New Projects in China

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This talk will focus on large scientific facilities for research.

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The projects selected and presented in these slides are subject to my own knowledge limitations and are by no means complete.

Outline

- **Introduction**
- **Accelerator projects in 3 categories**
  - Colliders
  - Synchrotron light sources & FELs
  - Proton & Heavy ion facilities
- **SRF infrastructures**
- **Summary**

Major accelerator facilities in main land China

Beijing

Beijing Electron Position Collider (BEPCII, BEPCII-U)

Beijing Synchrotron Radiation Facility (BSRF)

Shanghai-area

Shanghai Synchrotron Radiation Facility (SSRF)

Shanghai soft X-ray Free-Electron Laser facility (SXFEL)

Hefei-area

Hefei Synchrotron Radiation Facility (HLS)

Guangdong

China Spallation Neutron Source (CSNS)

Others

Dalian Coherent Light Source (DCLS)

Lanzhou Heavy Ion Research Facility (HIRFL)

China Accelerator Facility for super-heavy nEw Elements (CAFe2)

New projects (since 2015)

Beijing

High Energy Photon Source (HEPS)

Shanghai-area

Shanghai High Repetition Rate X-ray FEL and Extreme Light Facility (SHINE)

Zhejiang Industrial Photon Source (ZIPS)

Suzhou Laboratory (SZL)

Hefei-area

Hefei Advanced Light Facility (HALF)

Guangdong

China initiative Accelerator Driven System (CiADS)

High Intensity heavy ion Accelerator Facility (HIAF)

China Spallation Neutron Source - II (CSNS-II)

Shenzhen Superconducting Soft X-Ray FEL (S^3FEL)

Southern Advanced Photon Source (SAPS)

Others

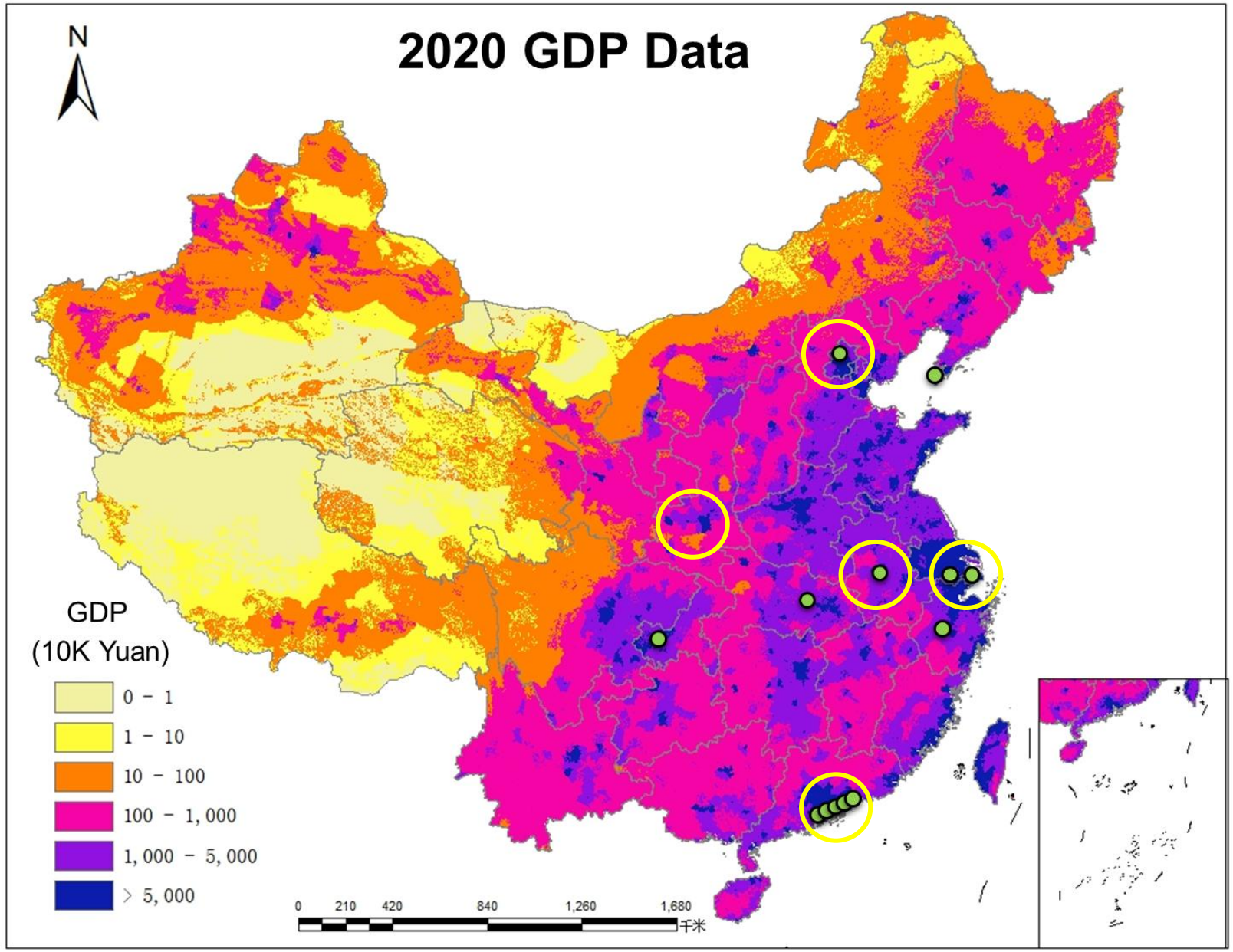
Ultrafast Transient Experimental Facility (UTEF)

Isotope Pharmaceutical Production Platform based on Superconducting Accelerator (IP-SAFE)

Dalian Advanced Light Source (DALS)

Wuhan Advanced Light Source (WALS)

Regional GDP and national science centers



- **Five Comprehensive National Science Centers**
  - Beijing
  - Shanghai
  - Great Bay Area
  - Hefei
  - Xi'an

- New projects are perfectly aligned with regional GPD and the national science centers

New projects (since 2015): non-exhaustive list

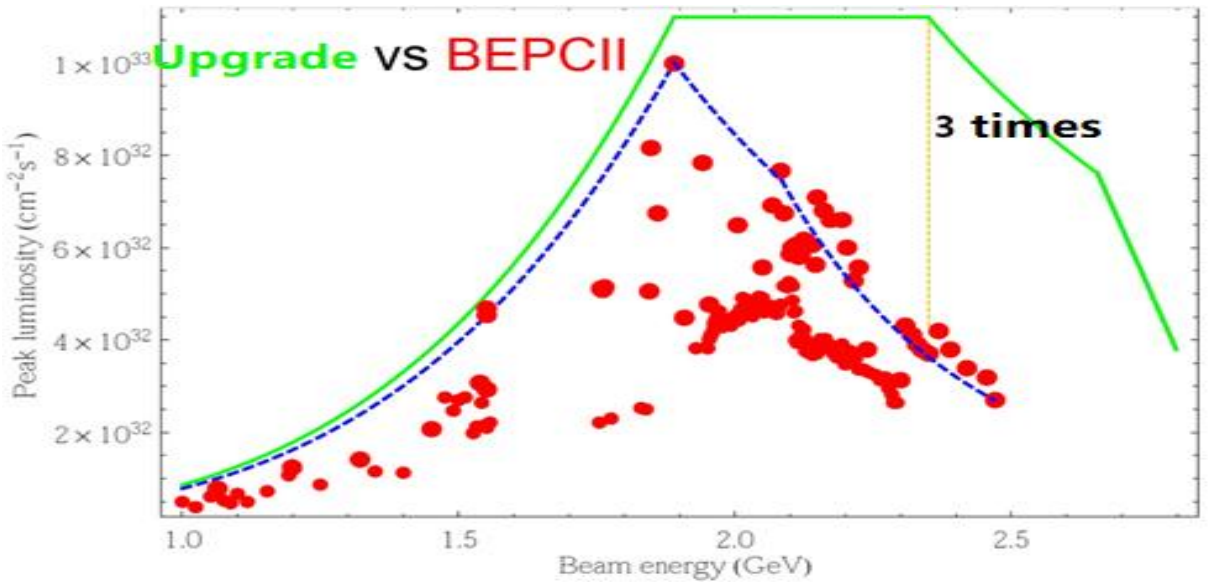
	Facility	E (GeV)	Time	Status	Type	RF tech.	HOM damping
Collider	BEPCII-U	2.8	2024-2025 (Dark)	Operation	Circular	SRF	Yes
	CEPC	180	2027~2037	Planning	Circular	SRF	Yes
	STCF	3.5	2028~2033	Planning	Circular	NCRF	Yes
Synchrotron light source	HEPS	6	2019~2025	Under constr.	Circular	SRF	Yes
	HALF	2.2	2023~2028	Under constr.	Circular	SRF	Yes
	UTEF	0.5	2022~2026	Under constr.	Circular	NCRF	Yes
	ZIPS	2.7	2026~2029	Planning	Circular	NCRF	Yes
	SZL	2.4	2025~2029	Approved	Circular	NCRF	Yes
	SAPS	3.5	TBD	Planning	Circular	NCRF	Yes
	WALS	1.5	2028~2032	Planning	Circular	NCRF	Yes
FEL	SHINE	8	2018~2027	Under constr.	Linear	SRF	Yes
	S^3FEL	2.5	Approved in 2023	Approved	Linear	SRF	Yes
	DALS	1	TBD	Planning	Linear	SRF	Yes
Proton & Heavy-ion	CSNS-II	0.3 (linac)	2024~2029	Under constr.	L+R	SRF	No
	CiADS	0.6	2021~2027	Under constr.	Linear	SRF	No
	HIAF	17.2MeV/u (linac)	2018~2025	Under constr.	L+R	SRF	No

Colliders

Beijing **E**lectron **P**ositron **C**ollider **II**
Beijing **S**ynchrotron **R**adiation **F**acility

BEPCII: overview

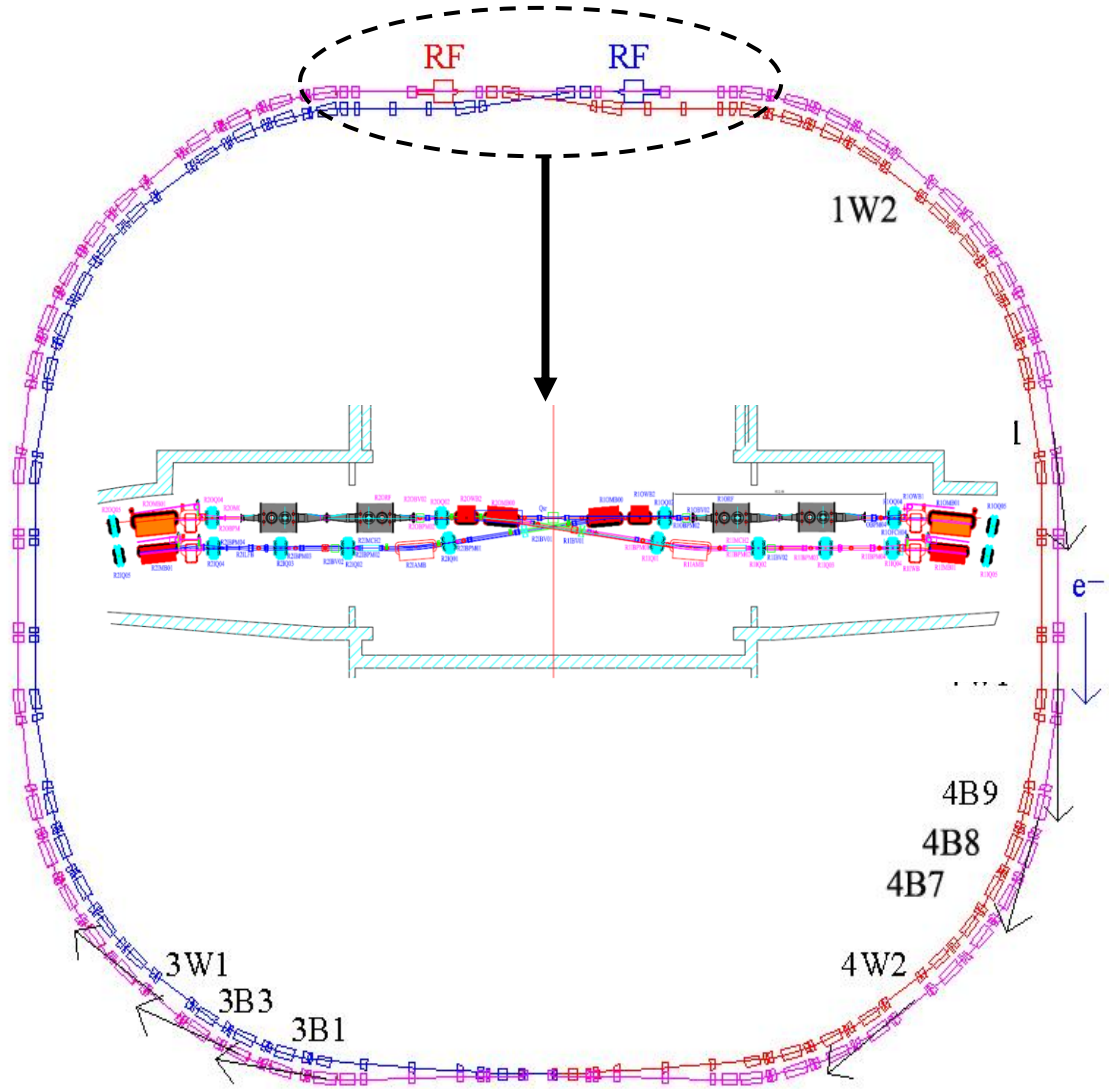
- e+ e- collider, 1st collider and 1st synchrotron light source in China (Parasitic use, 1st gen)
- **Location**: IHEP campus, Beijing city
- **Parameters**: 2.8GeV (max), 900mA (max), 242m circumference
- **Operation time**: 1991-2004, 2009-2024, 2025-now
- **Upgrade**: 2004-2008 to BEPCII, 2024-2025 to BEPCII-U (kept only the parasitic exp.)
- **Beamlines**: 8 beamlines (5 IDs), vacuum ultraviolet to hard X-ray
- **RF system**: 4×500MHz single-cell KEKB-type, 3 SSAs + 1 klystron
- **Latest upgrade**: increase luminosity by 3-fold & Increase beam energy to 2.8GeV



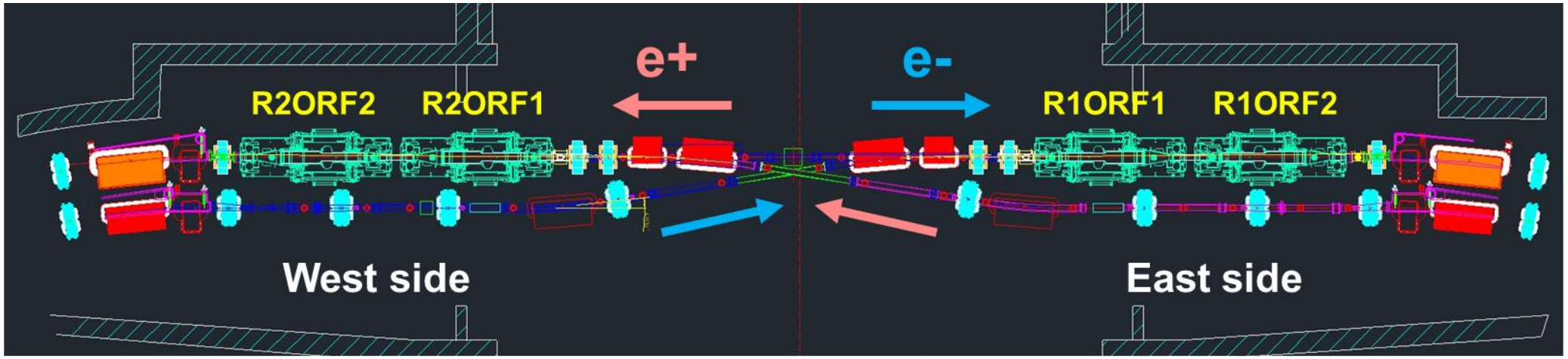
BEPCII-U: parameters

Key upgrade: Doubled beam power & optics & Higher-gradient magnets

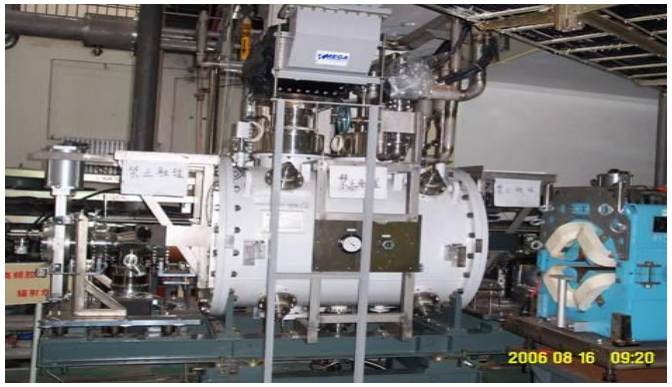
	BEPCII @ 2.35GeV	BEPCII-U @ 2.35GeV	BEPCII-U @ 2.8GeV
L $[10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$	**3.5**	**11**	**3.7**
β_y^* [cm]	**1.5**	**1.35**	**3.0**
Beam current [mA]	400	900	450
SR Power [kW]	**110**	**250**	**250**
$\xi_{y,\mathrm{lum}}$	0.029	0.033	0.043
Emittance [nmrad]	**147**	**152**	**200**
Couping [%]	**0.53**	**0.35**	**0.5**
Bucket Height	0.0069	0.011	0.009
$\sigma_{z,0}$ [cm]	1.54	1.07	1.4
σ_z [cm]	**1.69**	**1.22**	**1.6**
RF Voltage [MV]	**1.6**	**3.3**	**3.3**

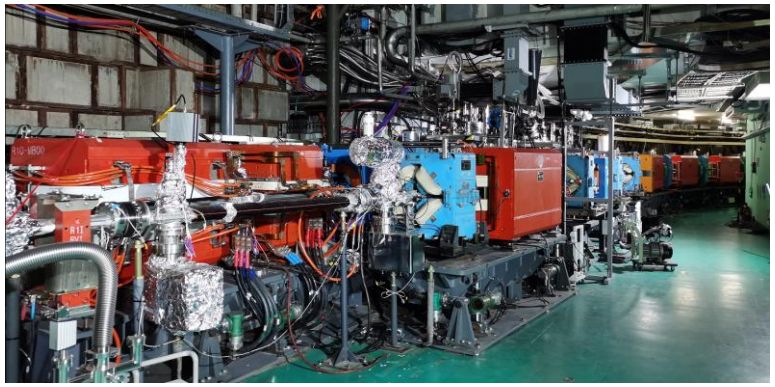


RF sections at BEPCII-U



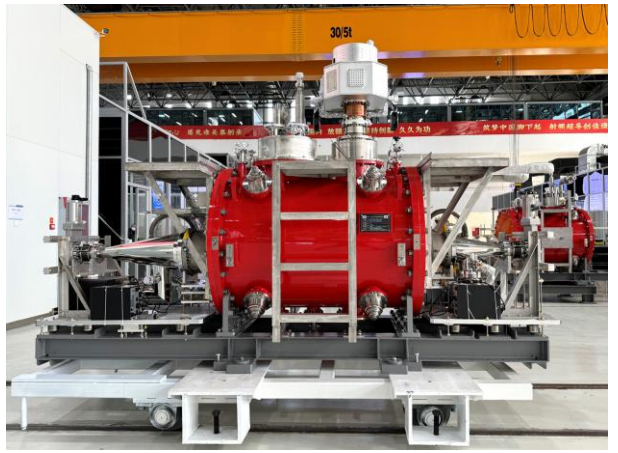
R2ORF2	R2ORF2	R1ORF1	R1ORF2
MHI East cavity (2006-2017)	MHI West cavity (2006-2024) (FPC exch. 2015)	BII-U cavity (Fab. 2024)	Spare cavity (2017-2024) (FPC exch. 2018)





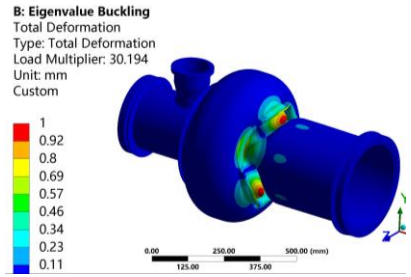
500MHz SRF cavities: optimized design

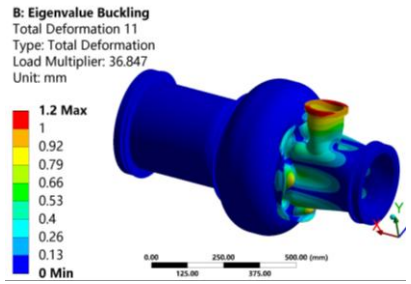
- Cavity geometry mechanically improved by adding a pair of stiffeners
- **Synergy with BEPCII-U, same cavity & same module**, different taper aperture (63mm vs. 150mm)
- Four cavities produced, BCP treated, all met VT specs., demonstrated excellent performance: Vc > 4MV with mild or no field-emission (FE)
- Three modules (1 BII-U & 2 HEPS) assembled, **excellent performance achieved in VT preserved in HT, no FE onset**, demonstrated cavity treatment and module assembly procedures

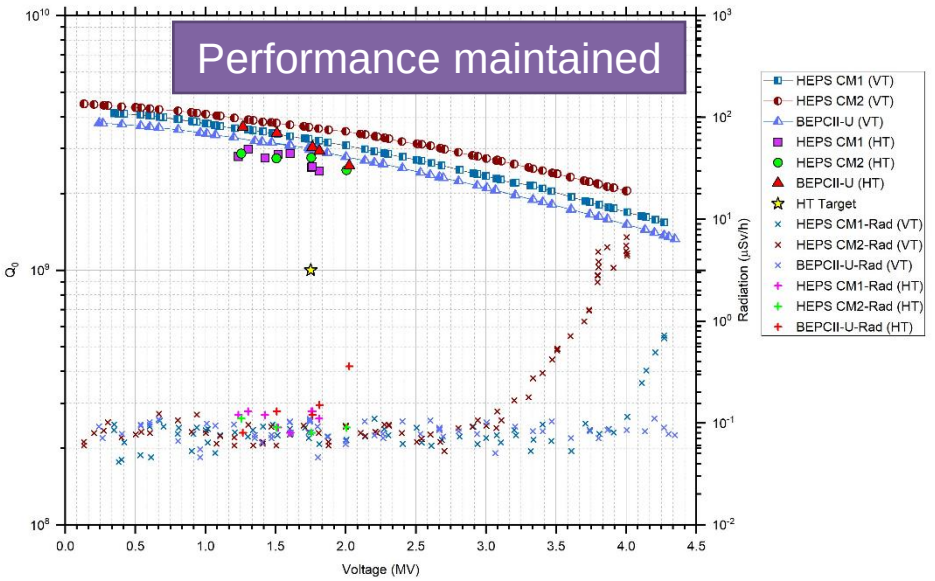


Static HL: 20~23W, Q0@1.75MV: 2.5e9
Dynamic HL: 11~13W, no FE onset

Parameter	Value	Unit
Frequency	499.8	MHz
Operating temp.	4.4	K
Design Vc	2.0	MV
Ep/Eacc	2.08	-
Bp/Eacc	4.63	mT/(MV/m)
R/Q (=V²/ωU)	95	Ω
Qext (HEPS)	8e4	-
Qext (BII-U)	2e5	-



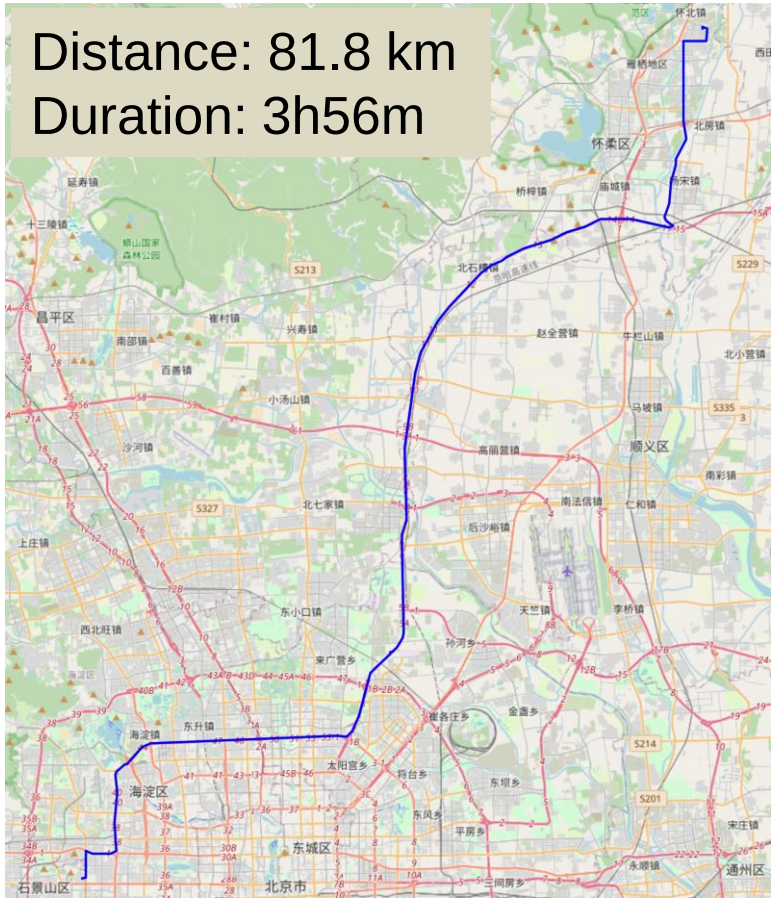


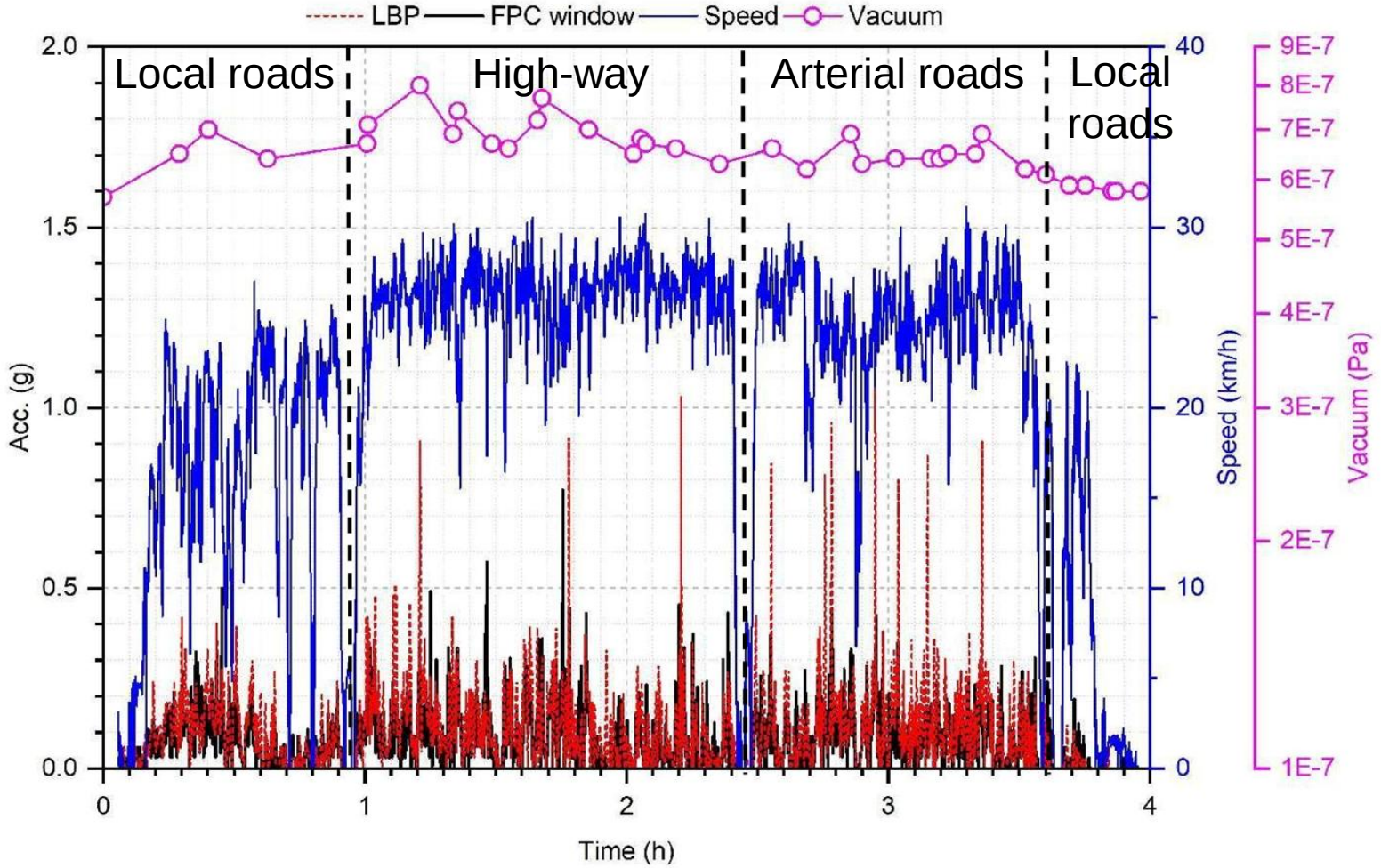


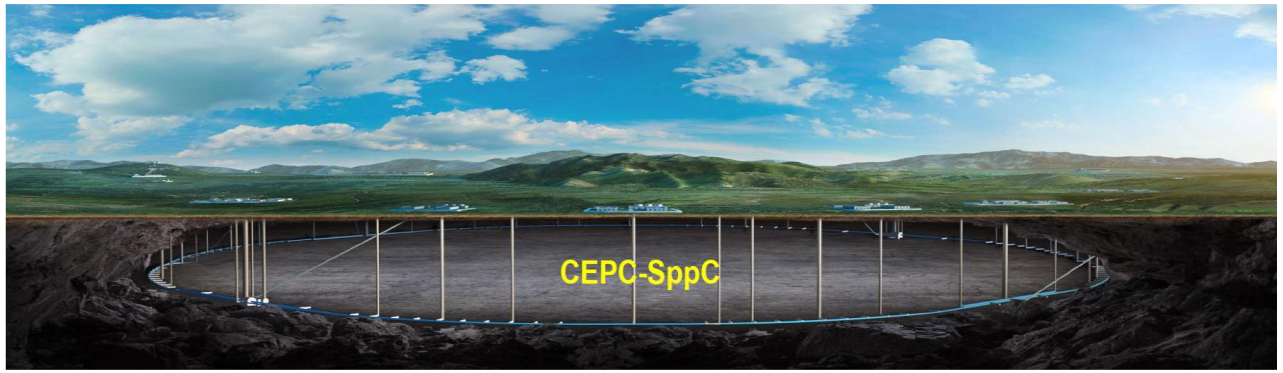
[1] H. Zheng *et al.*, *IEEE TAS* 31, 3500109 (2021) [2] H. Zheng *et al.*, *JINST* 19, P10031 (2024).

