2018年国家重点研发计划项目

“高能环形正负电子对撞机关键技术研发和验证”

中期考核

课题一：高能环形正负电子加速器关键技术验证

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2020年8月20日，北京

Outline

I. Overall progress

II. Important progress and achievements

III. Existing problems and solutions

IV. Use of personnel and funds

V. Summary

Task introduction

Task： Verification of key techniques of high energy circular electron positron accelerator

Task budget： 9.74 M RMB

Task in charge： IHEP, CAS

Task leader： Chi Yunlong

Number of participants： 18 （Senior 11，Other 7，4 Ph.D. students）

Task period: Jul.1, 2018~Jun.30, 2023

Main research：

Sub-Task1: High precision Low-field dipole magnet prototype

Sub-Task2: Vacuum pipe、RF shield bellows、NEG coating prototype

Sub-Task3: Electrostatic separator prototype

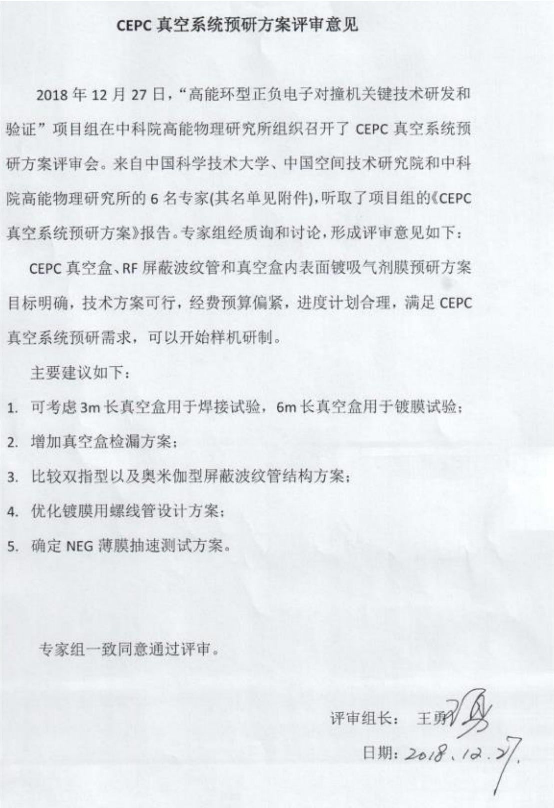
Sub-Task4: Z-pole Beam polarization design study

Overall progress in the medium term

	Index	Mid-term indicators	Performance
Sub-task1	Field precision	0.1%@60Gs	Reached
	Field reproducibility	0.05%@60Gs	Reached
Sub-task2	Vacuum pipe	3×10^{-10}Torr	
		Leak rate：3×10^{-10} Torr.L/s	3×10^{-10}Torr·L/s
	RF shielding bellow	Finger contact force：125±30g	125±25g
Sub-task3	Electric field strength	2.0MV/m@±110kV (in design)	Reached
	Good field region	(1‰)10×10 mm^2 (by simulation)	Reached
	Vacuum pressure	2×10^{-10}Torr (in design)	Reached
Sub-task4	Polarization design	The parameter selection of polarization insertion devices and the working mode of the precise energy measurement are defined	Reached
		The realization conditions of beam polarization > 50% are simulated.	Reached

Design review

- CEPC Vacuum system R&D design review meeting, Dec.27, 2018
- CEPC positron electron beam electrostatic separator prototype design review meeting, Jul.18,2019



CEPC 真空系统预研方案评审意见

2018 年 12 月 27 日，“高能环型正负电子对撞机关键技术研发和验证”项目组在中科院高能物理研究所组织召开了 CEPC 真空系统预研方案评审会。来自中国科学技术大学、中国空间技术研究院和中科院高能物理研究所的 6 名专家(其名单见附件)，听取了项目组的《CEPC 真空系统预研方案》报告。专家组经质询和讨论，形成评审意见如下：

CEPC 真空盒、RF 屏蔽波纹管和真空盒内表面镀吸气剂膜预研方案目标明确，技术方案可行，经费预算偏紧，进度计划合理，满足 CEPC 真空系统预研需求，可以开始样机研制。

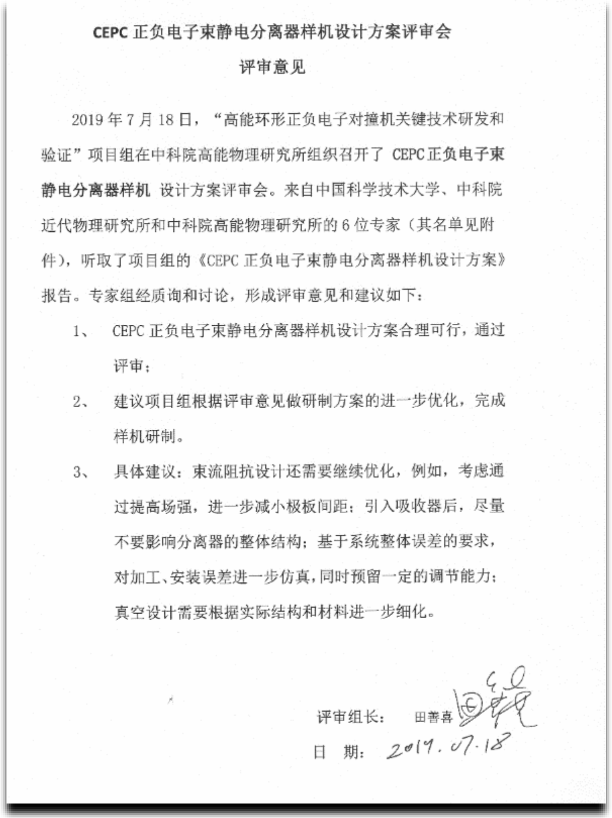
主要建议如下：

1. 可考虑 3m 长真空盒用于焊接试验，6m 长真空盒用于镀膜试验；
2. 增加真空盒检漏方案；
3. 比较双指型以及奥米伽型屏蔽波纹管结构方案；
4. 优化镀膜用螺线管设计方案；
5. 确定 NEG 薄膜抽速测试方案。

专家组一致同意通过评审。

评审组长：王勇

日期：2018.12.27.



CEPC 正负电子束静电分离器样机设计方案评审会

评审意见

2019 年 7 月 18 日，“高能环形正负电子对撞机关键技术研发和验证”项目组在中科院高能物理研究所组织召开了 CEPC正负电子束静电分离器样机 设计方案评审会。来自中国科学技术大学、中科院近代物理研究所和中科院高能物理研究所的 6 位专家（其名单见附件），听取了项目组的《CEPC 正负电子束静电分离器样机设计方案》报告。专家组经质询和讨论，形成评审意见和建议如下：

1、 CEPC 正负电子束静电分离器样机设计方案合理可行，通过评审；

2、 建议项目组根据评审意见做研制方案的进一步优化，完成样机研制。

3、 具体建议：束流阻抗设计还需要继续优化，例如，考虑通过提高场强，进一步减小极板间距；引入吸收器后，尽量不要影响分离器的整体结构；基于系统整体误差的要求，对加工、安装误差进一步仿真，同时预留一定的调节能力；真空设计需要根据实际结构和材料进一步细化。

评审组长： 田善喜

日　期： 2019.07.18

Outline

Low-field Booster dipole magnet R&D

Main Specifications of CEPCB dipole magnets

Quantity	16320	Magnetic Length (mm)	4700
Minimum field (Gs)	28	Good field region (mm)	55
Maximum field (Gs)	338	Field uniformity	0.1%
Gap (mm)	63	Field reproducibility	0.05%

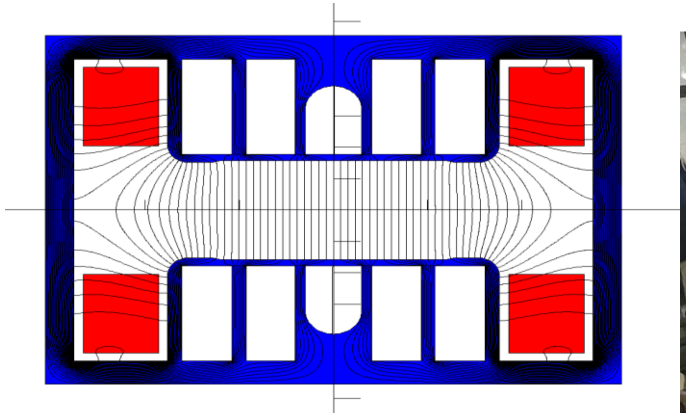
Midterm target

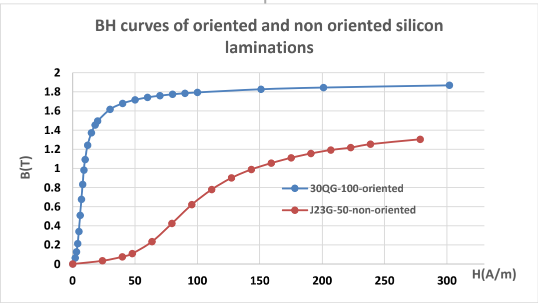
Quantity	1	Magnetic Length (mm)	1000
Minimum field (Gs)	60	Good field region (mm)	55
Maximum field (Gs)	338	Field uniformity	0.1%
Gap (mm)	63	Field reproducibility	0.05%

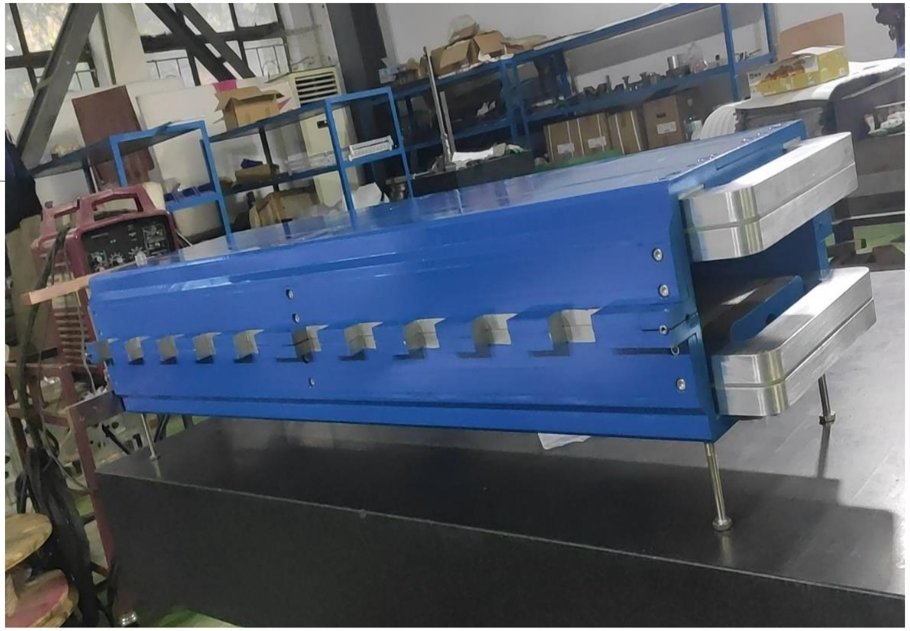
Two kinds of the subscale prototype magnet with and without iron cores have been designed and developed. The field specifications of both magnets reach the midterm target @60Gs.

