New ECAL implementation in Muon Collider simulation and performance study

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Introduction

• Do we have solutions alternative to the W-Si sampling calorimeter (CLIC CDR) for ECAL barrel?

• New idea: Crilin (crystal calorimeter with longitudinal information) -> a semi-homogeneous crystal calorimeter (PbF$_2$), where Cherenkov light is read by SiPMs.

• PbF$_2$ has good light yield (3 pe/MeV), fast signal (300 ps for muons, 50 ps for pions), radiation hard, relatively cheap.

• Five layers (40 mm thick), 10 x 10 mm$^2$ of cell area.

• Real cell prototype has been built at the National Laboratory of Frascati.

• In this talk: the full simulation is used to assess the performance of the new ECAL.
Implementation in DD4HEP

- The new ECAL barrel (Crilin) has been implemented in the Muon Collider simulation framework.
- As for the other detectors, the implementation is done with the DD4HEP interface to Geant4.
- 5 layers of 40 mm length, 10 X 10 mm$^2$ cell area. Dodecahedra geometry.

Elementary cell definition in DD4HEP
Timing

- Full simulation of the signal (H→bb) and beam-induced background in the detector with Crilin as ECAL barrel has been performed at 1.5 TeV.
- Timing is crucial to remove most of the beam-induced background.
- An acquisition time window of [-250,+250] ps wrt bunch crossing is applied. It is achievable with a time resolution of about 80 ps (window ≈ 3σ).
Longitudinal hit distribution

- The longitudinal measurement can be an important information for distinguish signal from background.
- This is evident in the 5 Crilin layers: the BIB leaves most of the hits in the first layer, on the other hand the signal is more uniform in all the 5 layers.
The forward region with $|z|>500$ mm and the central region with $|z|<500$ mm show different occupancies.

BIB hit distribution in the layer planes
Hit energy distribution: forward region

The hit energy distribution is different in the 5 layers (longitudinal information is important!)

- Thresholds on the hit energy are set as a function of the layer and of the region (forward or central).
- Thresholds are obtained as $E_{TH} = E_{BIB} + 2\sigma_{BIB}$, where $E_{BIB}$ is the average energy of the BIB distribution, and $\sigma_{BIB}$ is the standard deviation.
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Jet reconstruction performance

- The jet performance obtained with Crilin is compared with the one obtained with the W-Si ECAL barrel from the CLIC design report. A particle flow algorithm is used for the jet reconstruction (combined information from tracker and calorimeters).

- The performance obtained with Crilin is at the same level of W-Si (but the money cost of Crilin is a factor 10 less!)

- Notice that there are still many rooms for optimization, therefore these performance can be improved in the future.
Conclusions

• The performance of the jet reconstruction with Crilin as ECAL Barrel is at the same level of that obtained with the CLIC W-Si calorimeter.

• Even if the segmentation of the W-Si calorimeter is higher than Crilin, the BIB is a limiting factor, therefore the high segmentation is not really necessary. It is also true that Crilin can measure more precisely the energy (semi-homogeneous).

• There are still many rooms for improving the study: implement the lateral dead material around the cells (cables etc. but not present even in CLIC simulation), implement a better digitization model.

• The study should be also repeated when a better version of the reconstruction will be available.

• The flexibility of DD4HEP allows to easily implement new detectors in the Muon Collider framework.

• The full simulation is an excellent way to test the performance of a new detector.
Thanks for your attention!
Backup
Thresholds

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- Thresholds are obtained as $E_{TH} = E_{BIB} + 2\sigma_{BIB}$, where $E_{BIB}$ is the average energy of the BIB distribution, and $\sigma_{BIB}$ is the standard deviation.

- In the future more sophisticated algorithm to set the energy threshold will be applied (e.g. SoftKiller).

- Thresholds varies from 50 to 100 MeV.

- Clustering is performed with hits that have passed the threshold, using the PandoraPF algorithm. **ECAL endcaps are not used in this reconstruction.**
Full jet reconstruction algorithm

- The jet reconstruction algorithm used in previous studies is applied.
- It is a particle flow algorithm that combines information from tracker and calorimeters (ECAL + HCAL).

**Step 1:** calorimeter jet reconstruction with PandoraPFA and kt (R=0.5)

**Step 2:** regional tracking in cones (R=0.7) defined by the calorimeter jet directions

**Step 3:** final jet clustering using calorimeter clusters and tracks with PandoraPFA and kt (R=0.5)