HL-LHC Calorimetry Techniques and Trends
A CMS Perspective

Jeremiah Mans

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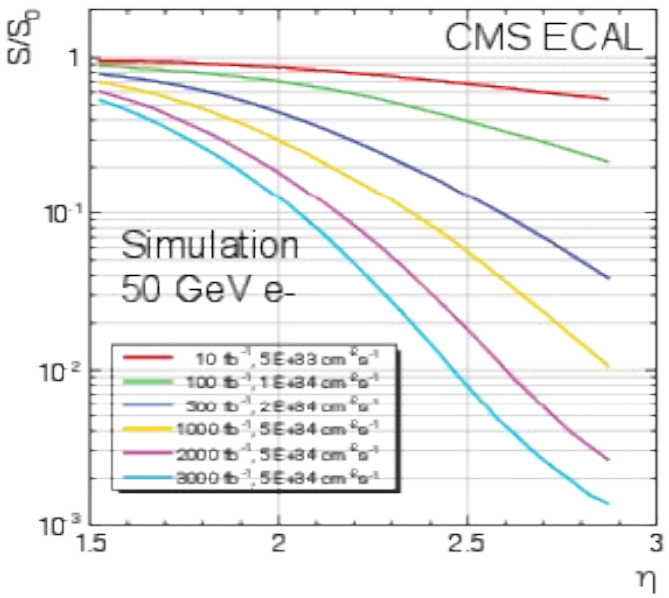
