The Circular Electron Positron Collider

Status of the proposal and plans

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3rd ECFA Workshop

Paris, October 10, 2024

CEPC

Contents:

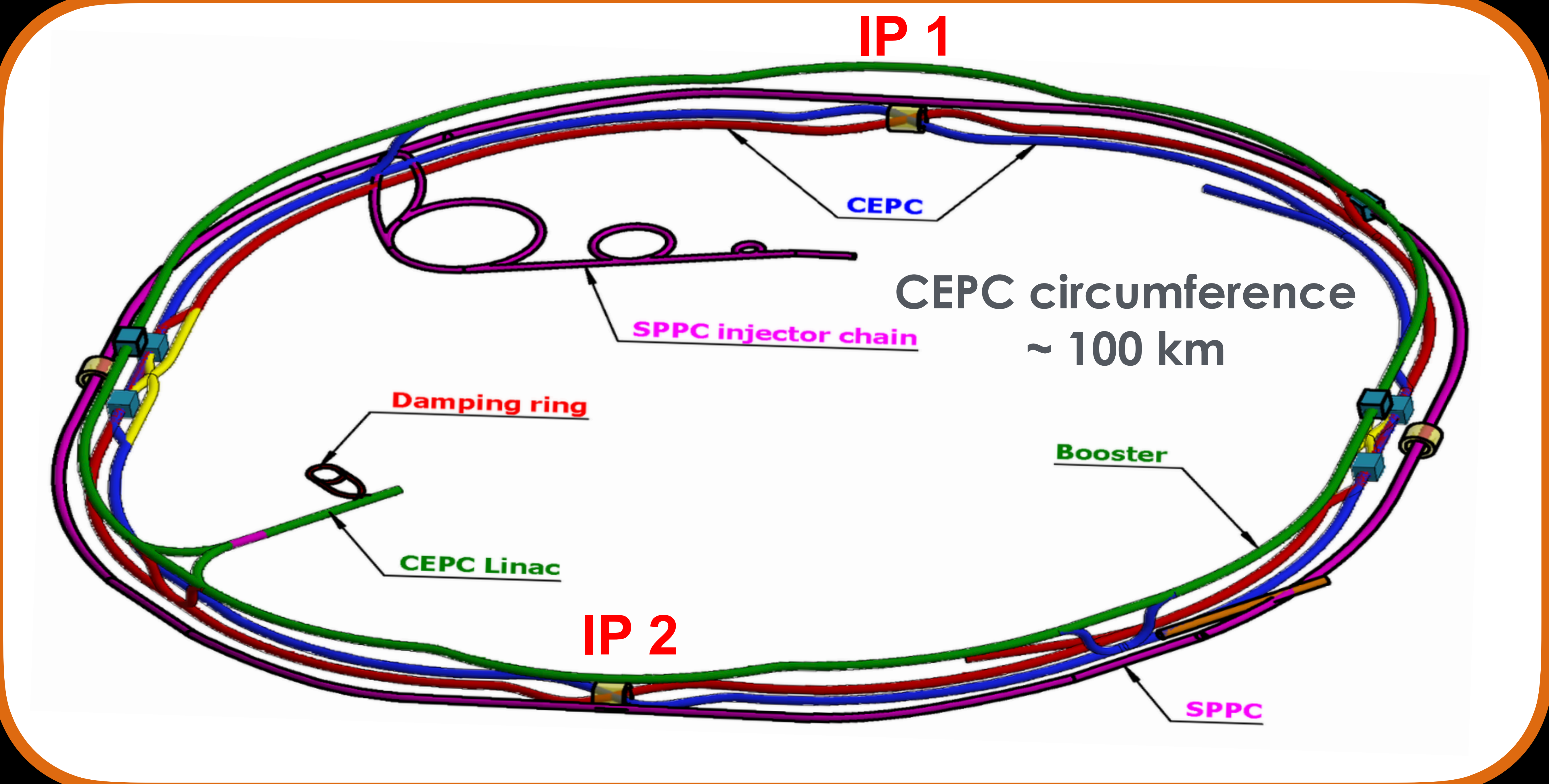
- Introduction
- CEPC Project Status and Progress
  - Accelerator Status
  - Detector Status
- The Super proton-proton Collider (SppC)
- CEPC Plan
- Final Remarks

Introduction: Project Overview

CEPC is an e^+e^- Higgs factory
possibly to be followed by a Super proton-proton Collider (SPPC)

Proposed in September 2012 right after the Higgs discovery

Tunnel can be reused for pp, heavy-ions, or ep collisions up to ~100 TeV



Mode	$\sqrt{s}$ (GeV)	Events
WH	240	>1 million
WW	160	
Z	90	Tera-Z

Upgrade path

1. Higher power: 30 MW → 50 MW
2. Higher energy → top quark pair production
3. Super pp Collider (SppC) at ~100 TeV

CEPC to start construction in ~2027/8 and deliver Higgs data in the 2030s

Introduction: Steps Towards Implementation

2013

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

2015

CEPC-SPPC

Preliminary Conceptual Design Report

Volume I - Physics & Detector

The CEPC-SPPC Study Group

March 2015

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

2015

CEPC-SPPC

Preliminary Conceptual Design Report

Volume II - Accelerator

The CEPC-SPPC Study Group

March 2015

Preliminary CDR

2018

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

CEPC

Conceptual Design Report

Volume I - Accelerator

The CEPC Study Group
August 2018

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

2018

CEPC

Conceptual Design Report

Volume II - Physics & Detector

The CEPC Study Group
October 2018

CDR

2023

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

CEPC

Technical Design Report

Accelerator

The CEPC Study Group
December 2023

VOLUME 8 · NUMBER 1 · MARCH 2024

中国核学会核电子学与核探测技术分会会刊

RADIATION DETECTION TECHNOLOGY AND METHODS

辐射探测技术与方法（英文）

2024

Springer

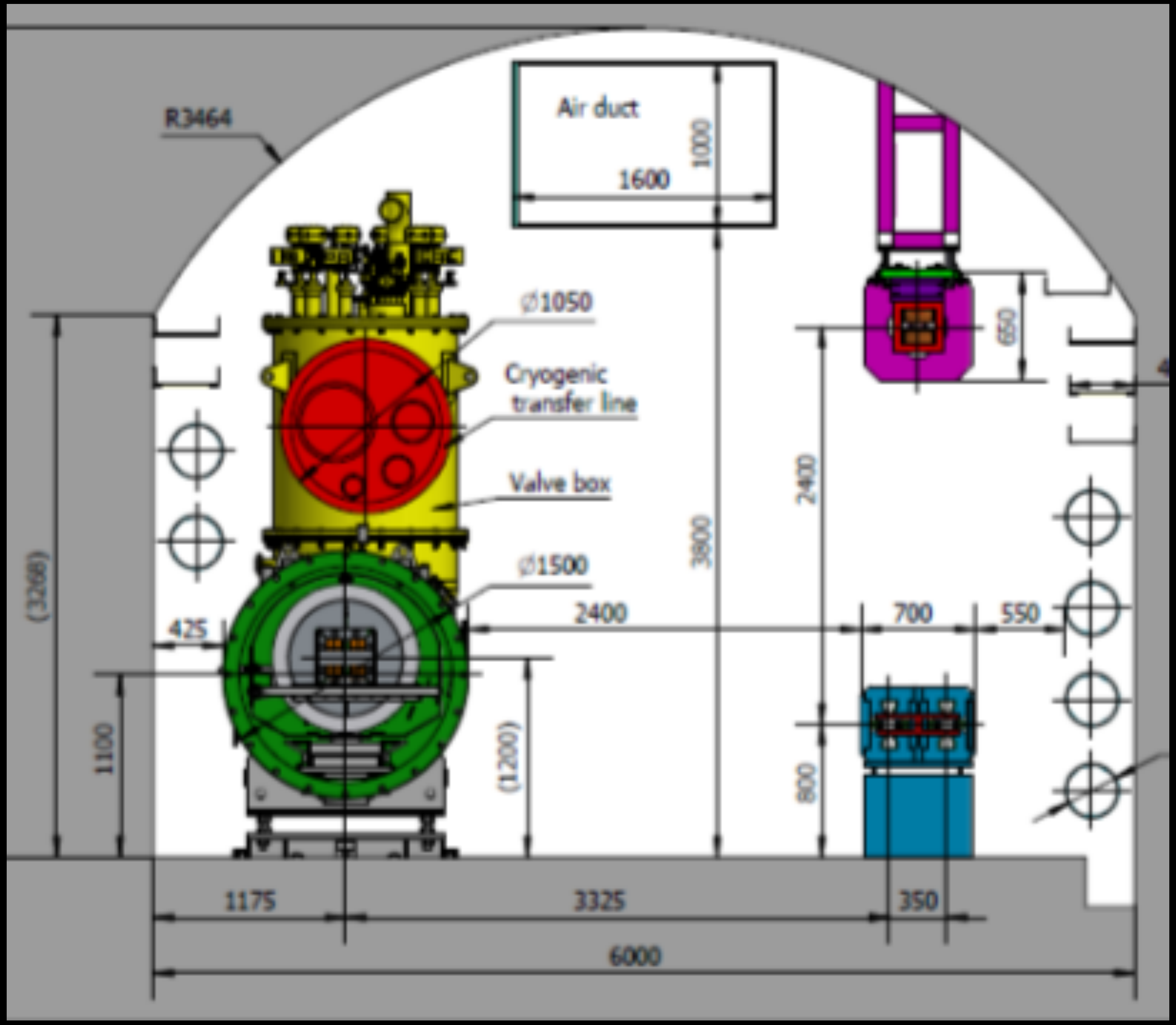
Accelerator TDR

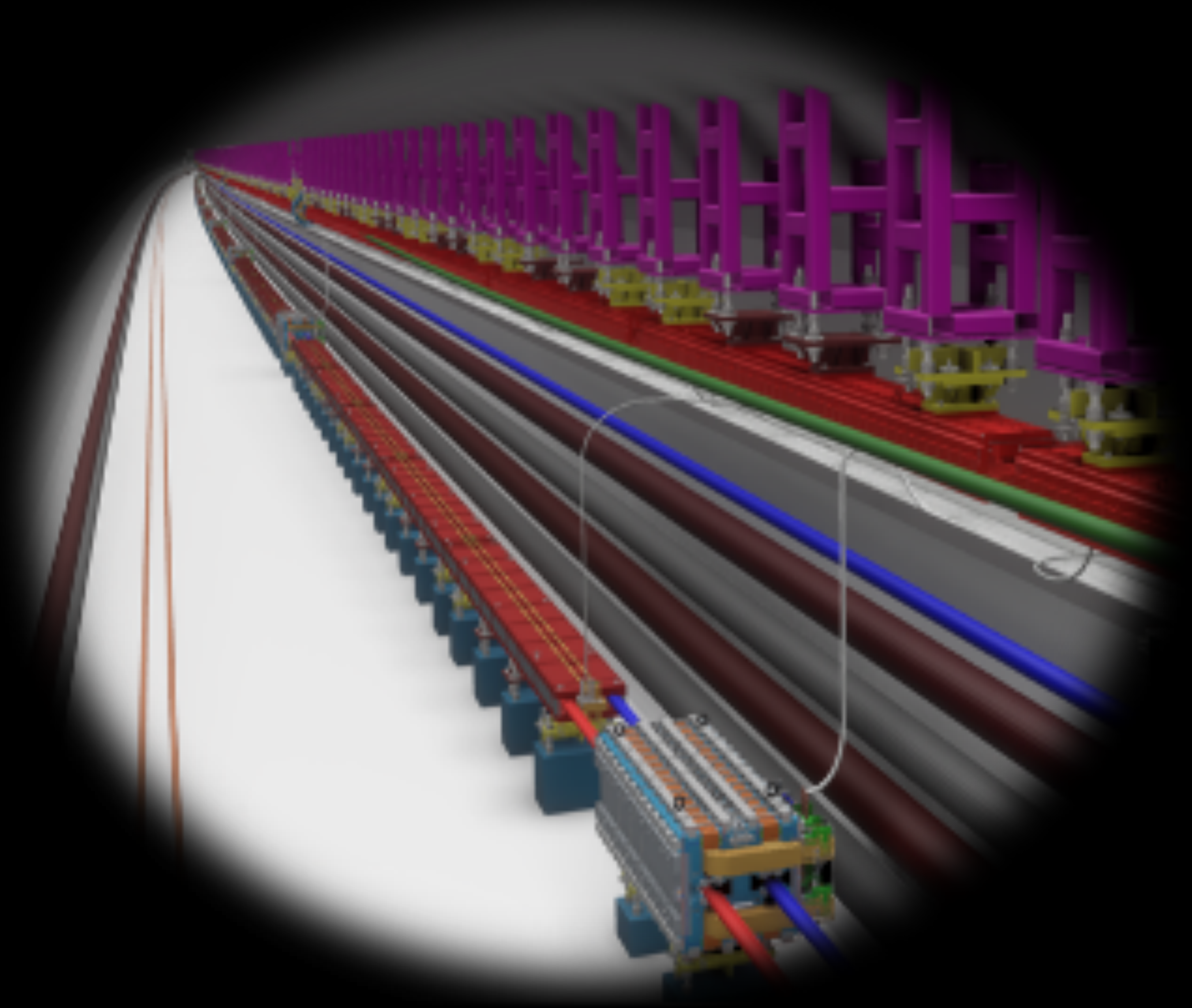
2025

Reference Detector TDR

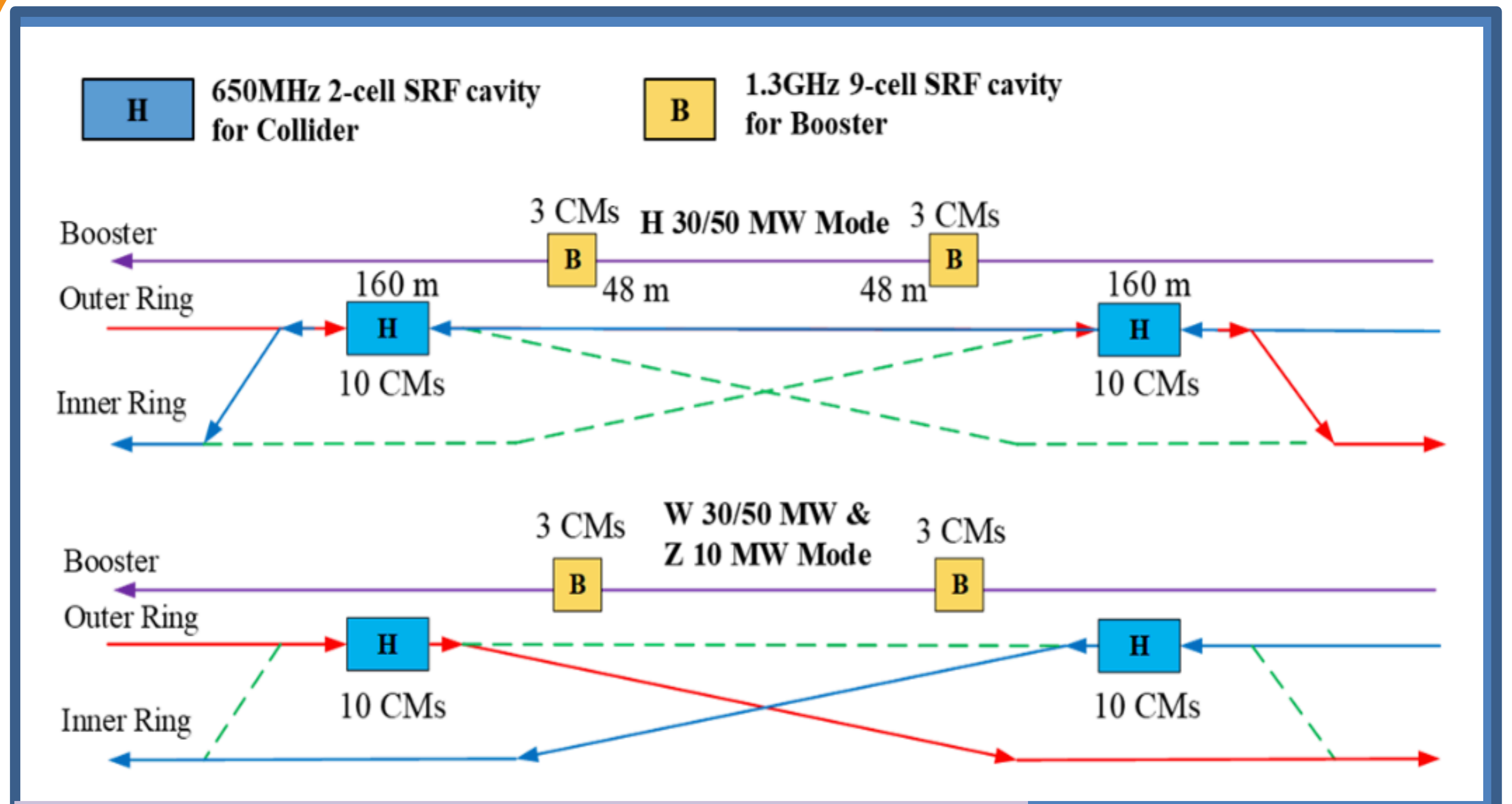
http://cepc.ihep.ac.cn

CEPC Status and Progress

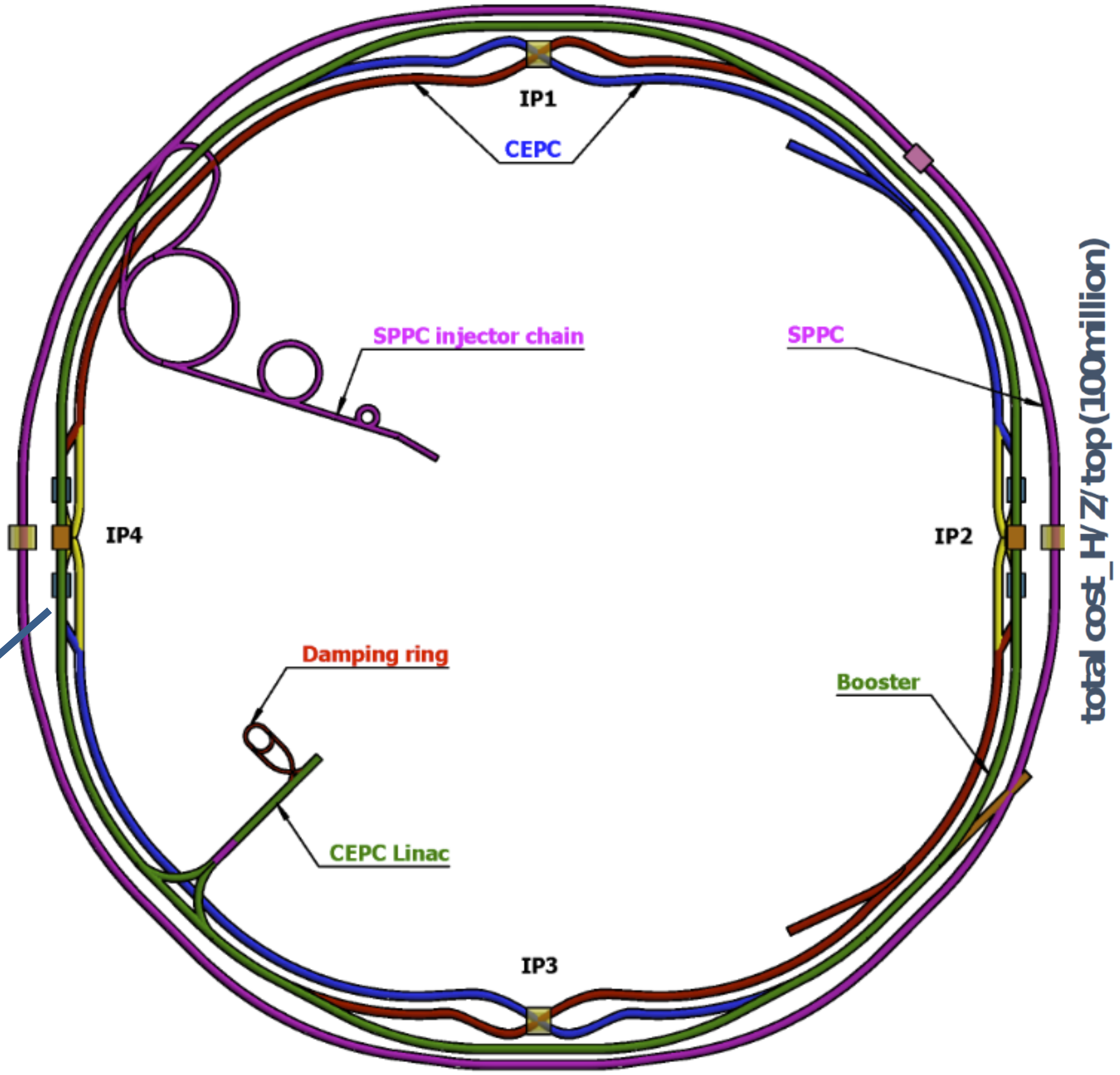




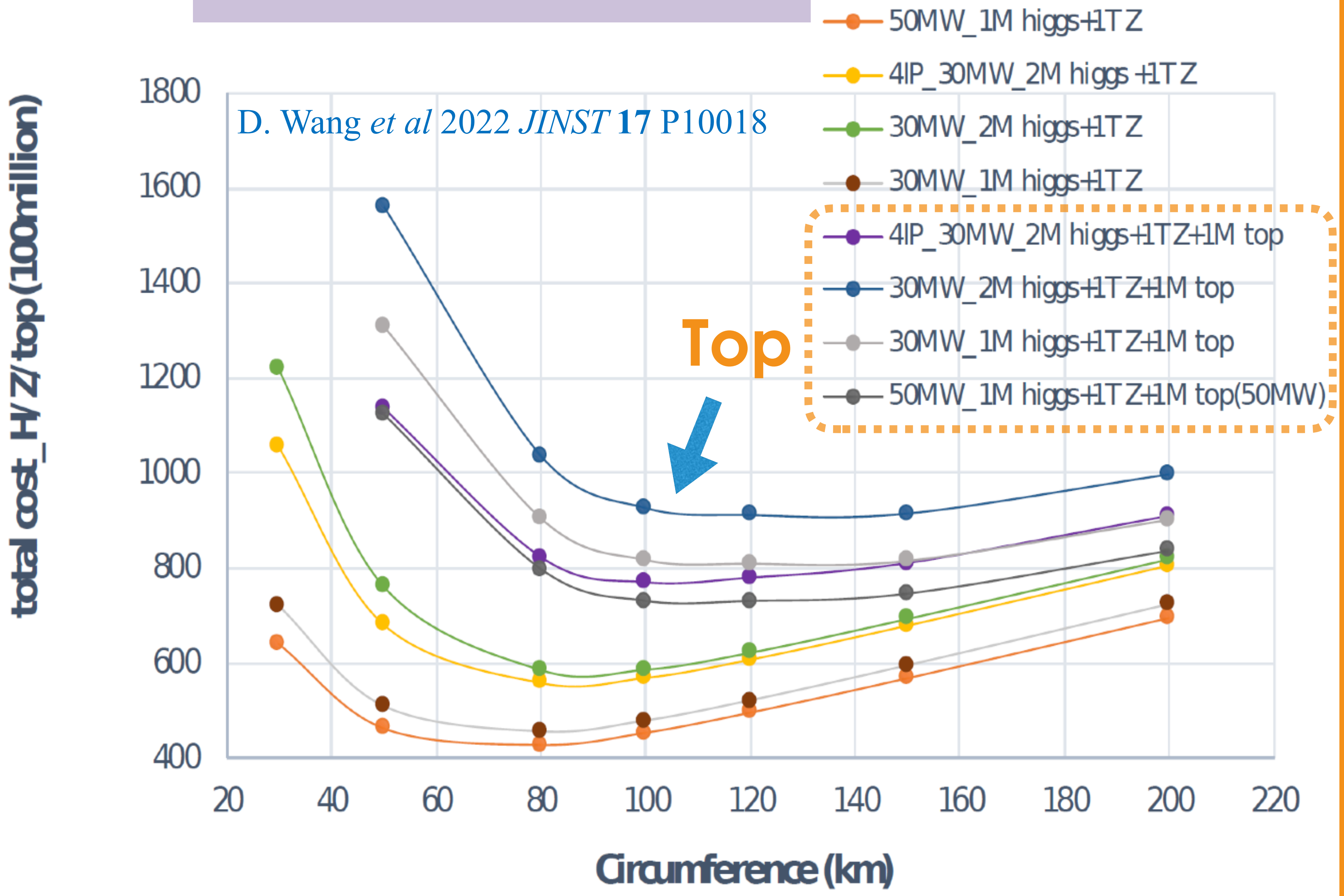
CEPC Higgs Factory and SppC in Accelerator TDR

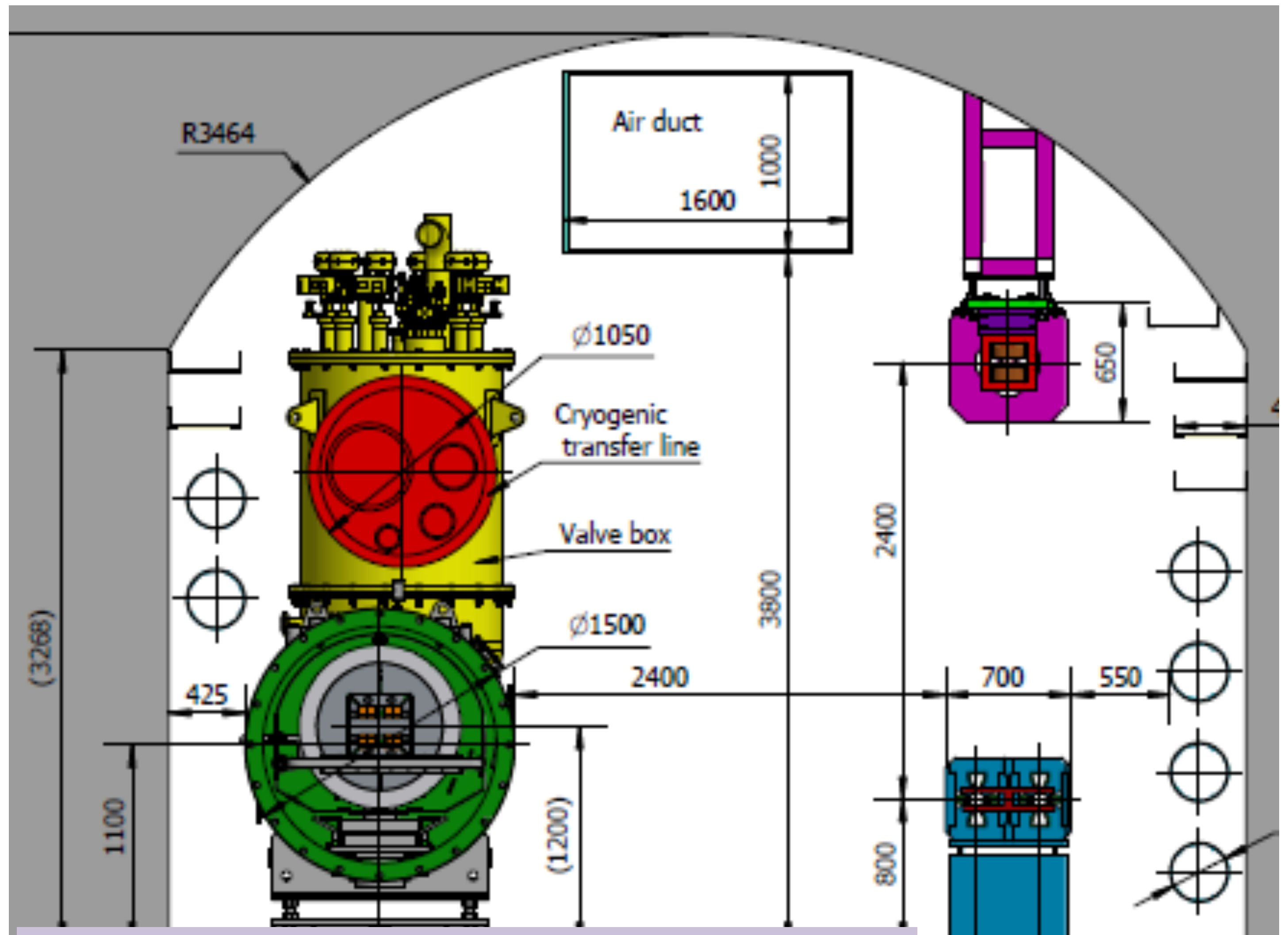


Switchable operation for Higgs W and Z



Cost optimization v.s. circumference



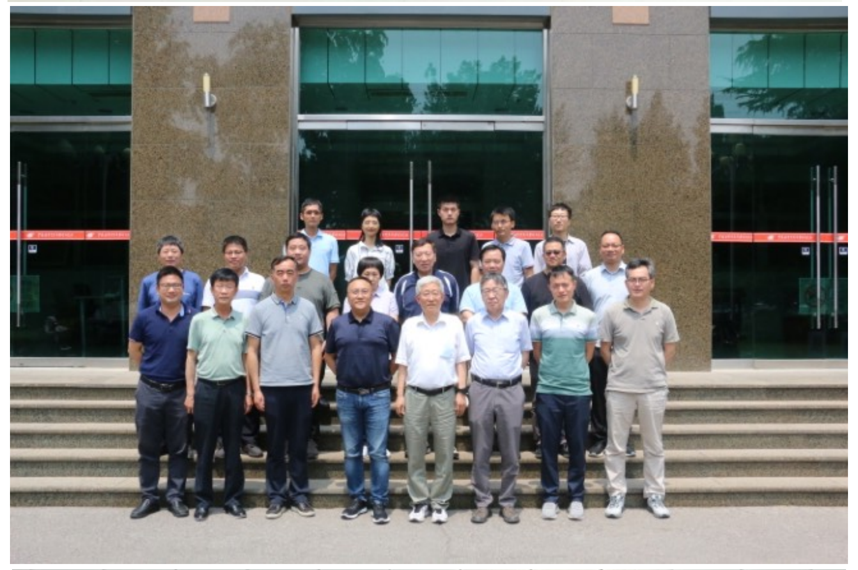


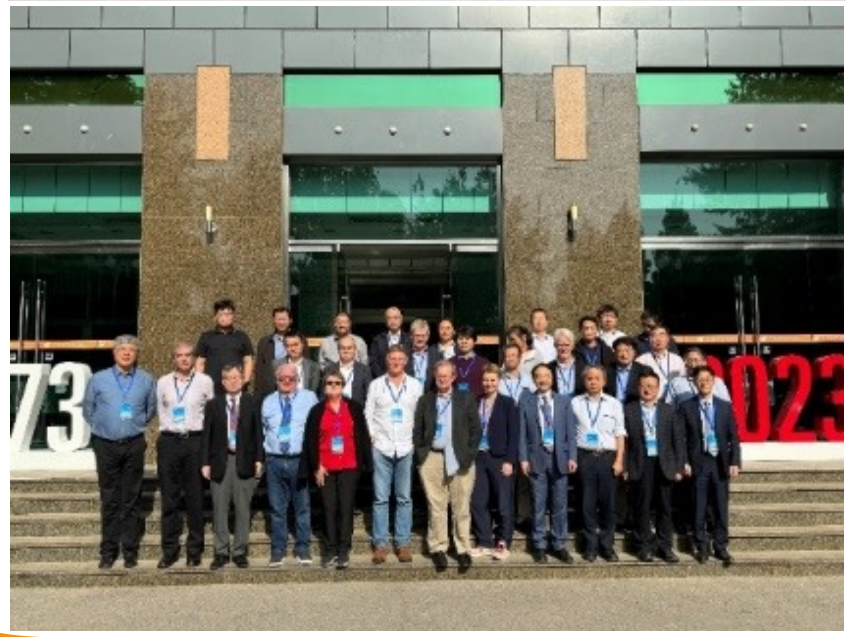
Common tunnel for booster/collider & SppC

