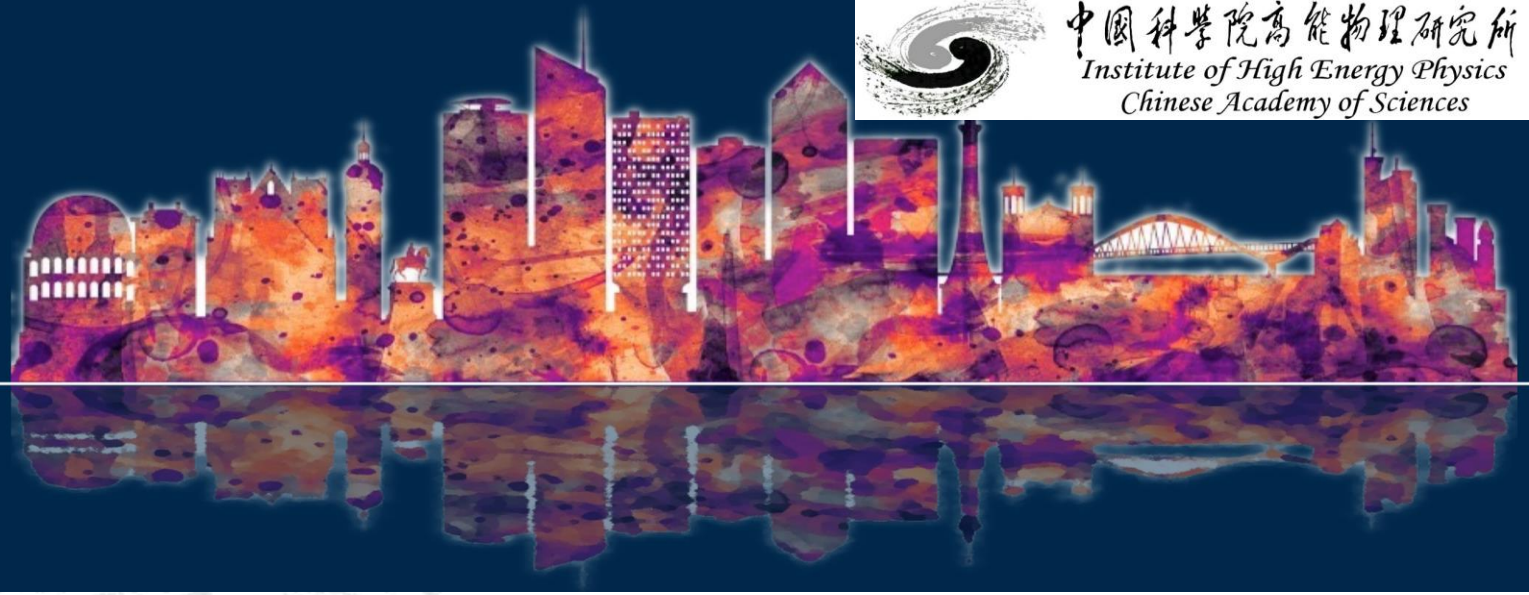
17th Workshop of the
FCPPN/L
France-China Particle Physics Network and Laboratory
Lyon, France • 29 June – 3 July 2026



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

IHEP SRF activities and collborations

Rui Ge

Institute of High Energy Physics, CAS

Outline

1. Introduction
2. SRF accelerator projects
3. R&D and infrastructures at IHEP
4. International collaborations
5. Summary

SRF Accelerator Projects at IHEP

	Operation	Construction	Design & R&D
Collider	**BEPCII** (1.89 GeV, 2 CAV, since 2006)	**BEPCII upgrade** (2.35 GeV, 4 CAV, complete in 2024)	**CEPC** (45.5-180 GeV, 288 ~ 980 CAV)
Synchrotron Light Source	**BSRF** (2.5 GeV, 2 CAV, since 2006)	**HEPS** (6 GeV, 10 CAV, complete in 2025)	
Proton & Heavy Ion	**ADS injector I** (10 MeV, 14 CAV, since 2016)	**CSNS-II** (300 MeV, 54 CAV, complete in 2028)	**CSNS-III** (1 GeV)

Superconducting RF Systems at IHEP

Light Sources & FELs

BSRF, HEPS, CW FEL, ERL

166 MHz (HEPS)
World's first very low freq
β=1 module

1.3 GHz (FEL, CEPC, ILC)
World's first mid-T high Q module

HEP Colliders

BEPCII&U, CEPC, ILC

500 MHz (BEPC-II&U, HEPS)
In-house-made, long-term operation
in large scientific facility

650 MHz (CEPC, ADS, CSNS)
World's first 650 MHz cryomodule

High Intensity Proton Linacs

ADS, CSNS-II, *ν* factory

325 MHz (ADS)
World's first spoke cavity linac

324 MHz (CSNS-II)
China's first double-spoke module

Outline

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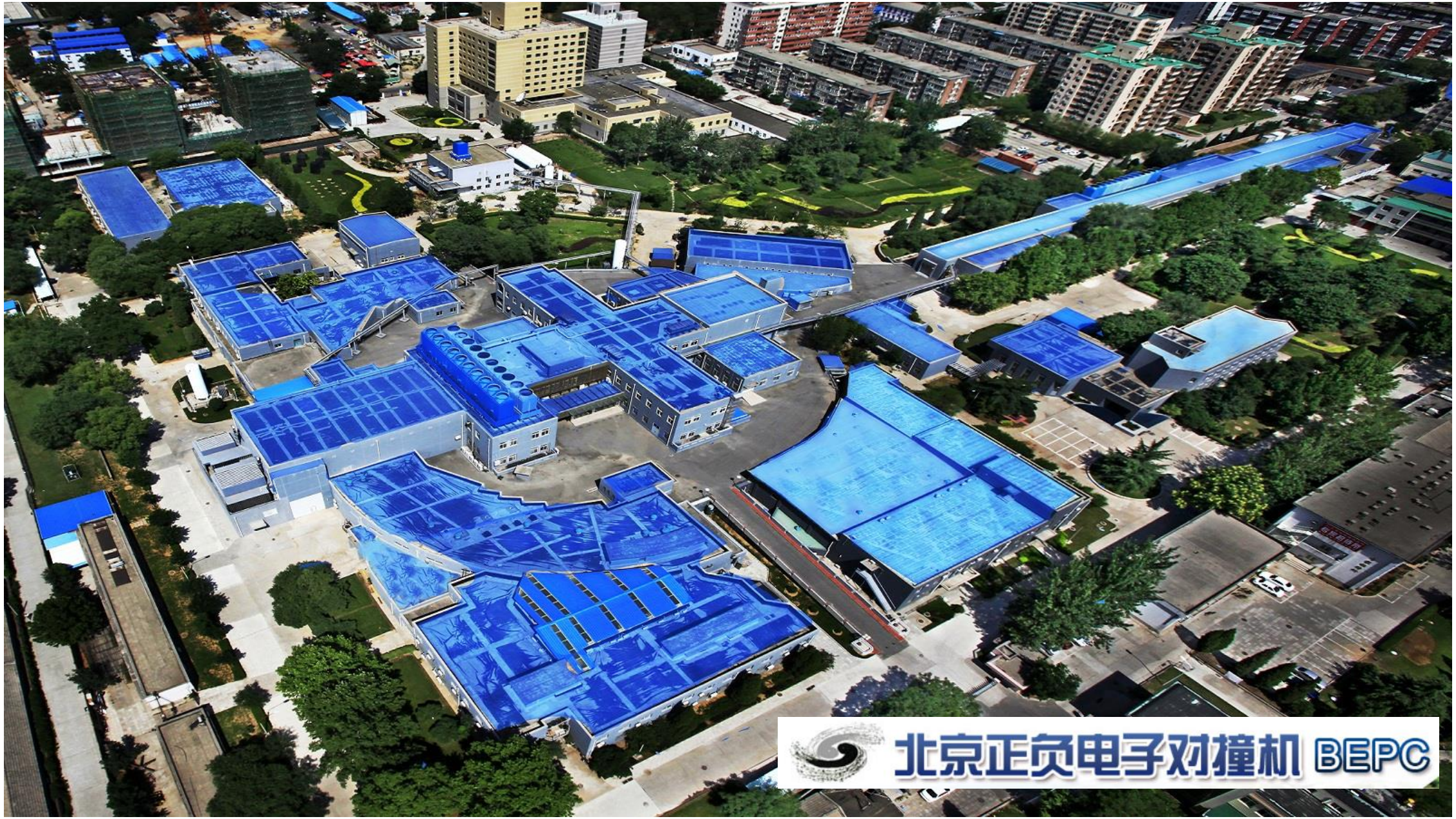
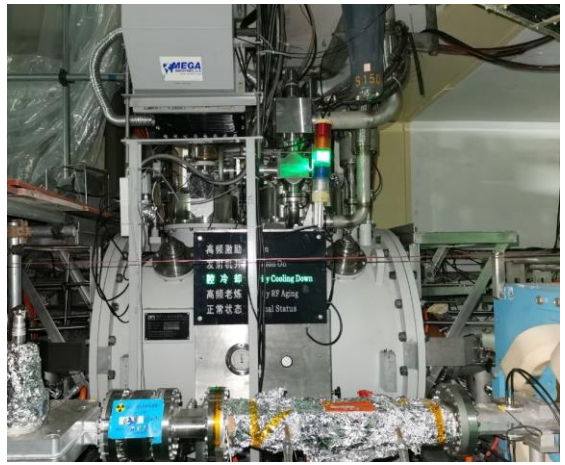
IHEP BEPCII and Upgrade



BEPCII SRF System

- BEPCII SRF system stable operation since 2006 with two imported cavities from Japan and in collaboration with KEK, reached design luminosity of $1x10^{33}$ $cm^{-2}s^{-1}$ (910 mA @ 1.89 GeV) in 2016.
- In 2017, east cavity replaced with in-house-made cavity and module, stable operation till now.
- Three imported sub-systems (SRF cavity and module, LLRF, RF power source) have been replaced with in-house-made ones.



In-house-made 500 MHz cavity and module

made in 2011, stable operation since 2017

Digital LLRF system

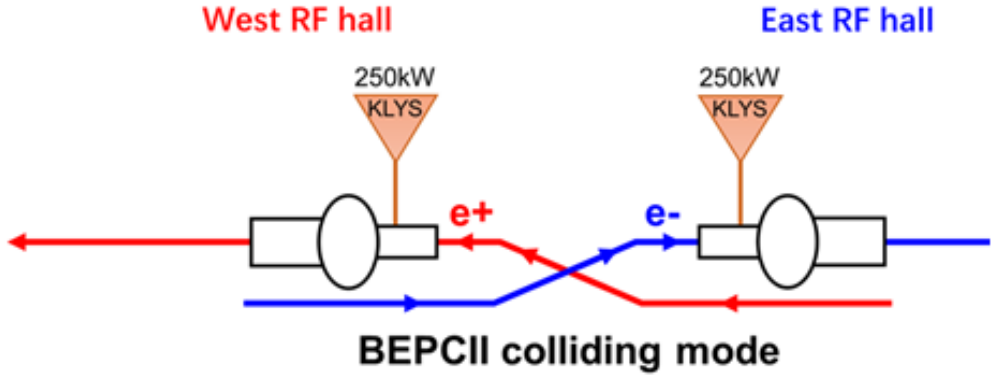
Stable operation since 2019

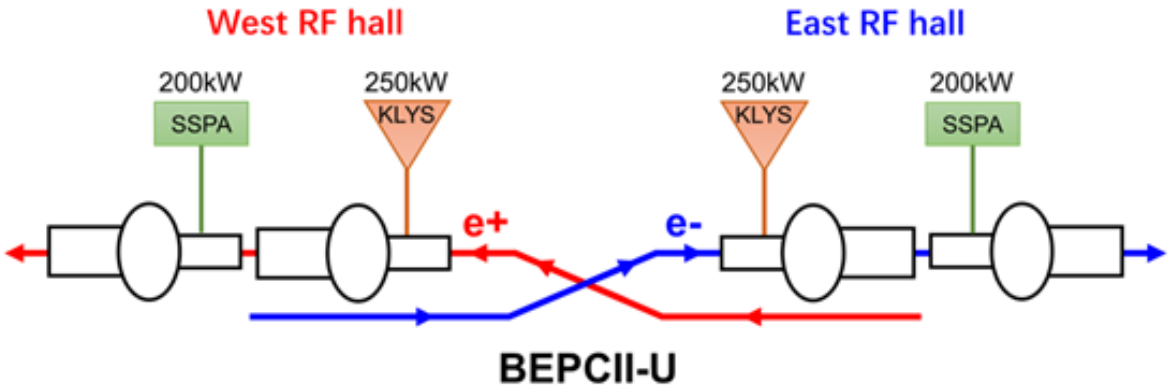
200 kW SSA

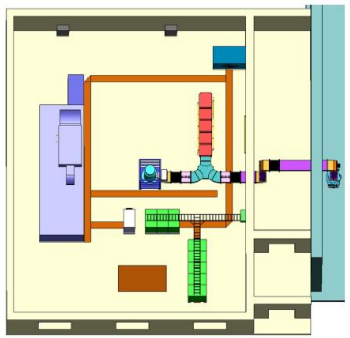
Operation since Oct. 2023

BEPCII-Upgrade SRF System

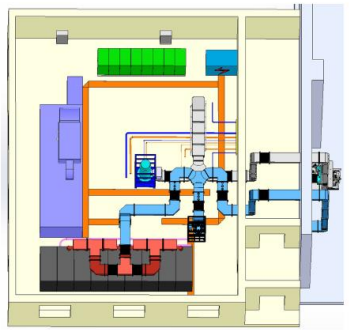
- BEPCII-U： Add two cavities and SSAs in 2024.
- Further R&D in 500 MHz cavity, LLRF and SSA.



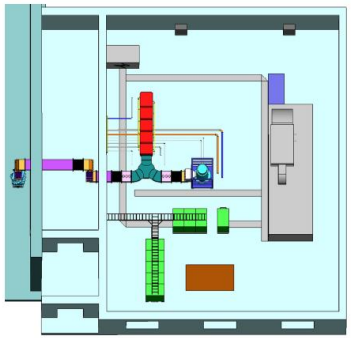




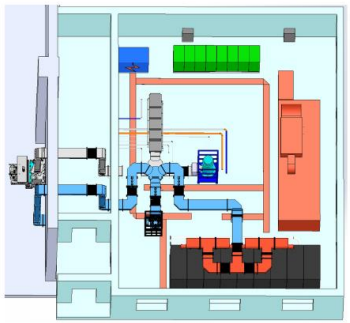
(a) West RF hall (BEPCII)



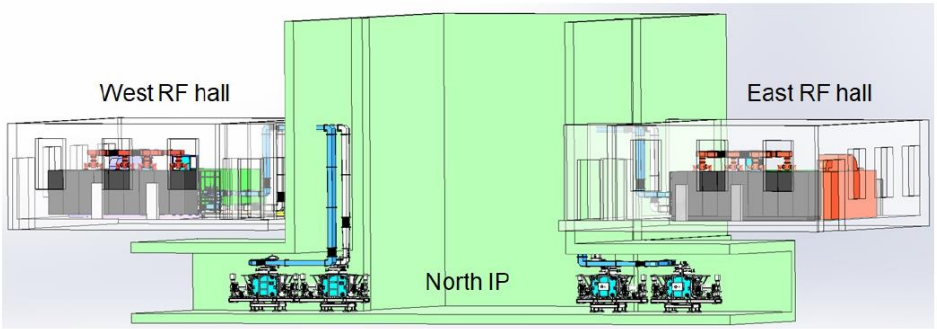
(b) West RF hall (BEPCII-U)



(c) East RF hall (BEPCII)



(d) East RF hall (BEPCII-U)



BEPCII-Upgrade SRF System

Table 1: Main parameters of BEPCII and BEPCII-U.

