Status of HGCal module assembly at IHEP

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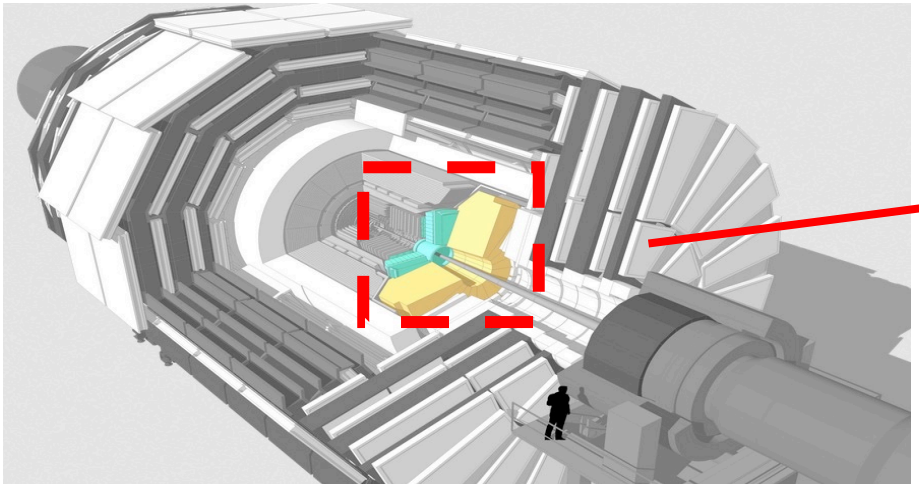
On behalf of Chinese HGCal group
2024.11.15

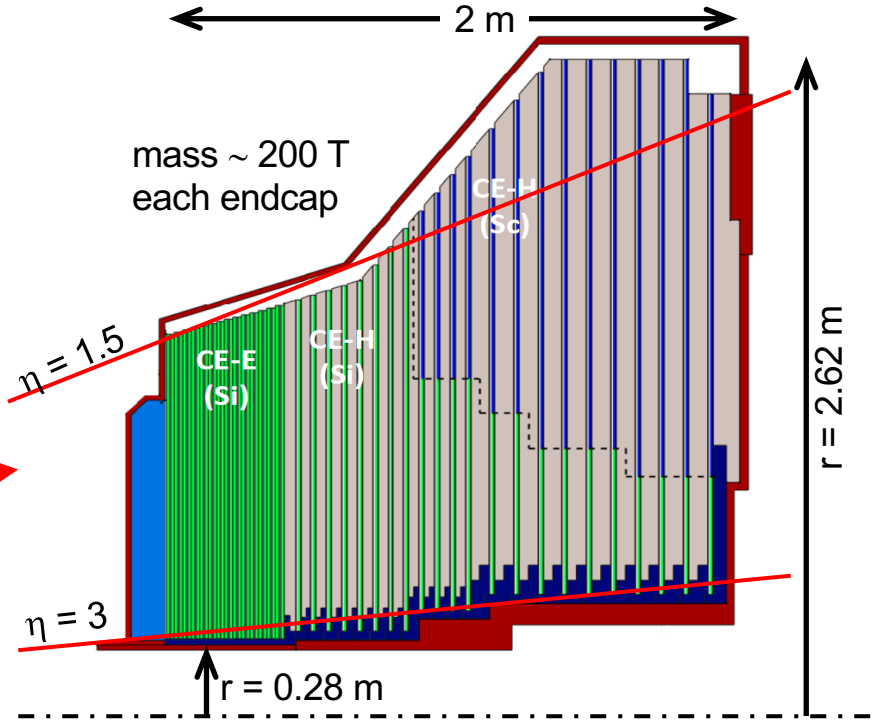
Outline

- Motivation
- CuW baseplate production
- HGCal si-module production
- Module beam test
- Summary

CMS-HGCal upgrade

- Key Parameters:
  - HGCAL covers 1.5 < |η |< 3.0
  - Full system maintained at -30°C
  - ~620m^2 of silicon sensors
  - ~370m^2 of scintillators
  - 6M Si channels, 0.5 or 1.1 cm^2 cell size
  - ~26000 Si modules
  - Power at end of HL-LHC: ~110 kW per endcap

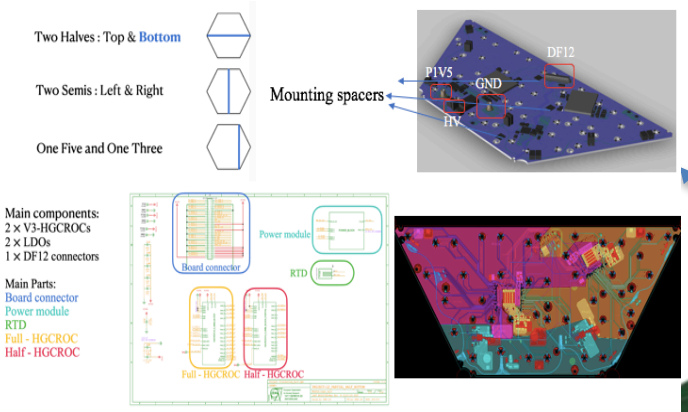




Endcap Electromagnetic calorimeter (CE-E): Si, Cu & CuW & Pb absorbers, 26 layers, 25.5 X_0 & ~1.3λ
Hadronic calorimeter (CE-H): Si & scintillator, steel absorbers, 21 layers, ~8.5λ

