A General High Resolution Hadron Calorimeter using Scintillator Tiles

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GOALS

Design a DHC (Digital Hadron Calorimeter) using Scintillating Tiles with overall minimum cost.

Build a prototype of the DHC to test it on a test beam.

SUB GOALS

• Find the optimal geometry for the tiles
• Find the optimal geometry for the groove (for WLSF)
• Find the optimal geometry for the DHC
• Find the ‘best’ choice for the absorber material
• Find a suitable method to ‘make’ the tiles, embed the WLSF, make the transition from WLSF to CF, route the CF out of the DHC volume
• Design the ‘minimal’ electronics required for the DHC
Optimizing the Geometry for the Tiles

As the tiles are made smaller, edge effects and lack of uniform response become quite important.

On first approximation, the edge effect is proportional to the perimeter of the cell and its height, and inversely proportional to its area.

There are only three convex shapes which could be used to ‘cover’ a surface. For equal cell height, the ratios [Perimeter]/[Area] give a measure of the edge effect:

- **Triangle**: \(4 \times \sqrt{3} / a\)
- **Rectangle**: \(4 / a\) \(= 4ab / (a+b)\)
- **Hexagon**: \(4 / (a \times \sqrt{3})\)
Optimizing the Geometry for the Groove

We made several hexagonal cells with different groove shapes and depths. After measuring the light output for each configuration, we selected two groove configurations as most promising:

**Straight Groove**
- length $\approx 38\text{mm}$
- width $\approx 0.2\text{mm}$ more than the WLSF diameter
- depth $\approx 3\text{mm}$

**Sigma Groove**
- length $\approx 85\text{mm}$
- same width and depth
To obtain the maximum light output from a scintillating cell, the surface should be covered by some material. This cover should create a diffusing/reflecting media. A well-known way to achieve this is by wrapping the scintillating cell in white Tivek paper. Unfortunately, this is a manpower-demanding task and, thus, unsuitable for the task involving one million or more cells.

The NIU/NICADD team has tested several alternatives to Tivek wrapping with interesting results.
Comparative Light Output Measurements

All measurements are made with the same conditions.

**Source**  Sr-90
**Hexagonal Cell** l=19mm, h=5mm
**Scintillator** BC-408
**WLSF** BCF-92 Ø1mm (mirrored)
**Groove** 1.2x3x37mm
**Fiber Length** 400mm
**Attenuation length** ~4000mm
**PMT** 16% efficiency

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<th>nA output</th>
<th>%</th>
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<tr>
<td>Al</td>
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"Direct" Light Output Measurements

Cosmic rays

CELL WLSF CF SPLICE VLPC AMPLIFIER ADC

▲ TYVEK Wrapping

WLSF ~400 mm
CF ~1500 mm
VLPC ~85% QEF
~70K Gain
Gain correction 1.8

Tyvek ~ 30 (Direct)
Acrylic ~ 25 (Calculated)

Cell 15 16.7*1.8(#) = 30.1 PE

Number of Events

PE

ADC Channel

1 77 153 229 305 381 457 533 609 685 761 837 913 989 106 1141 1217
Preliminary Design

- **Support material**
  - Inner Ring: Tungsten at least 5mm
  - Outer Ring: Aluminum structure
  - Radial (ends): Aluminum structure

- **Cell Geometry**
  - Hexagonal base Prism 19mm side

- **Scintillator Material**
  - BC-408 5mm thick

- **Absorber Material**
  - Brass 20.2mm thick

- **Fiber Material**
  - WLSF >> BCF-92, Y-11 (Kuraray)
  - CF >> BCF-98, Kuraray?

- **Fiber Geometry**
  - Ø .9 mm mirror end .64mm²

- **Groove Geometry**
  - Sigmoid (length ≈ 83mm)

- **Reflector Material**
  - Painted (Acrylic White Titanium Dioxide)
Number of cells and shapes is function of the architecture chosen.

- No Projective
  - Single Tower
  - Multiple Towers

- Projective on $\phi$
  - Single Tower
  - Multiple Towers

- Projective on $\phi$ and $\eta$
  - Single Tower
  - Multiple Towers
General Cell Structure and ‘Towers’ and ‘Layers’ for the CDHC using the ATLATS as Model

- Number of Layers: 39
- Number of Towers: 4 (layers 10+10+10+9)
- Inner Radius of first Tower: 1908 mm
- Number of Cells along φ: 212
- Inner Radius of second Tower: 2195 mm
- Number of Cells along φ: 242
- Inner Radius of third Tower: 2467 mm
- Number of Cells along φ: 272
- Inner Radius of fourth Tower: 2739 mm
- Number of Cells along φ: 302

First Absorber Layer: ~ 17 mm of Tungsten
All other Absorber layers: ~ 20 mm of Brass
Support outer ring: ~ 12.5 mm (Al structure)

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SIMULATION 1

- PLOTS HERE
- Total energy versus # of Hits
- Total energy versus # of Cells hit
SIMULATION 2

- PLOTS HERE

- # of Cells per Layer with ONE hit

- # of Cells per Layer with Two or More hits
SIMULATION 3

- PLOTS HERE

- Clusters on Layer 1 and Layer 39 with energy deposition per cell

- Clusters on Layer 1 and Layer 39 with
- Number of Hits
CONCLUSIONS

• We have demonstrated the feasibility of building a DHC using Hexagonal Scintillating Tiles
• The DHC proposed has NO cracks
• The simulation of the DHC shows excellent results in clustering and relation between Energy deposition and # of cells with hits
• Continuing efforts to:
  – Optimize Cell size
  – Building techniques
  – Simulation response (using G4)
  – Build a prototype with ~ 900 cells for testing on the beam line
“Direct” Light Output Measurements

Chan 10, Cell 15 16.7*1.8(#)=30.1 PE

ADC Counts

Number of Events

Chan 12, Cell 9 13.2*1.8(#)=23.8 PE

ADC Counts

Number of Events

Cosmic rays
VLPC + Charge to Voltage + ADC
► TIVEK Wrapping
▼ Enamel Paint