FCT Follow-up Meeting for Portuguese Trainees

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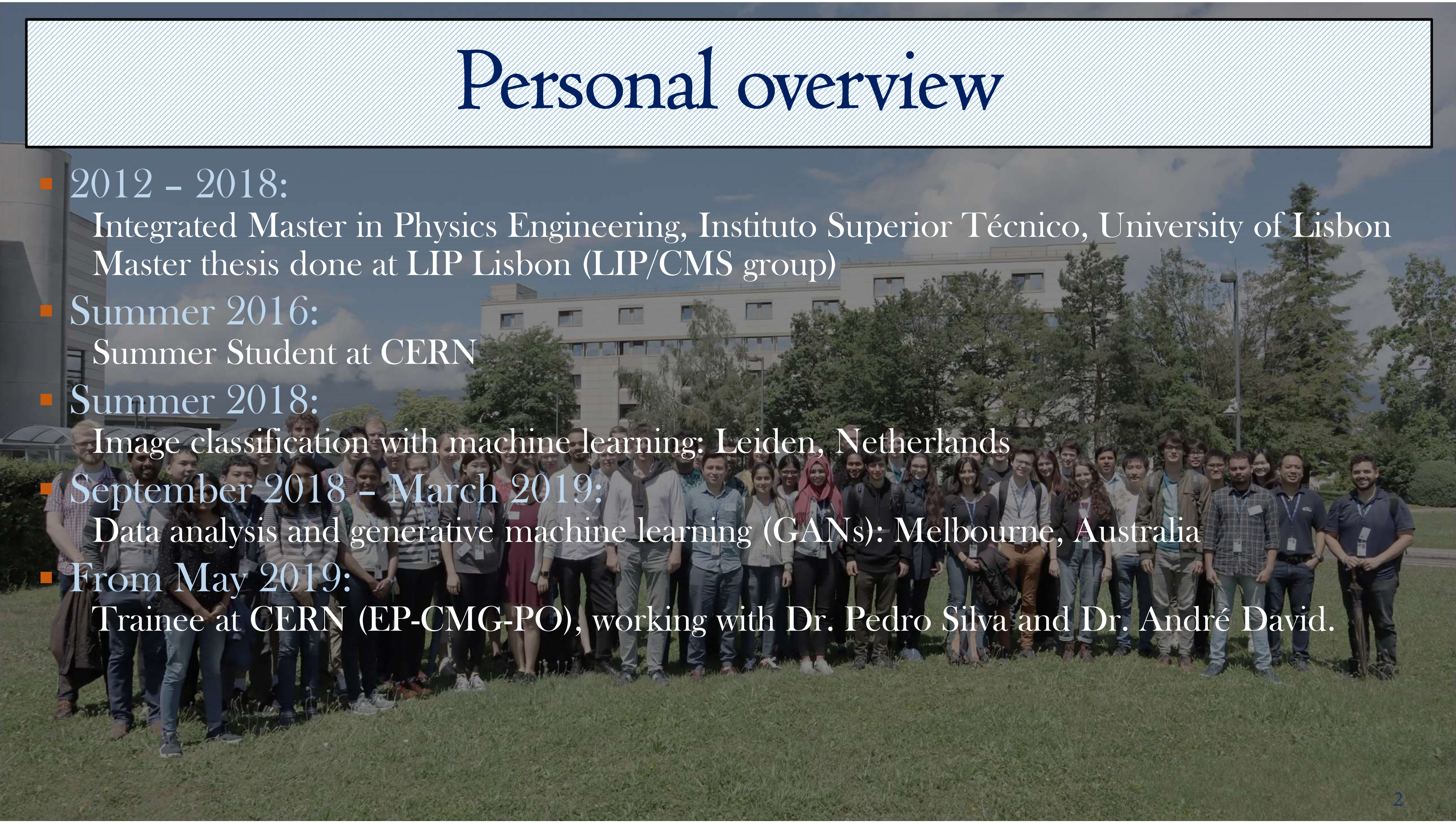
Partial wafers performance studies on the future CMS high granularity calorimeter

