Geometrical description of HGCAL in CMS software framework

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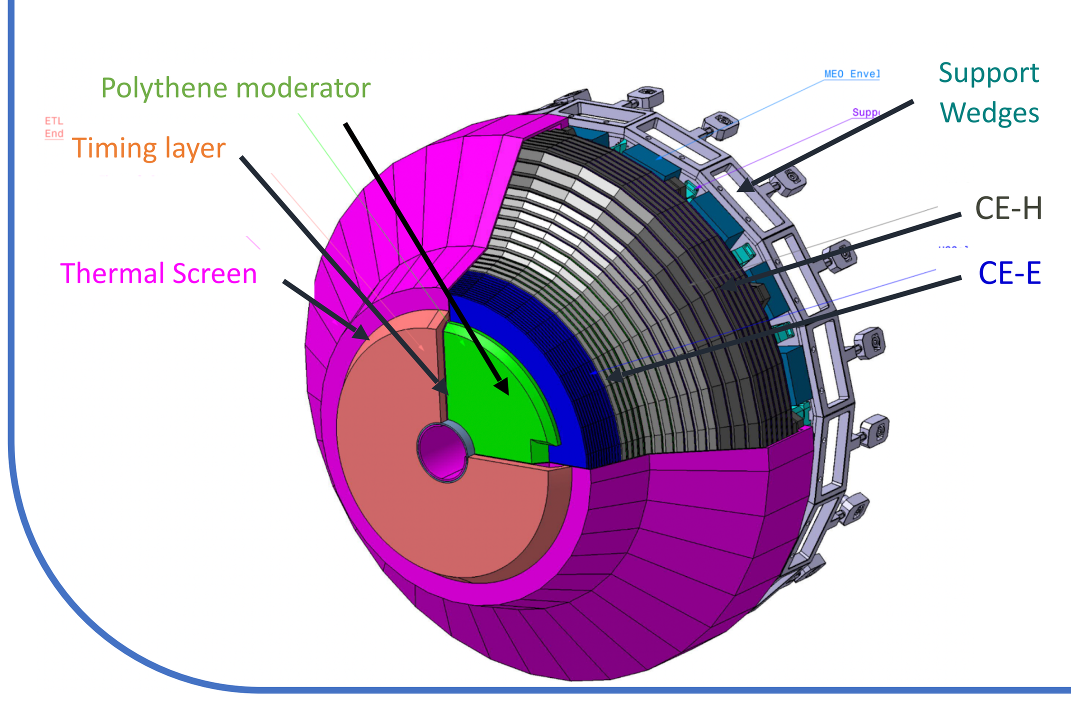
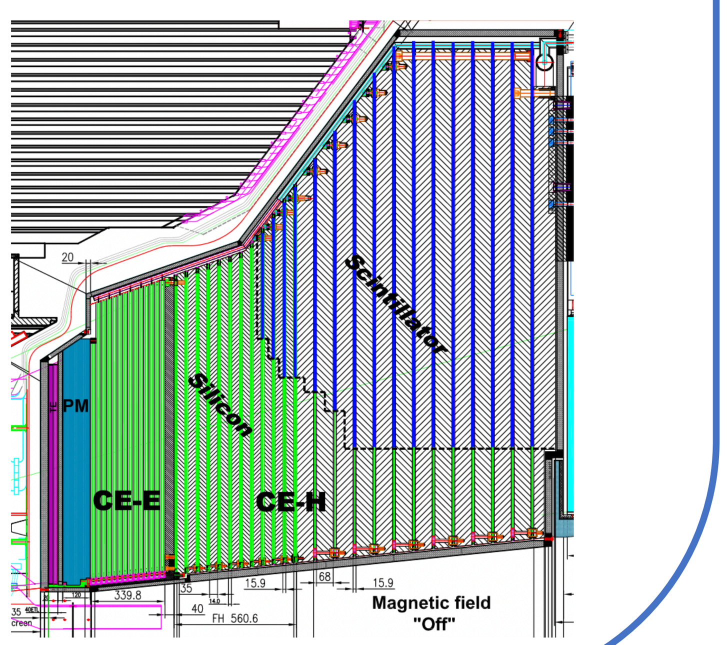
1 HGCAL Geometry

