RESULTS ON THE PERFORMANCE OF A VERY COMPACT LUMICAL PROTOTYPE

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ON BEHALF OF THE FCAL COLLABORATION

OUTLOOK

- Introduction
- Design and assembly of the thin detector module for electromagnetic sampling calorimeter
- Test-beam of the calorimeter prototype
- Electromagnetic shower development study
- Particle position reconstruction
- Summary

GOAL OF THE LUMICAL DETECTOR

- The goal is to measure the integrated luminosity but also to extend the calorimeter coverage at small polar angle.
- Bhabha events are used as a gauge process to define the luminosity
- LumiCal is an electromagnetic sampling calorimeter :
  - 40 layers of 3.5 mm thick tungsten plates
  - In between, 1 mm left for silicon sensors

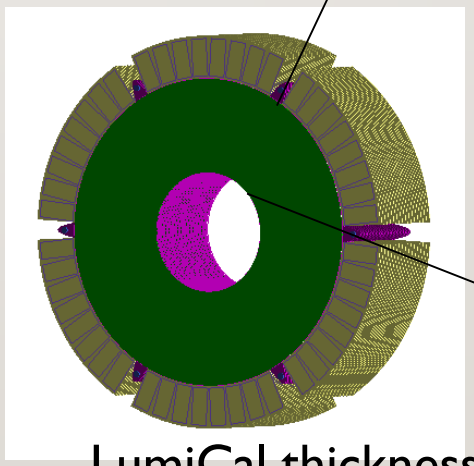
$$\mathcal{L} = N / \sigma$$

Count Bhabha events

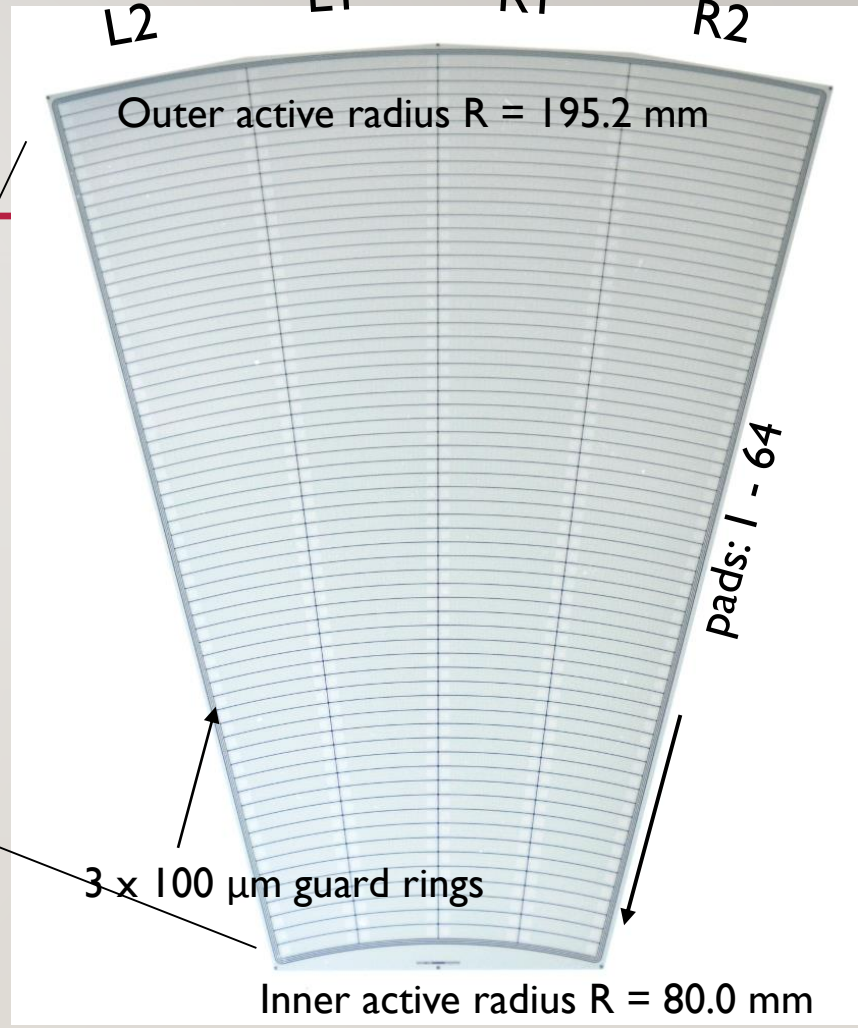
From theory

LUMICAL SENSOR

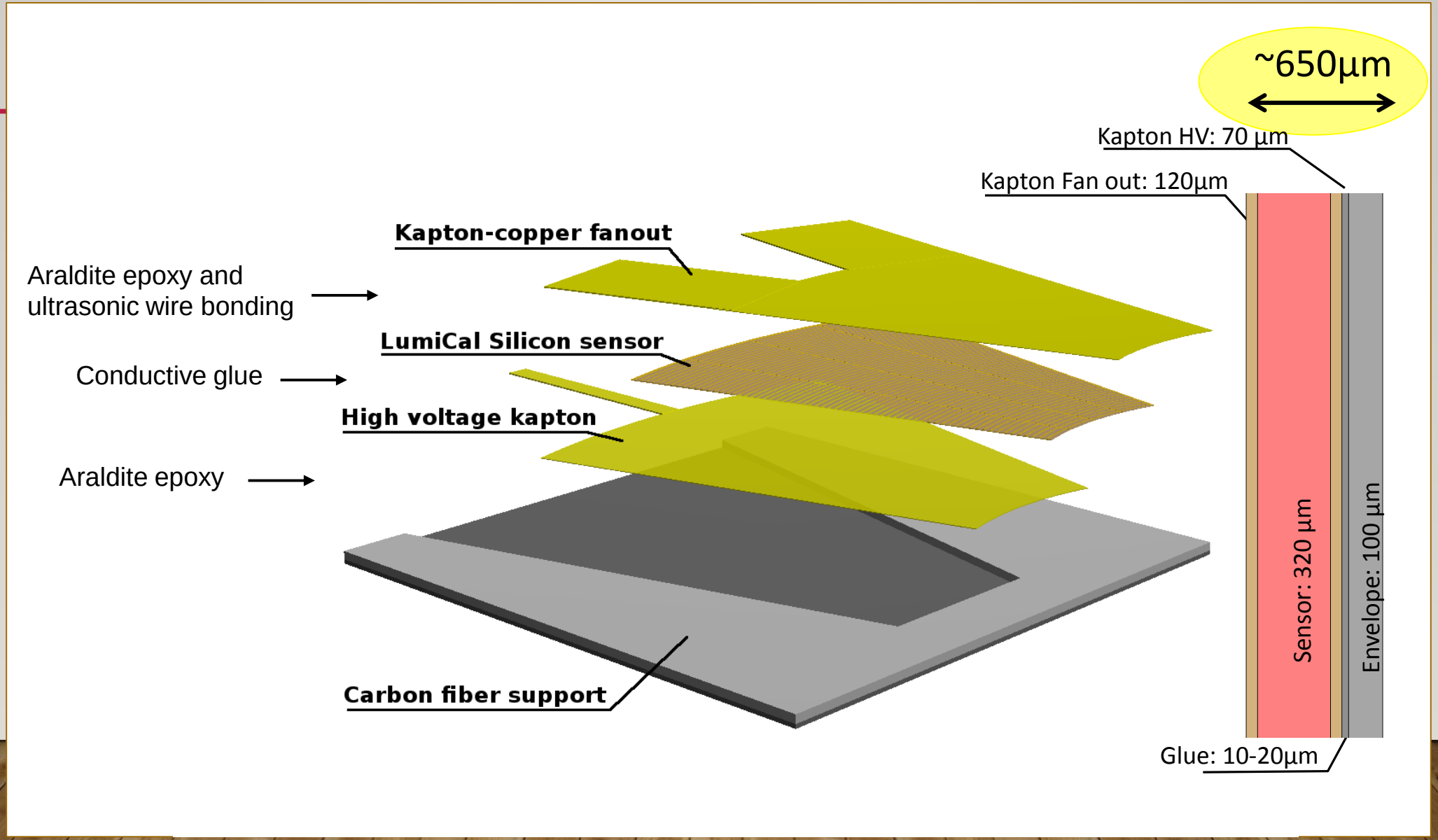
- thickness 320 μm
- DC coupled with readout electronics
- p+ implants in n-type bulk
- 64 radial pads, pitch 1.8 mm
- 4 azimuthal sectors in one tile, each 7.5°