Referência: SFRH/BEST/150186/2019

Geneva, 3rd September 2019

Personal overview



- 2012 – 2018:
  Integrated Master in Physics Engineering, Instituto Superior Técnico, University of Lisbon
  Master thesis done at LIP Lisbon (LIP/CMS group)
- Summer 2016:
  Summer Student at CERN
- Summer 2018:
  Image classification with machine learning: Leiden, Netherlands
- September 2018 – March 2019:
  Data analysis and generative machine learning (GANs): Melbourne, Australia
- From May 2019:
  Trainee at CERN (EP-CMG-PO), working with Dr. Pedro Silva and Dr. André David.

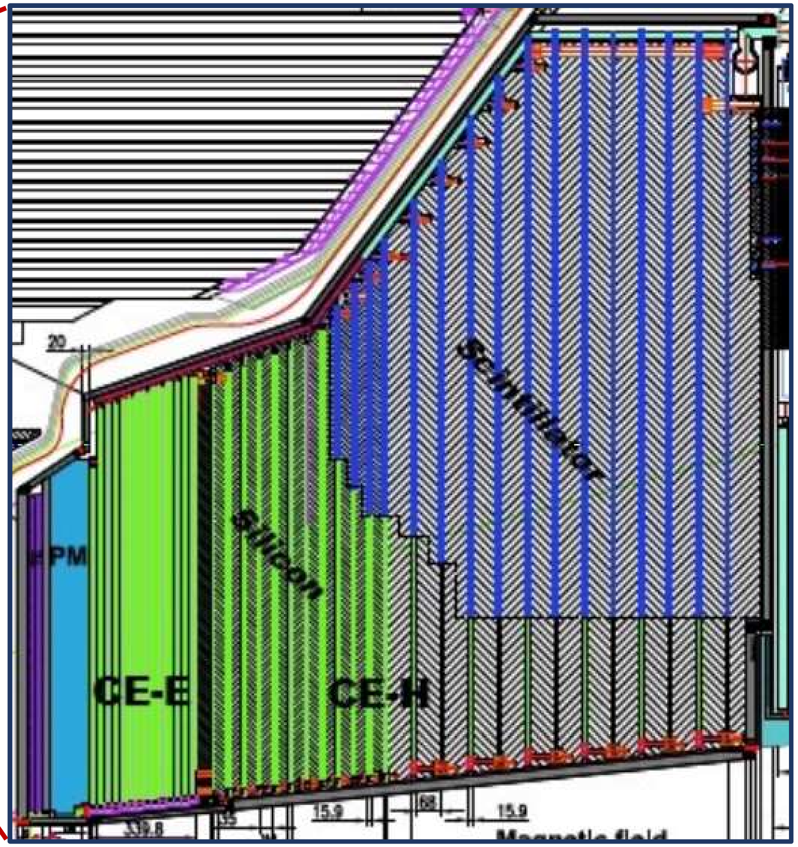
Project overview: HGCal

High luminosity LHC

- Operational phase starts late 2026
- Up to 200 collisions per proton bunch crossing
- 10 times more integrated luminosity than the LHC (very high fluences: up to 10^{16} n_{eq}/cm^2)
- Search for very rare processes (double Higgs, vector boson scattering, ...)
- Forward calorimetry is crucial for the success of the scientific programme

