The AGORA detector

Yiming Li

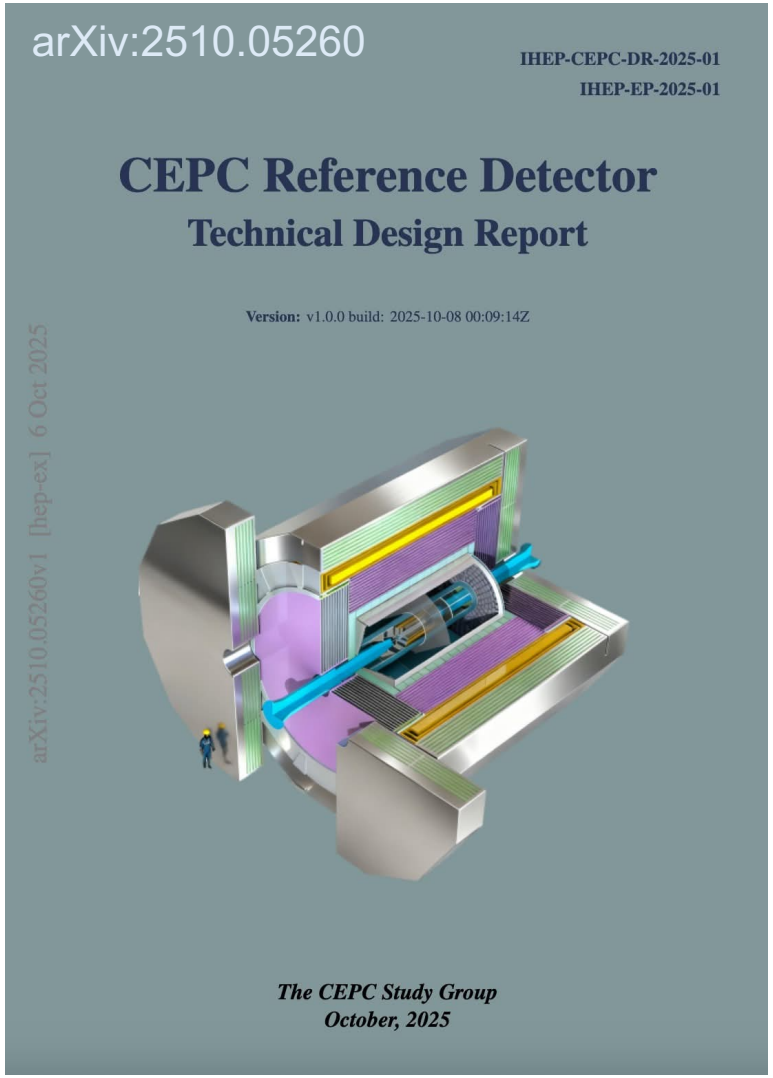
(Institute of High Energy Physics, CAS)

On behalf of the AGORA team

The 2026 International Workshop on the High Energy Circular Electron Positron Collider, 24th Oct 2026, Shanghai

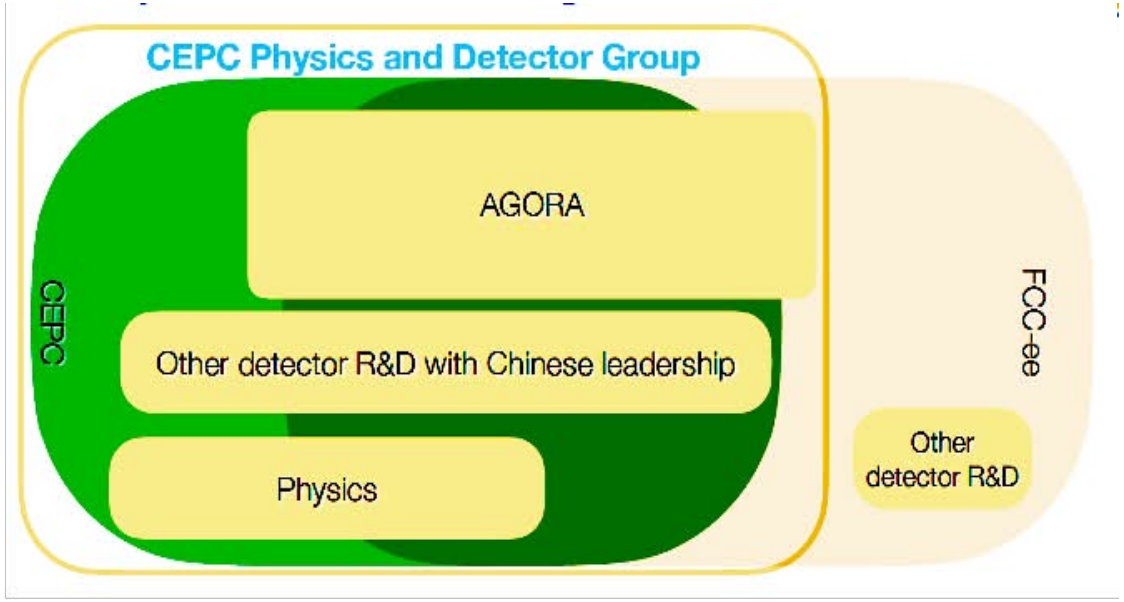
AGORA – what it is

https://agora.web.cern.ch/



- A next-generation experiment at future e^+e^- collider
- Developed initially as the Reference Detector for CEPC
- Recently proposed as a new detector concept for FCC

@FCC week, Helsinki, Jun 2026



See Joao's talk on AGORA evolvement and plans

Motivation

- For a 100 km e^+e^- collider as a Higgs / Z / W factory
- Key requirements
  - Precision Higgs physics / Electroweak physics / Flavour physics / …

CEPC Baseline scenario (30 MW)

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

CEPC Upgraded scenario (50 MW)

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

$2(4) \times 10^6$ Higgs

$0.6\ (4) \times 10^{12}$ Z boson

FCC-ee Baseline scenario

Working point	$\sqrt{s}$ (GeV)	Lumi/IP (10^{34} cm^{-2} s^{-1})	Lumi/year (ab^{-1})	Run time (year)	Integrated lumi. (ab^{-1})	Number of events
Z pole	88, 91, 94	140	68	4	205	6×10^{12} Z
WW thresh.	157, 163	20	9.6	2	19.2	2.4×10^8 WW
ZH	240	7.5	3.6	3	10.8	2.2×10^6 ZH + 65k WW → H
$t\bar{t}$ (340–350)	340–350	1.8	0.83	1	0.42	2×10^6 $t\bar{t}$ + 370k ZH
$t\bar{t}$ (365)	365	1.4	0.67	4	2.70	+ 92k WW → H

FCC feasibility study report, arXiv: 2505.00272

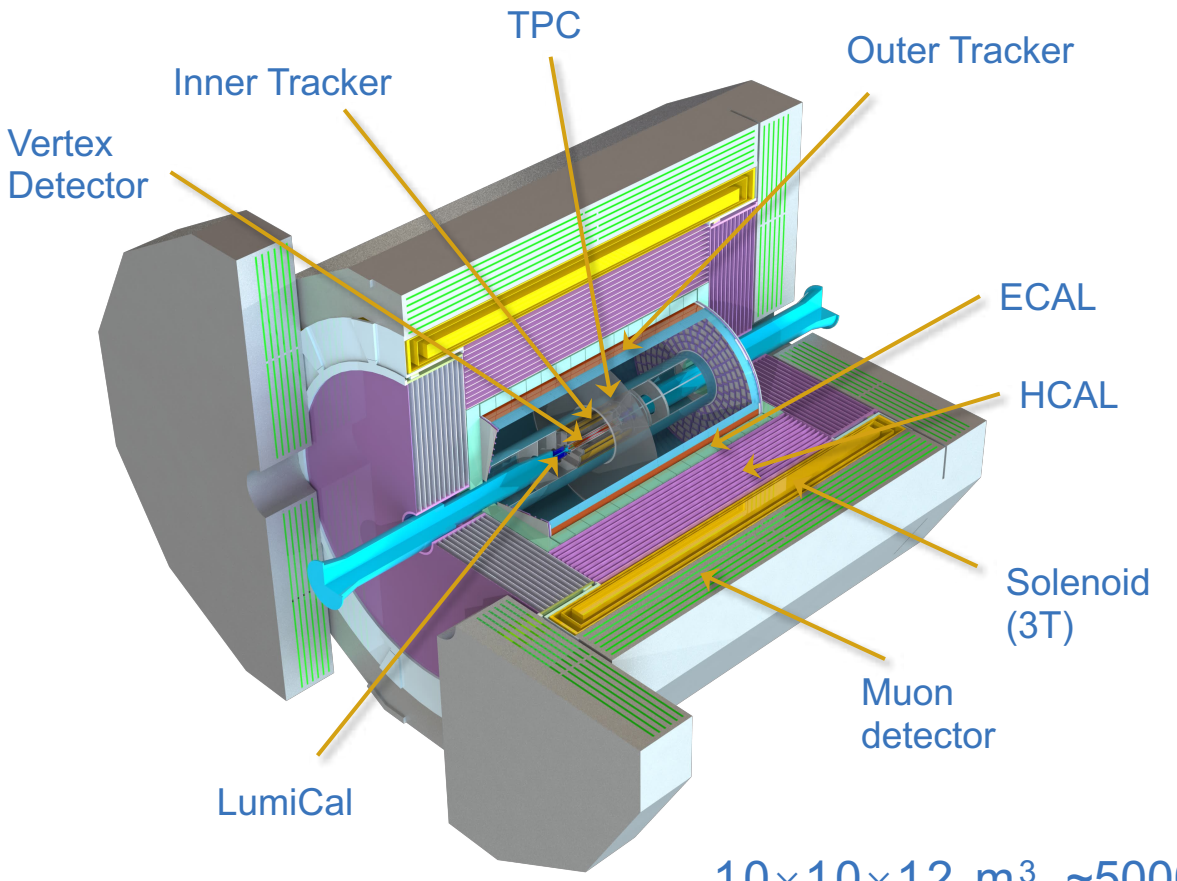
Motivation

- For a 100 km e^+e^- collider as a Higgs / Z / W factory
- Key requirements
  - Precision Higgs physics / Electroweak physics / Flavour physics / …