- **Circular collider**: Higher luminosity with crabwaist collision of double ring
- **100km circumference**: Optimum total cost
- **Shared tunnel**: Compatible design for CEPC and SppC
- **Switchable operation**: Higgs, W/Z, ttbar

Baseline: 100 km, 30 MW; Upgradeable to 50 MW, High Lumi Z, ttbar

CEPC Accelerator TDR Published





CEPC accelerator TDR has been completed and formally released on December 25, 2023

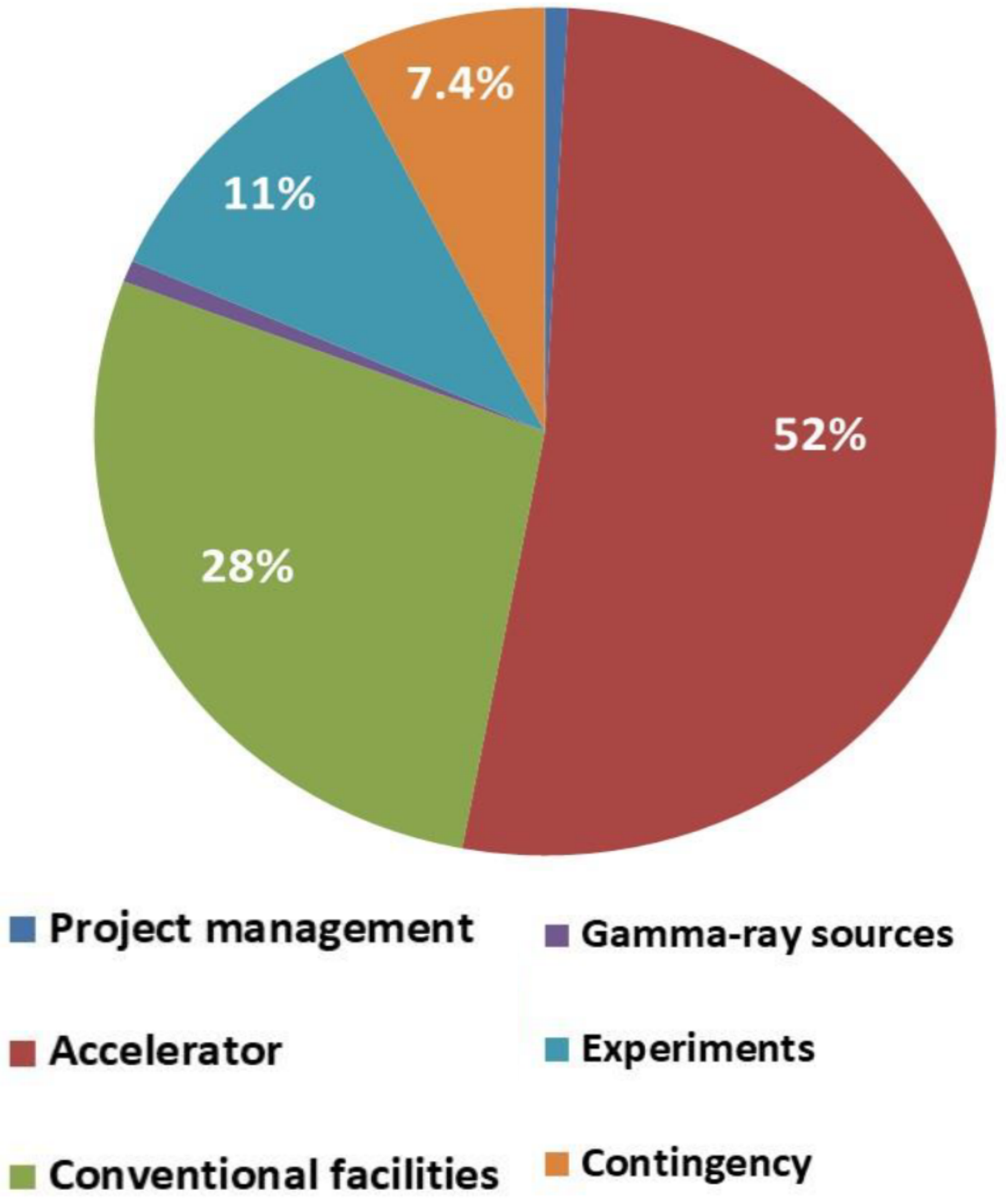
CEPC accelerator TDR link: (arXiv：2312. 14363)

CEPC accelerator TDR releasing news:

http://english.ihep.cas.cn/nw/han/y23/202312/t20231229_654555.html

published in
RDTM Vol.8
June 2024

Distribution of CEPC project total cost from TDR of
36.4B RMB (~ 5B €)



	Percentage	Cost (M€)
Total	100%	4,709
Project management	0.8%	38
Accelerator	52%	2,449
Conventional facilities	28%	1,318
Gamma-ray beam lines	0.8%	38
Experiments	11%	518
Contingency (8%)	7.4%	348

From TDR, Table 12.1.2
Converted with today's rate of 1 € = 7.73 RMB

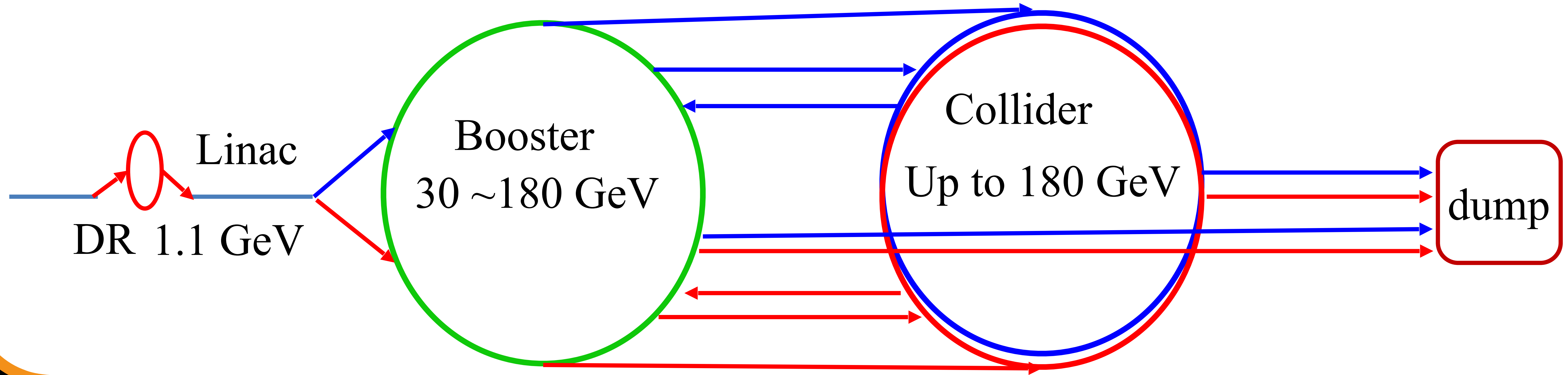
CEPC Accelerator Parameters

Booster

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

Baseline Collider

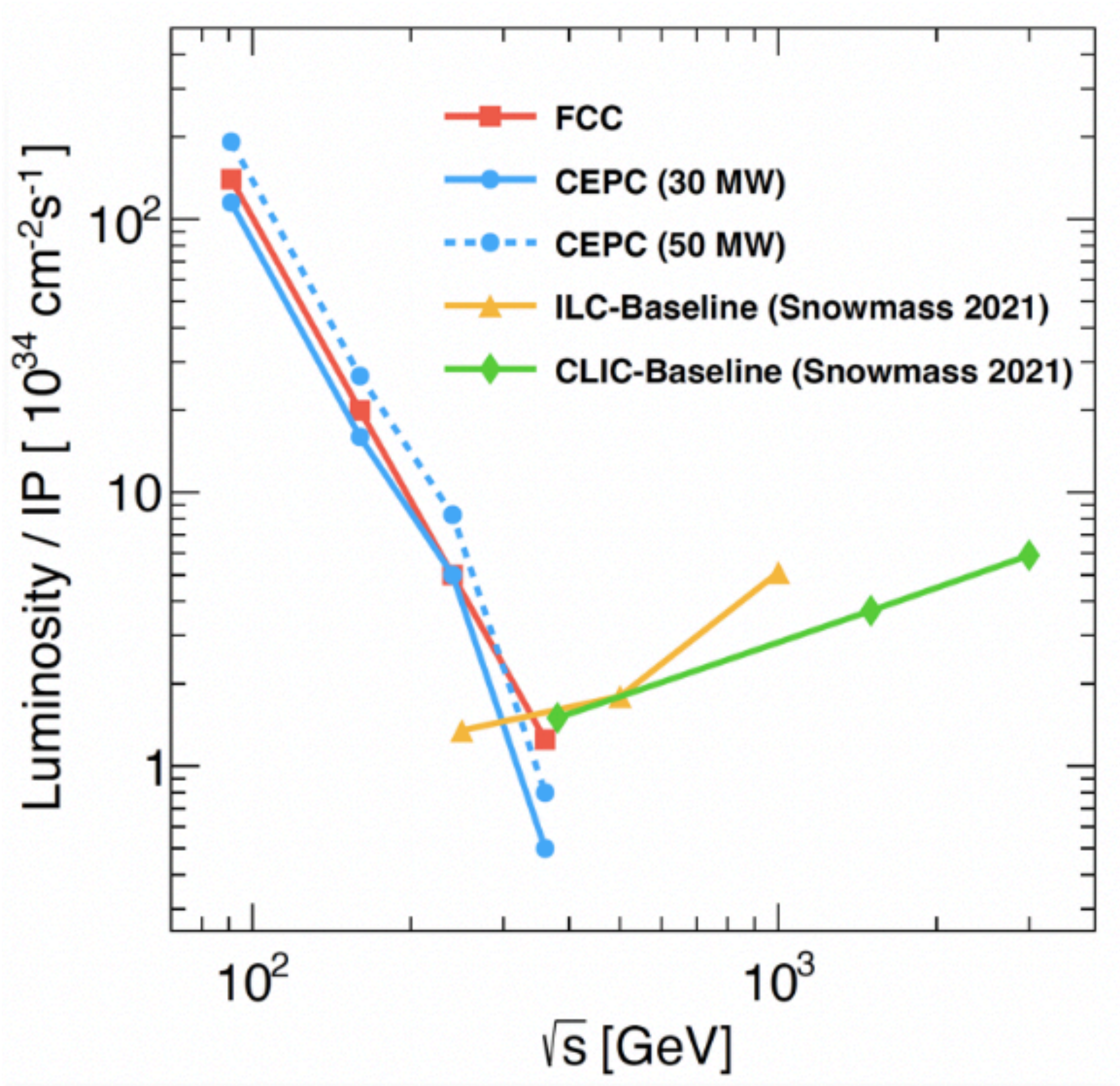
	Higgs	Z	W	tt
Number of IPs	2			
Circumference (km)	100			
SR power per beam (MW)	30			
Energy (GeV)	120	45.5	80	180
Bunch number	268	11934	1297	35
Emittance $\varepsilon_x/\varepsilon_y$ (nm/pm)	0.64/1.3	0.27/1.4	0.87/1.7	1.4/4.7
Beam size at IP σ_x/σ_y (um/nm)	14/36	6/35	13/42	39/113
Bunch length (natural/total) (mm)	2.3/4.1	2.5/8.7	2.5/4.9	2.2/2.9
Beam-beam parameters ξ_x/ξ_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} cm^{-2} s^{-1})	5.0	115	16	0.5



Running scenarios:
- Higgs 10 years
- Z 3 years
- W 1 year
- ttbar 5 years

CEPC Expected Performance

Luminosity per Interaction Point



CEPC baseline: 2 interaction points

FCC: 2 or 4 interaction points

CEPC numbers from Snowmass White Paper

arXiv: 2203.09451v1, Tables 1 (30 MW) and Table 2 (50 MW)
(Similar as CEPC TDR)

FCC numbers from Frank Zimmerman

FCC Week, June 10; Barcelona, Oct 7

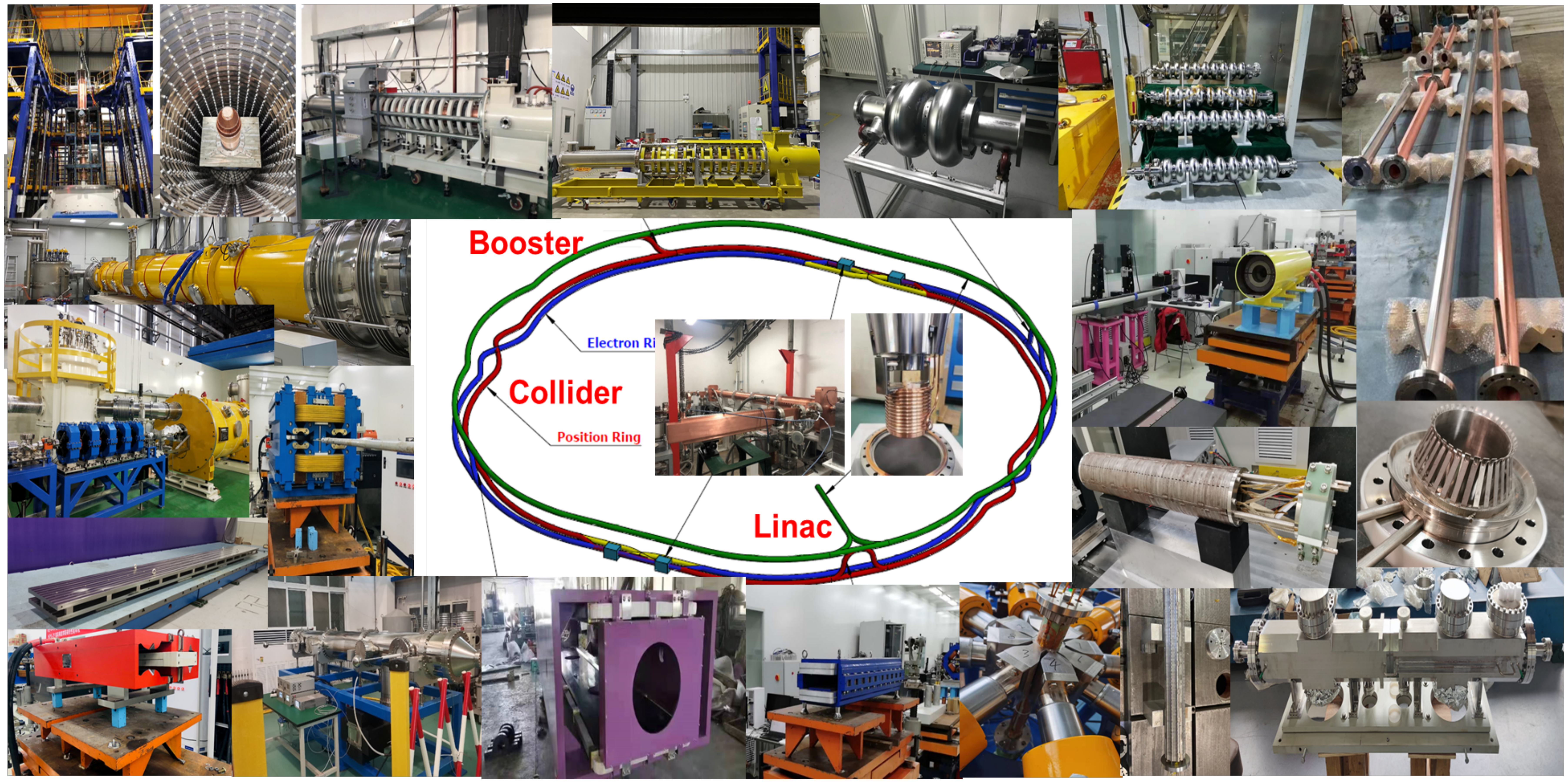
https://indico.cern.ch/event/1440785/contributions/6063263/attachments/2942055/5169598/FCC-accelerator-RD-short.pdf

https://indico.cern.ch/event/1298458/contributions/5975662/attachments/2874361/5035180/accelerator-FCCW-2024-final.pdf

CEPC Accelerator: Key Technology Readiness

R&D and Validation: Key technology R&D spanning all component in CEPC accelerator TDR

Ready for construction by 2027/2028



High Energy Photon Source (HEPS) just completed by IHEP
(many similar technologies to CEPC accelerator)

Accelerator	Cost Ratio
✓ 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%

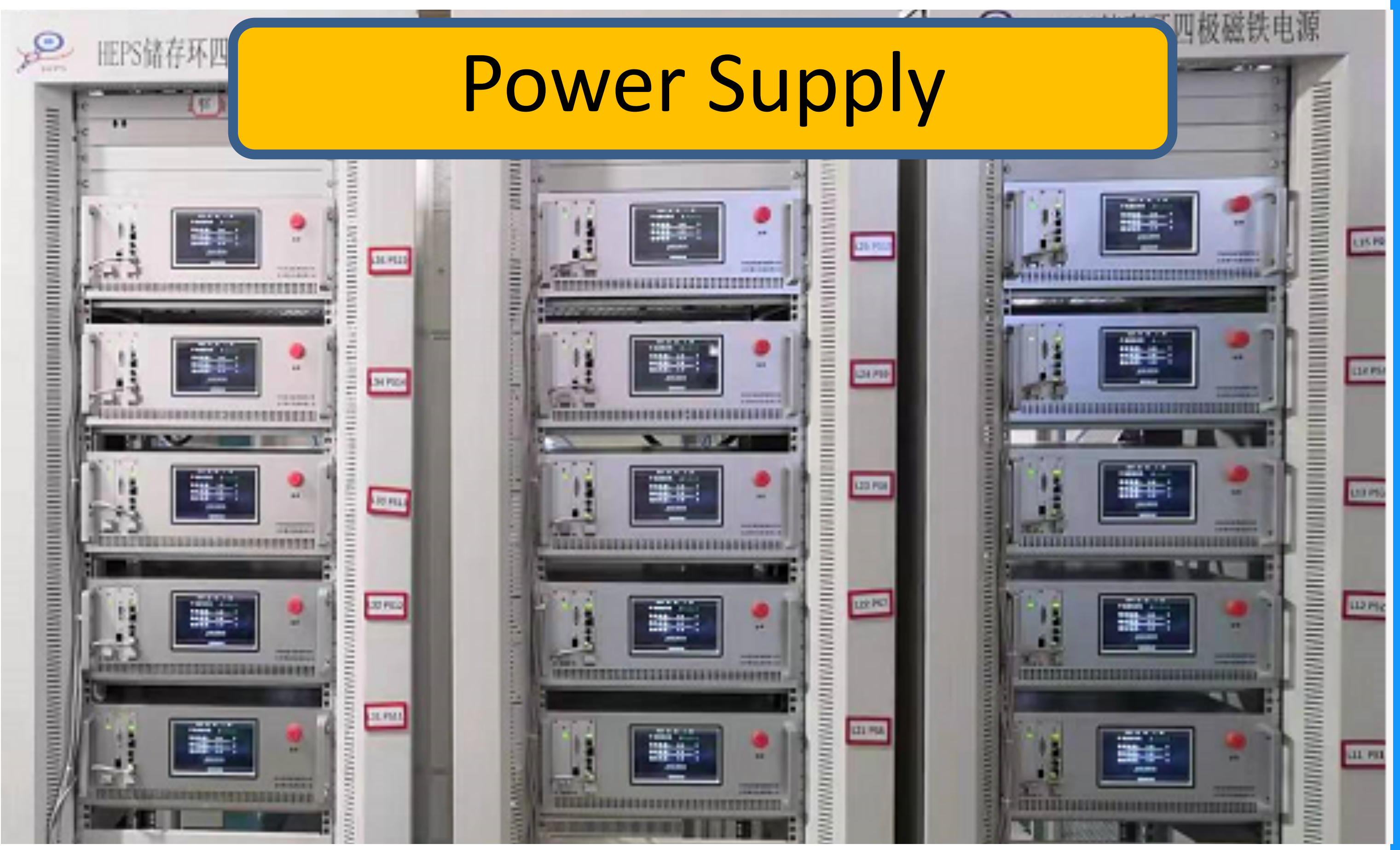
✓ Specification met

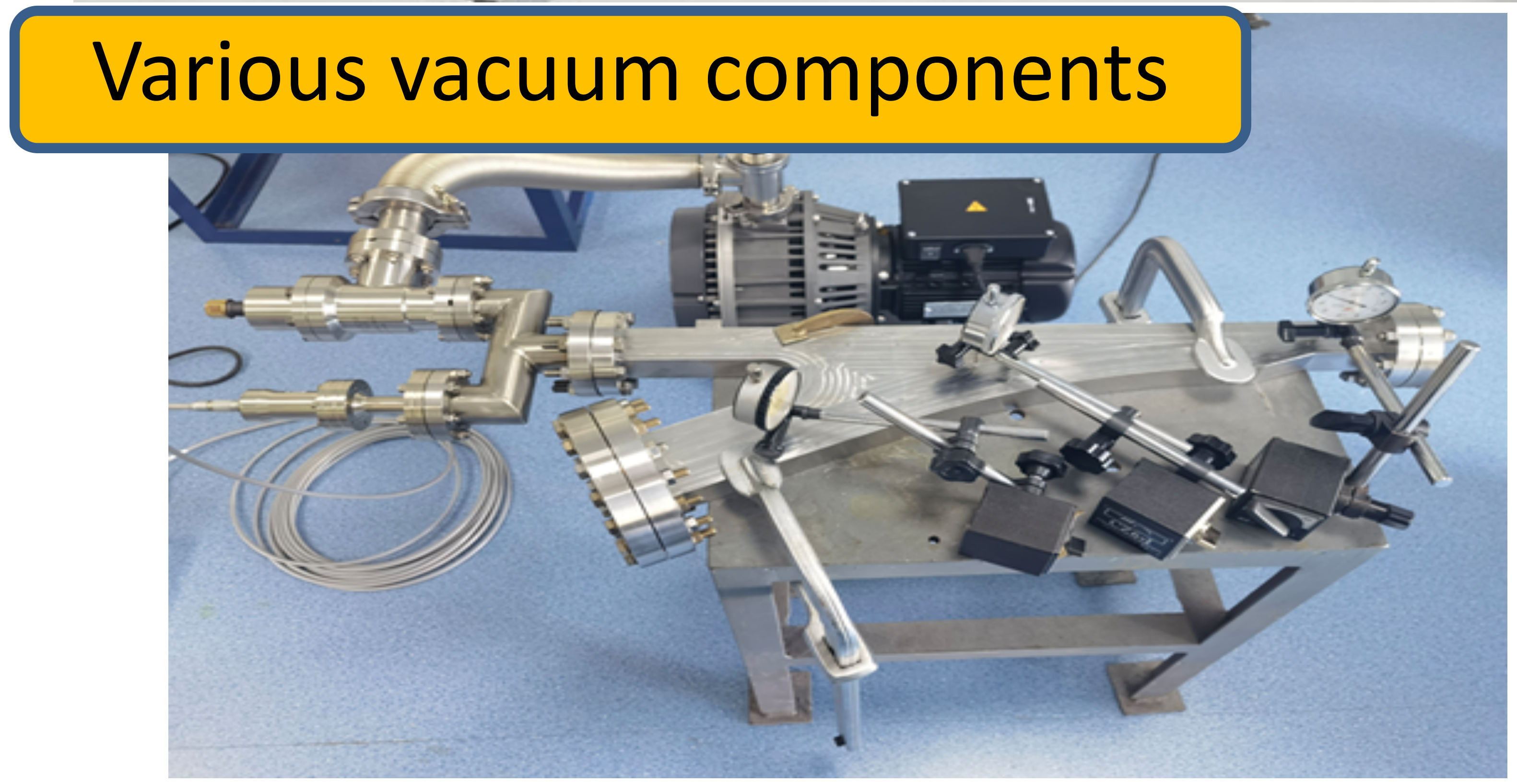
✓ Prototype manufactured but evaluation not finalized

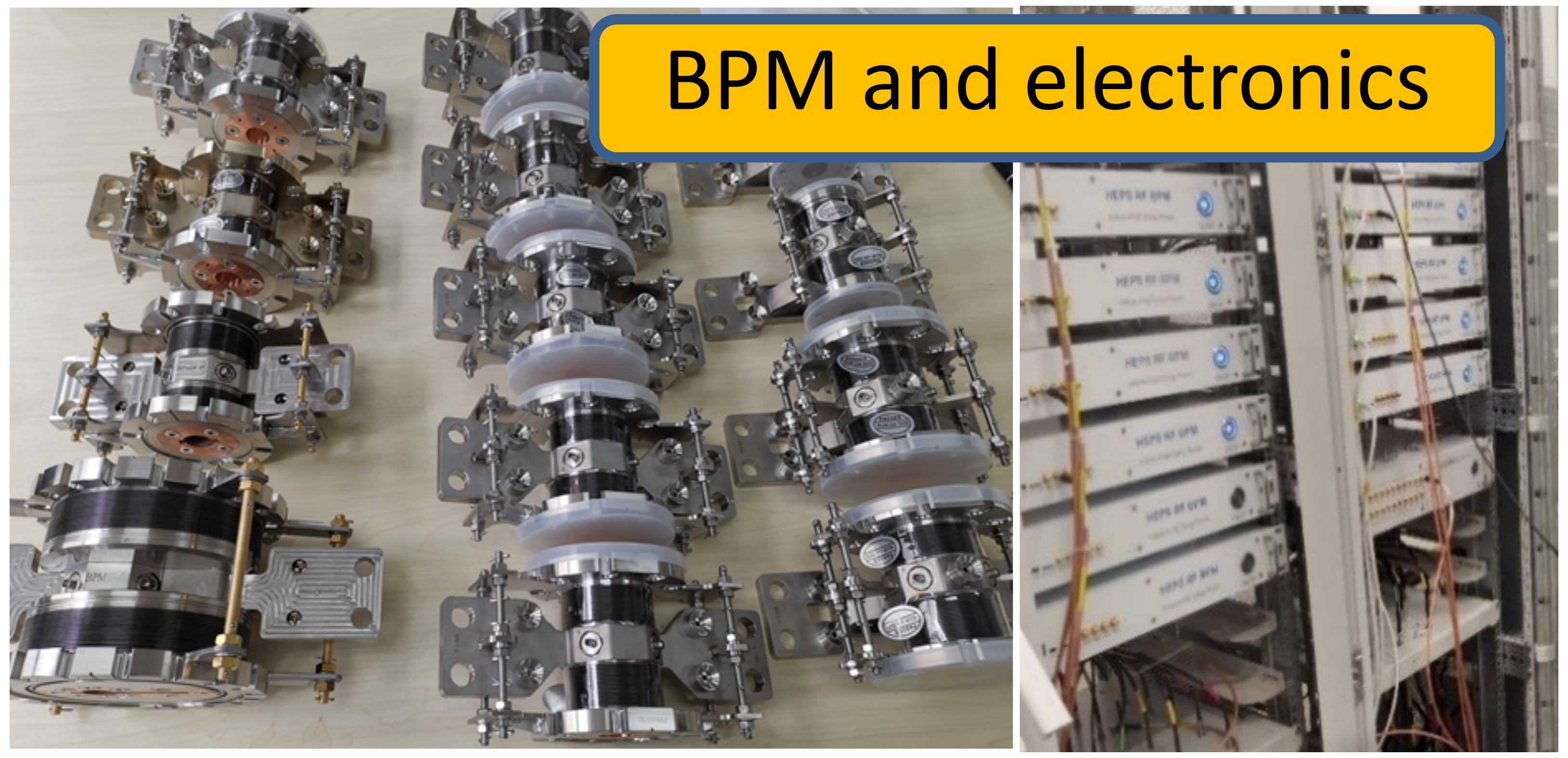
Highlight: conventional technology from HEPS/BEPC

- Many of the key technologies needed for CEPC were developed and verified in projects such as BEPCII and HEPS, conducted by IHEP. These technologies include conventional magnets, vacuum system, magnet power supply, mechanical system, alignment, etc.

