“高能环形正负电子对撞机相关的物理和关键技术预研究”中期执行情况

课题一、加速器物理设计

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中科院高能物理研究所
2018年12月26日

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一、课题基本情况

- 本课题主要是对CEPC加速器进行相应的物理设计
  - 将通过比较单环麻花轨道、带角度的crab-waist 局部双环或双环聚焦结构等设计方案的比较，在细致研究束流集体效应、束束作用等效应的基础上，完成一个在满足复杂约束条件下亮度和动力学孔径达到要求的高能环形正负电子对撞机的概念设计方案
  - 其中主环lattice 和注入增强器的设计、对撞区的设计是加速器物理设计中的关键。
- 课题经费：388万元，其中直接经费356万元，间接经费32万元
- 课题负责人：高杰研究员，中国科学院高能物理研究所
- 课题骨干人员：6人，高级职称5人，博士学位6人。

二、研究目标、内容和任务分解（1）

目标和指标

- **目标：**

1） 解决CEPC 对撞机的总体方案设计及优化选型。根据CEPC 的物理设计目标给出加速器总体不同设计方案，并进行相关方案的设计研究，找出关键瓶颈问题和对技术与造价的影响，通过比较给出最终设计方案建议。

2）对加速物理设计里的一系列关键的科学问题上有所突破，包括：高亮度指标、机器参数优化、、对撞机及环形加速器的物理理解和理论积淀，专业程序的改写和编写等。通过本课题的研究使我国的环形加速器设计达到世界领先的水平，为CEPC 的技术研究及未来的建造打下关键的设计基础。

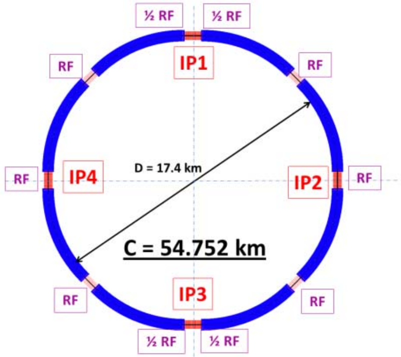
3）本课题的成果将通过杂志文章、会议报告和设计报告等形式对加速器领域产生学术影响，提升我国和国际加速器物理与设计的整体水平。

- **考核指标**：1）整体设计目标达到Higgs 240GeV达到 2×10^{34}, 2）Z 91GeV达到 1×10^{34}; 3）主环动力学孔径：0能量偏差粒子达到$20\sigma_x\times40\sigma_y$，能量偏差2%的粒子动力学孔径需要达到：$5\sigma_x\times10\sigma_y$(含磁铁误差和束束作用)；4）增强器：动力学孔径达到7σx×7σy，能量接受度1%。（其它系统指标见附件）

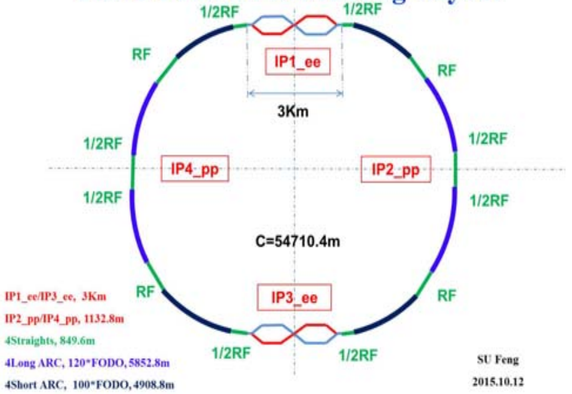
二、研究目标、内容和任务分解（2）

研究内容：

- 主环对撞方案的设计研究：
  - 单环麻花轨道
  - 局部双环
  - 双环
- 注入设计：
  - 直线注入器及增强器设计
  - 注入系统流程设计及效率优化
- 对撞区设计及MDI研究：
  - 对撞区的非线性动力学优化
  - 探测器螺线管耦合补偿
  - 加速器与探测器的匹配设计
- 性能评估研究
  - 束束作用
  - 集体效应



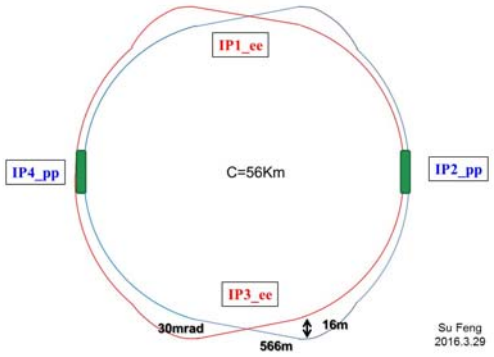
CEPC Partial Double Ring Layout



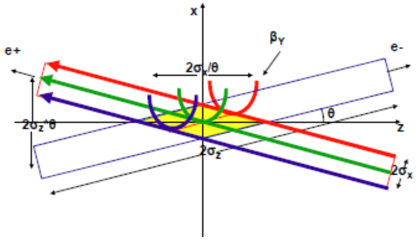
IP1_ee/IP3_ee, 3Km
IP2_pp/IP4_pp, 1132.8m
4Straights, 849.6m
4Long ARC, 120*FODO, 5852.8m
4Short ARC, 100*FODO, 4908.8m

SU Feng
2015.10.12

CEPC Double Ring Scheme Layout



Su Feng
2016.3.29



Crab-Waist 对撞

二、研究目标、内容和任务分解（3）

任务分解： CEPC加速器物理总体方案与关键物理问题研究

负责人：高杰 （整体方案，队伍组织，任务安排，国际合作，对外通报）

- CEPC 参数优化设计及lattice设计：王逗（参数），王毅伟（lattices设计)
- CEPC单环麻花轨道设计：耿会平

- CEPC增强器物理设计：边天剑（崔小昊）

- CEPC束束相互作用：张源

- CEPC动力学孔径：张源，王毅伟，王逗

- CEPC对撞区MDI：白莎

- CEPC lattice及SppC lattice关系：苏峰

- CEPC 束流不稳定性：王娜

CEPC加速器物理与硬件系统协调人：王逗

二、研究目标、内容和任务分解（4）

研究方法及技术路线：

- 针对不同的布局方案，考虑关键物理问题及硬件系统的约束限制，利用解析和模拟迭代优化不同能量下的总体参数。
- 利用解析方法，研究弧区lattice及对撞区的优化设计方案，达到动力学孔径设计指标。
- 确保从直线注入器、增强器到主环对注入过程设计的一致性，满足注入束和循环束对动量接收度和横向动力学孔径的要求，同时研究确保满足探测器的辐射防护及本底要求。
- 针对束束作用和集体效应，开展相关理论和模拟研究
- 利用并行模拟优化算法对机器相关参数及设计进行整体优化

二、研究目标、内容和任务分解（5）

年度计划（1）

2018年7月，完成中期目标：完成单环、局部双环（含先进局部双环）、和双环的物理设计的概念设计。

重要节点：

2017年11月，完成部分双环方案的全部概念设计并达到设计指标；完成单环麻花轨道方案全部概念设计并达到设计指标；

2018年5月，先进局部双环（APDR)和双环的全部概念设计

2018年 6月，召开课题中期专家评审会

2018年7月，完成中期报告。

中期

2016					2017																		
8月	9月	10月	11月	12月	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	1月	2月	3月	4月	5月	6月	7月
机器主要参数优化	■	■	■	■	■	■	■	■	■														
麻花轨道的lattice设计及集体效应研究	■	■	■	■	■	■	■	■	■	■													
弧区lattice优化	■	■	■	■	■	■	■	■	■	■													
不同方案的对撞区设计	■	■	■	■	■	■	■	■	■	■													
						束束效应的模拟对机器设计的检验优化	■	■	■	■	■	■	■	■	■	■							
									包含对撞区的麻花轨道的lattice设计研究	■	■	■	■	■	■	■	■	■	■	■				
										局部双环及双环方案的设计优化及集体效应	■	■	■	■	■	■	■	■	■	■			
																考虑实际lattice的机器性能模拟检验	■	■	■	■	■	■	■
																	机器设计的迭代优化，对比不同方案	■	■	■	■	■	■
																	注入增强器与主环设计的匹配	■	■	■	■	■	■
												专家评审会	■	年度报告	■					课题专家评审	■	中期评审	■

二、研究目标、内容和任务分解（6）

年度计划（2）

重要节点（后三年的工作）：

2019年1月，对建议方案进行系统详尽结合工程实施的完整的加速器设计方案研究，

对硬件系统的指标要求落到实处，并与隧道研究及SppC计划进行全面匹配

2020年 12月完成选定方案的可进行技术研究的完整物理设计方案

2021年7月， 完成设计报告的撰写，结束课题。

2018					2019												2020												2021						
8月	9月	10月	11月	12月	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月	1月	2月	3月	4月	5月	6月	7月
对硬件系统的指标要求落到实处，包括对撞区磁铁的误差效应、常规磁铁的误差及optics校正研究																																			
对建议方案进行系统详尽结合工程实施的完整的加速器设计方案研究																																			
与隧道研究及SppC计划进行全面匹配																		注入增强器、主环及探测器的一致性检验和调节，机器各项设计的精细优化																	
																		考虑各种主要物理效应，及硬件噪声的机器性能模拟评估																	
																		完成选定方案的可进行技术研究的完整物理设计方案											项目工作总结，课题结题						
专家评审会		年度报告										专家评审会		年度报告										专家评审会		年度报告								课题评审	

三、项目管理（1）

- 课题负责人负责本课题的研究活动安排，按项目计划进度安排研究工作。一般情况，每周开一次课题例会，开展课题组内部的学术交流、进展检查与工作布置。适时组织课题成员参加国际交流，确保课题目标的实现。
- 课题负责人主持的课题例会。确保项目按预定计划执行。例会，有纪要，有网站，并将相关报告上传到网上。
- 项目的成果主要是论文发表和设计报告。我们将严格遵守科技部相关政策和条例、以及各高能物理国际惯例。

三、项目管理（2）

- 本课题由中国科学院高能物理研究所承担，按科技部要求，有专门课题财务助理。

课题预算表

表B2 课题编号： 2016YFA0400401 课题名称： 加速器物理设计 金额单位：万元

序号	预算科目名称	合计	专项经费	自筹经费
	（1）	（2）	（3）	（4）
1	一、经费支出	388.00	388.00	
2	（一）直接费用	356.00	356.00	
3	1、设备费	188.50	188.50	
4	（1）购置设备费	188.50	188.50	
5	（2）试制设备费			
6	（3）设备改造与租赁费			
7	2、材料费			
8	3、测试化验加工费			
9	4、燃料动力费			
10	5、差旅费	4.86	4.86	
11	6、会议费	13.60	13.60	
12	7、国际合作与交流费	100.60	100.60	
13	8、出版/文献/信息传播/知识产权事务费	5.05	5.05	
14	9、劳务费	32.50	32.50	
15	10、专家咨询费	10.89	10.89	
16	11、其他支出			
17	（二）间接费用	32.00	32.00	

- 前两年经费主要支出情况：
  - 设备费：8.9万（此外，还有约100万正在办理支付手续）
  - 会议/差旅/国际合作与交流费：33万元

  共计：141.9万元。

- 总支出与计划支出经费（即：总直接经费的40%，142万）基本一致。

三、项目管理（3）

- 人员管理：
- 课题负责人：高杰
- 课题骨干：王逗、王毅伟、张源、白莎、崔小昊、王娜、魏源源、孟才、耿会平、等
- 博士生：苏峰、边天剑、宫殿君、肖邓杰，夏文昊、王晓宁
- 计划（博士后、临时人员、缺额情况）：新进博士生1人/年，博士后-3-4人/5年
- 海外国际合作：10人

风险评估与保障措施

- 1）由于本项研究对CEPC的各种可能方案均列入研究范围，如，单环，局部双环（PDR），改进型局部双环（APDR），及双环等，因此方案的风险不大，可以控制。

- 2）由于与国际上主要相关研究实验室有合作（如与BINP， SLAC, KEK， BNL,等）与交流，因此，在加速器设计物理与水平上的风险不大，可以控制。

- 3）由于现有的研究队伍尽管年轻，但通过刻苦研究，国际合作，培训提高，长期积累等方面的努力在队伍能力方面风险不大，可以控制。

课题任务书目标

课题目标	成果名称	成果类型	考核指标				考核方式（方法）及评价手段	本年度指标状态
			指标名称	立项时已有指标值/状态	中期指标值/状态	完成时指标值/状态		
1. 解决CEPC对撞机的总体方案设计及优化选型问题。根据CEPC的物理设计目标给出加速器总体不同设计方案，并进行相关方案的设计研究，找出关键瓶颈问题和对技术与造价的影响，通过比较给出最终设计方案建议。2.高能高亮度大型对撞机的设计主要面临的是亮度指标高、机器参数优化复杂、方案种类较多、原件数量巨大、找解和优化的难度和时间长、需要的计算能力高、对对撞机及环形加速器的物理理解和理论积淀要求高、对专业程序的使用、改写和编写提出了高要求、加速器物理设计与硬件之间的技术匹配复杂而艰难等。通过本课题的研究可使我国的环形加速器设计达到世界领先的水平。3.本项目将通过设计研究和优化给出CEPC加速器的总体物理方案设计和参数设计，对CEPC的技术研究及未来的建造打下关键的设计基础。4. 本课题的成果将通过杂志文章、会议报告和设计报告等形式对加速器领域产生学术影响。有了世界顶级加速器的设计能力，其他规模的不同用途的大科学工程中的加速器设计就会变得相对容易，提升我国和国际加速器设计的整体水平。加速器技术的应用设计科学研究、工业、军事和国防应用，本课题的完成也将大大提升我国在相关领域的水平	1. CEPC对撞机物理设计	√新理论 □新原理 □新产品 □新技术 √新方法 □关键部件 □数据库 □软件 □应用解决方案 □实验装置/系统 □临床指南/规范 □工程工艺 □标准 √论文 □发明专利 □其他	指标1.1：240GeV能区亮度(主环)	/	给出不同方案的设计	2×10^{34}cm^{-2}s^{-1}	同行专家评议	对240GeV能区，已进行了单环，局部双环，先进局部双环，以及双环四种方案的参数设计，确定了以双环为基准的设计方案，并召开了国际评审会
			指标1.2：91GeV能区亮度	/	给出不同方案的设计	1×10^{34}cm^{-2}s^{-1}	同行专家评议	对91GeV能区，对已进行了单环，局部双环，先进局部双环，以及双环四种方案的参数设计，最后以双环为基准的设计方案，并召开了国际评审会
			指标1.3：动力学孔径（主环）	/	给出不同方案的设计	$20\sigma_x/40\sigma_y/0.00$ (on momentum)，$5\sigma_x/5\sigma_y/0.02$ (off momentum, 含磁铁误差，束束作用)	同行专家评议	对动力学孔径的优化，已进行了单环，局部双环，先进局部双环，以及双环四种方案进行的探索，其结果成为是双环为基准的设计方案选择的重要依据，召开了国际评审会
			指标1.4：增强器	/	给出不同设计方案	$7\sigma_x/7\sigma_y/0.01$ (off momentum, 含磁铁误差)	同行专家评议	开展了直线方案以及带阻尼环两种方案的研究，最后确定了带阻尼环的方案，并召开了国际评审会

CEPC Design –Higgs Parameters

Parameter	Design Goal
Particles	e+, e-
Center of mass energy	2*120 GeV
Luminosity (peak)	>2*10^34/cm^2s
No. of IPs	2

CEPC Design – Z-pole Parameters

Parameter	Design Goal
Particles	e+, e-
Center of mass energy	2*45.5 GeV
Integrated luminosity (peak)	>1^34/cm^2s
No. of IPs	2
Polarization	to be considered in the second round of design

CEPC 加速器设计主要研究内容与进展

1）开展了参数优化设计与检验（beam-beam）（不同能量，不同长度，不同参数）
2） 关键物理瓶颈问题研究：Sawtooth及beam loading effects及解决方法
3）4种CEPC option的设计与比较：单环Pretzle，ADR，APDR，DR （2016年11月启动）
4）CEPC MDI 区域设计
4） Booster 两种方案设计：low field and alternating field
5） 注入器设计：四种设计方案（含damping ring）
以上研究CEPC的长度为~60km，并在2016年11月IAC会议上及俄罗斯RuPAC会议上汇报了研究进展

2016年11月CEPC SC 确定CEPC为100km后，上述研究转为100km。在2017年12月在日本召开的LCWS会议上首次对外明确。
根据研究进展和研究结果，CEPC加速器负责人高杰在2017年1月14日SC会议（扩大）给出建议，并得到会议的通过：1）CEPC DR 为Baseline，APDR为Alternative
2017年1月在香港的IAS会议上，CEPC加速器负责人高杰第一次在国际会议上介绍了CEPC baseline及alternative option选择过程与结果，明确了2017年底的CDR工作任务目标。

2017年1月完成CEPC加速器进展报告（或称CEPC黄皮书，4月17日印刷）
2017年11月完成CDR Draft，进行mini-国际评估
2018年6月28-30完成 CDR 国际评估。

CEPC 加速器五大系统介绍

10 GeV

1) 直线加速器

L=1.2km

电子

正电子

2) 增强器

C=100km

升能能力

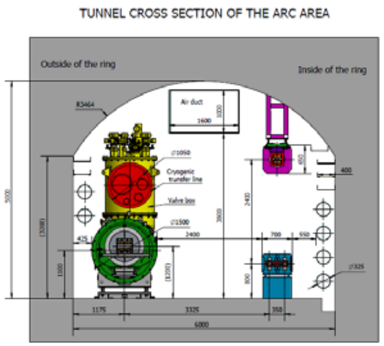
10 ->45/120GeV

三个环形加速器在同一隧道：

1）对撞环 2）增强器

3）SppC

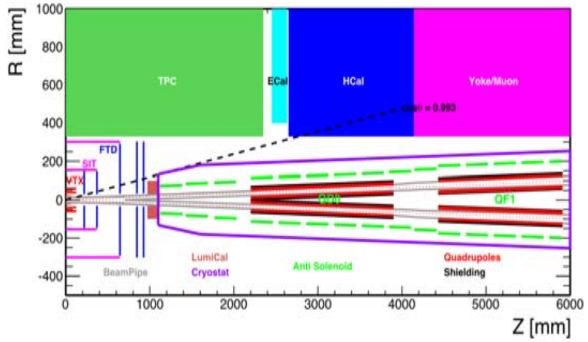
5） 土建工程



3) 对撞环

C=100km

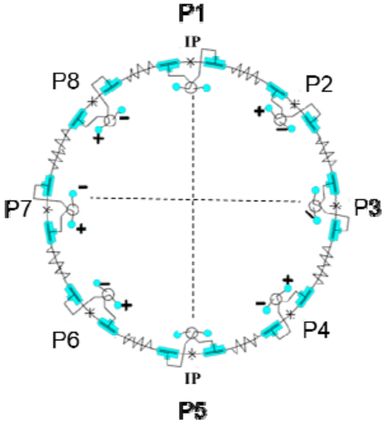
45/120 GeV



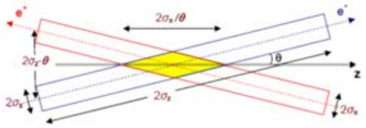
4） CEPC探测器

CEPC 四种设计选项的 CDR确定过程

CEPC 预概念设计报告(无角度对撞)

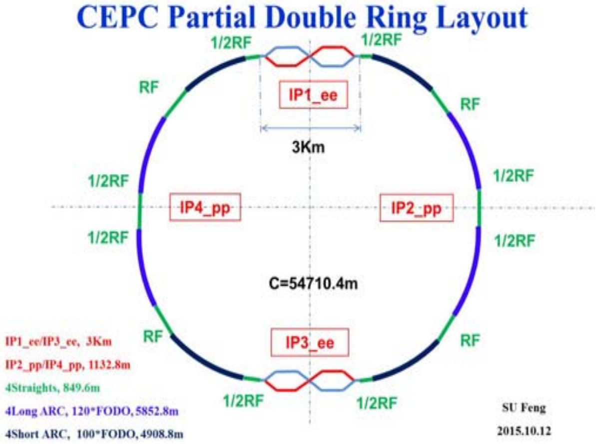


自 2012年10月

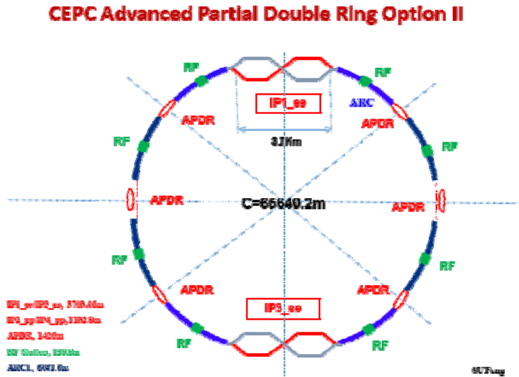


CEPC CDR 带角度Crab-waist对撞

CEPC 局部双环方案



自 2015年5月

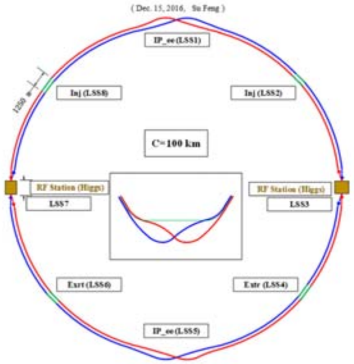


CEPC 先进局部双环方案

自 2016年5月

CEPC Alternative Design

Lower cost and reaching the fundamental requirement for Higgs and Z luminosities, under the condition that sawtooth and beam loading effects be solved



CEPC CDR 双环方案

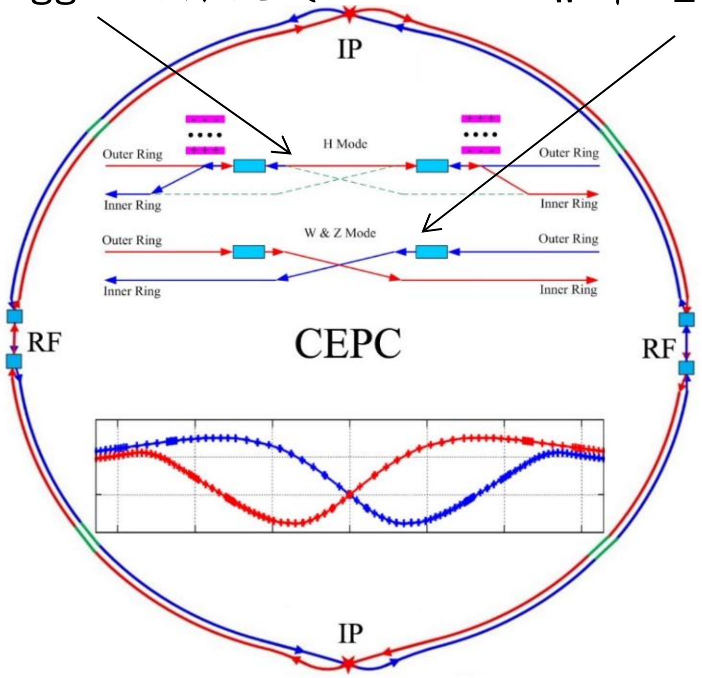
自2016年11月

CEPC Baseline Design

Better performance for Higgs and Z compared with alternative scheme, without bottle neck problems, but with higher cost
30MW synchrotron radiation power/beam

- ➢ 2016年11月CEPC 长度定为100km
- ➢ 2017年1月4日CEPC指导委员会确定了CEPC双环CDR基准设计 和先进局部双环作为备选方案

CEPC 超导微波加速器运行模式设计：Higgs, W, and Z



Higgs 运行模式

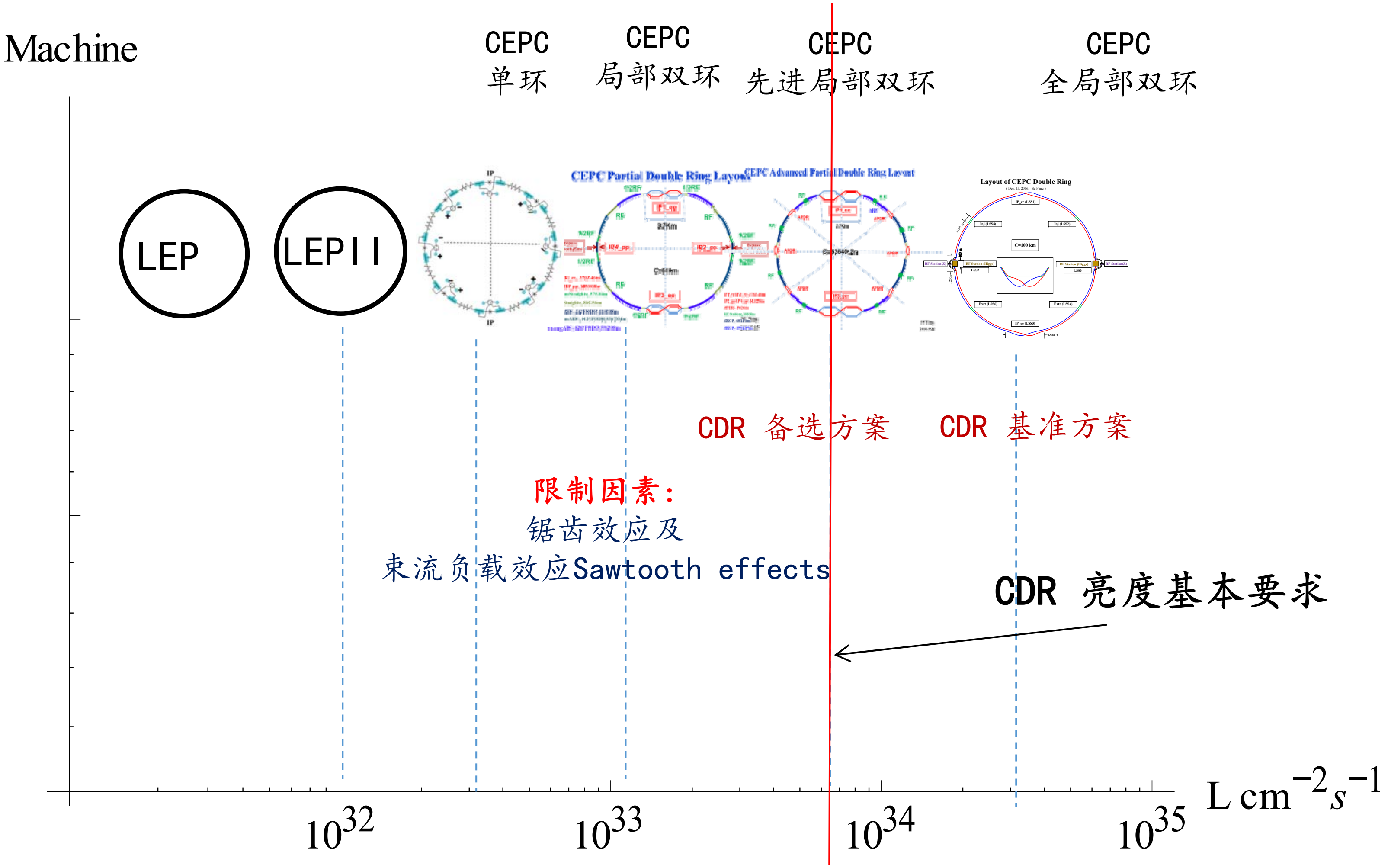
W 和 Z运行模式

- 希格斯工厂为首要优化目标，采用全局部双环方，正负电子束流共用相同的超导高频加速器系统
- W和Z工厂运行模式通过束流切换开关实现，是双环运行模式，电子和正电子具有独立超导高频加速器系统
- 希格斯工厂运行时电子和正电子束流辐射功率分别为30MW以便降低电网使用功率

