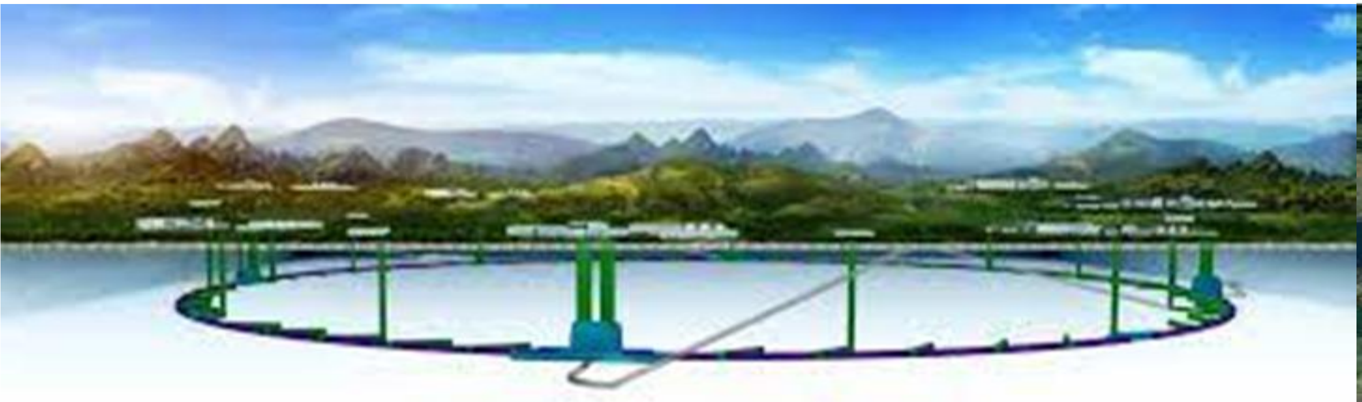
FCPPN/L 2026, Lyon

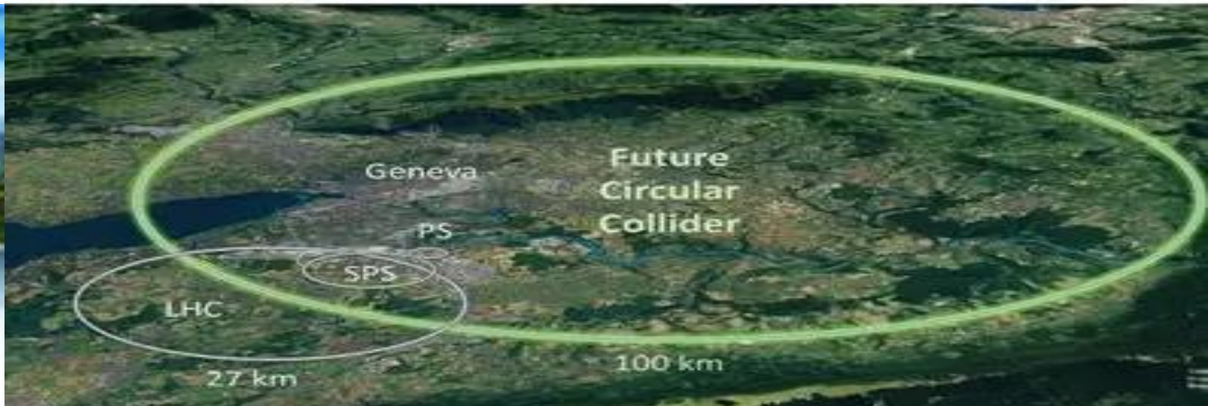
The AGORA Detector

for the CEPC and FCC colliders

Xinchou LOU

IHEP, Beijing



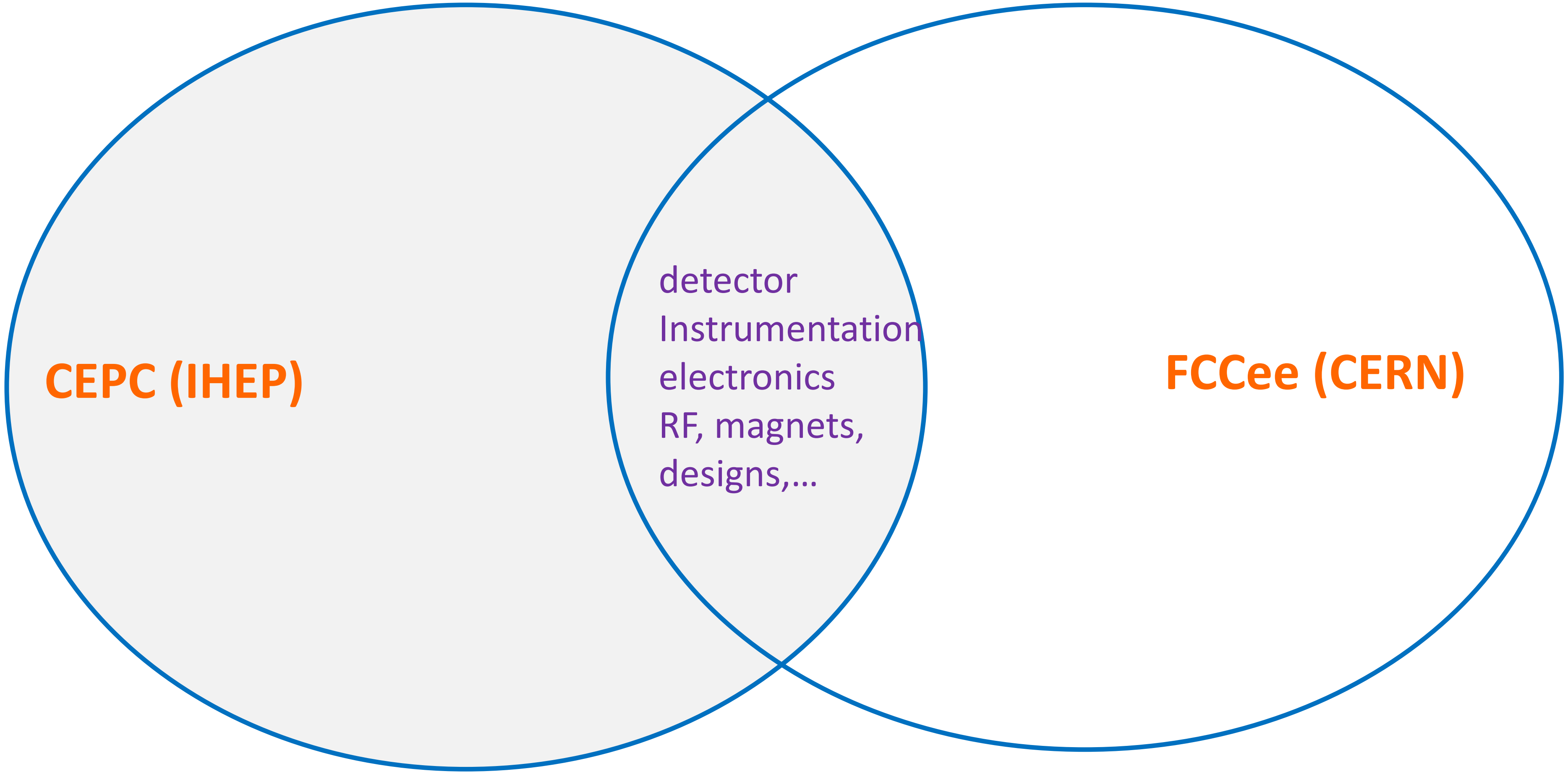


Outline

- Introduction： what is the AGORA detector?
- The AGORA detector: the design, validation & performance
- Optimizing AGORA for CEPC & FCC
- Opportunities: design, technologies and collaboration
- Summary

