EPICAL-2

Test-Beam Performance of a Digital Pixel Calorimeter

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International Workshop on Future Linear Colliders

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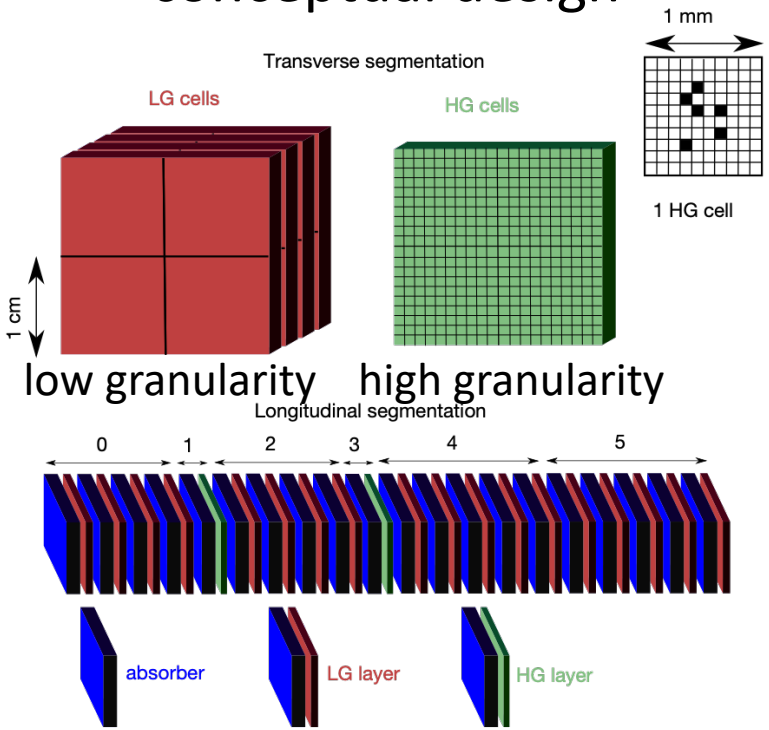
HGS-HIRe for FAIR
Helmholtz Graduate School for Hadron and Ion Research

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

EPICAL-2 Prototype

in the context of R&D
for the ALICE
Forward Calorimeter upgrade

FoCal-E (electromagnetic)
conceptual design



objective:
two-photon separation at few mm distance
- high-granularity layers in FoCal
- CMOS MAPS sensors – binary readout

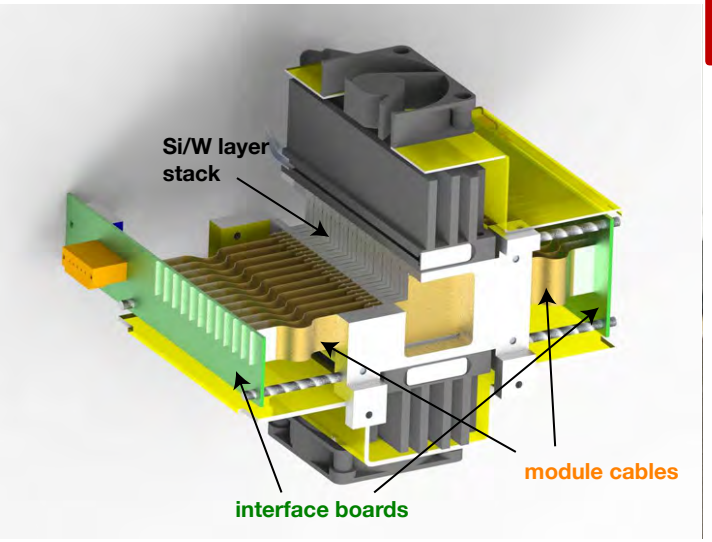
shower reconstruction
- single shower particle measurement
- 3D shower shapes

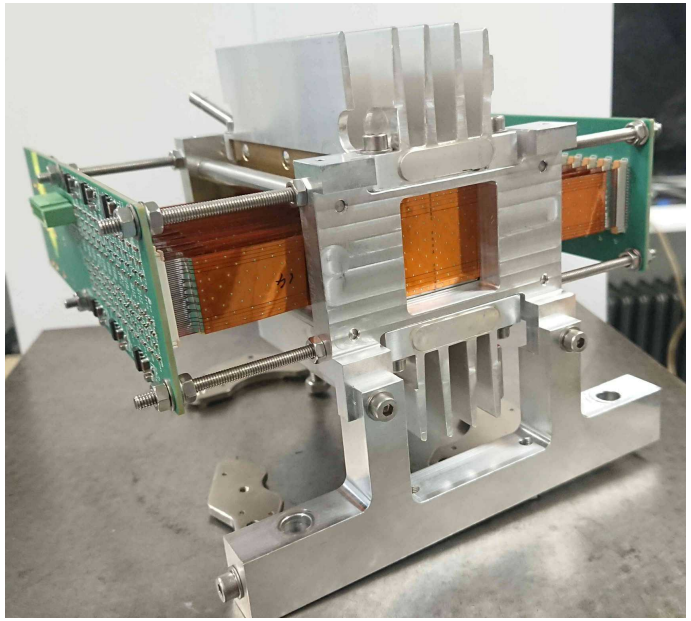
effective for particle flow approach

→ digital calorimeter with very small pixels

EPICAL-2 Prototype

high-granularity digital Electromagnetic PIxel CALorimeter



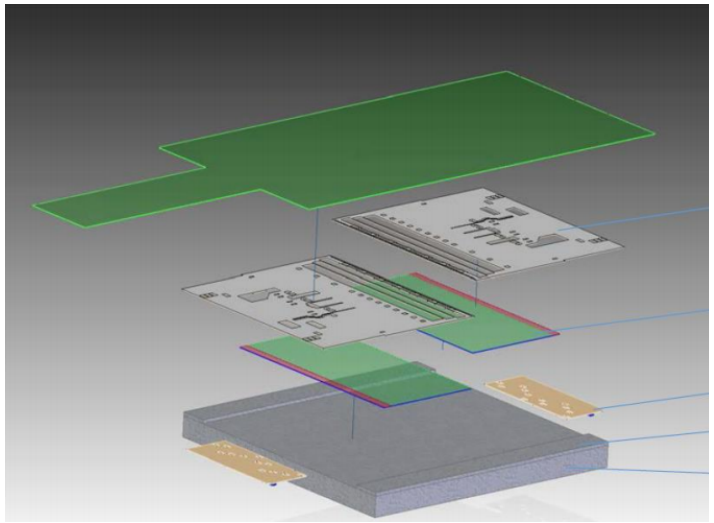


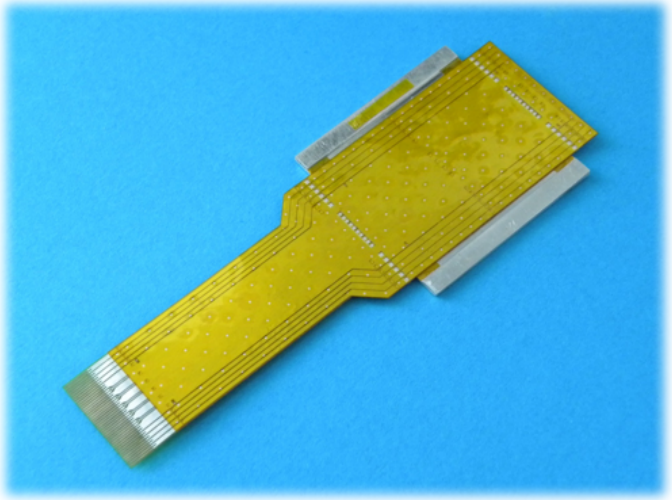
ALPIDE (MAPS)

- chip size 1.5 x 3 cm^2
- pixel size 29.24 x 26.88 μm^2
- 1024 x 512 pixel matrix

setup of prototype

- 24 layers with two sensors each
  → active area 3 x 3 cm^2 ($R_M \approx 11$ mm)
- 48 x 1024 x 512 = 25 M pixels
- 3 mm W (X_0 = 3.5 mm) absorber per layer
- water cooling system
- trigger: two SiPM scintillation counters

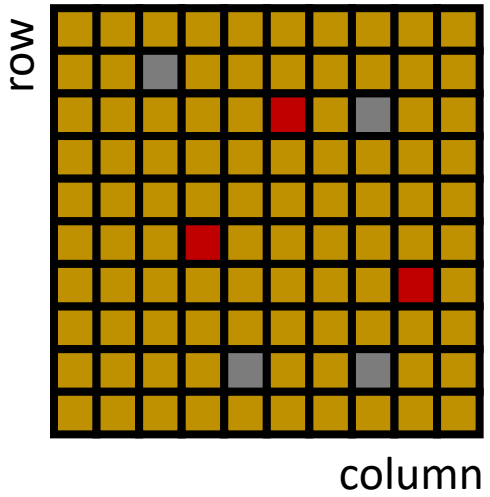




Analysis Setup

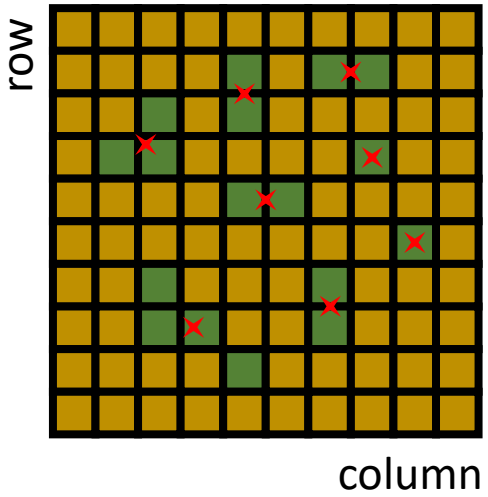
pixel masking

- noisy and dead pixel removal
- input:
  - chip classification from serial testing
  - pedestal runs
  - beam runs



