Performance Analysis of the CALICE-Digital Hadronic Calorimeter (DHCAL) for pion measurements

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CALICE – PARTICLE FLOW CALORIMETRY

• Need precision measurement of Standard Model
• Particle Flow Algorithm (PFA):
  - Identify individual particles in a jet
  - Improve the jet energy resolution
  - By using high granularity detectors
• CALICE detectors: Energy measurements, Tracking abilities and Timing
• Electromagnetic and Hadronic calorimeters (both analogue and digital)
DHCAL, MIN-DHCAL

- Digital Hadronic CALorimeter (DHCAL): A steel or tungsten absorber between every layer
- DHCAL with minimal absorber: only absorber is from the cassettes
- Resistive Plate Chambers (RPCs)

- Tetrafluoroethane (94.5%)
- Isobutane (5.0%)
- Sulfur hexafluoride (0.5%)

- Large avalanche signal
- Quick replenish time
MIN-DHCAL

- Three vertically located 32 x 96 cm² RPCs 96 x 96 cm² active area per layer
- 9216 1 x 1 cm² readout pads
- Min-DHCAL: 50 cassettes spaced 2.54 cm apart
- 460,800 readout channels
- Recorded hit data: t, x, y, z
DATA SELECTION

- Data taken at Fermilab: Beams provide a mixture of positrons, pions and muons

<table>
<thead>
<tr>
<th>Momentum (GeV)</th>
<th>#Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>107000</td>
</tr>
<tr>
<td>2</td>
<td>107000</td>
</tr>
<tr>
<td>3</td>
<td>62000</td>
</tr>
<tr>
<td>4</td>
<td>84000</td>
</tr>
<tr>
<td>6</td>
<td>109000</td>
</tr>
<tr>
<td>8</td>
<td>109000</td>
</tr>
<tr>
<td>10</td>
<td>226000</td>
</tr>
</tbody>
</table>
**SELECTION CUTS**

**Event Selection Cuts**

**Timing**

Only one cluster in the 1\textsuperscript{st} layer

>5 active layers

**Particle Selection Cuts**

<table>
<thead>
<tr>
<th>Particles</th>
<th>cuts</th>
<th>Particle Selection Cuts</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu$</td>
<td>$\hat{\mathcal{C}} = 0$</td>
<td>No interaction layer</td>
</tr>
<tr>
<td>$\pi^+$</td>
<td>$\hat{\mathcal{C}} = 0$</td>
<td>Interaction layer</td>
</tr>
<tr>
<td>$e^+$</td>
<td>$\hat{\mathcal{C}} \neq 0$</td>
<td>-</td>
</tr>
</tbody>
</table>
PARTICLE IDENTIFICATION

- Muons: least hits
- Positrons: higher hit density due to dense electromagnetic showers
- Pions: large distribution (interact electromagnetically and hadronically, fluctuations in deposited energy)
Min-DHCAL data

Monte Carlo data
MUON EVENT DISPLAY

Min-DHCAL data

Monte Carlo data
Min-DHCAL data

In progress: Monte Carlo data
**PION MEAN RESPONSE**

- Power law fit: \( N_{hit} = p_0E_{beam}^{p_1} \)
- Linear response: \( p_1 = 1 \)
- Limited granularity, only one hit is recorded, saturation of the response \( p_1 < 1 \)
- \( p_1 = 0.87 \) uncalibrated pion data

**preliminary MC data**
CONCLUSION

• Min-DHCAL data can be used to validate current hadronic shower models
• Thanks to high granularity calorimeter develop better GEANT4 simulations
• Ongoing: complete calibration and get energy resolution responses
• **RPCs avalanche mode**: initialized by a charged particle ionizing the molecules in the gas gap. The free electrons accelerated by a high voltage applied across the chamber ionize more electrons on their way. Default high voltage is 6.3 kV.

• **Min-DHCAL**: cassette thickness = 12.5 mm average of 0.41 radiation length ($X_0$) or 0.037 nuclear interaction lengths ($\lambda_t$). Each readout chip: 1.4 mm plastic casing (~ 30 cm $X_0$ for plastic) 1.4 mm plastic = 0.004 $X_0$ or $\frac{1}{100}$ of one active layer.

• DHCAL thickness $\sim 600 \ \frac{g}{cm^2}$ with 1 cm steel absorber between every layer, min-DHCAL thickness $\sim 210 \ \frac{g}{cm^2}$,

• 1 GeV muon stops in $565 \ \frac{g}{cm^2}$ 1 GeV muon won’t stop in the min-DHCAL
• “hit”: a cell recording a particle passing through it
• Threshold of each readout cell = 180 fC (digital readout) set to measure only passage of a particle in the gas gap
• Cells do not record any energy deposited measurements
• Digital calorimetry: estimated the energy of a full particle shower by counting the total number of hits recorded in an event