CMS Calorimeter upgrade

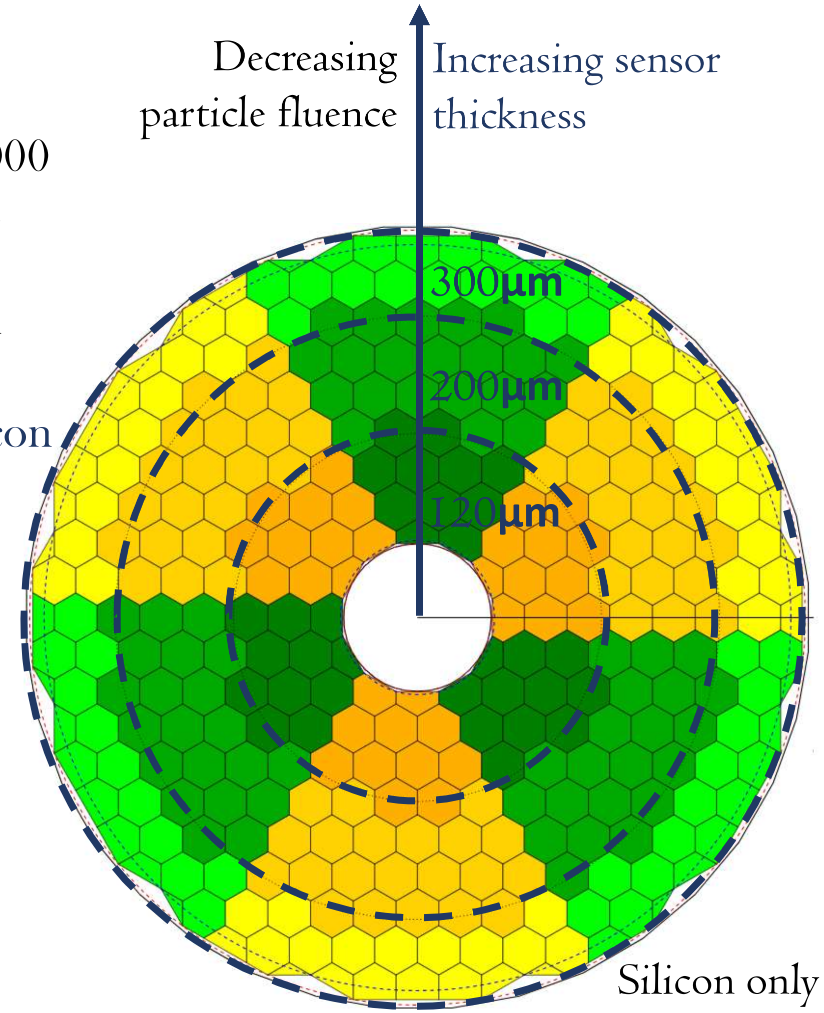
- $600 m^2$ silicon
- $500 m^2$ scintillators
- Weight: 228 x 2 tonnes
- More than 6.2 million channels



