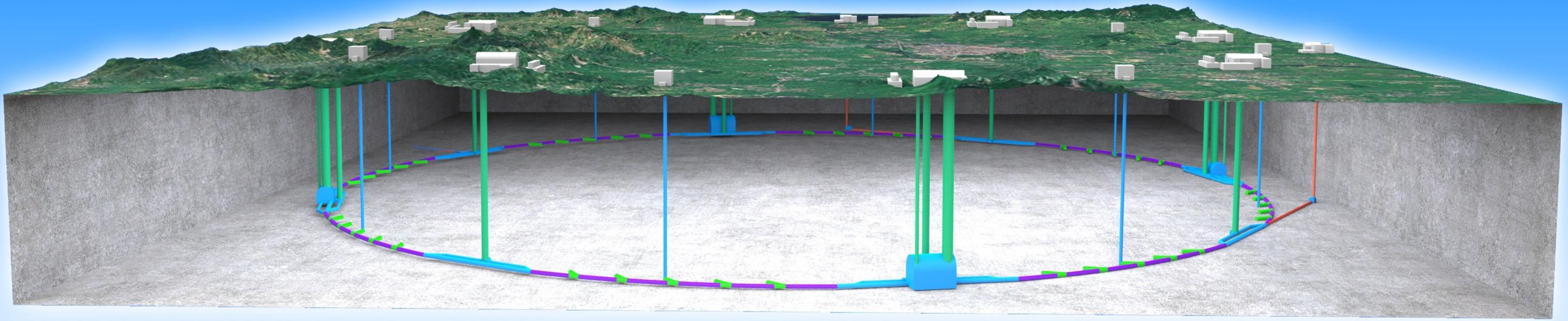
环形正负电子对撞机
CEPC



娄辛丑 (高能物理研究所)
代表 CEPC 研究工作组

10/19/2022

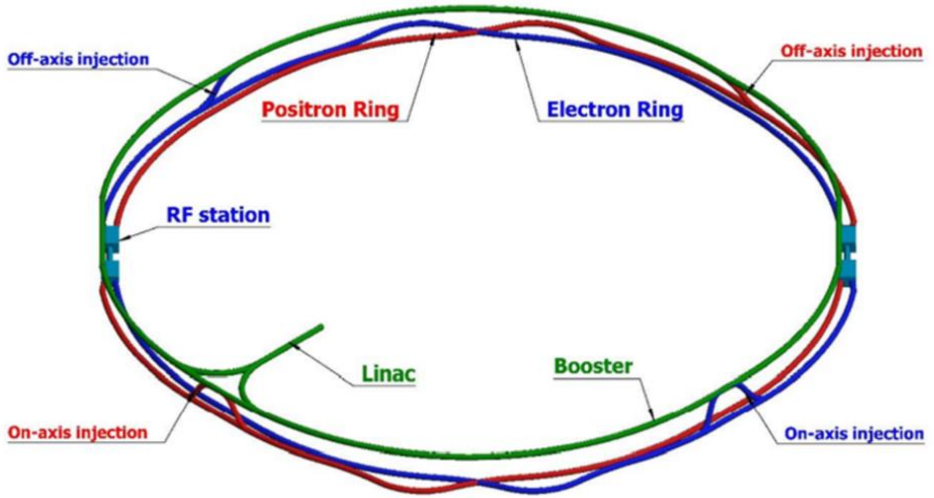
中科院大科学装置战略规划
国内专家组评审会议

目录

CEPC 简介

- CEPC: 环形正负电子希格斯工厂，也可产生大量的 **H**、**W**、**Z** 玻色子、并在升级后产生 **top** 夸克。目标是发现超出标准模型的新物理。
  - 2012年希格斯玻色子发现后，同年中国科学家提出了CEPC 和SppC方案
  - CEPC 在 2018 年发布《概念设计报告》，是首个环形正负电子希格斯工厂的概念设计报告
  - 关键技术预研达到成熟水平，预计于2023 年初发表《技术设计报告》，包含多个重要技术创新

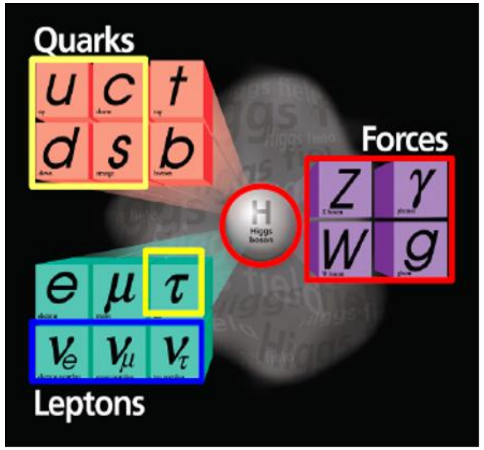
- 建议 2026 年左右开建，
  2030s 年代可以开始取数

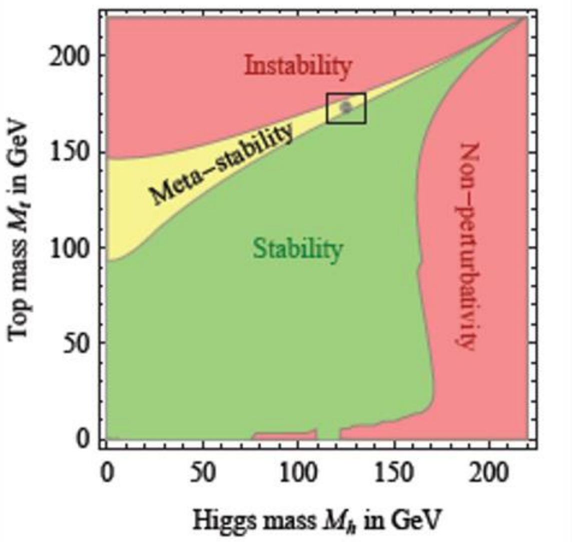


CEPC circumference ~ 100km

科学目标、科学意义和战略价值

- 标准模型虽然相当成功
- 但仍有很多待解决的悬疑问题:
  - 味对称背后是否有任何基本原理?
  - 基本粒子的质量等级是否正常?
  - 希格斯质量的Fine tuning自然么?
  - 为什么真空是亚稳态?
  - 什么暗物质粒子?
  - 标准模型无法解释物质反物质的不对称。
  - Dirac或Maiorana中微子质量问题?
  - 高能量作用力统一问题?
- 粒子物理处于一个转折点:
  - 更深的新理论?
  - 不同的实验方案?
    - e+e−, pp, ep, μ+μ− ……?





CEPC/FCC-ee : 最佳设施?

- 可以以最低代价搜索新物理存在的迹象；一旦确认，能立即转入直接搜索模式

$$\mathcal{L} = \mathcal{L}_{SM} + \sum_i \frac{c_i}{M^2}\mathcal{O}_{6,i} \qquad \delta \sim c_i \frac{v^2}{M^2}$$

到目前为止未能在 LHC 上发现新物理

直接搜索可达到能标：M ~ 1 TeV

10% 精度对应的能标：M ~ 1 TeV

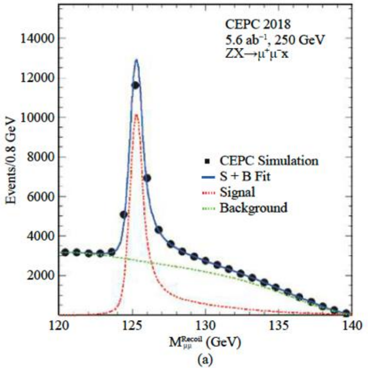
在CEPC/FCC-ee上寻找新物理

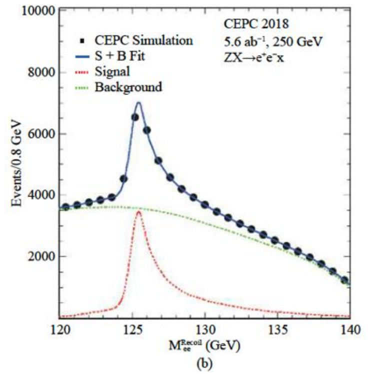
精度可比 HL-LHC提高 1 一个量级（1%）；对应的能标也提高1 个量级：M~10 TeV

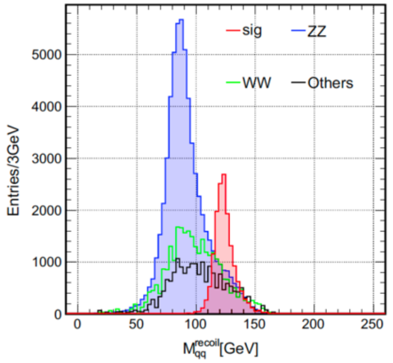
新物理能标大概率 <10 TeV→需要一个正负电子对撞机
如果未在这一能标发现新物理，预示着需要全新新的理论→
即使未看到新物理， 1%精度的对撞机也非常有意义

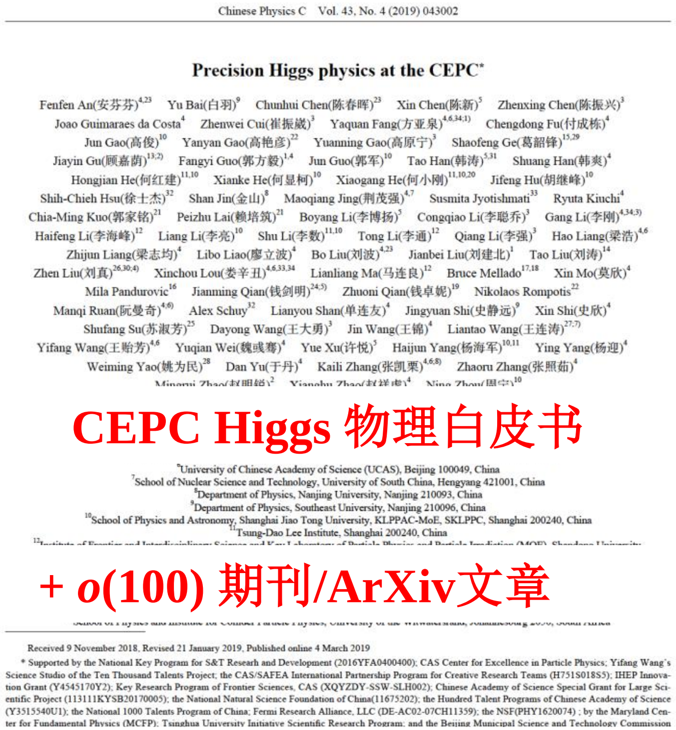
精度达到 1%水平的希格斯工厂可以解决一系列紧迫性的科学问题

科学目标、科学意义和战略价值





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Precision Higgs physics at the CEPC*

Received 9 November 2018, Revised 21 January 2019, Published online 4 March 2019

CEPC Higgs 物理白皮书

+ o(100) 期刊/ArXiv文章

Table 2.1: Precision of the main parameters of interests and observables at the CEPC, from Ref. [1] and the references therein, where the results of Higgs are estimated with a data sample of 20 ab^{-1}. The HL-LHC projections of 3000 fb^{-1} data are used for comparison. [2]

Higgs			*W, Z* and top		
Observable	HL-LHC projections	CEPC precision	Observable	Current precision	CEPC precision
M_H	20 MeV	3 MeV	M_W	9 MeV	0.5 MeV
Γ_H	20%	1.7%	Γ_W	49 MeV	2 MeV
$\sigma(ZH)$	4.2%	0.26%	M_{top}	760 MeV	$\mathcal{O}(10)$ MeV
$B(H \to bb)$	4.4%	0.14%	M_Z	2.1 MeV	0.1 MeV
$B(H \to cc)$	-	2.0%	Γ_Z	2.3 MeV	0.025 MeV
$B(H \to gg)$	-	0.81%	R_b	3×10^{-3}	2×10^{-4}
$B(H \to WW^*)$	2.8%	0.53%	R_c	1.7×10^{-2}	1×10^{-3}
$B(H \to ZZ^*)$	2.9%	4.2%	R_μ	2×10^{-3}	1×10^{-4}
$B(H \to \tau^+\tau^-)$	2.9%	0.42%	R_τ	1.7×10^{-2}	1×10^{-4}
$B(H \to \gamma\gamma)$	2.6%	3.0%	A_μ	1.5×10^{-2}	3.5×10^{-5}
$B(H \to \mu^+\mu^-)$	8.2%	6.4%	A_τ	4.3×10^{-3}	7×10^{-5}
$B(H \to Z\gamma)$	20%	8.5%	A_b	2×10^{-2}	2×10^{-4}
$Bupper(H \to \text{inv.})$	2.5%	0.07%	N_ν	2.5×10^{-3}	2×10^{-4}

通过系统全模拟研究、物理-唯像研究量化了CEPC物理潜力

- Higgs: 精度超过HL-LHC极限约一个量级
- 电弱物理: 精度在现有极限下提升 1-2 个量级
- 味物理：可观测10TeV甚至更高能标的新物理
- 对多种新物理信号极为敏感
- …

1.2、科学意义 & 2.1、关键具体科学问题

科学目标、科学意义和战略价值

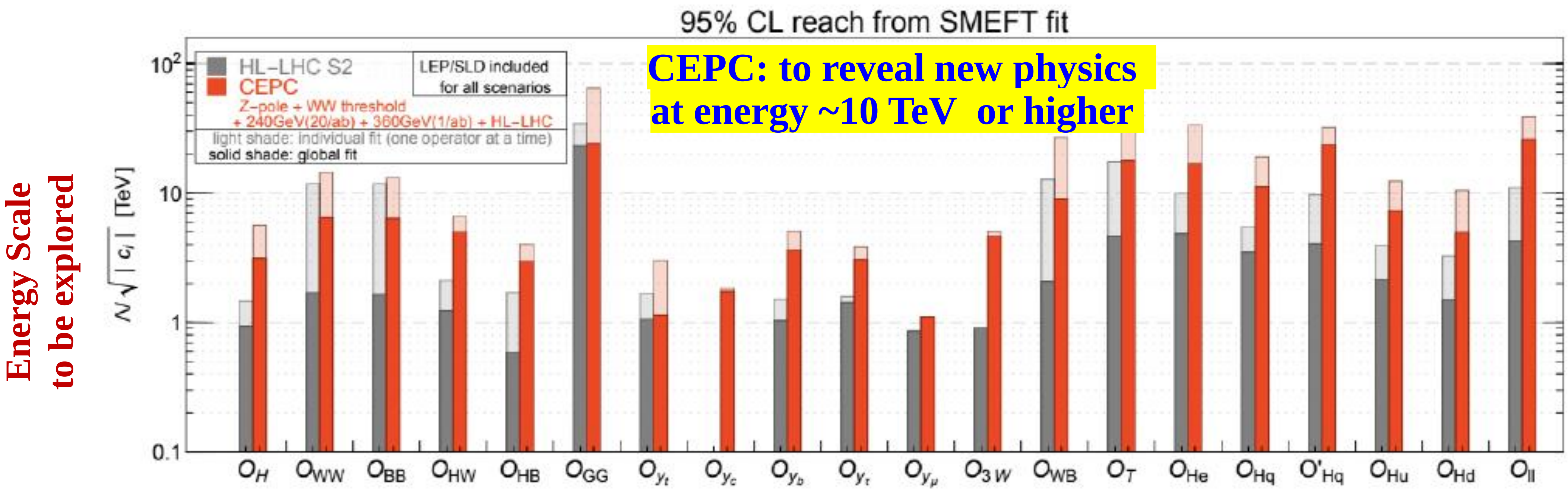


Figure 2.1: Covered energy scales of new physics from CPEC and HL-LHC, based on measurements of operators in the framework of the Standard Model Effective Field Theory (SMEFT). [1]

CEPC聚焦基础研究的重大突破， 去拓展人类对物质世界的认识

科学目标、科学意义和战略价值

正负电子希格斯工厂的科学意义和战略价值非常明确

高能物理学界明确的共识

2013年第464次和2016年第572次香山会议认为“**CEPC 是我国基于加速器的高能物理发展的最佳途径和重大历史机遇**”。

An electron-positron Higgs factory is the highest-priority next collider. For the longer term, the European particle physics community has the ambition to operate a proton-proton collider at the highest achievable energy. Accomplishing these compelling goals will require innovation and cutting-edge technology:

欧洲粒子物理战略讨论：“**正负电子希格斯工厂是未来对撞机发展的最高优先级**”。

Sridhara Dasu (Wisconsin)

Conclusion from Executive Summary

Given the **strong motivation** and existence of proven technology to build an **e+e− Higgs Factory in the next decade**, the **US should participate** in the construction of **any facility that has firm commitment** to go forward.

美国Snowmass讨论：“**美国需参与建设任一实质性推进的正负电子希格斯工厂项目**”

*In April 2022, the International Committee for Future Accelerators (ICFA) “reconfirmed the international consensus on the importance of **a Higgs factory as the highest priority for realizing the scientific goals of particle physics**”, and expressed support for the above-mentioned Higgs factory proposals. Recently, the United States also proposed a new linear collider concept based on the cool copper collider (C3) technology [31].*

ICFA：多次强调希格斯工厂项目的最高优先级和科学重要性

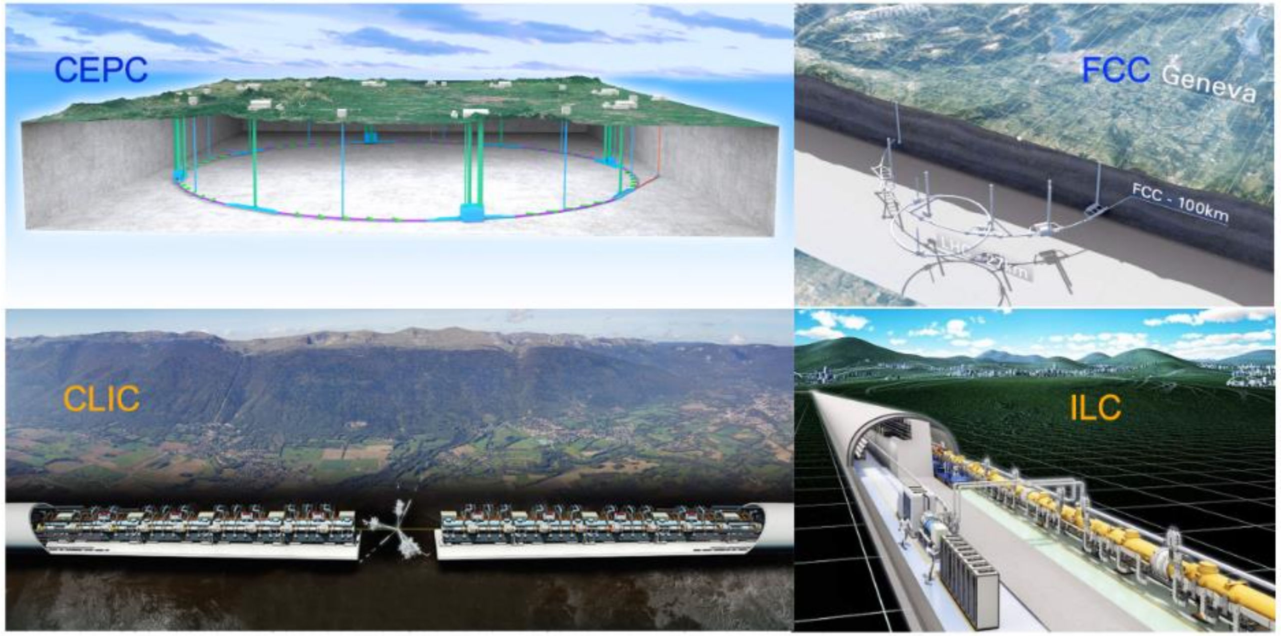
1.2 科学意义 & 1.3 战略价值

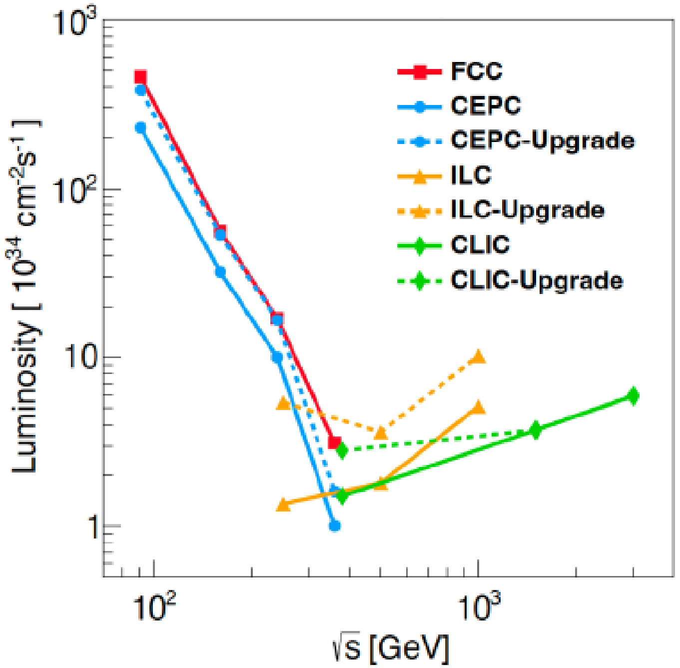
科学目标、科学意义和**战略价值**

- CEPC建成后将成为国际高能物理中心，将在高能物理领域中处于旗舰地位，带动全球科学研究。**它能将中国提升至国际粒子物理研究的领导地位。**

  - **科学** 将在基础科研和创新中发挥核心作用，对人类文明做出重大贡献。
  - **技术** 可大幅提升中国乃至世界的技术水平。
  - **国际合作** 将聚集几千名国际顶尖人才进行协同创新；加强国际交流，促进国际和平。
  - **教育及人才培训** 将培养大批具有国际水准的人才。
  - **经济带动** 培育高科技企业、作为科技中心带动经济发展。

关键科学和技术问题





- 正负电子对撞机被欧洲粒子物理战略等判断为未来对撞机发展的最高优先级。
- CEPC在所有已完成设计报告的正负电子对撞机中，优势明显：
  - **数据早**：预期于2030年代取数（领先FCC-ee约10年），**更大的隧道**（同时容纳pp和正负电子对撞机）
  - **更精确**：相对于直线对撞机有更高的W、Z粒子产额；同时有升级为**质子对撞机**的潜力。
  - **更经济**：造价约为FCC-ee的一半, 亮度指标与之相当。
- **CEPC被粒子物理学界广泛视作未来旗舰型项目的主要选择之一**。

