

Simulation of the LHCb Electromagnetic Calorimeter response with GEANT4

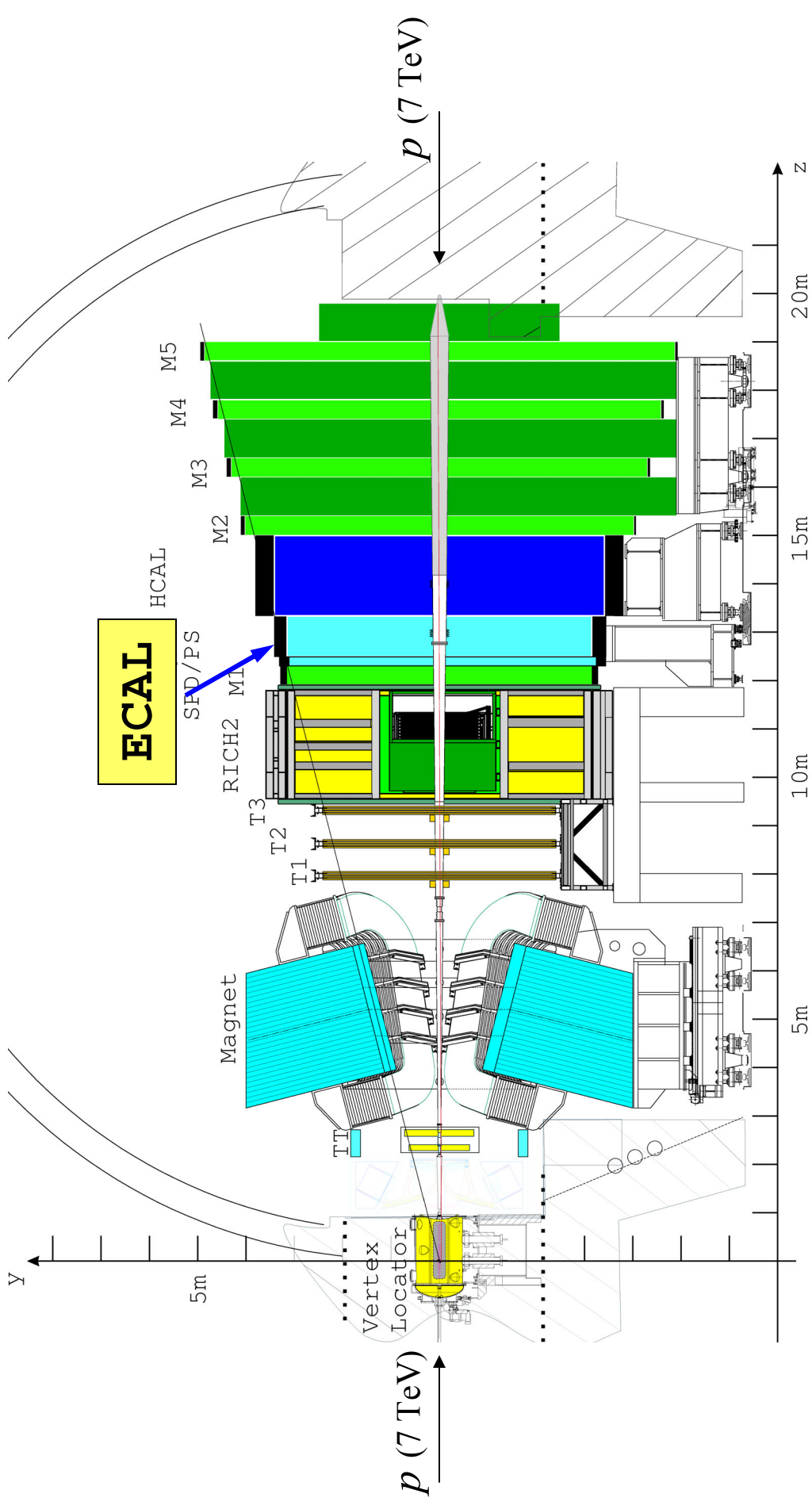
Patrick Robbe (LAL Orsay) for the LHCb Calorimeter Group, 5 May 2004



Outline

- Principles and setup of the LHCb ECAL Simulation
- Specific LHCb ECAL Implementations
- Comparison with test beam data

The LHCb Detector



Precision B physics experiment at LHC

The LHCb Electromagnetic Calorimeter (ECAL)

- Lead – Scintillator shashlik detector
 - Light collected by WLS fibers
 - Readout by PMT at the back of the detector
- Provides fast information for trigger (high p_T γ , e , π^0)
- Reconstruction of B hadrons with neutral final states
($B^0 \rightarrow K^{*0} \gamma$, $B^0 \rightarrow \pi^+ \pi^- \pi^0$, ...))
- Identification of e^\pm (for reconstruction, tagging, ...)

