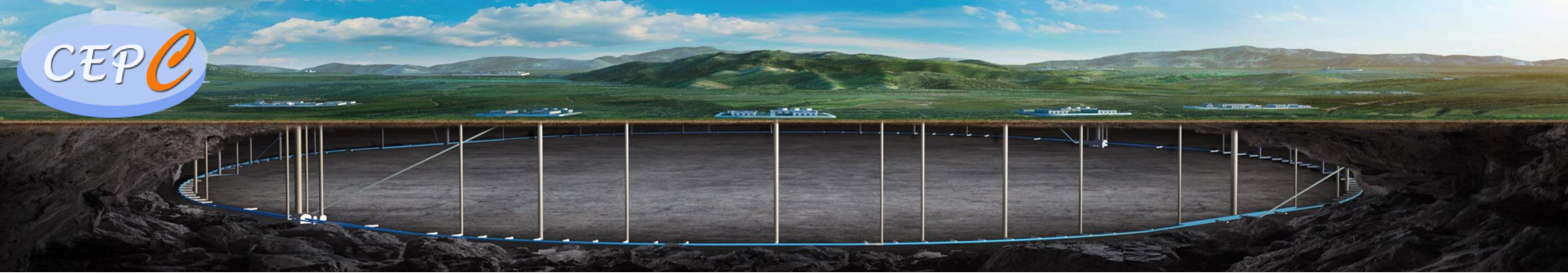


CEPC Accelerator Developments

Yuhui Li

On behalf of the CEPC accelerator team

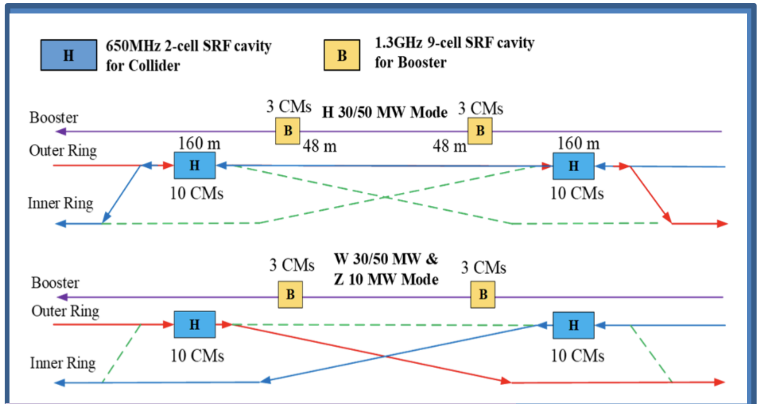
中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

8-11 July, Tokyo, Japan, LCWS2024 International Workshop on Future Linear Colliders

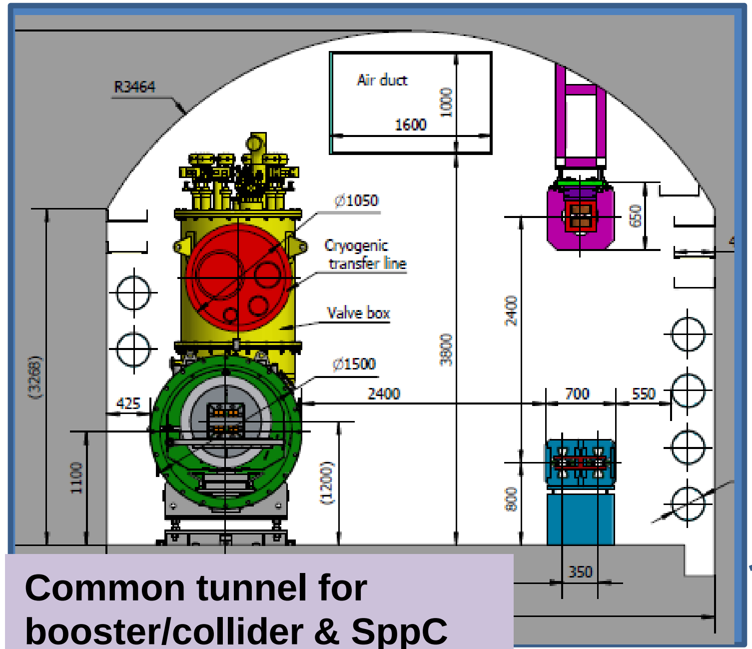
Content

- Accelerator complex layout and design essentials
- CEPC accelerator design and key technology R&D in TDR
  - Physics design
  - Key technology R&D
  - CEPC accelerator TDR review and release
- CEPC accelerator EDR plan
- Summary

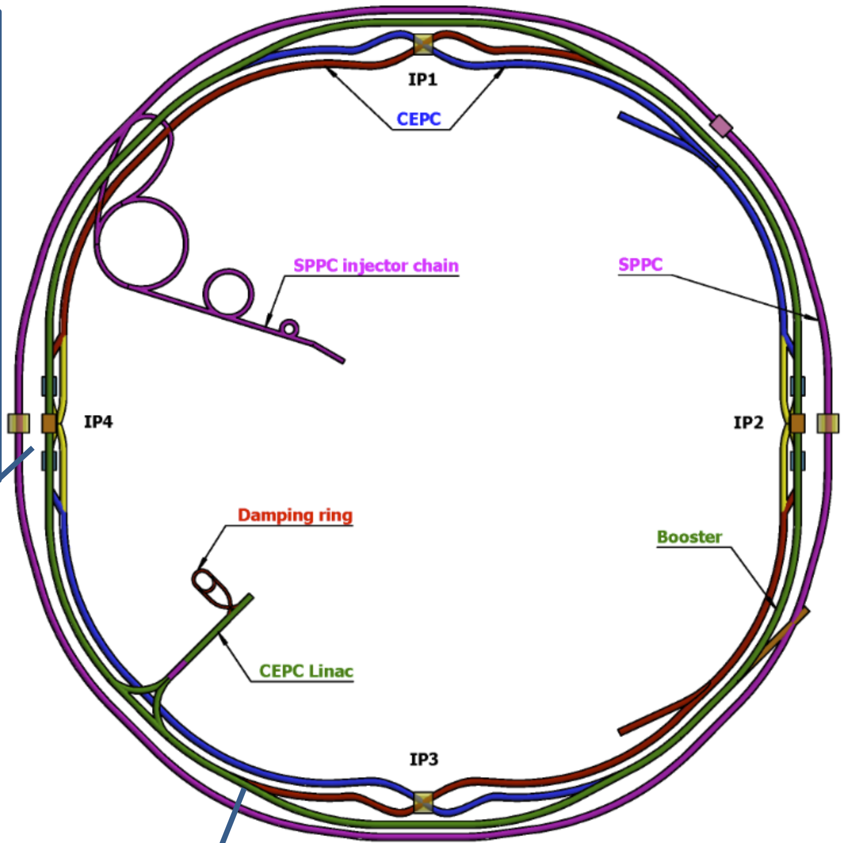
CEPC Layout and Design Essentials



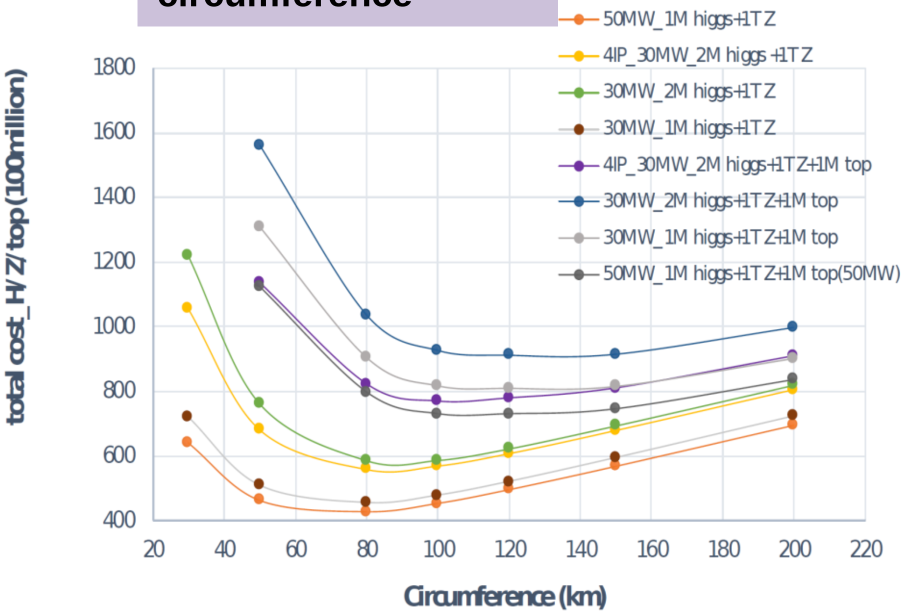
Switchable operation for Higgs W and Z



Common tunnel for booster/collider & SppC



Cost optimization v.s. circumference



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

- **Circular collider**: Higher luminosity than a linear collider
- **100km circumference**: Optimum total cost
- **Shared tunnel**: Compatible design for CEPC and SppC
- **Switchable operation**: Higgs, W/Z, top

Key parameters in different machines

- **Comprehensive parameters have been designed for: Linac, Booster, Collider, transport lines**

Linac

Parameter	Symbol	Unit	Baseline
Energy	E_{e-}/E_{e+}	GeV	**30**
Repetition rate	f_{rep}	Hz	100
Bunch number per pulse			1 or 2
Bunch charge		nC	1.5 (3)
Energy spread	σ_E		1.5×10^{-3}
Emittance	ε_r	nm	6.5

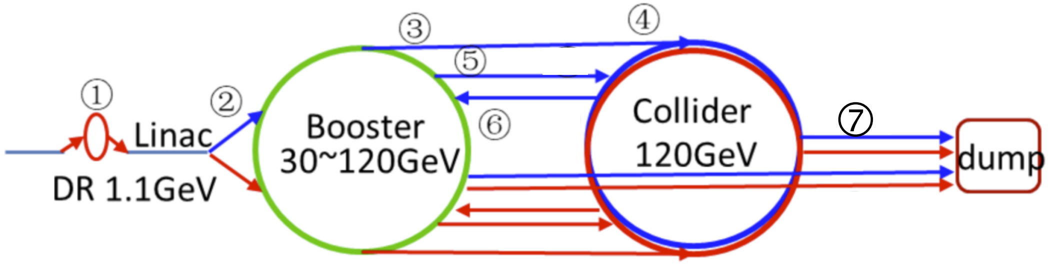
Booster

		tt	***H***		***W***	***Z***	
		Off axis injection	Off axis injection	On axis injection	Off axis injection	Off axis injection	
Circumfer.	km	**100**					
Injection energy	GeV	**30**					
Extraction energy	GeV	**180**	**120**		**80**	**45.5**	
Bunch number		35	268	261+7	1297	3978	5967
Maximum bunch charge	nC	0.99	0.7	20.3	0.73	0.8	0.81
Beam current	mA	0.11	0.94	0.98	2.85	9.5	14.4
SR power	MW	0.93	0.94	1.66	0.94	0.323	0.49
Emittance	nm	2.83	1.26		0.56	0.19	
RF frequency	GHz	1.3					
RF voltage	GV	9.7	2.17		0.87	0.46	
Full injection from empty	h	0.1	0.14	0.16	0.27	1.8	0.8

Collider

	Higgs	**Z**	**W**	$t\bar{t}$
Number of IPs	2			
Circumference (km)	**100.0**			
SR power per beam (MW)	**30**			
Energy (GeV)	**120**	**45.5**	**80**	**180**
Bunch number	268	11934	1297	35
Emittance $\varepsilon_x/\varepsilon_y$ (nm/pm)	0.64/1.3	0.27/1.4	0.87/1.7	1.4/4.7
Beam size at IP σ_x/σ_y (um/nm)	14/36	6/35	13/42	39/113
Bunch length (natural/total) (mm)	2.3/4.1	2.5/8.7	2.5/4.9	2.2/2.9
Beam-beam parameters ξ_x/ξ_y	0.015/0.11	0.004/0.127	0.012/0.113	0.071/0.1
RF frequency (MHz)	650			
Luminosity per IP (10^{34} cm^{-2} s^{-1})	**5.0**	**115**	**16**	**0.5**

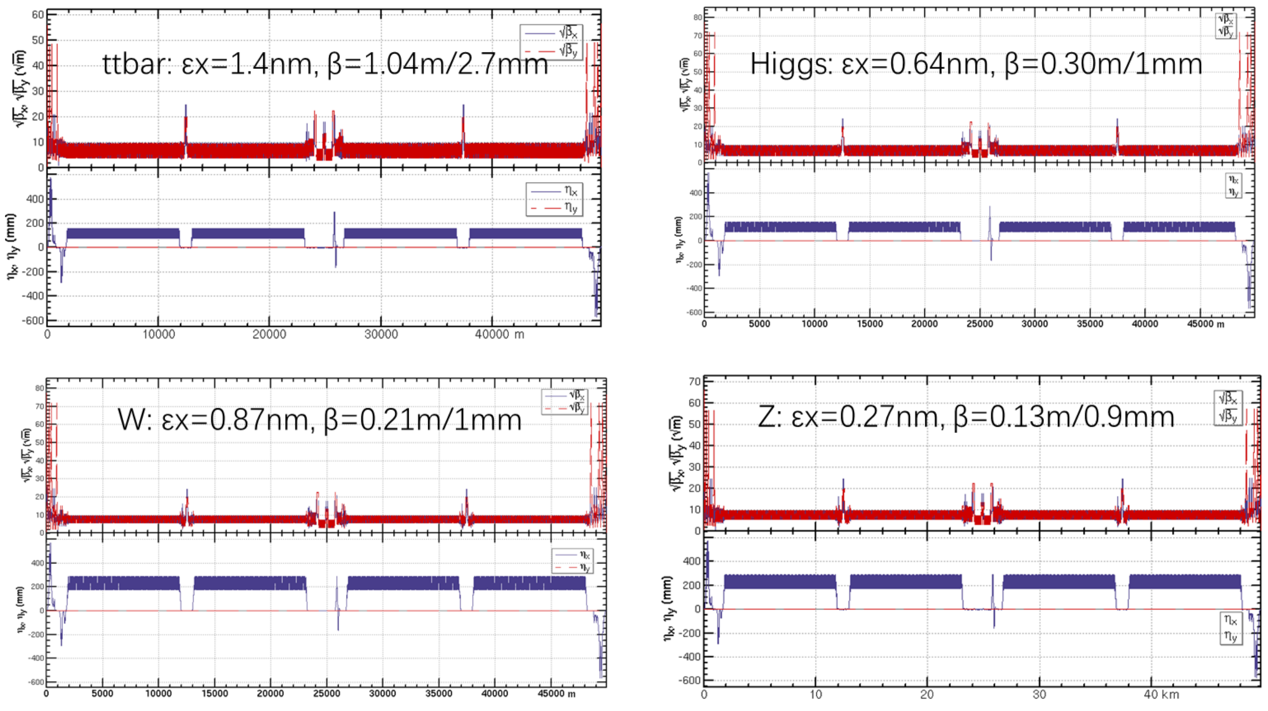
Transport line



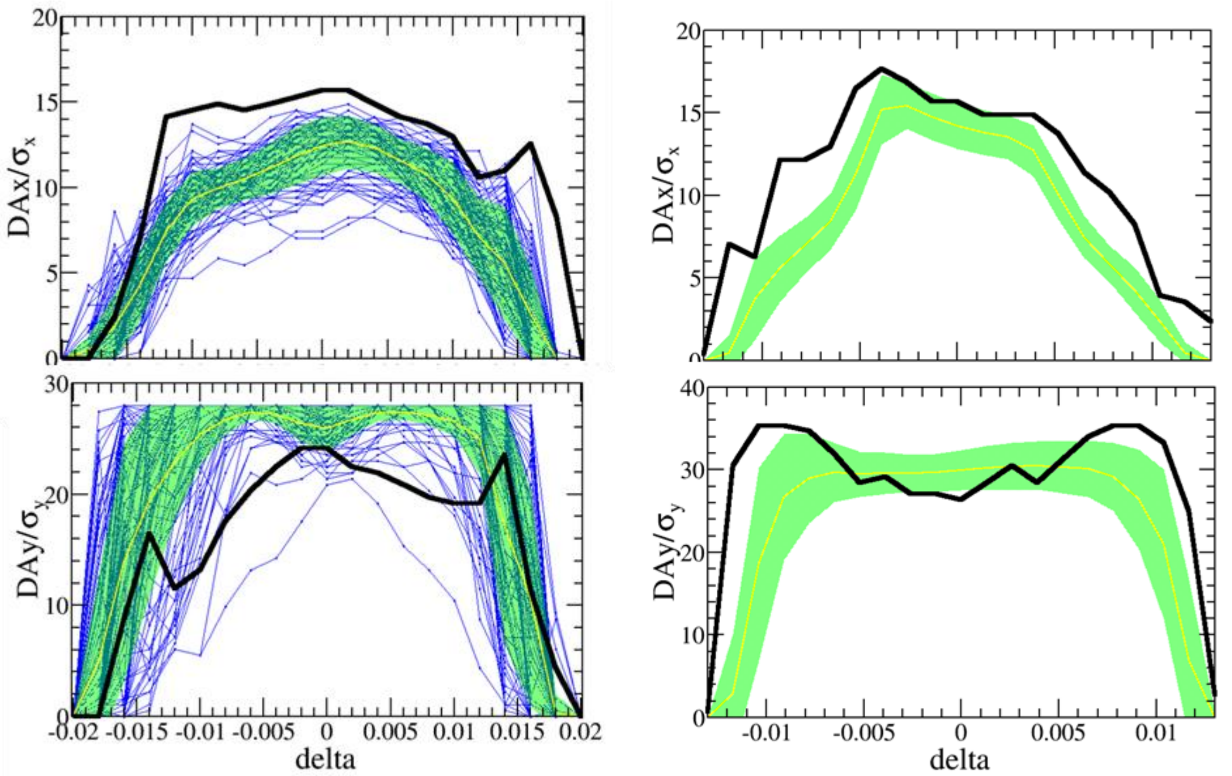
1. Injection/Extraction to the Damping ring (e^+)
2. Injection to the Booster ring from Linac (e^+/e^-)
3. Booster ring extraction system (e+/e-)
4. Collider off-axis injection system (e+/e-)
5. collider on-axis swap-out injection (e+/e-)
6. Collider swap-out extraction (e+/e-)
7. beam dump system (e+/e-)