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

Baseline design – CEPC Ref-Det

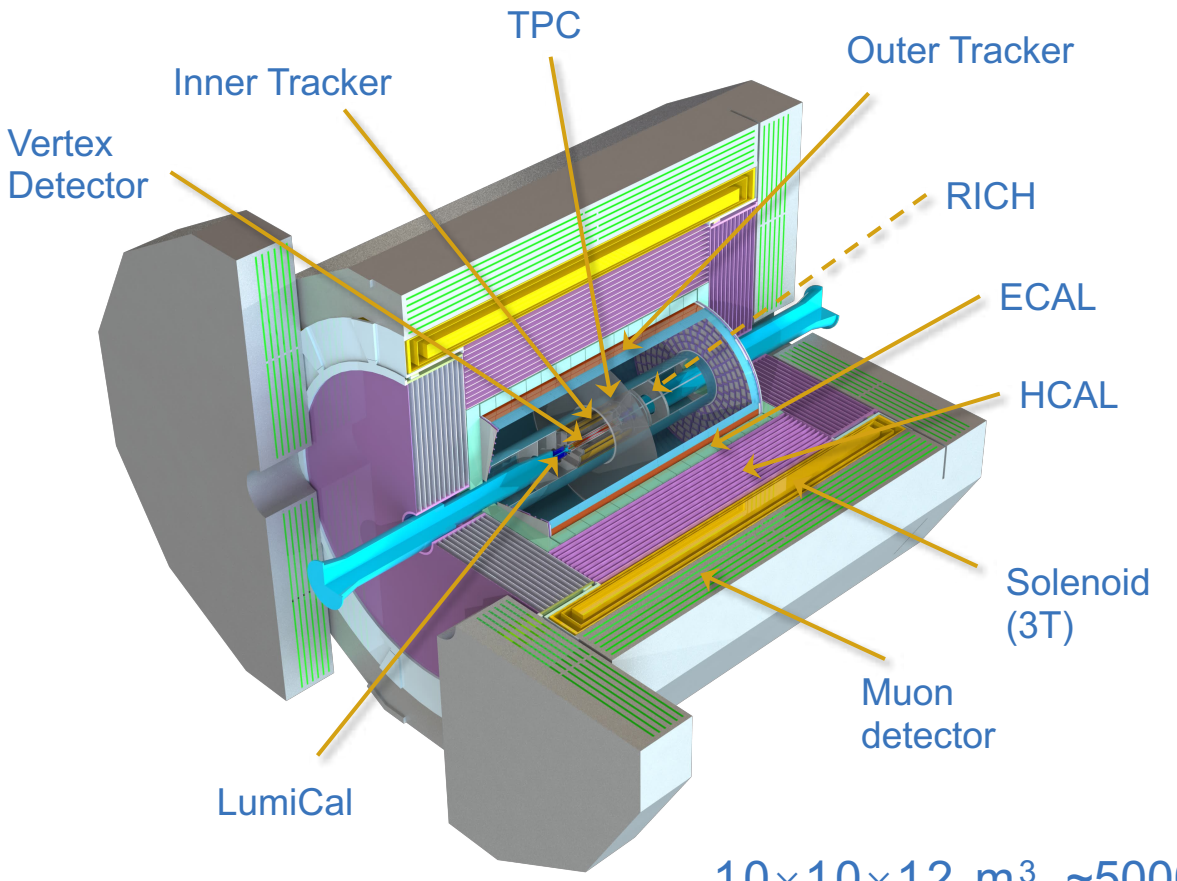
Sub-system	Technology
VTX	MAPS + stitching
ITK	HV-MAPS in 55nm
TPC	0.5 x 0.5 mm^2 readout, dN/dx PID
OTK	AC-LGAD with 50ps timing
ECAL	Crystal bar $1.3\%/\sqrt{E} \oplus 0.7\%$
HCAL	Glass-steel $30\%/\sqrt{E} \oplus 6.5\%$
Solenoid	SC solenoid 3T, 2T at Z-pole
Muon	Plastic Scintillator + SiPM
LumiCal	Silicon + LYSO



$10 \times 10 \times 12$ m^3, ~5000 ton

Baseline design - AGORA

Sub-system	Technology
VTX	MAPS + stitching
ITK	HV-MAPS in 55nm
TPC	0.5 x 0.5 mm^2 readout, dN/dx PID
OTK	AC-LGAD with 50ps timing
RICH	Aerogel + SiPM
ECAL	Glass cubic $3\%/\sqrt{E} \oplus 1\%$
HCAL	Glass cubic <15%$/\sqrt{E} \oplus 4\%$
Solenoid	SC solenoid 3T, 2T at Z-pole
Muon	Plastic Scintillator + SiPM
LumiCal	Silicon + LYSO



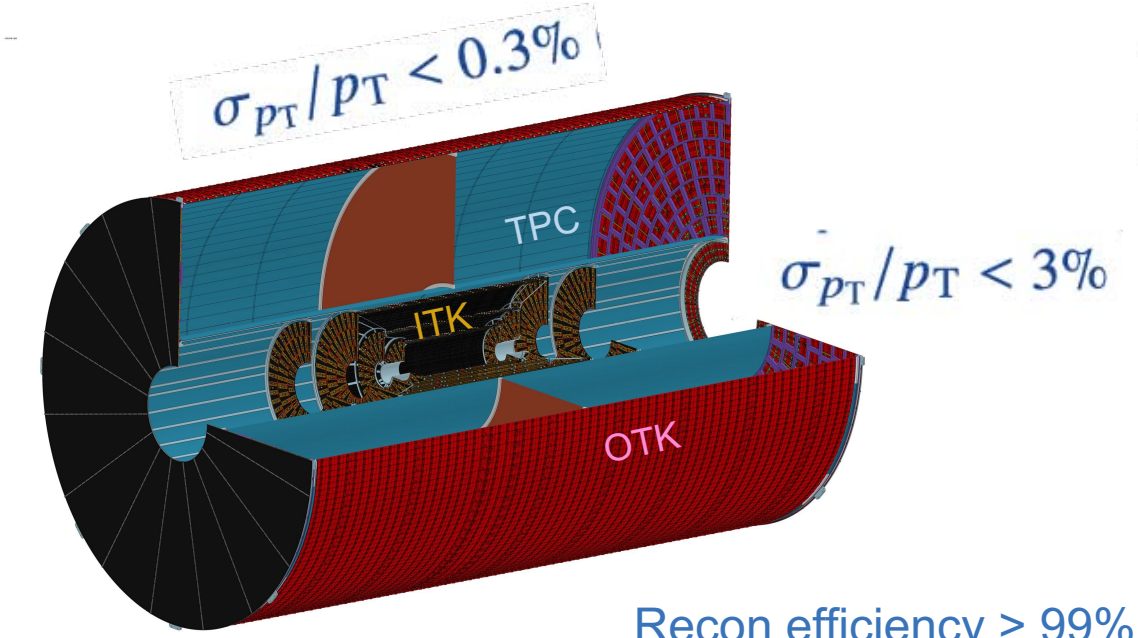
$10 \times 10 \times 12$ m^3, ~5000 ton

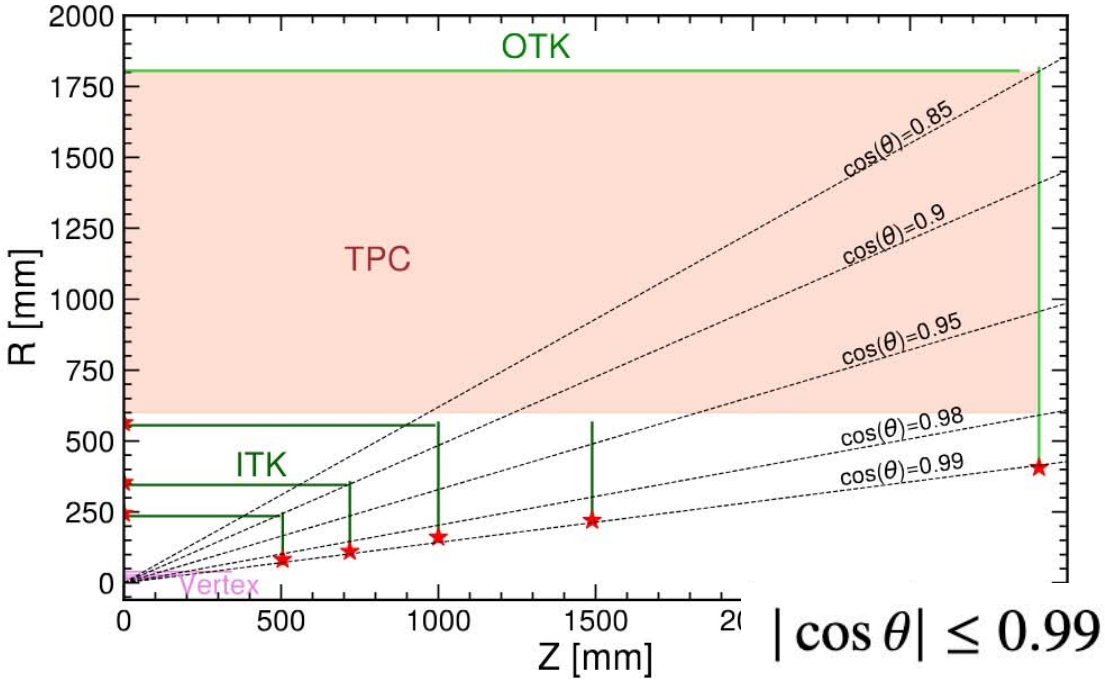
Tracking system & hadron PID

- Excellent vertexing & tracking

$$\sigma_{r\phi} = 5 \oplus \frac{10}{p(\text{ GeV}) \times \sin^{3/2}\theta} (\mu\text{m})$$

- Capability of K/pi separation



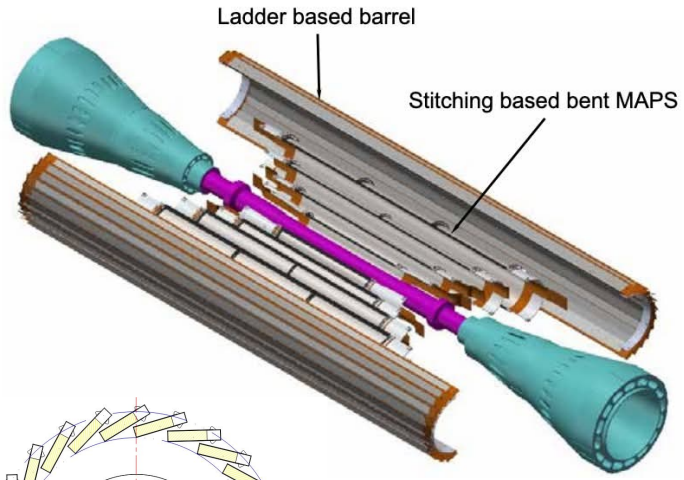


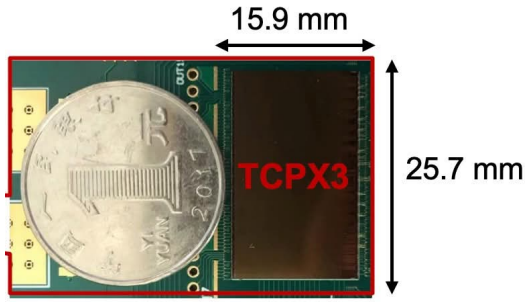
Recon efficiency > 99%

Vertex detector

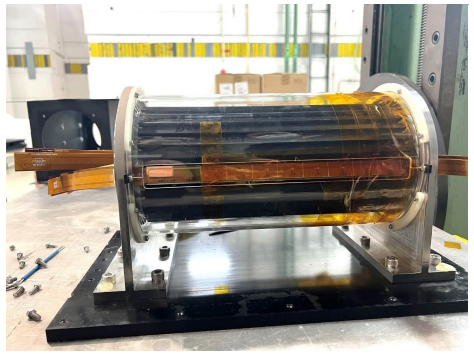
Spatial resolution	**~5 μm / layer**
Material budget	**~0.8% X_0 / layer**
Power consumption	**< 40 mW/cm² (air cooled)**
Angular coverage	**|cosθ| < 0.99**

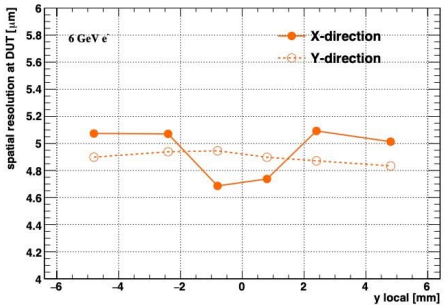
- 4 layers bent & stitched MAPS sensor + 2 double-sided ladders



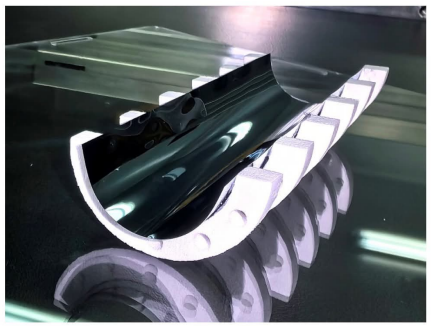


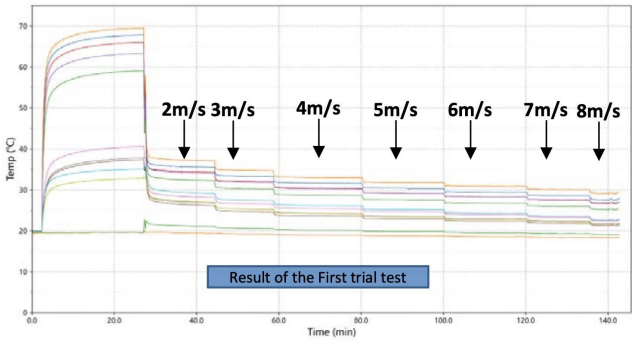
TaichuPix-3 chip vs. coin





TaichuPix-based ladder prototype tested @ DESY, spatial res. <5 μm


Figure 4.26: 12 mm bending radius.