关键科学和技术问题（路线）

新物理
~10 TeV

- ✓ 暗物质
- ✓ 拓展型Higgs
- ✓ 复合态Higgs
- ✓ 超对称
- ✓ ……

高精度
~1%

- ✓ Higgs: 1%-0.1%
- ✓ 电弱物理：比当前结果提升1-2量级
- ✓ 味物理
- ……

探测器
Particle Flow

- ✓ 高颗粒度
- ✓ 高分辨率
- ✓ 可靠的粒子鉴别
- ……

设计和实施
探测器 & 加速器

- ✓ 多用途的加速器
- ✓ 新概念探测器
- ✓ 造价、附加值
- ✓ 溢出效应
- ……

- ✓ 管理
- ✓ 合作
- ……

高亮度
~$10^{34\text{-}36}cm^{-2}s^{-1}$

- ✓ Higgs: 20 ab^{-1}
- ✓ Z: 100 ab^{-1}
- ✓ W: 6 ab^{-1}
- ✓ Top: 1 ab^{-1}

加速器
2 IPs/100 km

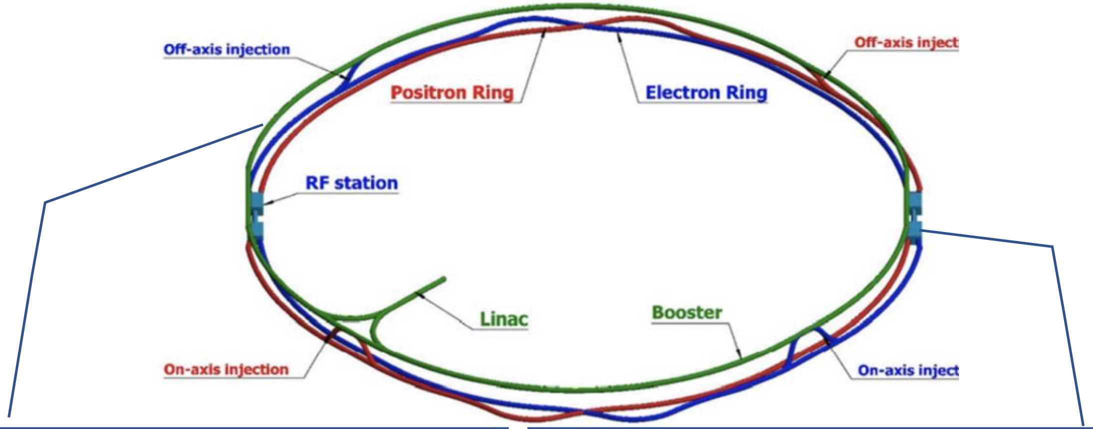
- ✓ 可切换运行
- ✓ 可升级性
- ✓ Large Piwinski angle with Crab-waist
- ……

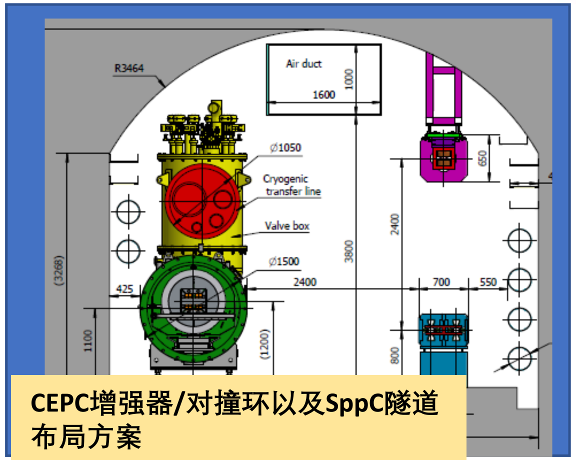
Operation mode	Z	W	Higgs
Center-of-mass energy (GeV)	91	160	240
Operation time (year)	2	1	10
Instantaneous luminosity/IP ($10^{34}cm^{-2}s^{-1}$)	115	16.0	5.0
Integrated luminosity (ab^{-1}, 2 IPs)	60	3.6	12
Event yield (30 MW)	2.5×10^{12}	1.0×10^{8}	2.5×10^{6}
Event yield (50 MW)	4.0×10^{12}	1.6×10^{8}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

2.1 关键科学问题 & 2.2关键技术路线

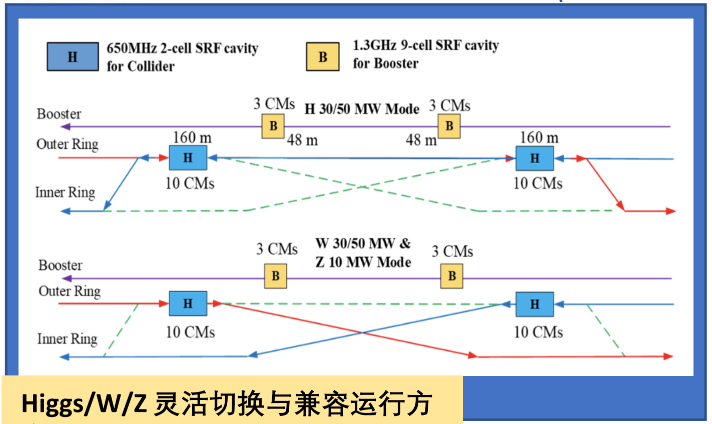
实验设施设计方案与技术指标

- **环形对撞机**: 较直线对撞机**亮度更高**
- **100km 周长**: 优化后的取值、有助于**SppC**达到高能量
- **共享隧道**: **CEPC**增强器、对撞环及未来**SppC**可共用同一隧道
- **能量灵活切换**: Higgs, W/Z, top 多能量模式运行

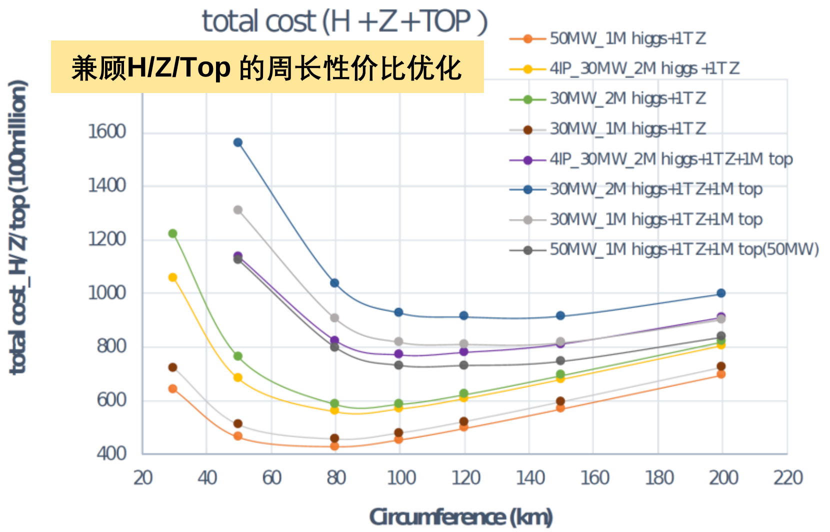




CEPC增强器/对撞环以及SppC隧道布局方案



Higgs/W/Z 灵活切换与兼容运行方案



D. Wang *et al* 2022 *JINST* **17** P10018

CEPC的加速器主要参数表

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

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2.3 项目的总体创新性 & 3.1 设施设计方案

实验设施设计方案与技术指标

创新性设计	➢ 100 km 完整/部分双环高亮度设计 ➢ 可灵活切换对撞能量：Higgs、W 、Z ➢ 多种能量的不同注入/引出模式 ➢ 世界上首个超高能量、通量的γ同步光源设计
高水平技术	➢ 高效速调管 (瞄准全球最高能量转换效率) ➢ 高性能超导射频腔 (全球领先技术水平) ➢ 新型加速器磁铁: 极弱场二极磁铁, 双孔径二/四极磁铁 (全球首台样机)
探索革命性技术	➢ 束流驱动等离子体尾场加速 (新加速原理) ➢ 高场超导磁体 (国际首倡铁基高场磁体技术)

通过创新性设计和高水平关键技术研发达到 CEPC 的高亮度性能指标。

实验设施设计方案与技术指标

目标

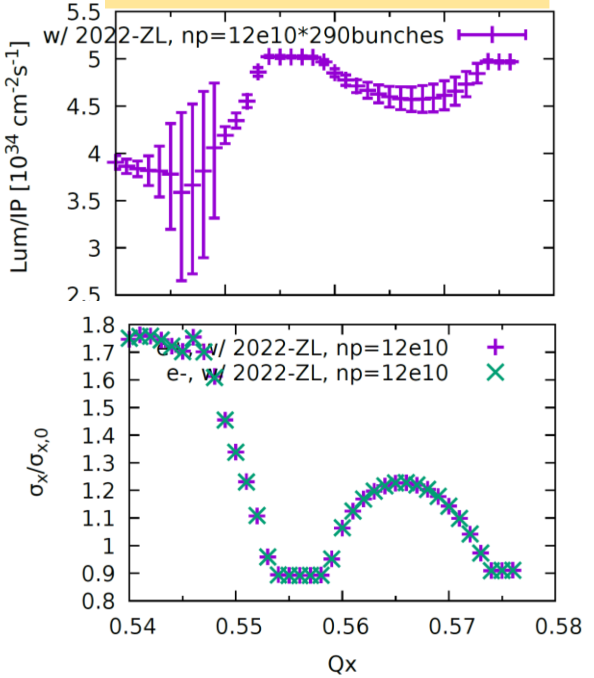
- 高亮度正负电子环形Higgs工厂
- 灵活切换Higgs, W, Z, Top运行模式
- 亮度优化兼顾节能设计

设计

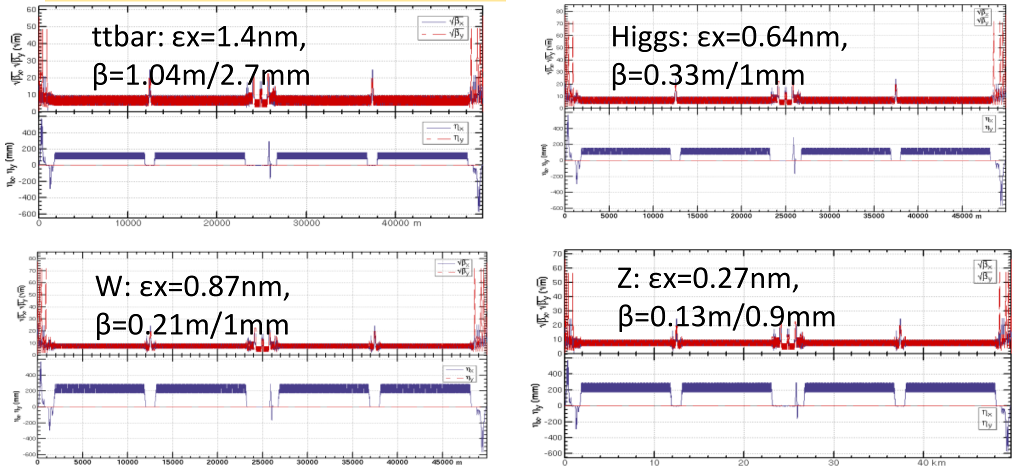
- 完整的加速器设计（包含最新的理念）
- 各能量模式下的lattice设计已完成
- 动力学孔径满足需求
- 充分考虑束束作用与集体效应

一个可工作的100公里包含不同能量模式的加速器设计— 已完成

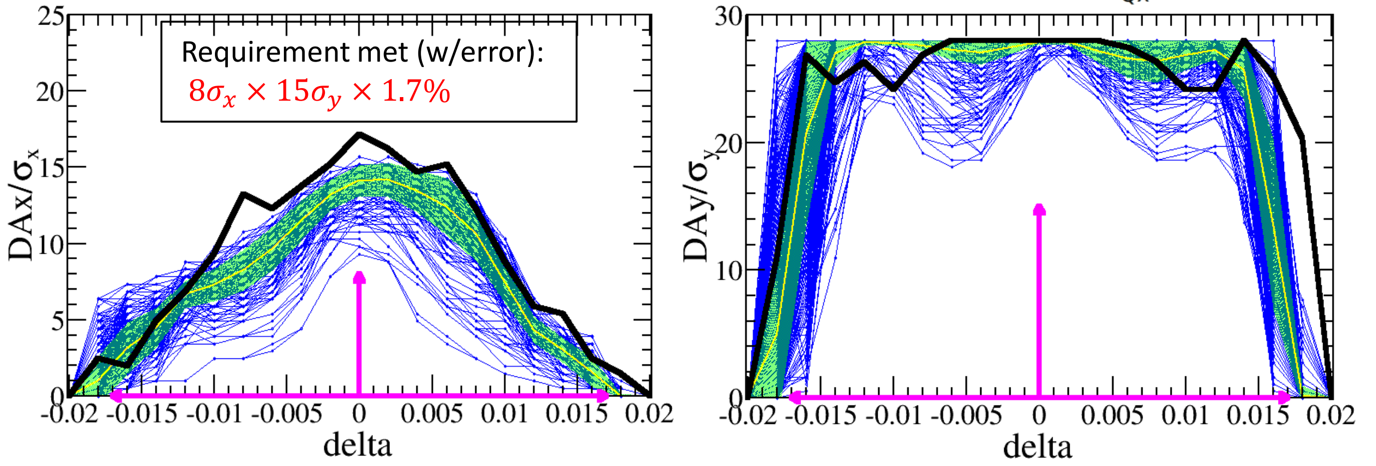
束束相互作用研究



各能量模式的磁聚焦结构



动力学孔径优化（含误差）



3.1 设施设计方案

实验设施设计方案与技术指标

关键技术

- 高效速调管
- 高Q值超导加速腔
- 新型加速器磁铁
- 等离子体加速注入器
- 高场超导磁体

研究现状

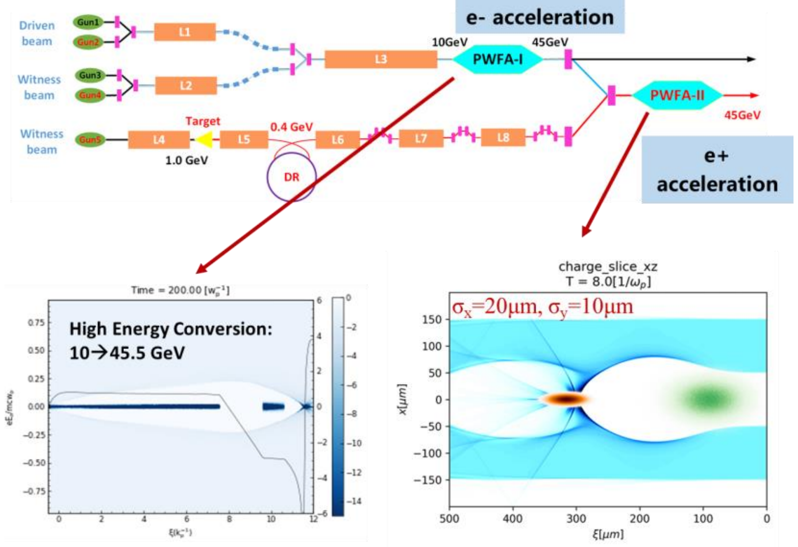
- 能量转换效率 >70%, 目标 80%
- 超过CEPC的设计需求
- 满足CEPC的设计需求
- 正电子加速、高能量(>10GeV)
- 铁基高温超导磁体技术应用

全球领先的技术

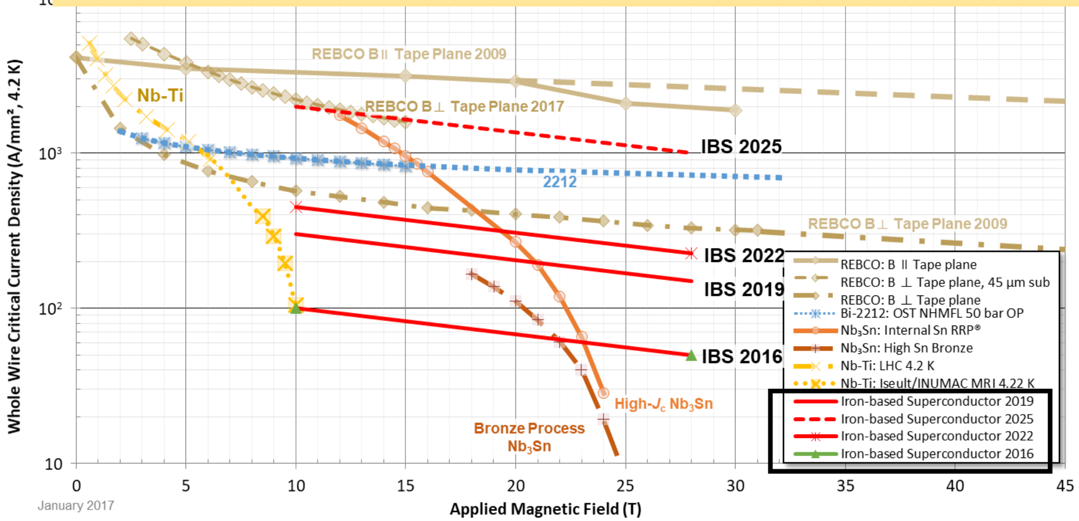
代表性的先进加速器技术与国际领先实验室比较

设备	指标要求	IHEP 现状	CERN 现状	Fermi 现状	KEK 现状	LBNL 现状
1.3 GHz SRF cavity	$Q = 3 \times 10^{10}$ @ 24 MV/m	$Q = 4.3 \times 10^{10}$ @ 31 MV/m	初步进展	与 IHEP 相当	与 IHEP 相当	无
650MHz SRF cavity (2-cell)	$Q = 4 \times 10^{10}$@ 22 MV/m	$Q = 6 \times 10^{10}$ @ 22 MV/m	无	与 IHEP 相当	无	无
高效速调管	效率 80%	效率约 70%	在研 80%	无	约 60%	无
高场磁体	20-24 T	已经达到 12.5 T, 正在建造内插高温超导线圈, 目标 16 T	14-16 T	14.5 T	10 T	14-16 T

束流驱动等离子体加速作为直线注入器的备选方案

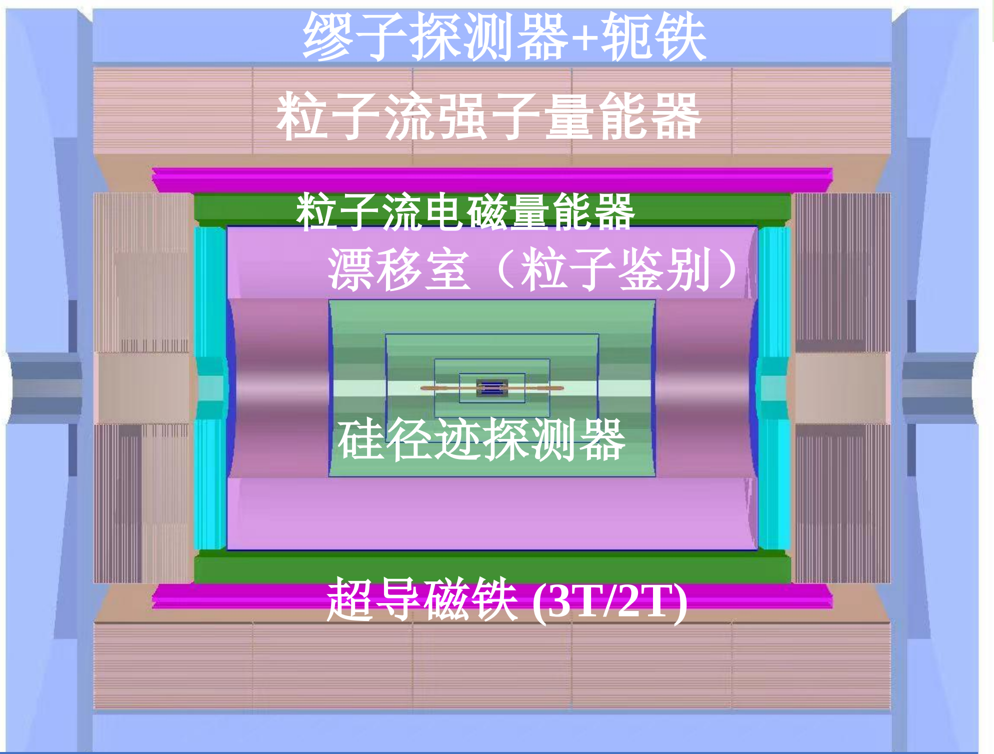


铁基超导技术近年来的快速发展



实验设施设计方案与技术指标

探测器



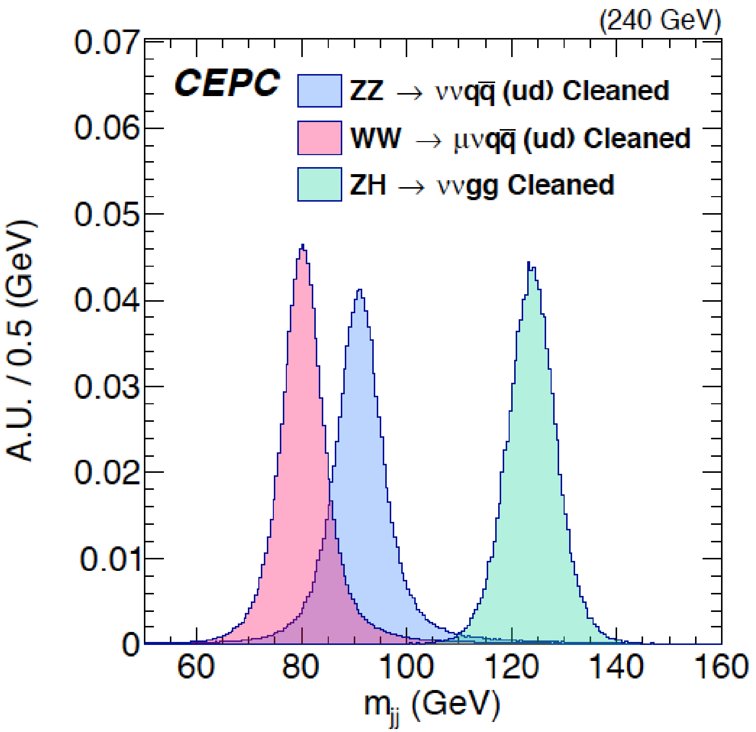
物理要求

玻色子质量分辨率 (BMR ~3%)

→

设计挑战

- 支持粒子流重建
- 高颗粒度
- 高精度的能量、径迹测量



全新的基于粒子流的量能器设计. 目标是将BMR从4% 提升至 3%

探测器	关键性能指标	世界水平	CEPC要求
基于粒子流的电磁量能器	电磁能量分辨率	~20%/√E	<3%/√E
基于粒子流的强子量能器	单强子能量分辨率	~50%/√E	~40%/√E

实验设施设计方案与技术指标

CEPC创新性设计和关键技术预研处于国际领先水平

	概念性创新	可升级	最先进技术	环保、节约	革命性原理	价值溢出
100km 环形对撞机	★	★				
局部及全双环	★	★		★		
H/W/Z能量可切换	★			★		
CEPC对撞环、增能环及SppC共用隧道	★	★		★		
高效速调管			★	★		★
超导射频加速腔			★	★		★
极弱场二极磁铁			★			
双孔径磁铁			★	★		
等离子体尾场加速注入器	★	★		★	★	★
铁基高温超导磁体	★		★	★	★	★
新型粒子流探测器	★		★		★	★

CEPC扩展升级空间及附加效益

单环束流同步辐射功率可升级至 50 MW: 获得更高的亮度 (8×10^{34} @ 240 GeV)

质心能量可升级至 **360 GeV**: 覆盖顶夸克的研究

可升级为高能质子对撞机 (SppC) 质心能量 >**100 TeV**

可扩展性: 提供高能量高通量同步辐射光（能量可达300MeV），对多学科的研究具有重要意义

带动多领域技术的发展:
快电子学, 机械, 真空, 束流, 高频, 低温, 新型磁铁, 高精度电源, 控制系统, 大数据, 自动化与智能化 等等

- CEPC升级方案: 设计和建设充分考虑了兼容性;
- CEPC进行多种升级、提升其发现能力, 预期其科学寿命将超过50年;
- **CEPC 对于多领域、多学科的研究及应用具有显著的溢出效应。**

4. 扩展功能、未来升级空间、溢出效应

CEPC 技术预研现状与成熟度

- 已得到科技部、中科院、国家自然科学基金等部门约2.6亿元的经费支持
- 多项关键技术已通过高能所负责的其它大型加速器得到验证: BEPCII, HEPS, …

