ND-GAr ECAL: experience from CMS SiPM-on-tile calorimeter

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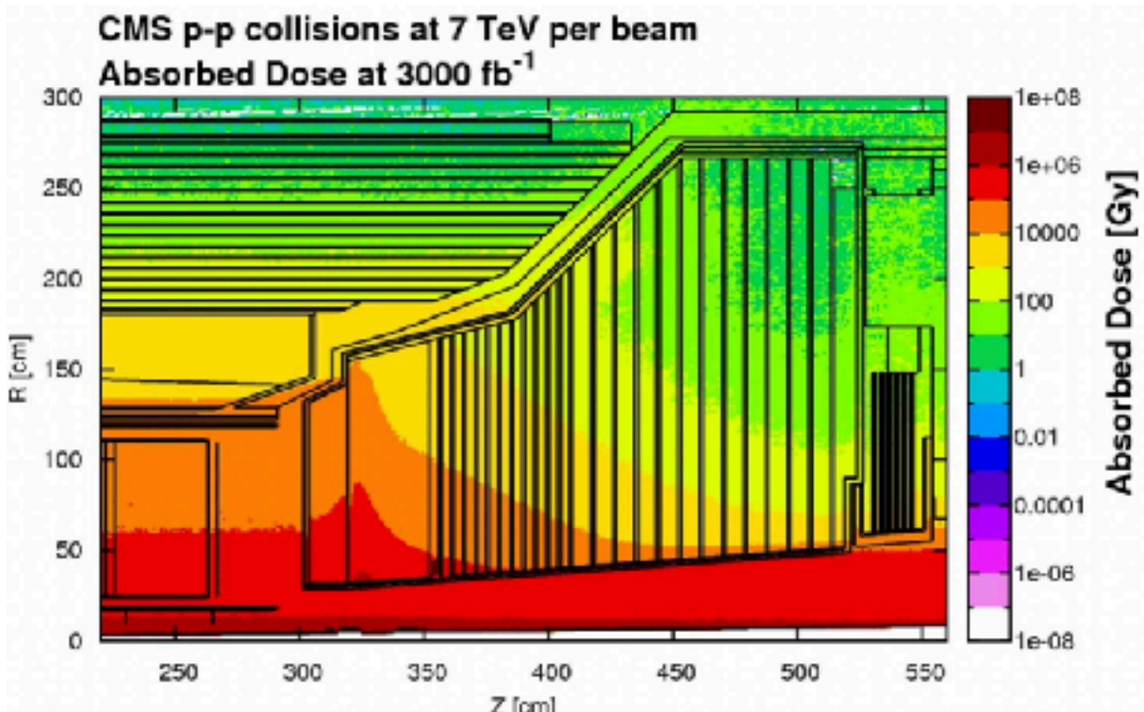
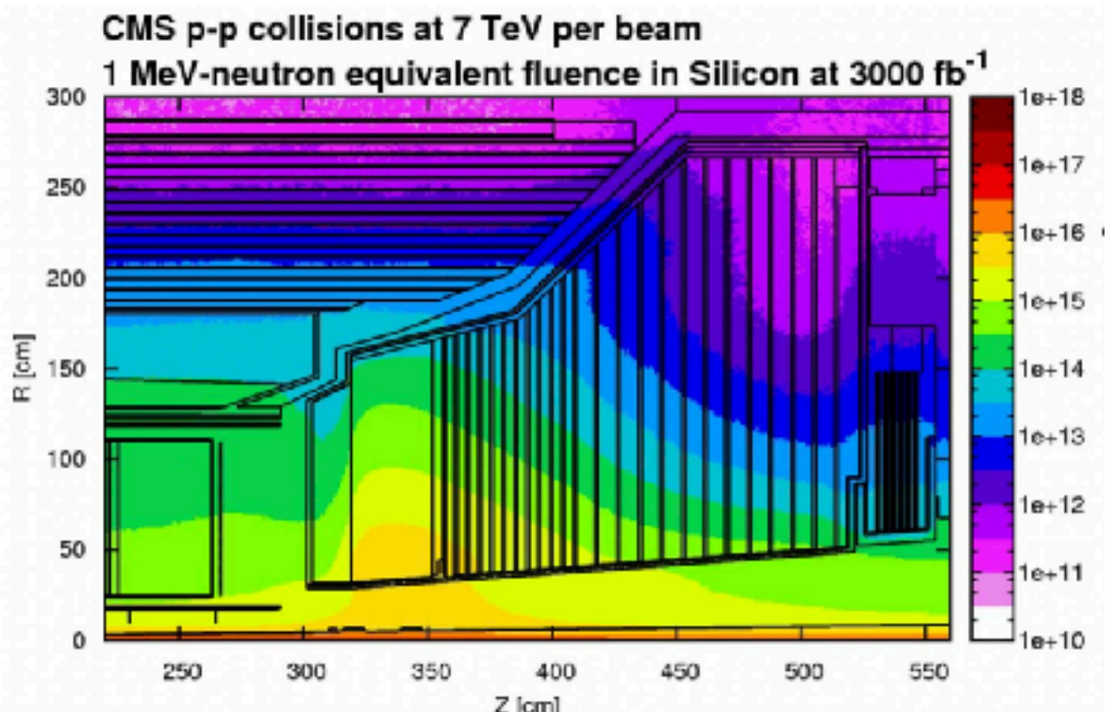
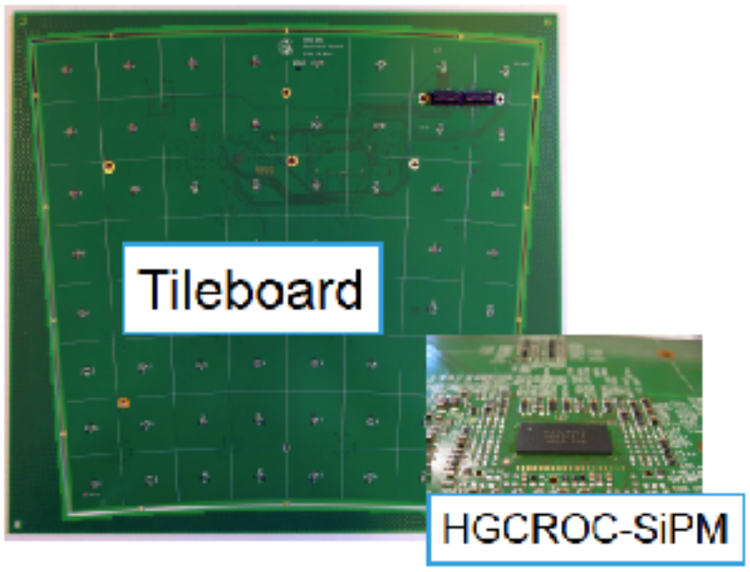
CMS SiPM-on-tile

