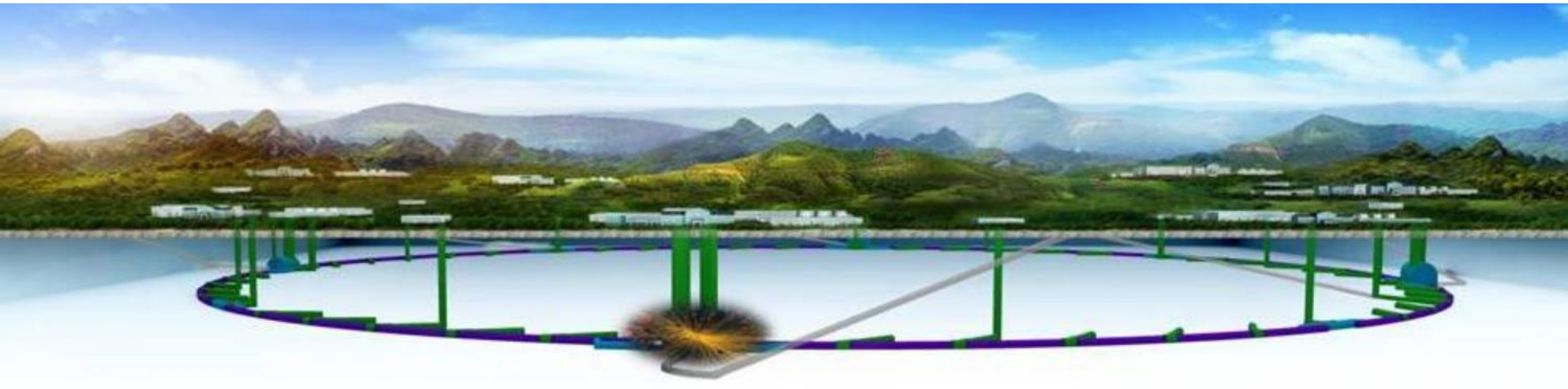
CEPC Project Overview

XinChou Lou

Institute of High Energy Physics (Beijing)

The 2019 Workshop on High Energy Circular Electron-Positron Collider



Outline

Introduction

- Reminders
- Goals and plan
- Roadmap and schedule

CEPC project development

- Conceptual design reports (CDR)
- Design-phys. enhancement, R&D, infrastructure
- International collaboration
- Site investigation & domestic relations
- Cultivation of CEPC

Reminders

Reminder about the CEPC-SppC

e^+e^- Higgs (Z) factory

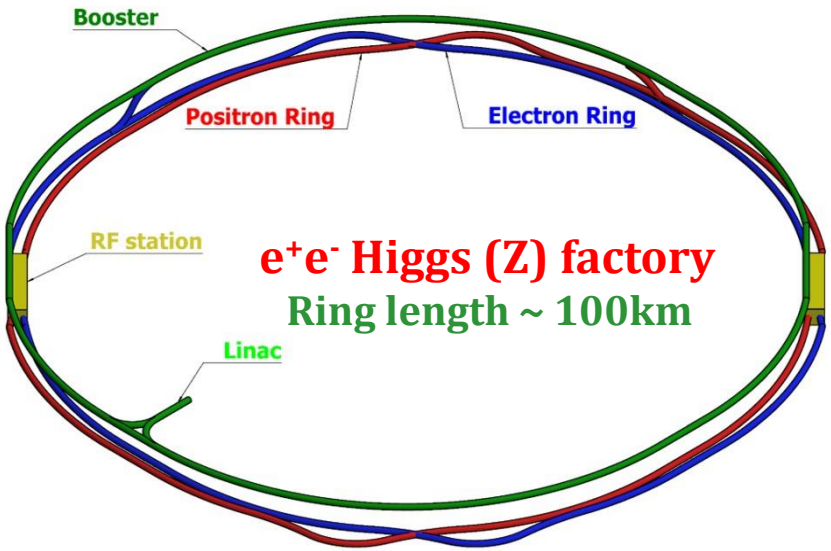
E_{cm}≈240GeV, luminosity ≥2×10^{34} $cm^{-2}s^{-1}$, 2IP，1M H in 10 years
at the Z-pole 10^{10}Z bosons/yr

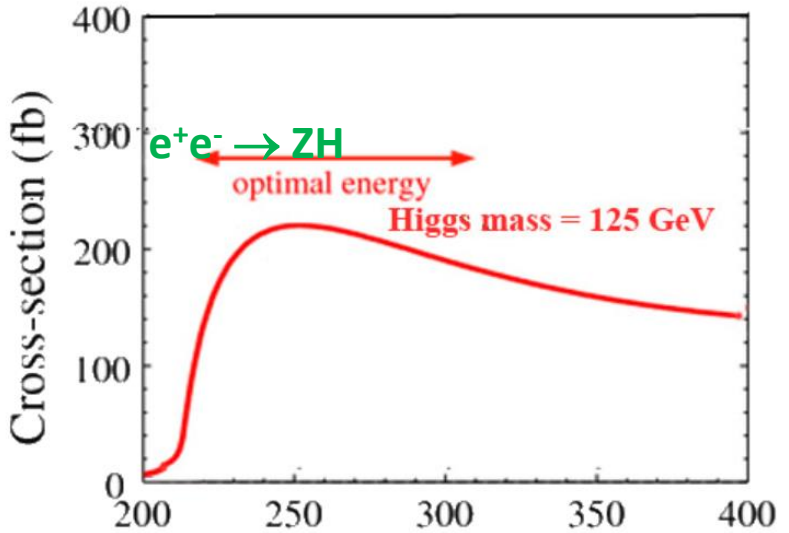
Precision measurement of the Higgs boson (and the Z boson)

Higgs precision
1% or better

Upgradable to pp collision with E_{cm} ≈ 50-100 TeV (with ep, HI options**)**

A discovery machine for BSM new physics





BEPCII will likely complete its mission ~ late 2020s;

CEPC – possible accelerator based particle physics program in China after BII

Reminder about the CEPC-SppC

Kick-off on Sept. 13, 2013 - inspired by the discovery of the Higgs boson at the LHC

CEPC study group formed in Beijing

PreCDR, March 2015 – initial investigations; no-show stoppers, identified issues & R&D

Funding, R&D, international collaboration, … – continuing effort since 2013

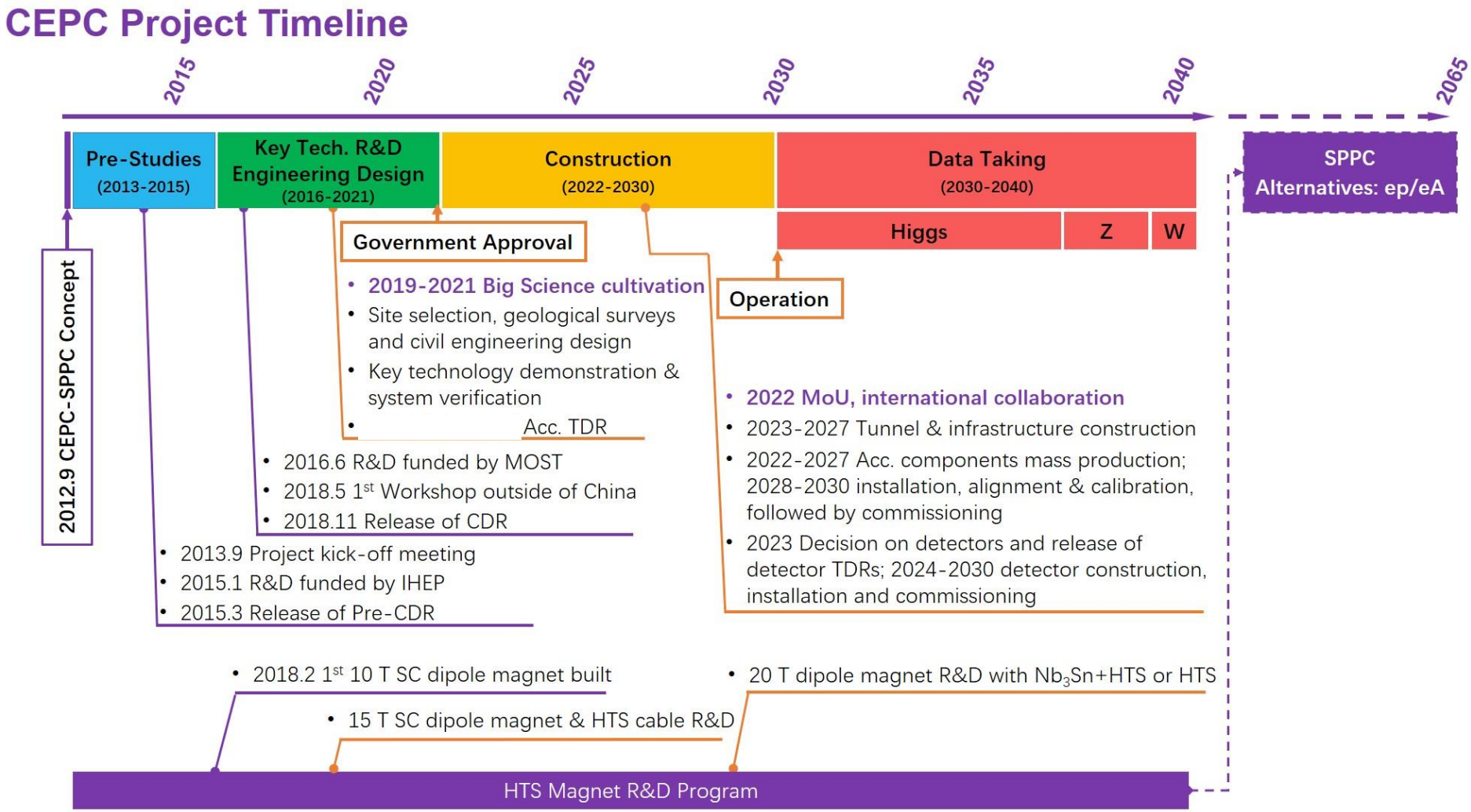
CDR, August-October 2018 – scientific goals well justified & aligned with intl priorities; endorsement for moving towards TDR, and …