CEPC CDR设计指导思想：首先是 Higgs 工厂，兼顾W和Z工厂 （三种运行模式）：

- Higgs, W, Z factories 采用相同的超导高频加速器硬件系统，通过束流切换开关进行三种不同运行模式之间的相互转化
- 希格斯工厂运行时电子和正电子束流辐射功率分别为30MW以便降低电网使用功率

对撞机选型与亮度对应关系



亮度 H: 10^32 （102GeV） <~2*10^34 >2~5*10^34 （cm^-2s^-1）

亮度 Z: 10^32 <~1*10^34 >10*10^34 (cm^-2s^-1)

Task force on CEPC option designs

	Single Ring	Partial Double Ring	Advance Partial Double Ring	Full Partial Double Ring
Parameter	Dou Wang	Dou Wang	Dou Wang	Dou Wang
Lattice Design	Huiping Geng	Yiwei Wang, Feng Su, Dou Wang	Yiwei Wang, Feng Su, Dou Wang)	Yiwei Wang, Feng Su, Dou Wang
Dynamic Aperture	Huiping Geng	Yiwei Wang, Feng Su, Dou Wang, Yuan Zhang, Tianjian Bian	Yiwei Wang, Feng Su, Dou Wang, Yuan Zhang, Tianjian Bian	Yiwei Wang, Feng Su, Dou Wang, Yuan Zhang, Tianjian Bian
Beam Loading		Jiyuan Zhai, Zhenchao Liu, Dianjun Gong	Jiyuan Zhai, Zhenchao Liu, Dianjun Gong	
Sawtooth	Huiping Geng, Chenghui Yu	Sha Bai, Chenghui Yu Tianjian Bian	Sha Bai, Chenghui Yu Tianjian Bian	
Collective effects	Na Wang, Hongjuan Zheng	Na Wang, Hongjuan Zheng	Na Wang, Hongjuan Zheng	Na Wang, Hongjuan Zheng
MDI	Sha Bai, Yiwei Wang	Sha Bai, Yiwei Wang	Sha Bai, Yiwei Wang	Sha Bai, Yiwei Wang
SRF	Jiyuan Zhai, Dianjun Gong	Jiyuan Zhai, Dianjun Gong	Jiyuan Zhai, Dianjun Gong	Jiyuan Zhai, Dianjun Gong
beam-beam	Yuan Zhang	Yuan Zhang	Yuan Zhang	Yuan Zhang
Injector	Cai Meng, jingru Zhang, Xiaoping Li	Cai Meng, jingru Zhang, Xiaoping Li	Cai Meng, jingru Zhang, Xiaoping Li	Cai Meng, jingru Zhang, Xiaoping Li

CEPC 加速器设计：从预概念设计报告到概念设计报告

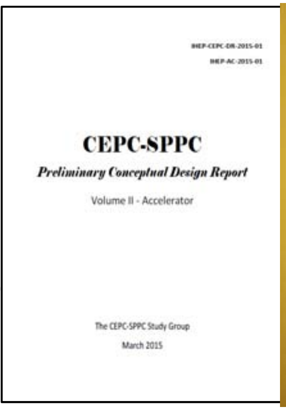
CDR Version for International Review June 2018, and formally relased on Sept. 2, 2018:arXiv：1809.00285,
http://cepc.ihep.ac.cn/CDR_v6_201808.pdf

Executive Summary

http://cepc.ihep.ac.cn

1. Introduction
2. Machine Layout and Performance
3. Operation Scenarios
4. CEPC Collider
5. CEPC Booster
6. CEPC Linac
7. Systems Common to the CEPC Linac, Booster and Collider
8. Super Proton Proton Collider
9. Conventional Facilities
10. Environment, Health and Safety
11. R&D Program
12. Project Plan, Cost and Schedule

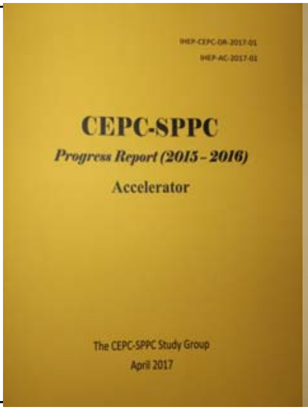
- Appendix 1: CEPC Parameter List
- Appendix 2: CEPC Technical Component List
- Appendix 3: CEPC Electric Power Requirement
- Appendix 4: Advanced Partial Double Ring
- Appendix 5: CEPC Injector Based on Plasma Wakefield Accelerator
- Appendix 6: Operation as a High Intensity γ-ray Source
- Appendix 7: Operation for e-p, e-A and Heavy Ion Collision
- Appendix 8: Opportunities for Polarization in the CEPC
- Appendix 9: International Review Report


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

CEPC-SPPC
Preliminary Conceptual Design Report
Volume II - Accelerator

The CEPC-SPPC Study Group
March 2015

2015年3月
预概念设计报告


IHEP-CEPC-DR-2017-01
IHEP-AC-2017-01

CEPC-SPPC
Progress Report (2015 - 2016)
Accelerator

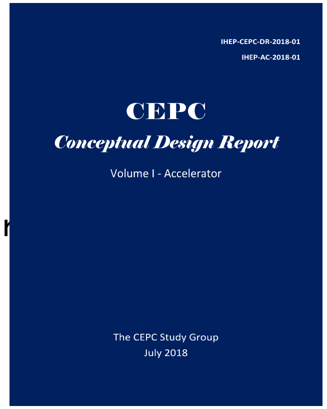
The CEPC-SPPC Study Group
April 2017

2017年4月
进展报告


CEPC-SPPC CDR
(draft_v2)

中国科学院高能物理研究所
2017年11月6日

2017年11月CEPC
CDR初稿，国际预评估


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

CEPC
Conceptual Design Report
Volume I - Accelerator

The CEPC Study Group
July 2018

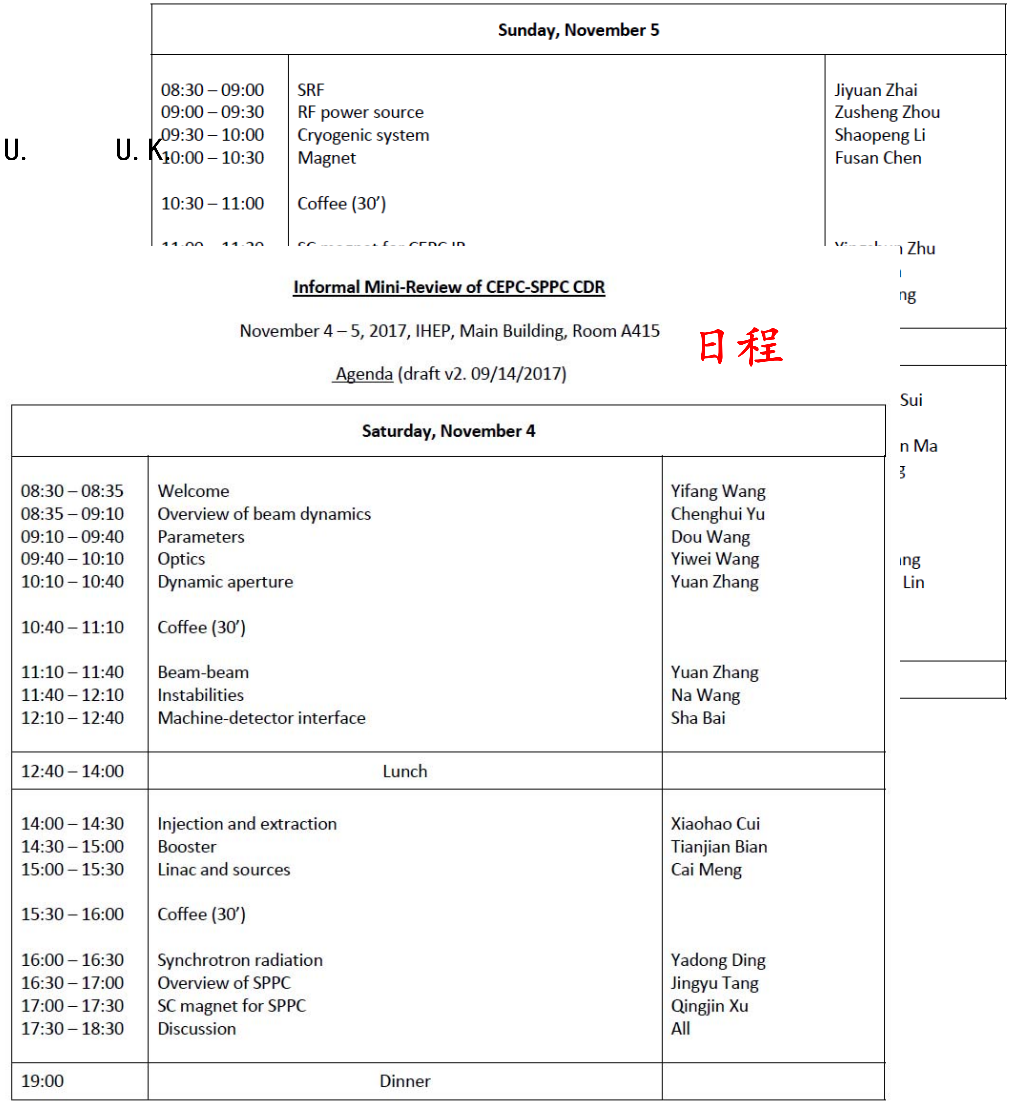
CDR内容(英文)

CEPC加速器概念设计报告CDR
2018年6月28-30日国际评估

CEPC-SPPC CDR国际预评估
(2017年11月 4-5日，高能所)

CEPC-SPPC CDR 国际预评估委员会成员

Name (alphabetical order)		
Anton Bogomyakov	BINP	Russia
Brian Foster	Oxford U.	U.K.
Eugene Levichev	BINP	Russia
Kexin Liu（刘克新）	Peking U.	China
Ernie Malamud	Fermilab	USA
Kazuhito Ohmi	KEK	Japan
Katsunobu Oide	CERN / KEK	Switzerland
Carlo Pagani	U. of	
John Seeman	SLAC	USA
Sergey Sinyatkin	BINP	Russia
Mike Sullivan	SLAC	USA
Chuanxiang Tang（唐传祥）	Tsinghua U.	China
Lin Wang （王林）	USTC	China
Xiangqi Wang（王相綦）	USTC	China
Akira Yamamoto	KEK	Japan



Sunday, November 5		
08:30 – 09:00	SRF	Jiyuan Zhai
09:00 – 09:30	RF power source	Zusheng Zhou
09:30 – 10:00	Cryogenic system	Shaopeng Li
10:00 – 10:30	Magnet	Fusan Chen
10:30 – 11:00	Coffee (30’)	
		Zhu

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Lin

Informal Mini-Review of CEPC-SPPC CDR

November 4 – 5, 2017, IHEP, Main Building, Room A415

Agenda (draft v2. 09/14/2017)

日程

Saturday, November 4		
08:30 – 08:35	Welcome	Yifang Wang
08:35 – 09:10	Overview of beam dynamics	Chenghui Yu
09:10 – 09:40	Parameters	Dou Wang
09:40 – 10:10	Optics	Yiwei Wang
10:10 – 10:40	Dynamic aperture	Yuan Zhang
10:40 – 11:10	Coffee (30’)	
11:10 – 11:40	Beam-beam	Yuan Zhang
11:40 – 12:10	Instabilities	Na Wang
12:10 – 12:40	Machine-detector interface	Sha Bai
12:40 – 14:00	Lunch	
14:00 – 14:30	Injection and extraction	Xiaohao Cui
14:30 – 15:00	Booster	Tianjian Bian
15:00 – 15:30	Linac and sources	Cai Meng
15:30 – 16:00	Coffee (30’)	
16:00 – 16:30	Synchrotron radiation	Yadong Ding
16:30 – 17:00	Overview of SPPC	Jingyu Tang
17:00 – 17:30	SC magnet for SPPC	Qingjin Xu
17:30 – 18:30	Discussion	All
19:00	Dinner	

CEPC CDR国际评估
(2018年06月 28-30日，高能所)

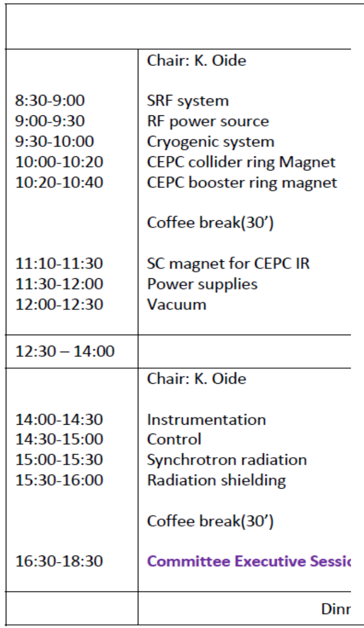
日程

International Review of CEPC CDR

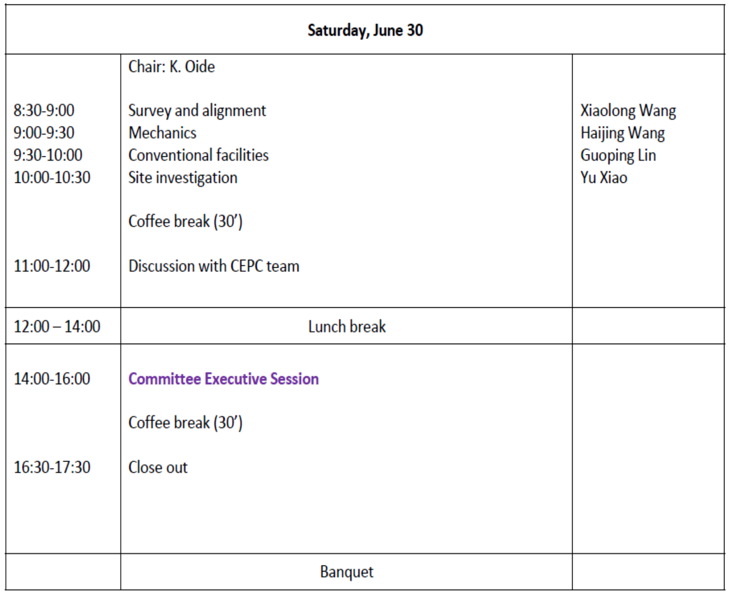
June 28 – 30, 2018, IHEP, Main Building, Room A415

Agenda

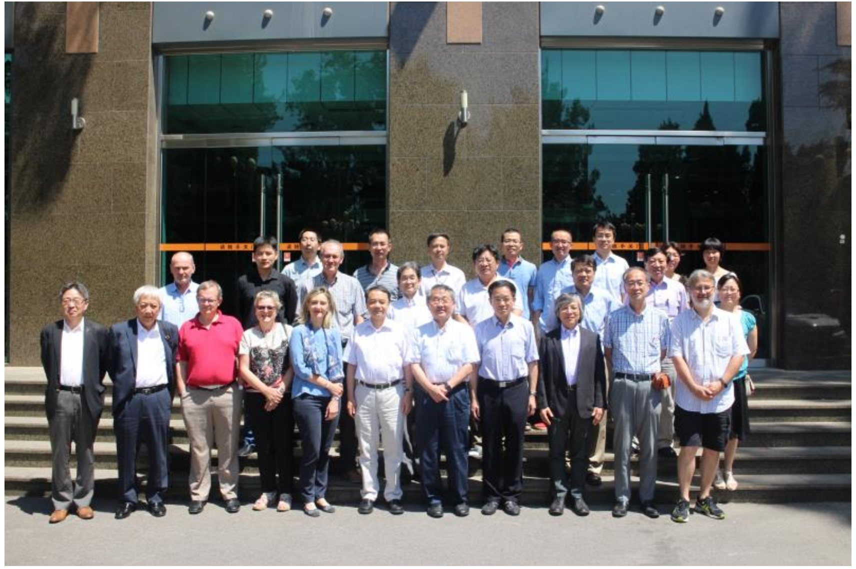
Thursday, June 28		
	Chair: K. Oide	
8:30-9:00	**Committee Executive Session**	
	Chair: Qing Qin	
9:00-9:05	Welcome	Yifang Wang
9:05-9:20	Overview of CEPC	Jie Gao
9:20-9:35	Overview of beam dynamics	Chenghui Yu
9:35-10:05	CEPC collider lattice design	Yiwei Wang
10:05-10:35	CEPC beam-beam and DA	Yuan Zhang
	Coffee break(30')	
	Chair: K. Oide	
11:05-11:35	Instabilities	Na Wang
11:35-12:05	Machine-detector interface	Sha Bai
12:05 – 14:00	Lunch break	
	Chair: K. Oide	
14:00-14:30	Booster	Dou Wang
14:30-15:00	Injection and extraction	Xiaohao Cui
15:30-16:00	Linac injector	Cai Meng
	Coffee break(30')	
16:30-18:30	**Committee Executive Session**	
19:00	Dinner of Committee	



	Chair: K. Oide
8:30-9:00	SRF system
9:00-9:30	RF power source
9:30-10:00	Cryogenic system
10:00-10:20	CEPC collider ring Magnet
10:20-10:40	CEPC booster ring magnet
	Coffee break(30')
11:10-11:30	SC magnet for CEPC IR
11:30-12:00	Power supplies
12:00-12:30	Vacuum
12:30 – 14:00	
	Chair: K. Oide
14:00-14:30	Instrumentation
14:30-15:00	Control
15:00-15:30	Synchrotron radiation
15:30-16:00	Radiation shielding
	Coffee break(30')
16:30-18:30	**Committee Executive Sessi**
	Dinr



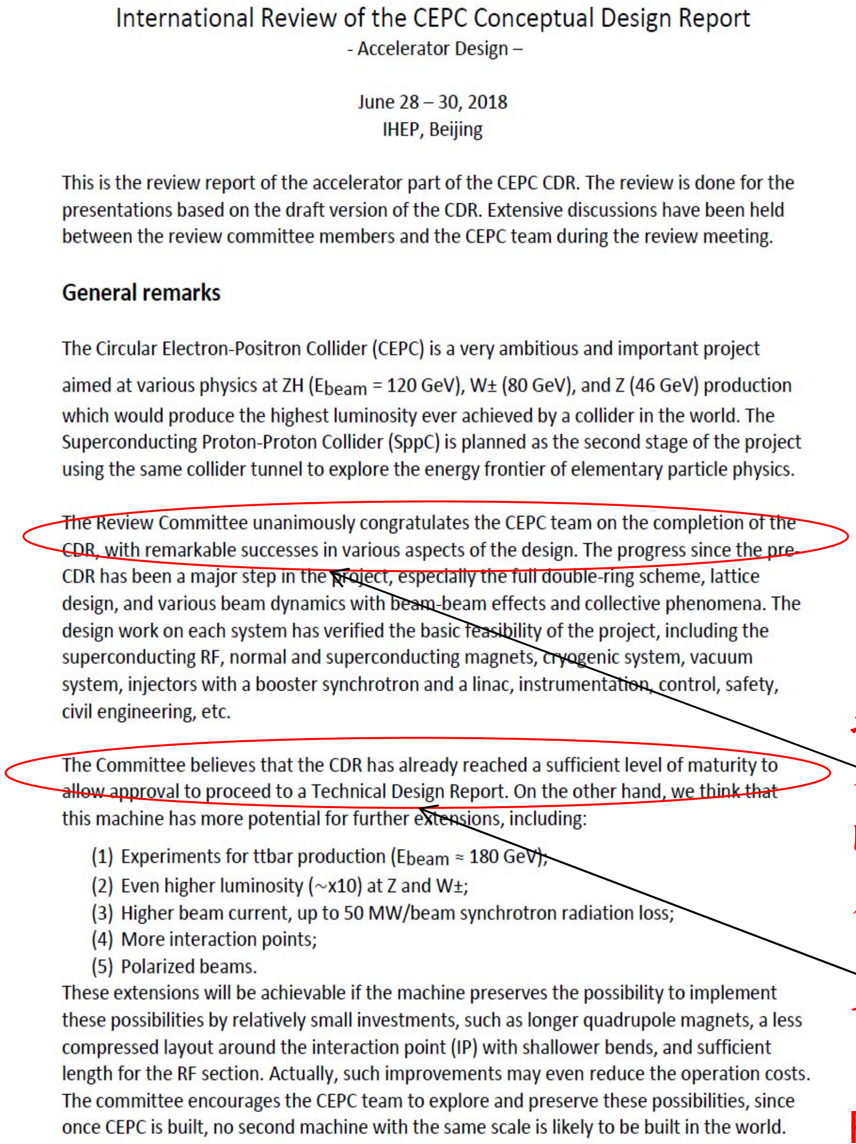
Saturday, June 30		
	Chair: K. Oide	
8:30-9:00	Survey and alignment	Xiaolong Wang
9:00-9:30	Mechanics	Haijing Wang
9:30-10:00	Conventional facilities	Guoping Lin
10:00-10:30	Site investigation	Yu Xiao
	Coffee break (30')	
11:00-12:00	Discussion with CEPC team	
12:00 – 14:00	Lunch break	
14:00-16:00	**Committee Executive Session**	
	Coffee break (30')	
16:30-17:30	Close out	
	Banquet	



CEPC-SPPC CDR 国际预评估委员会成员：

Brian Foster	Oxford U./DESY
Eugene Levichev	BINP
Katsunobu Oide (主席)	**CERN/KEK （Fcc ee)**
Kazuro Furukawa	KEK
Manuela Boscolo	INFN
Marica Biagini	INFN
Masakazu Yoshioka	KEK/Tohoko University
Norihito Ohuchi	KEK
Paolo Pierini	ESS
Steinar Stapnes	CERN
Yoshihiro Funakoshi	KEK
Zhengtang Zhao (absent)	SINAP

CEPC CDR 国际评估报告
（2018年7月8日最终版）



International Review of the CEPC Conceptual Design Report
- Accelerator Design –

June 28 – 30, 2018
IHEP, Beijing

This is the review report of the accelerator part of the CEPC CDR. The review is done for the presentations based on the draft version of the CDR. Extensive discussions have been held between the review committee members and the CEPC team during the review meeting.

General remarks

The Circular Electron-Positron Collider (CEPC) is a very ambitious and important project aimed at various physics at ZH (E_{beam} = 120 GeV), W± (80 GeV), and Z (46 GeV) production which would produce the highest luminosity ever achieved by a collider in the world. The Superconducting Proton-Proton Collider (SppC) is planned as the second stage of the project using the same collider tunnel to explore the energy frontier of elementary particle physics.

The Review Committee unanimously congratulates the CEPC team on the completion of the CDR, with remarkable successes in various aspects of the design. The progress since the pre-CDR has been a major step in the project, especially the full double-ring scheme, lattice design, and various beam dynamics with beam-beam effects and collective phenomena. The design work on each system has verified the basic feasibility of the project, including the superconducting RF, normal and superconducting magnets, cryogenic system, vacuum system, injectors with a booster synchrotron and a linac, instrumentation, control, safety, civil engineering, etc.

The Committee believes that the CDR has already reached a sufficient level of maturity to allow approval to proceed to a Technical Design Report. On the other hand, we think that this machine has more potential for further extensions, including:

(1) Experiments for ttbar production ($E_{beam} \approx$ 180 GeV);
(2) Even higher luminosity (~x10) at Z and W±;
(3) Higher beam current, up to 50 MW/beam synchrotron radiation loss;
(4) More interaction points;
(5) Polarized beams.

These extensions will be achievable if the machine preserves the possibility to implement these possibilities by relatively small investments, such as longer quadrupole magnets, a less compressed layout around the interaction point (IP) with shallower bends, and sufficient length for the RF section. Actually, such improvements may even reduce the operation costs. The committee encourages the CEPC team to explore and preserve these possibilities, since once CEPC is built, no second machine with the same scale is likely to be built in the world.

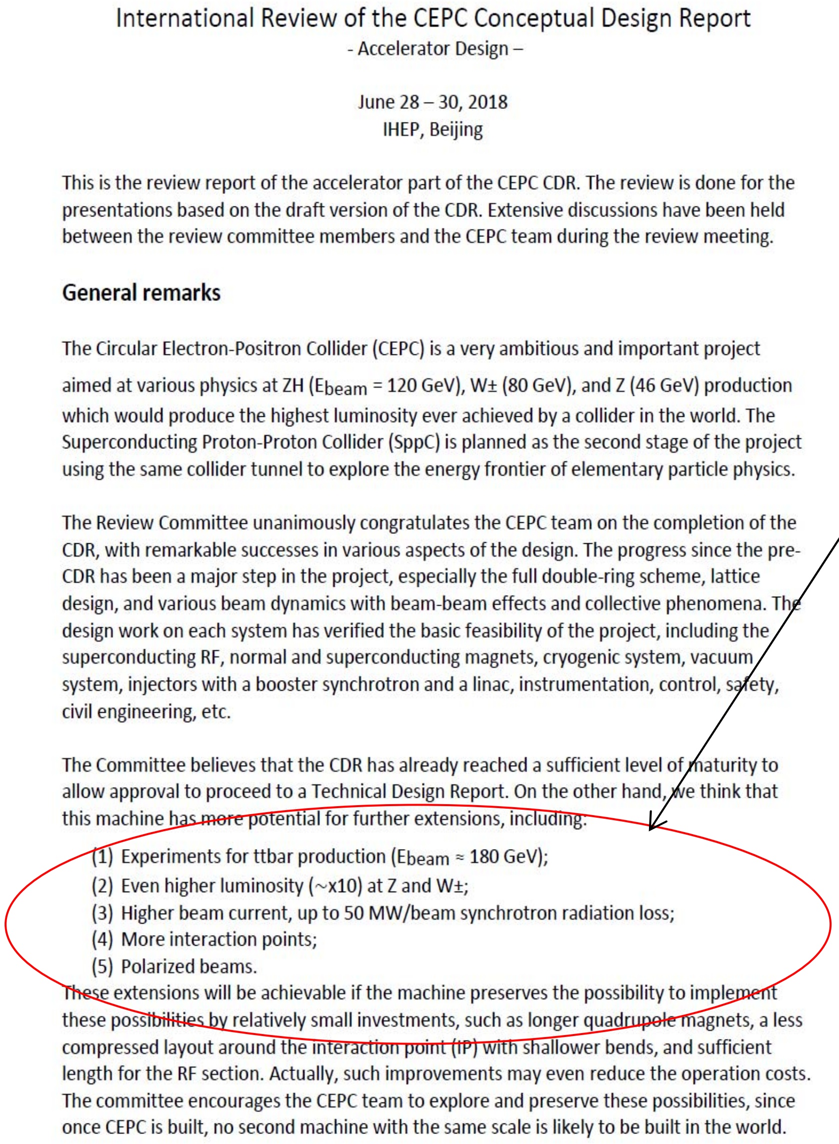
介绍：2018年6月28日至30日，高能环形正负电子对撞机（CEPC）加速器概念设计报告国际评审会在中科院高能物理研究所举行。会议由高能所主办，来自日本、俄罗斯、瑞士、意大利、英国、瑞典等6个国家的11名专家组成评审委员会，日本高能加速器机构（KEK）加速器部前主任Katsunobu Oide教授担任评审委员会主席，委员均为加速器物理与技术领域的世界顶尖专家和著名学者。在为期三天的会议期间，各位委员进行了紧张繁重的工作，撰写了30多页的初步评审意见。

报告结论：

全体评审委员一致对CEPC设计工作中取得的令人瞩目的进展进行了肯定，并对概念设计报告的完成表示祝贺...

认为设计工作已经证明项目的设计足够成熟并可以被批准进入技术设计报告（Technical Design Report，TDR）阶段...

CEPC CDR 国际评估报告
（2018年7月8日最终版）



International Review of the CEPC Conceptual Design Report
- Accelerator Design –

June 28 – 30, 2018
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(4) More interaction points;
(5) Polarized beams.