Introduction

Two high energy circular e+e- colliders under-going design + R&D over the past ~14 years

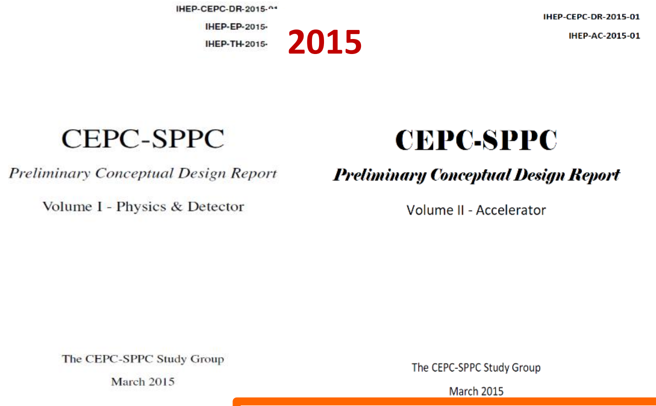


Introduction： what is the AGORA detector?

The CEPC team takes steps to advance, and has been persistent in design and R&D

2013

2015


IHEP-CEPC-DR-2015-01
IHEP-EP-2015-01
IHEP-TH-2015-01

CEPC-SPPC
Preliminary Conceptual Design Report
Volume I - Physics & Detector

The CEPC-SPPC Study Group
March 2015

IHEP-CEPC-DR-2015-01
IHEP-AC-2015-01

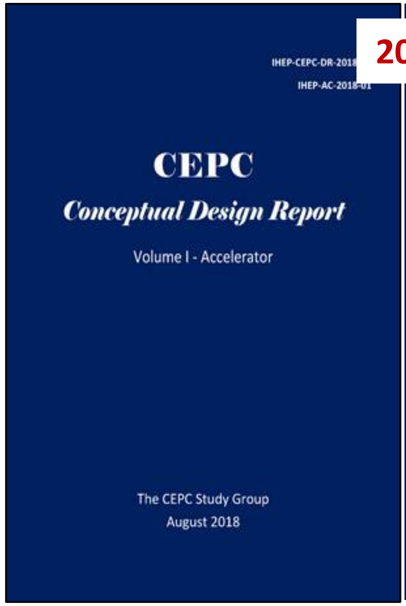
CEPC-SPPC
Preliminary Conceptual Design Report
Volume II - Accelerator

The CEPC-SPPC Study Group
March 2015

CEPC physics white papers:

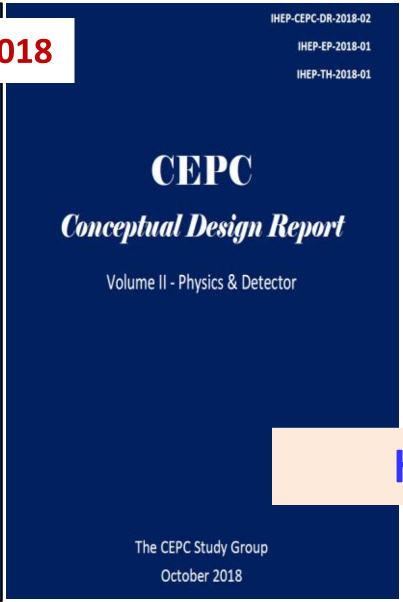
1. **Higgs physics,** arxiv:1810.09037
   Chin. Phys. C 43(2019) 043002
2. **Flavor physics,** Chin. Phys. C 49(2025) 10
3. **New Physics Search at the CEPC: a General Perspective**
   Chin. Phys. C 49(2025) 12
4. **Electroweak physics, to be published**
5. **QCD, to be published**

2018


IHEP-CEPC-DR-2018-01
IHEP-AC-2018-01

CEPC
Conceptual Design Report
Volume I - Accelerator

The CEPC Study Group
August 2018


IHEP-CEPC-DR-2018-02
IHEP-EP-2018-01
IHEP-TH-2018-01

CEPC
Conceptual Design Report
Volume II - Physics & Detector

The CEPC Study Group
October 2018

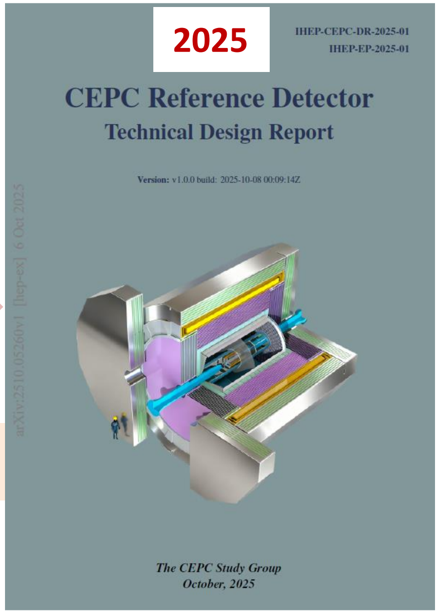
2023


IHEP-CEPC-DR-2023-01
IHEP-AC-2023-01

CEPC
Technical Design Report
Accelerator

The CEPC Study Group
December 2023

2025


IHEP-CEPC-DR-2025-01
IHEP-EP-2025-01

CEPC Reference Detector
Technical Design Report

Version: v1.0.0 build: 2025-10-08 00:09:14Z

The CEPC Study Group
October, 2025

http://cepc.ihep.ac.cn

The AGORA detector

guided & reviewed by a panel of international detector experts

AGORA: Advanced Glass Optimized Research Apparatus

- The name **AGORA** describes a next-generation experiment at a lepton collider (CEPC/FCC). The name emphasizes the unique glass calorimeter at the heart of the detector. The acronym AGORA is an english word that means "gathering place" or "assembly" and it intends to symbolize the international collaboration that we expect to flourish.
- The word derives from ancient Greek and it refers to the central public square in ancient Greek city-states. They functioned as the heart of the city‘s political, commercial, and social life, where citizens would gather to debate politics, conduct business, and trade at the market.
- AGORA is based on the CEPC reference detector and beyond it. **International collaboration is greatly welcome.**

