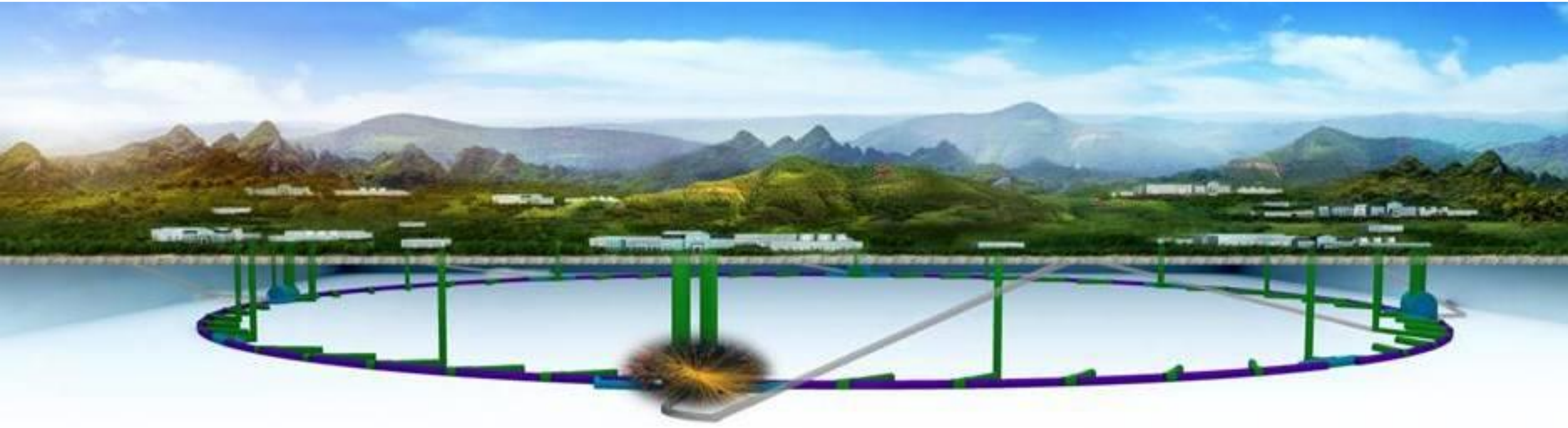
Overview of the CEPC Project
Implementation of 2020 IAC Recommendations

Haijun Yang
(for the CEPC working group)

The 7th CEPC IAC Meeting, Nov. 1-3, 2021



List of talks for IAC Meeting

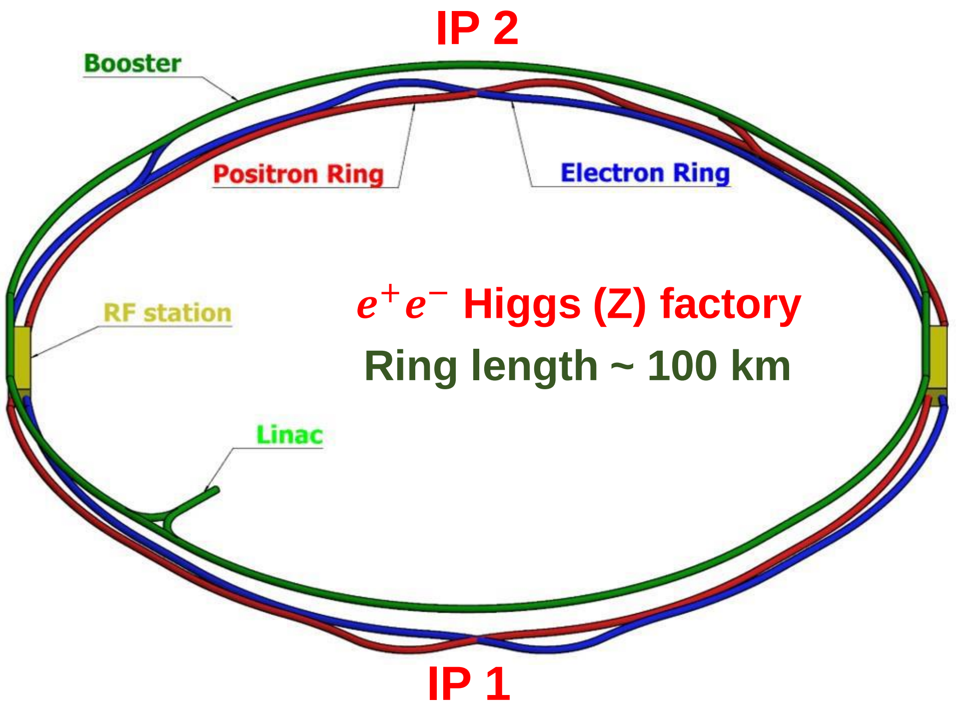
Date and Time	Topics	Speaker
Nov. 1, 20:10 – 20:55	Overview of the CEPC Project and Implementation of 2020 IAC Recommendations	Haijun Yang
Nov. 1, 20:55 – 21:45	CEPC Accelerator	Jie Gao
Nov. 1, 22:00 – 22:45	CEPC Detector R&D, Collaboration and Future	Joao Costa
	IAC Accelerator Group	
Nov. 2, 20:00 – 20:25	SppC Accelerator: HTS progress	Qingjin Xu
Nov. 2, 20:25 – 21:20	IARC Recommendation and Plan	Yuhui Li
Nov. 2, 21:20 – 21:55	Sites and Civil Engineering	Yu Xiao
	IAC Detector Group	
Nov. 2, 20:00 – 20:50	4^{th} Detector Concept and Validation	Jianchun Wang
Nov. 2, 20:50 – 21:35	Physics and White Papers	Yaquan Fang
Nov. 2, 21:35 – 22:00	Software Development	Weidong Li

Outline

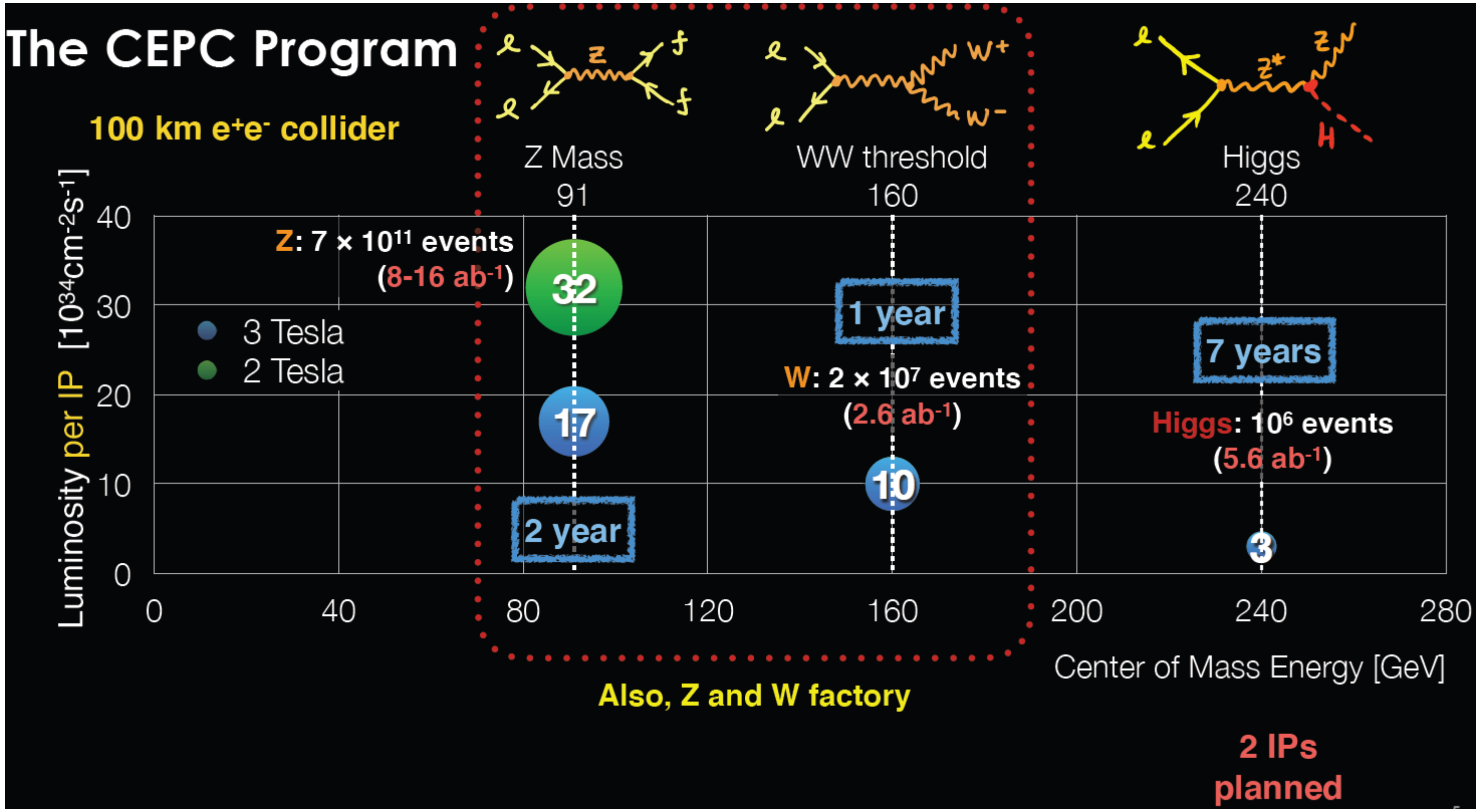
- Introduction of the CEPC
  - Goals and Plan
  - Roadmap and Schedule
  - Site Investigation
  - Collaboration with Industrial
  - Financial Model
- CEPC Project Development
  - Accelerator R&D
  - Physics Program
  - New Detector Concept and R&D
- Implementation of IAC Recommendations
- Summary and Prospect

Circular Electron Positron Collider (CEPC)

- The CEPC aims to start operation in 2030's, as a Higgs (Z/W) factory in China.
- To run at $\sqrt{s}$ ~ 240 GeV, above the **ZH** production threshold for ~1M Higgs; at the **Z** pole for ~Tera Z, at the **W^+W^-** pair, and possible $t\bar{t}$ pair production threshold.
- Higgs, EW, flavor physics & QCD, BSM physics (eg. dark matter, EW phase transition, SUSY, LLP, ...)
- Possible Super *pp* Collider (SppC) of $\sqrt{s}$ ~ 50–100 TeV in the future.



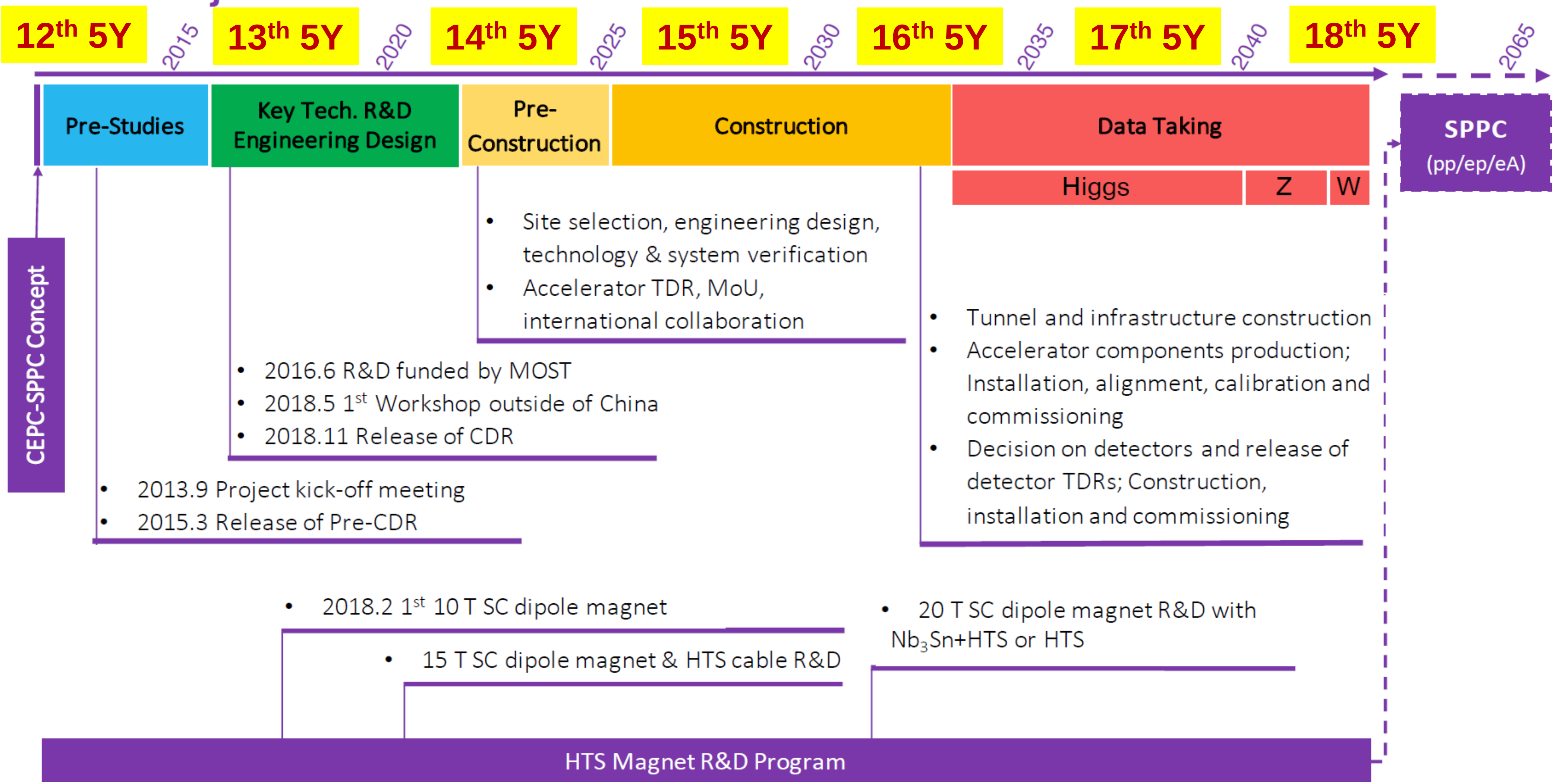
CEPC Accelerator: Jie Gao
CEPC Detector: Joao Costa



CEPC Roadmap and Schedule (ideal)

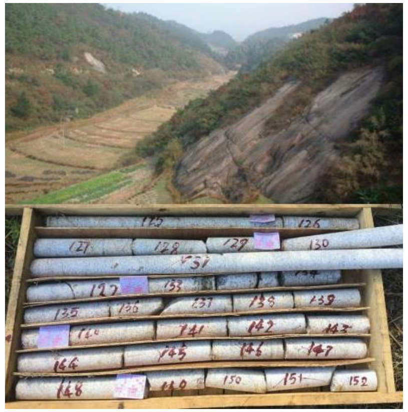
- 2013-2025： Key technology R&D， from CDR to TDR, Site selection, Intl. Collab.
- Ideal situation: Approval in the 15th Five-Year Plan, schedule will be shifted accordingly

CEPC Project Timeline

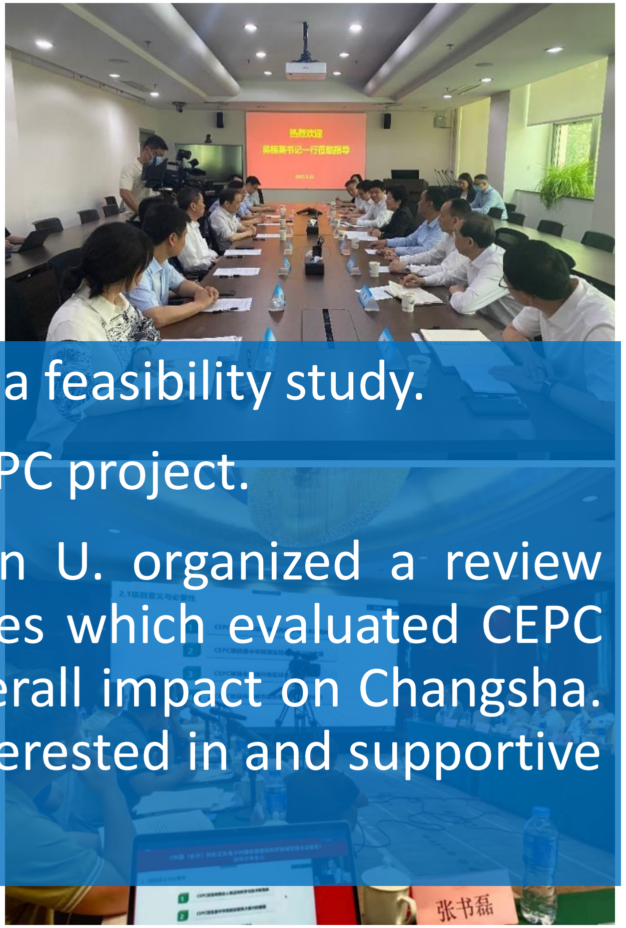


CEPC Site Selection

Sites and Civil Engineering: Yu Xiao



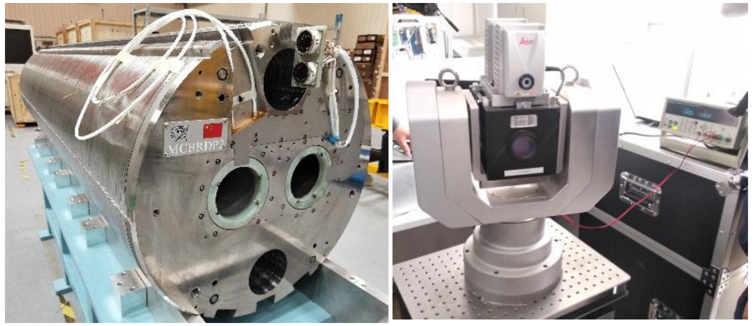
- Site selection is based on geology, electricity supply, transportation, environment for foreigners
- Local support & economy, …
- Initial CDR study is based on Qing-Huang-Dao site



- **July 5, 2021:** Changsha Bureau of S&T entrusted Hunan U. to conduct a feasibility study.
- **July 6-7, 2021:** Hunan U. delegation visited IHEP to communicate on CEPC project.
- **Sept 4, 2021:** Per request by the Changsha city government, Hunan U. organized a review meeting by a committee consisting of experts from multiple disciplines which evaluated CEPC for its science, feasibility of a new science city based on CEPC, and overall impact on Changsha. The overall conclusion is very positive. The local government is very interested in and supportive of the CEPC project.

CEPC Collaboration with Industry (CIPC)

CEPC 650MHz Klystron at Kunshan Co.



CERN HL-LHC CCT SC magnet

CEPC SC QD0 coil winding at KEYE Co.

CIPC was established in Nov. 2017, there are 70+ companies join the CIPC so far.

CEPC Detector SC coil winding tools at KEYE Company (Diameter ~7m)

CEPC long magnet measurement coil

1) Superconduting materials (for cavity and for magnets)
2) Superconducting cavities
3) Cryomodules
4) Cryogenics
5) Klystrons
6) Magnet technology
7)Vacuum technologies
8) Mechanical technologies
9)Electronics
10) SRF
11) Power sources
12) Civil engineering
13) Precise machinery
.....

More than 40 companies joined in first phase of CIPC，**and 70 companies now.**

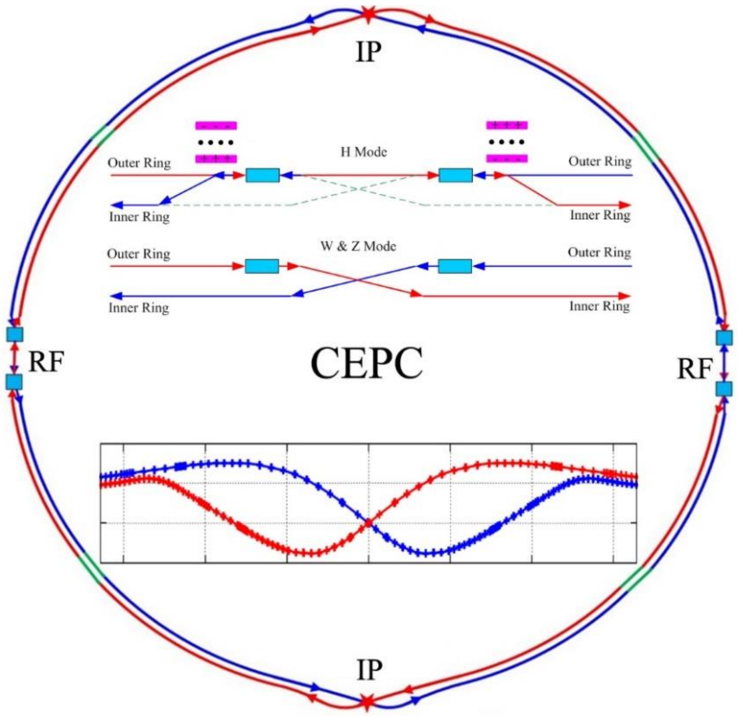
CEPC Financial Model

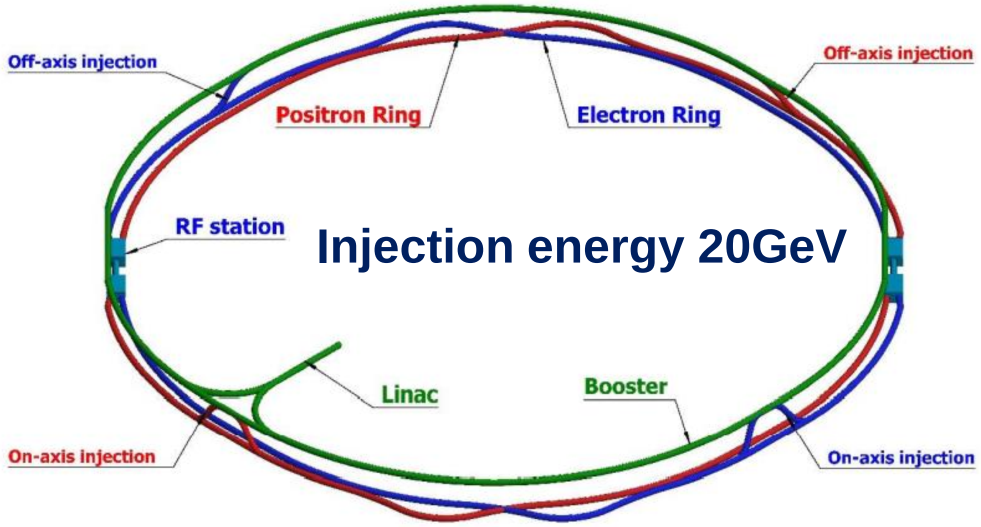
Funding Sources	Financial Model #1 （RMB）	Financial Model #2 (RMB)
Central Government	30B	6-10B
Local Government	Land, Infrastructure	25-18B
International Partners	1-5B	1-5B
Companies & Donations	0-3B	0-3B
Total Budget	36B	36B

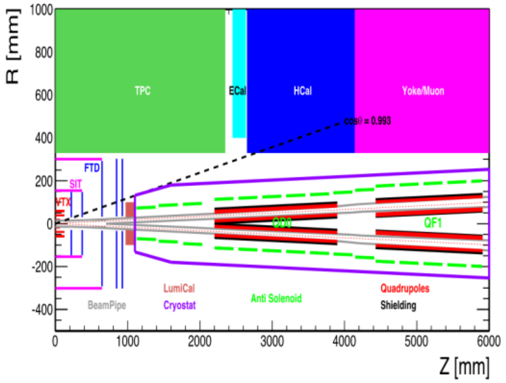
In Oct., 2021: Institute of Science and Technology Strategic Consulting, CAS is carrying out an independent assessment of Social Cost Benefit Analysis for the CEPC project, the report will be available in August, 2022.