Collider lattice for all energies

- Lattice design for MDI, Arc, straight line for all modes



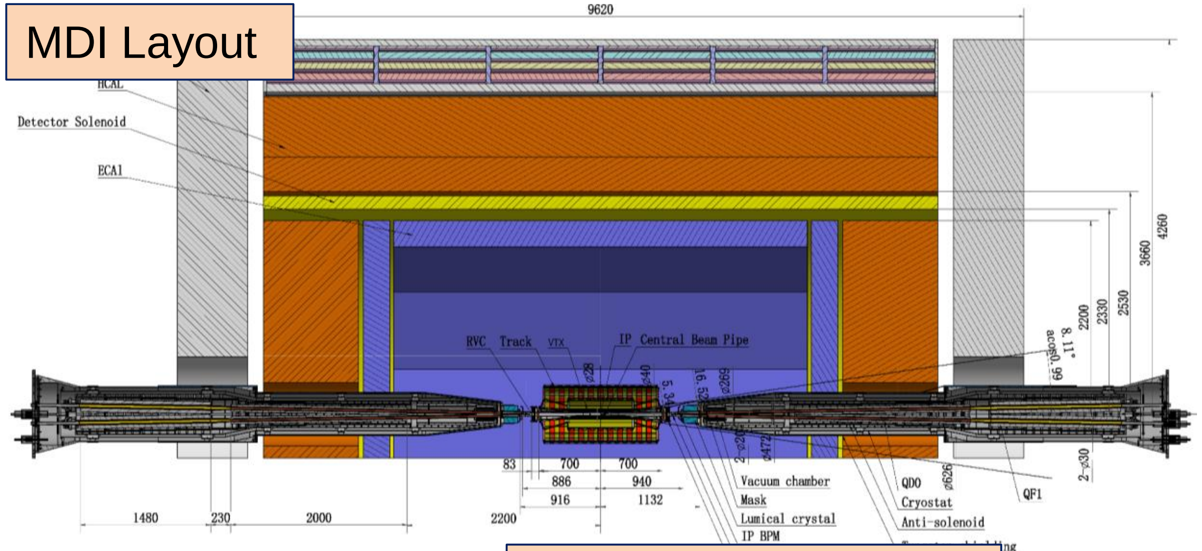
- Emittance & DA with errors



- The global lattice design for the regions of MDI, Arc, straight line, was conducted for all energies;
- Emittance and DA for all modes were optimized. Errors were included and mitigation measures were carried out;
- Based on the physical design, the CEPC main parameters, including luminosities, are calculated

MDI study

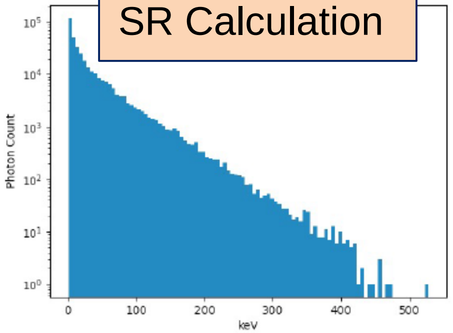
MDI Layout

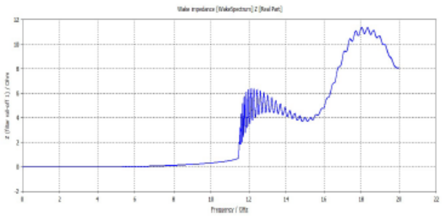


General Parameters

				end ngle	length	Beam stay clear region	Mini. distance between apertures	Beam pipe Inner diameter	Beam pipe outer diameter	Critical energy (Hor.)	Critical energy (Vert.)	SR power (Hor.)	SR power (Vert.)
L*	0~1.9m				1.9m								
Crossing angle	33mrad												
MDI length	±7m												
Acc. components in opening angle	8.11°												
QDa/QDb		3.5/2.8T	142/85T/m		1.21m	14.9/18.2mm	62.71/105.28mm	20/23mm	26/29mm	724.7/663.1keV	396.3/263keV	212.2/239.23W	99.9/42.8W
QF1		3.3T	96.7T/m		1.5m	24.48mm	155.11mm	32mm	38mm	675.2keV	499.4keV	472.9W	135.1W
Lumical	0.65~1.11m				0.16m								
Anti-solenoid before QD0		8.6T			1.1m								
Anti-solenoid QD0		3T			2.5m								
Anti-solenoid QF1		3T			1.5m								
Beryllium pipe					±85mm			20mm					
Last B upstream	64.97~153.5m			0.77mrad	88.5m					33.3keV			
First B downstream	44.4~102m			1.17mrad	57.6m					77.9keV			
Beampipe within QDa/QDb					1.21m							1.19/1.31W	
Beampipe within QF1					1.5m							2.39W	
					0.3m							26.5W	

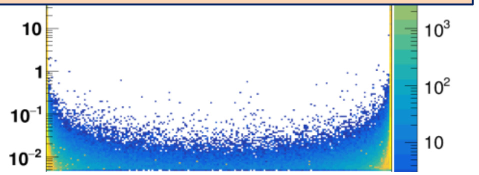
SR Calculation

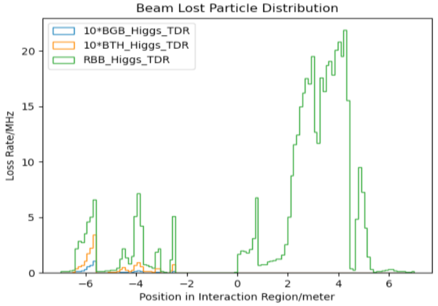




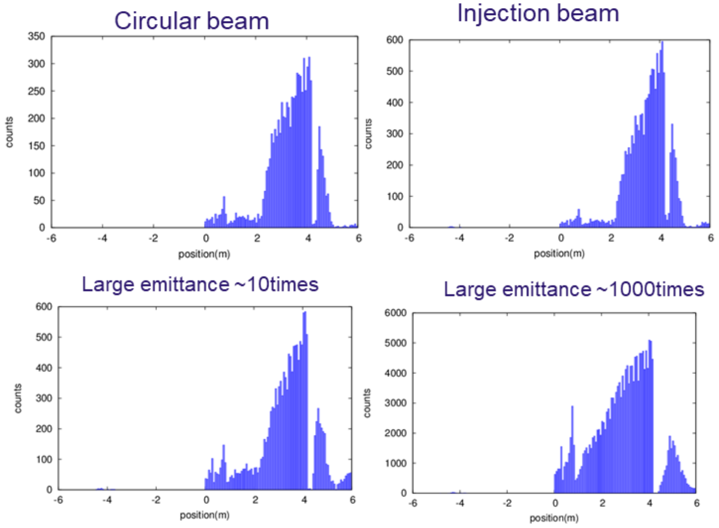
Radiation background

Radiative barbar, Beam-Gas, beam thermal photon scattering



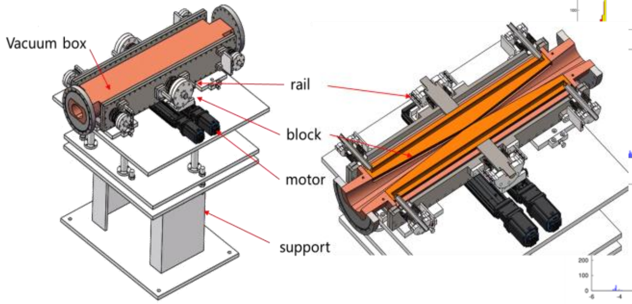


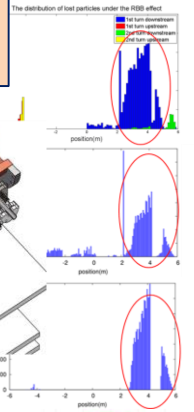
Injection background

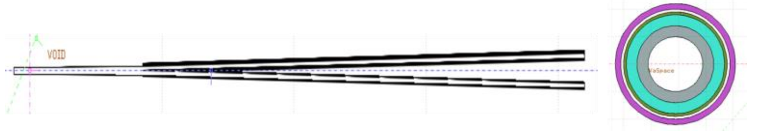


Radiation Mitigation

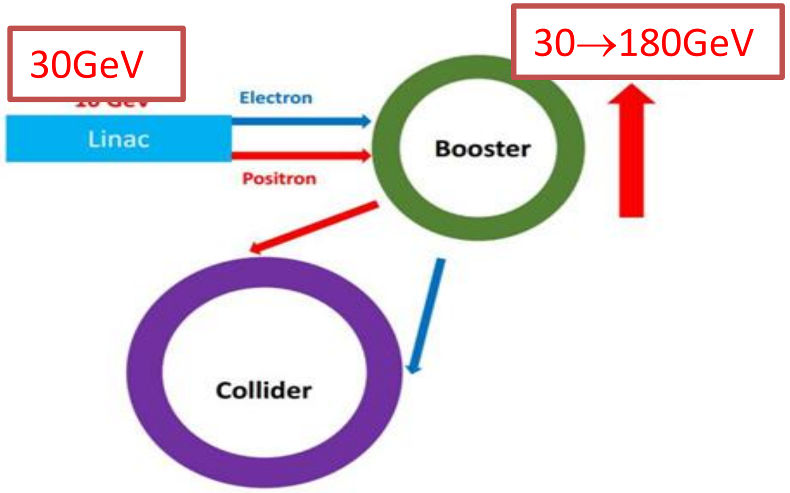
Masks, collimators, shielding



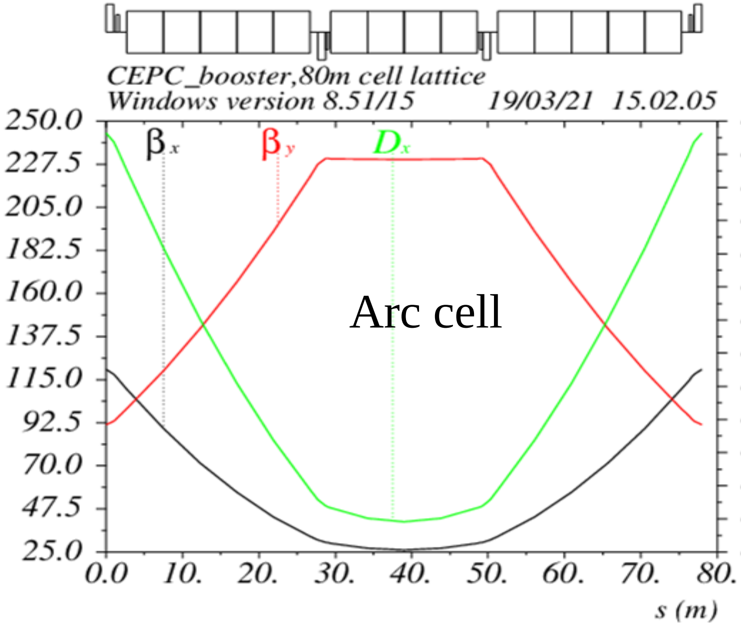


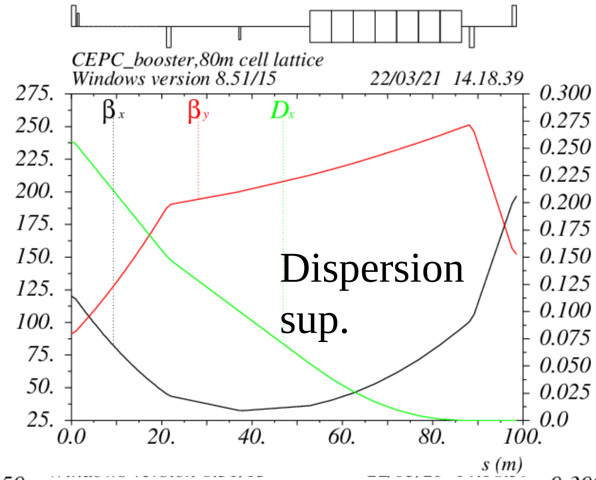


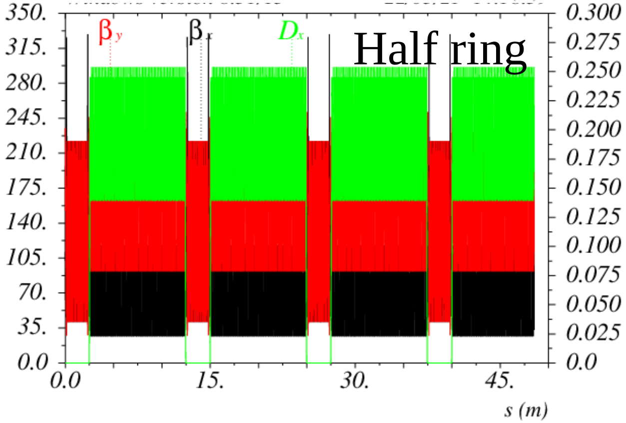
Booster design

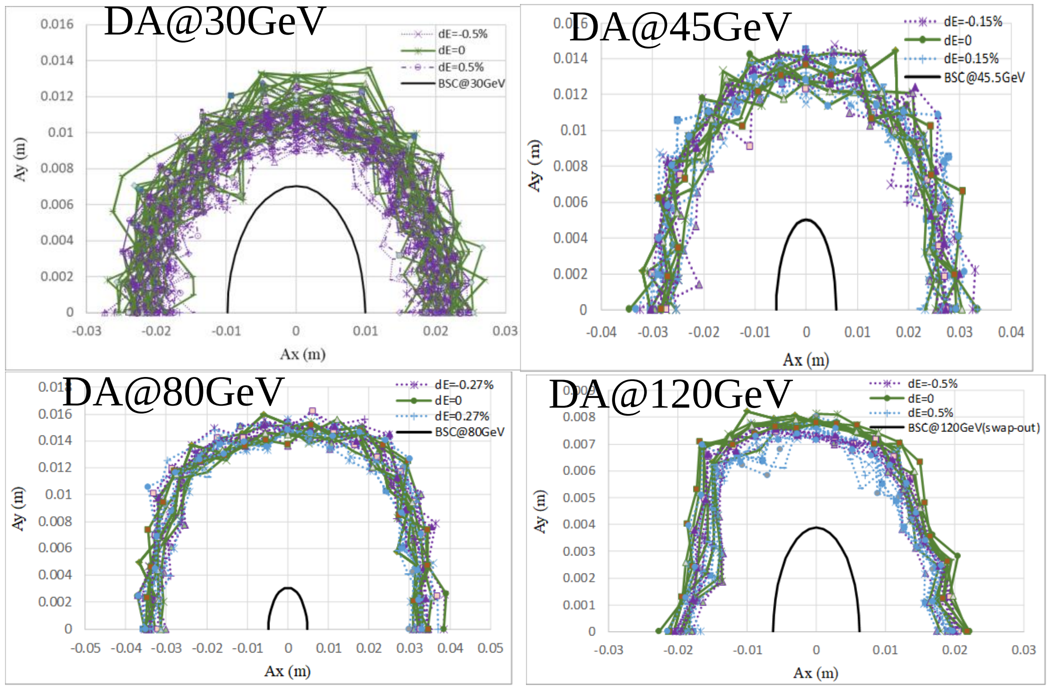


- TME like structure (cell length=78m)
- Interleave sextupole scheme
- Emittance@120GeV=1.26nm