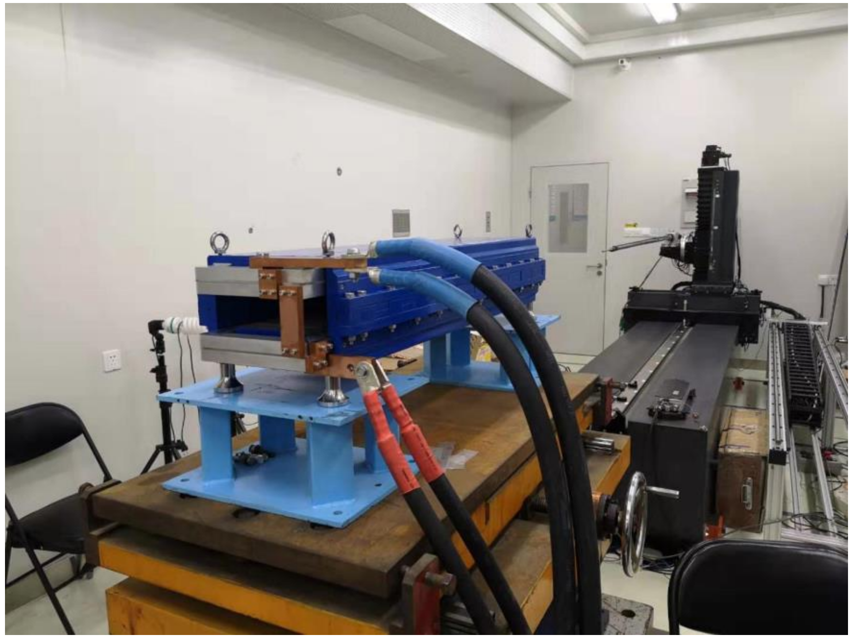
Low-field Booster dipole magnet R&D（with iron core）

- To increase field in the cores and decrease weight of the cores, the technology of core dilution is adopted.
- To reduce the influence of the remnant field on the low field precision, the grain-oriented silicon steel laminations are used to stack the magnet cores due to their low coercive and remnant field.





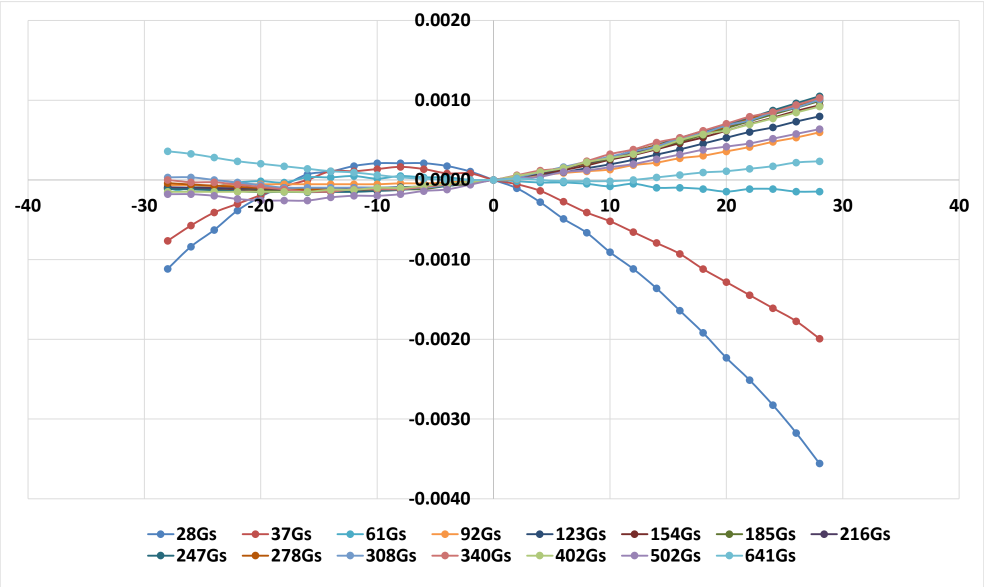


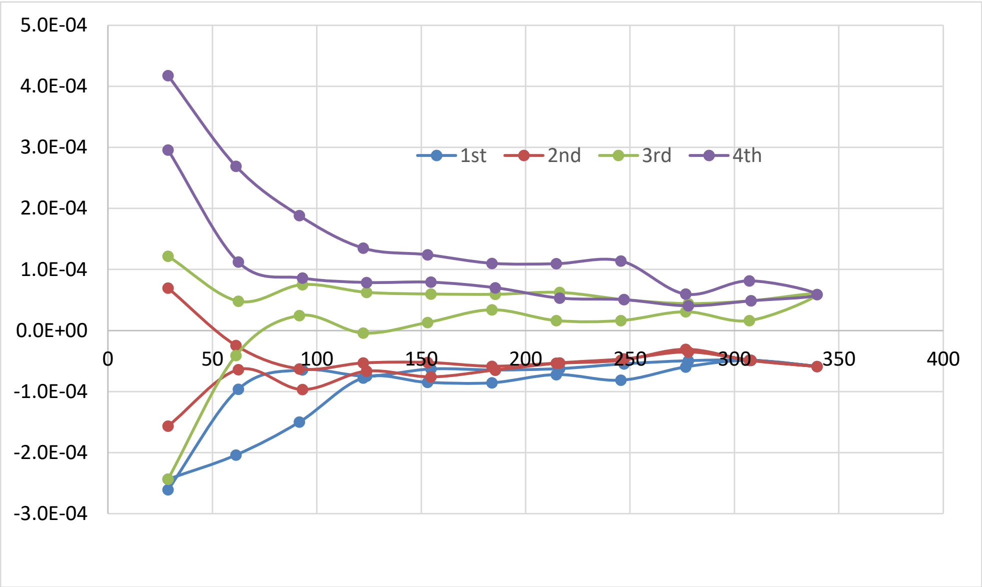


The dipole magnet with iron core was tested in the lab.

Low-field Booster dipole magnet R&D（with iron core）

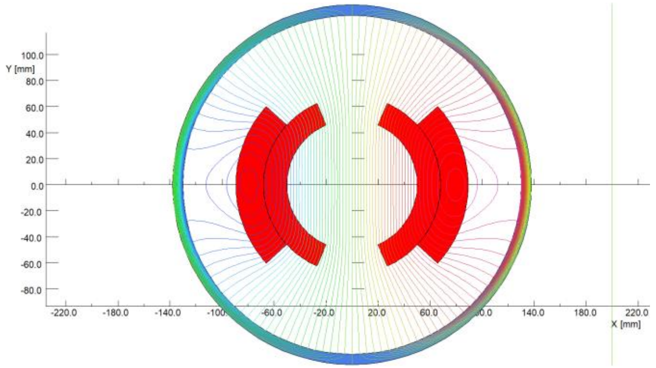
- ✓ The field uniformity in Good Field Region is about 0.3% at low field level of 28Gs (target 0.1%) and 0.1% at high field level, which can not meet the requirements.
- ✓ The magnet is excited for 4 times from 28Gs to 338Gs then back to 28Gs, the field reproducibility at all level is better than the required value of 5E-4.
- ✓ The field uniformity at 60Gs is about 3E-4, which is better than the midterm target.

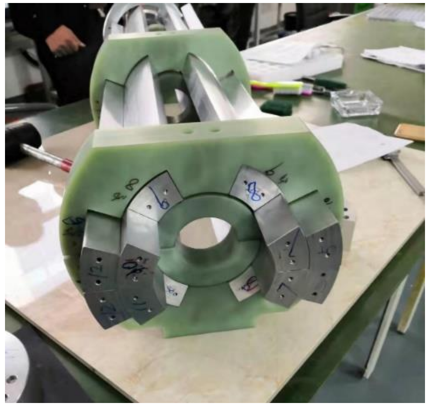
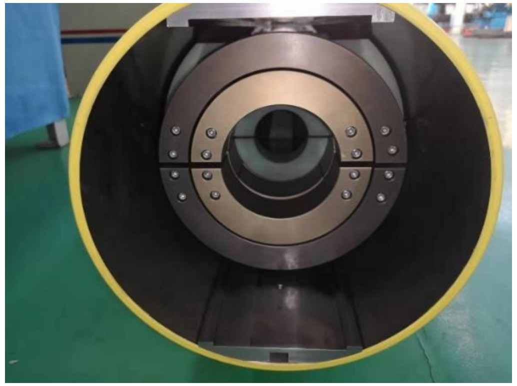