CEPC High Luminosity TDR Layout

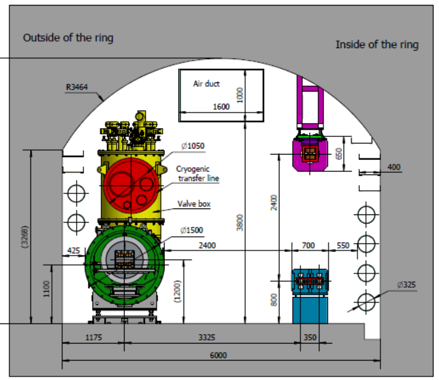
CEPC Accelerator: Jie Gao



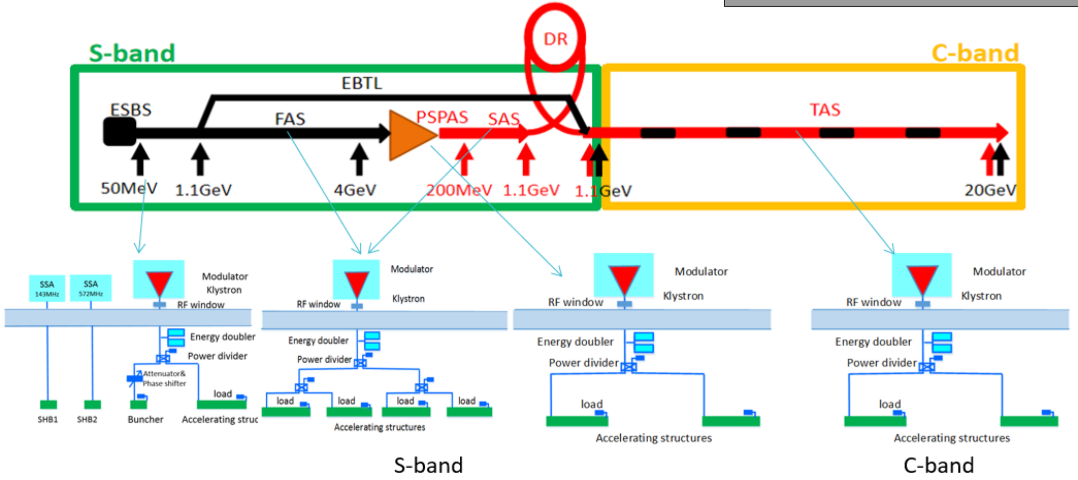




TUNNEL CROSS SECTION OF THE ARC AREA



- CEPC as Higgs / Z / W factory
- 100 km collider and booster ring
- Maximum energy of 180 GeV for ttbar
- New baseline for Linac (C-band, 20GeV)



CEPC Accelerator TDR Design Improvement

2018 CDR Baseline Design

	Higgs	W	Z（3T）	Z（2T）
Number of IPs	2			
Beam energy (GeV)	120	80	45.5	
Circumference (km)	100			
Synchrotron radiation loss/turn (GeV)	1.73	0.34	0.036	
Crossing angle at IP (mrad)	16.5 × 2			
Piwinski angle	3.48	7.0	23.8	
Particles /bunch N_e (10^{10})	15.0	12.0	8.0	
Bunch number	242	1524	12000 (10% gap)	
Bunch spacing (ns)	680	210	25	
Beam current (mA)	17.4	87.9	461.0	
Synch. radiation power (MW)	30	30	16.5	
Bending radius (km)	10.7			
Momentum compaction (10^{-5})	1.11			
β function at IP β_x^*/β_y^* (m)	0.36/0.0015	0.36/0.0015	0.2/0.0015	0.2/0.001
Emittance x/y (nm)	1.21/0.0024	0.54/0.0016	0.18/0.004	0.18/0.0016
Beam size at IP σ_x/σ_y (μm)	20.9/0.06	13.9/0.049	6.0/0.078	6.0/0.04
Beam-beam parameters ξ_x/ξ_y	0.018/0.109	0.013/0.123	0.004/0.06	0.004/0.079
RF voltage V_{RF} (GV)	2.17	0.47	0.10	
RF frequency f_{RF} (MHz)	650			
Harmonic number	216816			
Natural bunch length σ_z (mm)	2.72	2.98	[illegible]	
Bunch length σ_z (mm)	4.4	[illegible]	[illegible]	
Damping time $\tau_x/\tau_y/\tau_E$ (ms)	[illegible]	[illegible]	[illegible]49.5/849.5/425.0	
Natural Chromaticity	[illegible]	[illegible]	-491/-1161	-513/-1594
[illegible]	363.10 / 365.22			
[illegible]	0.065	0.040	0.028	
[illegible] (2 cell) (kw)	0.46	0.75	1.94	
Natural energy spread (%)	0.100	0.066	0.038	
Energy spread (%)	0.134	0.098	0.080	
Energy acceptance requirement (%)	1.35	0.90	0.49	
Energy acceptance by RF (%)	2.06	1.47	1.70	
Photon number due to beamstrahlung	0.082	0.050	0.023	
Beamstruhlung lifetime /quantum lifetime† (min)	80/80	>400		
Lifetime (hour)	0.43	1.4	4.6	2.5
F (hour glass)	0.89	0.94	0.99	
Luminosity/IP (10^{34} cm^{-2}s^{-1})	3	10	17	32

† include beam-beam simulation and real lattice

2021 Improved Design

	ttbar	Higgs	W	Z
Number of Ips		2		
Circumference [km]		100.0		
SR power per beam [MW]		30		
Half crossing angle at IP [mrad]		16.5		
Bending radius [km]		10.7		
Energy [GeV]	180	120	80	45.5
Energy loss per turn [GeV]	9.1	1.8	0.357	0.037
Piwinski angle	1.21	5.94	6.08	24.68
Bunch number	35	249	1297	11951
Bunch population [10^10]	20	14	13.5	14
Beam current [mA]	3.3	16.7	84.1	803.5
Momentum compaction [10^-5]	0.71	0.71	1.43	1.43
Beta functions at IP (bx/by) [m/mm]	1.04/2.7	0.33/1	0.21/1	0.13/0.9
Emittance (ex/ey) [nm/pm]	1.4/4.7	0.64/1.3	0.87/1.7	[illegible]/1.4
Beam size at IP (sigx/sigy) [um/nm]	39/113	15/36	[illegible]	[illegible]/35
Bunch length (SR/total) [mm]	2.2/2.9	2.3/[illegible]	[illegible]	2.5/8.7
Energy spread (SR/total) [%]	0.15/0.20	[illegible]	0.07/0.14	0.04/0.13
Energy acceptance (DA/RF) [%]	2.3/[illegible]	[illegible]/2.2	1.2/2.5	1.3/1.7
Beam-beam parameters (ksix/ksiy)	0.071/[illegible]	0.015/0.11	0.012/0.113	0.004/0.127
RF voltage [GV]	10	2.2	0.7	0.12
RF frequency [MHz]	650	650	650	650
HOM power per cavity (5/2/1cell)[kw]	0.4/0.2/0.1	1/0.4/0.2	-/1.8/0.9	-/-/5.8
Qx/Qy/Qs	0.12/0.22/0.078	0.12/0.22/0.049	0.12/0.22/	0.12/0.22/
Beam lifetime (bb/bs)[min]	81/23	39/18	60/717	80/182202
Beam lifetime [min]	18	12.3	55	80
Hour glass Factor	0.89	0.9	0.9	0.97
Luminosity per IP[1e34/cm^2/s]	0.5	5.0	16	115

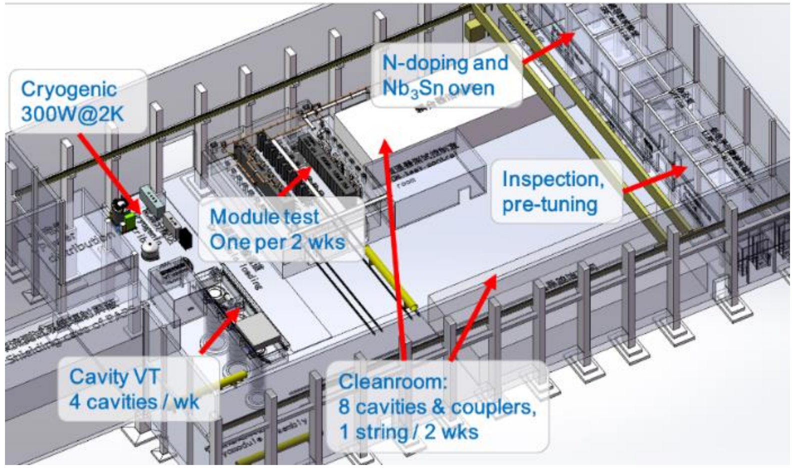
67%⇑

259%⇑

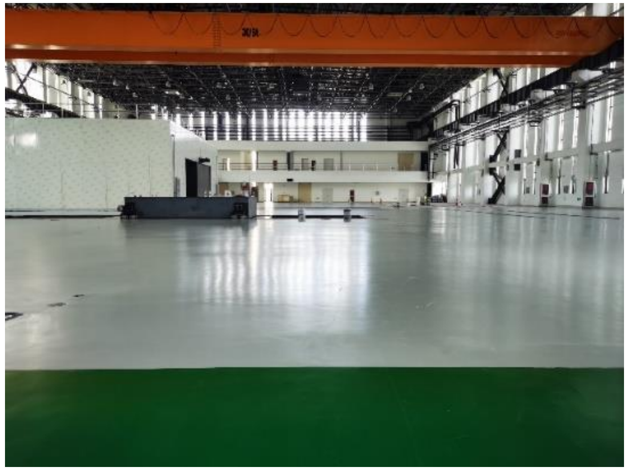
CEPC SCRF Test Facility

CEPC SCRF Test Facility is available: Beijing Huairou (4500m²)

New SC Lab Design (4500m²)



SC New Lab is available in 2021



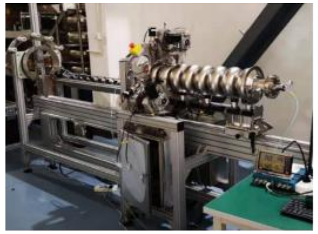
Crygenic system hall in 2020

Vacuum furnace (doping & annealing)

Nb3Sn furnace

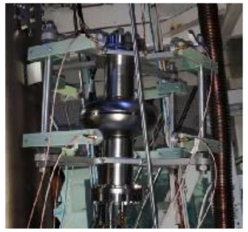
Nb/Cu sputtering device

Cavity inspection camera and grinder

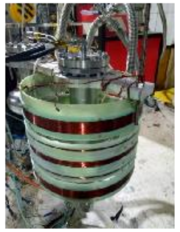


9-cell cavity pre-tuning machine

Temperature & X-ray mapping system



Second sound cavity quench detection system



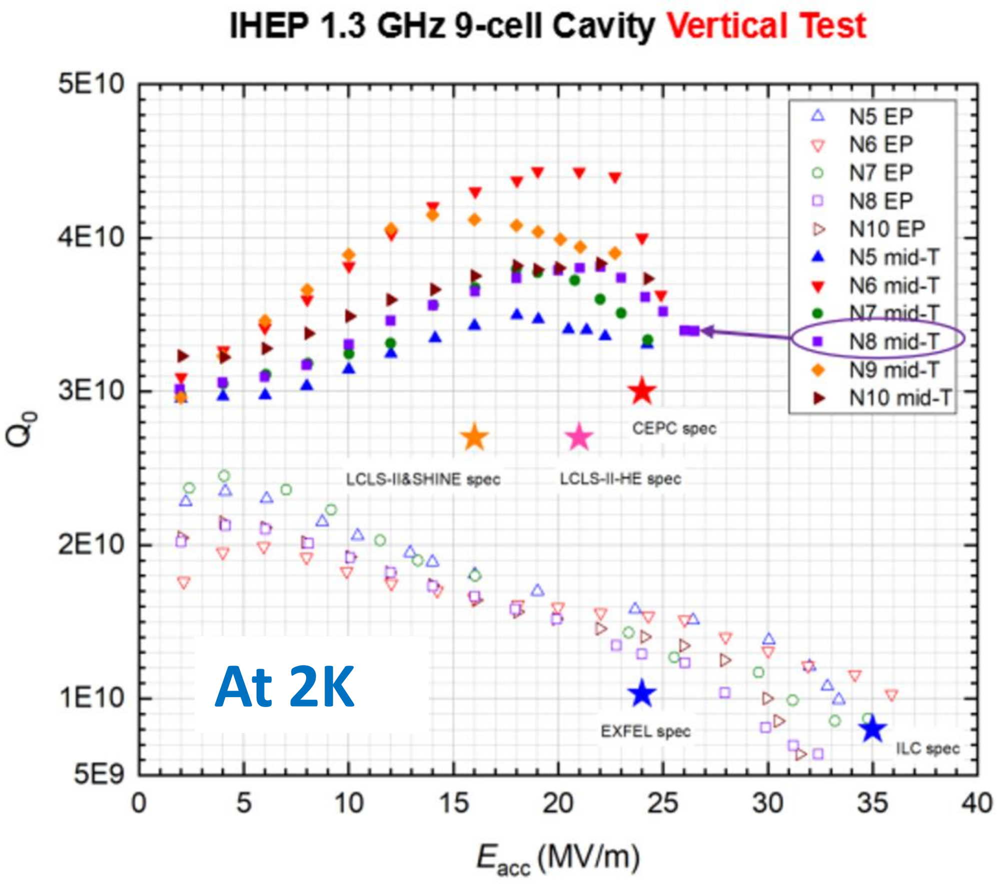
Helmholtz coil for cavity vertical test

Vertical test dewars

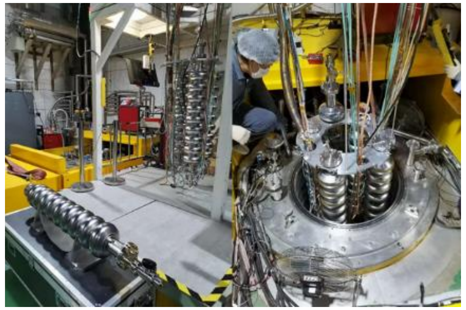
Horizontal test cryostat

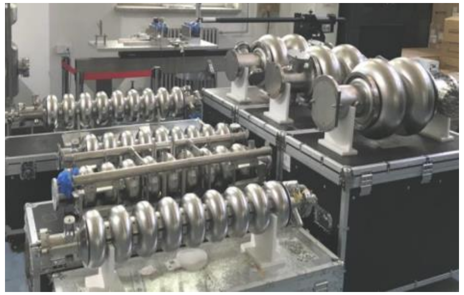
CEPC R&D: High Q SCRF Cavities

- 1.3 GHz 9-cell SCRF cavity for booster: Q_0 = 3.4E10 @ 26.5 MV/m
- 650 MHz 2-cell SCRF cavity for collider ring: Q_0 = 6.0E10 @ 22.0 MV/m
- SCRF cavities for both booster & collider ring reach CEPC design goal

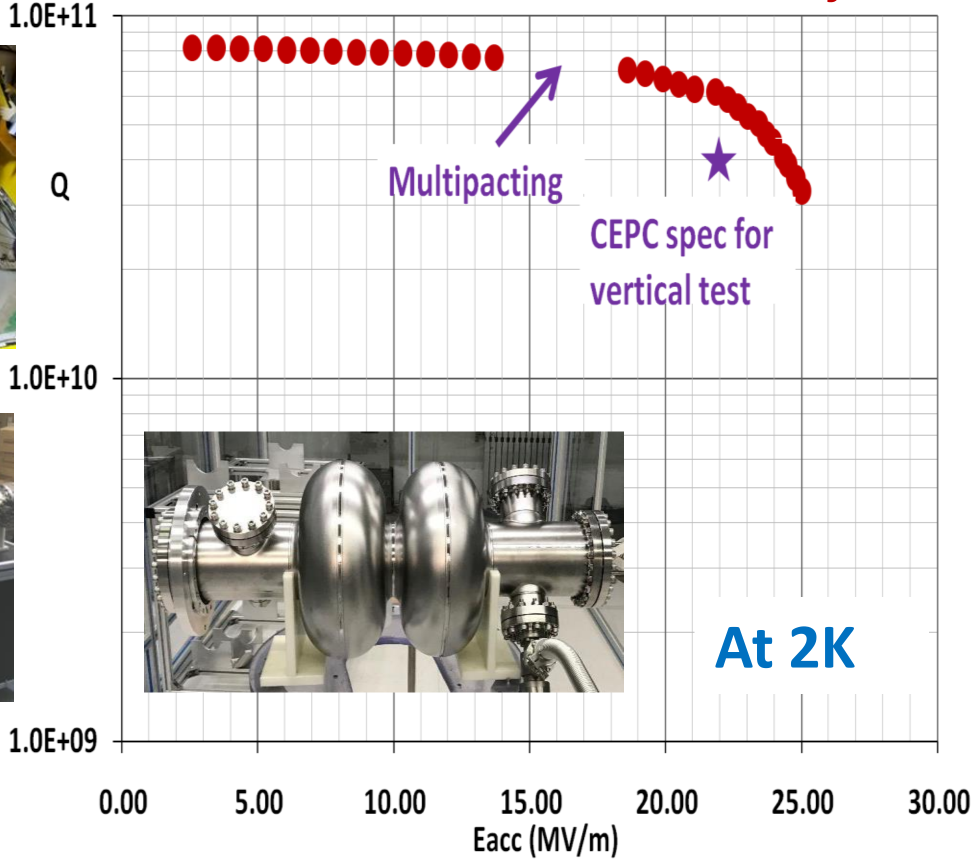


Medium-temperature (Mid-T) annealing adopted to reach Q_0 = 3.4E10 @ 26.5 MV/m





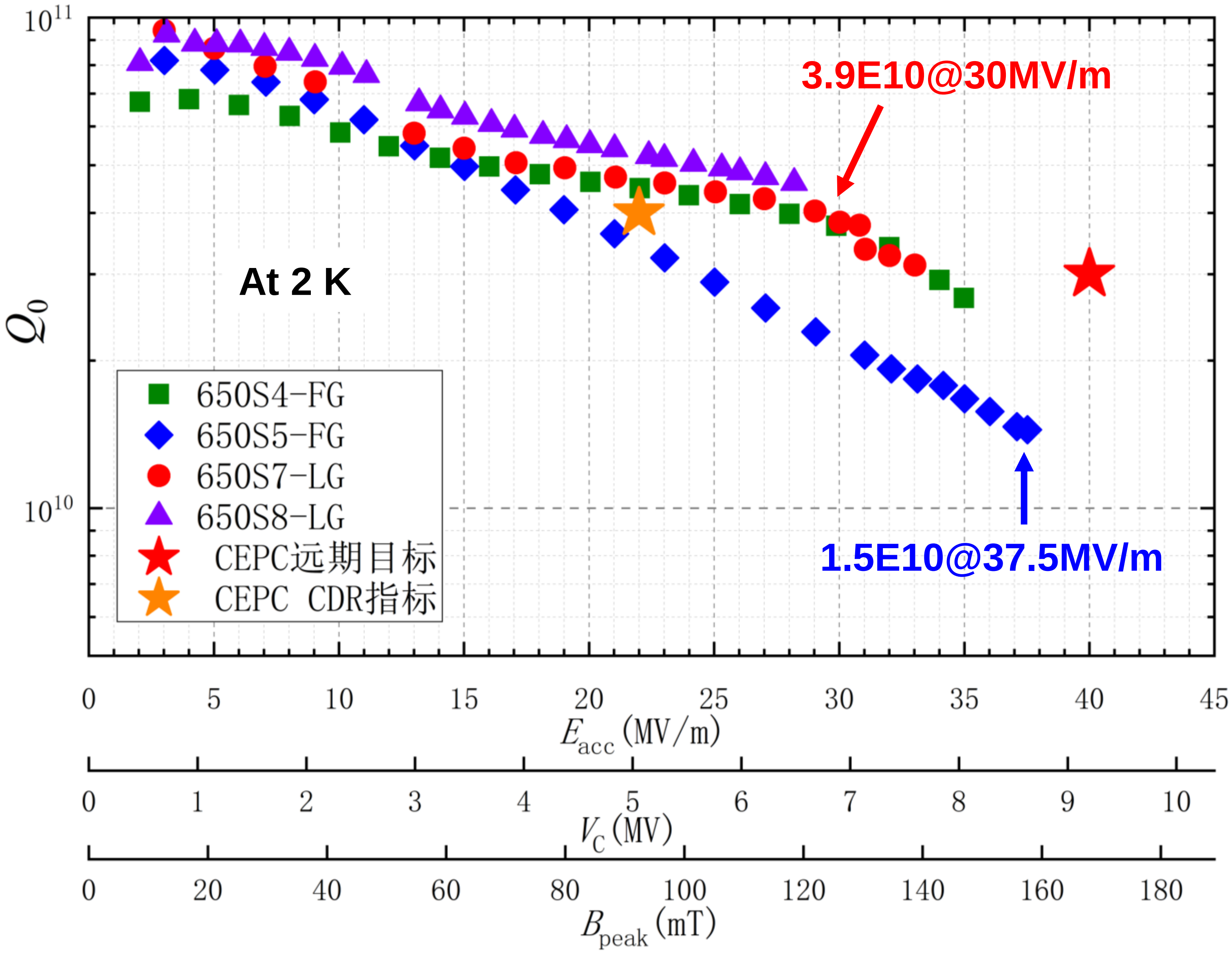
Vertical test of 650 MHz 2-cell cavity



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

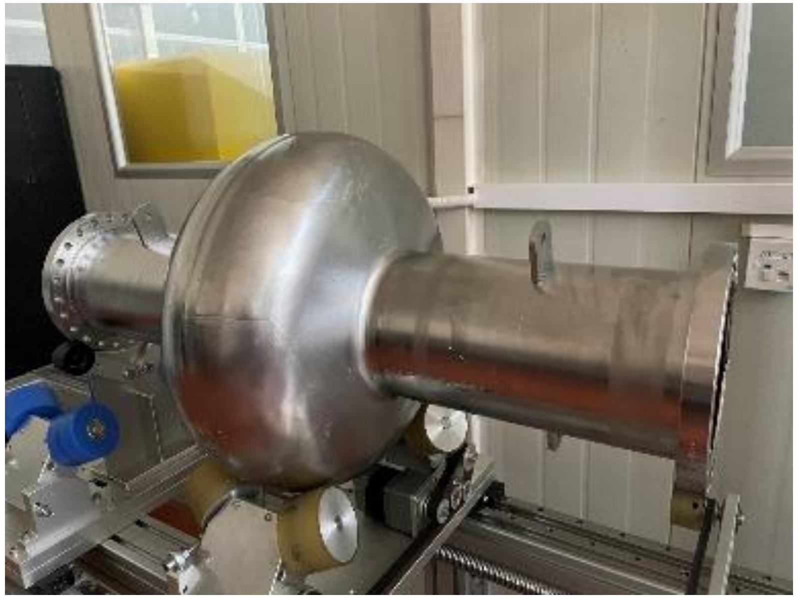
CEPC R&D: High Q SCRF 650 MHz 1-Cell Cavity

➢ **IHEP achieved Q_0=3.9E10@30 MV/m (650MHz 1-cell SCRF Cavity)**



CEPC CDR Goal:
Q_0 = 3.0E10 @ 22 MV/m

Test Results:
Q_0 = 3.9E10 @ 30 MV/m
Q_0 = 1.5E10 @ 37.5 MV/m

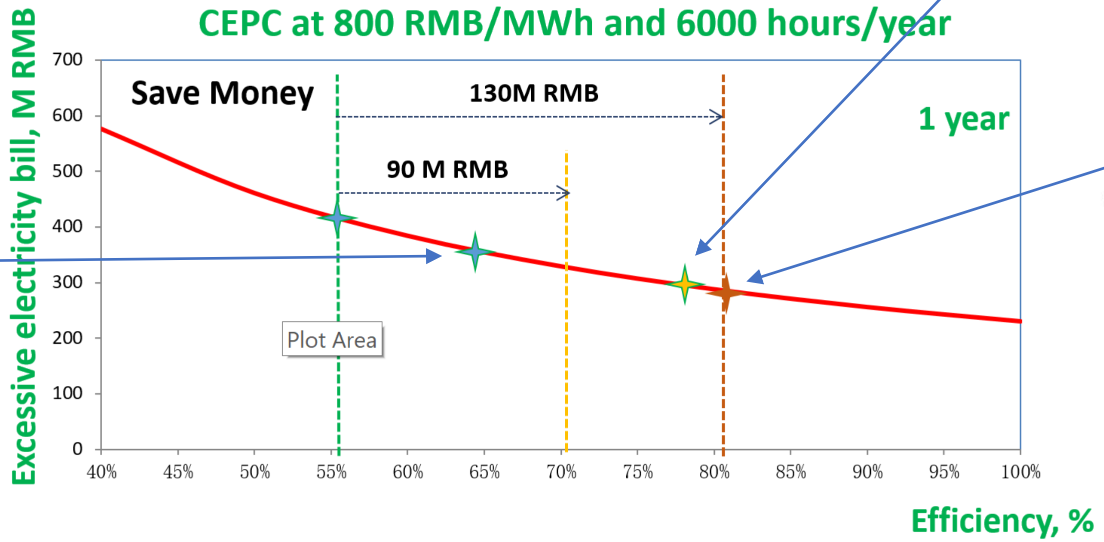


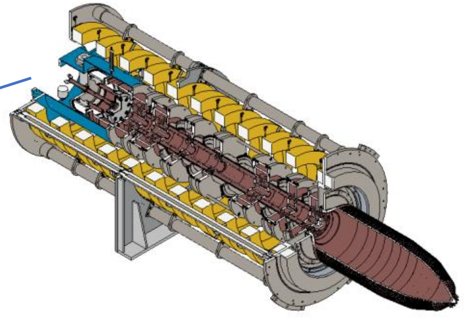
CEPC R&D: High Efficiency Klystrons

- The 1st prototype finished fabrication & passed the max. power test. Output power reaches 700 kW in CW mode, 800 kW in pulsed mode. **Design efficiency is 65%, achieved efficiency ~ 62%.**
- The 2nd klystron prototype is manufactured and being baked out, to be tested at PAPS in 2021, **design efficiency is ~ 77%.**
- Multi-beam Klystron design is finished, **design efficiency is ~ 80.5%.**
- High efficiency Klystron helps to reduce electricity consumption.