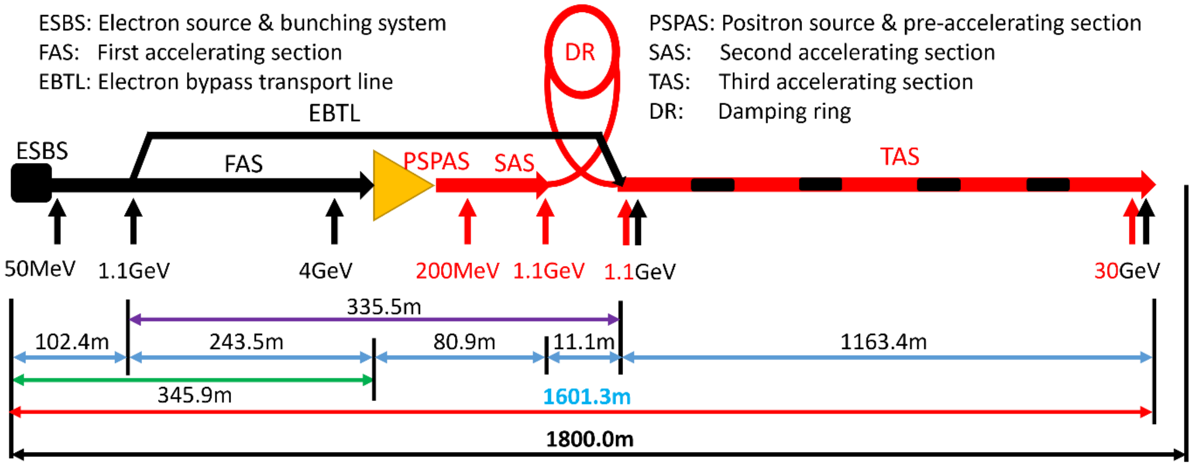




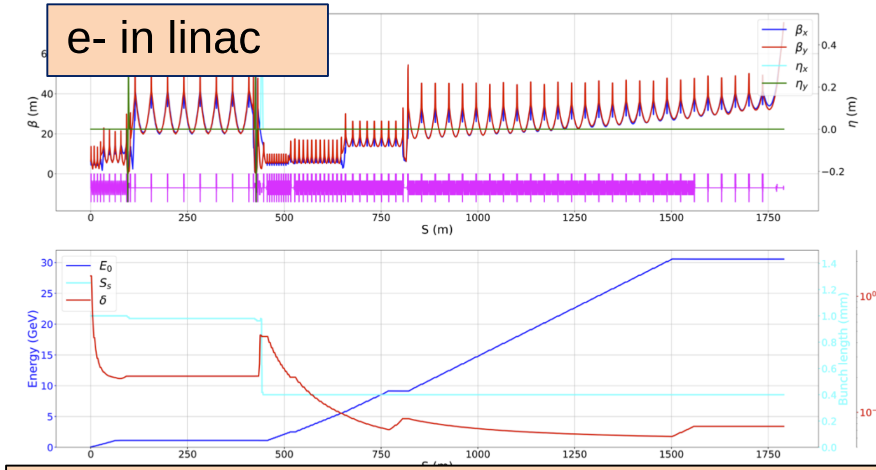


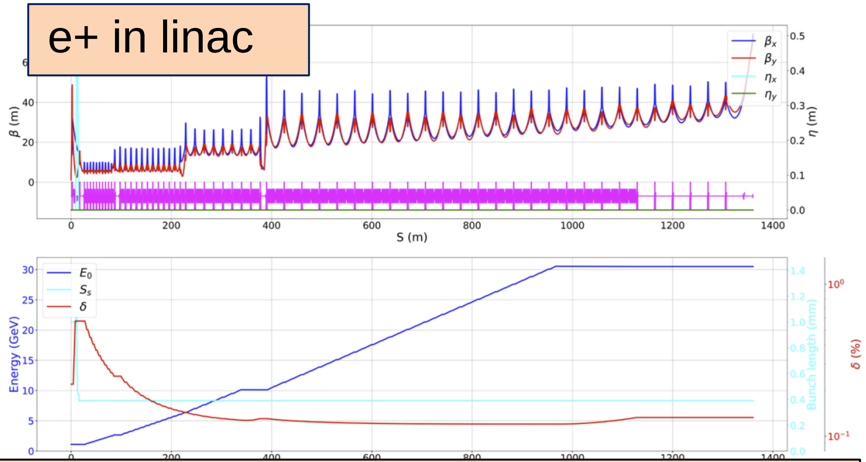
- **30 GeV injection energy, Maximum extraction energy @ 180GeV**
- **Lattice design with TME structure, lower emittance than CDR**
- **Sufficient Dynamic Aperture for all energies with errors**

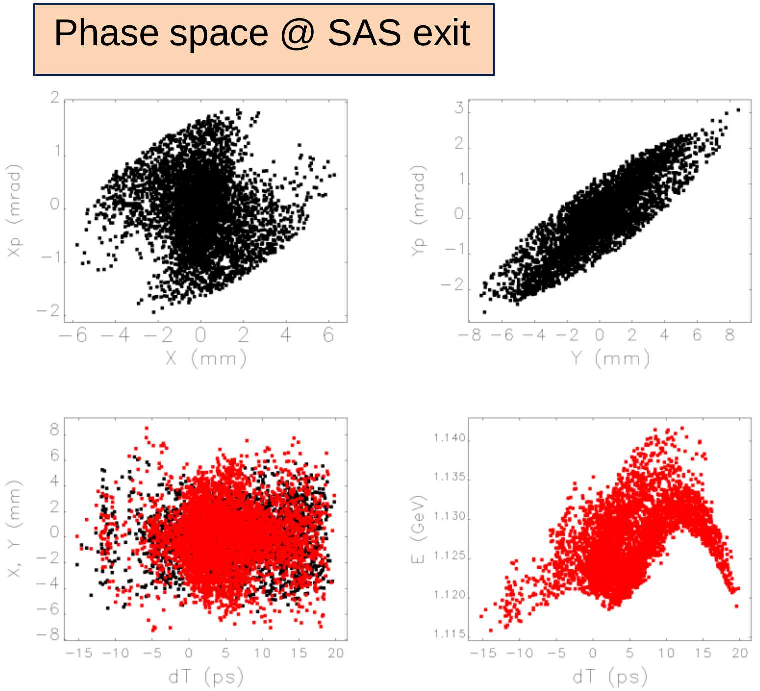
Linac design



Parameter	Symbol	Unit	Design value
Energy	E	GeV	30
Repetition rate	f_{rep}	Hz	100
Number of bunches per pulse			1 or 2
Bunch charge		nC	1.5
Energy spread	σ_E		1.5×10^{-3}
Emittance	ε_r	nm	6.5
Electron energy at target		GeV	4
Electron bunch charge at target		nC	10
Tunnel length	L	m	1800

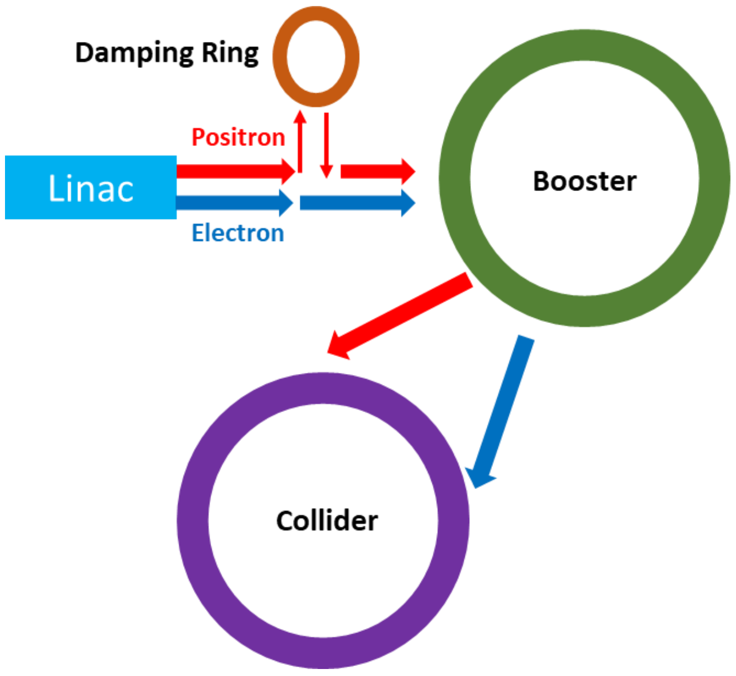




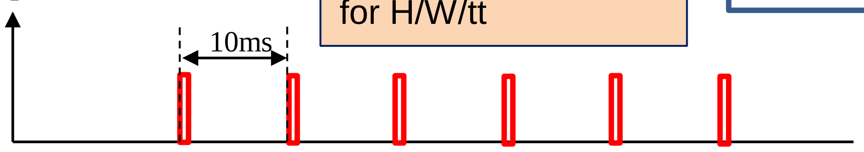


- **Linac energy increases to 30 GeV, with S+C band Accelerator;**
- **Start-to-end simulations were conducted for both electron/positron beams, with quality satisfying requirements.**

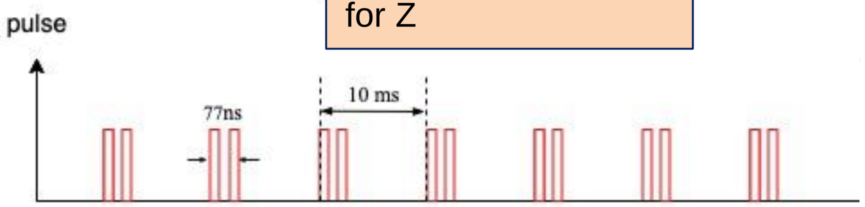
Transport line design and the timing



pulse

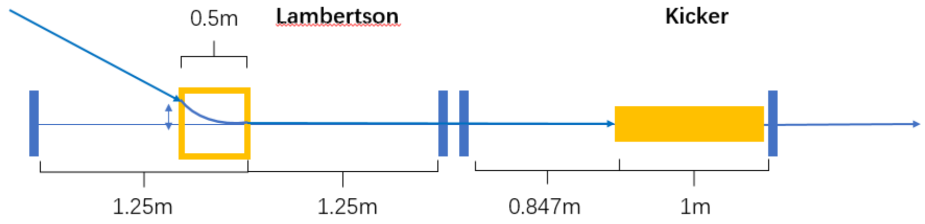


100Hz single bunch for H/W/tt

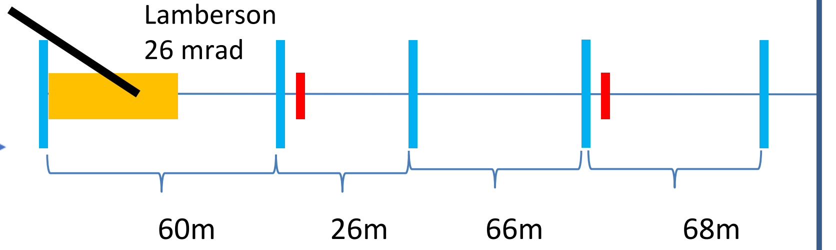


100Hz double bunch for Z

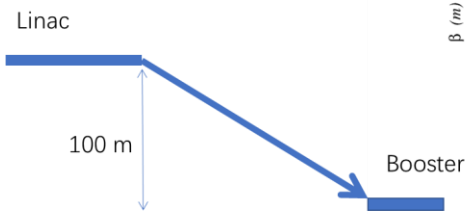
Linac to DR

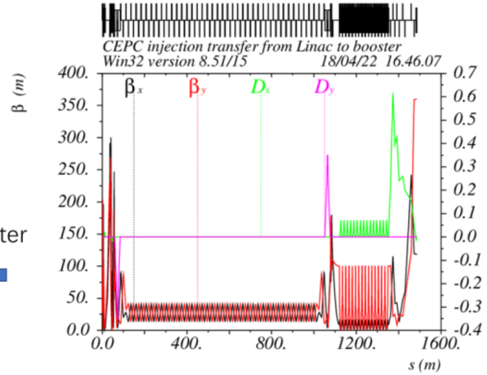


Booster to collider

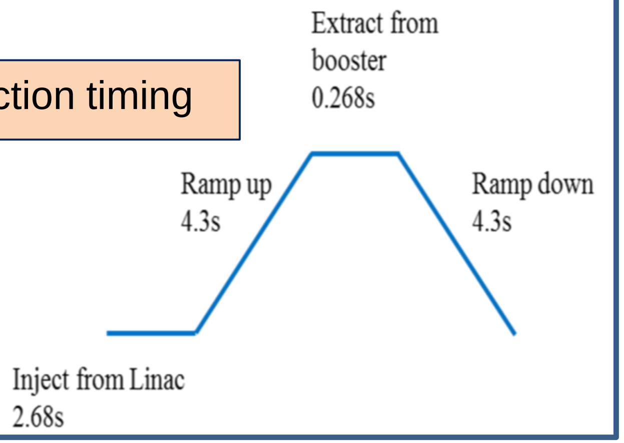


Injection to Booster

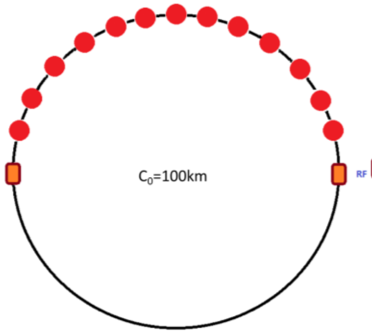




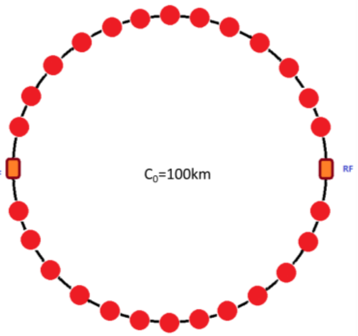
H injection timing



Higgs/ttbar



W/ Z

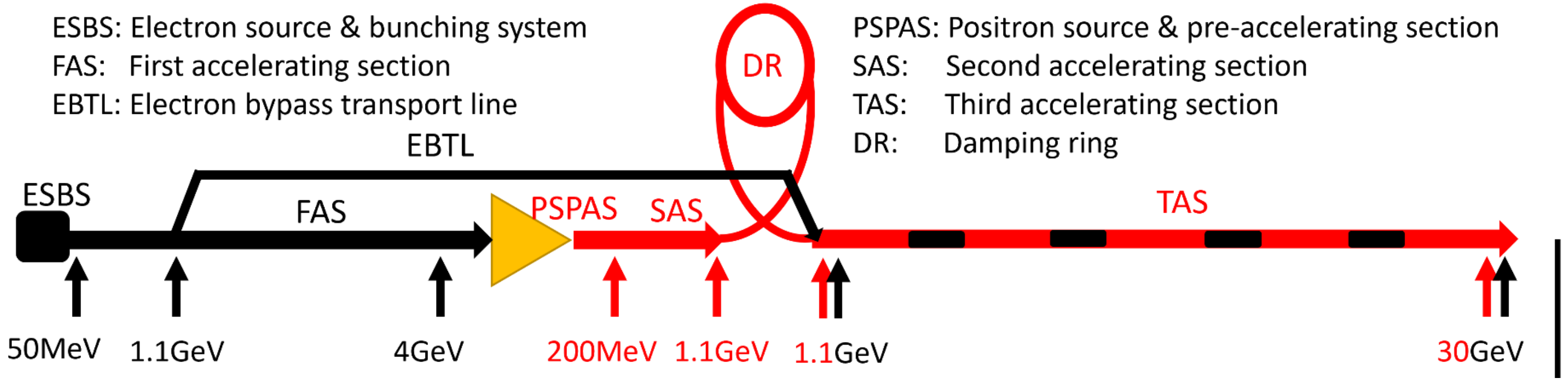


- **There are a number of transport lines in the CEPC accelerator complex.**
- **All transport lines are designed;**
- **Injection/ramping timing was given for different energies**