Low-field Booster dipole magnet R&D（w/o iron core）

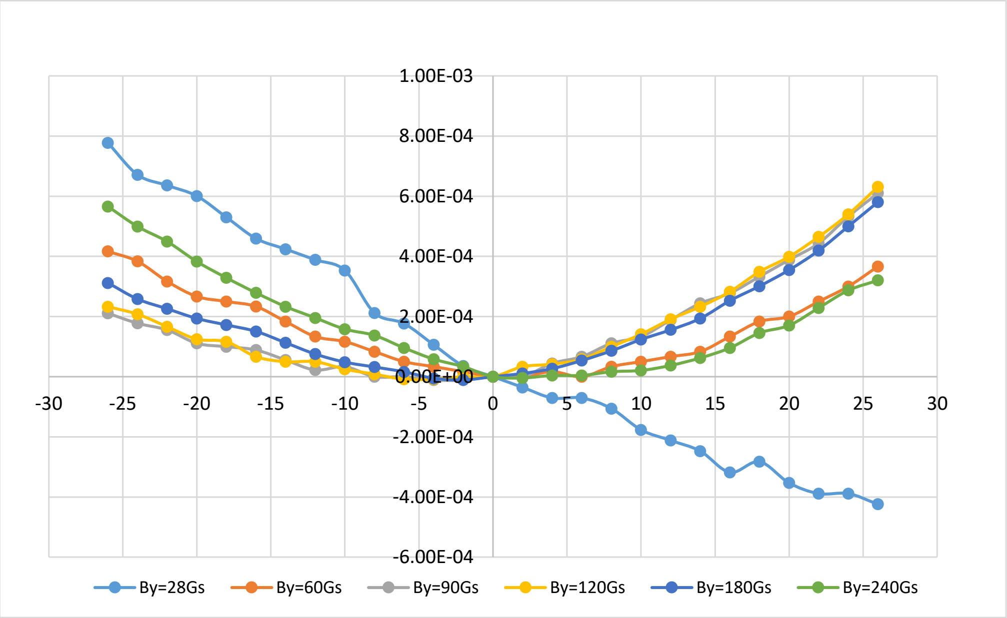
- The inner and outer conductors of the CT coils are directly fabricated from two aluminum tubes with the right diameters.
- The shielding cylinder was made from a long iron tube with inner diameter of 300mm.
- All the surfaces of the aluminum conductors were anodized for the insulation from turn to turn, the thickness of the anodized film is about 50 microns.
- The final assembling errors of the CT coil dipole magnet were checked to be less than 50 microns.

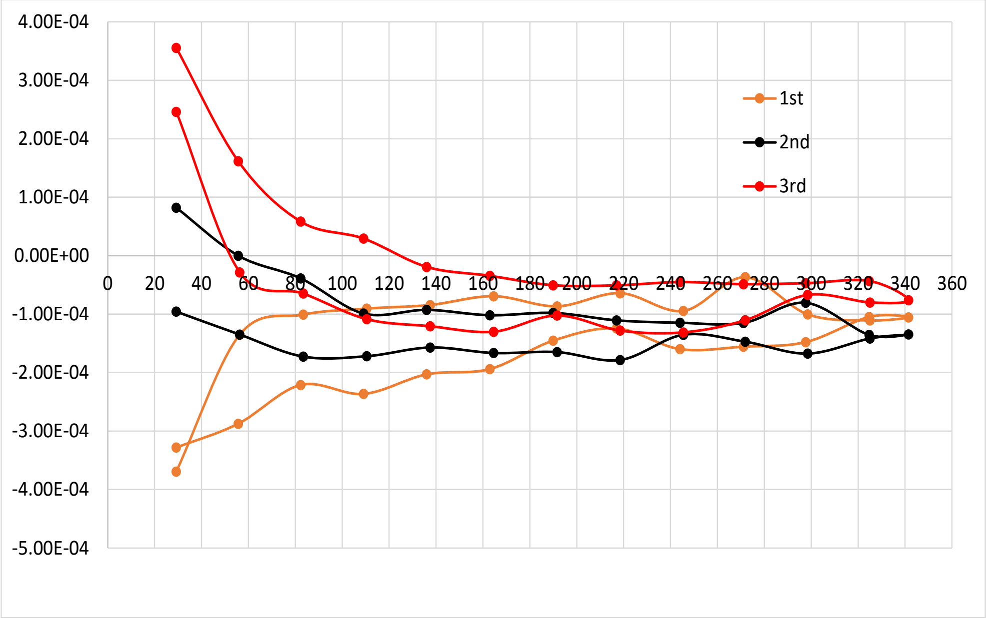



Low-field Booster dipole magnet R&D（w/o iron core）

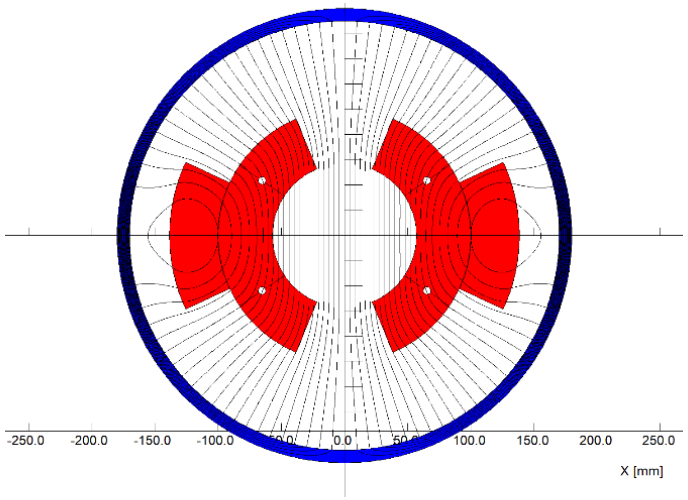
- ✓ The field precision at all level, especially at low field level of 28Gs, is better than the required value of 0.1%, which reaches the midterm target.
- ✓ The magnet is excited for 3 times from 28Gs to 338Gs then back to 28Gs, the field reproducibility at all level is better than the required value of 5E-4.

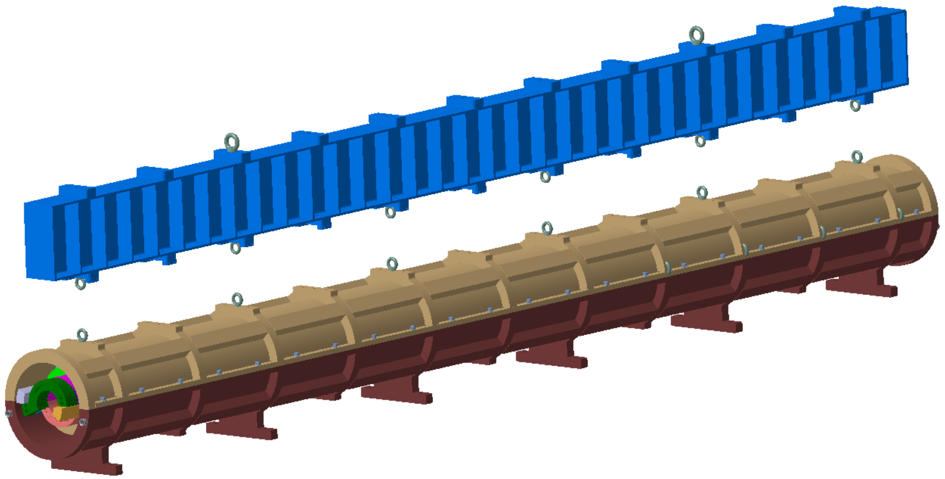




Design of the full-scale prototype CT coil dipole magnet

- On the base of good results from the subscale CT dipole magnet, the mechanical design of a full scale prototype CT dipole magnet was finished on the cooperation with 合肥 科烨 company. The production of the magnet will be begun in the coming month.
  - ✓ The total length of the magnet including the shielding tube is 5.1m.
  - ✓ The cooling tubes are inserted between the coil conductors to decrease temperature rise.
  - ✓ The touch resistance of the contacted surfaces of the conductors will be reduced by coated silver films.

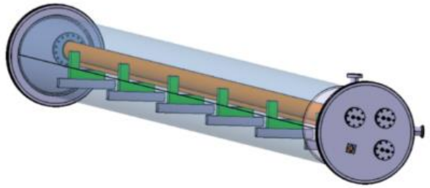




Vacuum Chamber prototype

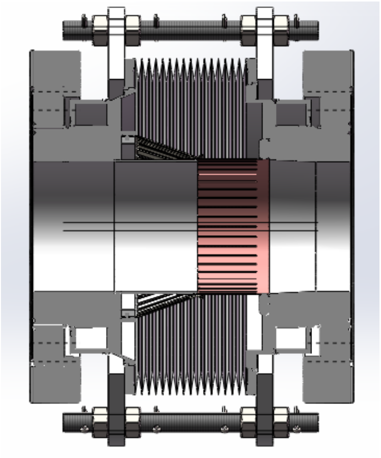
- A 6 m long simple vacuum furnace is fabricated, which is used to weld the water cooling channels of Cu chambers through low temperature brazing solder.
- The welding seams are checked by wire-electrode cutting. The welding joints are smooth and have good contacting.
- The prototypes of copper & aluminum vacuum chambers with a length of 6 m have been fabricated and tested, which meet the engineering requirements.
- Leak rate： 3×10^{-10} Torr.L/s

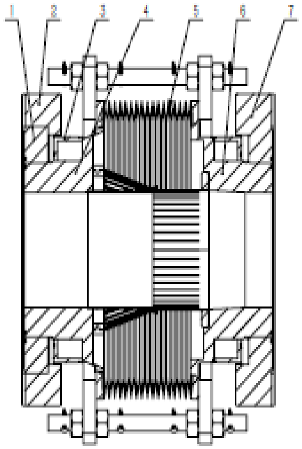


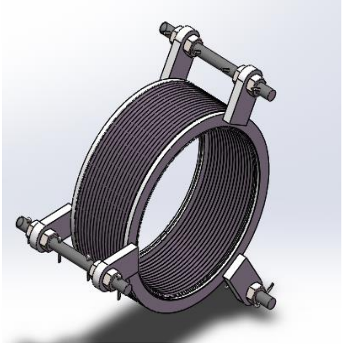


RF shielding bellows R&D

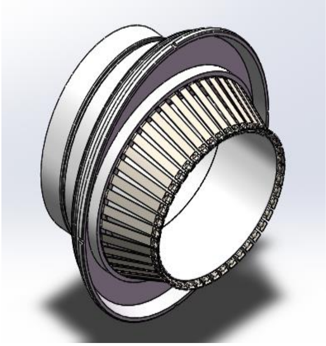
- Total length: 140 mm
- Inner and exterior diameter of bellows: 125mm/140mm
- Expansion/contraction: 5mm/12mm
- Offset: 2 mm
- Bending: 50 mrad
- Finger contact force: 125±25g (Midterm 125±30g)