Module transportation under vacuum

- Multiple road tests with dummy loads conducted before cav. transp.
- Cross-city transportation (~80km, BEPCII-U) of the **complete modules under cavity vacuum**, shock of sensitive components and vacuum level monitored, **vacuum integrity well preserved**





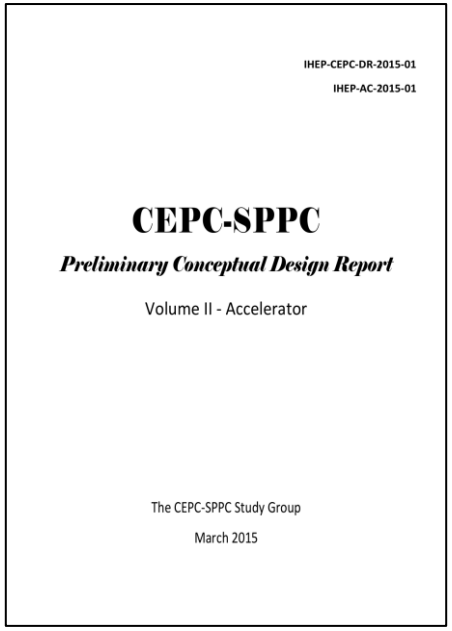


Circular **E**lectron **P**ositron **C**ollider

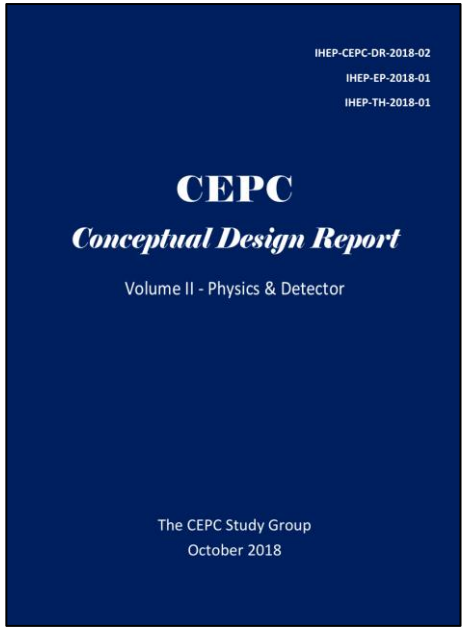
Circular Electron Positron Collider (CEPC)

- Next-gen electron-position collider (later upgrade to proton-proton collider) in China
- Design study launched in 2012, pre-CDR (2015), CDR (2018), TDR (2023), EDR (2027)
- The CEPC aims to start operation in 2030's, as a Higgs (Z/W) factory in China
- Construction and operation in 2 stages
  - 240~360 GeV electron-position (CEPC), 125 TeV proton-proton (SppC)
- **Goal**: High precision Higgs, EW measurements, probes new physics
- **Footprint**: 100 km circumference
- **Budget**: ~5 billion USD

Wang's talk on Monday



http://cepc.ihep.ac.cn/preCDR/Pre-CDR_final_20150317.pdf



arXiv: 1809.00285

arXiv: 2312.14363

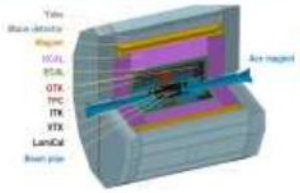
Operation mode		ZH	Z	W^+W^-	$t\bar{t}$
$\sqrt{s}$ [GeV]		~240	~91	~160	~360
Run Time [years]		10	2	1	5
30 MW	L / IP [$\times 10^{34}$ $cm^{-2}s^{-1}$]	**5.0**	**115**	**16**	**0.5**
	$\int L\,dt$ [ab^{-1}, 2 IPs]	13	60	4.2	0.65
	Event yields [2 IPs]	2.6×10^6	2.5×10^{12}	1.3×10^8	4×10^5
50 MW	L / IP [$\times 10^{34}$ $cm^{-2}s^{-1}$]	**8.3**	**192**	**26.7**	**0.8**
	$\int L\,dt$ [ab^{-1}, 2 IPs]	21.6	100	6.9	1
	Event yields [2 IPs]	4.3×10^6	4.1×10^{12}	2.1×10^8	6×10^5

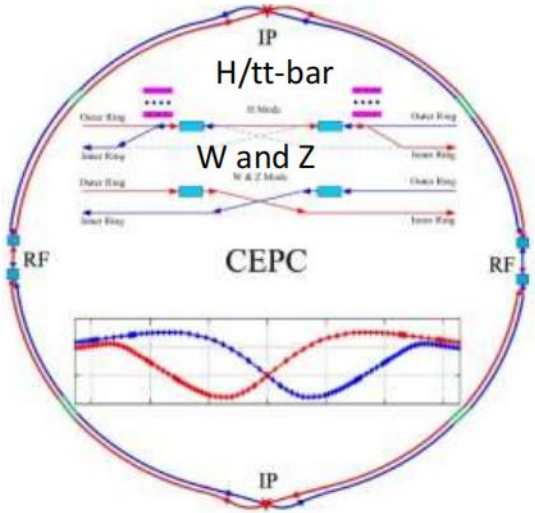
CEPC physics white papers:
1: Higgs physics, Chinese Physics C Vol. 43, No. 4 (2019) 043002
https://arxiv.org/pdf/1810.09037
2: Flavor physics, https://arxiv.org/pdf/2412.19743 (2024)
3: Electroweak physics, to be published
4: New Physics Search at the CEPC: a General Perspective
https://doi.org/10.48550/arXiv.2505.24810 (2025)
5: QCD, to be published

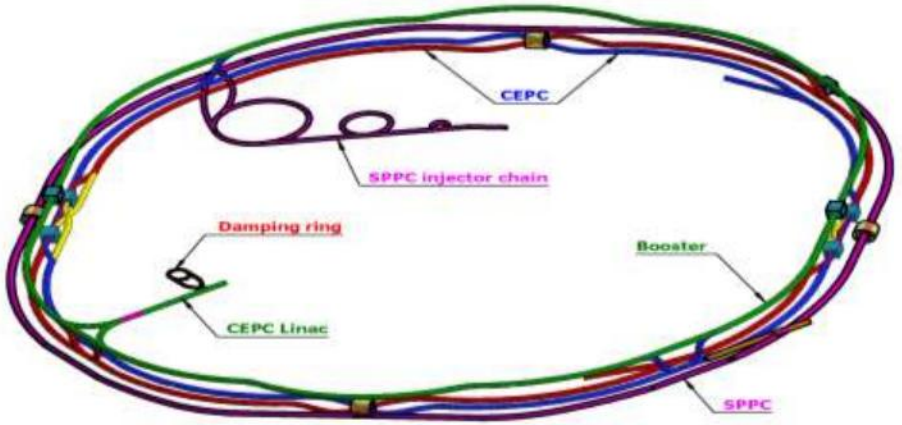
CEPC Higgs factory & SppC layout in TDR/EDR

CEPC as a Higgs Factory: H, W, Z, upgradable to ttbar, followed by a SppC (a Hadron collider) ~125TeV
30MW SR power per beam (upgradable to 50MW) , high energy gamma ray 100Kev~100MeV

CEPC has two detectors







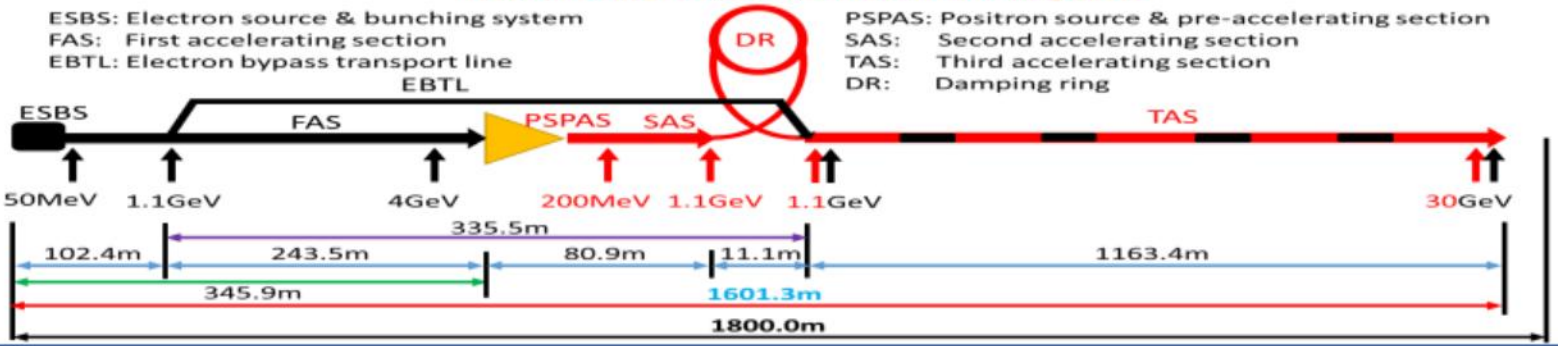
CEPC collider ring (100km)

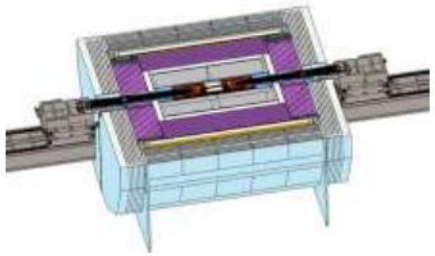
CEPC booster ring (100km)

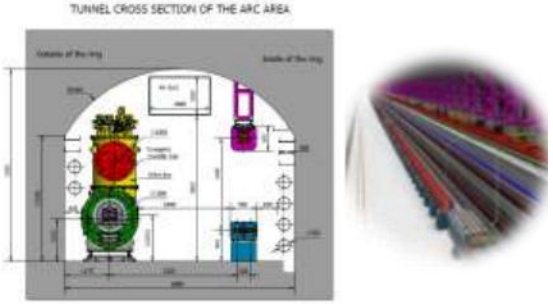
CEPC TDR S+C-band 30GeV linac injector

ESBS: Electron source & bunching system
FAS: First accelerating section
EBTL: Electron bypass transport line

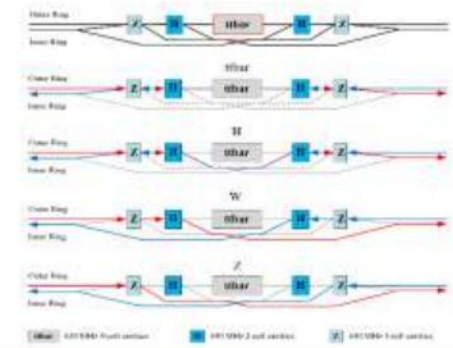
PSPAS: Positron source & pre-accelerating section
SAS: Second accelerating section
TAS: Third accelerating section
DR: Damping ring







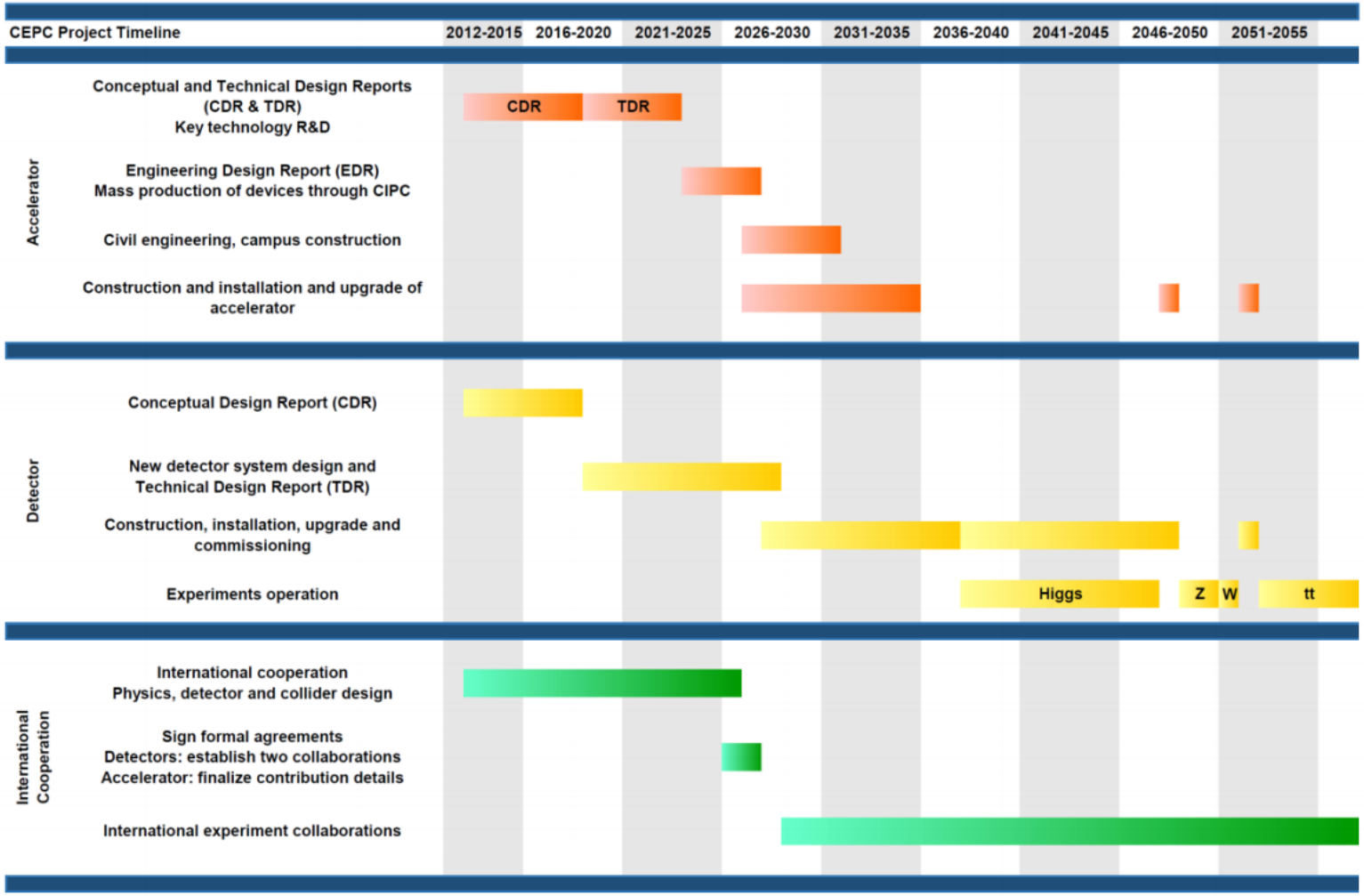
CEPC/SppC in the same tunnel



Z,W, Higgs and ttbar energies

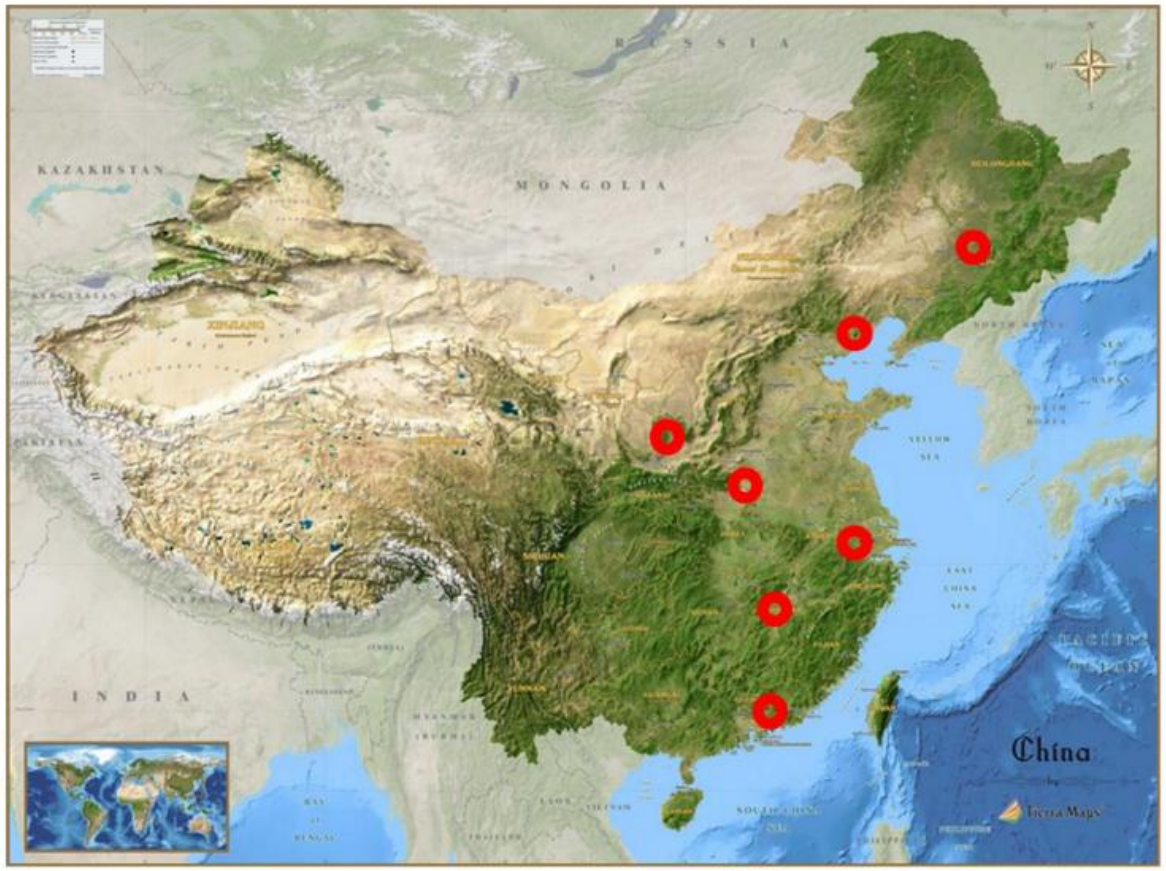
CEPC plan and schedule

TDR (2023), EDR(2027), start of construction (~2027)



- CEPC plans to submit the proposal to the central government(NDRC) within the "15th five year plan"
- For this purpose, CAS organized studies and reviews
- CEPC was ranked by CAS as the No. 1 for HEP & NP, and No.2 for Basic Science in the first round;
- 2nd review by CAS took place on September 8. Result not released yet.
- If selected by CAS CEPC will submit proposal to NDRC in October.
- Review by NDRC is expected to take place after that.

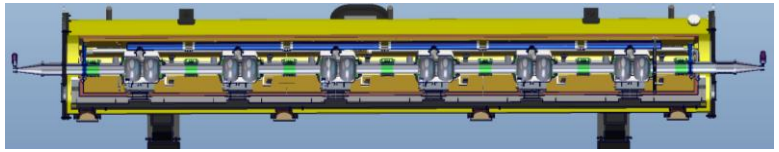
CEPC site selection



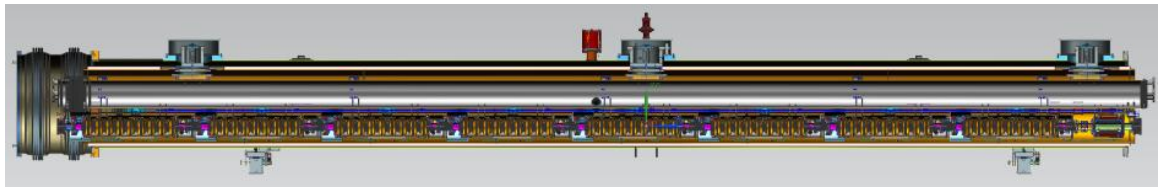
- All sites have been investigated: good geology, mostly granite
- Good living conditions, and local support

- Site selection will compare geology, electricity supply, transportation, environment for foreigners, local support & economy,…
- Final decision will depend on the negotiation between the central and local governments

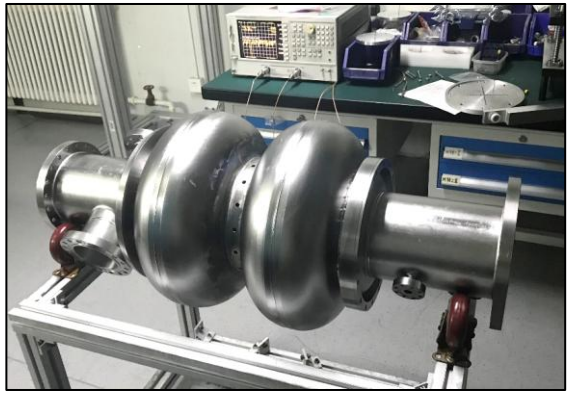
RF system of CEPC

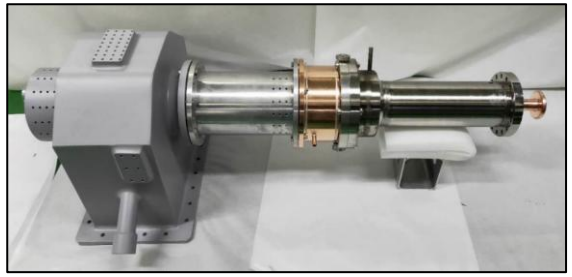


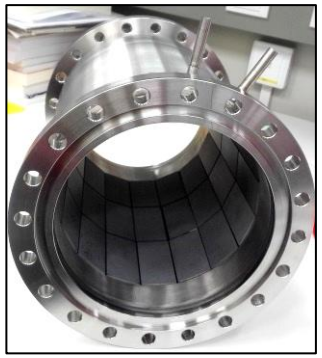
Collider 650 MHz Cryomodule (6x2-cell, 10 m)



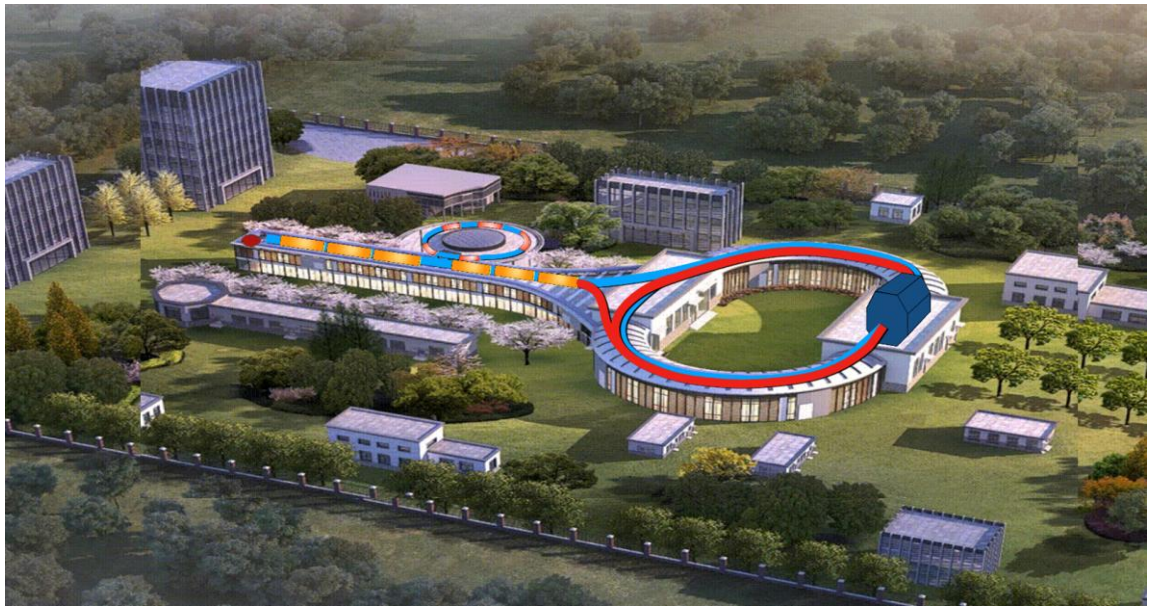
Booster 1.3 GHz Cryomodule (8x9-cell, 12 m)