CEPC drives PWFA study @ IHEP

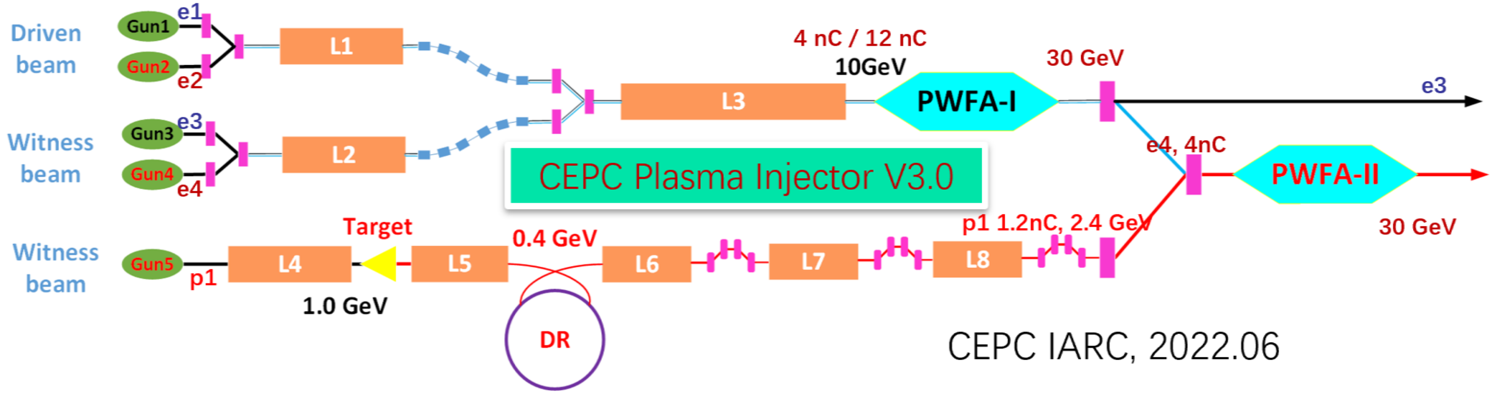
➢ Backup solution for CEPC linac, conceptual design based on simulation shows that the scheme is feasible

Conventional technology as the baseline design:



PWFA backup design:

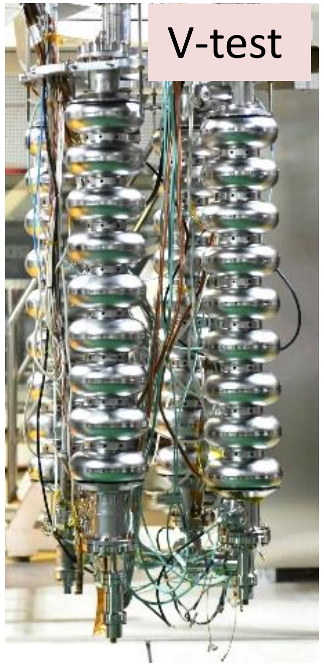
- **Main linac: 10GeV S-band**
- **L-band (10+ nC) and S-band (≤5nC) RF guns**
- **Compression and combination**
- **Different e+ acc. scheme**
- **e+ PWFA need to be cascaded**
- **e- PWFA with TR ~ 3.5**



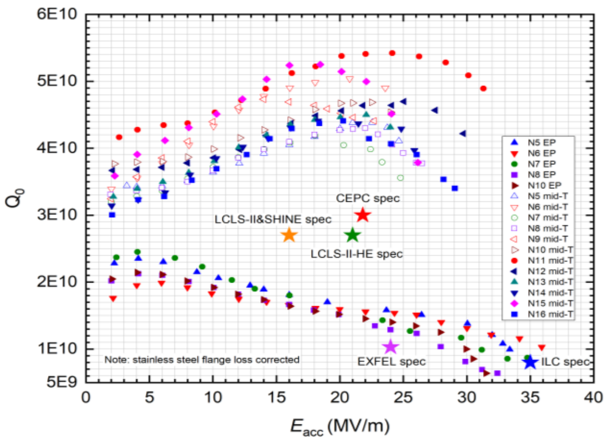
CEPC IARC, 2022.06

SRF cavities and modules

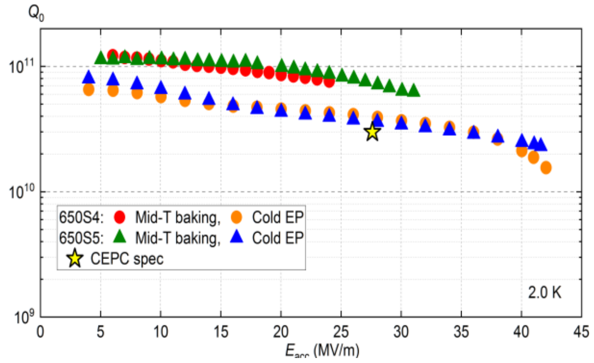
- Mid-T baking applied to 1.3GHz/650MHz cavities, resulting in High Q SRF cavity that exceeds the CEPC specification;
- Completed SRF modules for both 1.3GHz and 650MHz cavities were assembled;



1.3GHz 9-cell cavity VT



650 MHz 1-cell cavity VT



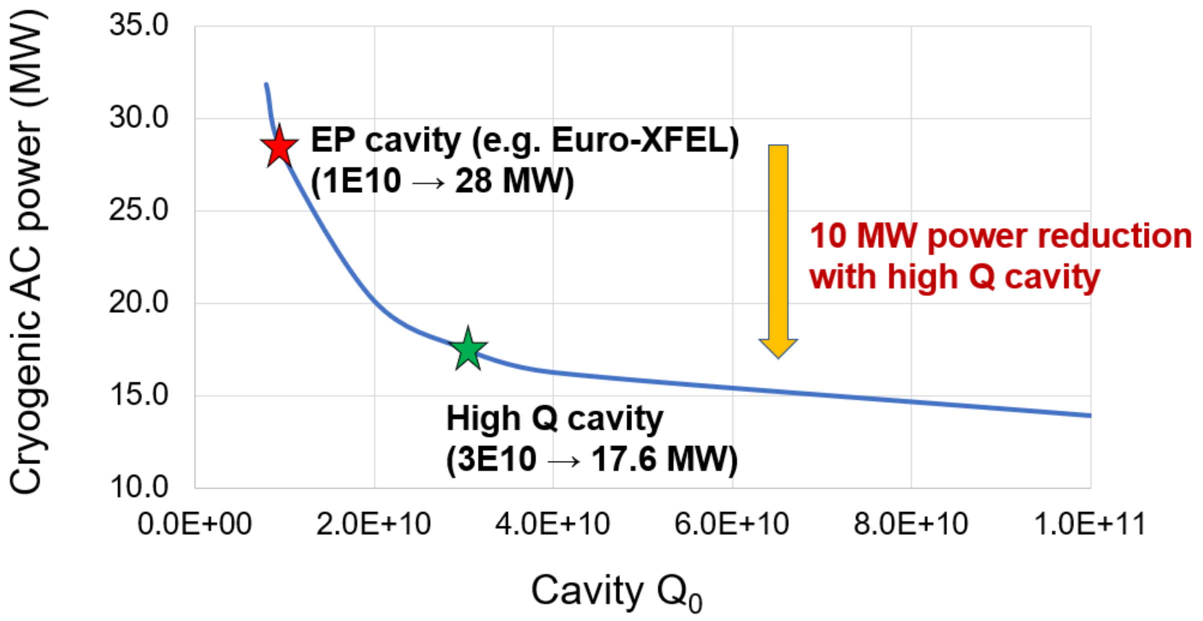
Parameters	Horizontal test results	CEPC Booster Higgs	LCLS-II, SHINE	LCLS-II-HE
Average Q_0 @ 21.8 MV/m	3.6×10^{10}	3.0×10^{10} @ 21.8 MV/m	2.7×10^{10} @ 16 MV/m	2.7×10^{10} @ 20.8 MV/m
Average CW E_{acc} (MV/m)	23.1			

- 650 MHz test cryomodules including cavities, couplers, HOM absorbers, tuners..., was built and tested OK
- A full eight 1.3 GHz 9-cell cavities with input couplers, tuners, SC magnet, BPM, cryostat, module cart, feed/end-cap, volve-box … was built and tested OK

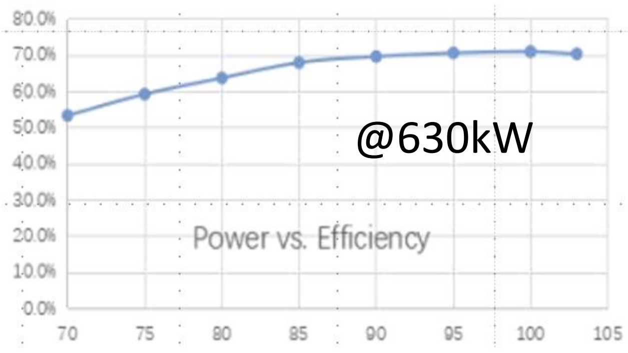
Significance of high Q SRF cavity and module

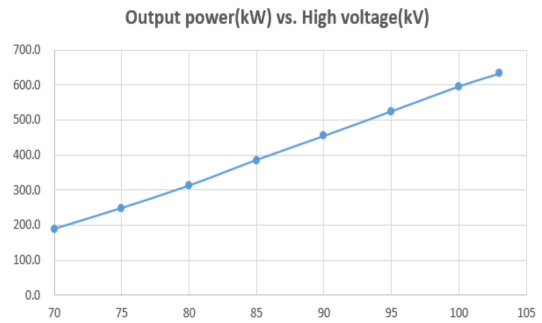
- The SRF system, along with its cryogenic auxiliaries, is one of the major electricity consumers. High Q-factor SRF cryo-modules effectively reduce the heat load, resulting in lower energy consumption
- The CEPC 1.3GHz SRF cavities adopt the mid-temp baking technology, which enhances the Q factor by 5 times compared to the EP technique.
- Using the high-Q SRF in CEPC may reduce the operational power by 10MW, which could result in an electricity savings of approximately 60M kWh per year.

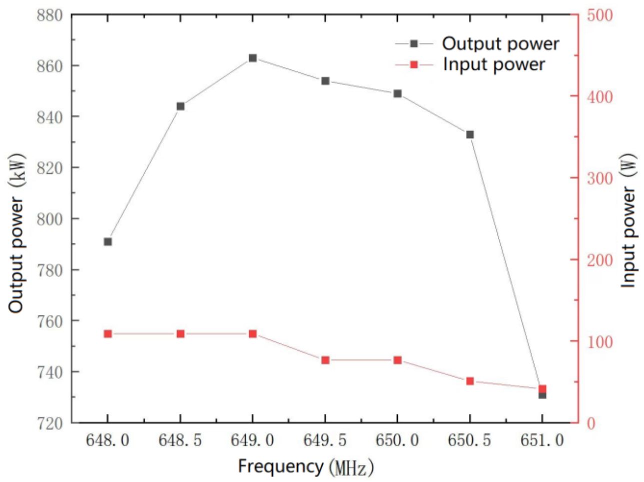
Power consumption with respect to the cavity Q-factor
CEPC 50MW Higgs operation



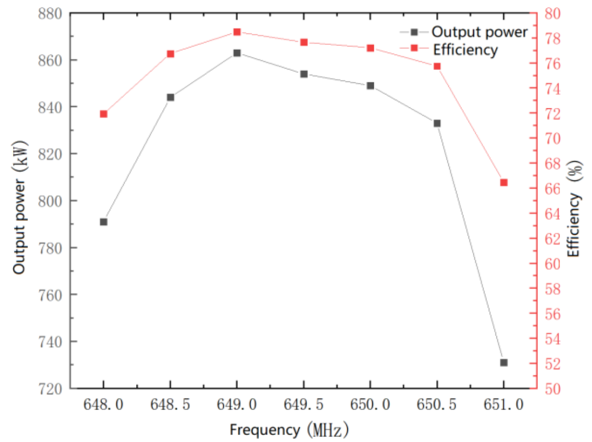
High efficiency klystron







Output power vs. input power



Output power vs. Efficiency

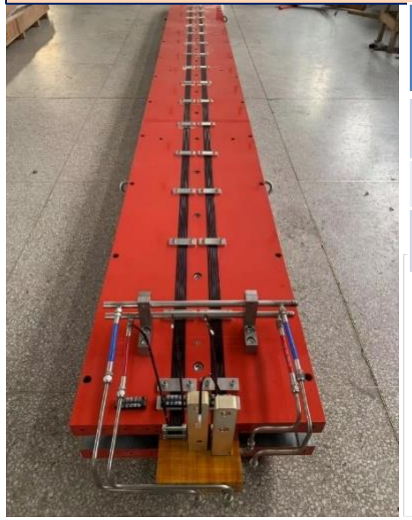
- 2nd round test since January of 2023, 77.2% @849 kW was achieved in pulse mode
- Further test is on going for wider pulse and CW mode

- 1st round test for the 2nd klystron was finished, achieving 70.5% @630kW in CW mode
- Cavity has been modified to suppress an unwanted frequency mode
- Ceramic window has been replaced to improve thermal distribution

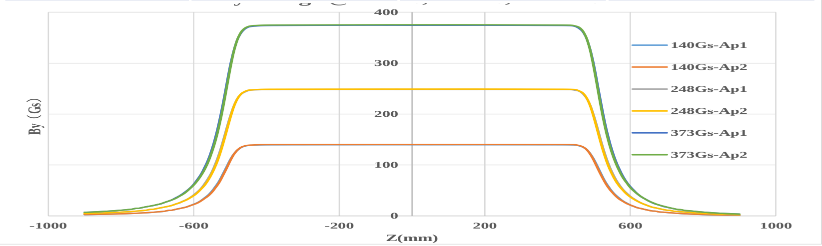
A Multi-Beam Klystron will be completed soon, with the high power test scheduled in 2024

Dual magnet R&D for collider

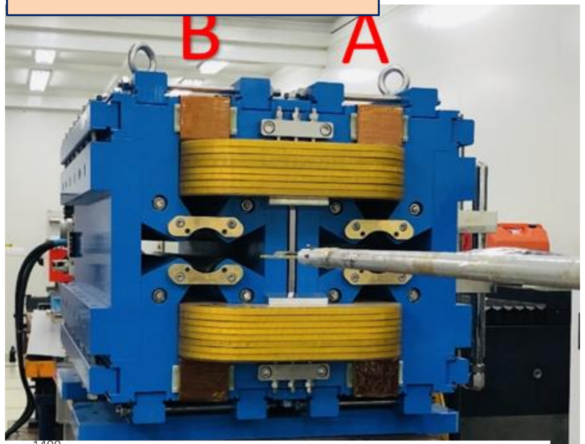
Full-length Dual aperture dipole



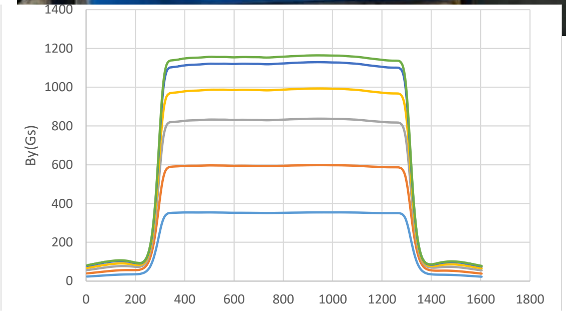
E(GeV)	Ap1 ByL(T.mm)	Ap2 ByL(T.mm)	Differ
45	15.3972	15.3765	-0.13%
80	27.3358	27.3199	-0.06%
120	41.2001	41.1810	-0.05%