ECAL Simulation with GEANT4

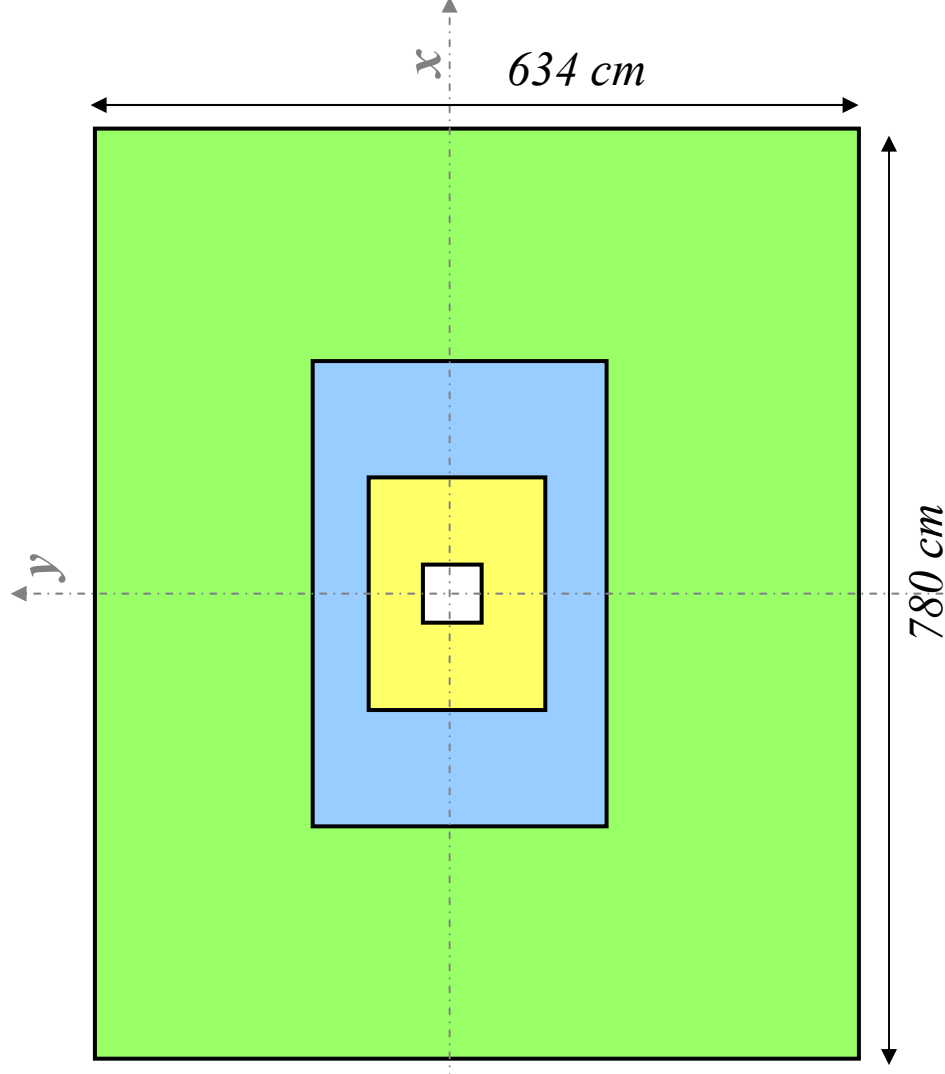
- Simulation of detector response is based on **GEANT4** and ECAL simulation is integrated into the entire LHCb simulation software.
- **General framework:**
 - **Primary particles** (produced by Pythia for the p-p collisions, EvtGen for B decays and from background) are given to GEANT4 for processing.
 - GEANT4 is set up with:
 - specific **LHCb geometry** and **material description**
 - **specific actions** to simulate ECAL behaviour
- **Execution speed** is an issue

Geometry Setup

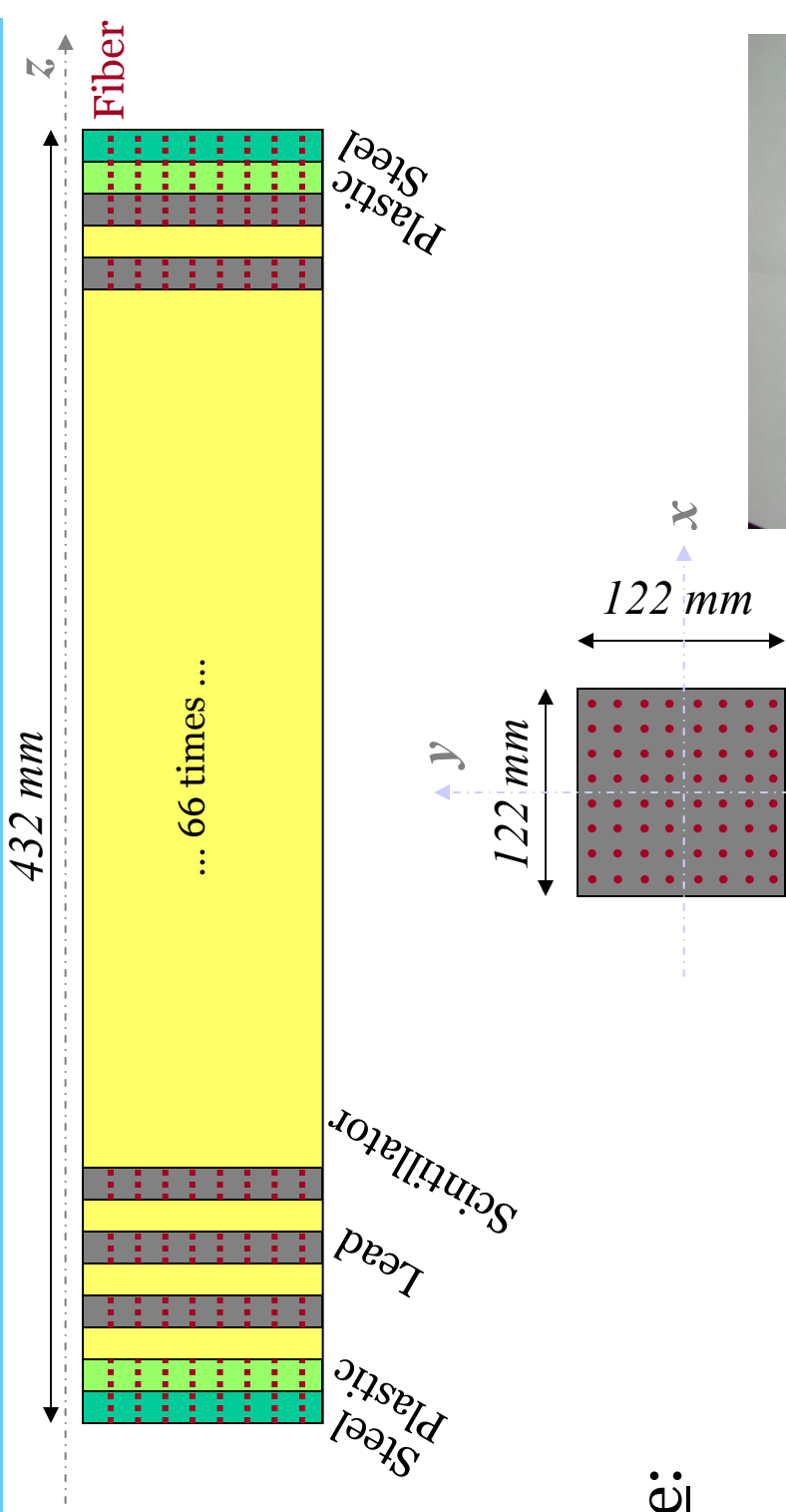
Outer ECAL: 2688 cells
(12 cm × 12 cm)