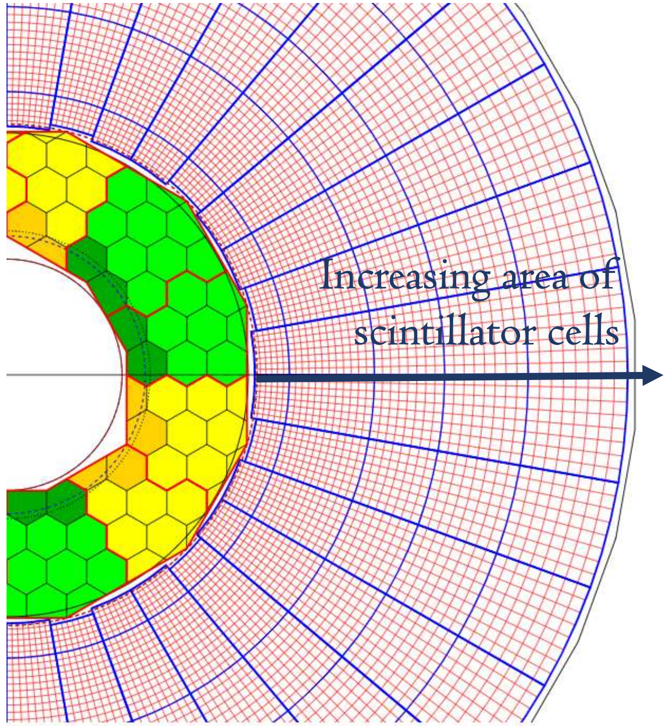
High Granularity Calorimeter

HGCal structure

- The HGCal will make use of:
  - Silicon sensors
    - 28+22 layers, with around 27000 silicon hexagonal wafers in total (high fluence region)
    - measures electromagnetic and hadronic showers
  - Plastic scintillators coupled to silicon PMs
    - 14 layers (low fluence region)
    - measures hadronic showers



