EPICAL-2

Test beam performance of a digital pixel calorimeter

Fabian Pliquett

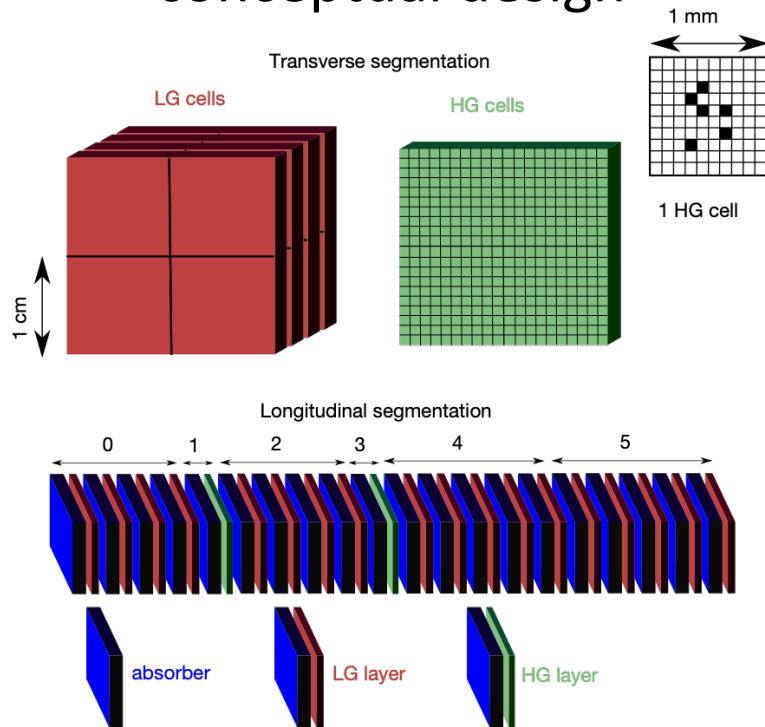Goethe University Frankfurt

International Workshop on Future Linear Colliders

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EPICAL-2 Prototype

development in the context
of the Forward Calorimeter
for the ALICE upgrade

FoCal-E (electromagnetic)
conceptual design

calorimetry with
particle flow approach (PFA)
- measurement of every shower particle
    => high granularity
    => transition from pads to pixels
    => one particle per pixel
    => 1-bit ADC readout per pixel

=> **digital calorimeter with very small pixels**

analog   digital   digital

$N_{pixels} < N_{particles}$ $N_{pixels} = N_{particles}$
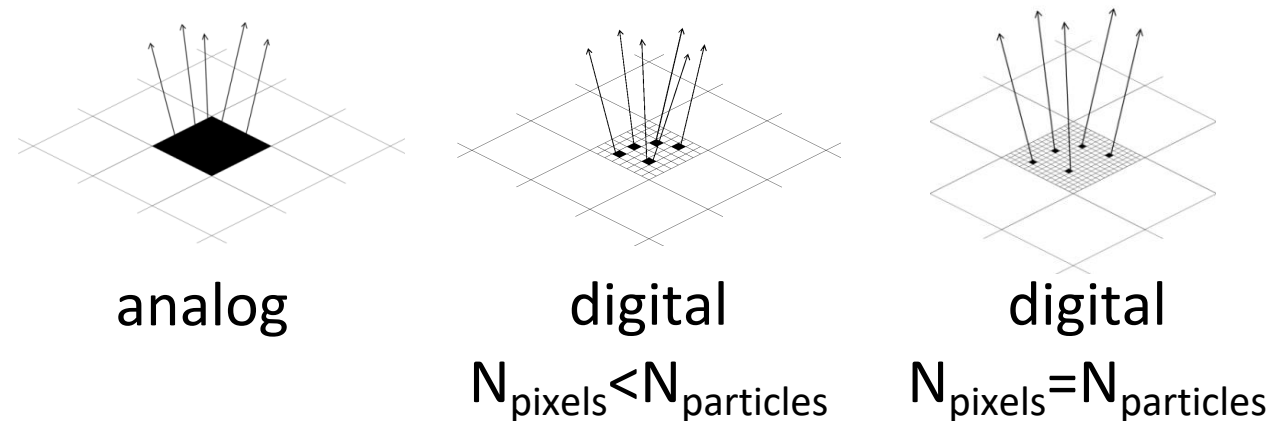
EPICAL-2 Prototype
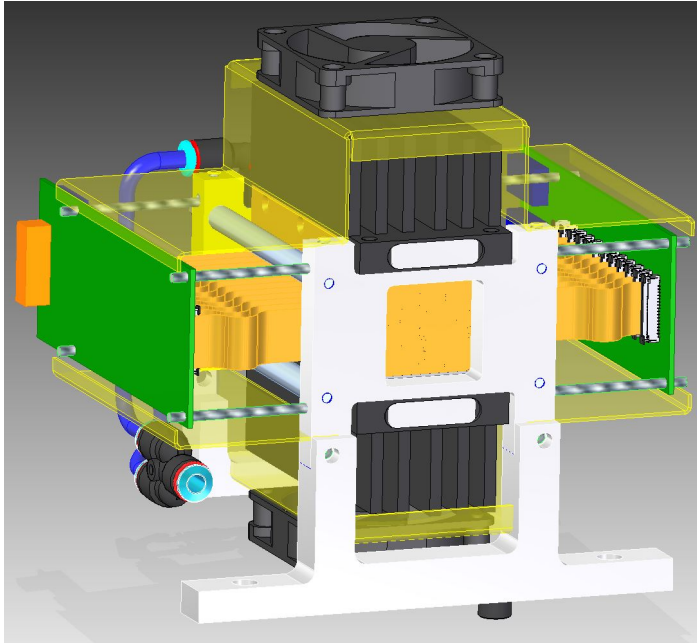
Monolithic **A**ctive **P**ixel **S**ensor (MAPS)
ALPIDE
- chip size 1.5 x 3 cm^2
- pixel size 29.24 x 26.88 µm^2
- 1024 x 512 pixel matrix

Setup of the prototype:
- 24 layers with two sensors each
  => active area 3 x 3 cm^2
- 48 x 1024 x 512 = 25 M pixels
- 3 mm W absorber per layer
- water cooling system
- Trigger: two SiPM scintillation counters
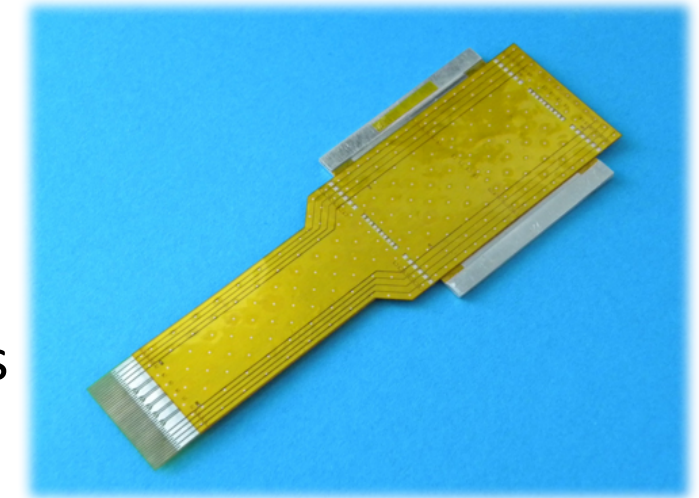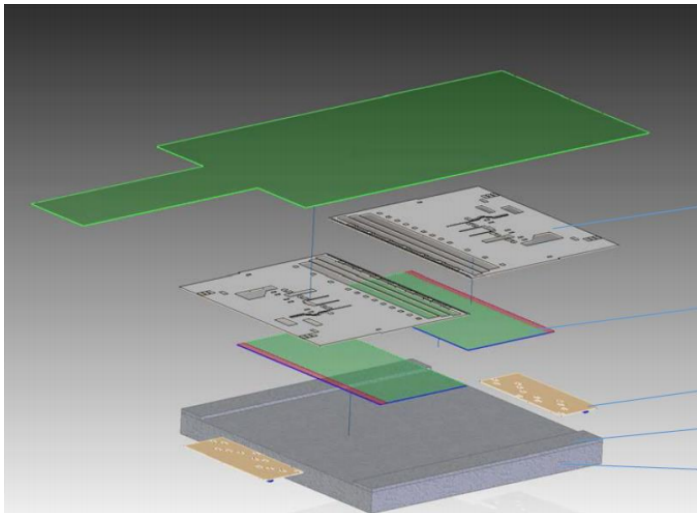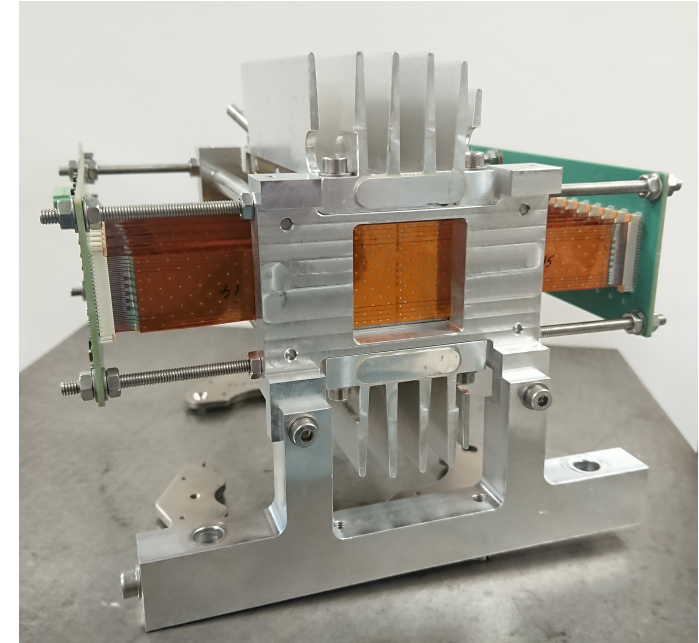
Data Taking Setup

