Overview of the CEPC Project

Haijun Yang (for the CEPC study group)

CEPC

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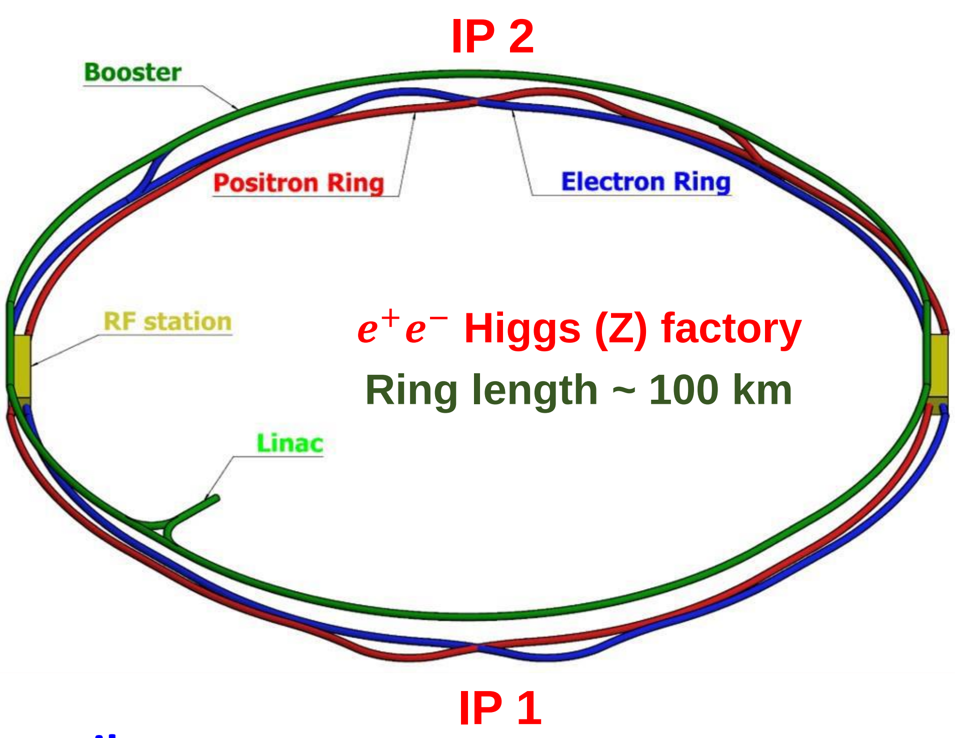
CEPC International Workshop at Marseille, April 8 – 11, 2024

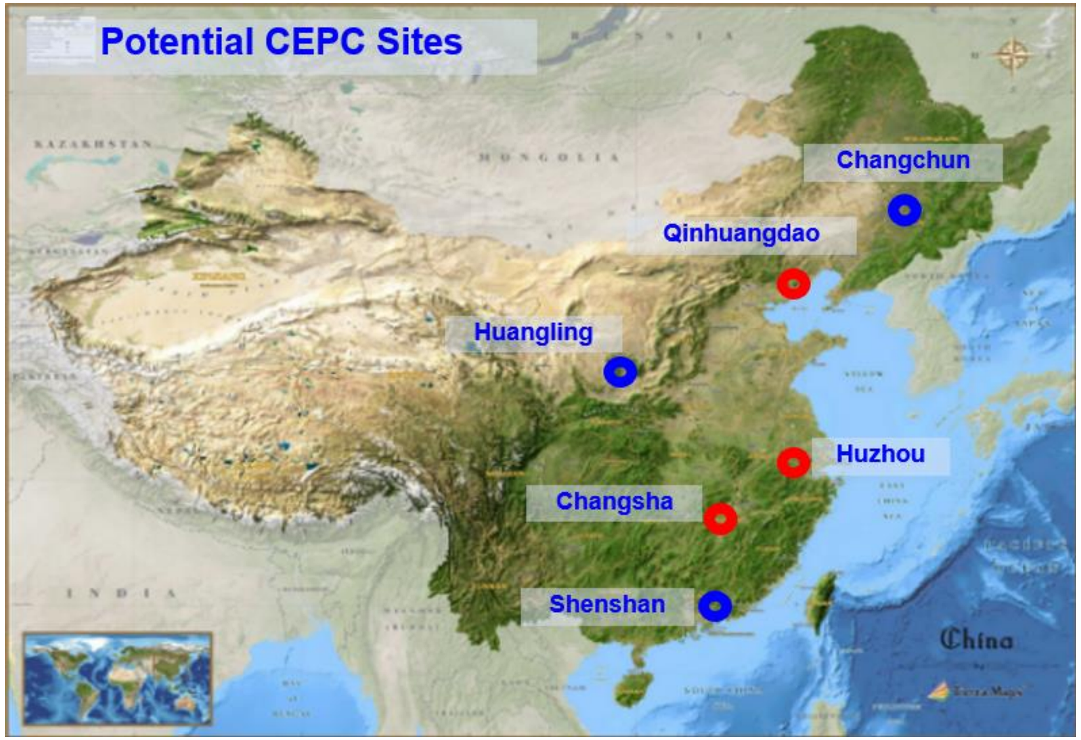
Outline

- Introduction to CEPC
  - Goal and major milestones
  - Consensus on e^+e^- Higgs Factory
- CEPC Status and Progress
  - Physics Program
  - Accelerator R&D
  - Detector R&D
- Project Planning and Development
- Summary

Circular Electron Positron Collider (CEPC)

- CEPC is an e^+e^- Higgs factory producing Higgs / W / Z bosons and top quarks, aims at discovering new physics beyond the Standard Model
- Proposed in September 2012 right after the Higgs discovery
- Upgrade: Super pp Collider (SppC) of $\sqrt{s}$ ~ 100 TeV in the future.





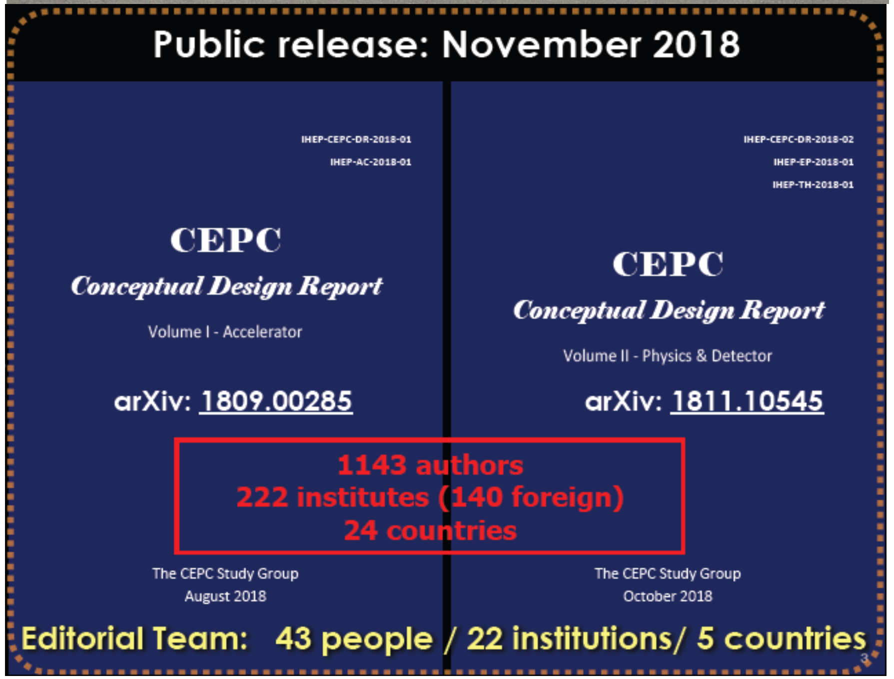
http://cepc.ihep.ac.cn

CEPC Major Milestones

CEPC-SPPC Kickoff (2013.9)

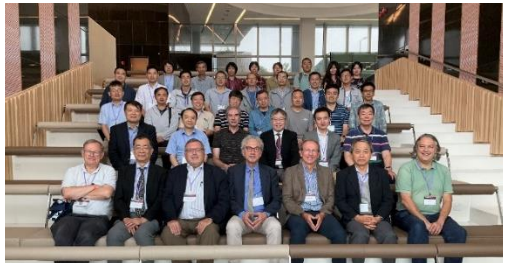
First CEPC IAC Meeting (2015.9)

CEPC CDR Released (2018.11)

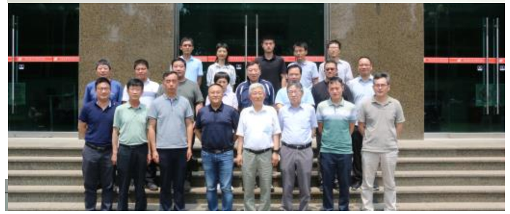


CEPC Major Milestones

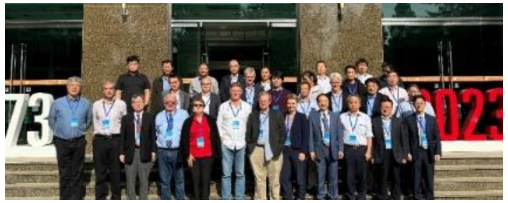
CEPC Accelerator TDR Review
June 12-16, 2023, Hong Kong



CEPC Accelerator TDR Cost Review
Sept. 11-15, 2023, Hong Kong



Domestic Civil Engineering
Cost Review, June 26, 2023, IHEP



9th CEPC IAC 2023 Meeting
Oct. 30-31, 2023, IHEP

CEPC Accelerator TDR released in December, 2023

IHEP-CEPC-DR-2023-01

IHEP-AC-2023-01

CEPC

Technical Design Report

Accelerator

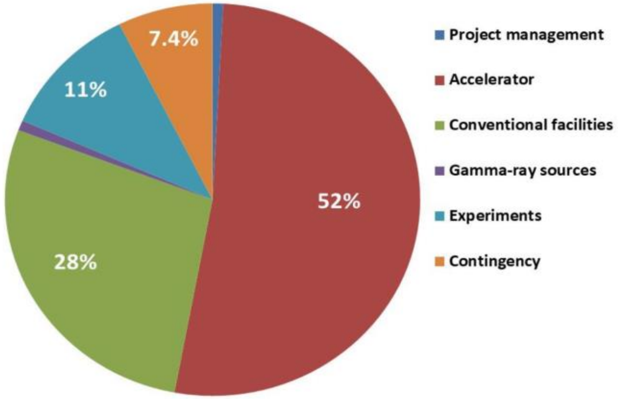
arXiv:2312.14363
1114 authors
278 institutes
(159 foreign institutes)
38 countries

The CEPC Study Group
December 2023

Distribution of CEPC Project **TDR cost** of **36.4B RMB (~4.7B Euro)**

Table 12.1.2: CEPC project cost breakdown, (Unit: 100,000,000 yuan)

Total	364	100%
Project management	3	0.8%
Accelerator	190	52%
Conventional facilities	101	28%
Gamma-ray beam lines	3	0.8%
Experiments	40	11%
Contingency (8%)	27	7.4%



Global HEP Consensus on Higgs Factories

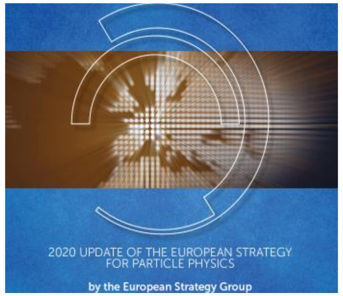
The scientific importance and strategical value of e^+e^- Higgs factories is clearly identified.

China

2013, 2016: *China Xiangshan Science Conference concluded that* ***CEPC is the best approach*** *and a major historical opportunity for the national development of accelerator-based high-energy physics program.*

JAHEP Japan

2017: *Japan Association of High Energy Physicists (JAHEP) proposes to construct* ***A 250 GeV center of mass ILC promptly as a Higgs factory.***



Europe

2020: *European Strategy for Particle Physics,* ***An electron-positron Higgs factory is the highest priority next collider.*** *For the longer term, the European particle physics community has the ambition to operate a proton-proton collider at the highest achievable energy.*

ICFA

2022, *ICFA "reconfirmed the international consensus on the importance of* ***a Higgs factory as the highest priority for realizing the scientific goals of particle physics****", and expressed support for the above-mentioned Higgs factory proposals*

Exploring the Quantum Universe

Pathways to Innovation and Discovery in Particle Physics

Report of the Particle Physics Project Prioritization Panel 2023

Exploring the Quantum Universe

Recommendation 6

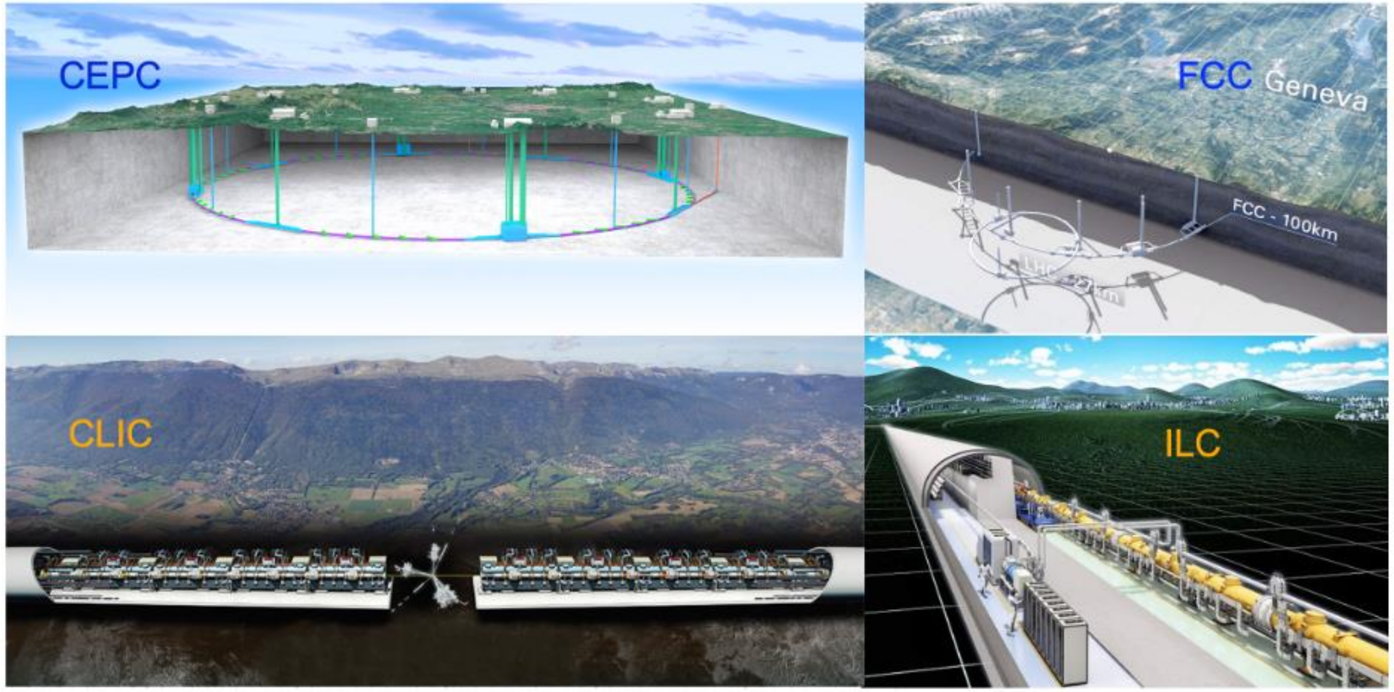
Convene a targeted panel with broad membership across particle physics later this decade that makes decisions on the US accelerator-based program at the time when major decisions concerning an off-shore Higgs factory are expected, and/or significant adjustments within the accelerator-based R&D portfolio are likely to be needed. A plan for the Fermilab accelerator complex consistent with the long-term vision in this report should also be reviewed.

The panel would consider the following:

1. The level and nature of US contribution in a specific Higgs factory including an evaluation of the associated schedule, budget, and risks once crucial information becomes available.
2. Mid- and large-scale test and demonstrator facilities in the accelerator and collider R&D portfolios.
3. A plan for the evolution of the Fermilab accelerator complex consistent with the longterm vision in this report, which may commence construction in the event of a more favorable budget situation.

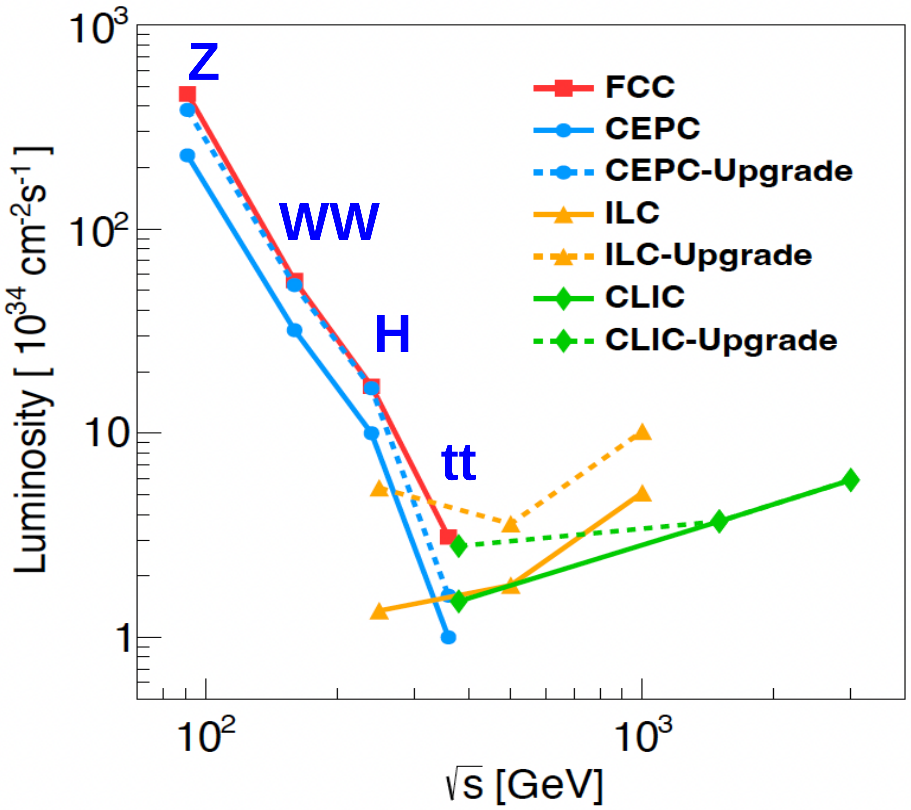
P5 report, USA, 2023

Comparison of Higgs factories: Circular vs Linear



CEPC has strong advantages among mature e^+e^- Higgs factories (design report delivered)

CEPC Accelerator white paper for Snowmass21, arXiv:2203.09451



Versus FCC-ee

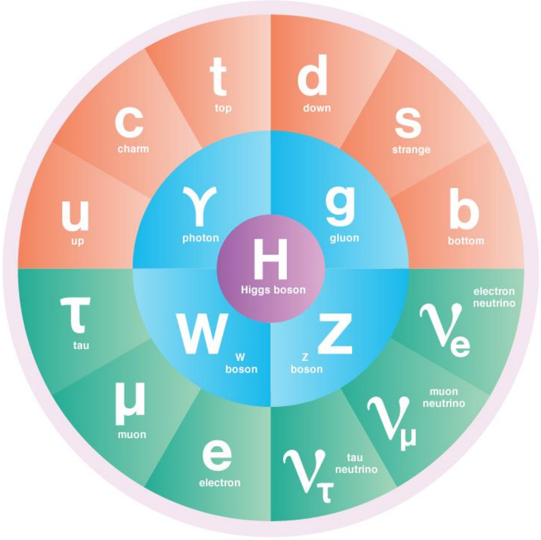
- Earlier data: collisions expected in 2030s (vs. ~ 2040s)
- Large tunnel cross section (ee & pp coexistence)
- Lower construction cost

Versus Linear Colliders

- Higher luminosity / precision for Higgs & Z
- Potential upgrade for pp collider

CEPC Physics Program

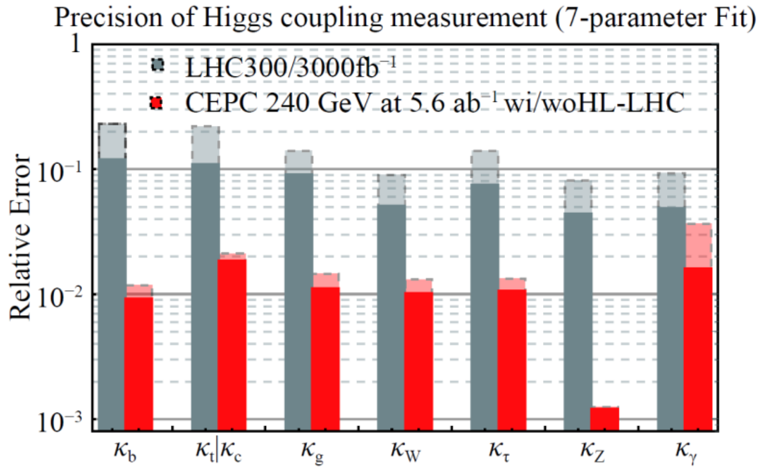
- ➢ **All elementary particles in the SM are discovered, it's a very successful theory. But we still have many open questions to be addressed:**
  - **Is mass hierarchy of elementary particles normal ?**
  - **Is fine tuning of Higgs mass natural ?**
  - **Why a meta-stable vacuum ?**
  - **What are the dark matter particles ?**
  - **Unification of interaction at very high energy ?**
  - **…**



