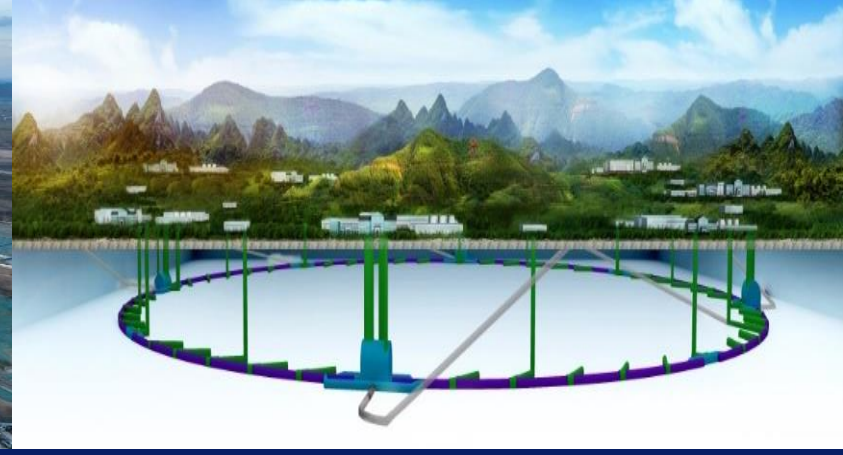




Accelerator Division

Yuhui Li

Institute of High Energy Physics

Sep. 20, 2023

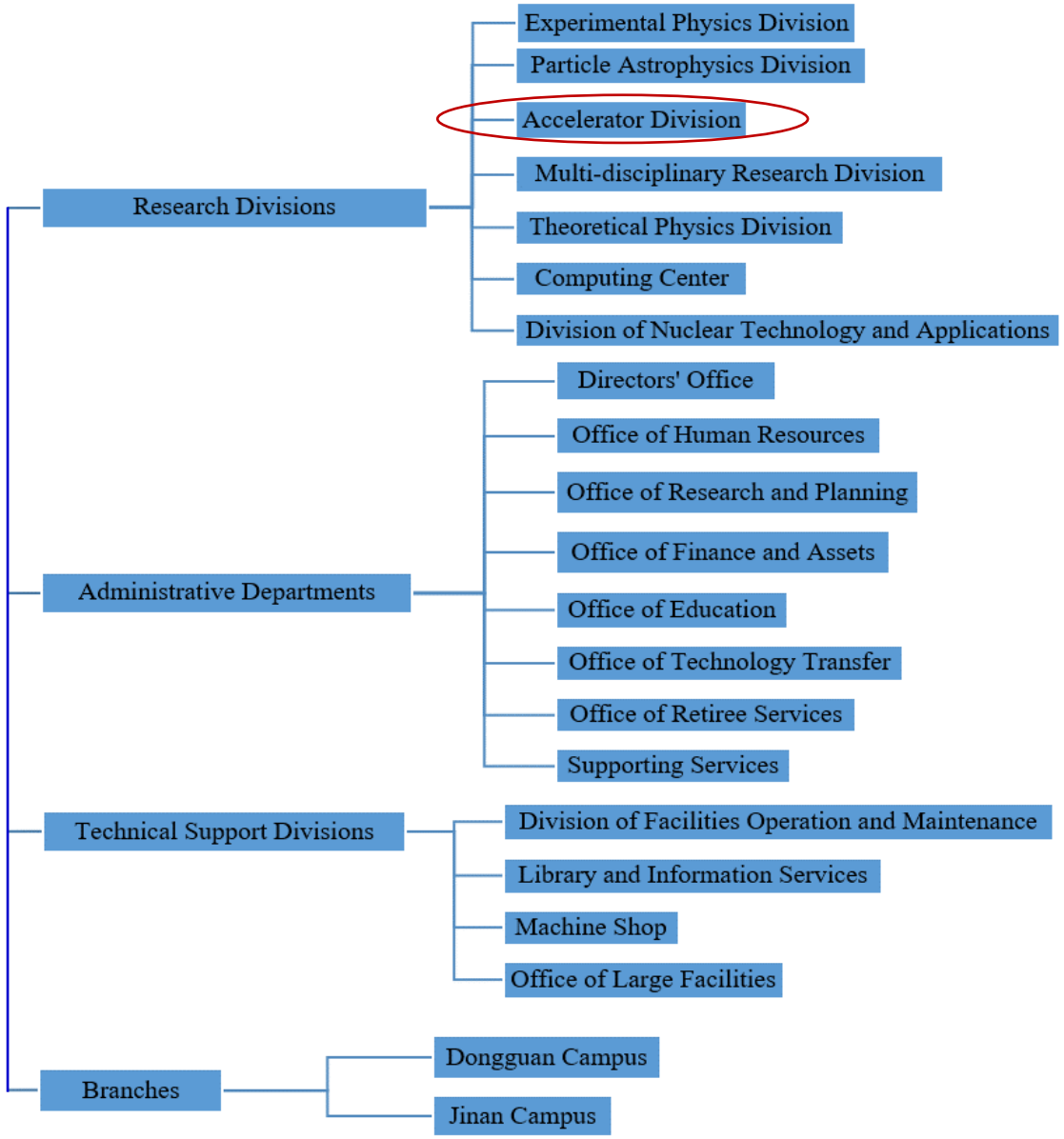
INTERNATIONAL ASSESSMENT 2023

Content

- Mission & Organization
  - Mission of accelerator division
  - Research groups at Accelerator division
- Improvements since 2018
  - Manpower and human resources
  - International involvement, publications, patterns, recruitment, group optimization, …
- Main activities & Achievements
  - BEPCII • HEPS • CEPC • Cutting-edge technology R&D
- Personnel & Budget
- Vision & Future plans

Mission

- Accelerator physics research and technology R&D, inventing powerful tools to support scientific exploration
- Design, construction, and operation of accelerator based large science facilities
- Support the transfer of accelerator technologies for civilian use
- Train students, young scientists/engineers for future projects



Organization

W. Pan (Head)

Y. Li (Deputy)

R. Ge (Deputy)

C. Yu (Deputy)

J. Yue (Deputy)

P. Zhang (Deputy)

J. Li (SG Lead)

Accelerator Division

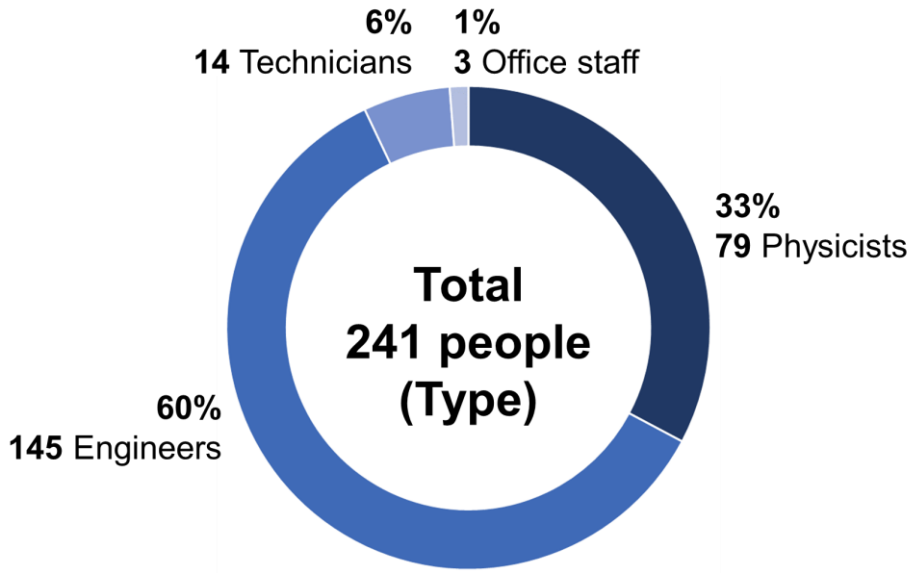
Science Group

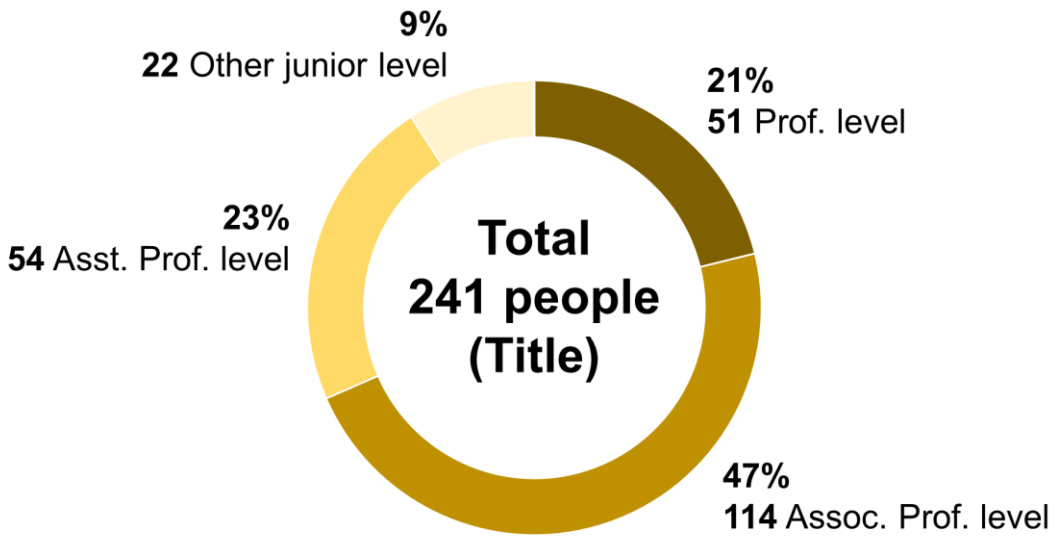
Administrative Secretary

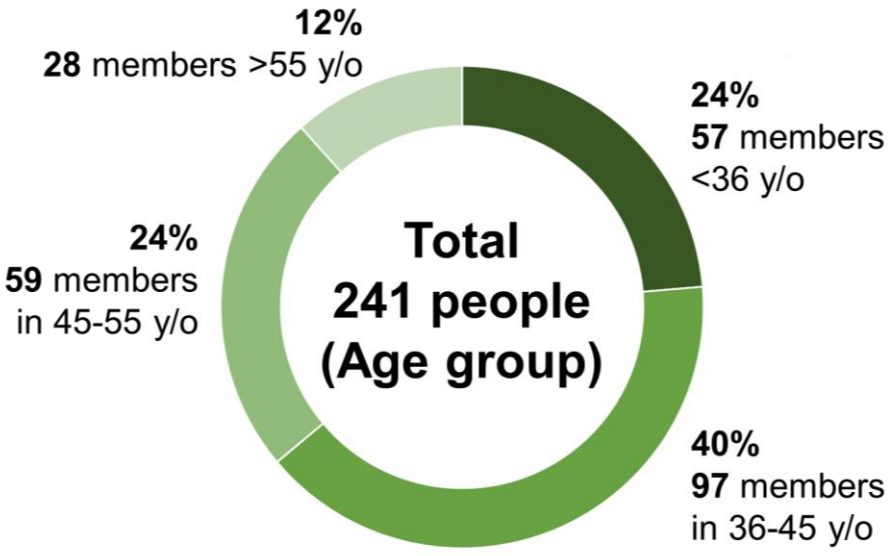
- Accelerator Physics
- Linac
- Beam Diagnostics
- Control
- SC Magnet
- Magnet
- Power Supply
- Mechanics
- Radio Frequency
- Vacuum
- Cryogenics
- Machine Operation

