DESY test beam facilities for HEP detector R&D

Yi Liu (DESY) for the DESY telescope and test beam crew
CLHCP, CCNU Wuhan, Dec 21, 2018

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY TEST BEAM. AIDA 2020

DESY.

Characterize the HEP detector R&D

A list characteristics of HEP detector:

- Spacial resolution:
  - Modern Pixel detector detector has fine granularity in order 10um
- Time resolution:
  - LHC bunch cross time is 25ns
  - New ATLAS HGTD ~30ps
- Hit Efficiency:
  - More hit recorded, better track reconstruction efficiency
- Noisy occupancy:
  - Fake hit will confuse the track reconstruction algorithm
- Material budget
  - Required to minimize the multiple scattering
  - some assembled components are not able to be calculated in math

A few methods which can measure the above detector characteristics

1. Radiation source
2. Infra Laser to imitate a particle track
3. Testbeam/Telescope with real high energy particle

   ...

Beam Test for HEP detector R&D

Better than radiation source, infra laser

Source measurements

- Known amount of deposited charge but no spatial information

Laser measurements

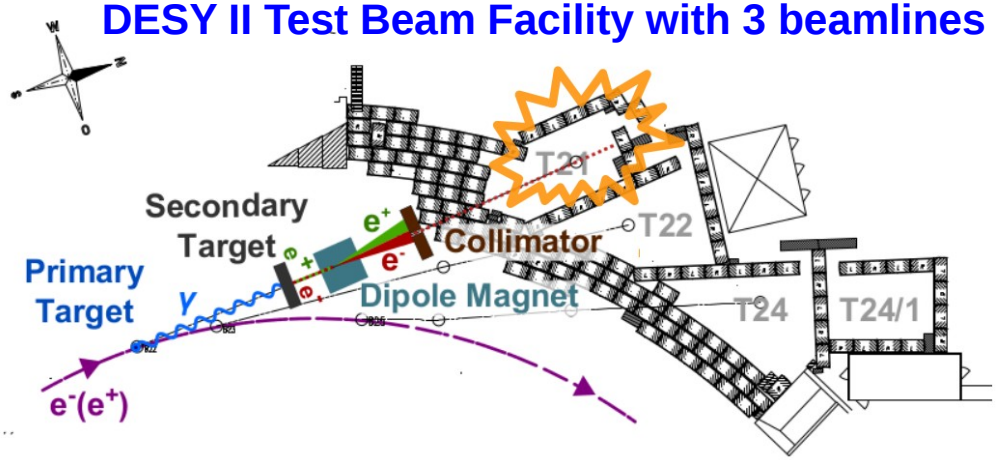
- Good spatial resolution but unknown charge deposition
- Optical diffusion and reflection

Beam Test

- Track position precisely known O(μm)
- Known charge deposition

  =>Characterization of sensors &readout at most realistic environment, eg. resolution, noise occupancy, efficiency

DESY II Test Beam Facility with 3 beamlines



- Source of 1-6 GeV e^+/e^-
- Operating in a magnetic field
- Average particle flux: 1-10 kHz/cm^2 e^- (@ 2 GeV/c)

EUDET-type telescopes family

Carleton UNIVERSITY

SLAC NATIONAL ACCELERATOR LABORATORY

CALADIUM @ SLAC in Stanford, USA

DESY.

