

Beam tests performance results of the LumiCal detector module.

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On behalf of the FCAL collaboration.



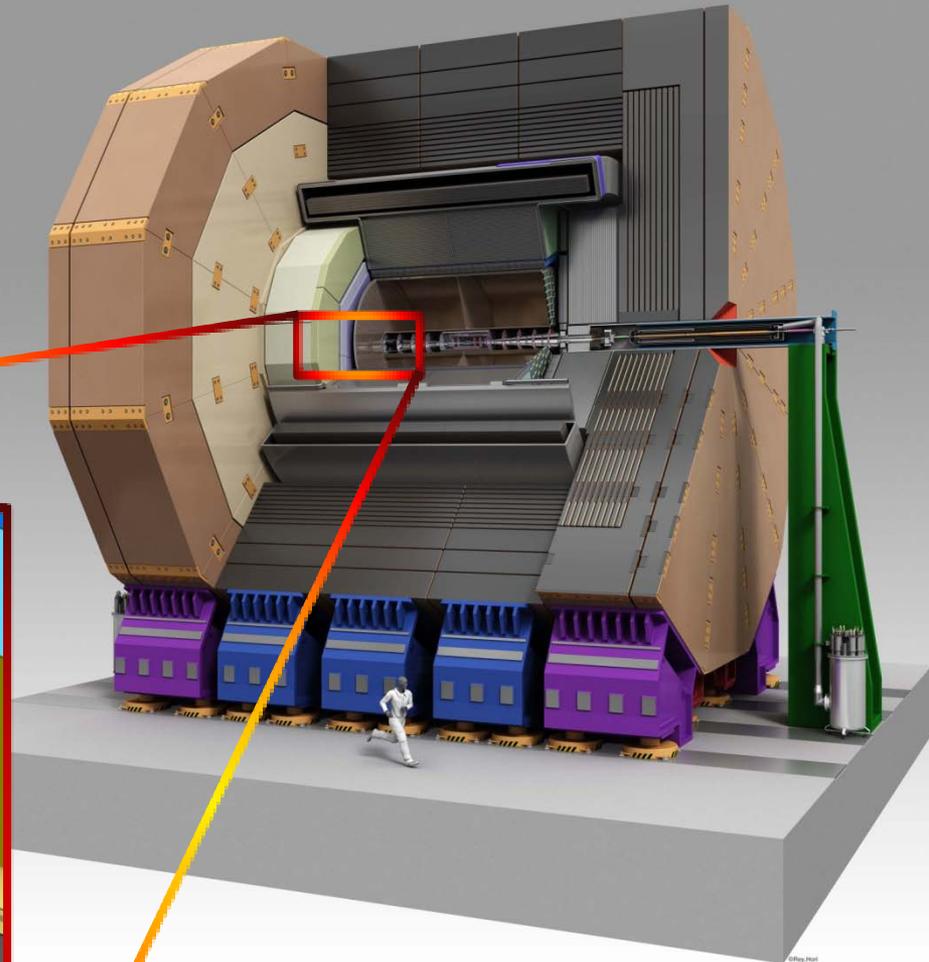
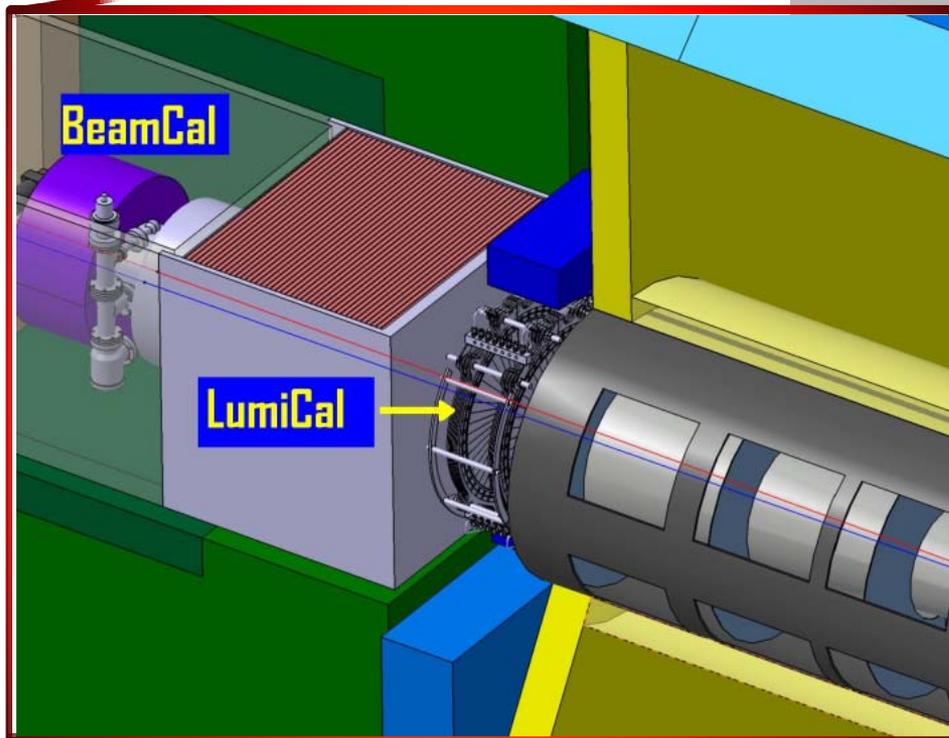
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Introduction

During 2010 and 2011 the FCAL collaboration performed three beam tests. These were the first tests of the LumiCal silicon- and the BeamCal GaAs-sensors prototypes equipped with a full readout chain. The readout chain included sensors, fan-outs, dedicated front-end electronics and, during the 2011 beam-tests, also a newly-designed 10-bit pipeline ADC was included. This talk will describe the beam tests setup and the LumiCal performance results. These include spectrum and correlation analysis in synchronous and asynchronous mode, combinations between sensor information and position-reconstruction and the development of electromagnetic showers in the tungsten absorber.

