Beam-test Results of Multilayer LumiCal Prototype

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On behalf of the FCAL collaboration

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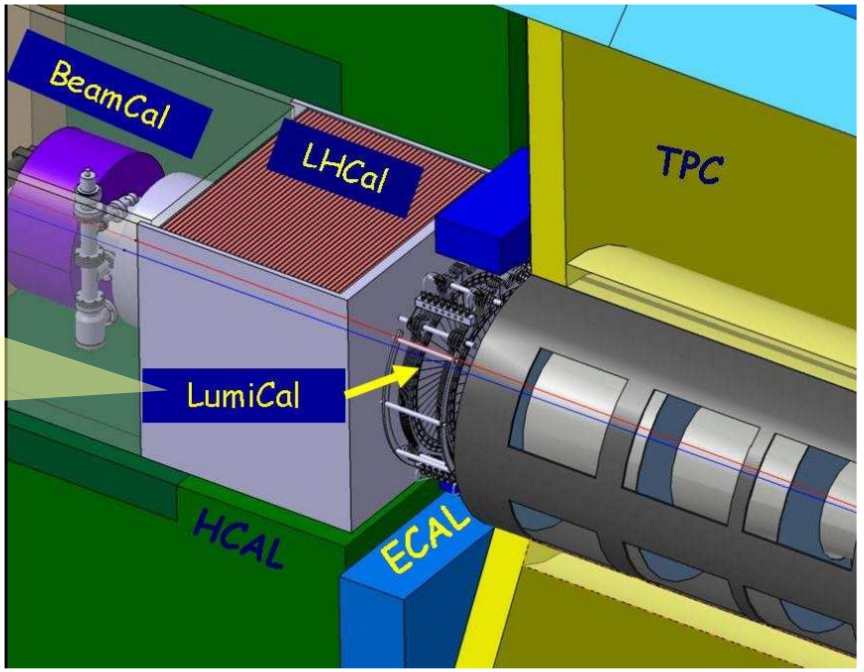
Overview

- LumiCal status
- Beam-test setup:
  - LumiCal module and beam test infrastructure;
  - DAQ synchronization.
- Telescope performance
- LumiCal data analysis results
- Summary

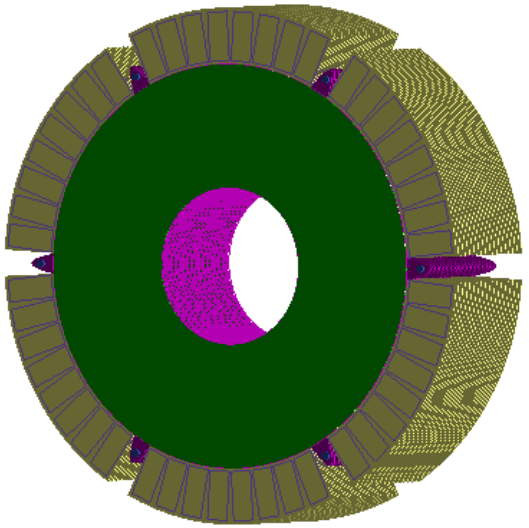
LumiCal in LC Detectors

- Precise integrated luminosity measurement;
- Extend a calorimetric coverage to small polar angles. Important for physics analysis.



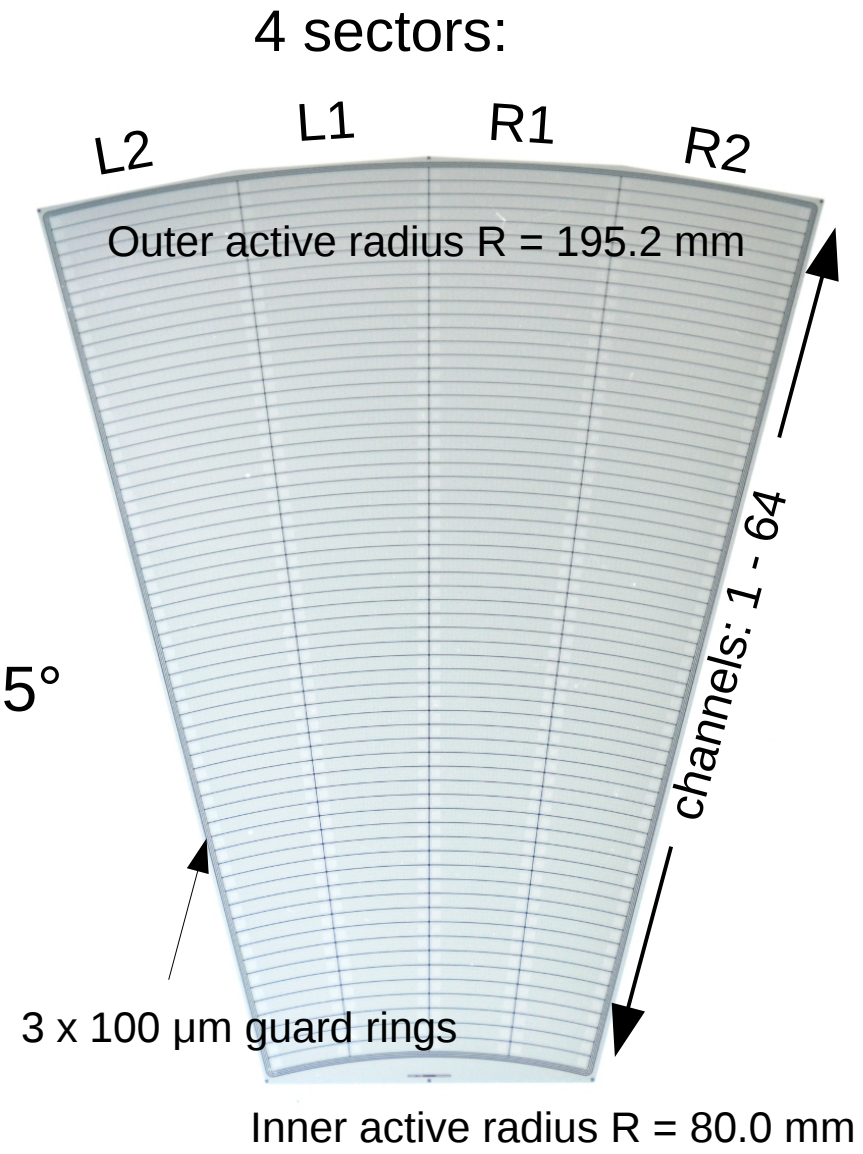
LumiCal: two tungsten-silicon calorimeters placed symmetrically on both sides of the interaction point at a distance of ~2.5 m.

Each calorimeter consists of 30 layers of 3.5 mm thick tungsten plates 1 mm apart interleaved with silicon sensors.



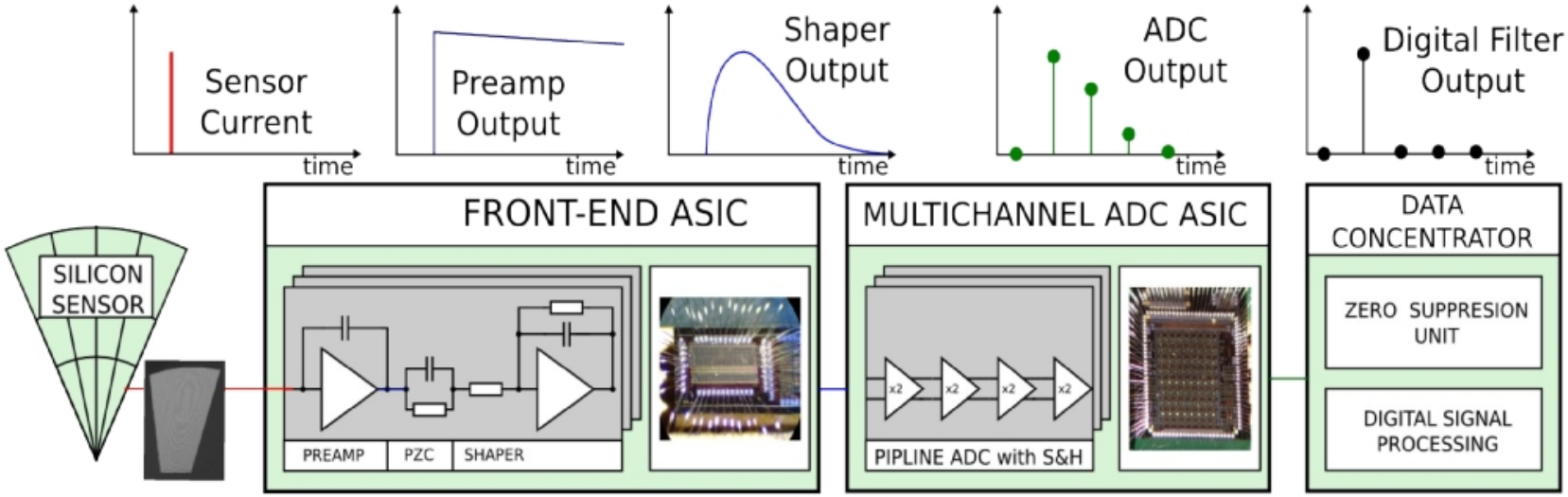
LumiCal Sensor

- Silicon sensor
- thickness 320 μm
- DC coupled with read-out electronics
- p+ implants in n-type bulk
- 64 radial pads, pitch 1.8 mm
- 4 azimuthal sectors in one tile, each 7.5°
- 12 tiles makes full azimuthal coverage
- 40 sensors were produced by Hamamatsu
- 5 modules were assembled