① Cosmic Muons

- May through October 2020 at Utrecht University
- charged particle tracks from cosmic muons
- ≈ 9000 events

② Electron Test Beam at DESY

- February 2020 at DESY TB22
- electron beam
- various energies:
  1.0, 2.0, 3.0, 4.0, 5.0 and 5.8 GeV
- ≈ 43 million events

measurement programs:
- **beam energy dependence**
- angular dependence
- beam position dependence
- temperature dependence
- positron runs

Data Taking Setup

cosmic

(1) Cosmic Muons

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non-showering particle
⇒ well-defined track
⇒ uniform mean energy deposition over all layers

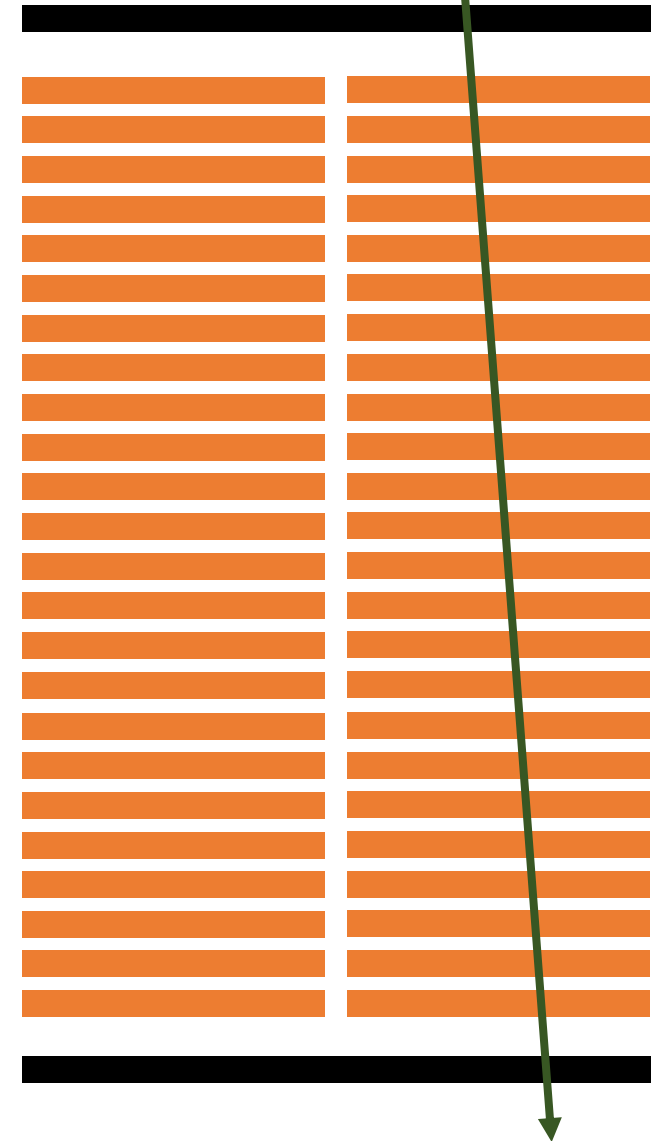**=> alignment, calibration**

trigger tile

48 chips
24 layers

trigger tile