CEPC accelerator TDR, DRD, luminosity enhancement, international collaboration, …

Goals and Plan

- Design + R&D (DR&D), validation, and industrial preparation
- Global collaboration and strategy
- Best positioning CEPC for national government's positive decision
- Realization of the CEPC project, the experimental program and pursue the science

CEPC Roadmap and Schedule (ideal)



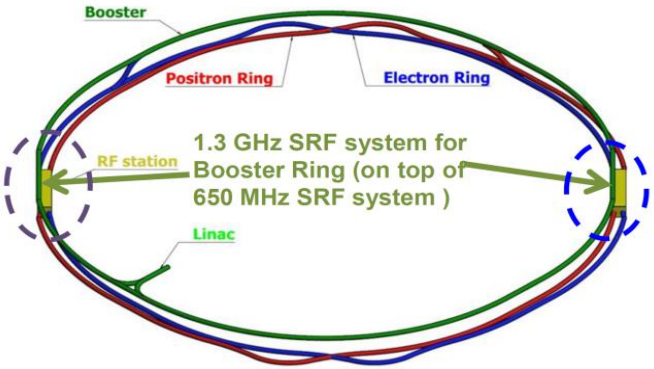
Conceptual design

CEPC CDR

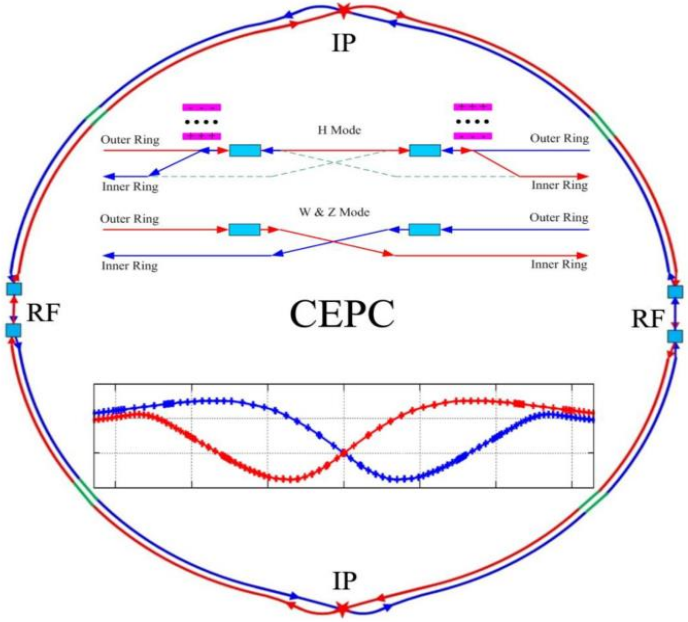
Lumi.	Higgs	W	Z	Z(2T)
$\times 10^{34}$	2.93	11.5	16.6	32.1

Luminosities exceeded those in the preCDR

- double ring baseline design (30MW/beam)
- switchable between H and Z/W w/o hardware change (magnet switch)
- use half SRF for Z and W
- can be optimized for Z with 2T detector



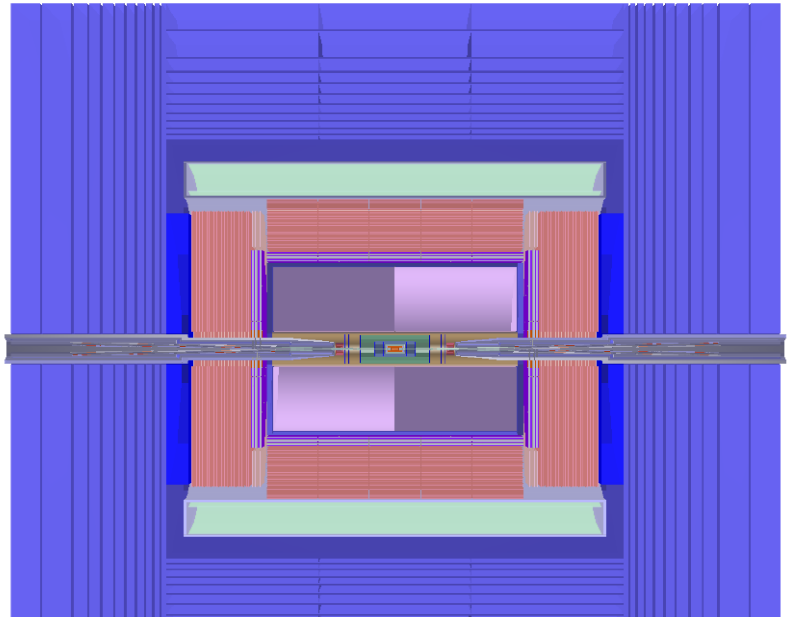
SRF system location of CEPC (two RF stations)



Layout of 650 MHz SRF system for Collider Ring

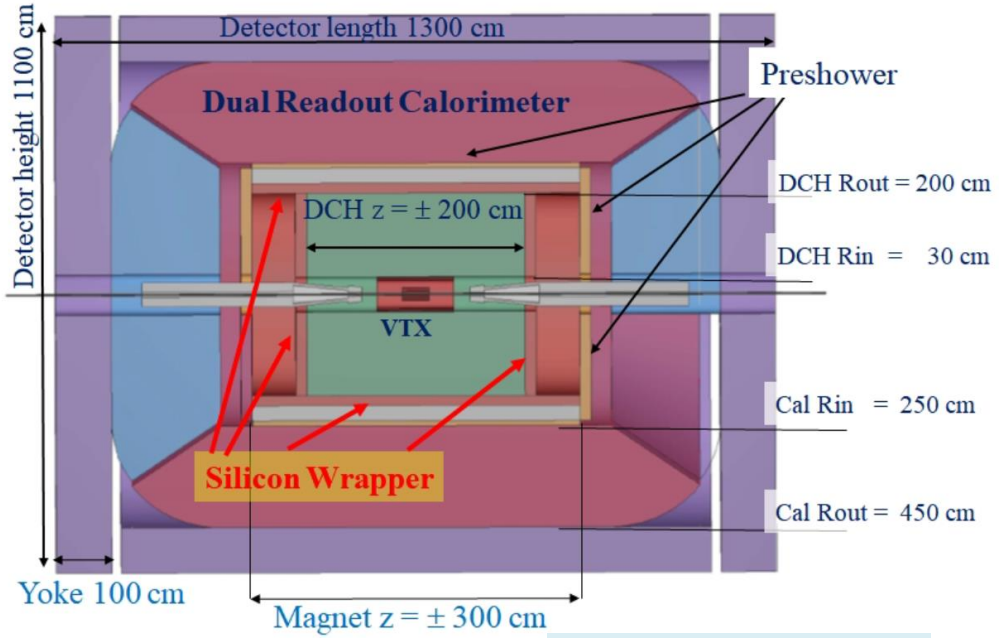
details from Jie

Progress and updates - Detector-Physics

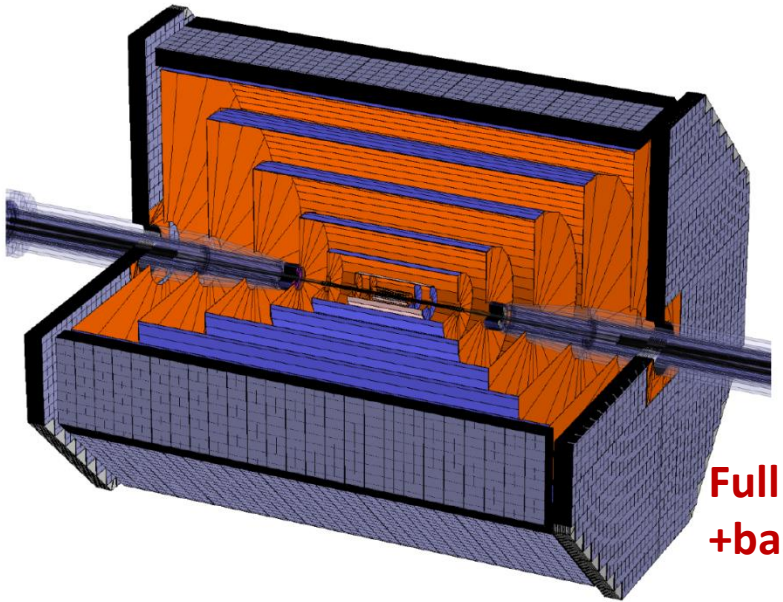


Baseline detector: pixel vertex detector, silicon inner tracker, a TPC, Si external tracker, ECAL, HCAL, 3 T B-field, embedded muon detector