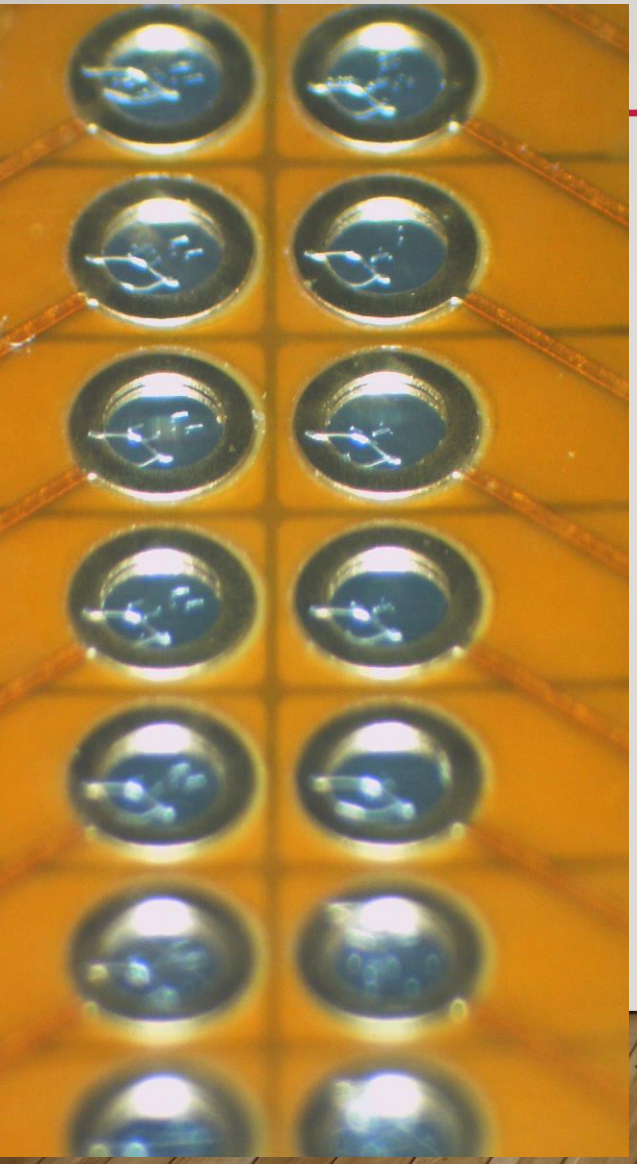
LumiCal thickness:
$30X_0$ –> 13.5 cm.