→ Zhijun Liang's talk

Sensor bending demo'd for 12mm radius

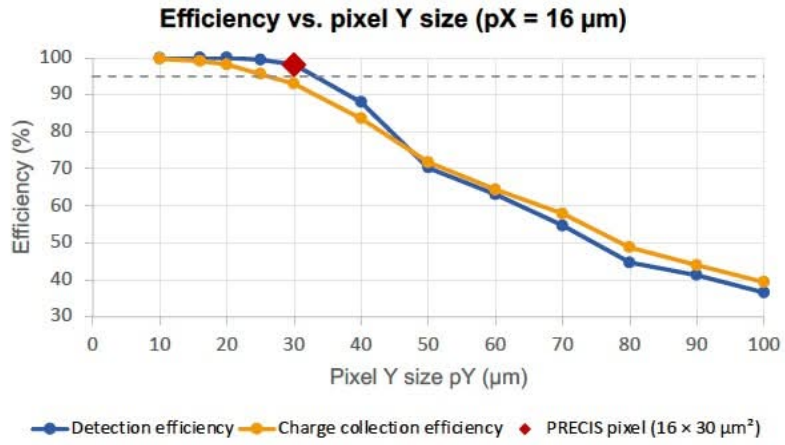
Thermal mockup built & tested for air-cooling up to 8 m/s → Jinyu Fu's talk

Vertex detector

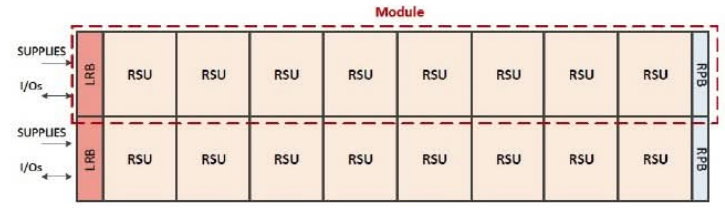
- 4 layers bent & stitched MAPS sensor
  + 2 double-sided ladders
- Spec changes / R&D forseen for FCC-ee:

	Item	CEPC Ref-TDR	AGORA @ FCC-ee (proposed)
●	**Hit-rate capability (L1)**	~40 MHz/cm^2	≥ 150–200 MHz/cm^2 incl. safety margin
●	**Power / cooling**	< 40 mW/cm^2, air	Stay ≤ 40–50 mW/cm^2
●	**Inner radius r_{min}**	11.06 mm	≥ ~13 mm (pipe r_{out} 11.7 mm; IDEA: 13.7 mm); re-optimize L2–L4 for $\|\cos\theta\| \leq 0.99$
●	**Pixel / resolution**	25 × 25 μm^2, ~5 μm	16 × 30 μm^2, $\sigma_{r\varphi}$ < 3 μm (already in HC90L first-run plan)
●	**Radiation**	~1–2 Mrad/yr	~10 Mrad/yr; ~10^{14} n_{eq}/cm^2 over Z run

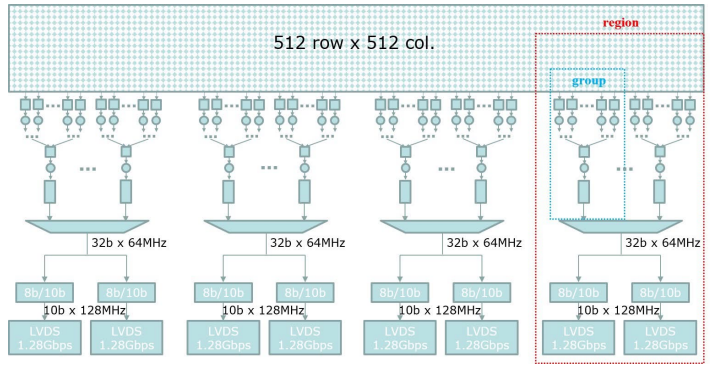
TCAD simulation on sensor size



- Sensor technology
  - Full-size chip with TJ 180nm
  - Baseline: TPSCo 65nm
  - Exploring: Hynix HC90L



Stitched module: RSUs between left-end (LRB) and right-end (RPB) blocks



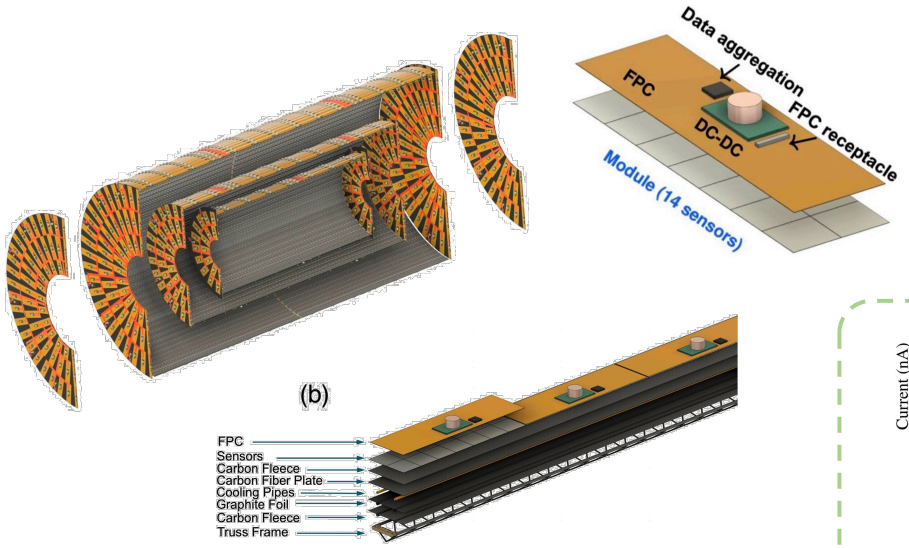
PRECIS design ongoing to tackle 200 MH/cm^2 rate and stitching

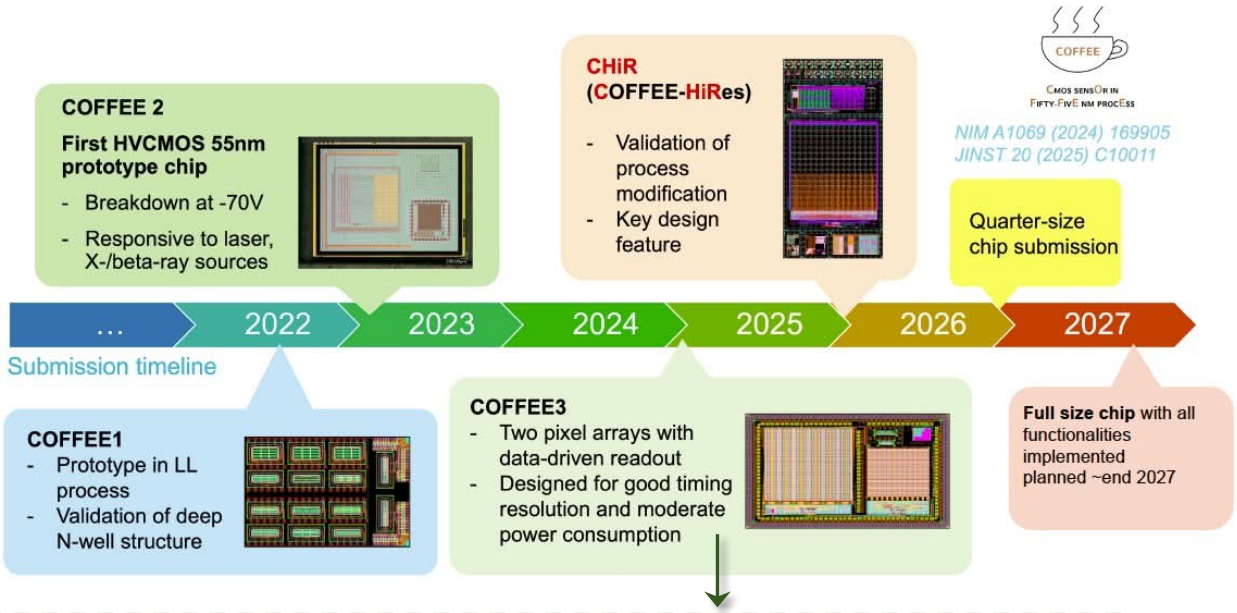
→ Zhijun Liang's talk

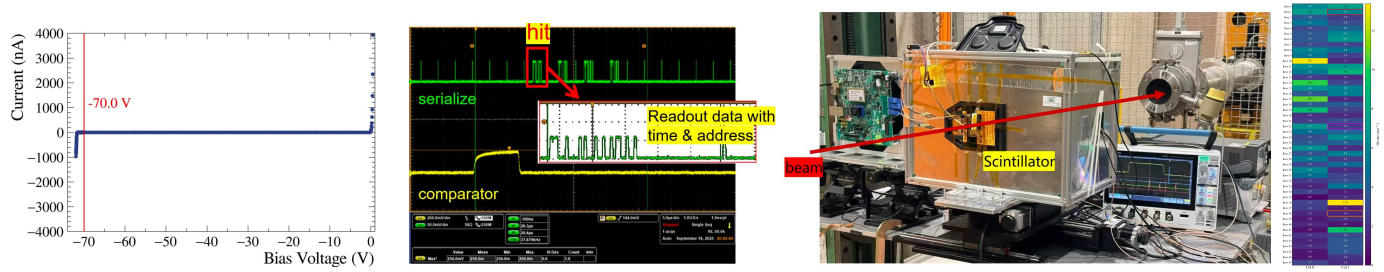
HV-CMOS based Inner Tracker

Area	~ 20 m^2
Spatial resolution	~ 8 μm
Time resolution	3~5 ns
Low material	~ 0.7%X_0 (barrel)
Power	<= 200 mW/cm^2

- 3 barrels + 4 pairs of endcap disks with common module design
- MAPS sensor on 55nm HVCMOS process developed to tackle the challenges
  - Colloaboration in DRD3 & LHCb upgrade





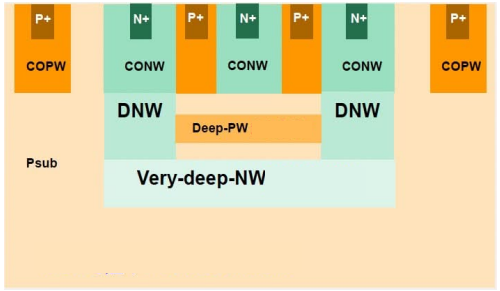


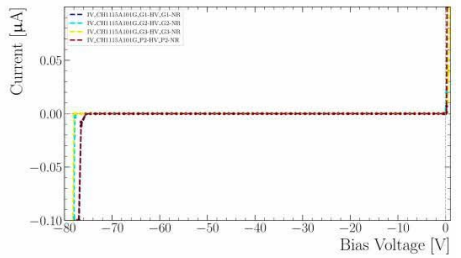
COFFEE3 pixel matrix validated in lab & CERN beam,
Low resistivity wafer & triple-well process limits performance