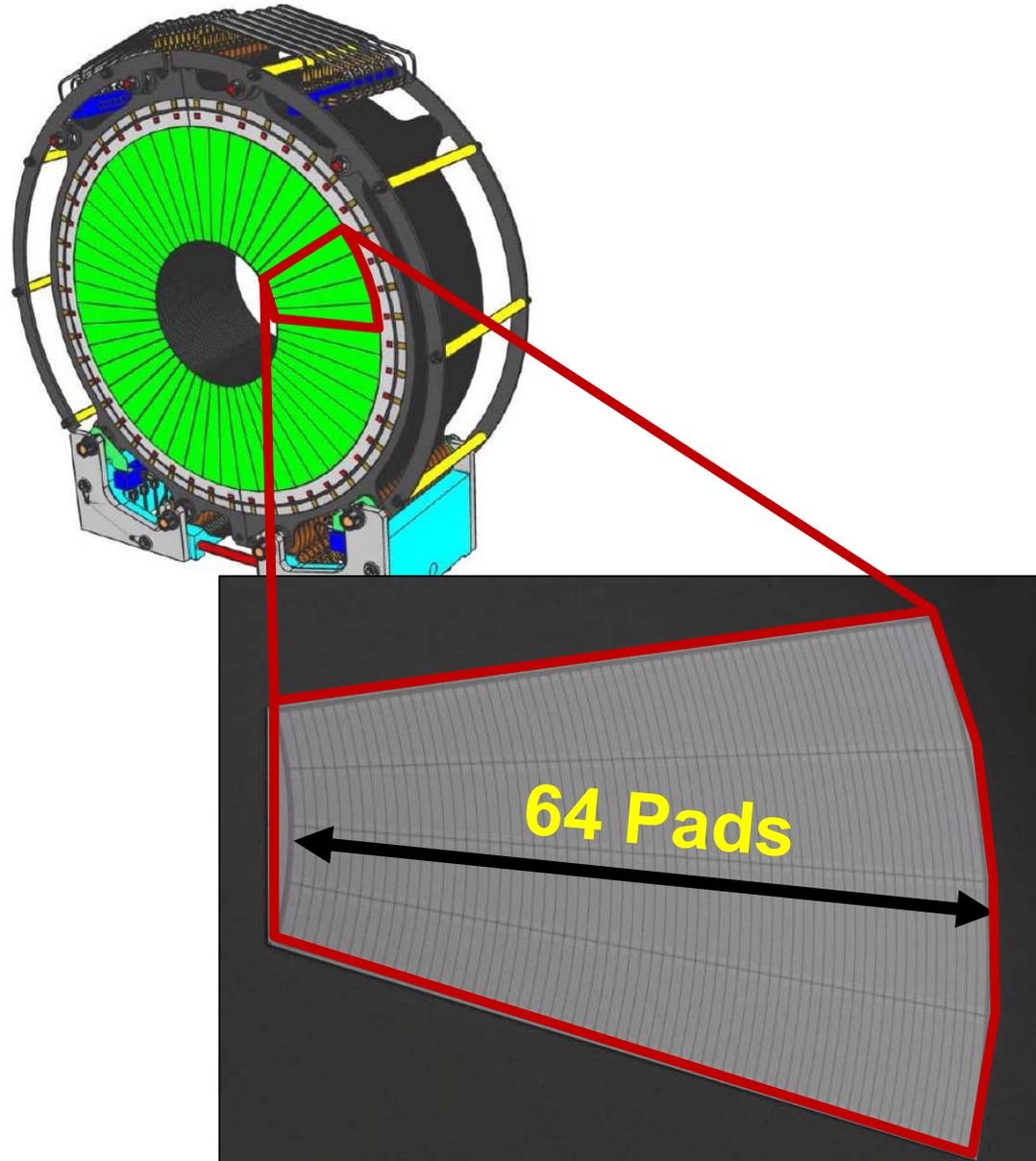
FCAL

In both detector concepts (ILD, SiD) of the future linear collider, two specialized calorimeters are foreseen in the very forward region, LumiCal for the precise measurement of the luminosity and BeamCal for a fast estimate of the luminosity and for the control of beam parameters.



The LumiCal sensor prototype

- LumiCal is a silicon-tungsten sandwich calorimeter with 30 (40) layers at the ILC (CLIC).
- In each layer 48 sectors in the angular direction with 64 radial pads.
- A silicon-sensor prototype was produced by Hamamatsu from 0.32 mm thick, 6" wafer high resistivity n-type silicon

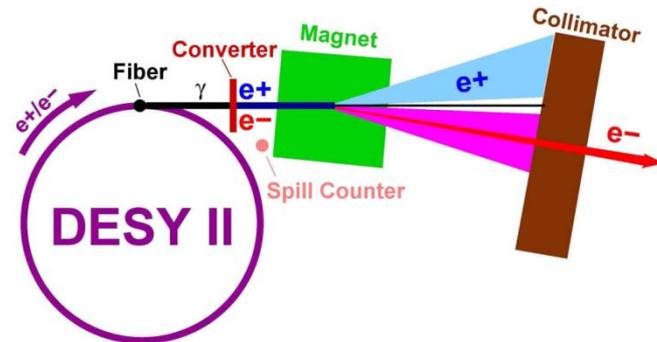
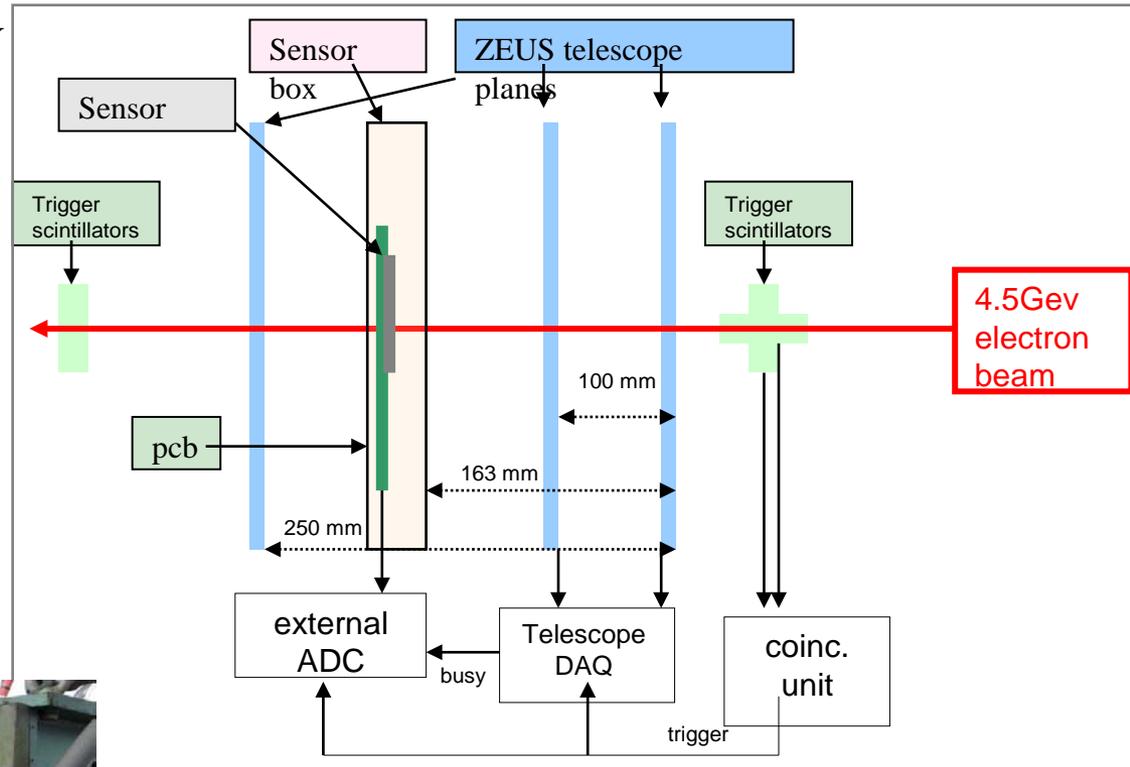