The 2nd Klystron (assembly)

The 1st Klystron (tested)

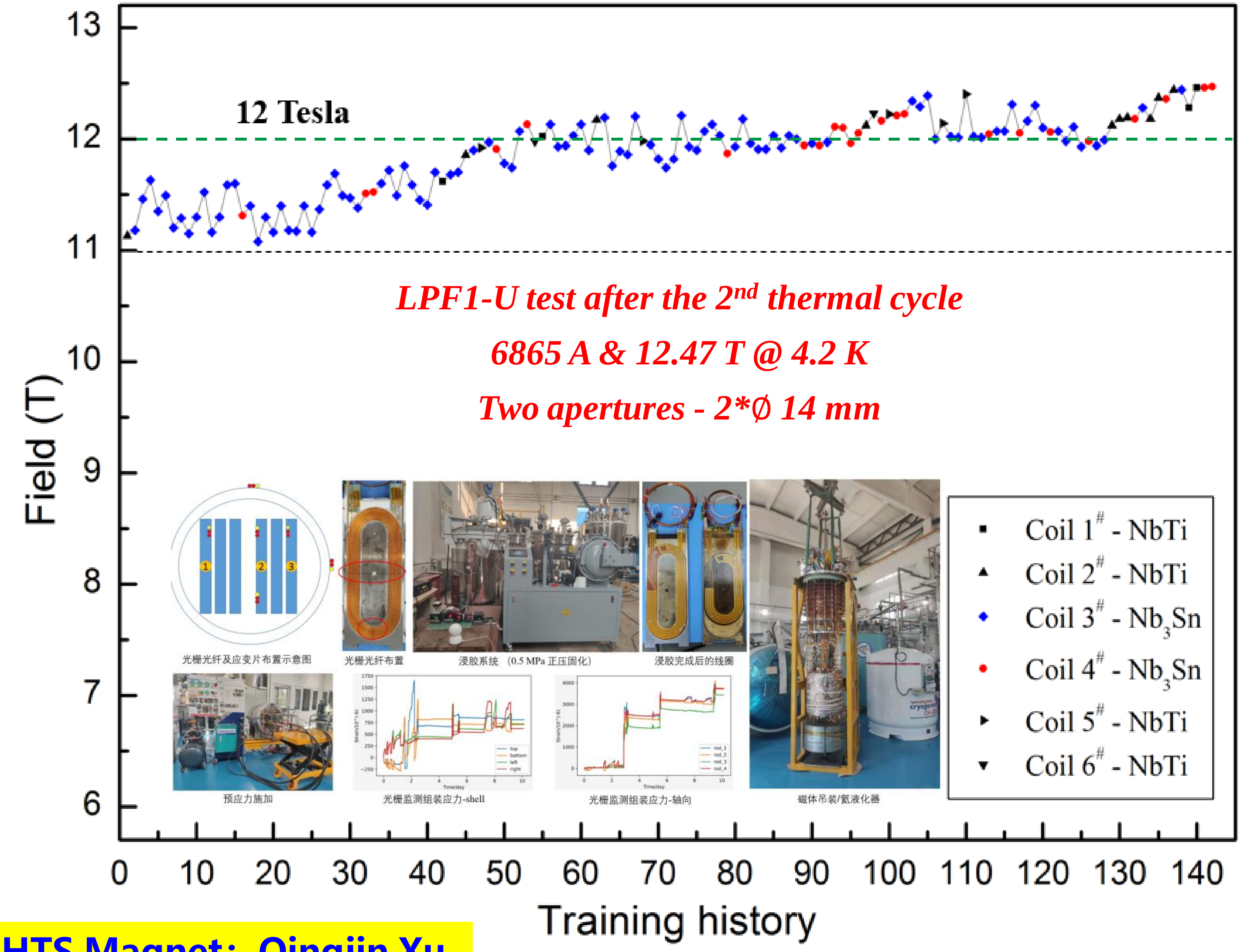


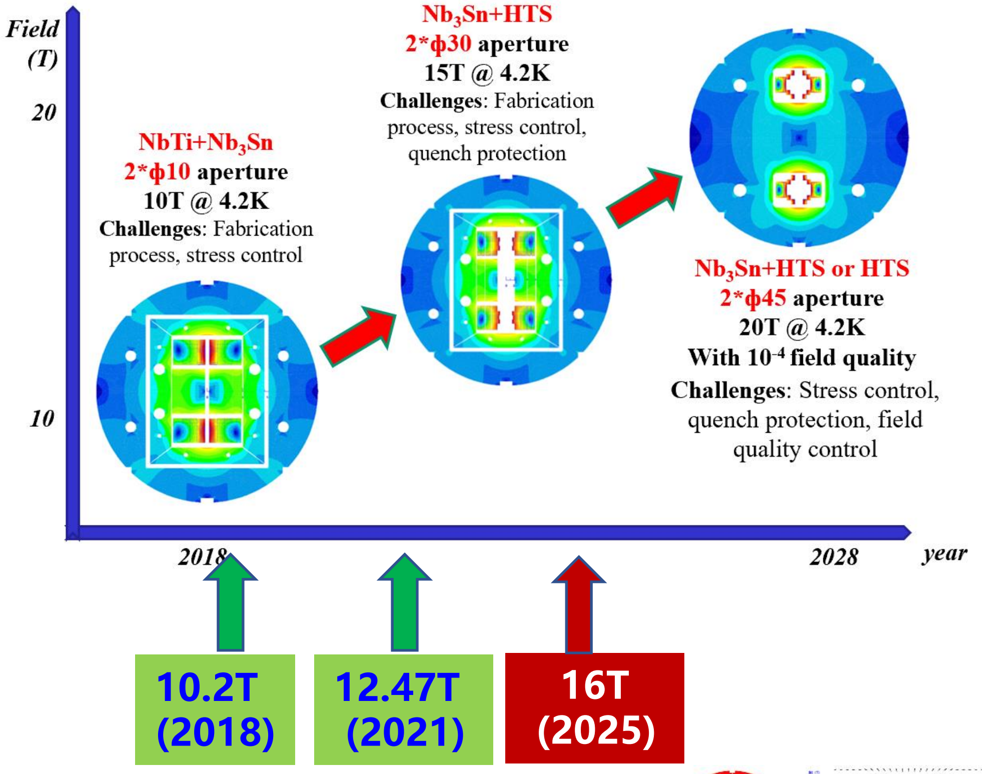


Multi-beam Klystron

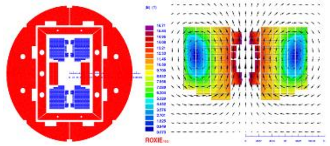
HTS SC Magnet (>12T)

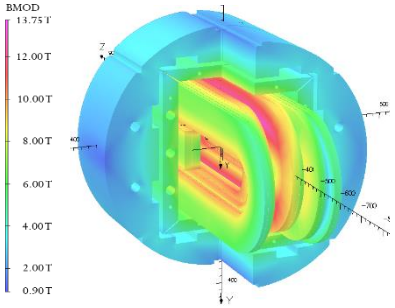
Domestic SC dipole magnet exceeded 12T (IHEP, June, 2021)





LPF3 16T Dipole Magnet:
Nb_3Sn 12~13 T + HTS 3~4 T

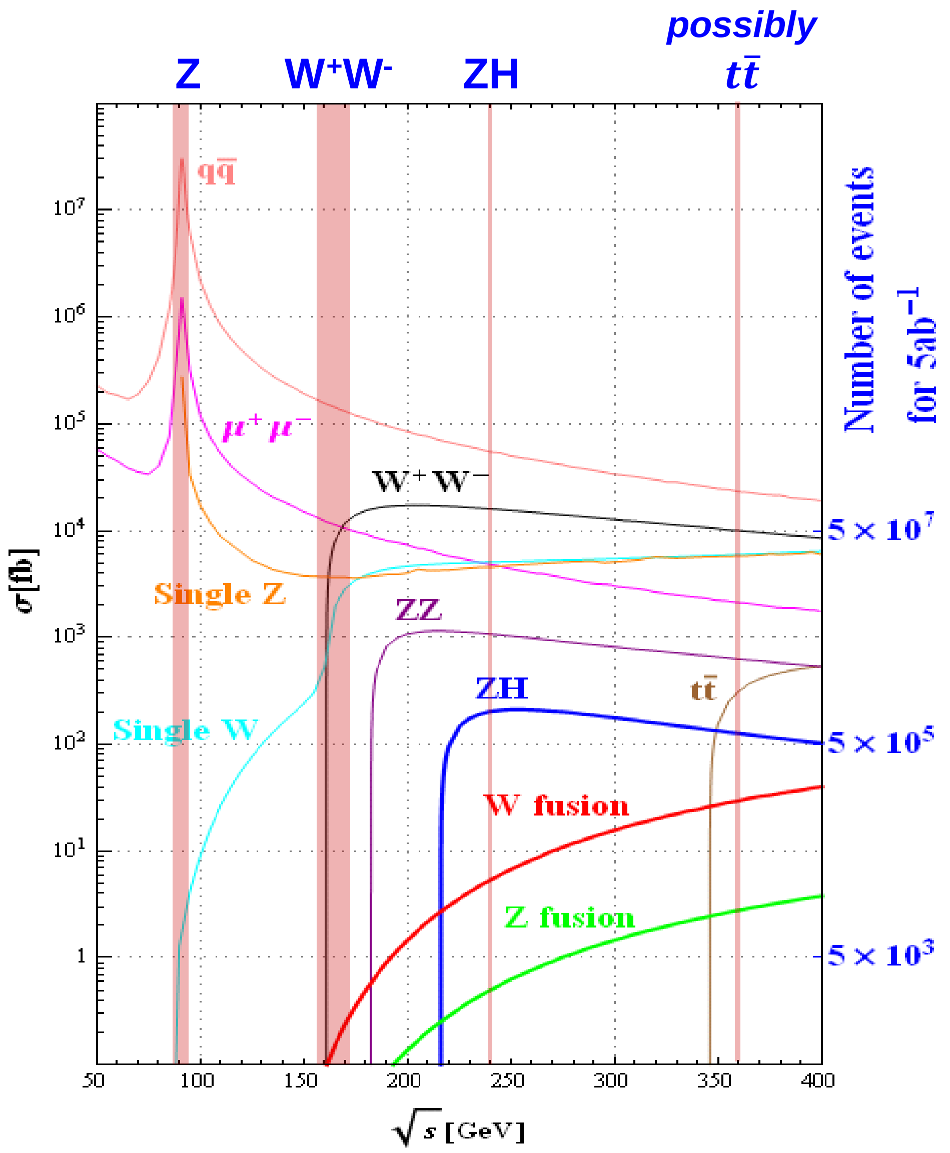




HTS Magnet：Qingjin Xu

The CEPC Physics Program

Physics & White Paper: Yaquan Fang



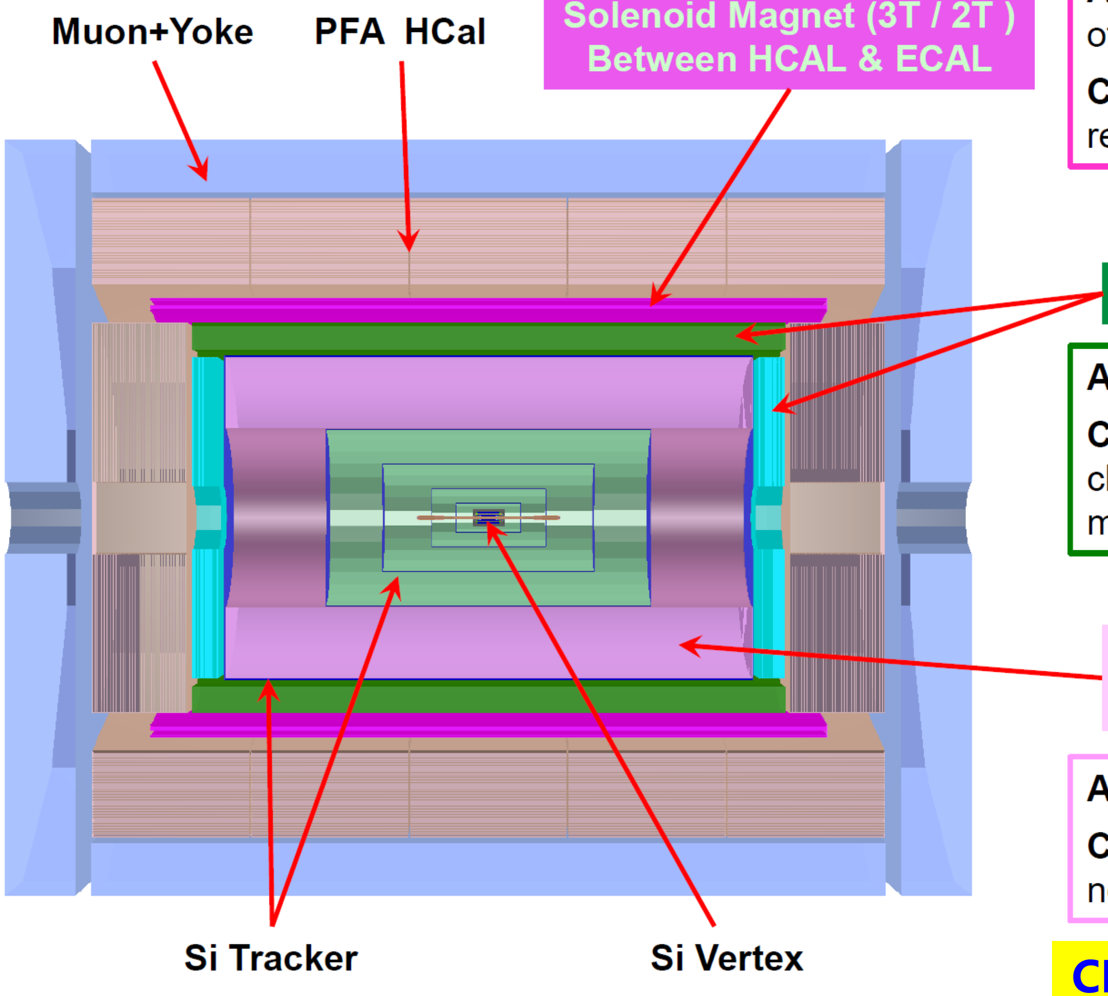
Operation mode		ZH	Z	W⁺W⁻	ttbar (new)
$\sqrt{s}$ [GeV]		~ 240	~ 91.2	~ 160	~ 360
Run time [years]		7	2	1	7.7
CDR	L / IP [$\times10^{34}$ cm^{-2}s^{-1}]	3	32	10	
	$\int L\,dt$ [ab^{-1}, 2 IPs]	5.6	16	2.6	
	Event yields [2 IPs]	1×10^6	7×10^{11}	2×10^7	
Latest	L / IP [$\times10^{34}$ cm^{-2}s^{-1}]	5.0	115	15.4	0.5
	$\int L\,dt$ [ab^{-1}, 2 IPs]	9.3	57.5	4.0	1.0
	Event yields [2 IPs]	1.7×10^6	2.5×10^{12}	3×10^7	3×10^5

- **CEPC Conceptual Design Report:**
  Volume 1 – Accelerator, arXiv:1809.00285
  Volume 2 – Physics & Detector, arXiv:1811.10545

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

The 4th Conceptual Detector Design

- New detector concept: Si Tracker + DC for PID + PFA Crystal ECAL + Thin Solenoid Magnet btw ECAL and HCAL + Scintillating Glass for HCAL



Advantage: the HCAL absorbers act as part of the magnet return yoke.

Challenges: thin enough not to affect the jet resolution (e.g. BMR); stability.

Transverse Crystal bar ECAL

Advantage: better π^0/γ reconstruction.

Challenges: minimum number of readout channels; compatible with PFA calorimeter; maintain good jet resolution.

Drift chamber that is optimized for PID

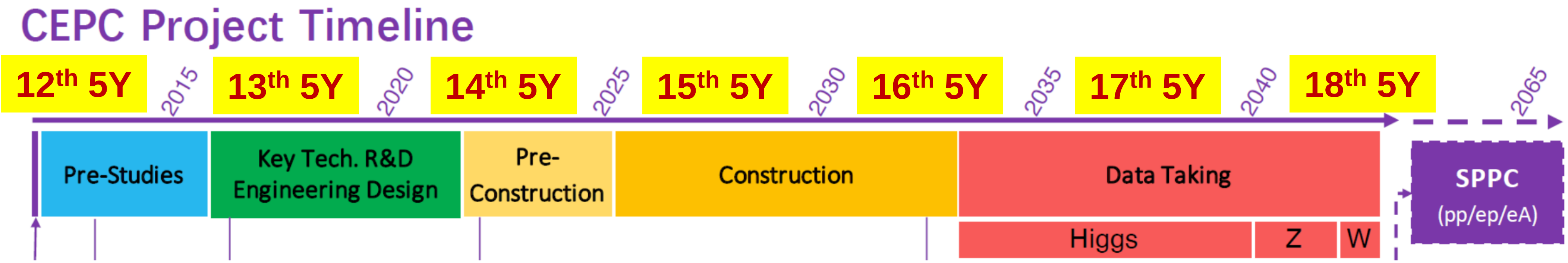
Advantage: Work at high luminosity Z runs

Challenges: sufficient PID power; thin enough not to affect the moment resolution.

CEPC Detector R&D: Joao Costa
New Detector Concept: Jianchun Wang

IAC Report: Recommendations

Recommendation 1: ***Update the timeline and include two separate accelerator and detector roadmaps in the timeline by the next IAC meeting.***



The CEPC accelerator roadmap (ideal)

2016-2021 MOST phase-1 accelerator R&D
2018-2023 MOST phase-2 accelerator R&D
2023-2028 MOST phase-3 accelerator R&D
2022-2023 Accelerator TDR completed
2023-2025 Site selection, engineering design, prototyping and industrialization
2026-2034 Construction and Installation

The CEPC detector roadmap (ideal)

2016-2021 MOST phase-1 detector R&D
2018-2023 MOST phase-2 detector R&D
2023-2028 MOST phase-3 detector R&D
Present-2024 Seek intl. collab., detector R&D
2025-2026 Prepare for intl. collab.
2027-2028 Detector TDR completed
2028-2034 Detector construction
2033-2034 Installation

IAC Report: Recommendations

Recommendation 2: ***Hold the International Accelerator Review Committee and the International Detector R&D Review Committee twice a year in person or virtually. The next meetings should take place within six months.***

IARC Recommendation and Plan: Yuhui Li

IARC Development:

- IARC meeting in May, 11 talks
- IARC meeting in Oct, 22 talks
- IARC delivered review reports, provides positive feedbacks, reminds missing studies and inconsistency, stressing the difficulties of key prototypes, it helps to make CEPC accelerator design a credible and feasible scheme.

https://indico.ihep.ac.cn/event/14295/

The 2021 CEPC International Accelerator Review Committee

Review Report

May 19, 2021

Overview

The CEPC International Accelerator Review Committee was held remotely due to the Covid-19 pandemic on May 11th and 12th 2021. This is the second IARC meeting.

The Circular Electron Positron Collider (CEPC+SppC) Study Group, currently hosted by the Institute of High Energy Physics of the Chinese Academy of Sciences, completed the conceptual design of the CEPC accelerator in 2018. As recommended by the CEPC International Advisory Committee (IAC), the group began the Technical Design Report phase for the CEPC accelerator in 2019, with a completion target year of 2022. Meanwhile an International Accelerator Review Committee (IARC) has been established to advise on all matters related to CEPC accelerator design, the R&D program, the study of the machine-detector interface region, and the compatibility with an upgrade to the t-tbar energy region, as well as with a future SppC. The first IARC meeting took place in Beijing during the CEPC international workshop on Nov. 18-21, 2019.

https://indico.ihep.ac.cn/event/15177/

2021 Second CEPC IARC Meeting

IARC Committee

October 20th, 2021

The Circular Electron Positron Collider (CEPC) and Super Proton-Proton Collider (SppC) Study Group, currently hosted by the Institute of High Energy Physics of the Chinese Academy of Sciences, completed the conceptual design of the CEPC accelerator in 2018. As recommended by the CEPC International Advisory Committee (IAC), the group began the Technical Design Report (TDR) phase for the CEPC accelerator in 2019, with a completion target year of 2022. Meanwhile an International Accelerator Review Committee (IARC) has been established to advise on all matters related to CEPC accelerator design, the R&D program, the study of the machine-detector interface region, and the compatibility with an upgrade to the t-tbar energy region, as well as with a future SppC.

The second 2021 CEPC International Accelerator Review Committee was held remotely due to the Covid-19 pandemic on October 11th to 14th 2021.

A total of 22 talks were presented on a variety of topics.

1 General comments

The Committee congratulates the CEPC team for the work performed in the last months and presented at this meeting. In particular, the progress on the R&D of the hardware components looks very promising. The team has updated the table of parameters for the high-luminosity running, as well as the lattices and components for all accelerator systems: sources, Linac, Booster and Collider.

IAC Report: Recommendations

Recommendation 2: ***Hold the International Accelerator Review Committee and the International Detector R&D Review Committee twice a year in person or virtually. The next meetings should take place within six months.***

IDRDC Development:

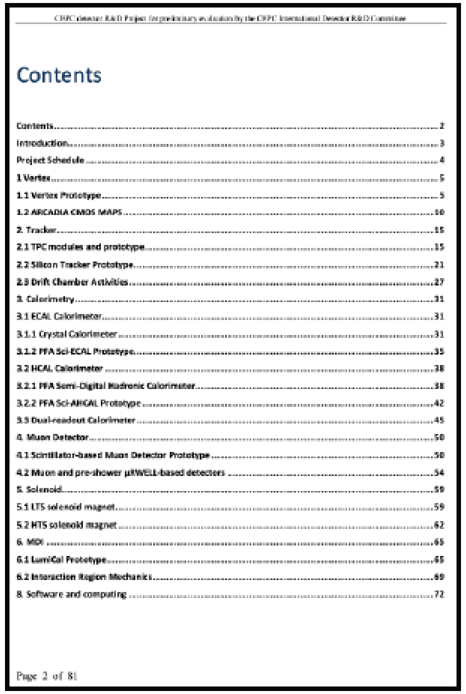
- ➔ CEPC detector R&D plan was submitted to the IDRDC
- ➔ Expect to have a review meeting as soon as possible

18 Documents,
95 subtasks, 80 pages
Submitted to IDRDC chair &
Waiting for feedback

CEPC detector R&D Project for preliminary evaluation by the CEPC International Detector R&D Committee

CEPC Detector R&D Project

Page 1 of 81



CEPC detector R&D Project for preliminary evaluation by the CEPC International Detector R&D Committee

Contents

Page 2 of 81

PBS	Task Name	Page	Subtasks	Context	Team	Document Responsible
	CEPC Detector R&D Project					
1	**Vertex**					
1.1	**Vertex Prototype**	5	9	CEPC	China+ international collaborators	Zhijun, Ouyang
1.2	**ARCADIA CMOS MAPS**	6	6	Generic	INFN, Italy	Manuel Rolo
2	**Tracker**					
2.1	**TPC Module and Prototype**	6	12	CEPC	IHEP, Tsinghua	Huirong
2.2	**Silicon Tracker Prototype**	6	8	Generic	China, UK, Italy	Harald Fox, Meng Wang
2.3	**Drift Chamber Activities**	4	3	FCC-ee/CEPC	INFN, Novosibirsk	Franco Grancagnolo
3	**Calorimetry**					
3.1	**ECAL Calorimeter**					
3.1.1	Crystal Calorimeter	5	6	CEPC	IHEP, Princeton + others	Yong Liu
3.1.2	PFA Sci-ECAL Prototype	3	3	CEPC	USTC, IHEP	Jianbei Liu
3.2	**HCAL Calorimeter**					
3.2.1	PFA Digital Hadronic Calorimeter	4	5	CEPC	SJTU, IPNL, Weizmann, IIT, USTC	Haijun Yang, Imad Laktineh, Shikma Bressler
3.2.2	PFA Sci-AHCAL Prototype	4	4	CEPC	USTC, IHEP, SJTU	Jianbei Liu
3.3	**Dual-readout Calorimeter**	5	5	FCC-ee/CEPC	INFN, Sussex, Zagreb, South Korea	Roberto Ferrari
4	**Muon Detector**					
4.1	Scintillator-based Muon Detector	4	5	CEPC	Fudan, SJTU	Xiaolong Wang, Liang Li
4.2	Muon and pre-shower μRWELL-	5	4	FCC-ee/CEPC	INFN, LNF	Paolo Giacomelli
5	**Solenoid**					
5.1	LTS solenoid magnet	4	4	CEPC	IHEP+Industry	Zhu Zian
5.2	HTS solenoid magnet	4	4	CEPC	IHEP+Industry	Zhu Zian
6	**MDI**					
6.1	LumiCal Prototype	4	2	ILC/CEPC	AC, IHEP	Suen Hou
6.2	Interaction Region Mechanics	3	4	CEPC	IHEP	Hongbo Zhu
8	**Software and Computing**	7	11	CEPC	IHEP, SDU	Li Weidong, Ruan Manqi, Sun Shengseng, Li Gang

IAC Report: Recommendations

Recommendation 3: ***Explore a possibility of commissioning an economics department of a prestigious Chinese university to carry out such an economic benefits study.***

Development:

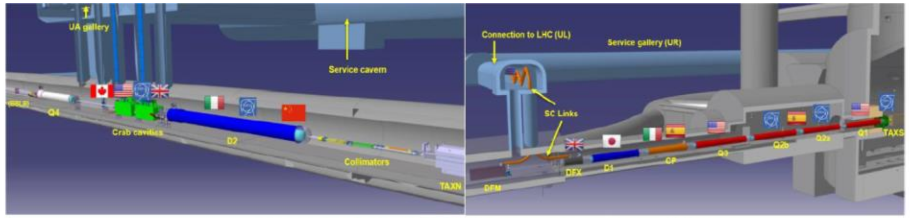
- **July, 2021:** Changsha local government entrusted Hunan U. to conduct a study on the benefit that CEPC could bring to local society.
- **Sept.4, 2021:** per request by the Changsha city government, Hunan University organized a review meeting by a committee consisting of experts from multiple disciplines which evaluated CEPC for its science, feasibility of a new science city based on CEPC, and overall impact on Changsha. The overall conclusion is very positive. The local government is very interested in and supportive of the CEPC project.
- **October, 2021:** Institute of Science and Technology Strategic Consulting, CAS is carrying out an independent assessment of Social Cost Benefit Analysis (SCBA) for the CEPC project, the report will be available in August, 2022.