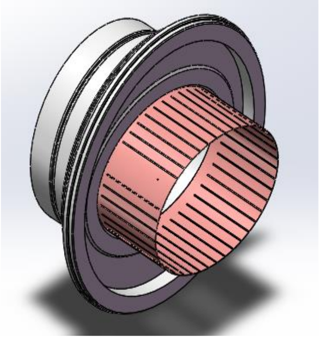




Bellows module



Spring fingers module

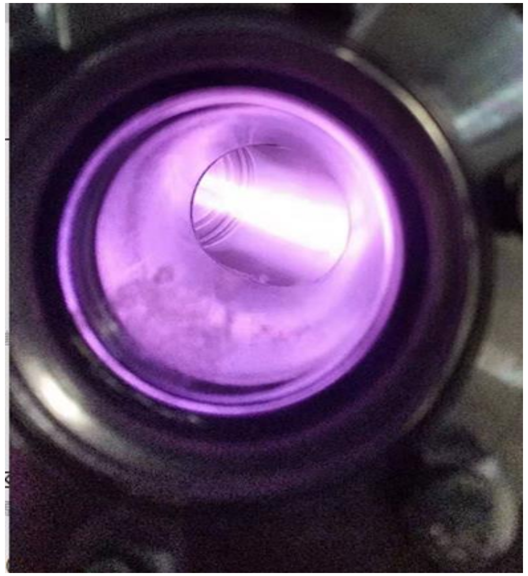


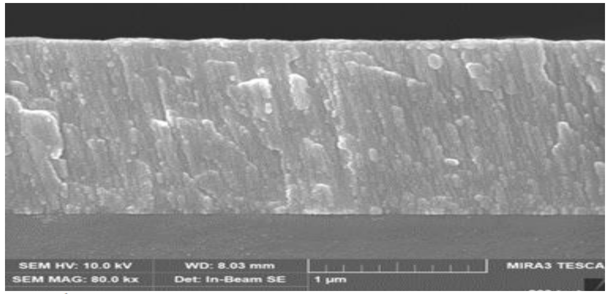
Contact fingers module

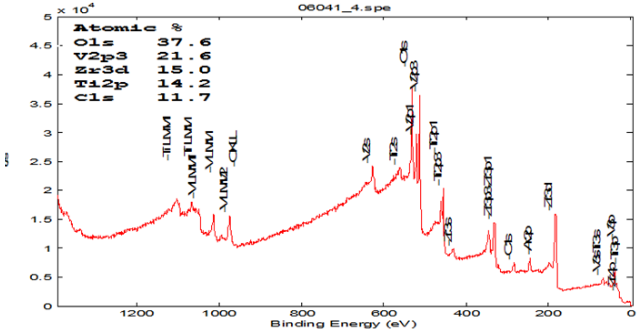
NEG coating setup

- The DC magnetron sputtering setup of NEG coating have been built and some experiments carried out with DN40 vacuum pipe.
- Thickness of film: ~1.1 μm; Proportion: Ti：Zr：V=0.28 : 0.3 : 0.42 (after Ar^{+} surface etching of 10 nm) ; Columnar film for high pumping speed.
- All related parameters (plasma gas pressure, substrate temperature, plasma current, and magnetic field value) are recorded and suitably adjusted to ensure the stability of the deposition process.

NEG coating setup





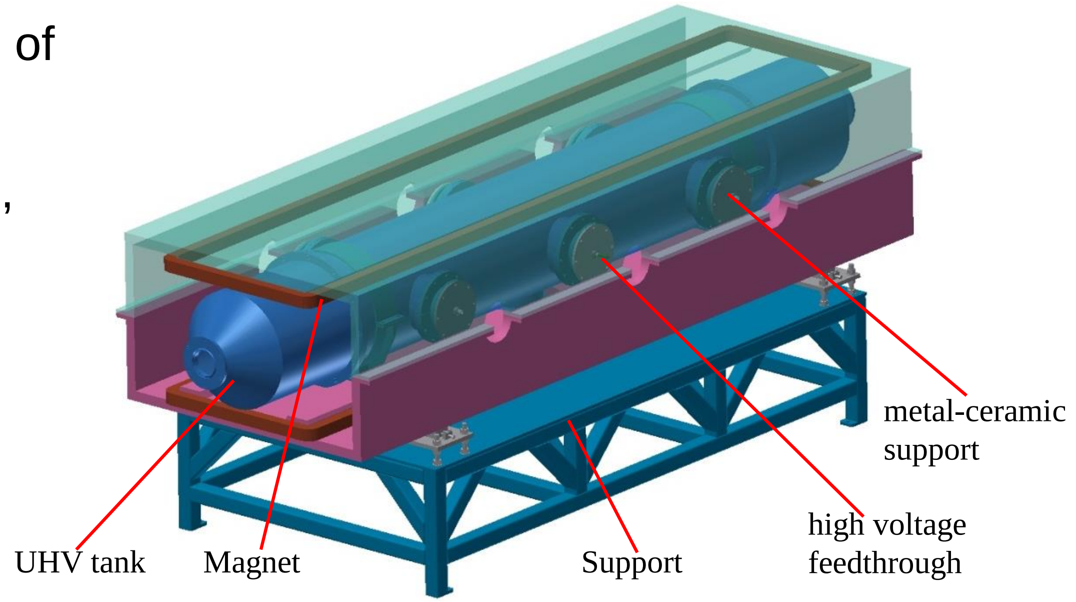


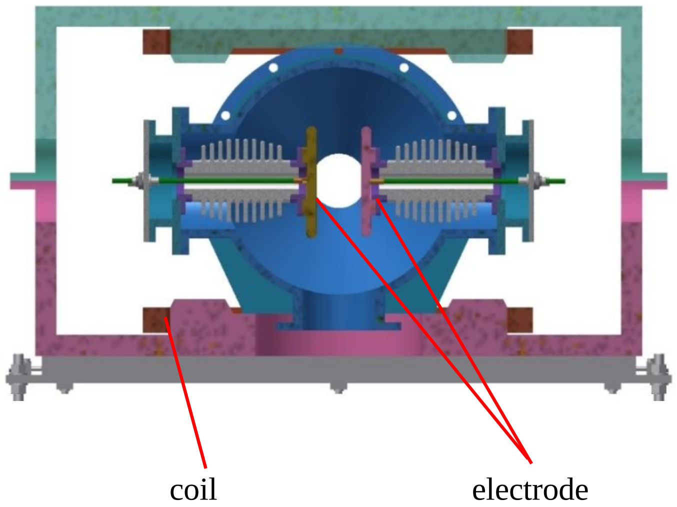
Electrostatic separator

The **Electrostatic-Magnetic Separator** is a device consisting of perpendicular **electric** and **magnetic** fields.

One set of Electrostatic-Magnetic Separators including 8 units, total 32 units needed for CEPC.

Separator length	4.5m
Inner diameter of separator tank	380mm
Electrode length	4.0m
Electrode width	180mm
Nominal gap	75mm
Maximum operating field strength	2MV/m
Maximum operating voltage	±75kV
Maximum conditioning voltage	±135kV
Good field region (0.5‰ limit)	46mm x 11mm
Nominal vacuum pressure	2.7e-8 Pa





Electrostatic Separator Design (midterm target)

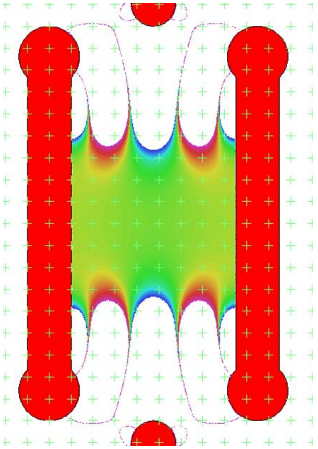
Electrode (a pair of metal flat plate)

- Dimension : 4m long and 180mm wide
- Material : Pure Titanium
- Field strength : 2MV/m

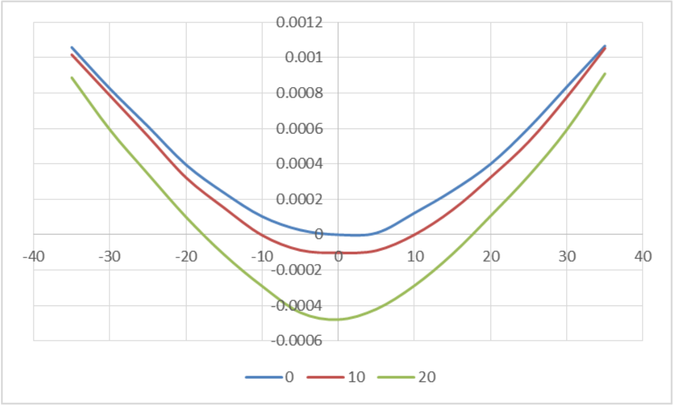
UHV tank

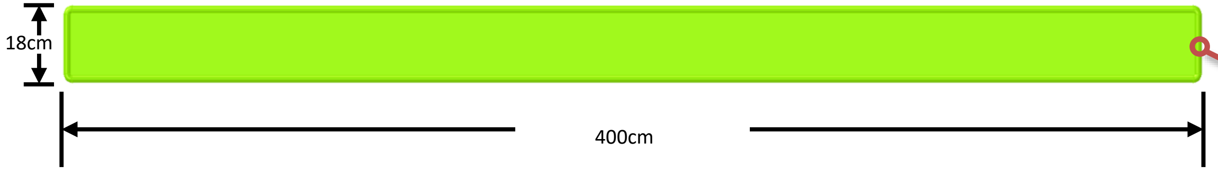
- 4.5m long and 38cm inner diameter
- Material : stainless-steel 316L

