The AGORA detector

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On behalf of the AGORA team

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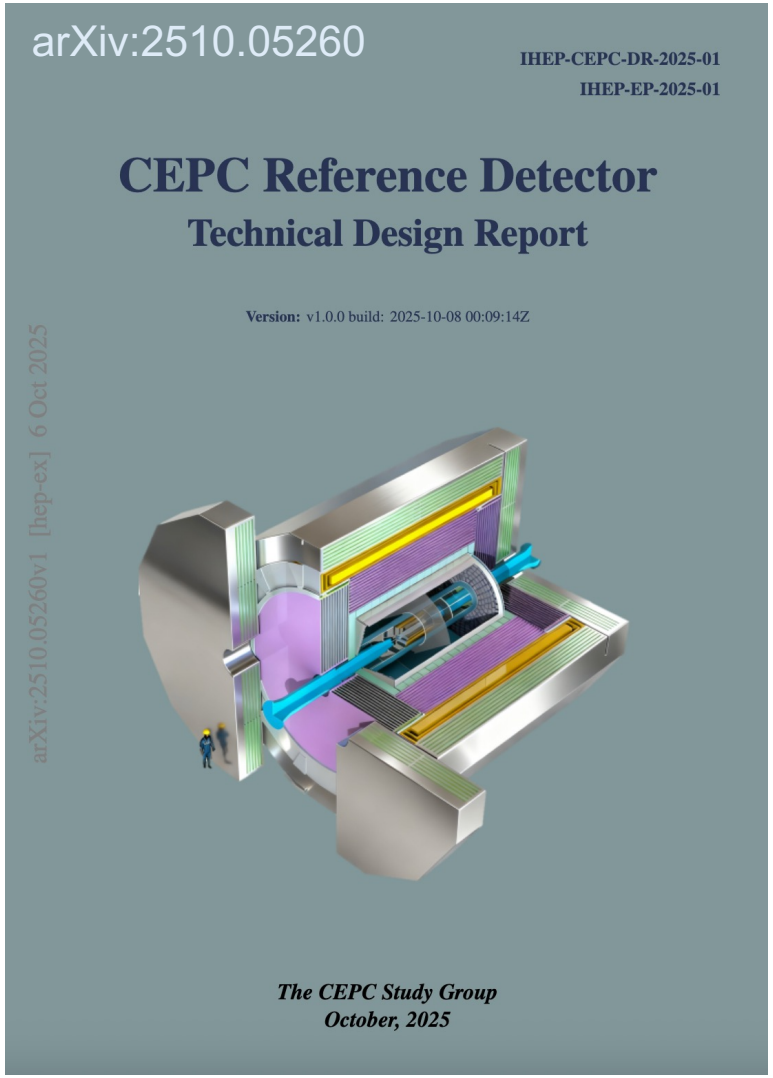
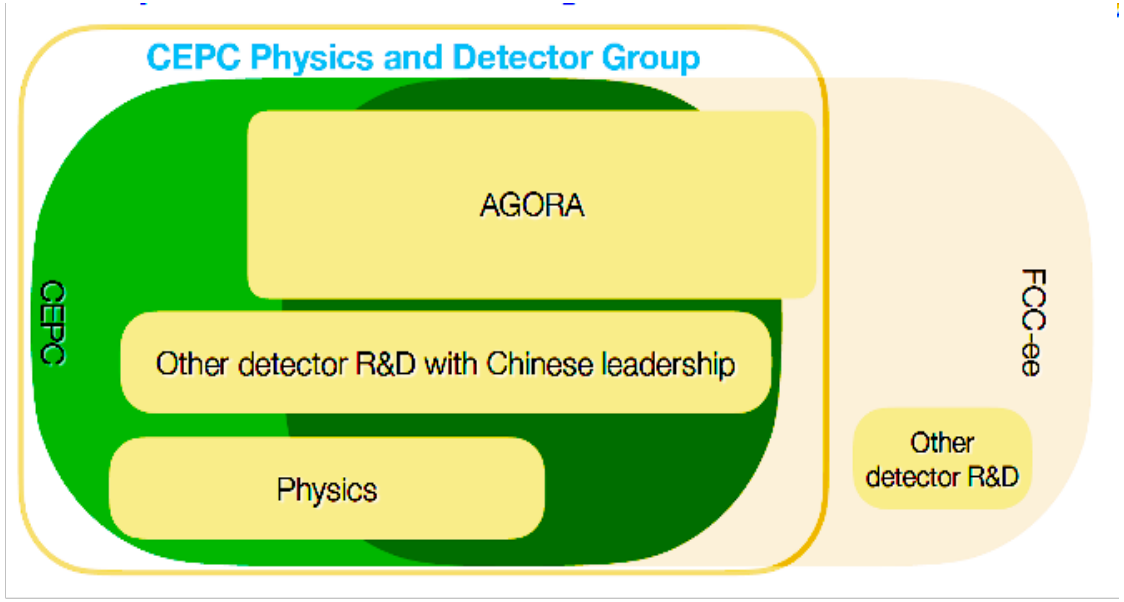
AGORA – what it is

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

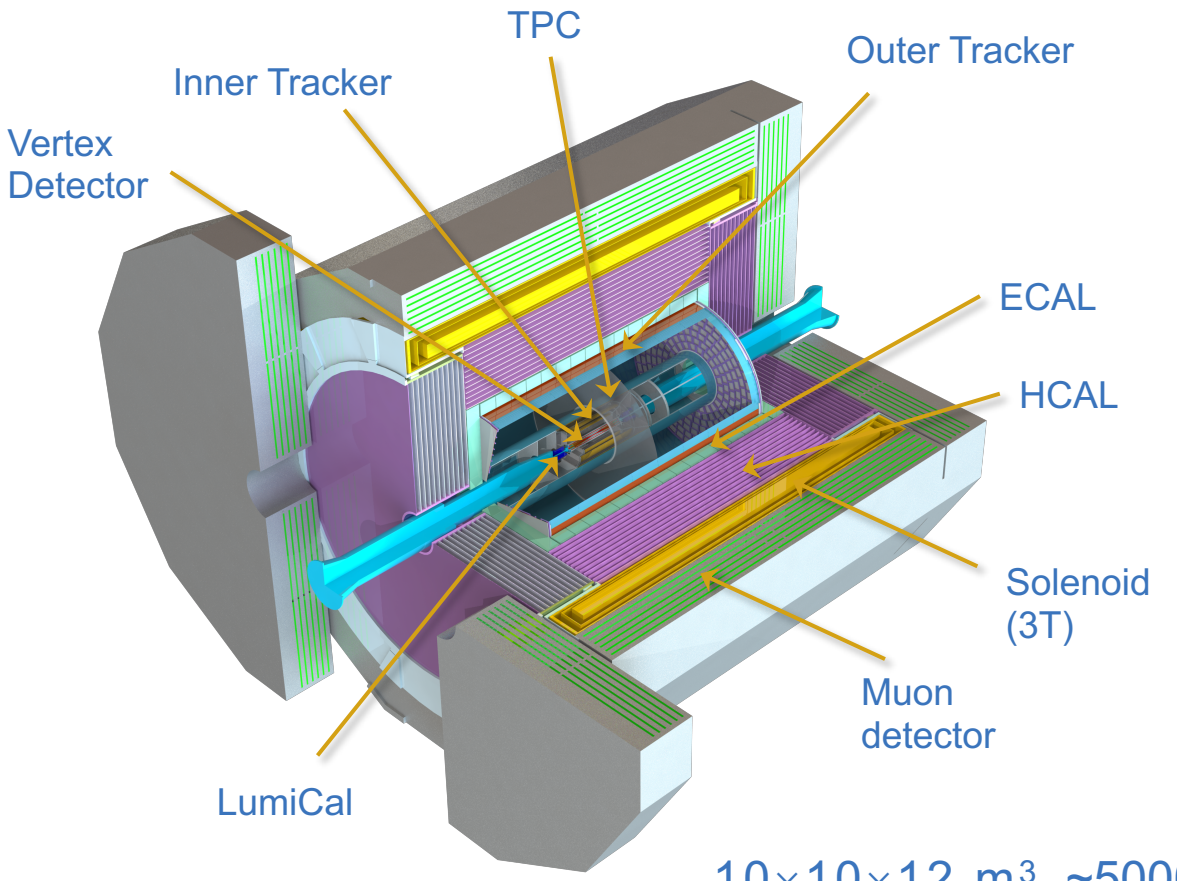
Motivation

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

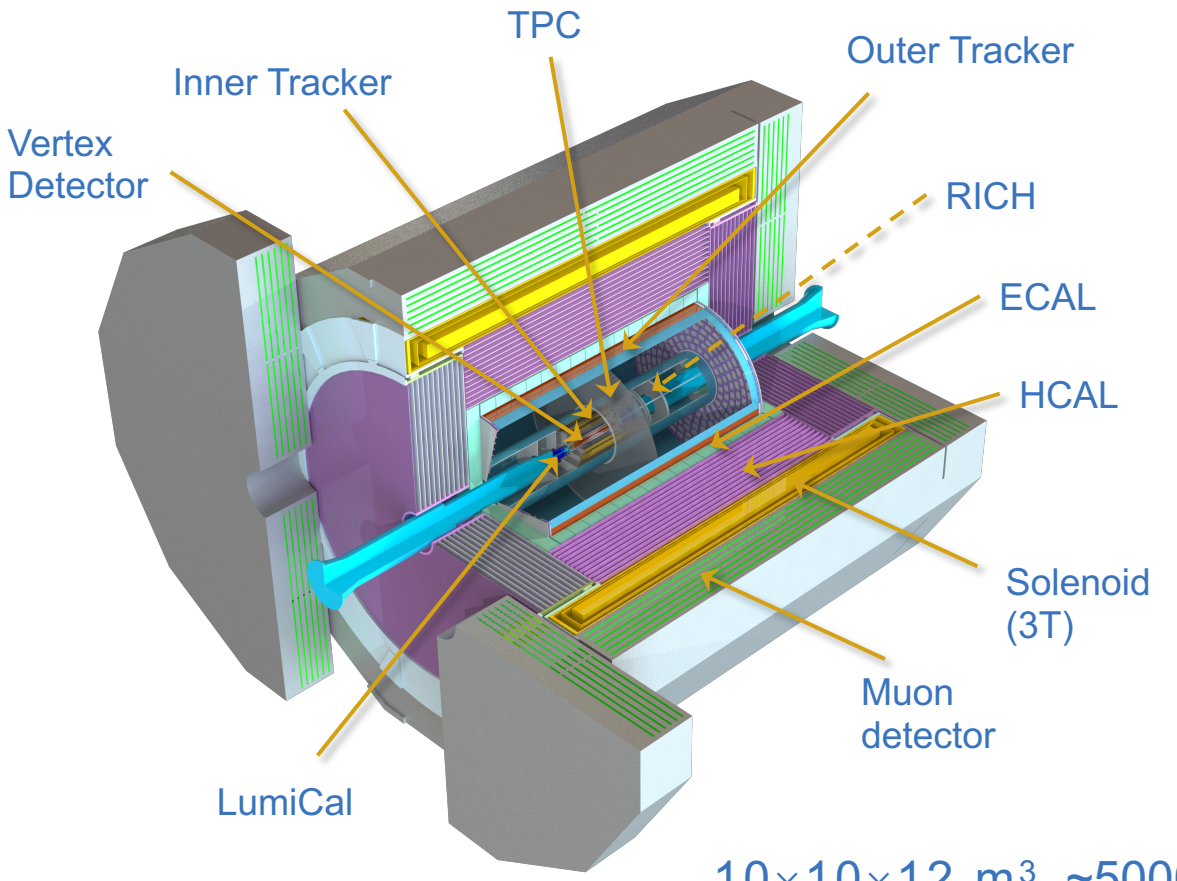
Sub-system	Technology
VTX	MAPS + stitching
ITK	HV-MAPS in 55nm
TPC	0.5 x 0.5 mm^2 readout, dN/dx PID
OTK	AC-LGAD with 50ps timing
ECAL	Crystal bar $1.3\%/\sqrt{E} \oplus 0.7\%$
HCAL	Glass-steel $30\%/\sqrt{E} \oplus 6.5\%$
Solenoid	SC solenoid 3T, 2T at Z-pole
Muon	Plastic Scintillator + SiPM
LumiCal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