CEPC项目预研覆盖 ~ 50% 加速器部件（造价占比）	➢ 高效束调管 ➢ **650MHz** 超导高频腔 ➢ 正电子源关键部件 ➢ 高性能直线加速器 ➢ 组合型静电分离器（电场磁场复合） ➢ 低温系统	➢ 新型磁铁: 弱场二极铁, 双孔径磁铁 ➢ 超快注入引出磁铁 ➢ 真空盒技术 ➢ 大型加速器勘测与准直技术 ➢ 探测器与加速器接口
BEPCII / HEPS覆盖 ~ 40% 加速器部件	➢ 高精度磁铁 ➢ 高稳定磁铁电源 ➢ **NEG**镀膜真空盒 ➢ 束测与反馈系统 ➢ 传统功率源 ➢ 超导高频腔	➢ 电子源与传统直线加速器 ➢ 勘测与准直技术 ➢ 高稳定机械系统 ➢ 辐射防护 ➢ 低温系统 ➢ 探测器与加速器接口

~10% 项目来自于未来加速器系统集成、参数联调等工作带来的挑战。
在开建前完成，也给国际合作留有空间。

5. 关键技术预研现状及技术成熟度

CEPC 技术预研现状与成熟度

✓ 样机指标已满足

☑ 样机研发中

	Accelerator	Cost (billion CNY)	Ratio
✓	Magnets	4.47	27.3%
✓	Vacuum	3.00	18.3%
☑	RF power source	1.50	9.1%
✓	Mechanics	1.24	7.6%
✓	Magnet power supplies	1.14	7.0%
✓	SCRF	1.16	7.1%
✓	Cryogenics	1.06	6.5%
✓	Linac and sources	0.91	5.5%
✓	Instrumentation	0.87	5.3%
☑	Control	0.39	2.4%
☑	Survey and alignment	0.40	2.4%
✓	Radiation protection	0.17	1.0%
☑	SC magnets	0.07	0.4%
✓	Damping ring	0.04	0.2%

Table 5.1: Summary of key technologies under R&D essential for CEPC

Device	Accelerator	Quantity	CEPC specification	R&D status
1.3 GHz SRF cavity (9-cell)	Booster	96	$Q=3\times10^{10}$ @ 24 MV/m	Specification met
650 MHz SRF cavity (2-cell)	Collider	240	$Q=4\times10^{10}$@22 MV/m	Specification met
650 MHz klystron	Collider	120	Efficiency: 80% Power: 800 kW	Prototype manufactured
C-band NC accelerating tube	Linac	292	Gradient: 45 MV/m	Prototype manufactured
S-band bunch compressor	Linac	35	Peak power gain: 7 dB	Prototype manufactured
Positron source flux concentrator	Linac	1	Central peak magnetic field >6 T	Specification met
Dual-aperture dipole magnet	Collider	2384	Field: 140 Gs-560 Gs aperture: 70 mm length: 28.7 m; harmonic< 5×10^{-4} relative field difference<0.5%	Specification met
Dual-aperture quadrupole magnet	Collider	2392	Gradient: 3.2-12.8 T/m length: 2 m; harmonic< 5×10^{-4} aperture: 76 mm relative field difference<0.5%	Specification met
Weak field dipole	Booster	16320	Field error $\leq 10^{-3}$@60 Gs	Specification met
Electrostatic separator	Collider	32	Electric field: 2.0 MV/m field uniformity: 5×10^{-4} good field region: 46 mm*11 mm	Specification met by prototype
Cryogenic refrigerator	Collider/ Booster	4	18 kW @ 4.5 K	Collaboration with IPC CAS, a refrigerator system of 2.5 kW @ 4.5 K has been developed
Ceramic vacuum chamber and coating	Transport lines	~ 20	$75\times56\times5\times1200$mm	Prototype in production
MDI SCQ	Collider	8	Gradient: 136T/m; length: 2m Aperture: 40mm; included angle: 33mrad	Prototype in manufacture
Visual instrument	All	11	Image accuracy: 5 μm+(5 μm/m) horizontal angle: 1.8 arc·second vertical angle: 2.2 arc·second	Prototype completed

Table 5.2: Summary of key technologies in engineering applications essential for CEPC

Device type	Accelerator	Quantity	CEPC specifications
S-band copper accelerating tube	Linac	111	~30 MV/m
vacuum chamber and coating	Collider/ Booster	Total length 200 km	Length: 6 m aperture: 56 mm vacuum: 3×10^{-10} Torr NEG coating pump speed for H_2: 0.5 L/s· cm^2
BPM and electronics	All	~5000	Closed orbit resolution: 0.6 μm
kicker & fast pulser	Transport line	~25	Pulse width <10 ns (strip-line) trapezoidal pulse width <250 ns (slotted-pipe)
Lambertson septum	Transport line	~20	Septum thickness ≤3.5 mm (in-air) thickness ≤2 mm (in-vacuum)
Power supply	All	9294	Stability 100-1000 ppm
RF-shielded bellows	Collider Booster	24000 /12000	Contact force 125±25 g/finger

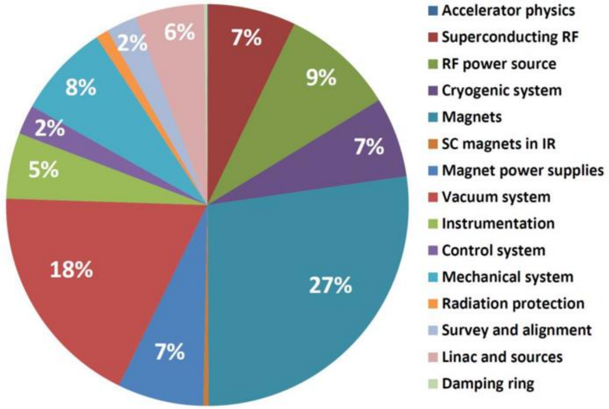


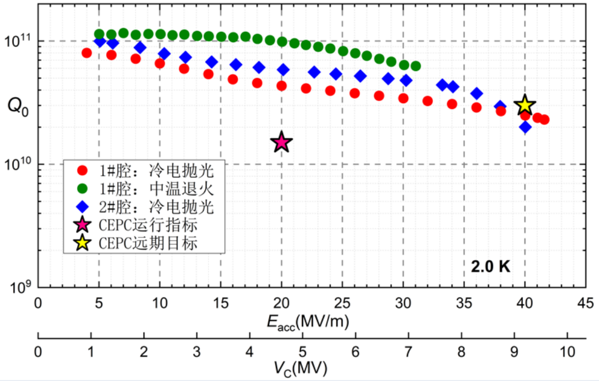
Figure 12.3: Cost breakdown of the CEPC accelerator technical systems.

5.1 关键技术预研现状与成熟度

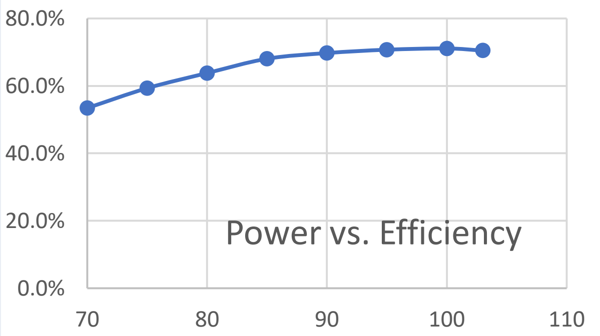
CEPC 技术预研现状与成熟度

国际先进的关键部件

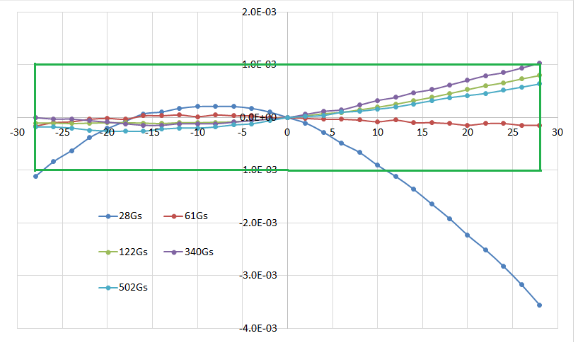
650MHz 超导射频腔



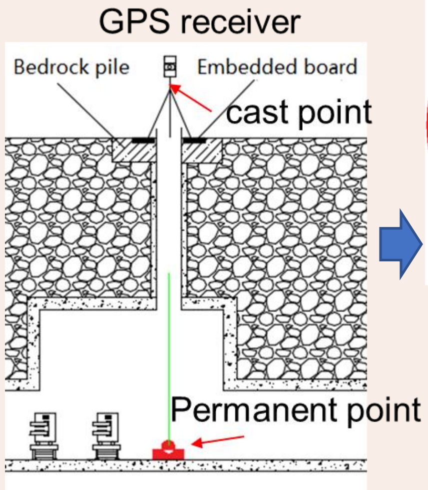
高效速调管

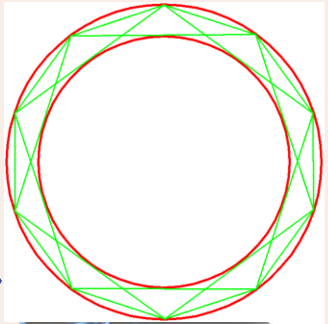


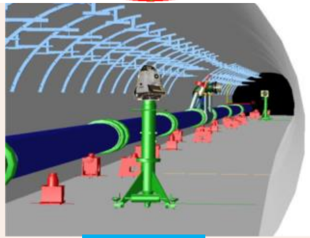
极弱场二极磁铁

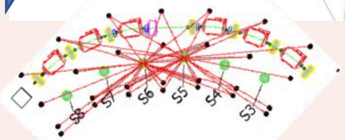


100km 加速器准直与安装预研





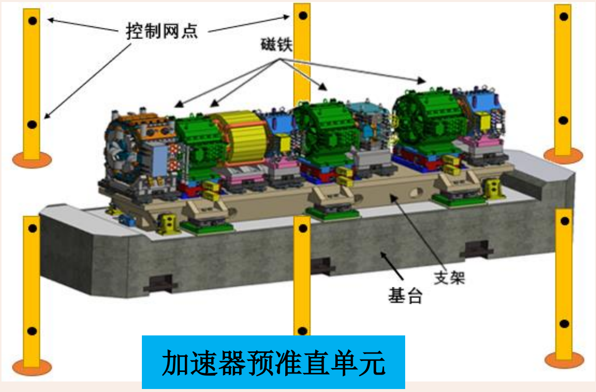




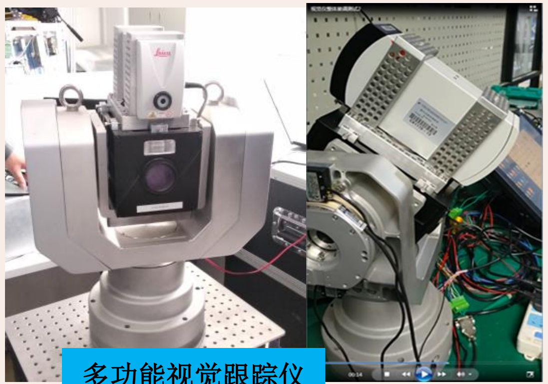
控制点

骨干网

隧道控制网络



加速器预准直单元



多功能视觉跟踪仪

高效的准直方案 + 新型准直设备研发 → 保证加速器设备安装4年内完成.

CEPC 技术预研现状与成熟度

- 团队在大装置上积累丰富经验
  - 漂移室、超导磁铁：（北京谱仪）
  - 硅微条探测器：（ATLAS升级）
- 关键技术研发
  - 硅像素探测器与时间投影室
  - 粒子流量能器

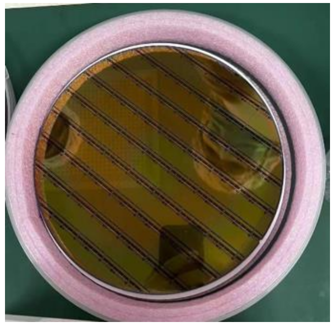
- 研发工作覆盖所有子探测器系统
- 进行深度的国际合作
  - 粒子流量能器：与CALICE 国际合作组联合研发
  - 时间投影室：与 LCTPC 国际合作组联合研发
  - 漂移室：与意大利INFN等单位联合研发
  - 硅径迹探测器：与英国/德国/意大利等单位联合研发
  - 硅像素探测器：与法国/西班牙等单位联合研发

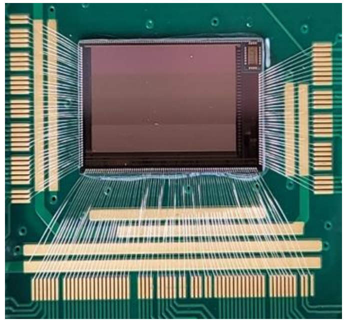
粒子流量能器

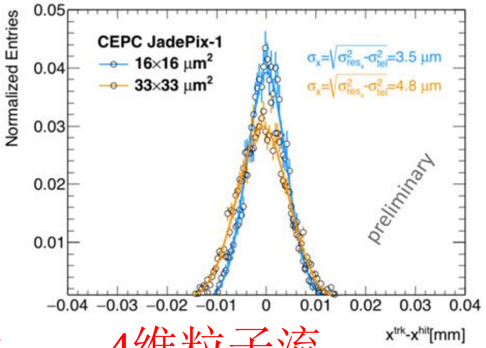
已经研发出样机，正在测试

探测器	指标	CEPC 物理需求	国际水平	CEPC 样机状态
硅像素探测器	空间分辨率	~3 微米	3-5 微米 [8-9]	3-5 微米（小型样机）[10-12]
TPC 时间投影室/漂移室	dE/dx (dN/dx) 分辨率	~2%	~4% [13-14]	~4%[15]–[17]（小型样机）
塑料闪烁体-钨的电磁量能器	电磁能量分辨率 颗粒度	$< 15\%/\sqrt{E(\mathrm{GeV})}$ $\sim 2\times2\ cm^2$	$12.5\%/\sqrt{E(\mathrm{GeV})}$ [18]	已研制。分辨率待测量 颗粒度 $0.5\times0.5\ cm^2$
4D 晶体电磁量能器	电磁能量分辨率 三维等效颗粒度	$\sim 3\%/\sqrt{E(\mathrm{GeV})}$ $\sim 2\times2\times2\ cm^3$	$\sim 2\%/\sqrt{E(\mathrm{GeV})}$ [19-20] N/A	研制中，预期 $\sim 3\%/\sqrt{E(\mathrm{GeV})}$ [21] 颗粒度满足要求
塑料闪烁体-钢的强子量能器	与粒子流算法匹配单强子能量分辨率	$< 60\%/\sqrt{E(\mathrm{GeV})}$	$57.6\%/\sqrt{E(\mathrm{GeV})}$ [22]	样机研制中
闪烁玻璃强子量能器	与粒子流算法匹配单强子能量分辨率	$\sim 40\%/\sqrt{E(\mathrm{GeV})}$	N/A	研制中，预期实现 $\sim 40\%\sqrt{E(\mathrm{GeV})}$
超导螺线管磁铁	磁场强度 径向厚度 物质量	2-3 T < 150 mm $< 1.5X_0$	1-4 T > 270 mm [23]–[25]	样机研发中 研制出小尺寸高温超导样缆

硅顶点像素探测器（3-5微米位置分辨率）

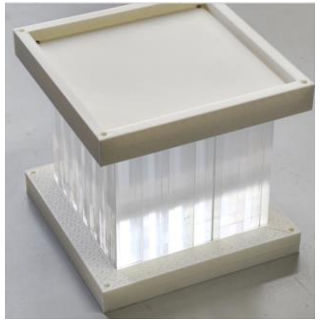






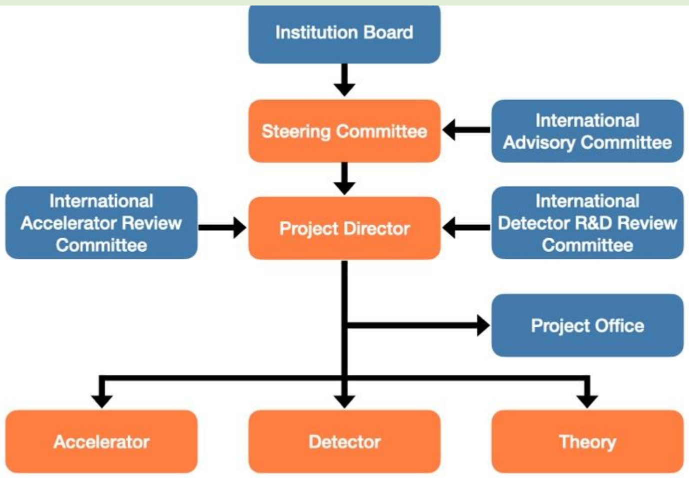
粒子流导向的闪烁体-钨的电磁量能器

4维粒子流晶体量能器



5. 关键技术预研现状，及技术成熟程度

核心团队、依托单位、已有条件及支持



- 机构委员会: 包括32所顶级大学或研究机构
- 管理团队: 拥有建设BEPCII/CSNS/HEPS等项目以及BESIII/Daya Bay/JUNO/等国际合作实验的全面管理经验
- 加速器团队: 在 BEPCII, HEPS 等项目中积累了丰富经验
- 物理和探测器团队:在 BESIII, Daya Bay, JUNO, ATLAS, CMS等项目中积累了丰富经验

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

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

管理团队,
世界级领军科学家

Table 7.3: Team of the CEPC accelerator system

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

Table 7.4: Team of the CEPC detector system

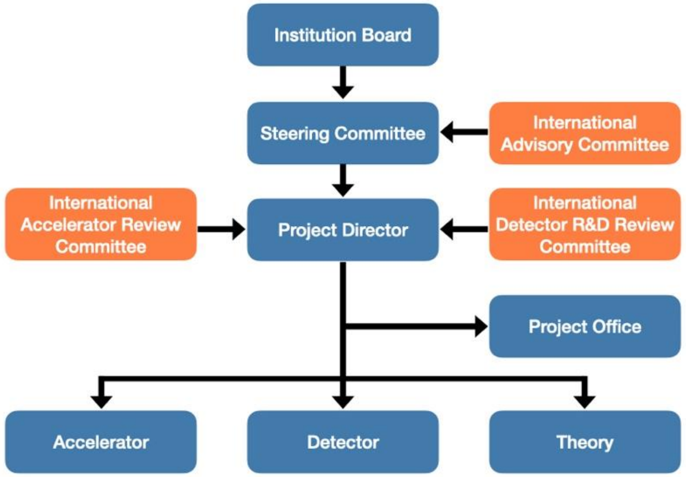
Number	Sub-system	Conveners	Institutions	Team (senior staff)
1	Pixel Vertex Detector	Zhijun Liang, Qun Ouyang, Xiangming Sun , Wei Wei	CCNU, IFAE, IHEP, NJU, NWPU, SDU, Strasbourg, ...	~ 40
2	Silicon Tracker	Harald Fox, Meng Wang, Hongbo Zhu	IHEP, INFN, KIT, Lancaster, Oxford, Queen Mary, RAL, SDU, Tsinghua,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

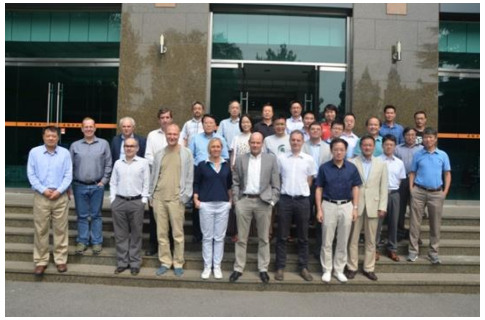
目前有117 个加速器方面 + ~300个物理探测器方面科学家；CEPC被批准后预期有规模相当的来自BEPC/BESIII/JUNO/HEPS等实验的科学家加入

6.1 核心人员队伍的完整性及竞争力

核心团队、依托单位、已有条件及支持

国际委员会





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

International Accelerator Review Committee

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

International Detector R&D Review Committee

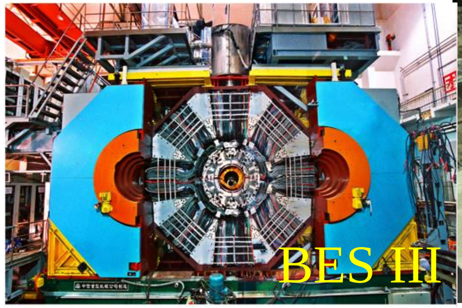
- Jim Brau, USA, Oregon
- Valter Bonvicini, Italy, Trieste
- Ariella Cattai, CERN, CERN
- Cristinel Diaconu, France, Marseille
- Brian Foster, UK, Oxford
- Liang Han, China, USTC
- Dave Newbold, UK, RAL (chair)
- Andreas Schopper, CERN, CERN
- Abe Seiden, USA, UCSC
- Laurent Serin, France, LAL
- Steinar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

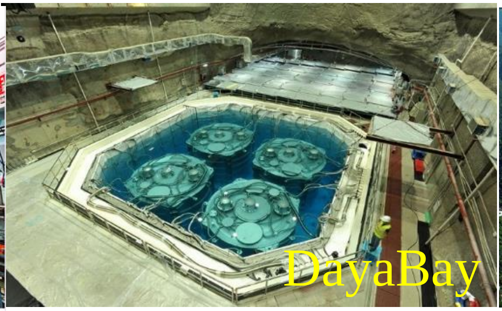
国际顾问委员会: 全球著名专家组成，大部分具有大科学装置组织、设计和管理经验，**2015年成立**

国际加速器和探测器委员会: 领域内领军专家，为项目预研工作提供指导

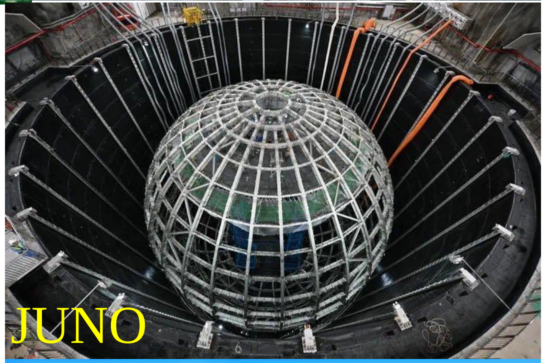
6.1 核心人员队伍的完整性及竞争力 + 6.3 国际合作程度

核心团队、依托单位、已有条件及支持





- 高能所是世界上少数拥有以下优势的机构之一：
  - 拥有多个大型基础科学研究设施的管理和成功建设经验
  - 拥有一个涵盖加速器和探测器全部项目的技术团队，特别是BEPC/BES团队
  - 拥有建设大型科研设备所需的全部基础设施
  - 运行多个国际大科学项目，如 BESIII, Daya Bay, JUNO, LHAASO等.
- **高能所投入CEPC；CEPC战略规划得到科学院支持**



核心团队、依托单位、已有条件及支持

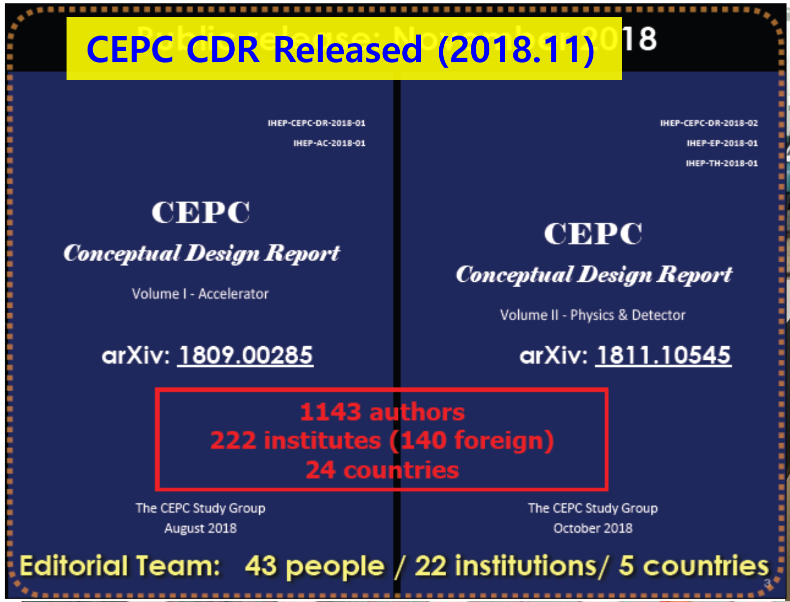
国际合作

CEPC 已吸引大量国际合作参与

- 概念设计报告: 来自221所单位（包括140个国外单位）的1143 名作者署名
- 已签署并执行超过20份合作备忘录

- 已开展深入的国际合作物理研究
- 海外科学家在各个子系统（特别是探测器系统）预研中做出了重要贡献

- 2014以来，每年召开CEPC国际会议
- 组织欧洲-美洲版CEPC国际会议: 下一次会议地点在马赛
- 2015年起，每年参加香港科技大学高能物理工作月



6.3 国际合作程度

核心团队、依托单位、已有条件及支持

国际影响

CEPC Input to the ESPP 2018 - Physics and Detector

CEPC Physics-Detector Study Group

Abstract

The Higgs boson, discovered in 2012 by the ATLAS and CMS Collaborations at the Large Hadron Collider (LHC), plays a central role in the Standard Model. Measuring its properties precisely will advance our understandings of some of the most important questions in particle physics, such as the naturalness of the electroweak scale and the nature of the electroweak phase transition. The Higgs boson could also be a window for exploring new physics, such as dark matter and its associated dark sector, heavy sterile neutrino, et al. The Circular Electron Positron Collider (CEPC), proposed by the Chinese High Energy community in 2012, is designed to run at a center-of-mass energy of 240 GeV as a Higgs factory. With about one million Higgs bosons produced, many of the major Higgs boson couplings can be measured with precisions about one order of magnitude better than those achievable at the High Luminosity-LHC. The CEPC is also designed to run at the Z-pole and the W pair production threshold, creating close to one trillion Z bosons and 100 million W bosons. It is … electroweak observables … urements are complement… C also offers excellent op… s, W, and Z bosons. The … tau leptons produced from the decays of the Z bosons are interesting for flavor physics. The clean collision environment also makes the CEPC an ideal facility to perform precision QCD measurements. Several detector concepts have been proposed for the C… epts can fulfill … potential and t… il in the Conce… o outline futur… ribe the plann… p for the CEPC … national collaboration would be crucial at this stage. This submission for consideration by the ESPP is part of our dedicated effort in seeking international collaboration and support. Given the importance of the precision Higgs boson measurements, the ongoing CEPC activities do not diminish our interests in participating in the international collaborations of other future electron-positron collider based Higgs factories.