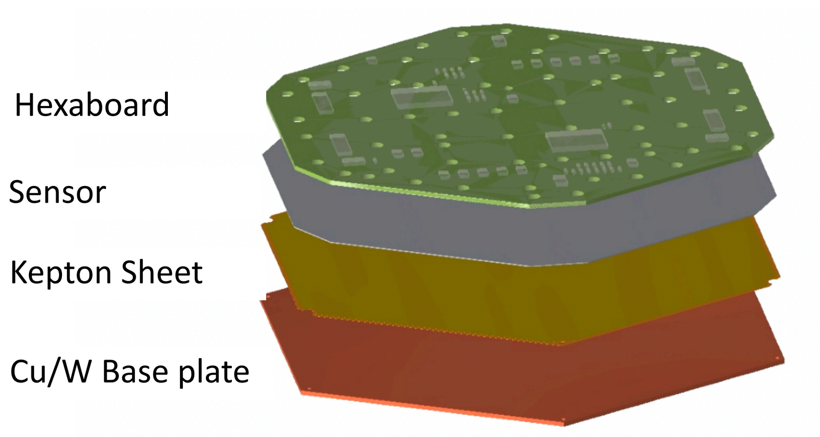
- The High Granularity Calorimeter (HGCAL) is planned to be installed by 2026 replacing the current endcap calorimeters of CMS.
- The HGCAL consists of silicon(Si) and scintillator detectors arranged in electromagnetic (CE-E) and hadronic (CE-H) sections.
- The CE-E section comprises 26 sampling layers whereas each layer is composed of multiple 8 inch silicon (Si) modules.
- There are 21 sampling layers comprising the CE-H section, where a layer is composed with 8 inch Si modules and SiPM on Scintillator tiles.