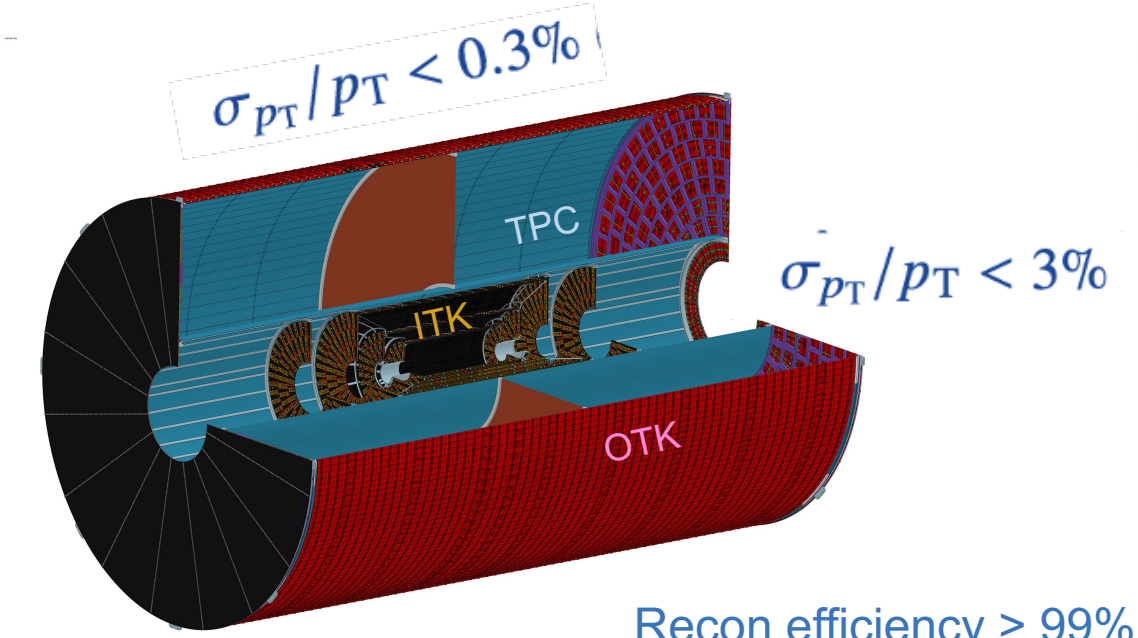
$10 \times 10 \times 12$ m^3, ~5000 ton

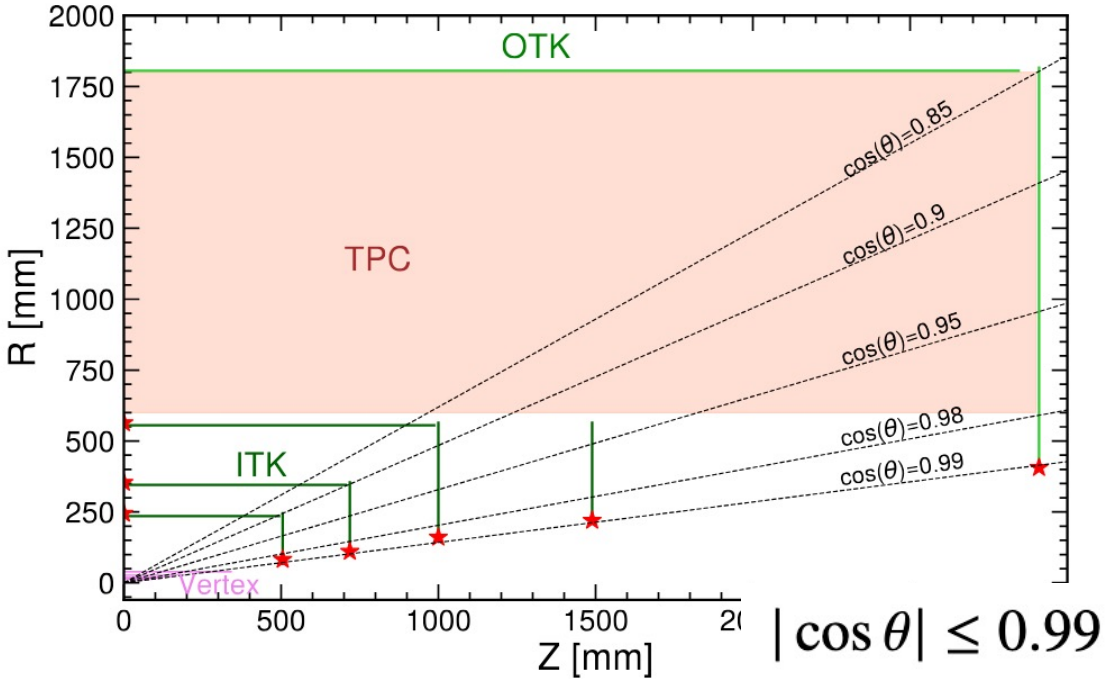
Tracking system & hadron PID

- 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



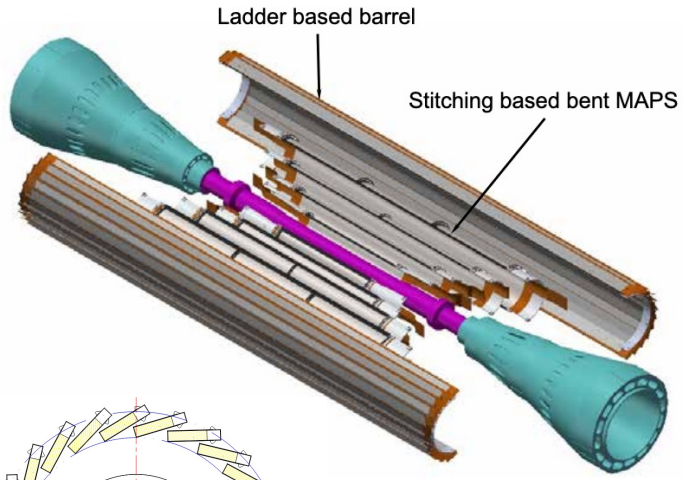


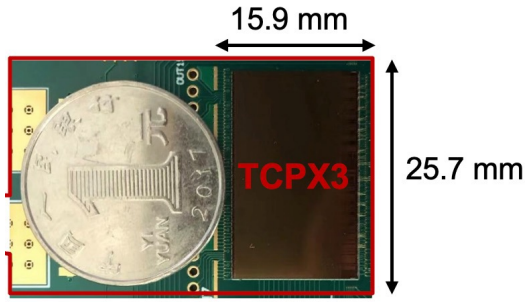
Recon efficiency > 99%

Vertex detector

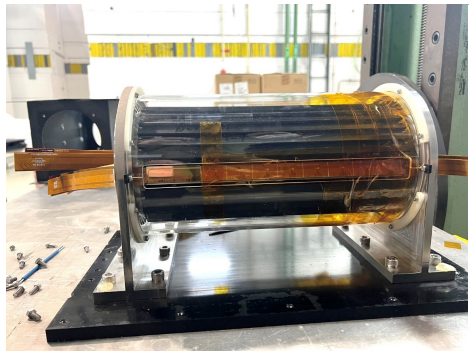
Spatial resolution	**~5 μm / layer**
Material budget	**~0.8% X_0 / layer**
Power consumption	**< 40 mW/cm² (air cooled)**
Angular coverage	**|cosθ| < 0.99**

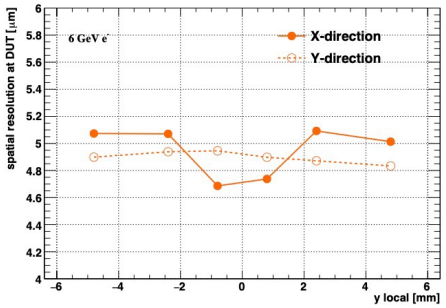
- 4 layers bent & stitched MAPS sensor + 2 double-sided ladders





TaichuPix-3 chip vs. coin





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

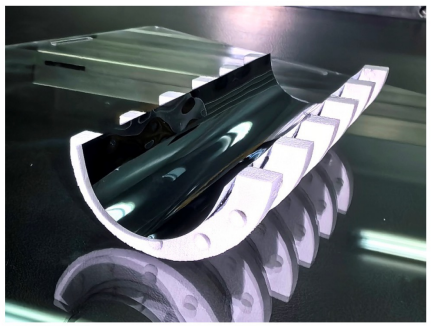
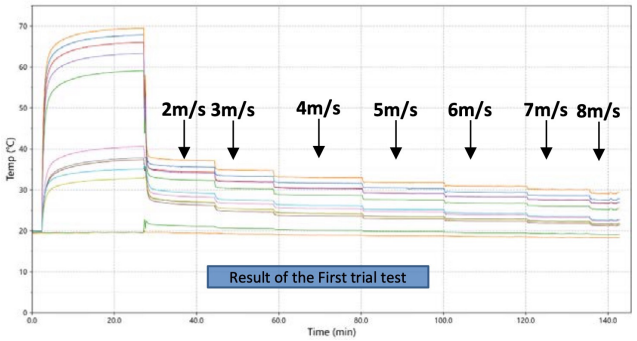


Figure 4.26: 12 mm bending radius.