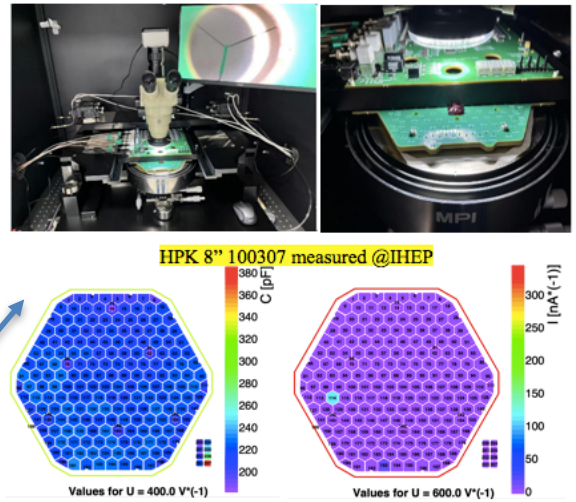
First time apply HGCal to experiment

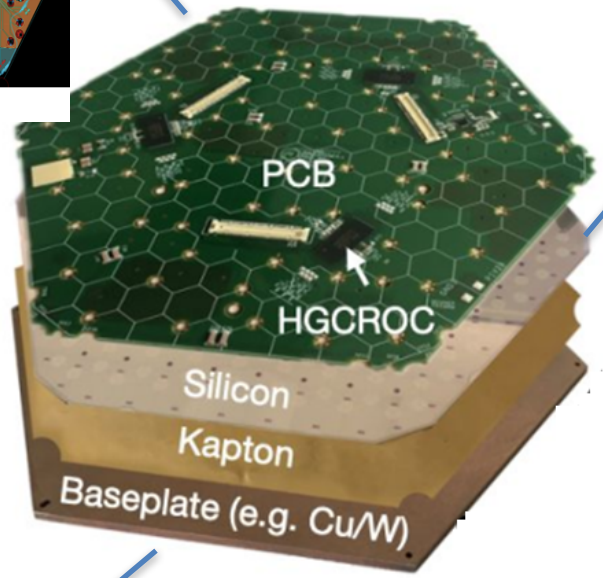
CMS-HGCal: CMS-China tasks

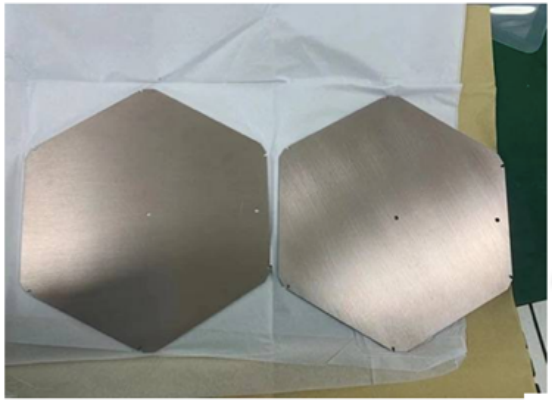


Partial hexaboard design is reviewed by CMS

Sensor Quality Control (SQC)







CuW baseplates production in China

- 1/5 (~5000) Low density (LD) full si-modules production @IHEP MAC
  - 100 m^2

IHEP+THU+ZJU+FDU+NJNU

CMS-HGCal: CuW baseplate production

CuW baseplate: CuW+Kapton+3M tape

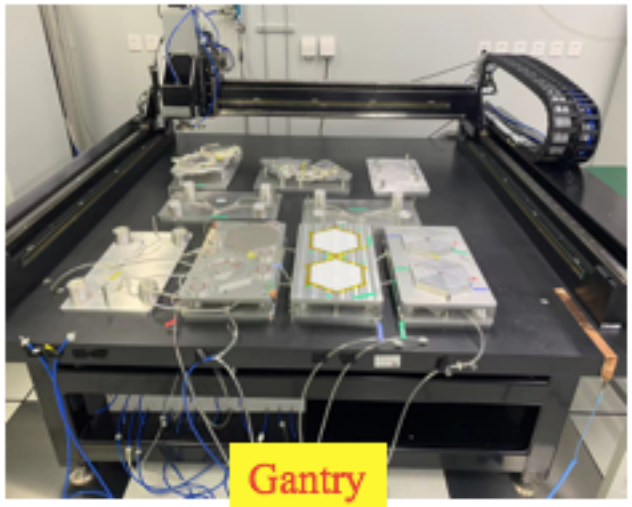
Refer to Han Wang' talk

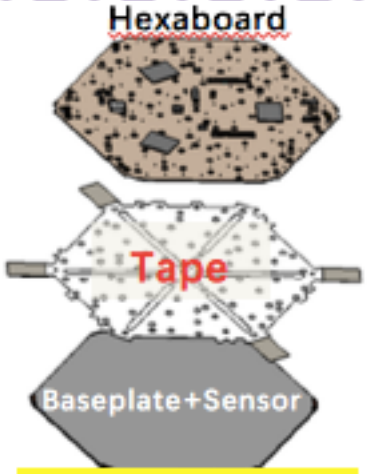
- ~ 90% of the area CuW baseplates will be produced in China
  - K-contract have been reviewed and signed by CERN and IHEP.
  - We are preparing the tendering for CuW baseplate
- CuW baseplate production
  - 30 CuW baseplates are produced this year
- R&D
  - Develop the kapton hot press lamination process
  - Irradiation test @KIT and CIEMAT for IHEP CuW baseplate

CuW baseplates are produced in China

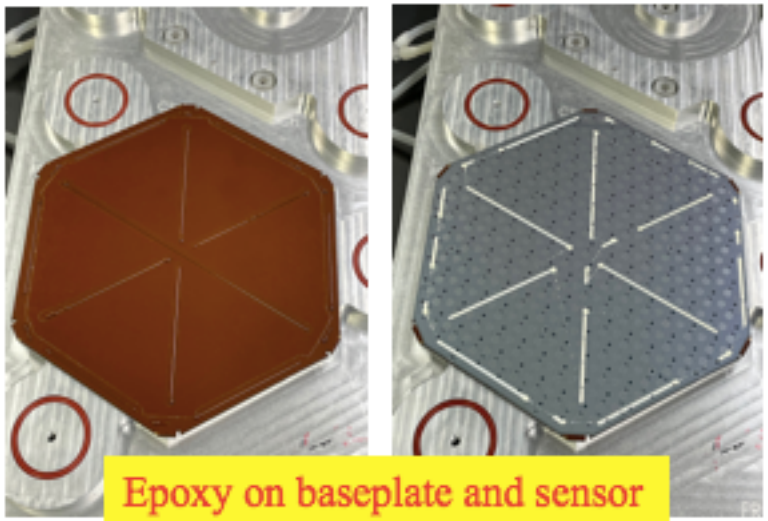
Batch	Date	Design	Number	Kapton Laminate method	Use fixture	3M tape on Surface	Status
1	May. 2024	V4_CuW_Baseplate	2	Pure adhesive	Yes	Yes	Sent to KIT
			7	Pure adhesive	Yes	Yes	Sent to NTU
			21	Pure adhesive	Yes	Yes	IHEP