AGORA

ADVANCED GLASS OPTIMIZED RESEARCH APPARATUS

Introduction： TDR for the AGORA detector

International Committee composed of 19 experts in detector physics

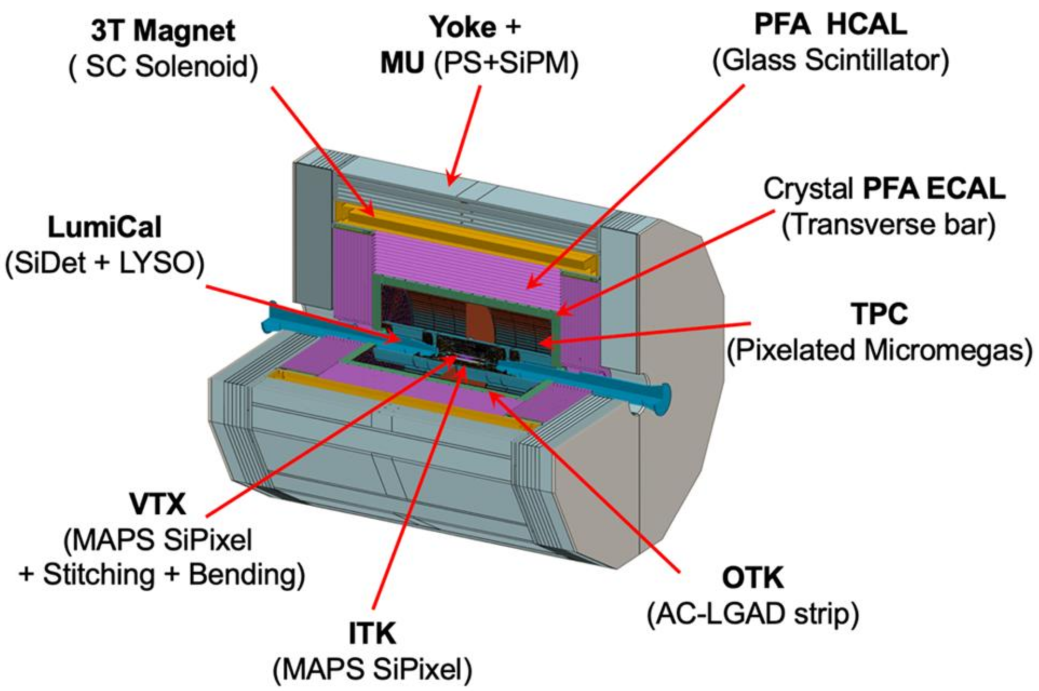
Name	Affiliation	Country/Region
Daniela Bortoletto (chair)	Oxford	UK
Colin Gay	UBC	Canada
Bob Kowalewski	U Victoria	Canada
Burkhard Schmidt	CERN	CERN
Liang Han	USTC	China
Paul Colas	Saclay	France
Christophe De La Taille	OMEGA, CNRS	France
Cristinel Diaconu	CPPM	France
Roman Poeschl	IJCLab	France
Maxim Titov	Saclay	France

Name	Affiliation	Country/Region
Frank Gaede	DESY	Germany
Anna Colaleo	INFN, Bari	Italy
Tommaso Tabarelli de Fatis	INFN Milano-Bicocca	Italy
Roberto Tenchini	INFN, Pisa	Italy
Akira Yamamoto	KEK	Japan
Hitoshi Yamamoto	Tohoku U., Valencia	Japan
Gregor Kramberger	IJS	Slovenia
Ivan Villa Alvarez	Santander	Spain
James Brau	Oregon	USA

Three review meetings were held from October 2024 to September 2025

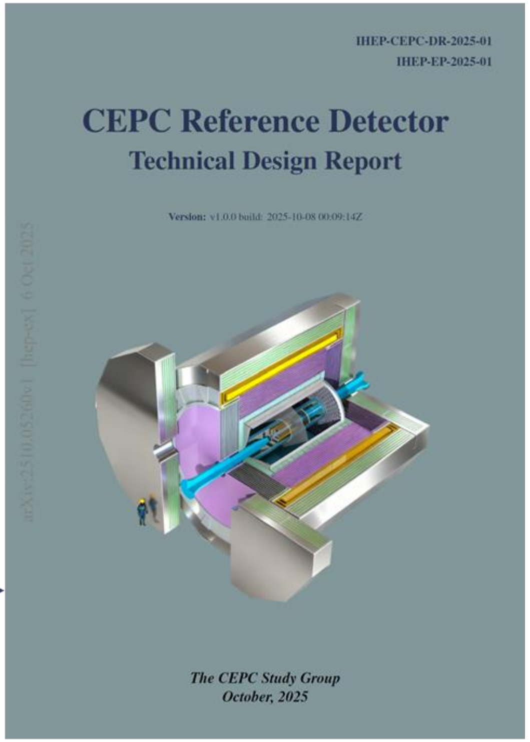
AGORA as a Reference Detector for CEPC - TDR

- **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.



$10\times10\times12\ m^3$, ~5000 ton

19 chapters
669 pages
1474 authors
383 institutes
43 countries



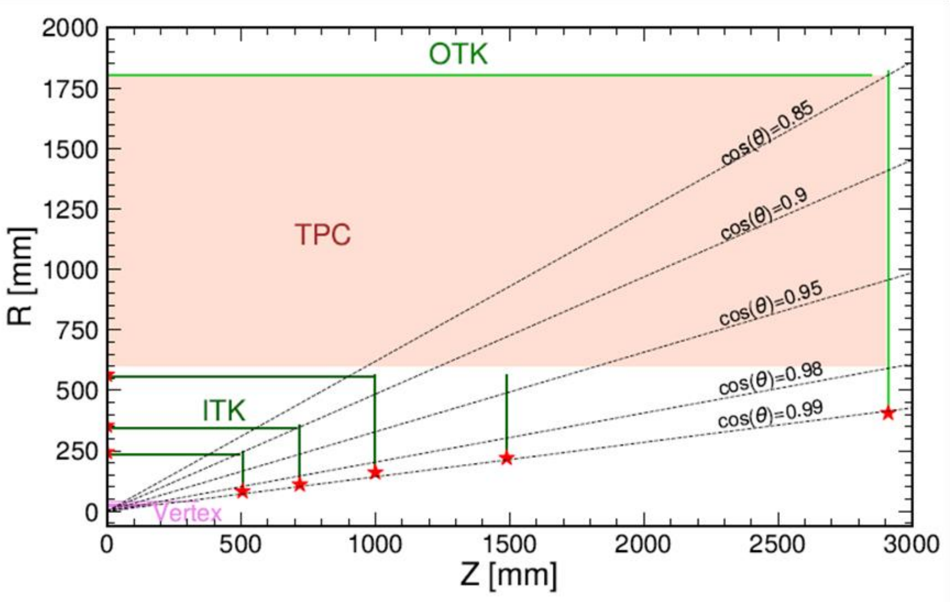
AGORA - the tracking system

Silicon detectors

- Vertex: MAPS silicon sensors bend to a tube, for σ of 5 μm
- 20 m^2 inner tracker using HV-CMOS pixel for σ ≈ 8 μm
- 85 m^2 outer tracker using AC-LGAD strips for σ ≈ 10 μm, σ_t ≈ 50 ps

Gaseous detector

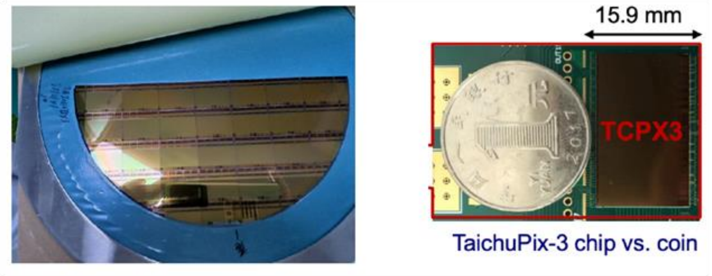
- TPC for tracking and PID for σ ≈ 100 μ m, dN/dx ≈ 3%



