Track Extrapolation/Shower Reconstruction in a Digital HCAL - ANL Approach

1st step - Track extrapolation thru Cal
- substitute for Cal cells in road (core + tuned outlyers)
- analog* or digital techniques in HCAL - S. Magill
- Cal granularity/segmentation optimized for separation of charged/neutral clusters

2nd step - Photon finder (use analytic long./trans. energy profiles, ECAL shower max, etc.) - S. Kuhlmann

3rd step - Jet Algorithm on tracks and photons - Done

4th step - include remaining Cal cells (neutral hadron energy) in jet (cone?) -> Digital HCAL?

* V. Morgunov, CALOR2002
Density-Weighted CAL Cells

Area ~ 40 cells

So far, 2D density (each layer)

Cell density weight = 3/40

Study with single 10 GeV pions

Why 40 cells?

E-weight: analog cal
D-weight: digital cal

Red - E fraction for density > 1/#
Blue - E fraction outside .04 cone
D-Weights ECAL Interaction Layer 20, Theta, Phi

Gaussian fits
D-Weights HCAL Interaction Layer 10, Theta, Phi

Gaussian fits
Density vs E - ECAL
Density vs E - HCAL

Cell Density vs Cell Energy (H)

- MIP signal - 36 MeV

- What's this?
Mokka, impact of the gas in HCAL
HCAL E fraction, E_{cell} > 1 MIP

Importance of threshold level

-> need to vary in test beam for scintillator cal
HCAL Cell Density Distribution (40 cell window)

31% single cell windows

mean ~ 4 cells

Cell Density (H)

entries: 481888
min: 0.025000
max: 0.70000
mean: 0.11423
rms: 0.10444
Seed Cell Distribution (cell density > 1/40)

-> in 1 layer

CAL Interaction Layer(E) 20 seeds
entries: 1486.0
min: 0
max: 24.000
mean: 2.6218
rms: 4.3587

CAL Interaction Layer(H) 10 seeds
entries: 1038.0
min: 0
max: 35.000
mean: 4.1640
rms: 5.3490

ECAL int. layer 20
HCAL int. layer 10
Energy fraction in seeds

Fraction of Total Energy in Seeds

~73% of energy in seed cells
Total Energy fraction in fixed cones (SNARK?)

Total Energy fraction in 0.04 cone

Cone size 0.04

Total Energy fraction in 1 cone

Cone size 0.1

Total Energy fraction in fixed cones (SNARK?)

Total Energy fraction in 0.04 cone

Total Energy fraction in 1 cone

Cone size 0.04

Cone size 0.1
Track Extrapolation/Shower Link Algorithm

1. Pick up all seed cells close to extrapolated track
   - Can tune for optimal seed cell definition
   - For cone size < 0.1 (~6°), get 85% of energy

2. Add cells in a cone around each seed cell through n layers

3. Linked seed cells in subsequent cones form the reconstructed shower
4. Discard all cells linked to the track

Of course, neutrals are Non-Linked Cells
Single 10 GeV Pion: D-weighted event display

Gap between ECAL/HCAL

Blue - all
Red - density > 1
Green - density > 3
Single 10 GeV Pion - event display comparison
Photon Analysis (S. Kuhlmann)

1. Cluster EM cells with cone algorithm of radius < 0.04 radians

2. Remove a cluster if a track points to within 0.03 radians, or, if the cluster is a mip in all 30 layers, remove if within 0.01 radians of a track

3. Require shower max energy deposit > 30 MeV (layers 8,9,10 summed)

4. Remove cluster if $E_{EM}/E_{track} < 0.1$ AND $\Delta R < 0.1$ (gets rid of charged pion fragments)

Remaining clusters classified as “Photons”
Hadronic Z Decays at \( \sqrt{s} = 91 \text{ GeV} \)

Mean = 0.25 GeV, Width = 2.8 GeV, Perfect EFLOW Goal is 1.4 GeV.

(Mean = 1.2 GeV, Width = 3.1 GeV without the “box” cut on EM/Track Ratio and Delta-R)

Total Photon Energy - Total Monte Carlo Photon Energy

Total Photon Energy - Total Monte Carlo Photons (GeV)
How the Tesla TDR analysis was done
JC Brient (Billy Bob’s version)

Photons

1) Extrapolate tracks thru the first 12 layers of EM (6 X0 for Tesla)
2) Remove the single cell in each layer that the track hit (1 cm x 1 cm cells for Tesla)
3) Take all the remaining hits in the first 12 layers and sum them in theta-phi with no other clustering, \( \exp(-\frac{7}{9} \times 6) = 0.0094 \) means >99% of the photons convert.
4) Order in energy. These are now the seeds for the rest of the EM calorimeter.
5) Do nearest neighbor clustering in all 40 layers using these seeds. Of course remove seeds from the list as they are absorbed into previous clusters.
6) Apply a chisq-type cut (not too critical since steps 3 and 4 are effectively a shower max cut, and charged particle fragments only in the latter 2/3 of the EM calorimeter are ignored because they didn’t have a seed).
Summary

1. Continuing work on implementation and tuning of shower link algorithm

2. Tune to single particles first, then to particles in jets

3. Add photons

4. Compare to analog version (SNARK)

5. Use final EFA to optimize transverse cell size of digital HCAL in SD, LD, TESLA detectors