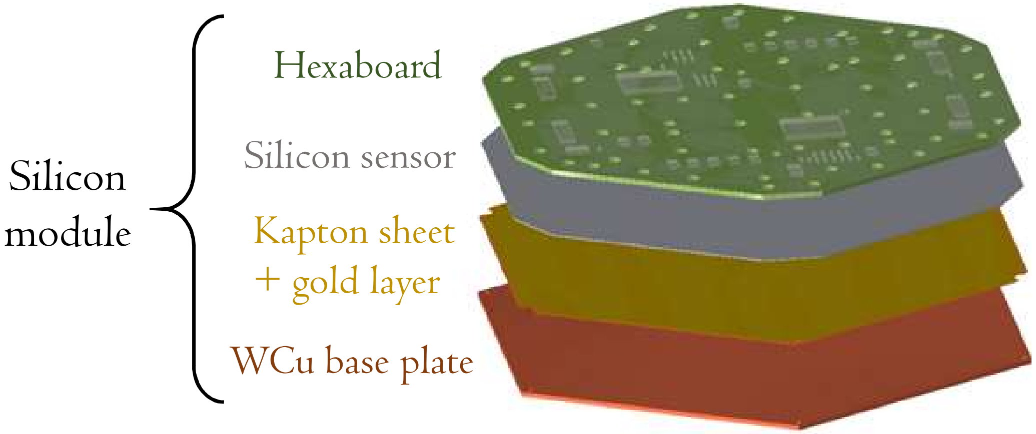
Silicon only layer

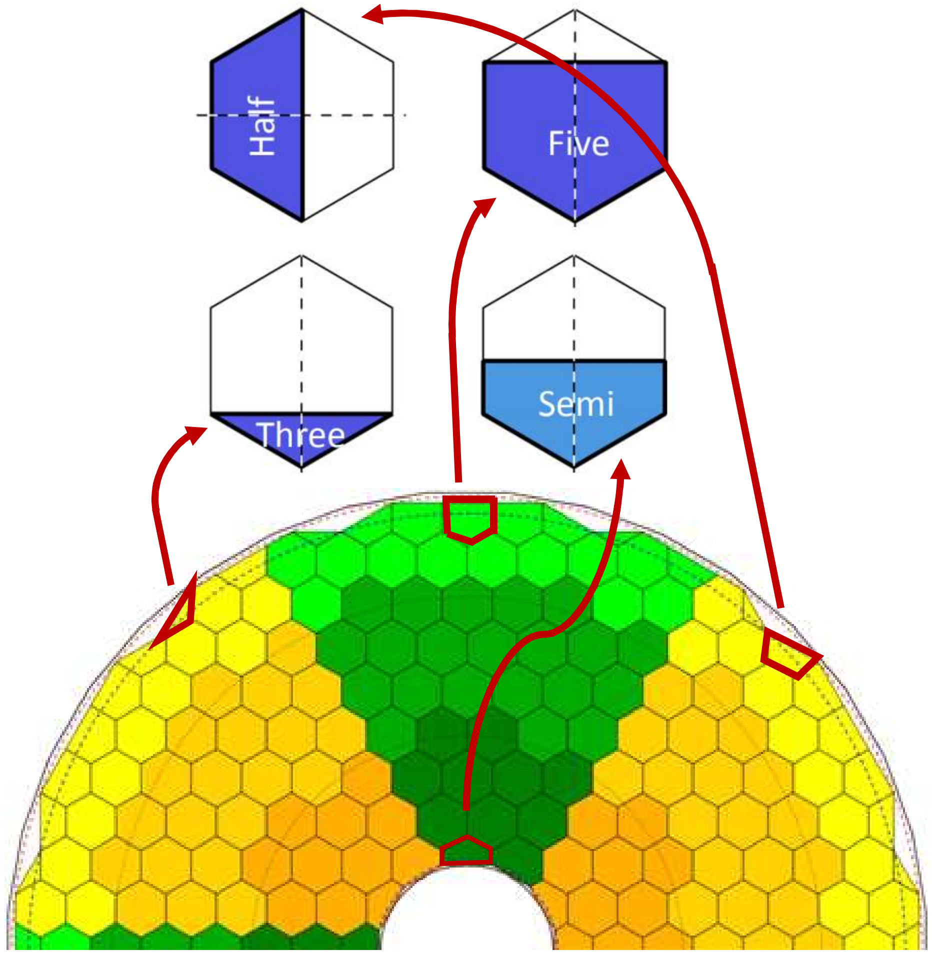


Silicon + scintillator layer

Project overview

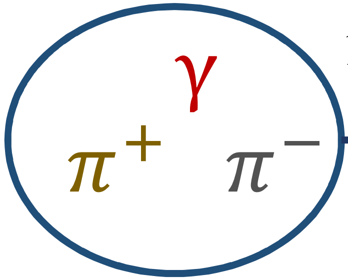
- What happens if other wafer shapes are considered near the boundaries?
  - Challenging mechanics and electronics problems
  - Study the impact of different Si wafer shapes
    - Physics performance?
    - Higher cost
    - Increased total man-hours





