

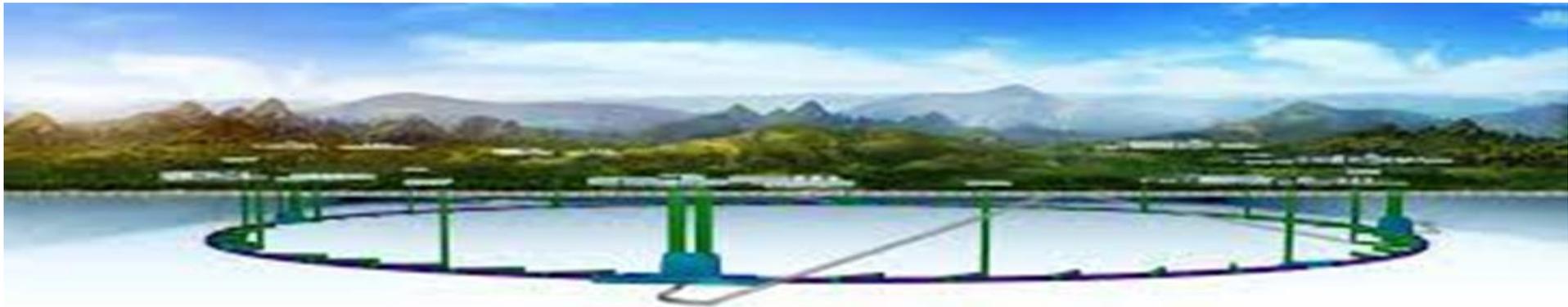
Lepton-Photon 2025

# Status and Plans

## The Circular Electron Positron Collider

XinChou LOU

IHEP, Beijing



# Outline

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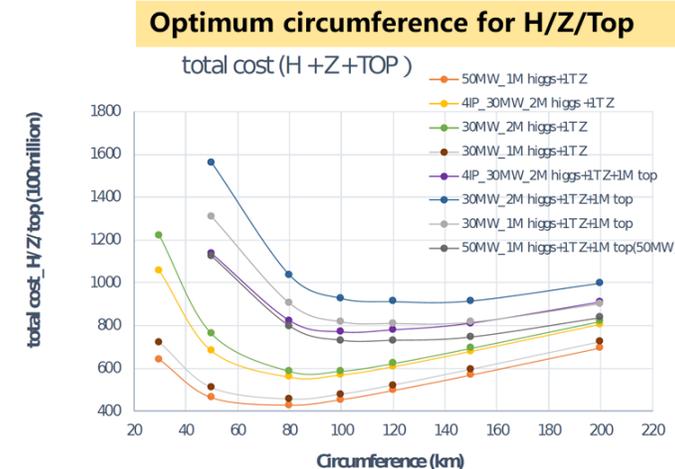
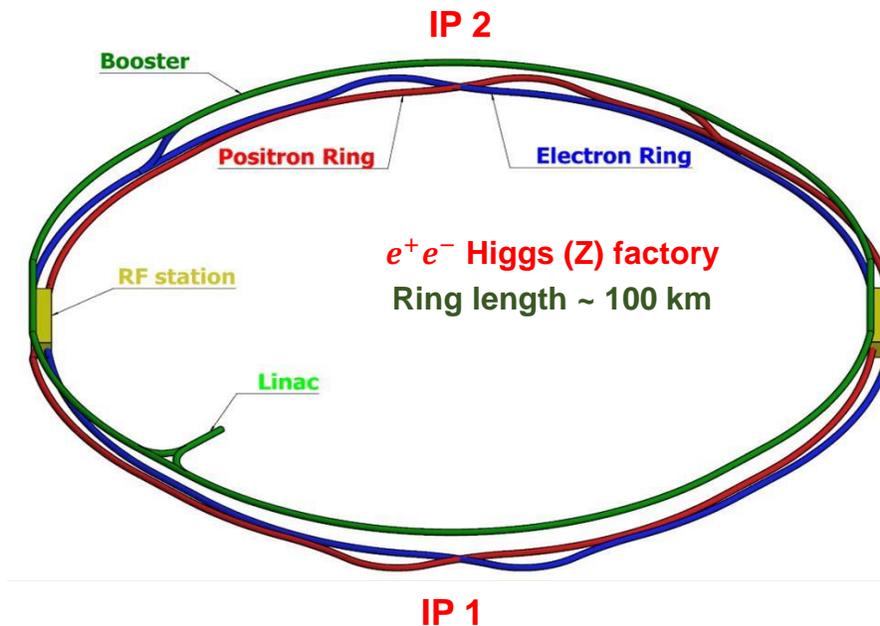
- **Introduction and reminder**
- **CEPC status and progress**
- **CEPC plan**
- **Summary**

# Introduction and reminder

Chinese HEP community had been contemplating the post BEPCII machine

After the Higgs discovery at CERN, the idea of CEPC followed by a possible Super proton-proton collider(SppC) was proposed in Sep. 2012, and quickly gained the momentum in IHEP and in the world

- Looking for Hints@ $e^+e^-$  Collider → If yes, direct search at pp collider
- The tunnel can be re-used for pp, AA, ep colliders up to ~ 100 TeV



A factory of Higgs, Z, W, hadrons, QCD and "new physics" for the world

See Hitoshi's talk about physics

# Introduction and reminder

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

2013



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

2015

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

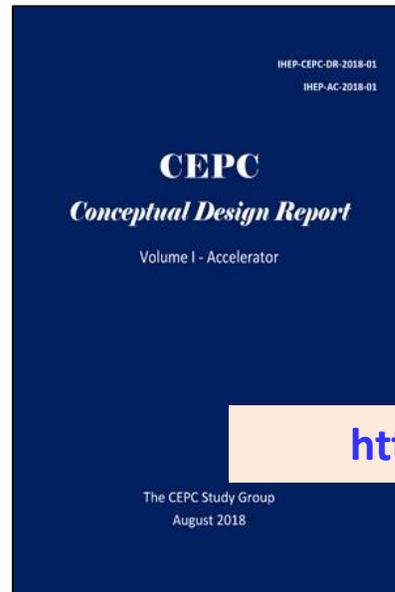
**CEPC-SPPC**  
*Preliminary Conceptual Design Report*  
Volume I - Physics & Detector

The CEPC-SPPC Study Group  
March 2015

**CEPC-SPPC**  
*Preliminary Conceptual Design Report*  
Volume II - Accelerator

The CEPC-SPPC Study Group  
March 2015

2018



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

# CEPC accelerator TDR Published

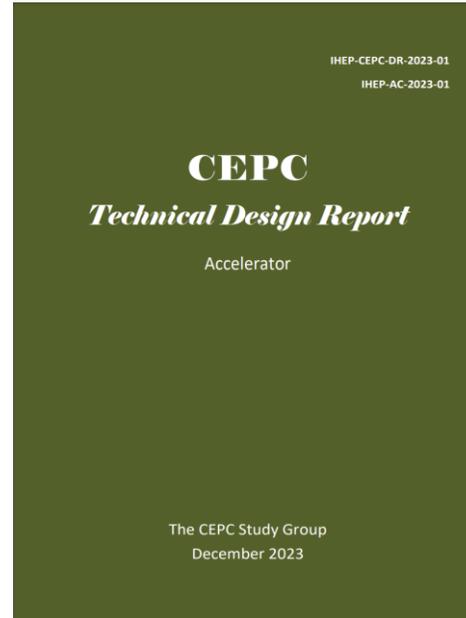
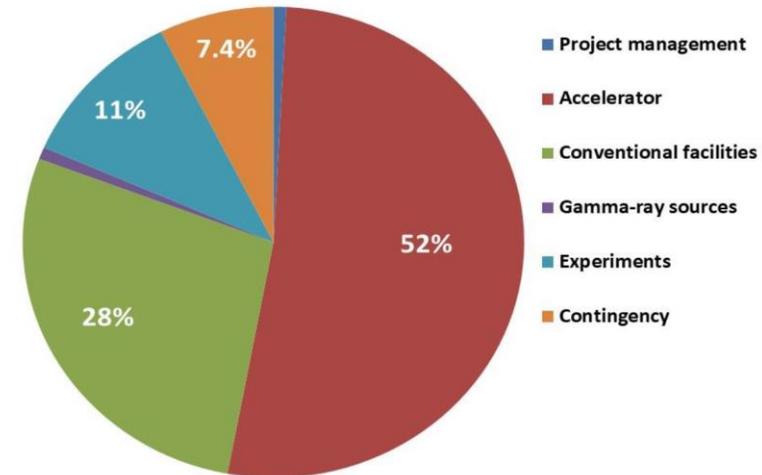


Table 12.1.2: CEPC project cost breakdown, (Unit: 100,000,000 yuan)

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%



Distribution of CEPC Project total TDR cost of **36.4B RMB (~ 5B €)**

**CEPC accelerator TDR has been completed and formally released on December 25, 2023**  
CEPC accelerator TDR link: ([arXiv: 2312.14363](https://arxiv.org/abs/2312.14363))  
CEPC accelerator TDR releasing news:  
[http://english.ihep.cas.cn/nw/han/y23/202312/t20231229\\_654555.html](http://english.ihep.cas.cn/nw/han/y23/202312/t20231229_654555.html)

published in **RDTM Vol.8**  
June 2024

Lepton Photon 2025, Madison



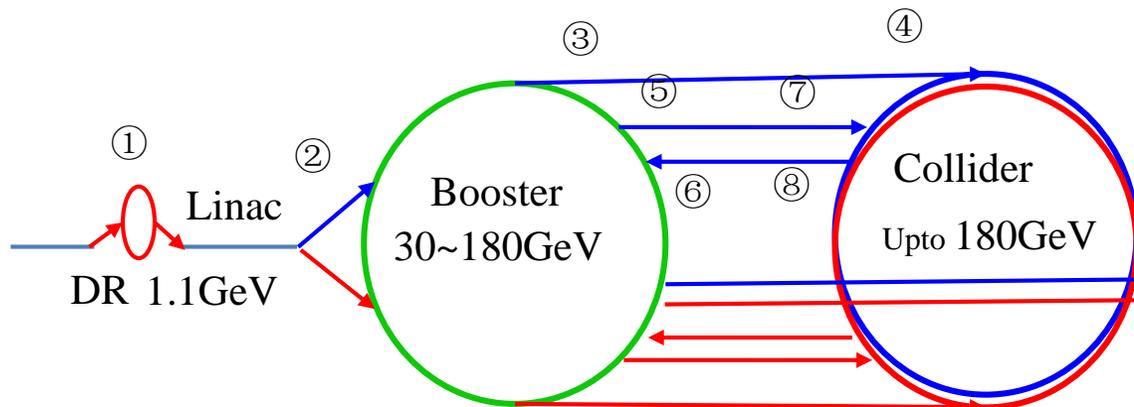
# CEPC parameters and layout

## Booster

		<i>tt</i>		<i>H</i>		<i>W</i>		<i>Z</i>	
		Off axis injection	Off axis injection	On axis injection	Off axis injection	Off axis injection			
Circumfer.	km	<b>100</b>							
Injection energy	GeV	<b>30</b>							
Extraction energy	GeV	<b>180</b>	<b>120</b>		<b>80</b>	<b>45.5</b>			
Bunch number		35	268	261+7	1297	3978	5967		
Maximum bunch charge	nC	0.99	0.7	20.3	0.73	0.8	0.81		
Beam current	mA	0.11	0.94	0.98	2.85	9.5	14.4		
SR power	MW	0.93	0.94	1.66	0.94	0.323	0.49		
Emittance	nm	2.83	1.26		0.56	0.19			
RF frequency	GHz	1.3							
RF voltage	GV	9.7	2.17		0.87	0.46			
Full injection from empty	h	0.1	0.14	0.16	0.27	1.8	0.8		

## Collider

	Higgs	Z	W	<i>t</i> $\bar{t}$
Number of IPs	2			
Circumference (km)	<b>100.0</b>			
SR power per beam (MW)	<b>30</b>			
Energy (GeV)	<b>120</b>	<b>45.5</b>	<b>80</b>	<b>180</b>
Bunch number	268	11934	1297	35
Emittance $\epsilon_x/\epsilon_y$ (nm/pm)	0.64/1.3	0.27/1.4	0.87/1.7	1.4/4.7
Beam size at IP $\sigma_x/\sigma_y$ (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
Beam-beam parameters $\xi_x/\xi_y$	0.015/0.11	0.004/0.127	0.012/0.113	0.071/0.1
RF frequency (MHz)	650			
Luminosity per IP ( $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ )	<b>5.0</b>	<b>115</b>	<b>16</b>	<b>0.5</b>



