Detector performance studies for the CMS High Granularity Calorimeter

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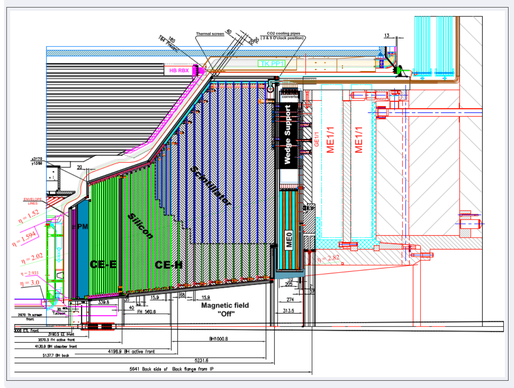
CMS High Granularity Endcap Calorimeter (HGCAL)

HGCAL Longitudinal cross section



The High Luminosity Large Hadron Collider (HL-LHC) will integrate ten times more luminosity than the LHC, posing significant challenges especially for calorimetry in the forward region namely

- radiation tolerance
- event pileup
- performance degradation of the existing forward calorimeters leads to unacceptable loss of the physics performance

Proposed design uses silicon sensors as active material in the front section and plastic scintillator tiles with SiPM read out towards the rear. The design has the following characteristics:

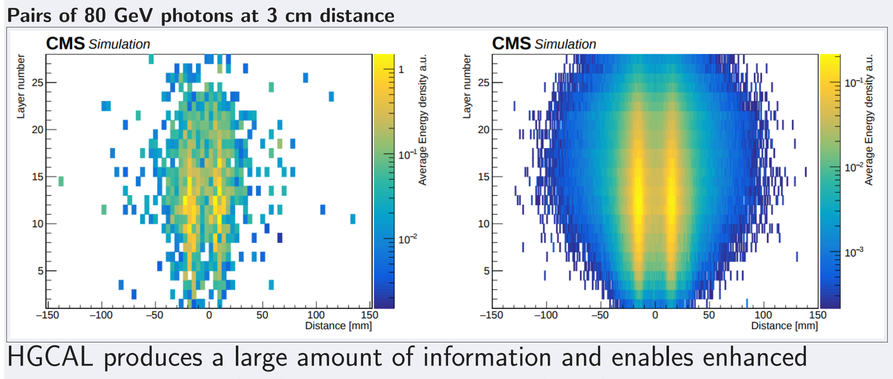
- radiation tolerance
- dense calorimeter
- fine lateral and longitudinal granularity
- precision measurement of the time of high energy showers
- ability to contribute to the level-1 trigger decision

HGCAL parameters

	CE-E	CE-H	
	Si	Si	Scintillator
Area (m^2)	368	215	487
Channels (k)	3916	1939	389
Si modules (Tileboards)	16 008	8868	(3960)
Partial modules	1008	1452	–
Weight (t)	23	205	
Si-only planes	28	8	
Mixed (Si+Scint) planes		16	

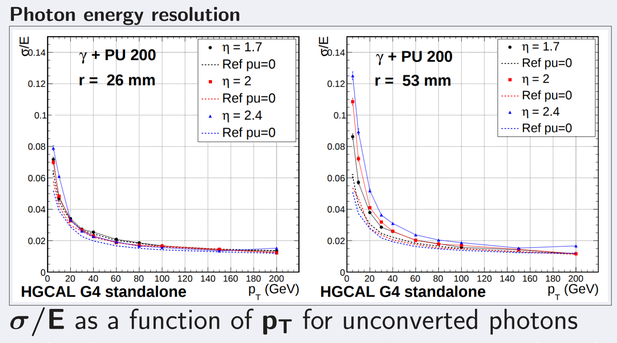
Intrinsic energy and position resolution

Pairs of 80 GeV photons at 3 cm distance



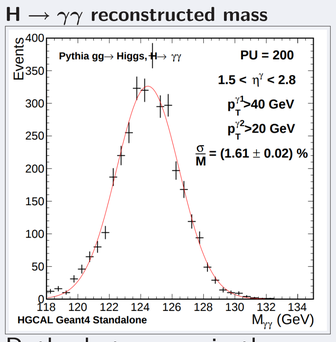
HGCAL produces a large amount of information and enables enhanced pattern recognition (left) - single photon pair, (right) - few thousand of photon pairs

Photon energy resolution



σ/E as a function of $\mathbf{p_T}$ for unconverted photons at (left) using a region of radius **2.6 cm** and (right) **5.3 cm** to sum the energy

$H \rightarrow \gamma\gamma$ reconstructed mass



Both photons are in the endcap and unconverted

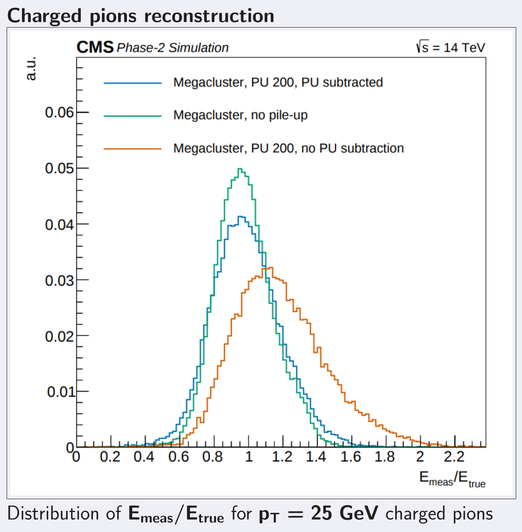
Reconstruction

The reconstruction currently consists of several steps:

- reconstruction of energy deposits from the recorded digital signals to give reconstructed hits (RecHits) approximately calibrated to correspond to energy lost in the absorber layers
- construction of two-dimensional (2D) clusters from RecHits in each of the 52 layers of the calorimeter
- layer clusters are collected into a three-dimensional clusters (megaclusters)

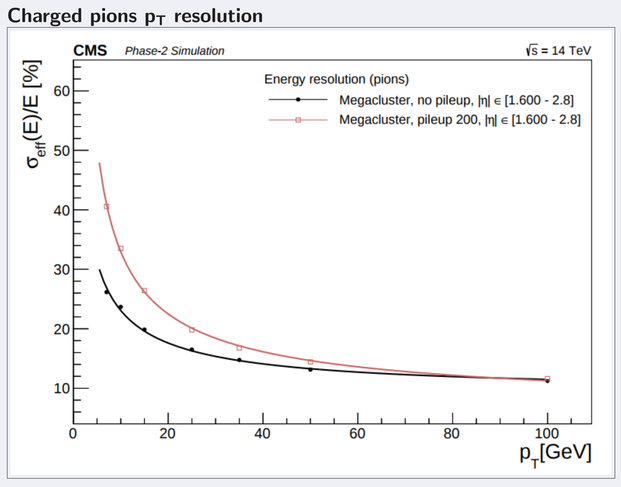
New clustering algorithms directly using 3D+timing information are being explored and are expected to achieve even better performance.

Charged pions reconstruction



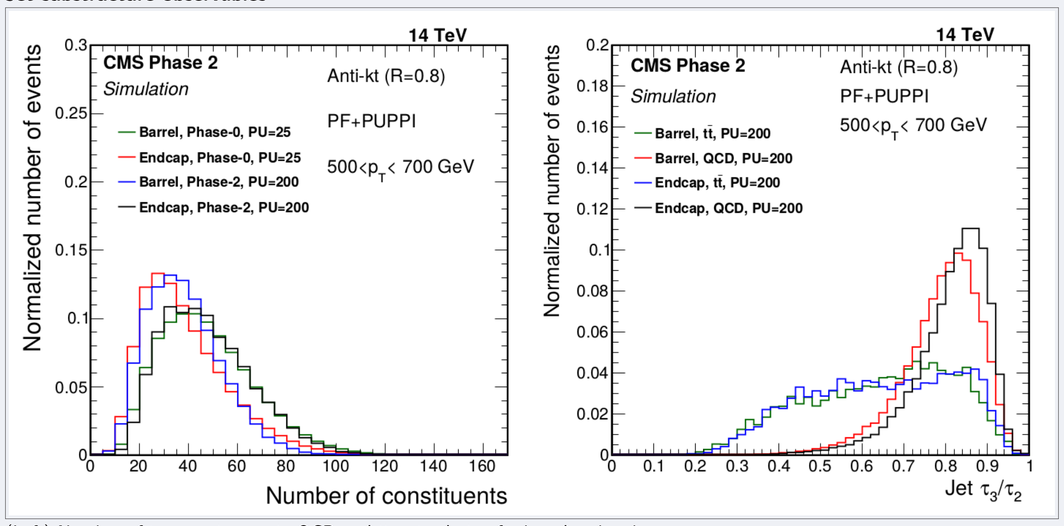
Distribution of $\mathbf{E_{meas}/E_{true}}$ for $\mathbf{p_T = 25\ GeV}$ charged pions

Charged pions p_T resolution



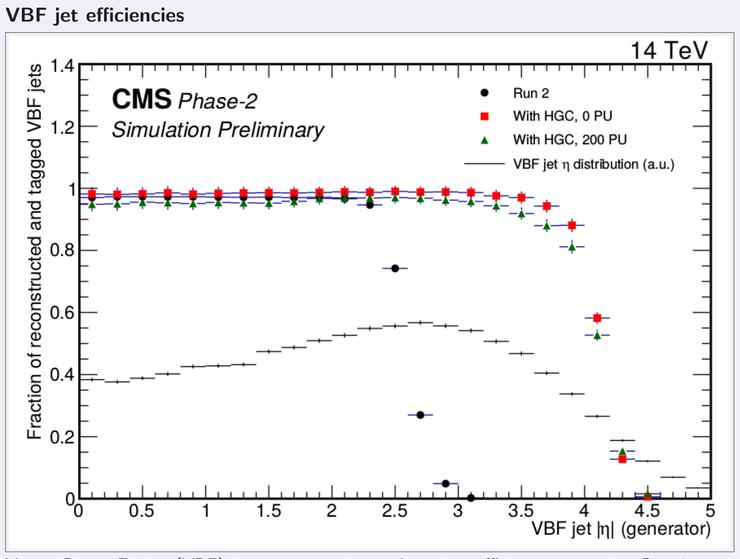
Physics Object Reconstruction

Jet substructure observables



(Left) Number of jet constituents in QCD multijet simulation for barrel and endcap
(Right) τ_3/τ_2 for top quark jets in resonant $\mathbf{t\bar{t}}$ production and in QCD multijet simulation

VBF jet efficiencies



Vector-Boson Fusion (VBF) jet reconstruction and tagging efficiency comparing Run 2 simulation to the upgraded Phase-2 detector for different pileup scenarios

Summary

- Endcap calorimeter upgrade will cope with irradiation, and help mitigate the effects of pileup
- Proposed Endcap Calorimeter upgrade has high granularity which enables good moomentum and spatial resolution
- Novel clustering techniques are being explored to exploit the intrinsic 3D+timing capabilities of this calorimete
- The $\mathbf{p_T}$ resolution for high momentum charged pions is better than 10%

References

- CMS Collaboration, "The Phase-2 Upgrade of the CMS endcap calorimeter, Technical Design Report", CERN-LHCC-2017-023, CMS-TDR-019

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