CMS HGCAL: Evaluation of the impact of different partial silicon wafer geometries in the response to electromagnetic showers

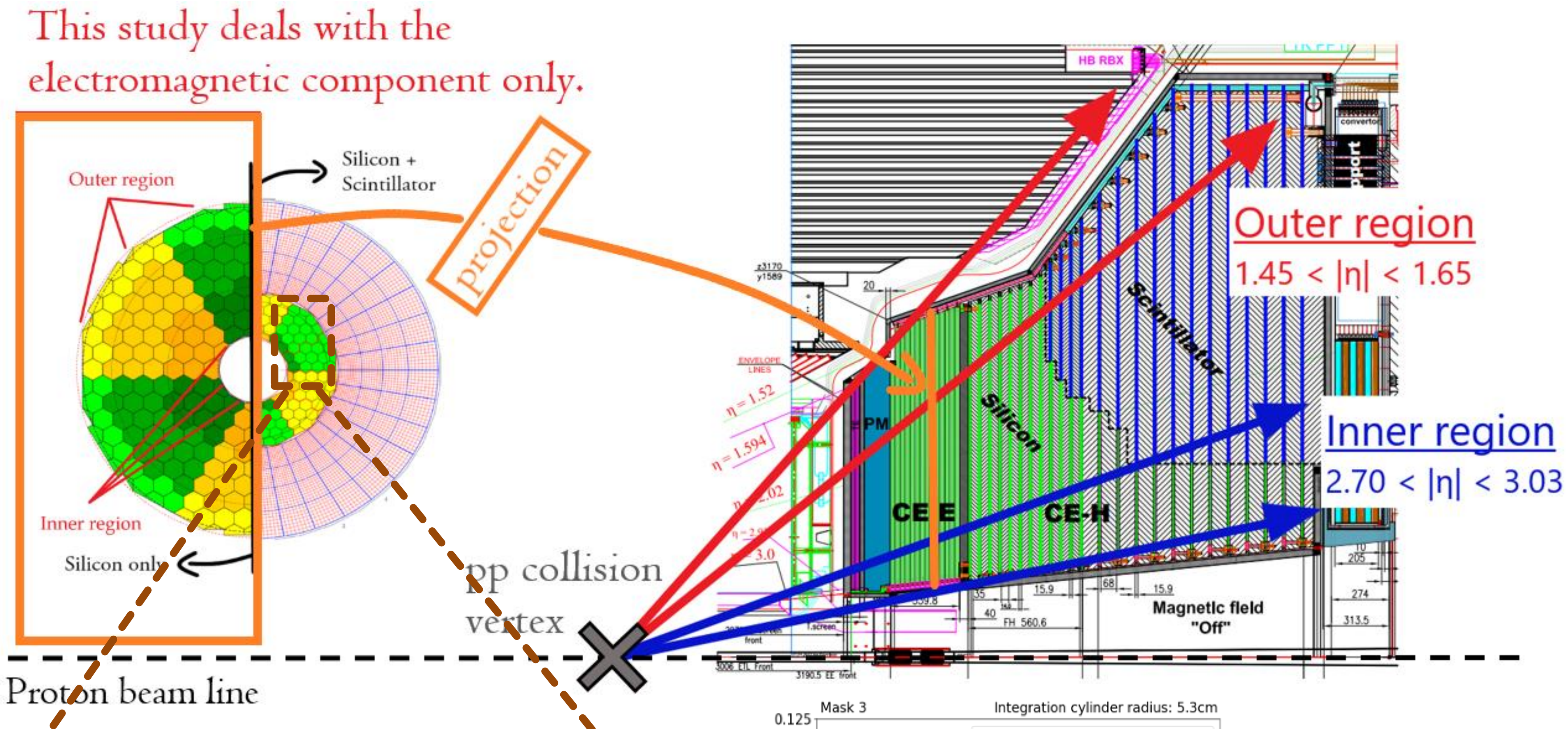
LHCC 2020 Winter Poster Session

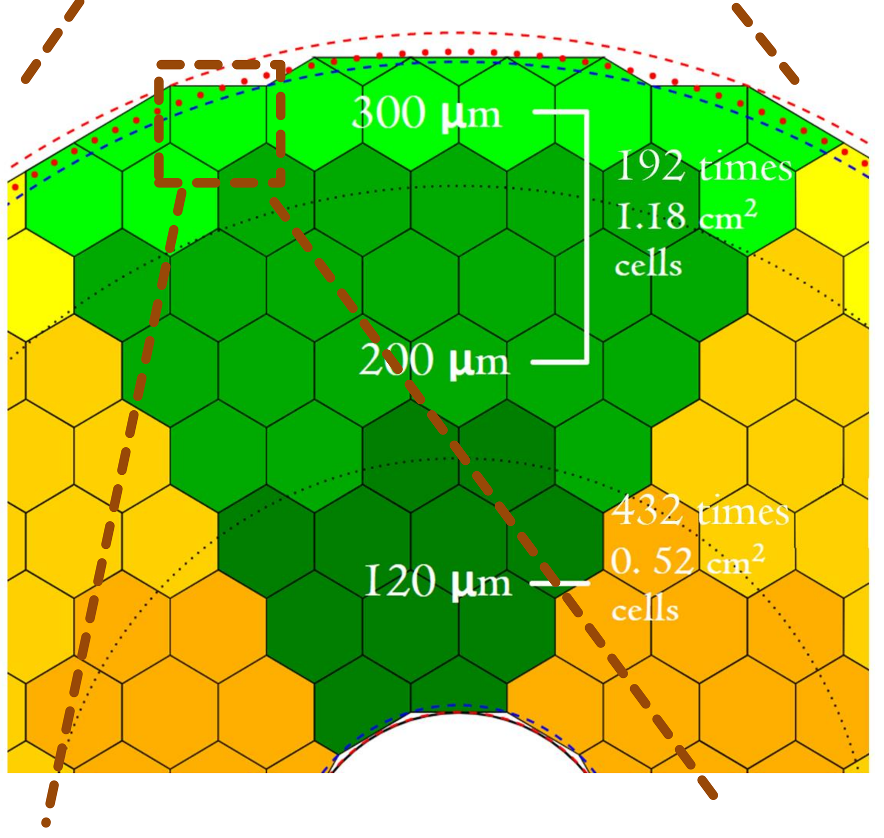
Bruno Alves (CERN)
for the CMS Collaboration

