SRF-based new accelerator projects in China : Related Infrastructures and Industries

Dong Wang

Shanghai Institute of Applied Physics
and Hard XFEL project at Shanghai

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SCLF

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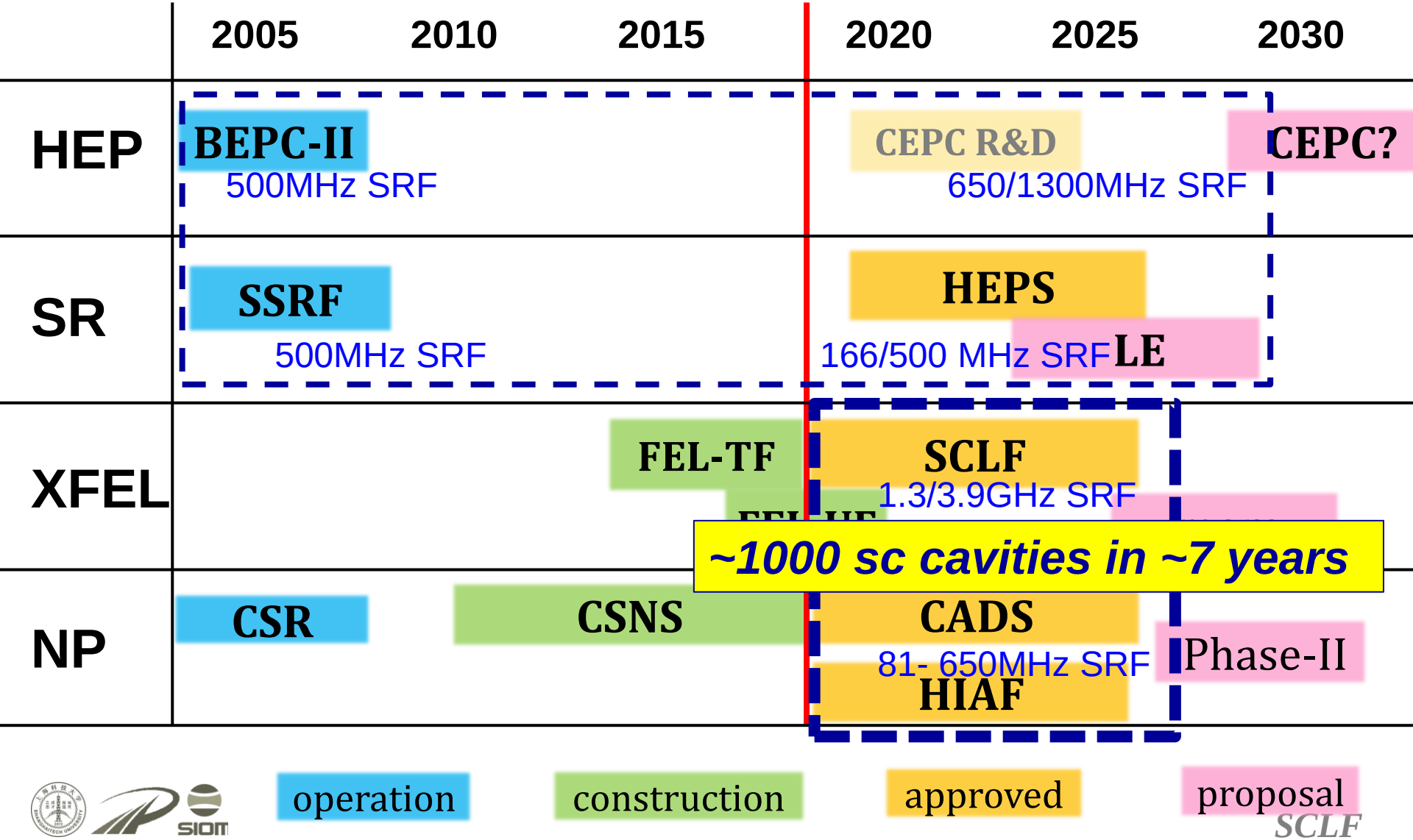
- Wuxi: H. Lu
- HIT: J. He

Outline

- Large accelerator projects in China
- SRF R&D needed for large projects
- New infrastructures in next 2 years
- Related Industries
- Remarks

Large Accelerator Projects in China

(2005-2025)