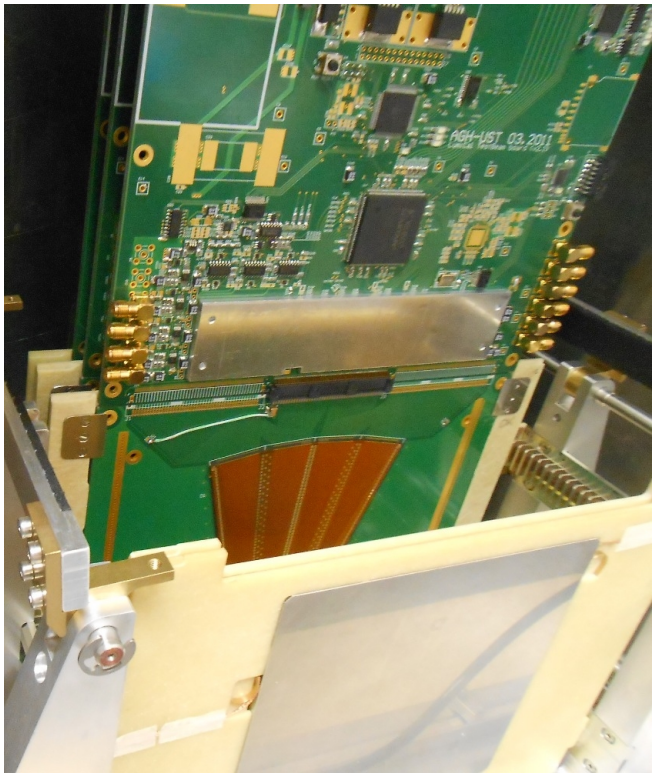
LumiCal Readout Electronics

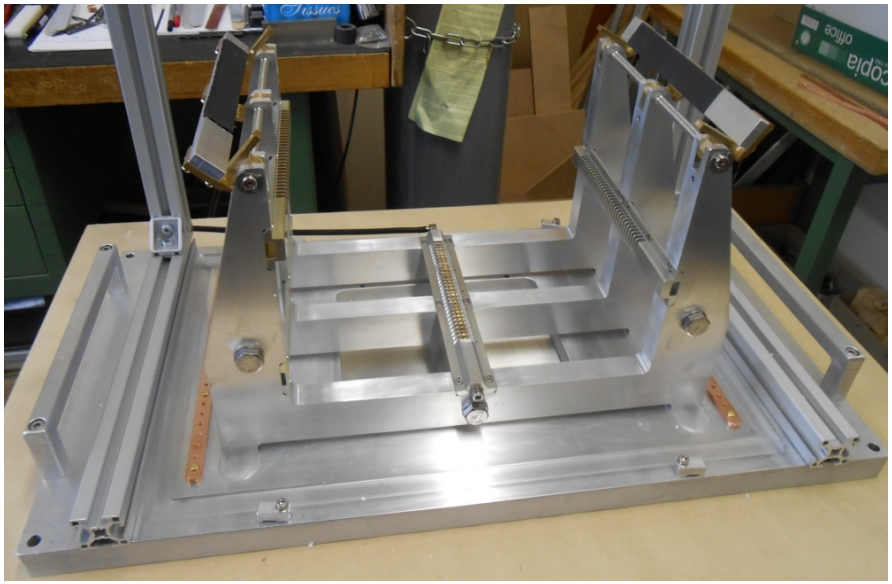
- Existing readout was developed in AGH-UST Cracow.
- It is a 32-channel readout system based on 8-channel front-end and ADC ASICs developed in AMS 0.35 μm.
- It has been used in test-beams in recent years.



- 8 channel front-end (preamp, shaper T_{peak} ~ 60 ns, ~9 mW/channel, configurable gain);
- 8 channel pipeline ADC, Tsmp ≤ 25 MS/s, ~1.2 mW/MHz;
- FPGA based data concentrator and further readout.

FCAL test beam infrastructure

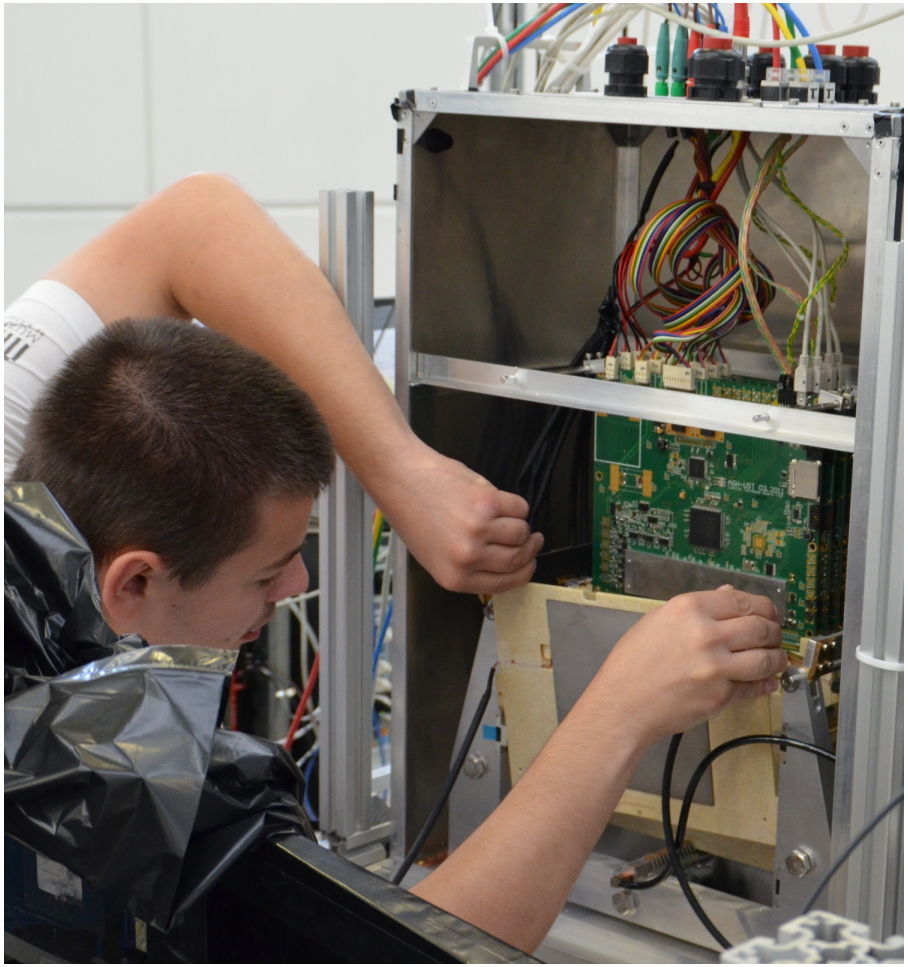




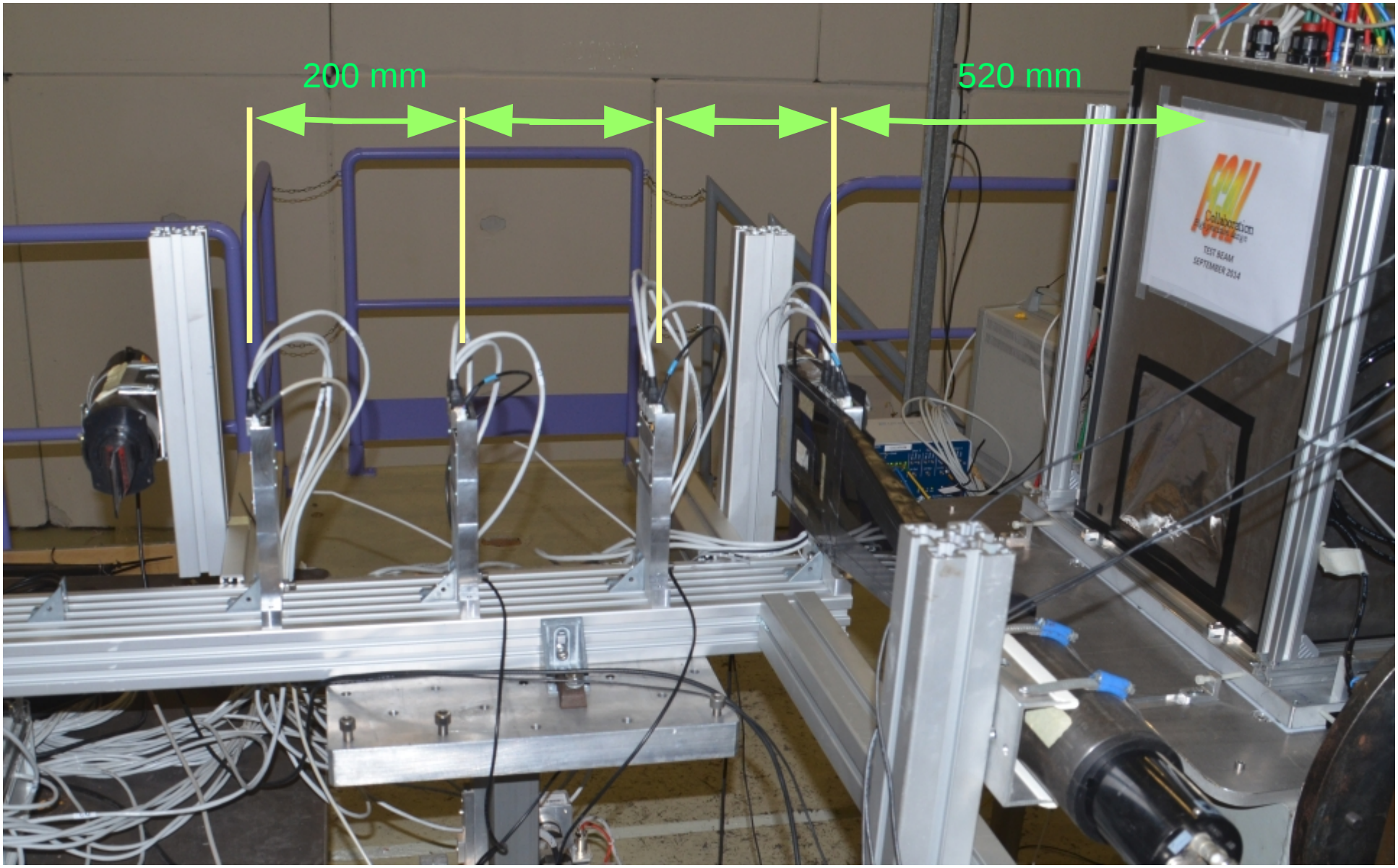
Test Beam Objectives

A good understanding of single plane performance of LumiCal and BeamCal detectors has been achieved during previous beam tests (arXiv:1411.4431).