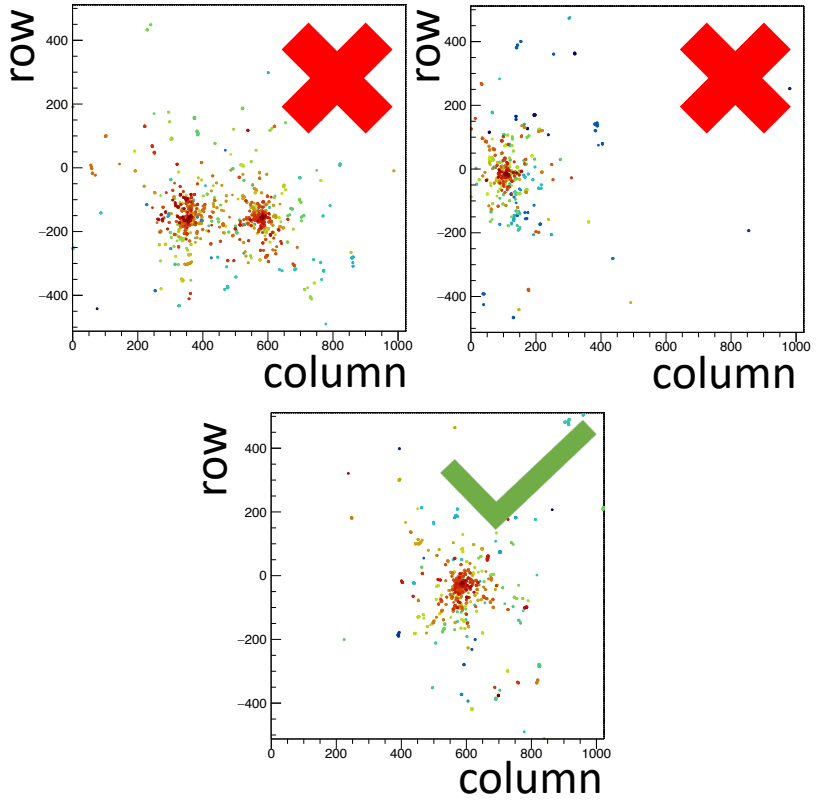
clustering

- pixel hits -> cluster
- DBSCAN algorithm
- cluster comprised of adjacent hit pixels (eight neighbors)



event selection

- single particles
- minimal lateral leakage



Data Taking Setup

1 Cosmic Muons

- May through October 2020 at Utrecht University
- charged particle tracks from cosmic muons

→ ≈ 9000 events

2 Electron Test Beam

- February 2020 at DESY TB22
- electron (positron) beam
- beam energies:
  1.0, 2.0, 3.0, 4.0, 5.0 and 5.8 GeV
- incident angles:
  0°, 2°, 10°, 20° and 180°
- various beam positions
- detector temperatures:
  20°C, 25°C and 30°C

→ ≈ 44 million events

Data Taking Setup

1 Cosmic Muons

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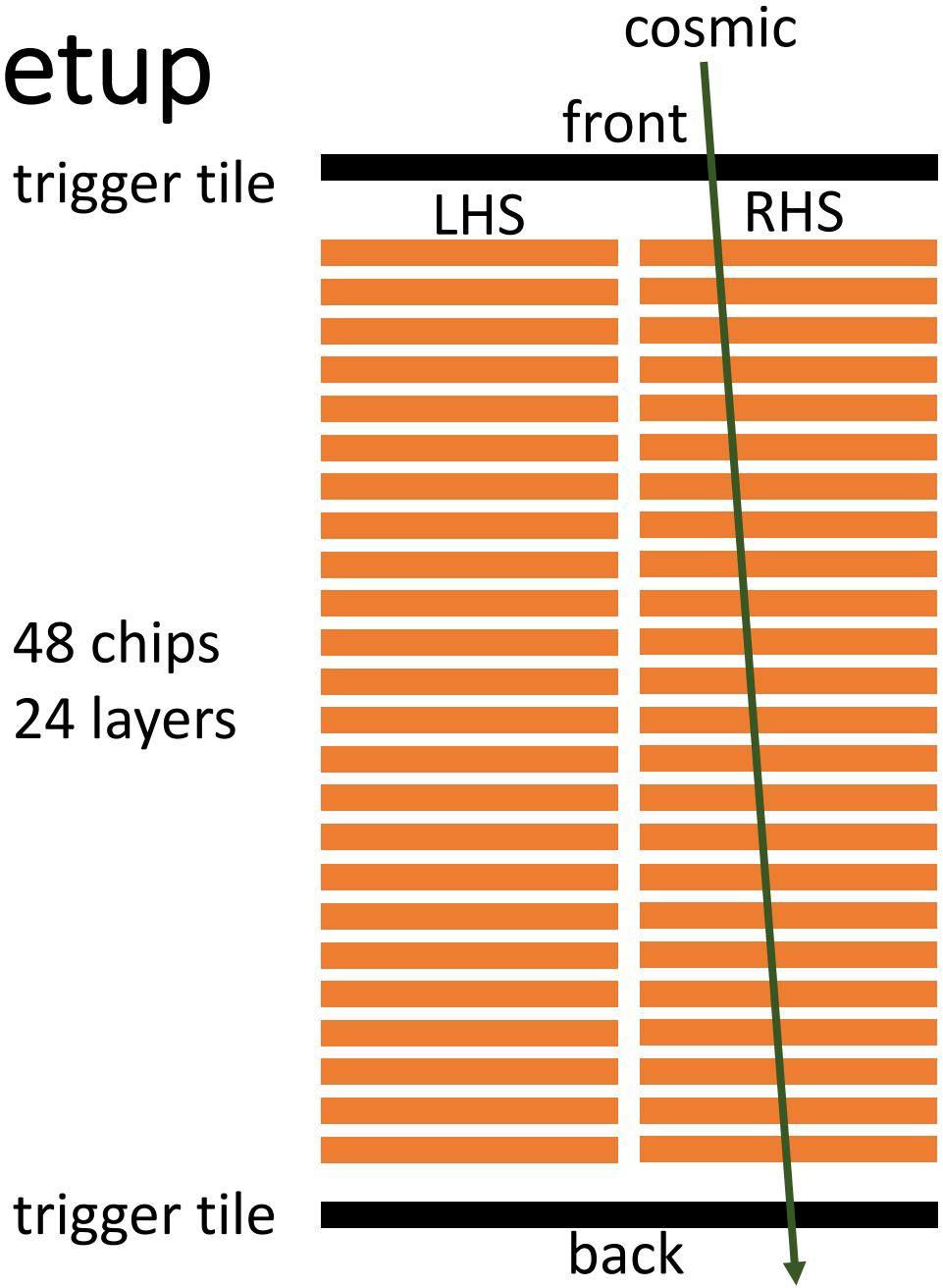
non-showering particle

- well-defined track
- uniform mean energy deposition over all layers

→ alignment, calibration



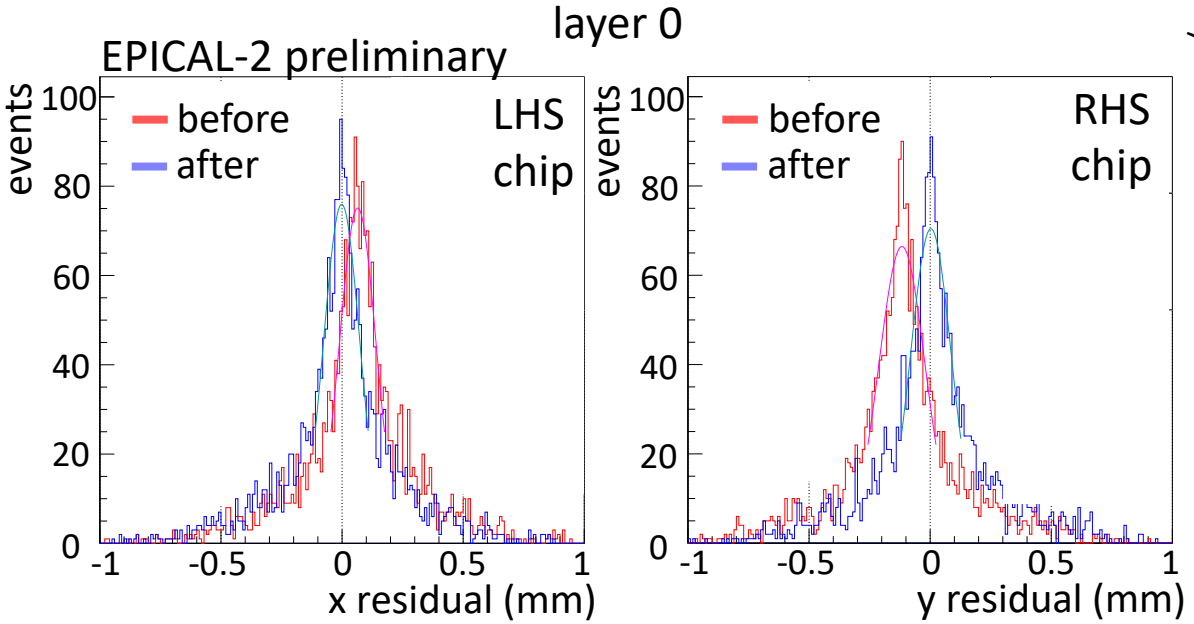
LHS: left-hand side
RHS: right-hand side

