Göttingen 2025 – scientific programme

T: Fachverband Teilchenphysik

T 72: Detectors VII (Calorimeters)

Thursday, April 3, 2025, 16:15–18:30, VG 1.102

Selection status for this session: not selected

⊕	16:15	T 72.1	Results of the Megatile prototype for the CALICE AHCAL — Volker Büscher, Lucia Masetti, •Anna Rosmanitz, and Sebastian Ritter
⊕	16:30	T 72.2	Fast Hadron Shower Simulation using the Discrete Cosine Transform with the CALICE AHCAL Prototype — •André Wilhahn, Zobeyer Ghafoor, and Stan Lai
⊕	16:45	T 72.3	CALO5D Calorimetry in five dimensions — Frank Simon, •Melike Akbiyik, Ulrich Einhaus, Lucia Masetti, Bohdan Dudar, Roman Pöschl, Xin XIA, Katja Krüger Krüger, and Vincent Boudry Boundry
⊕	17:00	T 72.4	Kinematic reconstruction of deep-inelastic tau-neutrino interactions with SND@SHiP — Vasilisa Guliaeva, Heiko Lacker, and •Eduard Ursov
	17:15	T 72.5	The contribution has been withdrawn.
⊕	17:30	T 72.6	Design of the SHiP Electromagnetic Calorimeter — •Claudia Caterina Delogu, Sebastian Ritter, and Matei Climescu
⊕	17:45	T 72.7	Pointing Studies with the SHiP Calorimeter Prototype — •Sebastian Ritter, Claudia Delogu, Rainer Wanke, Matei Climescu, and Volker Büscher
⊕	18:00	T 72.8	Control and safety systems for CMS high granularity calorimeter cassette assembly facility at CERN — •Maria Toms, Markus Klute, Ebru Simsek, Ziya Cihan Taysi, Bora Isildak, German Martinez, Andromachi Tsirou, and Piero Giorgio Verdini
⊕	18:15	T 72.9	Study of effects of detector mis-calibration on energy resolution for the SiPM-on-tile section of the High Granularity Calorimeter for CMS. — •Daria Selivanova

Rehearsal, 25/03/2025

Study of detector mis-calibration of the CMS HGCAL

Daria SELIVANOVA

DPG Spring Meeting 2025

T 72: Detectors VII (Calorimeters)

03/04/2025

HELMHOLTZ

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CMS

FTX

DESY.

Introduction

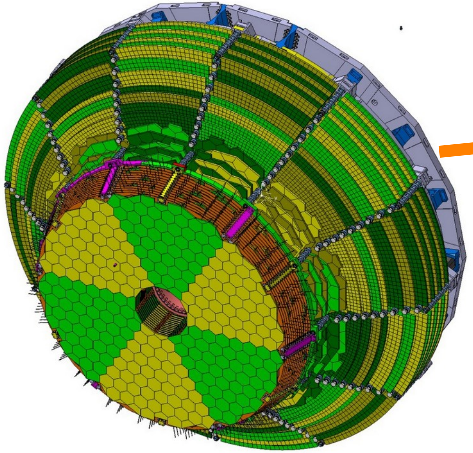
Motivation for the upgrade: High Luminosity LHC