### running scenarios

**Higgs** 10 years  
**Z** 3 years  
**W** 1 year  
**ttbar** 5 years

### data

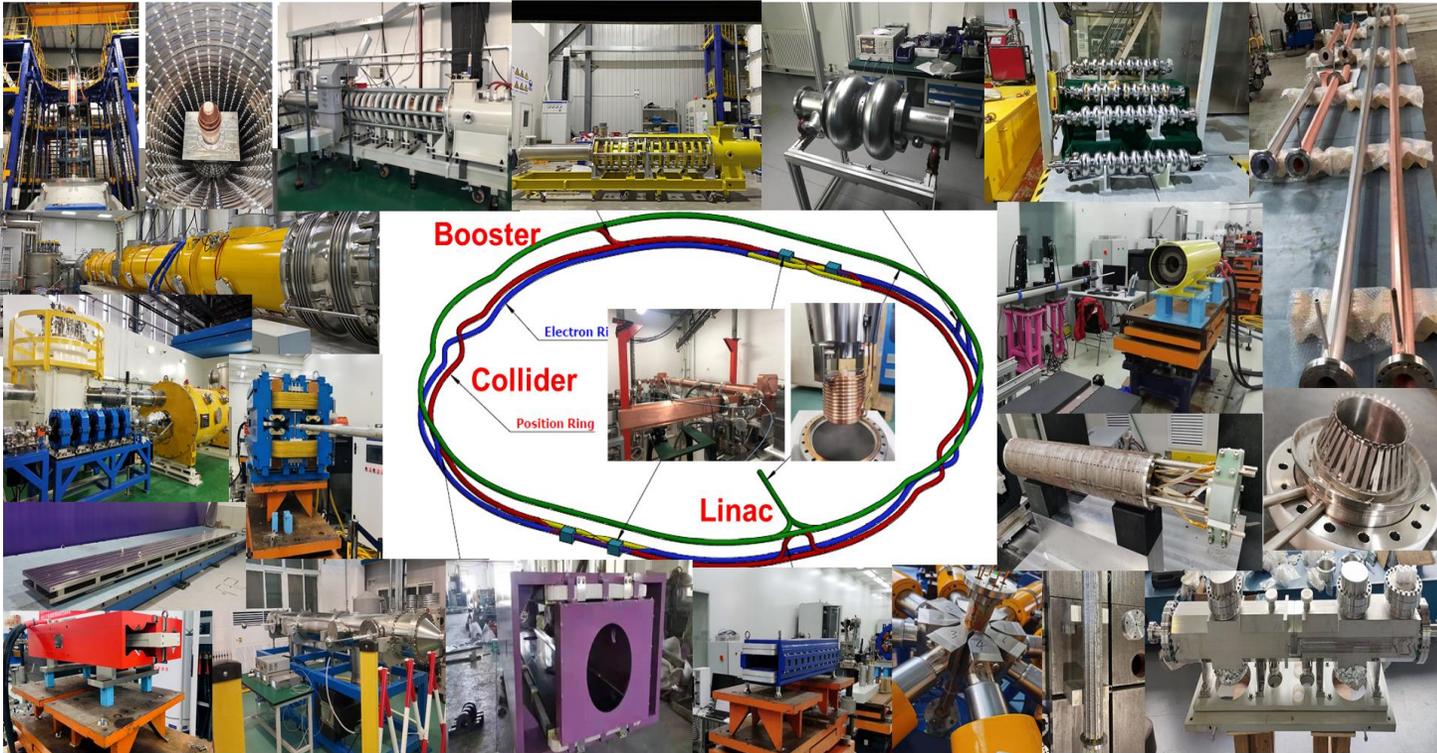
**4 Million Higgs**  
**4 Trillion Z bosons**  
**200 Million W<sup>+</sup>W<sup>-</sup> pairs**  
**600K top pairs**

# CEPC Status and Progress

- **Status of the  $e^+e^-$  collider design and R&D**
- **Engineering Design of the accelerator**
- **Technical Design of a reference detector**
- **Physics performance and whitepapers**
- **Keeping CEPC state of the art**
- **The sites**
- **International collaboration**
- **Industrial partners and suppliers**

# Key Accelerator Technology Readiness

- CEPC key components documented in TDR
- Remaining ~10% (eg. RF power source, control, alignment, SC magnets, machine integration) to be completed by 2026



**The HEPS light source has been just completed by IHEP**

✓ Specification Met

✓ Prototype Manufactured

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



# Key Accelerator Technology Readiness

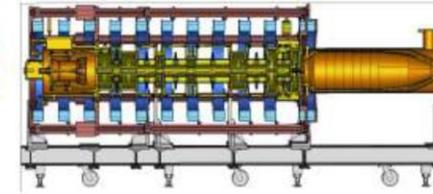
Klystron R&D



Klystron No. 1  
Efficiency 65%  
(2020)



Klystron No. 2  
Efficiency 77%  
(2021)



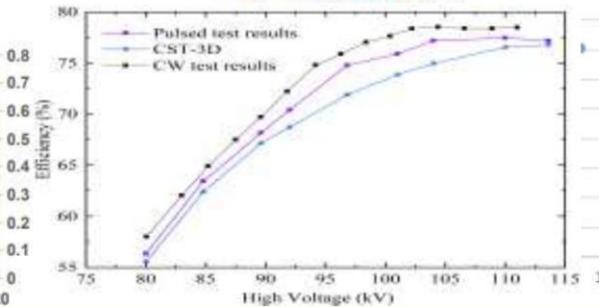
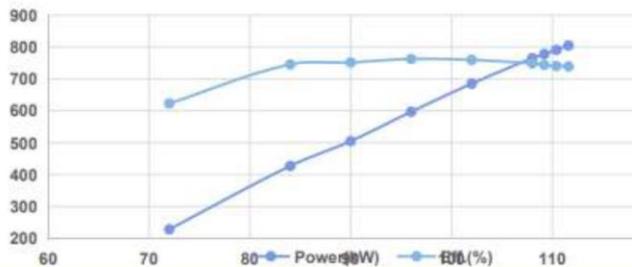
Klystron No. 3 (MBI)  
Efficiency 80.5%

to be completed in 2025

Pulsed RF Mode (30% duty factor, 60ms/5Hz)

**78.5% @ 803kW CW in 2024**

High Voltage vs. Power & Efficiency



**CEPC collider ring 650MHz klystron development in TDR phase**

# Gaining experience with electron accelerators

Learning & experimenting with a new light source (HEPS) and a working e+e- collider (BEPCII)



6 GeV, 36 nm-rad

HEPS 6 GeV, 36 nm-rad, 4<sup>th</sup> generation light source, 1.3 km circumference construction completed in 2025



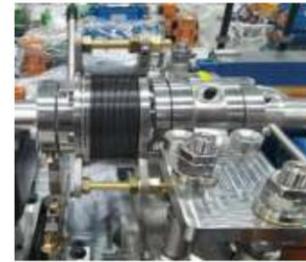
Magnets & alignment



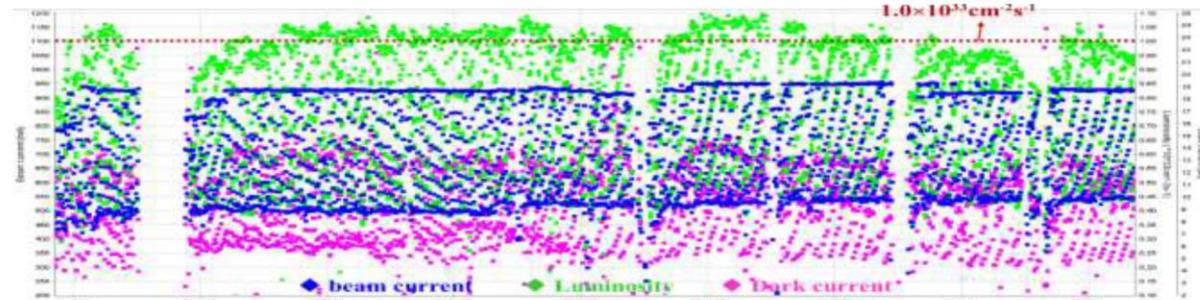
Vacuum pipe and NEG coating



L. Feedback kicker

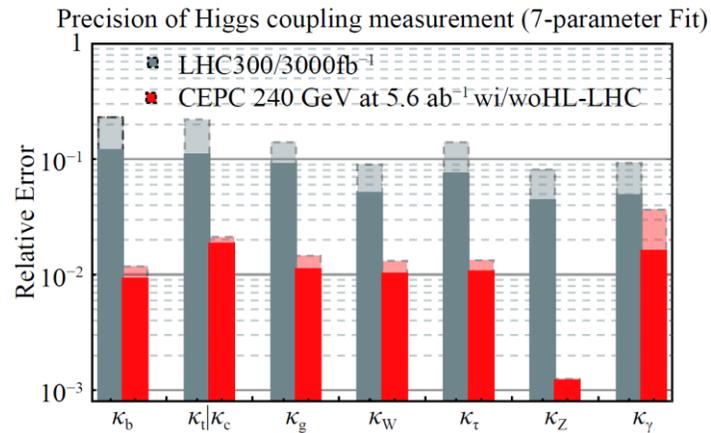


BEPCII high luminosity top-up injection physics data taking operation

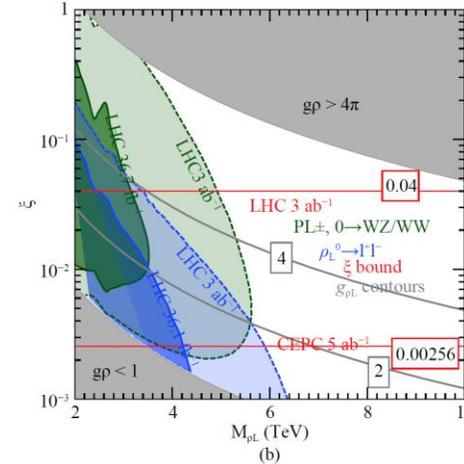
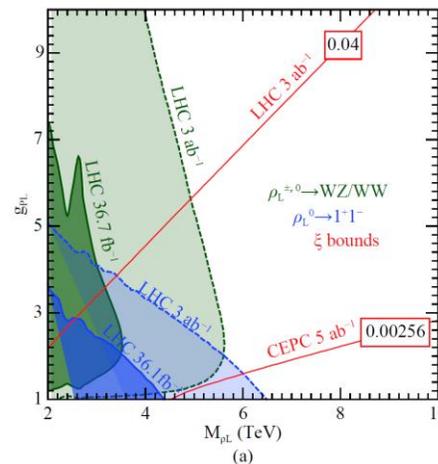


# Physics performance and whitepapers

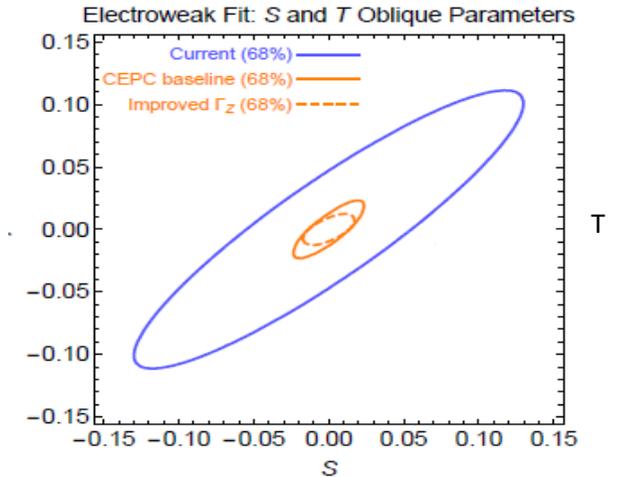
Higgs coupling measurement can be improved by orders magnitude