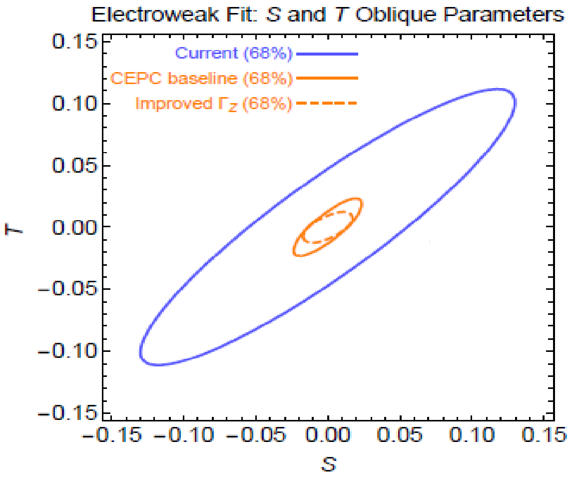
- ➢ **Higgs is considered as a new tool to explore physics beyond the SM.**
- ➢ **CEPC can produce millions of Higgs bosons and trillions of Z bosons with "clean" e+e- collision, it can provide unprecedented precision on Higgs, EW, QCD and flavor physics, and probe new physics up to 10 TeV.**

CEPC Physics Program: Precision Measurement

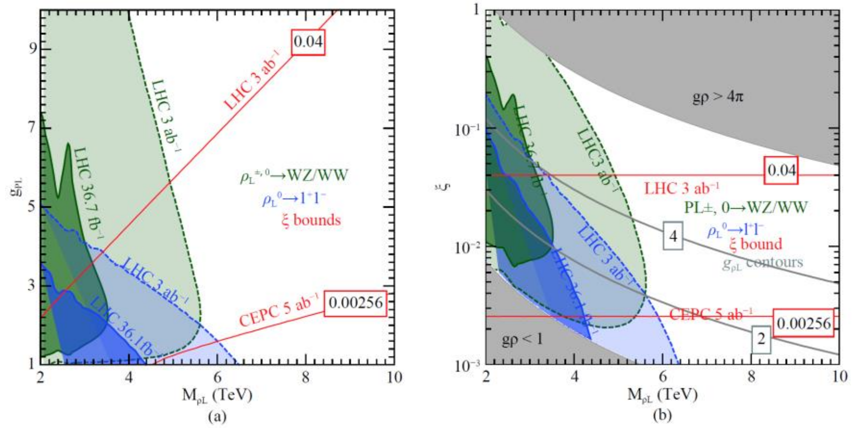
Higgs coupling precision can be improved by an order of magnititude

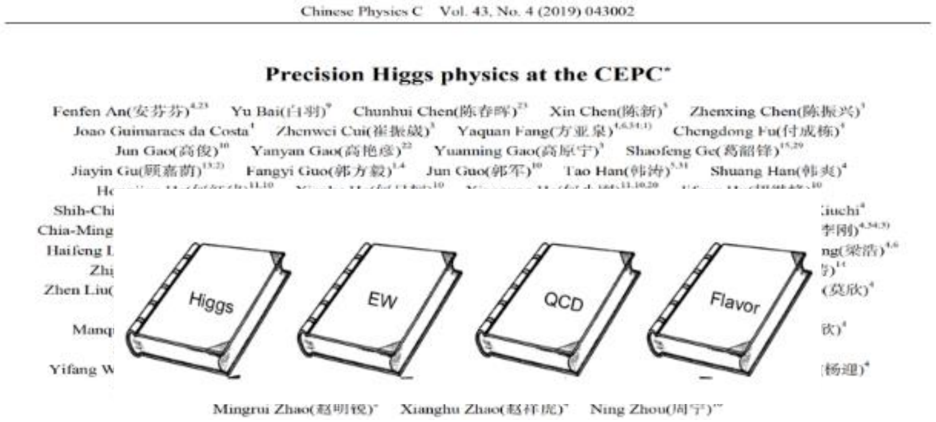


EW measurement can be improved by a large factor



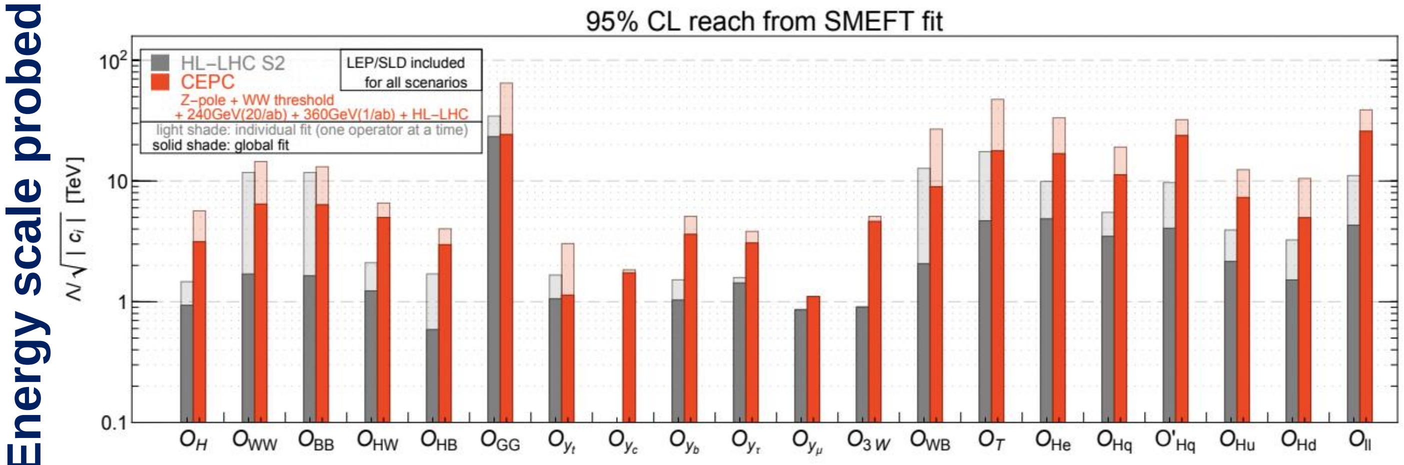
Direct and indirect probe to new physics up to 10 TeV, an order of magntitude higher than the HL-LHC




Chinese Physics C Vol. 43, No. 4 (2019) 043002

Precision Higgs physics at the CEPC*

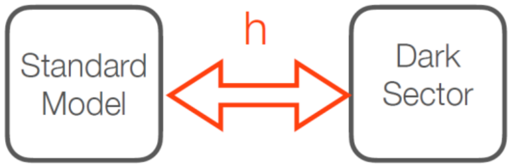
Chinese Physics C Vol. 43, No. 4 (2019) 043002



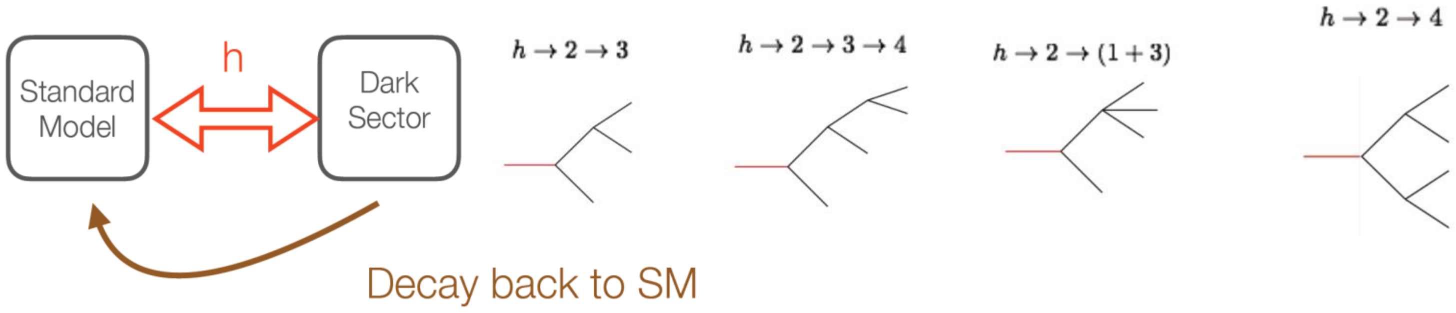
❖ ~ 300 Journal / arXiv papers

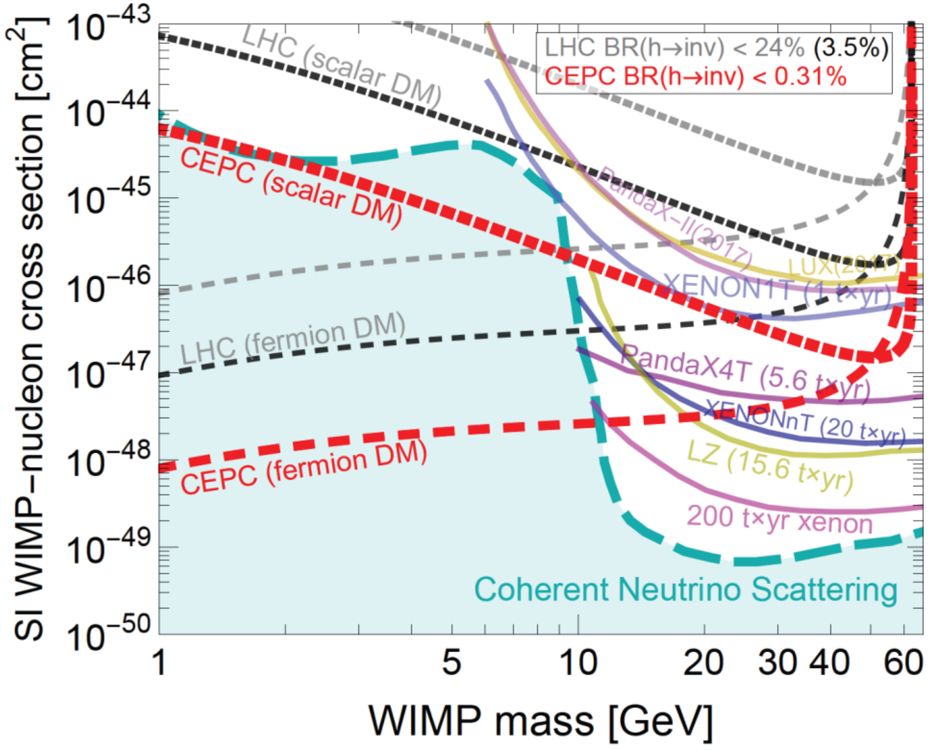
CEPC can reveal new physics at energy ~ 10 TeV or higher

CEPC Physics Program: Discovery Potential

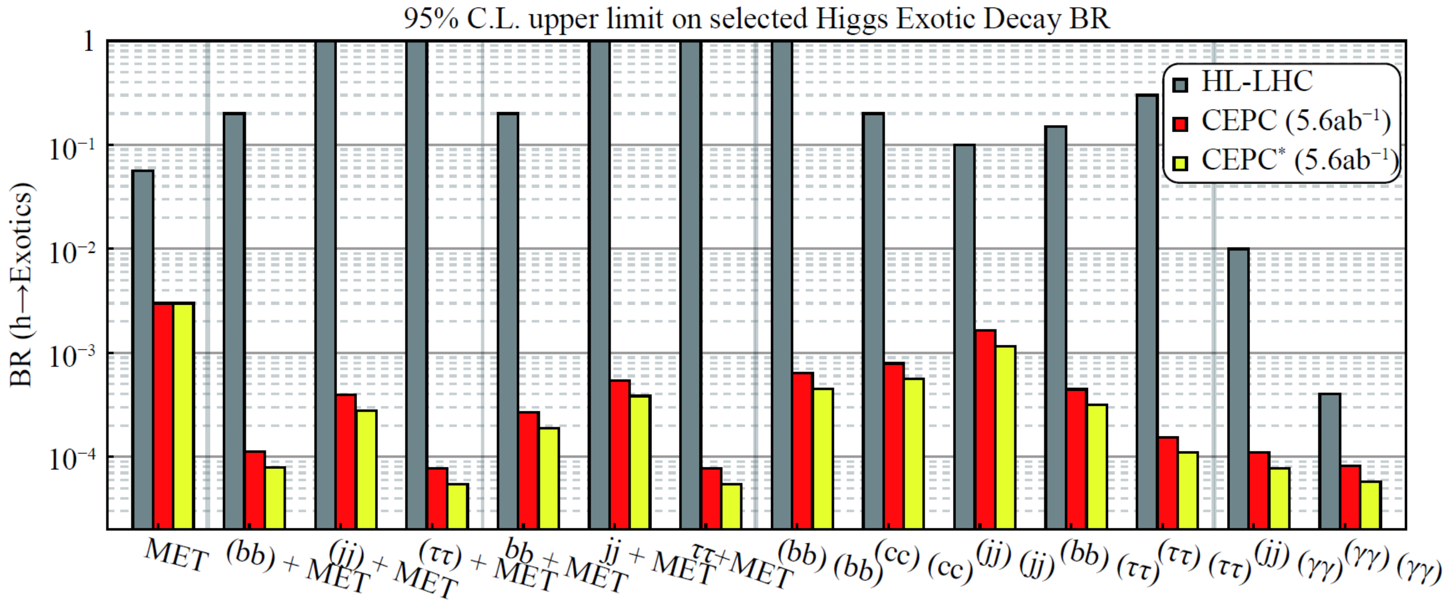


$$h \rightarrow X_{dm} X_{dm}$$





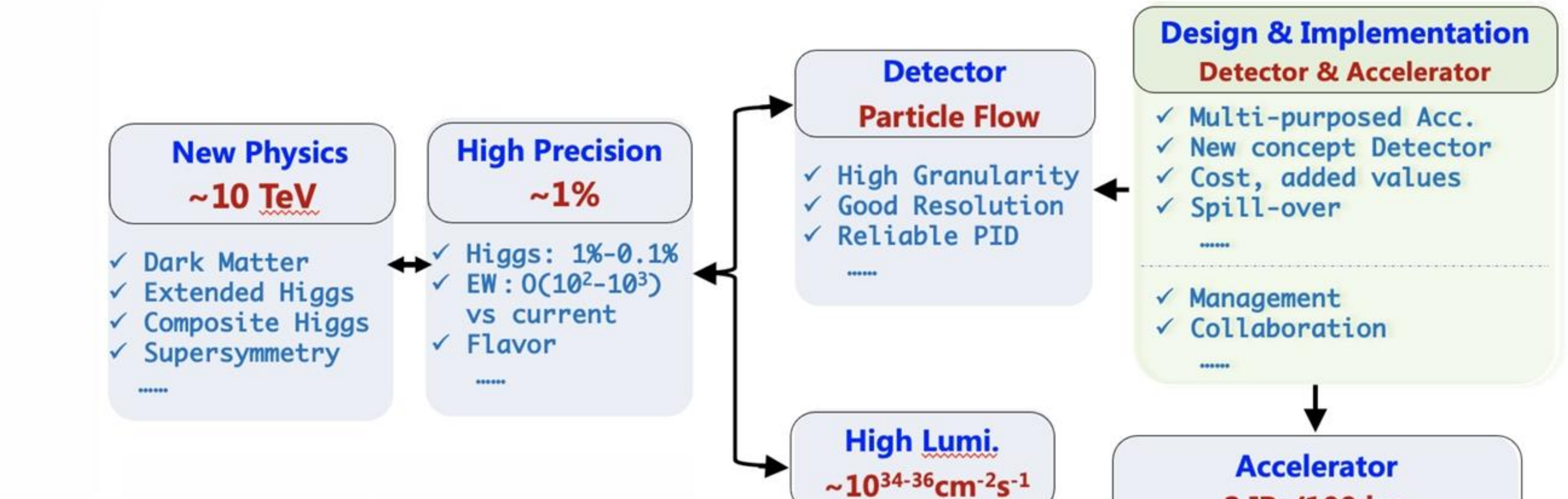
Higgs decays into BSM particles, H→ X_1X_2



Zhijun Liang's talk

CEPC has significantly better detection sensitivity for dark matter and selected Higgs exotic decays than HL-LHC

CEPC Key Scientific Issues and Technologies Route

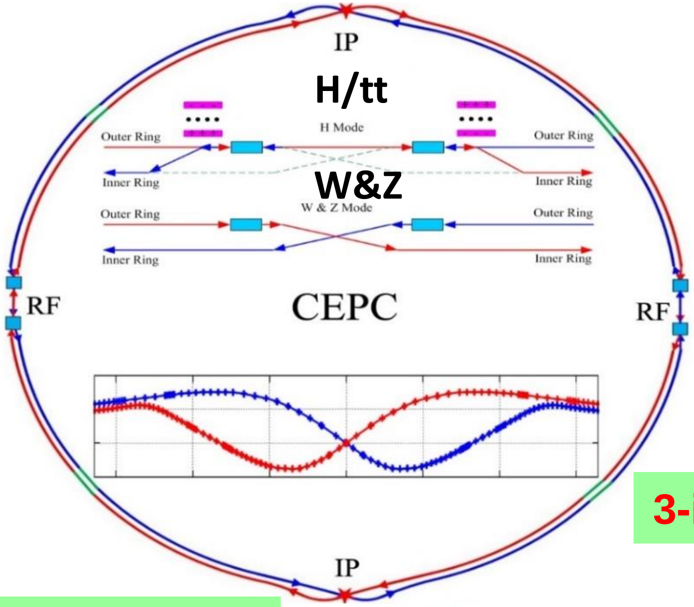


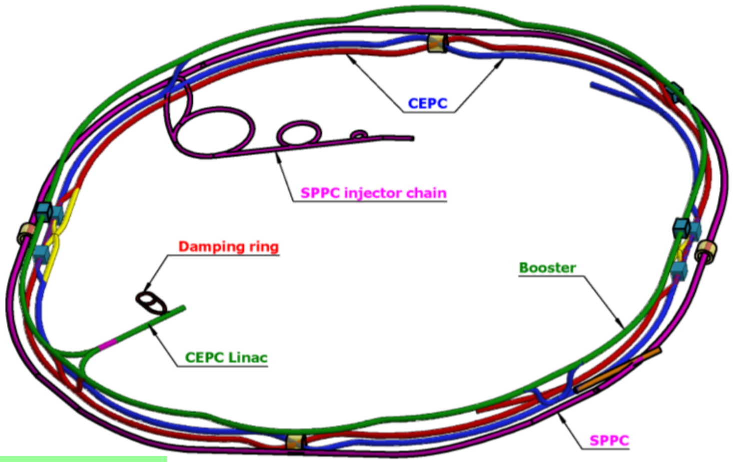
Operation mode	Z	W	Higgs
Center-of-mass energy (GeV)	91	160	240
Operation time (year)	2	1	10
Instantaneous luminosity/IP (10^{34}cm$^{-2}s^{-1}$)	115	16.0	5.0
Integrated luminosity (ab^{-1}, 2 IPs)	60	3.6	12
Event yield (30 MW)	2.5×10^{12}	1.0×10^{8}	2.5×10^{6}
Event yield (50 MW)	4.0×10^{12}	1.6×10^{8}	4.0×10^{6}

CEPC Accelerator Design and Layout

- 100 km double ring design (30 MW SR, upgradable to 50MW, ttbar)
- Switchable operation for H, Z, W and top modes
- Shared tunnel: compatible design for booster, CEPC and SppC

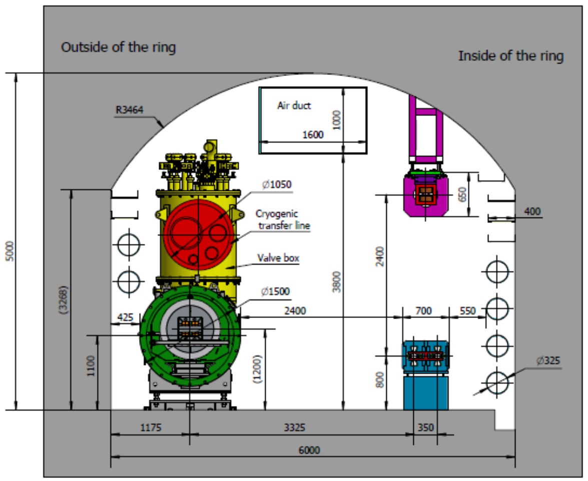
Yuhui Li's talk



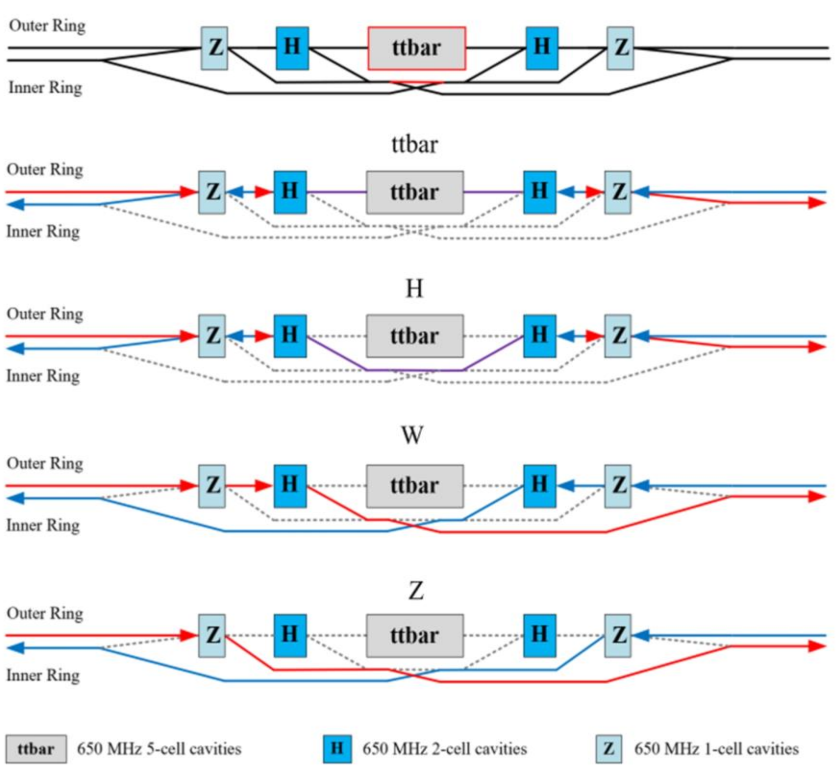


3-in-1 tunnel

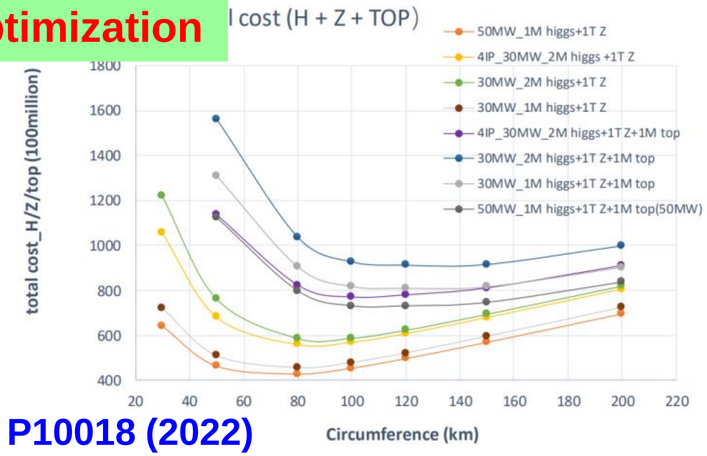
TUNNEL CROSS SECTION OF THE ARC AREA



H/W/Z/tt switching operation scheme



Cost optimization



JINST 17 P10018 (2022)

arXiv:2312.14363

CEPC Operation Plan

Mode	$E_{c.m.}$ (GeV)	Years	SR Power (MW)	Lumi. per IP ($10^{34}cm^{-2}s^{-1}$)	Integrated Lumi. per year (ab^{-1}, 2 IPs)	Total Integrated Lumi (ab^{-1}, 2 IPs)	Total Events
H*	240	10	50	8.3	2.2	21.6	4.3×10^6
			30	5	1.3	13	2.6×10^6
Z	91	2	50	192**	50	100	4.1×10^{12}
			30	115**	30	60	2.5×10^{12}
W	160	1	50	26.7	6.9	6.9	2.1×10^8
			30	16	4.2	4.2	1.3×10^8
$t\bar{t}$	360	5	50	0.8	0.2	1.0	0.6×10^6
			30	0.5	0.13	0.65	0.4×10^6