These extensions will be achievable if the machine preserves the possibility to implement these possibilities by relatively small investments, such as longer quadrupole magnets, a less compressed layout around the interaction point (IP) with shallower bends, and sufficient length for the RF section. Actually, such improvements may even reduce the operation costs. The committee encourages the CEPC team to explore and preserve these possibilities, since once CEPC is built, no second machine with the same scale is likely to be built in the world.

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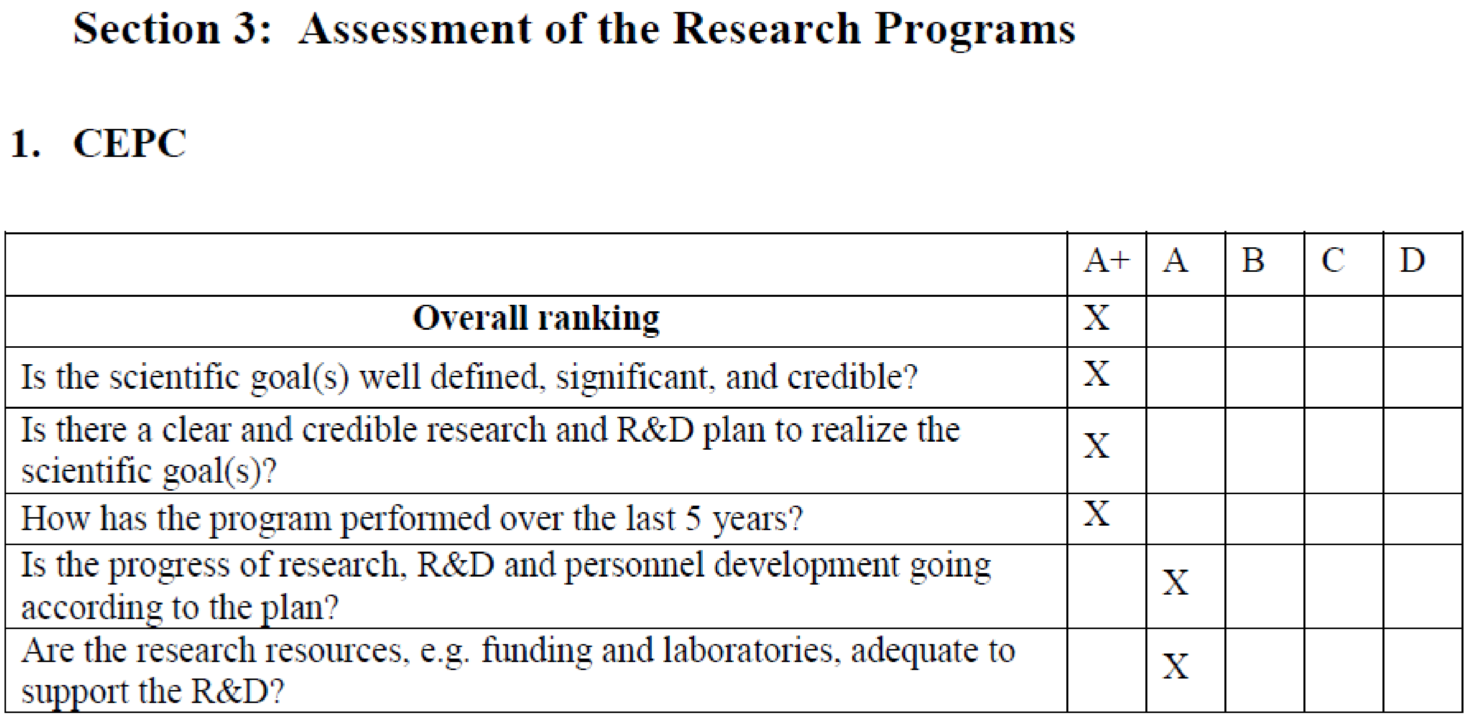
(4) More interaction points;
(5) Polarized beams.
These extensions will be achievable if the

2018年CEPC加速器参与高能所五年一度国际评估（评估结果，供参考）

2018年6月14日高能所进行了五年一度的国际评估，本项目负责人作为报告人做了”CEPC 加速器”的报告，对CEPC加速器的概念设计报告的过程进行了全面总结和汇报。2017年引力波诺贝尔奖获得者Prof. Barry Barish 是评估委员会主席。本次国际评估对CEPC研究项目的评价均为A以上，多为A+。

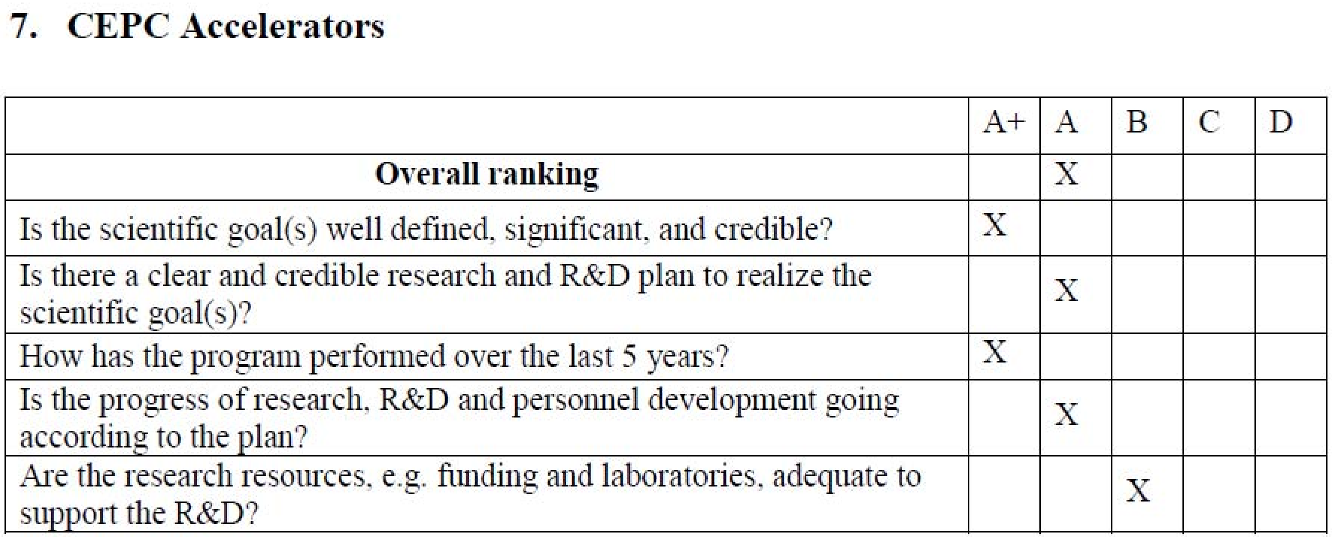


Section 3: Assessment of the Research Programs

1. CEPC

	A+	A	B	C	D
Overall ranking	X				
Is the scientific goal(s) well defined, significant, and credible?	X				
Is there a clear and credible research and R&D plan to realize the scientific goal(s)?	X				
How has the program performed over the last 5 years?	X				
Is the progress of research, R&D and personnel development going according to the plan?		X			
Are the research resources, e.g. funding and laboratories, adequate to support the R&D?		X			

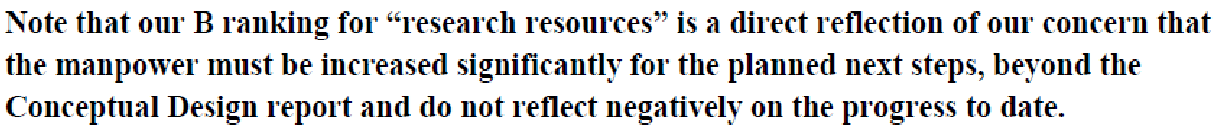
2018年CEPC加速器参与高能所五年一度国际评估（评估结果，供参考）



7. CEPC Accelerators

	A+	A	B	C	D
Overall ranking		X			
Is the scientific goal(s) well defined, significant, and credible?	X				
Is there a clear and credible research and R&D plan to realize the scientific goal(s)?		X			
How has the program performed over the last 5 years?	X				
Is the progress of research, R&D and personnel development going according to the plan?		X			
Are the research resources, e.g. funding and laboratories, adequate to support the R&D?			X		

评估报告对研究资源情况一栏结果为“B” 进行了说明：



Note that our B ranking for “research resources” is a direct reflection of our concern that the manpower must be increased significantly for the planned next steps, beyond the Conceptual Design report and do not reflect negatively on the progress to date.

说明中表示这个B不是对研究进展的评价，是对CEPC项目未来下一步人力资源增加的关切。

Prof. Barry Barish 是评估委员会主席， 他在提交正式评估报告结果后写给本项目负责人的评价是“Overall, the progress has been very impressive”。

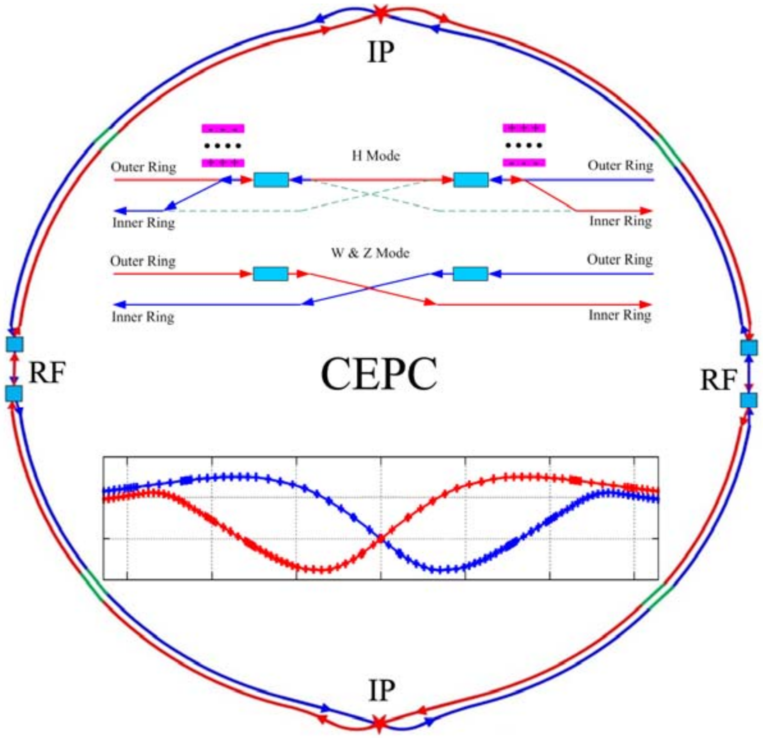
CEPC 概念设计报告参数表

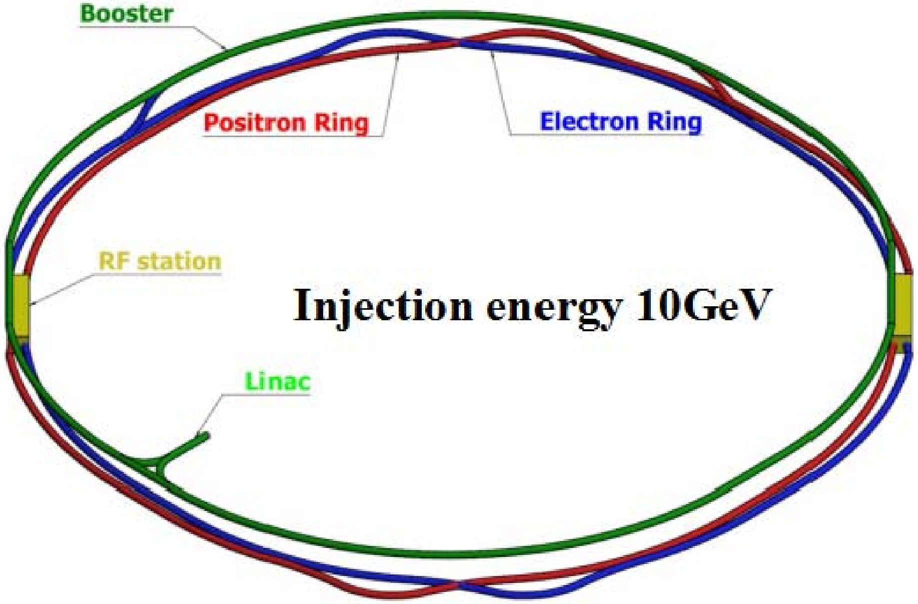
	Higgs	*W*	*Z*（*3T*）	*Z*（*2T*）
Number of IPs（对撞点数）	2			
束流能量（GeV）	120	80	45.5	
周长（km）	100			
Synchrotron radiation loss/turn（GeV）	1.73	0.34	0.036	
Crossing angle at IP（mrad）(对撞角）	16.5×2			
Piwinski angle	2.58	7.0	23.8	
Number of particles/bunch N_e（10^{10}）	15.0	12.0	8.0	
Bunch number（bunch spacing）	242（0.68μs）	1524（0.21μs）	12000（25ns+10%gap）	
Beam current（mA）（束流流强）	17.4	87.9	461.0	
Synchrotron radiation power /beam（MW）	30	30	16.5	
Bending radius（km）（偏转半径）	10.7			
Momentum compact（10^{-5}）	1.11			
β function at IP β_x^* / β_y^*（m）	0.36/0.0015	0.36/0.0015	0.2/0.0015	0.2/0.001
Emittance e_x/e_y（nm）（发射度）	1.21/0.0031	0.54/0.0016	0.18/0.004	0.18/0.0016
Beam size at IP s_x /s_y（μm）（对撞点横向尺寸）	20.9/0.068	13.9/0.049	6.0/0.078	6.0/0.04
Beam-beam parameters ξ_x/ξ_y	0.031/0.109	0.013/0.106	0.0041/0.056	0.0041/0.072
RF voltage V_{RF}（GV）（高频电压）	2.17	0.47	0.10	
RF frequency f_{RF}（MHz）（harmonic）（频率）	650（216816）			
Natural bunch length σ_z（mm）(自然束长）	2.72	2.98	2.42	
Bunch length σ_z（mm）（拉伸束长）	3.26	5.9	8.5	
HOM power/cavity（2 cell）（kw）（高次模功率）	0.54	0.75	1.94	
Natural energy spread（%）(自然能散）	0.1	0.066	0.038	
Energy acceptance requirement（%）	1.35	0.4	0.23	
Energy acceptance by RF（%）	2.06	1.47	1.7	
Photon number due to beamstrahlung	0.1	0.05	0.023	
Lifetime _simulation（min）	100			
Lifetime（hour）	0.67	1.4	4.0	2.1
F（hour glass）	0.89	0.94	0.99	
Luminosity/IP L（$10^{34}cm^{-2}s^{-1}$）（亮度）	2.93	10.1	16.6	32.1

CEPC 对撞环高频参数

Collider parameters: 20180222	**H**	**W**	**Z**
SR power / beam [MW]	30	30	16.5
RF voltage [GV]	2.17	0.47	0.1
Beam current / beam [mA]	17.4	87.9	461
Bunch charge [nC]	24	24	12.8
Bunch number / beam	242	1220	12000
Bunch length [mm]	3.26	6.53	8.5
Cavity number (650 MHz 2-cell)	240	2 x 108	2 x 60
Cavity gradient [MV/m]	19.7	9.5	3.6
Input power / cavity [kW]	250	278	276
Klystron power [kW] (2 cavities / klystron)	800	800	800
HOM power / cavity [kW]	0.54	0.86	1.94
Optimal Q_L	1.5E6	3.2E5	4.7E4
Optimal detuning [kHz]	0.17	1.0	18.3
Total cavity wall loss @ 2 K [kW]	6.6	1.9	0.2

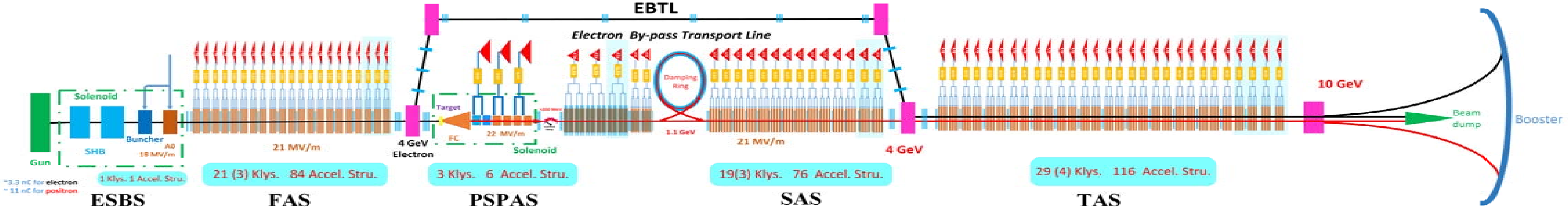
CEPC 概念设计报告布局





CEPC 对撞环（周长100公里）

CEPC 增强器（周长100公里）



CEPC 直线加速器注入器（1.2公里，能量：10GeV）

CEPC加速器解决的主要设计及束流动力学问题

- ✓ 对撞环 lattice 设计
- ✓ 超导高频加速器系统设计
- ✓ 对撞区设计，探测器背景噪音控制
- ✓ 束束相互作用研究
- ✓ 动力学孔径优化
- ✓ 轴向注入方案研究
- ✓ 阻抗和不稳定性研究
- ✓ 增强器设计
- ✓ 直线注入器设计
- ✓ 增强器注入引出研究

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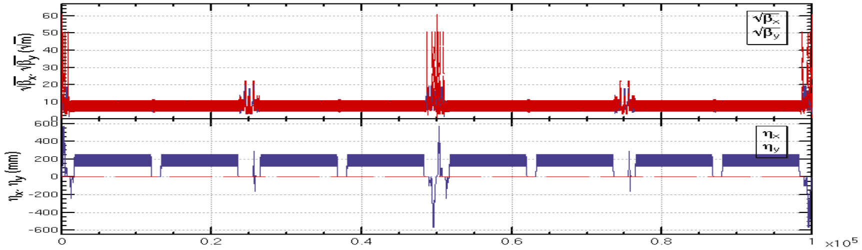
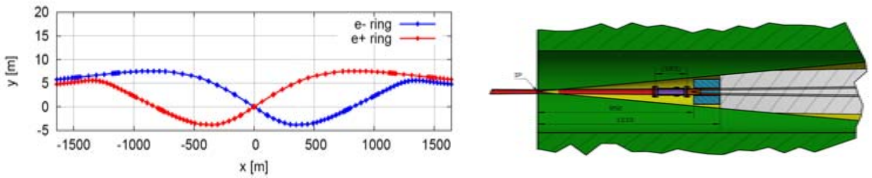
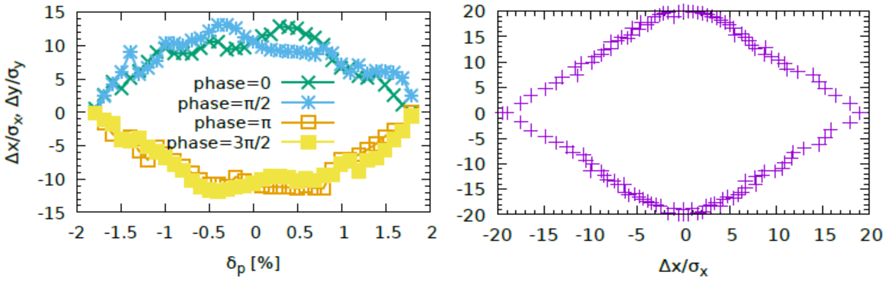


对撞环及增强器Lattice设计



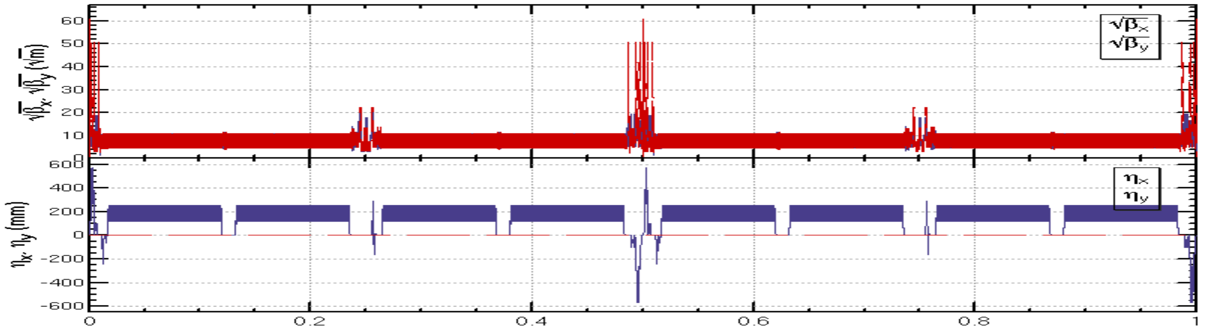
加速器-探测器区域（MDI）

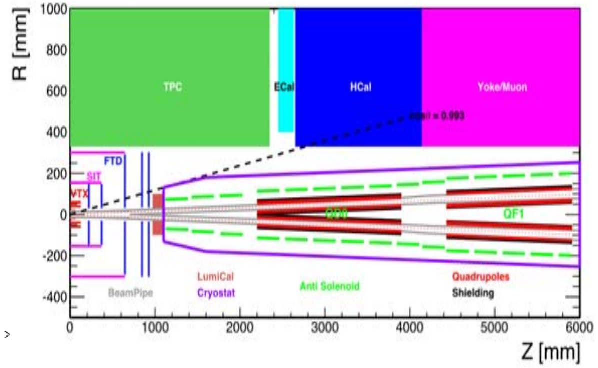


动力学孔径优化（DA）

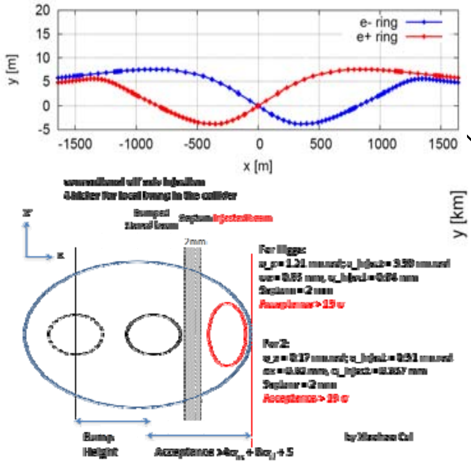
CEPC对撞环聚焦系统（Lattice ）及加速器-探测器区域（MDI）设计

满足设计参数表、几何布局、对撞区、探测器背景噪音、硬件技术要求等的CEPCLattice设计

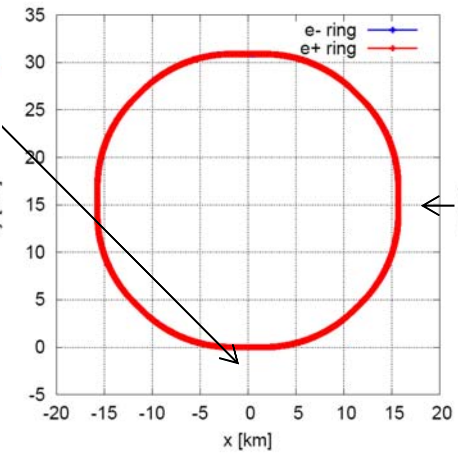




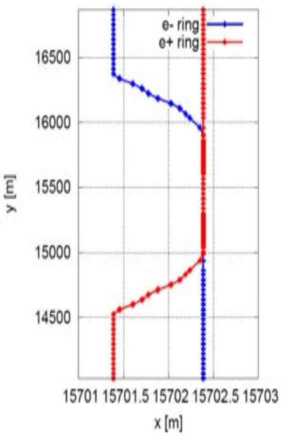
CEPC 探测器-加速器区（MDI）



对撞区及注入引出



对撞环



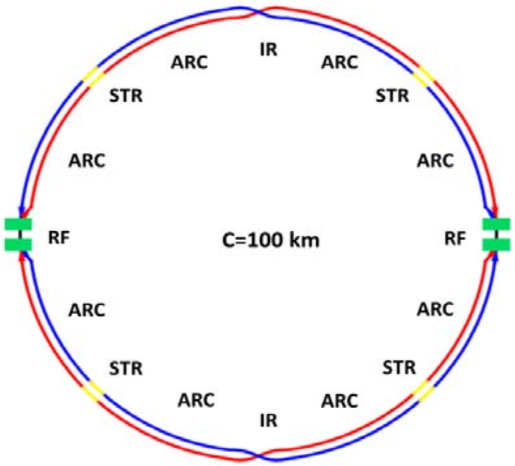
高频区

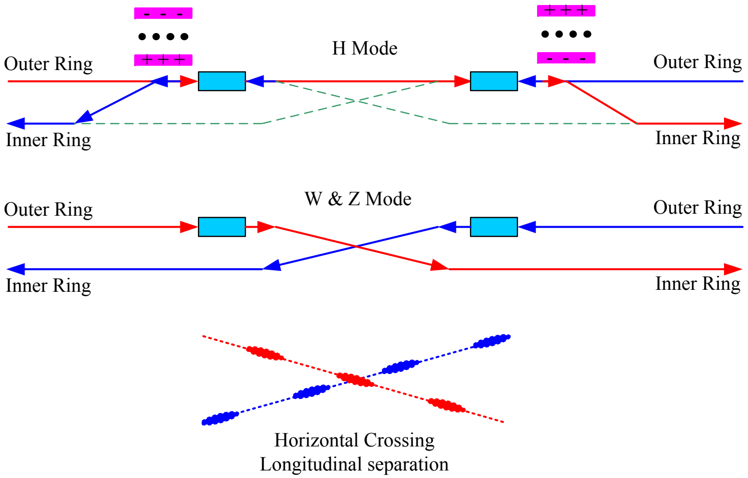
MDI parameters	Values
L^* (m)	2.2
Crossing angle (mrad)	33
Strength of QD0 (T/m)	150
Strength of detector solenoid (T)	3.0
Strength of anti-solenoid (T)	7.0

探测器-加速器区参数表

CEPC Collider Ring

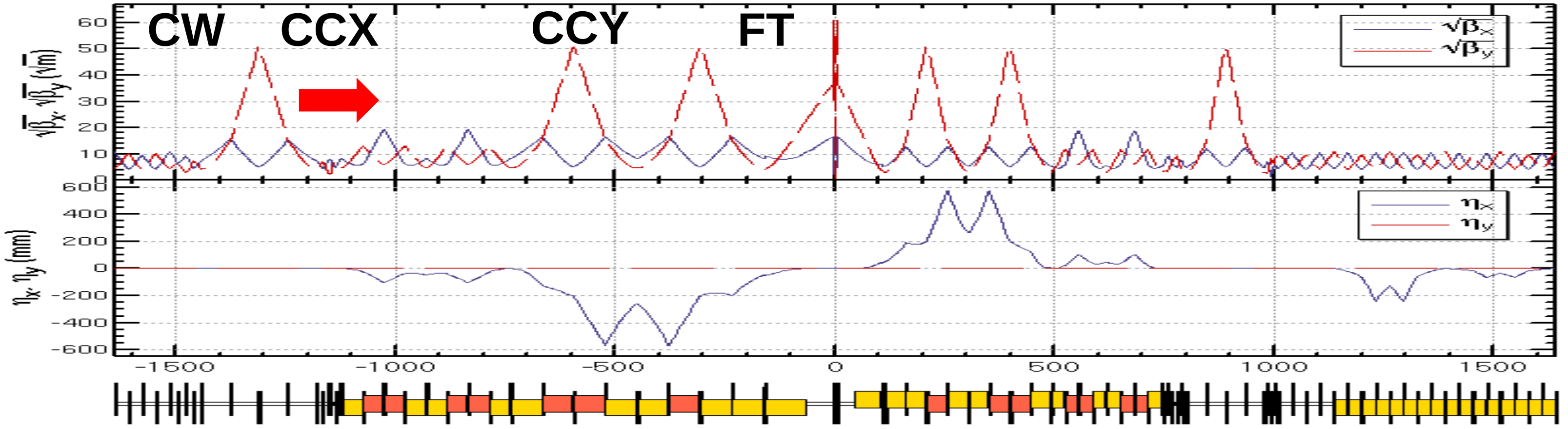
- The circumference of CEPC collider ring is **100 km**.
- In the RF region, the **RF cavities are shared by two ring for H mode**.
- **Twin-aperture of dipoles and quadrupoles is adopt in the arc region** to reduce the their power. The distance between two beams is 0.35m.
- Compatible optics for H, W and Z modes
  - For the **W and Z mode**, the optics except RF region is got by **scaling down the magnet strength with energy**.
  - For H mode, all the cavities will be used and bunches will be filled in half ring.
  - **For W & Z modes, half number of cavities will be used** and bunches can be filled in full ring



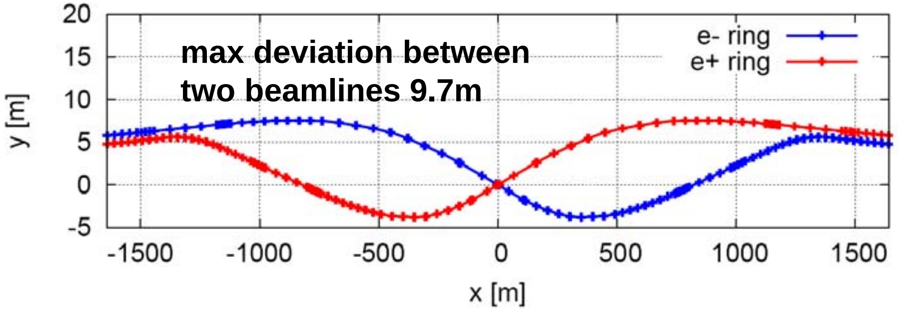


Linear optics of Interaction region

- Provide local chromaticity correction of both plane
- **L*=2.2m, θc=33mrad, GQD0=136T/m, GQF1=111T/m**
- IP upstream of IR: **Ec < 120 keV within 400m, last bend Ec = 45 keV**
- IP downstream of IR: Ec < 300 keV within 250m, last bend Ec = 97 keV
- The vertical emittance growth due to solenoid coupling is less than 4%.
- Relaxed optics for injection can be re-matched easily as the **modular design**.