Beam test set-up

Tests took place in beam line 22 of DESY II ring in Hamburg with several (2-4.5) GeV electrons. Measurements are the combination of our sensors, ZEUS MVD Telescope for position reconstruction

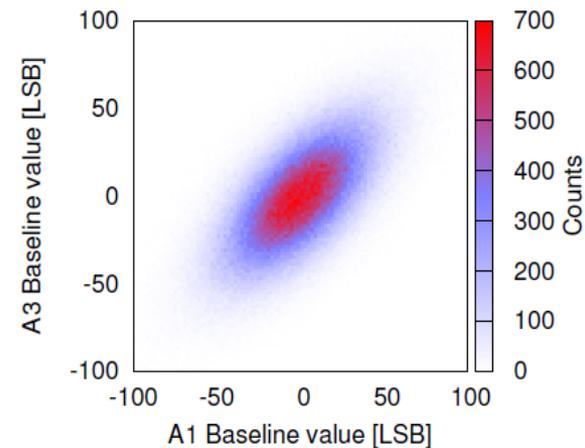
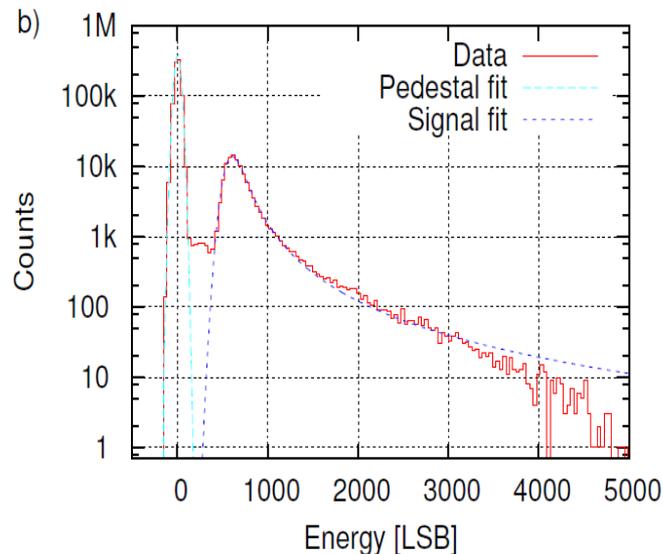
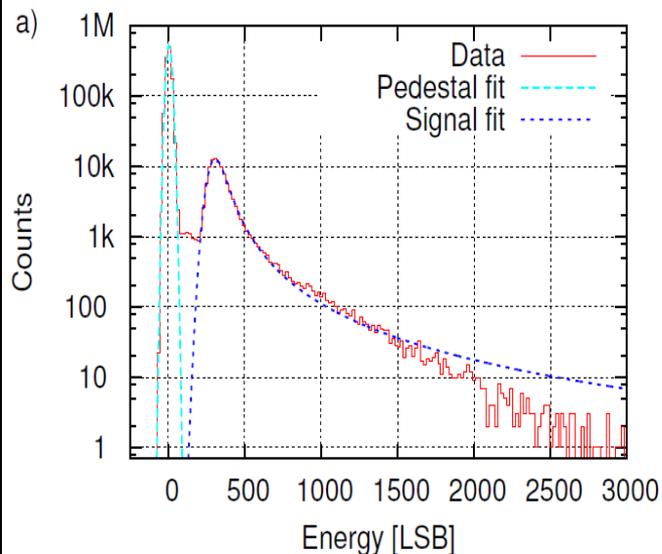
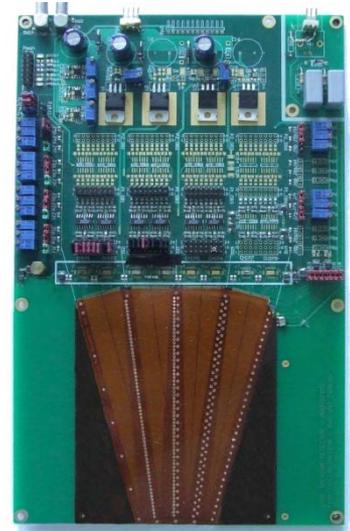
DAQ :

- 2010 - two systems (v1724 external ADC + Telescope) + veto mechanism.
- 2011 - EUDAQ + TLU (unique trigger).