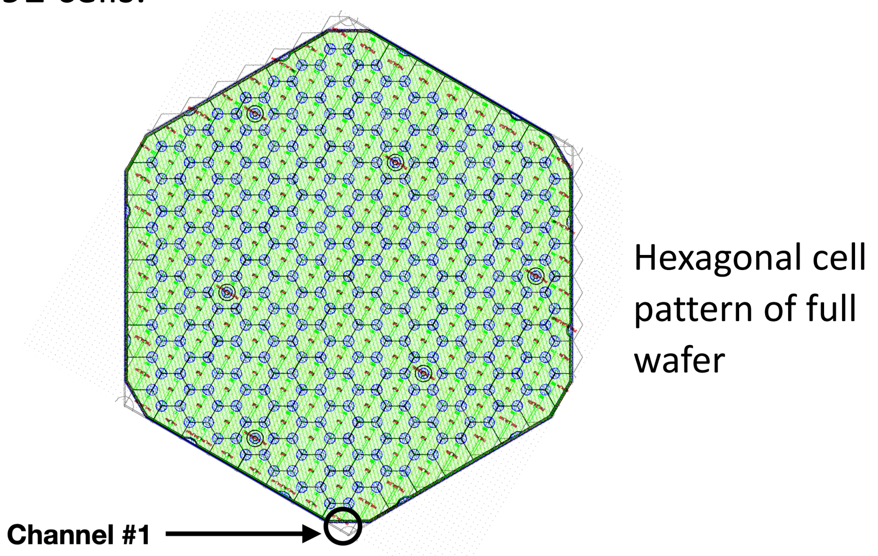


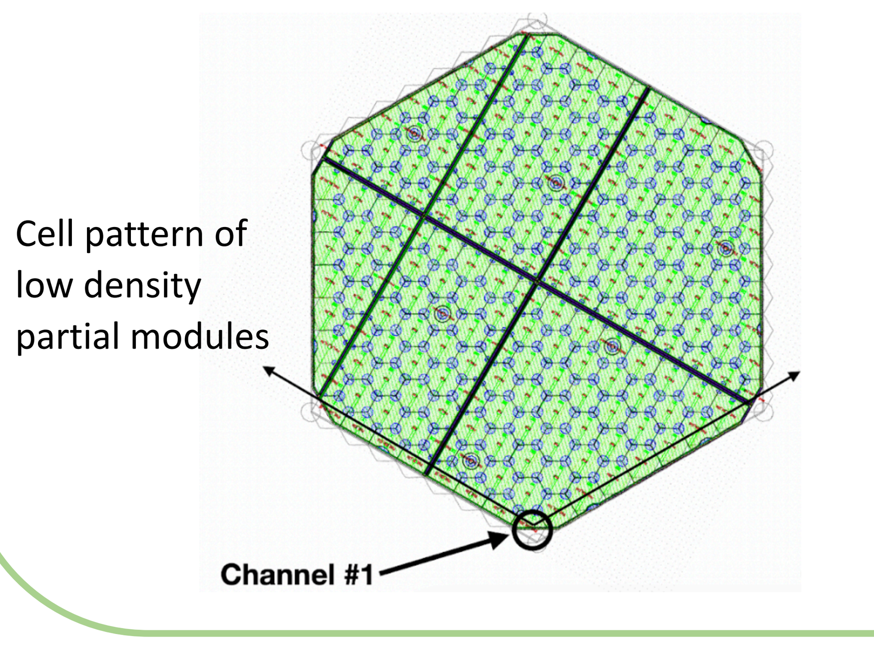


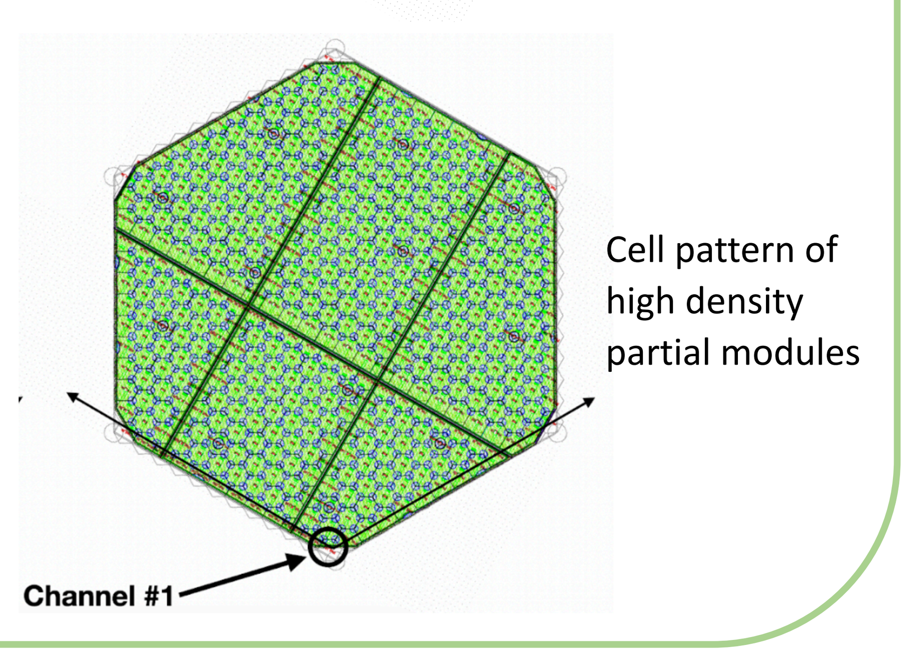
2 HGCAL silicon modules

- The Silicon modules are a stack of (i) baseplate, (ii) Kapton-gold sheet, (iii) Silicon sensor, and (iv) the printed circuit board (PCB) (Refer to talk 'Development of the HGCAL frontend system for the CMS experiment' by Irfanbeg for hardware aspect of same).
- Silicon sensors with three different sensitive (total) thickness are deployed: 300 (300), 200 (200), and 120 (300) µm.
- The 120 µm sensitive thickness sensor is designed with 432 cells, while the 200 and 300 µm sensitive thickness sensors are designed with 192 cells.