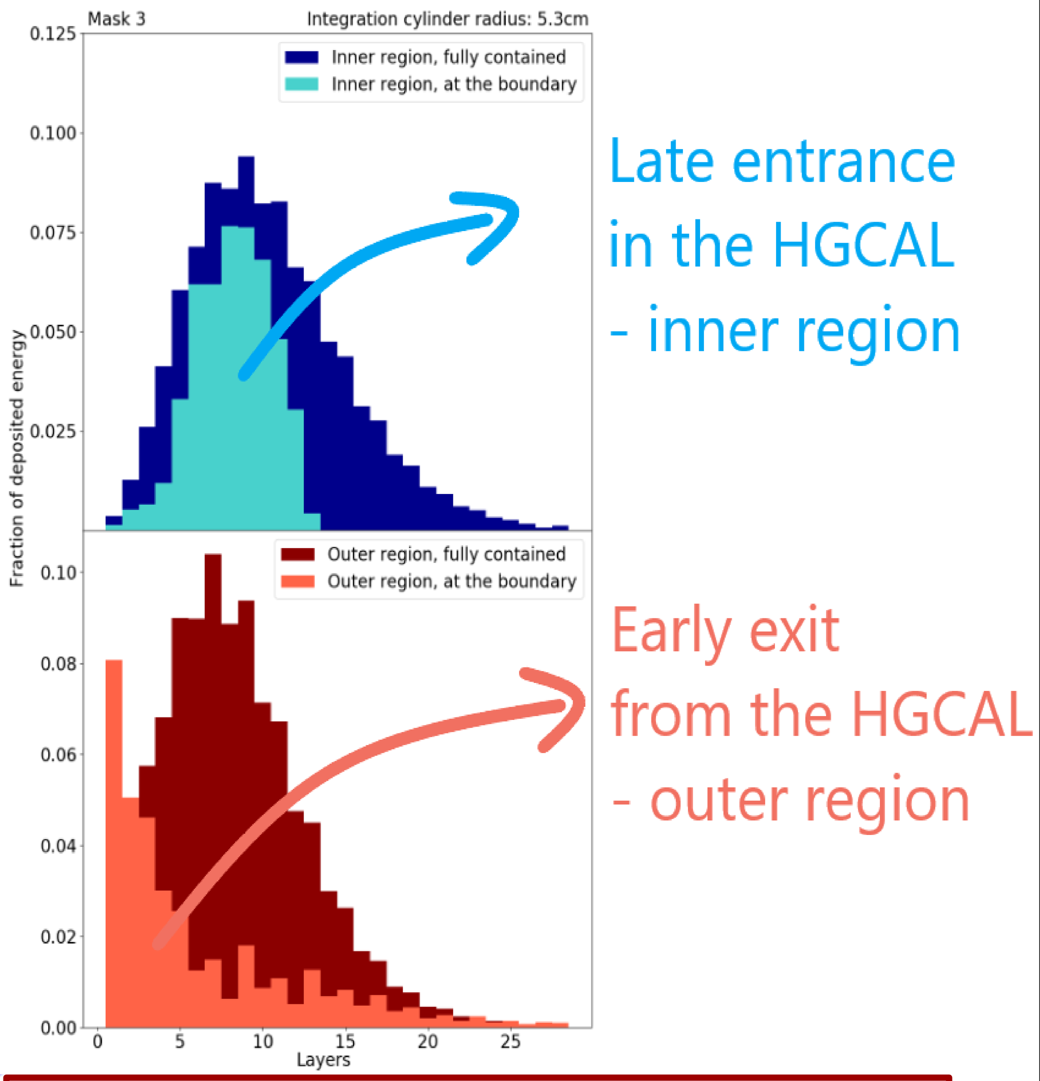
Motivation for this study

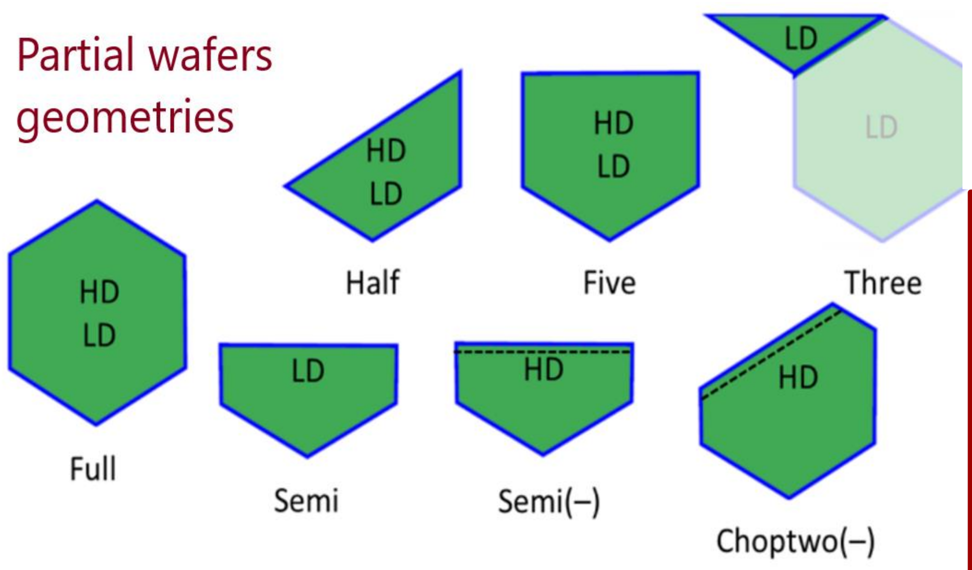
Study the impact of different coverages on the photons' energy response at the inner and outer boundaries of the electromagnetic section of the future High Granularity Calorimeter (HGCAL) using a set of non-hexagonal partial silicon wafers. The photons' energy response is presented after implementing two independent corrections for partially contained showers.