ESPPU input

arXiv: 1901.03170
1901.03169

Snowmass2021 White Paper AF3- CEPC

CEPC Accelerator Study Group[1]

1. Design Overview

1.1 Introduction and status

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

The … hosted by China. It … the ICFA Workshop *"Accelerators for a Higgs Factory: Linear vs. Circular"* (HF2012) in November 2012 at Fermilab. A Preliminary Conceptual Design Report (Pre-CDR, the White R… (the Yellow … was made. T… [3] has been … an internati… 018. In May … ergy Physics … DR, CEPC a… d by CEPC International Advisory Committee (IAC). In TDR phase, CEPC optimization design with higher performance compared with CDR and the key technologies such as 650MHz high power and high efficiency klystron, high quality SRF accelerator technology, high precision magnets for booster and collider rings, vacuum system, MDI, etc. have been carried out, and the CEPC accelerator TDR will be completed at

[1] Correspondance: J. Gao, Institute of High Energy Physics, CAS, China
Email: gaoj@ihep.ac.cn

Snowmass input

arXiv: 2203.09451
2205.08553

- CEPC 作为主要的未来对撞机设计参与了欧洲和美国的粒子物理战略讨论。
- 团队成员参与了上述战略讨论的组织、并作为特邀嘉宾参与了多次高端讨论。

CEPC吸引了显著、高效的国际合作，确保了项目设计和关键技术的先进性；获批后将得到国际高能物理学界长期稳定的支持。

6.3 国际合作程度

核心团队、依托单位、已有条件及支持

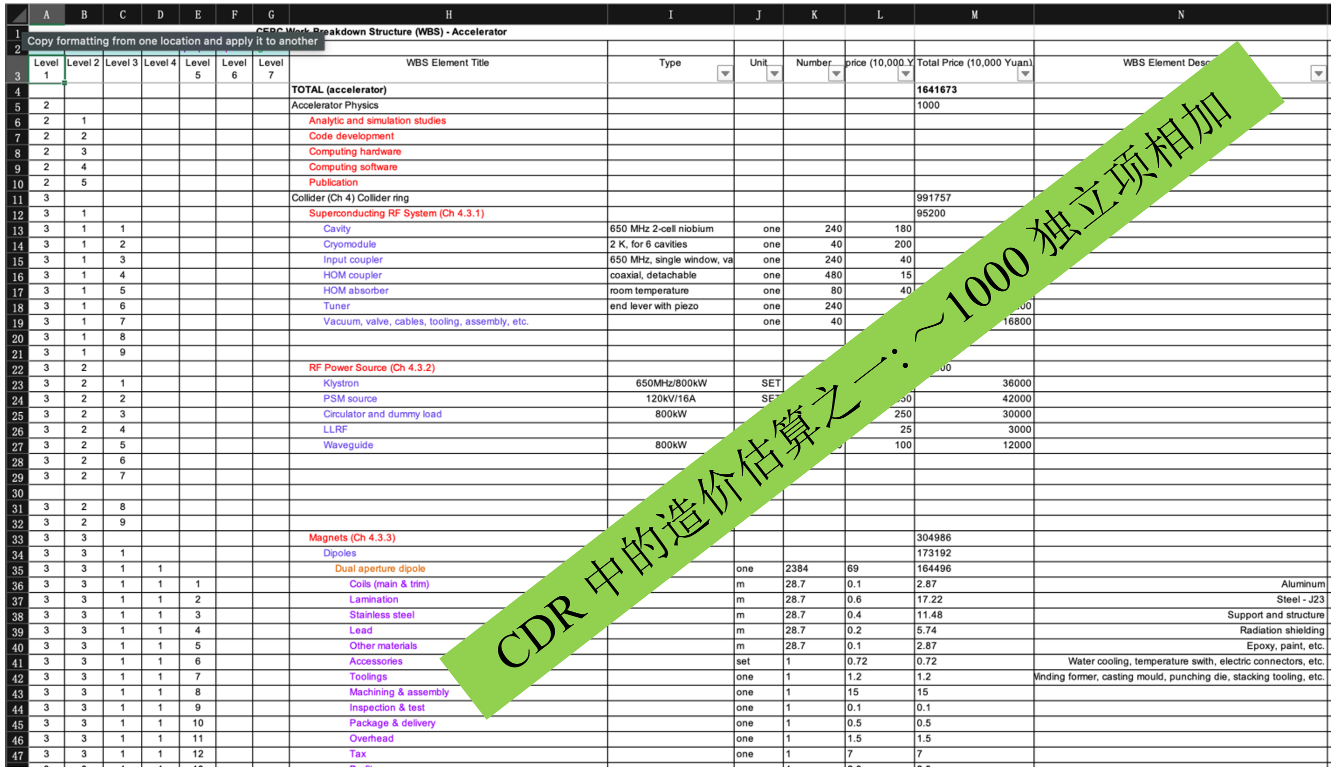
工业界的参与

- CEPC产业促进会（CIPC）成立于2017年，目前包括约70个高科技企业。覆盖超导材料、超导腔、低温恒温器、大型液氦低温系统、速调管、电子学器件、功率源、真空系统、土木工程等。CIPC通过联合研制和攻关，共同推动核心技术预研，促进产业协同发展，**为量产作好准备**。
- CEPC研究团队也在积极寻求**国际产业界的合作和供货**。
- CEPC将极大提升相关技术的发展(经济效益显著).

项目预研和建设预算，项目时间线

表 8.1：CEPC 各系统建设预算 (CDR)

总计（亿人民币）	358	
加速器	164	
对撞环		99.2
增强器		39.2
直线注入器与粒子源		9.1
阻尼环		0.44
Common：低温系统		10.6
检视 & 准直系统		4
辐射防护		1.7
土建施工	102	
探测器	40	
γ 束流线	3	
项目管理 (1%)	3	
不可预见费用 (15%)	46	



CEPC Work Breakdown Structure (WBS) - Accelerator

Copy formatting from one location and apply it to another

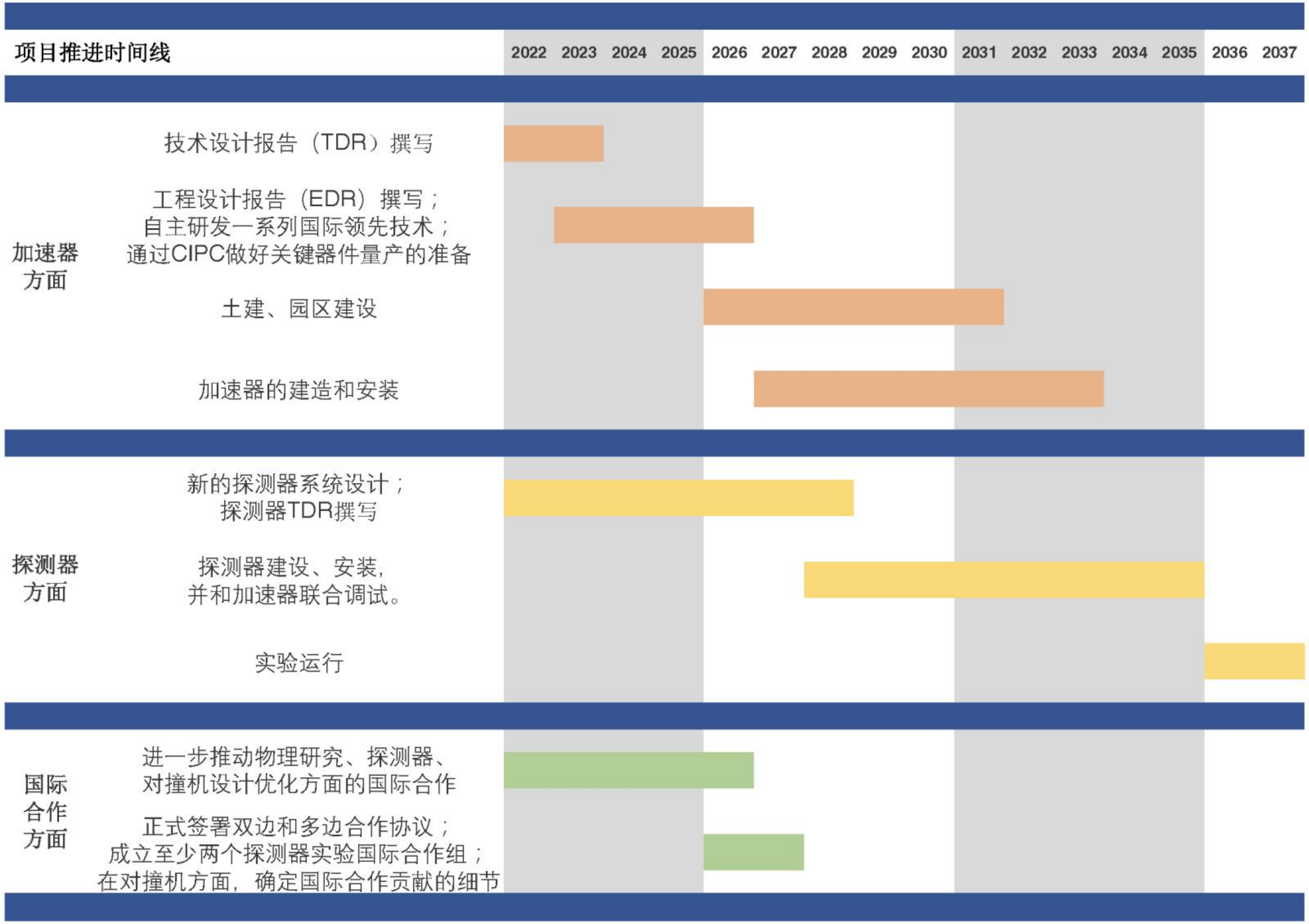
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
3	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	WBS Element Title	Type	Unit	Number	price (10,000 Y	Total Price (10,000 Yuan)	WBS Element Desc
4								TOTAL (accelerator)					1641673	
5	2							Accelerator Physics					1000	
6	2	1						Analytic and simulation studies						
7	2	2						Code development						
8	2	3						Computing hardware						
9	2	4						Computing software						
10	2	5						Publication						
11	3							Collider (Ch 4) Collider ring					991757	
12	3	1						Superconducting RF System (Ch 4.3.1)					95200	
13	3	1	1					Cavity	650 MHz 2-cell niobium	one	240	180		
14	3	1	2					Cryomodule	2 K, for 6 cavities	one	40	200		
15	3	1	3					Input coupler	650 MHz, single window, va	one	240	40		
16	3	1	4					HOM coupler	coaxial, detachable	one	480	15		
17	3	1	5					HOM absorber	room temperature	one	80	40		
18	3	1	6					Tuner	end lever with piezo	one	240		[illegible]	
19	3	1	7					Vacuum, valve, cables, tooling, assembly, etc.		one	40		16800	
20	3	1	8											
21	3	1	9											
22	3	2						RF Power Source (Ch 4.3.2)					[illegible]	
23	3	2	1					Klystron	650MHz/800kW	SET			36000	
24	3	2	2					PSM source	120kV/16A	[illegible]		[illegible]	42000	
25	3	2	3					Circulator and dummy load	800kW			250	30000	
26	3	2	4					LLRF				25	3000	
27	3	2	5					Waveguide	800kW			100	12000	
28	3	2	6											
29	3	2	7											
30														
31	3	2	8											
32	3	2	9											
33	3	3						Magnets (Ch 4.3.3)					304986	
34	3	3	1					Dipoles					173192	
35	3	3	1	1				Dual aperture dipole		one	2384	69	164496	
36	3	3	1	1	1			Coils (main & trim)		m	28.7	0.1	2.87	Aluminum
37	3	3	1	1	2			Lamination		m	28.7	0.6	17.22	Steel - J23
38	3	3	1	1	3			Stainless steel		m	28.7	0.4	11.48	Support and structure
39	3	3	1	1	4			Lead		m	28.7	0.2	5.74	Radiation shielding
40	3	3	1	1	5			Other materials		m	28.7	0.1	2.87	Epoxy, paint, etc.
41	3	3	1	1	6			Accessories		set	1	0.72	0.72	Water cooling, temperature swith, electric connectors, etc.
42	3	3	1	1	7			Toolings		one	1	1.2	1.2	Vinding former, casting mould, punching die, stacking tooling, etc.
43	3	3	1	1	8			Machining & assembly		one	1	15	15	
44	3	3	1	1	9			Inspection & test		one	1	0.1	0.1	
45	3	3	1	1	10			Package & delivery		one	1	0.5	0.5	
46	3	3	1	1	11			Overhead		one	1	1.5	1.5	
47	3	3	1	1	12			Tax		one	1	7	7	

- CDR采取两种独立的方法估算造价：差别在10% 以内
- CEPC 设计基于成熟的技术和研究结果，减少造价估算的不确定性
- TDR阶段的建设预算正在进行：估价没有明显变化

项目预研及建设经费 - 性价比分析

- CEPC可带来**价值不可估量**的发现和知识。CEPC预期在2030年代产生Higgs数据，将人类的科研带到一个全新的时代。
- CEPC进行了系统优化，通过设计和技术上的创新大幅压低了造价。
- CEPC将吸引、支持上千名科研人员进行长达数十年的科研。相对其他大科学工程、其他学科、每人每年平均的科研经费并没有提升、甚至更低（规模效应）。
- CEPC升级潜力巨大，大力推动技术发展，是全球人才培养和**协同创新**的高地；有望在若干关键技术上带来革命性突破，应用前景巨大。
- CEPC将吸引显著的**国际合作**，促进国际交流、促进国际和平。
- CEPC及其附近的科学城将显著推动当地经济发展。

项目预研和建设预算，项目时间线



7.3 项目时间进度安排

总结

CEPC

- 将探索粒子物理领域最重要、最紧迫的科学问题。
- 战略价值巨大，比较优势明显、建成后将成为领域内旗舰设施。
- 设计技术趋于成熟、优异升级潜力、重大附加值和溢出效应。
- 人员队伍完整、经验丰富并具有国际竞争力；得到高能所全力支持和有效的国际合作，为实施项目打下了基础。
- 提议：在“十五五”期间开建、于“十六五”期间建成并开始运行。
- 将使中国获得粒子物理研究的国际引领地位，对人类科学探索作出重大贡献。

Back up

Budgets for R&D and construction

Cost and benefit analysis

- *CEPC **is priceless** in revealing potential discoveries & knowledge. CEPC may provide the **Higgs data** in 2030s, thus brings upon mankind a new era in the science exploration.*
- *The **current CEPC design is optimized**. The cost is reduced through innovative design & new tech. development.*
- *CEPC will host **thousands of users and operates for decades**. The investment per researcher per year is comparable, or even smaller than that of other facilities & other disciplines.*
- *CEPC has the upgradable capability and provides **strong boost to the technologies**, is a highland for global talent training & **cooperative innovations**. It could revolutionize multiple key-tech. that has huge potential for application.*
- *CEPC attracts significant **International collaboration,** enhance the international communication, contribute to the World Peace.*
- *The science city of CEPC could strongly **promote** local **economic**.*

Summary

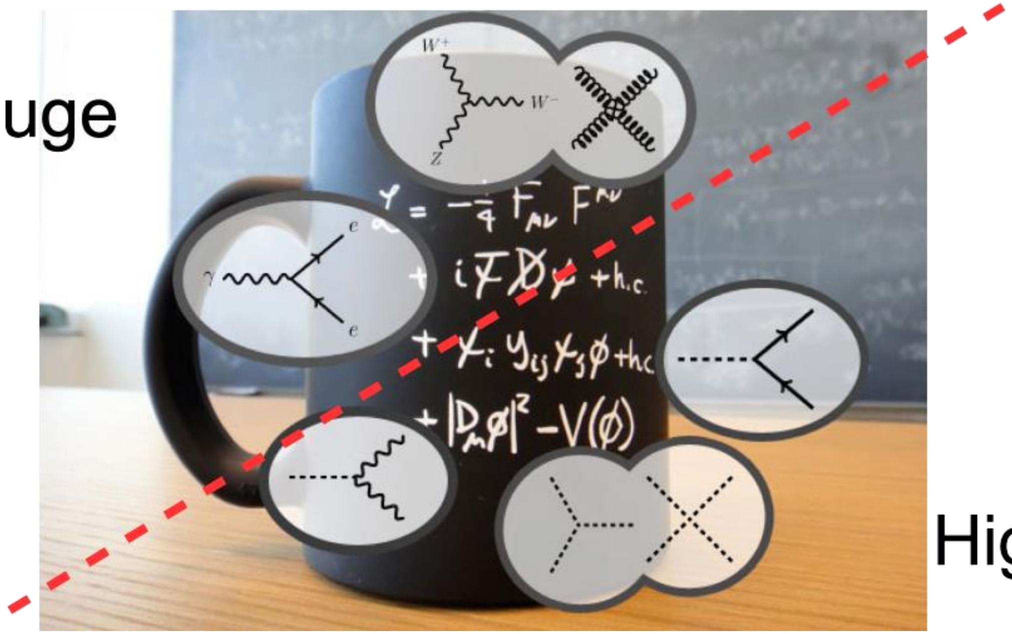
CEPC

- **will address most pressing & critical science problems**
- **adds enormous strategic values; has many advantages; will be in a leading position if realized.**
- **design-technologies reaching maturity; offers great upgrade options and many added values and benefits**
- **has a strong-experienced team, IHEP support and international cooperation, which are keys to bring CEPC to fruition**
- **schedule follows China's 5-year planning; expects to complete R&D and preparation to build the facility and carry out the science program**
- **will position China to be a leading position in particle physics and contribute to the world in a major way.**

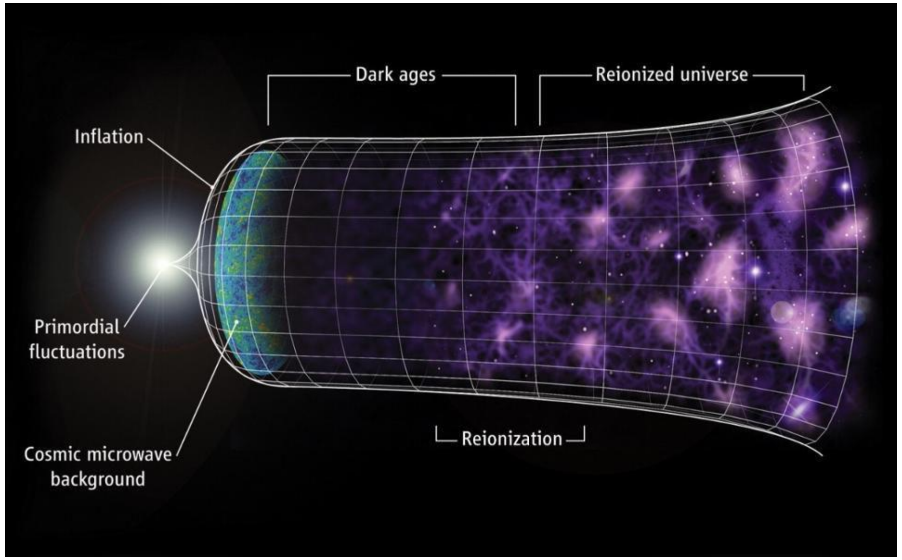
Science

Scientific objective: Higgs field & Challenges to the SM

Gauge



Higgs



- Hierarchy: From neutrinos to the top mass, masses differs by 13 orders of magnitude
- Naturalness: Fine tuning of the Higgs mass
- Masses of Higgs and top quark: meta-stable of the vacuum
- Unification?
- Dark matter candidate?
- Not sufficient CP Violation for Matter & Antimatter asymmetry

- **Most issues related to Higgs**

关键科学和技术问题（路线）

New Physics
~10 TeV

- ✓ Dark Matter
- ✓ Extended Higgs
- ✓ Composite Higgs
- ✓ Supersymmetry
- ……

High Precision
~1%

- ✓ Higgs: 1%-0.1%
- ✓ EW：$O(10^2\text{-}10^3)$ vs current
- ✓ Flavor
- ……

Detector
Particle Flow

- ✓ High Granularity
- ✓ Good Resolution
- ✓ Reliable PID
- ……

Design & Implementation
Detector & Accelerator

- ✓ Multi-purposed Acc.
- ✓ New concept Detector
- ✓ Cost, added values
- ✓ Spill-over
- ……