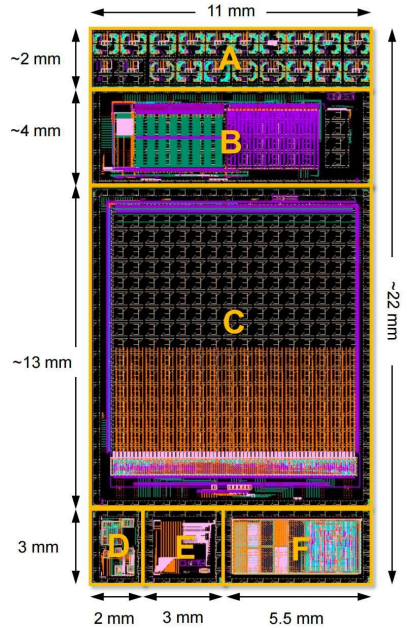
→ Zijun Xu's talk

HV-CMOS based Inner Tracker

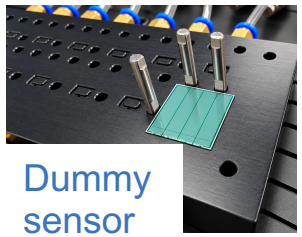
- Future R&D on improved process
  - CHiR1 submitted to validate isolation DPW & high resistivity wafer
- Prototyping efforts proceeds in parallel
- New ideas explored to reduce material:
  - Serial powering
  - Wireless transmission



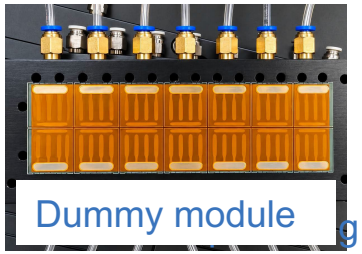




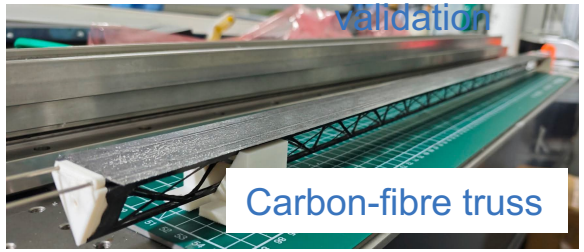
CHiR1 on '5-well' process



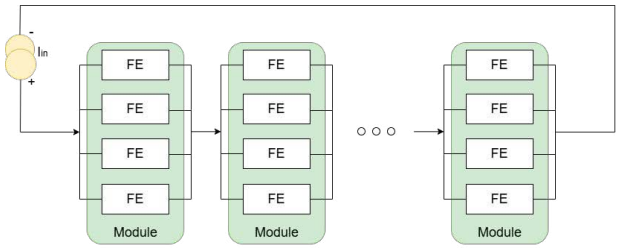
Dummy sensor

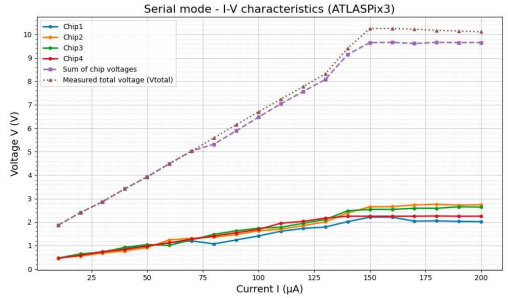


Dummy module validation



Carbon-fibre truss



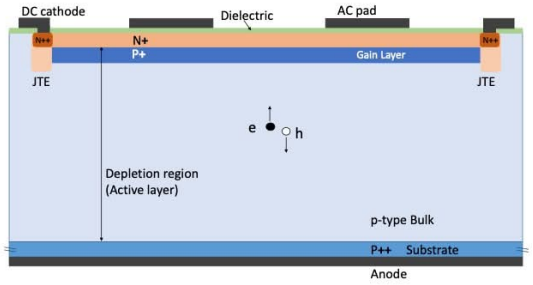


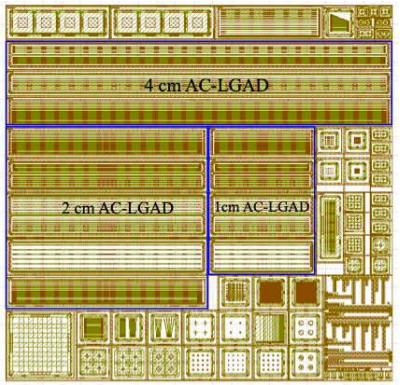
→ Zijun Xu's talk

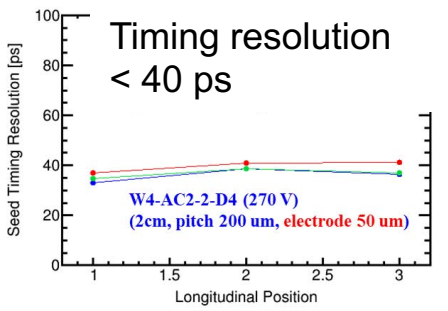
Outer Tracker & timing layer

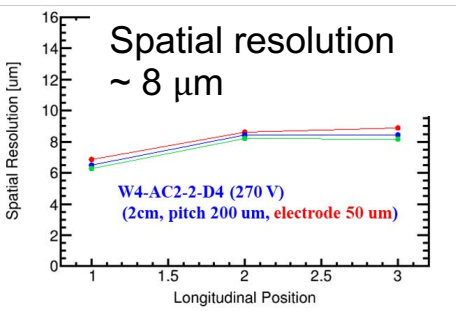
Area	~ 85 m^2
Time resolution	~ 50 ps
Spatial resolution	~ 10 μm

- AC-LGAD sensor based
  - Building on HGTD experience

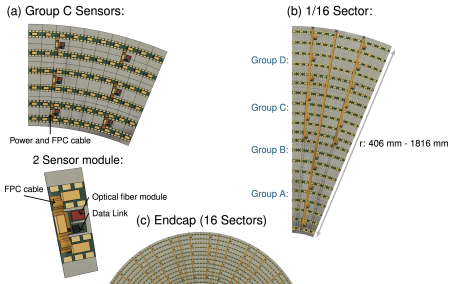


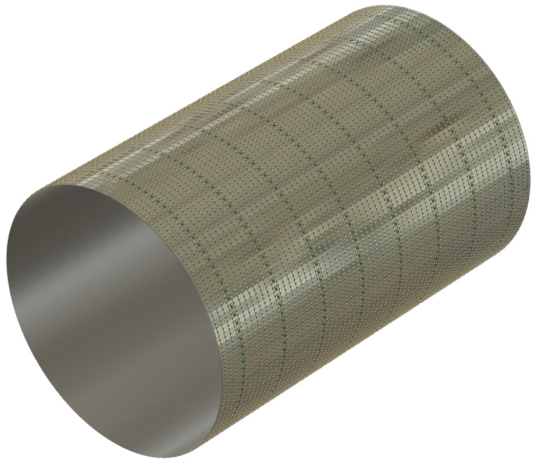


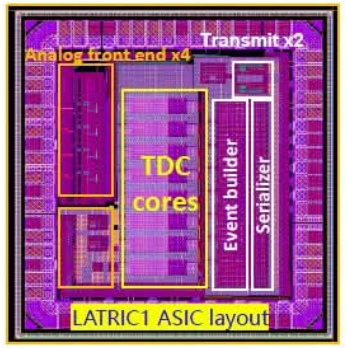




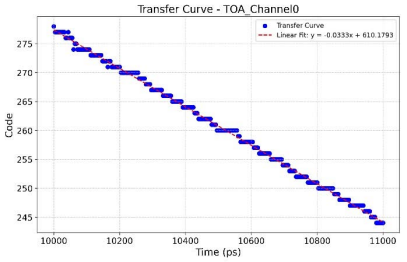
AC-LGAD sensor up to 4cm tests show good performance