CMS-HGCal: Si-Module assembly


Gantry

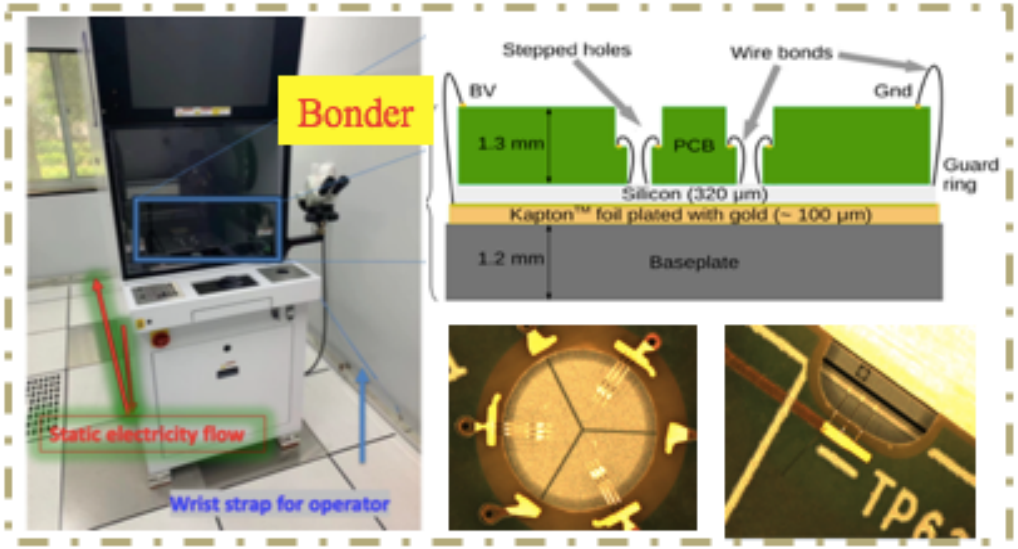


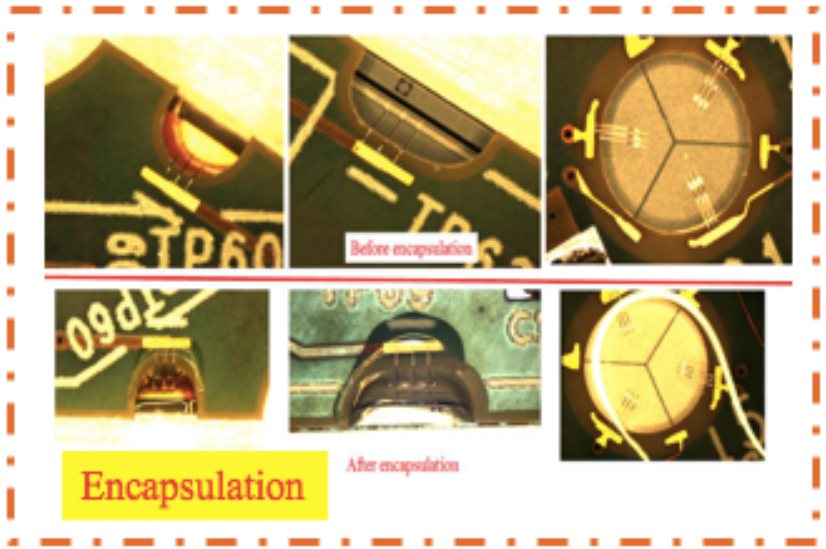
Hybrid assembly

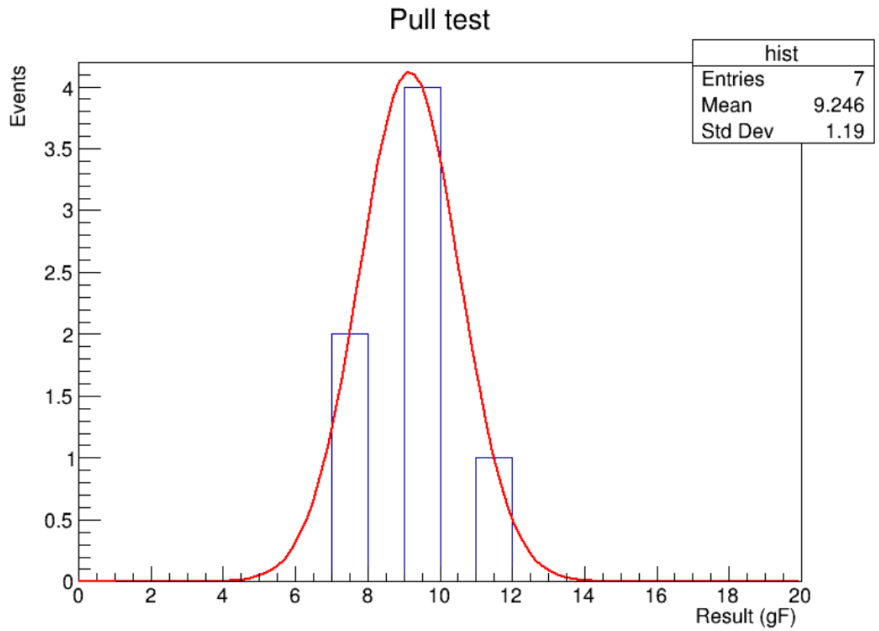

Epoxy on baseplate and sensor

- LD-V3 full Si-module
  - Pre-series modules： CuW baseplate+ sensor (pre-series sensor)+ hexaboard (HGCROCV3A)
  - Pre production modules： CuW baseplate+ sensor (production sensor)+ hexaboard (HGCROCV3B)
- Module assembly
  - All CuW baseplates of these modules are produced in CHINA.
  - Hybrid assembly (epoxy + transfer tape) method for improving the production rate
  - Two modules assembly at one time on gantry

CMS-HGCal: Si-Module assembly







- Program bonding is used
  - 5 modules bonding at most per day so far
  - Target：20 min/module once bonder setup
- Pull strength is close to 10 gF
- Automatic encapsulation
  - 15min/module once setup

CMS-HGCal: Summary of Live modules

Module Production: 1/23-4/24

	Numbers	Types	"Grade A"	Not "Grade A"		
				Bad IV	Bad Readout	Bad Placement
CMU	10	LD FULL	5	1		4
IHEP	23	LD FULL	18	3	3	
NTU	21	HD FULL / LD LEFT	16	5	2	
TTU	11	LD FULL	7	3	1	
UCSB	27	LD FULL / HD FULL / LD RIGHT	18	6	4	2

