Identification of back-scattering in LumiCal detector

Bohdan Dudar

Taras Shevchenko National University of Kyiv

bohdan96@gmail.com

March 27, 2019

TEL AVIV UNIVERSITY

Overview

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

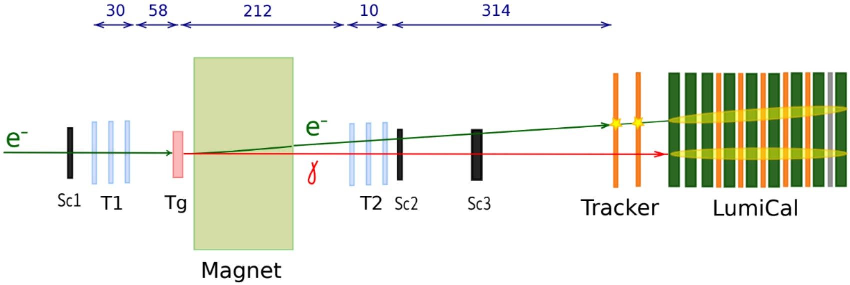


Figure: DESY test beam experimental setup

LumiCal

Idea of tracker planes in front of the calorimeter:

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

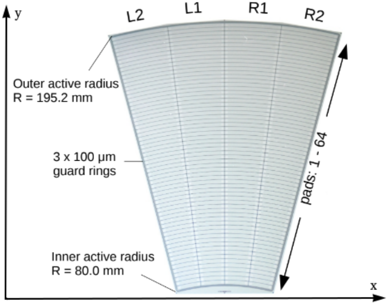
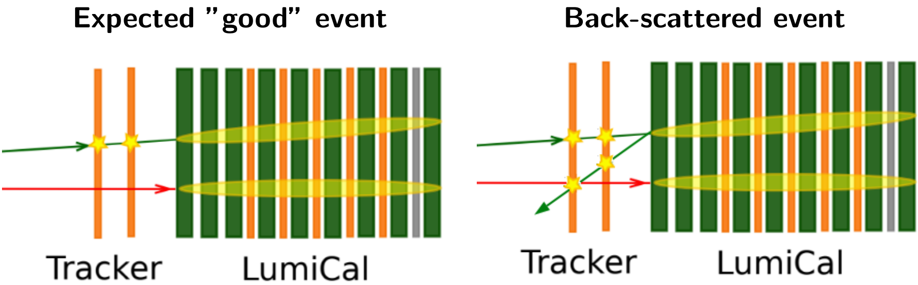


Figure: LumiCal Si sensor

LumiCal sensor:

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

Back-scattering events



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

It is interesting to study those events 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?
- Is it δ-electrons from tracker1?

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)

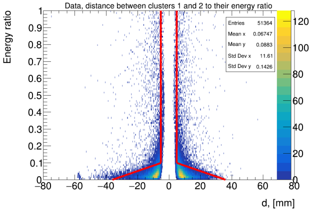
- $1 < \tau_{fit} < 3$
- $S_{max} < 2000$ ADC
- $t_{1,bin} - 2.7 < t_{0,fit} < t_{1,bin} - 0.5$
- $NN_{output} > 0.5$ (Neural Network output)

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

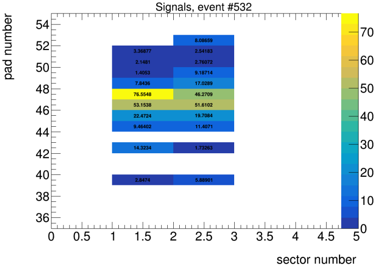
- **Clustering in towers**
- **E-clustering algorithm:**
  - Looks for hits with local maximum of deposited energy.
  - Makes them seeds for the clusters.
  - Then neighbor pads with descending energy are connected to the cluster seed.
- **Merge clusters if:**
  - $d < 9$ mm (d - distance between clusters)
  - $d < 36$ 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**

