THE CALICE AHCal & ScECal

Vishnu Zutshi
Northern Illinois University

Calorimeter for ILC

Northern Illinois University

Learning Today, Leading Tomorrow

Acknowledgements

- The work described herein represents effort carried out by the AHCal and ScECal groups as part of the CALICE Collaboration and showcases the R&D efforts carried out at institutions in Asia, Europe and North America.
- In particular my thanks to F. Sefkow, Y. Liu and M. Robles from who have been my source of many pictures and plots

Outline

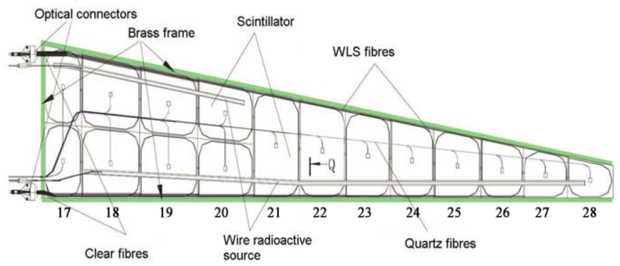
- Preliminaries
- AHCal Physics Prototype
- Scalability and a proof-of-principle
- Towards a technical design
- Testbeam and synergies

- ScECal prototyping

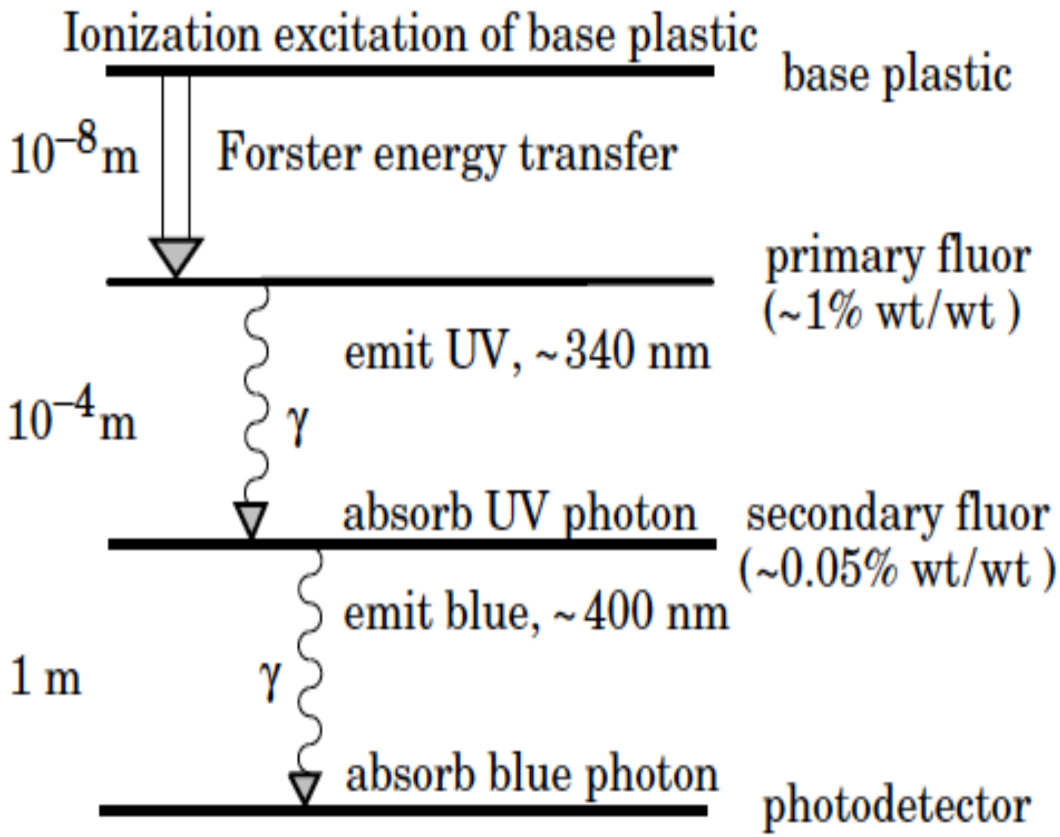
- Summary

AHCal & ScECal

- Employ plastic scintillator, a proven technology married to what was then an emerging solid-state photosensor technology
- Scintillator calorimetry had already been used extensively in HEP: robust, fast, reliable, largely linear (modulo Birks)
- Challenge was always going to be converting the photon signal to an electrical one for a design with high longitudinal and transverse segmentation as dictated by PFA
- Traditionally achieved by routing fibers (WLS and/or clear) outside the detector



Scintillation



Most applications have used guides or fibers (often WLS) to bring the light out

Photomultipliers

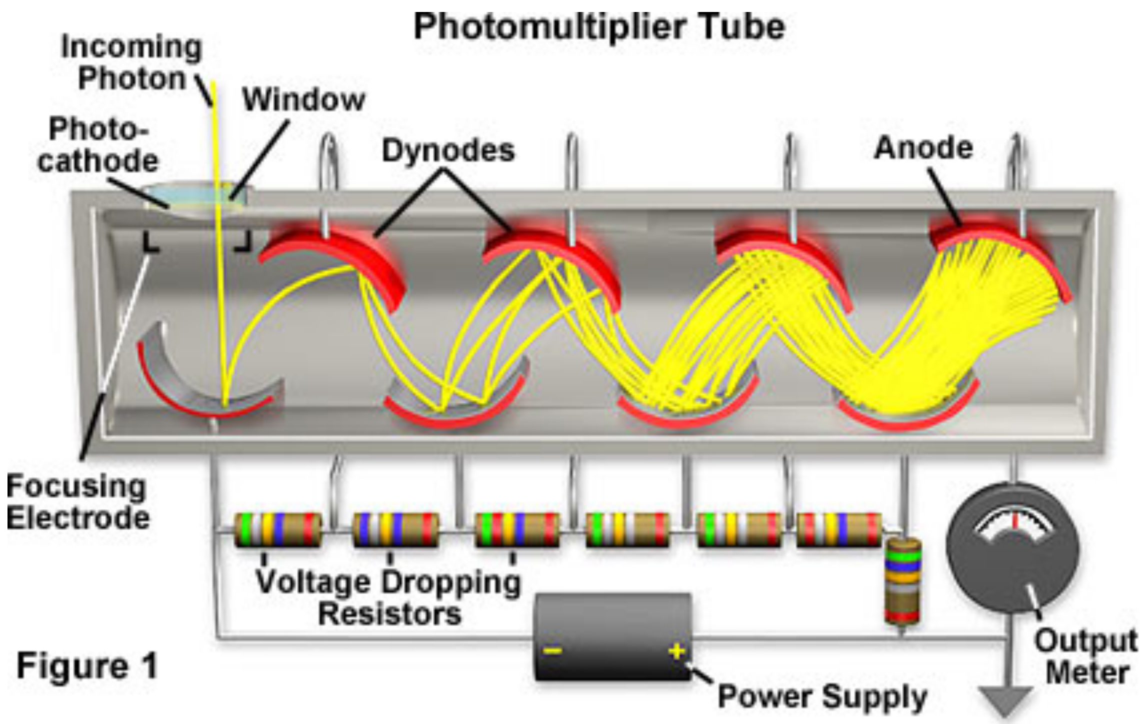
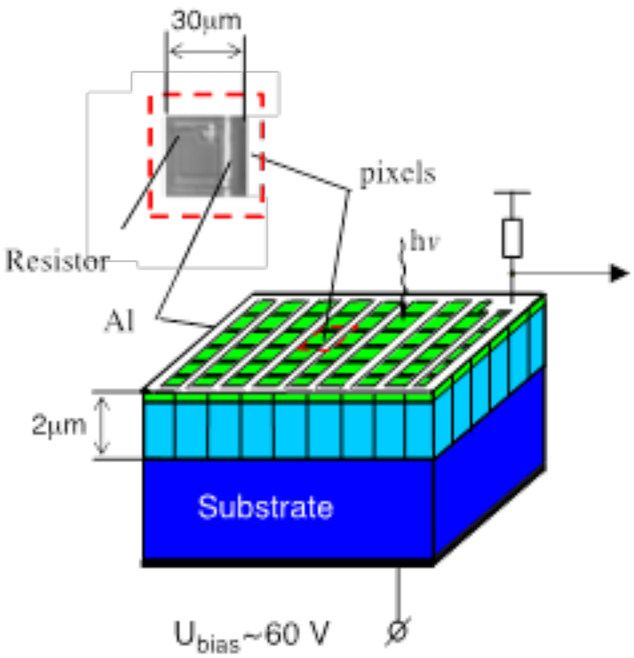
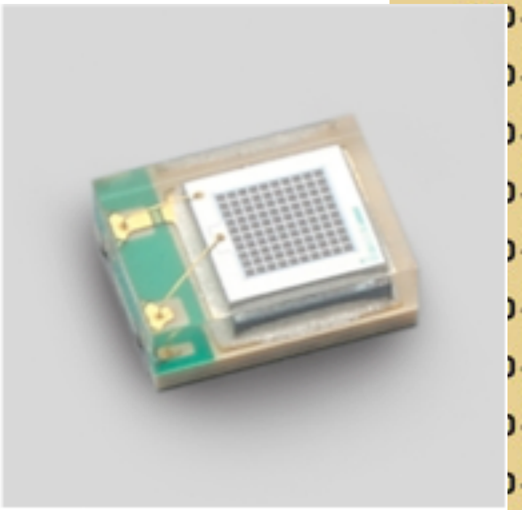


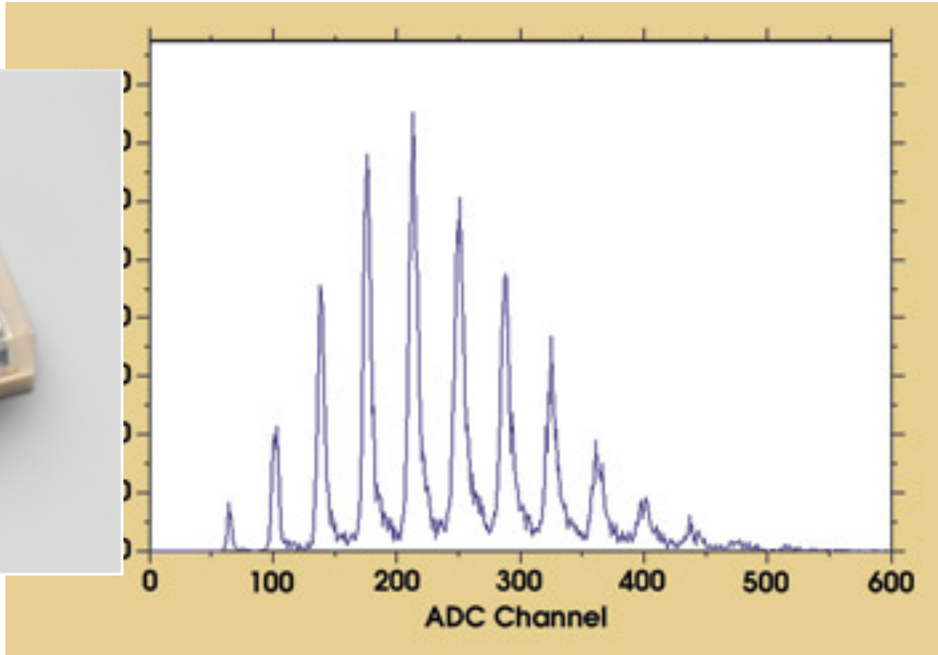
Figure 1

Generate a detectable electrical signal proportional to the small number of incident photons

Silicon Photomultipliers



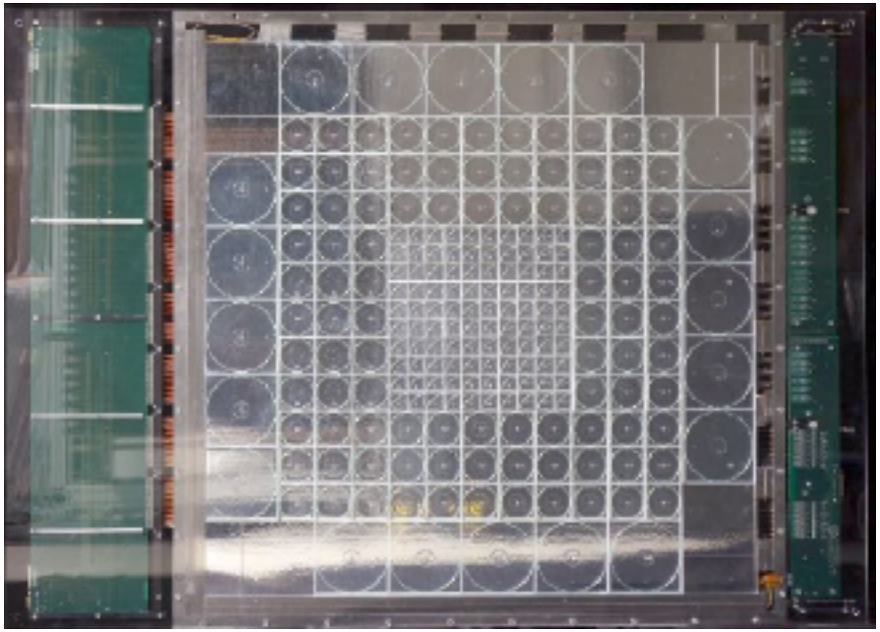


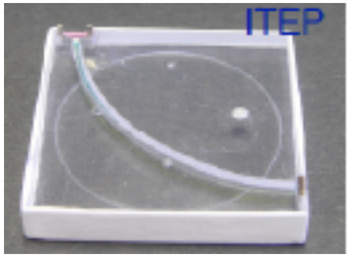


- Multi-pixel photo-diodes operating in the limited Geiger mode
- High gain ($\sim 10^6$), low bias (<100 V) and insensitive to B-fields

- Tremendous growth area in terms of vendors and quality of devices and the varied applications these photosensors are being used in

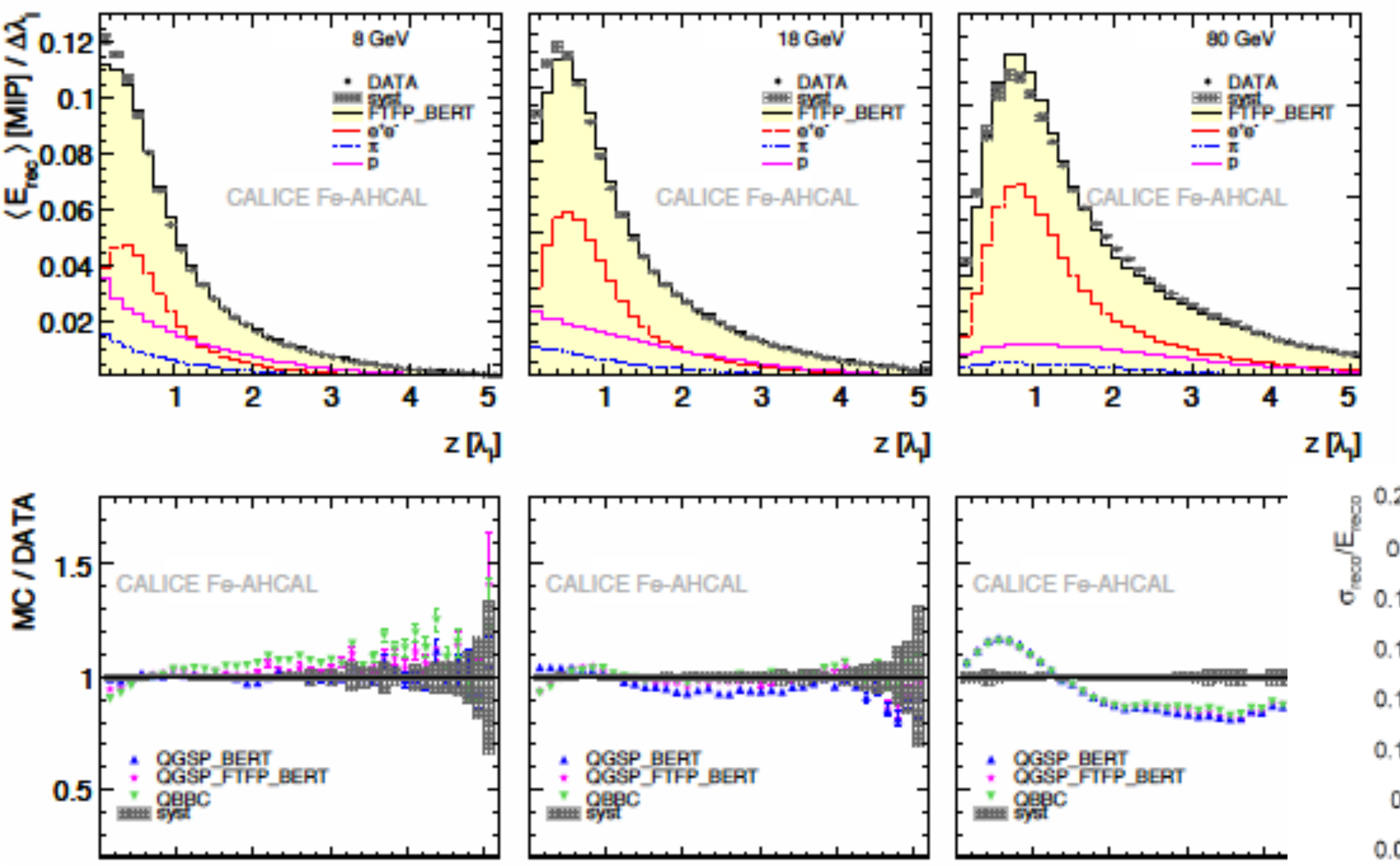
The AHCal Physics Prototype

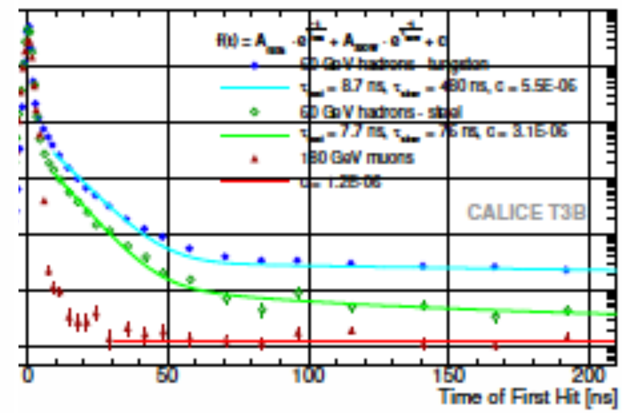


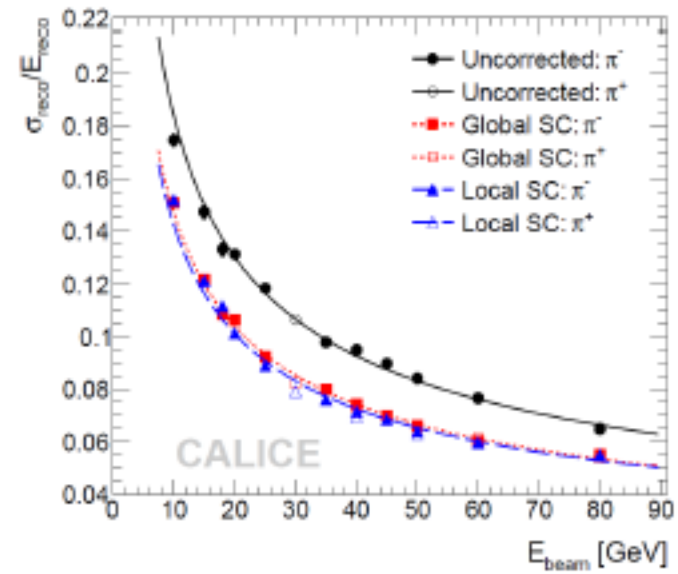


- First large-scale application of SiPMs for scintillator calorimetry
- Still used WLS fibers to mate to SiPMs but already a significant step in housing the sensor on the tile
- A lot operational experience with SiPMs

AHCal Physics Prototype

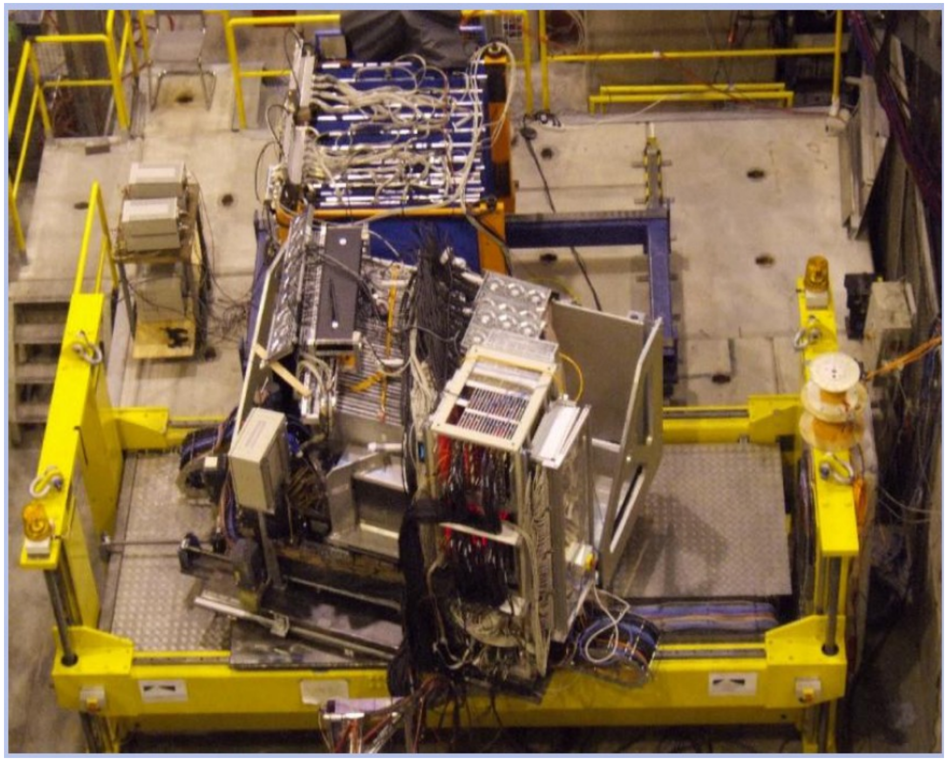






A rich physics harvest

CALICE AHCAL Prototype



Clear establishment of the scintillator-SiPM active media as a viable calorimetry option in a PFA-based detector

However significant scalability issues which elicited different responses and proposals from within the collaboration....