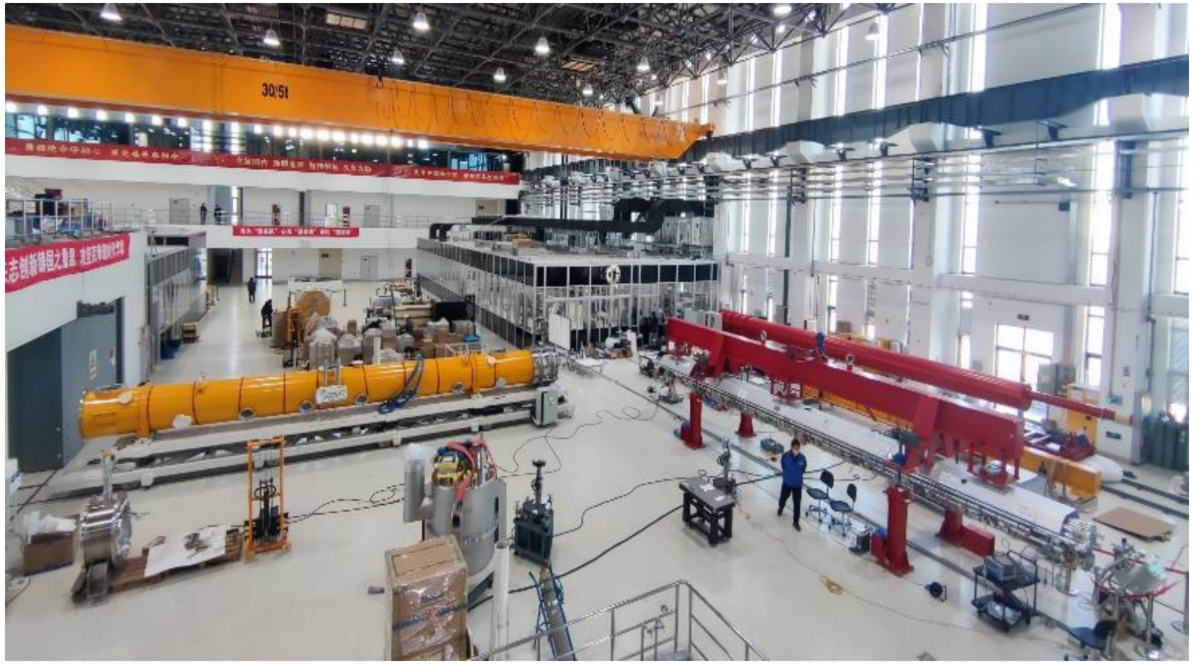
* Higgs is the top priority, the CEPC will commence its operation with a focus on Higgs.

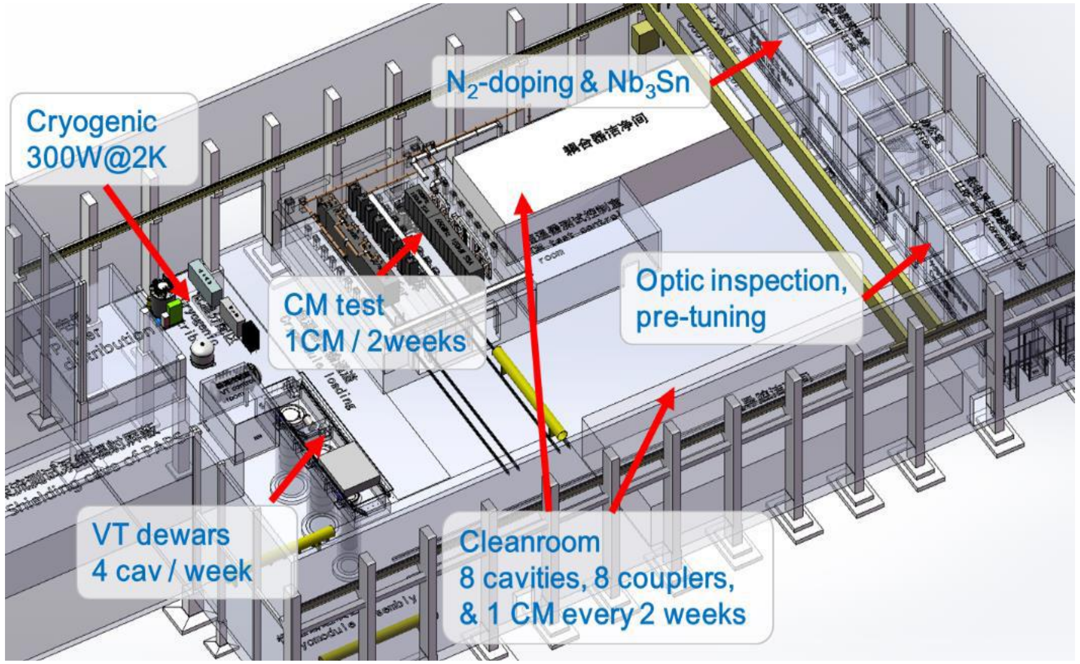
** Detector solenoid field is 2 Tesla during Z operation, 3 Tesla for all other energies.

*** Calculated using 3,600 hours per year for data collection (~250 days with 60% efficiency).

A New Lab: CEPC SRF Test Facility (PAPS)

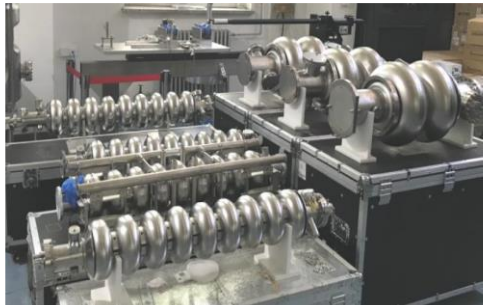
- New Lab (4500m^2) at Huairou Beijing, next to HEPS
- A cryogenic system: 2.5KW@4.5K or 300W@2K
- Ovens and clean rooms for cavity production
- 2 horizontal and 3 vertical SRF test stands
- About 200 SRF cavities / year
- Testing of klystrons, electron guns, magnets, etc.,
- NEG coating of vacuum pipes, ATF in the future





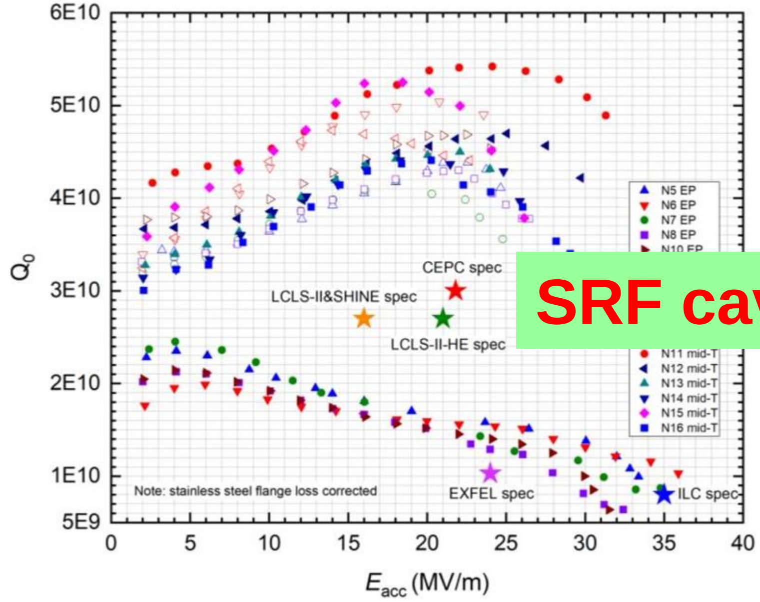
CEPC R&D: High Q SRF Cavities

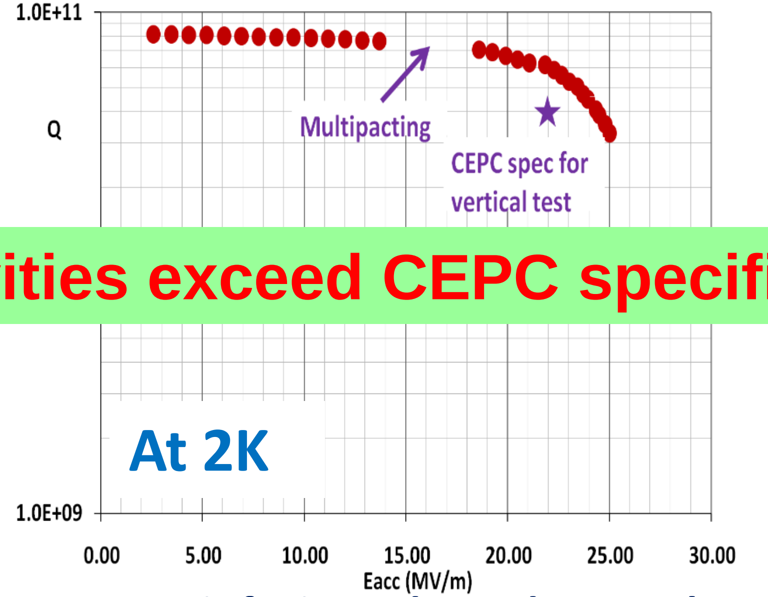
- 1.3 GHz 9-cell SRF cavity for booster: Q_0 = 3.4E10 @ 26.5 MV/m
- 650 MHz 2-cell SRF cavity for collider ring: Q_0 = 6.0E10 @ 22.0 MV/m
- 650 MHz 1-cell SRF cavity for collider ring: Q_0 = 6.0E10 @ 31.0 MV/m

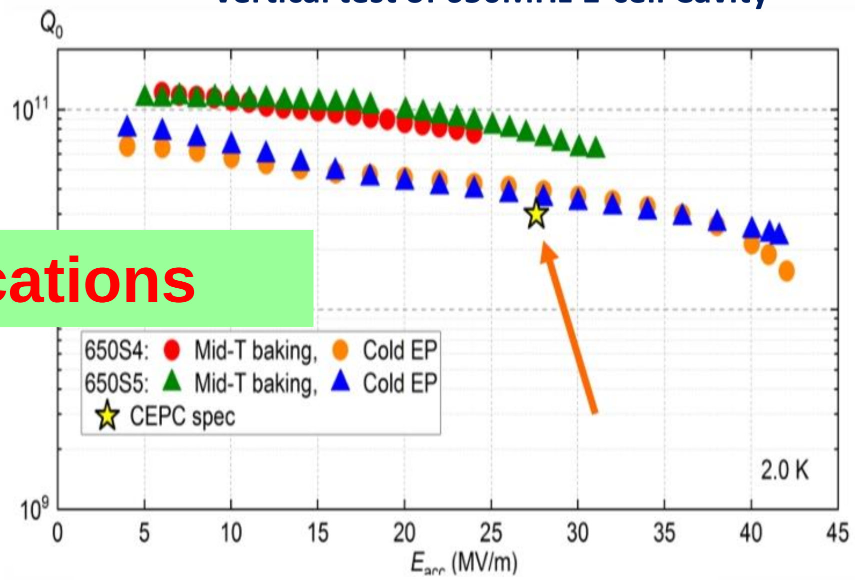


Vertical test of 650 MHz 2-cell cavity

Vertical test of 650MHz 1-cell Cavity







SRF cavities exceed CEPC specifications

Medium-temperature (Mid-T) annealing adopted to reach Q_0 = 3.4E10 @ 26.5 MV/m

N-infusion adopted to reach Q_0 = 6.0E10 @ 22.0 MV/m

Cold-EP and Mid-T baking Q_0 = 6.0E10 @ 31 MV/m

CEPC R&D: 8 × 9-cell High Q Cryomodule

CEPC Booster 1.3 GHz SRF R&D and industrialization in synergy with CW FEL projects

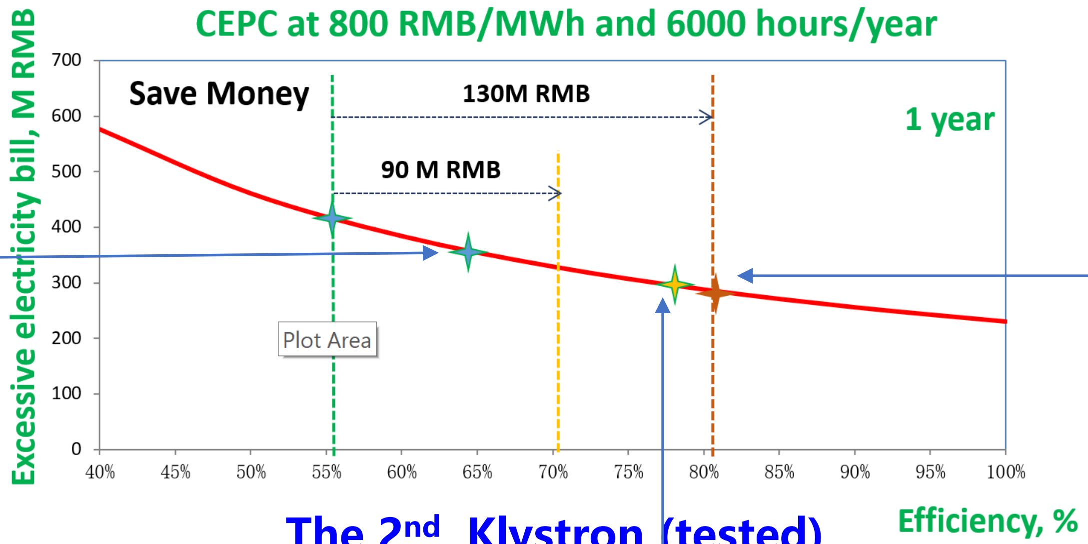
Parameters	Horizontal test results	CEPC Booster Higgs Spec	LCLS-II, SHINE Spec	LCLS-II-HE Spec
Average usable CW E_{acc} (MV/m)	23.1	3.0×10^{10} @ 21.8 MV/m	2.7×10^{10} @ 16 MV/m	2.7×10^{10} @ 20.8 MV/m
Average Q_0 @ 21.8 MV/m	3.4×10^{10}			

SRF cavities exceed CEPC specifications

CEPC R&D: High Efficiency Klystrons

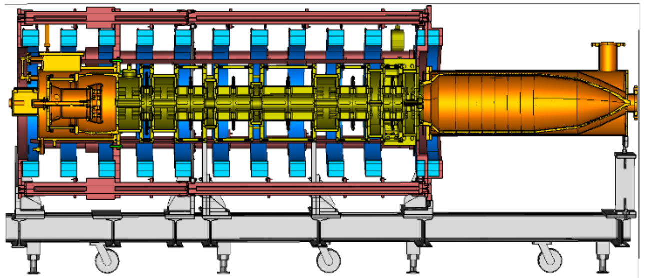
- The 1st Klystron prototype, achieved efficiency ~ 62%
- The 2nd Klystron prototype was tested in Feb. 2024, achieved efficiency ~ 77.2%
- The 3rd Klystron prototype (MBK) with manufacture underway, design efficiency is ~ 80%
- High efficiency Klystron helps to reduce electricity consumption

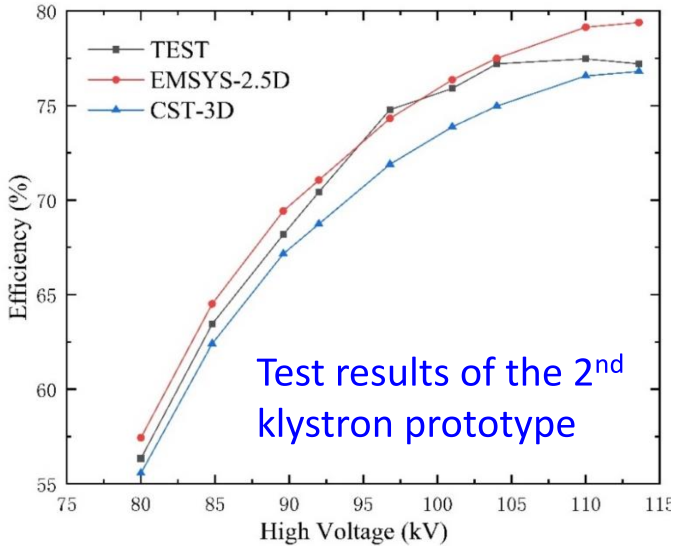
The 1st Klystron (tested)



The 2nd Klystron (tested)

The 3rd multi-beam Klystron (MBK) under fabrication

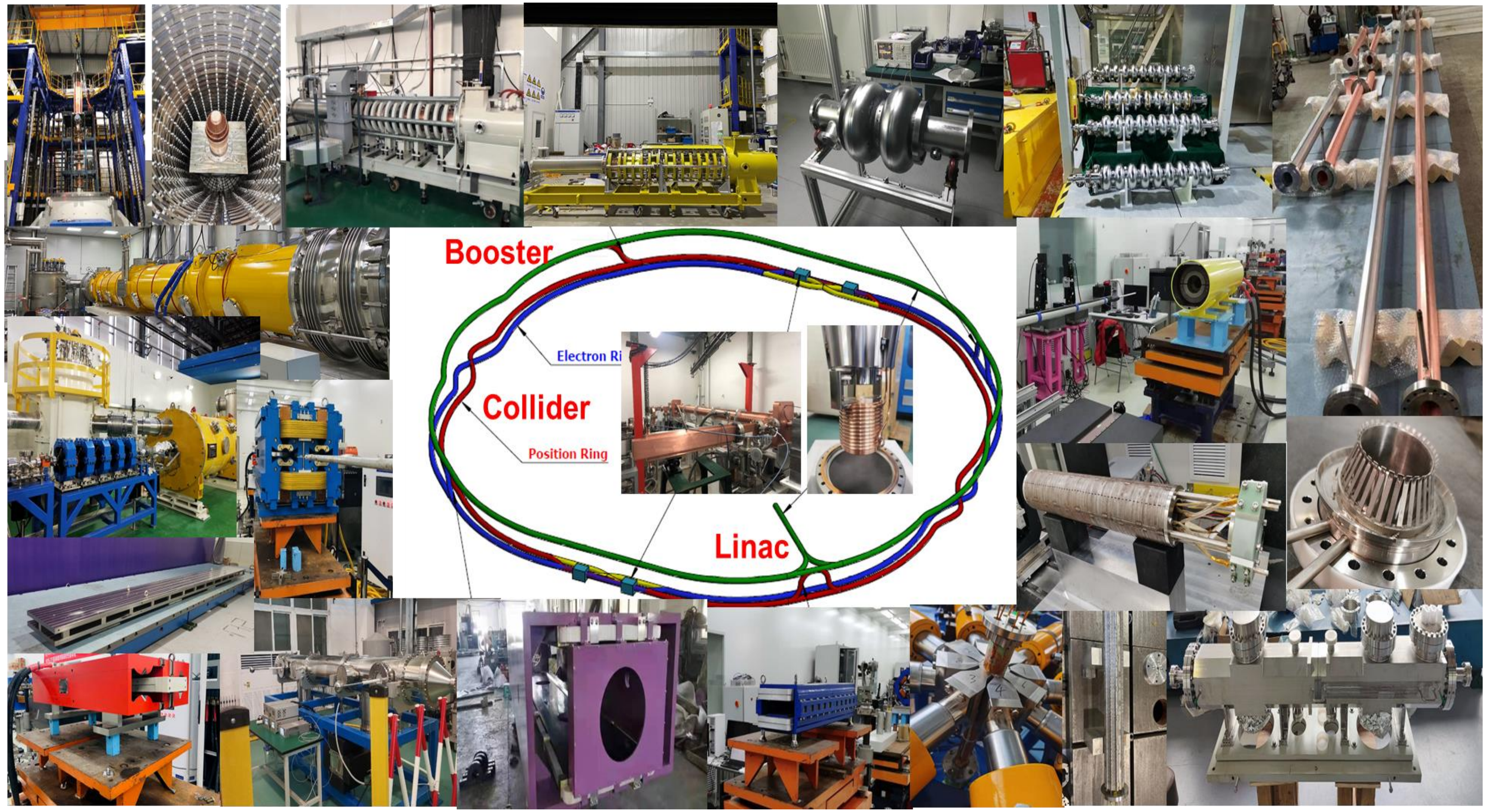




Test results of the 2nd klystron prototype

CEPC R&D: Accelerator Key Technologies

- CEPC accelerator key technologies R&D in TDR covers all component listed in the CDR.
- About 10% remaining (e.g. RF power source, machine integration, control, alignment) to be completed by 2026.