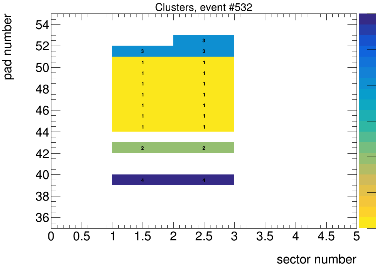
Example of clustering in one event

Signals in towers

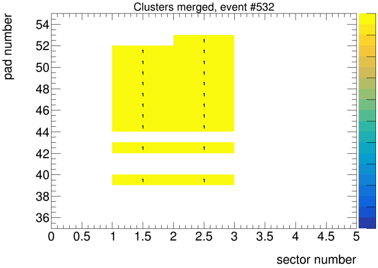


Only events with only 1 cluster in the calorimeter are considered for further efficiency and back-scattered analysis.

After clustering



After merging



3) Position reconstruction of the shower in the calorimeter

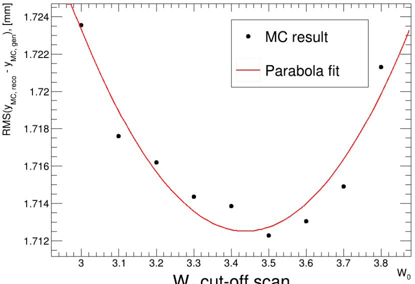
Position reconstruction method: Logarithmic weightings

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

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

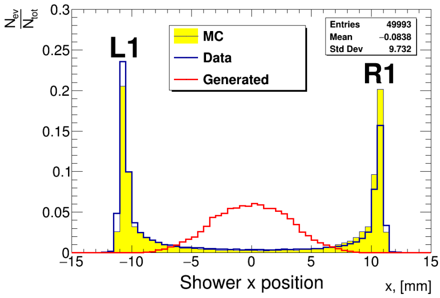
$\sum_i$ - sum over all hits (pads) in the cluster (not towers)

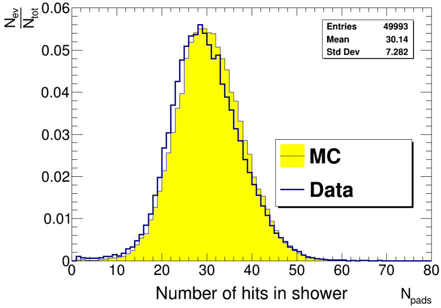
W_0 - cut-off. Best resolution is achieved with a value 3.4 (agrees with previous analysis by Sasha)



W0 cut-off scan

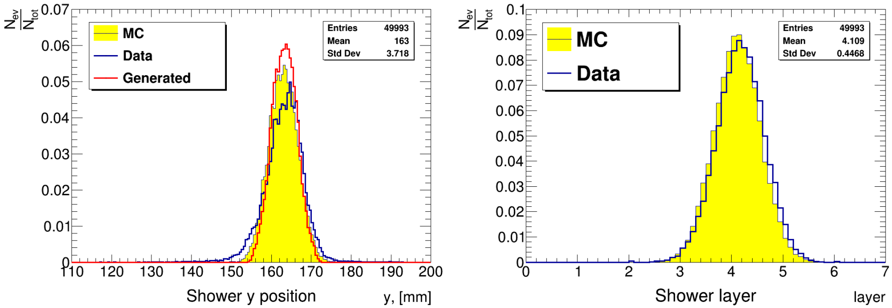
4) Calorimeter control plots





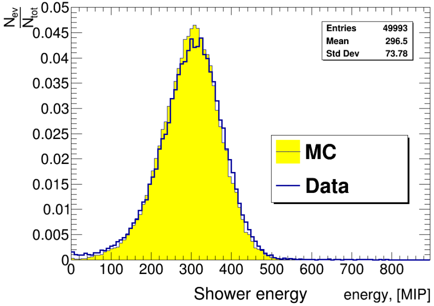
- Red histogram is "true" MC. Position of generated electron by MC.
- Two peaks correspond to L1 and R1 sectors
- Data has more events on the left than MC. It shows that electron gun was shooting left of the center of the detector