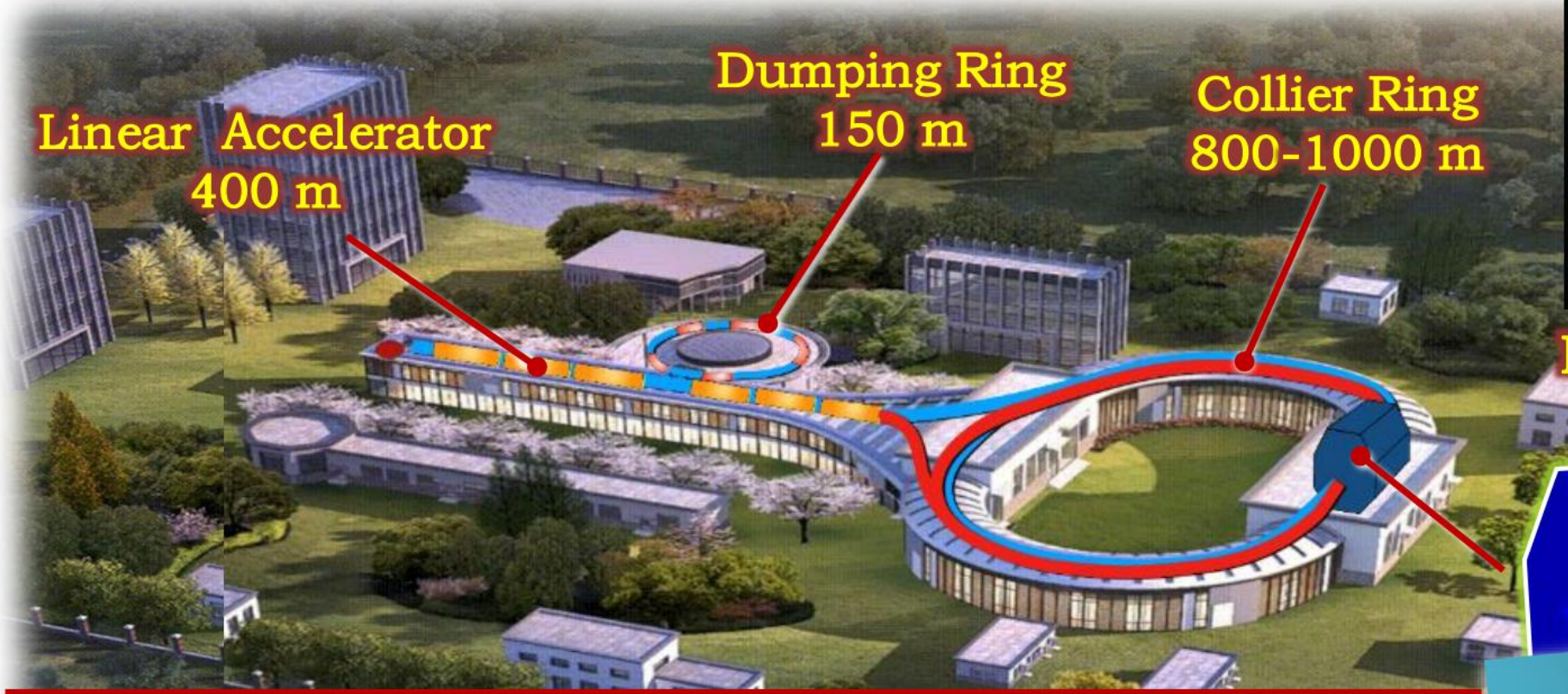
	H	W	Z
Collider Ring	**650 MHz 2-cell cavity**		
Lumi. / IP (10^{34} $cm^{-2}s^{-1}$)	2.93	10.1	16.6 / 32.1
RF voltage (GV)	2.17	0.47	0.1
Beam current (mA)	17.4 x 2	87.7	460
SR power / beam (MW)	30	30	16.5
Cavity number	240	108 x 2	60 x 2
Q_0 at max gradient	4E10 @ 22 MV/m (VT) 1.5E10 @ 20 MV/m (OP)		
2 K cavity wall loss (kW)	6.1	1.3	0.1
Booster Ring (extraction)	**1.3 GHz 9-cell cavity**		
RF voltage (GV)	1.97	0.585	0.287
Beam current (mA) peak	0.52	2.63	6.91
Cavity number	96	64	32
Q_0 at max gradient	3E10 @ 24 MV/m (VT) 1E10 @ 20 MV/m (OP)		

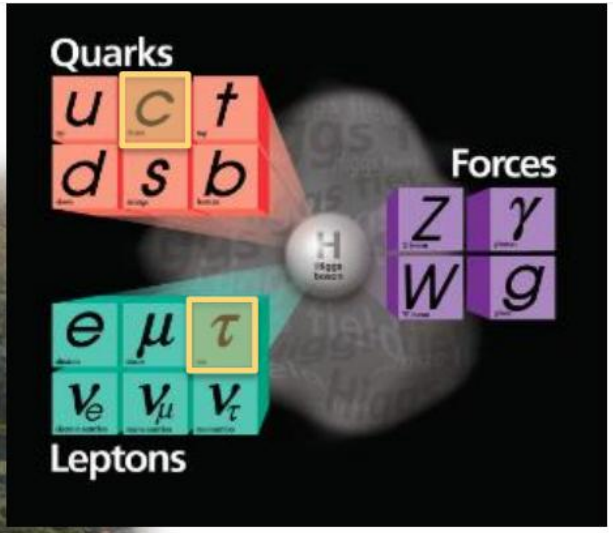


Super **T**au **C**harm **F**acility

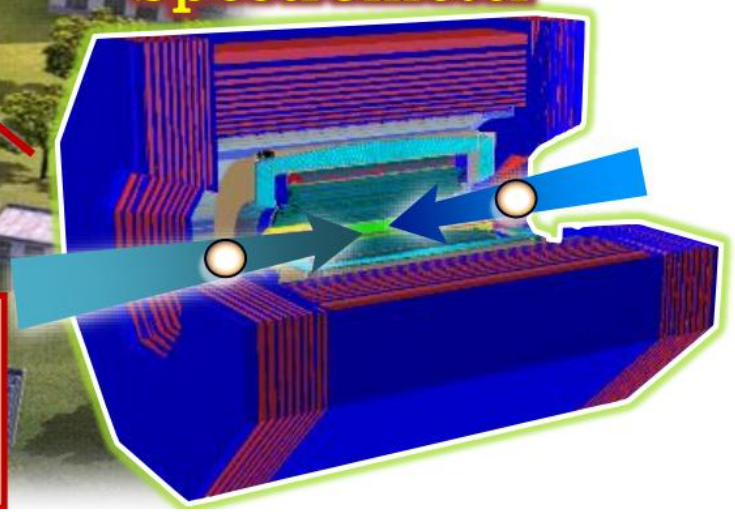
Super Tau Charm Facility (STCF)

A factory producing massive tau lepton and hadrons, to unravel the mystery of how quarks form matter and the symmetries of fundamental interactions



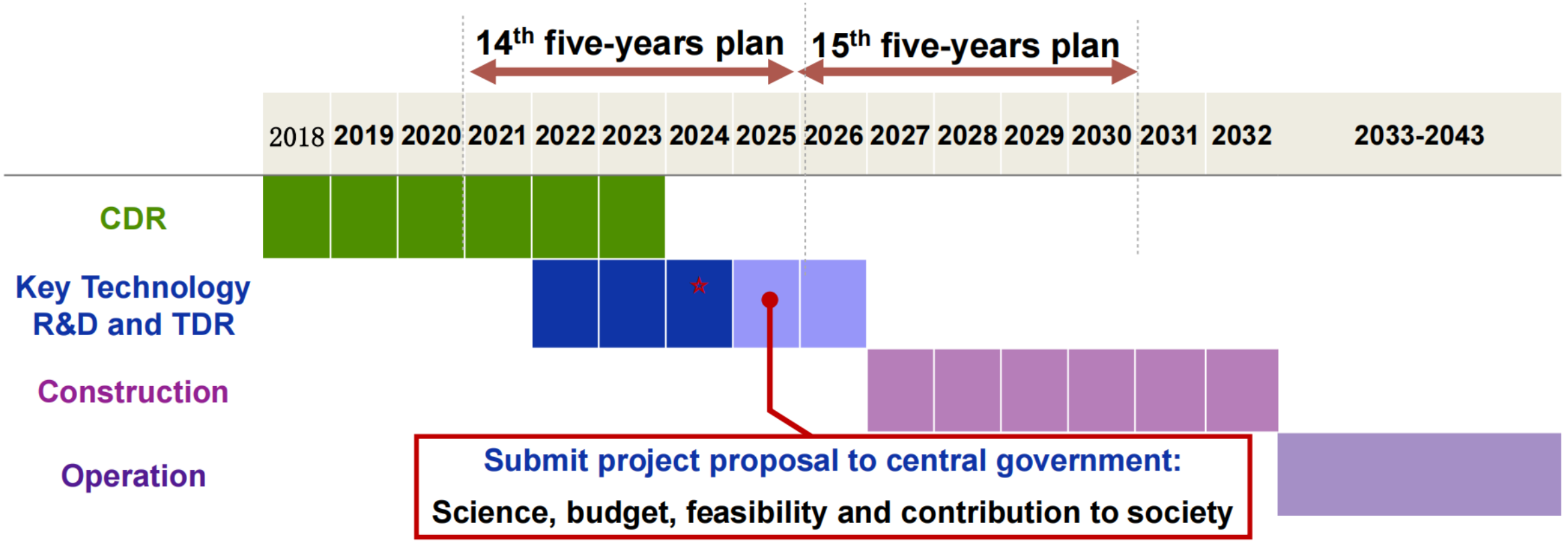


New generation Spectrometer



- E_{cm}= 2-7 GeV, $\mathcal{L} > 0.5\times10^{35}$ cm^{-2} s^{-1}
- Potential for upgrade to increase luminosity and realize polarized beam
- Site: 1 km^2, Hefei's suburban "Future Big Science City"

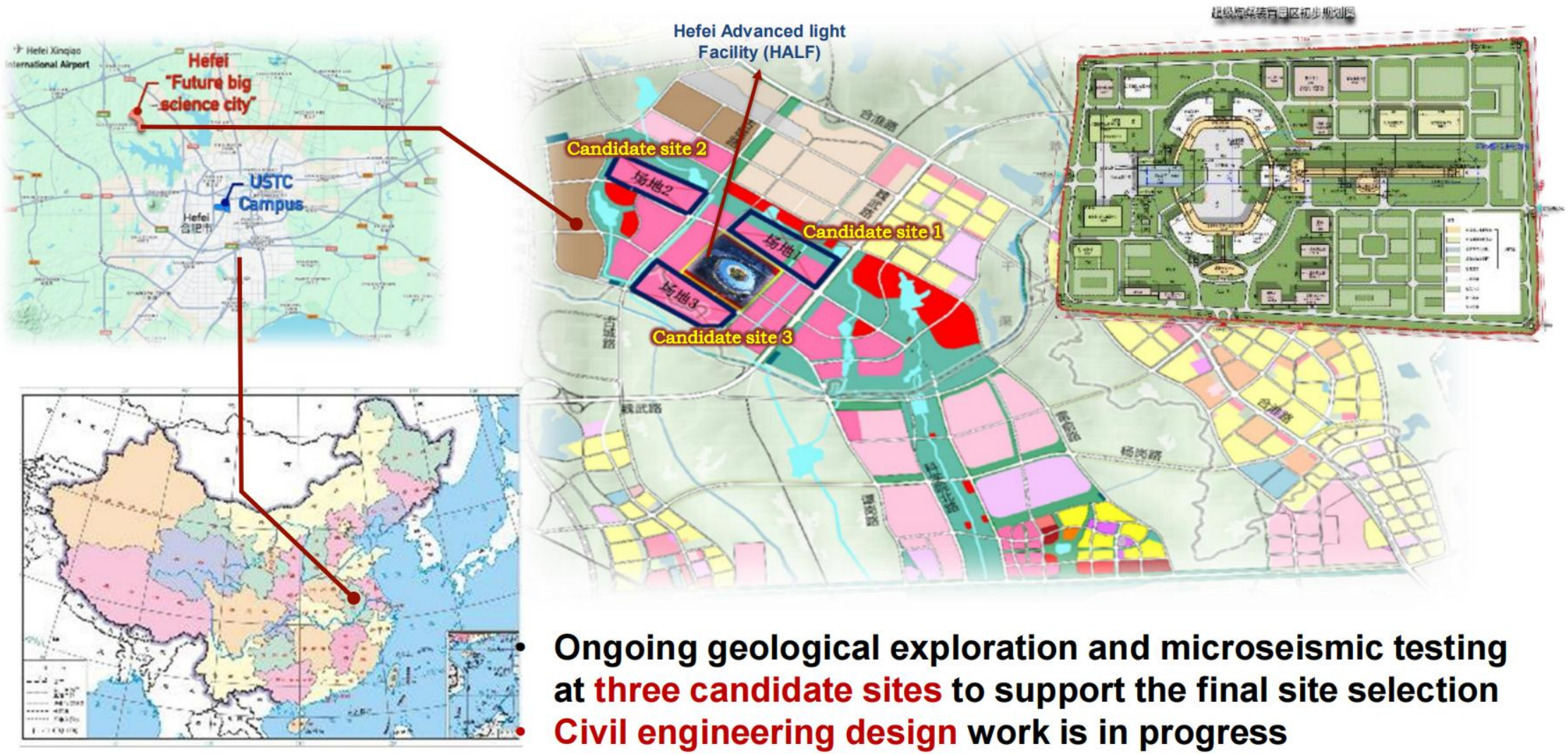
STCF tentative schedule



- 14th five-years plan : Conceptual design and R&D of Key technology, 364 M CNY
- 15th five-years plan : Construction 6 years, 4.98 B CNY
- Operating for 10-15 years, upgrade for 3 years, operating again for ~10 years

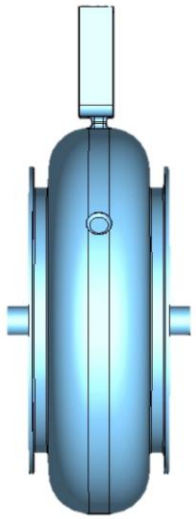
STCF site

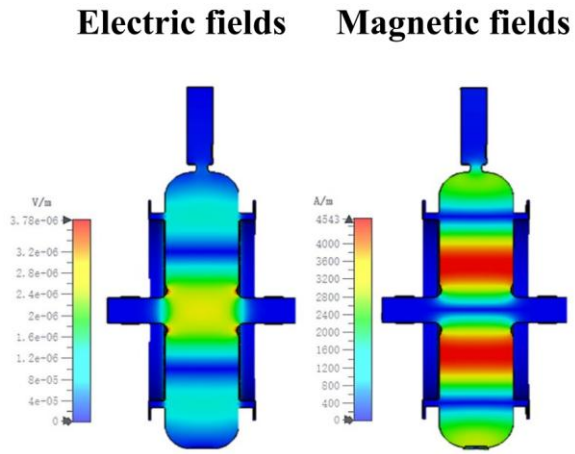
Hefei Future Big Science City



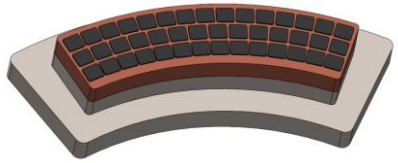
- Ongoing geological exploration and microseismic testing at three candidate sites to support the final site selection
- Civil engineering design work is in progress

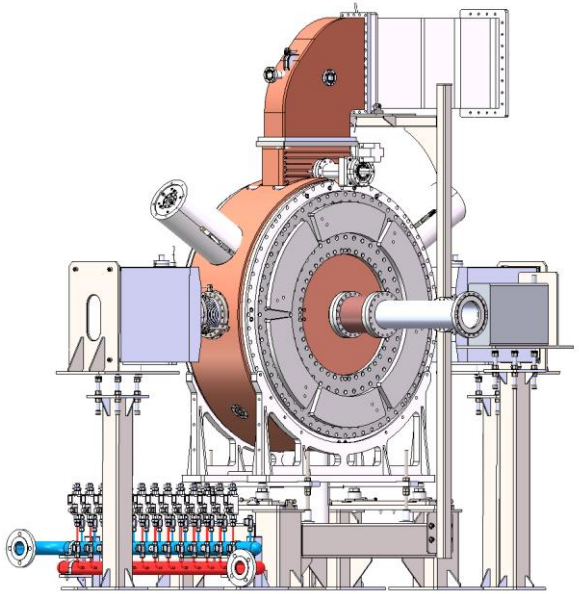
RF cavities of STCF





TM020 mode

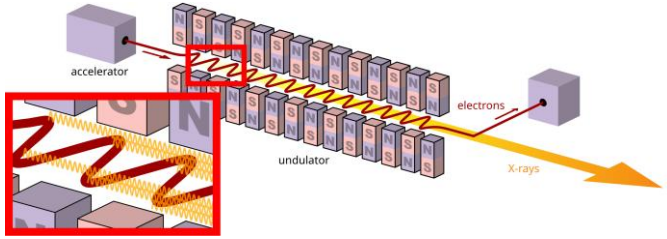




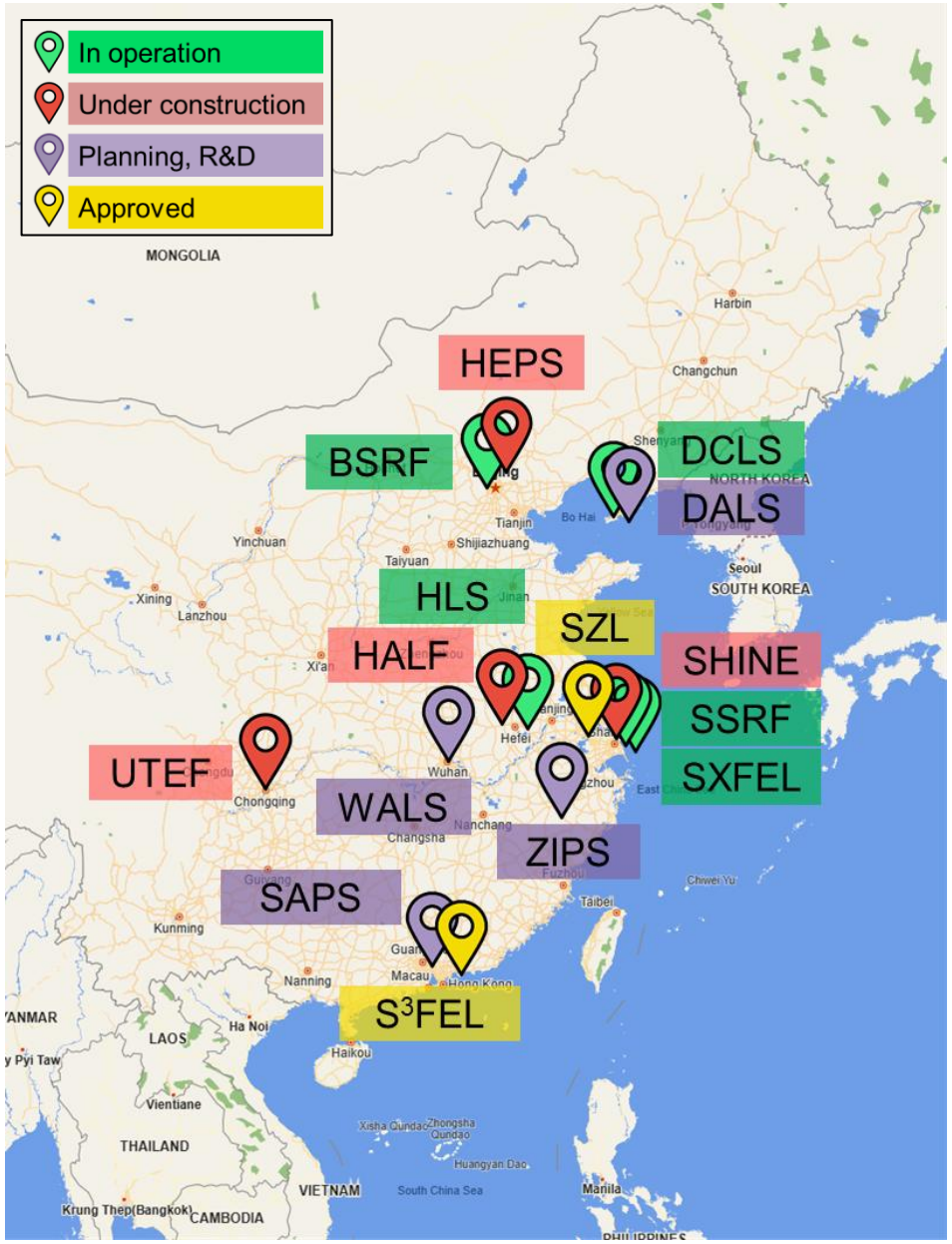
RF parameters	
Working mode	TM020
Frequency [MHz]	499.7
R/Q [Ω]	77.3
Unloaded quality factor	65110
E_p/E_{acc}	2.12
B_p/E_{acc} [mA/V]	2.55

	Values			
Beam Energy [GeV]	1.0	1.5	2.0	3.5
Circumference [m]	865.398			
Rev. freq. [kHz]	346.42			
RF Frequency [MHz]	499.7			
Harmonic Number	1442			
Number of Bunches	692			
Beam Current [A]	1.5	2	1.7	2
α_p	13.04e-4	13.65e-4	13.86e-4	14.14e-4
U0 [keV]	105.9	265.9	541	1477
SR Power [kW]	159	452	1082	2954
RF Voltage [MV]	1	2	3	6
Sync. Phase [deg]	174	172	170	166

Light Sources



Light sources in China



In operation

Blue: SRF, *Italic*: *FEL*

- 1990-now, Beijing Synchrotron Radiation Facility (BSRF)
- 1991-now, Hefei Light Source (HLS)
- 2009-now, Shanghai Synchrotron Radiation Facility (SSRF)
- *2018-now, Dalian Coherent Light Source (DCLS)*
- *2022-now, Shanghai soft X-ray Free-Electron Laser facility (SXFEL)*

Under construction

- *2018-2027, Shanghai High Repetition Rate X-ray FEL and Extreme Light Facility (SHINE)*
- 2019-2025, High Energy Photon Source (HEPS)
- 2022-2026, Ultrafast Transient Experimental Facility (UTEF)
- 2023-2028, Hefei Advanced Light Facility (HALF)

Approved

- *2023, Shenzhen Superconducting Soft X-Ray FEL (S^3FEL)*
- Suzhou Laboratory (SZL)

Planning

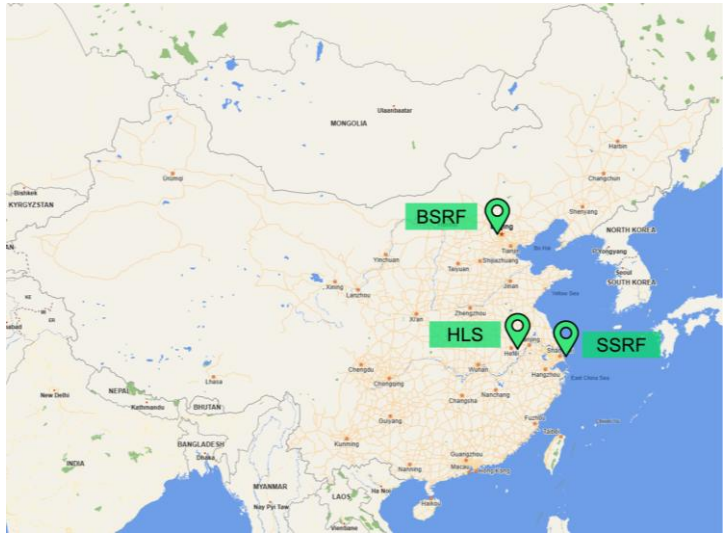
- Southern Advanced Photon Source (SAPS)
- *Dalian Advanced Light Source (DALS)*
- Wuhan Advanced Light Source (WALS, *WFEL*)
- Zhejiang Industrial Photon Source (ZIPS)

A bit of history: BSRF, 1990-now

Beijing Synchrotron Radiation Facility (BSRF, 1st gen)

1st generation

- **Location**: IHEP campus, Beijing city
- 1st synchrotron light source in China, start operation in 1990
- Parasitic use of synchrotron on an electron-position collider (BEPC)
- Latest upgrade in 2024 (BEPCII-U) eliminated dedicated sync. mode
- **Parameters**: 2.3~2.8GeV, 900mA, 242m circumference
- **Beamlines**: 8 BLs, vacuum ultraviolet to hard X-ray, 50eV~18keV
- **RF**: two pairs of 500MHz KEKB-type SRF cavities

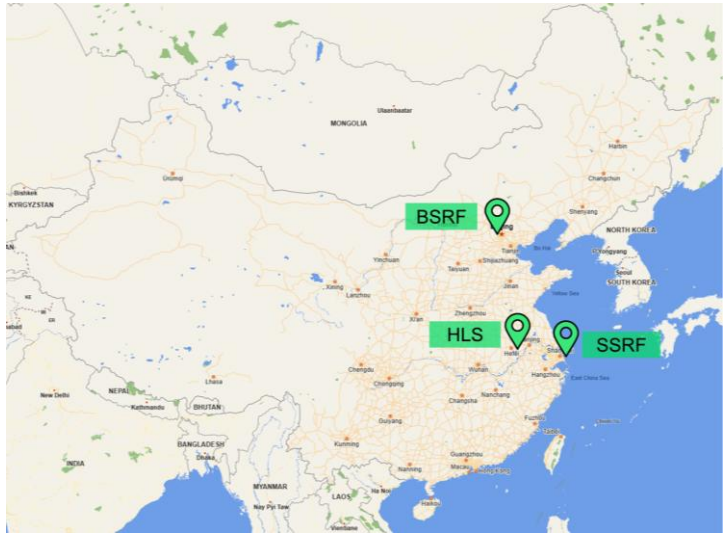


A bit of history: HLS, 1991-now

Hefei Light Source (HLS, 2nd gen)

2nd generation

- **Location**: USTC campus, Hefei, Anhui
- 1st dedicated synchrotron light source in China, start operation in 1991
- Start operation in 1991, upgraded in 1999-2004, 2010-2014
- **Parameters**: 800MeV, 500mA, 66m circumference
- **Beamlines**: 10 BLs, infrared to soft X-ray, 6meV~1000eV
- **RF**: One 204MHz NCRF cavity + One 816MHz NCRF cavity



A bit of history: SSRF, 2009-now

Shanghai Synchrotron Radiation Facility (SSRF, 3rd gen)

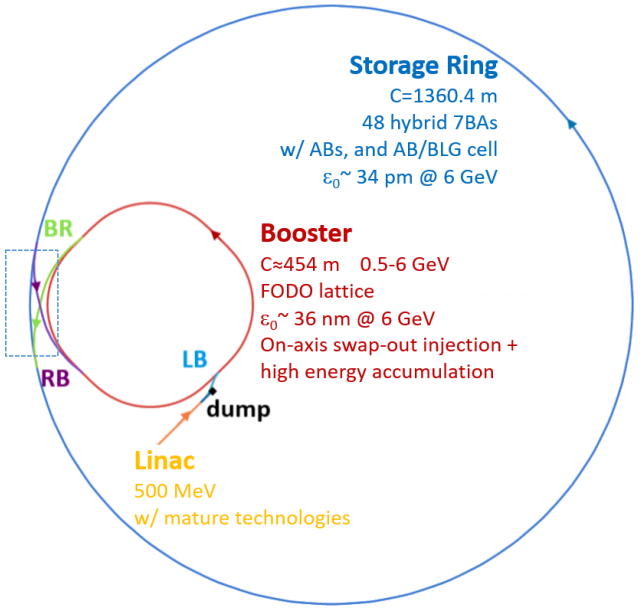
3rd generation

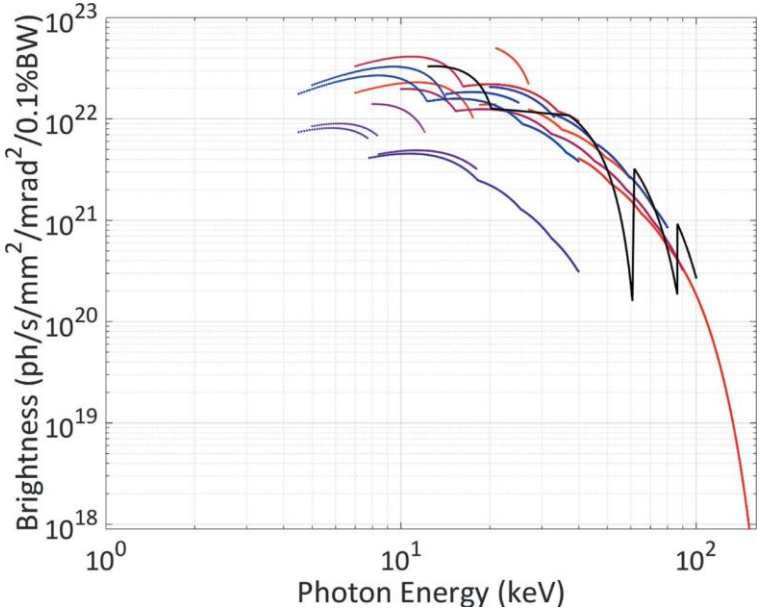
- **Location**: Zhangjiang district, Shanghai
- First 3rd-gen synchrotron light source in China, start operation in 2009
- Start operation in 2009, upgraded in 2016-2023
- **Parameters**: 3.5GeV, 300mA, 432m circumference
- **Beamlines**: 34 BLs, infrared to hard X-ray, gamma, 1meV~160keV
- **RF**: Three 500MHz CESR-type SRF cavities + One 1500MHz 2-cell SRF cavity

High **E**nergy **P**hoton **S**ource (Beijing)

High Energy Photon Source (HEPS)

- A diffraction-limited SR light source (4th gen), 1st high-energy SR light source in China
- **Location**: Huairou Science City, Beijing, **Construction time**: 2019~2025
- **Budget**: 4.76B CNY (~$652M)(excl. labor costs)
- **Parameters**: 6GeV, 200mA, 35pm·rad, 1360.4m circumference, 7BA lattice
- **Photon energy**: 0.1~300keV, soft X-ray to hard X-ray
- **Beamlines**: 14 BLs in phase 1, 28 additional BLs planned for phase 2, max. capacity 90 BLs





HEPS project schedule

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
HEPS-TF	Preparation			Execution									
HEPS				Preparation			Construction (6.5 yrs.)						

