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# Status of the CMS-HGCAL Module Assembly in China

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#### **CMS-HGCAL** project: motivations



- CMS endcap calorimeters: Phase-2 upgrade
  - Harsh environment at HL-LHC: high pile-up, high radiation level
  - Required to replace the existing endcap calorimeters
  - Construct a <u>High Granularity Calorimeter</u>: HGCAL project





### CMS HGCAL project overview

- Key Parameters (updated from the TDR)
  - HGCAL covers  $1.5 < \eta < 3.0$
  - Full system maintained at −30°C
  - ~640 m<sup>2</sup> of silicon sensors
  - ~370 m<sup>2</sup> of scintillator tiles
  - 6.1M silicon channels: 0.5 or 1.1 cm2 cell size
  - 240k scintillator-tile-SiPM channels
  - Data readout from all layers
- ~31k Si-modules: including spares
- Active layers and elements
  - Si-sensors (full and partial hexagons) in CE-E and high-radiation region of CE-H.
  - SiPM-on-Tile in low-radiation region of CE-H
- Electromagnetic calorimeter (CE-E)
  - **Si**, Cu/CuW/Pb absorbers
  - 28 layers, 25.5 X<sub>0</sub> (~1.7λ)
- Hadronic calorimeter (CE-H)
  - Si & scintillator, steel absorbers,
  - 22 layers, ~9.5 $\lambda$  (including CE-E)









#### **CMS-HGCAL:** active layers

**Outer Radius** 

Inner Radius



- Silicon-only layers in CE-E
  - 3 types: 120  $\mu m,$  200  $\mu m,$  300  $\mu m$  thick
- Mixed layers: silicon and scintillator-SiPMs
  - Boundary optimized for radiation tolerance









#### **CMS-HGCAL:** active elements



#### Silicon sensors





#### HGCAL China team focus on the silicon modules

#### Scintillator + SiPM





"SiPM-on-Tile" design demonstrated by CALICE-AHCAL prototype, adopted as the **baseline** for CMS-HGC scintillator part





#### Module Assembly Center (MAC)

- HGCAL: ~31,000 silicon modules
  - Module assembly chain
- Module Assembly Center (MAC)
  - 6 MACs around the world: 3 in Asia, 3 in US
  - Each MAC expected to assembly ~5000 modules
  - MAC in China: a dedicated silicon lab in IHEP campus (details in next pages)

Component

Testing



HGCAL Team in China (photo in 2019)

Wire-bonding

Module

Encapsulation



Not in the photo: Mingshui Chen, Huajie Cheng, Yubo Li, Jin Wang, ...



Module

Assembly

Module

Testing



#### MAC infrastructure development: clean rooms

- 4 clean rooms (class-1000) constructed: ready in Sep. 2019
  - Target temperature:  $21 \pm 1^{\circ}$ C; rel. humidity:  $45 \pm 10\%$







#### MAC infrastructure development: clean rooms

- Clean room: long-term commissioning during Sep. Oct. 2019
  - Temperature and humidity monitoring







## MAC preparations for key procedures (1)



- Component testing: optical gauging and visual check
  - Measurements of size, boundaries and thickness: (CuW) baseplates, PCBs, etc., without contact
  - Microscope: visual check of silicon sensors, PCBs (under development)







## MAC preparations for key procedures (2)



- Module assembly: with the main gantry and related tooling (camera, gantry head, fixtures, etc.)
  - Precision pick-and-place movements with components, fine glue dispensing, etc.
  - Automated operations with dedicated software







### MAC preparations for key procedures (2)



- Module assembly: with the main gantry and related tooling (camera, gantry head, fixtures, etc.)
  - Camera installed for pattern recognition: fiducial points at silicon sensors and PCBs
  - Gantry positioning calibrations: done with a laser interferometer



Details in the talk by Feng Wang (IHEP), "Progress on quality control of HGCAL module assembly" later in the same session







### MAC preparations for key procedures (3)



- Wire-bonding: electrical connections between silicon sensors and PCB (equipped with FE-ASICs)
  - Bonding machine ready, several rounds of training initiated, more exercises planned (dummies)
  - Wire-bonding quality: first with the bonding machine, later with a pull tester •



Schematics of wire-bondings of silicon modules (side view)











### MAC preparations for key procedures (4)



- Mini-gantry system: dispense glue to encapsulate the wire-bonds for better mechanical stability
  - Mini-gantry ready: to dispense glue points into the stepped holes of PCBs, training (Jul.-Aug. 2020)
  - Centrifuge ready: to remove bubbles in pre-mixed 2-component glue









### MAC preparations for key procedures (5)



- Test stand for silicon modules
  - Pedestal calibration, common-mode noise subtraction, charge injection for inter-calibrations







### MAC preparations for key procedures (5)



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#### MAC database development

- HGCAL Database an essential part of HGCAL construction
  - Record data of all steps in module production
  - GUI being developed: transmit information between local MAC and HGCAL database
  - Sensors, PCBs, baseplates, tooling; production steps and testing results; shipping

