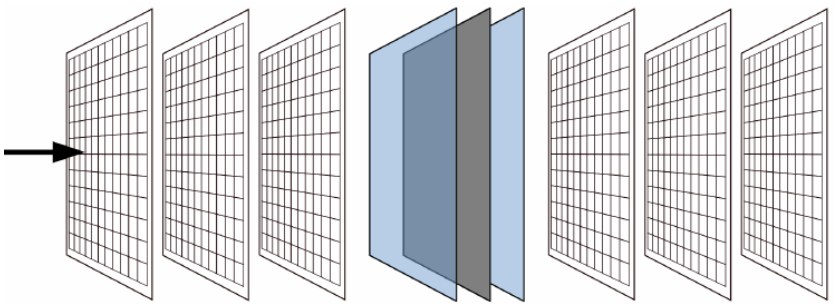
High precision tracking using pixel telescopes
(WP 15.2)

AIDA-2020 First Annual Meeting
14.06.2016

Paul Schütze
for the DESY
telescope crew



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654168.

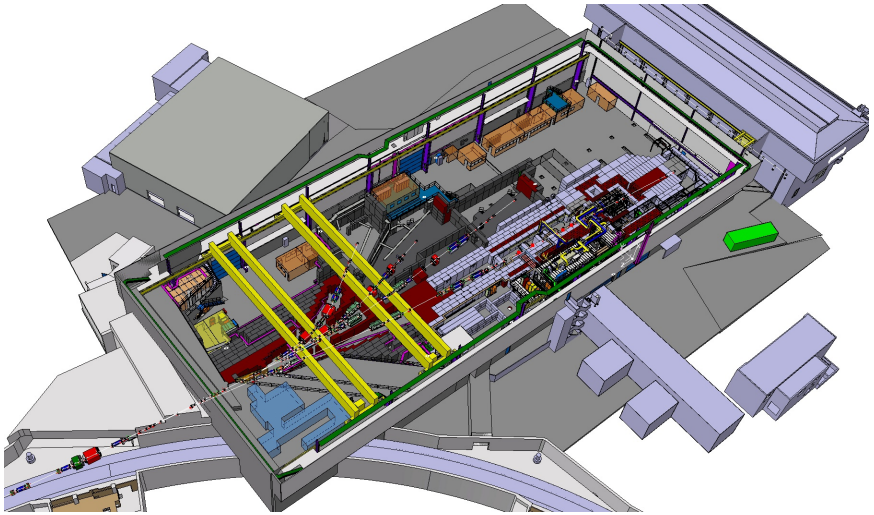
WP 15.2

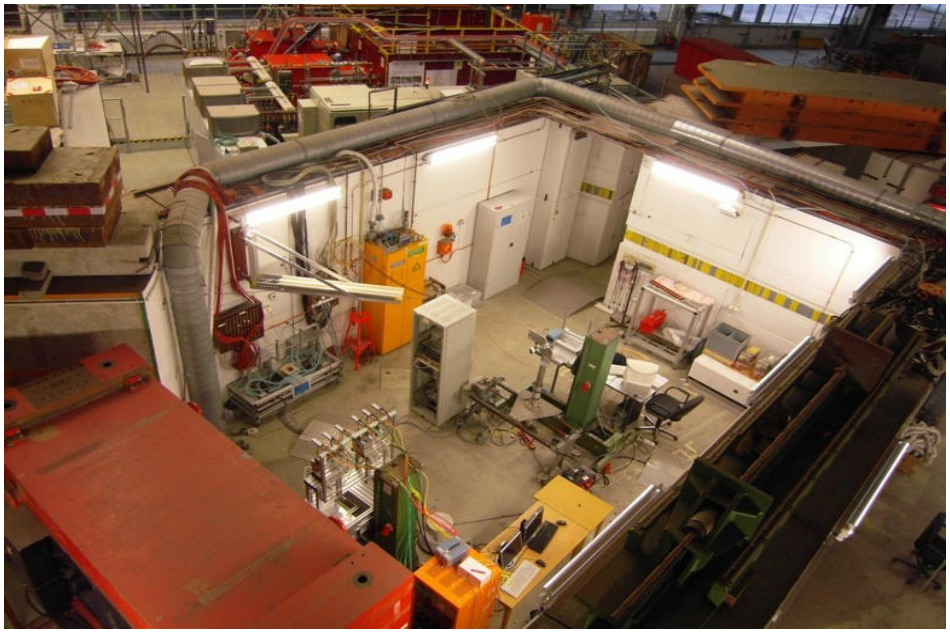
- WP 15: Upgrade of beam and irradiation test infrastructure
  - WP coordinators: Federico Ravotti (CERN), Marcel Stanitzki (DESY)

- WP 15.2:
  - Improvements of test beam infrastructure for high precision tracking
    - Assembly of pixel telescopes
    - User support for pixel telescopes at DESY and CERN test beam areas

Test beam for detector R&D

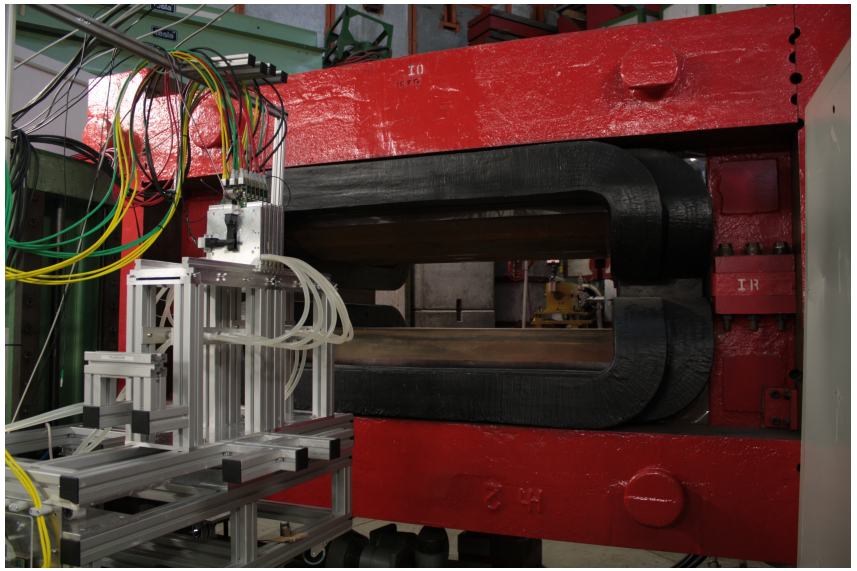
- Facilities included in WP 15.2:
  - CERN PS
  - DESY II