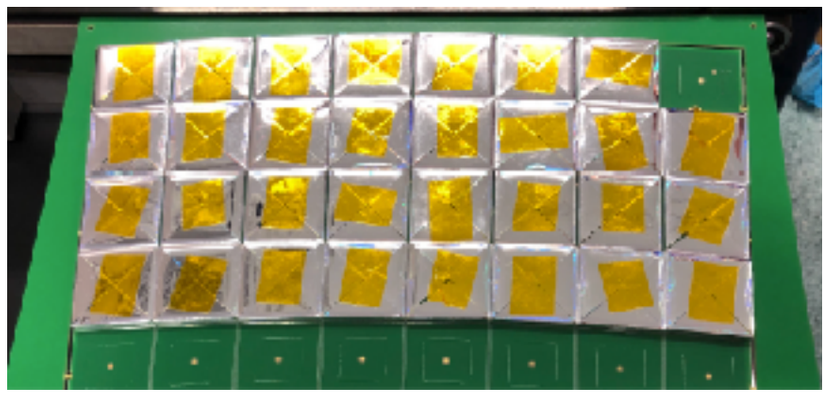


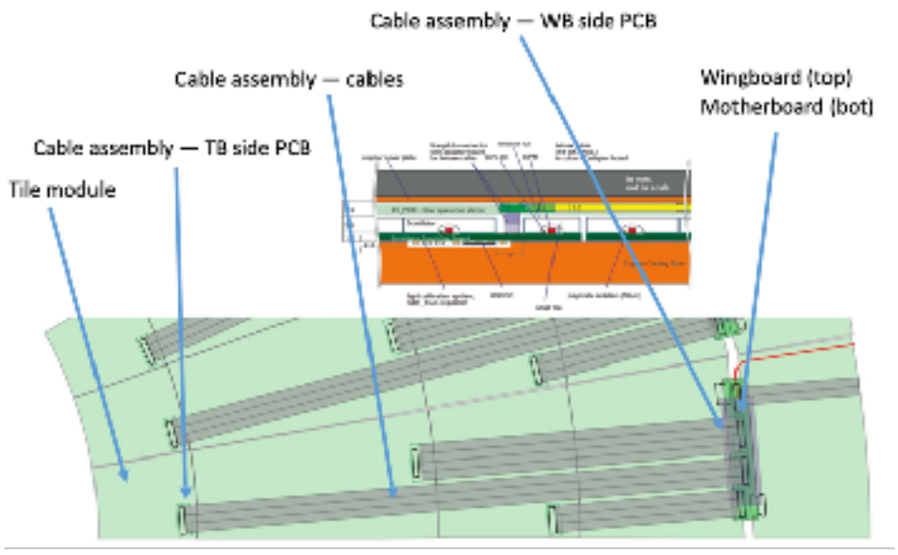


CALICE concept, chosen for radiation hardness(!) adapted to CMS geometry

SiPMs and scintillators can survive < 5E13







tile size and channel count ultimately driven by need to maintain MIP sensitivity to end of life

scintillator modules mounted on 30° copper plates, inserted into steel absorber

By the numbers

300k channels

~30 tile geometries (5-30 cm^2)

- each wrapped with an individual reflective wrapper

2 types of scintillator (cast and injection-molded)

2 sizes of SiPM (4 and 9 mm^2)

8 module types, some with 3 or 4 sub-types

14 layers × 2 endcaps

cold (-30 °C), hypoxic (3% O_2) environment covering several decades of dose rate

Why is it relevant?

The physics motivation and design concept for the proposed ND-GAr ECAL have been presented in Monday's session by Alfons.

The ND-GAr ECAL would represent the next step in scaling up the SiPM-on-tile technology (300k → 3M).

Three examples of enabling technologies carried forward by the CMS project:

- Injection molding of large numbers of individual tiles of different types → creativity for detector optimization.

- Leverage the dropping cost and outstanding uniformity of commercially produced SiPMs → streamline QC and calibration.

- Repeatable, efficient automated assembly of detector modules by pick-and-place → complete the task on time and within budget.

Electronic systems are very different — will not discuss here.

