Analysis of Performance of a Radiation-Hard, Highly-Segmented Shashlik Electromagnetic Calorimeter in the CERN H4 Testbeam

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Shashlik Goals

- Operation in a high integrated luminosity of 3000 fb\(^{-1}\)
- Radiation hardness of all components
- Ability to deal with pileup
- Fast scintillation of detector material
Shashlik Design

Broken up into modules
- 28 W plates 2.5mm thick
- 29 LYSO Plates 1.5mm thick
- 4 WLS Capillaries: 1mm diameter

Readout
- 1 channel per capillary
- SiPM (10μm pixels)
- Fermilab PADE Boards (Preamp/Digitizer)
Shashlik Design

Layered design is like a shish kebab!
Basic Capillary Structure

Rad Hard Quartz (Polymicro QA): OD:ID = 1mm:0.4mm

Conventional Optical Fiber

Thick Wall Profile

Rad hard quartz shell

WLS liquid core
Basic Capillary Structure

Rad Hard Quartz (Polymicro QA): OD:ID = 1mm:0.4mm

180 mm

Readout End

Thicker shell allows for greater radiation resistance

Thick Wall Profile

Rad hard quartz shell

WLS liquid core

Shashlik Calorimeter

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The Shashlik Design as Proposed for CMS Endcap Region

Elevation view

View from the IP

~30,500 LYSO/W modules per endcap
- Simulated using with the CMS detector environment

- As shown, the resolution holds up well against high radiation
A 4x4 array of shashlik modules was tested at CERN’s H4 testbeam.

10 million events accumulated at 20, 50, 100, 150, 200 GeV.
Preliminary results from the 2014 and 2016 200 GeV H4 Electron Beam Test

- Capillary resolution considered to be an upper limit
- Further analysis to increase the resolution ongoing
Nonlinearity of SiPMs

- ADC response does not increase linearly with the energy of the beam
- Largely due to the saturation of finite number of pixels in SiPMs
- Need to determine the relationship between energy and ADC response for each channel, and correct accordingly
Sampling over Many Positions

- Need to populate non-linearity curve with more points
- For each channel, I looked at hits within a small 2x2 areas across the module
Channel 20 $A/E_{beam}$ vs $A$ with Multiple Positions

\[
\chi^2 / \text{ndf} = 608.7 / 19
\]
\[
p_0 = 1.13 \pm 0.001471
\]
\[
p_1 = 2017 \pm 14.81
\]
Overlay of $A/E_{\text{beam}}$ vs $A$ using Center Channels

$\chi^2 / \text{ndf} = 2.382e+04 / 433$
$p_0 = 1.059 \pm 0.000345$
$p_1 = 2058 \pm 4.472$
Calculating Nonlinearity Correction

- From the nonlinearity curve, AMax is determined as the point where the fit crosses the x axis
- We then can calculate the correction as

\[ C = \frac{-A}{\ln \left(1 - \frac{-A}{A_{\text{max}}} \right) A_{\text{max}}} \]

\[ A_{\text{corr}} = \frac{A}{C} \]
Applying the Corrections

- These corrections were applied to every channel
- The effect on $E_{\text{chan}} / E_{\text{beam}}$ distribution was plotted for each beam energy
Individual vs Overall Correction

- In some channels, the overall correction did not appropriately line up the distributions

- In these cases, the individual channel-wise correction is preferred
Summary

- The shashlik detector is a radiation hard, highly segmented electromagnetic calorimeter

- From simulation, it is expected that the shashlik design maintains good energy resolution at high luminosity

- The resolution was tested using the CERN H4 test beam

- Preliminary results are encouraging, but further analysis steps are being taken to improve the resolution