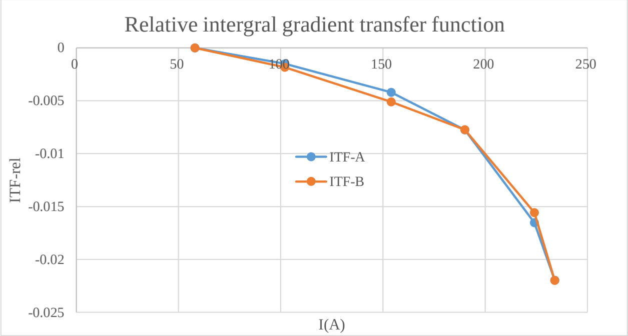


Dual aperture QUAD



E(GeV)	GL(T)-A	GL(T)-B	difference
45	-3.36	3.35	0.40%
80	-5.91	5.88	**0.59%**
120	-8.89	8.85	0.49%
148	-10.93	10.89	0.40%
175	-12.77	12.73	0.30%
182.5	-13.27	13.21	0.40%



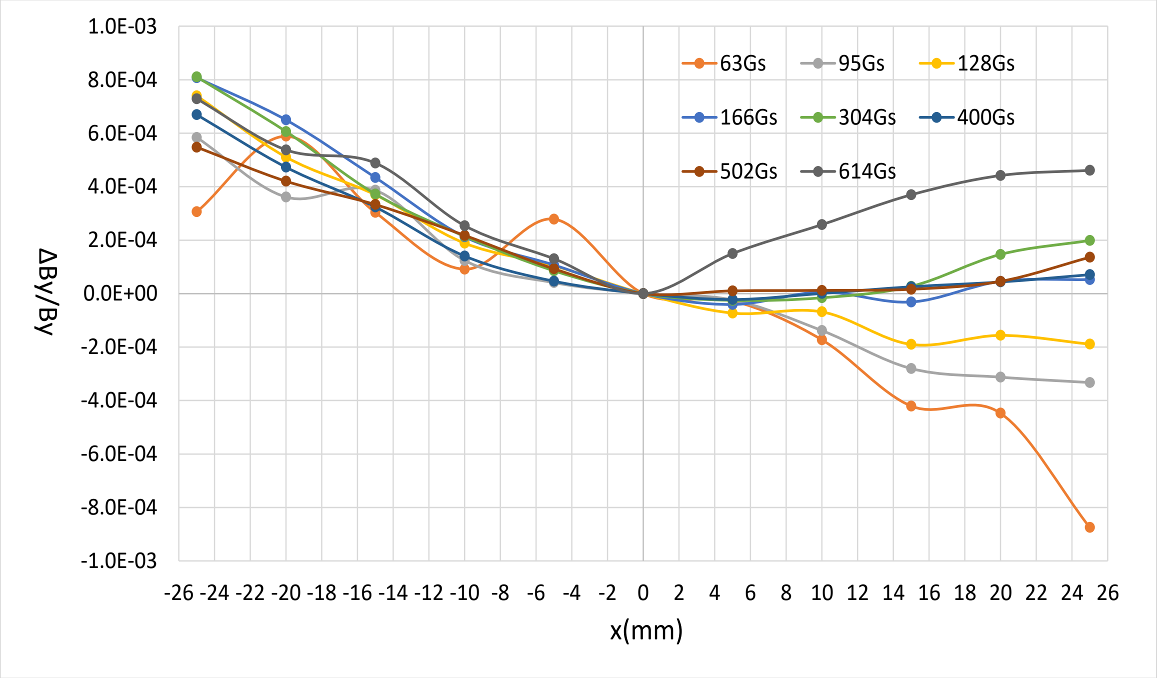


	Dipole	Quad.	Sext.	Corr.	Total
Dual aperture	3008	3008	-	-	**17562**
Single aperture	162	1120	3176	3544 *2	
Total length [km]	68.71	9.95	2.17	3.1	**83.9**
Power[MW] @120GeV	6	17.5	8.91	0.28	32.7

- Large quantity of dual-aperture dipoles (69km) and quad. (10km) are required;
- Full length dual-aperture dipole and dual aperture QUAD (short length) have been fabricated;
- Dipole/QUAD prototypes meet the requirements.

Weak field dipole for Booster

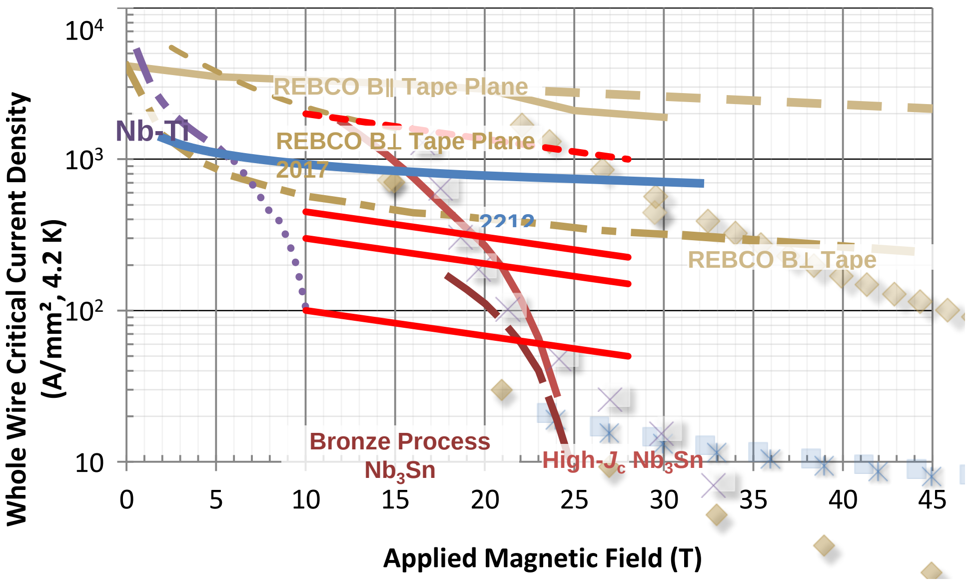
Magnet name	BST-63B-Arc	BST-63B-Arc-SF	BST-63B-Arc-SD	BST-63B-IR
Quantity	10192	2017	2017	640
Aperture [mm]	63	63	63	63
Dipole Field [Gs] @180 GeV	564	564	564	549
Dipole Field [Gs] @120 GeV	376	376	376	366
Dipole Field [Gs] @30 GeV	95	95	95	93
Sextupole Field [T/m^2] @180 GeV	0	16.0388	19.1423	0
Sextupole Field [T/m^2] @120 GeV	0	10.6925	12.7615	0
Sextupole Field [T/m^2] @30 GeV	0	2.67315	3.19035	0
Magnetic length [mm]	4700	4700	4700	2350
GFR [mm]	±22.5	±22.5	±22.5	±22.5
Field errors	$\pm 1\times10^{-3}$	$\pm 1\times10^{-3}$	$\pm 1\times10^{-3}$	$\pm 1\times10^{-3}$

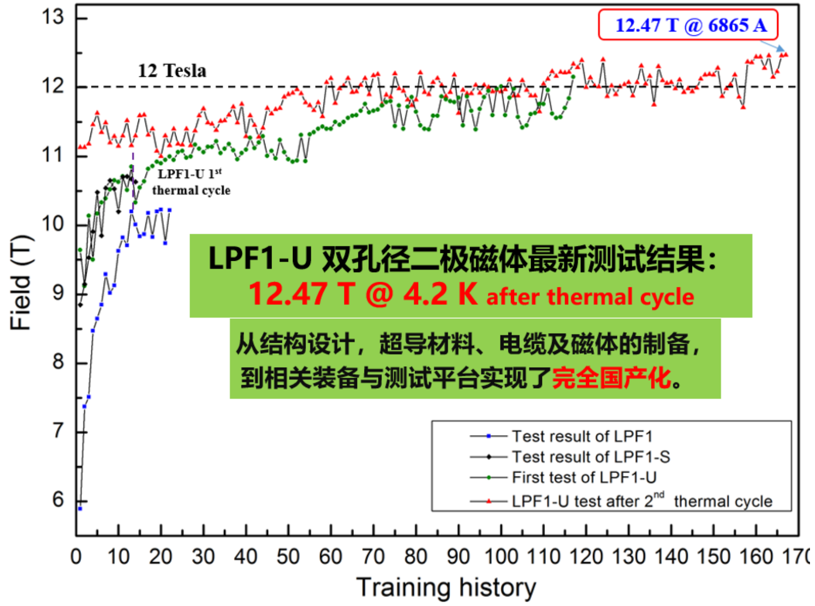


- Booster requires ~15k pieces magnets (68km);
- Booster dipoles are required to work at the low field of 95 Gs (30GeV) with error smaller than 1×10^{-3} ;
- Full length (4.7m) dipole was developed, and it meets the field specification;

High field magnet with HTS and Nb3Sn

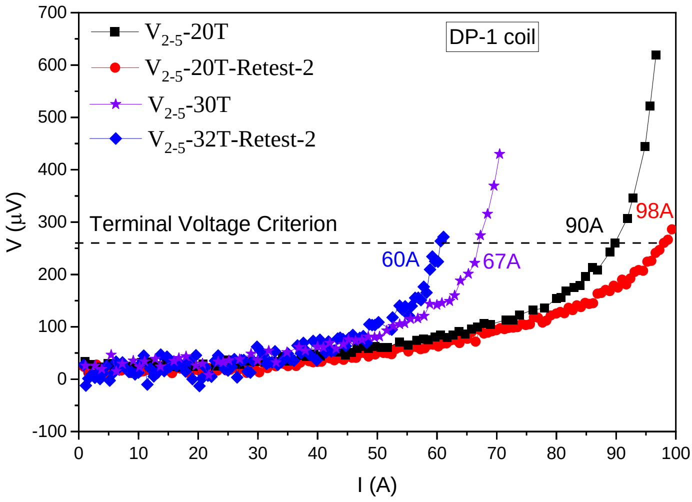
- Iron-based superconducting materials are very promising for high-field magnets
  - Isotropic
  - May go to very high field
  - Raw materials are cheap
  - Metal, easy for production
- Technology spin-off can be enormous
- Major R&D goals
  - High Jc: > 1000A/mm^2@4.2K
  - Long cable: > 1000 m
  - Low cost: < 5$/kA·m
- A collaboration formed in 2016 by IHEP, IOP, IOEE, SJTU, etc., and supported by CAS

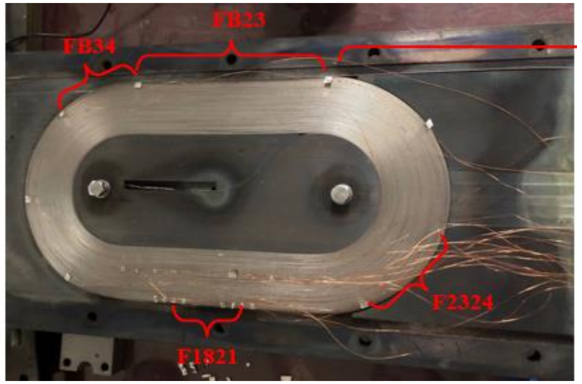




World first: 1000m IBS cable, IBS coil, ➔ magnet

1st Iron-based Superconducting solenoid Coil at 32T





Vacuum system R&D

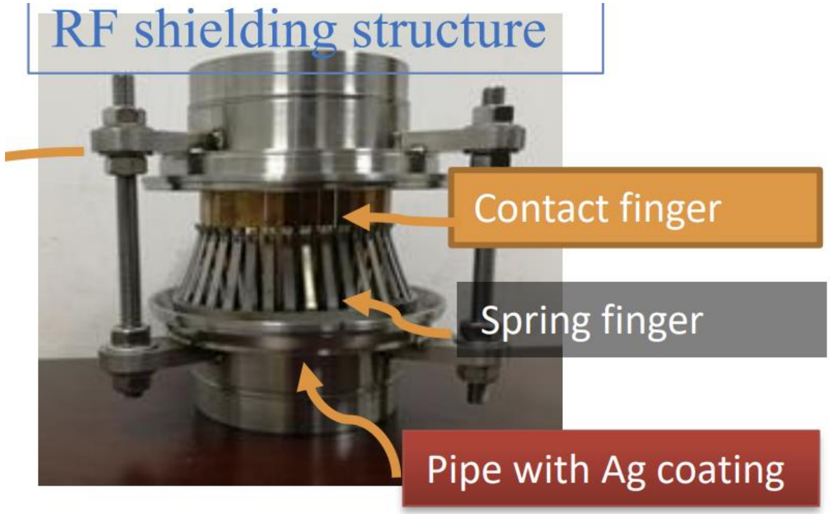
Collider

Classification	*length/m*
Arc beam pipe	78752
Straight section beam pipe	8456
RF Substitute pipe	1192
RF system	352
Insertion and extraction	286
Manifold for SIP	1333
Bellows	2082
BPM	300
Manifold for Gauge & RGA	247
Detector 1	12
Detector 2	12
Collider section	7000
Total length	100000

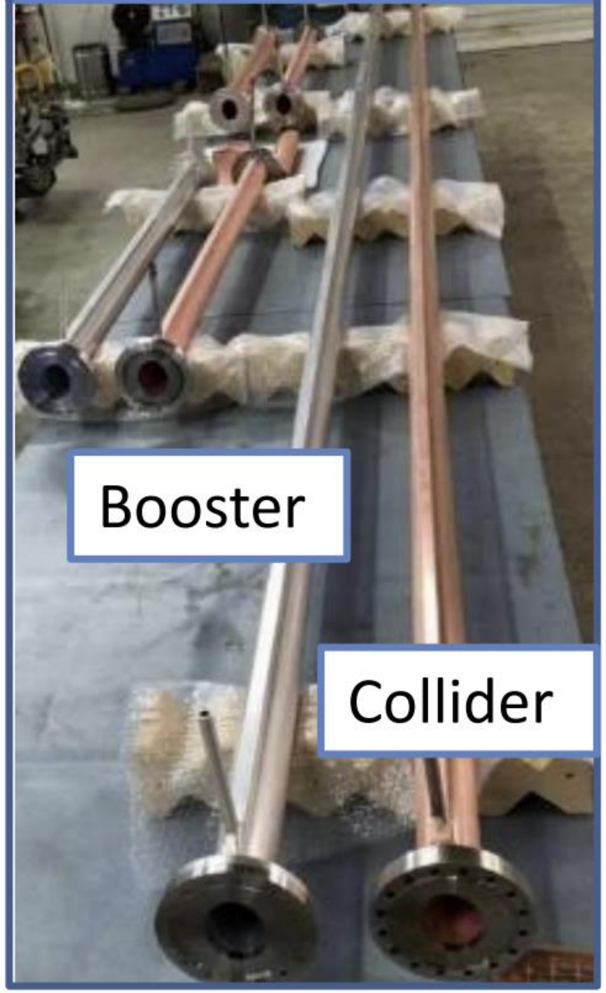
Booster

Classification	*length/m*
arc beam pipe	78428
Straight section beam pipe	17010
RF Substitute pipe	384
RF system	96
insertion and extraction	198
Manifold for SIP	1250
Bellows	850
BPM	240
Manifold for Gauge & RGA	1544
total length	100000

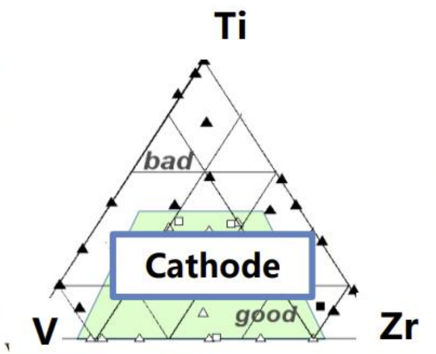
Key component

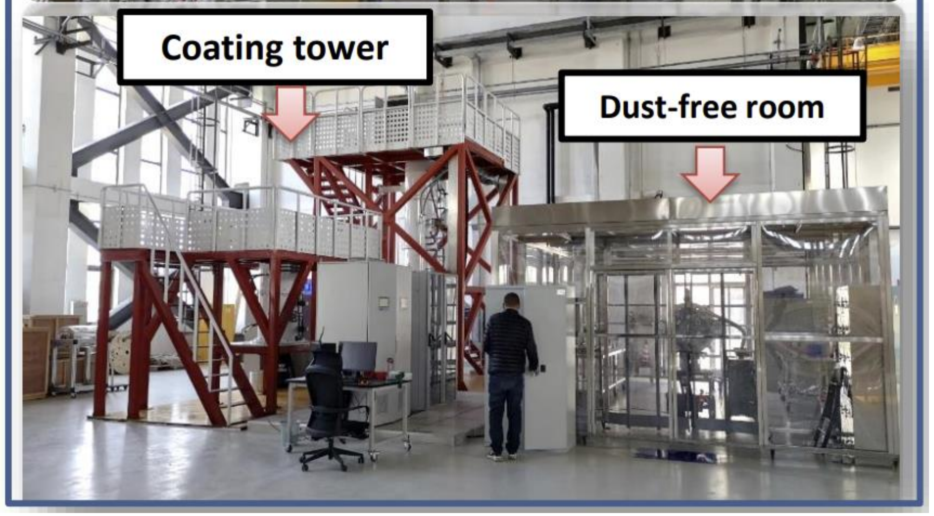


VC Prototypes with 6m length



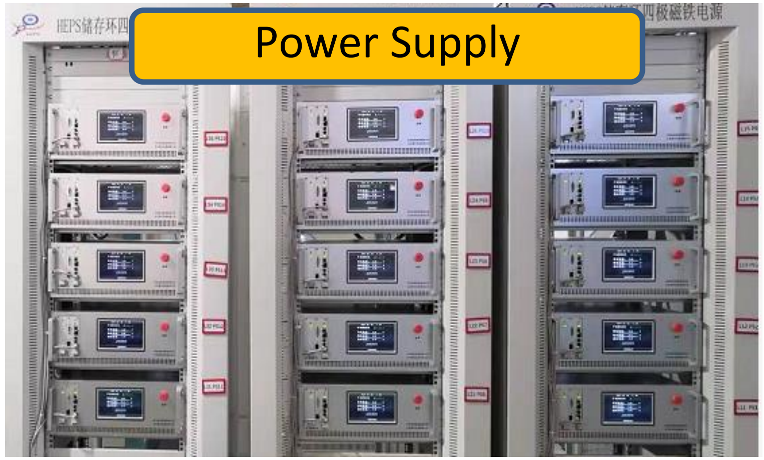
HEPS massive NEG coating e.g.