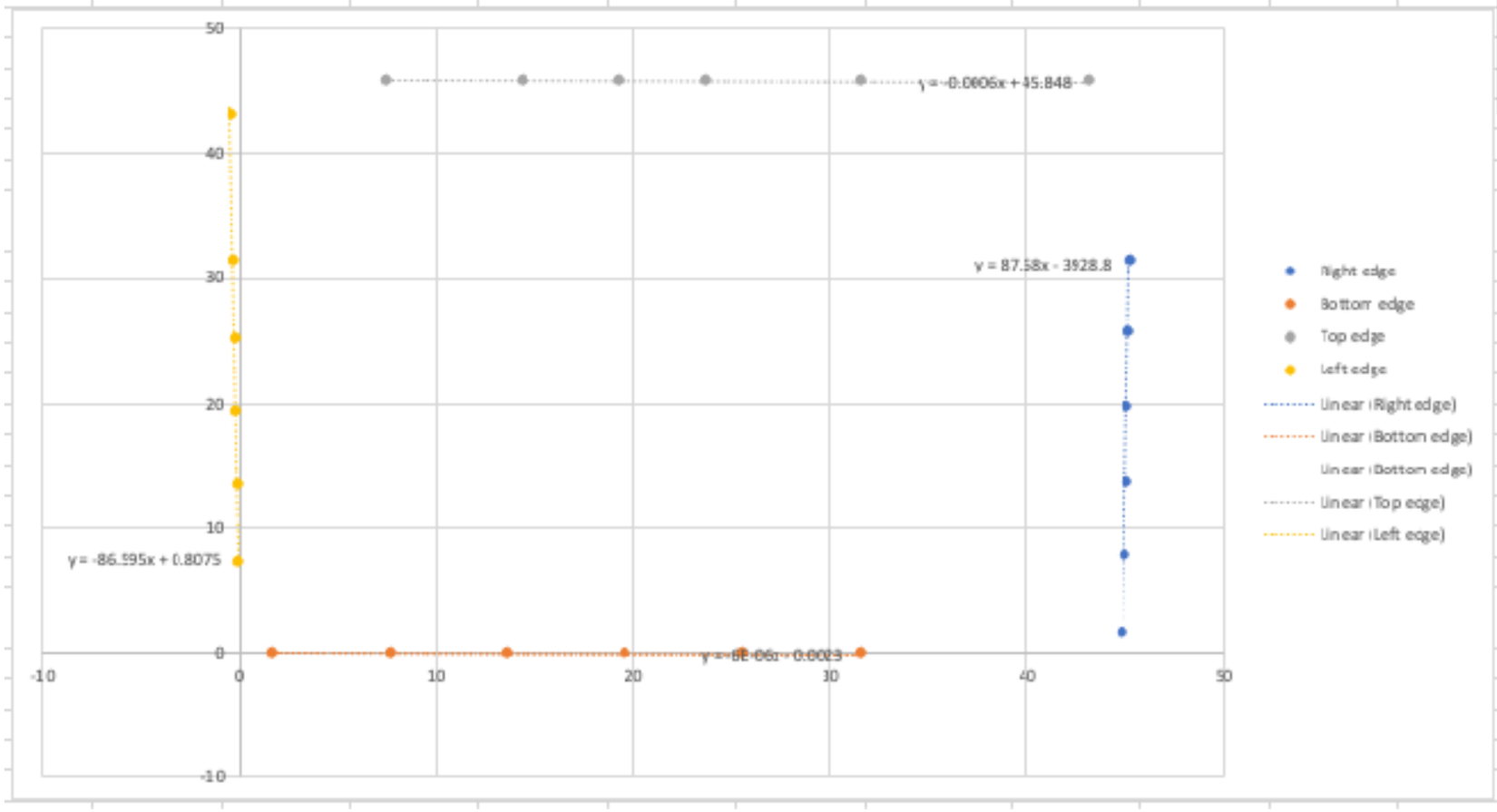
Injection molding

Injection molding of individual tiles gives essentially unlimited flexibility in the size and shape of the individual tiles. The raw materials are very inexpensive ($20k/ton).

Original plan to source injection molded scintillator from Protvino became impossible, so we developed the capability to do this at Fermilab.

Cost is mostly up-front in machining the molds, which requires a precise machining with good surface quality. In CMS we have had success in circumventing the machining of costly molds by making a single ‘master mold’ with replaceable inserts, enabling us to cheaply produce the full range of needed tile types for our design.

Injection molding (cont.)



- 12/19/2022 2pm 777.5 +13.2% / -7.7%
- 12/19/2022 3pm 815.2 +4.6% / -2.7%
- 12/19/2022 3:50pm 896.7 +2.8% / -1.5%

- 12/27/2022 1:30pm 888.2 +3.2% / -2.3%
- 12/27/2022 2:50pm 871.7 +1.4% / -2.6%
- 12/27/2022 4pm 841.0 +4.1% / -3.1%

Optical isolation of tiles

Figure 5.7: Automated scintillator tile wrapper overview. Shown in picture with labels are, 1–4: Actuator arms for folding the cut ESR flaps over the tiles, 5: Tile magazine and dispenser assembly, 6: z-axis (vertical up/down) end-effector with vacuum suction, 7: Kapton sticker dispenser.

