Progress of CMS China group on Phase II upgrade

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(On behalf of CMS-China group)

CMS Phase II upgrade

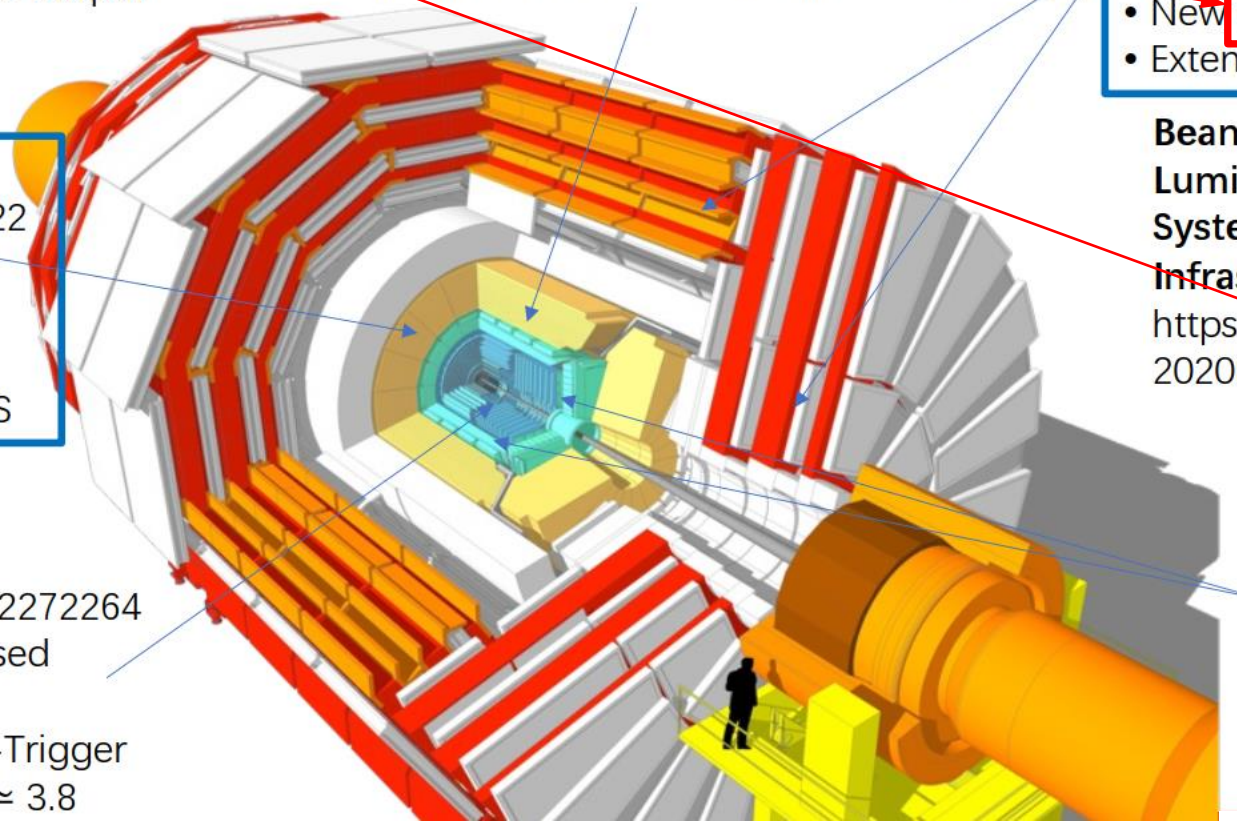
Tasks of China group

L1-Trigger HLT/DAQ
https://cds.cern.ch/record/2714892
https://cds.cern.ch/record/2759072
- Tracks in L1-Trigger at 40 MHz
- PFlow selection 750 kHz L1 output
- HLT output 7.5 kHz
- 40 MHz data scouting

Barrel Calorimeters
https://cds.cern.ch/record/2283187
- ECAL crystal granularity readout at 40 MHz with precise timing for e/γ at 30 GeV
- ECAL and HCAL new Back-End boards

Muon systems
https://cds.cern.ch/record/2283189
- DT & CSC new FE/BE readout
- RPC **Link**-board
- New **GEM/iRPC** $1.6 < \eta < 2.4$
- Extended coverage to $\eta \simeq 3$

Calorimeter Endcap
https://cds.cern.ch/record/2293646
- 3D showers and precise timing **HGCAL**
- Si, Scint+SiPM in Pb/W-SS

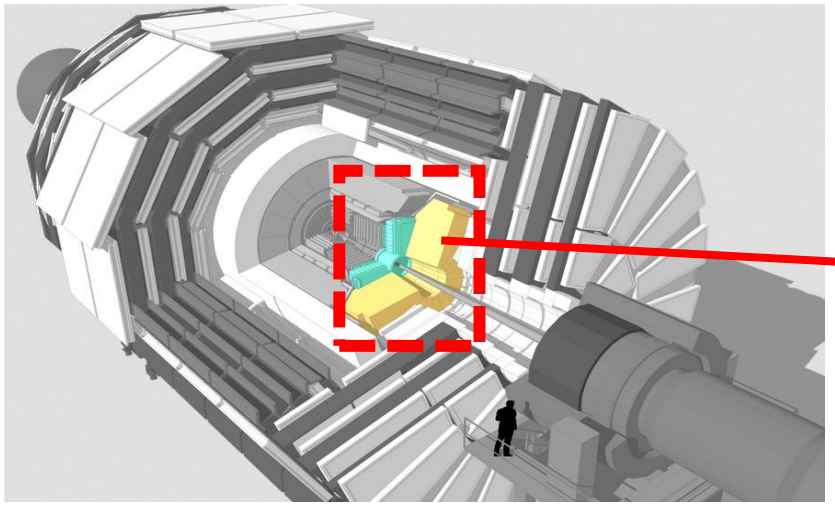


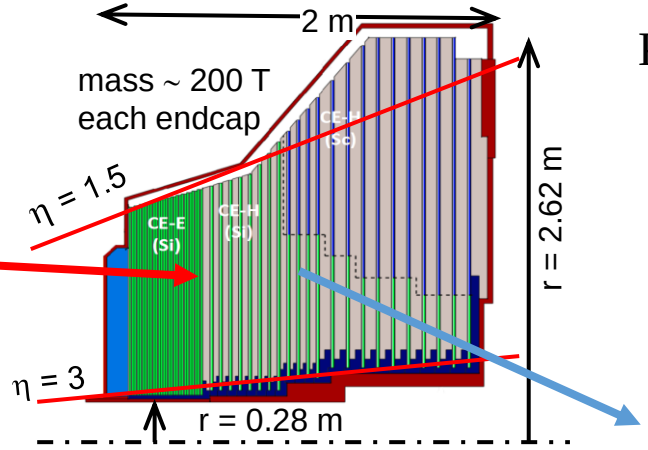
Beam Radiation Instr. and Luminosity, and Common Systems and Infrastructure
https://cds.cern.ch/record/2020886

Tracker
https://cds.cern.ch/record/2272264
- Si-Strip and Pixels increased granularity
- Design for tracking in L1-Trigger
- Extended coverage to $\eta \simeq 3.8$

MIP Timing Detector
https://cds.cern.ch/record/2296612
Precision timing with:
- Barrel layer: Crystals + SiPMs
- Endcap layer: Low Gain Avalanche Diodes

CMS HGCal upgrade: CMS-China tasks





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

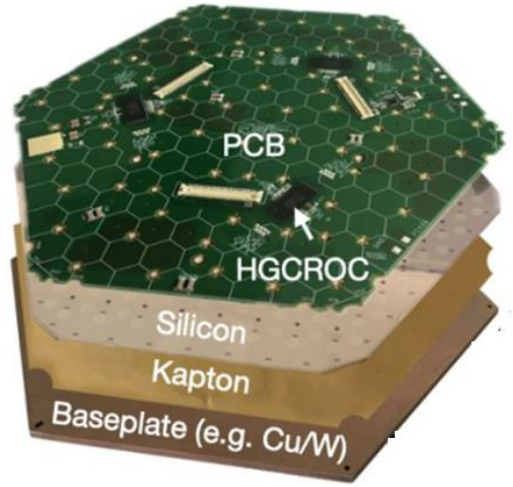
Endcap Electromagnetic calorimeter (CE-E):

- 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



LD full Si-module

CMS China tasks:

- ❑ 1/5 (~5000) Low density (LD) full Si-modules production
- ❑ CuW baseplate and kapton production
- ❑ Sensor Quality Control (SQC)
- ❑ Hexaboard partial board design

CMS HGCal upgrade: CuW baseplate production

CuW baseplate:

CuW+Kapton+3M tape

- ~90% of CuW baseplates will be produced in China
  - K-contract have been reviewed by CERN and IHEP, is in the process of signing by CERN firstly. We are preparing the tendering for CuW baseplate

- R&D:
  - Develop the kapton hot press lamination process
  - irradiation test @KIT and CIEMAT for IHEP CuW baseplate

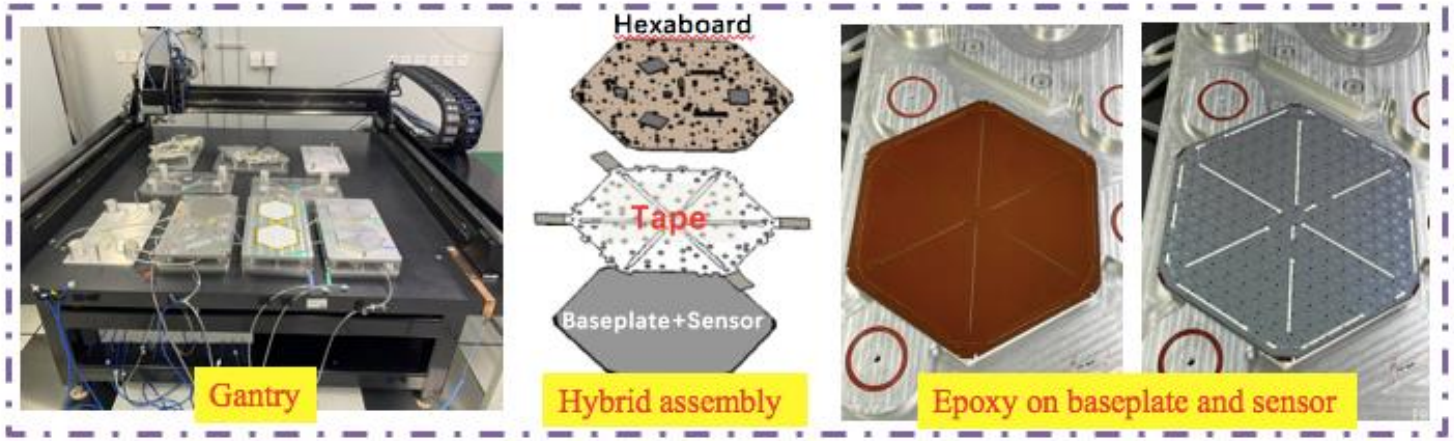
CuW baseplate produced in China: 30 produced this year

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 upgrade: Si-Module assembly

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.
- Various methods (Hybrid assembly, program bonding etc.) are used to improve production rate
- 5 modules bonding at most per day so far. Target： 20 min/module once bonder setup

Module Production: 1/23-4/24

	Numbers	Types	"Grade A"	Not "Grade A"		
				Bad IV	Bad Readout	Bad Placemer
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

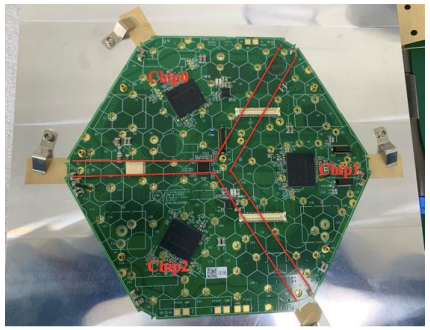
Module Production: 4/24 - 10/24

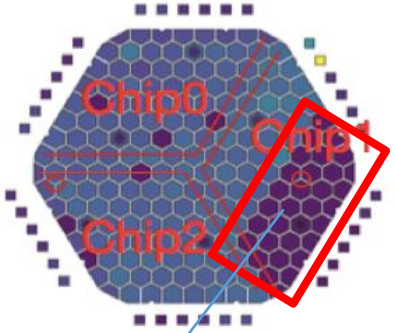
	Numbers	Types	"Grade A"	Not "Grade A"		
				Bad IV	Bad Readout	Bad Placement
CMU	12	LD FULL	8	1	1	3
IHEP	17	LD FULL	13	1	2	1
NTU	15	HD FULL	11		3	1
TTU	16	LD FULL				
UCSB	10	HD FULL / LD RIGHT	5		3	3

IHEP live modules (40 total, ~8 m^2): 33 pre-series modules (24 sent to CERN), and first batch of 7 pre-production modules were produced this year (only IHEP did and sent to CERN); 31 identified as grade A.

→ IHEP MAC did the best in both quality and quantity so far

CMS HGCal upgrade: Module test @IHEP





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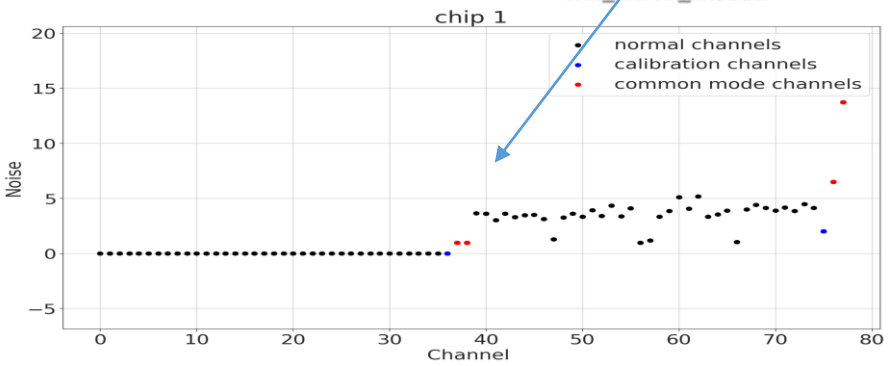
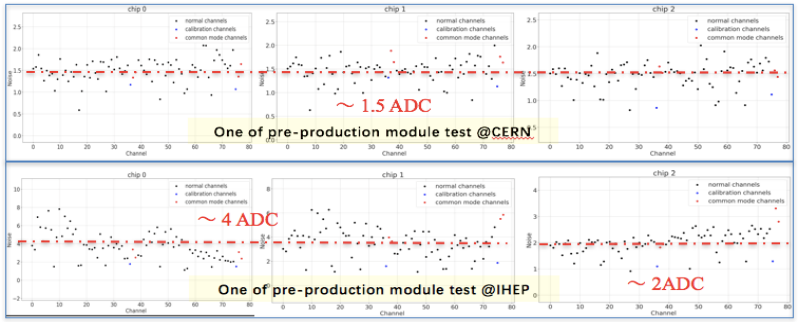


- During module assembly, three modules were found to have half non-functional channels in some chip.
- IHEP discovered the reason to be the static damage (confirm by CERN).
- These ESD happened in the stick tape on the hexaboard before assembly

