HGCal for VBS

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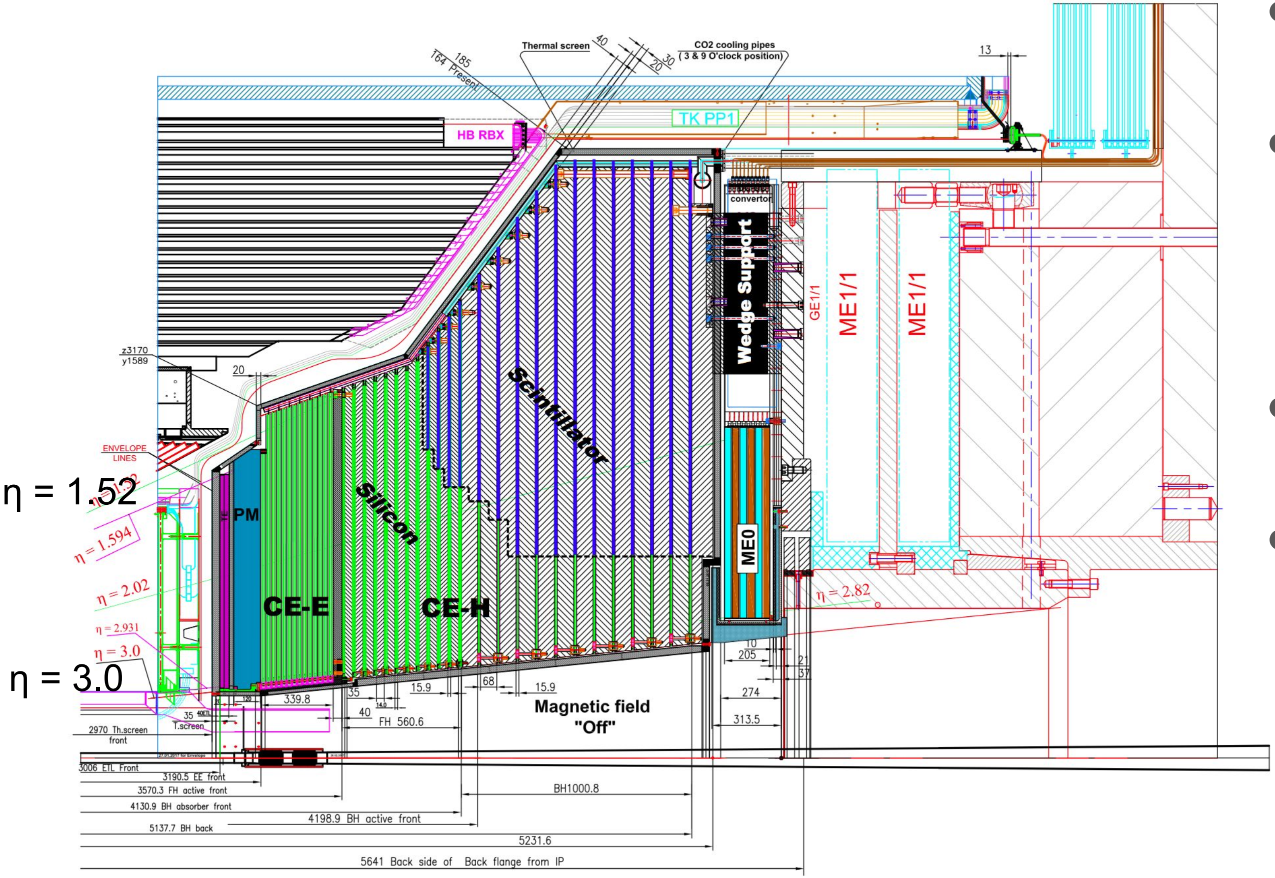
Material from CMS-TDR-019
VBSCAN Workshop: New techniques in particle reconstruction for VBS
Krakow, Poland
24.10.2018