NIU wrapper

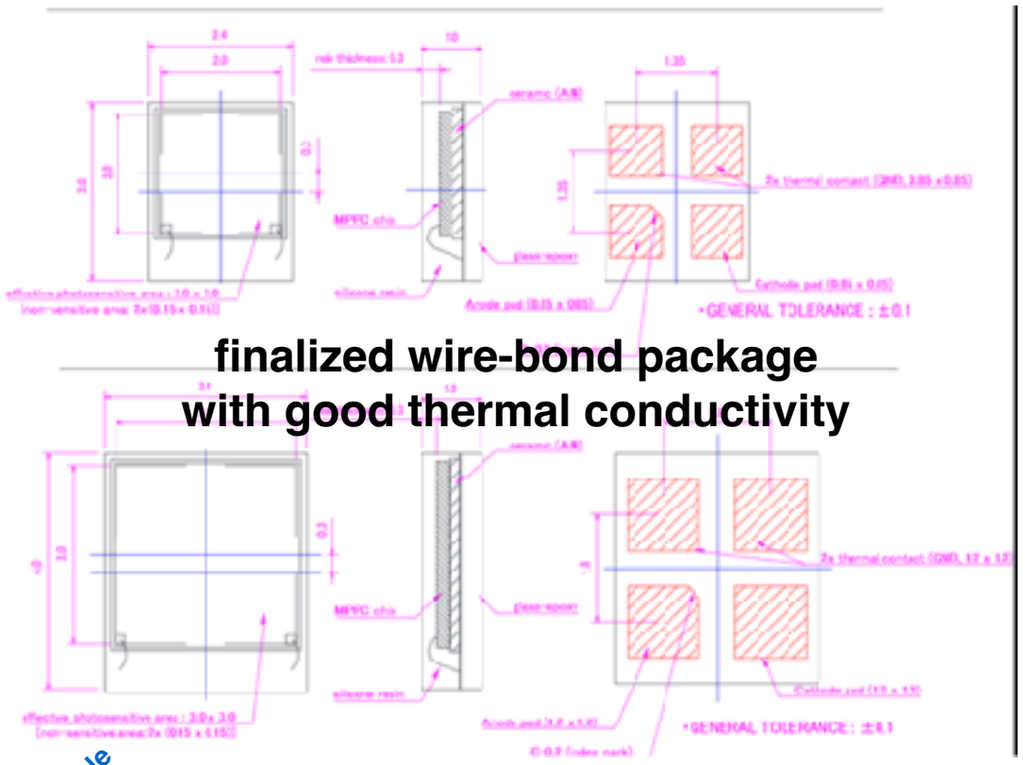
Individual wrapping of tiles by an automated machine is mostly working well for us, but ESR material (reflective wrapping) turns out to be a major (unanticipated) cost driver, approaching the cost of a small SiPM per channel!

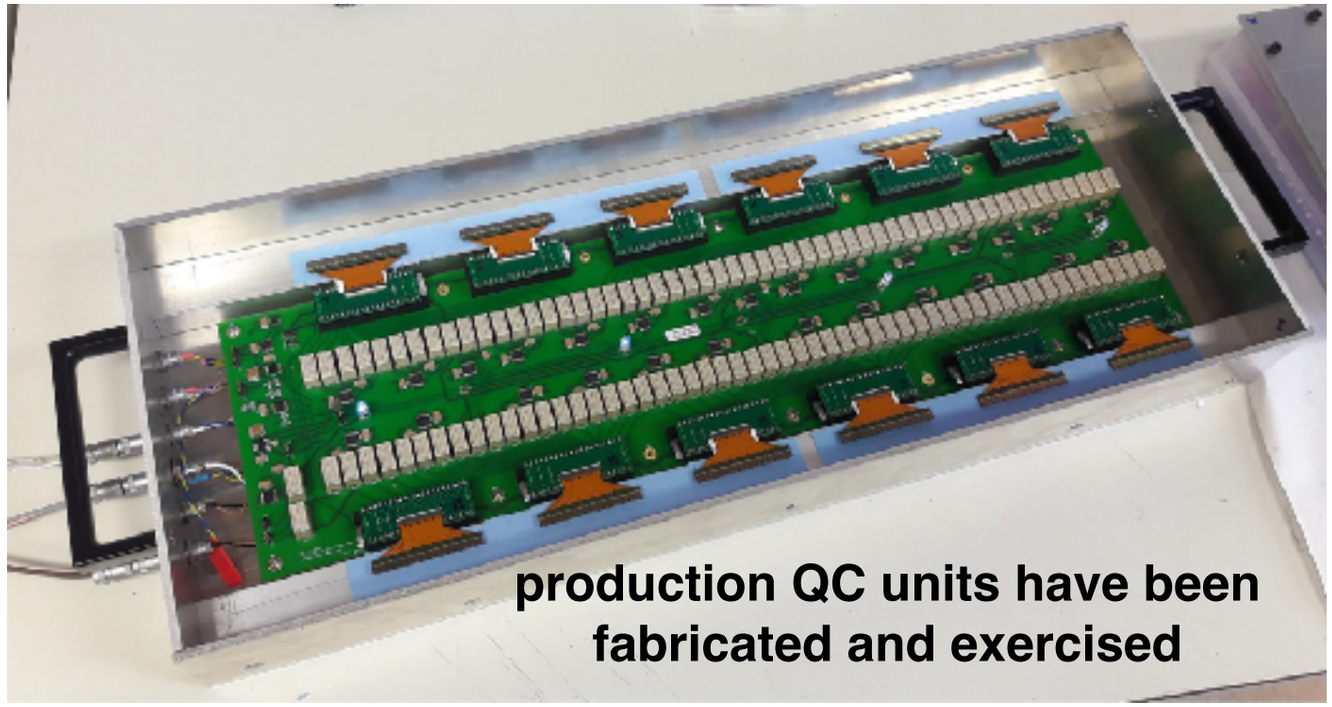
Cutting of foils with inexpensive CriCut machine being used at one wrapping site, more capable Aristo cutter at the other.