DATURA @ TB21

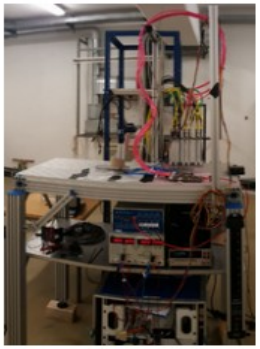
DURANTA @ *TB22*

CERN

ACONITE @ SPS, H6A

AIDA @ SPS, H6B

AZALEA @ PS, T10



ANEMONE @ BONN / ELSA

ELSA

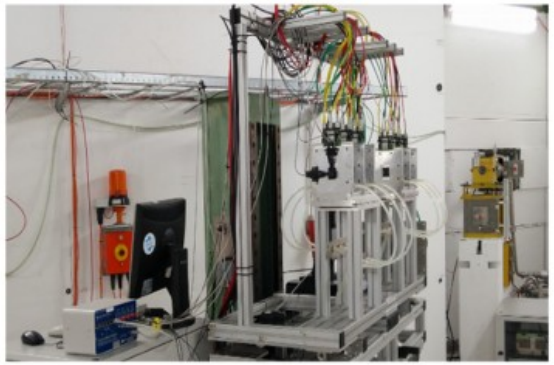
SI LAB Silizium Labor Bonn

The EUDET-type infrastructures

From data taking to results

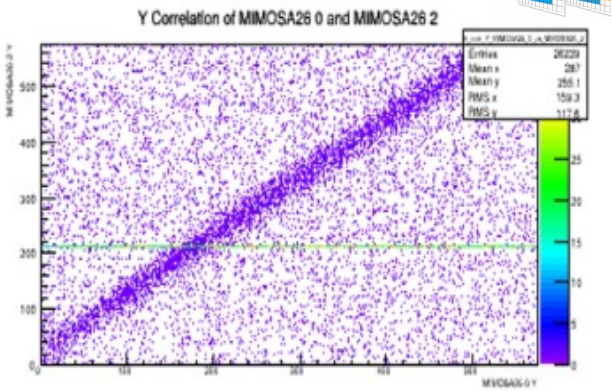
EUDET-type Hardware

- 6 Mimosa26 &DAQ
- Mechanics &integration
- Trigger system

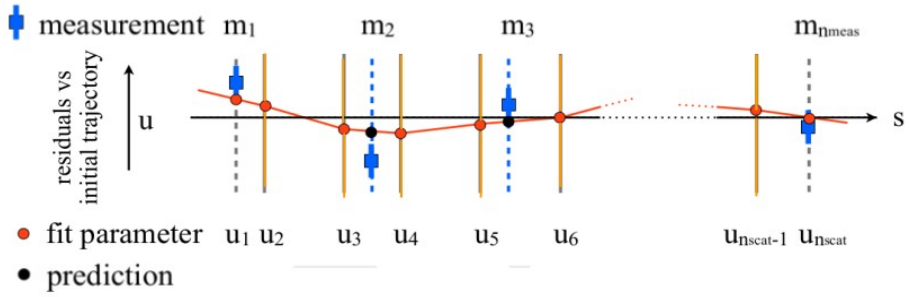


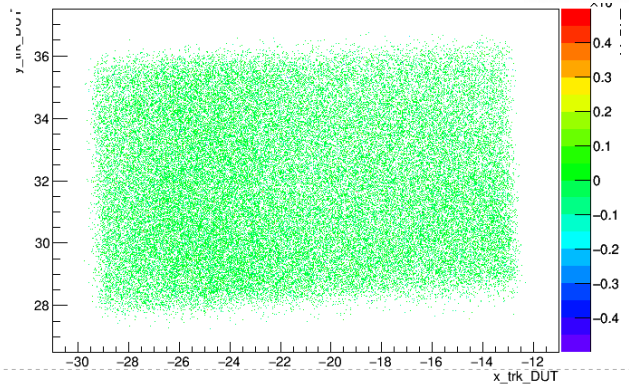
EUDAQ: Top-Level DAQ Software

- Central run control&monitoring
- Data Collector&synchronization
- Data Converter