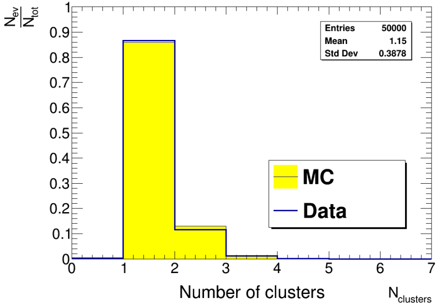
4) Calorimeter control plots



- Resolution on Y axis allows to reconstruct beam profile
- Data is wider than MC for low Y region
- MC is slightly shifted relative to the data in layers control plot.
- Generally data and MC agree

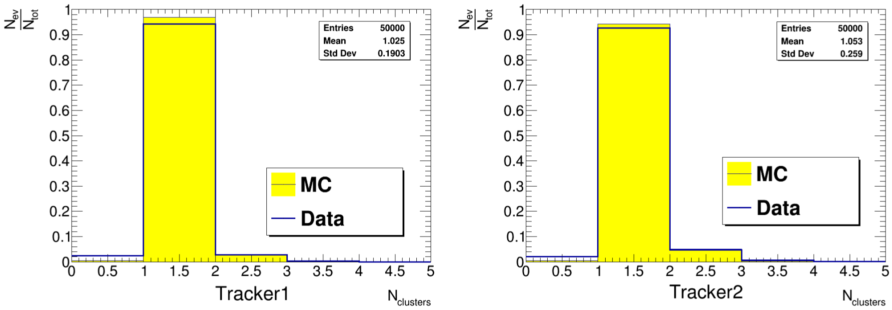
4) Calorimeter control plots





- Average shower energy is $\sim$ 300 MIPs
- Data and MC agree on energy
- MC has 0.8% more events with 2 clusters in calorimeter

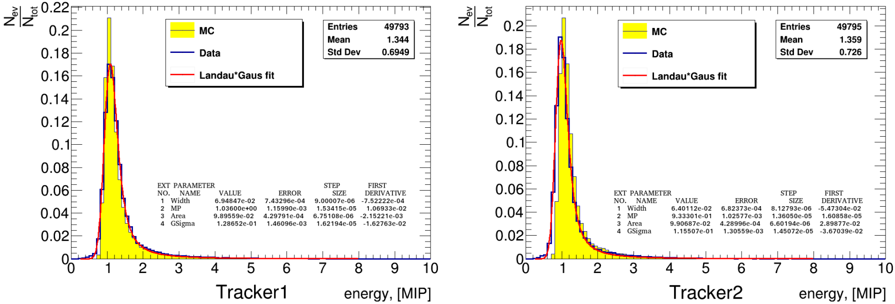
4) Tracker control plots



- 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. Those 2nd clusters can appear due to 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

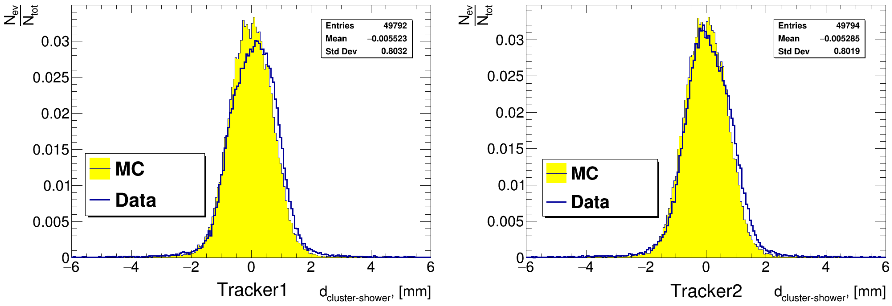
Event selection for efficiency calculation of Tracker1:

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

We select events with observed track from the 5 GeV electron in tracker2 and calorimeter