The relevant system cost for CEPC can be accordingly evaluated precisely







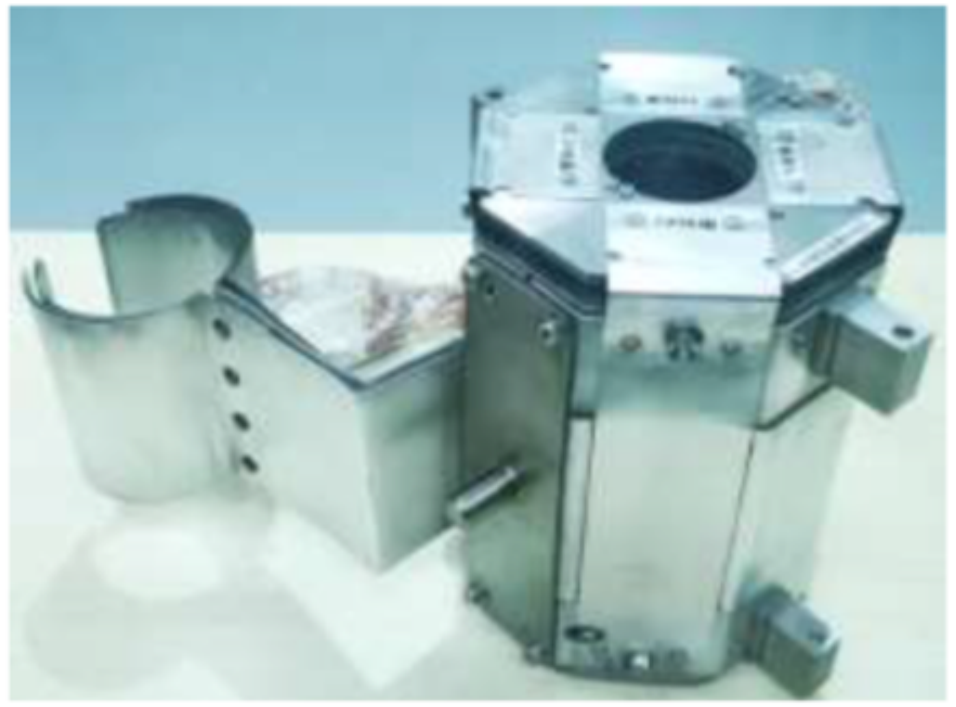
Key Accelerator Technology Readiness

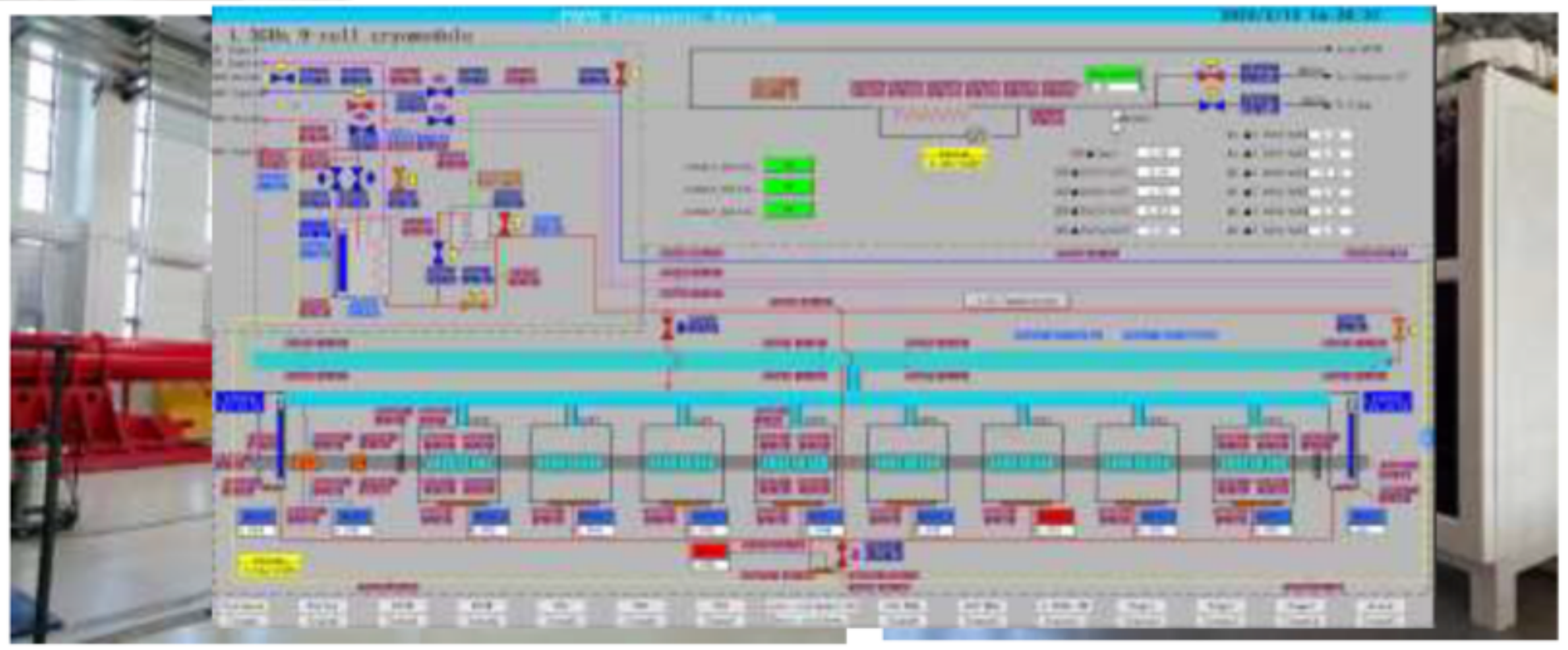
CEPC Booster 1.3 GHz 8 x 9-cell High Q Cryomodule

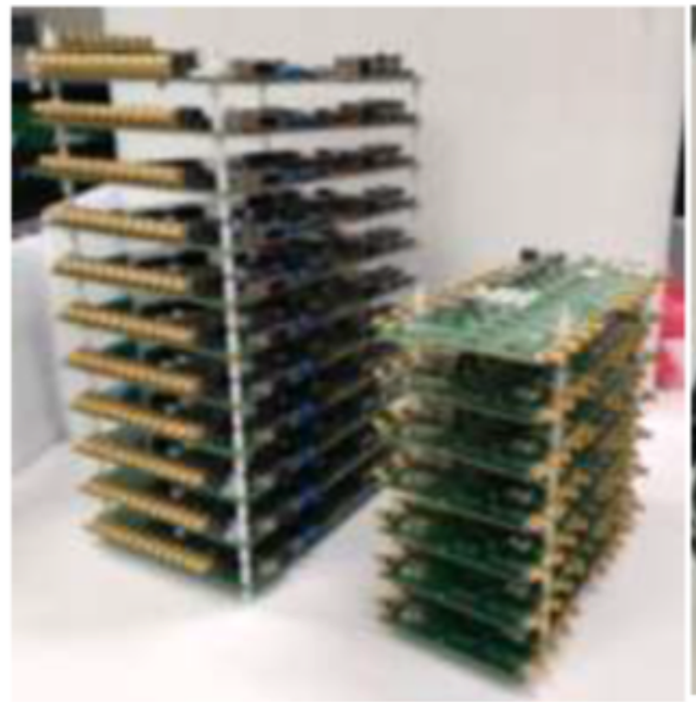
CEPC booster 1.3 GHz SRF R&D and industrialization in synergy with CW FEL projects.

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}			





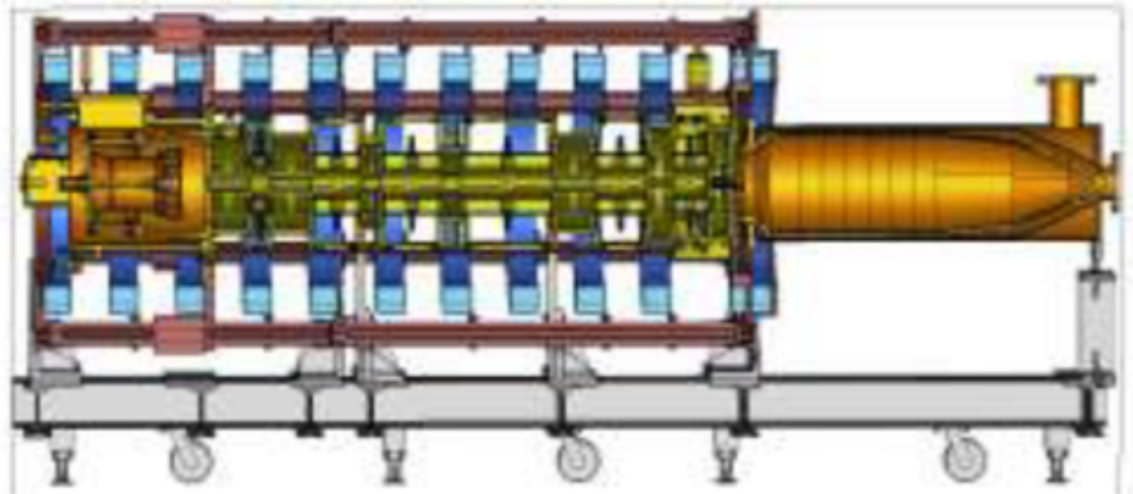

Key Accelerator Technology Readiness

CEPC

Klystron R&D

Klystron No. 1
Efficiency 65%
(2020)

Klystron No. 2
Efficiency 77%
(2021)

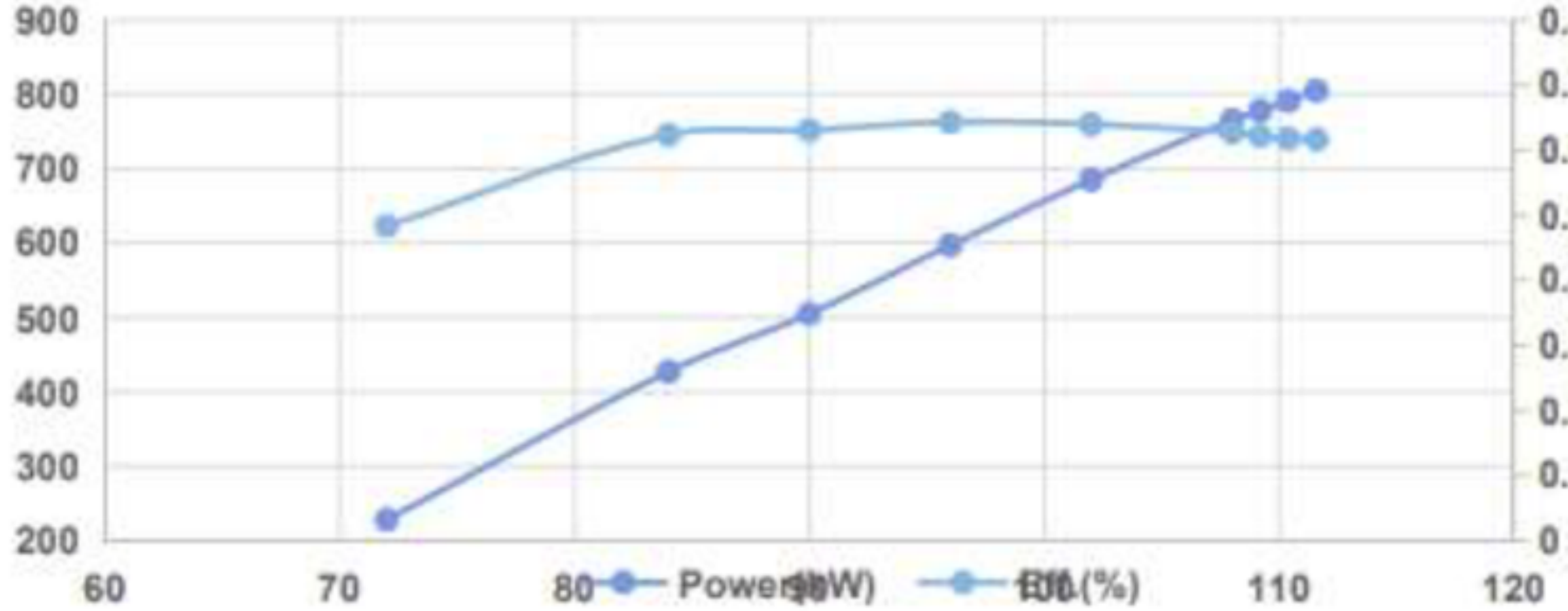


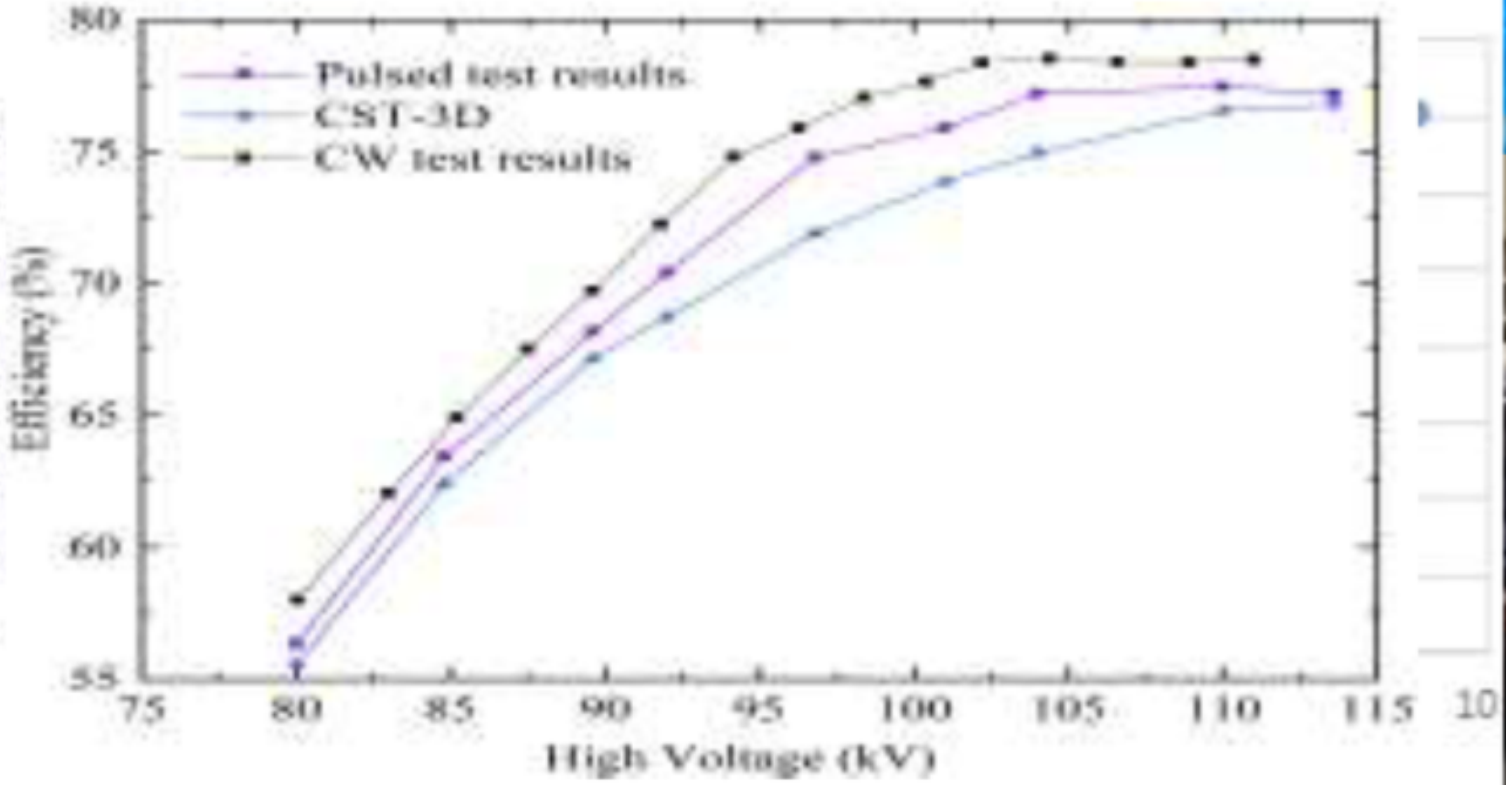
Klystron No. 3 （MBK
Efficiency 80.5%
To be completed in 2024

78.5%@803kW CW in 2024

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

High Voltage vs. Power&Efficency





CEPC collider ring 650MHz klystron development in TDR phase

Domestic civil review — site evaluation

Civil construction cost was evaluated by 3 experienced companies:

Yellow River Engineering Consulting Co., Ltd
HUADONG Engineering Corporation Limited,
ZHONGNAN Engineering Corporation Limited

Three sites were considered: Changsha, Huzhou and Qinhuangdao

International Panel has reviewed the cost evaluation given by the 3 companies

All sites can satisfy requirements for CEPC construction. The main geological problems encountered can be solved by engineering measures.

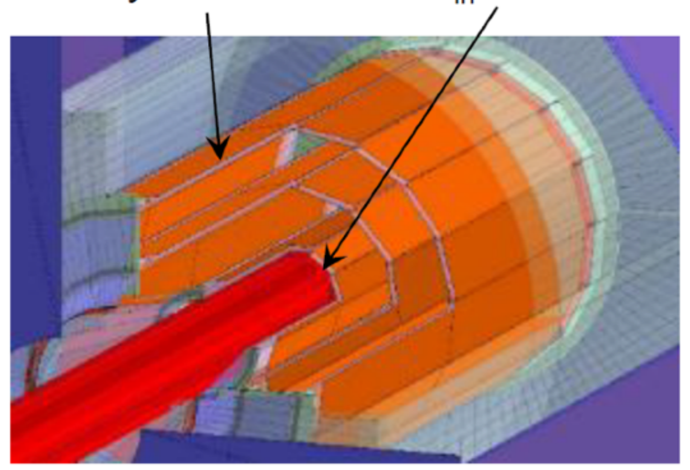
Advance the civil engineering design as soon as possible.

Decide the site
Complete the project proposal, feasibility study, preliminary design, and tender design before construction

CEPC Detector R&D

Vertex detector

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



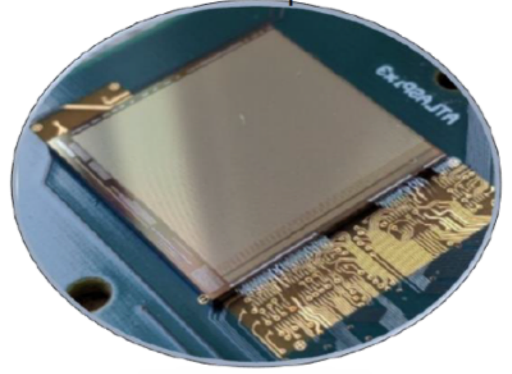
Goal: σ(IP) ~ 5 μm for high P track

CDR design specifications

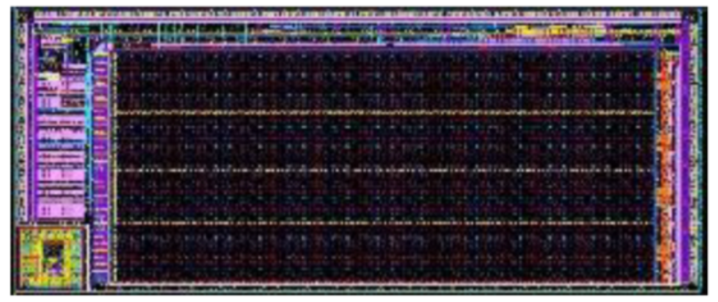
- **Single point resolution ~ 3μm**
- **Low material (0.15% X_0 / layer)**
- **Low power (< 50 mW/cm²)**
- **Radiation hard (1 Mrad/year)**

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

Develop
basing on ATLASPIX3 CN/IT/UK/DE
TSI 180 nm HV-CMOS process

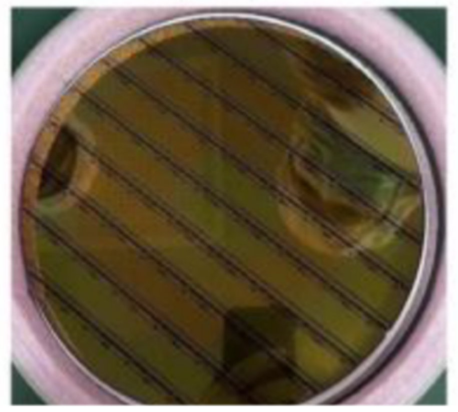


JadePix-3 Pixel size ~16×23 μm²

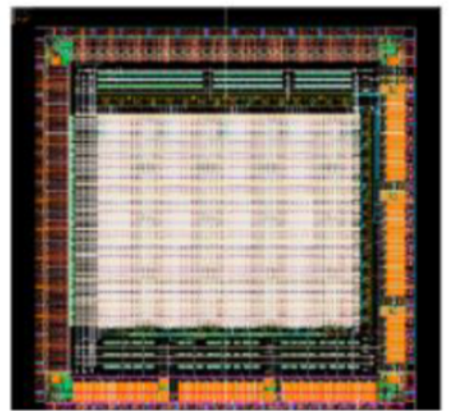


Tower-Jazz 180nm CiS process
Resolution 5 microns, 53mW/cm²

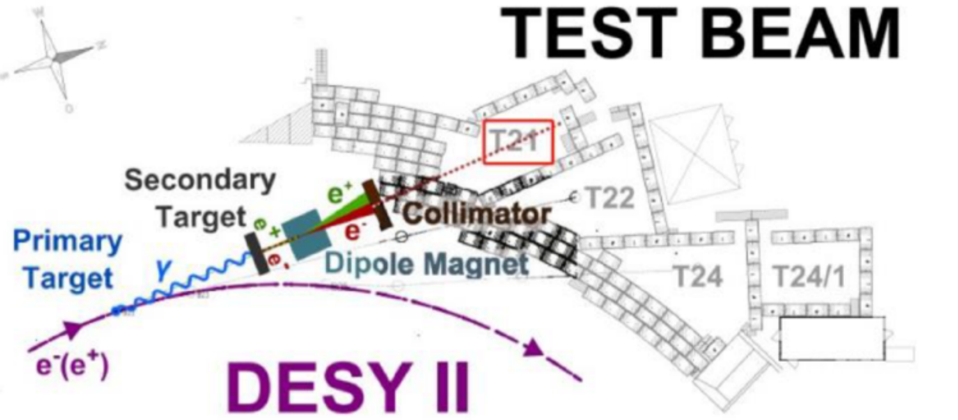
TaichuPix-3, FS 2.5x1.5 cm²
25×25 μm² pixel size

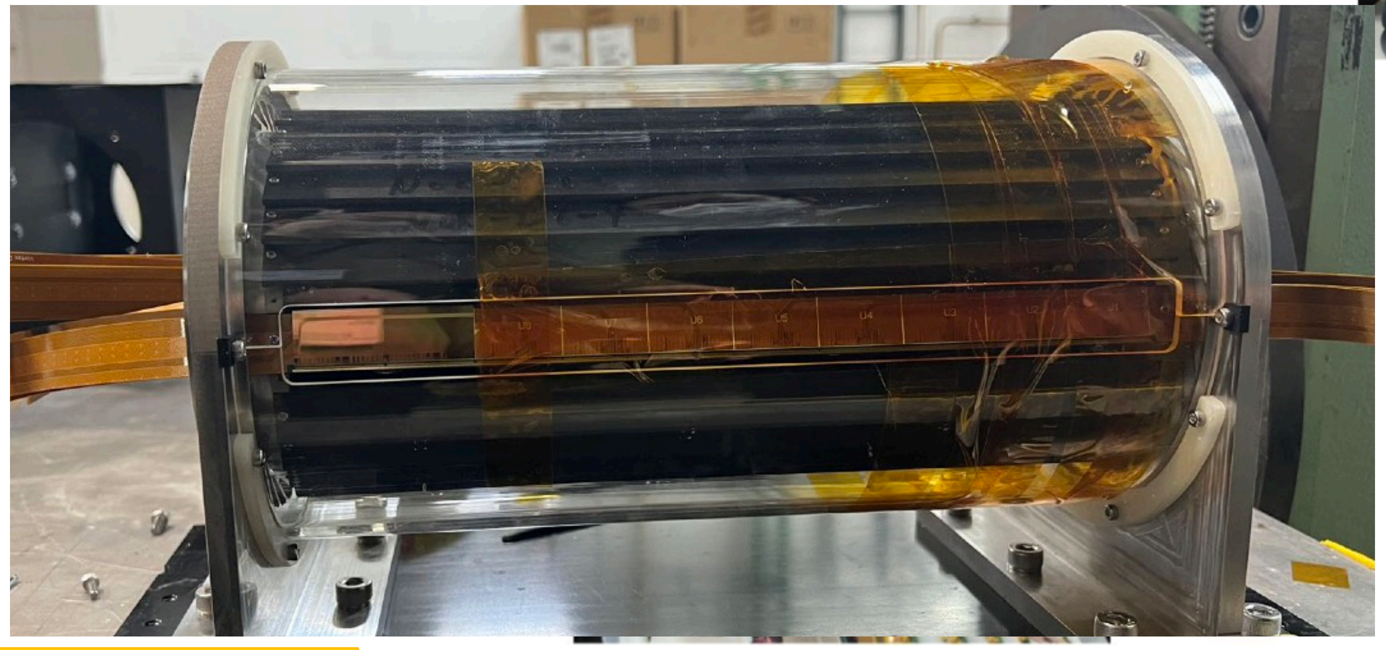


CPV4 (SOI-3D), 64×64 array
~21×17 μm² pixel size

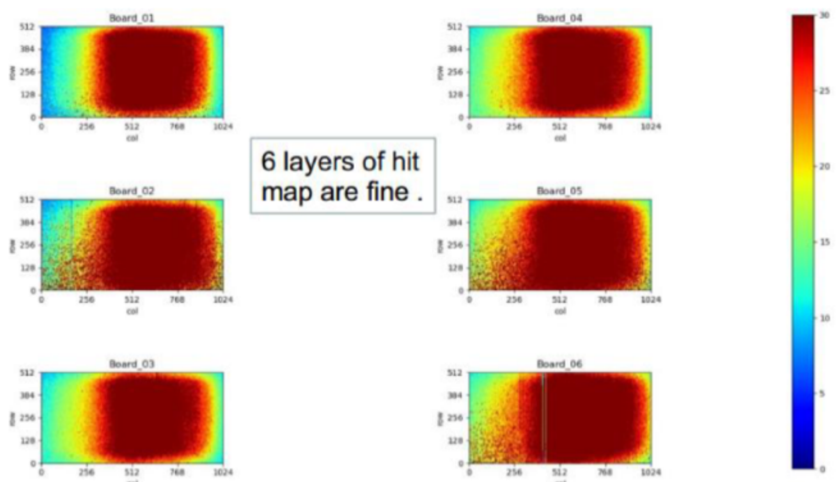


Arcadia by Italian groups
for IDEA vertex detector
LFoundry 110 nm CMOS



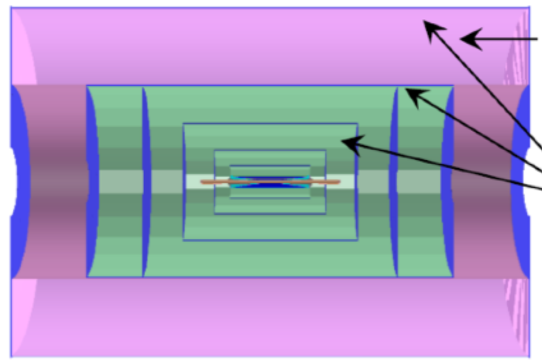


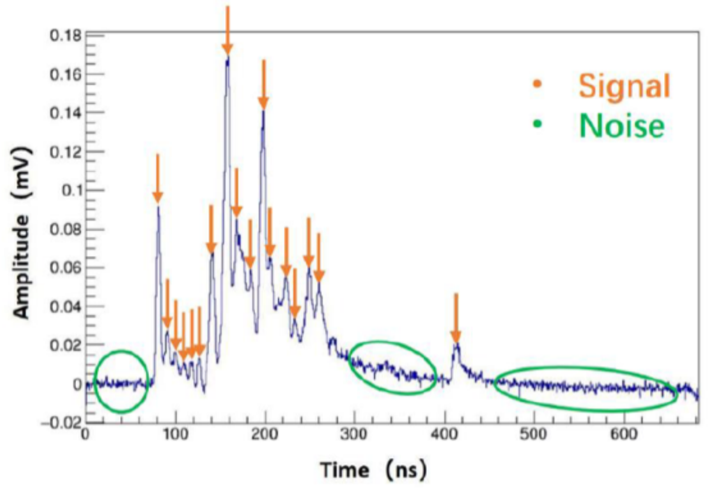
Hitmap of 4 GeV e⁺/e⁻ beam

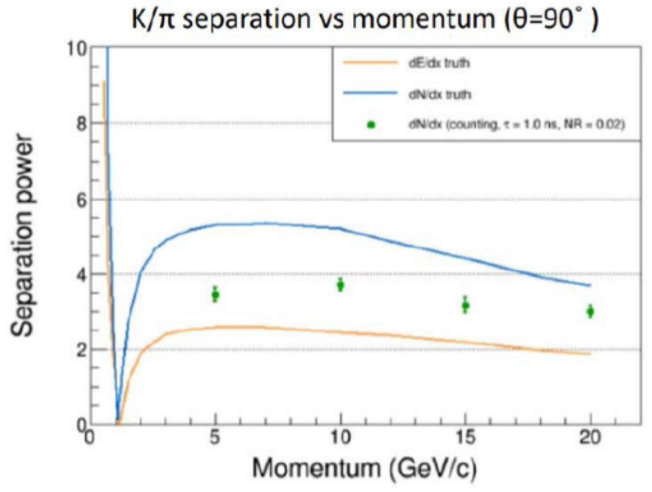


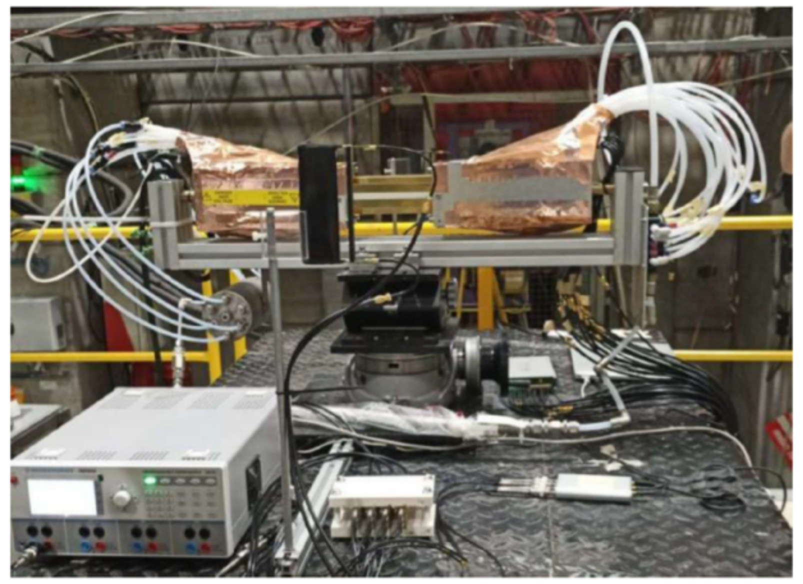
particle ID +main tracker

- **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.