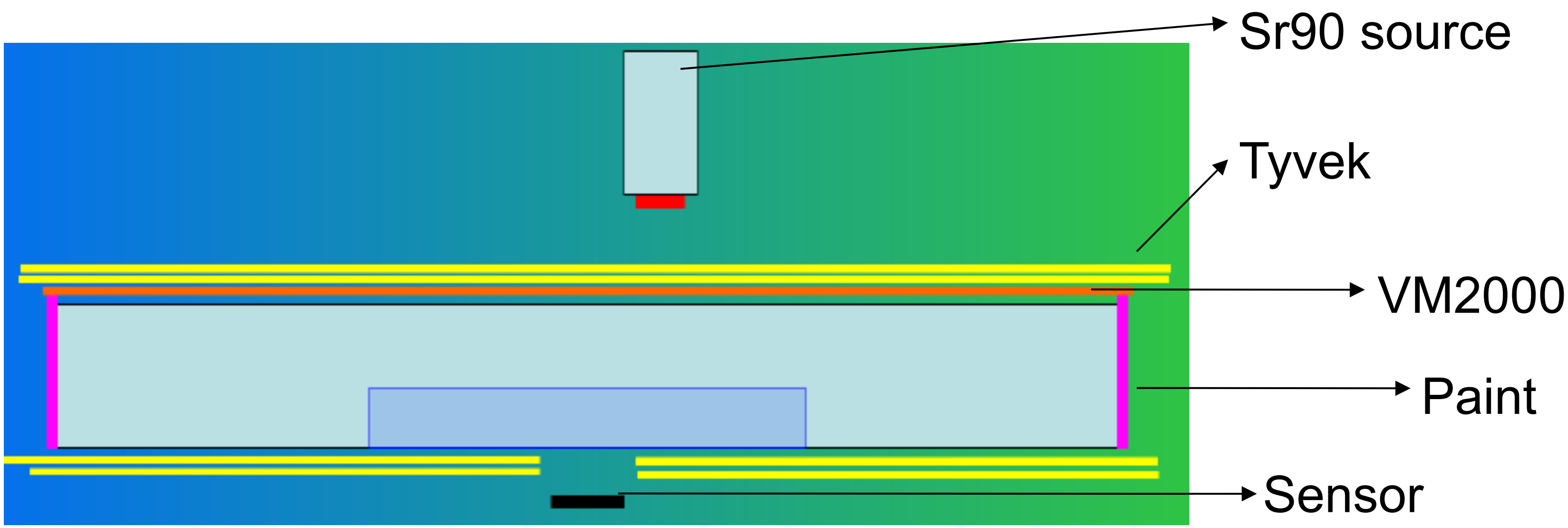
Integrated Readout Layer (IRL)

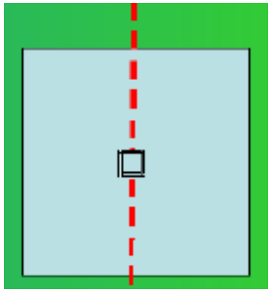
- Defined by making some interface choices:
- **Scintillator – Sensor**
  - With WLS fiber or <u>direct (i.e. fiber-less) coupling</u>
- **Sensor – PCB**
  - In tile or <u>surface-mounted on PCB</u>
- **Scintillator – PCB**
  - Individual tiles or tile arrays
- **Scintillator – LED**
  - Light distribution or <u>pulse distribution</u>

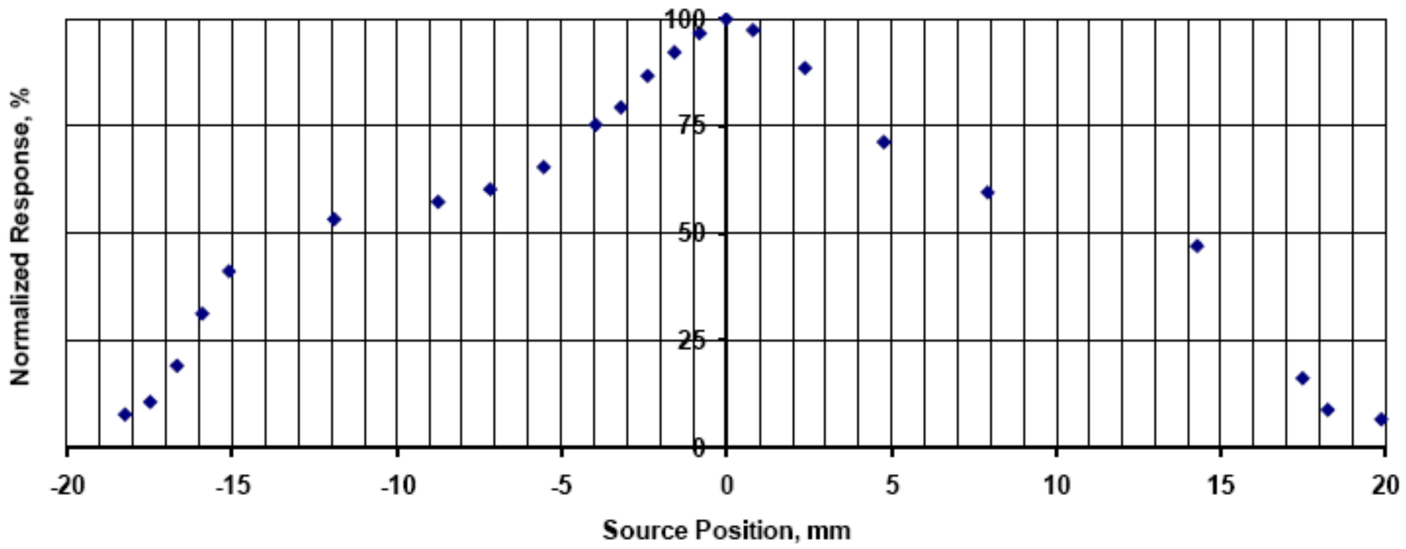
Direct Coupling

- Simplification in construction and assembly
- Greater electro-mechanical integrability
- Transverse segmentation flexibility
- Is there enough response and is the response uniform enough?
- Measurements initially done for 5 mm thick, 9 cm^2 tiles with 1 mm x 1 mm Hamamatsu MPPCs

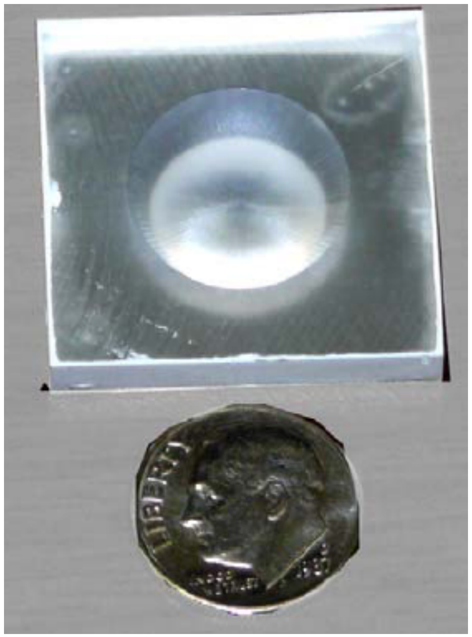
DC Response Uniformity

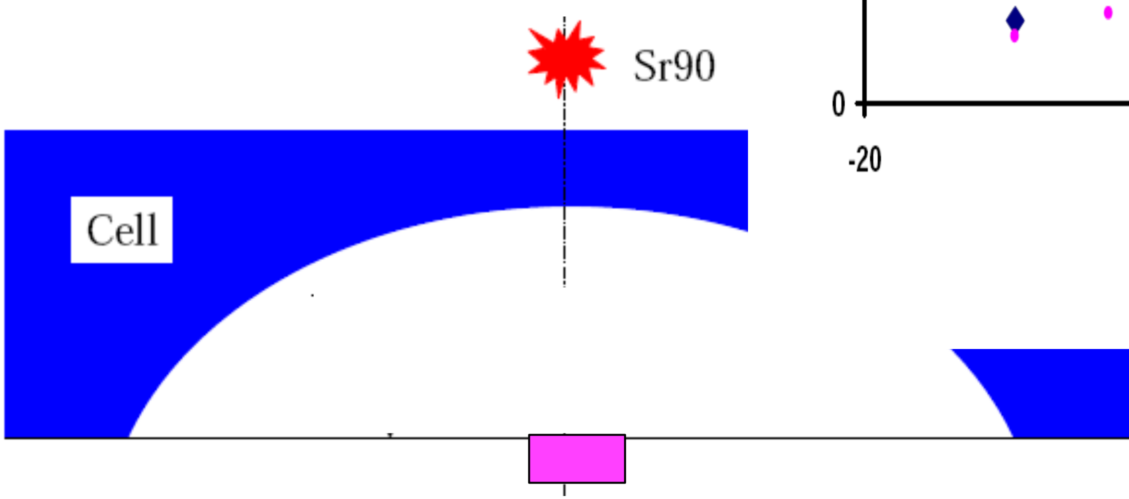


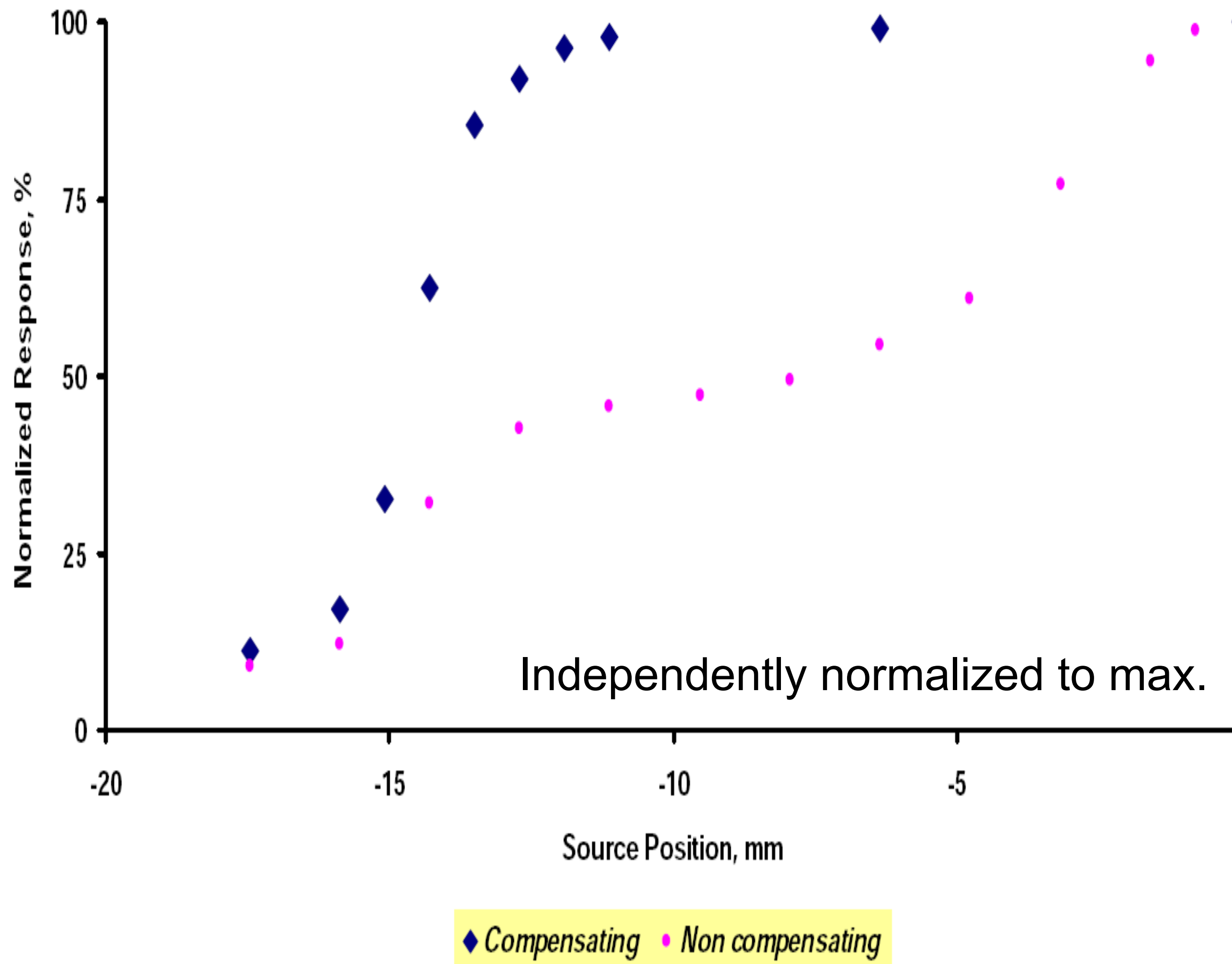




Dimpled Tile



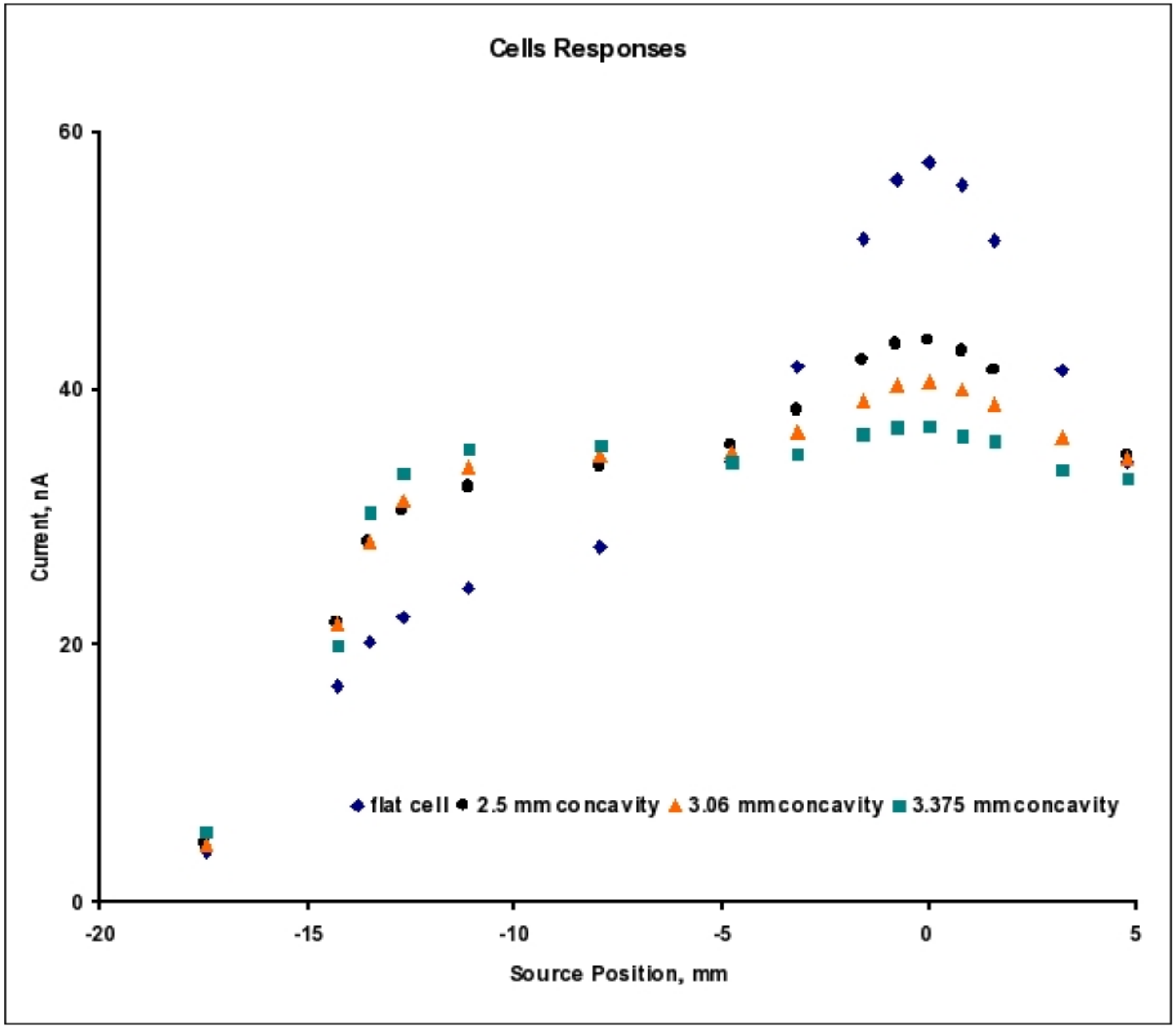




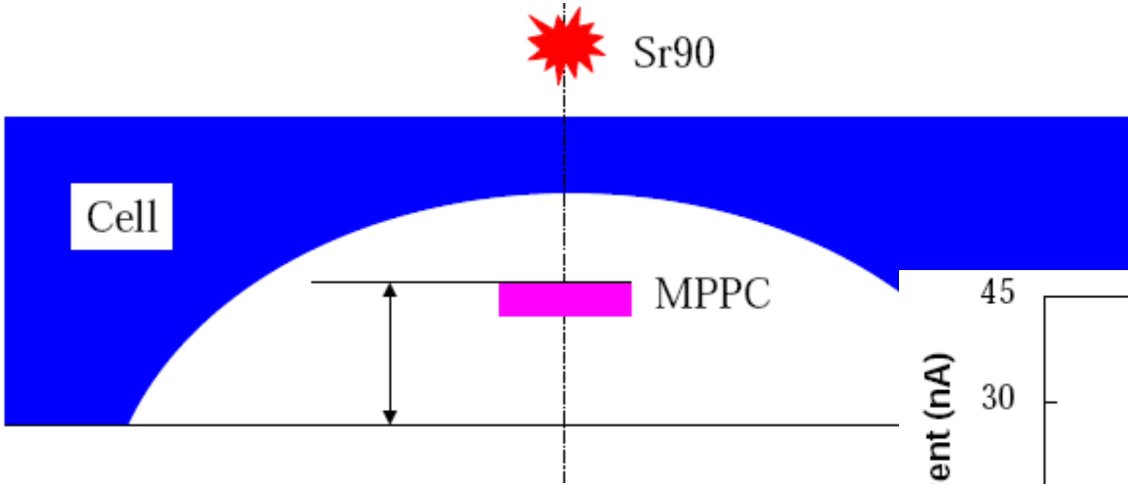
Adequate Uniformity

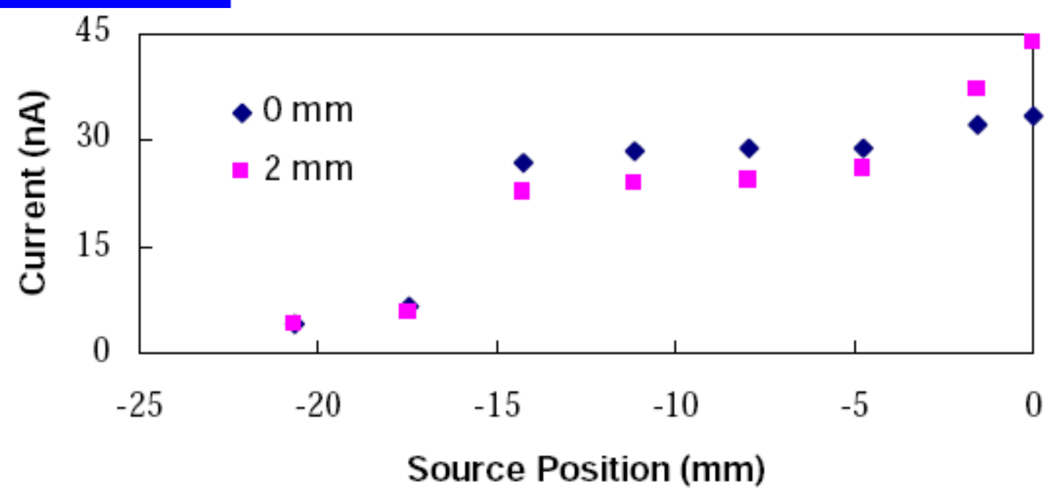
Response Evolution

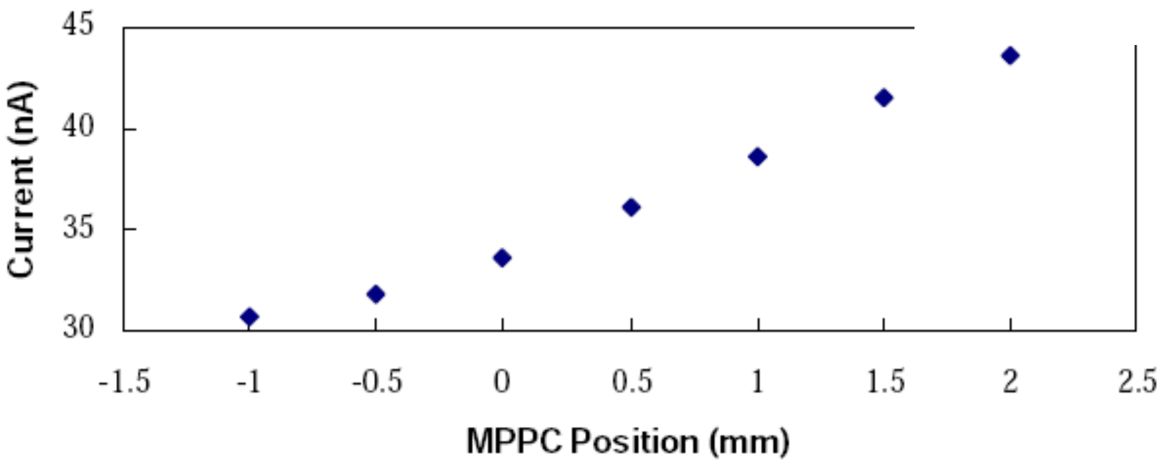
alternative design of concavity on side is described in:
F. Simon et al, NIM A 620, 2010