Middle ECAL: 1792 cells
(6 cm × 6 cm)

Inner ECAL: 1584 cells
(4 cm × 4 cm)



ECAL Outer Module

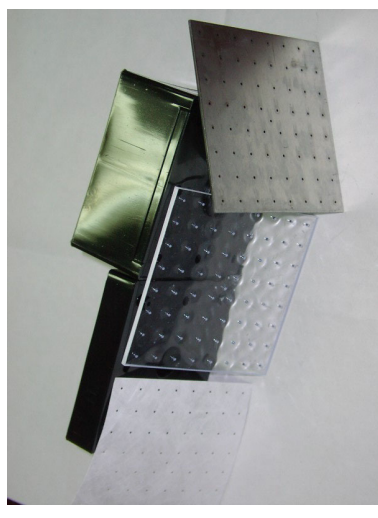


- Stack:

- Lead Tile:

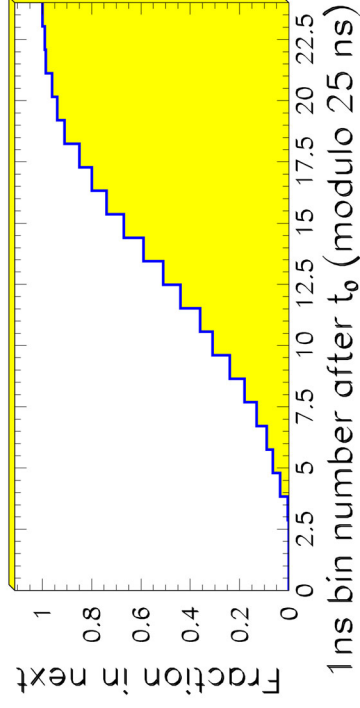
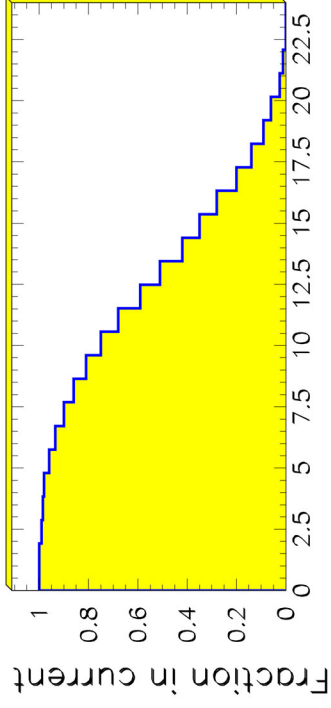
• Detailed and optimized geometry (for example, no fiber in Scintillator, but they are the same material)