NOW

HEPS project milestones

- 28.09.2016, Project settled in Huairou (Beijing)
- 15.12.2017, **Project proposal** approved by NDRC (CD0 equivalent)
- 28.12.2018, **Feasibility study** approved by NDRC (CD1 equivalent)
- 22.05.2019, **Preliminary design and budget** approved by NDRC (CD2 equivalent)
- 29.06.2019, **Construction started** in Huairou (CD3 equivalent)
- 31.12.2025, **Construction completed**, KPPs delivered, national acceptance (CD4 equivalent)

HEPS-TF (R&D project before HEPS)

- Schedule： 04.2016 - 10.2018, Budget: 321.6 M RMB (~48 M USD)

Conceptually imagined in 2008

NDRC: National Development and Reform Commission

HEPS construction & commissioning

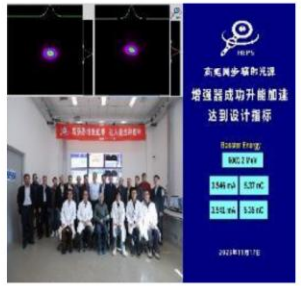
- 2025.03 ~ 2025.05, joint commissioning of accelerator and BLs
- 2025.05 ~ 2025.08, installation of SRF cavities and IDs, re-alignment of BS and SR
- **2025.09, beam current ramped above 100mA, KPPs of accelerator delivered**
- 2025.10, deliver KPPs of beamlines

May 12, 2022
The Linac Vacuum-sealing in the tunnel completed

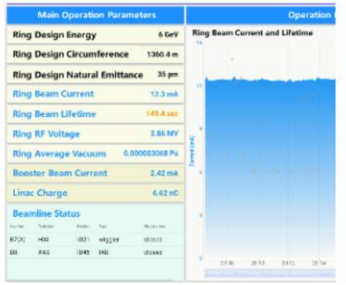
Jan. 13, 2023
The Booster Vacuum-sealing in the tunnel completed

Feb. 1,2023
The first girder was installed in the storage ring tunnel

Mar. 14, 2023
The first electron beam

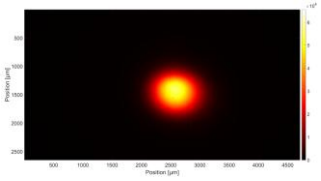


Nov. 17, 2023
Electron Beam Ramped Up to 6 GeV



Aug. 18, 2024
Electron beams with currents higher than 10mA were successfully stored.

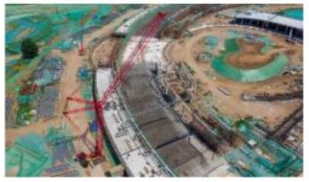
Oct. 12, 2024
the SR X-ray emitted from the R21 wiggler was successfully transmitted to the end station.



Sep. 29, 2025
Accelerator reached 100mA and <100pm·rad

June 29, 2019
Groundbreaking ceremony

July 1, 2020
The first steel beam was installed



Apr. 13, 2021
Utility installation in NO.2 Hall commenced

June 27, 2021
Roof-sealing work for the main ring building completed

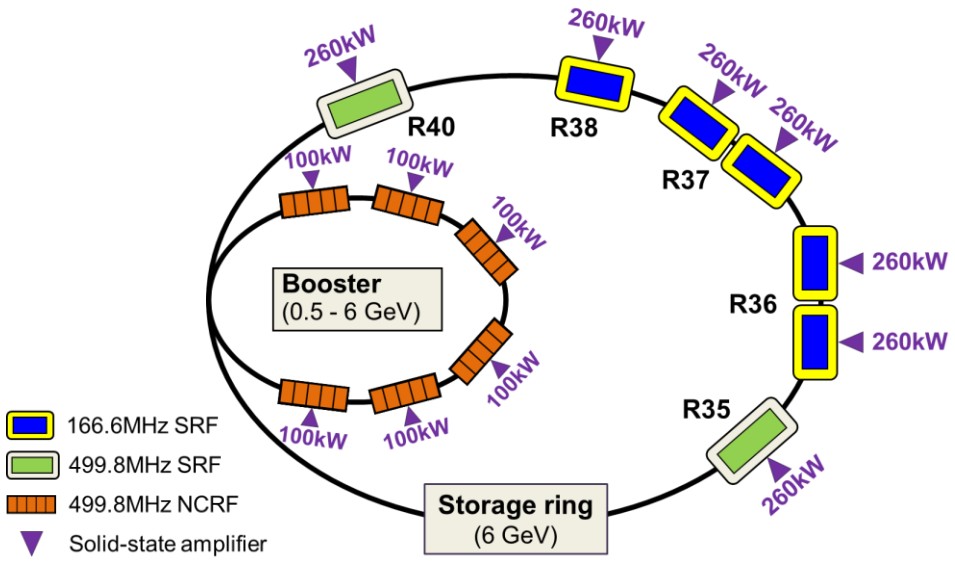
June 28, 2021
HEPS Installs First Piece of Accelerator Equipment in Linac Tunnel.

Nov. 3, 2023
Civil Construction for ancillary buildings completed

RF system of HEPS

- Double-frequency RF system: 166.6 MHz (fund) + 499.8 MHz (third harmonic)
- Active harmonic RF compatible with on-axis swap-out & on-axis accumulation injections
- SRF for storage ring, normal-conducting RF for booster ring
- Heavy damping of higher order modes for storage-ring SRF cavities
- Solid-state amplifiers for all RF transmitters, digital low-level RF control
- **World's first quarter-wave SRF cavity to accelerate ultra-relativistic electron beam**
- **Commissioning: five 166.6MHz SRF cavities successfully accelerated 100mA beam**
- Bunch elongation of a factor of ~4 achieved by fund + active HHC (~80ps -> ~400ps)

Zheng's talk on Tuesday

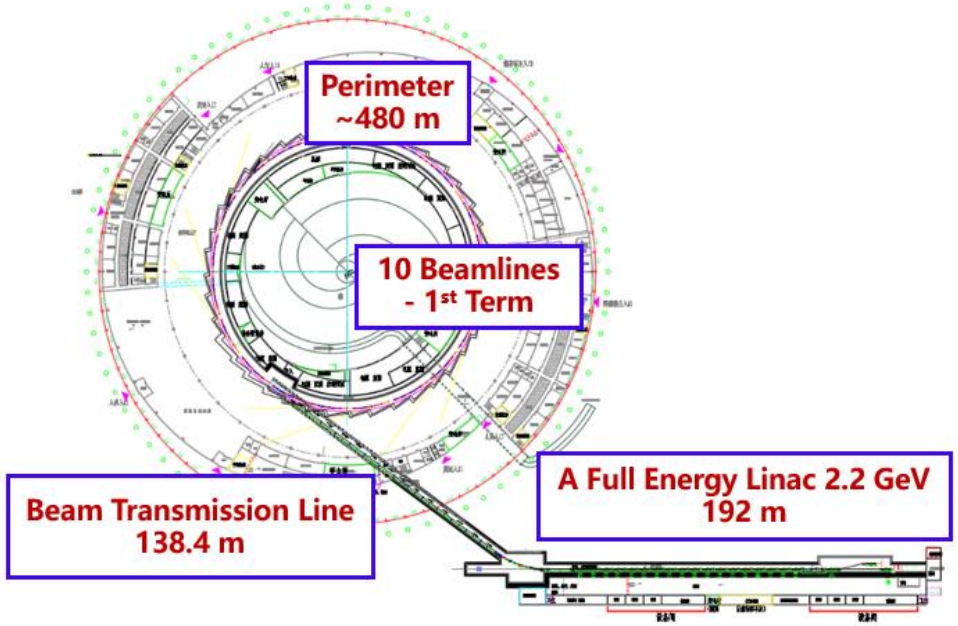


NEW

Hefei **A**dvanced **L**ight **F**acility
(Hefei, Anhui)

Hefei Advanced Light Facility (HALF)

- A low-energy 4th-gen storage ring light source
- **Location**: Hefei, Anhui, **Construction time**: 2023-2028
- **Budget**: 3.7B CNY (~$520M)
- **Parameters**: 2.2GeV, 350mA, 85pm·rad, 480m circumference
  full energy linac, 6BA lattice
- **Beamlines**: 10 beamlines in Phase I, max. capacity 35 BLs
- **Photon energy**: 5eV~10keV, VUV to soft X-ray



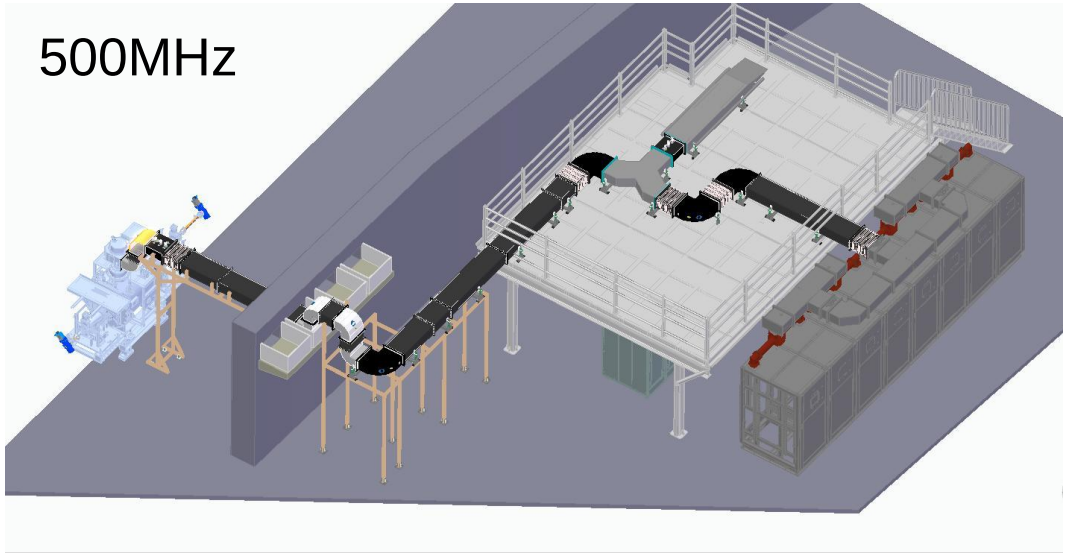
HALF storage-ring parameters

Parameters	Symbol	Value
Beam energy	E_0 [GeV]	2.2
Average current	I_0 [mA]	350
Harmonic number	h	800
Circumference	C [m]	~480
Energy spread	σ_p	0.00062
Nature emittance	ε_e	85 pm·rad
Momentum compaction	α	0.00009
Energy loss per turn (Phase I)	U_{s1} [MeV]	~0.4
Energy loss per turn (Phase II)	U_{s2} [MeV]	~0.6

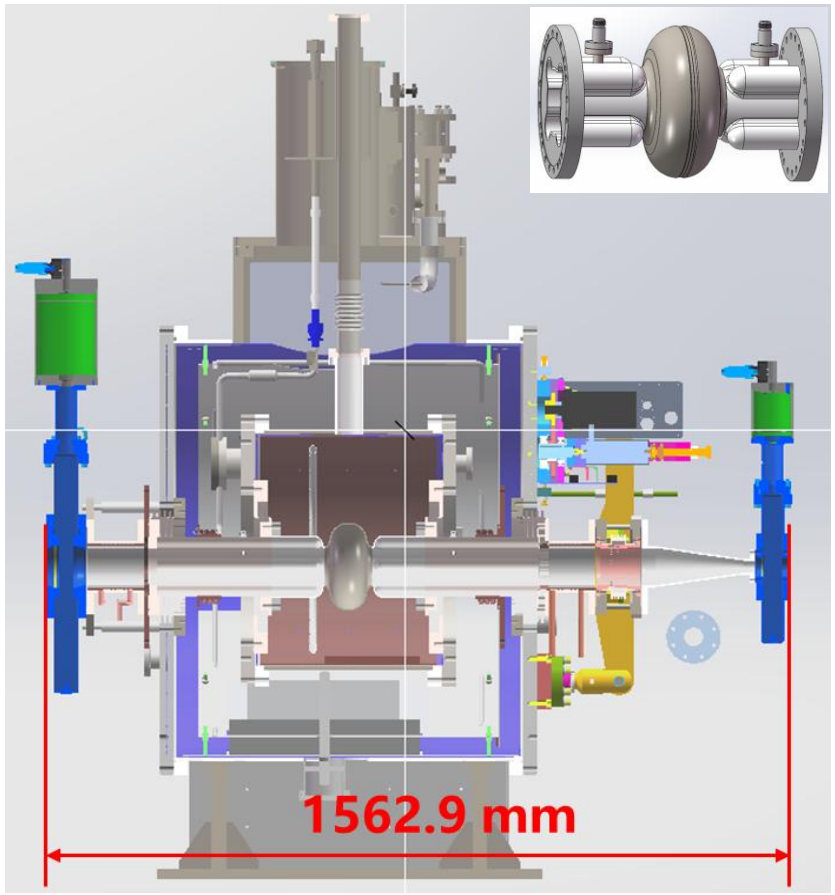
RF system of HALF

- Double-frequency RF system: 500 MHz (fund) + 1500 MHz (third harmonic)
- One 500MHz KEKB-type single cell SRF + One 1500MHz single-cell SRF
- SRF for storage ring, normal-conducting RF for vacuum scrubbing
- Solid-state amplifiers, digital low-level RF control

500MHz



1.5GHz



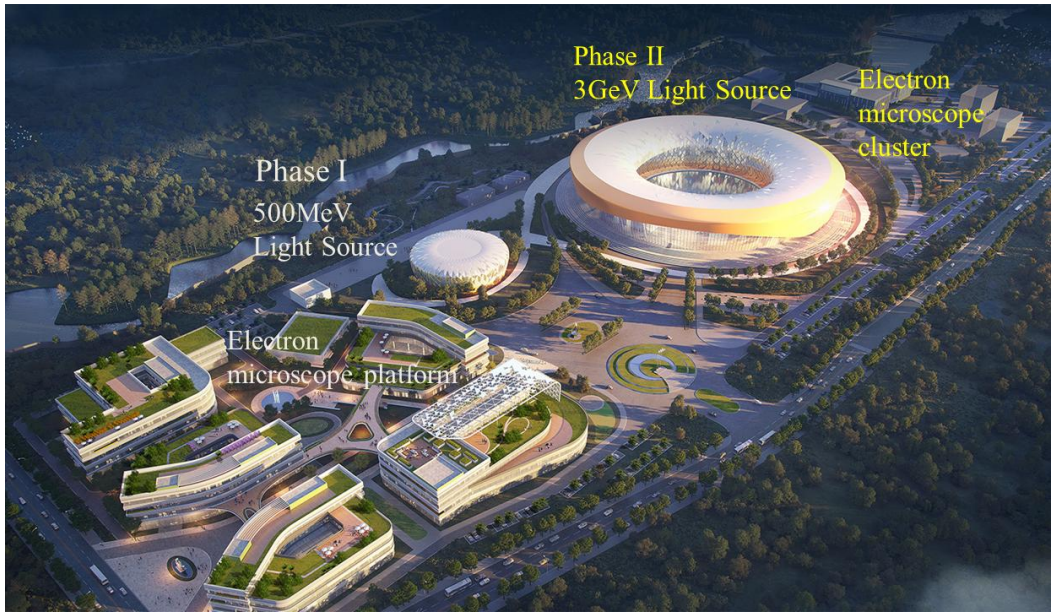
NEW

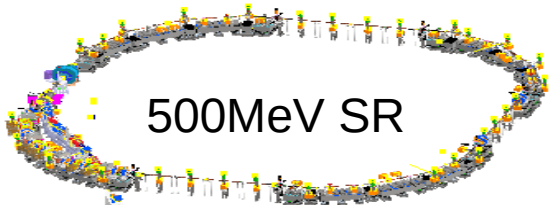
Ultrafast **T**ransient **E**xperimental **F**acility (Chongqing)

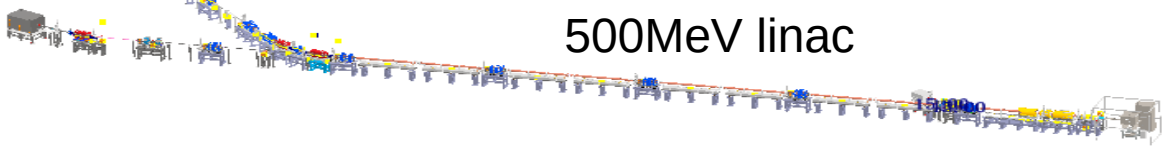
NEW

Ultrafast Transient Experimental Facility (UTEF)

- Low-energy high-flux synchrotron light source + electron microscope cluster
- **Location**: Chongqing, **Construction time**: 2022-2026, **Budget**: 847M CNY (~$119M)
- Construction in two phases: 500MeV LS (phase 1), 3GeV LS (phase 2)
- **Parameters**: 0.5GeV, 500mA, 6nm·rad, 76.78m circumference, 4BA lattice
- **Accelerator complex**: 500MeV linac + 500MeV storage ring
- **Photon energy**: 7~100eV, VUV to UV
- **Beamlines**: 1BL in phase 1, ARPES, 10~40eV, 0.4meV resolution



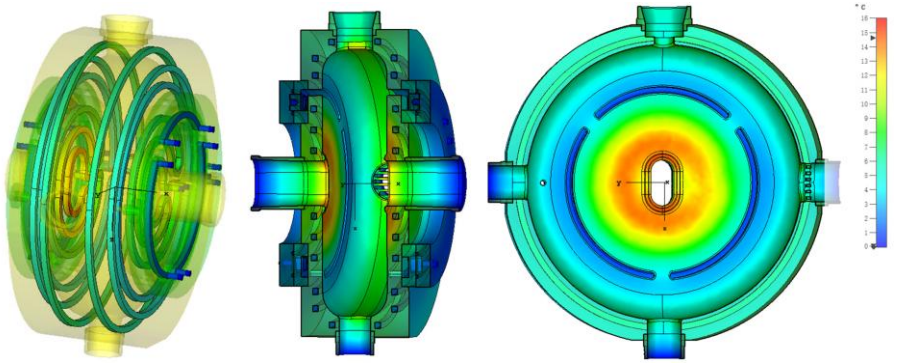


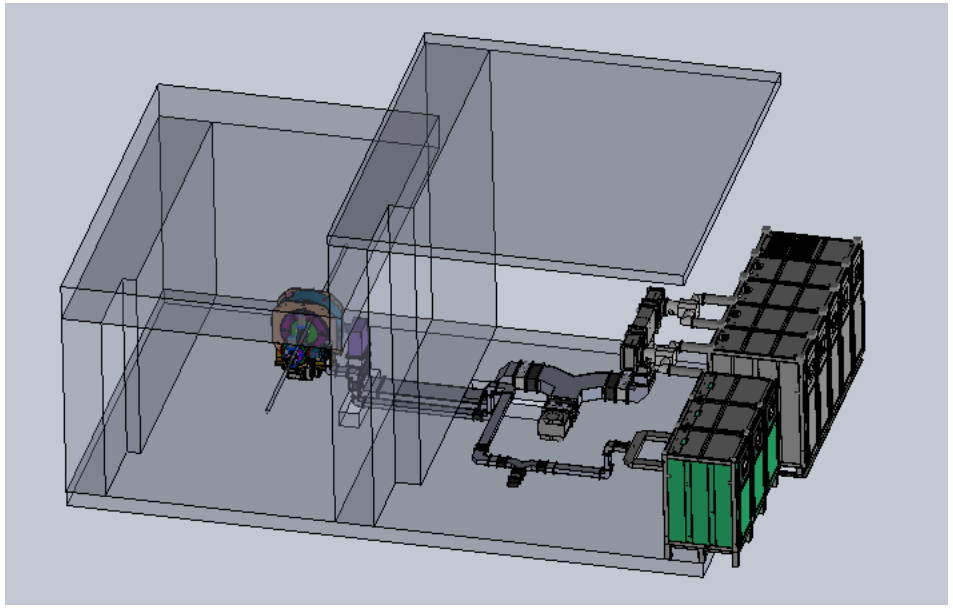


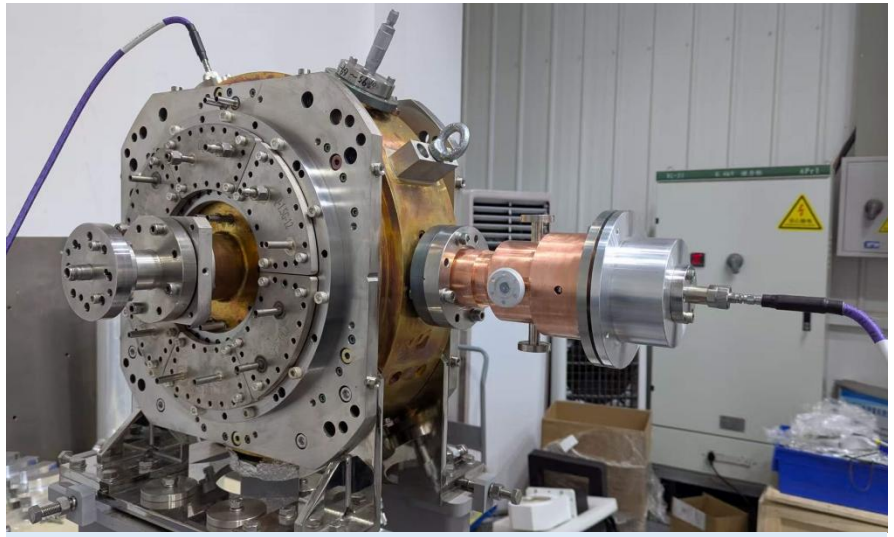
RF system of UTEF LS

- Double-frequency RF system: 500 MHz (fund) + 1500 MHz (third harmonic, active)
- TM020 normal-conducting cavities for both 500MHz and 1500MHz cavities
- 1500MHz cavity produced, cold tested, to be high-power tested
- 500MHz cavity designed, currently in production

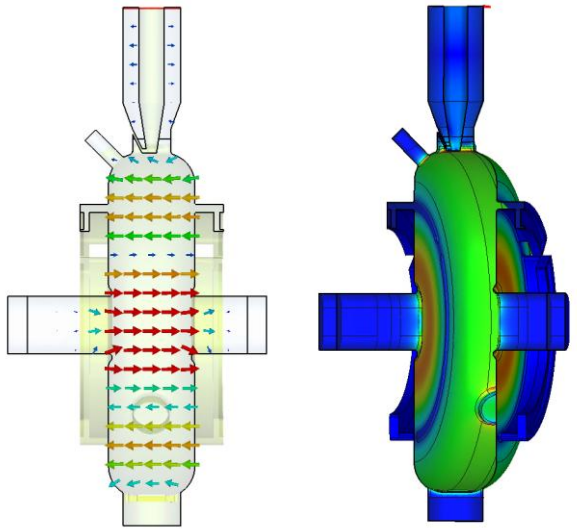
Freq. (MHz)	R/Q (Ω)	Q0	Ra (MΩ)
499.543	123.0	5.3e4	6.52
1499.504	55.5	3.6e4	1.98





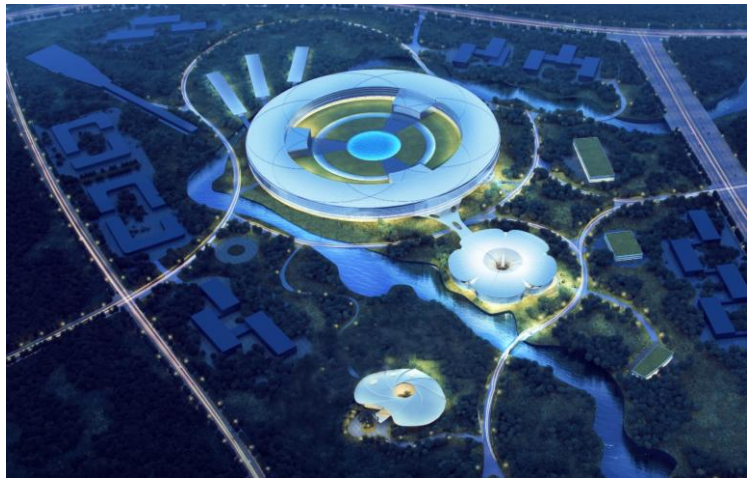


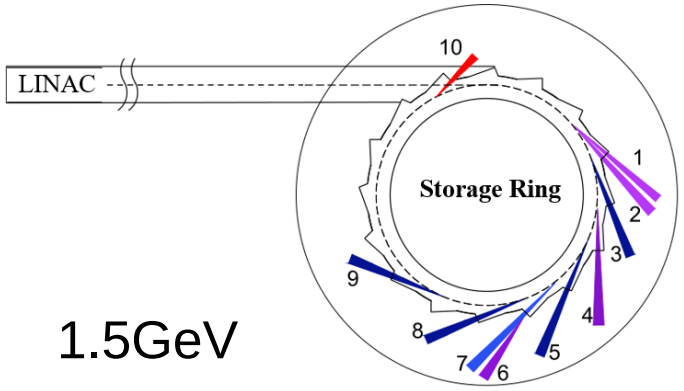
1500MHz cavity



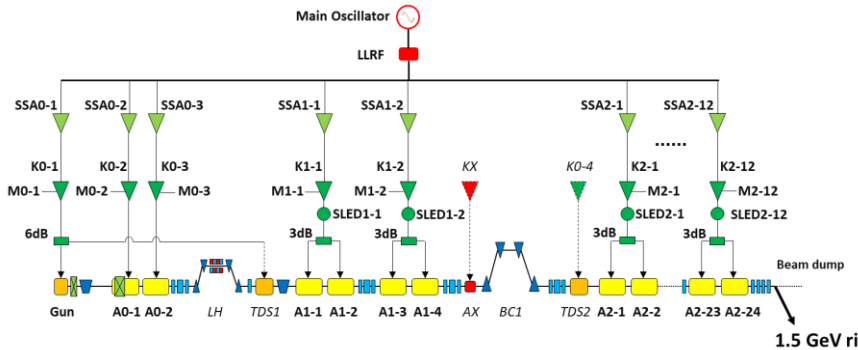
Wuhan Advanced Light Source (WALS)

