

IAS PROGRAM

# Fundamental Physics

January 12-16, 2026

## CEPC Reference Detector

**Miao He**

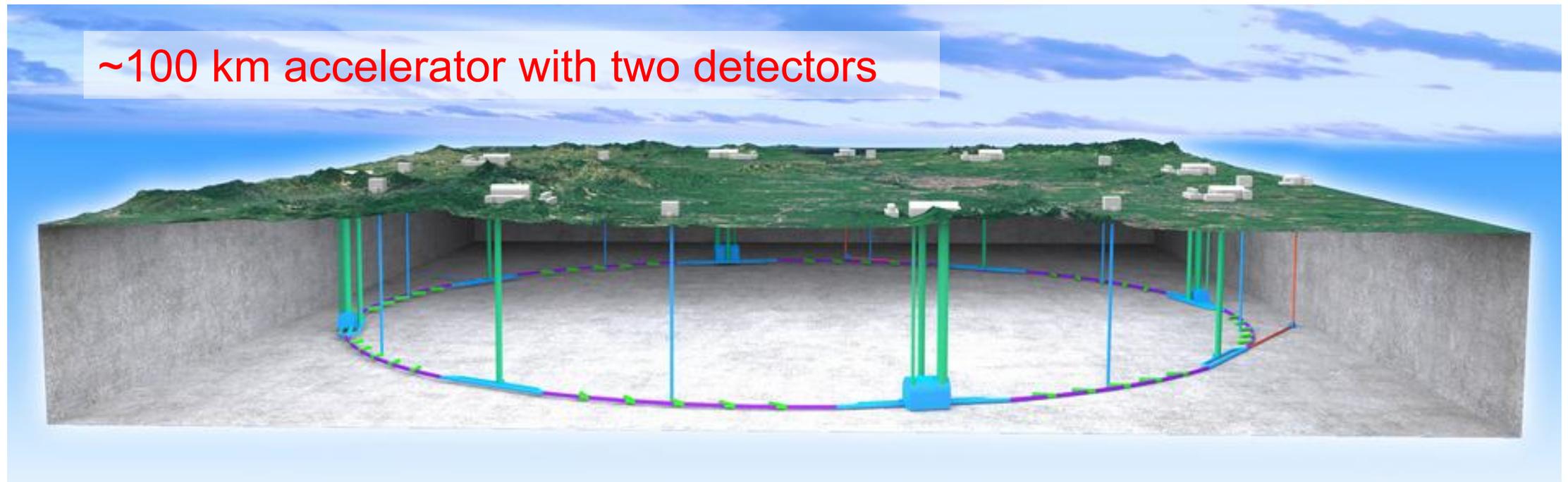
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*Institute of High Energy Physics*  
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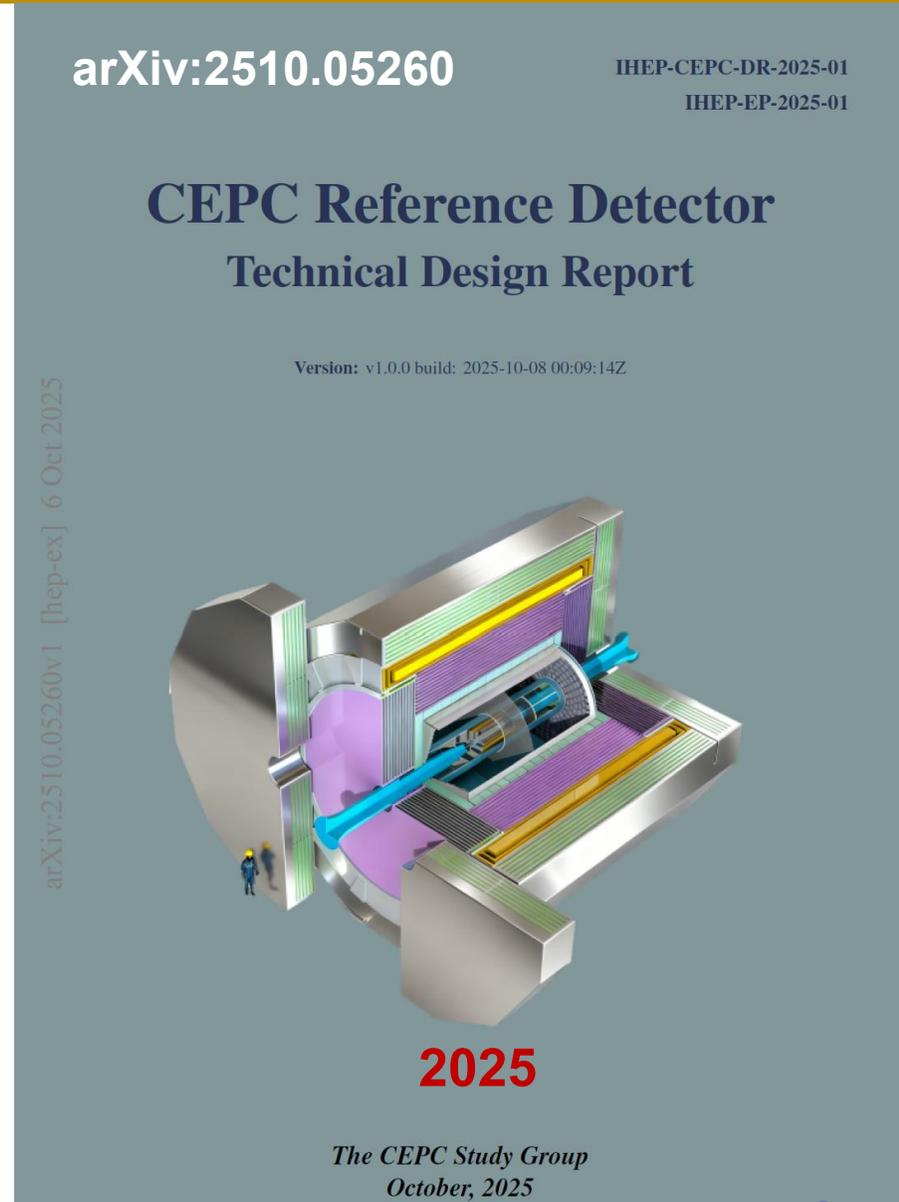
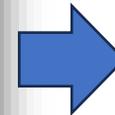
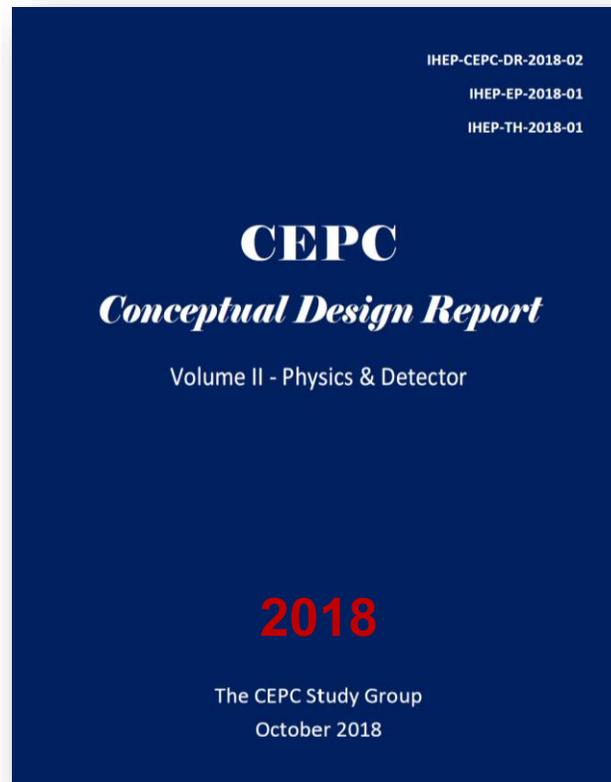
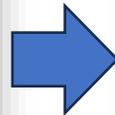
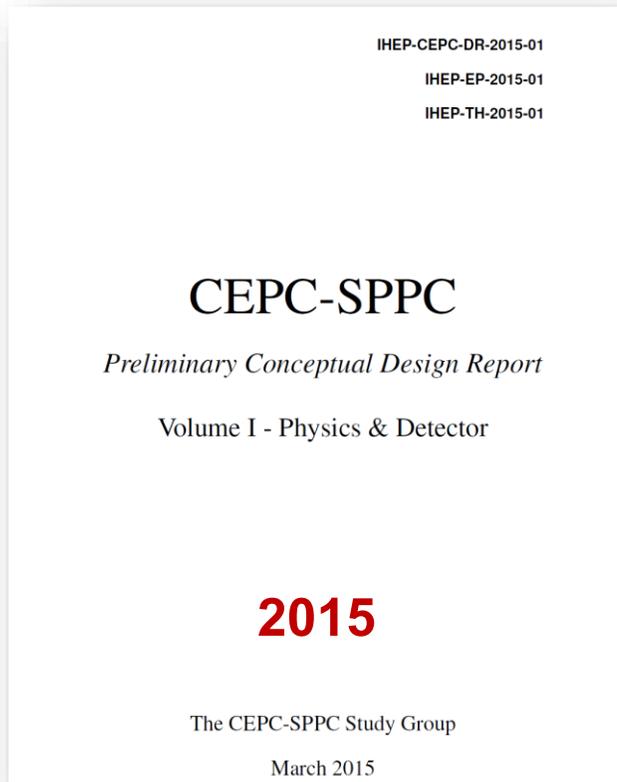
# Circular Electron Positron Collider (CEPC)

- The CEPC was proposed by the Chinese HEP community in 2012 right after the Higgs boson discovery, as a Higgs / Z / W factory in China.
- To produce Higgs / W / Z / top for high precision Higgs, EW measurements, studies of flavor physics & QCD, and probes of new physics beyond the SM.
- It is possible to upgrade to a pp collider (SppC) of  $\sqrt{s} \sim 100$  TeV in the future



# CEPC Reference Detector TDR

- **Technical Design Report** (TDR) released on Oct. 6, 2025
- **19** chapters, **669** pages
- **1474** authors from **383** institutes in **43** countries



# CEPC operation scenarios

- **CEPC reference detector TDR:** Demonstrate readiness for construction of detector for baseline scenario. A detector that could be constructed and commissioned within a decade.
- **After CEPC project approval:** Two CEPC detectors will be selected among international proposals. International collaborations will lead those detector designs and produce corresponding TDRs adapted to the final operational scenarios.

## Baseline scenario

Operation mode	$\sqrt{s}$ (GeV)	SR power (MW)	$\mathcal{L}$ ( $10^{34} \text{ cm}^{-2}\text{s}^{-1}$ )	$\int \mathcal{L}/\text{year}$ ( $\text{ab}^{-1}$ )	Years	Total $\int \mathcal{L}$ ( $\text{ab}^{-1}$ )	Event yields
$H$	240	30	5	0.65	15	10	$2.0 \times 10^6$
$Z$	91	12.1	26(*)	3.2	4	13	$5.6 \times 10^{11}$
$W^+W^-$	155-170	30	16	1.2	1	1.2	$1.0 \times 10^7$ (†)

## Upgraded scenario: with international contribution

Operation mode	$\sqrt{s}$ (GeV)	SR power (MW)	$\mathcal{L}$ ( $10^{34} \text{ cm}^{-2}\text{s}^{-1}$ )	$\int \mathcal{L}/\text{year}$ ( $\text{ab}^{-1}$ , 2 IPs)	Years	Total $\int \mathcal{L}$ ( $\text{ab}^{-1}$ , 2 IPs)	Event yields
$H$	240	50	8.3	2.2	10	21.6	$4.3 \times 10^6$
$Z$	91	50	192(*)	50	2	100	$4.1 \times 10^{12}$
$W^+W^-$	155-170	50	26.7	6.9	1	6.9	$5.5 \times 10^7$
$t\bar{t}$	360	50	0.8	0.2	5	1.0	$0.6 \times 10^6$

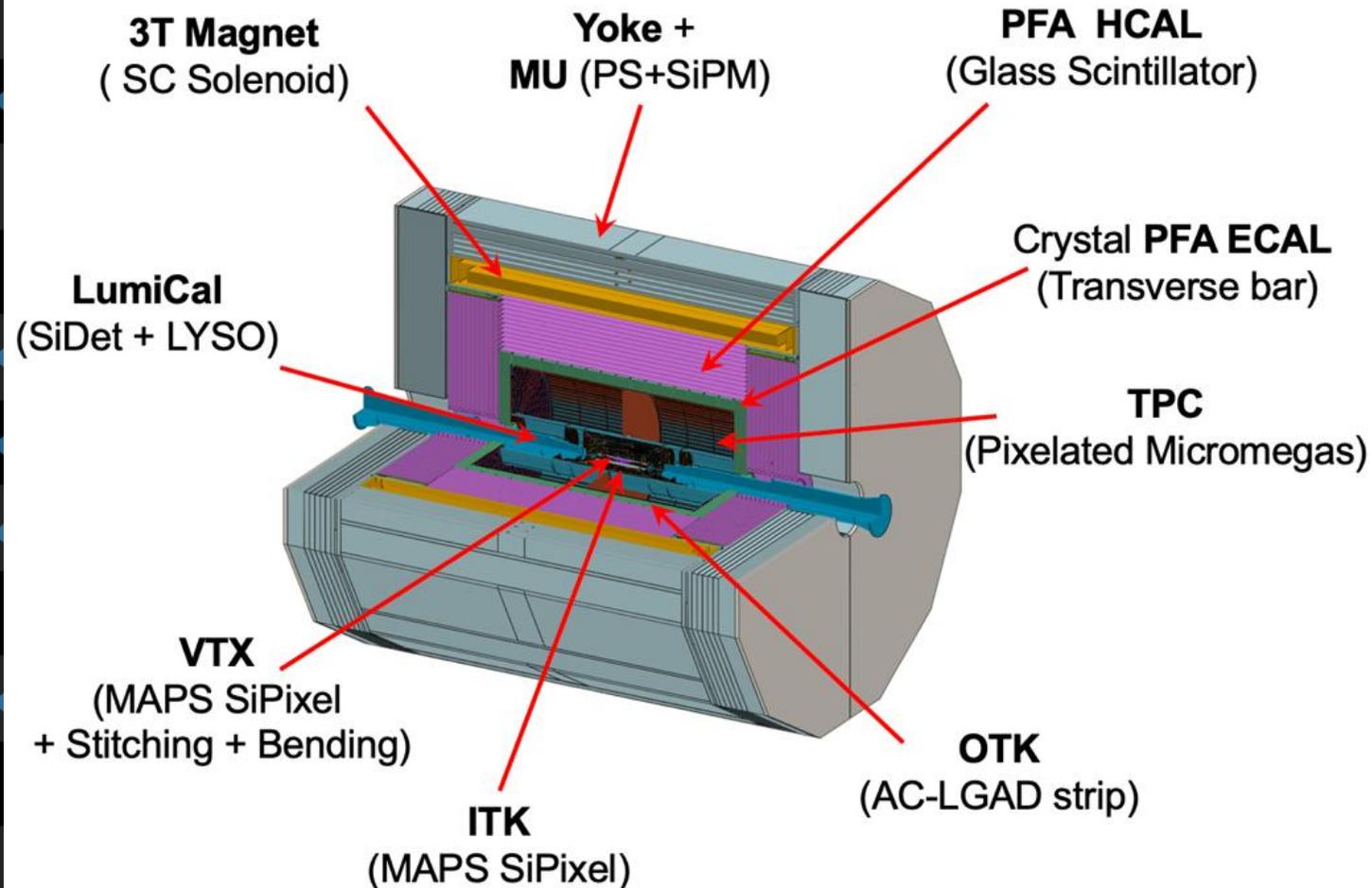
# Requirement to the detector

Physics objects	Measurands	Detector subsystem	Performance requirement
Tracking	Coverage	Tracker	$ \cos\theta  \leq 0.99$
	Recon. efficiency		$\geq 99\%$ ( $p_T > 1 \text{ GeV}/c$ )
	Resolution in barrel		$\sigma_{p_T}/p_T < 0.3\%$ ( $ \cos\theta  \leq 0.85$ )
	Resolution in endcap		$\sigma_{p_T}/p_T < 3\%$ ( $ \cos\theta  > 0.85$ )
Leptons ( $e, \mu$ )	PID efficiency	Tracker, ECAL	$\geq 99\%$ ( $p > 5 \text{ GeV}/c$ , isolated)
	Mis-ID rate	HCAL, Muon	$\leq 2\%$ ( $p > 5 \text{ GeV}/c$ , isolated)
Photons	PID efficiency	ECAL, HCAL	$\geq 95\%$ ( $E > 3 \text{ GeV}$ , isolated)
	Mis-ID rate		$\leq 5\%$ ( $E > 3 \text{ GeV}$ , isolated)
	Energy resolution		$\sigma_E/E \leq 3\%/\sqrt{E(\text{GeV})} \oplus 1\%$
Vertex	Position resolution	Vertex	$\sigma_{r\phi} = 5 \oplus \frac{10}{p(\text{GeV}) \times \sin^{3/2}\theta} (\mu\text{m})$
Hadronic jets	Energy resolution	Tracker	$\sigma_E/E \sim 30\%/\sqrt{E(\text{GeV})} \oplus 4\%$
	Mass resolution	ECAL, HCAL	BMR $\leq 4\%$
Jet flavor tagging	b-tagging efficiency	Full detector	$\sim 80\%$ , mis-ID of uds $< 0.3\%$
	c-tagging efficiency		$\sim 50\%$ , mis-ID of uds $< 1\%$
Charged kaon	PID efficiency, purity	Tracker, TOF	$\geq 90\%$ (inclusive Z sample)

# CEPC Reference Detector

Sub-system	Technologies
Beam pipe	Beryllium, $\phi$ 20 mm
LumiCal	Silicon tracker + LYSO crystals
Vertex	Si Pixels: CMOS MAPS+stitching
Inner tracker (ITK)	Si Pixels: CMOS MAPS 55-nm
Gas detector	TPC with high granularity
Outer tracker (OTK)	AC-LGAD $\rightarrow$ TOF
ECAL	4D transverse crystal bars
HCal	Glass scintillator, SiPM + Fe
Magnet	LTS Solenoid
Muon	Plastic scintillator bars, SiPM
TDAQ	Conventional
Back-end electronics	Common

**10×10×12 m<sup>3</sup>, ~5000 ton**



# Parallel talks at FP 2026

## ● Details extensively discussed in parallel talks

16:50

### Status of CEPC Hadronic Calorimeter

报告人: Haijun YANG (Shanghai Jiao Tong University)

 CEPC-HCAL-HKU...

14:00

### Silicon Vertex Detector at CEPC

报告人: Zhijun LIANG (Chinese Academy of Sciences)

 CEPC-vertex-202...

14:20

### Development of HVCMOS-based CEPC Inner Tracker

报告人: Zijun XU (Institute of High Energy Physics, Chinese Academy of Sciences)

 CEPC\_Inner\_Trac...

14:40

### Overview of the CEPC Outer Tracker and Recent Progress in Key Detector Technologies

报告人: Jiajian TEOH (Institute of High Energy Physics, Chinese Academy of Sciences)

 IASFP2026\_CEPC...

15:20

### Progress on TPC Technology for $e^+e^-$ Collider and Neutrino Detection

报告人: Huirong QI (Institute of High Energy Physics, Chinese Academy of Sciences)

 TPC\_RD\_HKUST\_...

16:30

### High-granularity crystal calorimeter for future Higgs factories

报告人: Yong LIU (Institute of High Energy Physics, Chinese Academy of Sciences)

 HGCCAL\_IAS\_FP...

16:50

### Luminosity measurement at the future $e^+e^-$ collider

报告人: Lei ZHANG (Nanjing University)

 2026Jan\_HKUST\_...

17:10

### CEPC Reference Detector Performance

报告人: Mingshui CHEN (Chinese Academy of Sciences)

 CEPC Reference ...

17:30

### Learning from All Reconstructed Particle at CEPC

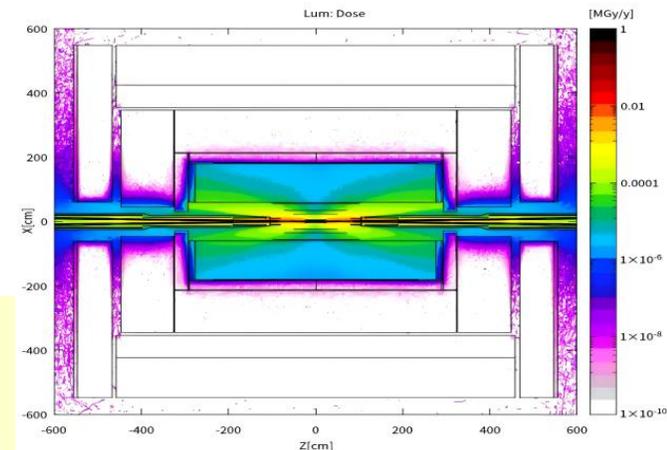
报告人: Manqi RUAN (Institute of High Energy Physics, Chinese Academy of Sciences)

 Learning From all ...