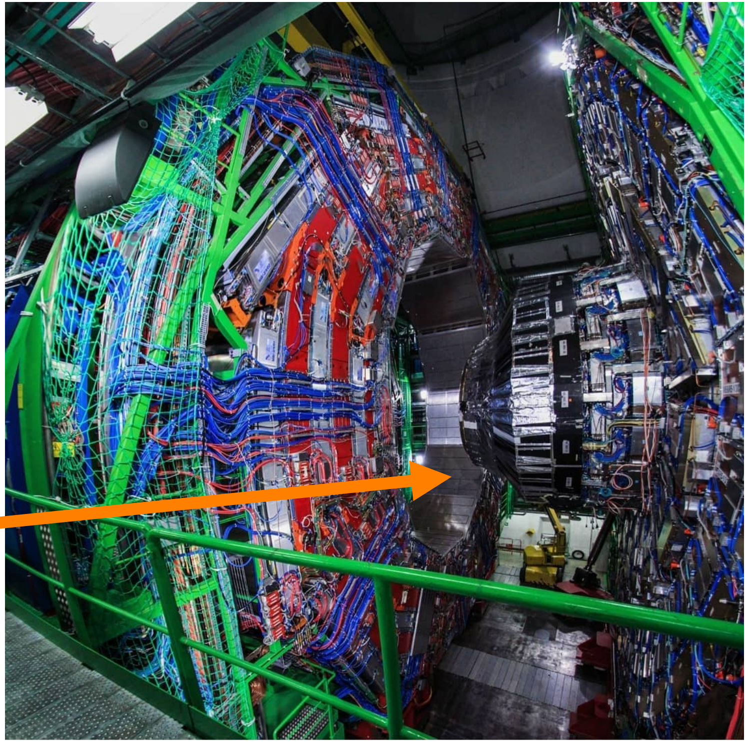
HL-LHC aims to achieve an integrated luminosity of 3000 fb^{-1} by its end of life - ten times higher than the LHC

Corresponding mean number of collisions (pile-up) per bunch crossing will be 140, with the possibility of achieving up to 200

High Granularity Calorimeter (HGCAL) upgrade:

- Sampling calorimeter with electromagnetic (CE-E) and hadronic sections (CE-H)
- Fine lateral and longitudinal segmentation: 47 layers, over 6M channels
- Pile-up rejection, shower imaging, particle flow algorithms