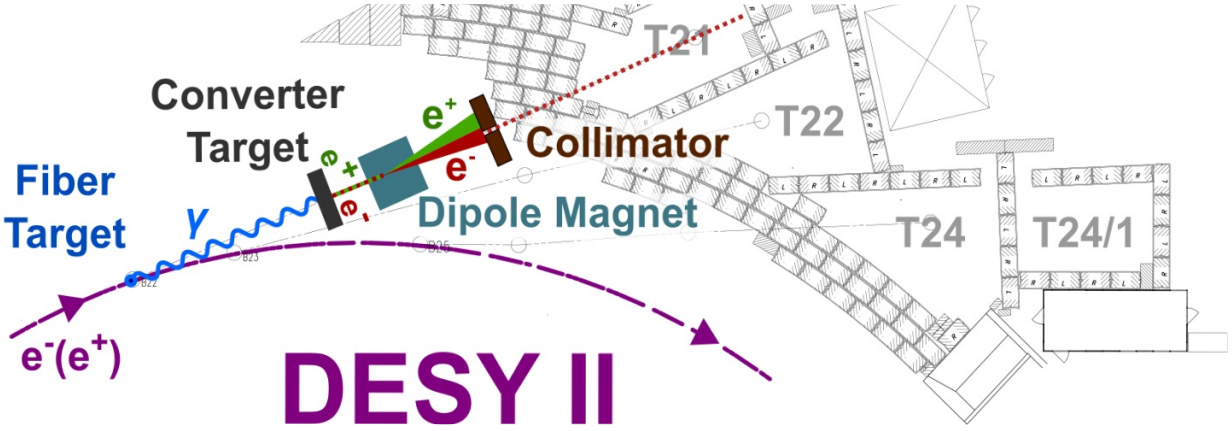




Test beam area - DESY

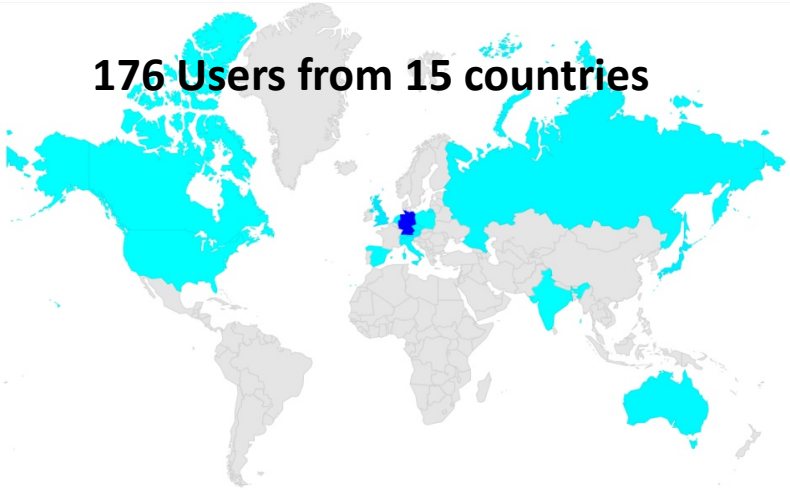
- Three beam lines (21, 22, 24)
- Electrons / Positrons, 1 – 6 GeV
- ~ 10 kHz particle rate
- TB 21:
  - 1 T dipole magnet
  - DATURA telescope
- TB 22:
  - DURANTA telescope
- TB 24/1:
  - 1 T superconducting magnet (PCMAG)
  - On request: DURANTA tel.

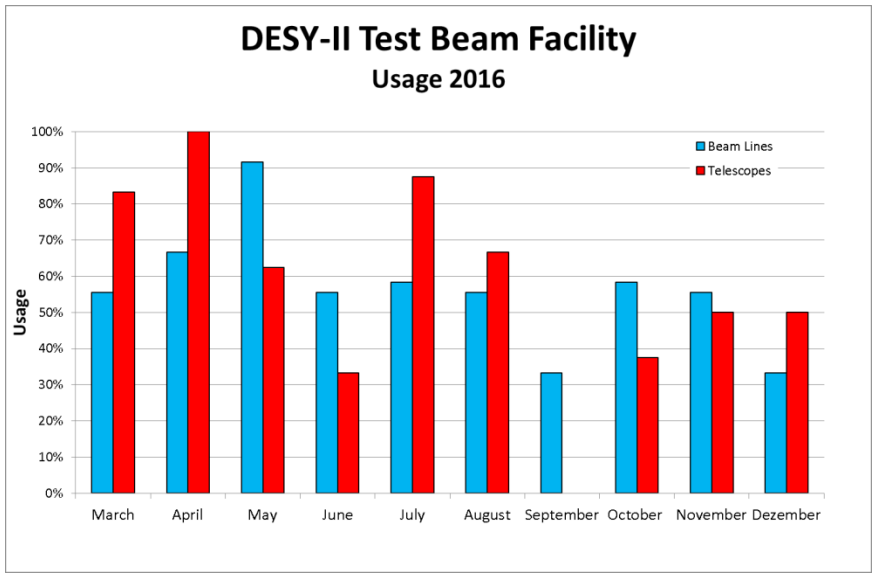


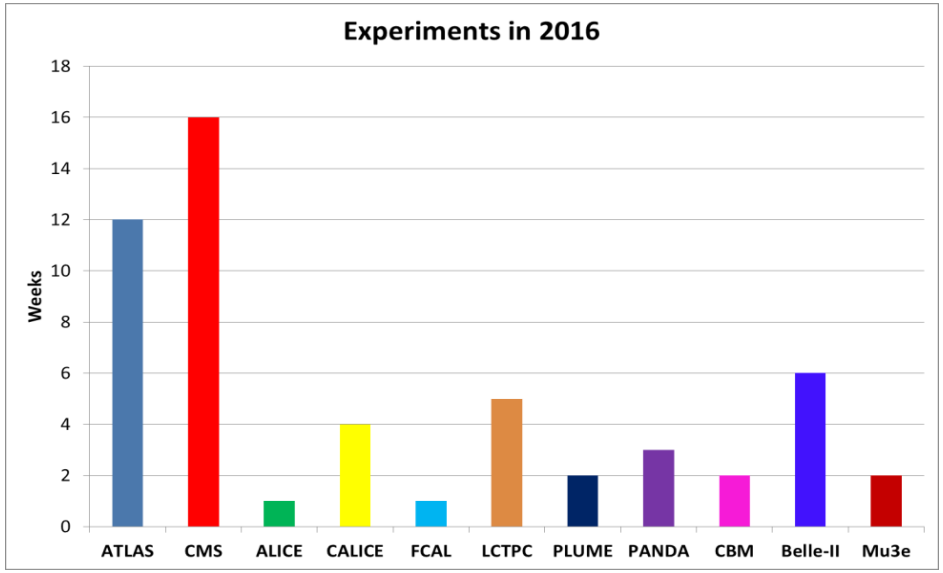


Test beam area - DESY

- Stats of 2016 run (effective June 2016)
  - 105 weeks available
  - 57 % already booked
  - 50 % LHC detector groups
  - 70 % telescope request







