Integrated Readout Layer for a Scintillator-SiPM Calorimeter

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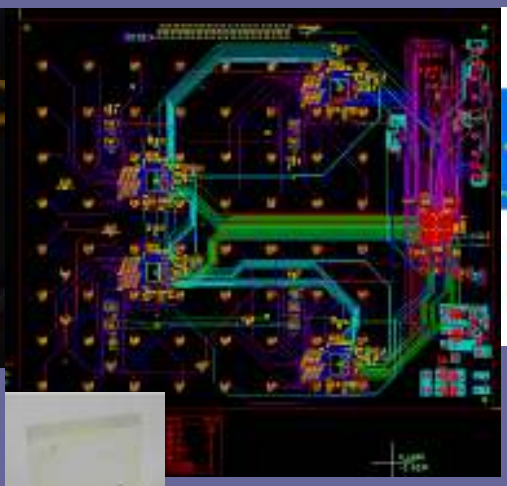
Abstract

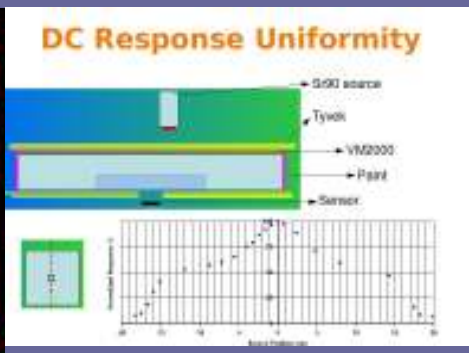
Northern Illinois Center for Accelerator Detector Development (NICADD) in collaboration with Fermilab is developing the concept of an integrated readout layer (IRL) for a fine-granularity scintillator calorimeter. The main objective of the project is to produce a scalable and simpler detector design that is cost efficient. Detector design for the International Linear Collider (ILC) will require millions of read out channels. The IRL implements design features such as surface mount SiPMs, on board calibration LEDs, and directly coupled dimpled scintillating tiles to render the required electro-mechanical integrability. This design promises to greatly simplify the construction and assembly of a high channel count scintillator-SiPM calorimeter. A good proof-of-principle in the form of the present prototype IRL, shown here, is under study.

The IRL board designed by Fermilab has 64 individual channels with amplitude and time stamp. Each channel also has a high gain and a low gain channel. The HV bias for the SiPMs is generated on board. The IRL is based on a Minerva front end board.

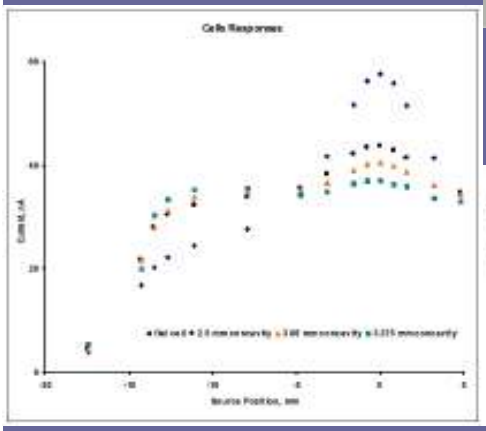


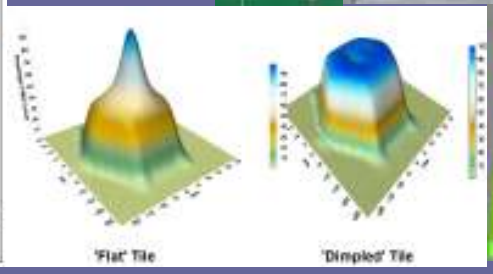
Previous tile design w/ WLS Fiber optic & SiPM

New tile design w/ concave dimple & surface mount SiPM

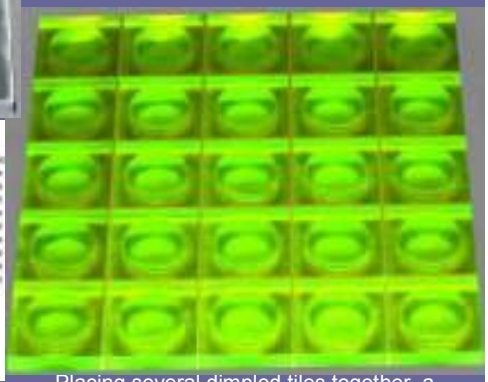


Previous designs have used scintillating tiles with WLS fibers connected to a photomultiplier tube (PMT) or SiPMs. Our design explores the direct or fibreless coupling of the tiles to SiPMs. The SiPMs are surface mounted on the PCB, and the tiles are placed directly above them without any WLS fiber. This is called direct coupling. Response and uniformity studies for direct coupling have been encouraging.

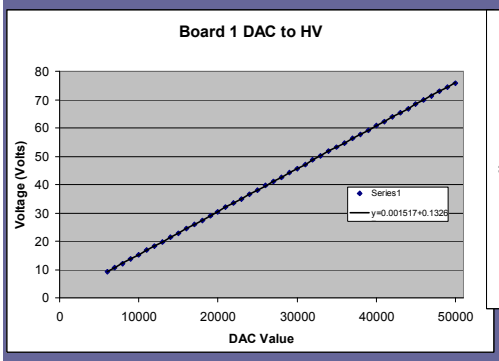




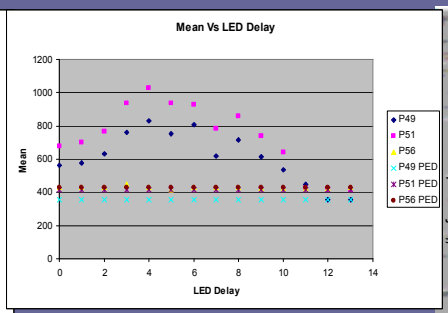
Machining a dimple on the flat scintillating tile changes the response. Using a strontium 90 (Sr90) radioactive source, various dimple sizes were scanned. The plot (above left) shows the response using various degrees of concavity. It appears 3.375 mm concavity gives the best uniform response. So, for direct coupling, the response is non-uniform; but adding a dimple (concave grove) on the scintillating tile, the response becomes uniform. This completely eliminates the need for WLS fiber optic.



Placing several dimpled tiles together, a "megatile" can be constructed. The 5 tile X 5 tile megatile is placed over the SiPMs on the PCB and measurements with this prototype IRL are underway (see below).



One of the first measurements taken was to determine if the SiPM bias voltage is linear with respect to DAC values. This plot shows the trend



Testing the LED delay to find the optimal LED amplitude and pulse width (PW) was done. The plot shows the three different SiPMs at 2.1V amplitude, 17ns PW, low gain; and their corresponding pedestals. The points labeled with "PED" are the pedestal values.

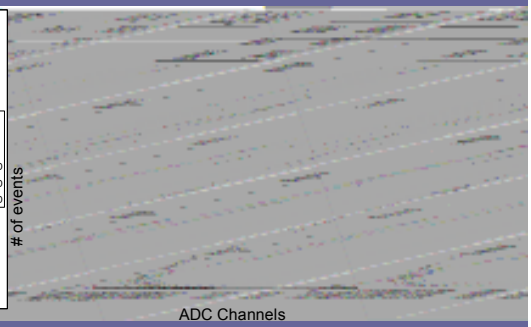


Photo electron spectrum from SiPMs surface-mounted on the IRL is shown above. External LED was used initially. But the real test was to show that the directly coupled components responded to the onboard LEDs with the megatile attached. Here, the fitted peaks show the gain of the SiPM in the low gain channel of pixel 49. Red=pedestal; Blue=peak#2; Green=peak#3