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)
- reference points:
  => one chip in top layer completely fixed (3 fixed parameters)
  => one chip in bottom layer fixed in x and y (2 fixed parameters)
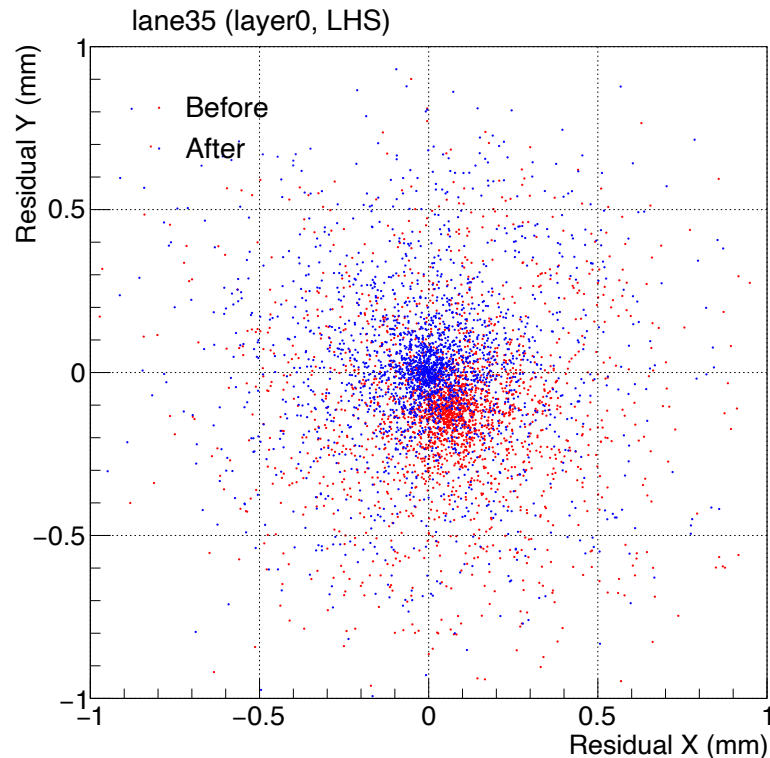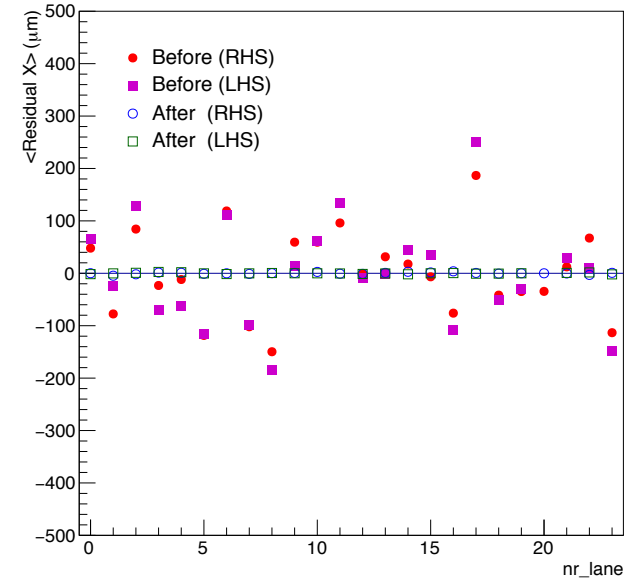=> alignment parameters: 48 x 3 – 5 = 139
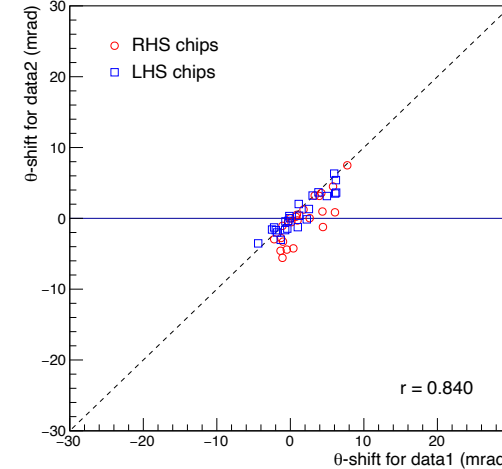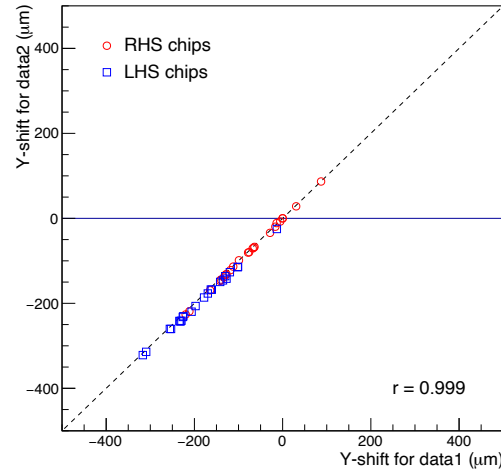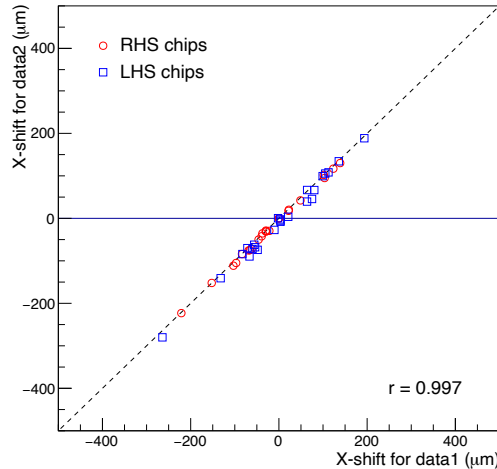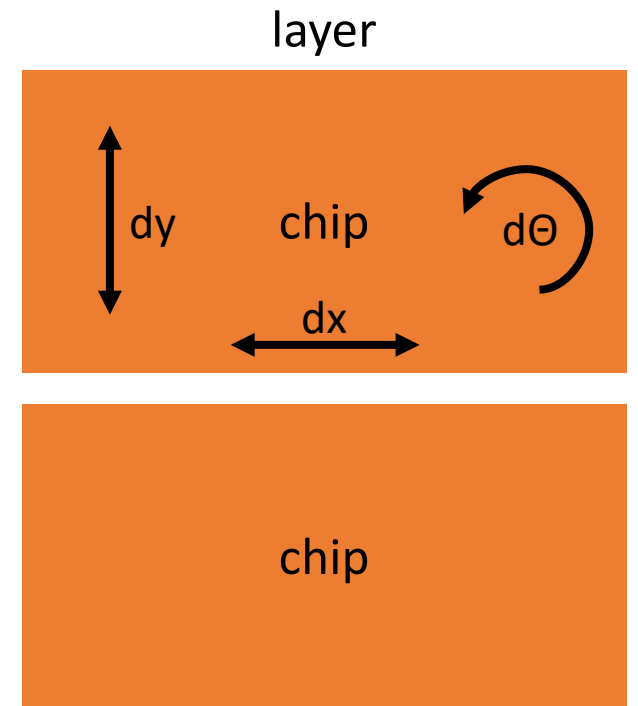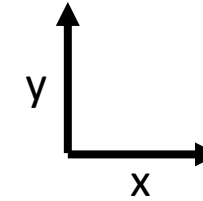
RHS:
right-hand side

LHS:
left-hand side

Alignment

residuals:
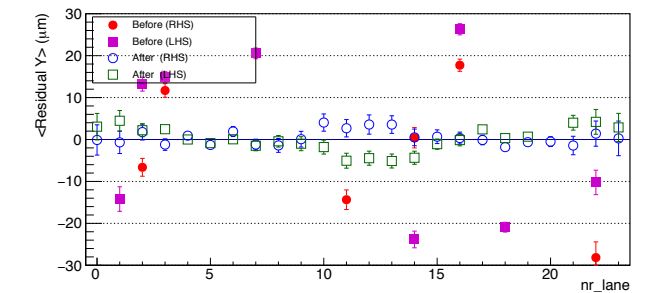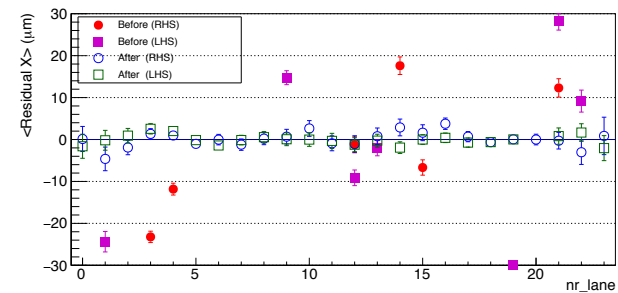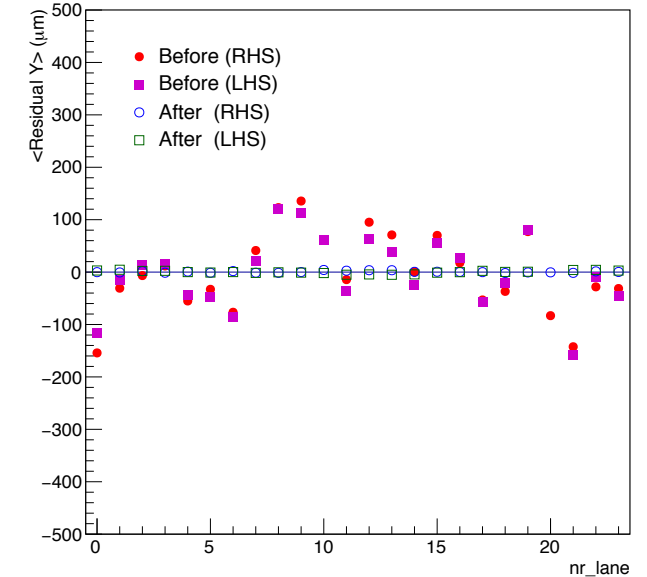difference between track fit and cluster

