Silicon module assembly and QA/QC for HGCAL

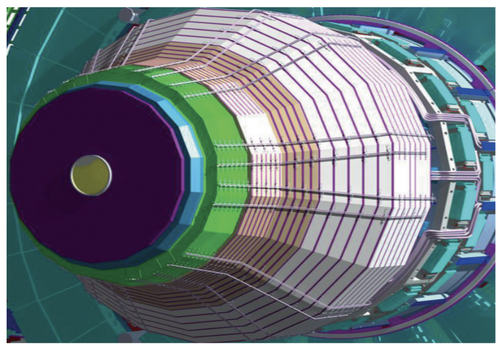
Xiao Zhao[1], Chaochen Yuan[1], Di Wang[2], Feng Wang[1], Huaqiao Zhang[1], Jialin Guo[1], Taozhe Yu[1], Xiaonan Hou[1], Yidong Gu[1], Yong Liu[1]

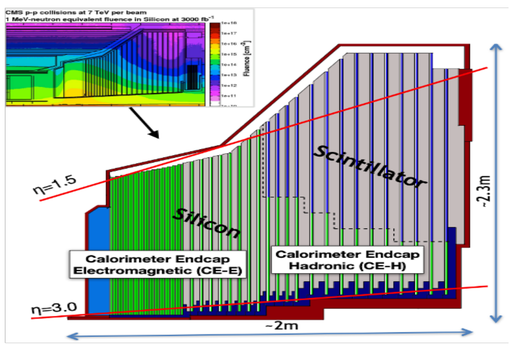
[1] *Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China*

[2] *Center for High Energy Physics, Tsinghua University, Beijing, China*

Introduction

The CMS Collaboration is preparing to build new endcap calorimeters to replace the existing endcap calorimeter for the HL-LHC era. Being a 3D imaging particle-flow calorimeter with timing capabilitie, the High Granularity Calorimeter (HGCAL) (**FIG.1(a)**) will offer high radiation tolerance, unprecedented transverse and longitudinal segmentation, and the ability to contribute to the L1 trigger decision. The HGCAL includes an electromagnetic part (CE-E) and a hadronic part (CE-H) (**FIG.1(b)**), the former of which will use lead as main absorbing material and hexagonal silicon sensors as active detectors.

a) 

b) 

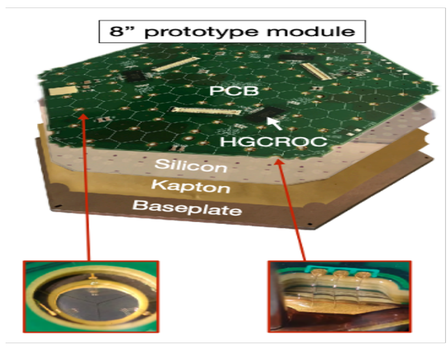
c) 

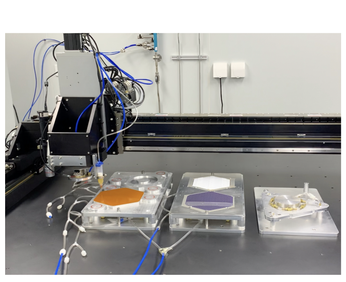
Figure 1. a) 3D drawing of one HGCAL installed on a CMS endcap. b) Side view of HGCAL showing the 50 detector layers. c) A hexagonal 8 inches silicon module prototype.

The construction of silicon modules (**FIG.1(c)**) requires the preparation of a series of well automated assembly lines in different Module Assembly Centers (MACs). The IHEP HGCAL team is participating in the HGCAL upgrading project as one of six MACs worldwide, making over 5,000 silicon modules in total.

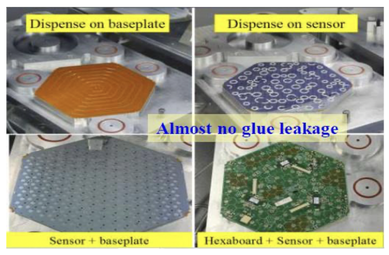
Silicon module assembly procedure

The HGCAL silicon modules are hexagonal assemblies comprising a printed circuit boards (PCB) baseplate, a silicon sensor and a PCB with front-end chips. The sensor and the front-end electronics PCB are attached by epoxy. Each detecting sensor cell and its readout channel is connected by aluminum wires of 25 micrometer in diameter, which are protected by encapsulation. As of July 2022, IHEP has successfully produced seven modules. Quality control, module thickness, and positioning accuracy meet the requirement.