IAC Report: Recommendations

Recommendation 4: ***Explore the CERN-Chinese relation as much possible. The IAC would like to hear a report on this matter at the next meeting, with an evaluation of the benefits to date, the strengths and weaknesses, and how it might be further improved.***

Development:

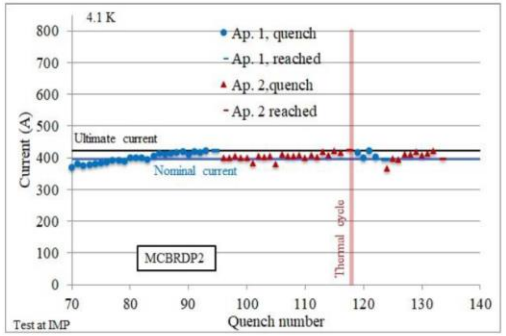
- 2019-present: China-CERN Joint Research Center (CCJRC), annual meeting
- We received NSFC grant to support accelerator and detector upgrade for HL-LHC experiments.
- Actively involve in the CALICE, LCTPC, RD collaborations for common detector R&D



Layout of the HL-LHC Magnets and Contributors

China will provide 12+1 units CCT superconducting magnets for the HL-LHC project

After more than 1 month test and training at 4.2K, both apertures reached the design current and ultimate current, and the field quality is within the limit.



Implementation of IAC Report

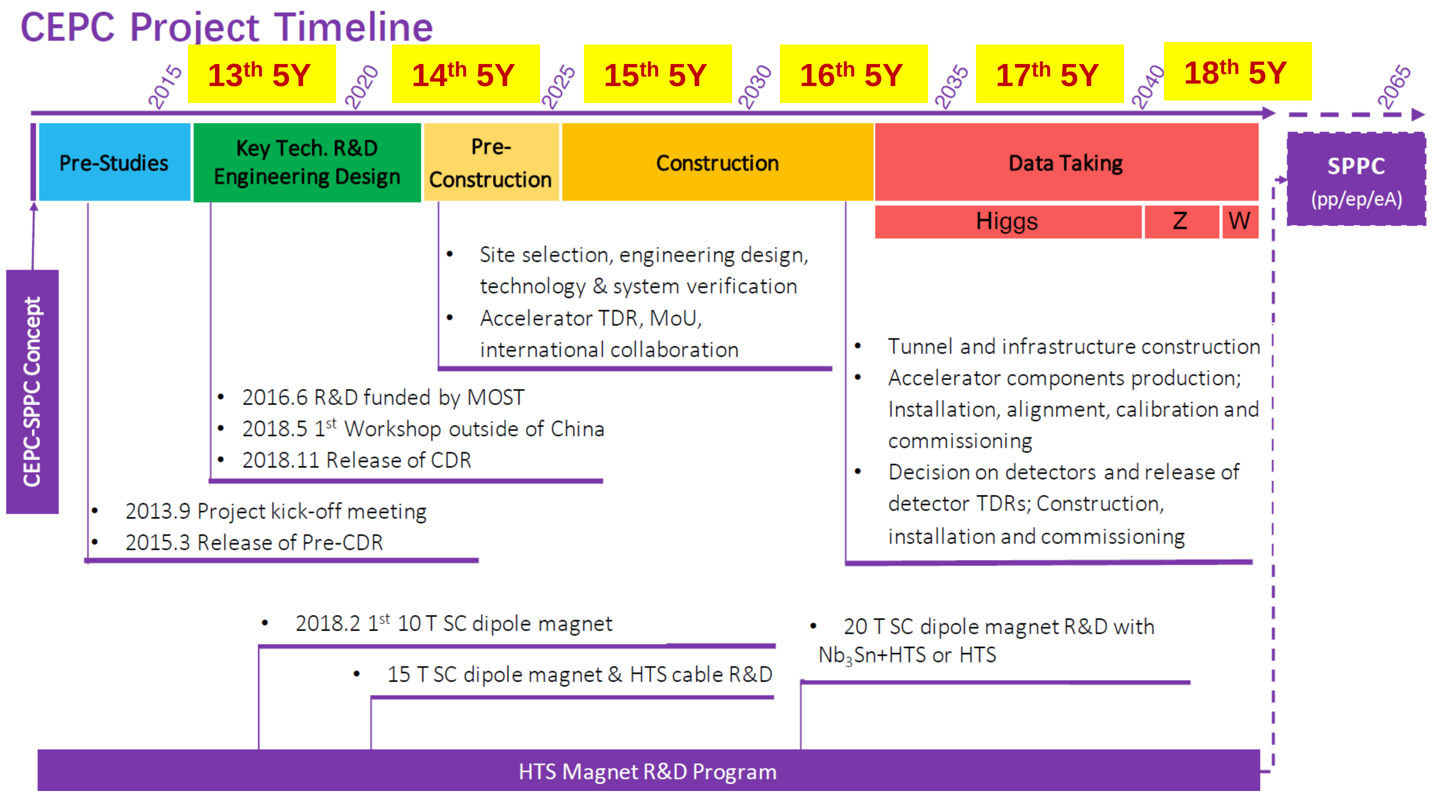
Recommendation 5: ***Maintain approximately the present schedule for the TDR, with an additional "pre-construction phase" added afterwards for further R&D, prototyping, industrialization, and collaboration setup to finalize an "engineering design".***

Development:

→ Accelerator TDR (2022)

→ Pre-construction (2022-2025)

- Key technologies R&D
- Prototyping
- Site selection
- Engineering design
- System verification
- Intl. collaboration (MoU)
- Financial model
- ……



Implementation of IAC Report

Recommendation 6: ***Review all the possible opportunities to gain the appropriate construction experience and present them at the next IARC meeting. The IAC believes that it is very important for the IHEP team to gain experience in the construction of a mammoth project such as this one. Normally that would entail the construction of an ~5% prototype.***

Development:

- IHEP team undertakes construction and operation of several large scale accelerator projects,
  - ✓ Beijing Electron Positron Collider (BEPC)
  - ✓ China Spallation Neutron Source (CSNS)
  - ✓ Platform of Advance Photon Source (PAPS)
  - ✓ High Energy Photon Source (HEPS, 4^{th} Generation)
- The key components of projects can be considered as good exercise for CEPC.

Implementation of IAC Report

Recommendation 7: ***Evaluate thoroughly the C-band option for the injector with a view to re-baselining the design. The IAC was encouraged by the C-band design and the costing that was demonstrated. It appears that the extra cost of the C-band machine is more than compensated by a reduction in the dipole costs.***

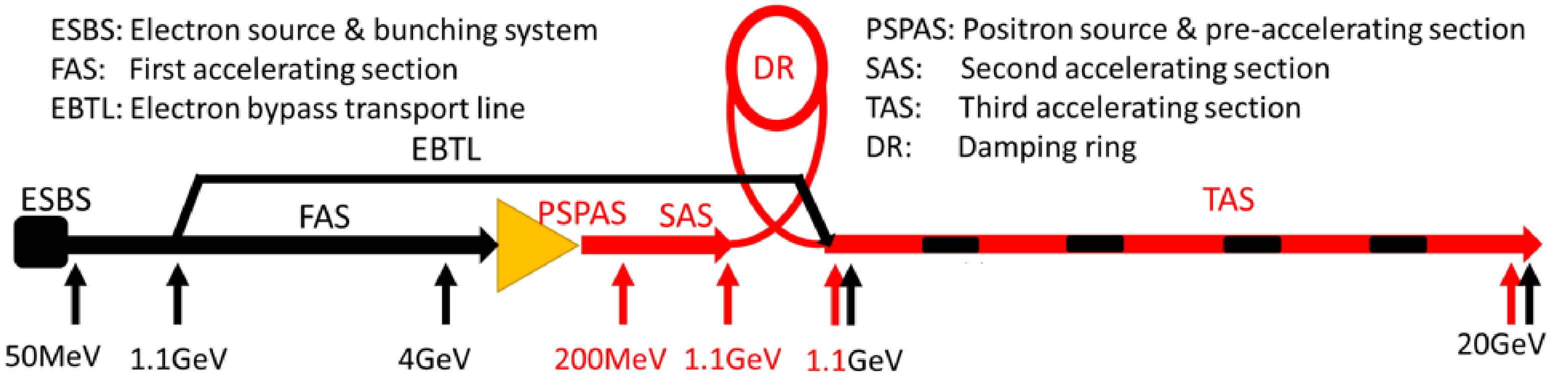
Development:

- The new baseline for CEPC Linac was reported to the IARC in 2021. With C-band acceleration, the Linac energy is increased from 10 GeV to 20 GeV.
- It helps to solve the challenges met by the booster dipole that diluted iron core magnets can be adopted instead of the CT iron-free magnets. The saving from the booster dipoles is enough to compensate extra cost of C-band in the Linac. IHEP has expertise for C-band design & fabrication via soft XFEL project in Shanghai.

Layout: Vertical electron bypass
EBTL: 1.2 m separation

S-band Linac: FAS: 4GeV + **PSPAS**: 200MeV + **SAS**: 1.1GeV

C-band Linac: TAS：
1.1GeV→20GeV



Implementation of IAC Report

Recommendation 8: ***Produce a plan for the appropriate prototyping of the accelerator control system. The IAC believes that the situation with the accelerator control system should be addressed. This seems to be short of funding and effort.***

Development:

- The readiness of CEPC control system is the weak point, it was also pointed out at the IARC meeting.
- In China, the largest electron storage ring is 1.3km long HEPS (under construction). There are many unexpected problems for CEPC control system with 100km ring.
- The preliminary evaluation reveals that constructing the control system based on EPICS is the optimal choice for IHEP in the present status.
- We are looking forward to the international collaborations for the control system.

Implementation of IAC Report

Recommendation 9: ***Discuss at the next IARC meeting whether to organize a "brainstorming" session of international experts looking with fresh eyes at the design both to validate it and to increase international involvement in the project.***

Development:

- The IARC meeting was conducted twice in 2021. Lots of suggestions and recommendations were addressed both to physical design and to prototypes progresses.
- The CEPC team are trying to attract more experts for review and discussion. Not only the IARC meetings, HKUST-IAS and CEPC workshops also offer opportunities for broader international involvement.
- Due to pandemic, it is difficult to have intensive international communication, especially for in person meeting/discussion/collaboration. We will enhance it as long as the pandemic situation is under control.

Implementation of IAC Report

Recommendation 10: ***Consider a process similar to the European Strategy Preparatory Group process and the Snowmass process in China. Experts from outside China should be brought into this process. It should aim to produce a report in around one year.***

Development:

- Similar process like European Strategy Preparatory Group and Snowmass exists in China, but with different formation. We have "HEP Strategic Plan for Accelerator- and non-Accelerated Based Experiments" and provide documents to funding agency in 2021.
- The process takes about one year to collect materials and organizes dedicated meetings for extensive discussions within HEP in China. The current process doesn't involve experts outside China.
- We will continue to suggest to funding agencies and Chinese HEP community to collect inputs from international community.

IAC Report: Recommendations

Recommendation 11: ***Not to tighten the R&D towards a predefined tight schedule. The IAC believes that R&D within a technically driven schedule is optimal. Given the longer timescale this allows, it is important to develop the best possible detector design. Innovation and creativity (i.e. new ideas) in the R&D leading to the development of a cutting-edge holistic detector design should be a goal.***

Development:

- The CEPC conceptual design continues to evolve with new technologies and ideas.
- CEPC team has proposed and is studying a new conceptual detector includes new technologies (dN/dx for PID, SiPM for photon detection), and emerging technologies under development (HTS SC magnet for compact detector).
- The CEPC general timeline is revised by adding pre-construction phase.
- Keep open to innovative options (eg. Plasma injector) that requires more R&D

Implementation of IAC Report

Recommendation 12: ***Reinforce the engineering efforts related to the detector design. Engineering studies are essential and now timely, for example in the following domains: cooling integration studies for the vertex detector, the beam pipe and the PFA calorimeters; light-weight supports and integration of the vertex detector; scalability of the calorimeters.***

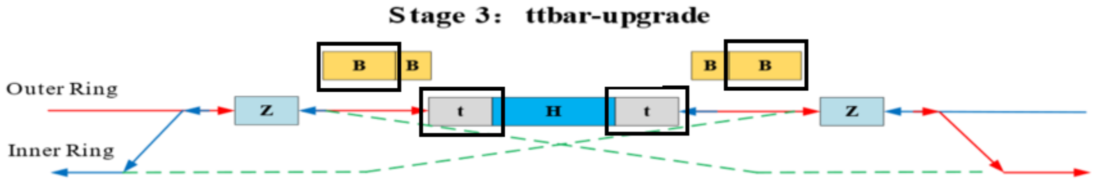
Development:

- A senior staff was appointed as project engineer, organized "The 2021 Workshop on CEPC Detector & MDI Mechanical Design" at Dongguan on Oct. 22-23, 2021.
- The team is making significant progress on overall mechanical design for detectors including MDI, beam pipe, vertex, tracker, lumiCalo, calorimeters, Yoke & SC, and exploring possible installation schemes etc.
- The team is also working on cooling and mechanics for vertex detector & beam pipe etc.
- People from Dongguan campus and JUNO experiment will join the engineering studies in the next 1-2 years.

https://indico.ihep.ac.cn/event/14392

Implementation of IAC Report

Recommendation 13: ***Assess the CEPC physics potential of the 360 GeV stage in full, including a demonstration that the accelerator design optimally fits the physics objectives at this stage. Even if the 360 GeV stage is still far away in time, it is an important element to the attractiveness of CEPC as a whole. Not emphasizing it strongly in the presentation of the CEPC program may discourage potential partners.***



Extra RF cavities for ttbar in collider ring and booster ring

Development:

- CEPC is upgradable for ttbar run (360GeV) with installation of extra RF cavities, quadrupole magnets for the final focusing and septum magnets for beam separation in RF regions.
- With 30MW SR, the current accelerator design offers ttbar $\mathcal{L} \sim 0.5\text{x}10^{34}$ $cm^{-2}s^{-1}$/IP, it is corresponding to integrated luminosity of $1ab^{-1}$ for 7.7 years running.
- To get $2ab^{-1}$ for 7.7 years by increasing SR power (50MW), reducing βy^*, coupling factor etc.
- Top mass precision can be improved by one order of magnitude compared with HL-LHC.
- The impact of 360 GeV Run on Higgs properties is also studied, especially the Higgs width can be improved by a factor of 2.
- The BSM search opportunities at 360 GeV are being studied as well.

Implementation of IAC Report

Recommendation 14: ***Assess the CEPC physics potential for the high luminosity Z factory stage. In particular it is important to fully develop the flavor physics program for this stage, from the perspective of weak interactions (e.g. precision measurements and rare and forbidden decays in the SM and BSM scenarios), as well as from the perspective of strong interactions (e.g. in the area of exotic hadrons, where unique studies of doubly heavy or fully heavy tetraquarks, also including b quarks, would be possible).***

Development:

- We are performing intensive Flavor Physics potential analyses at CEPC Z pole.
- Analyses include b->$s\tau\tau$, b->$\tau\nu$, B_0/B_s->2π, B_s->$J/\psi\phi$, exclusive Z decay, LFV etc. Those analyses are motivated to addressing the current R_D and R_K tension.
- Adding Drift Chamber as PID to improve π/K separation and to enhance flavor physics
- We plan to look into exotic hadrons in the future and prepare flavor physics white paper

Published papers:

- Analysis of $B_c \rightarrow tn_t$ at CEPC, T. Zheng et.al., *CPC 45, No. 2 (2021)*
- $B \rightarrow st^+t^-$ Physics at Future Z Factories, L.F. Li, T. Liu, *JHEP 06 (2021) 064*

Implementation of IAC Report

The active participation of CEPC experts, together with experts from ILC, CLIC and FCC, in the commonKey4hep/EDM4hep/DD4hep software infrastructure for detector description, event simulation and event reconstruction is seen as a big step forward since last year.

Recommendation 15: ***Further develop close relationships with FCC-ee colleagues in detector designs.***

Development:

- Silicon tracker project with UK colleagues likely to be common with FCC-ee
- New conceptual detector uses drift chamber as PID, collaborating with IDEA colleagues who are involving in both projects
- Active members in CALICE, heavily involving in PFA calorimeter prototypes R&D which are common technologies for CEPC and FCC-ee/ILC
- We are also involving Key4hep software development and computing etc.
- Joint workshops / discussions are desirable to develop close relationship

Summary and Prospects

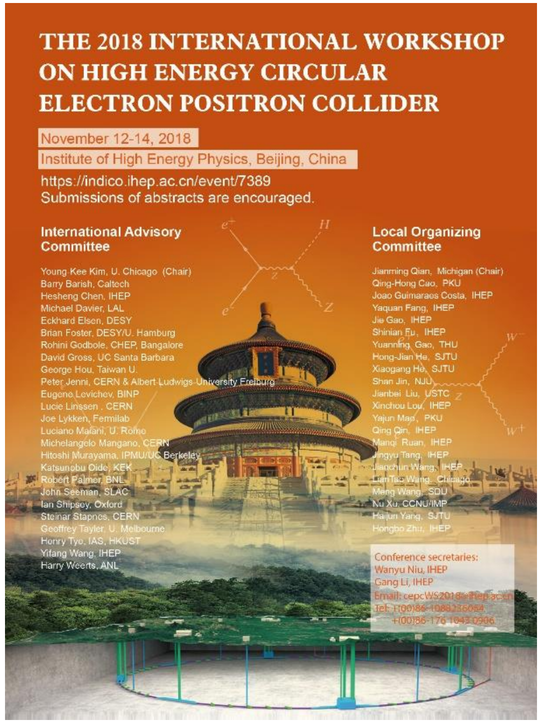
Continuing R&D and deep understanding of physics potentials

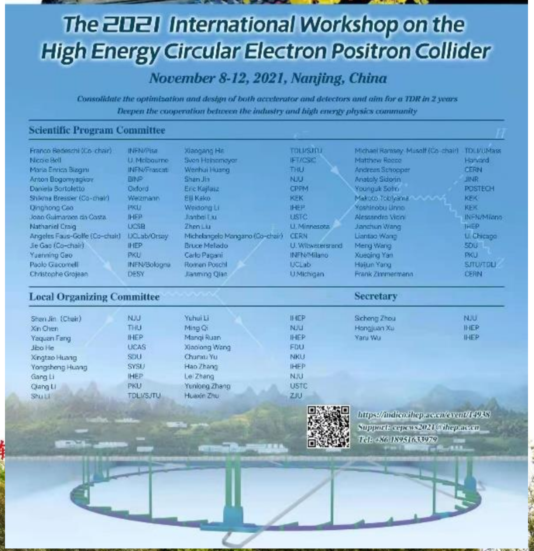
- Made suggestions to **MOST for R&D support** and validations of key technologies & innovations
- Carrying out **design improvement, R&D**, site investigations-study
- R&D and made major **progress + breakthroughs** in common technologies
- **CEPC physics whitepaper**; physics potentials in Snowmass 2021/2022 arena

International Collaboration and Engagement

- Engaging actively in **ILC, FCC as well as HL-LHC upgrade** activities, enhancing CERN-China relationship
- Actively participating international **detector R&D** collaborations: CALICE, LPTPC, RD*, …
- Finding and sharing solutions to common issues (design, accelerator/detector components, …)
- **Due to COVID-19 pandemic, it's impossible to have in-person meetings ……**

Recent CEPC Workshops



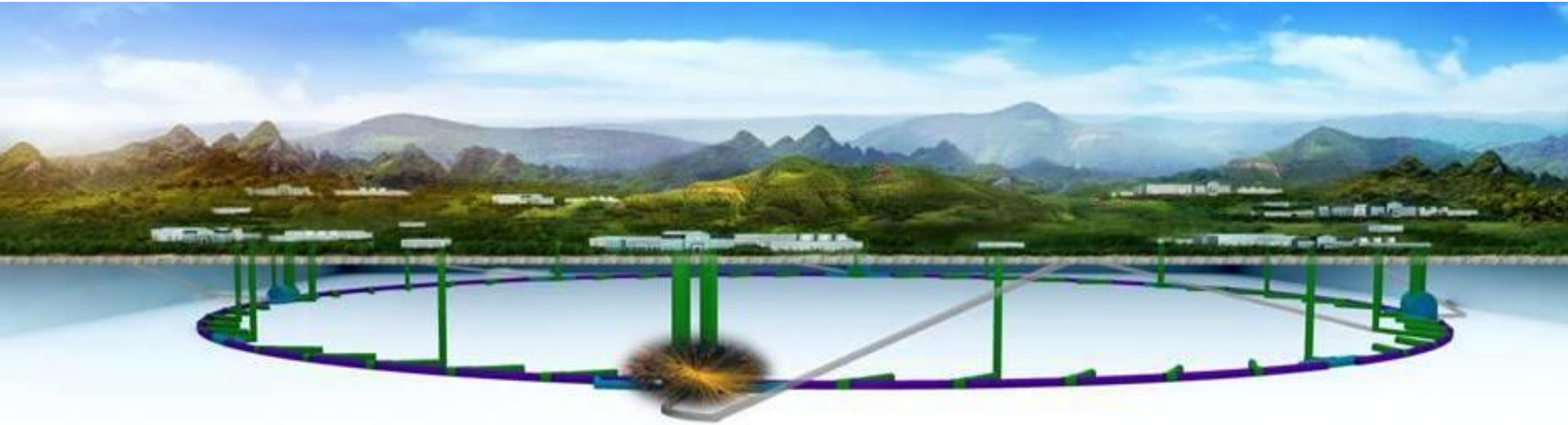


Next CEPC International Workshop will be held by Nanjing U. (online), Nov. 8-12, 2021

You are very welcome to participate

https://indico.ihep.ac.cn/event/14938/

Thank you !



Current CEPC Organization (only for Chinese)

October 2021

Institutional Board
YN GAO (PKU)
J. GAO (IHEP)

Steering Committee
YF WANG (IHEP),….