- Active material is **Scintillator Tile**

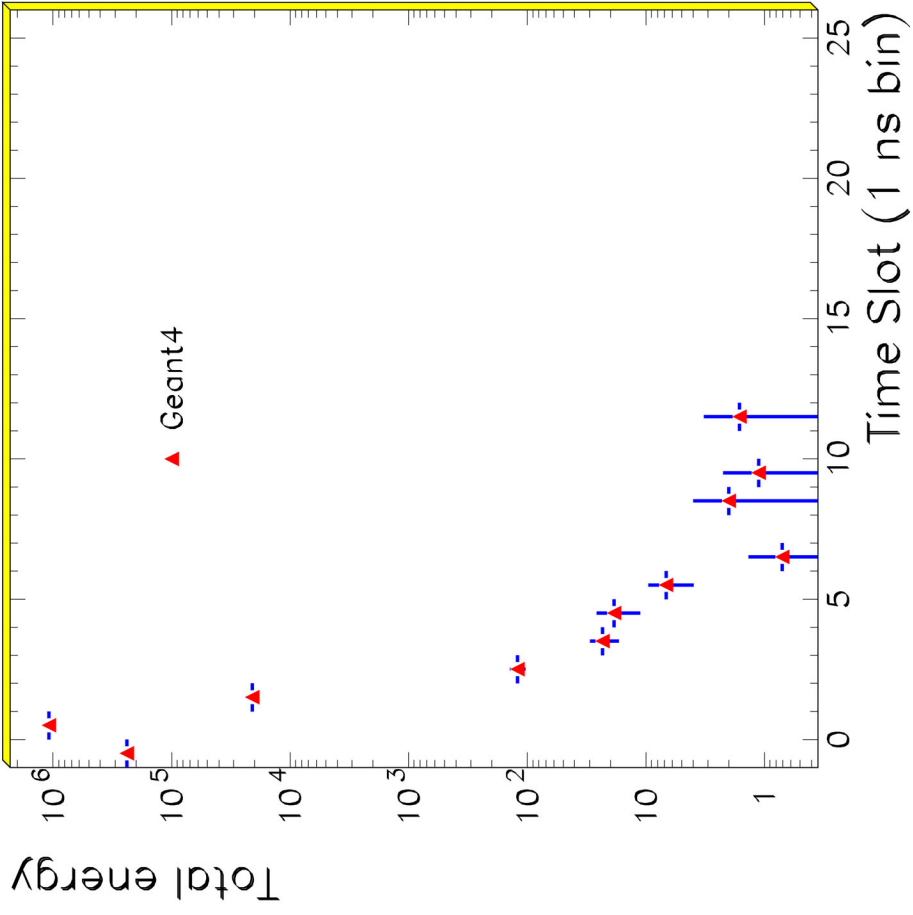


Timing (1)

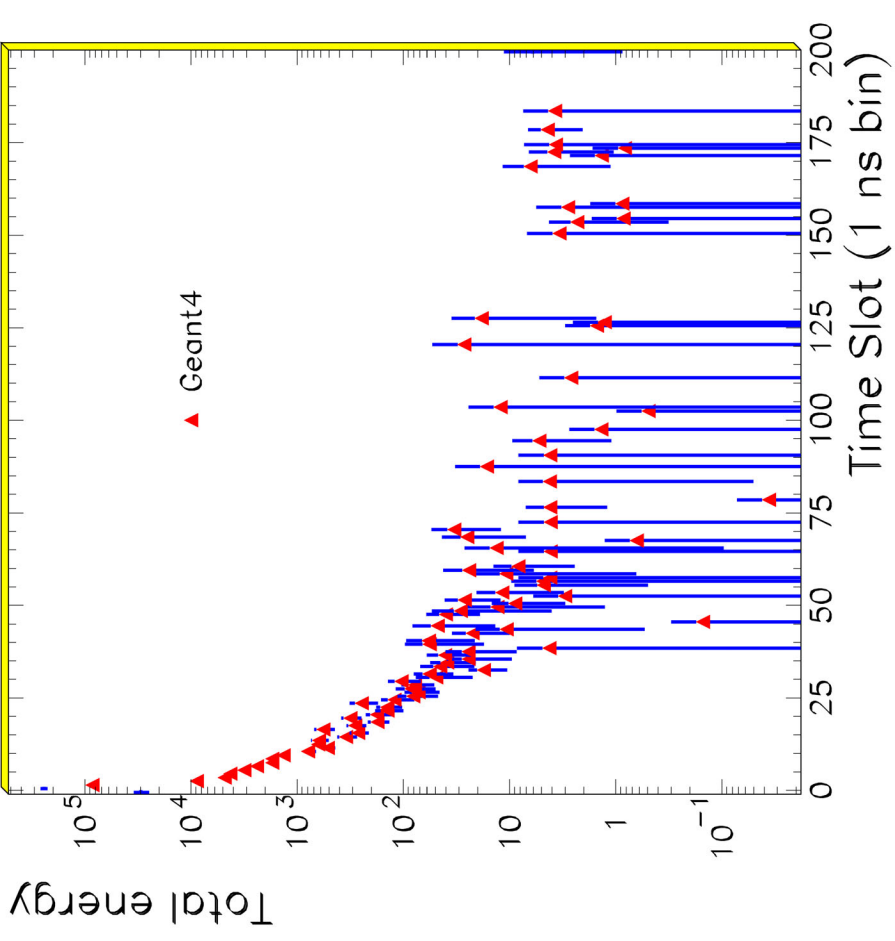
- Specific ECAL implementation
- Share each energy deposition in **two consecutive 25 ns time bins**, according to test beam measurements.
- Simulates signal integration by electronics chain.
- t_0 = time of arrival of photons at the z position of the maximum of the shower *ie* 11 cm after ECAL front surface.



Timing (2)



photons



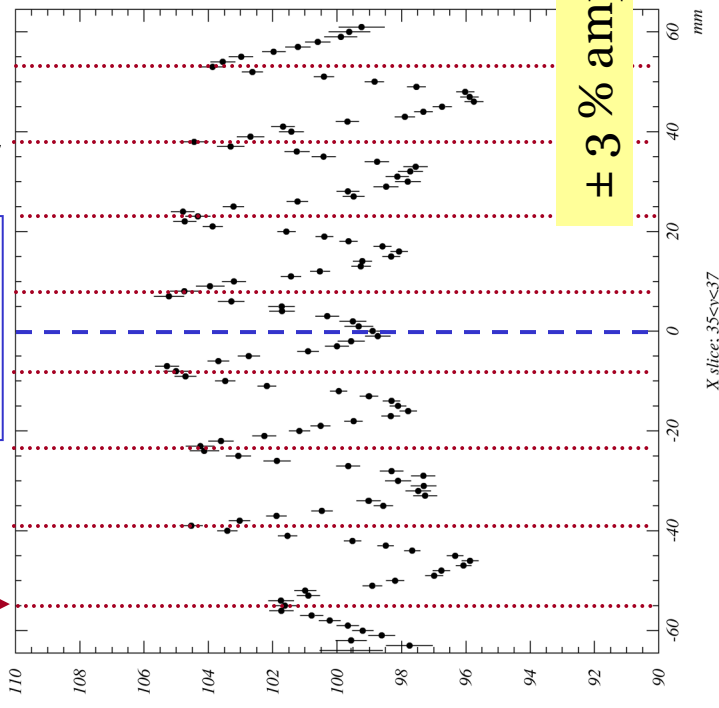
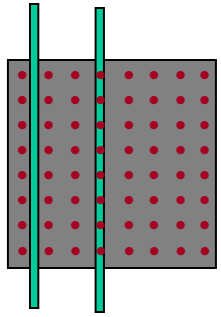
pions

