Pion-rejection studies with a CMS HGCAL test-beam prototype EM calorimeter

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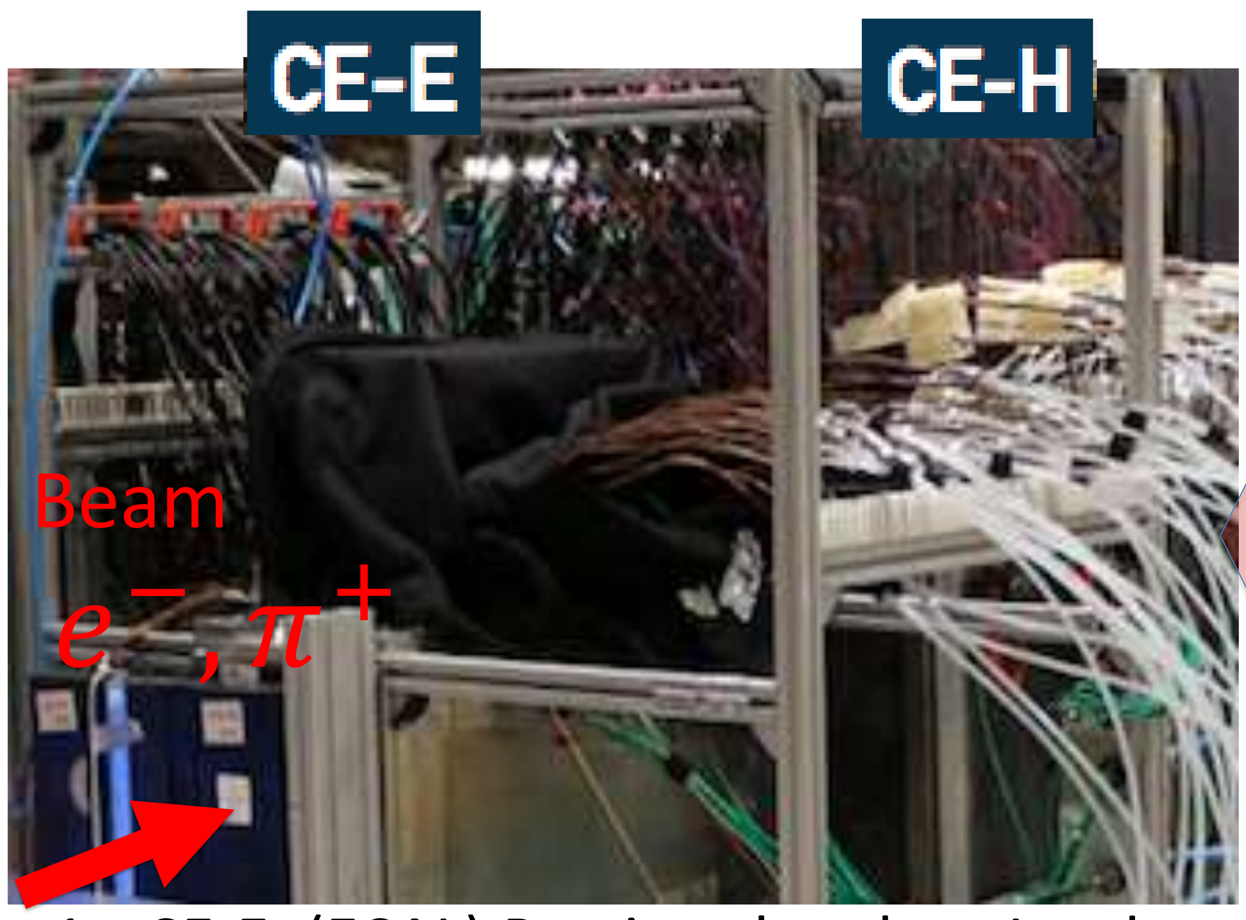
Introduction

The CMS experiment at LHC will replace the current Endcap calorimeter with a Si-pad High Granularity Calorimeter (HGCAL), a new generation state-of-the-art calorimeter, which can perform 3D imaging of the shower as well as provide ~30ps timing resolution. Charged-pion tagging and rejection are one of the strong points of HGCAL. Our main result is that HGCAL can provide a powerful discrimination between such pions that start showering after traveling a distance as Minimum Ionizing Particles inside the calorimeter, and incident electrons. This discrimination is achieved by introducing simple longitudinal shower variables.