Direct and indirect probe to new physics up to 10 TeV, ×10 higher than HL-LHC

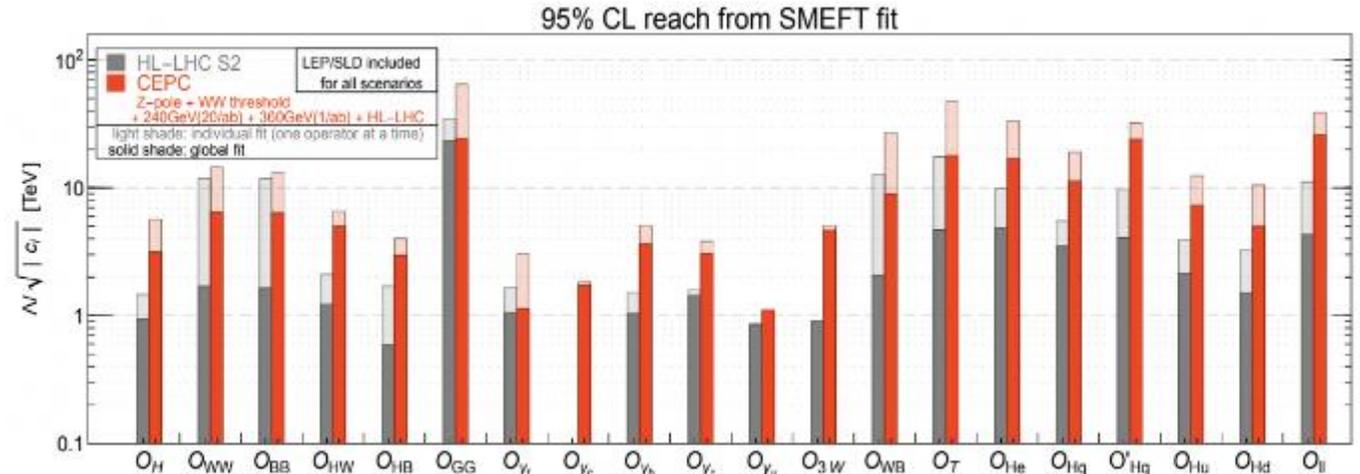


Electroweak measurement can be improved by a large factor



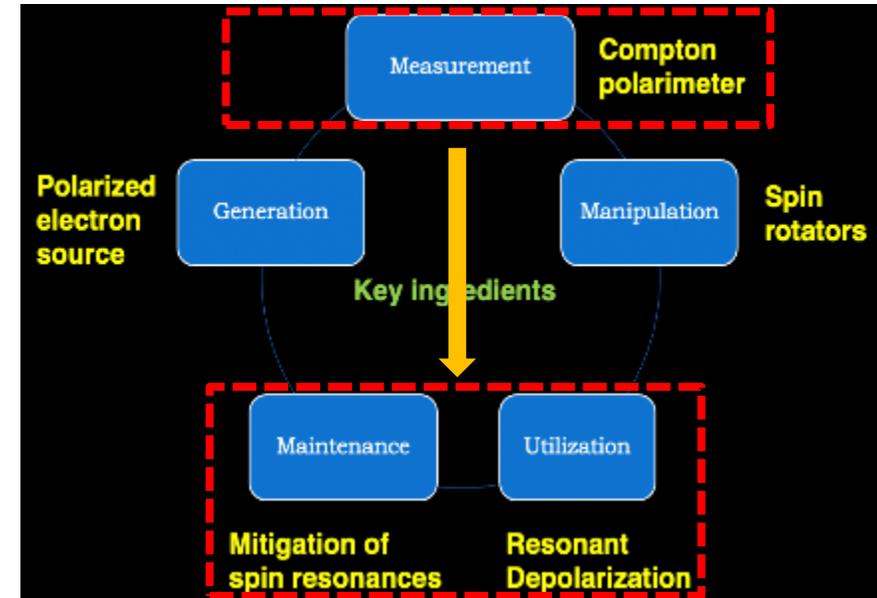
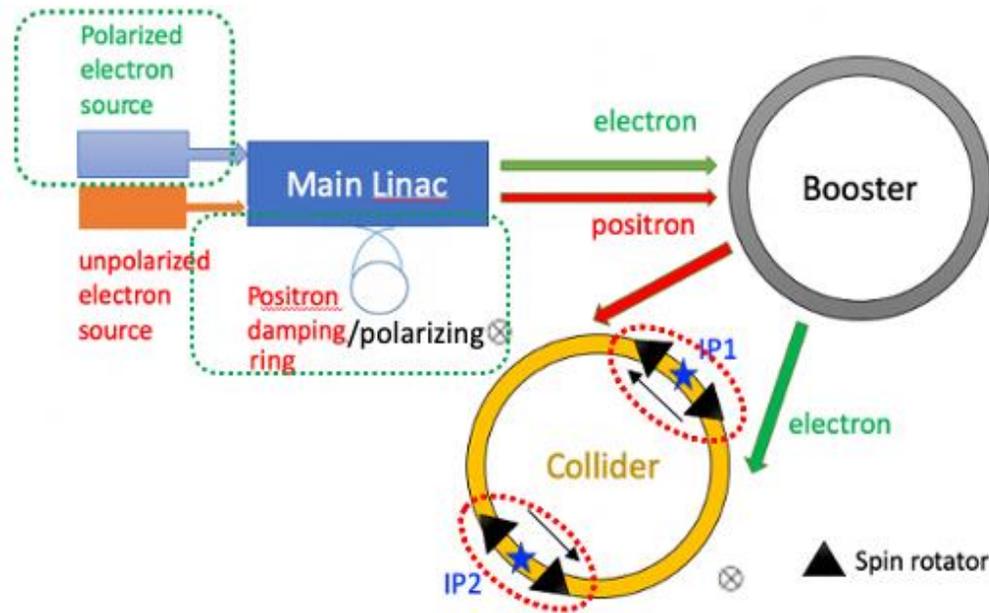
## CEPC physics white papers:

1. **Higgs physics**, arxiv:1810.09037  
Chin. Phys. C 43(2019) 043002
2. **Flavor physics**, arxiv:2412.19743
3. **New Physics Search at the CEPC:**  
a General Perspective arXiv.2505.24810
4. **Electroweak physics**, to be published
5. **QCD**, to be published



# Keeping CEPC state of the art

Both the transverse & longitudinal polarizations : **physics + energy calibration**



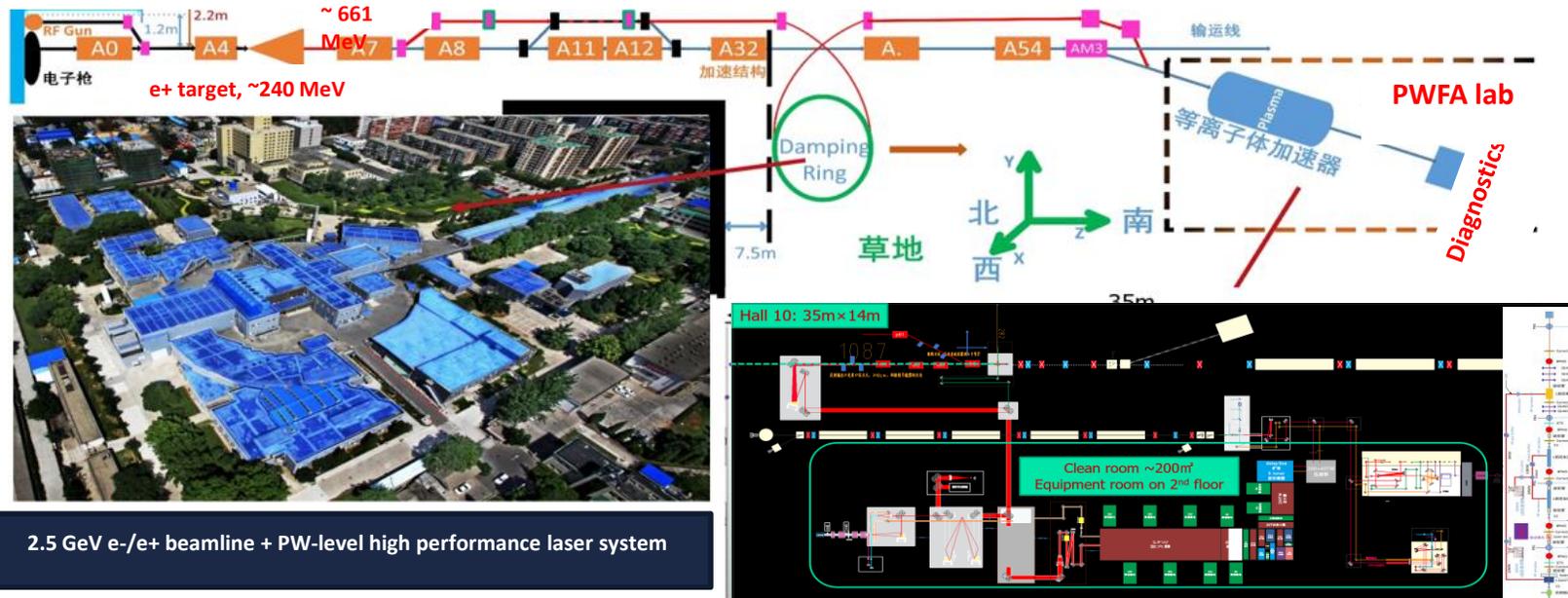
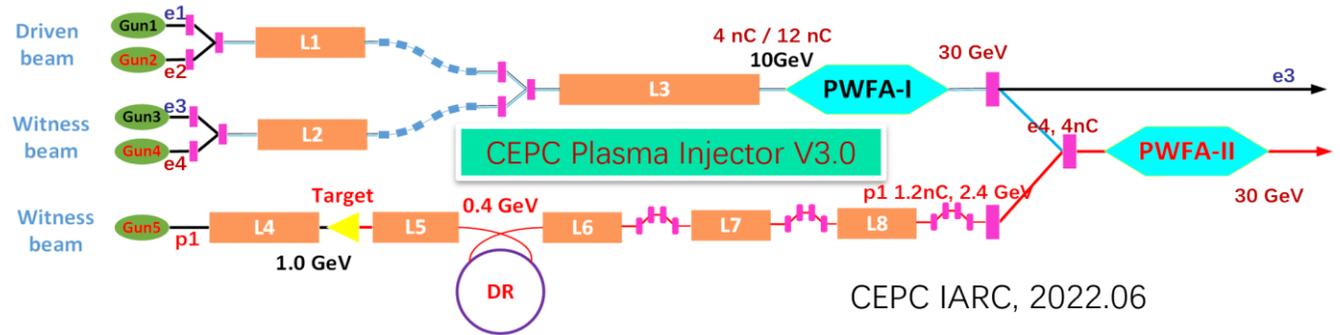
## Future Plan

- Implement the lattice design to accommodate polarized beams: spin rotator, wiggler, Compton polarimeters, dumping ring and booster design, etc.
- R&D of equipment: Compton polarimeter, polarized electron sources, spin rotator, etc.
- Simulate the process and effects of errors
- Carry out experiments at BEPCII & HEPS booster

# Keeping CEPC state of the art

## R&D for Future: Plasma accelerator as the CEPC Injector

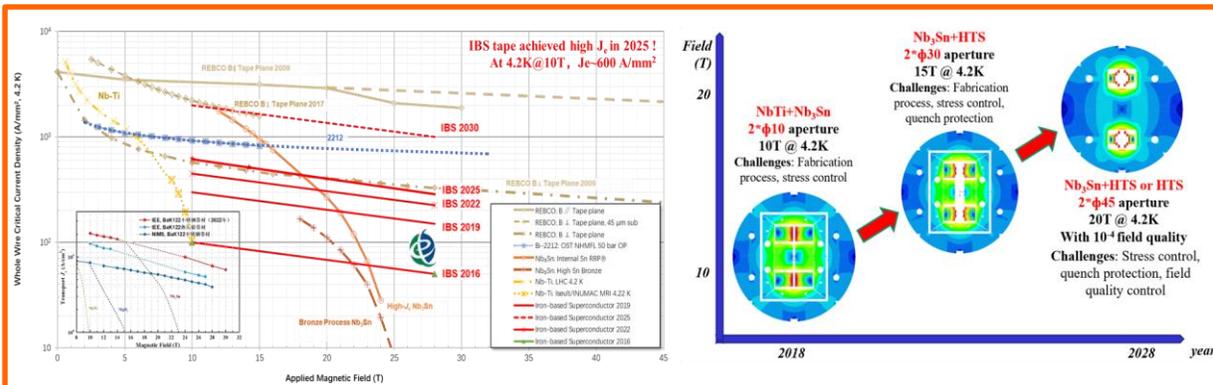
- conceptual design based on simulation
- for experimental proof and prototyping, a test facility based on the BEPCII LINAC is under construction:
  - Cascading, positron acceleration, ...
  - Technology: electron gun, laser, ...