Non Uniformities – Muon Test Beam

Scan with muons perpendicular to ECAL cell

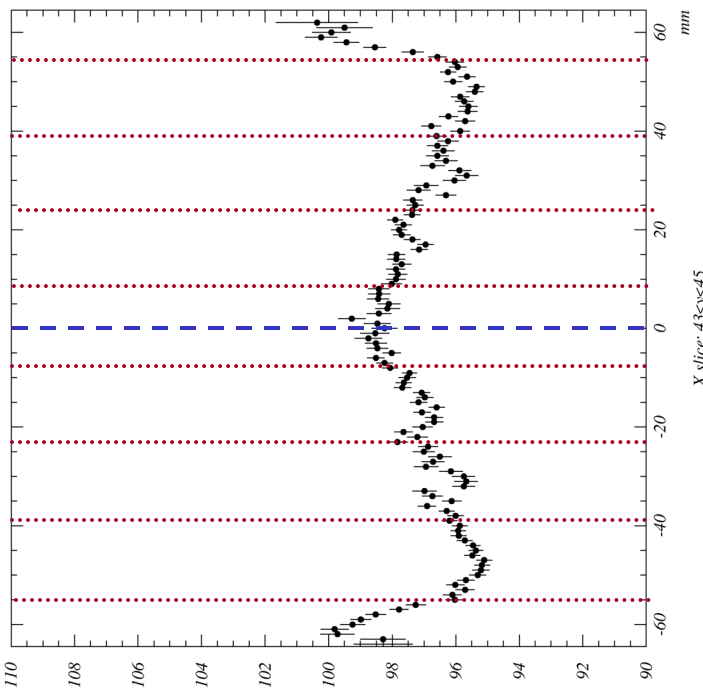
Fiber positions

Cell Center



X slice: $35 < y < 37$

Slice in a fiber row



X slice: $43 < y < 45$

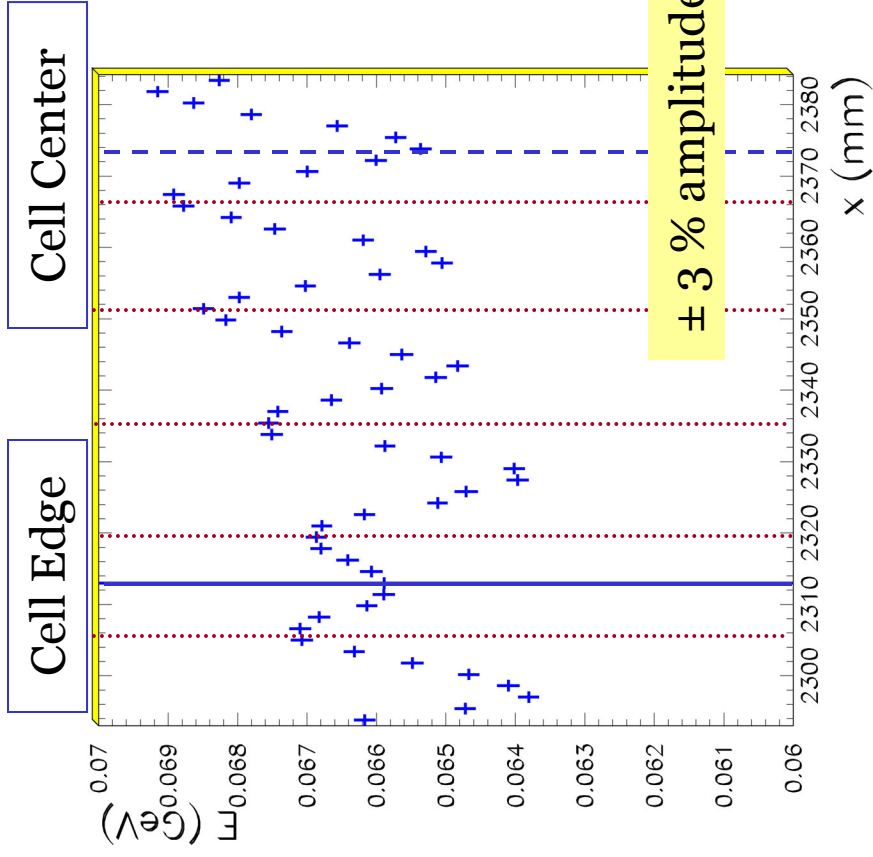
Slice between 2 fiber rows

Non Uniformities – Simulation

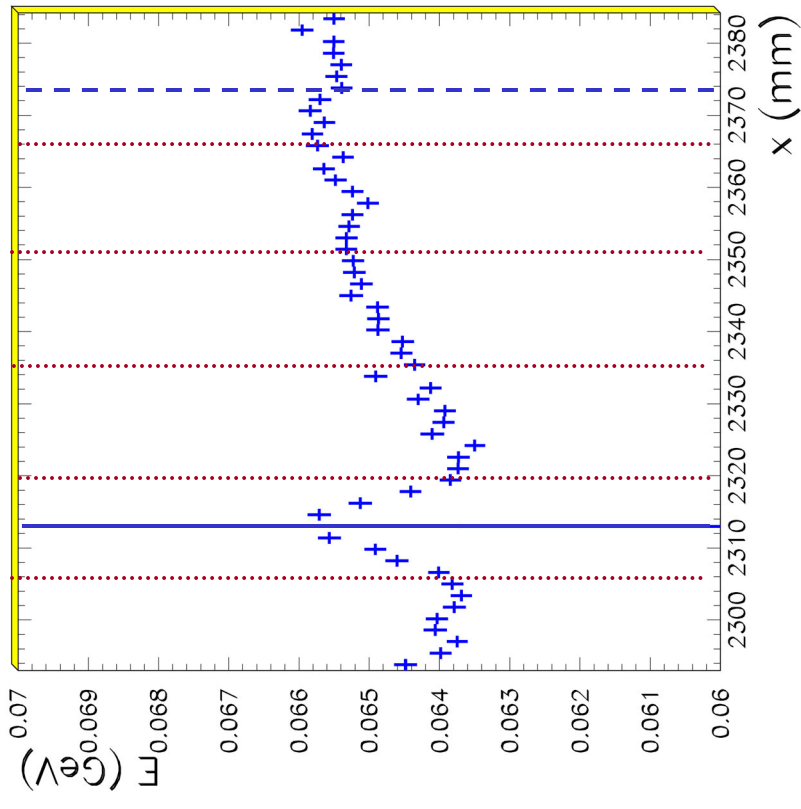
- 3 different components:
 - **Local Non Uniformity:**
 - $A \times (1 - \cos 2\pi(x-x_0)/d) \times (1 - \cos 2\pi(y-y_0)/d)$
 - (x_0, y_0) = center of the cell
 - d = distance between fibers
 - **Global Non Uniformity:**
 - $B \times (x-x_0+L/2)^2 \times (y-y_0+L/2)^2$
 - L = cell size
 - **Reflection on the edges of the tile (for one side):**
 - $C \times \exp(-|x-x_0+L/2|/D)$