① Cosmics

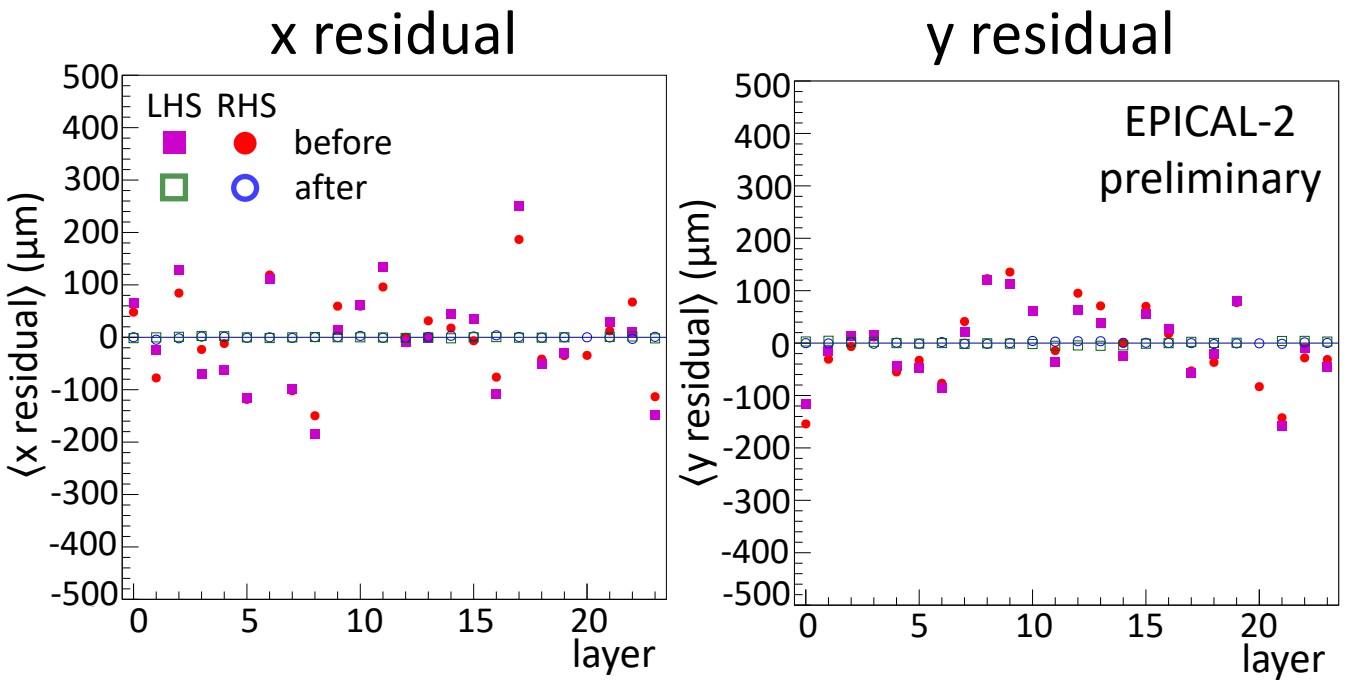
Alignment

chip-by-chip alignment

- longitudinal position fixed by absorber
- three parameters for lateral position
  → shift in chip plane (dx, dy)
  → rotation around z axis (dΘ)



residual: track fit - cluster position



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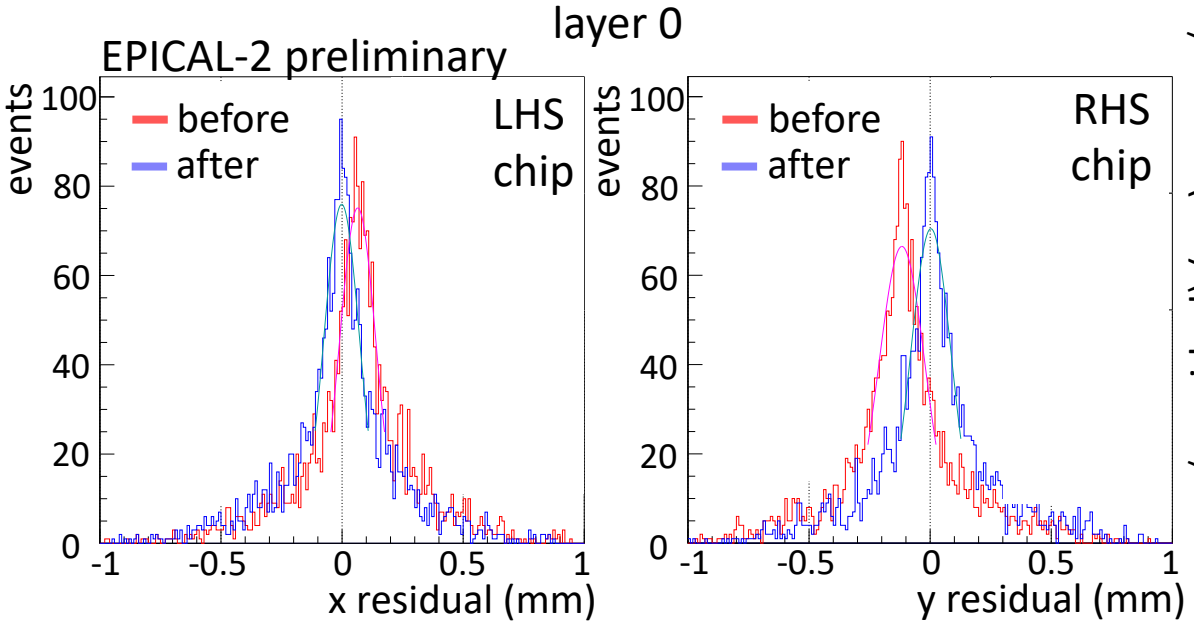

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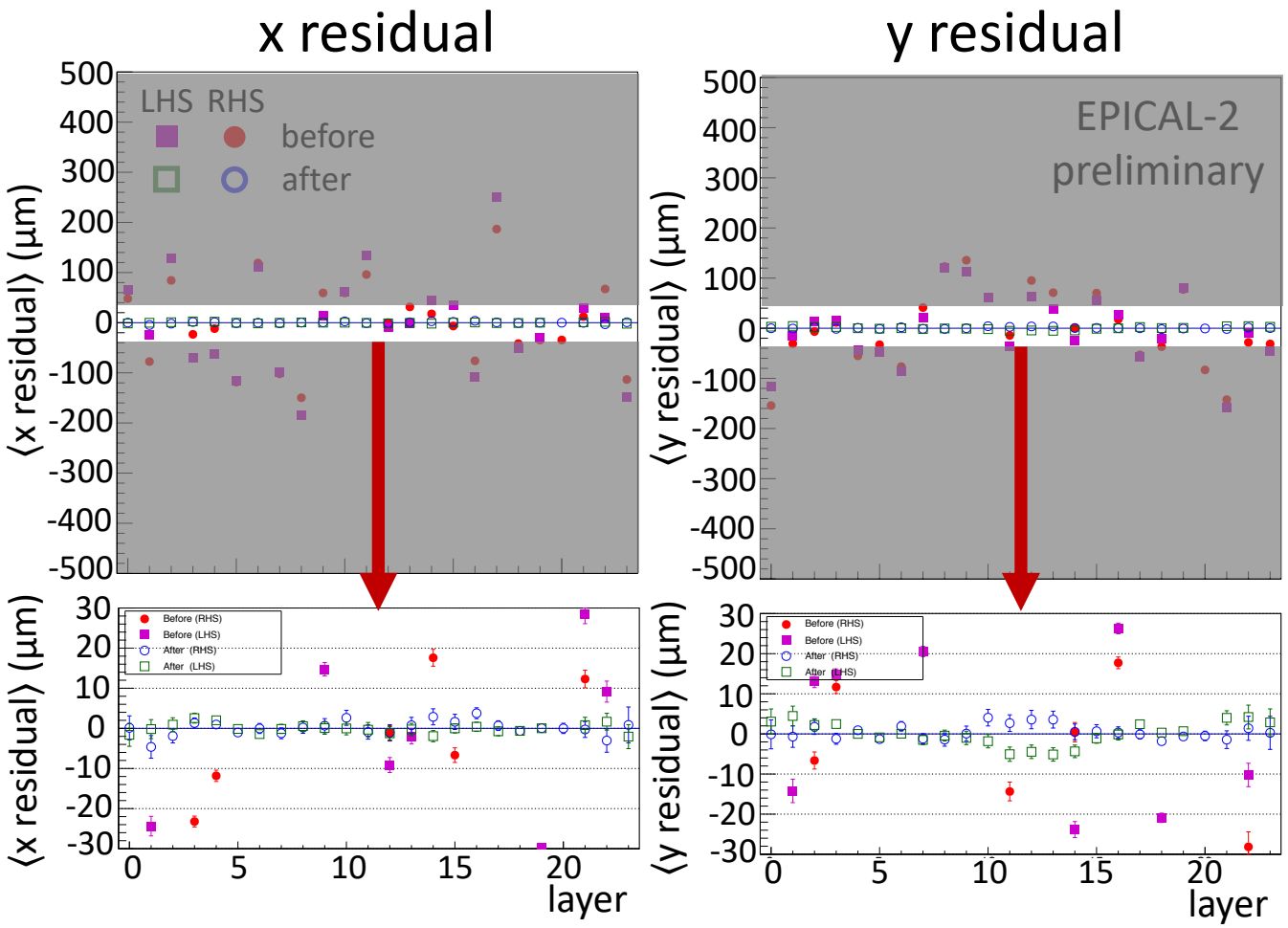