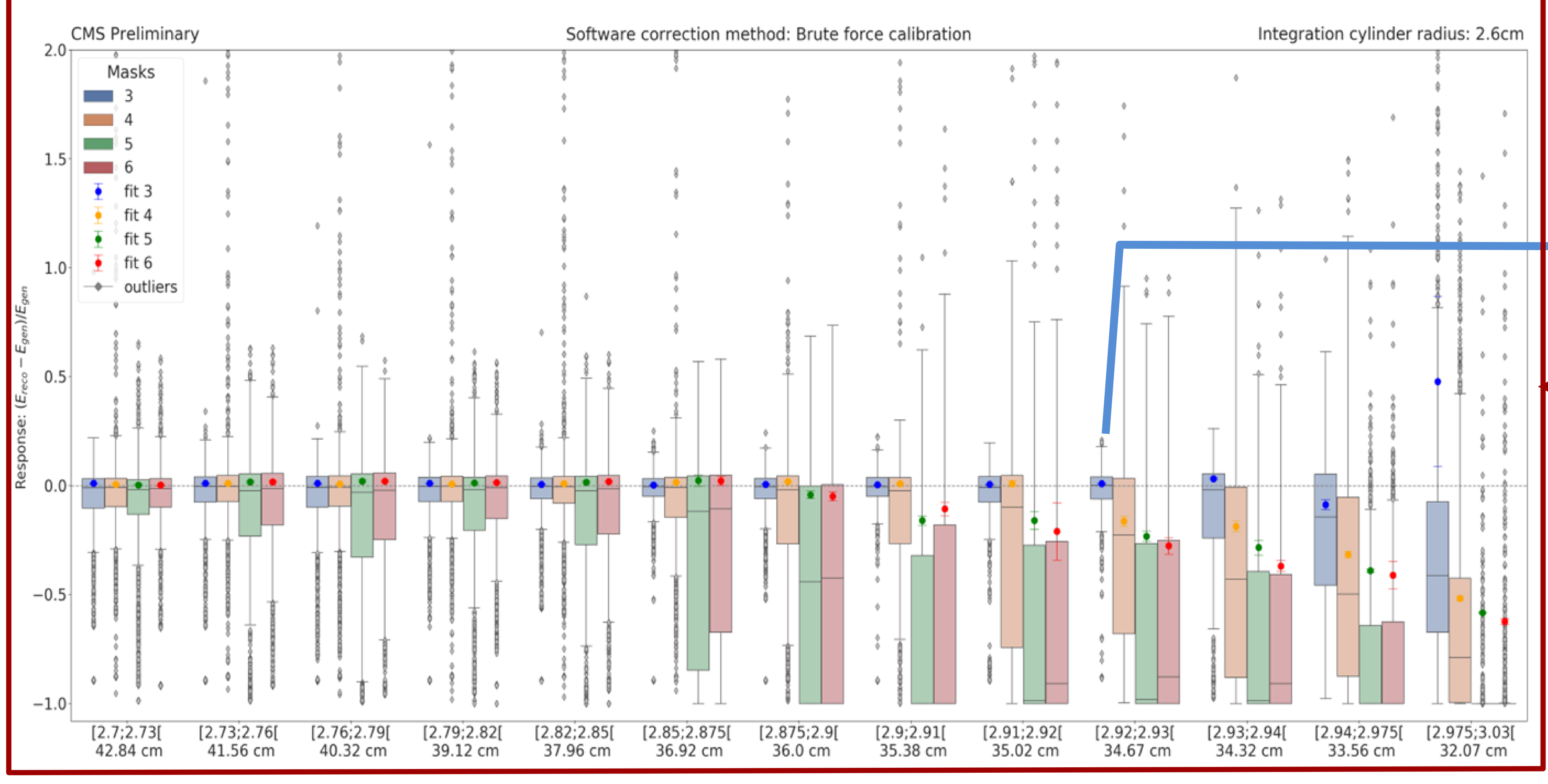
This study deals with the electromagnetic component only.











Conclusions

We quantified the impact that different choices of lateral coverage in the electromagnetic section of the HGCAL may have on the energy response of electromagnetic showers. The results evidence that the inner region is the most affected by the choice of different wafers. As expected, the geometries that yield the largest possible event coverage tend to be preferred. Future studies may include the impact of the clustering algorithm and pile-up in the shower leakage method, a more realistic description of the HGCAL geometry, and possible extensions to the hadronic section.

Why may partial wafers be required?

