Simulation of the LHCb Electromagnetic Calorimeter response with GEANT4

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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 $p_T \gamma, e, \pi^0$)
- **Reconstruction** of B hadrons with neutral final states ($B^0 \rightarrow K^{*0} \gamma, B^0 \rightarrow \pi^+ \pi^- \pi^0, \dots$)
- **Identification** of e (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 ($12\text{ cm} \times 12\text{ cm}$)

Middle ECAL: 1792 cells ($6\text{ cm} \times 6\text{ cm}$)

Inner ECAL: 1584 cells ($4\text{ cm} \times 4\text{ cm}$)

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

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

± 0.8 % amplitude

- 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

Outer
Module

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

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

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.