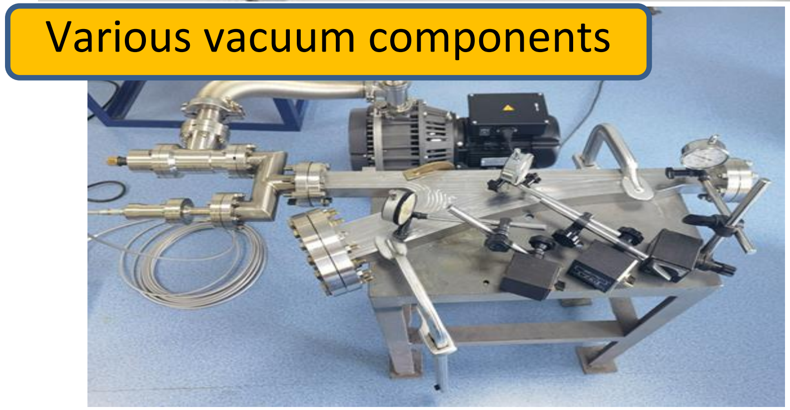


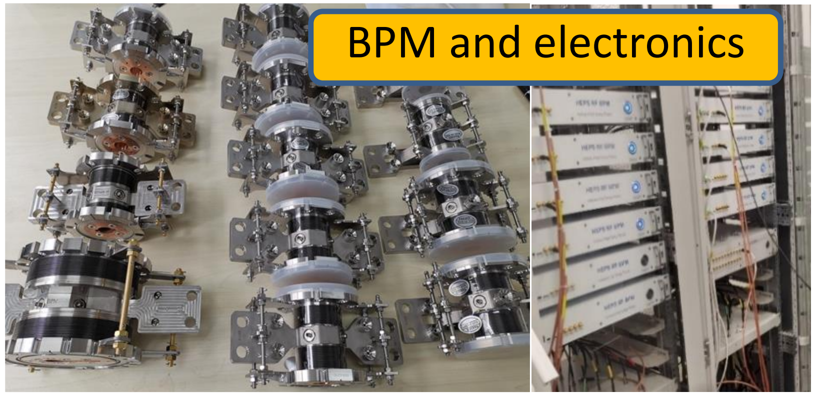


Conventional technology developed @ BEPCII/HPES

- Many of the CEPC needed key technologies were developed and verified in projects such as BEPCII and HEPS, which was conducted by IHEP. These technologies include conventional magnets, vacuum system, magnet power supply, mechanical system, alignment, etc.
- The relevant system cost for CEPC can be accordingly evaluated precisely.

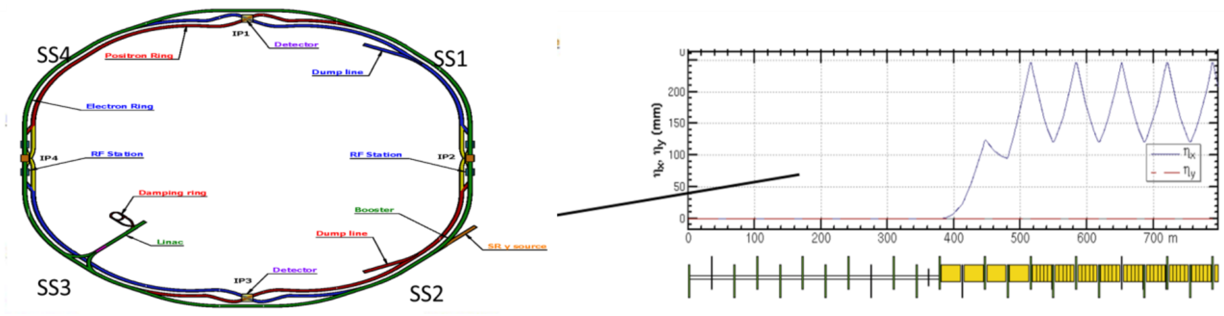




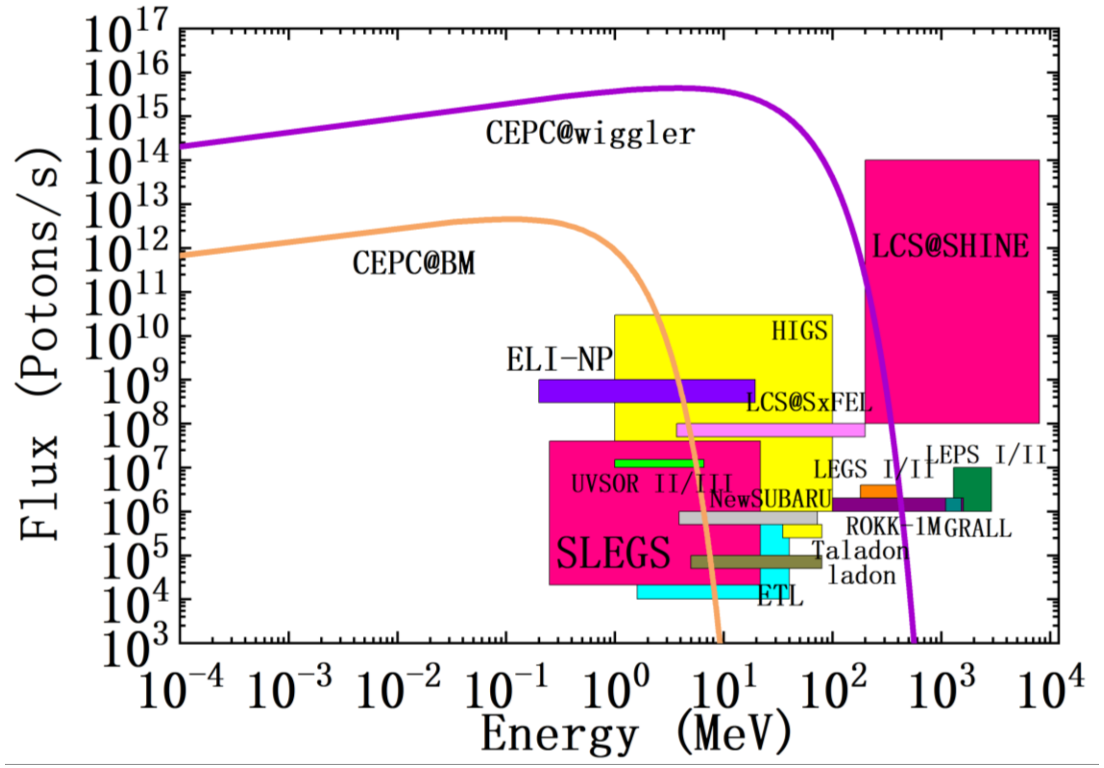


CEPC as a ultra-high energy γ-ray source

- Due to the high beam energy at the CEPC, which is approximately **120 GeV**, the photon energy spans a wide range, from 100 keV to a few **100 MeV,** by using the existing bending magnet and an additional 2T wiggler
- Switching on the wiggler increases additional 1% beam energy loss, which is acceptable according to specific simulations
- Compare to the SSRF, HEPS, (China) and oversea gamma-ray sources, CEPC provides much wider energy range, higher intensity, and maximum photon energy



Source	CEPC BM	CEPC Undulator	CEPC Wiggler	SSRF (China)	TUNL-HIGS (USA)	TERAS (Japan)	ALBL (Spain)
Gamma energy rang (*MeV*)	0.1~5	0.1~10	0.1~100	0.4-20 330-550	2-100	1-40	0.5-16 16-110 250-530
Energy resolution (*ΔE/E*)	continuous	~1%	continuous	5%	0.8~10%		
Flux (*phs/s*)	$>10^{12}$ @0.1%	$>10^{13}$ @0.1%	$>10^{16}$ @0.1%	10^6	10^8	10^4~10^5	10^5~10^7



CEPC accelerator EDR in the progress

2012.9	2015.3	2018.11	2023.12	2025	2027	15th five year plan
CEPC proposed	Pre-CDR	CDR	TDR	CEPC Proposal CEPC Detector reference design	EDR	Start of construction

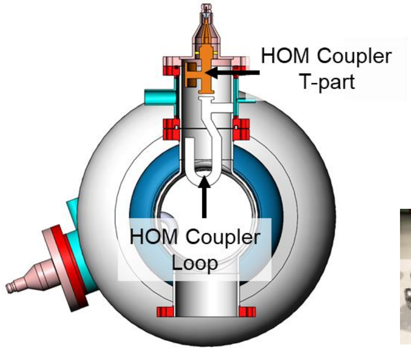
Flowing the completion of CEPC accelerator TDR in 2023, CEPC is in the Engineering Design Report (EDR) phase of 4 years (2024-2027) . During the EDR phase, the CEPC team make preparation for the CEPC proposal to be presented to the Chinese government around 2025, for the construction start in the "15th five year plan (2026-2030)"

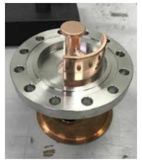
CEPC Accelerator EDR phase goals was discussed. (preliminarily) 35 WGs will be involved in the R&D, spanning the key technologies for the major system, as well as further optimization to the physics design

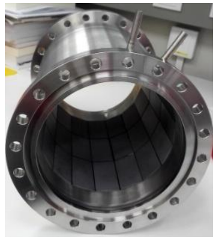
Full size module for the 650MHz SRF system

Key components and complete module R&D

650 MHz HOM coupler & HOM absorber





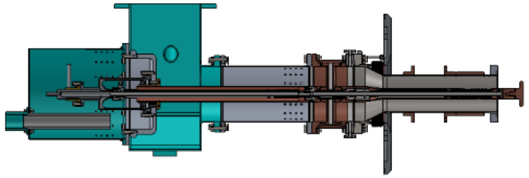


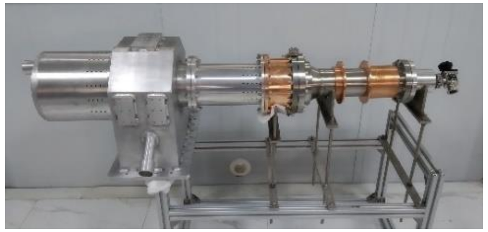
Double-notch wide-band 1 kW HOM coupler without FM tuning.

Broad band 5 kW absorber with SiC+AlN composite

650 MHz input coupler

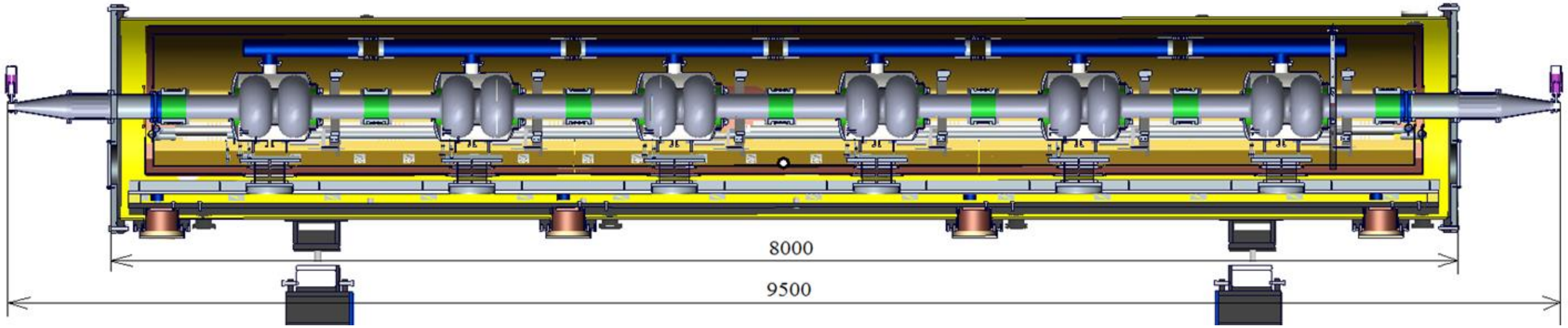
Variable, one-window, 300 kW CW

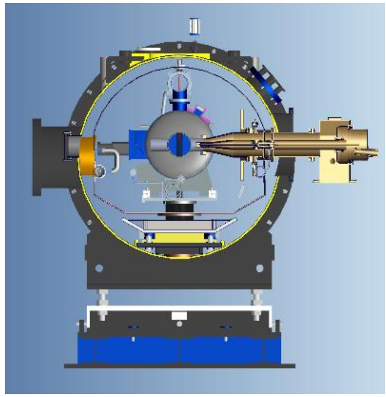




Tested to CW TW 150 kW (SSA power limit), SW 100 kW (corresponding to 400 kW TW power at the window)

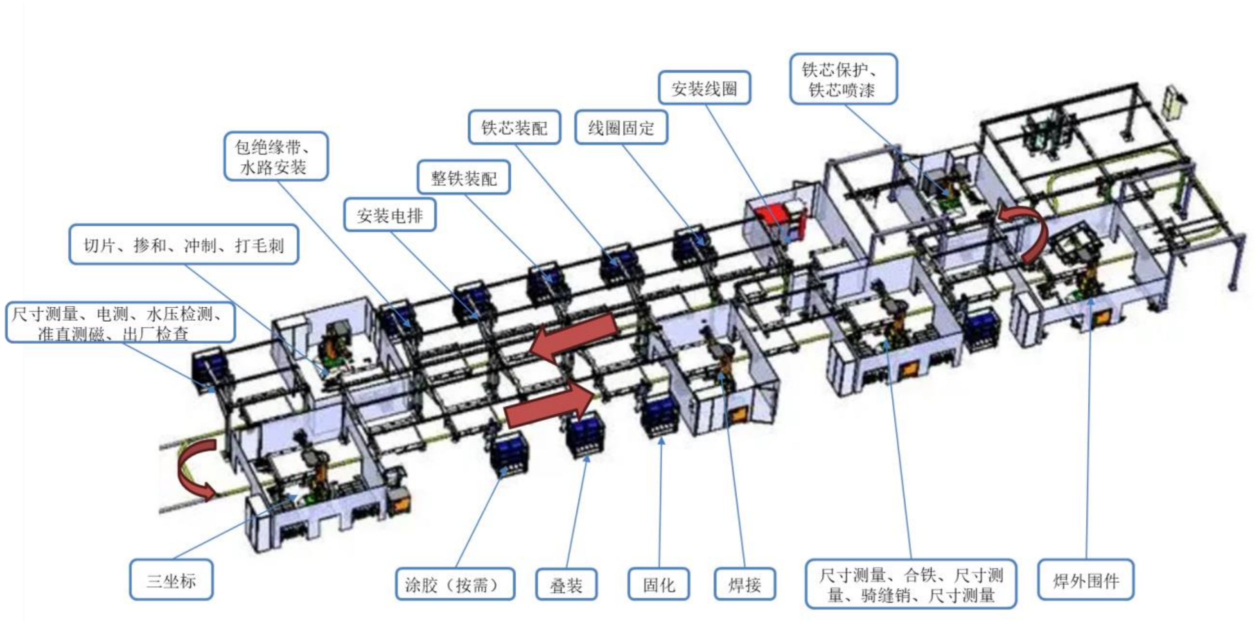
- Cavity helium vessel to cover the niobium ports to avoid overheating.
- High power variable couplers. Cooling and heat load design optimization. Conditioning with 650 MHz klystron 640 kW TW, 320 kW SW. Six couplers in the pCM operation. Design and develop 1 MW variable input coupler for Z-pole.
- HOM couplers. HOM power coaxial line design. 1 kW high power test at 2 K in the horizontal test stand