Tolerances

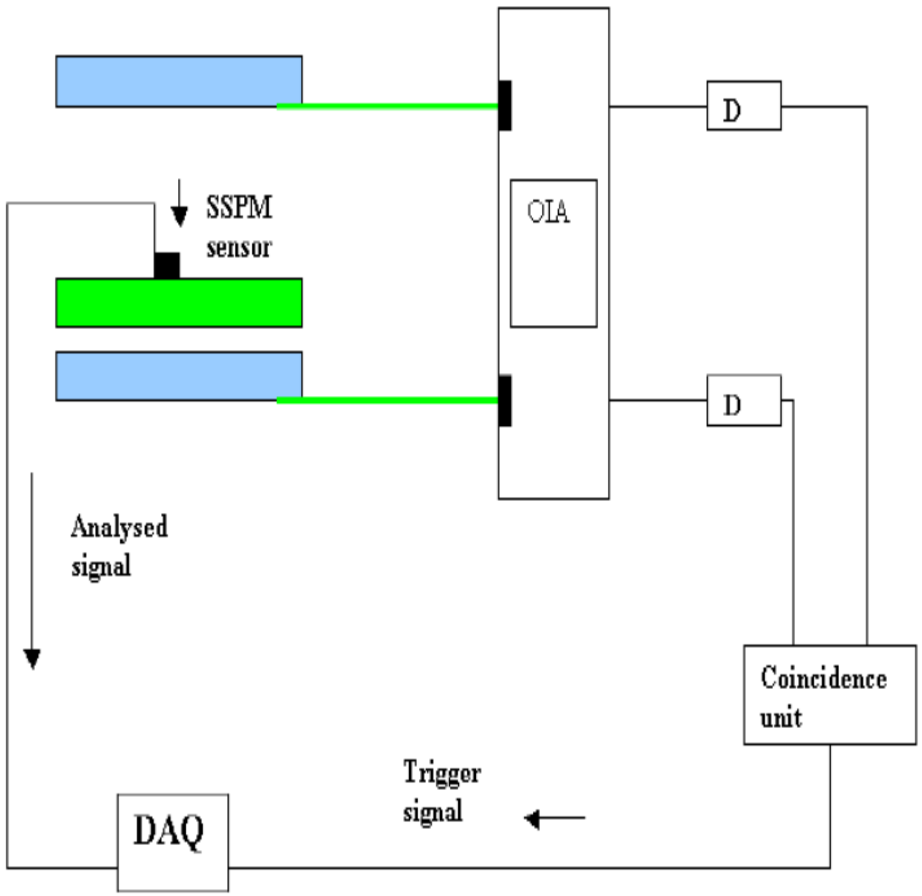


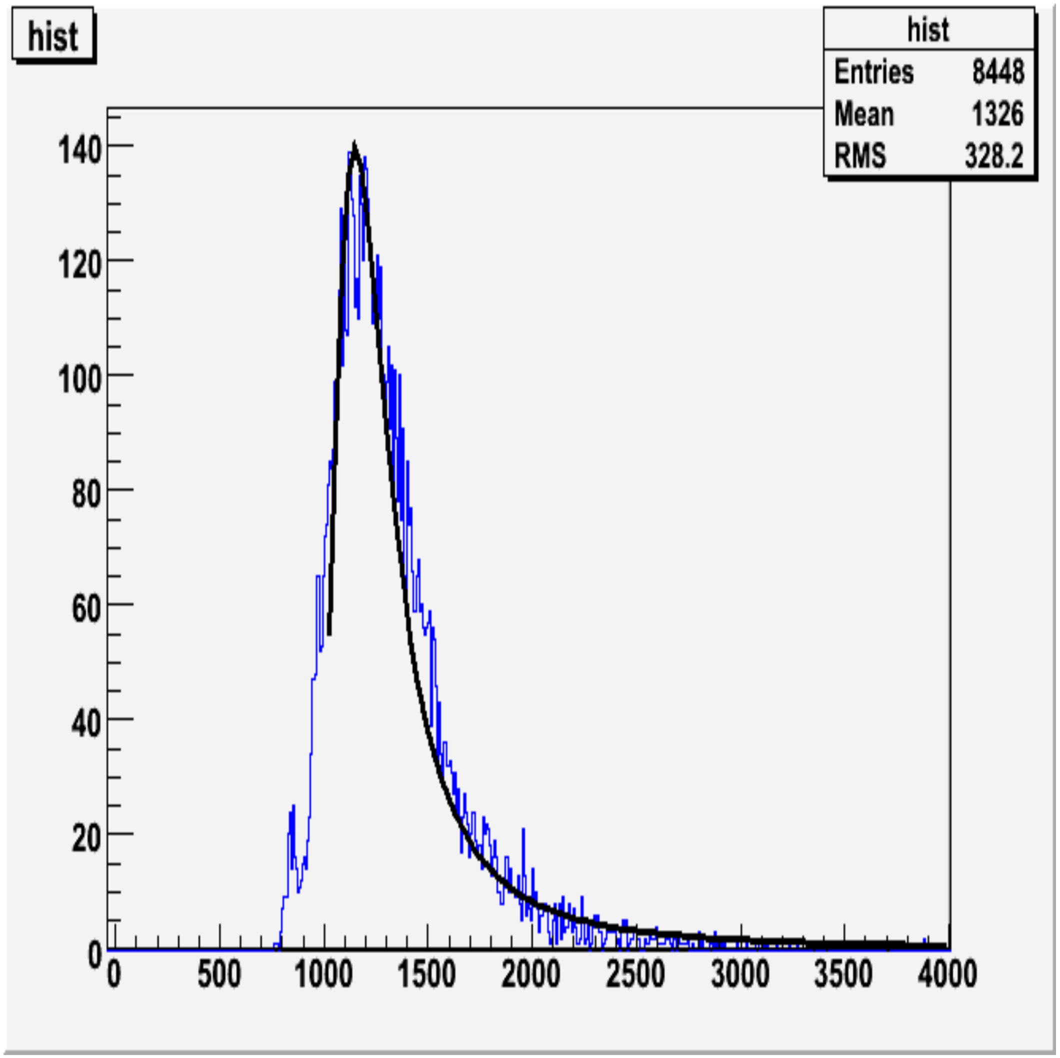




Rather comfortable

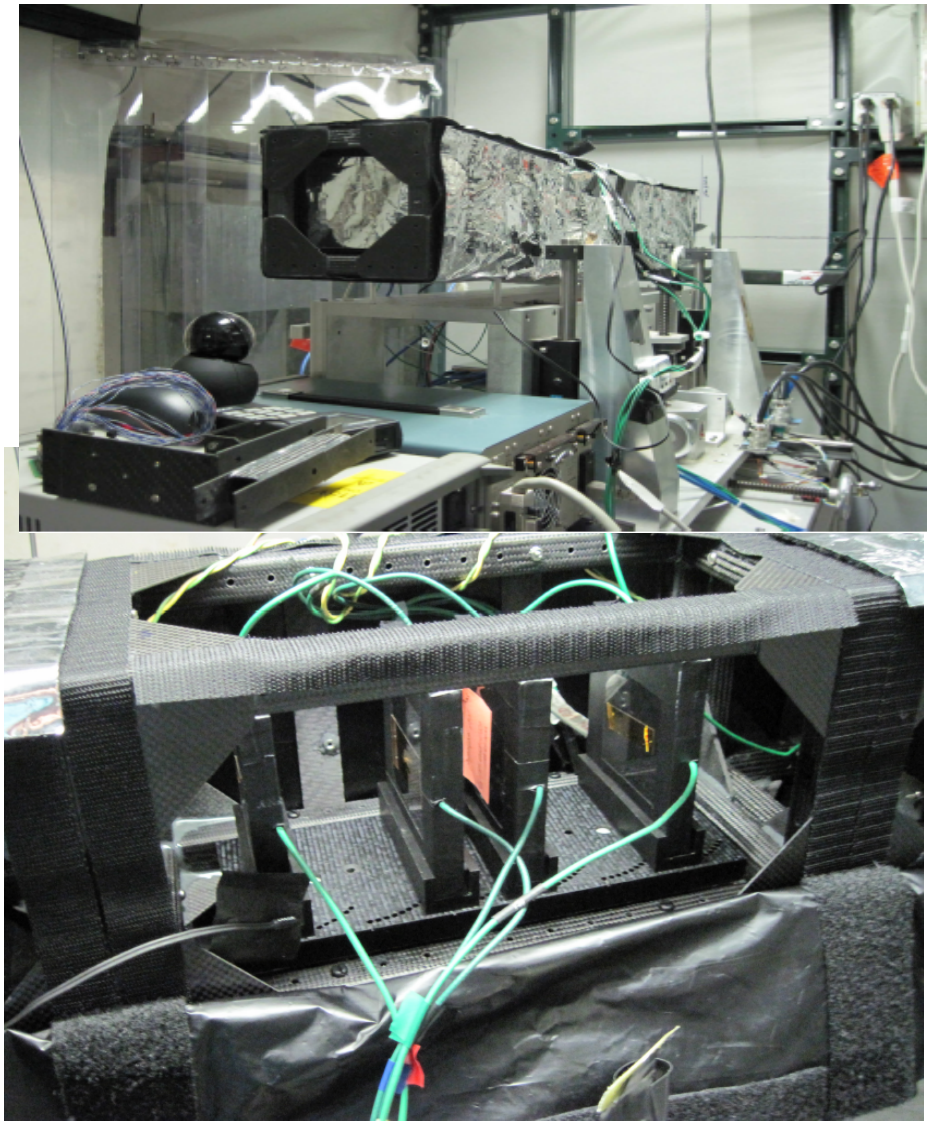
Response to Cosmics

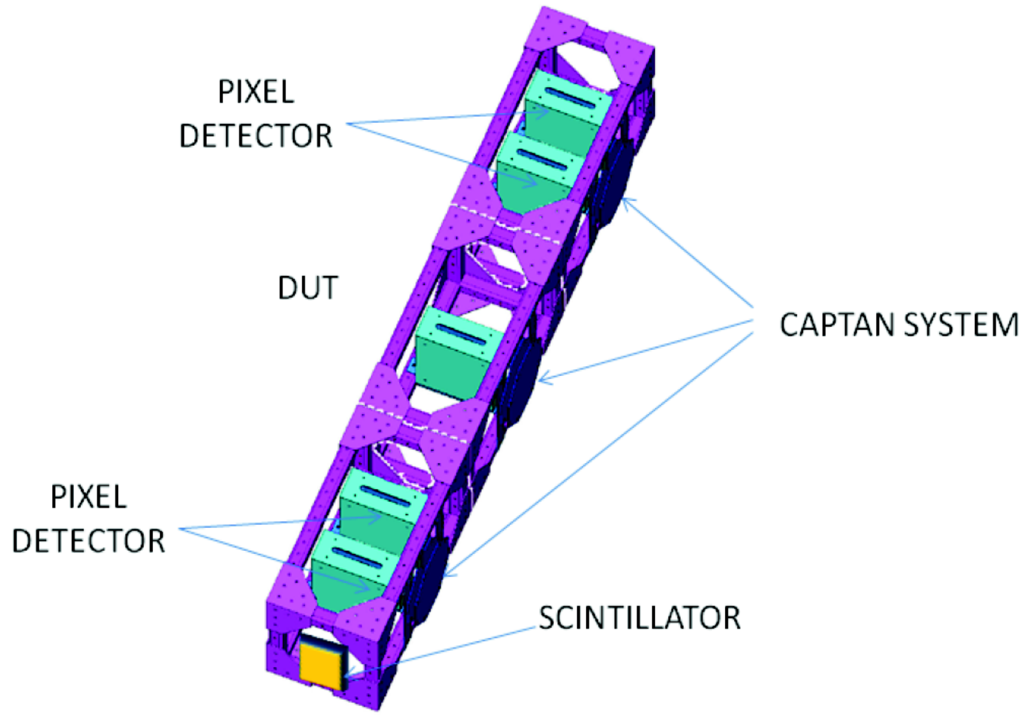




Adequate Light Yield

Testbeam Setup

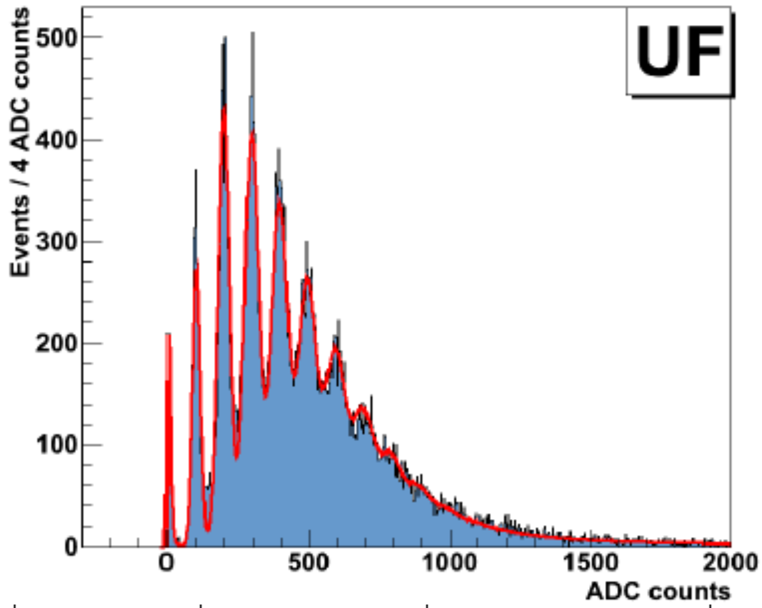


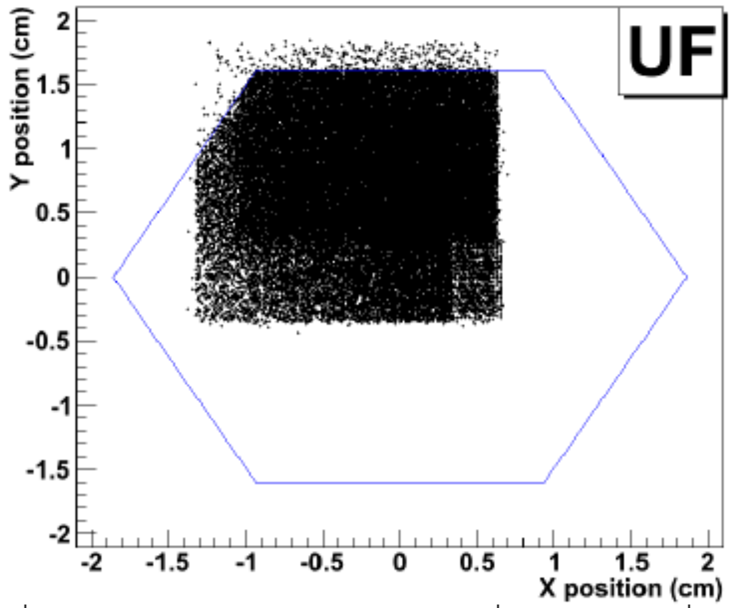


Testbeam carried out at Fermilab with 120 GeV protons using facility pixel telescope (active area of ~2cm x 2cm with ~40μm position resol).

Nucl.Instrum.Meth. A659 (2011) 348-354

Tiles in the beam

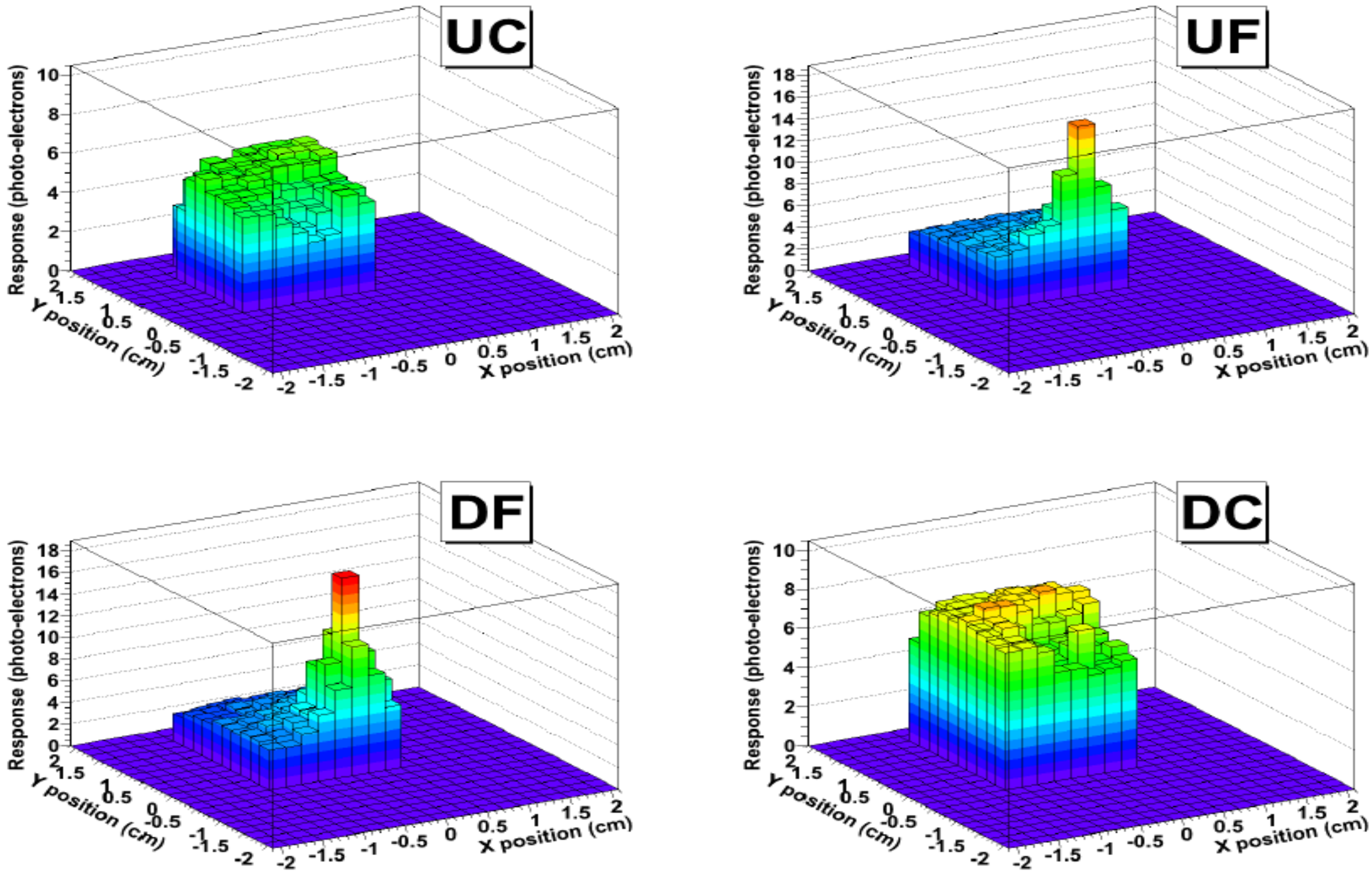




Tile	Z (cm)	Thick. (mm)	Shape/ Depth (mm)	Scin. Type	MPPC (Hamamatsu)	Pixel #	Pixel Size (μm^2)
UC	-11.8	5.0	Con. 3.0	Cast	S10362-11-025C	1600	25 x 25
UF	-3.0	5.0	Flat	Ext.	S10362-11-050C	400	50 x 50
DF	0.2	5.0	Flat	Ext.	S10362-11-050C	400	50 x 50
DC	8.2	5.2	Con. 3.0	Cast	S10362-11-025C	1600	25 x 25

