R&D of Small Tile ECAL

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19-23 April 2004, LCWS in Paris

- Introduction
- Structure of small tile calorimeter
- Beam test at KEK
- Gain calibration
- Energy response linearity and resolution
- Position resolution
- Uniformity
- Small tile calorimeter of JINR
- Summary
Our Base-line design for LC calorimeter

Lead/plastic scintillator sampling calorimeter for both ECAL and HCAL

- Hardware compensation for excellent hadron energy resolution and linearity → Pb/Scinti = 4/1
  - Good energy resolution for single particle
    - $\sigma_{E/E}=15%/\sqrt{E}$ for ECAL
    - $\sigma_{E/E}=40%/\sqrt{E}$ for HCAL

- Good granularity
  - Fine transverse/longitudinal granularity for “particle flow” analysis → 4cmx4cmx1mm tile

- Good hermeticity

- Established technology and Reasonable cost
  - Separate tiles → Mega-tile
Purposes of test beam studies of Tile/fiber ECAL

Fully understand and establish design and performance of tile/fiber calorimeter
☐ Examine uniformity with staggered WLS layouts
☐ Energy resolution and linearity
☐ Position resolution
☐ Particle ID etc

Beam test was done in this March 2004.
WLS fiber configuration
Two types of groove layout to smear non-uniformity

Separate tiles
Roundish-square groove layout
Circular groove layout

WLS: 0.7mmφ
Mega-tiles
Structure and readout of tile/fiber ECAL

4 Layers = 1 Super Layer
6SL = $17 \times X_0$
Total No. of R/O Ch: $5 \times 5 \times 6 = 150$
Beam test
KEK PS
pi2

e, pi, mu: 1– 4 GeV/c
Electron-ID:
  2 Cherenkov
counters
Tracking:
  8 Drift chambers
  (4X+4Y, σ<0.3mm
  at the ECAL surface)
“Preliminary” Results of Data Analysis

Gain calibration with hadron events

<table>
<thead>
<tr>
<th>Tower ID</th>
<th>Low Gain PMT</th>
<th>High Gain PMT</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADC Counts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative Error (%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NEMHi ADC Calibration $\{lx2,ly2,isl1\}$ 800V

- Entries: 797
- Mean: 86.84
- RMS: 55.64
- $\chi^2 / n df$: 63.94 / 64
- $p_0$: 29.82 ± 1.424
- $p_1$: 61.79 ± 1.482
- $p_2$: 36.36 ± 1.177

fit mean = 82.72 ± 1.621
Total energy deposit & Shower curve

**Diagram 1:**
- **Total energy deposit (MIPs):**
  - 1GeV
  - 2GeV
  - 3GeV
  - 4GeV

**Table:**
- **hTotal**
  - Entries: 5742
  - Mean: 29.26
  - RMS: 6.699
  - $\chi^2$/ndf: 28.88/11
  - Constant: 768.8 ± 13.45
  - Mean: 29.27 ± 0.08323
  - Sigma: 5.772 ± 0.07138

**Diagram 2:**
- **Shower Curve 1GeV to 4GeV**
  - 1GeV
  - 2GeV
  - 3GeV
  - 4GeV

**SL No.:**
- Layer #
Energy deposits at each Super Layer (4 GeV e)

SL1

SL2

SL3

SL4

SL5

SL6
Energy Response Linearity

Center

Edge

Corner

Center

Edge

Corner
Energy Response Linearity (cont’d)
Energy resolution

Center Edge Corner

$\sigma_{\text{stat}} = 17.5\%$ $\sigma_{\text{stat}} = 17.6\%$ $\sigma_{\text{stat}} = 16.1\%$

\[
\sigma_E = \frac{\sigma_{\text{stat}}}{\sqrt{E}} \oplus \sigma_{\text{const}} \quad (A \oplus B = \sqrt{A^2 + B^2})
\]
Position resolution

1. Center of gravity position from ECAL towers (Xcal)
2. True hit position from Drift Chamber (Xdrif)
3. Residual distribution \((X_{res} = X_{cal} - X_{drif})\)
4. Position resolution: \((\sigma_x \text{ of residual distribution})\)

Typical electron signal from tiles (1 event)

Residual distribution

\[ X_{res} = X_{cal} - X_{drif} \]
Position resolution vs. SL No. & Energy

4 GeV layer vs resolution

3rd SL

Energy vs resolution

SL No.

Energy (GeV)
Non-uniformity measurements (Uniformity mapping)

Better uniformity with alternating layout

X-uniformity scan across the edge of the tile (5mmx1mm mesh)
International Collaboration
JEM (JINR EMcal)

- R&D on Scinti-tile production based on MoU between JINR and KEK
- An EMcal test module made at JINR: similar design, but some differences:
  - Scintillator material: made by JINR
  - Tiles are made with pressure molding: good accuracy
  - WLS fibers glued to rectangular grooves:
  - Thinner Pb plate (2mm-thick): total thickness = 14.4 $X_0$

JEM was also tested at KEK: Detailed analysis and comparison are to be performed.
Resolution for 1 GeV electron is 12.5%, but longitudinal shower leakage (c.f. 14.4X_0) degrades energy resolution and linearity above 2 GeV.
Comparison of Calorimeter Resolution

<table>
<thead>
<tr>
<th>Cal Name</th>
<th>Pb t</th>
<th>Sci t</th>
<th>E Res</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tile Cal (NEM)</td>
<td>4mm</td>
<td>1mm</td>
<td>17%</td>
</tr>
<tr>
<td>Tile Cal (JEM)</td>
<td>2mm</td>
<td>1mm</td>
<td>12%</td>
</tr>
<tr>
<td>Strip Cal (TEM)</td>
<td>4mm</td>
<td>4mm</td>
<td>13%</td>
</tr>
</tbody>
</table>

1. JEM = NEM / sqrt(2)
2. TEM ↔ NEM: Photo Electron Statistics
Summary

1. Beam test has been done in this March at KEK with International collaboration, in order to fully understand and establish design and performance of tile/fiber calorimeter.
2. Very preliminary analysis showed reasonable results on Energy Response Linearity, Energy resolution, Position resolution for both Japanese and Russian Calorimeters.
3. We could get reasonably uniform response at the tile edge.
4. Detail analysis including particle ID performance will be done in several months.
おしまい