Measures are taken for **ESD protection:**

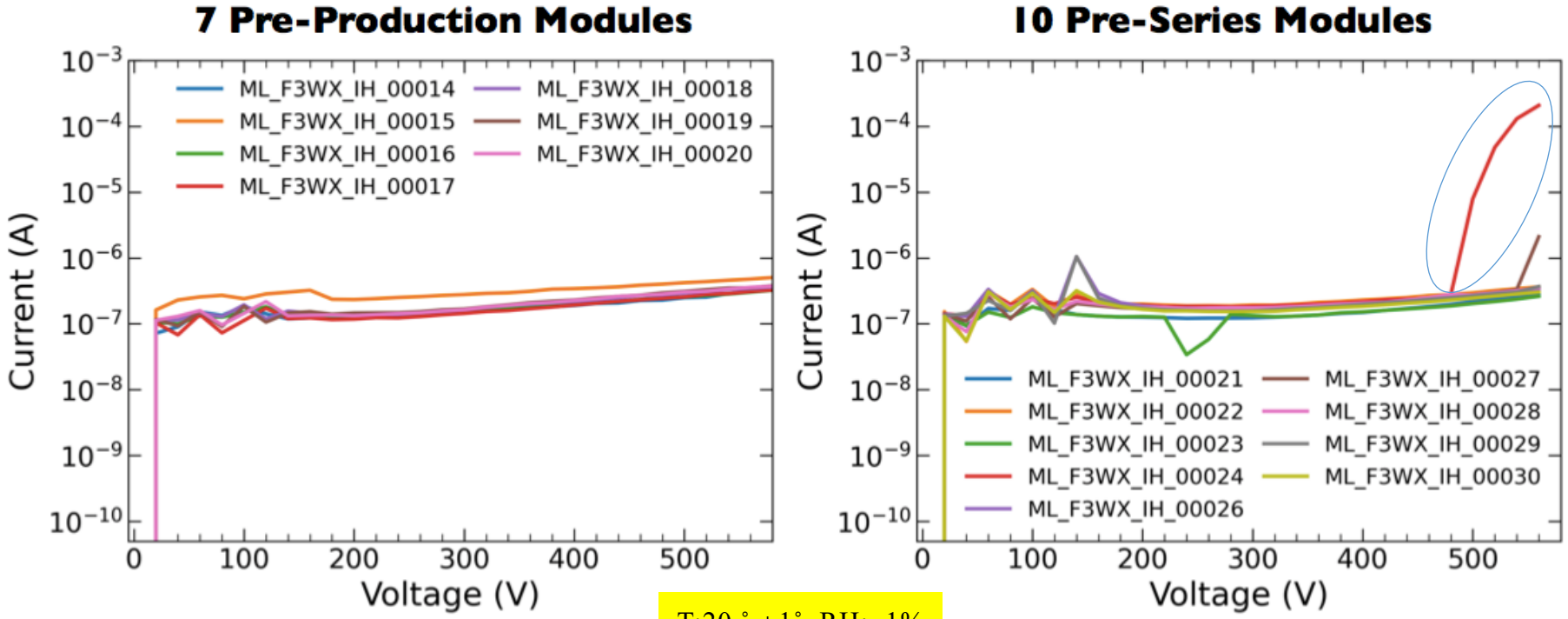
- Inspect each device and components in the clean room, replace materials and tool by anti-static ones, improve the lamination of tape to hexabarod.

- 7 pre-production and 10 pre-series modules were produced 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 upgrade: Module test @IHEP

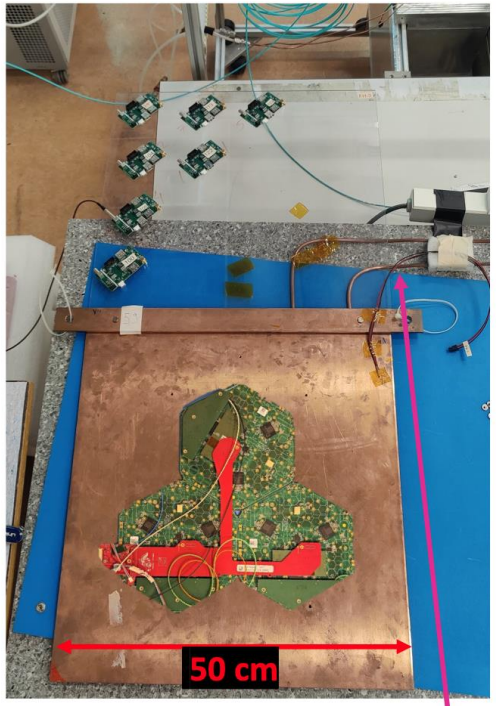
- Early breakdown found in three pre-series modules (<500V). Potential reasons could be:
  - Pre-series senor is not good enough
  - IV failures likely due to humidity
- No earlier break down happened in pre-production modules so far (up to 600V)

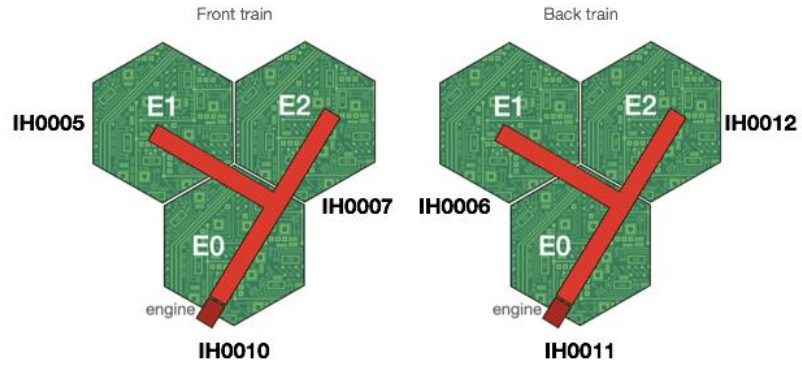


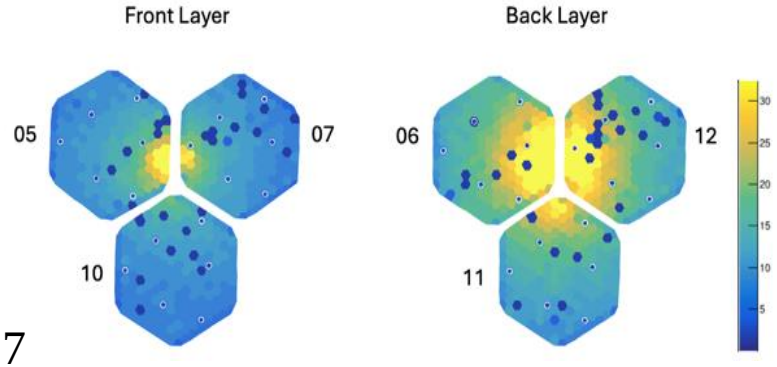
T:20 ° ±1°, RH:~1%

CMS HGCal upgrade: Beam test @ CERN

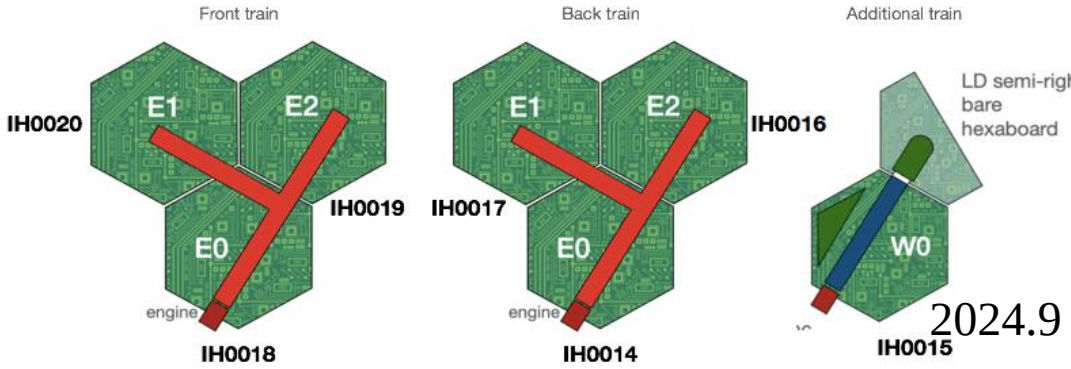
- Two HGCal beam test campaigns performed this year. All tested modules were provided by IHEP. 7 pre-production modules are use in verification of HGROCV3B
- All modules showed good performance in beam test



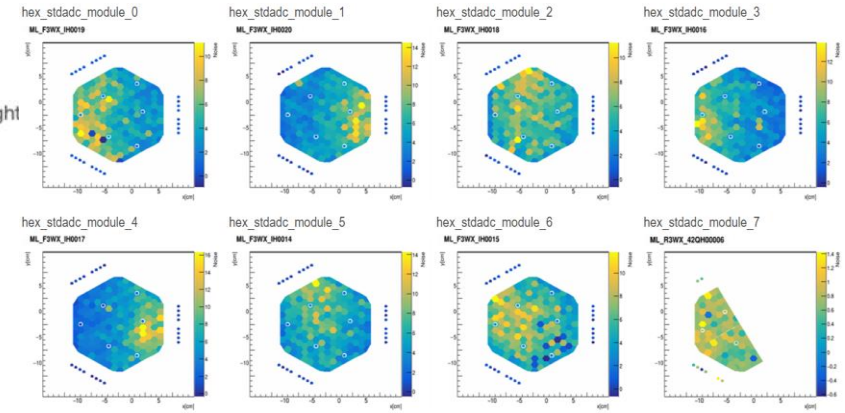




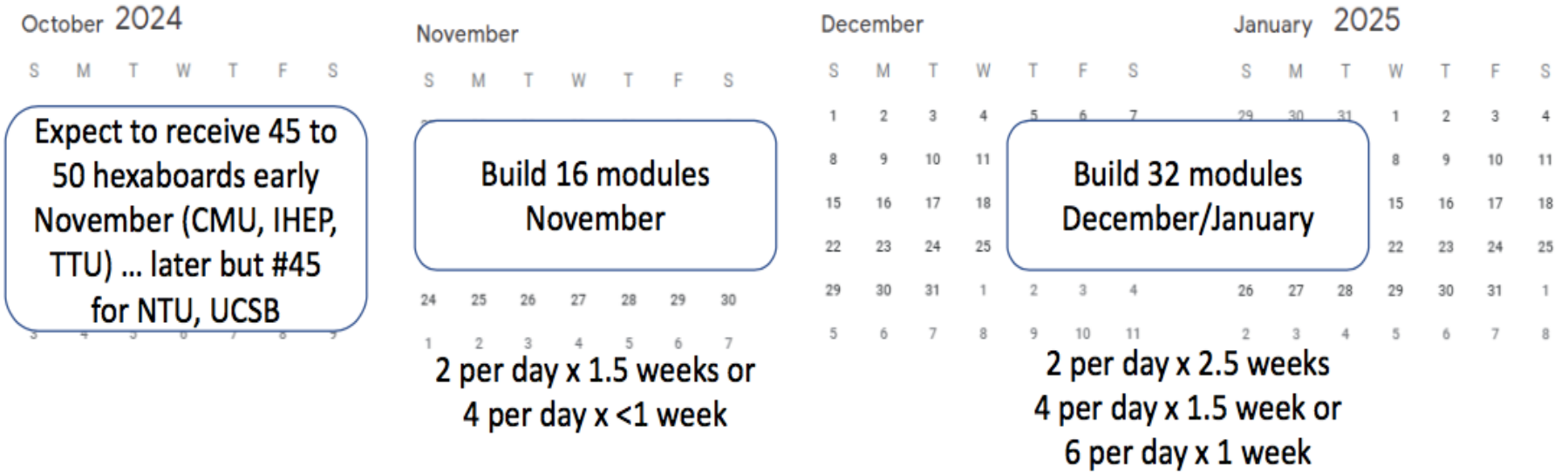
2024.7

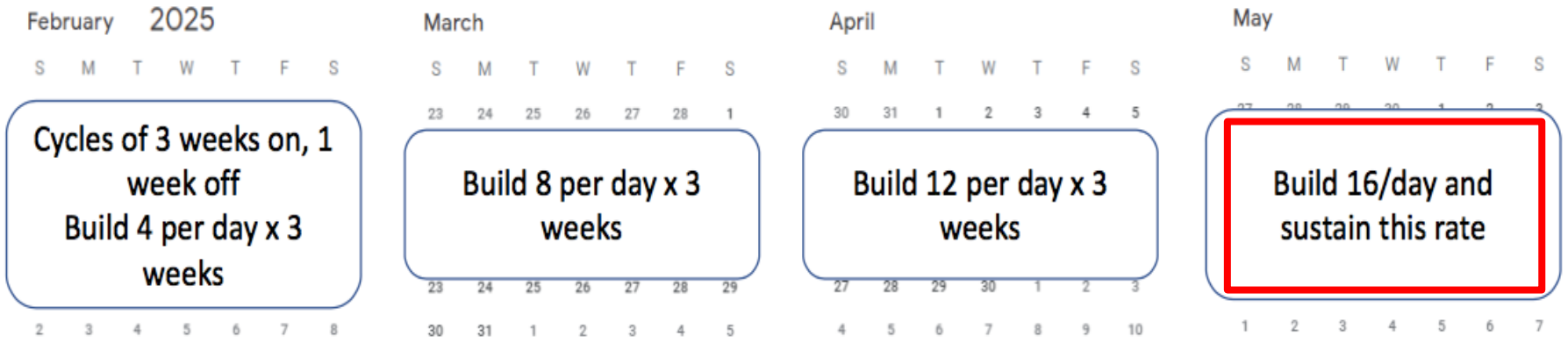


2024.9



CMS HGCal upgrade: Ramp-up in pre-production

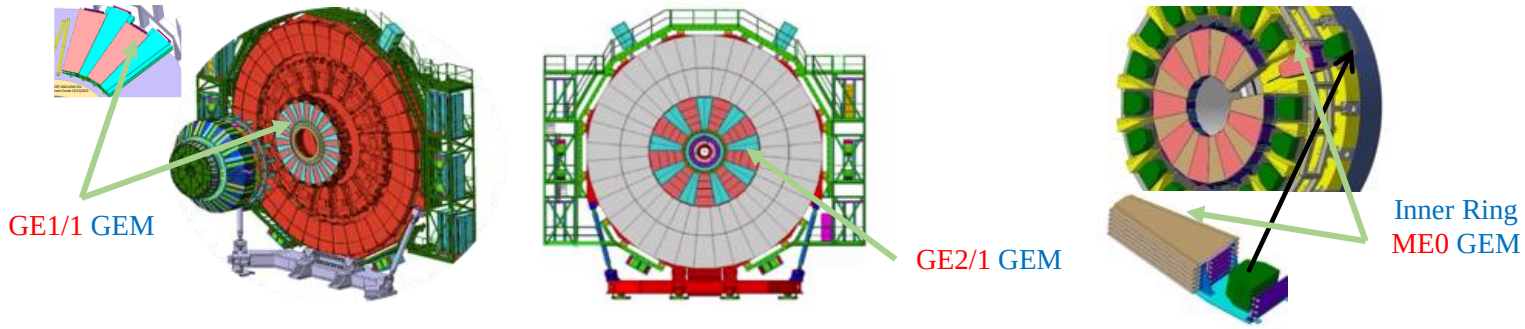




50 HGCal LD full silicon modules will be assembled in pre-production

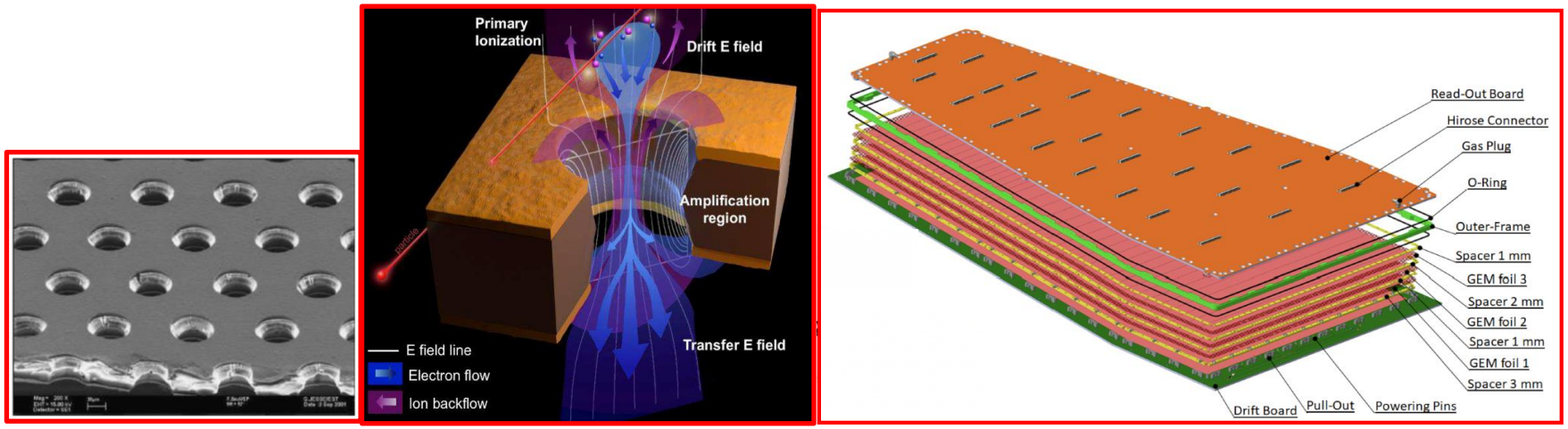
- Phase I : update assembly rate to 4 ~ 6 modules/day
- Phase II : update assembly rate to 8 ~ 12 modules/day
- Phase III : reach 16 modules/day and sustain this rate for coming mass production