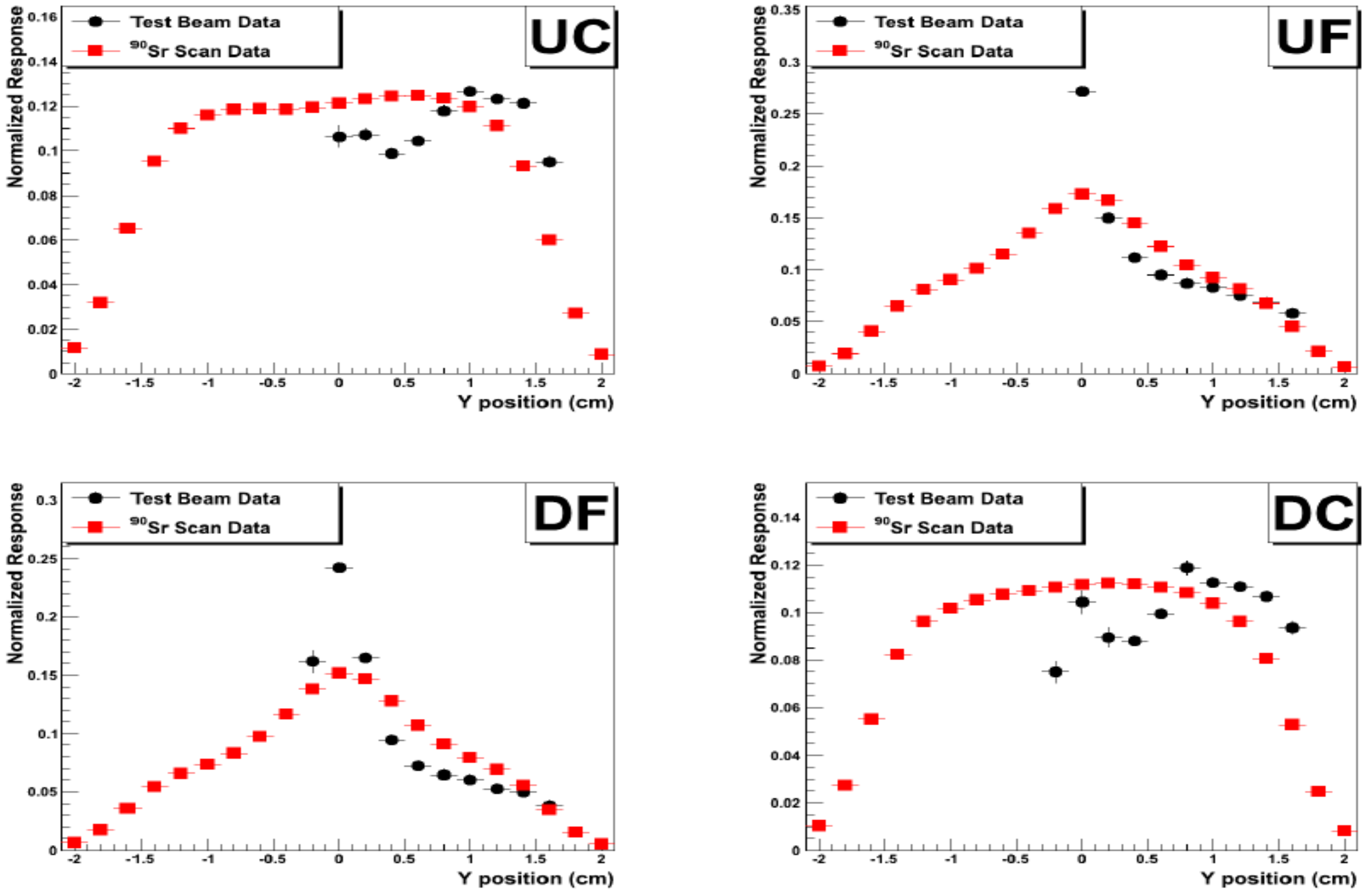
Tile Response

C = Concavity

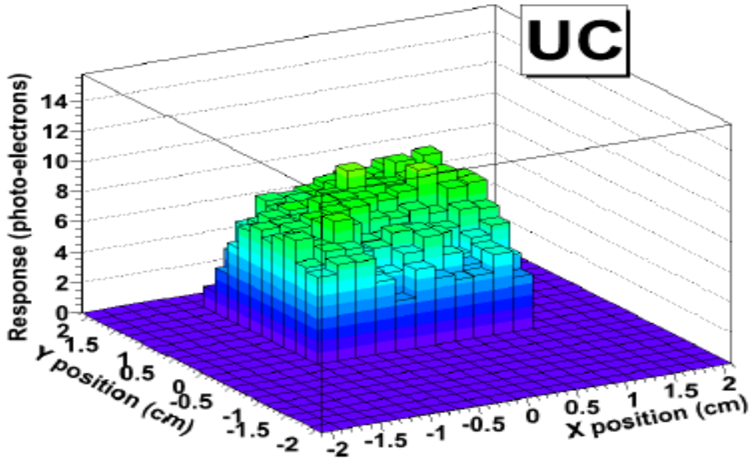


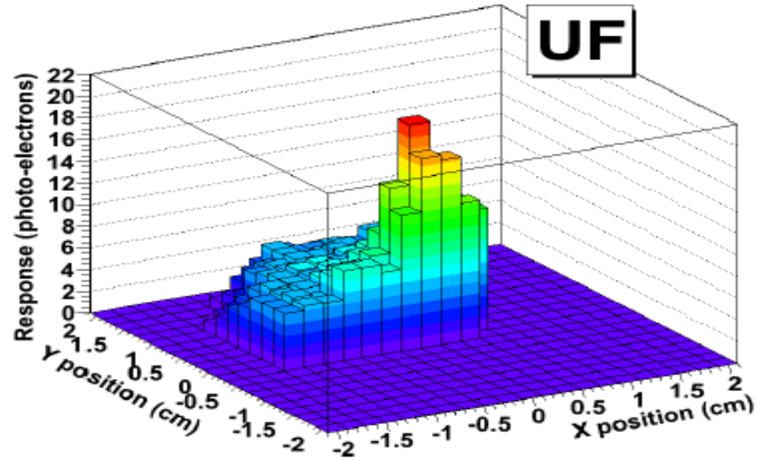
F = F

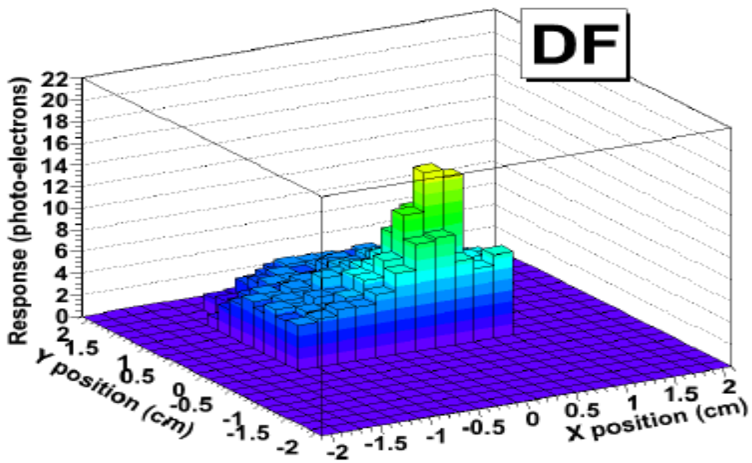
Beam vs. Source Scans

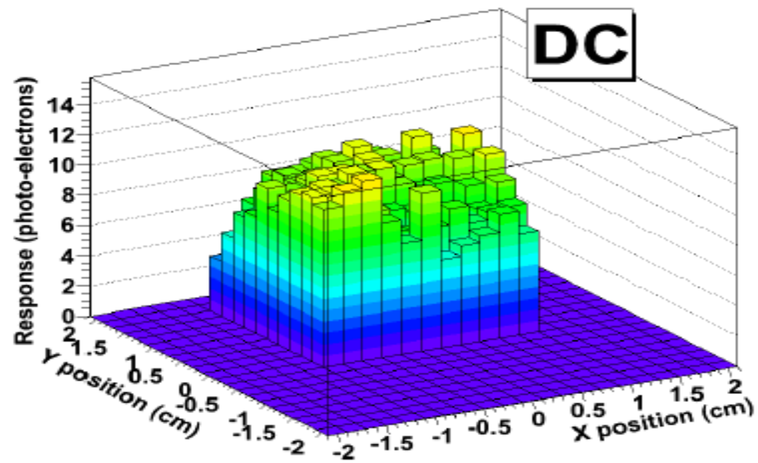


Response at 40^{o}

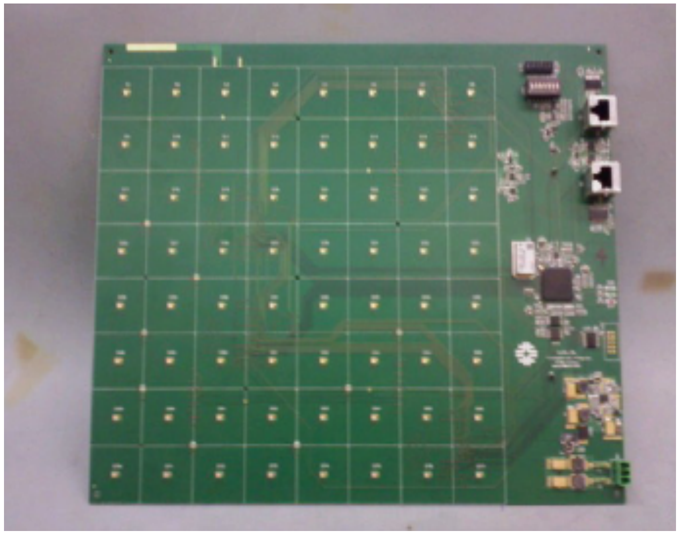


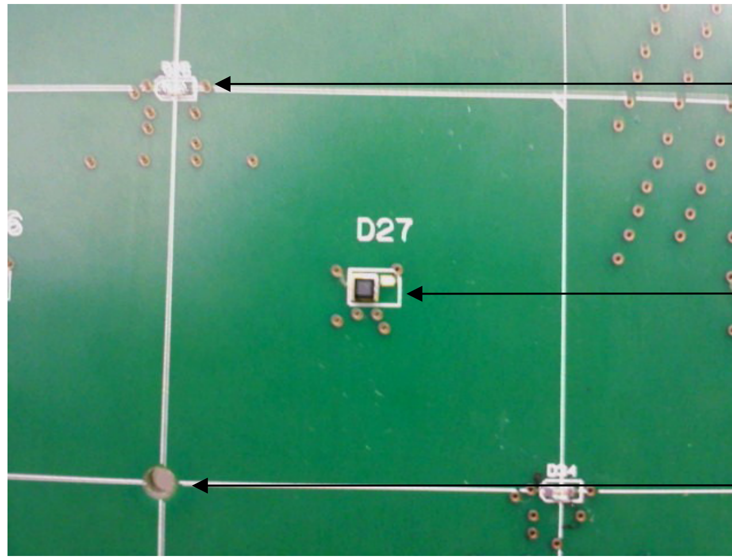






IRL Proof-of-Principle

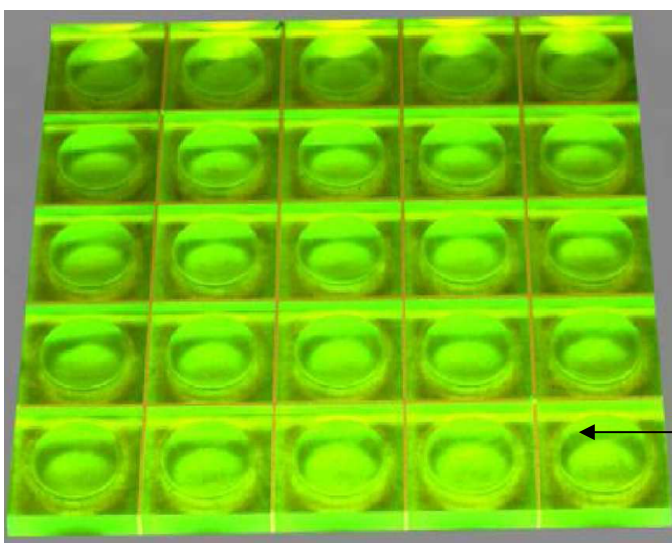


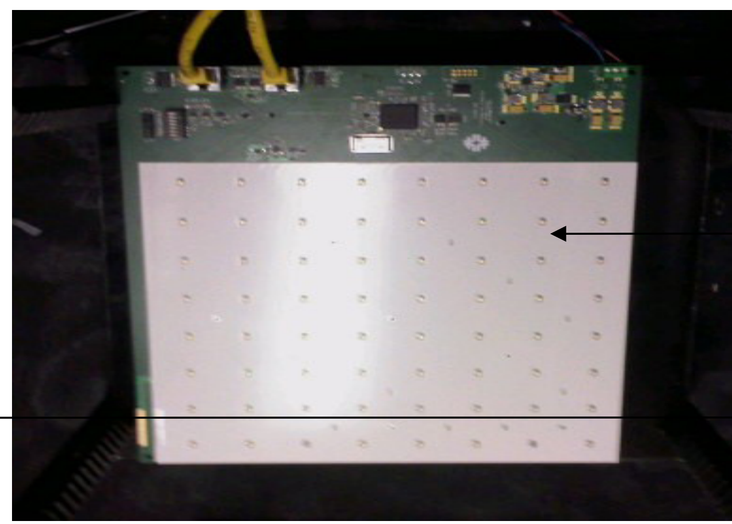


S/M LED, 1per 4 tiles

Surface Mount SiPM

Alignment pin



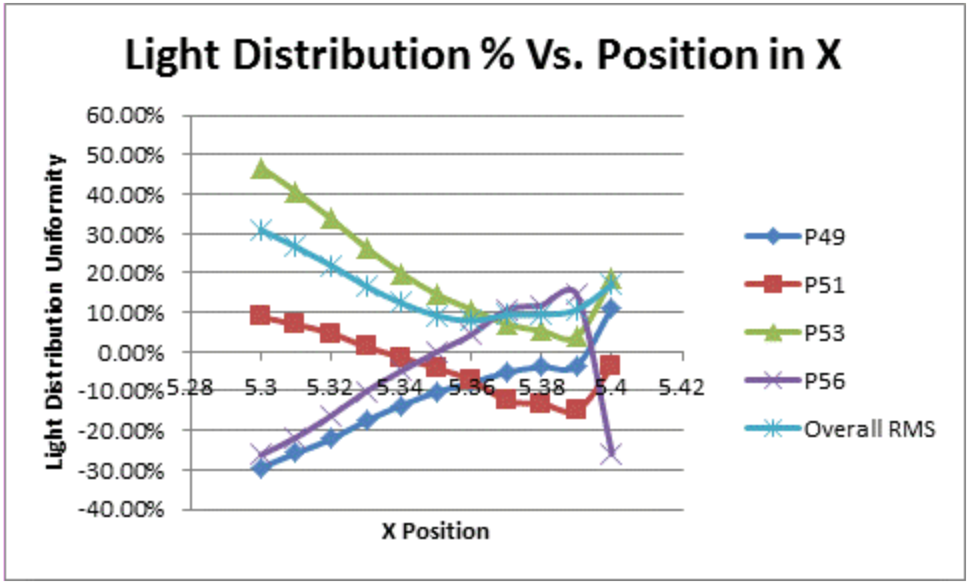


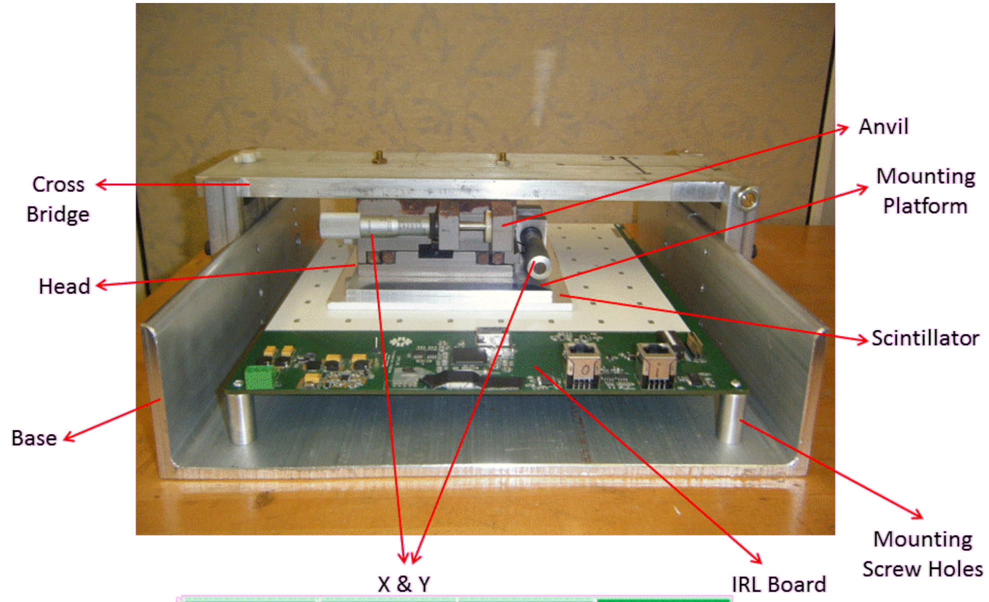
Reflector/spacer

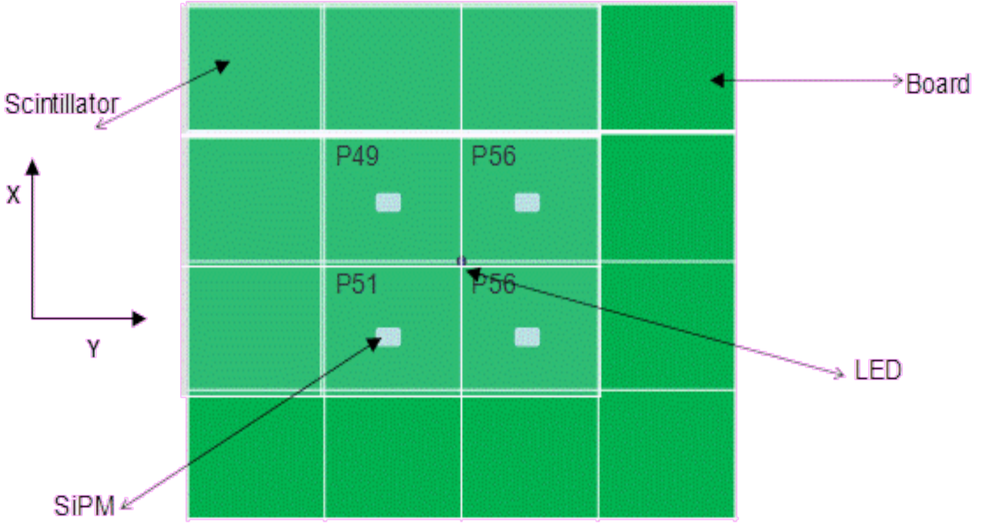
Megatile

LED Distribution Uniformity

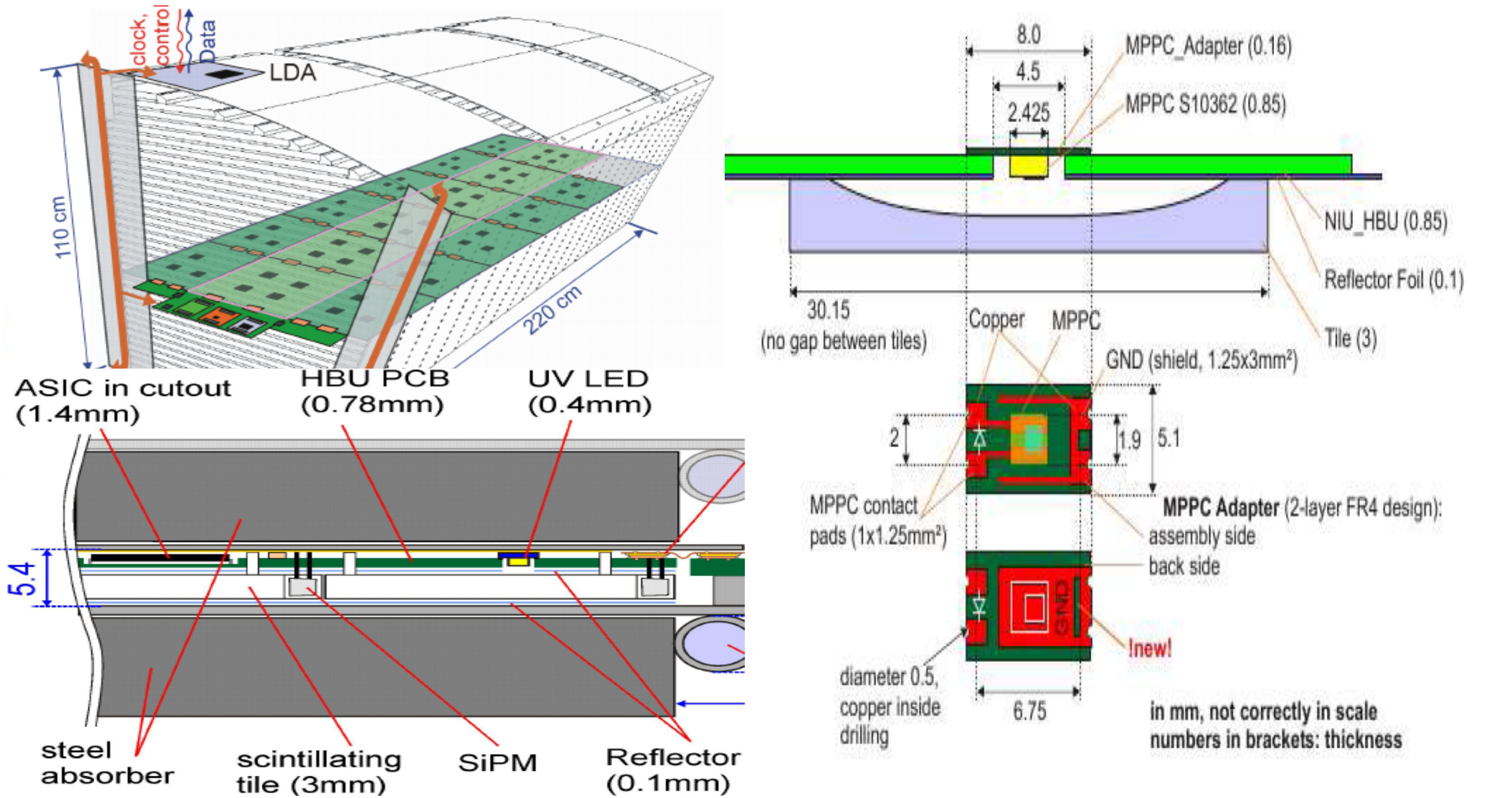
LED useful for gain calibration and saturation correction. This mean the light distribution should be within a factor of 2