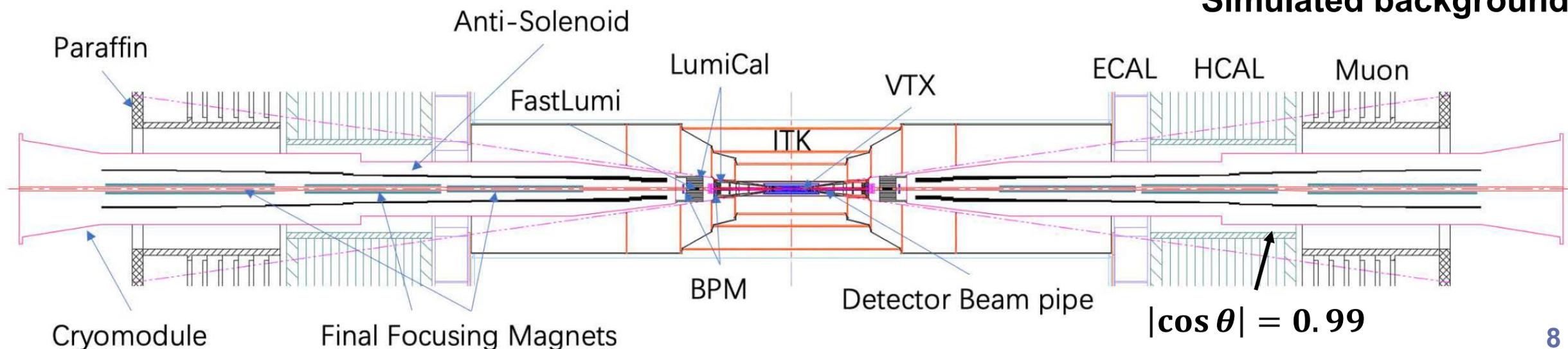
# Machine detector interface

- **Beam pipe:**  $\Phi_{\text{inner}}$  20 mm, double-layer Beryllium, 0.454%  $X_0$ , water or paraffin cooling
- **Beam-induced background:** background simulation and optimization of shielding
- **Luminosity measurement:**
  - ✓ Luminosity Calorimeter: silicon detectors + LYSO calorimeters
  - ✓ Fast Luminosity monitor: diamond slab + SiC detectors
  - ✓ Beam position monitor:  $\sigma \approx 1 \mu\text{m}$

**Deliver the maximum luminosity without affecting detector performance. Most challenging component.**



**Simulated background**

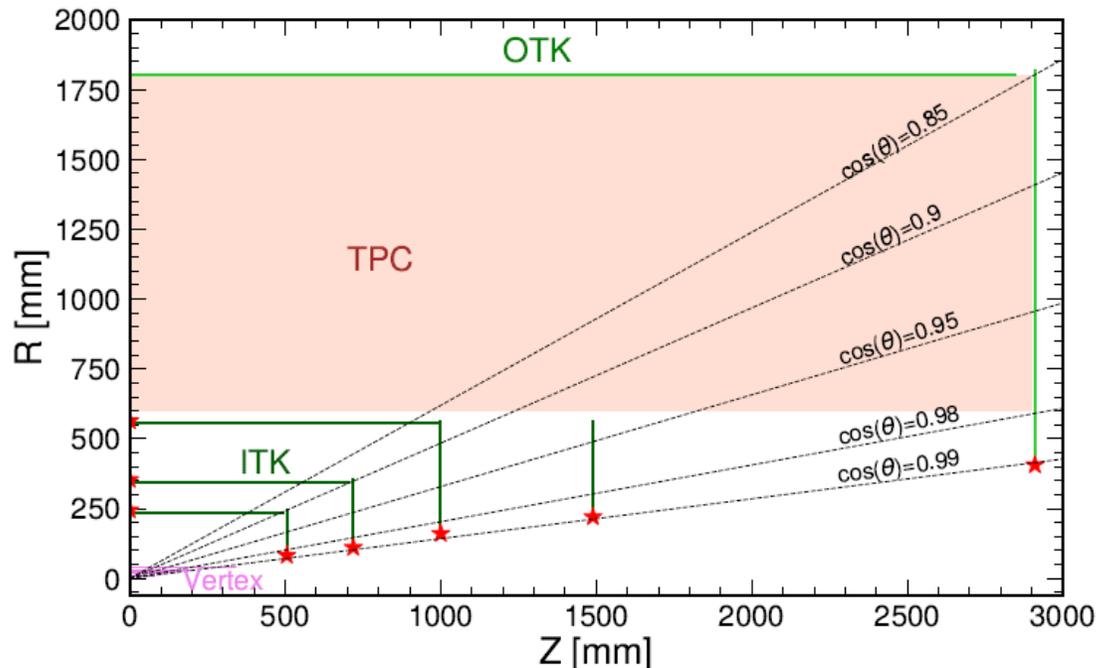


# Tracking system

Silicon detectors

Gaseous detector

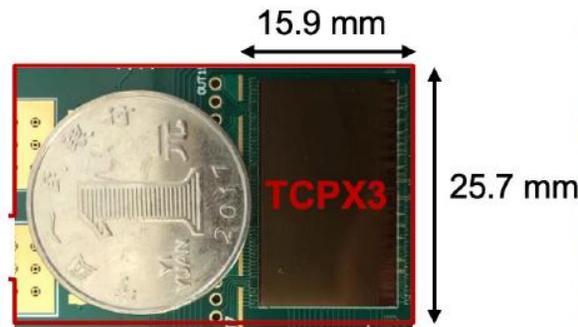
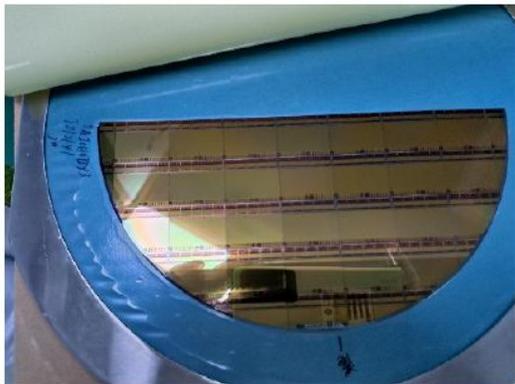
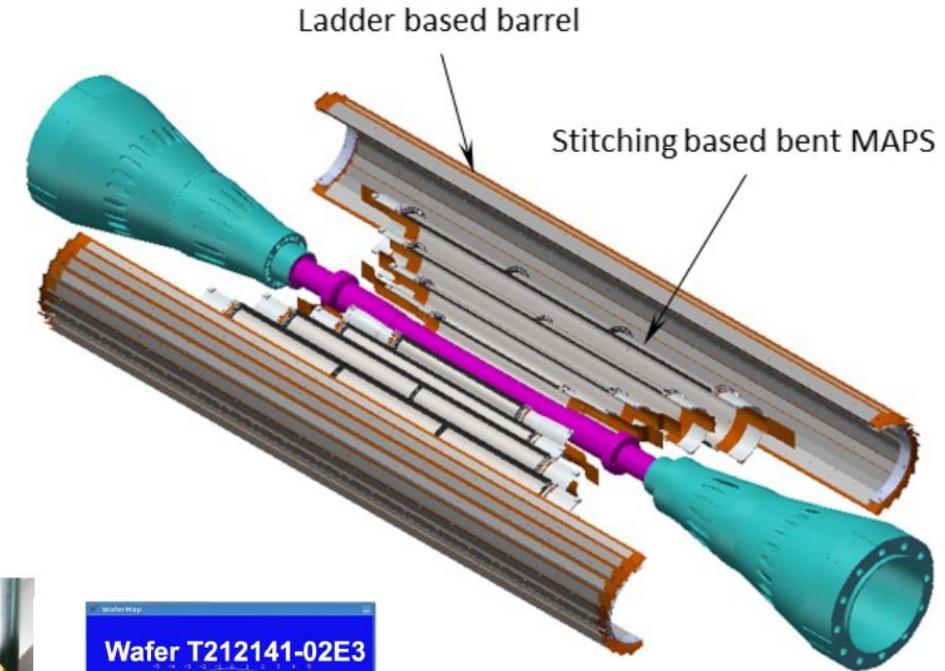
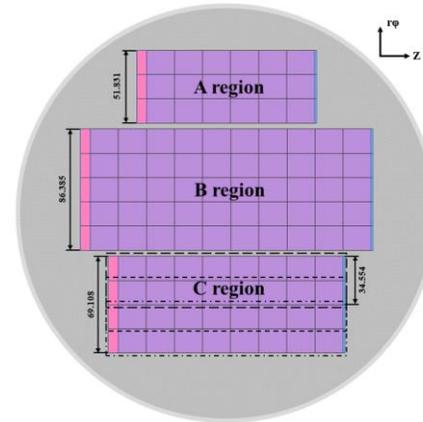
- Vertex: MAPS silicon sensors bend to a tube, for  $\sigma$  of 5  $\mu\text{m}$
- 20  $\text{m}^2$  inner tracker using HV-CMOS pixel for  $\sigma \approx 8 \mu\text{m}$
- 85  $\text{m}^2$  outer tracker using AC-LGAD strips for  $\sigma \approx 10 \mu\text{m}$ ,  $\sigma_t \approx 50 \text{ps}$
- TPC for tracking and PID for  $\sigma \approx 100 \mu\text{m}$ ,  $dN/dx \approx 3\%$



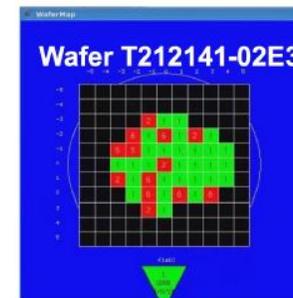
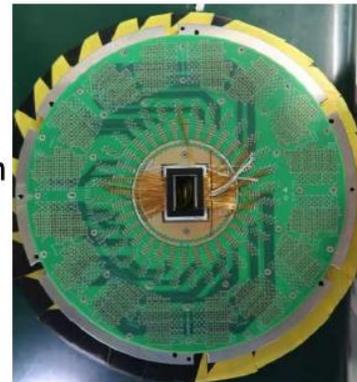
Measurands	Performance requirement
Coverage	$ \cos \theta  \leq 0.99$
Recon. efficiency	$\geq 99\%$ ( $p_T > 1 \text{ GeV}/c$ )
Resolution in barrel	$\sigma_{p_T}/p_T < 0.3\%$ ( $ \cos \theta  \leq 0.85$ )
Resolution in endcap	$\sigma_{p_T}/p_T < 3\%$ ( $ \cos \theta  > 0.85$ )

# Vertex detector

- Four inner layers of **bent MAPS stitched sensors**:  
 $\sim 0.15 \text{ m}^2$ ,  $\sim 0.06\%X_0$  each layer
- Two outer layers of double side conventional ladders:  $0.28\%X_0$  each layer
- Sitting on top of beam pipe:  
 inner layer radius 11.1 mm



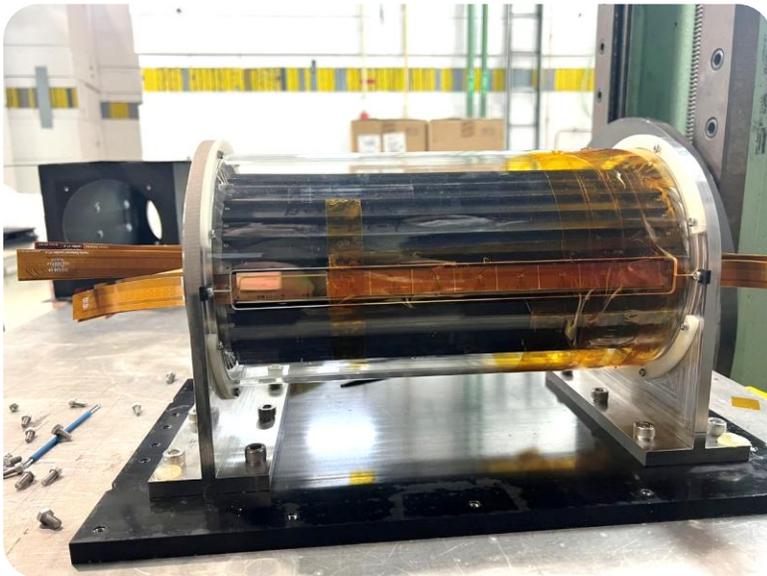
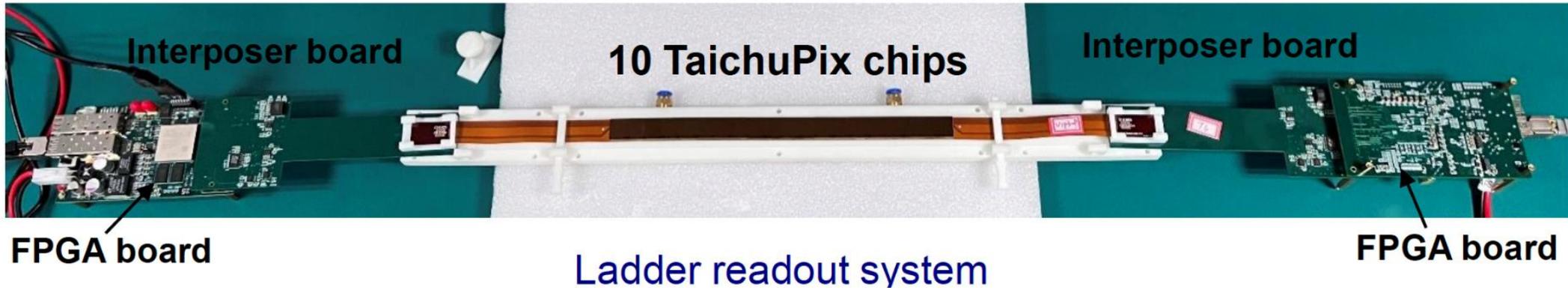
TaichuPix-3 chip vs. coin



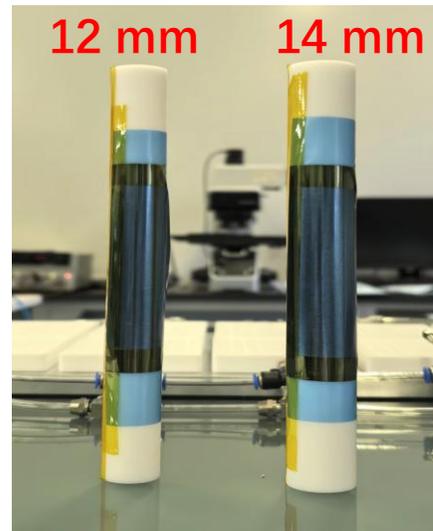
An example of wafer test result

	Status	CEPC final goal
CMOS chip technology	Full-size chip with TJ 180 nm CIS	TPSCo 65 nm MAPS Alternative: HLMC 55 nm MAPS

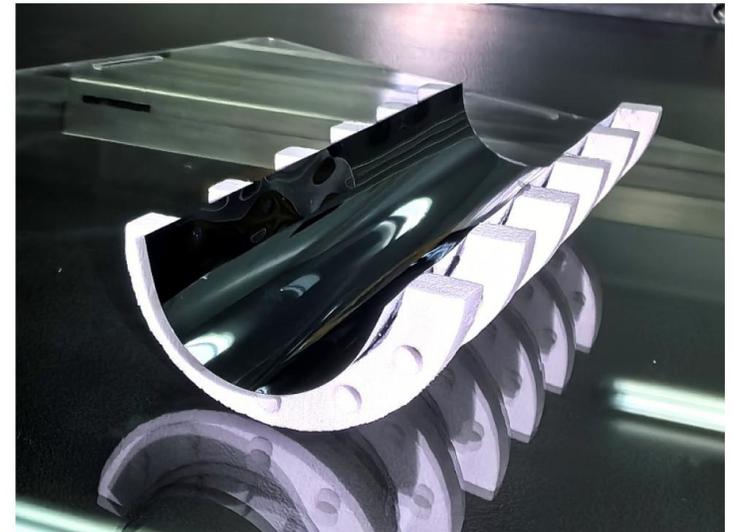
# Vertex detector: prototypes



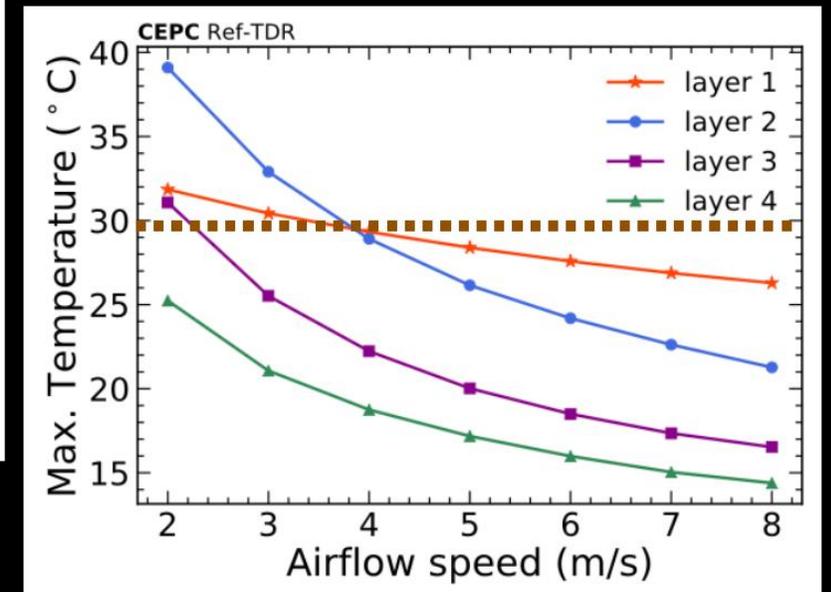
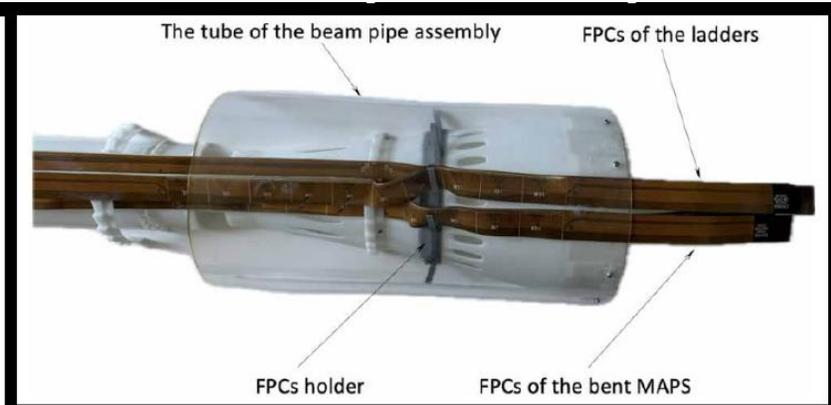
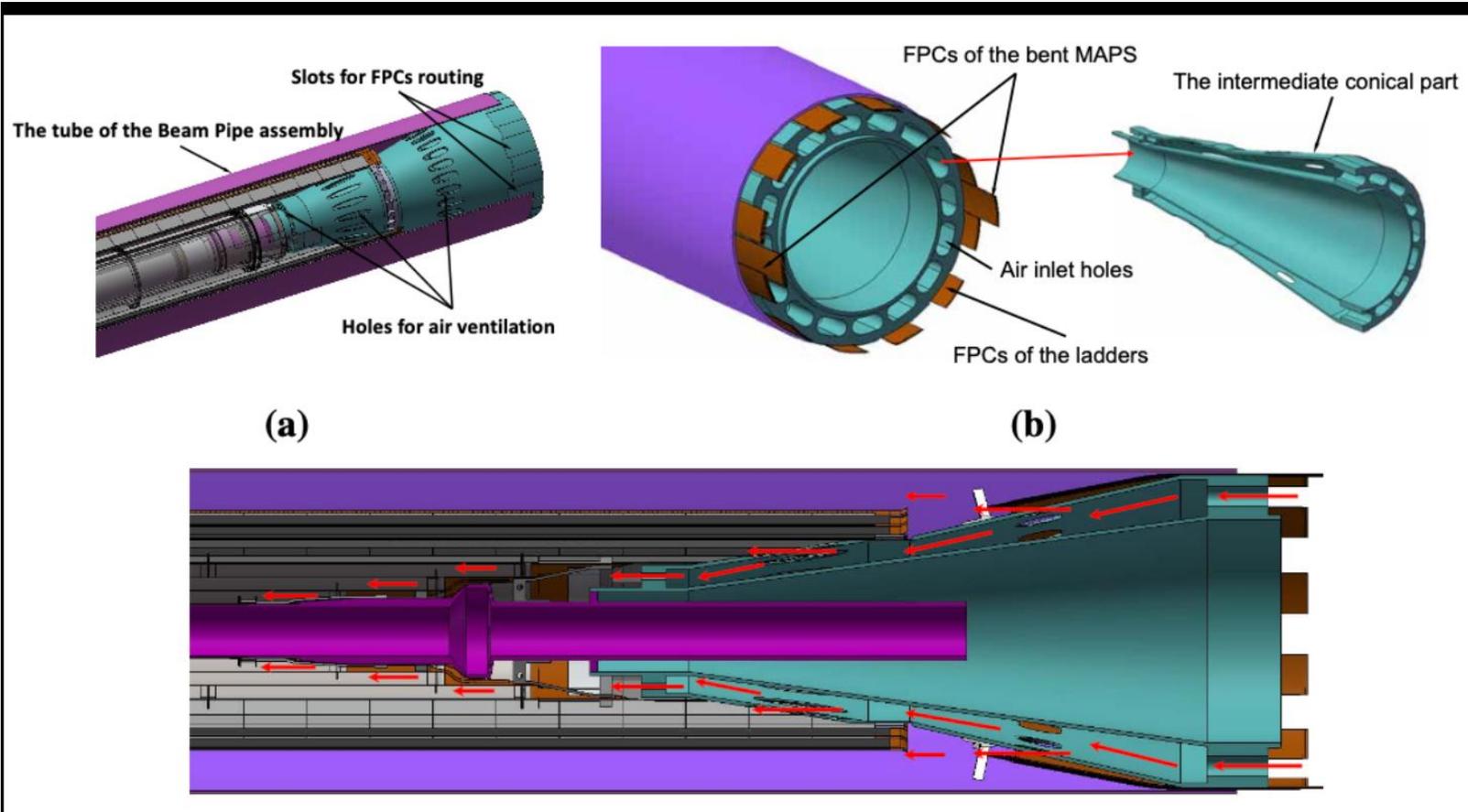
Prototype of 6 double-side ladders  
(no bent layers)