# Keeping CEPC state of the art

## R&D for Future: Iron-Based HTS Magnet

## Efforts Towards a Green Accelerator



### Why:

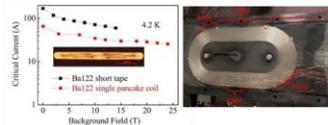
- "Metal", isotropic, ...
- Cheap: material (Ba<sub>0.6</sub>K<sub>0.4</sub>Fe<sub>2</sub>As<sub>2</sub>) and production (PIT, steel tube)

### Status

- Cable length >1000m with good J<sub>c</sub>
- Small-scale cable production techniques understood
- Test coil successful

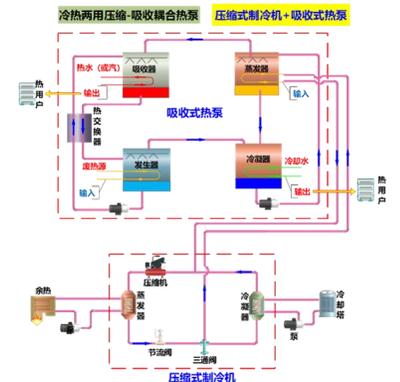
### Plan

- Continue to improve J<sub>c</sub> by × 2-3
- Mid-scale cable production
- Test magnet



- First short coil with 40%J<sub>c</sub>@24T
- First long coil with 80%J<sub>c</sub>@10T

- Construct the underground tunnel in granite: minimum use of concrete and steel, re-use of granite, ...
- Experience at HEPS
  - Solar panel: 10 MW → 10% saving
  - Permanent magnet: 5.6 GWh saving/yr
  - Hot water (13 MW@42°C) for heating
- R&D for CEPC
  - High eff. Klystron, energy recovery Klystron, Solid State Transformer, permanent magnet, ...
  - Design and R&D of a "cooling-compressor + heating-pump system" to recover hot water in winter and cooling water in summer for use at HEPS
  - Continue to investigate power generator using low-T hot water



# CEPC Status – site selection



- All sites have been investigated: good geology, mostly granite
- Good living conditions, and local support

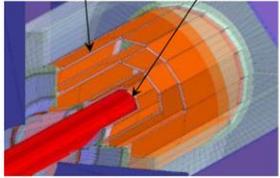
- Site selection will compare geology, electricity supply, transportation, environment for foreigners, local support & economy,...
- Final decision will depend on the negotiation between the central and local governments



# CEPC detector R&D

## Vertex detector

2 layers / ladder  $R_n \sim 16$  mm



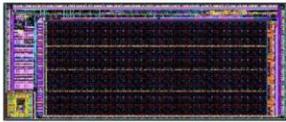
**Goal:**  $\sigma(IP) \sim 5 \mu\text{m}$  for high P track

**CDR design specifications**

- Single point resolution  $\sim 3 \mu\text{m}$
- Low material (0.15%  $X_0$  / layer)
- Low power ( $< 50$  mW/cm<sup>2</sup>)
- Radiation hard (1 Mrad/year)

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

**JadePix-3** Pixel size  $\sim 16 \times 23 \mu\text{m}^2$

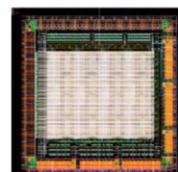


Tower-Jazz 180nm C1S process  
Resolution 5 microns, 53mW/cm<sup>2</sup>

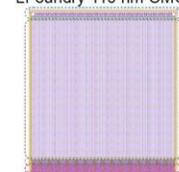
**TaichuPix-3**, FS 2.5x1.5 cm<sup>2</sup>  
25x25  $\mu\text{m}^2$  pixel size



**CPV4 (SOI-3D)**, 64-64 array  
 $\sim 21 \times 17 \mu\text{m}^2$  pixel size



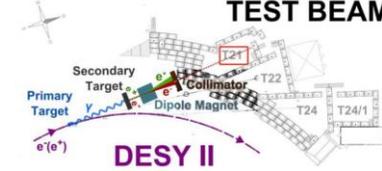
**Arcadia** by Italian groups for IDEA vertex detector  
LFoundry 110 nm CMOS



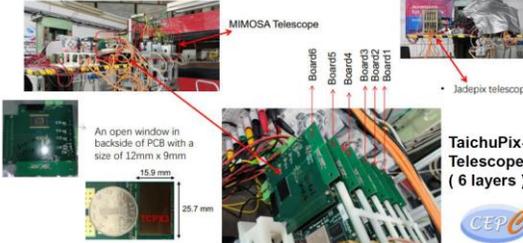
Develop CEPCPix for a CEPC tracker basing on ATLASPix3 CN/IT/UK/DE  
TSI 180 nm HV-CMOS process

Full vertex detector prototype (TaichuPix-3, JadePix-3) has TB at DESY in Dec. 2022.

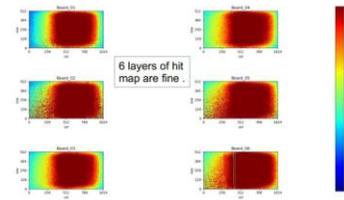
**TEST BEAM**



DESY II



**Hitmap of 4 GeV e<sup>+</sup>/e<sup>-</sup> beam**



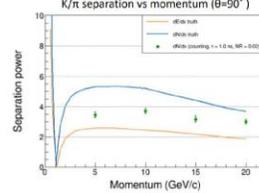
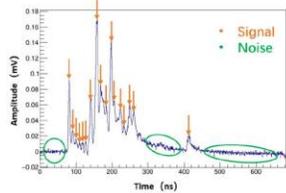
6 layers of hit map are fine.

**TaichuPix-3 Telescope (6 layers)**



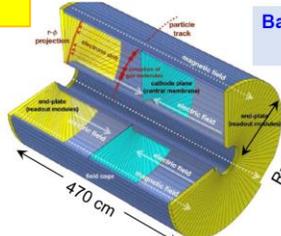
## particle ID + main tracker

- Goal:**  $3\sigma \pi/K$  separation up to  $\sim 20$  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.

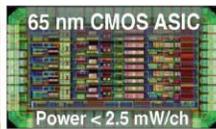


IHEP and Italian INFN groups have close collaboration and regular meetings. IHEP joined the TB (led by INFN group) in 2021 and 2022

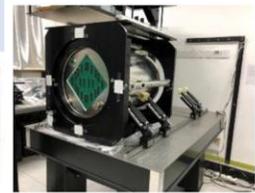
**Baseline main tracker**  
 $\sigma(r-\phi) \sim 100 \mu\text{m}$



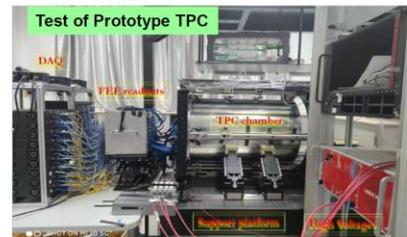
**MOST 1 (IHEP+THU)**  
65 nm CMOS ASIC  
Power  $< 2.5$  mW/ch



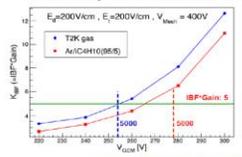
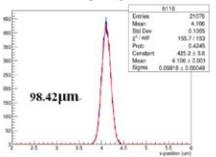
**GEM-MM cathode TPC Prototype + UV laser beams**



**Low power FEE ASIC**



**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.**

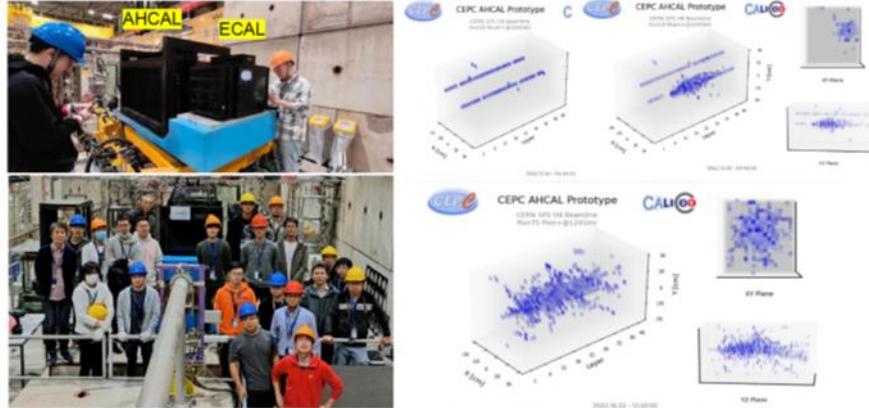



$\sigma_r < 100 \mu\text{m}$  for drift length of 27cm

# CEPC detector R&D

## EM + hadron calorimeters: prototypes

➤ PFA ScW-ECAL & AHCAL prototypes: Test Beam at CERN SPS H8 (Oct. 2022)



USTC, IHEP, SJTU, Japanese & Israel groups have close collaboration and regular meetings 32

## new crystal EM calorimeter for better resolution

**Goal**

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

**Bench Test**

**Crystal Fan Design** Fine segmentation in Z,  $\phi$ , r

Long bars: 1 x 40 cm, super-cell: 40x40 cm<sup>2</sup>  
Timing at both ends for positioning along bar.  
Significant reduction of number of channels.

**Performance with photons**

Reconstructed Mass of Higgs

**Performance with jets**

Reconstructed Mass of Higgs

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

## software

**Key4hep**: an international collaboration with CEPC participation  
**CEPCSW**: a first application of Key4hep – Tracking software  
**CEPCSW is already included in Key4hep software stack**

<https://github.com/cepc/CEPCSW>

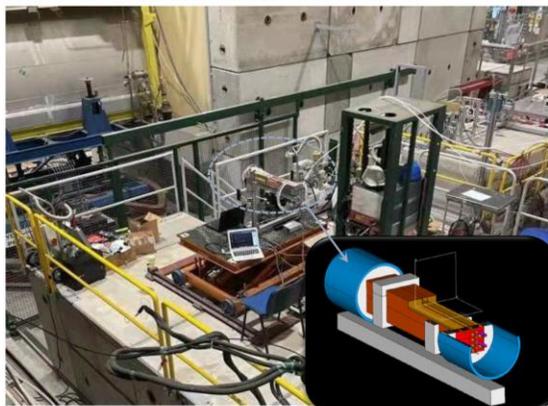
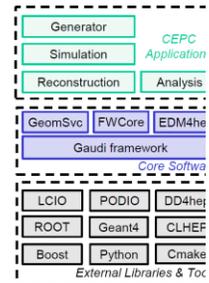
### Architecture of CEPCSW

- 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

### CEPCSW Structure



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



# International collaborations

---

- CEPC will be an international project, following the HEP tradition
- IHEP successfully organized large projects such as BESIII, Daya Bay and JUNO with ~50% non-Chinese members and international in-kind contributions of ~5%, ~30%, and ~15% respectively
  - BESIII has >600 members from 84 institutions in 17 countries and regions
  - Daya Bay had >250 members from 40 institutions in 6 countries and regions
  - JUNO has >700 members from 72 institutions in 17 countries and regions
- Based on the experience from above experiments, our plan for CEPC is the following:
  - Goal: international contributions at the level of ~10-30%
  - Although the management system is yet to be settled, most likely IHEP will be the host lab
  - A concept of the management structure has been endorsed by IAC, further discussion needed
  - Once CEPC is approved in China( ~ CDO in DOE), international collaboration can be formally started
    - Discussion with partners about the management
    - Form various committees
    - Call for detector proposals, and select proposals
    - Form international collaborations, deliver TDRs, sign MoUs, build detectors,....
  - Civil construction and most of the accelerator construction can start after the CD3 approval by NDRC, internationalized construction of detectors and other accelerator equipment may come a few years later