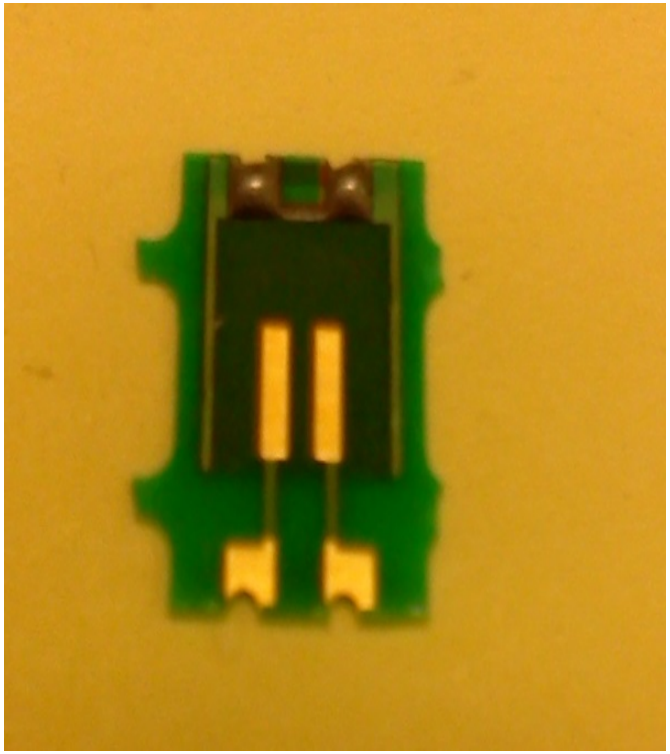


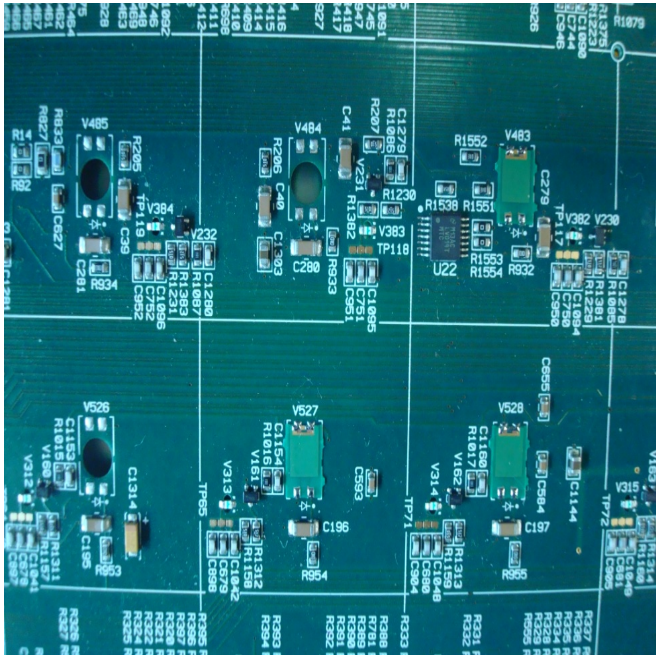


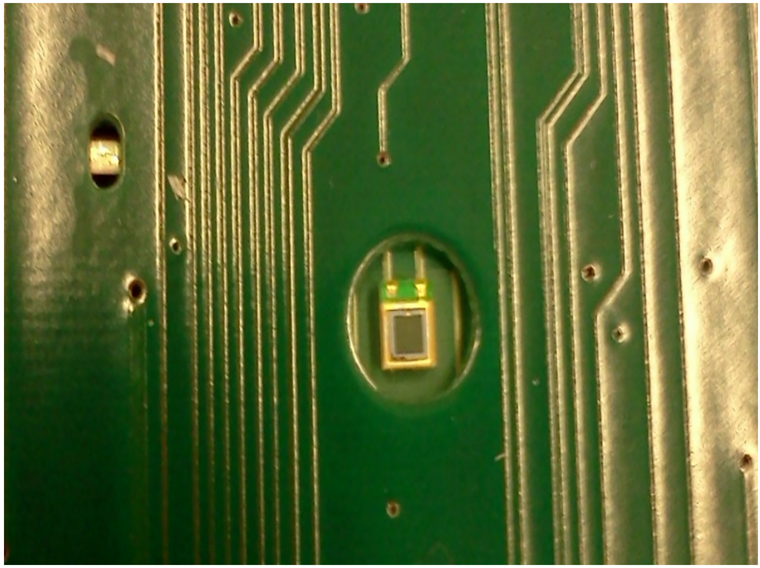
ILC Scintillator HCAL



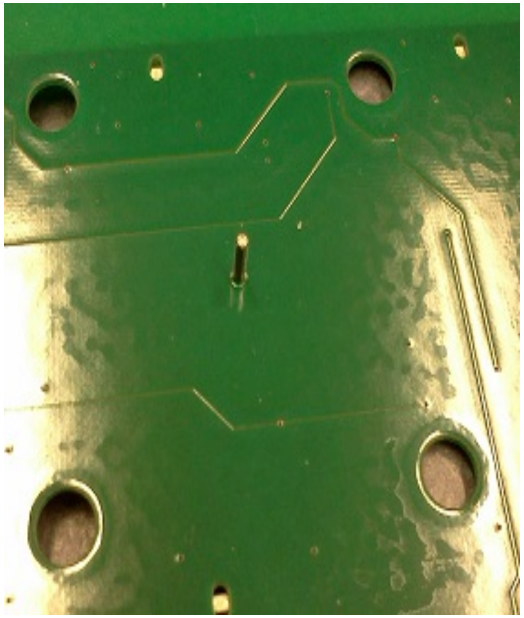
IRL Realization

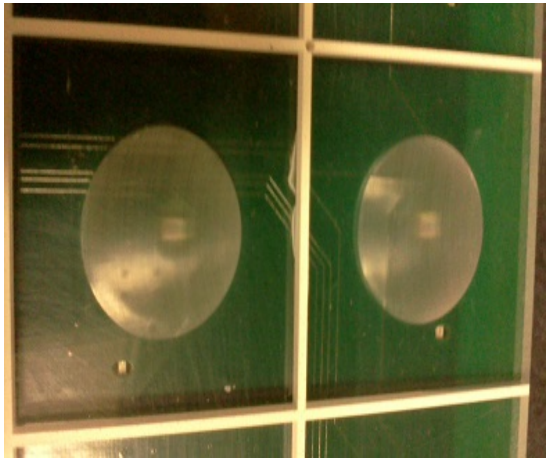




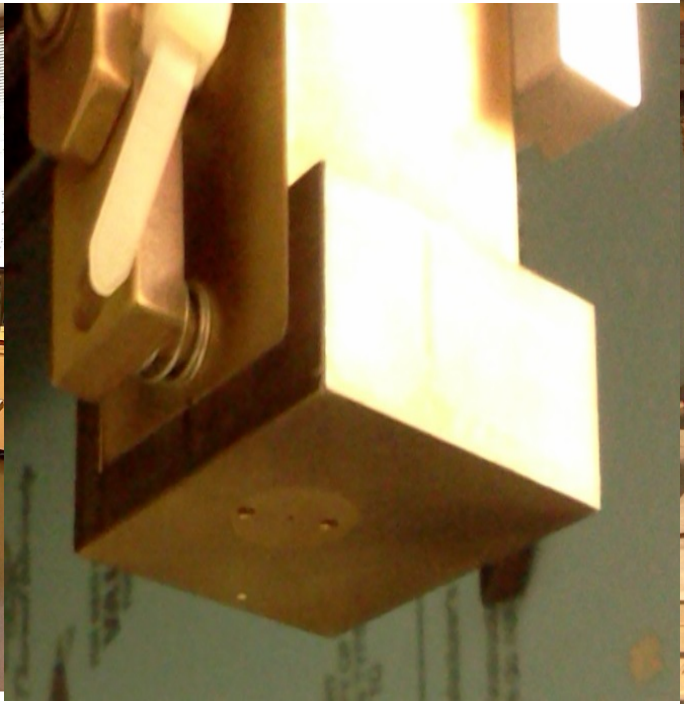


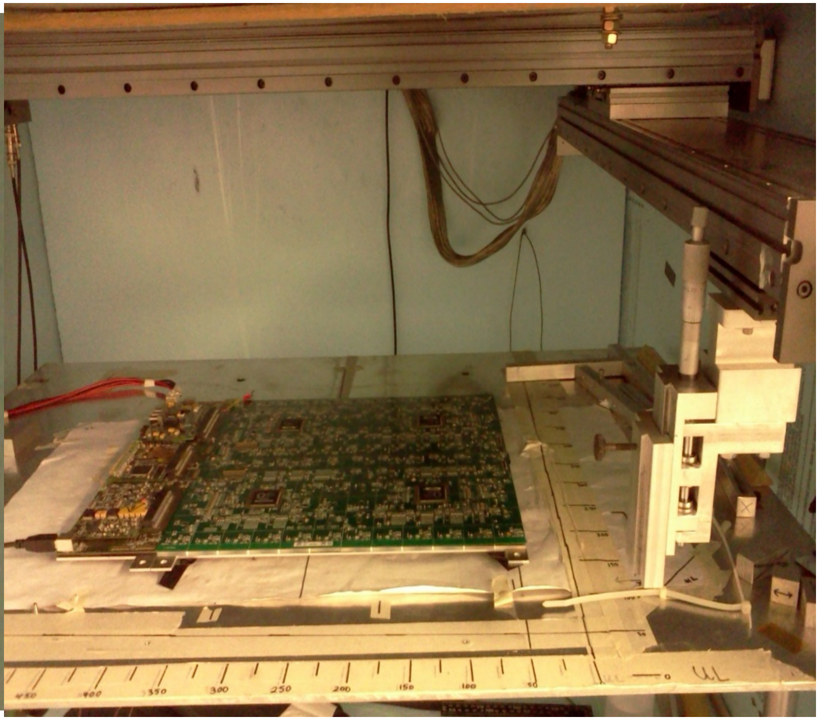
IRL Realization



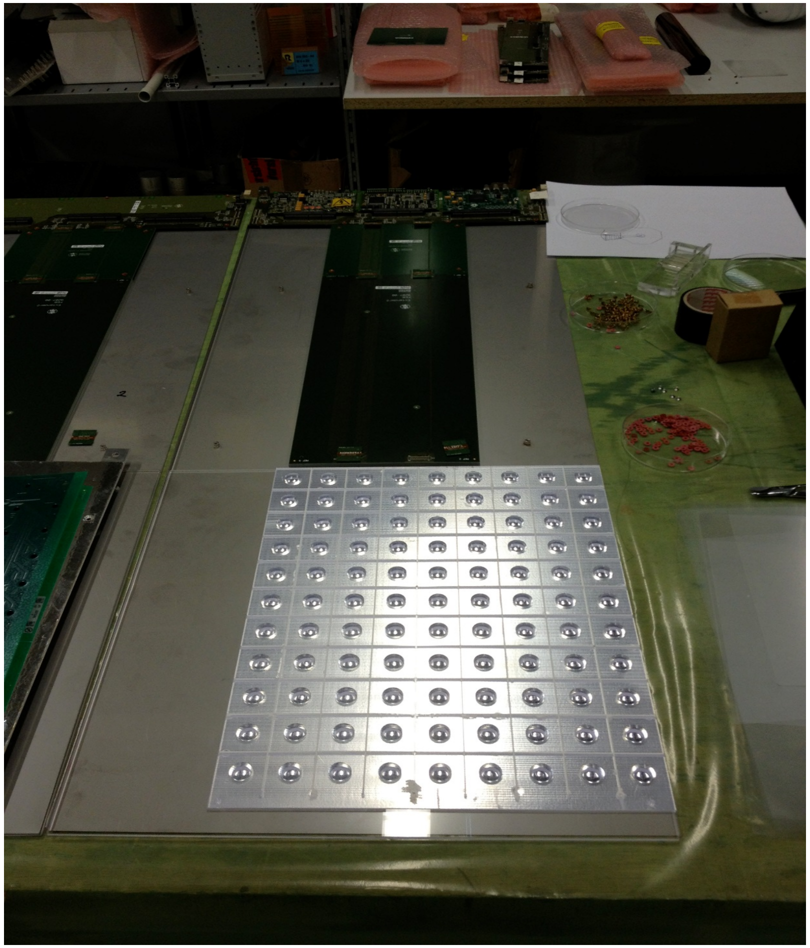


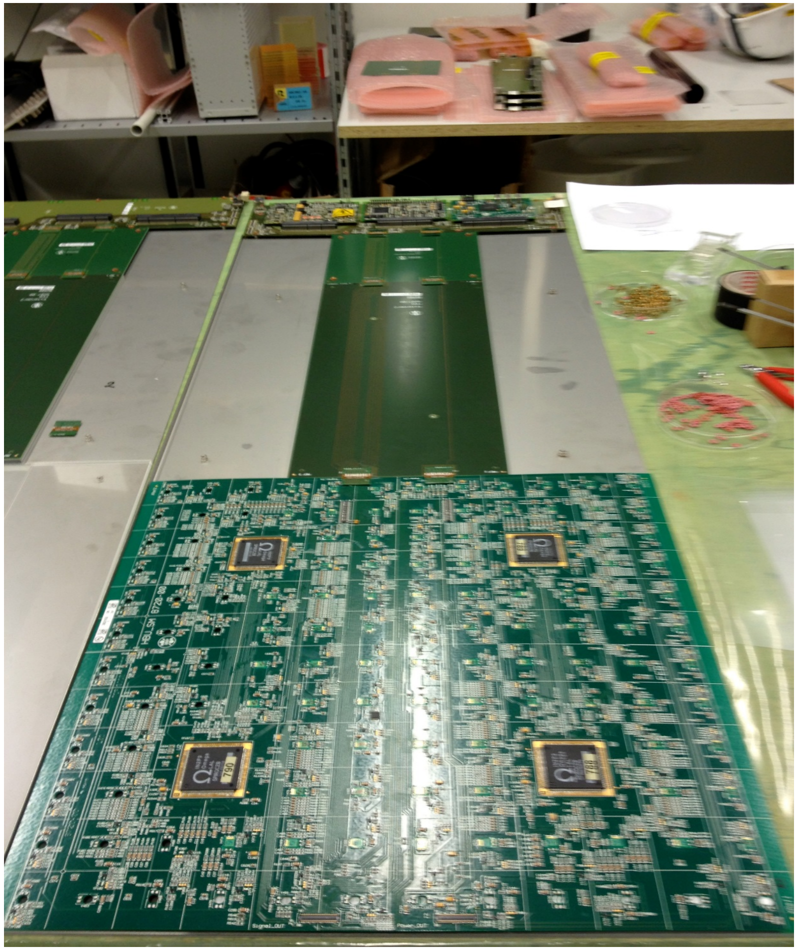
IRL Commissioning



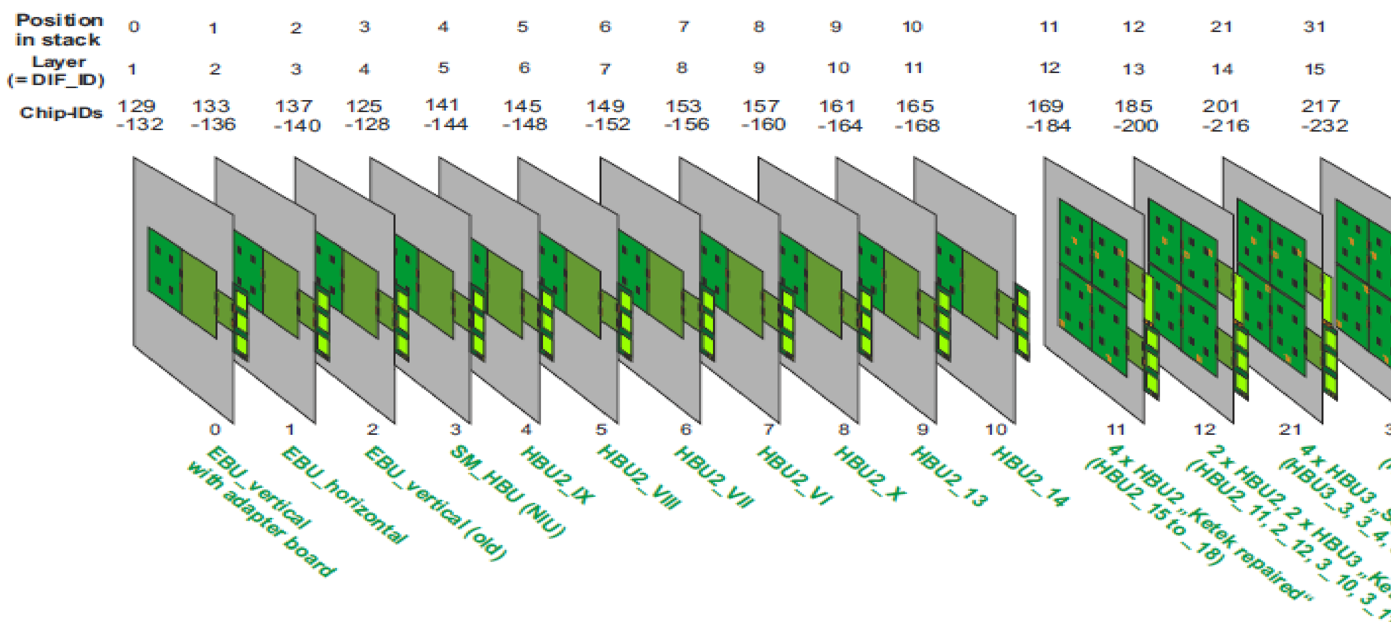


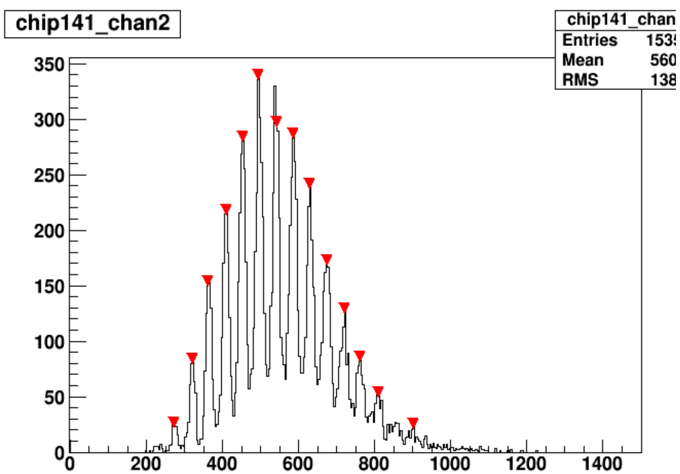
IRL in CALICE Testbeam

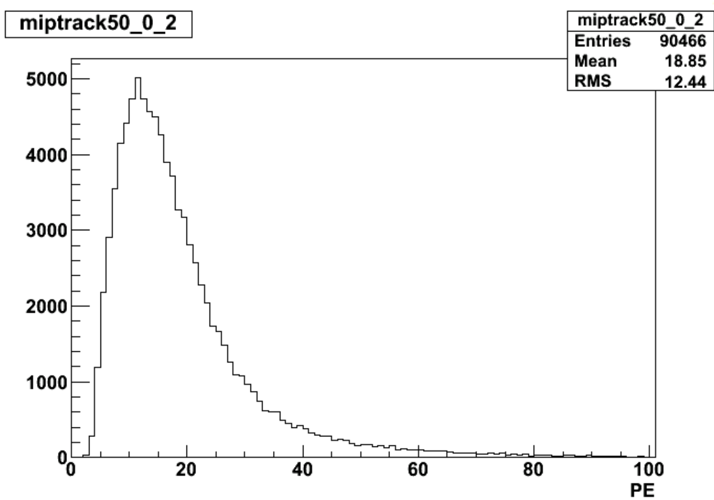


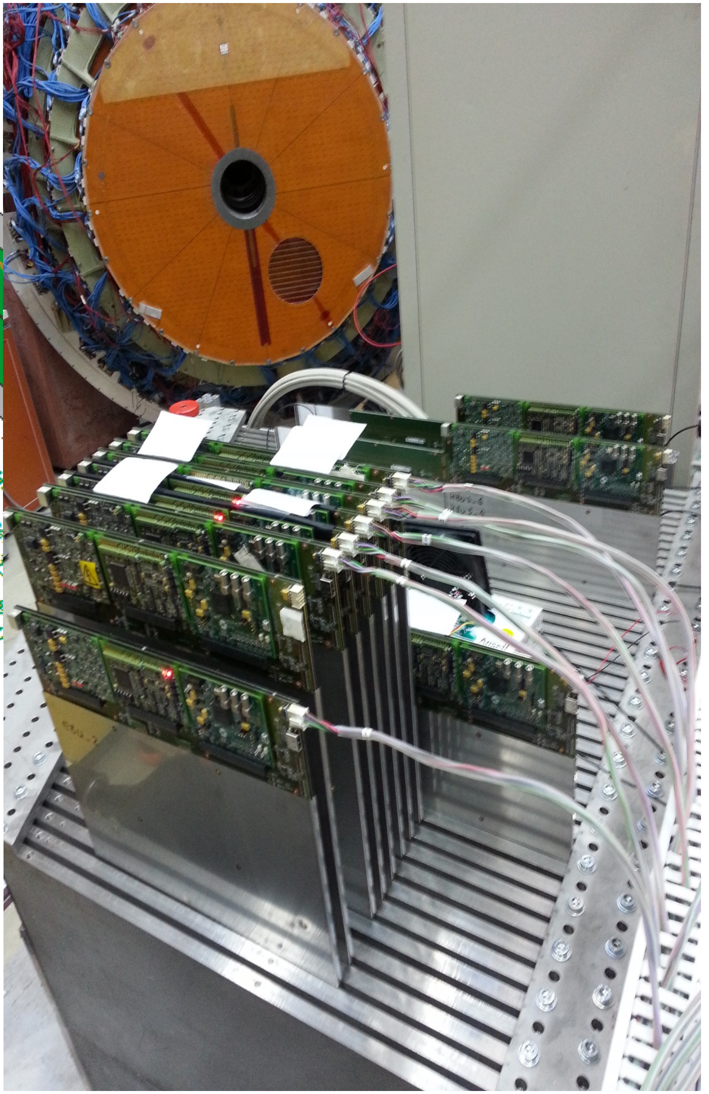


IRL in CALICE Testbeam





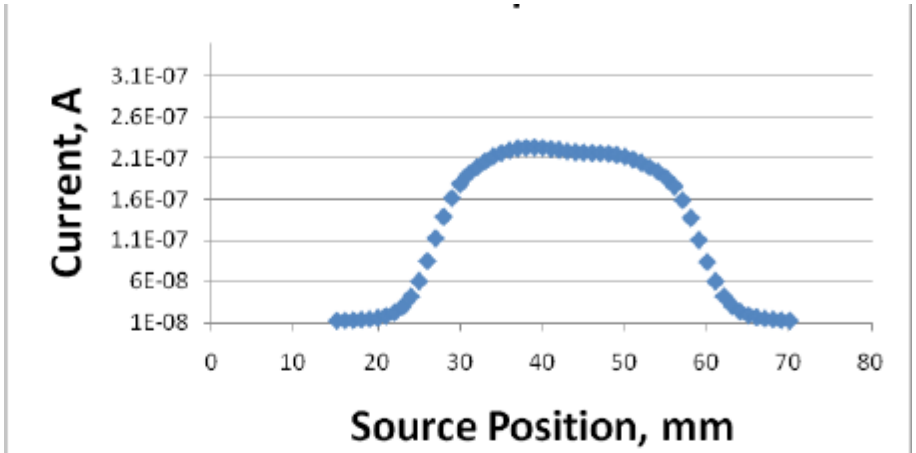




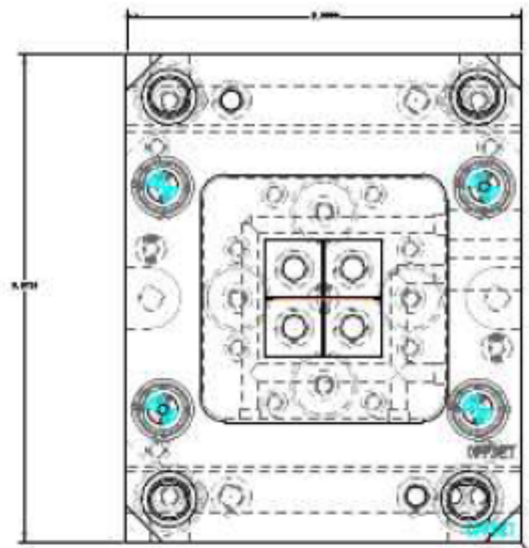
Injection Molded Tiles

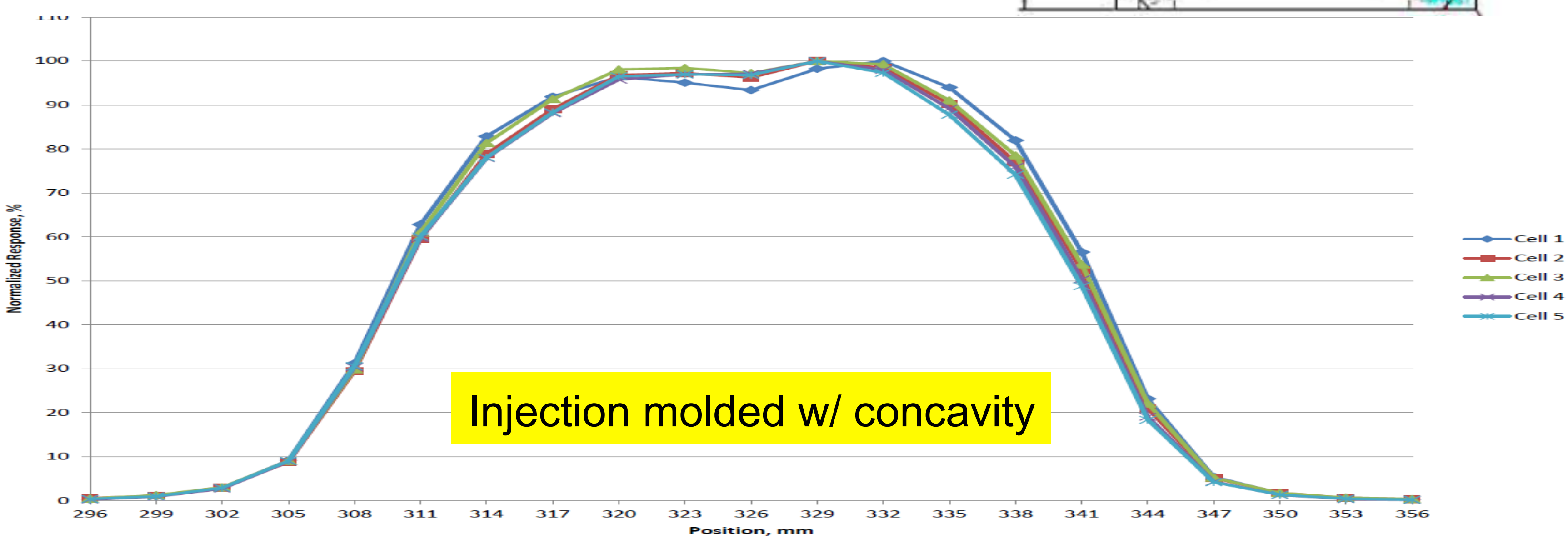
Promises to be cost effective in large quantities
Large phase space of production conditions, finishes etc.
Took a staged approach....

From Tiles to Arrays



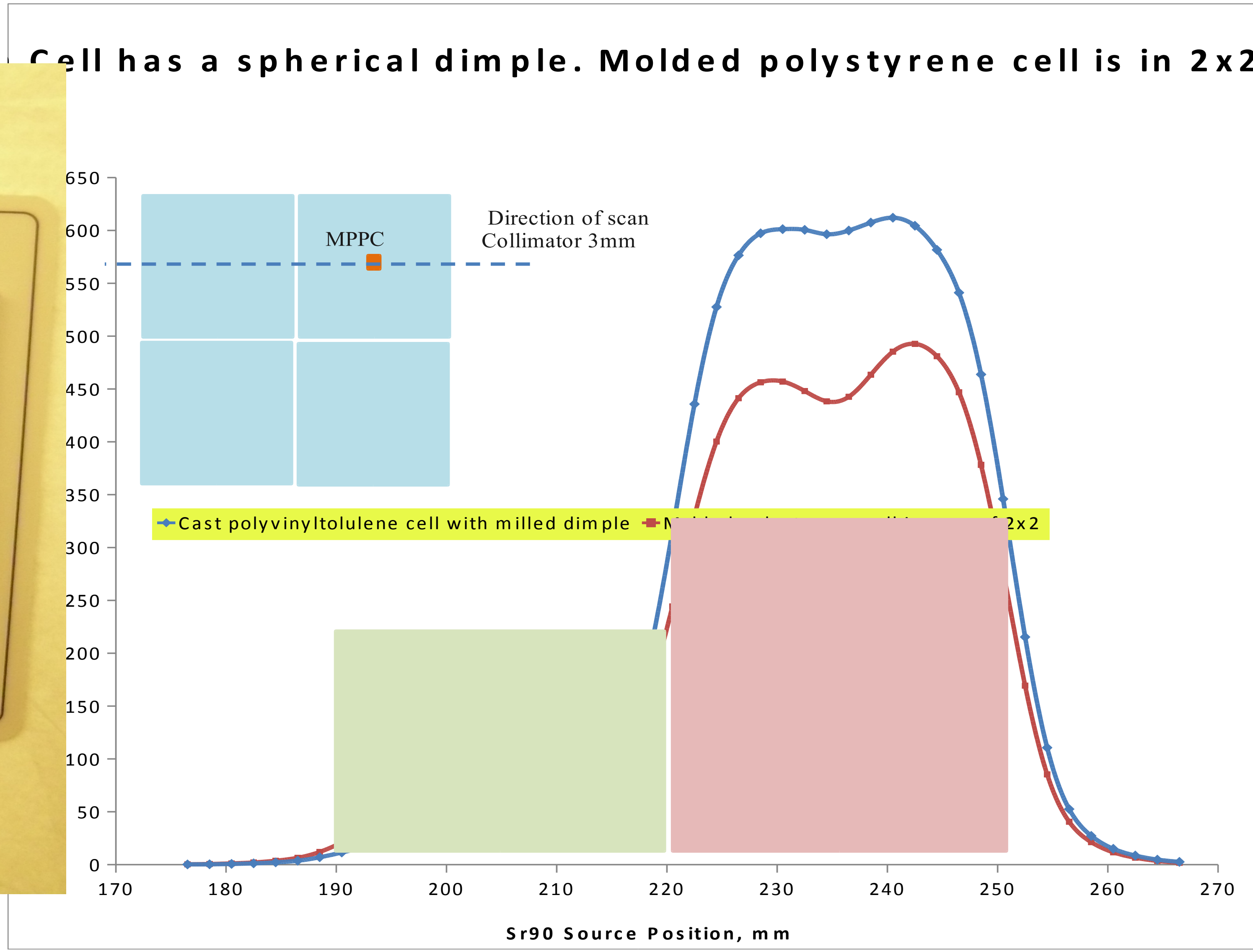
Injection molded flat, then machined





Injection molded w/ concavity

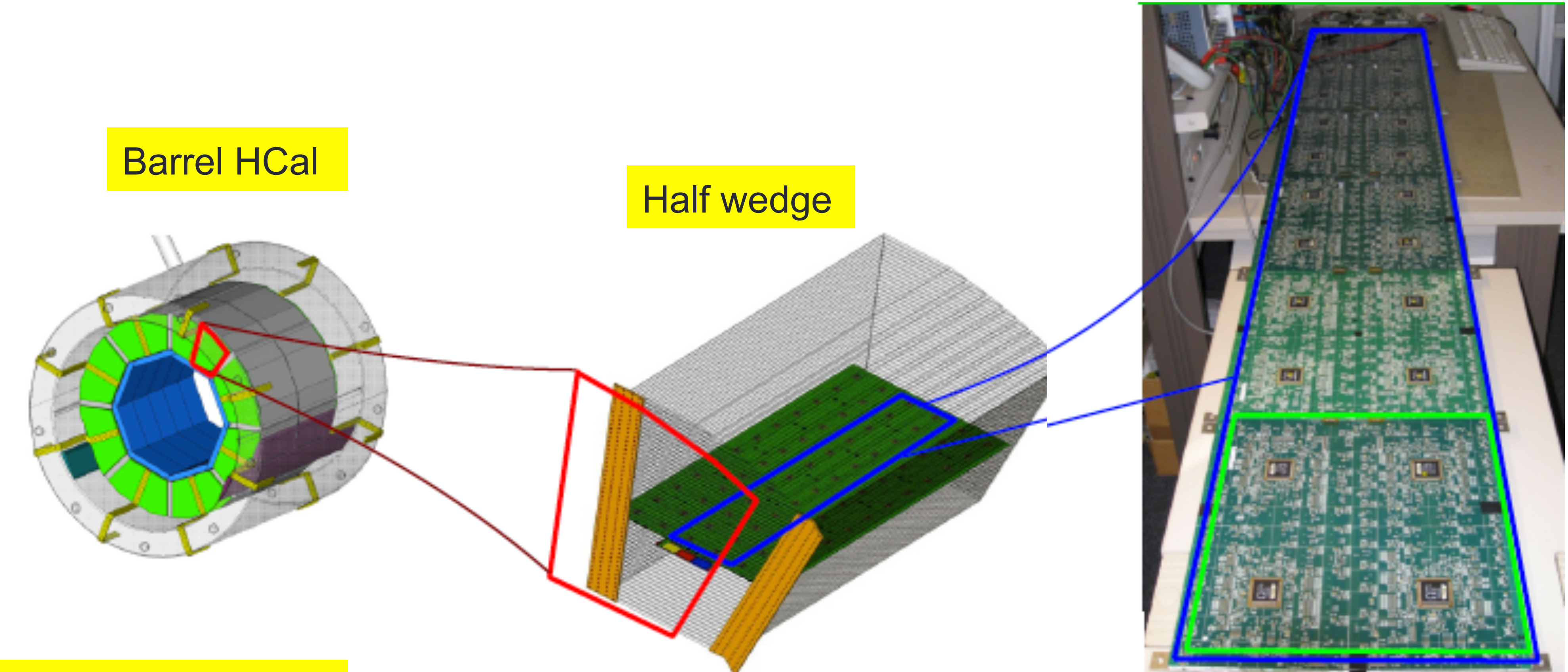
Injection Molded Array



Towards a technological design

- Over the last few years the IRL concept has undergone significant development, refinement and optimization in Europe which have improved the performance, robustness and scalability of the initial design concept.
- This has allowed for the proof-of-principle to mature as a technological design
- The following slides show the current state-of-the-art as far the AHCal is concerned