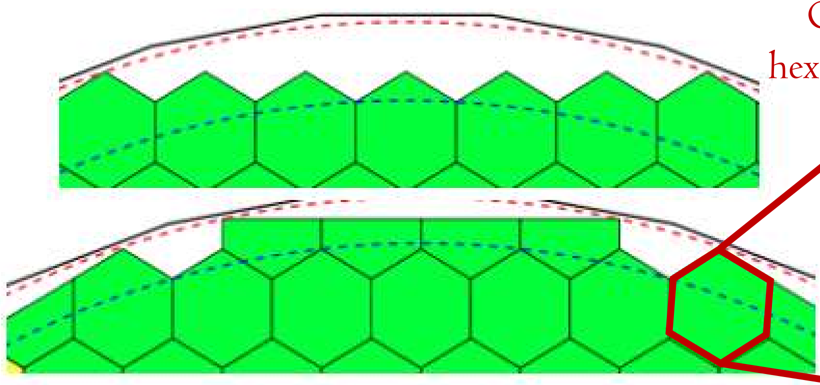
Silicon layer

Project workflow

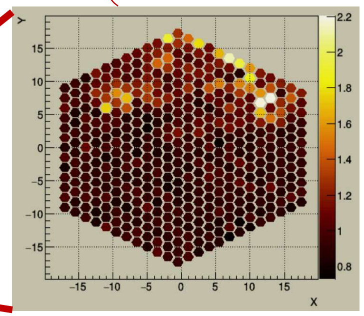


simulate the response to pions and photons for a chosen geometry

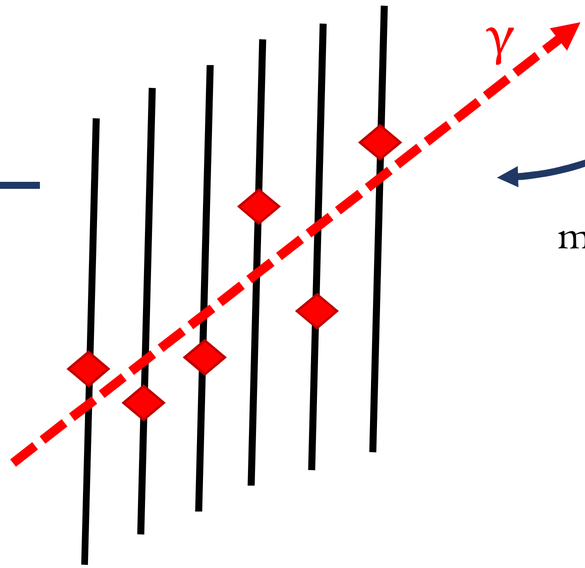
with and without pile-up



One hexagonal wafer contains tens of hexagonal cells (area of 0.5 or 1 cm^2 each)