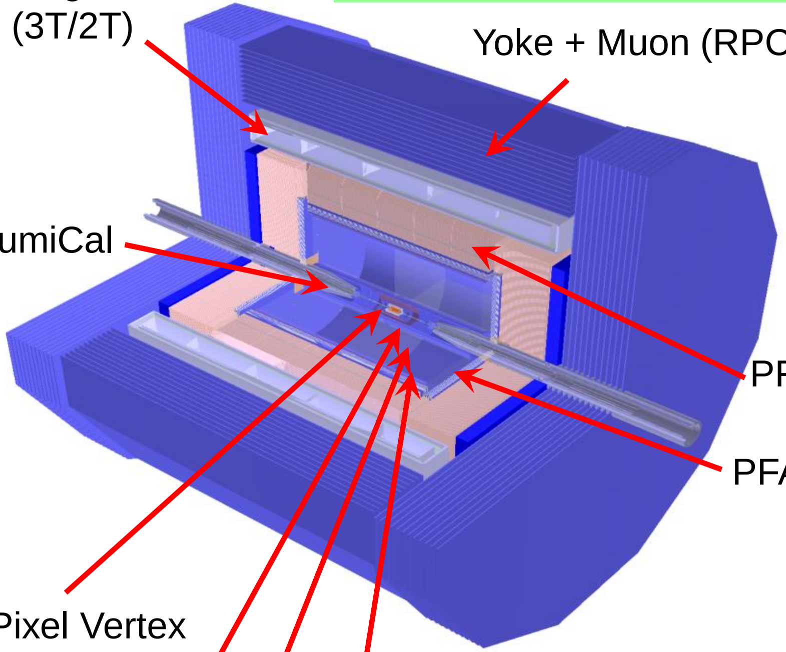


✓ Specification Met — ☑ Prototype Manufactured

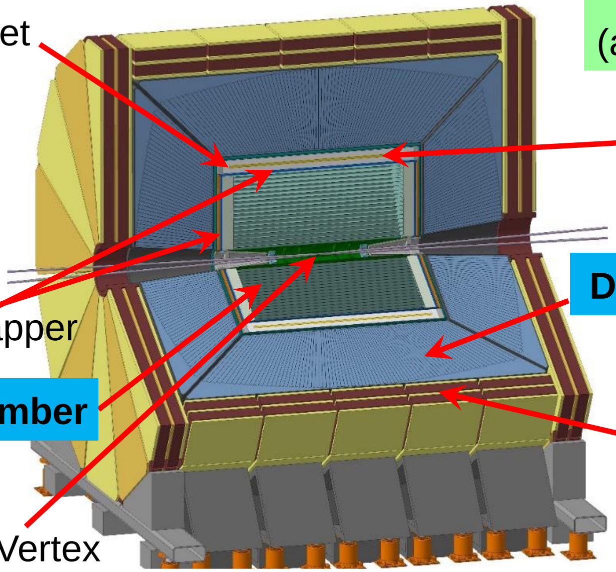
	Accelerator	Ratio
Specification Met	Magnets	27.3%
Specification Met	Vacuum	18.3%
Prototype Manufactured	RF power source	9.1%
Specification Met	Mechanics	7.6%
Specification Met	Magnet power supplies	7.0%
Specification Met	SC RF	7.1%
Specification Met	Cryogenics	6.5%
Specification Met	Linac and sources	5.5%
Specification Met	Instrumentation	5.3%
Prototype Manufactured	Control	2.4%
Prototype Manufactured	Survey and alignment	2.4%
Specification Met	Radiation protection	1.0%
Prototype Manufactured	SC magnets	0.4%
Specification Met	Damping ring	0.2%

CEPC Conceptual Detector Designs

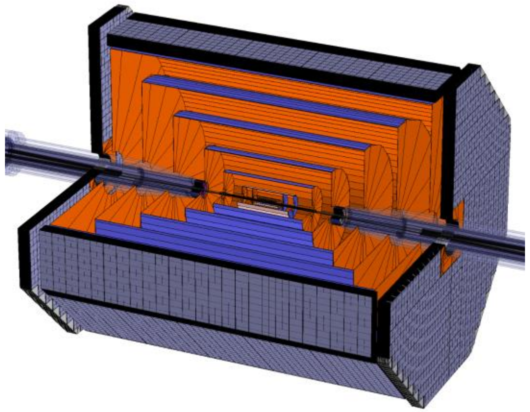
(Baseline Design)
Particle Flow Approach



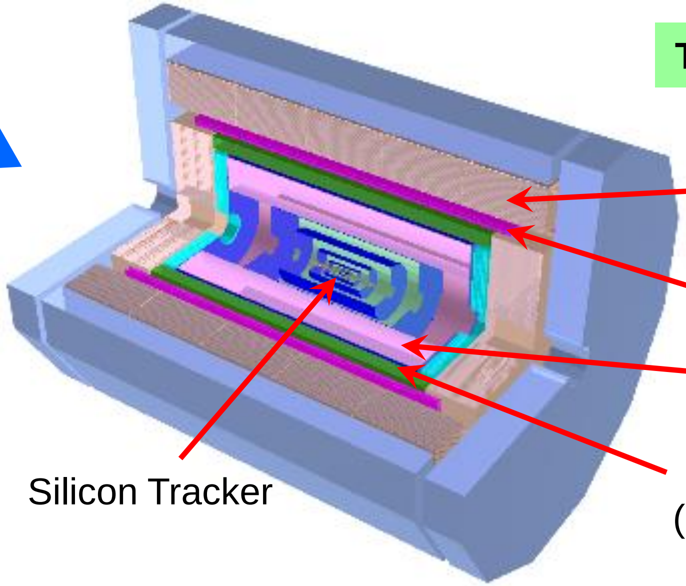
IDEA concept
(also proposed for FCC-ee)



FST concept
(Full Silicon Tracker)



The 4th Concept

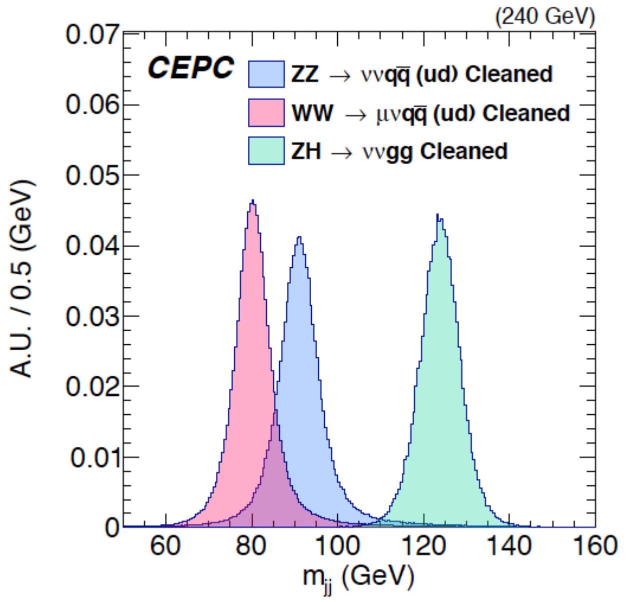


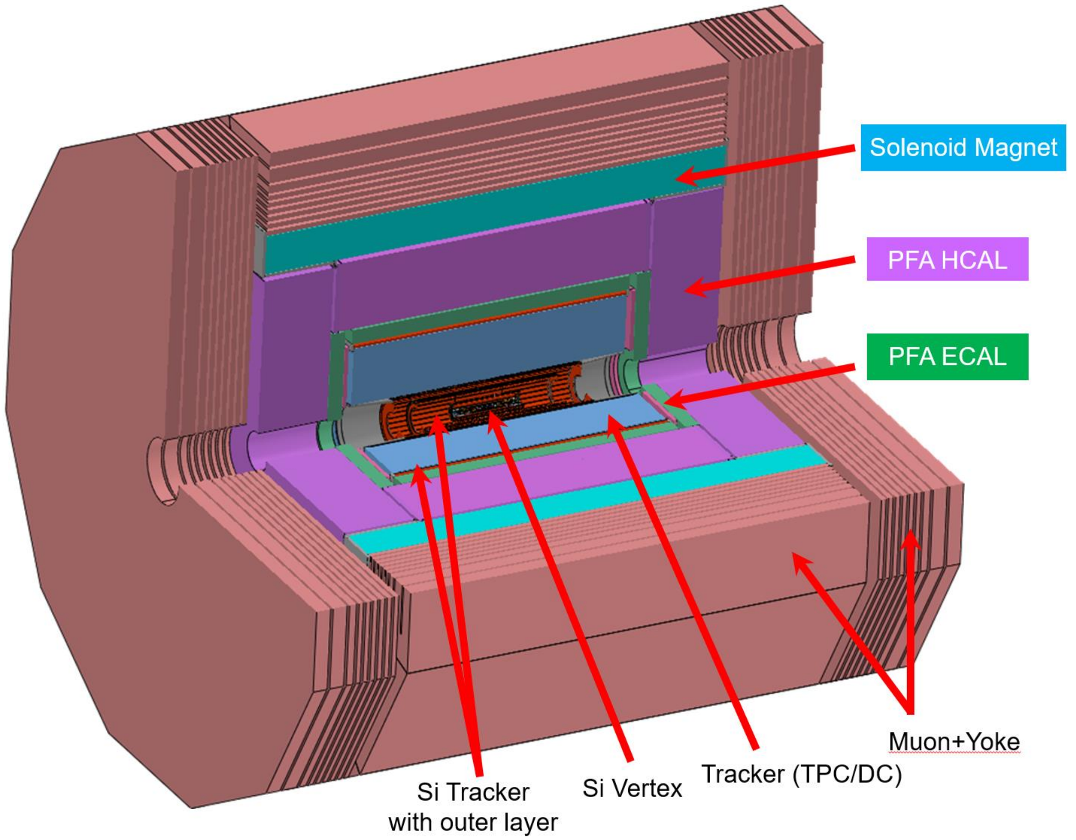
Idea of the "4th Concept"

Zhijun Liang's talk

Novel detector design based on PFA calorimeter. Aim at improving BMR from 4% to 3%

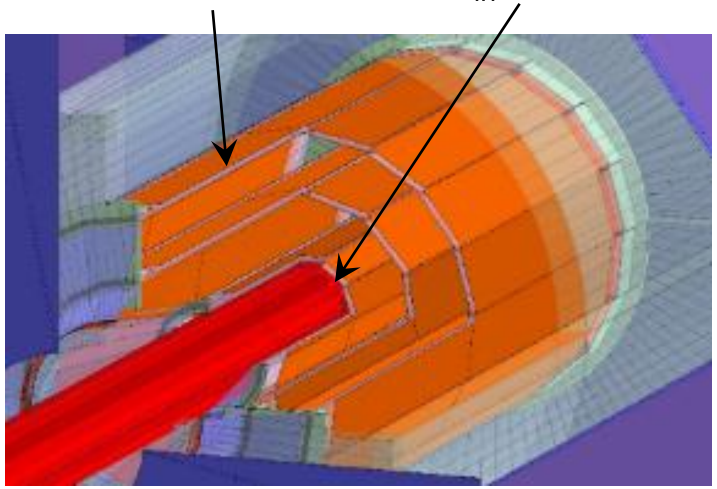
Detector	World-class level	4th concept
PFA based (ECAL)	~ 20% / √E	< 3% / √E
PFA based (HCAL)	~ 50% / √E	~ 40% / √E





- Silicon combined with TPC or DC for better tracking & PID
- Crystal ECAL with timing for PFA and better EM resolution
- Scintillating glass HCAL for better sampling and resolution

CEPC R&D: Silicon Pixel Chips



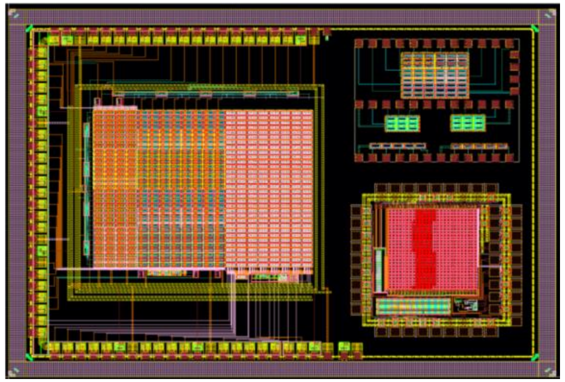
Goal: σ(IP) ~ 5 μm for high P track

CDR design specifications

- **Single point resolution ~ 3μm**
- **Low material (0.15% X_0 / layer)**
- **Low power (< 50 mW/cm^2)**
- **Radiation hard (1 Mrad/year)**

Silicon pixel sensor develops in 5 series: JadePix, TaichuPix, CPV, Arcadia, COFFEE

Develop **COFFEE** for a CEPC tracker using SMIC 55nm HV-CMOS process

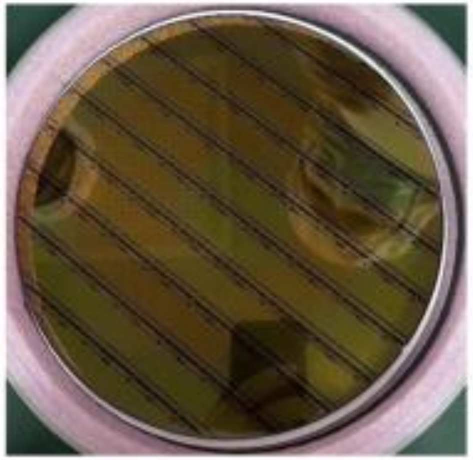


JadePix-3 Pixel size ~16×23 μm^2

Tower-Jazz 180nm CiS process
Resolution 5 microns, 53mW/cm^2

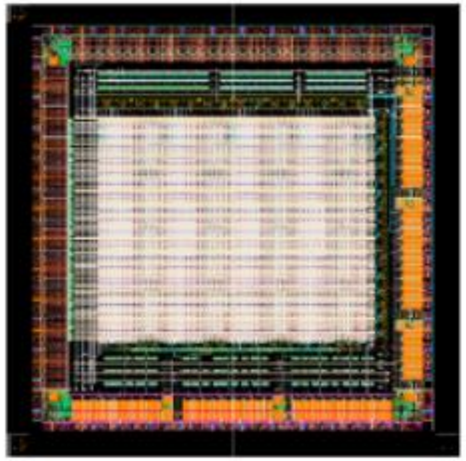
MOST 1

TaichuPix-3, FS 2.5x1.5 cm^2
25×25 μm^2 pixel size

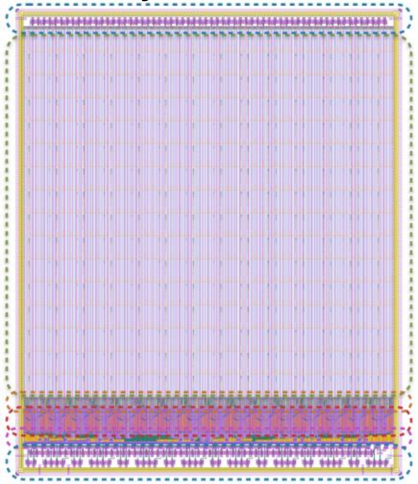


MOST 2

CPV4 (SOI-3D), 64×64 array
~21×17 μm^2 pixel size



Arcadia by Italian groups
for IDEA vertex detector
LFoundry 110 nm CMOS



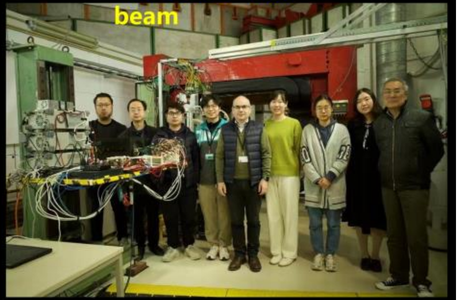
CEPC Detector R&D: Silicon, TPC, DC Prototypes

Test beam @ DESY

- 2^{nd} testbeam: April 11-23 2023 DESY test beam in Germany (4-6 GeV electron)
  - Vertex detector prototype testbeam
- 1^{st} testbeam: Dec 12-22 2022 DESY test beam in Germany (4-6 GeV electron)
  - TaichuPix Beam Telescope testbeam

2022 DESY test beam

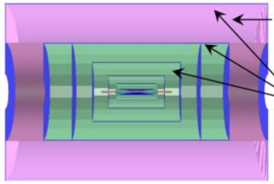
2023 DESY test beam

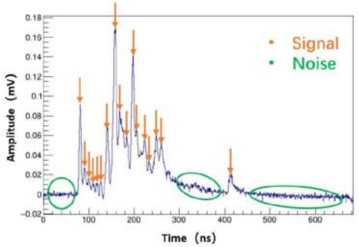


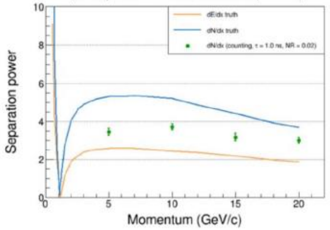
Excellent collaboration with DESY testbeam team

13

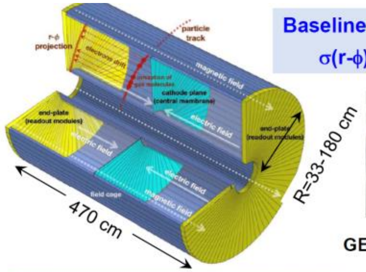
- **Goal: 3σ π/K separation up to ~20 GeV/c.**
- Cluster counting method, or **dN/dx**, measures the number of primary ionization
- **Can be optimized specifically for PID**: larger cell size, no stereo layers, different gas mixture.
- Garfield++ for simulation, realistic electronics, peak finding algorithm development.



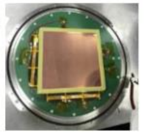




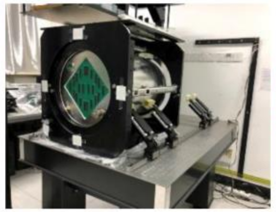
IHEP and Italian INFN groups have close collaboration and regular meetings.
IHEP joined the TB (led by INFN group) in 2021 and 2022



Baseline main tracker
σ(r-ϕ) ~100 μm



GEM-MM cathode



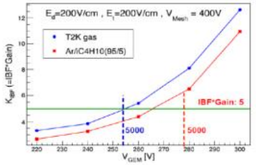
TPC Prototype + UV laser beams

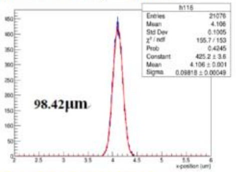
MOST 1 (IHEP+THU)

Low power FEE ASIC

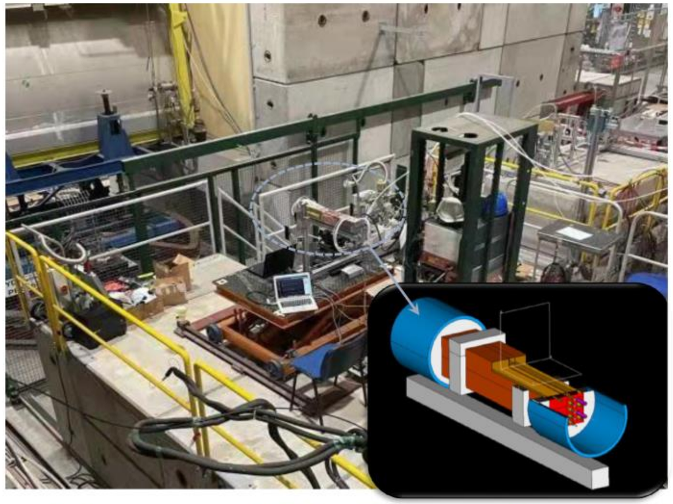
Test of Prototype TPC

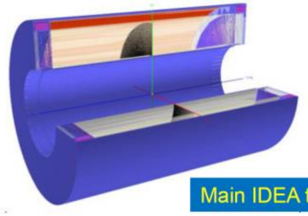
- Challenge: Ion backflow (IBF) affects the resolution. It can be corrected by a laser calibration at low luminosity, but difficult at high luminosity Z-pole.





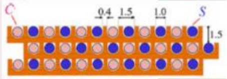
σ_x < 100 μm for drift length of 27cm

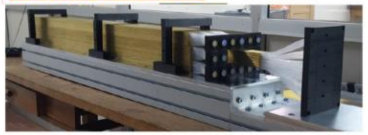




Main IDEA tracker

Dual Readout CAL

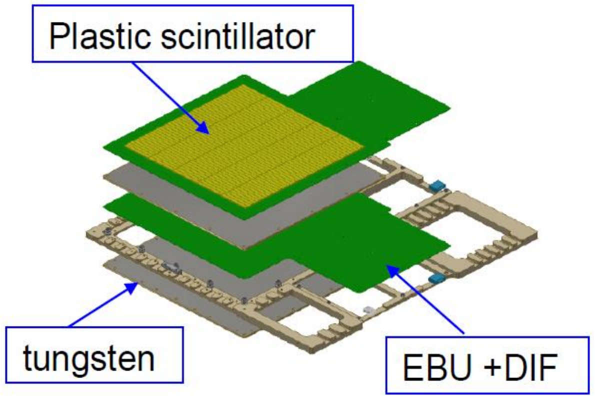


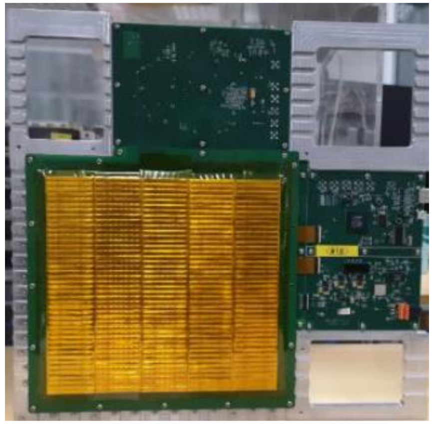


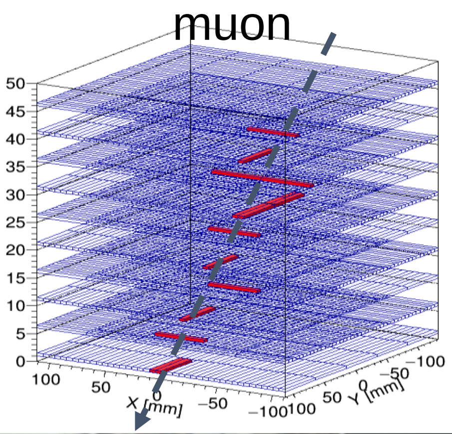
Italian groups and IHEP colleagues participated the test beam at CERN.