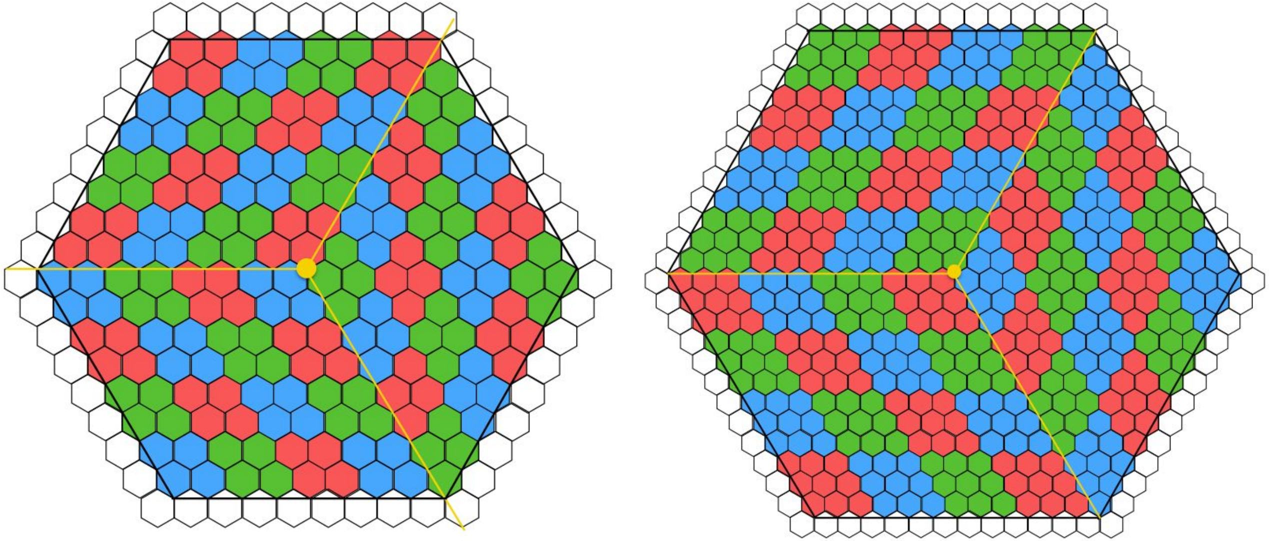
HGCal overview



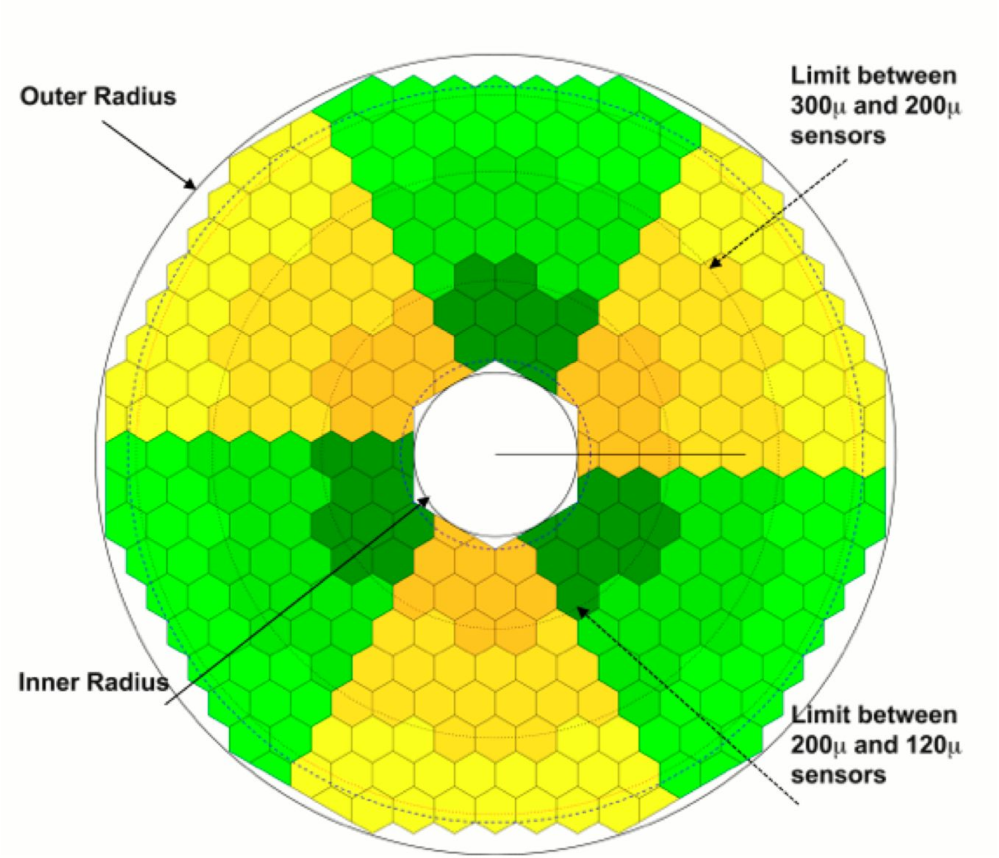
- Novel calorimeter concept
- Endcap calorimeter:
  - radiation hardness
  - cope with pileup (140-200 PU)
- Prioritise position over energy resolution
- 52 layers (sampling calo):
  - 28 electromagnetic
  - 12 front-hadronic
  - 12 back-hadronic (scintillator)