# International collaborations

## CEPC attracts significant International participation and collaborations

**Accelerator TDR report:** 1114 authors from 278 institutes ( including 159 International Institutes, 38 countries ) Published in **Radiation Detection Technology and Methods (RDTM)** on June 3, 2024:  
DOI: 10.1007/s41605-024-00463-y  
<https://doi.org/10.1007/s41605-024-00463-y>



- More than 20 MoUs have been signed with international institutions and universities
- CEPC International Workshop since 2014
- EU-US versions of CEPC WS since 2018
- Annual working month at HKUST-IAS (mini workshops and HEP conference) since 2015



## Design and R&D

- strong participations by international scientists for CDR and TDR
- reviews and guidance by many overseas experts

- Workshops and conf. at overseas sites
- Many Zoom meetings

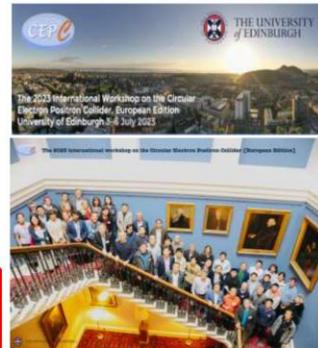
HKIAS23 HEP Conference, Feb. 14-16, 2023  
<https://indico.cern.ch/event/1215937/>



The 2024 HKUST IAS Mini workshop and conference were held from Jan. 18-19, and Jan. 22-25, 2024, respectively.  
<https://indico.cern.ch/event/1335278/timetable/?view=standard>

The 2025 HKUST IAS HEP conference: Jan. 13-17, 2025.  
CEPC Workshop EU Edition (Barcelona, Spain), May 5-8, 2024

The 2023 International Workshop on Circular Electron Positron Collider, EU Edition, University of Edinburgh, July 3-6, 2023  
<https://indico.ph.ed.ac.uk/event/259/overview>



The 2024 international workshop on the high energy Circular Electron Positron Collider (CEPC) will be held from Oct. 23-27, 2024, Hangzhou, China  
<https://indico.ihep.ac.cn/event/22089/>

The 2023 international workshop on the high energy Circular Electron Positron Collider (CEPC)  
<https://indico.ihep.ac.cn/event/19316/>



Professor Peter Higgs passed away on April 8, 2024. We miss him.

The 2024 international workshop of CEPC, EU-Edition were held in Marseille, France, April 8-11, 2024.  
<https://indico.in2p3.fr/event/20053/overview>



FCPPNL, Bordeaux, France, June 10-14, 2024  
<https://indico.in2p3.fr/event/20421/overview>

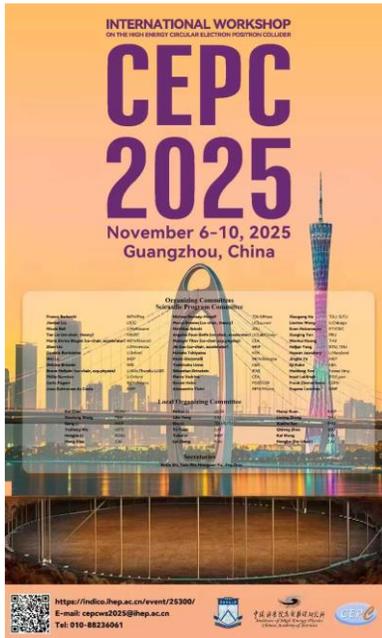
CEPC Workshop EU Edition (Barcelona, Spain) June 16-19, 2025  
<https://indico.ifae.es/event/2054/overview>



FCPPNL, Qingdao, China, July 21-25, 2025  
<https://indico.ihep.ac.cn/event/25400/>

# International collaborations

## Forthcoming workshops and meetings



**2025 international workshop on high energy  
Circular Electron Positron Collider (CEPC)  
November 6-10, 2025  
Guangzhou, China**

<https://indico.ihep.ac.cn/event/25300/>

**2026 HKUST IAS fundamental physics conference  
January 12-16, 2026,  
Hong Kong**

**2026 EU CEPC Workshop  
April 7-10, 2026  
Lisbon, Portugal**

**Please join us at these events**

# International collaborations

## Advising and reviews by international committees - recent



CEPC IARC meeting will be held from Sept. 16-19, 2025

CEPC IARC meeting was held from Sept. 18-20, 2024

<https://indico.ihep.ac.cn/event/22311/>



CEPC IAC meeting will be held from Nov. 20-21, 2025

CEPC IAC meeting in 2024 was held from Oct. 29-30, 2024

<https://indico.ihep.ac.cn/event/23450/timetable/>



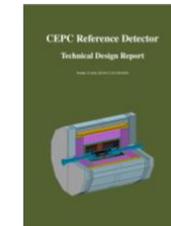
The International Detector Review Committee (IDRC) held its inaugural meeting at IHEP, Oct 21-23, 2024, to review the status and plan of Ref-TDR.

<https://indico.ihep.ac.cn/event/23265/>



CEPC IDRC meeting was held from April. 14-16, 2025

<https://indico.ihep.ac.cn/event/25539>



CEPC Detector Reference Design Report



# **CEPC Plan**

- **Accelerator Engineering Design towards an EDR**
- **A reference design detector for domestic evaluation**
- **Proposal for 15<sup>th</sup> 5–year plan and beyond**

# Engineering Design towards an EDR

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## CEPC EDR Phase General Goal (2024-2027):

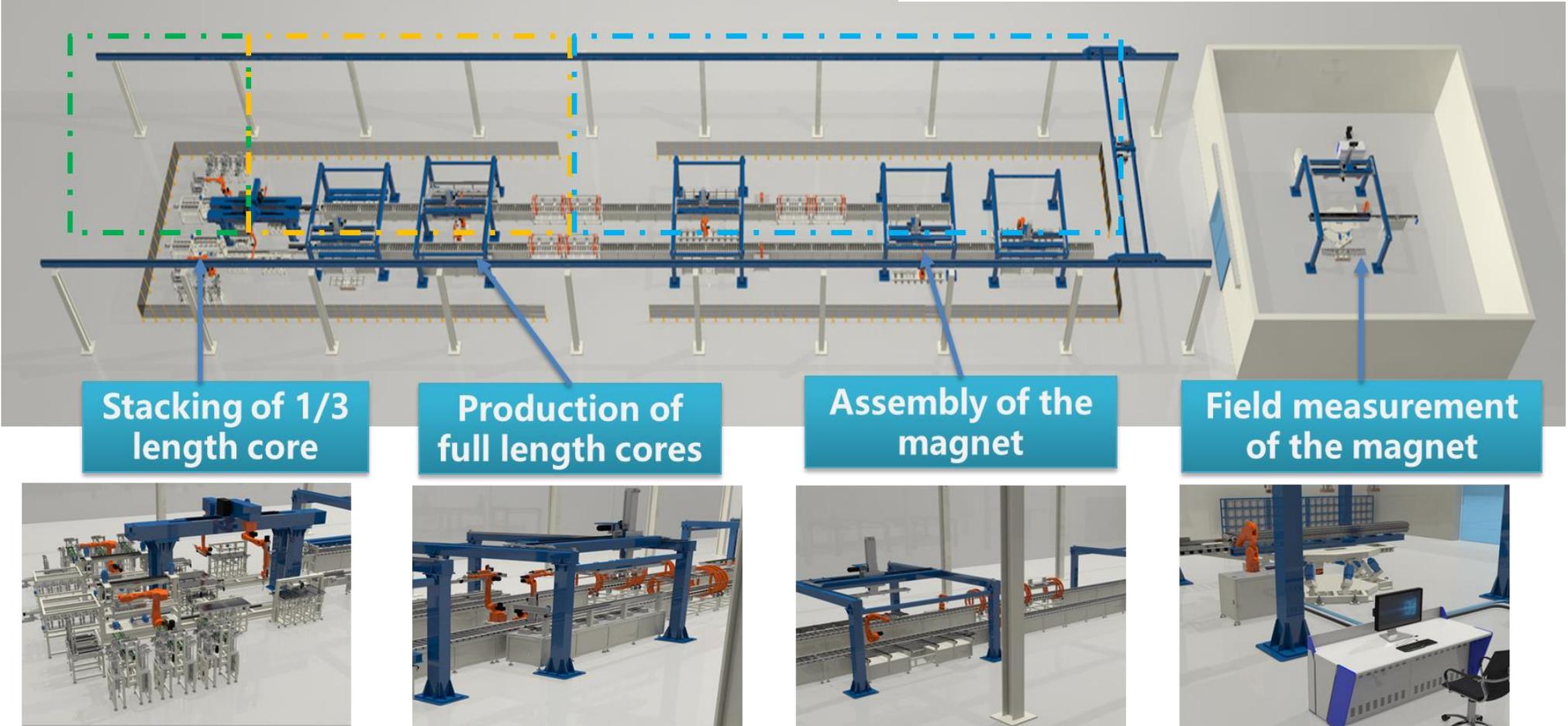
CEPC accelerator will enter the Engineering Design Report (EDR) phase (2024-2027); its also the preparation phase with the aim for CEPC proposal to the Chinese government ~2025 for approval.

**CEPC Accelerator EDR Phase goals, scope and the working plan (preliminary) of 35 WGs summarized in a documents of 20 pages reviewed and endorsed by IARC**

# EDR – examples magnet automatic production

4 booster magnets per day

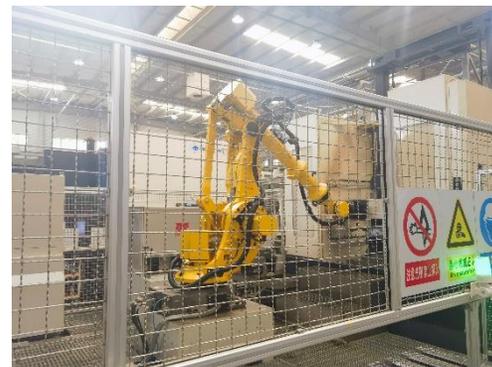
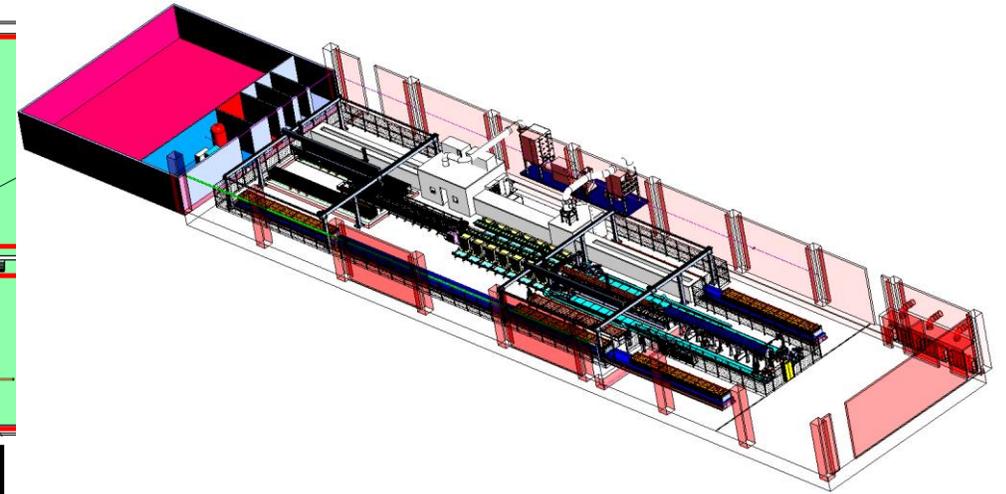
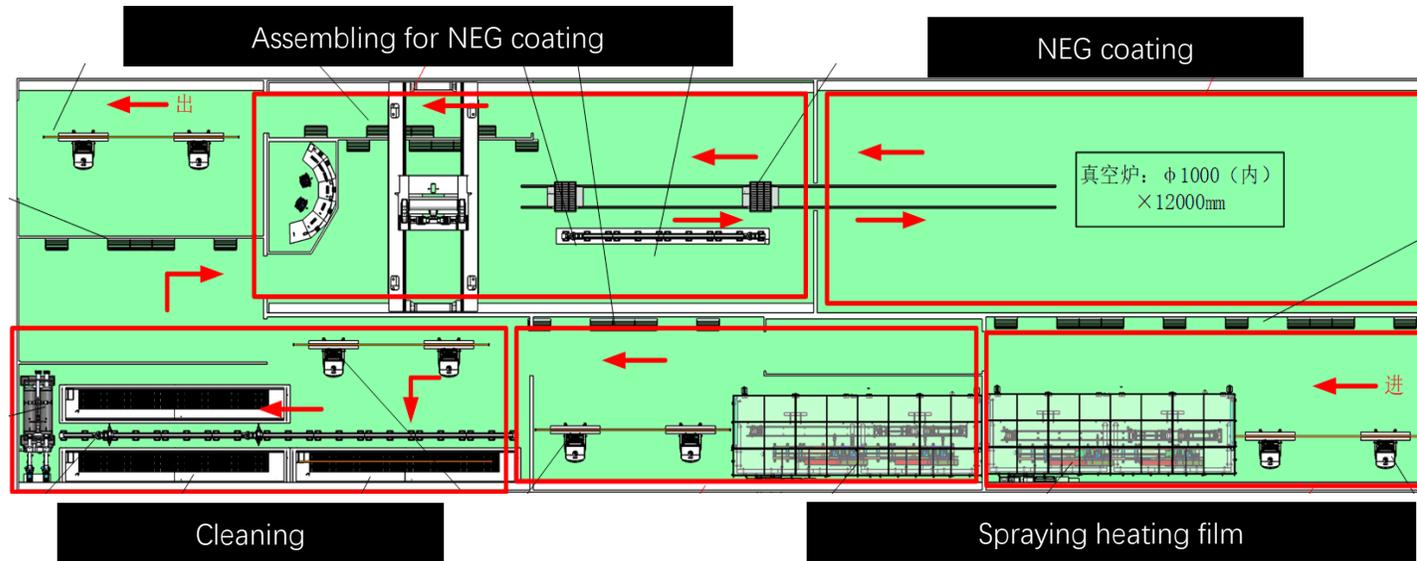
~15000 total dipole magnets in booster