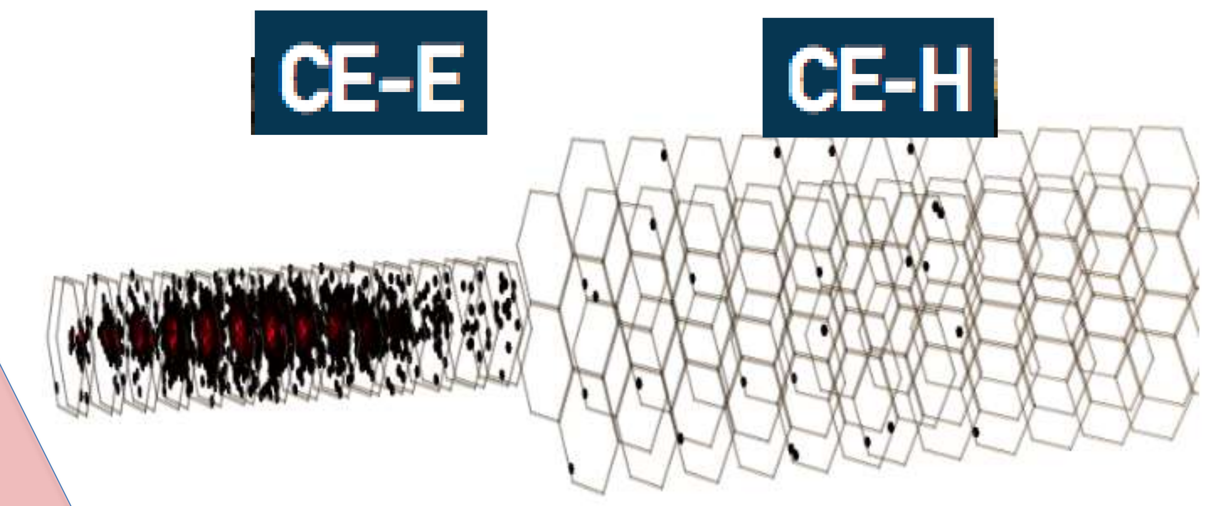
1. CE-E: (ECAL) Passive absorber: Lead
2. CE-H: (HCAL) Passive absorber: Steel
3. Active layer for both: silicon

Motivation

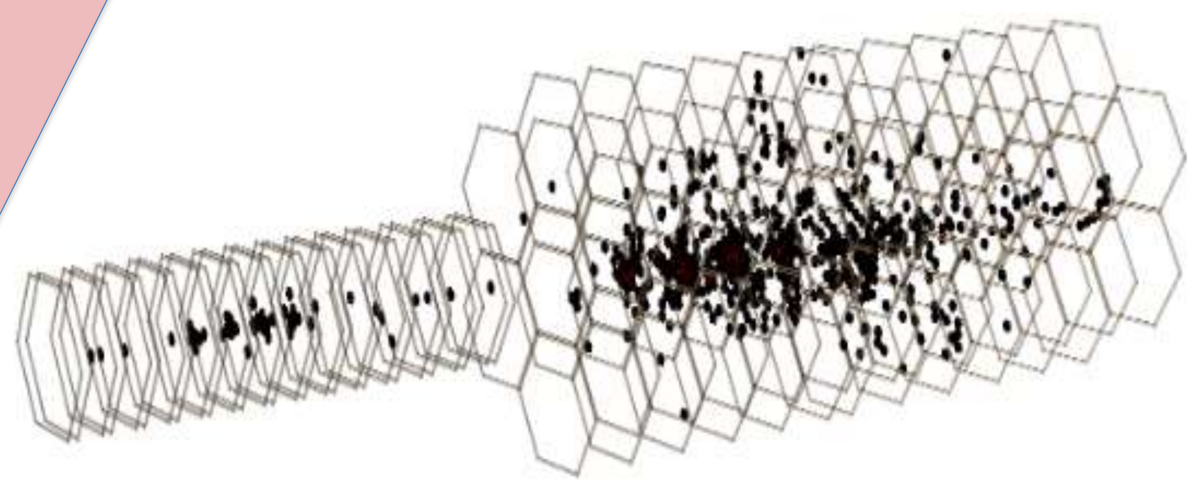
Exploit the fine granularity of HGCAL to reject pions that leave most of their energy in ECAL:

- They cannot be removed by energy leakage cut in the HADRONIC calorimeter
- They cannot be rejected by tight electron selection.

Here we use the longitudinal segmentation of HGCAL to reject some of these pions.



