

# Identification of back-scattering in LumiCal detector

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# Overview

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- General selection
- Clustering algorithm
- Position reconstruction
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- Trackers' efficiency
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## 4 Summary

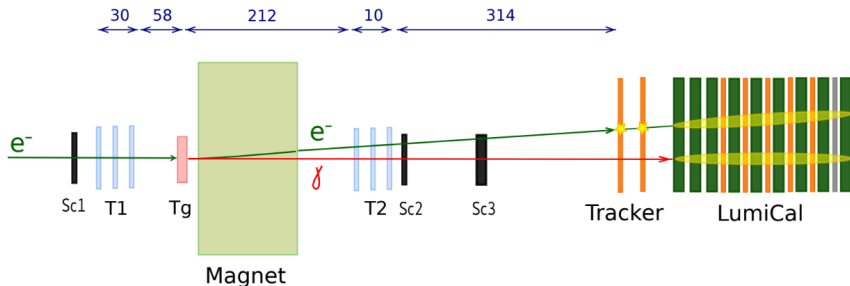
# Test beam 2016

## DESY test beam facilities:

- Electron beam 1-6 GeV
- Dipole magnet 1-13 kGs
- EUTelescope with 3+3 planes of Mimosa26 detectors

## Goals of the test beam

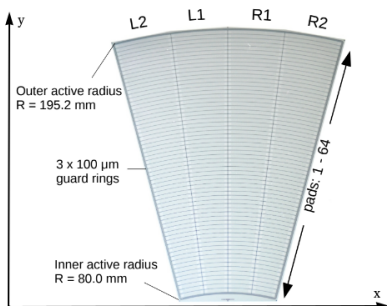
- Study performance of the compact calorimeter
- Test the concept of tracker detector in front of the calorimeter



**Figure:** DESY test beam experimental setup

## Idea of tracker planes in front of the calorimeter:

- Provides  $e^-/\gamma$  identification which can be used in various analyses
- Improves polar angle resolution
- LumiCal alignment



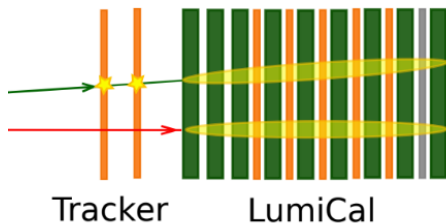
**Figure:** LumiCal Si sensor

## LumiCal sensor:

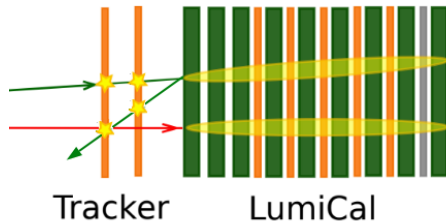
- Material: Si
- Readout chip: APV-25
- 4 sectors of  $7.5^\circ$  each
- 64 pads with 1.8 mm pitch
- $R_{inner} = 80$  mm
- $R_{outer} = 195.2$  mm

# Back-scattering events

Expected "good" event



Back-scattered event



- Back-scattered events may leave extra signals in trackers
- It affects  $e^-/\gamma$  identification and polar angle resolution

**It is important to study those events in order to take into account their possible effects**

## Back-scattering events

Events with only 1 cluster in the calorimeter were used for this table.

$N_{clusters}$ in Tr1	$N_{clusters}$ in Tr2	Data events, %	MC events, %
1	1	91.9	92.9
1	2	2.8	4
2	1	1	1.4
2	2	1.2	1
1	0	0.8	0.01
0	1	1.2	0.01
0	0	0.8	0.4

Total  $N_{events}$ : data = 48112, MC = 42992

**Around 5% of events have 2 clusters in one of the trackers.**

- Is it back-scattering?
- Is it noise?

# Goals/Motivation of the analysis

## Goals

- Study tracker's efficiency
- Identify back-scattering events

## Motivation

Test the idea of tracker planes in front of the calorimeter

## Data used for this analysis:

- 5 GeV electrons run 741 of the TB2016
- MC simulation by Itamar

# Plan

1. Define general signals selection
2. Define clustering algorithm
3. Define position reconstruction of the clusters
4. Control Plots with MC
5. Study efficiency of the trackers
6. Study back-scattered events



# 1) General selection

APV's CR-RC filter response function:  $S(t) = A \frac{t-t_0}{\tau} e^{-\frac{t-t_0}{\tau}} \Theta(t - t_0)$

## Signals selection: (taken from Sasha's analysis)

- $1 < \tau_{fit} < 3$
- $S_{max} < 2000$  ADC
- $t_{1,bin} - 2.7 < t_{0,fit} < t_{1,bin} - 0.5$
- $NN_{output} > 0.5$  (Neural Network output)