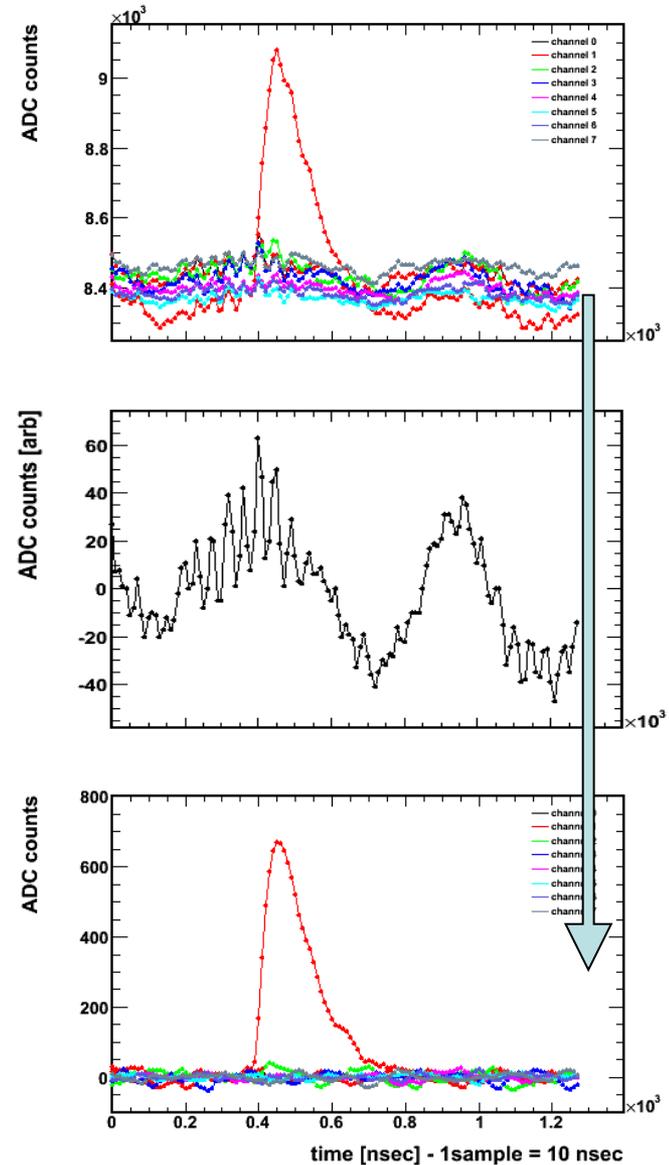
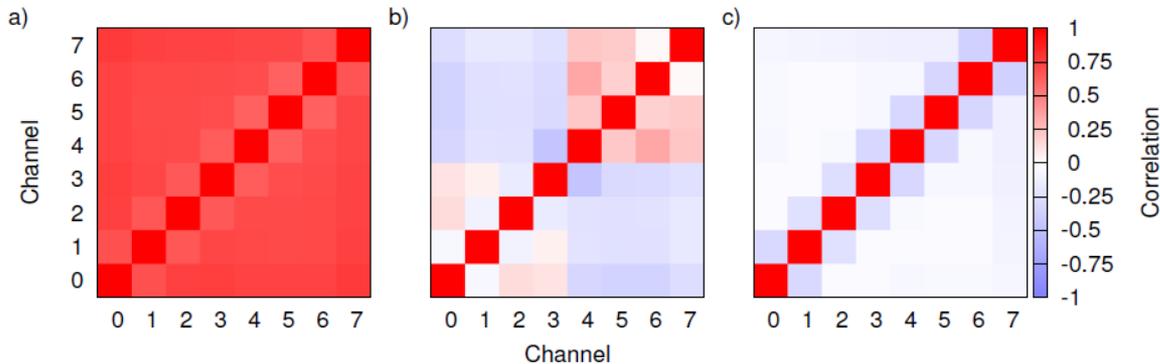
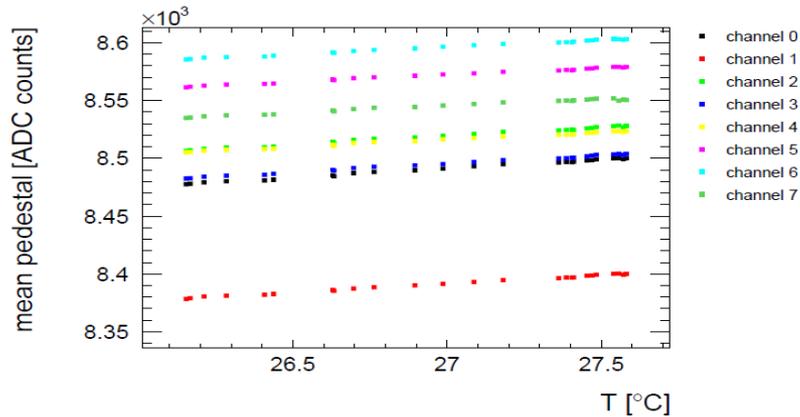
2010 test results (1)

- In the 2010 test an analog detector module was tested.
- The module included : Si-sensor, kapton fan-out, front-end ASICs, power supply, biasing circuits and line drivers.
- Read out of only 8 channels, in 2 groups.
- ASICs have 2 types of feedback loop, active feedback (MOS) – passive feedback (R_f), gain difference \sim order of 2 .
- Energy deposition spectrum built from pulse height analysis and fit nice to a convolution of a Landau distribution and a Gaussian.
- Uniform gain between channels ($\sim 2\%$).
- SNR : 16 – 20.
- High correlation factor between all channels.