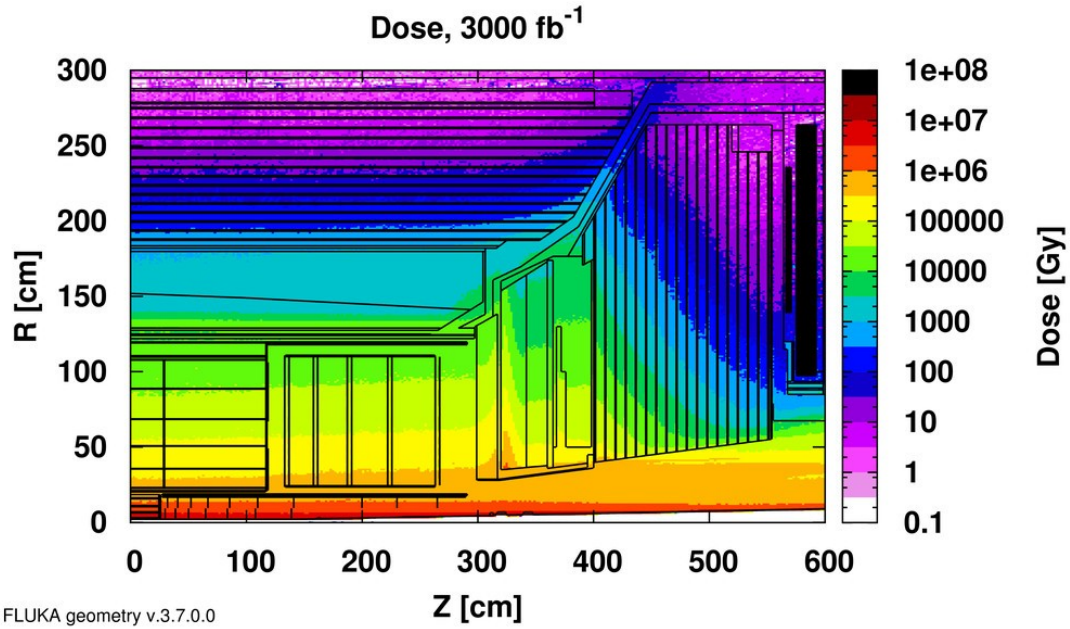
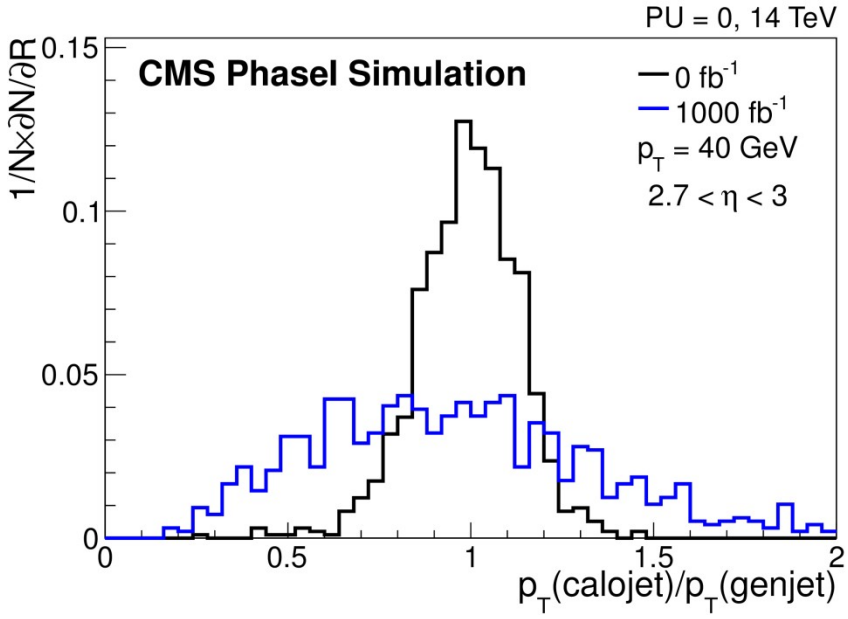
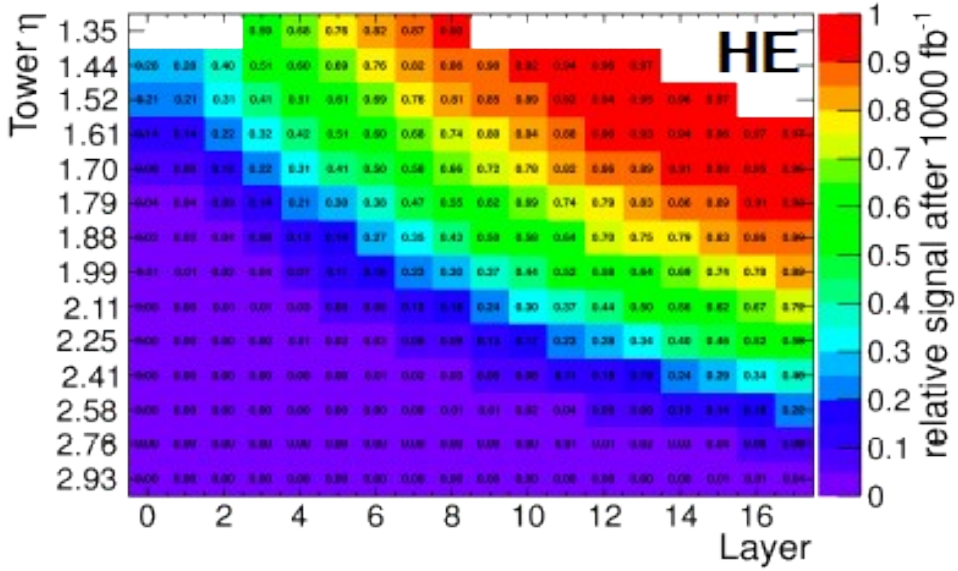
High Radiation/High Rate