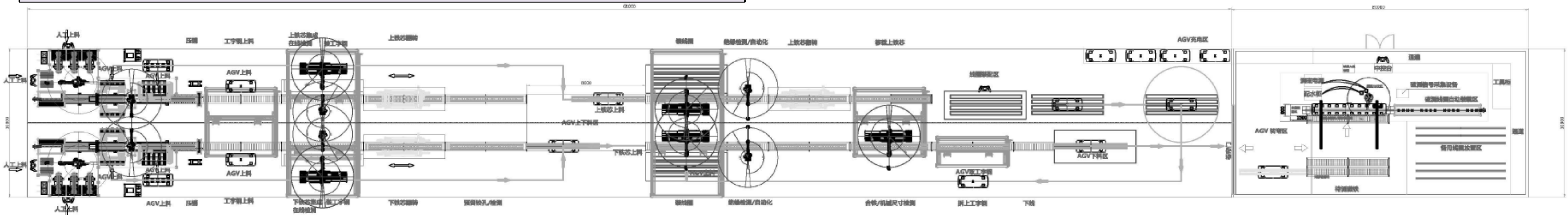




Magnet automatic production line R&D

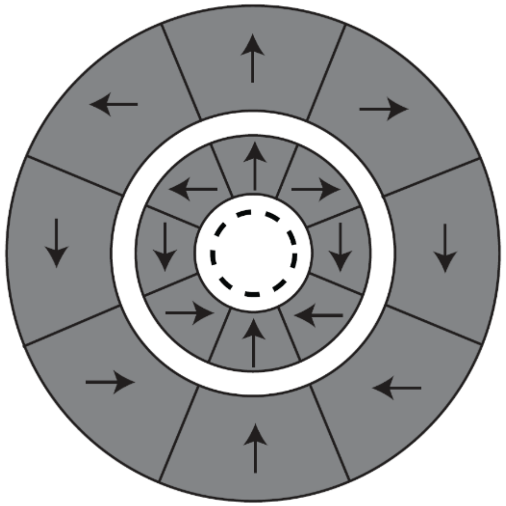
- The CEPC will utilize a substantial number of magnets, with a total length exceeding 100 km.
- The magnet system is the most costly in the CEPC, with a significant portion of the expenditure allocated to manpower.
- Automating the production of magnets can significantly reduce the total cost.
- The efficiency of production is assured by the automated production line.
- The quality of magnets is consistent.
- The conceptual design has been completed, and it is now in the detailed design phase.
- Spillover and benefit to other accelerator facilities.





Green machine: Field adjustable PM quadrupole

- **Dual-rings magnets enable field tenability in a large range**
- **Challenges:**
  - Movement synchronizing for ceaselessly field cancellation
  - Shimming technology for good field quality at all operation modes
  - Radiation shielding

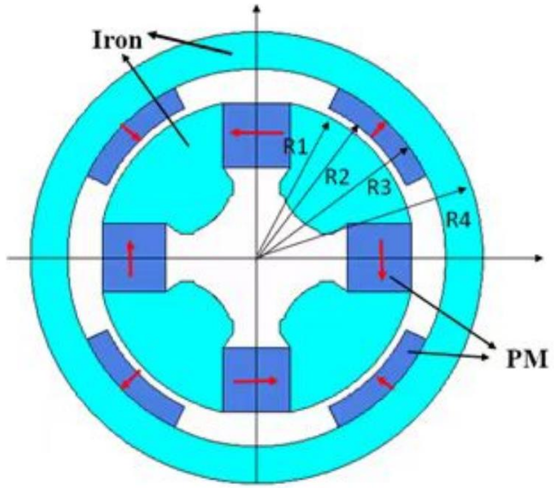


Halbach array

- **The CEPC uses permanent magnets (dipole, quadruple) for**
  - Damping ring
  - Transport line

CEPC				
Storage Ring	Z	W	H	TT
Beam Energy (GeV)	45.5	80.0	120.0	180.0
Current ratio	25%	44%	67%	100%
Power ratio	6%	20%	44%	100%
Dipoles (MW)	0.76	2.35	5.29	11.90
Quadrupoles (MW)	2.13	6.58	14.81	33.31
Sextupoles (MW)	1.28	3.96	8.91	20.04
Correctors (MW)	0.04	0.12	0.28	0.62
Power cables (MW)	1.26	3.90	8.77	19.74
Total magnet losses	5.47	16.91	38.05	85.62
Power demand (MW)	**6.40**	**19.78**	**44.51**	**100.14**

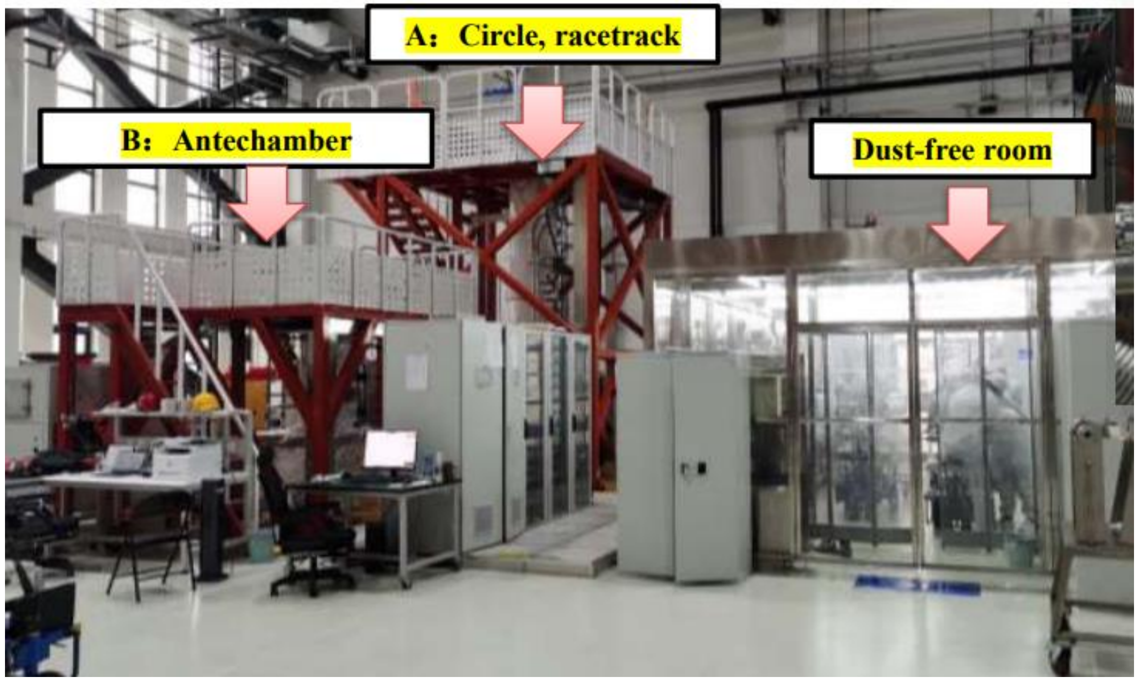
- **Explore novel ideas for collider QUAD**



Hybrid structure

Vacuum coating and EDR plan

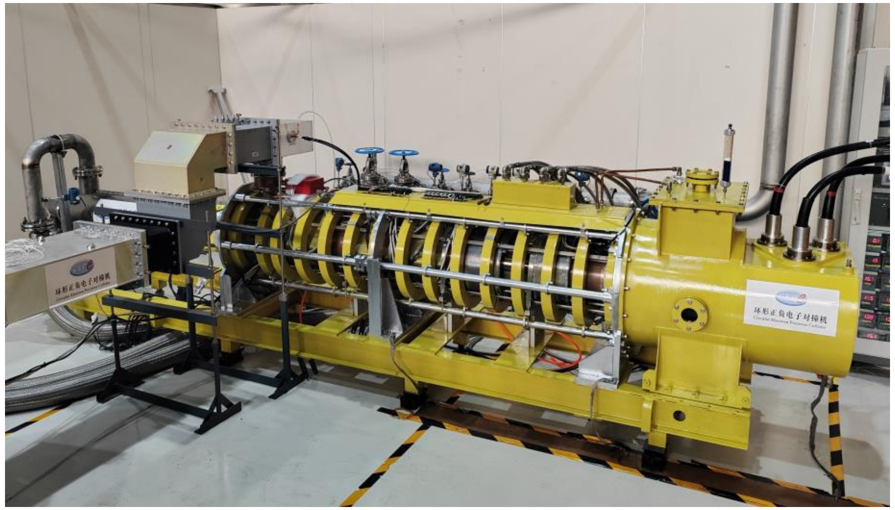
- The coating device A: Vacuum chambers are connected in parallel to 6 groups, each group of vacuum chambers length should be lower than 3.5m, outer diameter is about 0.47m;
- The coating device B: Antechamber are connected in parallel to 4 groups, each group of vacuum chambers length should be lower than 1.5m, due to its discharge difficulty.
- Two setups of NEG coating have been built for vacuum pipes of HEPS at IHEP Lab. And a lot of test vacuum pipes have been coated, which shows that NEG film has good adhesion and thickness distribution.
- In the EDR phase, automation will be developed for the vacuum system fabrication and NEG coating



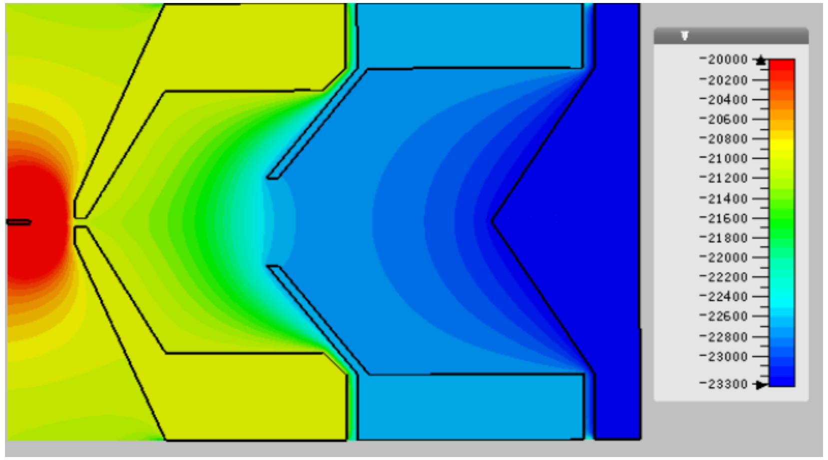
Continue the klystron R&D

EDR goal

- Continue the 650MHz high-efficiency klystron R&D: Start from the experience accumulated in previous TDR years, more klystrons will be produced and tested. The klystron design will be further refined based on the insights gained from the TDR prototype. A high level of efficiency and increased stability are anticipated.
- Develop a high-power 80 MW C-band klystron with a wide pulse. The CEPC linac will extensively use C-band klystrons. High power and stable operation are crucial. An 80 MW wide pulse klystron will provide a foundation for other advanced linacs, such as cold-copper accelerators.
- Try to develope the energy recovery technology for higher efficiency



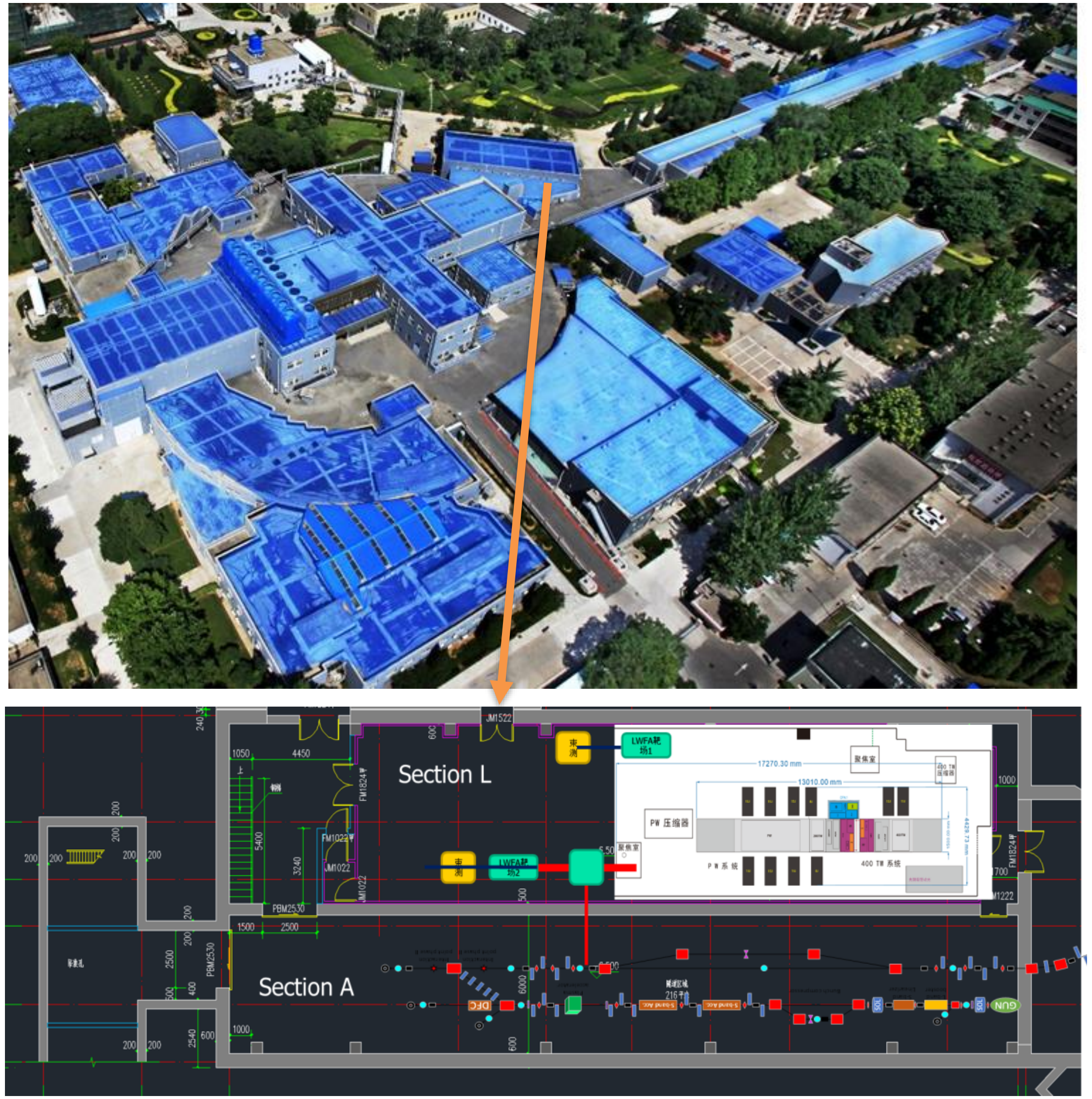
650 MHz HOM coupler & HOM absorber



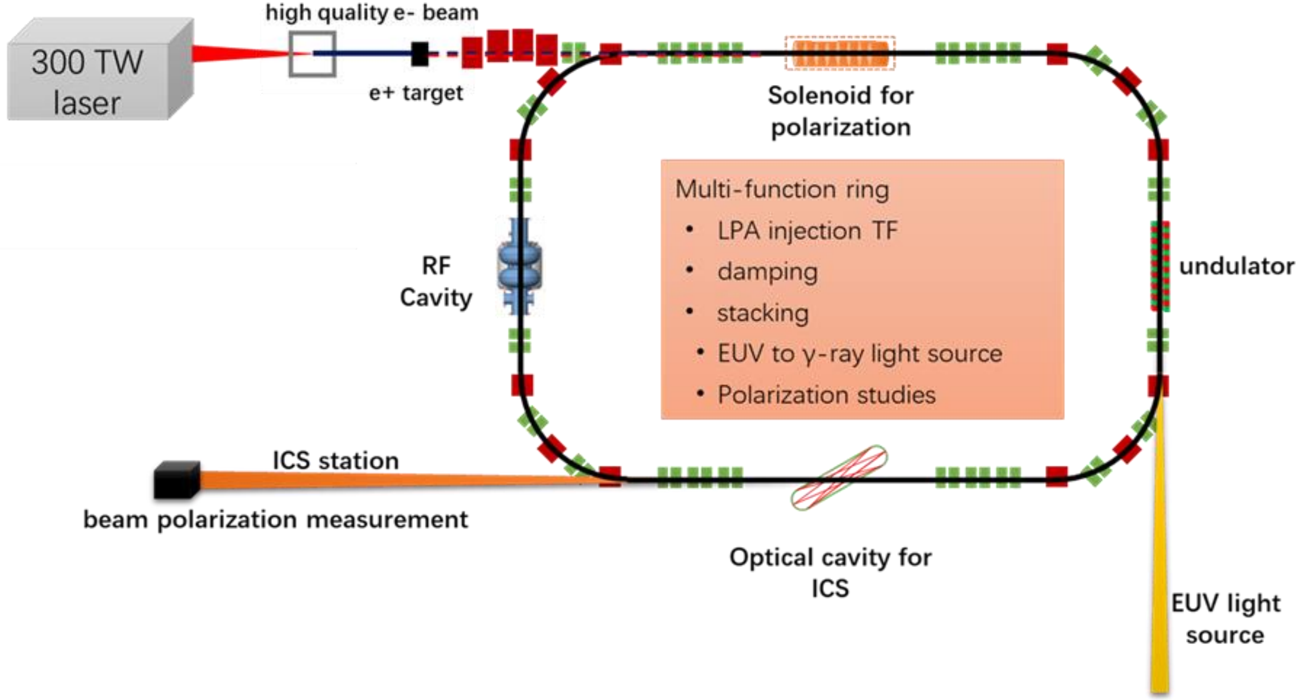
Simulations for the energy recovery scheme