Non Uniformities – Muon Simulation

Scan with muons perpendicular to ECAL cell



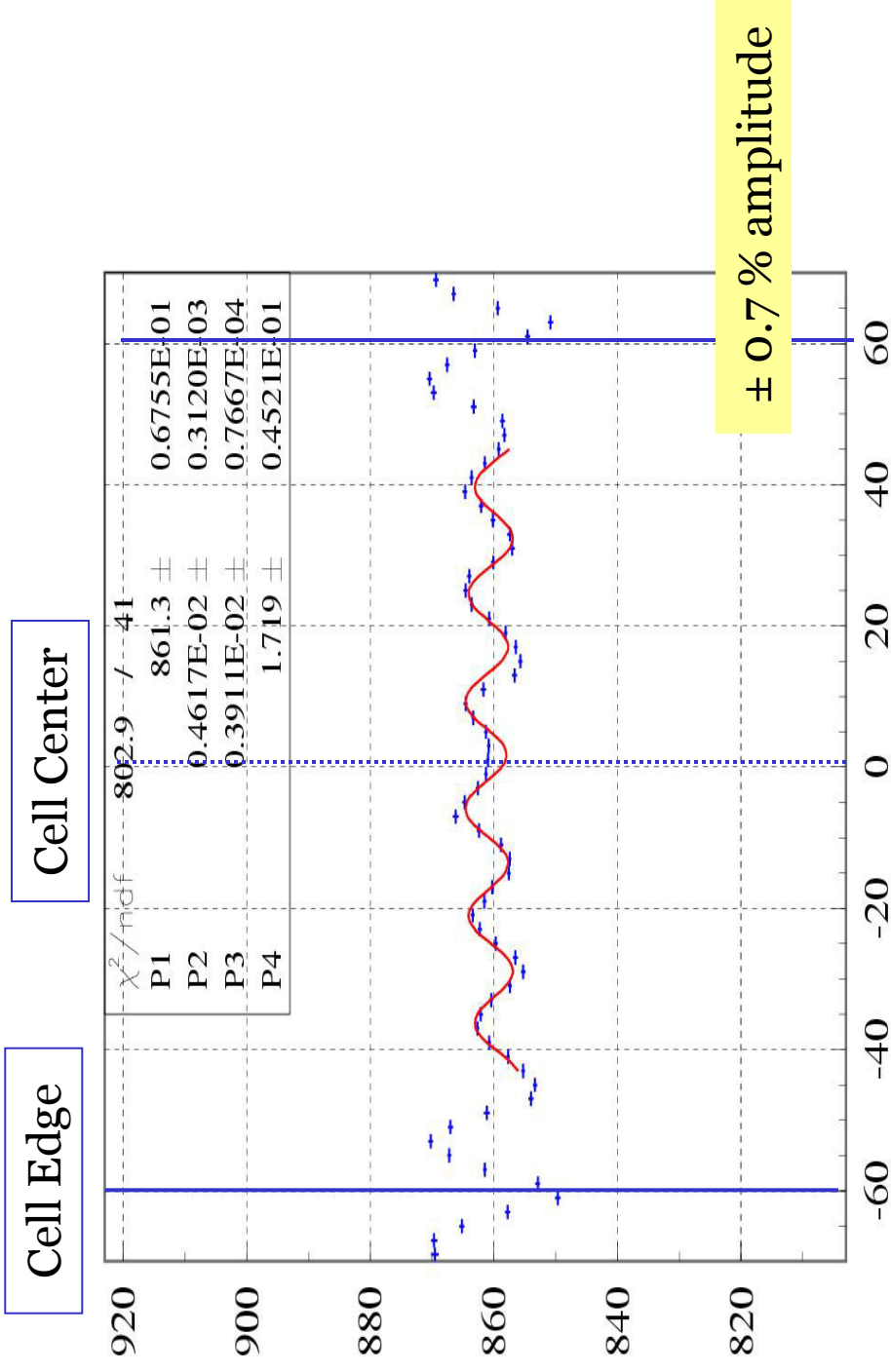
Slice in a fiber row



Slice between 2
fiber rows

Non Uniformities – Electron Test Beam

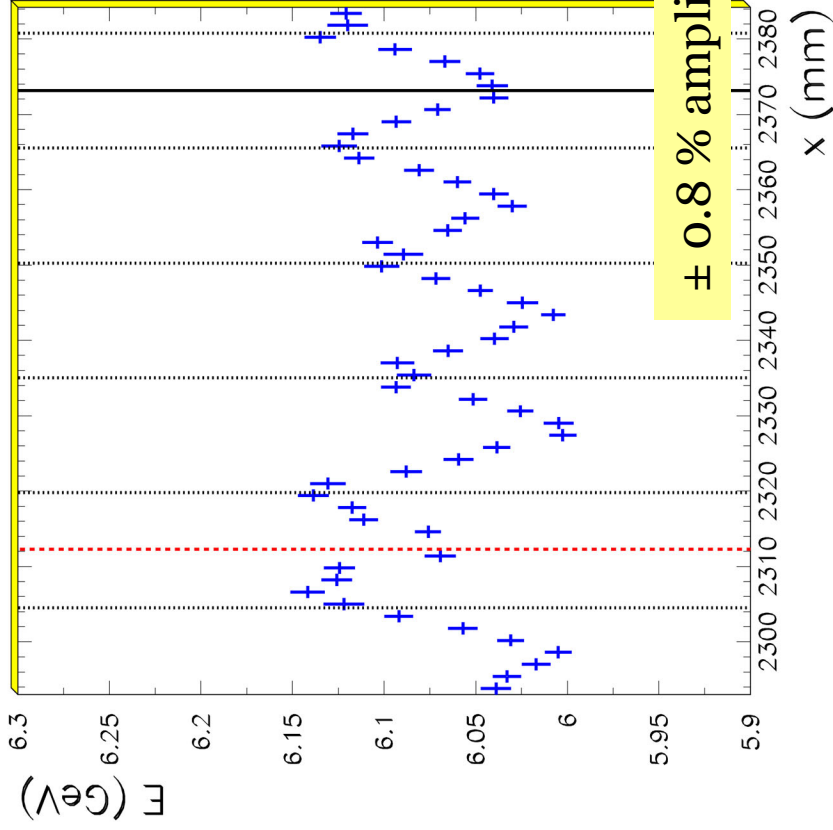
Scan with 50 GeV electrons perpendicular to ECAL cell



Preliminary results

Non Uniformities – Electron Simulation