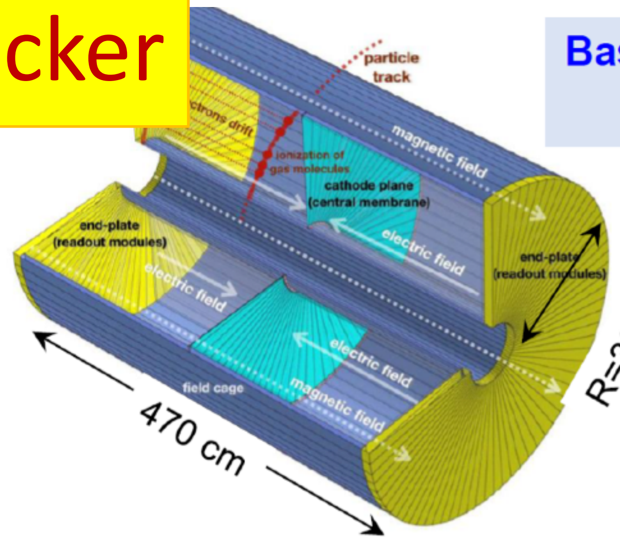




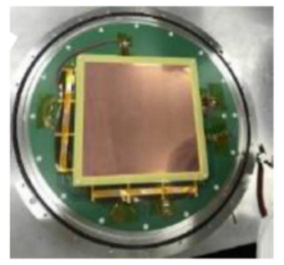




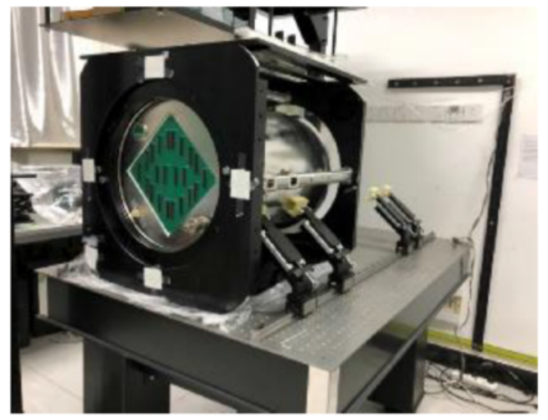
IHEP and Italian INFN groups have close collaboration and regular meetings.
IHEP joined the TB (led by INFN group) in 2021 and 2022



Baseline main tracker
σ(r-ϕ) ~100 μm

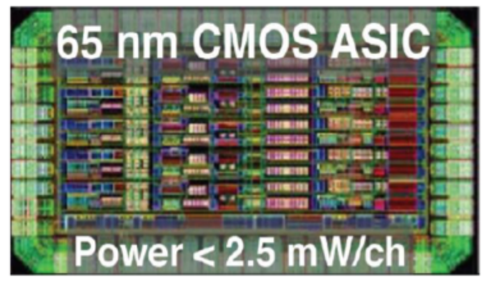


GEM-MM cathode



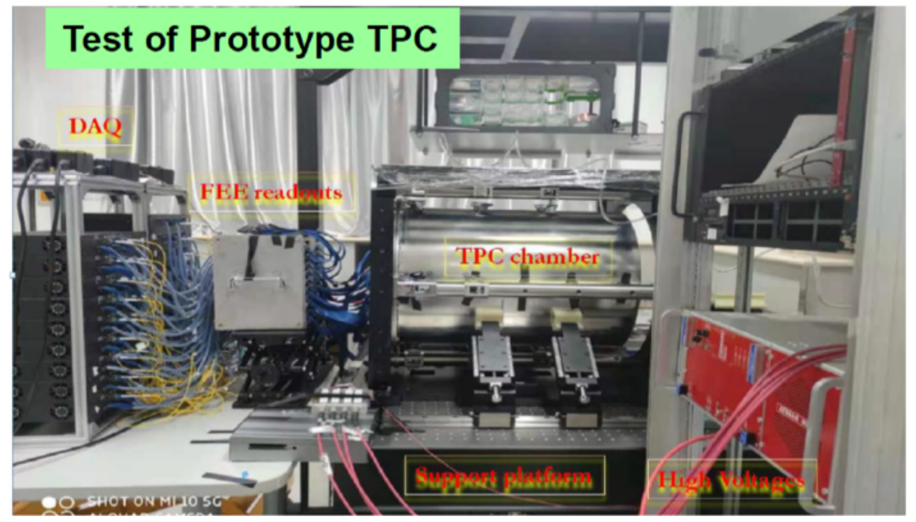
TPC Prototype + UV laser beams

MOST 1 (IHEP+THU)

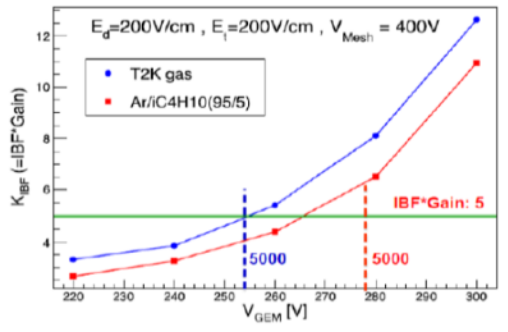


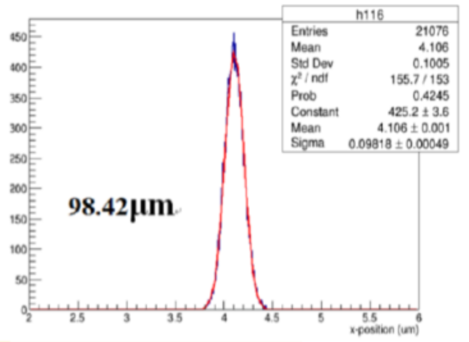
Low power FEE ASIC

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.



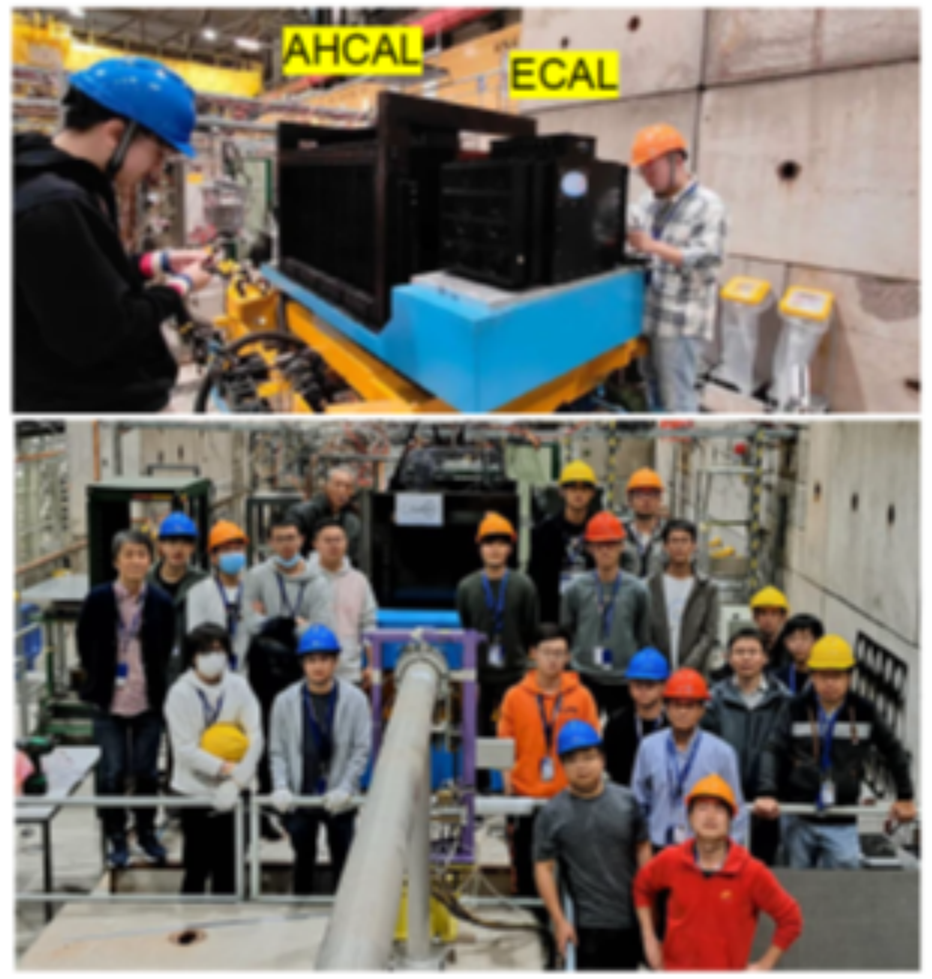


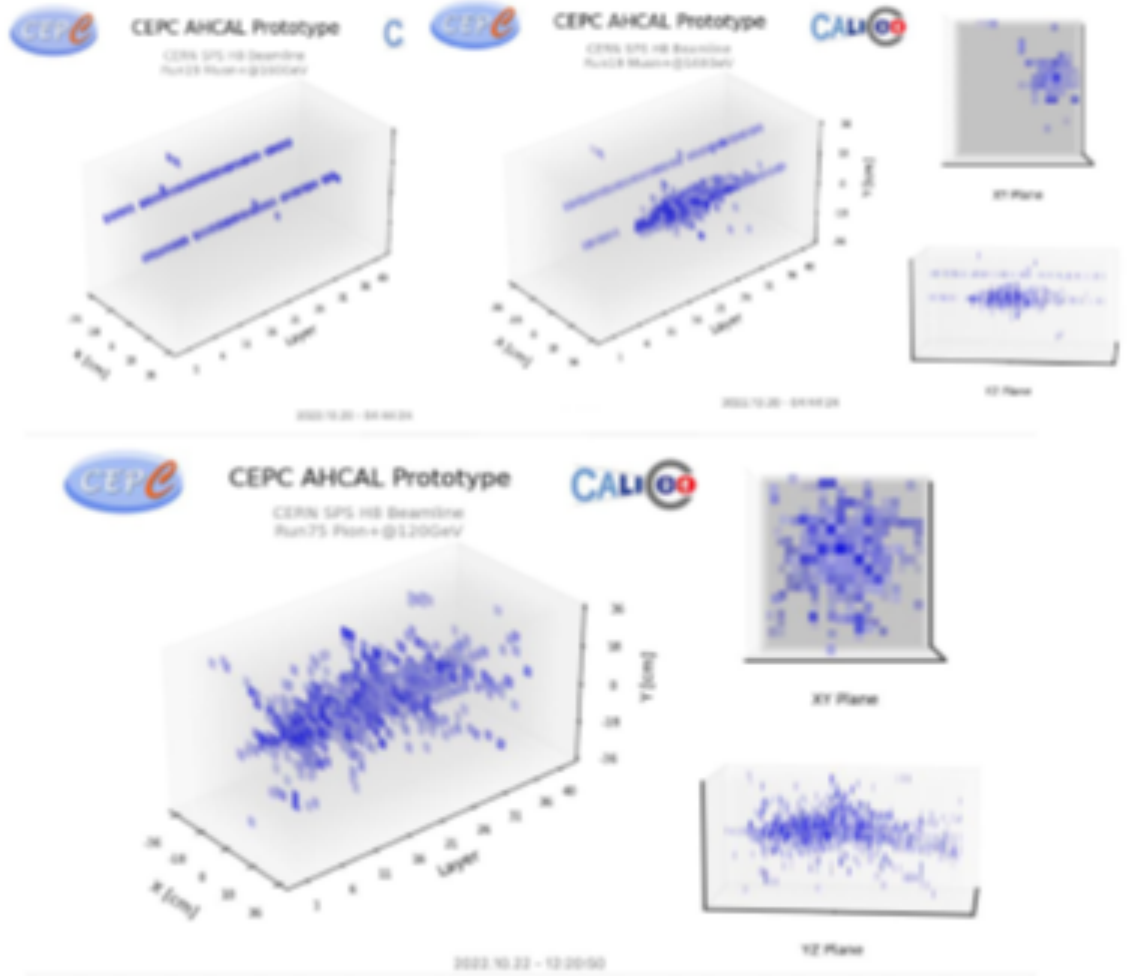
$\sigma_{r\phi}$ < 100 μm for drift length of 27cm

CEPC Detector R&D

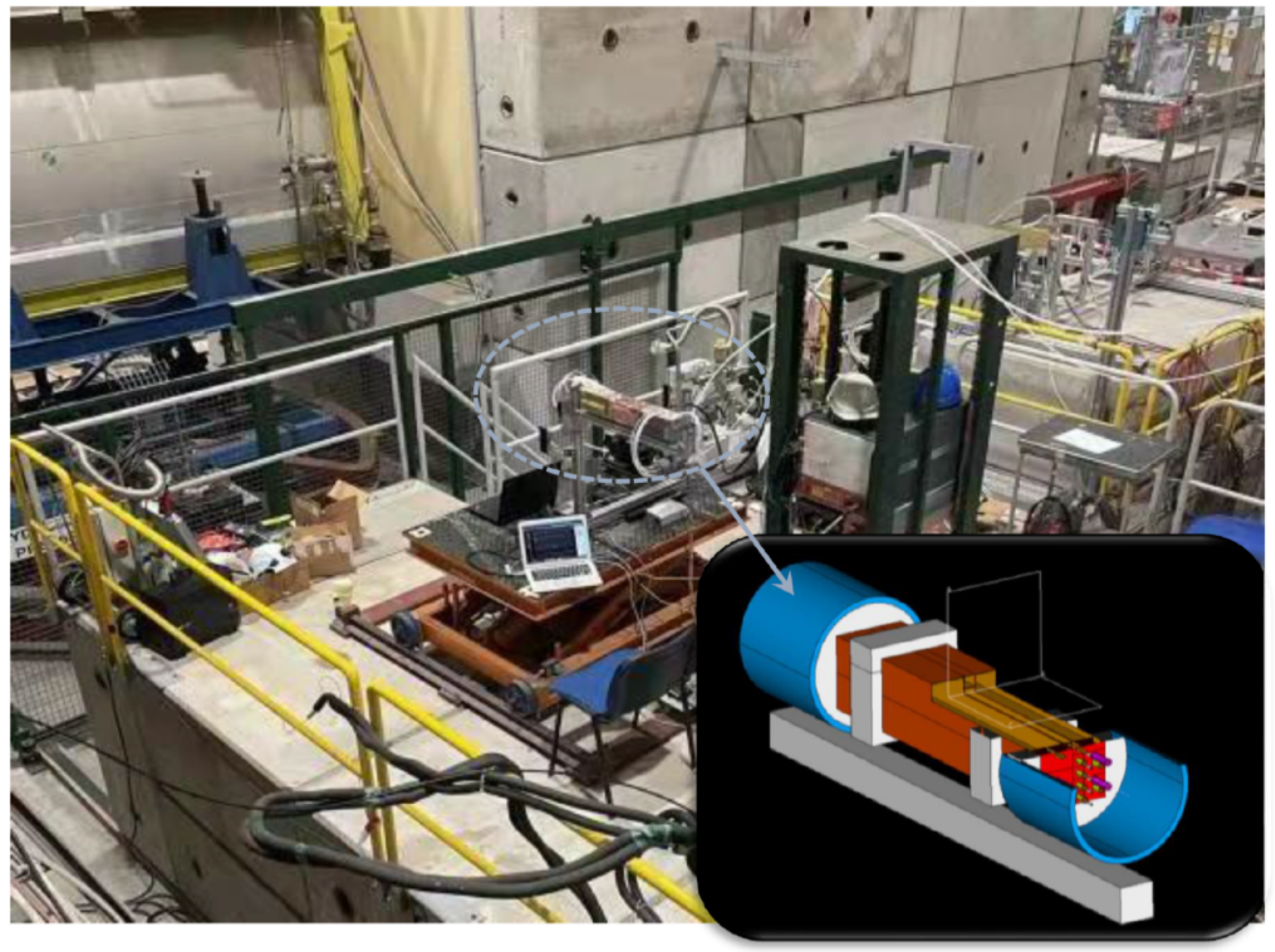
EM + hadron calorimeters： prototypes

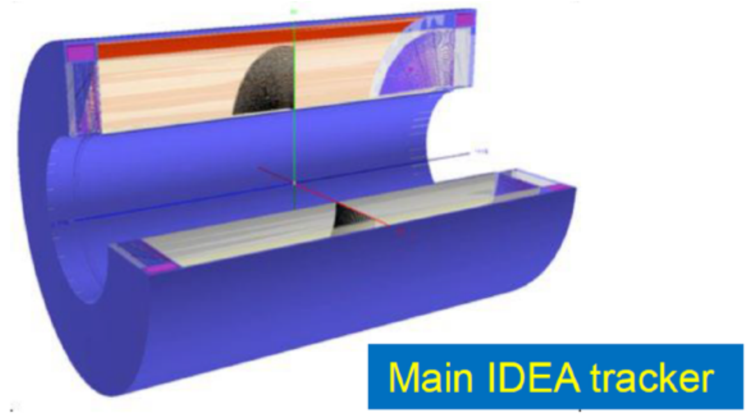
➢ **PFA ScW-ECAL & AHCAL prototypes: Test Beam at CERN SPS H8 (Oct. 2022)**



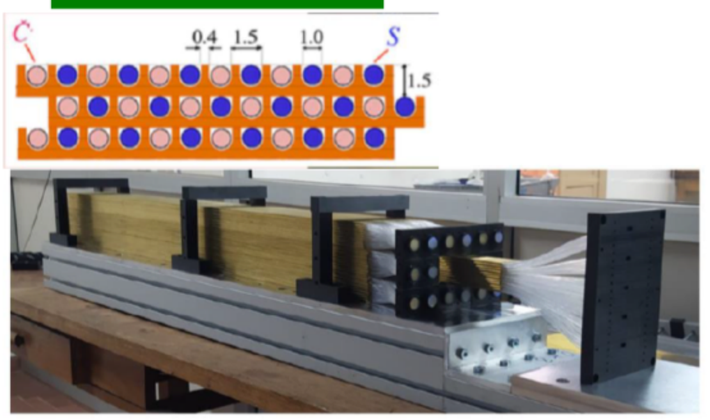


USTC, IHEP, SJTU, Japanese & Israel groups have close collaboration and regular meetings



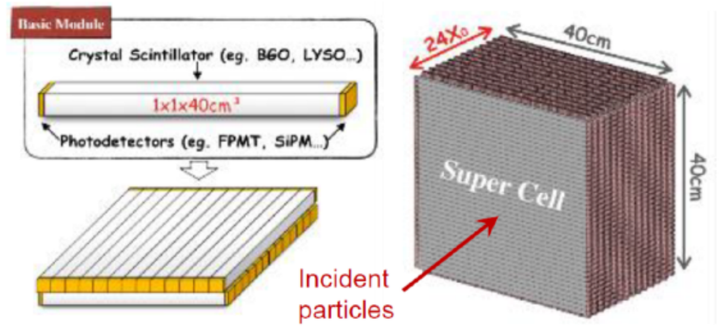


Dual Readout CAL



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

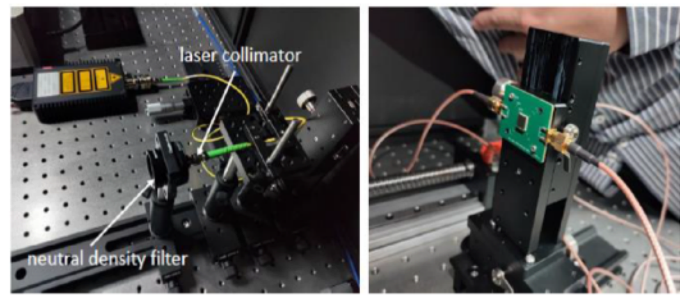
New crystal EM calorimeter for better resolution



Goal

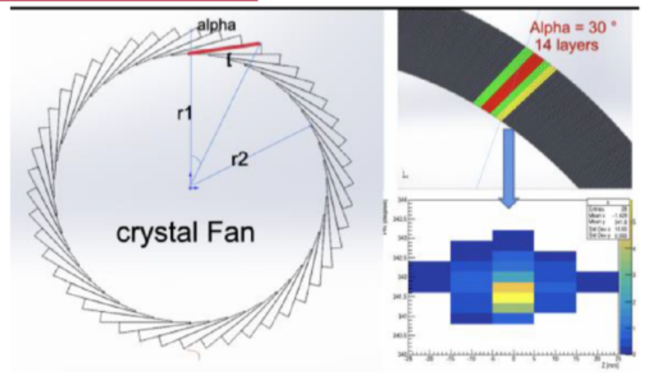
- Boson Mass Resolution < 4%
- Better BMR than ScW-ECAL
- Much better sensitivity to γ/e, especially at low energy.

Bench Test

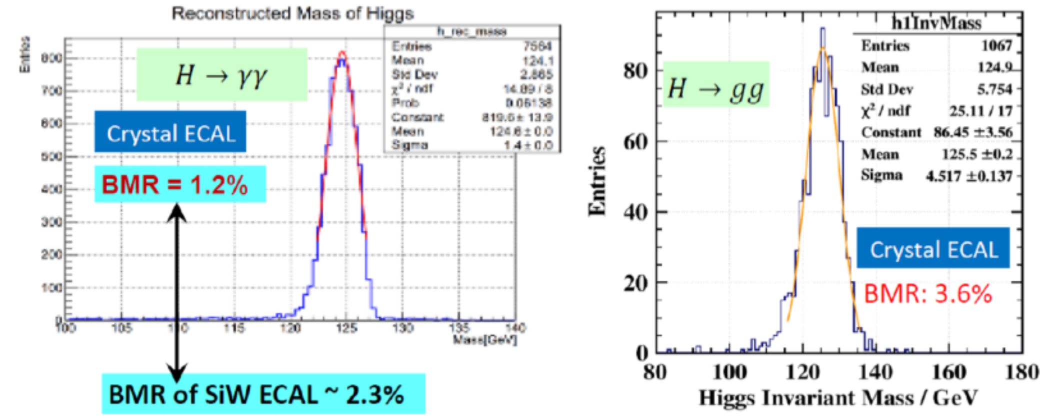


- Long bars: 1 x 40 cm, super-cell: 40x40 cm²
- Timing at both ends for positioning along bar.
- Significant reduction of number of channels.