The CMS detector with the current calorimeter endcap

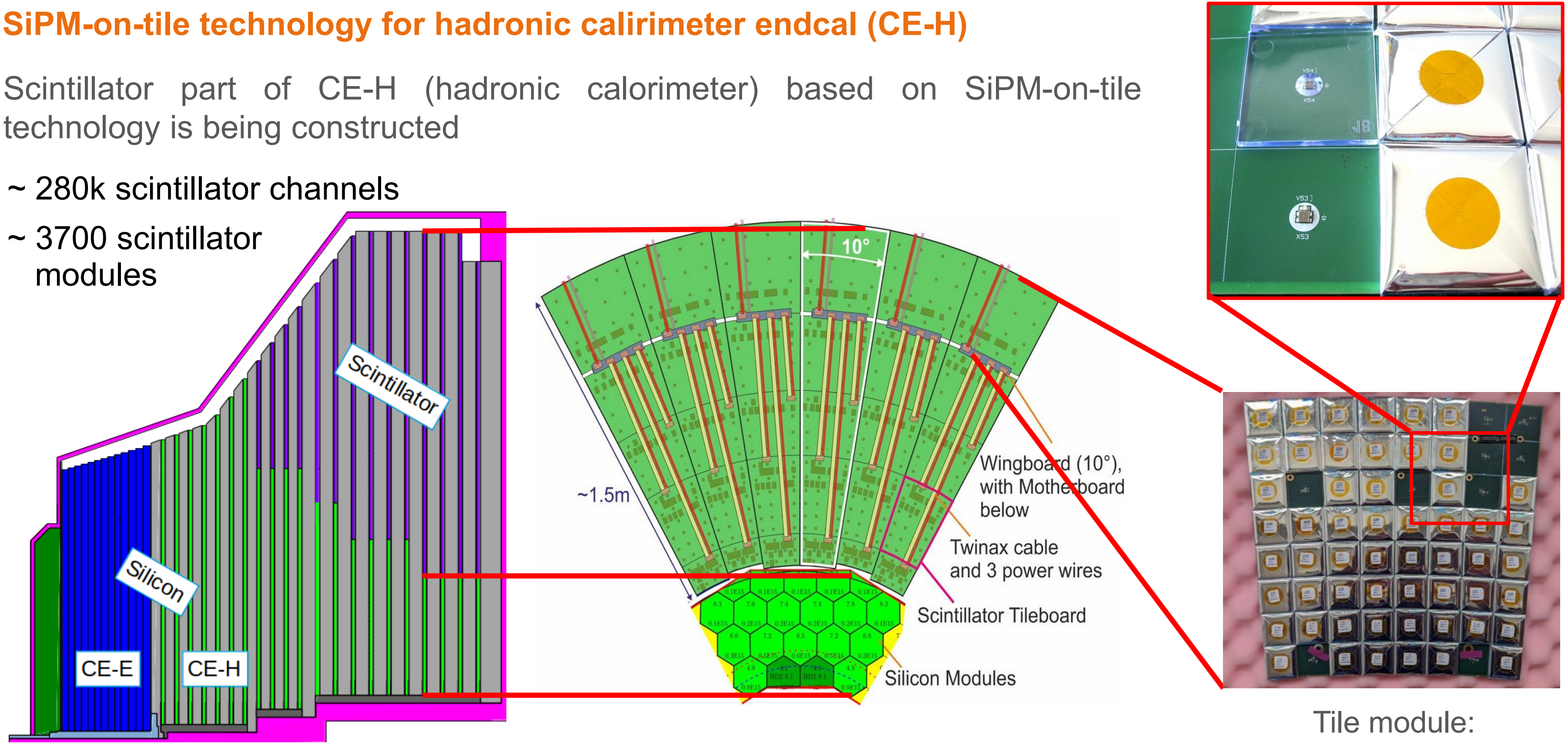
Scintillator section of CE-H

SiPM-on-tile technology for hadronic calirimeter endcal (CE-H)

Scintillator part of CE-H (hadronic calorimeter) based on SiPM-on-tile technology is being constructed

~ 280k scintillator channels

~ 3700 scintillator modules

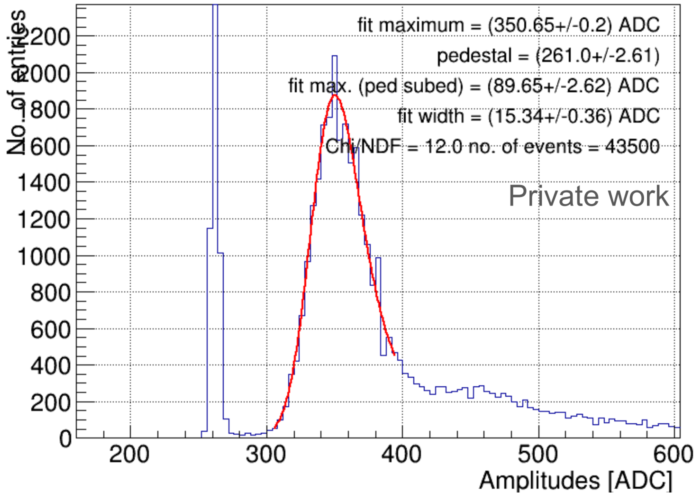


Tile module: basic detector unit

SiPM-on-tile technology

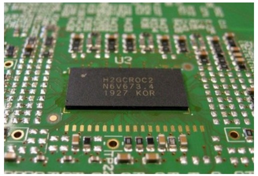
Response to charged particles

Plastic scintillators (3 mm thick), wrapped in reflective foil, coupled to a Si photomultiplier (SiPM). Signals from the SiPM are digitised by the read-out chip (ROC): receive an ADC value