lane35 (layer0, LHS)
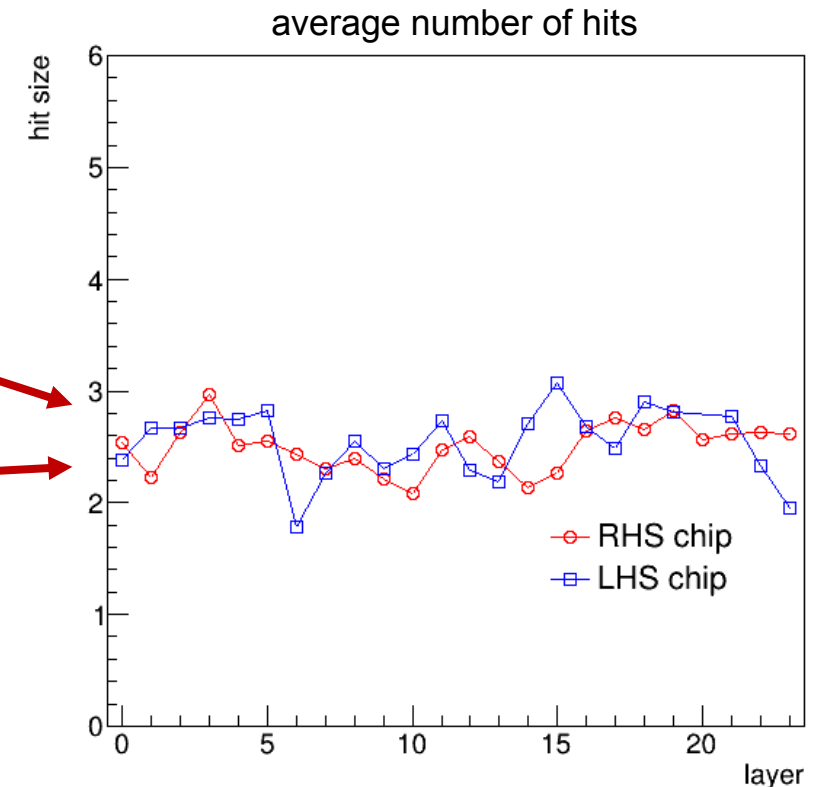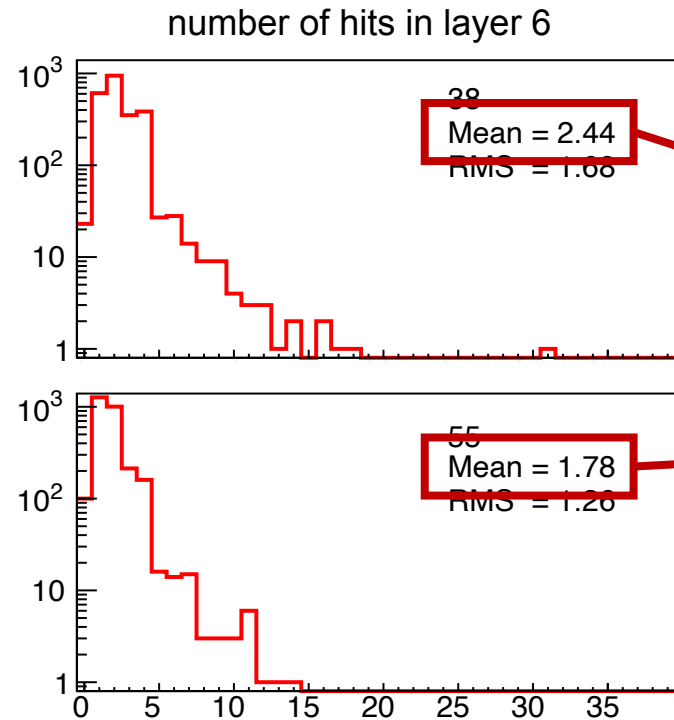
x residual   y residual

=> **alignment precision better than 10 μm**

chip-by-chip calibration:
- equalization of chip responses via number of hits
- event-by-event fluctuations

but:
uniform mean number of hits/cluster size

=> calibration factor from ratio to mean

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=> alignment, calibration

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- February 2020 at DESY TB22
- electron beam
- energies from 1.0 to 5.8 GeV
- ≈ 43 million events

measurement programs:
- **beam energy dependence**
- angular dependence
- beam position dependence
- temperature dependence
- positron runs

Data Taking Setup

beam particle

48 chips
24 layers

trigger tiles

showering particle:
$\Rightarrow$ secondary particle production in absorber
$\Rightarrow$ statistical process
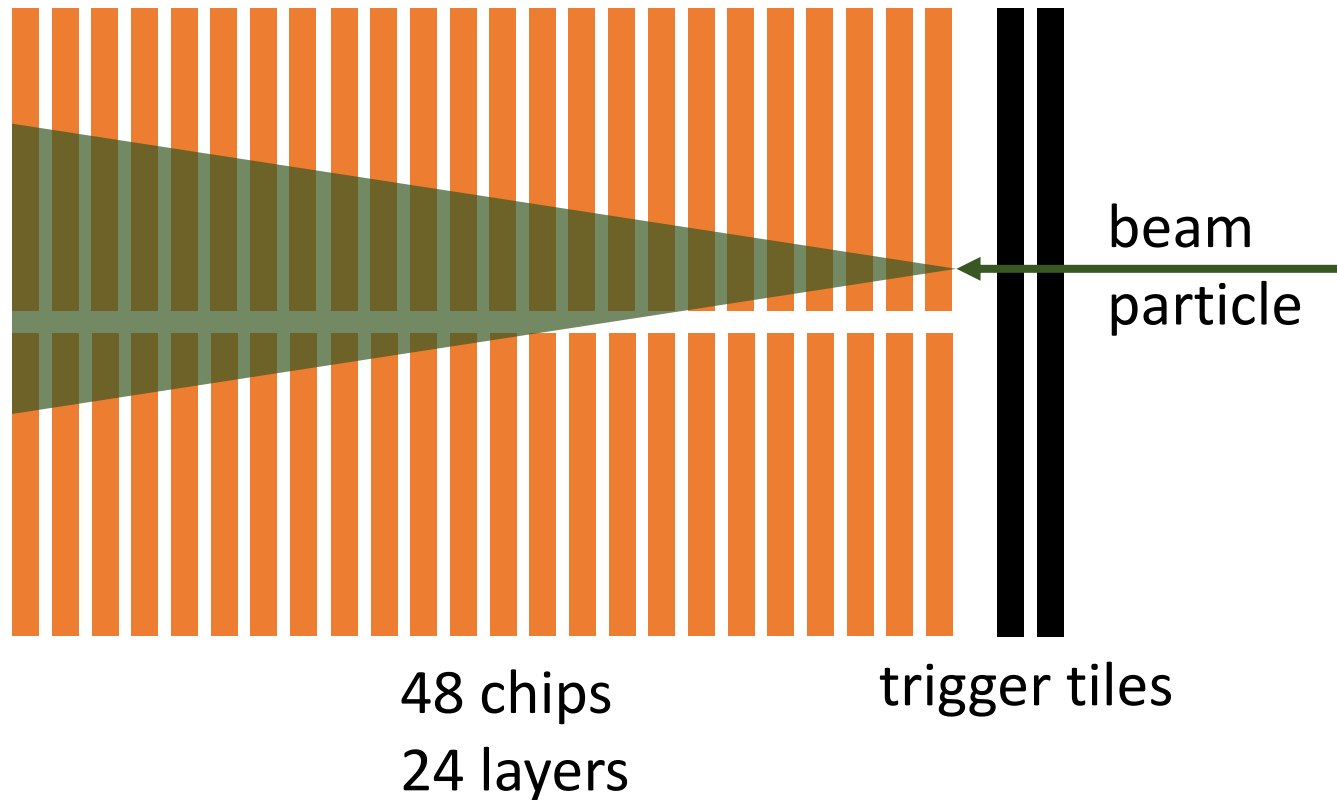$\Rightarrow$ distribution of hit pixels in every layer