Sensors

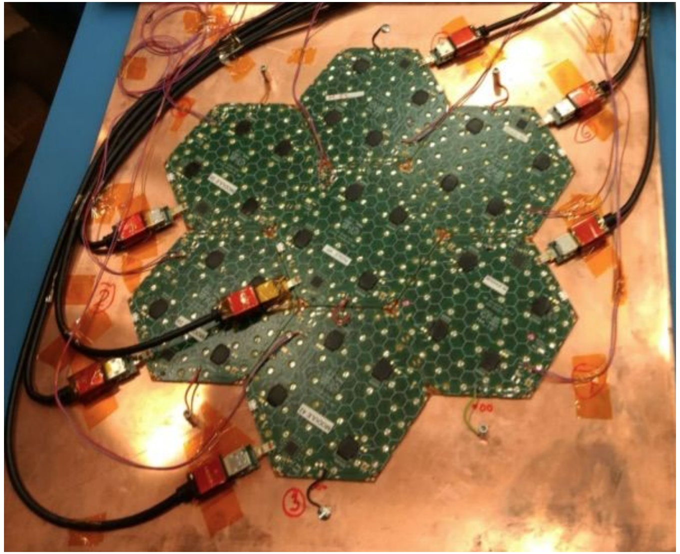
- 8 inch hexagonal wafers
- Different cell sizes depending on sensor thickness:
    - 300, 200, 120 µm sensor thickness with 1.18, 1.18, 0.52 cm^2 cell size



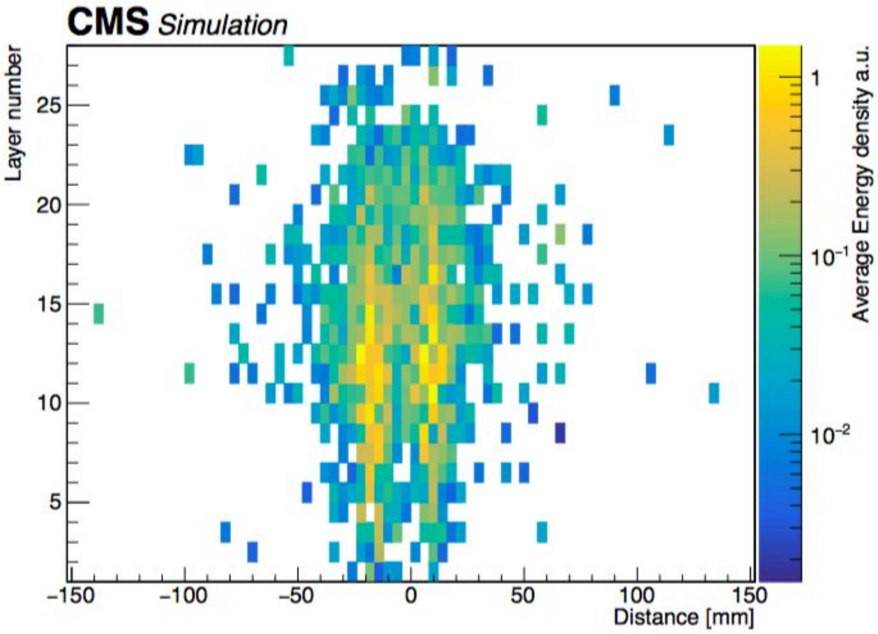
A single layer (here: 9th layer)