Test beam for detector R&D Infrastructure

- Three main pillars of the EUDET-style pixel telescope infrastructure

Hardware:	DAQ-software:	Analysis software:
sensors, mechanics, electronics, DAQ PCs, ...	modular framework, generic, common, ...	modular framework, reconstruction, analysis, ...
This talk	WP5, Yi Liu (parallel session)	This talk (only example)

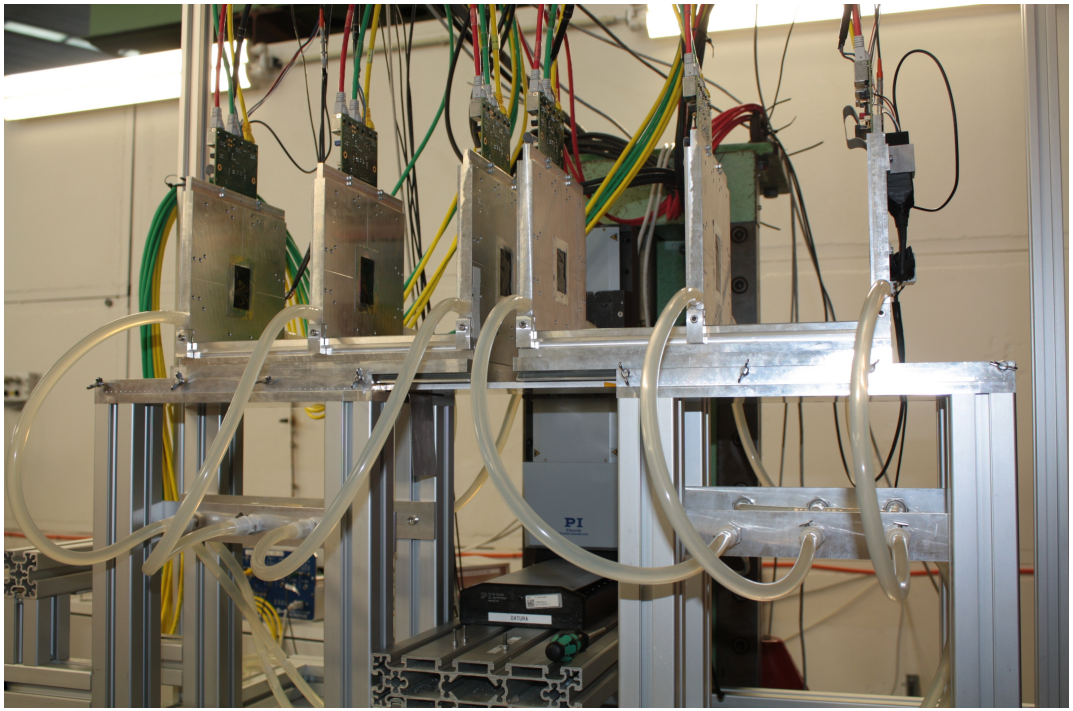
Pixel telescopes Overview

No.	Name	Location	Funded by	Year
1	(EUDET-) AIDA Telescope	CERN SPS	EUDET/AIDA FP6/7	
2	ANEMONE	Bonn	U Bonn	2011
3	ACONITE	CERN SPS	ATLAS	2012
4	DATURA	DESY	DESY	2012
5	CALADIUM	SLAC	Carleton U	2013
6	DURANTA	DESY	DESY	2015
7	AIDA2020	CERN PS	AIDA2020	2016

Pixel telescopes

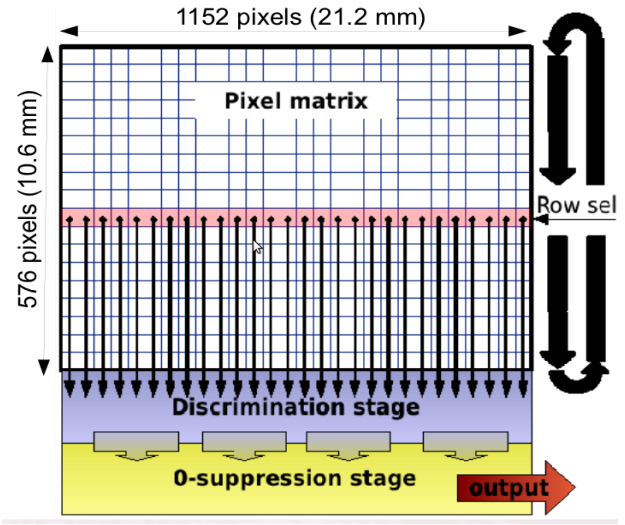
- High precision tracking of particle beams

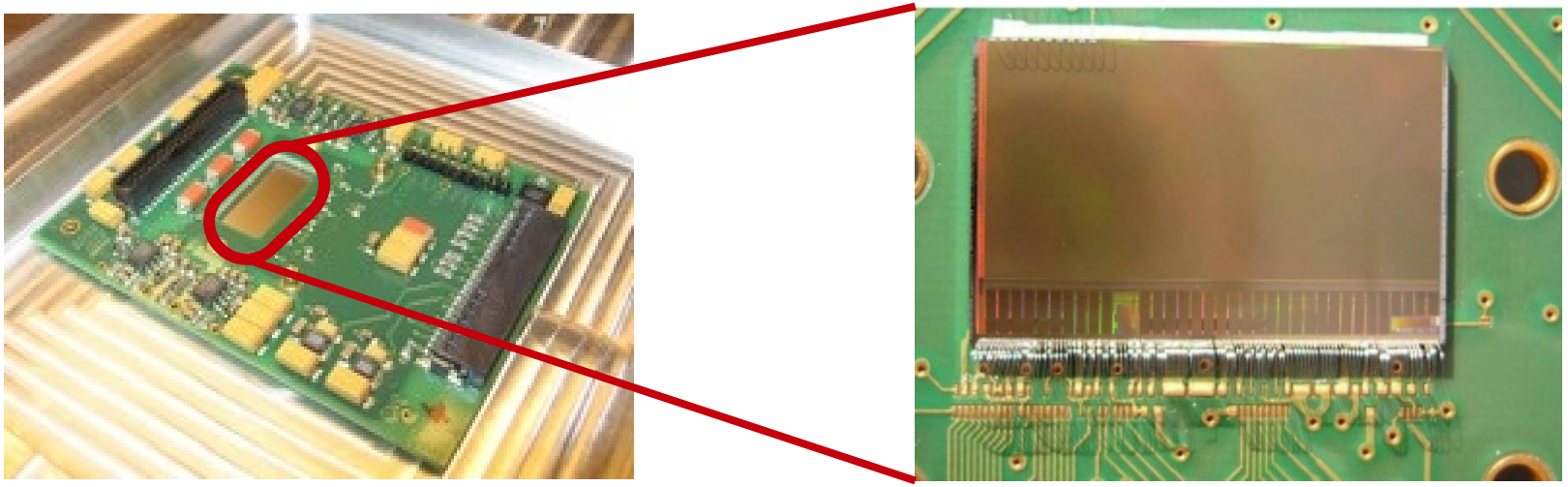
- 6 Sensors: Mimosa26
- 4 PMTs as coincidence trigger
- TDAQ system