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

5) Trackers' efficiency

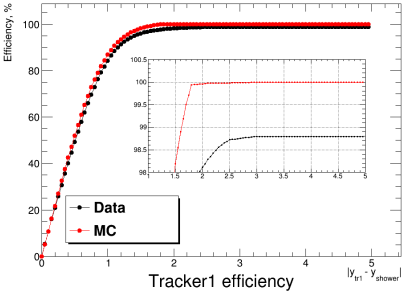


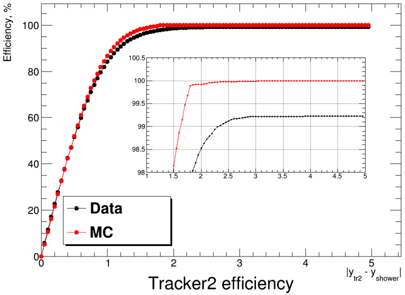
After alignment $\sim 95\%$ of clusters in trackers are situated within $2\sigma \approx 1.6$ mm range.

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.

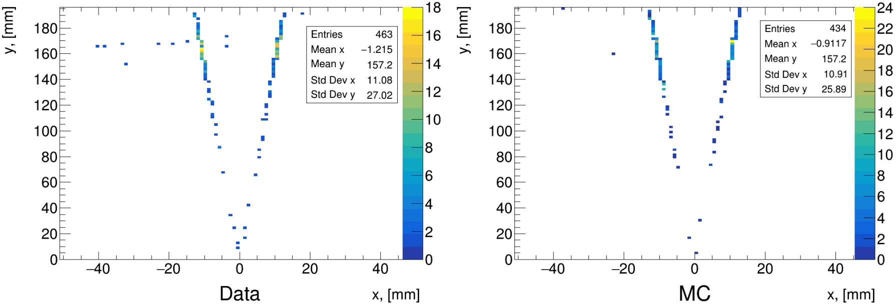




- Trackers' efficiency achieve 98% for 2 mm range cut-off
- MC doesn't seems to reproduce efficiency of the trackers. Corrections have to be made

6) Back-scattering events

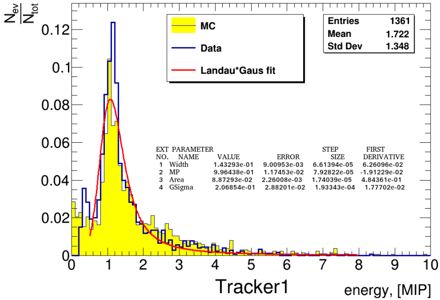
Tracks which are made from 2nd clusters in both trackers point approximately to the expected shower location in the calorimeter.

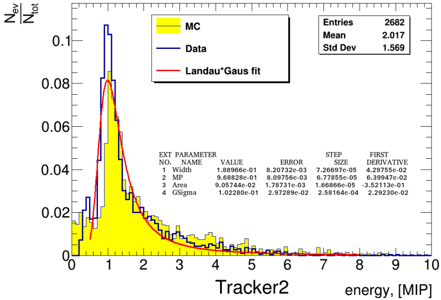


Noise would be distributed homogeneously along all pads (y axis). Therefore those are potential back-scattered events.

6) Back-scattering events

Energy distribution of secondary clusters in trackers

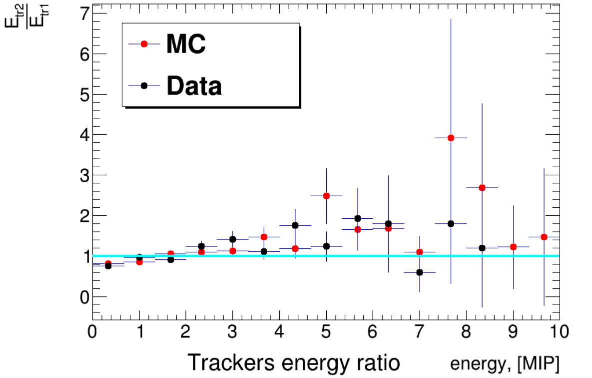




- Distribution looks like the one for primary clusters. It means those clusters are also from MIP particles