The Big Picture



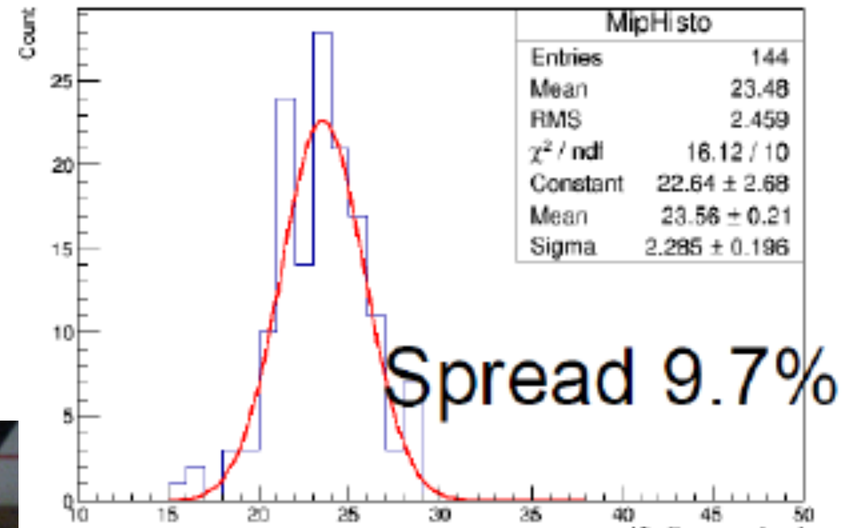
Sampling calorimeter with 3cm x 3cm tiles
Applicable to CLiC, ILD and SiD
~8 M tiles (ILD)

Signals and services brought out from the sides

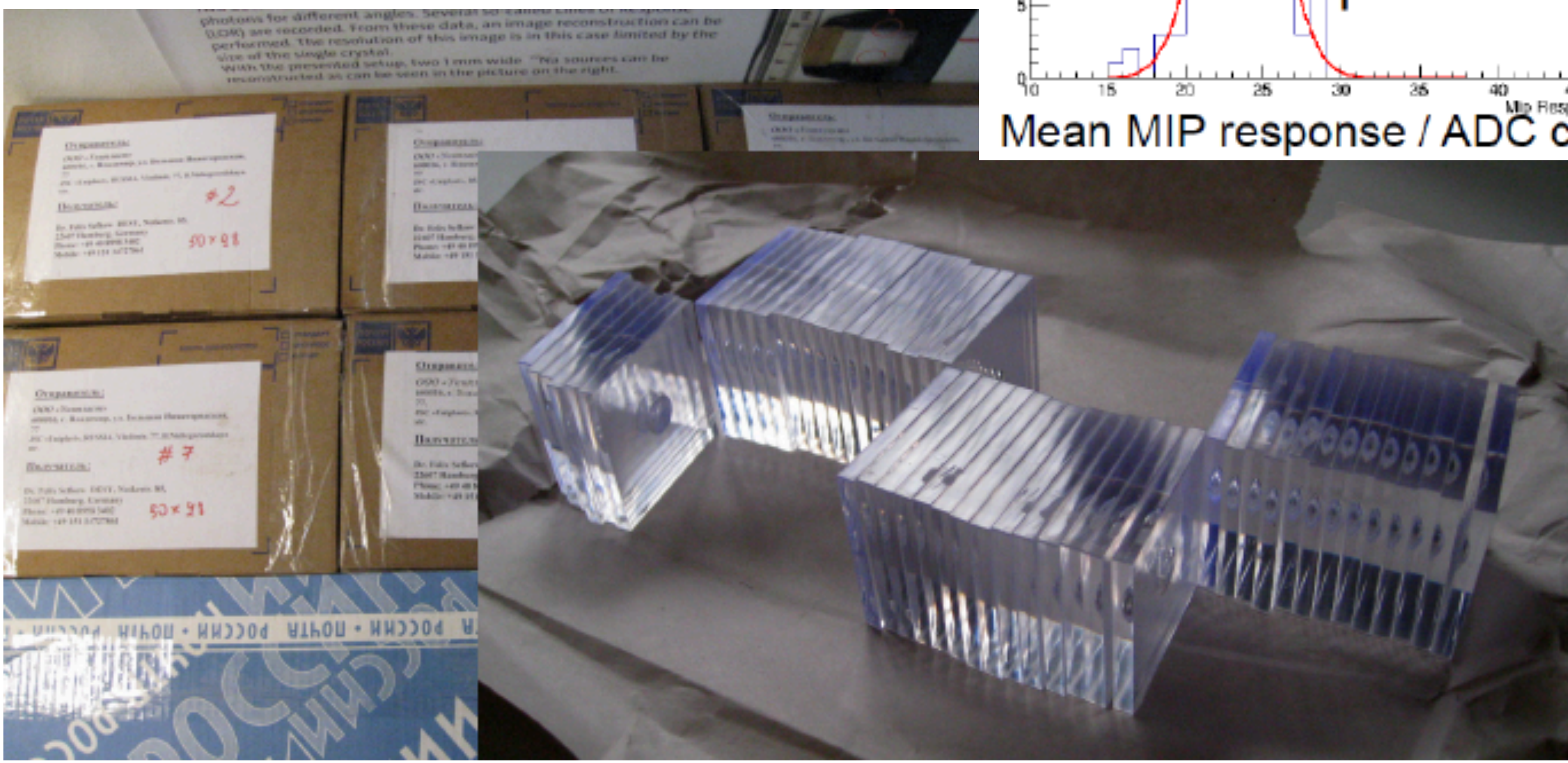
HBU: Hcal Base Unit

Tiles

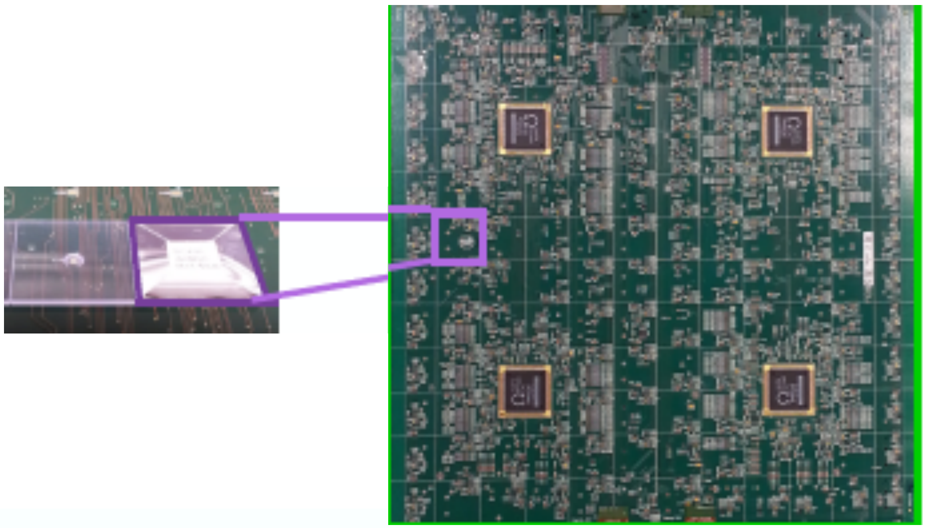
3mm thick injection molded with dimple



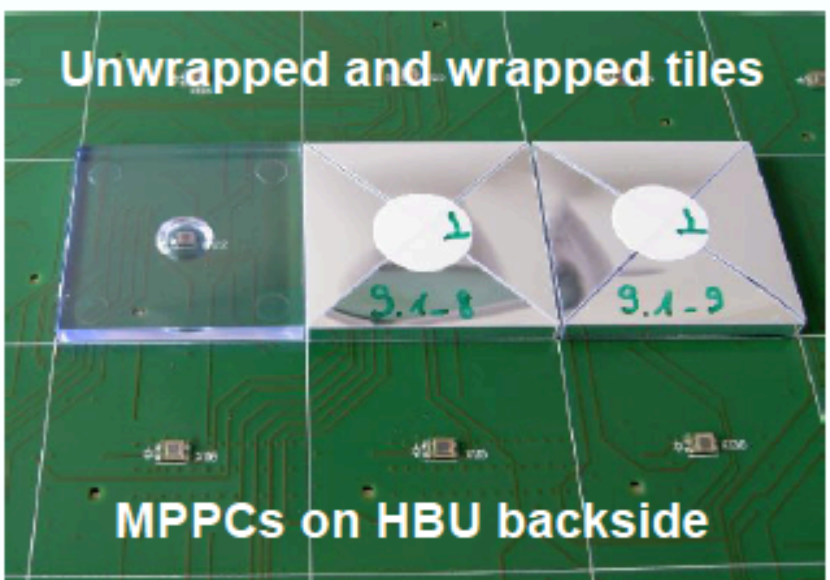
Mean MIP response / ADC counts



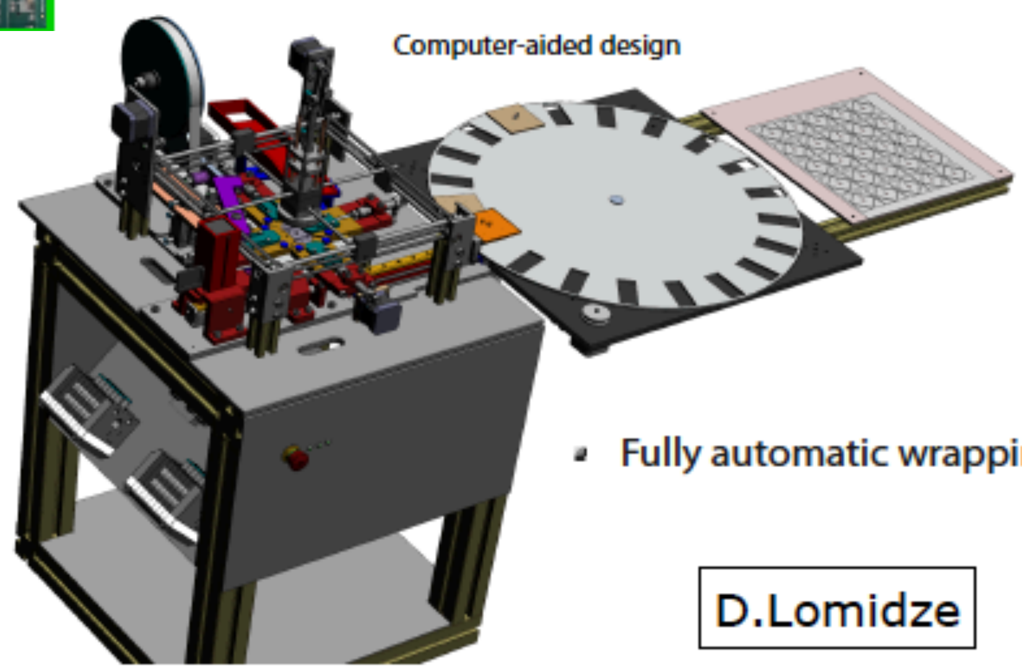
Tiles & Reflector Treatment



Watch the film at: https://www.youtube.com/watch?v=kmmTpUaW1z8&feature=youtu.be



Computer-aided design

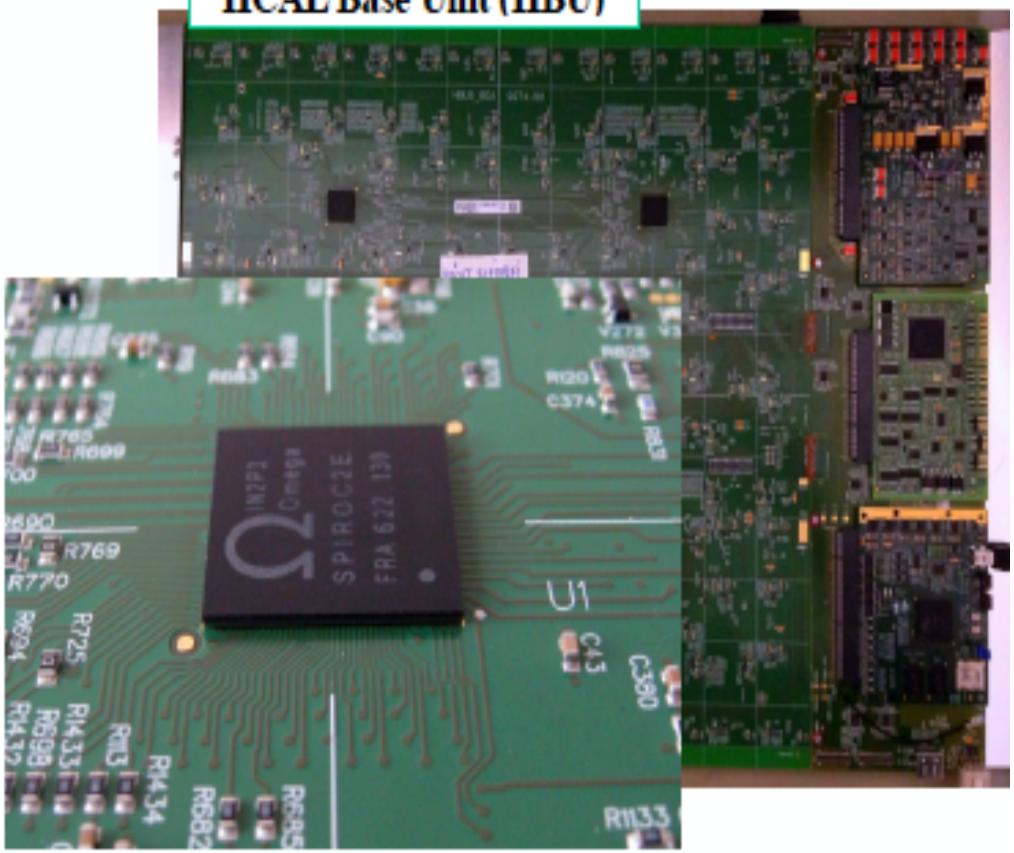


- Fully automatic wrapping

D.Lomidze

Assembly Automation

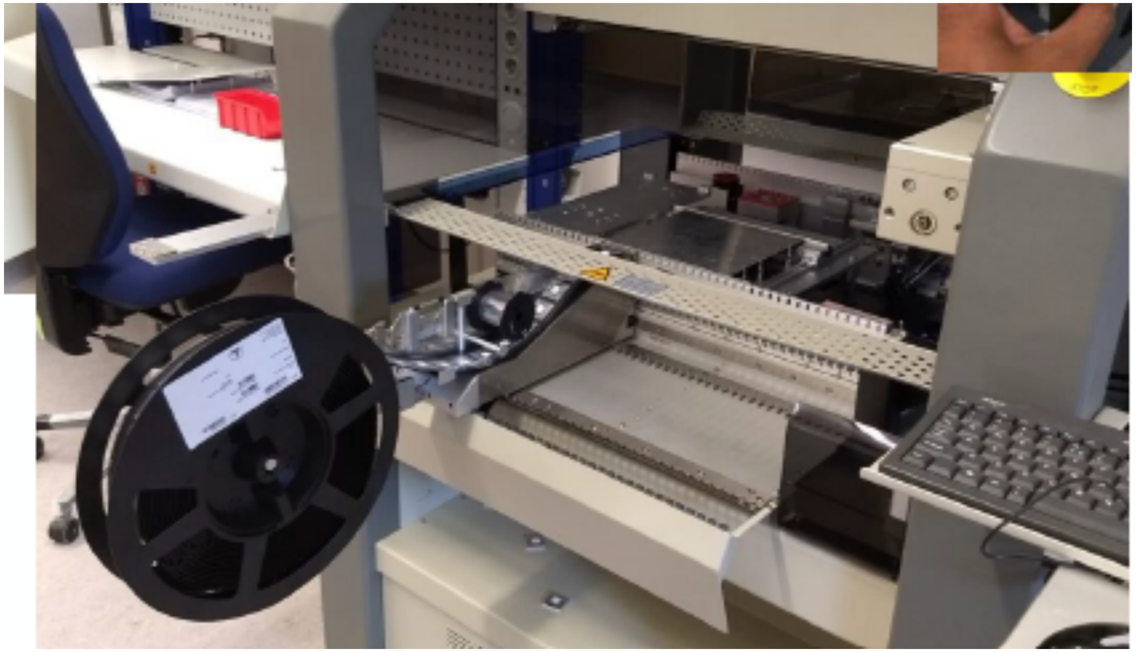
HCAL Base Unit (HBU)



Pick-and-place machine

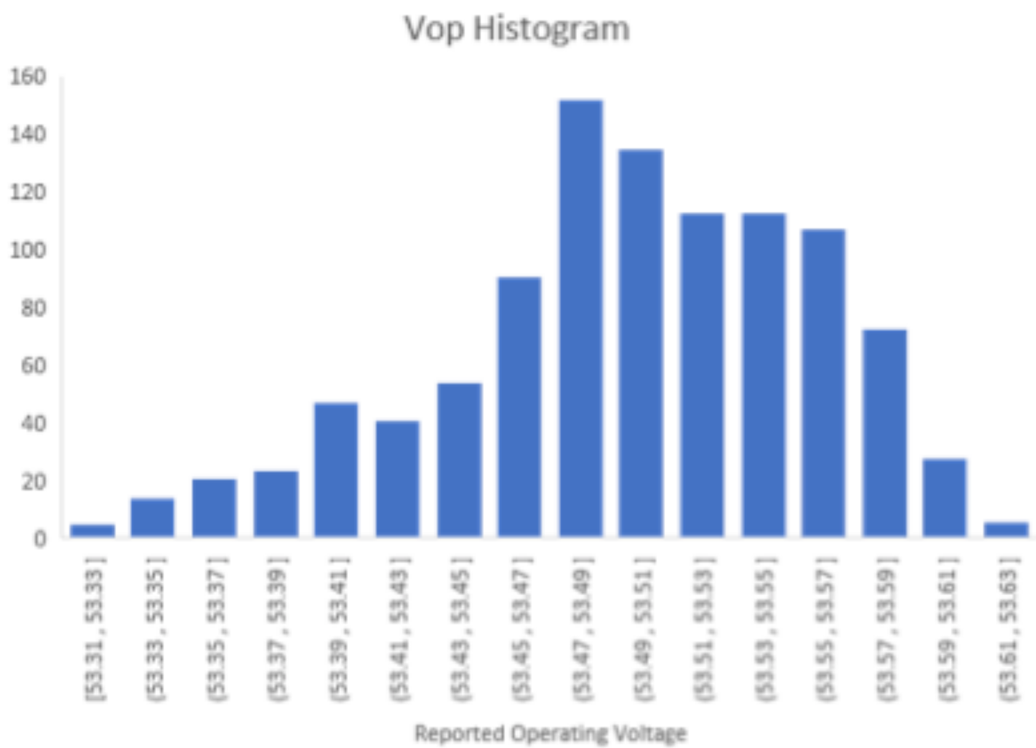
36cm x 36cm (144 channels)
readout by 4 ASICS

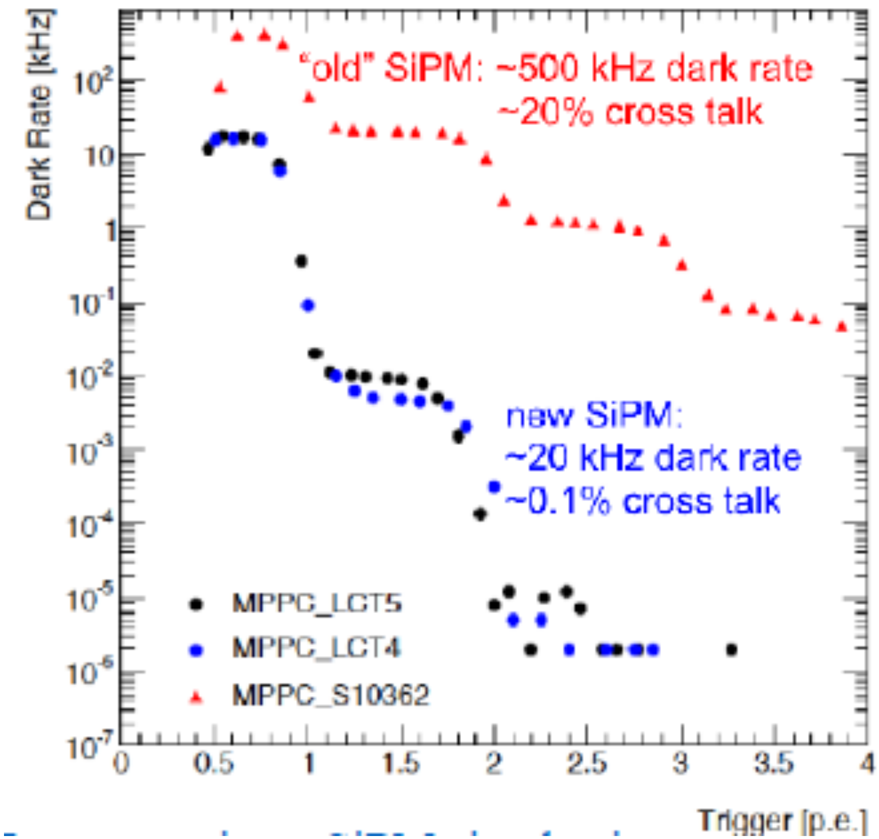
Did someone say surface-mount?