- ✓ Management
- ✓ Collaboration
- ……

High Lumi.
$\sim 10^{34\text{-}36}\,cm^{-2}s^{-1}$

- ✓ Higgs: 20 ab^{-1}
- ✓ Z: 100 ab^{-1}
- ✓ W: 6 ab^{-1}
- ✓ Top: 1 ab^{-1}

Accelerator
2 IPs/100 km

- ✓ Switchable Operations
- ✓ Upgradability
- ✓ Large Piwinski angle with Crab-waist
- ……

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

CEPC Measurement Precision

Table 2.1: Precision of the main parameters of interests and observables at CEPC, from Ref. [1] and the references therein, where the results of Higgs are estimated with a data sample of 20 ab^{-1}. The HL-LHC projections of 3000 fb^{-1} data [2] are used for comparison

Higgs			W, Z, and top		
Observable	HL-LHC projections	CEPC precision	Observable	Current precision	CEPC precision
M_H	20 MeV	3 MeV	M_W	9 MeV	0.5 MeV
Γ_H	20%	1.7%	Γ_W	49 MeV	2 MeV
$\sigma(ZH)$	4.2%	0.26%	M_{top}	760 MeV	$\mathcal{O}(10)$ MeV
$B(H \to bb)$	4.4%	0.14%	M_Z	2.1 MeV	0.1 MeV
$B(H \to cc)$	-	2.0%	Γ_Z	2.3 MeV	0.025 MeV
$B(H \to gg)$	-	0.81%	R_b	3×10^{-3}	2×10^{-4}
$B(H \to WW^*)$	2.8%	0.53%	R_c	1.7×10^{-2}	1×10^{-3}
$B(H \to ZZ^*)$	2.9%	4.2%	R_μ	2×10^{-3}	1×10^{-4}
$B(H \to \tau^+\tau^-)$	2.9%	0.42%	R_τ	1.7×10^{-2}	1×10^{-4}
$B(H \to \gamma\gamma)$	2.6%	3.0%	A_μ	1.5×10^{-2}	3.5×10^{-5}
$B(H \to \mu^+\mu^-)$	8.2%	6.4%	A_τ	4.3×10^{-3}	7×10^{-5}
$B(H \to Z\gamma)$	20%	8.5%	A_b	2×10^{-2}	2×10^{-4}
$B\text{upper}(H \to \text{inv.})$	2.5%	0.07%	N_ν	2.5×10^{-3}	2×10^{-4}

Accelerator Design, R&D & Maturity

Accelerator	Cost (billion CNY)	Ratio	CEPC R&D	BEPCII /HEPS
Magnets	4.47	27.3%	20.0%	7.0%
Vacuum	3.00	18.3%	10.0%	8.0%
RF power source	1.50	9.1%	5.0%	2.0%
Mechanics	1.24	7.6%	N.A	6.6%
Magnet power supplies	1.14	7.0%	0.5%	6.5%
SCRF	1.16	7.1%	5.1%	2.0%
Cryogenics	1.06	6.5%	3.0%	2.5%
Linac and sources	0.91	5.5%	2.0%	2.5%
Instrumentation	0.87	5.3%	2.3%	3.0%
Control	0.39	2.4%	0.1%	0.5%
Survey and alignment	0.40	2.4%	1.4%	1.0%
Radiation protection	0.17	1.0%	0.1%	0.2%
SC magnets	0.07	0.4%	0.2%	0.1%
Damping ring	0.04	0.2%	N.A.	N.A.
Total			**49.7%**	**41.9%**

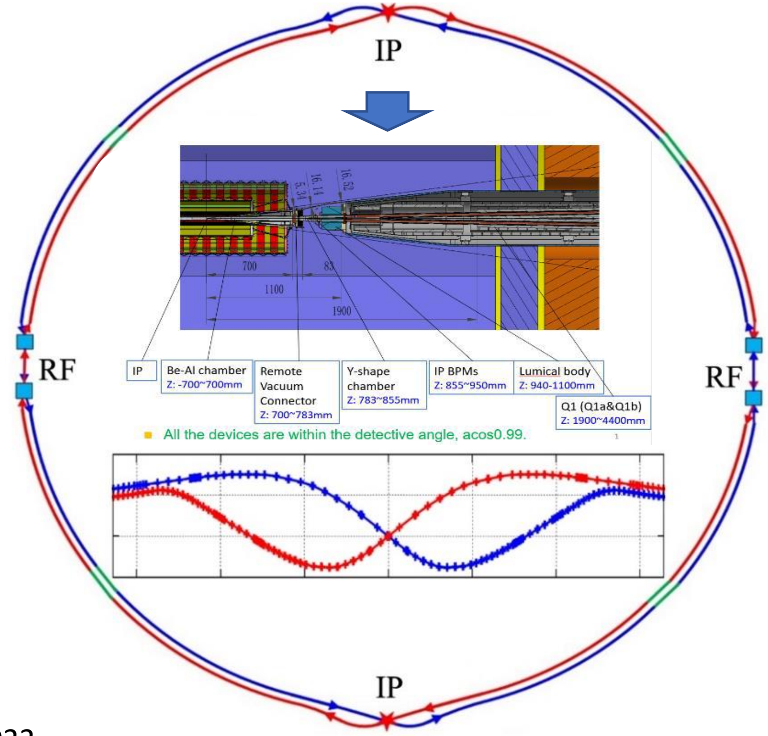
Accelerator design: Compatible Operation

DESIGN GOAL

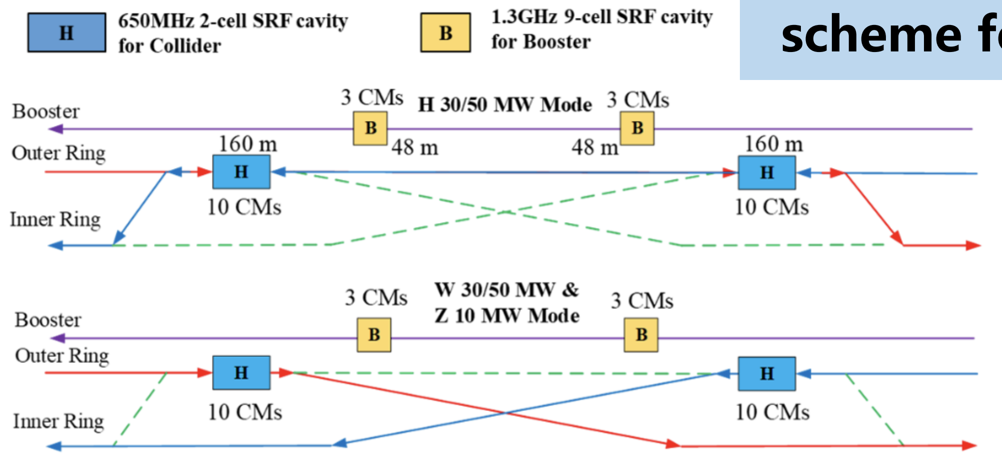
Compatible operation for Higgs, W, Z and Top runs

SOLUTIONS

- Partial/full partial double ring design with special RF station bypass scheme



RF station by pass scheme for Higgs, W, Z



4 IP design in progress...

Accelerator design: Environmental Friendly Design

DESIGN GOAL

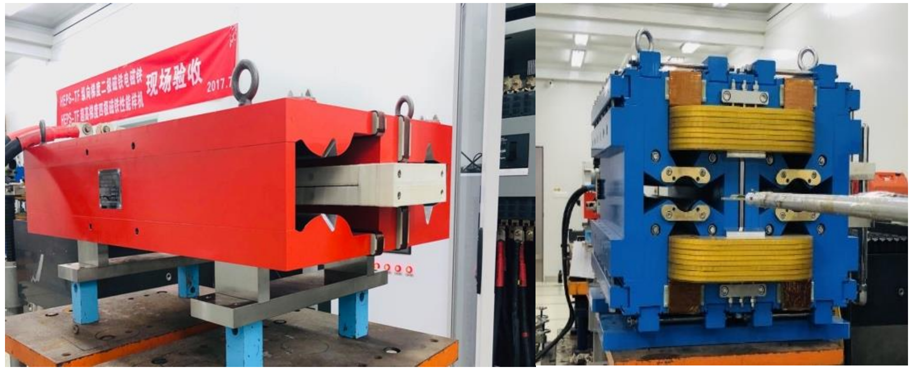
Environmental friendly & economic operation

SOLUTIONS

- High efficiency Klystron
- High Q SRF cavity
- Dual Aperture Magnets

High Q SRF Cavity & Module

High Efficiency Klystron



Dual Aperture Magnets

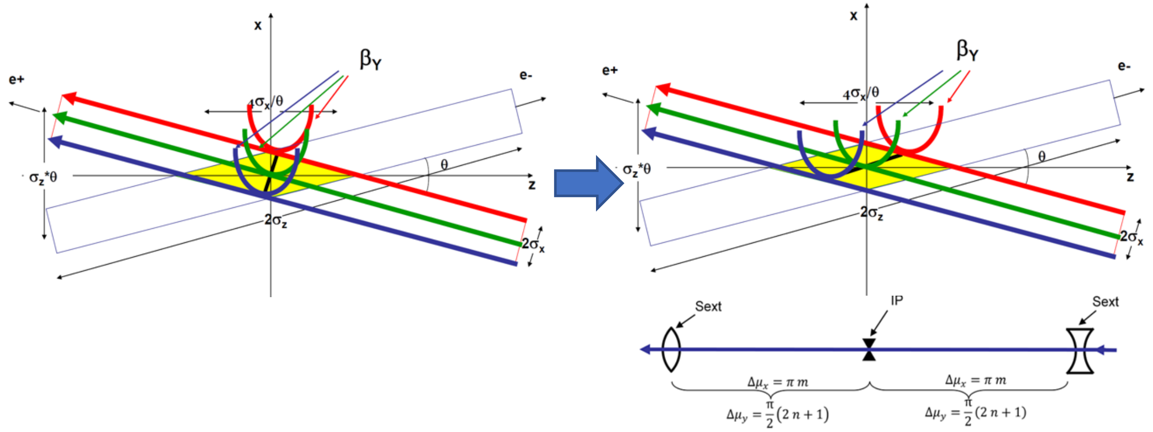
Accelerator design: Pursing high Luminosity

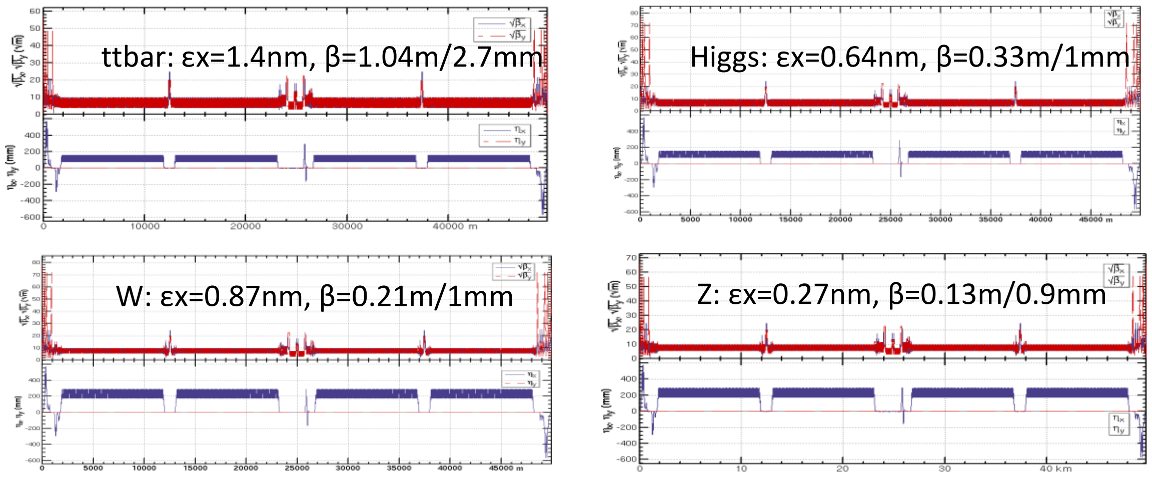
DESIGN GOAL

Increase Luminosity

SOLUTIONS

- **Lattice optimization for all energies**
- **Crab waist scheme with large cross angle and sextuples**



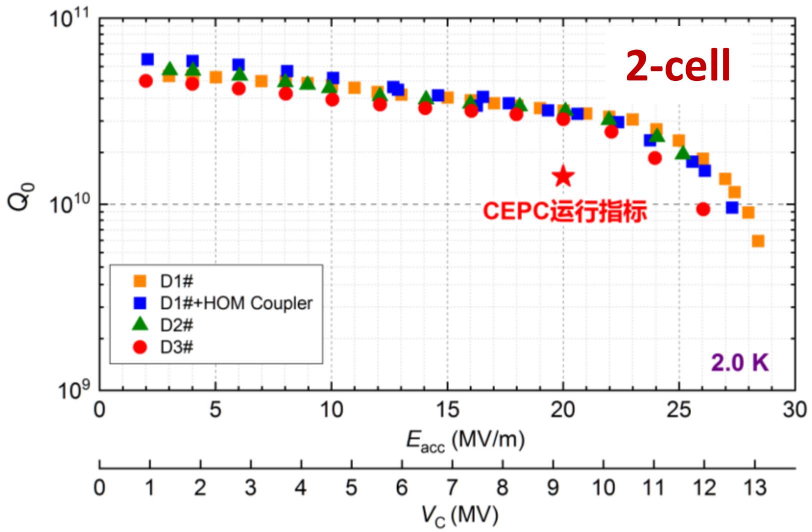


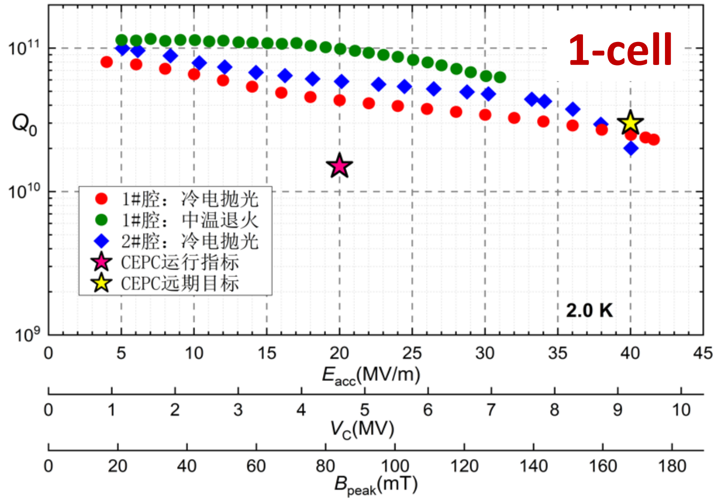
Accelerator technology Maturity

- Intensive R&D covers systems with a high budget ratio:
  - magnet (27%), vacuum (18%), RF power source (9%), mechanical (8%), superconducting RF (7%), cryogenic(7%), beam source and linac (6%), instrumentation (5%), and alignment (2%)

State-of-the-art SRF cavities

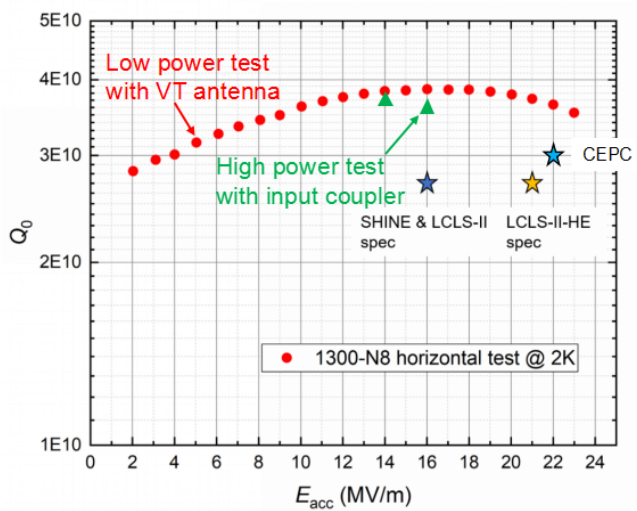
650 MHz 2- & 1-cell SRF cavity test results



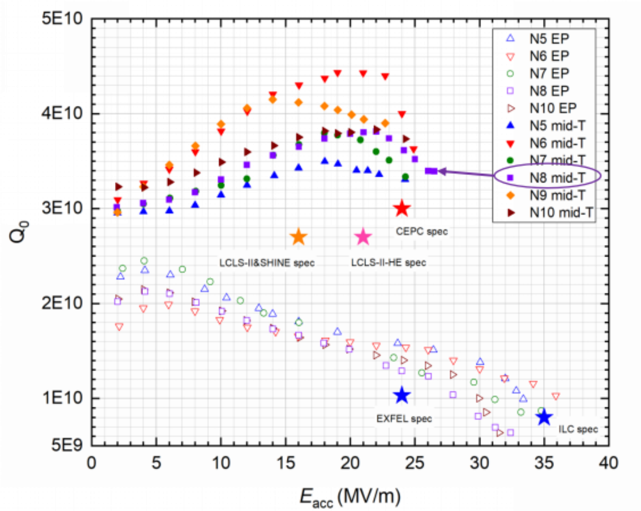


1.3GHz 9-cell SRF cavity test results

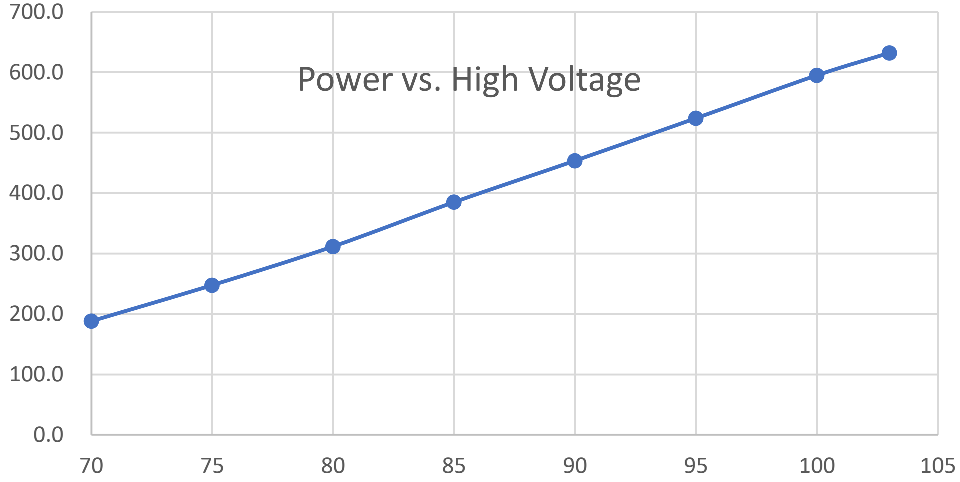
IHEP 1.3 GHz 9-cell Cavity Horizontal Test

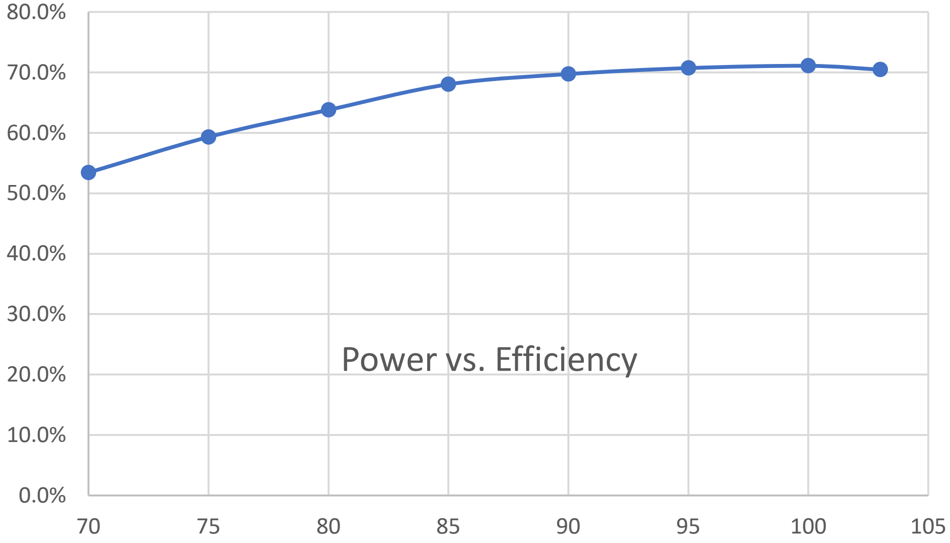


IHEP 1.3 GHz 9-cell Cavity Vertical Test



State-of-the-art P-band Klystron





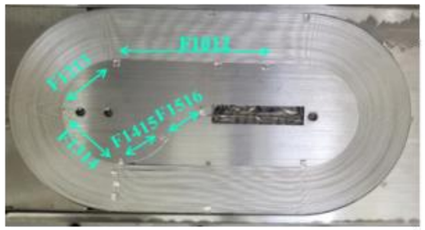
70.5% @ 630kW efficiency in the present status

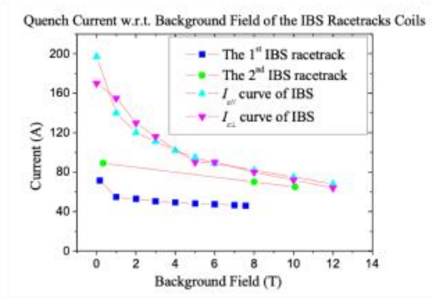
Goal: ~80% efficiency

State-of-the-art High Field Magnet

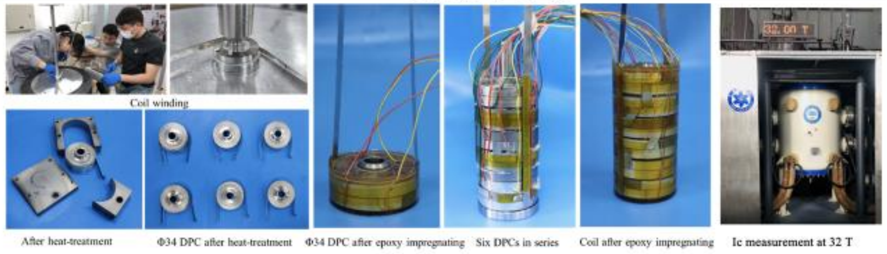
Iron based HTS coil

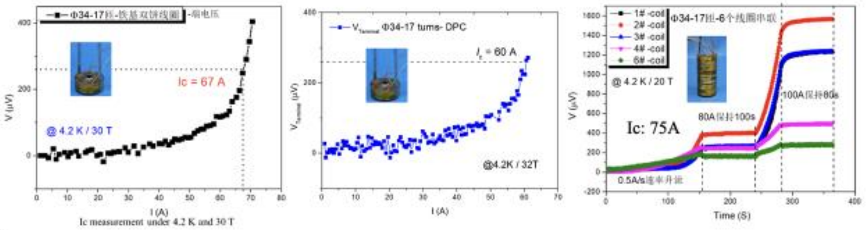
2021 。。。





2022 。。。



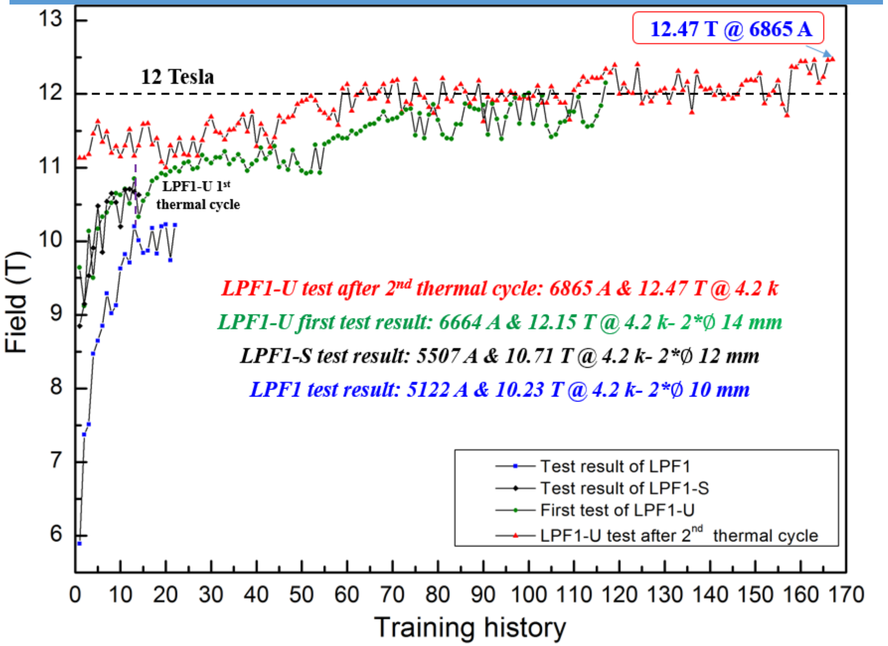


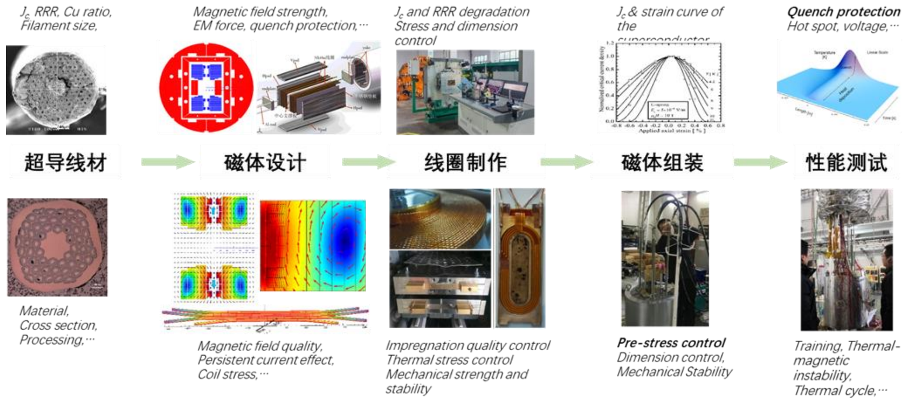
Comments from SUST reviewers :

a) ...the new results that can have a strong impact on the conductor and magnet community.
b) ...demonstrated the great potential of Iron-Based Superconductor in the development of next-generation accelerators.
c) It is of certain significance in the path of applications of Iron-Based Superconductor...