2010 test results (2)

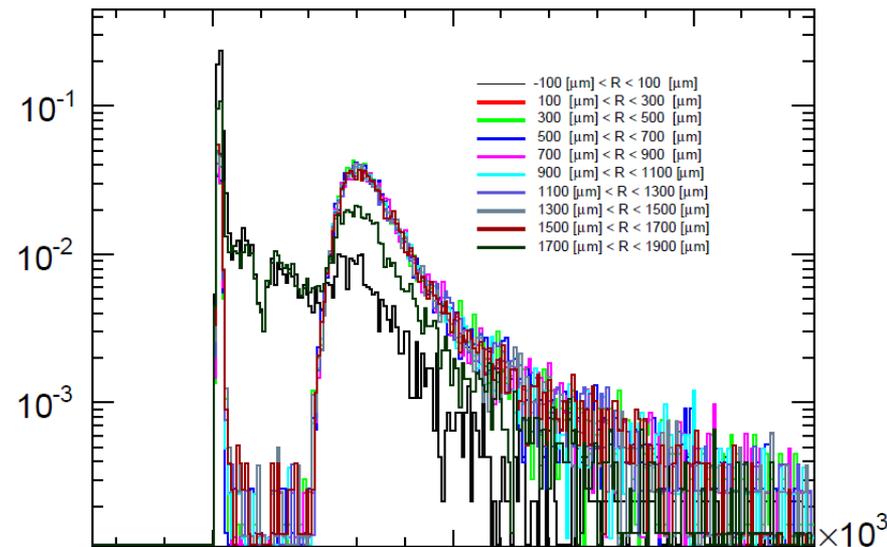
- High correlation factor between channel is a result of a common mode noise, CMN.
- First the CMN need to be extracted from all channels under threshold.
- Then CMN can be subtracted from all channels.
- Base-line temperature dependence and different channels gain need to be taken into account.



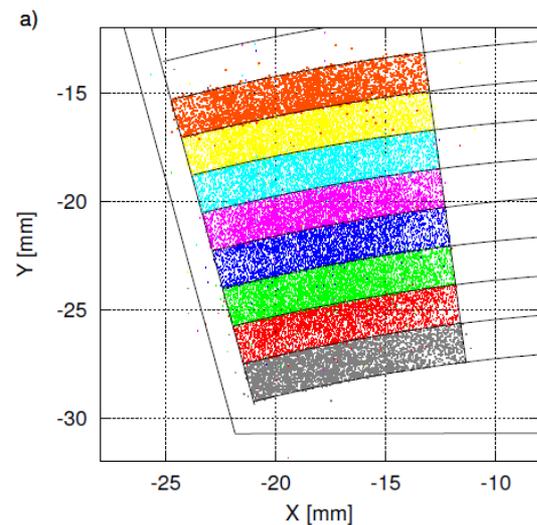
2010 test results (3)

- Using a track fit from the MVD telescope the impact position on the sensor is reconstructed.
- Uniformity – drop of 10% in CCE between pads.
- Detection efficiency just under 100%.
- The effect of charge sharing between pads is clear.

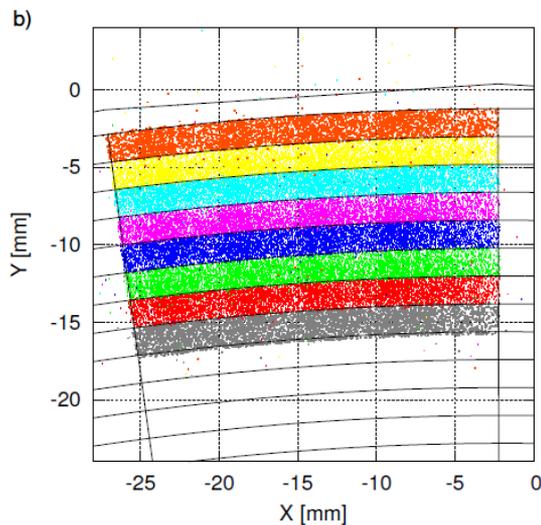
Number of signals



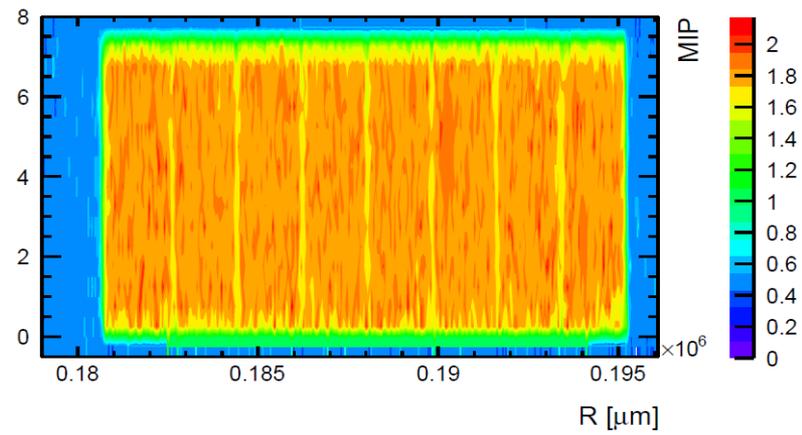
Q_{\max} [ADC counts]