Alternative detector

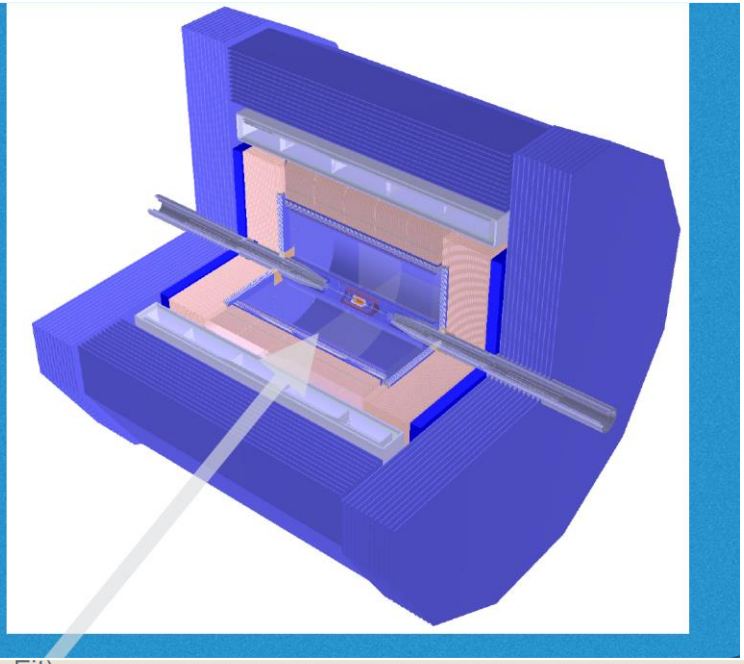


details from Joao

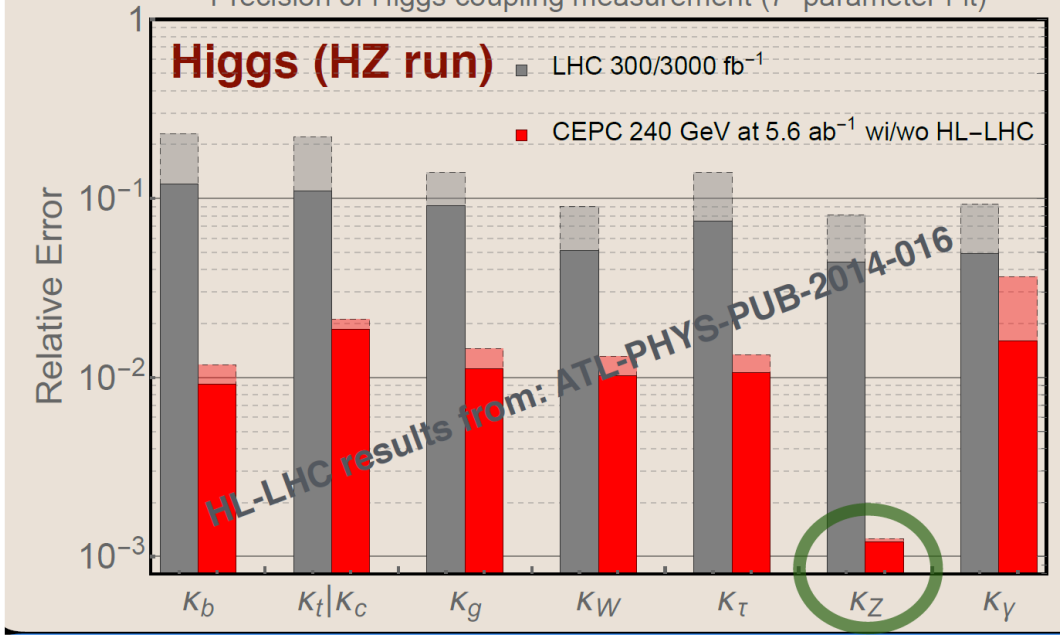


Full silicon tracker +baseline detector

Baseline detector
ILD-like
(3 Tesla)



Precision of Higgs coupling measurement (7–parameter Fit)

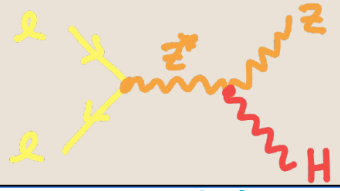


$$\kappa_f = \frac{g(hff)}{g(hff;\mathrm{SM})},\ \kappa_V = \frac{g(hVV)}{g(hVV;\mathrm{SM})}$$

CEPC K_x ~1% uncer

K_Z ~ 0.13 %

K_{inv} ~0.3%



Joao Guimaraes

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CEPC CDR Released on November 14, 2018

CEPC team handed the CDR to Institutional Board Chair and IHEP Director

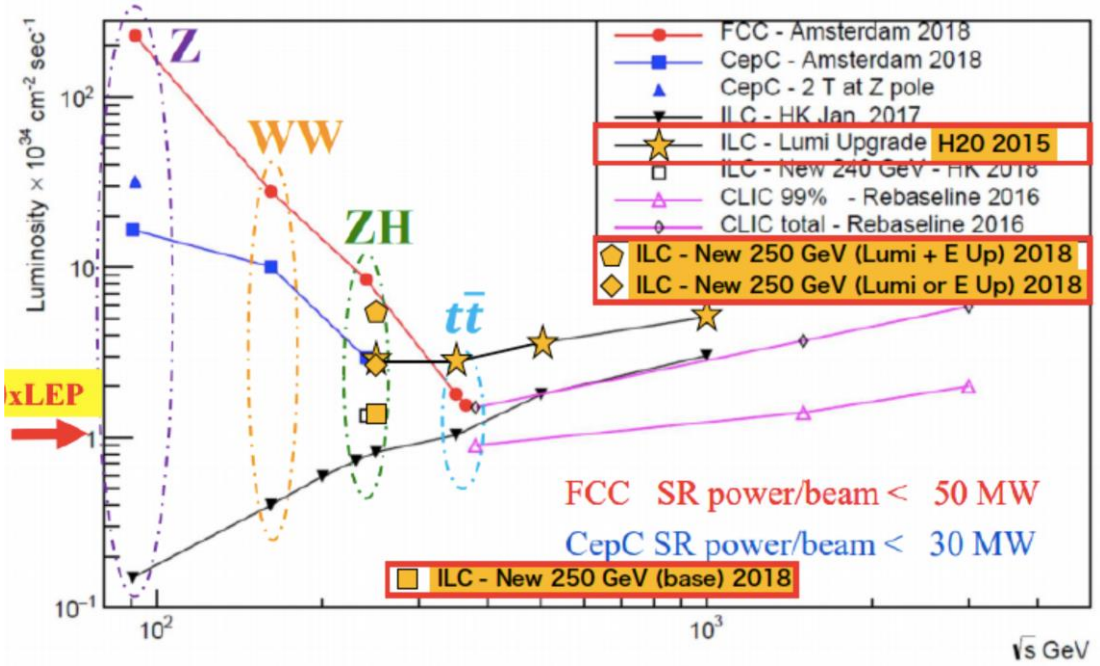
http://cepc.ihep.ac.cn/

Circular Electron-Positron Collider

Luminosity vs. CM energy

Circular:

offers higher lumi. @ LE
unprecedented Z,W,+H program
mature technology
HE synchrotron light source (?)
very long term: pp upgrade path



G. Taylor et al

Linear:

very impressive Higgs precision
best Lumi. at higher energies, or only option for VHE
(ILC lumi upgrade even better at the Higgs**)**

circular & linear colliders are ideally complementary to each other

Design&physics enhancement, R&D, and infrastructure

Progress and updates – CEPC Day

CEPC Day – post CDR monthly team meeting on progress, problems and issues, plus CEPC **Steering Committee Meeting,** held since February, this year.