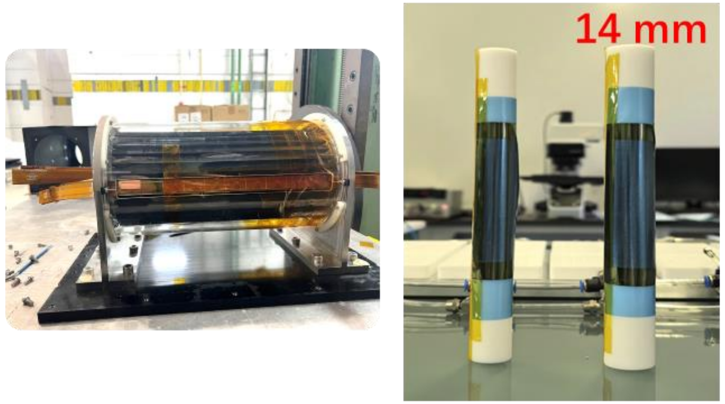
Measurands	Performance requirement
Coverage	$\lvert\cos\theta\rvert \leq 0.99$
Recon. efficiency	$\geq 99\%$ ($p_T > 1$ GeV/c)
Resolution in barrel	$\sigma_{p_T}/p_T < 0.3\%$ ($\lvert\cos\theta\rvert \leq 0.85$)
Resolution in endcap	$\sigma_{p_T}/p_T < 3\%$ ($\lvert\cos\theta\rvert > 0.85$)

AGORA - Key technologies in silicon detectors

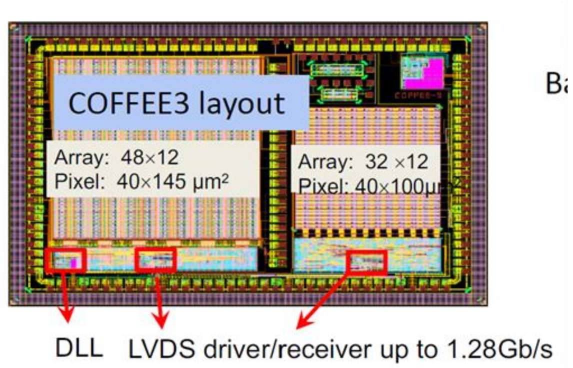
- **Vertex detector:** bending Monolithic Active Pixel CMOS (**MAPS**), for ultra-low material budget and low power

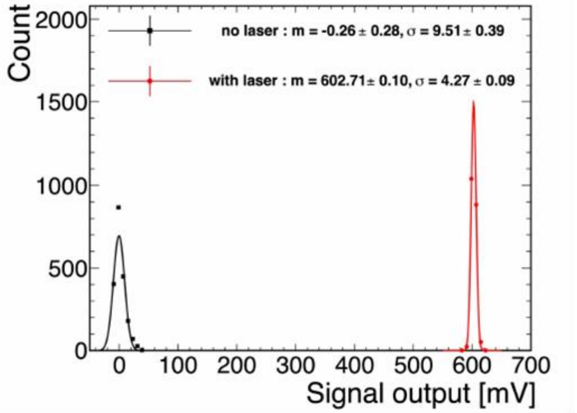


TaichuPix-3 chip vs. coin

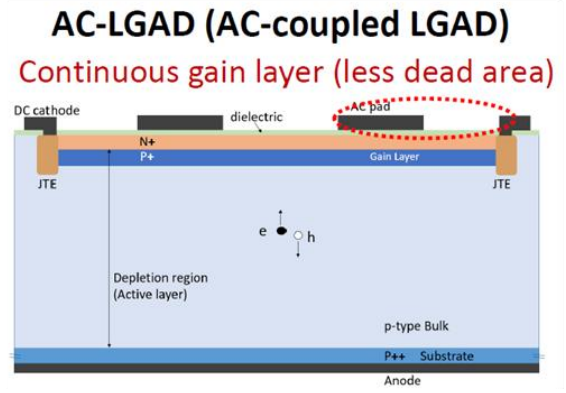


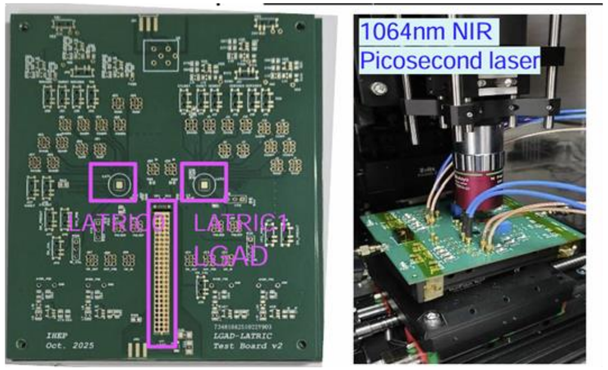
- **Inner tracker: HV-CMOS** MAPS fabricated using a **55 nm** CMOS process





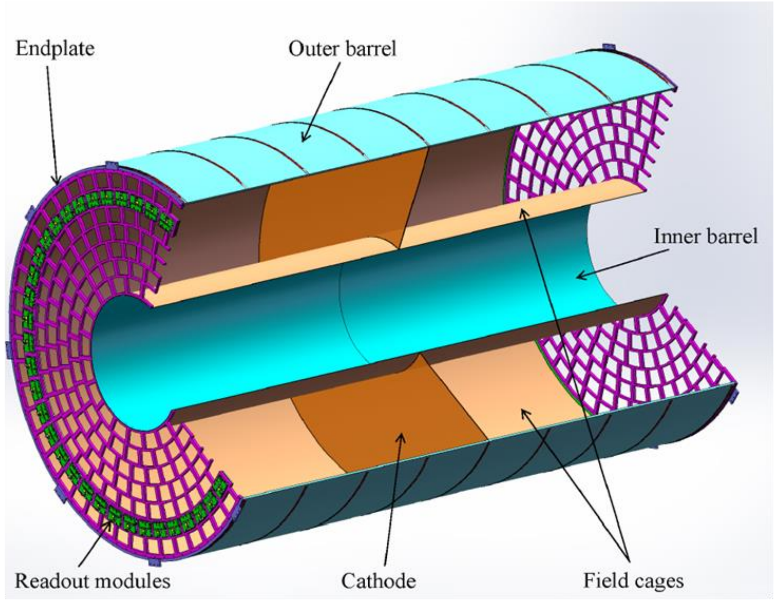
- **Outer tracker:** microstrip **AC-LGAD** with both good spatial and time resolution





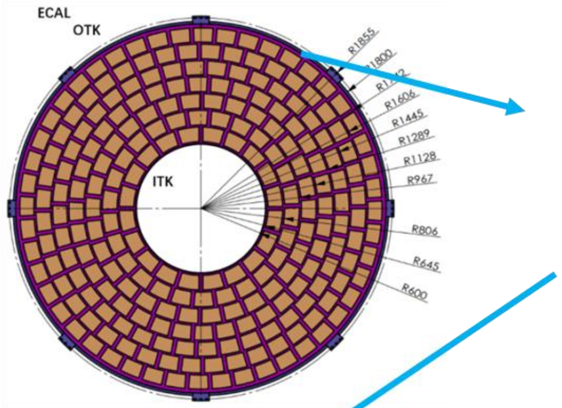
AGORA - the TPC outer tracker

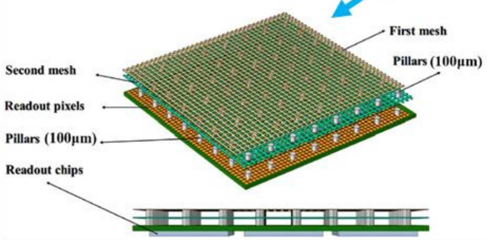
- A **chamber** (inner and outer cylinders, endplates) with gas mixture ($Ar/CF_4/iC_4H_{10}$ = 95/3/2), for low transverse diffusion and fast drift velocity.