Crystal Fan Design Fine segmentation in Z, ϕ, r



Full Simulation Studies + Optimizing PFA for crystals



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 Kep4hep – Tracking software
CEPCSW is already included in Key4hep software stack

https://github.com/cepc/CEPCSW

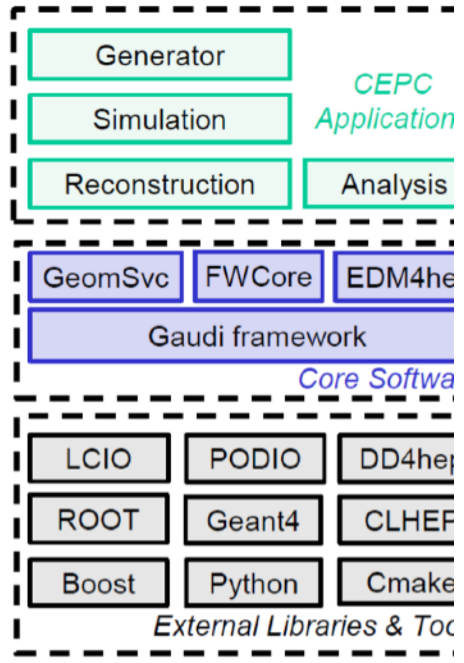
Architecture of CEPCSW

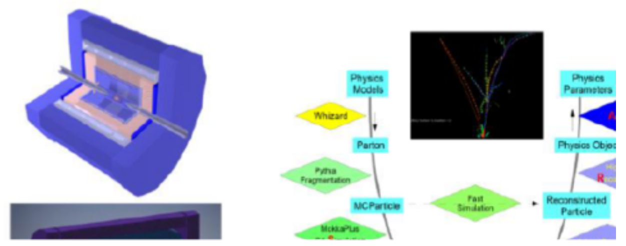
- External libraries
- Core software
- CEPC applications for simulation, reconstruction and analysis

Core Software

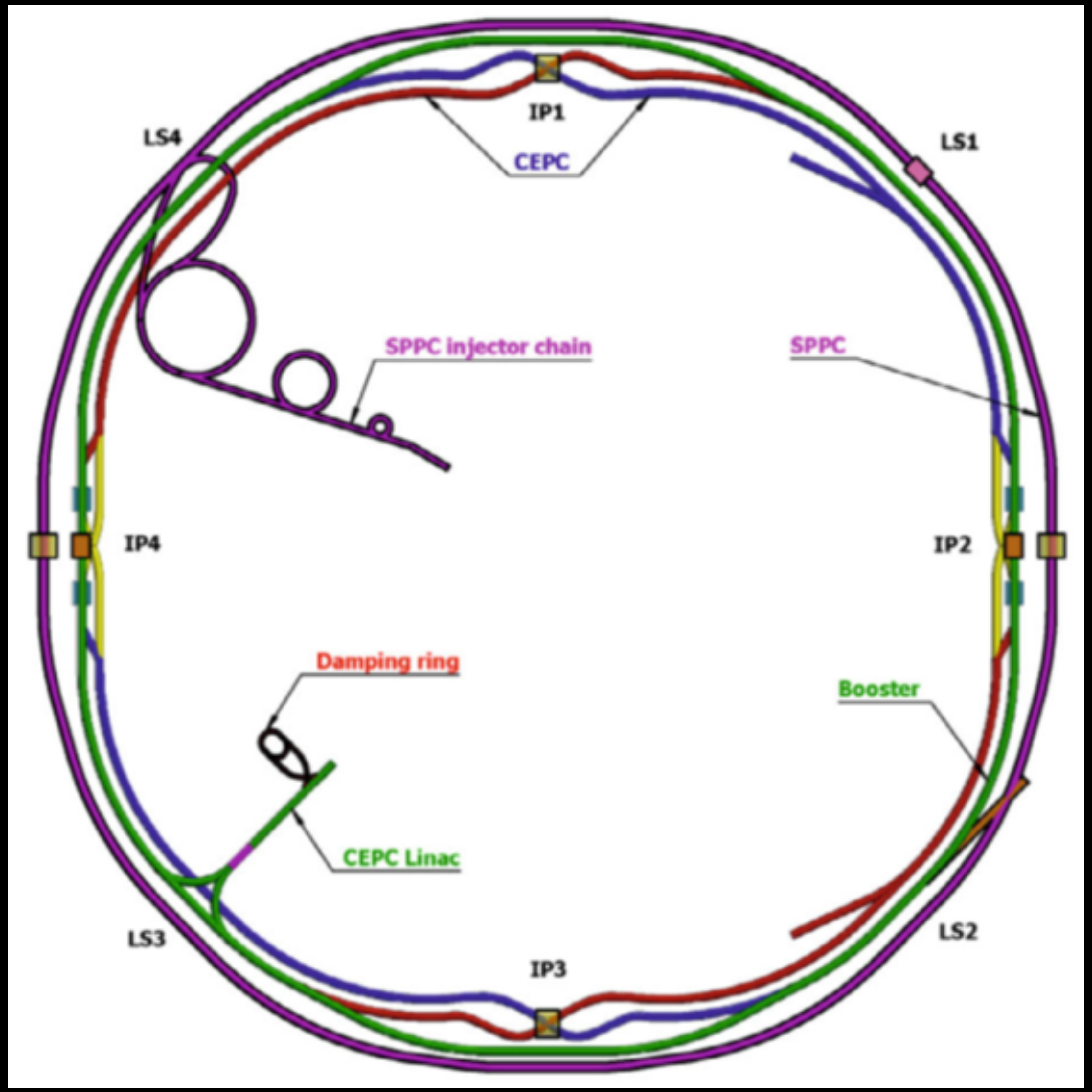
- Gaudi framework: defines interfaces of all software components and controls the event loop
- EDM4hep: generic event data model
- FWCore: manages the event data
- GeomSvc: DD4hep-based geometry management service

CEPCSW Structure





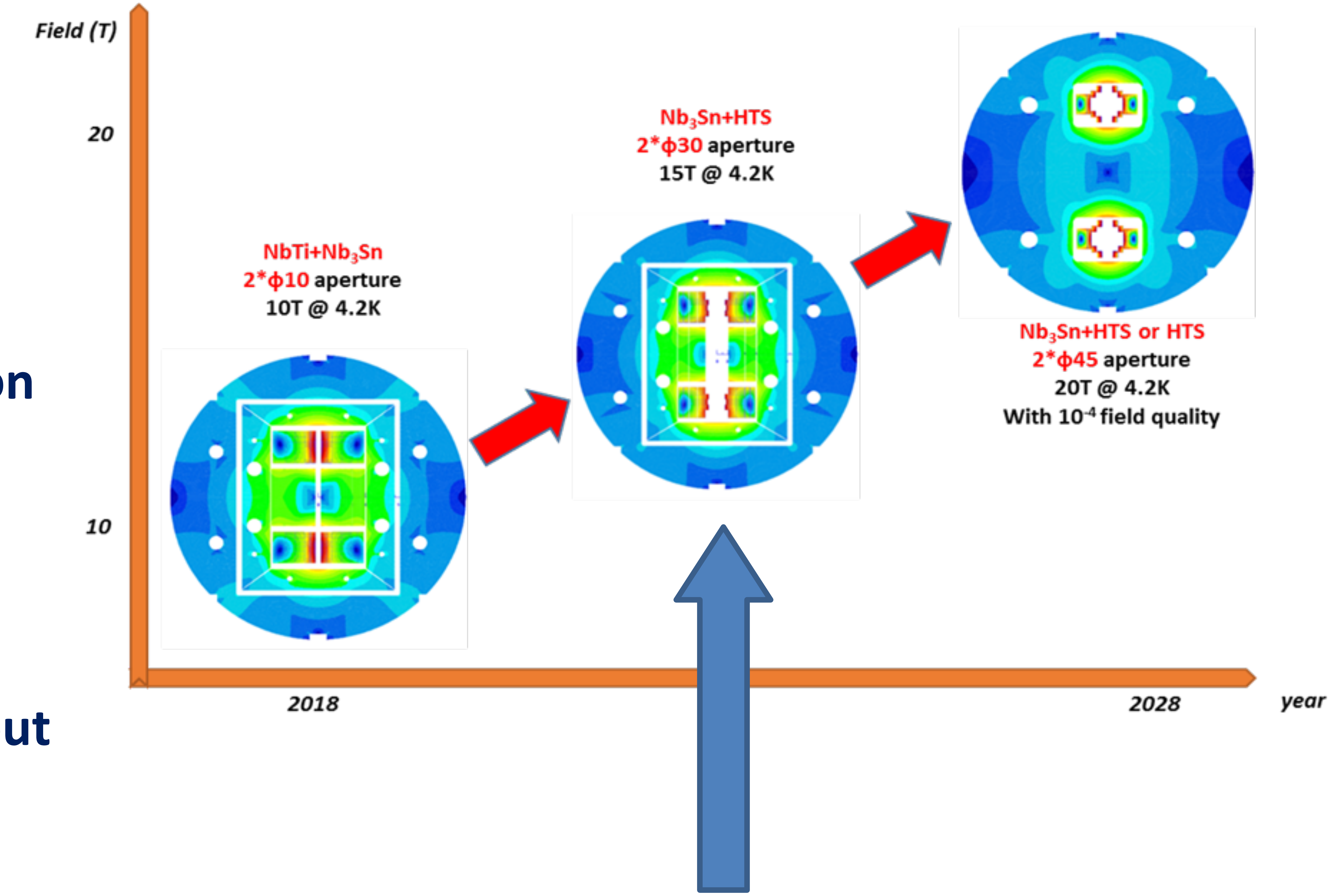
Super proton proton Collider (SppC)



Super proton-proton Collider (SppC)

Super proton-proton Collider

- E_{cm} up to 125 TeV with 100 km ring
- 2 IPs, 10^{35} $cm^{-2}s^{-1}$ per IP
- new machine after the CEPC
- can extend to heavy ion collisions
- retaining the CEPC collider add possible ep option



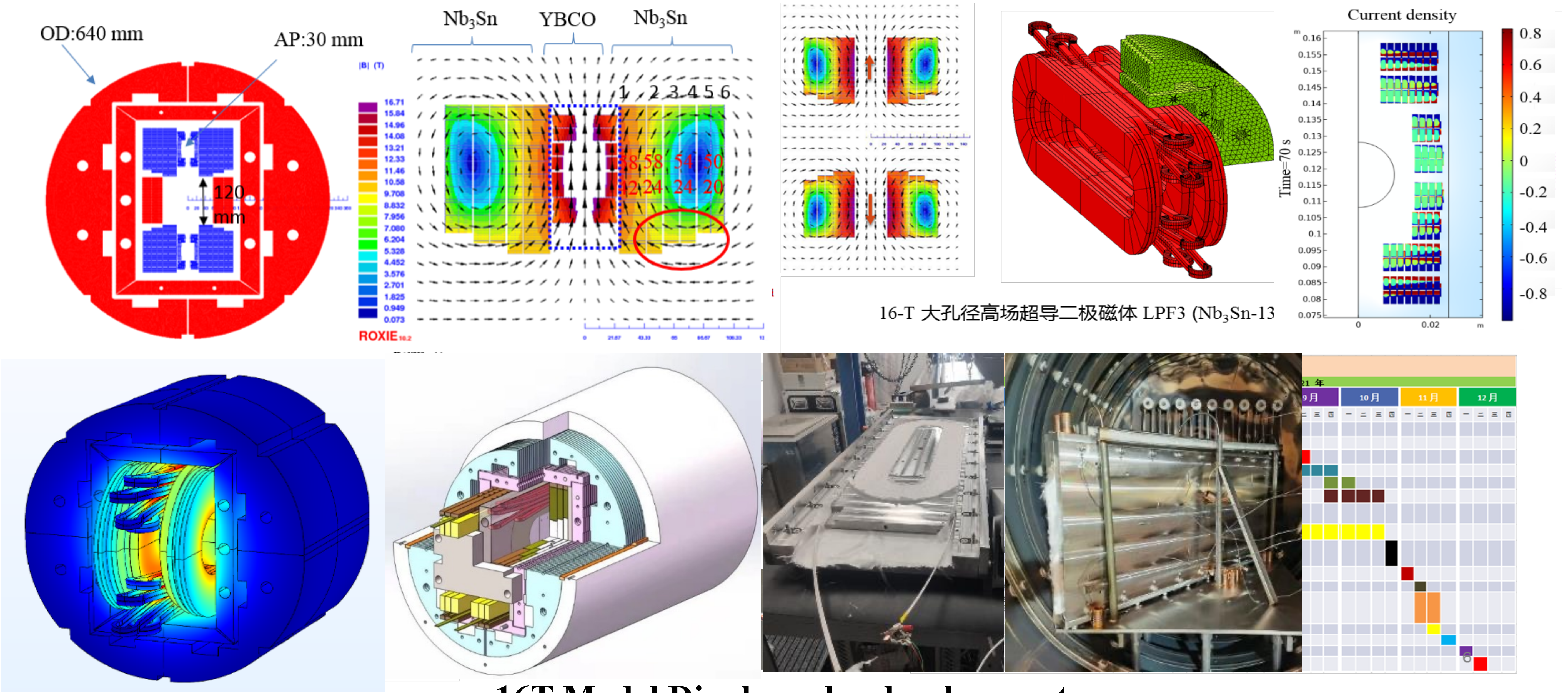
Current consideration for SppC

- CEPC design compatible with a future SppC layout
- 20T B field, twin-aperture magnets
- new HTS (even IBS) magnets (in 20-30 years)

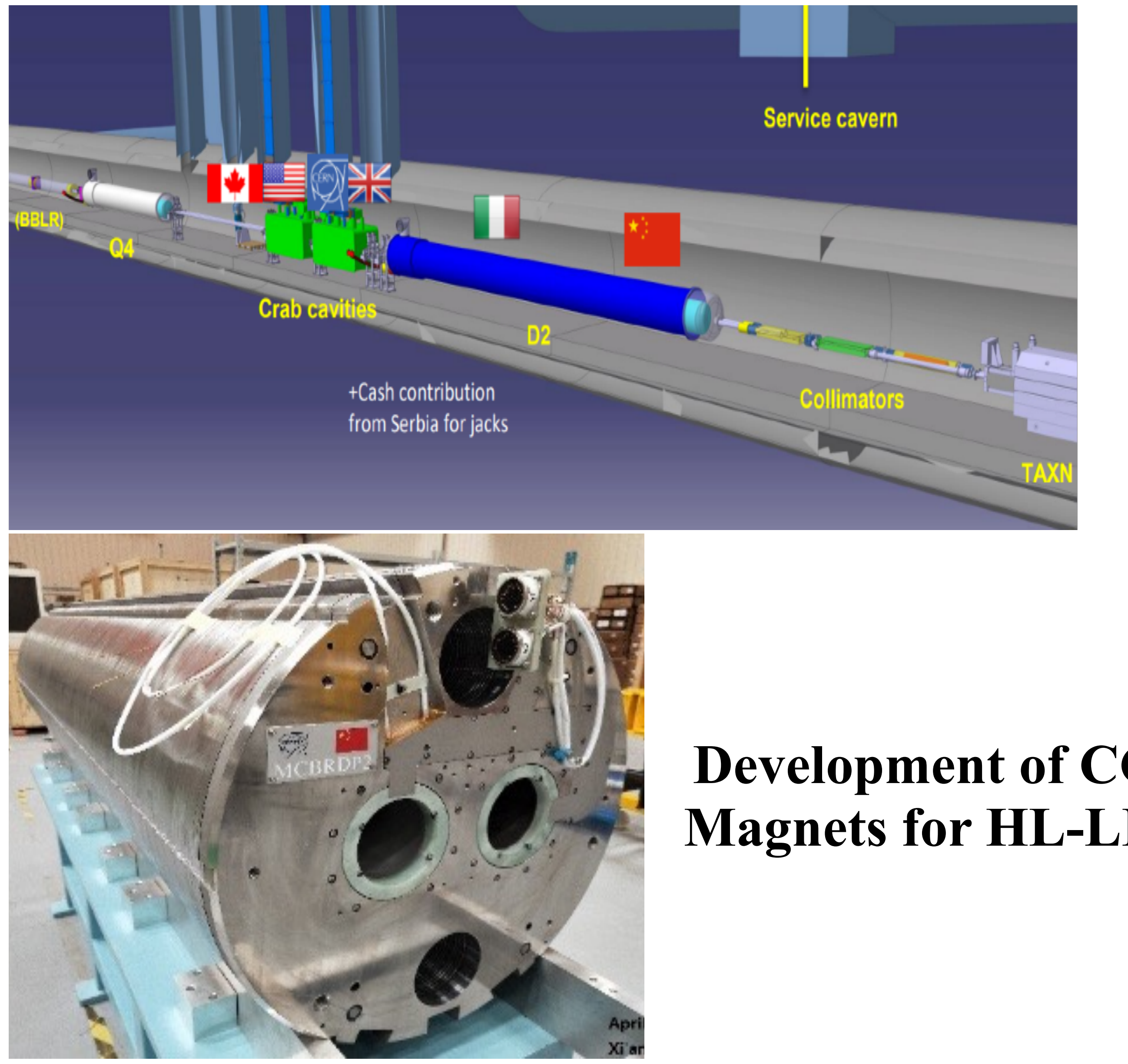
Super proton-proton Collider (SppC)

- **16T model dipole magnet under development:** Nb_3Sn 12~13T + HTS 3~4T
  - **The highest quench field reached over 14T @4.2K in 2023 → Goal: 16T @4.2K to be realized in 2024**
- **Stainless-steel stabilized IBS tape achieved the highest J_e in 2022.**
  - **Significantly reduced cost and raised mechanical properties IBS model coils reached 60A @32T**

- **China & CERN Collaboration on accelerator technology: development of HL-LHC CCT magnets going well.**
  - **Half of 12+1 magnets have been delivered to CERN**



16T Model Dipole under development



Development of CCT Magnets for HL-LHC

CEPC Plan

- Engineering Design towards an EDR
- Reference detector TDR for domestic evaluation
- 15th Five Year Plan

Engineering Design towards an EDR

CEPC

2012.9	2015.3	2018.11	2023.10	2025	2027 15th five year plan
CEPC proposed	Pre-CDR	CDR	TDR	CEPC Proposal	EDR Start of construction

today

CEPC EDR Phase General Goal (2024-2027):

CEPC accelerator is entering 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

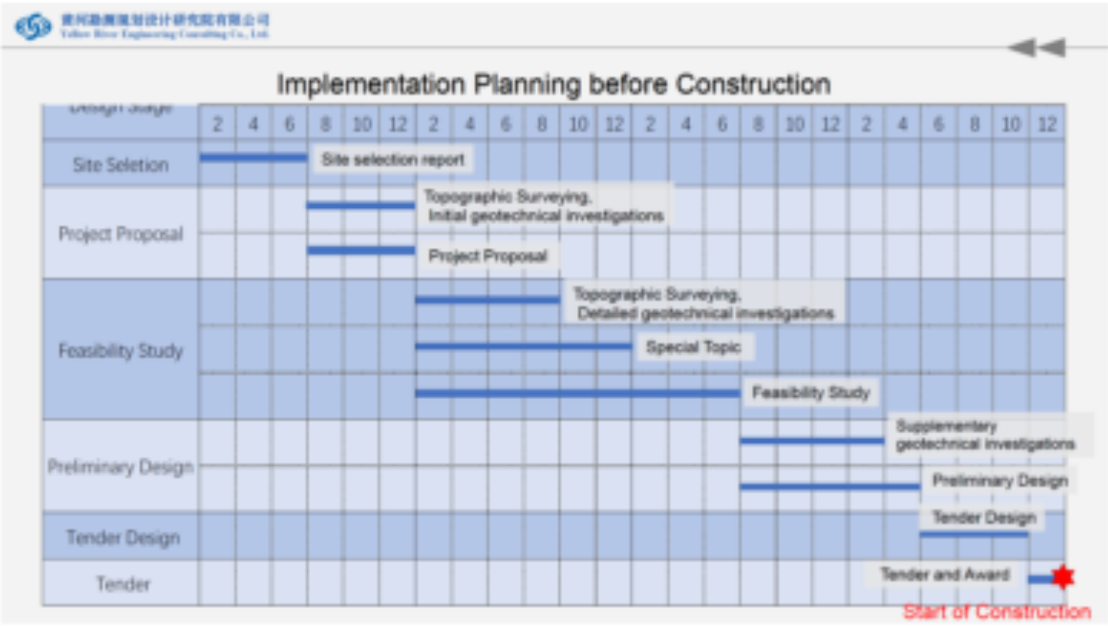
CEPC EDR includes accelerator and detector (TDRrd)
CEPC detector TDR reference design (rd) will be released by June 30, 2025

CEPC Accelerator EDR Phase goals, scope and the working plan (preliminary) of 35 Working Groups summarized in a document of 20 pages to be reviewed by IARC in 2024

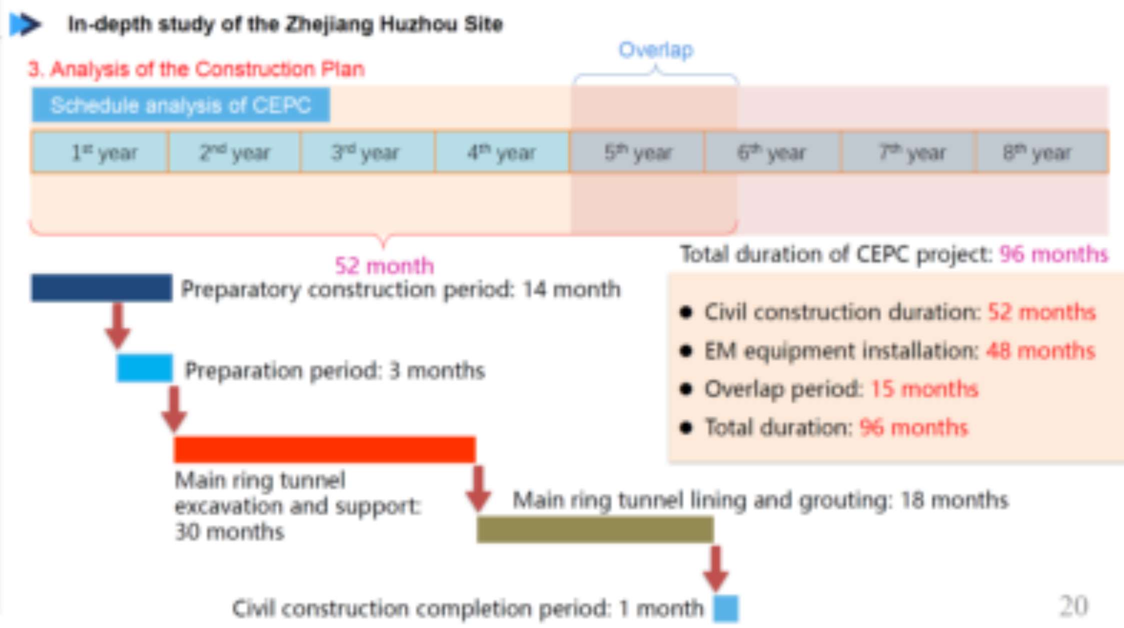
Engineering Design towards an EDR

CEPC Site Implementation and Construction Plans

CEPC site implementation plan in EDR



CEPC construction plan

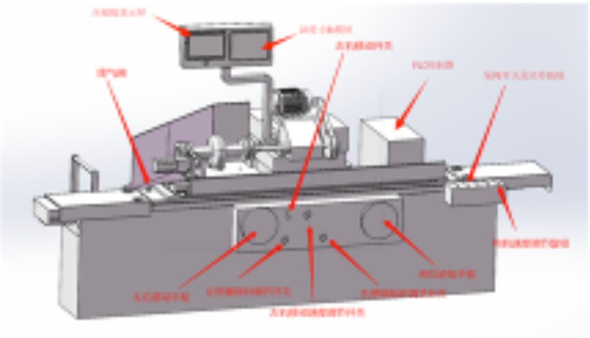


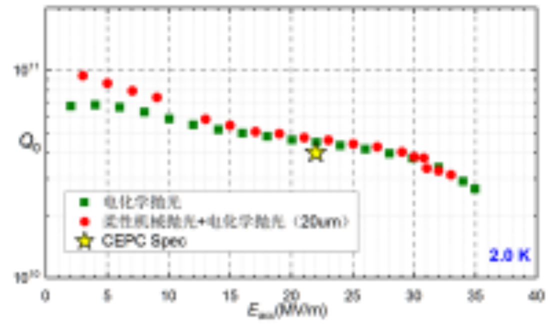
Future Plan for CEPC SRF

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034-2035	2036-2045	2046-2047	2048	2049-2053
EDR																
Civil construction																
Acc. construction & installation																
Commission & operation													H	Z	W	ttbar
SRF system engineering design	Layout, cost, module, beam-cavity, LLRF, interfaces ...															
650 MHz test module (2x2-cell)	Beam operation, replace with high Q cav & variable coupler															
650 MHz H module (6x2-cell)	Design	pCM fabrication		pCM test	Prepare	Production of 32 CM / 192 2-cell CAV for 30 MW H				Installation, Commissioning			Op & +24 CM	Operation		
1.3 GHz H module	High Q module	Mass production of modules with SCM and BPM			pCM fab	pCM test	Production of 12 CM / 96 9-cell CAV			Installation, Commissioning			Operation			
1.3 GHz Z module (high current)		Design and R&D			pCM fabrication		pCM test		Production of 4 CM / 32 9-cell CAV		Installation, Commissioning		Operation			
650 MHz HL-Z module	Conceptual design. 500 MHz high current module production.				Design and R&D							Produce and Install 60+40 1-cell CM		Op		
ttbar cavity and module	Design and R&D of high gradient high Q and new material (Nb3Sn etc.) 650 MHz and 1.3 GHz cavities and module for ttbar								pCM fabrication and test				Production and Installation of 48 CM / 192 650 MHz 5-cell CAV 32 CM / 256 1.3 GHz 9-cell CAV			Op

CEPC SRF Industrial Production Technology

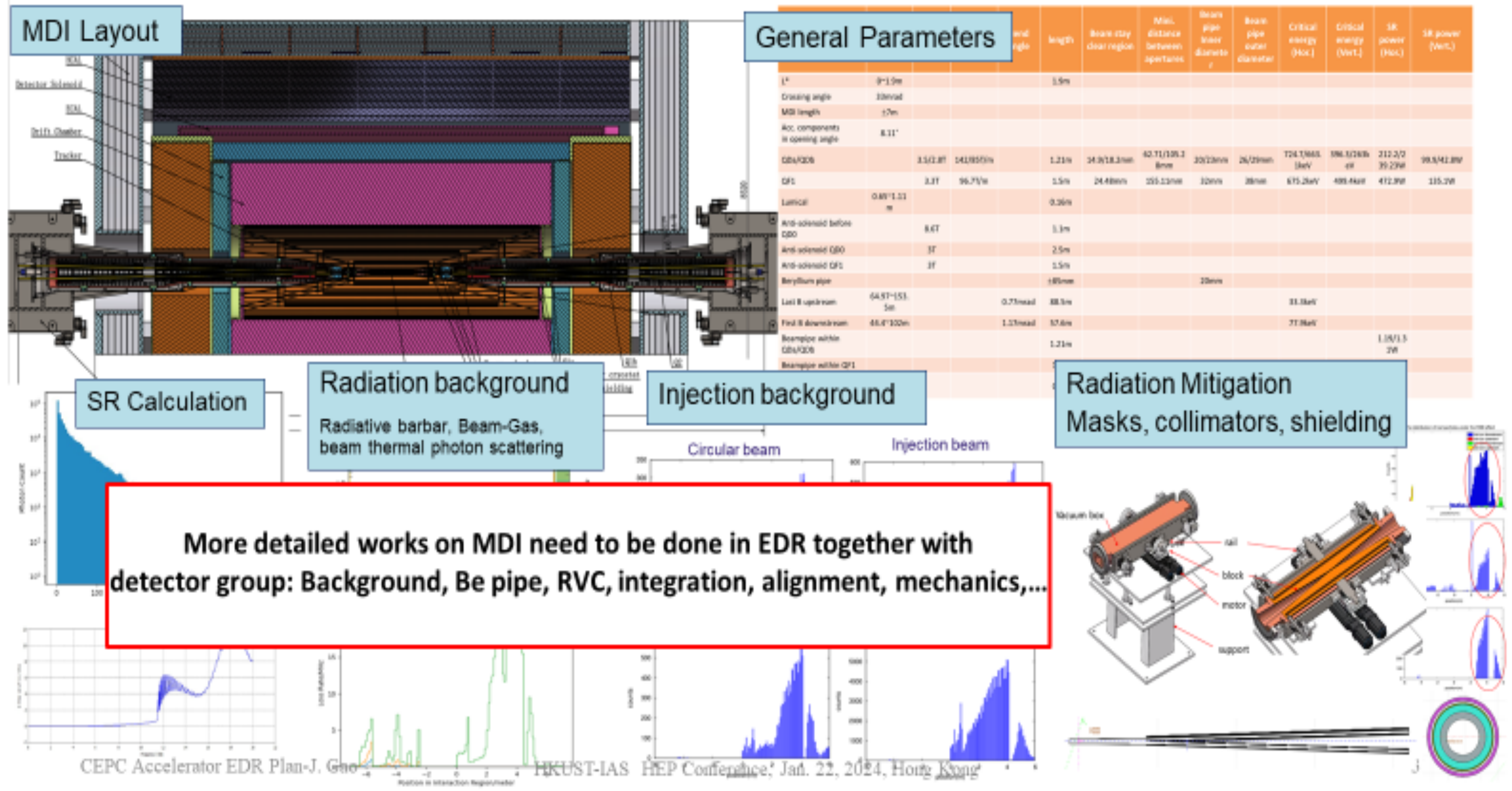
- In 2023, IHEP invented soft SRF cavity polishing equipment has been completed and it will be installed at IHEP soon, and it reached the same surface roughness as EP. CEPC 650 MHz cavity treated by the soft polishing equipment reached the CEPC specification





650 MHz SC measurement result with soft polishing technology

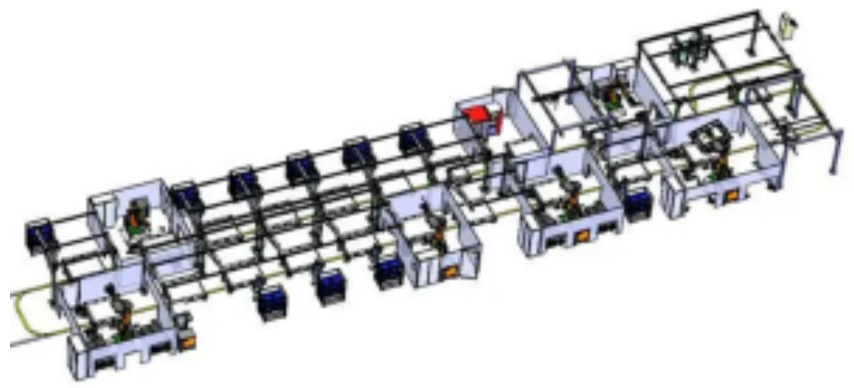
CEPC MDI in EDR



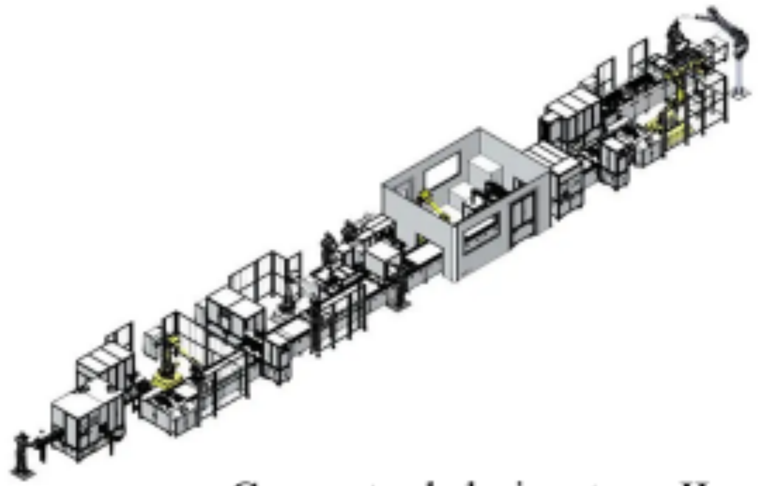
EDR - Examples

CEPC Magnets' Automatic Production Lines in EDR

To reduce the fabrication cost of the magnets of CEPC, automatic magnet production lines will be demonstrated in EDR and used during construction



Conceptual design type-I (Booster magnet)



Conceptual design type-II (Collider ring magnet)