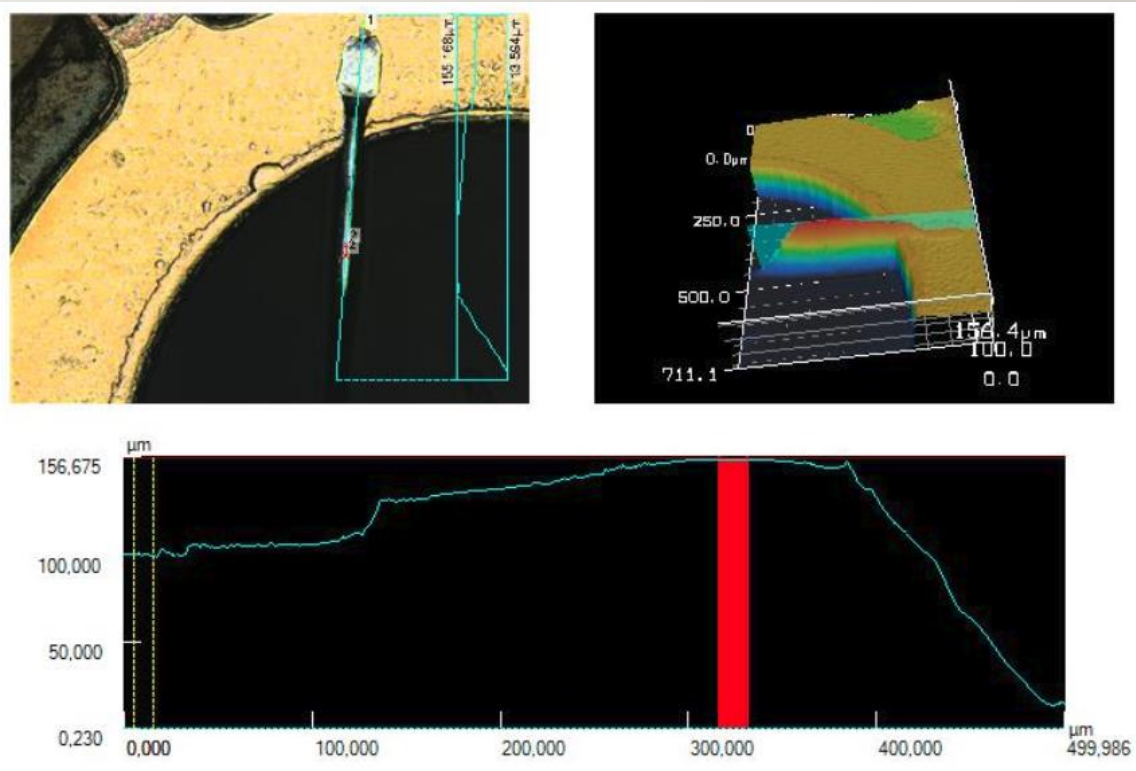
DESIGN OF THE THIN LUMICAL MODULE



WEDGE WIRE BONDING FOR FRONT-END CONTACT

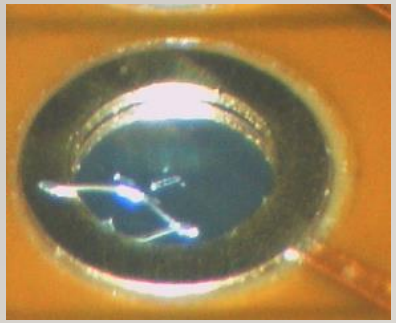


- Achievable size of the bonding loops is in the range 50 µm - 100µm.
- Bonding loop measured with 3D laser scanning confocal microscope at DESY Zeuthen.

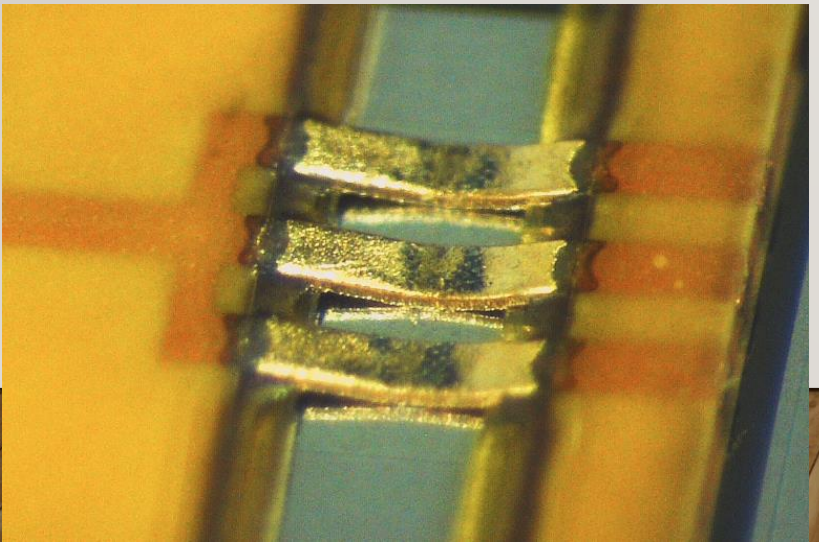


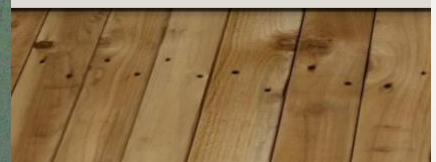
TAB TECHNOLOGY FOR FAN OUT–SENSOR CONTACT

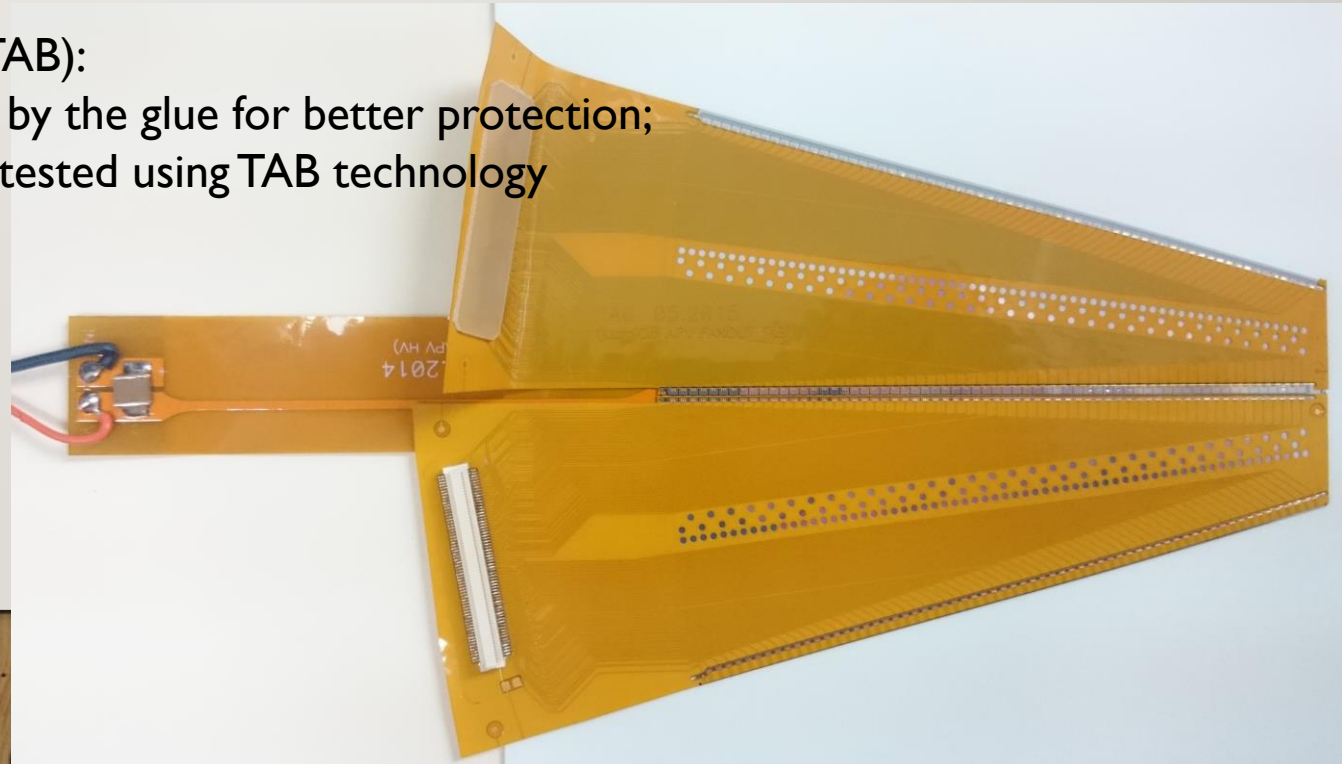
- Search for long-term stable contact between sensor and readout electronics which meets geometrical (compactness) requirement