Investigate options:

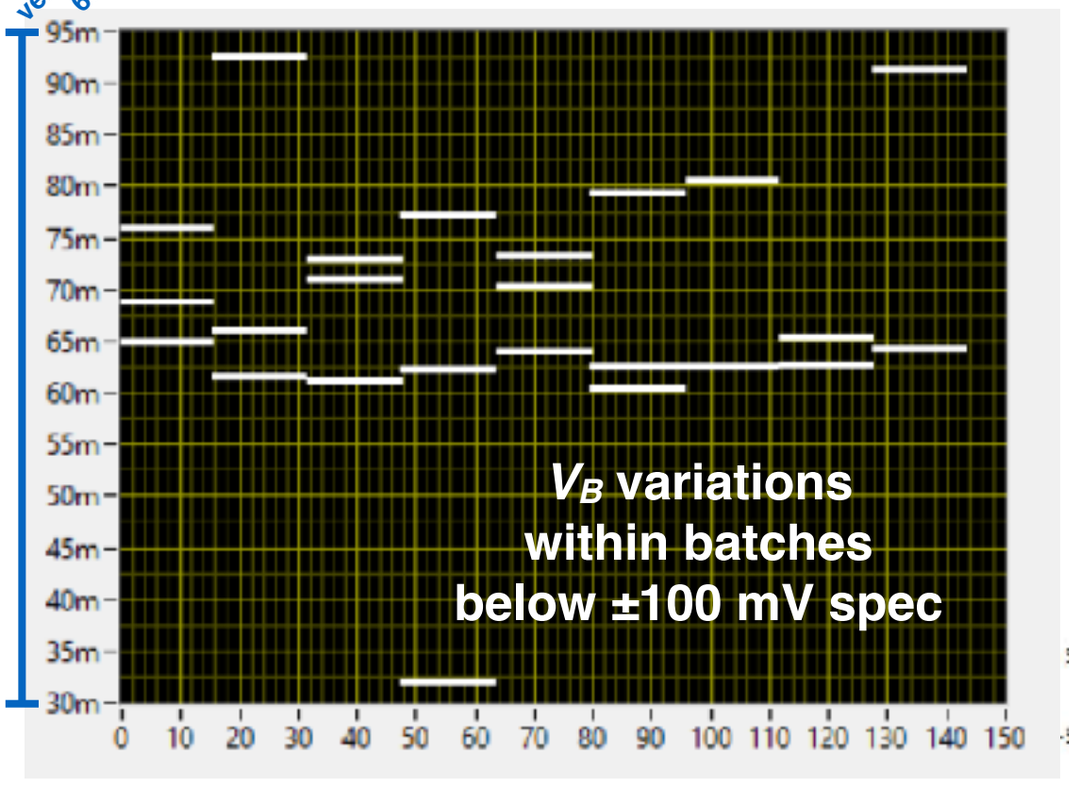
- Individual wrapping with cheaper material (Tyvek, mylar, …) at some cost in reflectivity.
- Megatile approach, with trenches filled with RTV silicone or similar, has proponents. In our case the increased optical cross talk was not acceptable, nor was the time saved so great.
- 3D printed frames have also been proposed.