Normal Electron

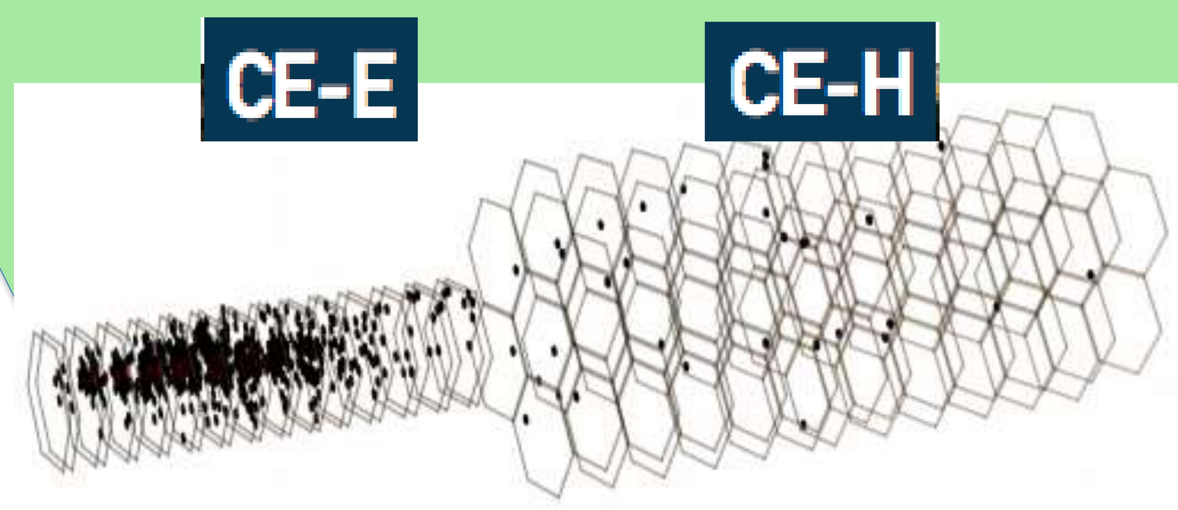


Normal Pion

e-like Pions(1)

- Early EM showering:

$\frac{E_{10}}{E_{total}}$ is similar to electrons, most of energy in the front detector, can't be distinguished from the electrons.

