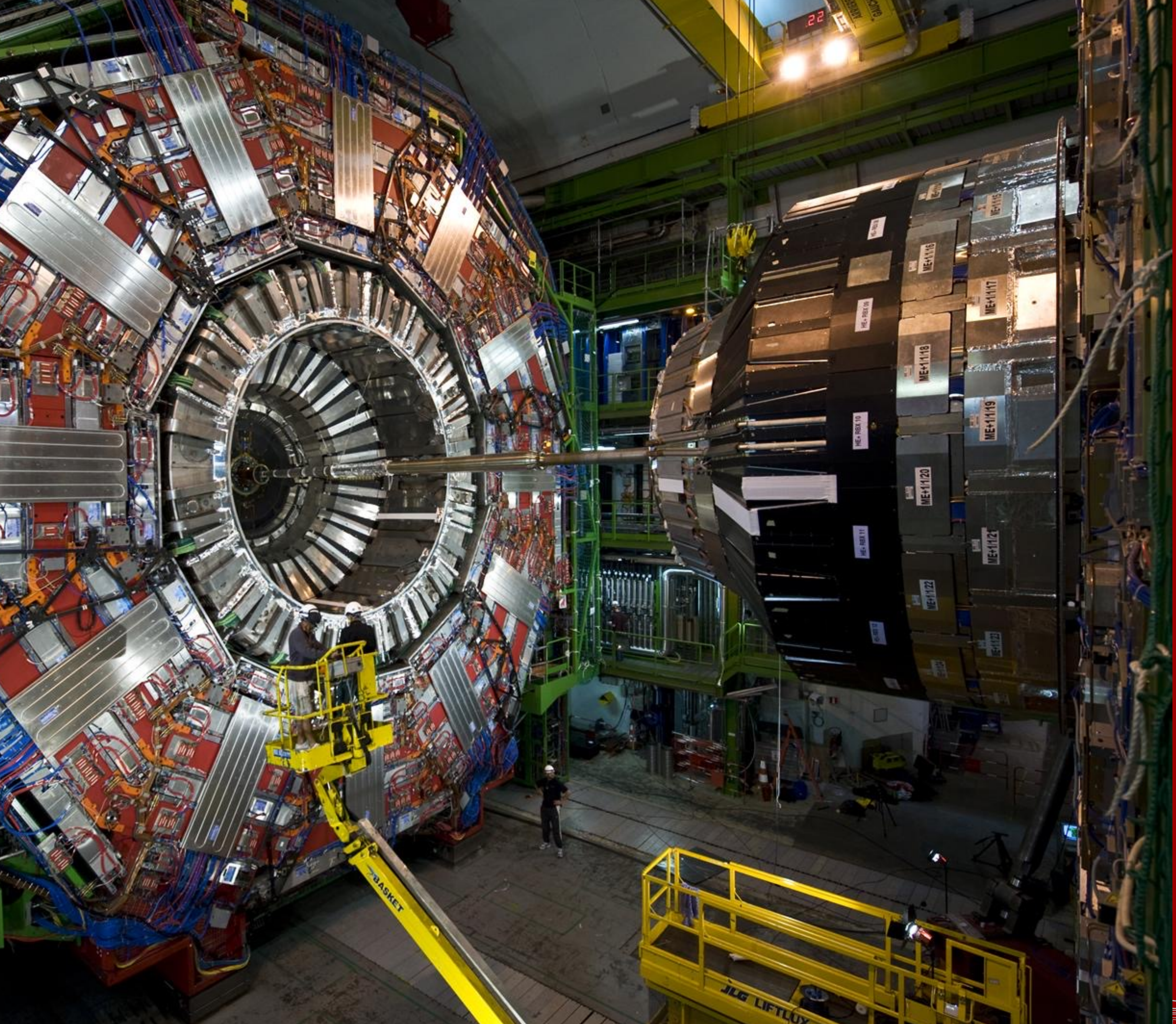

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# CMS Phase-II Upgrade

Xiaohu SUN
on behalf of CMS-China

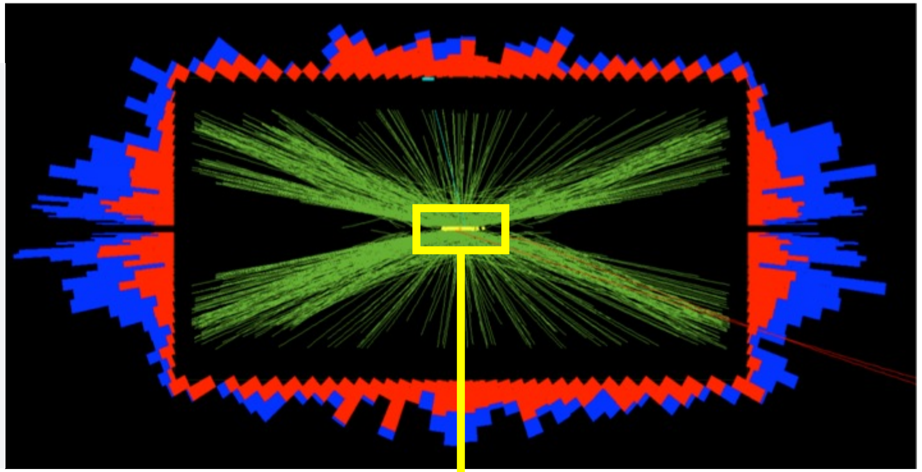
2022.11.27

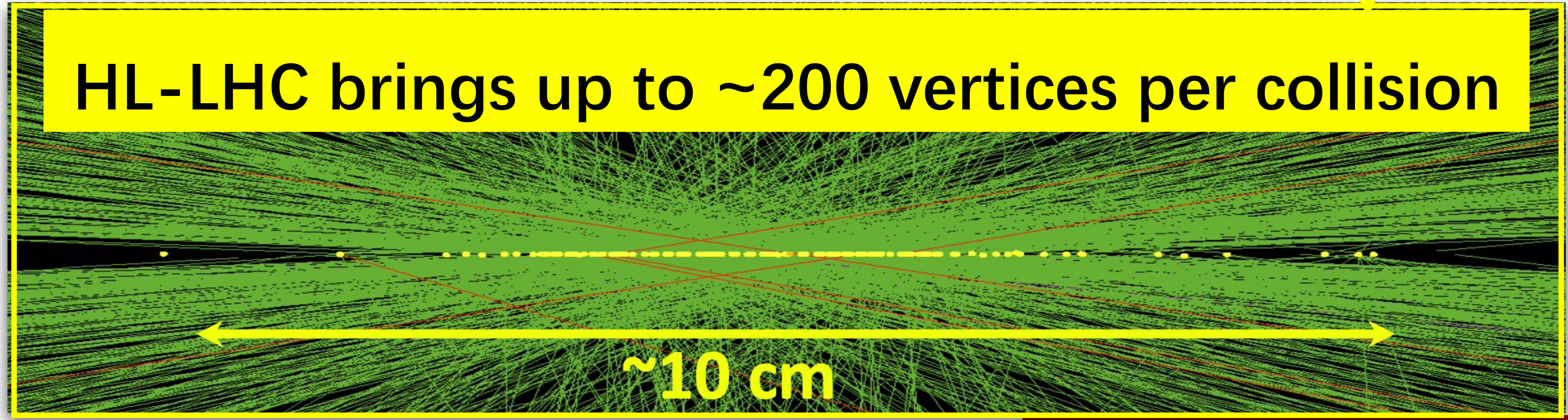
# Why upgrade the CMS detector?

The challenging HL-LHC data-taking

## It is all about the instantaneous luminosity!

| LHC | | HL-LHC |
|---|---|---|
| $2 \times 10^{34}\ s^{-1}\ cm^{-2}$ | → | up to $7.5 \times 10^{34}\ s^{-1}\ cm^{-2}$ |
| $O(10^{14}\ neq/cm^2)$ | | $>O(10^{15}\ neq/cm^2)$ |
| O(40) | | 140-200 |





# The Phase-II upgrade projects

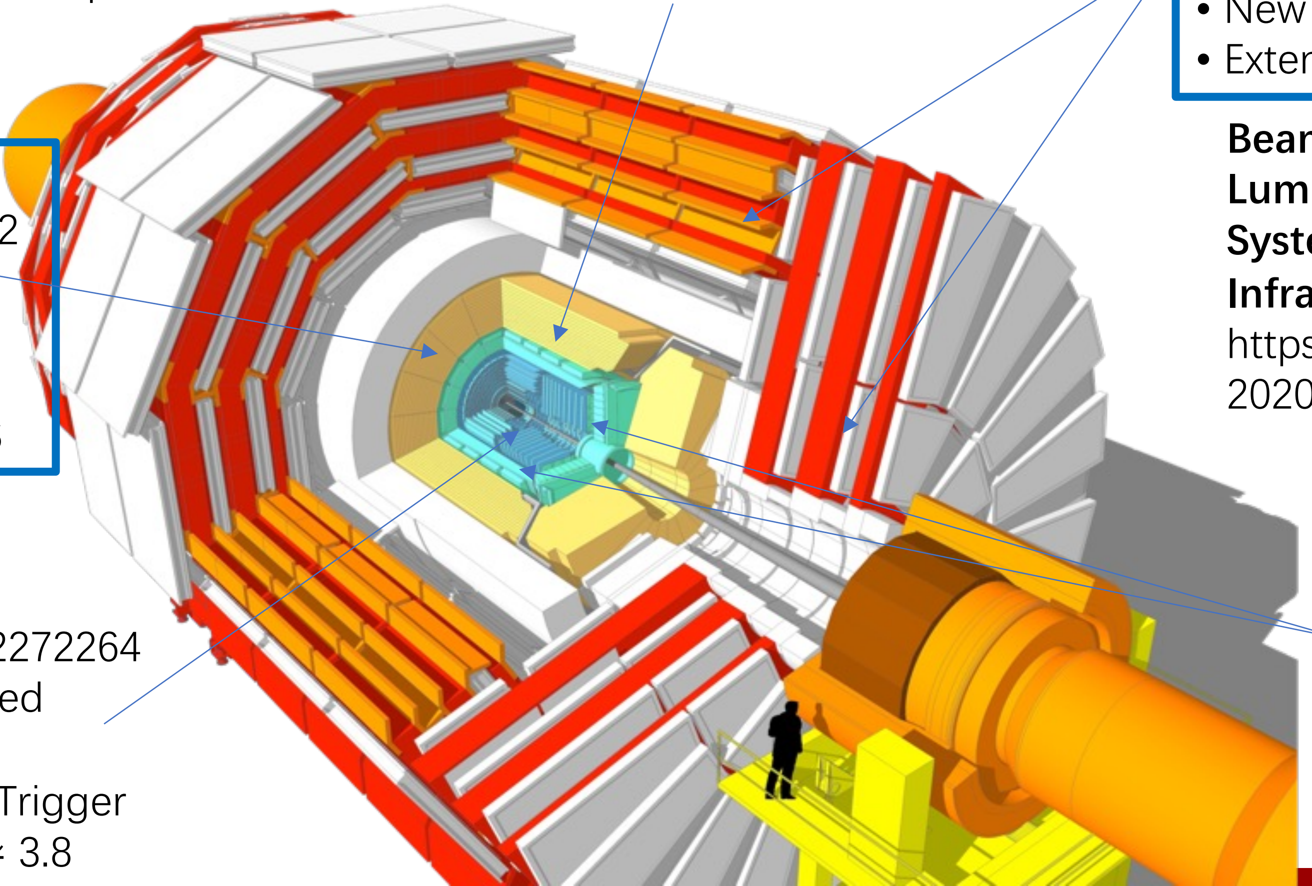


**L1-Trigger HLT/DAQ**
https://cds.cern.ch/record/2714892
https://cds.cern.ch/record/2759072
- Tracks in L1-Trigger at 40 MHz
- PFlow selection 750 kHz L1 output
- HLT output 7.5 kHz
- 40 MHz data scouting

**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



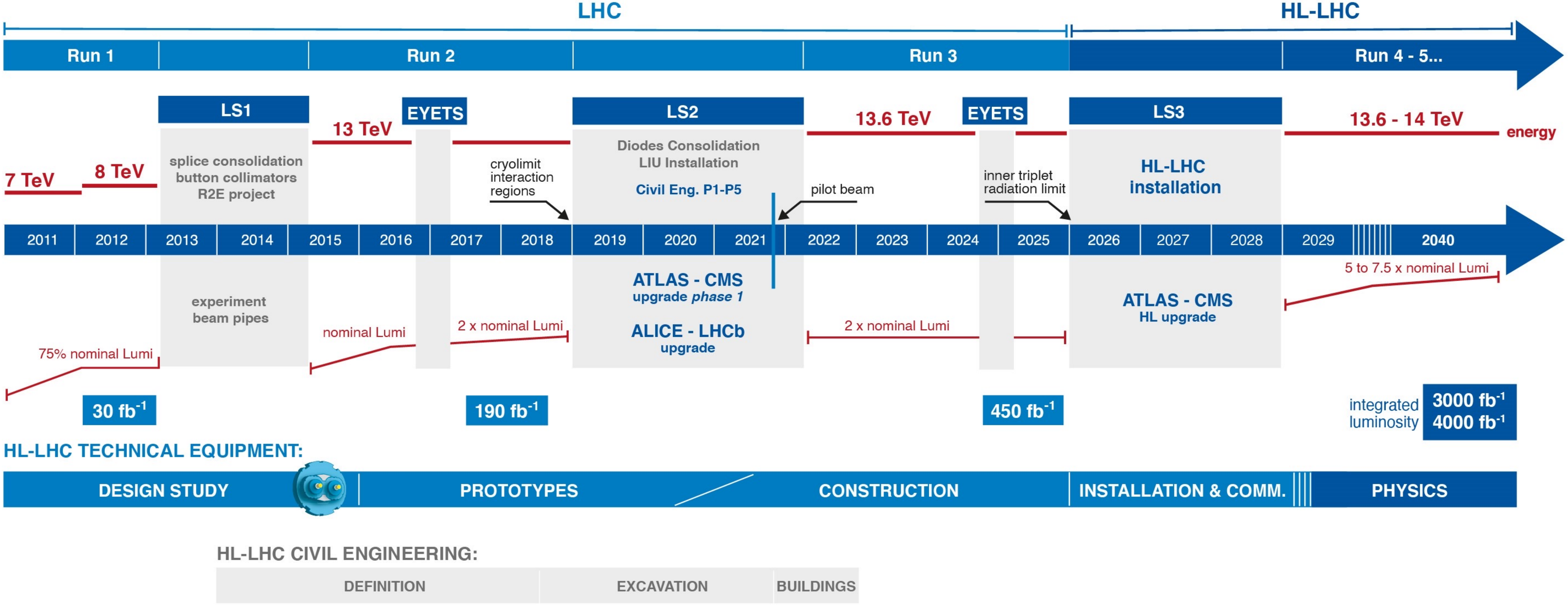
**Beam Radiation Instr. and Luminosity, and Common Systems and Infrastructure**
https://cds.cern.ch/record/2020886

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

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

# The timeline

LHC/ HL-LHC Plan (last update February 2022)




We are in the end of 2022. Most of the detector upgrades will be installed in 2026 or shortly after. 2022-2026 is crucial (assembly and QA/QC)!

# Upgrade projects with CMS-China involvements

This talk will focus on the progresses mainly from CMS-China

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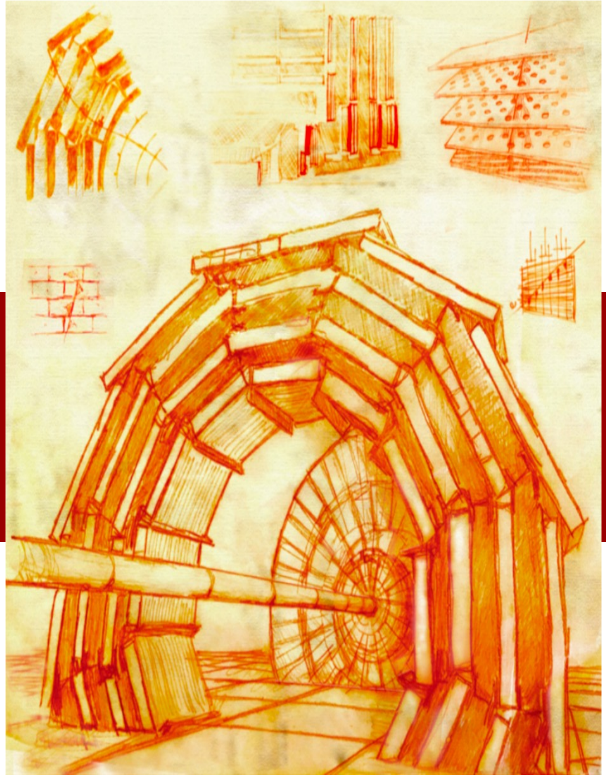
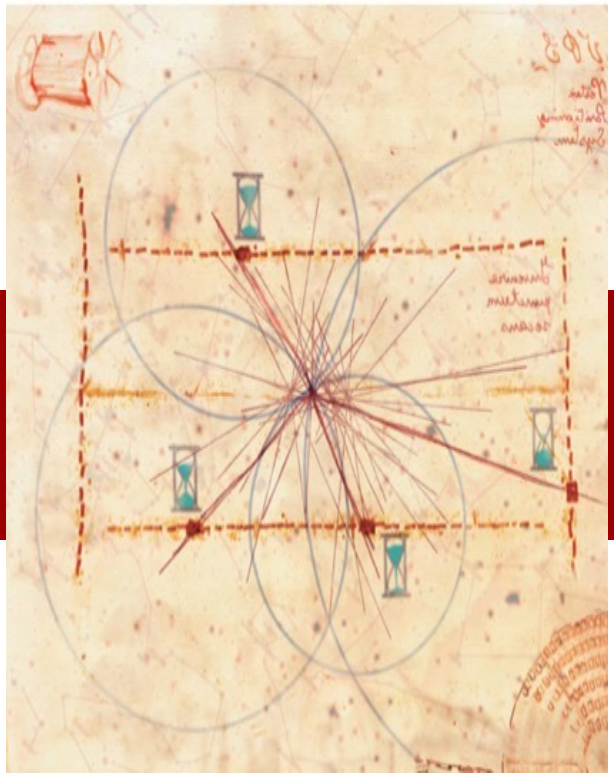