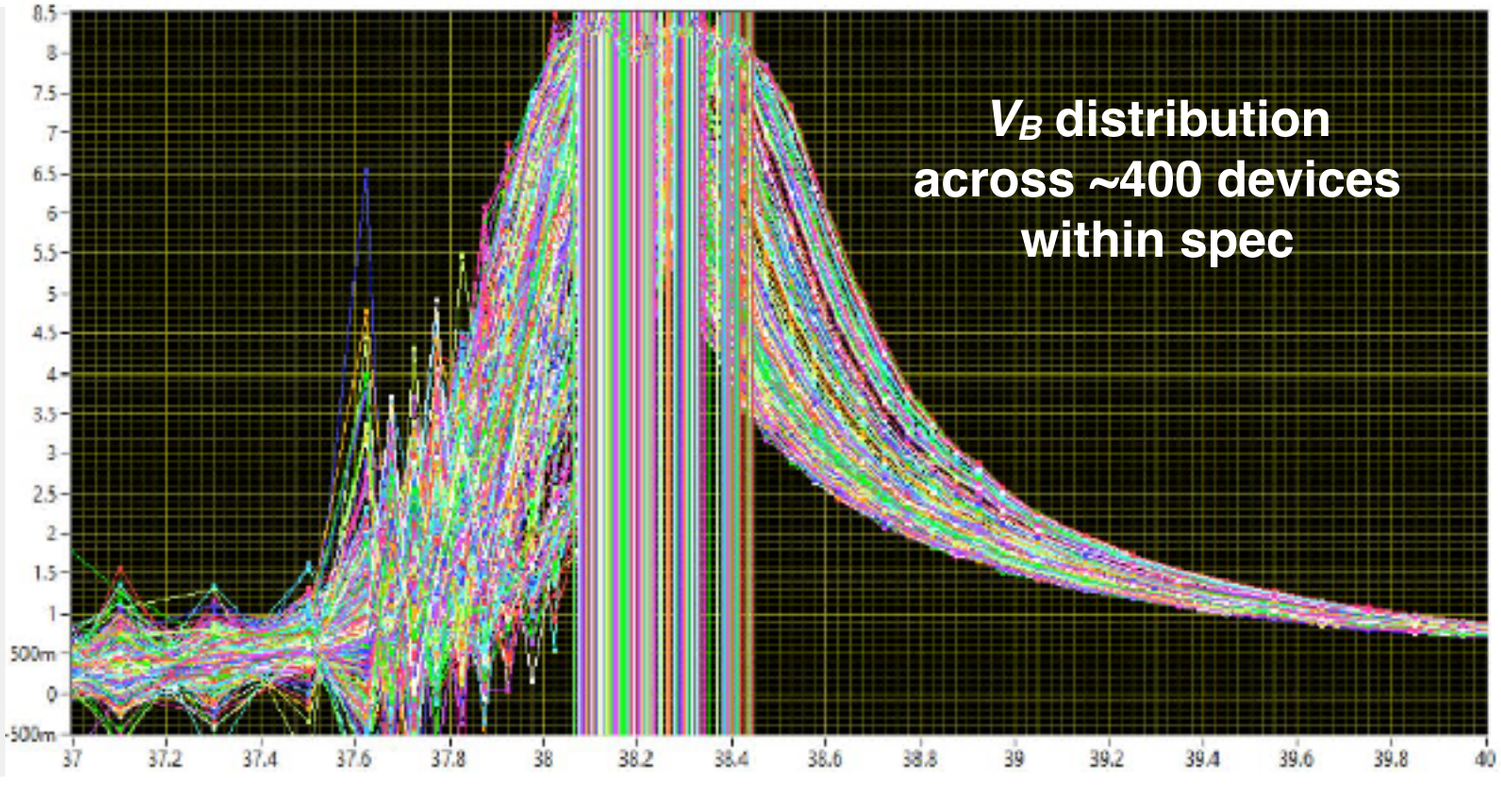
SiPMs



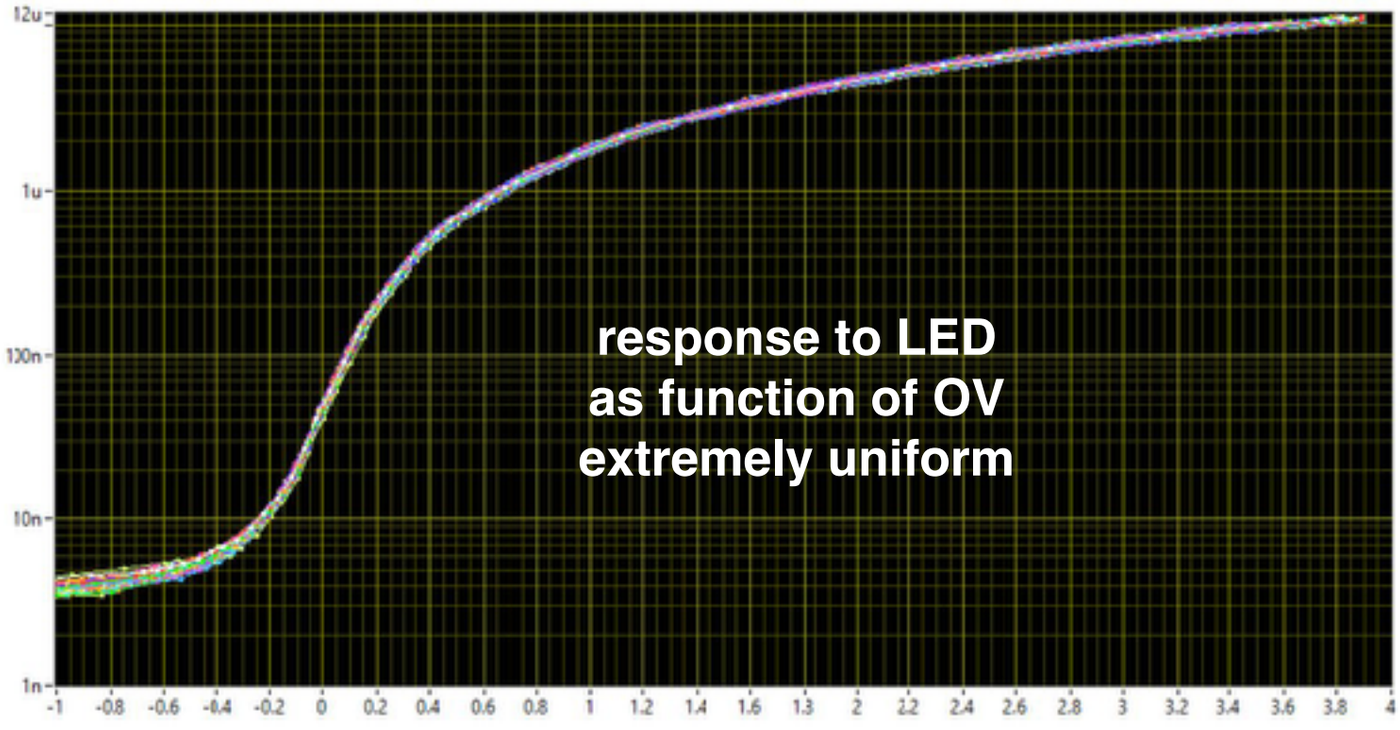


QC results from Notre Dame lab at CERN

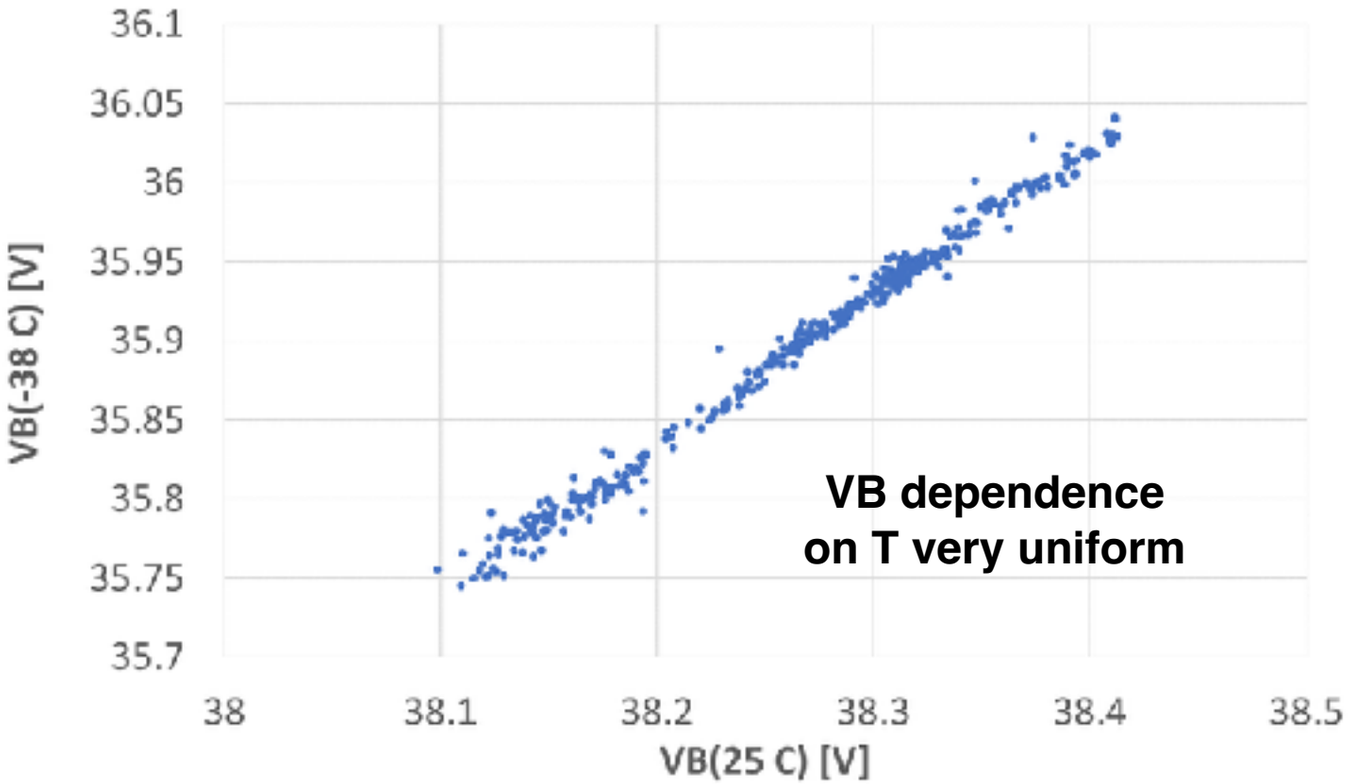


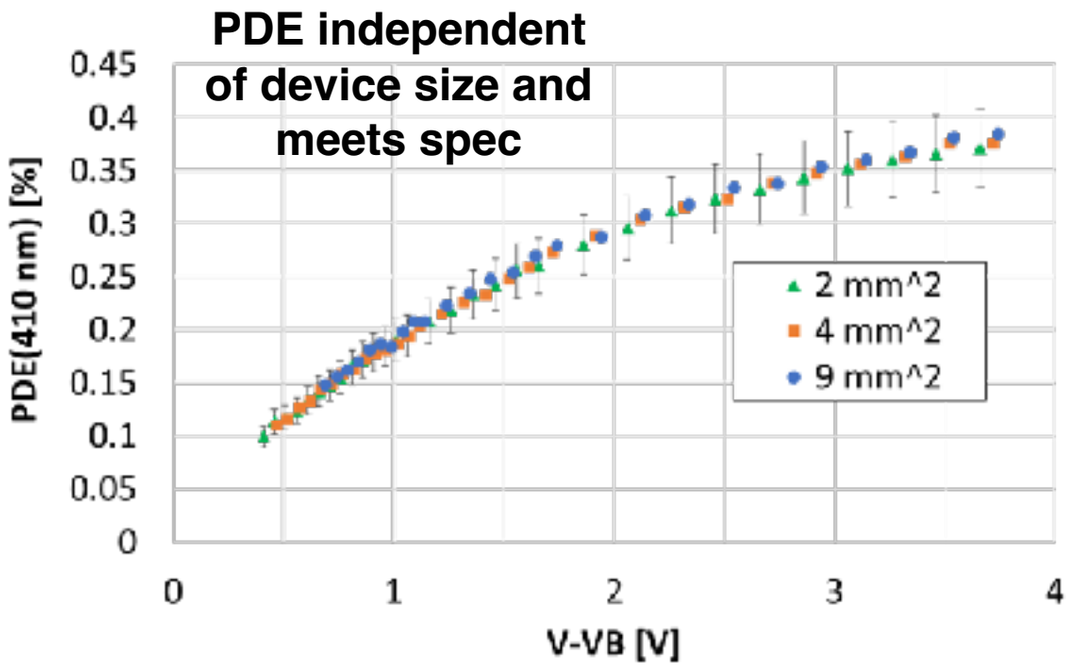


SiPMs

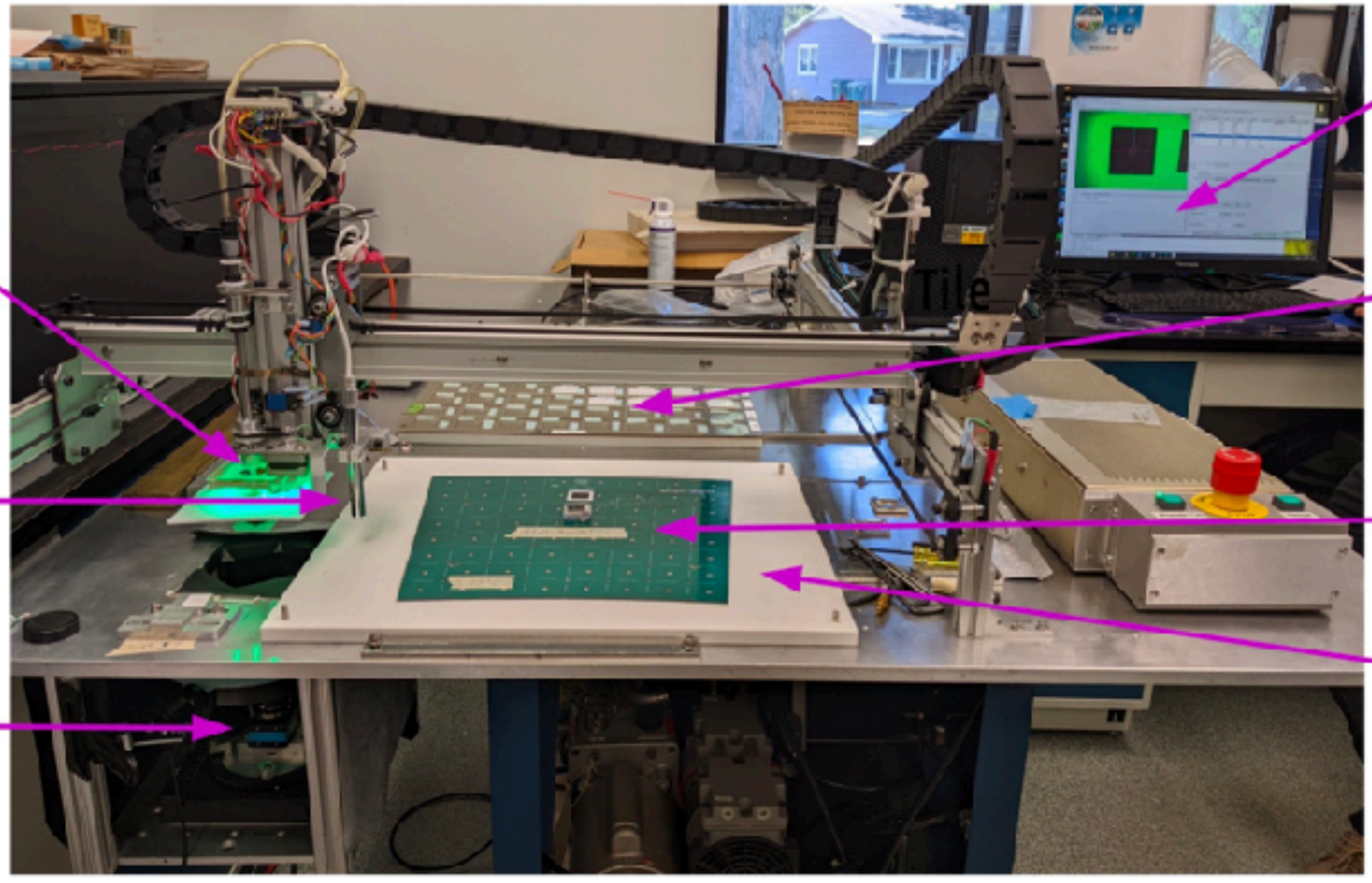


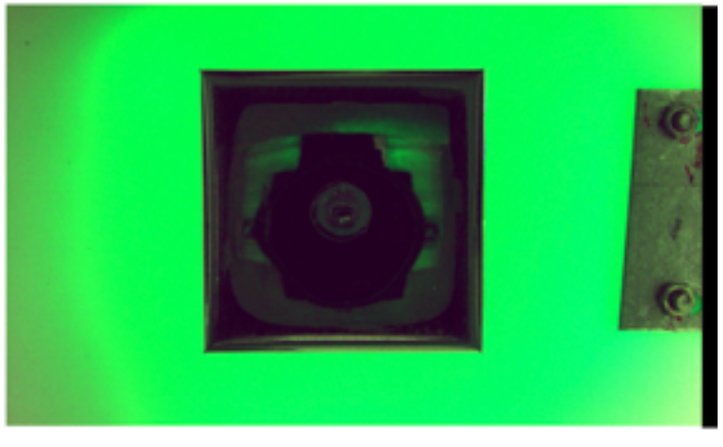
Very good uniformity of devices across all relevant parameters supports the approach of QC by spot sampling.





Module assembly





Efficient and repeatable operation
Exploring adhesive sheets rather than glue
CMS requires multiple tile sizes per module

Comment on design optimization

Because of the flexibility of the technology, the space of possible transverse segmentations and longitudinal stackups is very large, even if there were a fixed cost envelope!

There are a number of interesting tradeoffs regarding detector depth, energy resolution, angular resolution, timing performance, use of rear detector for μ/π, …

A short list of performance targets and/or a ranking of their relative importance would be a valuable aid in pruning the decision tree.

Summary

The flexible and cost effective nature of SiPM-on-tile technology makes it a natural choice for a variety of applications.

Our community has developed a lot of equipment, tooling, and human capital to assemble the HGCAL SiPM-on-tile calorimeter for CMS. Much of this has the potential to translate directly to the proposed ND-GAr ECAL design, and can give a leg up on assembling prototypes.

We are also interested in discussing simulation tasks related to detector optimization.