A General High Resolution Hadron Calorimeter using Scintillator Tiles

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for

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GOALS

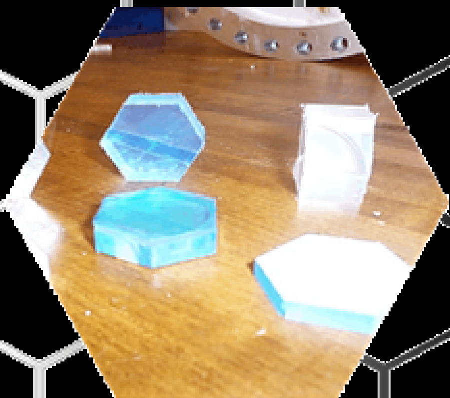
Design a DHC (Digital Hadron Calorimeter) using Scintillating Tiles with overall minimum cost.

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

SUB GOALS

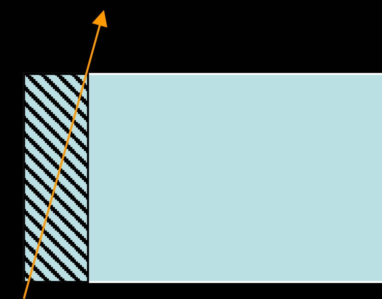
- Find the optimal geometry for the tiles
- Find the optimal geometry for the groove (for WLSF)
- Find the optimal geometry for the DHC
- Find the 'best' choice for the absorber material
- Find a suitable method to 'make' the tiles, embed the WLSF, make the transition from WLSF to CF, route the CF out 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.

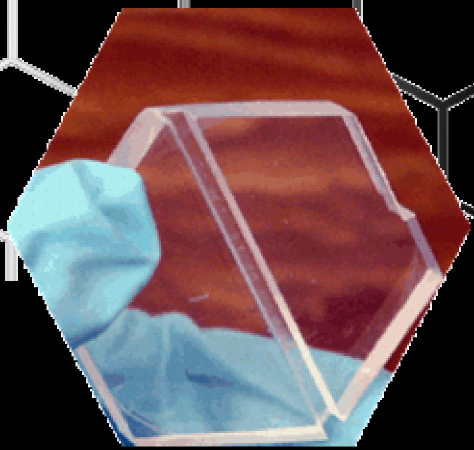
On first approximation, the edge effect is proportional to the perimeter of the cell and its height, and inversely proportional to its area.



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 $4 * 3^{1/2} / a$
- Rectangle $4 / a$ $4*a*b / (a+b)$
- Hexagon $4 / (a * 3^{1/2})$

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 ≈ 38mm width ≈ .2mm more than the WLSF diameter depth ≈ 3mm
Sigma Groove	length ≈ 85mm same width and depth

Surface Covering for the Cells

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

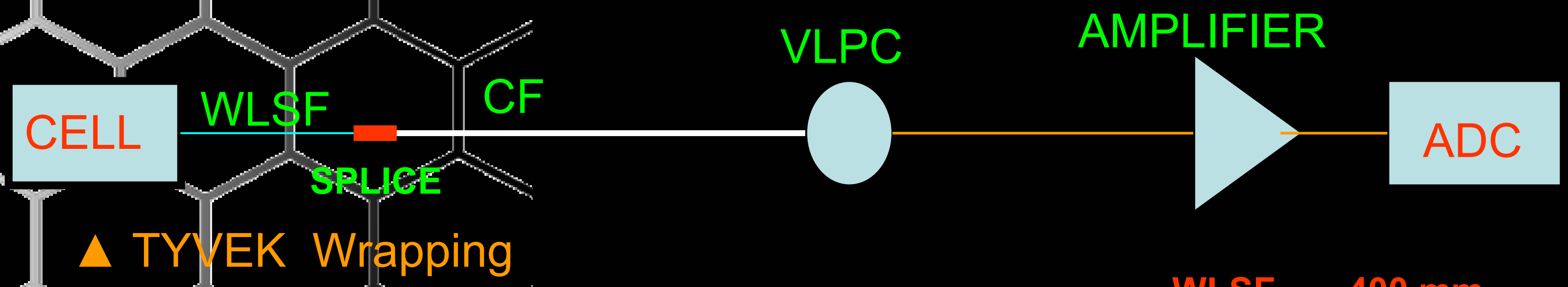
Attenuation length ~4000mm

PMT 16% efficiency

Surface Treatment		nA output	%
Wrapping	Tyvek	1000.9	100
	Aluminized Mylar Tape	465.9	46
Spray Painting	Vinyl	473.7	47
	Lacquer	439.4	43
	Acrylic	816.7	82
Sputtering	Al	233.5	23