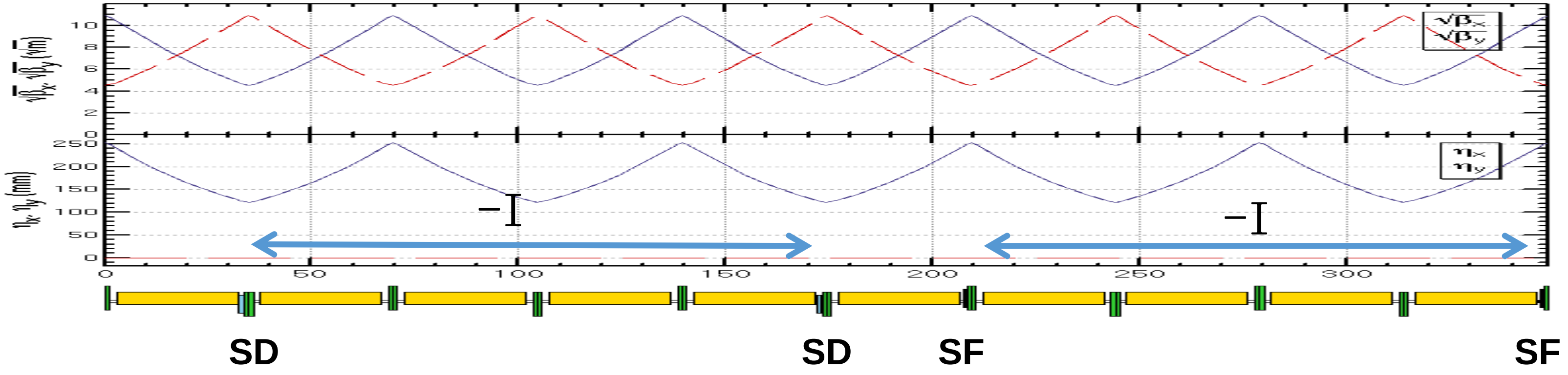


L*= 2.2m
βx*= 0.36mm
βy*= 1.5mm
GQD0≅-136T/m
GQF1≅111T/m
LQD0=2.0m
LQF1=1.48m

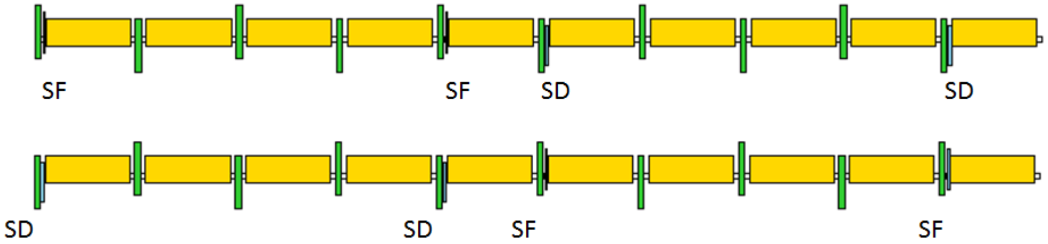

max deviation between two beamlines 9.7m

Linear optics design of ARC region

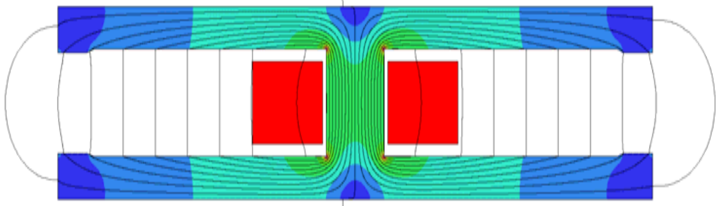
- **FODO cell, 90°/90°, non-interleaved sextupole scheme, period =5cells**

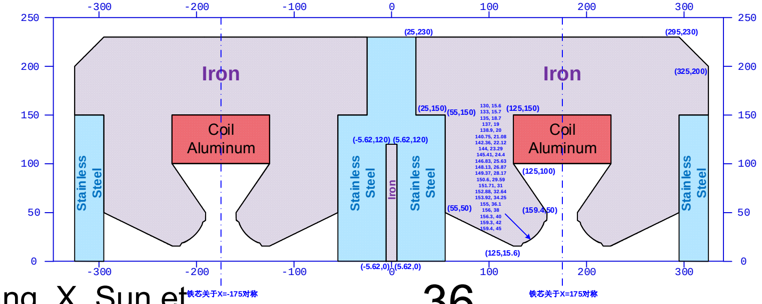


- **Twin-aperture of dipoles and quadrupoles* is adopt in the arc region** to reduce the their power. The distance between two beams is 0.35m.



***Ref: A. Milanese, PRAB 19, 112401 (2016)**

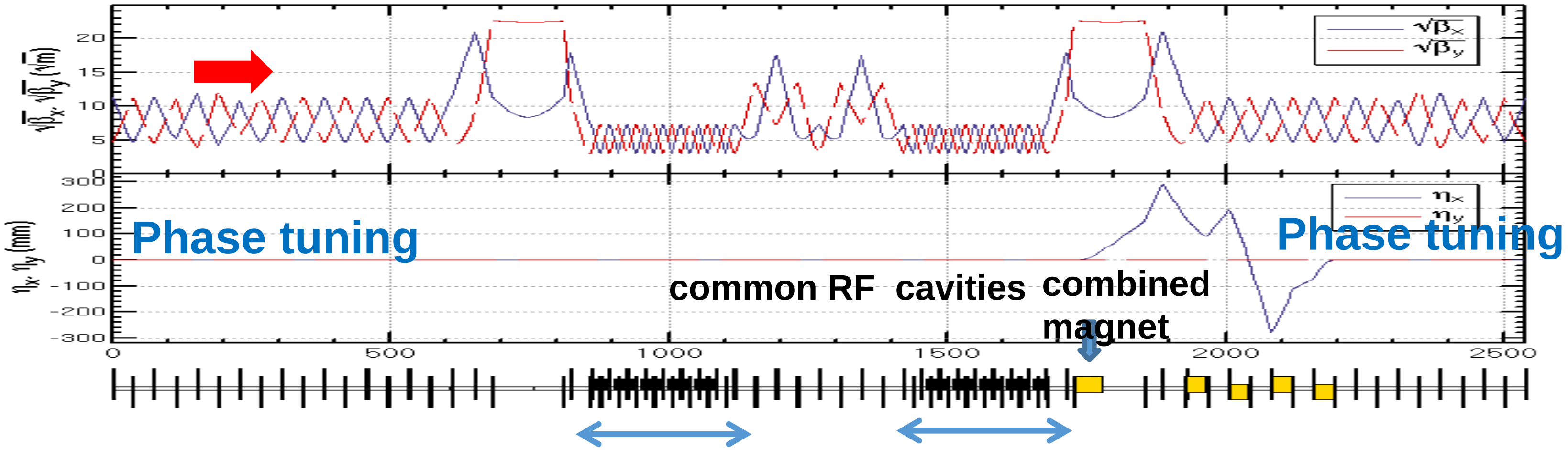


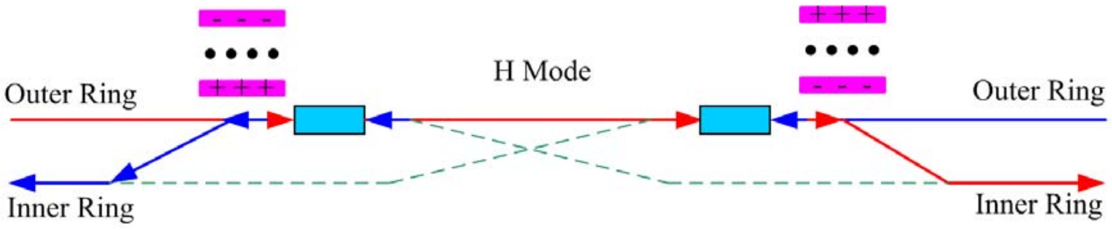


magnets designed by F. Chen, M. Yang, X. Sun et al.

Optics design of RF region

- **Common RF cavities** for e- and e+ ring (Higgs)
- An electrostatic separator combined with a dipole magnet to avoid bending of incoming beam(ref: K. Oide, ICHEP16)
- **RF region divided into two sections for bypassing half numbers of cavities in Z mode**

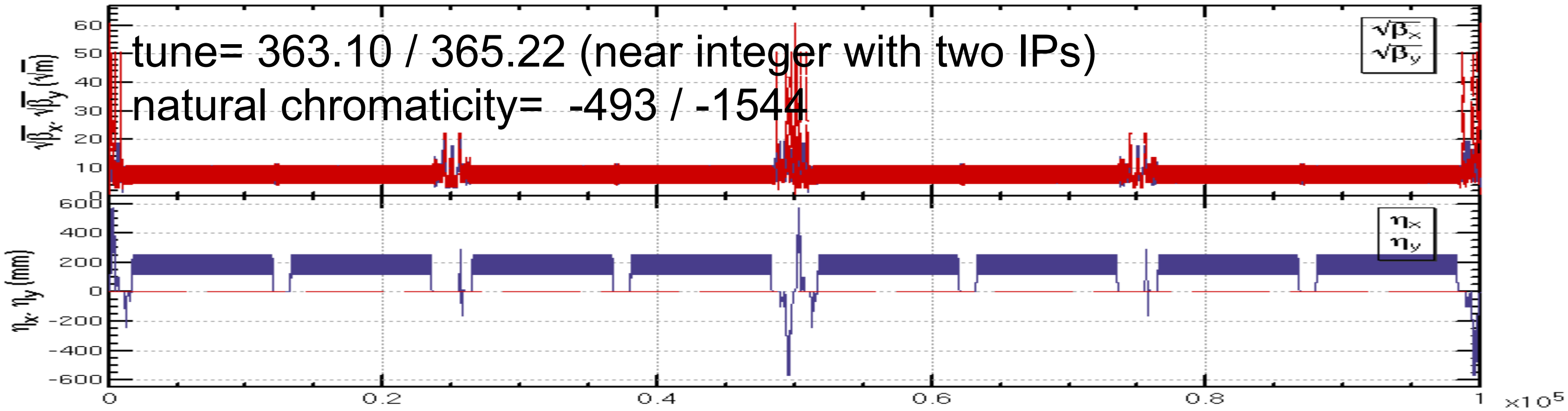




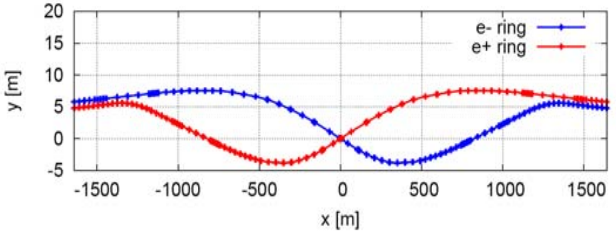
Esep=1.8 MV/m
Lsep=50m
Ldrift=75m
Δx=10cm at entrance of quad

Linear optics of the collider ring

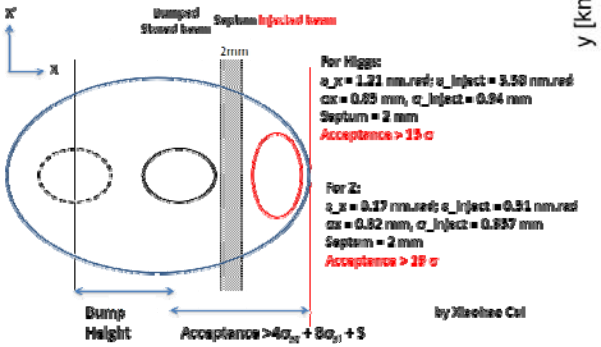
- An optics fulfilling requirements of the parameters list, geometry, photon background and key hardware.


tune= 363.10 / 365.22 (near integer with two IPs)

natural chromaticity= -493 / -1544



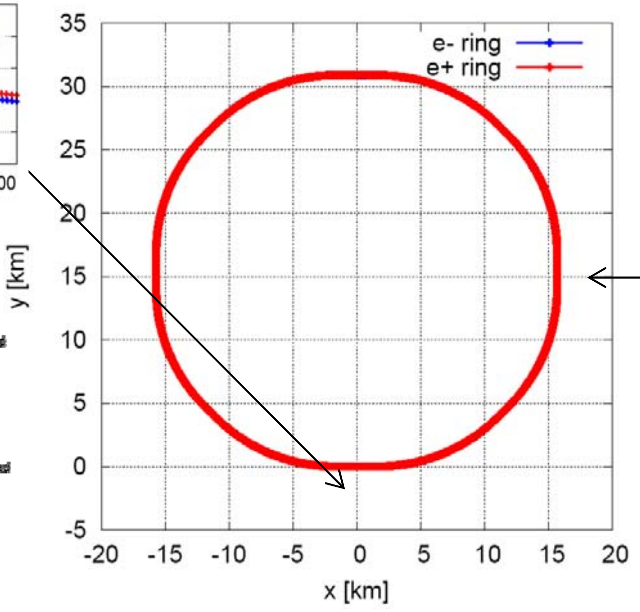
conventional off axis injection
4 kicker for local bump in the collider

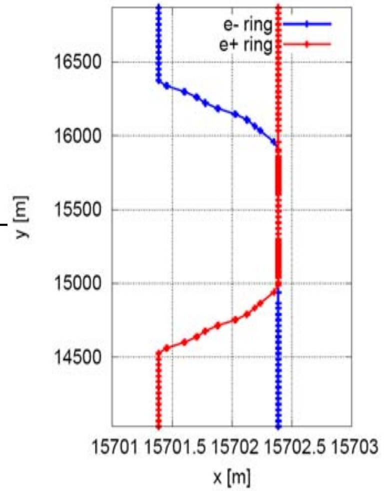


For Higgs:
ε_x = 1.21 nm.rad; ε_inject = 3.59 nm.rad
σx = 0.85 mm, σ_inject = 0.94 mm
Septum = 2 mm
Acceptance > 15 σ

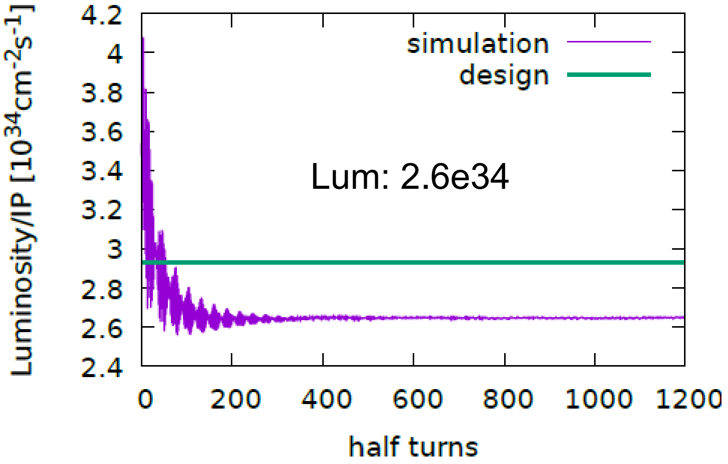
For Z:
ε_x = 0.17 nm.rad; ε_inject = 0.31 nm.rad
σx = 0.82 mm, σ_inject = 0.357 mm
Septum = 2 mm
Acceptance > 19 σ

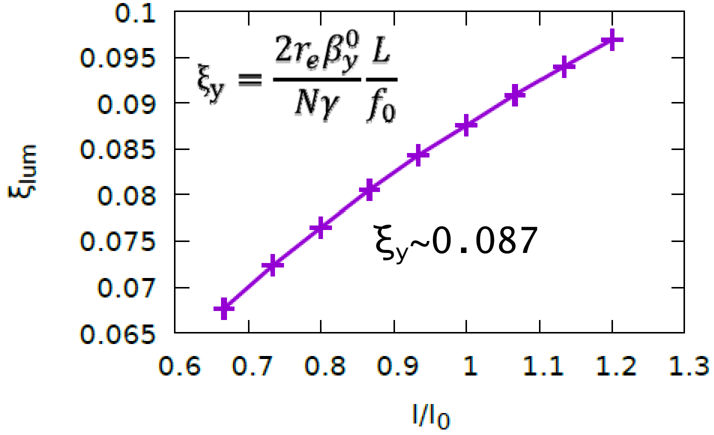
by Xiaohao Cui

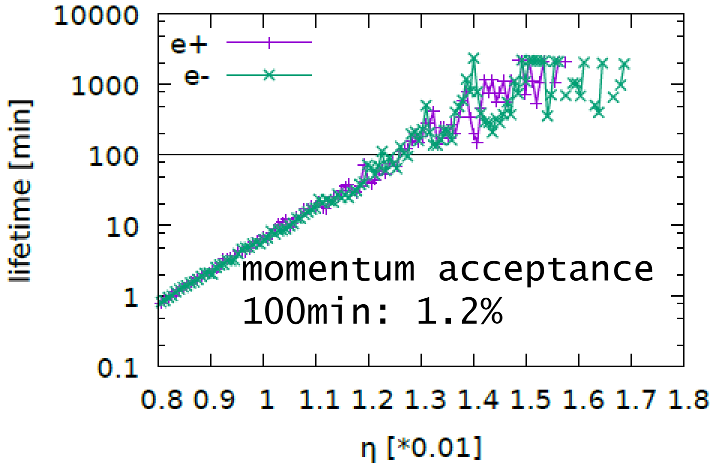


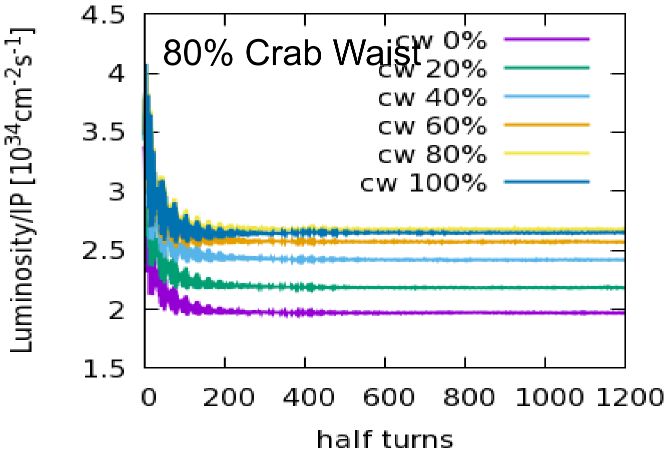


CEPC Beam-Beam Simulation at Higgs





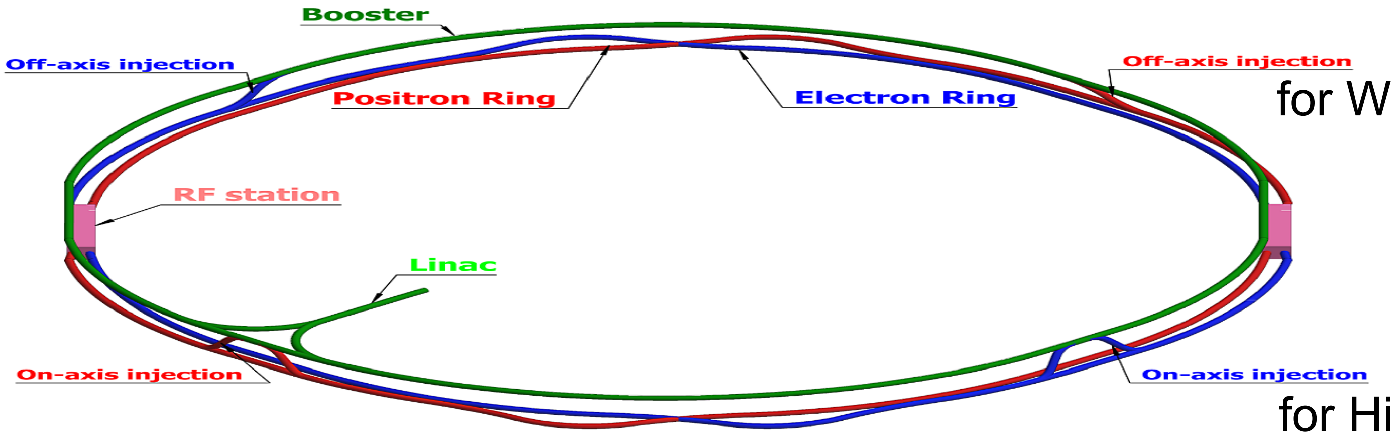




CEPC Collider Ring requirements on Dynamic Aperture

The requirements of dynamic aperture from injection and beam-beam effect to get efficient injection and adequate beam life time:

	Higgs	W	Z
with on-axis injection	$8\sigma_x \times 12\sigma_y \times 1.35\%$	-	-
with off-axis injection	$13\sigma x \times 12\sigma y \times 1.35\%$	$15\sigma_x \times 9\sigma_y \times 0.4\%$	$17\sigma_x \times 9\sigma_y \times 0.23\%$



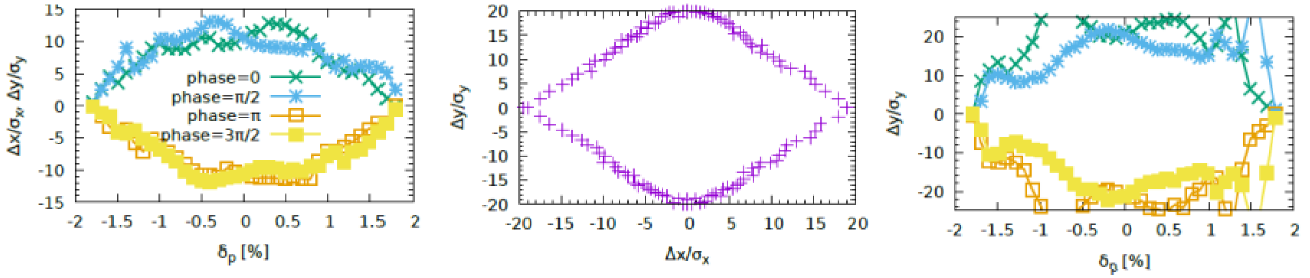
for W and Z

for Higgs

CEPC DA@Higgs,W and Z-pole

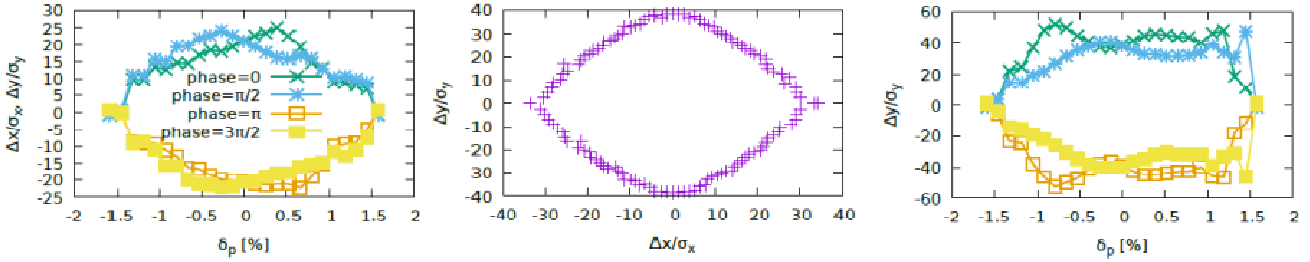
- Synchrotron radiation fluctuation is considered
- 100 samples are tracked
- 90% survival boundary is shown

H



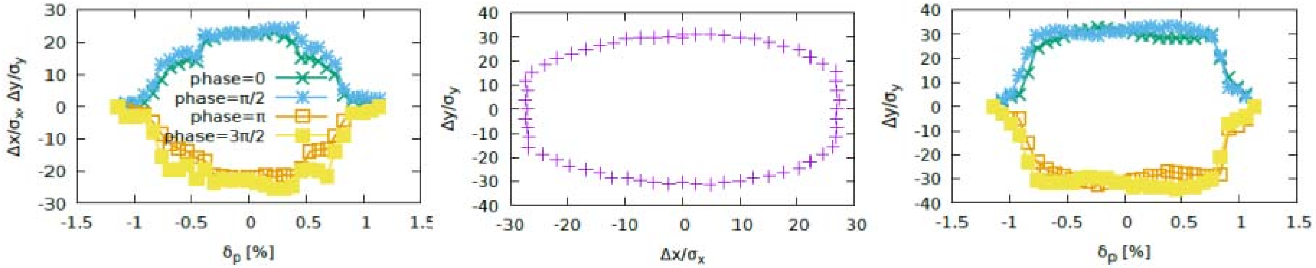
$20\sigma_x \times 20\sigma_y \times 0.018$