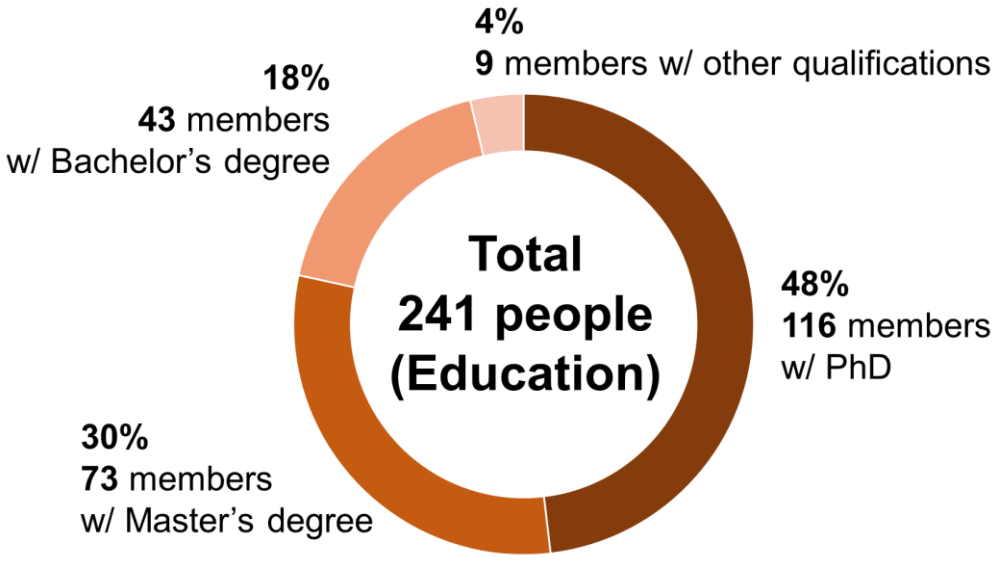
AD staff

Staff: 241 Graduate students: 84 Temporary staff: 21



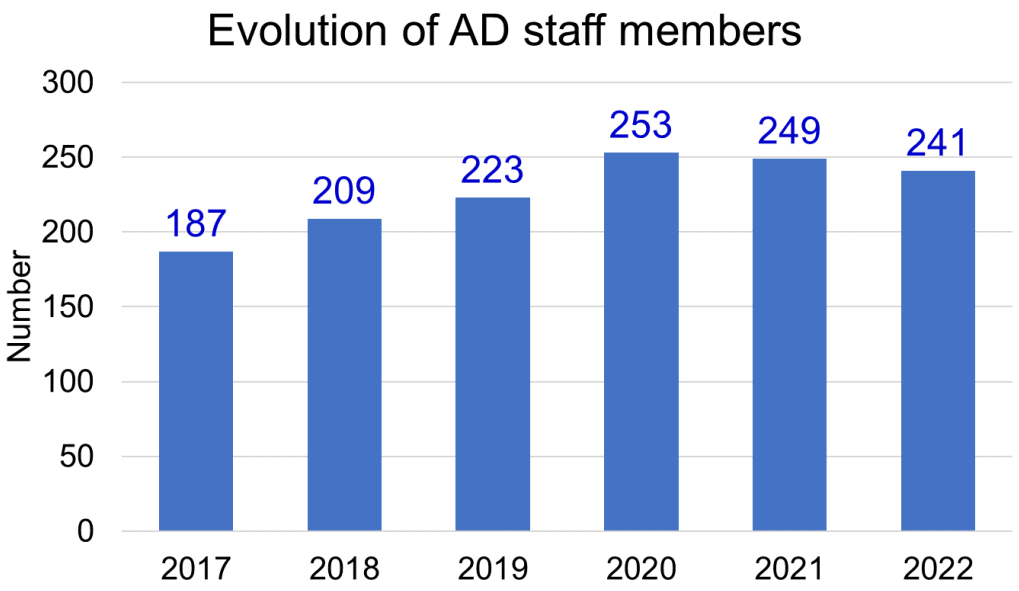






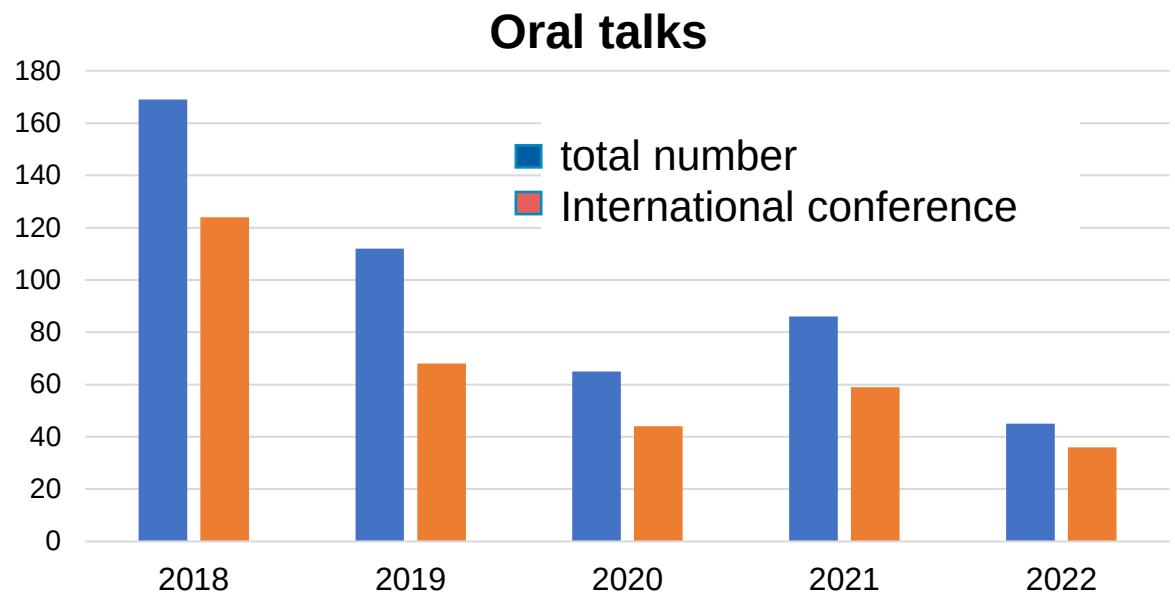
Major concerns during assessment 2018

- "A problem, however, is that the **human resources** may not be adequate to support such an ambitious program as is envisioned for the future (next 5 years or beyond), especially in areas relying on expertise in accelerator physics. The CEPC is a very ambitious project that will require more manpower, R&D and engineering resources, and international participation. It is important to take steps now to lay the groundwork and to position IHEP to take on such an ambitious future project."
- "The CEPC accelerator was ranked A, …While highly recognizing the progress, the judging panel also expressed concerns about research resources. The committee said that their B ranking for "research resources" was a direct reflection of our concern that the manpower must be increased significantly for the planned next steps, beyond the Conceptual Design report and did not reflect negatively on the progress to date."



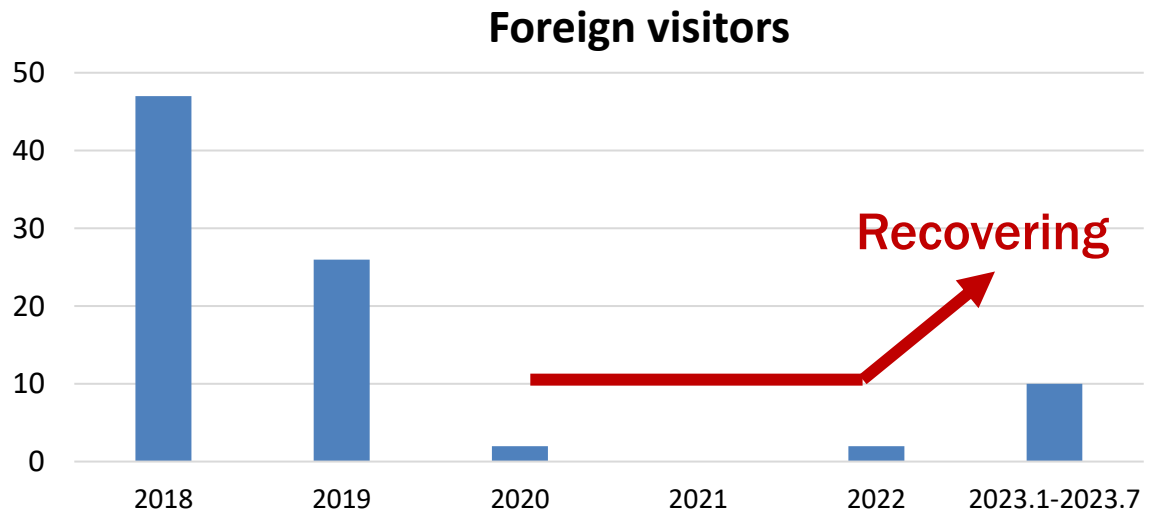
- Staff member significantly increased from 187 to 241 in the past 5 years, by 29%
- The staff is more senior and experienced, based on their age
- Optimize the matrix management, which involves assigning each person to different projects: BEPCII-HEPS-CEPC
- Overall, the construction of HEPS has proceeded according to schedule despite the impact of the pandemic; BEPCII keeps smooth operation with improved luminosity
- CEPC completed its TDR international review in 2023

International communication



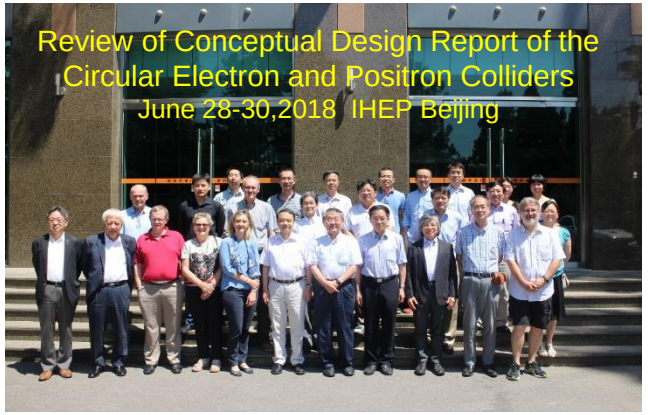
Invited + Contributed oral talks at IPACs

	Invited	Contributed	Total
2018	1	2	3
2019	2	2	4
2020	2	1	3
2021	1	1	2
2022	1	2	3
2023	1	0	1



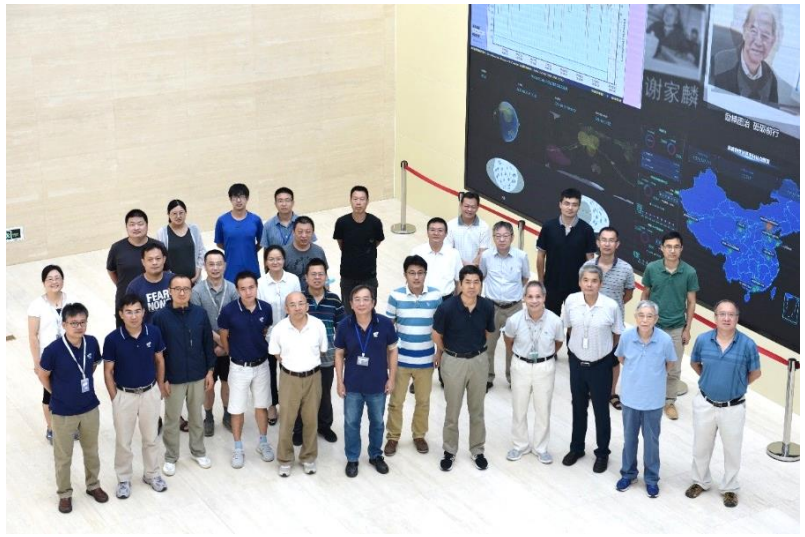
International seminars held by AD (IHEP)

Conferences and Workshops	Conference chair	Date	Number of participants
The 8th International Workshop on Cryogenics Operations (Cryo-Ops 2018)	GE Rui	2018.6.4-6.7	105
Review of Conceptual Design Report of the Circular Electron and Positron Colliders	QIN Qing	2018.6.28-6.30	41
29th International Linear Accelerator Conference (LINAC18)	CHI Yunlong	2018.9.16-9.21	391
Third Asian School on Superconductivity and Cryogenics for Accelerators (ASSCA2018)	GAO Jie	2018.12.10-12.16	85
7th IHEP-KEK SCRF Collaboration Meeting	GAO Jie	2018.9.22-23	30
The Micro Telecommunications Computing Architecture and Advanced Telecommunications Computing Architecture Workshop for Research and Industry (MTCA/ATCA Workshop 2019)	LI Jingyi	2019.6.23-25	99
9th IHEP-KEK SCRF Collaboration Meeting (**online**)	GAO Jie	2020.12.9	28
The 2nd Micro Telecommunications Computing Architecture and Advanced Telecommunications Computing Architecture Workshop for Research and Industry (MTCA/ATCA Workshop 2021)(**online**)	LI Jingyi	2021.8.24-25	114
10th IHEP-KEK SCRF Collaboration Meeting (**online**)	GAO Jie	2022.2.16	30
Review of Technical Design Report of the Circular Electron and Positron Colliders	GAO Jie	2023.6.12-16	53