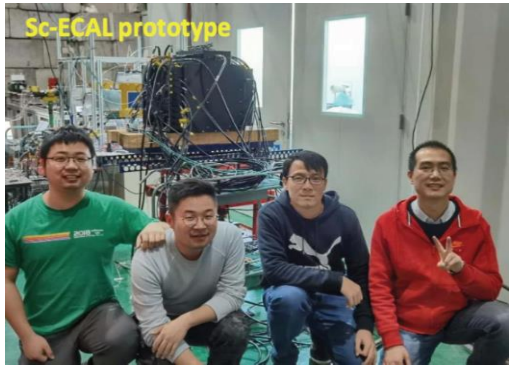
CEPC R&D: PFA Calorimeter Prototypes

ScW ECAL Prototype (32-layer, 6720-ch)

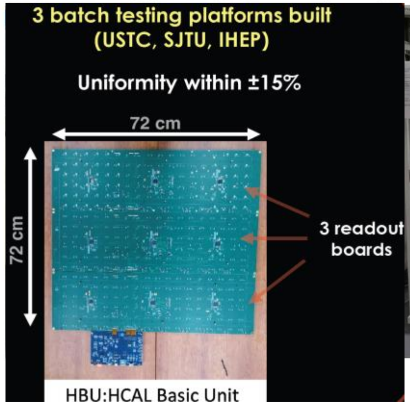


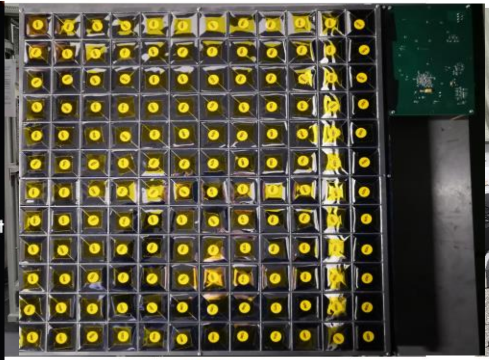






Scintillator + SiPM AHCAL Prototype (40-layer, 12960-ch)

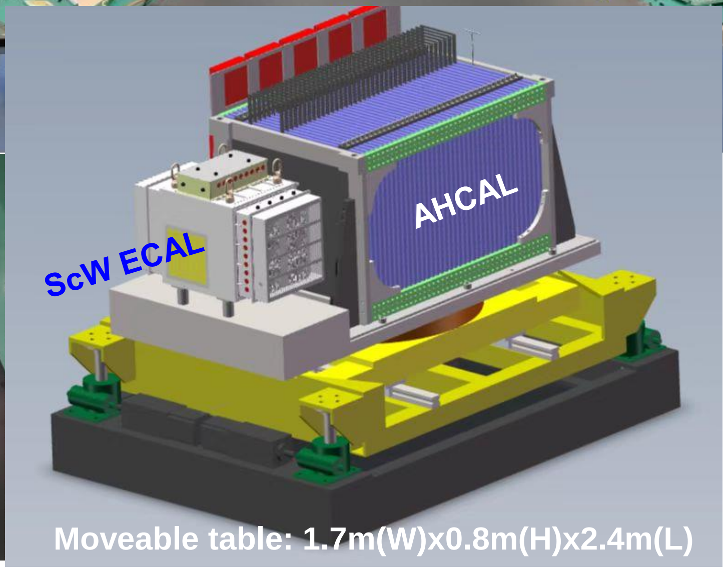




SJTU

IHEP

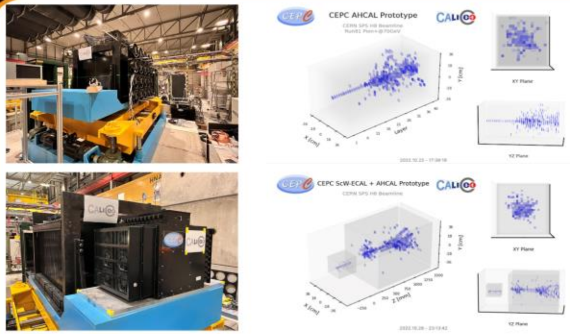
Combined: ScW-ECAL + AHCAL

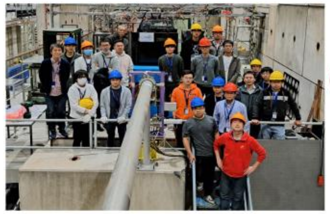


➔ Testbeam at CERN for two prototypes in 2022 and 2023

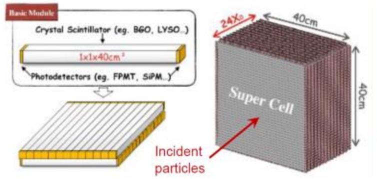
CEPC Detector R&D: Calorimeter Prototypes

CEPC calorimeter prototypes: beamtest in 2022



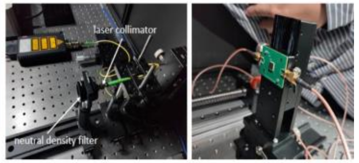


- Successful beamtest at CERN SPS H8: **Oct-Nov, 2022**
  - High energy particle beams: muons, positrons and hadrons (10 - 160 GeV)
  - Suffered from beam purity issue in pion and positron beams



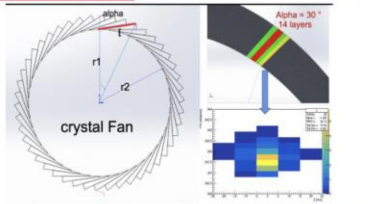
- Long bars: 1 x 40 cm, super-cell: 40x40 cm²
- Timing at both ends for positioning along bar.
- Significant reduction of number of channels.

Goal
- Boson Mass Resolution < 4%
- Better BMR than ScW-ECAL
- Much better sensitivity to γ/e, especially at low energy.



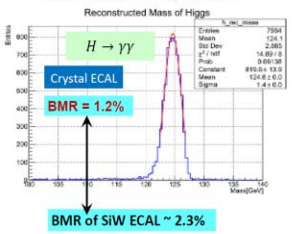
Bench Test

Crystal Fan Design Fine segmentation in Z, ϕ, r

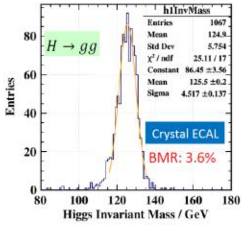


Full Simulation Studies + Optimizing PFA for crystals

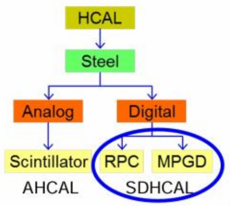
Performance with photons

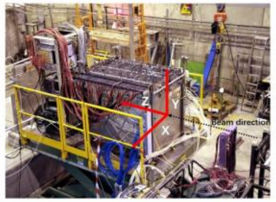


Performance with jets

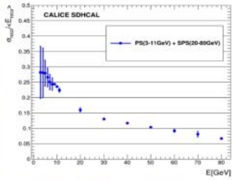


Dual readout crystal calorimeter also being considered by USA and Italian colleagues

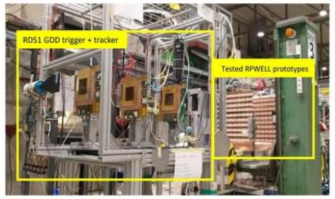




SDHCAL-GRPC (1.3 m³, IPNL)



JINST 15, P10009 (2020)
JINST 17, P07017 (2022)



RPWELL (50x50cm², WIS+IIT, Israel)

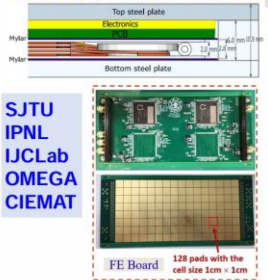
MOST 1: RPC and MPGD (RWELL) R&D, MIP Eff > 95%

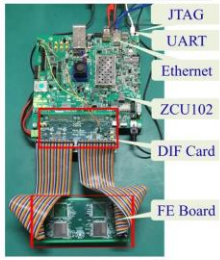
GRPC 1m x 1m (SJTU) RWELL 0.5m x 1m (USTC+IHEP)

JINST 16, P12022 (2021)

R&D Plan: 5-D SDHCAL (X, Y, Z, E, Time)
- MRPC + fast timing PETIROC ASIC (~40 ps)

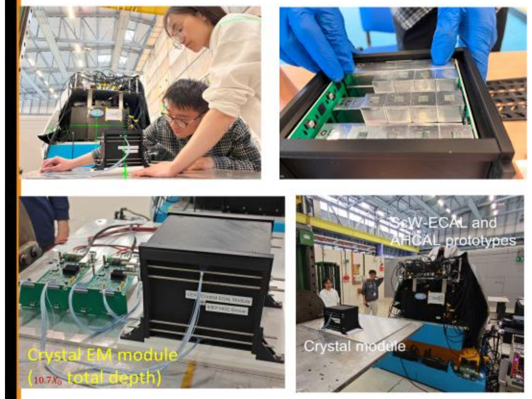
SJTU
IPNL
IJCLab
OMEGA
CIEMAT

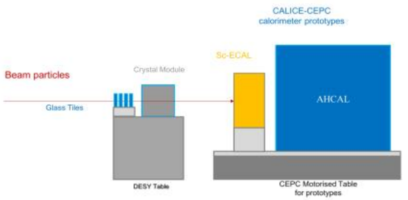




Crystal modules: beamtest at CERN in 2023

- Successful CERN beamtest: parasitic runs at PS-T9 (May 16-23, 2023)





- Achieved major goals
  - Commissioning of the first crystal module
  - Validation of simulation and digitization

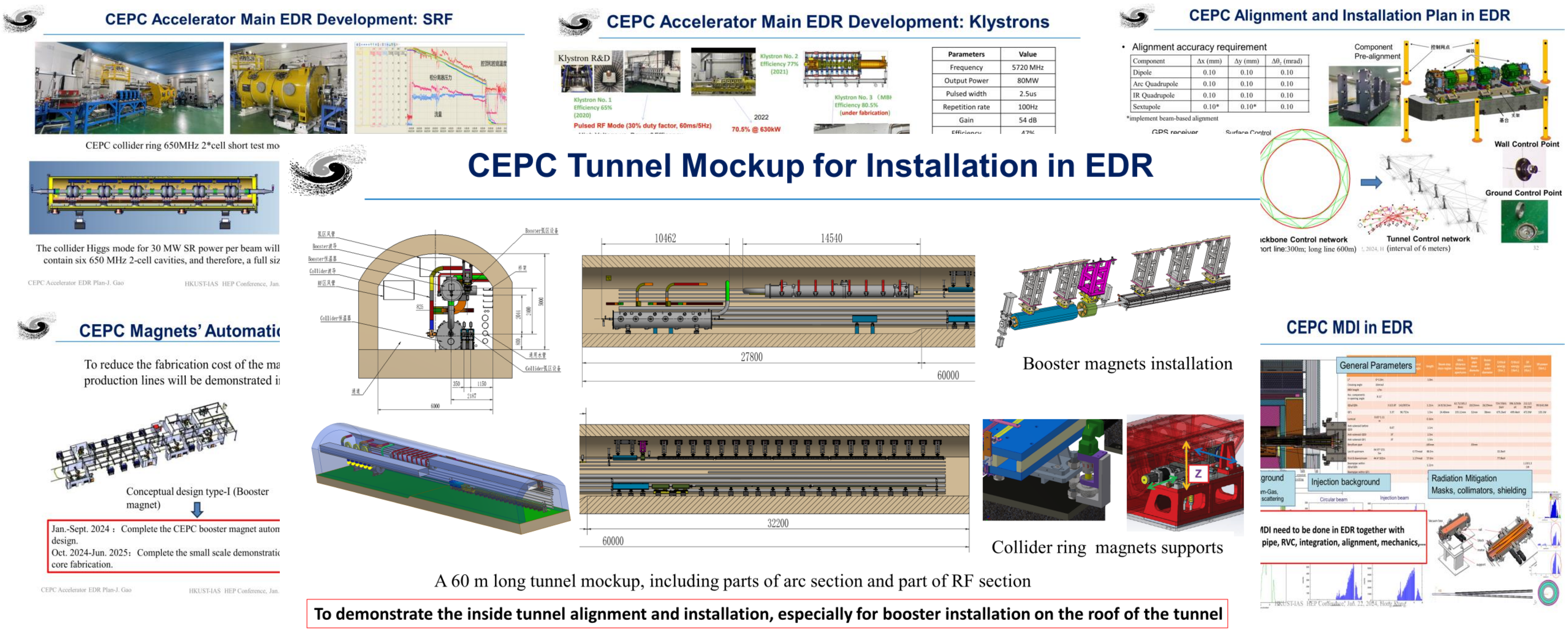
CEPC Reference Detector TDR

Det	Technology		Det	Technology
Pixel Vertex	JadePix		Calorimeter	Crystal ECAL
	TaichuPix			Stereo Crystal ECAL
	CPV(SOI)			Scint+W ECAL
	Stitching			Si+W ECAL
	Arcadia			Scint+Fe AHCAL
Tracker & PID	CEPCPix			ScintGlass AHCAL
	Silicon Strip			RPC SDHCAL
	TPC			MPGD SDHCAL
	Drift chamber			DR Calorimeter
	PID drift chamber		Muon	Scintillation Bar
	LGAD ToF			RPC
Lumi	SiTrk+Crystal ECAL			μ-Rwell
	SiTrk+SiW ECAL			HTS / LTS Magnet
	CEPC SW			MDI & Integration
	TDAQ			

- **Large number of detector technology options and R&D projects on-going, they are not at similar level of maturity.**
- **Need to converge technology options towards a CEPC reference detector TDR**
  - Start preparation in Jan. 2024
  - A draft version of TDR in Dec. 2024
  - **Official release of TDR in Jun. 2025**
- **Intl. detector collaborative efforts**
  - DRD proto-collaboration (DRD1-8), more than 130 colleagues from 11 Chinese institutes joined so far.
  - HL-LHC detector R&D efforts help to prepare teams for CEPC detectors.

CEPC Accelerator EDR

CEPC Accelerator EDR tasks start with 35 WGs aiming for key issues, detailed working plan and scope will be reviewed by IARC in Sept. 2024.



CEPC International Collaboration

CEPC attracts significant International participation

- Both CDR and TDR have significant intl. contributions
- 20+ MoUs signed with Intl. institutions and universities
- CEPC International Workshop since 2014
- EU-US versions of CEPC Workshop since 2018
- Annual working month at HKUST-IAS since 2015

CEPC CDR released (2018)

Public release: November 2018

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

CEPC
Conceptual Design Report
Volume I - Accelerator
arXiv: 1809.00285

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

CEPC
Conceptual Design Report
Volume II - Physics & Detector
arXiv: 1811.10545

1143 authors
222 institutes (140 foreign)
24 countries

The CEPC Study Group
August 2018

The CEPC Study Group
October 2018

Editorial Team: 43 people / 22 institutions/ 5 countries

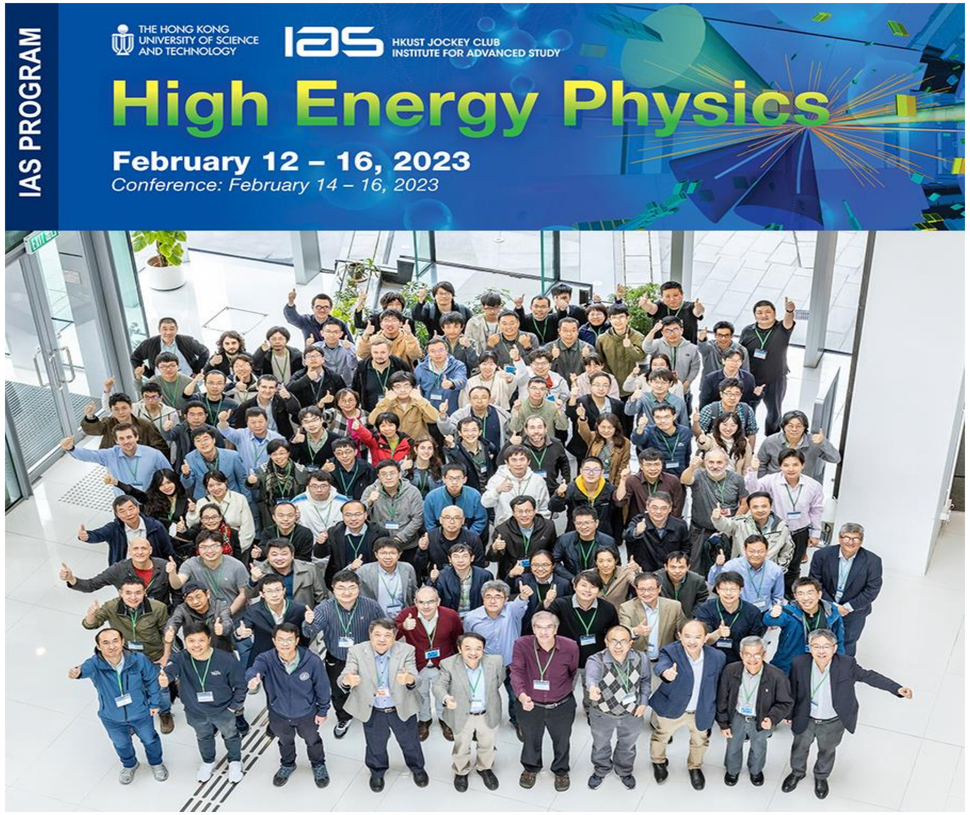
CEPC TDR released (2023)

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

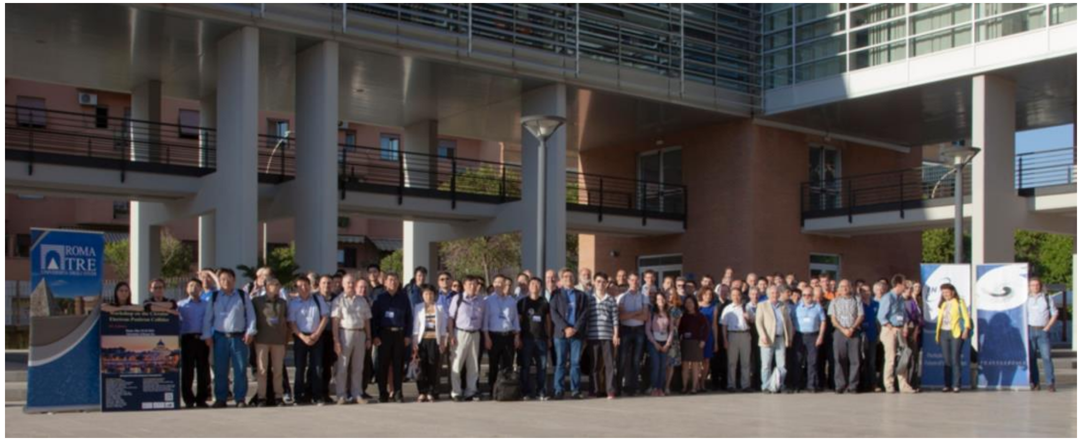
CEPC
Technical Design Report
Accelerator

arXiv:2312.14363
1114 authors
278 institutes
(159 foreign institutes)
38 countries

The CEPC Study Group
December 2023



CEPC International Collaboration



CEPC @ Rome, Italy, May 2018

CEPC @ Oxford, UK, April 2019

CEPC @ Edinburgh, UK, July 2023

CEPC @ U. Chicago, USA, Sept. 2019
CEPC @ Washington DC, USA, April 2020

Industrial Partners and Suppliers Worldwide

	System
1	Magnet
2	Power supplier
3	Vacuum
4	Mechanics
5	RF Power
6	SRF / RF
7	Cryogenics
8	Instrumentation
9	Control
10	Survey and alignment
11	Radiation protection
12	e^-e^+Sources

CEPC Industrial Promotion Consortium (CIPC, established in Nov. 2017)

LEIKE 雷科电子, KAITENG SIFANG, 汉光科技, 北广科技 BBEF, 统力电工 TOLY ELECTRIC, 高能锐新 HE-RACING TECHNOLOGY, 苏州八匹马超导科技有限公司, PUSU, VACREE, 慧宇 HUI YU, 上海超导, 地矿建设, 昆山国力电子科技股份有限公司, Western Superconducting Technologies Co.,Ltd., 中科富海 FULLCRYO, 上海辰光医疗科技股份有限公司 Shanghai Chenguang Medical Technologies Co. Ltd, 爱科赛博 ACTIONPOWER, 江苏克劳特低温 JiangSu Cryote Co., Ltd, JJvac 三井真空, 普达迪泰 PRODETEC, 北京航天测控 Beijing Grantel Technology Co., Ltd., 中铁装备 CREG, 正帆科技 GENTECH, VACUUM PRODUCTS, SEALTECH, SKY, HUALUN, 瑞隆, RAR, HDKY浩德科仪, RuiYuan, 天合精机, 中国铁建, 东方钽业 OTIC, 中国有色集团成员企业, NVT, 冰轮环境 MOON-TECH, JST, 金盘科技, 东方晨景 East Changing, EDWARDS, CBVAC, 黄河勘测规划设计研究院有限公司 Yellow River Engineering Consulting Co., Ltd., 中国电建 华东勘测设计研究院 HUADONG ENGINEERING CORPORATION, 中国电建集团昆明勘测设计研究院有限公司 POWERCHINA KUNMING ENGINEERING CORPORATION LIMITED, 海南展创光电技术有限公司 HZC PHOTONICS, 中国电建 POWERCHINA