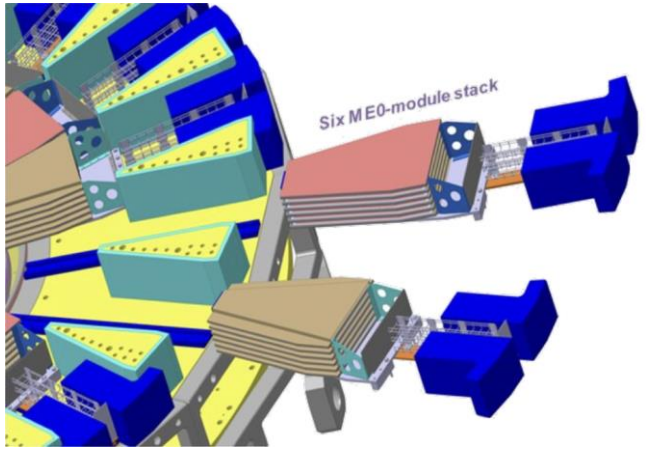
CMS GEM upgrade: CMS-China tasks



		GE1/1	GE2/1	ME0
Numbers*		288（=2×36×4）	288（=2×18×8）	216（=2×18×6）
plan	prototyping	2013-2017	2014-2022	2014-2023
	batch **production**	2017-2019	2022-2028	2024-2026
	Install&commission	2018-2020	2028-(?)	2027-2029
CMS-China **Contributions**		Production and test of all electronic boards(GEB) Participate assembly, test and commissioning at CERN	Design, production and test of all electronic boards(GEB) Assembly and QC of ~1/8 GEM detectors at PKU， Participate assembly, test and commissioning at CERN Production of FR4 frames, mechanical structures, etc	Design, production and test of all electronic boards(GEB)， Assembly and QC of ~1/5 GEM detectors at PKU， Participate assembly, test and commissioning at CERN Production of FR4 frames, mechanical structures, etc

CMS GEM upgrade: GEM module assembly





- **Vendors**
  - Manufacturing of the detector components
  - Shipment to CERN
- **Central Site (at CERN)**
  - Material inspection (QC1/QC2)
  - Pre-assembly work
  - Preparation of assembly kits
  - Shipment to/back from production sites
- **Production Sites**
  - Module assembly
  - QC2-QC5 tests
  - Data Base updates

Timeline

1st	2nd	3rd	4th & 5th	6th
Jul-Sep 2024	Oct-Dec 2024	Feb-Apr 2025	2025	2026

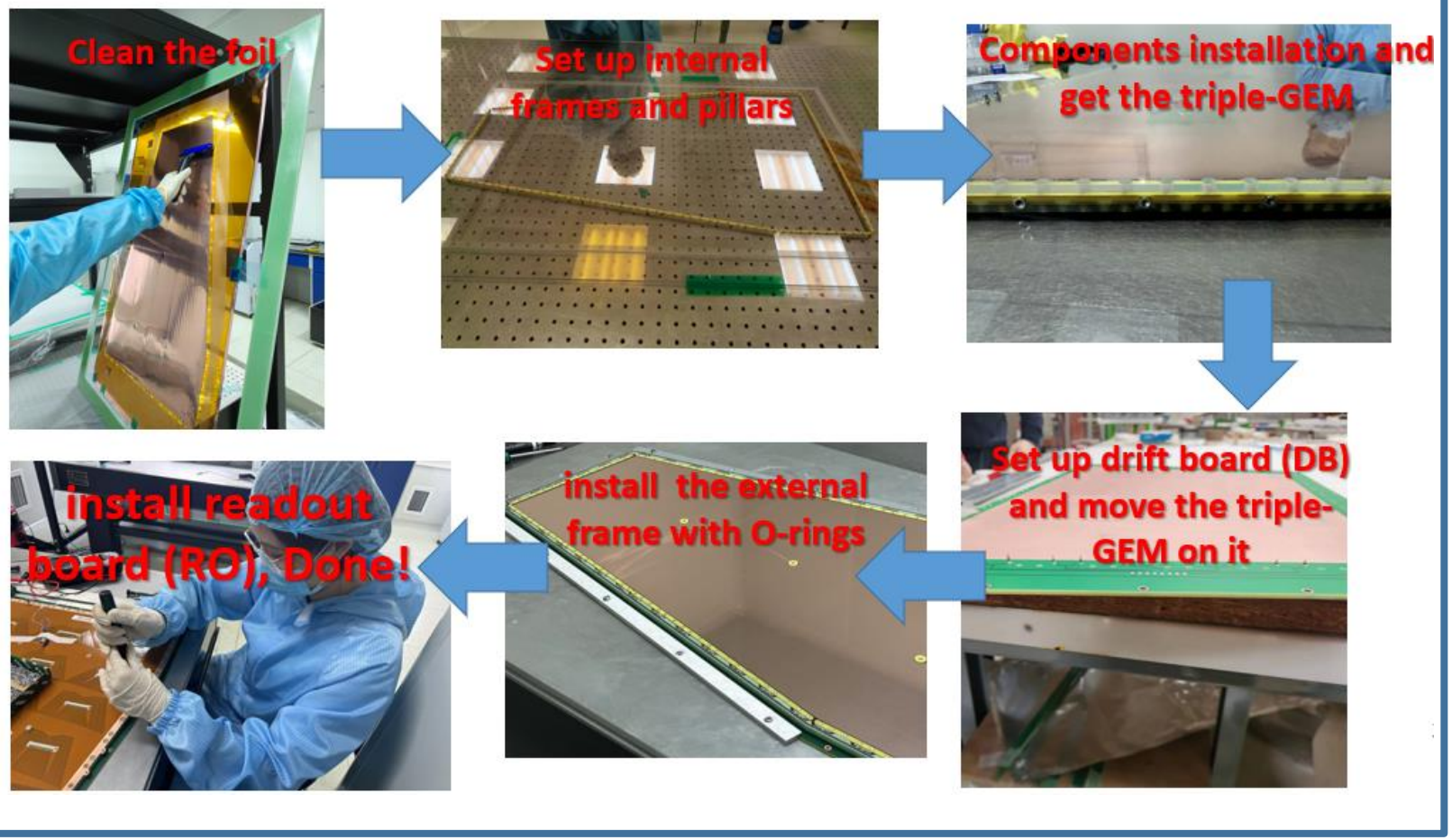
CERN
- QC 1: material inspection
- QC 2: GEM foils test (fast + long)

Production sites (e.g. PKU)
- QC 2: GEM foils test (fast)
- Assembly preparation + Assembly
- QC 3: gas leak test
- QC 4: HV test
- QC 5: gas gain calibration (gain + uniformity)

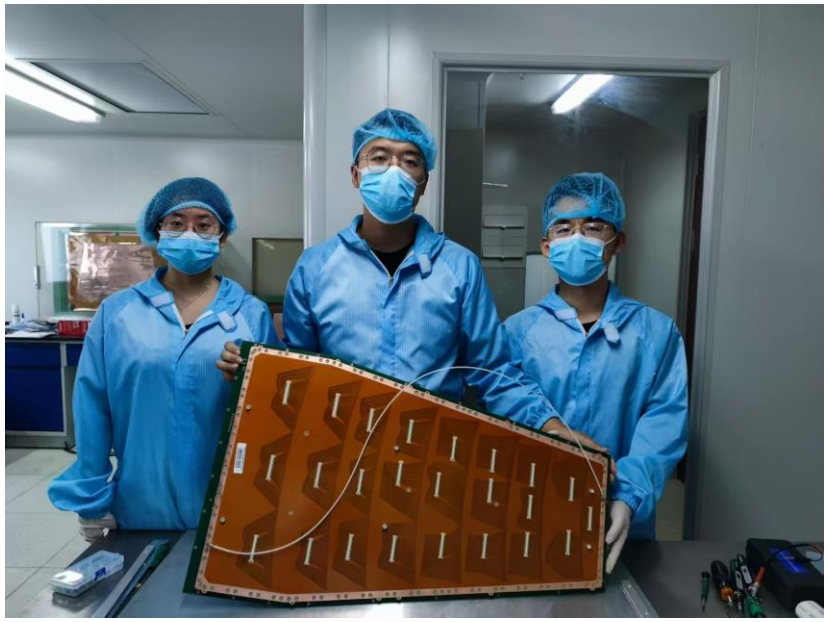
CERN
- QC 6: HV stability test
- QC 7: electronics connectivity test
- QC 8: cosmic ray test

CMS GEM upgrade: GEM module assembly

First batch of 10 GEM assembly and test at PKU (Sept.-Nov. 2024)



First ME0 module assembled at PKU

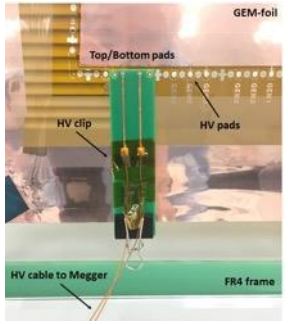


- Totally ~220 ME0 GEM modules will be produced
- PKU site is expected to produce 1/5 of them.

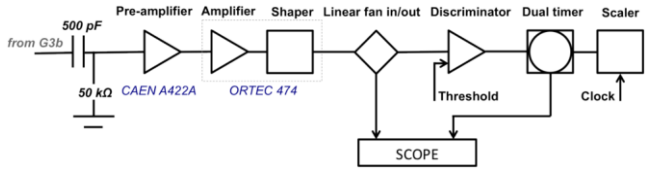
CMS GEM upgrade: GEM module QC test

All 10 GEM were qualified after eventual rounds of trouble-shooting

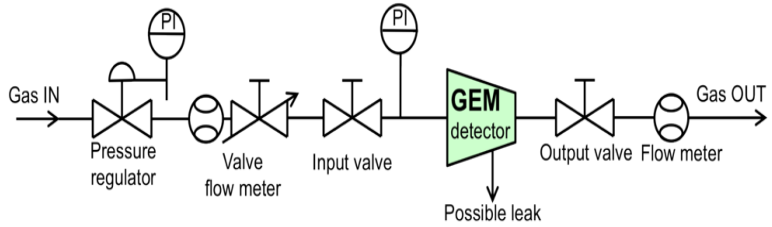
QC2:
GEM foil impedance



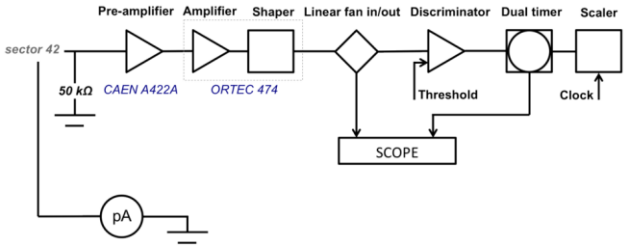
QC4:
V-I performance

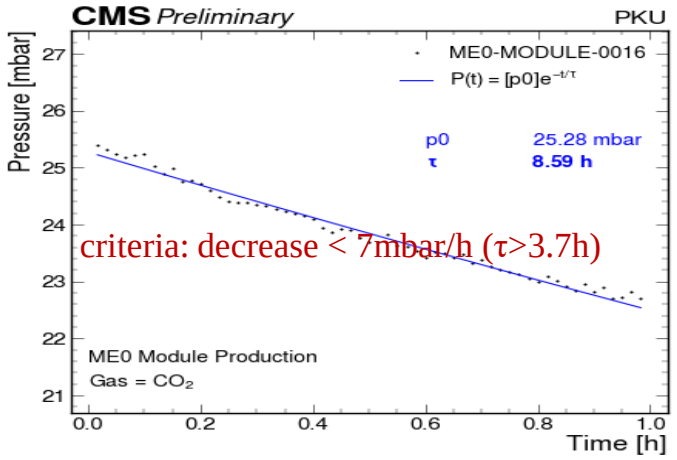


QC3:
gas leakage

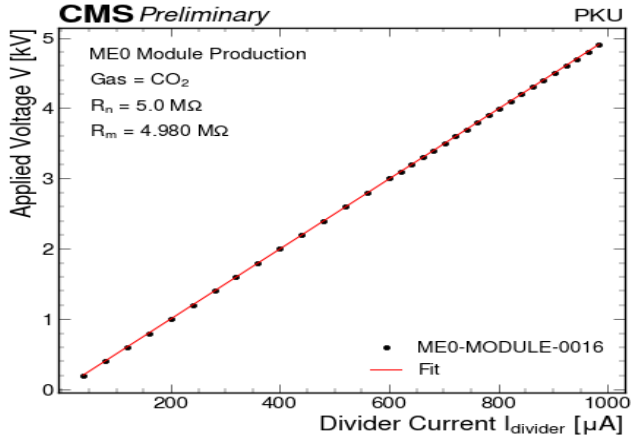


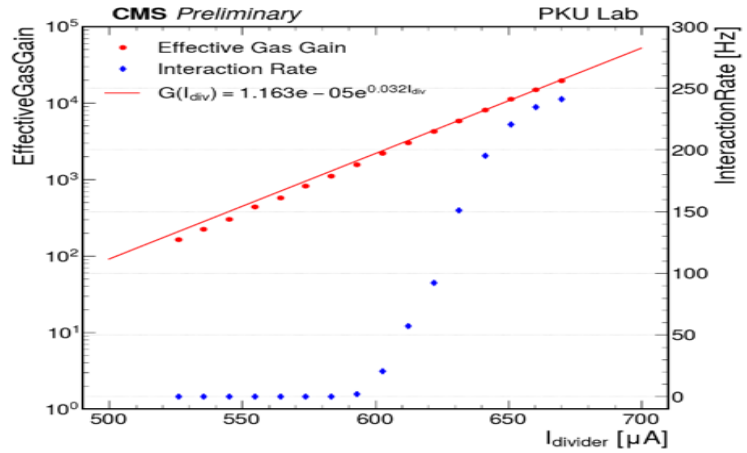
QC5:
effective gas gain





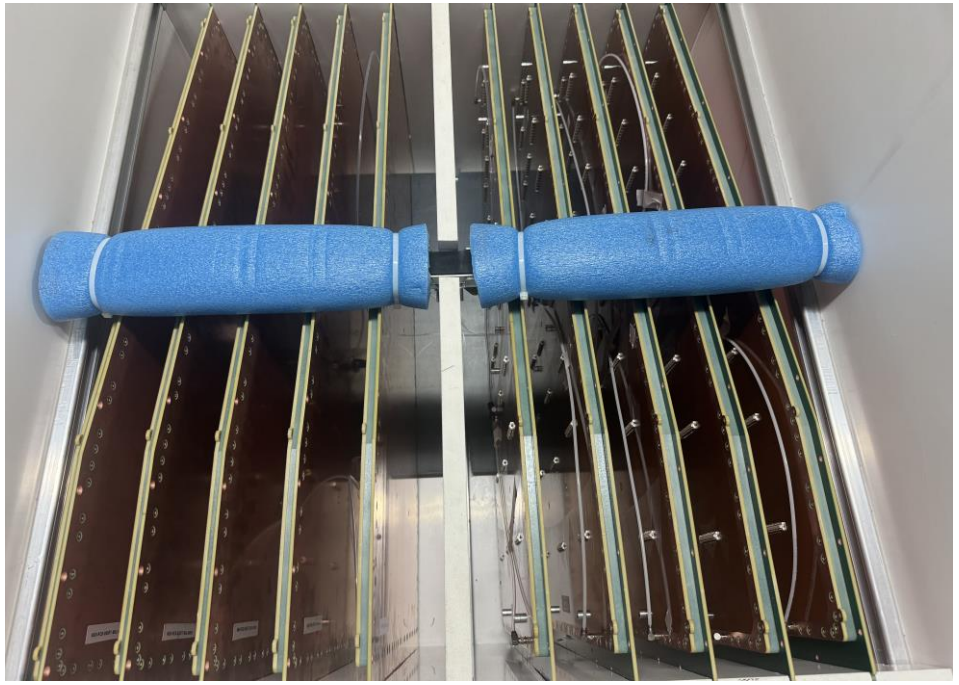
criteria: decrease < 7mbar/h (τ>3.7h)