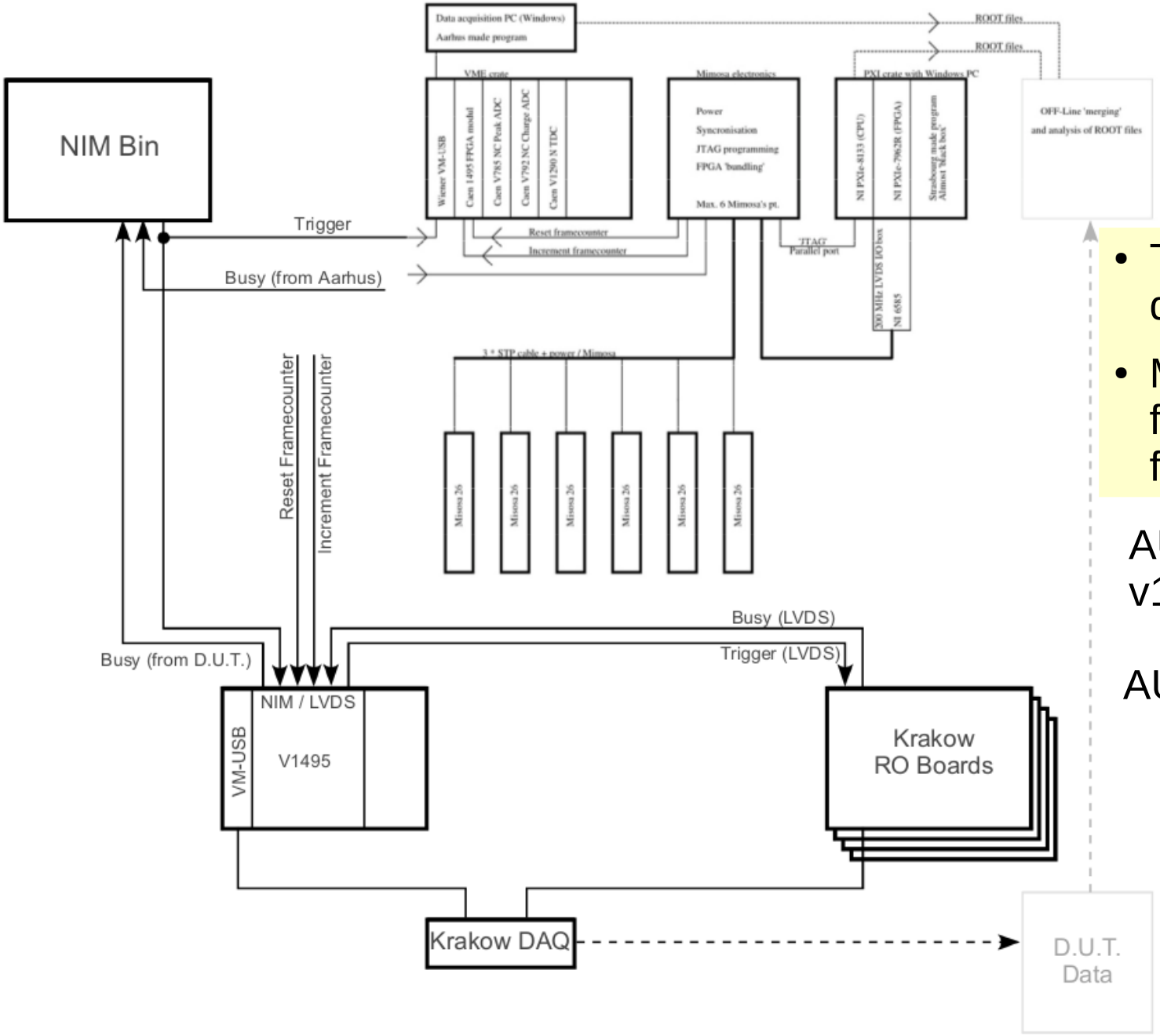
- Check for the first time multi-plane operation of the LumiCal prototype with 4 detector modules;
- Measure key parameters in multi-plane operation: baselines, noise, common-mode noise, signal-to-noise ratio, etc;
- Study the development of the electromagnetic shower in a precise and well known structure and compare with MC simulations.
- Check reconstruction algorithms on raw data and particle tagging (electrons and hadrons).
- Attempt to measure energy resolution and the precision of the polar angle reconstruction.



Telescope and LumiCal Layout



Combined LumiCal - Telescope System



- Two systems used different DAQ.
- MIMOSA hardware frame number was used for the synchronization.

AUX hardware based on v1495 I/O module

AUX software in EUDAQ.

LumiCal Beam Test Configurations

Three different configurations for the LumiCal were used.

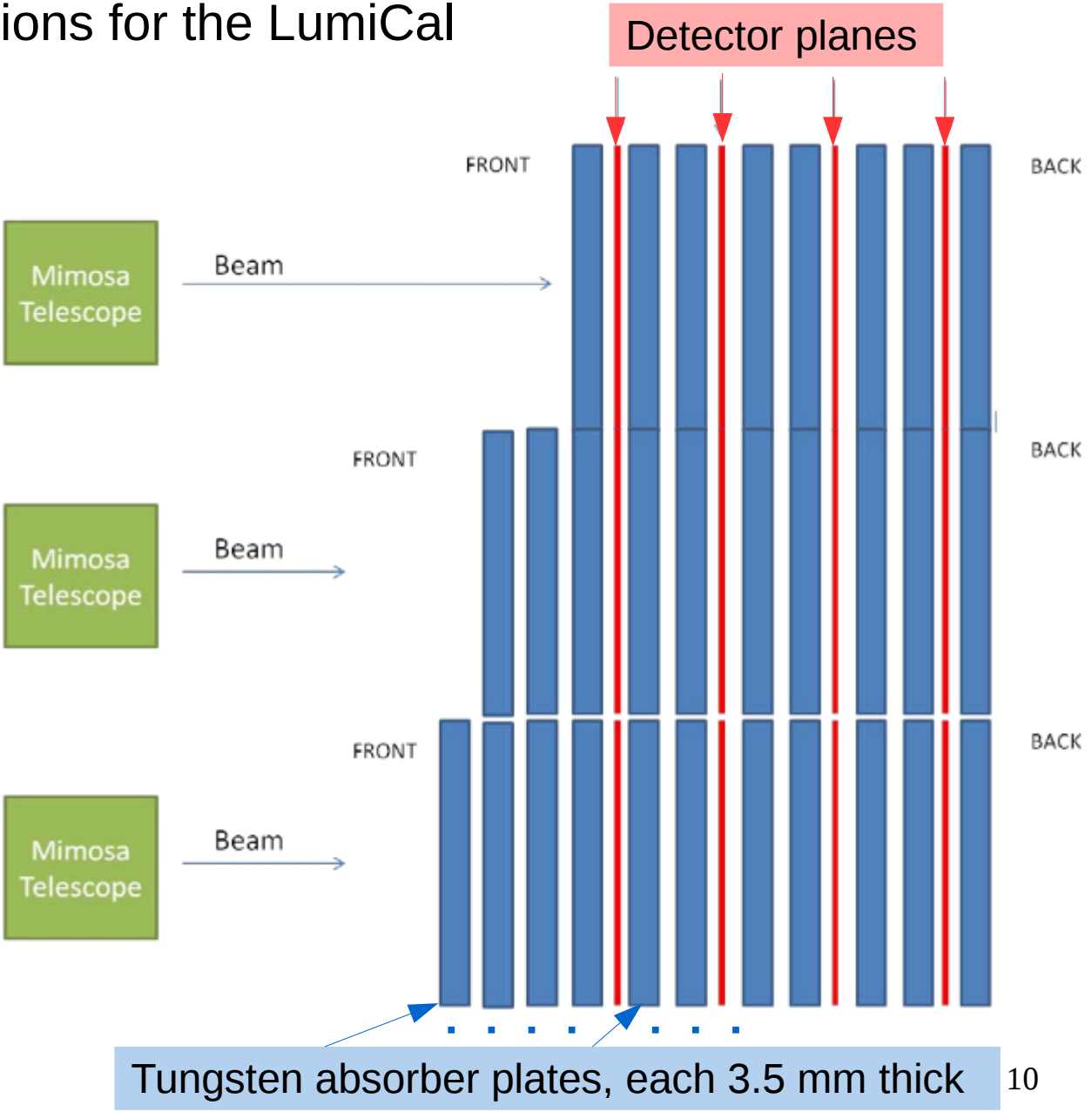
CERN PS beam at T9

5 GeV beam;

Trigger on:

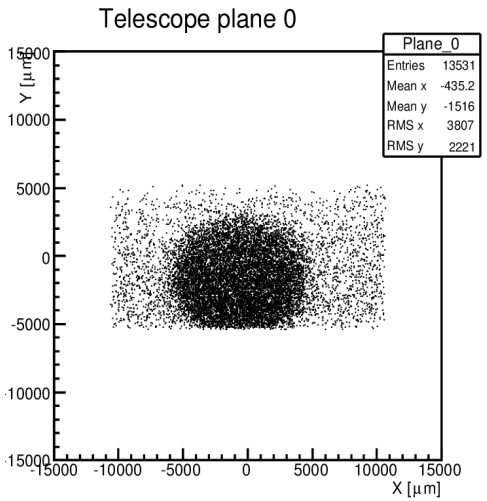
- Electrons and muons;
- Hadrons.

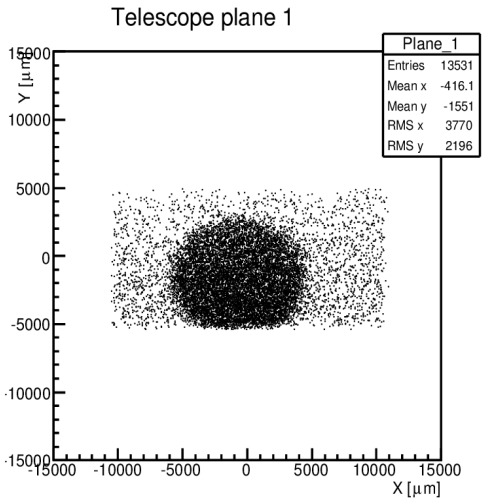
For different configurations 55k-75k e^- events were collected.