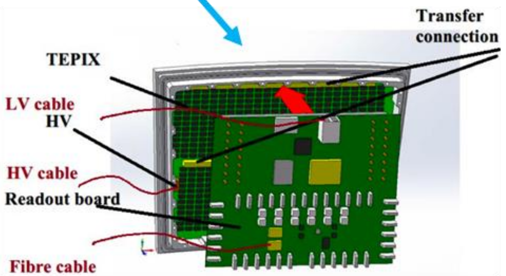
Length: 5.8 m, R extension: 0.6-1.8 m.

- High-granularity **readout** (500×500 μm²) of Micromegas for good tracking (σ~100 μm) and PID (dN/dx ~3%)





Double mesh micromegas readout board

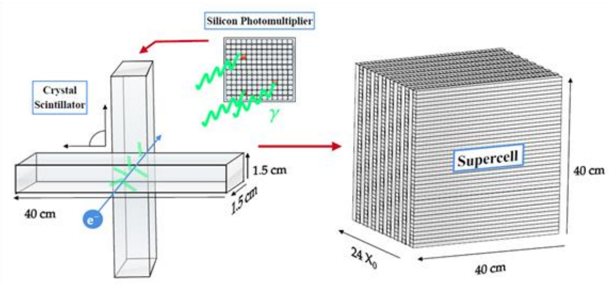


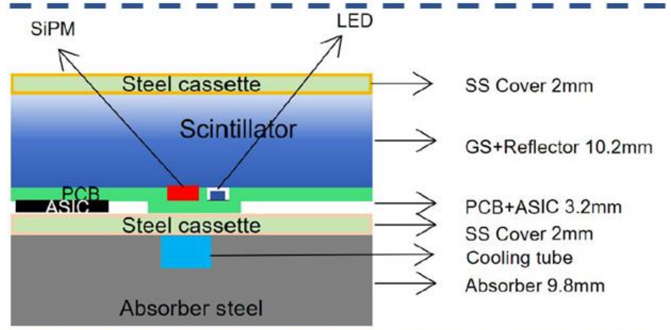
TEPIX: Low-power readout ASIC (<100 mW/cm²)

AGORA - Calorimeter Particle Flow Algorithm (PFA) oriented design

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: $\boxed{1.96\,\%/\sqrt{E(\mathrm{GeV})} \oplus 0.54\,\%}$



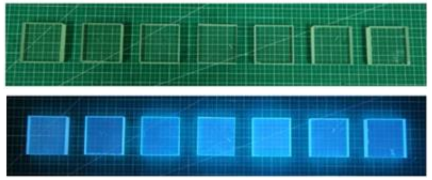


Hadron Calorimeter (HCAL)

- **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

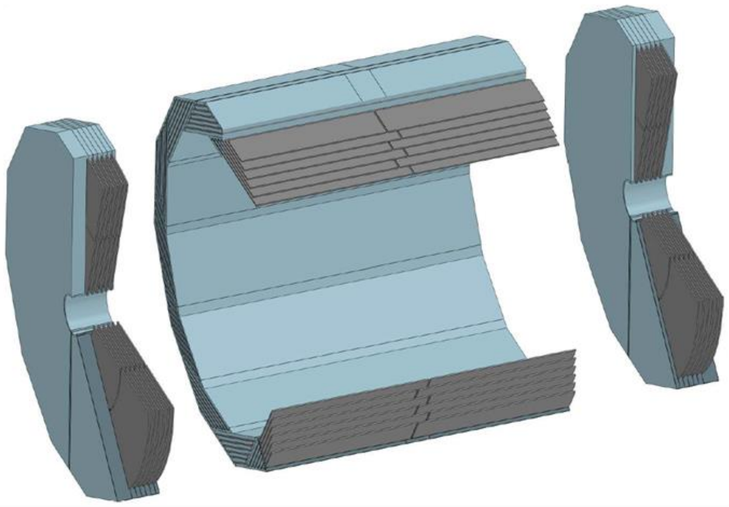


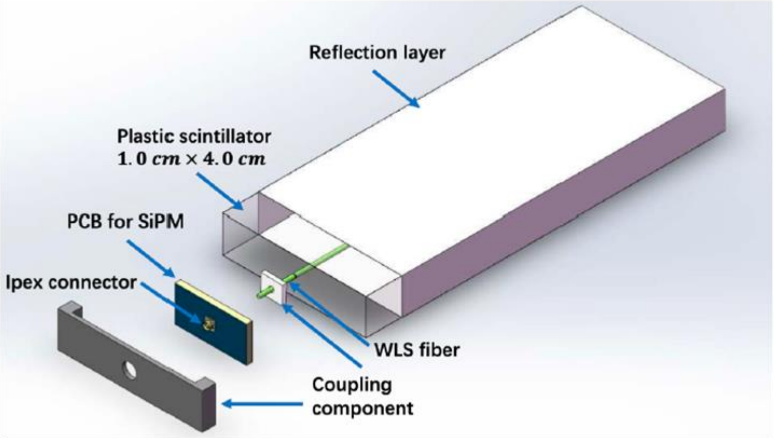
Glass scintillator under natural and ultraviolet light