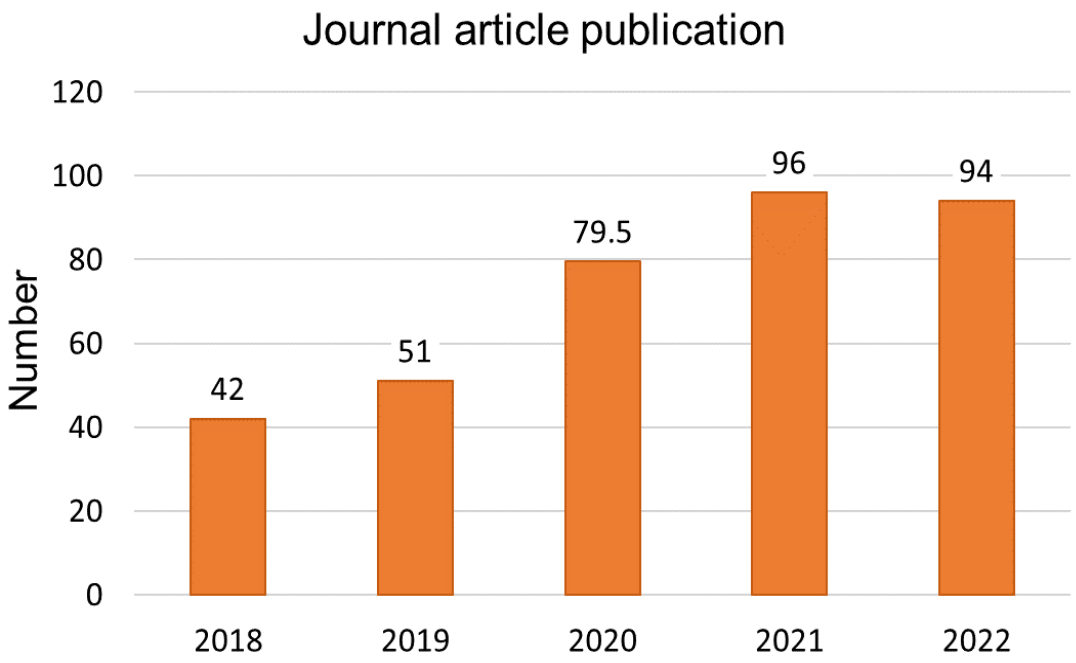
Accelerator strategical development discussion

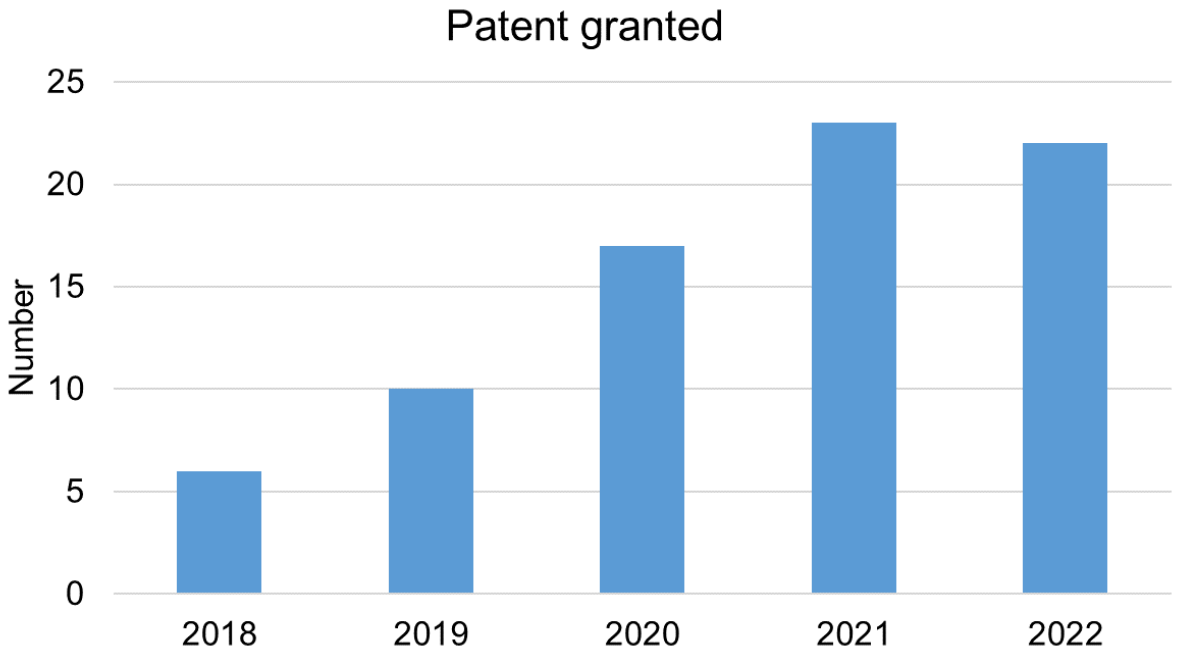
- **Focus on accelerator-based large science facilities**
  - Currently in operation of BEPC-II and aiming at better performance
  - In construction of the 4th-generation light source, HEPS
  - Continue the pre-study for CEPC
- **State-of-the-art design and technology**
  - Develop comprehensive accelerator physics and technologies for BEPC-II, HEPS and CEPC pre-study
  - Accumulate cutting-edge technologies in plasma acceleration, SRF, SC Magnet, miscellaneous technologies for green accelerator …



Publication

- **Journal article publication and granted patent increased dramatically in the past five years**
  - Summarize experience in an systematic way
  - Inspire innovation
  - Protect knowledge





Recruitment and re-organization

- **Recruitment**

Since last assessment in 2018, we successfully recruited 5 oversea researchers with national and CAS funding supports

- Lu Wei, Plasma acceleration, from USA & Tsinghua University
- Li Yuhui, Free electron laser and undulator, from Germany
- Zeng Ming, Plasma acceleration, from Germany
- Xin Tianmu, Photon injector, from USA

- **Re-organization**

- A new group set up for HTS high-field magnet, consisting of members from the magnet group and staffs from EPD

Activities and achievements in the past five years

- **BEPCII operation and update**

  - See details in Yu Chenghui's talk

- **HEPS construction progress**

  - See details in He Ping's talk

- **CEPC/SppC pre-study status**

  - See details in Gao Jie's talk

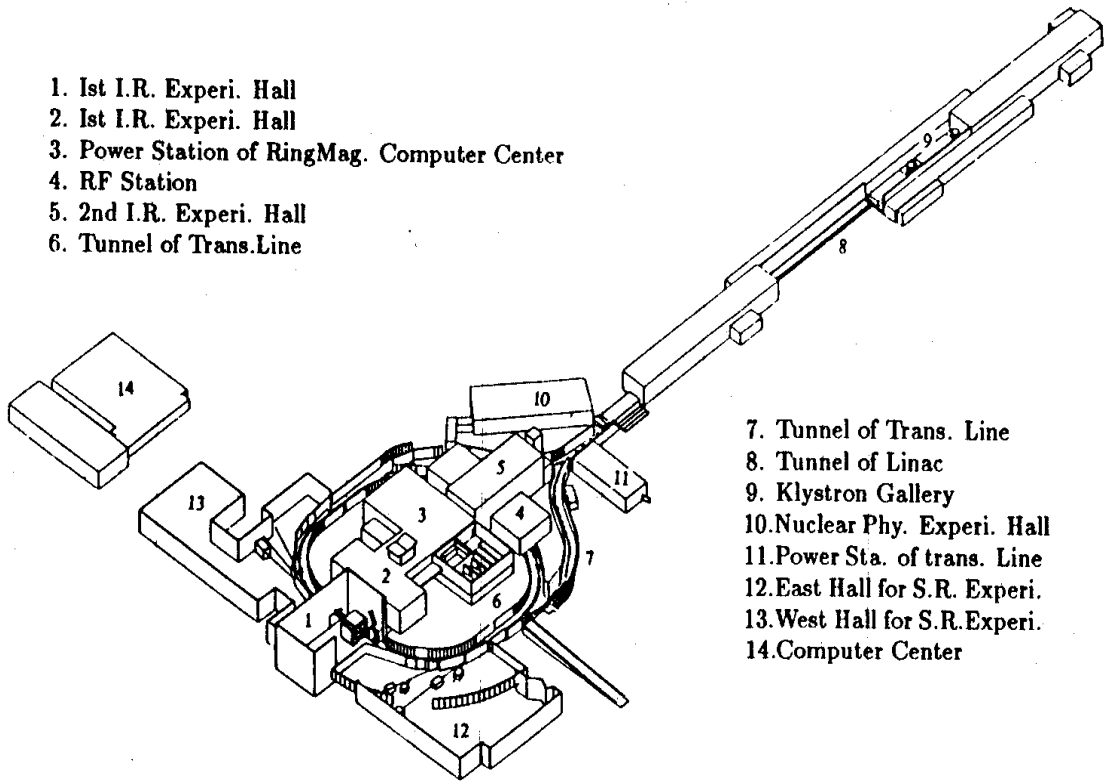
- **Key technology R&D platform and cutting-edge technology study**

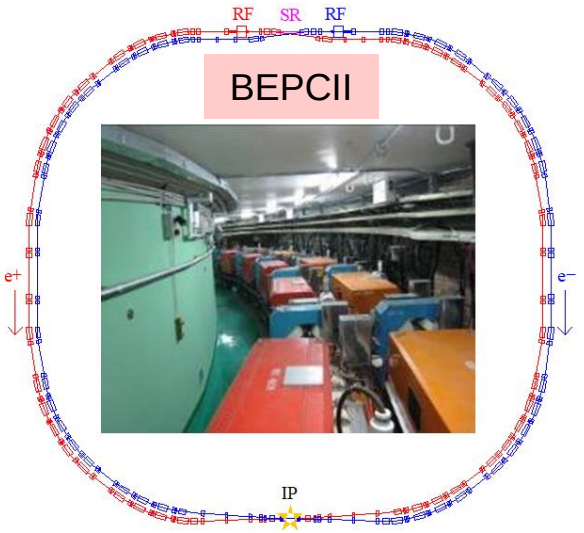
  - Plasma acceleration
  - SRF cavity & Module
  - HTS high-field magnet

Operation of BEPCII and performance enhancement

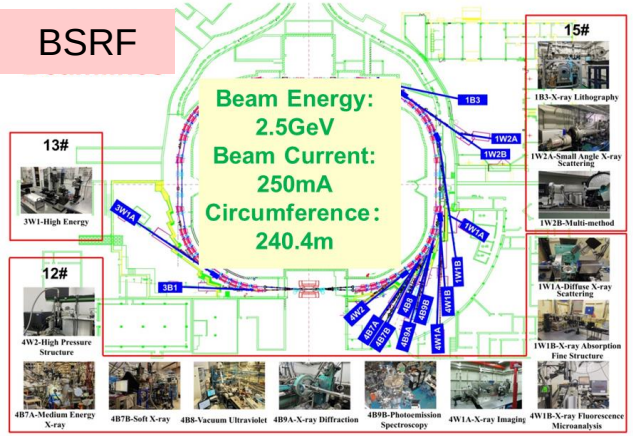
- **BEPCII**
  - Upgrade project of BEPC, operated since 2009
  - A double-ring factory-like collider
  - Collider & SR operation modes

More details in
Yu Chenghui's talk





Main Parameters	Design
Energy (GeV)	1.89
Beam current (mA)	910
Bunch current (mA)	9.8
Bunch number	93
RF voltage	1.5
Beam-beam parameter	0.04
β_x^*/β_y^* (m)	1.0/0.015
Inj. Rate (mA/min)	200 e^- / 50 e^+
Lum. ($\times 10^{33}cm^{-2}s^{-1}$)	1.0



BEPCII major achievements and significance

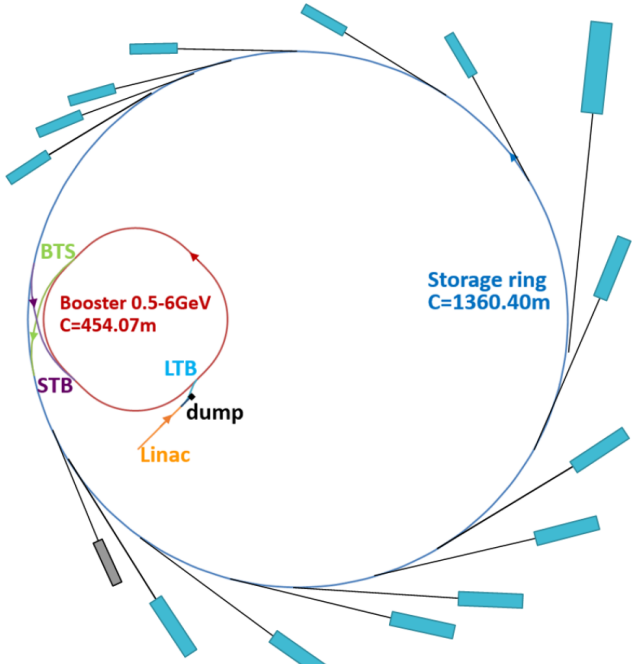
- **Major achievements in the past five years**
  - Energy upgrade completed: Full energy injection and storage up to 2.472 GeV
  - Top-up operation
  - Stable high-luminosity operation: beam current exceeds 900mA with the instantaneous luminosity of $1.1\times10^{33}cm^{-2}s^{-1}$; In the last operation year, the accumulated luminosity reached as high as 8.1 fb^{-1}