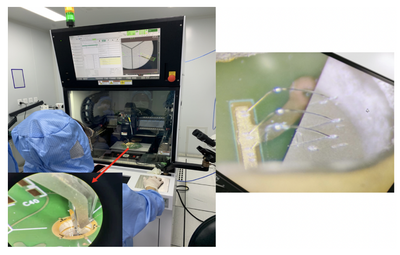
Figure 2. Silicon module assembly procedure



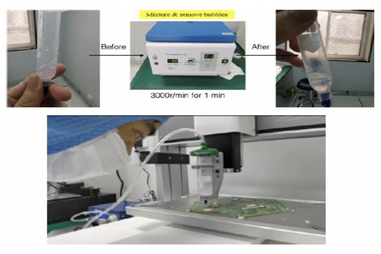
a)Sensors mounted on baseplates using gantry automaticly.



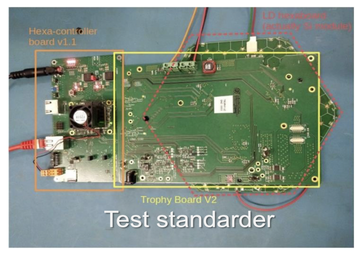
b)The high accurate control of 3D workbench and dispenser is realized.



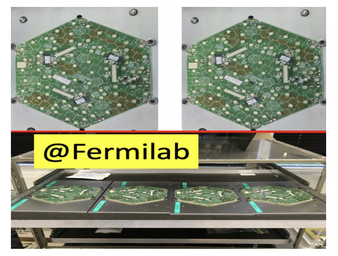
c)The connection to sensors cells is made with wire-bonding through hexaboard holes.



d)Module encapsulation after wire-bonding using mini-gantry system.



e)Test standarder of silicon module prototypes.



f)Silicon module prototypes made by IHEP.

QA & QC

Extensive measurements will be taken at each step throughout the entire assembly process using Optical Gauging Product (OGP) to control the quality and accuracy of the modules. All measured result will be uploaded to the database.

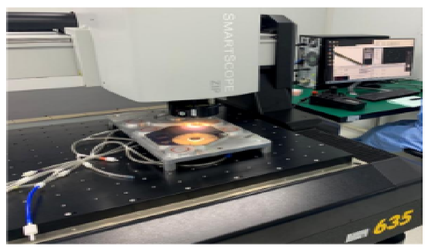


Figure 3. Checking a 8 inches silicon sensor under OGP before assembly into a module.

Database

A database is being developed based on the requirements of tracking the position and status of individual components, i.e. the silicon sensors. The database will log some activities and do some analysis.

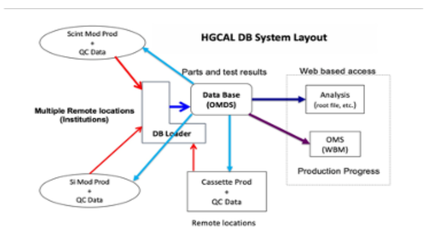


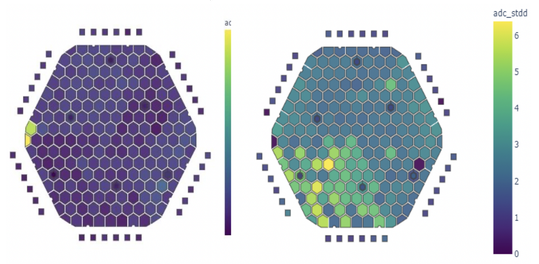
Figure 4. HGCAL database system layout.

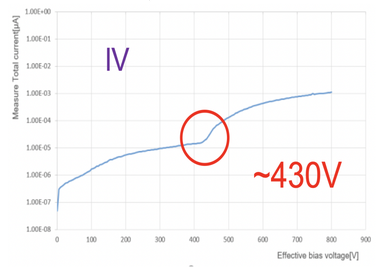
Beam test

Electronics tests show that the silicon module functions properly and the noise performance is as expected. Two silicon modules (HGCROC v2, v3) assembled by IHEP was tested at CERN SPS in Sep.-Oct. 2021. Hexaboard response to beam signal has successfully been seen.

a) 

b) 

c) 

d) 

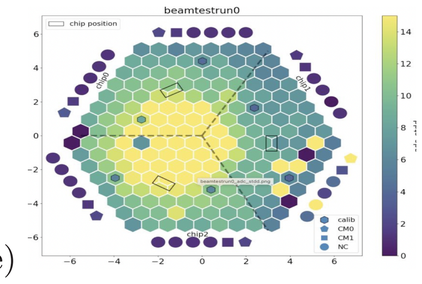
e) 

Figure 5. Beam testing at CERN SPS in Sep.-Oct. 2021. a) Instruments of beam test. b) Successfully seen hexaboard response to beam c) Low pedestal/noise result for silicon module. d) Good IV for silicon module. e) Signal map of hexaboard response to beam.

Conclusion

The IHEP HGCAL team participants in the components testing and full chain test in the silicon module assembly procedure and the project is progressing well. Moreover, the IHEP MAC has successfully passed the site qualification at 2021. As of July 2022, IHEP has assembled seven modules, all of which have met acceptance criteria. Now the team is preparing for mass production at the end of this year with the goal of achieving productivity goal: 24 modules per day.