AGORA - the muon system

6 layers of plastic scintillator strips embedded in the iron Yoke

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

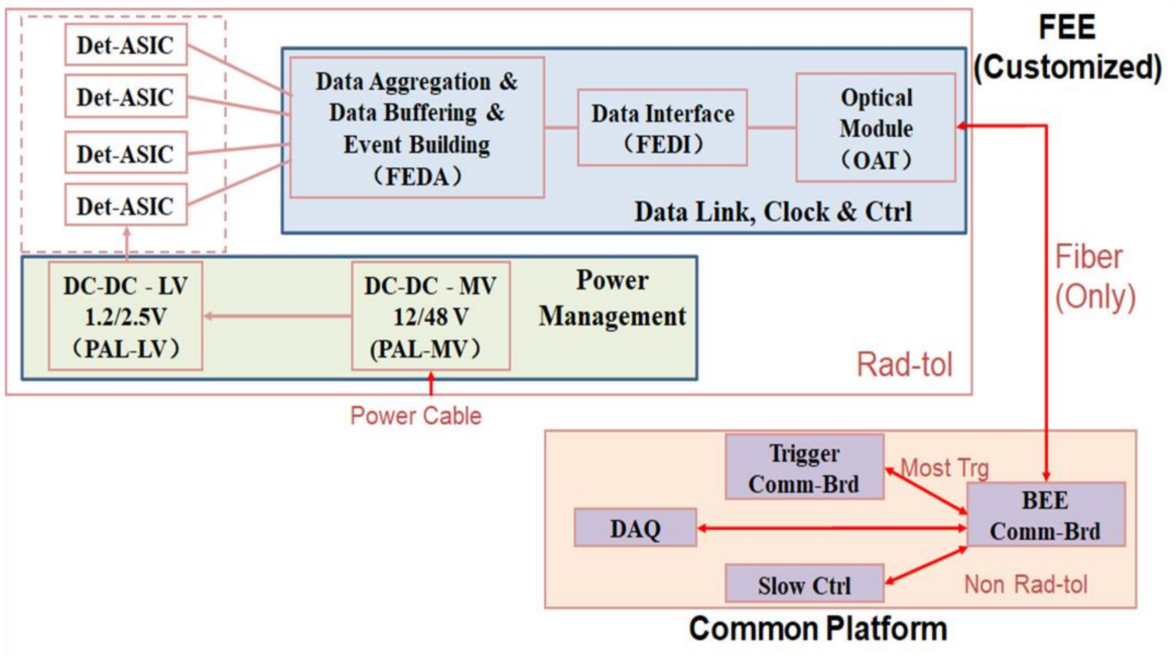




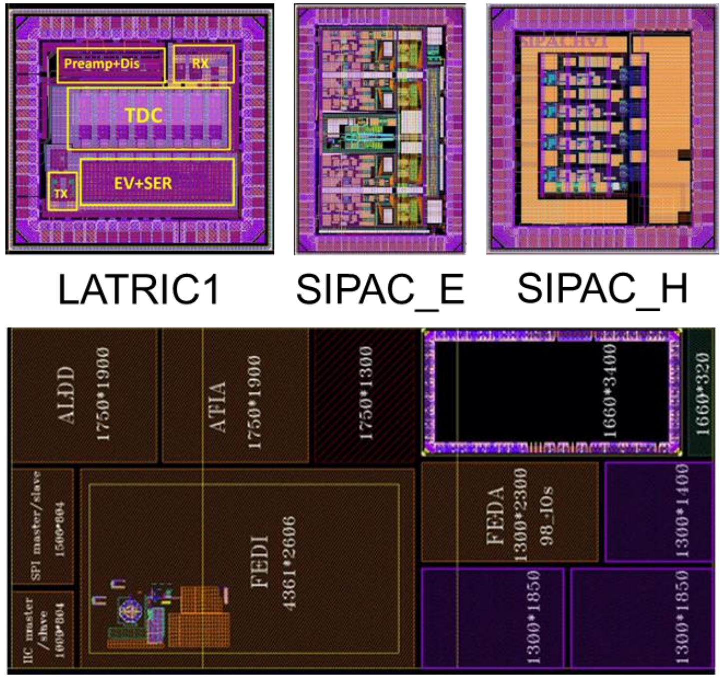
A 5-m plastic scintillator strip →

AGORA - Common electronics and data acquisition

- Customized on-det electronics, common data interface and backend electronics
- A serials of 55 nm ASICs
- Full data transmission is chosen 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)

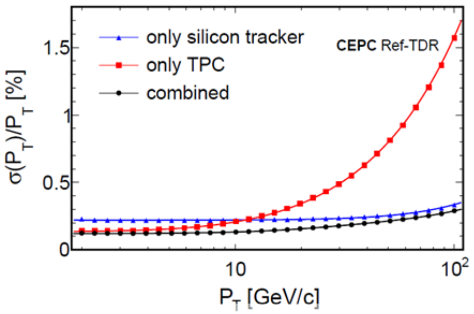


Framework of the common electronics

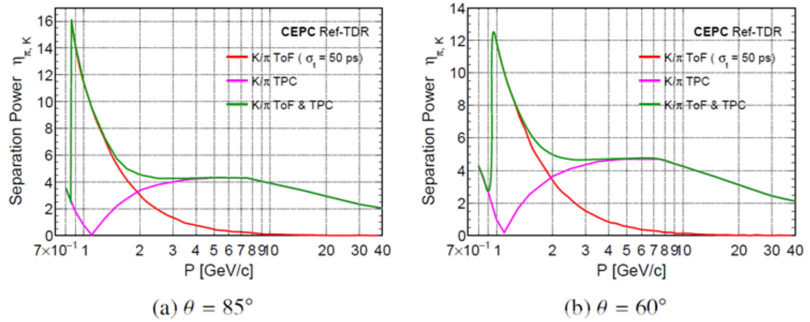


ASICs for the data interface

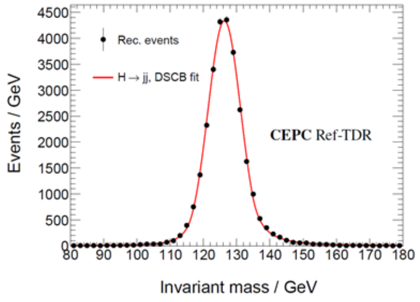
AGORA - Detector performance highlights



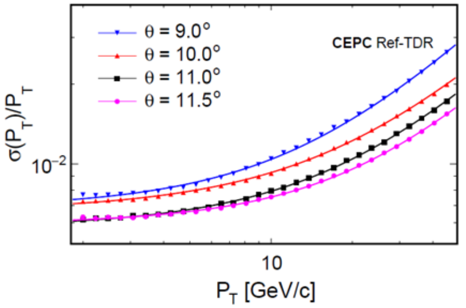
P_T resolution at 85°



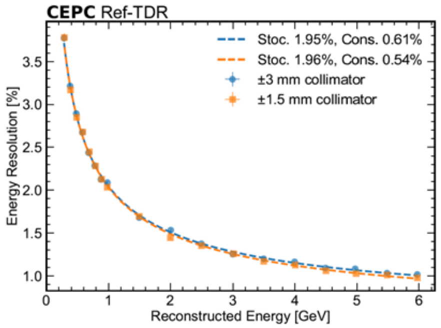
K/π separation power



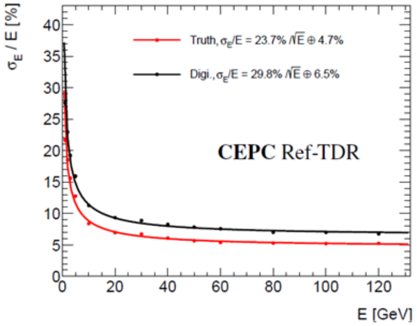
H→jj resolution



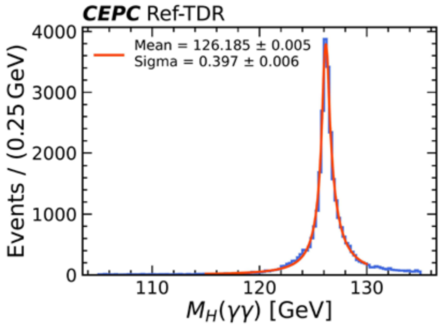
P_T resolution at different angles



EM resolution from beam test



Simulated Hadron resolution



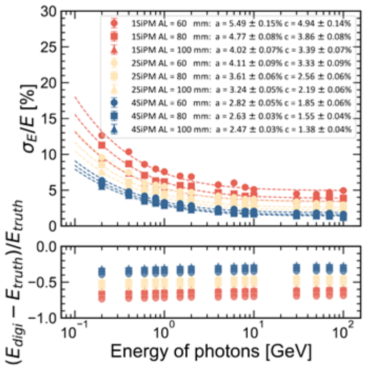
H→$\gamma\gamma$ resolution

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)	$2\%/\sqrt{E} \oplus 0.5\%$	3.87% (H->gg)

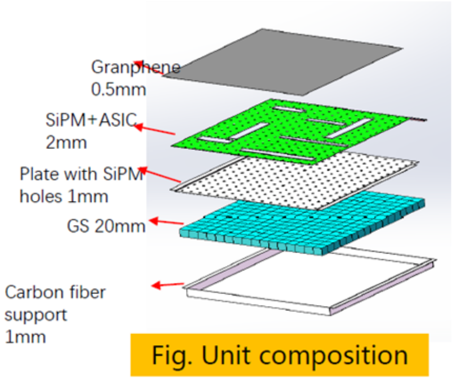
AGORA - new ideas to go beyond the TDR

An integrated design for ECAL and HCAL based on **glass scintillator (GS)**: trade-off between cost and physics

- GS-ECAL: 1/3-1/2 of BGO, channels × 7, better E/H ratio with hadronic shower
- GS-HCAL: optimization of sampling ratio to improve energy resolution