EUTelescope: Offline track reconstruction&analysis framework

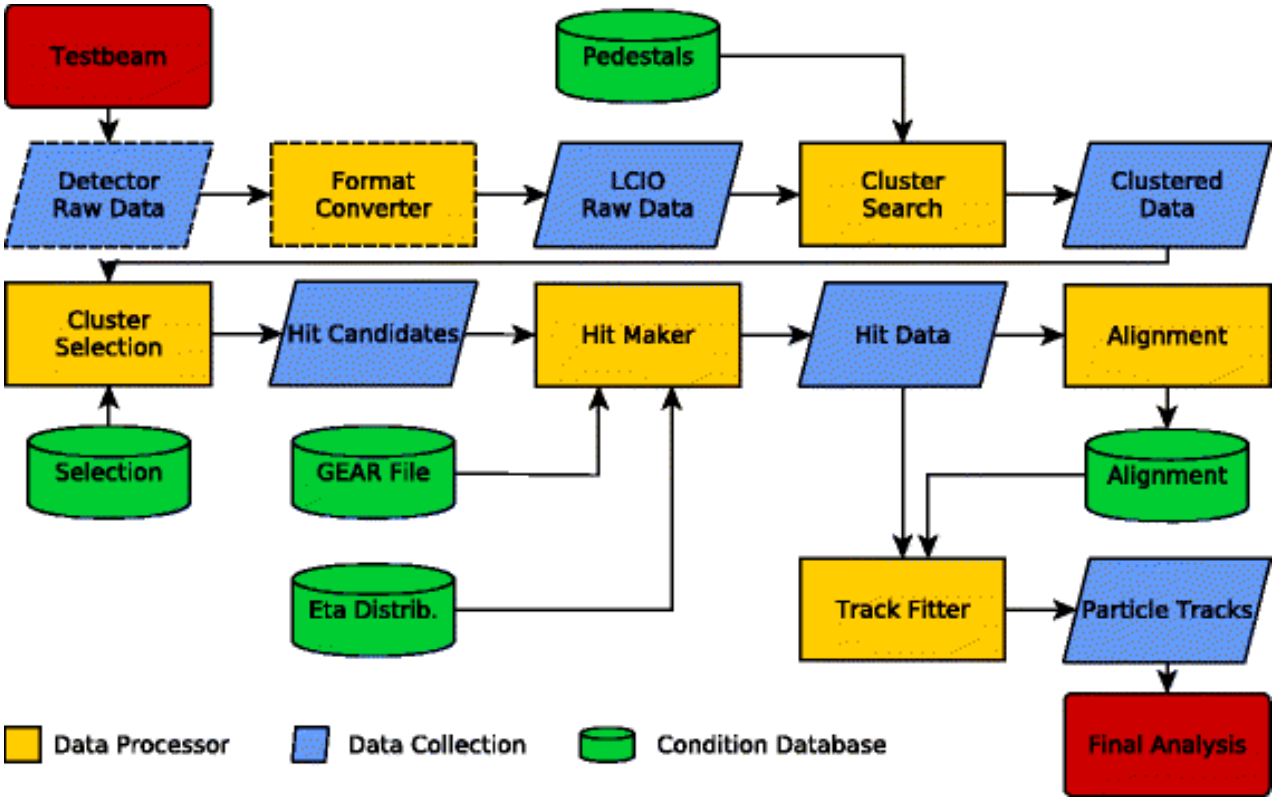




Track reconstruction

Take hits and output tracks

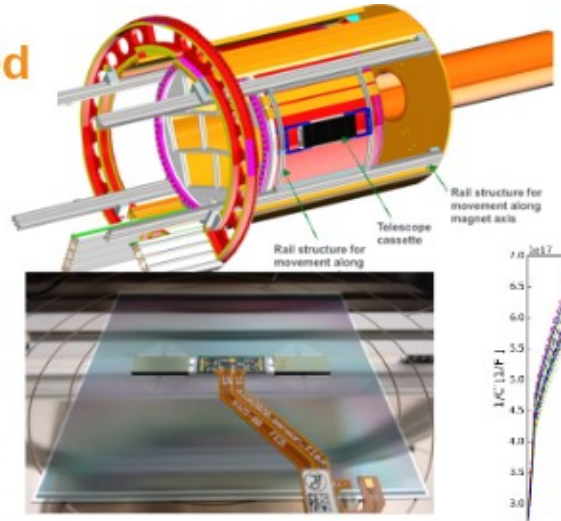
- EUTelescope is used for reconstruction&analysis of testbeam data