Plasma acceleration R&D

PWFA test facility @ BEPCII



PBA TF based on LPA + Storage Ring



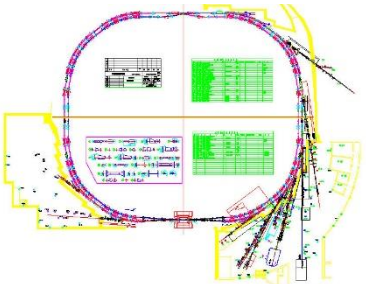
Develop the state-of-the-art technology of plasma acceleration

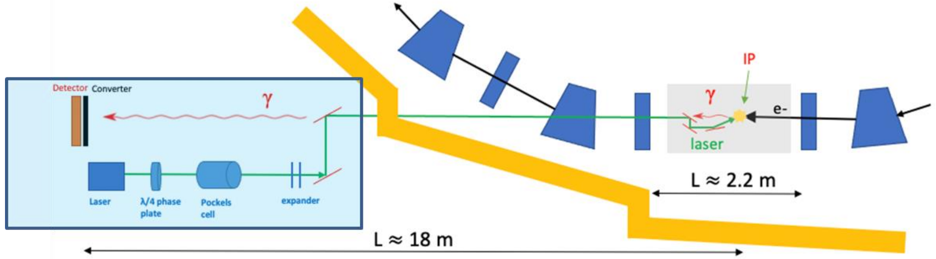
- A test facility for PWFA: ~2GeV e-/e+ beam from BEPCII; Independent e- beam with L-band photon gun; TW laster system; final focus & beam merge
- LPA driven storage ring: e-/e+ generation & direct injection; polarization generation & measurement; EUV source

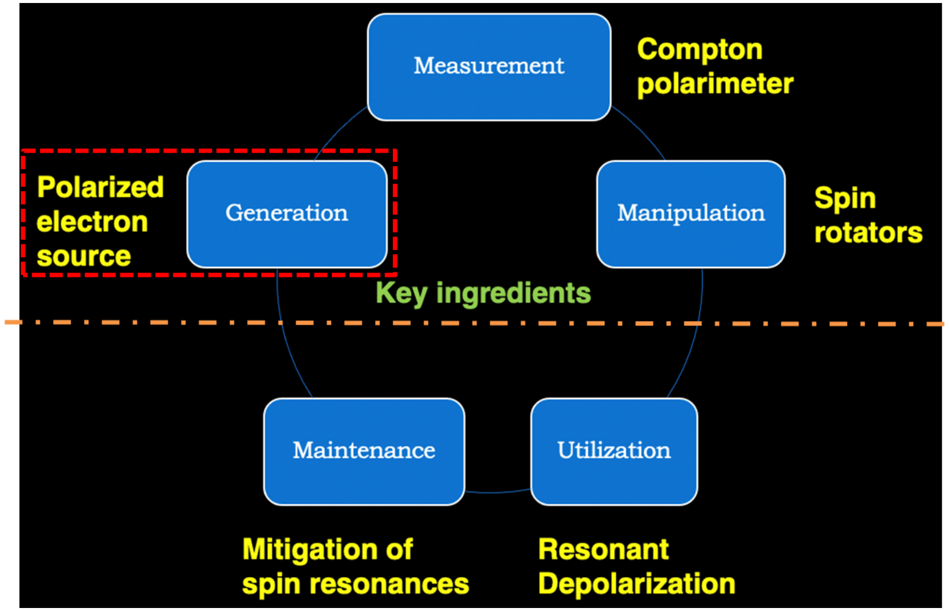
Polarization beam generation and measurement

Compton polarimeter measuring self-polarization @ BEPCII

- Reuse the beamline of the dismantled wiggler 4W2
- Detection of scattered γ position with TaichuPix detectors







Hardware R&D and beam tests

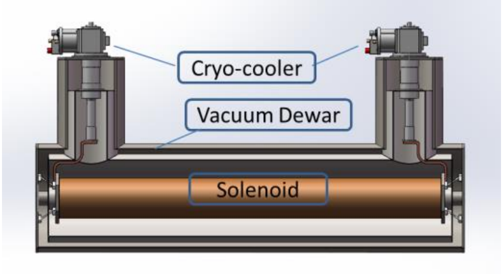
Enable

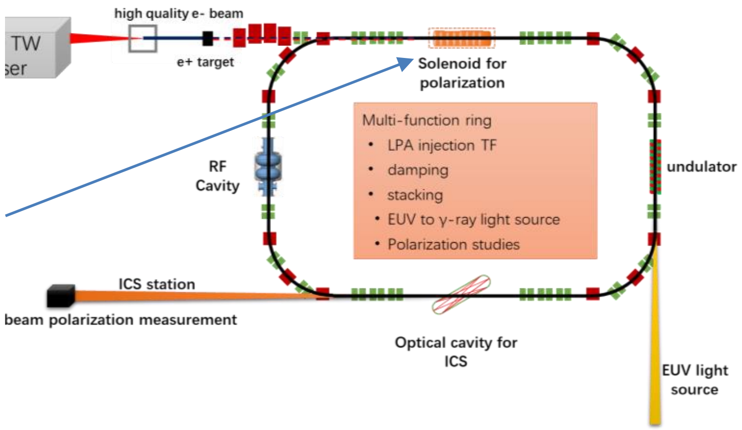
Experimental studies

Verify

Physics design

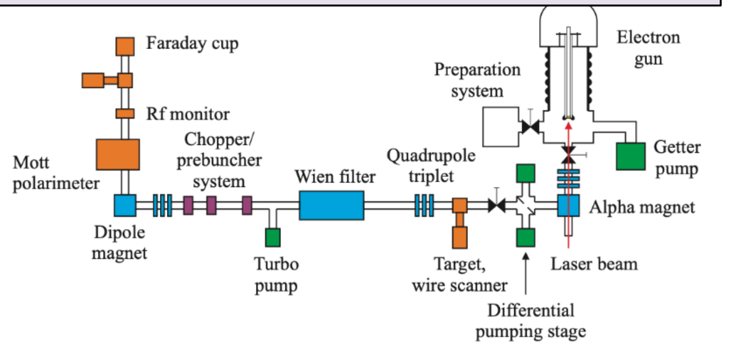
A 12 Tesla,10.5 T·m solenoid prototype





Convert HV DC photocathode gun @ PAPS to first domestic polarized electron gun for use in high energy accelerators

- GaAs/GaAsP cathode + 780nm drive laser -> ~85% polarization
- Wien filter + Mott polarimeter: manipulation and measurement of e- beam polarization



EDR plan in other systems

- **Further optimization to the physics design**
  - Explore better lattice for enhanced error tolerance
  - In-depth study combining effects of lattice-beam beam effect-impedance-beamstrahlung lift time …
  - Self-consistent simulation including complicated components (solenoid, quadrupoles, …)
  - Commissioning strategy and software development
  - MDI simulations
  - ……
- **Control system and diagnostics**
  - Control network topology; Optical fiber; Machine protection; Control logistic and layers; timing and reference line; Data acquisition and speed; Database; Automation and AI, …
  - Signal wireless transport, feedback system design, …
- **Alignment**
  - Geodetic measurement and level surface refining;
  - Studies on tunnel deformation, temperature distribution, …
  - Continue visual alignment R&D
  - High accuracy, long & invisible components alignment, SRF system, MDI, long magnets, …
  - …

EDR plan in other systems

- **Mechanics**
  - CEPC mock-up tunnel
  - Ground vibration,
  - Booster installation measures
  - …
- **Utilities and green machine**
  - Life cycle footprint analysis
  - CO2 footprint assessment
  - Energy recovery
  - CO2 footprint assessment
  - Clean energy utility
  - Efficiency improvement
- **High energy gamma-ray resource**
  - Continue the radiation calculation and evaluate the impact to beam
  - User survey
- **Linac**
  - Better e-gun for enhanced performance
  - Double-bunch test @ HEPS
  - Advanced C-band acceleration cavity
  - Positron source
  - …
- **Machine protection**
  - Shielding design for Linac & booster/collider ring
  - Dumps: linac, transport line, booster and collider
  - SR absorber and shielding
  - Radioactivity calculation according to the ventilation scheme and shielding
  - Environmental impact assessment

Continue & broaden the international collaborations

- **The CEPC aims to build an unprecedented accelerator complex. We need to foster wide-ranging collaborations in various ways**
  - Further optimization to the physics deign including comprehensive effects and improved error tolerance
  - Carry out in-depth sustainability studies and increase the efficiency, such as addressing the high efficiency klystron, high Q SRF system, permanent magnets, etc.
  - Develop relevant technologies to automate the large-scale mass production, such as magnet, vacuum system, in order to build the CEPC in budget, in schedule
  - Address challenges due to the ultra-size: alignment, control system, …
- **In the EDR phase, we plan to organize a series of workshops addressing a range of issues, including but not limited to:**
  - Physics design
  - Geodetic survey and alignment
  - control system and diagnostics
  - Sustainability and green machine
  - γ-ray synchrotron and multidisciplinary researches
- **We aim to cultivate young scientists and specialists. We also welcome researchers from both domestic and international backgrounds to join us.**
- **Continue the IARC review**

Summary

CEPC:

- has made strong and systematic progress; design and technologies are reaching maturity;
- releases the TDR for the e^+e^- accelerator on 25. Dec. 2023, after the international technology review and cost review; (arXiv: 2312.14363)
- is in the EDR phase (2024-2027), with clear research goals;
- aims schedule following China's 5-year planning (2026-2030); expects to complete the R&D and the preparation to build the facility and carry out the science program

Thanks to the CEPC-SppC accelerator team's hard work, international & CIPC collaborations

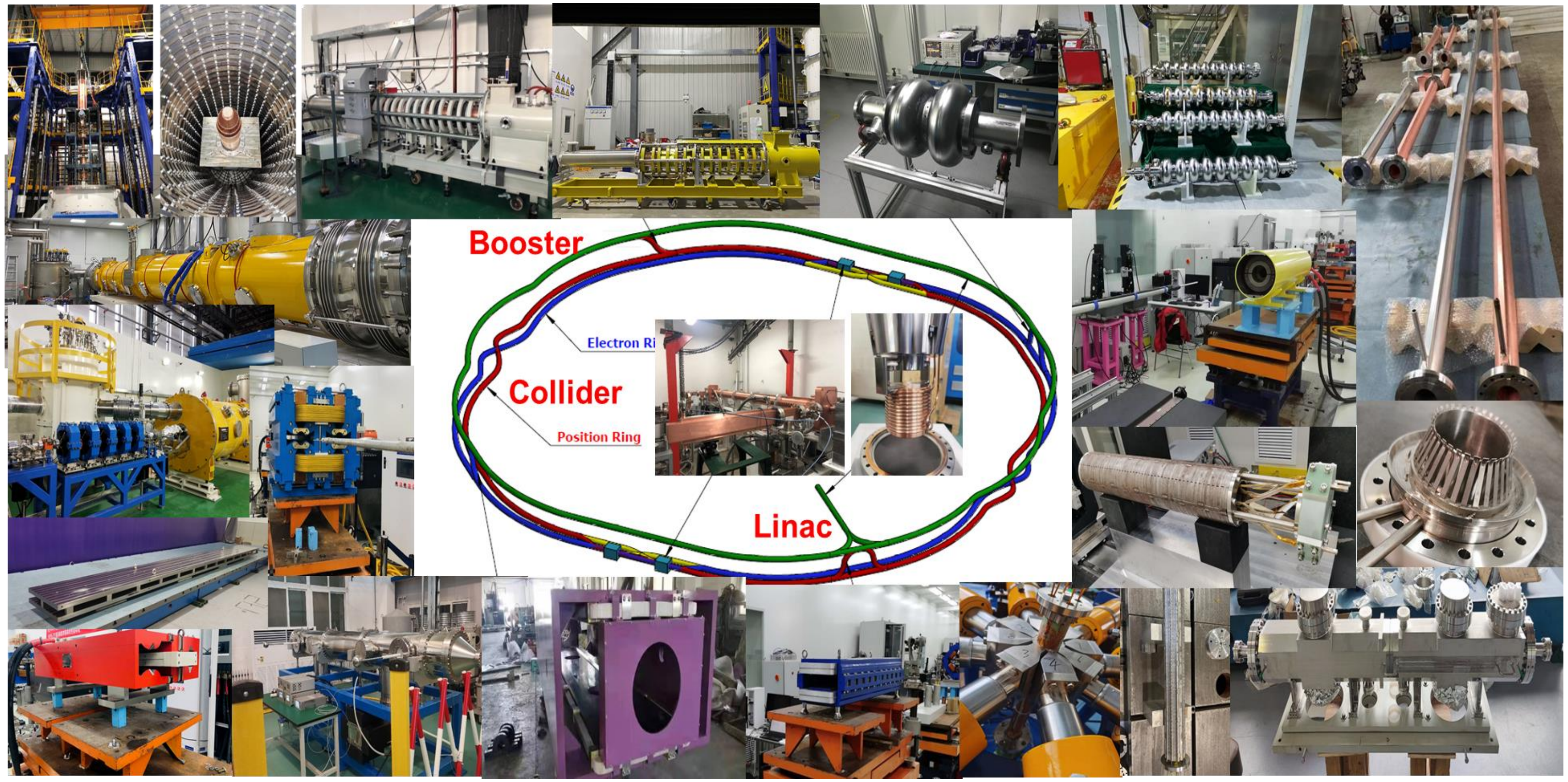
Special thanks to CEPC IAC, IARC and TDR review committees' critical advices and supports

Backup slides

Key components and prototype R&D

Specification Met ●   Prototype Manufactured ◐

Represented Key Technologies for the CEPC



Key technology R&D spans all component lists in CEPC CDR

Accelerator Total	Cost proportion	
Magnets	26.82%	●
Vacuum	16.70%	●
Linac and sources	9.64%	●
Mechanics	6.59%	●
RF power source	5.95%	◐
Instrumentation	5.43%	●
Cryogenics	5.20%	●
Magnet power supplies	4.74%	●
SRF	3.70%	●
Installation	2.83%	●
Commissioning	2.83%	●
Survey and alignment	2.70%	◐
Control	3.02%	●
Radiation protection	0.86%	●
Transport lines	0.83%	●
Inj. / Extr.	0.54%	●
Beam separation system	0.42%	●
Accelerator physics	0.42%	●
Damping ring	0.31%	●
SC magnets	0.46%	◐