Parameter	Symbol	BEPCII	BEPCII-U	Unit
Circumference	C	237.53	237.53	m
Beam energy	E_0	1.89	2.35	GeV
Beam current	I_0	910	900	mA
Bunch number	N_b	120	120	-
Total energy loss per turn	U_{tot}	0.116	0.277	MeV
Total power loss to SR	P_{SR}	106	250	kW
Parasitic loss	P_{HOM}	7.7	30	kW
Total beam power	P_b	114	290	kW
Revolution frequency	f_{rev}	1262.1	1262.1	kHz
Synchrotron tune	ν_s	0.03	0.04	-
Bunch length	σ_z	14	12	mm
Momentum compaction factor	α_p	0.018	0.017	-
RF frequency	f_{rf}	499.8	499.8	MHz
Total RF voltage	V_{rf}	1.6	3.3	MV
Radiation damping time (x)	τ_x	24.2	12.6	ms
Radiation damping time (y)	τ_y	25.8	13.4	ms
Radiation damping time (z)	τ_z	13.4	6.9	ms
β function at straight section	β_x	15	20	m
β function at straight section	β_y	15	20	m

Table 3: RF parameters for BEPCII-U (breakdown).

Parameter	Existing	To be added	Unit
RF frequency	499.8	499.8	MHz
Number of cavities	2(+1)	1	-
RF voltage per cavity (V_c^{op})	1.65	1.75	MV
Cavity unloaded Q at V_c^{op}	$\geq$5e8	$\geq$1e9	-
Operating temperature	4.2	4.2	K
Nominal RF power per cavity	145	145	kW
Loaded Q	2e5	2e5	-
Cavity loaded bandwidth	2.5	2.5	kHz
Number of RF stations	2	2	-
Number of transmitters	2	2	-
Transmitter type	Klystron	SSA	-
Nominal power per transmitter	250	200	kW
Min. output power per transmitter (including 15% transmission loss)	165	165	kW
FPC designed power (CW)	200	200	kW
Number of LLRF	2	4	-
Specified amplitude noise (pk-pk)	$\pm$1	$\pm$0.5	%
Specified phase noise (pk-pk)	$\pm$1	$\pm$0.5	$^\circ$

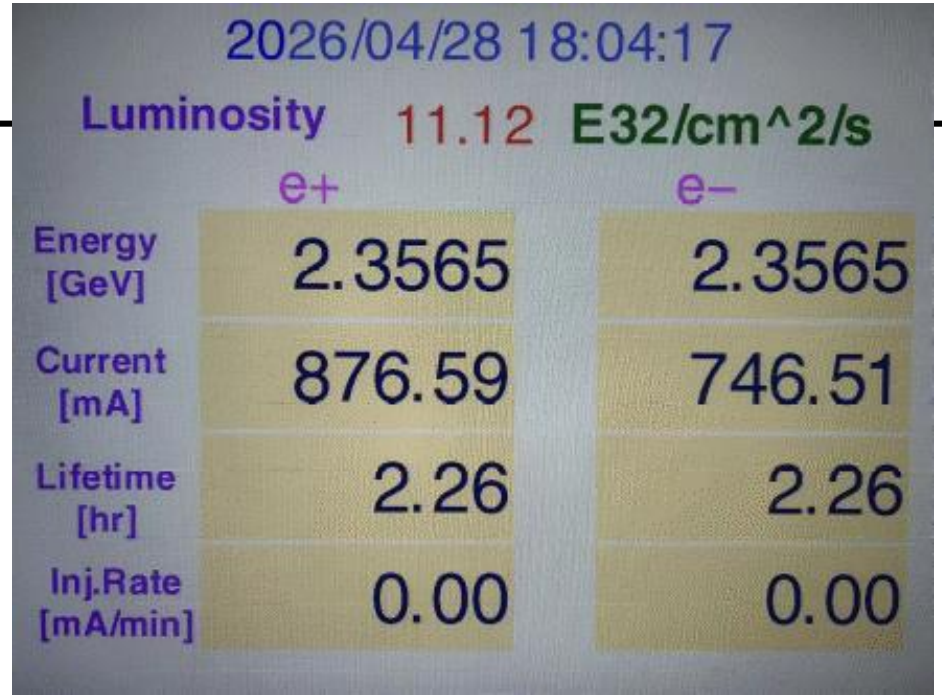
再创性能新高！北京正负电子对撞机峰值亮度圆满达成升级工程设计指标

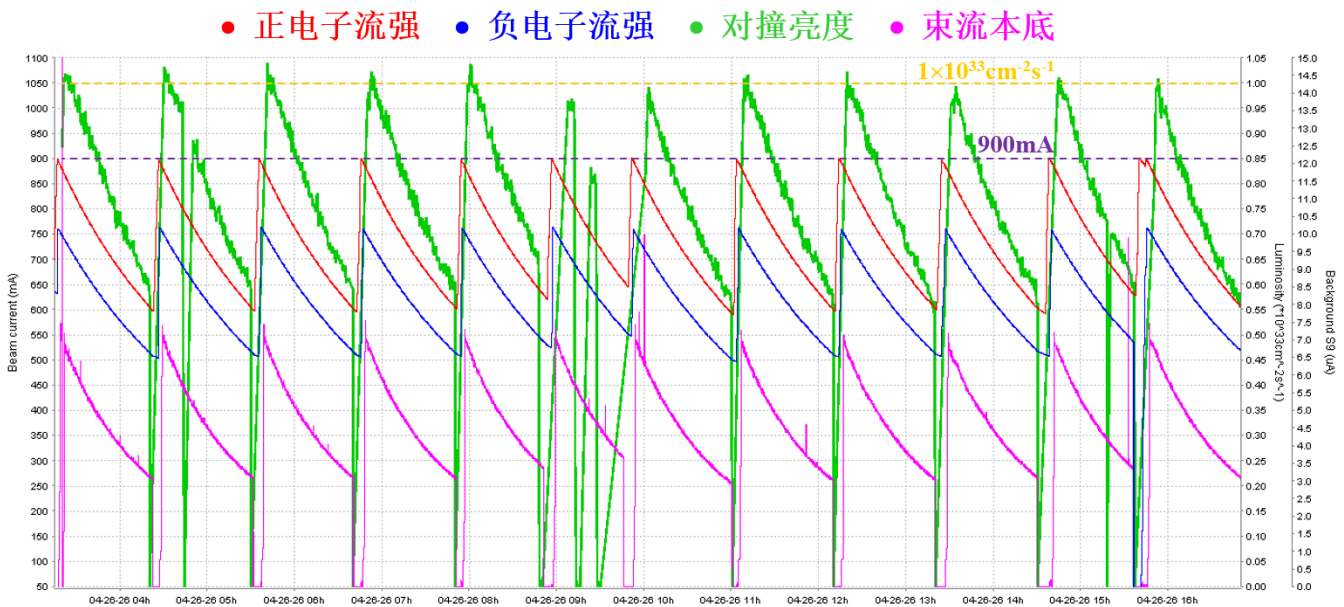
文章来源：加速器中心 2026-05-06 【大】【中】【小】

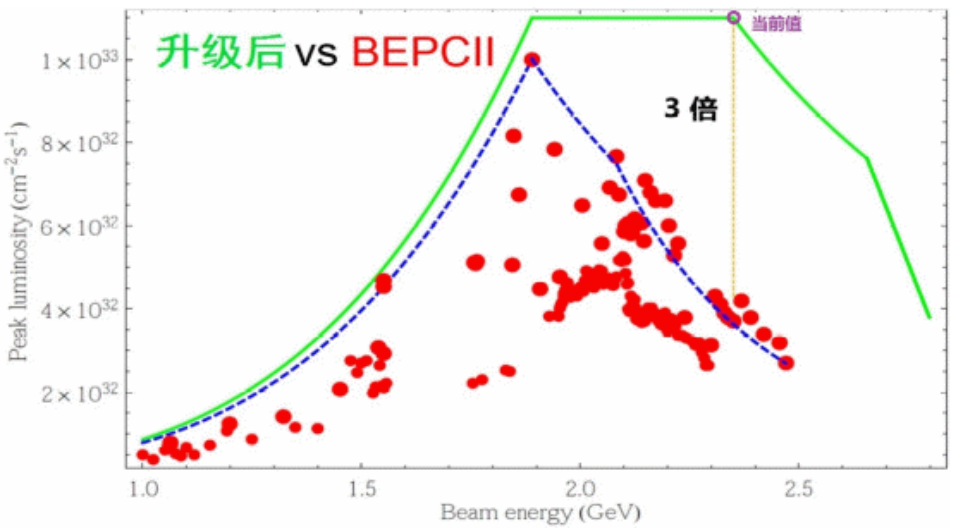
2026年4月28日，北京正负电子对撞机（BEPCII）运行取得重大进展。通过近一年持续的束流参数优化与流强稳步提升，BEPCII在2.35 GeV束流能量下峰值对撞亮度达到1.112×10^33 cm^-2s^-1，实现“北京正负电子对撞机对撞能量和取数效率升级”工程（以下称升级工程）的设计指标，峰值亮度和积分亮度均较升级前提升3倍以上，完成核心性能跨越式升级。此次在高束流能区的性能突破，为北京谱仪III（BESIII）开辟了全新实验窗口，提供了更高精度的数据支撑。

升级工程于2021年7月29日正式立项。面对核心设备研制难度大、研发周期紧张、新冠疫情等多重挑战，项目团队攻坚克难、稳步推进，历时三年自主完成射频超导模组、组合型超导磁铁、金属条型注入冲击磁铁、新型光子吸收器等一批关键核心设备的研制迭代，同步完成了直线加速器能量升级，全面夯实装置高性能运行的硬件基础。2024年7月至12月，升级工程高效完成全部设备的隧道内安装工作，2025年初进入调试阶段，直线加速器于1月2日开始带束运行，储存环于5月2日正式投入运行。同年5月17日，装置正式启动BESIII取数和北京同步辐射装置（BSRF）兼用光实验。

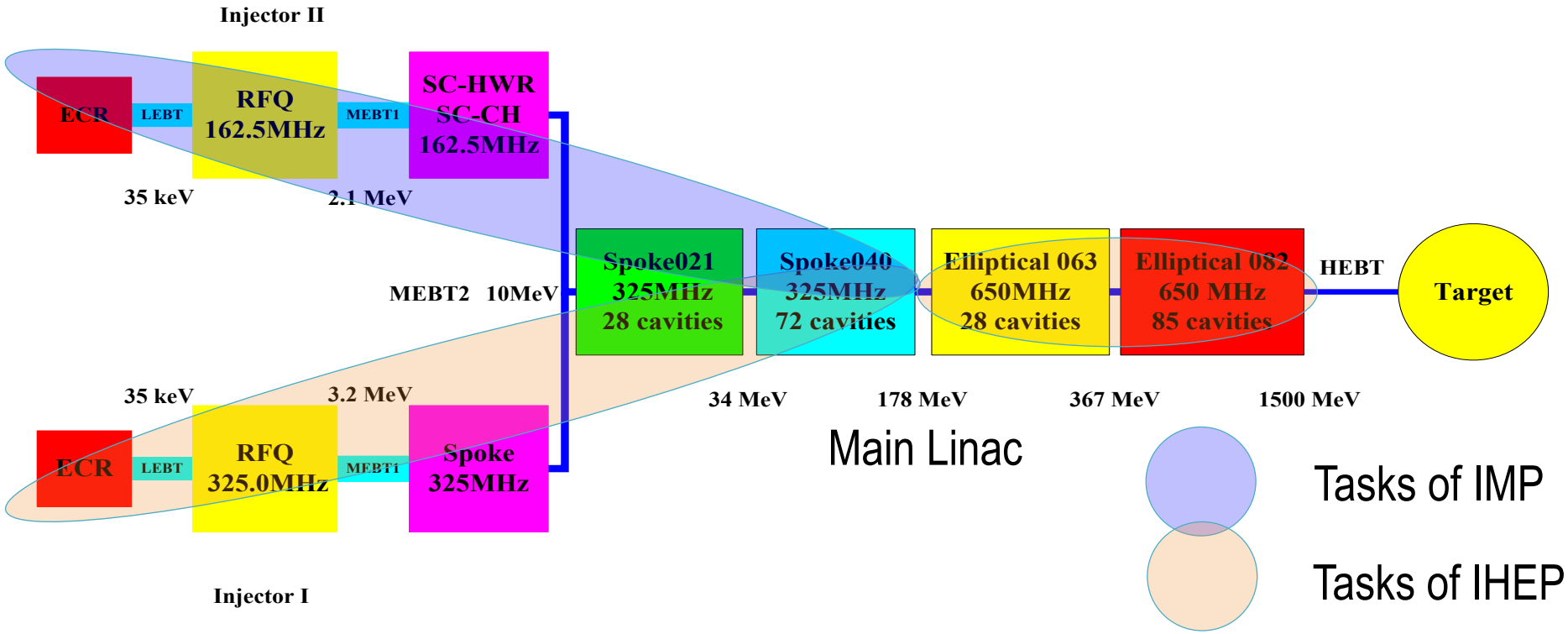
百尺竿头，更进一步，项目团队将持续深挖装置性能潜力，进一步优化束流品质、精细调节运行参数，持续提升对撞机运行稳定性与综合性能，支撑粒子物理前沿基础研究与关键核心技术攻关，充分发挥国家重大科技基础设施的平台优势，为国家基础科学创新与战略科技发展提供坚实保障。