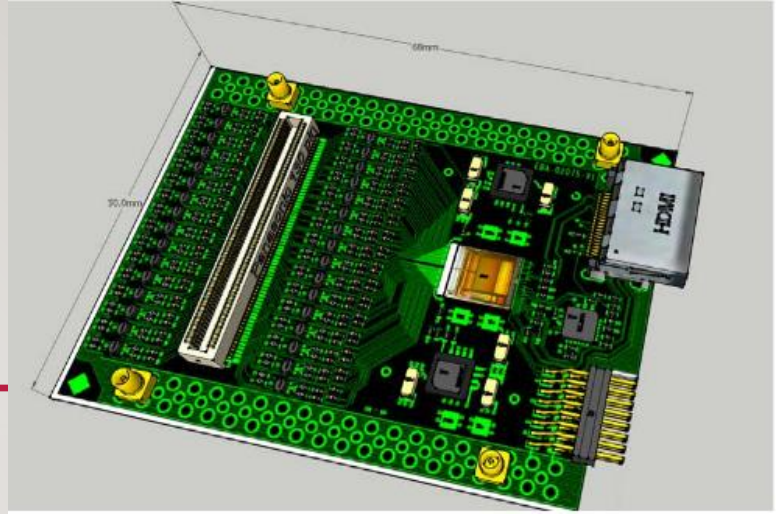
Single point Tape Automated Bonding (TAB):
No wire loop, the bond can be covered by the glue for better protection;
One LumiCal module is assembled and tested using TAB technology



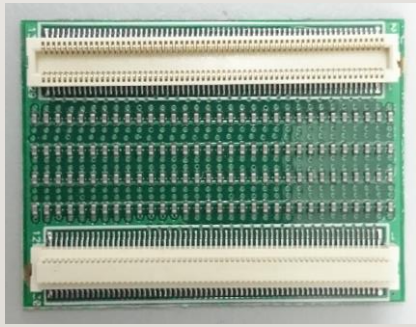


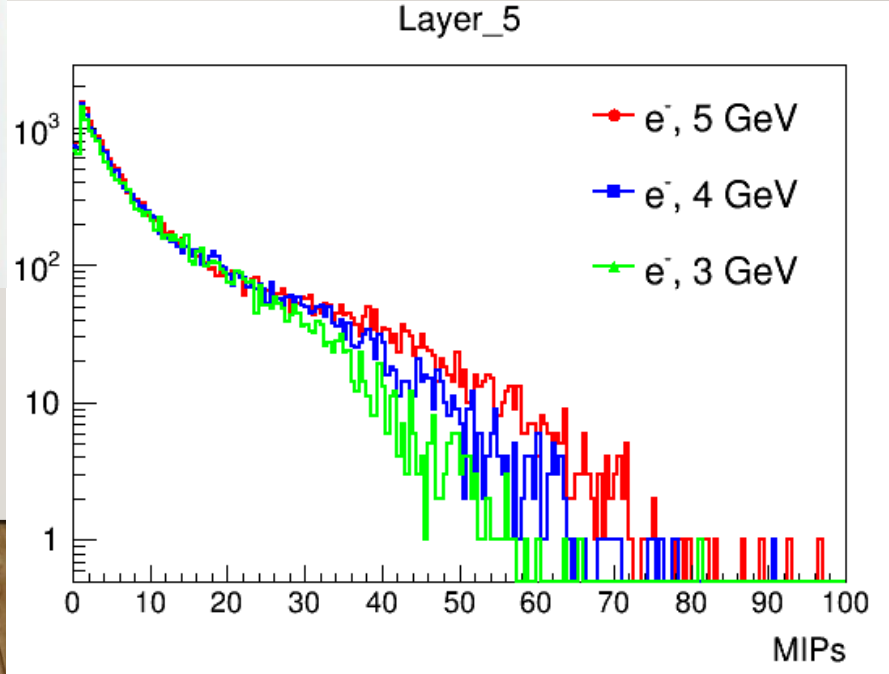


READOUT WITH SRS AND APV25



- Temporary solution
  - Designed for CMS silicon microstrip detectors;
  - 128 channels;
  - Shaping time (min): 50 ns;
  - Supports both signal polarity;
  - Sampling rate 40 MHz;
  - Supported by SRS;
  - Available at CERN stock.
- The APV-25 range in case of LumiCals sensor: ~ 8 MIPs
- Additional board of "capacitive charge divider" was designed and produced to reduce saturation effect.