CMS GEM upgrade: GEM module production

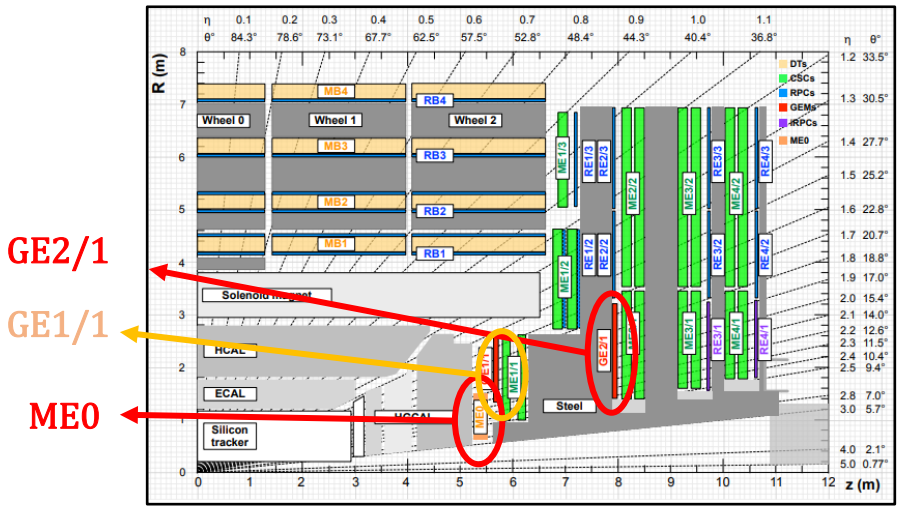
- The assembly of the first batch of 10 ME0 GEM at PKU is completed, all GEM modules have passed the QC tests, will be shipped to CERN at end of Nov.
- Next batch of 15 ME0 GEM production at PKU is scheduled in Feb. 2005, preparation is under way.



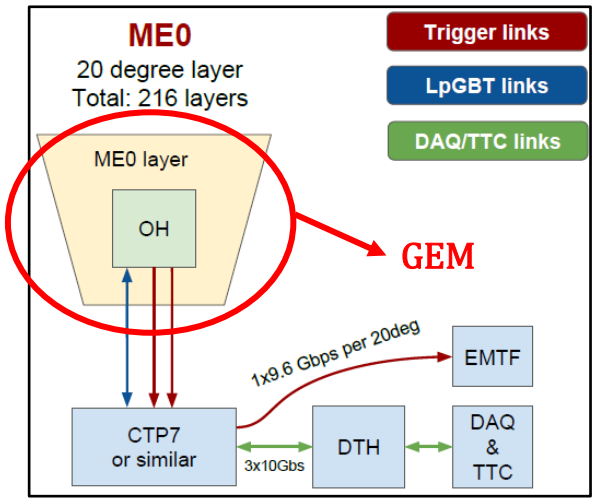
Performance expectation:

- 97% module efficiency
- $< 500\mu$rad space resolution
- 8-10 ns time resolution
- $\leq 15\%$ gain uniformity
- Work in high rate environment: 50kHz/cm^2
- Survive harsh radiation environment:7.9C/cm^2
- Discharge rate not impede performance or operation

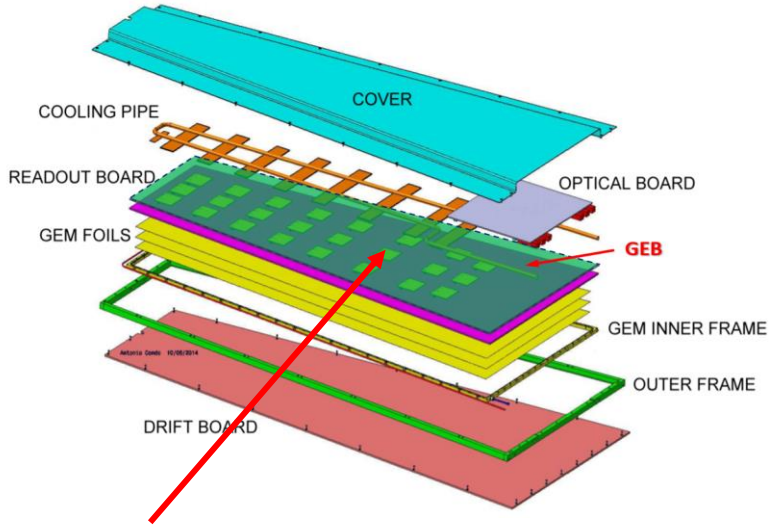
CMS GEM upgrade: ME0 GEB introduction



CMS detector cross section



DAQ system of CMS-GEM



GEB: front-end electronics board of upgraded CMS-GEM (GE1/1, GE2/1, ME0)

Function of GEB :

Carrier of front-end and back-end electronics system; front-end signal transmission carrier; provide direct shielding for GEM detectors

Tasks of CMS China group:

- Production and test of GE1/1 GEB
- Design、production and test of ME0 and GE2/1 GEB
- Development of automatic tester

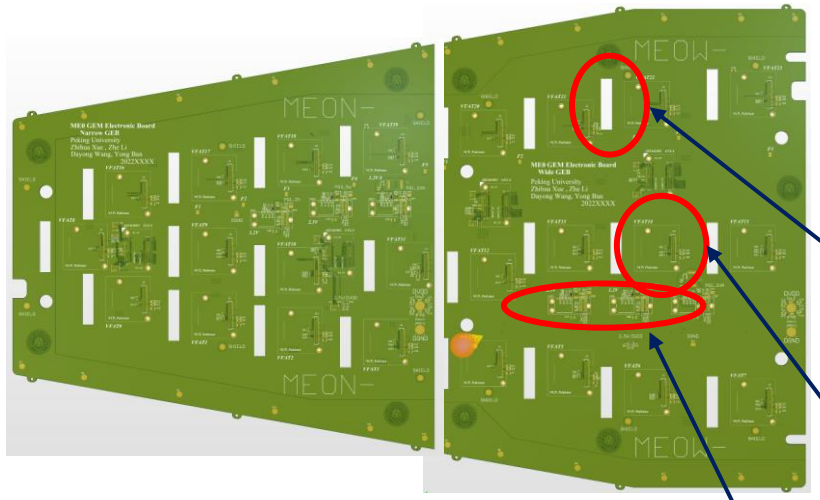
CMS GEM upgrade: ME0 GEB design

Design requirement:

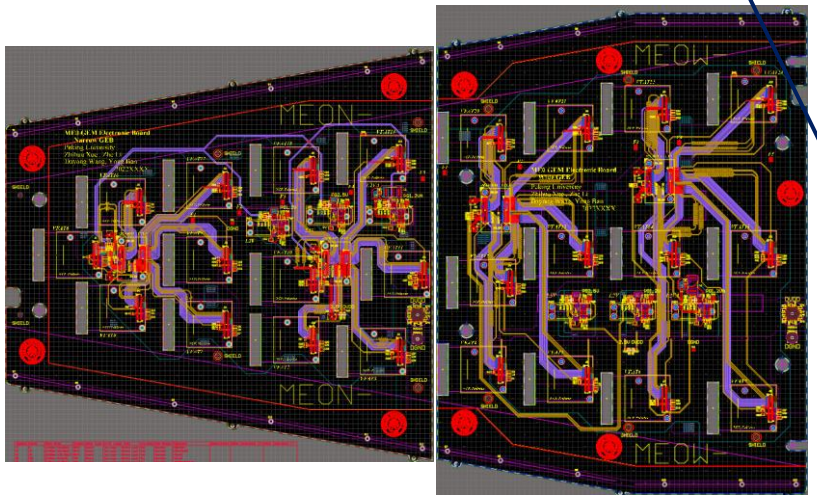
- Ensure signal integrity of Signal transmission, low BER (Bit Error Rate) and noise level
- Effective power distribution, shielding, and power, temperature monitor systems
- Good mechanical performance in terms of board, surface flatness and compatibility with other components and structure.

ME0 GEB design was finalized and approved by the collaboration **in 2022**

ME0 GEB production in Sinofast Shenzhen started in early 2023 completed in early 2024.



Narrow board Wide board



A set of GEB connects to:

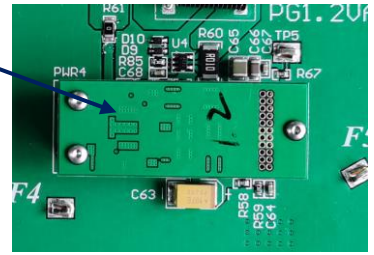
24 VFATs

The **VFAT chip** converts the signal on the readout strips into digital signal

4 ASIAGO boards (2 OH-CONN on each)

Electrical components on **OH board** convert the signal from GEB into an optical signal on the optical fiber

6 FEAST (1.2VA, 1.2VD and 2.5V)

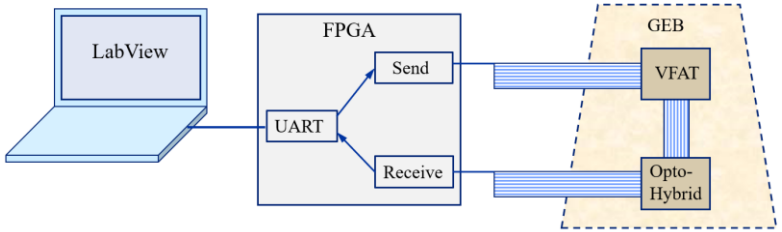


FEASTs provide voltage to chips on VFAT and OH board

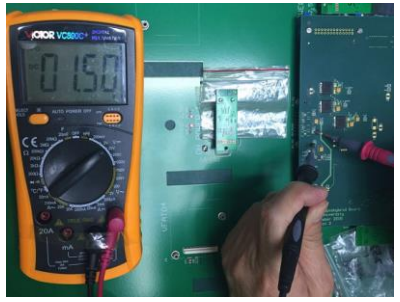
GEB with its function modules

CMS GEM upgrade: ME0 GEB production and test

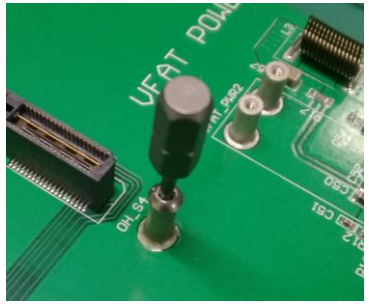
- **Milestone of ME0 GEBs production and test:**
  - 1st batch of 15 sets of ME0 GEBs produced on Jan. 2023, completed test at CERN in Apr. 2024
  - 240 sets of the remaining GEBs production completed in Feb. 2024, 2nd batch of 95 sets of GEBs tested in China and shipped to CERN in April 2024
  - 3rd batch of 145 sets of GEBs tested at China completed in Nov. 2024, shipped to CERN ~end of Nov. 2024
  - **Acceptance test at CERN:** make sure no damage in shipment.



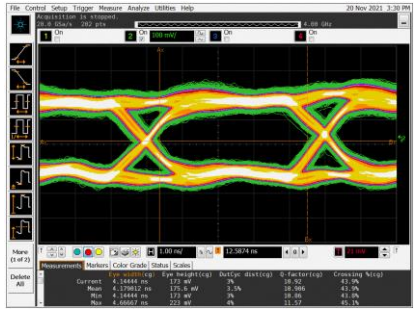
GEB Test (at Sinofast, FIT, Rice, CERN etc.):