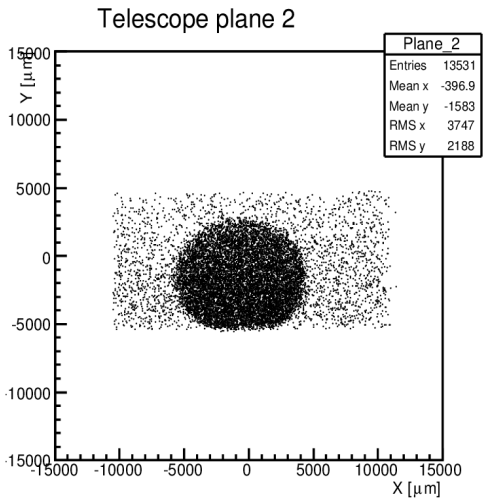


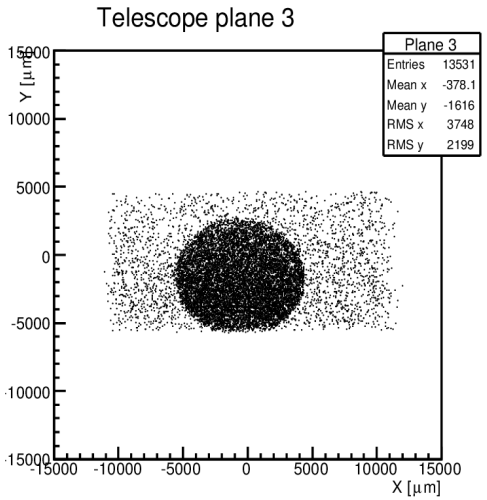
Occupancy in Telescope

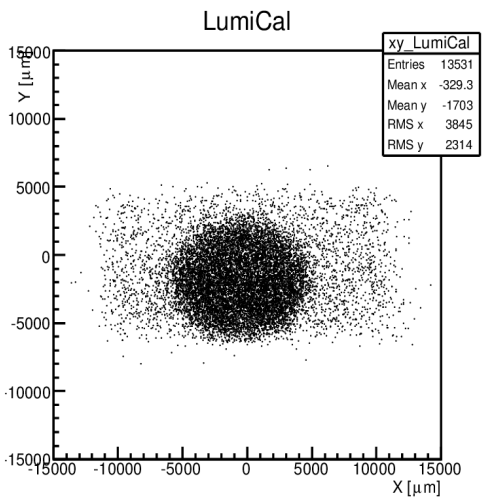
- Telescope data are reconstructed using TAF (TAPI Analysis Framework, IPHC, Strasbourg), a bit modified to enable synchronization with LumiCal;
- Alignment and tracking based on software from Aarhus University telescope group.
- Cut at 0.1% of single pixel occupancy to eliminate noisy pixels.