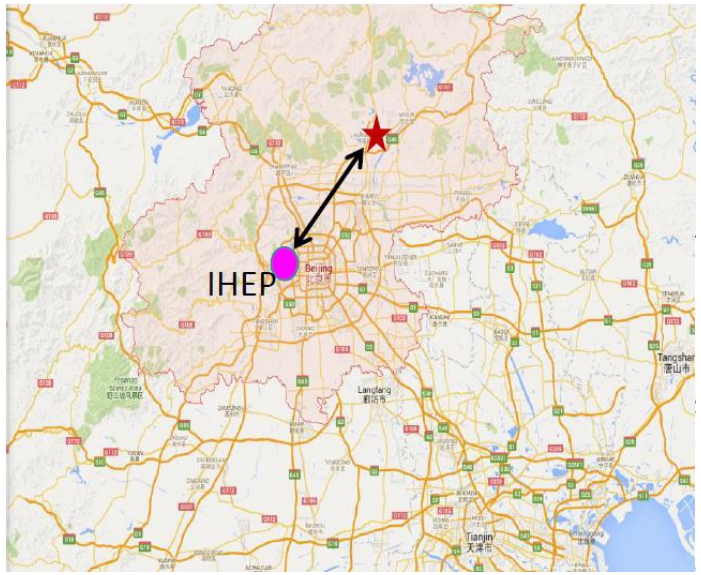
- **Significance**
  - Better knowledge on operating a high-current machine for high luminosity
  - Better control over collective instabilities through feedback
  - Invaluable experience for CEPC design and construction

HEPS construction

More details in He Ping's talk

Main parameters	Unit	Value
Beam energy	GeV	6
Circumference	m	1360.4
Emittance	pm·rad	< 60
Brightness	phs/s/mm^2/mrad^2/0.1%BW	>1x10^{22}
Beam current	mA	200
Injection		Top-up





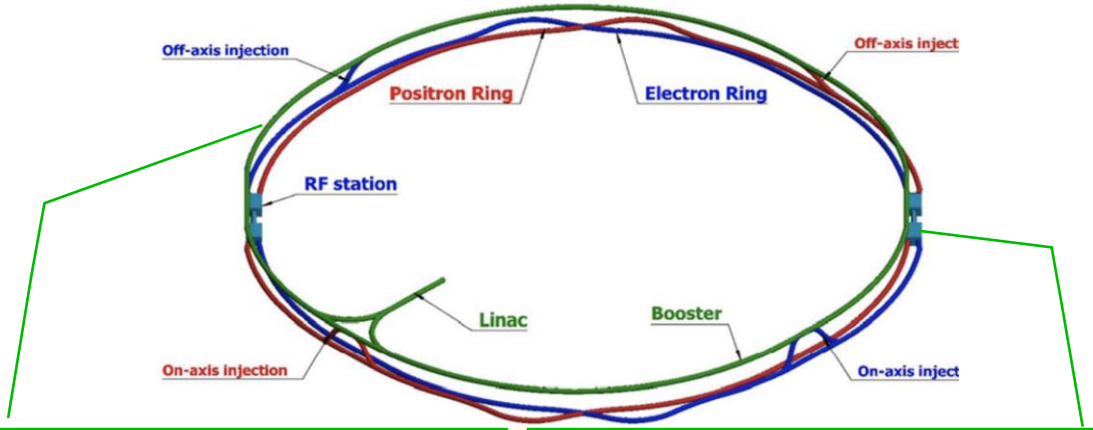
- Advanced 4th generation light source, promoting multi-disciplinary researches
- Accumulate conventional key technologies for CEPC

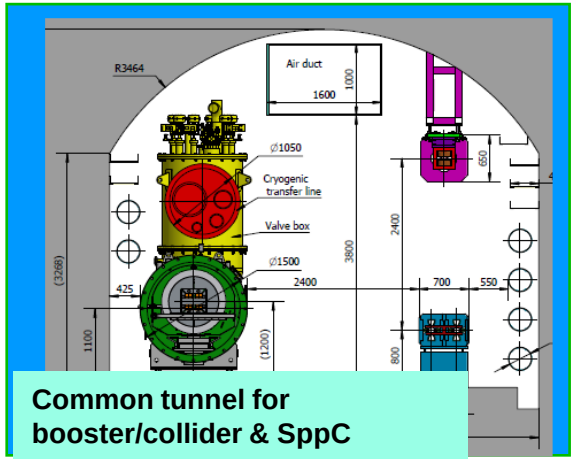
  - Magnet - Vacuum - Power supply - Beam instrumentation
  - Alignment - Control - Mechanical system - Linac complex
  - RF - Cryogenics - Utilities

CEPC TDR design

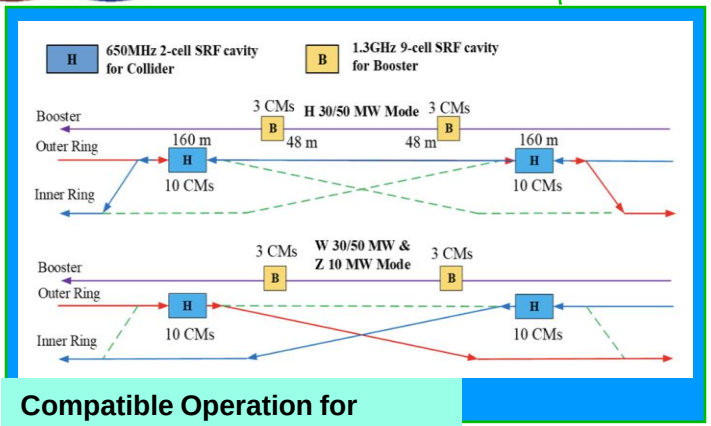
More details in Gao Jie's talk

- Circular collider: Higher luminosity than a linear collider
- 100km circumference: Optimum total cost, good also for SppC
- Shared tunnel: Accommodate CEPC booster &collider and SppC
- Switchable operation: Higgs, W/Z, top



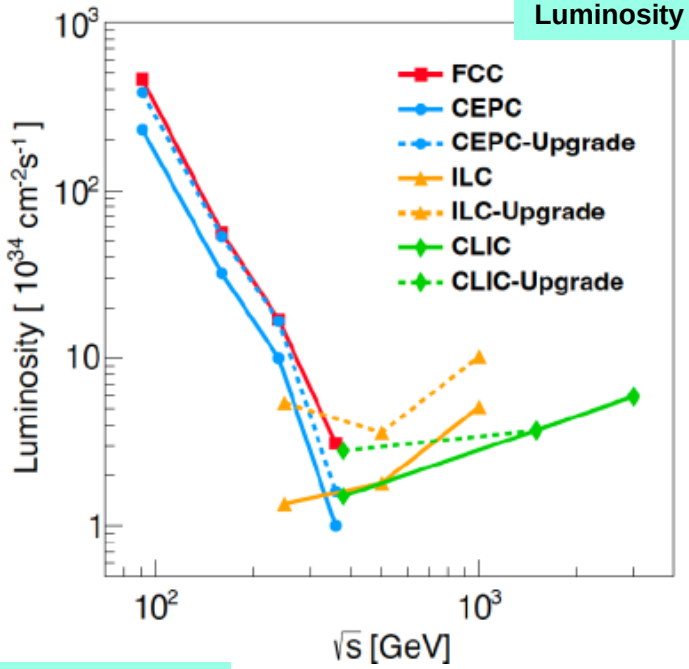


Common tunnel for booster/collider & SppC



Compatible Operation for Higgs W and Z

Luminosity comparison

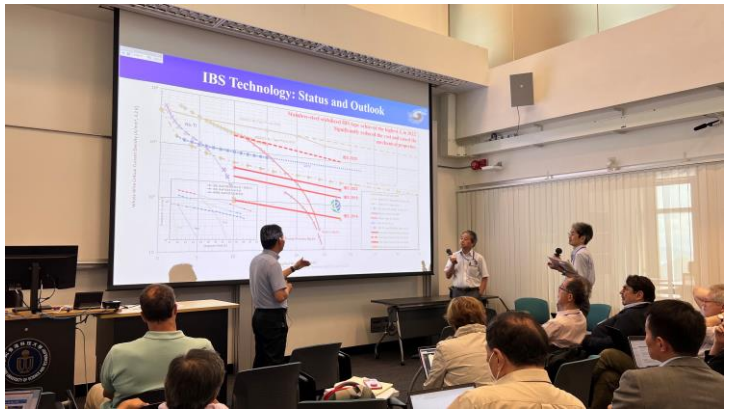


Main Parameters: High luminosity as a Higgs Factory

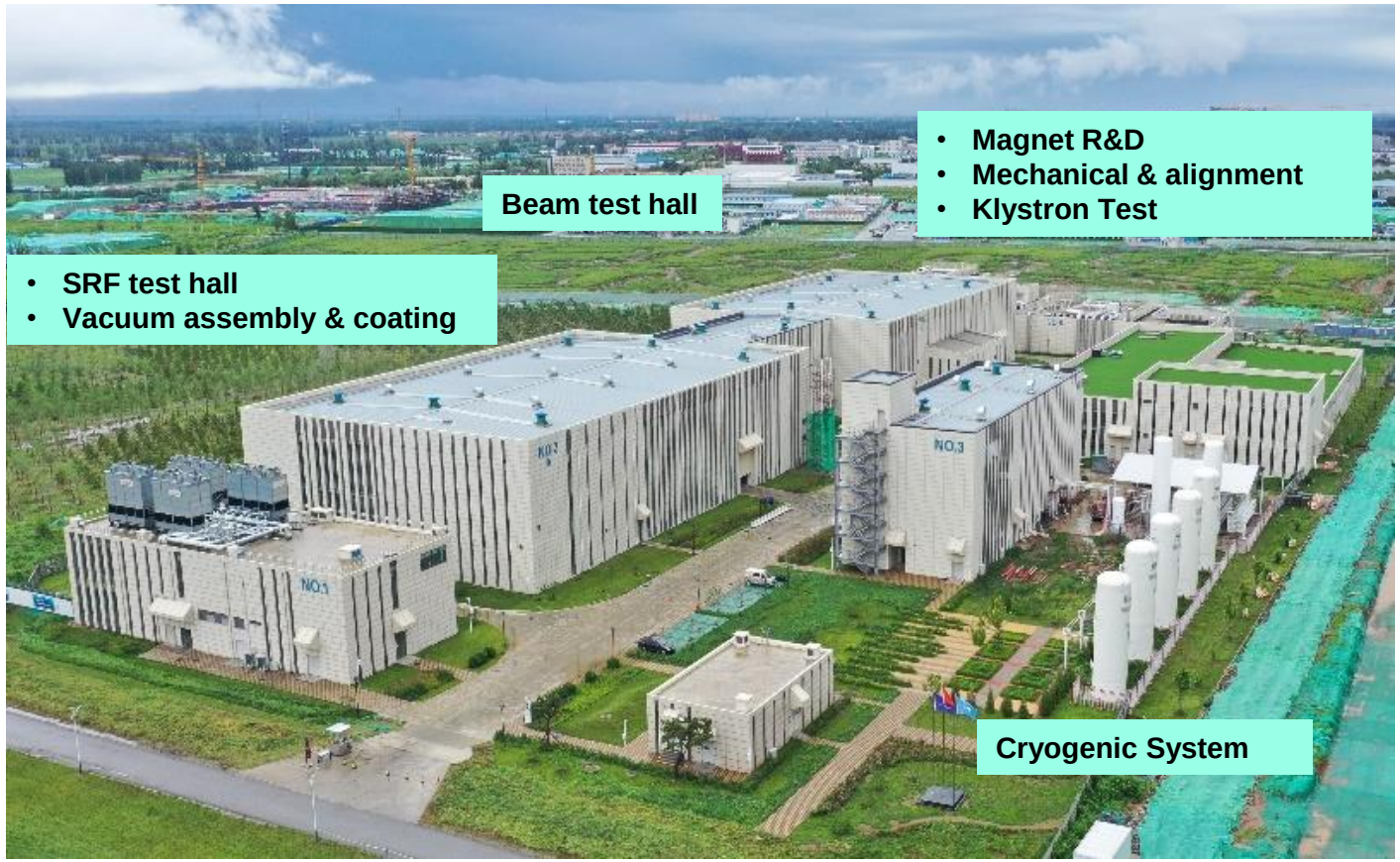
	Higgs	W	Z	ttbar
Number of IPs	2			
Circumference [km]	100.0			
SR power per beam [MW]	**50**			
Energy [GeV]	**120**	**80**	**45.5**	**180**
Bunch number	415	2161	19918	59
Emittance (εx/εy) [nm/pm]	0.64/1.3	0.87/1.7	0.27/1.4	1.4/4.7
Beam size at IP (σx/σy) [um/nm]	15/36	13/42	6/35	39/113
Bunch length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

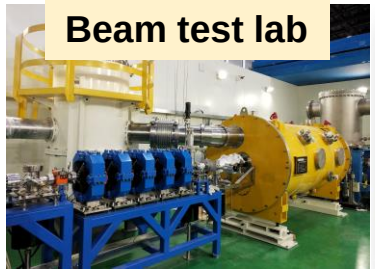
CEPC TDR international review

- An international review meeting was hosted at Hongkong University of Science and Technology during 12-16 Jun 2023; The physics design and key technology R&D status were reviewed
- The CEPC cost evaluation also passed the international review recently