CEPC Accelerator Control and Timing in EDR

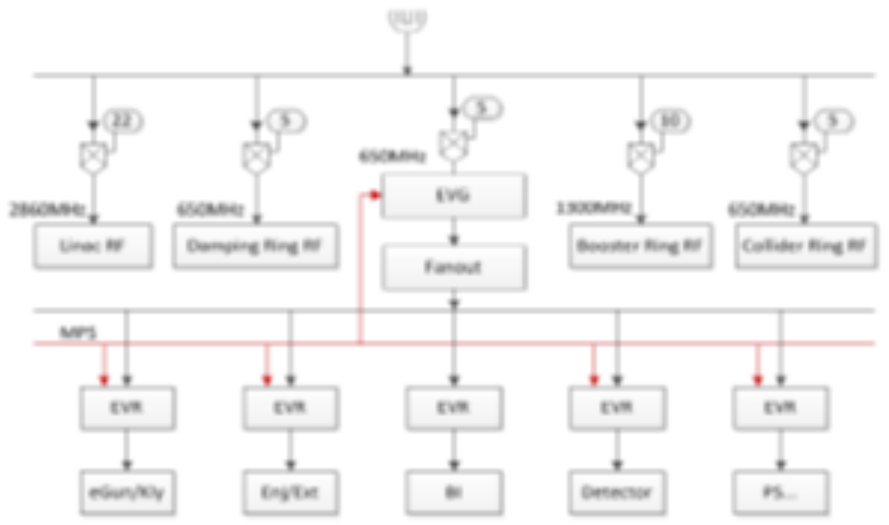
The basic structure of Timing System

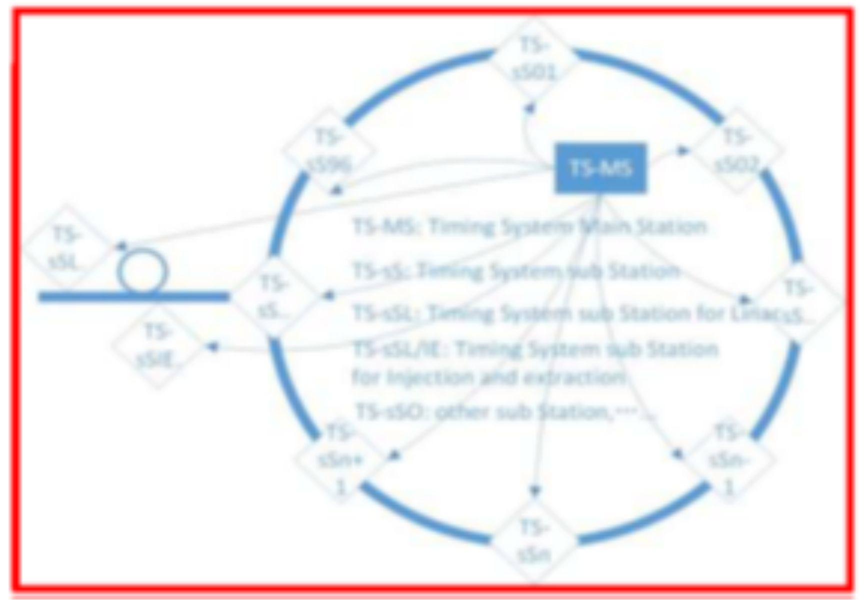
- Event system and RF transmission system
- Event system: Trigger signal and Low frequency clock signal
- RF transmission system: Transmit high stability RF signal

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

Temperature variation induced drift compensation

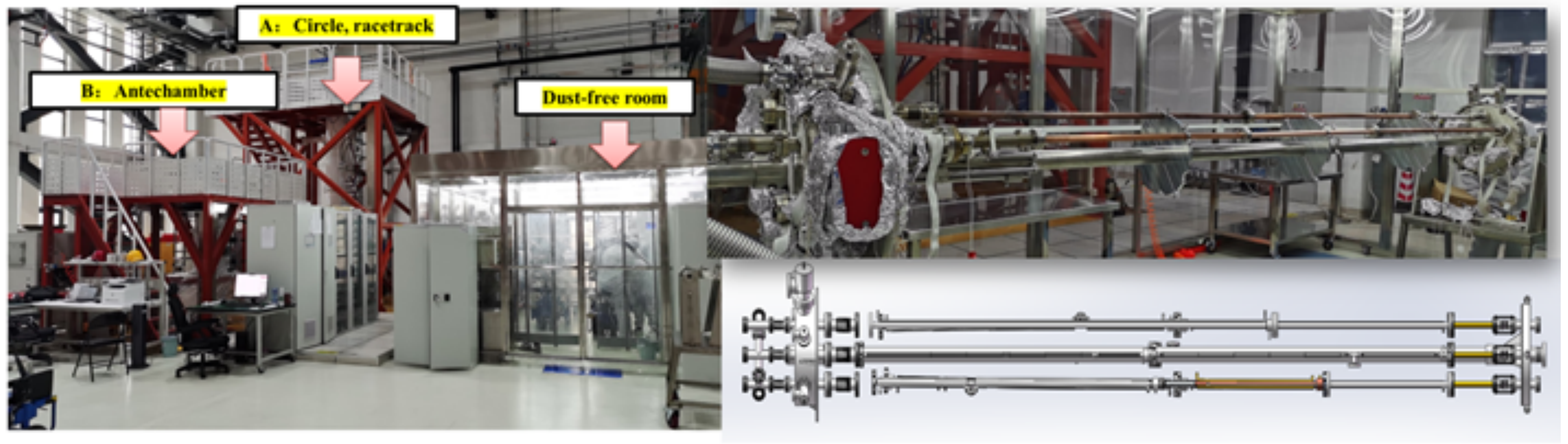
0.7ns for 10km optical fiber with 1 ℃ change normally





Massive Production Line of NEG Coating Vacuum Chambers in EDR

- The coating device A: Vacuum chambers are connected in parallel to 6 groups, each group of vacuum chambers length should be lower than 3.5m, outer diameter is about 0.47m;
- The coating device B: Antechamber are connected in parallel to 4 groups, each group of vacuum chambers length should be lower than 1.5m, due to its discharge difficulty.
- Two setups of NEG coating have been built for vacuum pipes of HEPS at IHEP Lab. And a lot of test vacuum pipes have been coated, which shows that NEG film has good adhesion and thickness distribution.
- **In EDR phase a dedicated CEPC NEG coated vacuum chamber production line is planned**



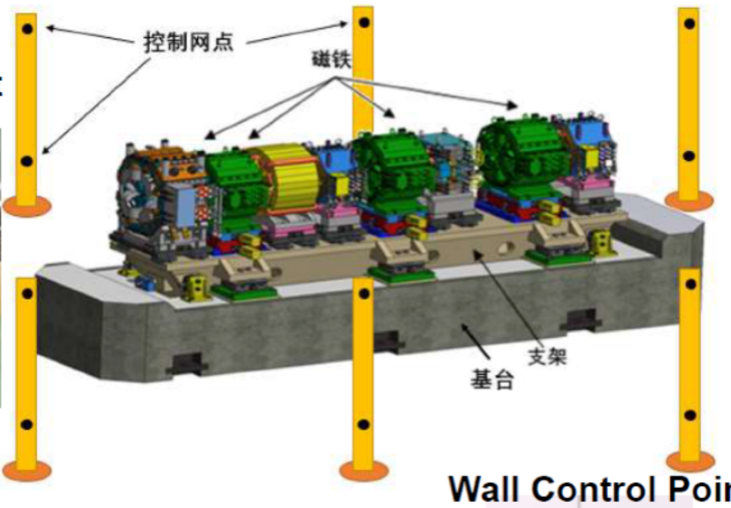
CEPC Alignment and Installation Plan in EDR

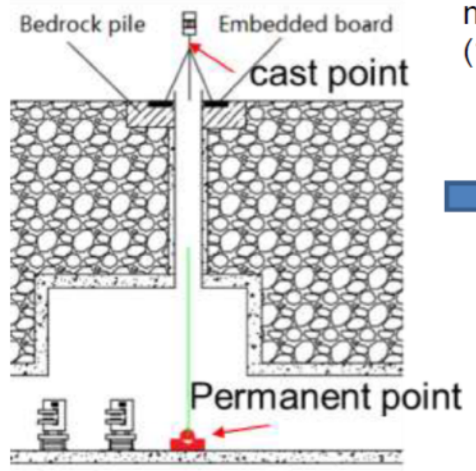
- Alignment accuracy requirement

Component	Δx (mm)	Δy (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

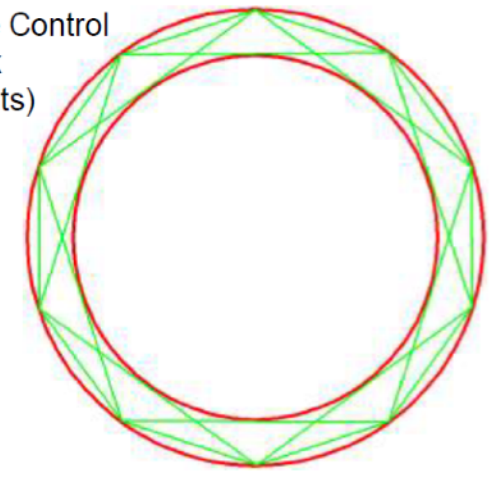
*implement beam-based alignment

Component Pre-alignment

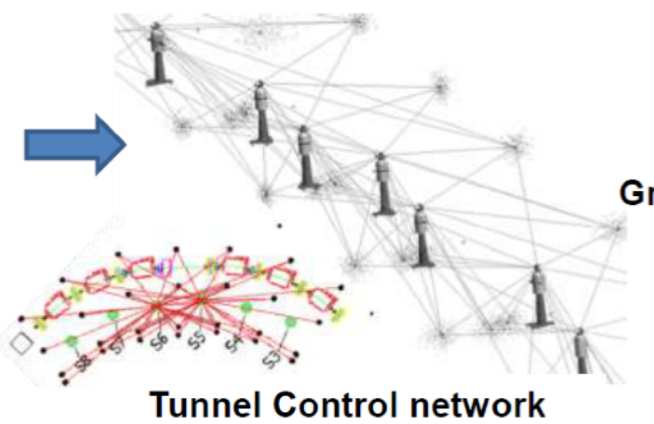




Surface Control network (14Points)



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



Tunnel Control network (interval of 6 meters)

Wall Control Point

Ground Control Point

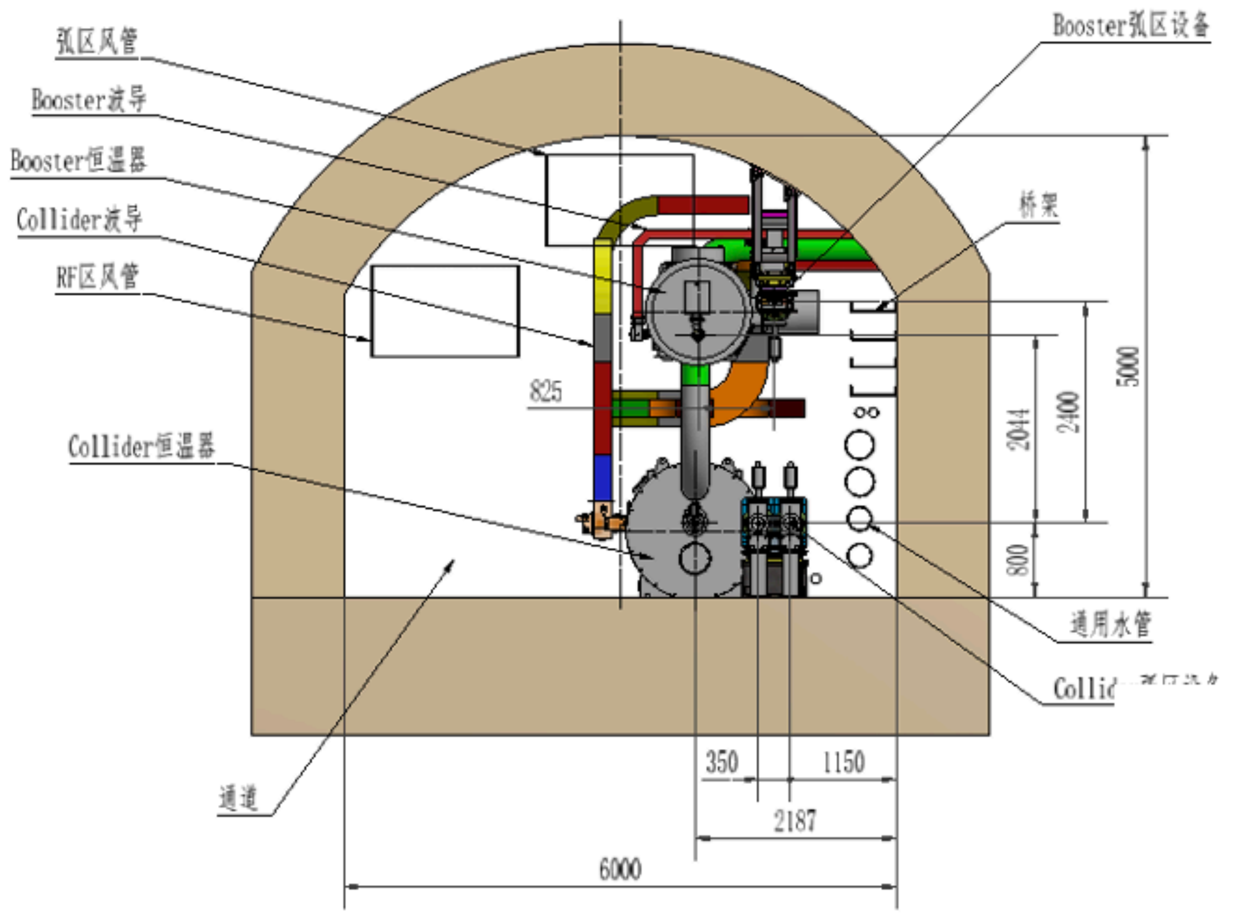
CEPC Accelerator EDR Plan-J. Gao

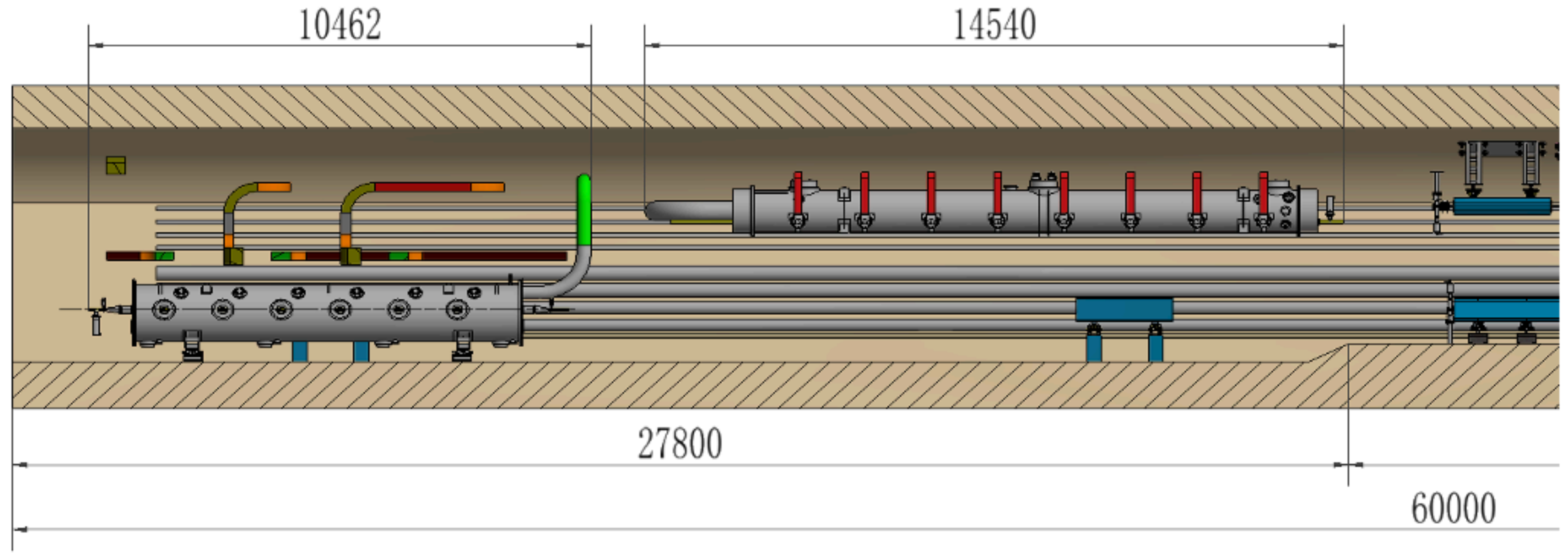
2024, H

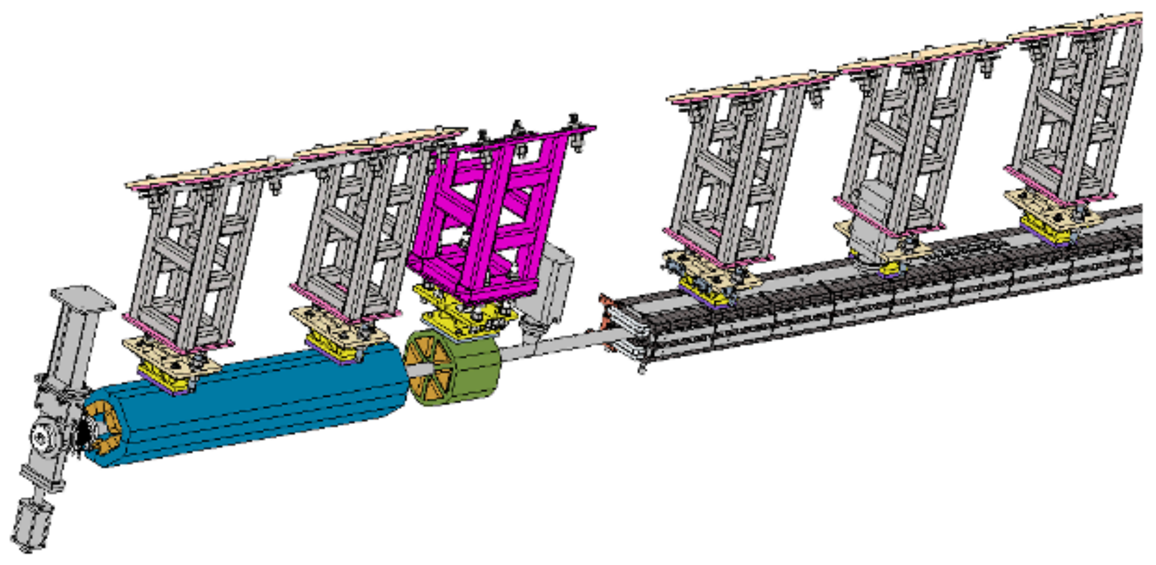
33

EDR - Examples

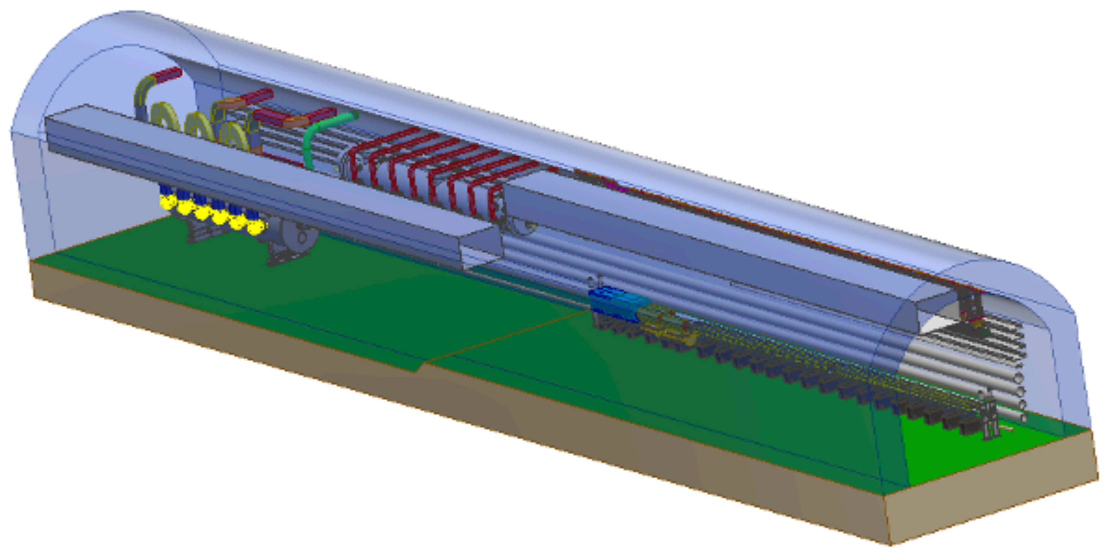
CEPC Tunnel Mockup for Installation in EDR

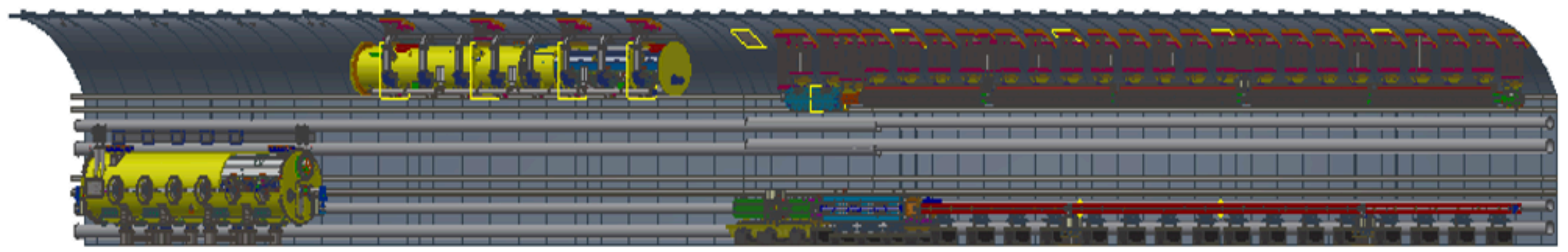


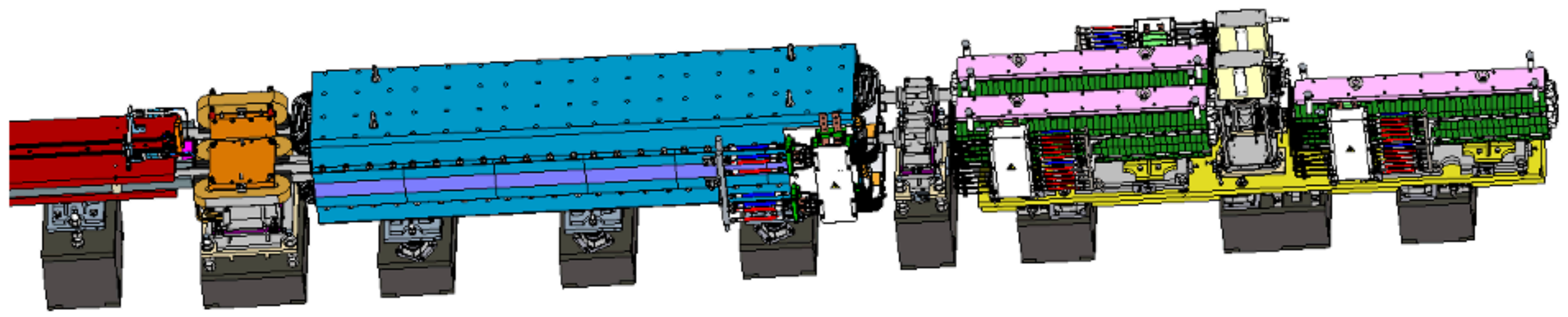


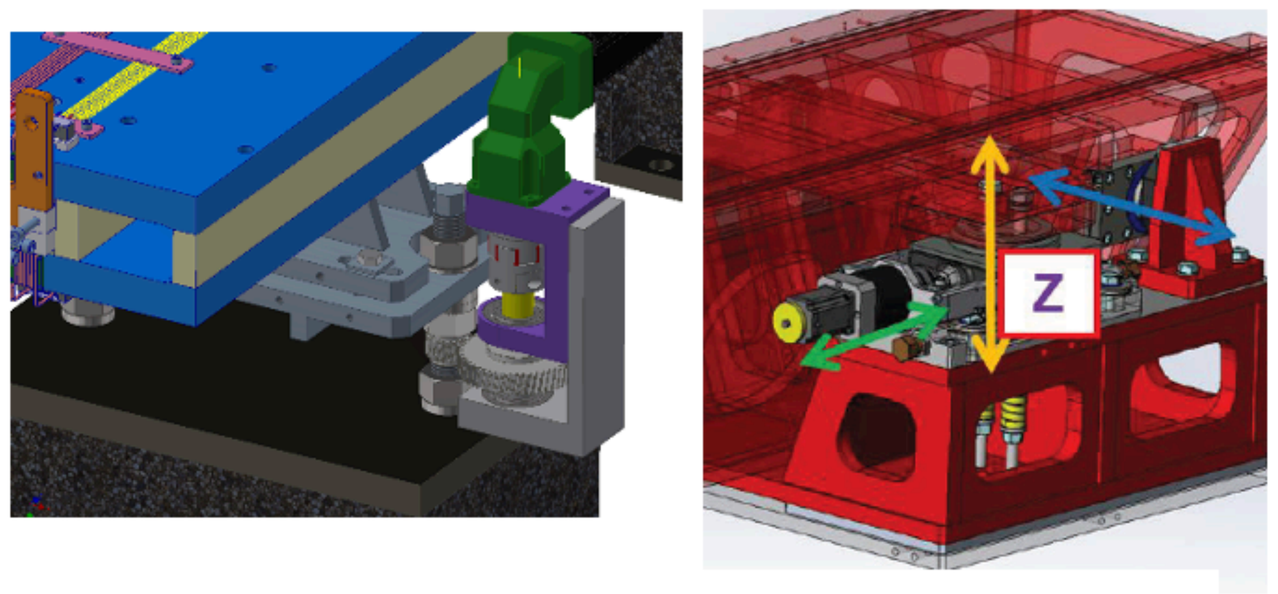


Booster magnets installation









Collider ring magnets supports

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

Technical review has been done on August 16, 2024, and construction will start soon

Accelerator EDR Plan - Review

CEPC International Accelerator Review Committee (IARC) Meeting held on September 18-20, 2024 at IHEP

CEPC International Accelerator Review Committee (IARC) Meeting was held from Sept. 18-20, 2024 at IHEP

The CEPC International Accelerator Review Committee (IARC) members visited IHEP 4th Generation 6GeV HEPS light source in Huairou campus of IHEP on Sept. 20, 2024 at IHEP

The CEPC International Accelerator Review Committee (IARC) members in the control room Of HEPS, and 30mA stored beam current have been reached during storage ring commissioning in Sept. 2024

Industrial Partners and Suppliers

	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)

Potential international collaborating suppliers and partners worldwide

IHEP Experience on Accelerator Construction

BEPC

Construction years: 1984-1988
Budget: 0.24 Billion CNY
On time, on budget

BEPCII & BESIII

Construction years: 2004-2008
Budget: 0.64 Billion CNY
On time, on budget

ADS

Construction years: 2011-2016
Budget: 0.40 Billion CNY
On time, on budget

CSNS

Construction years: 2011-2018
Budget: 1.87 Billion CNY
On time, on budget

HEPS

Construction years: 2019-2025
Budget: 4.8 Billion CNY
Completed in 2024, on schedule, on budget

IHEP has constructed large-scale accelerator facilities since 1980's, including **circular collider**, **proton superconducting linac**, **spallation neutron source**, and a **synchrotron radiation source**. All these high-budget accelerators have been built on schedule and on budget

CEPC in Synergy with Other Accelerator Projects in China

Total cost of accelerator projects under construction: 39B RMB

(more than CEPC cost of 36.4B RMB)

Project name	Machine type	Location	Cost (B RMB）	Completion time
CEPC	Higgs factory Up to ttbar energy	Led by IHEP, China	**36.4 (where 19B for accelerator)**	Around 2035 (starting time around 2027)
BEPCII-U	e+e- collider 2.8 GeV/beam	IHEP (Beijing)	**0.15**	2025
HEPS	4^{th} generation light source of 6 GeV	IHEP (Huairou)	**5**	2025
SAPS	4th generation light source of 3.5 GeV	IHEP (Dongguan)	**3**	2031 (in R&D, to be approved)
HALF	4th generation light source of 2.2 GeV	USTC (Hefei)	**2.8**	2028
SHINE	Hard XFEL of 8 GeV	Shanghai-Tech Univ., SARI and SIOM of CAS (Shanghai)	**10**	2027
S3XFEL	S3XFEL of 2.5 GeV	Shenzhen IASF	**11.4**	2031
DALS	FEL of 1 GeV	Dalian DICP	**-**	(in R&D, to be approved,)
HIAF	High Intensity heavy ion Accelerator Facility	IMP, Huizhou	**2.8**	2025
CIADS	Nuclear waste transmutation	IMP, Huizhou	**4**	2027
CSNS-II	Spallation Neutron source proton injector of 300 MeV	IHEP, Dongguan	**2.9**	2029

International Exchanges and Collaboration

- **Strong participation by international scientists for both CDR and TDR**
  - **Authors from 140-159 international institutions (24-38 countries)**
- **Reviews and guidance from many overseas experts**

- **Workshops and conferences at overseas sites**
  - **Rome, Oxford, Chicago, Edinburgh, Marseille, Barcelona (2025)**
- **More than 20 MoUs signed with international institutions and universities**

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

CEPC workshop in Chicago, 2019

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, EUEdition,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