A dummy wafer, thinned to 40  $\mu\text{m}$ ,  
can be curved to 12 mm



# Vertex detector: mechanics and cooling

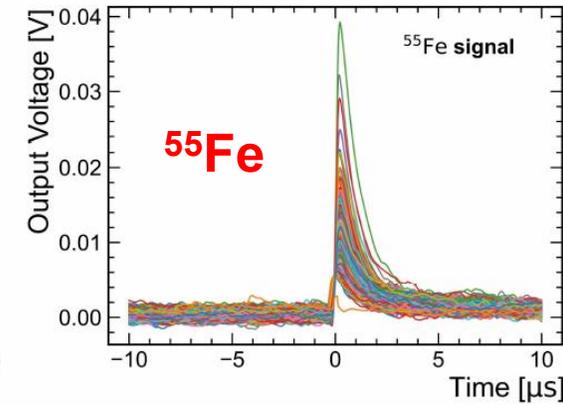
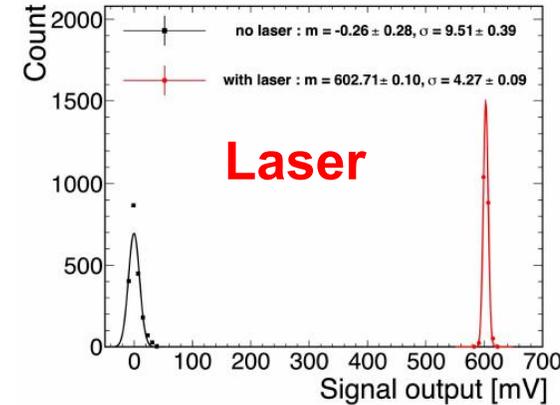


- Airflow speed of 7 m/s, equivalent to a total flow rate of 3500 L/min
- Required to keep temperature safely below 30 °C

# Inner tracker (ITK)

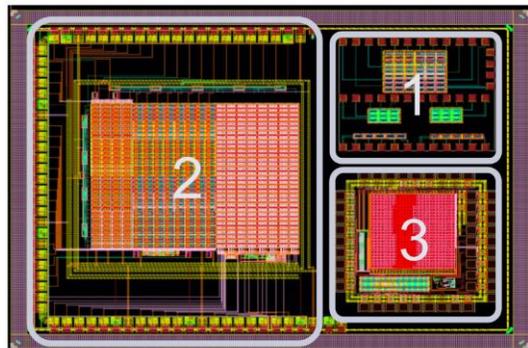
- Monolithic **HV-CMOS** pixel sensors fabricated using a **55 nm CMOS** process

Parameter	Value
Sensor size	2 cm × 2 cm (active area: 1.74 cm × 1.92 cm)
Sensor thickness	150 μm
Array size	512 × 128
Pixel size	34 μm × 150 μm
Spatial resolution	8 μm × 40 μm
Time resolution	3-5 ns
Power consumption	200 mW/cm <sup>2</sup>
Technology node	55 nm

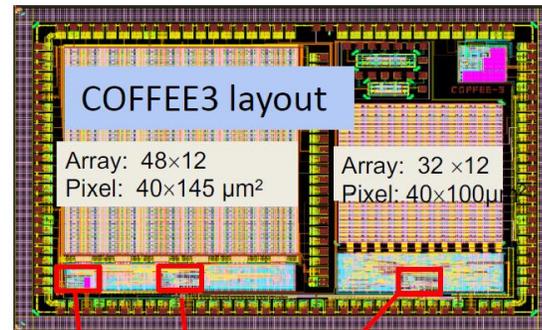


## Tests have been performed

- IV (breakdown at **-70 V**)
- CV (single pixel ~30-40 fF)
- Leakage current increased from 0.01 nA to ~1 nA after  $10^{14} n_{eq}/cm^2$  radiation
- Laser response observed
- Radioactive source ( $^{55}Fe$ ) observed



**COFFEE2: exploring and verifying process characteristics**

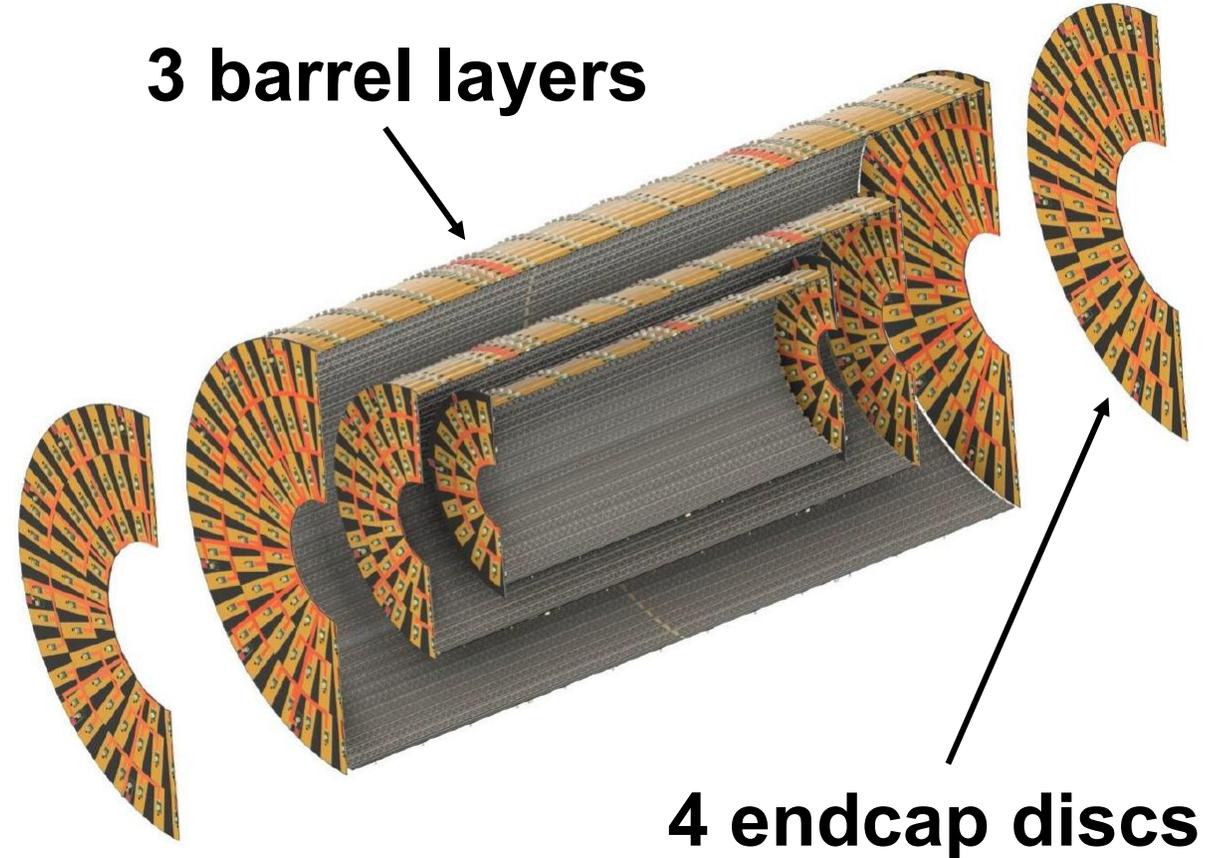
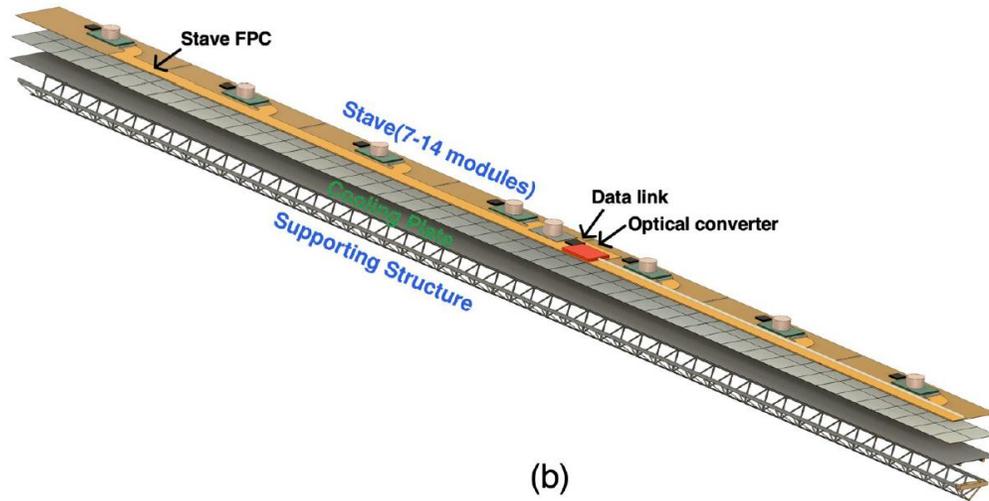
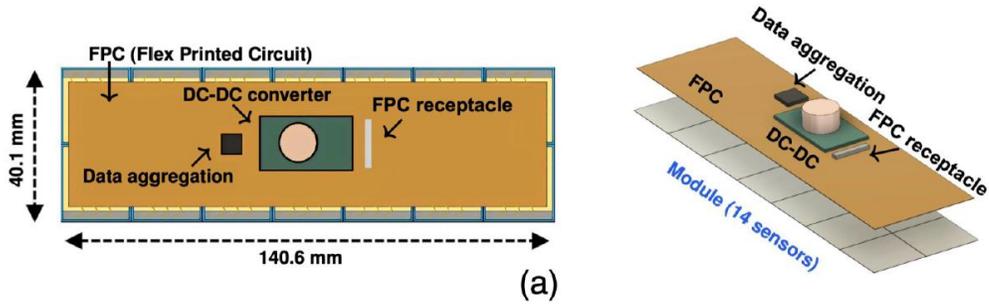


**COFFEE3: verifying readout circuit structures and core performances**

DLL LVDS driver/receiver up to 1.28Gb/s

# Inner tracker (ITK)

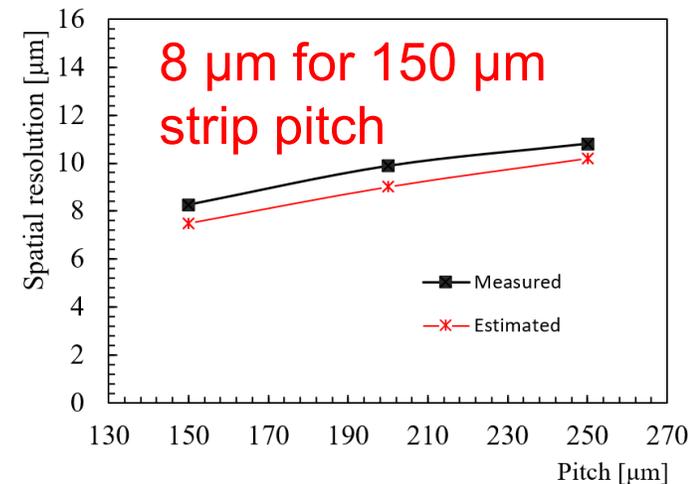
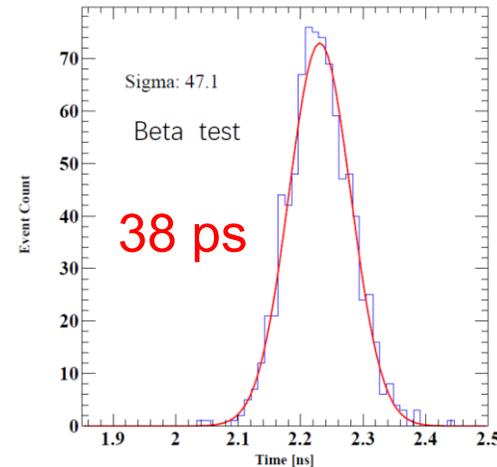
- ITK consists of 3 barrel layers and 4 endcap discs on both sides



**Sensor** → **Module** (14 sensors)  
→ **Stave** (7-14 modules)

# Outer Tracker (OTK/TOF)

- Using microstrip **AC-LGAD** technology to provide both good spatial resolution and time resolution, covering  $\sim 85 \text{ m}^2$
- R&D of large AC-LGAD strip (pitch  $100 \mu\text{m}$ )
- R&D of multi-channel readout chip with good timing (**LATRIC**)



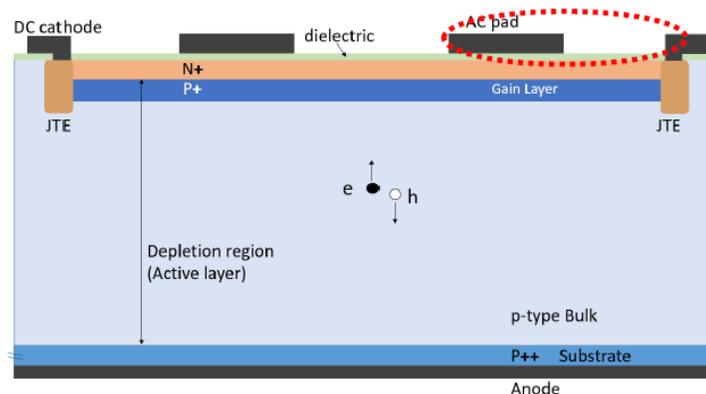
**AC-LGAD test performance**

## LGAD sensor specification for OTK

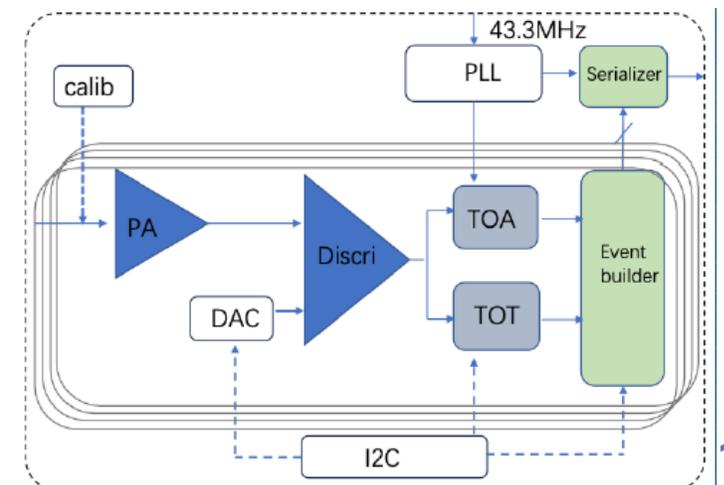
Sensor size	(3-4.5) cm $\times$ (3-5) cm
Strip pitch	$\sim 100 \mu\text{m}$
Spatial resolution	$10 \mu\text{m}$
Timing resolution	$50 \text{ ps}$
Power	$300 \text{ mW/cm}^2$

## AC-LGAD (AC-coupled LGAD)

Continuous gain layer (less dead area)

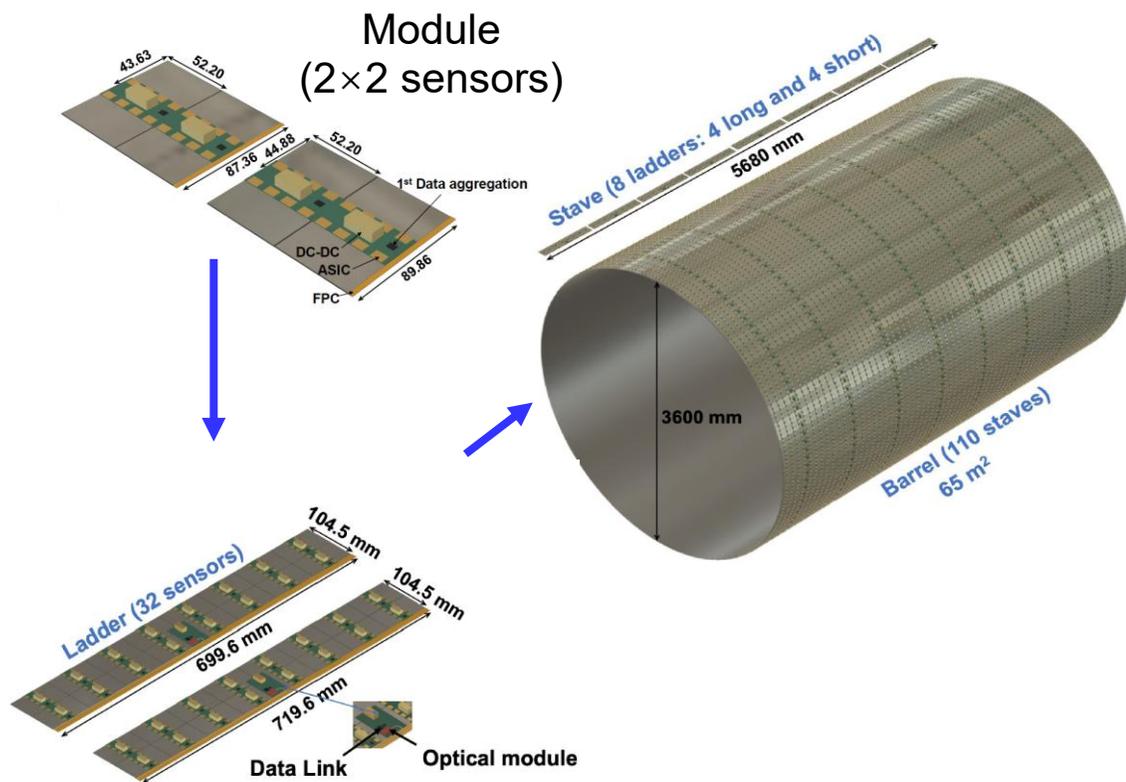


## LATRIC: LGAD Readout Chip

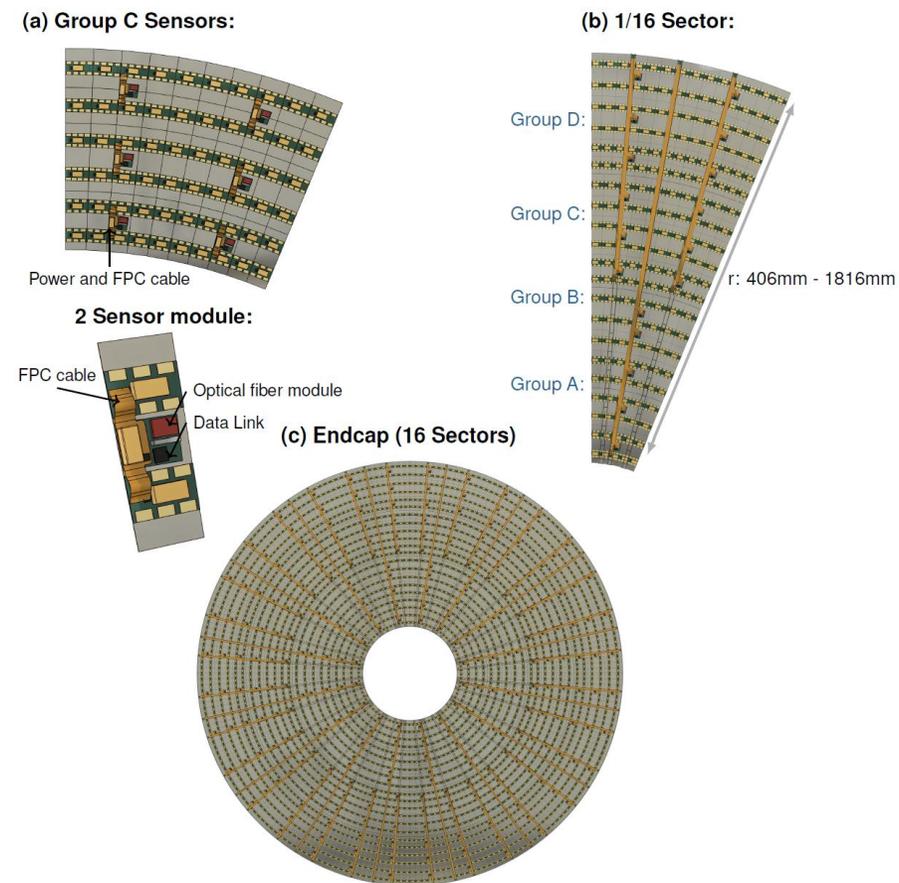


# Outer Tracker (OTK)

- OTK consists of one barrel and two endcap discs



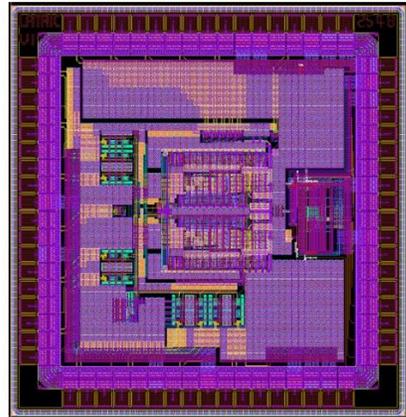
**Barrel: rectangle sensors**



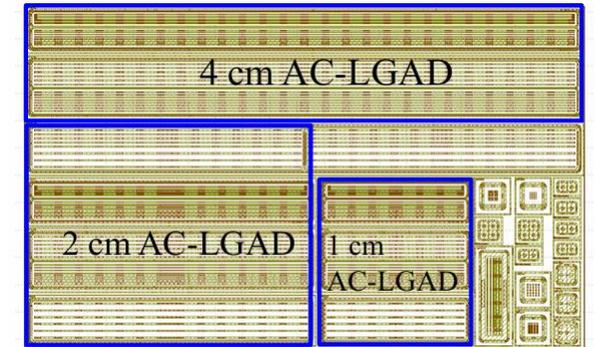
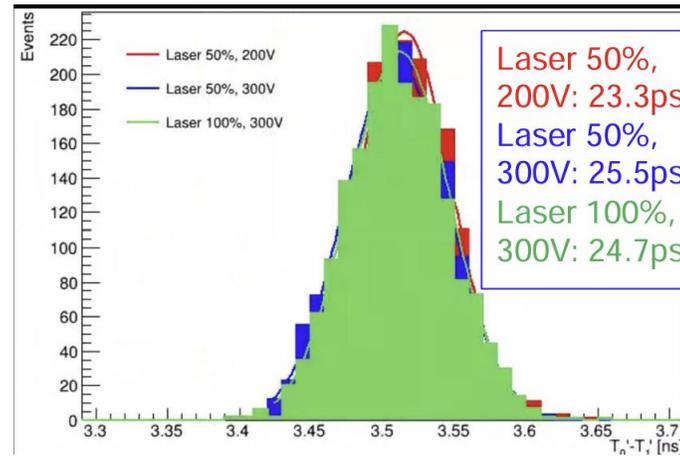
**Endcap: trapezoid sensors**