A0 A2 A4 A6 A7
A1 A3 A5 A7

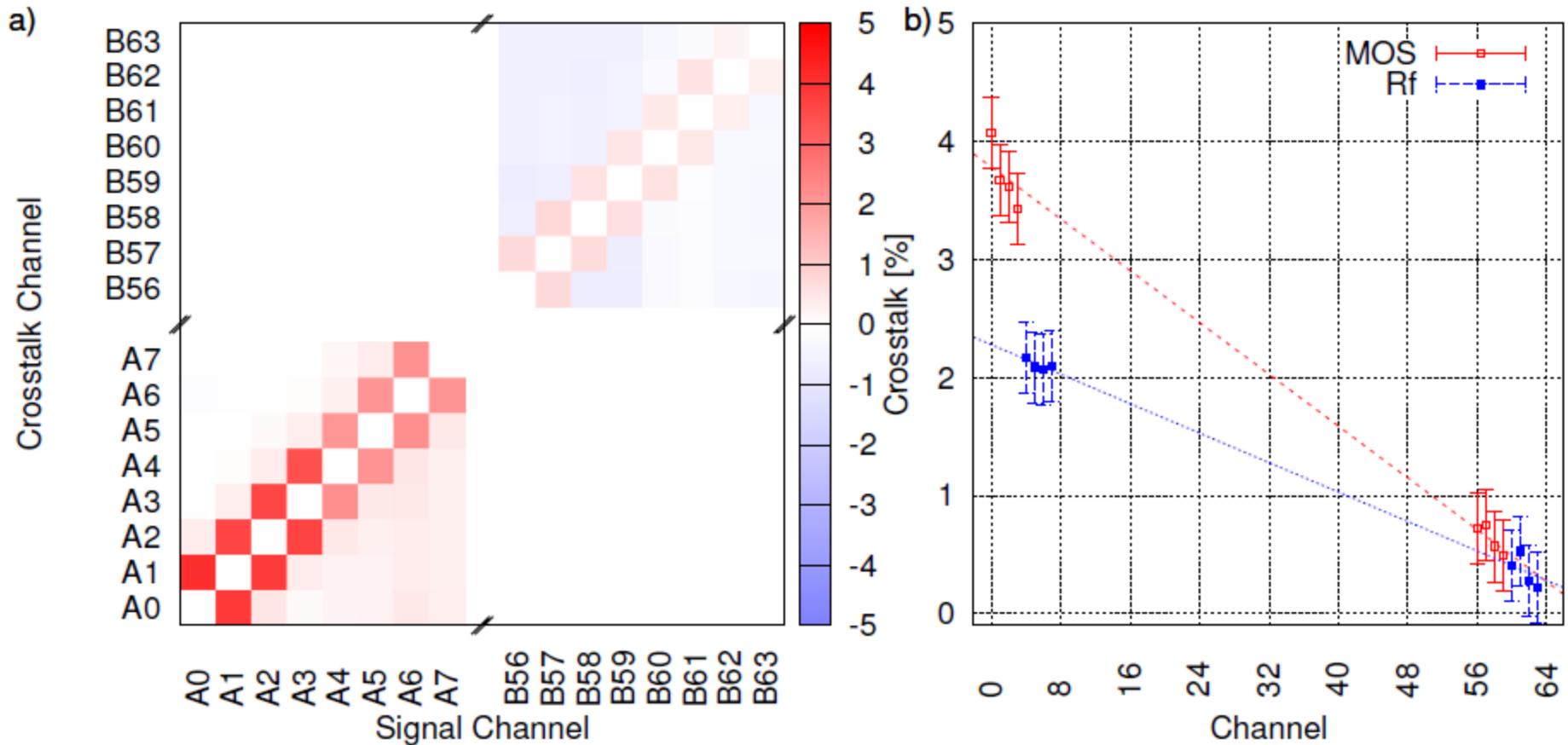


B56 B58 B60 B62
B57 B59 B61 B63



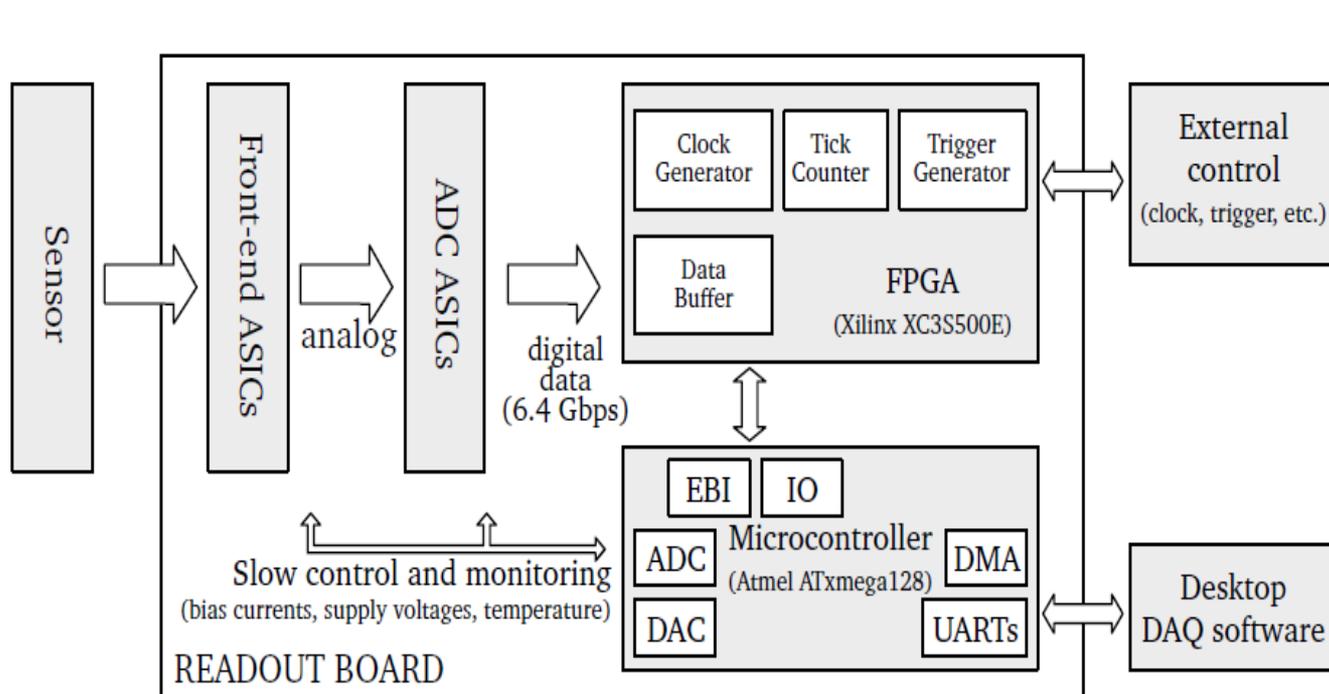
2010 test results (4)

- When using the position reconstruction after CMN subtraction to see hits far from the pad gap, SNR improves to 28-33.
- Same events are used to estimate cross talk between channels .