## Hits selection:

- sector: L1 or R1 only
- pad  $> 20$  - cross talk noisy area
- Energy in calorimeter pad  $> 1.4$  MIP - suppress noise

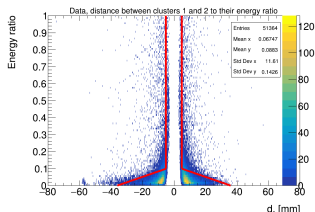
## 2) Clustering algorithm for shower reconstruction in calorimeter

- **Clustering in towers**
- **E-clustering algorithm:**
  - Looks for hits with local maximum of deposited energy.
  - Makes them seeds for the clusters.
  - Then neighbor pads with descending energy are connected to the cluster seed.

- **Merge clusters if:**

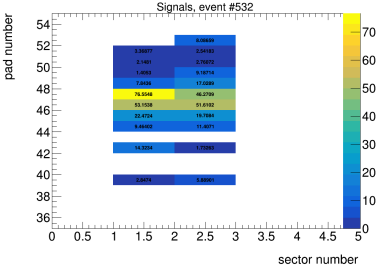
- $d < 9$  mm ( $d$  - distance between clusters)
- $d < 36$  mm and  $\frac{E_2}{E_1} < 0.1 \cdot (1 - 0.05 \cdot d)$   
( $E_i$  - energy of cluster  $i$ )

- **Clusters in calorimeter are ordered by energy. 1st cluster - most energetic one**
- **Clusters in tracker are ordered by  $y$  distance to the shower. 1st cluster - closest to the shower**



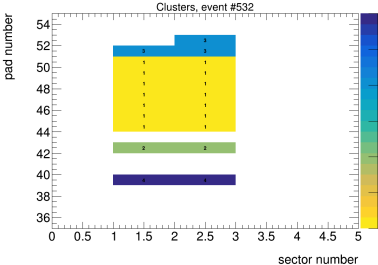
# Example of clustering in one event

## Signals in towers

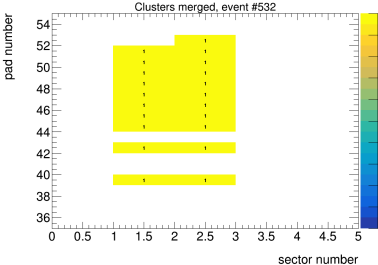


Only events with only 1 cluster in the calorimeter are considered for further efficiency and back-scattered analysis.

## After clustering



## After merging



### 3) Position reconstruction of the shower in the calorimeter

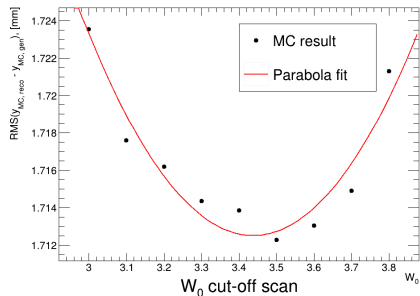
#### Position reconstruction method: Logarithmic weightings

$$y_{cluster} = \frac{\sum_i y_i \cdot w_i}{\sum_i w_i} \quad (1)$$

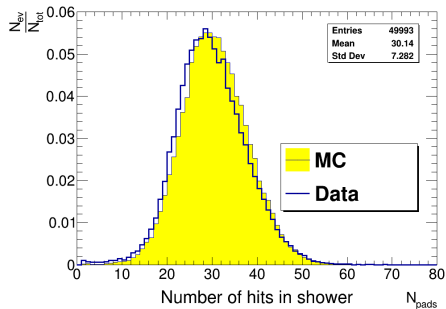
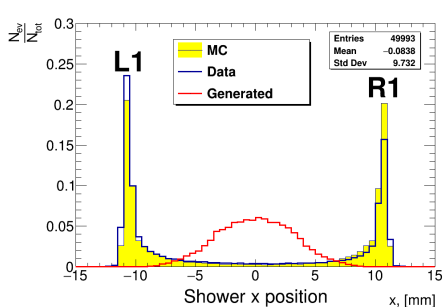
$$w_i = \max(0, W_0 + \ln \frac{E_i}{\sum_i E_i}) \quad (2)$$

$\sum_i$  - sum over all hits (pads) in the cluster (not towers)

$W_0$  - cut-off. Best resolution is achieved with a value 3.4 (agrees with previous analysis by Sasha)