W



$30\sigma_x \times 38\sigma_y \times 0.015$

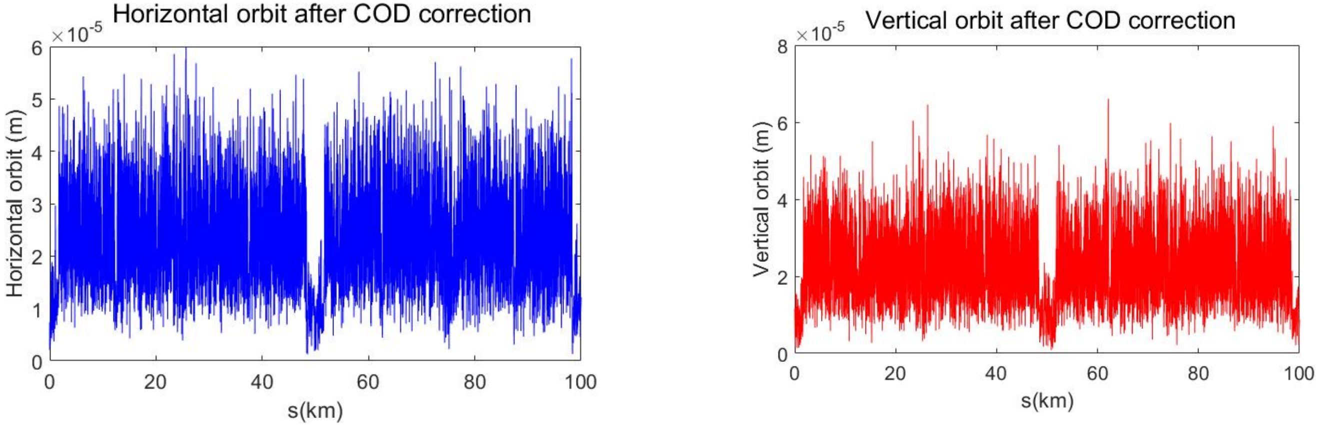
Z



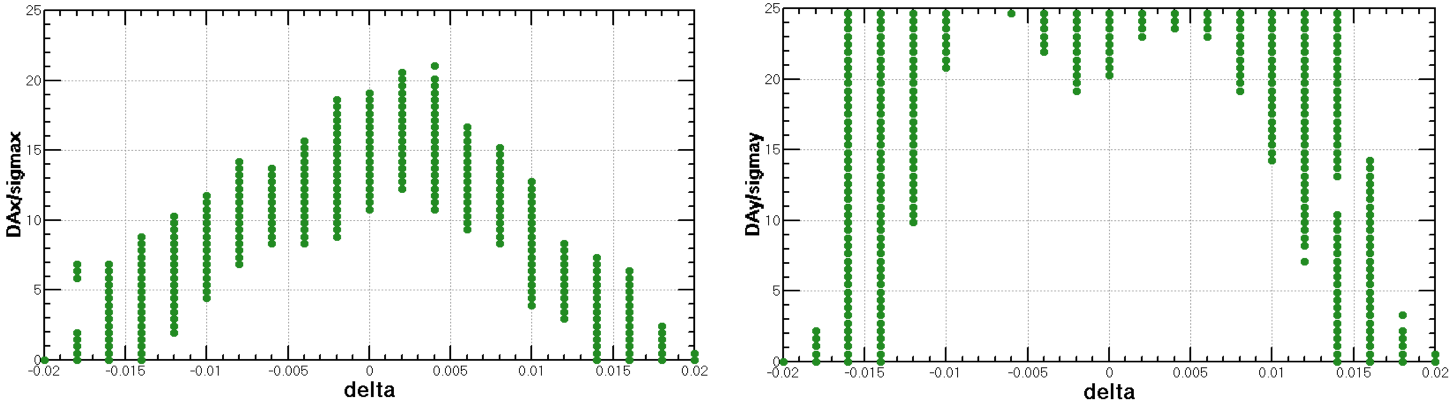
$28\sigma_x \times 30\sigma_y \times 0.012$

CEPC Collider Ring Dynamic Apertures (w/ errors)

Higgs mode



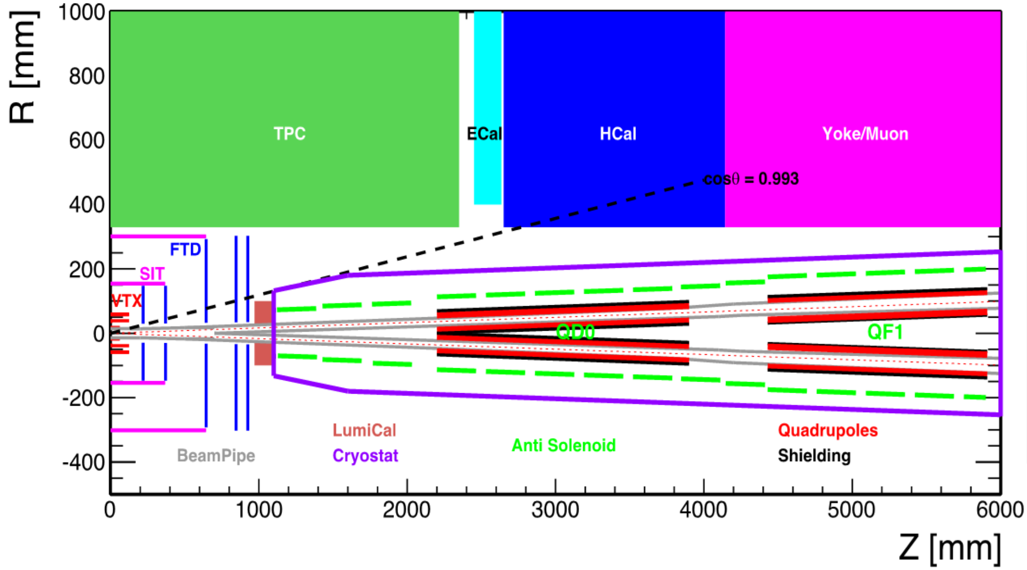
Close orbit corrections in x and y planes (0.1mm) with magnets' errors



$20\sigma_x \times 23\sigma_y$ & 0.018 w/o errors

$11\sigma_x \times 19\sigma_y$ & 0.014 w/ errors

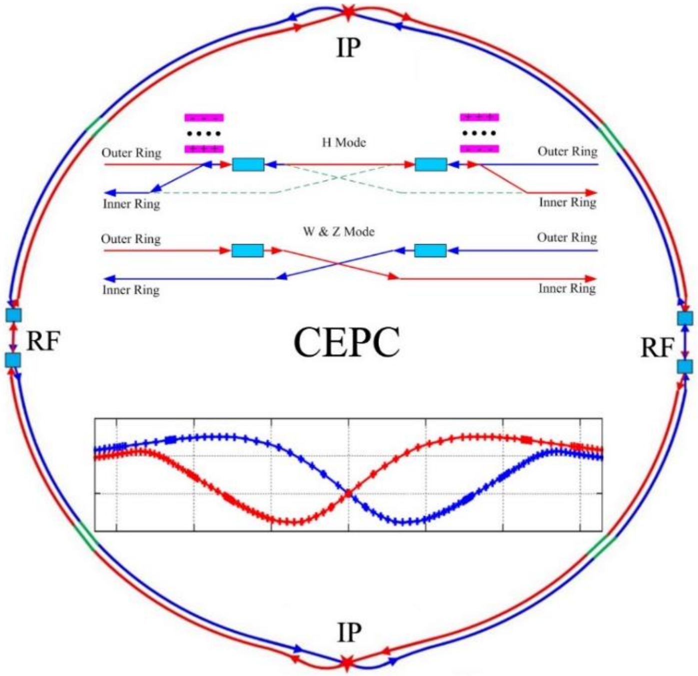
CEPC 探测器-加速器对撞区布局及参数



MDI parameters	Values
*L** (m)	2.2
Crossing angle (mrad)	33
Strength of QD0 (T/m)	150
Strength of detector solenoid (T)	3.0
Strength of anti-solenoid (T)	7.0

- CEPC探测器-加速器对撞区为对撞点两侧±7米的区域
- CEPC探测器超导磁铁强度为3Tesla，长度为7.6米
- 探测器加速器部件没有防护部分在张角为 cosθ=0.993的锥形空间内
- 正负电子束对撞水平对撞角为33mrad，超导四极铁的聚焦长度L*= 2.2米
- 亮度探测器位于对撞点纵向长度 0.95~1.11米范围内，内半径和外半径分别为28.5毫米和100毫米

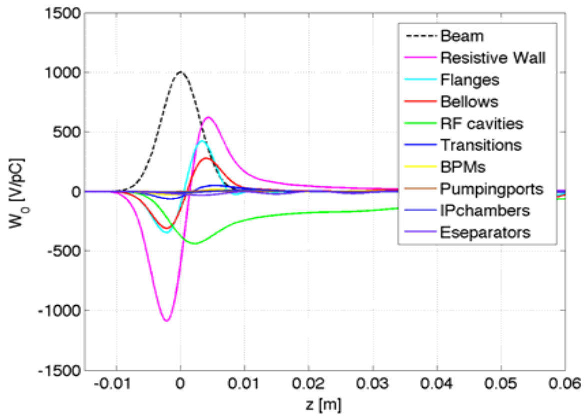
CEPC SRF Design Requirements



- Higgs long operation first:
  one-time full installation of all the same cavities for H, W, Z. Use part of the Higgs cavities for W and Z. Park the idle cavities (not off beamline).
- Cavity and cryogenics cost reduction:
  common H cavities, separate W/Z cavities.
- Upgradable to 50 MW SR per beam:
  longer tunnel, add cavities, variable coupler, RF configuration and cavity suitable for higher power.

CEPC Collider Ring Impedance Budget

Components	Number	$Z_{\|\|}/n$, mΩ	k_{loss}, V/pC	ky, kV/pC/m
Resistive wall	-	6.2	363.7	11.3
RF cavities	336	-1.4	315.3	0.41
Flanges	20000	2.8	19.8	2.8
BPMs	1450	0.12	13.1	0.3
Bellows	12000	2.2	65.8	2.9
Pumping ports	5000	0.02	0.4	0.6
IP chambers	2	0.02	6.7	1.3
Electro-separators	22	0.2	41.2	0.2
Taper transitions	164	0.8	50.9	0.5
Total		**10.5**	**876.8**	**20.4**



Longitudinal wake at the nominal σ_z = 3mm

Broadband impedance threshold:

Threshold	ttbar	Higgs	W	Z
$\|Z_L/n\|_{eff}$, mΩ	13.6	9.0	8.0	2.1
κ_y, kV/pC/m	81.2	61.6	69.0	38.7

CEPC Cillider Ring Impedance Requirement

- For different operation scenarios, the design of Z shows the most critical restriction for both broadband and narrowband impedances.

Parameter	Symbol, unit	Higgs	W	Z
Beam energy	E, GeV	120	80	45.5
Beam current	I_0, mA	17.4	88.0	183.1
Bunch number	n_b	242	3390	9524
Bunch current	I_b, mA	0.072	0.026	0.019
Bunch Population	N_e, $\times 10^{10}$	15.0	5.4	4.0
Threshold of broadband ZL	$\lvert Z_L/n \rvert_{\mathrm{eff}}$, mΩ	9.0	8.0	2.1
Threshold of broadband ZY	κ_y, kV/pC/m	61.6	69.0	38.7
Threshold of narrowband ZL	$\frac{f}{\mathrm{GHz}}\frac{\mathrm{Re}\,Z_L}{\mathrm{G\Omega}}e^{-(2\pi f\sigma_l)^2}$	3.5	0.08	3.0E-3
Threshold of narrowband ZY	$\frac{\mathrm{Re}\,Z_\perp}{\mathrm{G\Omega/m}}e^{-(2\pi f\sigma_l)^2}$	2.4	0.09	4.5E-3

CEPC Collider Ring Collective Instabilities

- The design single bunch intensity are all below the instability threshold.
- Transverse and longitudinal feedbacks are needed to damp the coupled bunch instabilities.

Beam instability	ttbar	Higgs	W	Z
Bunch lengthening, σ_l/σ_{l0}	13%	20%	22%	73%
Beam energy spread increase, σ_e/σ_{e0}	~0	~0	2%	15%
CSR threshold $N_{\mathrm{bth,}}$ nC	1565	622	201	38
Transverse impedance tune shift $\Delta v_{x,y}$	-0.02	-0.01	-0.006	-0.008
Transverse Mode Coupling N_{bth}, nC	207	93	37	16
Transverse resistive wall instability, ms	1986	298	39	11
Longitudinal RF HOMs CBI, ms	4.3E4	3.8E3	446	87
Transverse RF HOMs CBI, ms	1.2E4	1.7E3	352	85
Fast beam ion instability, ms	900	76	18	7

CEPC 增强器参数 @注入能量 (10GeV)

运行模式		*H*	*W*	*Z*
Beam energy （注入能量）	GeV	10		
Bunch number （束团数）		242	1524	6000
Threshold of single bunch current	μA	25.7		
Threshold of beam current (limited by coupled bunch instability)	mA	127.5		
Bunch charge （束团电量）	nC	0.78	0.63	0.45
Single bunch current	μA	2.3	1.8	1.3
Beam current （束流流强）	mA	0.57	2.86	7.51
Energy spread	%	0.0078		
Synchrotron radiation loss/turn	keV	73.5		
Momentum compaction factor	10^{-5}	2.44		
Emittance（发射度）	nm	0.025		
Natural chromaticity	H/V	-336/-333		
RF voltage （高频电压）	MV	62.7		
Betatron tune $\nu_x/\nu_y/\nu_s$		263.2/261.2/0.1		
RF energy acceptance	%	1.9		
Damping time （阻尼时间）	s	90.7		
Bunch length of linac beam	mm	1.0		
Energy spread of linac beam	%	0.16		
Emittance of linac beam	nm	40~120		

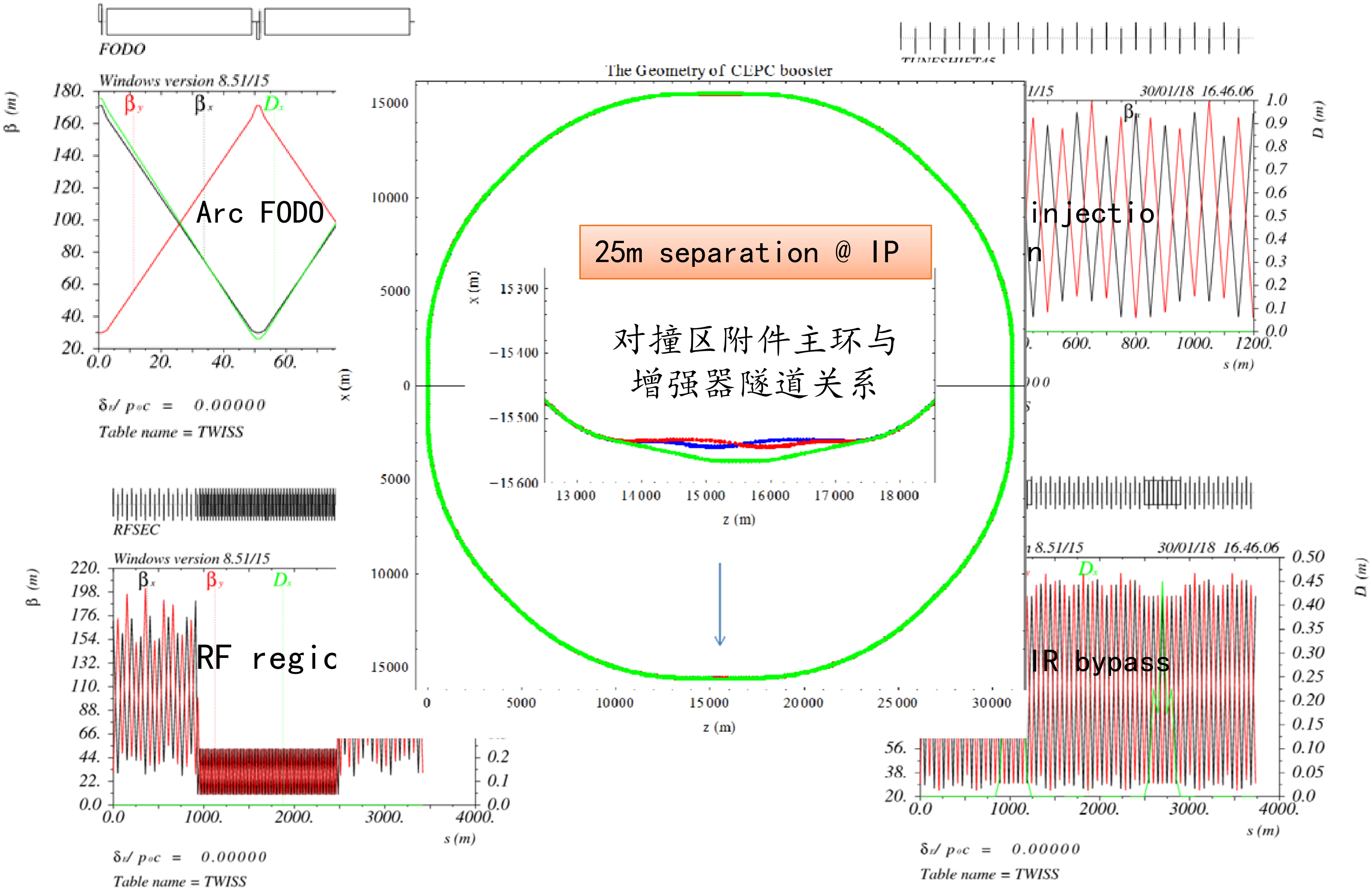
CEPC 增强器参数 @ 引出能量

运行模式		H		W	Z
		Off axis injection	On axis injection	Off axis injection	Off axis injection
Beam energy （束流能量）	GeV	120		80	45.5
Bunch number（束团数）		242	235+7	1524	6000
Maximum bunch charge	nC	0.72	24.0	0.58	0.41
Maximum single bunch current	μA	2.1	70	1.7	1.2
Threshold of single bunch current	μA	300			
Threshold of beam current （limited by RF power）	mA	1.0		4.0	10.0
Beam current （束流流强0	mA	0.52	1.0	2.63	6.91
Injection duration for top-up （Both beams）	s	25.8	35.4	45.8	275.2
Injection interval for top-up	s	73.1		153.0	438.0
Current decay during injection interval		3%			
Energy spread	%	0.094		0.062	0.036
Synchrotron radiation loss/turn	GeV	1.52		0.3	0.032
Momentum compaction factor	10^{-5}	2.44			
Emittance（发射度）	nm	3.57		1.59	0.51
Natural chromaticity	H/V	-336/-333			
Betatron tune ν_x/ν_y		263.2/261.2			
RF voltage （高频电压）	GV	1.97		0.585	0.287
Longitudinal tune		0.13		0.10	0.10
RF energy acceptance	%	1.0		1.2	1.8
Damping time（阻尼时间）	ms	52		177	963
Natural bunch length	mm	2.8		2.4	1.3
Injection duration from empty ring	h	0.17		0.25	2.2

CEPC 增强器超导高频加速器参数

10 GeV injection	**H**	**W**	**Z**
Extraction beam energy [GeV] （引出能量）	120	80	45.5
Bunch number（束团数）	242	1524	6000
Bunch charge [nC] （束团电荷）	0.72	0.576	0.384
Beam current [mA]（束流流强）	0.52	**2.63**	**6.91**
Extraction RF voltage [GV] （高频电压）	1.97	0.585	0.287
Extraction bunch length [mm]	2.7	2.4	1.3
Cavity number in use (1.3 GHz TESLA 9-cell) （频率及腔数）	96	64	32
Gradient [MV/m]（加速腔压）	19.8	8.8	8.6
Q_L	1E7	6.5E6	1E7
Cavity bandwidth [Hz]	130	200	130
Beam peak power / cavity [kW]	8.3	12.3	6.9
Input peak power per cavity [kW] (with detuning)	18.2	12.4	7.1
Input average power per cavity [kW] (with detuning)	0.7	0.3	0.5
SSA peak power [kW] (one cavity per SSA)	25	**25**	**25**
HOM average power per cavity [W]	0.2	0.7	**4.1**
Q_0 @ 2 K at operating gradient (long term)	1E10	1E10	1E10
Total average cavity wall loss @ 2 K eq. [kW]	0.2	0.01	0.02

CEPC 增强器Lattice & 布局


Arc FODO

injection

RF regic

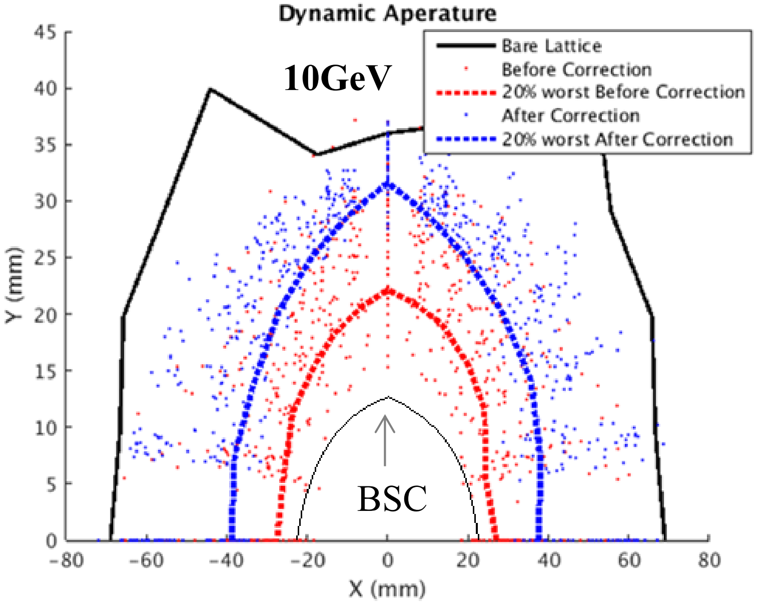
IR bypass

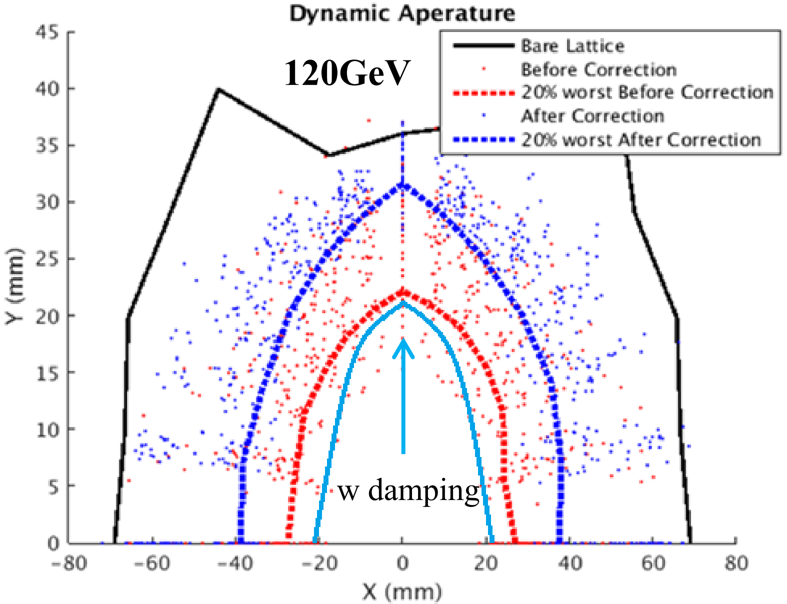
25m separation @ IP

对撞区附件主环与
增强器隧道关系

CEPC 增强器动力学孔径

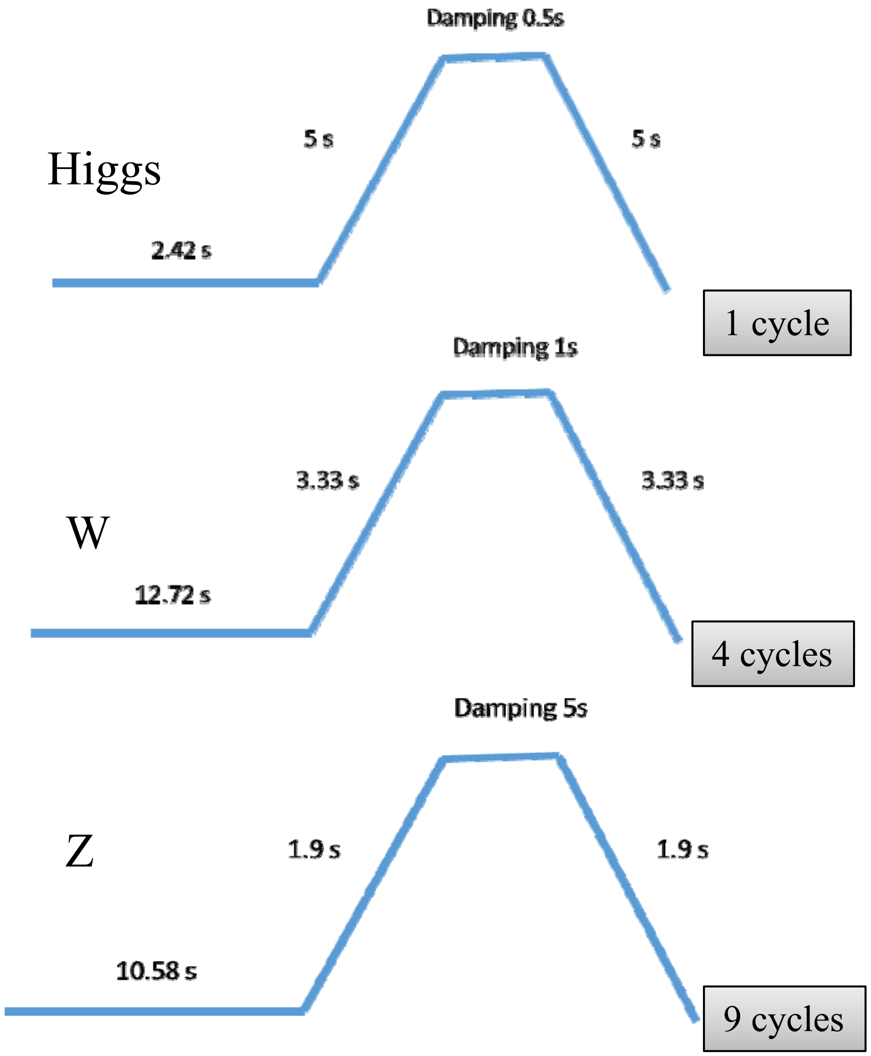
Parameters	Dipole	Quadrupole	Sextupole	Parameters	BPM (10Hz)
Transverse shift x/y (μm)	50	70	70	Accuracy (m)	1×10^{-7}
Longitudinal shift z (μm)	100	150	100	Tilt (mrad)	10
Tilt about x/y (mrad)	0.2	0.2	0.2	Gain	5%
Tilt about z (mrad)	0.1	0.2	0.2	Offset after BBA(mm)	30×10^{-3}
Nominal field	3×10^{-4}	2×10^{-4}	3×10^{-4}		

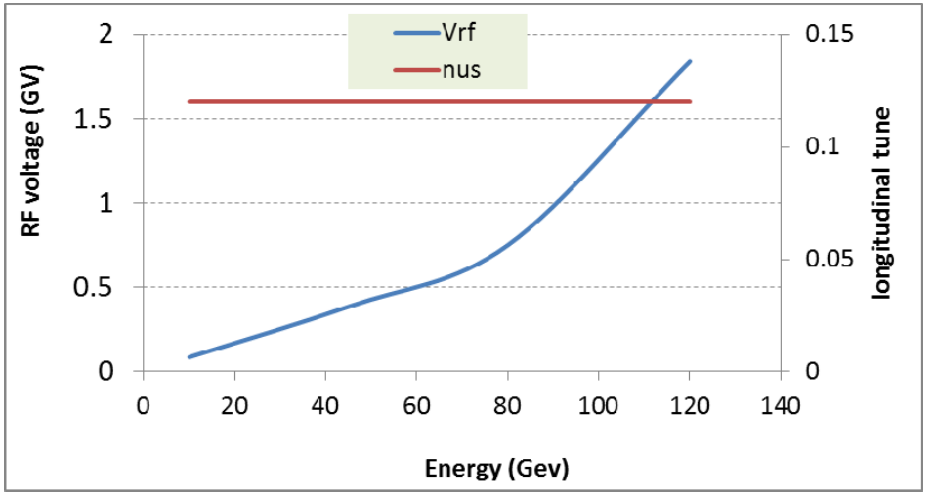




	DA requirement		DA results	
	H	V	H	V
10GeV ($\varepsilon_x = \varepsilon_y$ =120nm)	$4\sigma_x$ +5mm	$4\sigma_y$ +5mm	$7.7\sigma_x$ +5mm	$14.3\sigma_y$ +5mm
120GeV (ε_x=3.57nm, $\varepsilon_y = \varepsilon_x$*0.003)	$6\sigma_x$ +3mm	$16\sigma_y$ +3mm	$21.8\sigma_x$ +3mm	$1006\sigma_y$ +3mm