Scan with 50 GeV electrons perpendicular to ECAL cell

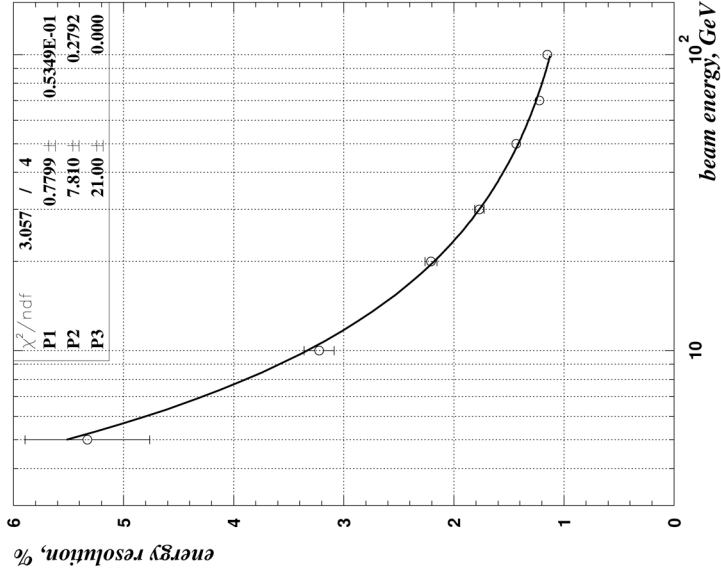


- Preliminary results
- Parameters that reproduce muon test beam data do not reproduce electron test beam data (factor 2 between them)
- This will be studied in more details (including other cell size of ECAL) with test beam this summer