Energy solution of GS-ECAL can reach 3%-4%

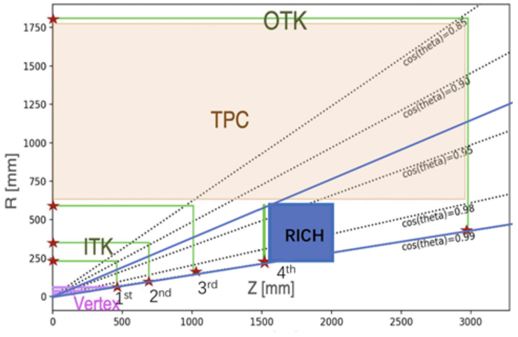


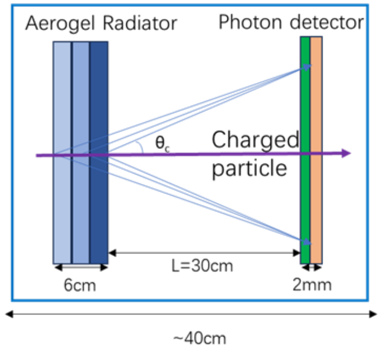
Preliminary design of a unit of GS-ECAL

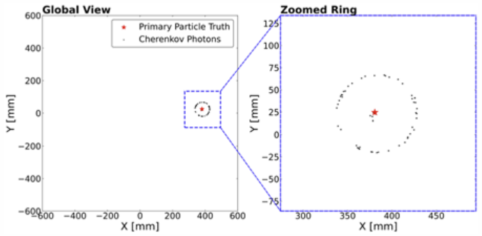
Reference (talk at CEPC workshop in Lisbon, April 2026): https://indico.cern.ch/event/1598929/contributions/7012849/

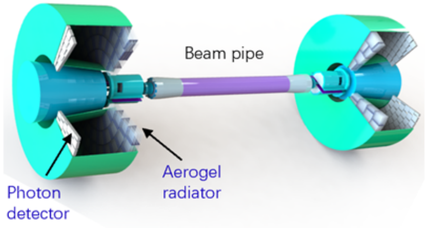
A Ring-Imaging Cherenkov (**RICH**) detector in the forward region

- To improve forward K/π separation
- Key technologies: aerogel radiators with low refractive index and radiation-hard SiPMs with low noise









Reference (talk at CEPC workshop in Lisbon, April 2026): https://indico.cern.ch/event/1598929/contributions/7014479/

The AGORA detector – merits or advantages

- **TDR completeness** — only detector with a full Technical Design Report, engineering details, and full cost estimate (333.3 MCHF)
- **Advanced TPC with cluster counting (dN/dx)**: K/π separation >3σ up to 20 GeV/c; resolution ~2% (vs traditional dE/dx at 4–5%)
  - Combined with OTK ToF (50 ps) → PID coverage from 0.5 to 20 GeV/c
- **Crystal ECAL performance**: EM resolution $1.14\%/\sqrt{E} \oplus 0.44\%$; BMR = 3.87%; Higgs mass precision 4 MeV
  - Competitive Higgs physics reach demonstrated via full simulation

Joao Guimaraes da Costa

CEPC Plan and Goals

In light that the Chinese Academy of Sciences did not support the submission of the CEPC proposal for government approval in October 2025, **the study group intends to join the FCC accelerator and detector projects, and to contribute in a significant way.**

The CEPC Study Group intends to continue advancing the critical and innovative R&D projects identified by the various international review and advisory committees, while contributing to FCC. The AGORA detector will be modified to be a great one for the FCC.

Only if the FCC is not approved within the current schedule, will the CEPC be submitted for approval in 2030 within China's 16th Five-year Plan

The AGORA detector – making it work at FCC and CEPC(Z)

Technical Challenges

- **CEPC → FCC-ee pivot**: MDI, final focus, background simulations must be re-optimised for FCC-ee conditions
- **Glass scintillator HCAL**: light yield only ~1500 ph/MeV (vs BGO 7500), attenuation length ~6 cm, slow decay (500 ns)
- **BGO ECAL scale-up**: 24 m^3 of crystals, 571k channels — mass production, quality control, SiPM cooling
- **TPC at Z pole**: ion back-flow from space charge; needs double-mesh Micromegas or graphene-coated cathode
- **Software migration**: CEPCSW (Gaudi) → full FCC Key4HEP; adapt digitisation and background

Project & Collaboration Challenges

- **Designed for CEPC, not FCC-ee** — the largest conceptual challenge
- Different MDI interface, beam parameters, civil engineering constraints
  - Electronics clock, bunch crossing rate
- Re-baselining requires some effort
- Must pivot physics goals from CEPC to FCC-ee

Detector R&D and Validation opportunities for collaboration

The TDR also documents future detector R&D plan details, many activities are with the DRD Collab.

AGORA is designed for CEPC, and can be readily adapted for use at FCC-ee

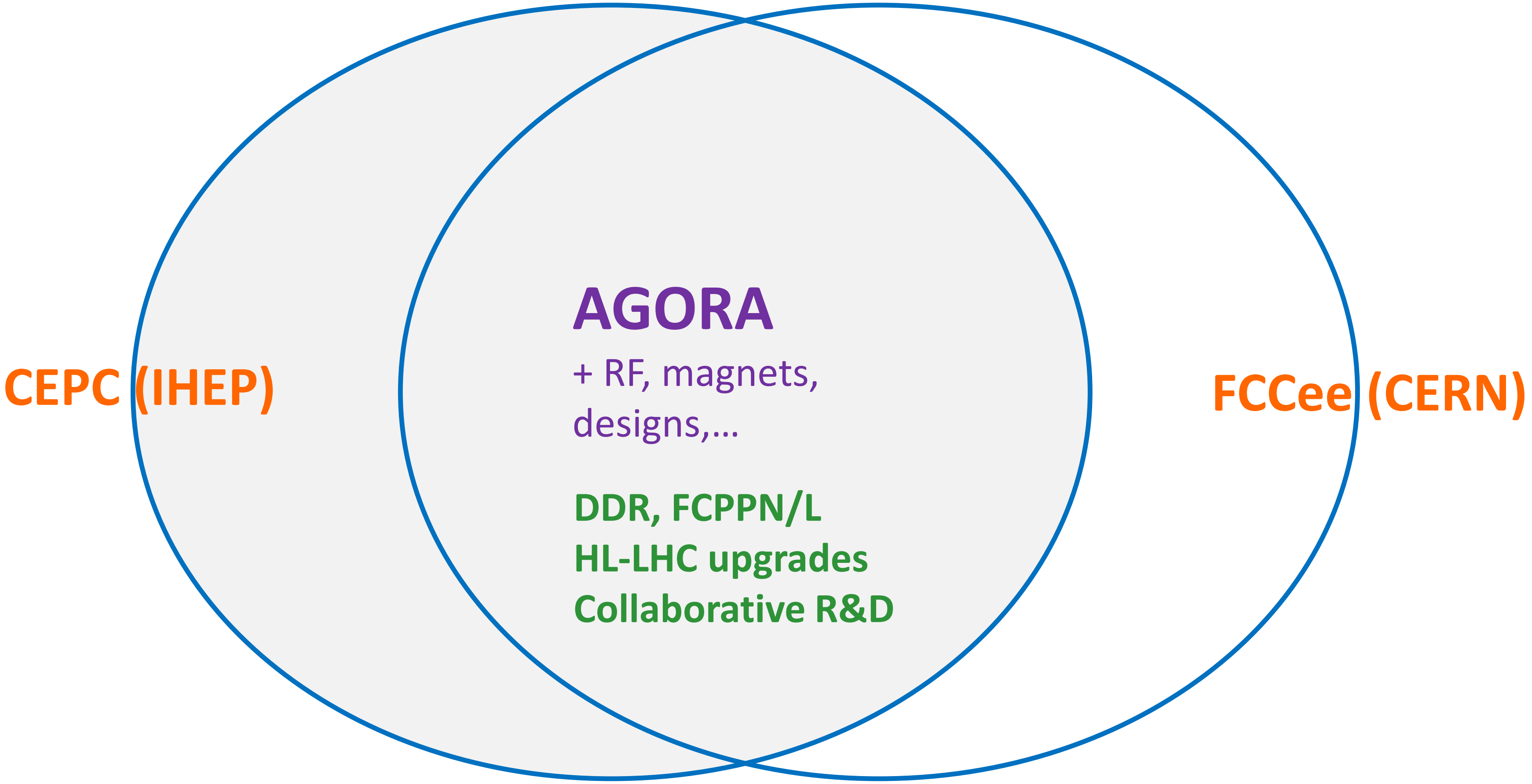
MDI and Luminosity	• **MDI:** Optimization of collimators and re-evaluation of cryogenics shielding/weight • **Luminosity measurement:** Validation of technologies • **Beam background:** improve s
Silicon Detectors	• **Vertex:** Development of wafer-s CIS stitching MAPSs with 65nm • **ITK:** HV-CMOS sensor R&D, hi • **OTK:** larger size, higher perforr towards multi-channels readout
Gaseous Detector	• **TPC:** Test and validation of higl back-flow, and electron transmi
Calorimeter and Muon Detectors	• **ECAL:** QA/QC specifications fc • **HCAL:** Glass scintillator advan • **Muon:** Enhance light yield and • R&D of **SiPM** and readout ASIC