**MUON**
**GEM**



**Timing**
**MTD**

**Calo endcap**
**HGCal**

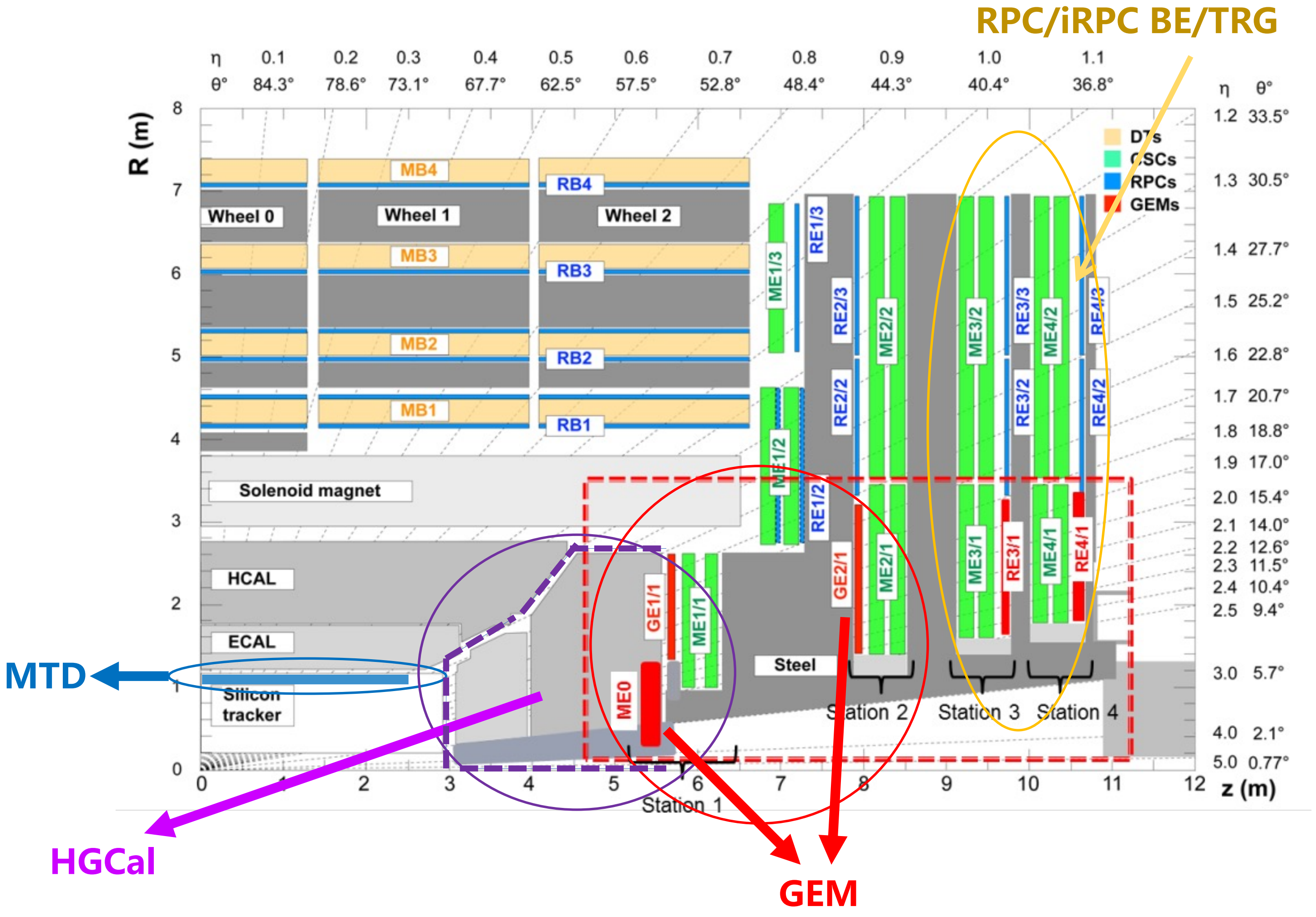
**Trigger**
**RPC/iRPC BE/TRG**

Dessin credit to Sergio Cittolin

# Where do they sit?

## The location of






Most of the projects are **close to the beam**

High **counting rate**

High **radiation**

# The GEM project

PKU+THU+SYSU+BUAA

## The three GEM stations

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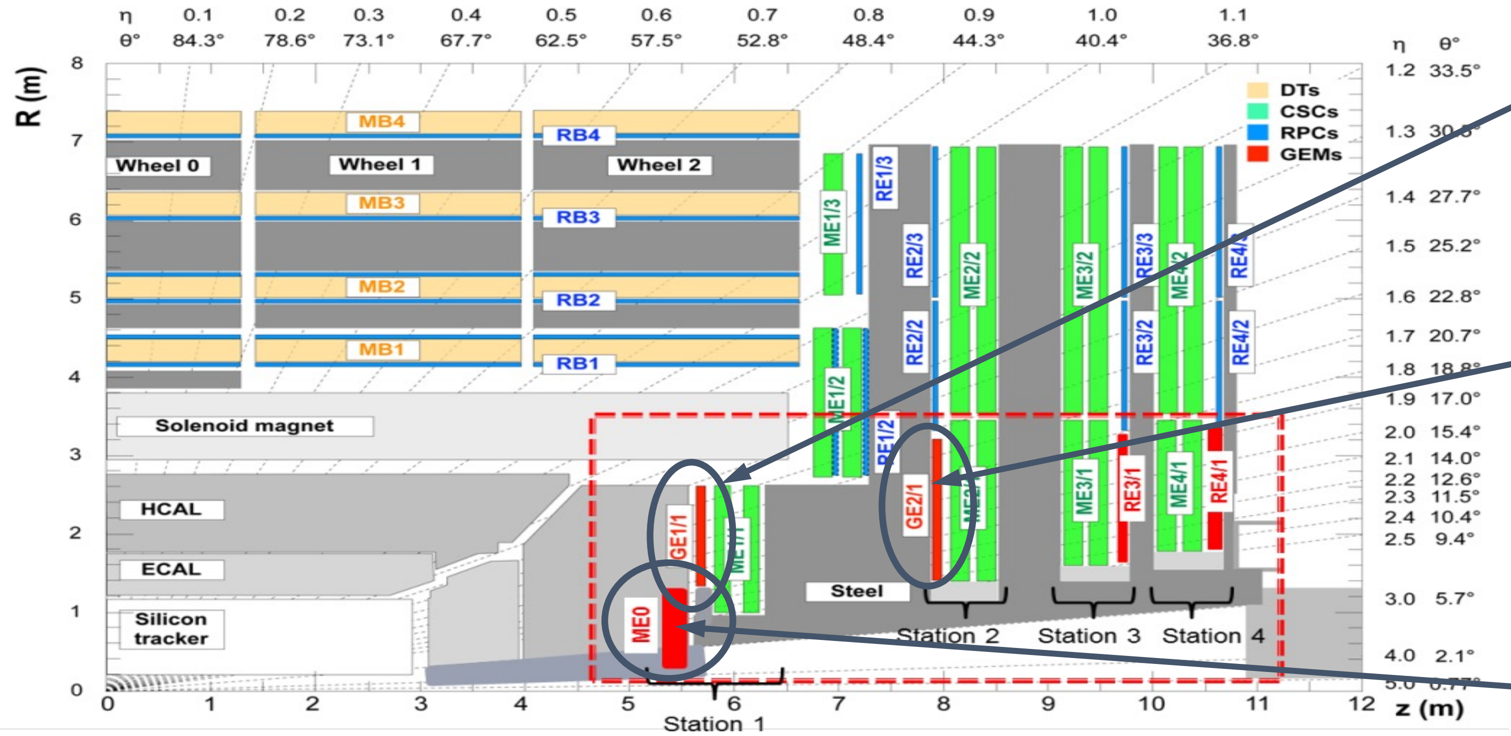


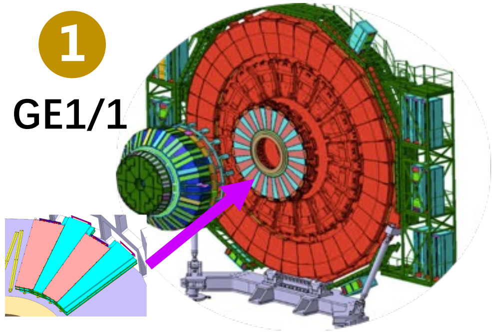

1. **GE1/1 GEM：production of all GEM Electronics Boards (GEB) in China (completed!); assembly and commission**

   Running in Run3

2. **GE2/1 GEM： Design, R&D and production of all GEB in China ; production of ~1/8 GEM at PKU, assembly and commission. Built 6 GEM detectors at PKU this Oct**

3. **ME0 GEM：Design, R&D and production of all GEB in China ; production of ~1/5 GEM at PKU, assembly and commission**

1

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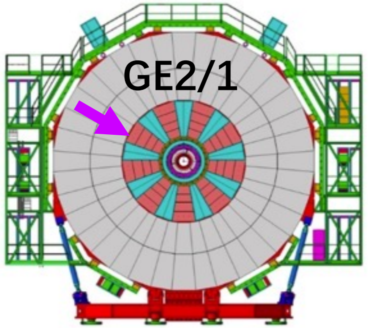


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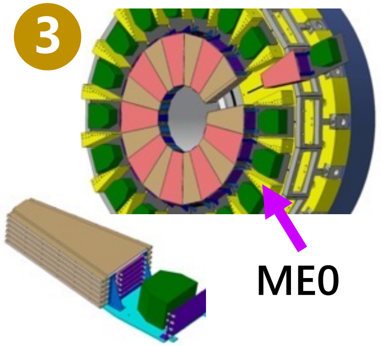
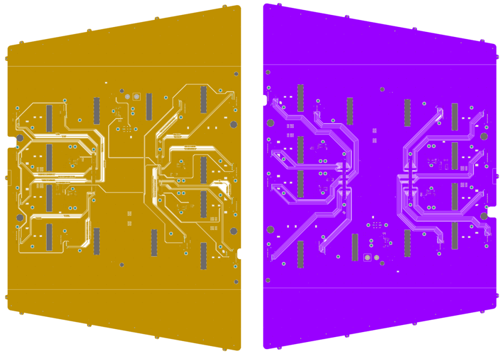


# GE2/1 GEB

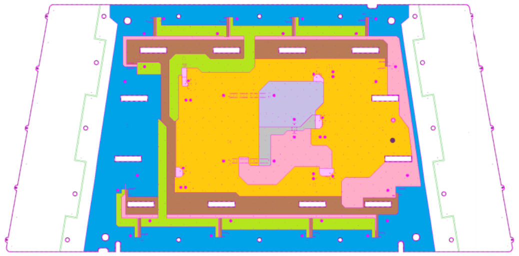
R&D and production of CMS-GEM GE21 Electronics boards



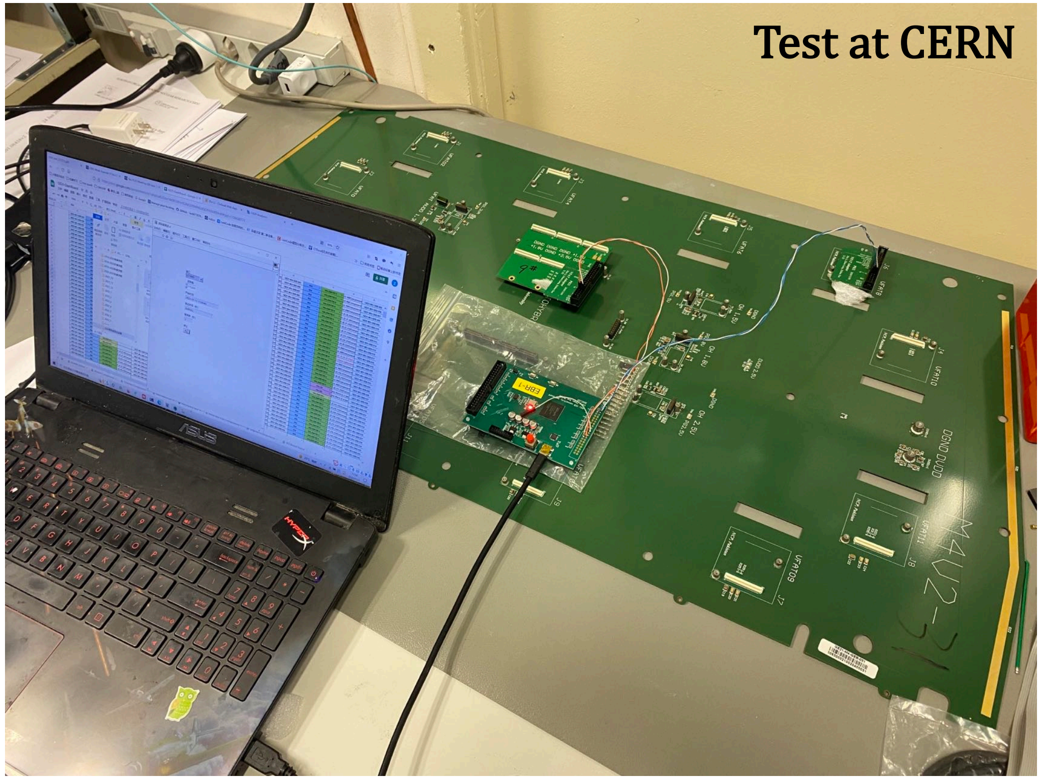
- Completed design of GE2/1 GEB, including the **signal transmission** (12 VFAT trigger unit & characteristic impedance matching), **power distribution** system (5 FEAST for VFAT), mechanical design, **power monitor** system
- Completed **tests in Shenzhen** (PKU & SYSU) this summer
- Completed **tests at CERN** this summer



Signal transmission system



Power distribution system



Test at CERN

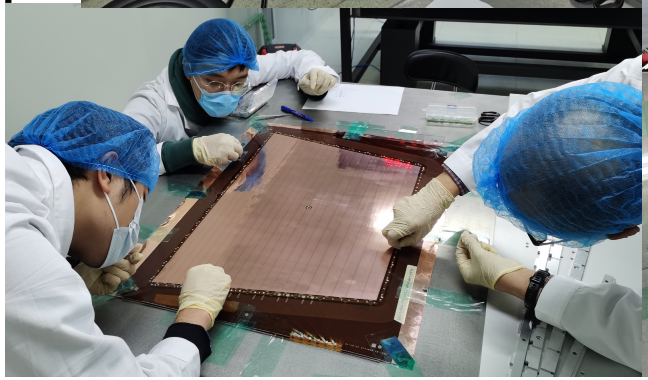
Test in Shenzhen

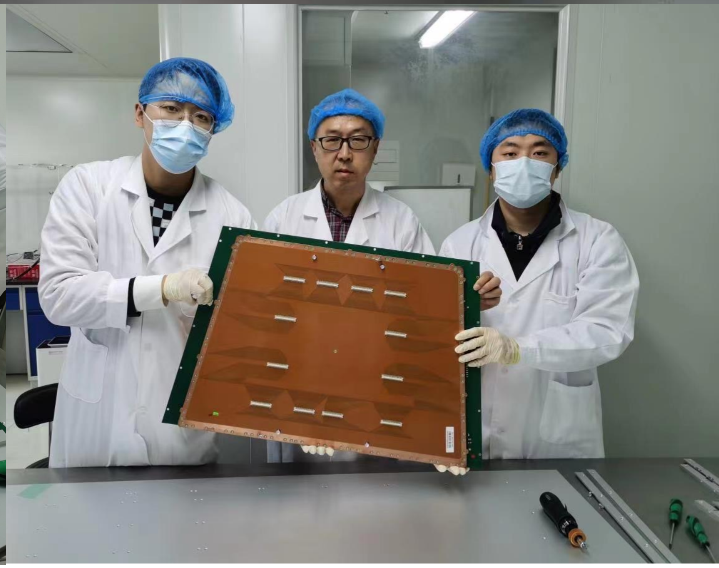
# GE2/1 detector assembly

Mass production at PKU NOW!

- **This is the first Phase-II mass production of the full-sized detector in China!**

- Assembly of GE2/1 in PKU started:
  - **6 GE2/1 M5 GEM have been assembled this October**
  - In total, **1/8 GE2/1 (37 pieces)** will be assembled at PKU
  - QC3, QC4 and some part of QC5 tests will be done in PKU

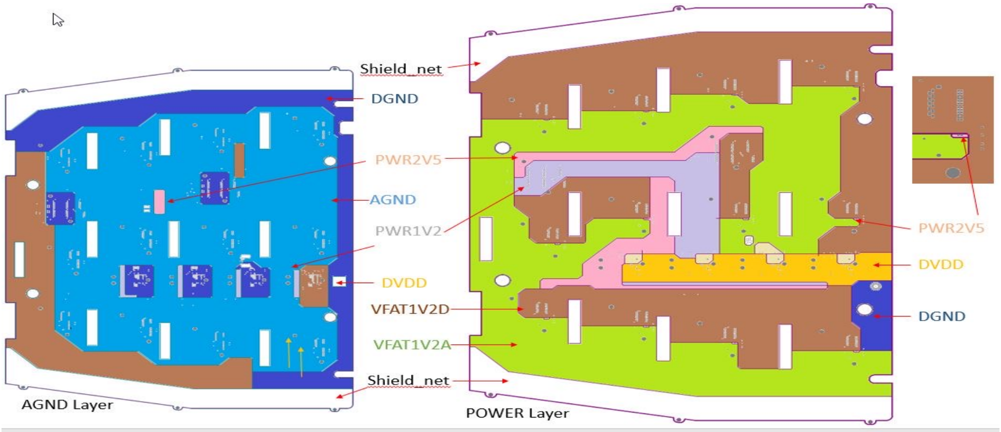


# ME0 GEB

## Design and R&D

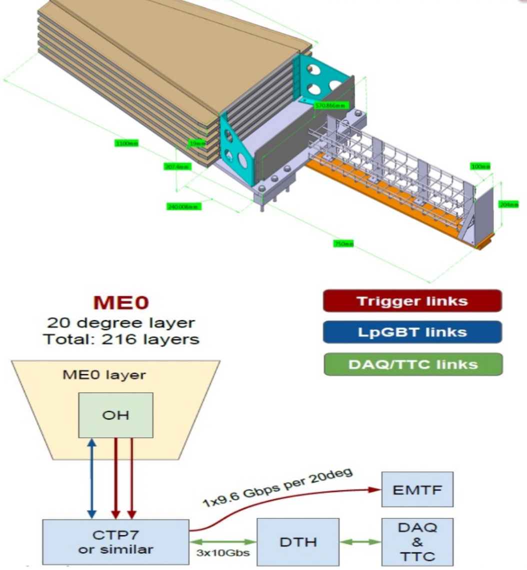


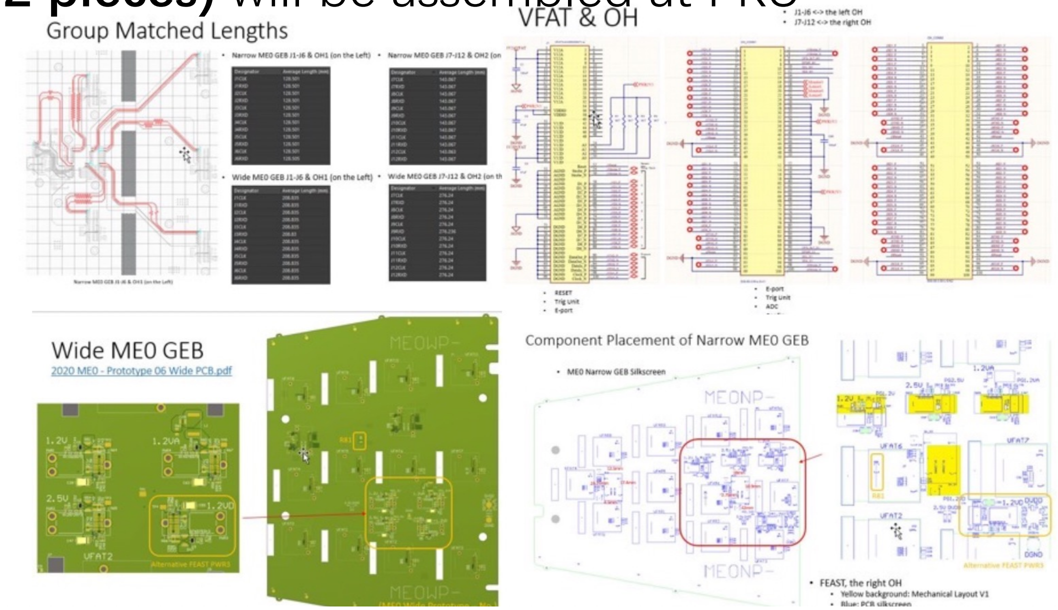
- The design of the 1st version of ME0 GEB by PKU group was completed, reviewed and validated by CMS-GEM collaboration
- The 1st prototypes of 7 sets were produced, shipped to CERN&USA in Feb. 2021, and have shown excellent test results
- Later 2022, ME0 GEB mass production is expected
- In total, **1/5 ME0 (42 pieces)** will be assembled at PKU

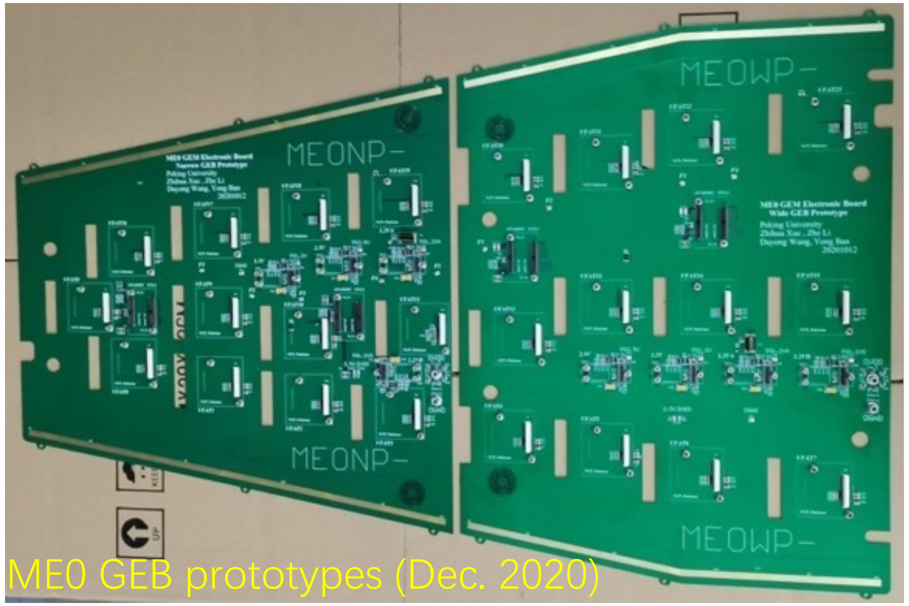



**Power distribution**

ME0 GEB Design



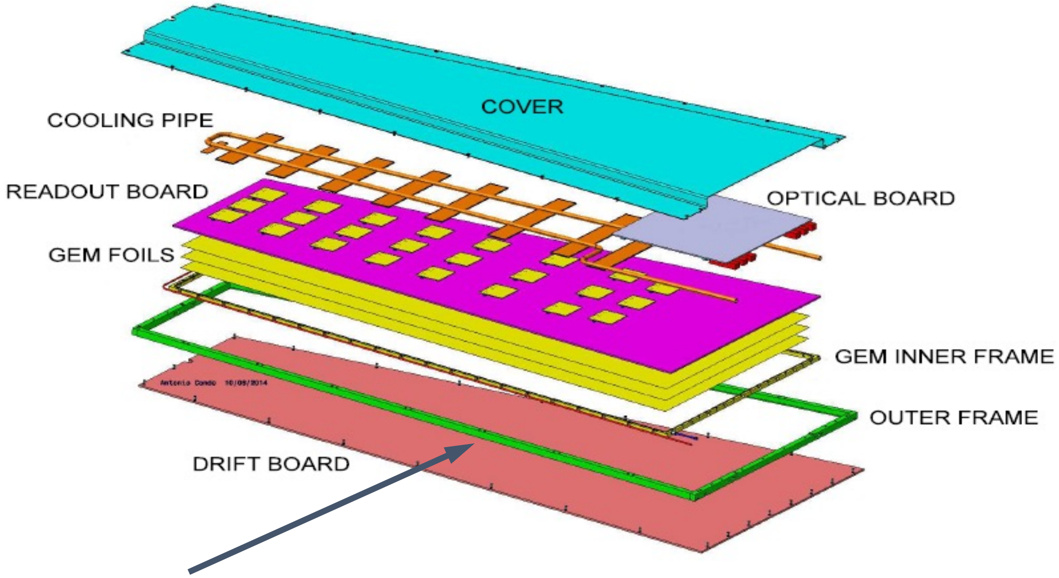




ME0 GEB prototypes (Dec. 2020)