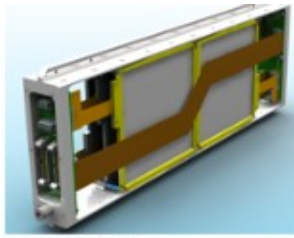


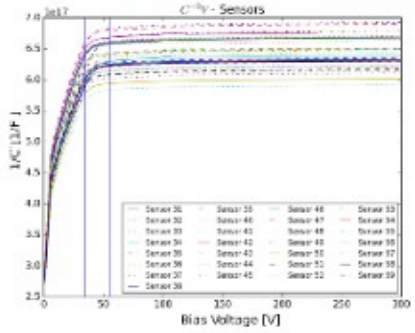
- **GBL** (General Broken Lines) tracking algorithm accounts for multiple scattering
- ROOT TGeo-based geometry description allows user-specific sensor layout (pixel/strip, Box/Annulus)

Ongoing Facility improvement

Large Area X-Y Coverage Readout Integrated Strip Telescope (LYCORIS) *(by Mengqing Wu)*

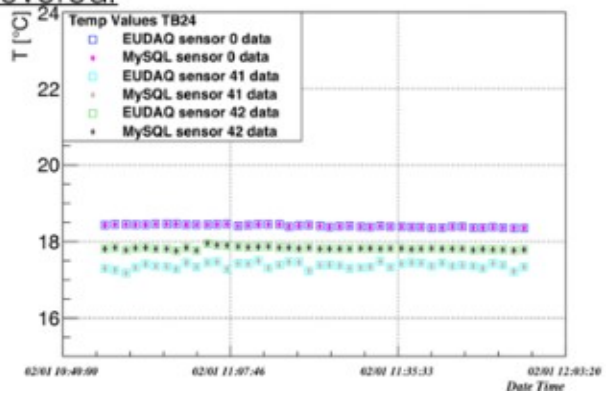






#1: A new environmental slow control system

- supported / maintained by DESY;
- Commercial Rack-based data logger with data stored in MySQL DB, integrated to a common DAQ used at test beam: EUDAQ2;
- Only temparature/humidity/dew point/air pressure sensor mounted, possible to mount new sensor;
- Easy to integrate User monitoring system via MySQL.
- Status: Delievered.



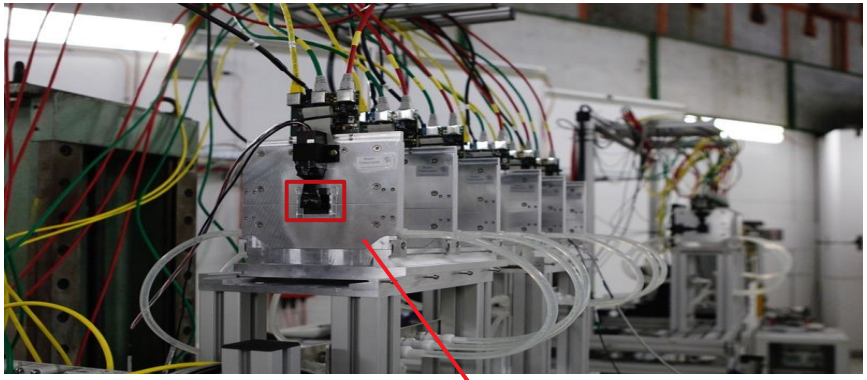
#2: A large area micro-strip telescope

- Build a new large area strip telescope (LYCORIS) within the 1T solenoid in DESY II beam area 24;
- Telescope design to address user demands:
  - Large active area (10x10 cm^2) to cover 90-96% particles; Limited space ~3.5 cm for a large DUT (e.g. a large prototype TPC);
  - Momentum measurements: spatial resolution better than 10 μm along bending direction;
  - Resolution along field axis less important: σ_Z > 1 mm
- Status: prototype delivery end of Jan. 2019.

