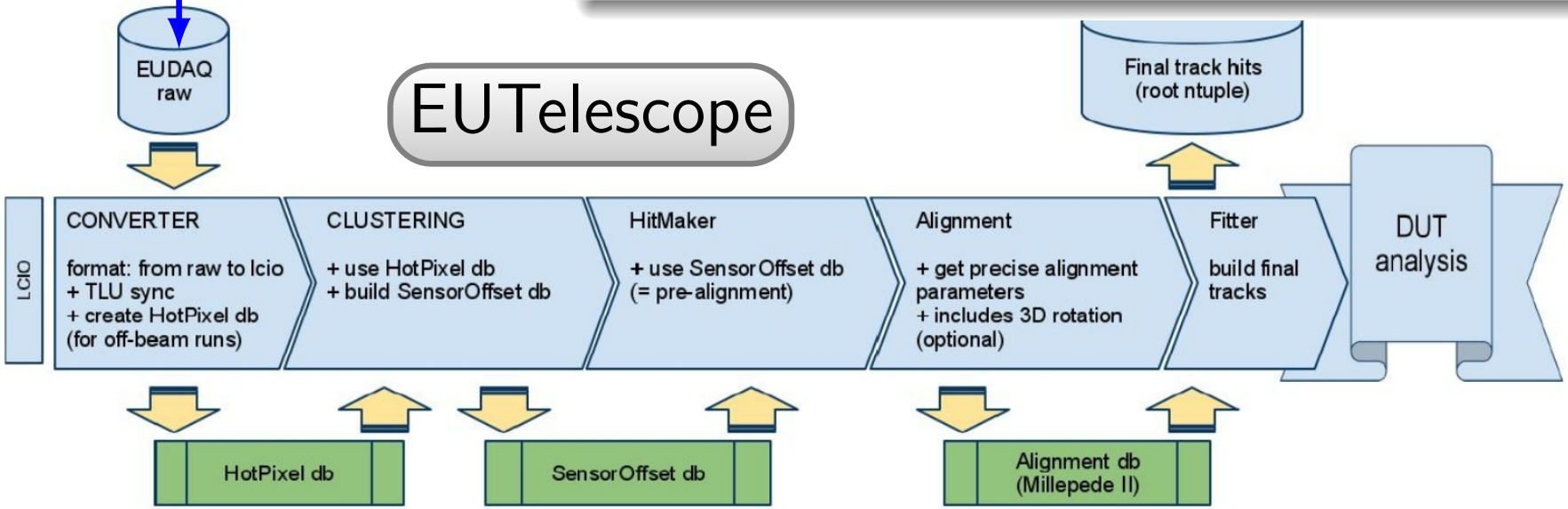
EUTelescope (Track Reconstruction & Analysis)

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



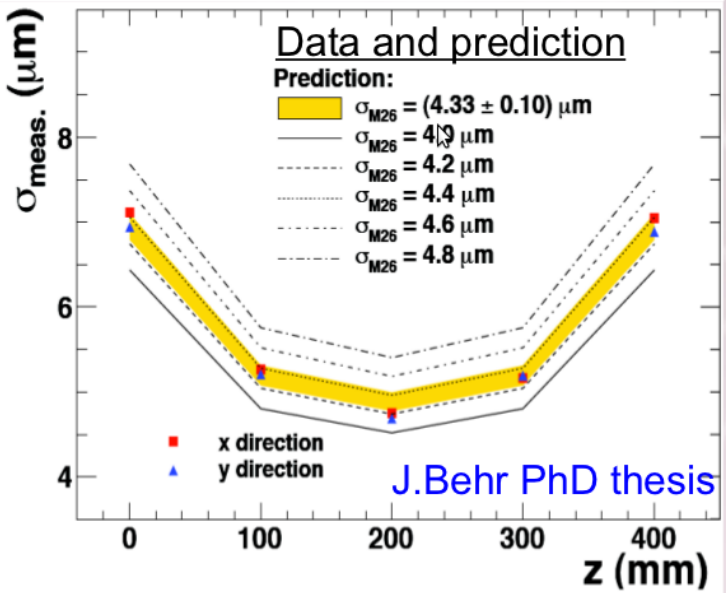


- EUDAQ system
  - DUT brings own DAQ
  - TLU handshake → sync'ed trigger
  - telescope data stream can include DUT
  - offers online monitor
- EUTelescope
  - track reconstruction software
  - stepwise transition from single pixel array to 3D coordinates of hits and fitted tracks in global frame
  - based on Marlin (ILCSoft)



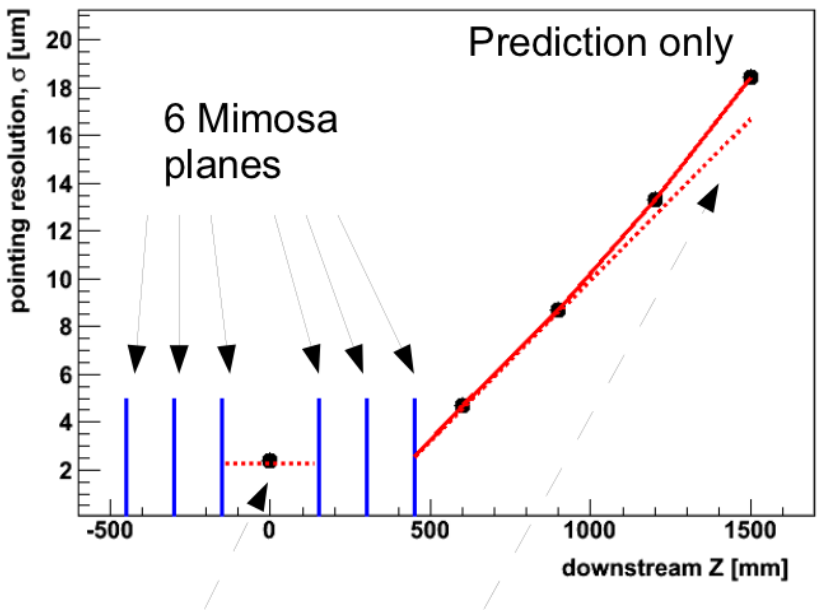
Telescope Performance

Pointing resolution in between the planes



$$\sigma^2_{meas} = \sigma^2_{m26} + \sigma^2_{pointing\text{-}resolution}$$

Track extrapolation accuracy far behind the telescope planes



A DUT within the telescope arms σ~2 μm

A DUT behind the telescope still can get a very reasonable track pointing resolution σ < 20 μm

I.Rubinskiy, DESY TIPP'2011 15

- data taken at CERN SPS (120 GeV pions)