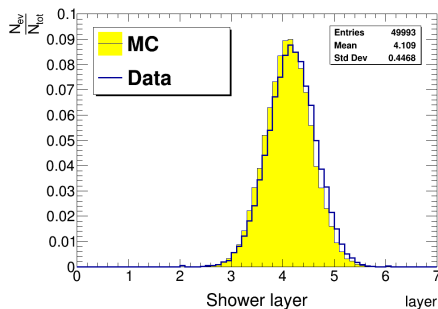
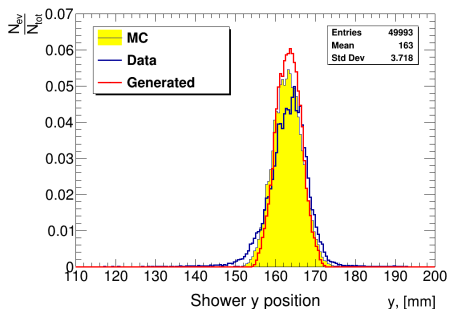


## 4) Calorimeter control plots



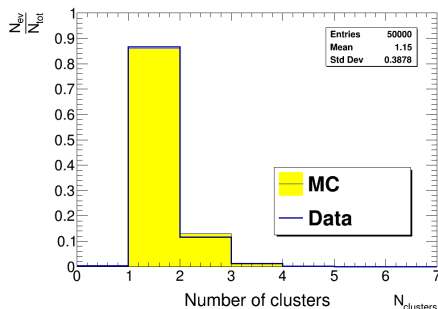
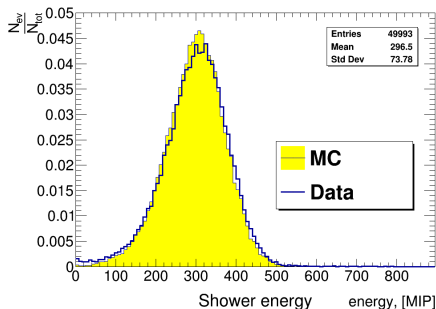
- Red histogram is "true" MC. Position of generated electron by MC.
- Two peaks correspond to L1 and R1 sectors
- Data has more events on the left than MC. It shows that electron gun was shooting left of the center of the detector

## 4) Calorimeter control plots



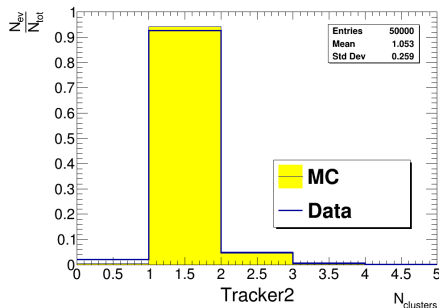
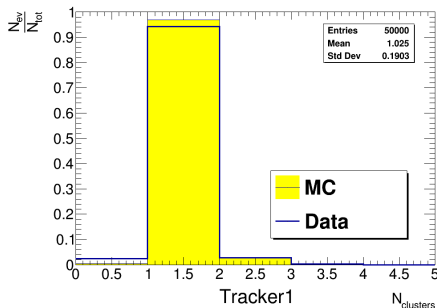
- Resolution on Y axis allows to reconstruct beam profile
- Data is wider than MC for Y axis
- MC is shifted relative to the data in layers control plot.
- Generally data agrees well with MC

## 4) Calorimeter control plots



- Average shower energy is  $\sim 300$  MIPs
- Data and MC agrees on energy
- MC has slightly more events with 2 clusters in calorimeter

## 4) Tracker control plots

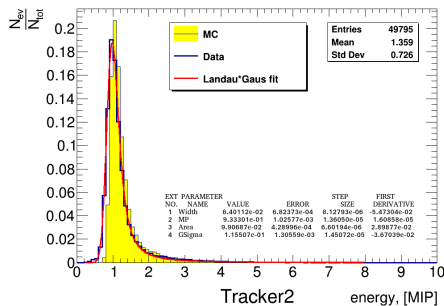
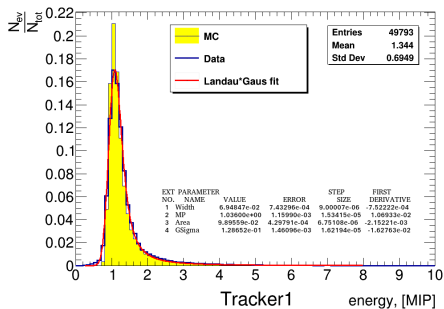


- Most events have only 1 cluster in both trackers
- MC badly describes events with no detected clusters
- Tracker2 has  $\sim 2\%$  more events with 2 clusters. They can events with particles that come from behind (back-scattered).