Booster Injection Time Structure





30Gauss @ 10GeV

Eddy current effect

- Transverse quantum lifetime@10GeV: **1.65×10^8s (ε_{inj}=120nm)**
- Beam loss due to lifetime << **1%**

CEPC Booster Kickers and Septums

Booster Injection

Component	Length (m)	Waveform	Deflection angle (mrad)	Field (T)	Beam-Stay-clear	
					H(mm)	V(mm)
Septum	2	DC	9.1	0.152	63	63
Kicker	0.5	Half_sin	0.5	0.034	63	63

Booster Extraction

Component	Length (m)	Waveform	Deflection angle (mrad)	Field (T)	Beam-Stay-clear	
					H(mm)	V(mm)
Septum	10	DC	10.4	0.41	20	20
Kicker	2	Half_sin	0.2	0.04	20	20

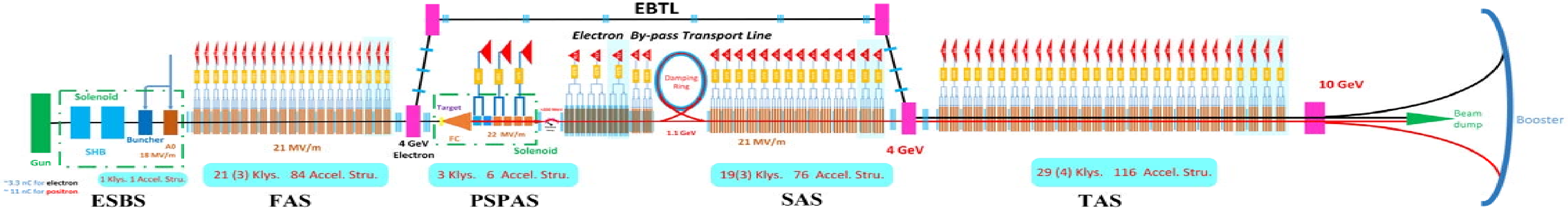
CEPC Booster SRF Parameters

10 GeV injection	**H**	**W**	**Z**
Extraction beam energy [GeV]	120	80	45.5
Bunch number	242	1524	6000
Bunch charge [nC]	0.72	0.576	0.384
Beam current [mA]	0.52	**2.63**	**6.91**
Extraction RF voltage [GV]	1.97	0.585	0.287
Extraction bunch length [mm]	2.7	2.4	1.3
Cavity number in use (1.3 GHz TESLA 9-cell)	96	64	32
Gradient [MV/m]	19.8	8.8	8.6
Q_L	1E7	6.5E6	1E7
Cavity bandwidth [Hz]	130	200	130
Beam peak power / cavity [kW]	8.3	12.3	6.9
Input peak power per cavity [kW] (with detuning)	18.2	12.4	7.1
Input average power per cavity [kW] (with detuning)	0.7	0.3	0.5
SSA peak power [kW] (one cavity per SSA)	25	**25**	**25**
HOM average power per cavity [W]	0.2	0.7	**4.1**
Q_0 @ 2 K at operating gradient (long term)	1E10	1E10	1E10
Total average cavity wall loss @ 2 K eq. [kW]	0.2	0.01	0.02

Main Parameters of Injector Linac

Parameter	Symbol	Unit	Designed
e^- /e^+ beam energy	E_{e-}/E_{e+}	GeV	**10**
Repetition rate	f_{rep}	Hz	**100**
e^- /e^+ bunch population	N_{e-}/N_{e+}		**$> 9.4\times10^9$ / $>9.4\times10^9$**
		nC	**> 1.5**
Energy spread (e^- /e^+)	σ_e		**$< 2\times10^{-3}$ / $< 2\times10^{-3}$**
Emittance (e^- /e^+)	ε_r	nm· rad	**< 120**
Bunch length (e^- /e^+)	σ_l	mm	**1 / 1**
e^- beam energy on Target		GeV	**4**
e^- bunch charge on Target		nC	**10**

- The total beam transfer efficiency from transfer line to the injection point of collider ring is higher than 90%.
- The transfer efficiency can be much higher with the application of damping ring which the beam energy is 1.1GeV.

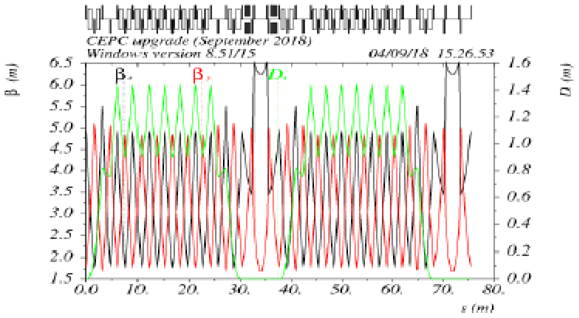


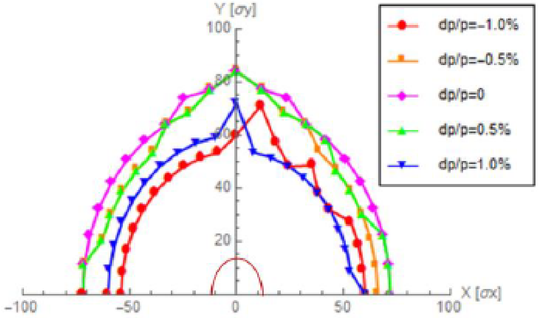
CEPC Linac Injector Damping Ring

Parameters, lattice and layout

DR V2.0	Unit	Value
Energy	GeV	1.1
Circumference	m	75.4
Storage time	ms	20
Bending radius	M	3.565
Dipole strength B_0	T	1.03
U_0	keV	36.3
Damping time x/y/z	ms	15.2/15.2/7.6
δ_0	%	0.05
ε_0	mm.mrad	376.7
$\sigma_{z,\ inj}$	mm	5.0
Nature σ_z	mm	7.5
ε_{inj}	mm.mrad	2500
$\varepsilon_{ext\ x/y}$	mm.mrad	530/180
$\delta_{inj}/\delta_{ext}$	%	0.2/0.05
Energy acceptance by RF	%	1.0
f_{RF}	MHz	650
V_{RF}	MV	2.0

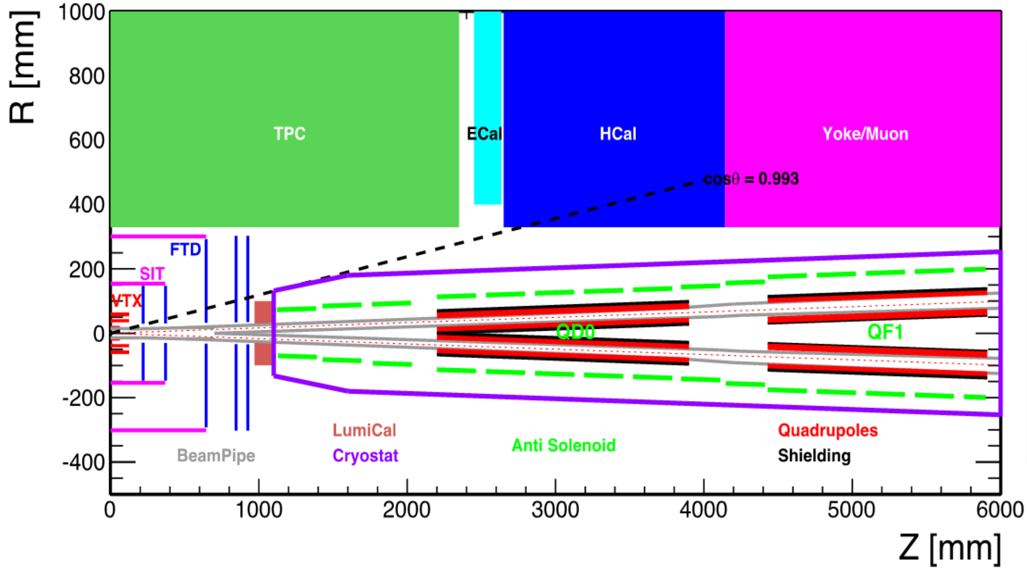
@ D. Wang





- Emittance not critical
- two bunch in DR (251ns)
    - 20ms
- IBS
    - Emittance growth
- CSR (Coherent synchrotron radiation)
    - CSR Instability
- Energy-spread compression system (ECS) before DR
- bunch compression system (BCS) after DT

CEPC 探测器-加速器对撞区布局及参数



MDI parameters	Values
*L** (m)	2.2
Crossing angle (mrad)	33
Strength of QD0 (T/m)	150
Strength of detector solenoid (T)	3.0
Strength of anti-solenoid (T)	7.0

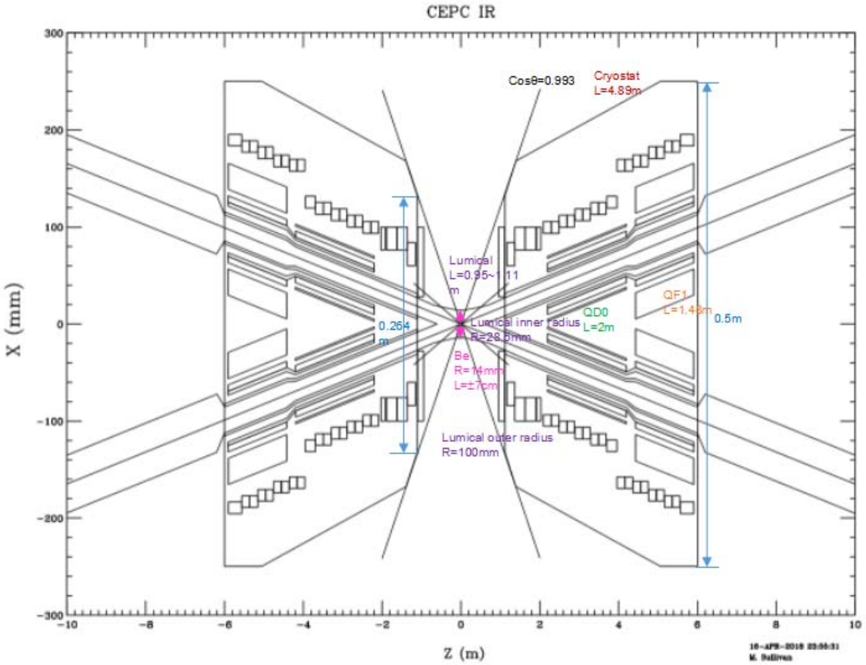
- CEPC探测器-加速器对撞区为对撞点两侧±7米的区域
- CEPC探测器超导磁铁强度为3Tesla，长度为7.6米
- 探测器加速器部件没有防护部分在张角为 cosθ=0.993的锥形空间内
- 正负电子束对撞水平对撞角为33mrad，超导四极铁的聚焦长度L*= 2.2米
- 亮度探测器位于对撞点纵向长度 0.95~1.11米范围内，内半径和外半径分别为28.5毫米和100毫米

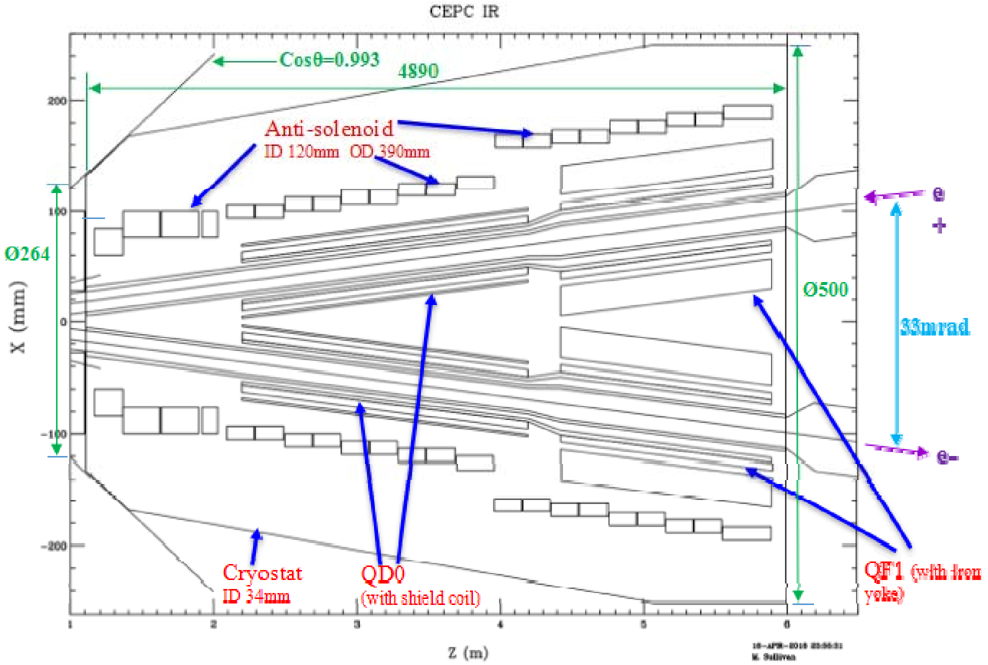
CEPC MDI Parameters

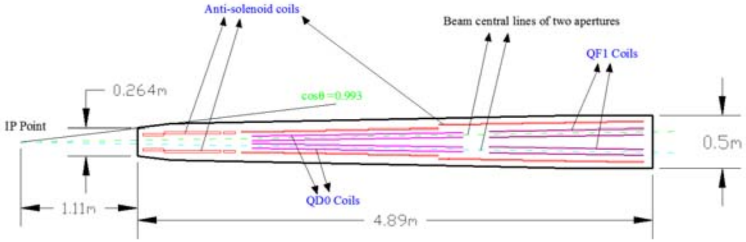
	range	Peak filed in coil	Central filed gradient	Bending angle	length	Beam stay clear region	Minimal distance between two aperture	Inner diameter	Outer diameter	Critical energy (Horizontal)	Critical energy (Vertical)	SR power (Horizontal)	SR power (Vertical)
L*	0~2.2m				2.2m								
Crossing angle	33mrad												
MDI length	±7m												
Detector requirement of opening angle	13.6˚												
QD0		3.2T	136T/m		2m	19.51mm	72.61mm	40mm	53mm	1.3MeV	527keV	639W	292W
QF1		3.8T	110T/m		1.48m	26.85mm	146.2mm	56mm	69mm	1.6MeV	299keV	1568W	74W
Lumical	0.95~1.11m				0.16m			57mm	200mm				
Anti-solenoid before QD0		7.26T			1.1m			120mm	390mm				
Anti-solenoid QD0		2.8T			2m			120mm	390mm				
Anti-solenoid QF1		1.8T			1.48m			120mm	390mm				
Beryllium pipe					±7cm			28mm					
Last B upstream	67.66~161.04m			1.1mrad	93.38m					45keV			
First B downstream	46.06~107.04m			1.54mrad	60.98m					97keV			
Beampipe within QD0					2m							2.9W	
Beampipe within QF1					1.48m							3.1W	
Beampipe between QD0/QF1					0.23m							36.2W	

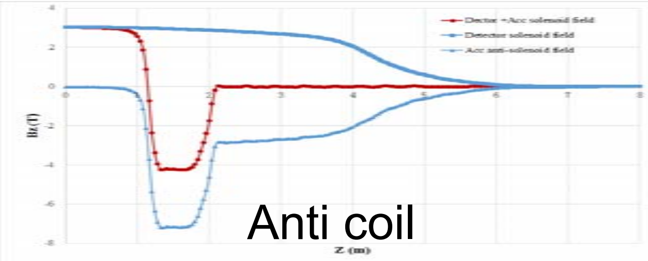
The superconducting magnet parameters are same in tt and higgs.

CEPC Final Focus Magnets & Cryostat

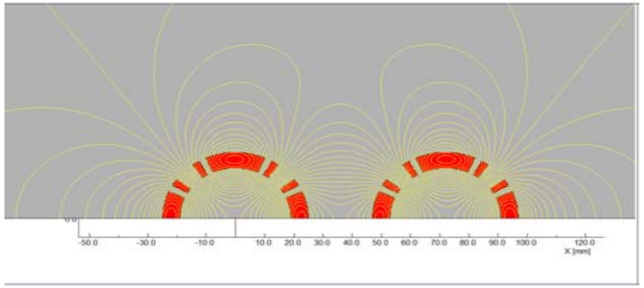




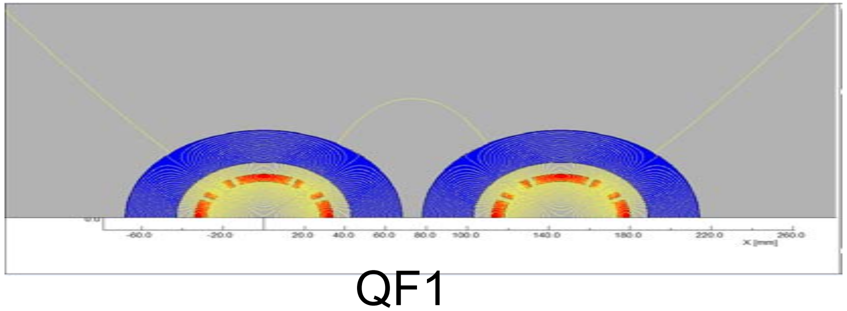




Anti coil



QD0



QF1

CEPC beam life time

	Beam lifetime	others
Quantum effect	>1000 h	
Touscheck effect	>1000 h	
Beam-Gas（Coulomb scattering）	>400 h	Residual gas CO， 10^{-7}Pa
Beam-Gas（bremsstralung）	63.8 h	
Beam-Thermal photon scattering	50.7 h	
Radiative Bhabha scattering	100 min	
Beamstrahlung	60 min	

CEPC CDR 加速器设计结果

CEPC 对撞环

参数	符号	单位	目标	设计结果
束流能量	E	GeV	120	120
长度	C	km	100	100.006
发射度	$\varepsilon_x/\varepsilon_y$	nm·rad	1.21 / 0.0036	1.208 / -
对撞点Beta 函数	β_x/β_y	m	0.36 / 0.002	0.36 / 0.002
能量接收度	$\Delta P/P$	%	1.35	1.8
动力学孔径	DA_x/DA_y	σ	13 / 12	20 / 20 (w/o errors)

Z 和 W也同时 满足 CDR设计要求

达到CDR 设计目标

CEPC 增强器设计结果

Parameters	Design goals	Design results
Beam current (mA)	<0.8	**0.54**
Emittance in x (nm rad)	<3.6	**3.1**
Dynamic aperture for 0.5% off-momentum particles	>3σ	**8.5σ**
Energy acceptance	>1%	**2.5%**
Timing	Meet the top-up injection requirements	√

增强器及直线
加速器注入器
达到CDR
设计目标

CEPC 直线加速器注入器设计结果

Parameter	Symbol	Unit	Goal	Status
e^- /e^+ beam energy	E_{e-}/E_{e+}	GeV	10	10/10
Repetition rate	f_{rep}	Hz	100	100
e^- /e^+ bunch population	$Ne-/Ne+$		$>6.25\times10^{9}$	$\tilde{}1.875\times10^{10}$ $\tilde{}1.875\times10^{10}$
	$Ne-/Ne+$	nC	>1.0	1.0/3.0*
Energy spread (e^- /e^+)	σ_E		$<2\times10^{-3}$	1.5×10^{-3} 1.4×10^{-3}
Emittance (e^- /e^+)		mm· mrad	<0.3	0.005/0.12**
e^- beam energy on Target		GeV	4	4
e^- bunch charge on Target		nC	10	10

CEPC 功率：Higgs 和 Z

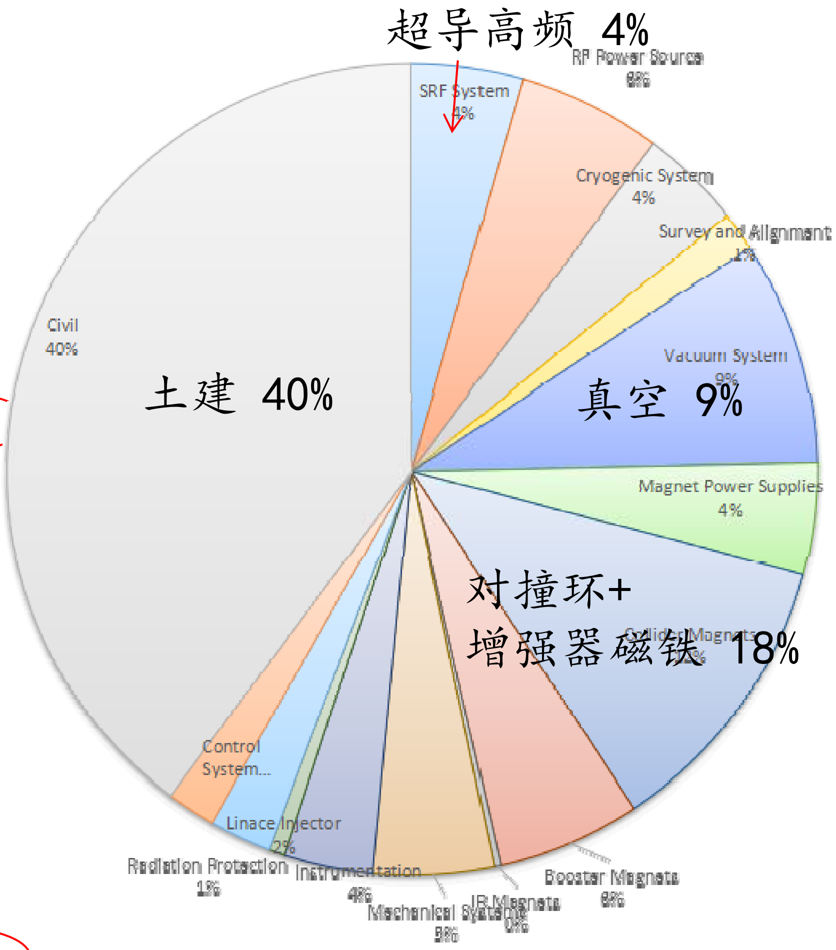
	System for Higgs (30MW)	Location and electrical demand(MW)						Total (MW)
		Ring	Booster	LINAC	BTL	IR	Surface building	
1	RF Power Source	103.8	0.15	5.8				109.75
2	Cryogenic System	11.62	0.68			1.72		14.02
3	Vacuum System	9.784	3.792	0.646				14.222
4	Magnet Power Supplies	47.21	11.62	1.75	1.06	0.26		61.9
5	Instrumentation	0.9	0.6	0.2				1.7
6	Radiation Protection	0.25		0.1				0.35
7	Control System	1	0.6	0.2	0.005	0.005		1.81
8	Experimental devices					4		4
9	Utilities	31.79	3.53	1.38	0.63	1.2		38.53
10	General services	7.2		0.2	0.15	0.2	12	19.75
	Total	213.554	20.972	10.276	1.845	7.385	12	266.032

Higgs 266MW

	System for Z	Location and electrical demand(MW)						Total (MW)
		Ring	Booster	LINAC	BTL	IR	Surface building	
1	RF Power Source	57.1	0.15	5.8				63.05
2	Cryogenic System	2.91	0.31			1.72		4.94
3	Vacuum System	9.784	3.792	0.646				14.222
4	Magnet Power Supplies	9.52	2.14	1.75	0.19	0.05		13.65
5	Instrumentation	0.9	0.6	0.2				1.7
6	Radiation Protection	0.25		0.1				0.35
7	Control System	1	0.6	0.2	0.005	0.005		1.81
8	Experimental devices					4		4
9	Utilities	19.95	2.22	1.38	0.55	1.2		25.3
10	General services	7.2		0.2	0.15	0.2	12	19.75
	Total	108.614	9.812	10.276	0.895	7.175	12	148.772

Z 149MW

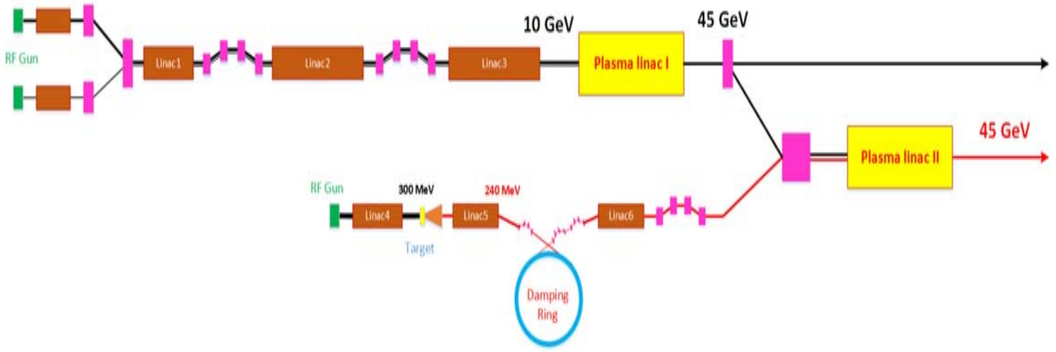
CEPC 造价细分
（不含 探测器）

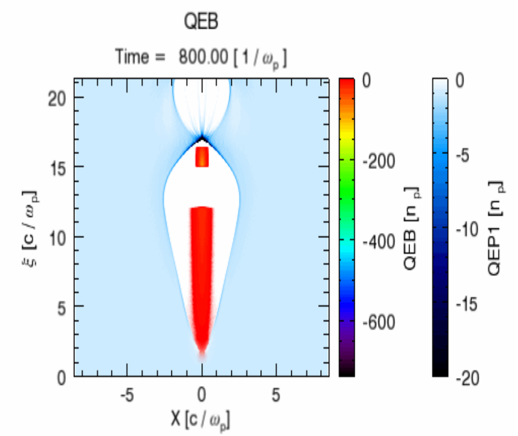


注：需要增加的功率是冷却用制冷机功率~50MW+增量功率（取决于选址年平均气温）

注入器备选方案：基于等离子体加速的CEPC直线注入器（注入能量45GeV）

等离子体加速有高效率，单级高增能比的特点（能量放大比为3-4）





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%

目前等离子体加速器方案正负电子束流参数满足CEPC增强器注入条件要求

CEPC Longitudinal polarization of electrons (minimalist option)

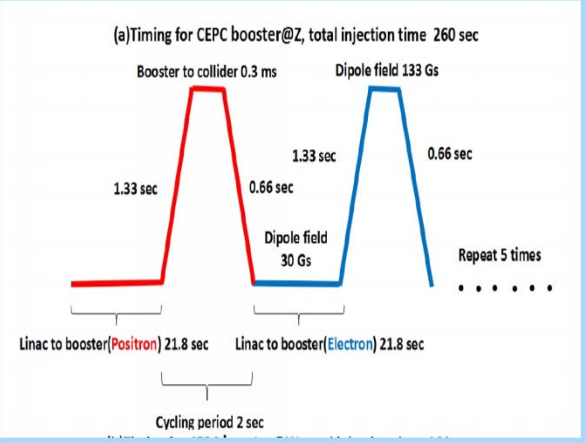
S. Nikitin

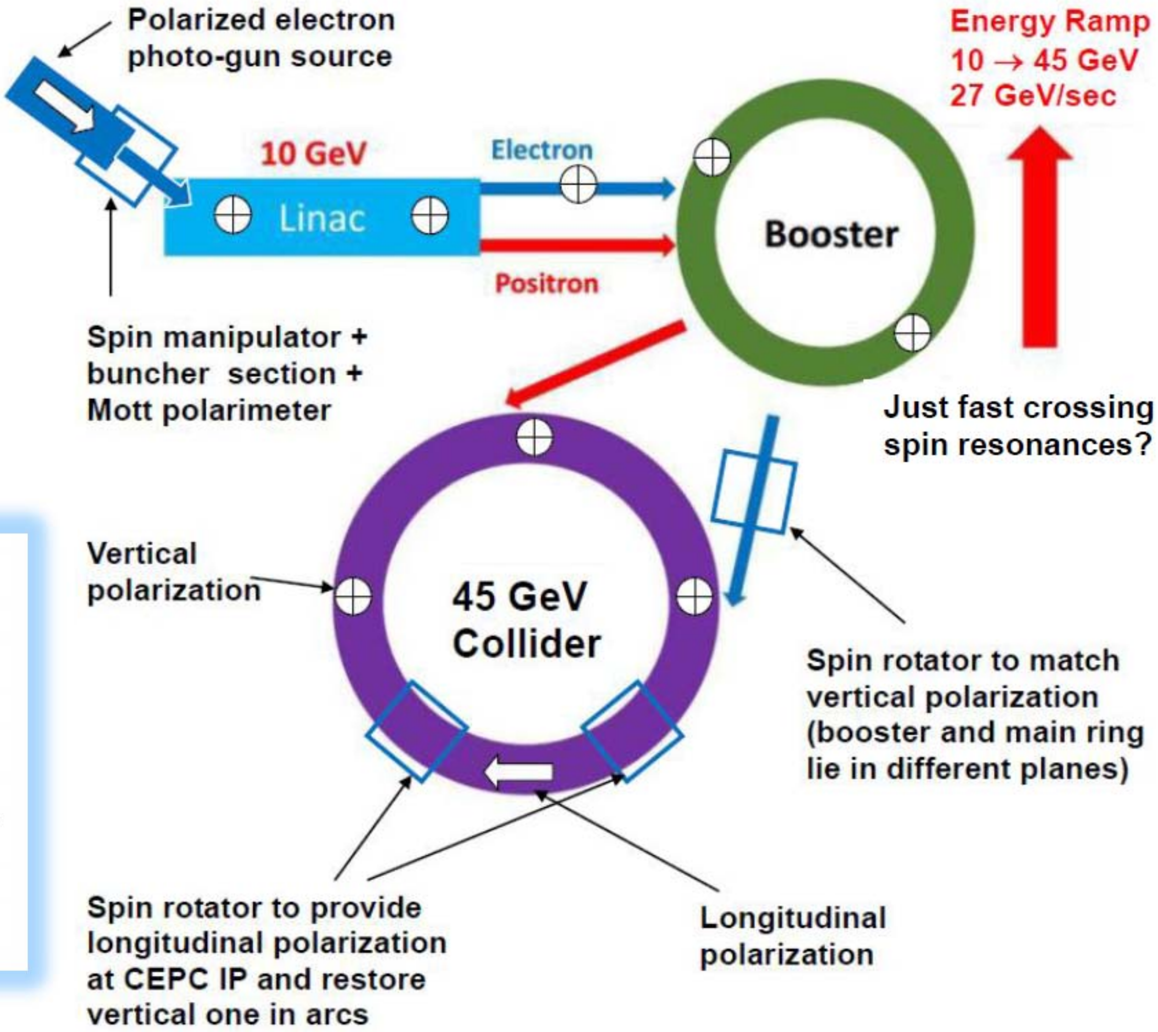
CEPC Chinese MOST Fund application contents in 2018

Electrons from gun source are longitudinally polarized. Spins are rotated to vertical plane in special transport section downstream of gun.Variants (CEBAF, NIKHEF):

a) Wien's Filter

b) Z-manipulator includes two bends by E-field and solenoids between them.