IAC
YK Kim (Chair)

Barry Barish, Caltech
Hesheng Chen, IHEP
Michel Davier, LAL
Marcel Demarteau, ORNL
Brian Foster, DESY
Rohini Godbole, CHEP, Bangalore
David Gross, UCSB
George Hou, Taiwan
Peter Jenni, CERN & Freiburg
Young-Kee Kim (Chair), Chicago
Eugene Levichev, BINP
Lucie Linssen, CERN
Joe Lykken, Fermilab
Luciano Maiani, U. Rome
Michelangelo Mangano, CERN
Hitoshi Murayama, Berkeley & IPMU
Tatsuya Nakada, EPFL
Katsunobu Oide, CERN & KEK
Robert Palmer, BNL
John Seeman, SLAC
Ian Shipsey, Oxford
Steinar Stapnes, CERN
Geoffrey Taylor, Melbourne

Project Director
XC LOU (IHEP)
HJ YANG (SJTU)

International Accelerator Review Committee

International Detector R&D Review Committee

Accelerator
J. GAO (IHEP)
JY Tang (SPPC,IHEP)
CH YU (IHEP)
YH LI (IHEP)

Theory
HJ HE (SJTU)
JP MA (ITP)
XG HE (SJTU)

Detector
Joao Costa (IHEP)
JC Wang (IHEP)
JB LIU (USTC)

Tasks：
Intl Relation– J GAO
PR – YN GAO
Conf. – J Shan
TDR – XC Lou et al.
……

IARC and IDRDC

International Accelerator Review Committee

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

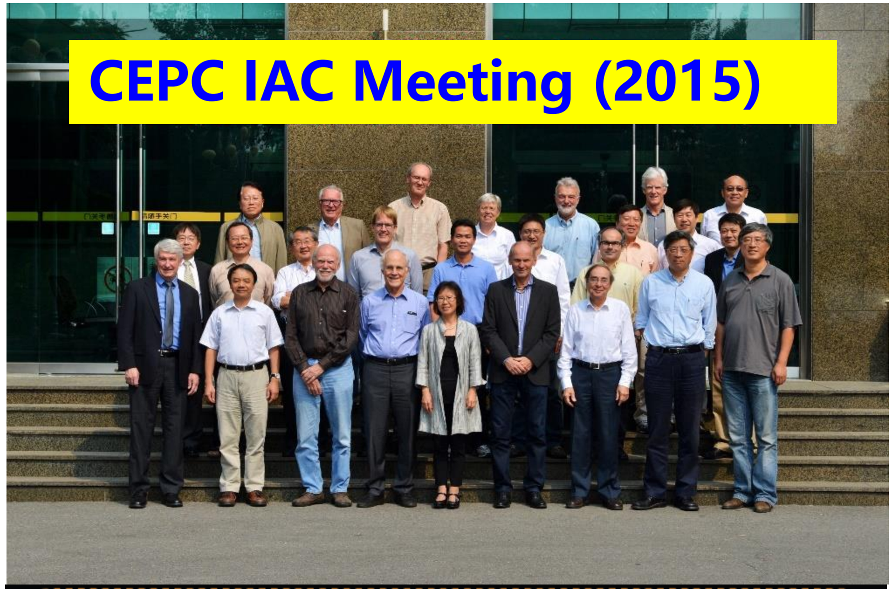
International Detector R&D Review Committee

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

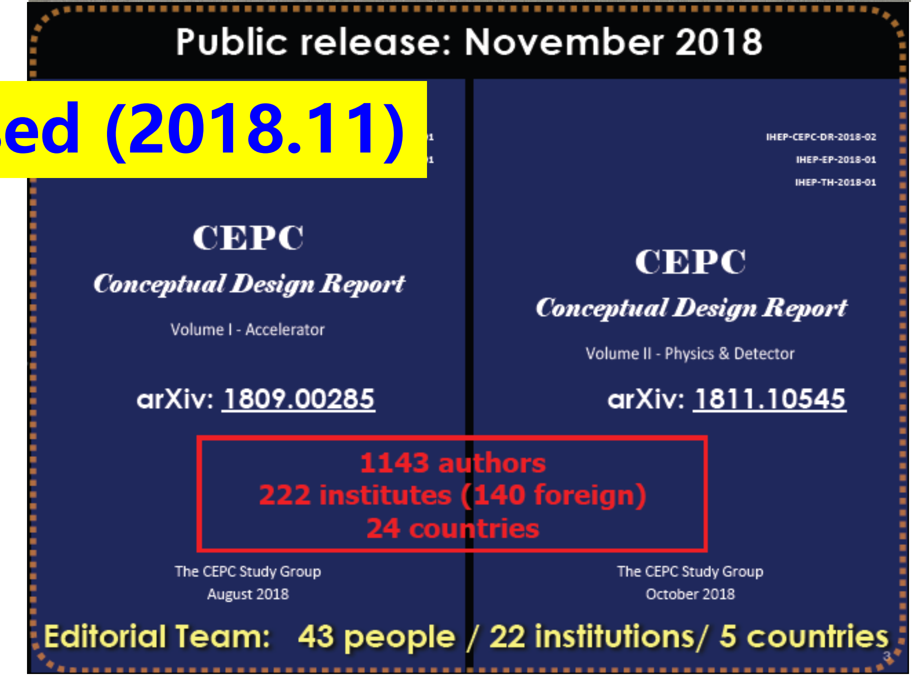
CEPC Major Milestones

CEPC-SPPC Kickoff (2013.9)

CEPC IAC Meeting (2015)



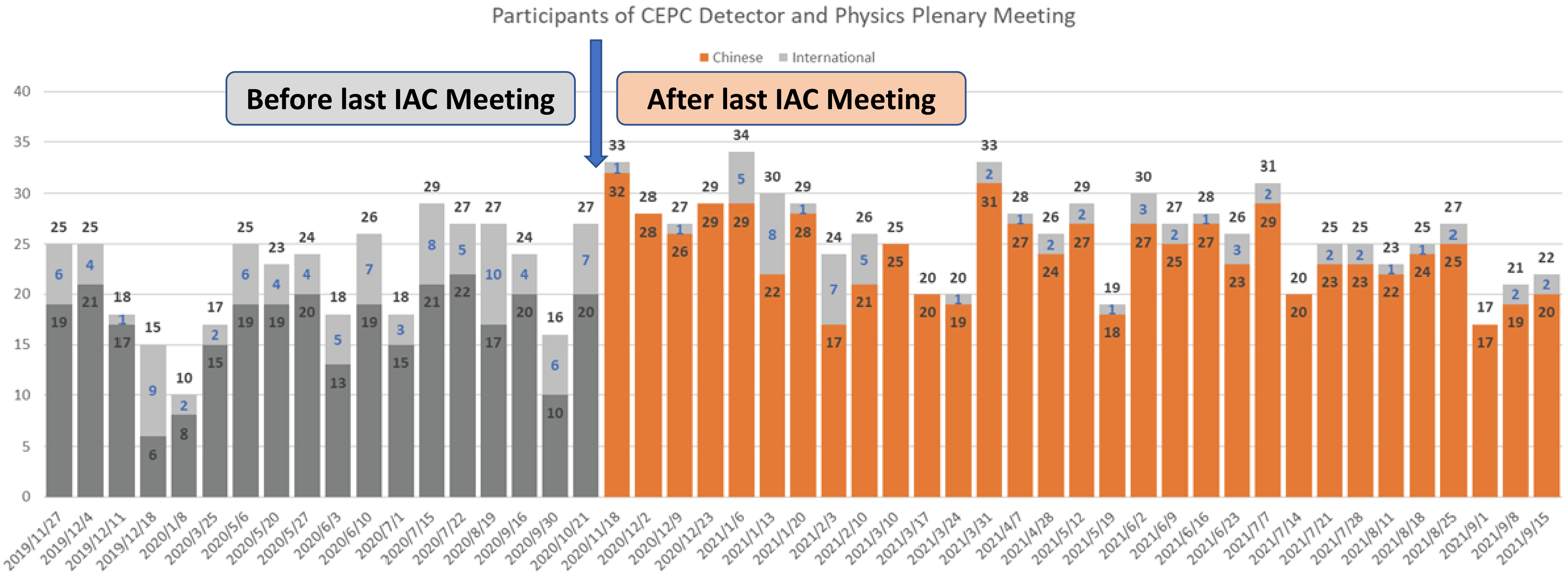
CEPC CDR Released (2018.11)



Implementation of IAC Report

Detector R&D and Physics Studies

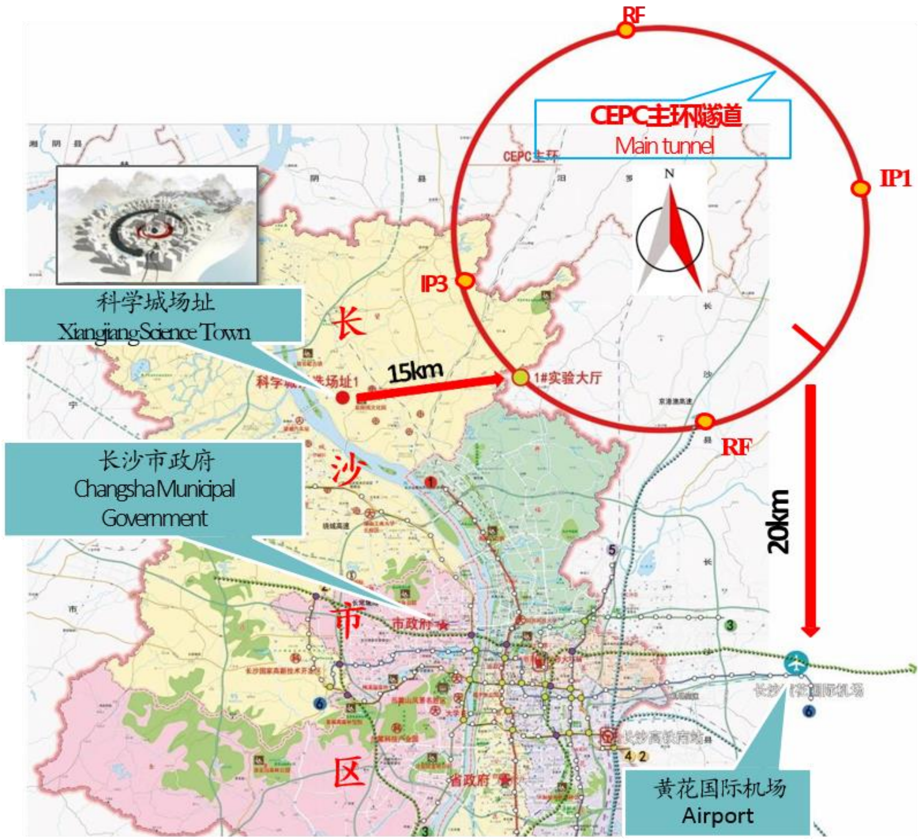
The IAC congratulates the CEPC team for the significant progress since last year on the detector and physics aspects. Following up on last year's recommendation, the IAC was pleased to see regular meetings taking place within the various topical groups and with significant participation from outside China.



http://indico.ihep.ac.cn/category/214

CEPC Site Selection

- One of the best cities in China, the UNESCO Creative City of Media Arts and the Culture City of East Asia.
- Changsha site and its surroundings have slight seismic activity in history, and are free of active faults. The peak ground acceleration is 50 Gal ($0.5 m/s^2$) and the seismic intensity is VI. The tectonic structure is stable.
- Site located in the north of Changsha City,
  - 15 km from science city
  - 20 km from downtown and intl. airport
- Accessibility and transport conditions: The existing transport and road network is sound and complete, with convenient access to downtown and airport.
- The site has open landform, pleasant environment with mountain and river, and complete supporting facilities around.



CEPC Accelerator Design Improvement

- **High luminosities at H and Z factories**
  - Optimization of parameters, improving dynamic aperture(DA) to include errors and more effects
  - New lattice for high luminosity at Higgs
  - New RF section layout
  - More detailed study of MDI
  - Optimization of the booster design and magnets
  - A new alternative design of the LINAC injector
  - A new plasma injector design
  - Injection design
  - ……
- **Accelerator Review Committee**
  - Recommended by the IAC, established & met in November, 2019
  - Two IARC meeting held in 2021

CDR scheme (Higgs)

✓ **L^*=2.2m, θc=33mrad, βx*=0.36m, βy*=1.5mm, Emittance=1.2nm**
- Strength requirements of anti-solenoids (peak field B_z~7.2T)
- Two-in-one type SC quadrupole coils (Peak field 3.8T & 136T/m)

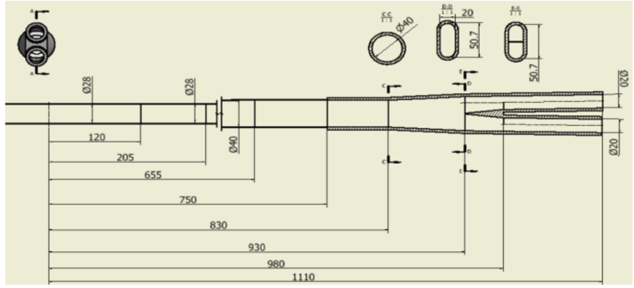
High luminosity scheme (Higgs)

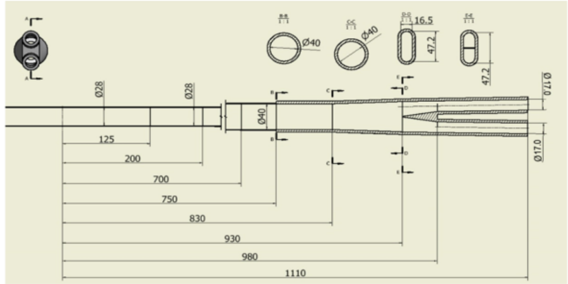
✓ **L^*=1.9m, θc=33mrad, βx*=0.33m, βy*=1.0mm, Emittance=0.68nm**
- Strength requirements of anti-solenoids (peak field B_z~7.2T)
- Two-in-one type SC quadrupole coils (Peak field 3.8T & 141T/m) with room temperature vacuum chamber & Iron yoke

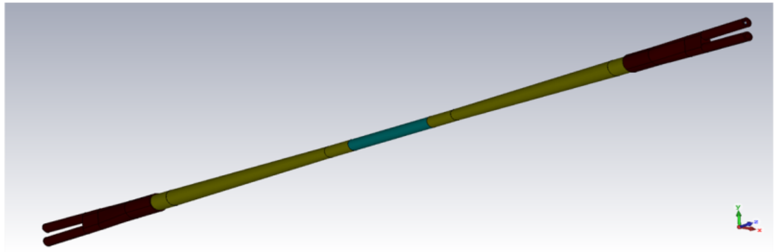
Change of IP chamber

CDR: Be pipe: 28mm, SCQ Beam pipe:20mm

High luminosity: Be pipe: 28mm, Beam pipe:17mm







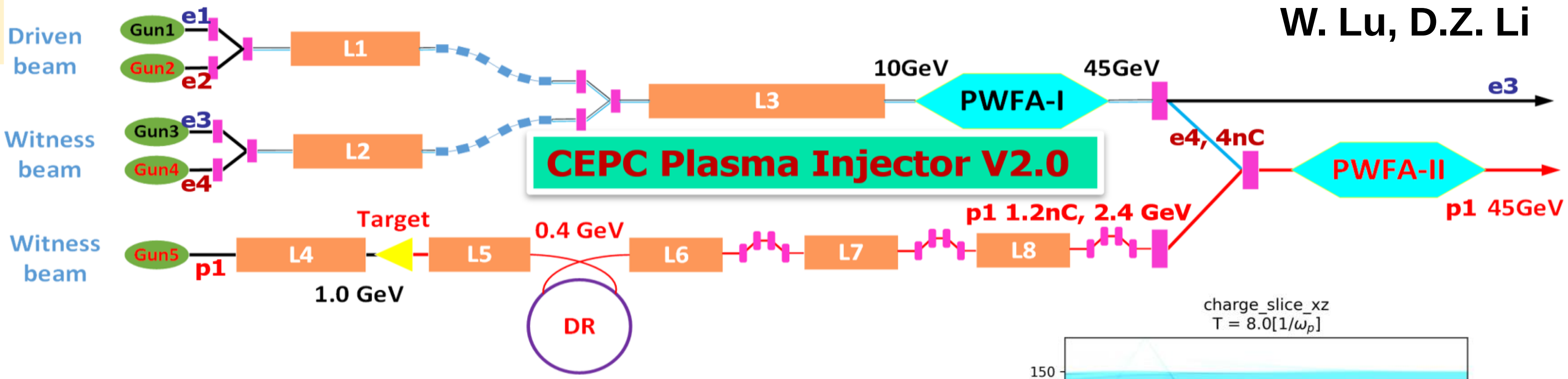
CEPC Accelerator: Plasma Injector

CEPC Plasma Injector V2.0

IHEP, THU, BNU

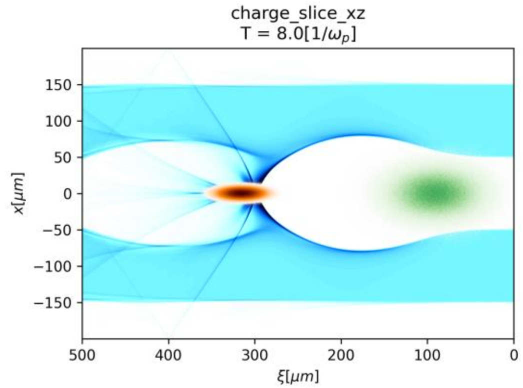
W. Lu, D.Z. Li

Booster Requirement	
Energy（GeV)	45.5
Bunch Charge（nC)	0.78
Bunch length (um)	<3000
Energy Spread (%)	0.2
ε_N (μm·rad)	<800
Bunch Size (um)	<2000

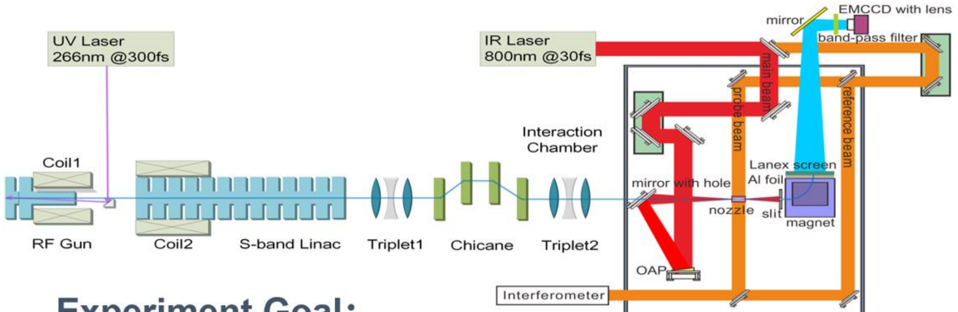


High efficiency uniform wakefield acceleration of a positron beam using stable asymmetric mode in a hollow channel plasma
S.Y. Zhou, W. Lu, et al., arXiv: 2012.06095

3D Quasi-static PIC simulations show:
Energy extraction efficiency ~ 30%
Energy spread ~ 1%

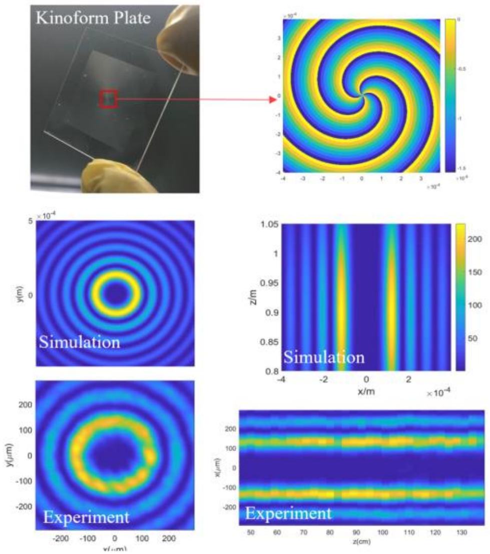


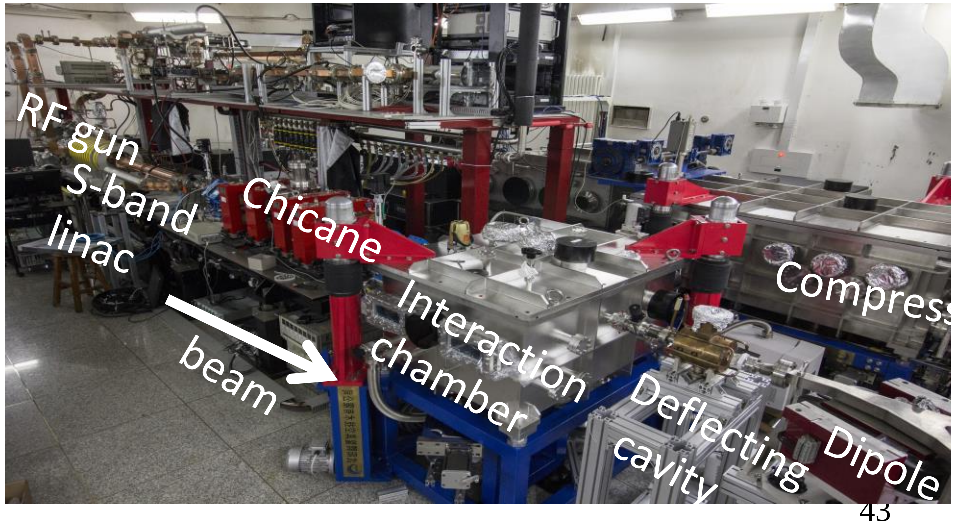
Plasma dechirper exp at SXFEL



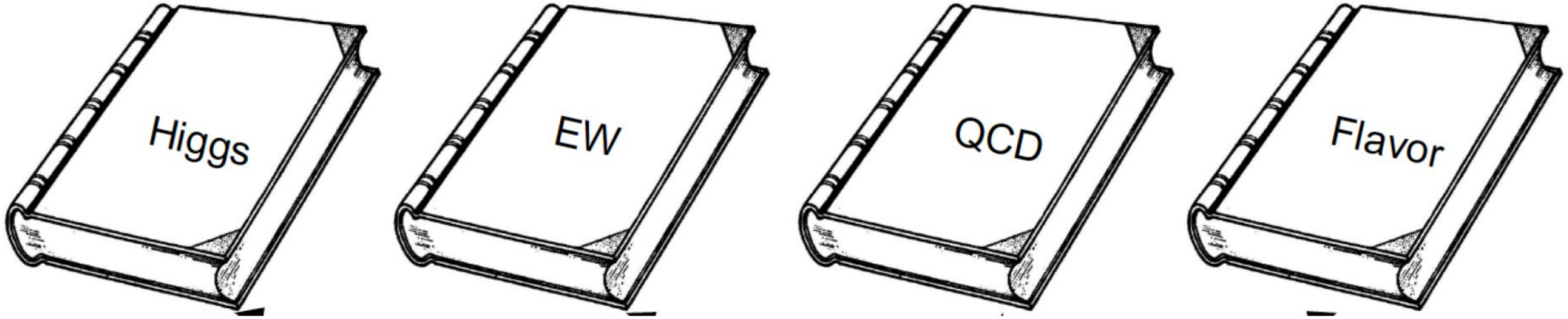
Experiment Goal:

1. Decrease the energy spread from 1% to 0.1%
2. Study Hollow channel impact on beam quality



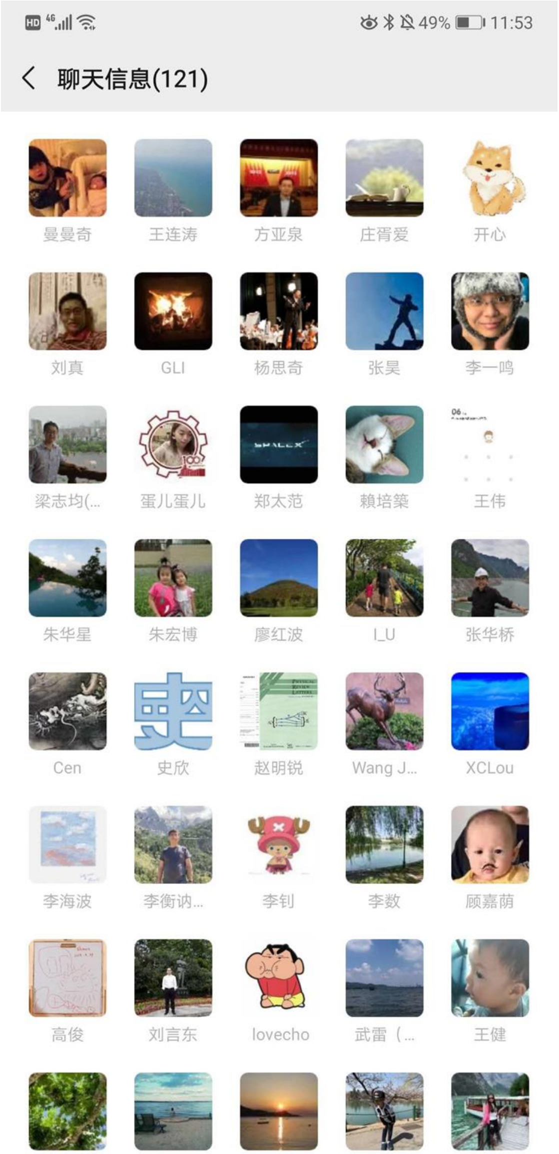


White papers



- To promote the physics study at TDR & to converge to the Physics White Papers
- Physics white papers:
  - Physics handbooks for new comers: PostDoc/Student
  - Official references for the physics potential
  - Guideline for future detector design/optimization
- Higgs white paper published in 2019

CEPC Study for Snowmass: Physics



WG	LoI
EF01	Higgs boson CP properties at CEPC
	Measurement of branching fractions of Higgs hadronic decays
EF02	Study of Electroweak Phase Transition in Exotic Higgs Decays with CEPC Detector Simulation
	Complementary Heavy neutrino search in Rare Higgs Decays
EF03	Feasibility study of CP-violating Phase ϕs measurement via Bs → J/Ψϕ channel at CEPC
	Probing top quark FCNC couplings tq\gamma, tqZ at future e+e- collider
	Searching for Bs → ϕ νν and other b → sνν processes at CEPC
EF04	Measurement of the leptonic effective weak mixing angle at CEPC
	Probing new physics with the measurements of e+e- → W+W- at CEPC with optimal observables
	NNLO electroweak correction to Higgs and Z associated production at future Higgs factory
EF05-07	Exlusive Z decays
EF08	SUSY global fits with future colliders using GAMBIT
	Probing Supersymmetry and Dark Matter at the CEPC, FCCee, and ILC
EF09-10	Search for t + j + MET signals from dark matter models at future e+e- collider
	Search for Asymmetric Dark Matter model at CEPC by displaced lepton jets
	Dark Matter via Higgs portal at CEPC
	Lepton portal dark matter, gravitational waves and collider phenomenology

CEPC Study for Snowmass: Detector R&D

Snowmass — Letters of Intent

14 CEPC-Related Detector LoI submitted

https://indico.ihep.ac.cn/event/12410/

Detector R&D

Conveners: Joao Guimaraes Costa, WANG Jianchun, Mr. Manqi Ruan (IHEP)