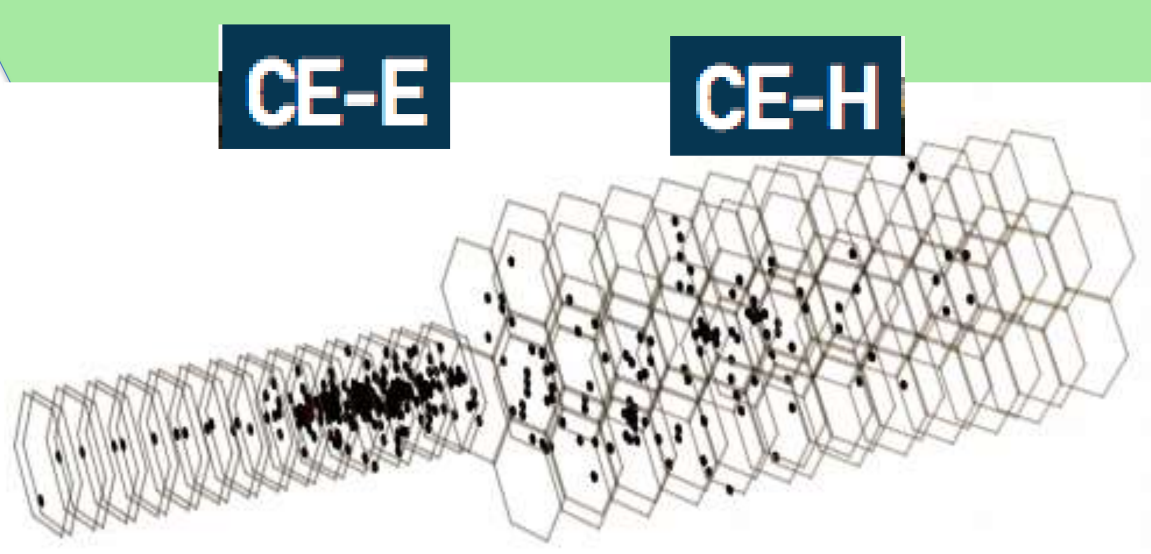


$$\frac{E_{first\ 10\ layers}}{E_{total}} = \frac{E_{10}}{E_{total}}$$

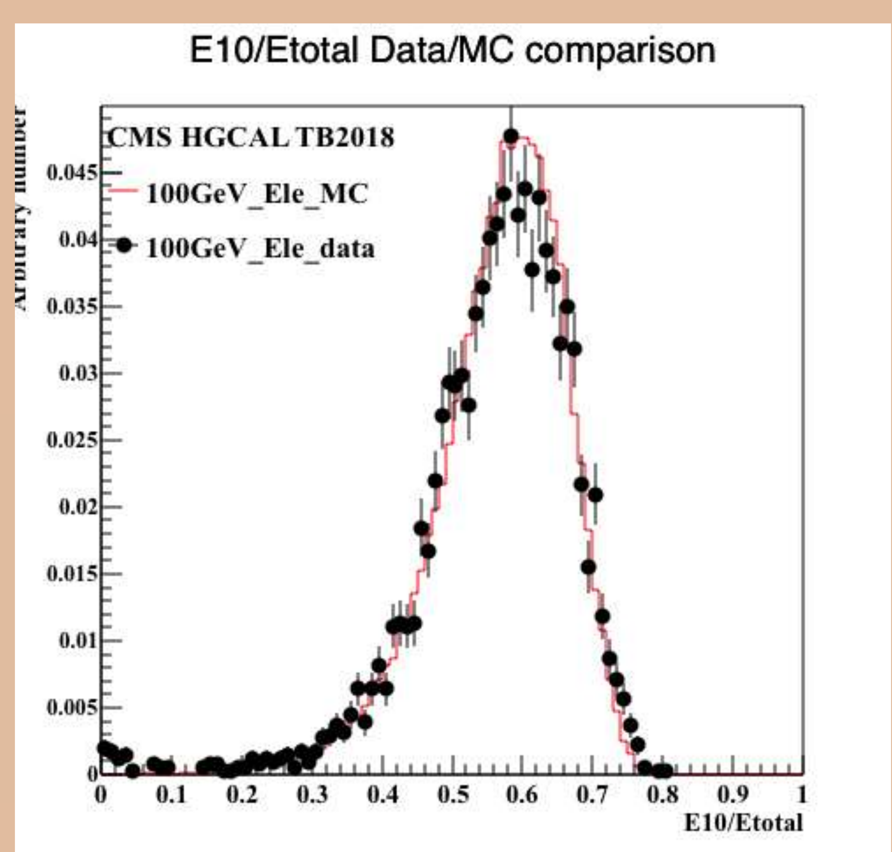
e-like Pions(2)

- Late EM showering :

Pions travel as MIPs for a few layers and then shower. Therefore, the energy fraction in the front of the calorimeter is small. We require at least ~20% of energy be deposited in the first 10 layers



Discriminant variable



Data/MC comparison for $\frac{E_{10}}{E_{total}}$

Results

We used the MC sample from October test beam. After tight electron selection with a pion rejection factor of 3600, we apply an additional selection using our proposed discriminating variable.

Our goal is to achieve a very high efficiency at the level of 99.9% for a significant pion rejection. The results are shown below.

Efficiency = $\frac{pass}{total}$ Rejection= $\frac{total}{pass}$

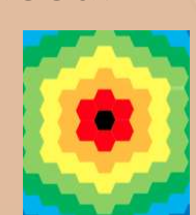
E10/Etotal cut	Signal Efficiency
> 0.18	99.56%+/-0.01%(syst)+/-0.20%(stat)
> 0.20	99.05%+/-0.01%(syst)+/-0.20%(stat)
> 0.22	98.91%+/-0.01%(syst)+/-0.20%(stat)

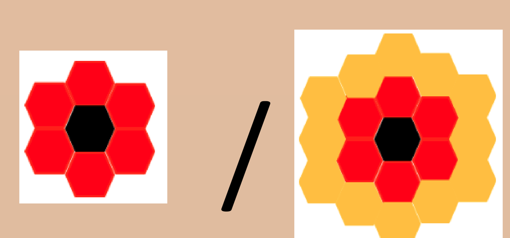
E10/Etotal cut	Background Rejection
> 0.18	1.52+/-0.27(stat)
> 0.20	1.53+/-0.26(stat)
> 0.22	1.56+/-0.24(stat)

Event selection

1. EM Shower Containment Cuts

a. [Energy in five rings/ Total energy] need. to bigger than 99%



b.  > 0.85

2. Energy Leakage to the Hadronic Calorimeter Cut

No more than 0.4% energy fraction in the Hadronic Part.

After this selection, we can tag "e-like pions"

Conclusion

A pion rejection of 1.5 is achieved for a 99.6+/-0.2% electron efficiency. This discriminant can be used by analyses in which pion induced backgrounds are very high.

References

[1]First beam tests of prototype silicon modules for the CMS High Granularity Endcap Calorimeter, N. Akchurin et al., ***JINST 13 (2018) no.10.***