Accelerator key technology R&D platform





Accelerator key technology R&D platform was established:

- ➢ SRF cavity and module
- ➢ High-precision magnet
- ➢ Vacuum assembly & coating
- ➢ High efficiency Klystron
- ➢ Mechanics & alignment
- ➢ Beam test facility

PAPS research high-light: SRF cryomodule

- 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

Parameters	Horizontal test results	CEPC Booster Higgs	LCLS-II, SHINE	LCLS-II-HE
Average Q_0 @ 21.8 MV/m	3.4×10^{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			

650MHz 2-cell

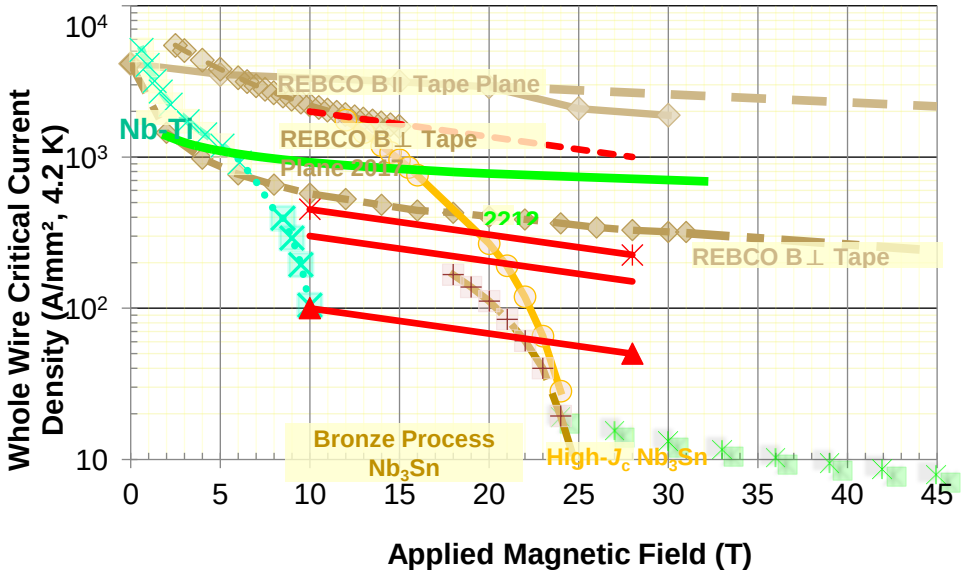
1.3GHz 9-cell

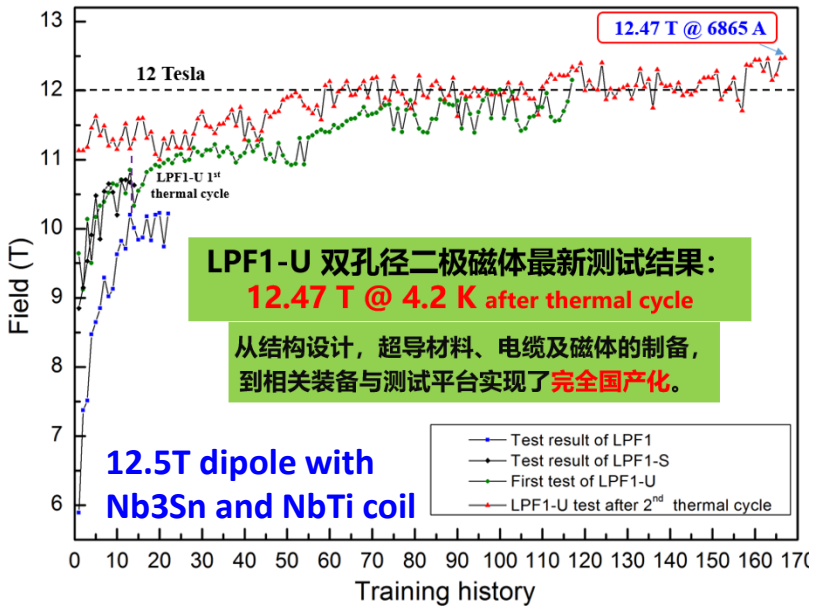
1.3GHz 9-cell

166MHz QW

R&D for Iron-based HTS magnets

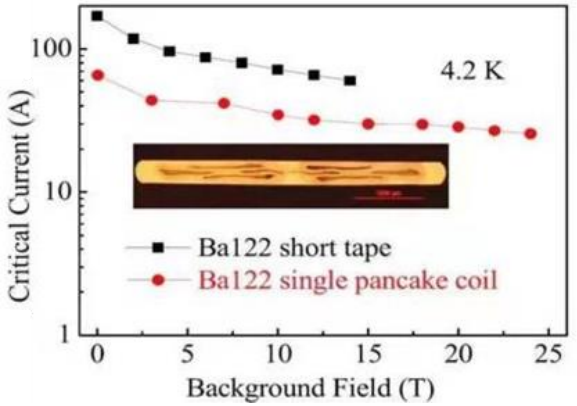
- Iron-based superconducting materials are very promising for high-field magnets
  - Isotropic
  - May go to very high field
  - Raw materials are cheap
  - Metal, easy for production
- Technology spin-off can be enormous
- Major R&D goals
  - High Jc: > 1000A/mm^2@4.2K
  - Long cable: > 1000 m
  - Low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

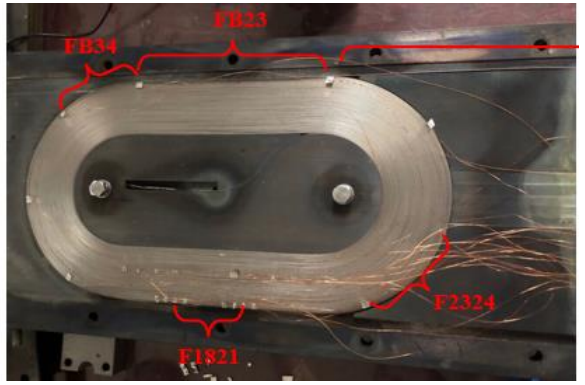




World first: 1000m IBS cable, IBS coil, ➔ magnet

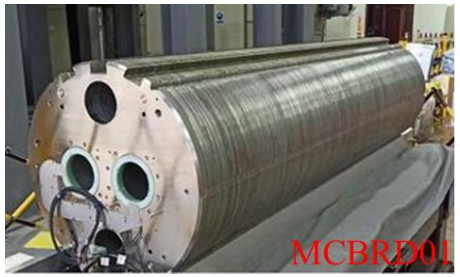
1st Iron-based Superconducting solenoid Coil at 24T



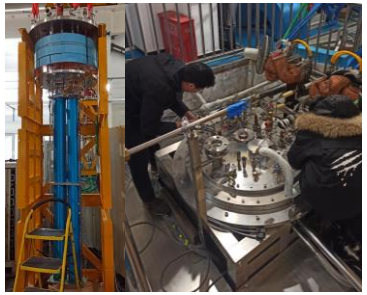


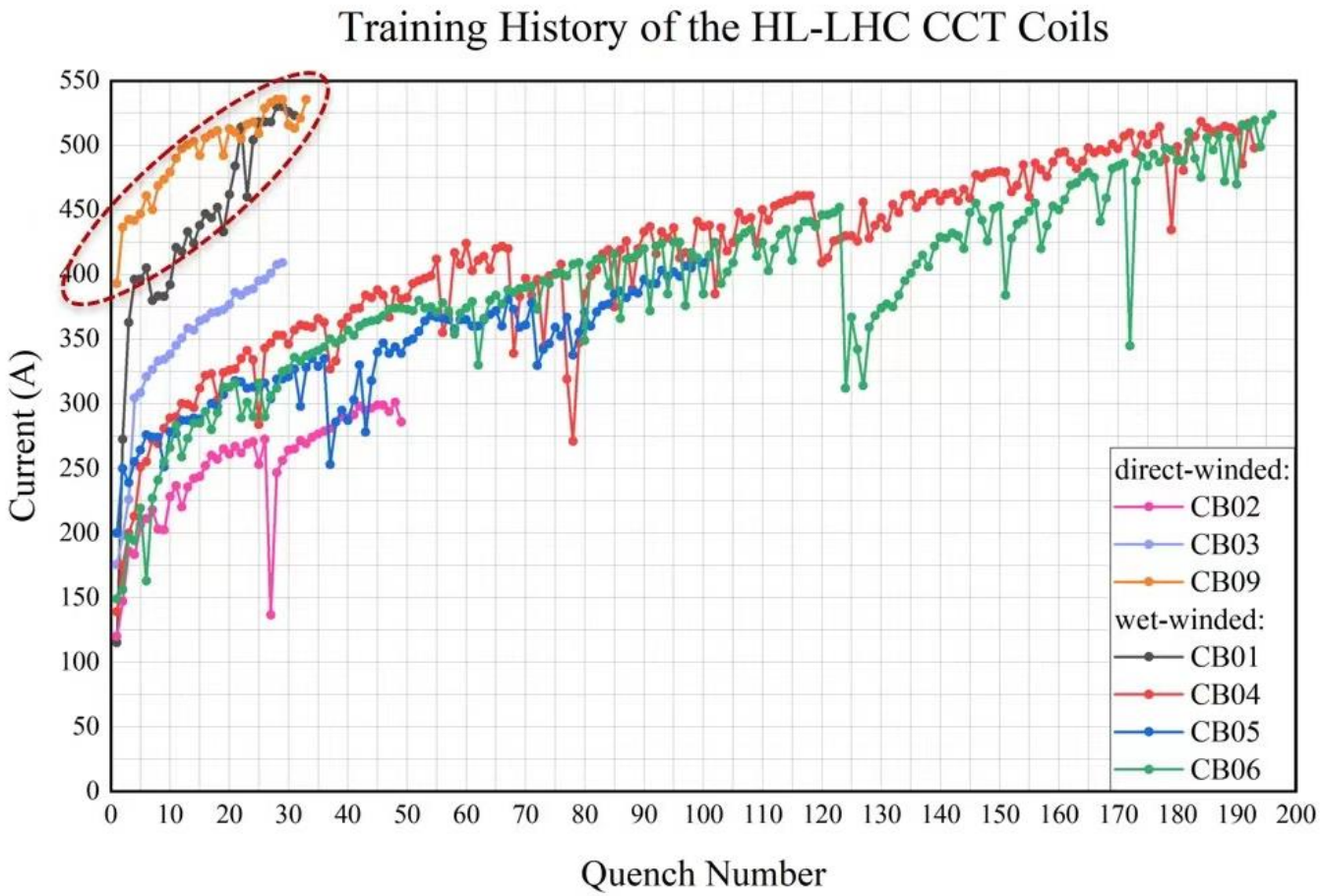
Collaboration with CERN for SC CCT magnet (HL-LHC)

- **Find a design deficiency, and reduce the quench number greatly in the training process：** **200→30**



Successful design upgrade to solve the “long training problem”, significantly reduced the times of quench during training, ensured the project progress “on track”.

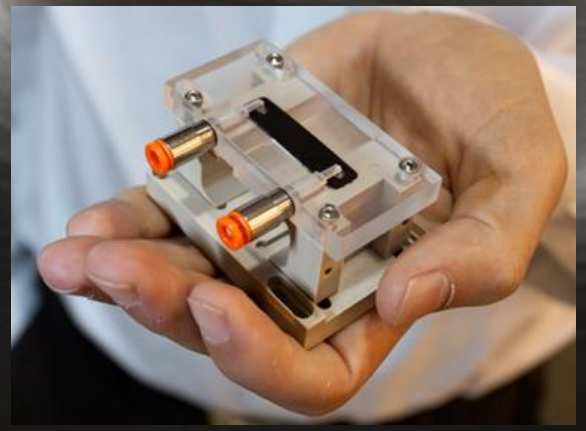




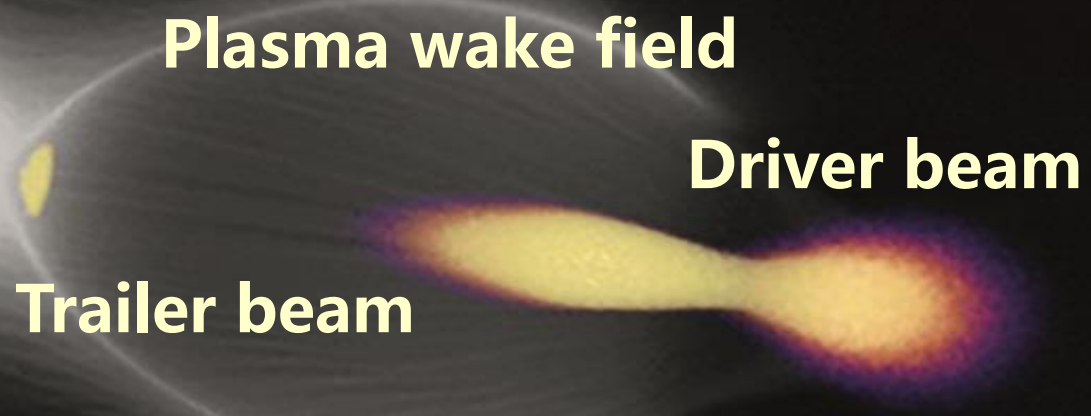
Significance of Plasma wake field acceleration