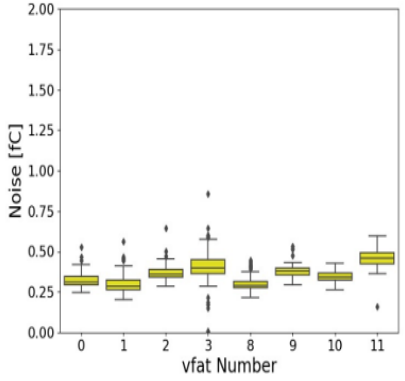
Power module test



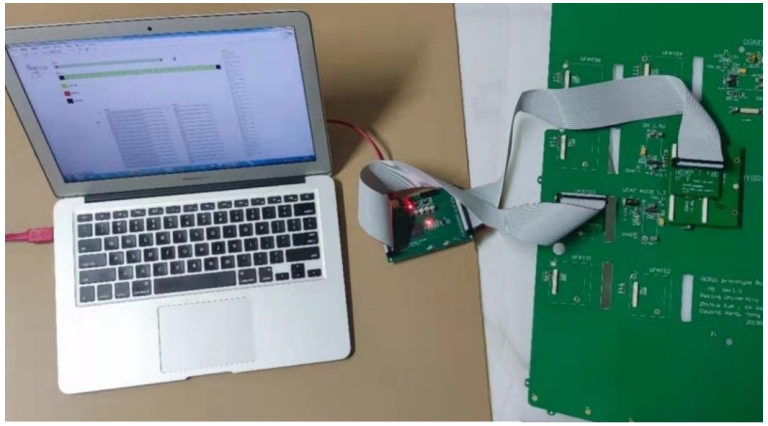
Mechanical compatibility test



eye diagram



noise level

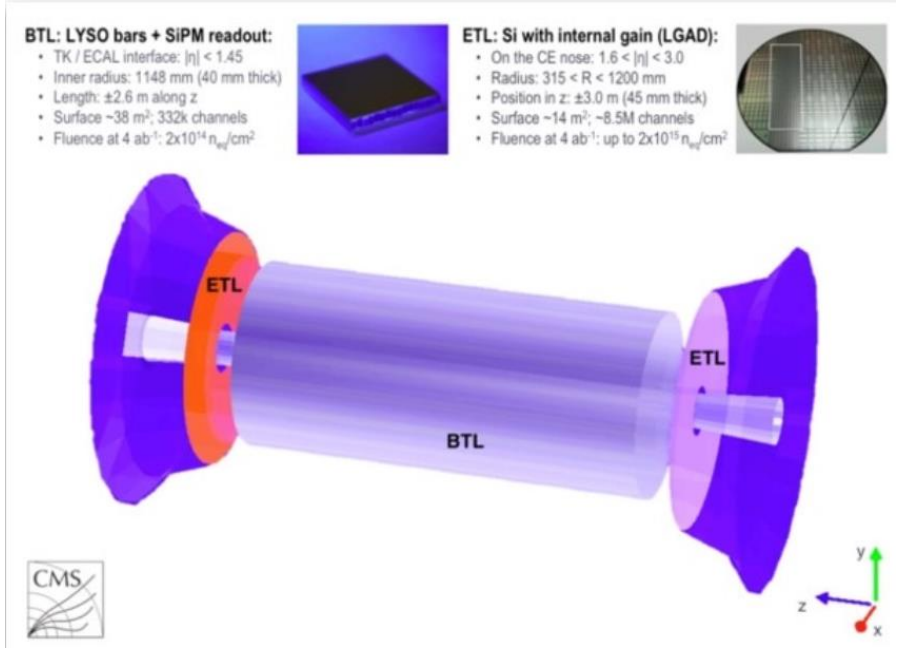


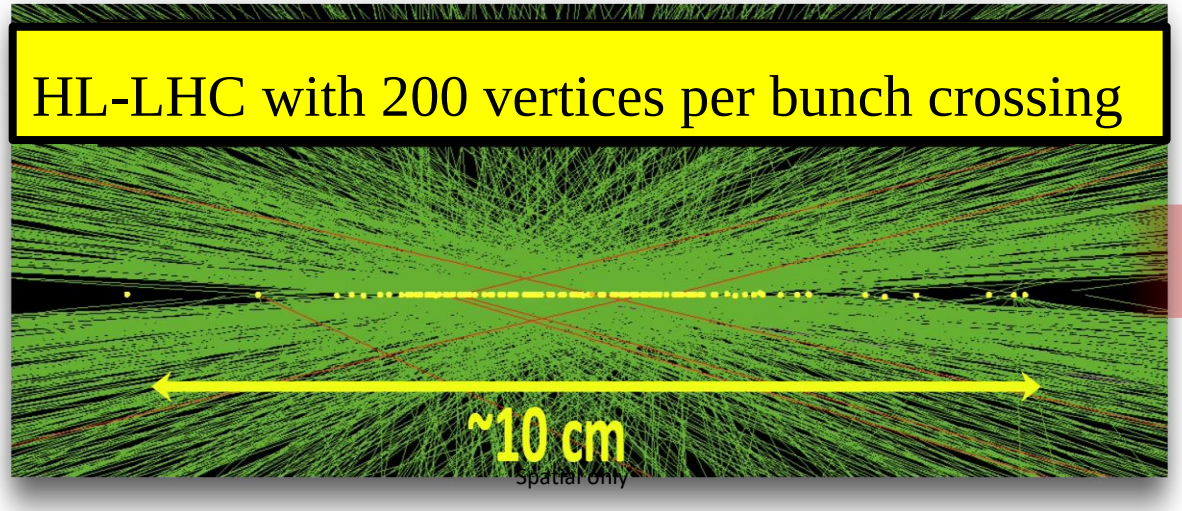
Signal connectivity test

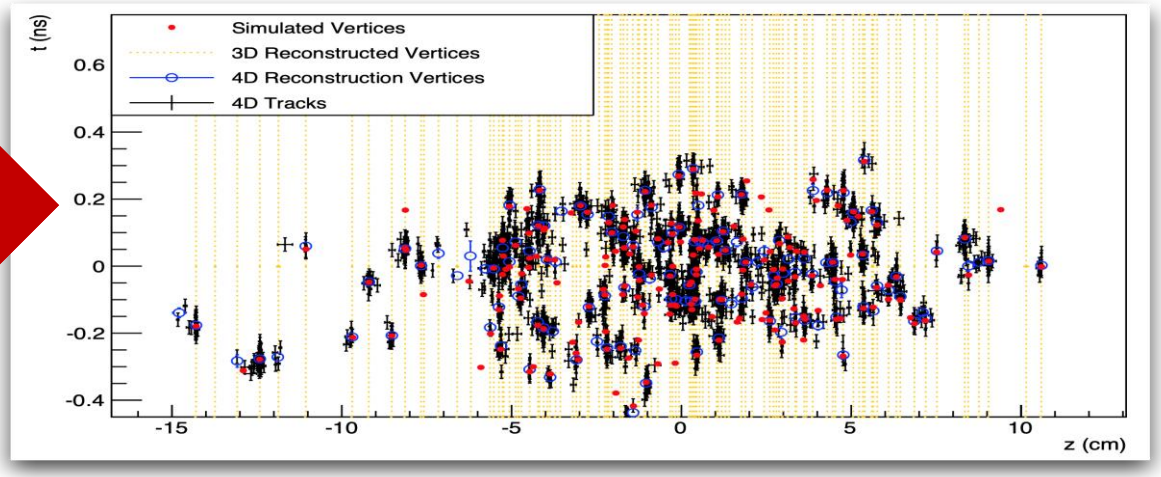
CMS MTD upgrade: CMS-China tasks

- MTD BTL is a novel timing detector dedicated in CMS barrel region aiming at mitigating the high pileup issue at HL-LHC

	CMS-MTD	ALICE-TOF	STAR-TOF	BESIII
Time resolution (ps)	30	56	80	68



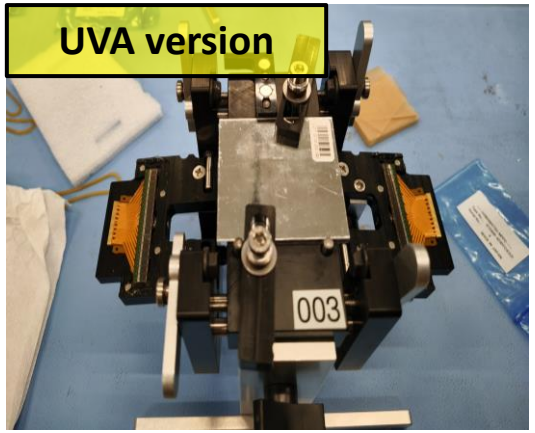


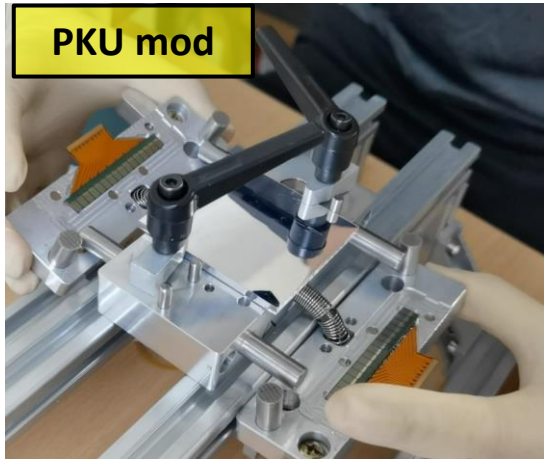


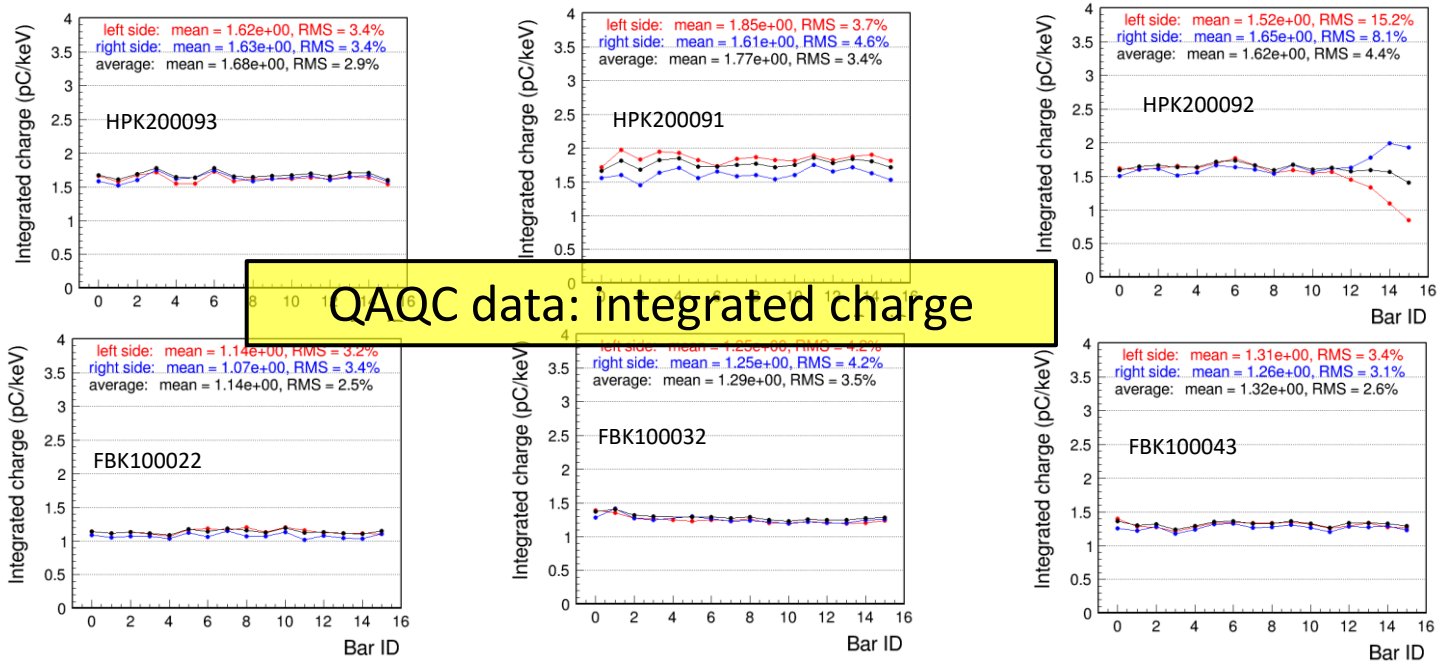
Spatial

CMS MTD upgrade: polish assembly tool

- Based UVA design further improve the assembly and reliability
  - Merge the two steps into one: preparing the glue + gluing
  - This can effectively avoid SiPM falling off the jig and reduce the time before gluing
- Increase the thickness of the stencil





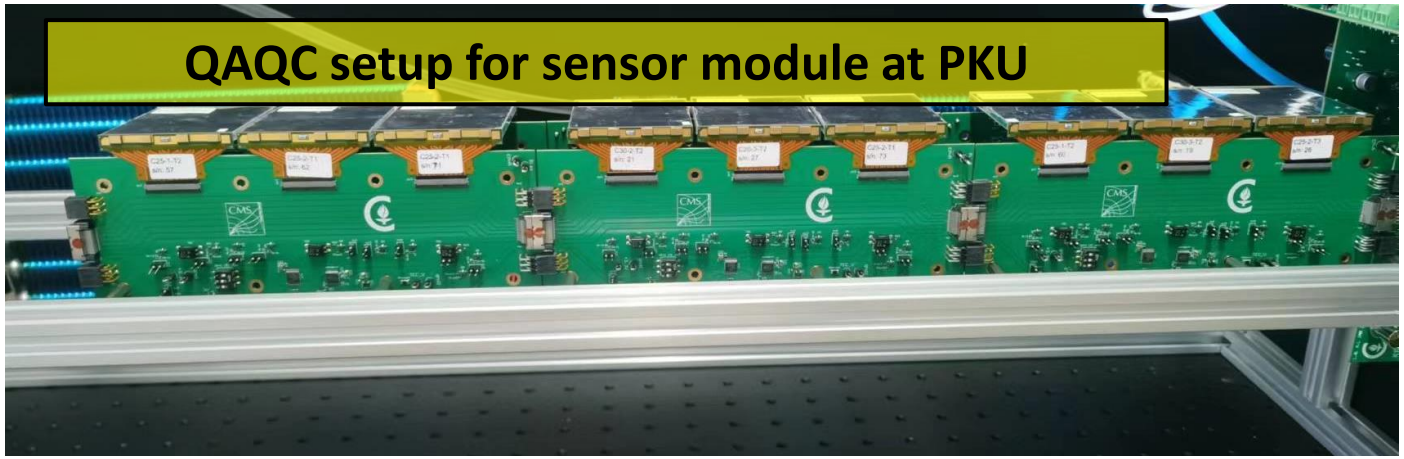


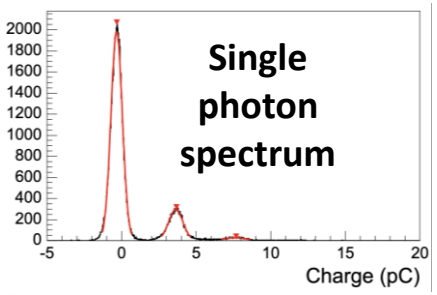
QAQC data: integrated charge

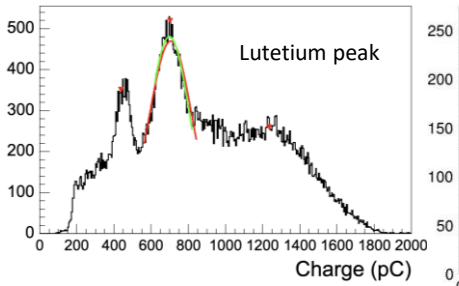
Polishing the tool at CERN

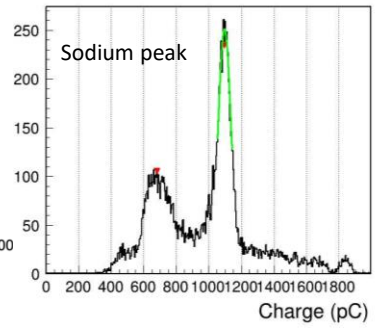
CMS MTD upgrade: QAQC of sensor modules

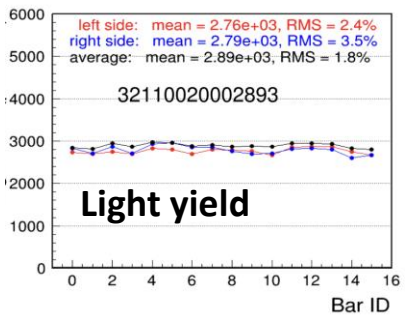
- The QAQC system for sensor modules is fully established at PKU
  - Automation of the transportation of radiation sources
  - Automation of data taking
  - Temperature control
  - Light shield