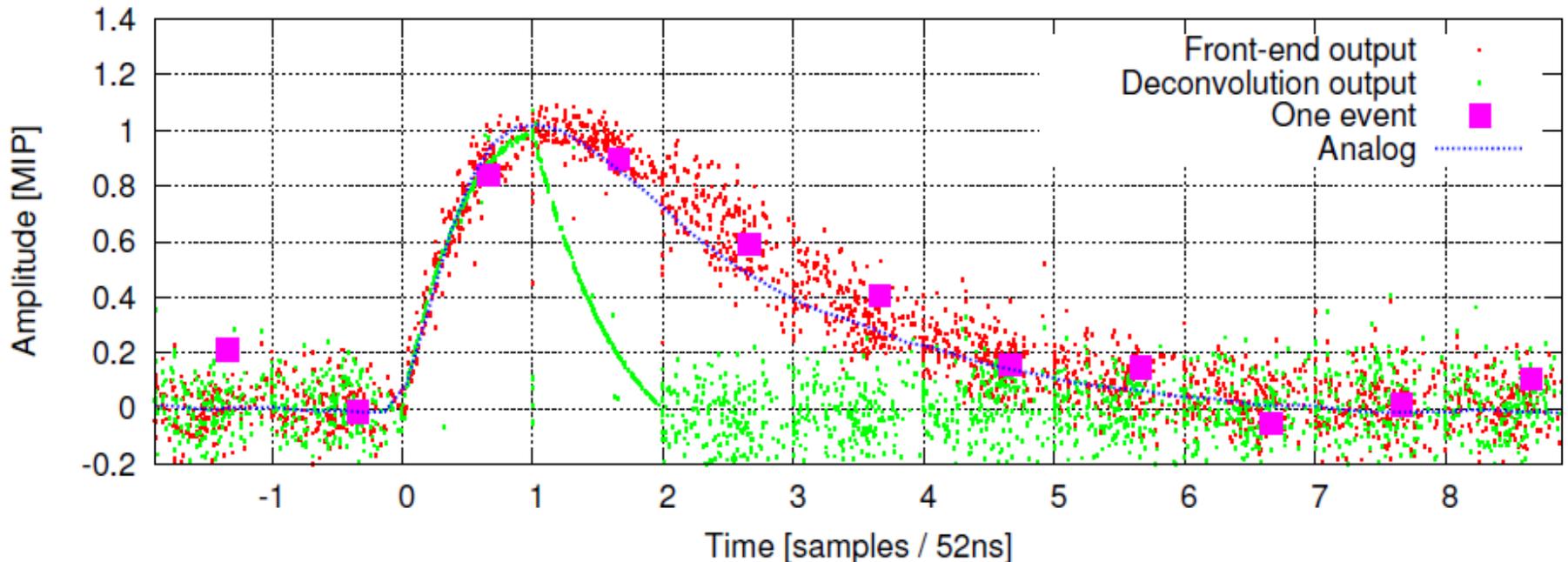
2011 tests (1)

- In the 2011 tests the complete detector module equipped with first level DAQ was tested.
- Include the operation of the complete readout chain: Si-sensor, kapton fan-out, front-end electronic and multichannel 10-bit pipeline ADC ASIC controlled by FPGA based data concentrator.
- The complete module has 4 multi channels chips with 8 channels each.
- Data was collected in two modes : synchronous (ILC mode) and asynchronous (test beam mode) with beam.



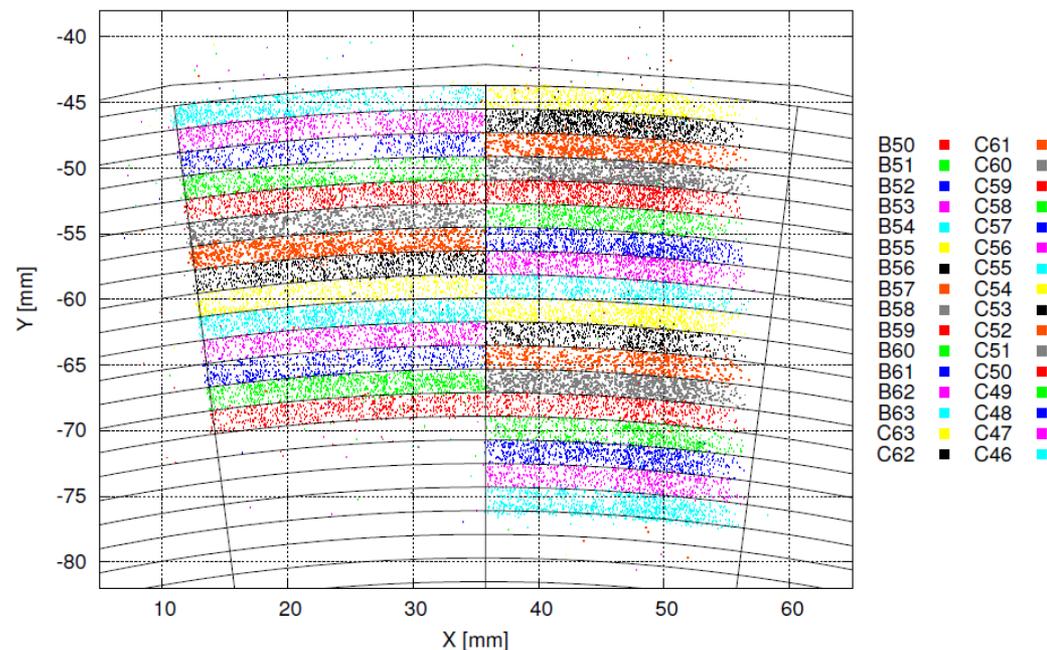
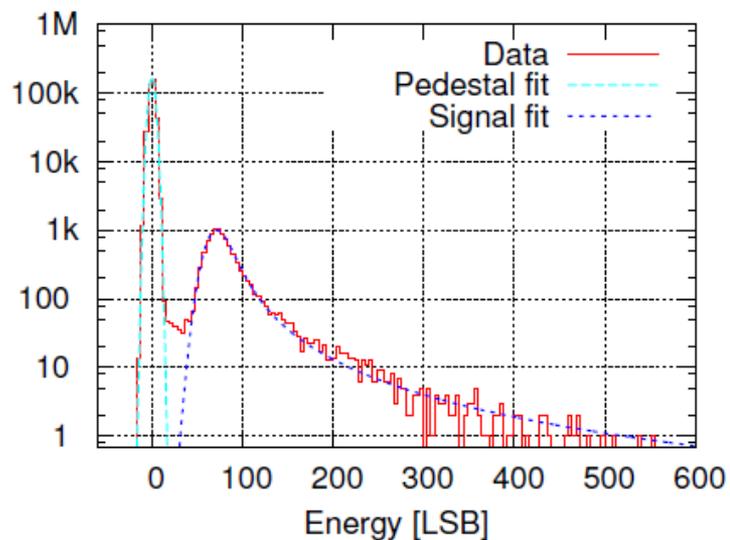
Readout with deconvolution

- As a preparation for high speed readout required in CLIC environment, the deconvolution method has been tested in the offline analysis.
- When using deconvolution, processed events can be precisely time-aligned and the exact amplitude and position can be determined.
- The measurements with an electron beam reproduce very well the results obtained in lab with a laser.