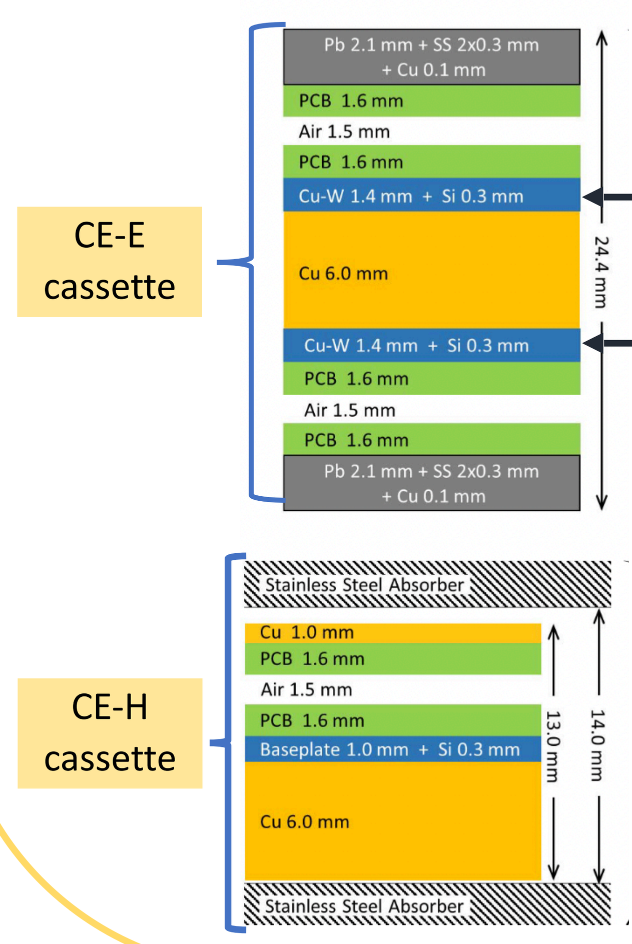


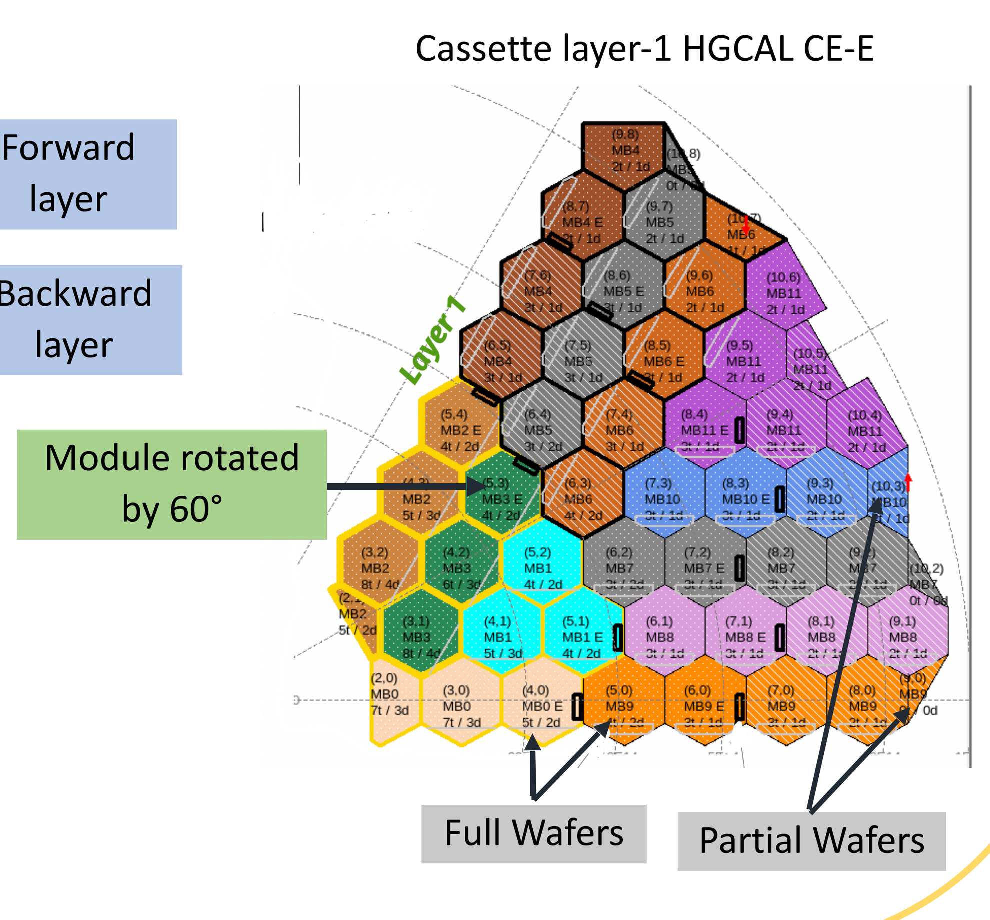




3 HGCAL sampling layers

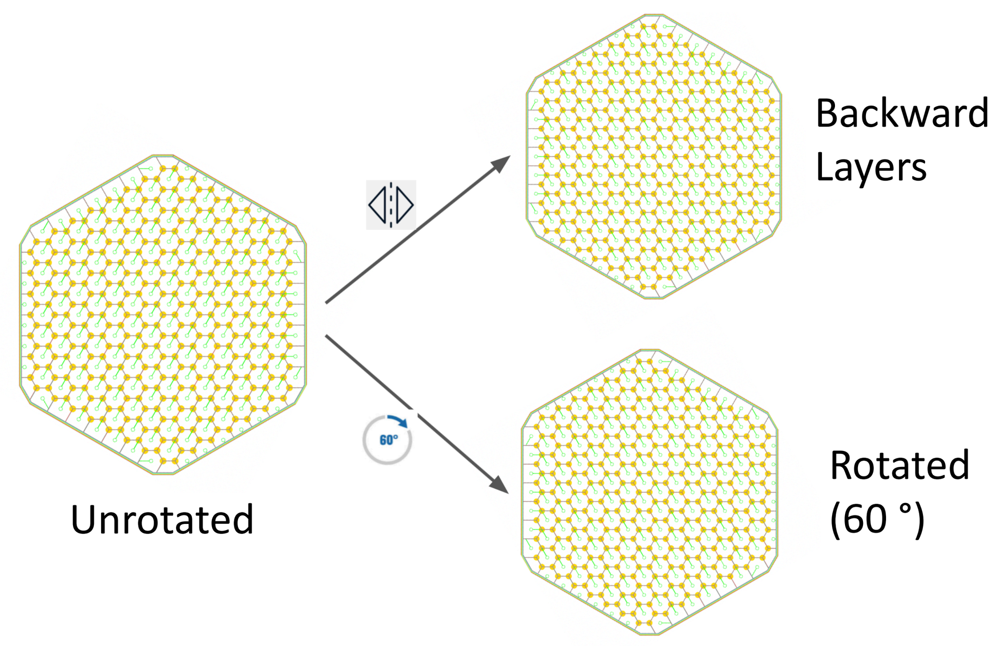
- The Si modules along with the absorber and cooling layers are grouped to form cassettes.
- The layout of the cassette is different for CE-E and CE-H parts of HGCAL.
- Each CE-E cassette consists of two sampling layers made of hexagonal modules with their baseplate facing the Cu cooling plate.
- Each CE-H cassette consists of one sampling layer made of hexagonal modules with their baseplate facing the Cu cooling plate.
- Due to Electronic limitations in cassette, many modules are placed in different orientations, rotated in plane in steps of 60° (0°, 60°, 120°, 180°, 240°, 300°).