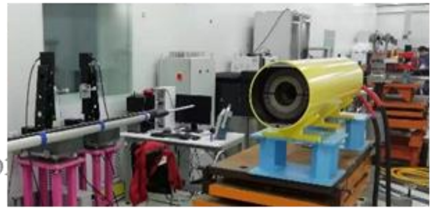
Potential international collaborating suppliers and partners worldwide

DANFYSIK, SCANDITRONIX, TOKINARC TOKIN CORPORATION, nichicon, HEINZINGER, DAWONSYS, CAEN Technologies Inc., Kudos Electrical Contracting, PFEIFFER VACUUM, Leybold, VAT, EDWARDS, mks, SUNR Sanei-Kikai Co.,Ltd, VIC INTERNATIONAL, Fujikin, MPC MIRAPRO, CPI Communications & Power Industries, Canon, THALES Building a future we can all trust, Air Liquide Engineering & Construction, Linde, Lake Shore CRYOTRONICS, SGL research, Osprey Distributed Control Systems, bergoz Instrumentation, Instrumentation Technologies, COSYLAB, dimtel, ThermoFisher SCIENTIFIC, ELSE NUCLEAR, HEXAGON

The 8th CEPC IAC Meeting 7

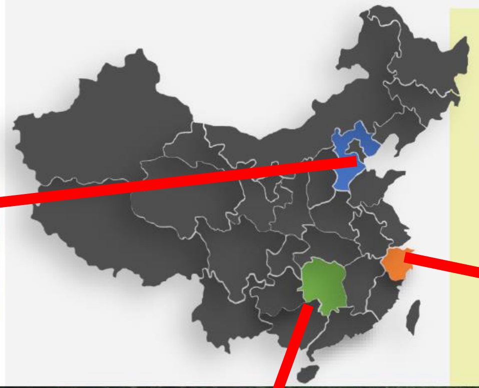


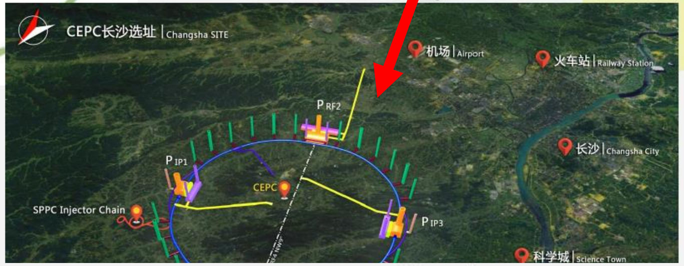


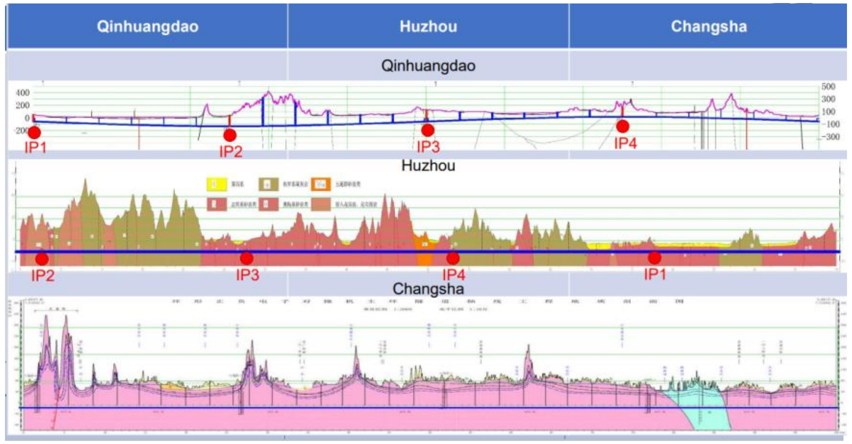



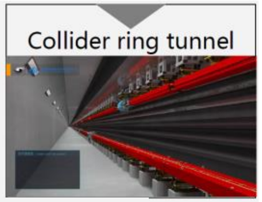

CEPC Site Selection

Qinhuangdao









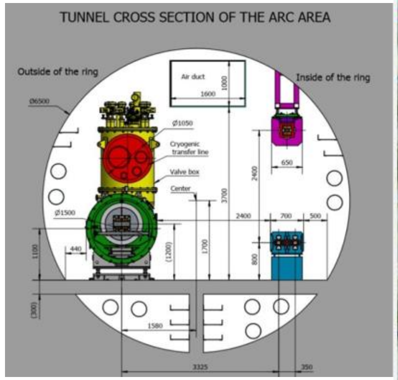
- 3 sites documented in accelerator TDR
- 75-95% of tunnel in granite, low cost

Huzhou

中国电建 POWERCHINA 中国电建集团华东勘测设计研究院有限公司 HUADONG ENGINEERING CORPORATION LIMITED

Changsha

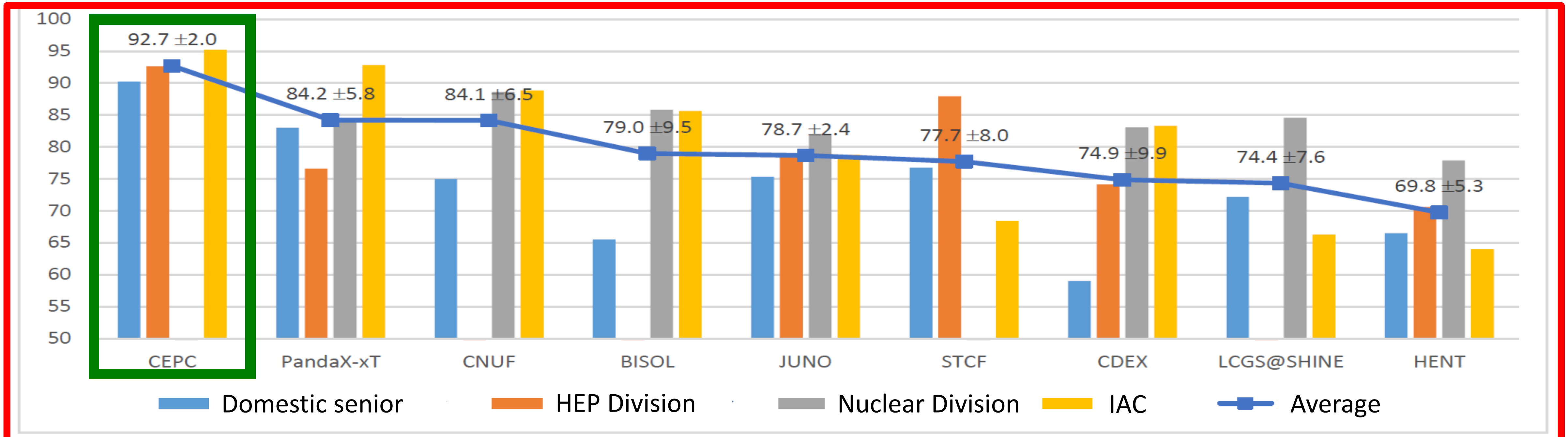
中国电建 POWERCHINA 中南勘测设计研究院有限公司 ZHONGNAN ENGINEERING CORPORATION LIMITED



TBM tunnel

CEPC Planning and Development

- CAS is planning for the 15th 5-year plan for large science projects, and a steering committee has been established, chaired by the president of CAS.
- High energy physics and nuclear physics is one of eight groups (fields).
- CEPC is ranked No. 1, by every committee (2 domestic and 1 international).
- A final report was submitted to CAS for consideration, this process is within CAS, and the following national selection process will be decisive.

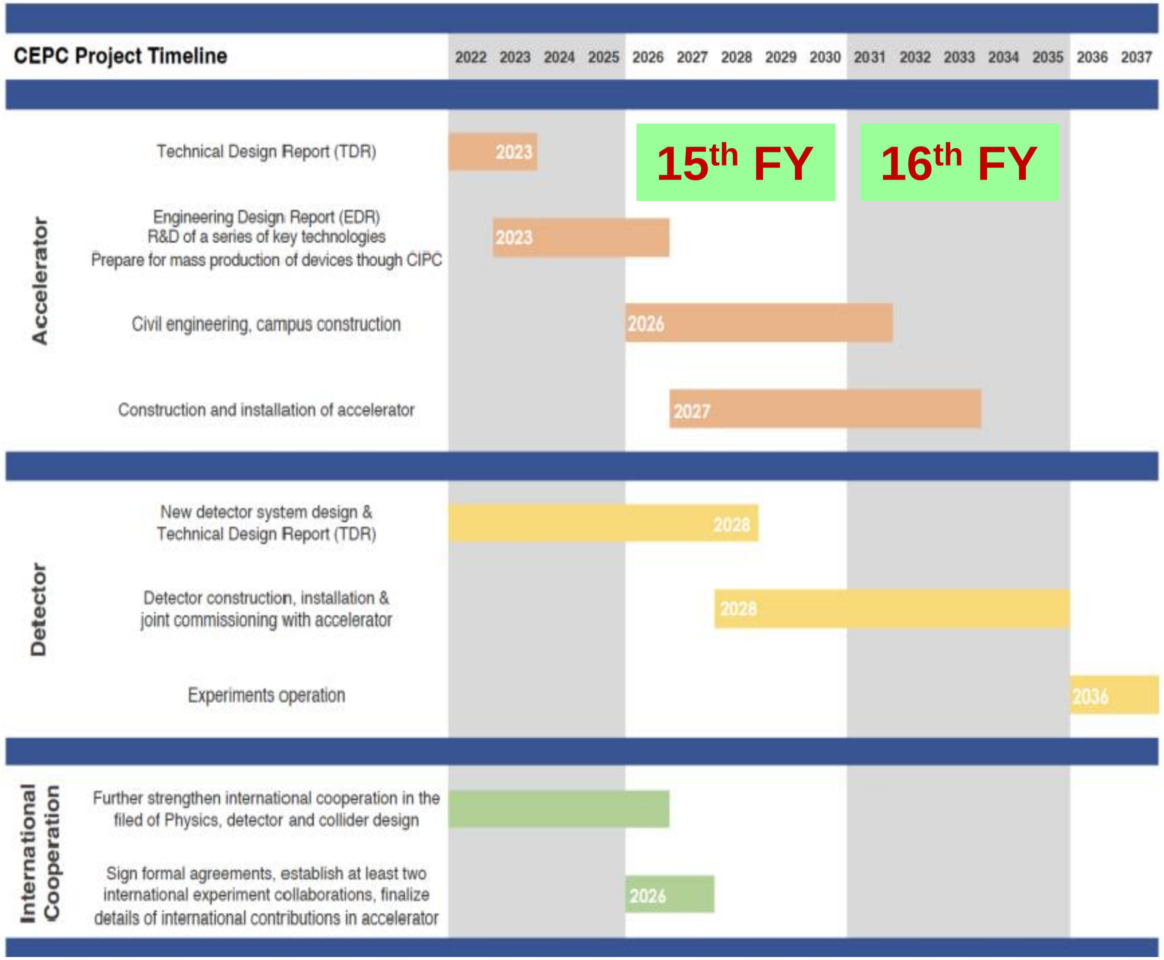


CEPC Planning and Schedule

2012.9	2015.3	2018.11	2023.12	2025.6	2027	15th five year plan (2026-2030)
proposed	Pre-CDR	CDR	Acc. TDR	Det. TDR	EDR	Start of construction

CEPC EDR Phase: 2024-2027

- **CEPC Accelerator EDR** starts with 35 WGs in 2024, to be completed in **2027**
- **CEPC Reference Detector TDR** will be released by June, **2025**
- **CEPC proposal** will be submitted to Chinese government for approval in **2025**
- **Upon approval**, establish at least two international experiment collaborations
- **CEPC construction starts** during the 15th five year plan (2026-2030, e.g. **2027**)
- **CEPC construction complete** around **2035**, at the end of the 16th five year plan



CEPC Planning and Schedule

2012.9	2015.3	2018.11	2023.12	2025.6	2027	15th five year plan (2026-2030)
proposed	Pre-CDR	CDR	Acc. TDR	Det. TDR	EDR	Start of construction

CEPC EDR Phase: 2024-2027

- Contributions from international colleagues for both accelerator EDR and reference detector TDR are warmly welcome.
- Several dedicated topical workshops (in-person + online) will be organized, such as tracker system, calorimeter system, MDI etc.
- A series of reviews will be organized for accelerator EDR and detector TDR.
- Joint study groups aiming for some common issues related to FCC/CEPC.
- International colleagues could contribute in many different ways, such as helping to organize workshops, report writing and editing, as reviewers etc.

Summary

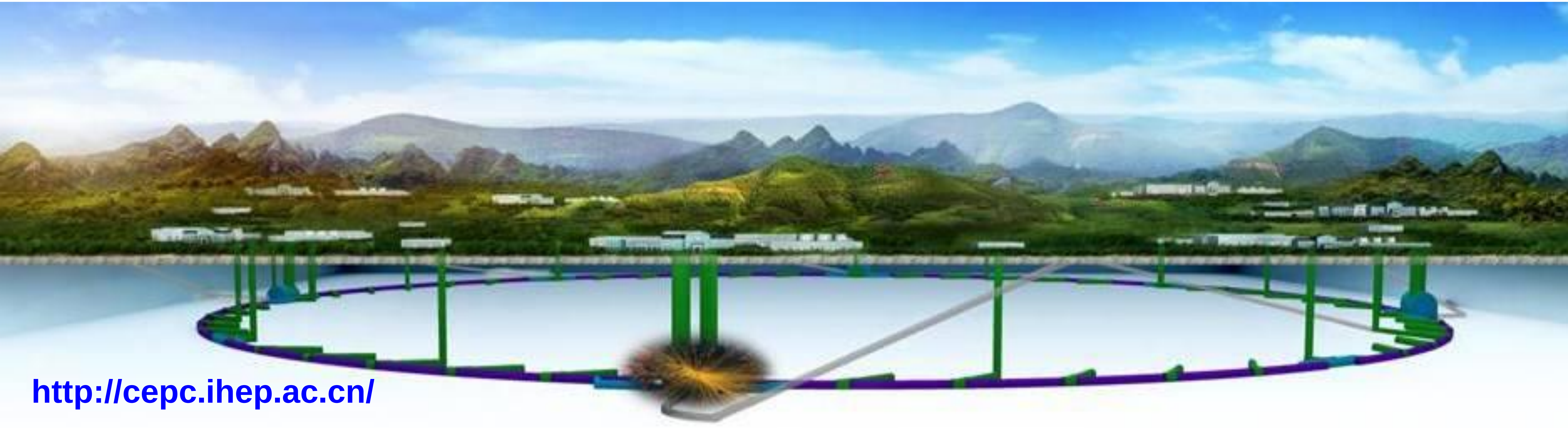
- CEPC addresses many most pressing and critical science problems in particle physics.
- Accelerator design and technology R&D are reaching maturity, TDR completed, enters EDR phase, ready for construction in 3-5 years.
- Reference detector TDR under preparation, to be completed by the mid-2025 for the proposal of China's 15th 5-year plan.
- CEPC schedule will follow the 15th 5-year plan, call for international experiment collaborations and proposals once CEPC is approved.
- Continue to work with government and funding agencies for support.
- CEPC will offer the worldwide HEP community an early Higgs factory.

Next CEPC Workshop

CEPC International Workshop at Hangzhou, Zhejiang U., Oct. 23-27, 2024

Acknowledgement

Thanks to CEPC team for enormous efforts and achievements
Special thanks to CEPC IAC, IARC and TDR review committee



http://cepc.ihep.ac.cn/

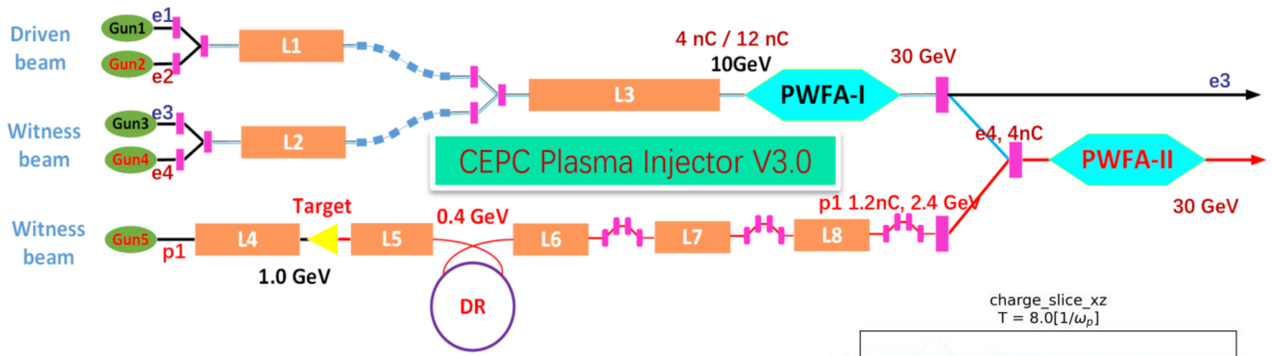
CEPC Machine Parameters

	Higgs	Z	W	$t\bar{t}$
Number of IPs	2			
Circumference (km)	100.0			
SR power per beam (MW)	30			
Half crossing angle at IP (mrad)	16.5			
Bending radius (km)	10.7			
Energy (GeV)	120	45.5	80	180
Energy loss per turn (GeV)	1.8	0.037	0.357	9.1
Damping time $\tau_x/\tau_y/\tau_z$ (ms)	44.6/44.6/22.3	816/816/408	150/150/75	13.2/13.2/6.6
Piwinski angle	4.88	24.23	5.98	1.23
Bunch number	268	11934	1297	35
Bunch spacing (ns)	591 (53% gap)	23 (18% gap)	257	4524 (53% gap)
Bunch population (10^{11})	1.3	1.4	1.35	2.0
Beam current (mA)	16.7	803.5	84.1	3.3
Phase advance of arc FODO (°)	90	60	60	90
Momentum compaction (10^{-5})	0.71	1.43	1.43	0.71
Beta functions at IP β_x^*/β_y^* (m/mm)	0.3/1	0.13/0.9	0.21/1	1.04/2.7
Emittance $\varepsilon_x/\varepsilon_y$ (nm/pm)	0.64/1.3	0.27/1.4	0.87/1.7	1.4/4.7
Betatron tune n_x/n_y	445/445	317/317	317/317	445/445
Beam size at IP s_x/s_y (um/nm)	14/36	6/35	13/42	39/113
Bunch length (natural/total) (mm)	2.3/4.1	2.5/8.7	2.5/4.9	2.2/2.9
Energy spread (natural/total) (%)	0.10/0.17	0.04/0.13	0.07/0.14	0.15/0.20
Energy acceptance (DA/RF) (%)	1.6/2.2	1.0/1.7	1.2/2.5	2.0/2.6
Beam-beam parameters x_x/x_y	0.015/0.11	0.004/0.127	0.012/0.113	0.071/0.1
RF voltage (GV)	2.2	0.12	0.7	10
RF frequency (MHz)	650			
Longitudinal tune n_s	0.049	0.035	0.062	0.078
Beam lifetime (Bhabha/beamstrahlung) (min)	39/40	82/2800	60/700	81/23
Beam lifetime (min)	20	80	55	18
Hourglass Factor	0.9	0.97	0.9	0.89
Luminosity per IP (10^{34} cm^{-2} s^{-1})	5.0	115	16	0.5

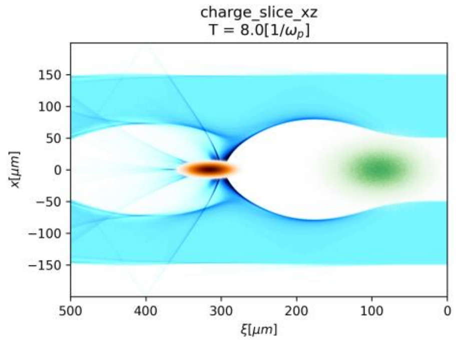
CEPC Accelerator: Plasma Injector

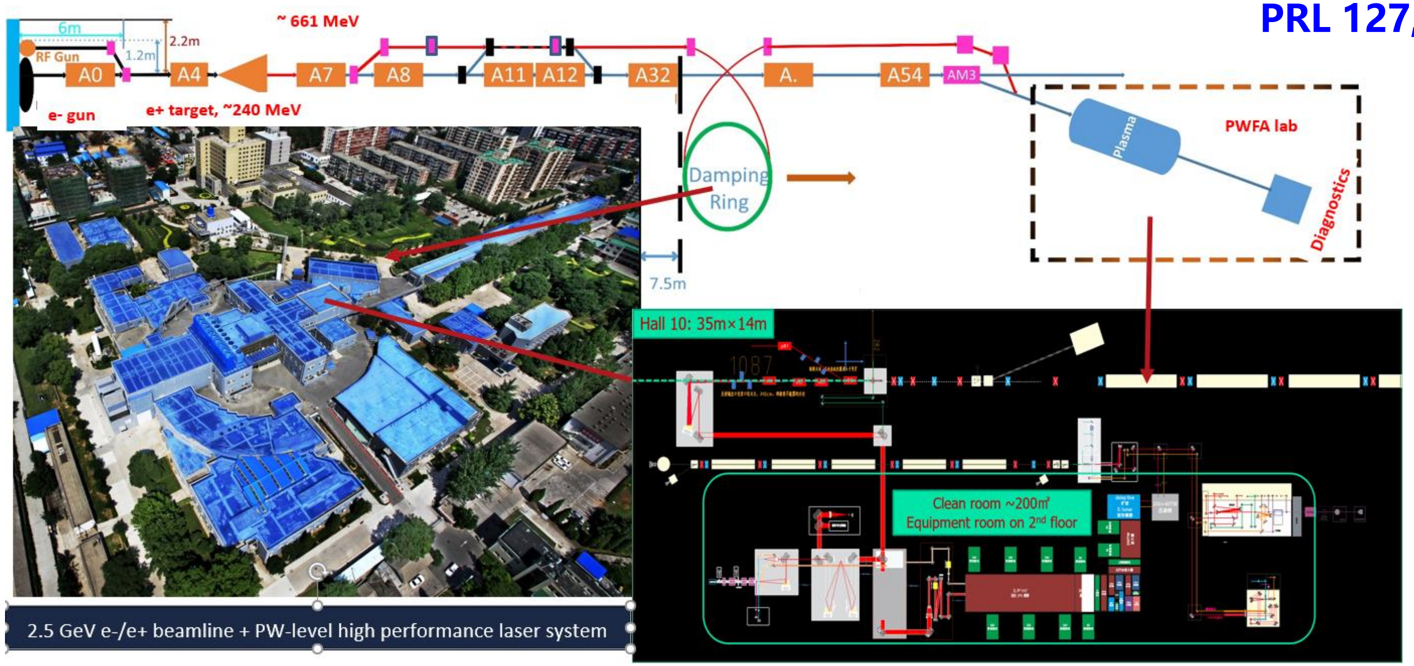
CEPC Plasma Injector Scheme
From 10 GeV → 30 GeV → TR ≥2