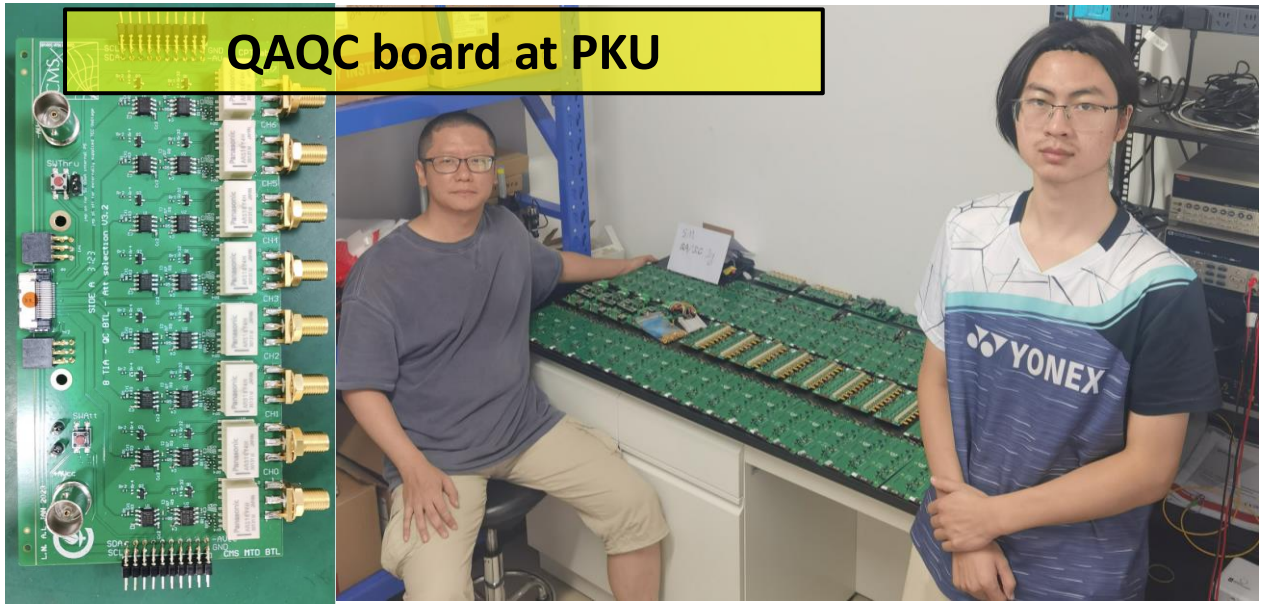








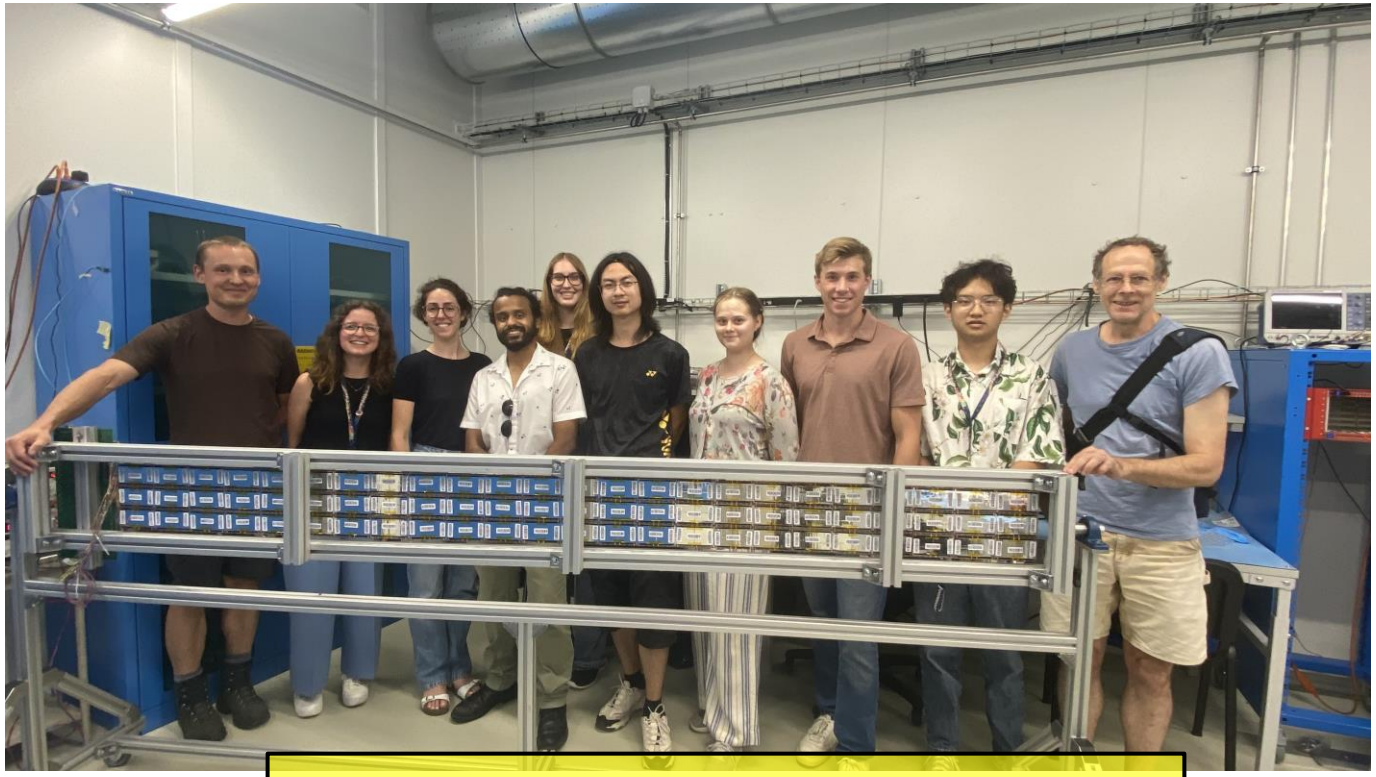




CMS MTD upgrade: first RU and first tray

- Made first readout unit (RU) at CERN in March 2024
- Completed first tray at CERN in July 2024

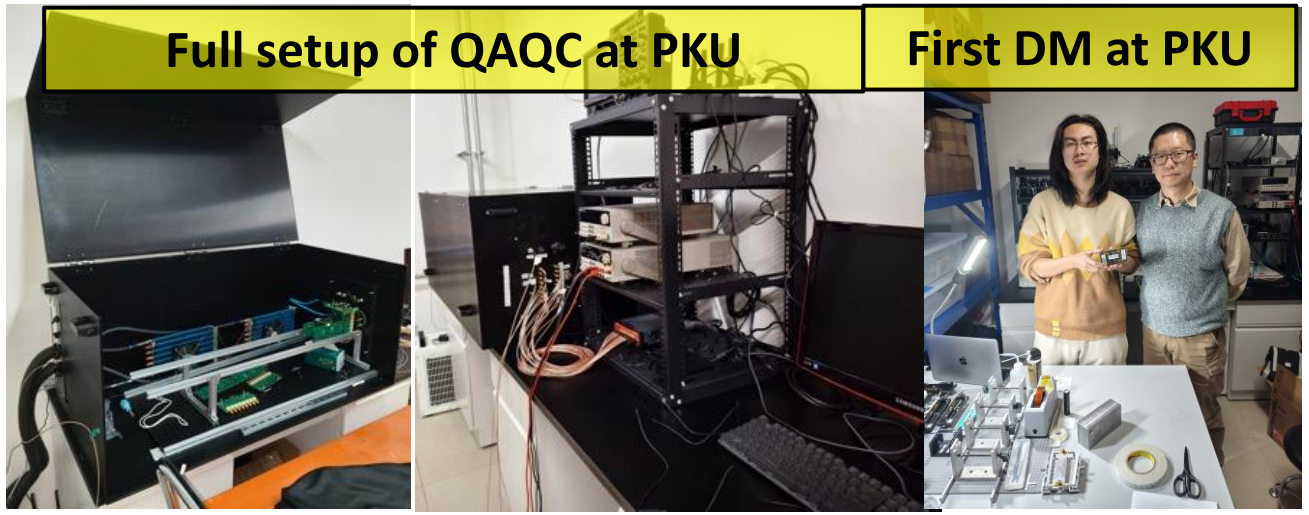
First RU at CERN

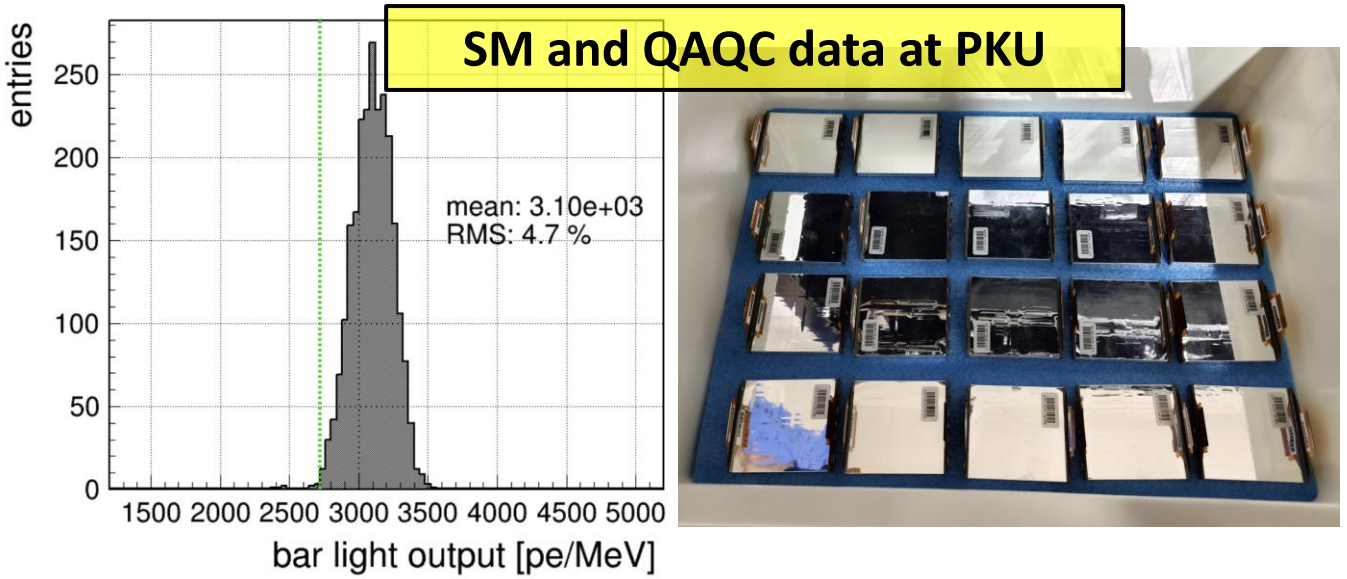


First tray at CERN

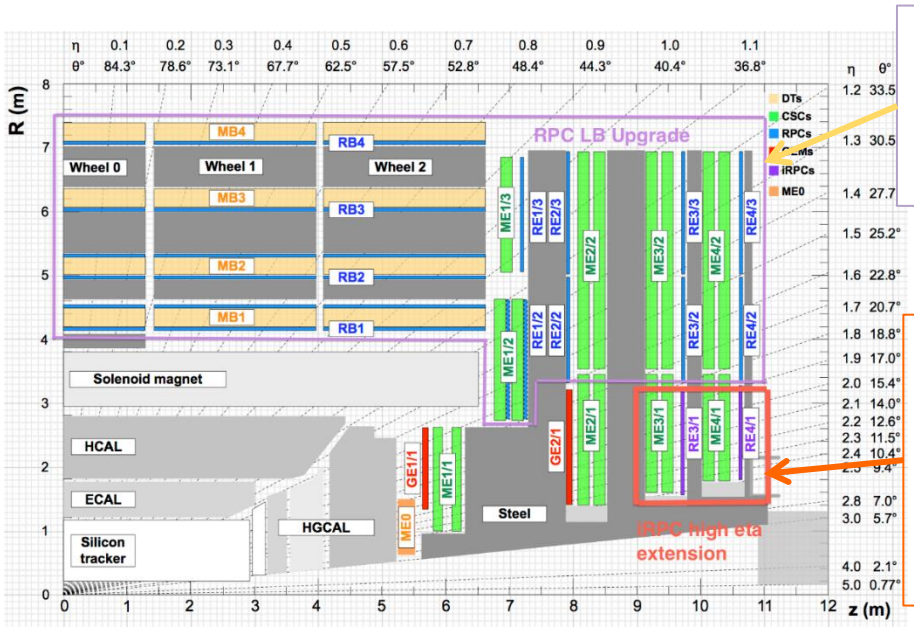
CMS MTD upgrade: progress

- **MTD BTL design is basically completed and we enter the era of mass production**
  - Had defined well the assembly techniques for sensor modules
  - Completed most parts of QAQC setup for sensor modules (signal yield with radiation sources)
  - Polishing the assembly techniques for detector modules
  - Progressing with the QAQC setup for detector module (thermal tests)
- End 2023, complete first small batches of sensor modules
- Sep 2024, started **mass production officially**
- Oct 2024, completed the assembly of 224 sensor modules and the first detector module at PKU



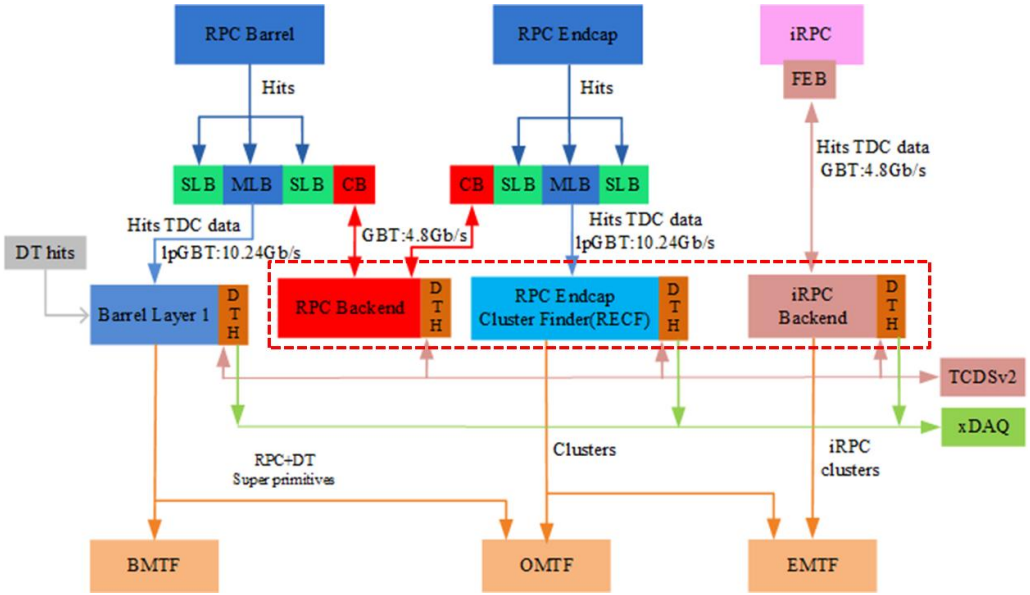


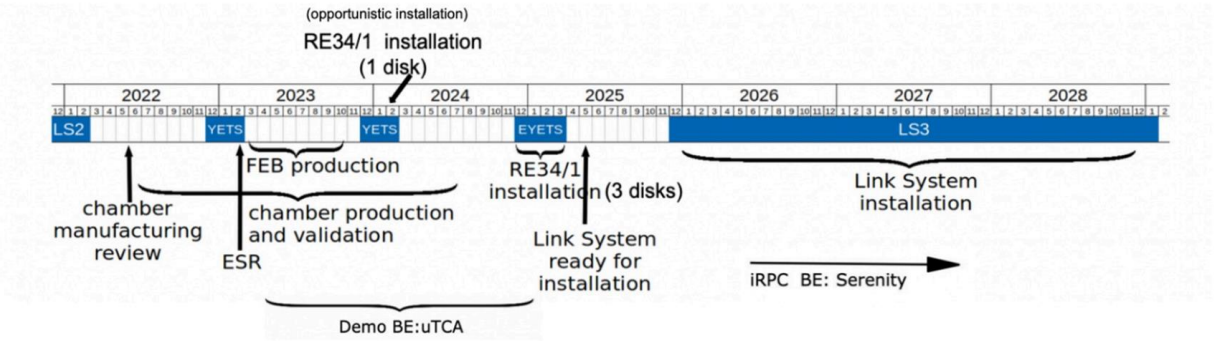
CMS iRPC/RPC upgrade: tasks



Upgrade of Link System to improve timing resolution for existing RPC ($|\eta| < 1.9$)

Extend the RPC coverage up to $|\eta|$ = 2.4 to increase redundancy in high eta region in stations 3 and 4





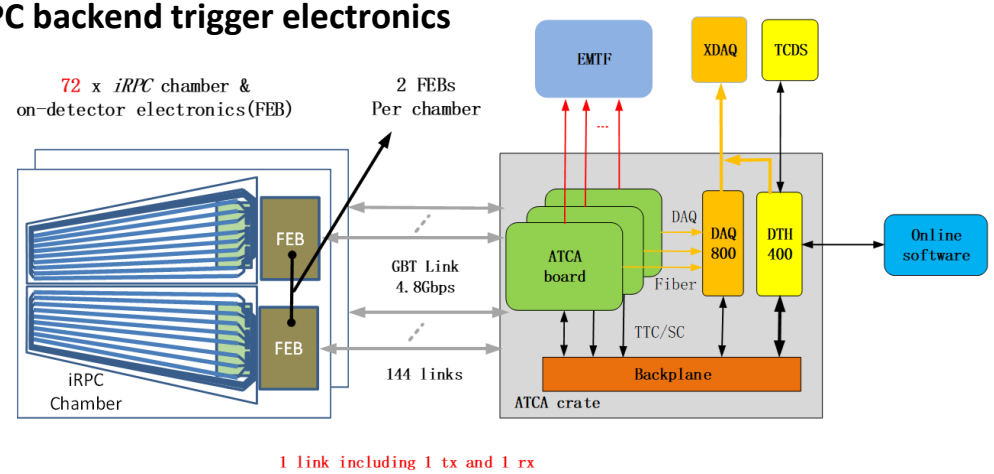
- **iRPC BackEnd Trigger(iRPC BE/TRG):**
  - Fast/Slow control(TTC),
  - Monitor
  - Data readout,
  - Trigger Primitive(Cluster) Generation
- **RPC Endcap Cluster Finder(RECF):**
  - Data readout
  - Trigger Primitive(Cluster) Generation
  - TP data Fanout

- **RPC backend:**
  - Fast control(TTC)
  - Slow control
  - monitor

CMS iRPC/RPC upgrade: progress

Completed the system design based on ATCA frame, and the mapping of FE/BE trigger electronics.