Module Production: 4/24 - 10/24

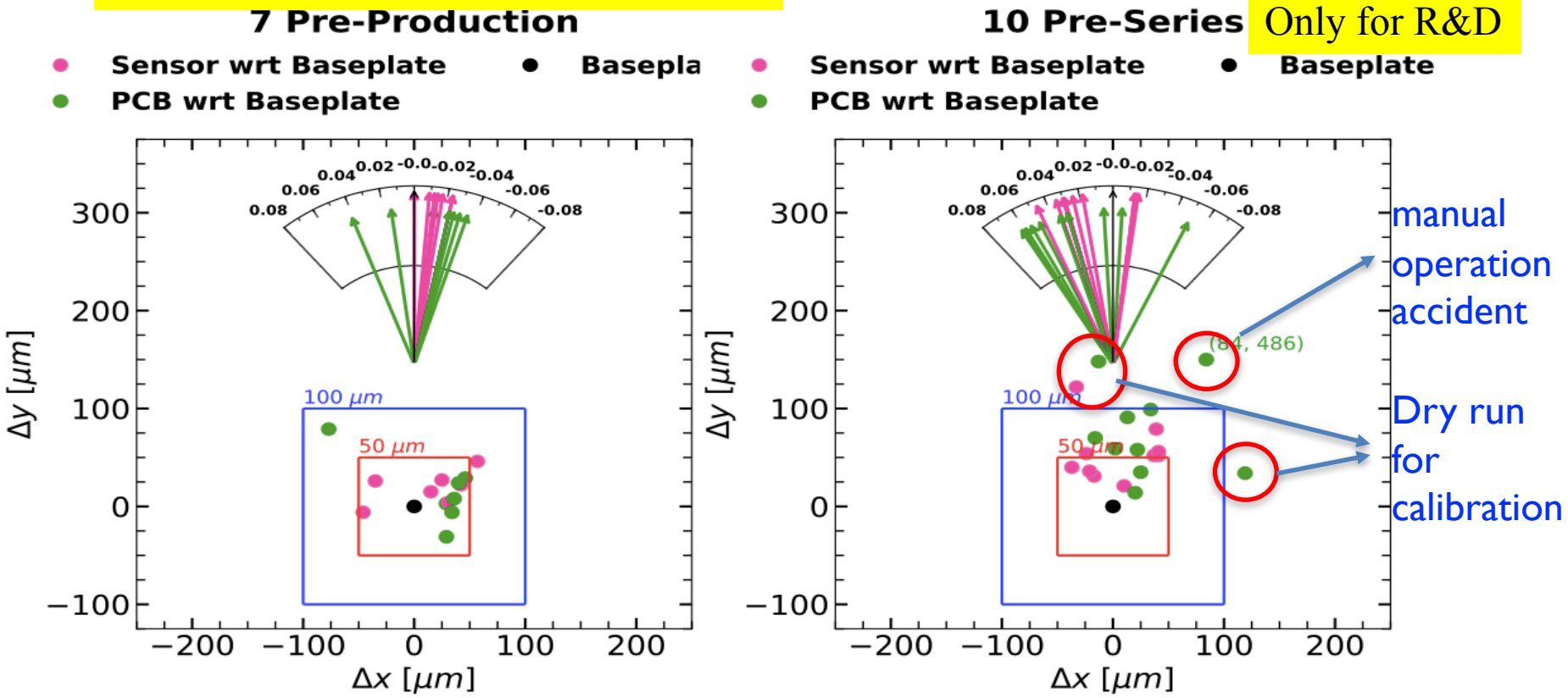
	Numbers	Types	"Grade A"	Not "Grade A"		
				Bad IV	Bad Readout	Bad Placement
CMU	12	LD FULL	8	1	1	3
IHEP	17	LD FULL	13	1	2	1
NTU	15	HD FULL	11		3	1
TTU	16	LD FULL				
UCSB	10	HD FULL / LD RIGHT	5		3	3

- Pre-series criteria
  - low current @ ≥ 500 V , ≤ 10 bad channels
  - Placement within 150 μm along XY axes
  - Angular alignment of layers better than 0.10°
- IHEP live modules (40 total, ~0.8 m^2)
  - 33 pre-series modules are produced in IHEP so far (24 modules sent to CERN)
  - The first 7 pre-production modules are produced in IHEP this year (all grade A and only IHEP did and sent to CERN in July)
  - 31 modules are identified as grade A. (non-grade A's modules are all pre-series module)
- IHEP MAC did the best in both quality and quantity so far