Simulation results show that it works on paper with reasonable error tolerances for both electron & positron beams injected to booster



PRL 127, 174801 (2021)





PWFA/LWFA TF based on BEPC-II Linac and HPL has founded by CAS, 120M RMB in Sept. 2023

Phase I（Year0-Year2）

1. Re-design and install transport beamline and FF system, optimize the e- / e+ beam quality
2. Clean room and high power laser system (20… installation200TW
3. Beam instrumentation s…
4. RF Gun platfor…
5. Comm…

Phase II（…

1. Up… …20/40 TW)
2. Test… …install it on the BEPC…

Phase III（Yea…

1. Add a positron dumping ring the bunch compression beamline to improve the e+ quality
2. PBA-based FEL studies

- **Positron and electron acceleration**
- **Cascading acceleration**
- **Future linear collider technologies**
- **High energy beam for detector R&D (possible application)**

CEPC R&D: Towards a Green Accelerator

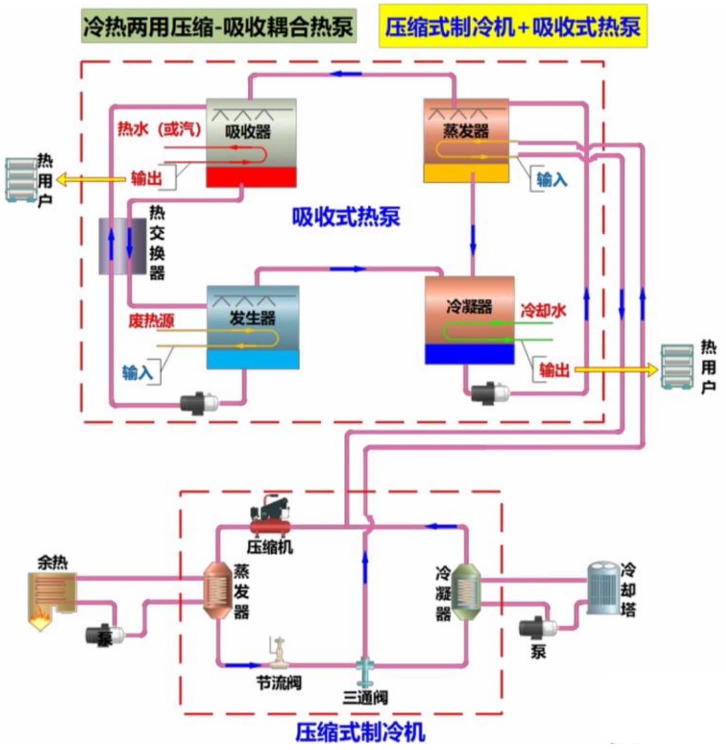
Experience at HEPS

- Solar panel:10 MW ➔ 10% saving
- Permanent magnet: 5.6 GWh saving/yr
- Hot water (13 MW @ 42 ^{0}C) for heating: more than what HEPS needs

R&D for CEPC

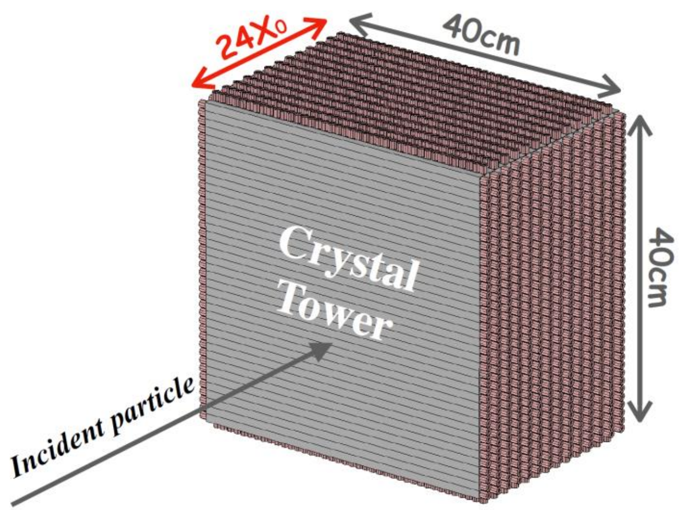
- High eff. Klystron, energy recovery Klystron
- R&D of a “cooling-compressor + heating-pump system” to recover hot water in winter and cooling water in summer for use at HEPS
- Investigate power generator using low-T hot water

Solar panel on the roof of HEPS



CEPC R&D: Calorimeters with PFA

Crystal ECAL



Energy resolution ~3%/√E ± ~ 1%

Features:

- Good energy resolution
- 3D shower info. with limited readout channel
- Shower separation < 4 cm

Main issues for R&D

- Jet reconstruction and PFA algorithm

Scintillation Glass HCAL

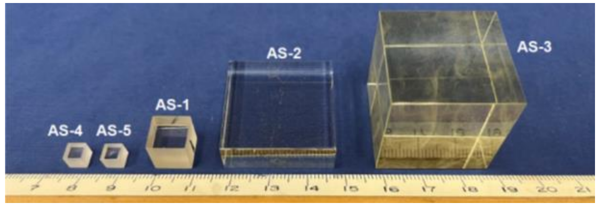
Energy resolution ~40%/√E ± ~ 2%

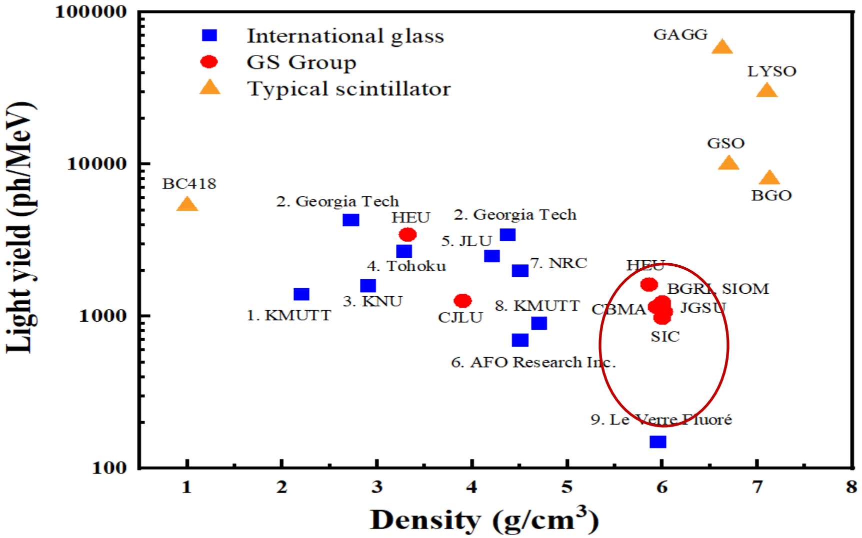
Features:

- Large sampling ratio at low cost

Main issues for R&D

- high density, high light yield, radiation hardness, production





CEPC Software Migration to Key4hep

Key4hep: an international collaboration with CEPC participation

CEPCSW: a first application of Kep4hep – Tracking software

CEPCSW is already included in Key4hep software stack

https://github.com/cepc/CEPCSW

Architecture of CEPCSW

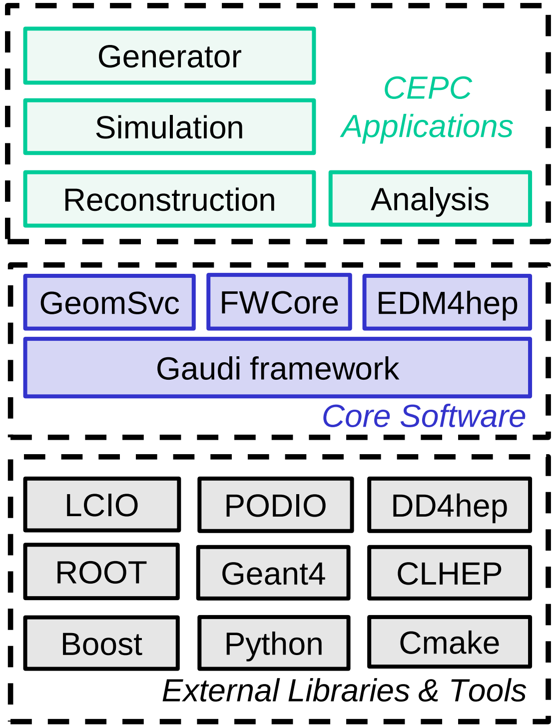
- **External libraries**
- **Core software**
- **CEPC applications for simulation, reconstruction and analysis**

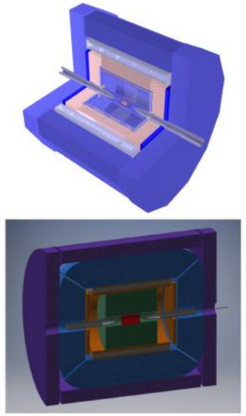
Core Software

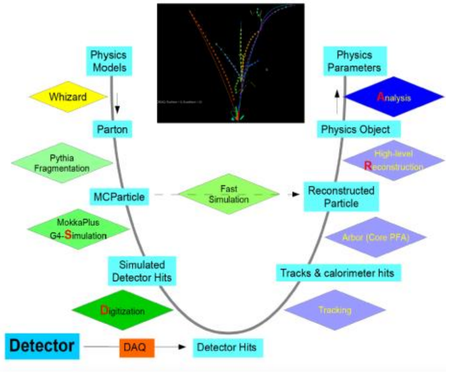
- **Gaudi framework: defines interfaces of all software components and controls the event loop**
- **EDM4hep: generic event data model**
- **FWCore: manages the event data**
- **GeomSvc: DD4hep-based geometry management service**

Ref: Weidong Li's talk

CEPCSW Structure



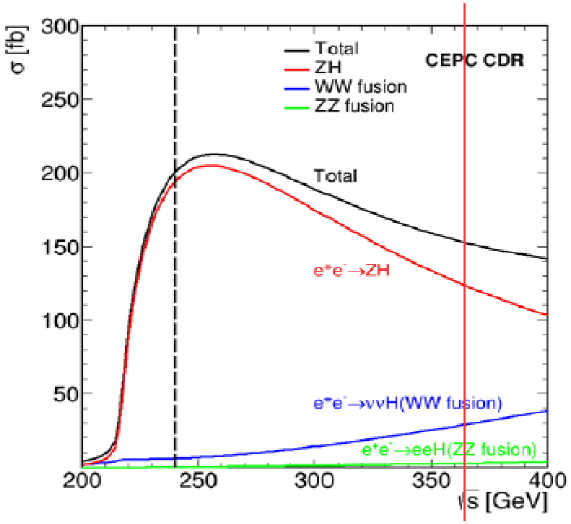


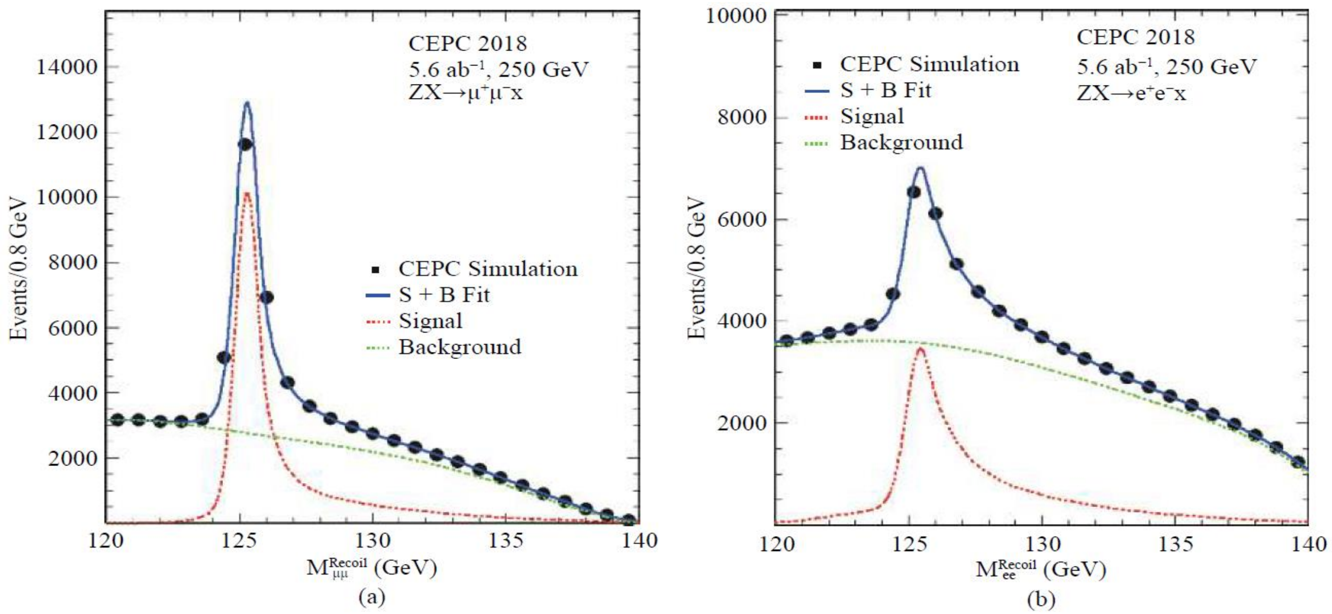


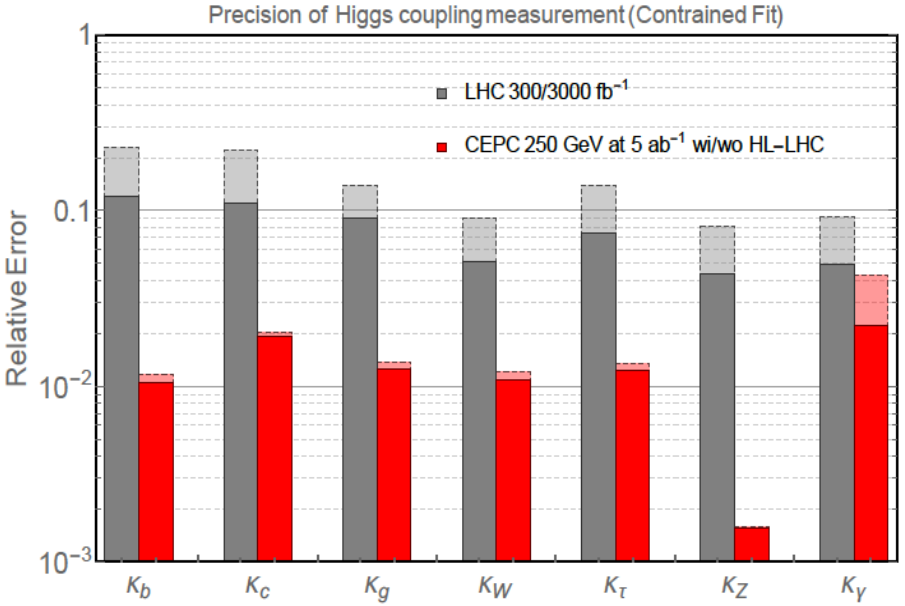
Full simulation reconstruction Chain functional, iterating/validation with hardware studies

CEPC Physics Program (CDR)

- CEPC can make detailed study of various physics processes
- Higgs bosons are detected via recoil mass of the Z, allowing for model independent & full investigation of the Higgs and related new physics that may reveal
- Very challenging events with missing neutrinos and jets are well reconstructed and identified







❖ ~300 Journal / arXiv papers

Chinese Physics C Vol. 43, No. 4 (2019) 043002

CEPC Physics Program

- **Precision Higgs, EW, flavor physics & QCD measurements at unprecedented precision**
- **BSM physics (e.g. dark matter, EW phase transition, SUSY, LLP, …) up to ~ 10 TeV scale**

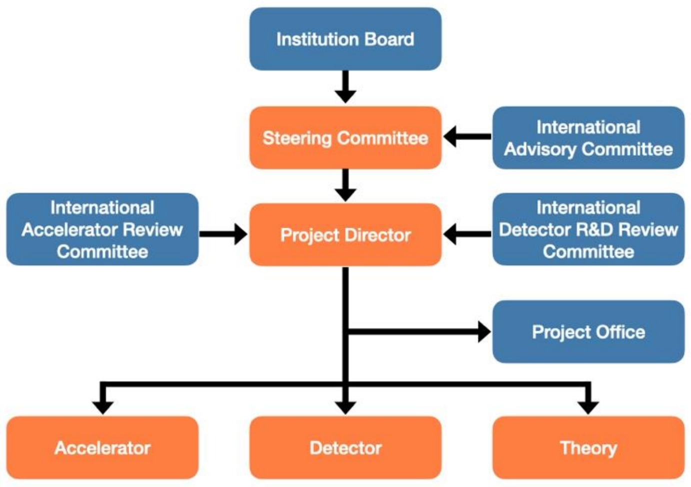
	240 GeV, 20 ab^{-1}		360 GeV, 1 ab^{-1}		
	ZH	vvH	ZH	vvH	eeH
inclusive	0.26%		1.40%	\	\
H→bb	0.14%	1.59%	0.90%	1.10%	4.30%
H→cc	2.02%		8.80%	16%	20%
H→gg	0.81%		3.40%	4.50%	12%
H→WW	0.53%		2.80%	4.40%	6.50%
H→ZZ	4.17%		20%	21%	
$H\to\tau\tau$	0.42%		2.10%	4.20%	7.50%
$H\to\gamma\gamma$	3.02%		11%	16%	
$H\to\mu\mu$	6.36%		41%	57%	
$H\to Z\gamma$	8.50%		35%		
$Br_{upper}(H\to inv.)$	0.07%				
Γ_H	1.65%		1.10%		

Observable	current precision	CEPC precision (Stat. Unc.)	CEPC runs	main systematic
Δm_Z	2.1 MeV [37–41]	0.1 MeV (0.005 MeV)	Z threshold	E_{beam}
$\Delta\Gamma_Z$	2.3 MeV [37–41]	0.025 MeV (0.005 MeV)	Z threshold	E_{beam}
Δm_W	9 MeV [42–46]	0.5 MeV (0.35 MeV)	WW threshold	E_{beam}
$\Delta\Gamma_W$	49 MeV [46–49]	2.0 MeV (1.8 MeV)	WW threshold	E_{beam}
Δm_t	0.76 GeV [50]	$\mathcal{O}(10)$ MeV[a]	$t\bar{t}$ threshold	
ΔA_e	4.9×10^{-3} [37, 51–55]	1.5×10^{-5} (1.5×10^{-5})	Z pole ($Z\to\tau\tau$)	Stat. Unc.
ΔA_μ	0.015 [37, 53]	3.5×10^{-5} (3.0×10^{-5})	Z pole ($Z\to\mu\mu$)	point-to-point Unc.
ΔA_τ	4.3×10^{-3} [37, 51–55]	7.0×10^{-5}(1.2×10^{-5})	Z pole ($Z\to\tau\tau$)	tau decay model
ΔA_b	0.02 [37, 56]	20×10^{-5} (3×10^{-5})	Z pole	QCD effects
ΔA_c	0.027 [37, 56]	30×10^{-5} (6×10^{-5})	Z pole	QCD effects
$\Delta\sigma_{had}$	37 pb [37–41]	2 pb (0.05 pb)	Z pole	lumiosity
δR_b^0	0.003 [37, 57–61]	0.0002 (5×10^{-6})	Z pole	gluon splitting
δR_c^0	0.017 [37, 57, 62–65]	0.001 (2×10^{-5})	Z pole	gluon splitting
δR_e^0	0.0012 [37–41]	2×10^{-4} (3×10^{-6})	Z pole	E_{beam} and t channel
δR_μ^0	0.002 [37–41]	1×10^{-4} (3×10^{-6})	Z pole	E_{beam}
δR_τ^0	0.017 [37–41]	1×10^{-4} (3×10^{-6})	Z pole	E_{beam}
δN_ν	0.0025 [37, 66]	2×10^{-4} (3×10^{-5})	ZH run ($\nu\nu\gamma$)	Calo energy scale

arXiv:2205.08553

CEPC Team

CEPC Organization



- **Institution Board:** 32 institutes, top universities/institutes in China
- **Management team:** comprehensive management experience at construction projects of BEPCII/CSNS/HEPS, and international projects of BESIII/Daya Bay/JUNO/…
- **Accelerator team:** fully over all disciplines with rich experiences at BEPCII, HEPS…
- **Physics and Detector team:** fully over all disciplines with rich experiences at BESIII, Daya Bay, JUNO, ATLAS, CMS, LHCb …

Table 7.2: Team of Leading and core scientists of the CEPC

Name	Brief introduction	Role in the CEPC team
Yifang Wang	Academician of the CAS, director of IHEP	The leader of CEPC, chair of the SC
Xinchou Lou	Professor of IHEP	Project manager, member of the SC
Yuanning Gao	Academician of the CAS, head of physics school of PKU	Chair of the IB, member of the SC
Jie Gao	Professor of IHEP	Convener of accelerator group, vice chair of the IB, member of the SC
Haijun Yang	Professor of SJTU	Deputy project manager, member of the SC
Jianbei Liu	Professor of USTC	Convener of detector group, member of the SC
Hongjian He	Professor of USTC	Convener of theory group, member of the SC
Shan Jin	Professor of NJU	Member of the SC
Nu Xu	Professor of IMP	Member of the SC
Meng Wang	Professor of SDU	Member of the SC
Qinghong Cao	Professor of PKU	Member of the SC
Wei Lu	Professor of THU	Member of the SC
Joao Guimaraes da Costa	Professor of IHEP	Convener of detector group
Jianchun Wang	Professor of IHEP	Convener of detector group
Yuhui Li	Professor of IHEP	Convener of accelerator group
Chenghui Yu	Professor of IHEP	Convener of accelerator group
Jingyu Tang	Professor of IHEP	Convener of accelerator group
Xiaogang He	Professor of SJTU	Convener of theory group
Jianping Ma	Professor of ITP	Convener of theory group