6) Back-scattering events

Ratio of energy histograms of secondary clusters in trackers

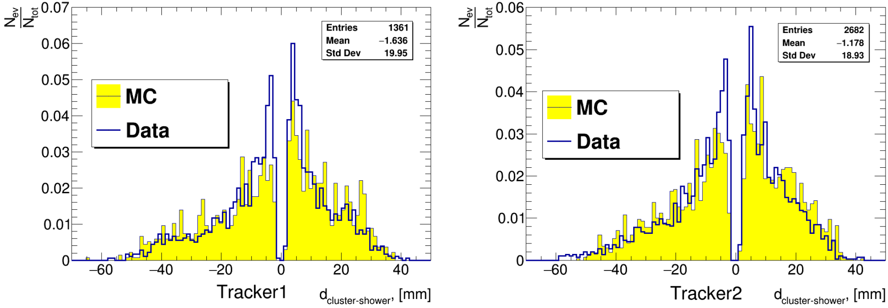


- Ratio higher than 1 is observed for the tail of Landau-Gauss distribution
- Small statistics yields bad MC and data agreement

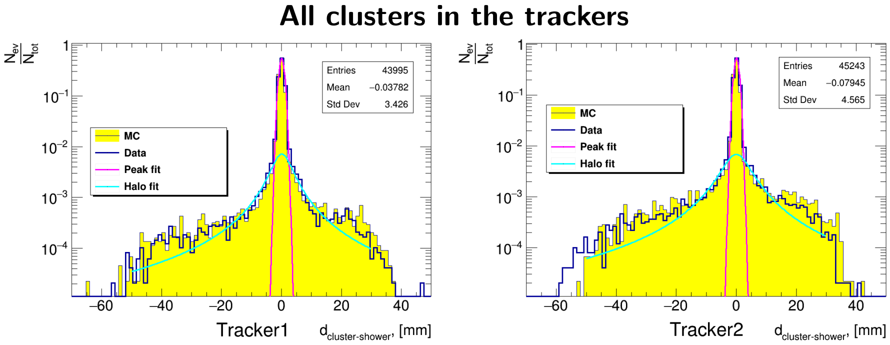
6) Back-scattering events

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

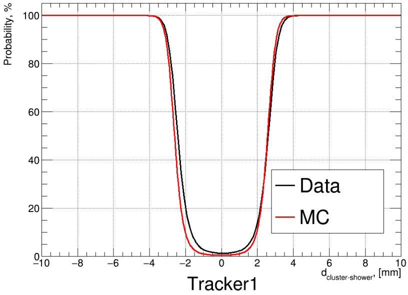


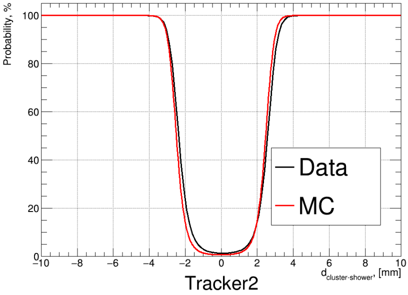
- 2 different behaviours are seen
- Peak represent clusters from initial 5 GeV electron entering the tracker
- Wide halo is potential back-scattered particles
- Fit with Gauss + Lorentzian

6) Back-scattering events

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

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





- 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 show good agreement. But efficiency corrections are needed.
- Trackers efficiency is calculated and equal $\sim 98\%$ for 2 mm distance to the shower selection
- Probability of back-scattered clusters in the trackers is obtained. Tracker clusters further than 4 mm from the shower considered as back-scattered

Further plans

- Corrections to the MC to improve data description
- Continue analysis on runs with photons where more than 1 cluster is expected
- Study influence of back-scattered events on e^-/γ identification efficiency
- Uncertainty calculation