## 4) Tracker control plots

### Energy distribution of primary clusters in trackers



- Data has wider energy distribution in trackers than MC
- Fit data with Landau convoluted with Gauss

## 5) Trackers' efficiency

Use the best events to calculate efficiency

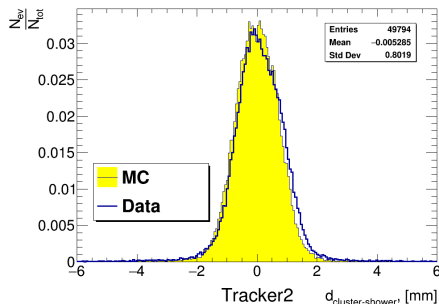
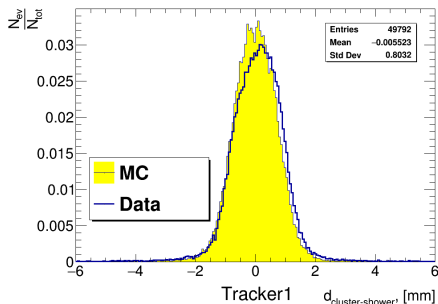
### Event selection for efficiency calculation of Tracker1:

- $N_{clusters,tr2} = 1$
- $N_{clusters,cal} = 1$
- $158 < y_{shower} < 168$  mm
- Cluster in the tracker2 *matches* cluster in the calorimeter

This selection basically means there was a track from the electron

Efficiency for tracker2 is calculated in the same way but with tracker1 instead of tracker2 the selection

## 5) Trackers' efficiency

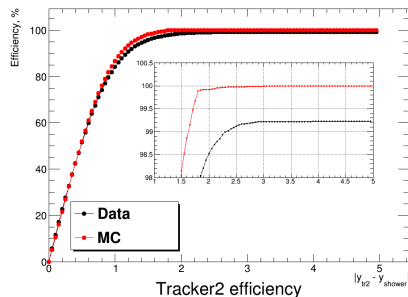
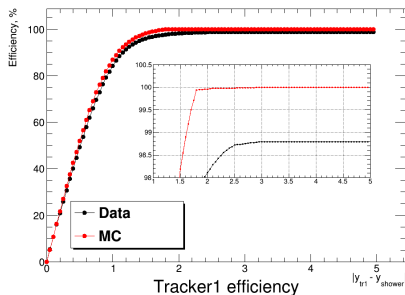


After alignment  $\sim 95\%$  of clusters in trackers are situated within  $2\sigma \approx 1.6$  mm range.

Define: cluster in tracker **matches** the shower if it's position within range of 1.6 mm

## 5) Tracker's efficiency

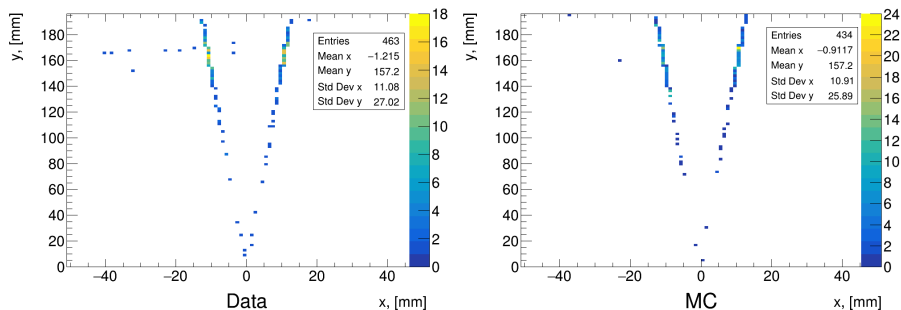
Tracker is considered efficient in the event if has a cluster within x range to the shower.



- Trackers' efficiency achieve 98% for 2 mm range cut-off
- MC doesn't seem to reproduce efficiency of the trackers. Corrections have to be made

## 6) Back-scattering events

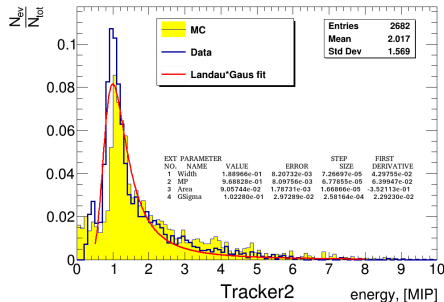
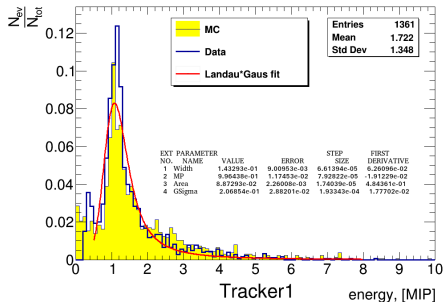
Tracks which are made from 2nd clusters in both trackers point approximately to the expected shower location in the calorimeter.