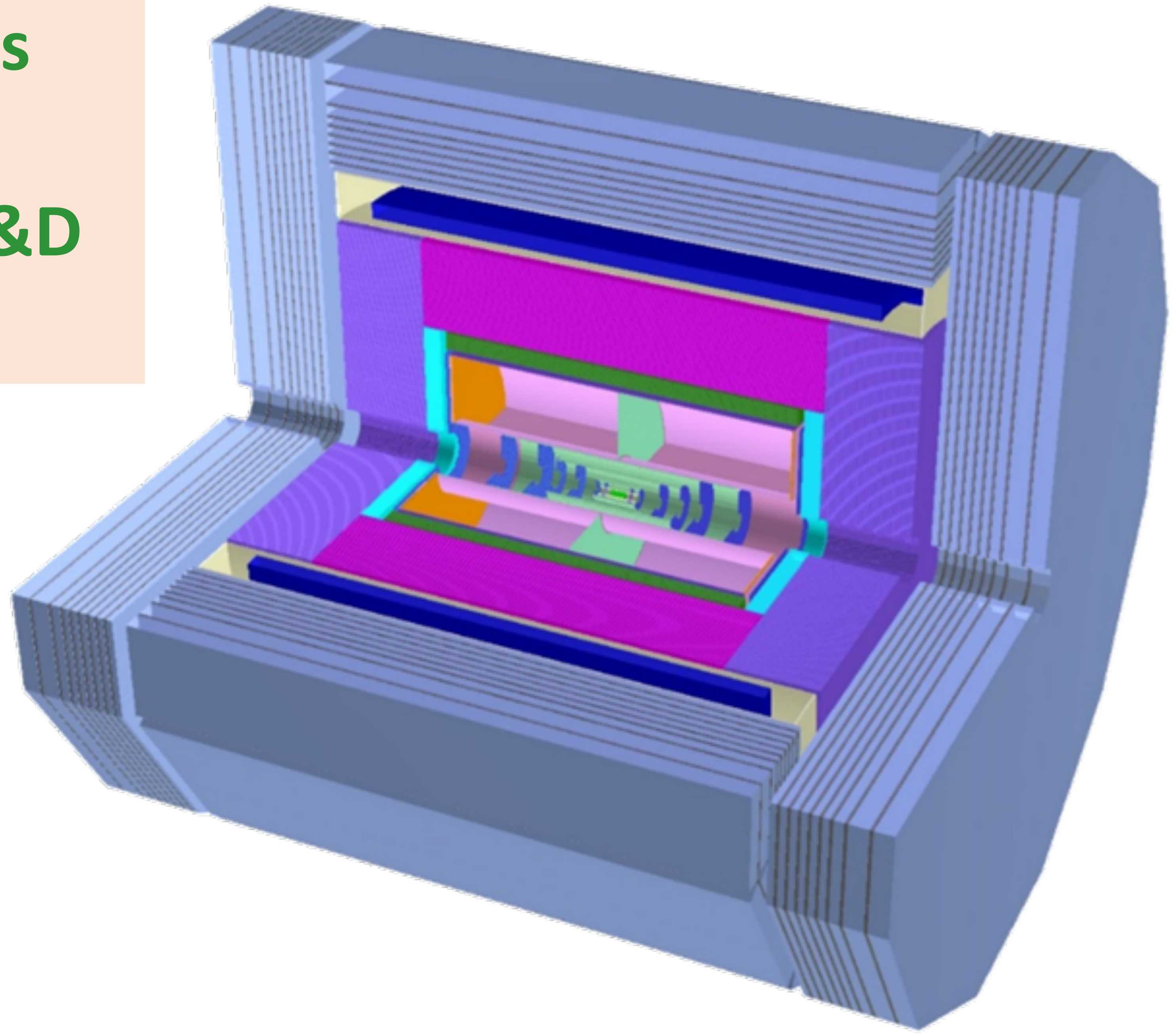
FCPPNL, Bordeaux, France, June 10-14, 2024
https://indico.in2p3.fr/event/20434/overview

TDR of a Reference Detector

CEPC

- The CEPC study group is producing the TDR of a reference detector (ref-TDR) by June 2025
  - Aiming primarily to domestic endorsement
  - An international review committee has been formed to guide and review the design

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



System	Technologies	
	Baseline	For comparison
Beam pipe	Φ20 mm	
LumiCal	SiTrk+Crystal	
Vertex	CMOS+Stitching	CMOS Pixel
Tracker	CMOS SiDet ITrk	
	Pixelated TPC	PID Drift Chamber
	AC-LGAD OTrk	SSD / SPD OTrk
		LGAD ToF
ECAL	4D Crystal Bar	PS+SiPM+W, GS+SiPM, etc
HCAL	GS+SiPM+Fe	PS+SiPM+Fe, etc
Magnet	LTS	HTS
Muon	PS bar+SiPM	RPC
TDAQ	Conventional	Software Trigger
BE electr.	Common	Independent

- CEPC will continue to evolve and adopting better technologies

Final detectors will be determined later by international detector collaborations

CEPC Plan: 15th Five Year Plan

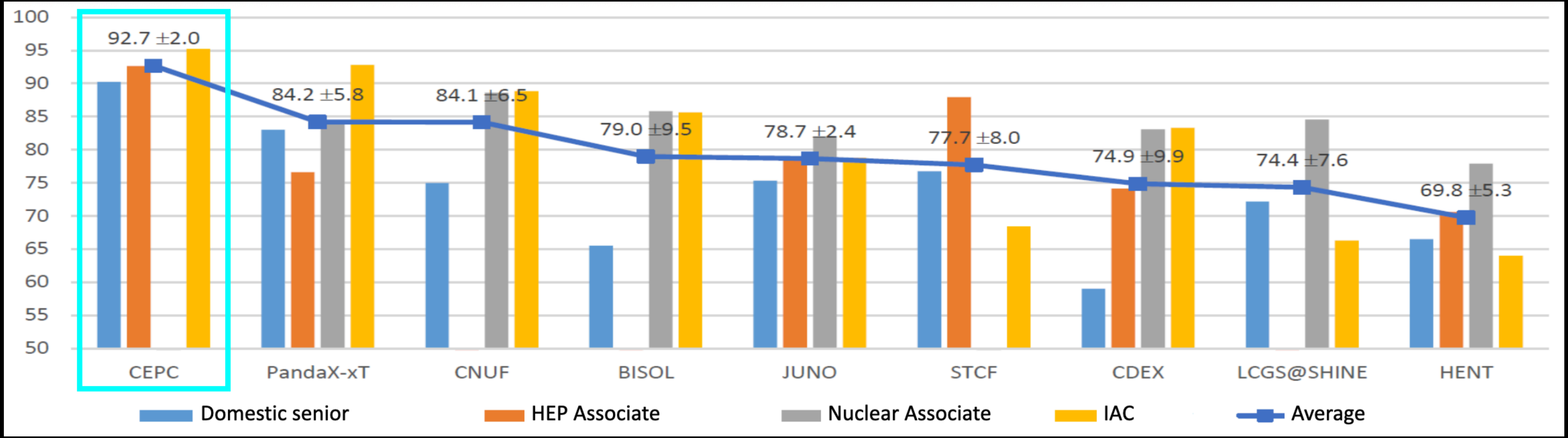
Preparation for China's 15th Five-Year-Plan (2026-2030)

- Preparation is beginning….
- Procedure not clear yet
- The overall funding not known yet
- Coordination among IHEP, CAS, local and national governments expected
- CEPC aims at a start date in 2027-8, in the middle of the 15th Five-Year-Plan

In the near future, the CEPC team will:
- complete the detector TDR_rd
- proceed well into the EDR work
- make ready the necessary documents for the proposal

CEPC Plan: 15th Five Year Plan — Chinese Academy of Sciences

- CAS planning for the 15th 5-years plan for large science projects
  - A steering committee has been established, chaired by the president of CAS
- High energy physics, as one of the 8 groups, accomplished the following:
  - Set up rules and selection standards (based on scientific and technological merits, strategic value and feasibility, R&D status, team and capabilities, etc.); established domestic and international advisory committees
  - 9 proposal selected (from 15 submitted)
  - Evaluations and ranking by committees after oral presentations by each project
- CEPC was ranked No. 1, with the smallest uncertainties, by every committee
- A final report was submitted to CAS for consideration



Final remarks

CEPC continues to evolve towards possible approval in the near future

CEPC EDR Phase: 2024 - 2027

Reference Detector TDR: by June 2025

Documentation to be completed for government's approval within 15th Five-Year-Plan of China

Aim to start construction in 2027-2028 → Physics collisions in 2030's

CEPC is committed to strive to maximize international collaboration

Help from international scientists and labs will be essential to maximize the CEPC physics outcome (at least 2 international experiments are expected)

Important to continue exploring the R&D synergies between CEPC, FCC-ee and other international HEP projects

If successful, CEPC will offer the HEP community an early Higgs factory

Acknowledgments

- 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) Committee for their critical advices, suggestions and supports
- Funding agencies, CAS and IHEP for their financial supports

The end

TDR main parameters

Brief TDR design parameters for the different accelerator complex

Linac

Parameter	Symbol	Unit	Baseline
Energy	E_e/E_{e+}	GeV	**30**
Repetition rate	f_{rep}	Hz	100
Bunch number per pulse			1 or 2
Bunch charge		nC	1.5 (3)
Energy spread	σ_E		1.5×10^{-3}
Emittance	ε_r	nm	6.5

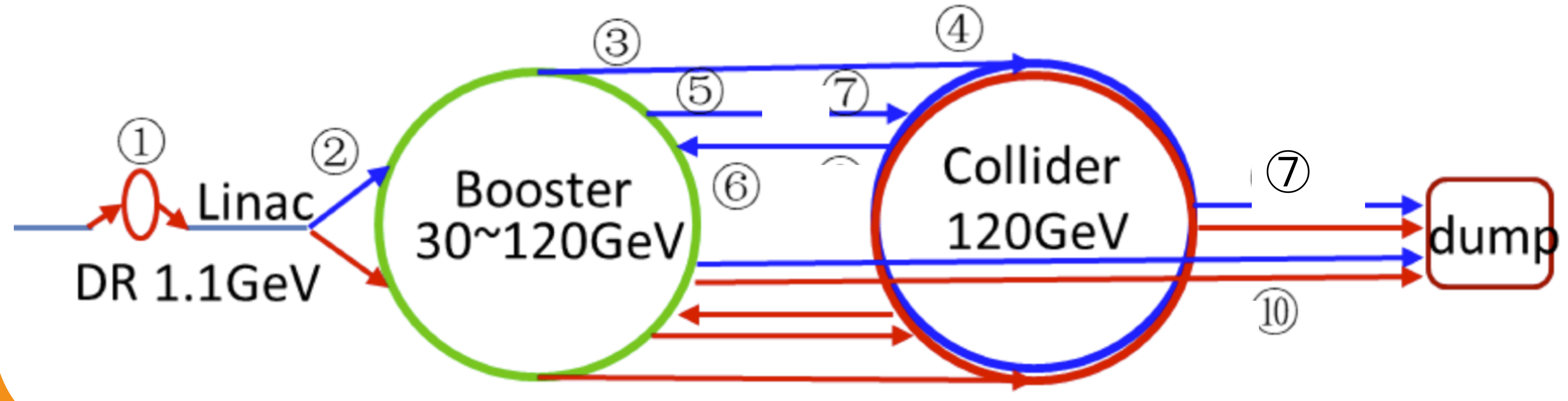
Booster

		tt	*H*		*W*	*Z*	
		Off axis injection	Off axis injection	On axis injection	Off axis injection	Off axis injection	
Circumfer.	km	**100**					
Injection energy	GeV	**30**					
Extraction energy	GeV	**180**	**120**		**80**	**45.5**	
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	
Number of IPs	2			
Circumference (km)	**100.0**			
SR power per beam (MW)	**30**			
Energy (GeV)	**120**	**45.5**	**80**	**180**
Bunch number	268	11934	1297	35
Emittance $\varepsilon_x/\varepsilon_y$ (nm/pm)	0.64/1.3	0.27/1.4	0.87/1.7	1.4/4.7
Beam size at IP σ_x/σ_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 ξ_x/ξ_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} cm^{-2} s^{-1})	**5.0**	**115**	**16**	**0.5**

Transport line



1. Injection/Extraction to the Damping ring (e^+)
2. Injection to the Booster ring from Linac (e^+/e^-)
3. Booster ring extraction system (e+/e-)
4. Collider off-axis injection system (e+/e-)
5. collider on-axis swap-out injection (e+/e-)
6. Collider swap-out extraction (e+/e-)
7. beam dump system (e+/e-)

CEPC TDR Parameters (upgrade version - 50 MW)

Main Parameters: High luminosity

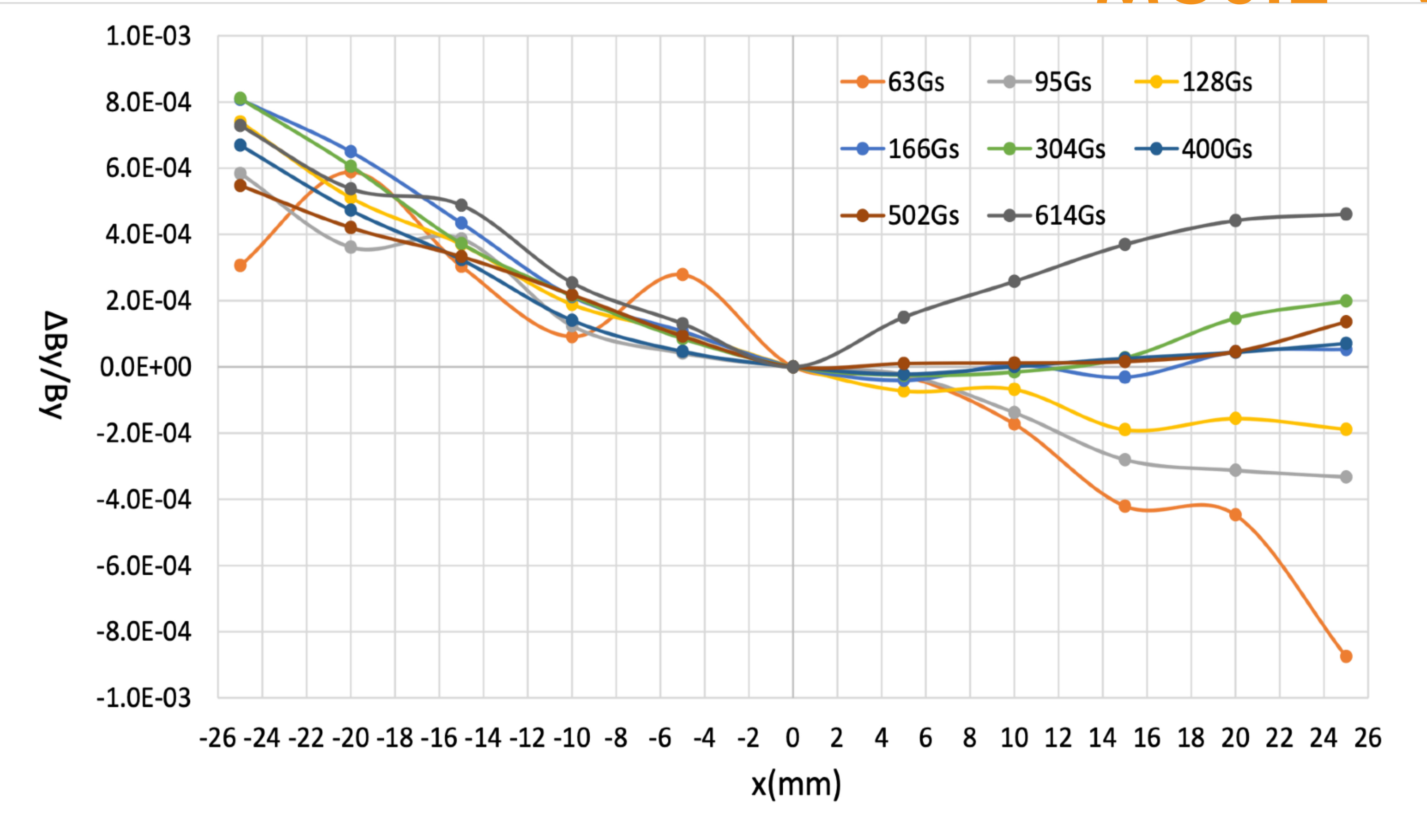
	Higgs	W	Z	ttbar
Number of IPs	2			
Circumference [km]	100.0			
SR power per beam [MW]	**50**			
Energy [GeV]	**120**	**80**	**45.5**	**180**
Bunch number	415	2161	19918	59
Emittance (εx/εy) [nm/pm]	0.64/1.3	0.87/1.7	0.27/1.4	1.4/4.7
Beam size at IP (σx/σy) [um/nm]	15/36	13/42	6/35	39/113
Bunch length (SR/total) [mm]	2.3/3.9	2.5/4.9	2.5/8.7	2.2/2.9
Beam-beam parameters (ξx/ξy)	0.015/0.11	0.012/0.113	0.004/0.127	0.071/0.1
RF frequency [MHz]	650			
Luminosity per IP[10^{34}/cm^2/s]	**8.3**	**27**	**192**	**0.83**

Increase relative to CDR: x 2.8 x 2.7 x 6

Highlights: weak field dipole for booster

MOST2

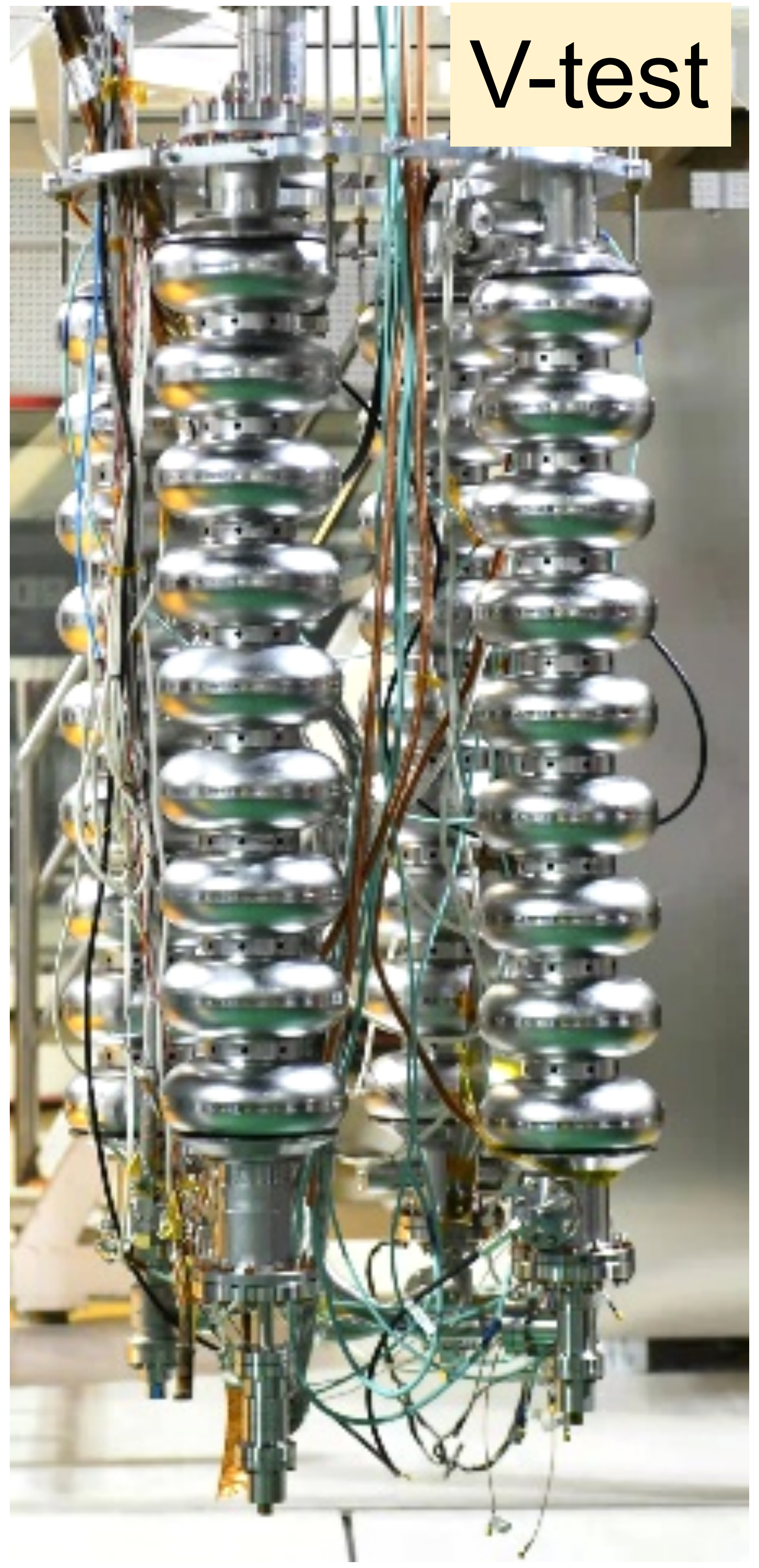
Magnet name	BST-63B-Arc	BST-63B-Arc-SF	BST-63B-Arc-SD	BST-63B-IR
Quantity	10192	2017	2017	640
Aperture [mm]	63	63	63	63
Dipole Field [Gs] @180 GeV	564	564	564	549
Dipole Field [Gs] @120 GeV	376	376	376	366
Dipole Field [Gs] @30 GeV	95	95	95	93
Sextupole Field [T/m^2] @180 GeV	0	16.0388	19.1423	0
Sextupole Field [T/m^2] @120 GeV	0	10.6925	12.7615	0
Sextupole Field [T/m^2] @30 GeV	0	2.67315	3.19035	0
Magnetic length [mm]	4700	4700	4700	2350
GFR [mm]	±22.5	±22.5	±22.5	±22.5
Field errors	$\pm 1\times10^{-3}$	$\pm 1\times10^{-3}$	$\pm 1\times10^{-3}$	$\pm 1\times10^{-3}$

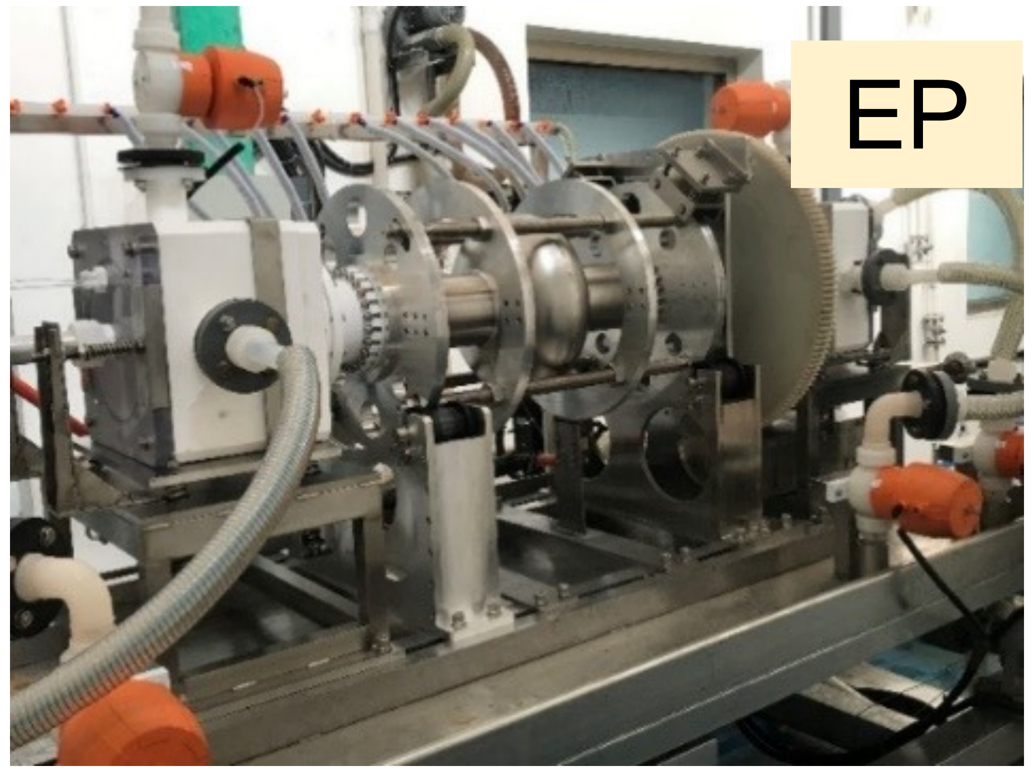


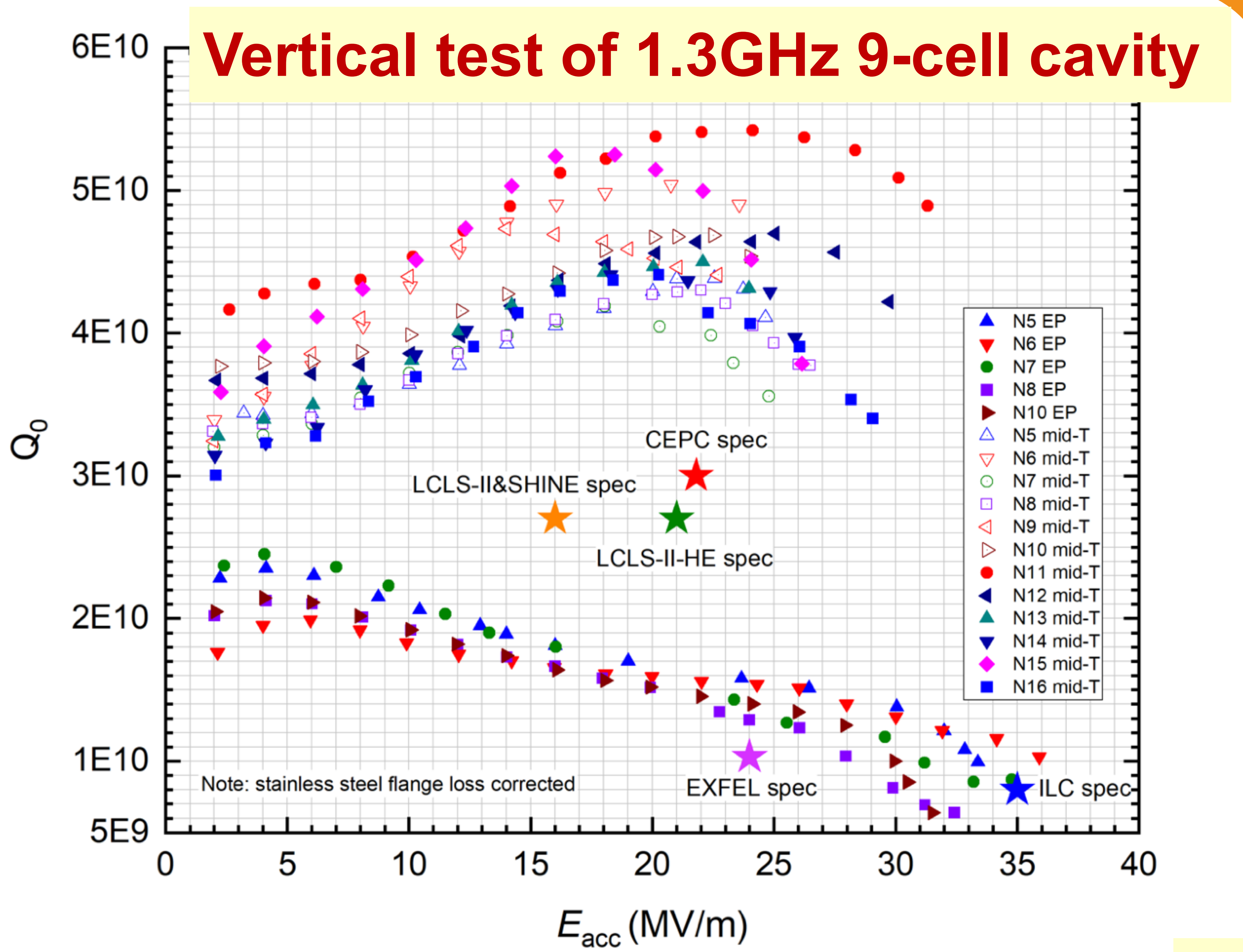
- Booster requires ~15k pieces magnets (68km);
- Booster dipoles are required to work at the low field of 95 Gs (30cGeV) with error smaller than **1×10^{-3}** ;
- Full length (4.7m) dipole was developed, and it meets the field specification;