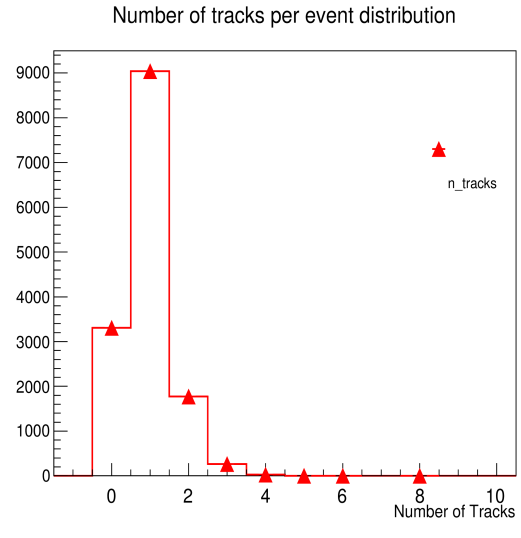




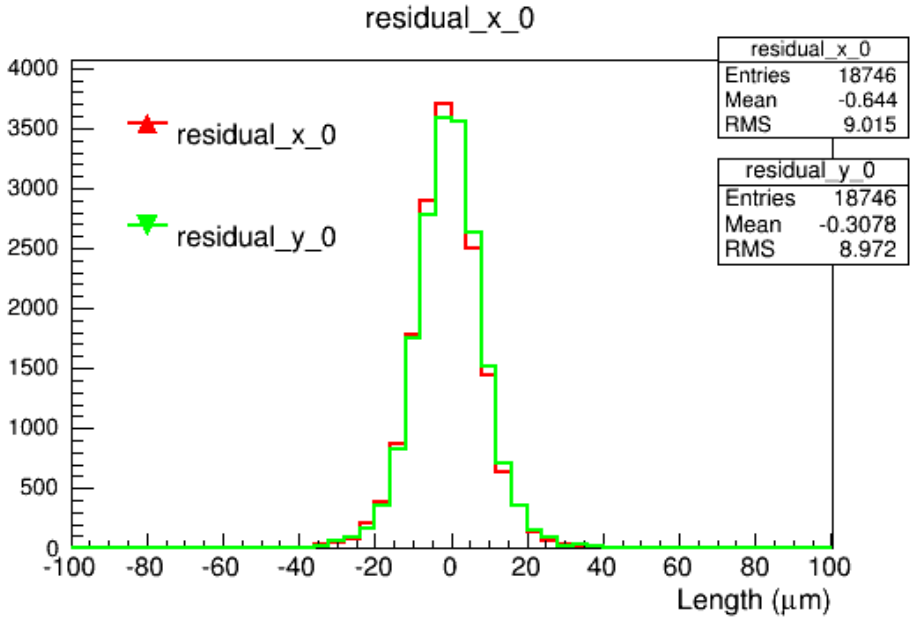


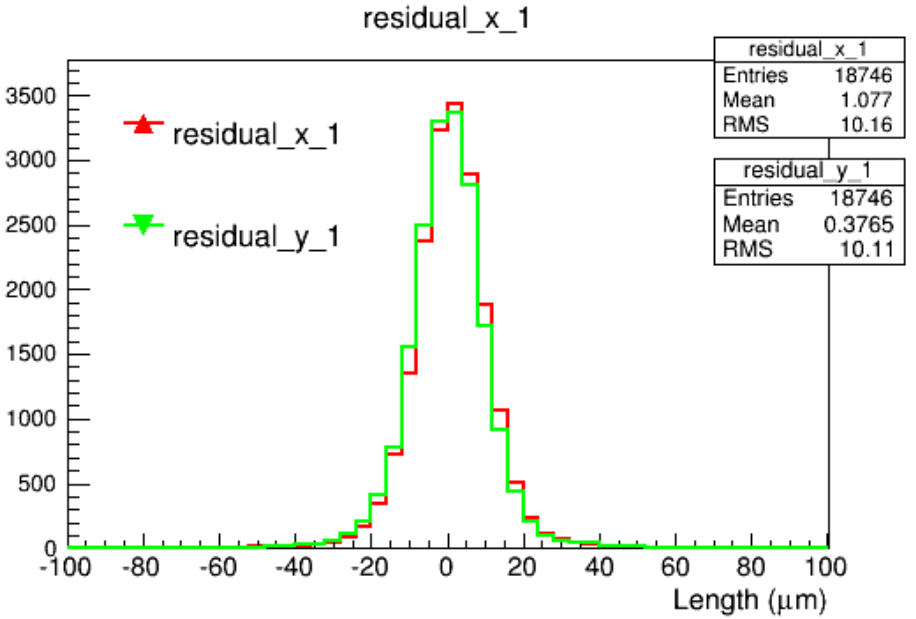


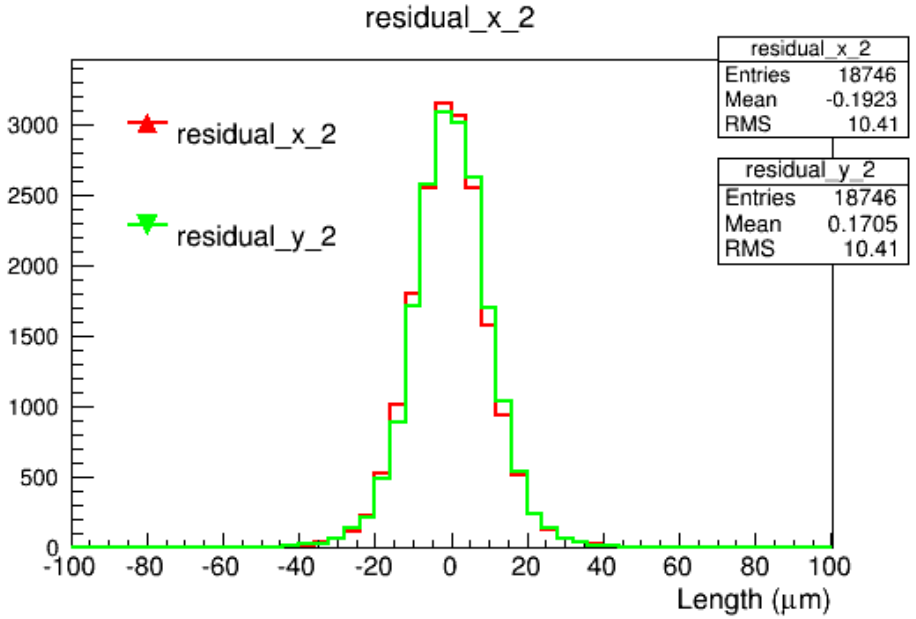


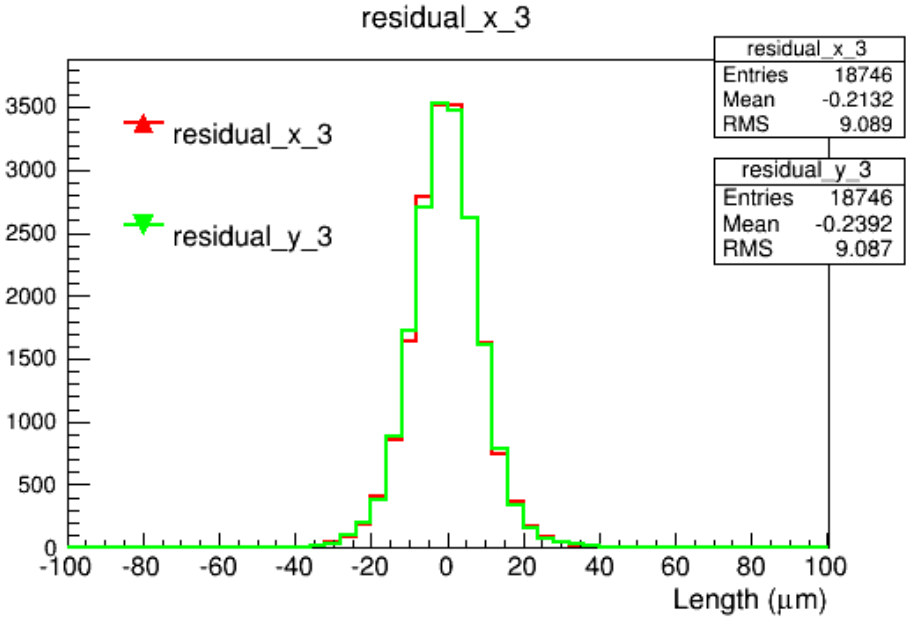


Telescope Position Resolution

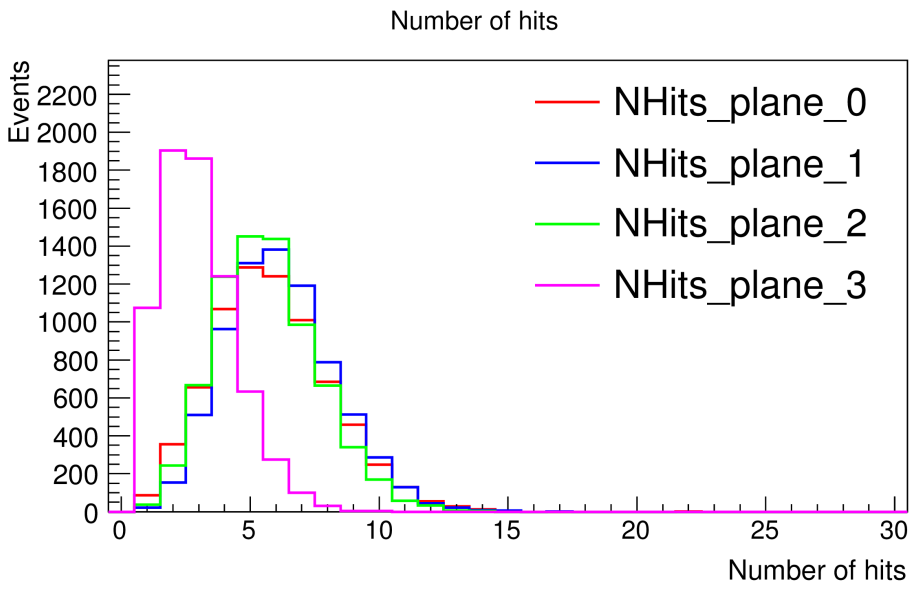


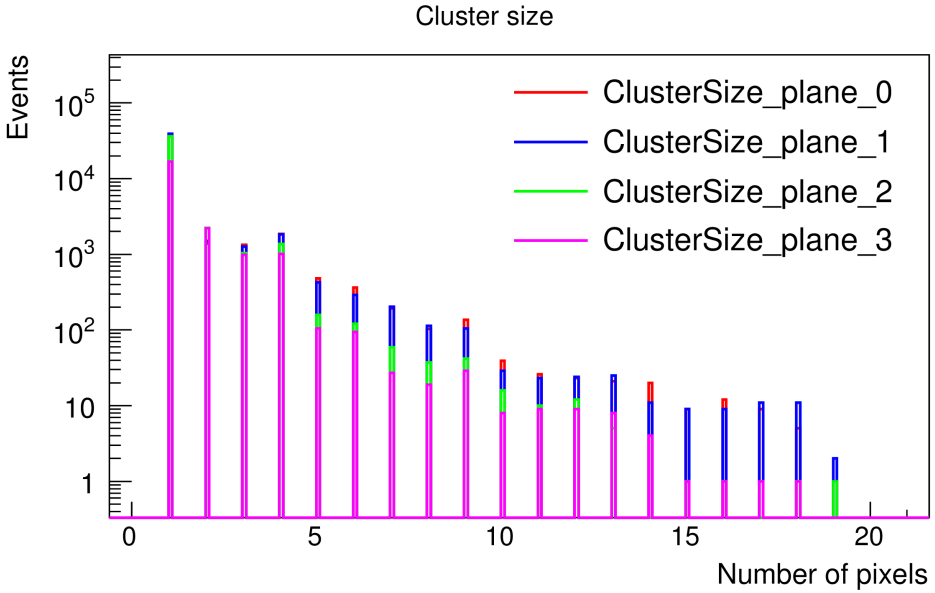


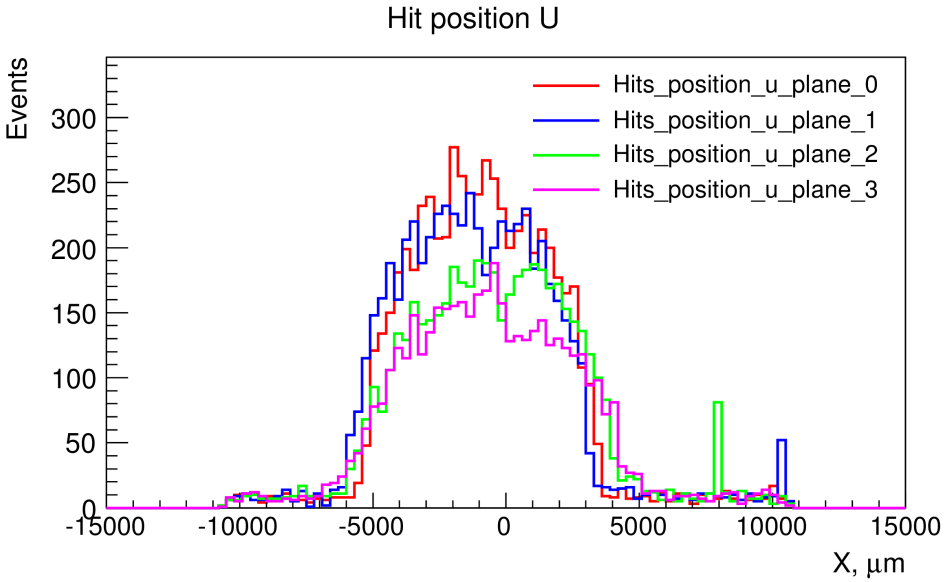


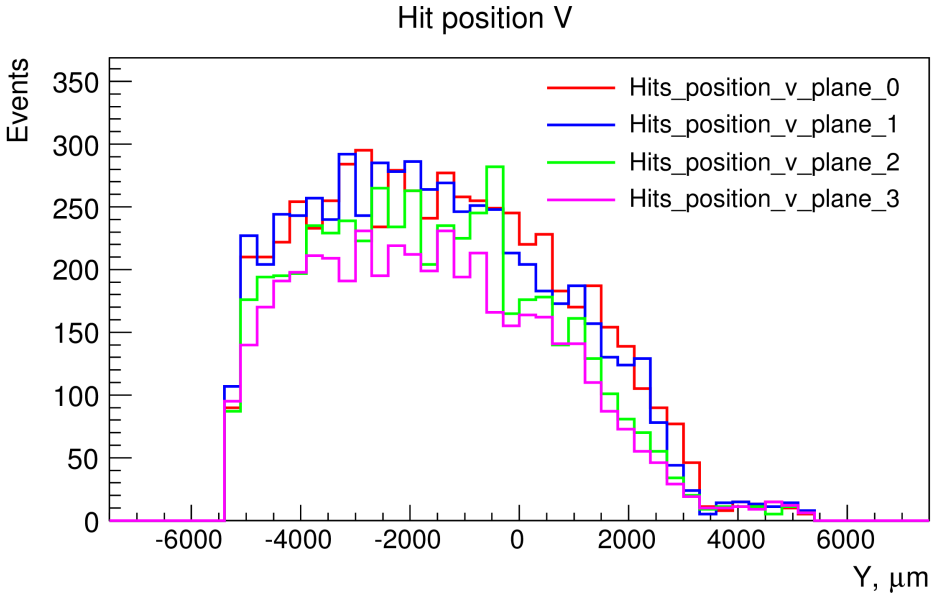


Hits Reconstruction in Telescope, (hadron run)