- **High gradient:** ~10-100GV/m, ~**1000times higher than conventional Acc.**
- **High energy conversion rate**
- **High repetition rate possibility**
- **Focus on PWFA acceleration**

Conventional linac



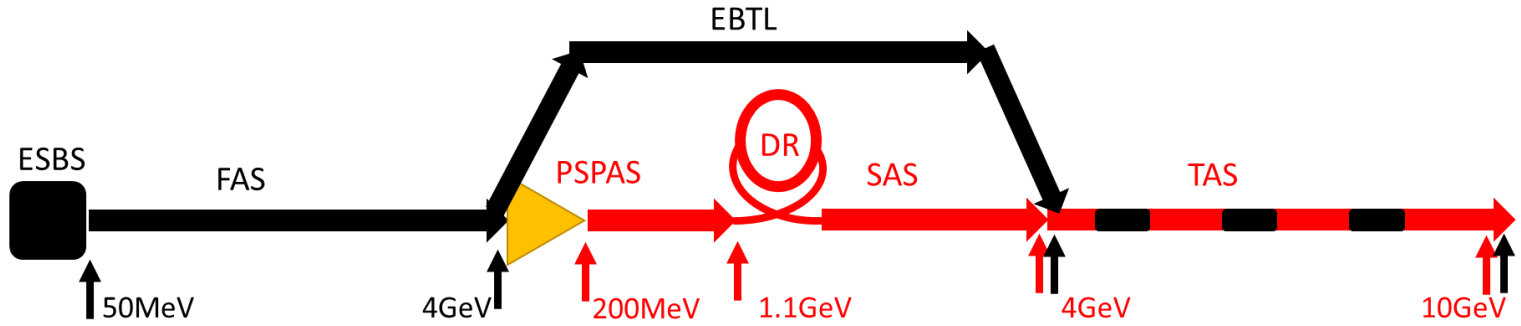
1GeV accelerator in hand



CEPC drives PWFA study @ IHEP

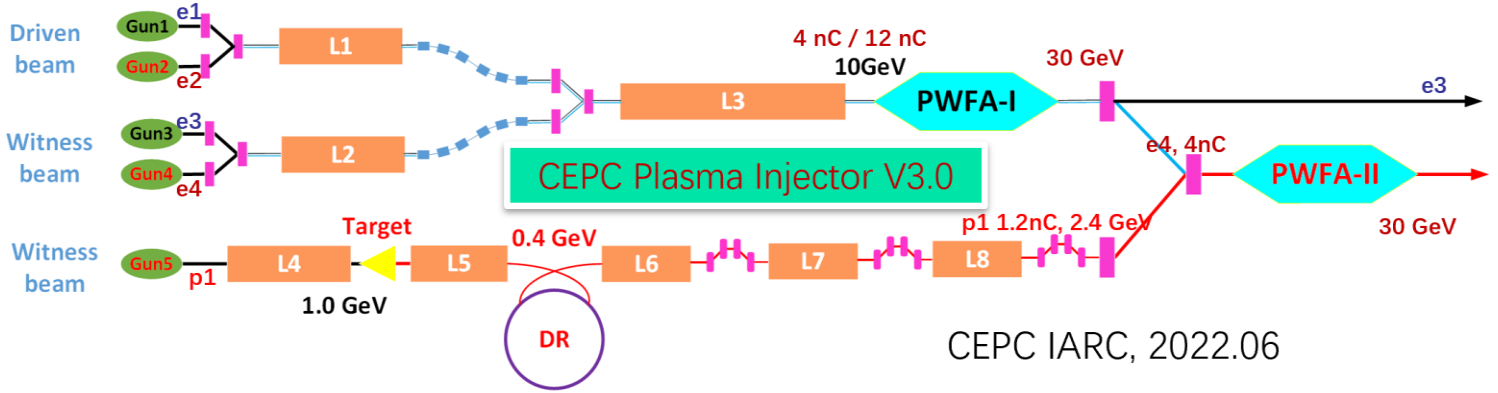
- Backup solution for CEPC linac, conceptual design based on simulation shows that the scheme is feasible

Conventional technology as the baseline design:



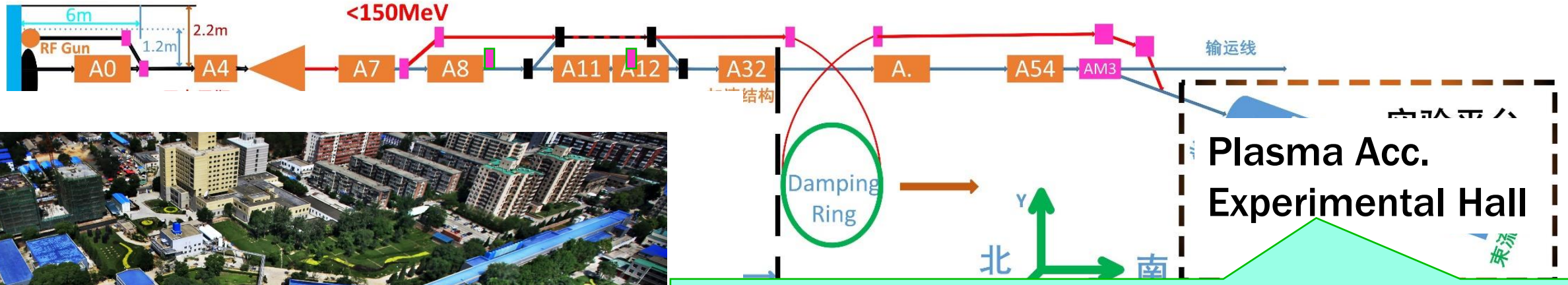
PWFA backup design:

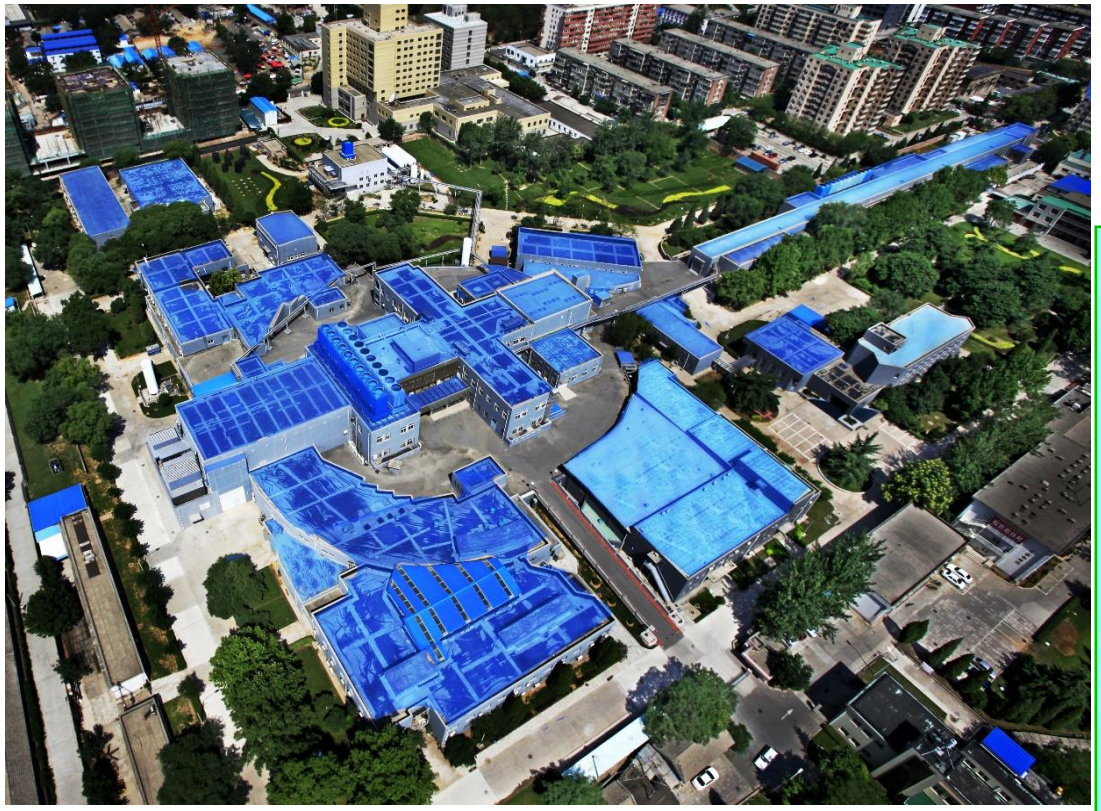
- **Main linac: 10GeV S-band**
- **L-band (10+ nC) and S-band (≤5nC) RF guns**
- **Compression and combination**
- **Different e+ acc. scheme**
- **e+ PWFA need to be cascaded**
- **e- PWFA with TR ~ 3.5**