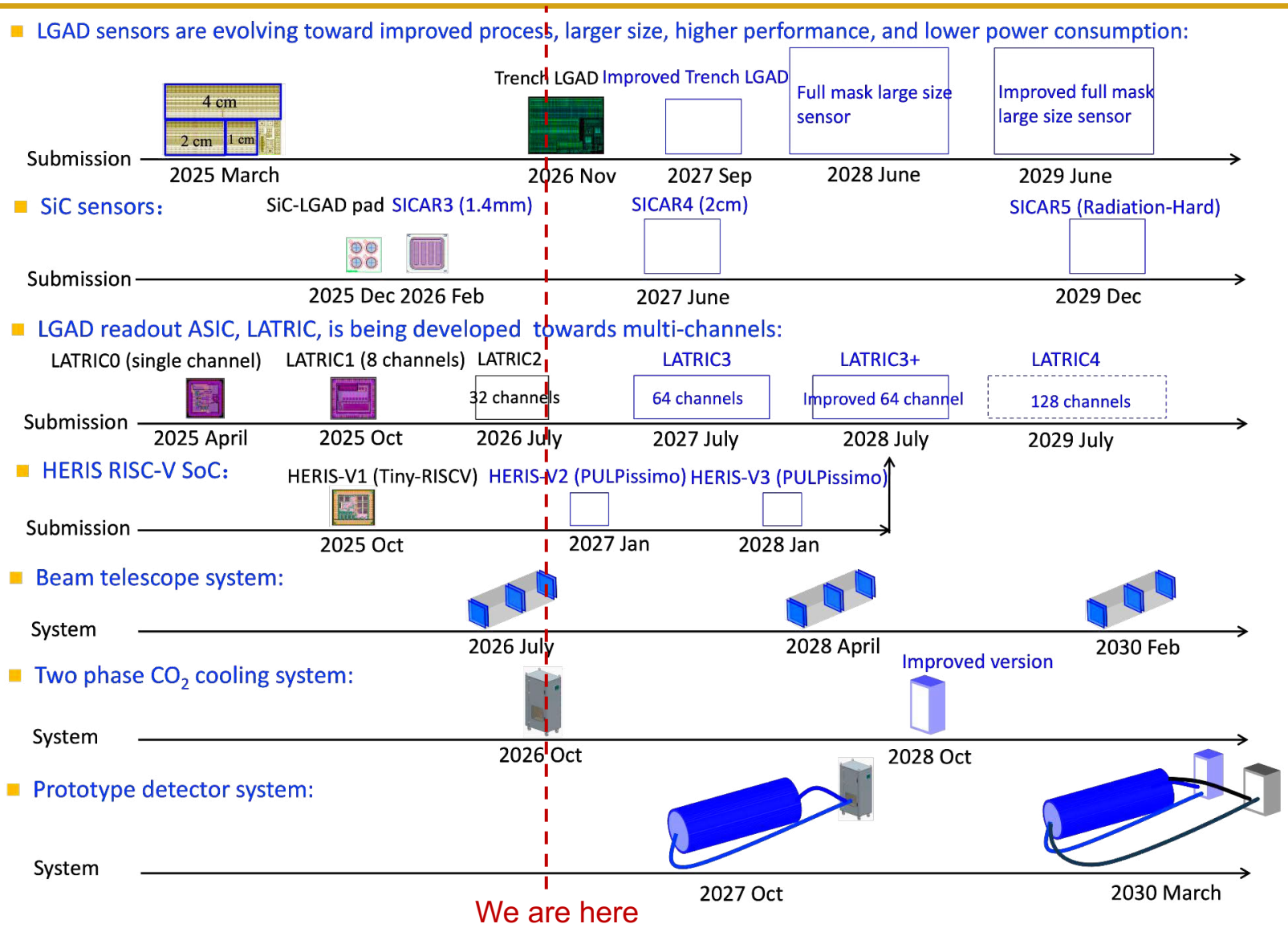




Readout ASIC LATRIC1 with 8-channel: LSB ~ 30ps

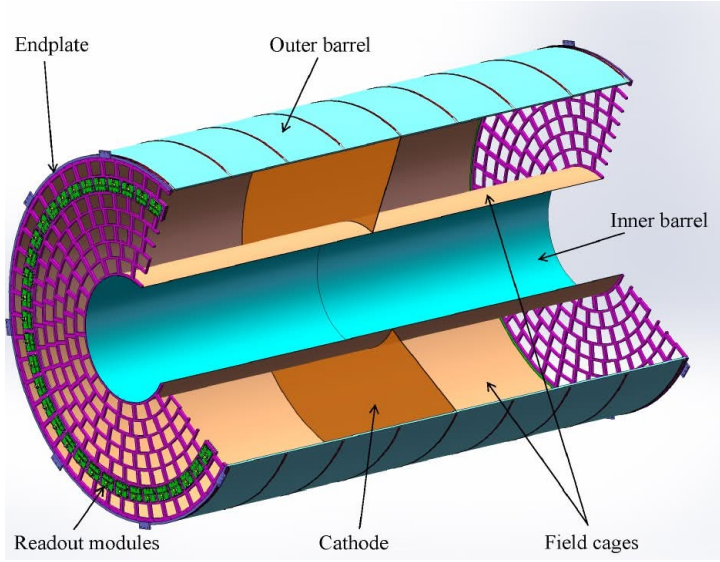
→ Jiajian Toeh and Mei Zhao's talks

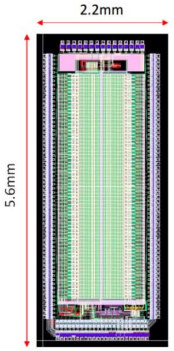
Outer Tracker & timing layer



Time Projection Chamber

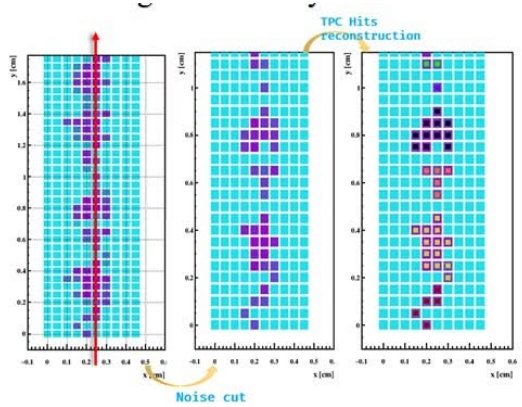
- Aiming at good spatial resolution ($\sigma \sim 100\ \mu m$) and PID using novel dN/dx method
  - Length: 5.8 m, radius 0.6~1.8 m
  - Micromegas detector with 500 x 500 μm^2 high-granularity readout
  - Space charge distortion can be treated for Higgs and low-lumi Z operation
- Drift Chamber is studied as an alternative
- Adaption to FCC-ee high lumi to be studied

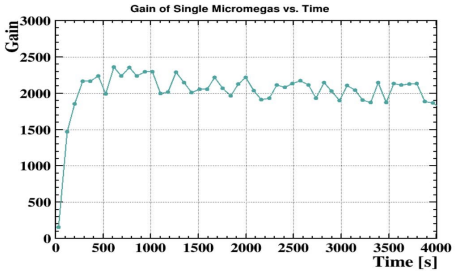










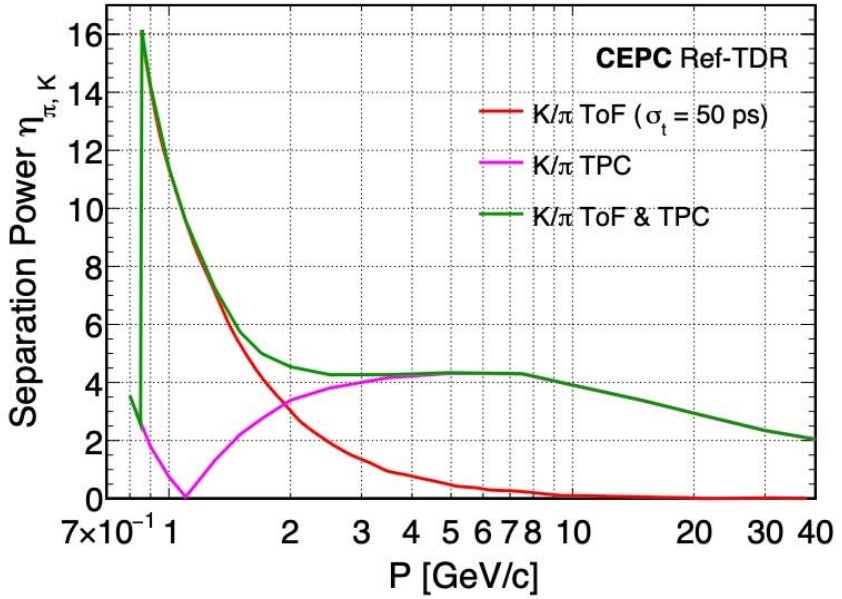


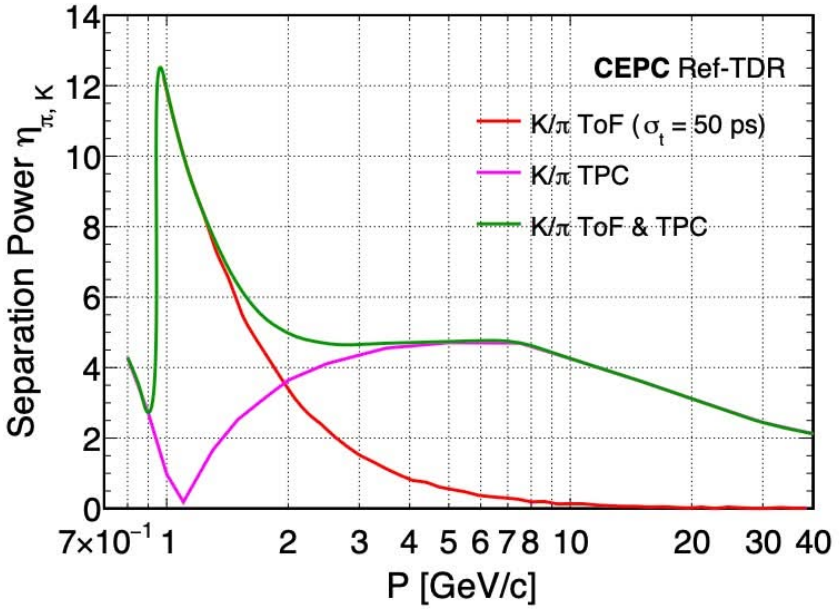
DC:

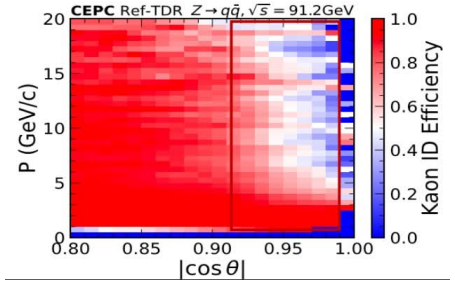
→ Huirong Qi's talk on TPC
→ Jianbo Zheng's talk on BIB challenge
→ Guang Zhao's talk on dN/dx method
→ Hongbin Liu's talk on DC readout

PID performance

- Separation power > 3 up to 20 GeV in barrel region
  - OTK fills the gap at low momentum region for TPC





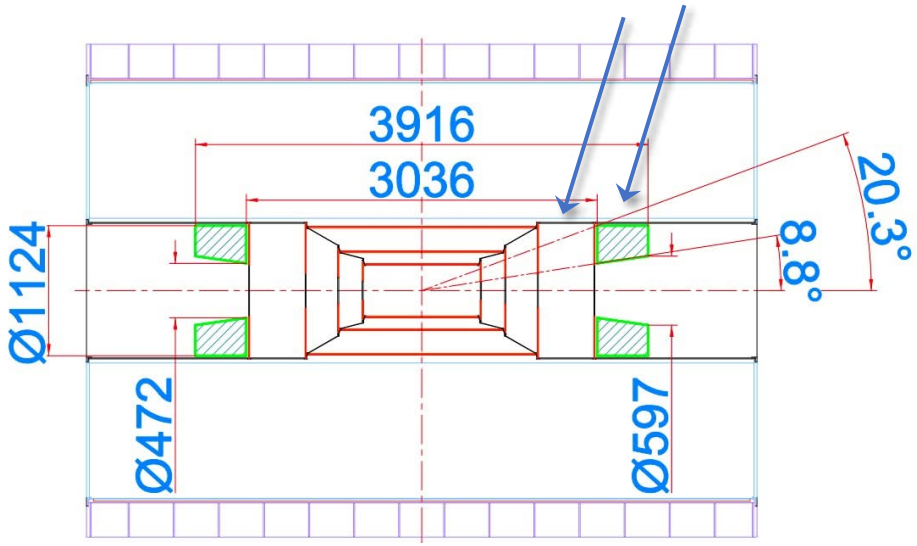


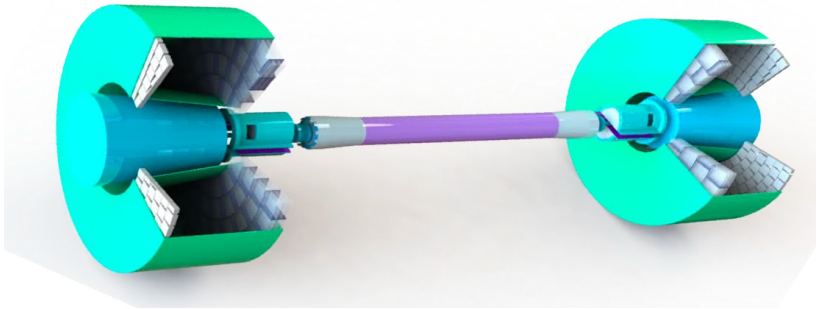
What about the forward region?

