EFA/DHC\textsc{cal} development at NIU

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Introduction

- Primarily interested in exploring the digital hadron calorimeter option in general, with scintillator as the active material in particular
- This talk focuses on the algorithm development aspects
- Results are preliminary
The Calorimeter

- 30 layer Silicon-Tungsten ECAL
- 5mm x 5mm transverse segmentation
- 34 layer Scintillator-Steel HCAL
- Transverse cell size varied between 2-9cm²
- Cells are projective in θ and φ
- No support structures/dead spaces
- Immersed in 5T magnetic field
N vs. E

Graph showing data points for different energies.
Sampling Weights

- Determined from 10 GeV charged pions
- Minimize:
  \[(1/N) \sum (E_0 - a_i L_i)^2\]
  where:
  - \(E_0\) is the incident energy
  - \(a_i\) is the weight for layer \(i\)
  - \(L_i\) is the energy/number of hits in lyr \(i\)
- For simplicity \(i=2\) considered here
Energy Resolution

- Analog
- Digital (0.8x0.8)
- Digital (1.41x1.41)
- Digital (2.45x2.45)
- Digital (3.0x3.0)

single threshold

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Energy Resolution

Dual threshold

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Extruded Scintillator

OUTPUT RESPONSE FOR BC408 AND 'MINOS' CELLS

MINOS
BC408

NUMBER OF TEST

RESPONSE [nA]
Setting up for extrusion
Preliminary Measurements

UNIFORMITY RESPONSE FOR A NEW DESIGN OF CELL (FROM SIDE TO SIDE)

- Position of radioactive source [mm]
- Response [nA]
“Density”

- Need a hierarchy for cells, in the absence of an energy measurement
- Clumpiness of surroundings?
- A simple-minded realization of this:
  \[ d_i = k \sum \left( \frac{1}{R_{ij}} \right) \text{ where } R_{ij} \text{ is the angular distance between cell ‘i’ and cell ‘j’} \]
Position Resolution

Since Energy-Flow invariably involves associating clusters near an extrapolated track……..

Best way to this in a digital calorimeter?

Used charged pions in the HCAL

Resolution is defined w.r.t. the extrapolated Monte Carlo generated track
Position Resolution

$5 \text{ GeV } \pi^\pm$

Chart showing position resolution for $5 \text{ GeV } \pi^\pm$ particles, with histograms for different weighting schemes.
10 GeV $\pi^\pm$

Cell area at first layer = 2 cm$^2$

Measured relative to the energy weighted resolutions
10 GeV $\pi^{\pm}$

Cell area at first layer = 6 cm$^2$

Cell area at first layer = 9 cm$^2$

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Clustering

- Local density maxima chosen as seeds
- Membership of each cell in the seed clusters decided with a distance function
- Only unique membership considered here
- Calculate centroids
- Iterate till distortion is below some threshold
Density weighted $\theta-\phi$

High asymmetry

\[ \pi^0 \to \gamma\gamma \]
\[ \pi^0 \rightarrow \gamma \gamma \]
10 GeV $\pi^0$

Recon. energy

Recon. mass

18%
20 GeV $\pi^0$

Recon. energy

Recon. mass
Energy Asymmetry

\[ A = \frac{\text{abs}(E_{\gamma_1} - E_{\gamma_2})}{E_{\gamma_1} + E_{\gamma_2}} \]
\[ \Sigma^+ \rightarrow p\pi^0 \]
$\Sigma^+ \rightarrow \rho \pi^0$
\[ \Sigma^+ \rightarrow n\pi^+ \]
“Jet” Reconstruction

- A 0.7 simple cone (no splits or merges) algorithm used
- Operates on a $p_t$ ordered list of final state, visible MC particles
- $p_t$ weighted $\theta-\phi$ used as centroid
$Z \rightarrow jj$

Generated mass
Further “Jet” Reconstruction

- Use the generated jet centroid as the seed
- Grab clusters within 0.7 of seed
- Extrapolate MC tracks into calorimeter
- Replace E with p for matched clusters
Jet $E_{\text{rec}}/E_{\text{gen}}$

Calorimeter only

~60% better
Jet $E_{\text{rec}}/E_{\text{gen}}$
jet-jet mass

- 50% improvement over calo
- EF analog
- EF digital
- Calo only
- 2 cm² cells
jet-jet mass
Short Term Goals

- Better track extrapolation taking into account the energy loss and scattering in the material
- Introduce particle id to supplement pattern recognition
- Alternative measures of density
- The long road to optimization
Summary

- A first version of a ‘digital’ Energy Flow algorithm implemented with encouraging results
- Detailed optimization studies beginning
- Not discussed here, but hardware prototyping studies proceeding
- Hope to cross-fertilize hardware design with algorithm development