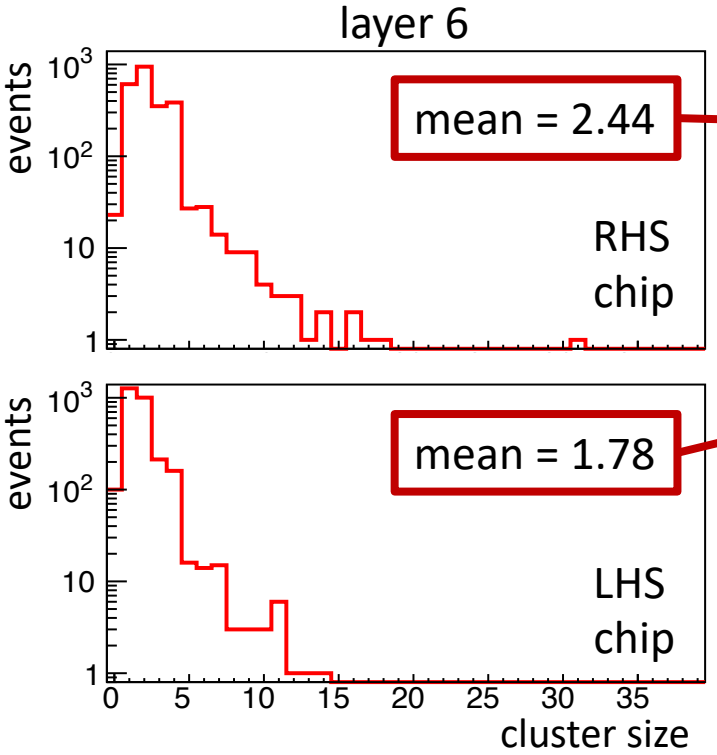
→ alignment precision better than 10 µm

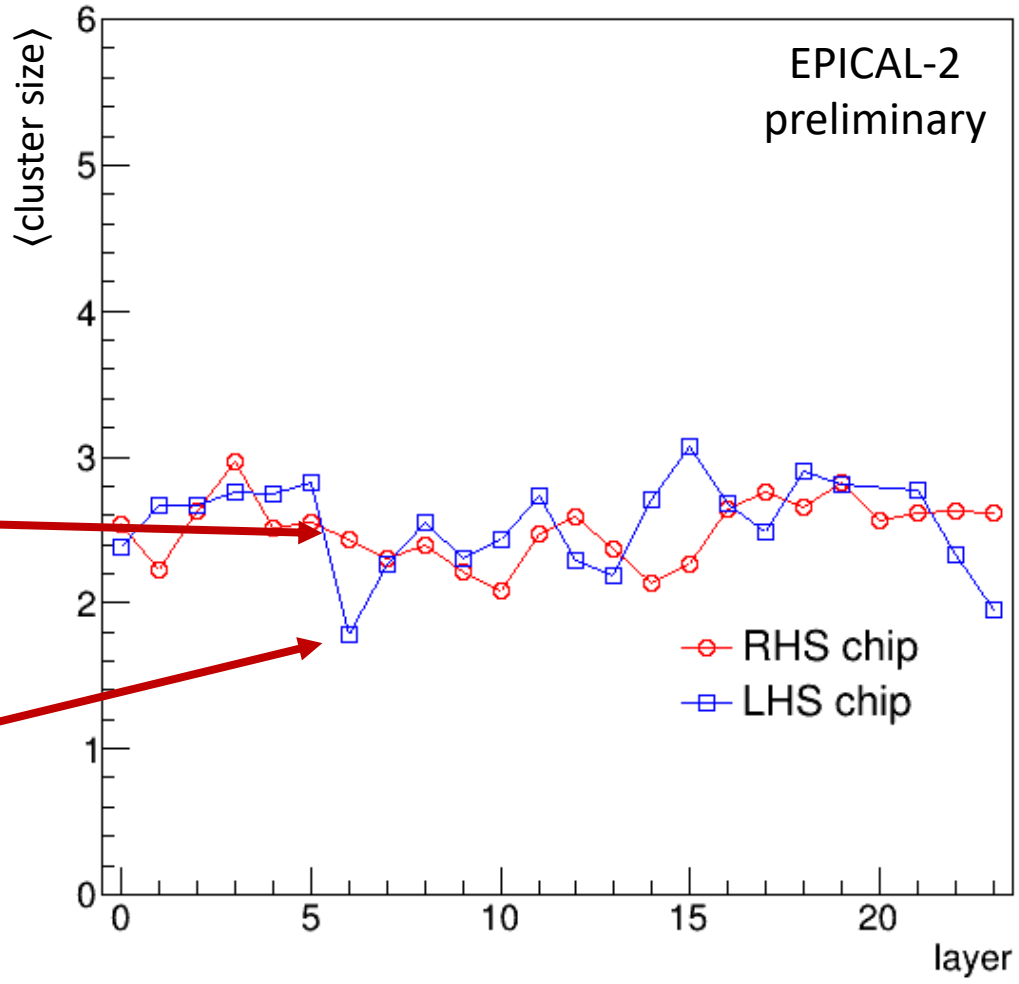
1 Cosmics

Calibration

chip-by-chip calibration

- mean from cluster-size distributions
- equalization of mean cluster sizes





→ calibration of chip responses

Data Taking Setup

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→ alignment, calibration

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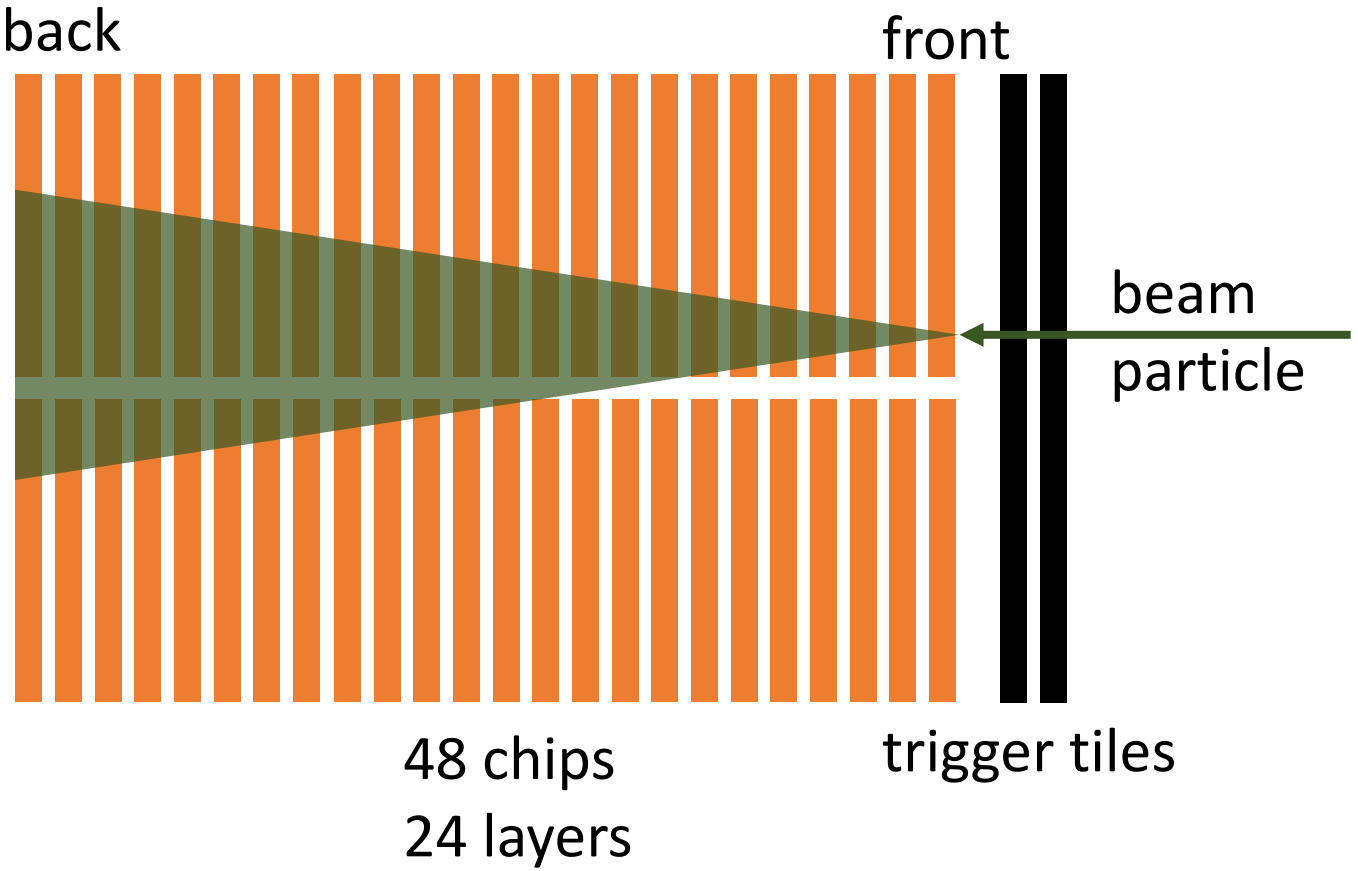

showering particle
- secondary particle production in absorbers
- number of hit pixels or clusters as calorimeter signal

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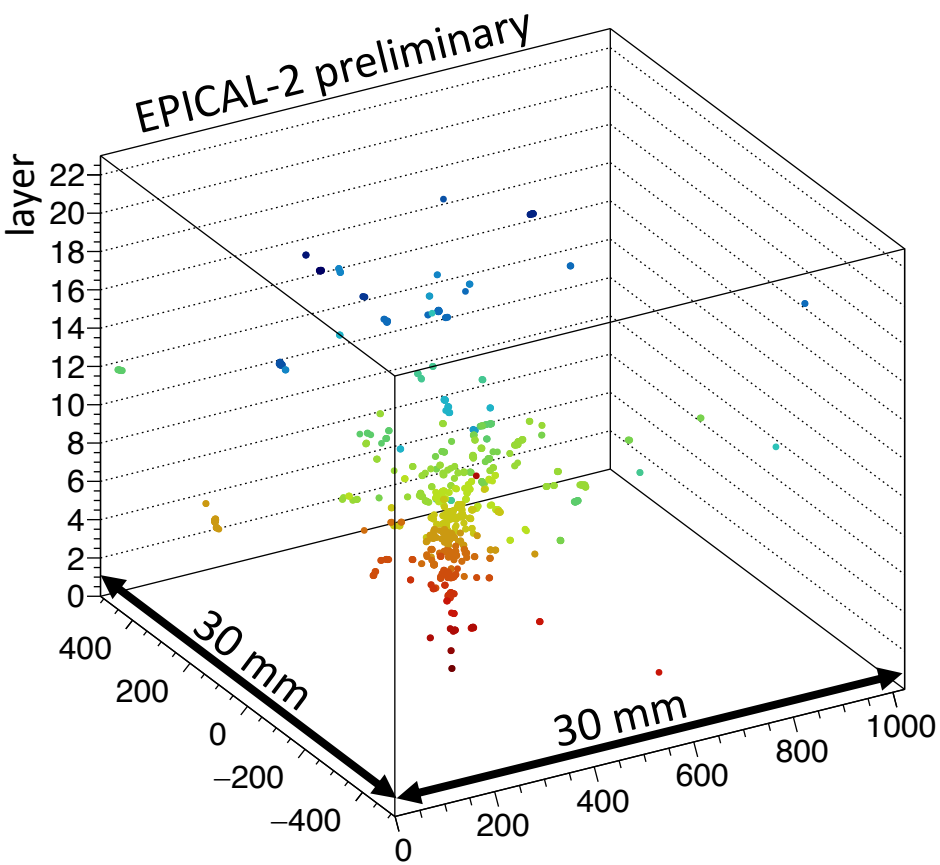
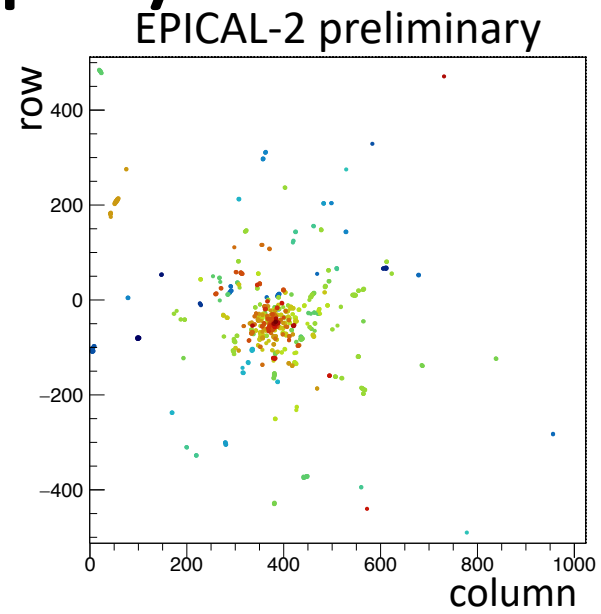
→ **energy linearity, energy resolution, shower profiles**