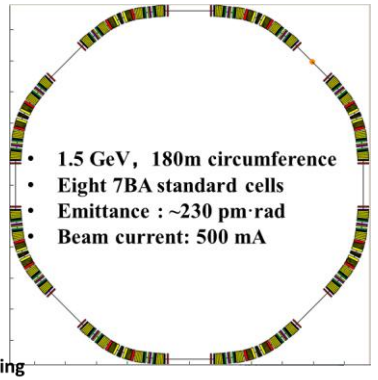
- Wuhan University has planned three facilities on campus: WALS / WAPS / WFEL
- **First stage**: 1.5GeV LS, 8-10 BLs (max 20), 7BA lattice, IR, VUV, EUV, Soft X-ray to Hard X-ray
- Accelerator physics design of the WALS completed in 2023
- **Planned construction time** of WALS: 2028-2032, **Budget**: 1.12B CNY (~$160M)

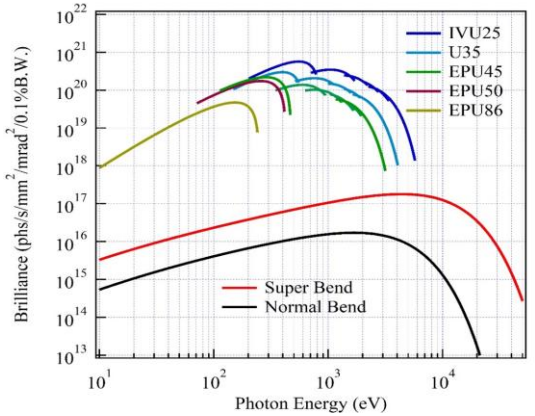




1.5GeV

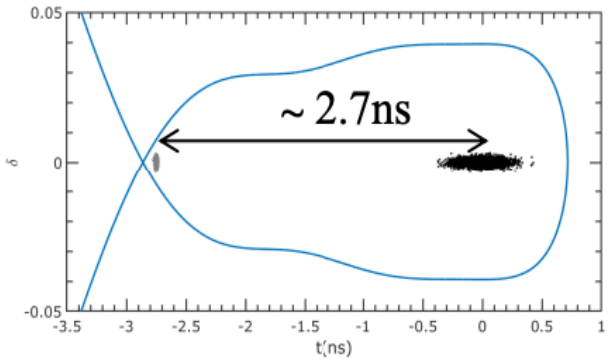




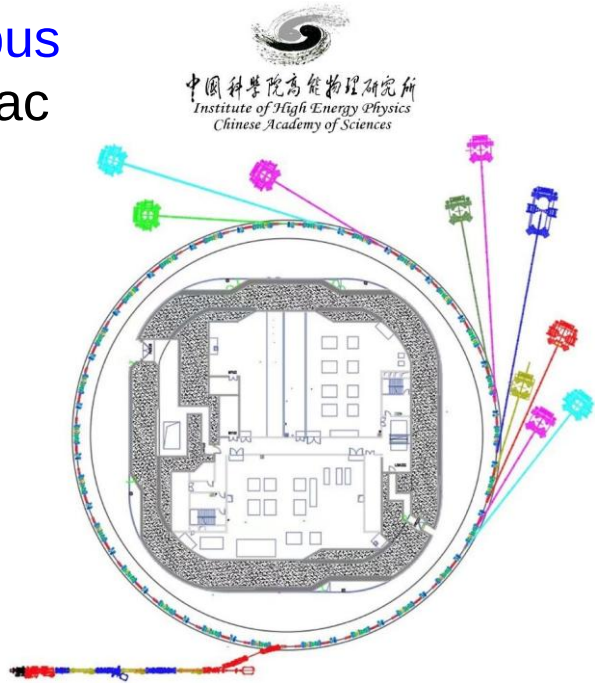


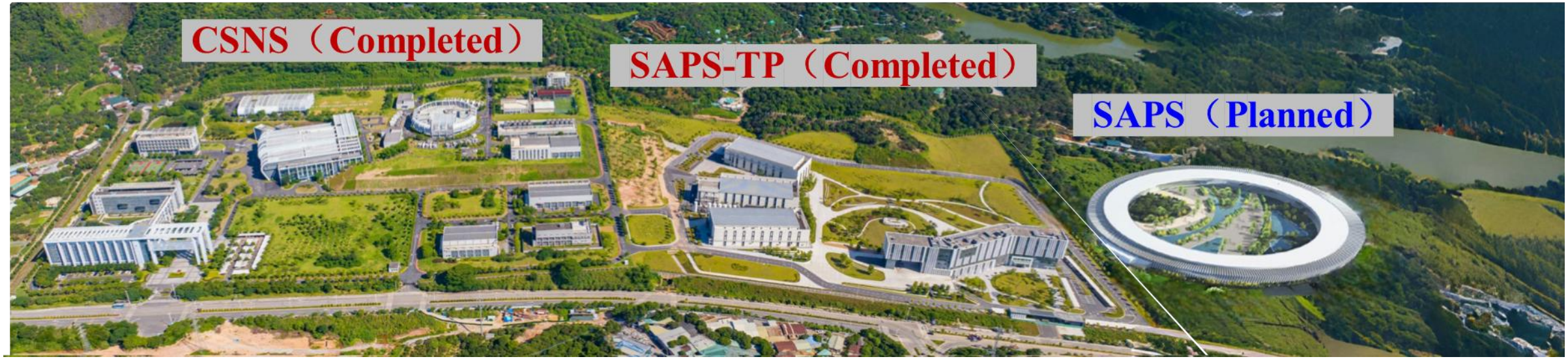
Southern Advanced Photon Source (SAPS)

- A medium energy 4th-gen light source proposed by IHEP in CSNS campus
- **Parameters**: 3.5GeV, <60pm·rad, 810m circ., 7BA lattice, full-energy linac
- **Beamlines**: 10 BLs in phase 1, max. capacity 60 BLs
- The physical design has been completed, triple RF system (166 fund.)



Parameters	Values	Values	Values
Frequency (MHz)	166.6	333.3	499.8
Voltage (MV)	1.63	0.945	0.33
Phase (°)	169.33	64.21	-48.81
Beam power (kW)	150.9	425.5	-125.9





Other synchrotron light source proposals

Two new light sources proposed to complement the existing facilities in the Shanghai area

- **Zhejiang Industrial Photon Source (ZIPS)**
  - Demand from the industries, designed by USTC
  - Planned construction time: 2026-2029
  - **Parameters**: 2.7GeV, 0.64 nm·rad, 270m circ., 5BA
  - **Accelerator**: 150MeV linac + 2.7GeV BST (244m) + 2.7GeV SR, BST and SR in the same tunnel
  - **Beamlines**: 6 BLs in phase 1, 80eV~60keV

- **Suzhou Laboratory (SZL) - LS**
  - Approved and hosted by the Suzhou National Lab
  - Planned construction time: 2025-2029
  - **Parameters**: 2.4GeV, 0.8nm·rad, 288m circ., 6BA
  - **Accelerator**: linac + BST + SR, BST and SR in the same tunnel
  - **Beamlines**: 10 BLs in phase 1

Major FEL facilities in China

Blue: SRF, Black: NCRF

In operation

- 2018-now, Dalian Coherent Light Source (DCLS)
- 2022-now, Shanghai soft X-ray Free-Electron Laser facility (SXFEL)

Under construction

- 2018-2027, Shanghai High Repetition Rate X-ray FEL and Extreme Light Facility (SHINE)

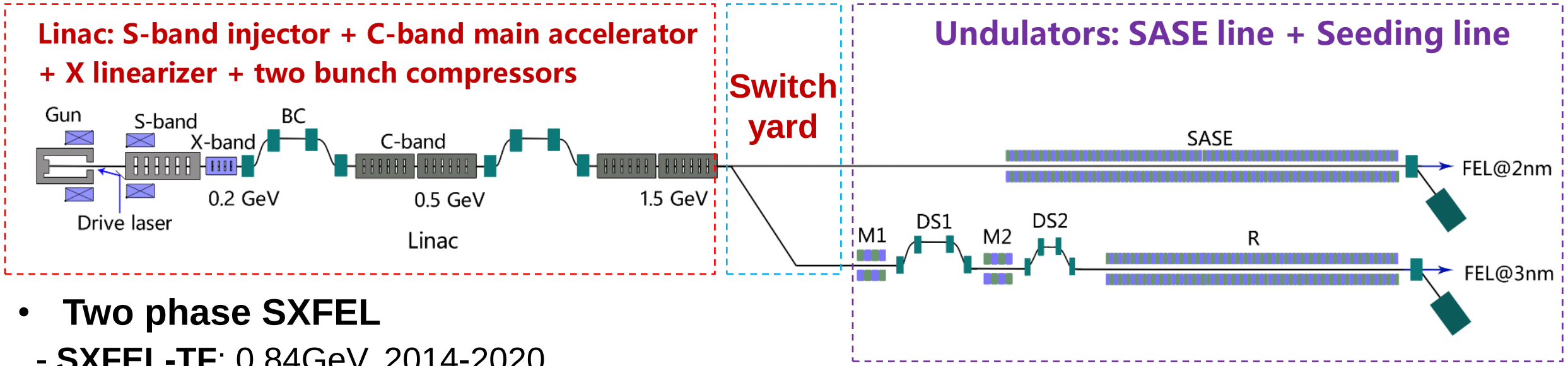
Approved

- 2023, Shenzhen Superconducting Soft X-Ray FEL (S^3FEL)

Planning

- TBD, Dalian Advanced Light Source (DALS)

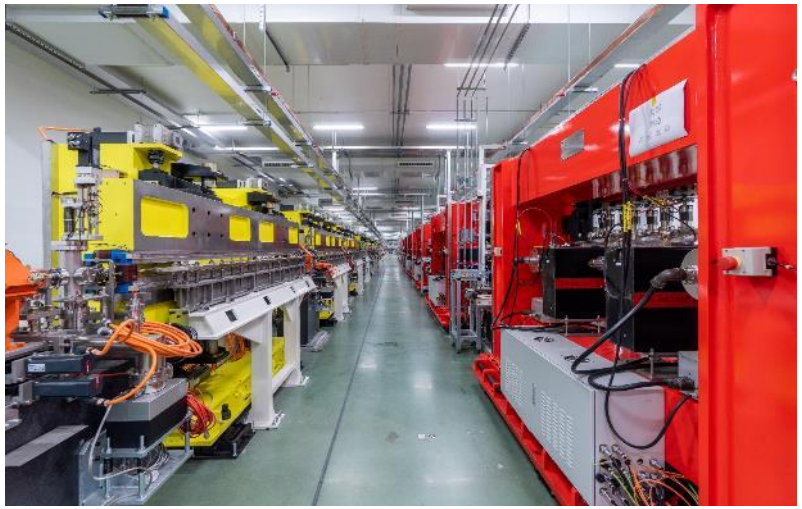
Shanghai soft X-ray FEL Facility (SXFEL)



- **Two phase SXFEL**

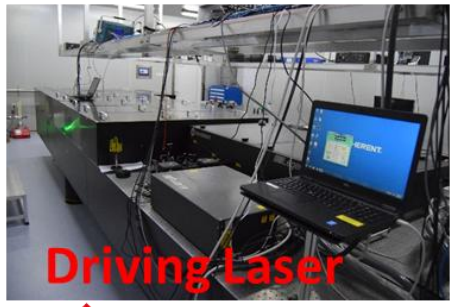
  - **SXFEL-TF**: 0.84GeV, 2014-2020

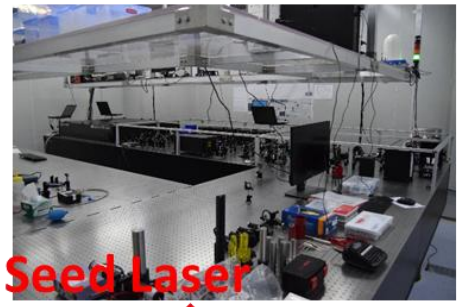
  - **SXFEL-UF (+SBP)**: upgrade to 1.5GeV in 2022, user operation since 2023

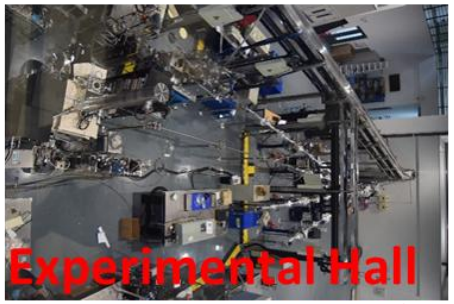


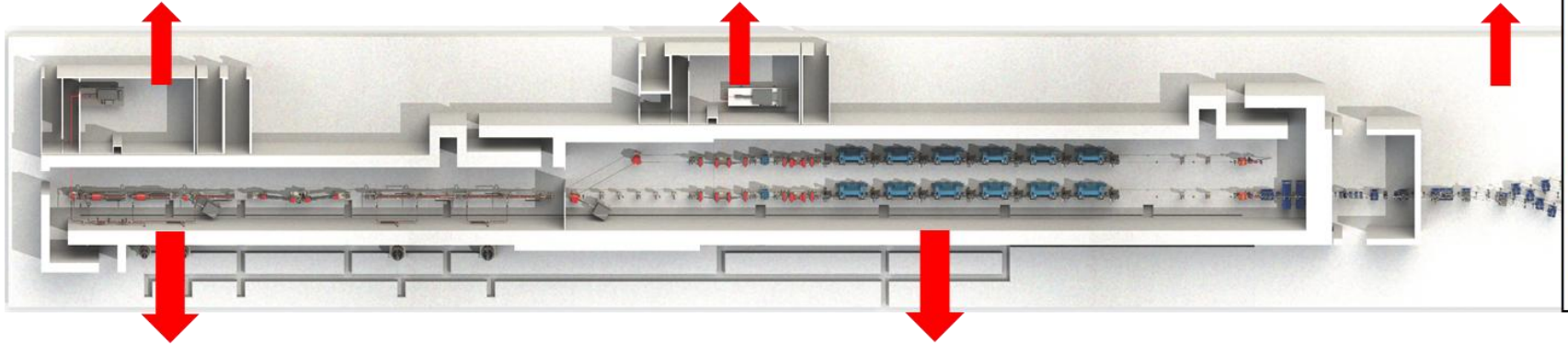
Parameter	Value
Total length	532 m
Electron energy	0.6 - 1.5 GeV
Photon energy	90 - 620 eV
Pulse length	~100 fs
Repetition rate	10 - 50 Hz
Peak photon power	1 GW

Dalian Coherent Light Source (DCLS)









LIGHT SOURCES

Unique free electron laser laboratory opens in China

New device will probe smog and other gaseous phenomena

By **Dennis Normile**

China is joining the elite club of countries that have built the potent sources of high-energy photons called free electron lasers (FELs) for their researchers. The Dalian Coherent Light Source, whose completion was announced this week in Beijing, has a twist that makes it unique: It is the only large laser light source in the world dedicated to the particular range of short-wavelength light called vacuum ultraviolet, which makes it "a new tool for the detection and analysis of molecules undergoing chemical reactions," says Alec Wodtke, a physical chemist at the Max Planck Institute for Biophysical Chemistry and the University of Göttingen in Germany.

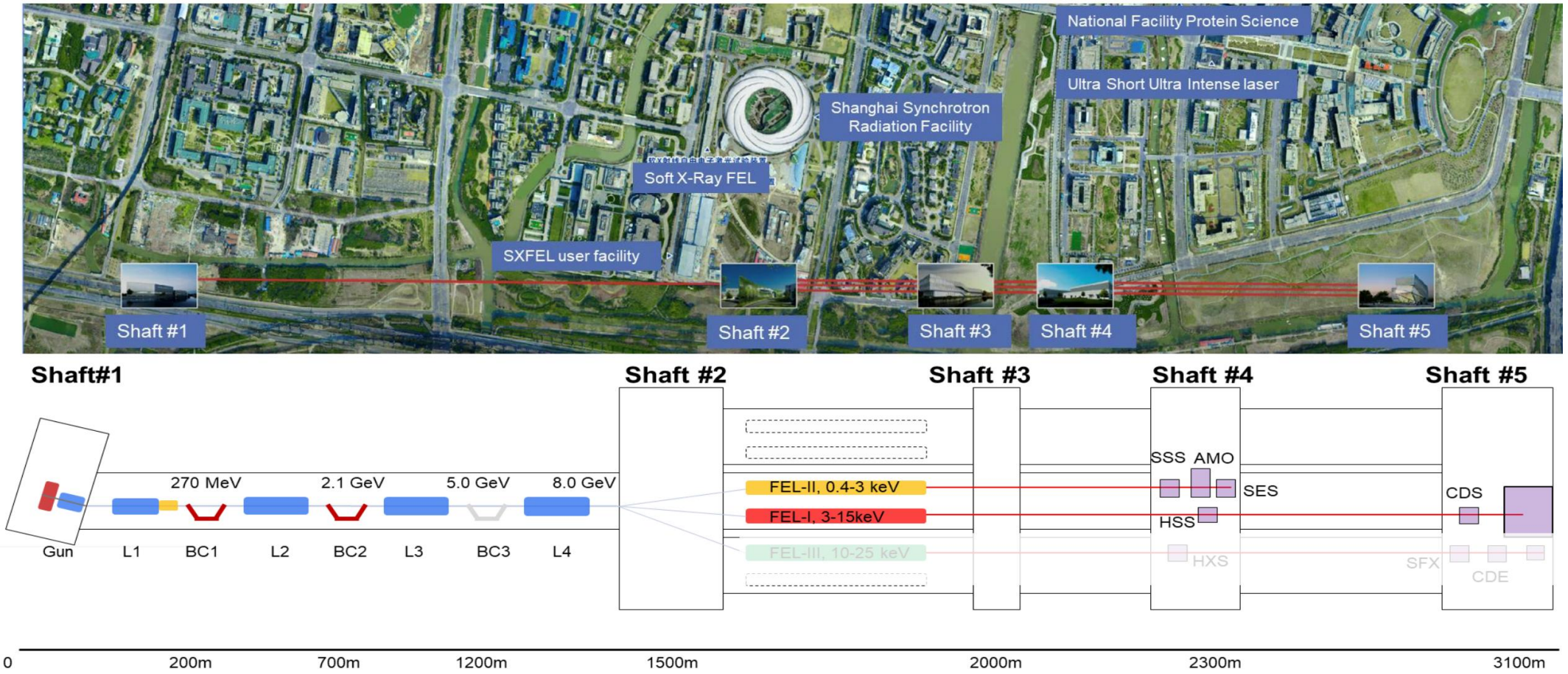
ing in Europe, Japan, and the United States produce "hard" x-ray laser beams, with wavelengths down to 0.1 nanometers, ideal for studying crystallized proteins and other solids. But the beams are so powerful "they break up molecules" in gases, says Yang Xueming, a physical chemist at the Chinese Academy of Sciences's (CAS's) Dalian Institute of Chemical Physics, which hosts the new machine. A laser in the vacuum ultraviolet range—the Dalian facility will cover 50-150 nanometers—"has a soft touch," he says, making it "the best way to detect molecules and atoms in a gas."

Yang expects researchers to use the FEL pulses to probe what happens during fuel combustion and catalysis, and study proteins and how reactions proceed at solid-gas interfaces. Some experiments could have

- Warm accelerator:**0.3 GeV**
- Tunable Wavelength: **50-150 nm**
- Pulse Energy: **> 100 μJ**
- Pulse length: **100 fs**
- Repetition Rate: **50 Hz**
- **Operation since Aug. 2018**
- More than **6000 hours per year**

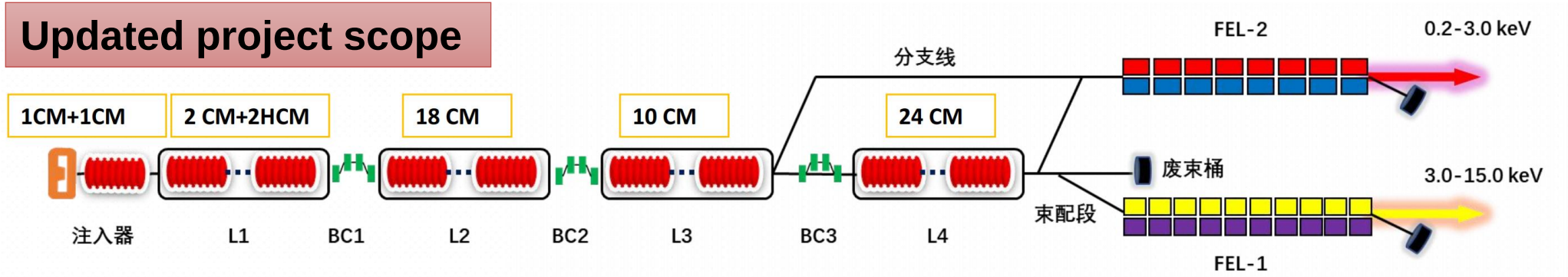
Shanghai Hard X-ray FEL Facility (SHINE)

- CW SCRF linac based high rep-rate XFEL facility, the largest acc. project in China
- **Parameters**: 8GeV CW beam, 3.1km, 0.2~3keV (FEL II), 3~15keV (FEL I)
- **Construction time**: 2018~2027, **Budget**: ~10B CNY (~$1.5B)
- **Updated project scope in 2025**: add bypass for low-energy FEL beamline (3~4.5GeV), FEL III put on hold, reduced number of cavities w/ raised Eacc and Q0



Shanghai Hard X-ray FEL Facility (SHINE)

Updated project scope



Original: Q0 ≥ **2.7e10 @ 16MV/m**, usable Eacc ≥ **16MV/m**

~300 cavities completed

New spec.: Q0 ≥ **3.0e10 @ 20MV/m**, usable Eacc ≥ **20MV/m**, CM voltage ≥ **166MV**

Injector

Cryomodules in L1 section

3.9GHz cryomodules

SRF FELs

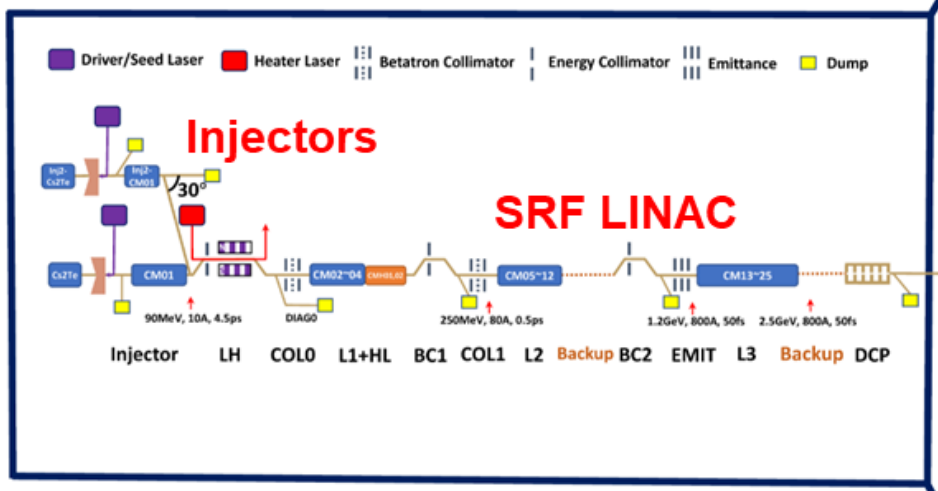
Facility	Wavelength	Country	LINAC	Beam Energy/GeV	Photon Energy/keV	Rep. Rate/Hz	Status
Eu. XFEL	Hard X-ray	EU	SRF	17.5	8.4-30	27,000	Operation
LCLS-II	Hard X-ray	US	CW SRF	4 (8, HE)	0.2-5	1,000,000	Operation
SHINE	Hard X-ray	CN	CW SRF	8	0.4-25	1,000,000	Under constr.
FLASH	Soft X-ray	DE	SRF	1.35	0.014-0.3	5,000	Operation
S^{3}FEL	Soft X-ray	CN	CW SRF	2.5	0.04-1	1,000,000	Approved
DALS	EUV SX	CN	CW SRF	1.0	0.008-0.6	1,000,000	Proposed

Shenzhen Superconducting Soft X-Ray FEL (S^3FEL)