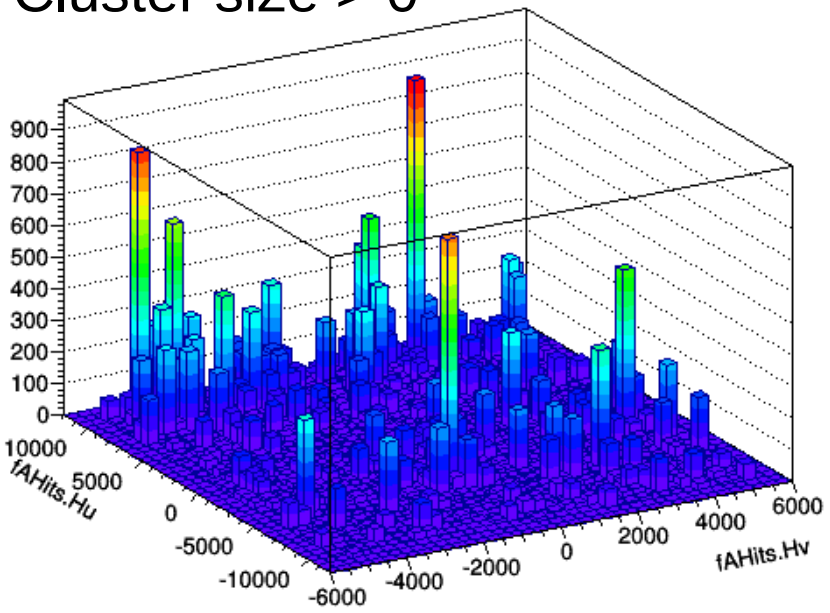




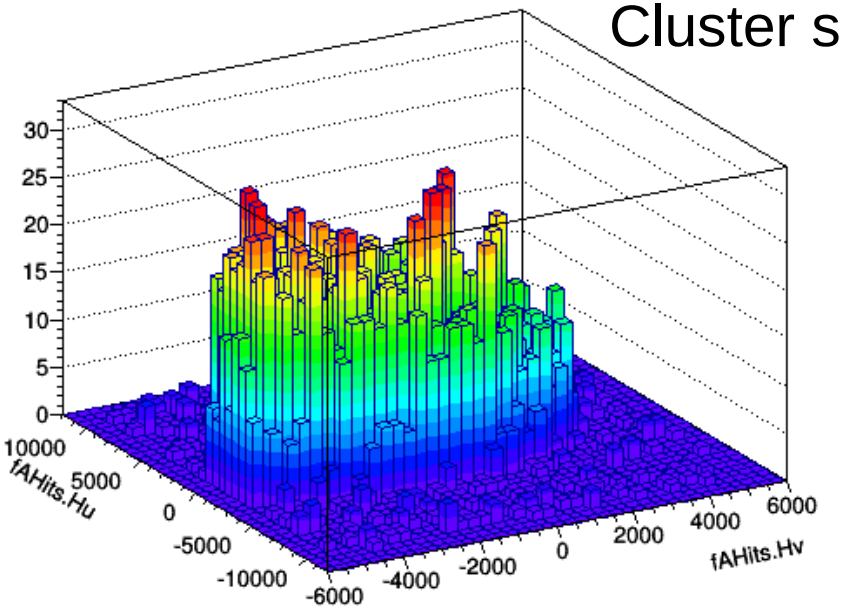
One-pixel clusters are excluded from the position histograms.

Hits Position

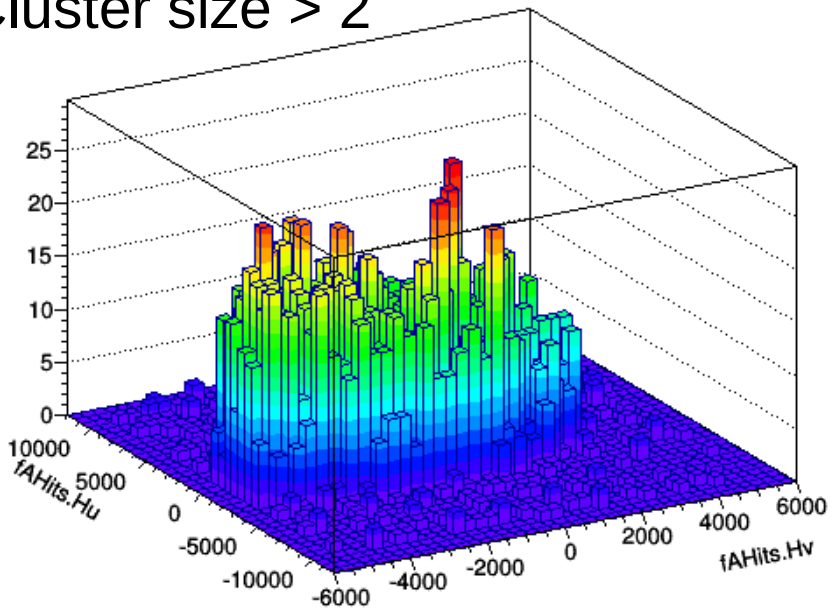
Cluster size > 0



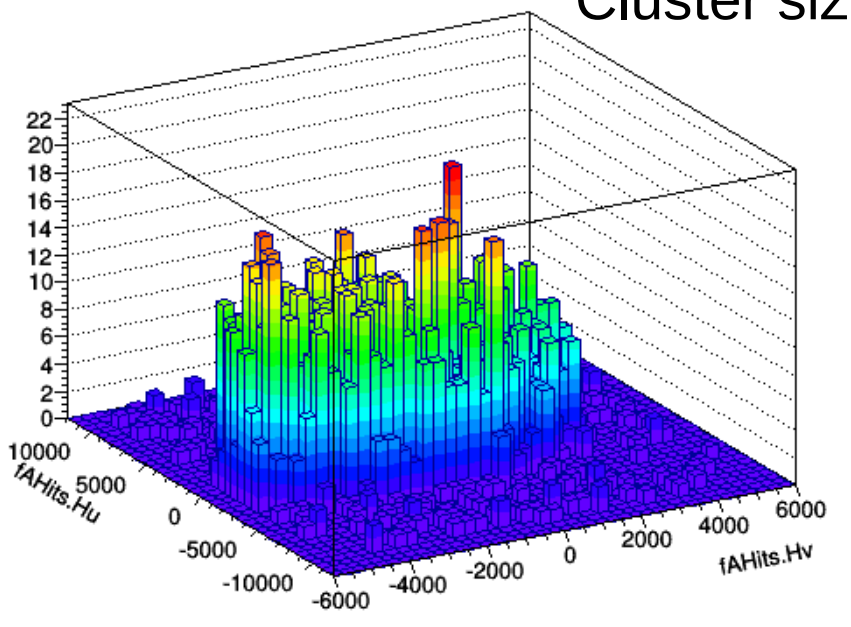
Cluster size > 1



Cluster size > 2

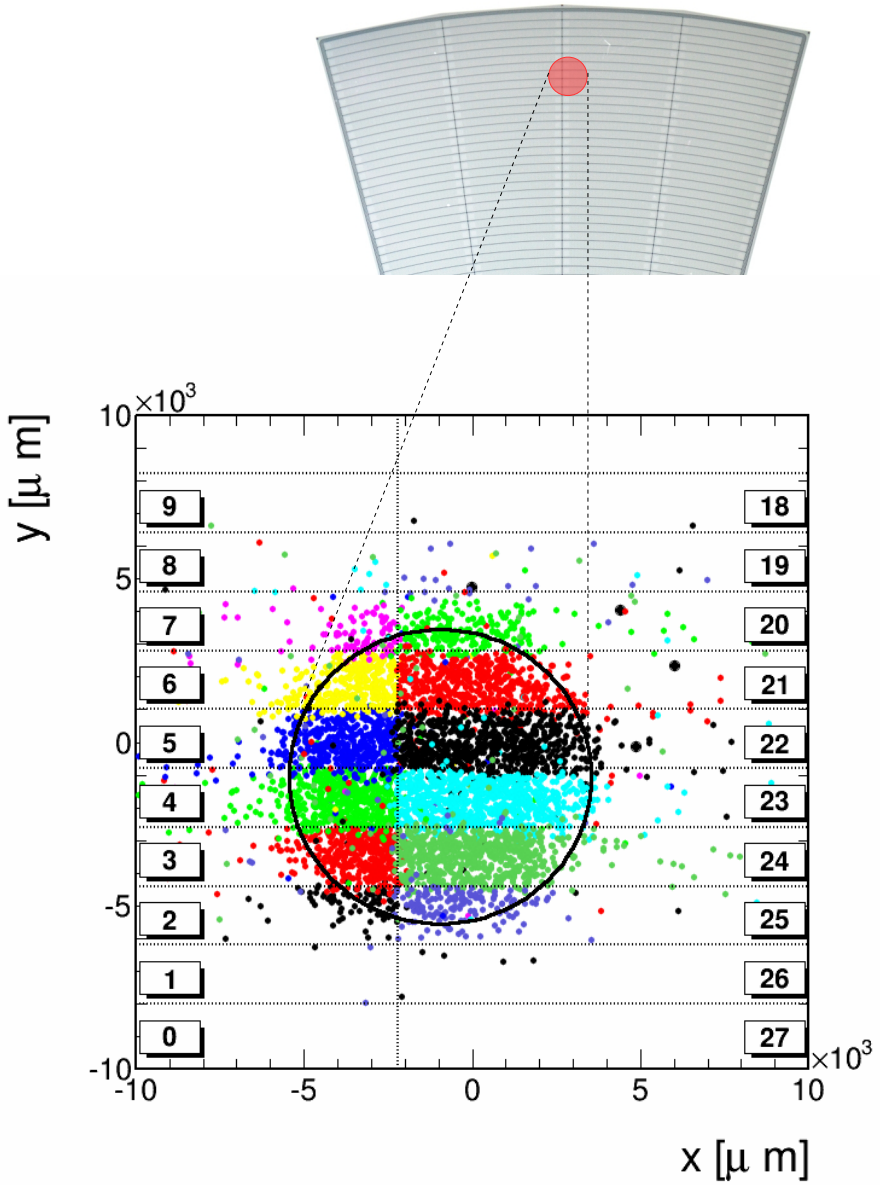


Cluster size > 3

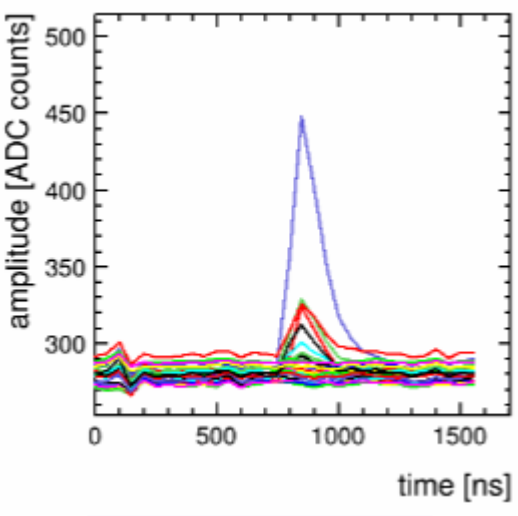


Test of LumiCal -Telescope Synchronization

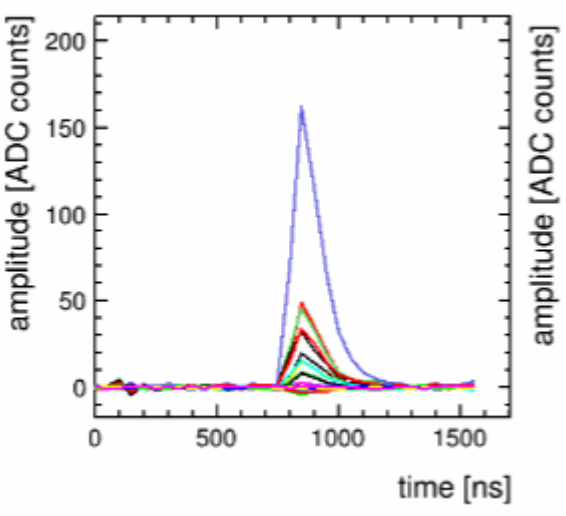
- Extrapolation of the tracks reconstructed in the telescope to the first layer of LumiCal reproduces the round shape of the trigger scintillators.
- Position of the point is defined by the reconstruction of telescope data;
- Color of the point is defined by the channel which has a signal in corresponding event in LumiCal;
- The fact that this type of plot reproduce the pad structure of LumiCal sensor means that synchronization works successfully.