→ Zhijun Liang's talk

Sensor bending demo'd for 12mm radius

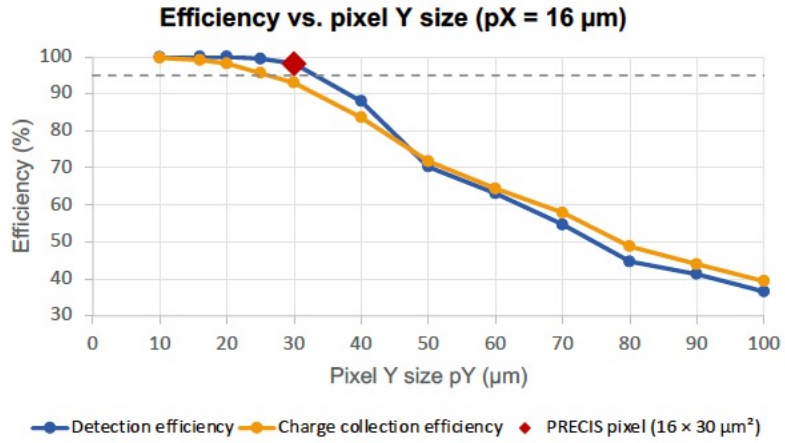
Thermal mockup built & tested for air-cooling up to 8 m/s → Jinyu Fu's talk

Vertex detector

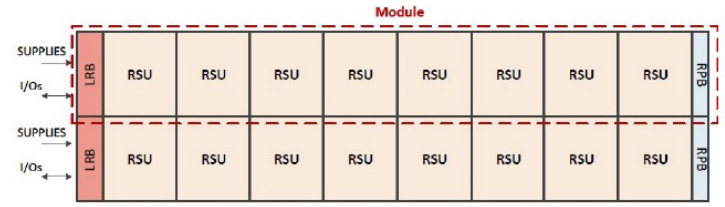
- 4 layers bent & stitched MAPS sensor
  + 2 double-sided ladders
- Spec changes / R&D forseen for FCC-ee:

	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

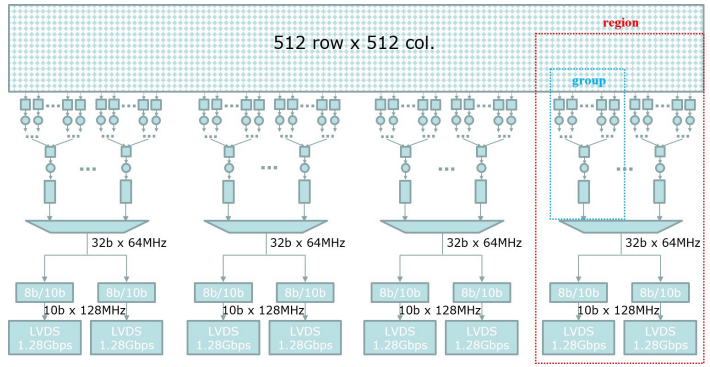
TCAD simulation on sensor size



- 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



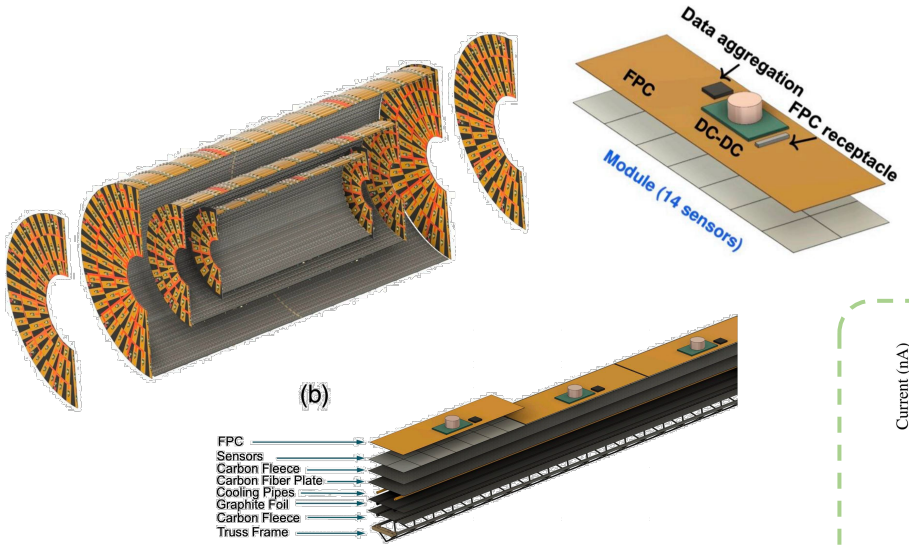
PRECIS design ongoing to tackle 200 MH/cm^2 rate and stitching

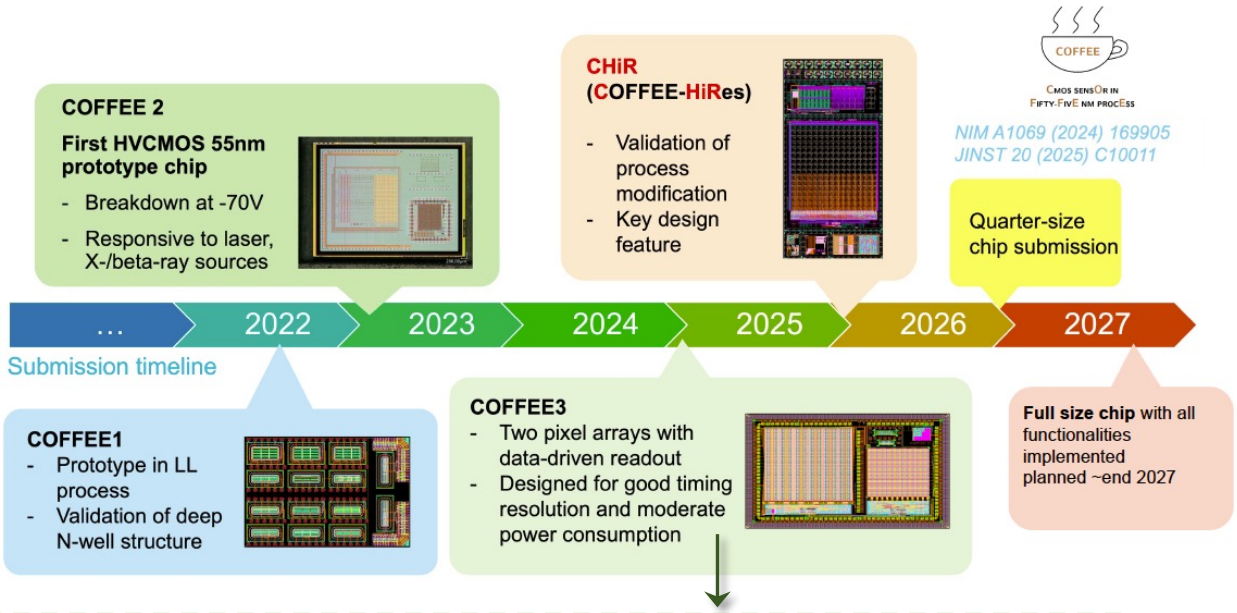
→ Zhijun Liang's talk

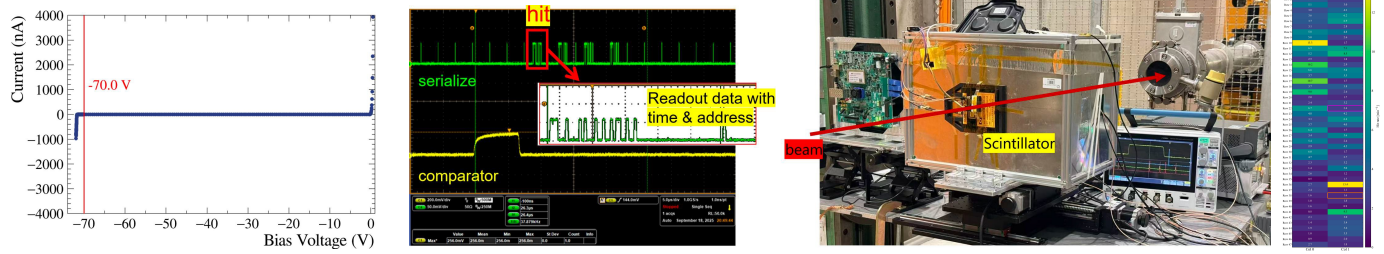
HV-CMOS based Inner Tracker

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





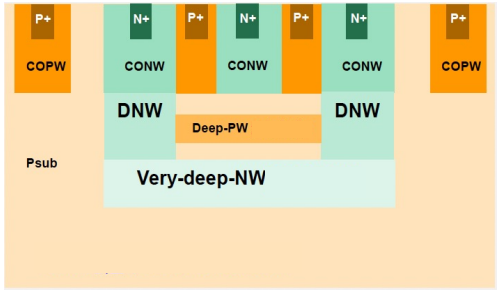


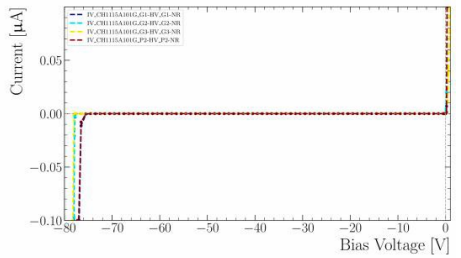
COFFEE3 pixel matrix validated in lab & CERN beam,
Low resistivity wafer & triple-well process limits performance

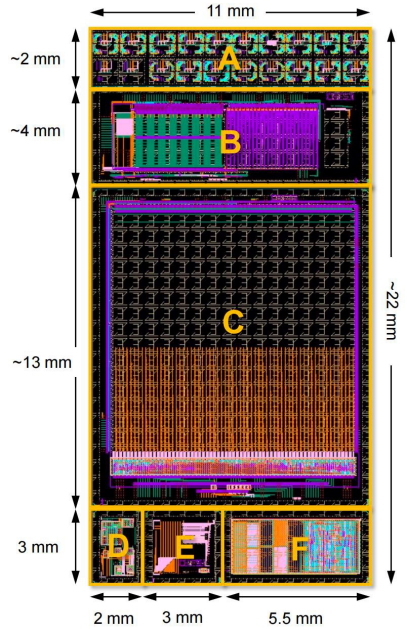
→ Zijun Xu's talk

HV-CMOS based Inner Tracker

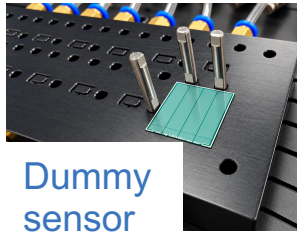
- Future R&D on improved process
  - CHiR1 submitted to validate isolation DPW & high resistivity wafer
- Prototyping efforts proceeds in parallel
- New ideas explored to reduce material:
  - Serial powering
  - Wireless transmission