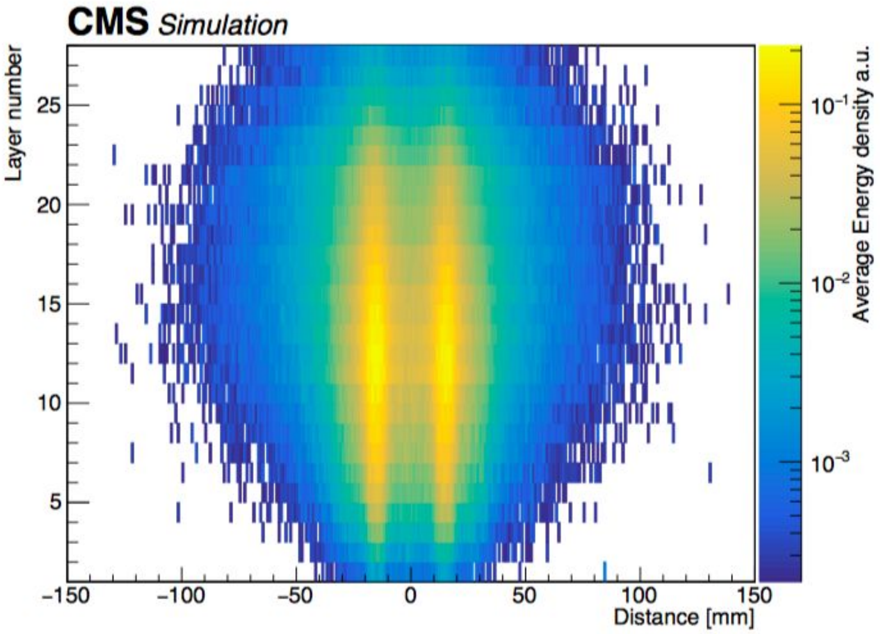


Testbeam setup



Particles in the HGCal

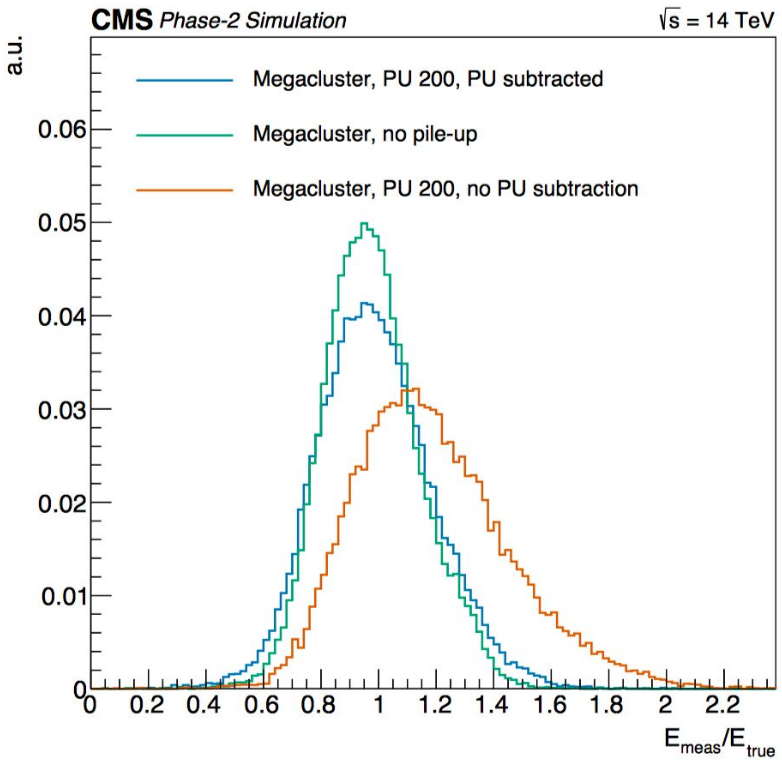




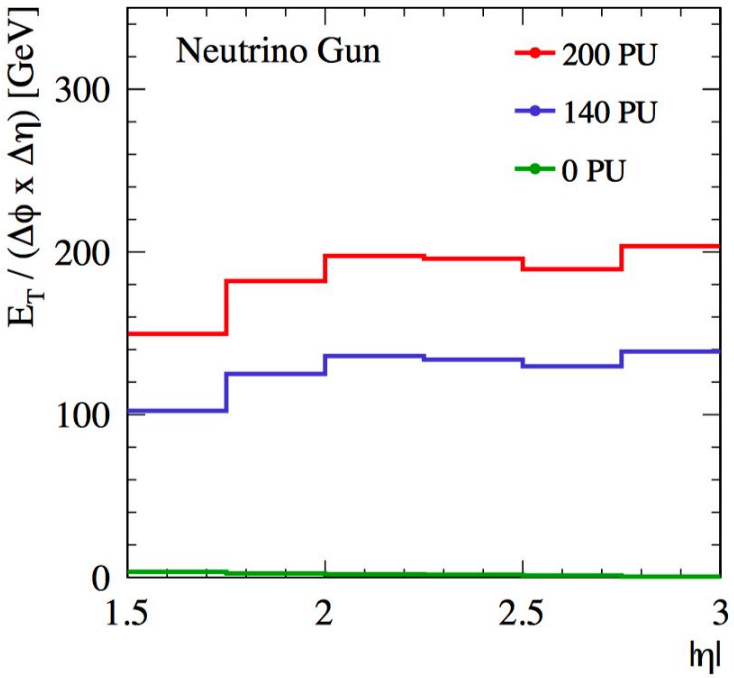
Can follow particles through the calorimeter - here: two unconverted photons