LYCORIS delivery is planed at the end of Jan 2019

Ongoing Facility improvement

ALPIDE based telescope



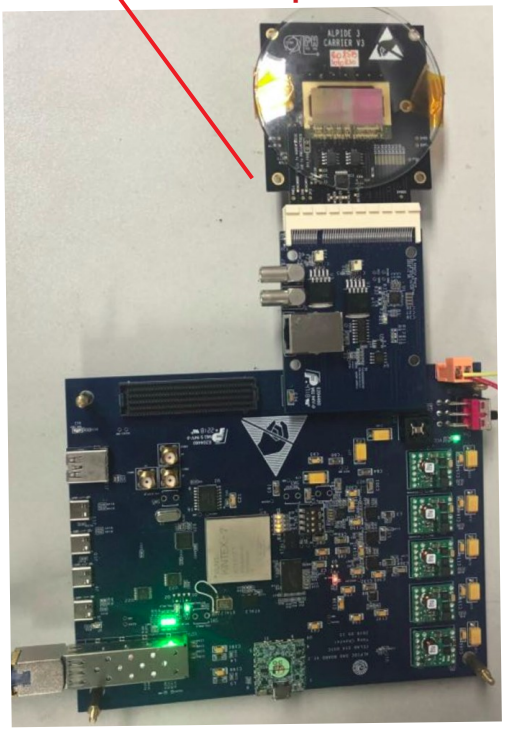
To be replaced

- ALPIDE sensor key features:
  - 29um x 27um pixel pitch
  - 30x 13.8mm area (1024x512 pixels)
  - Global shutter readout (*important)
  - Time resolution 2-4 μs
  - Noiseless

- The new telescope:
  - 6 sensor planes with independent readout
  - Integrated with current trigger system
  - Integrated with current DAQ (EUDAQ)
  - Provides same interface as current EUDET telescope
  - Capability of online tracking and automatic alignment

- USTC is working with DESY and developing the readout electronic.

- The new telescope prototype test on testbeam is planed in February 2019.