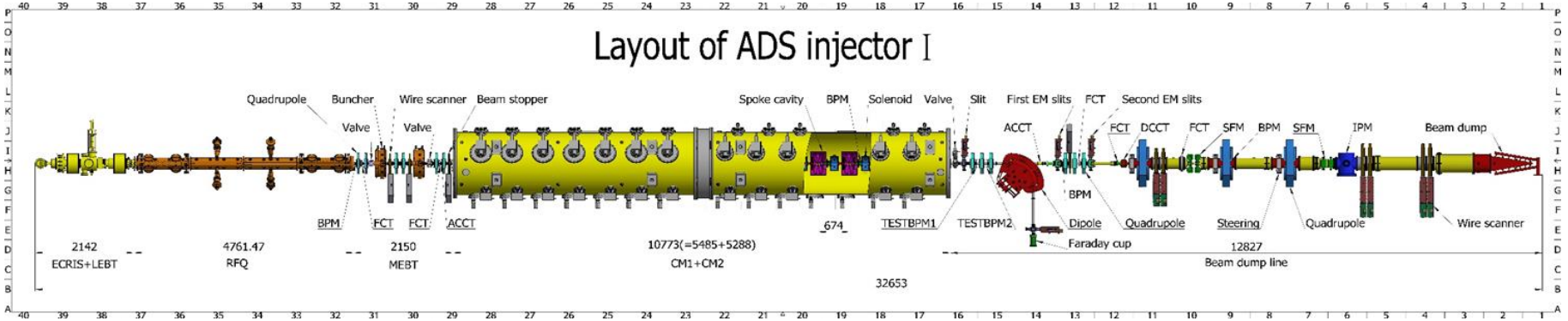


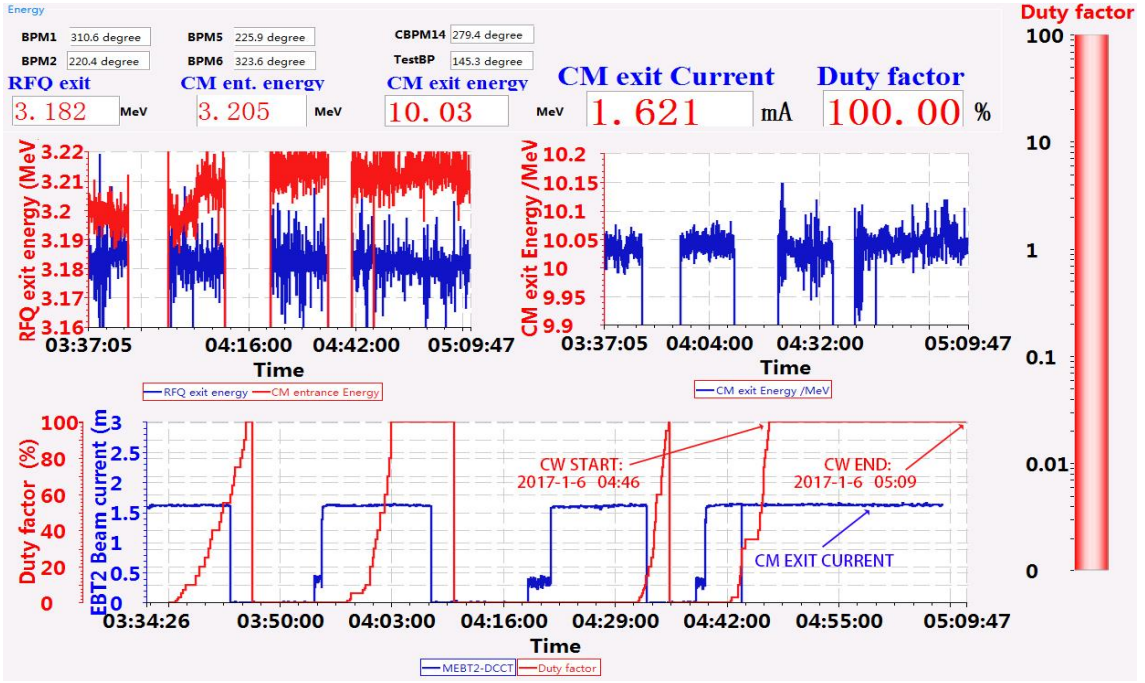
ADS Injector I



- 2011-2017 “Strategic Priority Research Program of the Chinese Academy of Science”“Accelerator Drive Subcritical System（ADS）”
- The task is undertaken by two institutes IMP and IHEP
- The first time several superconducting cavities and magnets integrated in one cryomodule, which lays the foundation for the future large scale superconducting accelerators
- Now the new CiADS project in under construction in IMP Huizhou campus

IHEP ADS Injector SRF System





14 spoke012 cavities accelerate 2 mA CW proton beam to 10 MeV in Injector-I at IHEP.

6 spoke021 cavities increase CW proton beam to 25 MeV in Injector-II at IMP.

ADS Injector SRF System

- Batch production of Spoke012 and Spoke021, meet spec
- SSR024/040, HWR325, MB082 prototypes

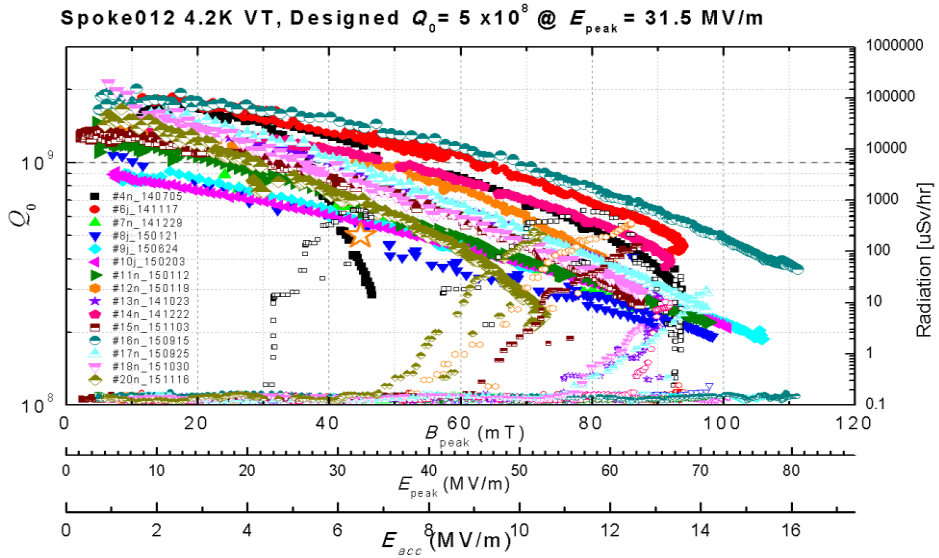
Spoke012 cavity string

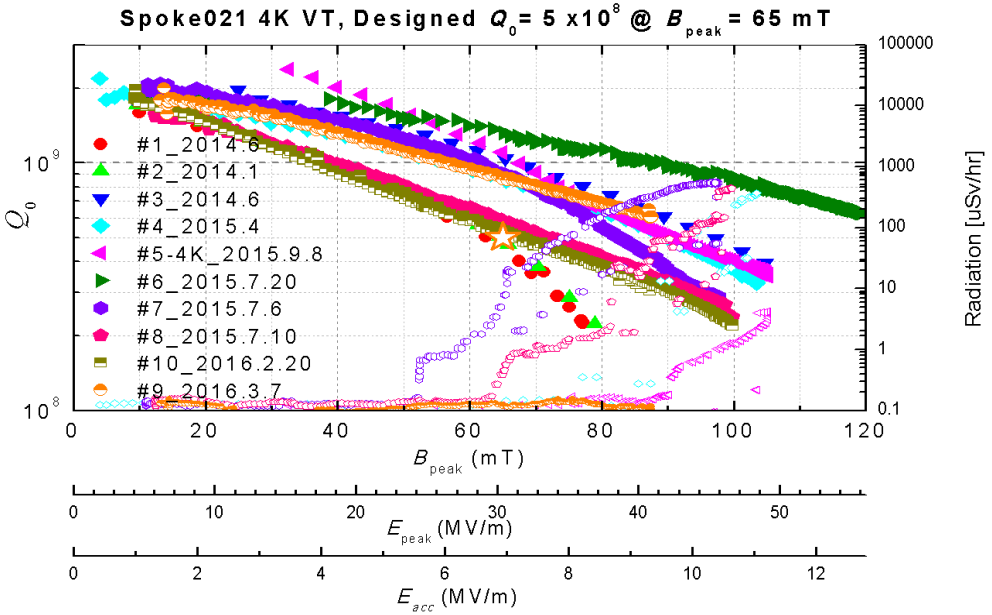
650 MHz 5-cell cavity (beta 0.82)

325 MHz Spoke cavity (beta 0.21)

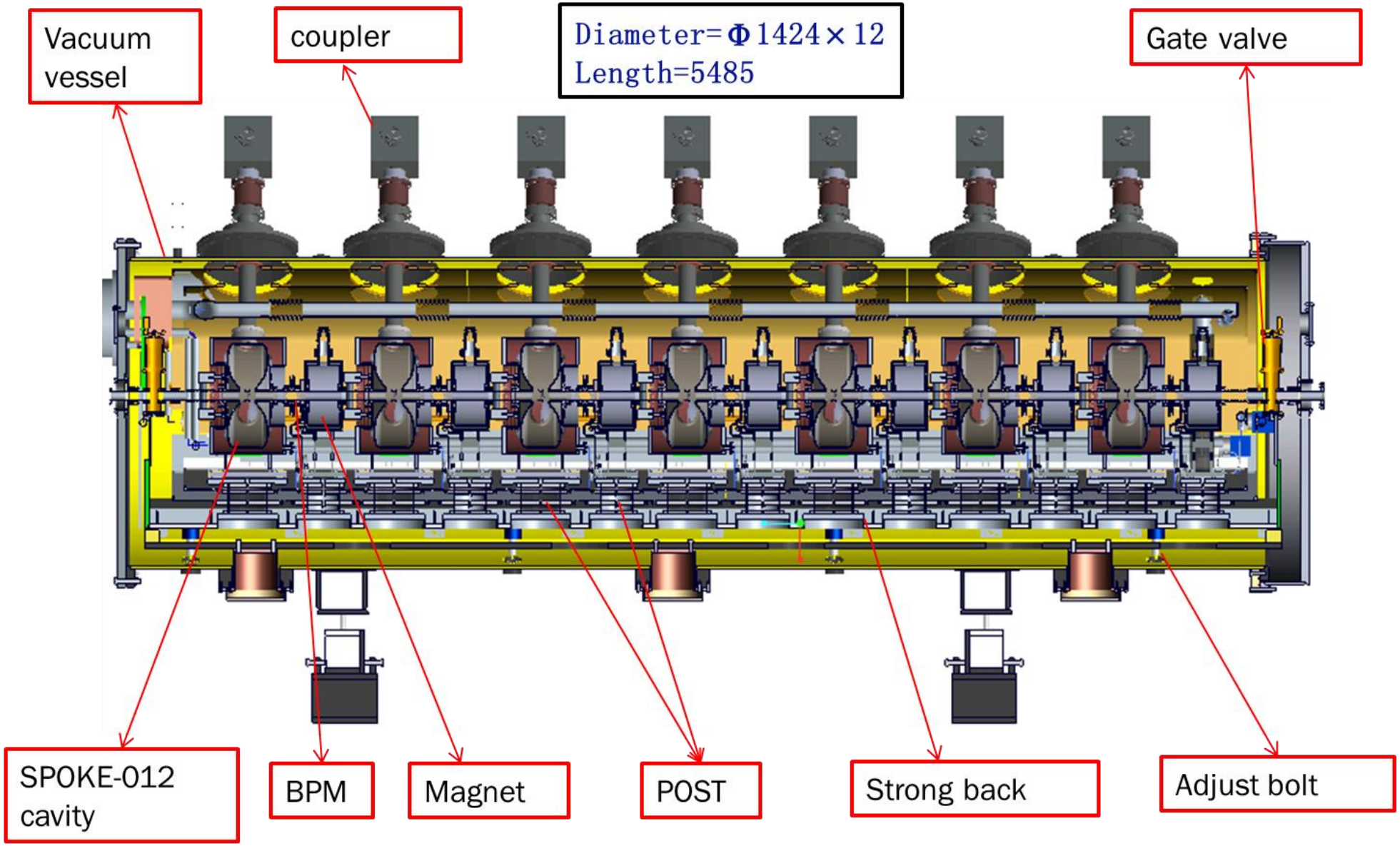
325 MHz Spoke cavity (beta 0.40)

325 MHz HWR cavity (beta 0.14)





ADS Spoke cavity cryomodule



高能同步辐射光源

(HEPS | High Energy Photon Source)

建设内容：加速器、光束线站、配套土建工程及辅助设施等;

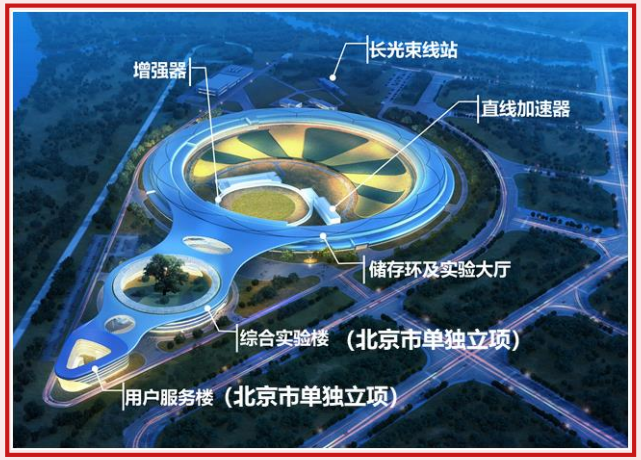
工　　期：6.5年，2019年7月-2025年12月;

法人单位：中科院高能物理研究所;

建设地点：北京怀柔科学城北部核心区;

占地面积：976亩;

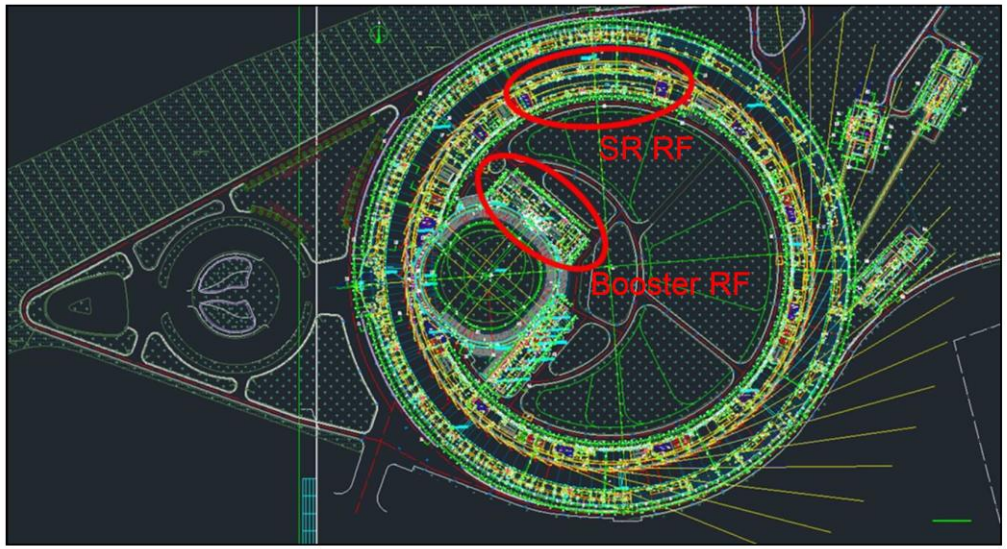
建筑面积：12.5万平米。



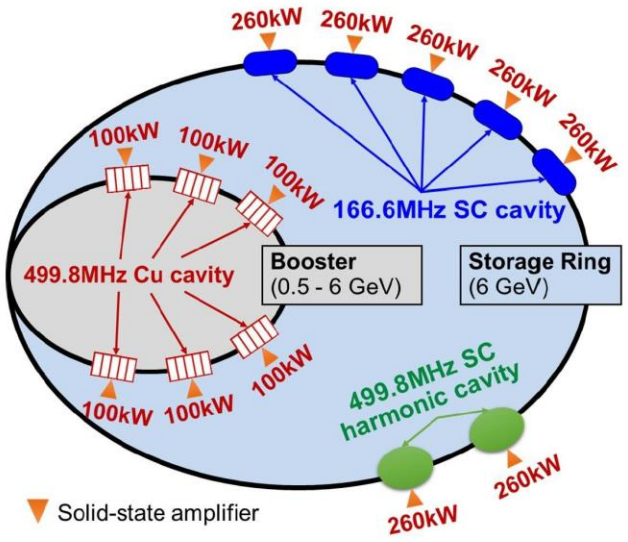
Main parameters	Value	Main parameters	Value
Beam energy	6 GeV	**Emittance**	< 60 pm·rad
Circumference	1360.4 m	**Brightness**	$>10^{22}$