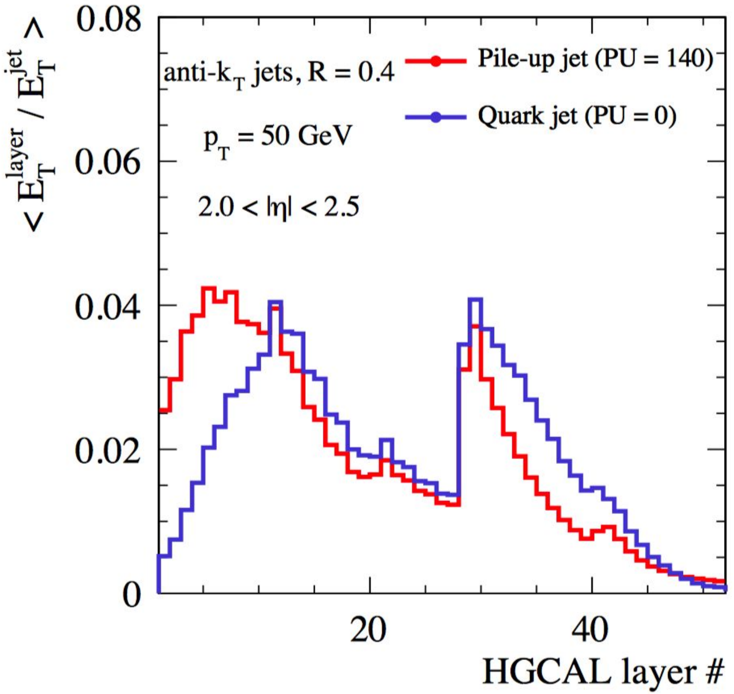
Reconstruction

- Start from reconstructed hits, corrected for energy loss in absorbers
- Correct for hadronic energy scale for hadrons
- Perform different clustering steps (to be revisited):
  - Cluster in each layer
  - Build 3D clusters
  - Mega-/Superclusters for single particle hypothesis
- Timing information (ps-level resolution) not promises to be very powerful (not shown here)



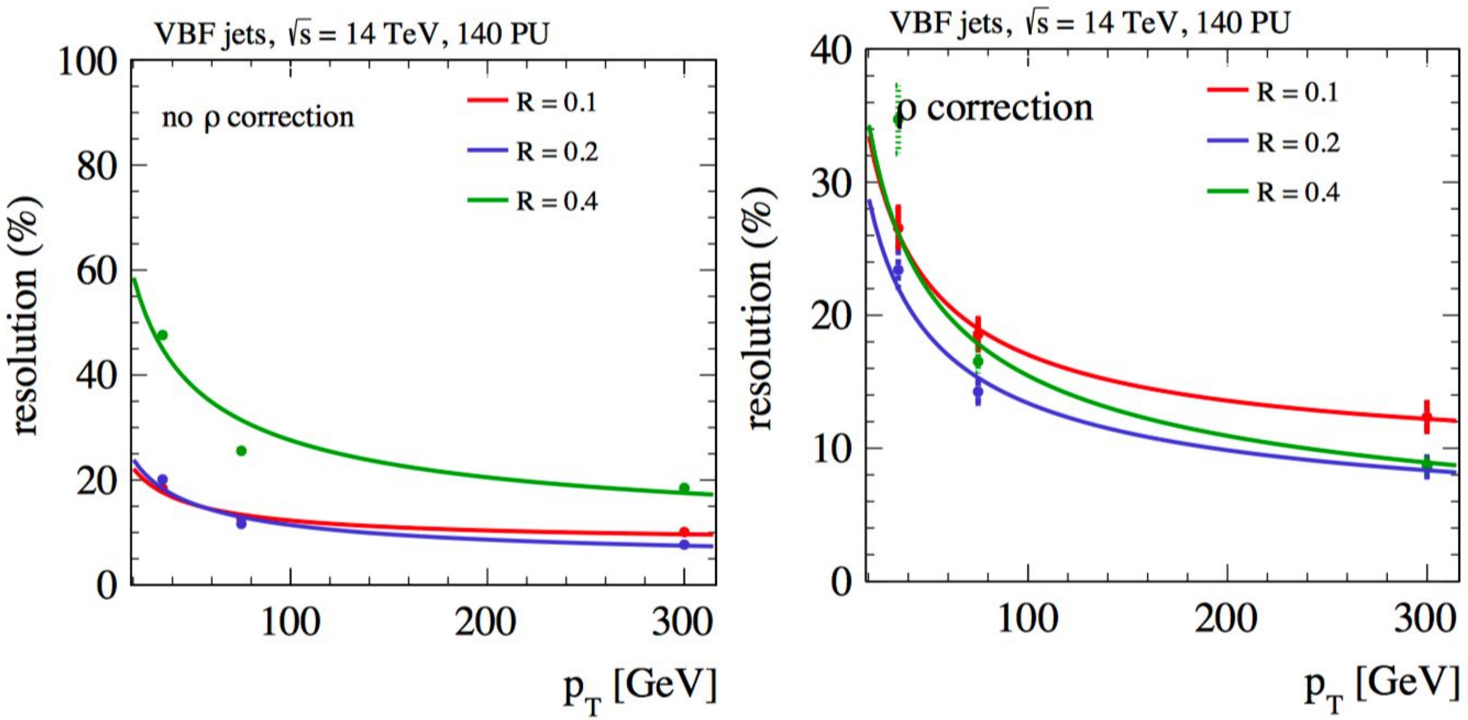
Pileup





Profit from longitudinal segmentation to discriminate pileup jets

Revisiting jet size



- Given the granularity of the calorimeter, jet size to be revisited
- Smaller jet size collects less pileup - no ρ correction needed (but PU ID)