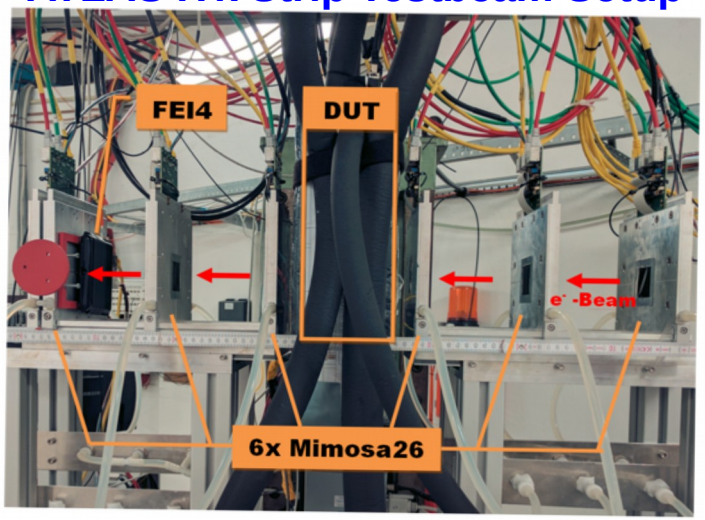
ALPIDE readout by USTC

User Example: ATLAS ITk Strip

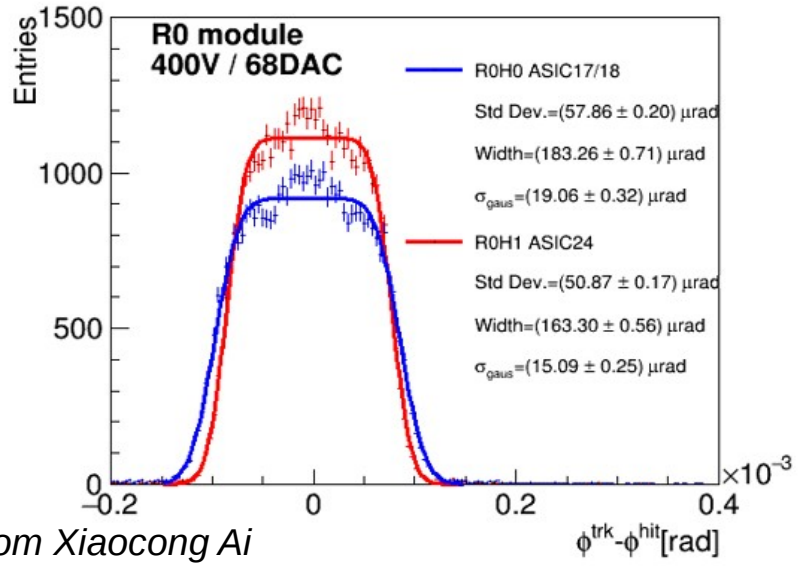
Sensor Spatial resolution

- **Goal**: Characterization of assembled ITk Strip modules
- **Setup**: 6 M26s+DUT+FEI4 timing plane
  - Additional FEI4 (25 ns timing resolution) is used to match tracks to triggers for correct efficiency calculation

ATLAS ITk Strip Testbeam Setup

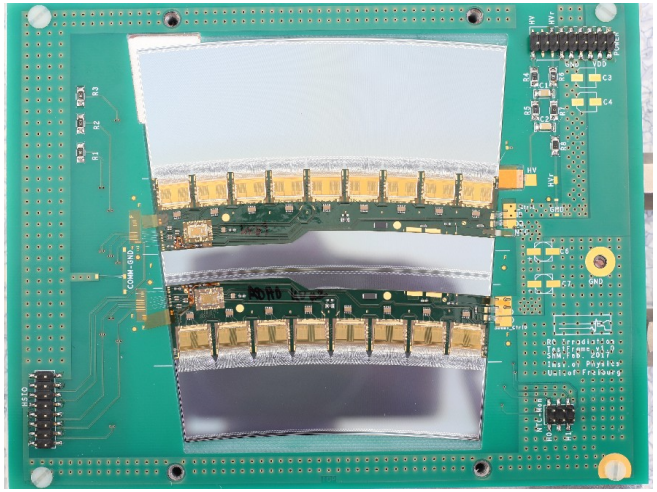


ITk Strip R0 module angular Residual ($\phi^{track} - \phi^{hit}$)



From Xiaocong Ai

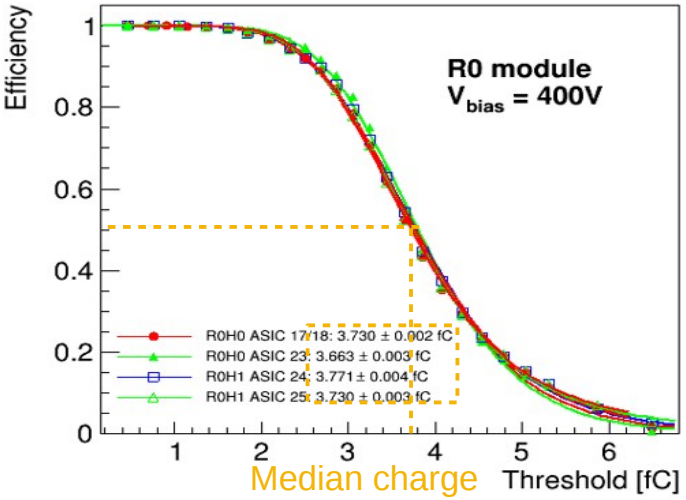
ATLAS ITk Strip R0 module



User Example: ATLAS ITk Strip

Sensor Efficiency &interstrip behavior

Efficiency vs thresholds (S-curve)