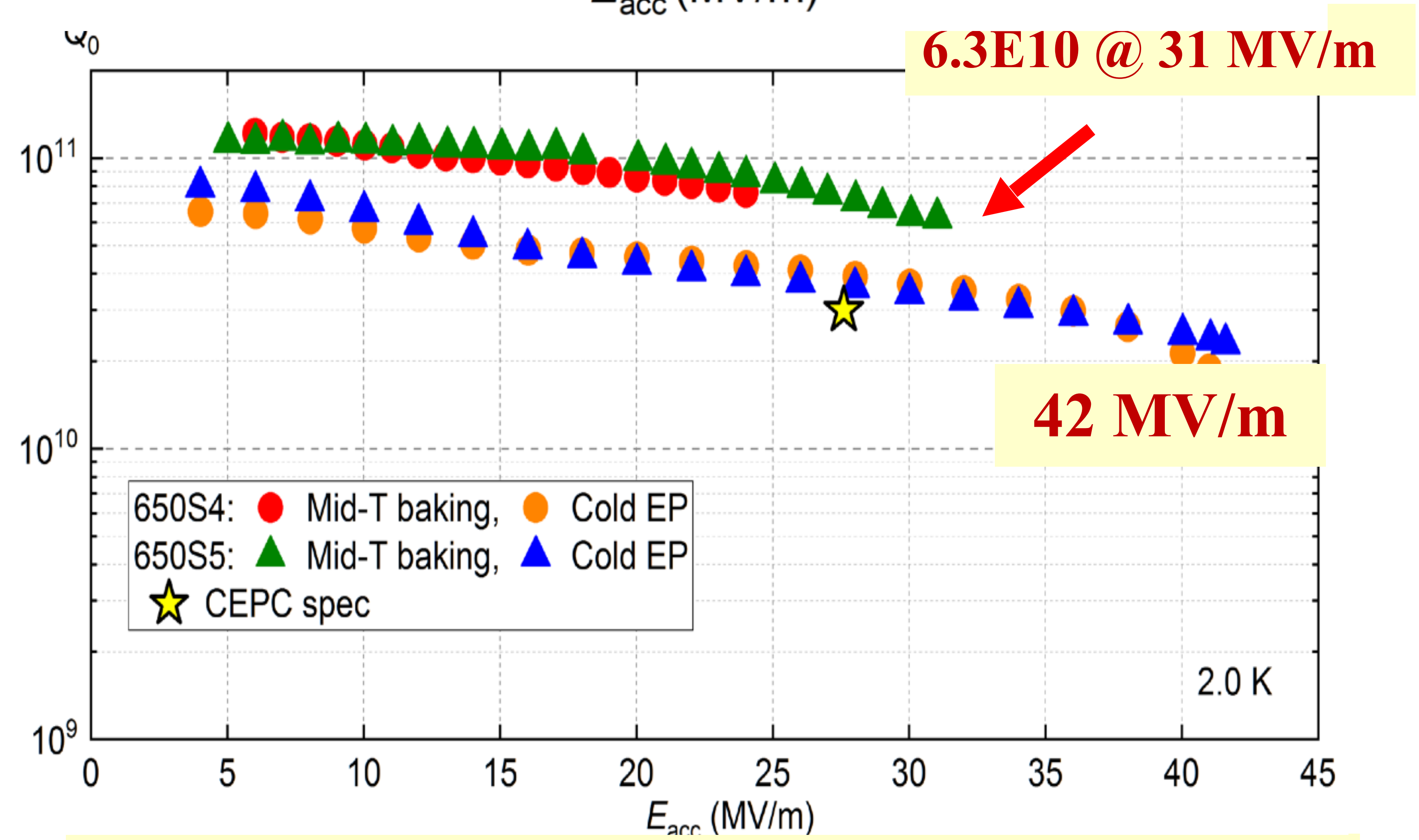
Highlights: SRF cavities and modules

- Mid-T baking applied to 1.3GHz/650MHz cavities, resulting in High Q SRF cavity that meets the CEPC specification;
- Completed SRF modules for both 1.3GHz and 650MHz cavities were assembled;









Vertical test of 650 MHz 1-cell cavity

Highlight: Vacuum system

Collider

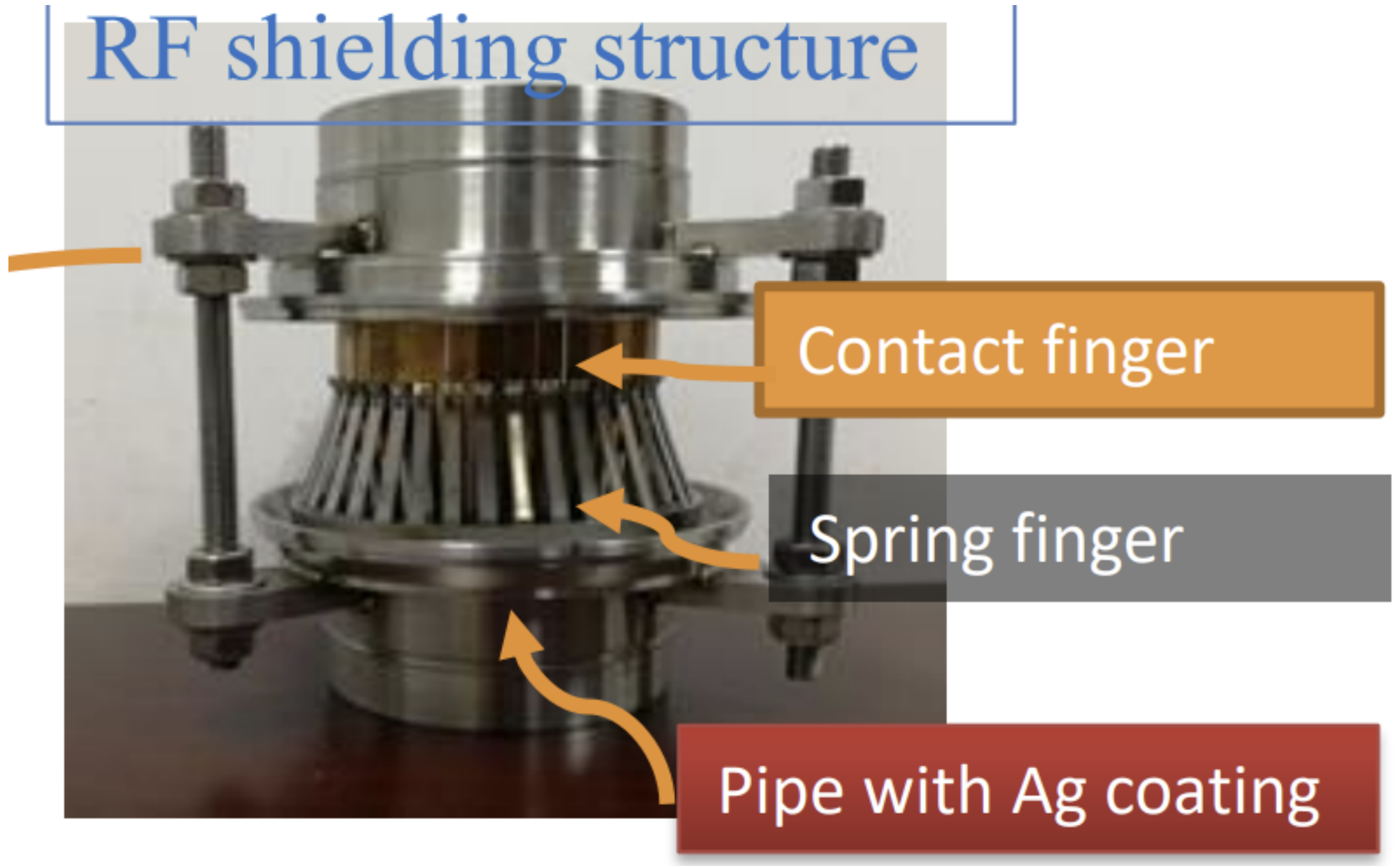
Classification	*length/m*
Arc beam pipe	78752
Straight section beam pipe	8456
RF Substitute pipe	1192
RF system	352
Insertion and extraction	286
Manifold for SIP	1333
Bellows	2082
BPM	300
Manifold for Gauge & RGA	247
Detector 1	12
Detector 2	12
Collider section	7000
Total length	100000

Booster

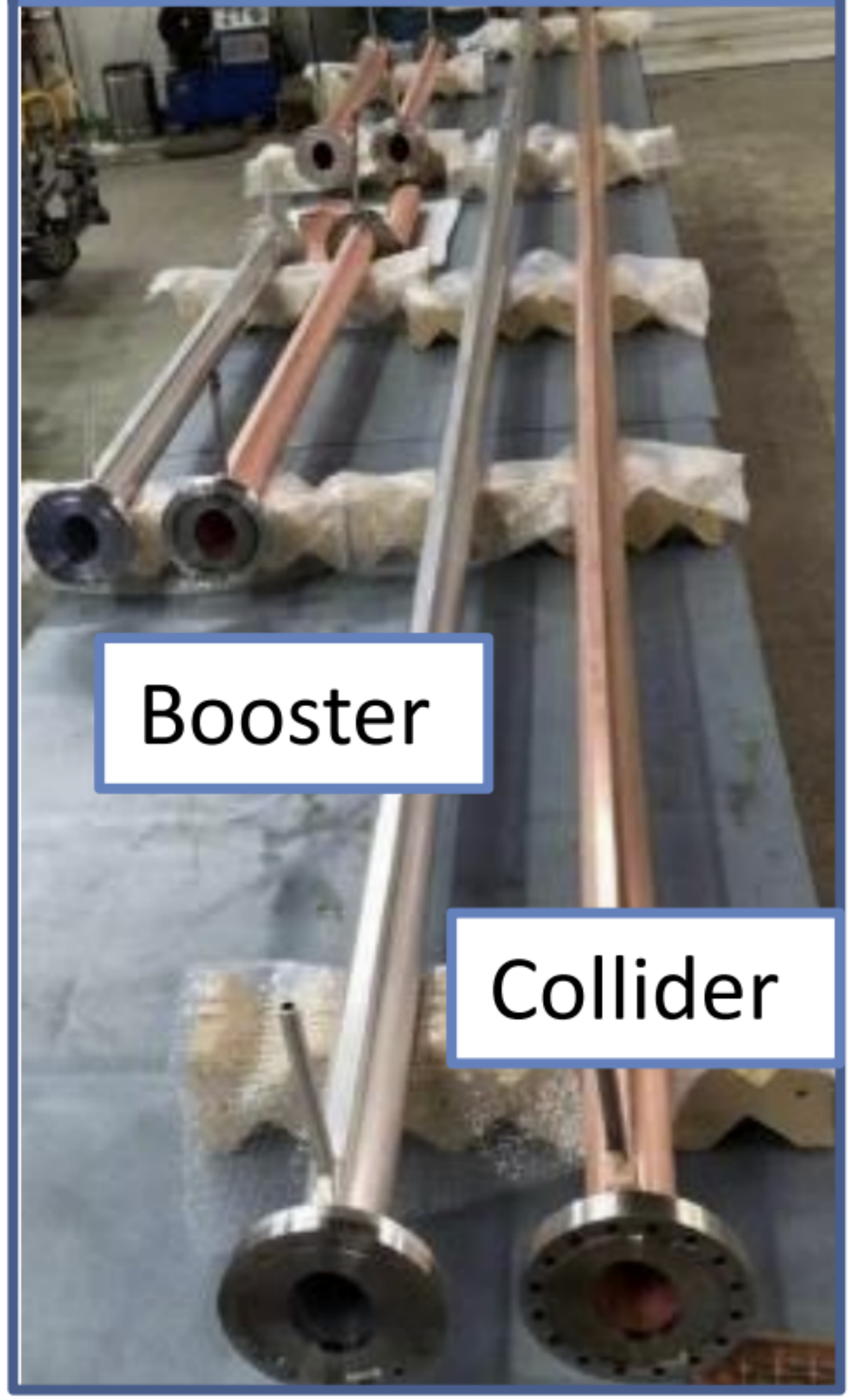
Classification	*length/m*
arc beam pipe	78428
Straight section beam pipe	17010
RF Substitute pipe	384
RF system	96
insertion and extraction	198
Manifold for SIP	1250
Bellows	850
BPM	240
Manifold for Gauge & RGA	1544
total length	**100000**

MOST2

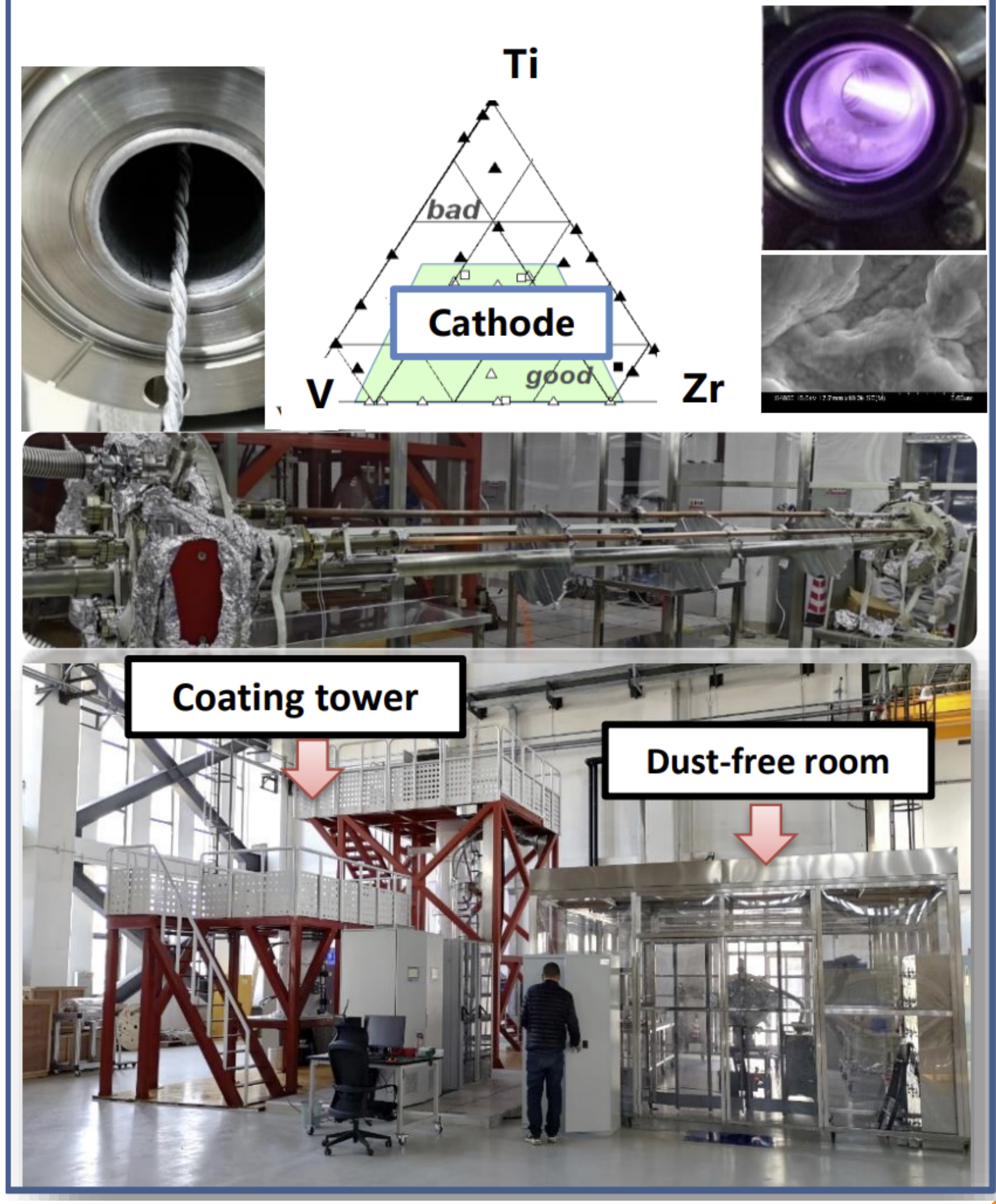
Key component



VC Prototypes with 6m length



HEPS massive NEG coating e.g.

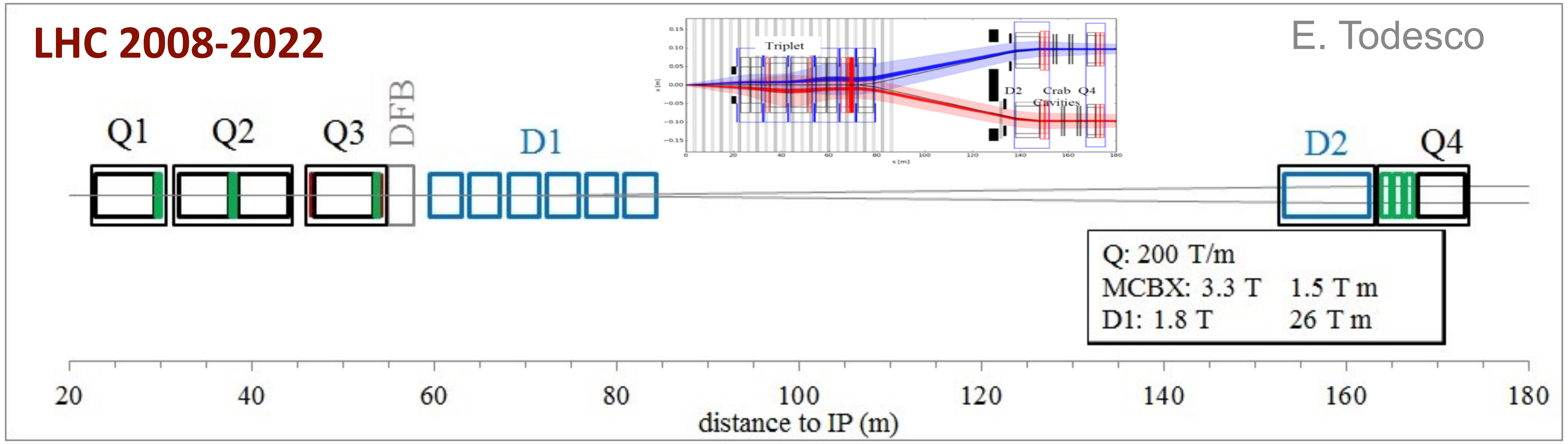


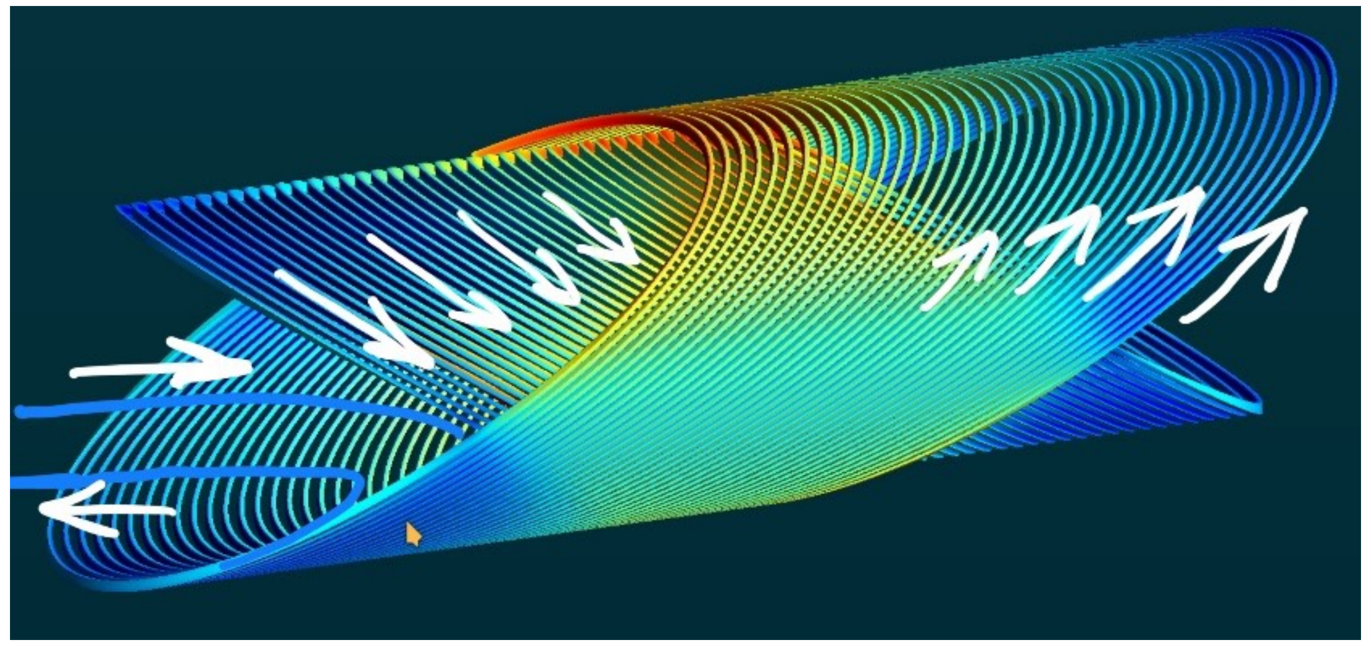
Development of HL-LHC CCT Magnets

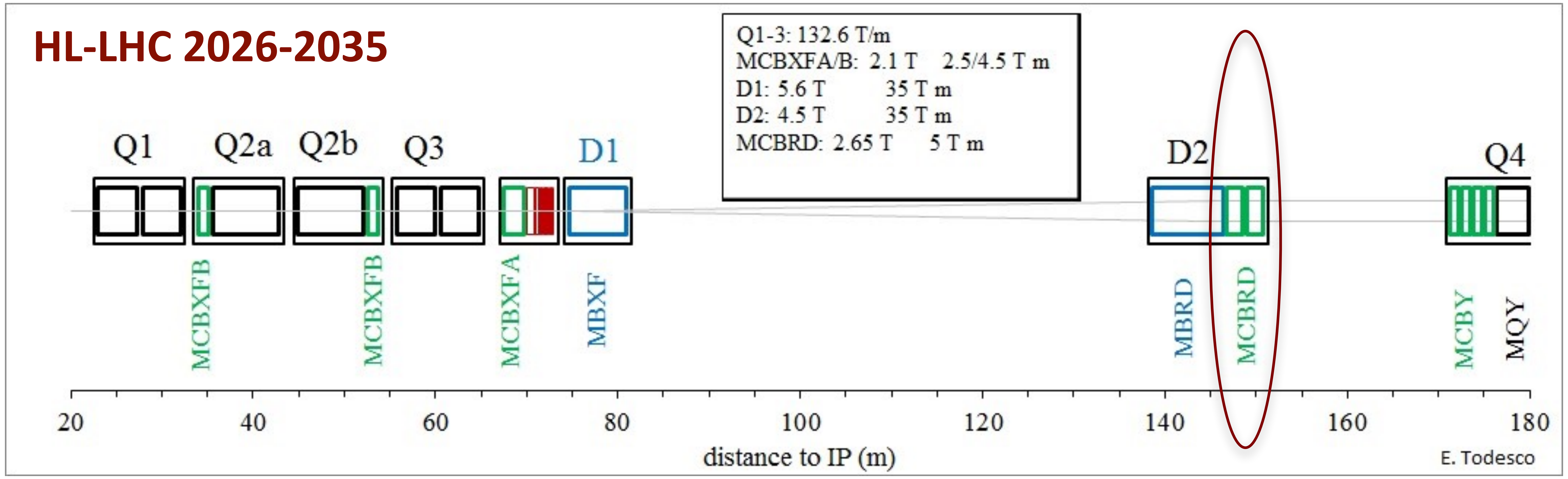
China provides 12+1 units of CCT twin-aperture dipole magnets for HL-LHC

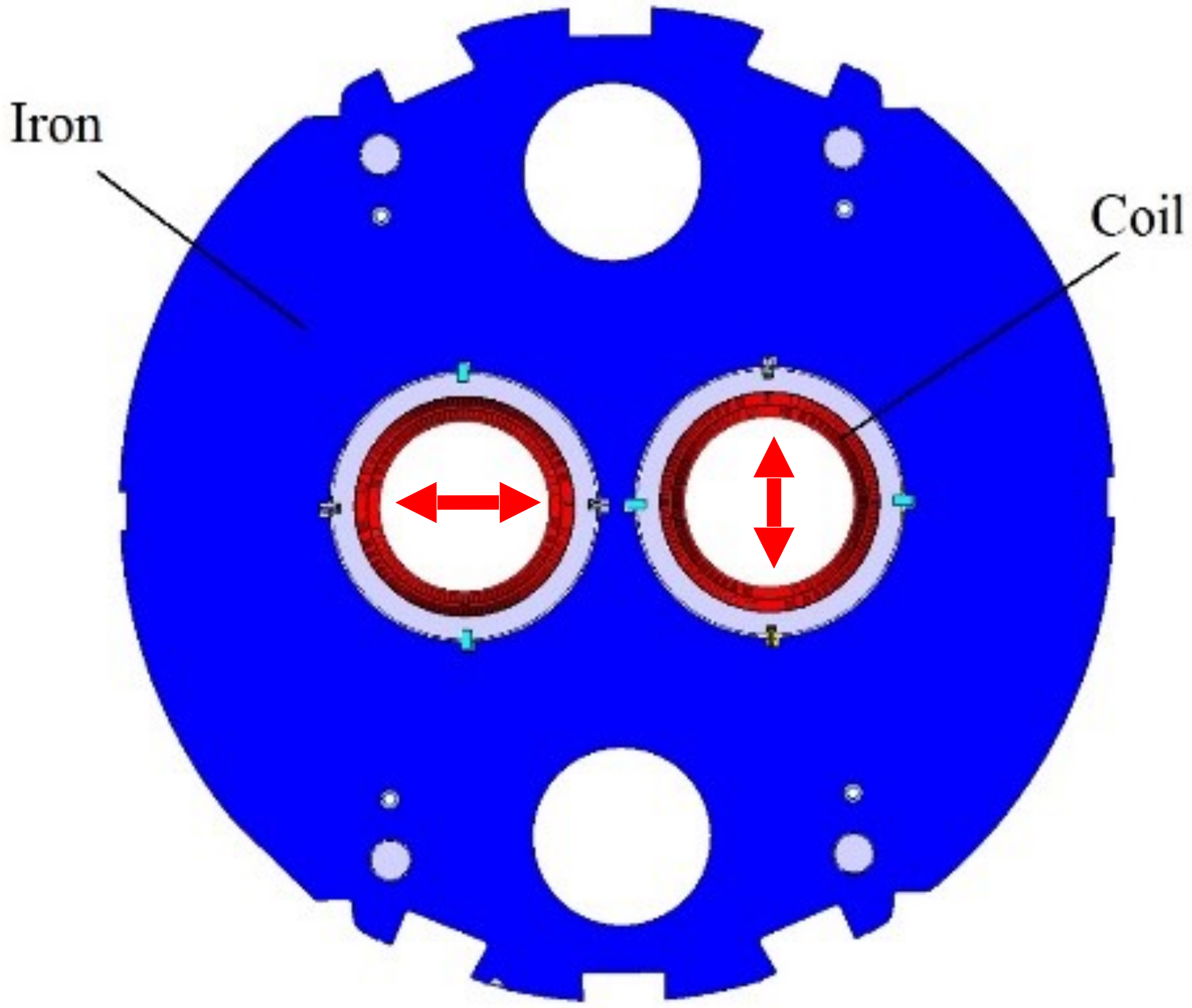
MCBRD: the HL-LHC D2 orbit correctors, 12+1 units, providing a 5 Tm integrated field in two apertures

To be installed in the ATLAS and CMS interaction regions, helps increase the luminosity by 5 times









EDR Scope and Plan

Based on the CEPC TDR accelerator design, demonstrate a complete and coherent feasibility EDR design, which will guarantee the construction, commissioning, operation, and upgrade possibilities .

The CEPC EDR accelerator design should guarantee the physics goals with required energies (Higgs, W and Z pole, with ttbar as upgrade possibility) and corresponding required luminosities with 30MW synchrotron radiation power/beam as a baseline, and 50MW as upgrade possibility.

Based on the CEPC TDR accelerator key technology R&D achievement, complete the accelerator engineering design and necessary EDR R&D to be ready for industrial fabrications.

Complete a practical procurement strategy and logistics with both domestic and international suppliers.

In the Engineering Design Phase, create and maintain a complete database, such as cost items with information regarding technology maturity (TRL), design completeness, and cost basis, to identify and prioritize areas for R&D, prototyping and industrialization.

Work out a detailed construction time line and plan in relation with industrial fabrications, measurements, transportations, storage warehouses, installation, human resource evolution, etc.

Workout details on 3% installation and 3% commissioning items of the total accelerator cost.

Improve design maturity of several systems (particularly MDI and cryogenics) and develop system integration.

Implement the risk-mitigation plan in the production and procurement plans to eliminate major risk during the mass production, providing multiple vendors and multiple production lines (for example, demonstrate automatic magnets production line and NEG coated vacuum chambers mass production facility)

Reviewed by IARC committee in September

In collaboration with local government, CAS and MOST (central government), CEPC sites converge from serval candidates to a EDR construction site satisfying the required geological conditions, electric power and water resources, social and environment conditions, domestic and international transportation network conditions, international science city, and sustainable development , etc.

Complete detailed construction site geological studies and corresponding site dependent civil engineering design and general utility facility design.

Complete the radiation, security, environment assessment studies and necessary documents –so called CEPC PROPOSAL, around 2025ready for the application to the central government to get the formal approval of construction in the “15th five year plan”

Make detailed analysis and preparation for the human resources needed for the completion of CEPC construction.

Consider re-optimizing the technical design of components and systems with large electricity consumption taking into account both capital and operational expenditure

Define unambiguously what constitutes the end of the construction project.

For labour-intensive, high-volume activities, in particular the components of the collider and booster, refine and review the production model to check the availability of in-house resources.

Risk assessment and risk management

Based on TDR cost estimate, make an updated EDR cost estimate.

Carefully consider the recommendations from CEPC accelerator TDR review and TDR cost review committees, IARC and IAC, etc.

Continues efforts in green collider and sustainable development with energy saving technologies, wast heat reuse, energy recovery, and green energy utilization, etc.

Establish more international collaborations, international involvement, and industrial preparations both from domestic and international companies and suppliers.

Refine the CEPC management structure in relation with host lab. Refine the CEPC construction funding modes.

Obtain the necessary EDR plan and scope related fundings.

Complete “CEPC Proposal” around 2025 ready for application of final selection of the 15th 5-year plan, and complete EDR around 2027 before the construction.

HL-LHC Magnets