¼-1/3 of the overall CEPC will be covered each CEPC Day, complete coverage 3-4 months

Set aside time for detailed discussions

example **morning—afternoon sessions are open to all CEPC stakeholders**

September 27, 2019

9:00 – 12:00 Detector, Software, Physics

12:00 – 13:45 Steering Committee Meeting

14:00 --17:30 Accelerators

Vidyo link:

http://vidyo.ihep.ac.cn/flex.html?roomdirect.html&key=P1kF5j5SQDoTFh2veKCFcXJGPGQ

Room Extension: 0020188011001

Indico Page:

https://indico.ihep.ac.cn/event/10617/

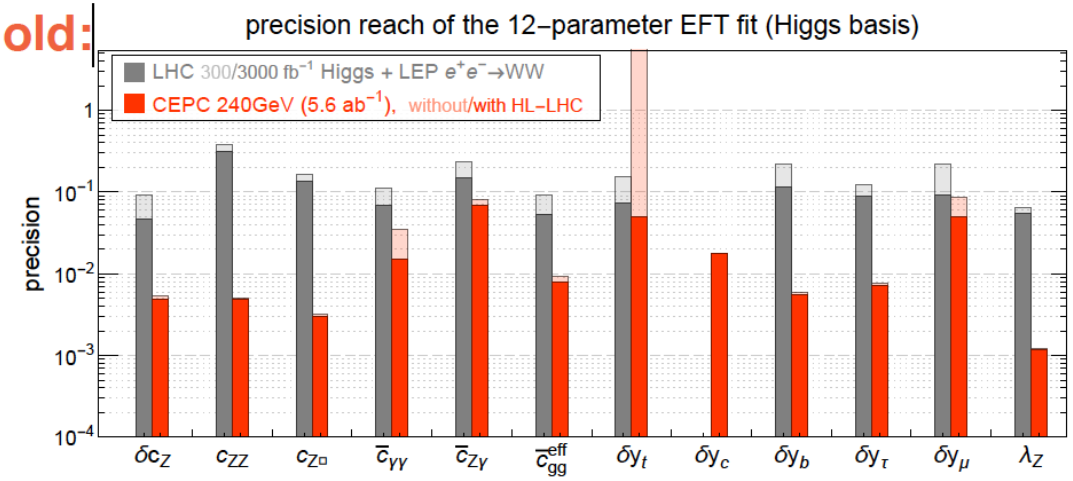
Progress and updates – Simulation Study

- Physics: white paper preparations towards the TDR
- Topical WS on CEPC Physics and detector at PKU
  - Covers the topic on QCD, Flavor, EW, and Higgs
  - Multiple benchmarks proposed and corresponding roadmap discussed
  - Related Performance studies (i.e., Pid, Lambda/Ks, Tau reconstruction) are presented
  - Interpretation & Global Fit
  - EW: provide the essential input for the EUSPP and ECFA Higgs Working groups
- Recent Performance Studies

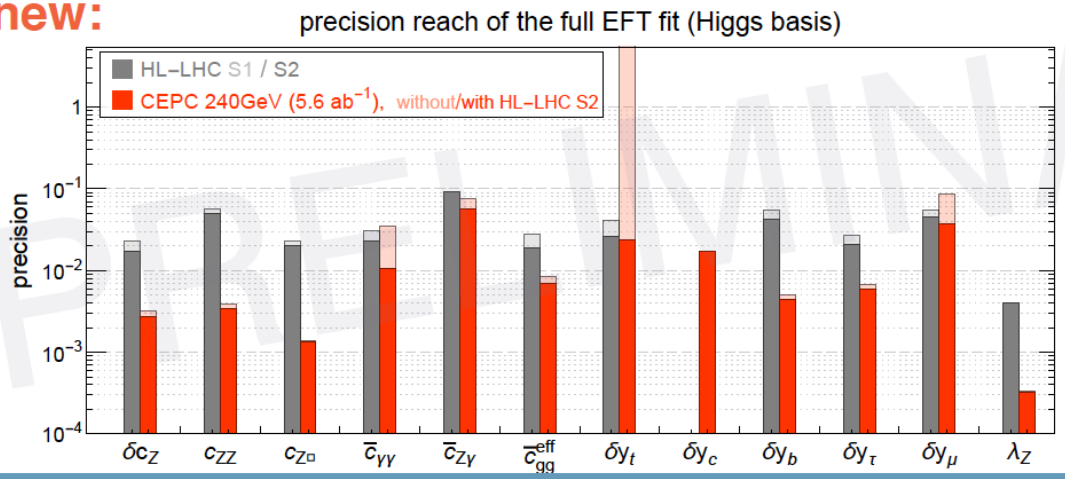
Manqi RUAN

CEPC: old *vs.* new (Higgs basis)

old:



new:



- Full fit: only the Higgs parameters are shown.
- HL-LHC: ATLAS and CMS are combined. (The correlation between ATLAS/CMS are not provided by the WG.)

Manqi RUAN

Development – expert committees

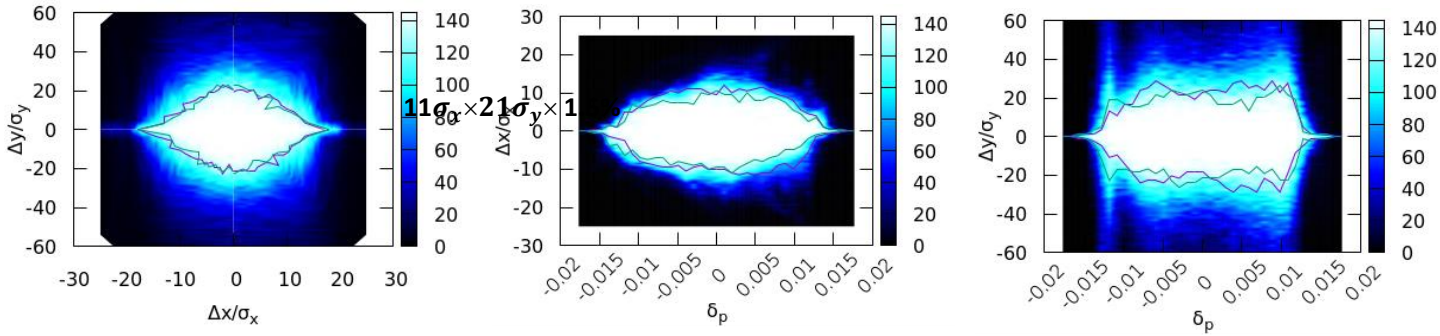
- **Accelerator review committee** – recommended by the IAC, established and will meet in this week at this workshop (November, 2019)
- **Detector R&D committee** – recommended by the IAC, a large committee (~16 members) has been established; first meeting at this workshop

We expect to benefit greatly from these committees

CEPC design enhancement

Dynamic aperture optimization

- Dynamic aperture optimized with the new lattice aiming at luminosity of $\mathbf{5 \times 10^{34}/cm^2/s}$.
  - Effects of nonlinearity in lattice, synchrotron radiation, beam-beam interaction are included.
  - Multi-Object Deferential Evolution (MODE) algorithm used to make global optimization.
  - DA goal $8\sigma_x \times 15\sigma_y \times 1.7\%$
- More efforts will be made to enlarge the momentum acceptance.
- The goal will be adjusted with further beam lifetime study which is under going.

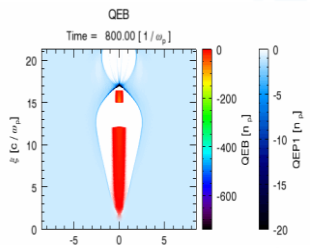


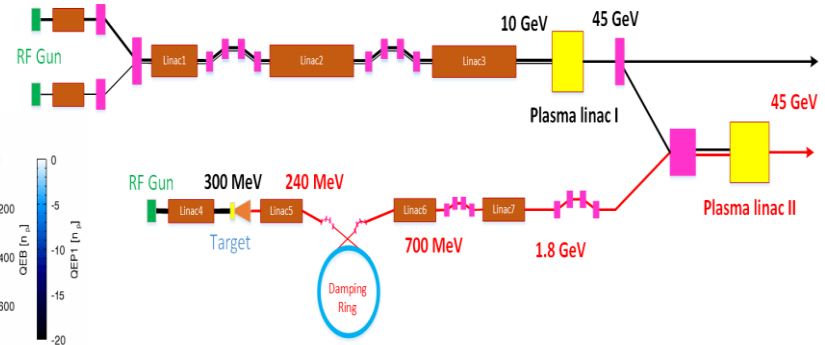
Jie GAO

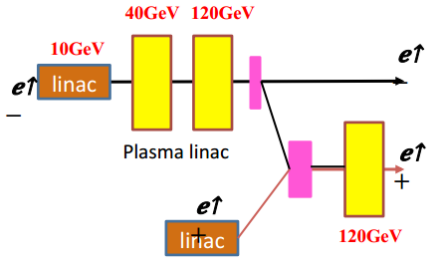
CEPC design enhancement

Experimental Verification Planfor CEPC Plasma Injector Scheme

A dedicated budget of 8Million has been alocated by IHEP



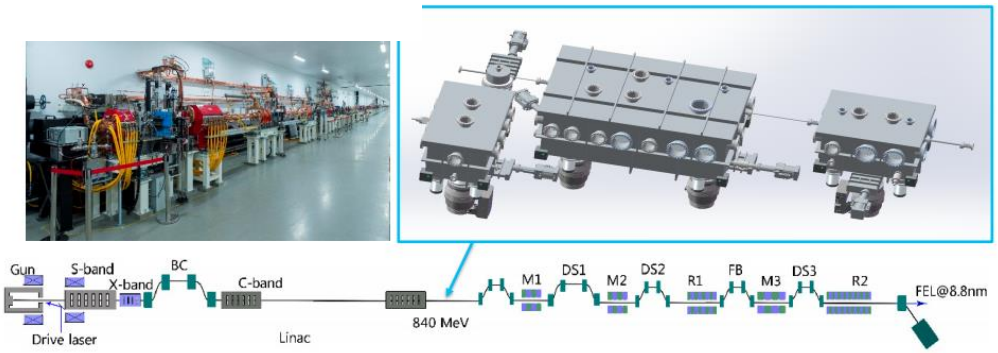




Technical design review has been done (August 22,2019)