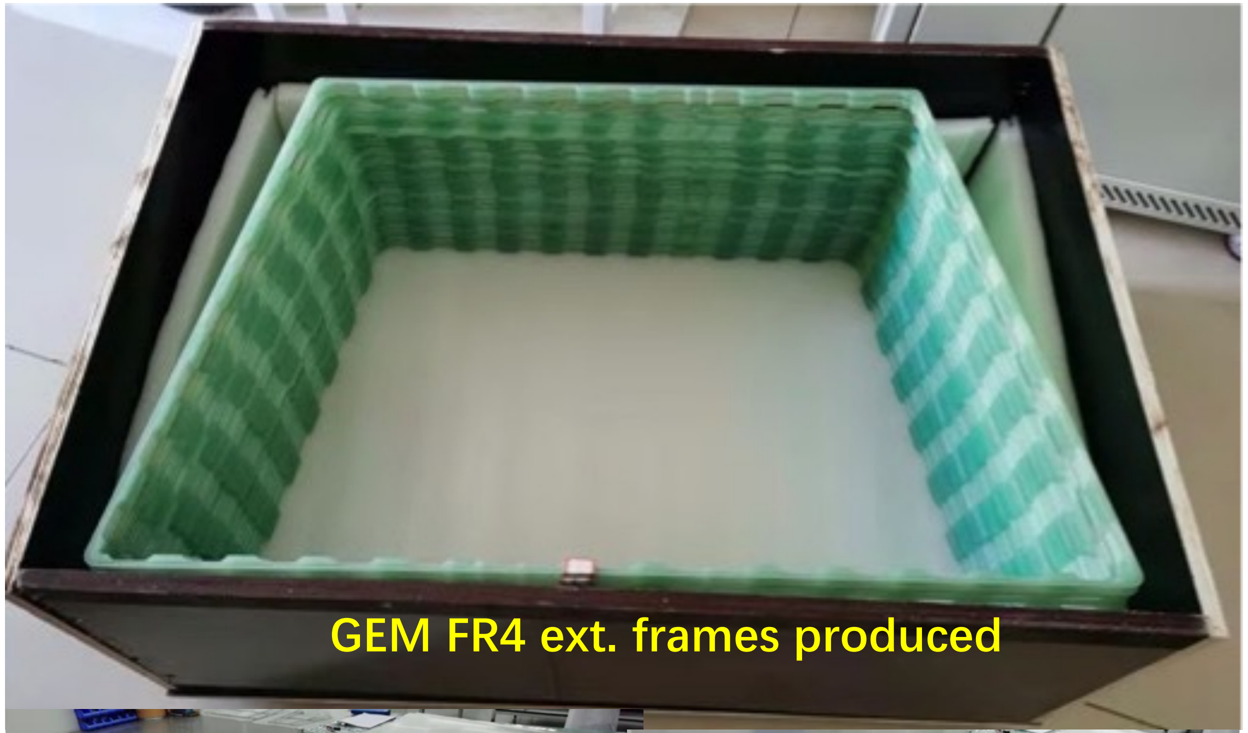
# External Frames and SM Structures

R&D and production

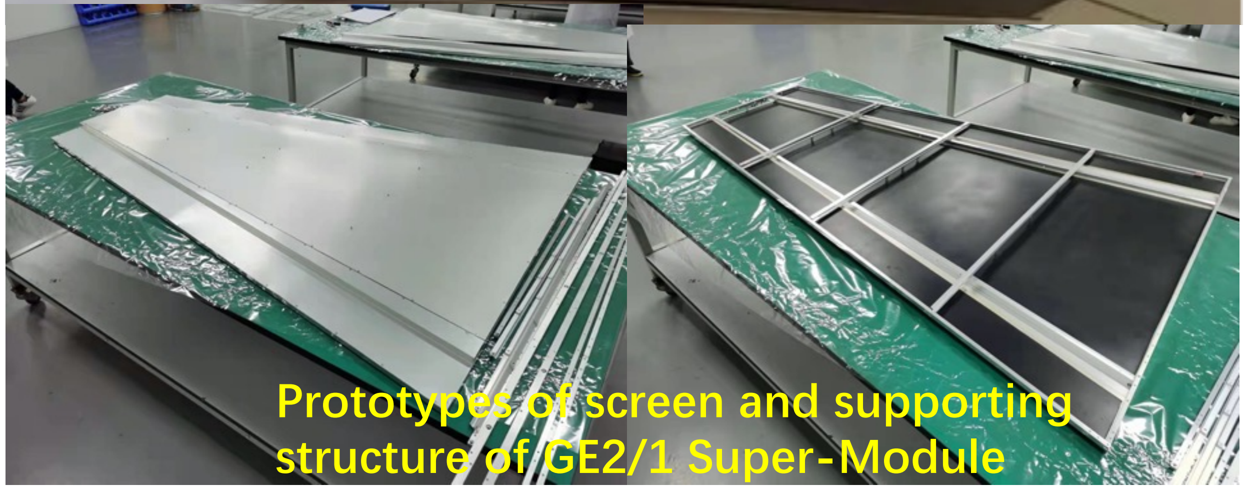
- **GEM External Frame**: fabricated with FR4 materials with very high precision (**tolerance on thickness < 0.03 mm**)
  - Production of all GE2/1 FR4 external frames (320 sets) completed, tested and shipped to CERN May 2021
- **Screen and supporting structure** of GE2/1 Super-Module (SM): 2 types (~1×2m$^2$) holds 8 GEM chambers (M1-M8), providing mechanical support, insulation, screening
  - Started mass production early 2022




**GEM external frames (FR4): extremely high requirements on mechanical tolerance**



GEM FR4 ext. frames produced

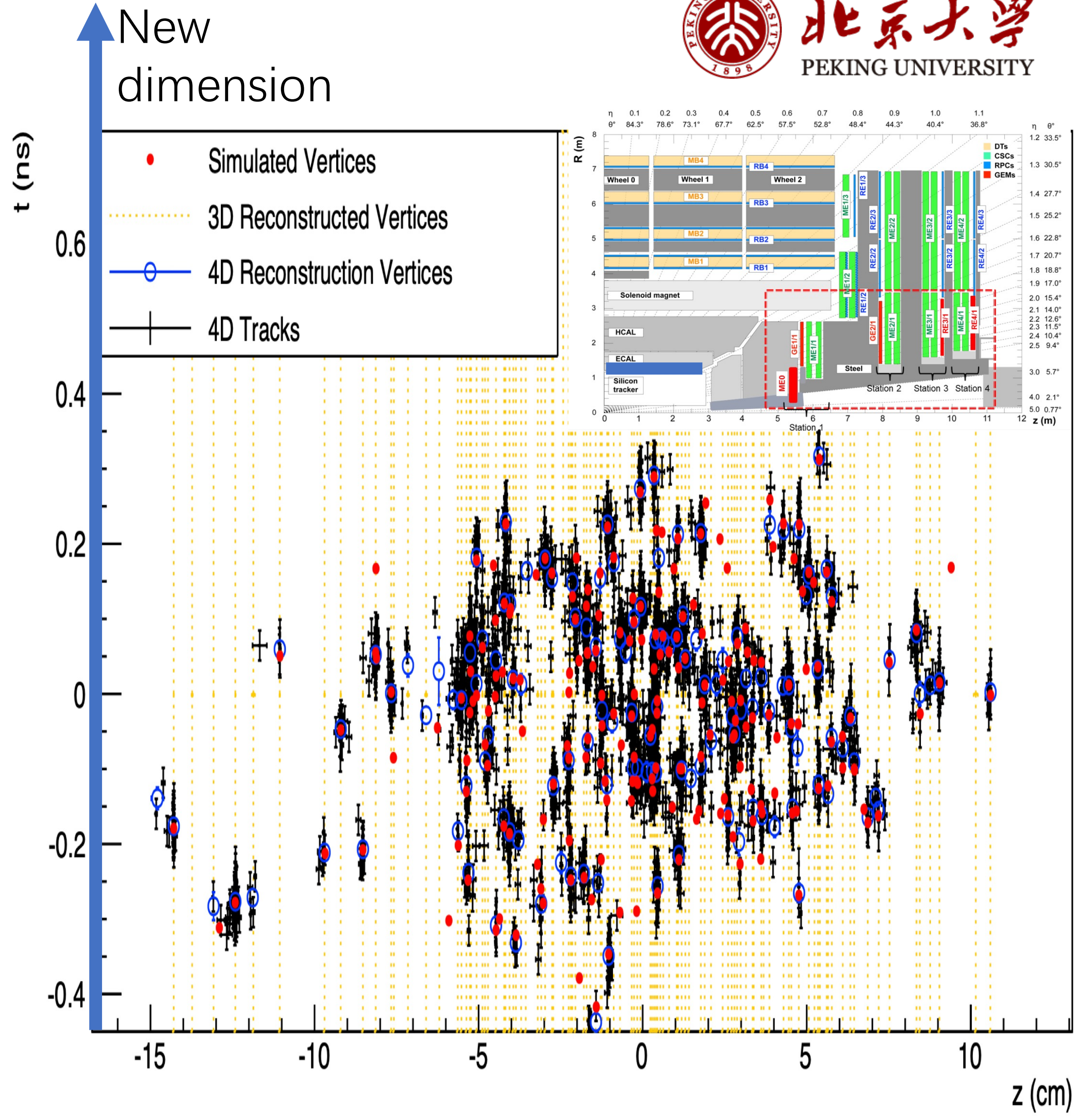


Prototypes of screen and supporting structure of GE2/1 Super-Module

# The MTD Project PKU+THU+BUAA

## The motivation

- At HL-LHC, the instantaneous lumi is ~4x of the current one
  - Faster accumulation of data
  - **BUT severe pileup**
- Demand a good separation of pileup and interested vertices
  - Improve further the spacial resolution to a next level
  - NEW idea: introduce time information of the particles
- This new idea bring CMS a new detector called **MTD (MIP timing detector)**
- Time info provides a brand **new dimension** to use in identifying the pileup vertices
  - Assuming a **time resolution of 30 ps,** then one can make 6-7 bins in the y-axis on top of the spacial separation of the vertices
  - Big impact on physics in HL-LHC (Higgs, HH, SUSY, LLP , flavor physics etc.)

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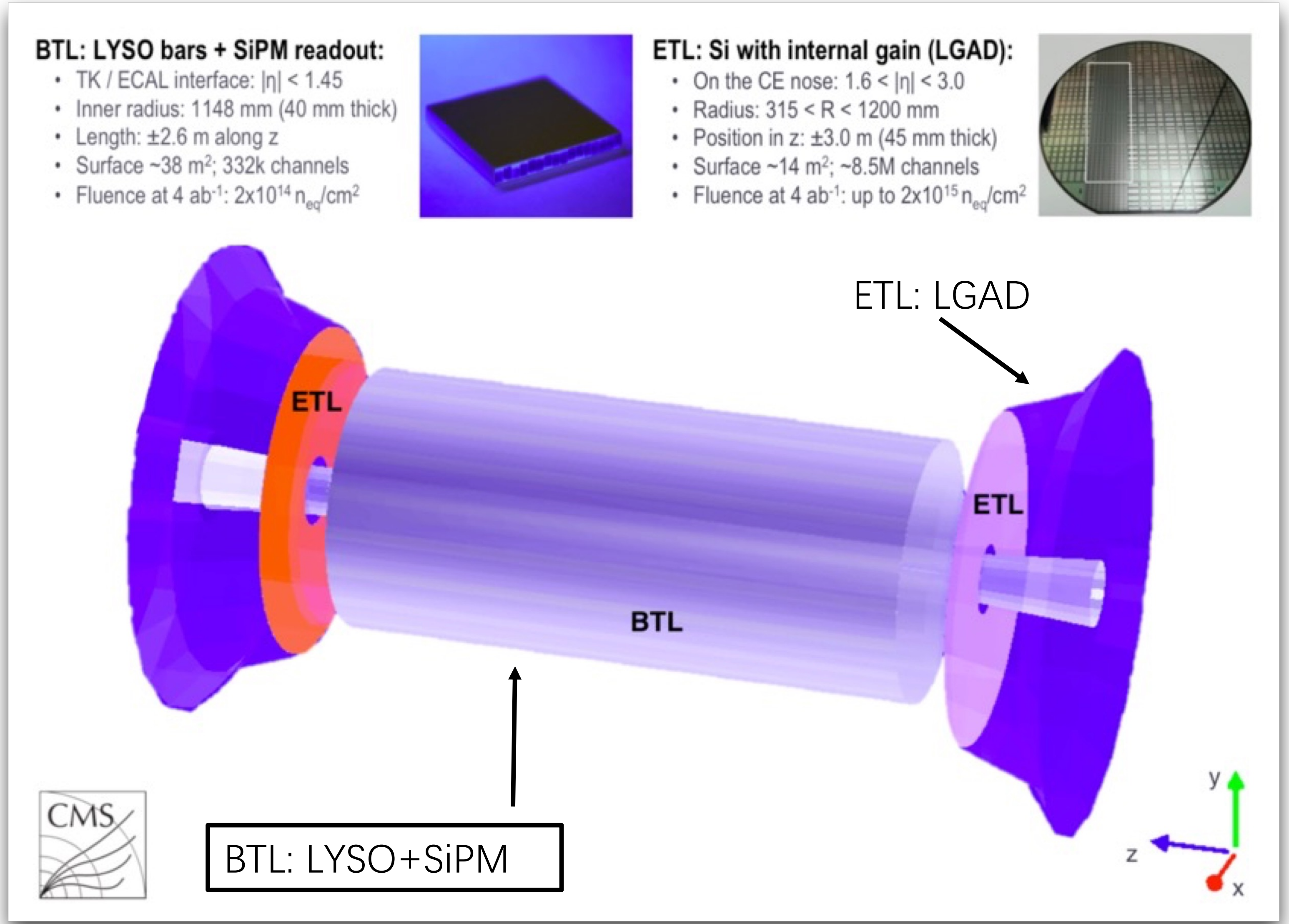
# The MTD Project

## The overview

- The MTD detector is designed to head for a time resolution of **30 ps** in both barrel and endcap
- MTD will be install between the tracker and ECAL, and shares the same dry/cold volume with the tracker
  - MTD is **compact** enough to fit the cooling chamber in the track and leave **negligible impact** to the downstream calorimeter
- MTD is composed of the barrel (BTL) and the endcap (ETL)
  - BTL uses LYSO + SiPM duel readout
  - ETL uses LGAD
- BTL covers up to $|\eta|<1.45$
  - Surface ~38 $m^2$
  - Inner radius ~1.2m, length +-2.6m
  - 332k channels (SiPMs)
- In this talk, we will focus on BTL which China MTD mostly focuses on at the moment



# The sensor

## LYSO + SiPM

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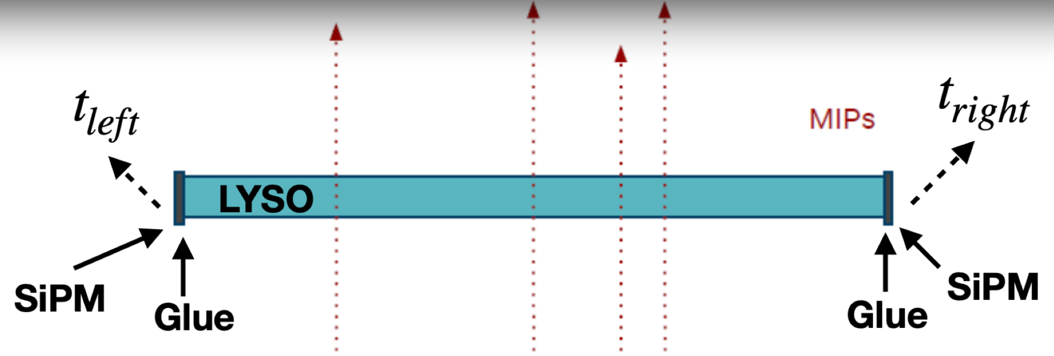
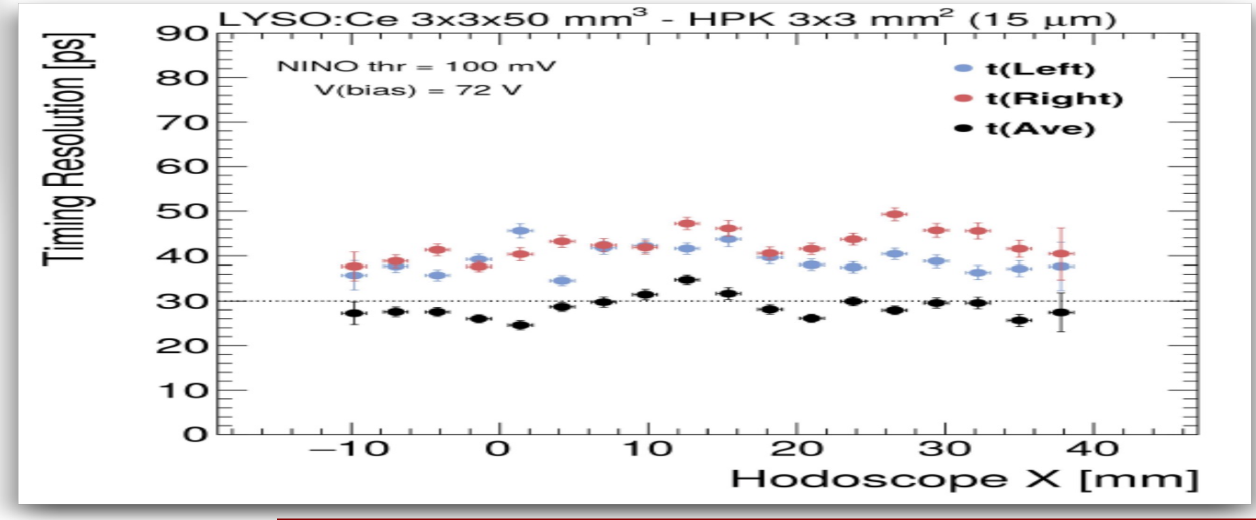