② **Electron Test Beam at DESY**

• February 2020 at DESY TB22
• electron beam
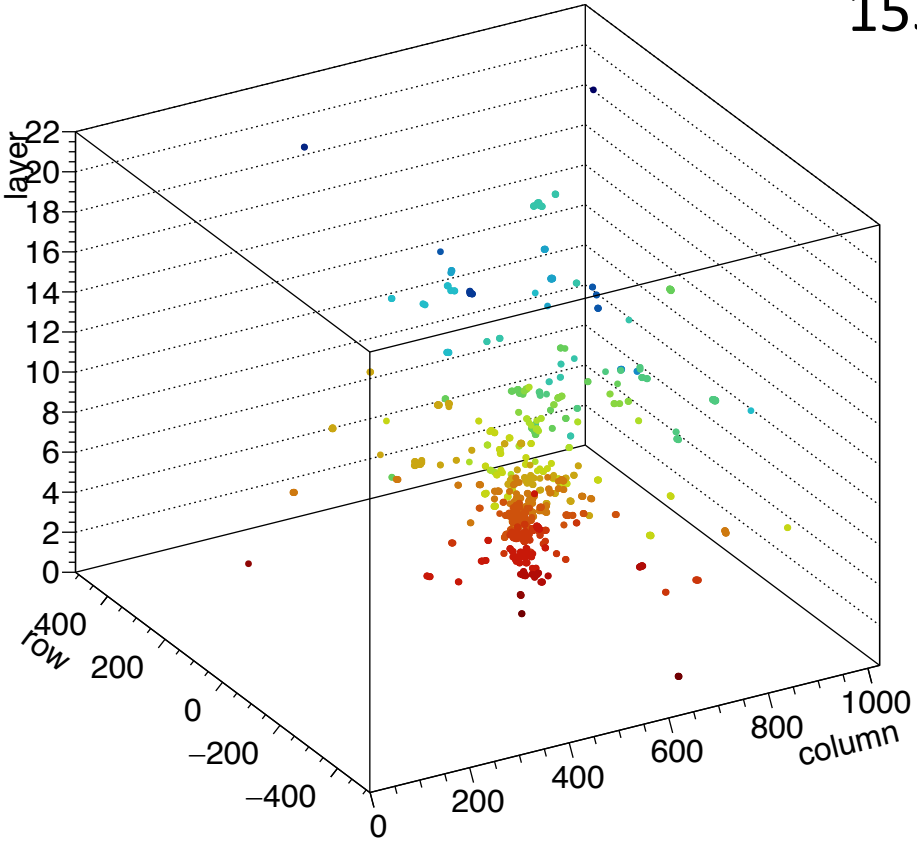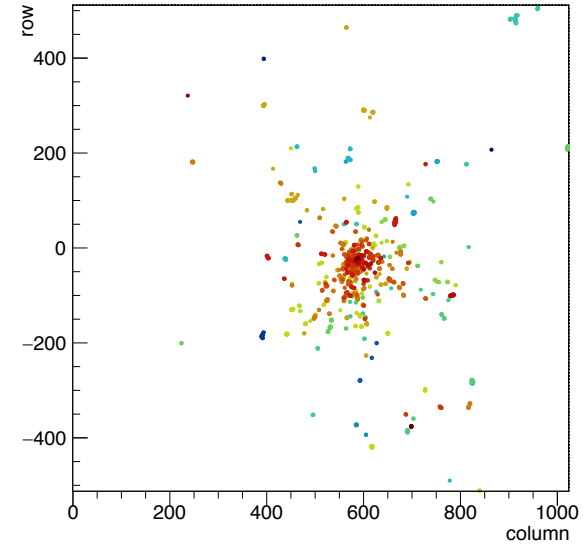• energies from 1.0 to 5.8 GeV
• ≈ 43 million events

measurement programs:
• **beam energy dependence**
• angular dependence
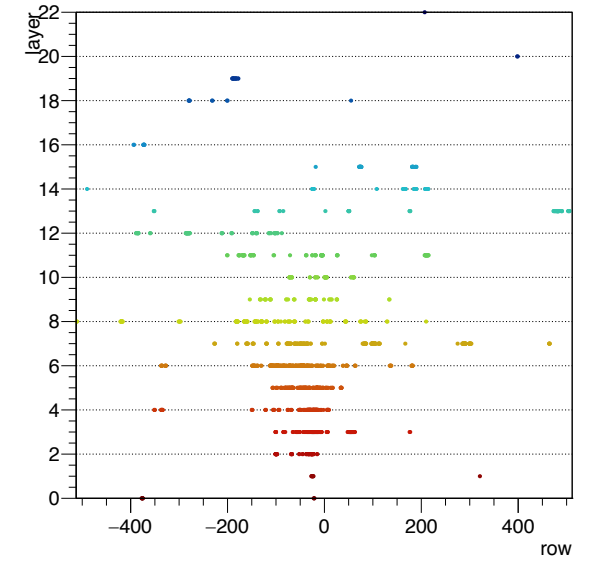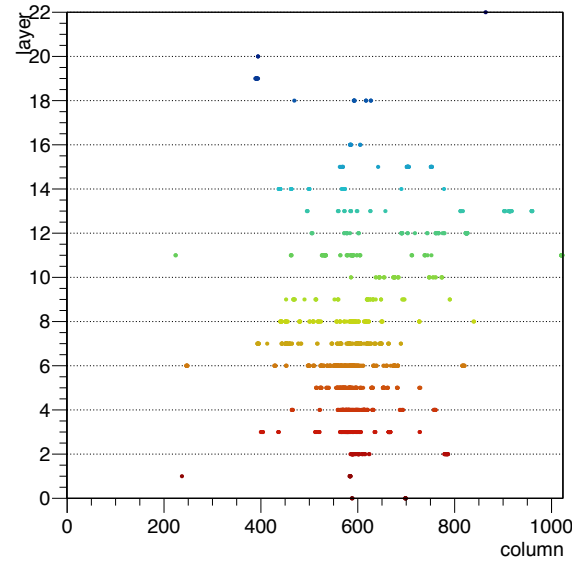• beam position dependence
• temperature dependence
• positron runs

=> **linearity, resolution, shower profiles**

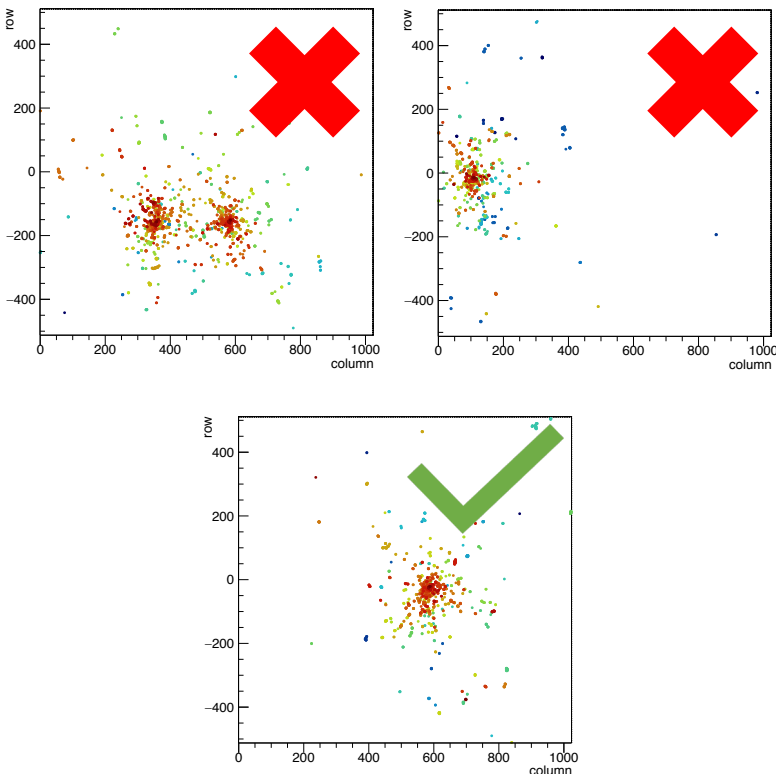# Event Display

one-electron event

1535 hits in total

=> detailed evolution of shower
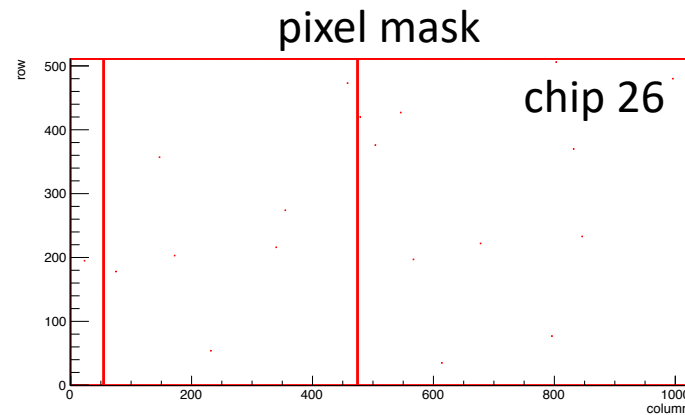
Analysis Setup