# LGAD and LATRIC Combined Test

- A joint test for LGAD and the LATRIC (V0) readout chip
- New progress on LGAD (V1) and LATRIC (V1)

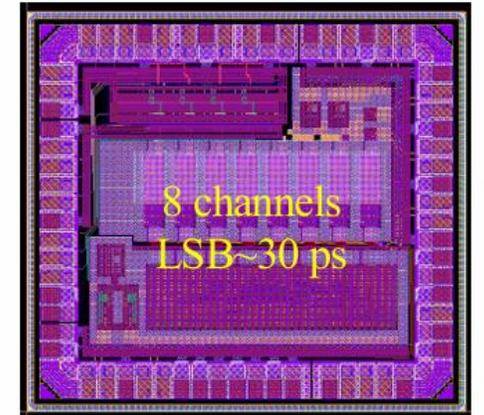


LATRIC-V0

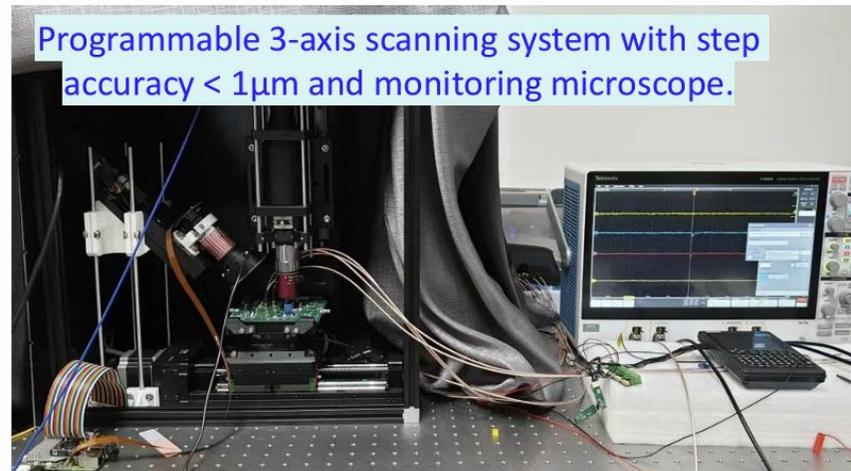
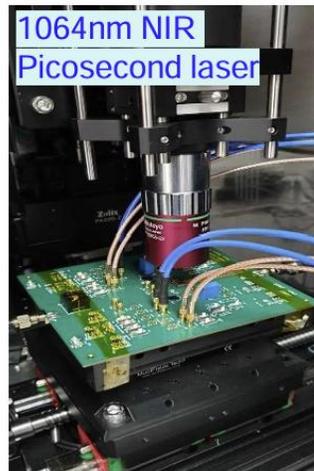
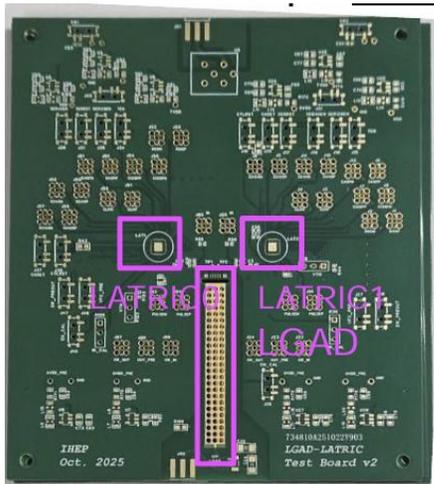


LGAD v1: first two tape-out wafers returned

LATRIC-V1

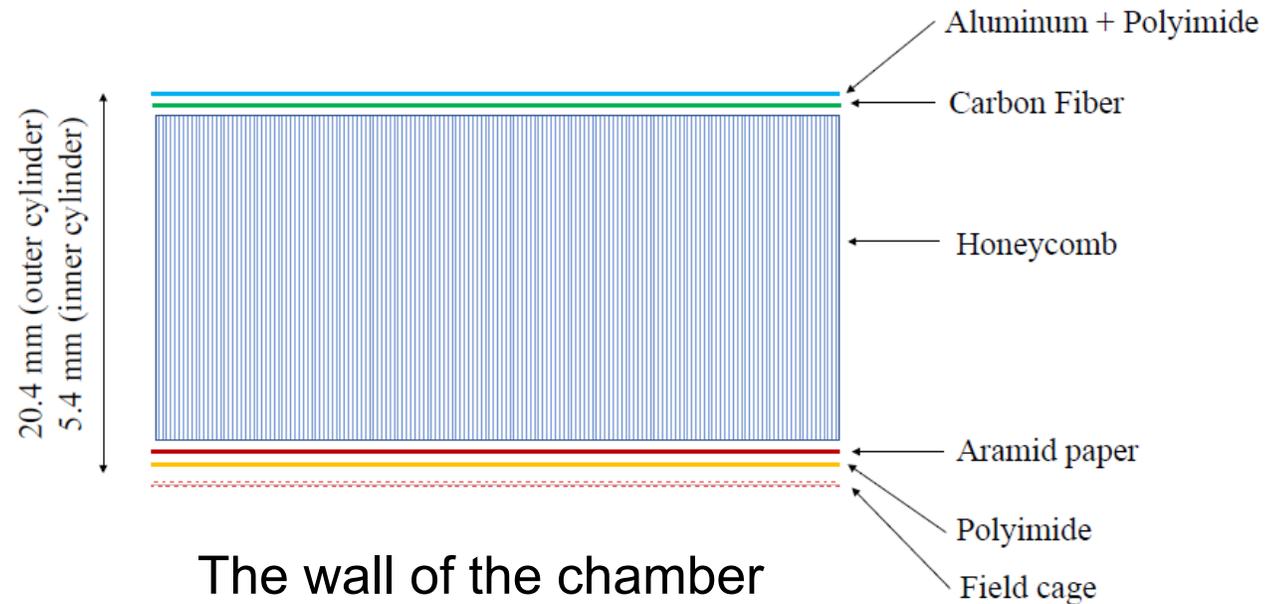
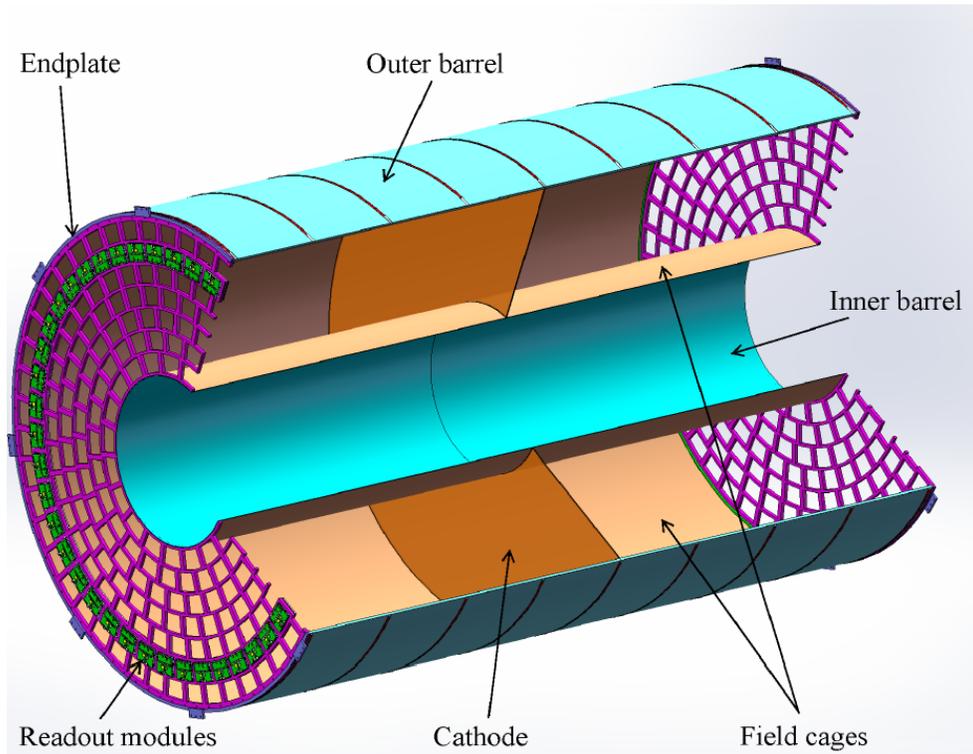


The new 8-channel LATRIC-V1 submitted for tape-out



# Time Projection Chamber (TPC)

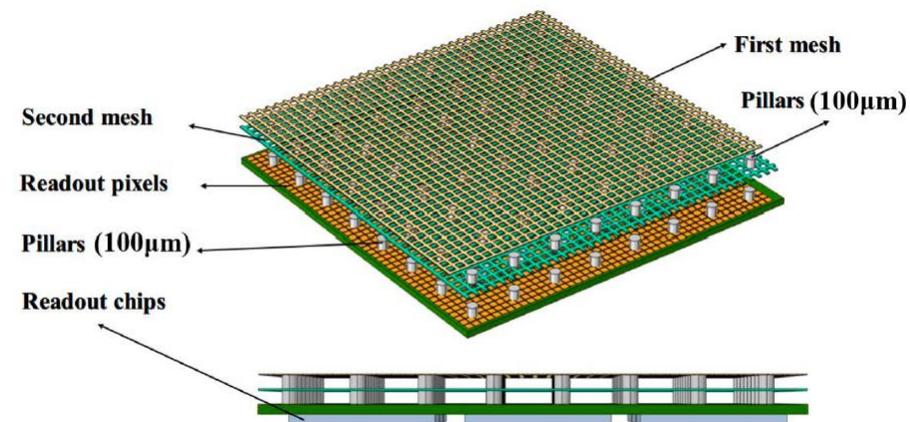
- A **chamber** (inner and outer cylinders, endplates) with gas mixture ( $\text{Ar}/\text{CF}_4/i\text{C}_4\text{H}_{10} = 95/3/2$ ), for low transverse diffusion and fast drift velocity.
- Length: 5.8 m, R extension: 0.6-1.8 m.



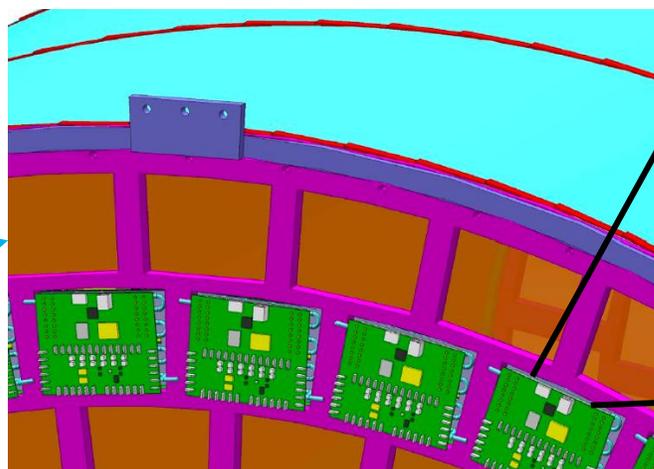
The wall of the chamber  
outer cylinder: 20.4 mm, 0.69%  $X_0$   
Inner cylinder: 5.4 mm 0.45%  $X_0$

# Time Projection Chamber (TPC): Readout

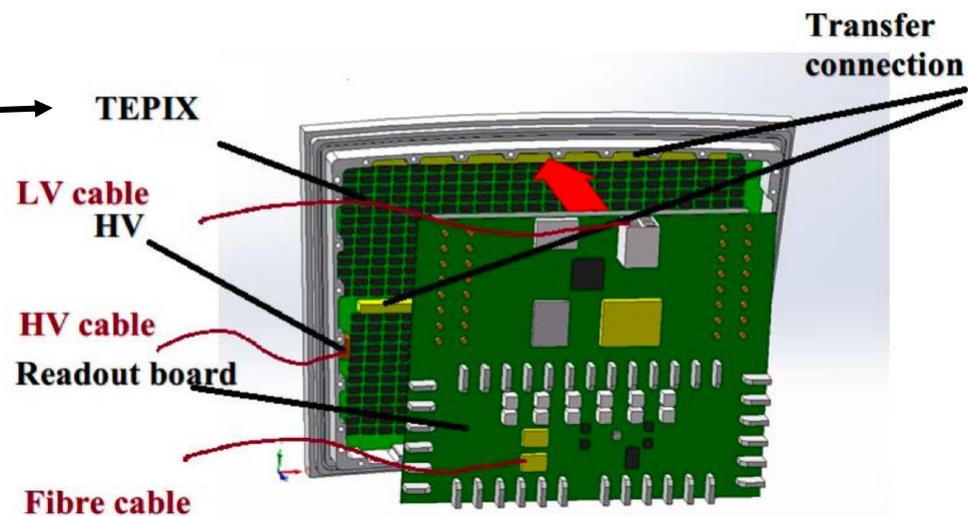
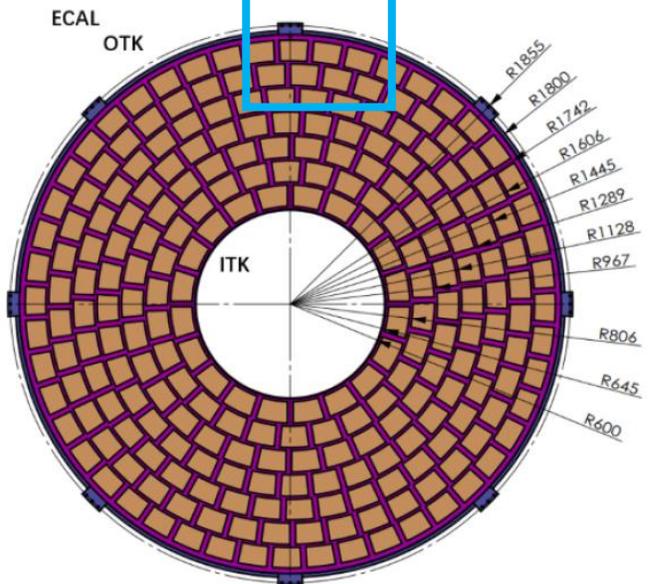
- High-granularity **readout** ( $500 \times 500 \mu\text{m}^2$ ) of Micromegas for good tracking ( $\sigma \sim 100 \mu\text{m}$ ) and PID ( $dN/dx \sim 3\%$ )



Double mesh micromegas readout board



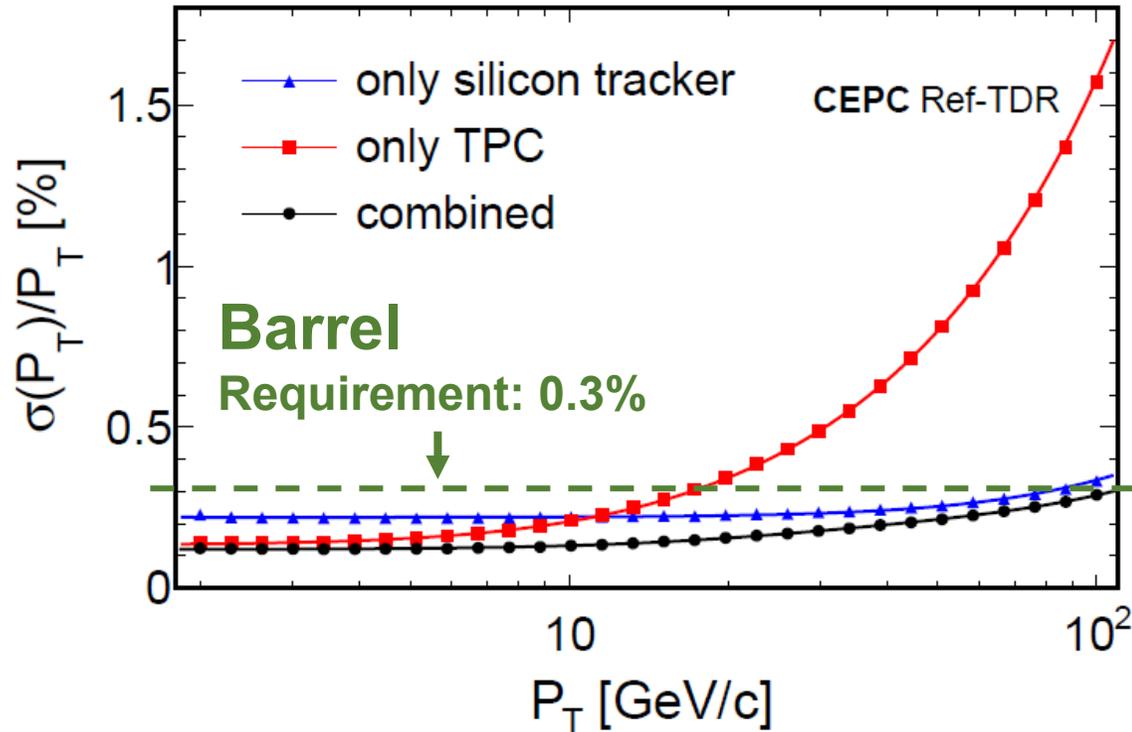
244 detector modules per endplate



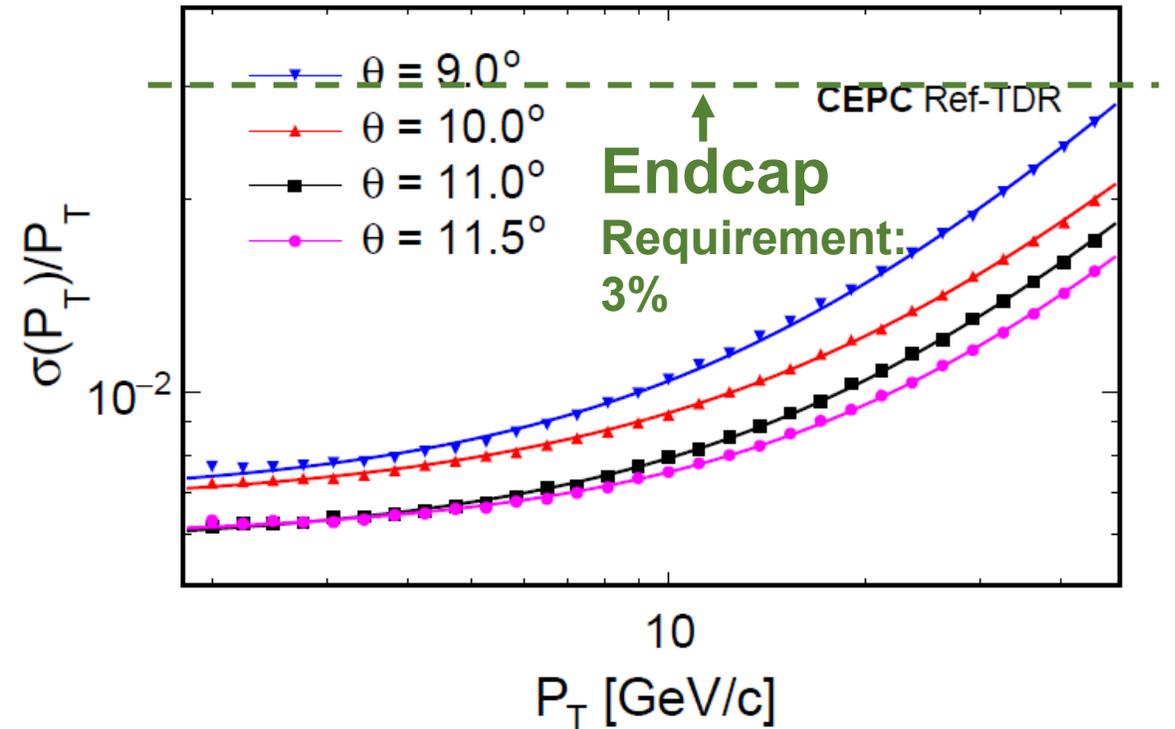
TEPIX: Low-power readout ASIC ( $<100 \text{ mW/cm}^2$ )  
One ASIC for 256 small pads