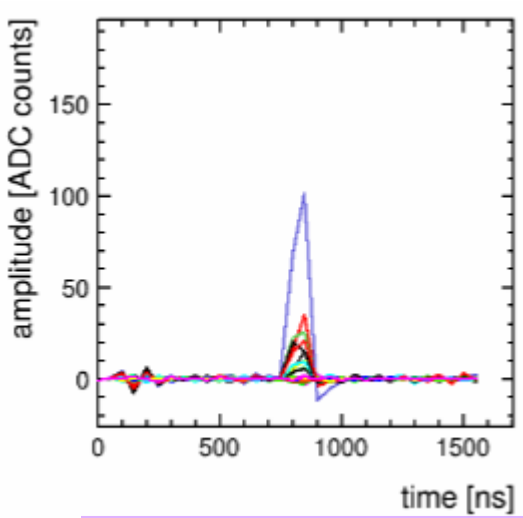
Signal Processing



Raw data

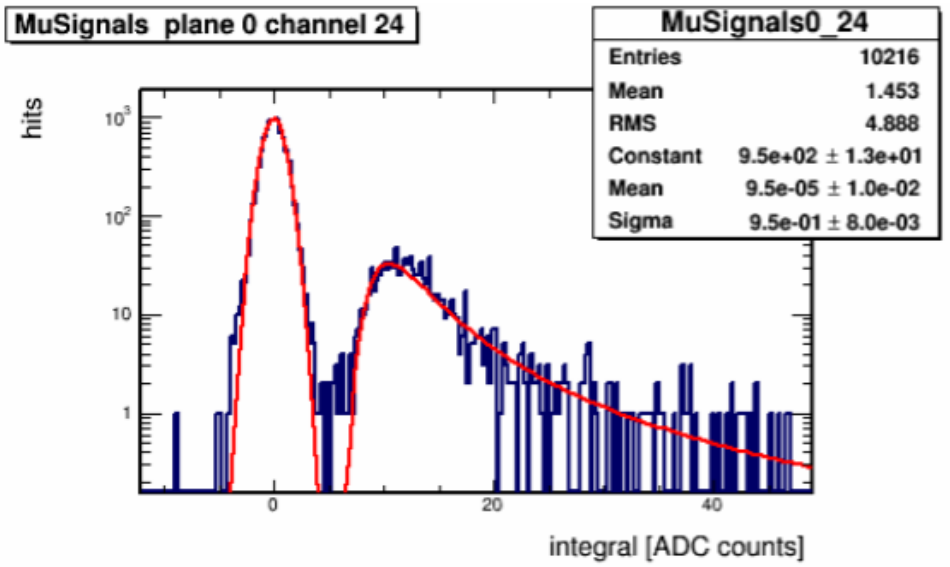


Baseline and common mode noise correction



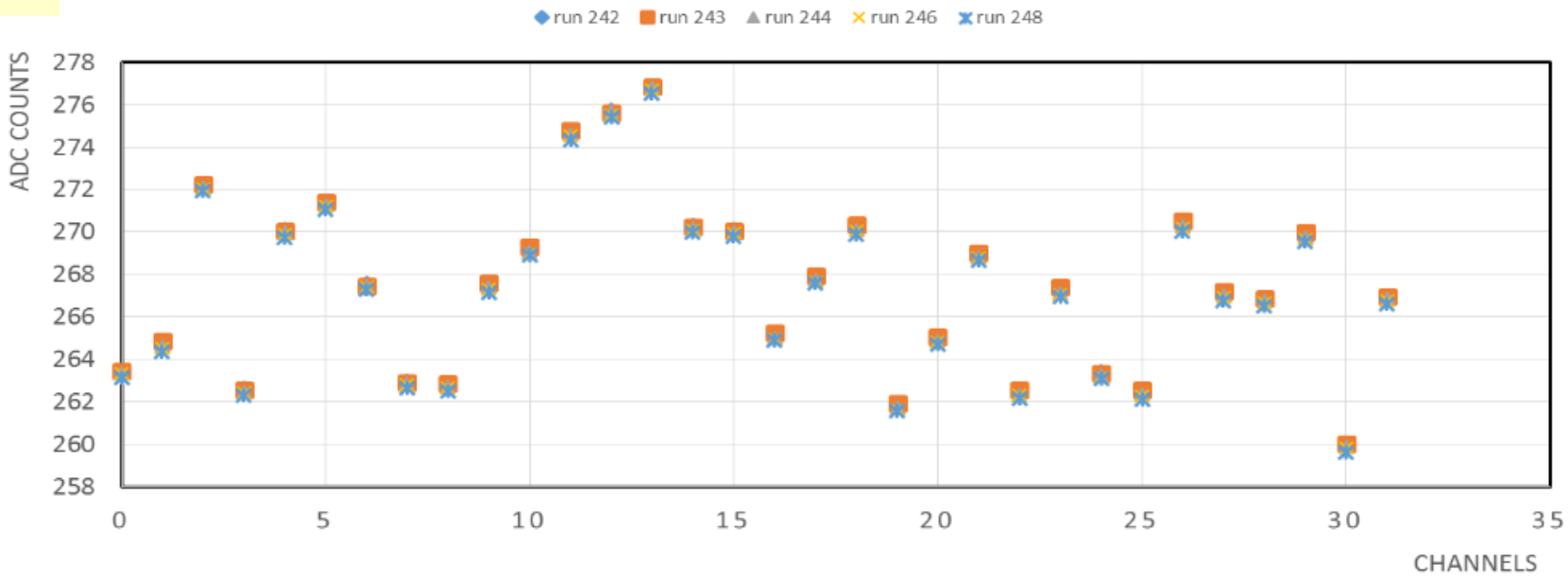
Deconvolution

- Gain results obtained in the lab using the same method (deconvolution) as data analysis;
- It was corrected using deposited energy distribution from muon events.