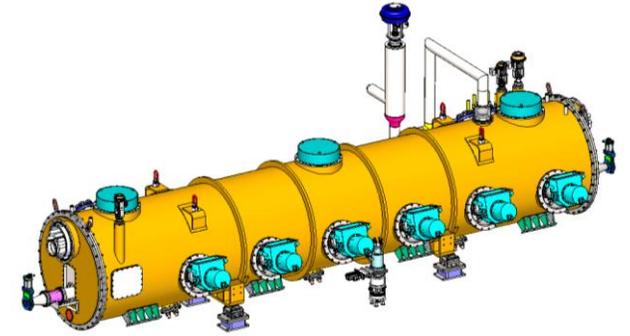
Status: construction started, to be completed in 2025

Lepton Photon 2025, Madison

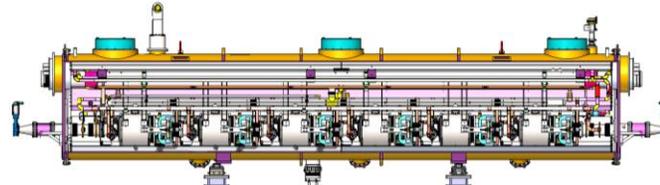
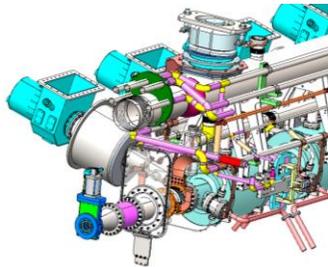
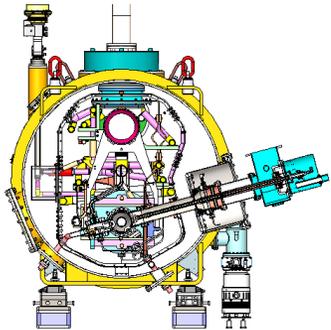
# EDR - Examples NEG coated vacuum chamber



# EDR - Examples Collider cryomodule



CEPC collider ring 650MHz 2\*cell short test module has been completed in TDR phase



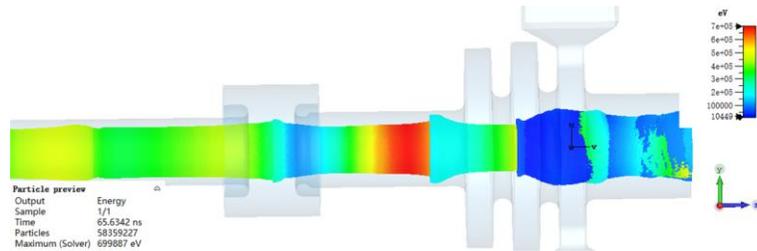
**A full size 650 MHz cryomodule will be developed in EDR**

The collider Higgs mode for 30 MW SR power per beam will use 32 units of 11 m-long collider cryomodules containing six 650MHz 2-cell cavities

# EDR - Examples Energy recovery klystron

**C band 5720MHz 80MW  
Klystron design completed**

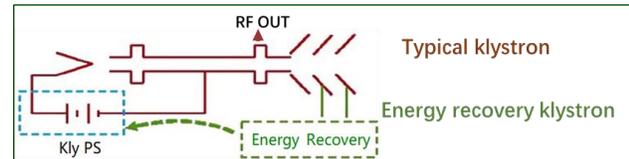
**Technical assessment has been done  
on August 12, 2024, construction  
started , to be completed in 2025**



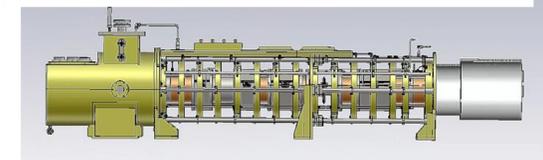
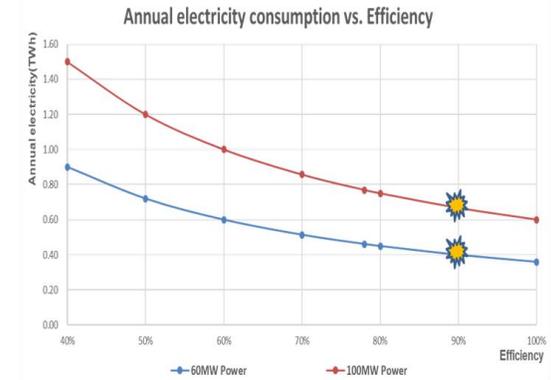
**CEPC 650Mhz Energy Recovery Klystron Development**

**4<sup>th</sup> review held on July 8, 2025**

**The 4<sup>th</sup> Klystron (Energy recovery, one stage)**



Parameter	Value
Operating frequency	650 MHz
Beam Voltage	113 kV
<b>Efficiency</b>	<b>77.5%</b>
Output power	800 kW
Beam perveance	0.25 $\mu$ P
Beam current	9.5A
<b>Efficiency (one-stage depressed collector)</b>	<b>85%</b>

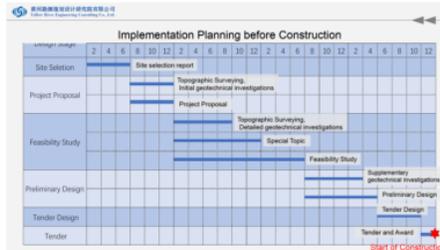


**The 4<sup>th</sup> Klystron (Energy recovery, one stage) technical review has been done on July 8, 2025**

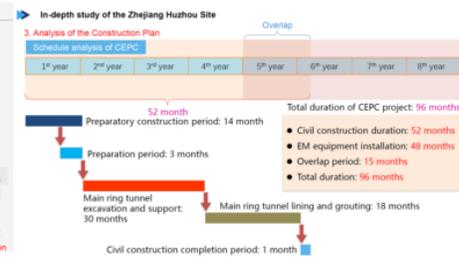
# Engineering Design towards an EDR

## CEPC Site Implementation and Construction Plans

### CEPC site implementation plan in EDR



### CEPC construction plan

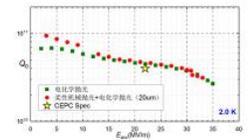
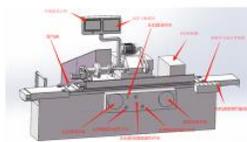


## Future Plan for CEPC SRF

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034-2035	2036-2045	2046-2047	2048	2049-2053
<b>EDR</b>	[Timeline bar]															
<b>Civil construction</b>	[Timeline bar]															
<b>Acc. construction &amp; installation</b>	[Timeline bar]															
<b>Commission &amp; operation</b>	[Timeline bar]															
<b>SRF system engineering design</b>	Layout, cost, models, beam-cavity, LLRF, interfaces ...															
<b>650 MHz test module (2x2-cell)</b>	Beam operation, replace with high Q cav & variable coupler															
<b>650 MHz H module (6x2-cell)</b>	Design, pCM fabrication, pCM test, Prepare, Production of 32 CM / 152 2-cell CAV for 30 MW H, Installation, Commissioning, Op & +24 CM, Operation															
<b>1.3 GHz H module</b>	High Q module, Mass production of modules with SCM and IPM, pCM fab, pCM test, Production of 12 CM / N 9-cell CAV, Installation, Commissioning, Operation															
<b>1.3 GHz Z module (high current)</b>	Design and R&D, pCM fabrication, pCM test, Production of 4 CM / 2 3-cell CAV, Installation, Commissioning, Operation															
<b>650 MHz HL-Z module</b>	Conceptual design, 500 MHz high current module production, Design and R&D, Produce and install 60-80 1-cell CM, Op															
<b>tbar cavity and module</b>	Design and R&D of high gradient high Q and new material (Nb3Sn etc.) 650 MHz and 1.3 GHz cavities and module for tbar, pCM fabrication and test, Production and installation of 48 CM / 152 650 MHz 5-cell CAV, 32 CM / 256 1.3 GHz 9-cell CAV, Op															

## CEPC SRF Industrial Production Technology

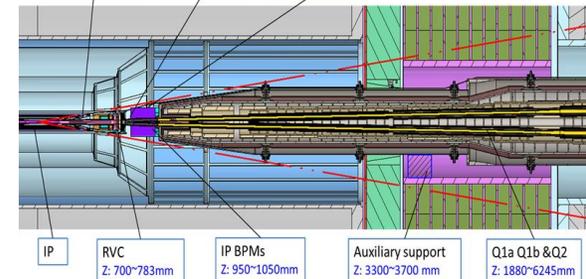
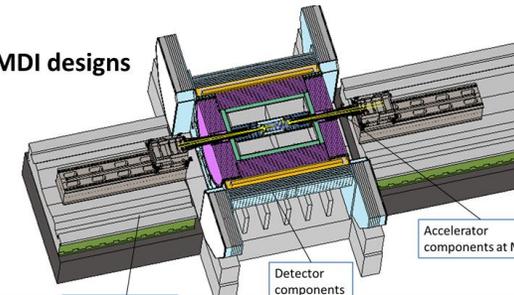
- In 2023, IHEP invented soft SRF cavity polishing equipment has been completed and it will be installed at IHEP soon, and it reached the same surface roughness as EP. CEPC 650 MHz cavity treated by the soft polishing equipment reached the CEPC specification



650 MHz SC measurement result with soft polishing technology



## CEPC MDI designs



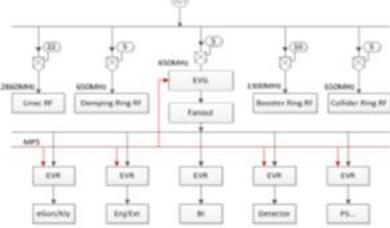
# EDR - Examples

## CEPC Accelerator Control and Timing in EDR

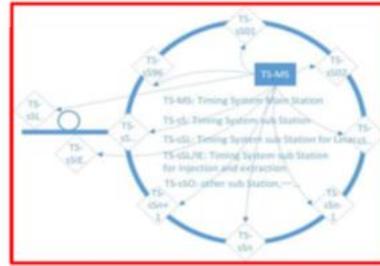
### The basic structure of Timing System