Module Assembly User Interface			- 0	× 🔳 Module Assembly User Interface
Parts, tooling, supplies baseplates sensors PCBs protomodules modules tooling supplies	Baselate ID 0   New Save   Zdit     location   shipsents go to selected	baseplate qualification & preparation Corner height 0 (nm) Corner height 1 Corner height 2 Corner height 3 Corner height 3 Corner height 4 Corner height 5 Flatness (nm)	sensor application sensor step On protomodule module On module Go to Go to	Parts, tooling, supplies baseplates sensors PCBs protomodules
Production steps and testing routines kapton placement steps sensor placement steps PCB placement steps UV curve V curve Shipping and receiving shipments	Identifier Manufacturer Material Size (inches) Size (inches) Shape Chirality	kapton tape applied thickness (mm) kapton seplication kapton step check leakage current check leakage current check leakage current check surface check surface check flateness (mm) check flateness (mm) c	° ° ° ° ° ° ° ° ° ° ° ° ° ° ° ° ° ° °	modules tooling supplies Production steps and testing routines kapton placement steps sensor placement steps
	Comments delete selected	for double kapton baseplates second kapton application kapton step	0 3 corner numbering reference 0 4 5 0 0	PCB placement steps unbiased DAQ IV curve Shipping and receiving shipments





#### Selected highlights: teamwork for the MAC developments

Gantry Alignments (Dec. 2019 - Jan. 2020)





OGP delivered and installed (Apr. 2020)

NIM module under test for cosmic-ray test stand









#### Selected highlights

#### • CMS and HGCAL management visited IHEP MAC (Sep. 2019)









#### Preparations for the MAC site qualification

# Task list for site qualification (with latest updates)

1		TIFR (BARC)		CMU		IHEP		NTU		TTU		UCSB	
2		5/46 completed		16/46 completed		14/46 completed		16/46 completed		14/46 completed		24/46 completed	
3	Task	1	Date	√	Date	√	Date	- √	Date	√	Date	✓ =	Date \Xi
6	Establish dry air cabinets		3/1		3/1		3/1	$\checkmark$	3/1	$\checkmark$	3/1	$\checkmark$	3/1
7	Establish particle count monitoring		3/1		3/1		3/1	$\checkmark$	3/1	$\checkmark$	3/1	$\checkmark$	3/1
8	Establish humidity monitoring		3/1		3/1		3/1	$\checkmark$	3/1	$\checkmark$	3/1		3/1
9													
10	EQUIPMENT INSTALLED		3/1		3/1		3/1		3/1		3/1		3/1
11	Gantry		3/1	$\checkmark$	3/1								
12	Wire Bonder		3/1		3/1		3/1	$\checkmark$	3/1	$\checkmark$	3/1		3/1
13	Pull Tester	$\checkmark$	3/1		3/1		3/1	$\checkmark$	3/1	$\checkmark$	3/1	$\checkmark$	3/1
14	Mini Gantry	$\checkmark$	3/1		6/18		3/1	$\checkmark$	3/1		3/1	$\checkmark$	3/1
15	Measuring Microscope	$\checkmark$	3/1		3/1		3/1	$\checkmark$	3/1		3/1	$\checkmark$	3/1
16	Work station		3/1		3/1		3/1	$\checkmark$	3/1	$\checkmark$	3/1	$\checkmark$	3/1
17	Test stand		8/1		8/1		8/1		8/1		8/1		8/1

MAC-IHEP in the same preparation stage as most MACs (Note: MAC-UCSB serves as the pilot MAC)

https://docs.google.com/spreadsheets/d/1vfSE06QK9bD-7gekQWap2C9huU5StMJjjxXoj0PJ1U/edit

#### Milestones and timelines (Note: made early 2020; impacts from Covid-19 not yet included; adjustments expected)

	Milestone De	scription		Duration	Finish by		
1	Cleanroom lab	o space set u	р				
2	Have all equip	ment install	ed		Sep 11 <sup>th</sup> 2020		
3	Train operator	rs on all equi	pment		Sep 11 <sup>th</sup> 2020		
4	Acquire all the	e necessary t	ooling		Oct 23 <sup>rd</sup> 2020		
5	Acquire all du	mmy compo	nents and supplies		Oct 23 <sup>rd</sup> 2020		
6	Qualify the ga	ntry and wir	ebonder		Nov 6 <sup>th</sup> 2020		
7	Develop glue	patterns usir	ng acrylic dummies	2 weeks	Nov 20 <sup>th</sup> 2020		
8	Build 10-15 du	ummies with	blank silicon	4-6 weeks at one glue step per day	Jan 8 <sup>th</sup> 2021		
9	Acquire all rea	al componen	ts		Jan 15 <sup>th</sup> 2021		
10	Build 4 dumm	ies with HPK	dummy sensors	2 weeks	Jan 22 <sup>nd</sup> 2021		
11	Build 2 real m	odules!		1 week	Feb 1 <sup>st</sup> 2021		
	Vilestone	WBS	Title		Date		
•	CE.MO.4	7.4.5	All Si module assembly sites & procee	01 Feb 21			
•	CE.MO.7	7.6.2	Silicon Module components orders pla	2 DEC 21			
•	CE.MO.9	7.6.4	Silicon Modules production 5% comple	ete (HL)	26 OCT 22		
•	CE.MO.10	7.6.6	Silicon Modules production 50% comp	lete (HL)	21 OCT 23		
1	CE.MO.11	7.6.8	Silicon Module production 100% comp	olete (HL)	22 JUL 24		

Ref.: Huaqiao Zhang, CMS-HGCAL Upgrade Project, LHC Detector Upgrade Workshop, Aug. 2020







## Summary

- Steady progress in the HGCAL Module Assembly in China
  - Infrastructure and instrumentation: developed/procured
    - 140m<sup>2</sup> clean room, key equipment, test stands, services
    - Commissioning, personnel training
  - Given impacts from Covid-19: expect adjustments for the schedule
- Now focus on the preparations of the MAC site qualification
- Interests from universities in China: expected contributions from
  - Zhejiang University: <u>HGCAL PCB ("Hexaboard") design, DC-DC boards</u>
  - Fudan University: involvements with the MAC development