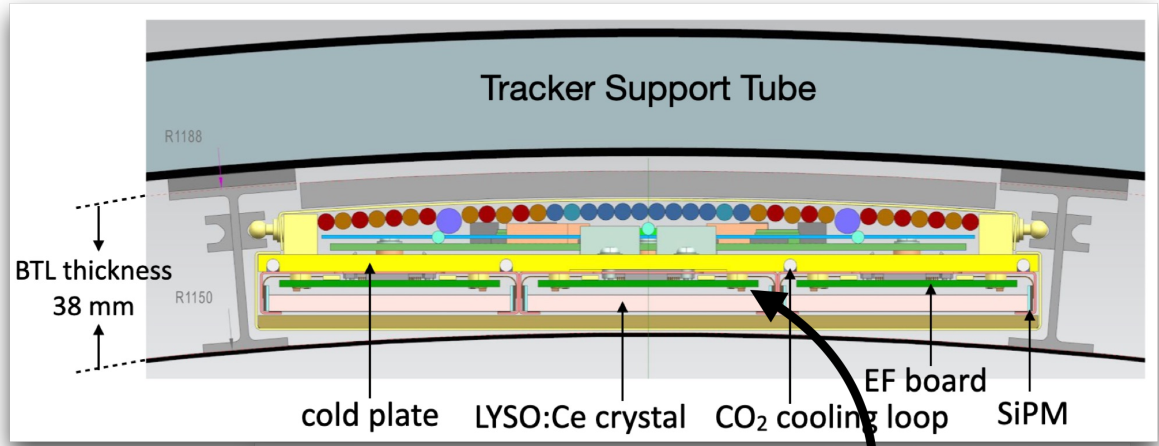

- Sensor module has 16 **LYSO** bars (3×3×57 mm3)
  - High light yield (~ 40000 photons/ MeV)
  - Fast scintillation rise time (< 100 ps)
  - Short decay time (~40 ns)
- Dual readout by 2 **SiPM** arrays
  - Photo-detection efficiency (PDE): 20-40%, with optimal cell size of 15 μm
  - Gain: 1.5-4×$10^5$
- Cooled to -35 to -40°C with CO2 and -10°C with thermo-electric cooler (TEC)
- The time resolution can reach 30 ps regardless of the position of inducing particles



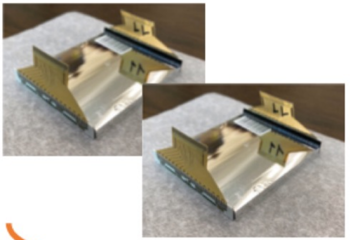
# The assembly

## Sensor module – detector module - readout unit - tray

- BTL detector mounted on inner surface of Tracker Support Tube (TST) and share the cooling
- **Sensor Modules** (SM): LYSO+SiPM & TEC
- **Detector Modules** (DM): SMs+FE
- DMs are grouped in **Readout Units** (RU)
- Mechanical support & CO2 via cooling plate in a **Tray**
- **We got approved to build a MTD BTL assembly center**

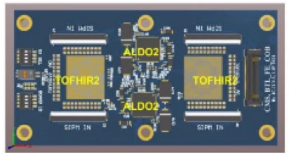


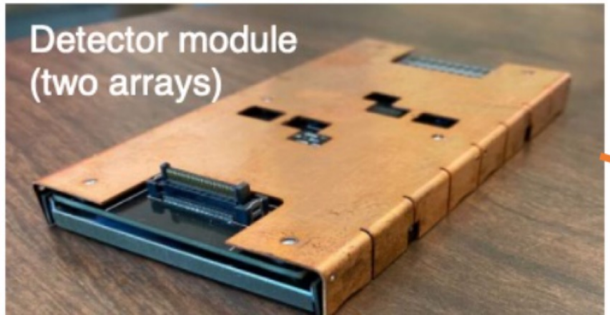

LYSO+SiPM
Sensor Modules

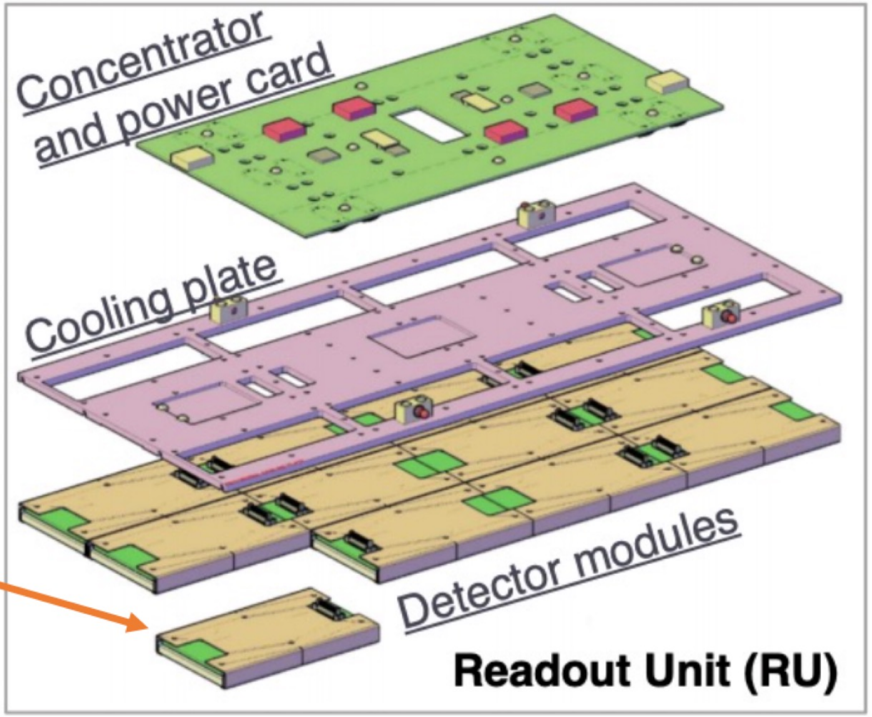


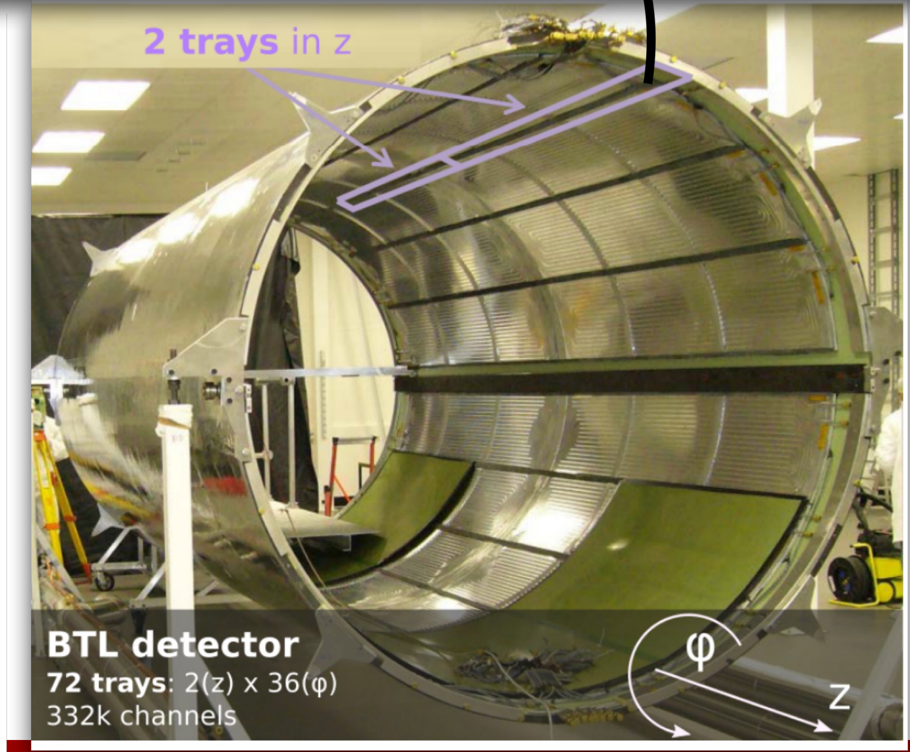
+

FE Boards housing
TOFHIR ASICs



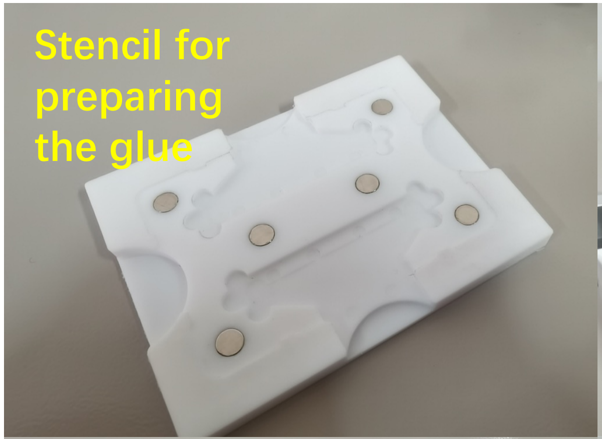



# Local preparation of the assembly center

PKU lab activities

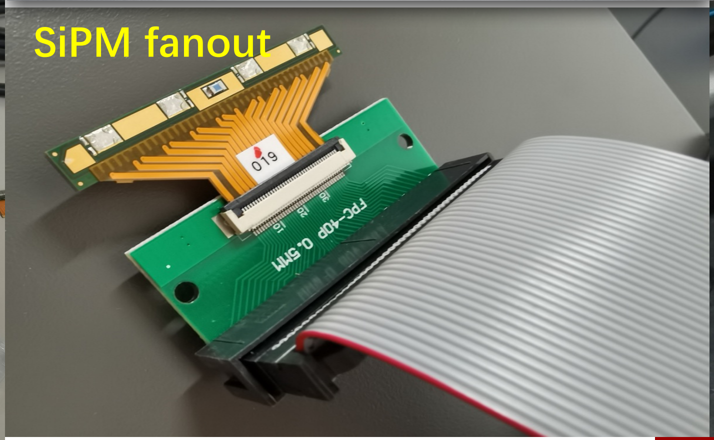


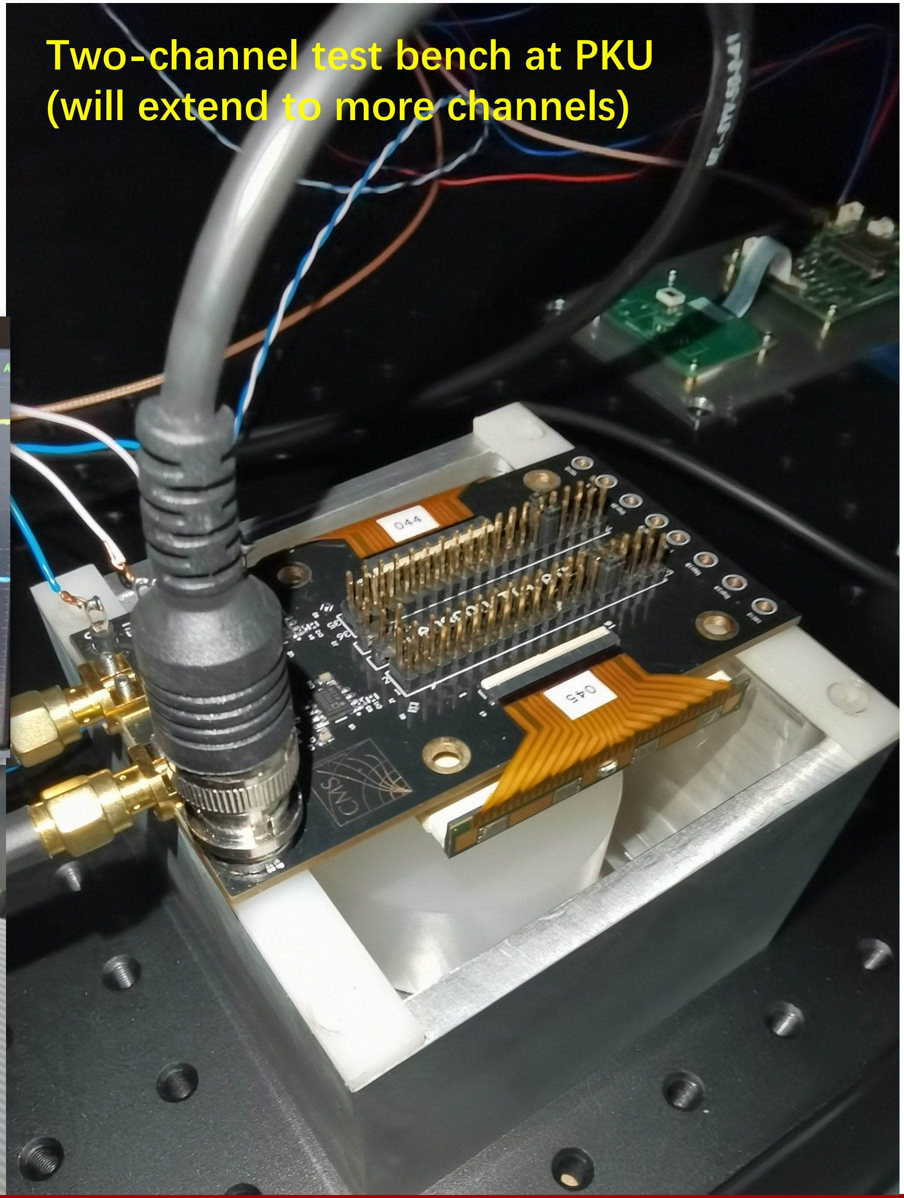
- Actively preparing the assembly center
- Improving the tool for **coupling the LYSOs and the SiPMs**
- Setting up **the test bench for the sensor modules**









# MTD BTL test beam studies

Test beam at H8

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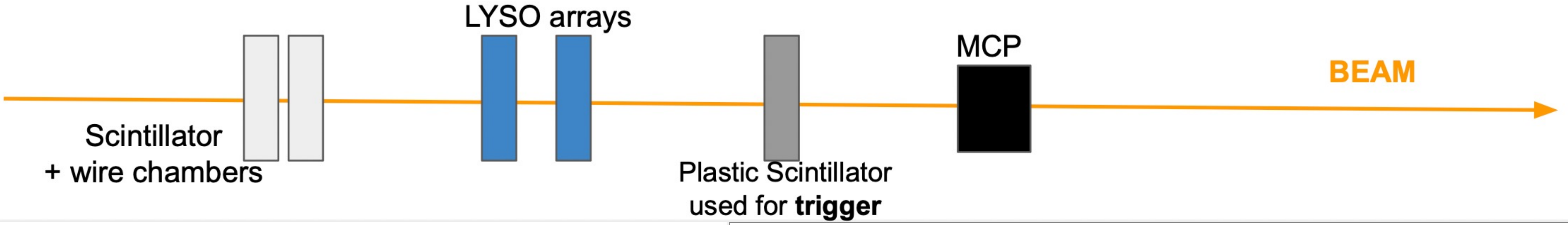
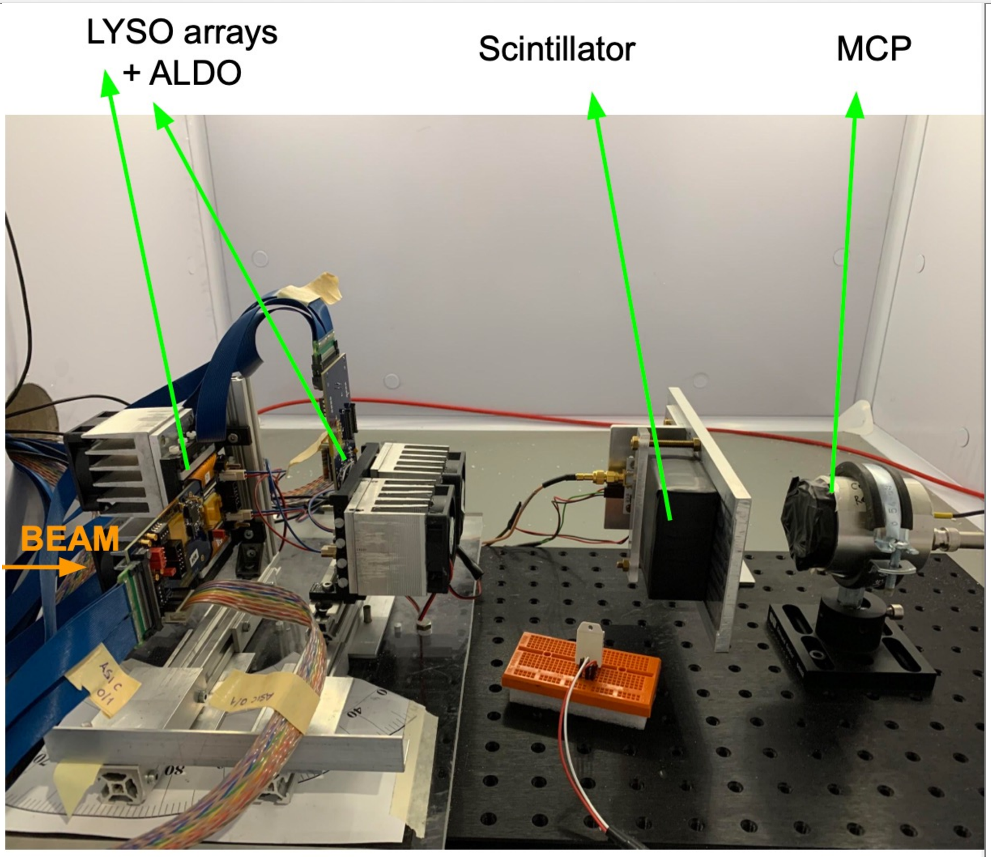
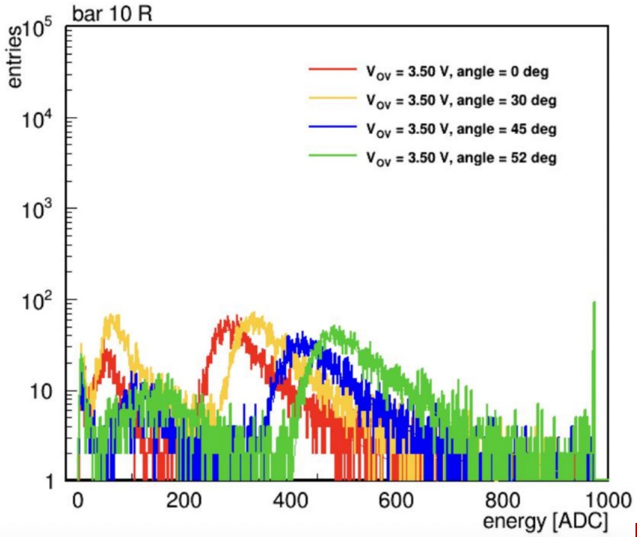
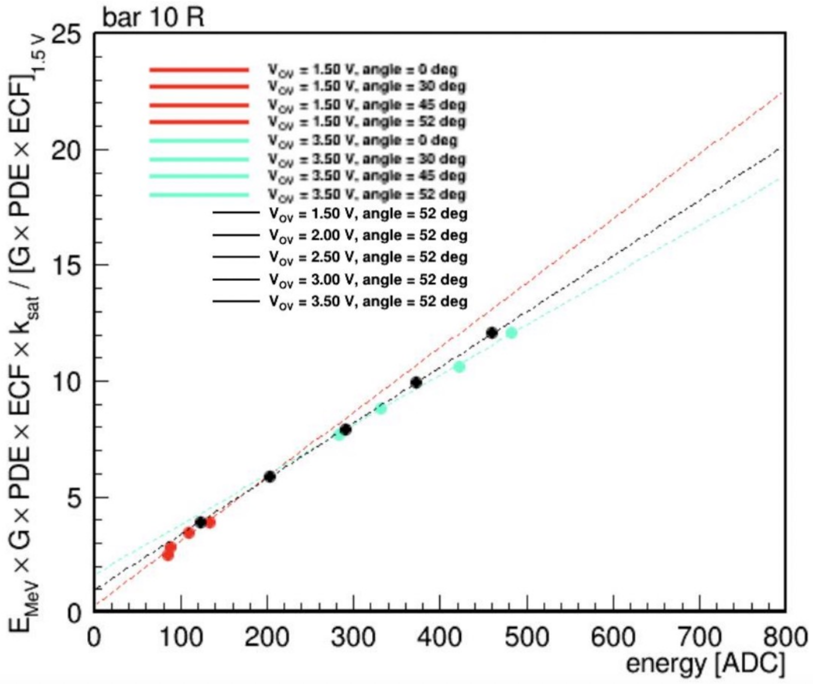







- Participate test beam studies
- Focus on the **energy linearization**, varying the angle, Vov, temperature and the irradiation