“Direct” Light Output Measurements

Cosmic rays



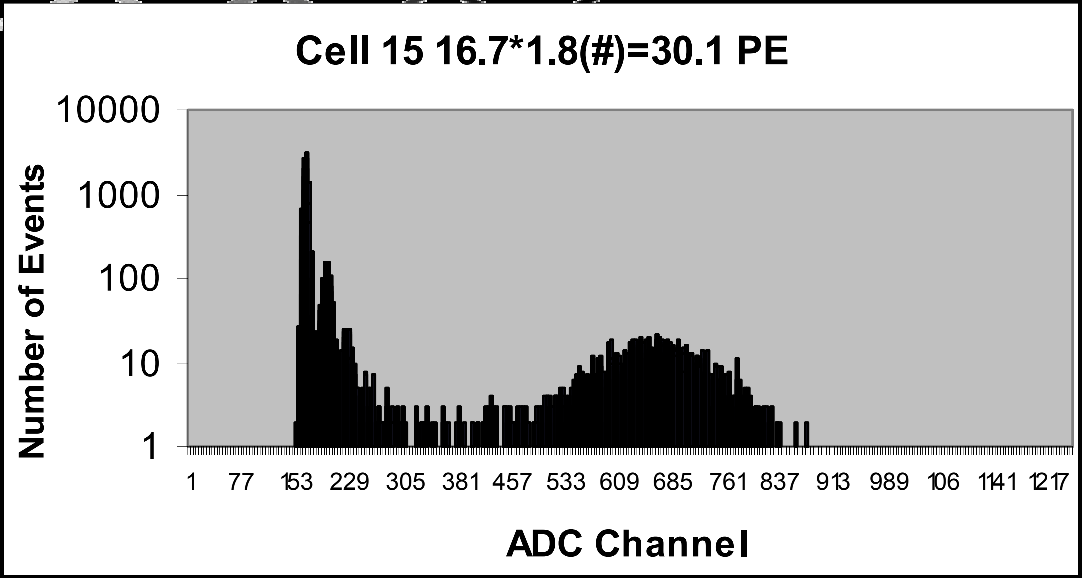
WLSF ~400 mm

CF ~1500 mm

VLPC ~85% QEF

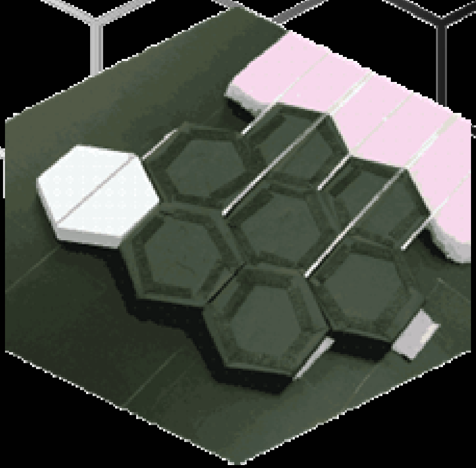
~70K Gain

Gain correction 1.8



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

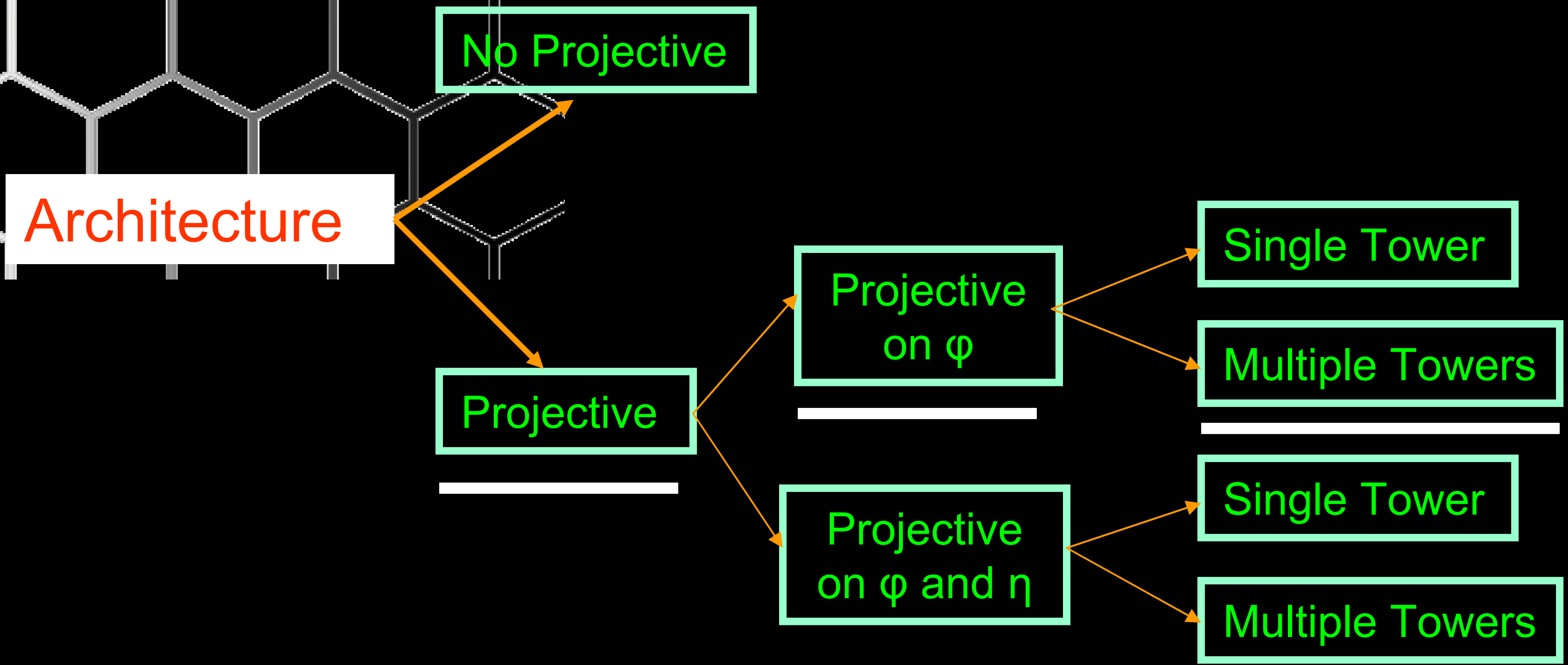
Preliminary Design



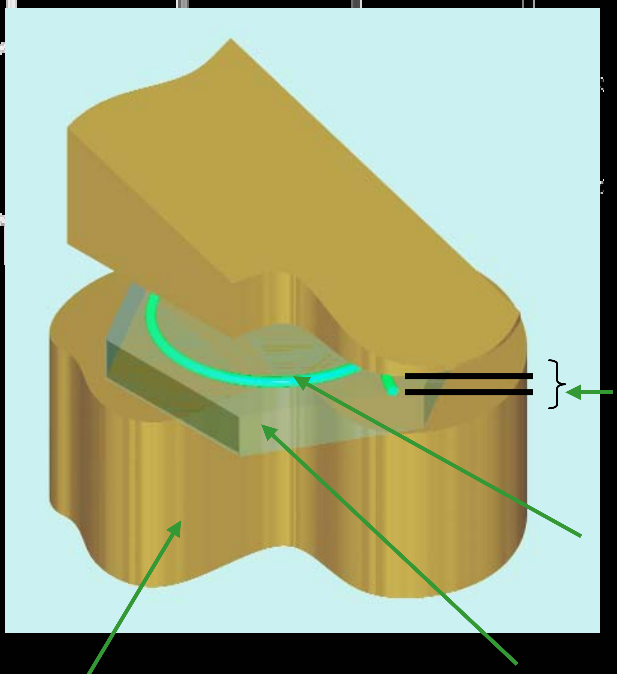
- **Support material**
  - **Inner Ring: Tungsten at least 5mm**
  - **Outer Ring: Aluminum structure**
  - **Radial (ends): Aluminum structure**
- **Cell Geometry**
  - **Hexagonal base Prism 19mm side**
- **Scintillator Material**
  - **BC-408 5mm thick**
- **Absorber Material**
  - **Brass 20.2mm thick**
- **Fiber Material**
  - **WLSF >> BCF-92, Y-11 (Kuraray)**
  - **CF >> BCF-98, Kuraray?**
- **Fiber Geometry**
  - **Ø .9 mm mirror end .64mm^2 (R)**
- **Groove Geometry**
  - **Sigmoid (length ≈ 83mm)**
- **Reflector Material**
  - **Painted (Acrylic White Titanium Dioxide)**

DHC
DESIGN CHOICES

Number of cells and shapes is function of the architecture chosen



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)

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

Cosmic rays

VLPC + Charge to Voltage + ADC

◀ TIVEK Wrapping

▼ Enamel Paint