VBF vs. PU jets

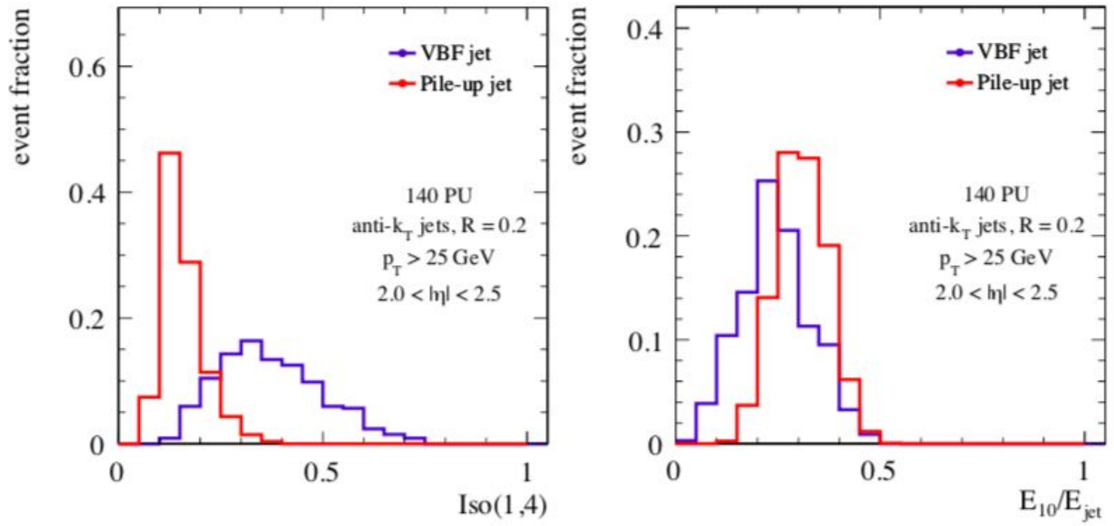
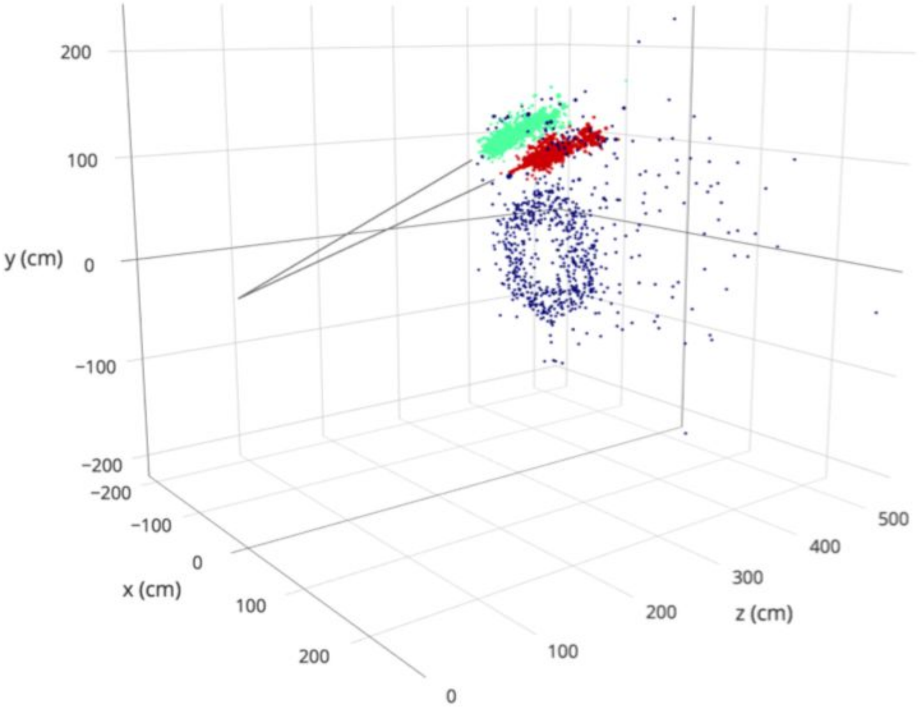


Figure 5.14: Distributions of the two variables used to build the PU jet ID discriminant for both VBF jets (blue histograms), and jets found in pileup (red histograms).

- Iso(1,4) = E(R=0.1)/E(R=0.4)
- E_{10}/E_{jet} = fraction of E in first 10 layers
- Lots of room for optimisation - but already powerful

Showers as 3D/4D images

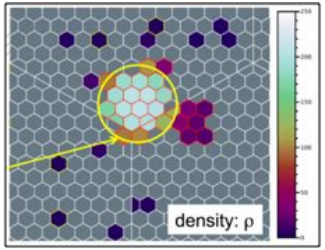
- Current “standard” reconstruction uses sequential clustering
- However, directly clustering hits in 3 or 4 (timing) dimension probably yields better performance
- Computationally more challenging
  - Use GPUs(?)
  - Possible at trigger level?