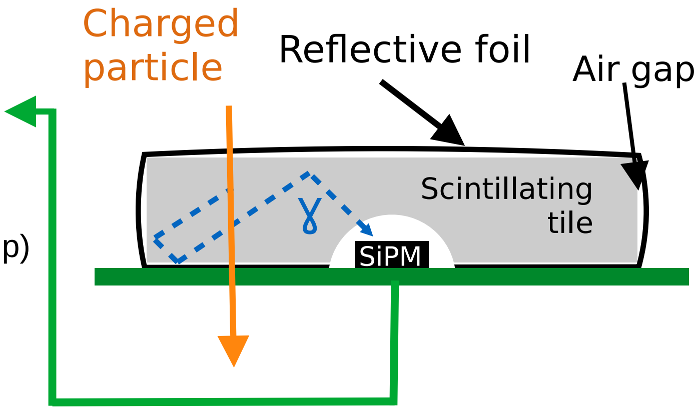


SiPM-on-tile channel response to a charged particle

Signal amplification and Digitization



HGCROC (HGCAL Read Out Chip)



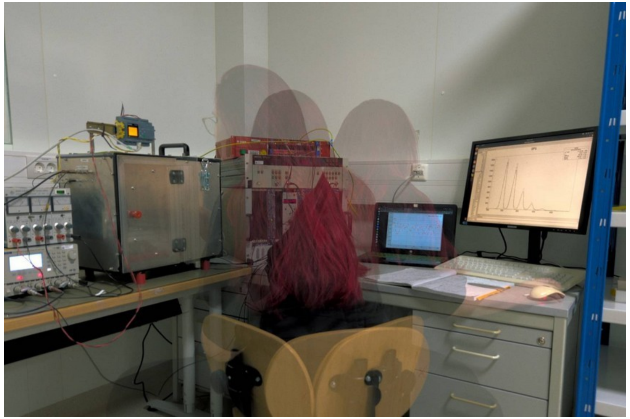
SiPM-on-tile technology

Starting calibration with Minimum Ionising Particles

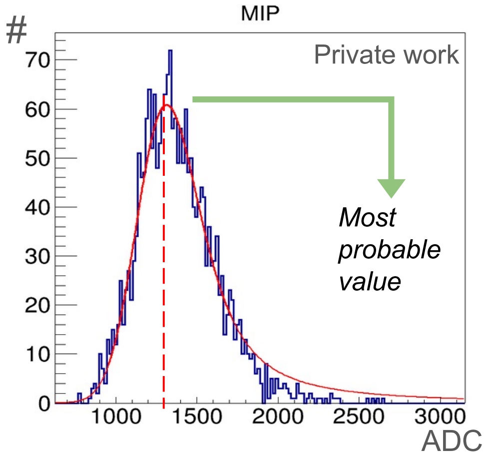
Response to a MIP as a standard candle – a powerful tool for sampling calorimetry: it allows to convert to the MIP scale and do measurements by counting particles

Most probable value in ADC per one MIP is a well defined feature and is used as the calibration constant

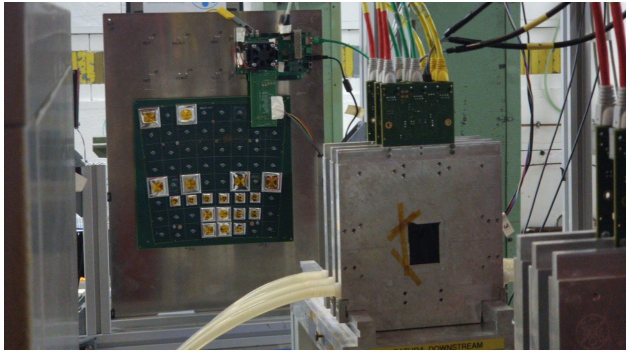
Mostly obtained in Tile Quality Control (QC) during production and in test beams