# Tracking performance: Transverse momentum

- Transverse momentum resolution better than 0.3% in barrel and 3% in endcap



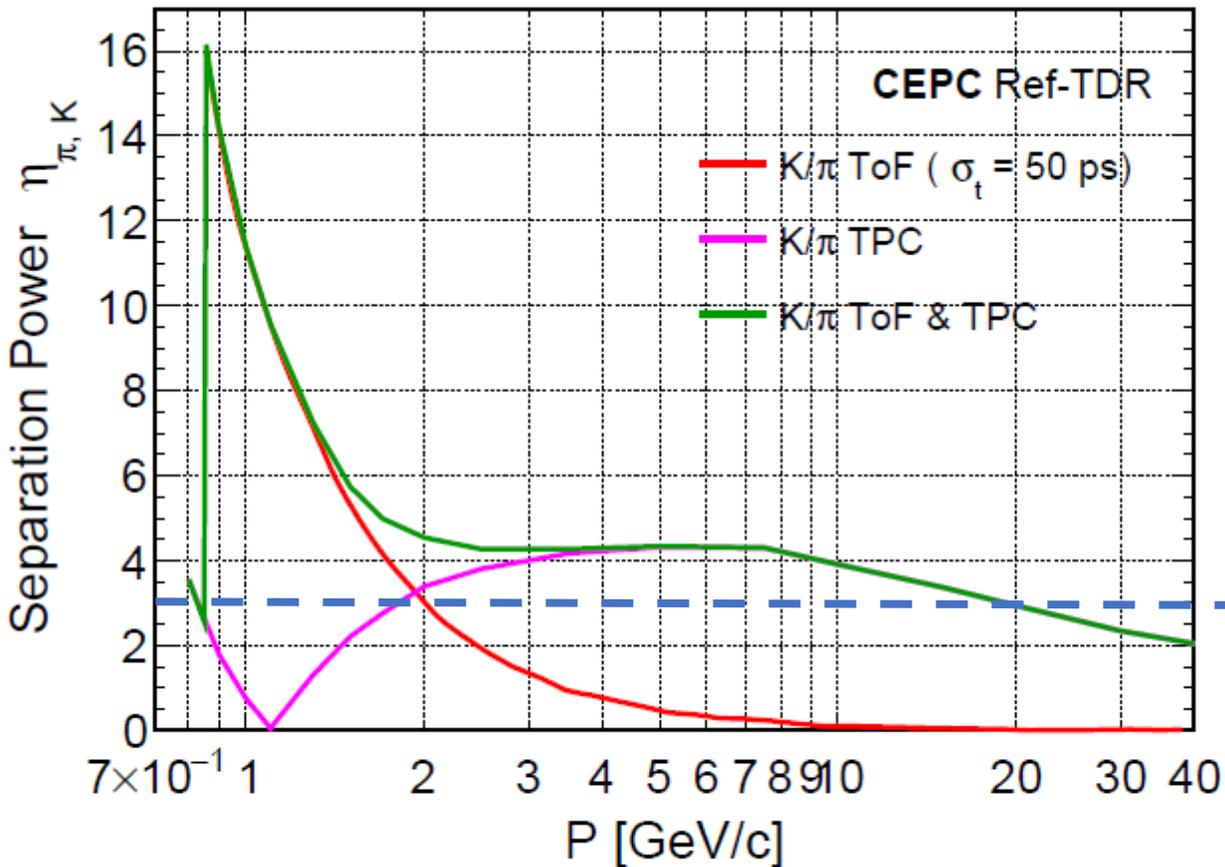
Resolution of different detectors at  $85^\circ$



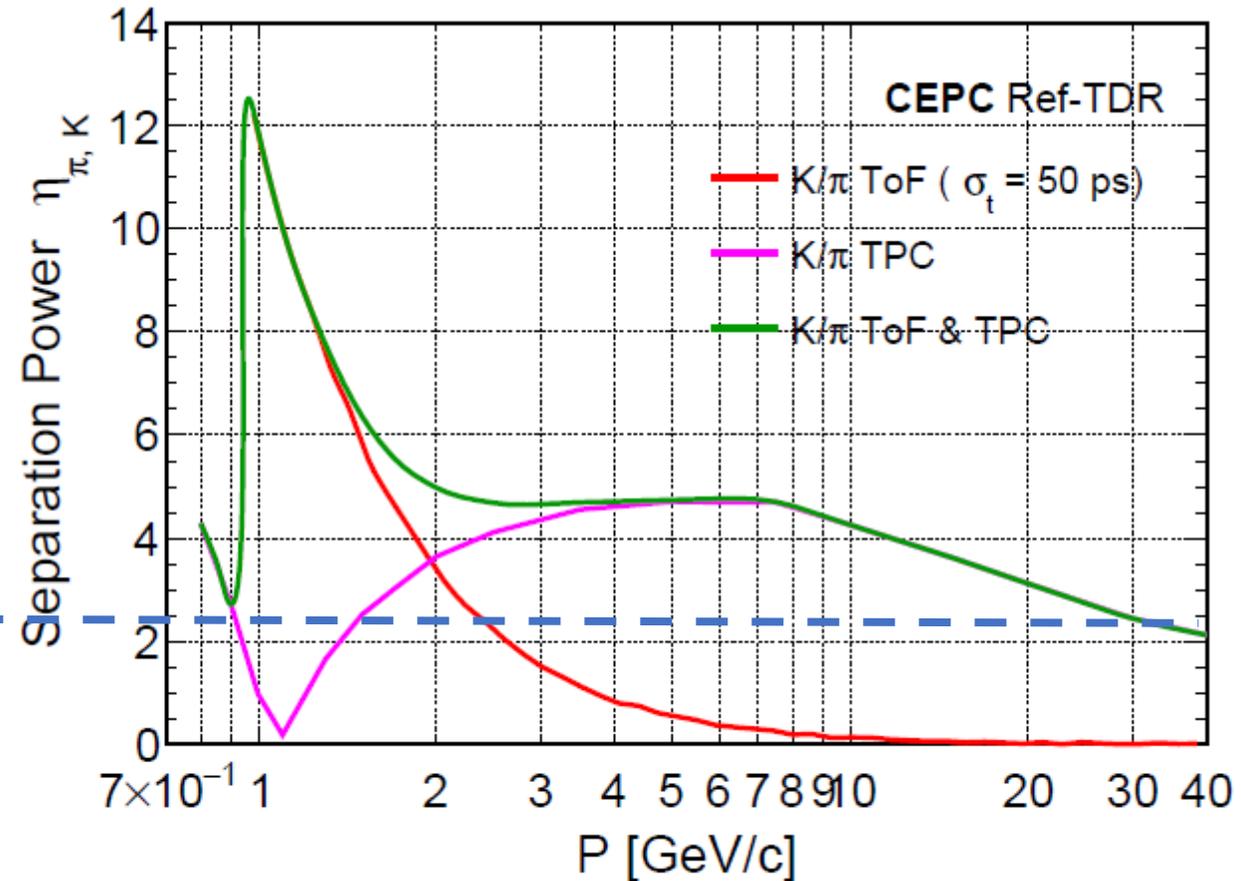
Resolution of the tracking system at different polar angles

# Tracking performance: Particle Identification

- Separation power larger than 3 up to 20 GeV when combining TPC and OTK/TOF



(a)  $\theta = 85^\circ$

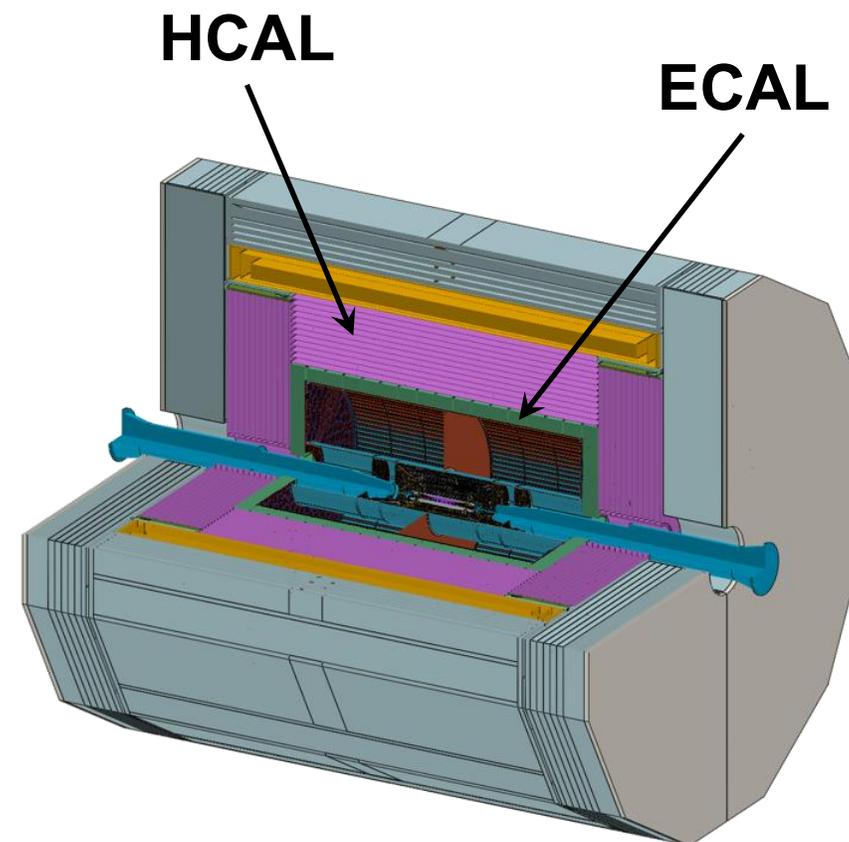


(b)  $\theta = 60^\circ$

# Calorimeter

- Particle Flow Algorithm (PFA) oriented design
- BGO Electromagnetic Calorimeter (ECAL)
- Glass scintillator Hadron Calorimeter (HCAL)

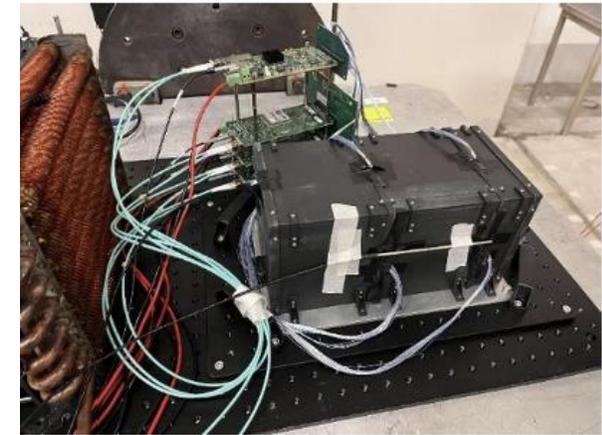
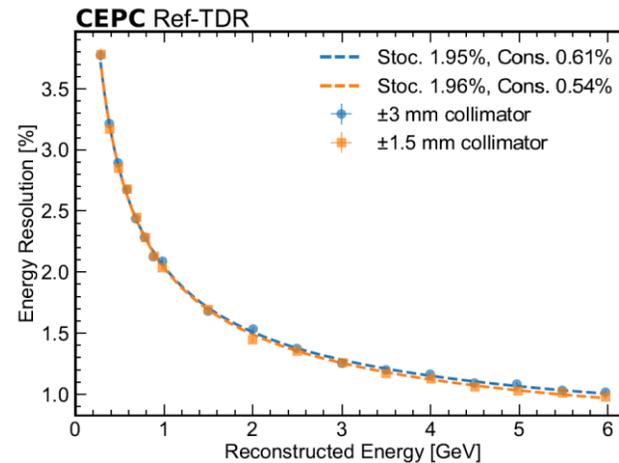
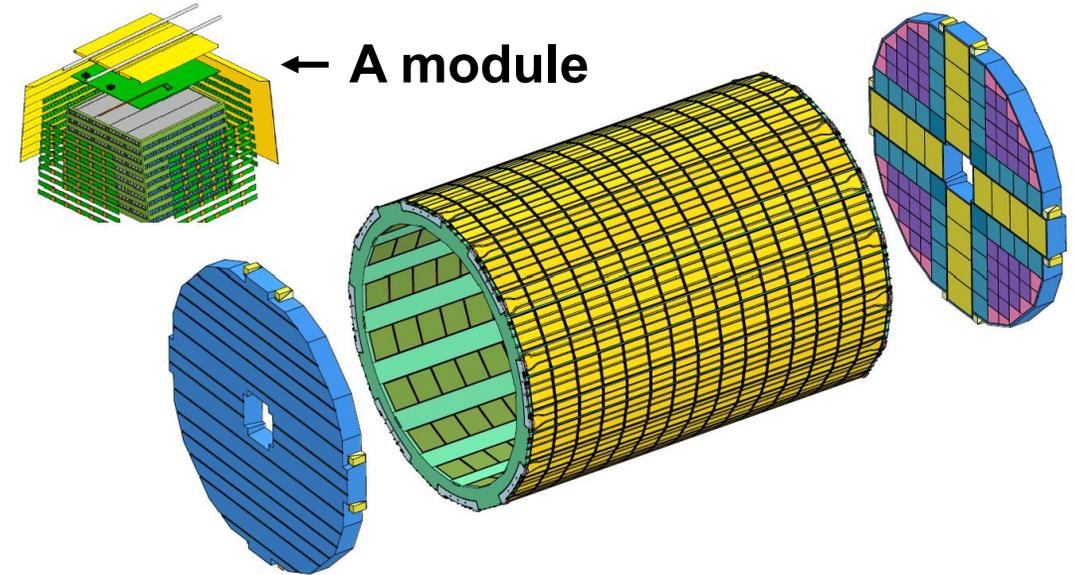
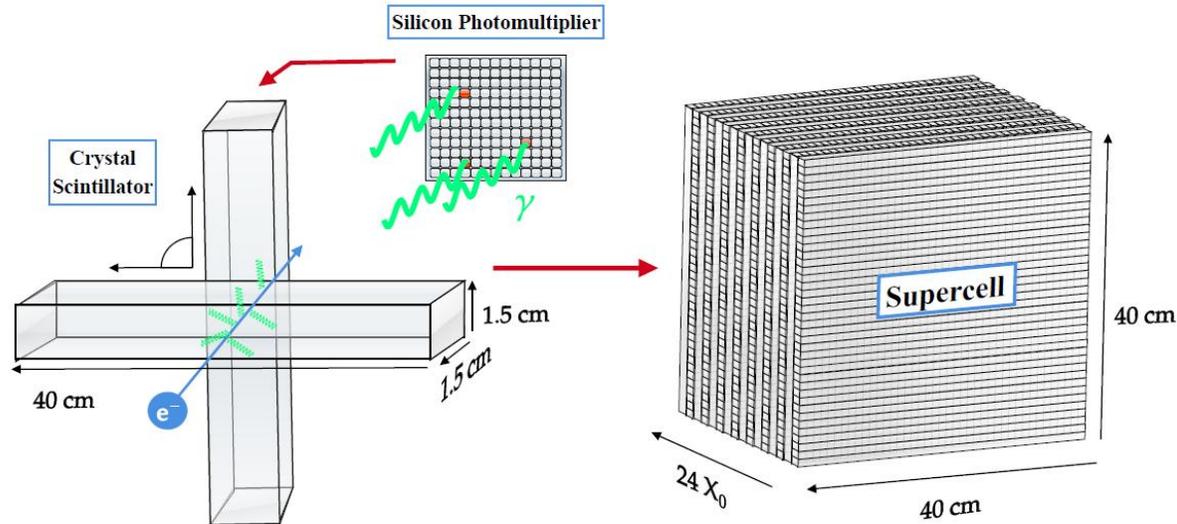
Physics objects	Measurands	Detector subsystem	Performance requirement
Leptons ( $e, \mu$ )	PID efficiency	Tracker, ECAL	$\geq 99\%$ ( $p > 5 \text{ GeV}/c$ , isolated)
	Mis-ID rate	HCAL, Muon	$\leq 2\%$ ( $p > 5 \text{ GeV}/c$ , isolated)
Photons	PID efficiency	ECAL, HCAL	$\geq 95\%$ ( $E > 3 \text{ GeV}$ , isolated)
	Mis-ID rate		$\leq 5\%$ ( $E > 3 \text{ GeV}$ , isolated)
	Energy resolution		$\sigma_E/E \leq 3\%/\sqrt{E(\text{GeV})} \oplus 1\%$
Hadronic jets	Energy resolution	Tracker	$\sigma_E/E \sim 30\%/\sqrt{E(\text{GeV})} \oplus 4\%$
	Mass resolution	ECAL, HCAL	BMR $\leq 4\%$
Jet flavor tagging	b-tagging efficiency	Full detector	$\sim 80\%$ , mis-ID of uds $< 0.3\%$
	c-tagging efficiency		$\sim 50\%$ , mis-ID of uds $< 1\%$



# Electromagnetic Calorimeter

- 18 layers of BGO crystal bars ( $1.5 \times 1.5 \times 40 \text{ cm}^3$ ), arranged in the x-y direction alternatively, in perpendicular to the beam, to achieve fine 3D granularity, and good position and energy resolution
- 24  $\text{m}^3$  BGO, 570,000 SiPM readout channels
- Energy resolution from 2025 beam test:

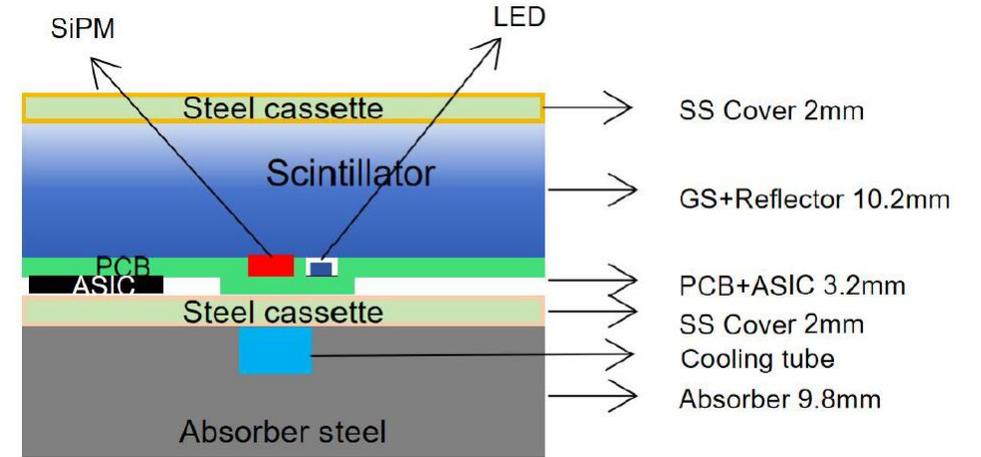
$$1.96 \% / \sqrt{E(\text{GeV})} \oplus 0.54 \%$$



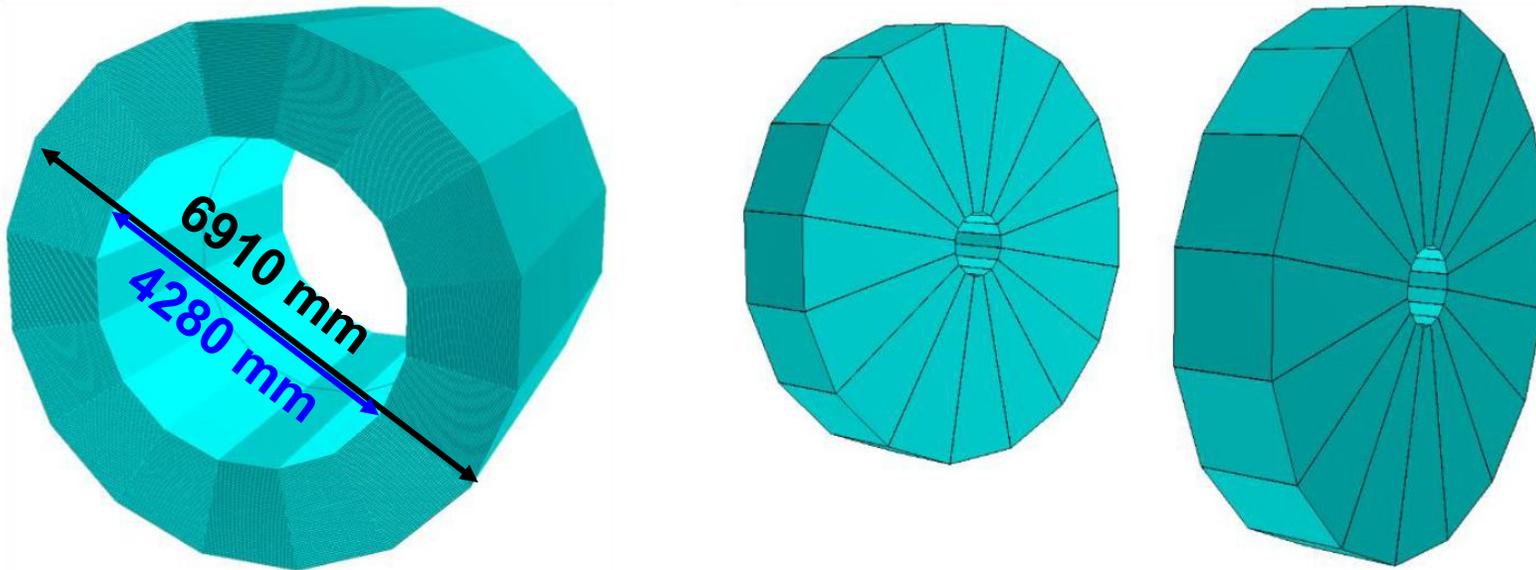
**Beam test in 2025: 72 BGO + 12 BSO bars for a tower of  $12 \times 12 \times 28 \text{ cm}^3$  ( $24.9 X_0$ )**