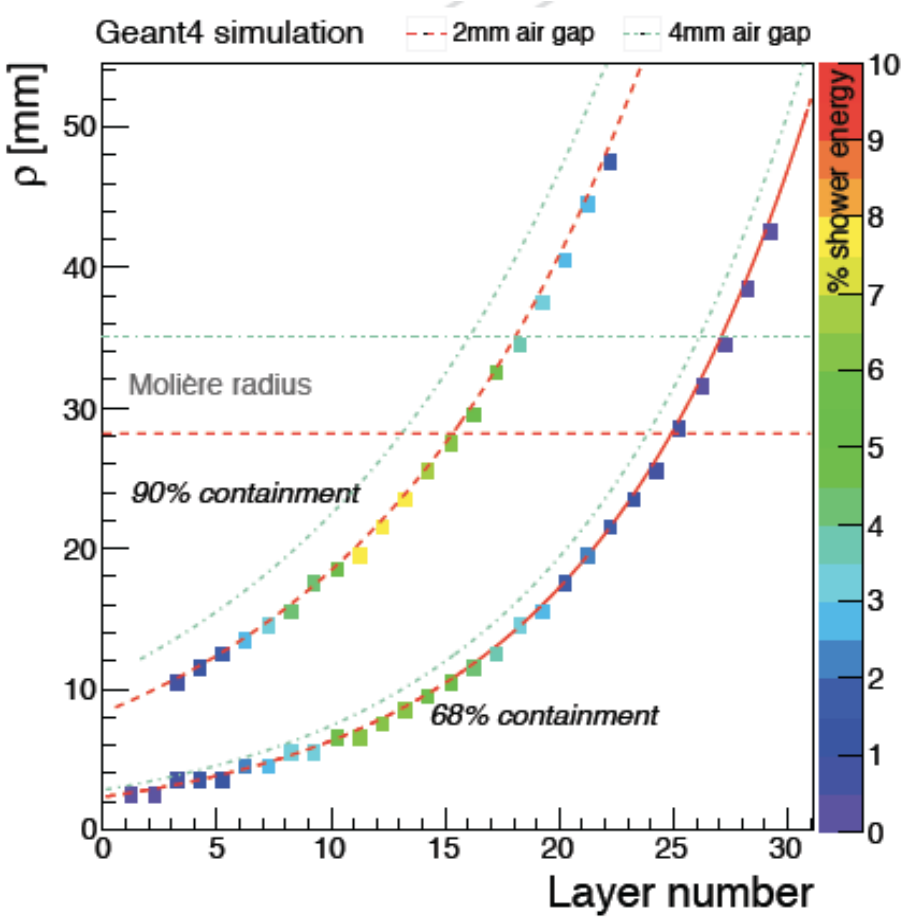




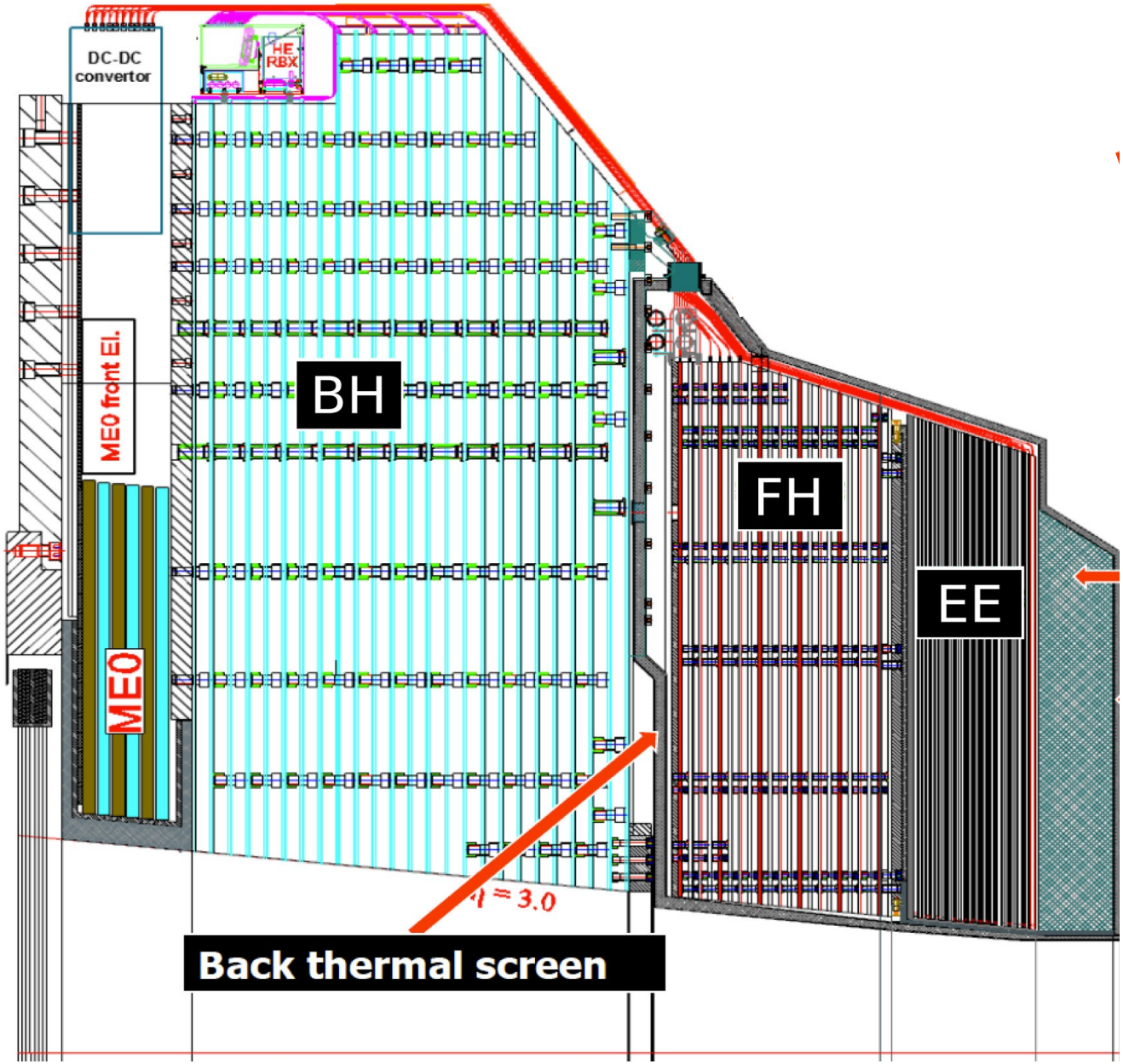


High Granularity Endcap Calorimeter

- Change from pure scintillator-based calorimetry in the endcap to silicon-based calorimetry backed with scintillators where the radiation doses are lower
- We understand how to make silicon take the very high radiation fluences required (10^{16} n/cm^2)
- Effective use of silicon in the HL-LHC environment requires small cells (1 cm^2 or 0.5 cm^2) and high depth segmentation
  - Provides a unique opportunity to manage pileup using very precise sampling of the showers