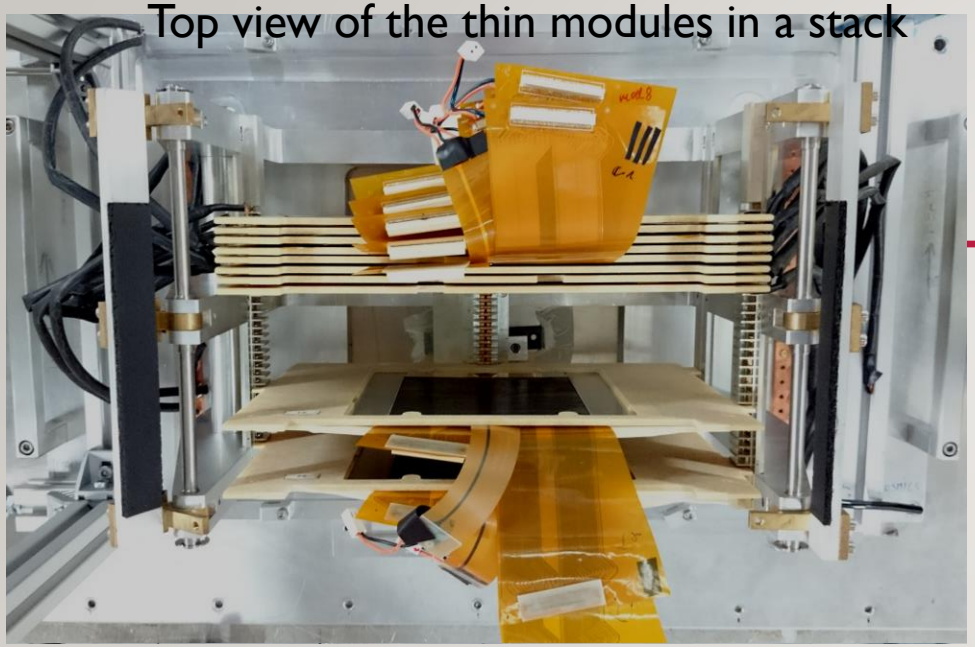


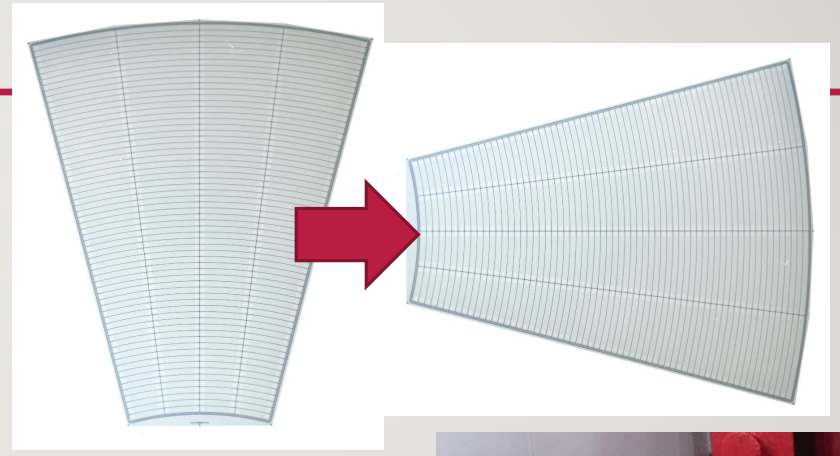
THIN MODULE BEAM TEST GOALS

- **Performance of the compact LumiCal prototype:**
  - Detector modules performance: noise, saturation, S/N, etc;
  - Energy response to e^- beam of 1 – 6 GeV;
  - Electromagnetic shower development study, Moliere Radius measurement.
- **e/γ identification with tracking detector in front of LumiCal:**
  - Backscattering as a function of distance from LumiCal;
  - Identification efficiency.

TEST BEAM SETUP

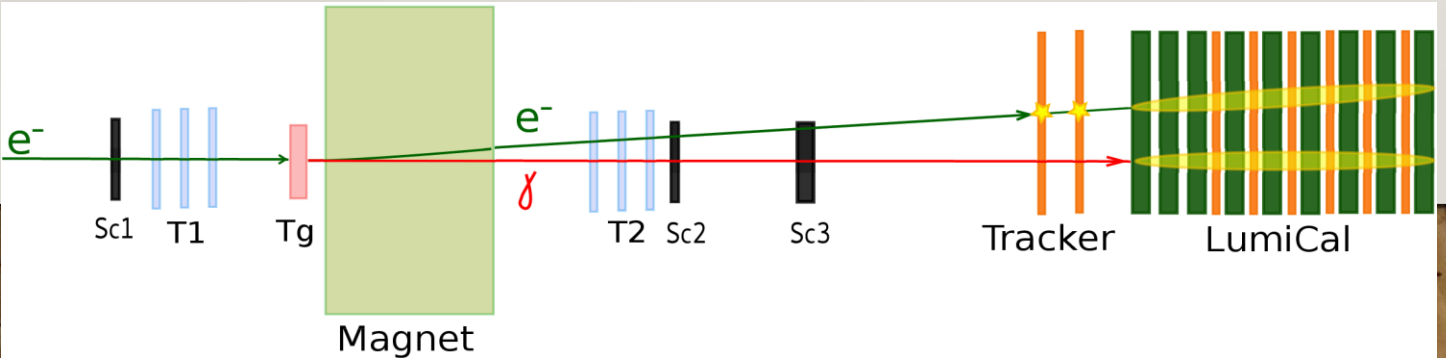
Top view of the thin modules in a stack

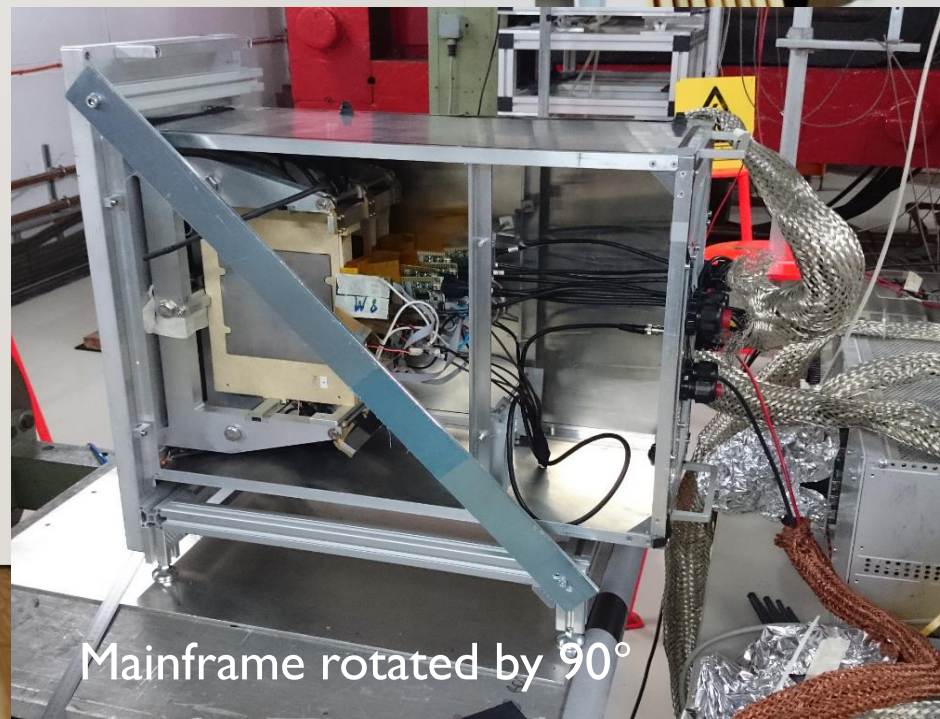




APV-25 front-end boards connected to the short side of the fan-out

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



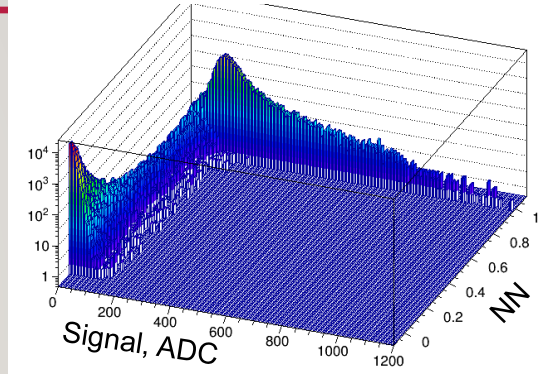


Mainframe rotated by 90°

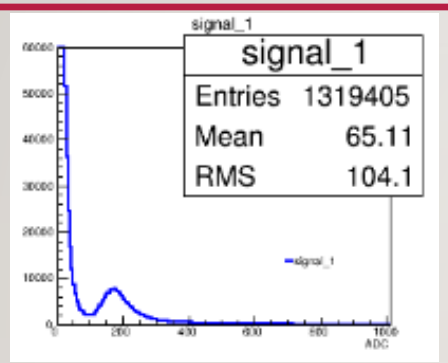
Energy Response of the Calorimeter

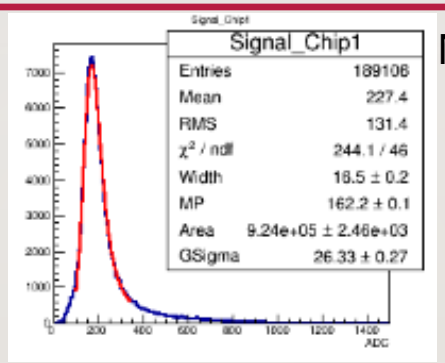
Cosmic muon reconstruction in LumiCal module readout by APV25