Field homogeneity: 7.5cm*5cm 0.5‰

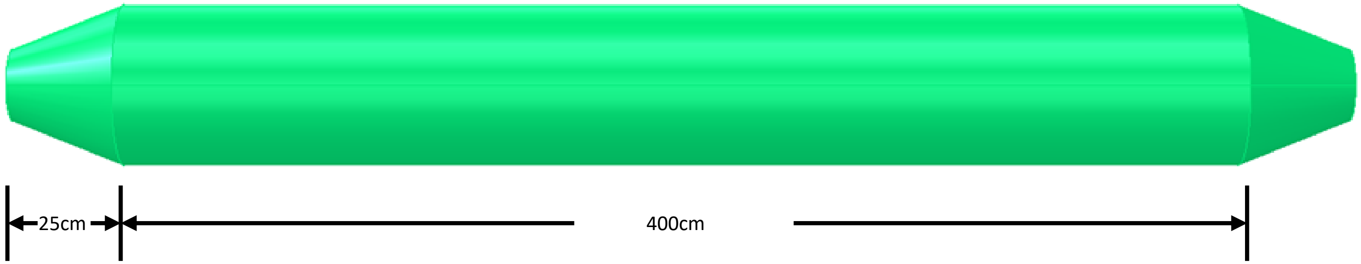


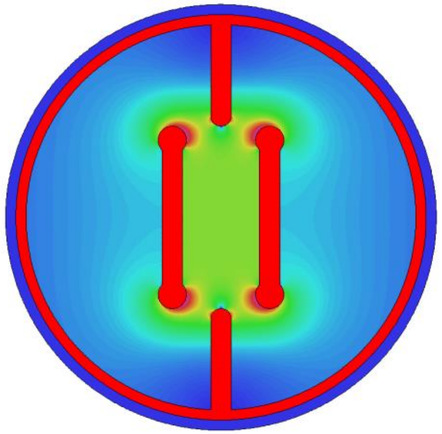
Integrated electrical field uniformity : 4.6cm*3cm 0.5‰





Length: 400cm
With: 18cm
Thickness: 2cm
Radius: 1.5cm
Density: 4.54g/cm^3
Weight: ≈65kg

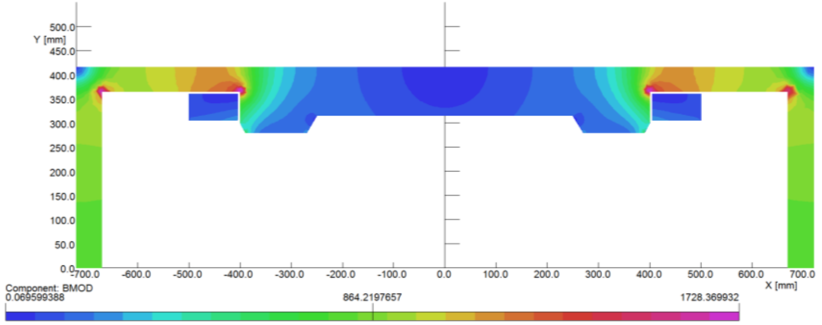




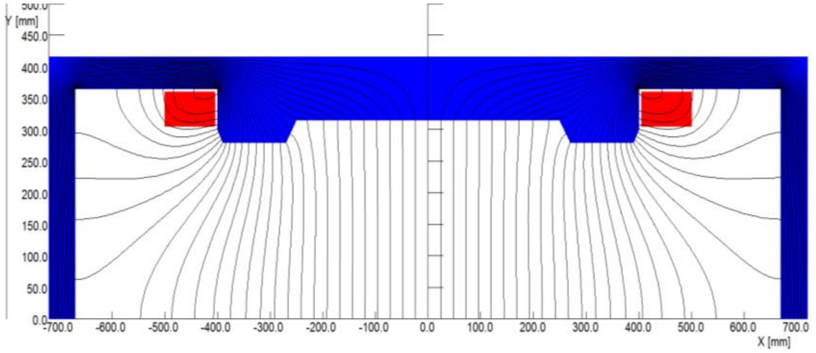
Maximum field strength:
3.86MV/m @150kV
6.95MV/m @270kV

Separator dipole magnet Design

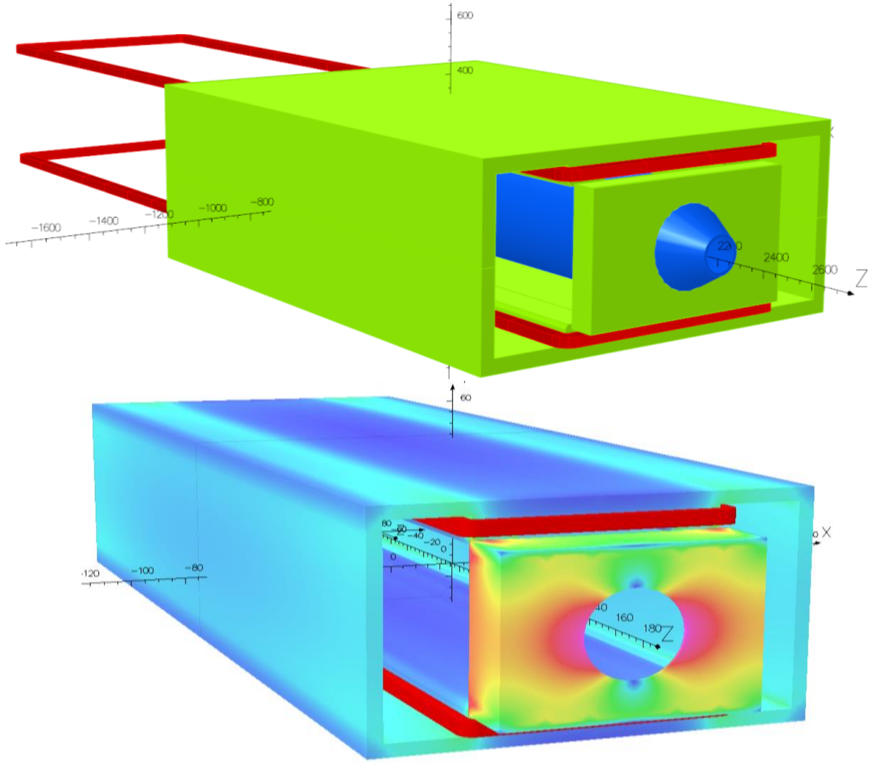
- The magnet adopts h-type yoke structure, because of the higher field integrals uniformity and installation consideration of the electro-static system.
- The magnetic field design and manufacturing technology are quite mature.
- The magnet development is supported by IHEP internal fund.



Field Distribution



Magnetic flux density distribution in the core



3D Model and Magnetic flux density distribution

Electrostatic separator prototype

- Complete design of electrostatic separator both electrical and mechanical design, all parameters are meets design indicators (midterm target)
- The prototyping contract signed in Mar. 2020
- Review of the manufacturer's design carried out on May 11, 2020
- The fabrication is scheduled to be complete by mid of Oct. 2020

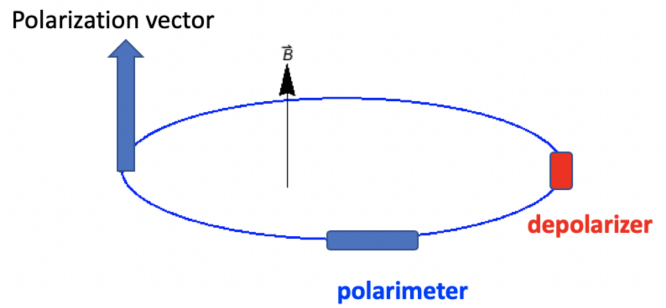
Large flange of UHV tank machining

The body of the vacuum chamber for processing

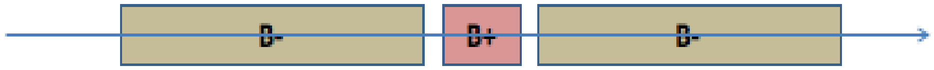
The flange welding

Z-pole Beam polarization design

- Parameter selection of polarization insertion devices and the working mode of the precise energy measurement using resonant depolarization (mid-term indicator 1)
  - Using asymmetric wigglers to boost polarization build-up from 250 hours down to ~ 20 hours
  - Determined the asymmetric wiggler parameters and implemented into the CEPC lattice
  - Designed the scheme of resonant depolarization measurements to continuously monitor the beam energies

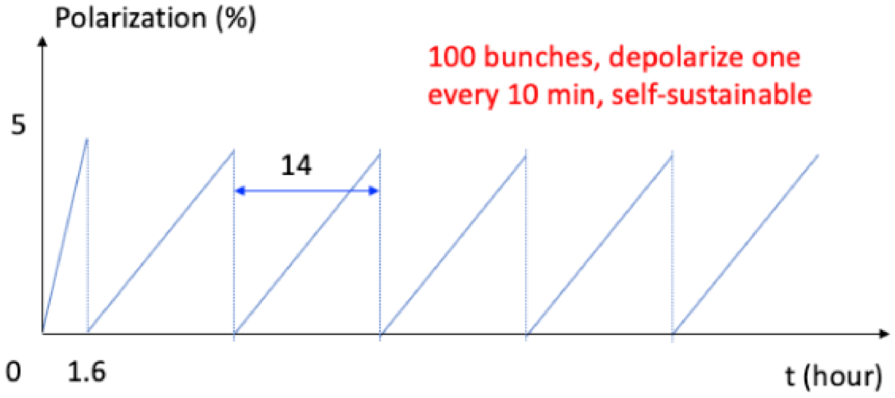


参数	Wiggler 关闭	Wiggler 开启	
Wiggler 数量 N_w	0	1	12
正极性磁场强度 B_+(T)		1. 3	0. 635
负极性磁场强度 B_-(T)		0. 106	0. 051
正极性磁极长度 L_+(L)		0. 65	0. 65
负极性磁极长度 L_-(L)		4. 0	4. 0
自极化时间 τ_p (h)	256	27. 4	21. 9
单圈同步辐射能量损失 U_0(MeV)	36	39. 6	45. 7
非对撞束流能散度 σ_δ	3. 8e-4	1. 1e-3	1. 1e-3
同步辐射功率 (MW)	16. 5 (12000 束团，461 mA)	0. 03 （100 束团，0. 76 mA）	0. 035 （100 束团，0. 76 mA）



Operation scheme

- 100 non-colliding dedicated bunches
- Turn on wigglers only to polarize these bunches
- Afterwards, colliding bunches injected and physics starts
- Self-substainable process