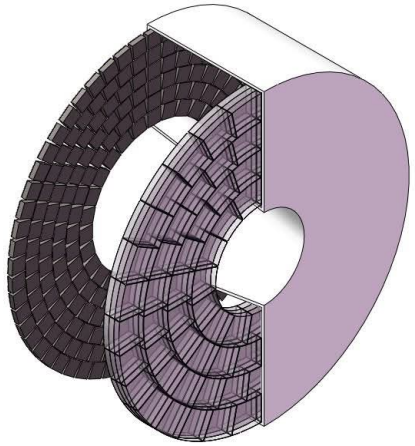
New development: RICH

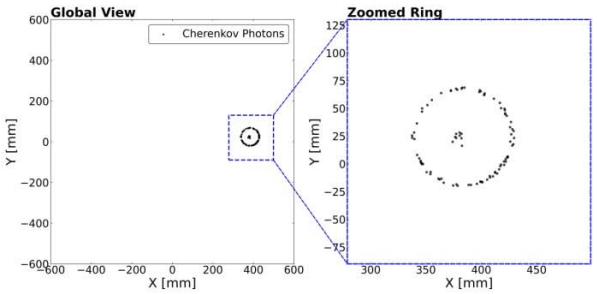
- Ring Imaging Cherenkov Detector using Aerogel + SiPM to promote forward PID
  - Radiator: ~0.9 m^2, 90 aerogel tiles in 4 layers, each tile ~10 x 10 cm^2
  - Photon detector: ~0.8 m^2, 258 modules in 6 layers, each module ~ 5 x 5 cm^2

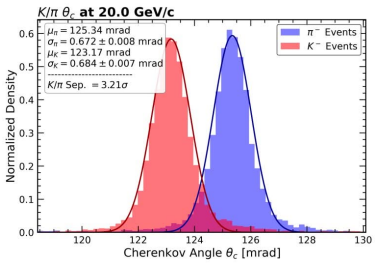
Exact location to be decided

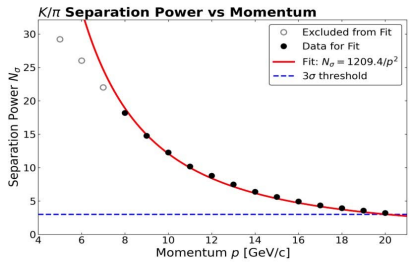












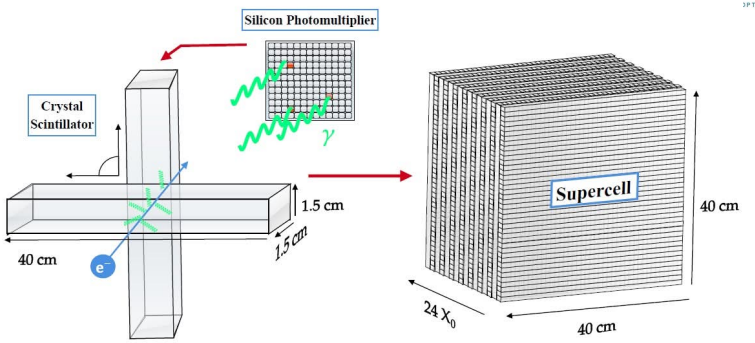
→ Zhonghua Qin's talk
→ Ziqiu Yang's talk on its impact on flavour physics
→ Alexander Barnyakov's talk on aerogel R&D

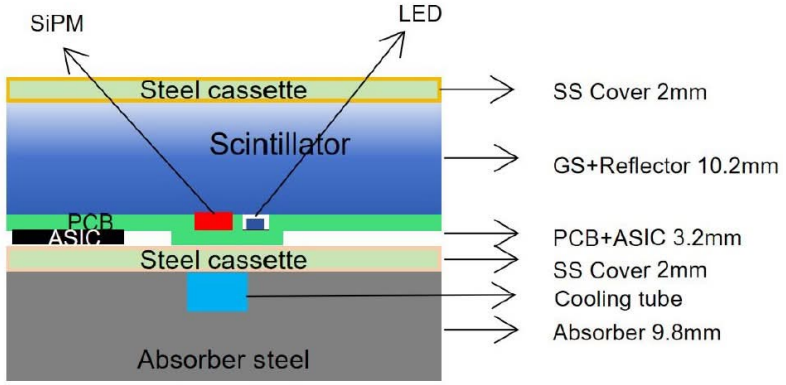
Simulation shows 3σ K/π separation up to 20 GeV

PFA oriented Calorimeters

Electromagnetic Calorimeter (ECAL)

- 24 m^3 of BGO crystal bars (1.5×1.5×40 cm^3), arranged in the x-y direction alternatively, in perpendicular to the beam, to achieve fine 3D granularity. 570,000 SiPM readout channels.
- Energy resolution from 2025 beam test: $1.95\%/\sqrt{E} \oplus 0.61\%$





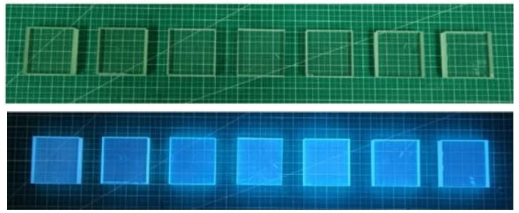
Hadron Calorimeter (HCAL)

- **85 m^3 glass scintillator** tiles (4×4×1 cm^3) interspersed with steel plates, 6λ_I, 5.3 million SiPM readout channels, good 3D granularity
- High sampling ratio (~30%) and good energy resolution ~$30\%/\sqrt{E}$

Key technologies

- **BGO crystal**: expensive, developing BSO as an alternative
- **Glass scintillator**: high-density and large-yield, technically challenging
- **SiPM+ASIC**: different requirements from ECAL and HCAL

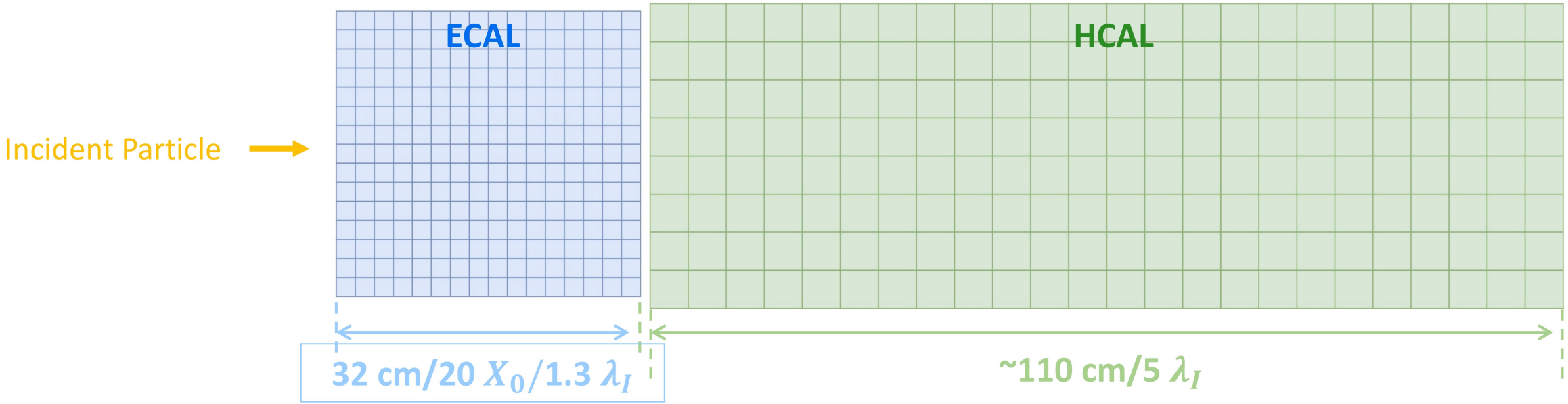
→ Junfeng Chen's talk on BSO crystal, Jack Rolph's talk on crystal ECAL



Glass scintillator under natural and ultraviolet light

New: full-absorption glass calorimetry

- GFO glass with Ce^{3+} doping achieves high density (~6 g/cm3) & high light yield (~2000 ph/MeV)
- New design: a high-granularity, full-absorption glass ECAL + higher HCAL sample ratio (70%)

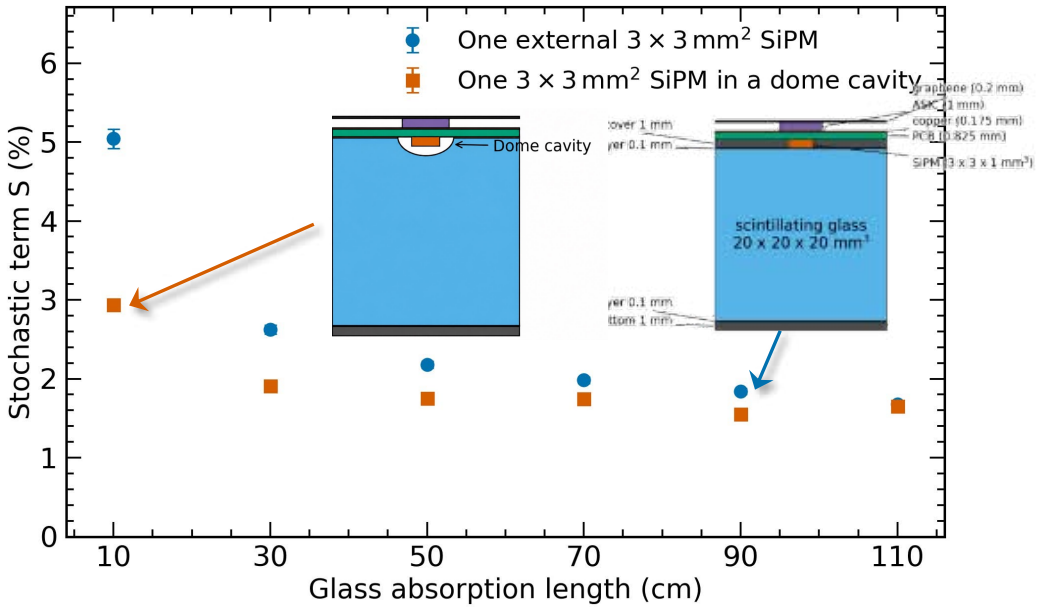


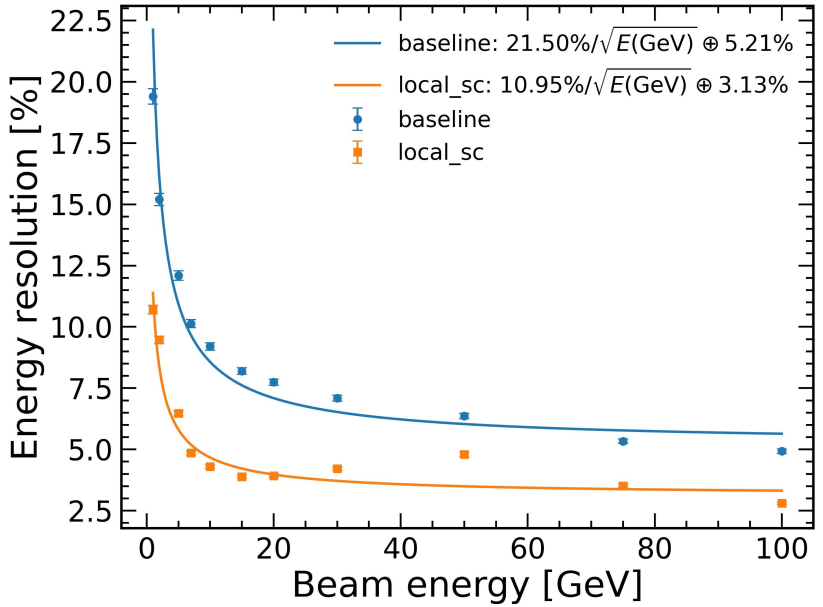
Typical glass cell:	2 × 2 × 2 cm^3	4 × 4 cm^2, 3~4 cm thick
Resolution target:	< $3\%/\sqrt{E} \oplus 1\%$	~ $15\%/\sqrt{E} \oplus 4\%$

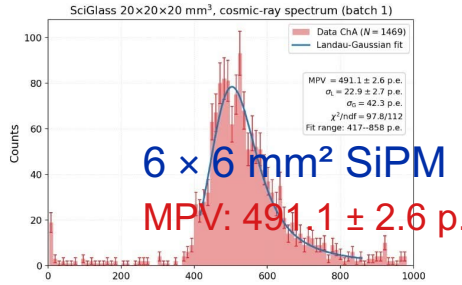
→ Weizheng Song's talk
→ Yang Zhang's talk on reconstruction

New: full-absorption glass calorimetry

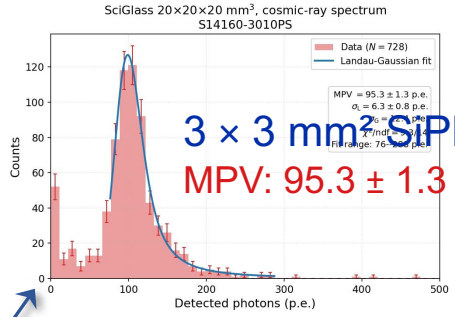
- Readout: 3 x 3 mm² SiPM inside a dome-shaped cavity
  - ECAL (AL = 30 cm): 1.91%/√E ⊕ 0.54%
  - Hadronic energy resolution (with software compensation): 10.95%/√E ⊕ 3.13%
- First batch of samples tested with cosmic muons



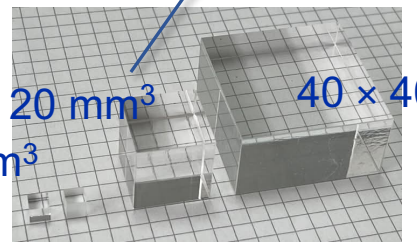




6 × 6 mm² SiPM
MPV: 491.1 ± 2.6 p.e.