Preparation for the future SPPC upgrade, and significant potential for multiple applications

Dual aperture SC dipole (NbTi+Nb3Sn) achieves 12.47 T at 4.2 K





Feasibility study: Polarized Beams

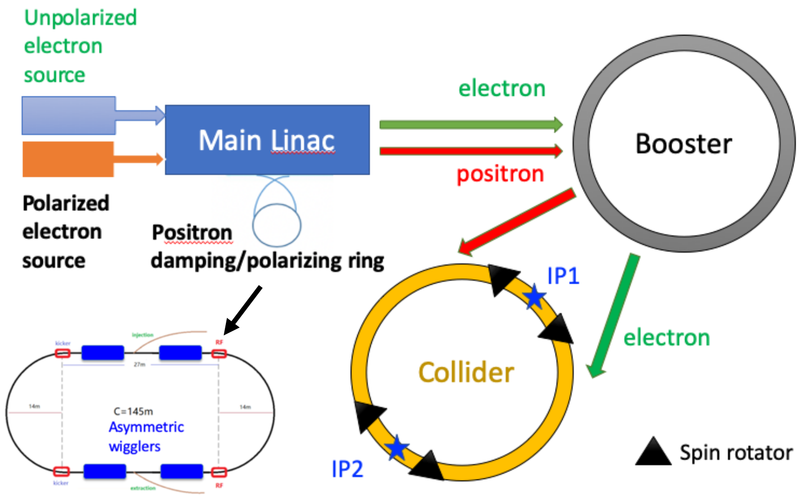
DESIGN GOAL

Resonant Depolarization for 10^{-6}-level precision beam energy calibration at Z, W

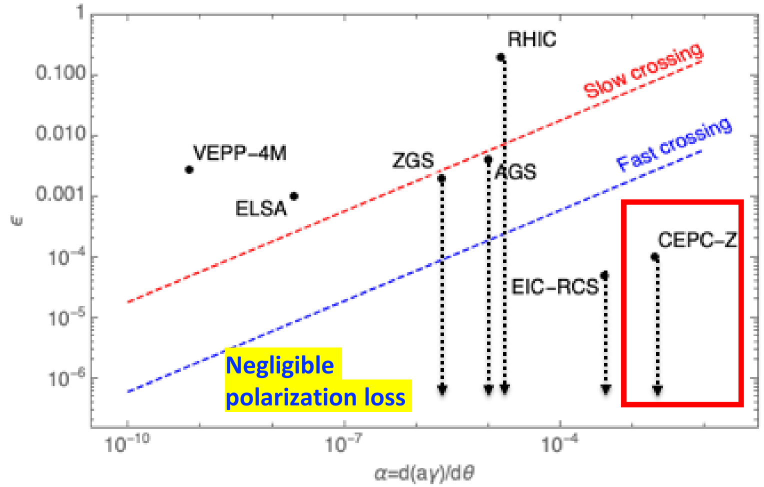
>50% longitudinal polarization for Z, W and even Higgs

SOLUTIONS

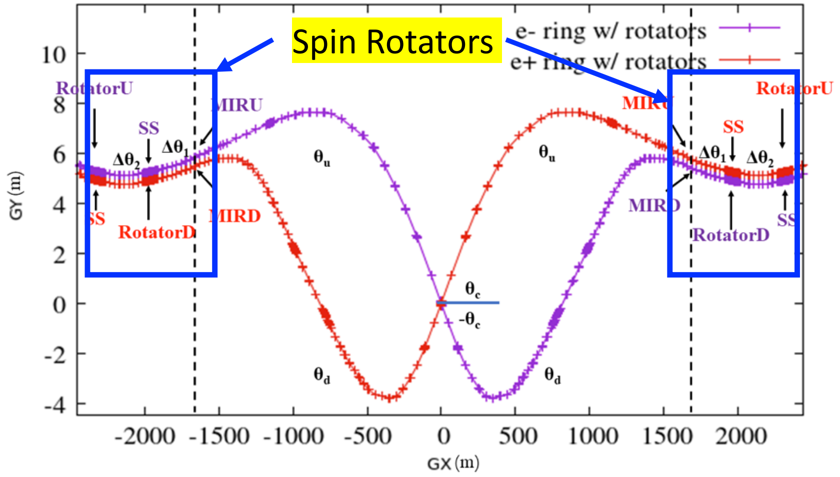
- Injection of polarized beams
  - Polarized beam generation from the source
  - Polarization maintenance with "Spin resonance free" booster design
- Solenoid-based spin rotators in the collider rings



Extension for polarized beams



Spin resonance free booster

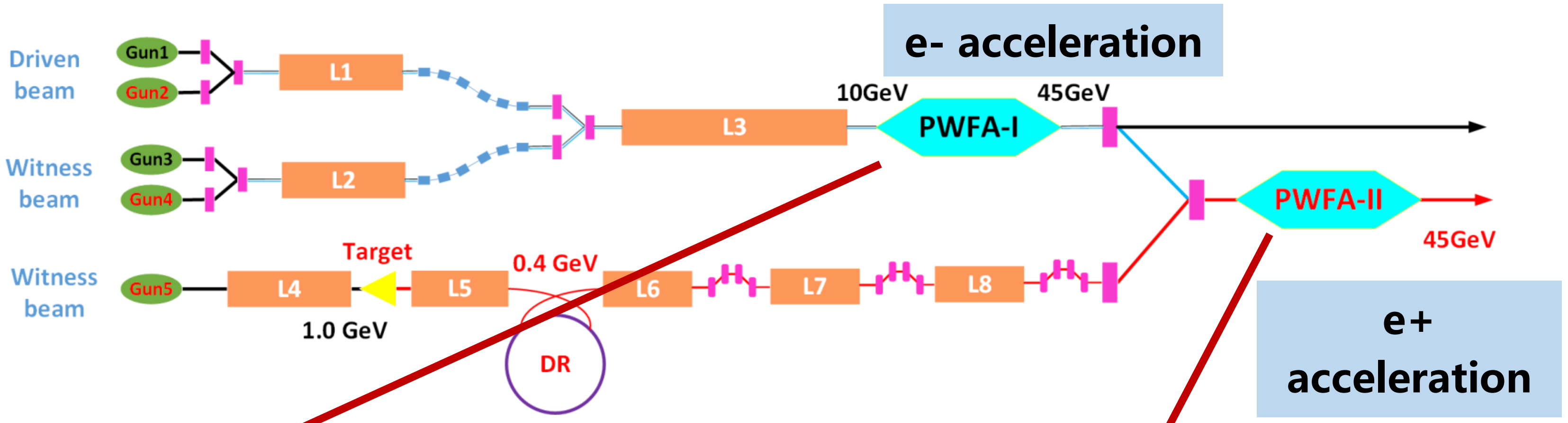


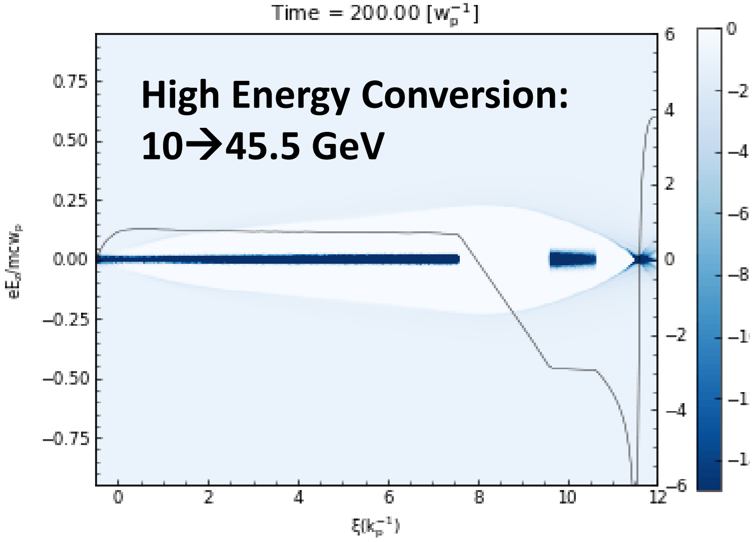
Spin rotators in Collider rings

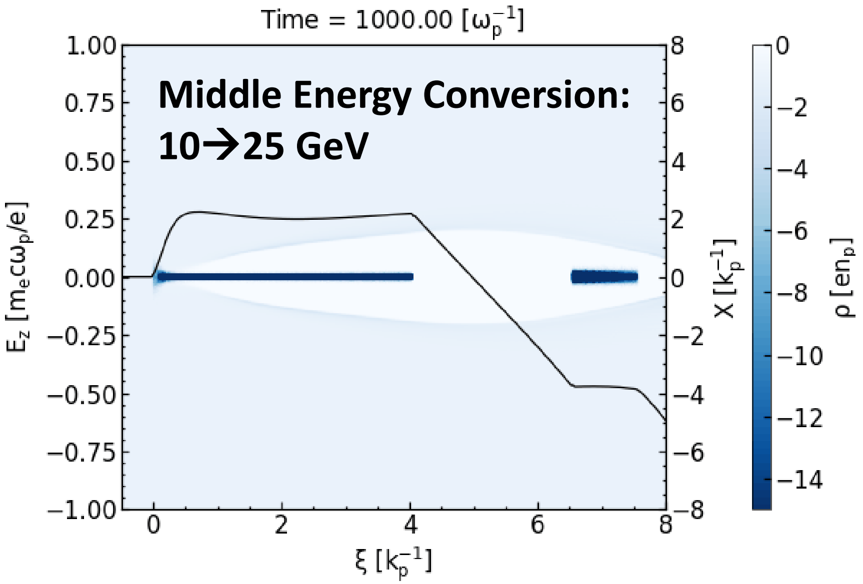
Novel Acceleration Principle: PWFA Wakefield

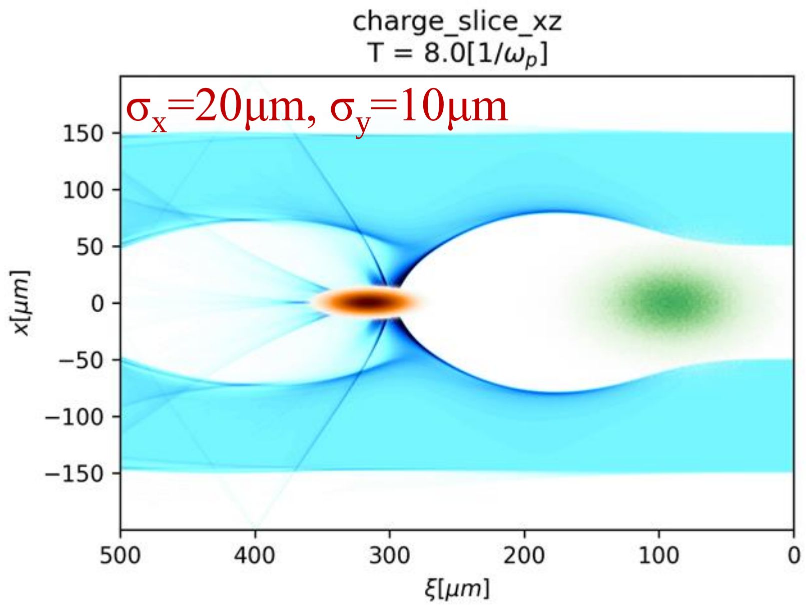
PWFA plasma acceleration as an alternative option for high performance Linac, promoting acceleration technology:

- Cascaded Acceleration
- Positron Acceleration
- High bunch charge









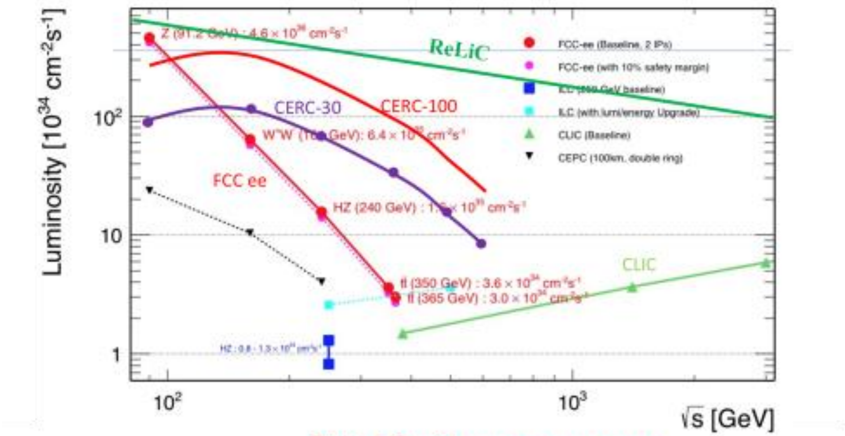
Key technologies validated by BEPC II & HEPS

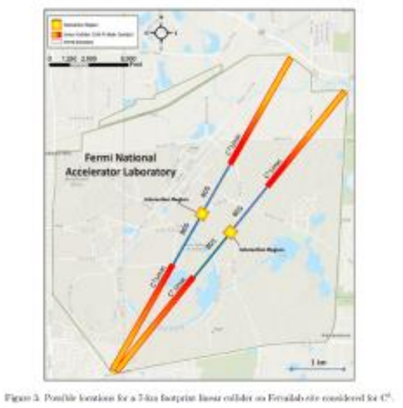
Device type	Accelerator	Quantity	CEPC specifications
S-band copper accelerating tube	Linac	111	~30 MV/m
vacuum chamber and coating	Collider/ Booster	Total length 200 km	Length: 6 m aperture: 56 mm vacuum: 3×10^{-10} Torr NEG coating pump speed for H_2: 0.5 L/s· cm^2
BPM and electronics	All	~5000	Closed orbit resolution: 0.6 μm
kicker & fast pulser	Transport line	~25	Pulse width <10 ns (strip-line) trapezoidal pulse width <250 ns (slotted-pipe)
Lambertson septum	Transport line	~20	Septum thickness $\leq$3.5 mm (in-air) thickness $\leq$2 mm (in-vacuum)
Power supply	All	9294	Stability 100-1000 ppm
RF-shielded bellows	Collider Booster	24000 /12000	Contact force 125±25 g/finger

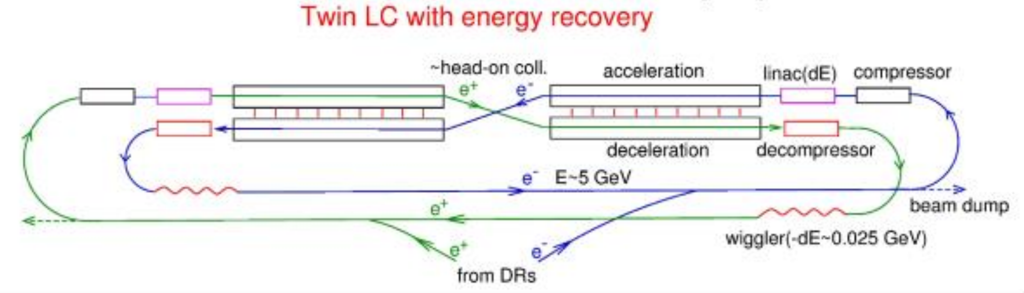
- BEPC, BEPC II: 40 years experience of designing, constructing, and operating collider.
- HEPS: light source with highest brightness through advanced accelerator technology.

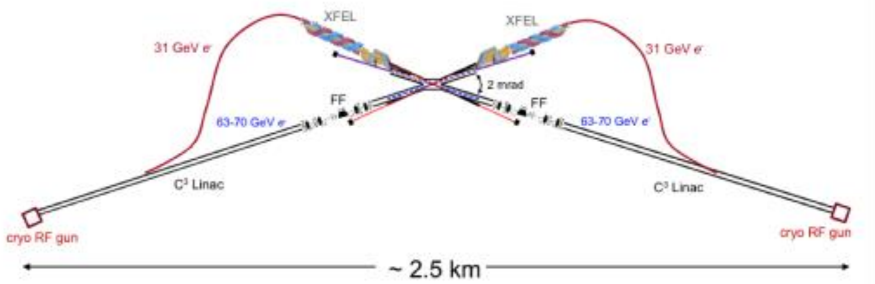
All the CEPC systems are well covered by currently accumulated technologies, the R&D, and validation projects.

Compared to New collider Designs









- Multiple new proposals in recent years, especially in the snowmass studies
  - Handful of new electron positron collider design (i.e., C3, HELEN, etc)
  - Colliders with different particles: Muon collider, Photon Collider, electron-photon collider
- Compared to the electron-positron Higgs factories, the luminosity and scientific potential of these new designs are relatively limited, and corresponding technologies are relatively immature.

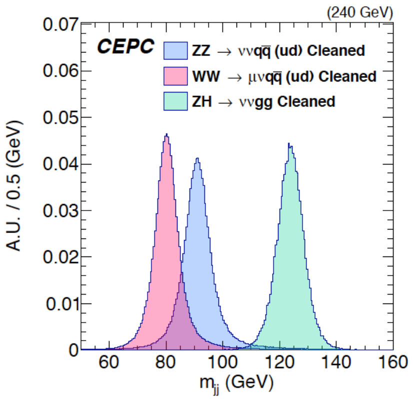
Detector Design & R&D

Detector design

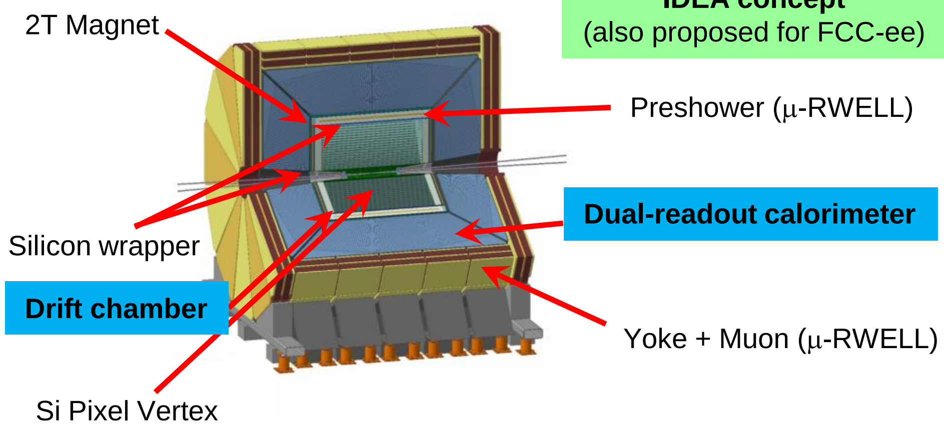
Well understood Physics Requirements.

Significant International Collaboration

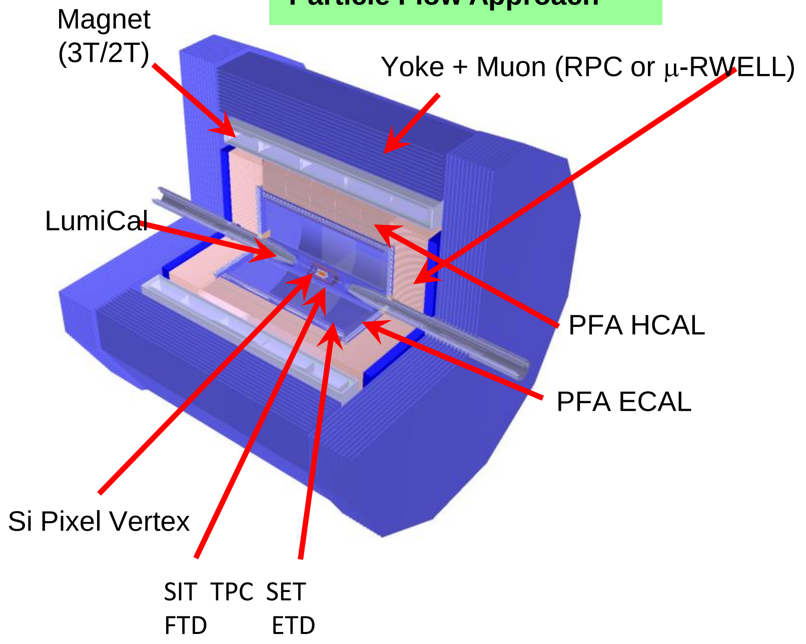
PFA oriented design emphasizing the performance of ECAL & Pid to enhance the physics cases, especially flavor, etc.