CMS-HGCal: Alignment

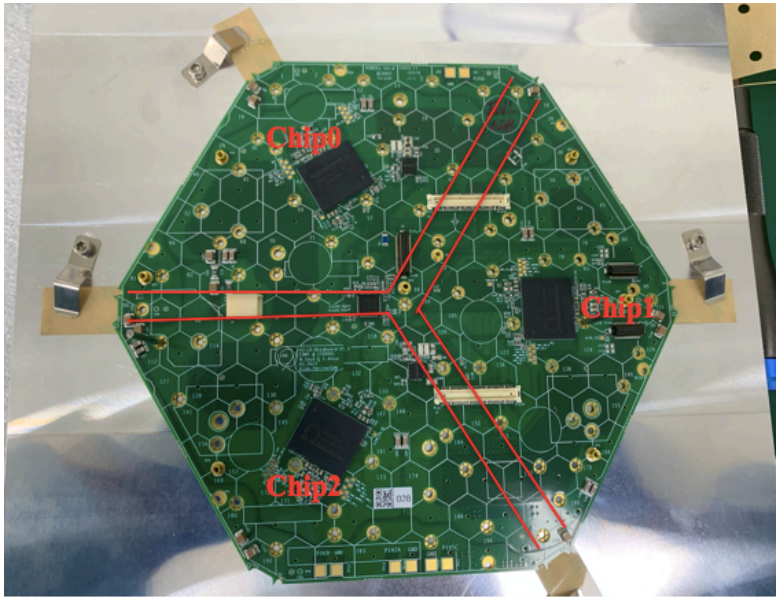
For R&D, will install on CMS probably

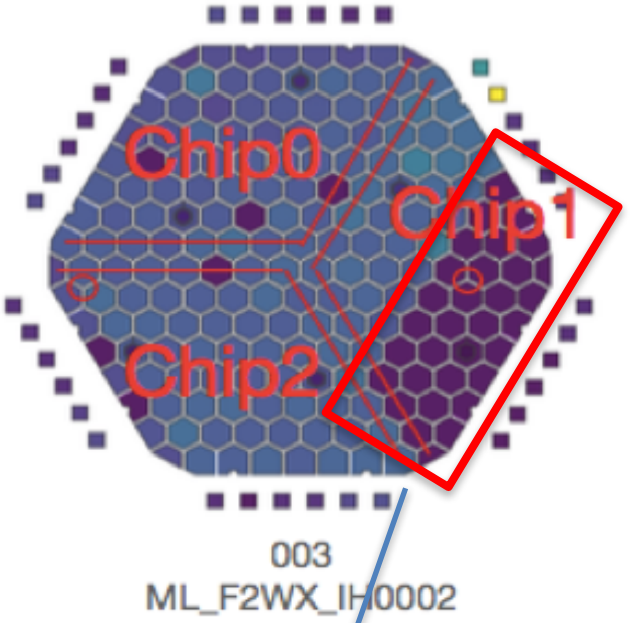
Only for R&D



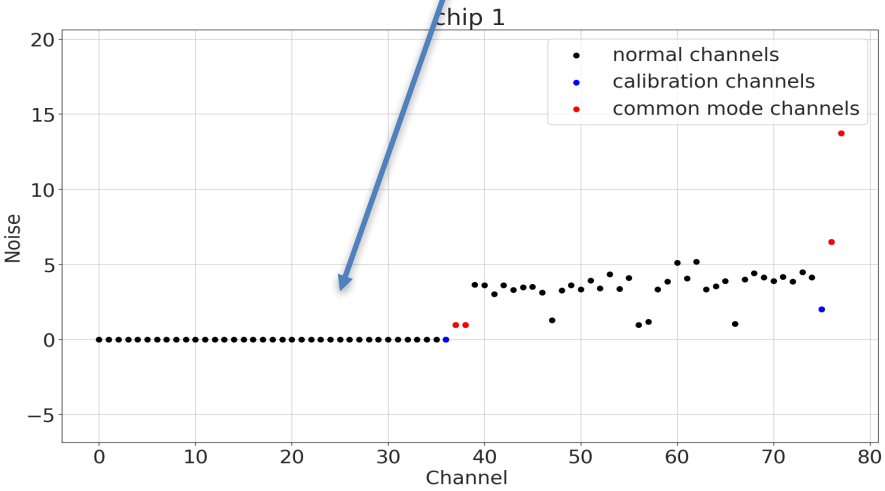
- Three modules are misalignment: one due to manual operation and the other two for calibration
- Accordingly, the protection code of gantry was implemented.
- The others meet the requirement of accuracy

CMS-HGCal: Module test @IHEP



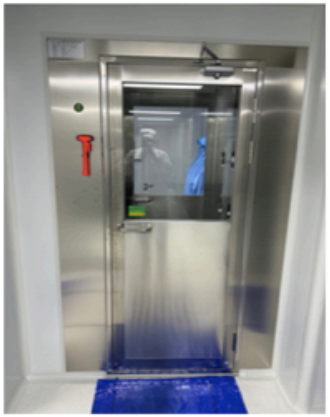


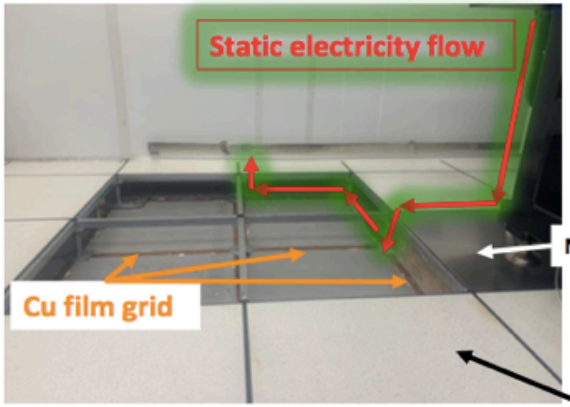
- Three modules have half non-functionl channels in some chip.
- In IHEP MAC, all these ESD happened in the stick tape on the hexaboard before assembly
- IHEP discovered and proposed first that it due to the static damage (confirm from CERN later).