# Hadron Calorimeter

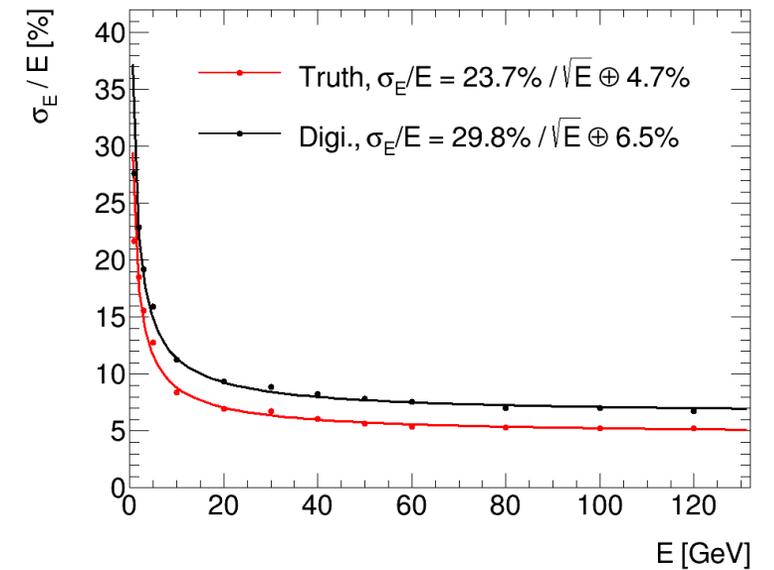
- 48 layers of **glass scintillator** tiles ( $4 \times 4 \times 1 \text{ cm}^3$ ) interspersed with steel plates,  $6\lambda_I$ , 5.3 million SiPM readout channels, good 3D granularity,
- **85 m<sup>3</sup>** glass scintillator, high sampling ratio ( **$\sim 30\%$** ) and good energy resolution  **$\sim 30\%/\sqrt{E}$**



**A detector unit**



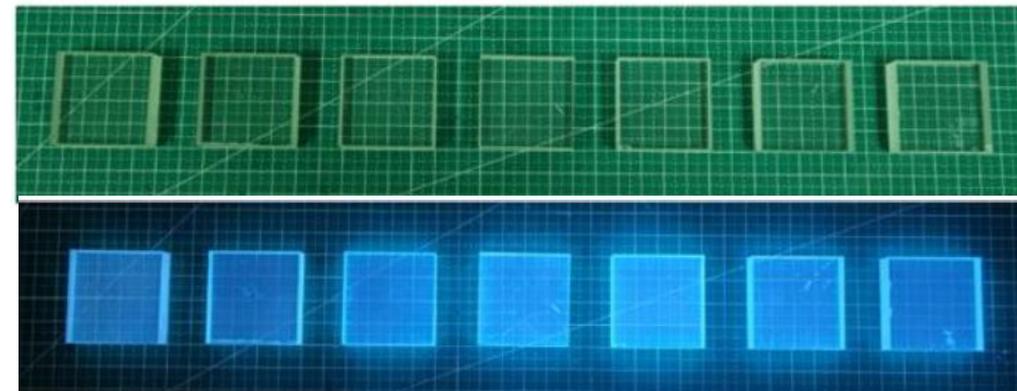
**Geometric configuration of the GS-HCAL system**



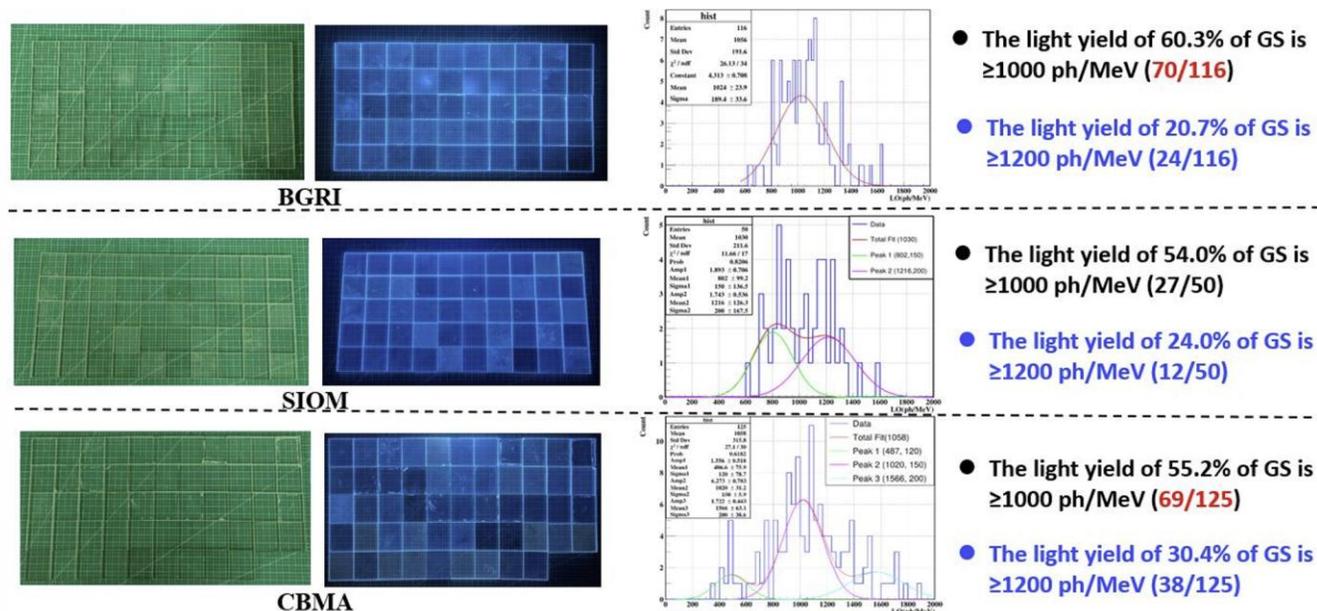
**Simulated energy resolution 24**

# Glass scintillator

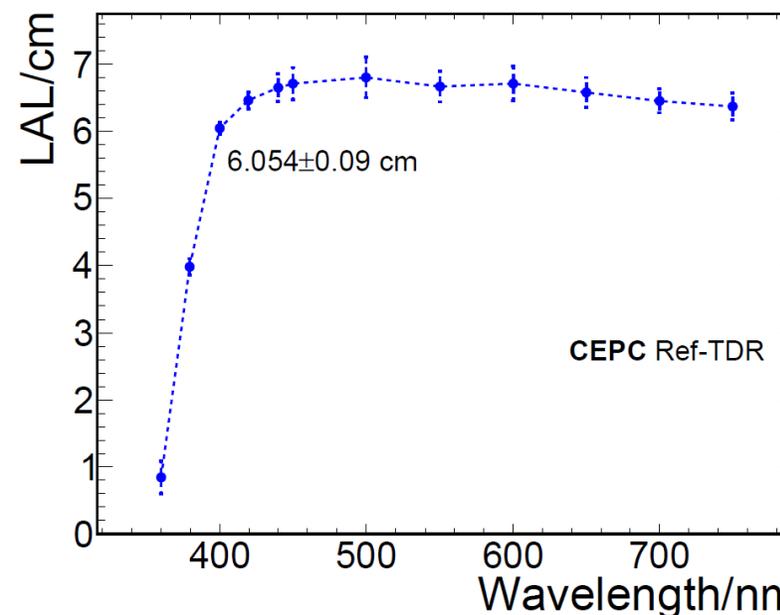
- Using Gadolinium Fluoro-Oxide (GFO) glass
- Total volume  $\sim 85 \text{ m}^3$ : High density ( $6 \text{ g/cm}^3$ ), large light yield ( $1500 \text{ ph/MeV}$ ), decay time: 500 ns
- A glass scintillator collaboration for R&D: 291 GS tiles produced by three companies, about 57% of GS tiles with light yield greater than  $1000 \text{ ph/MeV}$



Glass scintillator under natural and ultraviolet light



Light yield of glass scintillators



Attenuation length spectrum of the best sample

# SiPM and electronics

SiPM Type	NDL EQR06	NDL EQR10	HPK S14160-3010PS
Pixel Pitch $\mu\text{m}$	6	10	10
Pixel Quantity in $3 \times 3 \text{ mm}^2$	244,719	90,000	89,984
Pixel Gain	$8 \times 10^4$	$1.7 \times 10^5$	$1.8 \times 10^5$
Typical peak PDE	30 % (at 420 nm)	36 % (at 420 nm)	18 % (at 460 nm)
Typical DCR (20 °C)	2.5 MHz	3.6 MHz	700 kHz
Inter-pixel Crosstalk	12 %	N/A	< 1 %
Terminal Capacitance (pF)	45.9 pF	31.5 pF	530 pF

## Candidates of SiPM for ECAL

Supplier	HPK		NDL	JBT
Type	S14160-3015PS	S14160-3050HS	EQR20-11-3030-S	JSP-TP3050-SMT
Pitch [ $\mu\text{m}$ ]	15	50	20	50
Number of pixels	39984	3531	22500	3364
Terminal capacitance [pF]	530	500	157.5	170 (fF)
Breakdown voltage ( $V_B$ ) [V]	$38 \pm 3$	$38 \pm 3$	$27.2 \pm 1$	$24.6 \pm 0.2$
Recommended operation voltage [V]	$V_B + 3$	$V_B + 2.7$	$V_B + 5$	$V_B + 2$
Peak sensitive wavelength [nm]	450	450	420	420
Peak PDE at PSW [%]	32	50	47.8	35
PDE at 400 nm [%]	27	47	45	33
Gain	$3.6 \times 10^5$	$2.5 \times 10^6$	$8.0 \times 10^5$	$2.1 \times 10^6$
DCR [kHz/mm <sup>2</sup> ]	700–2100	10–100	150–450	120–270

## Candidates of SiPM for HCAL

- An issue common to ECAL, HCAL and Muon Detector
- ECAL: larger dynamic range; HCAL: higher detection efficiency
- New ASIC **SIPAC**: SiPM ASIC for Calorimeter

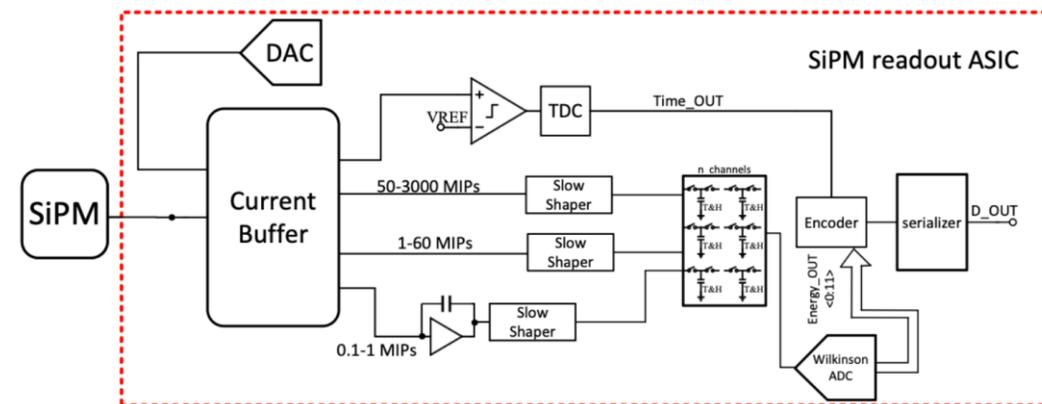
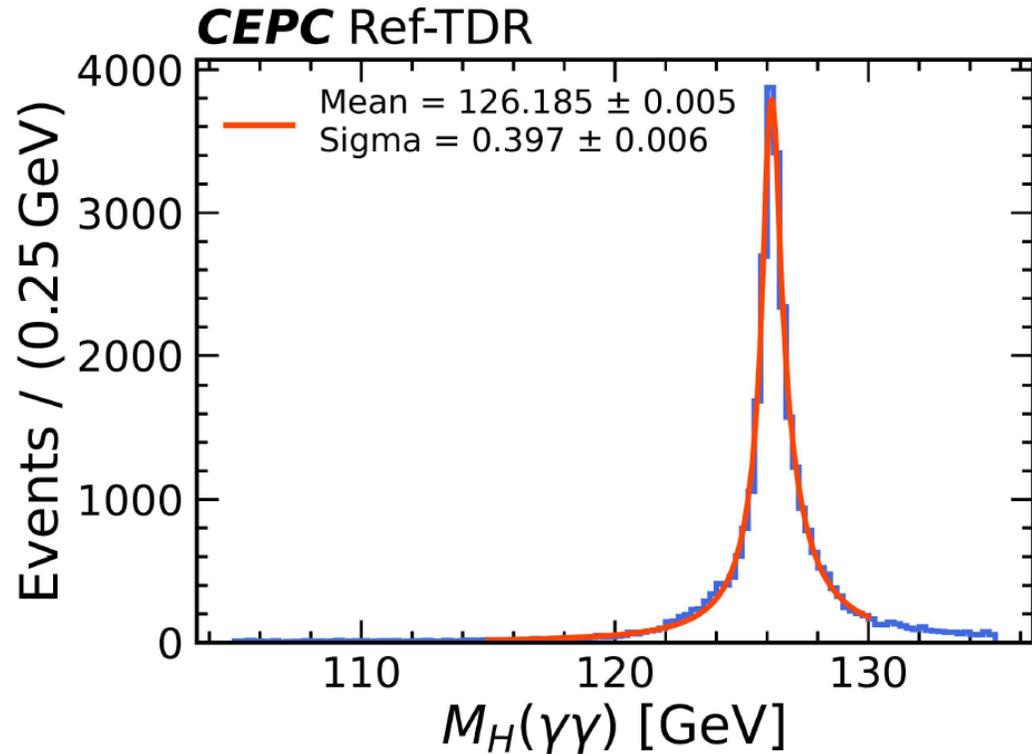


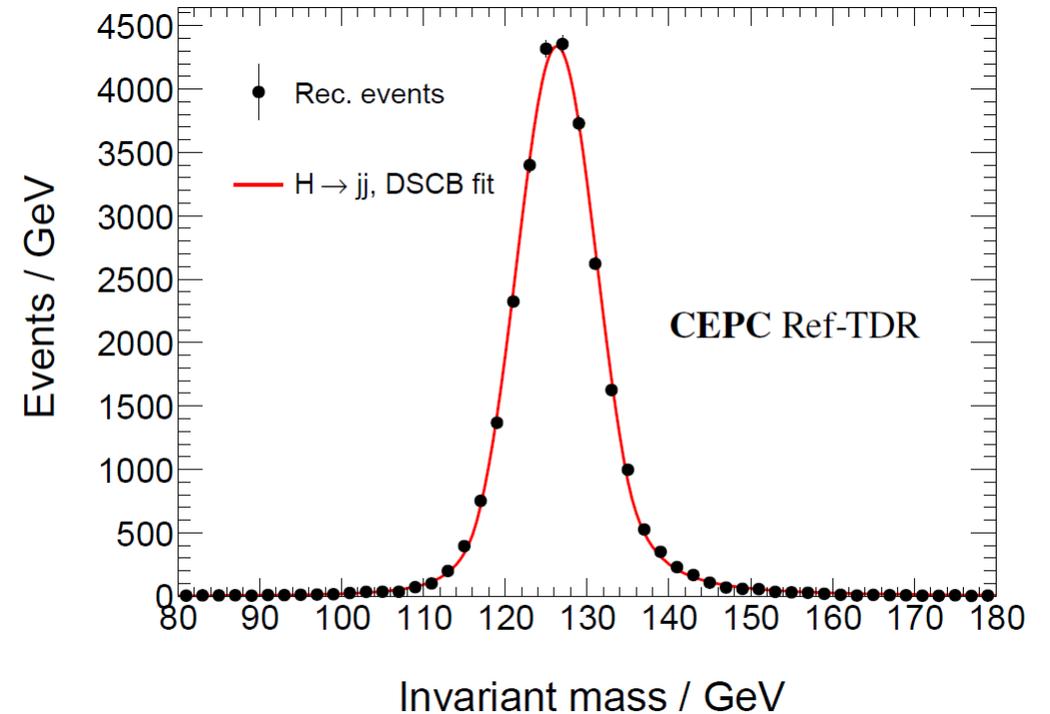
Diagram of SIPAC

# Calorimeter performance on Higgs

- Higgs boson invariant mass resolution (BMR) based on simulation events including tracker, ECAL, and HCAL



$H \rightarrow \gamma\gamma$ : BMR = **0.31%**

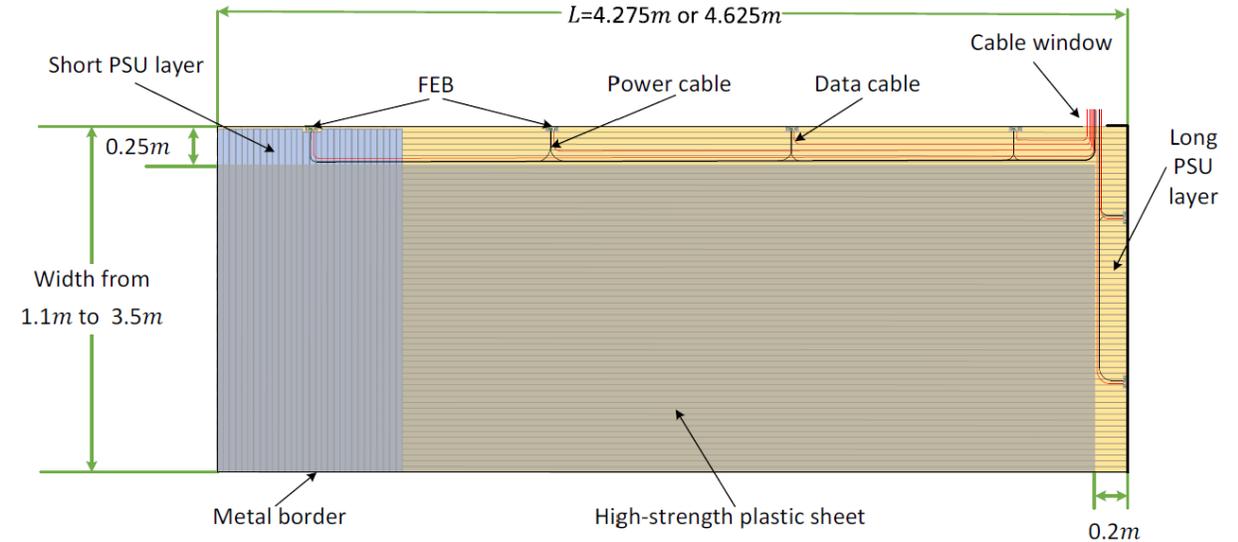
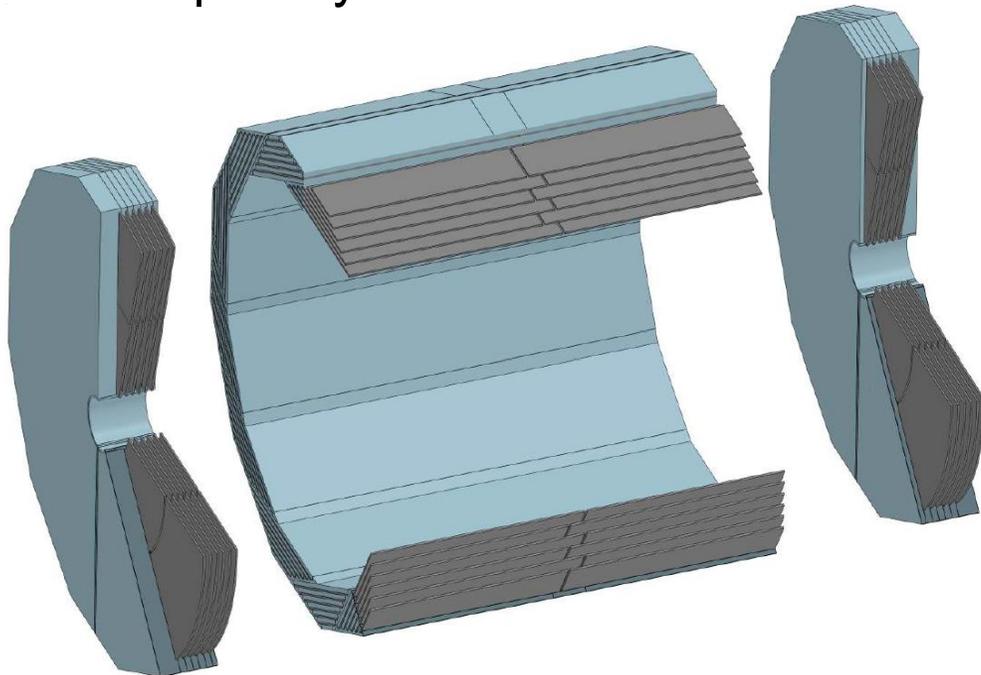


$H \rightarrow jj$ : BMR = **3.88%**

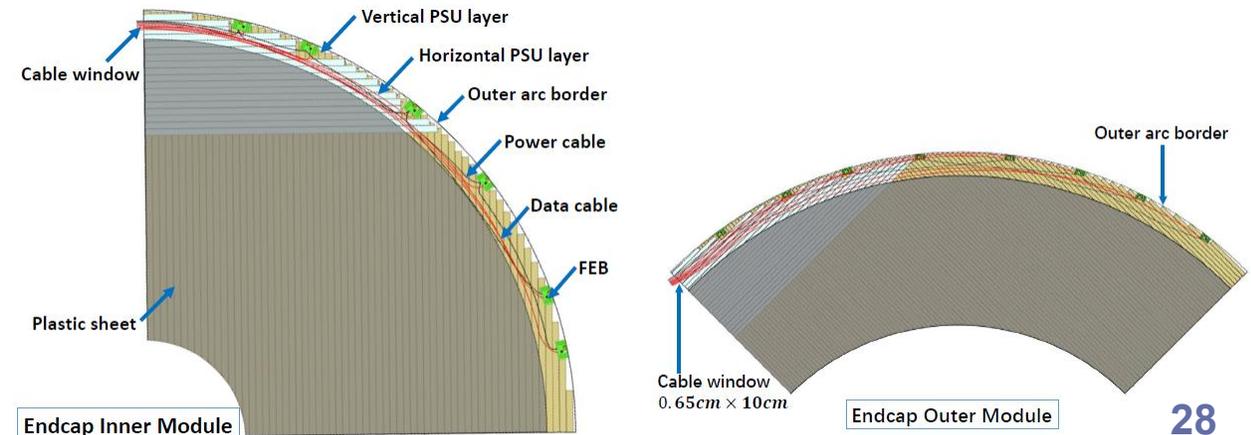
# Muon detector

6 layers of **plastic scintillator** strips embedded in the iron Yoke

- Solid angle coverage:  $> 98\% \times 4\pi$
- $\mu$  identification efficiency:  $> 95\%$
- $\pi \rightarrow \mu$  fake rate:  $< 1\%$
- Spatial resolution:  $\sim 1$  cm
- Time resolution:  $\sim 1$  ns
- Rate capability:  $50$  Hz/cm<sup>2</sup>