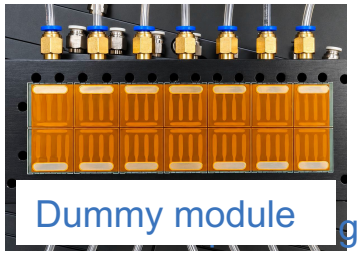




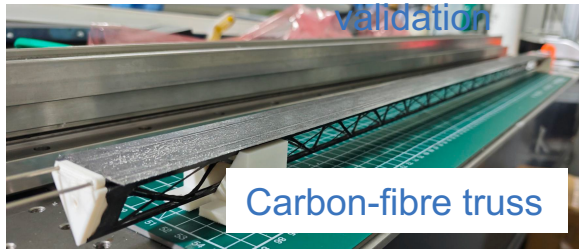
CHiR1 on '5-well' process



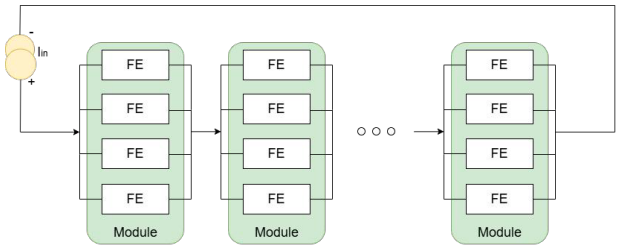
Dummy sensor

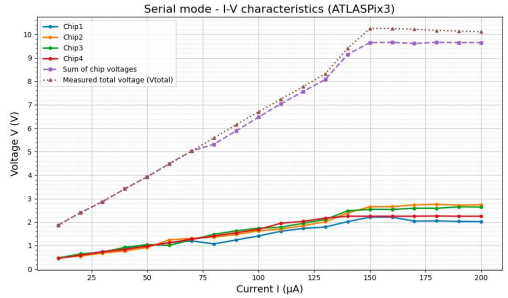


Dummy module



Carbon-fibre truss



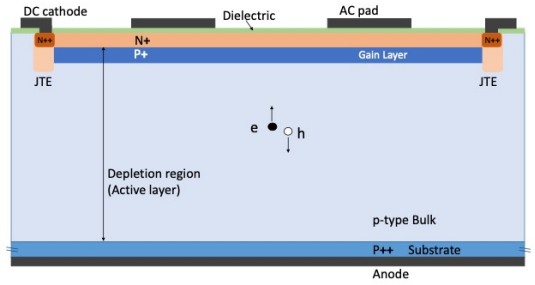


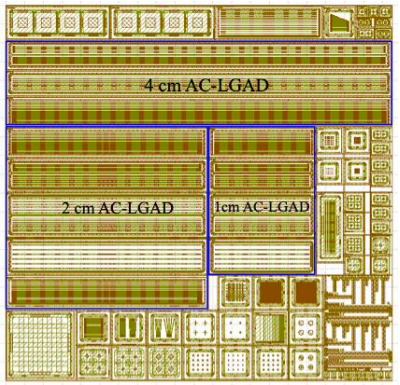
→ Zijun Xu's talk

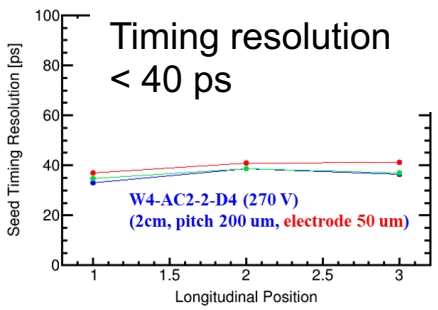
Outer Tracker & timing layer

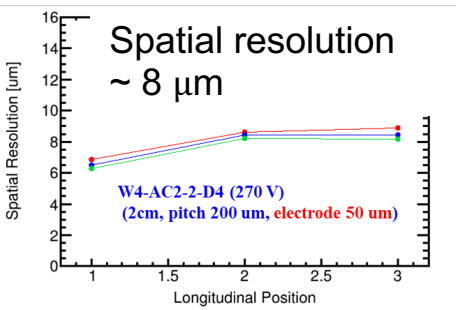
Area	~ 85 m^2
Time resolution	~ 50 ps
Spatial resolution	~ 10 μm

- AC-LGAD sensor based
  - Building on HGTD experience

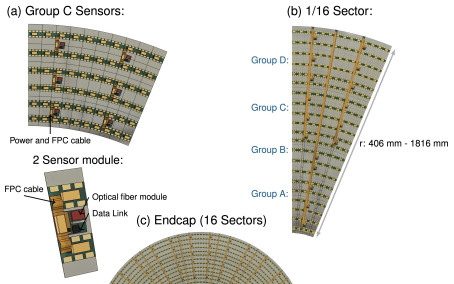


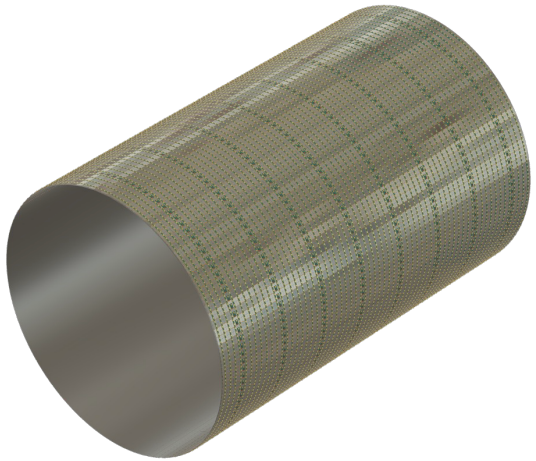


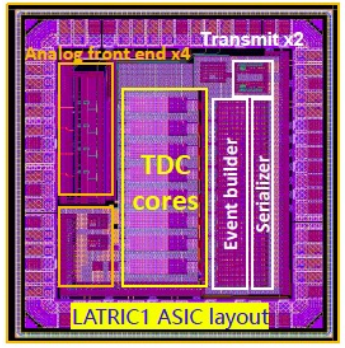


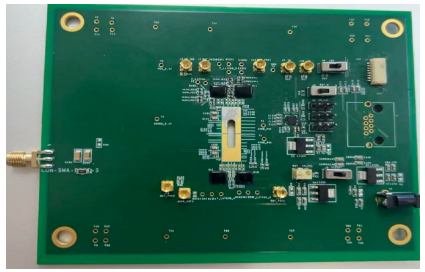


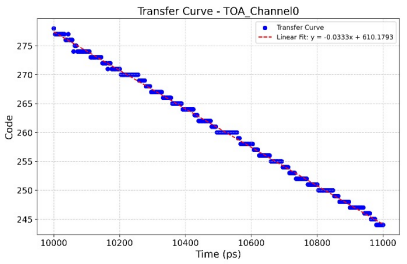
AC-LGAD sensor up to 4cm tests show good performance