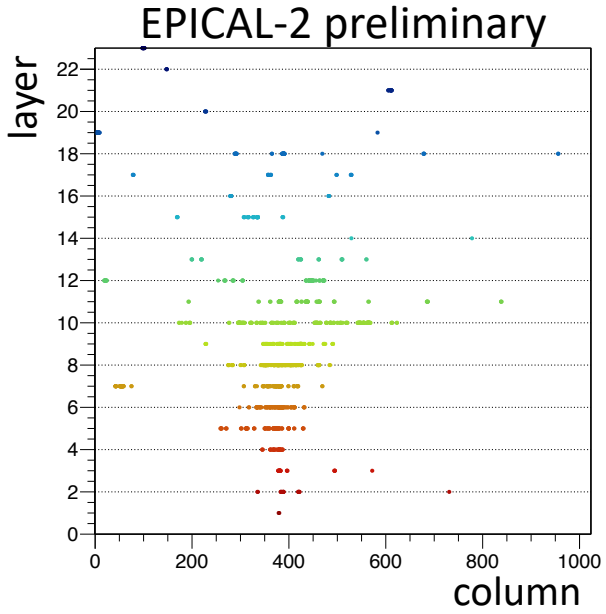
Event Display

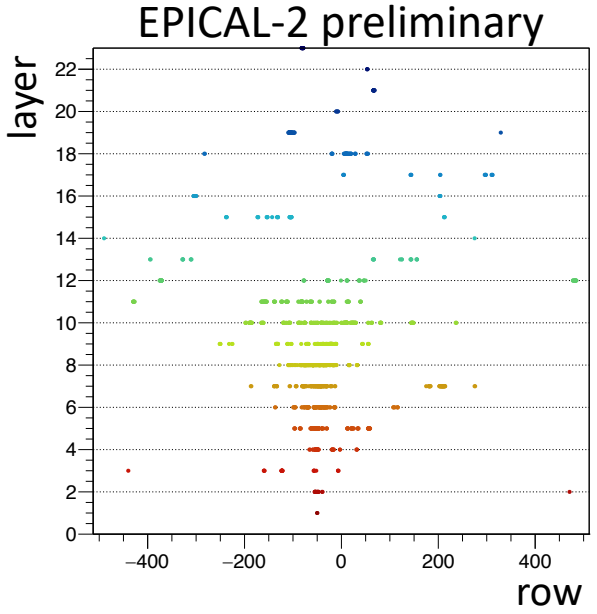
one-electron event
5 GeV
raw data





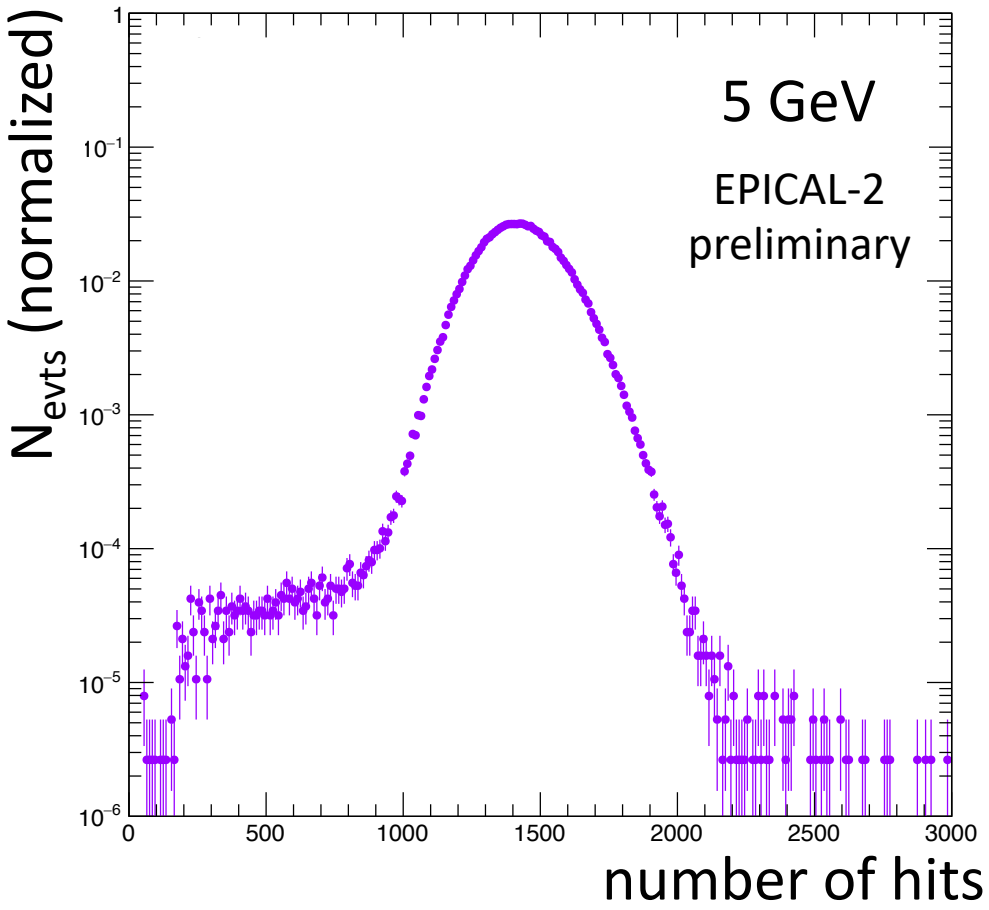
color coding
→ layers

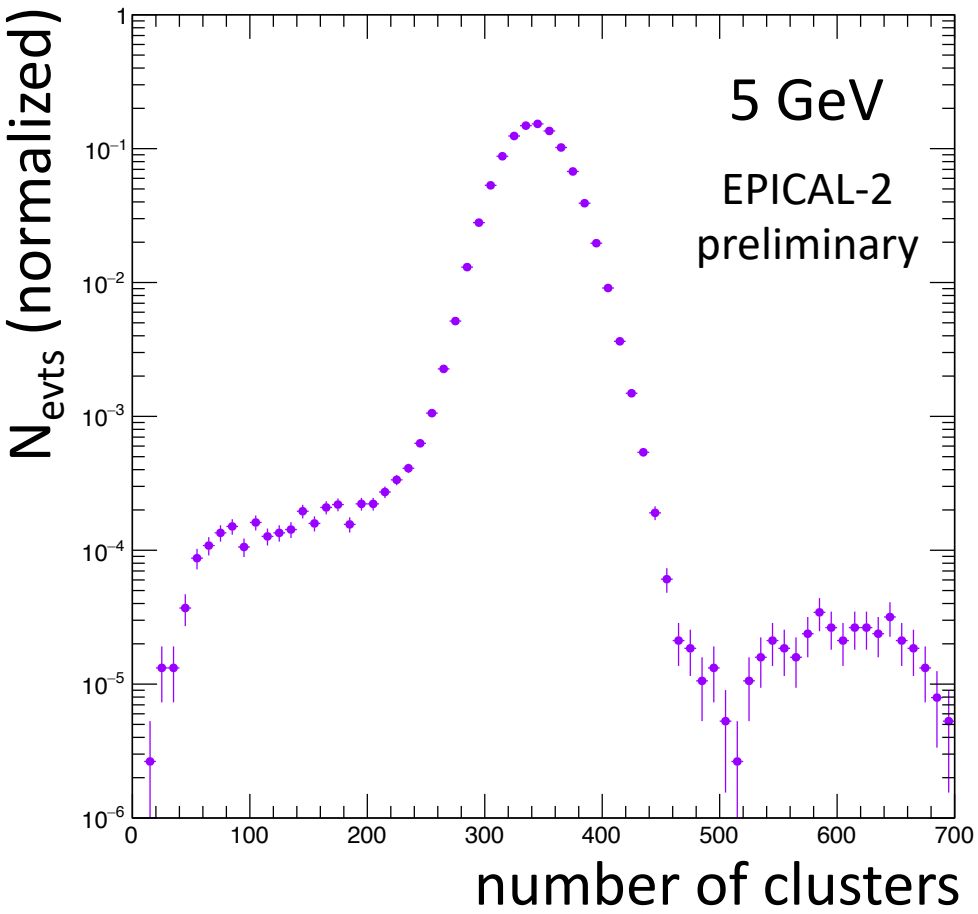




→ detailed evolution of shower

Signal Distribution

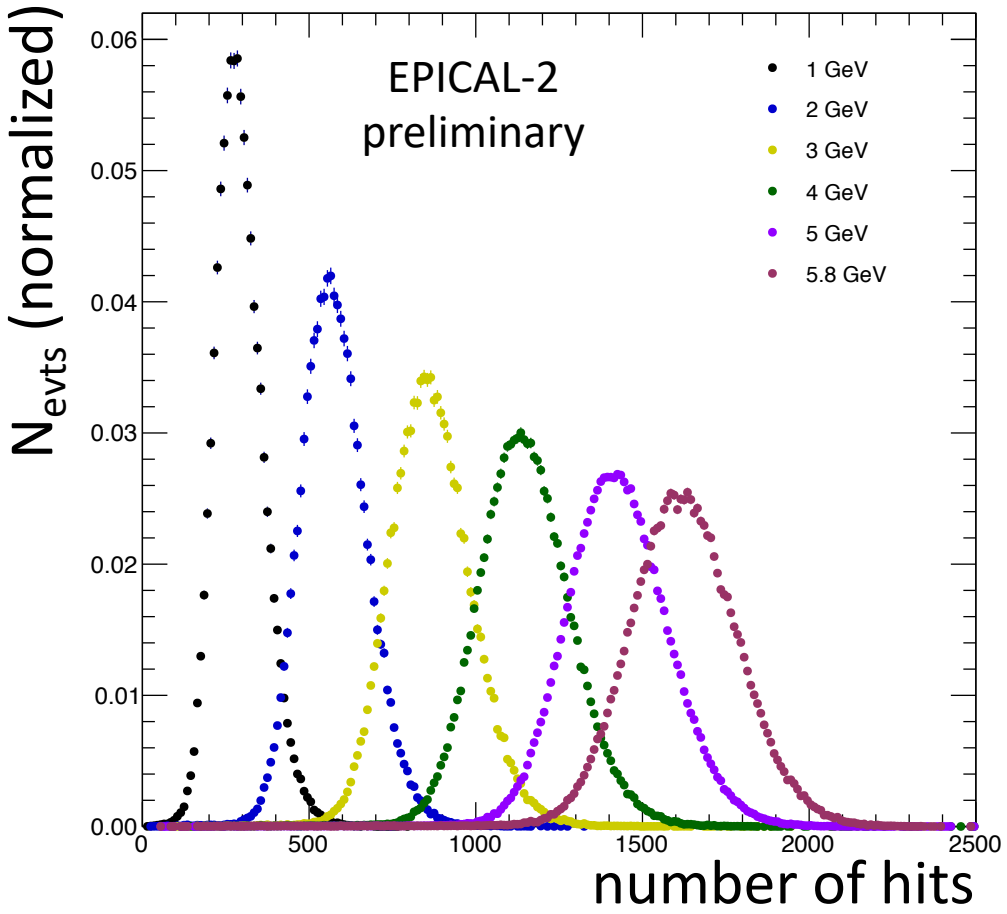


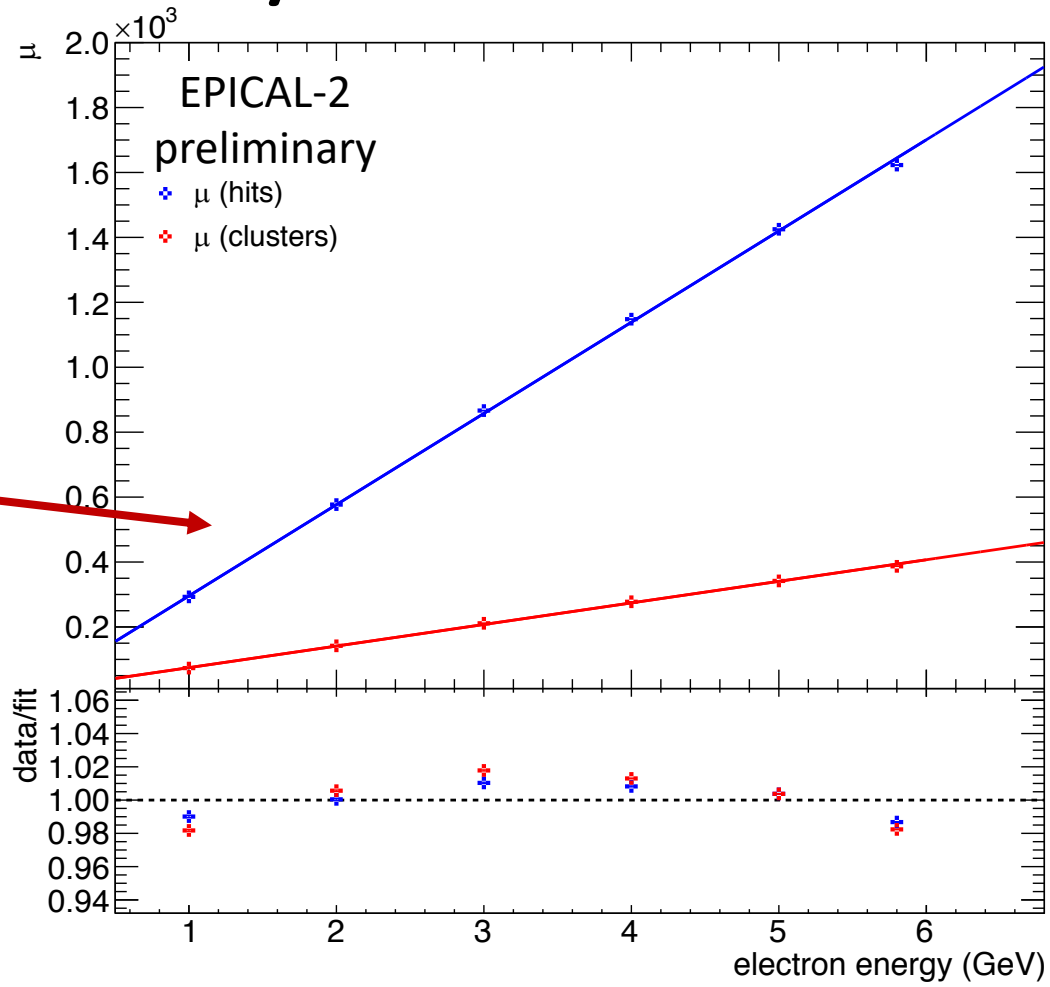