event selection

- single electrons
- minimal lateral leakage
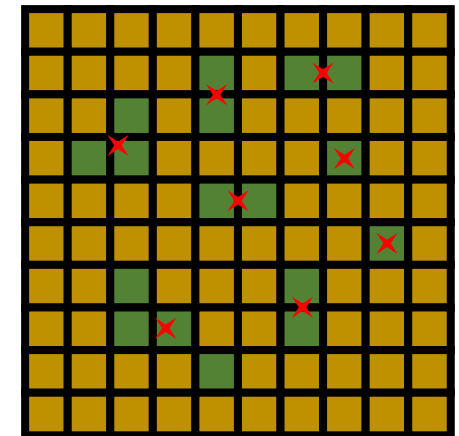

pixel masking

- noisy and dead pixels from:
  - chip classification
  - pedestal runs
  - beam runs
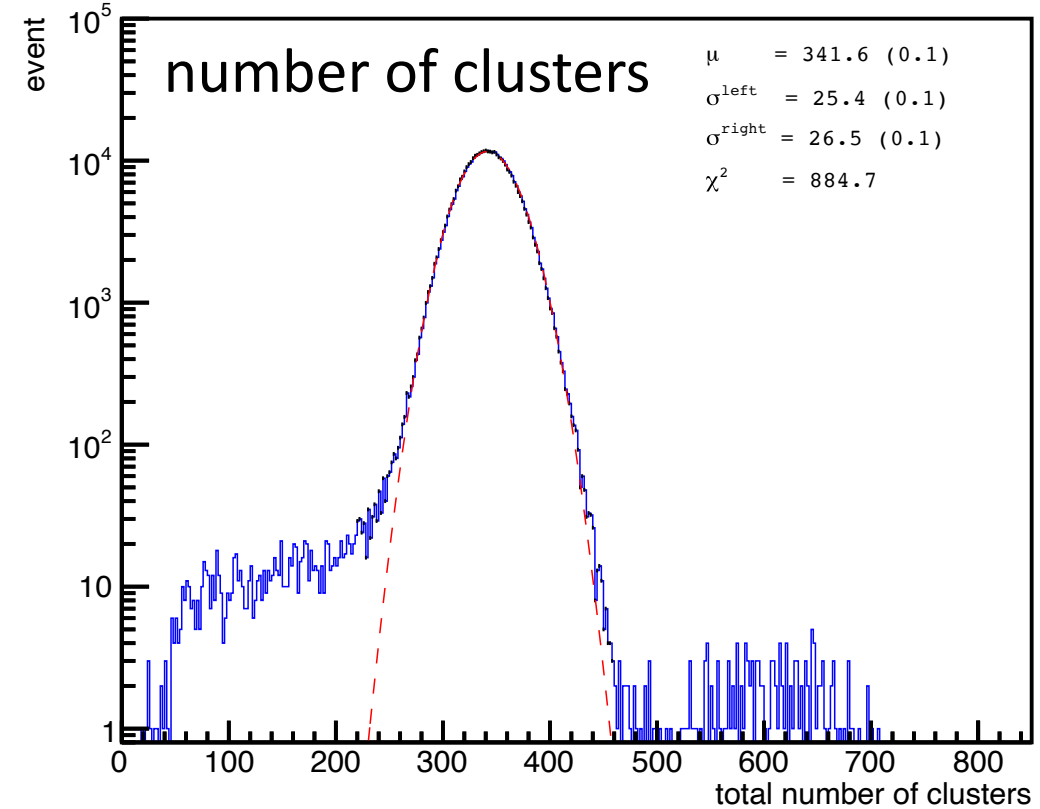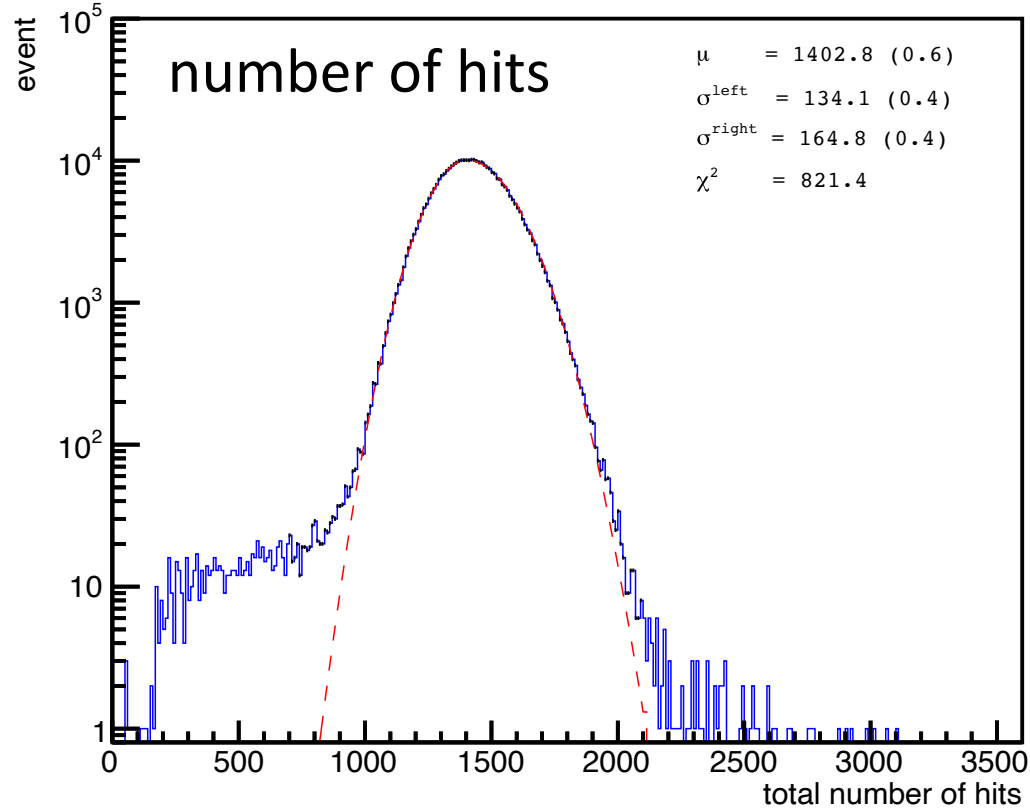
pixel mask