Barrel Module



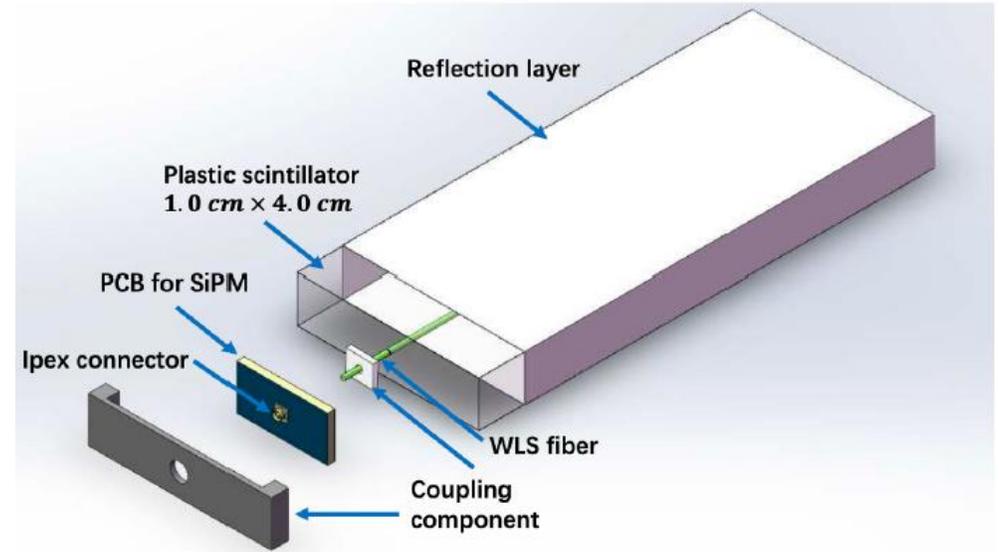
Endcap Inner Module

Endcap Outer Module

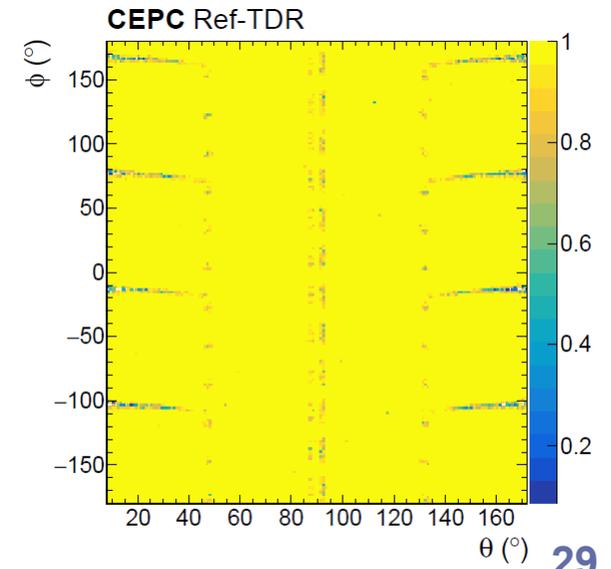
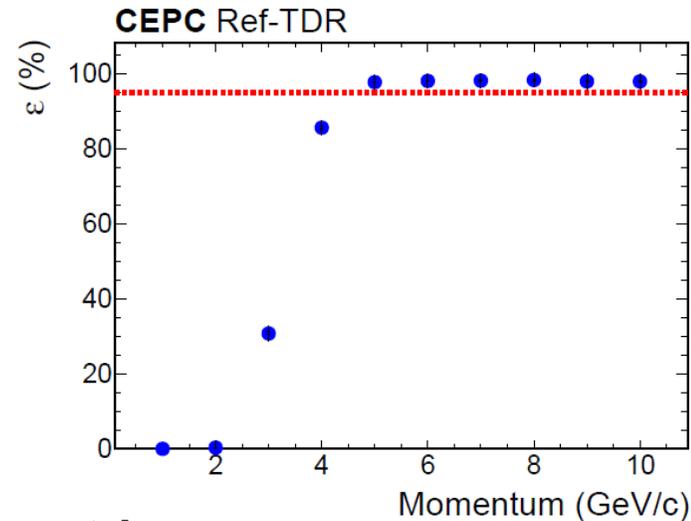
# Muon detector R&D



- Extensive R&D on long plastic scintillator strips with wavelength-shifting fibers, SiPM and readout electronics



- Standalone detection efficiency ~98% for muons above 4.5 GeV/c

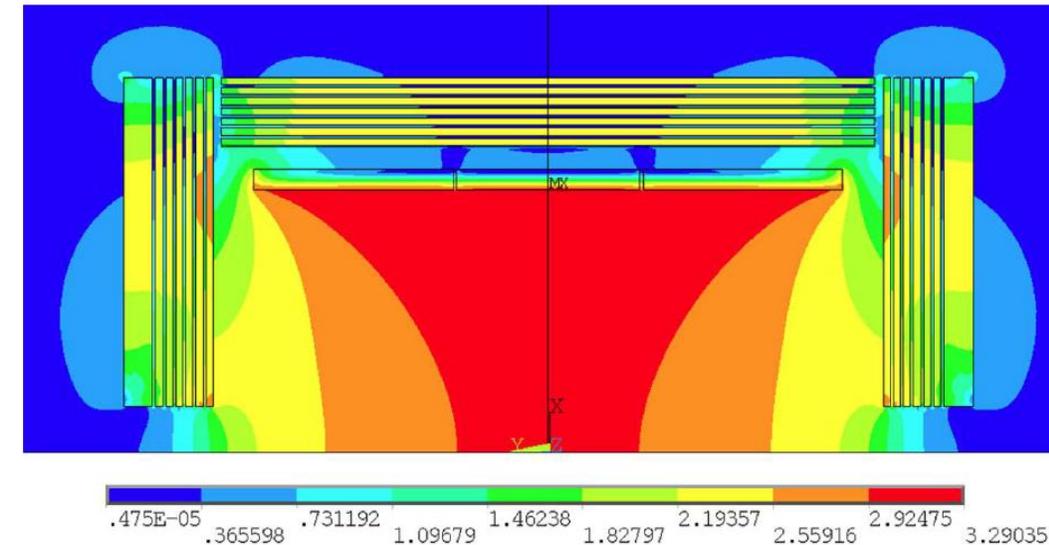
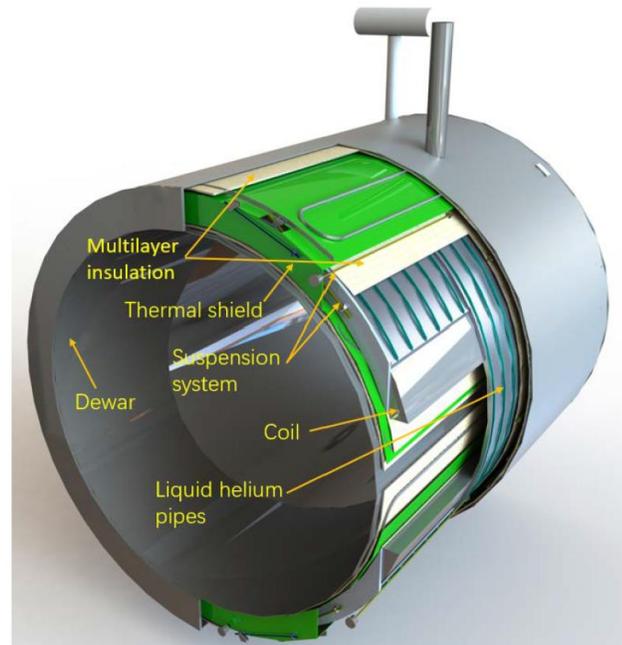
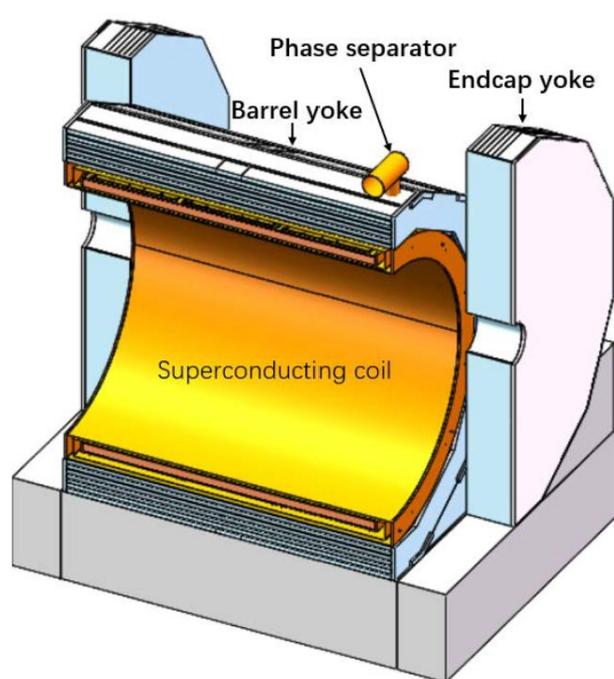


← A 5-m plastic scintillator strip

# Detector magnet system

- Iron-yoke-based solenoid superconducting magnet, located between HCAL and Muon Detector
- Low Temperature Superconductor (LTS) NbTi Rutherford cable, operation temperature 4.5 K

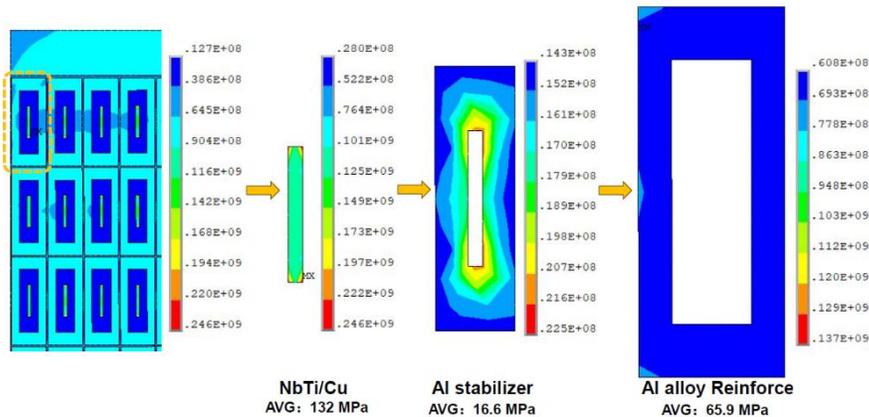
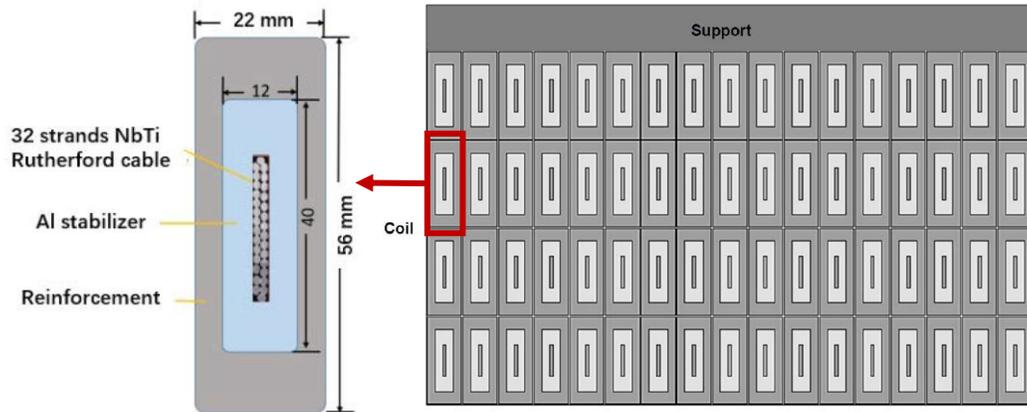
Parameter	Value
Inner diameter	7070 mm
Thickness	700 mm
Outer diameter	8470 mm
Length	9050 mm



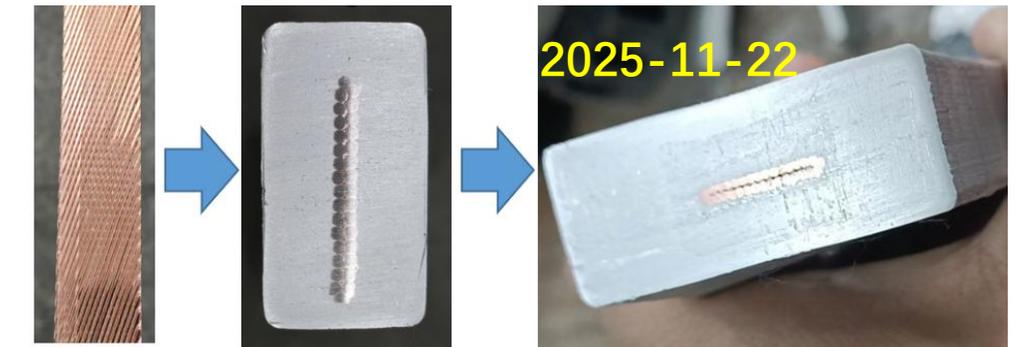
Magnetic field uniformity  
~7% as required by TPC

# Aluminum stabilized superconducting cable

- Double co-extrusion **Box-type** cable for sufficient strength to survive stress energized under cold.
- Very **complex procedure**: 16 → 32 coils, first → second co-extrusion, short → long.
- First **50-cm long full-scale** cable developed on Nov. 22, 2025. Plan for a 100-m cable in 2026.
  - ✓ 5-m long full-scale dummy cable (using copper instead of NbTi) on Dec. 13, 2025



FEA shows sufficient safety margins for stress



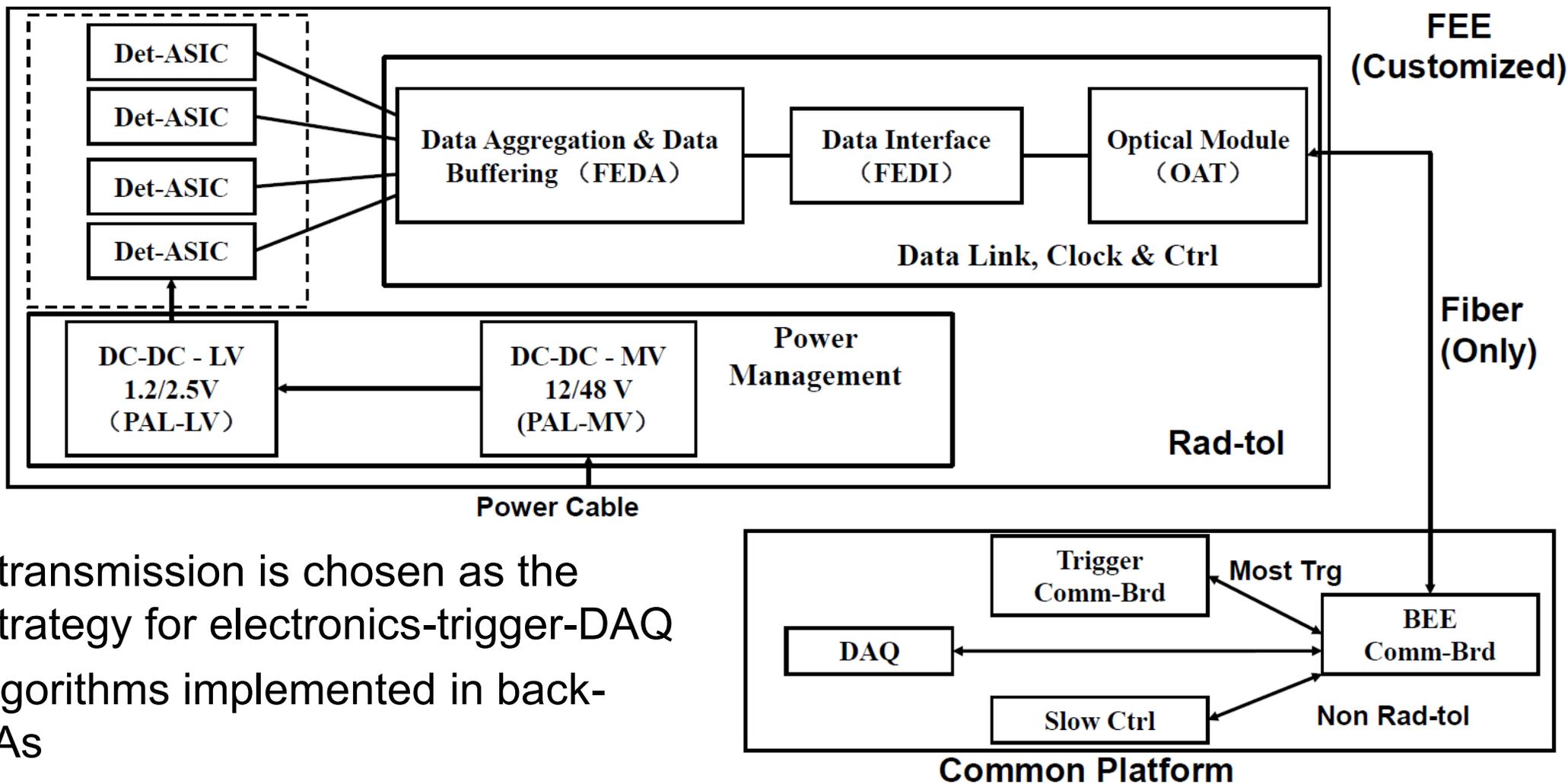
32 strands NbTi Rutherford cable → Al stabilized conductor 16\*30 mm<sup>2</sup> Al stabilizer + Rutherford cable → First co-extrusion conductor 16\*30 mm<sup>2</sup> Al stabilized conductor 22\*56 mm<sup>2</sup>

First co-extrusion

Second co-extrusion

Manufacturing of double co-extrusion box-type cable 31

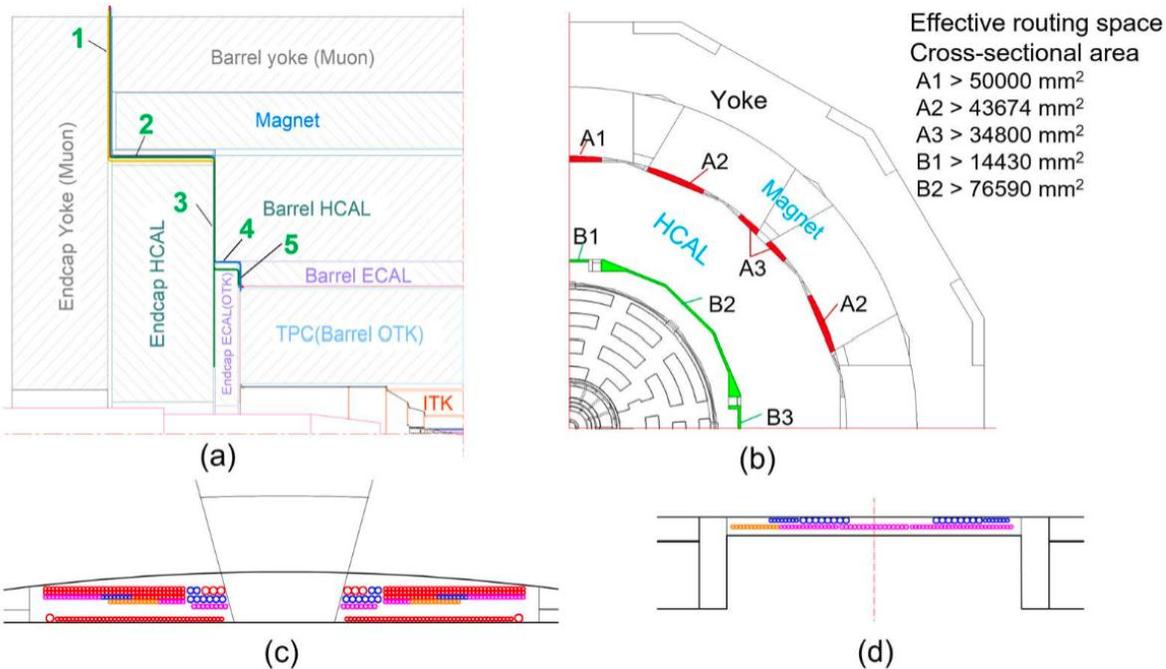
# Common electronics and data acquisition



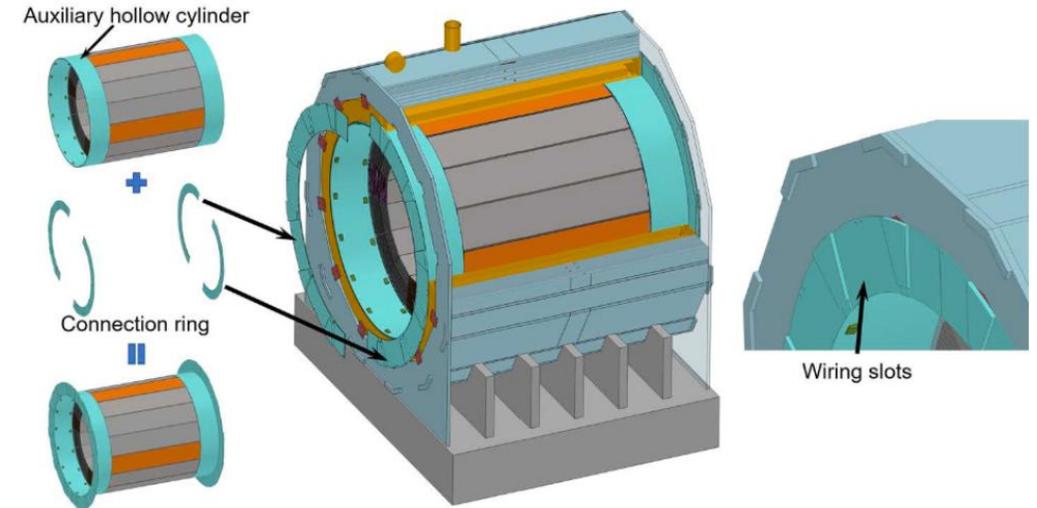
- Full data transmission is chosen as the primary strategy for electronics-trigger-DAQ
- Trigger algorithms implemented in back-end FPGAs
- Data storage rate 0.4/6.7 Gb/s for Higgs(50 MW)/Z(12.1 MW)