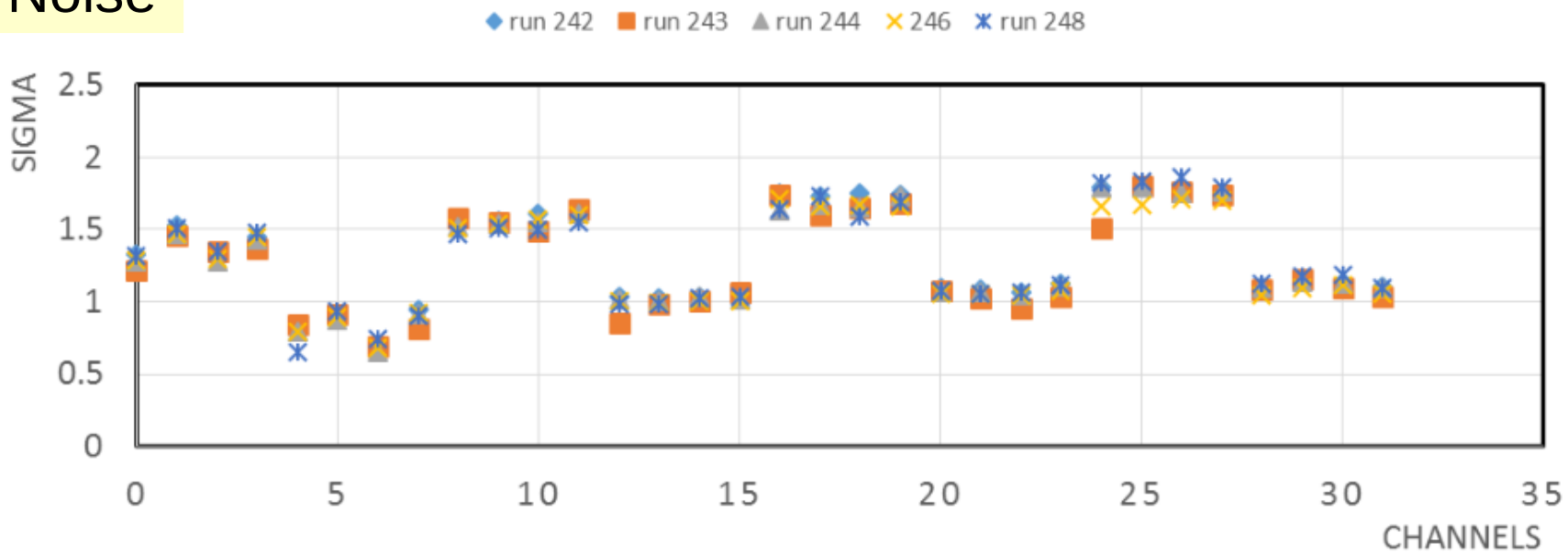


LumiCal Pedestal and Noise

Pedestal

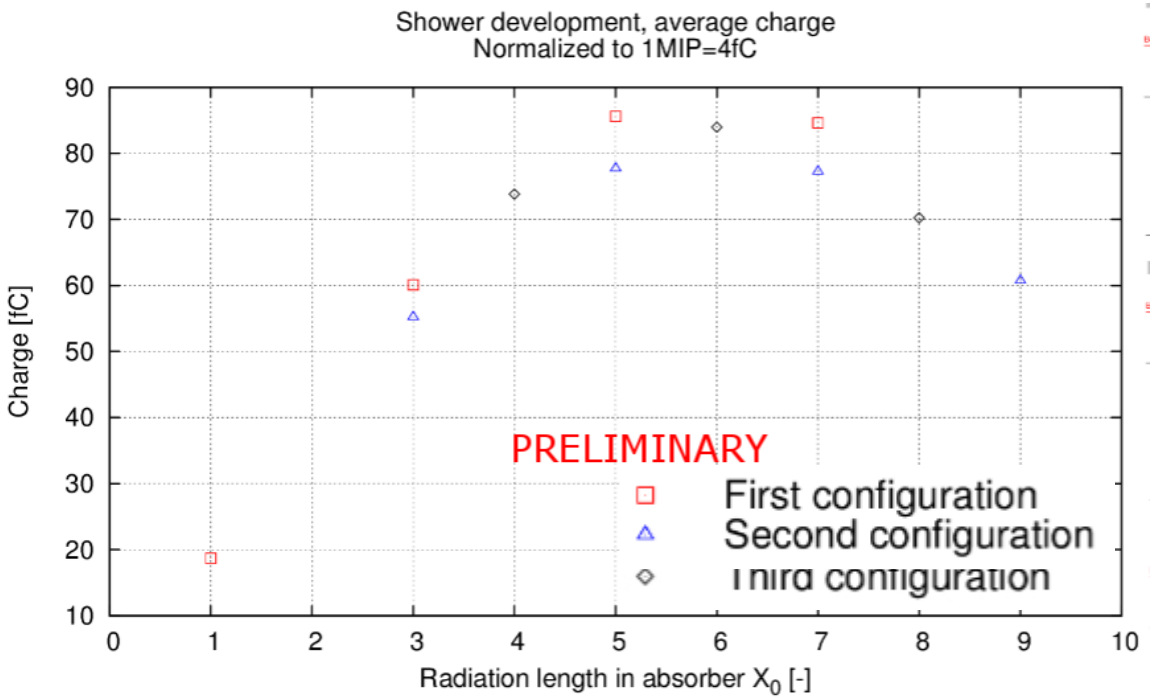


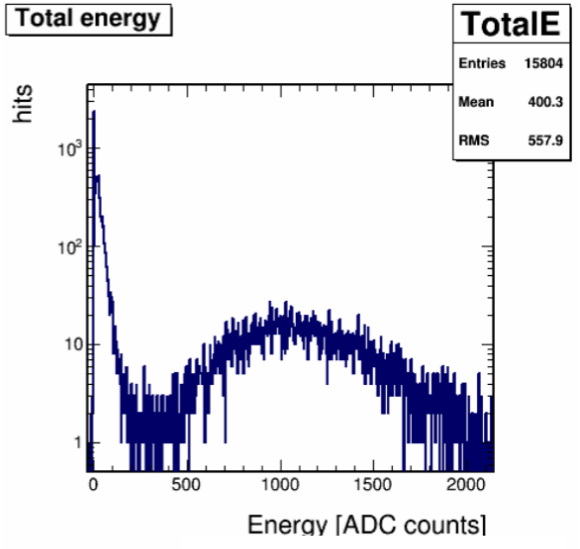
Noise



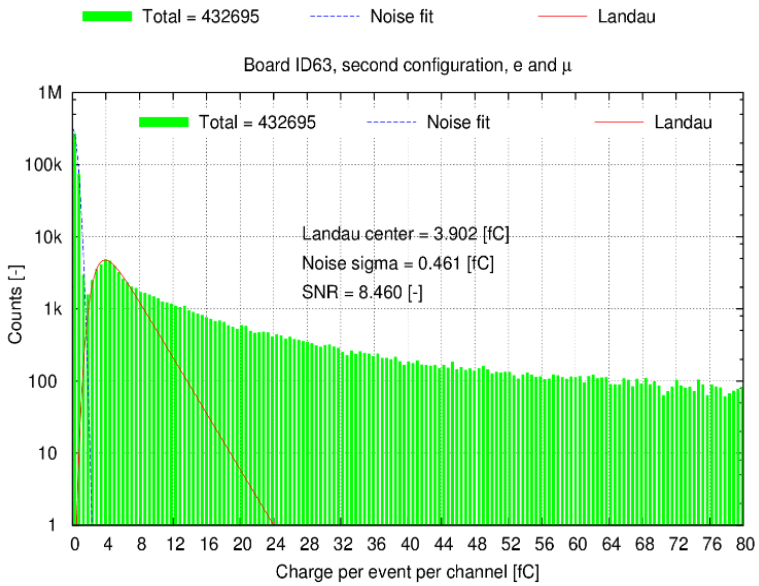
Deposited Energy and Shower Development

PRELIMINARY
BT data reconstruction

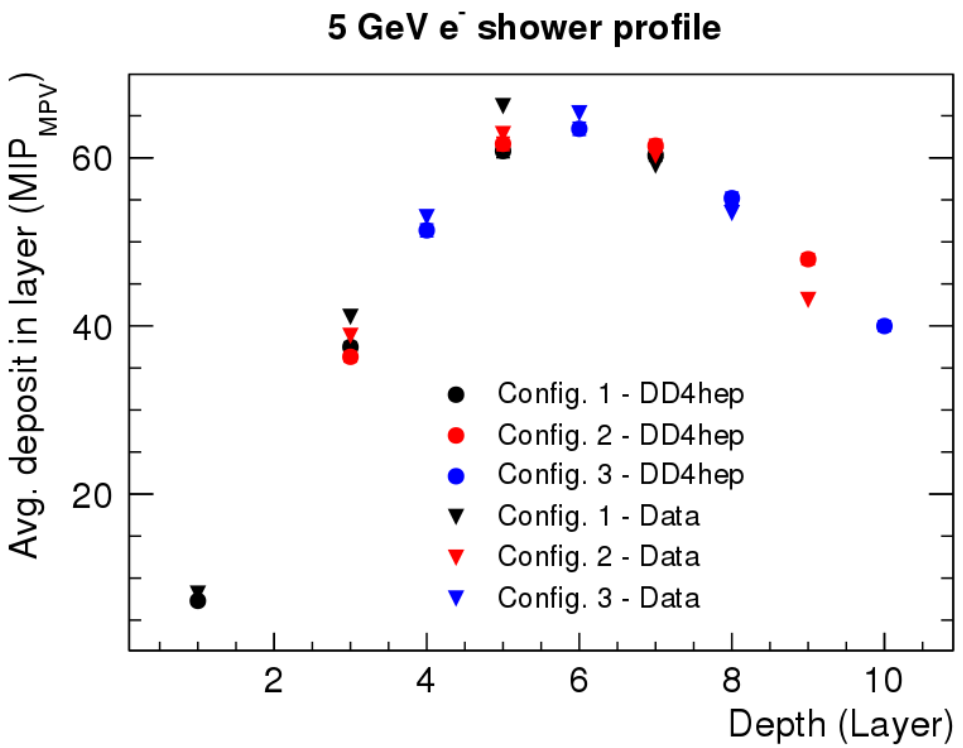




e^- & μ^- run data

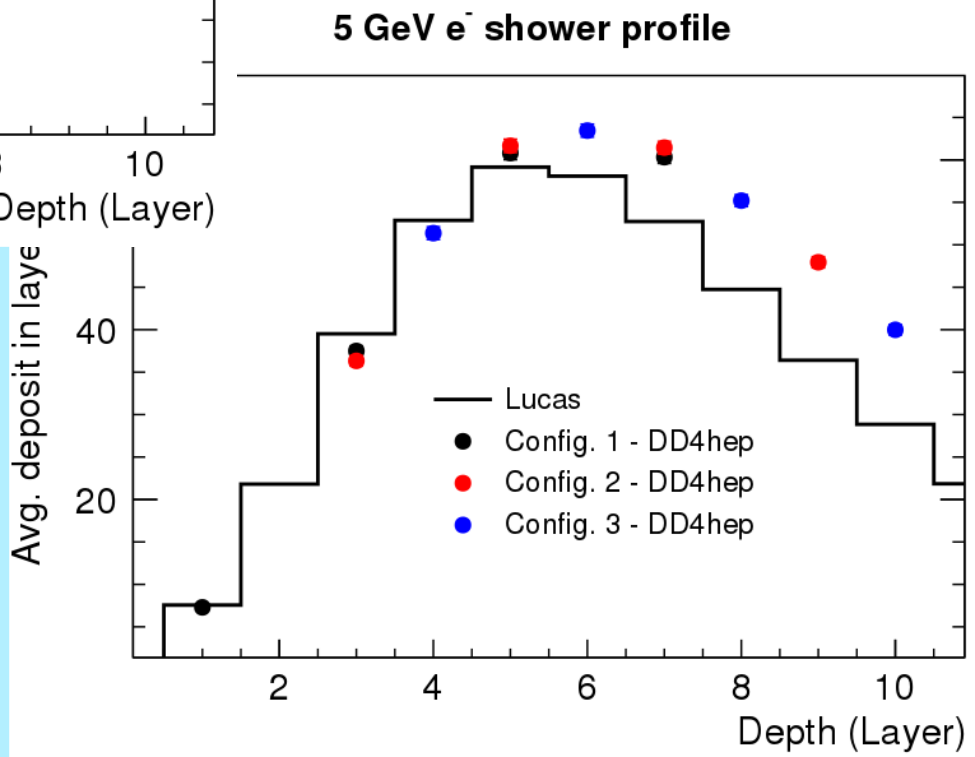


Geant4 Similations



DD4hep:

- Pure 5 GeV electrons with zero divergence, zero lateral spread and zero energy spread;
- No material in from of the prototype;
- Fairly detailed geometry.



- Longitudinal profile is in quite good agreement with data;
- Reasonable agreement with LuCaS;
- Details of geometry and material definition to be checked in both simulations.

Summary

- LumiCal 4-module prototype beam test demonstrated good performance of the system.
- New approach for events synchronization between telescope and LumiCal prototype was successfully implemented.
- Telescope reconstruction optimization is in progress.
- There is reasonable agreement between LumiCal beam-test data and simulation. Ongoing study to understand the details.
- Plans are also to study electromagnetic shower position reconstruction in LumiCal prototype.

Thank you for attention!