Tile Quality control test stand



Tile calibration with Sr90 tile Quality Control test stand



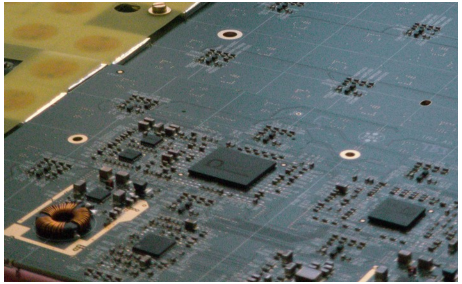
Tile module setup @ DESY Testbeam

Calibration in-situ

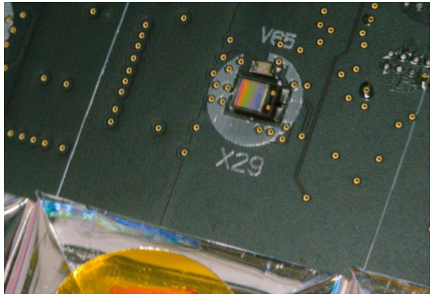
From measured signals to physics research

MIP counting is the foundation of the data-taking chain and it is imperative to maintain the scale well calibrated. Thus, we need to monitor the evolution of the signal compared to the starting conditions, evaluating the degradation of all of components with absorbed dose

HGCAL Read Out Chip

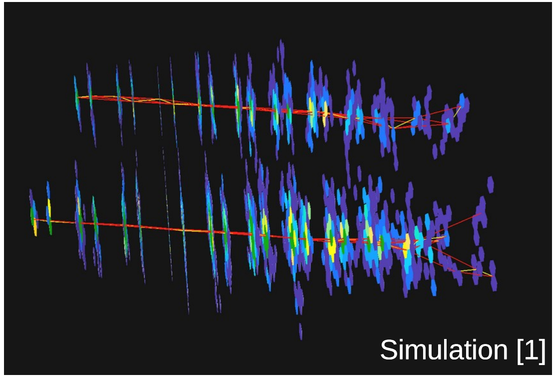


SiPM-on-tile channel



CE-H layer

Clusters of hits in multiple layers



ADC → Charge Q → Number of MIPs in one layer → Sum of numbers of MIPs in a shower

↓

Energy

Mis-calibration

Sources of uncertainties in the SiPM-on-tile channels

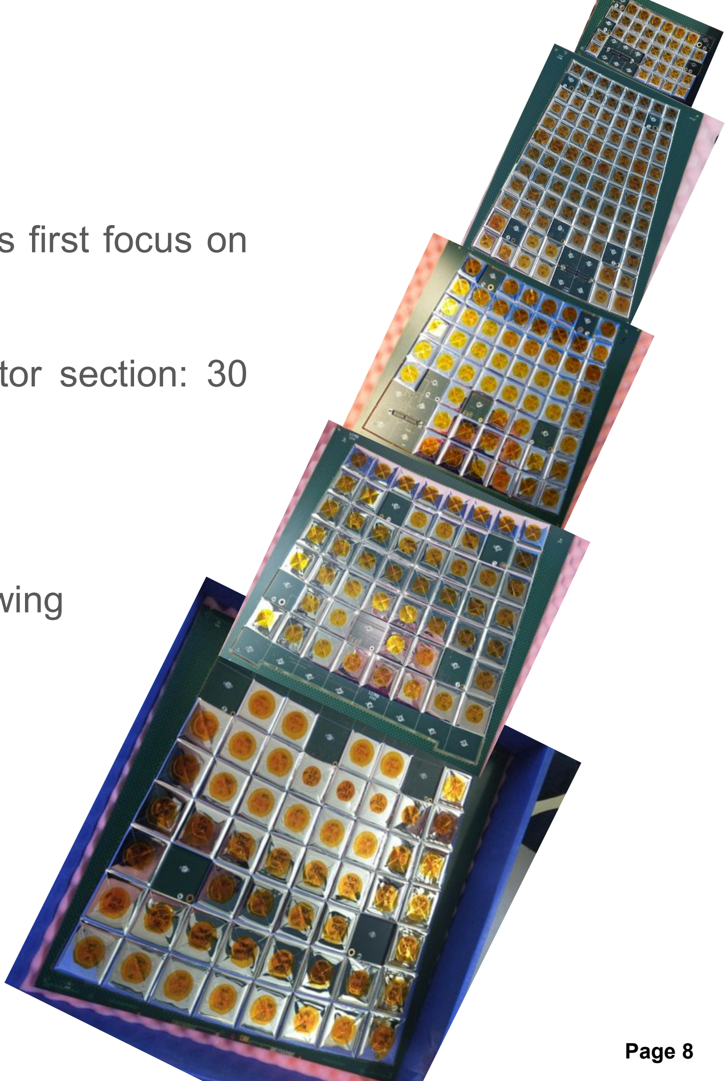
Although the Read-out Chip will also suffer radiation damage, let's first focus on the channels: SiPMs and scintillators