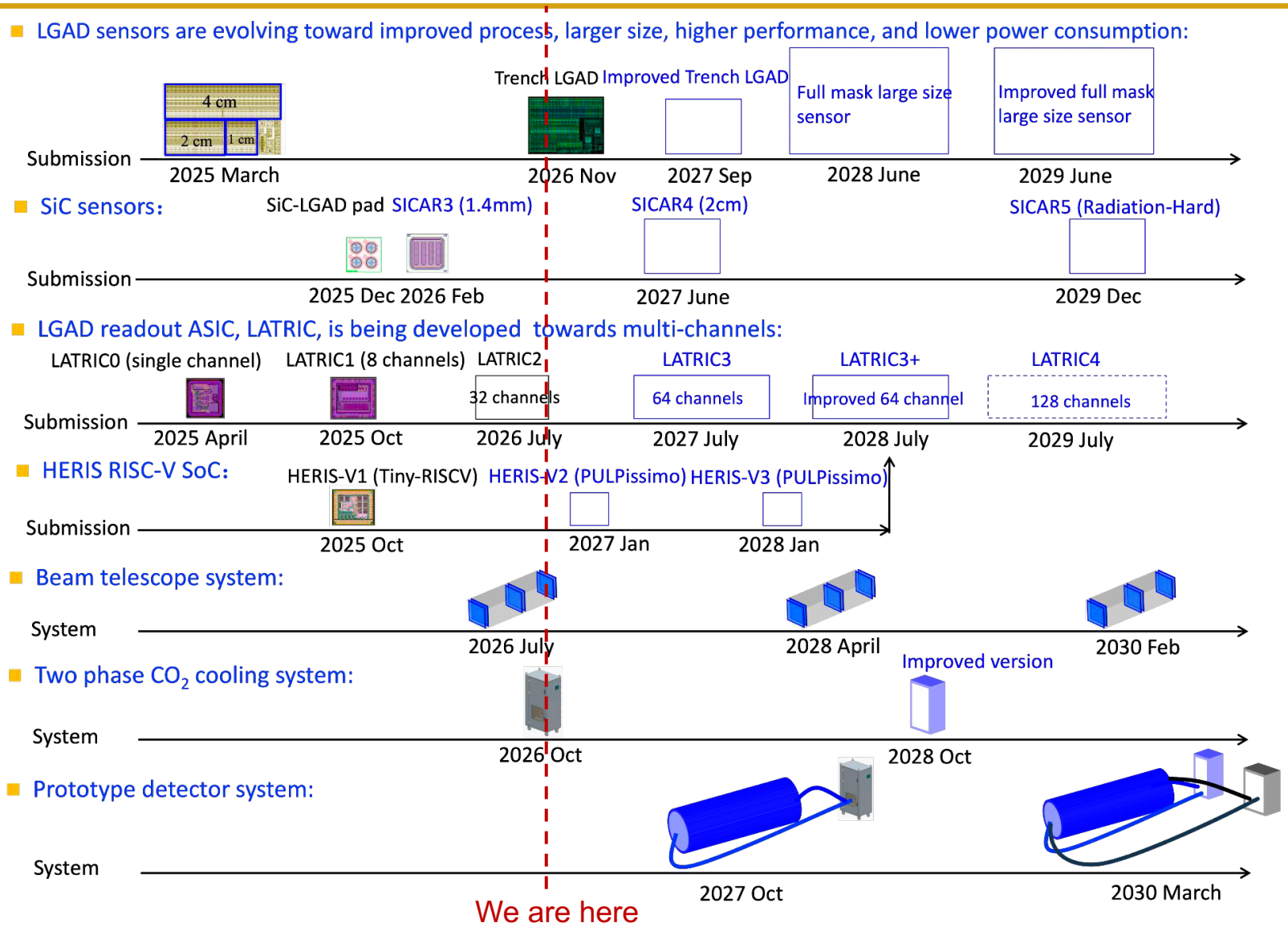




Readout ASIC LATRIC1 with 8-channel: LSB ~ 30ps

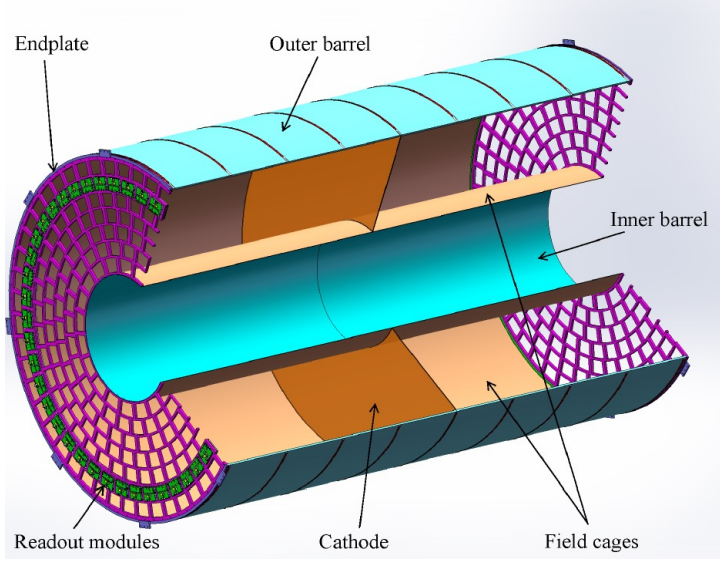
→ Jiajian Toeh and Mei Zhao's talks

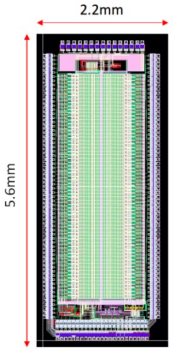
Outer Tracker & timing layer



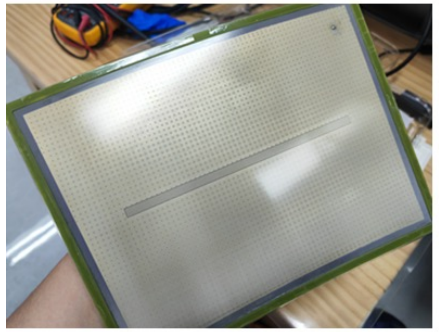
Time Projection Chamber

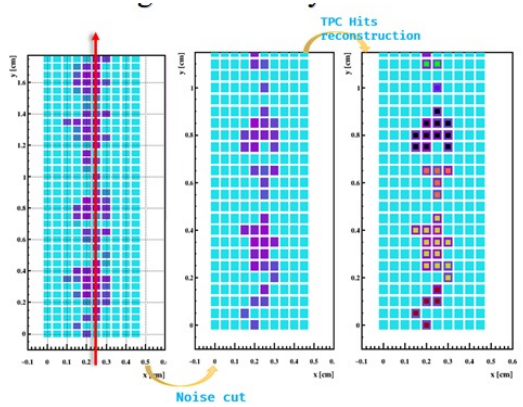
- Aiming at good spatial resolution ($\sigma \sim 100\ \mu m$) and PID using novel dN/dx method
  - Length: 5.8 m, radius 0.6~1.8 m
  - Micromegas detector with 500 x 500 μm^2 high-granularity readout
  - Space charge distortion can be treated for Higgs and low-lumi Z operation
- Drift Chamber is studied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

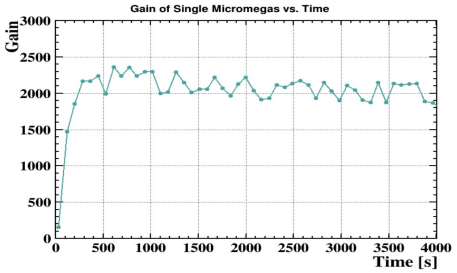










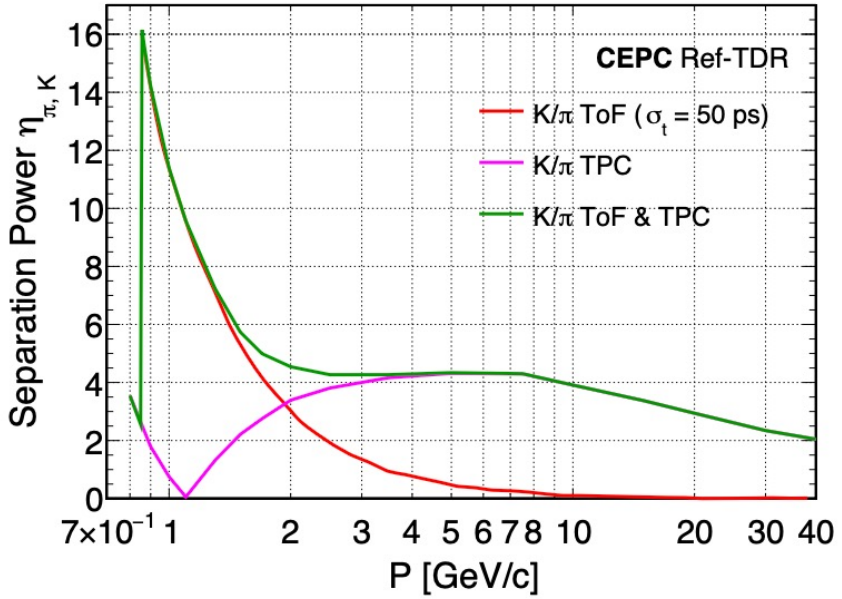


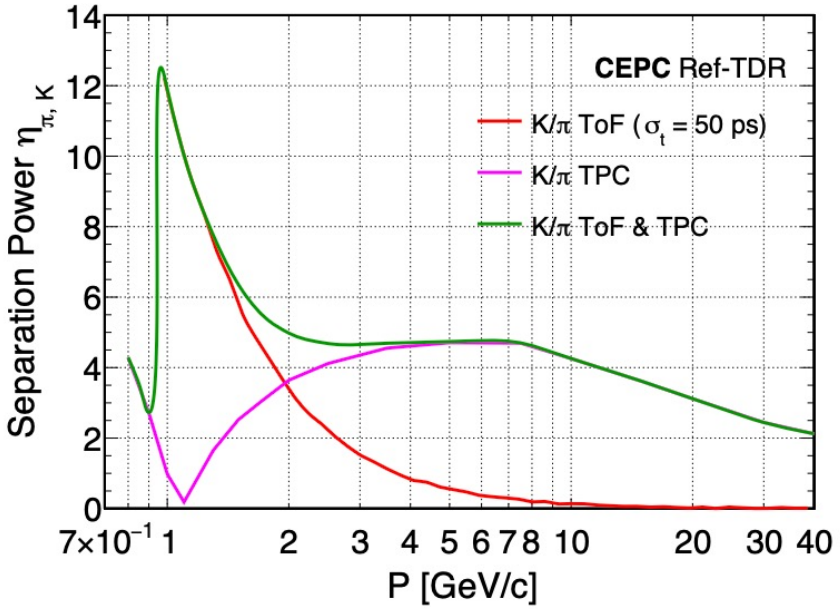
DC:

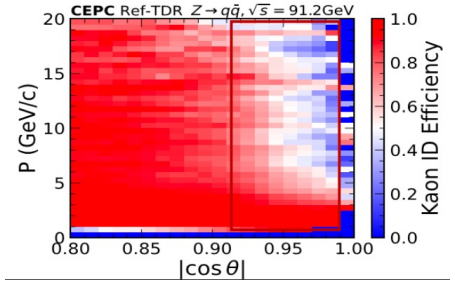
→ Huirong Qi's talk on TPC
→ Jianbo Zheng's talk on BIB challenge
→ Guang Zhao's talk on dN/dx method
→ Hongbin Liu's talk on DC readout

PID performance

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





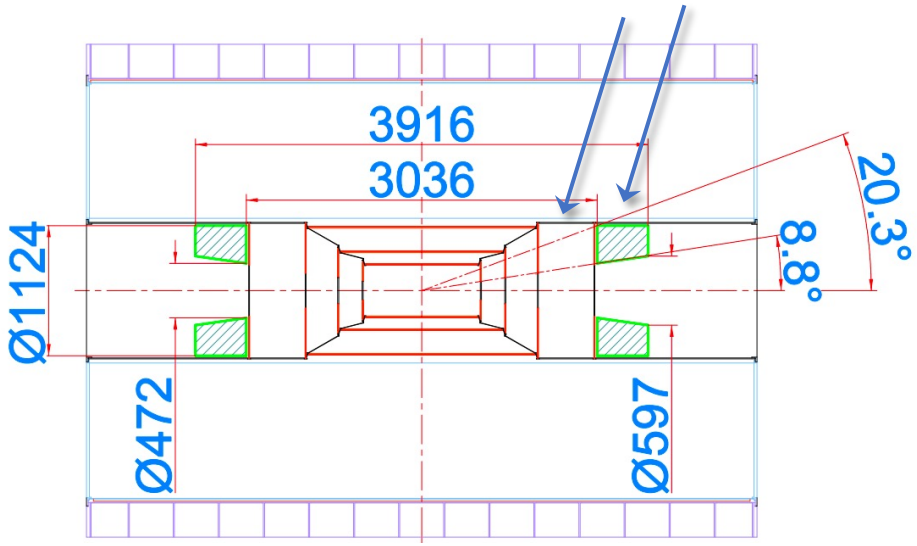


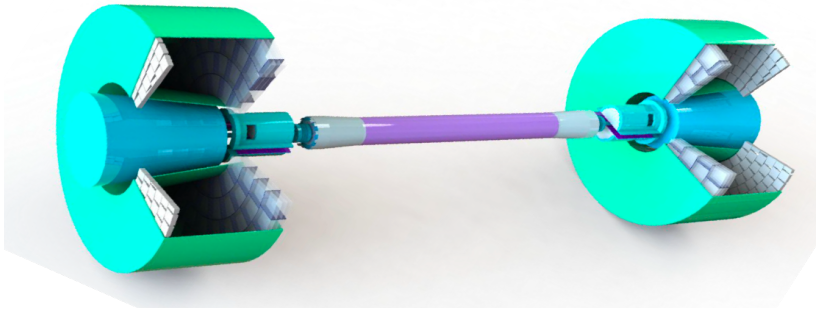
What about the forward region?