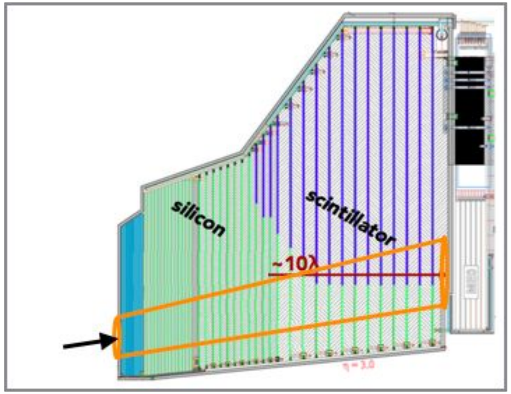


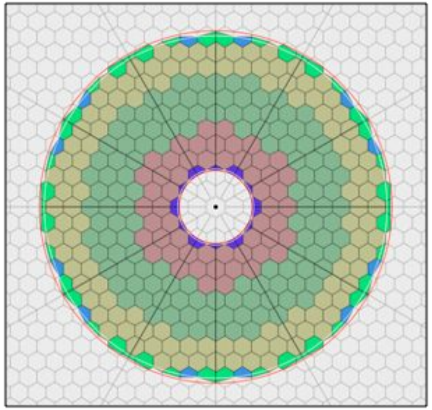
Build HGCal structure in Neural Network

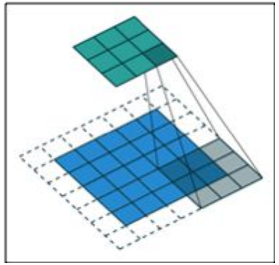
- 3D imaging problem: CNNs

- Sensors hexagonal
- Sensor size/area changes with layers
- Sensor size/area changes within one layer

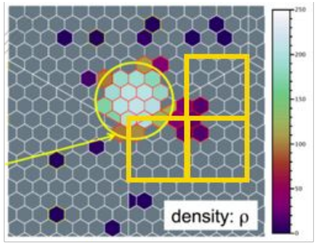


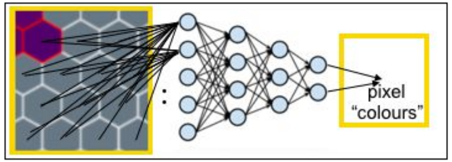


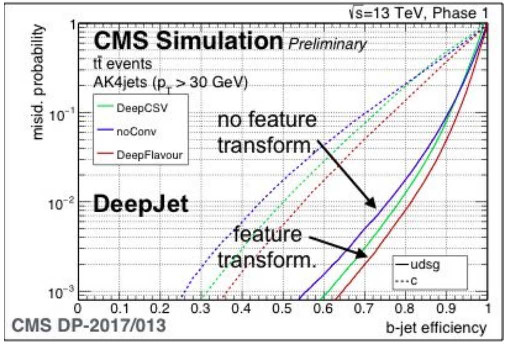




Mapping of Sensors to Pixels

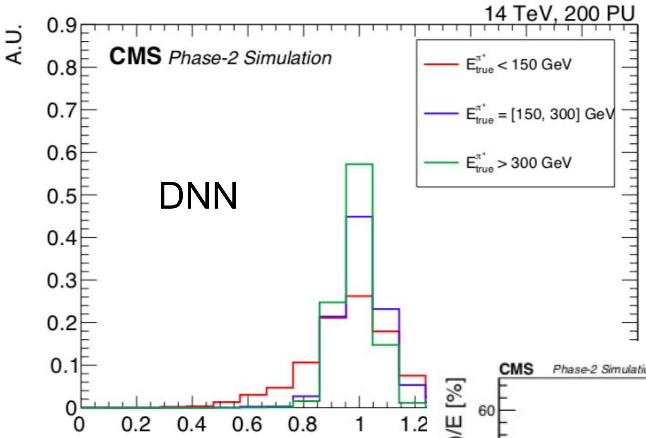




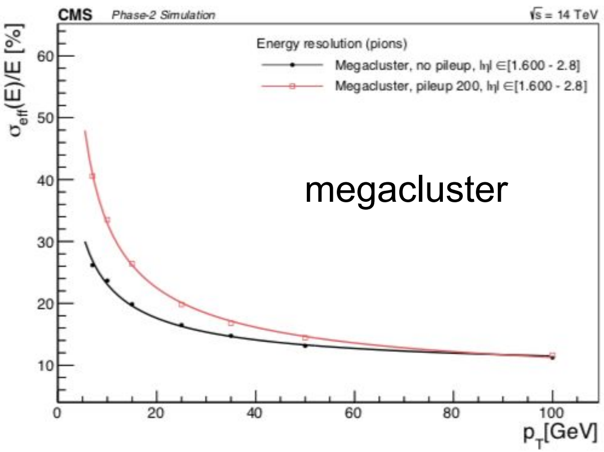


- Chose rather coarse pixelisation
  - Here up to 6 sensors per pixel
- Per sensor information
  - Relative eta, phi w.r.t pixel centre, time, energy
- Add per-pixel information
  - eta, phi w.r.t seed
  - layer
- Build pixel “colours” with a small dense, translation invariant network
- (1x1x1 conv)
  - Use full available granularity
  - Only a few more parameters
  - Network can learn metric
- Very similar to DeepFlavour