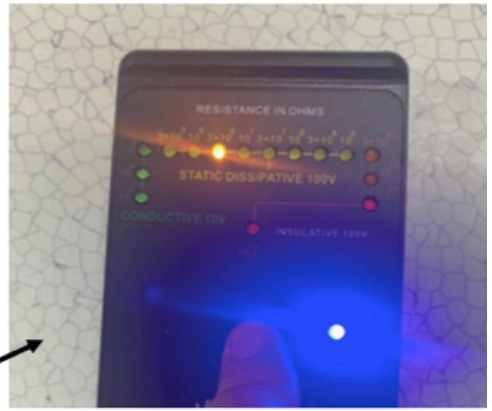


Refer to Zhipeng Cui' talk

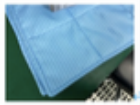
CMS-HGCal: ESD protection







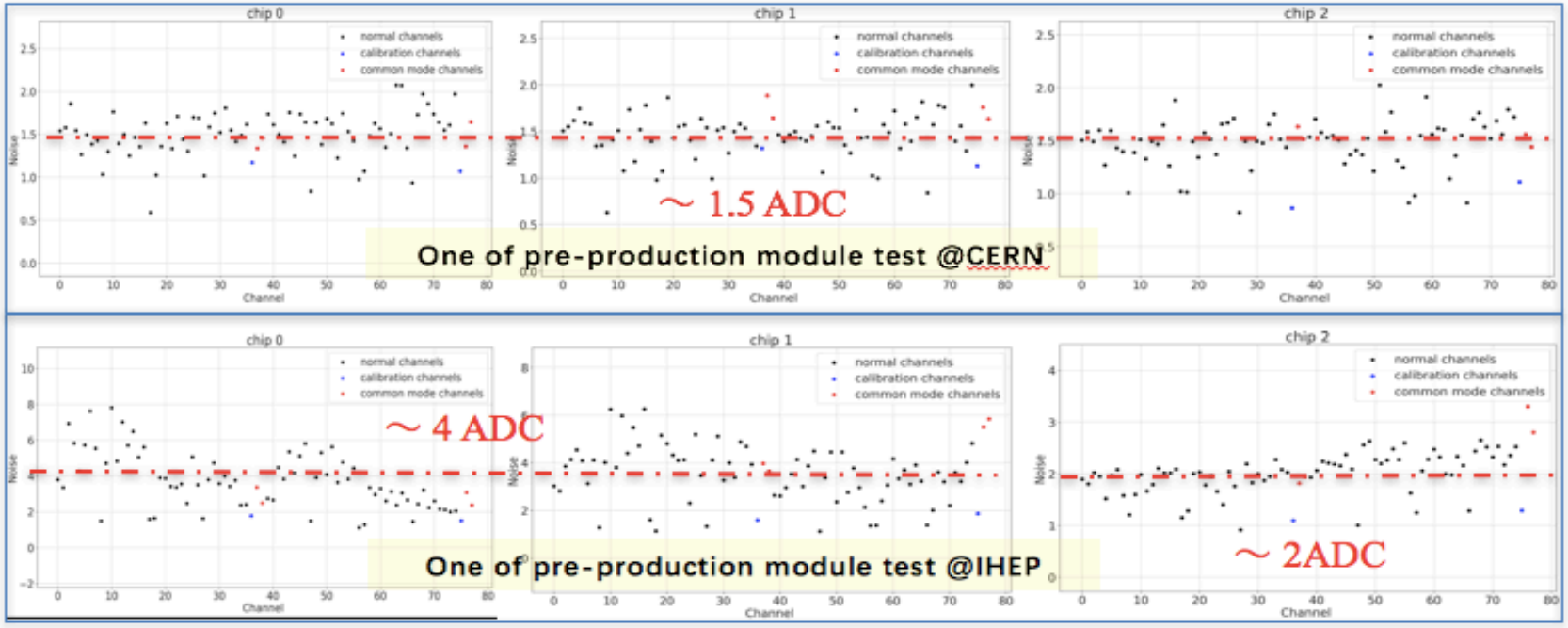
Anti-static PVC floor mat

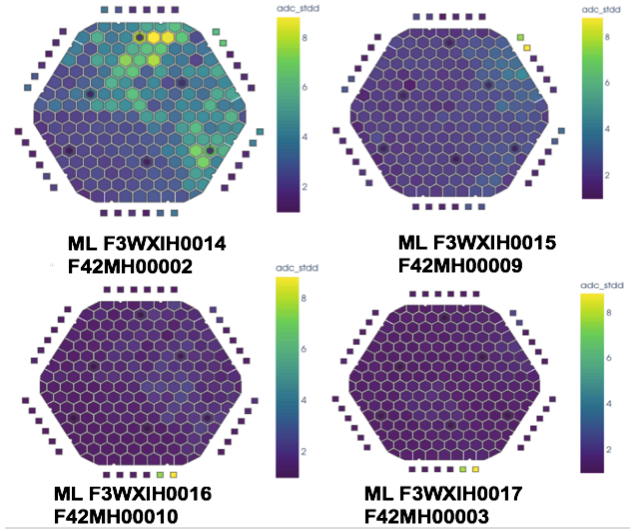
Name	Photo	Electrostatic field before rubbing (keV)	Electrostatic field after rubbing (keV)	5s ion blow	Another 10s ion blow	Resistance (Ω)
Anti static cleaning cloth (multi-layer)		0	0.4-0.8 (decline gradually)	0	/	// 10^{12} ⊥ 10^{7}
PVC flexible tube		0	0.05-0.2	0	/	10^{10}
syringe		0.2	0.8 (decline quickly)	0	/	10^{10}

Silicon release liner		0	0.4 (local)	0	/	10^{10}
		0.1	0.3	0	/	10^{11}
Mouse pad		0-0.3 (unevenly distributed)	0-0.9 (local)	0-0.3	0	10^{10}
Plastic sealed bag		0.1	0.9	0.4	0.1	10^{10}
cling film		0-0.3	<1.2	0.5	0.1	10^{10}

- We review the grounding of clean room, each equipment and person
- Check the anti-static performance of materials and tools in our lab.
- Improve the lamination process of tape to hexabarod.

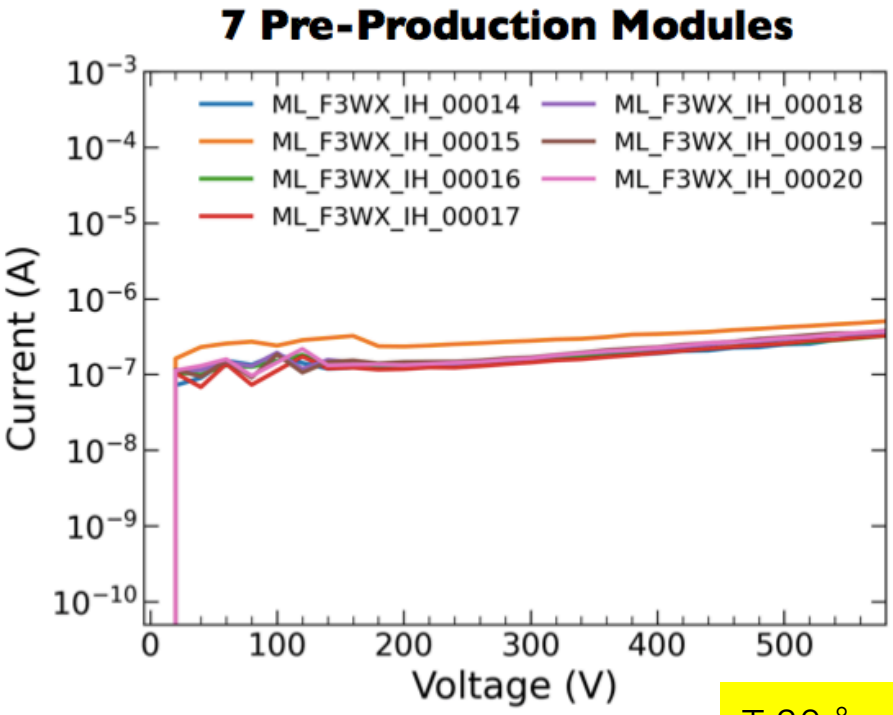
CMS-HGCal: Module test @IHEP

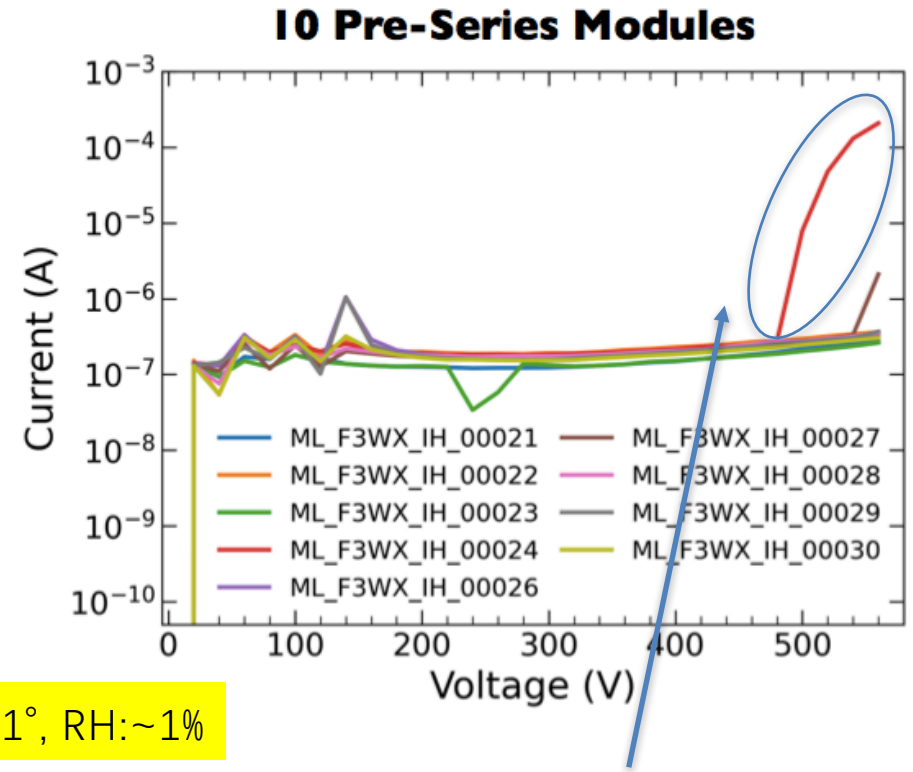




- We have produced 7 pre-production and 10 pre-series modules since this July.
- No ESD happened in these modules.
- No more bad channel is introduced in module assembly. All dead channels are from initial PCB itself.