Pixel telescopes
Mimosa 26

- Mimosa26 sensors:
  - Pixel pitch: 18.4 µm x 18.4 µm
  - Active area: 10.6 mm x 21.2 mm
  - Thickness: 50 µm (+ 50 µm kapton)
  - Rolling shutter readout
  - Integration time: 115.2 µs





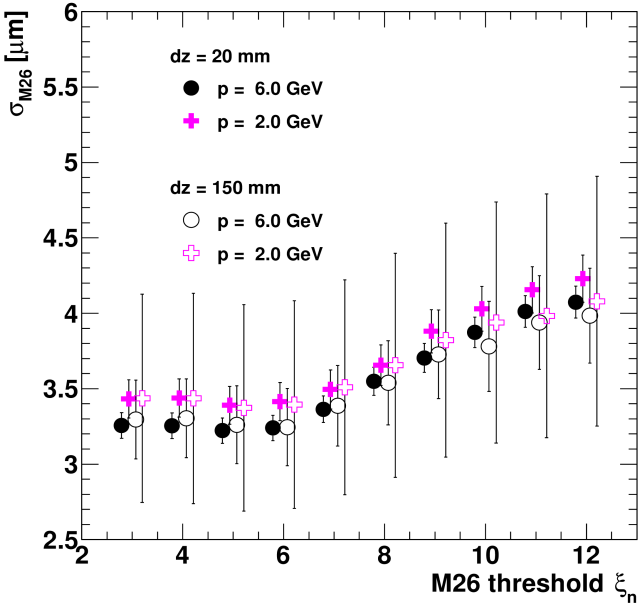
Pixel telescopes TDAQ

- TDAQ system:
  - NI crate for readout of Mimosa26 sensors
  - DAQ PC
  - Trigger Logic unit (TLU)
  - Based on EUDAQ
- Further equipment / infrastructure:
  - Water cooling for telescope planes
  - x – y – phi stage
  - Local network
  - User support on site
  - …

Pixel telescopes Performance

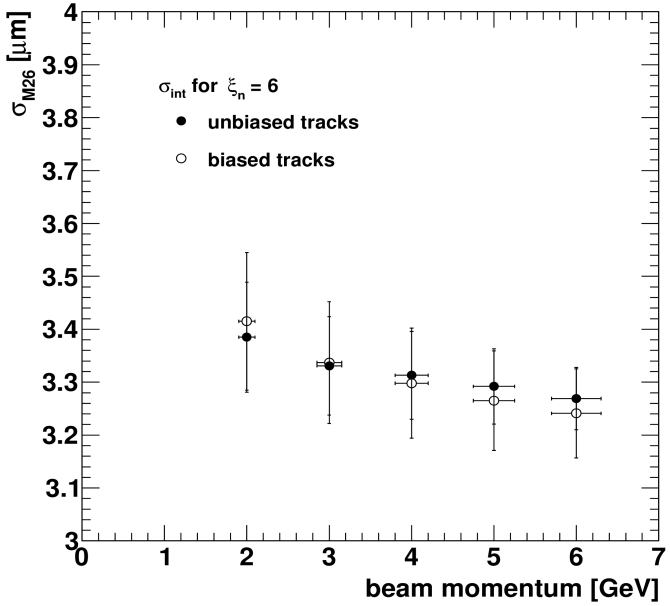
- Measured intrinsic resolution of Mimosa26 sensor:
  - σ = (3.24 ± 0.09) µm
  - Dependent on particle momentum and sensor threshold

Intrisic resolution vs threshold



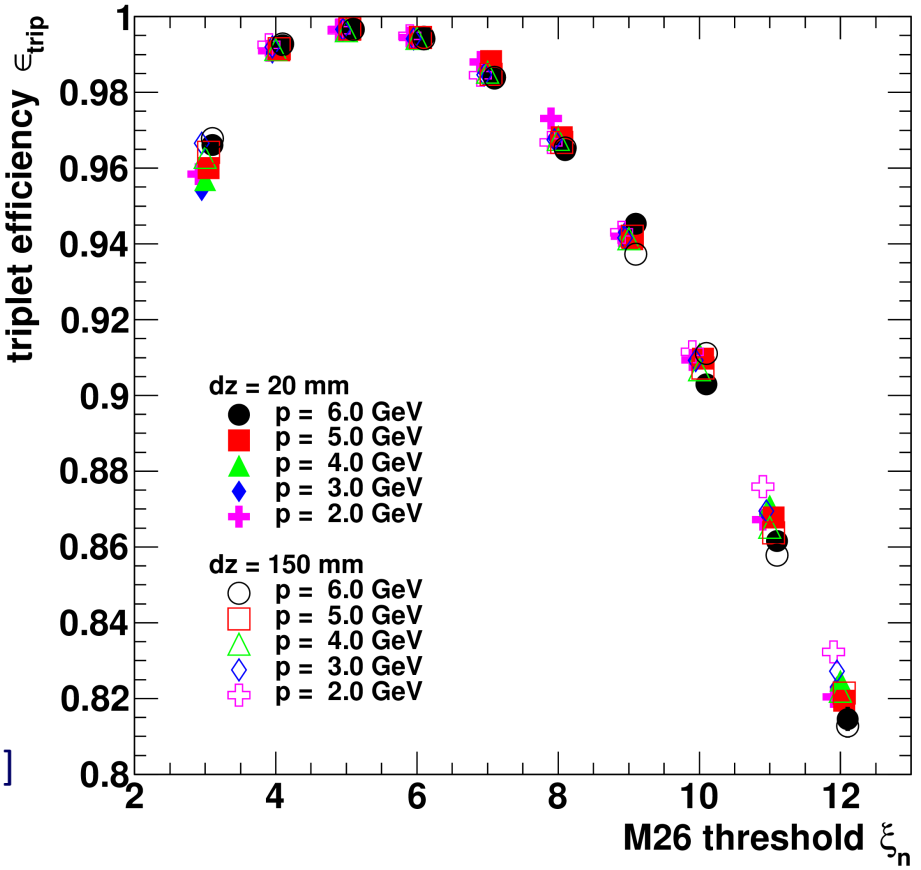
[1]

Intrisic resolution vs particle momentum



Pixel telescopes Performance

- Measured Mimosa26 efficiency:
  - Up to ε = 99.6 %
- Noise occupancy:
  - $6 \cdot 10^{-5}$ / frame
- Published in:
  H. Jansen, S. Spannagel et al., Performance of the EUDET-type beam telescopes, Mar. 2016
  - arXiv:1603.09669