3 × 3 mm² SiPM
MPV: 95.3 ± 1.3 p.e.



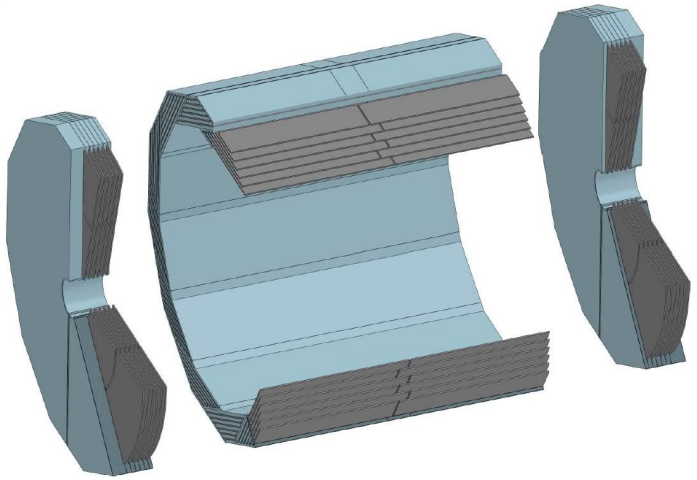
20 × 20 × 20 mm³
5 × 5 × 5 mm³

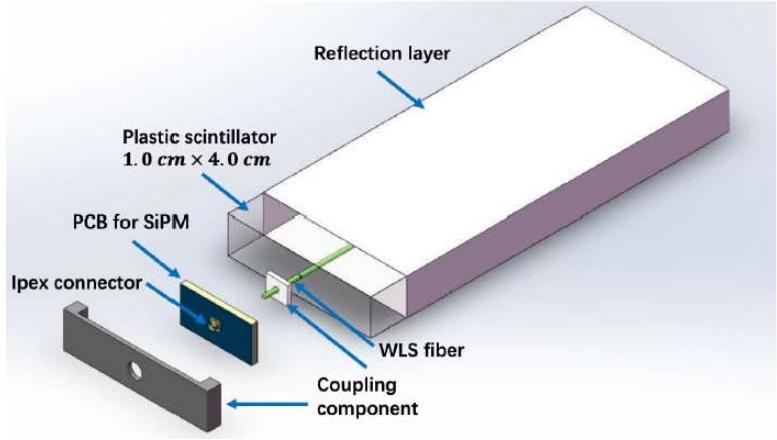
40 × 40 × 40 mm³

→ Weizheng Song's talk
→ Yang Zhang's talk on reconstruction

Muon

- 6 layers of plastic scintillator strips embedded in the iron Yoke
  - Solid angle coverage: > 98% × 4π
  - μ identification efficiency: > 95%
  - $\pi \rightarrow \mu$ fake rate: <1%
  - Spatial resolution: ~1 cm
  - Time resolution: ~1 ns
  - Rate capability: 50 Hz/cm2





A 5-m plastic scintillator strip →

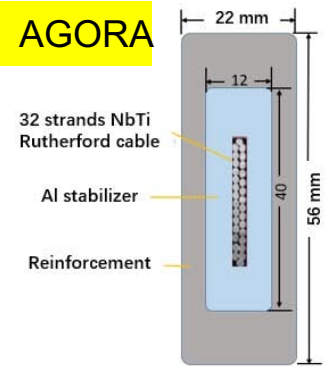


→ R&D at JINR on scintillator (Aleksandr Simonenko) and WLS fibre (Vladimir Baranov)

Magnet

- High-field superconducting solenoid
  - Current conductor design needs improvement
  - Production line in IHEP for LTS & HTS conductors

AGORA



LTS conductor

Full-size Box type Superconducting Cable

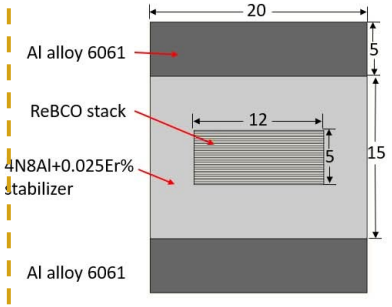
2026.09.10



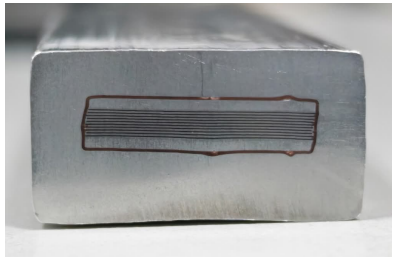


Start End

1.The cable co-extrusion process proceeded smoothly, the speed was 0.50–0.55 m/min. 4 meters cable was produced.
2.Surface quality was good, demonstrating the capability for long-length production.
2026.09.10



HTS conductor



17.5*9 mm²

30 m cable



12 mm wide HTS tape, small prototype cable

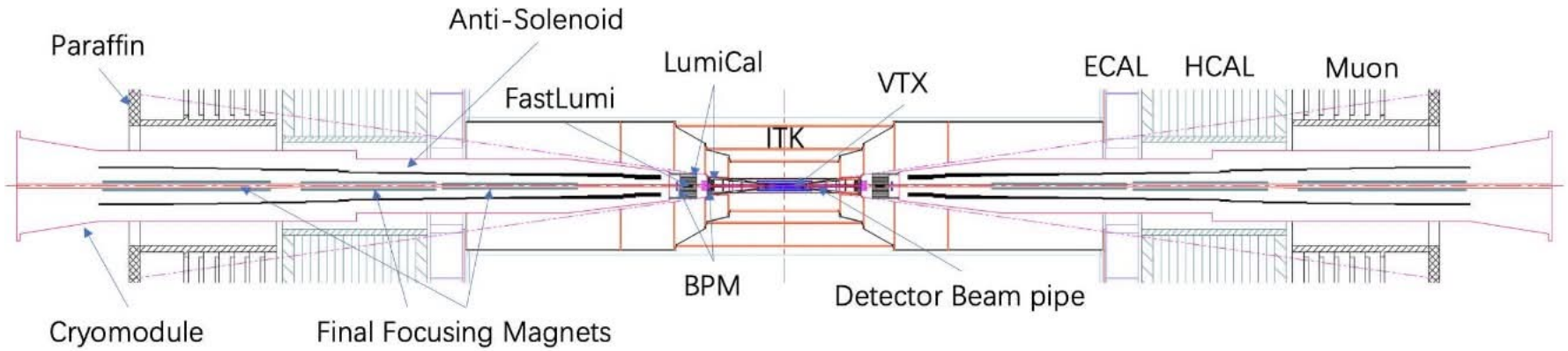
→ Feipeng Ning's talk

	AGORA
Central field	3T
Warm Bore Diameter(m)	7.07
Length(m)	9.05
Characteristic	Calorimeter inside the magnet

Coil parameters:

Central magnetic field	3 T
Inner diameter	7300 mm
Operating current	17 kA
Cable length	33 km
Inductance	11 H
Stored Energy	1.54 GJ

MDI



- Interaction region is strongly constrained by the machine → to be adapted to FCC
- FCC MDI accelerator components further away from the IP

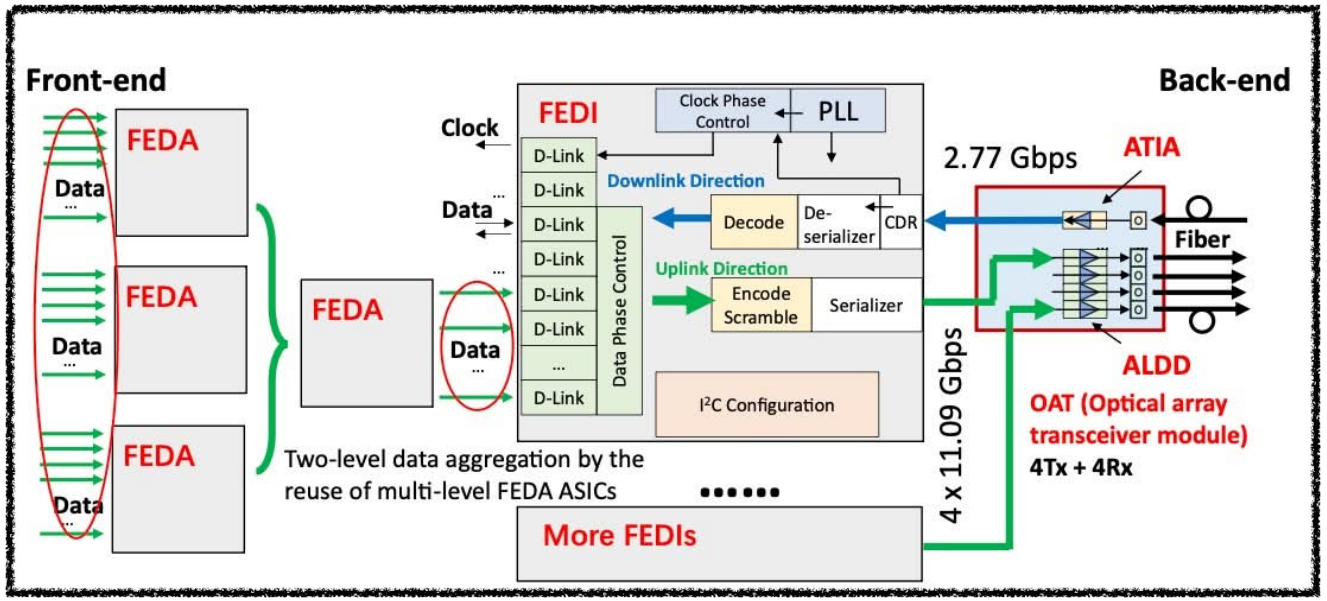
Parameter	FCC-ee	CEPC
Full crossing angle	30 mrad	33 mrad
Half crossing angle	15 mrad	16.5 mrad
Boundary / stay-clear angle	100 mrad	8.1° ≈ 141 mrad
Radial space at s = 1.5 m	150 mm	212 mm
Radial space at s = 2.0 m	200 mm	283 mm
Ratio	1.00	1.41

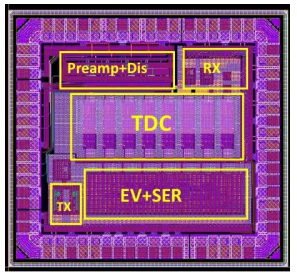
Parameter	FCC-ee	CEPC
L*	2.2 m	1.9 m
MDI region extent	~20 m	±7 m
Screening solenoid/anti-solenoid start	≥ 1.55 m (at 100 mrad)	~1.13 m
Cryostat start	~1.4 m from IP	~1.05 m from IP
Beam pipe separation	Remote vacuum connection, two independent beam pipes	Double-ring, shared interaction region