CMS-HGCal: Module test @IHEP





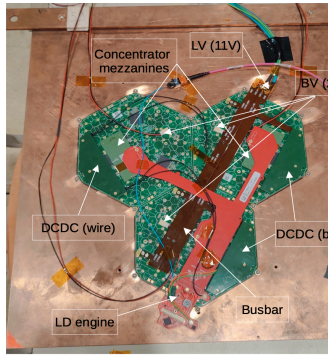
T:20 ° ±1°, RH:~1%

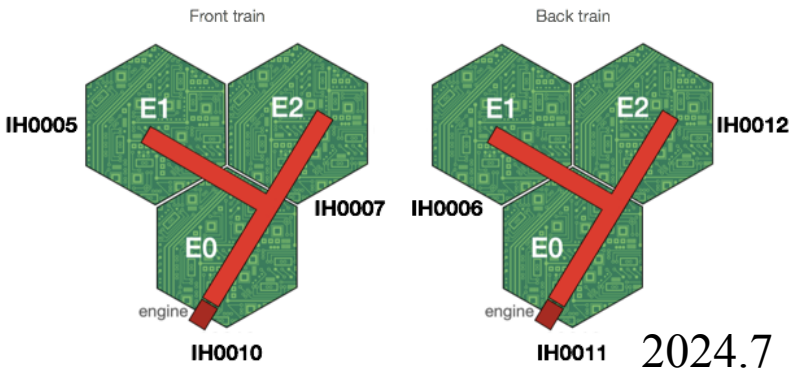
- Potential reasons for early breakdown in three pre-series modules (<500V)
  - IV failures likely due to humidity
- No earlier break down happened in pre-production modules so far (up to 600V)

CMS-HGCal: beam test @CERN

- There are two times beam test this year
  - The modules for testing are all and only provided by IHEP MAC
  - 7 pre-production modules are use in verification of HGROCv3B
- All modules work normal in beam test
- Data analysis is ongoing

Refer to Baorui Hou' talk





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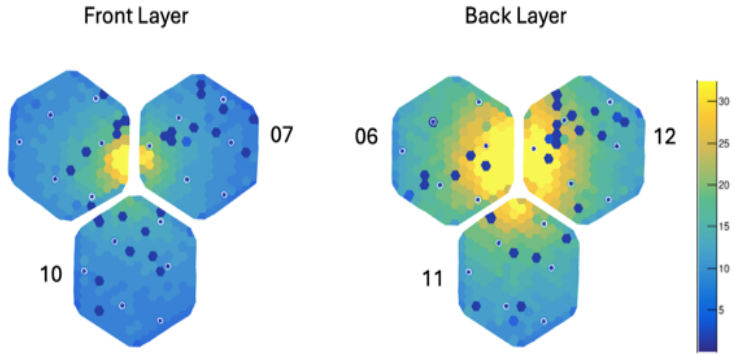
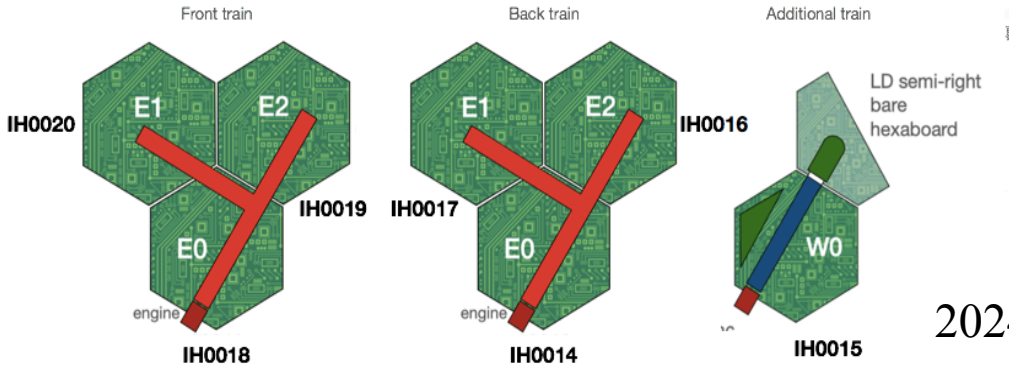
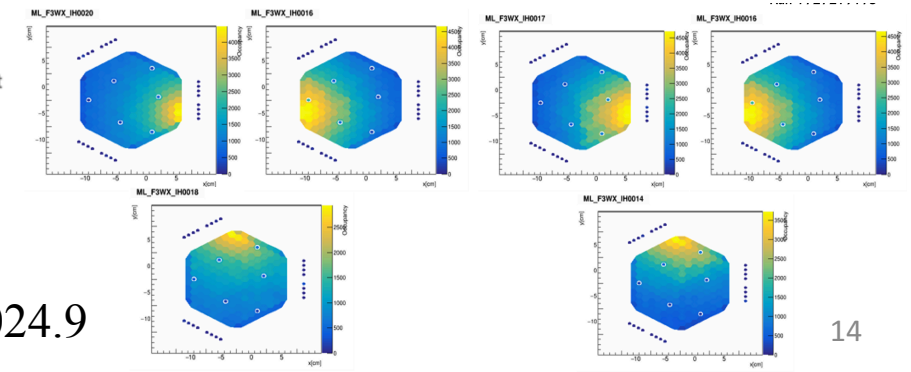
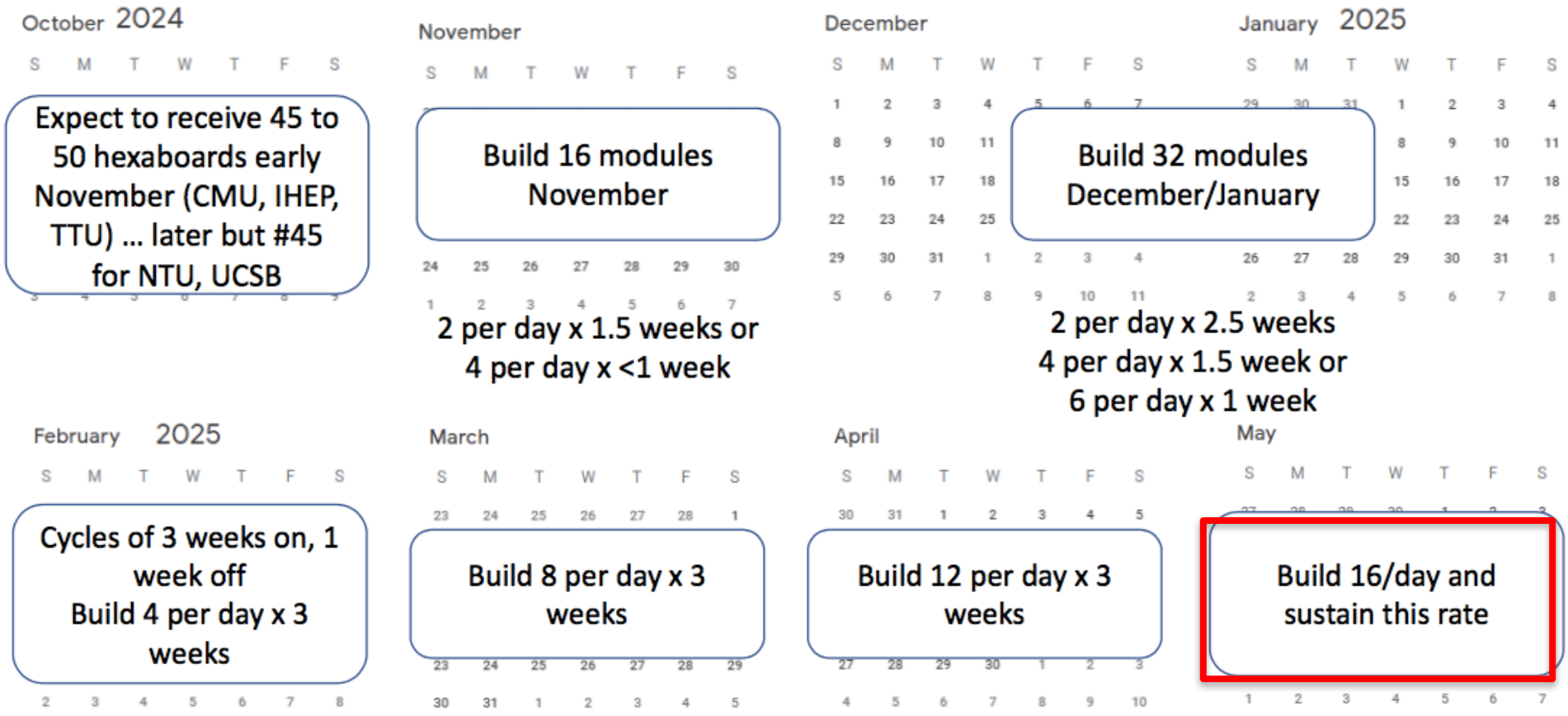