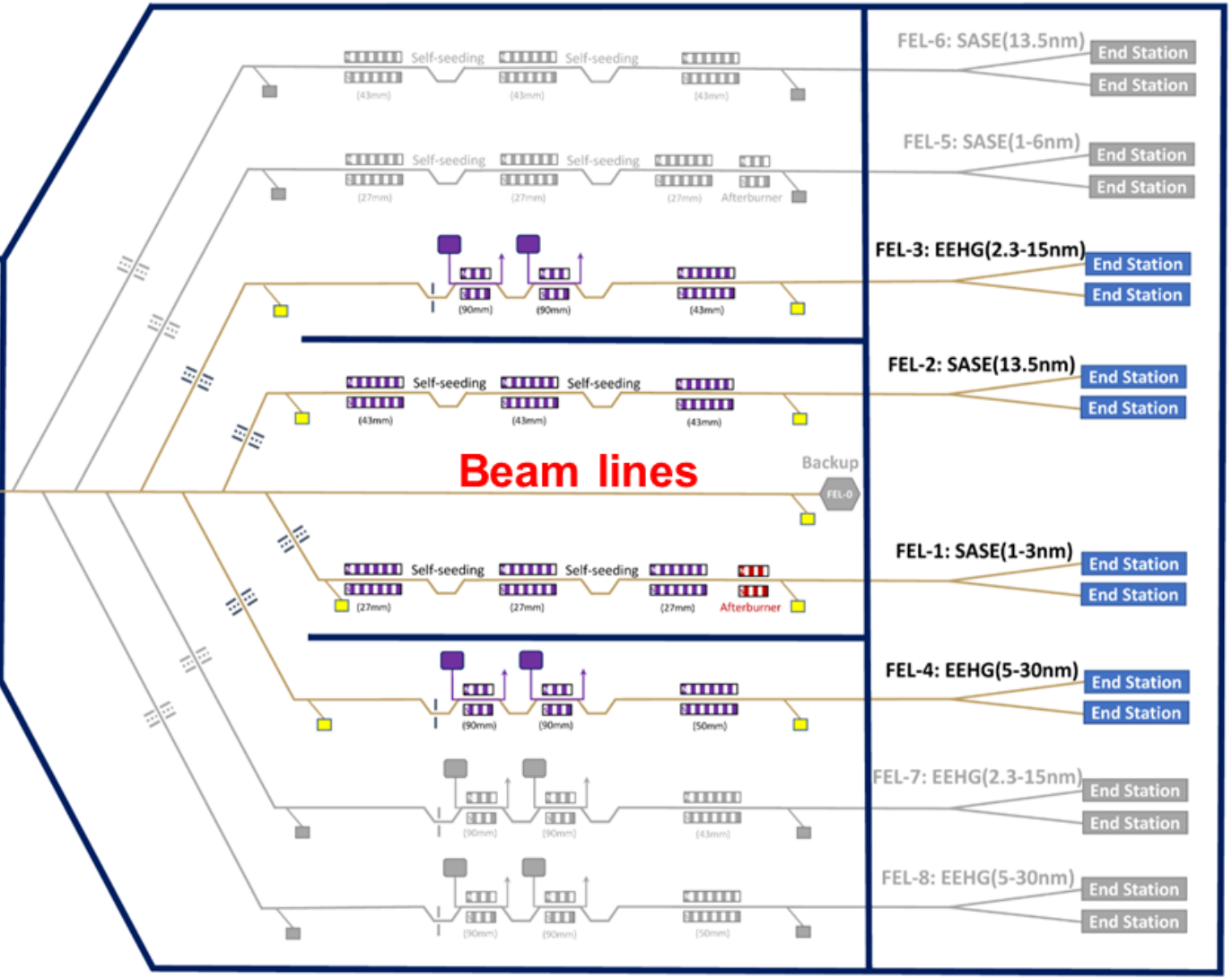
Approved in 2023

MHz Repetition rate Soft X-ray FEL

- 2.5 GeV CW SRF accelerator
- Charge/pC: 100



- Emittance/mm-mrad: 0.5
- Repetition rate/MHz: 1
- FEL wavelength/nm: 1-30

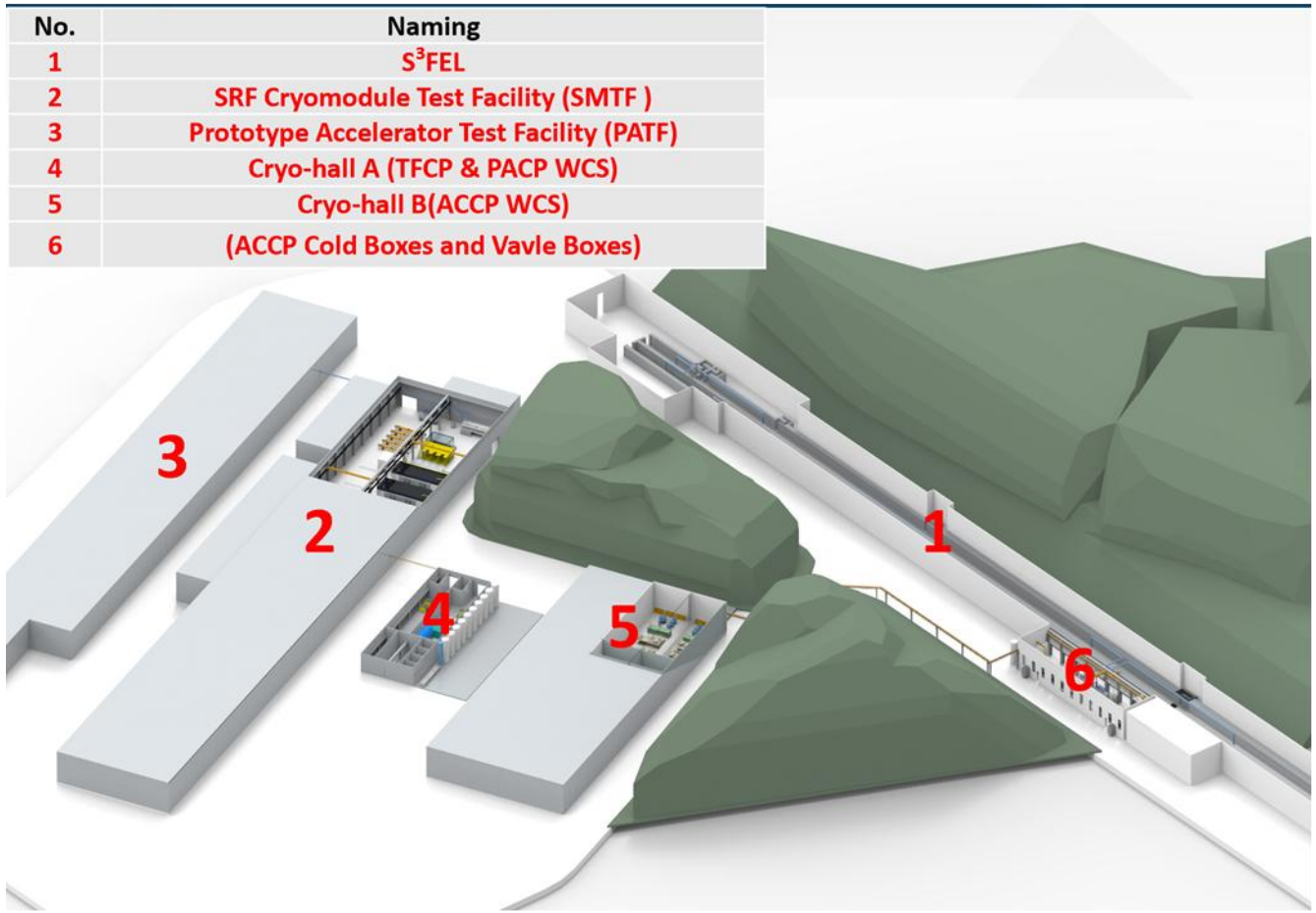


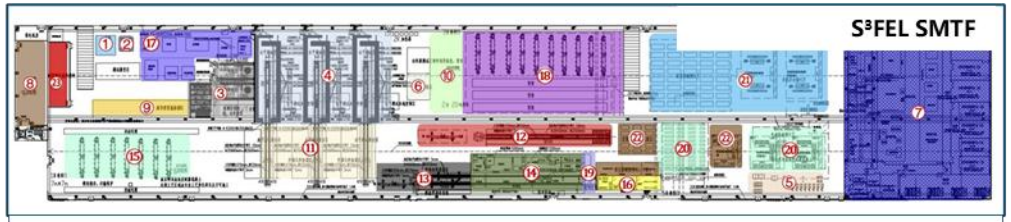
LINAC: 740 m — Spreader: 400 m — Undulator: 270 m — BL & ES: 340 m

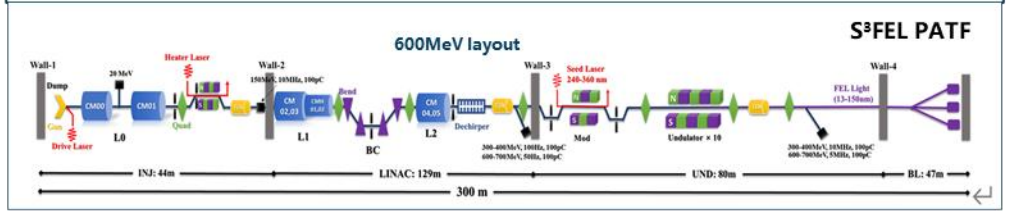
Cryomodule requirements for S³FEL

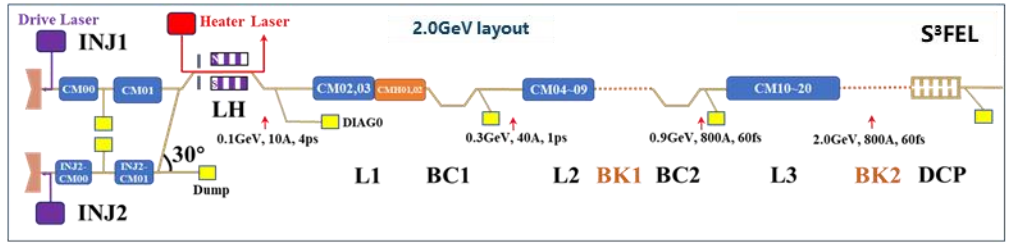
219 1.3GHz 9-cell cavities and 40 3.9GHz 9-cell cavities in total.

No.	Naming
1	S³FEL
2	SRF Cryomodule Test Facility (SMTF)
3	Prototype Accelerator Test Facility (PATF)
4	Cryo-hall A (TFCP & PACP WCS)
5	Cryo-hall B(ACCP WCS)
6	(ACCP Cold Boxes and Vavle Boxes)







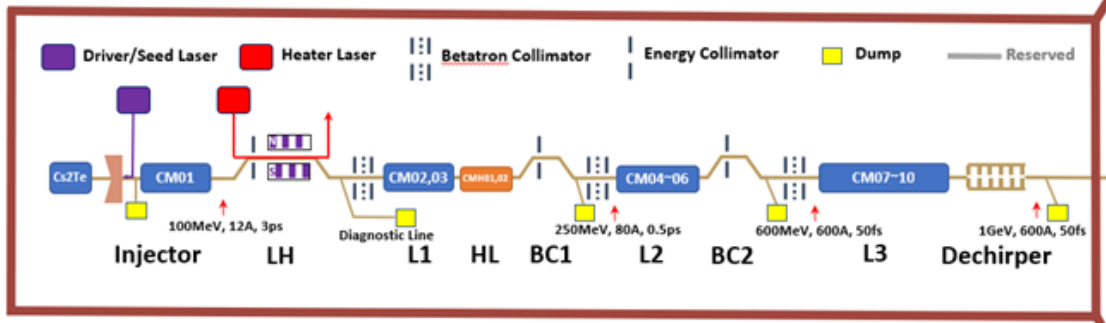


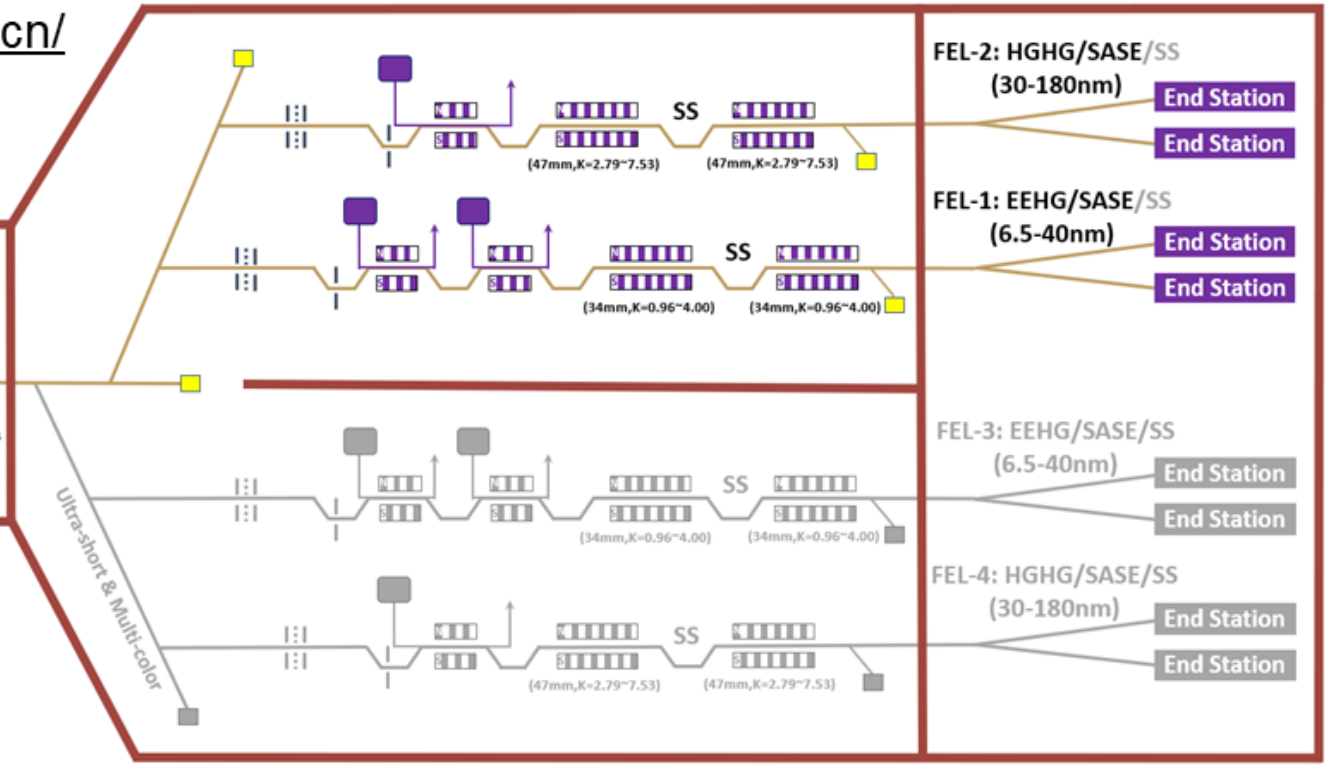
	SMTF	PATF	S³FEL	Total
1.3 GHz 8×9cell CM	1	5	21	27
3.9 GHz 8×9cell CM	1	2	2	5
1.3GHz 1×9cell CM	/	1	2	3
Subtotal	2	8	25	35

Dalian Advanced Light Source (DALS)

http://www.dcls.dicp.ac.cn/ https://cryo.dicp.ac.cn/

Located at Dalian, Northeast of China





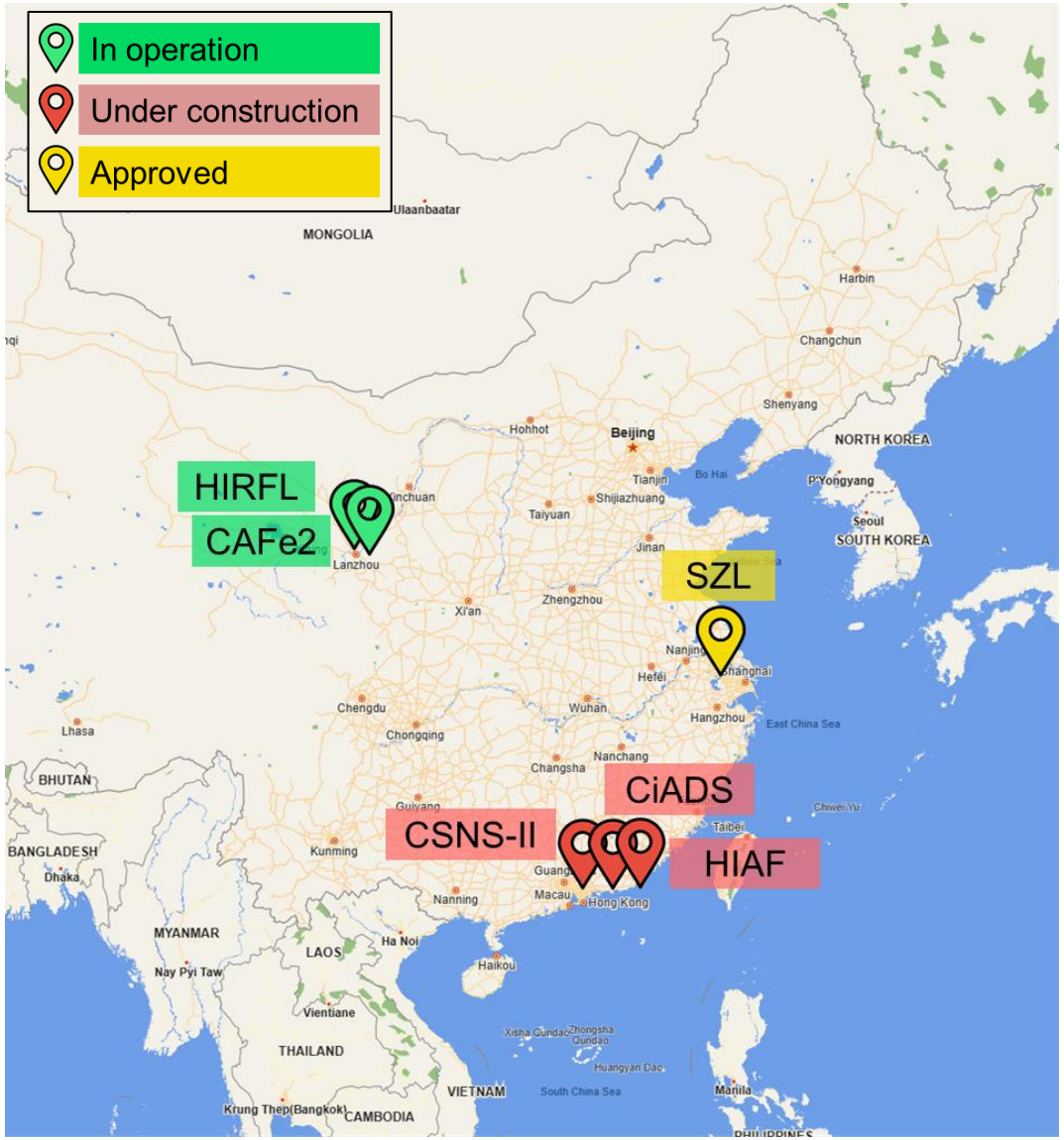
EUV Free Electron laser machine

Plan	Phase I	Phase II
Wavelength	FEL-1: 6.5-40 nm FEL-2: 30-180 nm	FEL-3: 6.5-40 nm FEL-4: 30-180 nm
Mode	HGHG/EEHG/SASE /self-seeding	HGHG/EEHG/SASE /self-seeding
Peak power	>1.0 GW	>1.0 GW
Pulse length	~50 fs	≤10 fs
Repetition Rate	1 MHz	1 MHz

- Proposed by Dalian Institute of Chemical Physics (DICP)
- 1.0 GeV CW SRF accelerator
- Ten 1.3 GHz Cryomodules & two 3.9 GHz Cryomodules
- ~100 SRF Cavities
- One dedicated cryoplant (~3 kW @ 2 K)

Proton & Heavy-ion Facilities

Proton & heavy-ion facilities



Blue: SRF, Black: NCRF

In operation

1988-now, Lanzhou Heavy Ion Research Facility (HIRFL)

2018-now, China Spallation Neutron Source (CSNS)

2021-now, China Accelerator Facility for super-heavy nEw Elements (CAFe2)

Under construction

2018-2025, High Intensity heavy ion Accelerator Facility (HIAF)

2021-2027, China initiative Accelerator Driven System (CiADS)

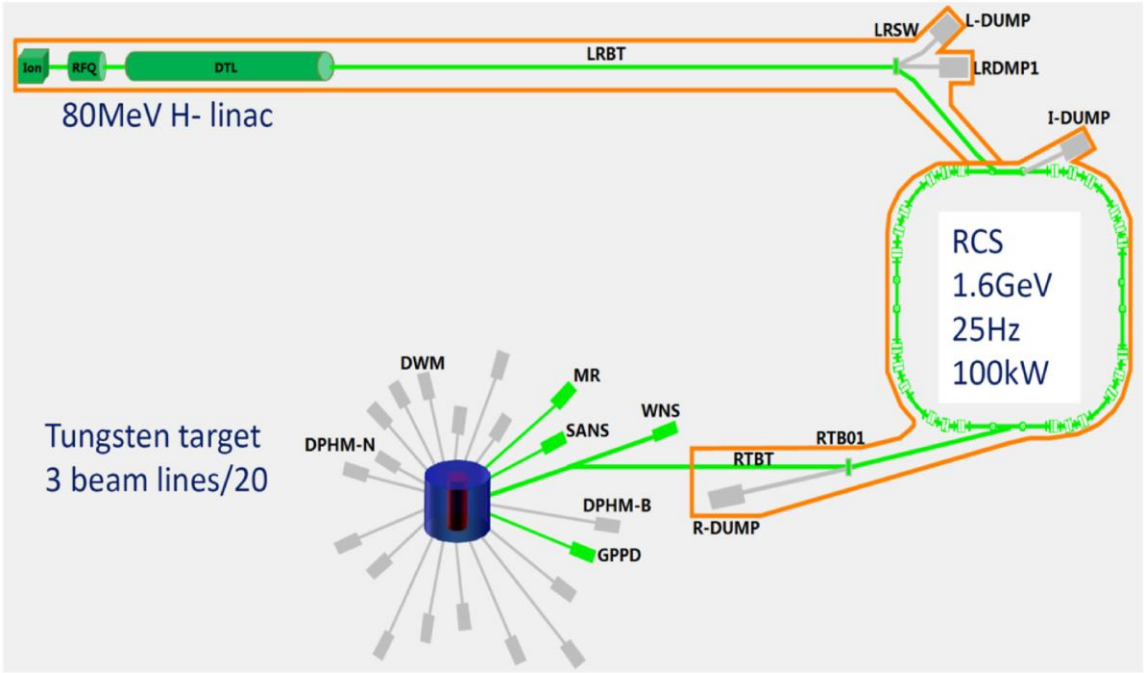
2024-2029, China Spallation Neutron Source - II (CSNS-II)

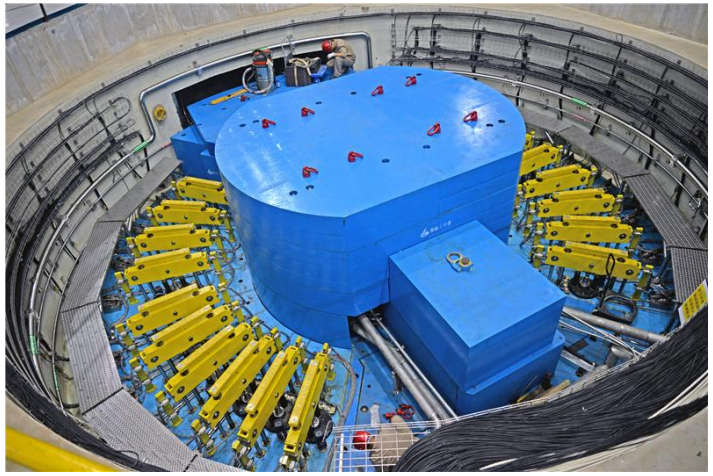
Approved

2025-2029, Suzhou Laboratory (SZL)

China Spallation Neutron Source (CSNS)

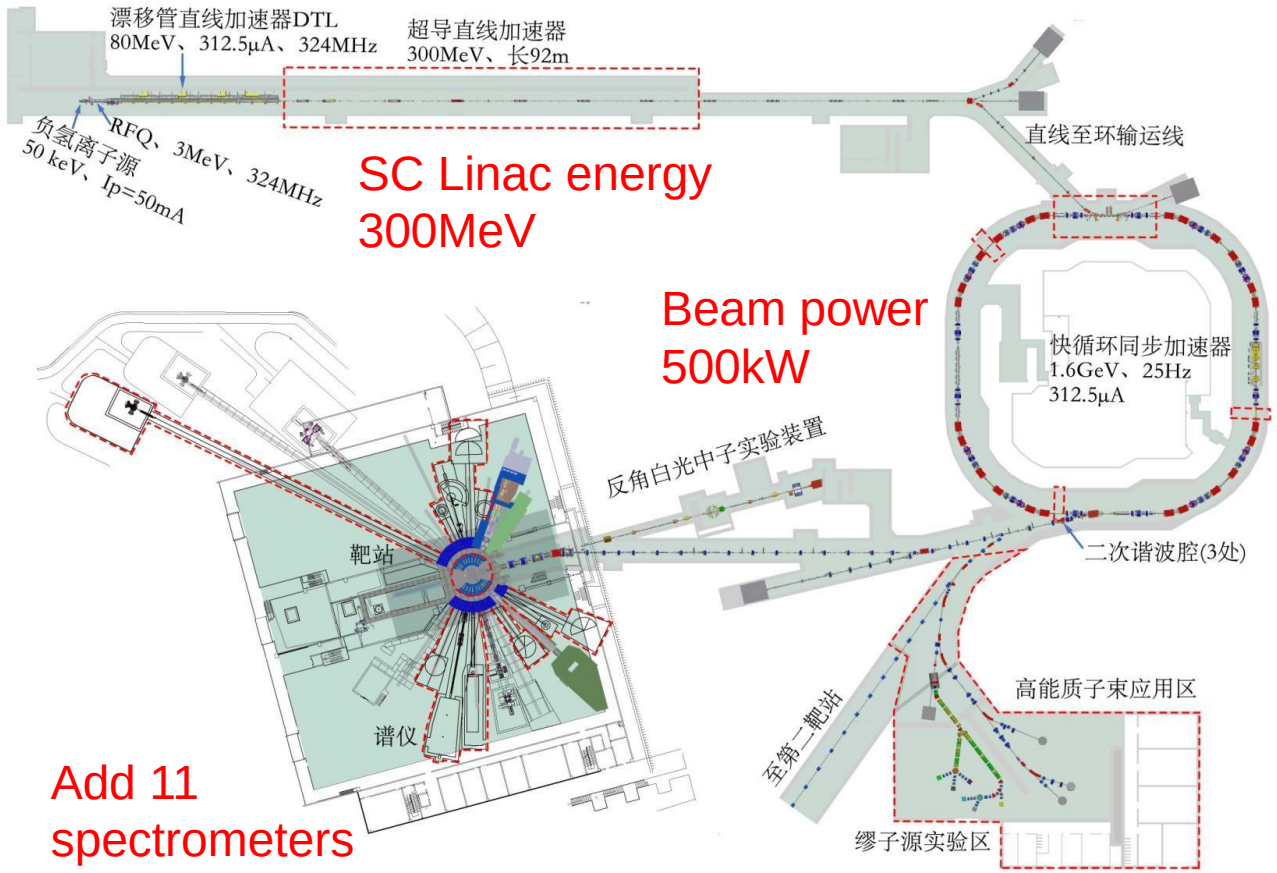
- First spallation neutron source in China
- Design, construct and operation by IHEP
- **Location**: Dongguan, Guangdong
- **Operation**: 2018-now
- **Parameters**: 100kW, 25Hz, 1.6GeV
  - Linac: 80MeV, DTL, 324MHz
  - RCS: 1.6GeV, 228m

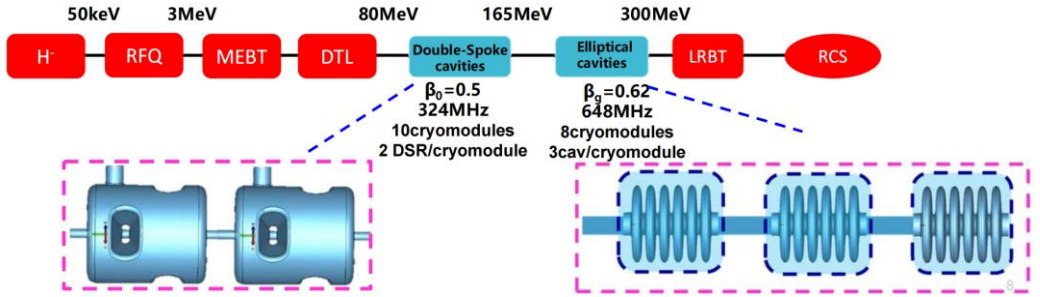




CSNS-II

- Upgrade of CSNS to higher beam power and build more spectrometers
- **Parameters**: beam power to 500kW, linac energy to 300MeV
- **Construction time**: 2024~2029, **Budget**: 3B CNY (~$420M)