Resolution – Test Beam

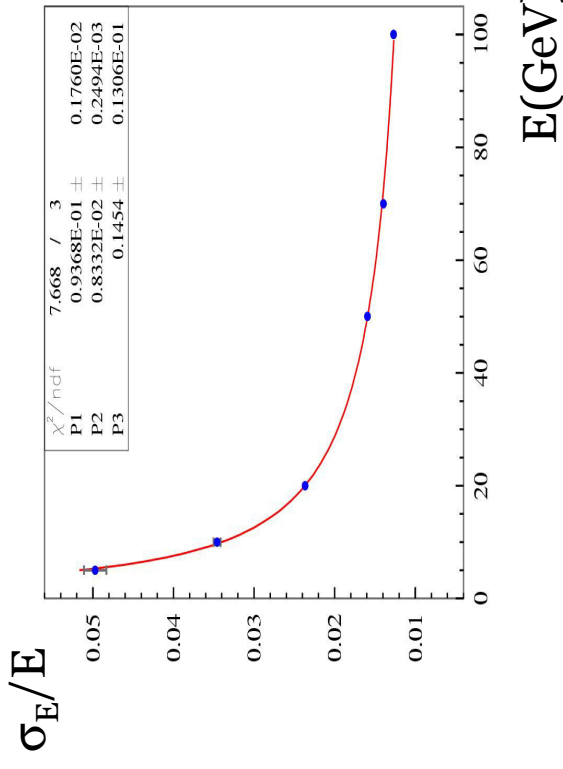
Electrons perpendicular to the module

Middle Module



$$\sigma_E/E = (7.8 \pm 0.3)\%/E^{0.5} \oplus (0.78 \pm 0.05)\%$$

Outer Module

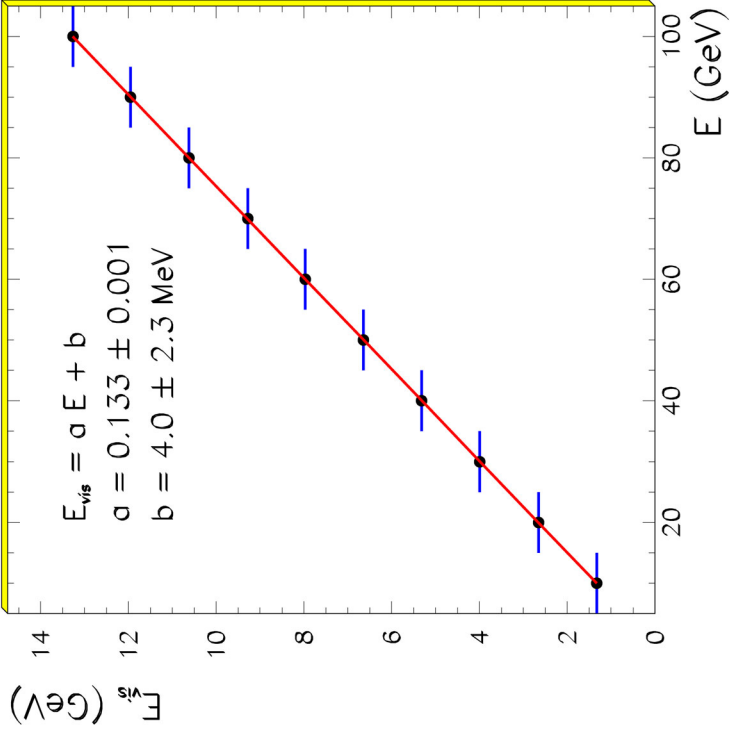


$$\sigma_E/E = (9.4 \pm 0.4)\%/E^{0.5} \oplus (0.83 \pm 0.02)\%$$

Resolution – Simulation

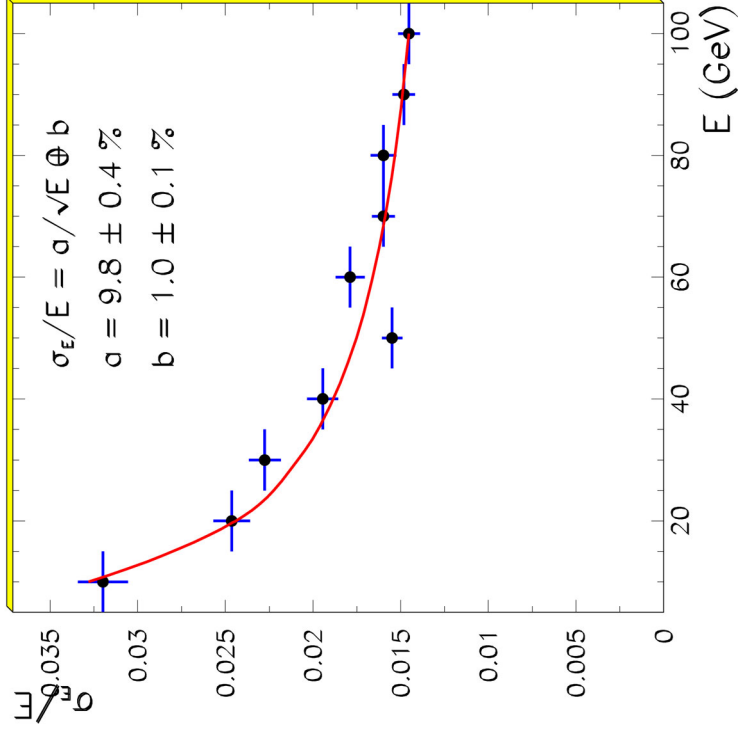
Electrons perpendicular to one Outer Module

Linearity



Active / Total = 7.5 ± 0.1

Resolution



$\sigma_E/E = (9.8 \pm 0.4)\%/E^{0.5} \oplus (1.0 \pm 0.1)\%$

Conclusions

- LHCb simulation software contains a realistic simulation of ECAL detector.
- Timing and non uniformities are taken into account in the simulation.
- For non uniformities, more detailed studies with new test beam data will be performed in the near future.