2024.9



CMS-HGCal: Ramp-up in pre-production



- 50 HGCal LD full silicon modules will be assembly in pre-production
  - Phase I : update assembly rate to 4 modules/day~~ 6 modules/day
  - Phase II : update assembly rate to 8modules/day~~ 12 modules/day
  - Phase III : 16 modules/day and sustain this rate for coming mass production

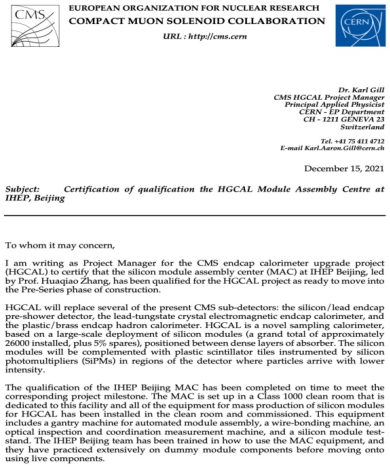
CMS-HGCal: Summary and Plan

- 90% of the area CuW baseplate will be produced in China
  - K-contract is reviewed and signed by CERN and IHEP
  - We are preparing the tendering for CuW baseplate
  - 30 CuW baseplates are produced in China this year
  - Irradiation test @KIT and CIEMAT for IHEP CuW baseplate
  - All CuW baseplate of module at IHEP are produced in China
- HGCal assembly @IHEP
  - We produce 40 HGCal LD full silicon modules this year（～0.8 m^2）
  - IHEP is the first and only one who produce pre-production module so far
- Beam Test @CERN
  - There are two times beam test this year
  - The modules（13 pcs total）for testing are all and only provided by IHEP
  - All modules performed good in beam test
- Preparation for pre-production
  - Ramp-up the production rate to 16 modules/day
  - Mass production will be followed the original schedule

HGCal MAC @IHEP

CMS-HGCal: Si-Module assembly center (MAC)

- IHEP MAC was certified officially in 2021
- Produce the first 8 inch real HGCal si-module for CMS（2021）
- 11 real modules have done at IHEP MAC
- Clean room and key equipment have worked well and stale for 3 years.



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December 15, 2021

***Subject:** Certification of qualification the HGCAL Module Assembly Centre at IHEP, Beijing*

To whom it may concern,

I am writing as Project Manager for the CMS endcap calorimeter upgrade project (HGCAL) to certify that the silicon module assembly center (MAC) at IHEP Beijing, led by Prof. Huaqiao Zhang, has been qualified for the HGCAL project as ready to move into the Pre-Series phase of construction.

HGCAL will replace several of the present CMS sub-detectors: the silicon/lead endcap pre-shower detector, the lead-tungstate crystal electromagnetic endcap calorimeter, and the plastic/brass endcap hadron calorimeter. HGCAL is a novel sampling calorimeter, based on a large-scale deployment of silicon modules (a grand total of approximately 26000 installed, plus 5% spares), positioned between dense layers of absorber. The silicon modules will be complemented with plastic scintillator tiles instrumented by silicon photomultipliers (SiPMs) in regions of the detector where particles arrive with lower intensity.

The qualification of the IHEP Beijing MAC has been completed on time to meet the corresponding project milestone. The MAC is set up in a Class 1000 clean room that is dedicated to this facility and all of the equipment for mass production of silicon modules for HGCAL has been installed in the clean room and commissioned. This equipment includes a gantry machine for automated module assembly, a wire-bonding machine, an optical inspection and coordination measurement machine, and a silicon module test-stand. The IHEP Beijing team has been trained in how to use the MAC equipment, and they have practiced extensively on dummy module components before moving onto using live components.