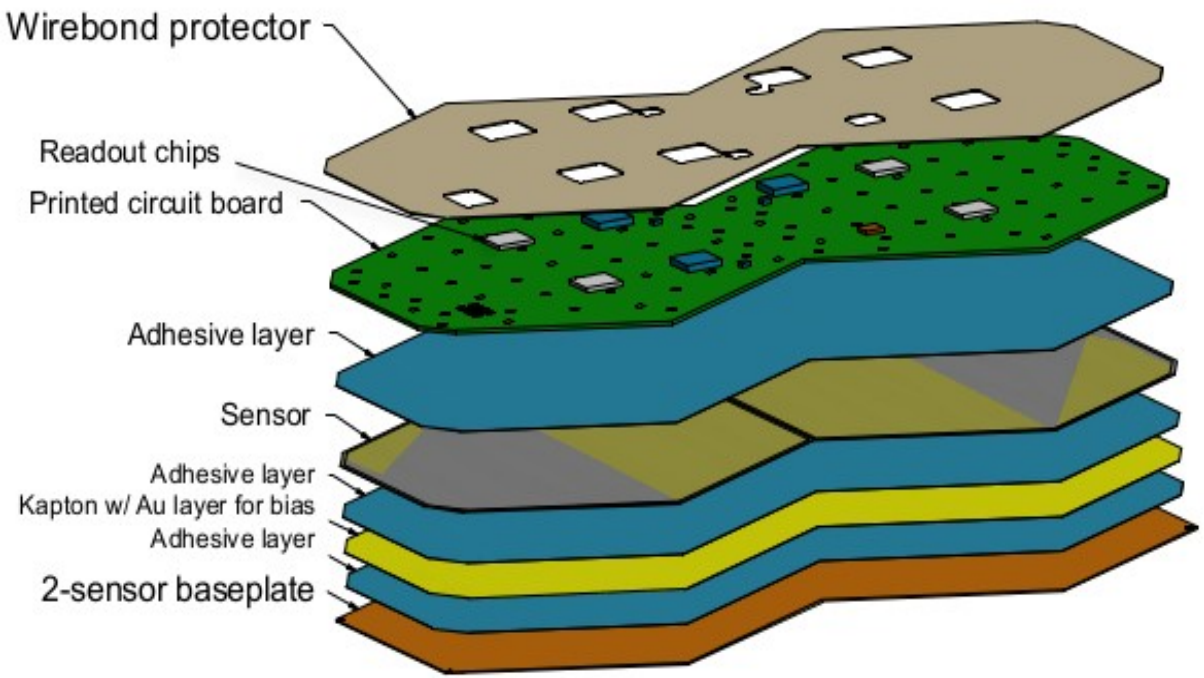


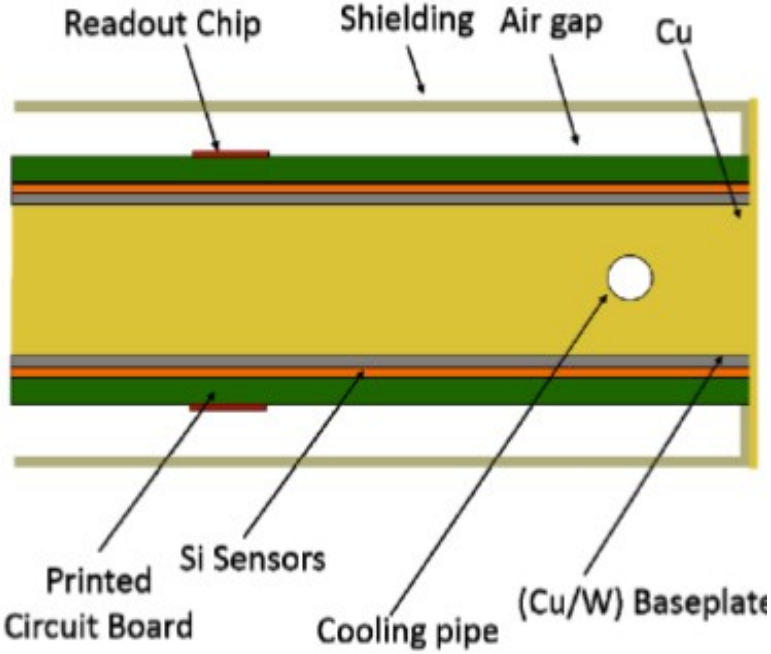
Detector Structure

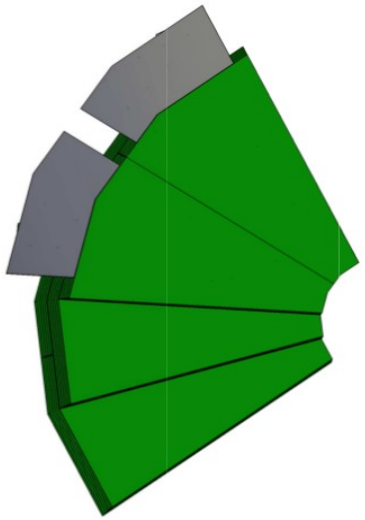


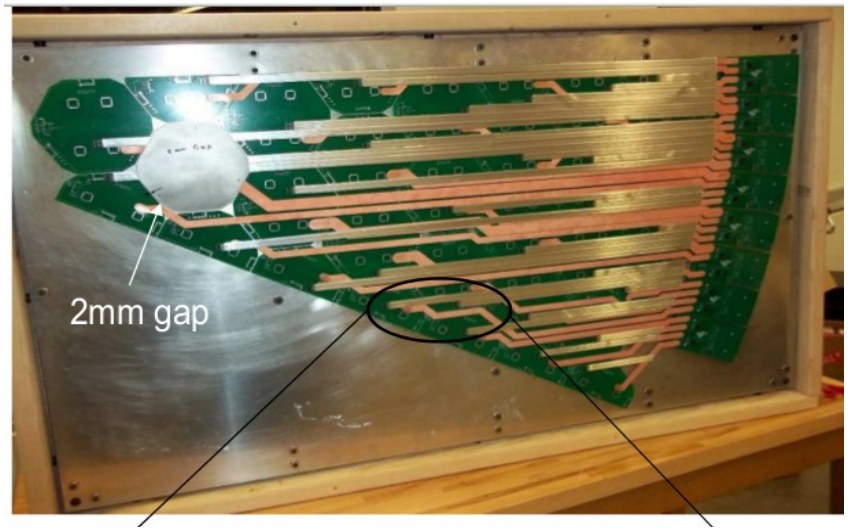
- EE
  - 28 layers of silicon
  - Tungsten/copper absorber
- FH
  - 12 layers of silicon
  - Brass absorber
- BH
  - 12 layers of plastic scintillator
  - Brass absorber

Structures


Wirebond protector
Readout chips
Printed circuit board
Adhesive layer
Sensor
Adhesive layer
Kapton w/ Au layer for bias
Adhesive layer
2-sensor baseplate


Readout Chip
Shielding
Air gap
Cu
Printed
Circuit Board
Si Sensors
Cooling pipe
(Cu/W) Baseplate




2mm gap

Timing

- Another area of strong focus in HL-LHC calorimetry is the development of timing techniques to help suppress neutral pileup or even help with finite vertex resolution effects
  - New crystal EB electronics expected to have better than 100 ps cluster time resolution
  - HGCAL “Time Over Threshold” electronics should allow cluster time resolutions at the 40 ps level
  - R&D ongoing for possible “pre-shower” MIP-capable timing detector
- Exciting technique, particularly for any extended-lifetime heavy states and for photon analyses at high luminosity
  - System issues must be solved
- Exact mode of operation depends on mechanics of HL-LHC beam crossing

What does it mean for physics?

- VBF-type topologies
  - Narrow jets very well-resolved down to low pT in moderate forward region ($1.5 < |\eta| < 3.0$)
  - Higgs (including H invisible), vector boson scattering
- Exotic remnants
  - Very detailed shower structures available for displaced decays or decay-in-detector
- Timing
  - Photon association with jets/vertex at high pileup
  - Long-lived states