Z-pole Beam polarization design

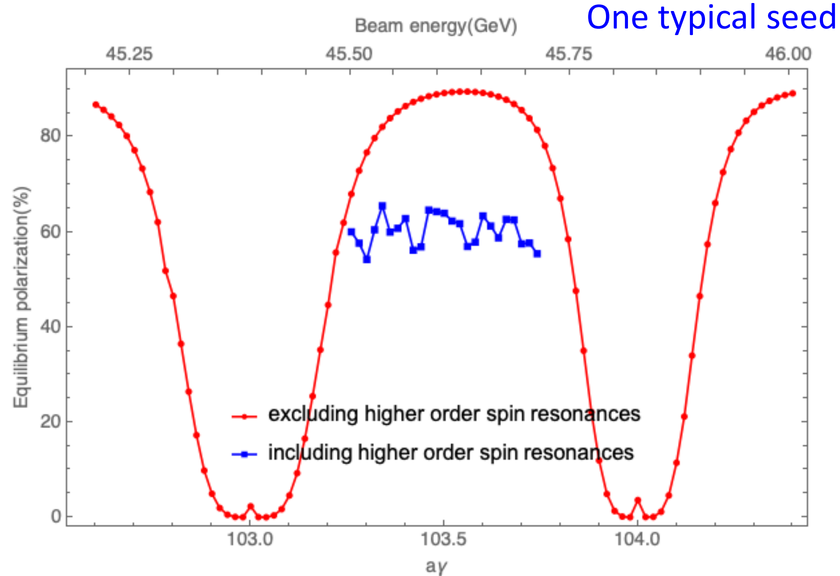
- The realization conditions of beam polarization > 50% are simulated (mid-term indicator 2)
  - <u>Simulated the equilibrium beam polarization of imperfect lattices</u>
    - Updated the simulation program based on PTC, and simulated the equilibrium polarization for realistic imperfect lattice seeds after dedicated correction
    - The equilibrium beam polarization is above 50% for a beam energy of 45.6 GeV ($a\gamma=103.5$) for the 10 simulated lattice seeds, and the polarization time is above 100 hours, much larger than the beam lifetime of 2~3 hours
  - <u>Identified the realization condition of average beam polarization > 50% during colliding beam experiments</u>
    - top-up injection
    - Injected beam polarization > 50%
    - Polarization time >> beam lifetime

Injected beam polarization

Radiative polarization: equilibrium beam polarization in the ring

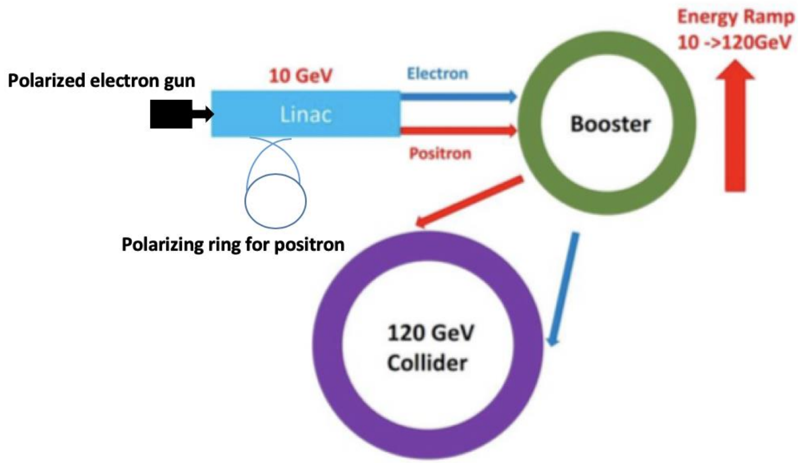
$$P_{avg} = \frac{P_{ens,DK}}{1+\tau_{DK}/\tau_b} + \frac{P_0}{1+\tau_b/\tau_{DK}} \approx P_0$$

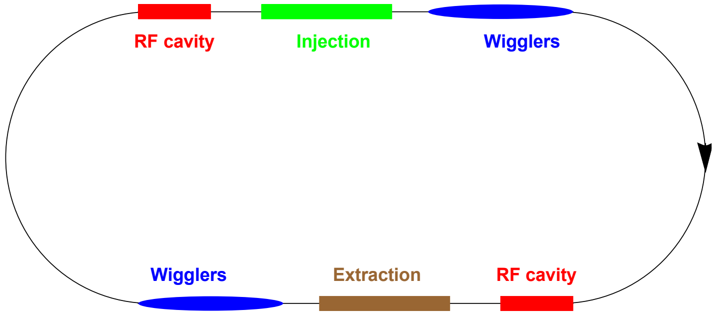
One typical seed



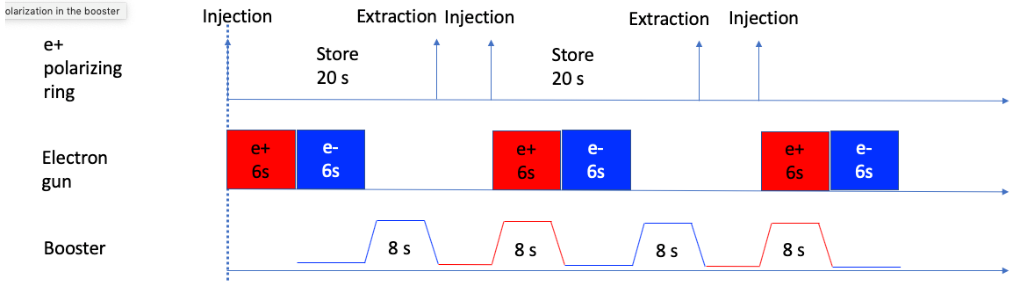
Z-pole Beam polarization design

- To address the great challenges in polarized e+ source, proposed to **convert the e+ damping ring into a e+ polarizing ring**, by introducing asymmetric wigglers, to booster **self-polarization** build-up down to **~20 second**, this novel idea looks promising to facilitate polarized e+/e- colliding beams.
  - Plan: detailed lattice design of e+ polarizing ring, collective effects





CEPC top-up injection timing w/ e+ polarizing ring



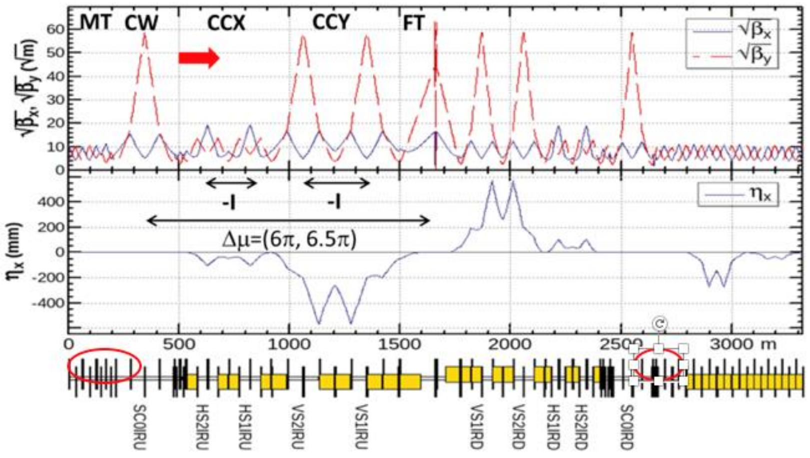
A tentative parameter table of e+ polarizing ring

Parameter	value
Beam energy (GeV)	2.5
Circumference (m)	200
Wiggler total length (m)	22
B+/B- (Tesla)	15[2] / 1.5
U0 (MeV)	4
Polarization build-up time (s)	**17**
rms energy spread	~0.3%
Natural emittance (nm)	~10
Radiation damping time (ms)	~1

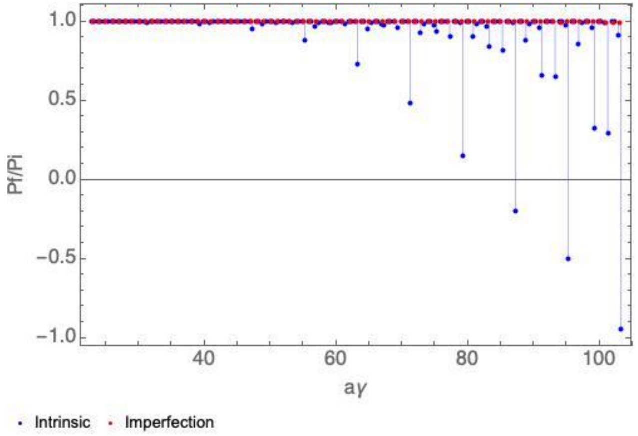
Z-pole Beam polarization design

- Spin rotators in the collider rings to realize longitudinal polarization at IPs
  - Just did first attempt to insert simplified spin rotators into the lattice
  - Plan to do spin matching studies and iterative lattice optimization to achieve high luminosity and polarization, to be delivered by late-2021
- Maintenance of beam polarization in the booster
  - Evaluated the spin resonance strengths throughtout the acceleration and the polarization loss
  - Proposed a concept of Siberian snakes using fixed strength solenoid snakes
  - Plan to carry out detailed design and simulations, to be delivered by mid-2022

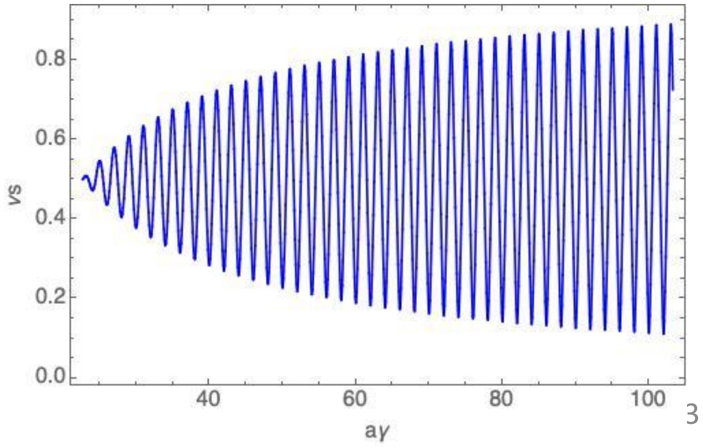
Solenoid spin rotator in the collider ring lattice



Remaining beam polarization after crossing a spin resonance



Closed orbit spin tune for a no-ramping solenoid snake with decreasing s over the beam energy



Papers, patents and international conference talks

Journal Paper:
[1] G. Y. Tang, et al, “The circular electron-positron collider beam energy measurement with Compton scattering and beam tracking method”, Rev. Sci. Instrum. 91, 033109 (2020).

Conference Paper:
[1] Z. Duan et al., “Concepts of longitudinally polarized electron and positron colliding beams in the Circular Electron Positron Collider”, Proc. IPAC 2019, MOPMP012.