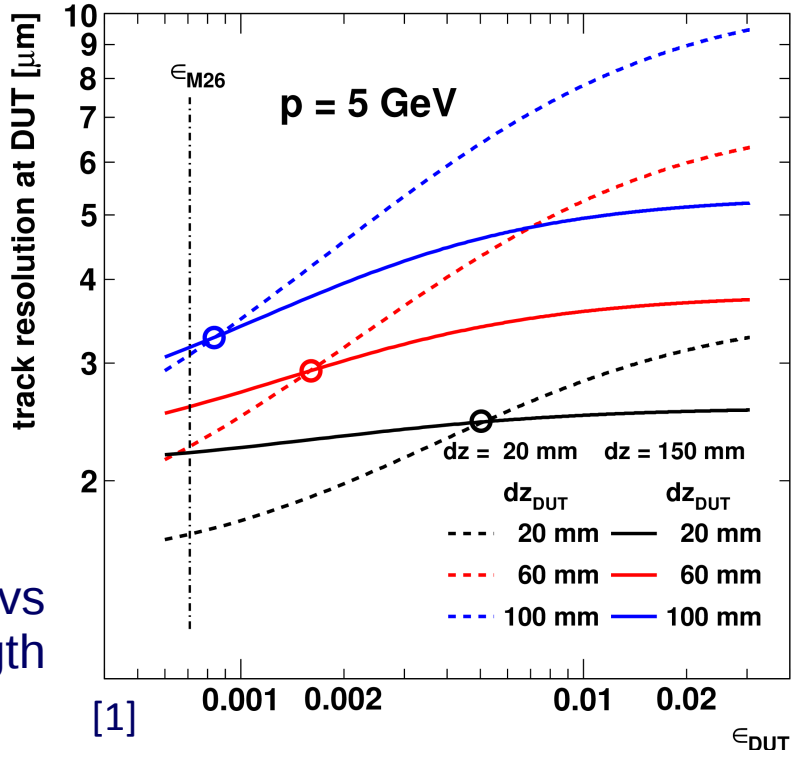


[1]

Pixel telescopes Resolution simulator

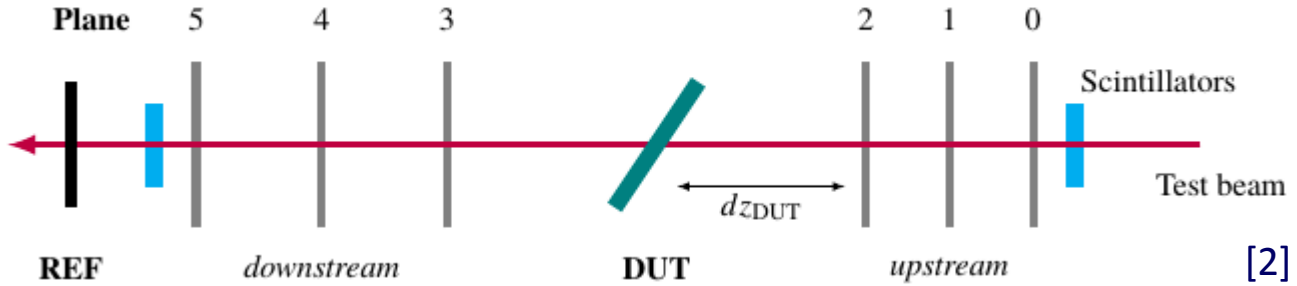
- Resolution simulator
  - Based on measured intrinsic resolution and GBL formalism
  - Predicts the telescope track resolution for your setup
  - Helps on finding the optimal telescope setup for your test beam
  - Available on github
  - https://github.com/simonspa/resolution-simulator
- Predicted telescope track resolution @DUT (DESY, 5 GeV, 0.1 % X0):
  - σ > 1.86 µm

Track resolution vs DUT rad. length

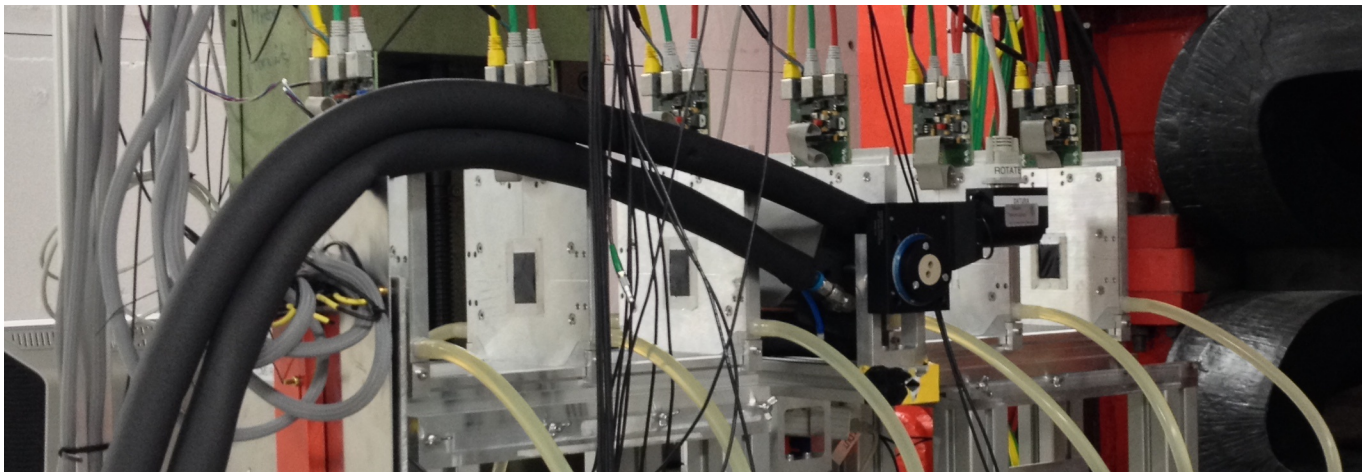


[1]

Pixel telescopes
Use case – CMS pixel det.



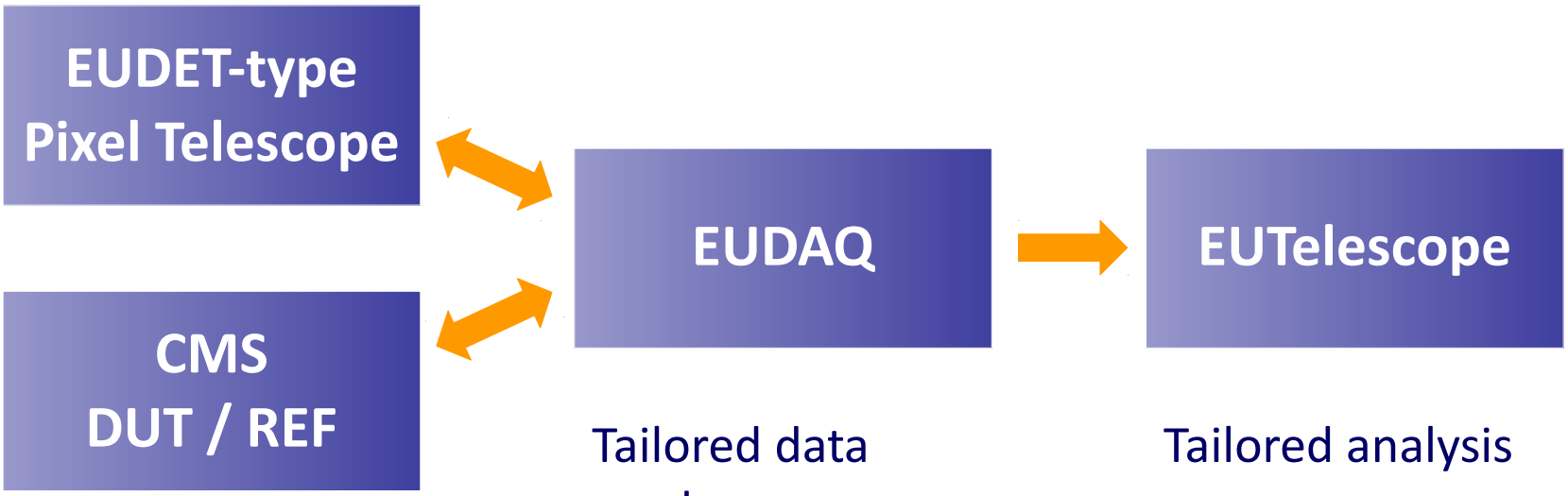
[2]