measure the reconstructed hits in the calorimeter



data analysis

- Particle shower reconstruction
- Energy calibration

\+ compensation for hadronic component

\+ noise removal for non-zero pile-up

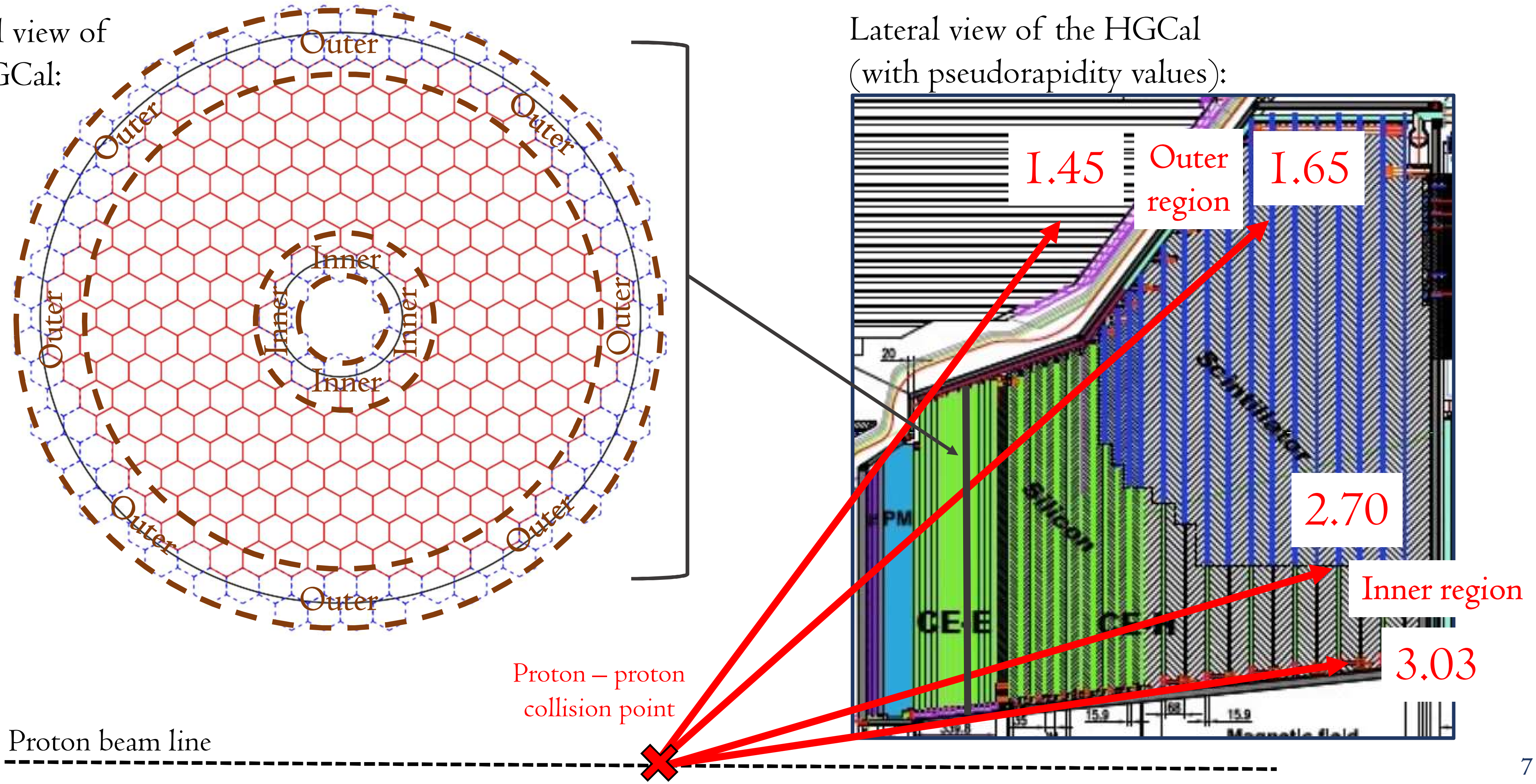
Software correction of the detector's response