- Gaussian shape
- small asymmetry
- narrower shape for clusters

→ **arithmetic mean and standard deviation of distribution**

Energy Linearity



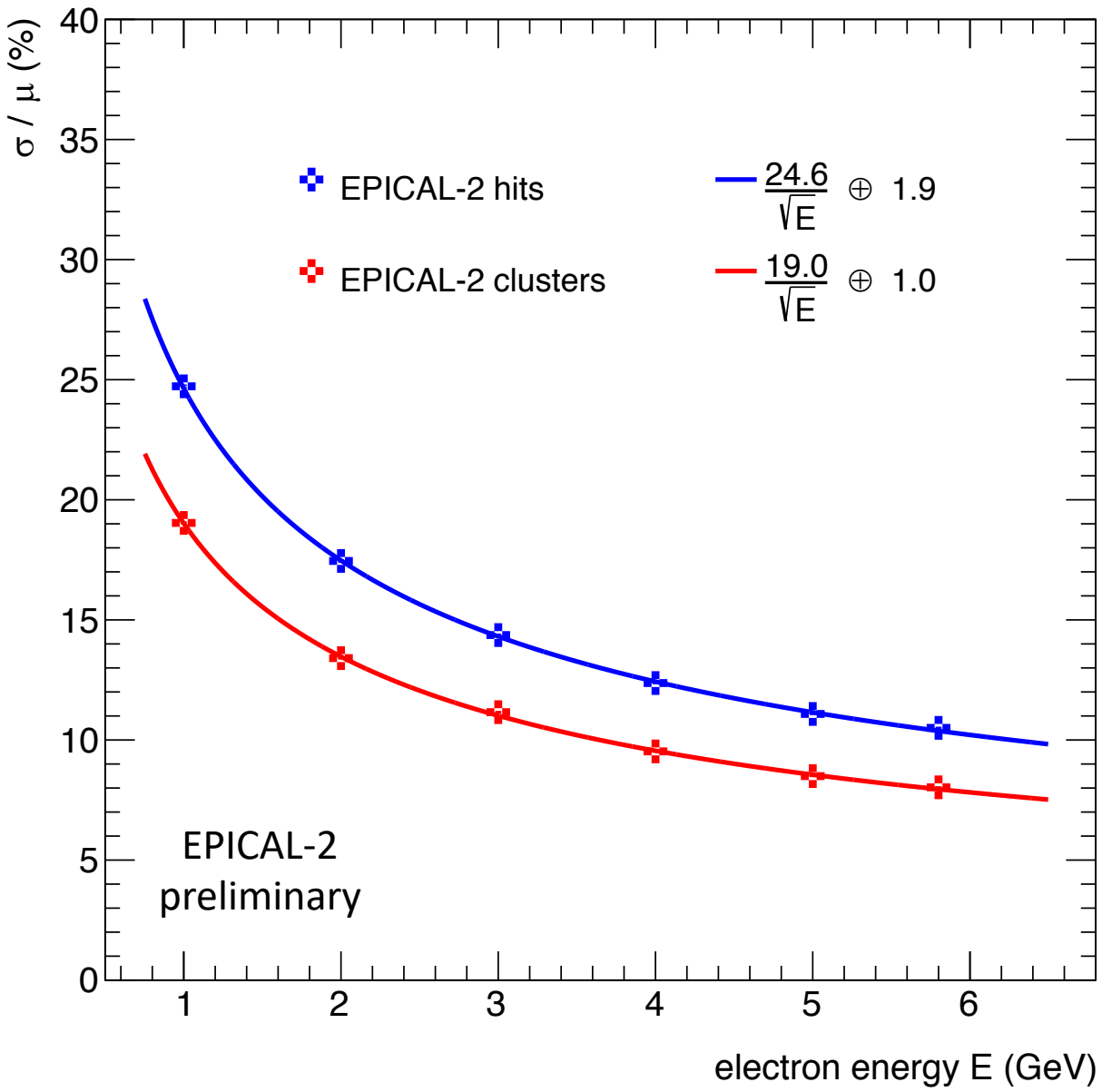


arithmetic mean (μ) and standard deviation (σ) of hit and cluster distributions

- dependence of mean on test-beam energy
- similar performance for hits and clusters