Conference talk:
[1] W. Kang, “Development of the prototype dipole magnet for CEPC Booster”, Workshop on the Circular Electron Positron Collider, EU Edition 2019, Oxford, UK, 2019.4.
[2] W. Kang, “CEPC Booster and Collider Ring Magnets R&D”, IAS Program on High Energy Physics 2020, Jan.19-23, Hong Kong, China.
[3] Haiyi Dong, “CEPC Vacuun System”, Workshop on the Circular Electron Positron Collider, Beijing, 2019.11
[4] Bin Chen, “Electrostatic-Magnetic Deflector and Magnet Power supply for CEPC ”, International Workshop on the Circular Electron Positron Collider, Beijing, 2019.11
[5] Bin Chen, “Design of the Electrostatic-Magnetic Deflector for CEPC”, IAS Program on High Energy Physics 2019, Jan.21-24, Hong Kong, China.
[6] Z. Duan, “Polarized electron and positron beams at CEPC”, mini-workshop on “Beam polarization in future colliders”, IAS-HKUST, HK, 2019. 1.
[7] W. H. Xia, “Preliminary studies of beam polarization in CEPC”, mini-workshop on “Beam polarization in future colliders”, IAS-HKUST, HK, 2019. 1.
[8] Z. Duan, “CEPC Z-pole polarization”, Workshop on the Circular Electron Positron Collider, EU Edition 2019, Oxford, UK, 2019.4.
[9] Z. Duan, “CEPC Z-pole polarization”, Workshop on the Circular Electron Positron Collider, Beijing, 2019.11.

Seminar:
[1] Z. Duan, “Longitudinally polarized colliding beams at the Circular Electron Positron Collider”, TDLI & INPAC Joint Theoretical Particle Physics Seminar Series, Shanghai Jiaotong University, 13/01/2020.

Outline

I. Overall progress

II. Important progress and achievements

III. Existing problems and solutions

IV. Use of personnel and funds

V. Summary

Existing problems and solutions

Mission 1- Low-field Booster dipole magnet :

– No

Mission 2- Main ring vacuum system :

– No

Mission 3- Electrostatic separator :

– No

Mission 4- Beam polarization design ：

– Due to the Covid-19 pandemic, international travels have been delayed till indefinite future. This impedes collaborative studies of CEPC beam polarization with experts from BINP of Russian.

Solution ：

– Attempt to establish some mechanism of routine video meetings with BINP colleagues

– Attempt to organize video mini-workshops at a later stage, to invite more discussions from international experts

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Use of personnel and funds

1. 人员及经费投入情况

- 本课题批准的的专项经费为974万，到账经费为872.9万元，是项目经费的 89.6 %。
- 已累计支出约453.1 万元，相对到账经费的执行率约51.9 %。
- 课题投入人员 18人，包括 11 名高级职称，7 名中级职称，另有4名博士：孙晓阳、马永胜（在职）、朱建斌、夏文昊。

2. 课题经费拨付情况

- 无

九、课题参加人员基本情况表

填表说明：
1.职称分类：A、正高级　B、副高级　C、中级　D、初级　E、其他；
2.投入本课题的全时工作时间（人月）是指在课题实施期间该人总共为课题工作的满月度工作量；累计是指课题组所有人员投入人月之和；
3.课题固定研究人员需填写人员明细；
4.是否有工资性收入：Y、是　N、否；
5.人员分类代码：A、课题负责人　B、课题骨干　C、其他研究人员；
6.工作单位：填写单位全称，其中高校要具体填写到所在院系。

序号	姓名	性别	出生日期	身份证号码（军官证、护照）	技术职称	职务	学位	专业	投入本课题的全时工作时间（人月）	人员分类	在课题中分担的任务	是否有工资性收入	工作单位
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1	池云龙	男	1964-08-03	110108196408039013	正高级	加速器中心副主任	学士	加速器技术	40	课题负责人	课题负责人	是	中国科学院高能物理研究所
2	康　文	男	1972-04-03	622201197204031535	正高级	组长	博士	磁铁技术	30	课题骨干	高精度低场磁铁方案设计	是	中国科学院高能物理研究所
3	杨　梅	女	1982-01-12	429006198201125426	中级	无	硕士	磁铁技术	20	课题骨干	高精度低场磁铁磁场设计	是	中国科学院高能物理研究所
4	陈　沅	男	1979-09-20	110102197909202313	副高级	无	博士	磁铁技术	30	课题骨干	高精度低场磁铁磁场设计	是	中国科学院高能物理研究所
5	周建新	男	1983-06-12	420621198306128955	副高级	无	博士	磁铁技术	30	课题骨干	高精度低场磁铁磁场测量	是	中国科学院高能物理研究所
6	刘　鹏	男	1990-02-21	110105199002215819	中级	无	硕士	电源技术	30	课题骨干	静电分离器高压部件设计	是	中国科学院高能物理研究所
7	董海义	男	1964-02-04	110107196402041239	正高级	组长	硕士	真空技术	30	课题骨干	真空系统设计研究	是	中国科学院高能物理研究所
8	宋　洪	女	1963-08-12	110107196308121283	正高级	无	学士	真空技术	30	课题骨干	真空盒设计研究	是	中国科学院高能物理研究所
9	李　琦	女	1971-09-12	110103197109120623	副高级	无	学士	真空技术	30	课题骨干	真空盒设计研究	是	中国科学院高能物理研究所
10	黄　涛	男	1983-02-21	420583198302212811	中级	无	硕士	真空技术	30	课题骨干	真空盒内表面镀膜设计研究	是	中国科学院高能物理研究所
11	刘佳明	男	1987-05-20	152221198705204614	中级	无	硕士	真空技术	30	课题骨干	RF 屏蔽波纹管设计研究	是	中国科学院高能物理研究所
12	马永胜	男	1986-10-16	622424198610160017	中级	无	硕士	真空技术	30	课题骨干	RF 屏蔽波纹管设计研究	是	中国科学院高能物理研究所
13	陈　斌	男	1974-02-14	110106197402141836	副高级	无	学士	电源技术	30	课题骨干	静电分离器研究	是	中国科学院高能物理研究所
14	王冠文	男	1987-04-16	22020419870416151X	中级	无	博士	电源技术	30	课题骨干	静电分离器机械结构设计	是	中国科学院高能物理研究所
15	李小平	男	1982-04-18	350583198204187116	副高级	无	博士	加速器技术	20	课题骨干	极化束流源研究	是	中国科学院高能物理研究所
16	王　逗	女	1983-09-03	61052119830903062X	副高级	无	博士	加速器物理	10	其他研究人员	极化束工作模式与参数研究	是	中国科学院高能物理研究所
17	王毅伟	男	1985-09-24	350681198509240013	中级	无	博士	加速器物理	30	课题骨干	磁聚焦结构设计优化	是	中国科学院高能物理研究所
18	段　哲	男	1986-09-26	61050219860926025X	中级	无	博士	加速器物理	20	课题骨干	极化束数值模拟与误差分析	是	中国科学院高能物理研究所

Task1: Comparison between Implementation and Budget until Midterm

序号	预算科目名称	total	Budget until Midterm	Implementation until 2020/6/30	Rate of expense/total budget	Rate of expense/midterm budget
2	（一）direct fee	878.19	430.49	379.5	43.21%	88.16%
3	1、device fee	456	261	333.2	73.07%	127.66%
4	(1) purchase device	140	75	105.9	75.64%	141.20%
5	(2) trail device	296	166	227.3	76.79%	136.93%
6	(3) modifed device	20	20	0.00	0.00%	0.00%
7	2、material fee	116	56	2.9	2.50%	5.18%
8	3、testing fee	76.2	24.7	2	2.62%	8.10%
9	4、power fee	18	4	0	0.00%	0.00%
10	5、travel/conference/international communication	131.1	53.2	21.9	16.70%	41.17%
11	6、publication	20.29	15.19	1.6	7.89%	10.53%
12	7、labor	51	13.6	17.9	35.10%	131.62%
13	8、consult	9.6	2.8	0	0.00%	0.00%

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Summary- Magnet

- Two kinds of subscale prototype dipole magnets with and without iron cores were fabricated and tested.
- Although the field precision of the dipole magnet with iron cores has reached the midterm target at 60Gs, it is difficult to meet the precision requirement at low level of 28 Gs due to the unavoidable influence of the remnant field.
- The CT coil dipole magnet without iron cores has high precision and good reproducibility field both at low and high field level, which is satisfied with the final requirements.
- The full-scale CT dipole magnet has been designed on the basis of the good test results of the subscale prototype magnet and will be fabricated in the April of next year.

Summary- Vacuum

- The prototypes of copper & aluminum vacuum chambers with a length of 6 m have been fabricated and tested, which meet the engineering requirements. Surface treatment of copper will be taken into accountant.
- The key components experiments such as spring fingers and contact fingers have been carried out. Contact force is uniform by different fingers and meets the target of 125±25g.
- 1.5m long vacuum pipe have been coated to explore the coating parameter at geometrical shape of 56mm×75mm.
- 6m long vacuum chambers will be coated by moving the solenoid by a horizontal coating equipment .