Plasma density $n_0(cm^{-3})$	5.15×10^{16}
Driver charge $Q_d(nC)$	6.47
Driver energy $E_d(GeV)$	10
Driver length $L_d(\mu m)$	285
Driver RMS size $\sigma_d(\mu m)$	10
Driver normalized emittance $\epsilon_{nd}(mm\ mrad)$	10
Trailor charge $Q_t(nC)$	1.25
Trailor energy $E_t(GeV)$	10
Trailor length $L_t(\mu m)$	35
Trailor RMS size $\sigma_t(\mu m)$	5
Trailor normalized emittance $\epsilon_{nt}(mm\ mrad)$	100

Trailor energy $E_t(GeV)$	45.5
Trailor normalized emittance $\epsilon_{nt}(mm\ mrad)$	98.9
TR	3.55
Energy spread $\delta_E(\%)$	0.7
Efficiency (driver -> trailor)	68.6%



- **Electron plasma acceleration will be tested in Shanghai's Soft XFEL Facility**
- **Positron plasma acceleration scheme will be tested at FACET-II at SLAC**

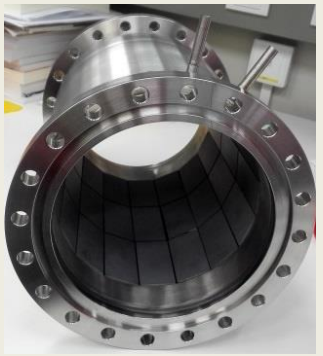
Jie GAO

CEPC R&D

CEPC SCRF R&D in Progress

High power coupler

HOM



Absorber

CEPC 650 MHz Cryomodule

Jie GAO

CEPC R&D

1st CEPC 650MHz Klystron Prototype Manufacture

① Components

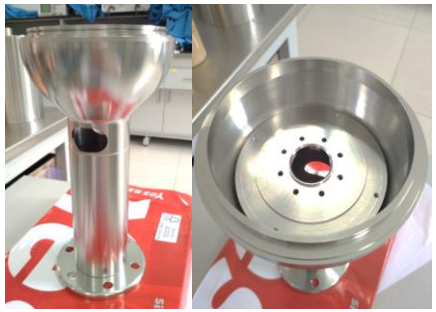
De-gassing facility

Modulator anode

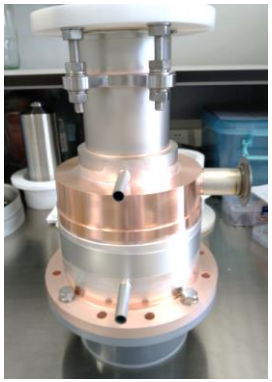
Pumping out pipe

Input coupler

Cavity



Focusing electrode



Output window

Cathode

Gun support

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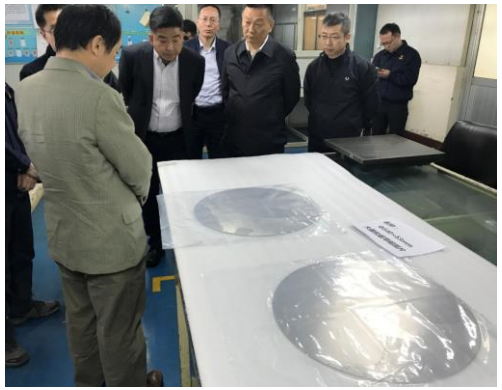
Jie GAO

CEPC R&D

650 MHz 1-Cell Cavity (Large Grain)

- 650 MHz 1-cell cavity (large grain) is favorable for HL-Z, which have higher Q and gradient than fine grain.
- Target of Vertical test: **5E10 @ 42MV/m at 2.0 K**.
- Four cavities are under fabrication now, which will be tested in the middle 2019.



Large grain Nb sheets made by OTIC

Jie GAO

For the long run – SppC and FCC(pp)

Fabrication and test of the 1st IBS solenoid coil at 24T

The 1st solenoid coil with IBS tape fabricated and tested with up to 24T background field. Performance is more than expected.

IOP Publishing Superconductor Science and Technology
Supercond. Sci. Technol. 32 (2019) 04LT01 (5pp) https://doi.org/10.1088/1361-6668/ab09a4

Letter

First performance test of a 30mm iron-based superconductor single pancake coil under a 24T background field

Dongliang Wang[1,2,5], Zhan Zhang[3,5], Xianping Zhang[1,2], Donghui Jiang[4], Chiheng Dong[1], He Huang[1,2], Wenge Chen[4], Qingjin Xu[3,6] and Yanwei Ma[1,2,6]

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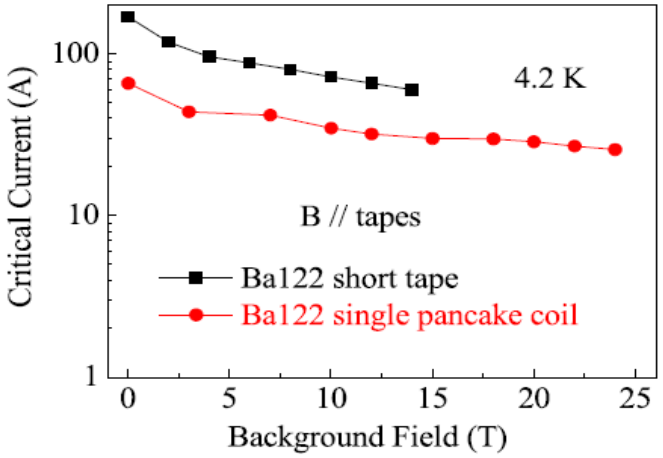
[2] University of Chinese Academy of Sciences, Beijing 100049, People's Republic of China
[3] Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, People's Republic of China
[4] High Magnetic Field Laboratory, Chinese Academy of Sciences, Hefei 230031, People's Republic of China



Viewpoint by NHMFL

'From a practical point of view, **IBS are ideal candidates for applications**. Indeed, some of them have quite a **high critical current density, even in strong magnetic fields**, and a low superconducting anisotropy.

Moreover, **the cost of IBS wire can be four to five times lower than that of Nb_3Sn**……

IOP Publishing Superconductor Science and Technology
Supercond. Sci. Technol. 32 (2019) 070501 (3pp) https://doi.org/10.1088/1361-6668/ab1fc9

Viewpoint

Constructing high field magnets is a real tour de force

Jan Jaroszynski
National High Magnetic Field, Laboratory, Tallahassee, FL, 32310, United States of America
E-mail: jaroszy@magnet.fsu.edu

This is a viewpoint on the letter by Dongliang Wang *et al* (2019 *Supercond. Sci. Technol.* **32** 04LT01).

Following the discovery of superconductivity in 1911, Heike Kamerlingh Onnes foresaw the generation of strong magnetic fields as its possible application. He designed a 10 T electromagnet made of lead–tin wire, citing only the difficulty

Q. J. Xu

CEPC Infrastructure

IHEP New SC Lab under Construction (Status August 2019)

Jie GAO

See talks by Jie’s, Joao’s and Qingjin for details

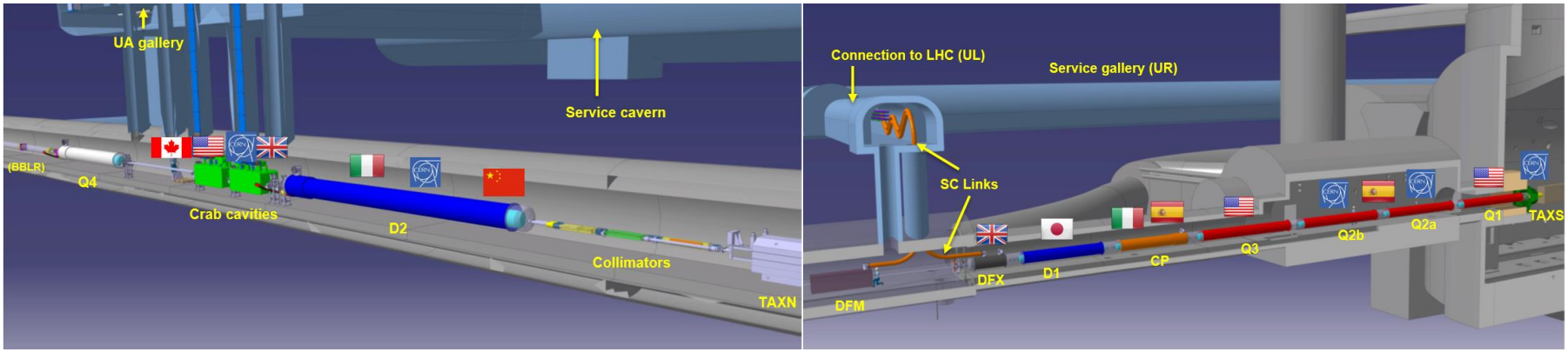
International collaboration

R&D of HL-LHC CCT Magnets

China provides 12+1 units CCT corrector magnets for HL-LHC before 2022

2*2.6T dipole field in the two apertures. 2.2m prototype being fabricated.