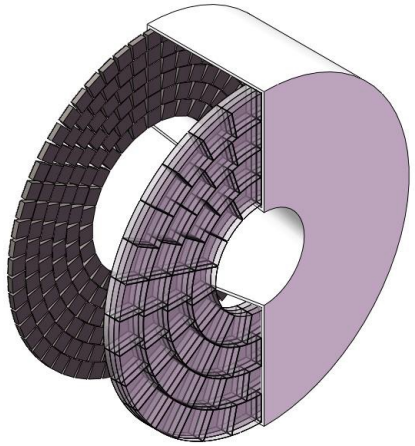
New development: RICH

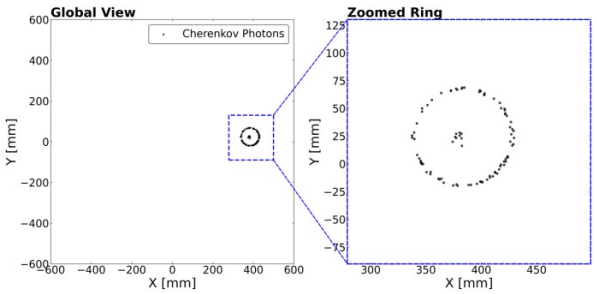
- Ring Imaging Cherenkov Detector using Aerogel + SiPM to promote forward PID
  - Radiator: ~0.9 m^2, 90 aerogel tiles in 4 layers, each tile ~10 x 10 cm^2
  - Photon detector: ~0.8 m^2, 258 modules in 6 layers, each module ~ 5 x 5 cm^2

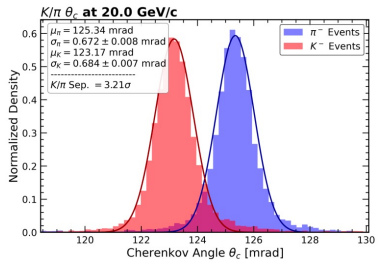
Exact location to be decided

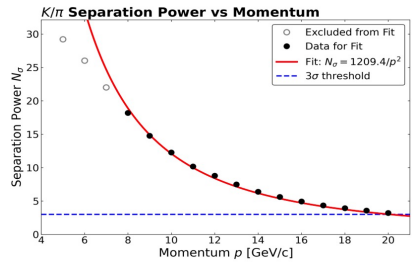












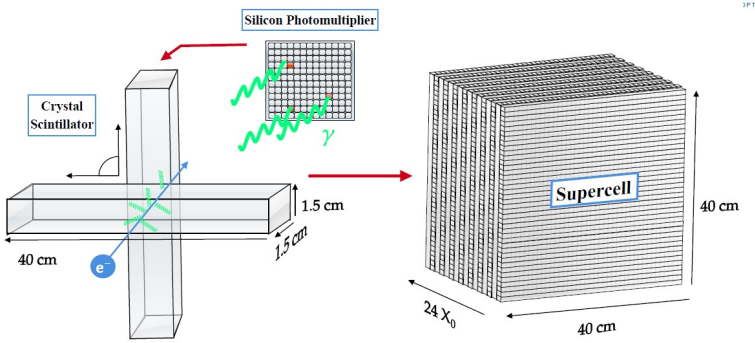
→ Zhonghua Qin's talk
→ Ziqiu Yang's talk on its impact on flavour physics
→ Alexander Barnyakov's talk on aerogel R&D

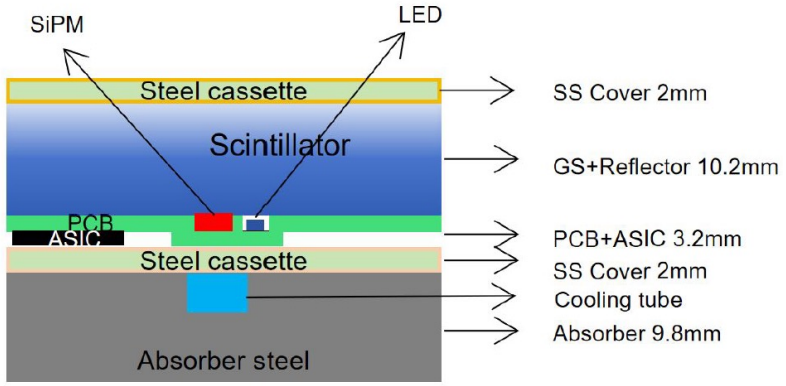
Simulation shows 3σ K/π separation up to 20 GeV

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: $1.95\%/\sqrt{E} \oplus 0.61\%$





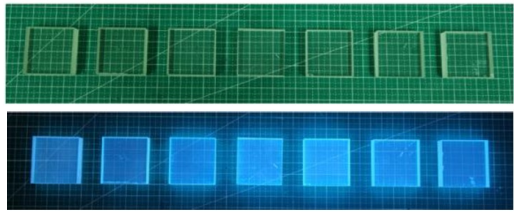
Hadron Calorimeter (HCAL)

- **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

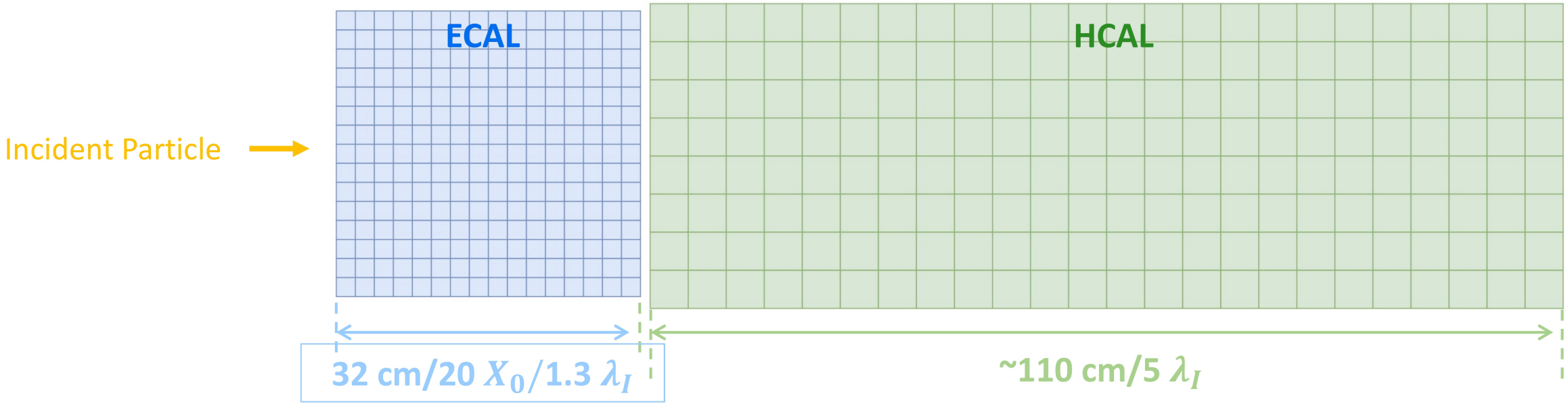
→ Junfeng Chen's talk on BSO crystal, Jack Rolph's talk on crystal ECAL



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%)

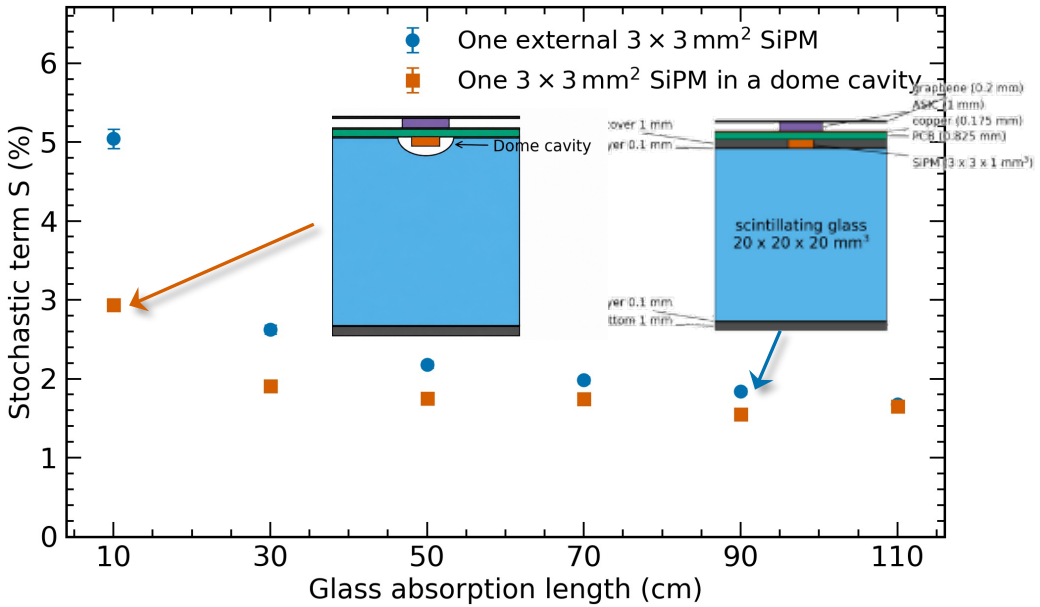


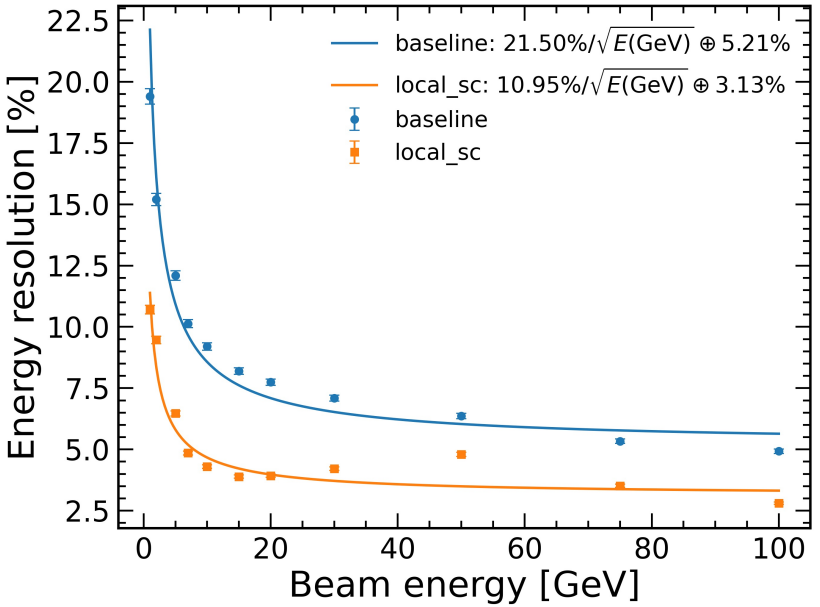
Typical glass cell:	2 × 2 × 2 cm^3	4 × 4 cm^2, 3~4 cm thick
Resolution target:	< $3\%/\sqrt{E} \oplus 1\%$	~ $15\%/\sqrt{E} \oplus 4\%$