→ preliminary energy-linearity check

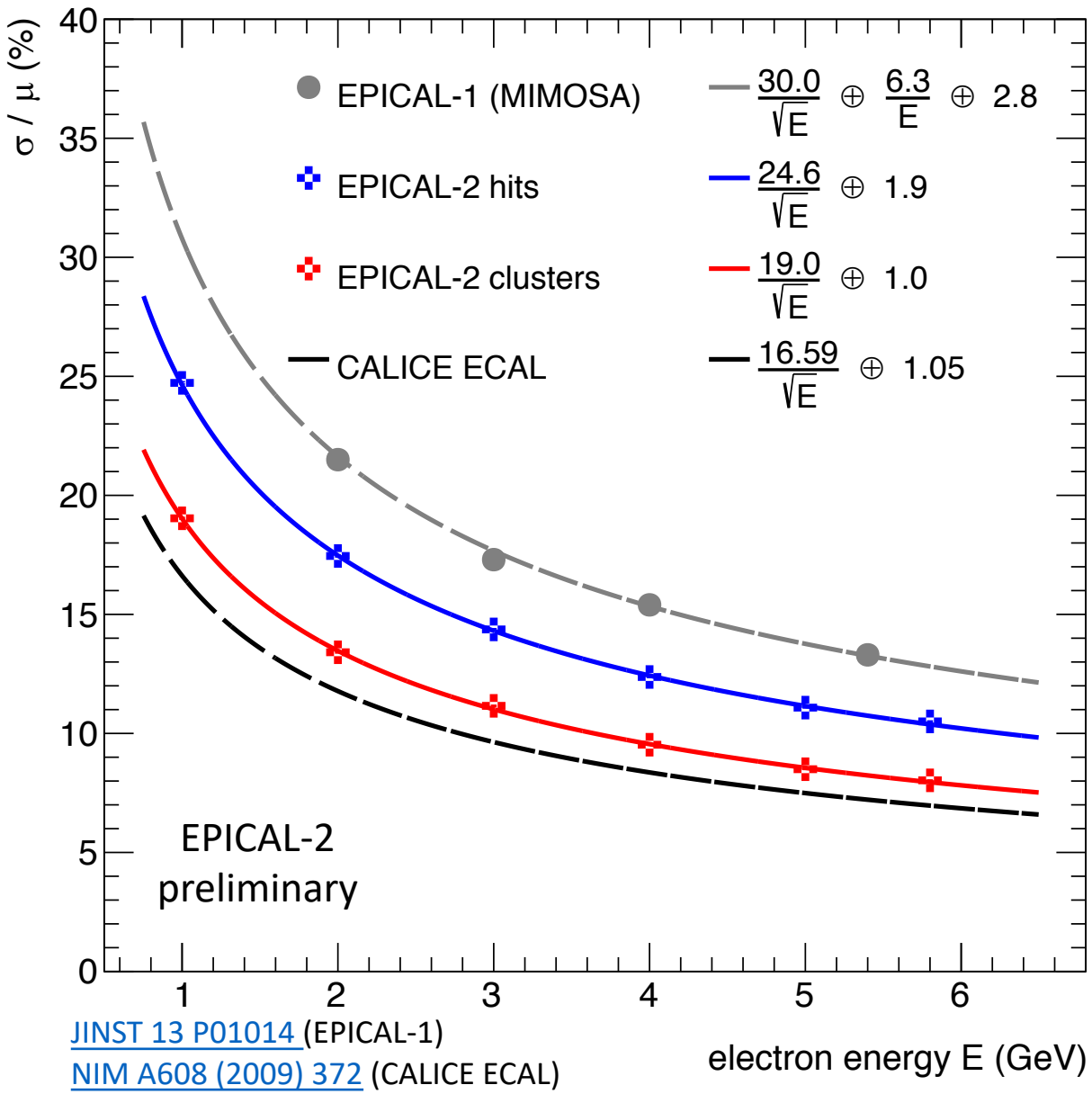
Energy Resolution



arithmetic mean and standard deviation from corresponding distributions:

- noise term negligible
- better performance for clusters

Energy Resolution



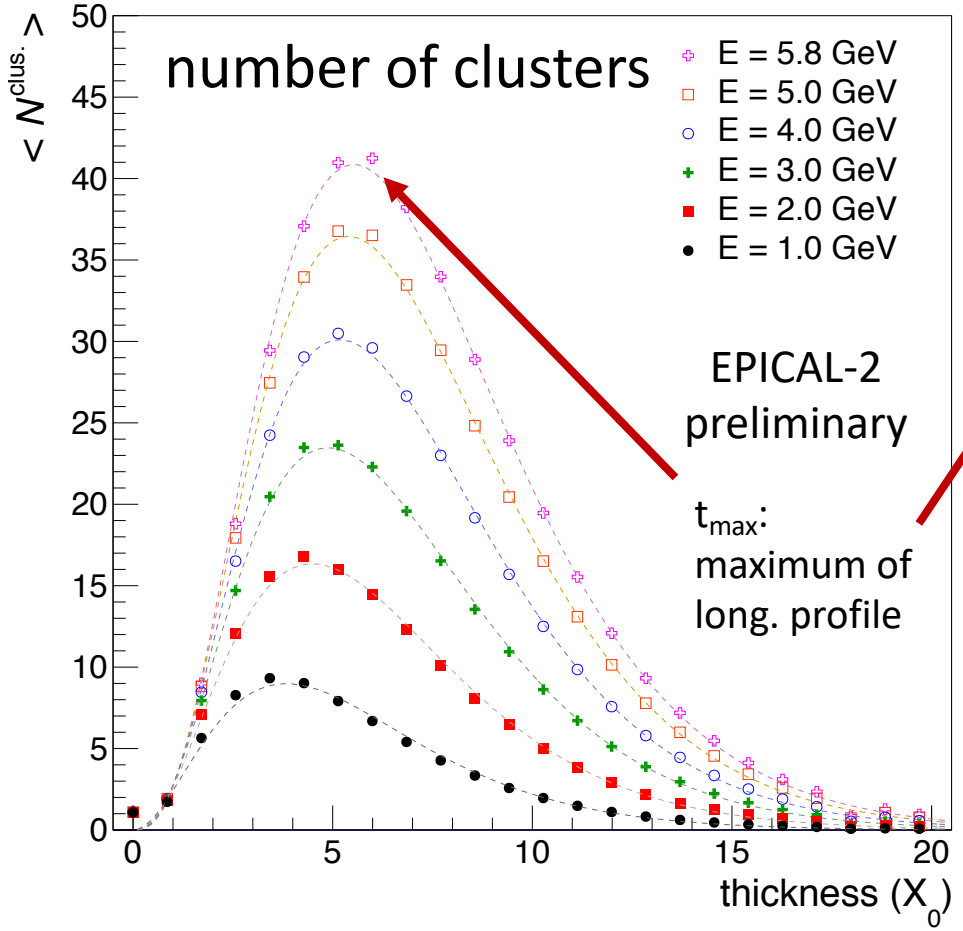
JINST 13 P01014 (EPICAL-1)
NIM A608 (2009) 372 (CALICE ECAL)

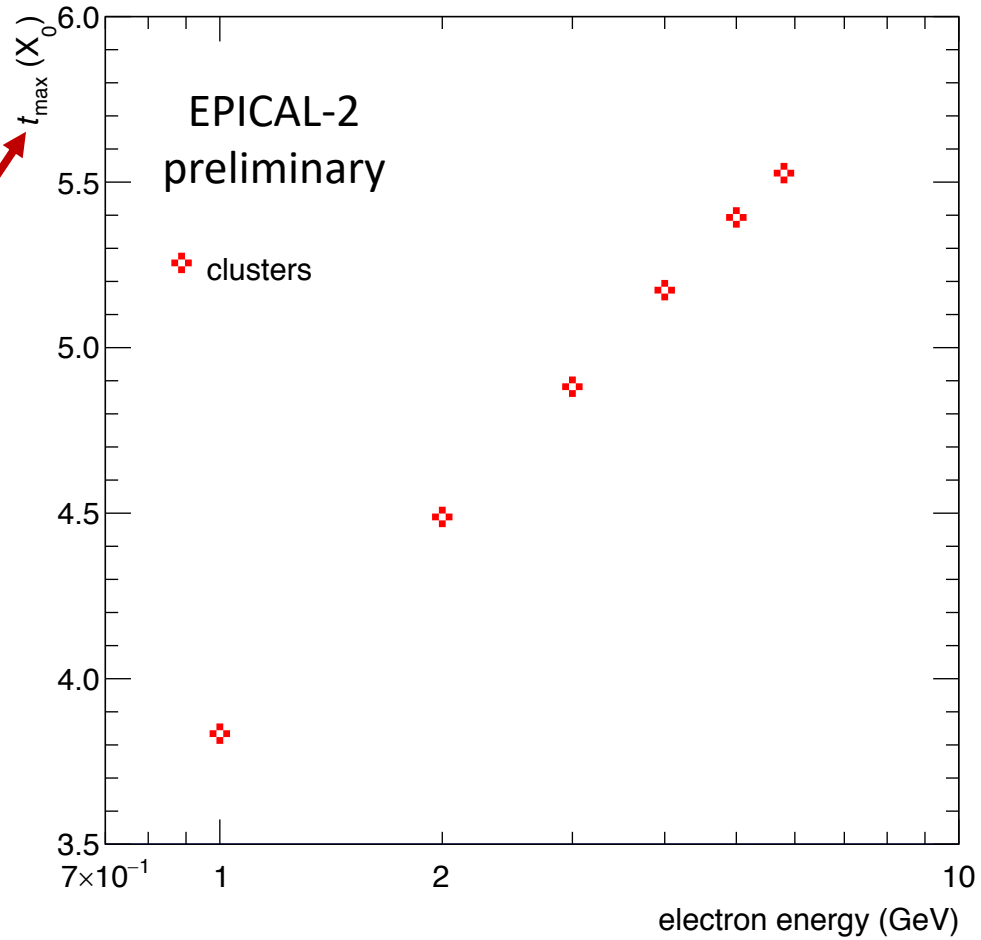
arithmetic mean and standard deviation from corresponding distributions:

- noise term negligible
- better performance for clusters

→ energy resolution superior to previous prototype

Longitudinal Shower Profiles



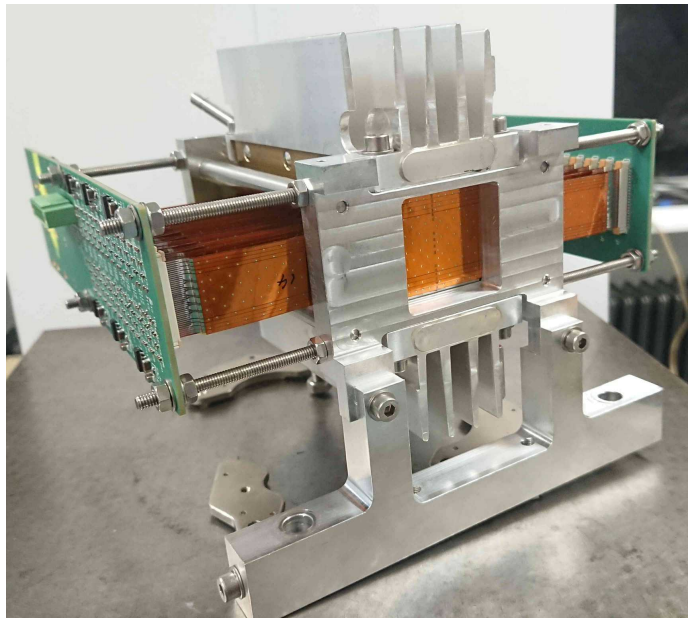


longitudinal shower profiles

- good description with gamma function already for preliminary calibration
- good performance for hits and clusters

→ **first step in detailed shower-shape analyses**

Summary



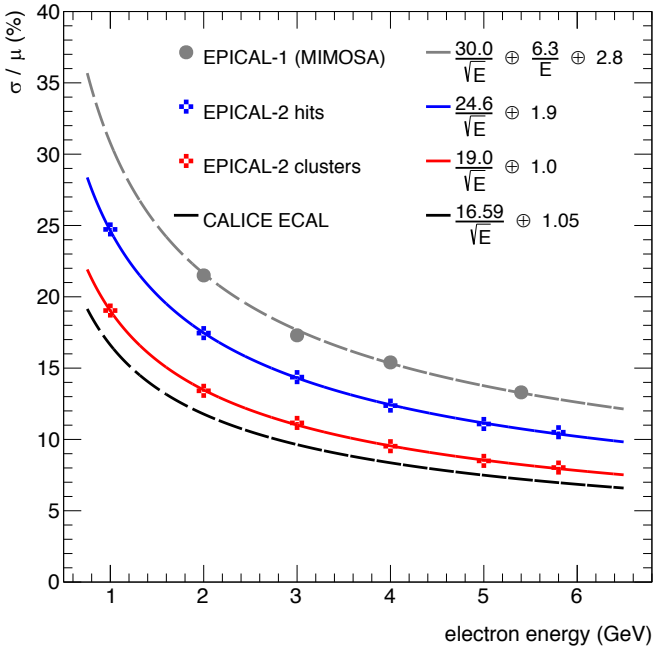
EPICAL-2

- high-granularity digital Electromagnetic PIxel CALorimeter
- 24 layers of
  - two CMOS MAPS chips (30 x 30 μm^2 pixel size)
  - tungsten absorber

→ compact design with very small pixel size

electron test beam

- energy resolution superior to previous MIMOSA prototype
- first step in detailed shower-shape analyses



→ ALICE FoCal requirements satisfied
→ good candidate for ILC application

EPICAL-2 Team

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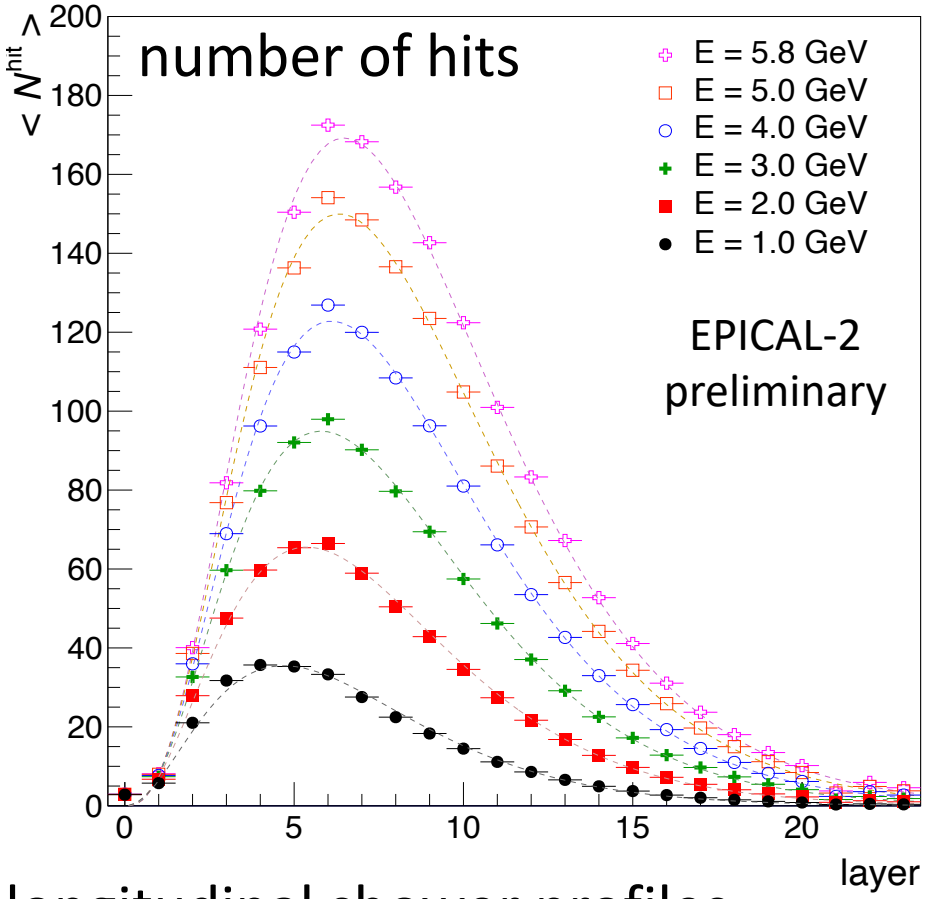
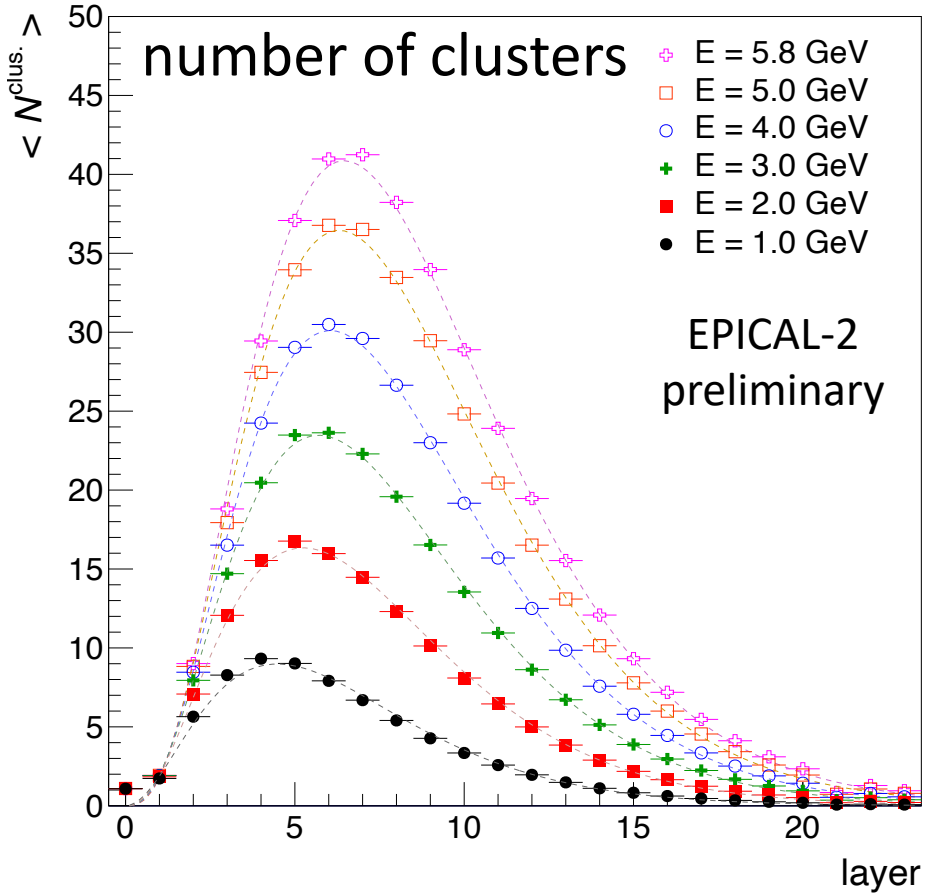
Else Okkinga
Thomas Peitzmann
Sebastiaan van Rijk
Marcel Rossewij
Hiroki Yokoyama

backup

Shower Profiles





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→ **first step in detailed shower shape analyses**