chip 26

clustering

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

Signal Distribution

5 GeV

number of hits

μ = 1402.8 (0.6)
σ^{left} = 134.1 (0.4)
σ^{right} = 164.8 (0.4)
χ^2 = 821.4

number of clusters

μ = 341.6 (0.1)
σ^{left} = 25.4 (0.1)
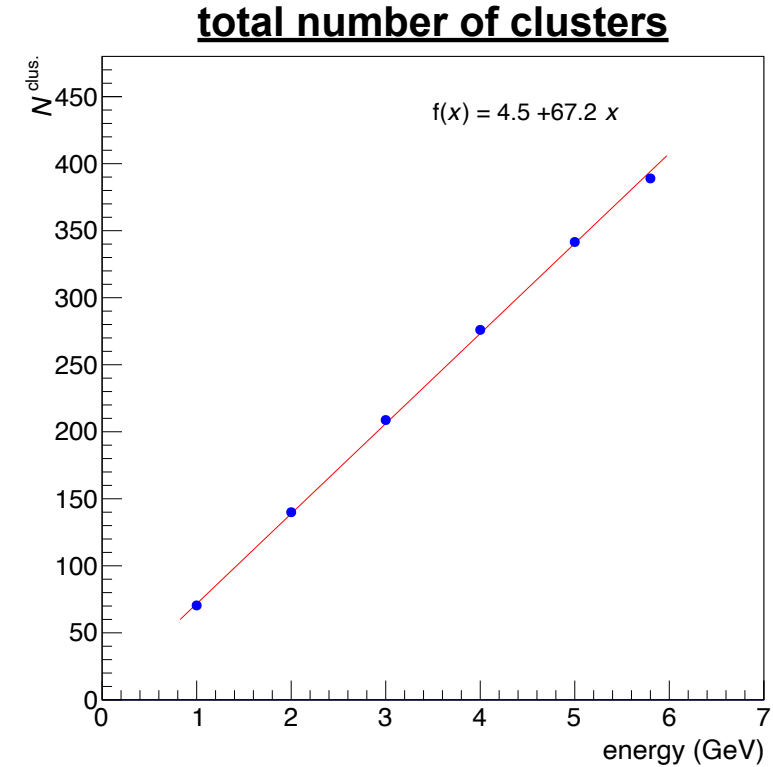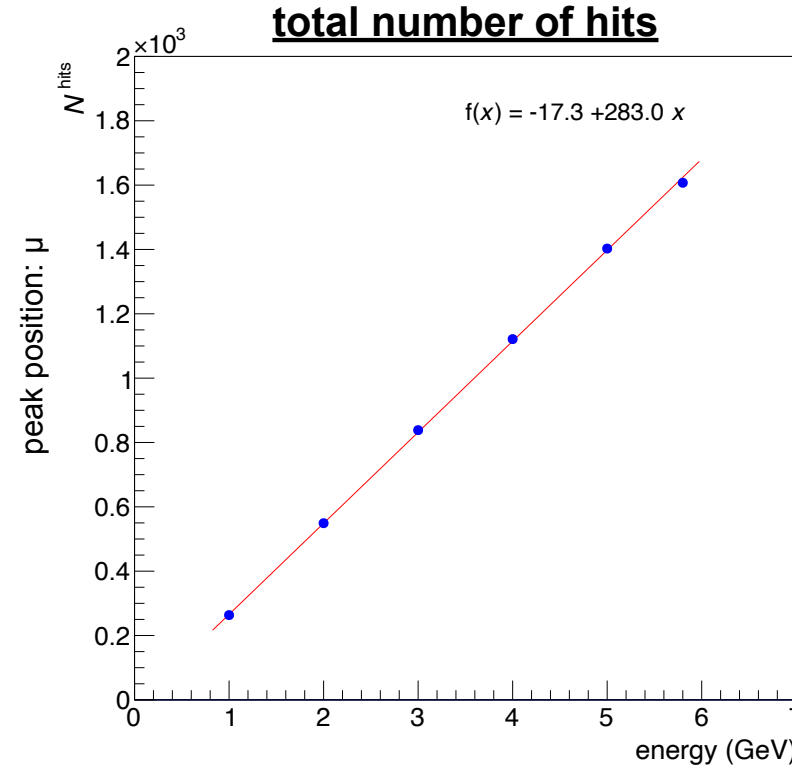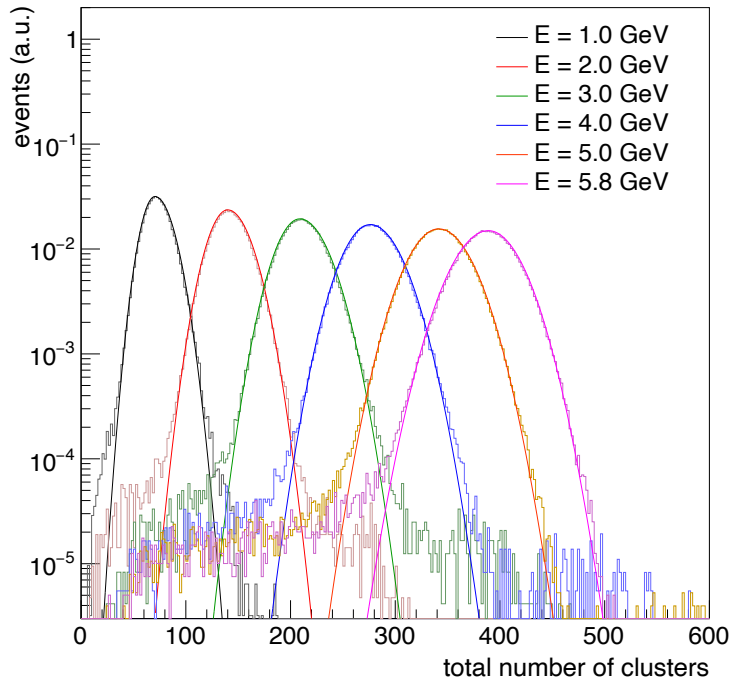σ^{right} = 26.5 (0.1)
χ^2 = 884.7

- Gaussian shape
- small asymmetry
- left shoulder from low-energy beam contamination
- narrower shape for clusters

parametrization with asymmetric Gaussian

=> **mean and width of disitribution**

Linearity

events (a.u.)

- E = 1.0 GeV
- E = 2.0 GeV
- E = 3.0 GeV
- E = 4.0 GeV
- E = 5.0 GeV
- E = 5.8 GeV

total number of clusters

total number of hits

N^{hits}

peak position: μ

$f(x) = -17.3 + 283.0\ x$

energy (GeV)

total number of clusters
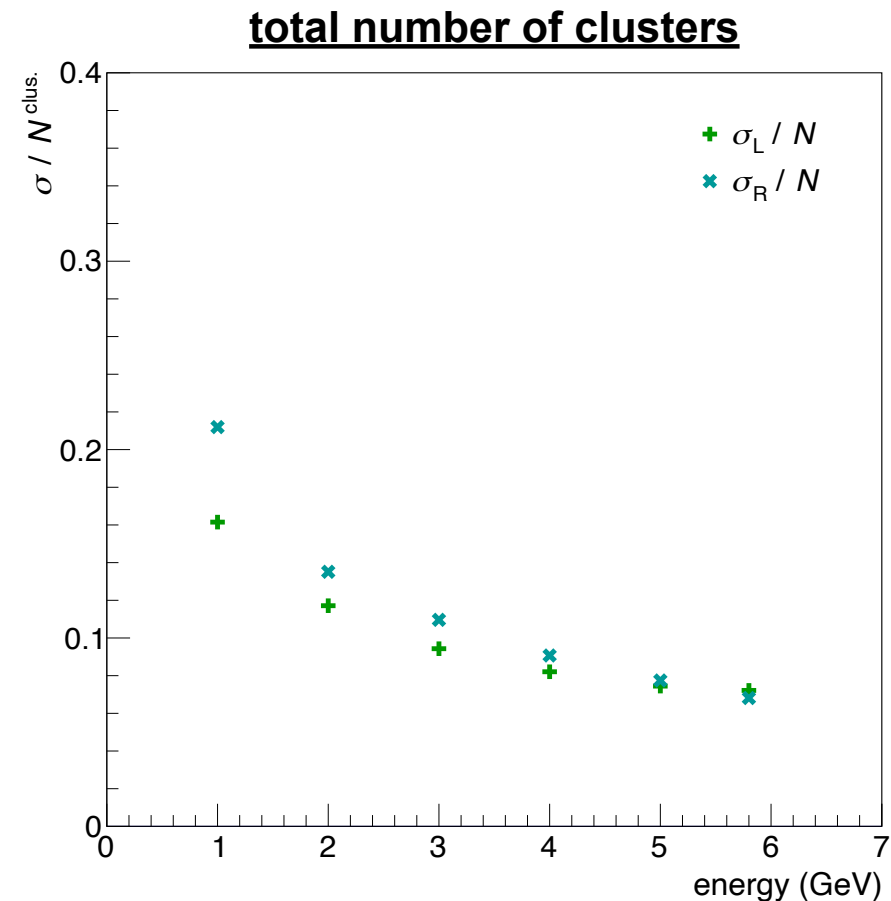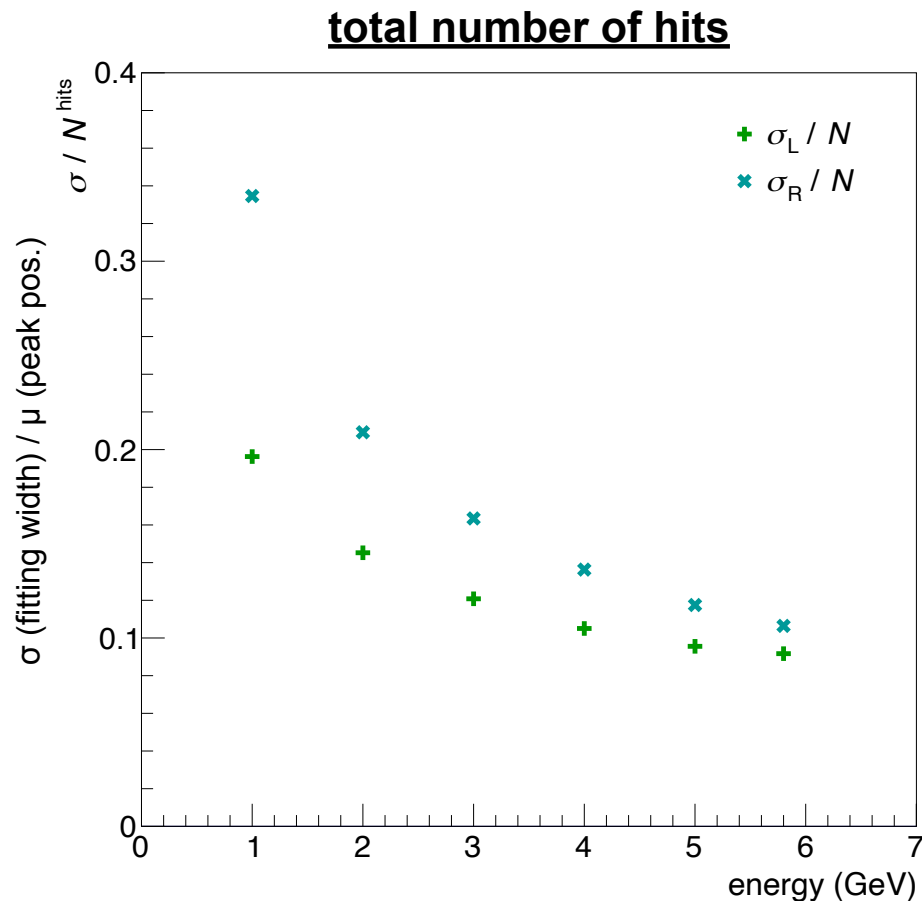
$N^{clus.}$