Significant steps towards large-scale assembly required for the detector

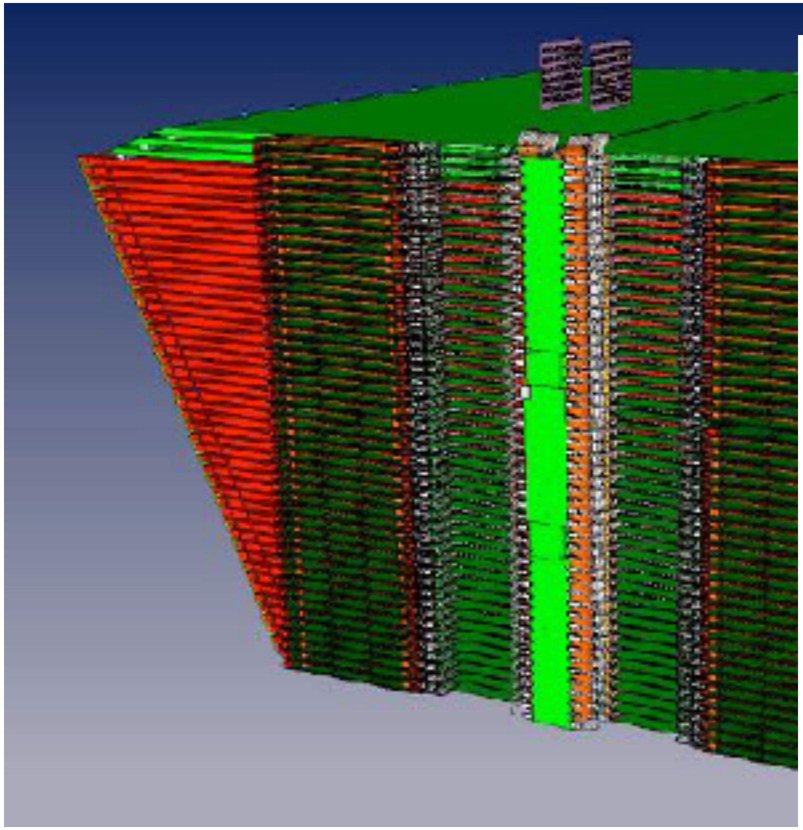
SiPMs

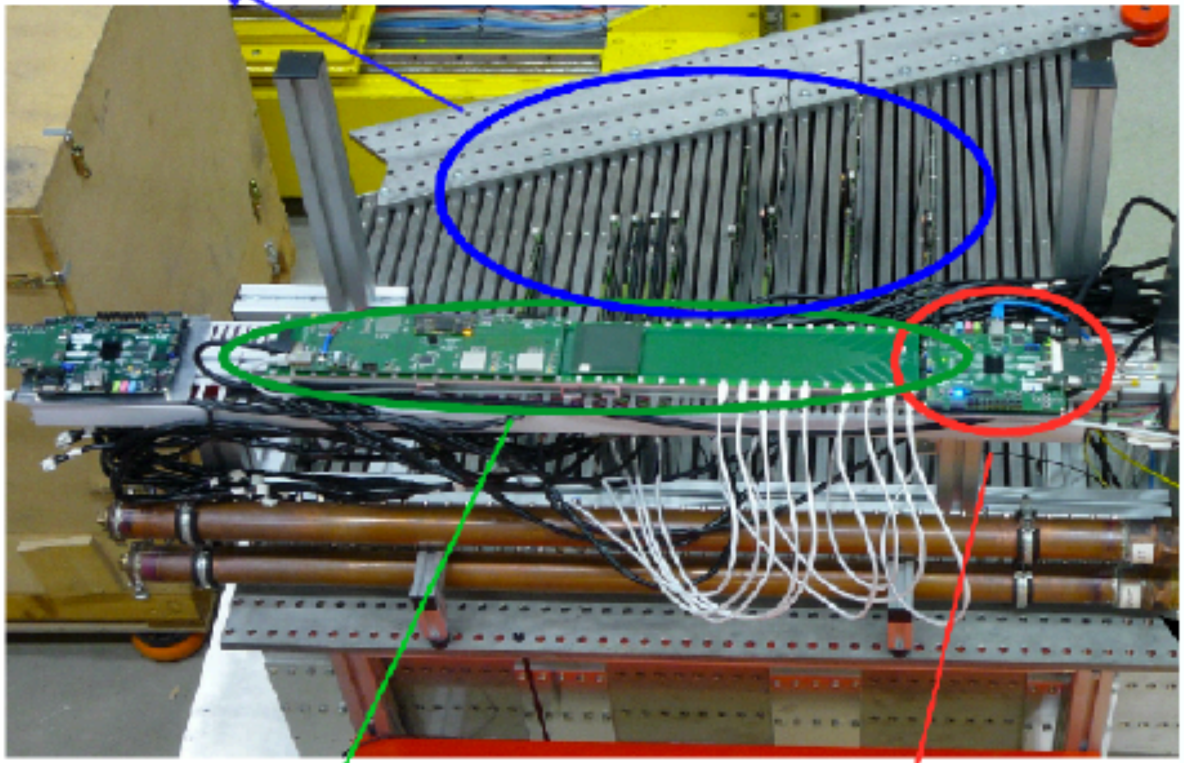




Excellent improvement in device characteristics and uniformity by vendors

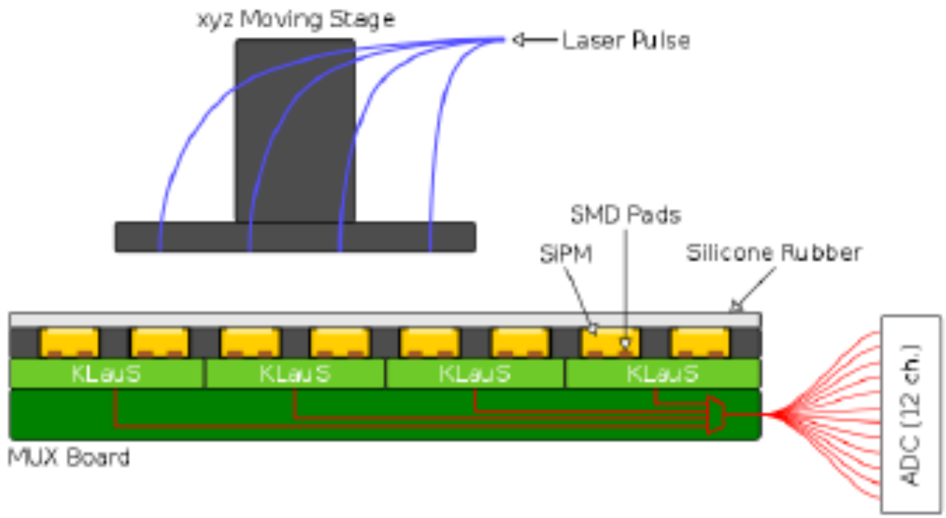
Absorber Structure & Integration



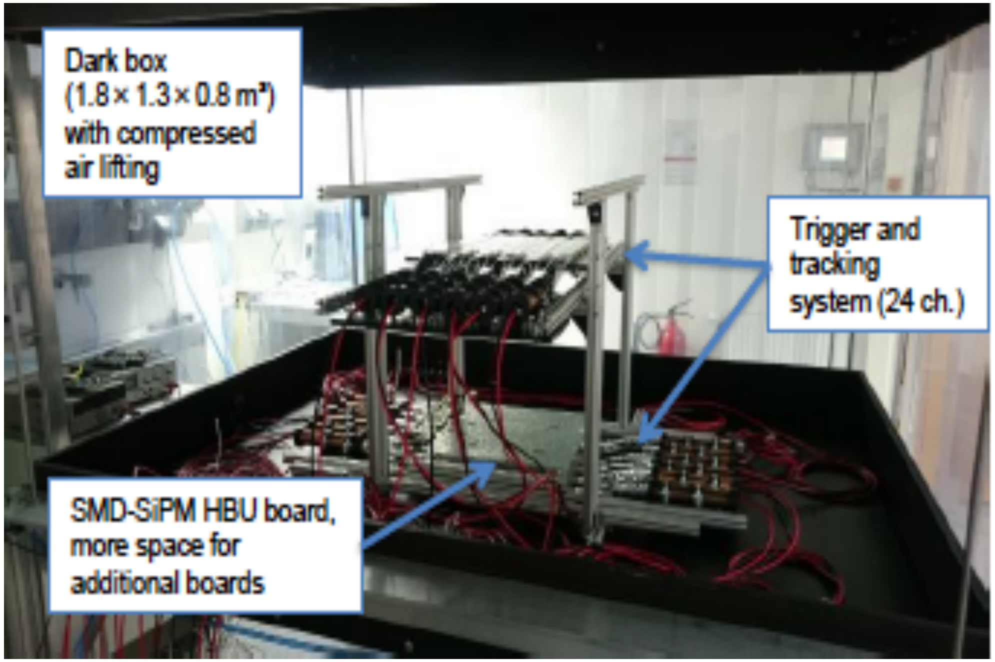


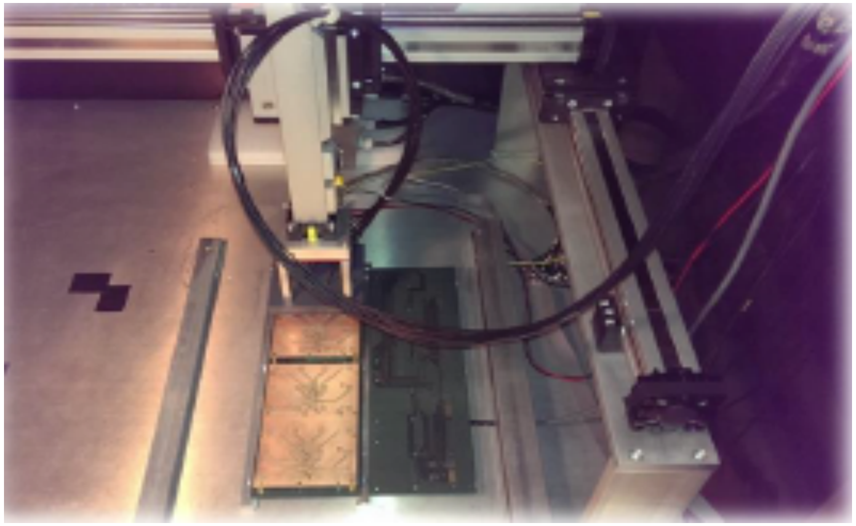
Testbeam Campaign

Testing Cosmics & SiPM



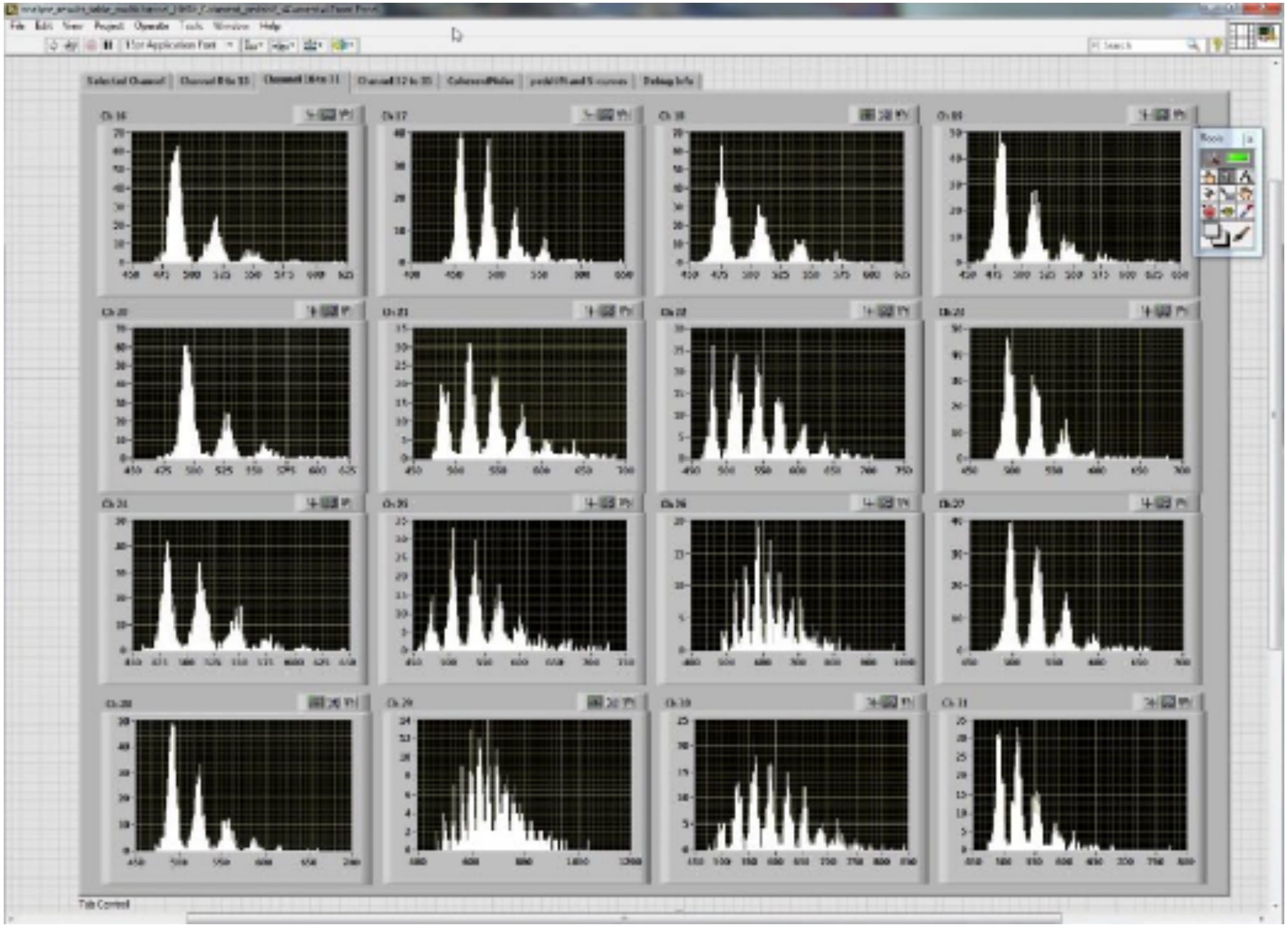
SMD SiPM schematic view



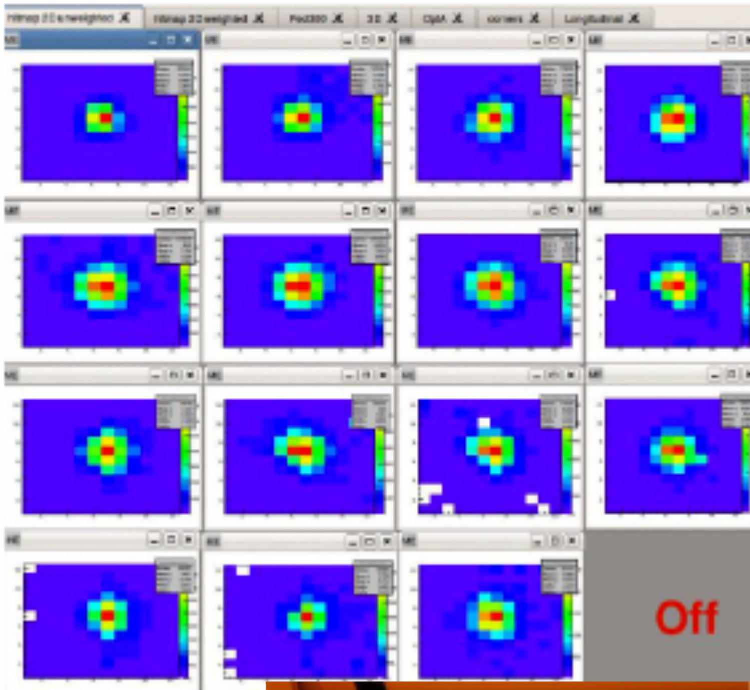


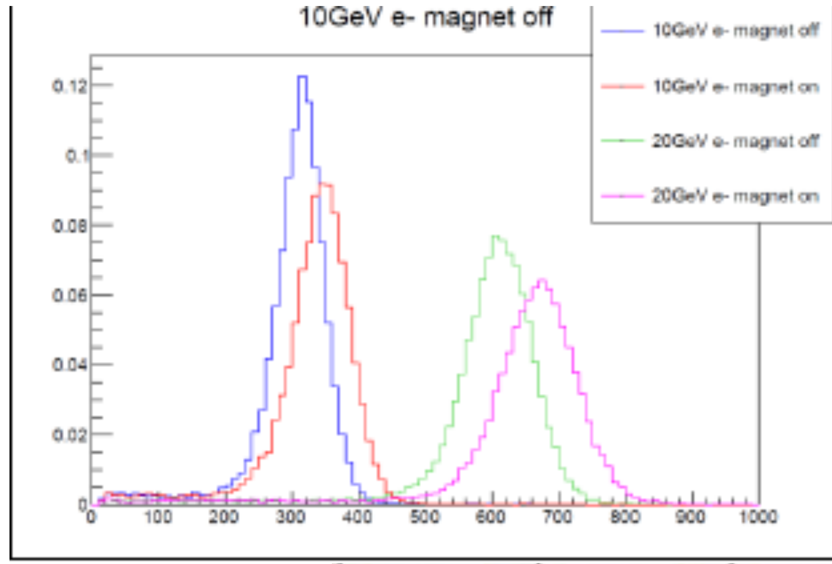
Testing and commissioning of all the components of the active layer before exposure to the test beam.