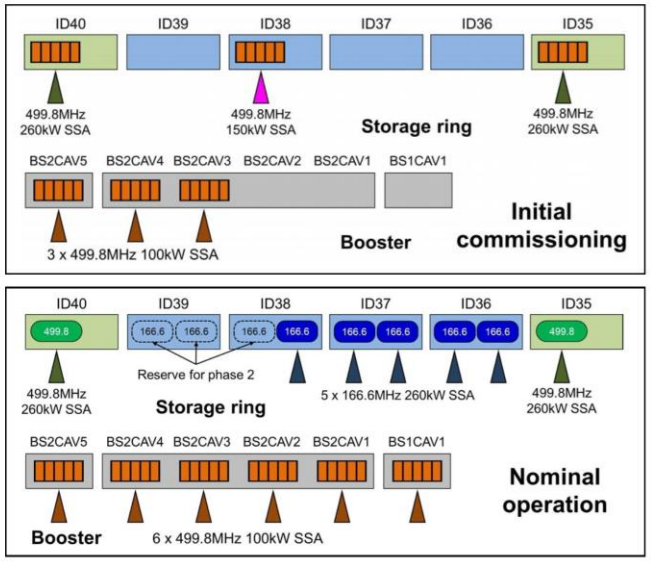
IHEP Huairou campus HEPS and PAPS

HEPS RF System



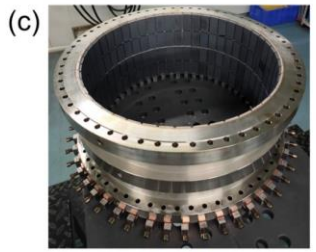
Parameter	Value	Unit
Beam energy	6	GeV
Circumference	1360.4	m
Beam current	200	mA
Lattice type	7BA	-
Number of sectors	48	-
Natural emittance	34.2	pm·rad
Natural bunch length	5.06	mm
Energy loss (bare lattice)	2.64	MeV
Total no. of IDs (Phase I)	14	-
Total beam power	850	kW
Radiation damping time (x/y/z)	10.85/20.62/18.76	ms
RF frequency (main, 3rd harm.)	166.6, 499.8	MHz
Main RF voltage (w/ harm. cav.)	5.16	MV

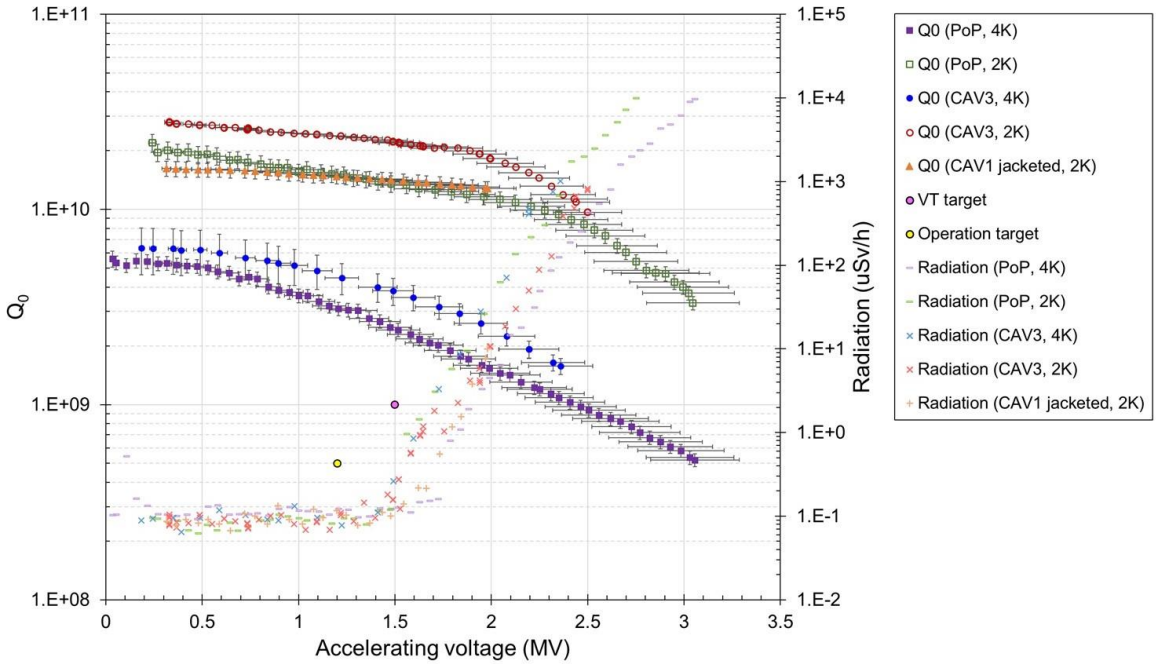




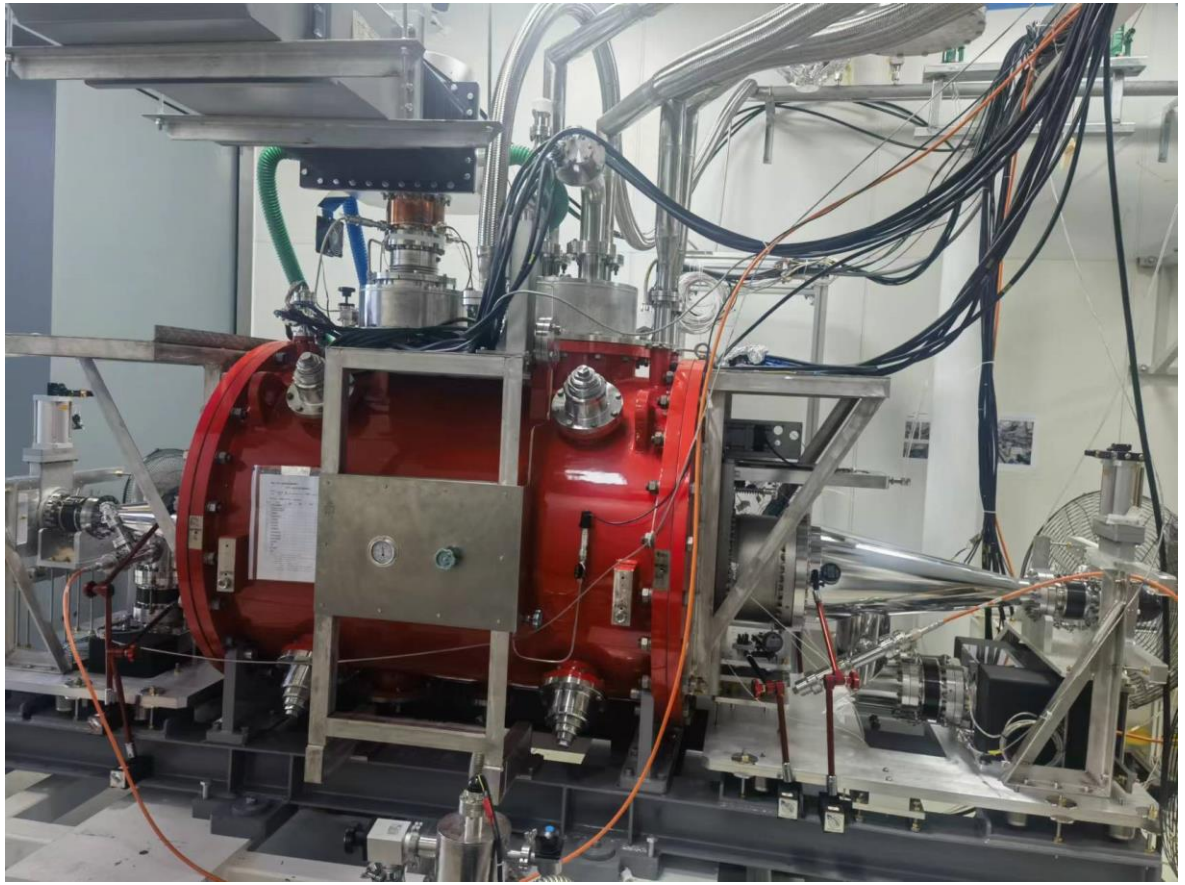
Parameter	Value	Unit
Circumference	1360.4	m
RF frequency (f_0)	166.6	MHz
Total energy loss per turn (U_0)	4.14	MeV
Total beam power (P_b)	850	kW
Total RF voltage (V_{RF})	5.16	MV
Number of main RF cavities	5	-
RF power per main cavity	170	kW
Cavity type	SRF cavity	-
HOM control	Heavy damping	-
Harmonic RF frequency (f_{HC})	499.8	MHz
Number of RF stations	5 + 2	-
Transmitter power per RF station	260	kW
Field noise (pk-pk)	±0.1%, ±0.1°	-

IHEP HEPS 166 MHz Cavity and Cryomodule



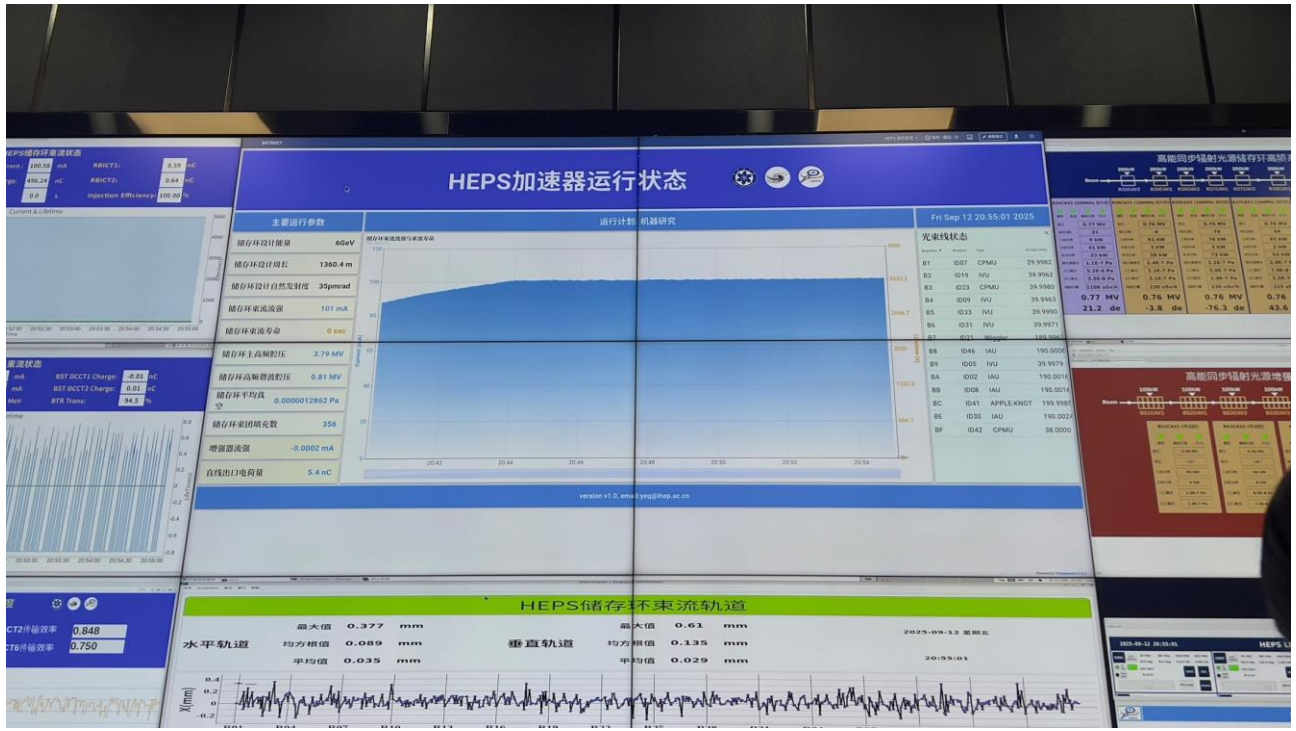


HEPS 166.6MHz and 499.8MHz cryomodule



Five 166.6MHz and two 499.8MHz cryomodule tested in PAPS

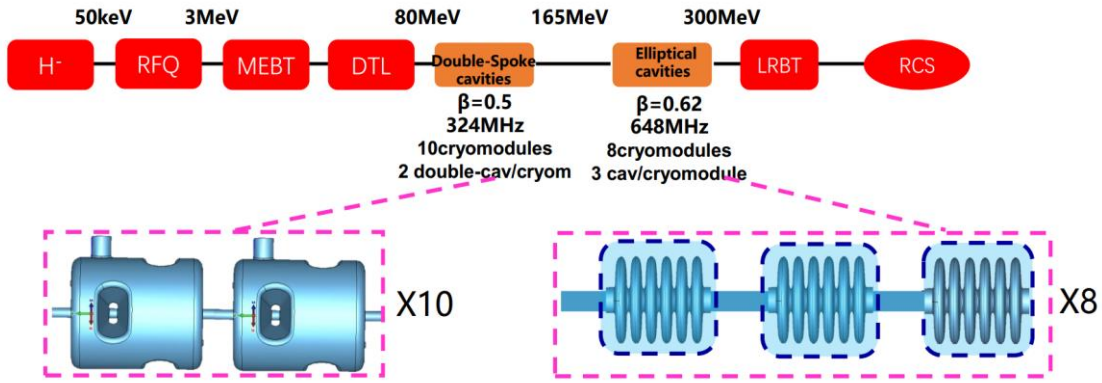
HEPS machine commissioning



- In Aug 7th 2025, SRF and Cryogenic system finished the final installation and test, and then move HEPS machine commissioning .
- In Sep 12th 2025, HEPS bean current first time reached 100mA, one of the key parameters of HEPS accelerator.
- Both RF system and cryogenics system maintain high-quality and stable operation