Agreement For HL-LHC CCT Magnets Signned in Sep 2018



Layout of the HL-LHC Magnets and Contributors

Progress and updates – Intl Collaboration

- Strengthen cooperation with CERN
- Joined CALICE collab., ILD TPC collab., RD collab.s

- First international workshop on CEPC in Europe – Rome May, 2018
- Second CEPC workshop (EU) in Oxford, UK, April 15-17, 2019
- Third planned for Marseille, France, May 4-6, 2020
  https://indico.in2p3.fr/event/20053/

- First US workshop at UChicago, September 16-18, 2019
- Second US workshop planned for April 22-23, 2020 (TBC）
  Catholic University in Washington DC, USA

- Fifth CEPC IAC meeting (Nov. 21-22, 2019)

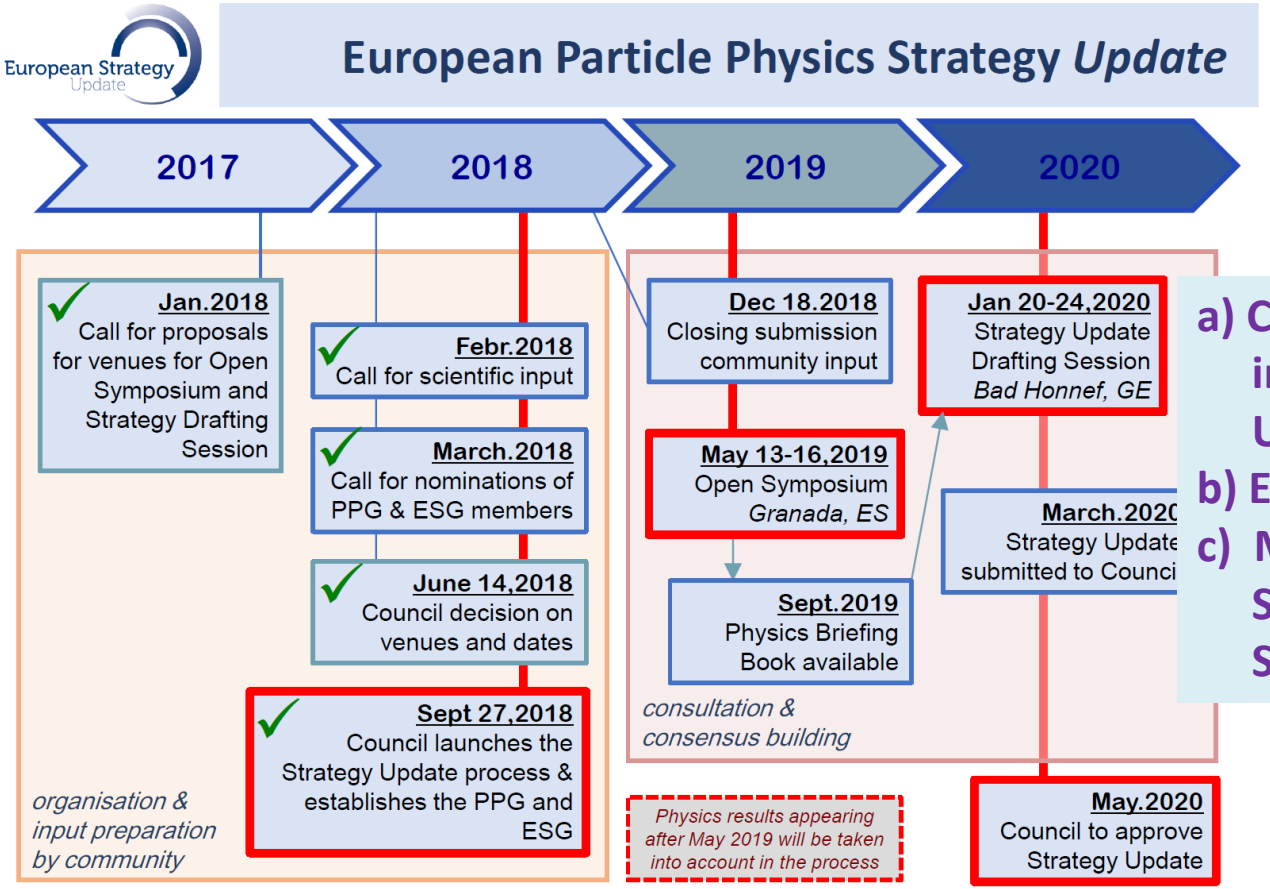
to focus on international collaboration and other aspects

Progress and updates – Intl Collaboration

Preparation for European Strategy for Particle Physics update

Inputs (CEPC accelerator, physics-detector) have been submitted

CEPC accelerator: ArXiv: 1901.03169, CEPC Physics/Detector: 1901.02170



a) CEPC team submitted two input documents to the USPPU;
b) Engaging with PPG and ESG;
c) Many attend the Open Symposium in Granada, Spain.

Development – CEPC Organization

CEPC Input to the European Particle Physics Strategy Update 2018-2020
Addendum: The Planning of CEPC

"The current priority of the CEPC project is to secure its position as one of the seed projects of this program. The official approval of the CEPC project, at the earliest, could happen in 2022. The accelerator construction could start soon after the approval. At the same time, **a call for detector Letters of Intent is planned. Two detectors will be selected and the International collaborations will be formed accordingly. The collaborations should deliver their Detector Technical Design Reports within two years after the starting of the construction of the accelerator**"

"To achieve this goal, two International Committees will be established. The first is an **Accelerator Review Committee** that advises on all matters related to the accelerator design and R&D including the Machine-Detector Interface and upgrade capabilities. The second is a **Detector R&D Committee** that reviews and endorses the Detector R&D proposals from the international community, such that the international participants could apply for funds from their funding agencies and make effective and sustained contributions."

Development – CEPC Organization

CEPC Input to the European Particle Physics Strategy Update 2018-2020
Addendum: The Planning of CEPC

"International collaboration is vital for the CEPC project. Active collaborations have been established between the domestic CEPC study groups and multiple international research institutions. Through these collaborations, many key challenges of the CEPC detector design and physics studies have been identified and being addressed through dedicated R&D programs. "

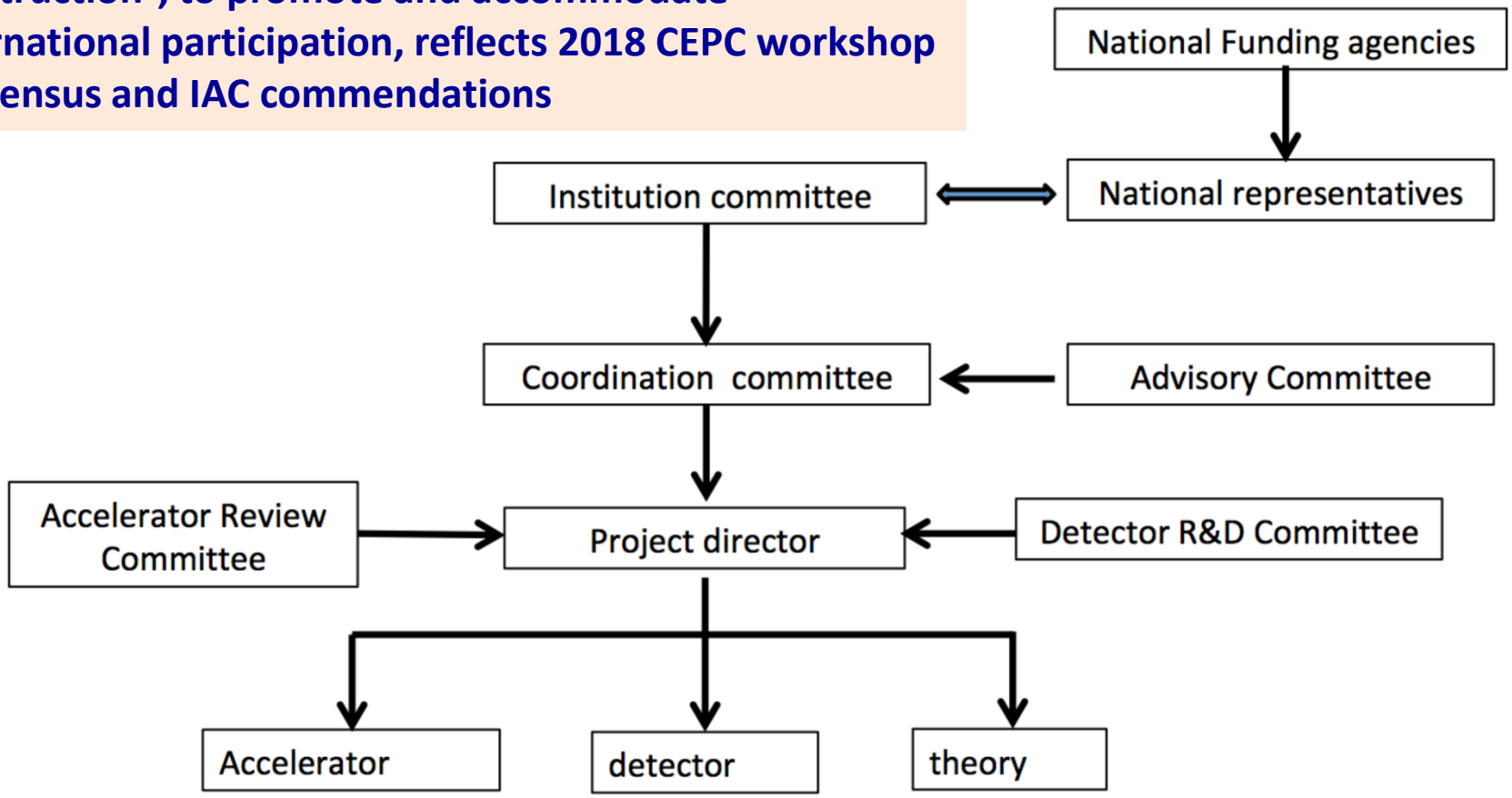
"**The organization will evolve with time**. In the construction and operational phase, the **organization will naturally evolve to include the council representing the participating countries and the host lab management who provide supervision to this project**."