# Mechanics and Integration

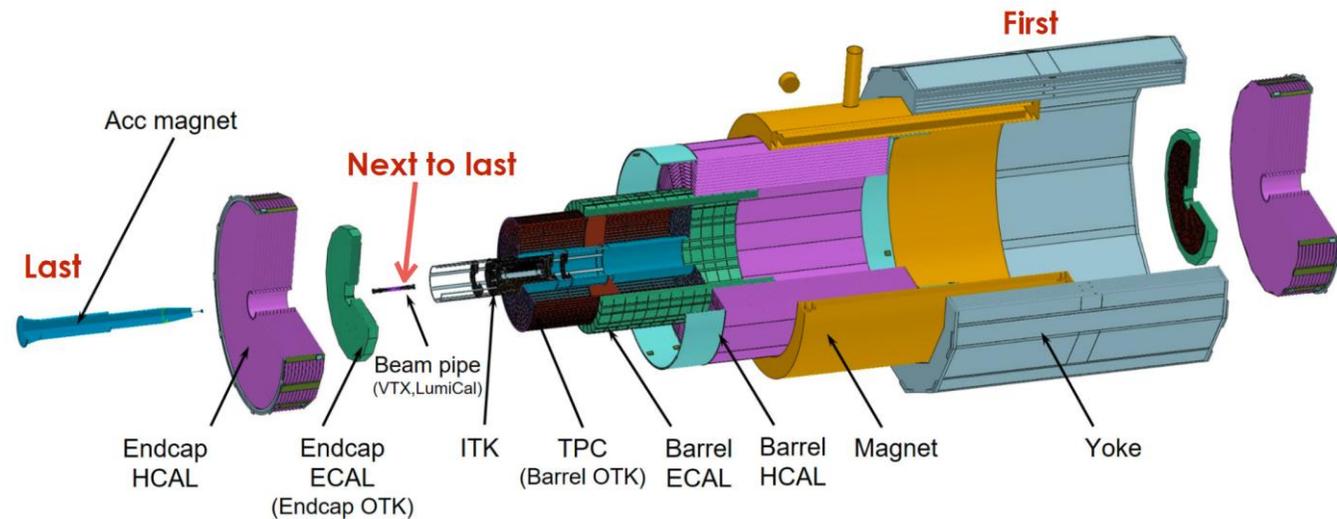
- Sub-detector interconnections and installation was studied in detail
- Layout design of underground halls



Cable routing and services connections



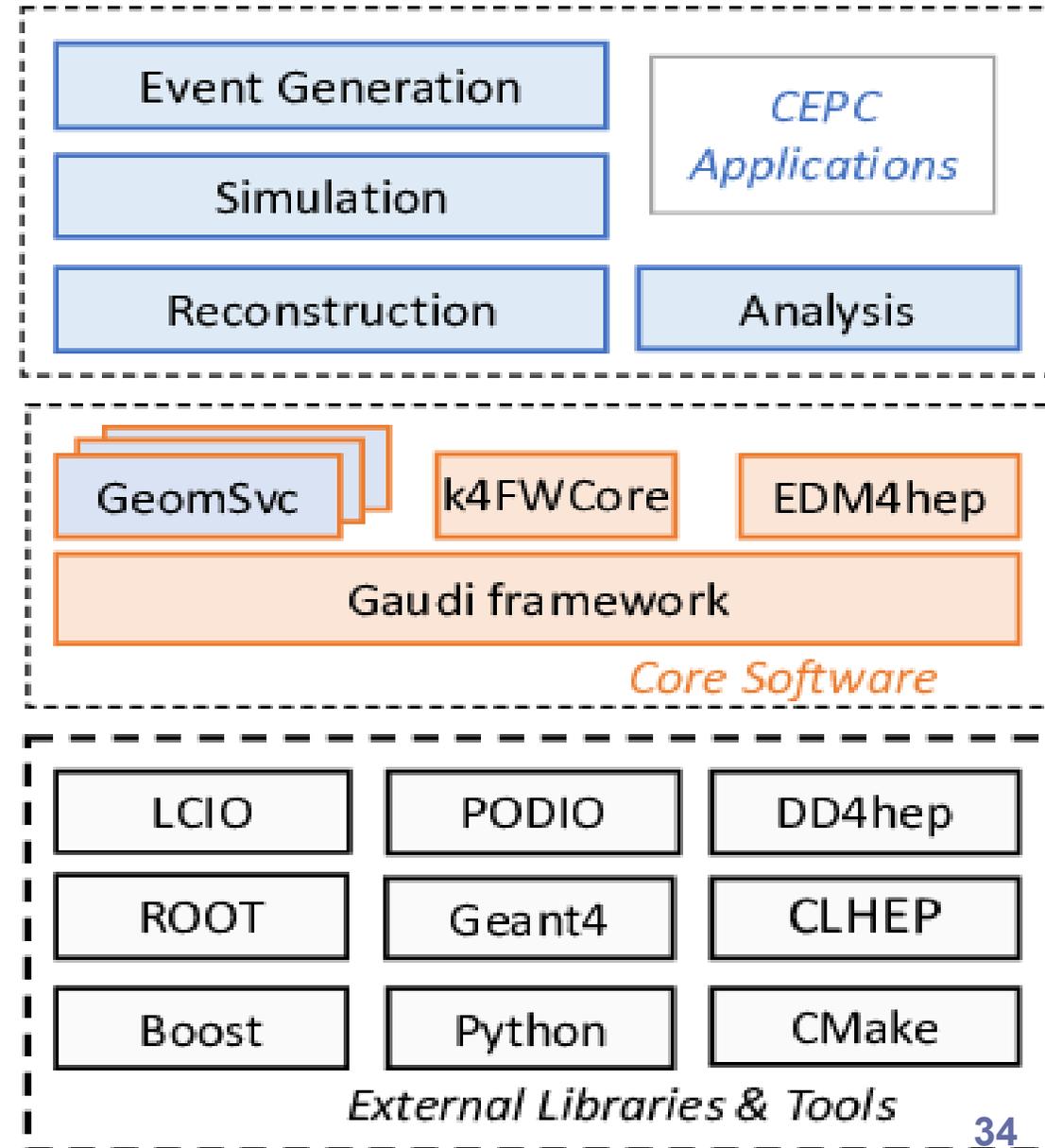
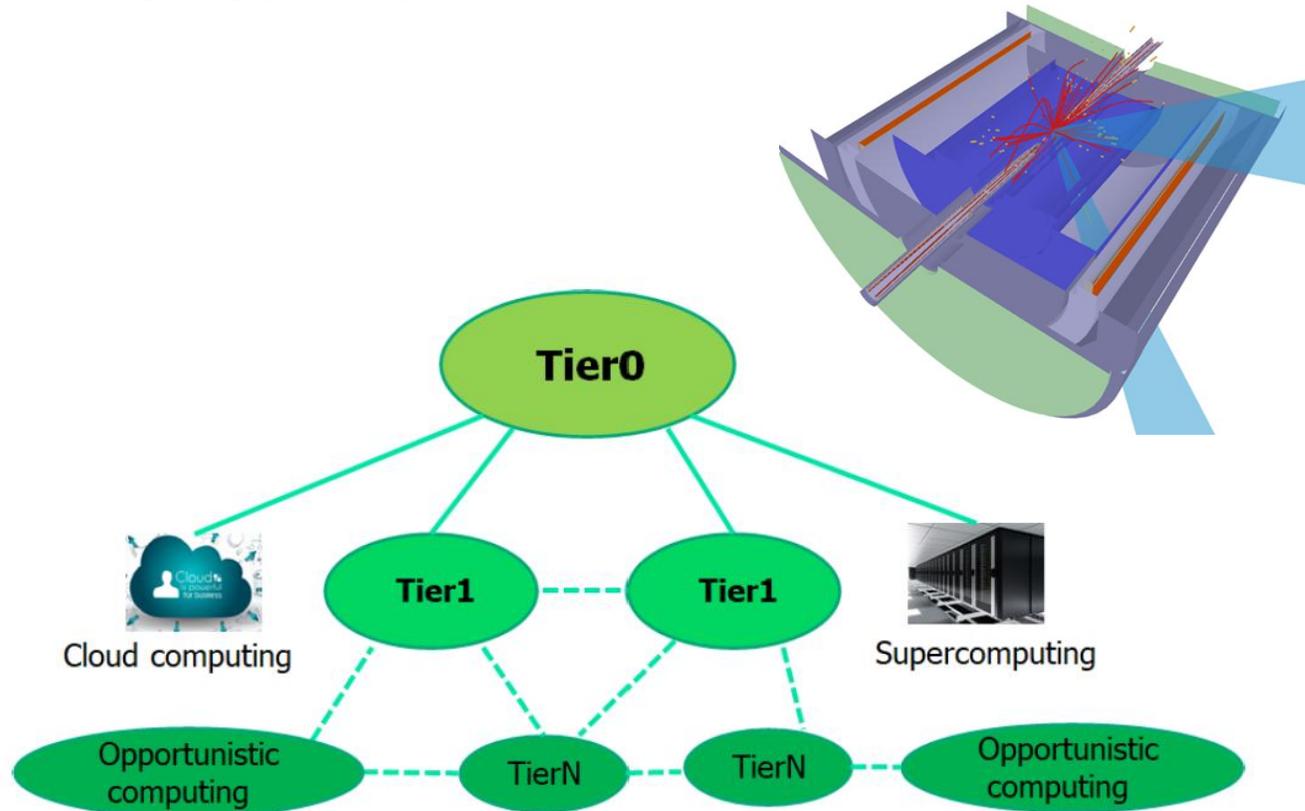
Example: Connection structure of the barrel HCAL.



Installation will proceed from outside inwards 33

# Software and Computing

- CEPC is one of the pioneers in integrating with Key4hep
- Unified software stack developed for future collider experiments such as CEPC, CLIC, FCC, and ILC
- CEPCSW based on Gaudi framework and EDM4hep event data model



# Detector International Review Committee (IDRC)

- International Committee composed of 19 experts in detector & physics, chaired by Daniela Bortoletto
- **Three review meetings** were held from October 2024 to September 2025
- **Final report outcome:** In summary, the CEPC detector programme is entering a decisive stage. **A significant portion of the technical groundwork is complete**, but the coming years must consolidate the design through focused R&D, integrated prototyping, and system validation.
- **Readiness for construction after R&D and engineering preparations:** With sector/module demonstrators, thermal and mechanical mock-ups, full DAQ chains, and formal design/production reviews (FDR/PRR), the project can credibly achieve production readiness... **remaining work is system-level validation and final down-selection on an agreed schedule.**

The CEPC International Detector Committee Meeting in 2024

Oct 21-23, IHEP

THE CEPC INTERNATIONAL DETECTOR COMMITTEE MEETING IN 2025

APR 14-16, IHEP

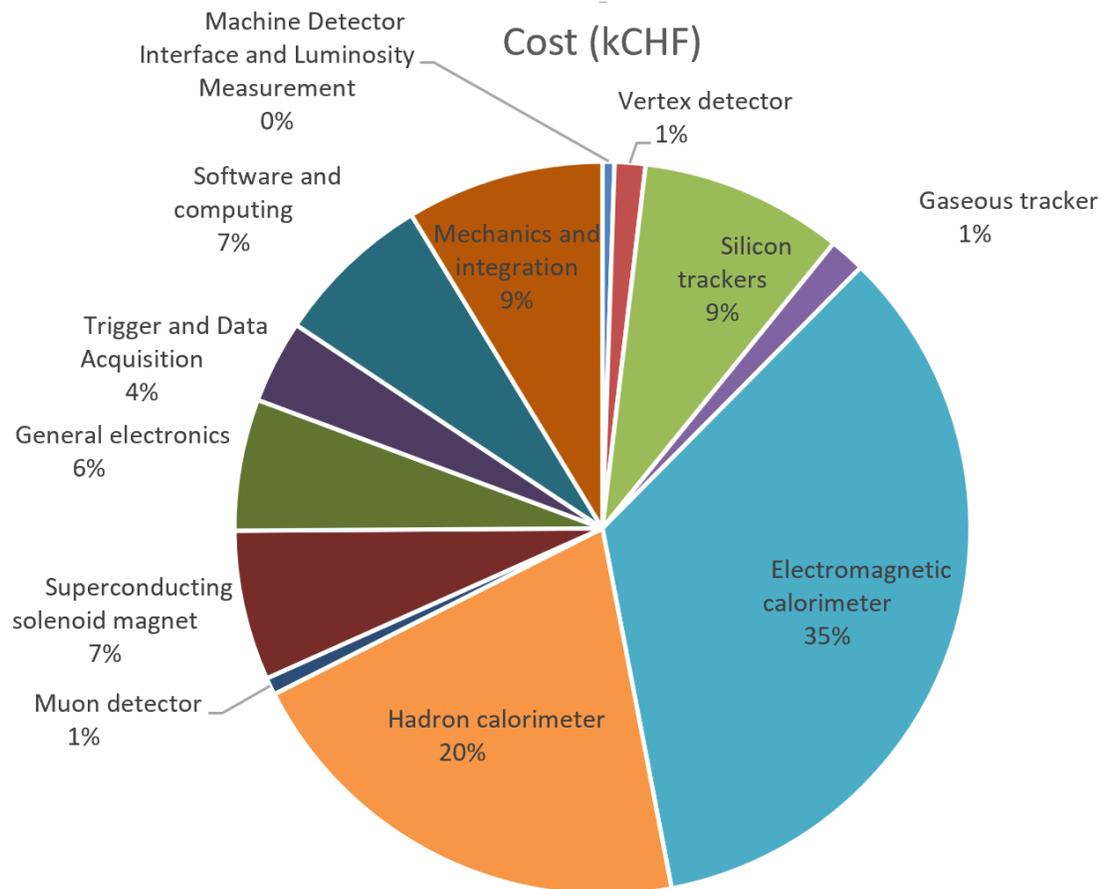
CEPC International Detector Review Committee Meeting

SEP. 2025, BEIJING

# Detector Cost

System	Cost (MCHF)	Ratio
MDI and Luminosity	1.8	0.5%
Vertex detector	4.5	1.3%
Silicon trackers	29.7	8.9%
Time Projection Chamber	6.2	1.9%
Electromagnetic calorimeter	115.0	34.5%
Hadron calorimeter	68.3	20.5%
Muon detector	2.5	0.8%
Detector Magnet System	22.0	6.6%
Readout electronics	19.3	5.8%
Trigger and Data Acquisition	12.2	3.7%
Software and computing	23.1	6.9%
Mechanics and integration	28.9	8.7%
<b>Total</b>	<b>333.3</b>	<b>100.0%</b>

3% installation included; 8% contingency not included.



**Cost comparable to other large-scale experimental projects: e.g. FCC-ee, 1,300+290=1590 MCHF for 4 detectors → 397.5 MCHF for 1 detector in average**

# Future plan

## MDI and Luminosity

- **MDI:** Optimization of collimators and re-evaluation of cryogenics shielding/weight
- **Luminosity measurement:** Validation of technologies
- **Beam background:** improve simulation tools and compare with BESIII/BEPCII

## Silicon detectors

- **Vertex:** Development of wafer-scale stitching MAPSs with 180 nm technology; explore CIS stitching MAPSs with 65nm/55nm technology
- **ITK:** HV-CMOS sensor R&D, high-resistivity wafers to improve S/N performance
- **OTK:** larger size, higher performance, and lower power consumption for LGAD; moving towards multi-channels readout ASIC LATRIC

## Gaseous detector

- **TPC:** Test and validation of high granularity readout modules, focusing on resolution, ion back-flow, and electron transmission; development of low-noise and low-power ASIC

## Calorimeter and Muon detectors

- **ECAL:** QA/QC specifications for mass production; development of BSO crystal
- **HCAL:** Glass scintillator advancements in light yield and attenuation length
- **Muon:** Enhance light yield and photon collection efficiency of the 5-m PS strips
- R&D of **SiPM** and readout ASIC for each detector

# Future plan

## Detector Magnet

- Develop longer full-size aluminum-stabilized NbTi Rutherford cable
- Enhance mechanical strength, achieving self-supporting structures, and ensuring bonding strength
- Cryogenic system and mechanical design

## Readout electronics and TDAQ

- Prototype verification, front-end chip development, and electronics common interface
- Development of advanced trigger algorithms, high-speed transmission technology for trigger electronics, and high-bandwidth distributed parallel computing.
- Small-scale experimental verification based on the new ATCA standard architecture

## Mechanics and integration

- Further design of yoke, sub-detectors, connection structure, and cooling
- Service: cabling and piping, electrical & gas system, crane, forks ...
- Installation scheme optimization, design of the tooling and fixtures

## Software and simulation

- Optimization of geometry coverage.
- Study of standalone tracking for displayed vertex.
- Simulation for physics impact and new physics.

# Collaborations in DRD

- Integration into European R&D Framework
- Open to extensive collaboration with FCC-ee

Sub-system	DRD	Sub-system	DRD	Sub-system	DRD
Pixel Vertex Detector	3	Electromagnetic Calorimeter	6	Superconducting Solenoid	
Inner Silicon Tracker	3	Hadron Calorimeter	4, 6	Mechanical and Integration	8
Outer Silicon Tracker	3	Machine Detector Interface	8	General Electronics	7
Gas Tracker (TPC / DC)	1	Luminosity Calorimeter		Trigger and DAQ	7
Muon Detector	1 (RPC)	Fast Luminosity Monitor	3	Offline Software	Key4hep

# Summary

- The Reference Detector TDR was finished in October 2025
  - The detector is an innovative, but challenging concept, capable of delivering the CEPC physics
  - The technical design of each sub-system is well advanced although some R&D remains necessary
  - Focus will shift into consolidating the designs and further development of key components, such as silicon sensors, readout chips, and glass scintillator
- CEPC workshop
  - Past: Guangzhou (Nov. 6-10, 2025), >400 participants
  - Next: **Lisbon (April 7-11, 2026)**, <https://indico.cern.ch/e/CEPC2026EU>



**Table 2.2:** Key technologies and parameters of the CEPC reference detector, the dimensions listed in the table are for the sensitive parts.

Detector	Technology	In (mm)	Out (mm)	Comment
Vertex	Silicon pixel	$r_{in} = 11.1$	$r_{out} = 47.9$	4 single, 2 double layers
ITK (barrel)	Silicon pixel	$r_{in} = 235.0$	$r_{out} = 555.6$	3 layers
ITK (endcap)	Silicon pixel	$ z_{in}  = 505.0$	$ z_{out}  = 1489$	4 disks
LumiCAL (front)	Silicon pixel	$r_{in} = 12$ $ z  = 560$	$r_{out} = 42$	1 double layer disk
LumiCAL (back)	Silicon pixel	$r_{in} = 12$ $ z  = 640$	$r_{out} = 51$	1 double layer disk
OTK (barrel)	Silicon microstrip	$r = 1800$ $ z  \leq 2840$		1 layer
OTK (endcap)	Silicon microstrip	$r_{in} = 406$ $ z  = 2910$	$r_{out} = 1816$	1 disk
TPC	Gaseous tracking	$r_{in} = 600$ $ z  \leq 2900$	$r_{out} = 1800$	MPGD high-granularity readout
ECAL (barrel)	Crystal + SiPM	$r_{in} = 1830$ $ z  \leq 2900$	$r_{out} = 2130$	18 layers, 32 sectors
ECAL (endcap)	Crystal + SiPM	$r_{in} = 350$ $ z_{in}  = 2930$	$r_{out} = 2130$ $ z_{out}  = 3230$	$1.5 \times 1.5 \times 3 \text{ cm}^3$ 3D granularity 18 layers, 24 $X_0$ , 1.2 $\lambda_I$
LumiCAL (front)	LYSO + SiPM	$r_{in} = 12$ $ z_{in}  = 647$	$r_{out} = 56$ $ z_{out}  = 670$	14 layers 2 $X_0$
LumiCAL (back)	LYSO + SiPM	$r_{in} = 12$ $ z_{in}  = 800$	$r_{out} = 110$ $ z_{out}  = 950$	10 layers 13.4 $X_0$
HCAL (barrel)	Glass scintillator + SiPM	$r_{in} = 2140$ $ z  \leq 3230$	$r_{out} = 3455$	48 layers, 16 sectors
HCAL (endcap)	Glass scintillator + SiPM	$r_{in} = 400$ $ z_{in}  = 3260$	$r_{out} = 3385$ $ z_{out}  = 4575$	$4 \times 4 \times 1 \text{ cm}^3$ pixel 48 layers, 6 $\lambda_I$
Muon (barrel)	Plastic scintillator + SiPM	$r_{in} = 4245$ $ z  \leq 4475$	$r_{out} = 5185$	6 layers, 12 sectors
Muon (endcap)	Plastic scintillator + SiPM	$r_{in} = 550$ $ z_{in}  = 4635$	$r_{out} = 5085$ $ z_{out}  = 5875$	