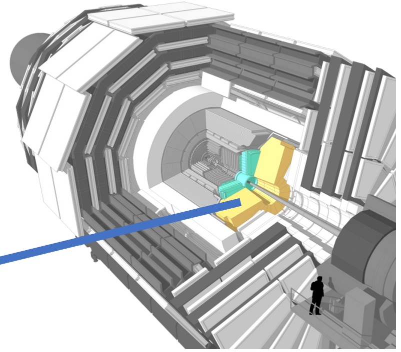


IHEP+THU+ZJU+Fudan

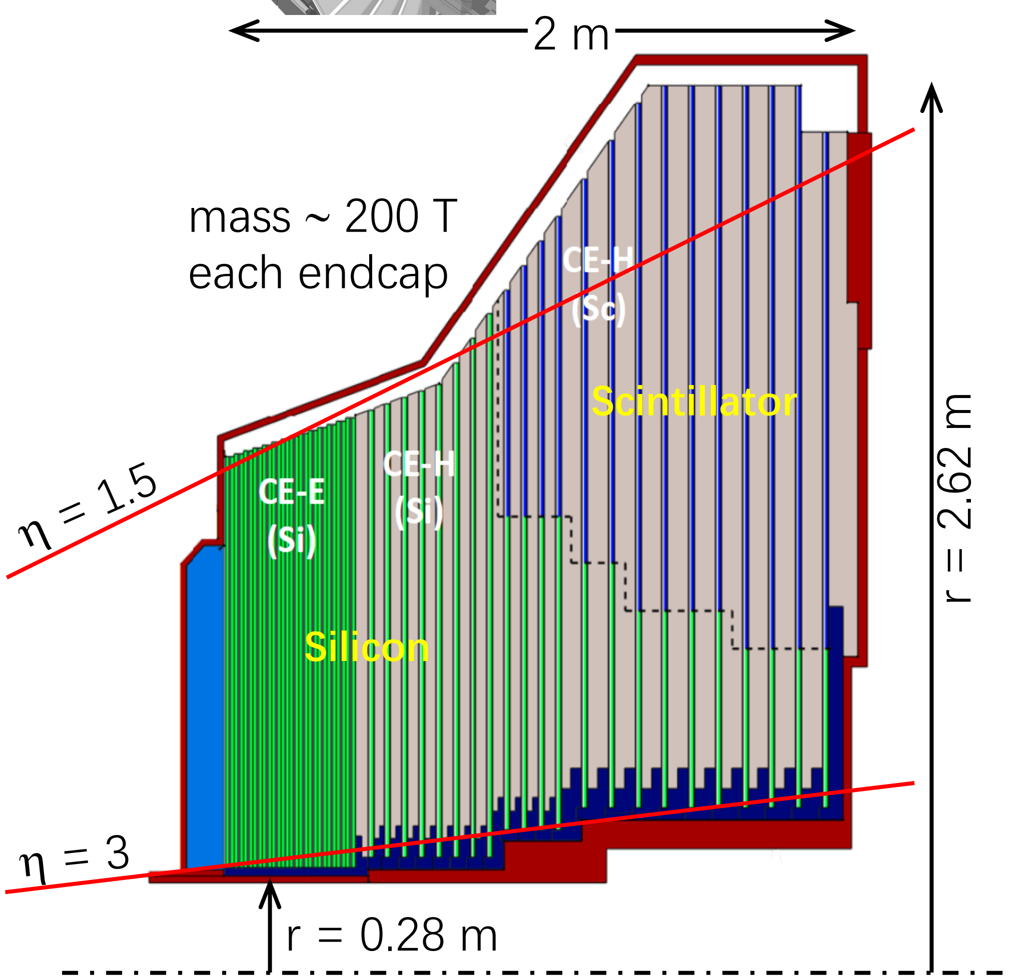
# The HGCal project

## A 5D calorimeter

Demand high granularity detector in the forward region for PF jets, VBF topology and highly-boosted jets (W/Z) at HL-LHC

**HGCal (High Granularity Calorimeter)** will replace its endcap calorimeters




Calorimeter Endcap (CE), divided into CE-E and CE-H

**Active Elements:**

- **Si sensors** (full and partial hexagons) in CE-E and high-radiation region of CE-H.
- **SiPM-on-Scintillating tiles** in low-radiation region of CE-H

Electromagnetic calorimeter (**CE-E**): **Si**, Cu/CuW/Pb absorbers, 28 layers, 25.5 $X_0$ & ~1.7$\lambda$

Hadronic calorimeter (**CE-H**): **Si** & **scintillator**, steel absorbers, 22 layers, ~9.5$\lambda$ (including CE-E)

**Key Parameters (updated from the TDR):**

- HGCAL covers $1.5 < \eta < 3.0$
- **Full system maintained at -30ºC**
- **~640 m$^2$** of silicon sensors ~3x tracker
- **~370 m$^2$** of scintillators
- 6.1M Si channels, **0.5 or 1.1 cm$^2$ cell size** (*6M*)

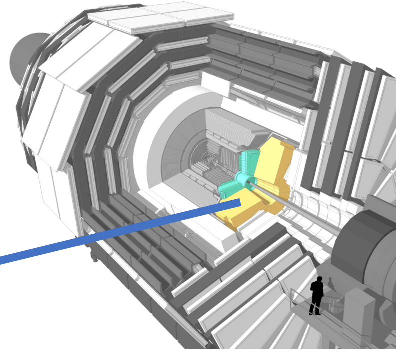
  240k scint-tile channels ($\eta$–$\phi$)
  - Trigger readout from alternate layers in CE-E and all in CE-H
- **~31000 Si modules** (incl. spares)

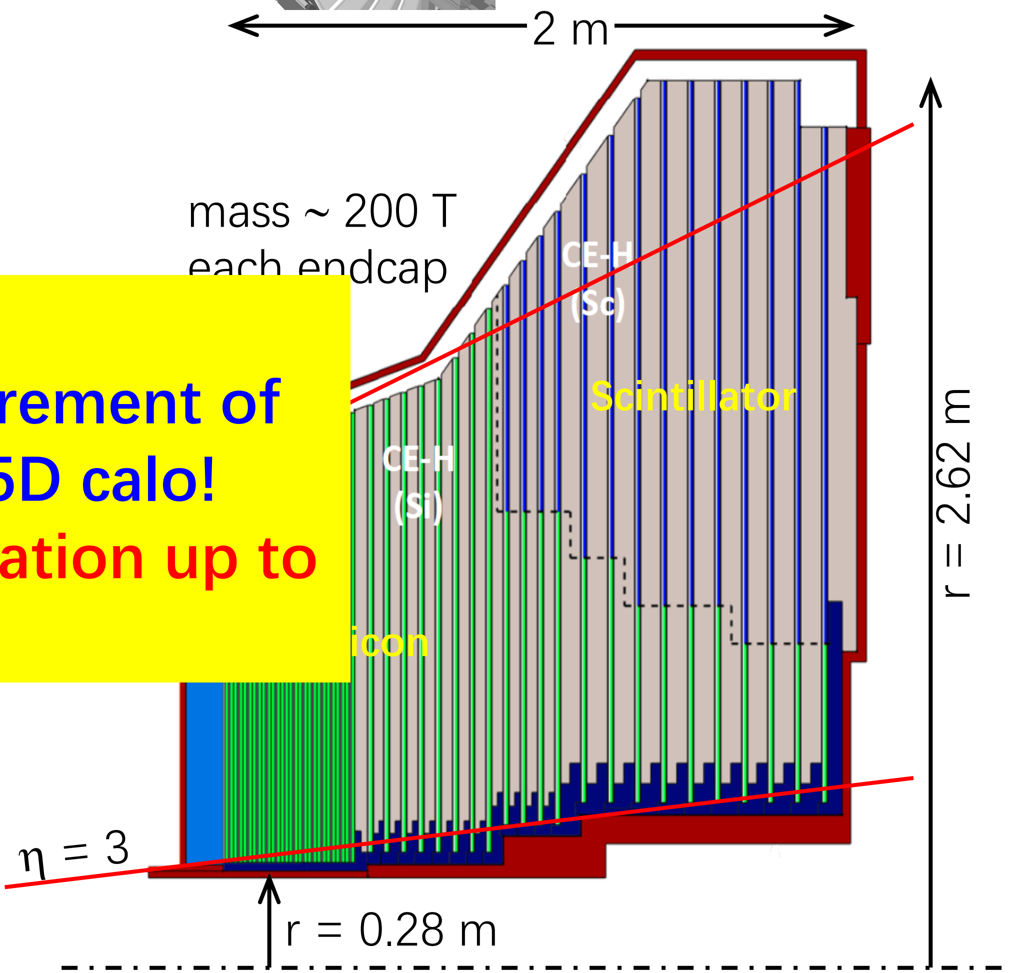
# The HGCal project

## A 5D calorimeter

Demand high granularity detector in the forward region for PF jets, VBF topology and highly-boosted jets (W/Z) at HL-LHC

HGCal (High Granularity Calorimeter) will replace its endcap calorimeters




Calorimeter Endcap (CE), divided into CE-E and CE-H

**Readout granularity is 1 cm$^3$**

**Providing simultaneous measurement of energy, 3D position and time: 5D calo!**

**Stable performance after irradiation up to $10^{16}$ $n_{eq}/cm^2$**

**Active Elements:**

- Si sensors (full and partial hexagons) in CE-E and high-radiation region of CE-H.
- SiPM-on-Scintillating tiles in low-radiation region of CE-H

Electromagnetic calorimeter (**CE-E**): **Si**, Cu/CuW/Pb absorbers, 28 layers, 25.5 $X_0$ & ~1.7λ

Hadronic calorimeter (**CE-H**): **Si** & **scintillator**, steel absorbers, 22 layers, ~9.5λ (including CE-E)

- 6.1M Si channels, **0.5 or 1.1 cm$^2$ cell size** (*6M*)

  240k scint-tile channels (η–ϕ)
  - Trigger readout from alternate layers in CE-E and all in CE-H
- **~31000 Si modules** (incl. spares)

# Module Assembly Centers (MAC)

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The IHEP MAC site was officially certified by CERN!

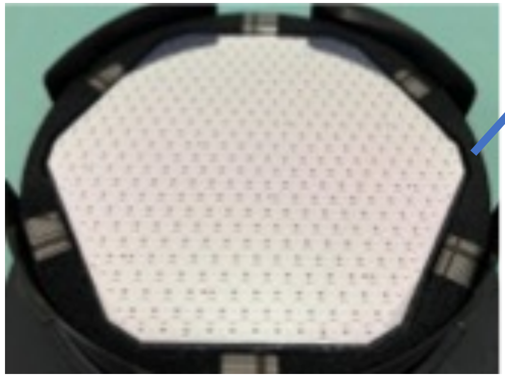
**Silicon sensors** are sandwiched with electronic boards and CuW base plates to form **a hexagonal module**, which will be tiled and stacked to make a cassette

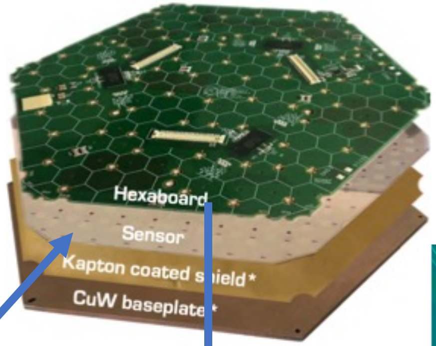
5 MACs are now qualified

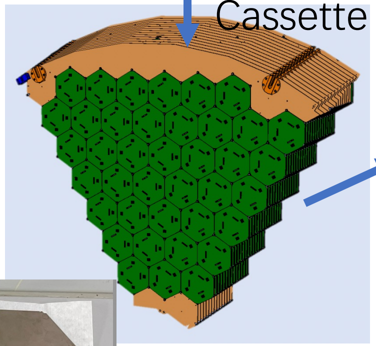
- UCSB, CMU, TTU, Taiwan, **IHEP** Beijing
- Setting up No. 6 at TIFR, good progress
- Each taking **5000 modules**

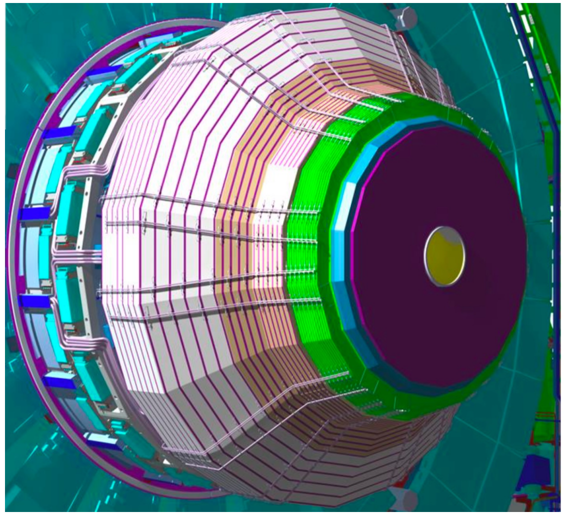
Alternative suppliers for **CuW** base plates

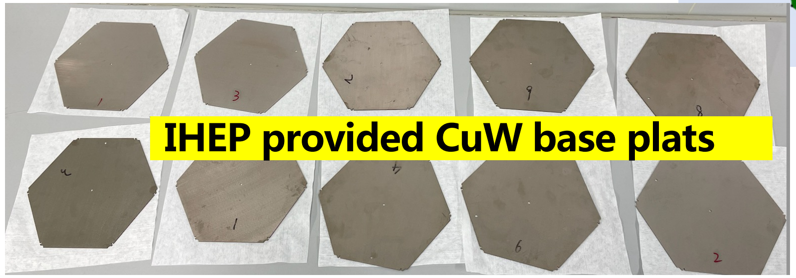
- Nominally Protvino deliverable
- Prototypes also made at KIT Karlsruhe, **IHEP** Beijing and TIFR Numbai





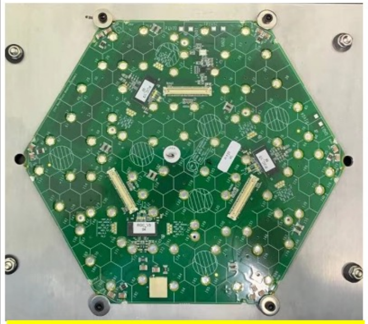





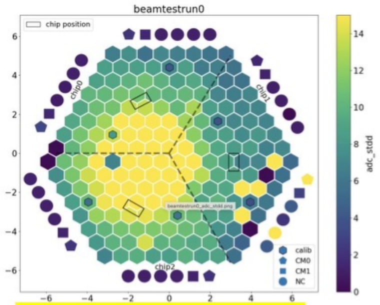
IHEP provided CuW base plats

Clean room @ IHEP

First 8in silicon model in CMS by IHEP



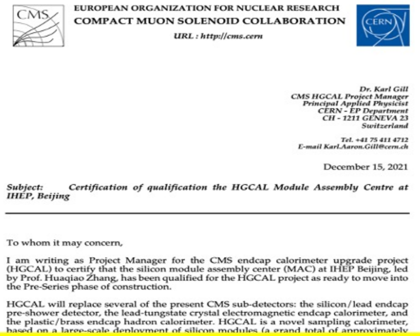
8in si model @ IHEP




CERN TB for this model

Certified MAC at IHEP

IHEP MAC team



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
COMPACT MUON SOLENOID COLLABORATION
URL : http://cms.cern

*Dr. Karl Gill*
*CMS HGCAL Project Manager*
*Principal Applied Physicist*
*CERN - EP Department*
*CH - 1211 GENEVA 23*
*Switzerland*

*Tel. +41 75 411 4712*
*E-mail Karl.Aaron.Gill@cern.ch*

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.

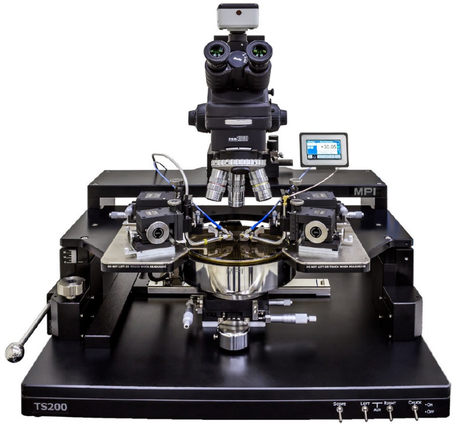
HGCAL will replace several of the present CMS sub-detectors: the silicon/lead endcap pre-shower detector, the lead-tungstate crystal electromagnetic endcap calorimeter, and the plastic/brass endcap hadron calorimeter. HGCAL is a novel sampling calorimeter, based on a large-scale deployment of silicon modules (a grand total of approximately

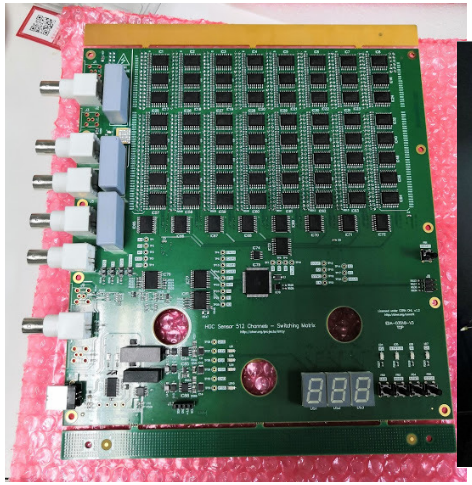
The certification letter for the IHEP MAC site

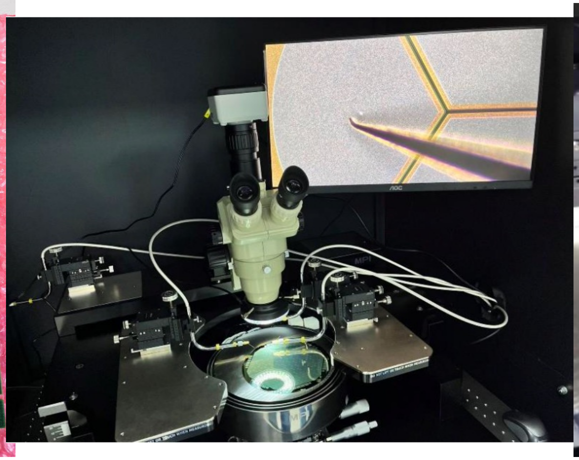
# NEW test bench for the silicon sensors

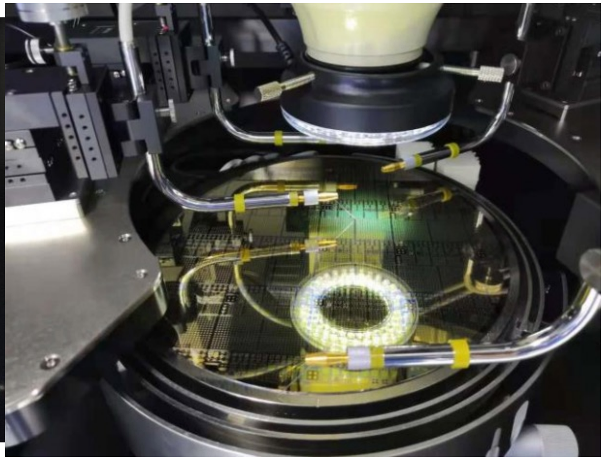
IHEP



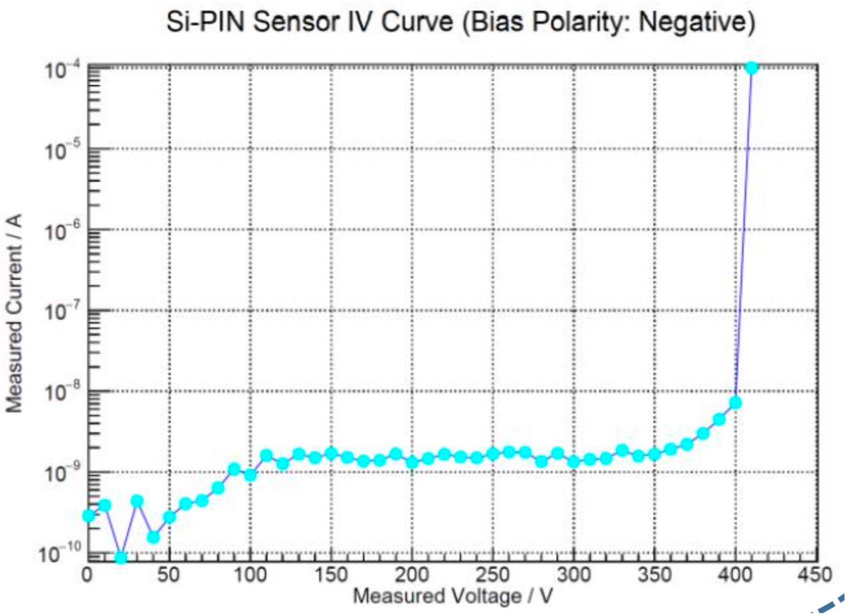






- Participated the sensor testing at CERN
- Developed **the test bench locally at IHEP** for large areas of silicon sensor
  - Probe card
    - In place for 6 inch sensors (used for prototyping)
    - In plan to accommodate 8 inch sensors
  - Switch matrix
    - In place, 512 channels, can be used for both 6 and 8 inch sensors
  - Probe bench
    - Use probes to directly reach the sensors for the testing