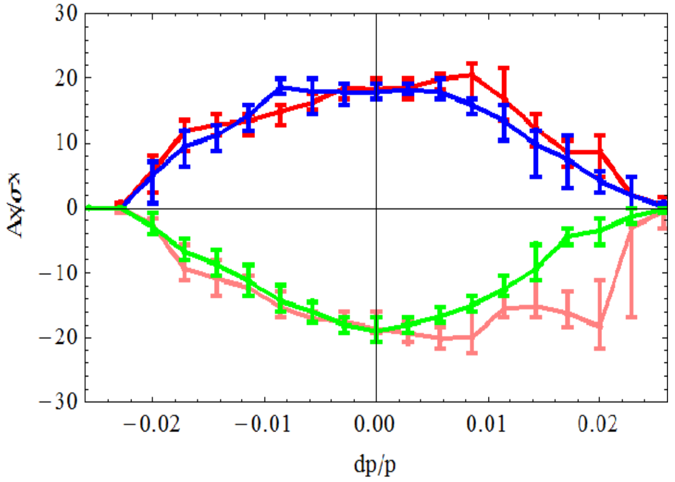
CEPC upgrade potential

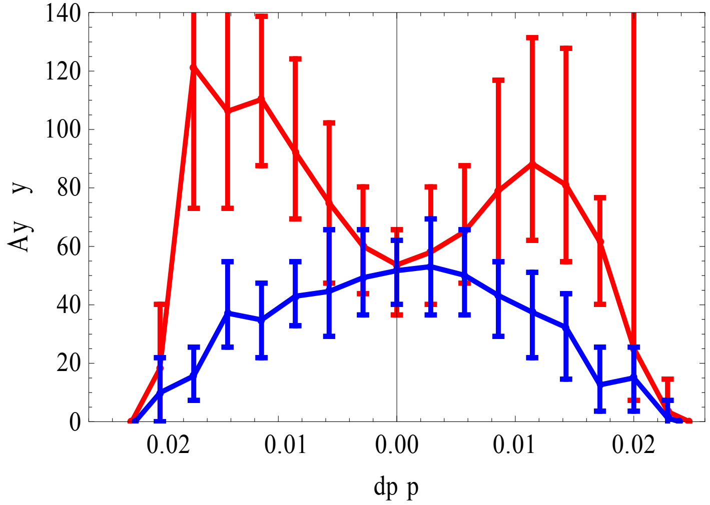
	tt @ 3T
Number of IPs	2
Energy (GeV)	**175**
Circumference (km)	100
SR loss/turn (GeV)	7.61
Half crossing angle (mrad)	16.5
Piwinski angle	0.91
N_e/bunch (10^{10})	24.15
Bunch number	34
Beam current (mA)	3.95
SR power /beam (MW)	30
Bending radius (km)	10.9
Momentum compaction (10^{-5})	1.14
β_{IP} x/y (m)	**1.2/0.0037**
Emittance x/y (nm)	2.24/0.0068
Transverse σ_{IP} (um)	51.8/0.16
ξ_x/ξ_y/IP	0.077/0.105
V_{RF} (GV)	8.93
f_{RF} (MHz) (harmonic)	650 (217500)
Nature bunch length σ_z (mm)	2.54
Bunch length σ_z (mm)	2.87
HOM power/cavity (kw)	0.53 (5cell)
Energy spread (%)	0.14
Energy acceptance requirement (%)	1.57
Energy acceptance by RF (%)	2.67
Photon number due to beamstrahlung	0.19
Lifetime due to beamstrahlung (hour)	1.0
Lifetime (hour)	
F (hour glass)	0.89
L_{max}/IP ($10^{34}cm^{-2}s^{-1}$)	**0.38**

@ 175GeV
@ 50MW

- Without changing the specification of hardware
- QF1→ QD1
- Large β*
- Relatively lower luminosity
- Ability of PS, KLY and magnets
- Enough length of RF region
- Ability of booster design

$18\sigma_x \times 30\sigma_y$ & 0.024 @ tt



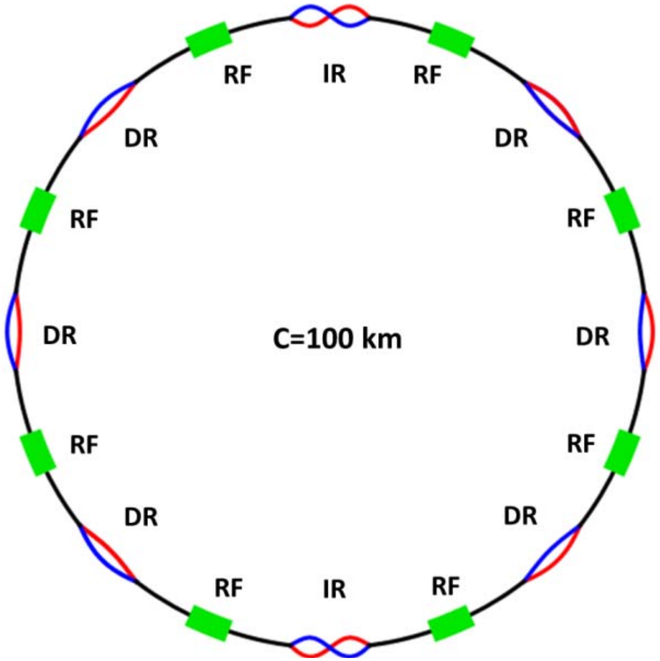


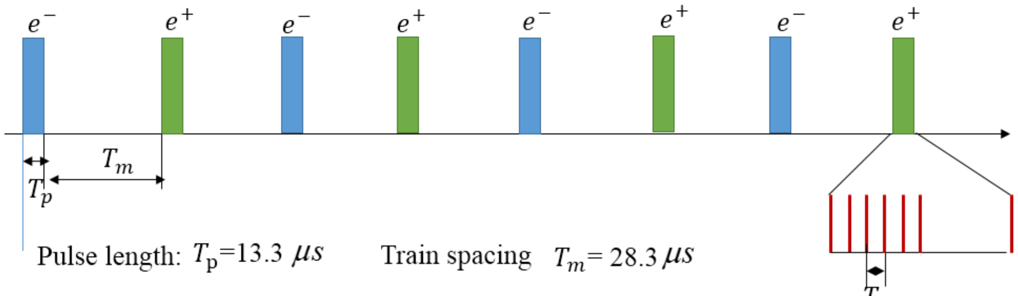
CEPC Alternatives and New Ideas in CDR Appendixes

CEPC Alternative APDR Main parameters

	Higgs	***W***	***Z***
Number of IPs	2	2	2
Energy (GeV)	120	80	45.5
Circumference (km)	100	100	100
SR loss/turn (GeV)	1.61	0.32	0.033
Half crossing angle (mrad)	16.5	16.5	16.5
Piwinski angle	2.28	4.4	8.83
N_e/bunch (10^{10})	9.68	6.0	2.6
Bunch number	420	900	3400
Beam current (mA)	19.5	26.0	42.5
SR power /beam (MW)	**31.4**	**8.3**	**1.41**
Bending radius (km)	11.4	11.4	11.4
Momentum compaction (10^{-5})	1.15	1.15	1.15
β_{IP} x/y (m)	0.36/0.002	0.36/0.002	0.36/0.002
Emittance x/y (nm)	1.18/0.0036	0.52/0.0016	0.17/0.0029
Transverse σ_{IP} (um)	20.6/0.085	13.7/0.056	7.85/0.076
ξ_x/ξ_y/IP	0.025/0.085	0.016/0.098	0.0097/0.049
RF Phase (degree)	128	135	151
V_{RF} (GV)	**2.03**	**0.45**	**0.069**
f_{RF} (MHz) (harmonic)	650	650	650
Nature σ_z (mm)	**2.75**	**2.96**	**2.92**
Total σ_z (mm)	2.85	3.68	4.2
HOM power/cavity (kw)	0.42 (2cell)	0.16 (2cell)	0.1(2cell)
Energy spread (%)	0.096	0.064	0.036
Energy acceptance (%)	1.1		
Energy acceptance by RF (%)	1.98	1.48	1.2
n_γ	0.19	0.18	0.13
Life time due to beamstrahlung_cal (minute)	63		
F (hour glass)	0.93	0.963	0.987
L_{max}/IP (10^{34}cm^{-2}s^{-1})	2.0	2.12	1.02

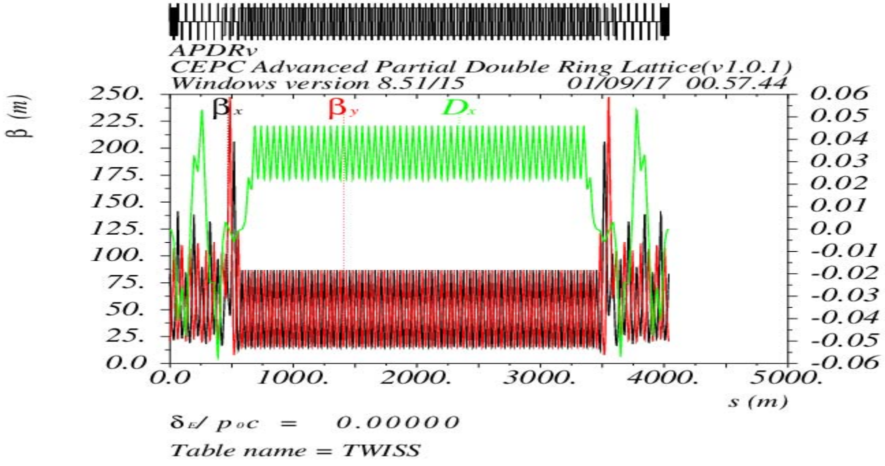
CEPC Alternative: APDR Lattice Design

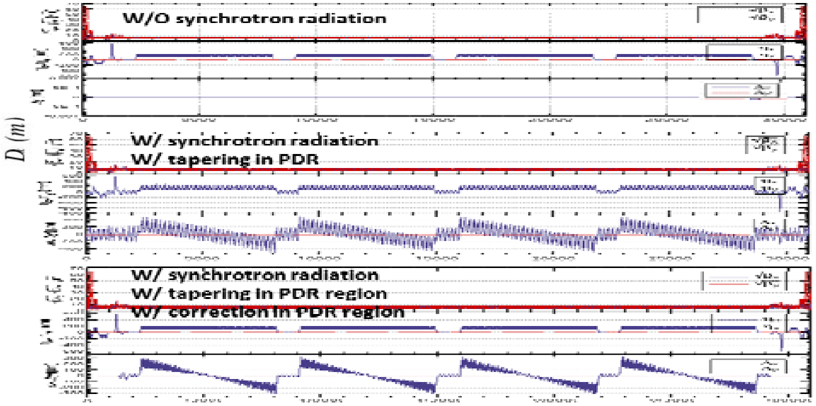




Pulse length: T_p=13.3 μs Train spacing T_m= 28.3 μs

Bunch spacing: T_b=15.4ns (Z), 127ns (Higgs)





Sawtooth effects

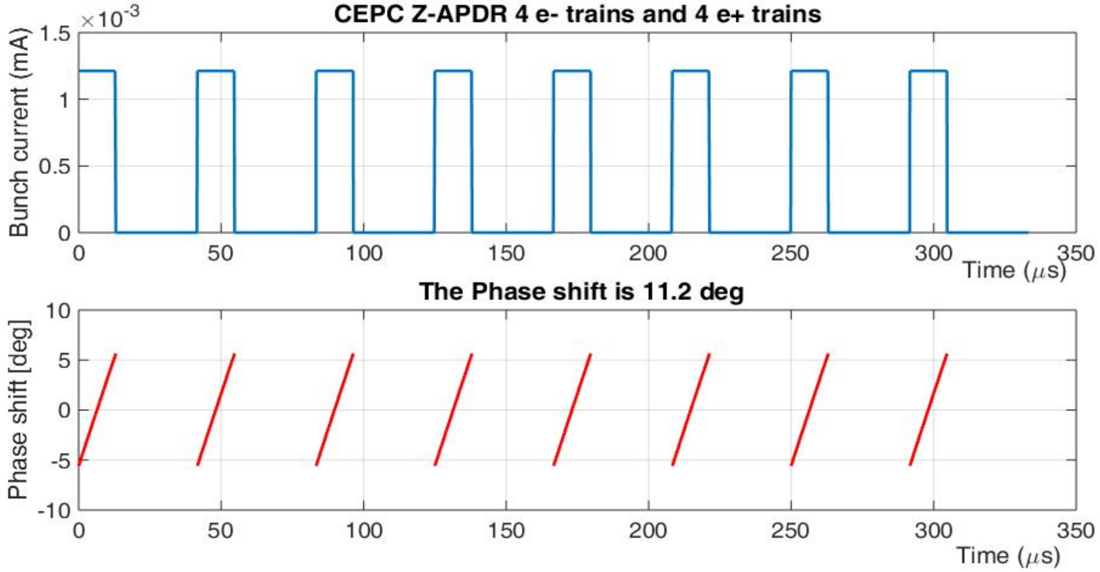
CEPC APDR RF Parameters

- 8 RF stations are uniformly spaced along the collider ring
- totally 336 SRF cavities with working frequency 650MHz and 5 cells

Parameter	**Unit**	**Higgs**	**W**	**Z**
Beam Energy	*GeV*	120	80	45.5
Circumference	*km*	100	100	100
SR loss/ turn	*GeV*	1.61	0.32	0.033
Luminosity (10^{34})	$cm^{-2}s^{-1}$	2.0	2.1	1.03
Momentum compaction (10^{-5})		1.15	1.15	1.15
Beam current	*mA*	19.5	25.9	42.4
SR power/beam	MW	31.4	8.3	1.4
Bunch number		420	900	3400
Bunch number/ train		105	225	850
Bunch charge	*nC*	15.5	9.6	4.2
RF frequency	*MHz*	650	650	650
RF voltage	GeV	2.03	0.45	0.069
Cavity number in use		336	64	12
Synchrotron phase	*deg*	37.5	44.7	61.4
Cavity voltage	*MV*	6.04	7.34	5.75
Input power/ cavity	*kW*	275	175	233
Loaded Q (10^5)		9.5	9.5	6.9
Optimal detuning	*kHz*	0.26	0.33	0.87
Cavity bandwidth	*kHz*	0.7	0.7	0.9
Cavity stored energy	*J*	43	64	39
Max voltage decrease		7.6%	8.4%	17.5%
Max phase shift	*deg*	6.7	6.8	11.2

CEPC APDR Beam Loading Analysis

- Electron beam and position beam share the same RF system.
- Both the beam gaps and the pulse currents are large.
- CEPC APDR Z-pole suffers from serious beam loading effect.
- The phase shift are calculated by K. Bane's formula and simulated by beam transfer function.



For CEPC APDR Z-pole, the phase shift is 11.2 deg, it will cause 12% bunch length spread, 12% Sync. Freq. spread and 0.15% RF acceptance drop. All these parameters are in the limit of the system, **the RF system of CEPC APDR can work theoretically in consideration of the beam loading effects**.

CEPC IAC Conclusions and Requirements

(Nov. 15-16, 2018)

The IAC congratulates the CEPC team for the successful completion of the Conceptual Design Report (CDR)...

The IAC believes that the studies reported in the CDR fully achieved the goals appropriate at this stage of the project and the team is positioned to begin the designs of the technical components and R&D of the critical technologies related to the CEPC.

The IAC believes that producing the TDR for accelerator systems on the time scale of 3-5 years is a good and achievable goal, and that it is essential to form an International Accelerator Review Committee which advises the team on all matters related to CEPC accelerators.

CEPC towards TDR

CEPC Accelerator Optimization Design towards TDR （from 2019-2022）

Refine all sub-systems, such as damping ring, booster, collider rings

Injection/extract physics and hardwares' design

Magnets and other hardwares' errors effects on DA, the advanced
close orbit corrections method maintain DA reduction acceptable,
keeping the tolerences requirments to reasonable values

All connecting transfer lines matching the collider accelerator chain requirements

Detector bakgroud reduction, beam-beam for long lifetime

Impedance studies including collimators

MDI SC magnets' optimazation design

Magnets' studies with H, W, and Z all modes

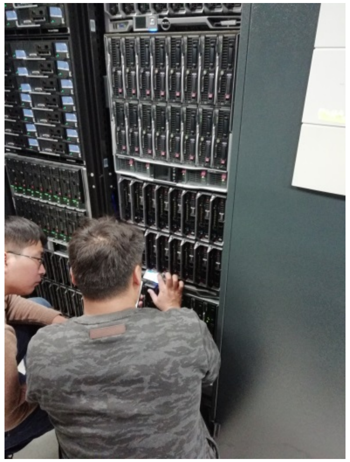
Upgrade possibility studies

....

购置CEPC计算机刀片服务器

CEPC 动力学孔径优化含磁铁误差需要大量高效计算，因此特为CEPCTDR优化设计购置了500核的计算机群（CDR阶段曾经借用JUNO及多学科中心）

- 16台刀片服务器Dell M640 + 1个Dell M1000E机箱
  - CEPC MOST1（高杰）及科学院前沿科学重点研究项目（高杰）各支付48.25万元，共96.5万元
  - 16刀片，共16*2*18=576核、16*128G内存
  - 已经完成上架安装
  - 计算中心正在配置加入高能所计算集群


国际国内会议，报告，文章等成果

国内会议

序号	姓名	会议时间	会议名称	会议地点	报告题目	报告形式
1	王逗	2016.09	CEPC-SppC study group meeting	北京航天航空大学	CEPC parameter choice and partial double	报告
2	王逗	2017.04	CEPC-SppC study group meeting	武汉华中师范大学	CEPC parameter optimization and lattice d	报告
3	王逗	2016.06	高能所创新项目CEPC预研中期进展报告	高能所	Accelerator Design of CEPC PDR and APDR	报告
4	C. Meng, Y.	2017.08.28-30	SAP2017	湖南，中国	CEPC LINAC DESIGN AND ERROR STUDY	Poster
5	J.Gao	2017.4.8	超导模组Cryomodule技术研讨会	Shanghai	Introduction to 1.3 GHz SC Linac Cryomodu	报告
6	Sha Bai	2016.09	CEPC-SppC study group meeting	Beijing	CEPC main ring magnets' error effect on D	会议报告
7	Sha Bai	2017.04	CEPC-SppC study group meeting	Wuhan	CEPC sawtooth effect	会议报告
8	Sha Bai	2017.04	CEPC-SppC study group meeting	Wuhan	Introduction to CEPC MDI	会议报告
9	王毅伟	2017.4.19-21	CEPC-SPPC workshop	武汉	Lattice Design for CEPC Main Ring	口头报告
10	王毅伟	2016.4.8-9	CEPC-SPPC workshop	高能所	DA Study for the CEPC Partial Double Ring	口头报告
11	王毅伟	2016.9.2-3	CEPC-SppC Study Group Meeting	北航	Optimization of CEPC Dynamic Aperture	口头报告
12	刘振超	2016.09	CEPC-SppC study group meeting	北京航天航空大学	CEPC ADPR SRF and beam dynamics study	报告
13	Sha Bai	2017.11.4-11.5	CEPC Informal Mini-Review of CDR	高能所	Machine-Detector Interface for CEPC	口头报告
14	Sha Bai	2017.11.6-11.8	International Workshop on High Energy	高能所	CEPC MDI	口头报告
15	崔小昊	2017.04	CEPC-SppC study group meeting	武汉华中师范大学	CEPC injection and Booster design	报告
16	崔小昊	2018.04	CEPC-SPPC workshop	高能所	CEPC injection design	口头报告
17	孟才	43141	CEPC CDR internal review	IHEP,Beijing	CEPC Injector：Damping Ring	口头报告
18	王逗	2018.02.10	CEPC CDR internal review	高能所	CEPC booster design	口头报告
19	王逗	2018.06.16	A mini workshop on High Energy Physics	高能所	ILC & CEPC Status	口头报告
20	高杰	2017.4	CEPC-SppC study group meeting	武汉	CEPC-SppC towards CDR	口头报告
21	高杰	2018.7	International Workshop onPhysics Beyon	上海	Completion of CEPC Accelerator CDR and	口头报告

国内会议共计21人次.