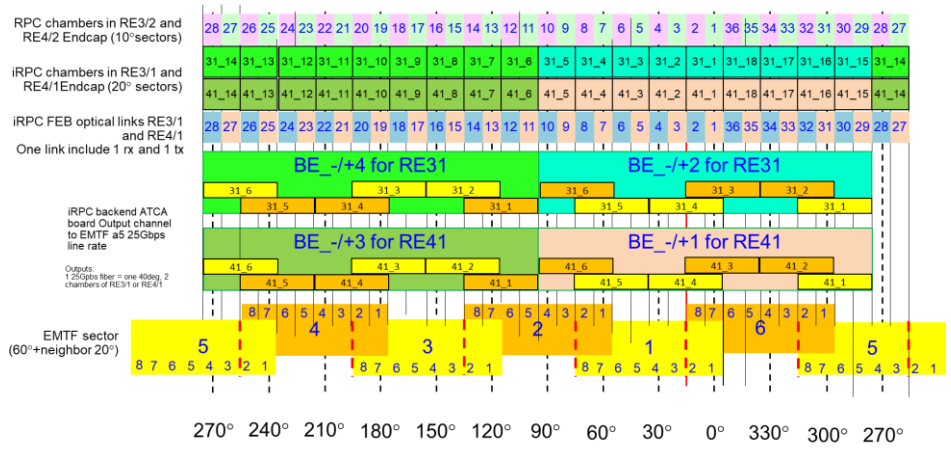
iRPC backend trigger electronics



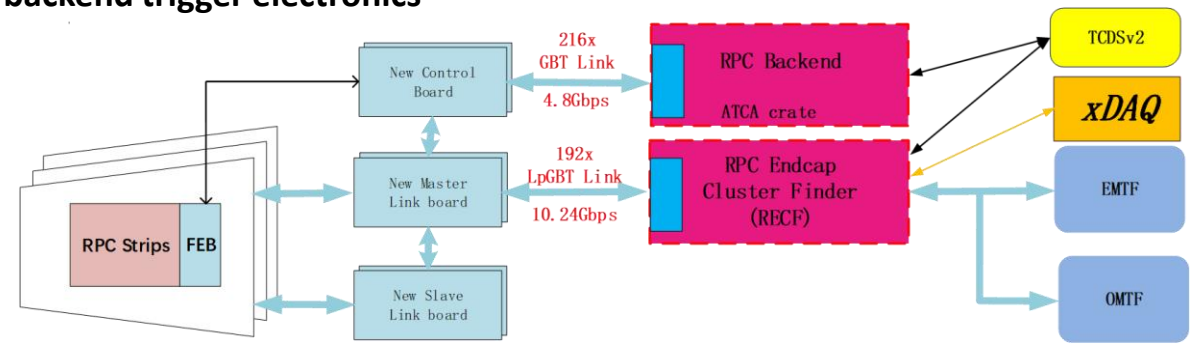
1 link including 1 tx and 1 rx

iRPC FEB-BE-EMTF mapping(update)

20240213 version for 2024 CMS ESR

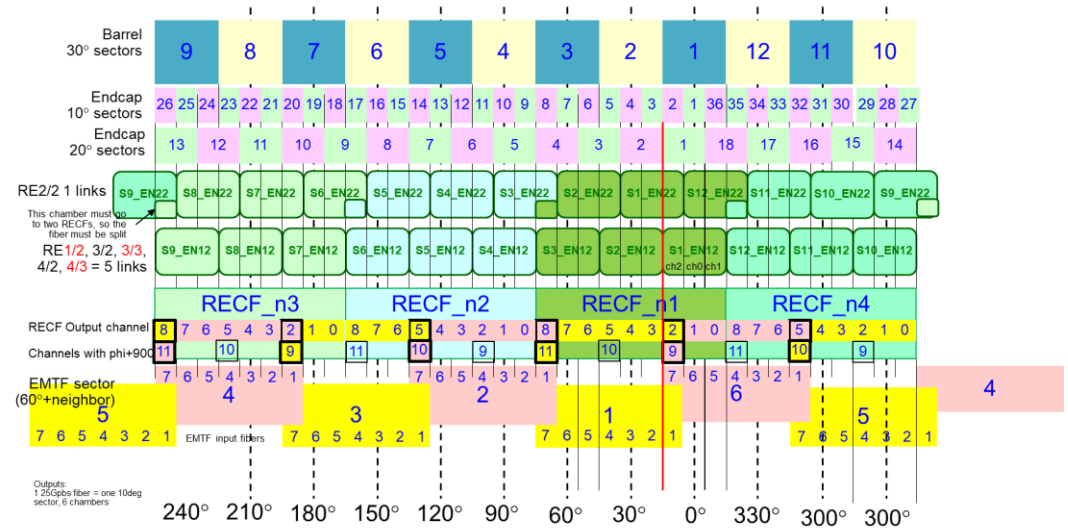


RPC backend trigger electronics



Phase-II one side RPC-RECF-EMTF connection(update)

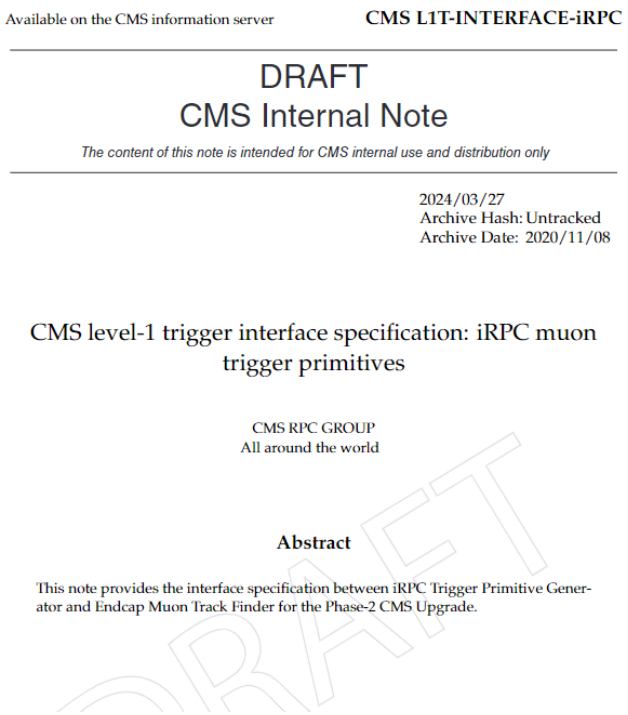
20240130 version for 2024 CMS ESR



CMS iRPC/RPC upgrade: RPC BE/TRG electronics ESR

Completed the 1st version of the mapping scheme of RPC BE/TRG electronics and ENTF, approved in CMS ESR Review on 15 Feb. 2024.

→ (https://indico.cern.ch/event/1357604/)



Available on the CMS information server **CMS L1T-INTERFACE-iRPC**

DRAFT
CMS Internal Note

The content of this note is intended for CMS internal use and distribution only

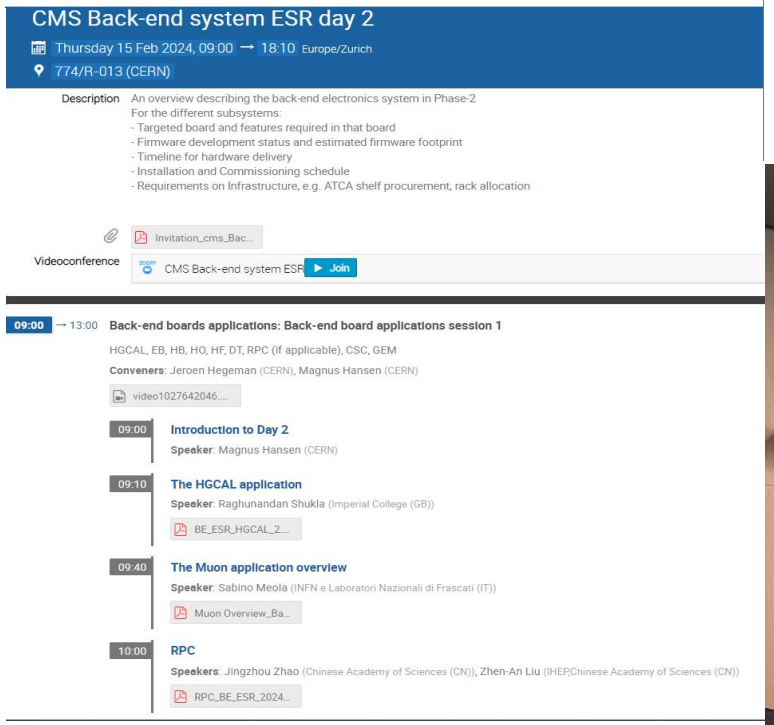
2024/03/27
Archive Hash: Untracked
Archive Date: 2020/11/08

CMS level-1 trigger interface specification: iRPC muon trigger primitives

CMS RPC GROUP
All around the world

Abstract

This note provides the interface specification between iRPC Trigger Primitive Generator and Endcap Muon Track Finder for the Phase-2 CMS Upgrade.



CMS Back-end system ESR day 2

Thursday 15 Feb 2024, 09:00 → 18:10 Europe/Zurich

774/R-013 (CERN)

Description: An overview describing the back-end electronics system in Phase-2
For the different subsystems:
- Targeted board and features required in that board
- Firmware development status and estimated firmware footprint
- Timeline for hardware delivery
- Installation and Commissioning schedule
- Requirements on Infrastructure, e.g. ATCA shelf procurement, rack allocation

Invitation_cms_Bac...

Videoconference: CMS Back-end system ESR — Join

09:00 → 13:00 **Back-end boards applications: Back-end board applications session 1**

HGCAL, EB, HB, HO, HF, DT, RPC (if applicable), CSC, GEM

Conveners: Jeroen Hegeman (CERN), Magnus Hansen (CERN)

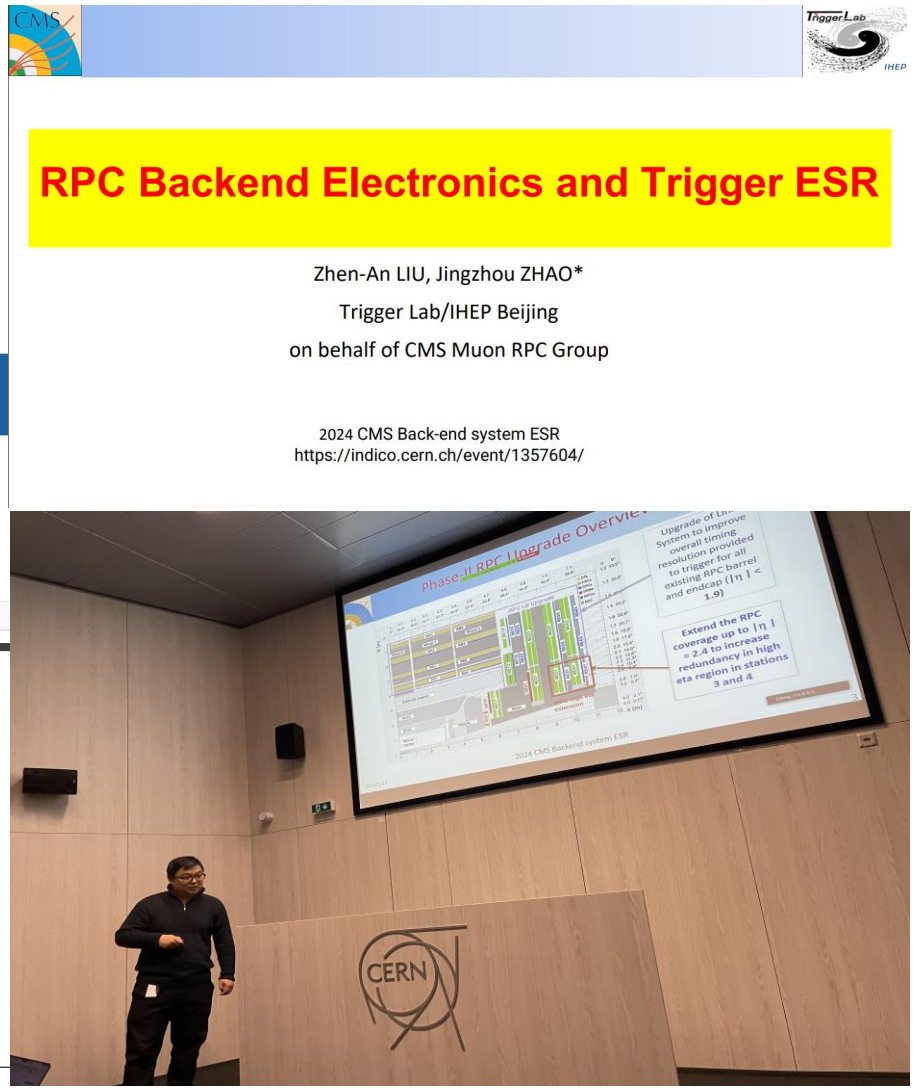
video1027642046....

09:00 **Introduction to Day 2**
Speaker: Magnus Hansen (CERN)

09:10 **The HGCAL application**
Speaker: Raghunandan Shukla (Imperial College (GB))
BE_ESR_HGCAL_2....

09:40 **The Muon application overview**
Speaker: Sabino Meola (INFN e Laboratori Nazionali di Frascati (IT))
Muon Overview_Ba...

10:00 **RPC**
Speakers: Jingzhou Zhao (Chinese Academy of Sciences (CN)), Zhen-An Liu (IHEP,Chinese Academy of Sciences (CN))
RPC_BE_ESR_2024...