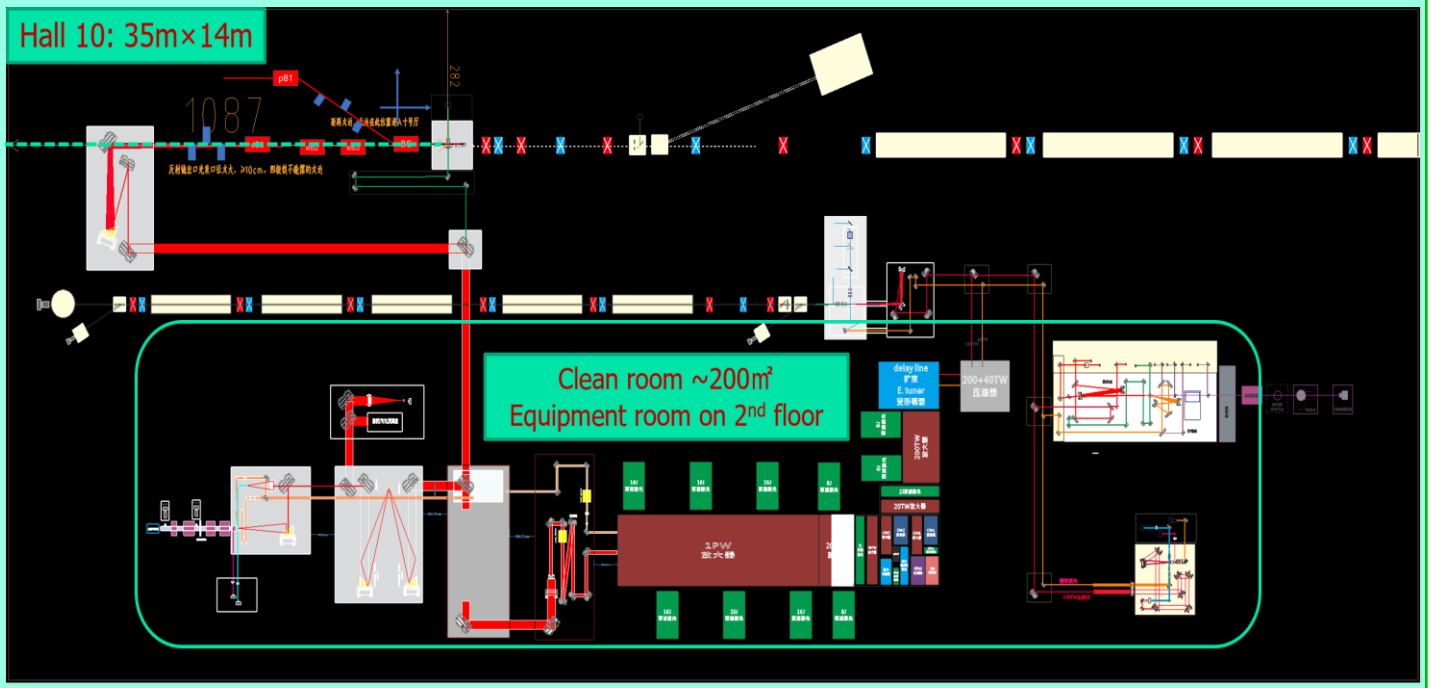


CEPC IARC, 2022.06

Test facility to be built at BEPCII



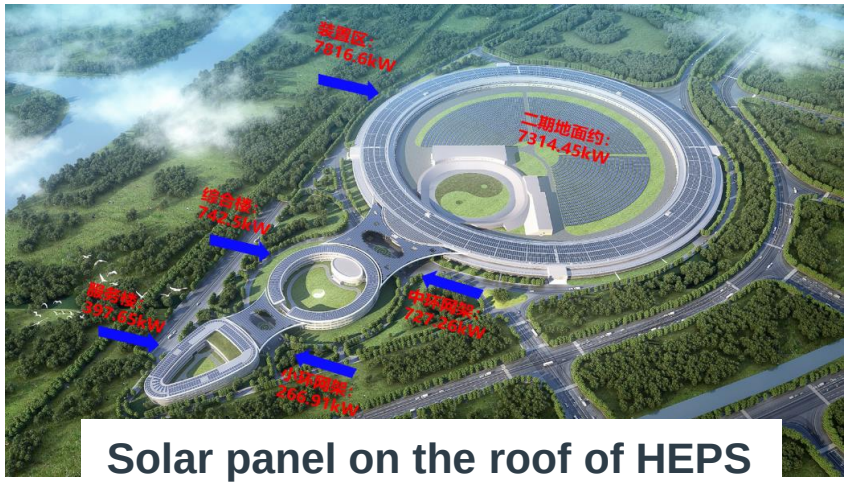




2.5 GeV e-/e+ beamline + PW-level high performance laser system

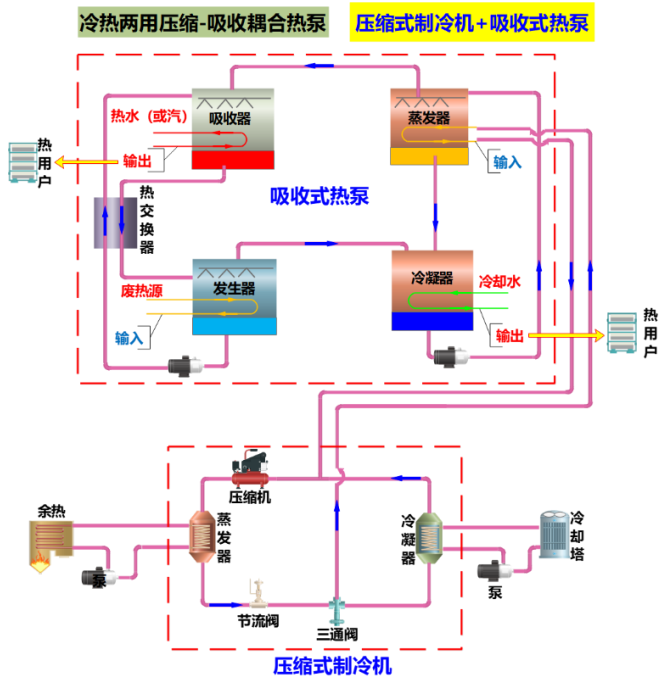
Efforts on green accelerator

- **Measures at HEPS**
  - Solar panel on roof: 10 MW ➔ 10% saving
  - Permanent-magnet dipole @ storage ring: 5.6M kWh saving/yr
  - Energy recovery from cooling water (13 MW@42°C) : Exceeds HEPS heating requirement



Solar panel on the roof of HEPS

- **R&D for CEPC**
  - High Q SRF cavity: reduce 10MW operation power in a comprehensive evaluation, saving electricity consumption ~60M kWh per-year
  - R&D effort for High efficiency & Energy recovery klystron: improve the efficiency from the conventional value (55%) the high efficiency of 80%, CEPC will save 160M kWh electricity per-year
  - Proposal and R&D for “heating-cooling” switchable waste energy recovery system, and increasing the re-use of energy in the cooling water
  - R&D and prototypes for dual-aperture magnets with a common coil



Leading scientists

BEPCII & BEPC-U

Chenghui Yu	(Project leader)
Jiuqing Wang	(Acc. Physics)
Yuan Zhang	(Acc. Physics)
Pei Zhang	(RF)
Fusan Chen	(Magnet)
Rui Ge	(Cryogenics)

HEPS

Weimin Pan	(Project Manager)
Huamin Qu	(Chief Engineer)
Jingyi Li	(Injector)
Ping He	(Storage Ring)
Yi Jiao	(Acc. Physics)
Junhui Yue	(Beam Diagnostics)
Fusan Chen	(Magnet)
Rui Ge	(Cryogenics)
Fengli Long	(Power supply)
Pei Zhang	(RF)

CEPC & SPPC

Jie Gao	(Convener)
Yuhui Li	(Convener)
Chenghui Yu	(Convener)
Dazhang Li	(Plasma Acc.)
Qingjin Xu	(SC Magnet)


F. Chen


J. Gao


R. Ge


P. He


Y. Jiao


D. Li

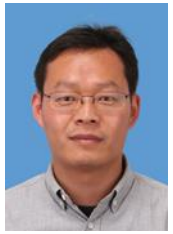

J. Li


Y. Li


F. Long


W. Pan


H. Qu


Q. Xu


J. Wang


C. Yu


J. Yu


P. Zhang


Y. Zhang

Personnel (FTE by projects)

Current staff members: 241

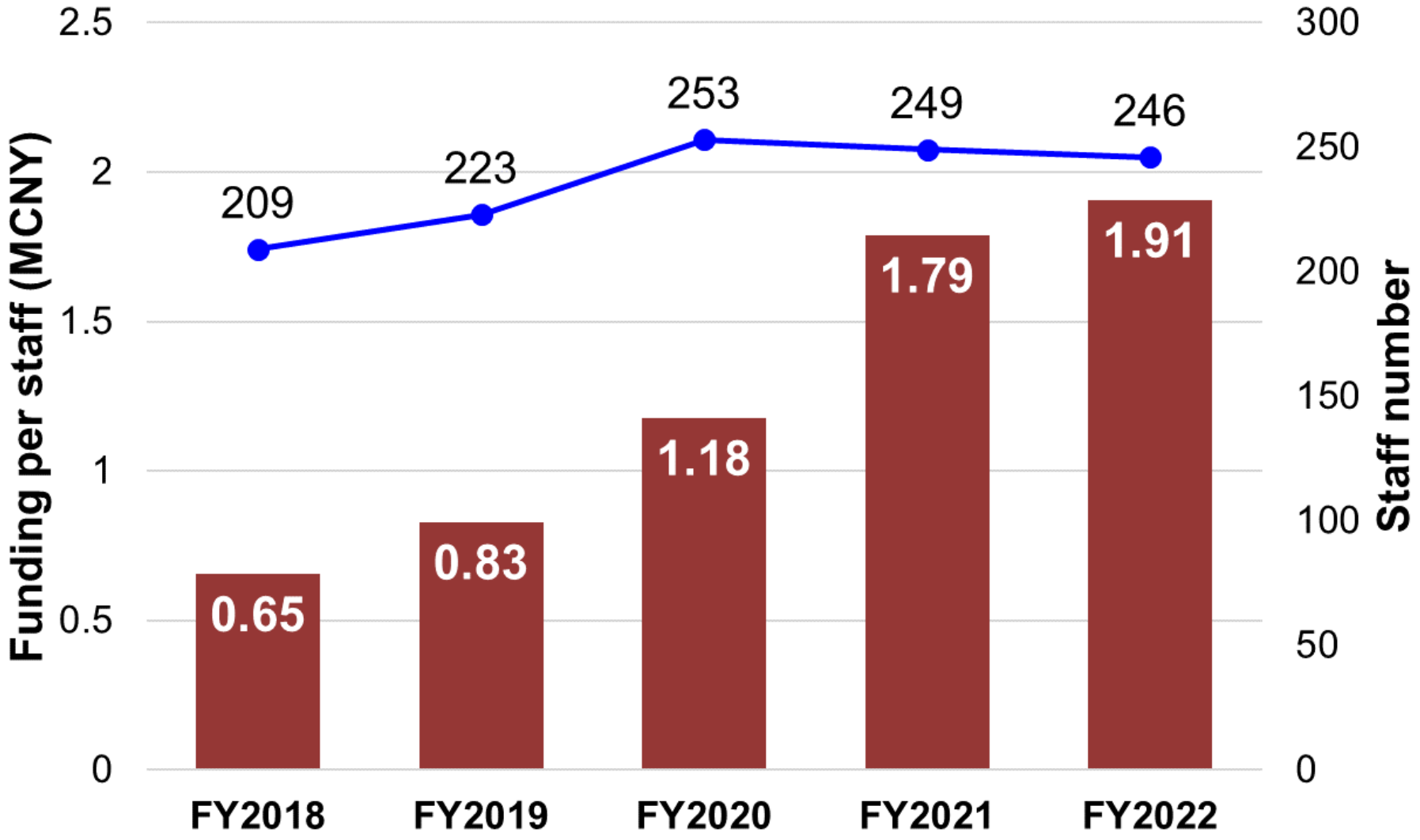
2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026 onward
HEPS-TF (~60 FTE)										
	PAPS constr. (~20 FTE)				PAPS Op. (~10 FTE)					
			HEPS constr. (~120 FTE)							HEPS Op. (~100 FTE)
BEPCII Op. (~50 FTE)					BEPCII Op. (~30 FTE)					
					BEPCII-U constr. (~30 FTE)					BEPCII-U Op. (~30 FTE)
Miscellaneous R&D (~30 FTE)										
CEPC R&D (~20 FTE)										CEPC constr. (>200 FTE)
Total: ~160	~180	~180	~240	~240	~240	~240	~240	~240	~240	**>240**

Funding in 2018-2023

Unit: Million CNY

Funding Source	FY2018	FY2019	FY2020	FY2021	FY2022
HEPS Project	2.0	64.9	217.5	384.9	391.8
PAPS Project	80.2	57.9	0	2.0	0
BEPCII Operation	22.2	22.2	22.2	22.2	22.2
MOST Grants	10.7	2.6	4.0	0	4.8
NSFC Grants	2.8	4.7	3.6	2.4	6.9
CAS Grants	17.7	27.0	41.8	29.3	35.0
Miscellaneous	1.2	5.3	8.6	4.2	8.0
Total	**136.7**	**184.6**	**297.5**	**445.0**	**468.7**

Personnel budget in the past five years



Vision and future plan

- By taking advantage of the accelerator-based projects currently under construction and planned by IHEP, we aim to become one of the leading accelerator research centers worldwide.
- With the continuous development of Accelerator Physics and Key Technology, we are confident to complete the HEPS project in the near future, and able to commence the CEPC once it is approved
- Develop cutting-edge accelerator technologies, including the plasma accelerator technology, HTS high-field magnet, miscellaneous technologies for a green accelerator, etc.
- Try to attract more excellent researchers from around the world to join the Accelerator Division, and educate more young scientists and engineers
- Contribute to the well-being of the society through knowledge transfer of the accelerator technologies developed

