Two Particle Separation with tile HCAL

V. Morgunov, A. Raspereza

DESY

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Particle Flow Concept

- P-flow concept: attempt to reconstruct every single particle in event
- Tracker information $\rightarrow$ 4P vectors of charged objects
- Ecal $\rightarrow$ 4P vectors of photons
- Ecal + HCal $\rightarrow$ 4P vectors of neutral hadrons (contain ~ 14% of jet energy)
- Efficient separation of neutral and charged objects is an issue $\rightarrow$ highly granulated calorimeters are required
Simulation
(Set up and Goals of Study)

- **Goals**
  - Develop shower reconstruction/separation procedure
  - Investigate shower separation capability of algorithm in dependence of calorimeter granularity, distance between showers, particle energies

- **Simulation setup (closely follows envisaged prototype geometry)**
  - 40 layers of ECAL
    - layers 1-30 : 1.4mm W, 1mm G10, 0.5mm Si, 1mm G10
    - layers 31-40 : 4.2mm W, 1mm G10, 0.5mm Si, 1mm G10
  - 40 layers of tile HCAL (analog)
    - each layer : 20mm Fe, 5mm Scintillator

- **Studied tile size options / readout schemes :**
  - 1x1cm² x 1lay, 3x3cm² x 1lay, 3x3cm² x 2lay, 5x5 cm² x 1lay

- Simulation is done with GEANT3, FLUKA+MICAP
Reconstruction
Step #1 : Clustering

Two steps of reconstruction
1. Clustering
2. Shower building

- Clusters : structures inside shower
- Hits are classified into 3 categories:
  - MIP : hits from single tracks
  - EM : high density hits
  - HAD : hits produced by group of close-by tracks in vicinity of nuclear interaction
- Clustering is performed separately on each category (clustering algorithm from V. Morgunov)
- Fourth hit category after clustering:
  - Neutron hits (spatially separated from reconstructed clusters)

![Graph showing hit spectrum](image-url)
Clustering (Event Displays)

CLUSTERS: MIP EM HAD NEUT

π+, 5 GeV
Step #2: Shower Reconstruction

- Shower – tree of HAD and EM clusters topologically connected by tracks (MIP clusters) + initiated by neutrons (spatially disconnected from tree) hits/clusters
- Track reconstructed with tracking system seeds shower: find starting cluster (cluster closest to track intersection point with ECAL front plane)
- Reconstruction of total shower by collecting clusters into tree and adding close neutron hits/clusters (iterative procedure: parameters governing shower reconstruction are iteratively adjusted till $E_{\text{shower}}$ fits best $P_{\text{track}}$) → algorithm is self-adaptive to HCAL segmentation
- Remaining clusters/hits are assigned to neutral objects
- Initial study: analysis of simple situation of two close by showers (neutral and charged)
Two showers from 5GeV $\pi^+$ and 5GeV $K^0$
Distance – 15cm
Shower Separation

Criterion to estimate performance:
Energy spectrum of neutral shower as a function of
distance between initial particles and HCAL tile size

Distance between particles

15 cm 10 cm 7 cm
Definition of Shower Separation Quality

Separation quality = fraction of events in which reconstructed energy of neutral shower lies in the range $E_{\text{true}} +/\!- 3\sigma$, $\sigma$ – nominal energy resolution of neutral shower (no close by shower)
Separation Quality vs Transversal and Longitudinal Segmentation

**HCAL only**

- 1x1x1
- 3x3x1
- 5x5x1
- 3x3x2

**ECAL+HCAL**

- 1x1x1
- 3x3x1
- 5x5x1
- 3x3x2

Distance between showers [cm]
Energy Dependence of Shower Separation Quality

Two showers: $\pi^+, K_L^0$

- $E_{\pi} = 2\text{GeV}$
- $E_{\pi} = 5\text{GeV}$
- $E_{\pi} = 10\text{GeV}$

$E_{K_L} = 10\text{GeV}$
Distance = 10 cm
1x1x1

Fraction of events/1 GeV

Energy of Neutral Shower [GeV]
Algorithm of shower separation / reconstruction is being developed within DESY CALO group.

First results showed that reconstruction quality is sensitive to transversal and longitudinal segmentation of tile HCAL.

Quality of reconstruction gets worse with increasing tile size and going to readout scheme when layers are joined in depth.

Further development/tuning of algorithm and more detailed study are planned (from simple two particle case to realistic jets).