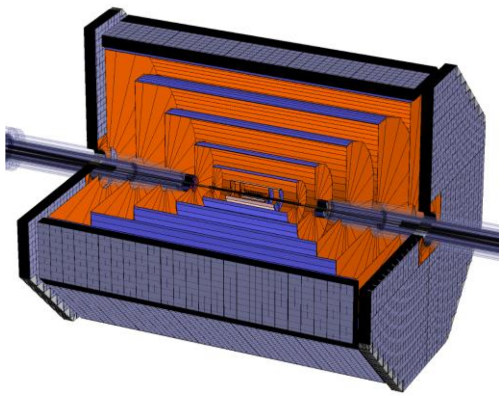
IDEA concept
(also proposed for FCC-ee)

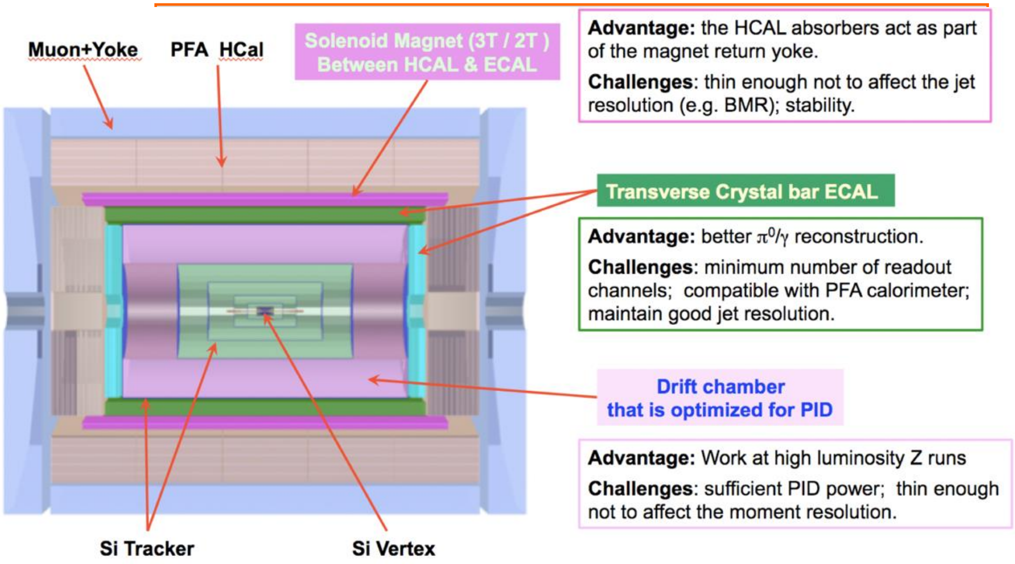


(Baseline Design)
Particle Flow Approach



PFA approach with Full Silicon Tracking





Sub-detectors and Key techs

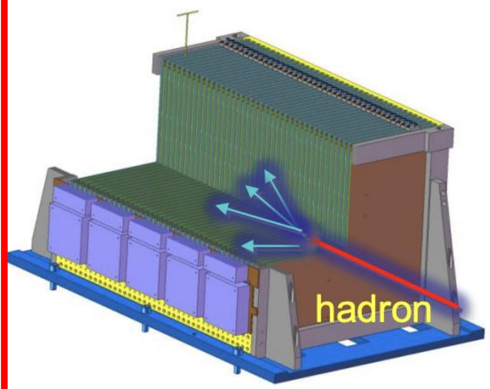
Table 3.2: All sub-detectors and the key technologies

Sub-detector	Key technology	Key Specifications
Silicon vertex detector	Spatial resolution and materials	$\sigma_{r\phi} \sim 3\ \mu$m, $X/X_0 < 0.15\%$ (per layer)
Silicon tracker	Large-area silicon detector	$\sigma(\frac{1}{p_T}) \sim 2 \times 10^{-5} \oplus \frac{1\times10^{-3}}{p\times\sin^{3/2}\theta}(\mathrm{GeV}^{-1})$
TPC/Drift Chamber	Precise dE/dx (dN/dx) measurement	Relative uncertainty 2%
Time of Flight detector	Large-area silicon timing detector	$\sigma(t) \sim 30$ ps
Electromagnetic Calorimeter	High granularity 4D crystal calorimeter	EM energy resolution $\sim 3\%/\sqrt{E(\mathrm{GeV})}$ Granularity $\sim 2 \times 2 \times 2$ cm^3
Magnet system	Ultra-thin High temperature Superconducting magnet	Magnet field $2-3$ T Material budget $< 1.5X_0$ Thickness < 150 mm
Hadron calorimeter	Scintillating glass Hadron calorimeter	Support PFA jet reconstruction Single hadron $\sigma_E^{had} \sim 40\%/\sqrt{E(\mathrm{GeV})}$ Jet $\sigma_E^{jet} \sim 30\%/\sqrt{E(\mathrm{GeV})}$

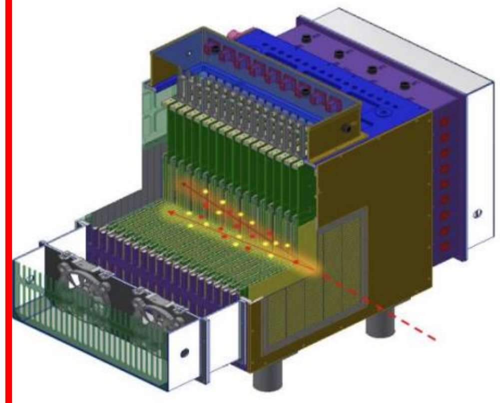
CEPC EM calorimeter

- PFA-oriented High granularity calorimeters were constructed based on mature technology
  - Scintillators + iron hadron calorimeter (AHCAL)
  - Scintillators + TungstenCAS EM calorimeter (Sci-W ECAL)

Sub-detector	Specification	Requirement	World-class level	CEPC prototype
Scintillator-W	Energy Resolution	$< 3\%/\sqrt{E}$	12.5% [18]	to be measured
ECal	Granularity	$\sim 2\text{cm} \times 2\text{cm}$		$5\text{mm} \times 5\text{mm}$
				Prototyping [19]
Scintillator-Steel HCal	Single Hadron Energy Resolution	$< 60\%/\sqrt{E}$	57.6% [20]	Prototyping

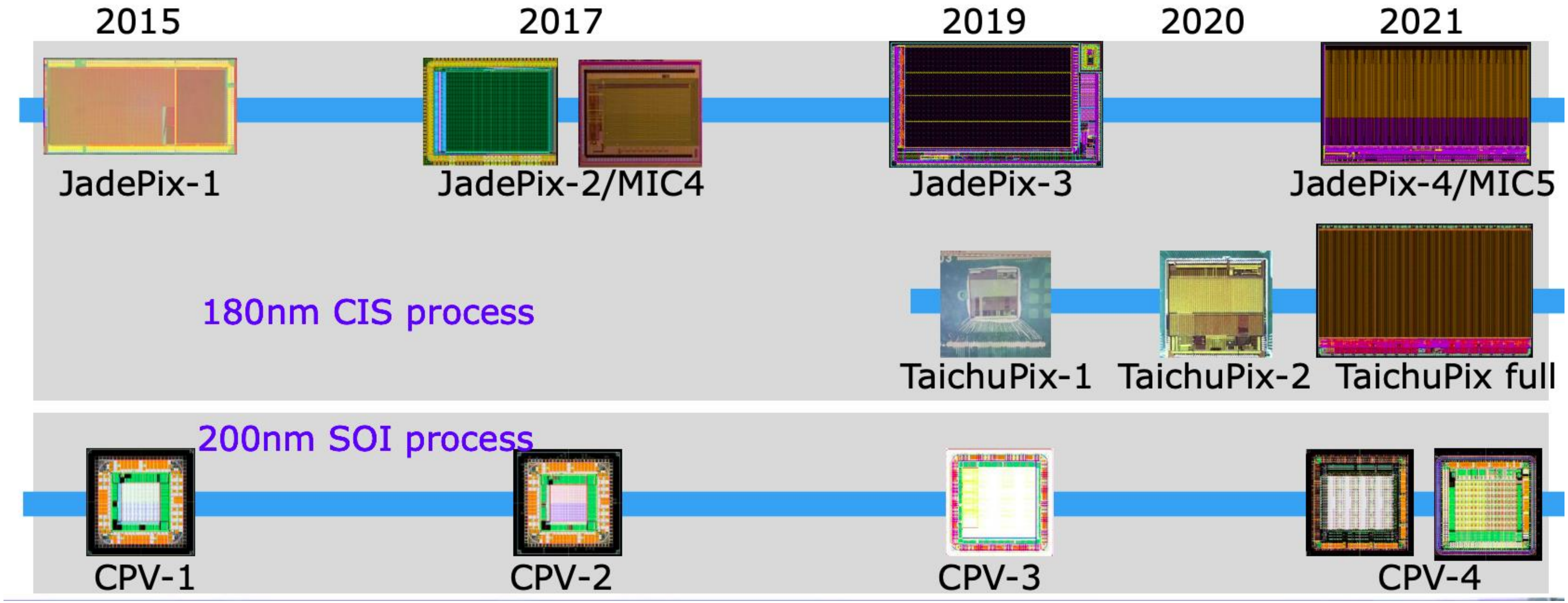


AHCAL


Sci-W ECAL

CEPC Vertex detector R & D

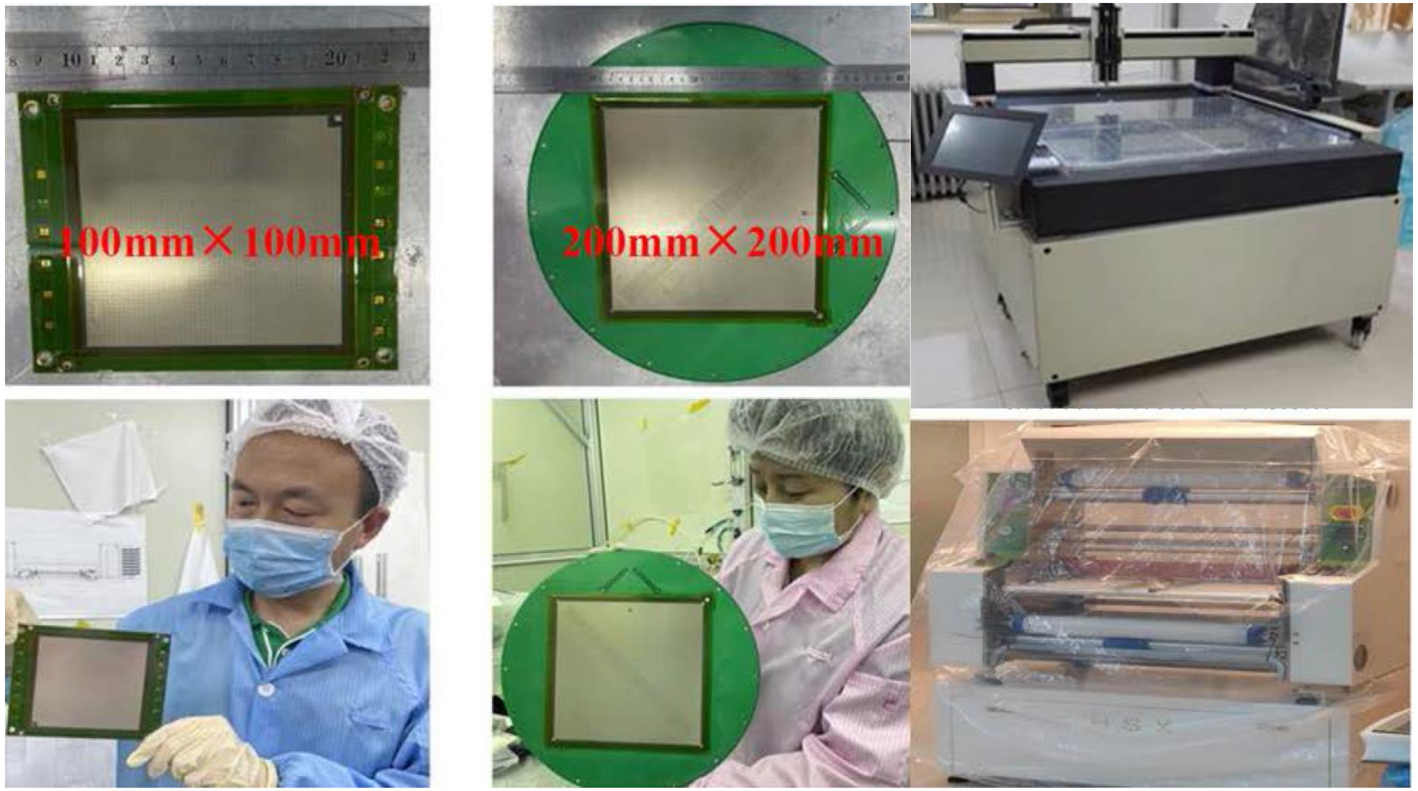
- CEPC Vertex detector sensor R & D timeline
  - Based on Tower Jazz CIS 180nm process (Jadepix , TaichuPix)
  - Based SOI 200nm process (CPV chip)



CEPC TPC detector R & D

- Highlights of CEPC TPC detection technology R&D
  - Pad readout towards pixelated readout TPC to increased PID to 2-3%
  - Massive production and assemble MPGD lab has been setup at IHEP
  - Very activate international collaboration with LCTPC and RD51

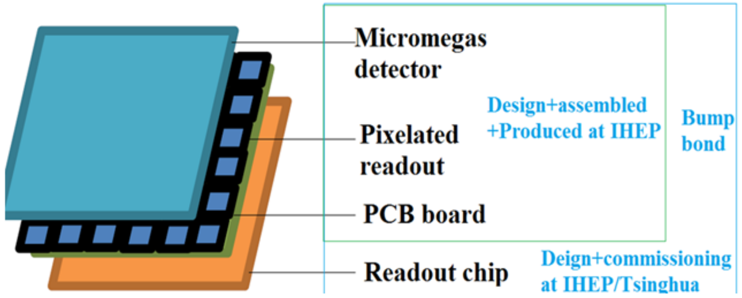
Publications by TPC group:
https://doi.org/10.1016/j.nima.2022.167241
https://doi.org/10.1109/NSS/MIC44867.2021.9875566
https://doi.org/10.1088/1748-0221/15/09/C09065
https://doi.org/10.1088/1748-0221/15/05/P05005
https://dx.doi.org/10.1142/S0217751X20410146
https://doi.org/10.1088/1674-1137/41/5/056003
https://doi.org/10.1088/1748-0221/15/02/T02001



Prototype plan at IHEP

- **Realization of pixelated technology collaborated with Tsinghua**

Bump bond pixelated readout with Micromegas detector	Module size	To be addressed by R&D
• ≥300 μm×300 μm • Developed the readout chip by Tsinghua University • Developed the Micromegas detector sensor at IHEP • Development of the new module and prototype in the end of 2022	1-2 cm^2	• Research on pixelated readout technology realization • Optimization of cluster profile and pad size • Study of the 'dN_{cl}+dx'
	100 cm^2	• Study the distortion using UV laser tracks and UV lamp to create ions disk • In-situ calibration with UV Laser system • Study of the 'dE/dx+dN_{cl}/dx'



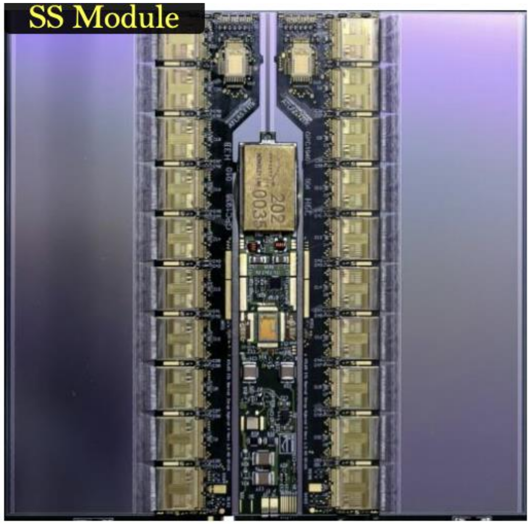
Tsinghua University
University

25

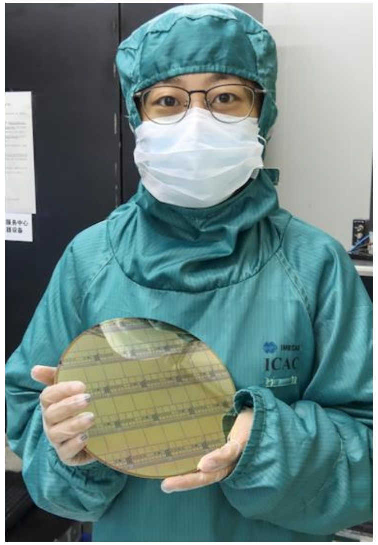
CEPC Team @ LHC upgrade

LHC upgrade Project	Contribution	IHEP member Leadership
ATLAS high granularity timing detector (HGTD)	~34% modules and sensors (~2700modules, sensor by Chinese foundry)	Project leader Coordinators in Sensors/ modules
LHCb UT tracker upgrade	System design, test and integration	Deputy project leader
ATLAS ITK strip detector upgrade	~10% modules in Barrel (100 modules)	Coordinator in China/UK cluster
CMS HGcal	~ 20% modules (~100 m^2 area) silicon module	
High luminosity LHC upgrade	Contributing 13 CCT magnetic	

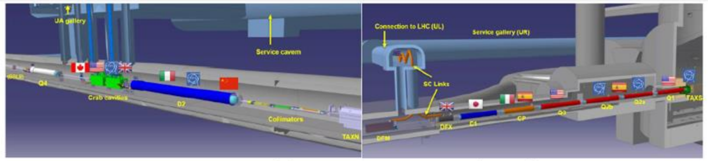
ATLAS ITK strip upgrade
Module prototyping



ATLAS HGTD
Sensor developed by IHEP



CMS HGcal
module prototyping



Team

Organization @ R&D stage

CEPC has a complete and competitive core team that is **well-positioned to realize and operate this project**

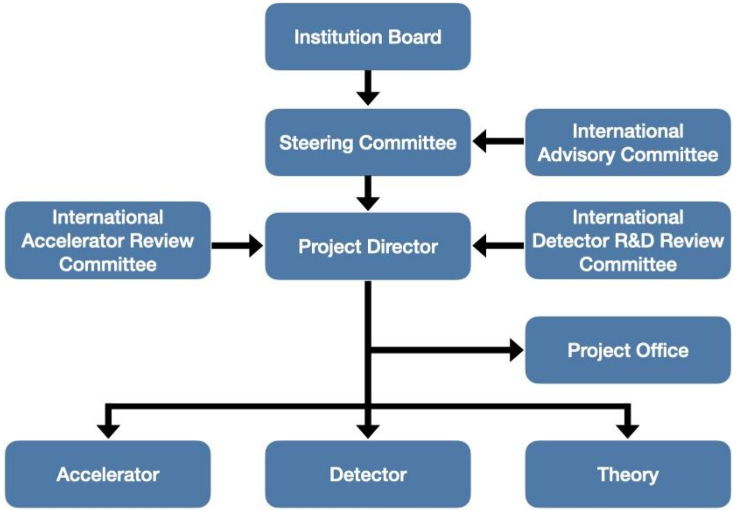
Institution Board composed of 32 institutions, including multiple top university/institutes

Management team with comprehensive experience in project initiation, design, construction, operation, maintenance, management, and upgrade.

IARC & IDRC composed of leading experts of this field, provide valuable guide

IAC composed of global renowned scientists and top laboratory or project leaders who have ample experience in project management, planning, and execution of strategies

Younger talents responsible for physics study and key technology R&D. The CEPC accelerator & detector R&D team composed of ~400 staffs, with equivalent number of postdocs and students.



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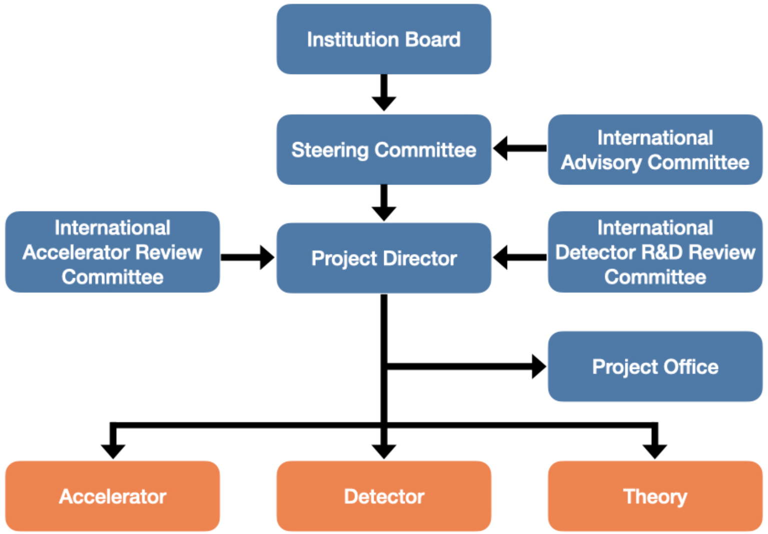
Core R&D team: young and active scientists



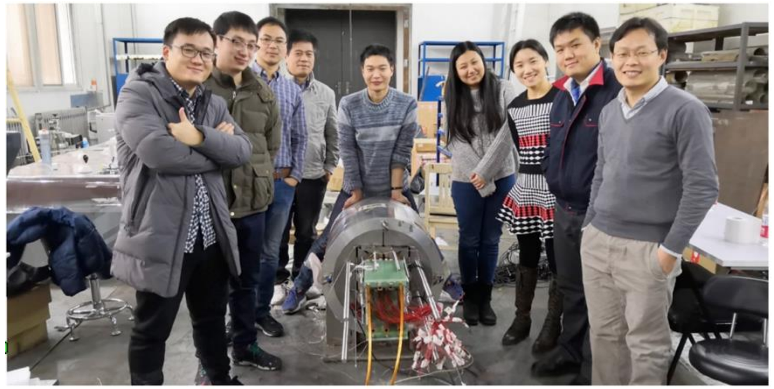


Table 7.3: Team of the CEPC accelerator system

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

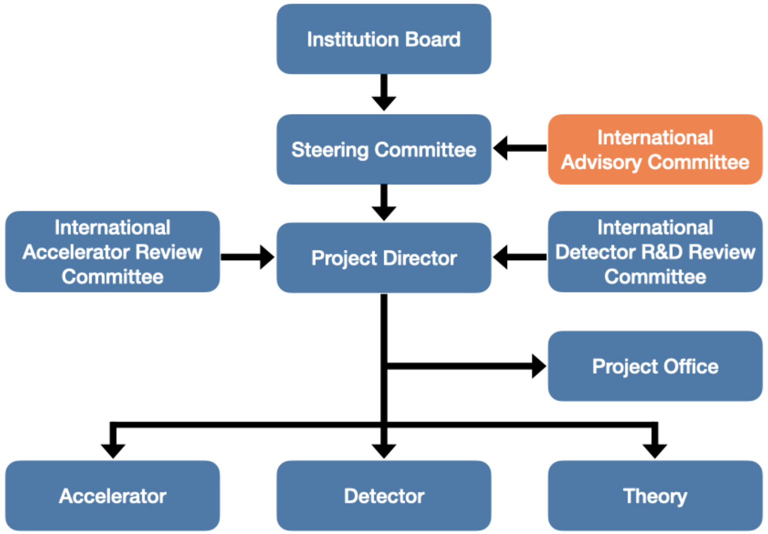
Table 7.4: Team of the CEPC detector system

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

Younger talents responsible for physics study and key technology R&D.
The CEPC accelerator & detector R&D team composed of ~400 staffs, with equivalent number of postdocs and students.