There are more than 60 types of scintillator tiles in the scintillator section: 30 variations in size, 2 - in material

Even a single module has at minimum 5 variants of tiles

When evaluating the calibration of channels and modules the following should be taken into account:

- SiPM non-linearity
- SiPM gain and efficiency stability
- Variation of scintillator response with size and material



Mis-calibration

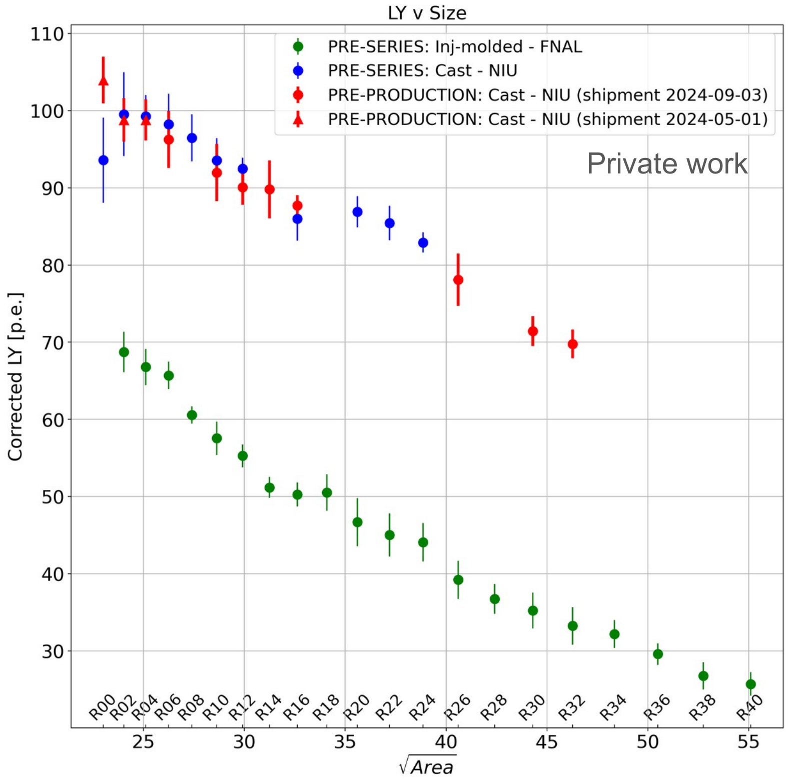
How to use experimentally obtained values

Scintillator tiles can be compared using light yield, defined as the response a MIP normalized to SIPM gain

Quality control during detector construction can provide starting calibration, parametrized for a uniform detector response

Existing channel variations further exaggerated after suffering radiation damage during operation in potentially unpredictable ways

Calibration strategies can be established in advance of data-taking by simulating signal generation and investigating signal worsening scenarios