国际会议-1

序号	姓名	会议时间	会议名称	会议地点	报告题目	报告形式
1	Dou Wang	2017.05	IPAC2017	丹麦	DESIGN STUDY ON CEPC POSITRON DAM	文章及海报
2	Dou Wang	2017.05	IPAC2017	丹麦	100 KM CEPC PARAMETERS AND LATTICE	文章及海报
3	Dou Wang	2017.01	IAS2017	香港	100 km CEPC parameters and lattice desig	口头报告及文章
4	Dou Wang	2016.08	ICHEP2016	芝加哥	CEPC partial double ring scheme and crab-	文章及海报
5	Dou Wang	2016.05	IPAC2016	釜山	CEPC parameter choice and partial double	文章及海报
6	Dou Wang	2017.03	FCPPL2107	清华大学	100km CEPC Parameters and Lattice Desig	口头报告
7	Dou Wang	2017.07	全球华人物理大会OCPA9	清华大学	CEPC parameters and lattice design	口头报告及海报
8	Dou Wang	2017.08	The 13th Symposium on Accelerator Physics	吉首	CEPC Parameter Choice	口头报告及文章
9	Dou Wang	2017.05	FCC Week 2017	柏林		
10	宣殿君	2017.07.29-08.04	18th International Comferemce on RF Supercondu	Lanzhou, China	Cavity Fundamental Mode and Beam Intera	Poster
11	C. Meng, Y.	2017.05.14-19	IPAC2017	Copenhagen, Denma	CEPC LINAC DESIGN AND BEAM DYNAMI	poster
12	J.Gao	2016.8.3-10	ICHEP2016	Chicago, US	Status of the CEPC Project: Physics, Acceler	报告及文章
13	J.Gao	2016.11.21-25	RuPAC2016	St.Petersburg, Russia	CEPC-SppC Accelerator Status	报告及文章
14	J.Gao	2016.7.10-16	PASCOS 2016 越南	越南	CEPC-SppC Status	报告
15	J.Gao	2016.8.15-26	SSI 2016, SLAC	美国	Introduction to CEPC-SppC	报告
16	J. Gao	2016.9.14-16	RDMS annual conference	VARNA, India	Introduction to CEPC-SppC	报告及文章
17	J.Gao	2016.12.5-9	LCWS2016	日本	Circulay e+e- colliders	报告
18	J.Gao	2017.1.16-18	AFDA2017	IMP, Lanzhou	CEPC-SPPC Scientific Goalsand Accelerator	报告
19	J.Gao	2017.01.23-16	IAS 2017	Hongkong	CEPC-SppC Status	报告及文章
20	J.Gao	2017.05.14-18	IPAC2017	Sweden	CEPC-SPPC TOWARDS CDR	报告
21	耿会平	2016.10.24-27	eeFACT2016	Cockcroft Institute at	Issues in CEPC pretzel and partial double ri	口头报告
22	耿会平	2017.5.14-19	IPAC17	COPENHAGEN, DEN	SAWTOOTH EFFECT IN CEPC	海报
23	Sha Bai	May8-13	IPAC16	Korea	MDI design in CEPC partial double ring	会议文章
24	Sha Bai	May8-13	IPAC16	Korea	Magnet error effect on dynamic aperture i	会议文章
25	Sha Bai	May14-19	IPAC17	Denmark	MDI issues in CEPC double ring	会议文章
26	Sha Bai	March27-30	FCPPL2017	Beijing	CEPC MDI status and challenges	会议报告
27	边天剑	2017.05.14-19	IPAC17	丹麦	CEPC Booster Lattice Design Study	poster
28	Yiwei Wang	2017.05.14-19	IPAC17	丹麦	OPTICS DESIGN FOR CEPC DOUBLE RING	报告及海报
29	王毅伟	2017.1.23-26	HKUST IAS conference	香港科技大学	Lattice design and dynamic aperture optimi	口头报告
30	王毅伟	2017.3.27-30	10th FCPPL workshop,	清华大学	Lattice Design and Dynamic Aperture Opti	口头报告
31	王毅伟	2016.5.8-13	IPAC17	韩国首尔	Dynamic Aperture Study of the CEPC Main	海报
32	刘振超	2016.08.15-19	International Symposium on Higgs Boson and Beyo	Weihai	SCRF System Studies for CEPC APDR and B	口头报告
33	Dou Wang	2018.01	IAS2018	香港	CEPC Parameter Optimization and Booster	口头报告
34	王毅伟	2018.1.22-25	HEP conference 2018 of IAS	香港	Lattice design for the CEPC collider ring	口头报告
35	王毅伟	2018.1.15-17	7th low emittance workshop	瑞士	Beam Optics design for the CEPC collider ri	口头报告
36	王毅伟	2017.12.6-8	1st workshop on applications of high energy Circula	北京	Beam Optics design for CEPC collider ring	口头报告
37	王毅伟	2017.11.6-8	International Workshop on High Energy Circular El	北京	Optics design for CEPC collider ring	口头报告
38	王毅伟	2017.11.4-5	CEPC Accelerator CDR mini-review	北京	Optics_design_for_CEPC_collider_ring	口头报告
39	王毅伟	2017.11.1-3	ICFA mini-workshop on dynamic aperture	北京	Optics design with DA considerations for CE	口头报告
40	王毅伟	2017.5.14-19	IPAC17	丹麦	OPTICS DESIGN FOR CEPC DOUBLE RING	海报及会议文章

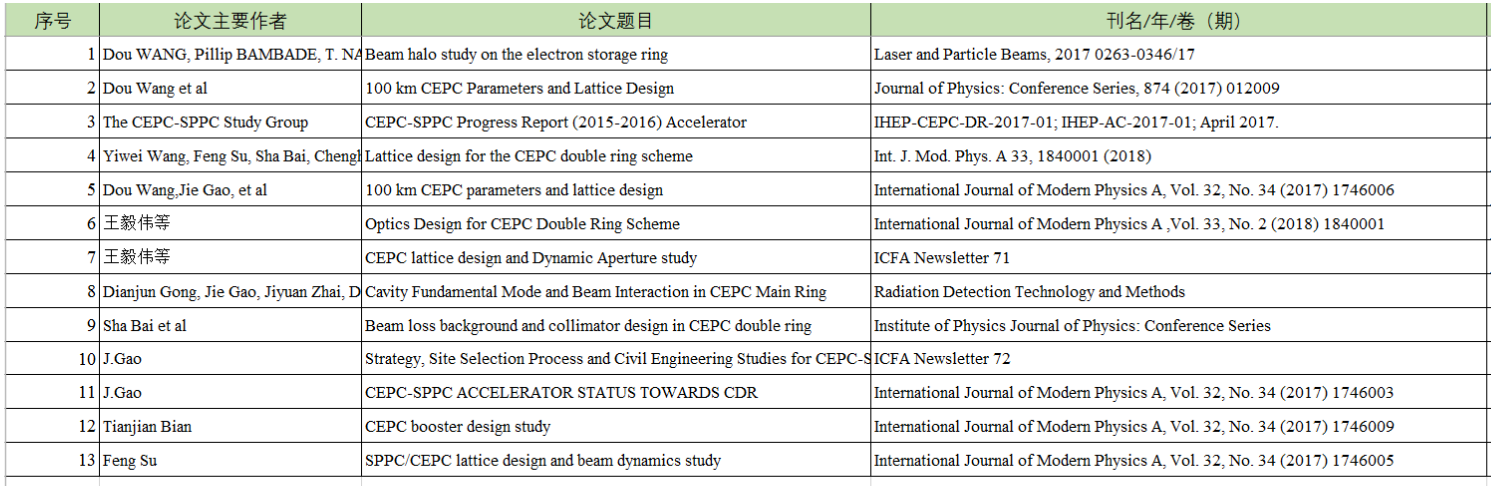
国际会议-2

序号	姓名	会议时间	会议名称	会议地点	报告题目	报告形式
41	王毅伟	2017.3.27-30	10th FCPPL workshop,	清华大学	Lattice Design and Dynamic Aperture Opti	口头报告
42	王毅伟	2017.1.23-26	HKUST IAS conference	香港	Lattice design and dynamic aperture optim	口头报告
43	王毅伟	2016.5.8-13	IPAC16	韩国首尔	Dynamic Aperture Study of the CEPC Main	海报及会议文章
44	Sha Bai	2018.1.22-25	HKUST IAS conference	Hongkong	CEPC MDI	口头报告
45	C.Meng	2017.11.6-11.8	International Workshop on High Energy Circular El	Beijing,China	CEPC injector Linac beam dynamics	口头报告
46	C.Meng	22-25 January 2018	HEP2018(High Energy Physics)	Hong Kong, China	CEPC Linac Injector	口头报告
47	高杰	2017.5.14-5.20	IPAC17	丹麦	/	
48	高杰	2017.5.27-6.4	FCC Week 2017	德国柏林	/	
49	高杰	2017.9.1-9.5	The 12th International Scientific Workshop in Mem	俄罗斯	CEPC and SppC: Status and Future Plans	口头报告
50	高杰	2017.8.26-8.30	Workshop on Future of Fundamental Physics	希腊	CEPC and SppC: status and future plans	口头报告
51	高杰	2017.10.22-10.28	LCWS2017	法国	/	
52	高杰	2017.12.13-12.17	pp workshop	德国DESY	sppc Status and perspective	口头报告
53	Sha Bai	2017.5.27-6.4	FCC Week 2017	德国柏林	/	
54	Sha Bai	2018.4.29-5.4	IPAC18	加拿大温哥华	Beam loss background and collimator desig	口头报告
55	Sha Bai	2018.5.24-5.26	CEPC workshop(EU edition)	意大利罗马	Overview of MDI for CEPC	口头报告
56	Sha Bai	2018.7.4-7.11	ICHEP2018	韩国首尔	Machine-Detector Interface for CEPC	口头报告
57	C.Meng	April 9-13,2018	FCCWEEK2018	Amsterdam, Netherla	CEPC linac design	口头报告
58	C.Meng	24-26 May 2018	Workshop on Circular Electron Positron Collider	Roma， Italy	CEPC Linac Injector	口头报告
59	C.Meng	April 29 to May 4，	IPAC2018	Vancouver, BC, Cana	THE PROGRESS OF CEPC POSITRON SOUR	海报
60	王逗	2018.05.27-06.01	HQL2018	日本山形	CEPC Design Status	口头报告
61	王逗	2018.05.24-05.26	Workshop on the Circular Electron-Positron Collide	意大利罗马	CEPC optics and booster optics	口头报告
62	王逗	2018.04.29-05.04	IPAC18	加拿大温哥华	The CEPC lattice design with combined dipo	海报及会议文章
63	王逗	2018.04.09-04.13	FCC Week 2018	荷兰	The CEPC lattice design with combined dipo	海报
64	王逗	2018.06.28	CEPC CDR international review	北京	CEPC Booster Design	口头报告
65	王毅伟	2018.4.9-13	FCC week 2018	荷兰	Lattice design for the CEPC collider ring and	口头报告
66	高杰	2018.01	IAS	香港科技大学	CEPC Status towards CDR	口头报告
67	高杰	2017.11	Dubna	俄罗斯	CEPC-SppC Accelerator CDR Statusand Pe	口头报告
68	高杰	2018.5	CEPC-SppC international workshop	罗马	Completion of CEPC CDR towards TDR	口头报告
69	高杰	2018.07	ICHEP2018	韩国首尔	Completion of CEPC Accelerator CDR,and	口头报告
70	高杰	2018.07	Higgs Hunting	法国	Completion of CEPC CDR towards TDR	口头报告
71	高杰	2018.8	Windows on Universe	越南	Aisa HEP:ILC-CEPC	口头报告

国际会议共计71人次

论文发表

期刊文章14篇，其中SCI 6篇，EI 1篇。



序号	论文主要作者	论文题目	刊名/年/卷（期）
1	Dou WANG, Pillip BAMBADE, T. NA	Beam halo study on the electron storage ring	Laser and Particle Beams, 2017 0263-0346/17
2	Dou Wang et al	100 km CEPC Parameters and Lattice Design	Journal of Physics: Conference Series, 874 (2017) 012009
3	The CEPC-SPPC Study Group	CEPC-SPPC Progress Report (2015-2016) Accelerator	IHEP-CEPC-DR-2017-01; IHEP-AC-2017-01; April 2017.
4	Yiwei Wang, Feng Su, Sha Bai, Chengh	Lattice design for the CEPC double ring scheme	Int. J. Mod. Phys. A 33, 1840001 (2018)
5	Dou Wang,Jie Gao, et al	100 km CEPC parameters and lattice design	International Journal of Modern Physics A, Vol. 32, No. 34 (2017) 1746006
6	王毅伟等	Optics Design for CEPC Double Ring Scheme	International Journal of Modern Physics A ,Vol. 33, No. 2 (2018) 1840001
7	王毅伟等	CEPC lattice design and Dynamic Aperture study	ICFA Newsletter 71
8	Dianjun Gong, Jie Gao, Jiyuan Zhai, D	Cavity Fundamental Mode and Beam Interaction in CEPC Main Ring	Radiation Detection Technology and Methods
9	Sha Bai et al	Beam loss background and collimator design in CEPC double ring	Institute of Physics Journal of Physics: Conference Series
10	J.Gao	Strategy, Site Selection Process and Civil Engineering Studies for CEPC-S	ICFA Newsletter 72
11	J.Gao	CEPC-SPPC ACCELERATOR STATUS TOWARDS CDR	International Journal of Modern Physics A, Vol. 32, No. 34 (2017) 1746003
12	Tianjian Bian	CEPC booster design study	International Journal of Modern Physics A, Vol. 32, No. 34 (2017) 1746009
13	Feng Su	SPPC/CEPC lattice design and beam dynamics study	International Journal of Modern Physics A, Vol. 32, No. 34 (2017) 1746005

2018 March 1, ILC Newsline: 2018, A milestone year for Higgs factories in Asia
2018 June 1, CERN Courier: China's bid for a circular electron-positron collider
2018 July, 2018, 科学通报，2018, 63（21）：2102-2106
亚洲希格斯玻色子工厂里程碑之年，

代表性文章10篇

请列出论文、专利、技术标准等代表性成果（总数不超过 10 项）：

1 Dou WANG, Pillip BAMBADE, T. NAITO, K. YOKOYA and Jie GAO Beam halo study on the electron storage ring Laser and Particle Beams, 2017 0263-0346/17

2 Dou Wang et al 100 km CEPC Parameters and Lattice Design Journal of Physics: Conference Series, 874 (2017) 012009

3 Yiwei Wang, Feng Su, Sha Bai, Chenghui Yu, Jie Gao Lattice design for the CEPC double ring scheme Int. J. Mod. Phys. A 33, 1840001 (2018)

4 Dou Wang,Jie Gao, et al 100 km CEPC parameters and lattice design International Journal of Modern Physics A, Vol. 32, No. 34 (2017) 1746006

5 王毅伟等 Optics Design for CEPC Double Ring Scheme International Journal of Modern Physics A ,Vol. 33, No. 2 (2018) 1840001

6 Dianjun Gong, Jie Gao, Jiyuan Zhai, Dou Wang Cavity Fundamental Mode and Beam Interaction in CEPC Main Ring Radiation Detection Technology and Methods

7 Sha Bai et al Beam loss background and collimator design in CEPC double ring Institute of Physics Journal of Physics: Conference Series

8 J.Gao CEPC-SPPC ACCELERATOR STATUS TOWARDS CDR International Journal of Modern Physics A, Vol. 32, No. 34 (2017) 1746003

9 Tianjian Bian CEPC booster design study International Journal of Modern Physics A, Vol. 32, No. 34 (2017) 1746009

10 Feng Su SPPC/CEPC lattice design and beam dynamics study International Journal of Modern Physics A, Vol. 32, No. 34 (2017) 1746005

经费情况

课题一：加速器物理设计

负责人：高杰，中科院高能所

所属单位： 清华
财务联系人： 杨露萍
经费外拨时间（如有）： 无外拨

		项目预算经费（万元）	到账经费（万元）	到账时间	截止目前执行情况（万元）
课题	总额	388	279.2	2017.5.18	64.9
	直接经费	356	256.4	2017.5.18	42.1
	间接经费	32	22.8	2017.5.18	22.8

截止2018年6月30日课题总体经费执行情况	设备费（万元）	劳务费（万元）	其他（万元）	总额（万元）
任务书预算	188.5	32.5	167	388
实际执行	8.9*	0	56.0	64.9

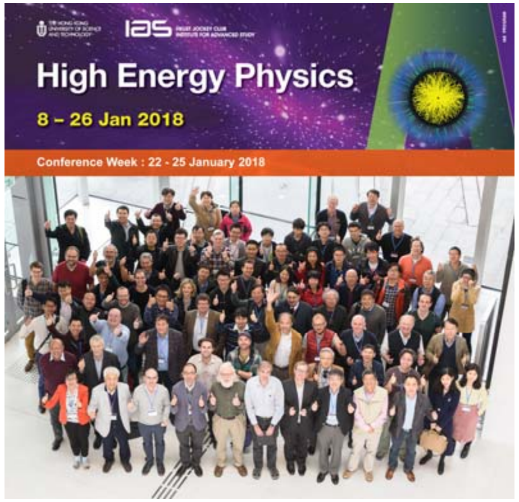
- 此外，还有约100万设备费，正在办理支付手续。
- 预计总支出164.9万元。与总经费的40%，即155.2万元，基本持平。超出部分由已到账经费支出。

Other important issues

CEPC International Collaboration

The first CEPC-SppC international Collaboration Workshop
Nov 6-8, 2017, IHEP, Bejing

http://indico.ihep.ac.cn/event/6618



IAS Higgh Energy Physics Workshop
(Since 2015-2018)

http://iasprogram.ust.hk/hep/2018

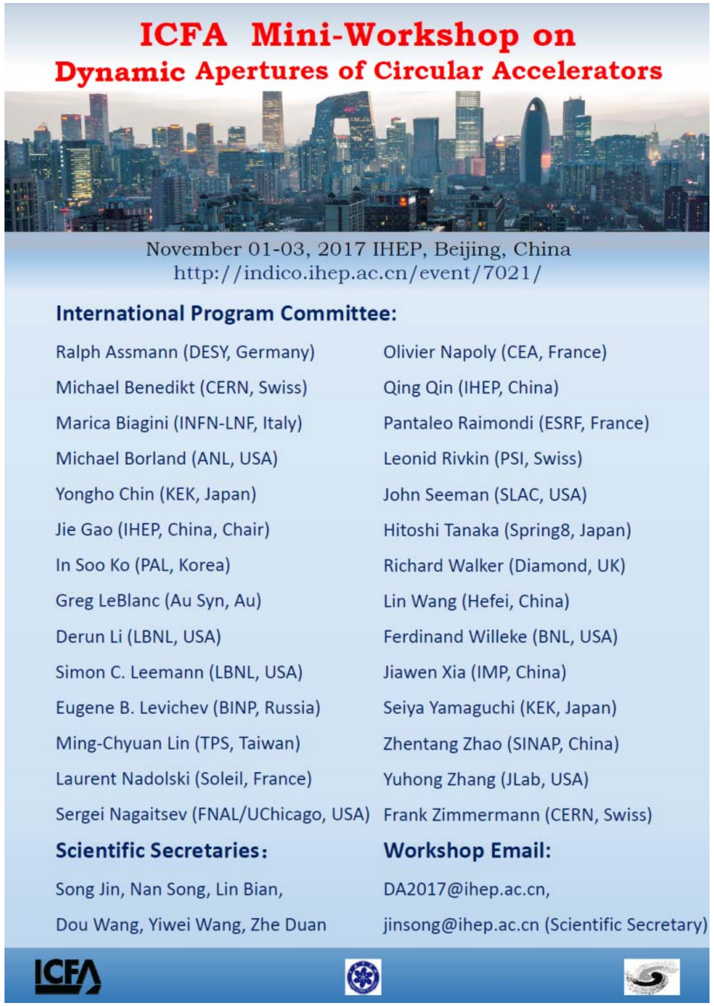
Workshop on the Circuar Electron Positron Collider-EU edition

May 24-26, 2018, Università degli Studi Roma Tre, Rome, Italy

https://agenda.infn.it/conferenceDisplay.py?ovw=True&confId=14816

The sencond CEPC-SppC international Collaboration Worksho
Nov 12-14, 2018, IHEP, Bejing
https://indico.ihep.ac.cn/event/7389/

ICFA Mini Workshop on Dynamics Aperture of Circular Accelerators （会议主席： 高杰）



ICFA Mini-Workshop on
Dynamic Apertures of Circular Accelerators

November 01-03, 2017 IHEP, Beijing, China
http://indico.ihep.ac.cn/event/7021/

International Program Committee:

Ralph Assmann (DESY, Germany)
Michael Benedikt (CERN, Swiss)
Marica Biagini (INFN-LNF, Italy)
Michael Borland (ANL, USA)
Yongho Chin (KEK, Japan)
Jie Gao (IHEP, China, Chair)
In Soo Ko (PAL, Korea)
Greg LeBlanc (Au Syn, Au)
Derun Li (LBNL, USA)
Simon C. Leemann (LBNL, USA)
Eugene B. Levichev (BINP, Russia)
Ming-Chyuan Lin (TPS, Taiwan)
Laurent Nadolski (Soleil, France)
Sergei Nagaitsev (FNAL/UChicago, USA)
Olivier Napoly (CEA, France)
Qing Qin (IHEP, China)
Pantaleo Raimondi (ESRF, France)
Leonid Rivkin (PSI, Swiss)
John Seeman (SLAC, USA)
Hitoshi Tanaka (Spring8, Japan)
Richard Walker (Diamond, UK)
Lin Wang (Hefei, China)
Ferdinand Willeke (BNL, USA)
Jiawen Xia (IMP, China)
Seiya Yamaguchi (KEK, Japan)
Zhentang Zhao (SINAP, China)
Yuhong Zhang (JLab, USA)
Frank Zimmermann (CERN, Swiss)

Scientific Secretaries:

Song Jin, Nan Song, Lin Bian,
Dou Wang, Yiwei Wang, Zhe Duan

Workshop Email:

DA2017@ihep.ac.cn,
jinsong@ihep.ac.cn (Scientific Secretary)

http://indico.ihep.ac.cn/event/7021/

40 participants from USA, Russia, Swiss, Japan, France, Korea, China..., concentrating the key beam dynamic aperture problem for CEPC also...

Experts from pp, e+e-, ep, eA, light source, damping ring for ILC....

International collaborations

Example 1 (with Super KEK B in 2018)

In 2018, under the envelope of MoU between IHEP and KEK on Super KEK B and circular e+e- collider in general.

March 17, 2018 Jie Gao, Yiwei Wang(3) participated the first round Super KEK B commissioning and operation and collider ring collaboration for one week.

In May, Sha Bai visited Super KEK B on MDI, Kanazawa-san provided RVC design materials of Super KEK B MDI for reference.

In June, 2018, Yuan Zhang, visited Super KEK B on beam beam and dynamic apertures for one week.

In July 5, Jiyuan Zhai and Dianjun Gong visited Super KEK B on SCRF system of Super KEK B for one week.

From Oct. 2018, Dr. Haoyu SHI at KEK, started to visit for three months under IHEP-KEK MoU with Hiroyuki Nakayama and Shuji Tanaka, on MDI detector part.

From Nov. 2018, Jingru Zhang will visit KEK super B linac for one week.

From Nov. 2018 Dou Wang will visit KEK Super B on damping ring, booster and collider ring for one week.

In 2018 IHEP is working with BINP to form a new body of collaboration to be signed at the end of 2018, aiming at collaboration on key issues of e+e- colliders, such as lattice DA, polarization, SC magnets of MDI...

CEPC Z-pole polarization already started in 2017, between IHEP and BINP (Sergei Nikitin)

HK IAS Mini workshop on polarization from Jan. 17-18, 2019

HKIAS Mini-Workshop on Polarization in Future Colliders
(Jie Gao, Yuhong Zhang, co-convener)
(Dec. 22, 2018)

Thursday, Jan. 17, 2019

Session 1: Yuhong Zhang, convener

9:00 – 9:10	Opening Remarks	Jie Gao (IHEP)	
9:10 – 9:45	Polarized Beams: A Brief History and Future Prospect	Yaroslav Derbenev (JLab)	theory
9:45 – 10:20	Introduction to CEPC	Jie Gao (IHEP)	
10:20 – 10:50	coffee break		
10:50 – 11:25	ILC Polarized Electron and Positron Sources	Kaoru Yokoya (KEK)	e+e-
11:25 – 12:00	Resonant Depolarization at Z and W beam energy	Ivan Koop (BINP)	e+e-
12:00 – 2:00	Lunch break		

Session 2: Kaoru Yokoya, convener

2:00 – 2:35	Polarization Issues in the Circular Electron-Positron Supercolliders	Sergey A. Nikitin (BINP)	e+e-
2:35 – 3:10	Polarized Electron and Positron Beams in CEPC	Zhi Duan (IHEP)	e+e-
3:10 – 3:45	BINP's Polarization Proposal for Tau-Charm Factory	Ivan Koop (BINP)	e+e-
3:45 – 4:15	coffee break		
5:15 – 4:50	Code Development and Simulation Studies of Polarized Beams	Francois Meot (BNL)	simulation
4:50 – 5:25	Re-evaluation of Spin-Orbit Dynamics of Polarized e^+e^- Beams in High Energy Circular Accelerators and Storage Rings: Bloch Equation Approach	Klaus Heinemann (Univ. of New Mexico)	simulation

No host dinner (time and location to be determined)

Friday, Jan. 19, 2019

Session 3: Jie Gao, convener (all remote presentations)

9:00 – 9:35	TBD	Joseph Grames (JLab) (8:00 – 8:35 PM, Virginia Time)	source
9:35 – 10:10	Overview of Electron Polarimetry (Remote)	David Gaskell (JLab) (8:35 – 9:10 PM, Virginia Time)	polarimetry
10:10 – 10:40	coffee break		
10:40 – 11:15	Spin Matching in Electron (Positron) Rings (Remote)	Vadim Ptitsyn (BNL) (9:40 – 10:15 PM, New York time)	ep
11:15 – 11:50	Beam Polarization in Future Colliders (eRHIC and FCC-ee) (Remote)	Eliana Gianfelice-Wendt (Fermilab) (9:15 – 9:50 PM, Chicago Time)	ep,e+e-
11:50 – 2:00	Lunch break		

Session 4: Yaroslav Derbenev, convener

2:00 – 2:35	JLEIC Electron Beam Polarization	Yuhong Zhang (JLab)	ep
2:35 – 3:10	Design of the beam polarimeter for FCC-ee	Nikolai Muchnoi (BINP)	polarimetry
3:10 – 3:45	Preliminary Studies of Beam Polarization in CEPC	Jiawen Hao (IHEP)	e+e-
3:45 – 4:15	coffee break		
4:15 – 4:45	Discussion moderated by Jie Gao and Yuhong Zhangsc		

Workshop Chairs:
Jie Gao (IHEP)
Yuhong Zhang (Jlab)

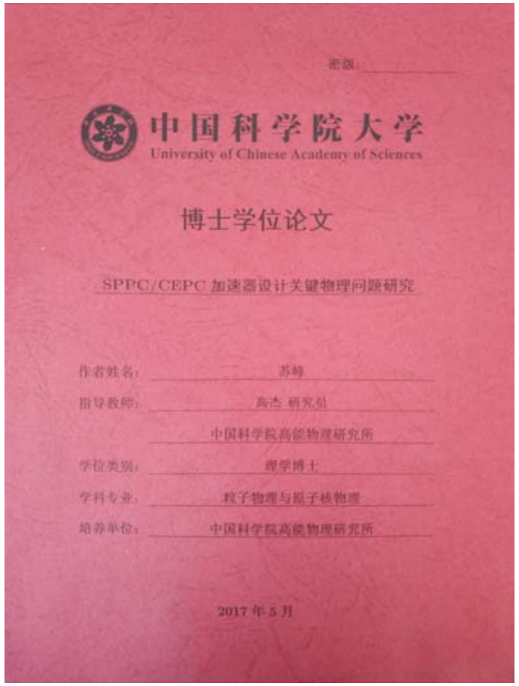
Aims:

Through this workshop we connected the polarization accelerator physicists of all projects in the world

This workshop will make
CEPC polarization study stronger later
(MOST II has this subject included)

CEPC 博士生培养

博士生：
苏峰：CEPC-SppC （2017年毕业）
边天剑：CEPC booster （2018年毕业）
宫殿君 CEPC SRF
夏文昊 CEPC 加速器物理 (极化）
王晓宁 CEPC 加速器物理 （TDR）



密级：

中国科学院大学
University of Chinese Academy of Sciences

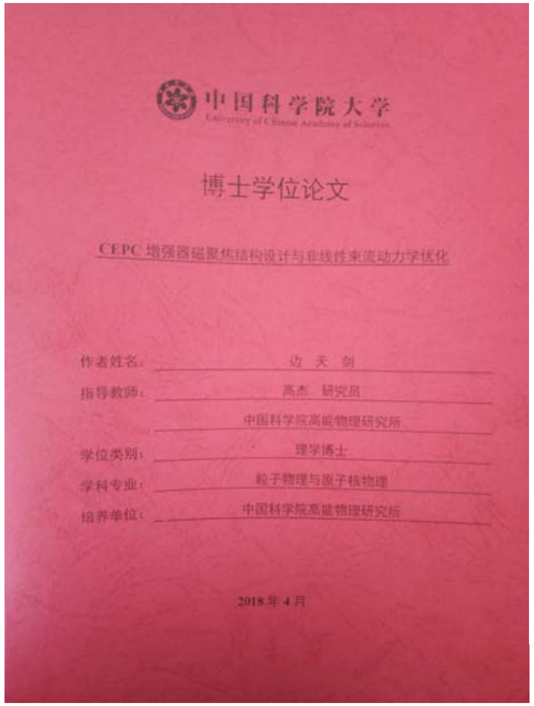
博士学位论文

SPPC/CEPC 加速器设计关键物理问题研究

作者姓名：苏峰
指导教师：高杰 研究员
中国科学院高能物理研究所
学位类别：理学博士
学科专业：粒子物理与原子核物理
培养单位：中国科学院高能物理研究所

2017 年 5 月

2017年5月毕业



中国科学院大学
University of Chinese Academy of Sciences

博士学位论文

CEPC 增强器磁聚焦结构设计与非线性束流动力学优化

作者姓名：边 天 剑
指导教师：高杰 研究员
中国科学院高能物理研究所
学位类别：理学博士
学科专业：粒子物理与原子核物理
培养单位：中国科学院高能物理研究所

2018 年 4 月

2018年5月毕业

结论

- 经过对CEPC对撞环四种方案和不同周长的设计进行系统的比较研究，发现了不同方案与亮度之间的相互关系，并确定100km全局部双环方案为基准方案，先进局部双环方案为备选方案。研究过程发表在CEPC 进展报告中。CEPC-SppC progress report（2017年4月）。
- 对基准方案进行研究，达到概念设计报告CDR（不含磁铁误差）的设计指标，并通过国际评估。研究结果发表在CEPC 概念设计报告中（2018年7月）。基准方案可以在使用相同硬件的情况下在H,W和Z能量模式之间转换。
- CEPC备选方案在研究过程中。
- CEPC增强器完成设计，达到概念设计报告要求。
- 直线加速器中完成阻尼环设计。
- 完成CEPC 对撞区概念设计。
- 提出等离子体加速注入器方案，作为直线加速器注入器备选方案。
- 购置500核计算机为下一步TDR优化设计打下计算能力基础
- 国际合作，国际国内会议，发表文章，博士生培养等方面取得显著成果。
- 研究队伍水平得到显著提高
- 经费使用正常

Thank you for your attention

Thanks go to

CEPC accelerator team and international collaborators