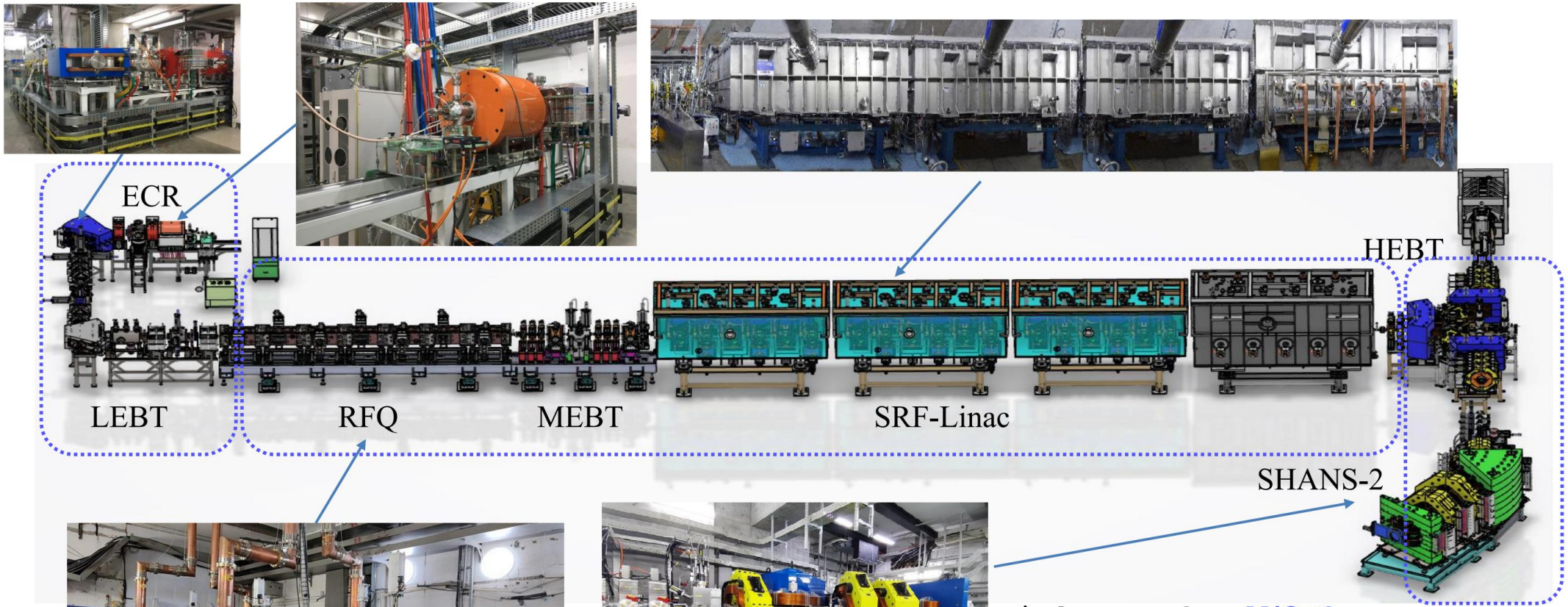




	CSNS	CSNS-II
Beam power (kW)	100	**500**
Pulse repetition rate (Hz)	25	25
No. of target station1	1	1
Average beam current (μA)	62.5	**312**
Beam energy (GeV)	1.6	1.6
Inj. energy to RCS (MeV)	80	**300**
No. of neutron instruments	3	9+**11**

CAFe and CAFe2

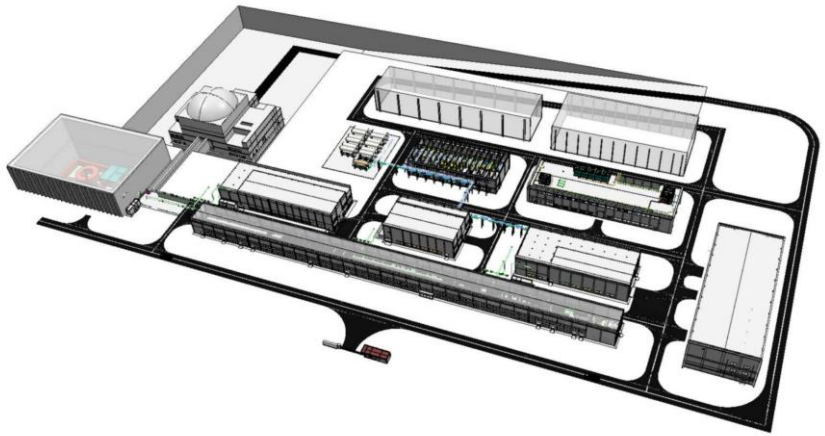
- 2017~2021, **ADS demo linac**, 20MeV, 10mA, 200kW proton beam
- 2022~now, high-intensity **heavy ion linac** dedicated to super heavy element



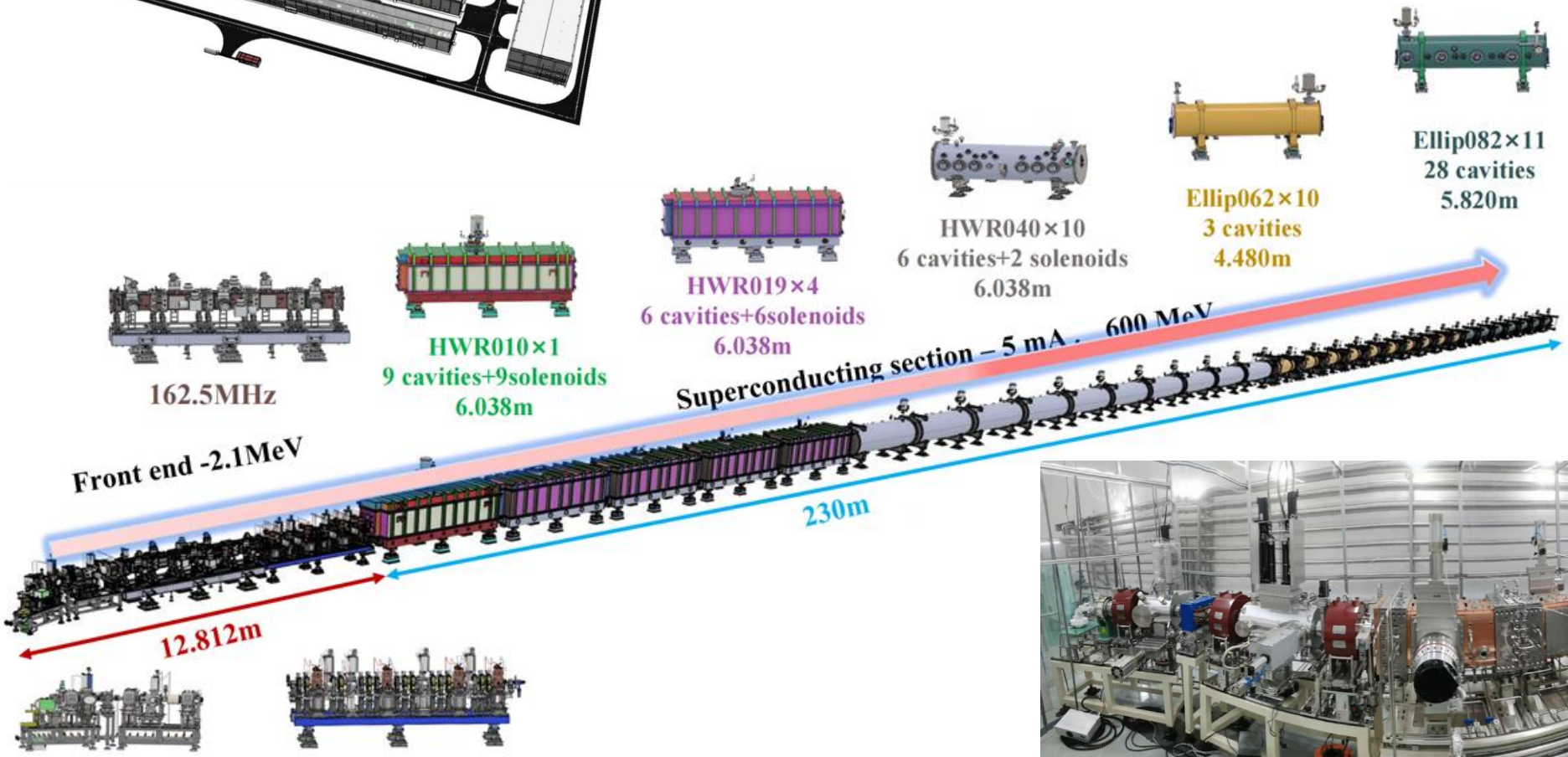
- **Ion species: M/Q≤3**
- **Beam Energy: 4-8 MeV/u**
- **User facility for:**
  - **Super Heavy Element synthesis**

NEW

China initiative Accelerator Driven System (CiADS)



- **Construction time**: 2021~2027
- **Budget**: 4B CNY (~$560M)
- **Location**: Huizhou, Guangdong
- **Parameters**: 600MeV (up to 2GeV), 5mA (up to 10mA), <10MW

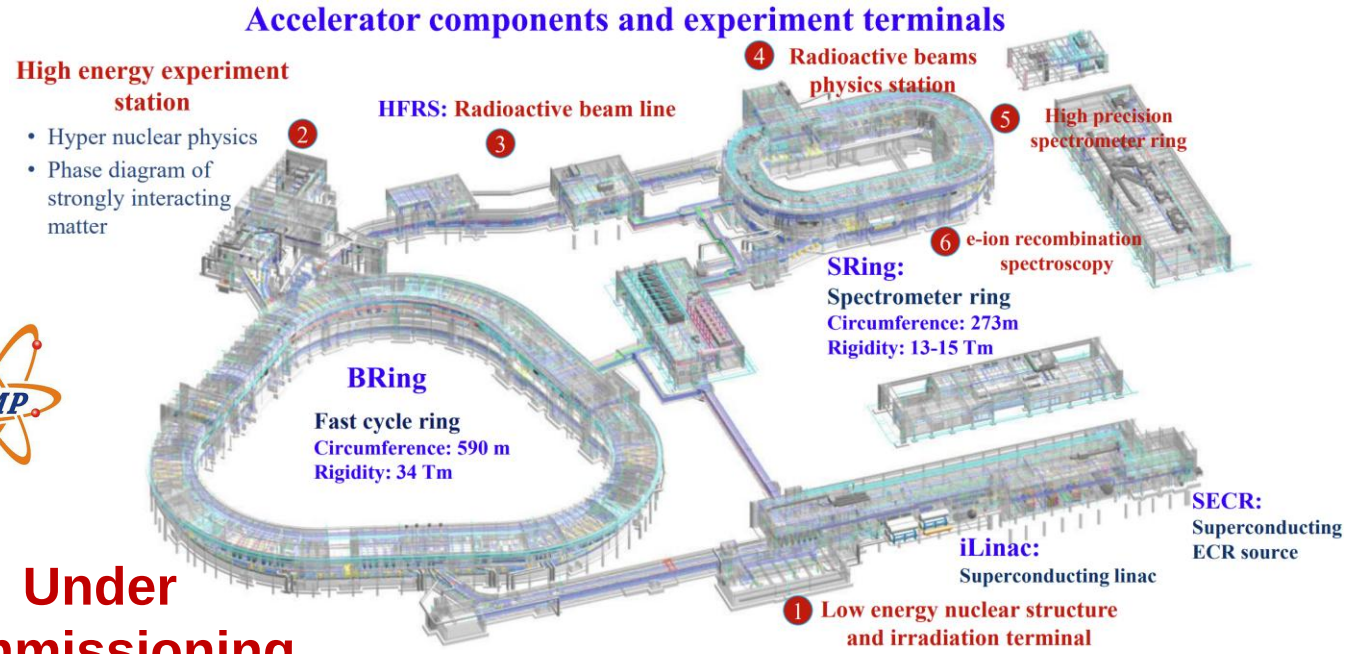


Series cavity prod. to be launched

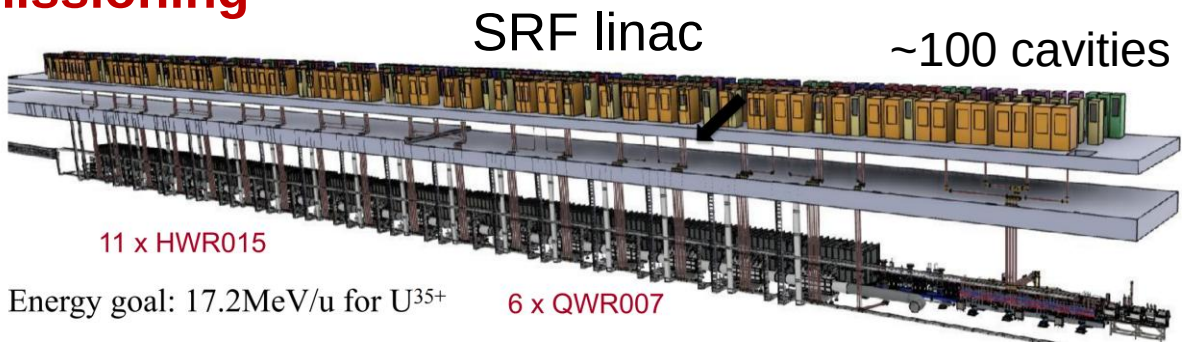
NEW

High Intensity heavy ion Accelerator Facility (HIAF)

- Mainly designed to provide high energy (~800MeV/u) and high intensity heavy ion beams
- **Construction time**: 2018~2025, **Location**: Huizhou, Guangdong, **Budget**: 3B CNY (~$420M)
- 6 experiment terminals: nuclear physics, atomic physics and application studies



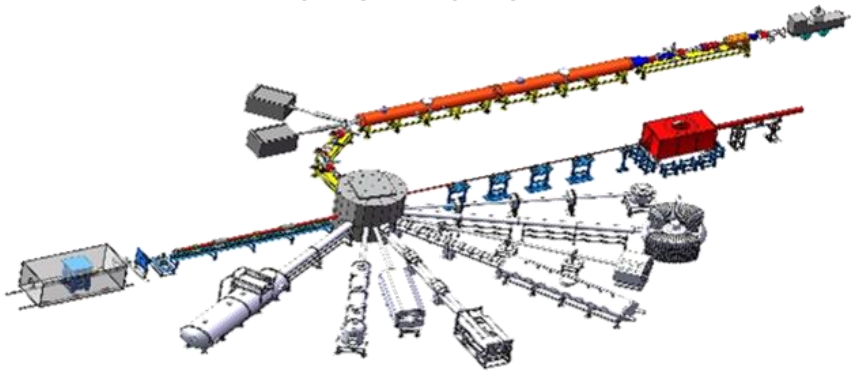
Under commissioning



Suzhou Laboratory

Neutron Source

2025~2029

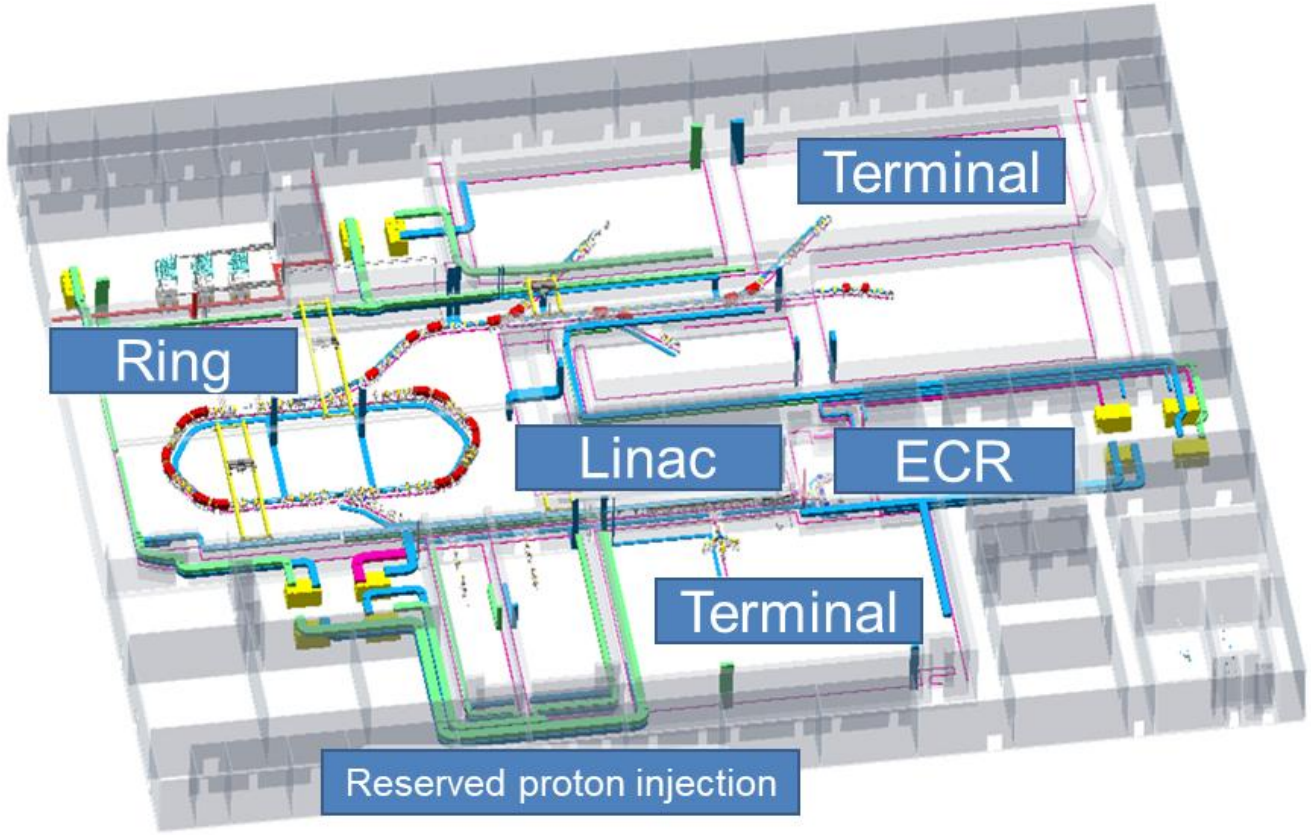


ECR + RFQ + DTL + PIMS

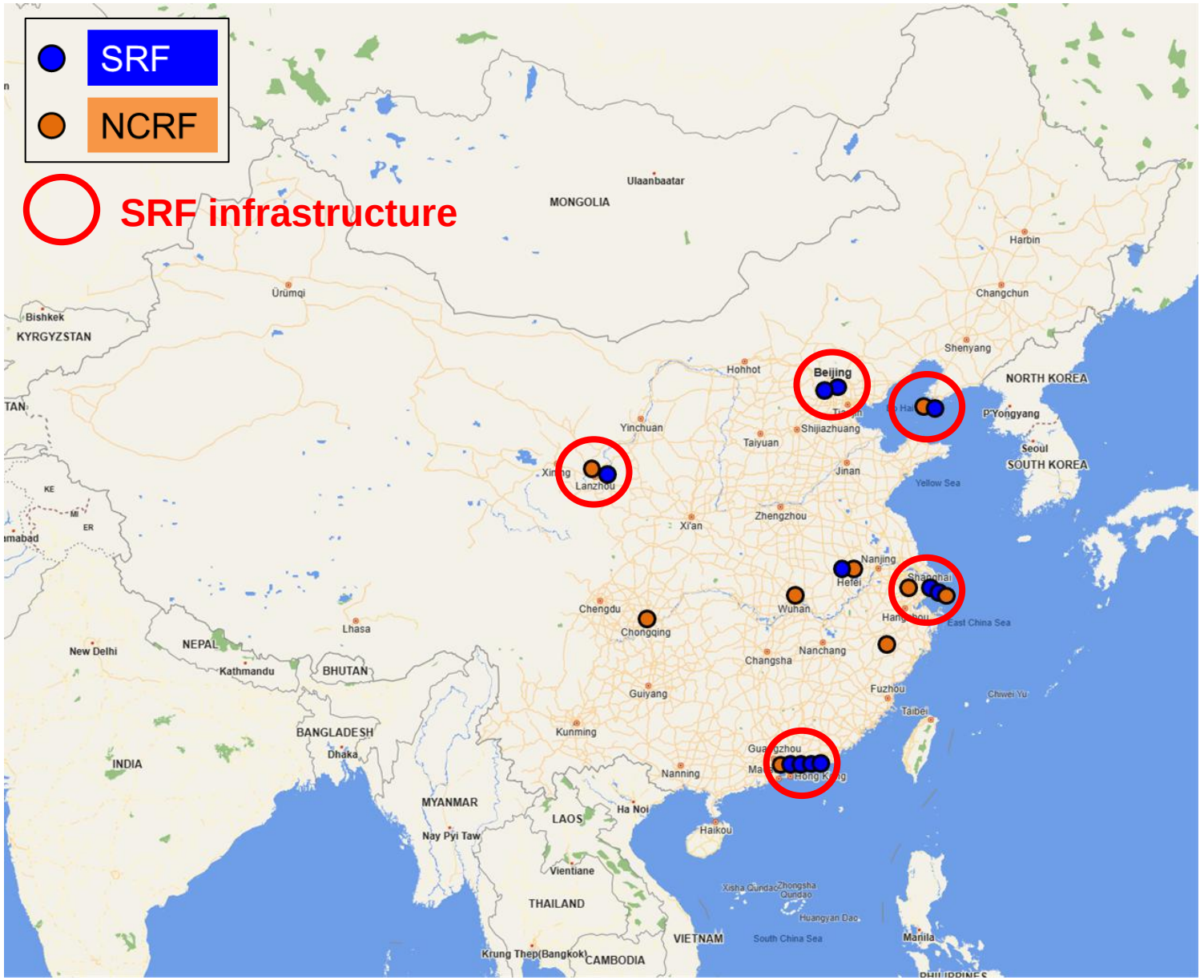
Parameter	Value
Peak current	50 mA
Accelerator energy	150 MeV
Duty cycle	2%
Rep. rate	50 Hz
Avg. beam power	150 kW
Beam	Proton

Ion Source

- Carbon energy ≥ 500 MeV/u, current ≥ 2e9 ppp
- Two terminals: single event effect, irradiation



New projects: SRF and NCRF



SRF
BEPCII/BSRF
HEPS
HALF
SHINE
S³FEL
DALS
CSNS-II
HIAF
CiADS
CEPC

NCRF
UTEF LS
ZIPS
SZL
SAPS
WALS
DCLS
STCF

Bold: under construction

SRF requires substantial infrastructures and shared expertise.

PAPS (Beijing)

Platform of Advanced Photon Source Technology R&D

- **Construction**: 2017 - 2020 (500M CNY)
- **Operation**: 2021 - now
- **SRF infrastructure**
  - 4000m^2 hall, 500m^2 clean room (ISO4-7)
  - HPR, FPC baking oven, Nb3Sn oven, Nb/Cu, etc.
  - 2.5kW @ 4.5K or 300W @ 2K cryogenic system
  - 3 VT Dewar, 2 HT bunkers, 1 single-cavity cryostat
- **Test capabilities**
  - 200-400 cavities (couplers)/year, 20 CMs/year

SRF hall

Cryogenics hall

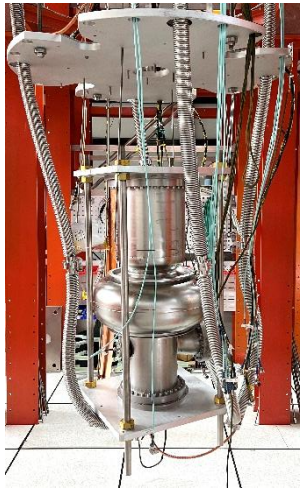
Vertical test stand

PAPS (Beijing)

166MHz cavity and cryomodule



500MHz cavity and cryomodule




1.3GHz cavity and cryomodule


650MHz cavity

324MHz double-spoke

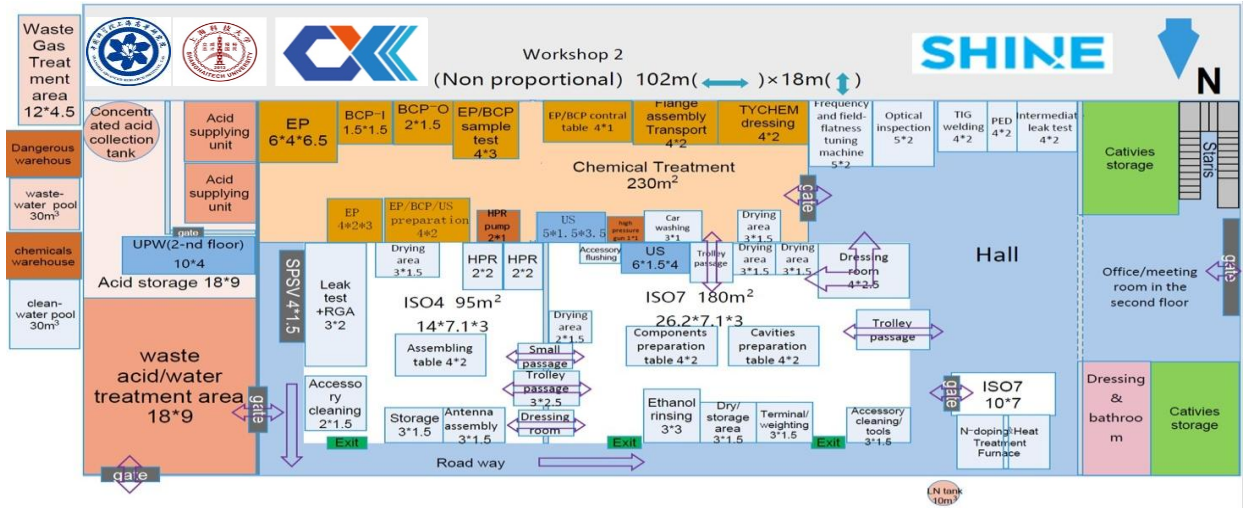
SAPS-TP (Guangdong)

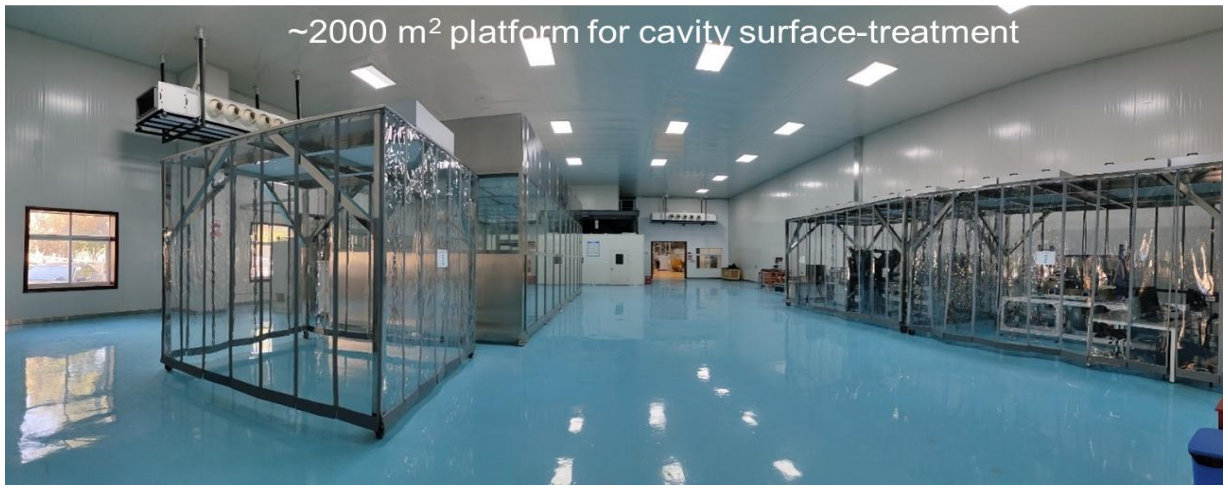
Southern Advanced Photon Source – Test Platform

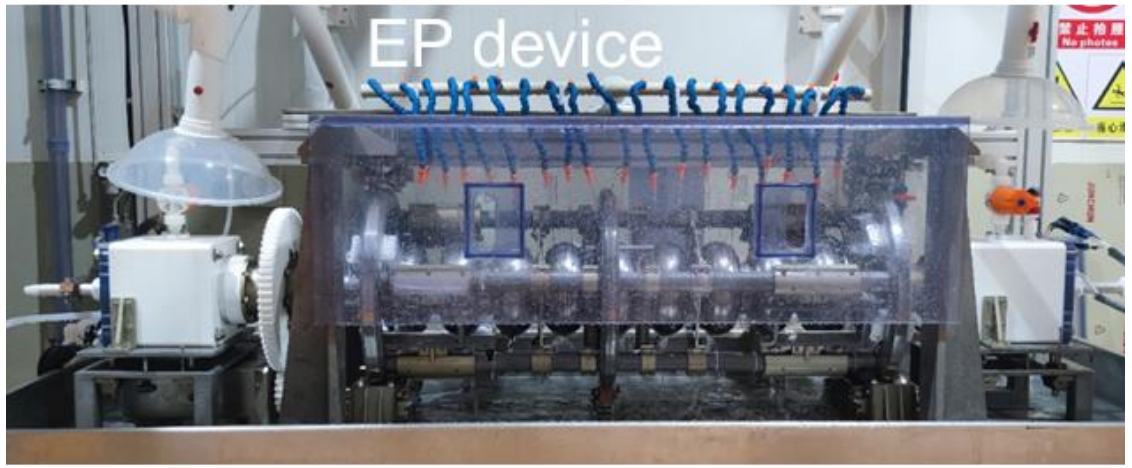
- **Construction**: 2019 - 2022 (600M CNY)
- **Operation**: 2022 - now
- **SRF infrastructure**
  - 4520m^2 hall, 315m^2 clean room (ISO4/6)
  - 850W @ 4.5K or 100W @ 2K cryogenic system
  - 2 VT Dewar, 1 HT bunkers, 1 single-cavity cryostat