RPC Backend Electronics and Trigger ESR

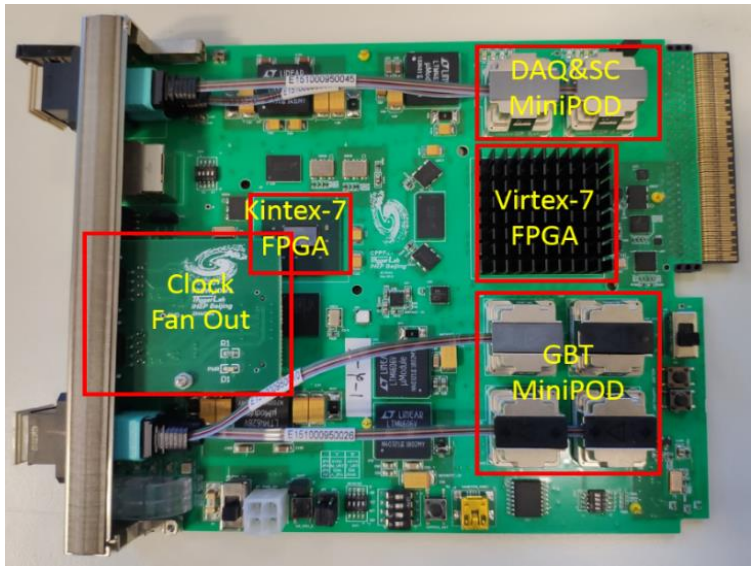
Zhen-An LIU, Jingzhou ZHAO*
Trigger Lab/IHEP Beijing
on behalf of CMS Muon RPC Group

2024 CMS Back-end system ESR
https://indico.cern.ch/event/1357604/

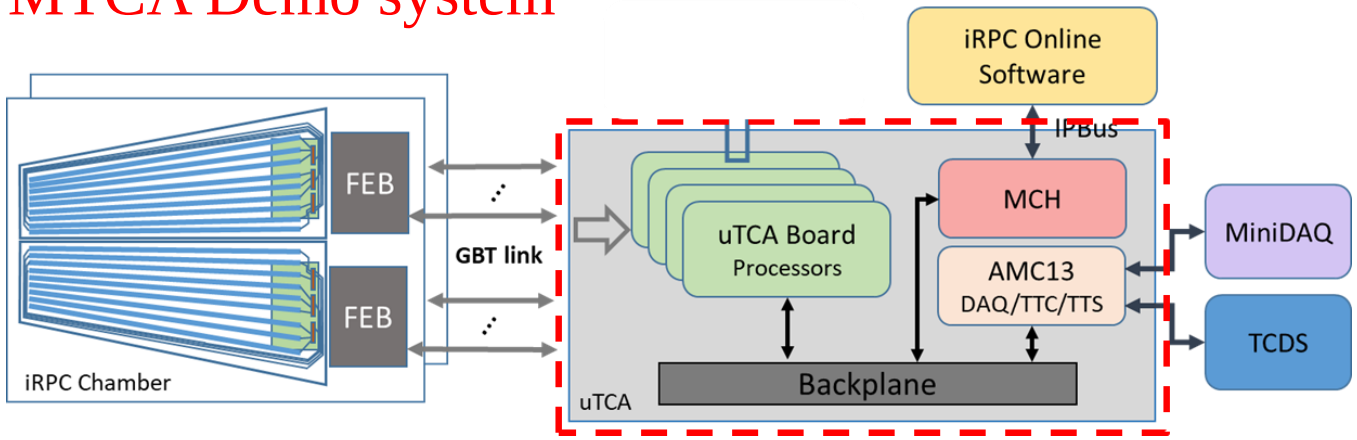
CMS iRPC/RPC upgrade: backend trigger electronics

Development of RPC BE/TRG electronics MTCA Demo system

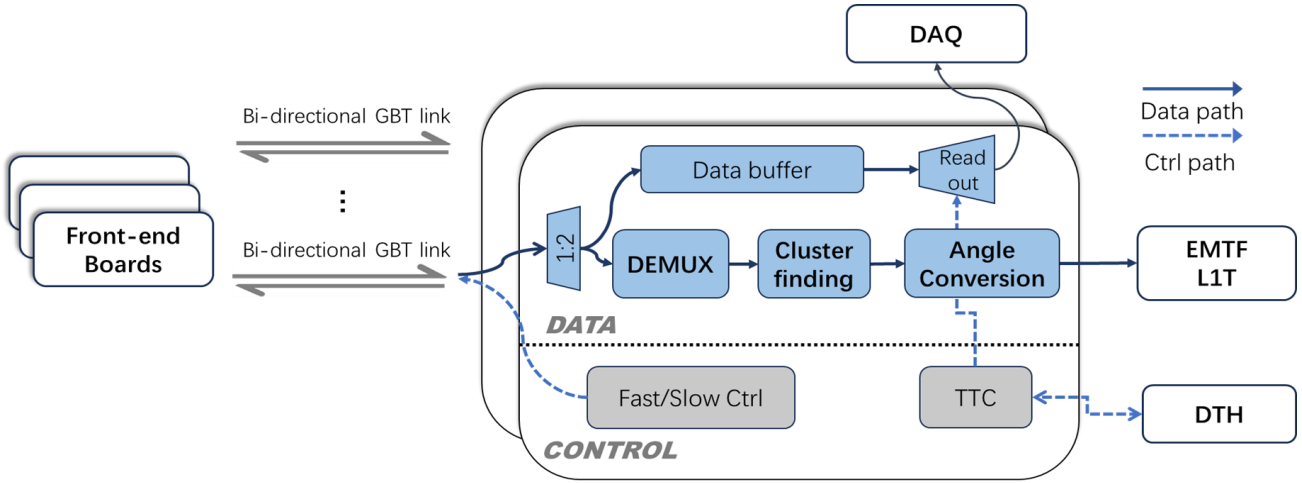
- Before the availability of last version ATCA serenity board, we developed BE/TRG electronics Demo system based on MTCA for system study, using the BE/TRG board-designed by IHEP trigger group
- The system was used in the studies of CSP data sending scheme, cluster finding algorithm with cosmic ray. It can be used in detector performance study as well.



BE/TRG board designed by IHEP trigger group



Framework of Demo system for iRPC BE/TRG electronics based on MTCA

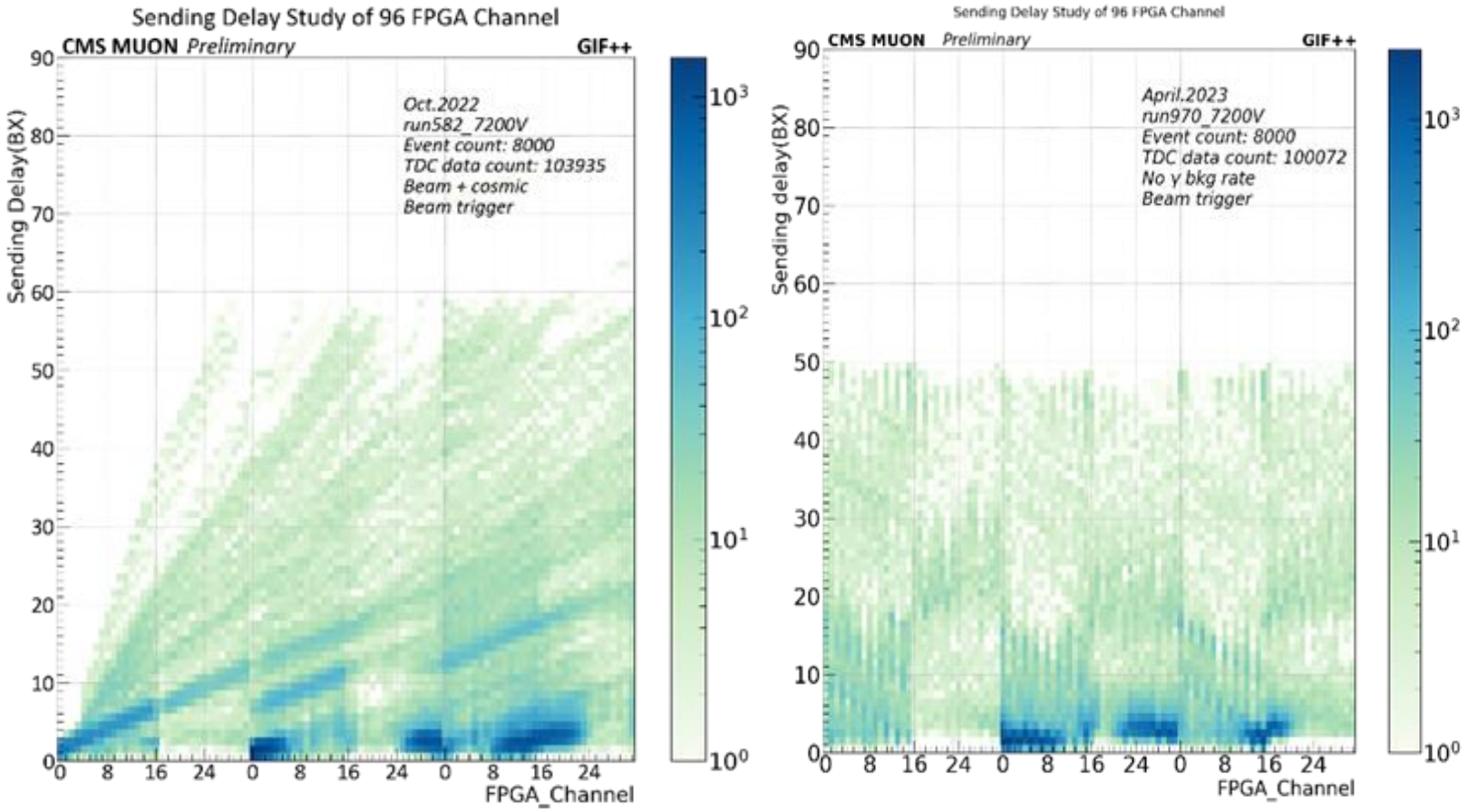


Framework of iRPC BE/TRG electronics firmware

CMS iRPC/RPC upgrade: CSP data sending

CSP data sending mechanism was adopted by the collaboration

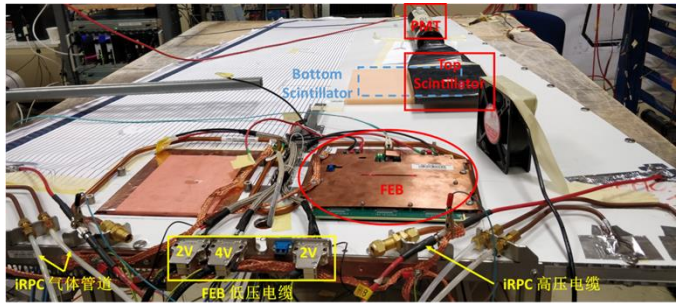
- Check-Sort-Push （CSP）mechanism was proposed by IHEP trigger team to deal with iRPC data sending characteristics
- Based on time priority principle, the sending delay of each channel was balanced, the cluster generation delay was also decreased
- The CSP mechanism was proposed and approved by the collaboration



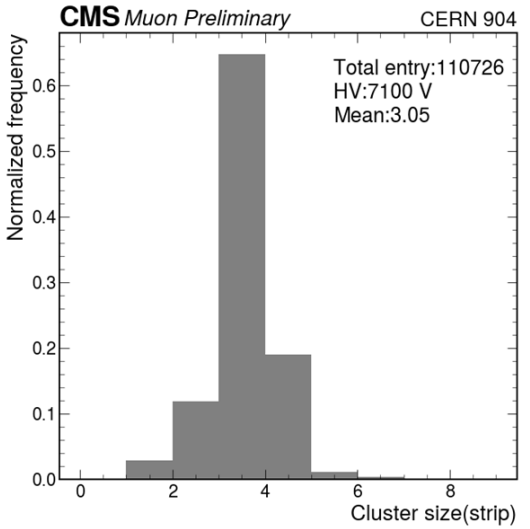
CMS iRPC/RPC upgrade: Cluster finding

Important progress in cluster finding algorithm study

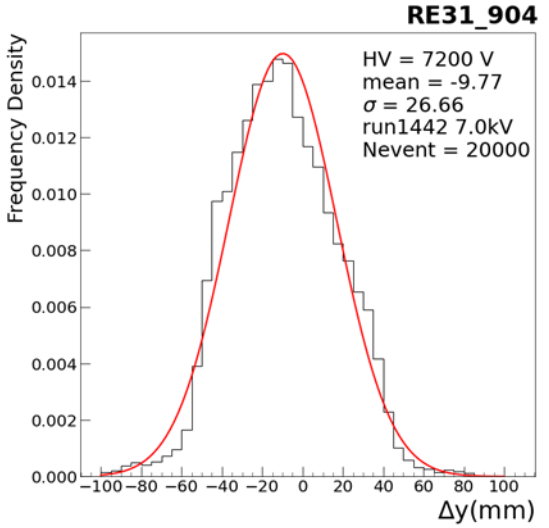
A cluster finding scheme was defined by study the characteristics of the cluster, and the comparison of different approaches. The scheme was validated primirarily by cosmic and teat beam results.



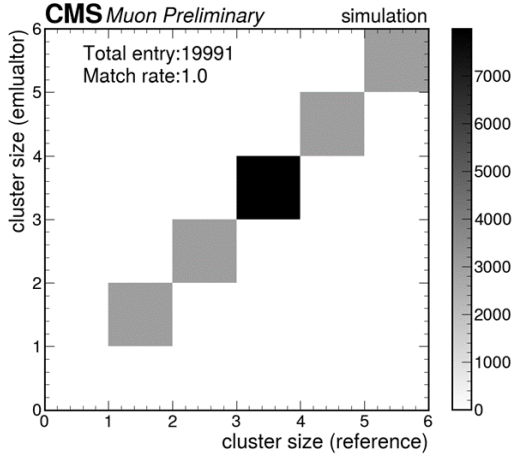
Cosmic ray study platform for cluster study



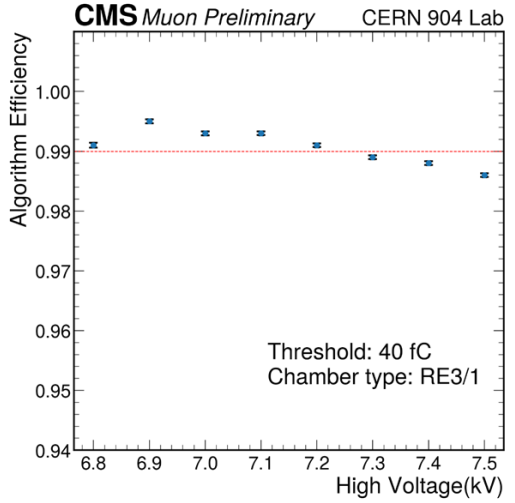
Cluster size in cosmic rays



Special resolution at 16 radial divisions



Matching of cluster size with data



Efficiency of cluster finding in cosmic ray

Phase II upgrade of CMS China: Summary and Plan

HGCal:

- 90% of the area CuW baseplate will be produced in China. K-contract signing and tendering are in progress. 30 CuW baseplates are produced in China this yearisIrradiation test is in progress
- 40 HGCal LD full silicon modules are produced this year. IHEP is the first and only one who produce pre-production module so far. All modules performed well in CERN beam test
- IHEP MAC is ramping-up for pre-production, towards the production rate to 16 modules/day.

GEM:

- PKU CMS-GEM production site operates well, 10 ME0 GEM were successfully assembled and tested this year. Next batch of 25 ME0 GEM is scheduled to be produced from Feb. 2025
- The design, production and test of all CMS-GEM GEB are successfully completed by the end of Oct. 2024 (except the acceptance test of the last batches of ME0 GEBs at CERN)
- The investigation of ME0 stack structure production in China is under way.

Phase II upgrade of CMS China: Summary and Plan

MTD:

- The QA/QC system for sensor modules is fully established at PKU MTD production site. Made first readout unit (RU) and first tray at CERN this year.
- MTD BTL design is basically completed and the mass production started, completed the assembly of 224 sensor modules and the first detector module at PKU by Oct.

iRPC/RPC:

- Completed the system design of BE/TRG based on ATCA frame, approved by CMS ESR review.
- Developed RPC BE/TRG electronics MTCA Demo system, validated CSP data sending mechanism which was adopted by the collaboration, and used in cluster finding study with cosmic ray data.

In summary, CMS China group completed all shared annual tasks on schedule, all upgrade works are pushed forward steadily in accordance with CMS overall plan.

Thanks!