Signal selection with neural network (NN)



No cuts

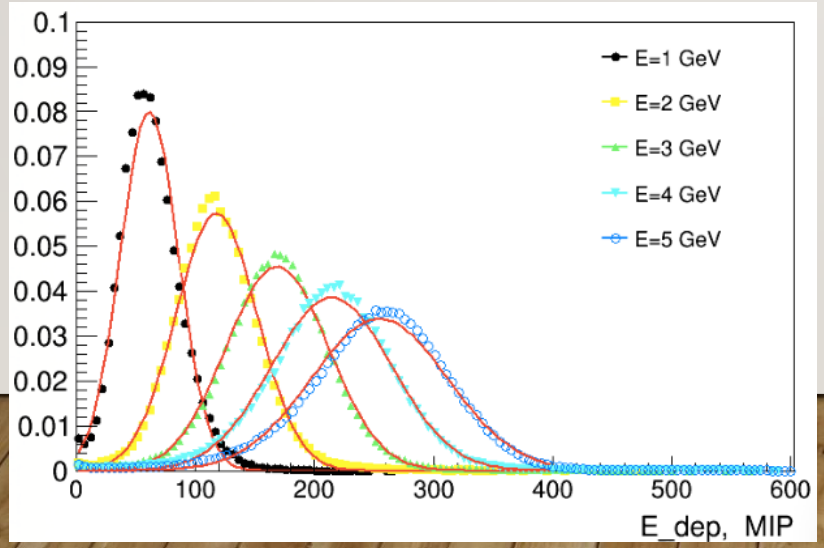


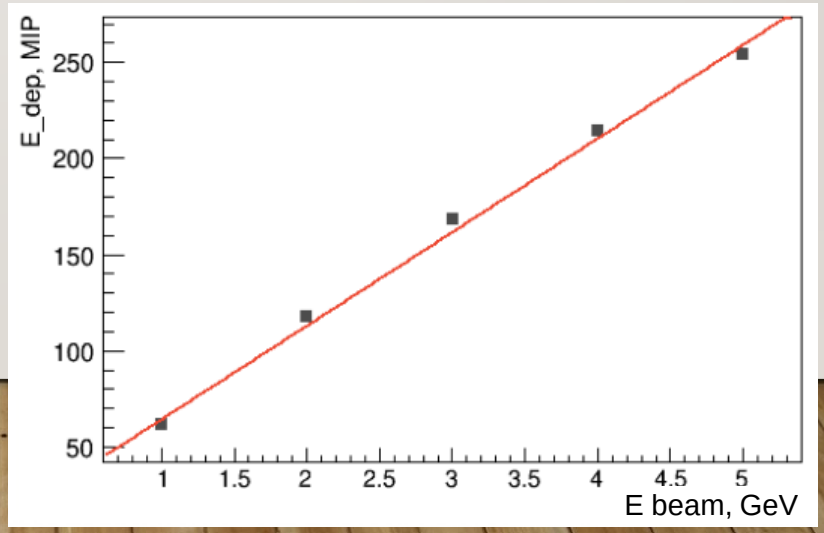


NN cut

Energy deposited in LumiCal sensor by cosmic muon (ADC)

LumiCal response when running with charge divider

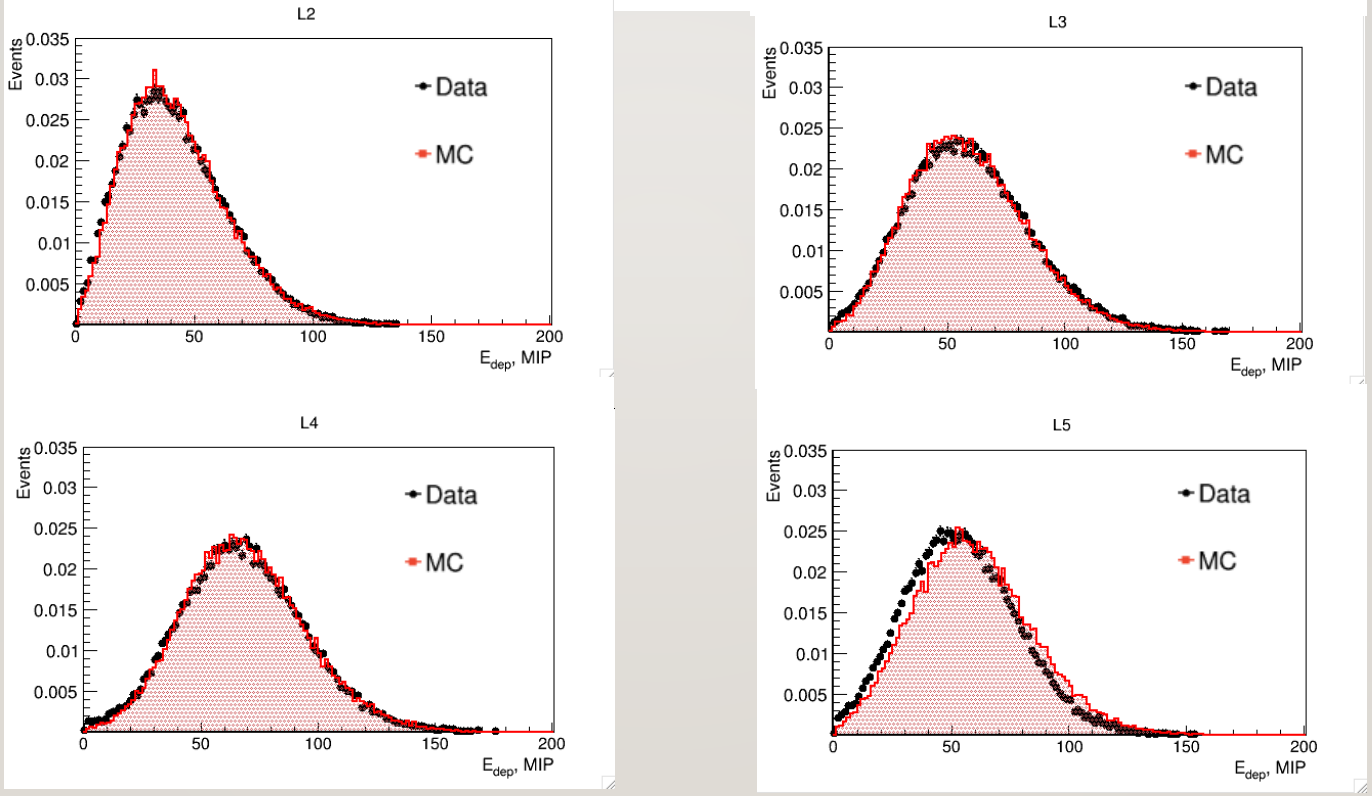




Longitudinal Shower

Work in progress...