Noise would be distributed homogeneously along all pads (y axis). Therefore those are potential back-scattered events.

## 6) Back-scattering events

### Energy distribution of secondary clusters in trackers

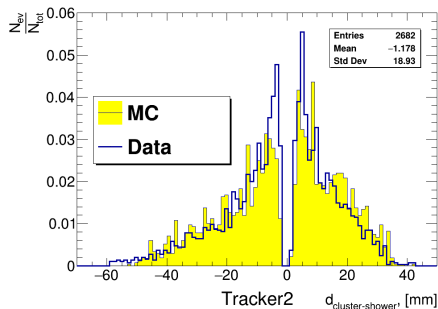
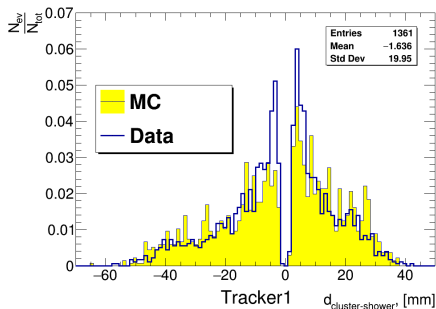


- Distribution looks like the one for primary clusters. It means those clusters are also from MIP particles

## 6) Back-scattering events

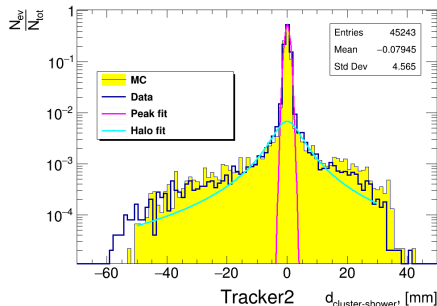
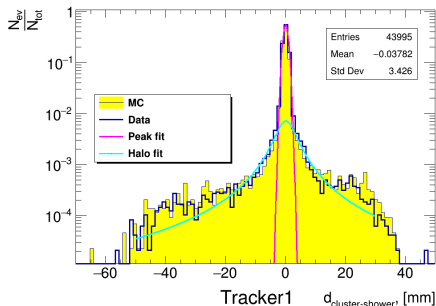
Homogeneously back-scattered particles by polar angle will leave Lorentzian peak on the tracker's plane.

### Secondary clusters in the trackers



## 6) Back-scattering events

### All clusters in the trackers



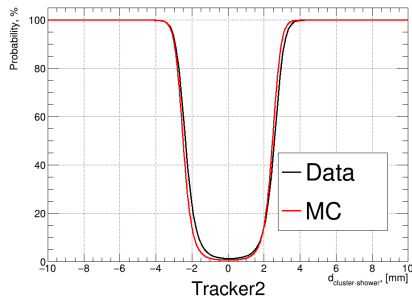
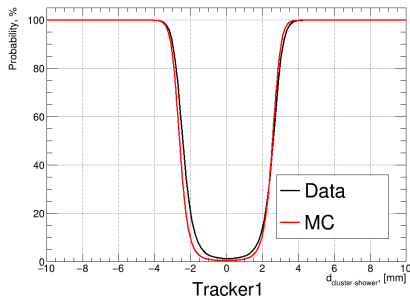
- 2 different behaviours are seen
- Peak represent clusters from initial 5 GeV electron entering the tracker
- Wide halo is potential back-scattered particles
- Fit with Gauss + Lorentzian



## 6) Back-scattering events

Ratio of two fits allows to measure probability of the cluster in the tracker to be from back-scattered particle

$$\text{Fits ratio: } 100\% \cdot \frac{Halo_{fit}}{Total_{fit}}$$



- MC agrees with data pretty well
- If cluster in the tracker further than 4 mm from shower position it is most probably signal from back-scattering particle

# Summary

## Results

- MC and data mostly agree. But efficiency corrections are needed.
- Trackers efficiency is calculated and equal  $\sim 98\%$  for 2 mm distance to the shower
- Probability of back-scattered clusters in the trackers is obtained. Tracker clusters further than 4 mm from the shower are back-scattered

## Further plans

- Continue analysis on runs with photons where more than 1 cluster is expected
- Do corrections to the MC to improve data description
- Study influence of back-scattered events on  $e^-/\gamma$  identification efficiency
- Do systematic uncertainty calculation