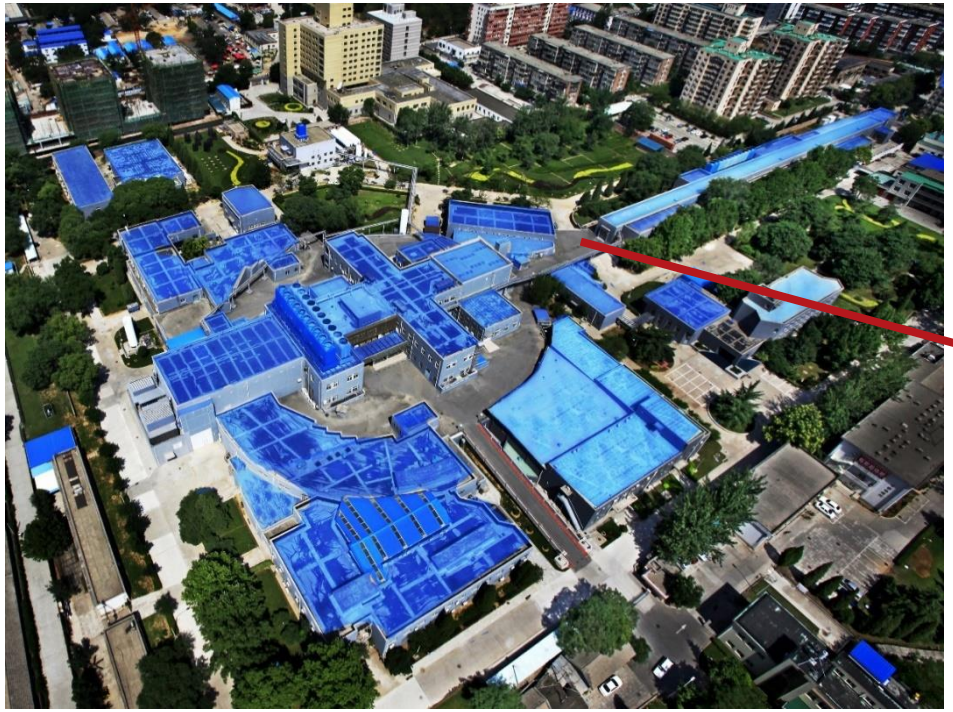
Summary

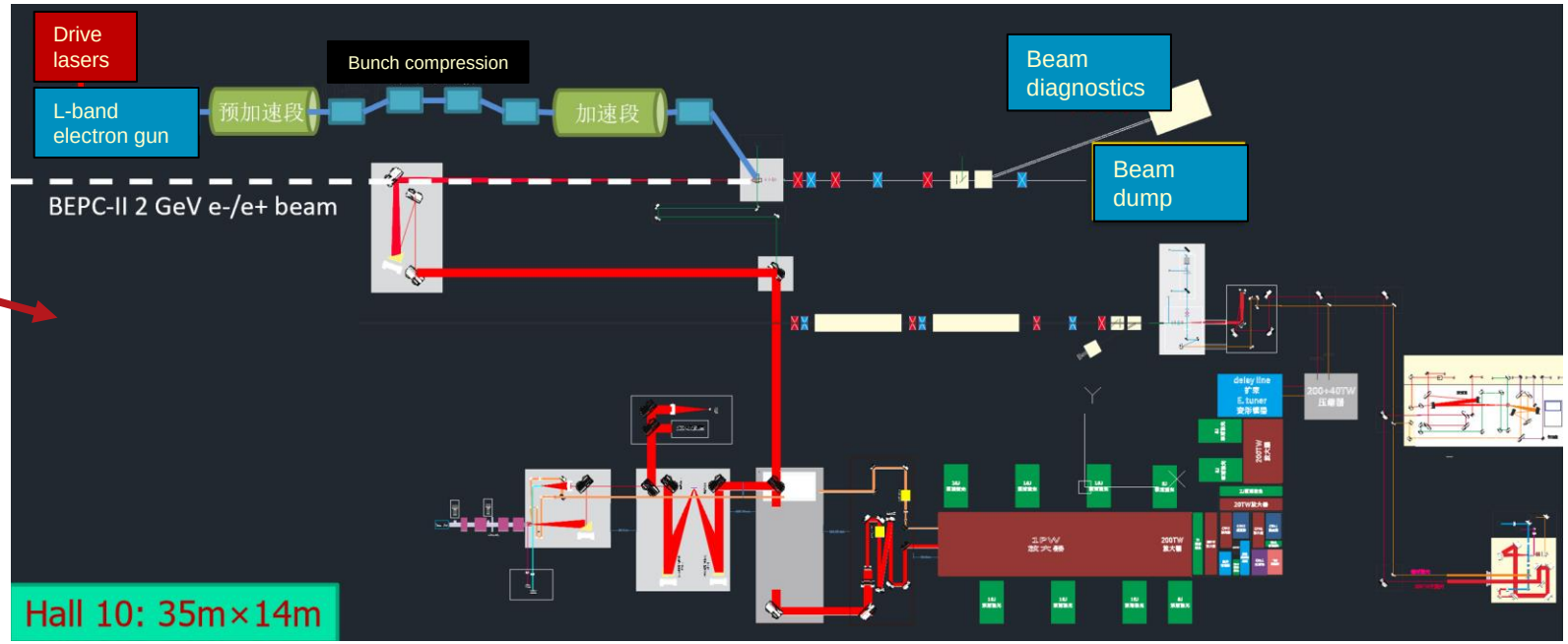
- In the past 5 years, the Accelerator Division has made significant progress, including the progress in BEPCII operation, the construction of HEPS and CEPC TDR researches
- Research funding has increased annually, and the manpower has increased by 29% over the last 5 years
- AD will try to complete the HEPS accelerator construction according to the schedule, and begin the Engineering Design Report studies for the CEPC
- More projects, such as the PWFA plasma test facility already planned and will be started soon

Thank you for your attention

Backup slides

PWFA plasma acceleration TF @ BEPC-II





	Beam quality parameters										
	bunch size	bunch length	normalized emittance	charge	energy	energy spread	Peak Current	longitudinal beam profile	transverse jitter	longitudinal jitter	tilt
Current beam e0 / p0	/	10ps	400μm 1600μm	2nC 50pC	2GeV	0.50%	0.2kA 5A	Gaussian	?	?	?
eL 200TW Laser produced	10μm	10μm 3fs	1μm	100pC	0.5GeV	＜5%	≥5kA	to be measured	1μm	0.1ps	1mrad
e1_H After optimization	100μm	300μm 1ps	400μm	2nC	2GeV	＜0.5%	≥2kA	Gaussian	100μm	1ps	1mrad
p1 After optimization	100μm	300μm 1ps	1600μm	50pC	2GeV	＜0.5%	≥0.05kA	Gaussian	300μm	5ps	1mrad
e2 After change the e- gun	50μm	600μm 2ps	100μm	≥5nC	2GeV	＜0.5%	≥5A	Gaussian Triangle	100μm	1ps	1mrad
p2 After install DR	50μm	100μm 0.3ps	40μm	1nC	2GeV	＜0.5%	~3kA	Gaussian	100μm	1ps	1mrad

Key PWFA experiments:

1. HTR e- PWFA
2. High quality e+ PWFA
3. High efficiency staging
4. PWFA-based FEL
5. Beam and wakefield diagnostic

CEPC TDR R&D maturity

- CEPC received ~ 260 Million CNY from MOST, CAS, NSFC, etc for the key technology R&D
- Large amount of key technology validated in other project by IHEP: BEPCII, HEPS, …

CEPC R&D ~ 40% cost of acc. components	➢ High efficiency klystron ➢ SRF cavities ➢ Positron source ➢ High performance accelerator	➢ Novel magnets: Weak field dipole, dual aperture magnets ➢ Extremely fast injection/extraction ➢ Electrostatic deflector ➢ MDI
BEPCII / HEPS ~ 50% cost of acc. components	➢ High precision magnet ➢ Stable magnet power source ➢ Vacuum chamber with NEG coating ➢ Instrumentation, Feedback system	➢ Survey & Alignment ➢ Ultra stable mechanics ➢ Radiation protection ➢ Cryogenic system ➢ MDI

~10% remaining (the machine integration, commissioning etc.) and is anticipated to be completed by 2026, and the international contribution/collaboration may be needed.

Personnel

- **Human resources**
  - Staff: 241 (including 4 secretaries)
  - Graduate students: 84
  - Temporary staff: 21

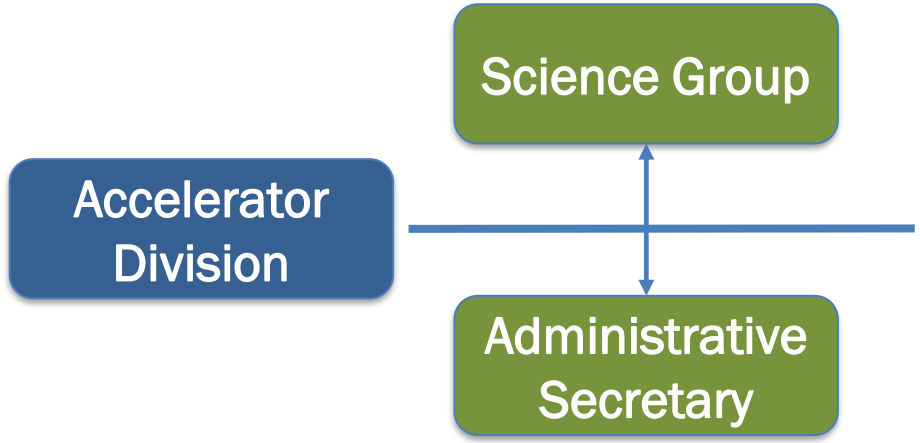
Researcher:	79
Engineer:	145
Experimentalist:	14
Admin. & Secretary	4

2018-23
new staff
↑ 35%

Will keep stable in the near future

BEPCII:	63
HEPS:	120
CEPC:	18
PAPS:	8
Tech. R&D:	28
Secretariat:	4

Organization & Staffing

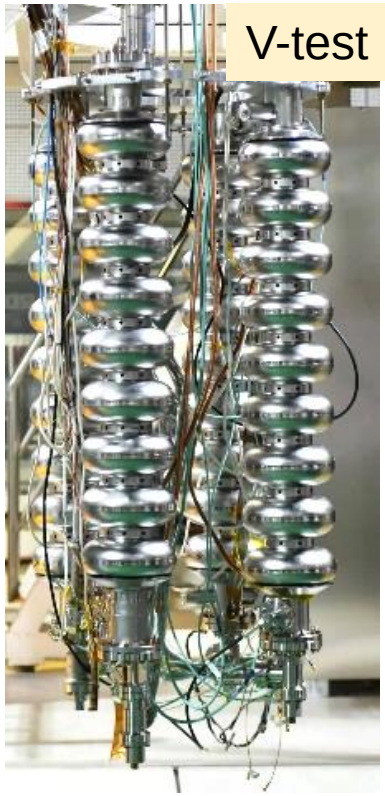


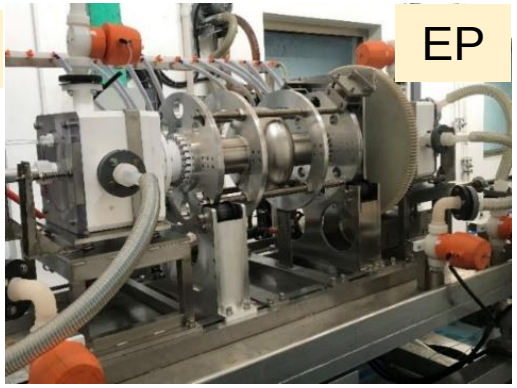
Staff No.	Age		Education Background		Title		Type	
241	<36	57	PhD	116	Professor	51	Researcher	79
	36-45	97	Master	73	Associate	114	Engineer	145
	46-55	59	Bachelor	43	Assistant	54	Experimentalist	14
	>55	28	Others	9	Junior	22	Secretary	3

Graduate students: 84 Temporary staff: 21

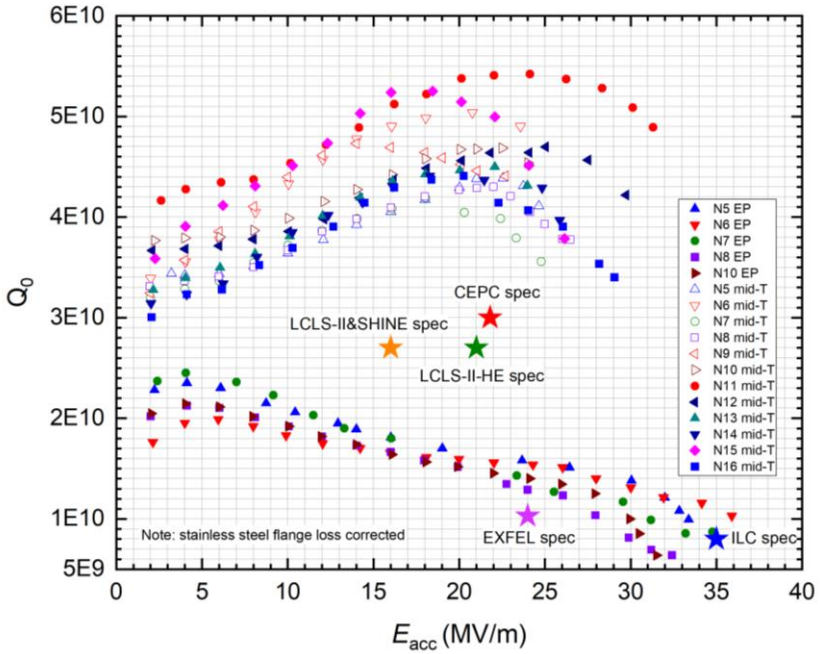
SRF cavity achievement

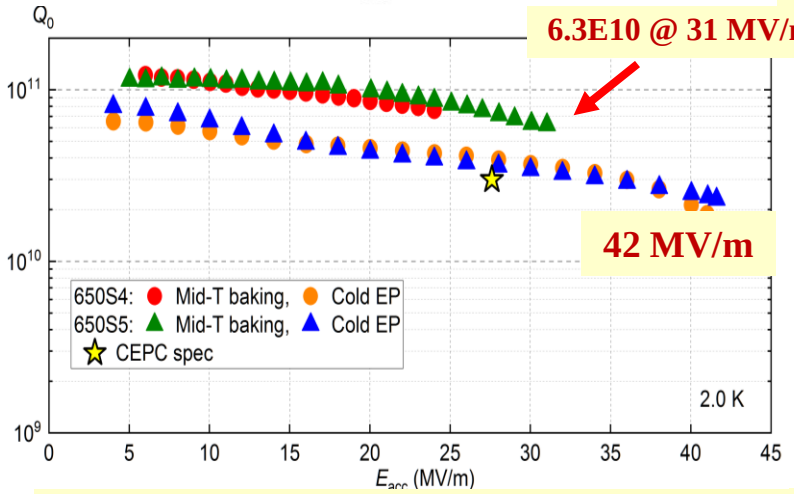
- Mid-T baking (O-doping) vs. N-doping: higher E_{acc} & Q, simple process, less EP
- Excellent results obtained, exceeding requirements of CEPC, SHINE, LCLS-II, etc.
- ILC-type cavities with higher E_{acc} is also under development





Vertical test of 1.3GHz 9-cell cavity





Vertical test of 650 MHz 1-cell cavity