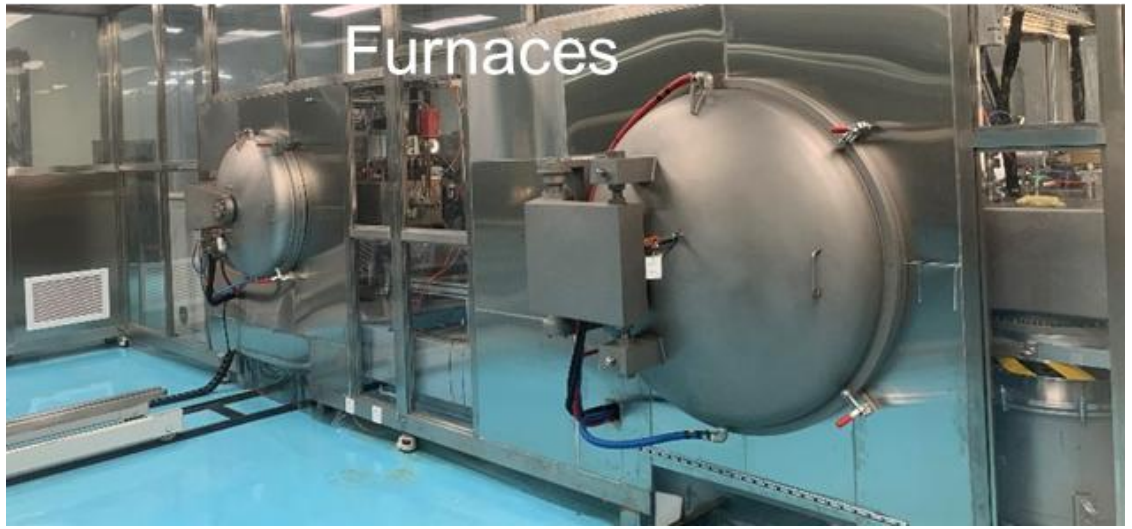
Cavity Surface-Treatment Platform (Wuxi)

- **Cavity surface-treatment platform** (co-built)**:** SHINE facilities at Wuxi Creative
- **Goal**: R&D and mass production for cavity surface-treatment
- **Design:** All the procedures after cavity fabrication and before VT, capacity: >200 cavities per year
- **Status:** **Operation since 2021**, surface-treatment for SHINE all domestic cavities, >180 cavities treated







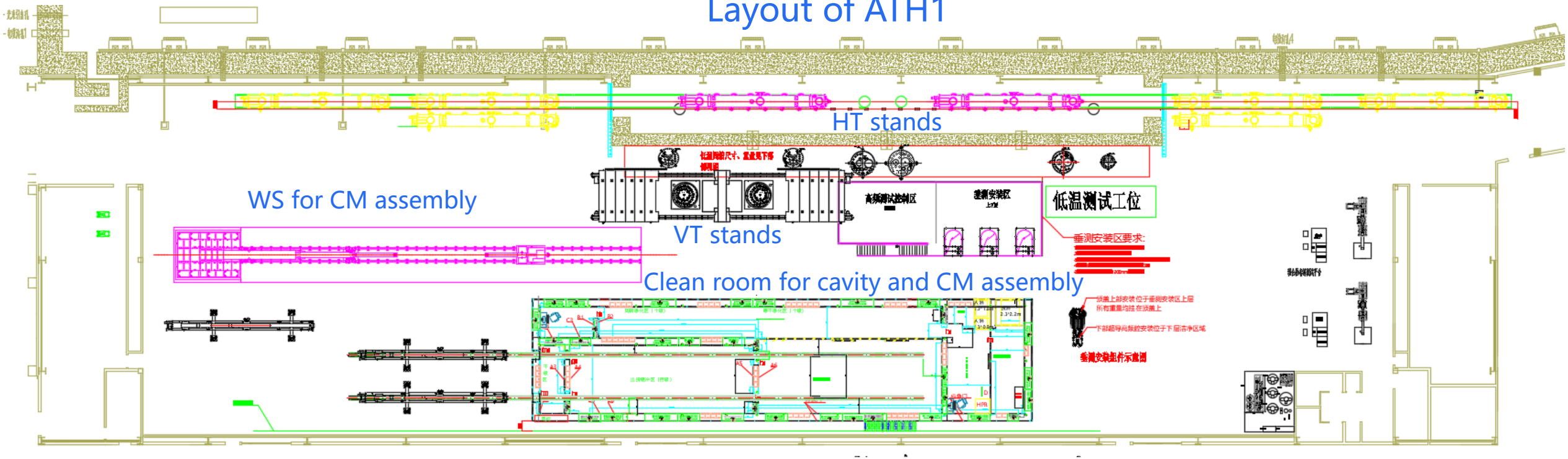


CM Assembly and Test Platforms (Shanghai)

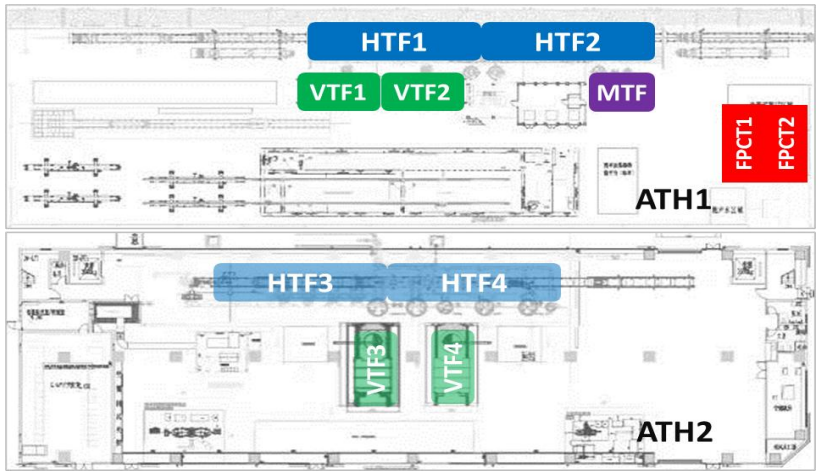
SHINE

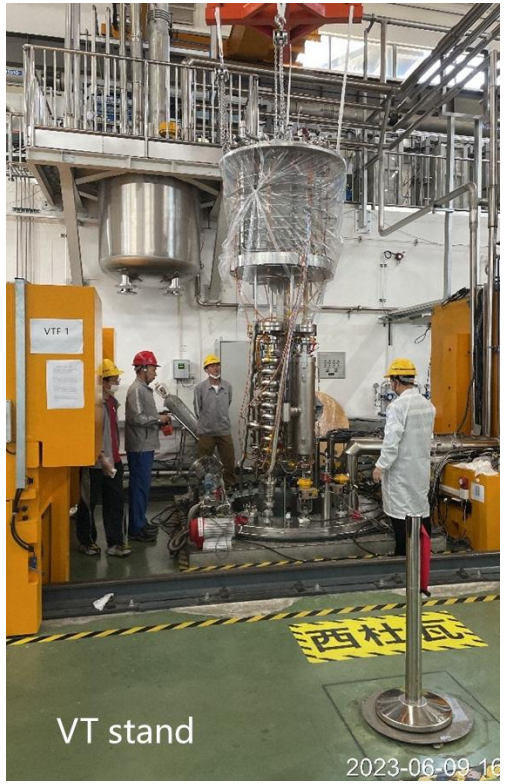
- Two 3000 m^2 for CM Assembly and Test Halls (ATH1 & ATH2)
- 2 CM clean-assembly lines, 4 VT stands and 4 HT stands
- **Commissioning and operation since 2021**
- More than 20 CMs assembled and tested, reached high performance

Layout of ATH1



CM Assembly and Test Platforms (Shanghai)





High-volume usage in SHINE
CM mass production and testing

Baiyin Post-processing Base (Lanzhou)

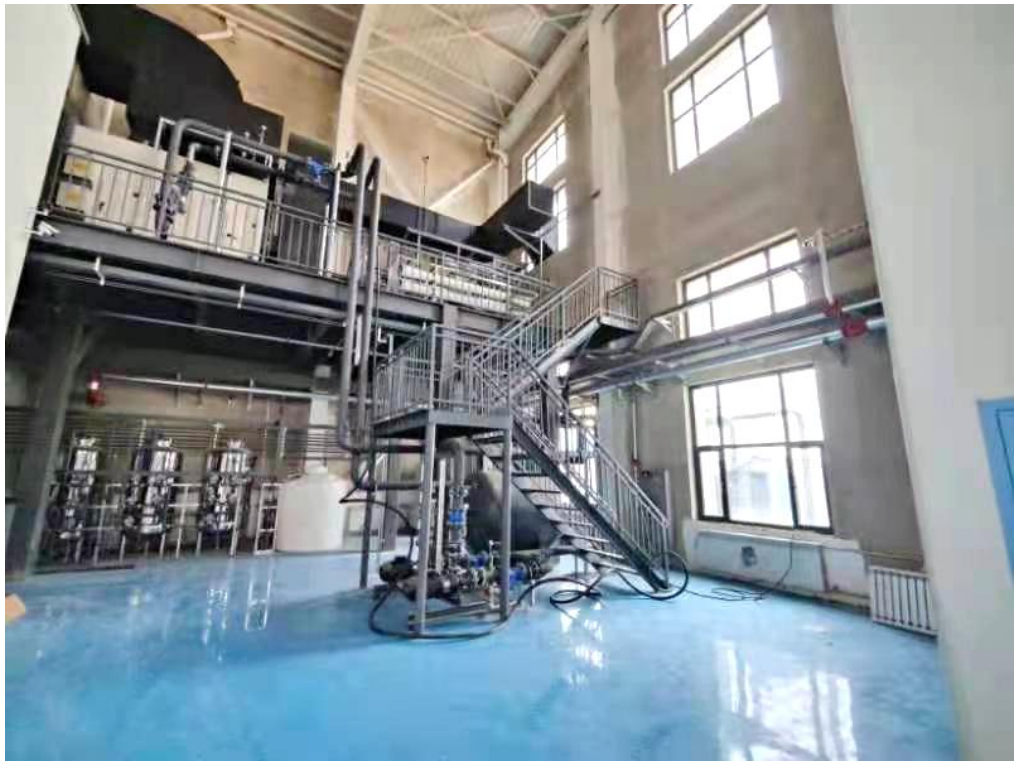
Ultrasonic Cleaning → BCP/EP → Vacuum Annealing

- Location: Baiyin city, Gansu Province
- Capability: Post-processing of QWR, HWR, Spoke, Elliptical cavities from 81.25 MHz to 3.9 GHz
- Serves both engineering and research projects

HPR in ISO-5 clean environment

Lanzhou New Area Clean Assembly Facility

- Location: Lanzhou, ISO-4 clean environment, ~250m^2
- Three clean-compatible robots, 360 kg load
- Capable of assembling cavity string of 12 meters, covering all mainstream accelerator types
- Mainly serves IP-SAFE project (isotope production)



Huizhou headquarter SRF platform

- Total area 445m^2, with 176m^2 ISO-4 clean area
- 4 clean-compatible robots, 360 kg load
- Capable of assembling cavity string of 6 meters
- Mainly serves research projects
- 1kW@4K LHe system
- 2 VT dewars, 1 HT bunker

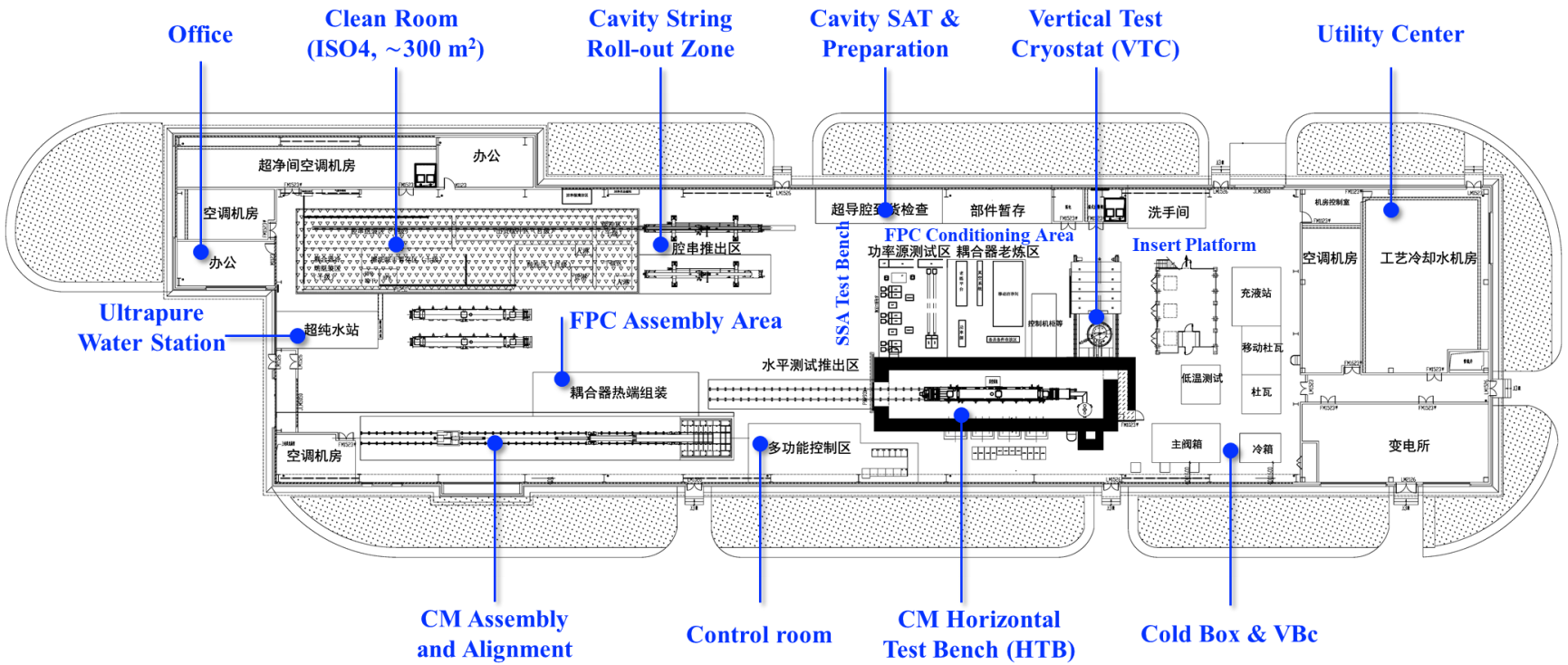
Huizhou CiADS Clean Assembly Facility

- Total area 950m^2, with 350m^2 ISO-4 clean area
- 9 clean-compatible robots, 360 and 500 kg load
- Capable of assembling cavity string of 12 meters
- Mainly serves HIAF and CiADS projects
- 4.5kW@4K LHe system
- 4 HT dewars (single cell), 2 HT bunker (under constr.)

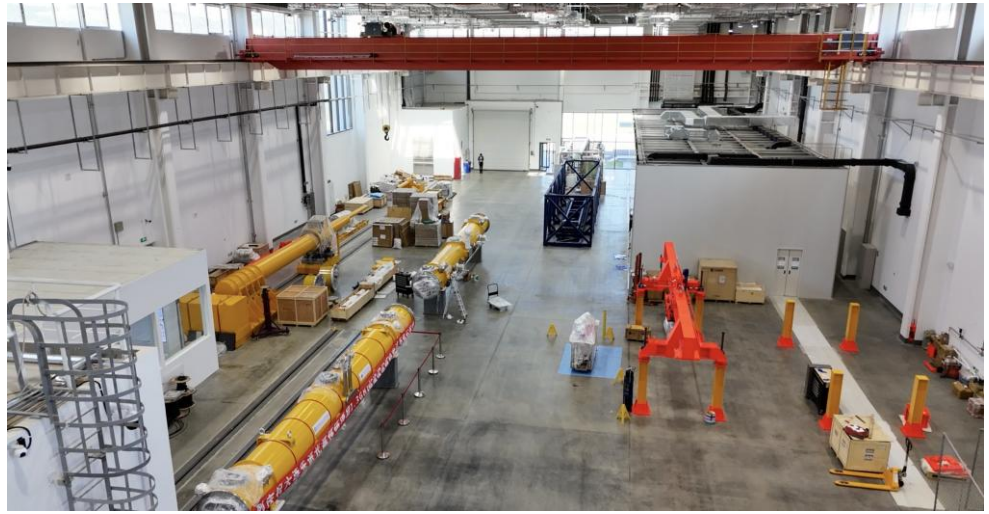
DALS SMTF (Dalian)

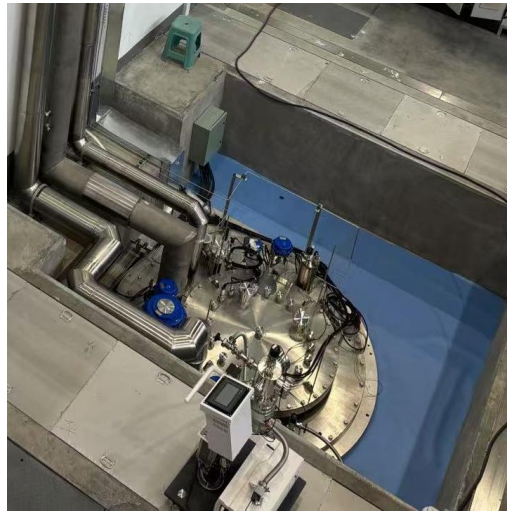
Dalian Advanced Light Source R&D

- **Construction**: 2019 - 2024, operation since 2024
- **SRF Module Test Facility (SMTF)**
  - 3150m^2 hall, 300m^2 clean room (ISO4)
  - HPR, FPC cond., assembly, VT, HT
  - 370W @ 2K cryo. system, 1 VT Dewar, 1 HT Bench
- **Test capabilities:** 1CM/month



DALS SMTF (Dalian)





SMTF at IASF (Shenzhen)

深圳综合粒子设施研究院
Institute of Advanced Science Facilities,Shenzhen,China

SRF Module Test Facility (SMTF)

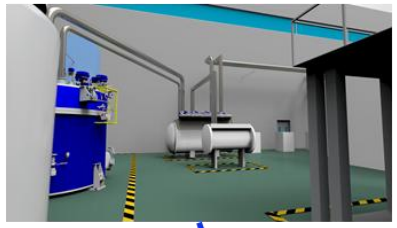
Total area of SMTF Hall: About 15,000 m²

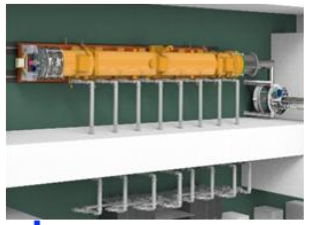
Very much like AMTF for European XFEL

R & D of SRF accelerator key components and CM mass production

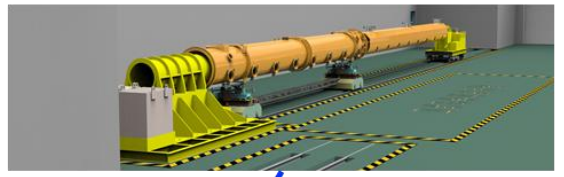
- **One Magnet Test Bench**
- **SRF cavity test facility**
  - ✓ Nb material and surface inspection
  - ✓ Mechanical Grinding & baking oven
  - ✓ Two Vertical Test Cryostats (VTCs)
  - ✓ Quenching diagnosis and performance recovery
  - ✓ FPC conditioning bench
- **Three CMTBs**
- **Clean room for cavity string assembl**
- **CM assembly infrastructure**
- **Two prototype CMs**
- **Dedicated cryoplant (~500 W@2K)**
- **Primary schedule: 2023-2027**

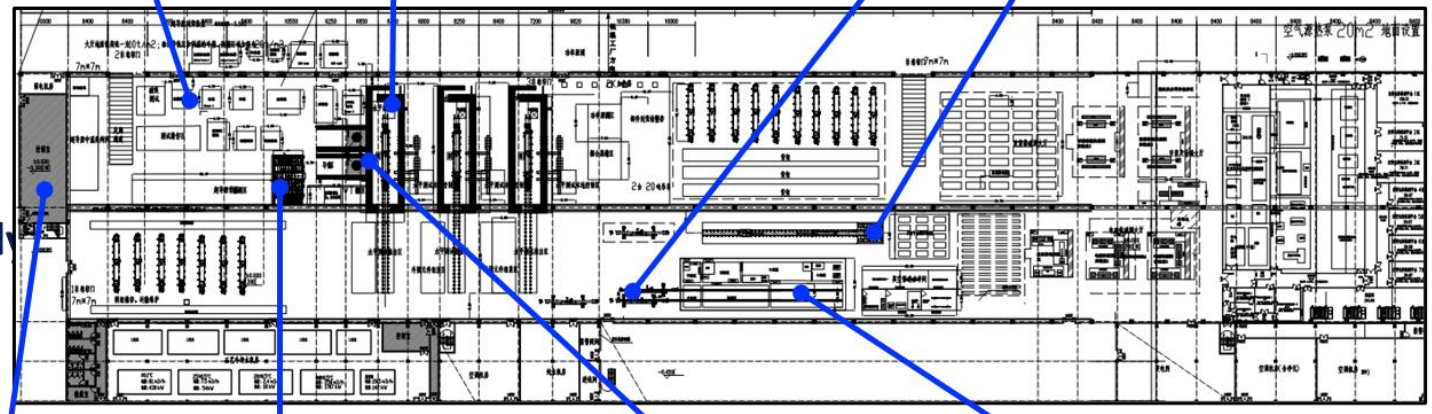
Test capabilities: 2CMs/month


Cryoplant

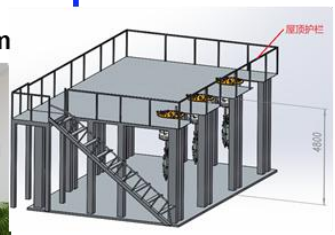

CMTB

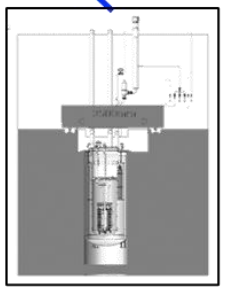

CM Alignment

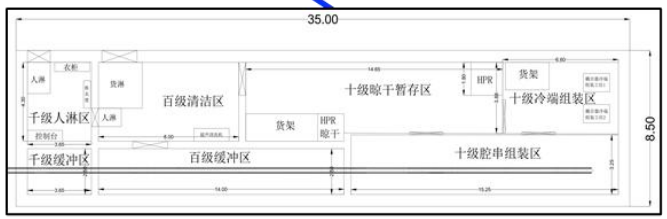

CM Assembly




Control room

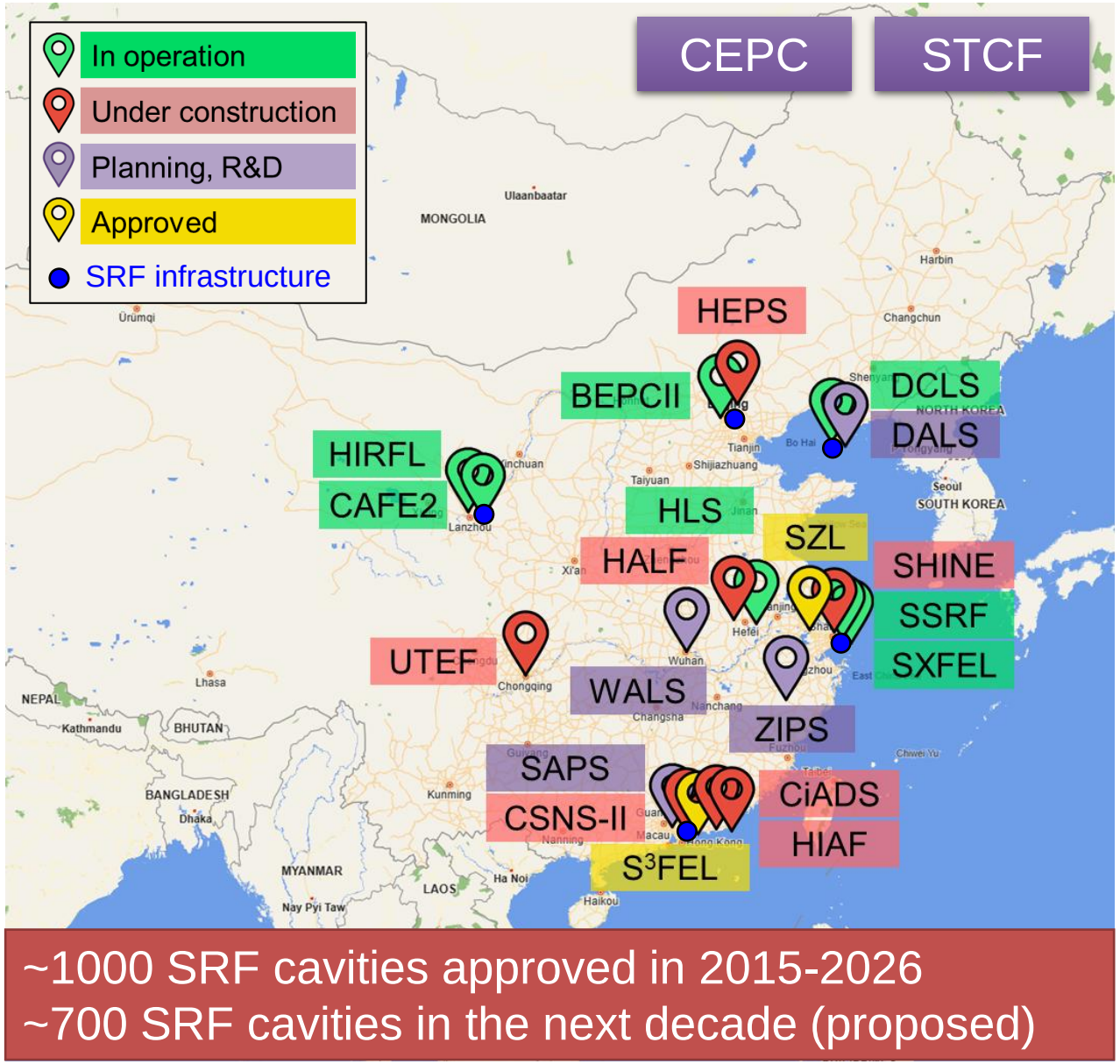

Insert Station


VTC



Clean room (10 class)

Summary



~1000 SRF cavities approved in 2015-2026
~700 SRF cavities in the next decade (proposed)

- Large accelerator facilities have seen rapid development in the last decade in China, including light sources, FELs, proton & heavy ion facilities
- Large collider projects after BEPCII are under discussion
- SRF technology adopted by most projects under construction, while new proposals mixed with NCRF and SRF
- SRF infrastructures at various facilities have been built and in operation

	Op.	Const.	Proposed
Collider	1	0	2
Sync. LS	3	3	4
FEL	2	1	2
Proton & Heavy ion	3	3	2

Welcome to HEPS

Huairou, Beijing, China