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
Electronics and TDAQ	• Prototype verification, front-end chip development, and electronics common interfac • Development of advanced trigger algorithms, high-speed transmission technology fo 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 Computing	• Optimization of geometry coverage. • Study of standalone tracking for displayed vertex. • Simulation for physics impact and new physics.

not a full list

Work with the FCC

- **going forward, intensified collaboration with FCC will position the FCC project optimally for ultimate realization at CERN ;**
- **making AGORA a great detector for the FCC**



The AGORA detector

2026 intl. CEPC workshop
Shanghai, October 22-26

https://indico.ihep.ac.cn/event/28911/

2027 EU CEPC Workshop
Belgrade, Serbia
June 8-11, 2027

Please join us in person or online

Summary

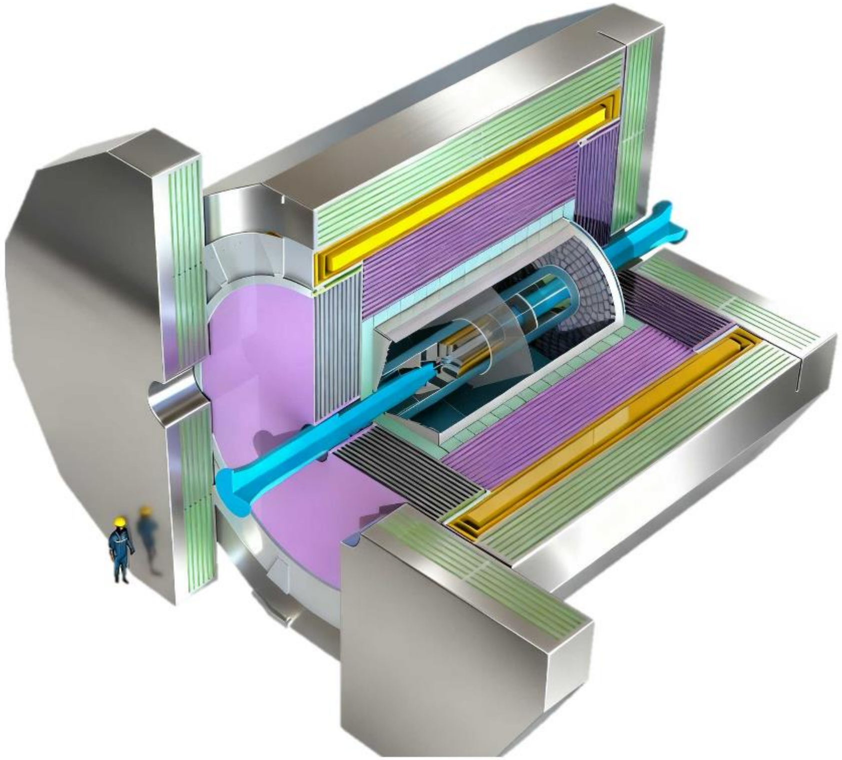
- though CEPC was not supported by CAS for 15th FYP; IHEP will continue to develop CEPC and technology development
- will carry out technical validations, pursue new technologies, and enhance the AGORA design and international collaborations
- CEPC team will collaborate actively with/in the FCC, making AGORA compatible and a great detector with the FCCee
- many wonderful opportunities to collaborate on AGORA (and the accelerator, the physics, and more…)

Merci!
谢谢！

Acknowledgements

- CEPC team's hard work, very fruitful international and CIPC collaborations have been critical to the CEPC program
- Special thanks to CEPC IB, SC, IAC, IARC and **IDRC** committees for their critical advices, suggestions and supports
- Funding agencies, local government, CAS and IHEP for their financial supports

The CEPC detector – follow-up R&D



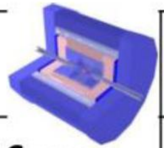
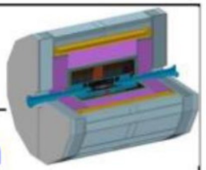
Sub-system	Technologies
Beam pipe	Beryllium, ϕ 20 mm
LumiCal	Silicon tracker + LYSO crystals
Vertex	Si Pixels: CMOS MAPS+stitching
Inner tracker (ITK)	Si Pixels: CMOS MAPS 55-nm
Gas detector	TPC with high granularity
Outer tracker (OTK)	AC-LGAD → TOF
ECAL	4D transverse crystal bars
HCal	Glass scintillator,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

- ❑ **prototyping with vital subsystems**
- ❑ **continuing to improve the design**
- ❑ develop combined system to evaluate their performance

AGORA

Detector progress in significant areas - TDR

Yoke
Muon detector
Magnet
HCAL
ECAL
OTK
TPC
ITK
VTX
LumiCal
Beam pipe

	CDR 	**RefDet-TDR** 
VTX	Inner radius of **16 mm**	Inner radius of **11 mm**
	Material Budget: 0.15%*6+0.14%(beampipe)= **1.05% X0**	Material Budget: 0.06%*4(inner)+0.165%*2(outer)+0.2%(beampipe)= **0.77% X0**
Gaseous Tracker	TPC with **1 mm* 6 mm** readout	TPC with **0.5 mm* 0.5 mm** readout **dN/dx resolution 3%**
ToF & Outer tracker	-	AC-LGAD, with **50 ps** per MIP, 10 um
ECAL	Si-W-ECAL: **17%**/√E ⊕ 1%	Crystal Bar-ECAL: **1.3%**/√E ⊕ **0.7%**
HCAL	RPC-Iron: **60%**/√E ⊕ 2%	Glass-Steel: **30%**/√E ⊕ **6.5%**