# A small batch production of 4 modules at IHEP

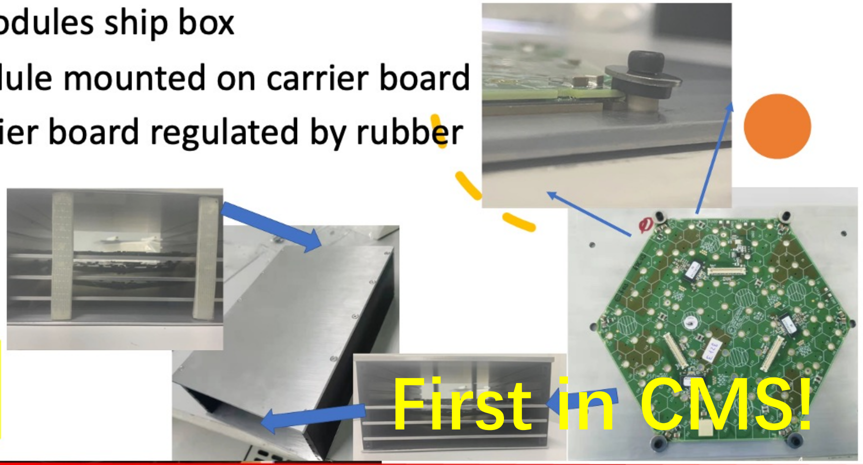
PEKING UNIVERSITY

Competed the first batch of 6 sensors in China, sent to Fermilab

**2022 Match to April**

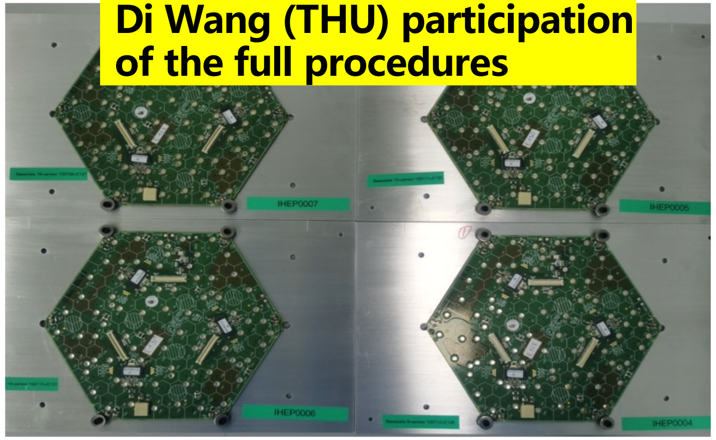
## successed small "mass" pre-production

- 5 modules ship box
- Module mounted on carrier board
- Carrier board regulated by rubber

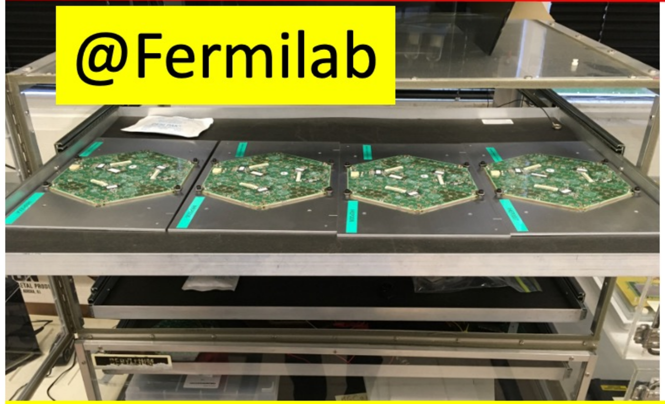



@IHEP

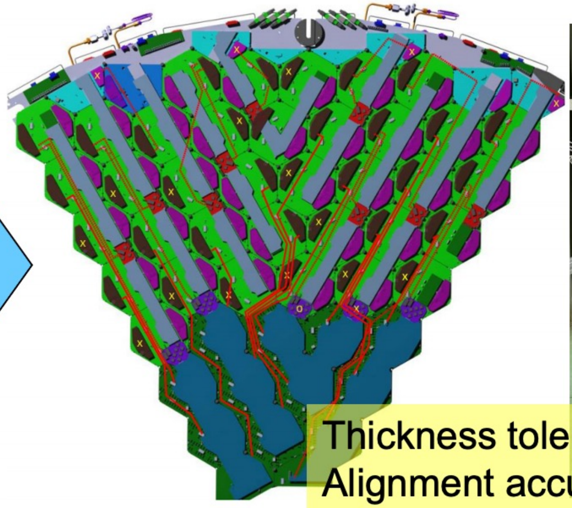
**Di Wang (THU) participation of the full procedures**

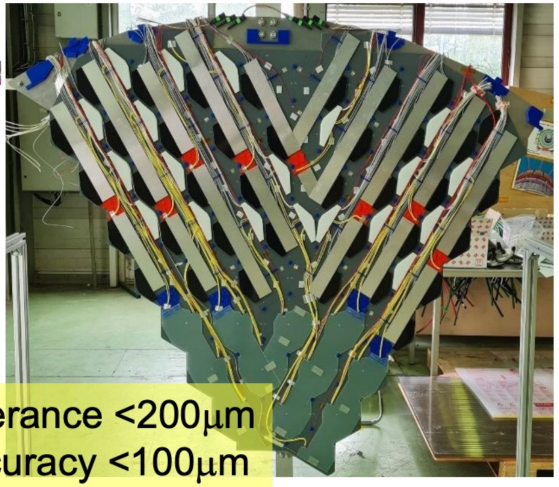


@Fermilab



4 Modules were accepted by Fermilab on 13 Apr. for cassette test



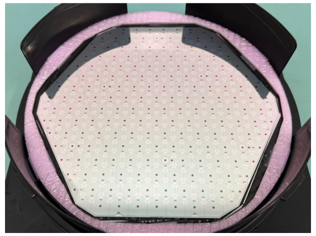


Thickness tolerance <200μm
Alignment accuracy <100μm

# Half-hexaboard design

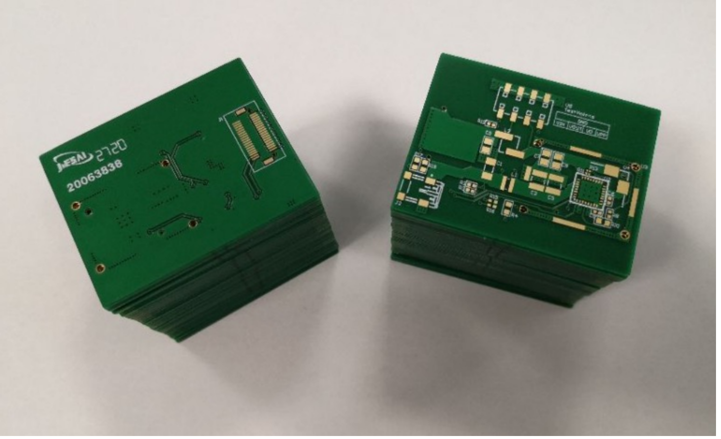
ZJU's designing the half module front-end board

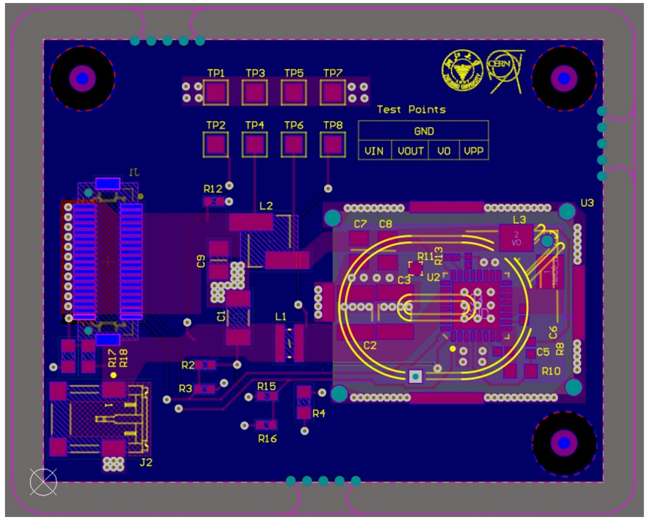




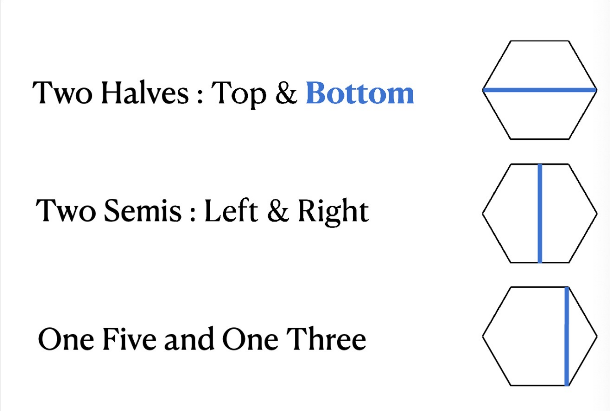
北京大學
PEKING UNIVERSITY

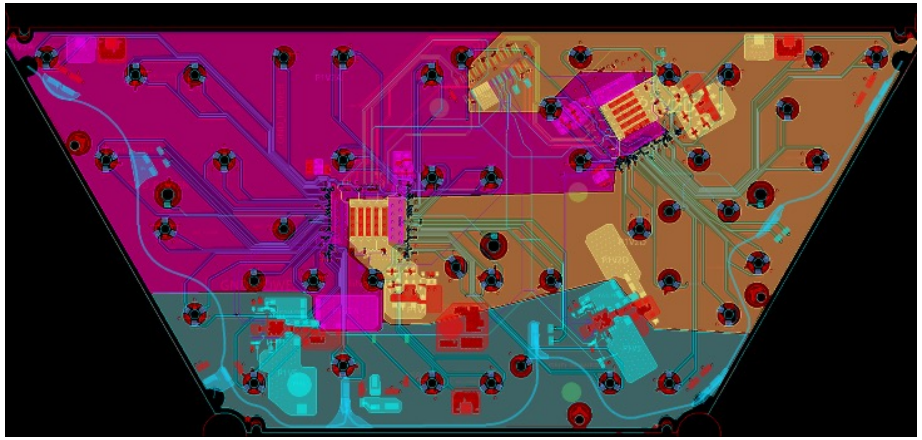
- DCDC PCB design and test production of 60 boards
- Half bottom partial hexaboard design
  - 8-layer layout
  - Preliminary version reviewed by HGCal









# Activities at CERN

TB for the first 8 inch modules at H8, qualification of HGCROC2 and hexaboards, etc.

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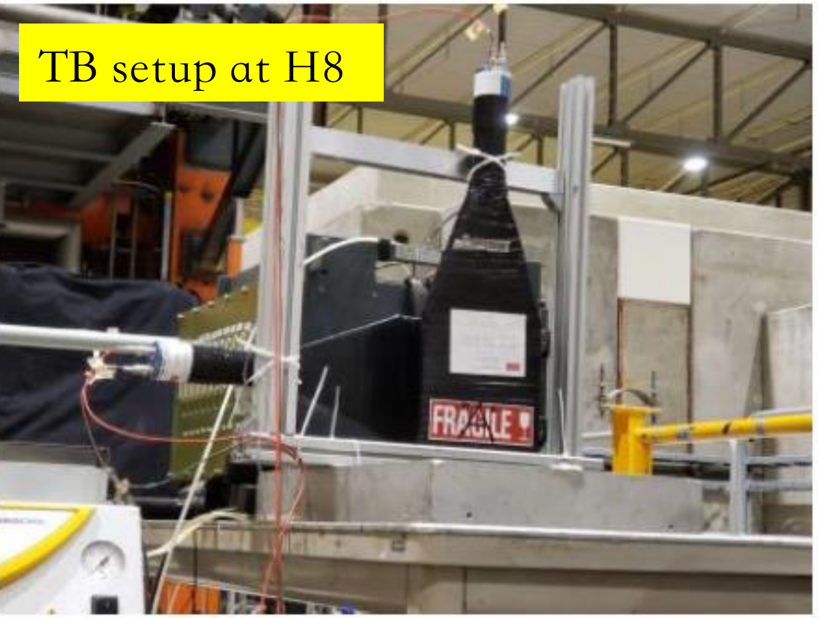
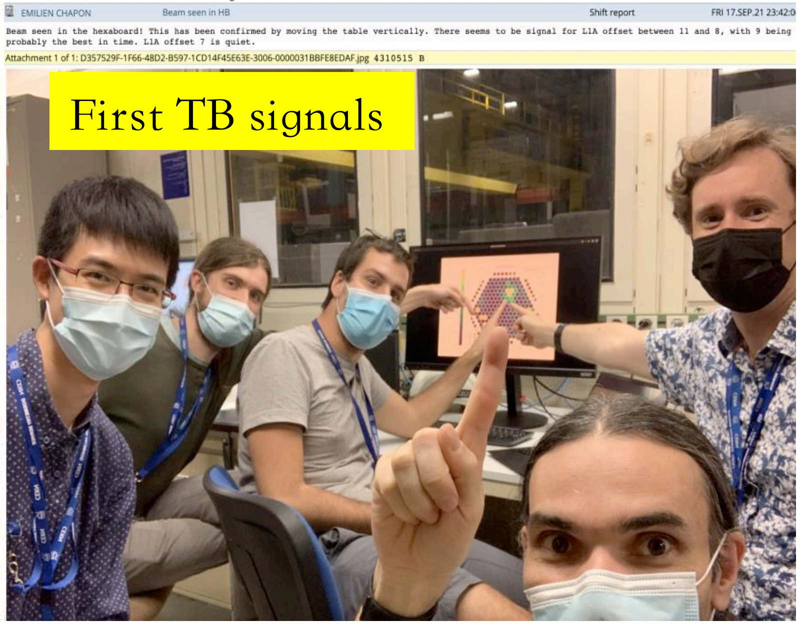
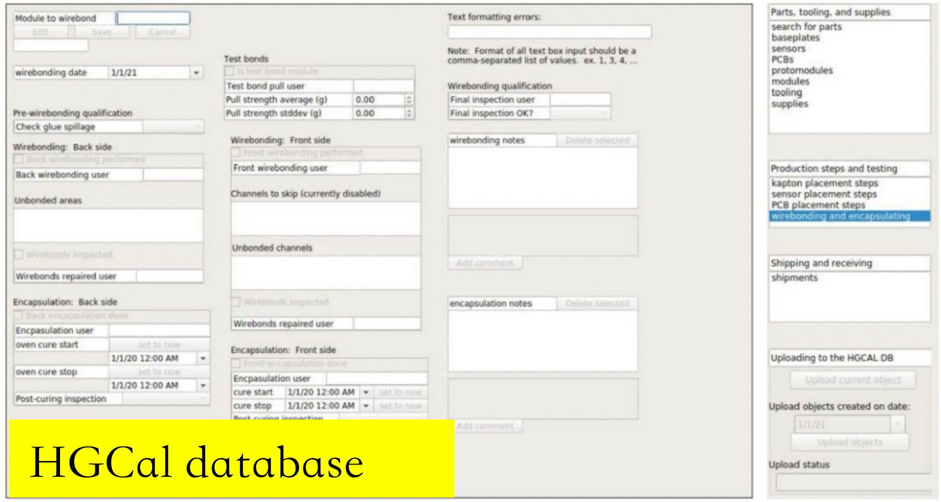


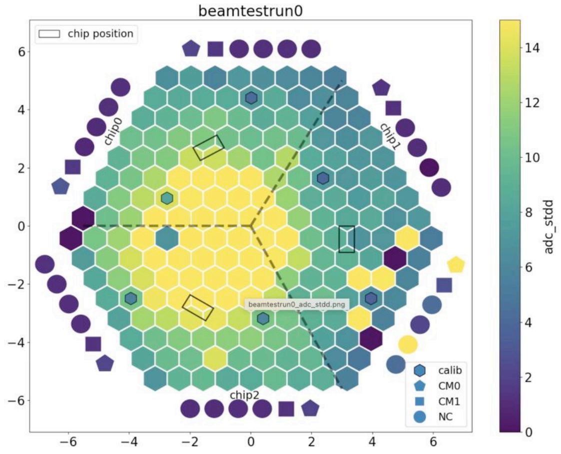
TB setup at H8



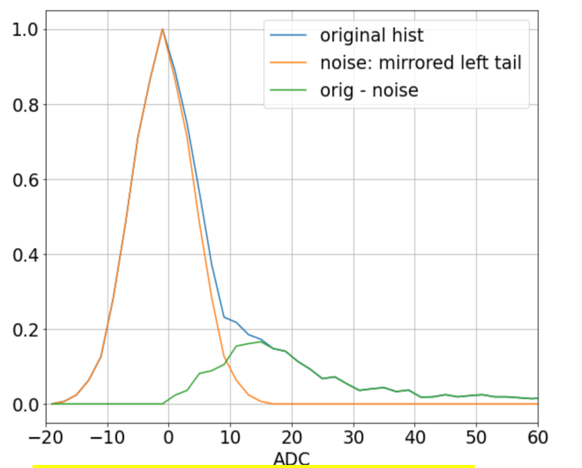

First TB signals



HGCal database




Shower signals from TB




Sign of MIP signals

Émilien Chapon, Fabio Monti (IHEP)

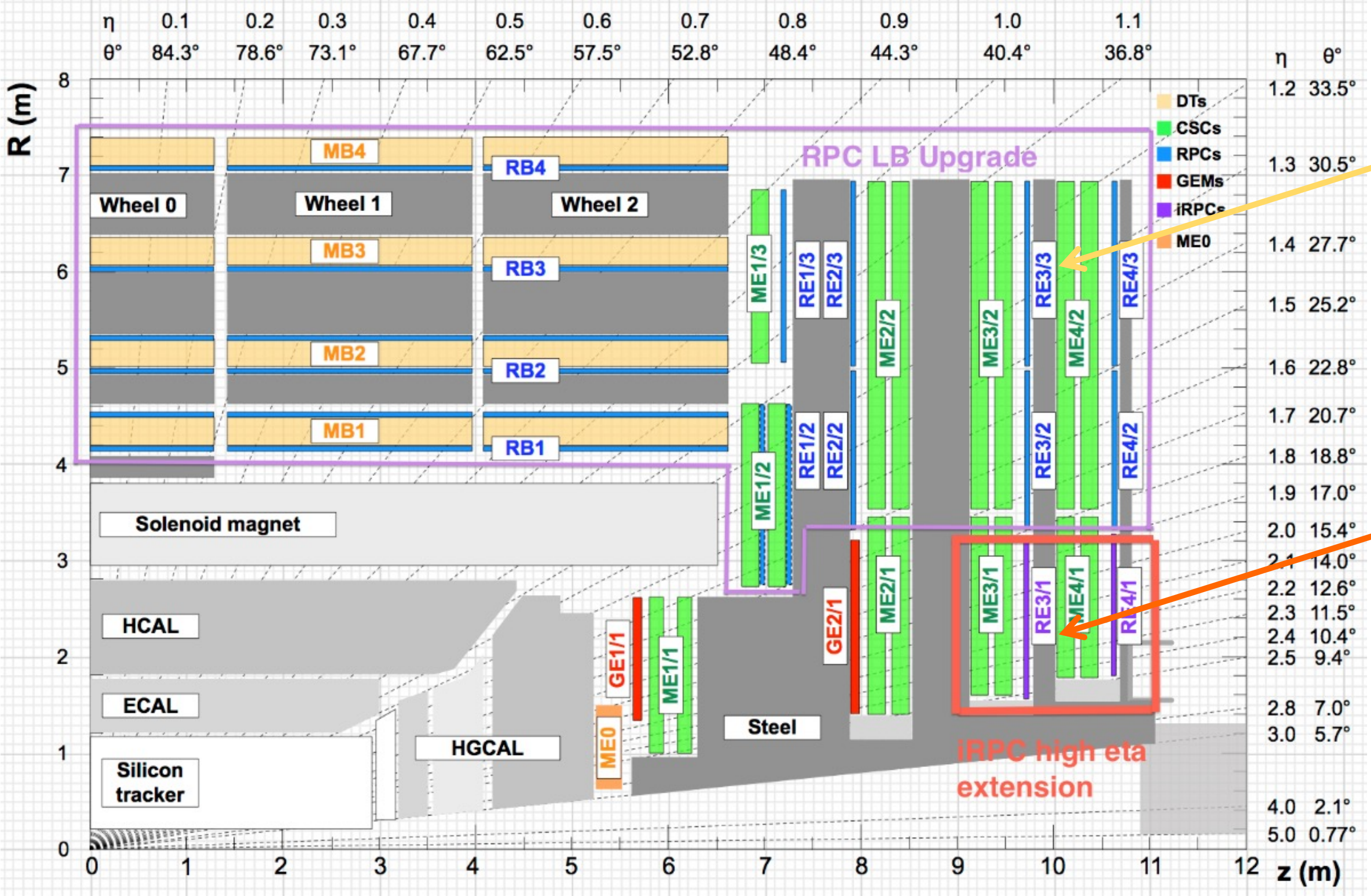

FE tests

HGCAL Database: an essential part of HGCAL project

- **Record data of all steps in module production**
- Transmit information between local MAC and HGCAL database
- Sensors, PCBs, baseplates, tooling; production steps and testing results; shipping