Summary- Separator

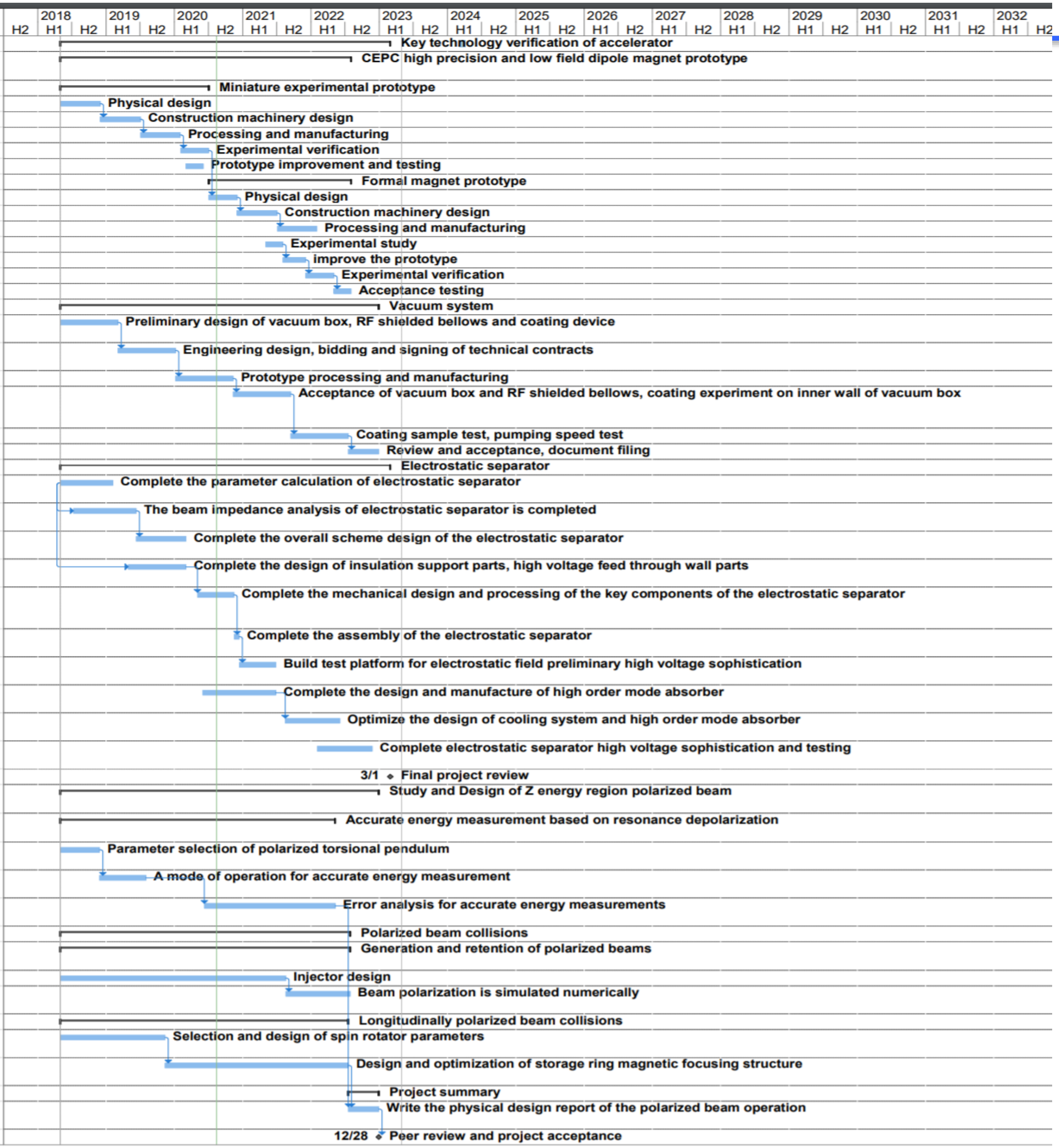
- Complete design of electrostatic separator both electrical and mechanical design, all parameters are meets design indicators.
- Carried out design of separator dipole magnet, The magnetic field design and manufacturing technique is quite mature. The magnet R&D is supported by IHEP internal fund.
- Start separator prototype fabrication and scheduled to be complete by mid of October 2020.

Summary- Polarization

- Mid-term assessment indicators have been reached
  - Operation scheme of polarized beam for energy calibration
  - Simulation of beam polarization for realistic imperfect lattices
- Some progresses beyond mid-term have been made
  - Proposal of e+ polarizing ring
  - Maintenance of polarization in Booster
  - Spin rotator in the Collider ring

Schedule

ID	WBS	Chinese Name	Task Name	Duration	Start	Finish
1	**1**	**高能环形政府电子对撞机加速**	**Key technology verification of accelerator**	**1261 days**	**18/5/1**	**23/3/1**
2	**1.1**	**CEPC高精度低场二极磁铁样机**	**CEPC high precision and low field dipole magnet prototype**	**1111 days**	**18/5/1**	**22/8/2**
3	**1.1.1**	**小型实验样机**	**Miniature experimental prototype**	**568 days**	**18/5/1**	**20/7/2**
4	1.1.1.1	物理设计	Physical design	153 days	18/5/1	18/11/29
5	1.1.1.2	工程机械设计	Construction machinery design	153 days	18/11/30	19/7/2
6	1.1.1.3	加工制造	Processing and manufacturing	153 days	19/7/3	20/1/31
7	1.1.1.4	实验验证	Experimental verification	109 days	20/2/3	20/7/2
8	1.1.1.5	样机改进及测试	Prototype improvement and testing	66 days	20/3/3	20/6/2
9	**1.1.2**	**正式磁铁样机**	**Formal magnet prototype**	**543 days**	**20/7/3**	**22/8/2**
10	1.1.2.1	物理设计	Physical design	108 days	20/7/3	20/12/1
11	1.1.2.2	工程机械设计	Construction machinery design	153 days	20/12/2	21/7/2
12	1.1.2.3	加工制造	Processing and manufacturing	151 days	21/7/5	22/1/31
13	1.1.2.4	实验研究	Experimental study	66 days	21/5/3	21/8/2
14	1.1.2.5	样机改进	improve the prototype	88 days	21/8/3	21/12/2
15	1.1.2.6	实验验证	Experimental verification	107 days	21/12/3	22/5/2
16	1.1.2.7	测试验收	Acceptance testing	66 days	22/5/3	22/8/2
17	**1.2**	**真空系统**	**Vacuum system**	**1217 days**	**18/5/1**	**22/12/28**
18	1.2.1	真空盒、RF屏蔽波纹管、镀膜装置初步设计	Preliminary design of vacuum box, RF shielded bellows and coating device	220 days	18/5/1	19/3/4
19	1.2.2	工程设计、招投标、签订技术合同	Engineering design, bidding and signing of technical contracts	220 days	19/3/5	20/1/6
20	1.2.3	样机加工和制造	Prototype processing and manufacturing	220 days	20/1/7	20/11/9
21	1.2.4	真空盒、RF屏蔽波纹管验收，真空盒内壁镀膜实验	Acceptance of vacuum box and RF shielded bellows, coating experiment on inner wall of vacuum box	220 days	20/11/10	21/9/13
22	1.2.5	镀膜样品检测，抽速测试	Coating sample test, pumping speed test	220 days	21/9/14	22/7/18
23	1.2.6	评审验收，资料归档	Review and acceptance, document filing	117 days	22/7/19	22/12/28
24	**1.3**	**静电分离器**	**Electrostatic separator**	**1261 days**	**18/5/1**	**23/3/1**
25	1.3.1	完成静电分离器参数计算	Complete the parameter calculation of electrostatic separator	200 days	18/5/1	19/2/4
26	1.3.2	完成静电分离器束流阻抗分析	The beam impedance analysis of electrostatic separator is completed	240 days	18/7/10	19/6/10
27	1.3.3	完成静电分离器的整体方案设计	Complete the overall scheme design of the electrostatic separator	190 days	19/6/11	20/3/2
28	1.3.4	完成绝缘支撑件、高压馈电穿墙件设计	Complete the design of insulation support parts, high voltage feed through wall parts	220 days	19/4/30	20/3/2
29	1.3.5	完成静电分离器各关键部件的机械设计及加工	Complete the mechanical design and processing of the key components of the electrostatic separator	140 days	20/5/4	20/11/13
30	1.3.6	完成静电分离器整体组装	Complete the assembly of the electrostatic separator	20 days	20/11/16	20/12/11
31	1.3.7	搭建测试平台，进行静电场初步高压老练	Build test platform for electrostatic field preliminary high voltage sophistication	140 days	20/12/14	21/6/25
32	1.3.8	完成高阶模吸收器的设计及加工	Complete the design and manufacture of high order mode absorber	280 days	20/6/1	21/6/25
33	1.3.9	进行冷却系统和高阶模吸收器的优化设计	Optimize the design of cooling system and high order mode absorber	210 days	21/8/16	22/6/3
34	1.3.10	完成静电分离器高压老练和测试	Complete electrostatic separator high voltage sophistication and testing	210 days	22/2/3	22/11/23
35	1.3.11	项目结题评审	Final project review	0 days	23/3/1	23/3/1
36	**1.4**	**Z能区极化束流的研究与设计**	**Study and Design of Z energy region polarized beam**	**1217 days**	**18/5/1**	**22/12/28**
37	**1.4.1**	**基于共振退极化的精确能量测量**	**Accurate energy measurement based on resonance depolarization**	**1050 days**	**18/5/1**	**22/5/9**
38	1.4.1.1	极化扭摆器的参数选择	Parameter selection of polarized torsional pendulum	150 days	18/5/1	18/11/26
39	1.4.1.2	精确能量测量的工作模式	A mode of operation for accurate energy measurement	178 days	18/11/27	19/8/1
40	1.4.1.3	精确能量测量的误差分析	Error analysis for accurate energy measurements	500 days	20/6/9	22/5/9
41	**1.4.2**	**极化束流对撞**	**Polarized beam collisions**	**1108 days**	**18/5/1**	**22/7/28**
42	**1.4.2.1**	**极化束流的产生和保持**	**Generation and retention of polarized beams**	**1108 days**	**18/5/1**	**22/7/28**
43	1.4.2.1.1	注入器设计	Injector design	861 days	18/5/1	21/8/17
44	1.4.2.1.2	束流极化度保持数值模拟	Beam polarization is simulated numerically	247 days	21/8/18	22/7/28
45	**1.4.2.2**	**纵向极化束流对撞**	**Longitudinally polarized beam collisions**	**1100 days**	**18/5/1**	**22/7/18**
46	1.4.2.2.1	自旋旋转器参数选择与设计	Selection and design of spin rotator parameters	400 days	18/5/1	19/11/11
47	1.4.2.2.2	储存环磁聚焦结构设计与优化	Design and optimization of storage ring magnetic focusing structure	700 days	19/11/12	22/7/18
48	**1.4.3**	**项目总结**	**Project summary**	**117 days**	**22/7/19**	**22/12/28**
49	1.4.3.1	撰写极化束流运行的物理设计报告	Write the physical design report of the polarized beam operation	117 days	22/7/19	22/12/28
50	1.4.3.2	同行评议和项目验收	Peer review and project acceptance	0 days	22/12/28	22/12/28



Thank you for your attention！