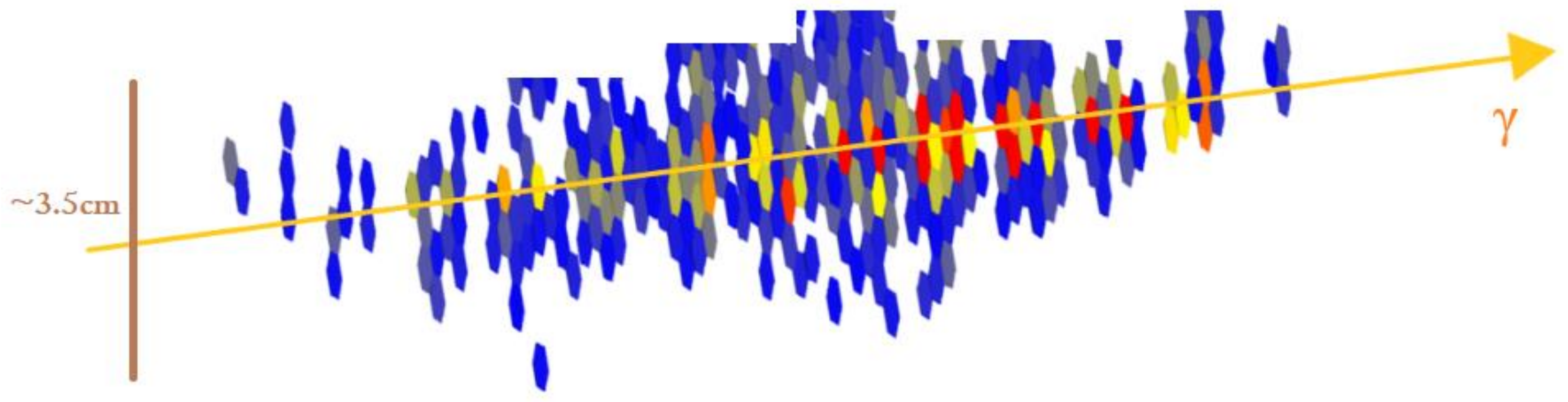
- The electromagnetic section of the HGCAL will comprise hexagonal silicon sensors assembled into 26 layers (adding to 26 X_0).
- Given the circular endcap geometry, the inner and outer regions need to be carefully designed to optimize the hermeticity.
- Differently shaped silicon wafers (partials) may be necessary to ensure the latter requirement, and potentially have an impact in the energy resolution.

γ response studies with different partial wafers

Energy response formula:

$$\text{Response} = \frac{E_{\text{reco}} - E_{\text{gen}}}{E_{\text{gen}}}$$

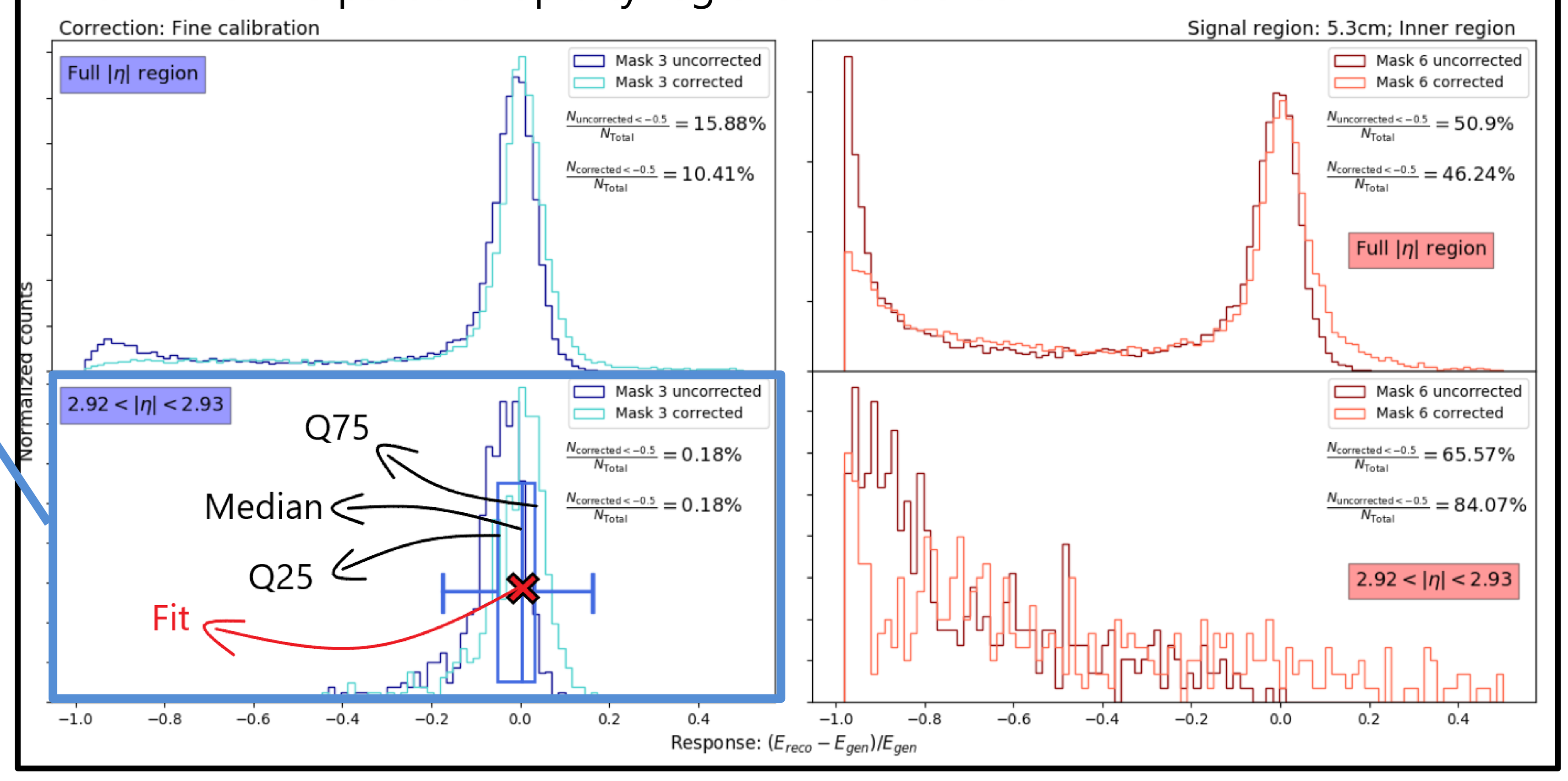
Longitudinal shower energy profile:



- Regions: Inner ($1.45 < |\eta| < 1.65$) and outer ($2.70 < |\eta| < 3.03$) boundaries.
- Signal integration regions: Shower axis-centered cylinders with 1.3, 2.6 and 5.3 cm radii. These values encompass the expected Molière radius (~28mm) and take into account the size of the silicon cells, with the smallest cylinder covering one cell plus its nearest neighbors. The shower energy is reconstructed summing the energy deposited in each cell of the cylinder.
- Baseline calibration: Calibration of the response using fully contained electromagnetic showers (based on fixed pseudo-rapidity ranges). It is iteratively calculated by interpolating the median response as a function of ϕ, $|\eta|$ and E_{reco}.

Two correction methods are considered:
- Shower leakage method: physics-driven weight-based method, where showers that partially missed the detector are corrected using the average of longitudinal profiles of fully contained showers.
- Fine calibration: additional calibration using fine pseudorapidity bins

Iterative fitting procedure: approximate the gaussian core of the response, separating it from the tail of misreconstructed showers that changes abruptly within the fine pseudo-rapidity regions considered.



Final results ($|\eta|$-dependent photon energy response distributions):

- Box plots (one colour per partial geometry).
  - The lines represent 25% and 75% quantiles and the median of the distributions;
  - Outliers are shown individually in grey diamonds; all the other points lie within the grey whiskers.
- The results of the iterative fits are displayed as full dots, having the colour of the corresponding geometry. The error bars were taken from the gaussian fits, whenever these converged. Otherwise, they were simply taken from the underlying distributions.
- As expected, for the inner region the response degrades substantially as one approaches higher $|\eta|$ values, and for the same $|\eta|$ bin, the masks with less coverage provide a significantly worse result.

Reference:
The CMS Collaboration, *The Phase-2 upgrade of the CMS Endcap Calorimeter*, CERN-LHCC-2017-023, CMS-TDR-019, Novembre 2017

Bruno Alves is supported by CERN and FCT grant SFRH/BEST/150186/2019

Fundação para a Ciência e a Tecnologia