Management team, leading scientists

Table 7.3: Team of the CEPC accelerator system

Number	Sub-system	Convener	Team (senior staff)
1	Accelerator physics	Chenghui Yu, Yuan Zhang	18
2	Magnets	Wen Kang, Fusan Chen	12
3	Cryogenic system	Rui Ge, Ruixiong Han	11
4	SC RF system	Jiyuan Zhai, Peng Sha	12
5	Beam Instrumentation	Yanfeng Sui, Junhui Yue	7
6	SC magnets	Qingjin Xu	10
7	Power supply	Bin Chen, Fengli Long	9
8	Injection & extraction	Jinhui Chen	7
9	Mechanical system	Jianli Wang, Lan Dong	4
10	Vacuum system	Haiyi Dong, Yongsheng Ma	5
11	Control system	Ge lei, Gang Li	6
12	Linac injector	Jingyi Li, Jingru Zhang	13
13	Radiation protection	Zhongjian Ma	3
Sum			117

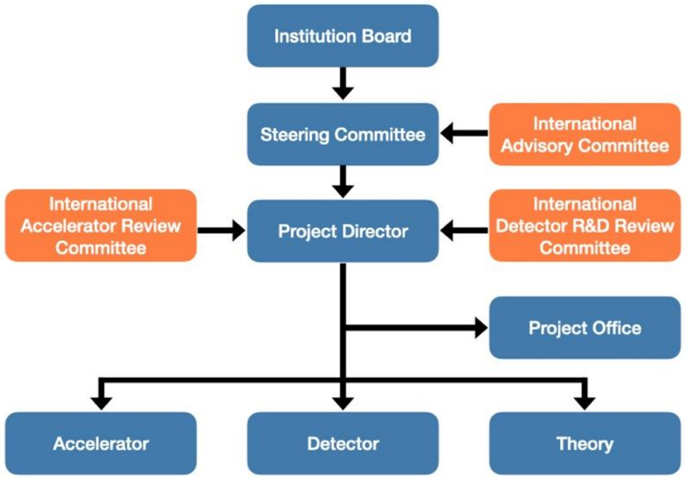
Table 7.4: Team of the CEPC detector system

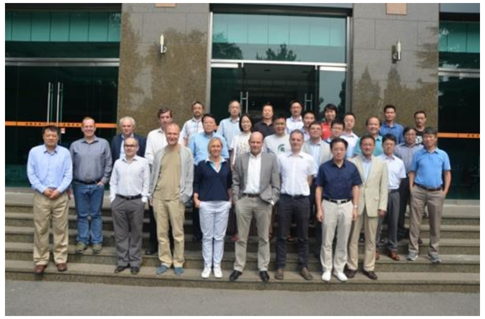
Number	Sub-system	Conveners	Institutions	Team (senior staff)
1	Pixel Vertex Detector	Zhijun Liang, Qun Ouyang, Xiangming Sun, Wei Wei	CCNU, IFAE, IHEP, NJU, NWPU, SDU, Strasbourg, ...	~ 40
2	Silicon Tracker	Harald Fox, Meng Wang, Hongbo Zhu	IHEP, INFN, KIT, Lancaster, Oxford, Queen Mary, RAL, SDU, Tsinghua, Bristol, Edinburgh, Livepool, USTC, Warwick, Sheffield, ZJU, ...	~ 60
3	Gaseous detector	Franco Bedeschi, Zhi Deng, Mingyi Dong, Huirong Qi	CEA Saclay, DESY, LCTPC Collab., IHEP, INFN, NIKHEF, THU ...	~ 30
4	Magnet	Feipeng Ning	IHEP	~ 10
5	Calorimetry	Roberto Ferrari, Jianbei Liu, Haijun Yang, Yong Liu	CALICE Collab., IHEP, INFN, SJTU, USTC..	~ 40
6	Muon	Paolo Giacomelli, Liang Li, Xiaolong Wang	FDU, IHEP, INFN, SJTU ...	~ 20
7	Physics	Manqi Ruan, Yaquan Fang, Liantao Wang, Mingshui Chen	IHEP, FDU, SJTU, ...	~ 80
8	Software	Shengseng Sun, Weidong Li, Xingtao Huang	IHEP, SDU, FDU, ...	~ 20
Sum				~ 300

117 accelerator + ~300 detector staffs currently, + ~ 400 from BEPC/BESIII/JUNO/HEPS/… once CEPC approved

CEPC International Committees

CEPC Organization





International Advisory Committees

Name	Affiliation	Country
Tatsuya Nakada	EPFL	Japan
Steinar Stapnes	CERN	Norway
Rohini Godbole	CHEP, Bangalore	India
Michelangelo Mangano	CERN	Switzerland
Michael Davier	LAL	France
Lucie Linssen	CERN	Holland
Luciano Maiani	U. Rome	San Marino
Joe Lykken	Fermilab	U.S.
Ian Shipsey	Oxford/DESY	U.K.
Hitoshi Murayama	IPMU/UC Berkeley	Japan
Geoffrey Taylor	U. Melbourne	Australia
Eugene Levichev	BINP	Russia
David Gross	UC Santa Barbara	U.S.
Brian Foster	Oxford	U.K
Marcel Demarteau	ORNL	USA
Barry Barish	Caltech	USA
Maria Enrica Biagini	INFN Frascati	Italy
Yuan-Hann Chang	IPAS	Taiwan, China
Akira Yamamoto	KEK	Japan
Hongwei Zhao	Institute of Modern Physics, CAS	China
Andrew Cohen	University of Science and Techbnology	Hong Kong, China
Karl Jakobs	University of Freiburg/CERN	Germany
Beate Heinemann	DESY	Germany

International Accelerator Review Committee

- Phillip Bambade, LAL
- Marica Enrica Biagini (Chair), INFN
- Brian Foster, DESY/University of Hamburg & Oxford University
- In-Soo Ko, POSTTECH
- Eugene Levichev, BINP
- Katsunobu Oide, CERN & KEK
- Anatolii Sidorin, JINR
- Steinar Stapnes, CERN
- Makoto Tobiyama, KEK
- Zhentang Zhao, SINAP
- Norihito Ohuchi, KEK
- Carlo Pagani, INFN-Milano

International Detector R&D Review Committee

- Jim Brau, USA, Oregon
- Valter Bonvicini, Italy, Trieste
- Ariella Cattai, CERN, CERN
- Cristinel Diaconu, France, Marseille
- Brian Foster, UK, Oxford
- Liang Han, China, USTC
- Dave Newbold, UK, RAL (chair)
- Andreas Schopper, CERN, CERN
- Abe Seiden, USA, UCSC
- Laurent Serin, France, LAL
- Steinar Stapnes, CERN, CERN
- Roberto Tenchini, Italy, INFN
- Ivan Villa Alvarez, Spain, Santader
- Hitoshi Yamamoto, Japan, Tohoku

- ➤ **IAC: global renowned scientists and top laboratory or project leaders who have ample experience in project management, planning, and execution of strategies, operating since 2015**
- ➤ **IARC & IDRC: leading experts of this field, provide guide to the project director**

CEPC International Efforts

ESPPU input

CEPC Input to the ESPP 2018
- Physics and Detector

CEPC Physics-Detector Study Group

Abstract

The Higgs boson, discovered in 2012 by the ATLAS and CMS Collaborations at the Large Hadron Collider (LHC), plays a central role in the Standard Model. Measuring its properties precisely will advance our understandings of some of the most important questions in particle physics, such as the naturalness of the electroweak scale and the nature of the electroweak phase transition. The Higgs boson could also be a window for exploring new physics, such as dark matter and its associated dark sector, heavy sterile neutrino, et al. The Circular Electron Positron Collider (CEPC), proposed by the Chinese High Energy community in 2012, is designed to run at a center-of-mass energy of 240 GeV as a Higgs factory. With about one million Higgs bosons produced, many of the major Higgs boson couplings can be measured with precisions about one order of magnitude better than those achievable at the High Luminosity-LHC. The CEPC is also designed to run at the Z-pole and the W pair production threshold, creating close to one trillion Z bosons and 100 million W bosons. It is projected to improve the precisions of many of the electroweak observables by about one order of magnitude or more. These measurements are complementary to the Higgs boson coupling measurements. The CEPC also offers excellent opportunities for searching for rare decays of the Higgs, W, and Z bosons. The large quantities of bottom-quarks, charm-quarks, and tau leptons produced from the decays of the Z bosons are interesting for flavor physics. The clean collision environment also makes the CEPC an ideal facility to perform pre[illegible]oposed for the [illegible]ncepts can full[illegible] potential and [illegible]tail in the Co[illegible]so outline fut[illegible]scribe the planning and the international organization of the CEPC. The next step for the CEPC team is to perform detailed technical design studies. Effective international collaboration would be crucial at this stage. This submission for consideration by the ESPP is part of our dedicated effort in seeking international collaboration and support. Given the importance of the precision Higgs boson measurements, the ongoing CEPC activities do not diminish our interests in participating in the international collaborations of other future electron-positron collider based Higgs factories.

arXiv: 1901.03170
1901.03169

Snowmass input

Snowmass2021 White Paper AF3- CEPC

CEPC Accelerator Study Group[1]

1. Design Overview

1.1 Introduction and status

The discovery of the Higgs boson at CERN's Large Hadron Collider (LHC) in July 2012 raised new opportunities for large-scale accelerators. The Higgs boson is the heart of the Standard Model (SM), and is at the center of many biggest mysteries, such as the large hierarchy between the weak scale and the Planck scale, the nature of the electroweak phase transition, the original of mass, the nature of dark matter, the stability of vacuum, etc. and many other related questions. Precise measurements of the properties of the Higgs boson serve as probes of the underlying fundamental physics principles of the SM and beyond. Due to the modest Higgs boson mass of 125 GeV, it is possible to produce it in the relatively clean environment of a circular electron–positron collider with high luminosity, new technologies, low cost, and reduced power consumption. In September 2012, Chinese scientists proposed a 240 GeV *Circular Electron Positron Collider* (CEPC), serving two large detectors for Higgs studies and other topics as shown in Fig. 1. The ~100 km tunnel for such a machine could also host a *Super Proton Proton Collider* (SPPC) to reach energies well beyond the LHC.

The CEPC is a large international scientific project initiated and to be hosted by China. It was presented for the first time to the international community at the ICFA Workshop *"Accelerators for a Higgs Factory: Linear vs. Circular"* (HF2012) in Novemb[illegible]he White R[illegible]he Yellow F[illegible]was made. Tl[illegible][3] has been[illegible]an internati[illegible]18. In May [illegible]gy Physics[illegible]R, CEPC accelerator entered the phase of Technical Design Report (TDR) endorsed by CEPC International Advisory Committee (IAC). In TDR phase, CEPC optimization design with higher performance compared with CDR and the key technologies such as 650MHz high power and high efficiency klystron, high quality SRF accelerator technology, high precision magnets for booster and collider rings, vacuum system, MDI, etc. have been carried out, and the CEPC accelerator TDR will be completed at

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arXiv: 2203.09451
2205.08553

ICHEP 2022


ICHEP 2022


ESPPU 2019

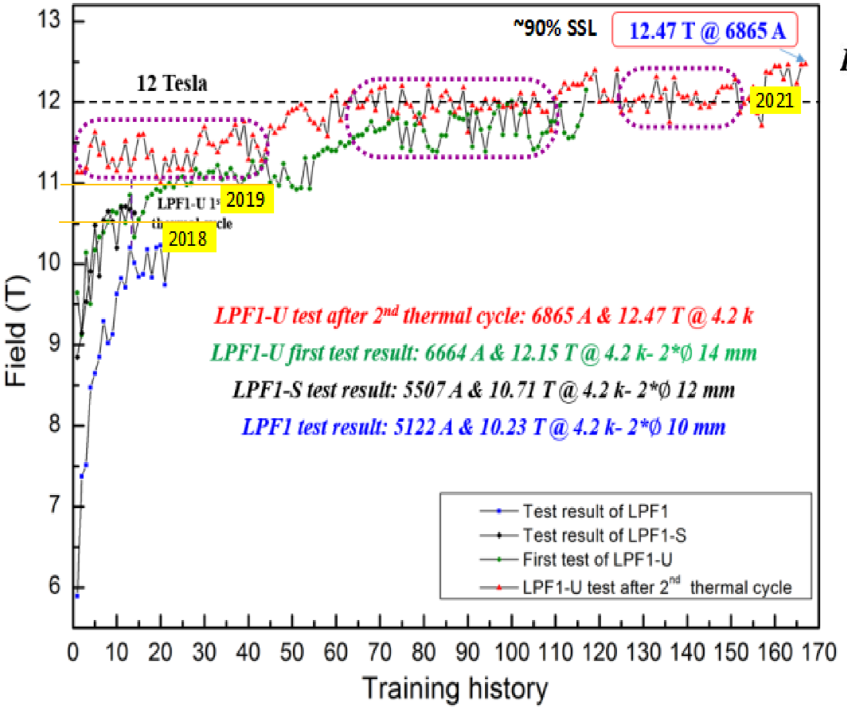
ICHEP 2018

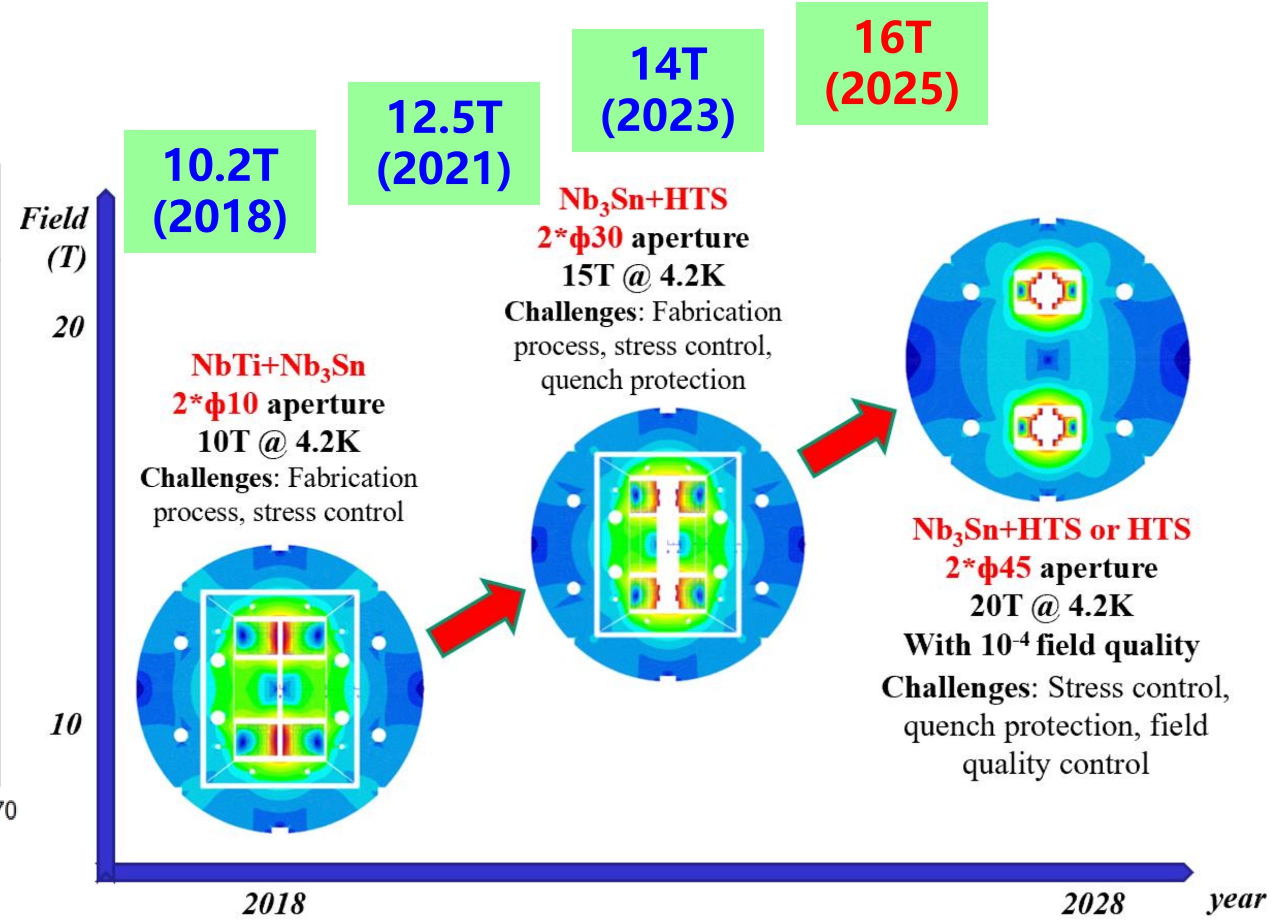
- **CEPC provides critical input to ESPPU & Snowmass as a major player**
- **Team member actively participated intl. study (ESPPU and Snowmass committees) and Panel discussions**
- **CEPC attracts intensive international collaboration, ensuring that the CEPC design and technology are among the most advanced in the world.**

SPPC R&D: HTS SC Magnet

SppC 16 T Dipole: Nb_3Sn 12~13 T + HTS 3~4 T
Dual aperture superconducting dipoles fabricated in China reached 14T @ 4.2K in 2023. The next goal is 16-20T.

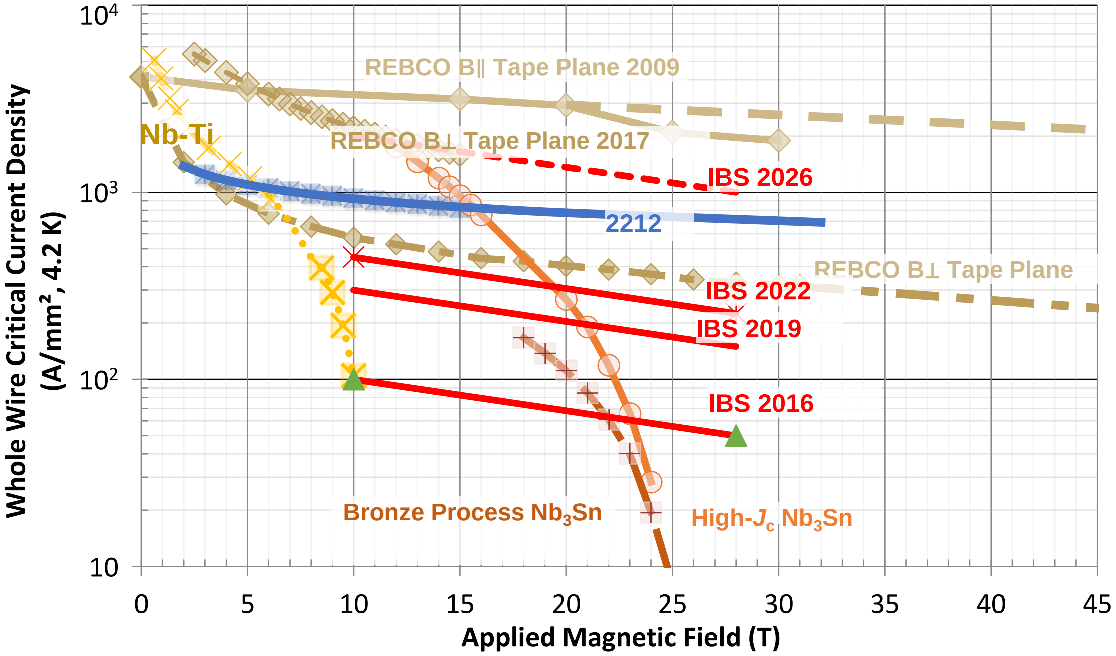
Picture of LPF1-U

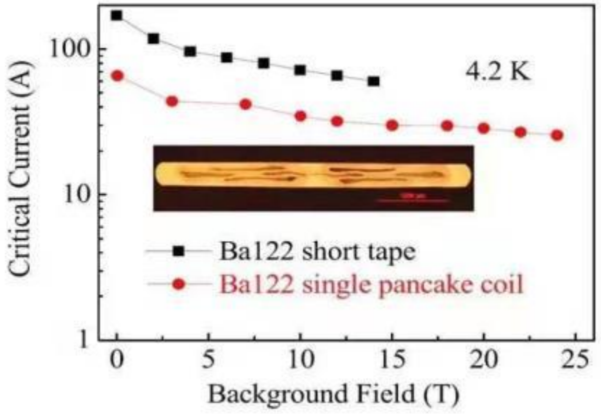


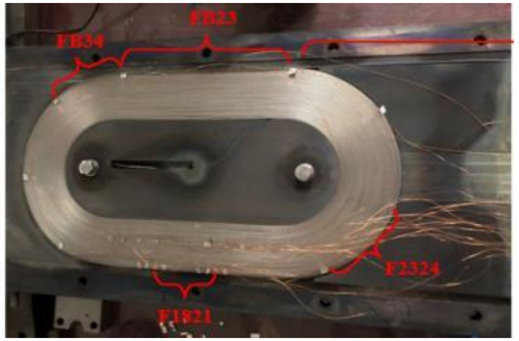


SPPC R&D: HTS SC Magnet

- ❖Iron-based superconducting materials are very promising for high-field magnets
  - Isotropic, metal
  - Cheap for raw materials and production
- ❖Technology spin-off can be enormous
- ❖Major R&D goals
  - High Jc: > 1000A/mm^2@4.2K
  - Long cable: > 1000 m
  - Low cost: < 5 $/kA·m
- ❖A collaboration formed in 2016 by IHEP, IOP, IOEE, etc., and supported by CAS
- ❖The world first: 1000m IBS cable, IBS solenoid coil (24T) ➔ magnet







1st Iron-based Superconducting solenoid Coil at 24T