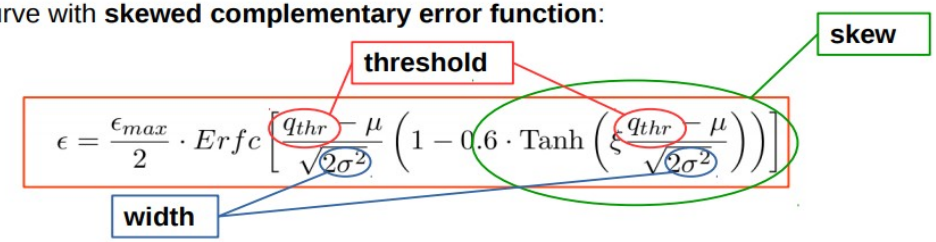


- ITk Strip uses binary read-out

  =>Information about amount of charge lost

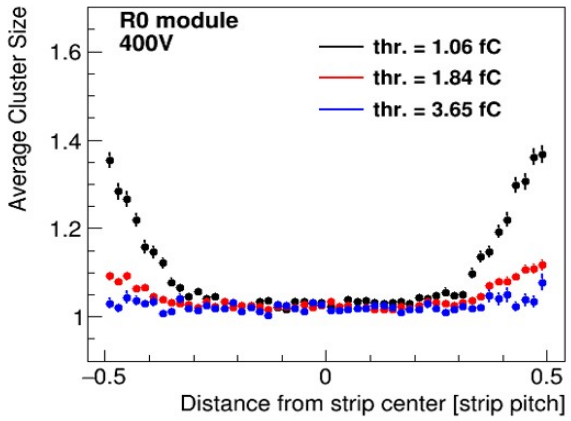
  =>threshold scan: gives fraction of electrons depositing that charge

Fit to s-curve with **skewed complementary error function**:

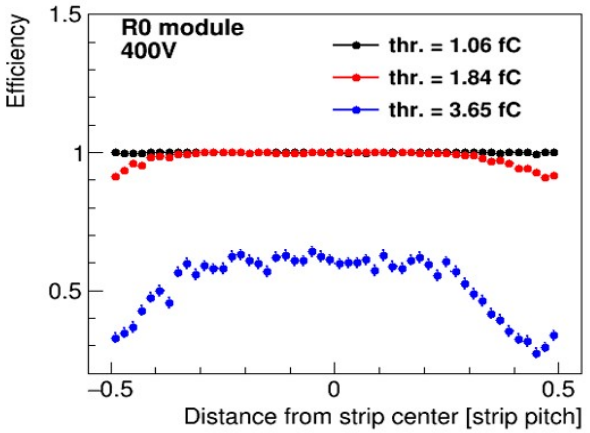


- Excellent pointing resolution allows looking at inter-strip behavior

Inter-strip cluster size



Inter-strip efficiency

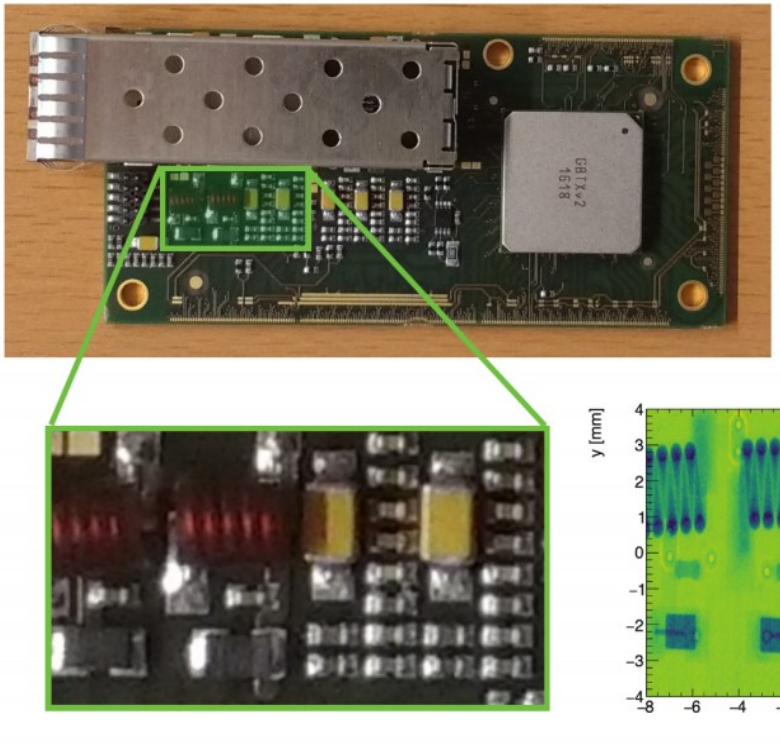


User Example: ATLAS ITk Strip

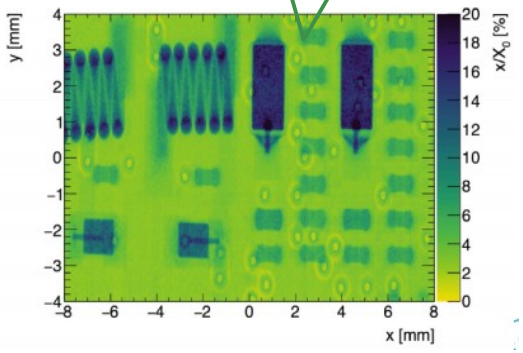
Material Budget Measurement

- **Goal**: Position-dependent measurement of material budget by measuring the scattering angle
- **Setup**: 6 M26s+passive DUT(no readout)

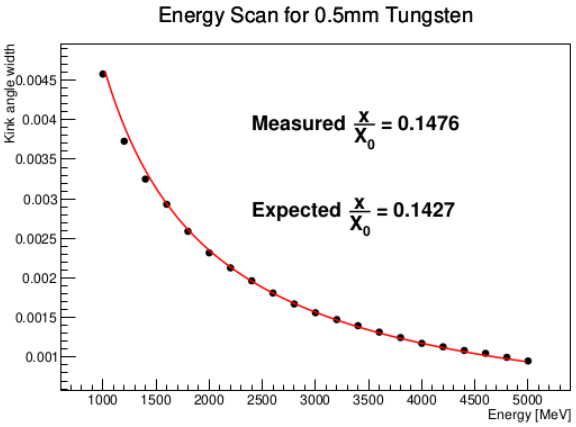
ITk End-of-Petal Card



Excellent spatial resolution to resolve subtle structure (eg. electrical vias)



From Jan-Hendrik Arling, Claire David, Michaela Queitsch-Maitland



Highland formula

$$\theta_0 = \frac{13.6[\mathrm{MeV}]}{p}\left(\frac{x}{X_0}\right)^{0.555}$$

The Gaussian distributed width of the scattering angle (Θ_0) is dependent on:

- momentum of the scattering particles(p),
- the thickness (x) and radiation length (X_0) of the scatterer

Info for DESY testbeam users

- Further Information of DESY testbeam:
  https://tesbeam.desy.de
- EUDET telescope setup and user DUT integration:
  https://telescopes.desy.de

- A check list to plan testbeam:
  - Beam properties: particle type, rate, energy
  - Detector runtime condition: cooling, humanity, voltage, or different setups
  - Accumulated luminosity: total testbeam time
  - Synchronization with telescope data: trigger interface in hardware

To plan a detailed testbeam, book a DESY testbeam time slot by email: testbeam-coor@desy.de

Summary

- Testbeam with telescope fits requirements to characterize the HEP detector.
- EUDET telescopes play a significant role at DESY testbeam
- Telescope developments are ongoing
- A user case: ATLAS upgrade phase-II ITk strip testbeam
- Information to book a testbeam time slot at DESY

Thank you