Charged Pion Energy Reconstruction



pT = E/5



- Trained with flat energy between 10-500 GeV, 0 and 200PU, e,pi+,gamma,muons
- Based on 3D convolutional NN
- Quite good hadron reconstruction even with 200PU
- DNN performs better

Calorimeter based particle ID (DNN)

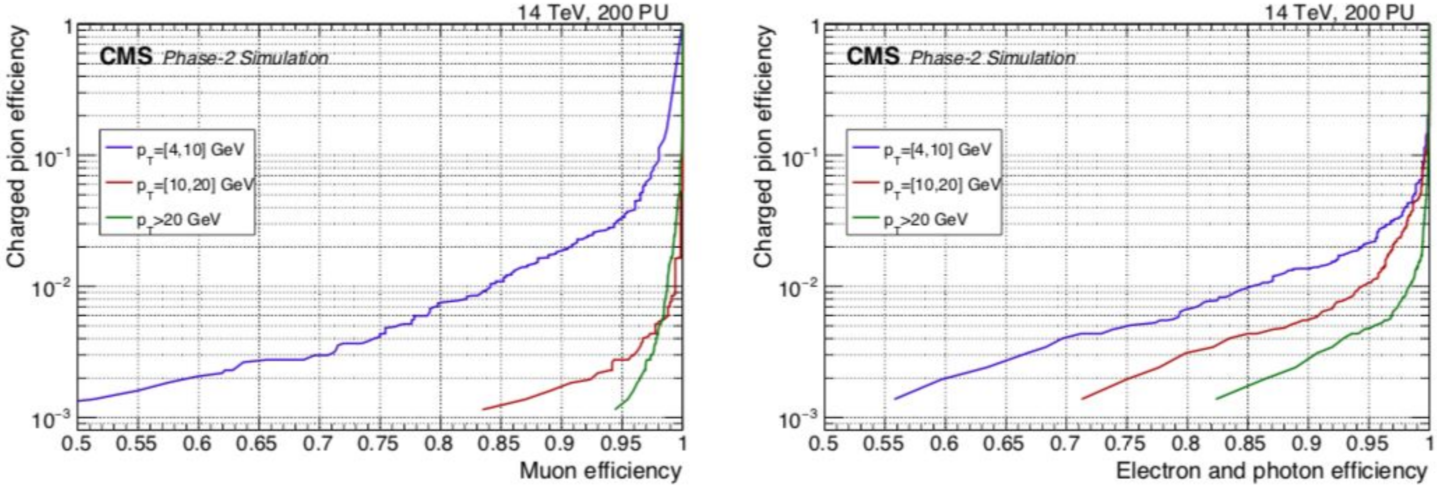
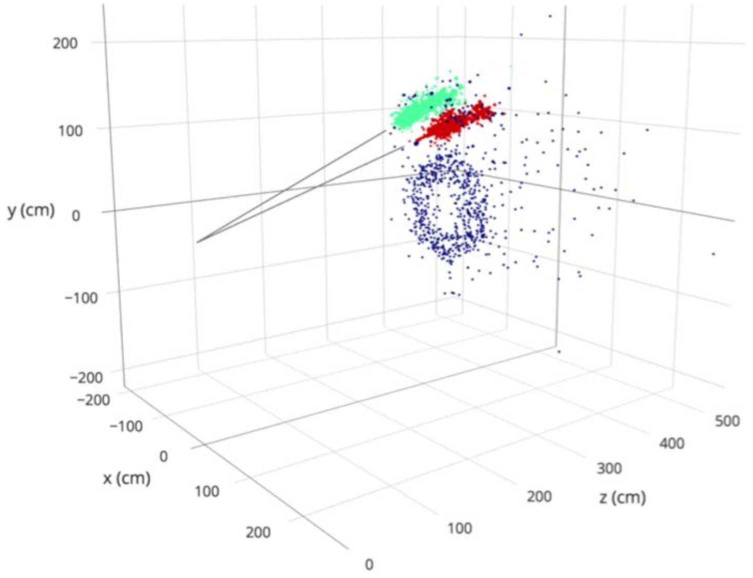


Figure 10.3: Efficiency for the discrimination of a muon from a charged pion (left) and for the discrimination between an electromagnetic shower from an electron or photon and showers from charged pions (right).

Conclusion & outlook

- HGCal novel calorimeter concept for the HL-LHC phase 2 upgrade (at this scale)
- Crucial for VBS
- Requires new approaches to reconstruction
- Real potential will be way beyond of what we have just shown



Reference for all plots: CMS-TDR-019