Sensitive layers are installed after 3, 4, 5, 6 tungsten plates, it roughly corresponds to 3, 4, 5, 6 X0.



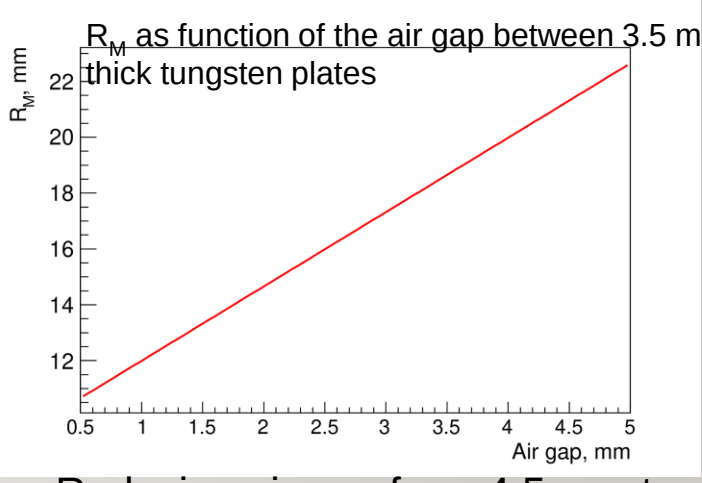
- The difference between data and MC for layer 5 to be understood.
- Possible reasons: noisy channels cause loss of information about small depositions which becomes significant as shower develops.

SHOWER STUDY IN TRANSVERSE PLANE

Procedure was developed for 2014 beam test of LumiCal prototype at CERN (PS, 5 GeV e- beam).

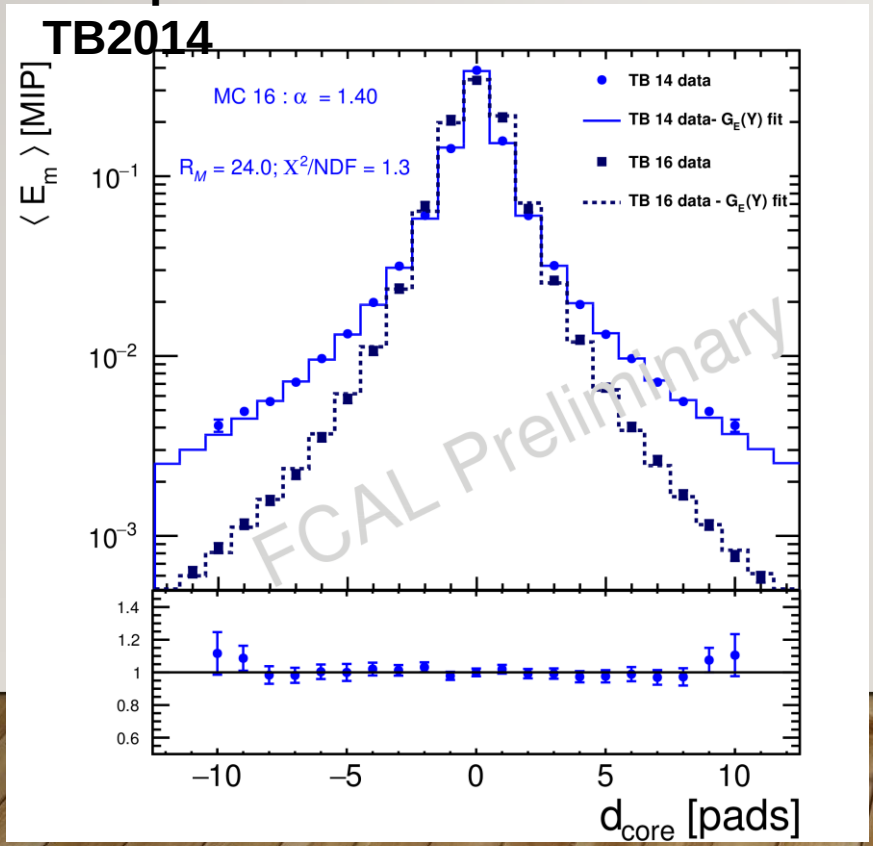
Result is **R_M=24.0 ± 0.6(stat.) ± 1.5(syst.) mm**.

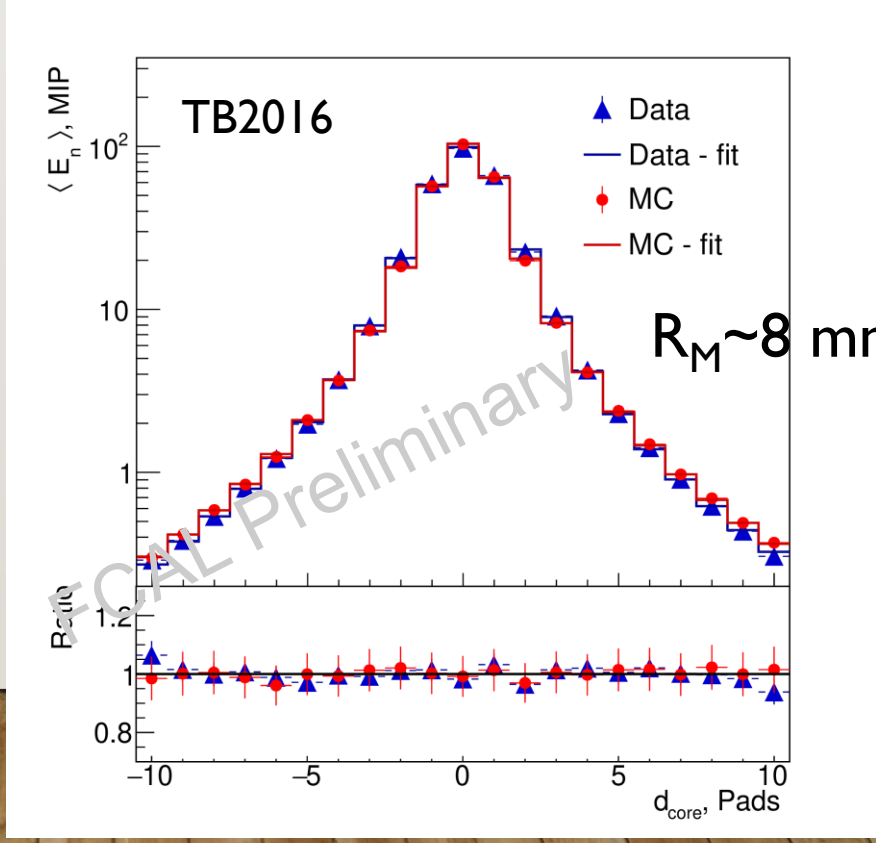
(Eur. Phys. J. C 78 (2018) 135 [1705.03885])