$f(x) = 4.5 + 67.2\ x$

energy (GeV)

parametrization of
hit and cluster distributions
for all measured energies:
- energy dependence of mean
- similar performance for hits
  and clusters

=> **good linearity for test beam energies**

Resolution

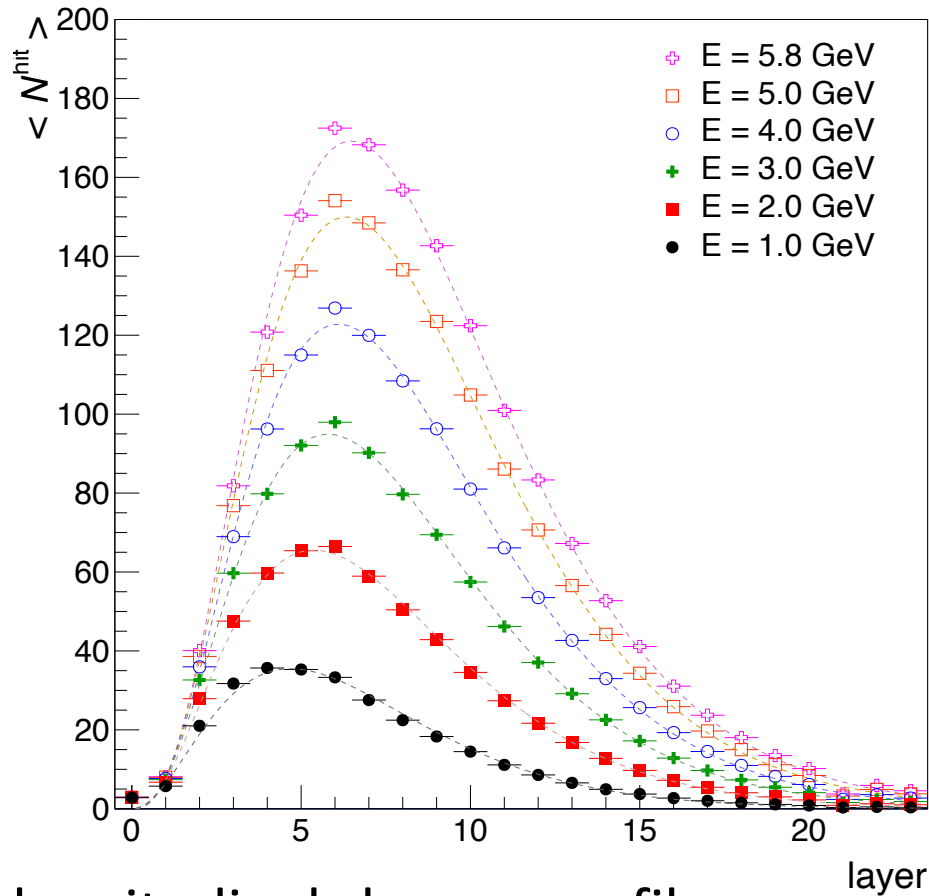**total number of hits**

total number of clusters

left and right width from

asymmetric Gaussian parametrization:
- more symmetric at higher energies
- better performance for clusters

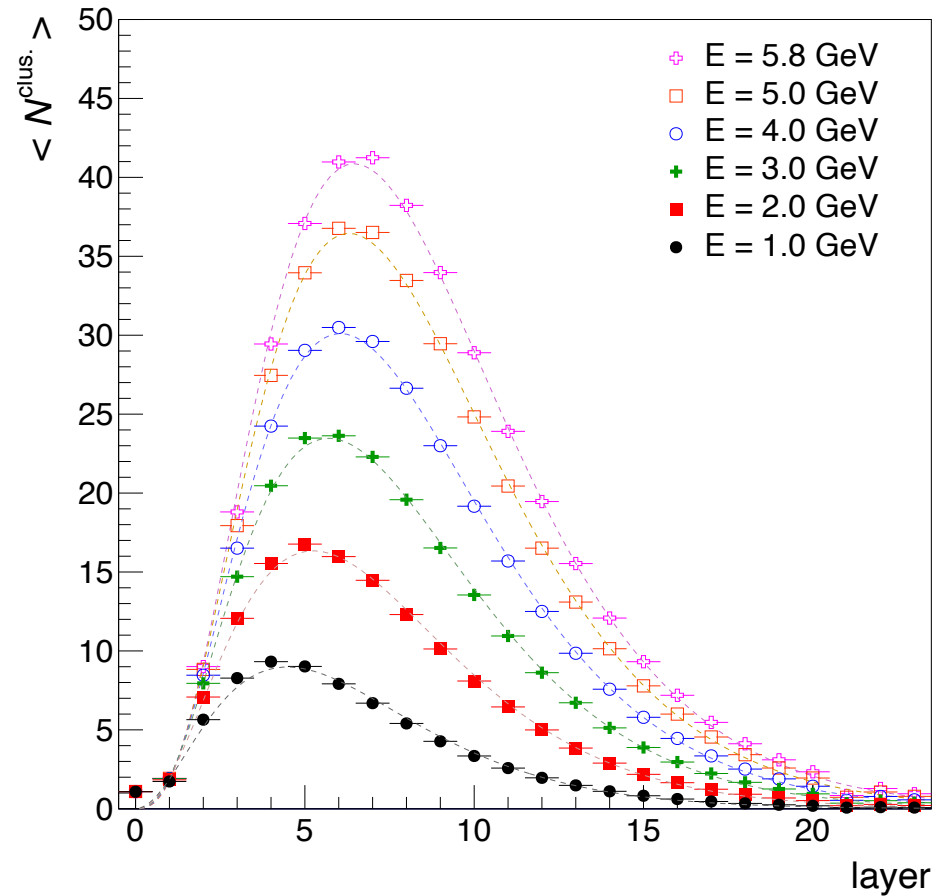=> **energy resolution superior to previous prototyp**

Shower Profiles

hit measurement

cluster measurement

longitudinal shower profiles:

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

=> **detailed shower shape analyses possible**

Summary