- DUT / REF:
  - Single Chip module for Pixel Detector CMS Phase I Upgrade
  - 52 x 80 pixels, 100 µm x 150 µm pitch

Pixel telescopes
Use case – CMS pixel det.

Pixel telescopes
Use case – CMS pixel det.



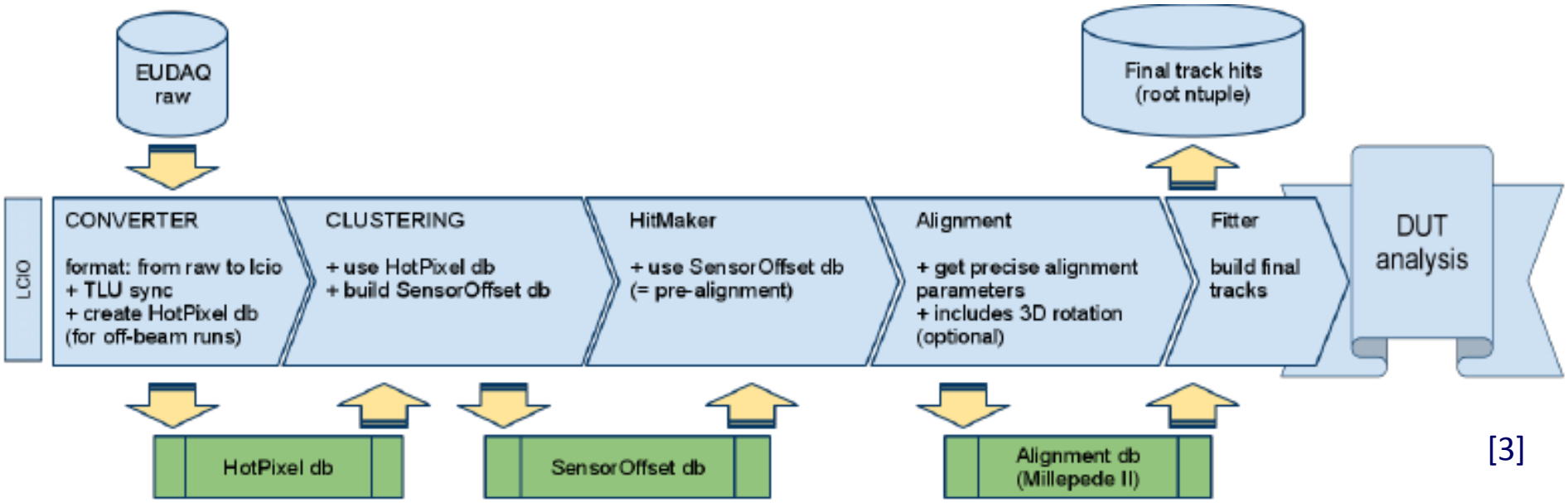
Tailored data producer developed for the EUDAQ framework[1]

Tailored analysis processor developed for the EUTelescope framework[1]

[1] Thanks to S. Spannagel

Pixel telescopes
Use case – CMS pixel det.

- Eutelescope workflow

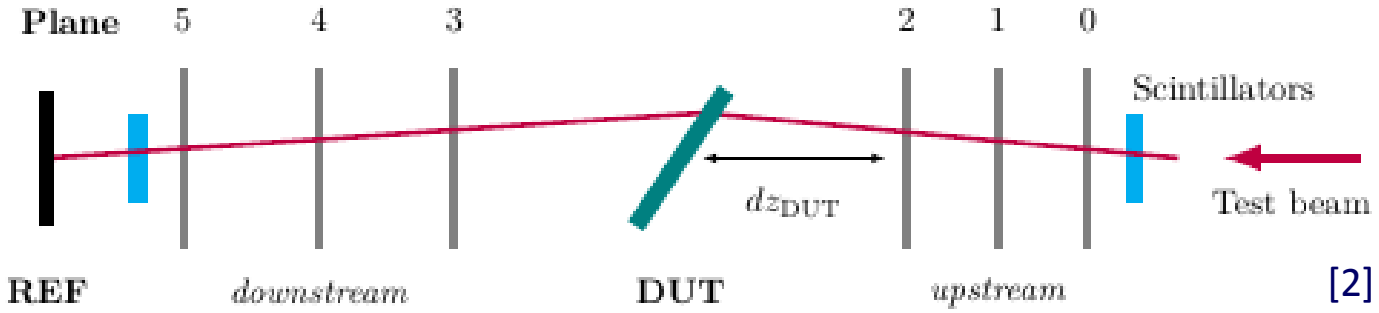


[3]

- Ready-to-use processors available in framework
- Any analysis step can be rewritten / replaced

Pixel telescopes
Use case – CMS pixel det.

- DUT analysis example:
  - Track finding algorithm allows for kink at the position of the DUT