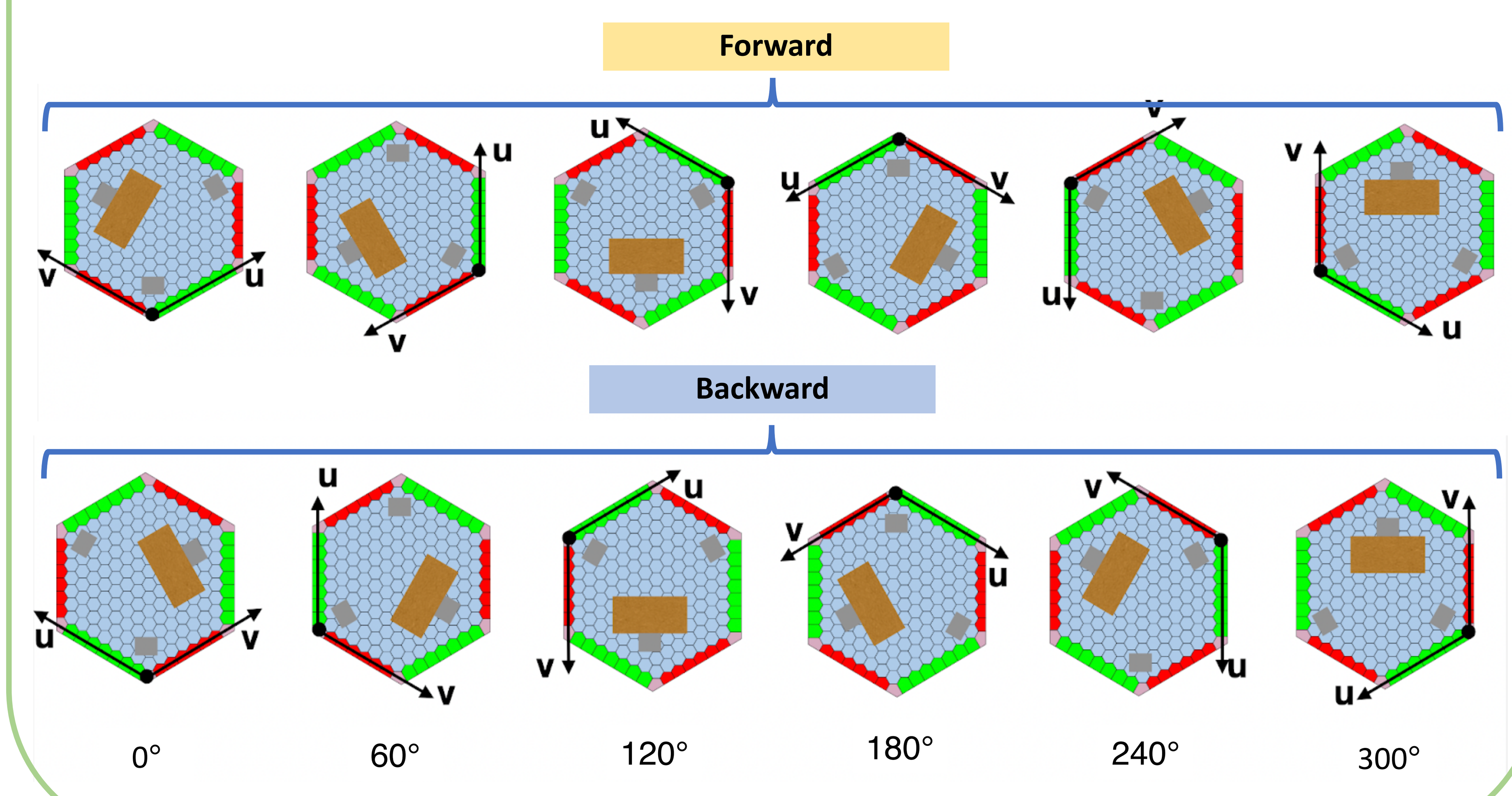




4 Implementation in CMS software

- In CMS software the geometry is defined using xml files, which are then interpreted by different plugins to create the geometry.
- The same xml files are used to interpret the geometry during reconstruction.
- The latest update of the geometry added the provision of rotated full modules, and cassette shifting.
- The hexagonal readout cells inside the sensors break their rotation symmetry, requiring new definitions for different sensor orientations.
- In the CE-E cassettes the modules located on the back side of Cu cooling plate have module that is flipped along y-axis.
- There are 12 possible orientations of modules 6 rotations for forward and 6 for backward wafers. With each possible orientation having its own coordinate system.
- The origin is taken at the cell that is designated as channel-1 by the electronics.
- Inclusion of the flipped/rotated pattern requires,
  - Definition of rotated wafers in the xml geometry files, also updating the required plugins.
  - Modification of the formula for Physics (x,y) --> Electronics (u,v) mapping and likewise Electronics(u,v) --> Physics(x,y), which are used during the simulation and reconstruction.
- Three new algorithms were implemented [for x, y → u, v transformation] related to the rotation of full-wafers.
- These new algorithms improve the processing time ~ 10/12 times compared to the existing method.
- The definition of partial wafers has also been updated to follow the new convention, and have correct cell patterns.
- The update also involved correcting the size of Silicon sensors to account for machining tolerances.





5 Summary and Outlook

- The rotated full wafers for all the 12 orientations have been implemented and added to the latest version of HGCAL geometry in CMS software.
- We developed independent algorithm (10 times faster) to find the (u, v) of the cell given the (x,y) coordinate of the hit (with respect to wafer center) for all possible orientations.
- We also worked on correcting the border cells to resolve an issue with wafer separation.
- We also updated the partial wafers to have the correct representation of the cells and follow similar coordinates as full wafers.
- Muon Tomography and Fireworks has been used to debug and validate the geometry
- Overlaps in the geometry are validated using GEANT4 overlap tool.
- We are currently involved in debugging cassette shift discovered using the Muon Tomography tool (Refer to talk 'Development of Muon Tomography for the validation of the HGCAL simulation geometry of CMS').
- The next phase of development involve:
  - Incorporating CE-E and then CE-H support bars.
  - Introducing calibration cells.
  - Introduce inhomogeneities in electronics/motherboard layers

6 Acknowledgement

- We would thank HGCAL DPG conveners for the opportunity.