In-situ Calibration



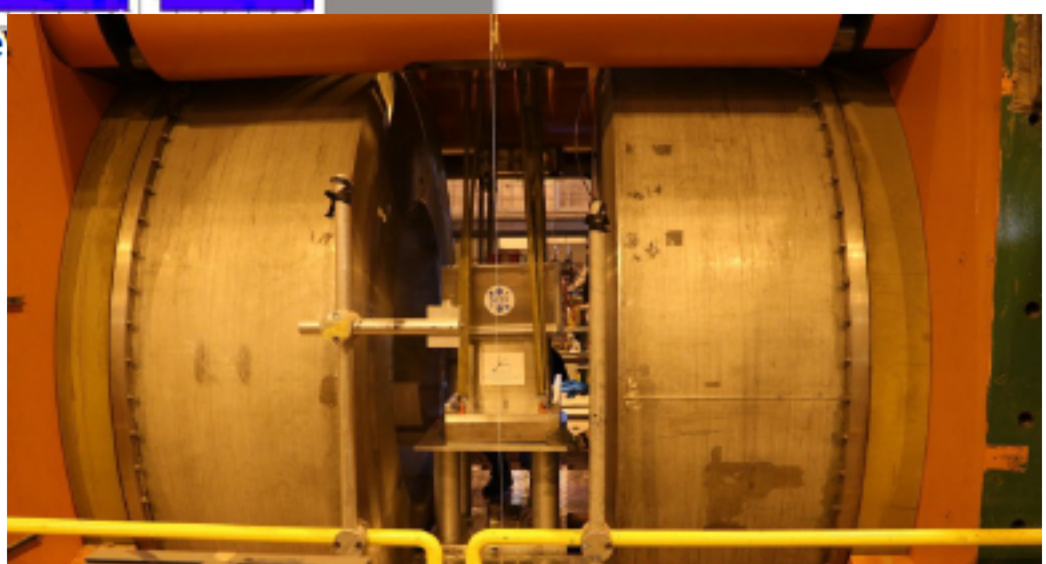
Not to forget the B-field

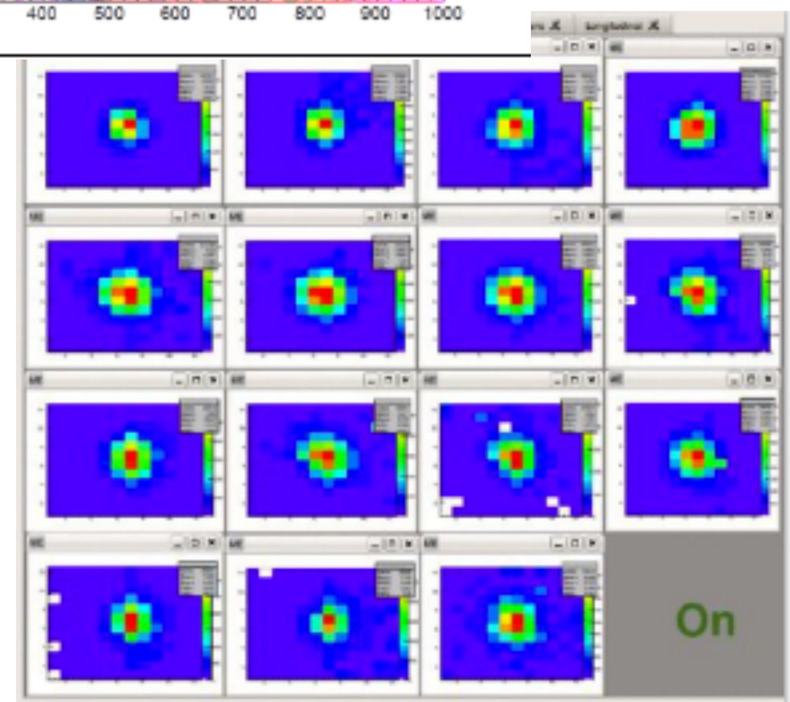




B = 1.5 T

20 Ge

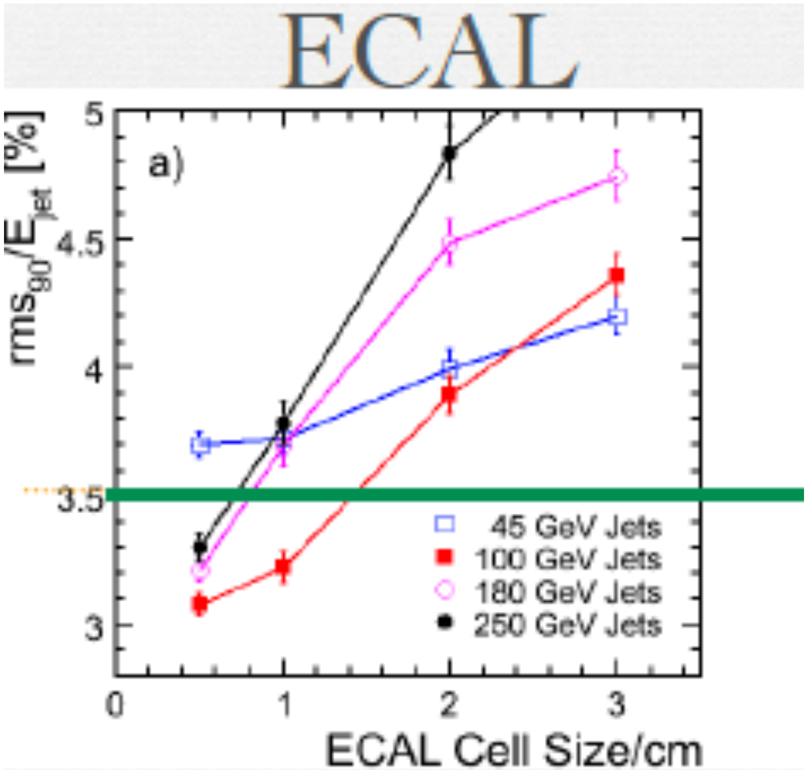


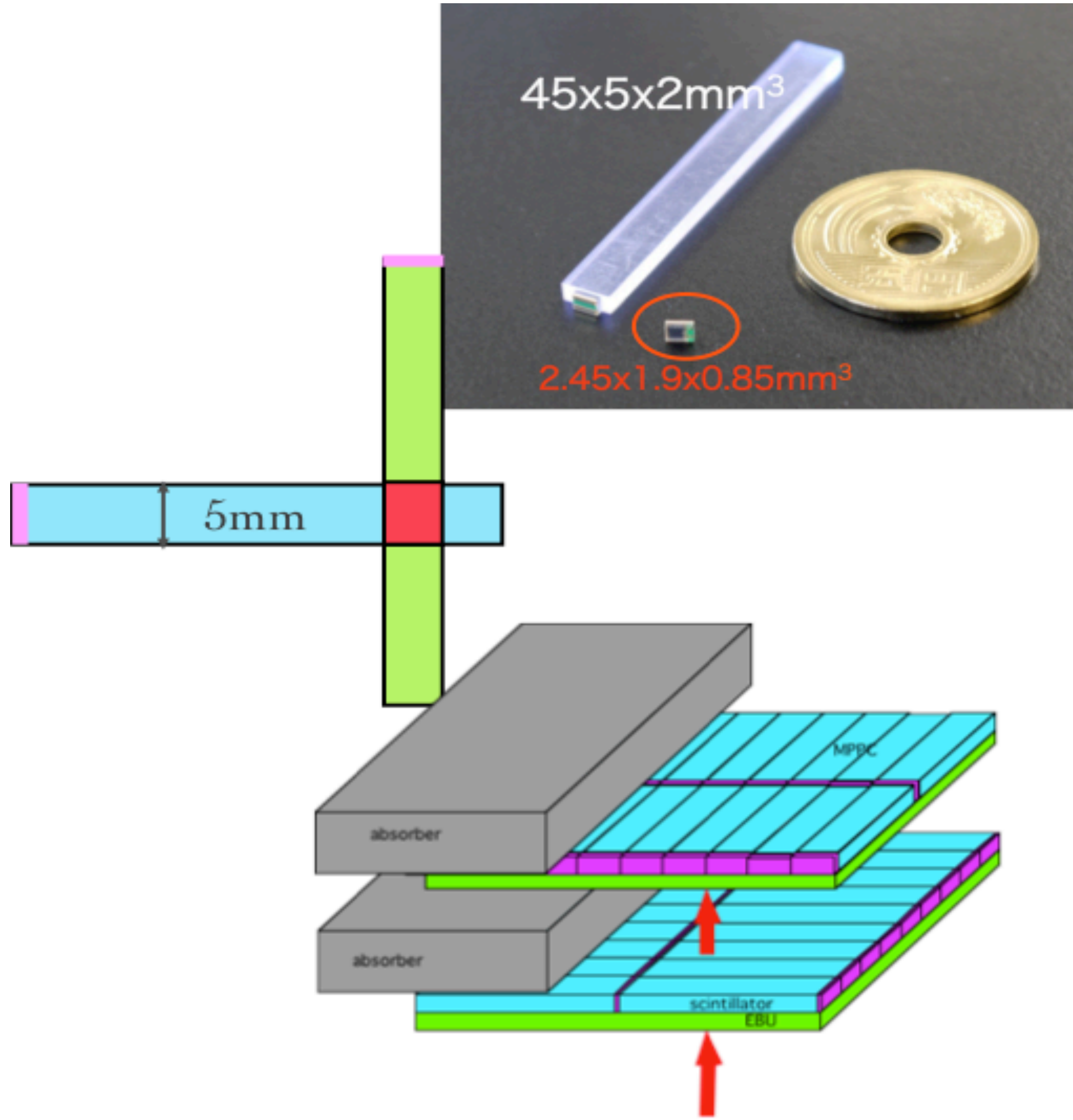


20 GeV electrons magnet ON

Not Just for the ILC

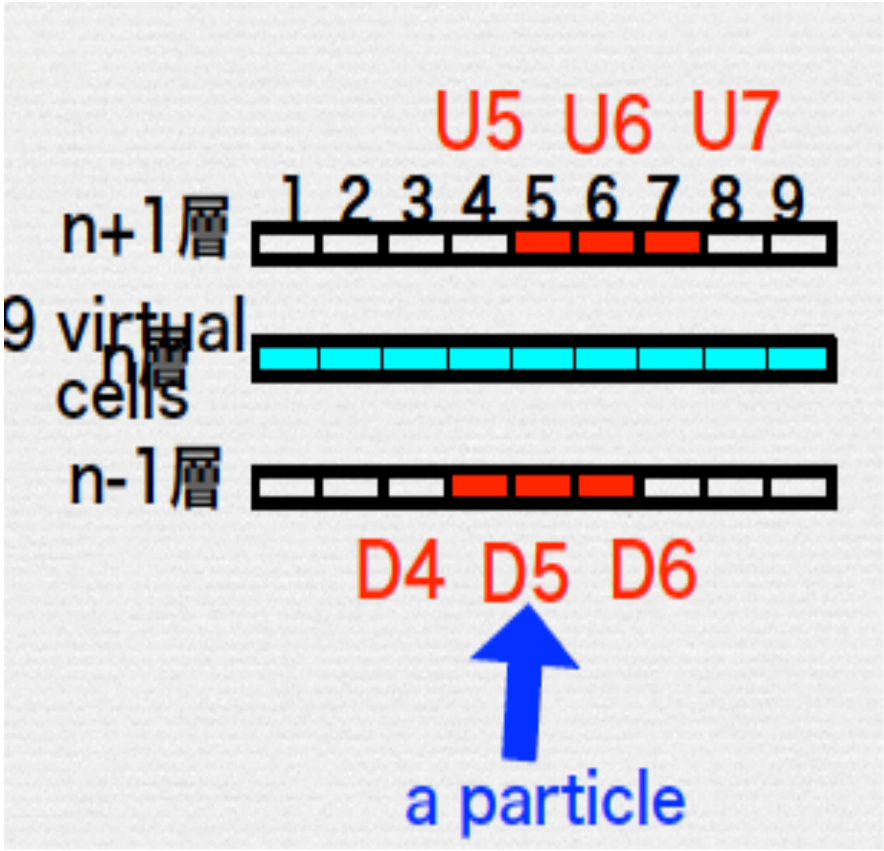
Scintillator ECal (?)

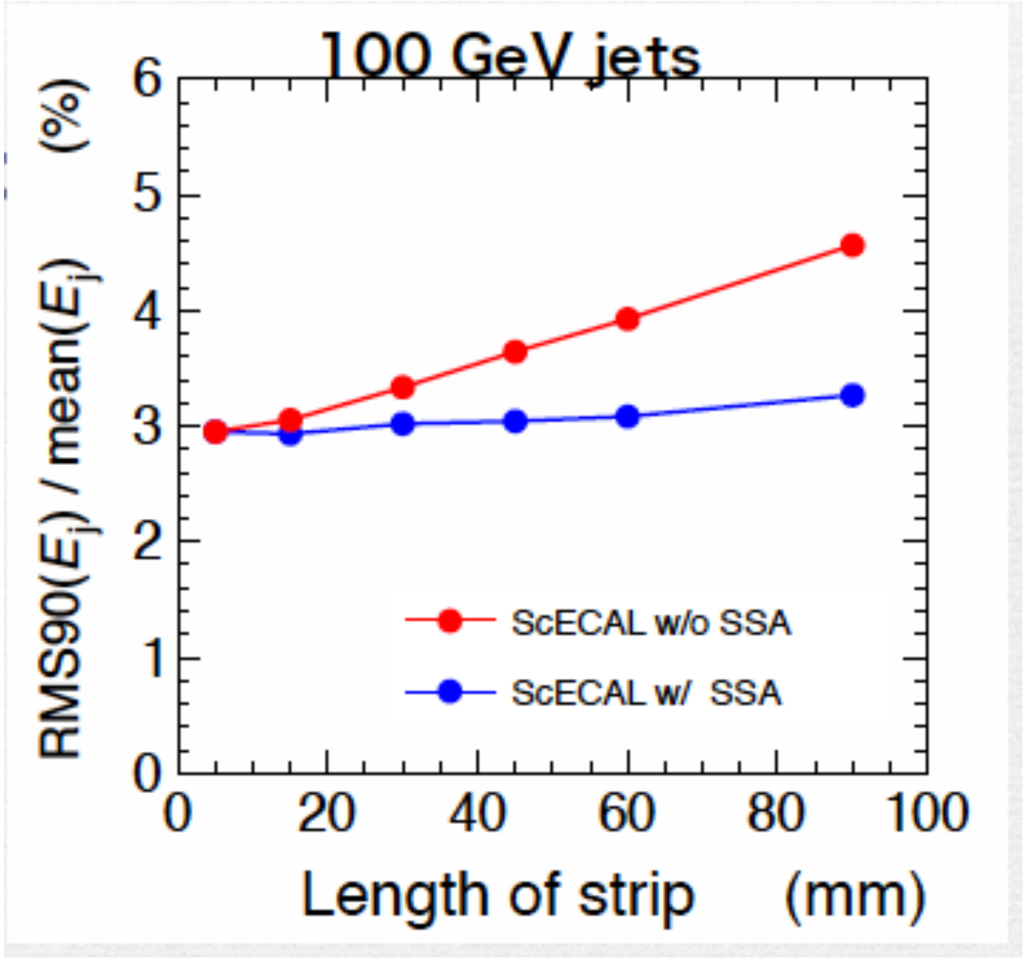




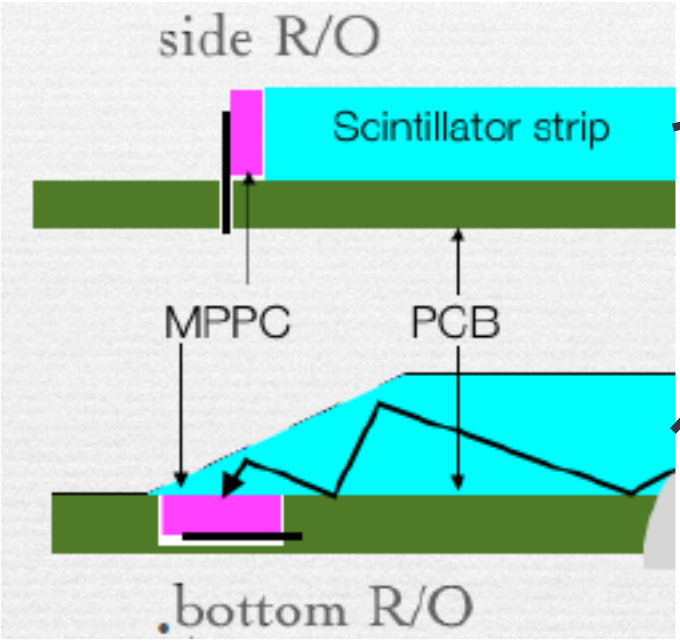
Idea under active development that could potentially offer required performance at lower channel count

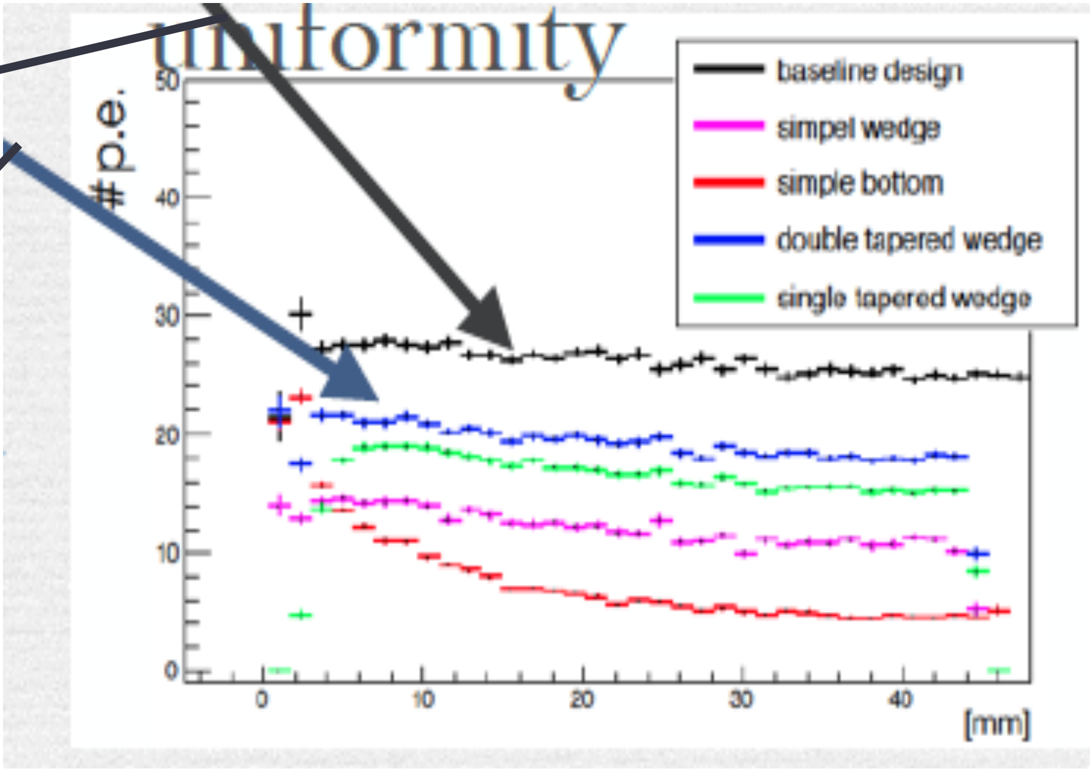
Virtual Tiling

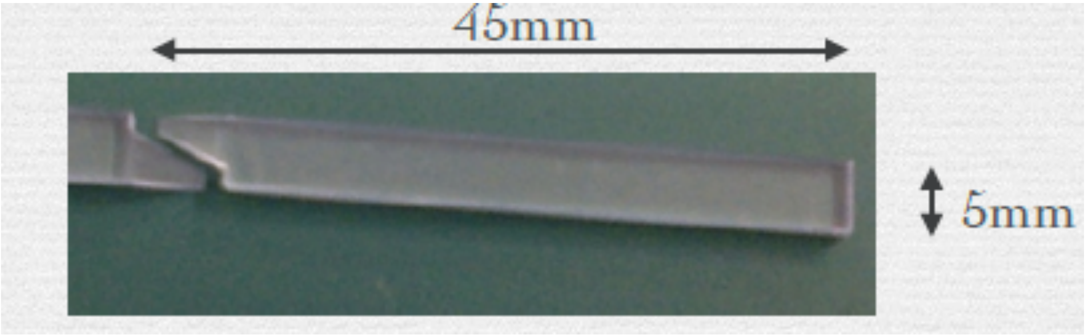




Readout Options

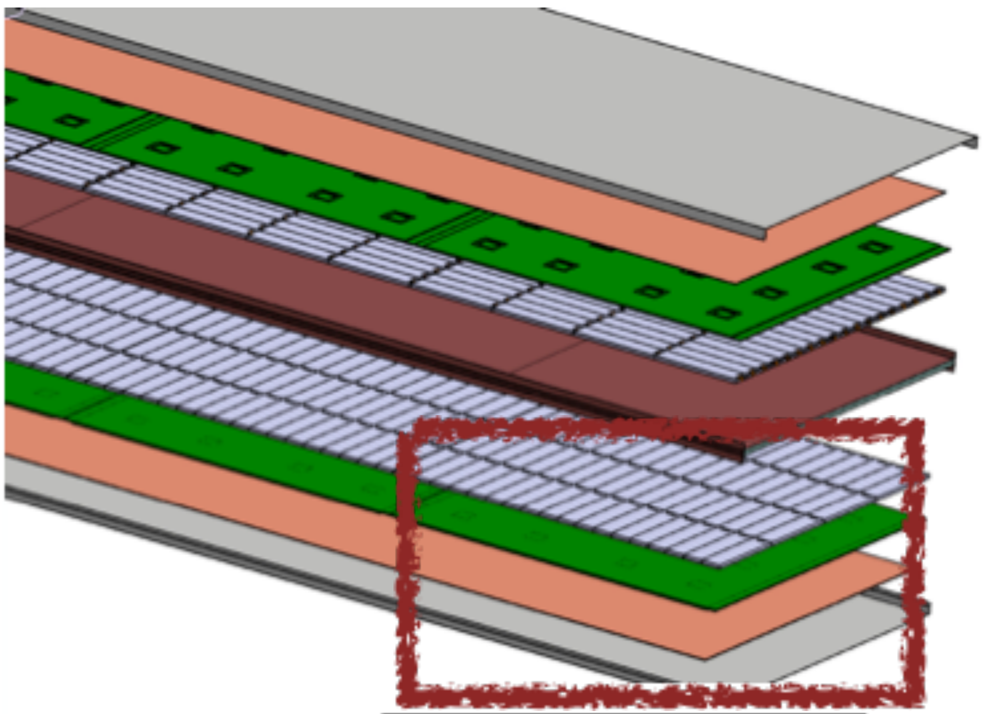


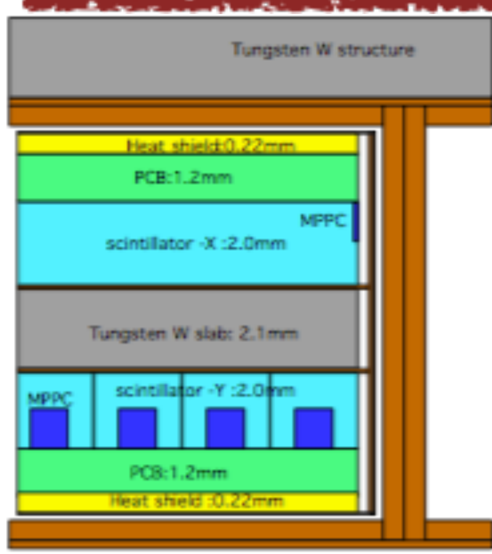


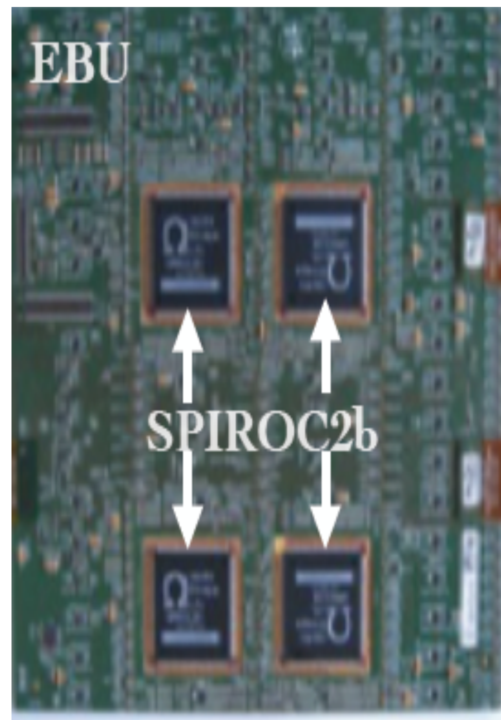


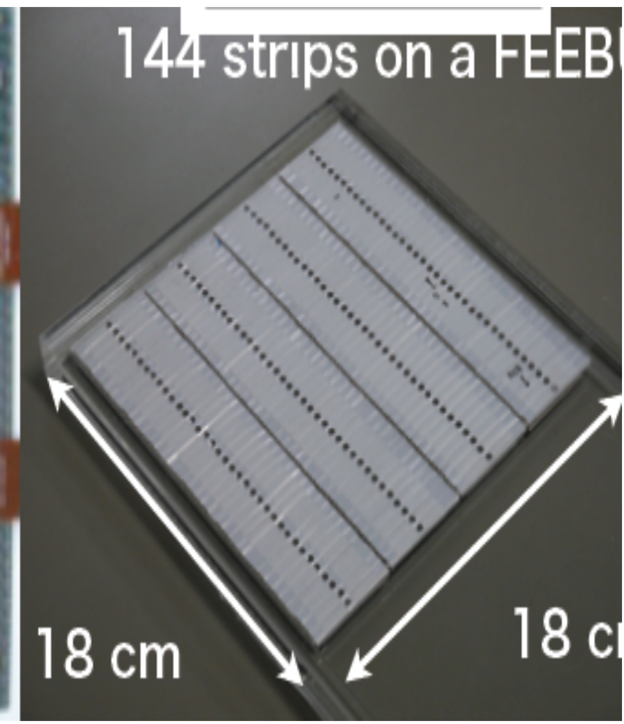
Strips with bottom readout

EBU





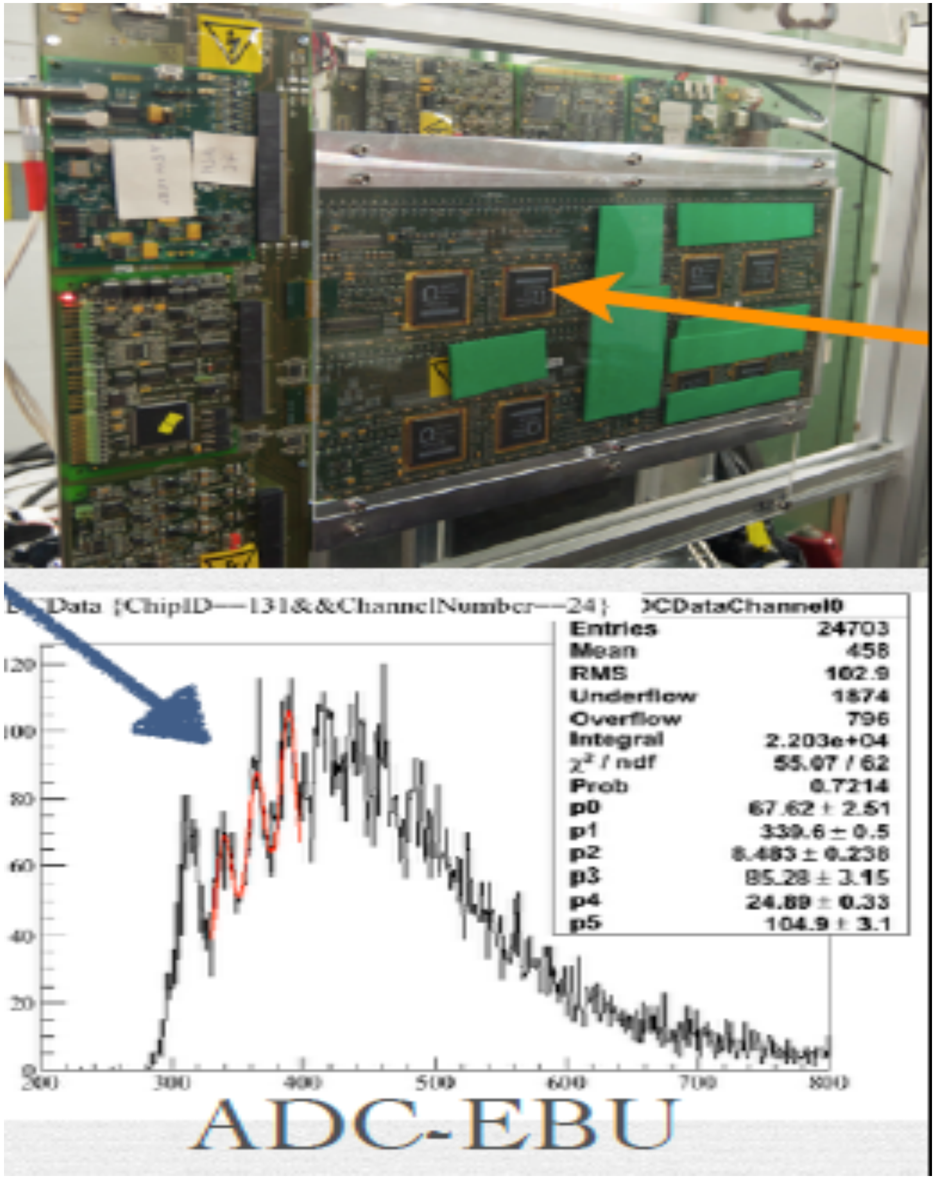




Ecal Base Unit: basic R/O unit of ScECal
ASIC with amplifier, shaper, digitizer along with self-trigger and bias control facility
May need tuning as this option develops

Prototype Tests

- Dynamic range is an important factor since you want to detect MIPS as well as large EM showers
- Interesting optimization between sensor size, pixel size, response etc.
- Tests underway



Summary

- The CALICE AHCal using small scintillator tiles directly-coupled to SiPMs is at a mature stage poised for implementation in a detector at proposed facilities
- Extensive component and system tests with the current design underway
- Like the Si-W ECal interesting synergies with LHC upgrade (CMS endcap hadron calorimeter upgrade)
- Active R&D underway to evaluate a strip-SiPM design for an ECal