$$\frac{E_{gen} - E_{reco}}{E_{gen}}$$

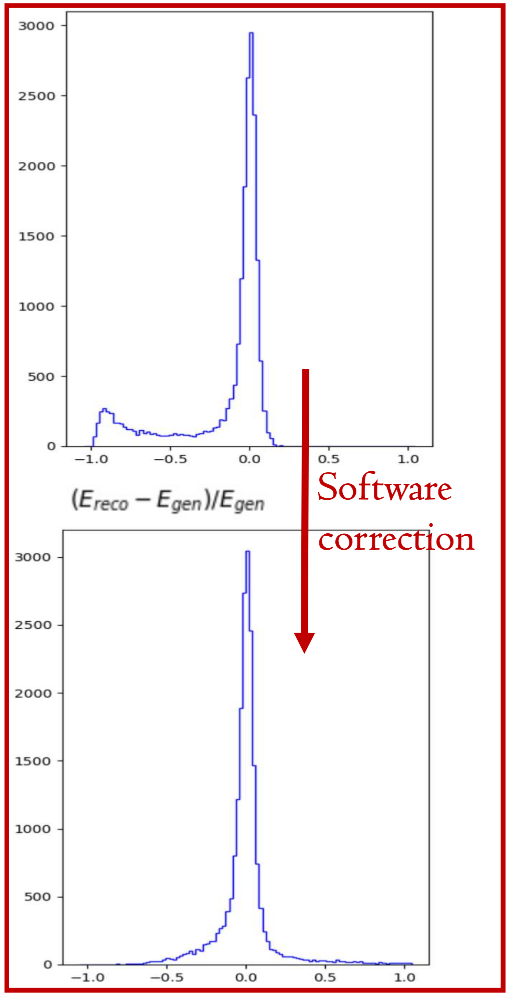
Regions of the detector studied

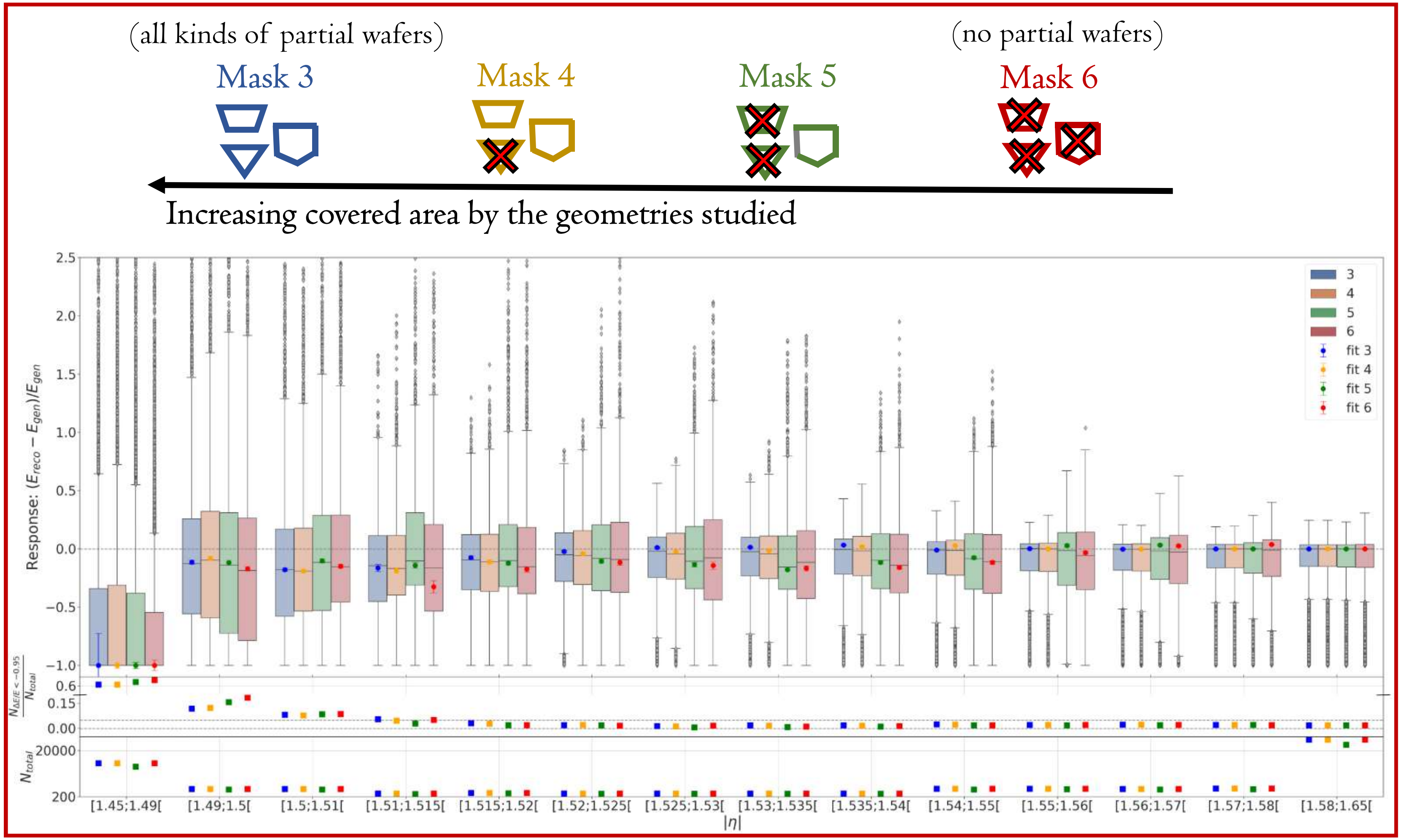
Frontal view of the HGCal:

Lateral view of the HGCal (with pseudorapidity values):



Final results





Experience acquired

- Computing:
  - Linux/Unix
  - C/C++, Python, Shell / Bash
  - Git (and related GitHub and GitLab online tools)
  - Job submission to the computing grid
  - Data visualization
  - Near future
  - CMS Hackaton: https://indico.cern.ch/event/835728/overview
  - Openlab course #1: Computer architecture and efficient programming
  - Openlab course #2: Programming and environments for parallelism
  - Next project: GPUs (with potentially some machine learning)

- Scientific:
  - Mathematics and Statistics
  - Calorimeter and detection physics

- Others:
  - Regular presentations/discussions in weekly group meetings
  - Writing a CMS "Detector's Note"

Thank you.

GitHub page: https://github.com/b-fontana

CV: https://github.com/b-fontana/CV

Final results (inner region)

(all kinds of partial wafers) (no partial wafers)

Mask 3 Mask 4 Mask 5 Mask 6