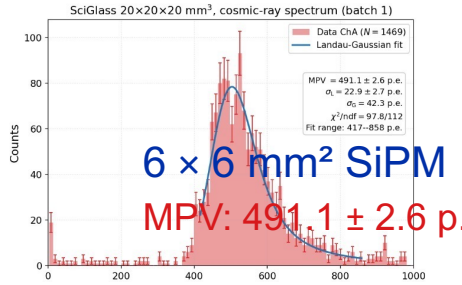
→ Weizheng Song's talk
→ Yang Zhang's talk on reconstruction

New: full-absorption glass calorimetry

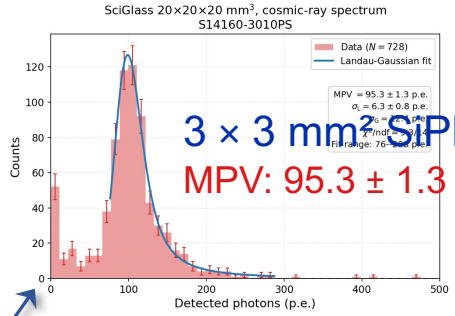
- Readout: 3 x 3 mm² SiPM inside a dome-shaped cavity
  - ECAL (AL = 30 cm): 1.91%/√E ⊕ 0.54%
  - Hadronic energy resolution (with software compensation): 10.95%/√E ⊕ 3.13%
- First batch of samples tested with cosmic muons



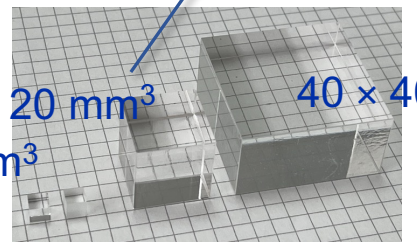




6 × 6 mm² SiPM
MPV: 491.1 ± 2.6 p.e.



3 × 3 mm² SiPM
MPV: 95.3 ± 1.3 p.e.

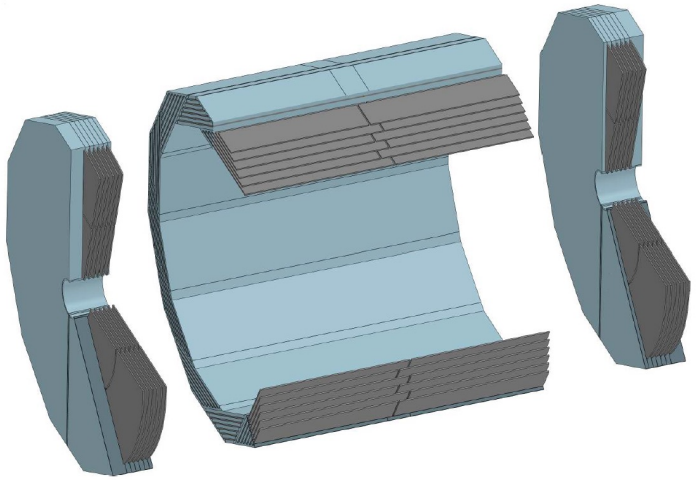


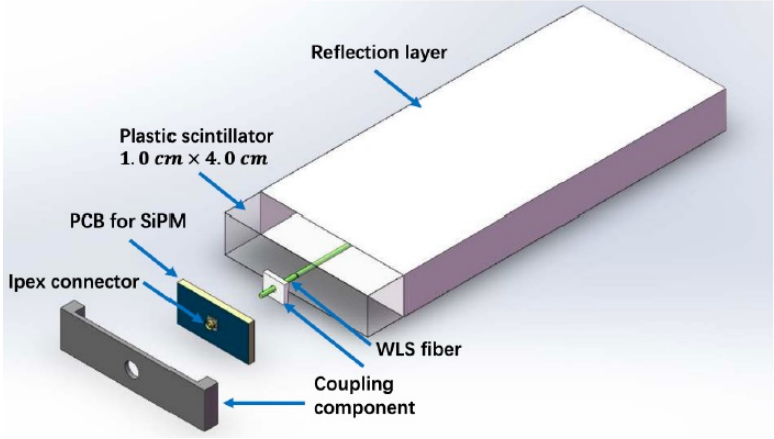
20 × 20 × 20 mm³
5 × 5 × 5 mm³
40 × 40 × 40 mm³

→ 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 →

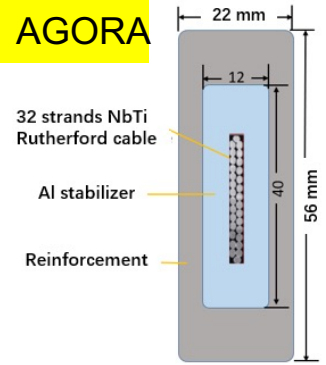


→ R&D at JINR on scintillator (Aleksandr Simonenko) and WLS fibre (Vladimir Baranov)

Magnet

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

AGORA

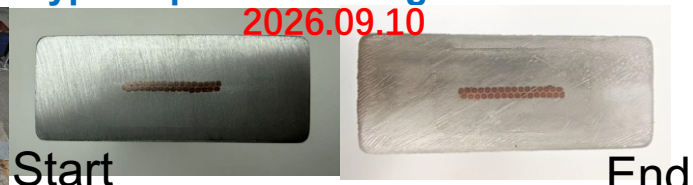


LTS conductor

Full-size Box type Superconducting Cable

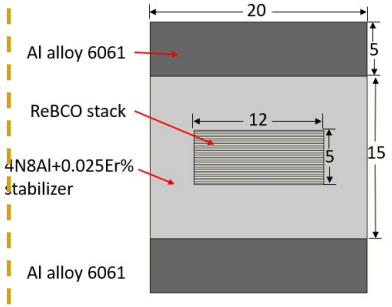
2026.09.10



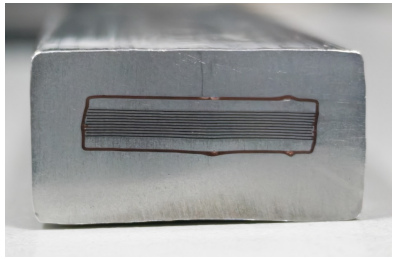


Start End

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

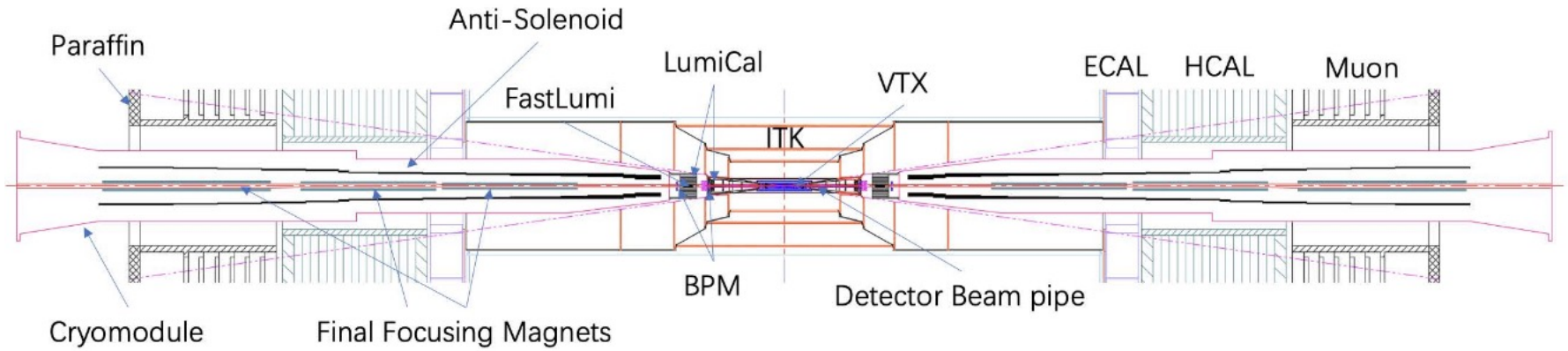
→ Feipeng Ning's talk

	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

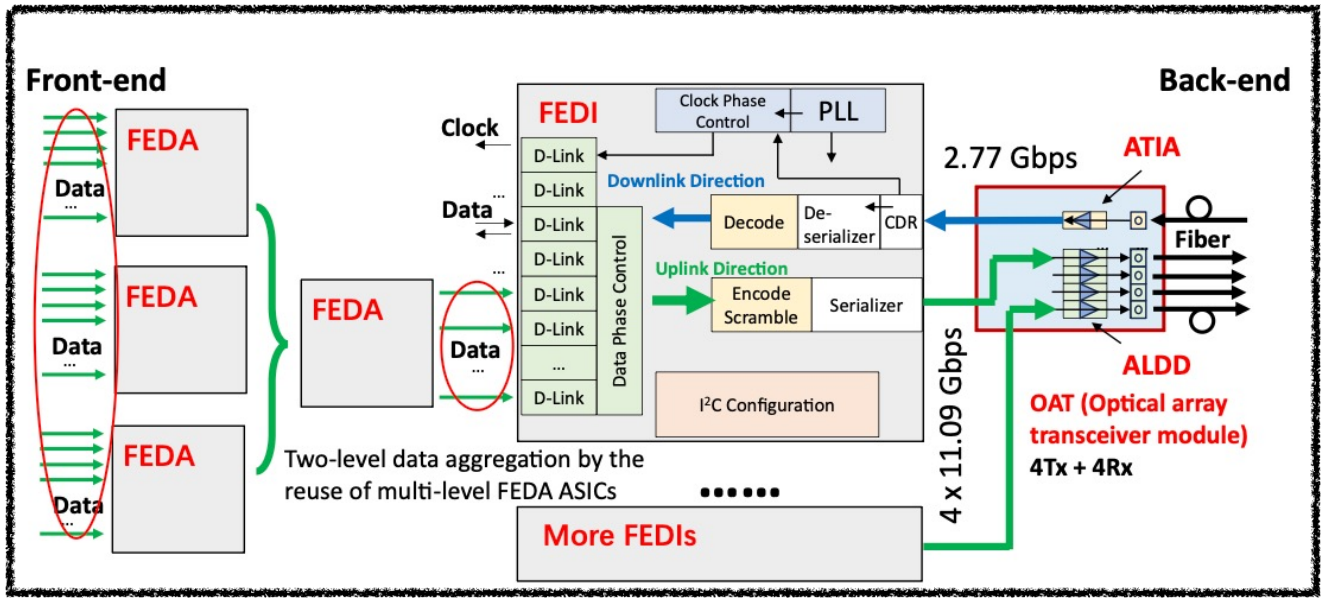
Parameter	FCC-ee	CEPC
Full crossing angle	30 mrad	33 mrad
Half crossing angle	15 mrad	16.5 mrad
Boundary / stay-clear angle	100 mrad	8.1° ≈ 141 mrad
Radial space at s = 1.5 m	150 mm	212 mm
Radial space at s = 2.0 m	200 mm	283 mm
Ratio	1.00	1.41

