Object Reconstruction in Non-Pointing Geometry

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Non-Pointing Geometry

Fibers and towers run parallel to beam axis.

The calorimeter covers $1.5 < \mid \eta \mid < 4$

Signal in fibers is readout at the back of the calorimeter.

One signal for Q and one signal for S in each tower.

A 5 GHz (or more) sampler provides depth segmentation based on time structure of Q signal.

Brass absorber structure, 2 mm fiber spacing (between Q and S), 2x2 cm$^2$ transverse segmentation.
Transverse Shower Shapes
Based on the transverse shower shape and Q/S, reasonable e/gamma background rejection can be achieved.

Ratio: E(7x2)/E(10x42)

A conservative approach was taken to estimate performance at the L1 trigger level (40 MHz).

Longitudinal segmentation based on time slicing is not included at the level but will be used offline.
The amount of pileup present in clusters increases at higher pseudo-rapidities.

Transverse shower shapes remain a good observable for background rejection.

Improvements have been suggested to FE electronics (TDC, 80MHz sampling) to add more handles at this level.
Using only transverse shower shape and Q/S, the non-pointing geometry achieves similar background rejection to the pointing case. Cluster sizes and shapes have not been rigorously optimized in the case.
The offline PID takes into account the time measurements of the Q signals.

For a fixed signal efficiency (80%) the charged pion rejection is ~99 %.
A particle impacts from left and shower propagates to the right at the speed of c whereas the Cherenkov light travels to the right slower at $c/n_{\text{eff}}$. The deeper part of the shower signal reaches the photo-sensors on the right first.
The position is determined from the location of the shower at the face of the detector. Showers that develop deeper in the absorber contribute a small tail in the resolution resulting from the incorrect position. This tail can be corrected by taking the time into account.
Time Slicing

- **e- 100 GeV, 0 PU**
  - Back (early)
  - Front (late)

- **e- 100 GeV, 140 PU**
  - Back (early)
  - Front (late)

- **pi- 100 GeV, 0 PU**
  - Back
  - Front

- **pi- 100 GeV, 140 PU**
  - Back
  - Front

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Cowden - Non-Pointing Reconstruction
Electron mean time resolution scales with $E^{-1/2}$ and can be parametrized as above.
Arrival Times of Photons (Cherenkov Photons)

Photon arrival time from pion decreases with increasing energy.

Time resolution of photons arriving from pion showers is ~300 ps.

Time resolution of photons arriving from electron showers is ~20-30 ps.

First photon from electron showers goes like log(E)
Pulse Shape Analysis

Signal propagates in fibers via several helical modes.

The effective index of refraction shows a long tail because of the slow propagation.

Optically these modes could be controlled to some degree by numeric aperture and light guide interface.
Conclusions

A fine transverse segmentation (for both EM and hadronic) in the proposed CFC provides a good object identification and background rejection, even in the HL-LHC environment.

Advances in FE electronics allows more powerful L1 discriminants which can improve the estimated performance.

The inclusion of pulse shape analysis in offline reconstruction further improves the capabilities of the detector.

This approach makes possible 3D energy reconstruction in such a device.

Thank You