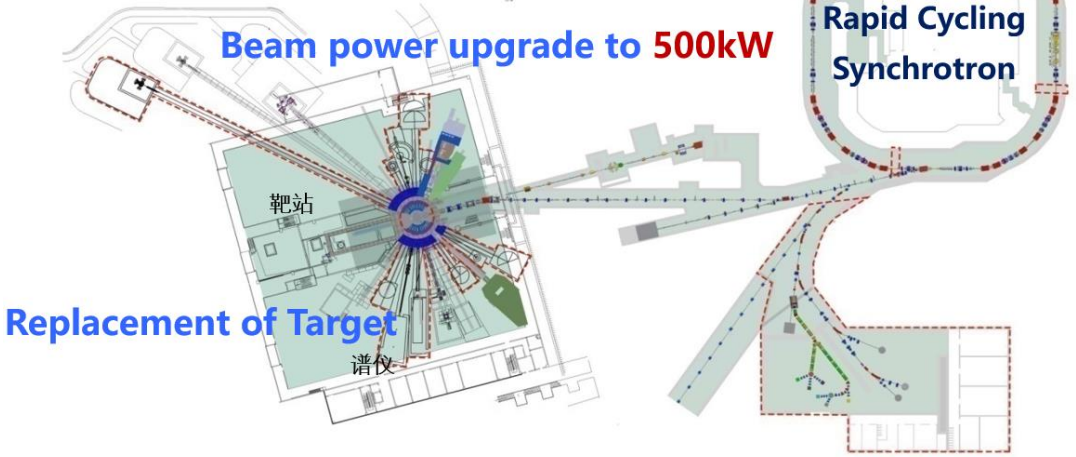
CSNS-II

CSNS-II and Future Plan January 2024—October 2029



Linac upgrade from 80MeV to 300MeV

Beam power upgrade to 500kW

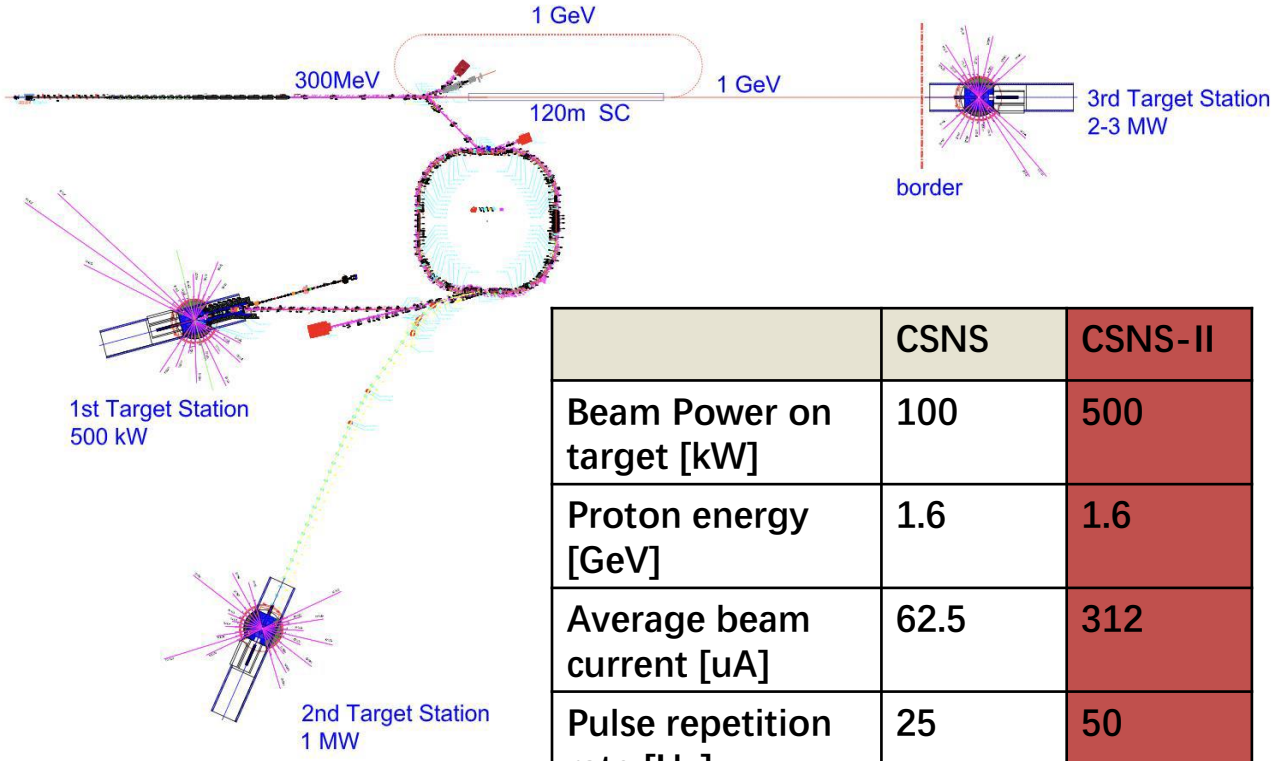


Rapid Cycling Synchrotron

Replacement of Target

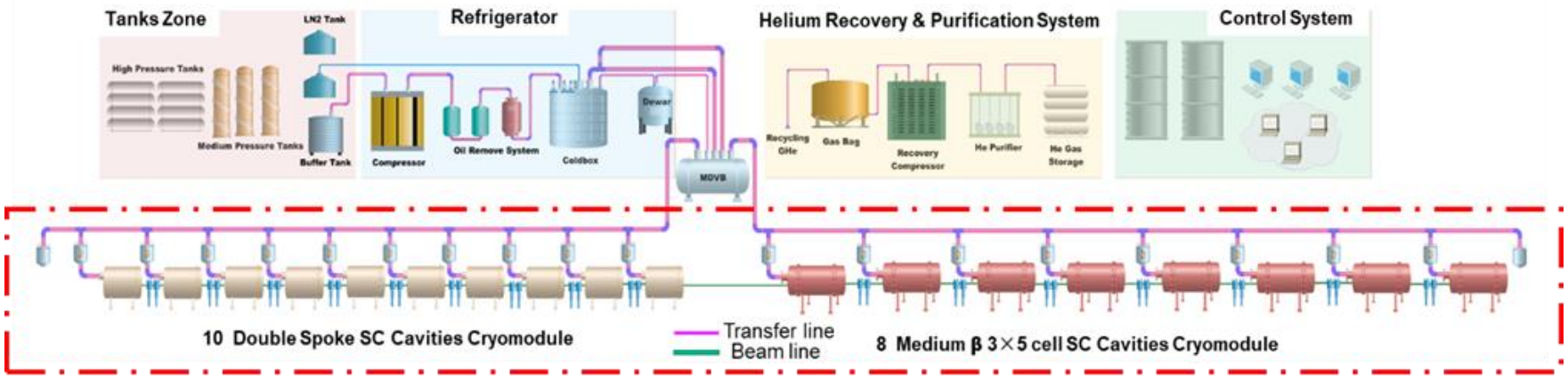
9 neutron instruments

Proton & muon Experimental station



	CSNS	CSNS-II
Beam Power on target [kW]	100	500
Proton energy [GeV]	1.6	1.6
Average beam current [uA]	62.5	312
Pulse repetition rate [Hz]	25	50
Linac energy [MeV]	80	300
Linac type	RT	RT+SC
Linac RF frequency [MHz]	324	324/648
Spectrometers	3	11+8

CSNS-II SRF System

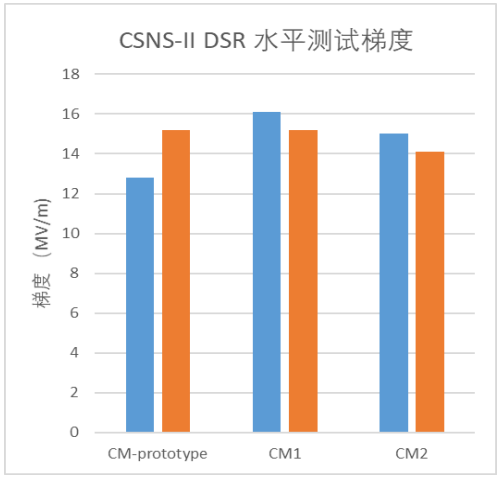


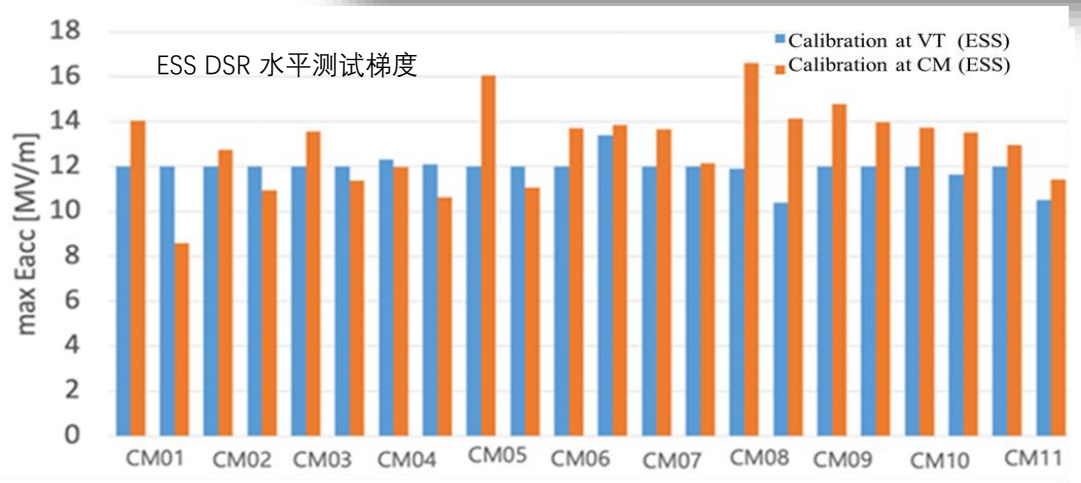
- **CSNS-II upgrade (2023-2028)**
  - Linac energy: 80 MeV → 300 MeV
  - Linac beam current: 15 mA → 40 mA
  - Linac beam pulse length: 400 μs → 600 μs
- **20 324 MHz β=0.5 double-spoke cavities**
  - Prototype cavities and cryomodule meet design spec, Mass production undergoing
- **24 648 MHz β=0.62 6-cell cavities**
  - Prototype cavities and cryomodule meet design spec, Mass production undergoing

Parameter	Value
f (MHz)	324
TTF	0.79
β_0	0.5
Eacc (MV/m)	7.3 (9)
Ep/Eacc	3.44
Bp/Eacc mT/(MV/m)	8.86
R/Q (Ω)	401.8
G (Ω)	118.6

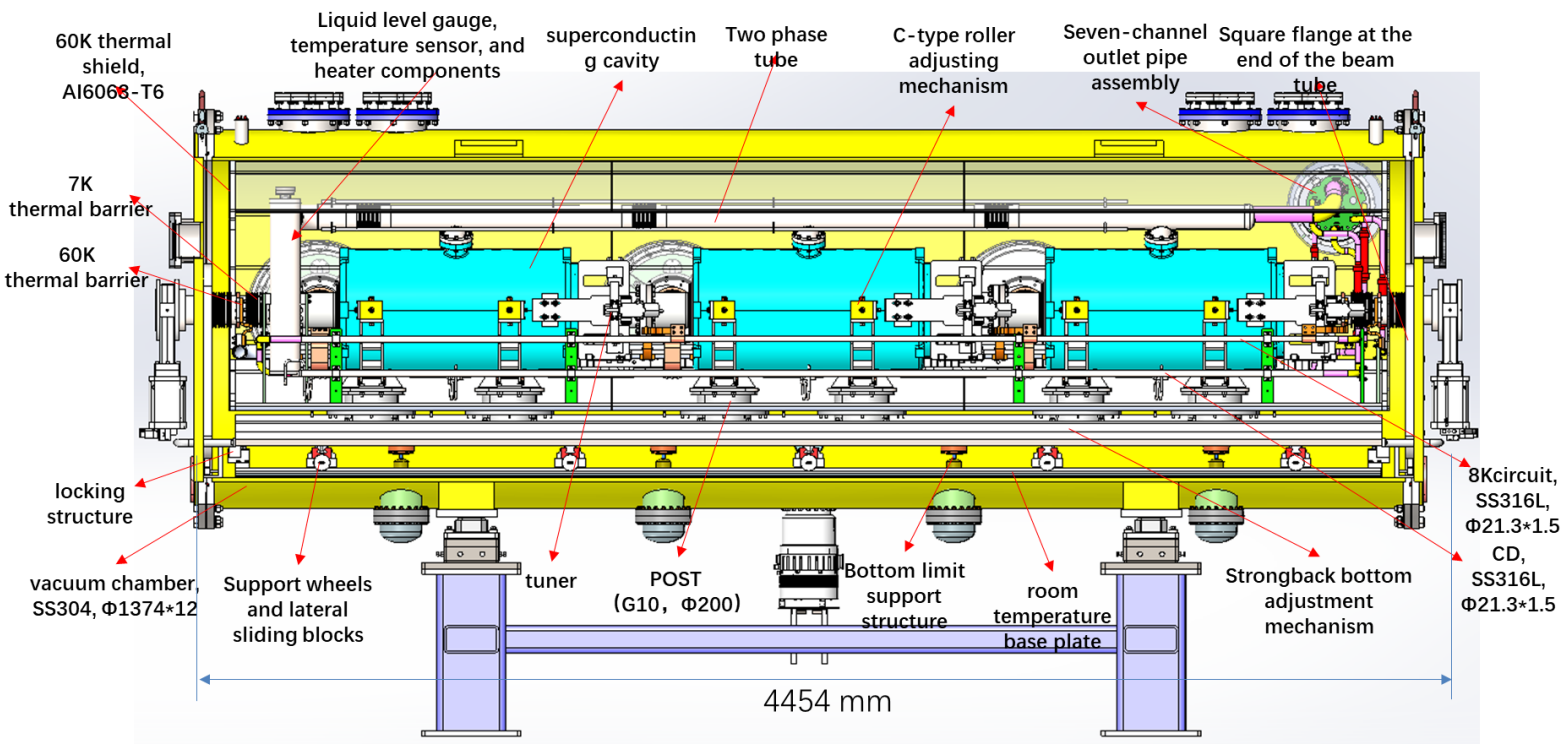
Parameter	Value
f (MHz)	648
TTF@βg	0.7
βg	0.62
Eacc (MV/m)	14
Ep/Eacc	2.53
Bp/Eacc mT/(MV/m)	5.45
R/Q (Ω)	309
G (Ω)	177
Beam tube diameter (mm)	105/120
Cell-cell coupling (%)	1.35