# The RPC BE/TRG project IHEP

iRPC/RPC backend electronics and trigger system




**New link system for existing RPC**

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

**New iRPC and FEB**

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

**Backend Electronics(BE) and Trigger(TRG) need to be designed for new RPC Link System and iRPC.**

Improved Resistive Plate Chamber, **iRPC**, designed for high particle fluxes (up to **2k Hz · cm$^{-2}$**) will be equipped in high pseudorapidity stations (**RE3/1** and **RE4/1**)
These are double-gap RPC (gap size of 1.4mm) to reduce the amount of the avalanche charge produced -> improved RPC count rate
Challenges in electronics: low-noise, high time resolution, able to deal with lower charge signal

# iRPC/RPC BE/TRG task and schedule

Three major components by IHEP

## ◆ iRPC backend:

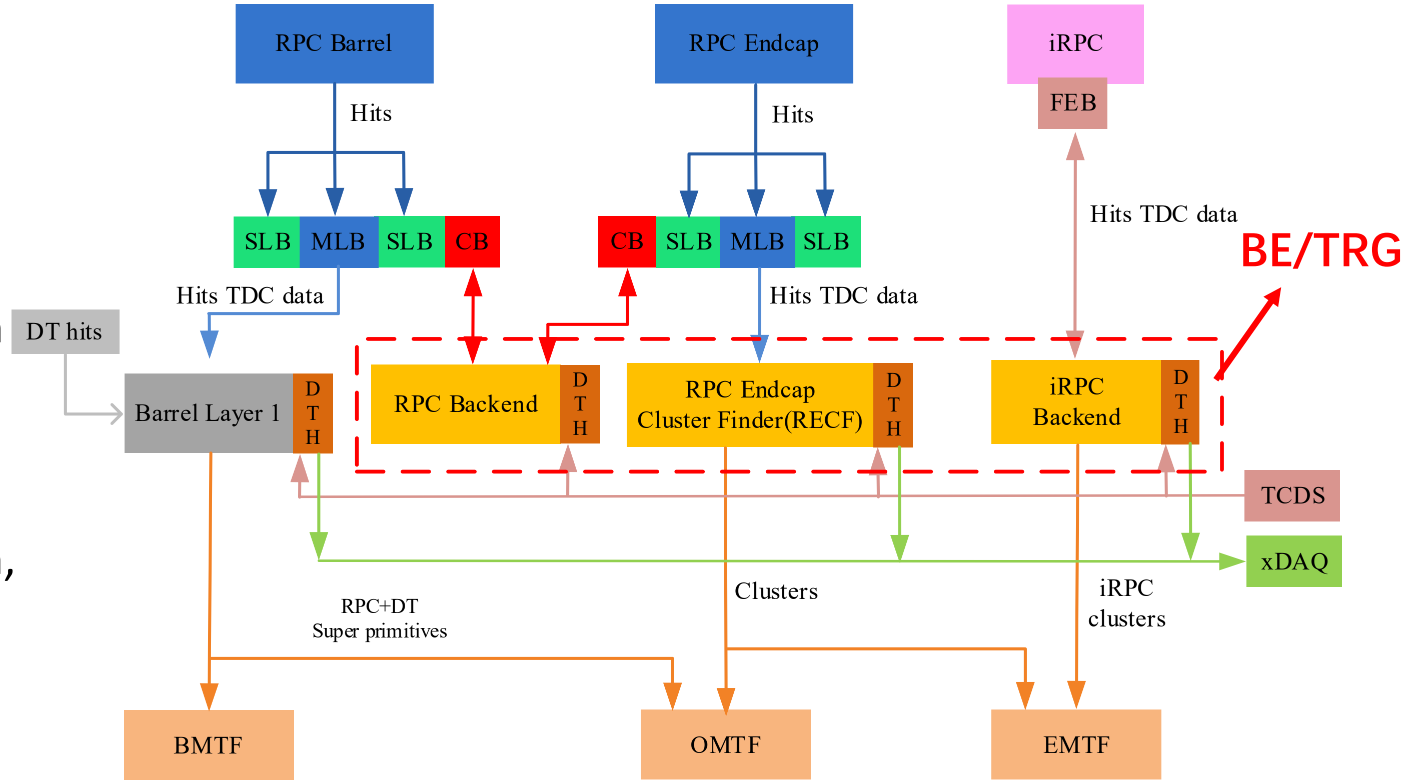
- Fast Control/TTC,
- Slow control/Monitor,
- Data readout,
- Trigger Primitive(Cluster) Generation

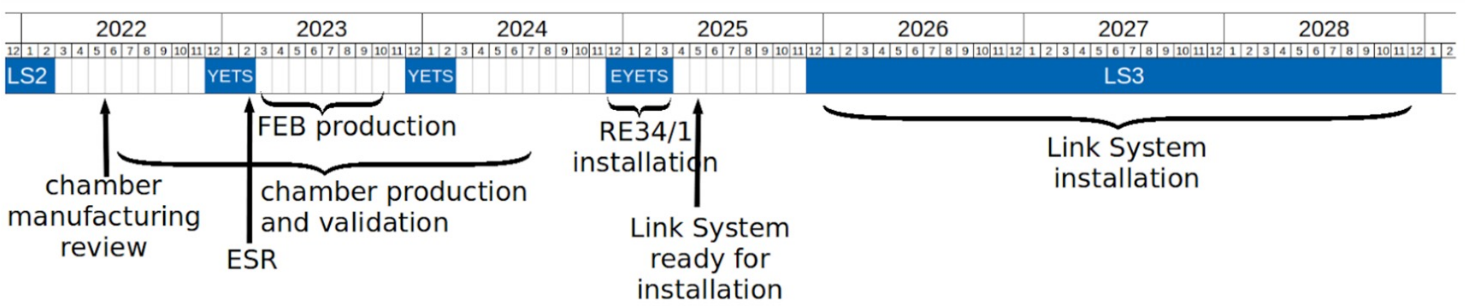
## ◆ RPC Endcap Cluster Finder(RECF):

- Data readout,
- Trigger Primitive(Cluster) Generation,
- TP data Fanout

## ◆ RPC backend:

- Fast Control/TTC
- Slow control,
- monitor

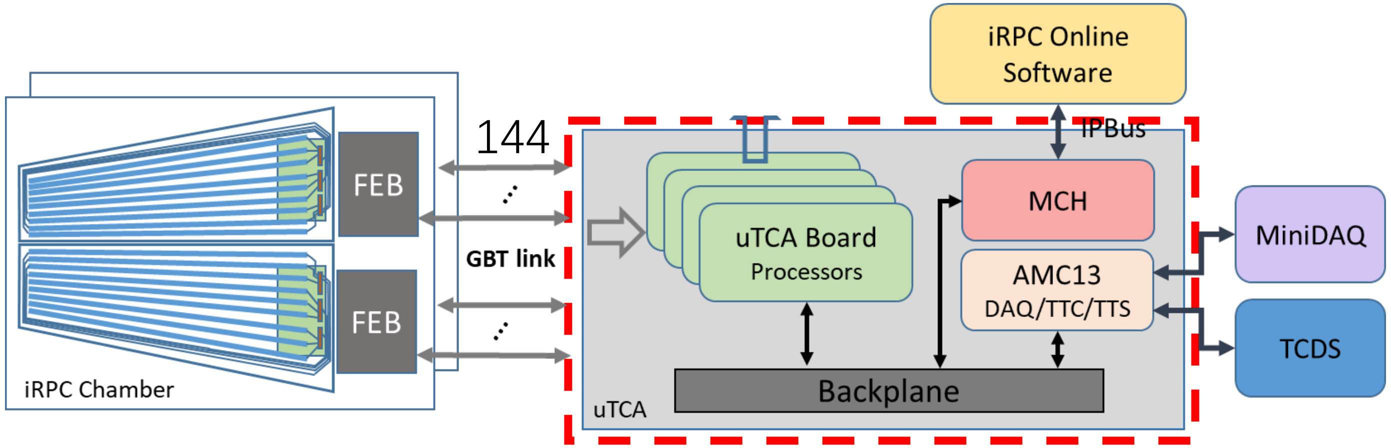


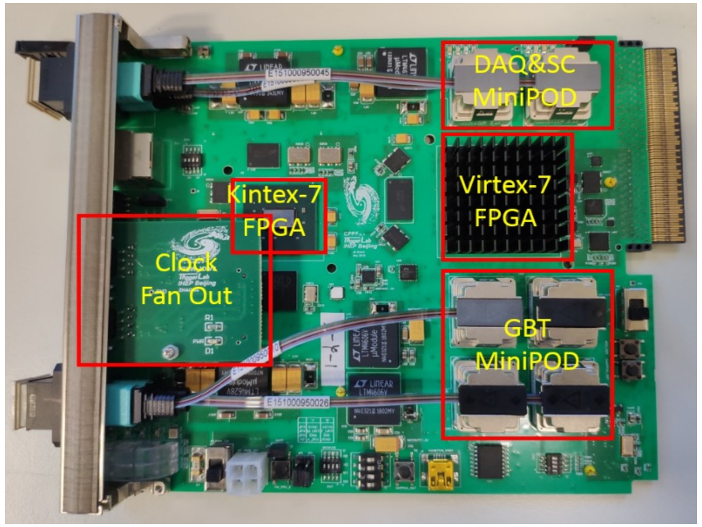
# iRPC µTCA BE/TRG demonstrator system

Layout of the components

- iRPC BE/TRG demonstrator system
  - **µTCA compliant BE boards**
    - core board
  - an AMC13 card
    - system clock and fast control
  - a µTCA Carrier Hub (MCH)
    - manage the whole system
  - a µTCA crate
  - a sever PC
    - slow control and DAQ




- BE/TRG board:
  - Virtex-7 FPGA： Core FPGA ( GBT Communication with Feb + data processing)
  - Kintex-7 FPGA： Control FPGA (clock configuration , SC)



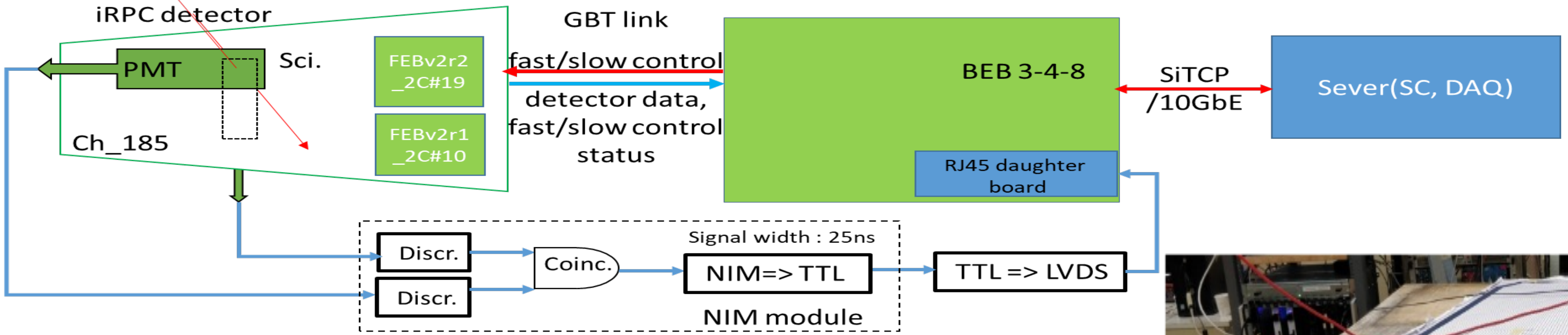
# Joint test with FEB and Chamber in 904

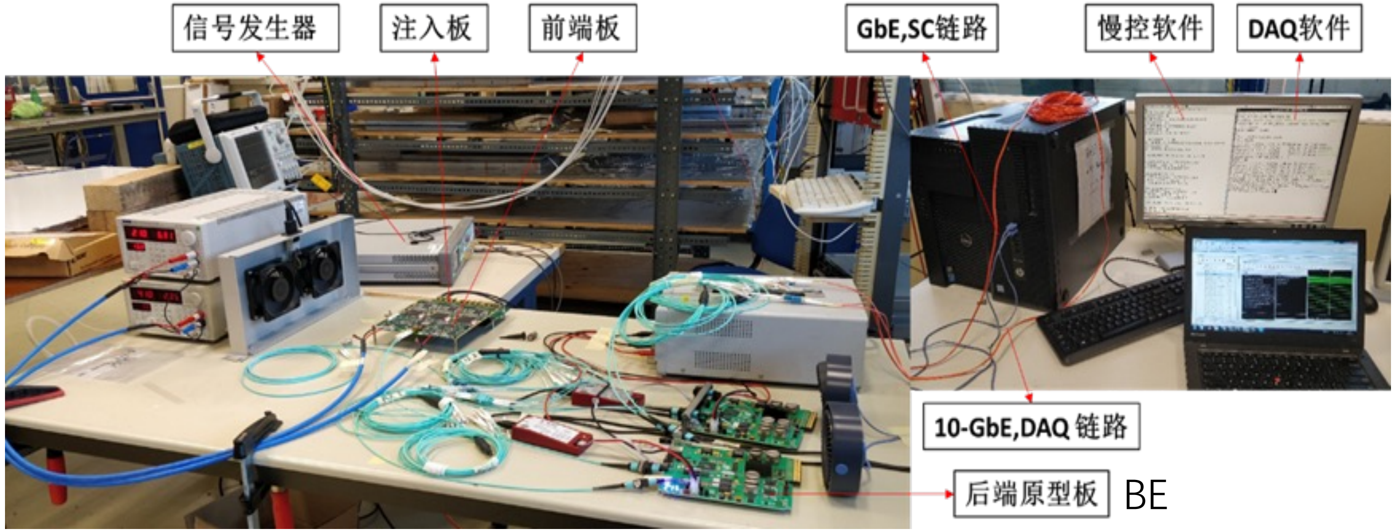
Testing the RPC chamber, FEB and BE all together with cosmic data

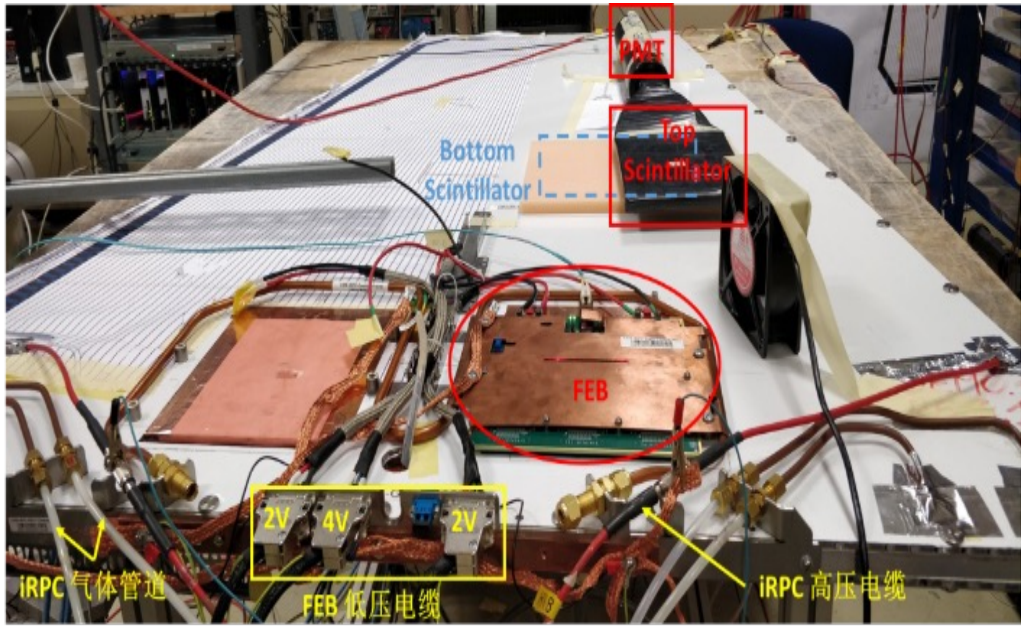
PEKING UNIVERSITY 北京大學

Joint test system setup at CERN in 904 from July 2021, **basic function of BE has been verified**

Second stage of Joint test started from Oct 2021 and focused on **cosmic data taking** for FEB and backend performance studies



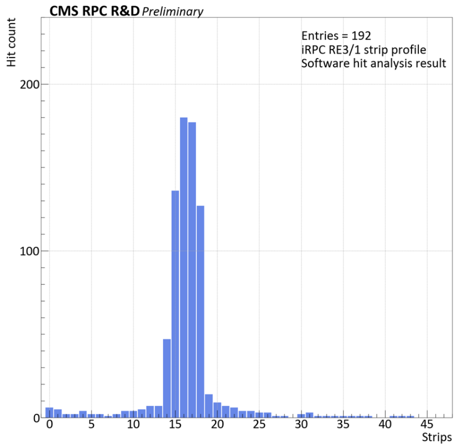
# Joint test with FEB and Chamber in 904

## Test results with cosmic data

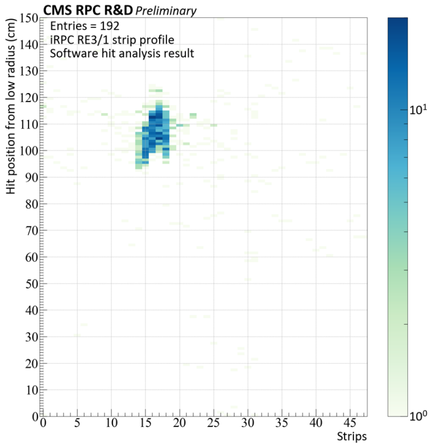
Cosmic Data taking successfully with FEB and chamber

Study on hit position, cluster position distribution and other cluster characteristics

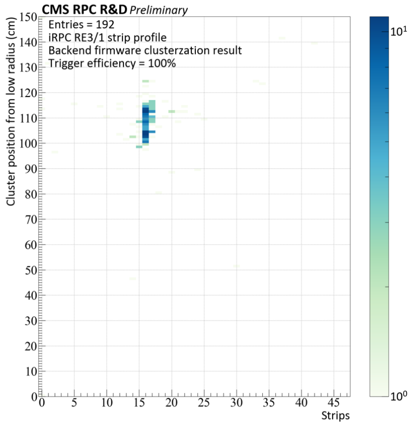
Studying on high voltage efficiency scan under different **DAQ readout windows** and proposing solution suggestion to FEB team