R&D team actively participate the LHC experiments & HL-LHC upgrade

International Advisory Committee (since 2015)



2nd IAC meeting, 2016

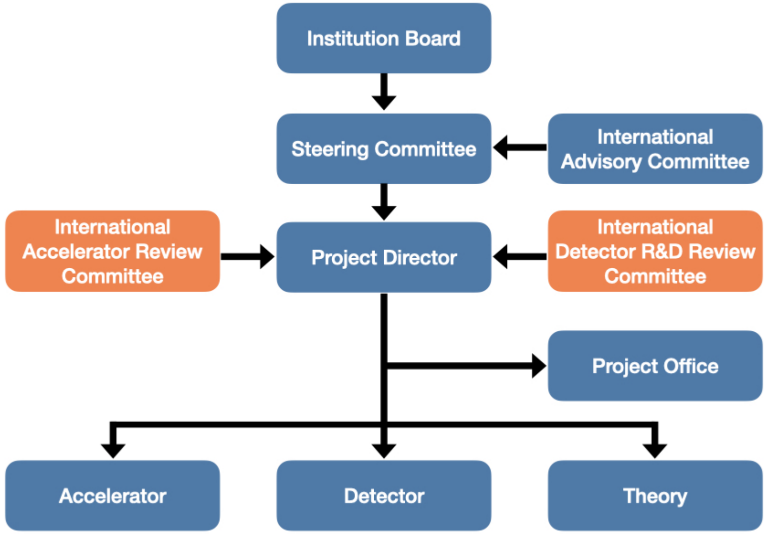
7th IAC meeting, 2021

1st IAC meeting, 2015

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

Global renowned scientists and top laboratory or project leaders who have ample experience in project management, planning, and execution of strategies

IARC & IDRC



Project guided by International Accelerator and Detector Review Committees composed of leading experts of this field

International Accelerator Review Committee

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

International Detector R&D Review Committee

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

2021 Second CEPC IARC Meeting

IARC Committee

October 20th, 2021

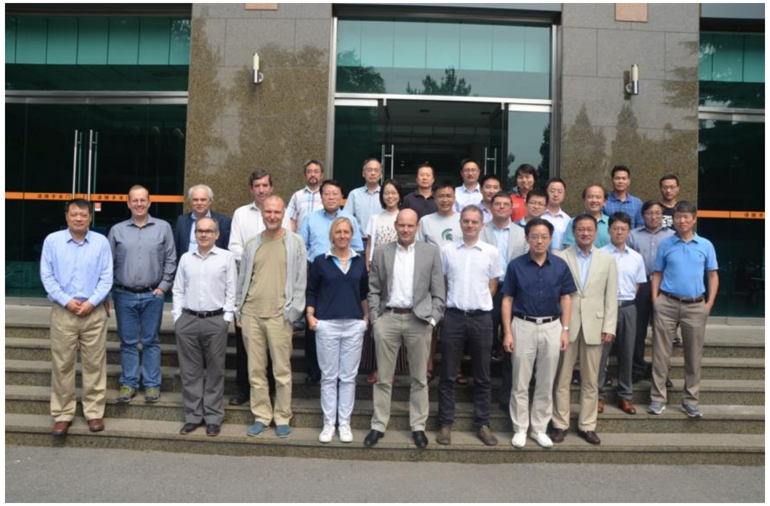
The Circular Electron Positron Collider (CEPC) and Super Proton-Proton Collider (SppC) Study Group, currently hosted by the Institute of High Energy Physics of the Chinese Academy of Sciences, completed the conceptual design of the CEPC accelerator in 2018. As recommended by the CEPC International Advisory 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.

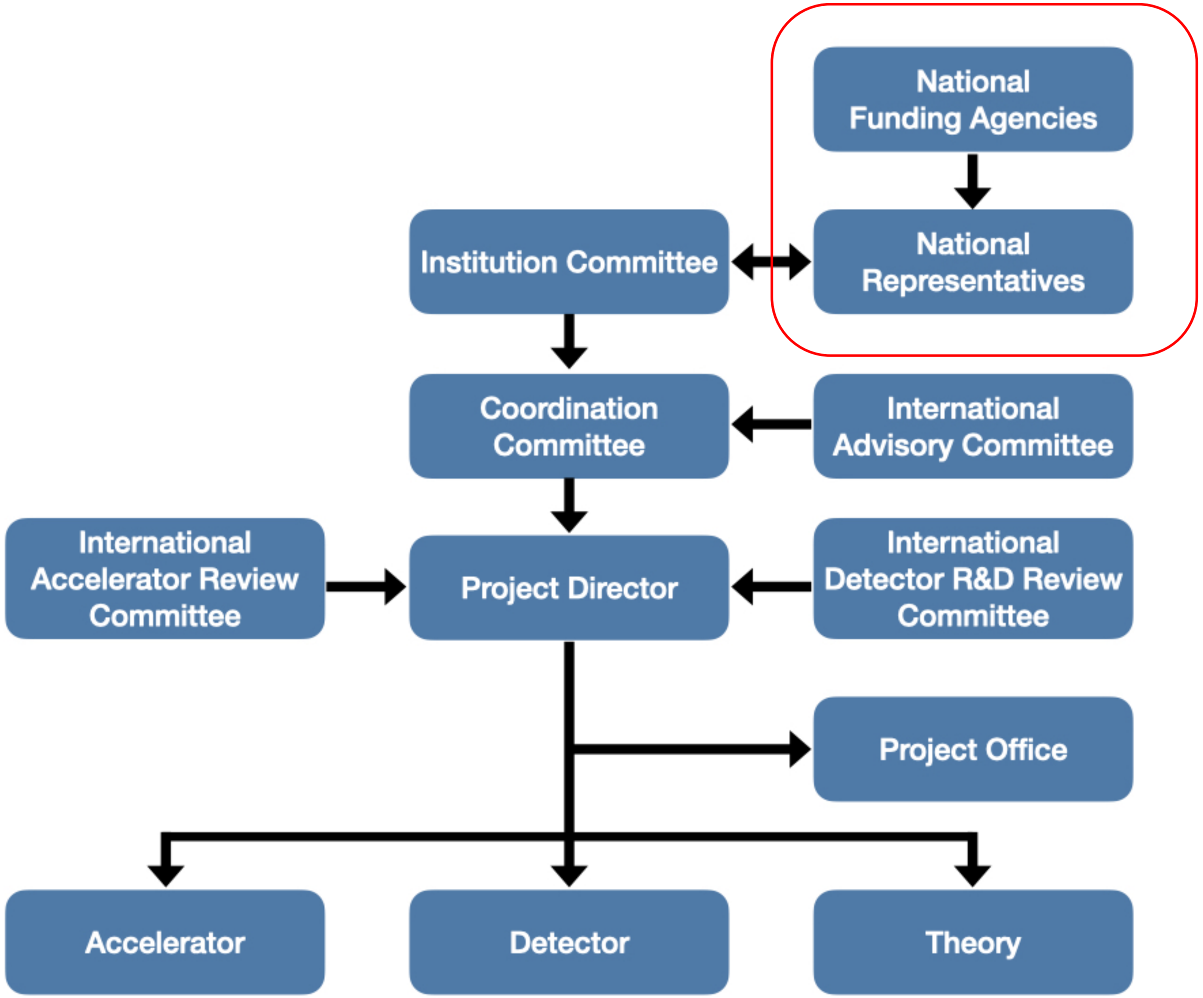
A total of 22 talks were presented on a variety of topics.

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.

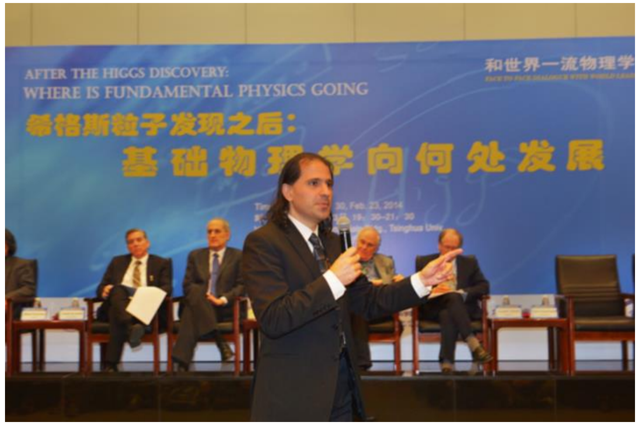


Organization: toward construction & operation



Embrace the International collaboration

Engaging with theory community



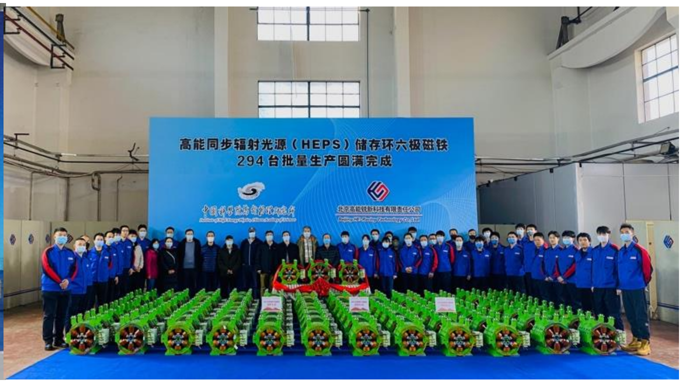
Support

Large-Scale Acc. Facilities: High Energy Photon Source

beam energy 6 GeV, 1.36KM, ≤ 0.06nm·rad, 14 beam lines

Carried out by IHEP, to be completed in 2025,
great training and preparation for CEPC: validate significant part of CEPC technologies

Device type	Accelerator	Quantity	CEPC specifications
S-band copper accelerating tube	Linac	111	~30 MV/m
vacuum chamber and coating	Collider/ Booster	Total length 200 km	Length: 6 m aperture: 56 mm vacuum: 3×10^{-10} Torr NEG coating pump speed for H_2: 0.5 L/s· cm^2
BPM and electronics	All	~5000	Closed orbit resolution: 0.6 μm
kicker & fast pulser	Transport line	~25	Pulse width <10 ns (strip-line) trapezoidal pulse width <250 ns (slotted-pipe)
Lambertson septum	Transport line	~20	Septum thickness ≤3.5 mm (in-air) thickness ≤2 mm (in-vacuum)
Power supply	All	9294	Stability 100-1000 ppm
RF-shielded bellows	Collider Booster	24000 /12000	Contact force 125±25 g/finger



Support by Platform of Advanced Photon Source

- **Support Key Technology R&D:**
  - ➢ SRF ➢ Magnet ➢ Vacuum ➢ Klystron ➢ Electric Power Source ➢ Cryogenic System
  - ➢ Mechanical system & Alignment ➢ e- gun

Facility: CEPC SCRF test facility (lab) is located in IHEP Huairong Area of 4500m^2

New SC Lab Design (4500m^2)

New SC Lab will be fully functional in 2021

Crygenic system hall in Jan. 16, 2020

Vacuum furnace (doping & annealing)

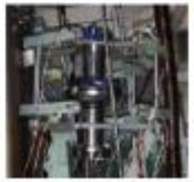
Nb3Sn furnace

Nb/Cu sputtering device

Cavity inspection camera and grinder

9-cell cavity pre-tuning machine

Temperature & X-ray mapping system



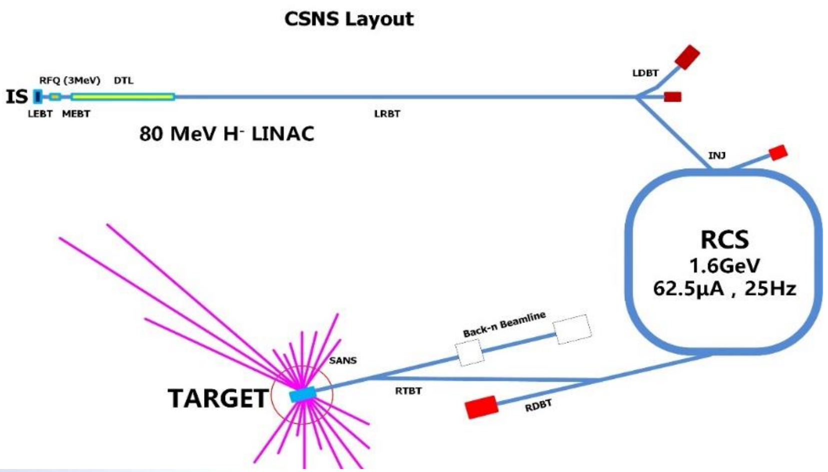
Second sound cavity quench detection system

Helmholtz coil for cavity vertical test

Vertical test dewars

Horizontal test cryostat

Large-Scale Acc. Facilities: China Spallation Neutron Source



- One of the four pulsed Spallation Neutron Sources in the world
- Construction completed in 2018

Budget and timeline

Budget of R&D & Construction

Table 8.2: Two funding models of the CEPC

	Funding model I (100 M CNY)	Funding model II (100 M CNY)
Central government	250	100
Local government	50	200
International contribution	60	60
Donations	0-35	0-35

Funding model: iteration and interaction with relevant entires, especially Local Grovements. (Leading contributor)

International contribution: 20% according to convention.

7.1 Budget for the project design, R&D and construction

CEPC Status

FCC Week, Paris

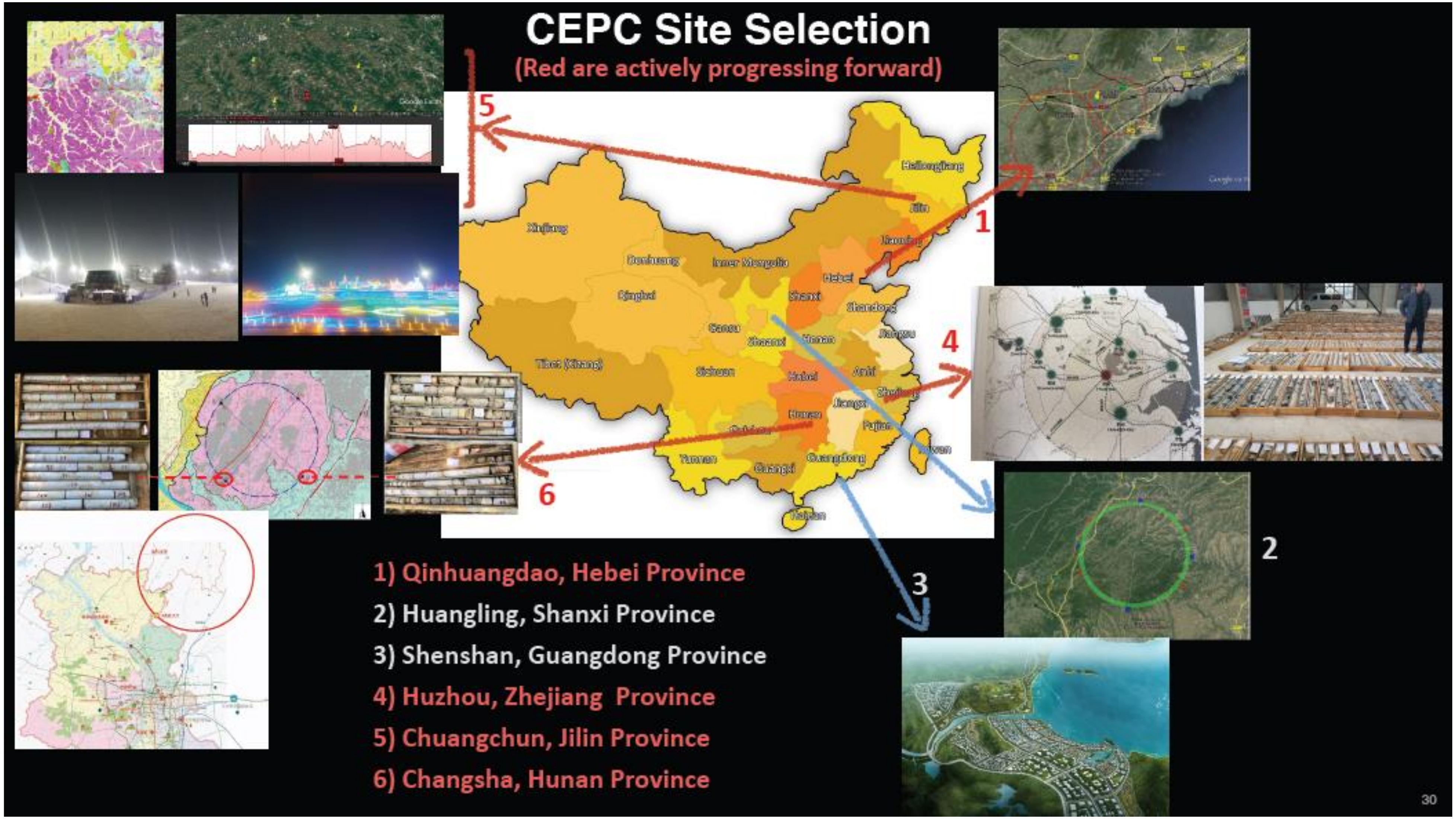
CEPC Accelerator TDR

- **Consistent TDR high luminosity parameter design as a Higgs factory**
- **Key components with prototyping, technical feasibility demonstrated, no technical show stopper**
- **Design and R&D technical documentation (data, drawings, etc.)**
- **CEPC accelerator TDR document release planned for 2023**

CEPC Accelerator EDR Plan; ~Jan. 2023-Dec. 2025 preliminary

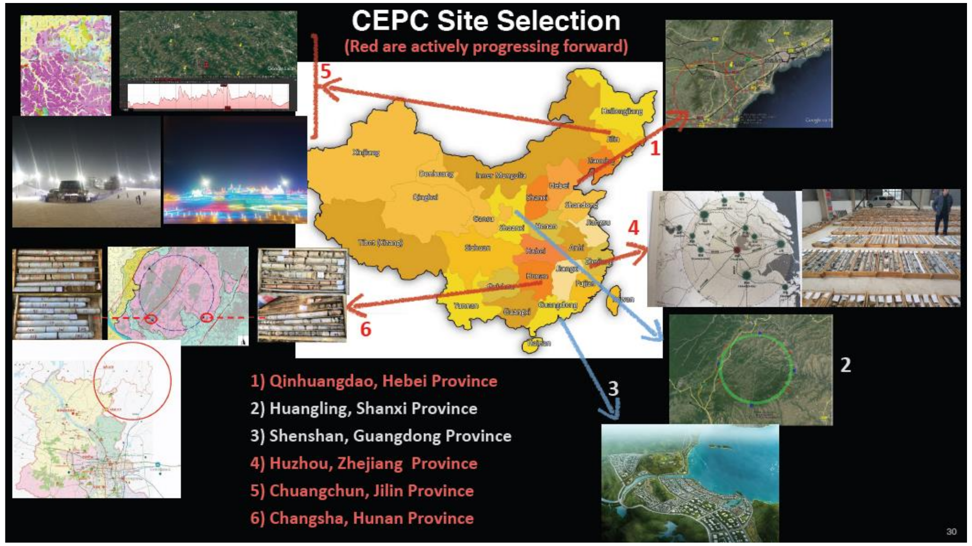
- CEPC site study will converge to one or two with feasibility studies (tunnel and infrastructures, environment)
- Engineering design of CEPC accelerator systems and components
- Site dependent civil engineering design implementation preparation
- EDR document completed for government's approval of starting construction in 2026 (the starting of the "15th five year plan")
- There will be more discussions on the planning

Site Selection

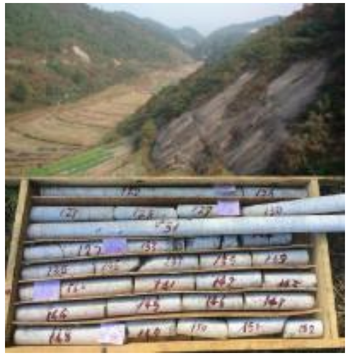


Multiple candidate sites & strong supports from Local Government

Site Selection



Factors: geology, electricity supply, transportation, international-friendly, local supports …



July 5, 2021: Changsha Bureau of S&T entrusted Hunan U. to conduct a feasibility study.

Sept 4, 2021: Hunan U. organized a review by a committee of experts from multiple disciplines. The committee evaluated scientific potential of CEPC, feasibility of a new science city based on CEPC, and overall impact on Changsha. The overall conclusion is very positive. The local government is interested and very supportive to the CEPC project.

Cost Benefit performance

- *The Higgs boson is probably the most promising portal to the new physics. The CEPC is capable to provide the **Higgs data** in 2030s, which can reveal potential discoveries & knowledges that **are priceless** to mankind. (…)*
- *The **current CEPC design is optimized**. Taking into account the balance of scientific requirements, technological maturity, and advancement, cost-effectiveness, and other aspects, the CEPC accelerator is designed to have a circumference of 100 kilometers and the compatibility of partial double-ring (Higgs) and double-ring (W/Z).*
- *Compared to the FCC-ee proposed by CERN, CEPC reaches the similar performance with a much lower cost.*
- *The CEPC not only perform excellent scientific exploration, but also provide **strong boost to the technologies**, and serves as a highland for global talent training & cooperative innovations. It is of great strategics value with optimized construction and operation cost.*
- *Because of the excellent scientific program, the CEPC could attract significant **International collaboration**, which further increases its cost-efficient.*
- *The CEPC project is huge with **lifetime of 40-50 years**, and the city where it is located will build a science city based on the CEPC, attracting thousands, if not tens of thousands, of scientists, engineers, and support personnel to live there, considerably **boosting local economic and technological growth**. Multiple local governments shows strong interests to host CEPC.*

Summary

CEPC will address most pressing & critical science problems

- **Science Merit:** The CEPC enables exploration to the most important questions of contemplate particle physics. Though large amount of Higgs, Z, W bosons produced in an extremely clean environment, CEPC can search for new physics in an energy scale higher than HL-LHC and current boundaries by one order of magnitude or more.

CEPC adds enormous strategic values, has many advantages, will be in a leading position if realized

- **Stategical Value & Comparative advantages in International Competition:** The scientific importance and strategical value of CEPC, or in general electron positron Higgs factories are well identified by Global Particle Physics community. Among multiple Higgs factory proposals, the CEPC has strong comparative advantages, and can be the first to deliver data in 2030s.

CEPC design-technologies reaching maturity, great upgrade options offered, plus many added values and benefits

- **Maturity, Upgradibility & Added value:** The CEPC performs intensive R&D, pushing multiple critical technologies to the state-of-art level. Its antipate performances is among the best of future proposals. The CEPC can be upgraded in several highly valuable ways that further strengthen its discovery power, providing high-impact science program spans for decades. The CEPC wil bring series of technological innovations, and has strong synergies with scientific research at other disciplinaries, especially through high energy gamma synchotron light source.

Summary

Strong-experienced team, IHEP support and international cooperation are there or to be implemmented to bring CEPC to fruition

- **Team, Current Support & International Collaboration** The CEPC is well support by the international community, the host lab, and relevant projects. The CEPC study group completes the Design of CEPC accerlerate and detectors, assembled a team of highly professional scientific & engineering staff, and will soon complete the R&D. The CEPC study group is well-positioned to realize and operate this project, and is capable to establish International collaborations to achive its scientific goals.

CEPC schedule follows China's 5-year planning; expects to complete R&D and preparation to build CEPC and carry out the science program

- **Timeline:** We propose to commence the construction of the CEPC during China's 15th Five-year plan (2026 - 2031), and complete, commission, and operate the CEPC during the 16th Five Year plan (2031 - 2036). The maturity of CEPC R&D meets this proposed timeline. Firm connections has been established to the indusrial, facilate the future mass production and construciton of CEPC.

CEPC will position China to be a leading position in particle physics and contribute to the world in a major way

- The CEPC meets the natioanl positioning on basic science, and **will significantly promotes China** in the international community of Paritcle Physics research.