- Event system and RF transmission system
- Event system: Trigger signal and Low frequency clock signal
- RF transmission system: Transmit high stability RF signal

Temperature variation induced drift compensation  
0.7ns for 10km optical fiber with 1 °C change normally



In EDR phase CEPC high precision timing and control technology will be developed

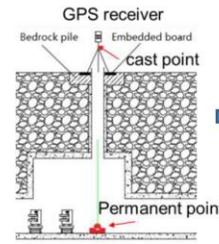


## CEPC Alignment and Installation Plan in EDR

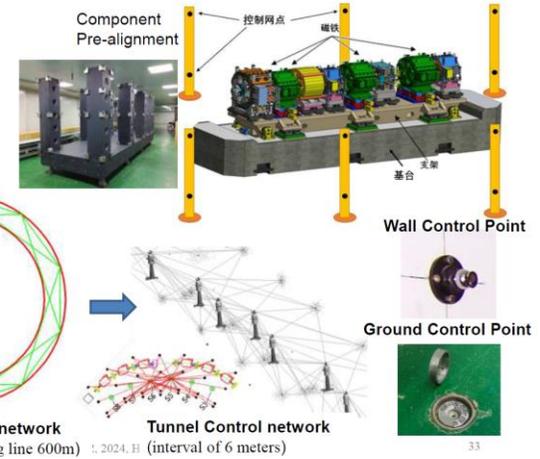
### Alignment accuracy requirement

Component	$\Delta x$ (mm)	$\Delta y$ (mm)	$\Delta\theta_z$ (mrad)
Dipole	0.10	0.10	0.10
Arc Quadrupole	0.10	0.10	0.10
IR Quadrupole	0.10	0.10	0.10
Sextupole	0.10*	0.10*	0.10

\*implement beam-based alignment



CEPC Accelerator EDR Plan-J. Gao

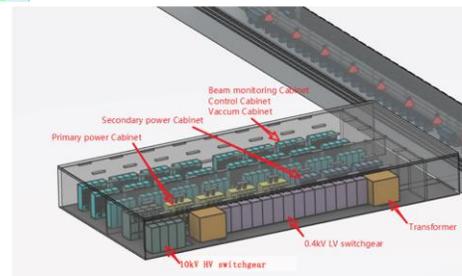
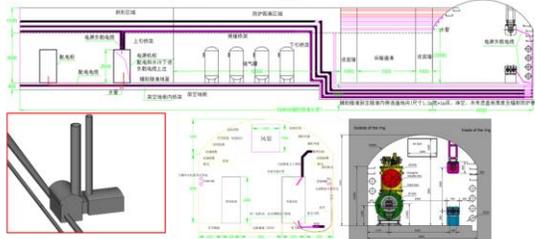
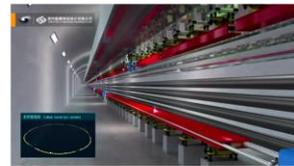
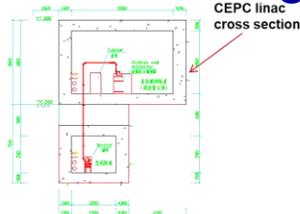
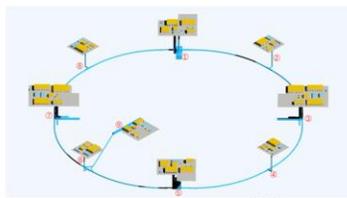


Backbone Control network  
(short line:300m; long line 600m)

Tunnel Control network  
(interval of 6 meters)

## Civil Engineering and Conventional Facilities

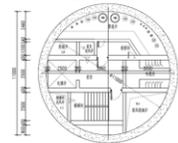
CEPC general layout and auxiliary tunnel /500m along 100km



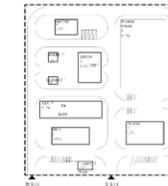
CEPC general layout 100km



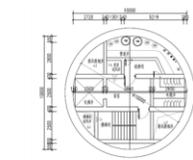
IP-1 surface building



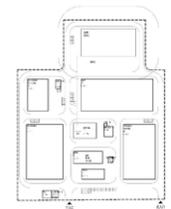
IP-1 auxiliary hall shaft



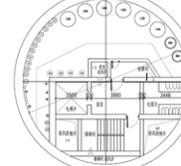
Arc shaft surface building



Arc shaft hall shaft



SRF shaft surface building



SRF shaft

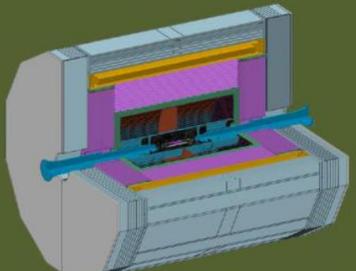
# Technical Design of a reference detector system

- The CEPC study group is developing a TDR for a reference full-detector by end of 2025, aiming mainly for domestic endorsement with a design and a budget
- An international review committee has been has been guiding and reviewing the TDR design
- CEPC will continue to adopt better technologies; final detectors will be determined by international detector collaborations to be formed

CEPC Reference Detector  
Technical Design Report

Date: June 9, 2025  
Version: 0.1 build: 2025-04-02 01:08:51+08:00

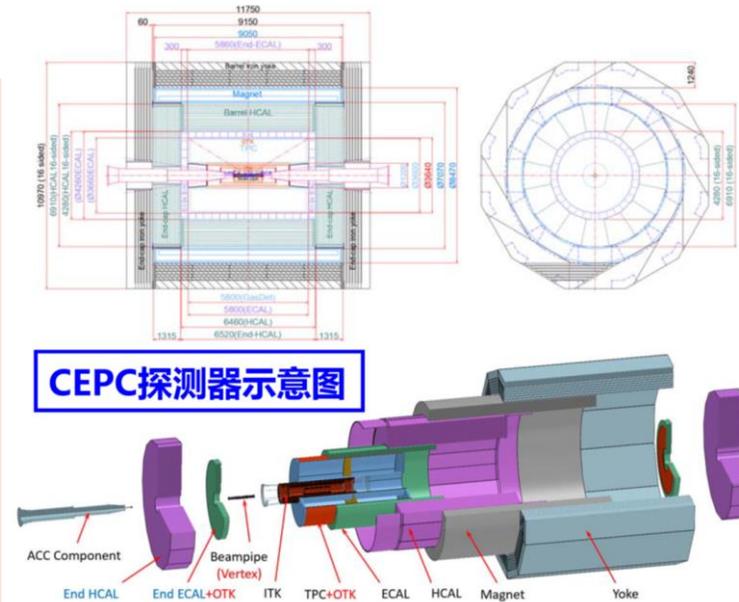
Draft, to be published soon  
~ 100 institutions involved



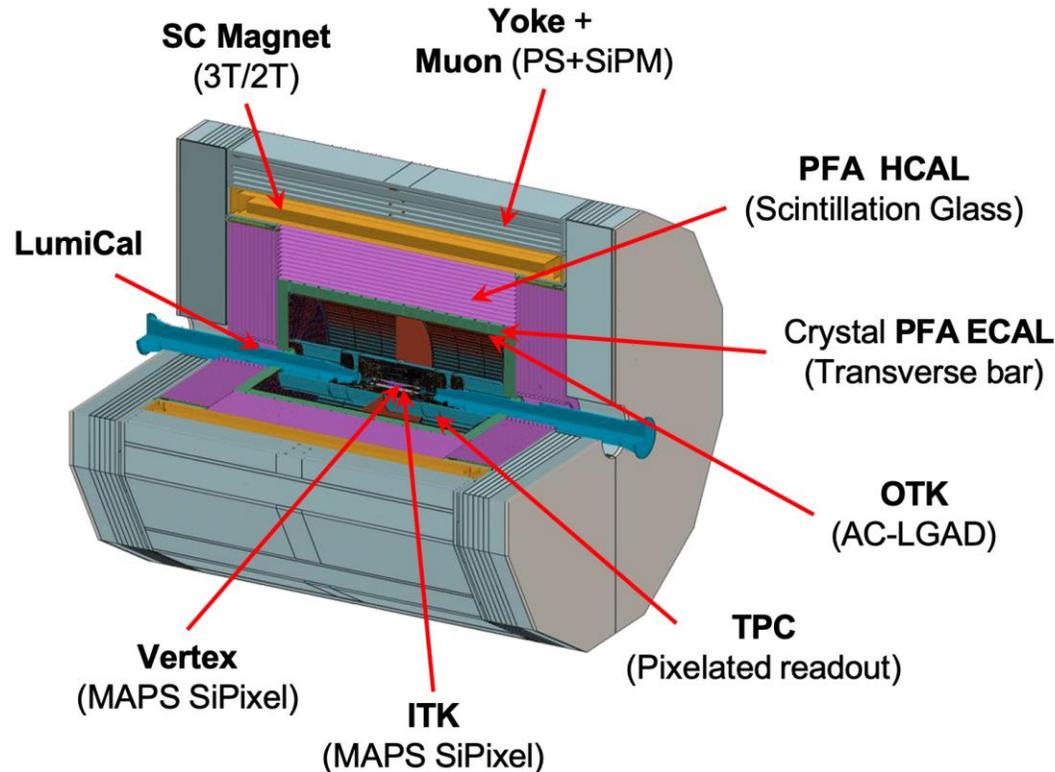
presently under review

## Foundations:

- CEPC Instrumentation R&D
- LHC detector upgrade projects
- other HEP experiments
- progress in HEP worldwide R&D
- development in industry



# The reference detector: **the concept**



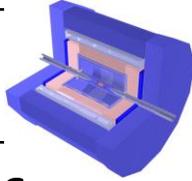
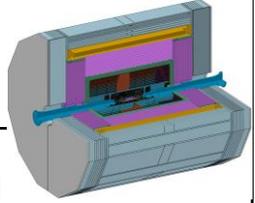
## ■ Silicon tracker+TPC: **precision tracking and PID**

- **Inner tracker:** three barrel layers and 2×4 endcap layers of MAPS HV-CMOS pixel sensors using 55nm tech.
- **TPC for PID and tracking:** Pixelated readout ( $500 \times 500 \mu\text{m}^2$ ) of Micromegas for good tracking and PID
- **Outer tracker for PID and tracking:** one barrel layer and two endcap disks based on AC-LGAD to measure timing and position simultaneously

## ■ **PFA-oriented ECAL:** 18 layers of BGO crystal bars ( $1.5 \times 1.5 \times 40 \text{ cm}^3$ ), arranged in the x-y direction alternatively, in perpendicular to the incident particle, to achieve fine 3D granularity, and **good position and energy resolution**

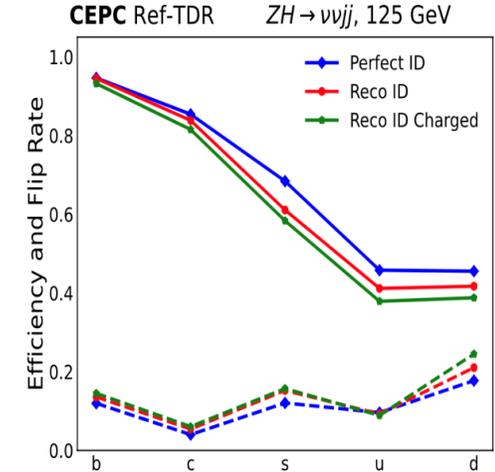
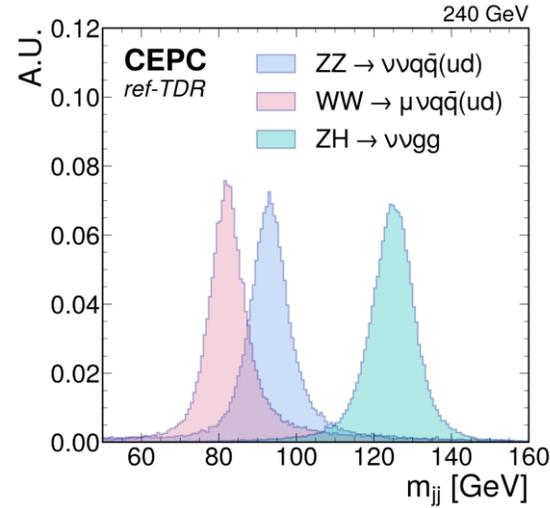
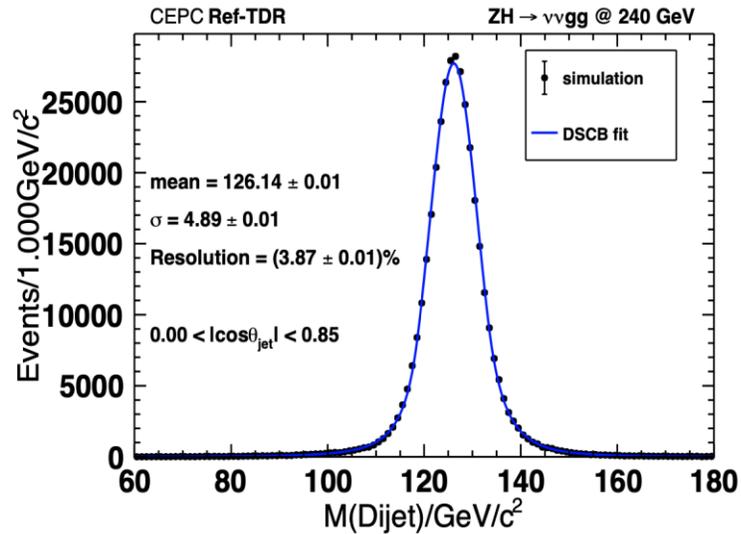
## ■ **PFA-oriented HCAL:** 48 layers of glass scintillator tiles ( $4 \times 4 \text{ cm}^2$ ) interspersed with steel plates for good 3D granularity and resolution