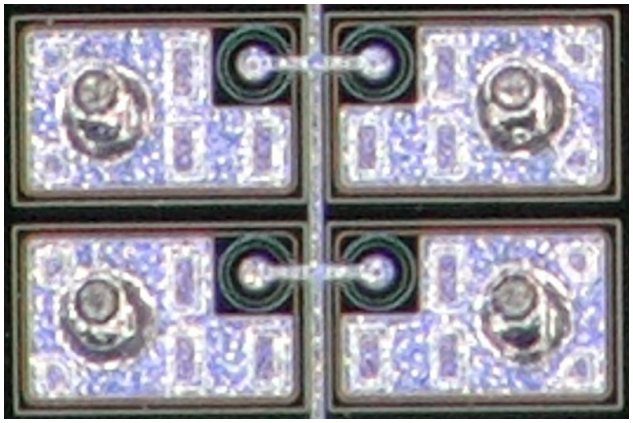


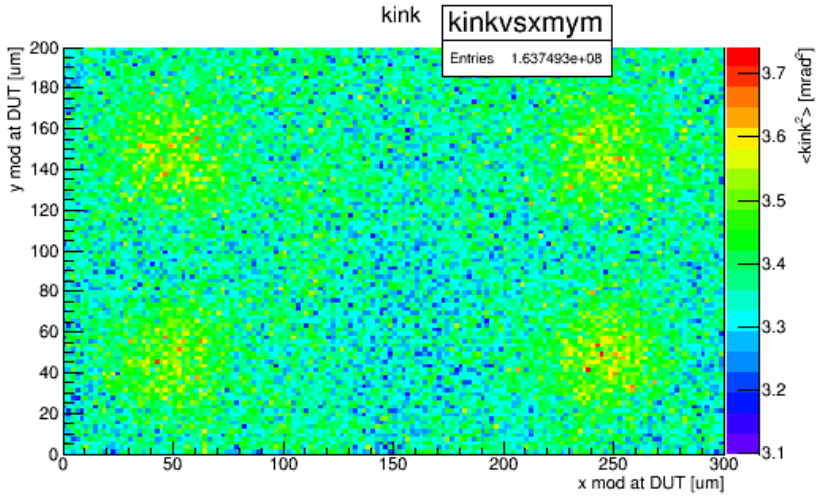
[2]

  - Kink angle gives information on material budget

Pixel telescopes
Use case – CMS pixel det.

- DUT analysis example:
  - Track finding algorithm allows for kink at the position of the DUT
  - Kink angle gives information on material budget
  - High precision tracking enables visualization of small structures
  - Example: Higher material budget due to solder balls





Pixel telescopes
Current development

- Since AIDA2020 Kickoff Meeting (May 2015):
  - Sept. 2015: Commissioning of DURANTA telescope at DESY
  - Oct. 2015: CALADIUM installed at SLAC
  - Nov. 2015: 1st EUDAQ workshop at DESY
  - Feb. 2016: 4th Beam Telescope & Test Beam Workshop at LAL (Orsay, F)
  - Mar. 2016: Update of miniTLU EUDAQ interface
  - Mar. 2016: Publication "Performance of the EUDET-type beam telescopes" (arXiv:1603.09669, under review at EPJ, to be cited as telescope reference)
  - Apr. 2016: 3 SALAT planes moved from IPHC to DESY (AIDA deliverable)
    - SALAT: 4 x Mimosa 28, 4 cm x 4 cm, 20 µm pitch
    - Large area telescope planes
  - Apr. 2016: Belle II testbeam @DESY (telescope inside PCMAG)

Pixel telescopes
Current development

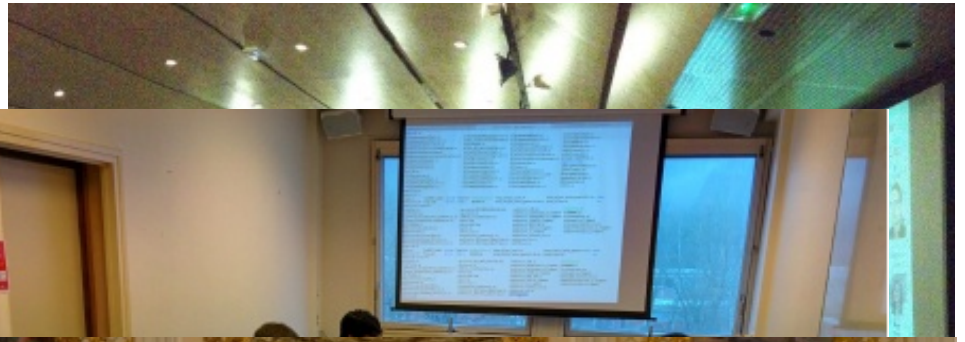
- 4th Beam Telescope & Test Beam (BTTB) Workshop at LAL (Orsay, FR)
  - 3 days
  - 60 participants
  - 45 contributions
- 5th BTTB Workshop in Feb. 2017
  - Location tba

Pixel telescopes
Current development

- 4th Beam Telescope & Test Beam (BTTB) Workshop at LAL (Orsay, FR)
  - 3 days
  - 60 participants
  - 45 contributions
- 5th BTTB Workshop in Feb. 2017
  - Location tba

Pixel telescopes
Current development

- 4th Beam Telescope & Test Beam (BTTB) Workshop at LAL (Orsay, FR)
  - 3 days
  - 60 participants
  - 45 contributions
- 5th BTTB Workshop in Feb. 2017
  - Location tba



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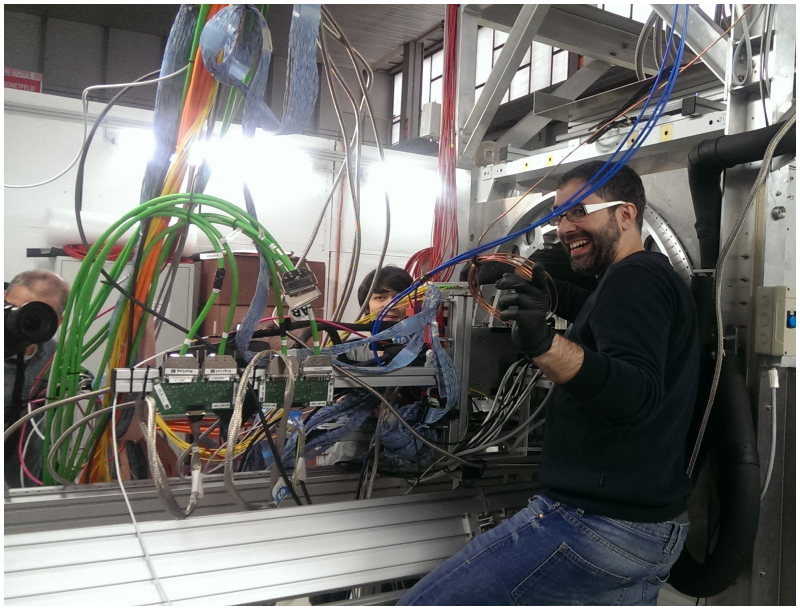
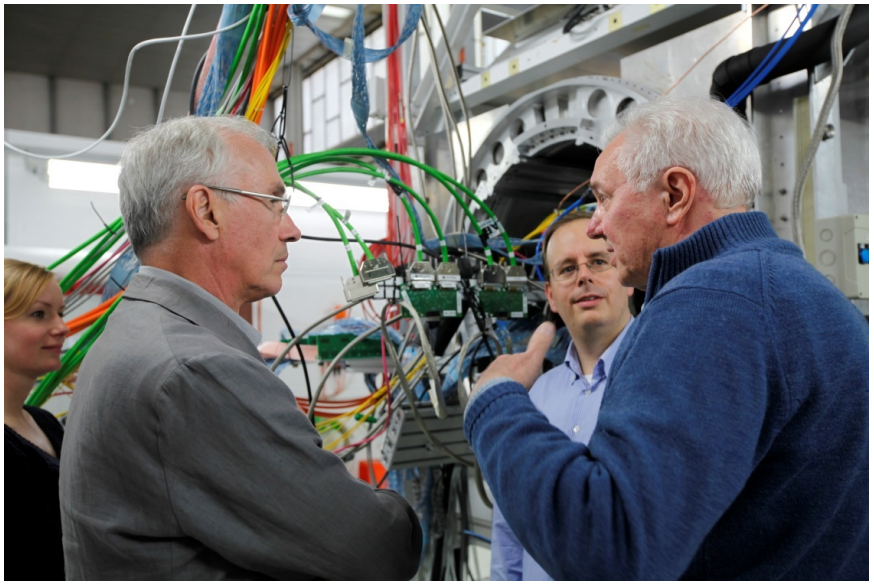
Pixel telescopes
Current development