Reducing air gap from 4.5 mm to 1 mm gives RM: 21 mm -> 12 mm

Comparison of transverse shower in TB2016 (compact design) with TB2014



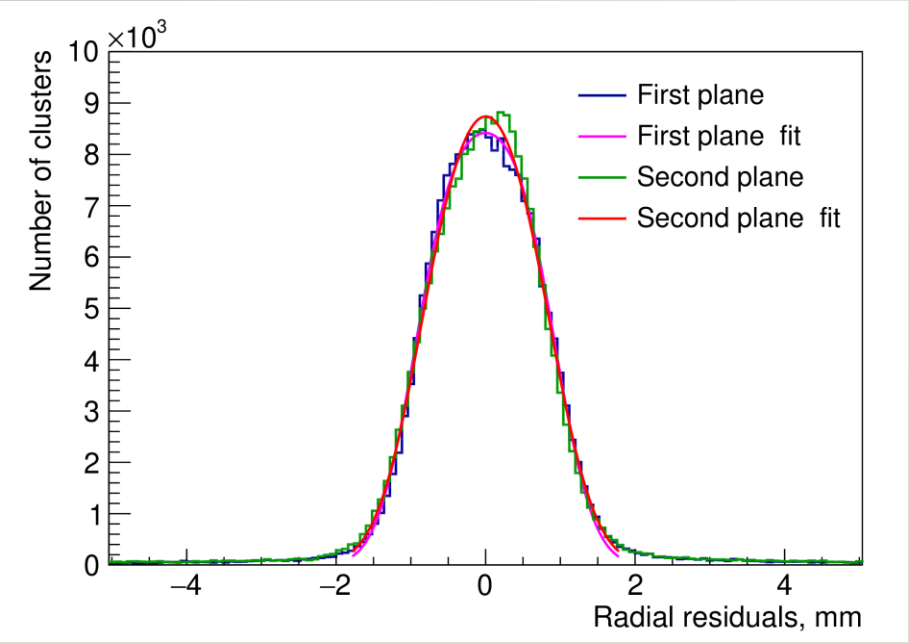


R_M~8 mm

Position Reconstruction and e/γ Identification

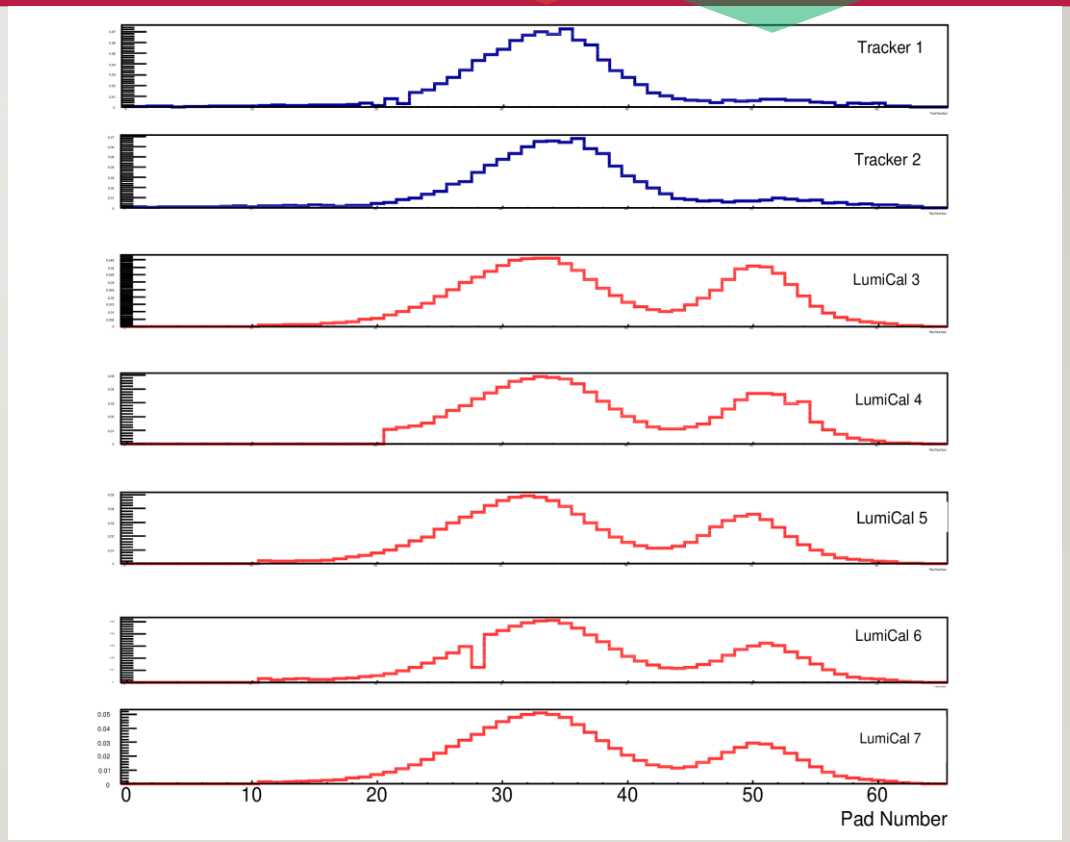
5 GeV electron beam

Reasonable agreement between parameters of reconstructed clusters in simulation and in data.



Residuals between position in calorimeter and tracking planes

Occupancy plot shows electron and photon showers



Identification efficiency:

- electron ~95%
- photon ~87%

CONCLUSION

- One LumiCal module prototype with TAB technology has been produced and installed for the beam test. Reasonable data were collected, further analysis will give more information.
- The calorimeter (LumiCal) prototype with eight modules of submillimeter thickness installed in 1 mm gap between tungsten absorbers, was tested with electron beam. Data analysis is in progress and preliminary results are following:
- LumiCal prototype demonstrates good linear response to the beam of 1 GeV – 5 GeV.
- Compact assembly of LumiCal with thin detector module results in significantly narrower transverse shower compared to previous beam tests and much smaller Moliere radius (~8 mm). This value is closed to the technological limit.
- The resolution of particle position reconstruction in radial direction of the sensor with logarithmic weighting algorithm for 5 GeV electrons is 0.36 mm (MC) and 0.44 mm (Data). The difference is explained by misalignment of sensitive layers (need more time with cosmic muons)
- Future (2019):
  - Construction of a prototype with 18-20 layers : tungsten provided by Dubna and new test system provided by CERN (thanks to Eva) as the carbon envelop (thanks to Konrad)
  - Final electronic will be tested