"Though the CEPC project is initiated by and to be hosted in China, **it is envisioned to be an international project. The organization and the management of the project will reflect the international participation of its stakeholders.** The successful international participation played a critical role in the delivery of the CEPC conceptual design, and it will certainly become more important in the future."

Development – CEPC Organization

CEPC Input to the European Particle Physics Strategy Update 2018-2020
Addendum: The Planning of CEPC

The organization structure is for the period "2019 – construction", to promote and accommodate international participation, reflects 2018 CEPC workshop consensus and IAC commendations



In addition to ESPPU, CEPC team is looking forward to the US P5 update

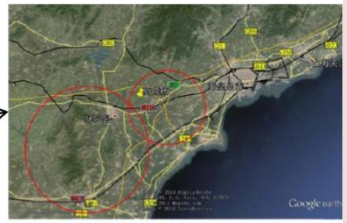
Summary

- **Asia is a major contributor to the world of HEP**
  - **HEP programs in Asia cover a wide range of scientific frontiers**
  - **Projects under development will bring exciting physics opportunities**
  - **Large e^+e^- colliders (ILC, CEPC) – options for the world**
- **Many of the Asian HEP physicists are trained in the West and are global minded – good for international collaboration**
- **Continued effort, world-wide coordination, improved design and technological advance are crucial for realizing future high energy frontier e^+e^- collider(s)**
- **Asia by itself does not produce a single HEP strategy. It is very important that European ESPP and US P5 include Asia**

Xinchou Lou at DPF 2019

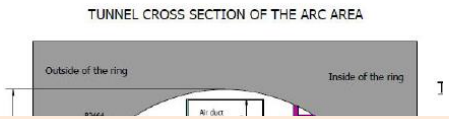
Site investigation & domestic relations

CEPC site investigation and facility study



- ✓ site visits & study
- ✓ facility deign
- ✓ construction plan

....



CEPC is conducting country wide site visits and study. Local government agencies are very receptive and supportive to CEPC. CDR study is based on site 1 (Qing Huang Dao).

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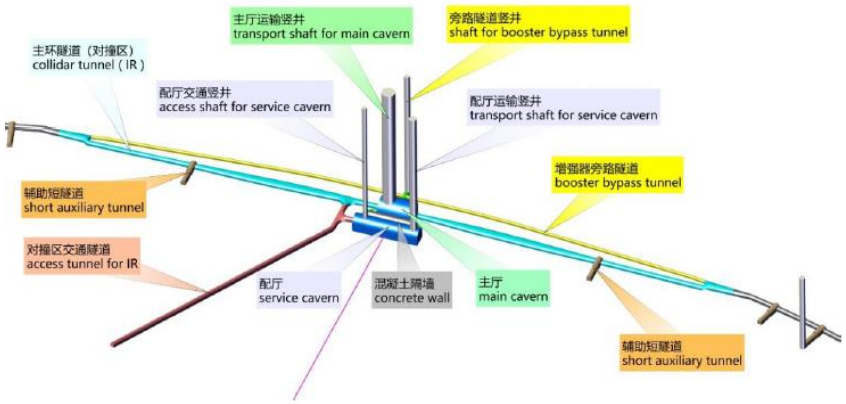
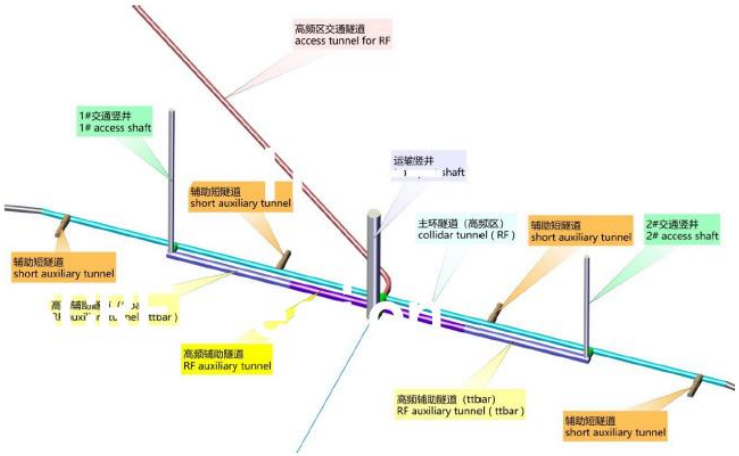
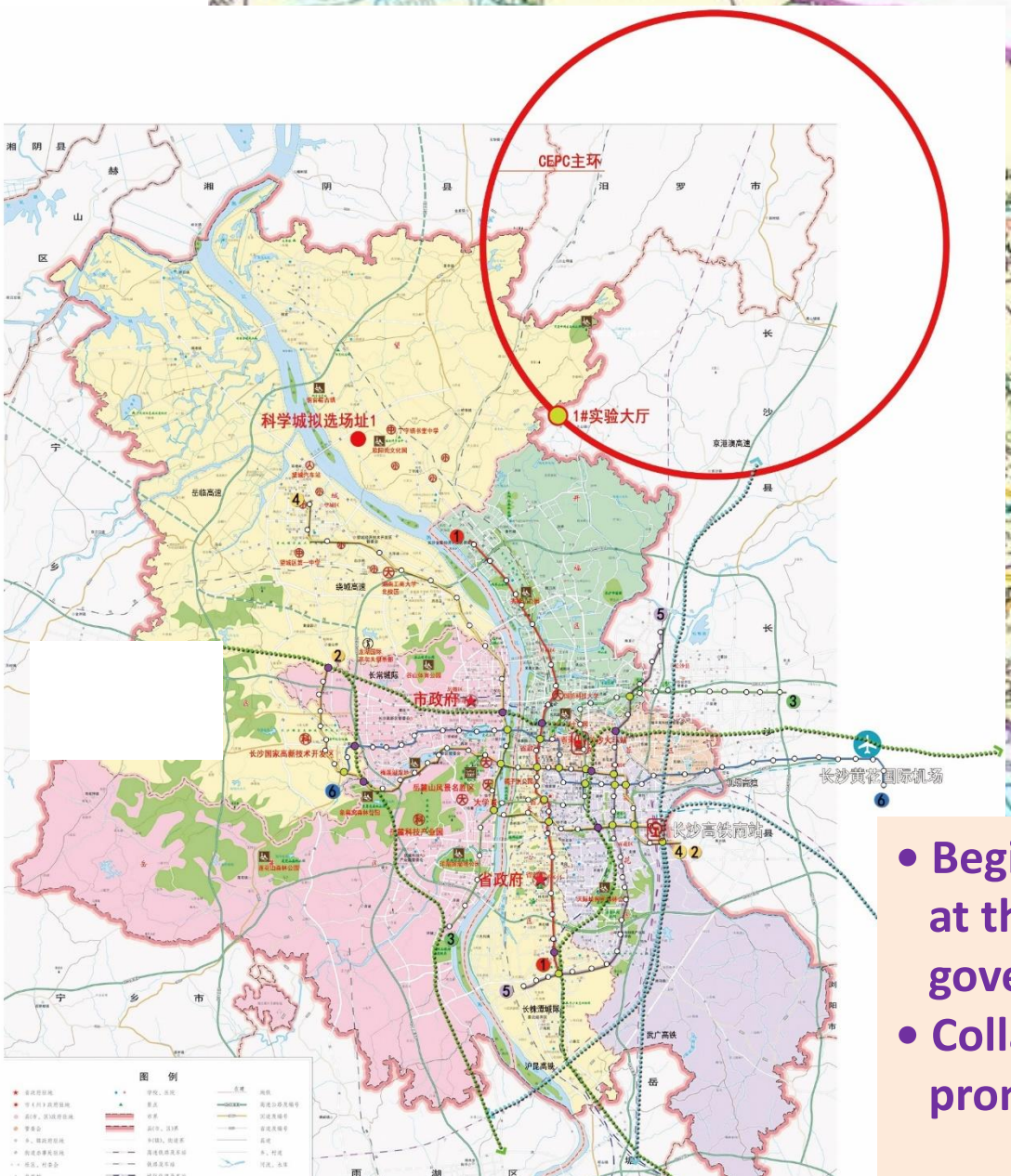
CEPC Interaction Region