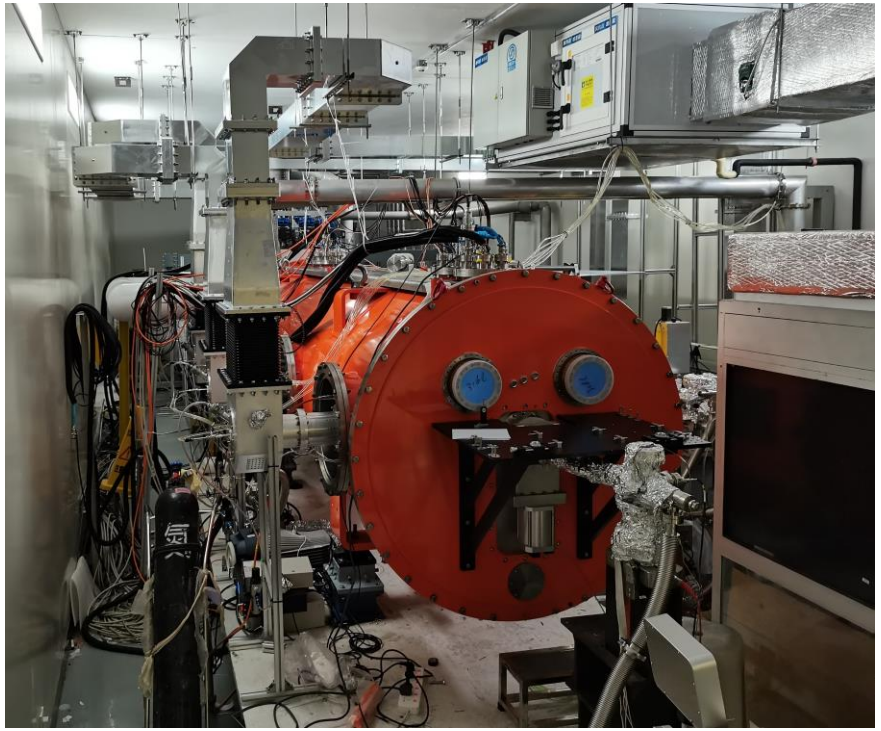
324MHz double spoke cavity cryomodule





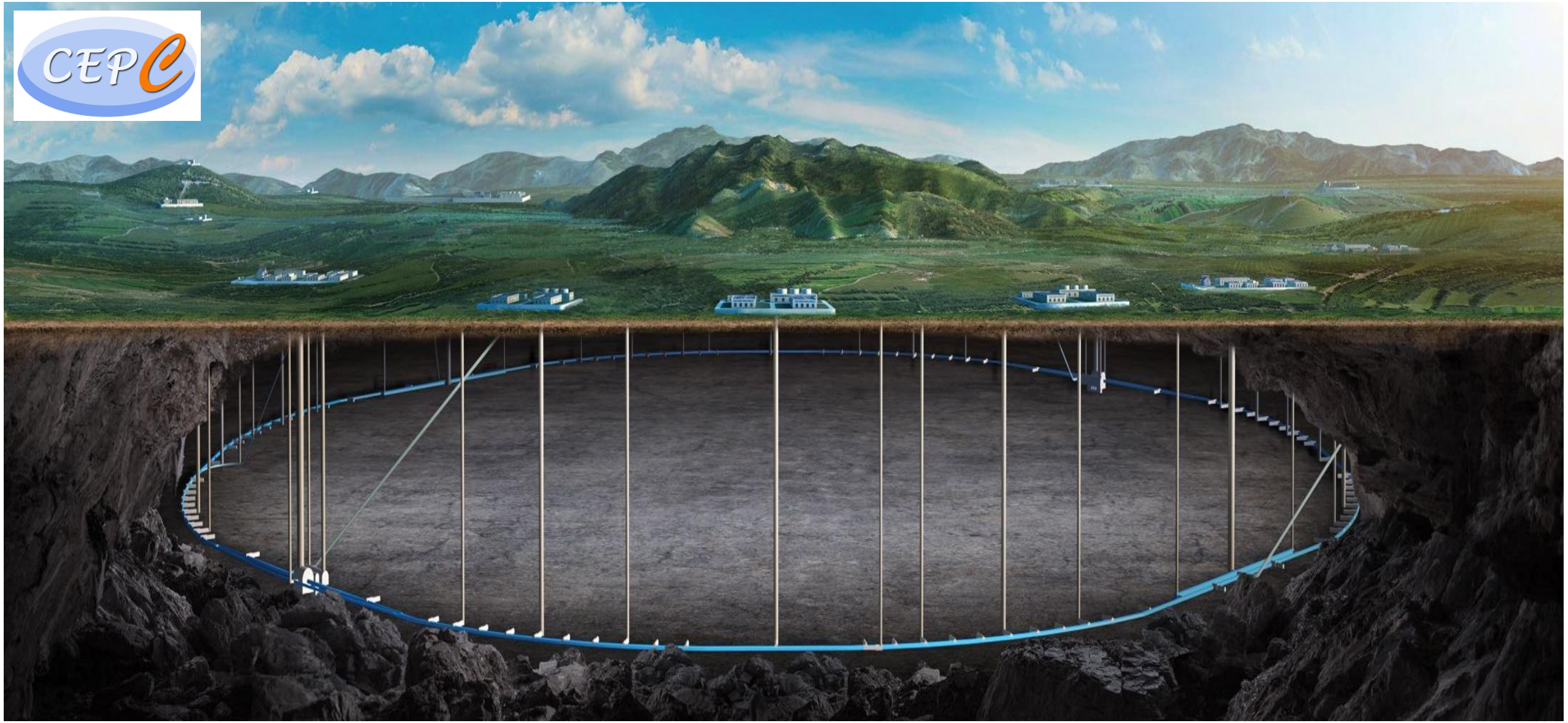
648MHz elliptical cryomodule





- The first elliptical cavity cryomodule have passed horizontal test, Acc gradients are 26.76MV/m, 24.57MV/m and 19.08MV/m
- All of the parameters have met or exceeded the technical requirements

CEPC



CEPC SRF and Cryogenic System

- CEPC is a positron and electron collider, and the beam is accelerated to 30 GeV by linear acceleration section, and then further accelerated to 120 GeV by RF cavities in the Booster and Collider ring.
- Cryogenic system is designed to provide a reliable and stable cooling environment (4.5K or 2K) for RF cavities and magnets.

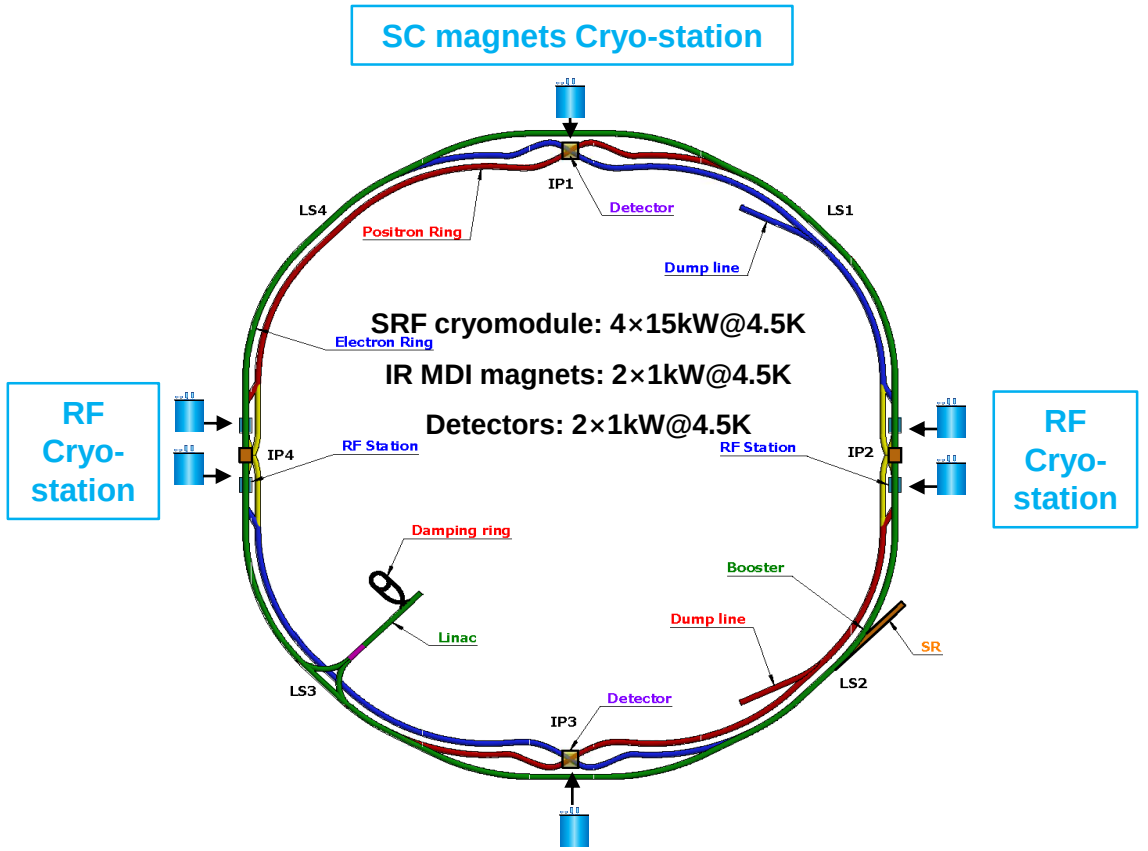
Report focus

Booster ring:

- 1.3 GHz 9-cell cavities, 96 cavities
- 12 cryomodules
- 3 cryomodules/each station
- Temperature: 2K

Collider ring:

- 650MHz 2-cell cavities, 240 cavities
- 32 cryomodules for Higgs 30MW, 56 for Higgs 50MW
- 8 or 14 cryomodules/each station
- Temperature: 2K



Overview of the CEPC cryogenic system

MDI IR magnets:

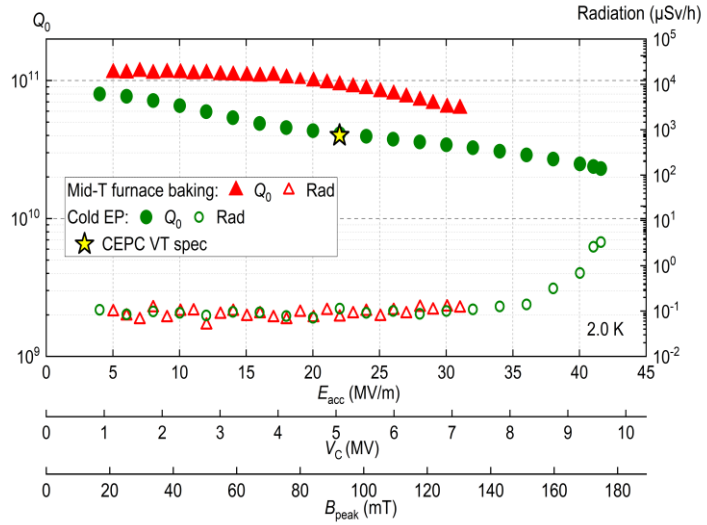
- 4 IR magnets, 4 cryostats
- Temperature: 4.5K/2K

Detectors:

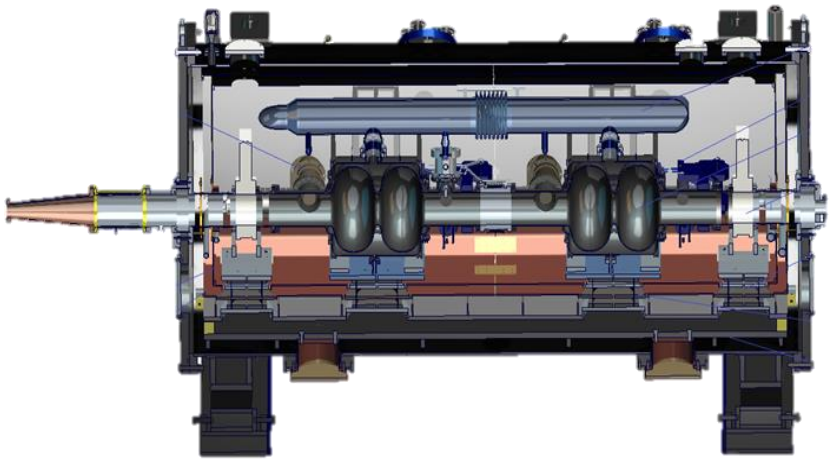
- 2 detector magnets
- HeI/Thermosiphon cooling

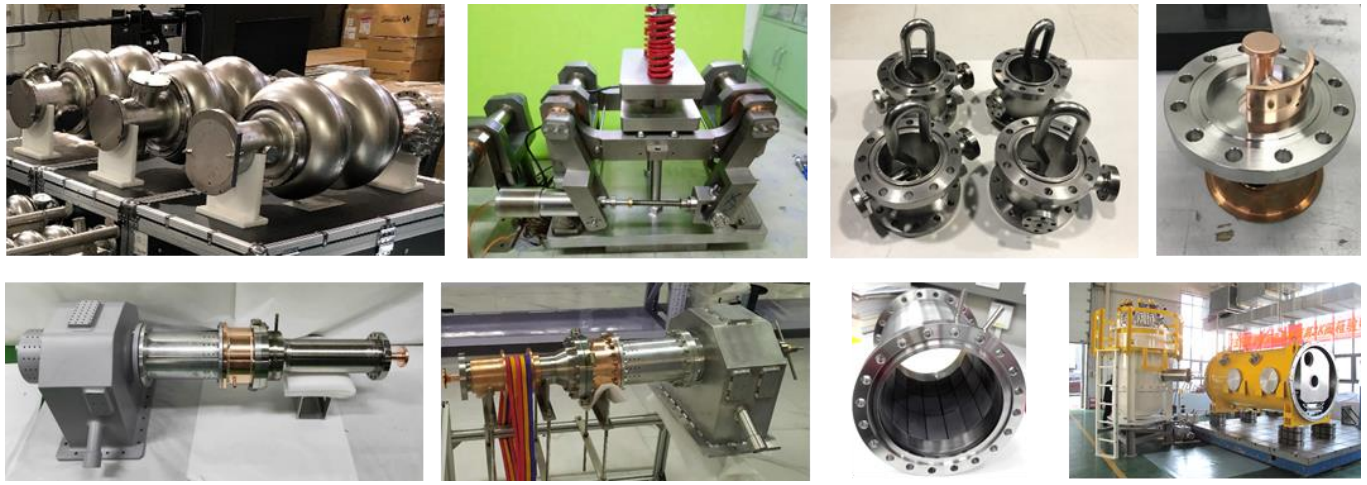
CEPC 650 MHz SRF System R&D

650 MHz test cryomodule with 2x2-cell cavities. Beam test soon.



High G High Q 650 MHz 1-cell Cavity
EP treated: 2.3E10@41.6 MV/m@2 K
Mid-T treated: 6.3E10@31 MV/m@2 K

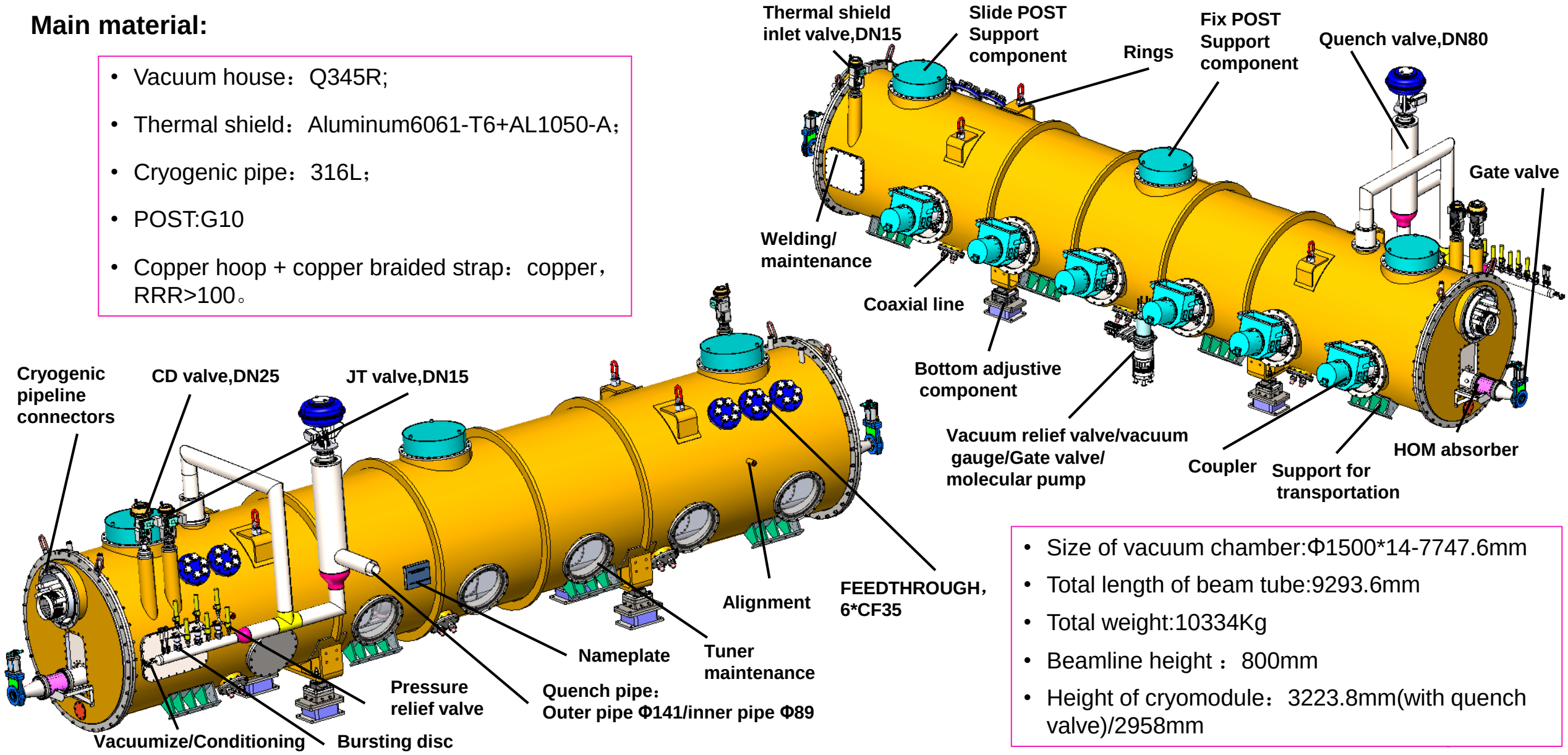




650 MHz full-size Cryomodule Design

Main material:

- Vacuum house：Q345R;
- Thermal shield：Aluminum6061-T6+AL1050-A；
- Cryogenic pipe：316L；
- POST:G10
- Copper hoop + copper braided strap：copper，RRR>100。



- Size of vacuum chamber:Φ1500*14-7747.6mm
- Total length of beam tube:9293.6mm
- Total weight:10334Kg
- Beamline height ： 800mm
- Height of cryomodule：3223.8mm(with quench valve)/2958mm

IHEP 1.3 GHz SRF R&D

2003-2015

Early research
Technology R&D

1-cell and 9-cell cavities

ILC test cryomodule

Important collaboration with PKU, KEK, INFN-LASA, FNAL, JLAB, DESY …

2016-2020

Technology transfer
Performance breakthrough

HERT 11 TESLA 9-cell cavities

EP 36 MV/m (reach ILC spec)

Mid-T 5E10@21 MV/m (world record)

4 BCP + 4 mid-T high Q cavities delivered to SHINE

2021-2025

Cavity mass production
Cryomodule prototyping

SHINE

150 9-cell cavities by HERT

DALS 1.3 GHz high Q cryomodule

2026-2035

Cavity and cryomodule mass production

Engage in these projects:

SHINE (600 CAV, 75 CM)

S^3FEL (208 CAV, 26 CM)

Other CW FELs

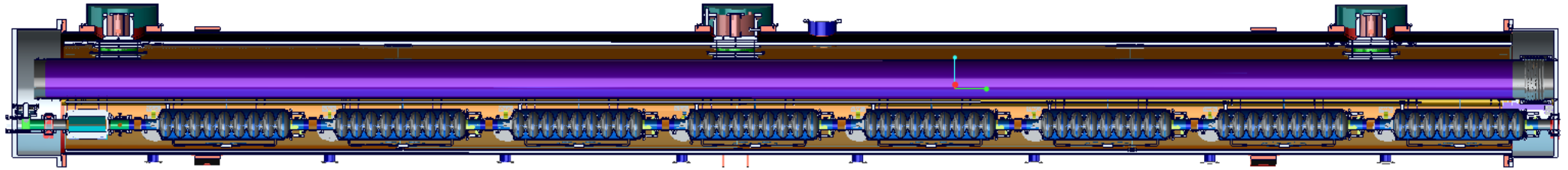
CEPC booster (352 cavities)

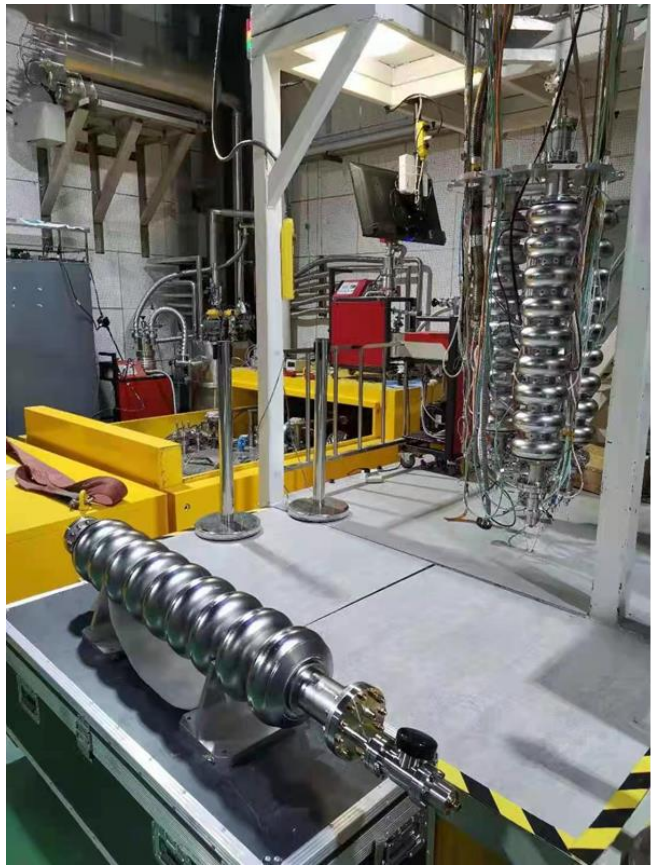
ILC (8000+8000 cavities)

…

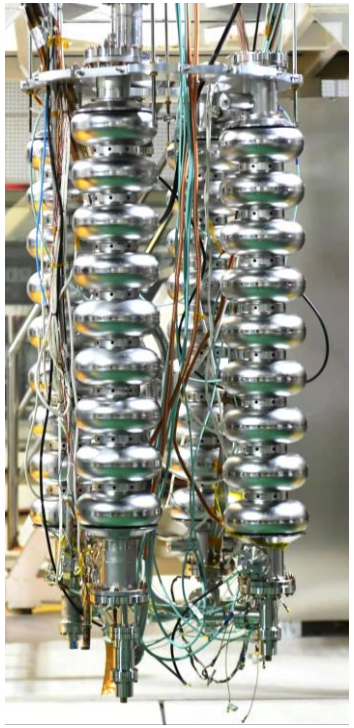
High Q high gradient and new material R&D

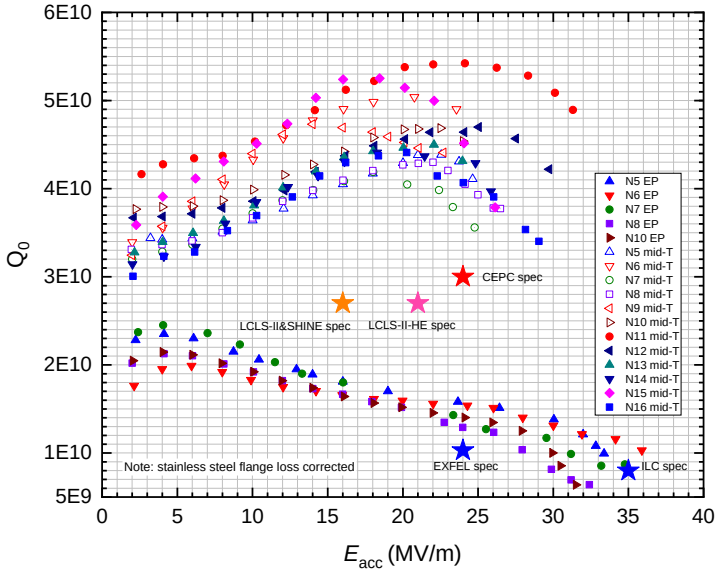
IHEP 1.3 GHz SRF R&D



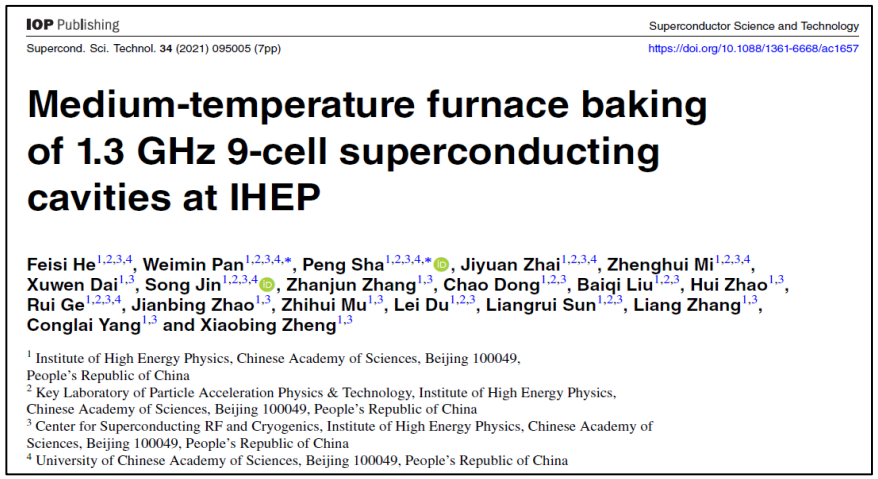


IHEP 1.3 GHz SRF R&D





High average Q_0 of 4.5E10 at 16 ~ 21 MV/m.
Mid-T bake recipe has distinct advantages over nitrogen-doping



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Medium-temperature furnace baking of 1.3 GHz 9-cell superconducting cavities at IHEP

Feisi He[1,2,3,4], Weimin Pan[1,2,3,4,*], Peng Sha[1,2,3,4,*], Jiyuan Zhai[1,2,3,4], Zhenghui Mi[1,2,3,4], Xuwen Dai[1,3], Song Jin[1,2,3,4], Zhanjun Zhang[1,3], Chao Dong[1,2,3], Baiqi Liu[1,2,3], Hui Zhao[1,3], Rui Ge[1,2,3,4], Jianbing Zhao[1,3], Zhihui Mu[1,3], Lei Du[1,2,3], Liangrui Sun[1,2,3], Liang Zhang[1,3], Conglai Yang[1,3] and Xiaobing Zheng[1,3]

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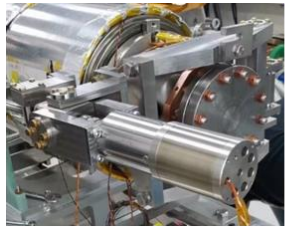
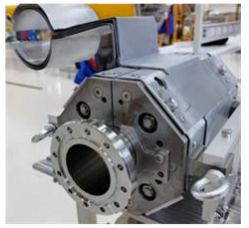
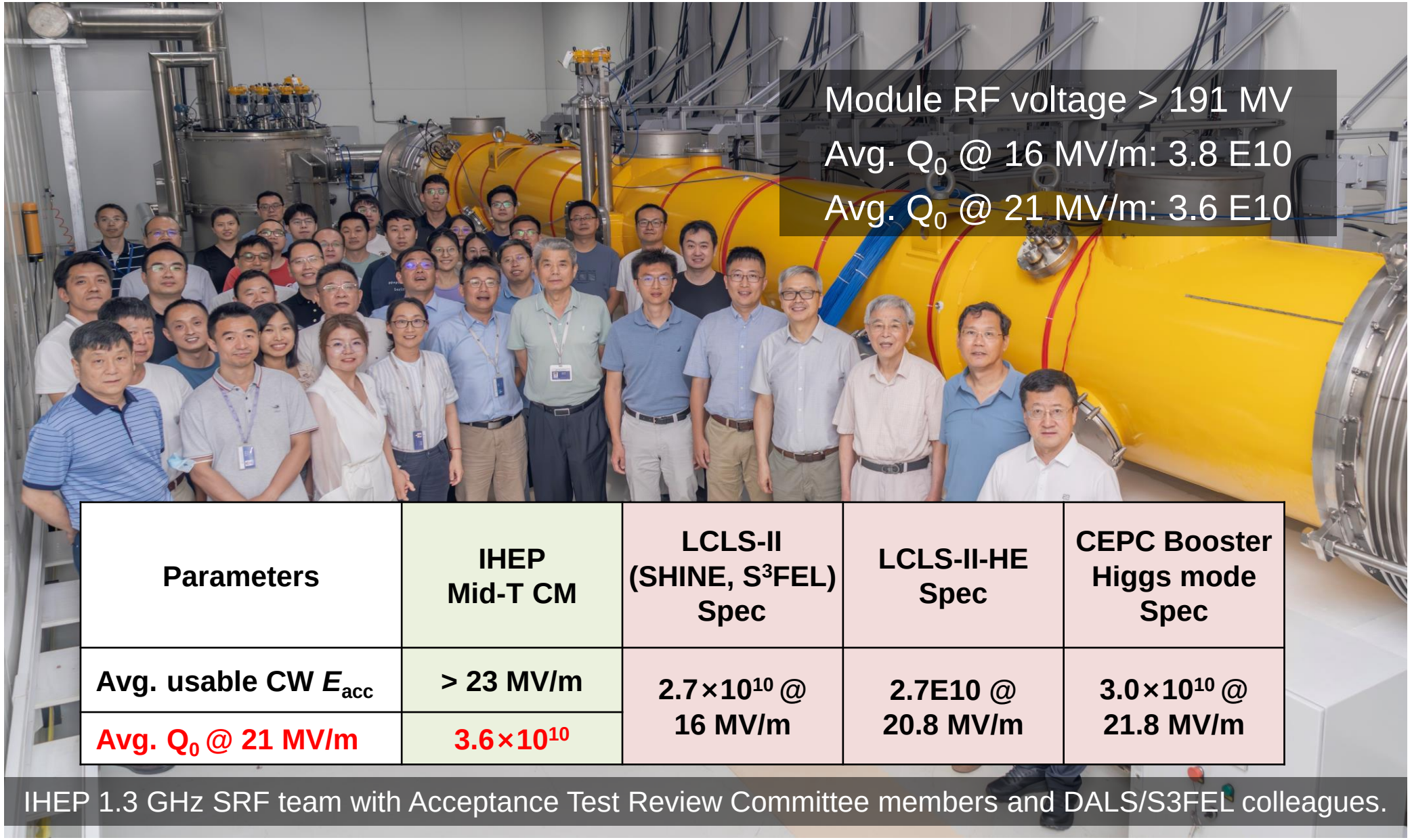




World's first Mid-T 1.3 GHz Cryomodule with Record High Q_0



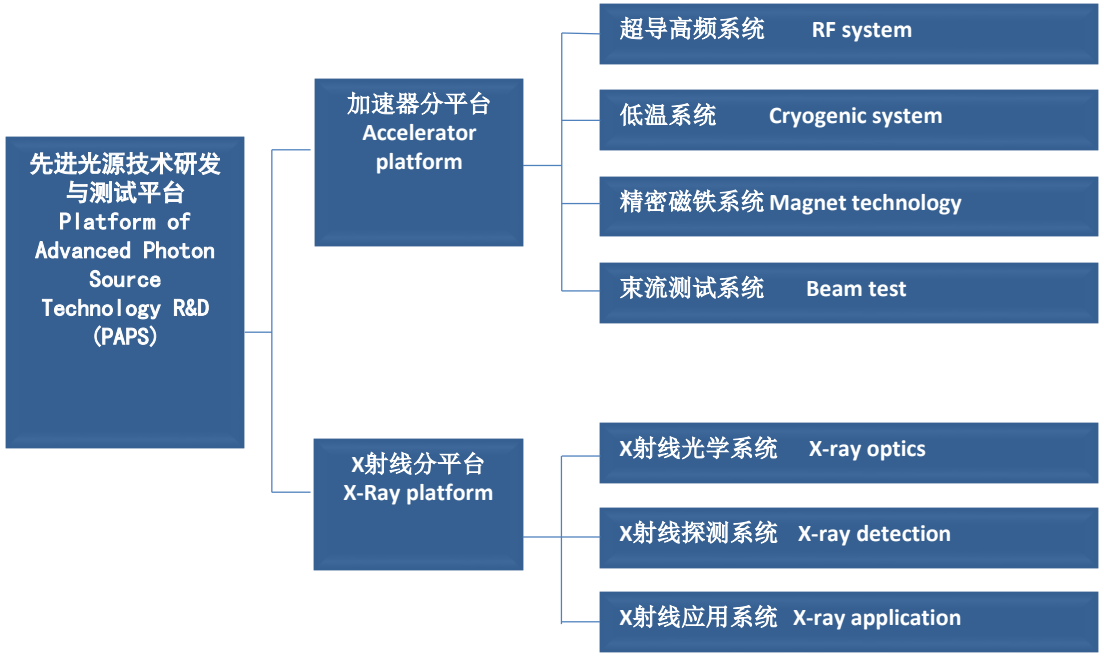
Parameters	IHEP Mid-T CM	LCLS-II (SHINE, S³FEL) Spec	LCLS-II-HE Spec	CEPC Booster Higgs mode Spec
Avg. usable CW E_{acc}	> 23 MV/m	2.7×10^{10} @ 16 MV/m	2.7E10 @ 20.8 MV/m	3.0×10^{10} @ 21.8 MV/m
Avg. Q_0 @ 21 MV/m	3.6×10^{10}			

IHEP 1.3 GHz SRF team with Acceptance Test Review Committee members and DALS/S3FEL colleagues.