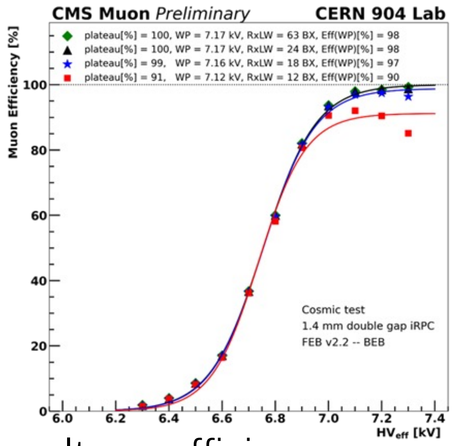

Hits distribution on strips



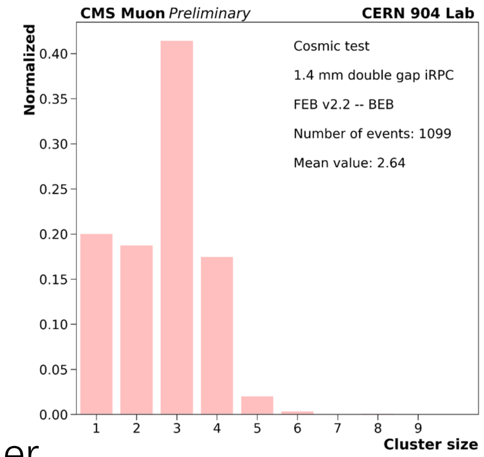

**Hits** position distribution on chamber



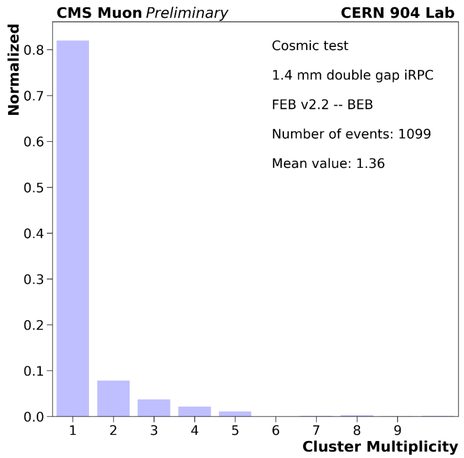

**Cluster**ization distribution




High voltage efficiency scan under different DAQ readout window




**Cluster size** distribution



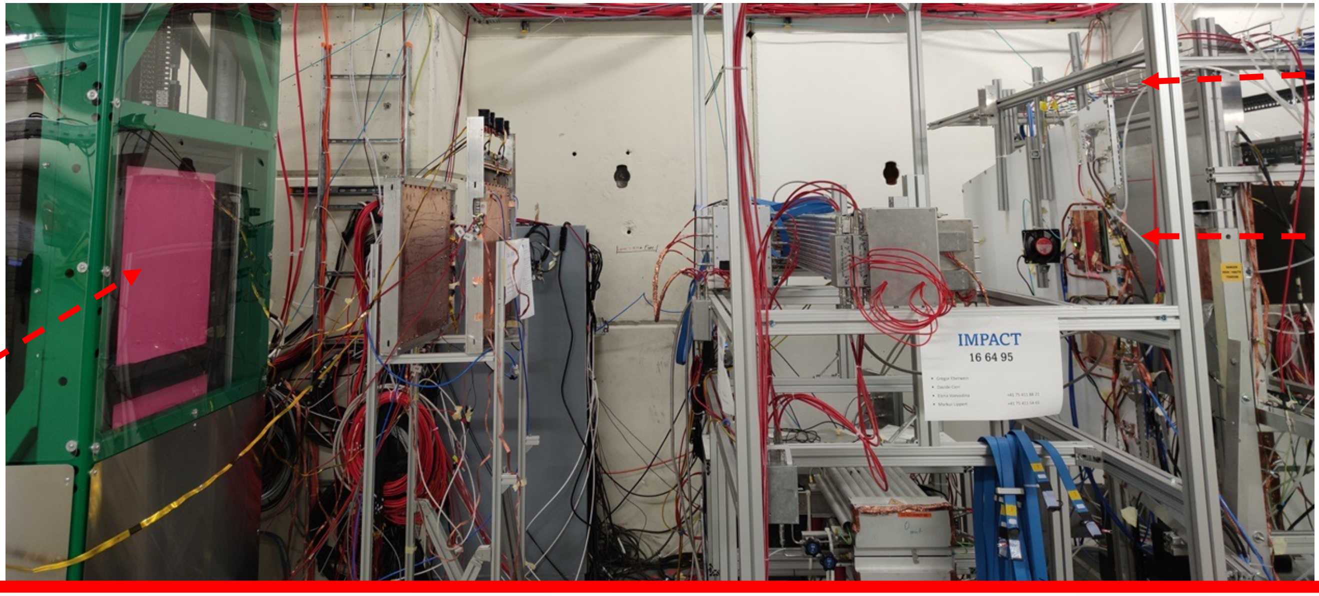

**Cluster multiplicity**

# iRPC BE/TRG beam test in GIF++

The setup

北京大學 PEKING UNIVERSITY

Beam test in GIF++ conducted from 2022.10.19 to 11.2.



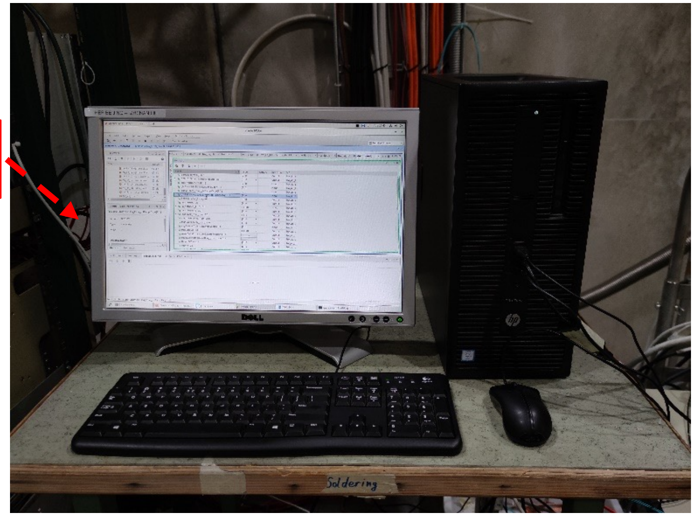

γ background source

Chamber_190

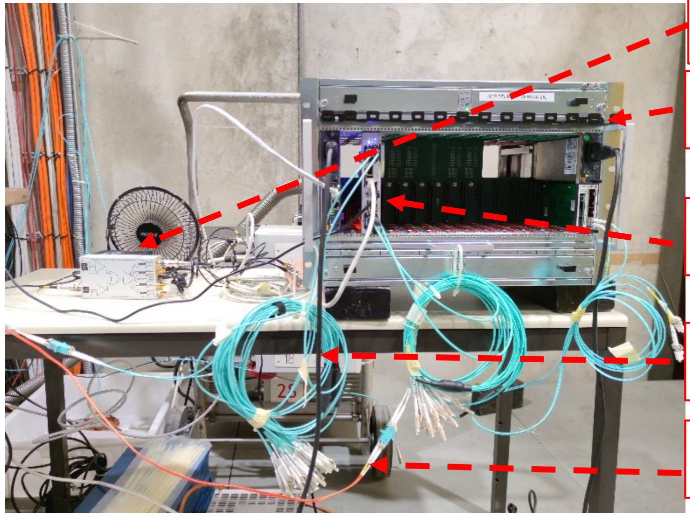
FEB v2_2c

Inside bunker

Outside bunker



DAQ and IPbus SC server



L1A trigger

mTCA crate

BEB

GBT link

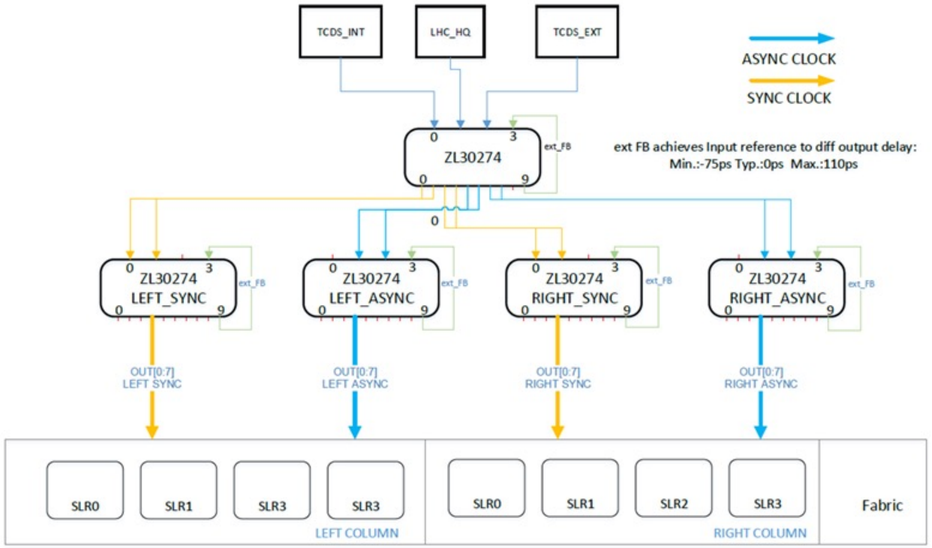
10GbE DAQ

# Serenity S1 board design

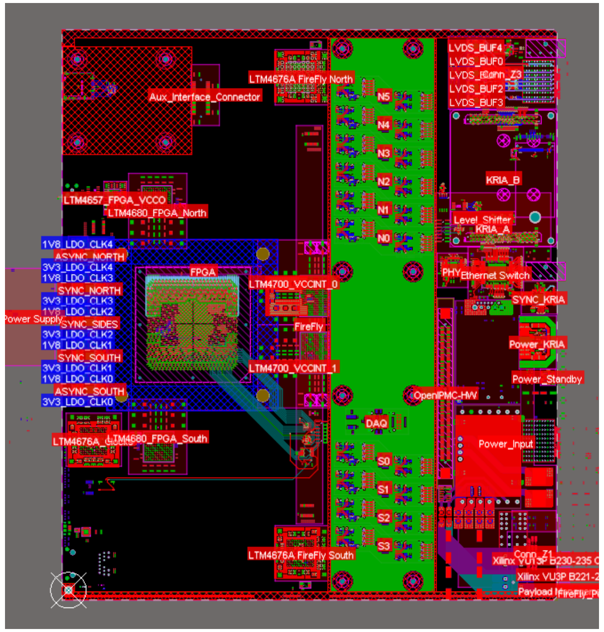
## The DAQ system

Joined Serenity steering committee, design group and layout group for Serenity board design

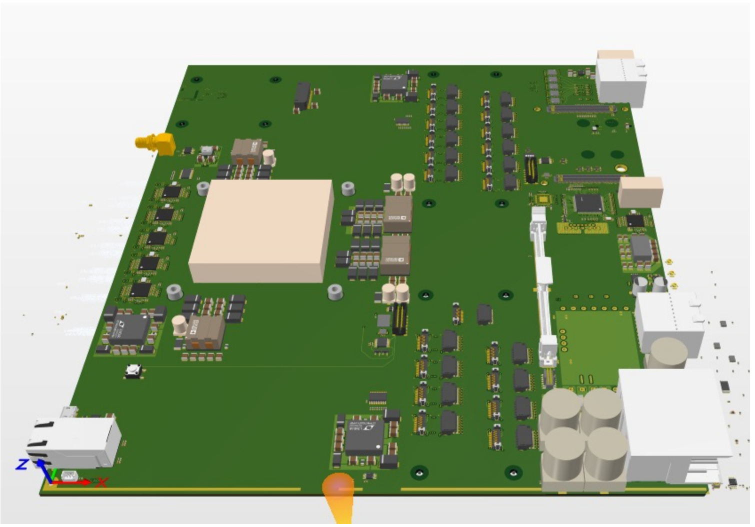
Provided **clock tree design scheme**, and joint the schematic and PCB layout design




Clock tree design scheme for Serenity S1



2D view of Serenity S1 PCB



3D view of Serenity S1 PCB

# Summary

Activities mainly from the last year

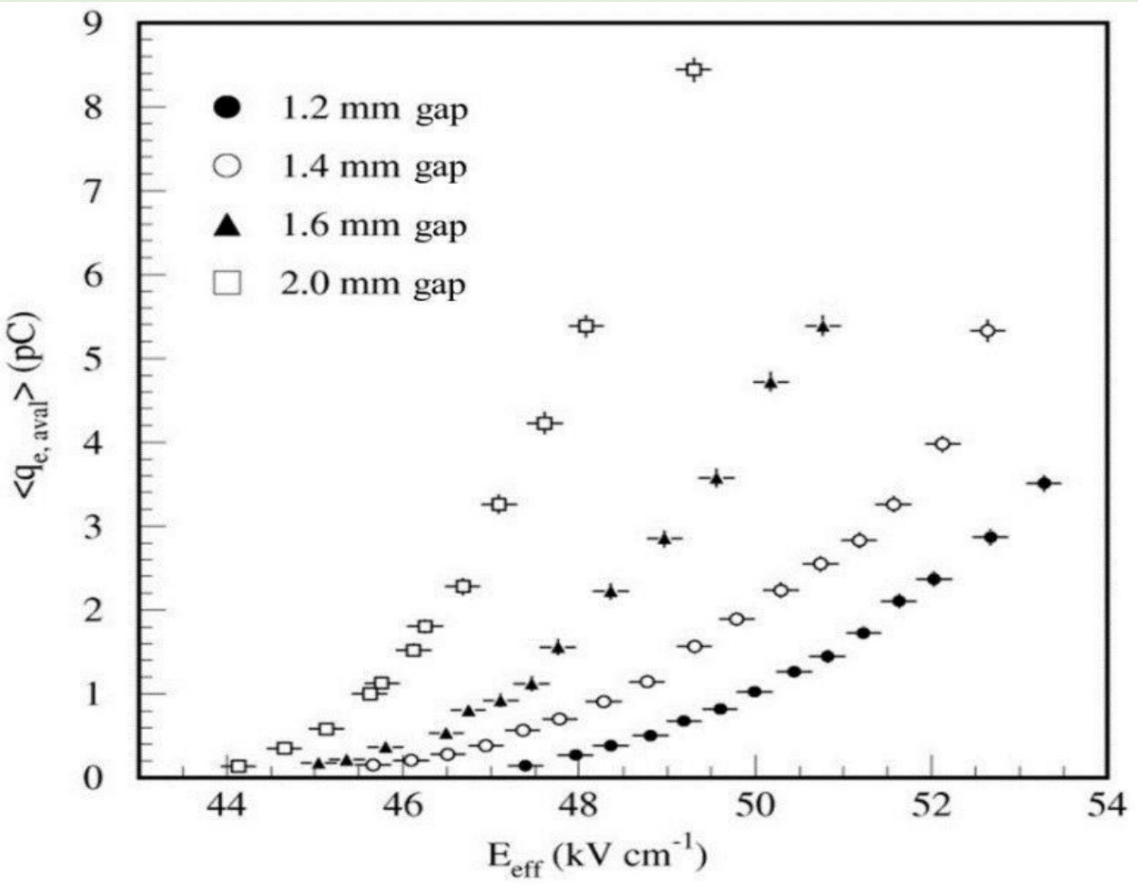
PEKING UNIVERSITY

- CMS Phase-II upgrade projects are progressing smoothly, with many important contributions from CMS-China
  - **GEM** completed the GE2/1 GEB design and production, started the first batch of **mass production of GE2/1 full detector** (first in CMS!)
  - **MTD** is actively preparing the **assembly center** and test benches
  - **HGCal** produced first small **batch of 8 inch silicon modules** (first in CMS!)
  - **iRPC/RPC** BE/TRGB had **joint test with FEBs and cambers** using cosmic data taking, joined serenity board design with main contribution in the **clock tree scheme**
- Three assembly centers GEM, MTD and HGCal are going to take significant fraction of the detector assembly work
  - **PKU GEM and IHEP HGCal** got CERN certification of the assembly centers
  - **PKU MTD** got approved to build the assembly center and started the preparation

# Backup slides

# iRPC

| | RPC | iRPC |
|---|---|---|
| N gas gap | 2 | 2 |
| Gas Gap | 2 mm | 1.4 mm |
| High Pressure Laminate | 2 mm | 1.4 mm |
| Resistivity (Ωcm) | 1 - 6 x $10^{10}$ | 0.9 - 3 x $10^{10}$ |
| Strip pitch | 2-4 cm | 0.7-1.2 cm |
| Electronics Threshold | 150 fC | 10 fC |
| Chamber dimension | 10 degrees | 20 degrees |




The thinner gap thicknesses:

- more effectively retard the fast growth of the pickup charges of the ionization avalanches
- reduce aging effect
- reduce of the operational high voltage from 9.5 kV to 7.1 kV improving the robustness of the system and reducing the failure probability of the HV system

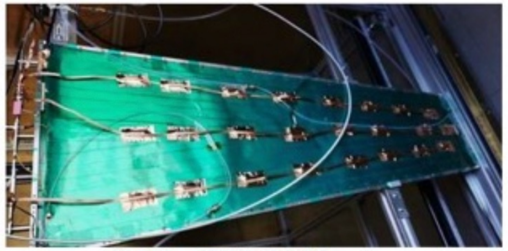
# PKU production site and activities at CERN

## Local and CERN

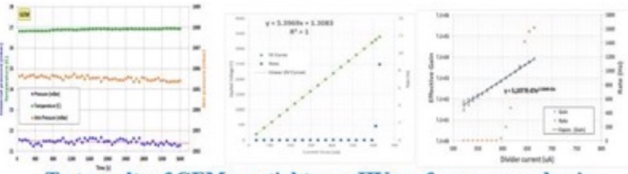
- PKU GEM assembly and QC laboratory ready, with cleanroom and hardware/software platforms
  - Mar. 2021: PKU GEM Lab. **passed the review of CMS-GEM collaboration, becomes one of the official CMS-GEM production sites**
- Summers in 2021 and 2022: PKU members participated the assembly and test of GE2/1 GEM at CERN

- Completed gas-tightness, HV performance and gain test etc. with **full-size GE1/1 GEM**, QC procedure setup done.

GEM X ray gain test at PKU



Full-size GE1/1 GEM detector



Test results of GEM gas-tightness, HV performance and gain

→ GEM Production site in PKU is ready

Test of Full-size GE1/1 GEM at PKU lab


### GE21 Production Plan

**Module Assignment:**

| Site | Readiness | Assigned Modules | Quantity to be produced/tested | Expected start date | Comments |
|---|---|---|---|---|---|
| Aachen | | M1 | 38 | April/May 2021 | QC only |
| PU | | M2 | 19 | April/May 2021 | APV25 not yet ready |
| DU | | M2 | 19 | April/May 2021 | |
| NCP | | M7 | 38 | October/November 2021 | |
| INFN-LNF | | M6 | 38 | September 2021 | |
| INFN-BARI | | M8 | 38 | September 2021 | |
| UGHENT | | M3 + M1 | 38 + 19 | May (M1) / August (M3) | |
| PKU | | M5 | 38 | June 2021 | SRS test at CERN |
| UOC/UOR | | M4 + M1 | 38 + 19 | June 2021 | |


Note: adjustments should be possible in case a production site runs late/early or due to component availability

Jeremie A. Merlin GEM Upgrade Workshop CERN, Mar. 30, 2021 p. 19

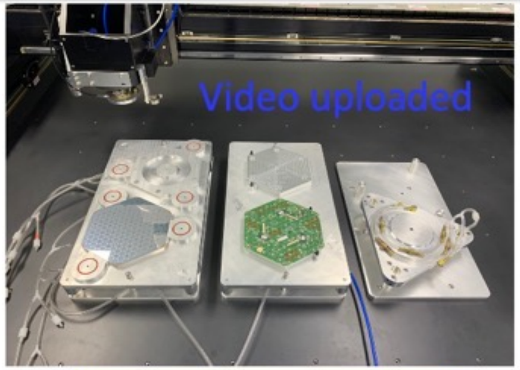
Production share

# Responsibilities of MACs

From module assembly to QA/QC as required by the MAC certification



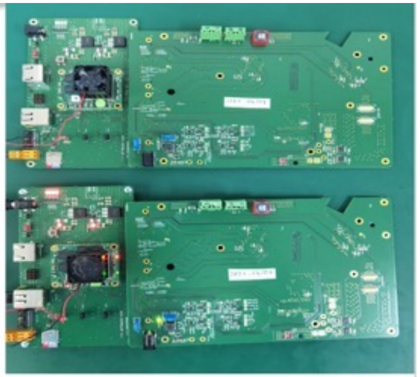
componat tests →



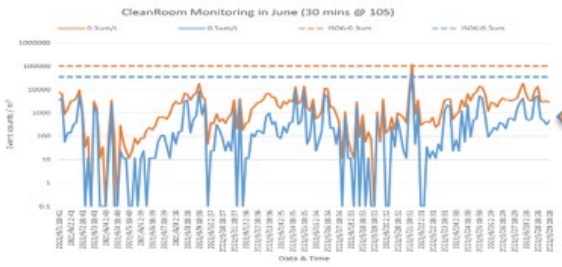

Module assembly →


Wire bonding →

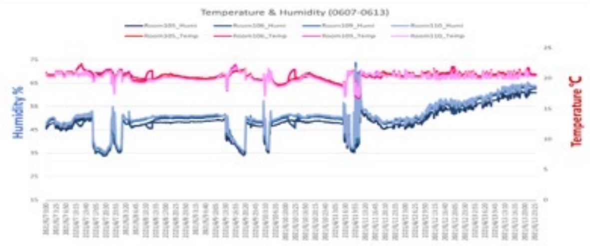

encapsulation →

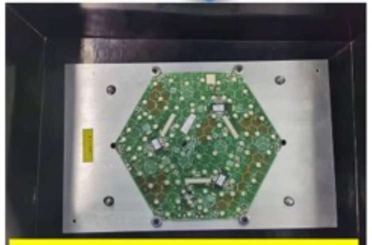


Module testing




Cleanroom status
- Cleanness
- Temperature
- Humility



Ship back to CERN

- Clean room and major equipment are installed, operator trained
- Fixture for gantry, wire bonder, pull tester, encapsulation are fabricated
- Glue parttern for assemly, encapsulation and wire bonding code are tested
- Go through full production chain for the first time on real componats (next slide)