CEPC Injection Region

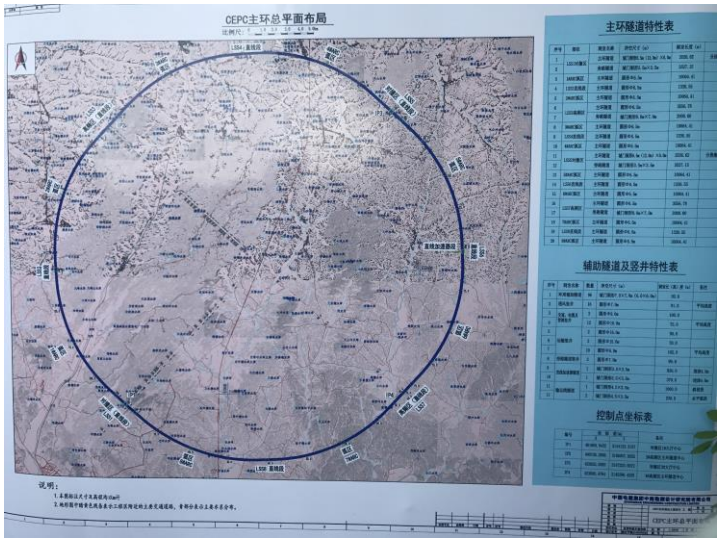


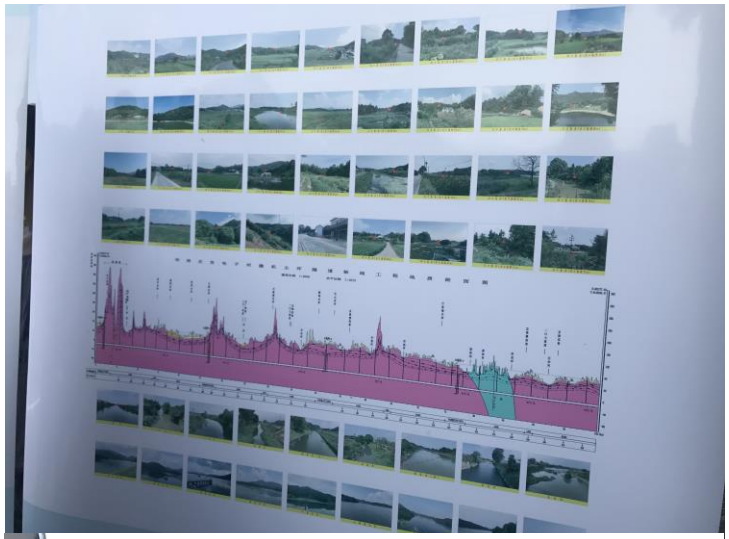
CEPC site investigation and facility study



- Begins site study in Changsha长沙 at the request of the provincial government;
- Collaborative MOUs signed to prompt CEPC and HEP

CEPC site investigation and facility study





Changsha (Hunan Provice)

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CEPC site investigation and facility study

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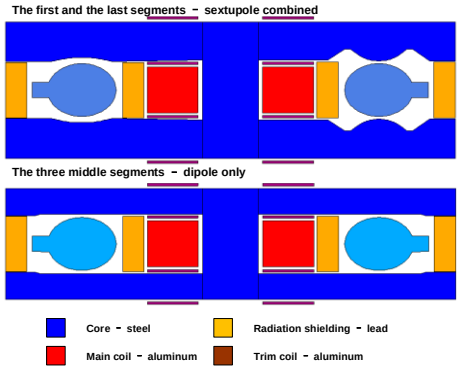
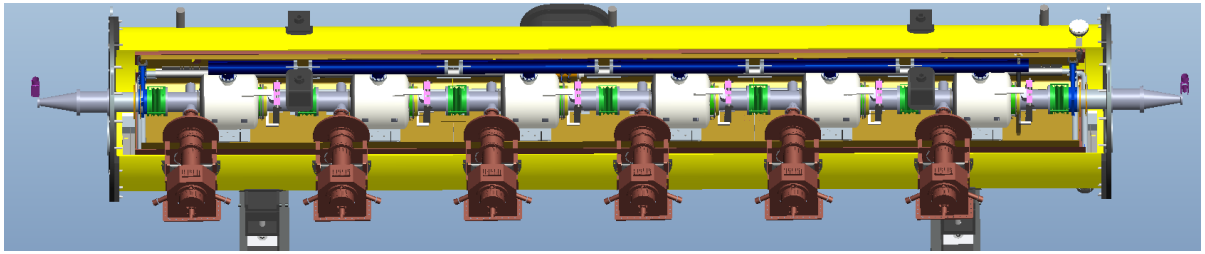
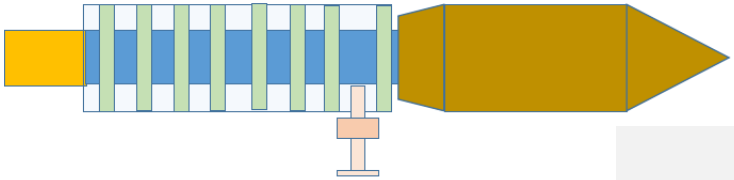
Changsha (Hunan Provice)

CEPC Industrial Promotion Consortium (CIPC)

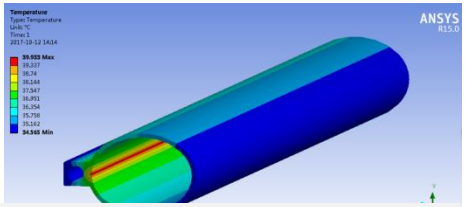
was established in 2017 to prepare for industrial production of CEPC components

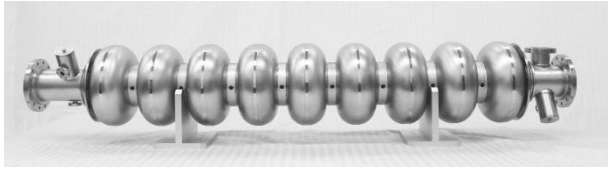






High Efficiency RF cavity section





Cultivation of CEPC

Progress and updates – Path to realization

Chinese Government：”actively initiating major-international science project…”
国发〔2018〕5号（2018.3.14）http://www.gov.cn/zhengce/content/2018-03/28/content_5278056.htm

- focuses on “**frontier science, large-fundamental science , global focus, international collaboration, …**”
- by year 2020，3-5 projects will be chosen to go into “preparatory stage”, among which 1-2 projects will be selected. More projects will be selected in later years.
- The task of selecting the projects, and develop them further falls on the Ministry of Science and Technology (MOST)
- MOST committees formed, are writing the guidelines
- **This is a likely path to realize CEPC. We are paying close attention to this opportunity**

- **CEPC team is in regular contact with MOST expert committee**
- **Selection criteria seem to be in place, but selection process is not clear, expect to be rather volatile**
- **CEPC is focusing on working, & making progress according to the roadmap-schedule**

Progress and updates – Path to realization

1st Wave 积极牵头组织国际大科学计划和大科学工程项目培育建议书

Suggested Large International Science & Engineering Project for Cultivation

项目名称： 环形正负电子对撞机培育 **Cultivation of CEPC**

所属领域： 物质科学

申报单位： 中国科学院高能物理研究所 **Host: IHEP**

项目负责人： 王贻芳 **PI: YiFang Wang**

Cultivation proposal submitted to on November 13, 2019

Progress and updates – Funding Model

The cost of the CEPC accelerator and two detectors have been estimated to be 36 billion CNY (~ 5 billion US Dollars), under the assumption that the local government will provide the land, and the necessary infrastructure for the CEPC facility

Option 1：

32B CNY from Chinese central government + 4B CNY International
（1US$ = 7 CNY)

Option 2:

12B CNY from Chinese central government
10B CNY from MOST International science project
10B CNY from local government
4B CNY International

Under discussion: funding breakdown across various 5-yeatr periods

Progress and updates – Path to realization

2nd Wave

国家重点研发计划
项目预申报书

Focused R&D - preproposal

项目名称：	环形正负电子对撞机 **Cultivation of CEPC**
所属专项：	战略性国际科技创新合作重点专项
指南方向：	物质科学领域
项目管理专业机构：	中国科学技术交流中心
推荐单位：	中国科学院 **Recommendated by CAS**
申报单位：	中国科学院高能物理研究所 **Host: IHEP**
项目负责人：	王贻芳 **PI: Yifang Wang**

4 areas to cultivate

1. **Science goals**
2. **R&D + preparation**
3. **International consultation, dissemination & planning**
4. **Organization & operation model development**

Pre-proposal submitted to MOST on July 12, 2019

Summary

- The CEPC accelerator enhancement in design and TDR process is on going;
- At the IAC's recommendation, strong committees have been formed to guide the detector R&D and collaboration, and for the accelerator TDR;
- The CEPC Study Group has submitted to MOST the cultivation suggestion, and is working with CAS to move the project forward
- Funding model and schedule are under further study to fit CEPC to the government's planning and timescale
- …