→ Haoyu Shi's talk on MDI,
→ Suen Hou's talk on LumiCal, Xiyuan Zhang's talk on Fast Lumi using SiC

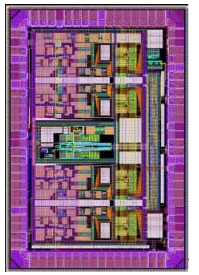
Common electronics & data acquisition

- Customized on-det electronics, common data interface and backend electronics
  - CEPC main clock 43.33 MHz, all designed to be compatible with 40 MHz
- Full data transmission as the primary strategy for electronics-trigger-DAQ
- Data storage rate 0.4/6.7 Gb/s for Higgs(50 MW)/Z(12.1 MW)

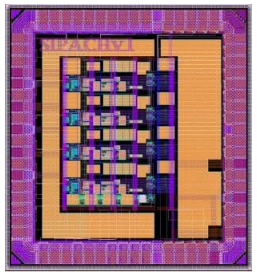




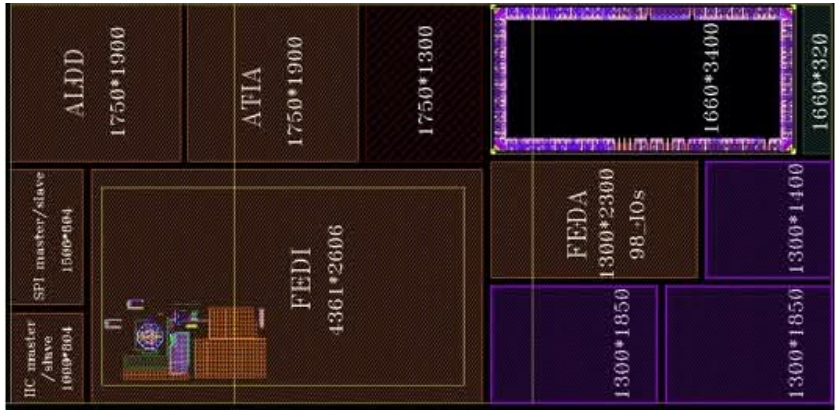
LATRIC1



SIPAC_E



SIPAC_H



ASICs for the data interface

→ Jingbo Ye's talk

Mechanics, cooling, integration

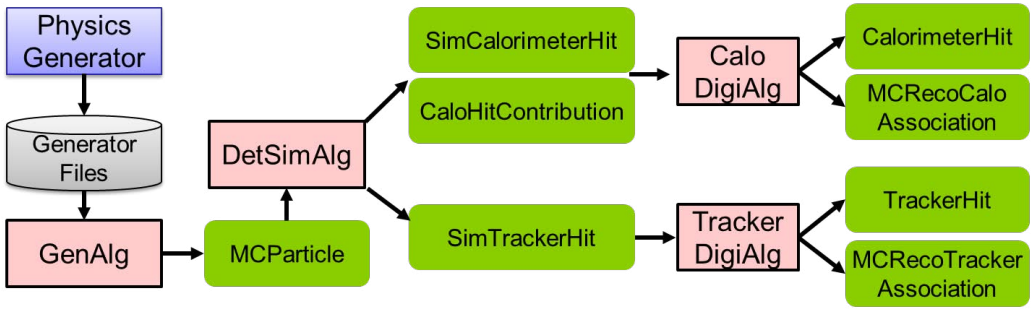
FCC-ee	AGORA
Differs from CEPC in **MDI interface**, geometric constraints, **beam parameters** and magnetic **field scheme**	■ Re-define **global mechanical envelope** and allocate dimensions among sub-detectors ■ Re-design **sub-detector connections and support** ■ For some sub-detectors — notably the **central beam pipe and VTX — design must be done jointly** across background, cooling and support, not as a simple dimensional rescale.
Differ from CEPC in **civil-engineering constraints** •Cavern layout •Experimental-hall crane capacity •Maintenance access	■ AGORA **installation and assembly strategy** may contain infeasible steps in the FCC-ee hall (e.g. Pre-installation point→ collision point) ■ Must be re-evaluated against the new requirement: e.g. lifting method, Pre-installation point→ collision point

Meanwhile mechanical / cooling studies for sub-systems ongoing

→ Talks at MDI, mechanics & integration session

Software and computing

- CEPC software framework built on Key4hep and EDM4hep
  - Simulation chain (including background) established for TDR
  - Dedicated tools: tracking, CyberPFA, automated validate, RDAnalysis…
- Ongoing development
  - Key4hep stack upgrade, Gaussino-based simulation
  - VoDiT4CAL: DiT-based fast simulation for the crystal ECAL
- Integration into FCCWS



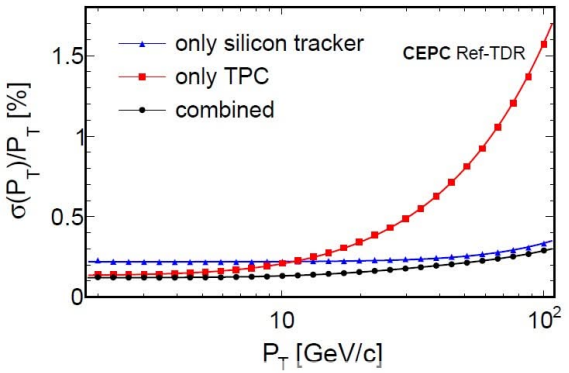
Repository	AGORA developments	Checks
FCC-config	Run configurations, simulation/reconstruction job options and full-chain examples	Reproducible processing
k4geo	DD4hep geometry, compact XML, plugins and detector tests	Materials, IDs and overlaps
k4RecTracker	Tracking and relevant digitization components; EDM4hep interfaces	Collection interfaces and tracking quality

- Calorimeter reconstruction
  - Extend k4RecCalorimeter when needed; keep detector-specific configurations separate
- CEPC-specific code
  - Use a small AGORA repository for code not covered by existing shared packages

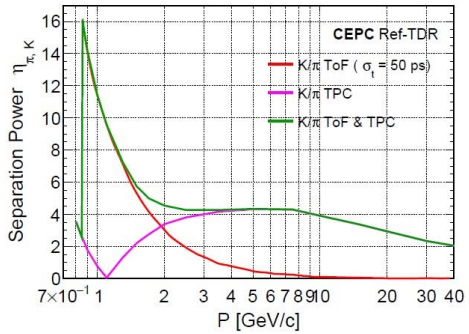
→ Tao Lin's talk

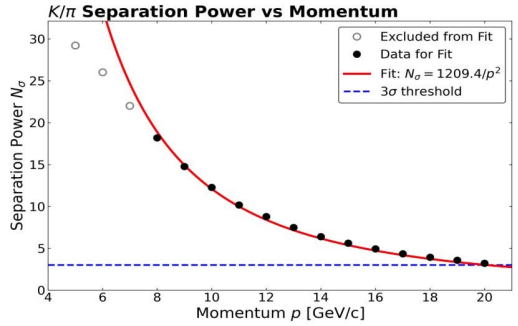
Physics performance

Tracking efficiency	Tracking σ_{pT}	Vertexing $\sigma_{x,y,z}$	π-k separation	EM resolution	BMR
>99.7% (for p>1 GeV)	**~0.1%** for majority	**< 3.5 μm**	**3σ** (1-20 GeV)	**2%/√E ⊕ 0.5%**	**3.87%** (H->gg)

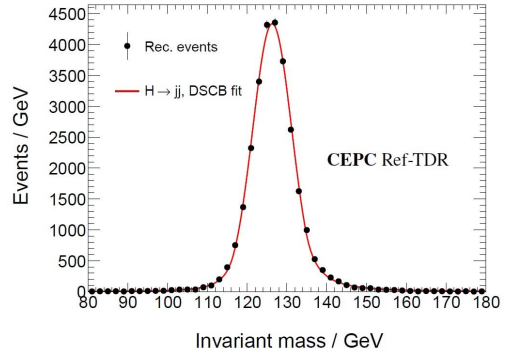


P_T resolution at 85°

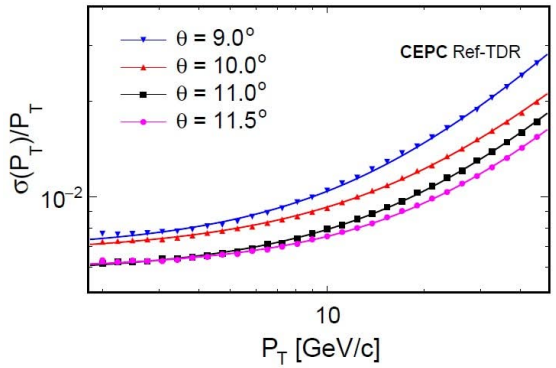




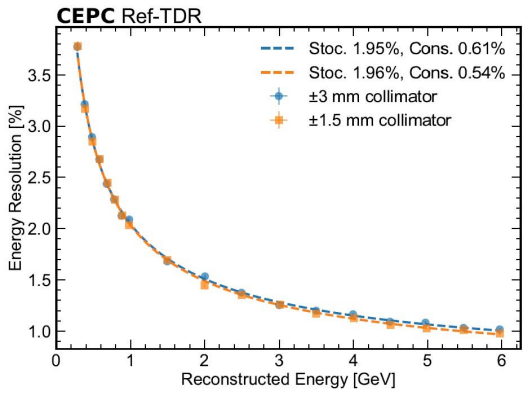
K/π separation power



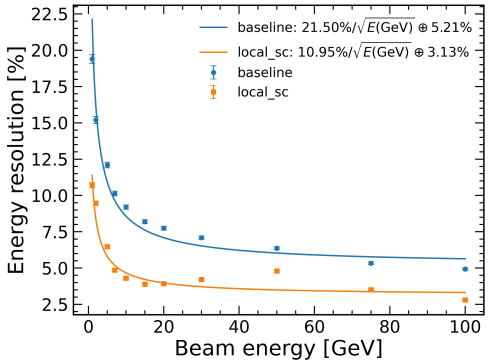
H→jj resolution



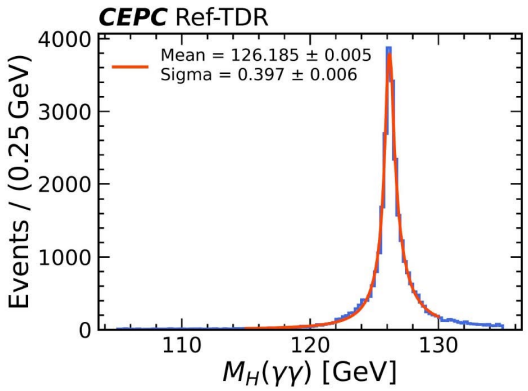
P_T resolution at different angles



EM resolution from beam test



Simulated Hadron resolution



H→γγ resolution

Summary

- AGORA detector concept evolved from CEPC Reference detector, which published its TDR recent, reaching maturity
- Novel technology being studied for better performance
  - Glass scintillator for all-absorption calorimeters
  - Advanced silicon technologies pursued: stitching, 55nm MAPS, AC-LGAD,…
  - RICH proposed for better forward PID
- Adaptation to FCC-ee still being estimated
  - MDI, mechanics and integration
  - Change of inner radius & design for higher data rate at VTX
  - Mitigation strategy for gas detector at high-lumi Z operation
  - …
- Your interest / collaboration / participation are highly welcome!