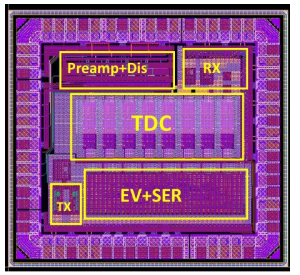
Parameter	FCC-ee	CEPC
L*	2.2 m	1.9 m
MDI region extent	~20 m	±7 m
Screening solenoid/anti-solenoid start	≥ 1.55 m (at 100 mrad)	~1.13 m
Cryostat start	~1.4 m from IP	~1.05 m from IP
Beam pipe separation	Remote vacuum connection, two independent beam pipes	Double-ring, shared interaction region

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

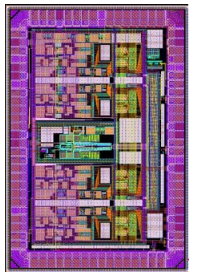
Common electronics & data acquisition

- 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)

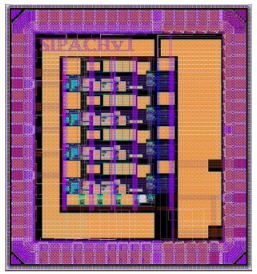




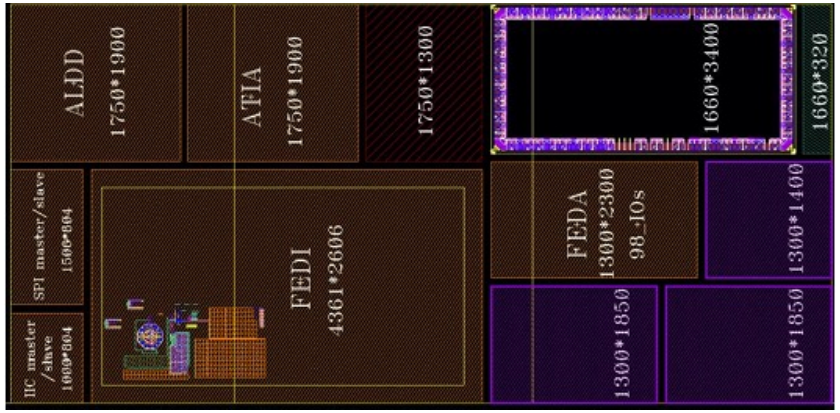
LATRIC1



SIPAC_E



SIPAC_H



ASICs for the data interface

→ Jingbo Ye's talk

Mechanics, cooling, integration

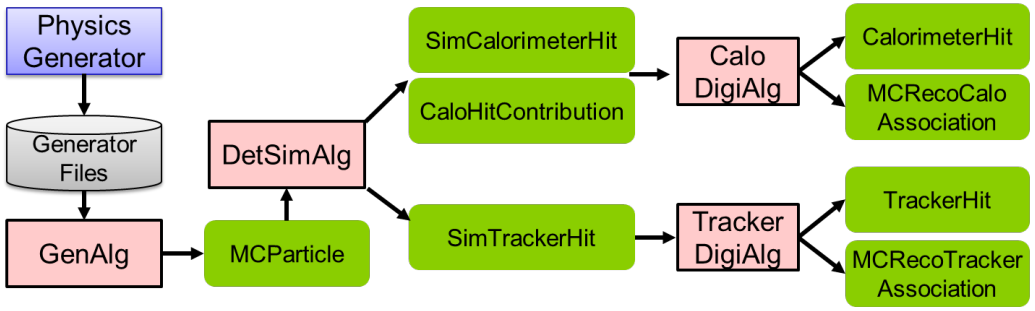
FCC-ee	AGORA
Differs from CEPC in **MDI interface**, geometric constraints, **beam parameters** and magnetic **field scheme**	■ Re-define **global mechanical envelope** and allocate dimensions among sub-detectors ■ Re-design **sub-detector connections and support** ■ For some sub-detectors — notably 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



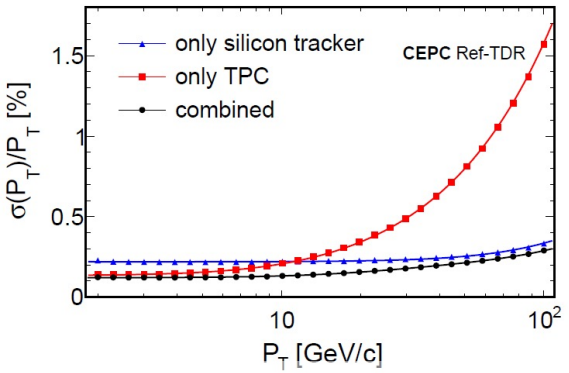
Repository	AGORA developments	Checks
FCC-config	Run configurations, simulation/reconstruction job options and full-chain examples	Reproducible processing
k4geo	DD4hep geometry, compact XML, plugins and detector tests	Materials, IDs and overlaps
k4RecTracker	Tracking and relevant digitization components;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

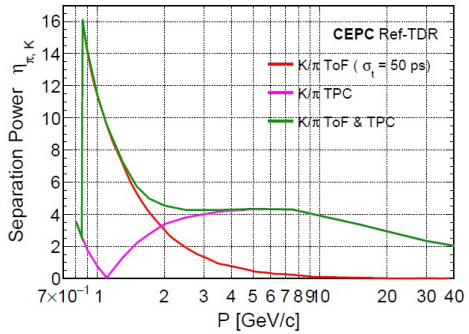
→ Tao Lin's talk

Physics performance

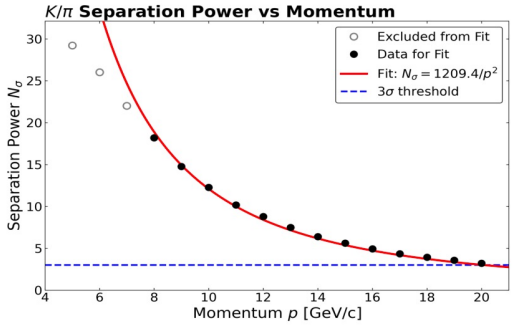
Tracking efficiency	Tracking σ_{pT}	Vertexing $\sigma_{x,y,z}$	π-k separation	EM resolution	BMR
>99.7% (for p>1 GeV)	**~0.1%** for majority	**< 3.5 μm**	**3σ** (1-20 GeV)	**2%/√E ⊕ 0.5%**	**3.87%** (H->gg)



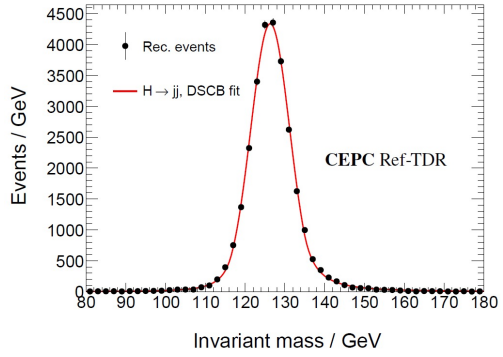
P_T resolution at 85°



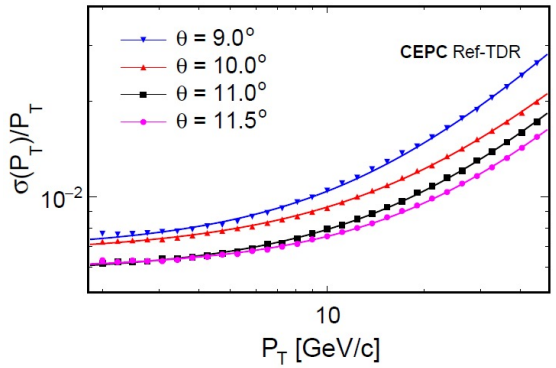
(a) $\theta = 85°$



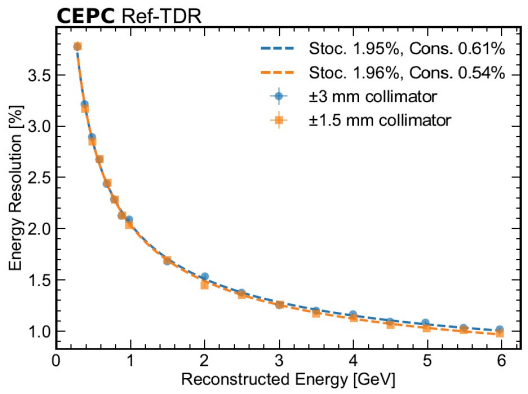
K/π separation power



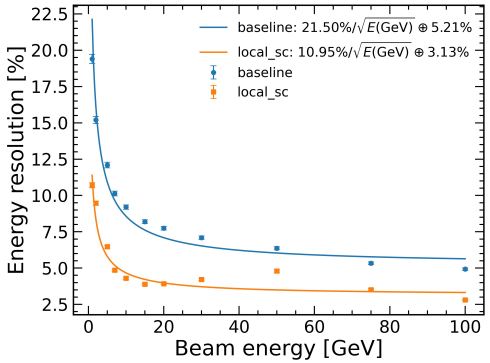
H→jj resolution



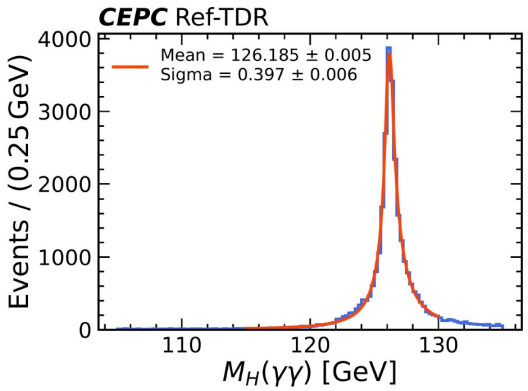
P_T resolution at different angles



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!