Outline

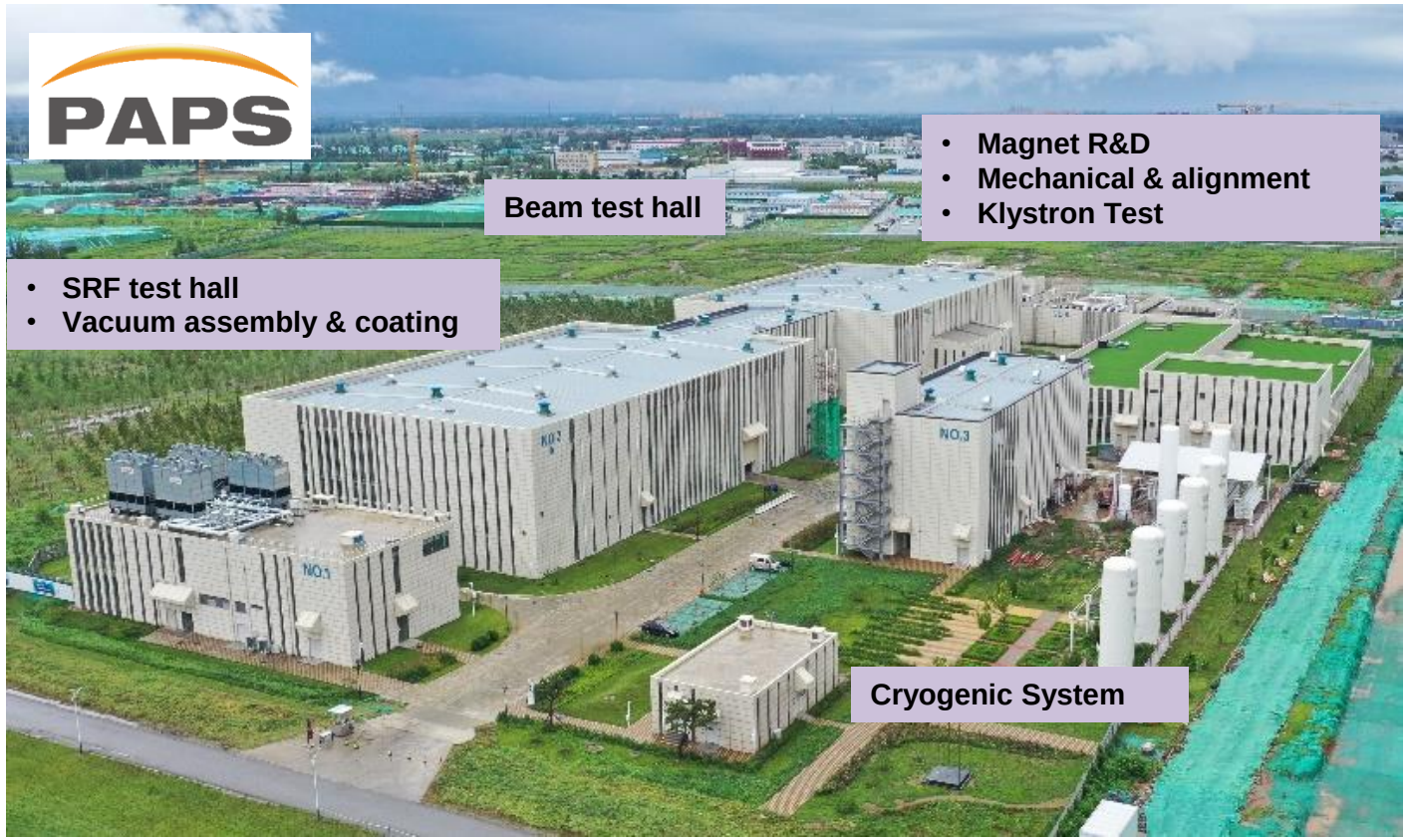
1. Introduction
2. SRF accelerator projects
3. R&D and infrastructures at IHEP
4. International collaborations
5. Summary

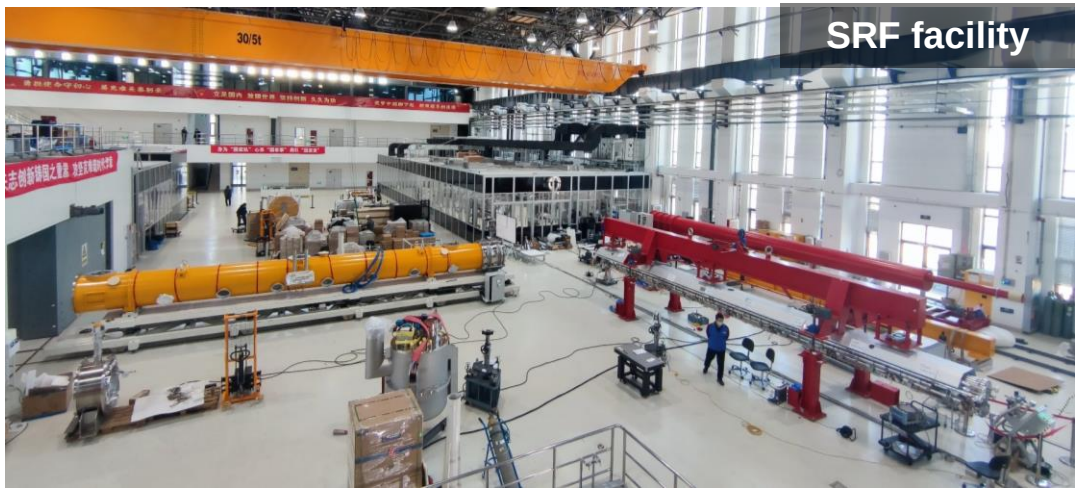
Platform of Advanced Photon Source Technology R&D (PAPS)



- "Platform of Advanced Photon Source Technology R&D", The goal of the PAPS project is to provide a good foundation and condition for R&D, engineering testing and verification for the high energy phone source (HEPS) project to be completed on schedule and to achieve the expected design target.
- Budget: 590M CNY funded by Beijing Gov.
- Construction: 2017.5-2021.6

IHEP PAPS SRF Infrastructure in Huairou, Beijing

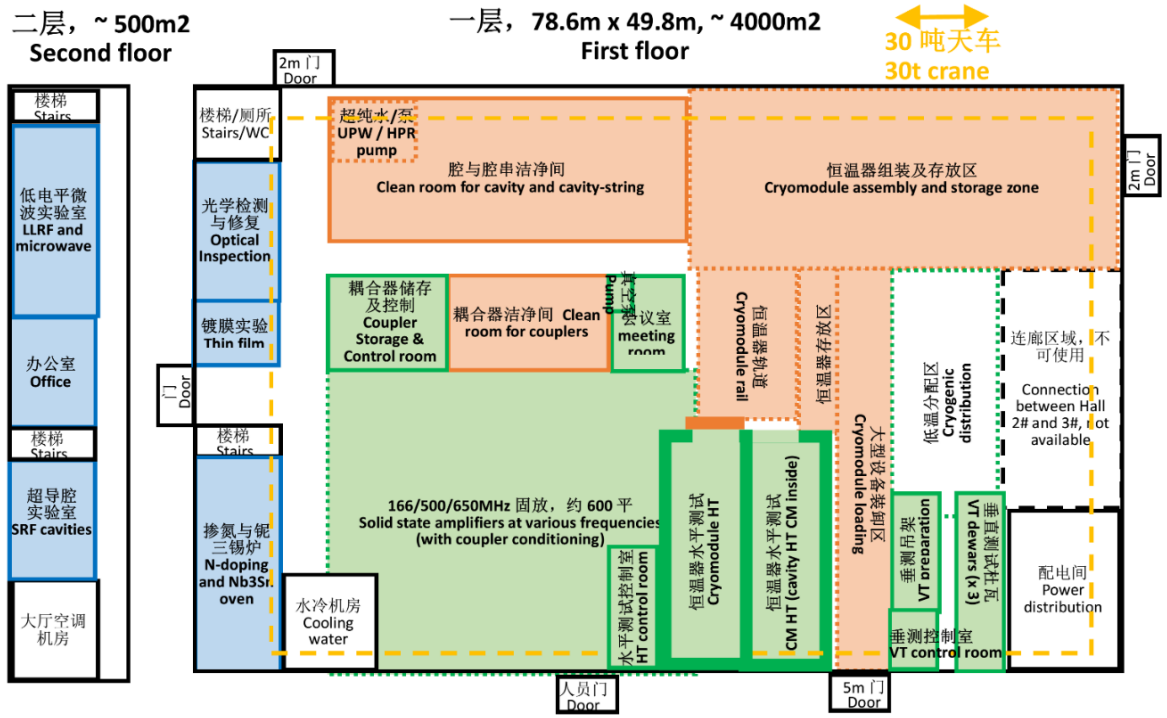


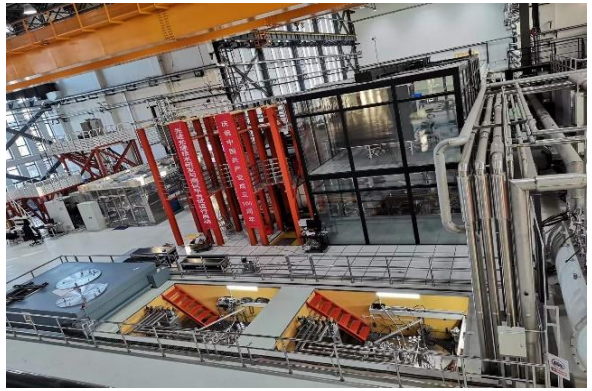


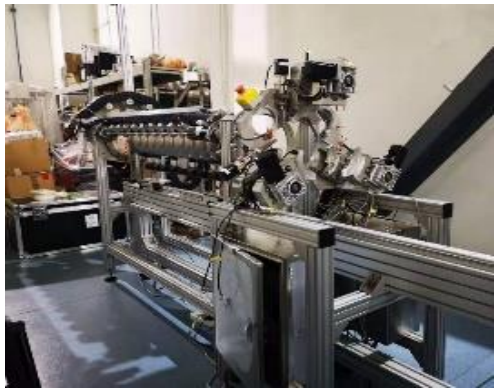
Accelerator key technology R&D and Testing platform:

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

IHEP PAPS SRF Infrastructure Fully Operational







PAPS SRF Infrastructure Testing Capability and Status

Facilities (capability per year)	Devices	Tests since 2021	Related Projects
Cavity vertical test stand (400 cavities per year)	**Cavities**: 166 MHz, 325 (324) MHz, 500 MHz, 650 (648) MHz, 1.3 GHz	~ 200	HEPS, BEPCII-U, CEPC, CSNS-II, SHINE, DALS, RAON …
Cryomodule assembly and horizontal test stand (20 modules per year)	**Cryomodules**: 166 MHz, 324 MHz, 500 MHz, 650 MHz, 1.3 GHz	~ 20	HEPS, DALS, BEPCII-U, CSNS-II, CEPC …
Coupler high power test stand (200 couplers per year)	**Couplers**: 166 MHz, 324 MHz, 500 MHz, 650 MHz, 1.3 GHz	~ 40	HEPS, SHINE, DALS, CSNS-II, CEPC …
Clean assembly and HPR (2 assembly lines and 2 HPRs)	**Cavities and cavity strings**: 166 MHz, 324 MHz, 500 MHz, 650 MHz, 1.3 GHz	~ 180	HEPS, CEPC, CSNS-II, SHINE, DALS, BEPCII-U …

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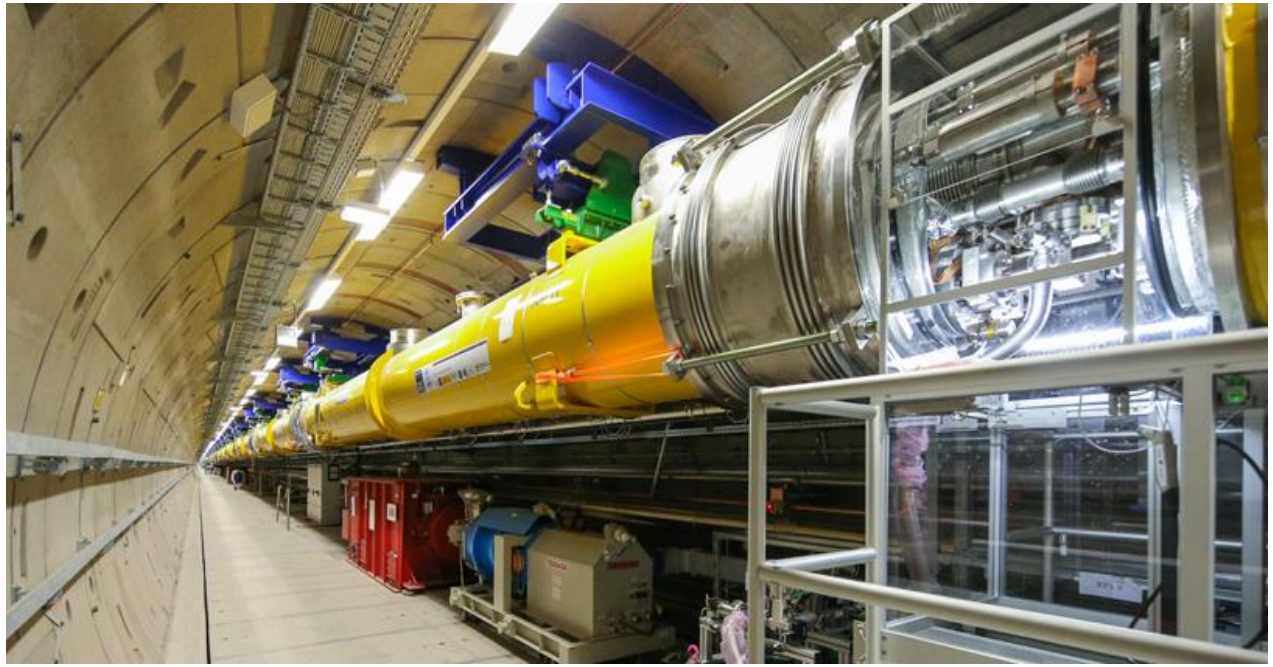
International collaborations

- European-XFEL cryomodule prototype and mass production(58sets)
- LCLS-II cryomodule and key components technical support
- Annual IHEP-KEK SRF collaboration meeting has been held 13 times
- Technical and personnel exchanges on SRF with other lab or facility such as Jlab, FNAL, ESS…
- Possible collaboration between IHEP French laboratory?



European-XFEL cryomodule collaboration

LCLS-II cryomodule collaboration

Summary

- 20 years blooming SRF accelerator R&D at IHEP, we are in a golden era of large SRF accelerator facilities design and construction.
- Many challenges in the design, development, construction and operation of accelerators for the colliders, light sources & FELs and proton linacs.
- We aim to expand cooperation with French laboratory in SRF technology under the framework of FCPPN/L.