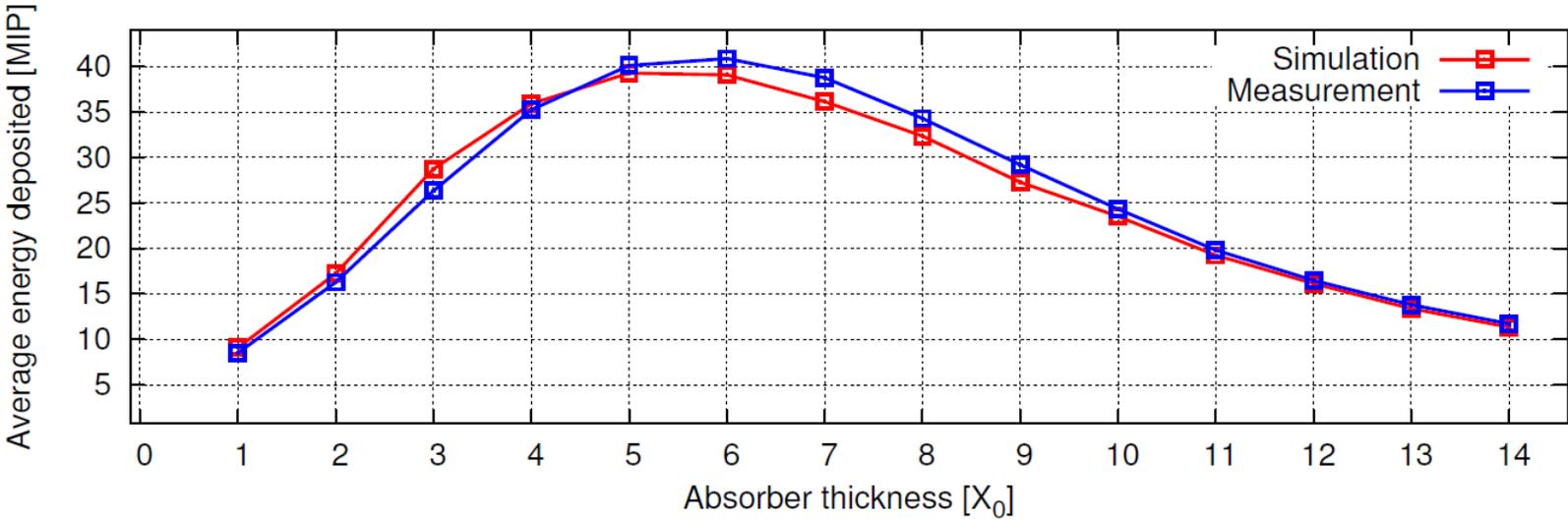
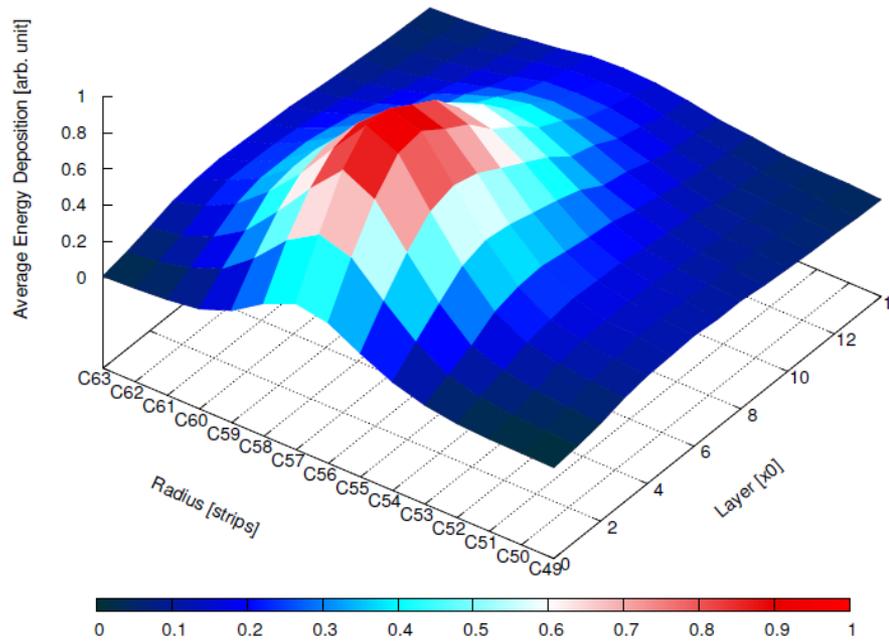
2011 tests (2)

- Similar measurements as in the 2010 test have been performed with the complete detector module in the 2011 one.
- The main changes in the 2011 beam test was in the number of channels (32), ADC resolution (10-bit instead of 14-bit) and somewhat worse SNR (19-22).
- The probed area was limited by the range of the X_Y table.



Shower development

- Several data runs were taken with tungsten absorber of different thickness in front of the sensor .
- Only statistical parameters can be analyzed.
- A MC simulations with GEANT4 was used by the IFJ PAN (Cracow, Poland) group in order to compare with the test results.
- Shower maximum observed after six radiation length and the agreement with MC is found to be reasonable.



Summary

- Operation of the LumiCal complete detector module with complete readout chain was successfully verified under beam tests conditions.
- Good performance results have been obtained from the beam test campaign:
 - Good SNR ~ 20 .
 - Sensor Uniformity and Detection efficiency.
 - Low level cross-talk.
- Advance readout and analysis technique were tested.
- The response of the detector to shower development has been studied.
- In the near future the beam test will evolve to a prototype beam test with several sensor plane to simulate a full sector of the LumiCal detector.