15:00 **CEPC Detectors Overview LoI** 1'
CEPC Detector Overview LOI
SNOWMASS21-EF1_EF4-IF9_IF0-260.pdf
Speakers: Joao Guimaraes Costa, Mr. Manqi Ruan (IHEP), WANG Jianchun
Material: **Paper** **Slides**

15:02 **IDEA Concept** 1'
Speaker: Franco Bedeschi (INFN-Pisa)
Material: **Paper**

15:03 **Dual Readout Calorimeter** 1'
Speaker: Roberto Ferrari (INFN)
Material: **Paper**

15:04 **Drift Chamber** 1'
Speaker: Franco Grancagnolo
Material: **Paper**

15:06 **mu-RWELL (muons, preshower)** 1'
Speaker: Paolo Giacomelli (INFN-Bo)
Material: **Paper**

15:08 **Time Detector LoI** 1'
Speaker: Prof. Zhijun Liang (IHEP)
Material: **Slides**

15:09 **Key4hep** 1'
Speakers: Dr. Weidong Li (高能所), Dr. Tao LIN (高能所), Prof. Xingtao Huang (Shandong University), Wenxing Fang (Beihang University)
Material: **Slides**

15:10 **PFA Calorimeter** 1'
Speakers: Haijun Yang (Shanghai Jiao Tong University), Dr. Jianbei Liu (University of Science and Technology of China), Dr. Yong Liu (Institute of High Energy Physics)
Material: **Slides**

15:11 **High Granularity Crystal Calorimeter** 1'
Speaker: Dr. Yong Liu (Institute of High Energy Physics)
Material: **Paper** **Slides**

15:12 **Muon Scintillator Detector** 1'
Speaker: Dr. Xiaolong Wang (Institute of Modern Physics, Fudan University)
Material: **document**

15:13 **Vertex LoI** 1'
Speaker: Prof. Zhijun Liang (IHEP)
Material: **Slides**

15:15 **MDI LoI** 1'
Speaker: Dr. Hongbo ZHU (IHEP)
Material: **Slides**

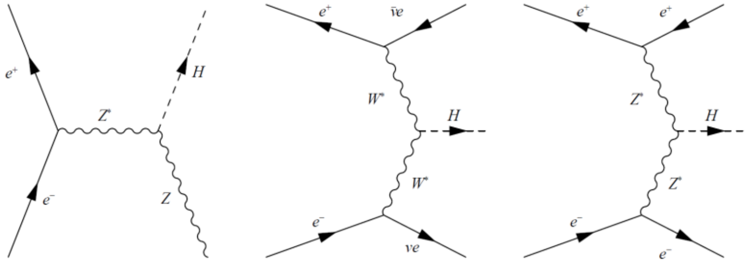
15:16 **TPC LoI** 1'
Speaker: Dr. Huirong Qi (Institute of High Energy Physics, CAS)
Material: **Slides**

15:17 **Solenoid R&D LoI** 1'
Speaker: Dr. Feipeng NING (IHEP)
Material: **Slides**

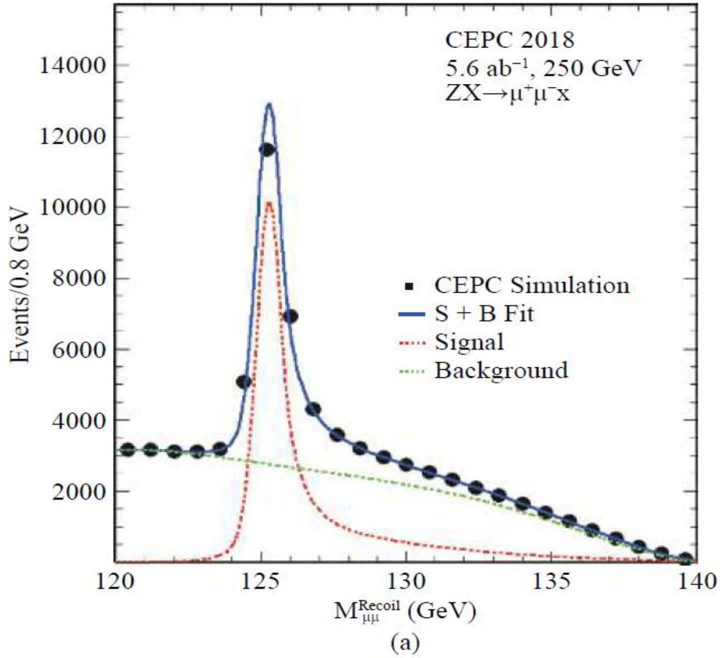
34

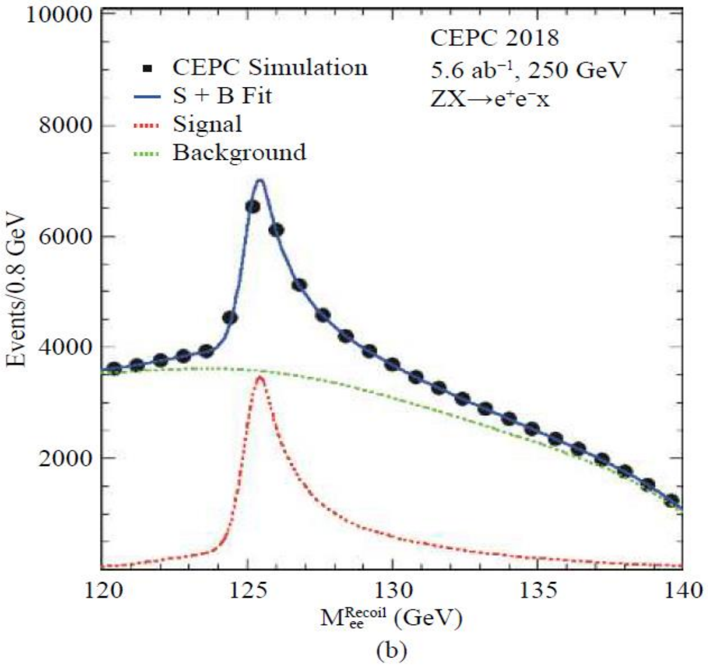
CEPC Physics Performance (CDR)

e⁺e⁻ annihilations at the CEPC

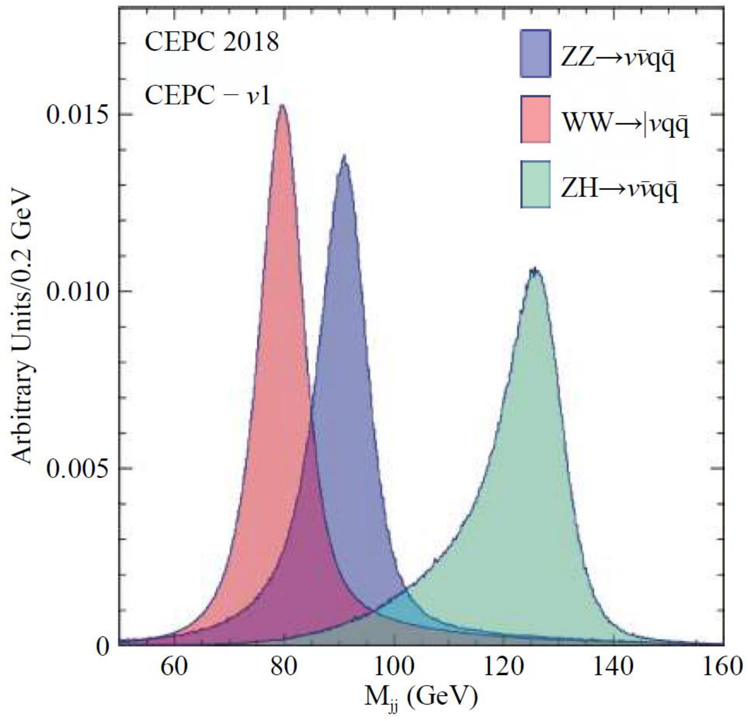


- **CEPC can make detailed study of various physics processes**
- **Higgs bosons are detected via recoil mass of the reconstructed Z, allowing for model independent & full investigation of the Higgs and any new physics that Higgs may reveal**
- **Very challenging events with missing neutrinos and jets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





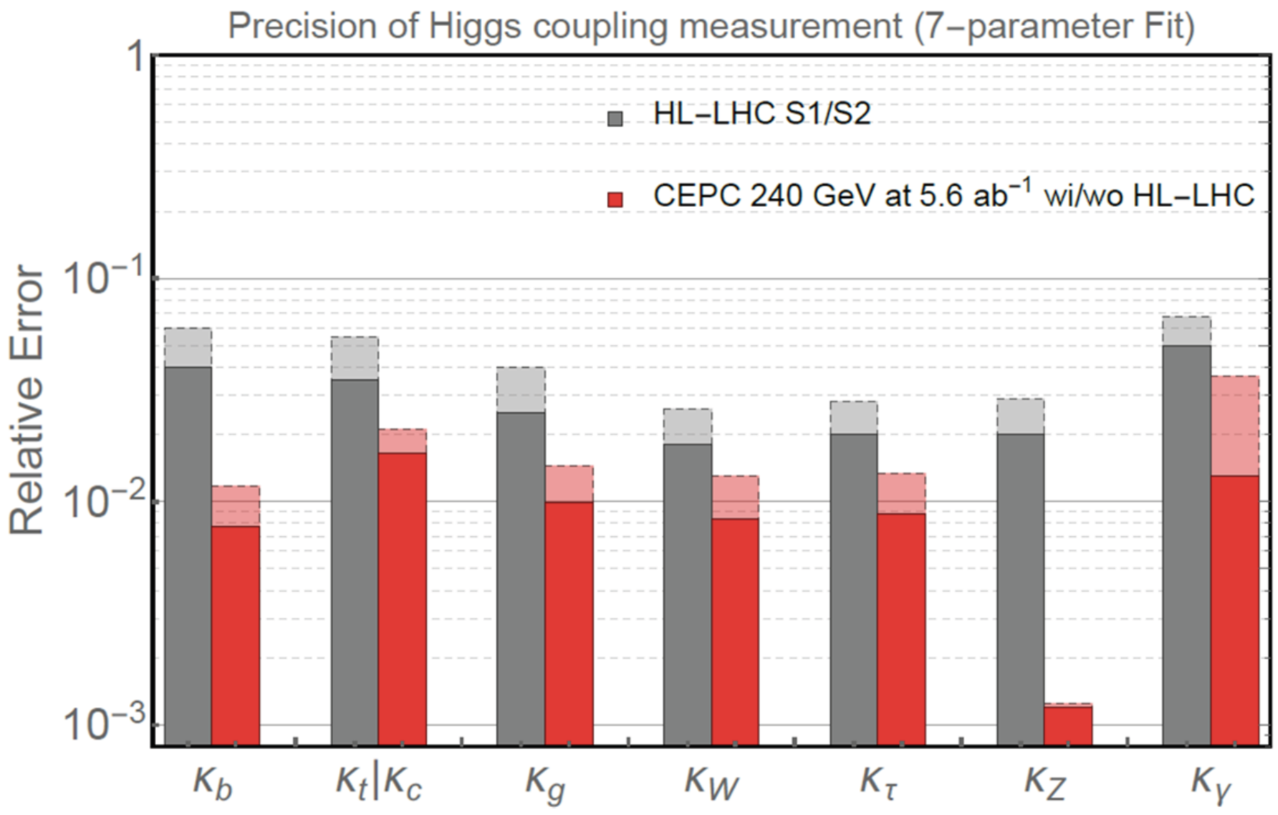
Chinese Physics C Vol. 43, No. 4 (2019) 043002



CEPC Physics Performance (CDR)

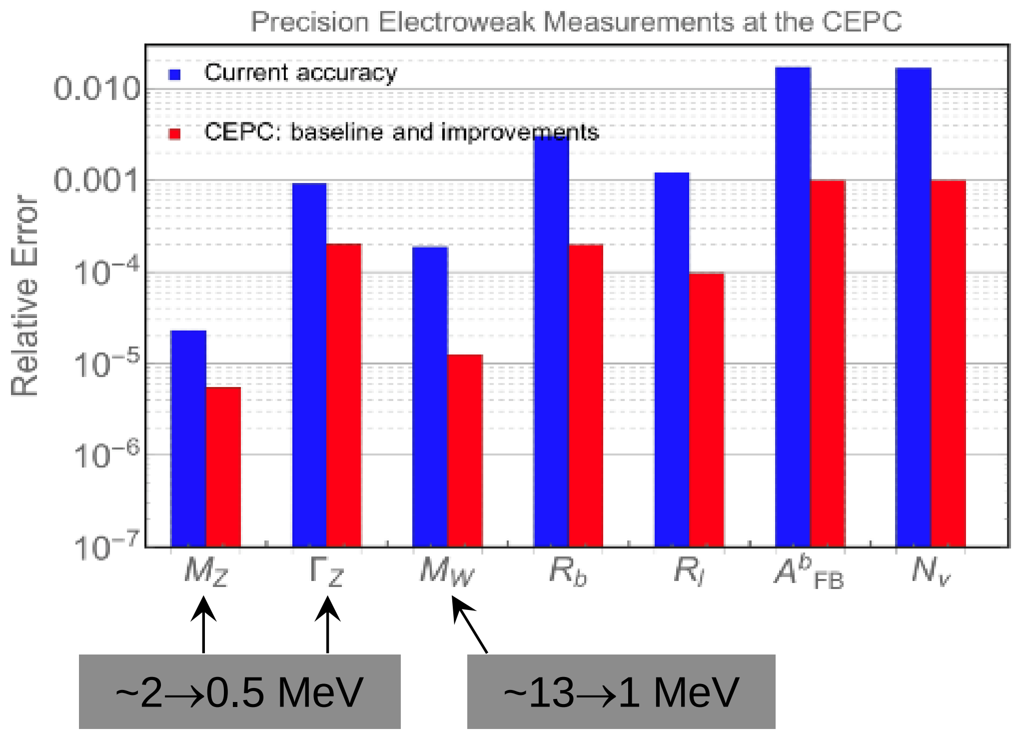
Order of magnitude improvement in precision ⇒ Unknown / discoveries

Compare to the HL-LHC, CEPC can improve the precision of Higgs couplings significantly



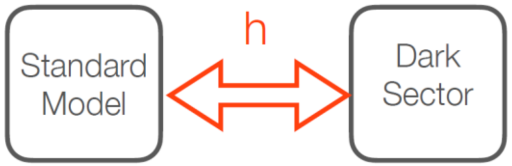
Chinese Physics C Vol. 43, No. 4 (2019) 043002

CEPC can improve the precision of the EW parameters by a factor of ~ 5-10

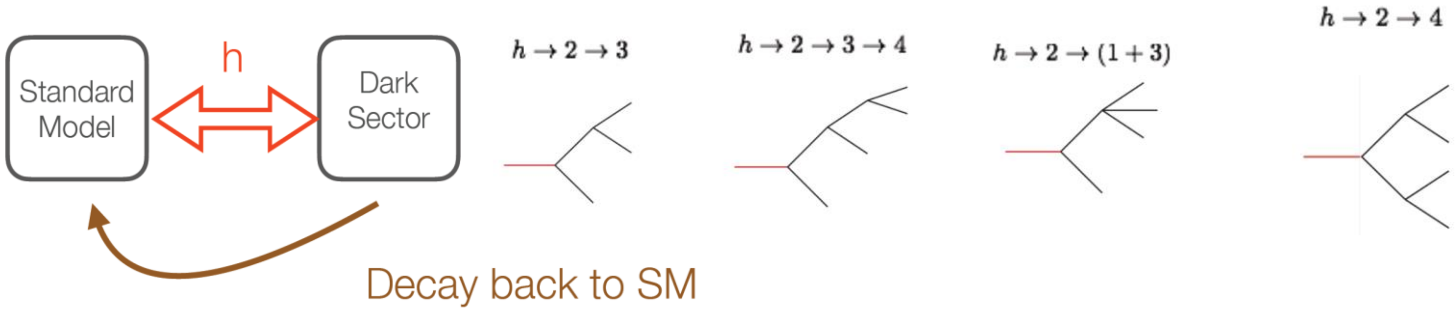


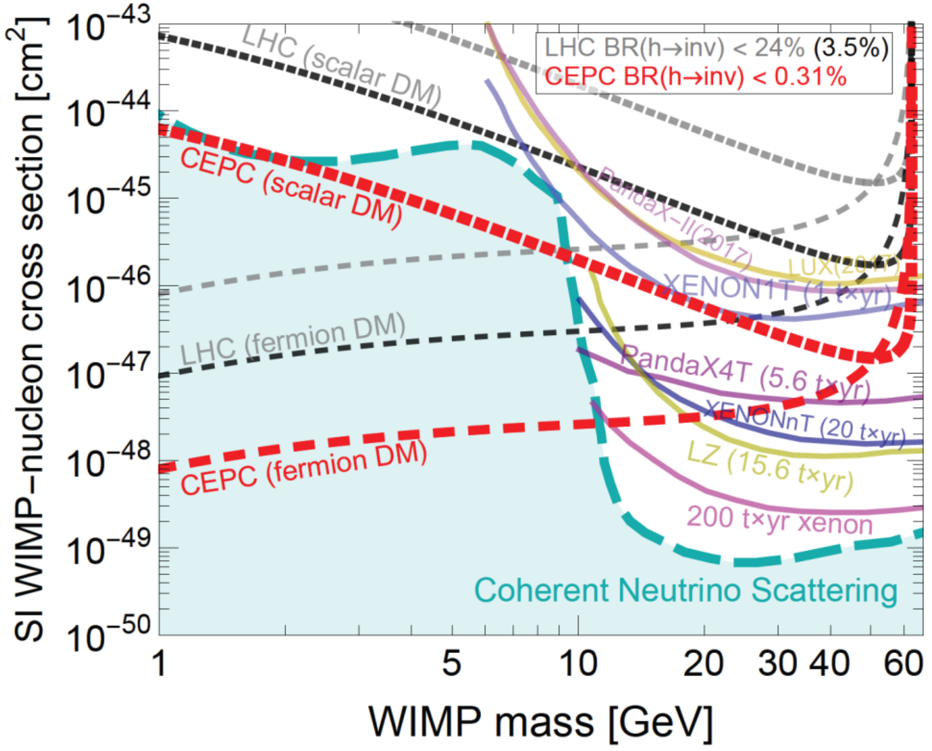
- ❑ **Precision EW measurements,**
- ❑ **Flavor physics (b, c, tau),**
- ❑ **Study of QCD,**
- ❑ **Probe physics BSM.**

Discovery Potential for New Physics

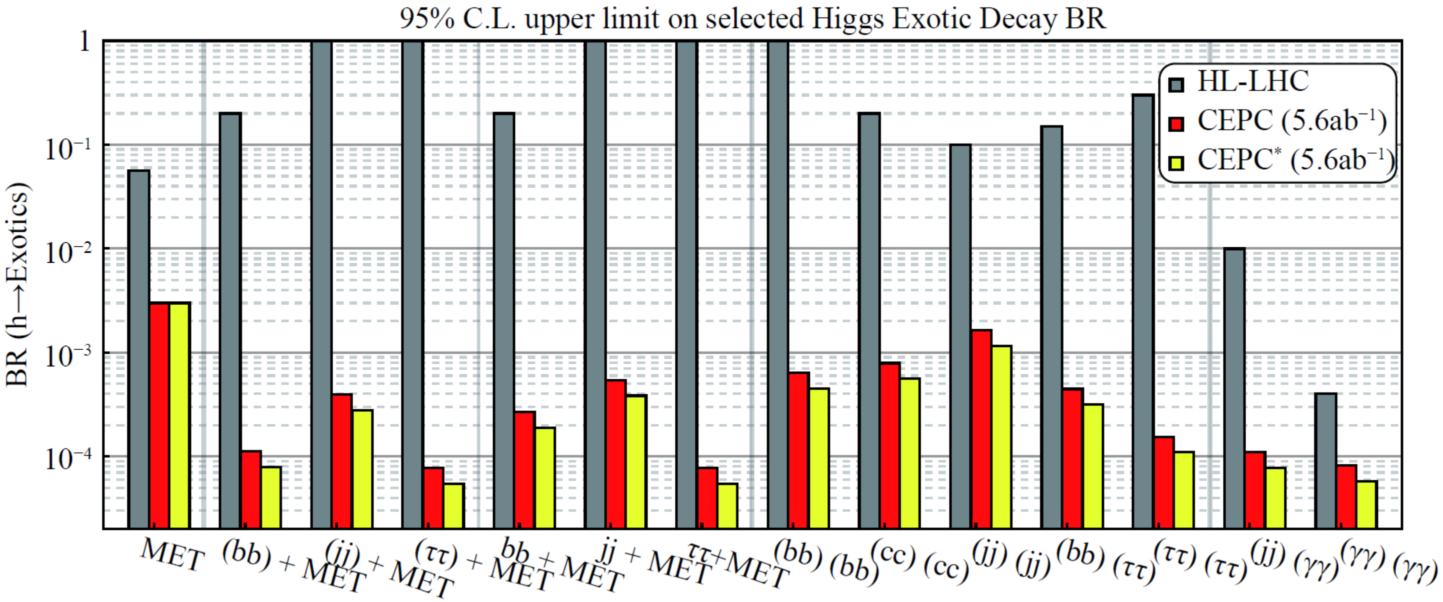


$$h \rightarrow X_{dm} X_{dm}$$





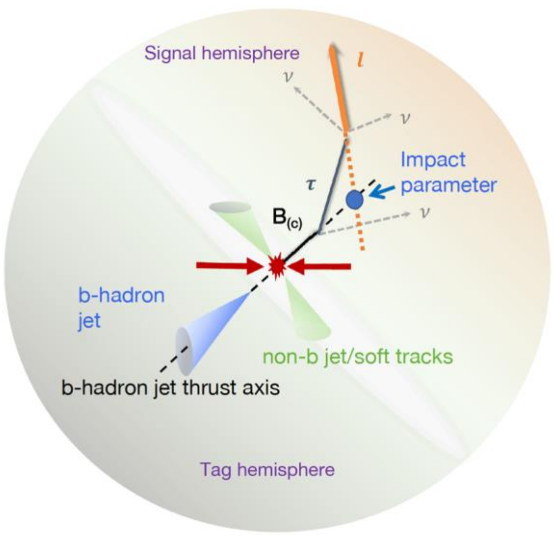
Higgs decays into BSM particles, H→ X_1X_2

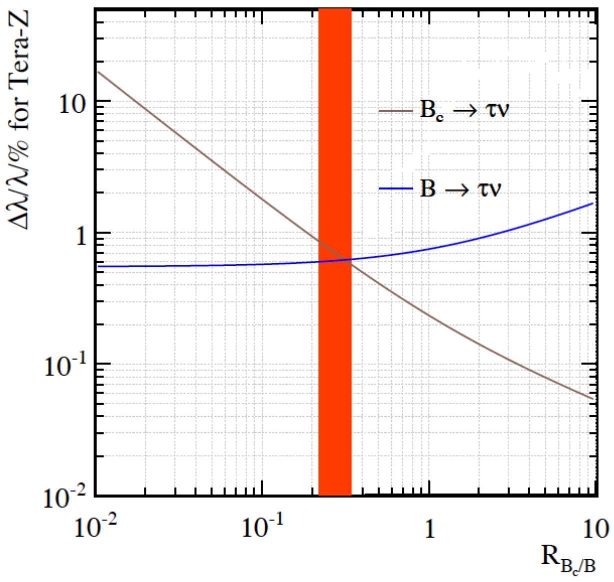


CEPC has significantly better detection sensitivity for dark matter and selected Higgs exotic decays than HL-LHC

CEPC Flavor Physics

Analysis of $B_c \to \tau\nu_\tau$ at CEPC → |Vcb|~O(1%)
T. Zheng et.al., CPC 45, No. 2 (2021)





Chinese Physics C Vol. 45, No. 2 (2021)

Analysis of $B_c \to \tau\nu_\tau$ at CEPC*

Taifan Zheng(郑太范)[1] Ji Xu(徐吉)[2] Lu Cao(曹璐)[3] Dan Yu(于丹)[4] Wei Wang(王伟)[2] Soeren Prell[5] Yeuk-Kwan E. Cheung(张若筠)[1] Manqi Ruan(阮曼奇)[4†]

[1]School of Physics, Nanjing University, Nanjing 210023, China
[2]INPAC, SKLPPC, MOE KLPPC, School of Physics and Astronomy, Shanghai Jiao Tong University, Shanghai 200240, China
[3]Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn, 53115 Bonn, Germany
[4]Institute of High Energy Physics, Beijing 100049, China
[5]Department of Physics and Astronomy, Iowa State University, Ames, IA, USA

Abstract: Precise determination of the $B_c \to \tau\nu_\tau$ branching ratio provides an advantageous opportunity for understanding the electroweak structure of the Standard Model, measuring the CKM matrix element $|V_{cb}|$, and probing new physics models. In this paper, we discuss the potential of measuring the process $B_c \to \tau\nu_\tau$ with τ decaying leptonically at the proposed Circular Electron Positron Collider (CEPC). We conclude that during the Z pole operation, the channel signal can achieve five-σ significance with $\sim 10^9$ Z decays, and the signal strength accuracies for $B_c \to \tau\nu_\tau$ can reach around 1% level at the nominal CEPC Z pole statistics of one trillion Z decays, assuming the total $B_c \to \tau\nu_\tau$ yield is 3.6×10^6. Our theoretical analysis indicates the accuracy could provide a strong constraint on the general effective Hamiltonian for the $b \to c\tau\nu$ transition. If the total B_c yield can be determined to $O(1\%)$ level of accuracy in the future, these results also imply $|V_{cb}|$ could be measured up to $O(1\%)$ level of accuracy.