Light Yield (LY) – response to a MIP normalized to SiPM gain

[1] https://hgcal.web.cern.ch/Visualization/visualization/

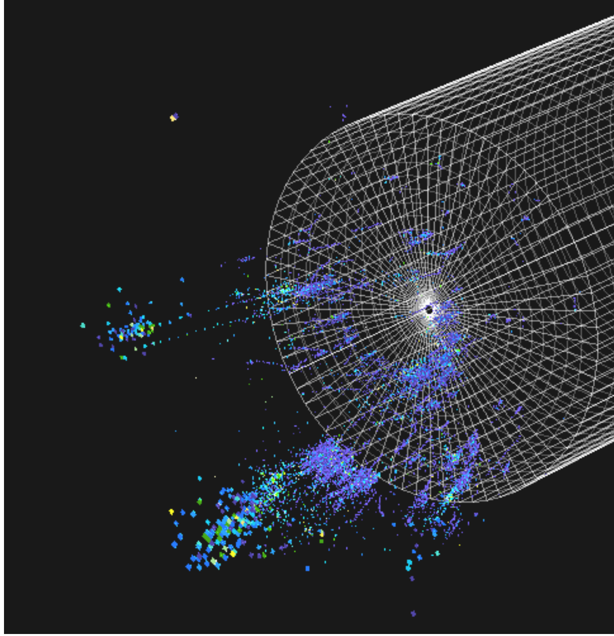
Simulation

Framework

CMSSW (CMS Software) is a software environment that can be utilised to perform detailed simulation of various steps in the data-taking process in HGCAL:

- **Generation -** Monte-Carlo Event Generators for HEP events
- **Geometry -** Detector parameters specified using DD4hep framework
- **Digitization -** Channel response
  - Geant4 simulated energy deposition in keV
  - Energy to charge conversion: emulation of photodetector
  - Charge to ADC conversion: emulation of the read-out-chip
- **Hit Calibration -** Conversion from ADC back to energy
- **Reconstruction -** Layer clustering

Simulation [1]

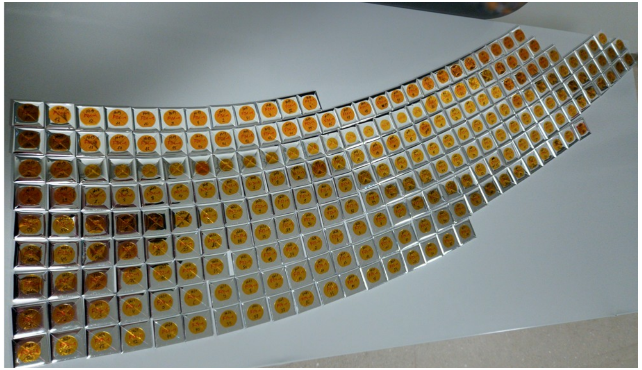


Simulation

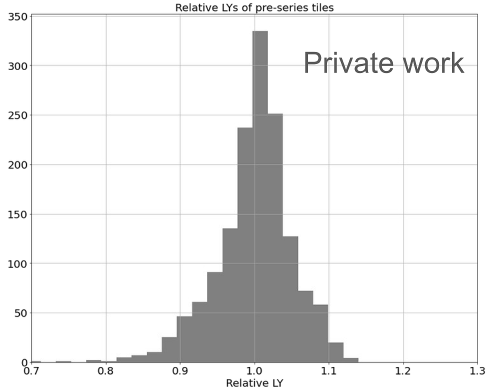
Adding detail

The existing model of the SiPM-on-tile section needs to be updated with precise characteristics of components obtained experimentally

Test bench measurements as well as beam tests performed with more that 1500 tiles during the pre-series phase provide the required data for the quantitative study of mis-calibration



Scintillator tiles 3.4x3.4 cm^2 – 3.9x3.9 cm^2



Relative light yield of pre-series tiles

Conclusion

Final remark and next steps

High Granularity Calorimeter under construction for the HL-LHC

- SiPM-on-tile technology in the hadronic section of the HGCAL will perform measurements in the MIP scale, but that requires calibration at various steps
- Fine segmentation of a complex geometry poses challenges to parametrization of channel-to-channel variation
  - Further complications arise from potentially unpredictable nature of radiation damage effects

- Calibration strategies to be established following a detailed simulation of detector components and modes of operation during physics runs
  - Experimental data will be used to fine-tune the data-taking chain emulation
- Developed model can be validated by simulating upcoming beam tests

Backup