- Apr. 2016: Belle II vertex detector collaboration @DESY Test Beam
- Belle II DURANTA telescope operated inside PCMAG

Pixel telescopes
Current development

- Apr. 2016: Belle II vertex detector collaboration @DESY Test Beam
- Belle II DURANTA telescope operated inside PCMAG
  - Strong support by test beam and telescope coordinators





Pixel telescopes
Current development

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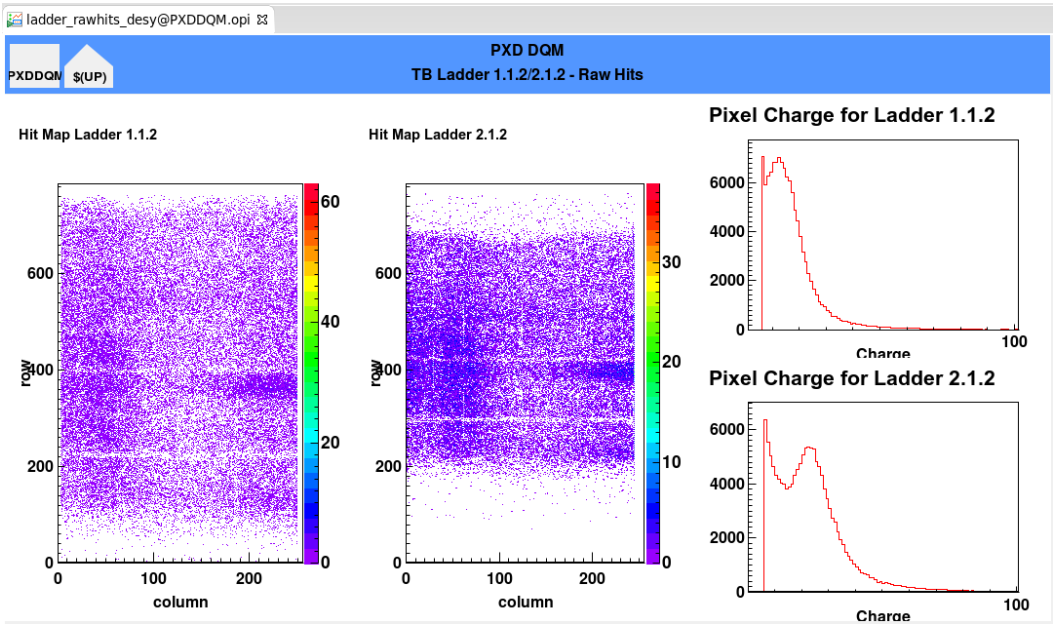
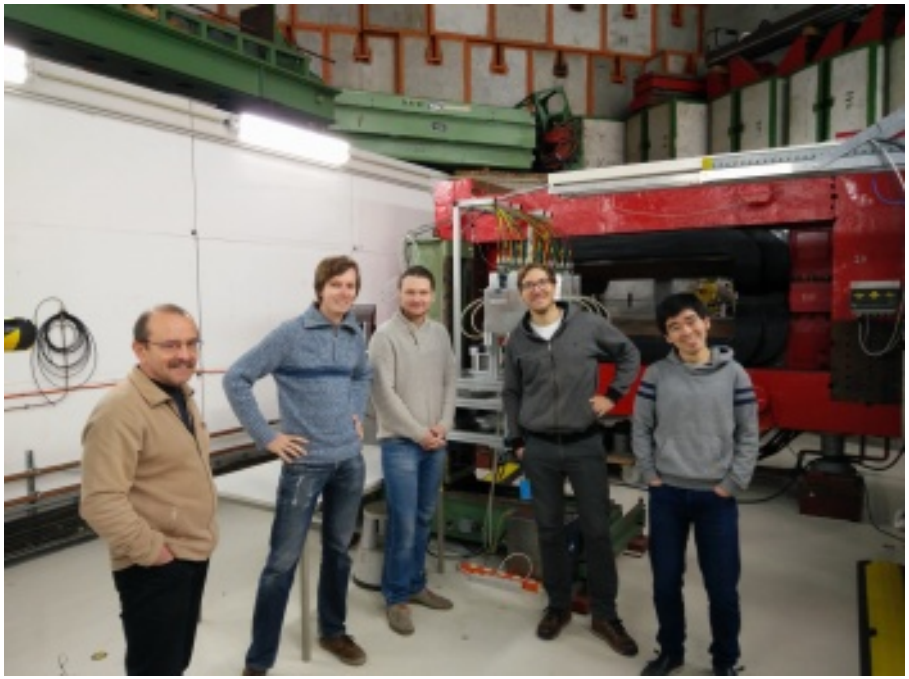


Pixel telescopes
Current development

- Work in progress:
  - Construction of AIDA2020 telescope:
    - Since Jan. 2016: Purchase and construction of components, sensor characterization
    - Assembly will start soon
    - Shipping to CERN and commissioning in Aug./Sep. 2016
  - Integration of miniTLU → Higher trigger rates
  - EUDAQ development (see talk by Yi Liu, parallel session)
  - Plans for CO2 cooling of DUTs
  - Large area telescope planes

Pixel telescopes
User support

- User support for pixel telescopes
- DESY crew:
  - Jan Dreyling-Eschweiler (coord.), Hendrik Jansen (coord.), Thomas Daubney, Uli Koetz, Dmitry Kisler, Yi Liu, Paul Schütze, Yuri Soloviev, Simon Spannagel
- Contact:
  - testbeam.desy.de
  - telescope-coor@desy.de



Summary

- Summary:
  - High request on DESY test beam
  - High demand for pixel telescopes
  - Support and development ongoing
  - Telescope plane and tracking performance measured

- References:
  - [1]: *H. Jansen, S. Spannagel et al.*, Performance of the EUDET-type beam telescopes, 2016
  - [2]: *S. Spannagel*, Test Beam Measurements for the Upgrade of the CMS Pixel Detector and Measurement of the Top Quark Mass from Differential Cross Sections, 2015
  - [3]: *I. Rubinsky*, EUTelescope. Offline track reconstruction and DUT analysis software., 2010