Test of Lepton-Flavor-Universality (LFU)
L.F. Li, T. Liu, JHEP 06 (2021) 064

	Experimental	SM Prediction
R_K	$0.745^{+0.090}_{-0.074} \pm 0.036$	1.00 ± 0.01 [4]
R_{K^*}	$0.69^{+0.12}_{-0.09}$	0.996 ± 0.002 [5]
R_D	0.340 ± 0.030	0.299 ± 0.003
R_{D^*}	0.295 ± 0.014	0.258 ± 0.005

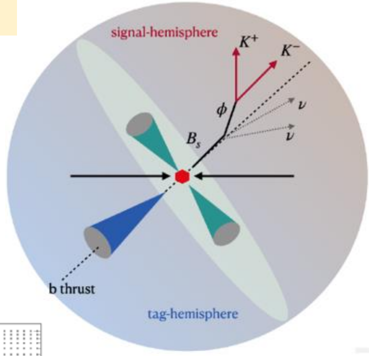
R_{K^*} & R_{D^*} anomalies at level of 2-3σ.

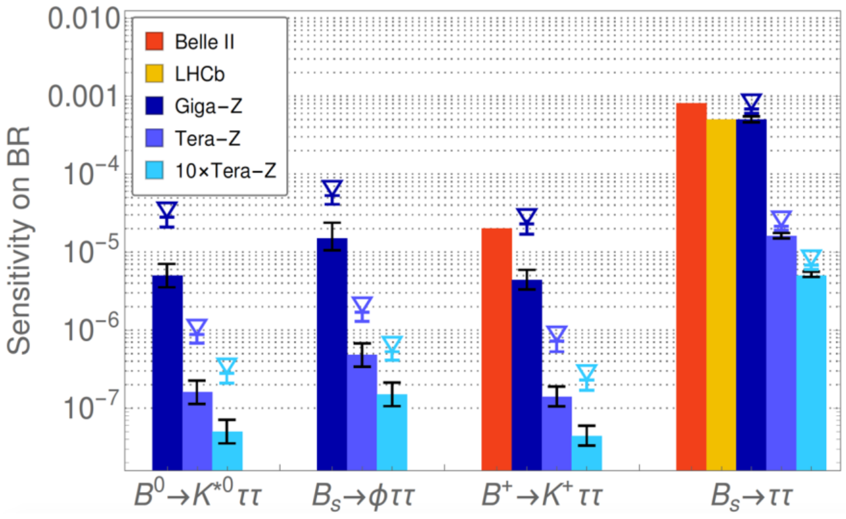
$$R_{K^{(*)}} \equiv \frac{\mathrm{BR}(B \to K^{(*)}\mu^+\mu^-)}{\mathrm{BR}(B \to K^{(*)}e^+e^-)}$$

$$R_{D^{(*)}} \equiv \frac{\mathrm{BR}(B \to D^{(*)}\tau\nu)}{\mathrm{BR}(B \to D^{(*)}\ell\nu)}$$

$b \to s\,\tau^+\tau^-$ is motivated to address LFU violating puzzle involving 3rd generation lepton directly.

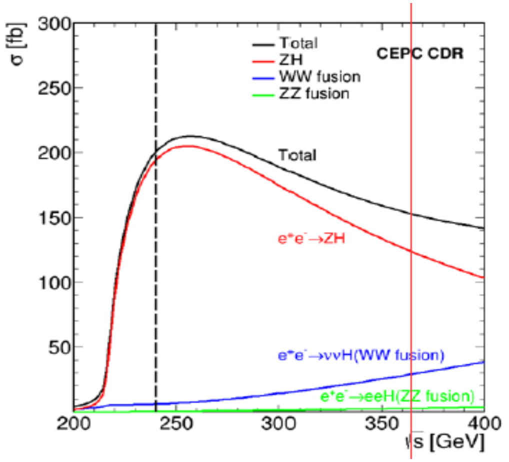
Channel	SM prediction for BR
$B^0 \to K^{*0}\tau^+\tau^-$	$(0.98 \pm 0.10) \times 10^{-7}$ [11]
$B_s \to \phi\tau^+\tau^-$	$(0.86 \pm 0.06) \times 10^{-7}$ [11]
$B^+ \to K^+\tau^+\tau^-$	$(1.20 \pm 0.12) \times 10^{-7}$ [11]
$B_s \to \tau^+\tau^-$	$(7.73 \pm 0.49) \times 10^{-7}$ [12]



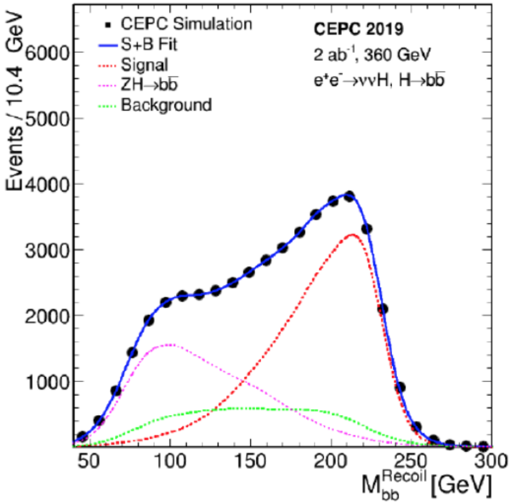


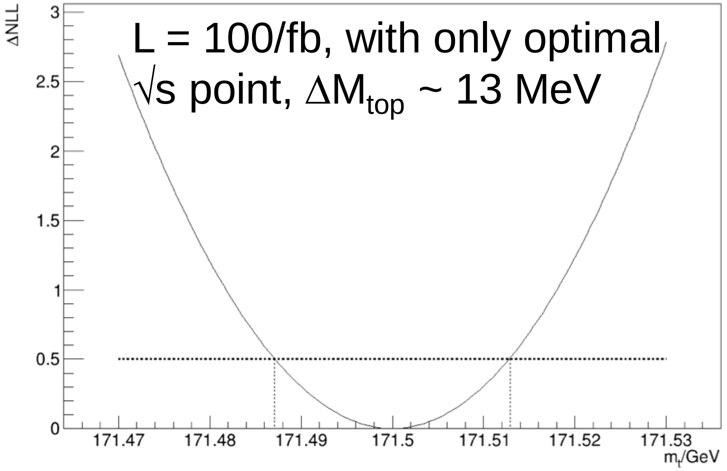
CEPC Physics at 360 GeV

- 360 GeV run provides critical inputs from the WW-fusion Higgs productions
- Useful for measuring $\kappa_W, \kappa_Z, \Gamma_h$, Global EFT fit
- With 2 ab^{-1}, H width precision ~ 1.4% (x2 improvement)

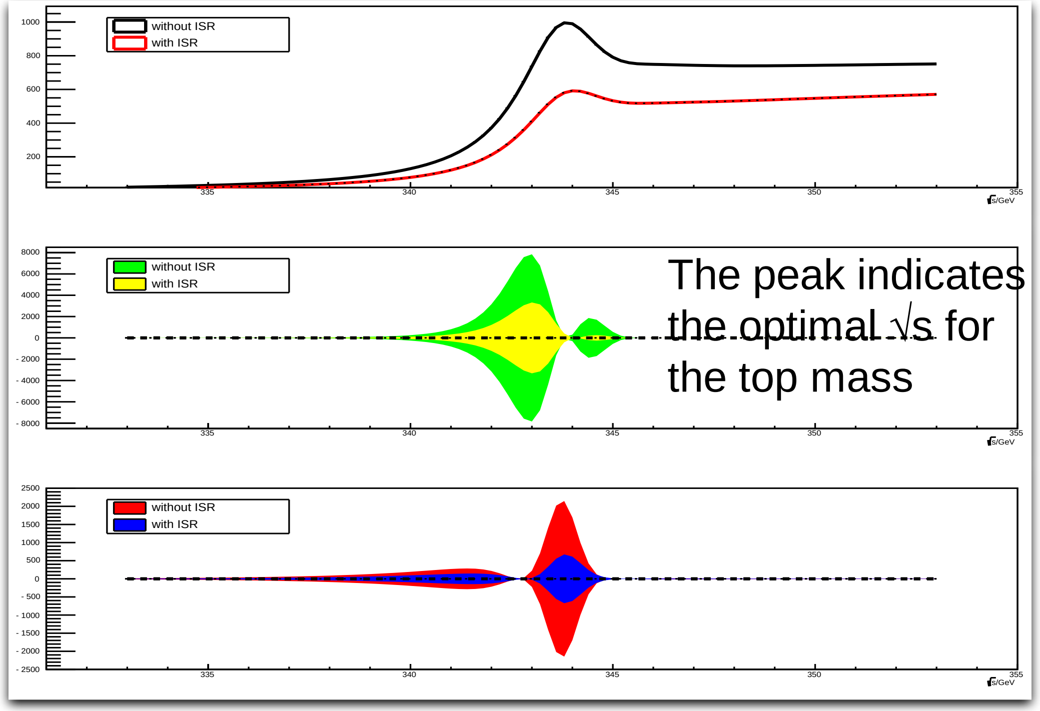


	240GeV, 5.6ab^{-1}	360GeV, 2ab^{-1}	
	ZH	ZH	ννH
any	0.50%	1%	\
$\mathrm{H} \to \mathrm{bb}$	0.27%	0.63%	0.76%
$\mathrm{H} \to \mathrm{cc}$	3.3%	6.2%	11%
$\mathrm{H} \to \mathrm{gg}$	1.3%	2.4%	3.2%
$\mathrm{H} \to \mathrm{WW}$	1.0%	2.0%	3.1%
$\mathrm{H} \to \mathrm{ZZ}$	7.9%	14%	15%
$\mathrm{H} \to \tau\tau$	0.8%	1.5%	3%
$\mathrm{H} \to \gamma\gamma$	5.7%	8%	11%
$\mathrm{H} \to \mu\mu$	12%	29%	40%
$\mathrm{Br_{upper}}(\mathrm{H} \to \mathrm{inv.})$	0.2%	\	\
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to Z\gamma)$	16%	25%	\
Width	2.8%	1.4%	





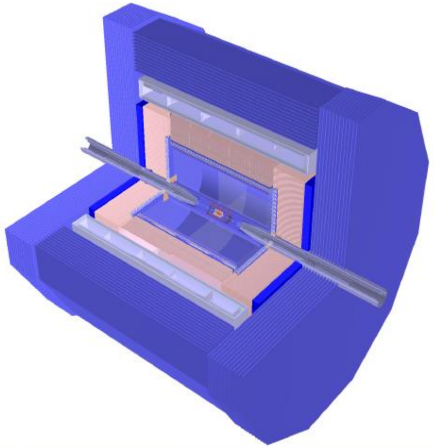
- Currently we study the top mass and width using tt threshold method:
  - One order of magnitude better precision than the LHC is expected
  - A quick energy scan with low lumi to find the optimal energy point before data taking with the full lumi. is proposed

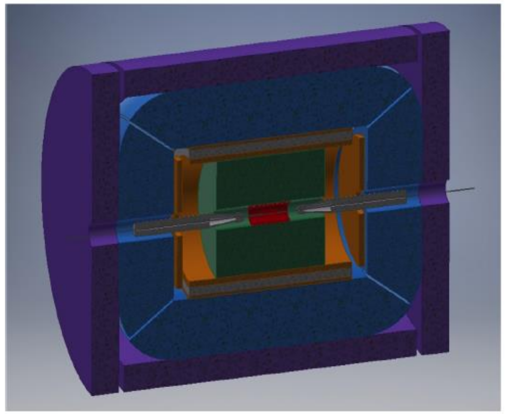


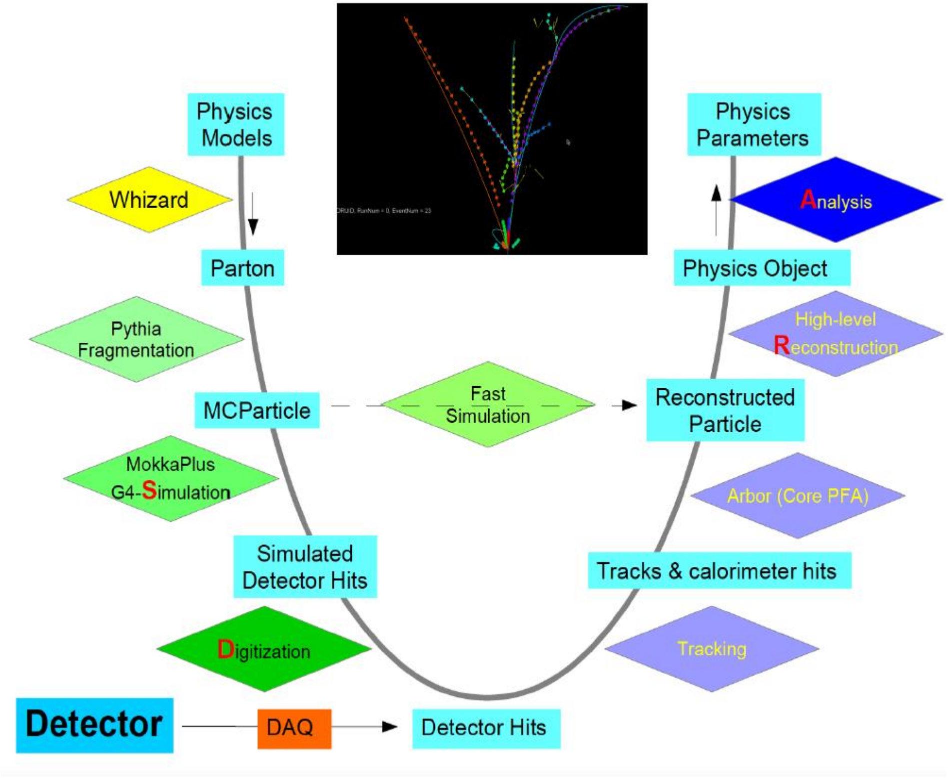
CEPC Detector and Software

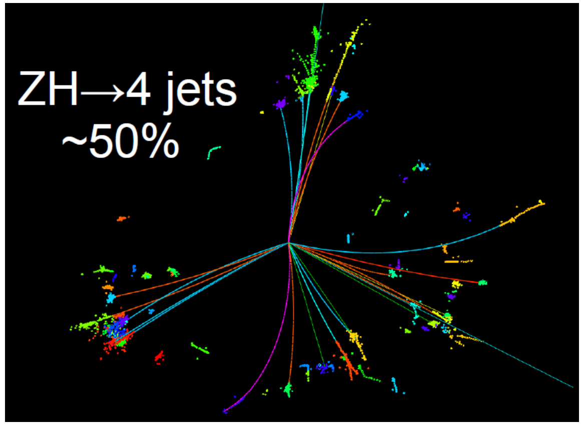
Recent added CEPC software applications:

- **Software for SiTrk + DC design, detector description and track fitting**
- **Cluster counting method of Drift Chamber (DC)**
- **Simulation and simplified digitization of the crystal bar ECal**

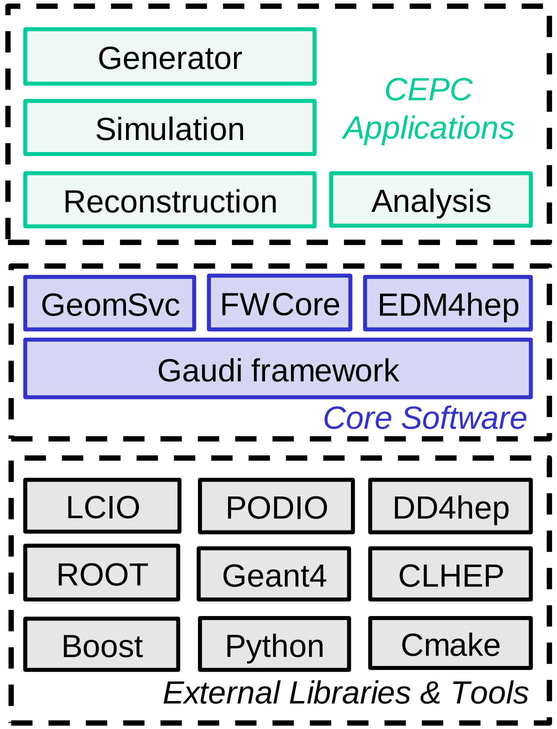








CEPCSW Structure



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

Requirements of CEPC Detector

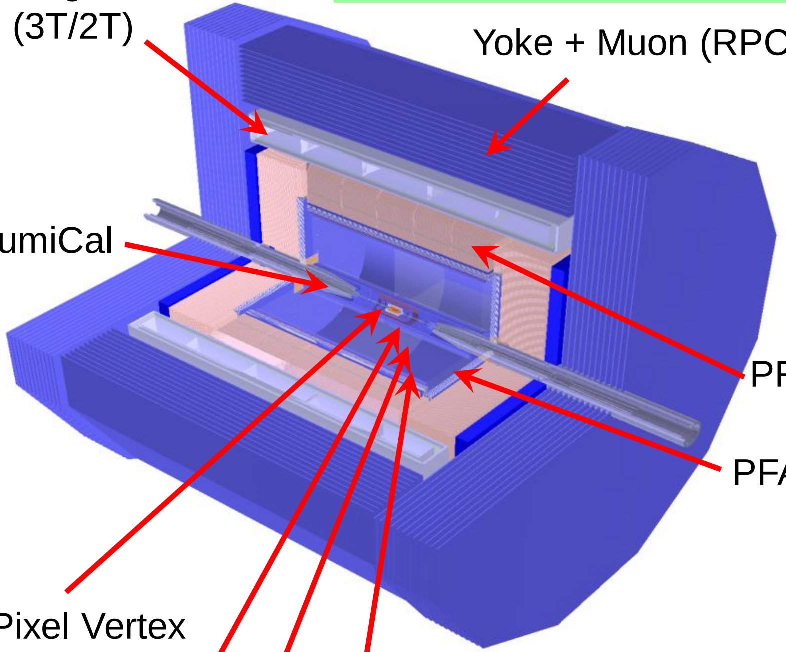
The physics motivations dictate our selection of detector technologies

Physics process	Measurands	Detector subsystem	Performance requirement
$ZH, Z \to e^+e^-, \mu^+\mu^-$ $H \to \mu^+\mu^-$	$m_H, \sigma(ZH)$ $\mathrm{BR}(H \to \mu^+\mu^-)$	Tracker	$\Delta(1/p_T) =$ $2 \times 10^{-5} \oplus \frac{0.001}{p(\mathrm{GeV}) \sin^{3/2}\theta}$
$H \to b\bar{b}/c\bar{c}/gg$	$\mathrm{BR}(H \to b\bar{b}/c\bar{c}/gg)$	Vertex	$\sigma_{r\phi} =$ $5 \oplus \frac{10}{p(\mathrm{GeV}) \times \sin^{3/2}\theta} (\mu\mathrm{m})$
$H \to q\bar{q}, WW^*, ZZ^*$	$\mathrm{BR}(H \to q\bar{q}, WW^*, ZZ^*)$	ECAL HCAL	$\sigma_E^{\mathrm{jet}}/E =$ $3 \sim 4\%$ at 100 GeV
$H \to \gamma\gamma$	$\mathrm{BR}(H \to \gamma\gamma)$	ECAL	$\Delta E/E =$ $\frac{0.20}{\sqrt{E(\mathrm{GeV})}} \oplus 0.01$

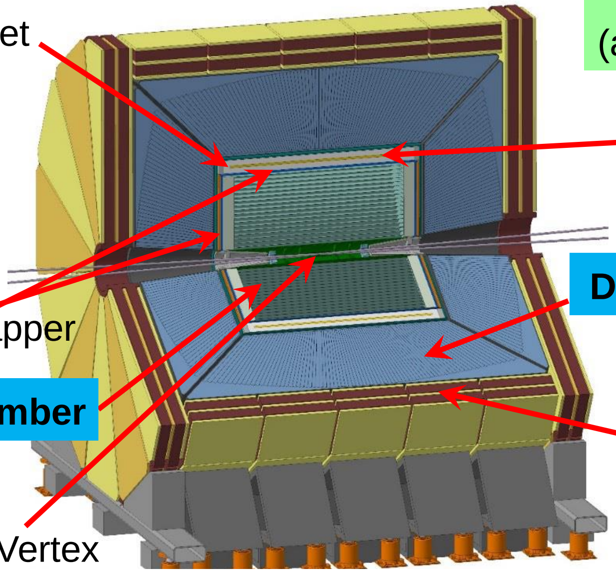
- **Flavor physics $\Rightarrow$ Excellent PID, better than 2σ separation of π/K at momentum up to ~20 GeV.**
- **EW measurements $\Rightarrow$ High precision luminosity measurement, $\delta L / L \sim 10^{-4}$.**

Conceptual Detector Designs

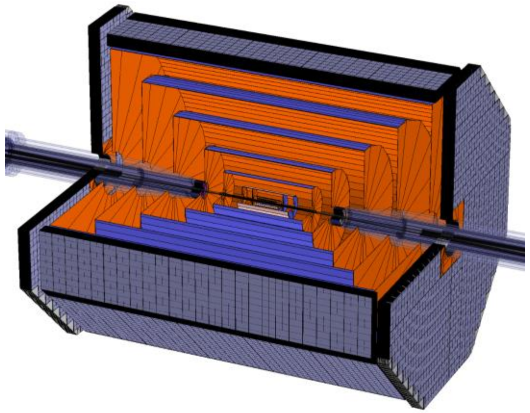
(Baseline Design)
Particle Flow Approach



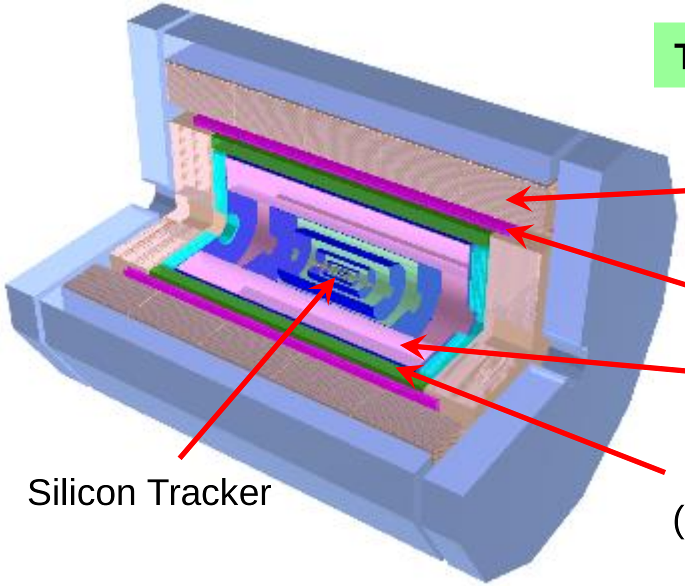
IDEA concept
(also proposed for FCC-ee)



FST concept
(Full Silicon Tracker)