# The reference detector: a leap forward from the CDR

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

# Technical Design of a reference detector

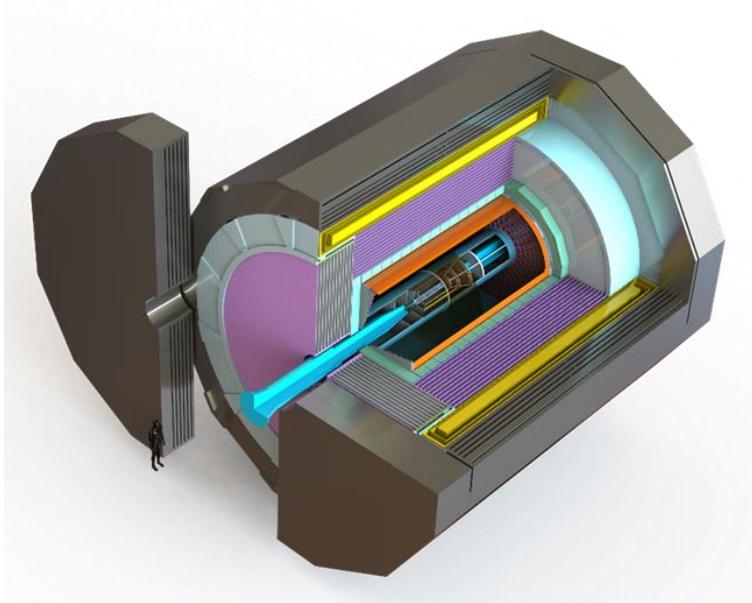
## jet performance



- Dijet Higgs well reconstructed, BMR in barrel reaches **3.87%**, design goal achieved (<4%)
- For the same BMR, crystal ECAL has a much better energy resolution
- Glass HCAL has a very good energy resolution, may be suitable for ECAL if light yield further improved  $\rightarrow$  A full absorption ECAL+HCAL

# Technical Design of a reference detector

## future detector R&D

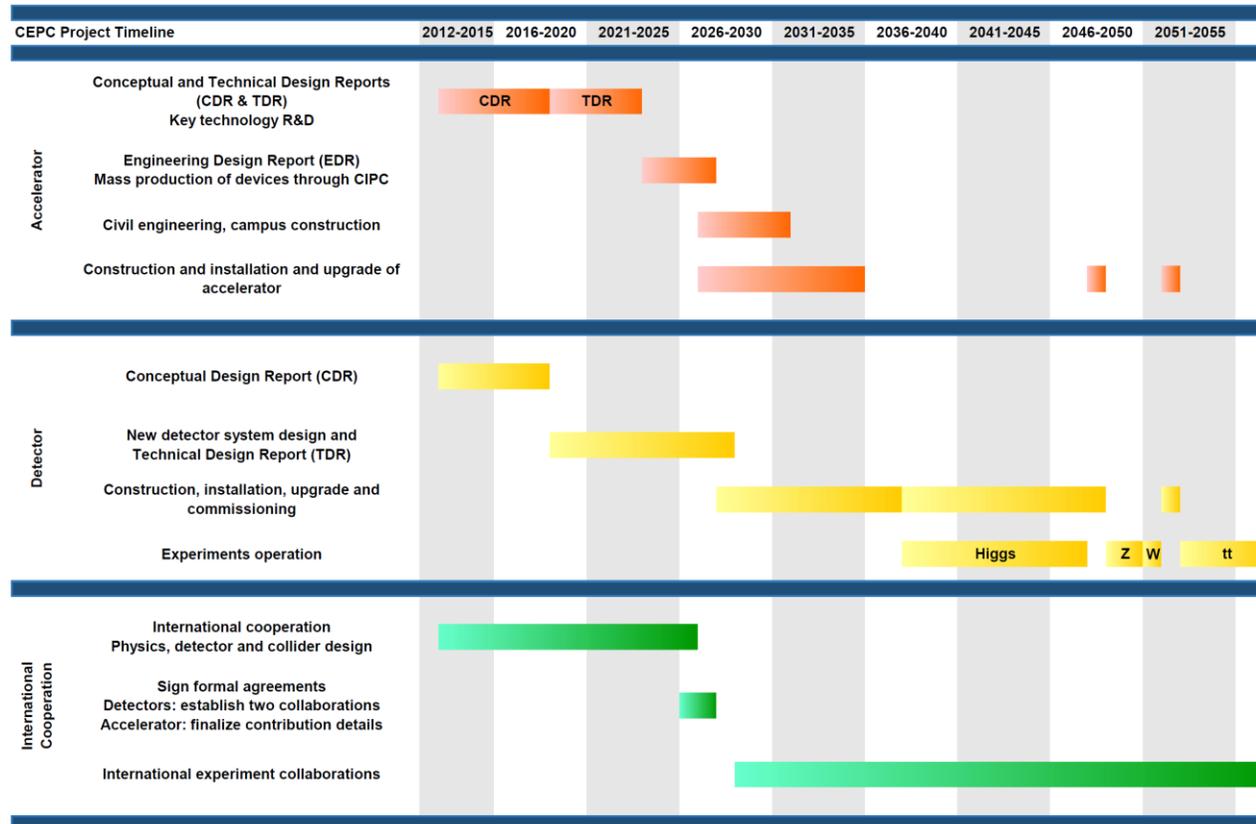


- ❑ prototyping with all subsystems
- ❑ develop full-scale slice system to evaluate their performance under realistic and integrated operating conditions

System	Technologies	
	Baseline (Ref-TDR)	Alternative
Beam pipe	Φ20 mm	
LumiCal	SiTrk + LYSO ECAL	SiTrk + SiW ECAL
Vertex	CMOS + Stitching	CMOS Si Pixel
Tracker	CMOS Si Pixel ITK	SSD + RO Chip, CMOS SSD
	Pixelated TPC	PID Drift Chamber
	AC-LGAD OTK	SSD / SPD OTK
		LGAD ToF
ECAL	4D Crystal Bar	Stereo Crystal Bar, GS+SiPM, PS+SiPM+W, SiDet+W
HCAL	GS+SiPM+Fe	PS+SiPM+Fe, RPC+Fe, MPGD+Fe
Magnet	LTS	HTS
Muon	PS bar+SiPM	RPC, μ-Rwell
TDAQ	Semi-Conventional	Software Trigger
BE electr.	Common	Independent

# CEPC Plan and Schedule

## TDR (2023), EDR(2027), start of construction (~2027)



- CEPC plans to submit the proposal to the central government(NDRC) within the “15<sup>th</sup> five year plan”
- For this purpose, CAS organized studies and reviews
- CEPC was ranked by CAS as the No. 1 for HEP & NP, and No.2 for Basic Science
- We are waiting for the 2<sup>nd</sup> review by CAS later this year
- Waiting for the “call for proposals” by NDRC by the end of this year

NDRC: National Development and Reform commission



# Summary

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## CEPC

- addresses many pressing & critical science problems in particle physics, and is on the path to converge into a complete package
- accelerator design and technology R&D are reaching maturity, TDR completed, ready for construction in ~2 years
- reference detector TDR is under preparation now, to be completed this year for the proposal of the 15th 5-year plan
- is making strong effort to complete a proposal to the government for approval
- is committed to strive to maximize international collaboration, call for collaborations and proposals once CEPC is (preliminary) approved (~CD0)
- will offer the HEP community an early Higgs factory if successful

# Acknowledgements

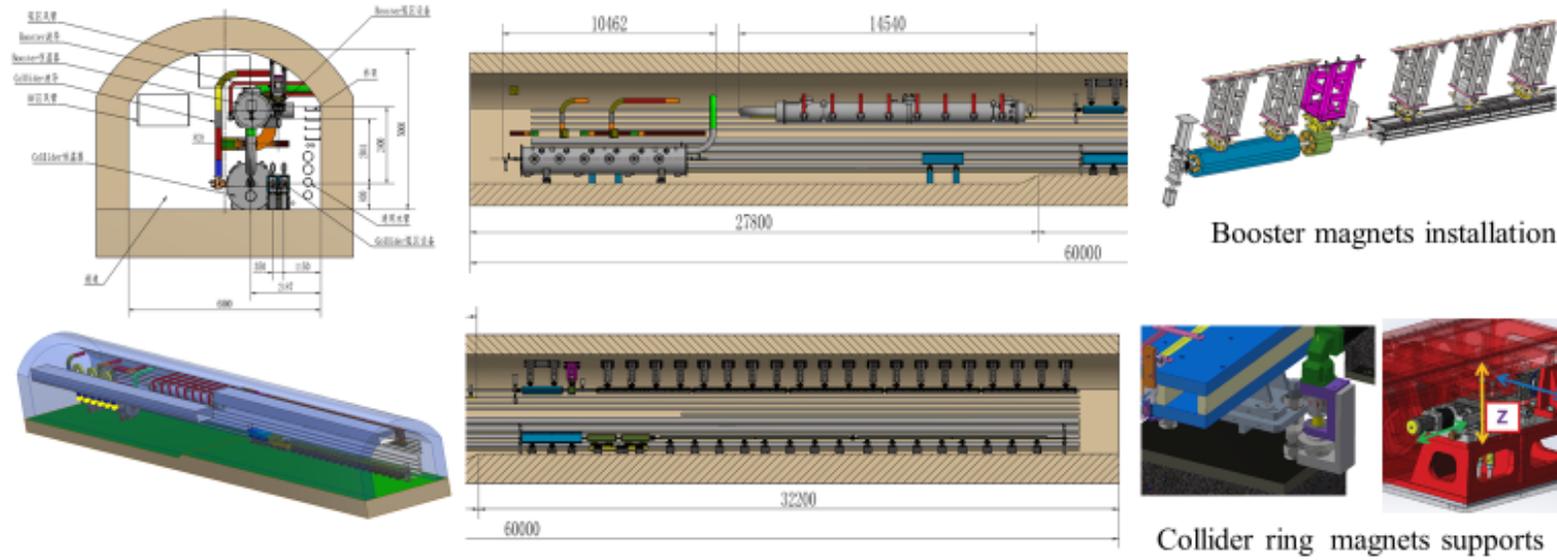
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- CEPC team's hard work, very fruitful international and CIPC collaborations have been critical to the CEPC program
- Special thanks to CEPC IB, SC, IAC, IARC and TDR review (+cost) Committees for their critical advices, suggestions and supports
- Funding agencies, CAS and IHEP for their financial supports

# BACKUP SLIDES

# EDR - Examples

## CEPC Tunnel Mockup for Installation in EDR



A 60 m long tunnel mockup, including parts of arc section and part of RF section

To demonstrate the inside tunnel alignment and installation, especially for booster installation on the roof of the tunnel