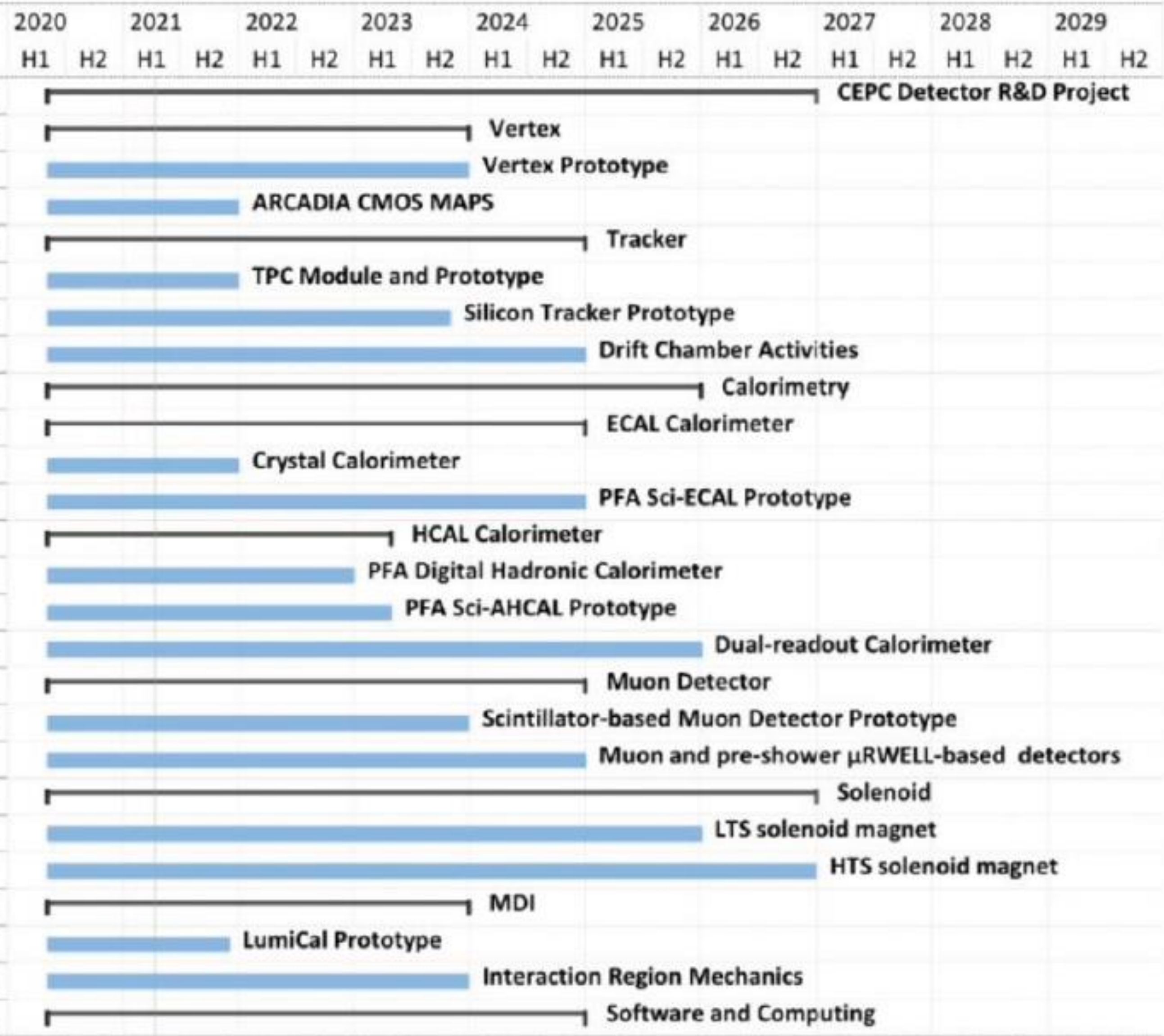
The 4th Concept



IDRDC Preparation: R&D Schedule

Scheduled R&D activities included in summary document

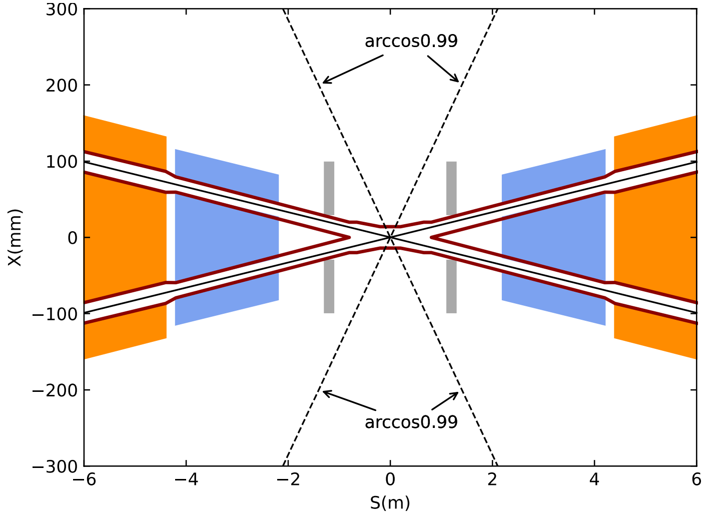
PBS	Task Name	Start	Finish
	CEPC Detector R&D Project	**2020/5/7**	**2026/12/31**
1	**Vertex**	**2020/5/7**	**2023/12/29**
1.1	Vertex Prototype	2020/5/7	2023/12/29
1.2	ARCADIA CMOS MAPS	2020/5/7	2021/12/31
2	**Tracker**	**2020/5/7**	**2024/12/31**
2.1	**TPC Module and Prototype**	**2020/5/7**	**2021/12/31**
2.2	**Silicon Tracker Prototype**	**2020/5/7**	**2023/10/31**
2.3	**Drift Chamber Activities**	**2020/5/7**	**2024/12/31**
3	**Calorimetry**	**2020/5/7**	**2025/12/31**
3.1	**ECAL Calorimeter**	**2020/5/7**	**2024/12/31**
3.1.1	Crystal Calorimeter	2020/5/7	2021/12/31
3.1.2	PFA Sci-ECAL Prototype	2020/5/7	2024/12/31
3.2	**HCAL Calorimeter**	**2020/5/7**	**2023/4/28**
3.2.1	PFA Digital Hadronic Calorimeter	2020/5/7	2022/12/30
3.2.2	PFA Sci-AHCAL Prototype	2020/5/7	2023/4/28
3.3	**Dual-readout Calorimeter**	**2020/5/7**	**2025/12/31**
4	**Muon Detector**	**2020/5/7**	**2024/12/31**
4.1	Scintillator-based Muon Detector Prototype	2020/5/7	2023/12/29
4.2	Muon and pre-shower μRWELL-based detectc	2020/5/7	2024/12/31
5	**Solenoid**	**2020/5/7**	**2026/12/31**
5.1	LTS solenoid magnet	2020/5/7	2025/12/31
5.2	HTS solenoid magnet	2020/5/7	2026/12/31
6	**MDI**	**2020/5/7**	**2023/12/29**
6.1	LumiCal Prototype	2020/5/7	2021/12/1
6.2	Interaction Region Mechanics	2020/5/7	2023/12/29
8	**Software and Computing**	**2020/5/7**	**2024/12/31**

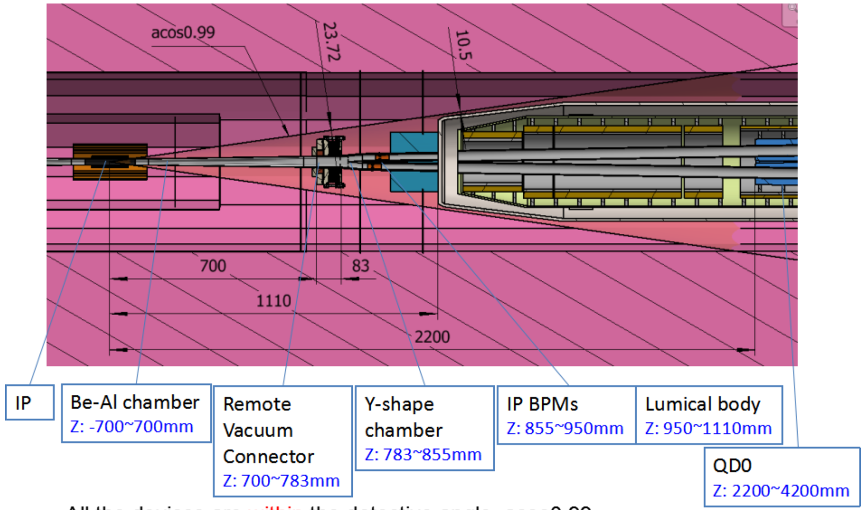


CEPC R&D: Machine Detector Interface (MDI)

Crossing angle: 33 mrad

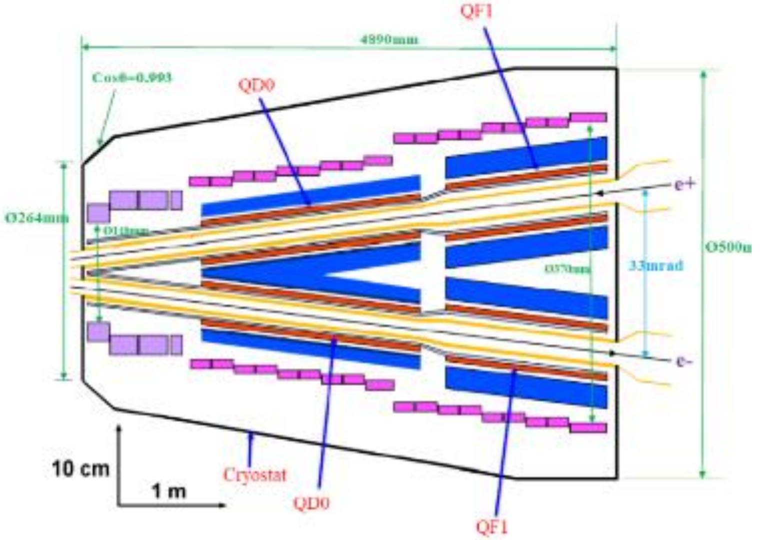
Focal length: 2.2 m





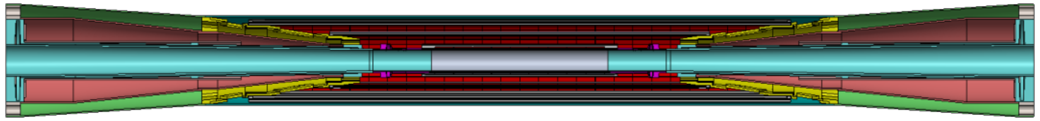
- All the devices are within the detective angle, acos0.99.

Final focusing magnets (QD0, QF1) with Segmented Anti-Solenoidal Magnets

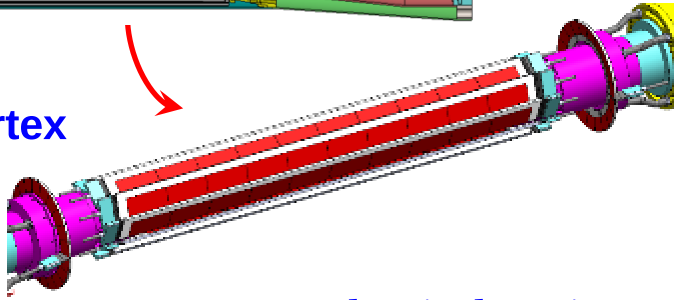


Beam Pipe

ϕ 28→20 mm, Be thickness: 0.85→0.35 mm

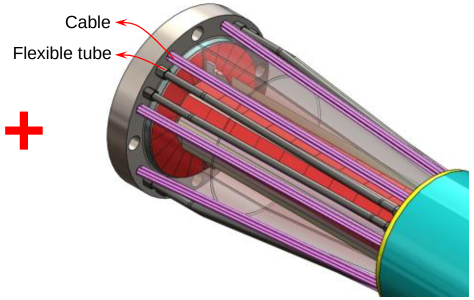


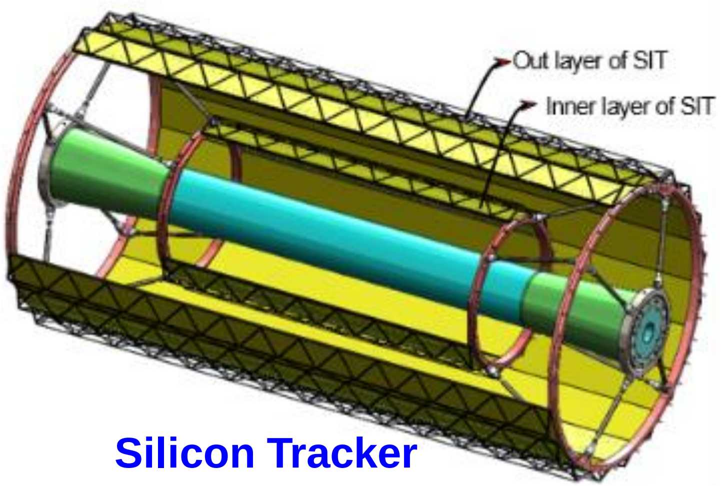
Vertex



+

LumiCal Tracker



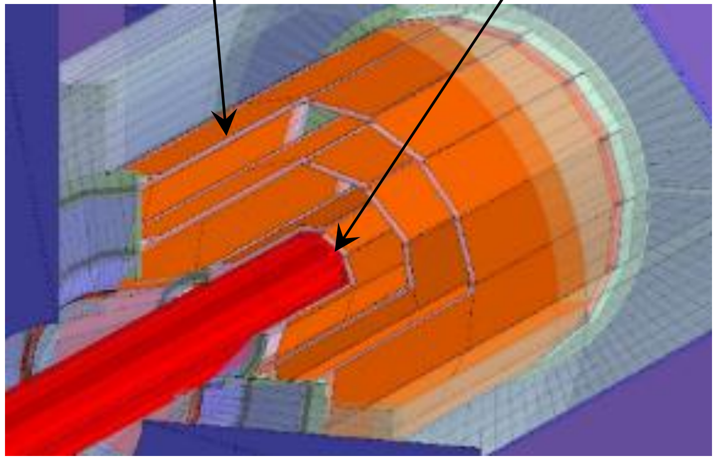


Silicon Tracker

2021 Workshop on CEPC Detector & MDI Mechanical Design
https://indico.ihep.ac.cn/event/14392/ Dongguan, Oct.22-23,2021

CEPC R&D: Silicon Pixel ASIC Chips

2 layers / ladder R_{in}~16 mm



Goal: σ(IP) ~ 5 μm for high P track

CDR design specifications

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

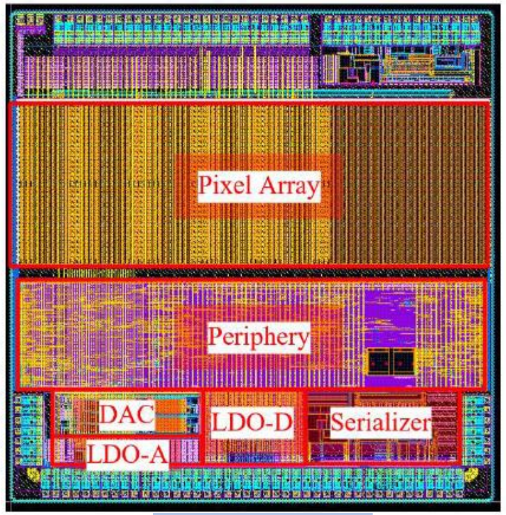
Silicon pixel sensor develops in 3 series:
JadePix, TaichuPix, CPV

JadePix-3 Pixel size ~16×23 μm^2

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

MOST 1

TaichuPix-2, 64×192 array
25×24 μm^2 pixel size

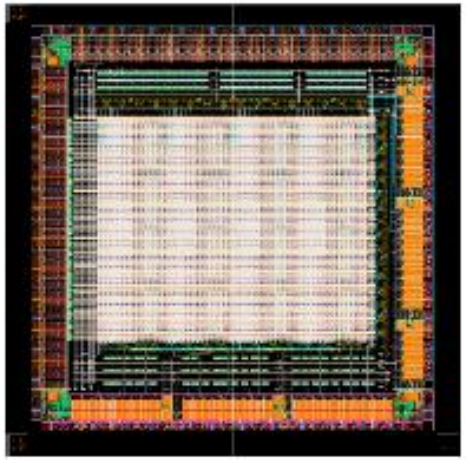


Full size TaichuPix-3 to be used for prototyping ladder

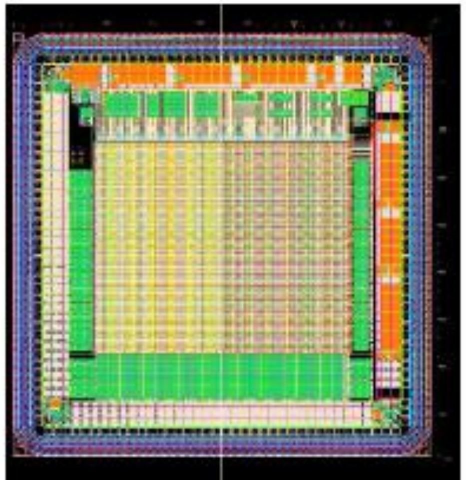
MOST 2

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

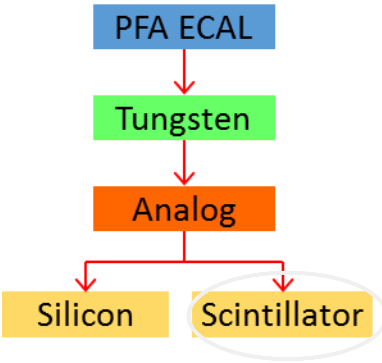
Upper chip



Lower chip



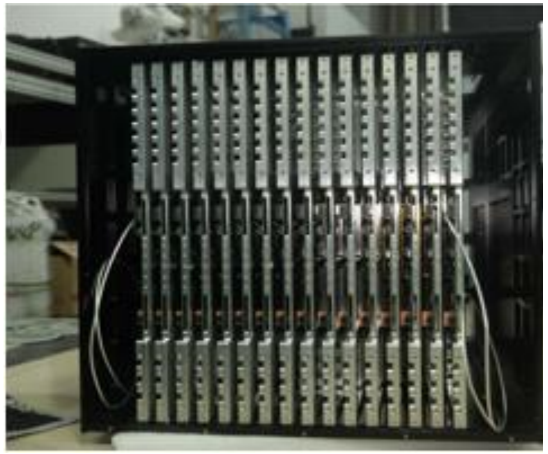
CEPC R&D: ScW-ECAL Prototype

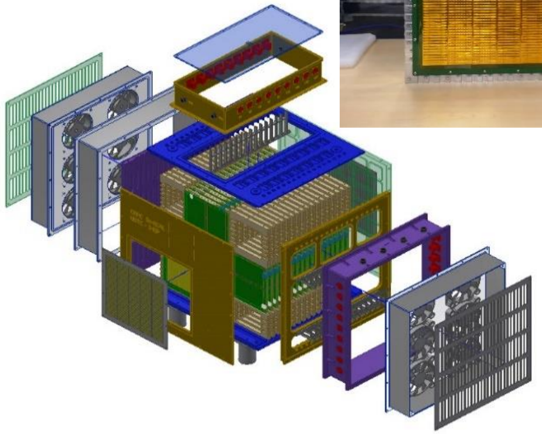


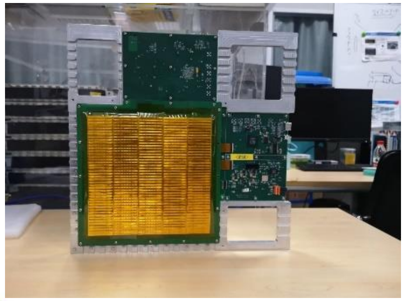
Goal of ECAL+HCAL+…

4% BMR, e.g. in (Z→νν) (H→gg)

MOST 1







ScECAL prototype with 6700 channels

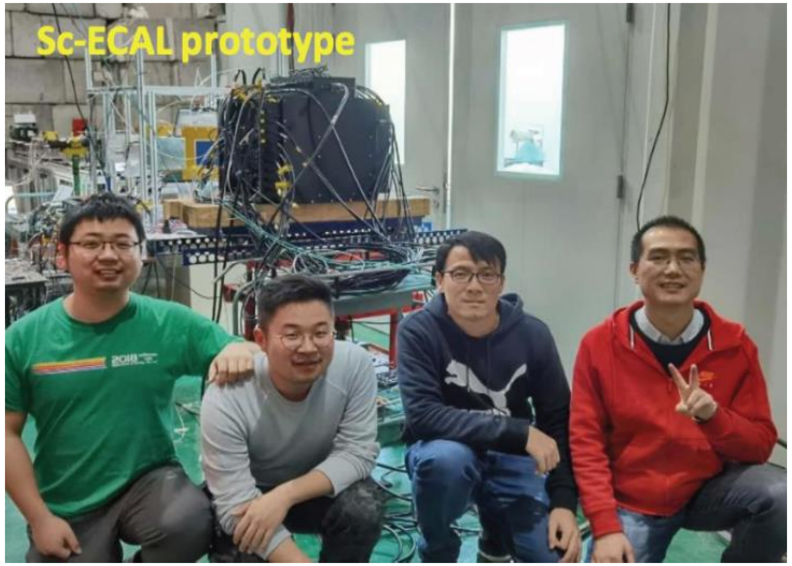
32 layers (EBU), 22 x 22 cm^2, ~22X_0

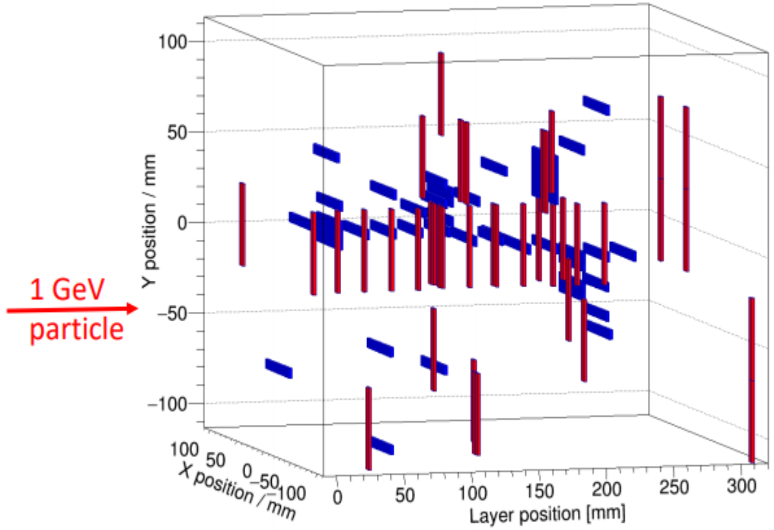
Scintillator (5×45mm^2) + MPPC S12571

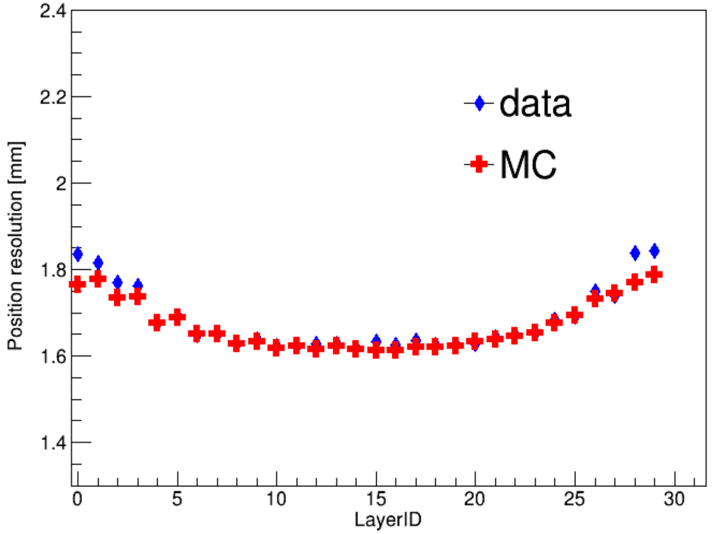
Embedded FEE (192 SPIROC2E ASICs)

It has been tested with cosmic rays & an electron beam at IHEP (Nov. 2020).

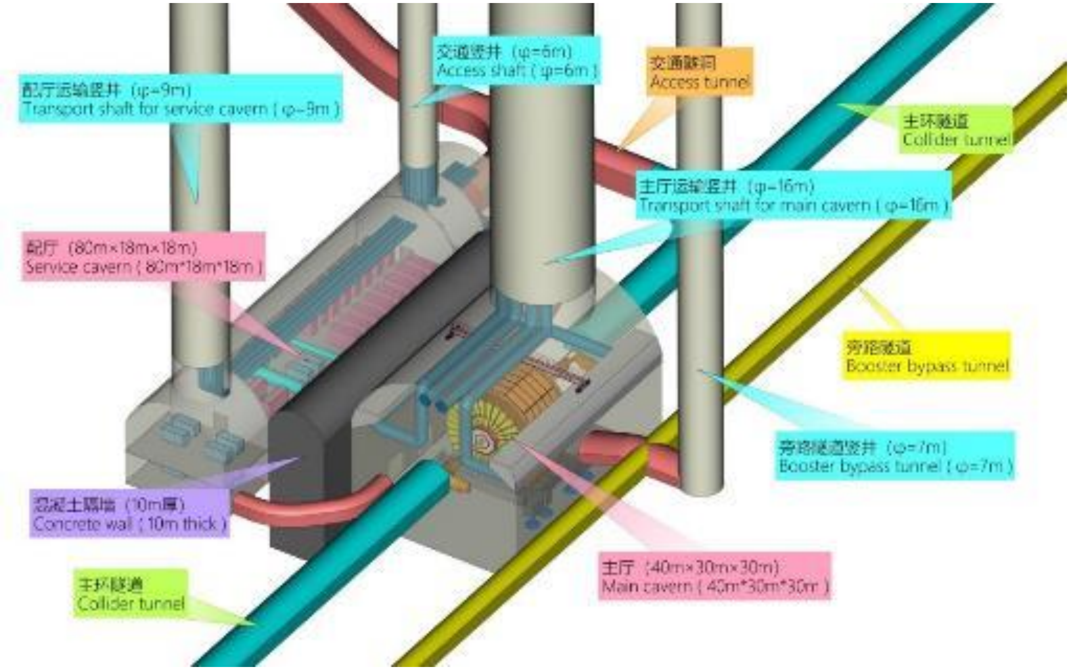
Cell Granularity: 5mm × 5mm
Position resolution: 1.6-1.8mm







The Experimental Area



Ground level buildings

Main cavern to host the detector

- 40*30*30 m^3 (L*H*W)
- One main access shaft, Ø16 m
- An 1K-ton gantry crane for large heavy objects

Auxiliary cavern for peripheral equipment and devices

- 80*18*18 m^3 (L*H*W)
- One service shaft of Ø9 m
- One personnel access shaft Ø6 m

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