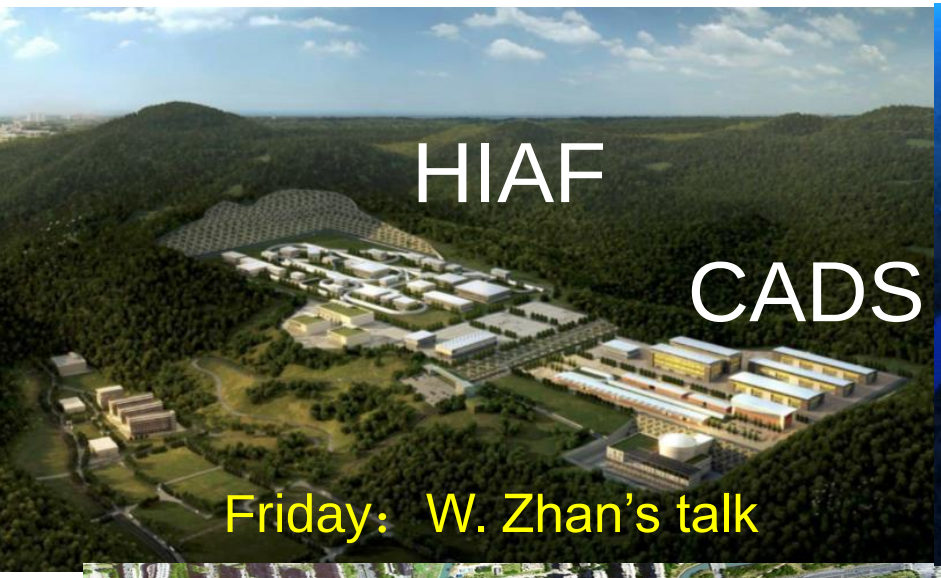
Large Accelerator Projects in China

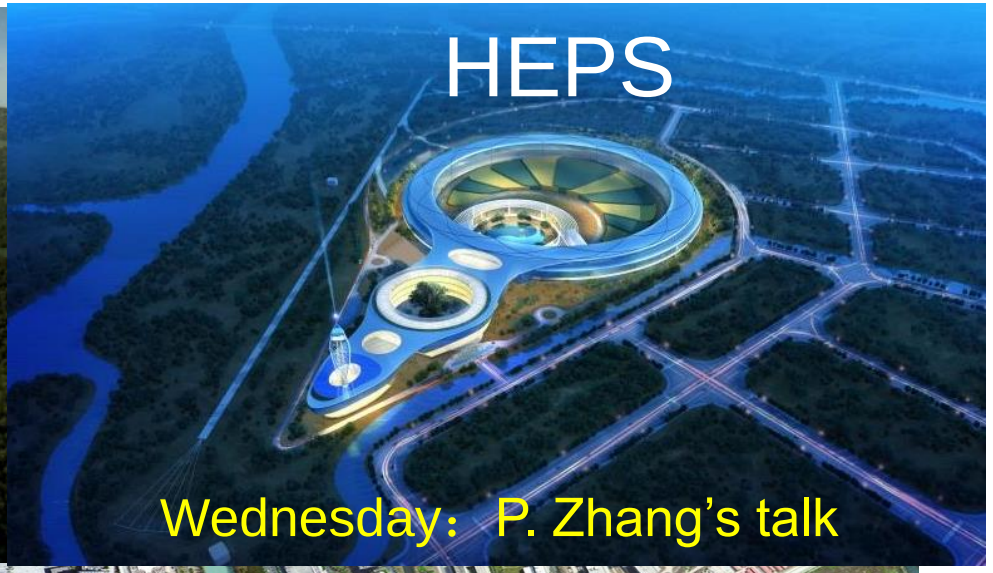
	Year	Host	Type	Dimen.	Energy	Cost
BEPC-II	2003-08	IHEP	e+e- ring	240m C	2.5 GeV	~100M $
SSRF	2004-09	SINAP	e- ring	432m C	3.5 GeV	220M $
CSR	2004-10	IMP	i ring	129m C	0.4 GeV/u	~50M $
CSNS	2010-18	IHEP-GD	p lin+ring	100+200m	1 GeV	~330M $
XFEL-TF	2014-18	SINAP	e- linac	293m L	0.8 GeV	~30M $
XFEL-UF	2016-19	SINAP	e- linac	532m L	1.5 GeV	110M $
CiADS	2018-25	IMP-GD	p linac	~200m L	0.5 GeV	~400M $
HIAF	2018-24	IMP-GD	i lin+ring	~530m C	4.2 GeV/u	~350M $
H-XFEL	2018-25	SINAP	e linac	3100m L	8 GeV	~1.4B $
HEPS	2018-25	IHEP	e ring	1300m C	6 GeV	~700M $

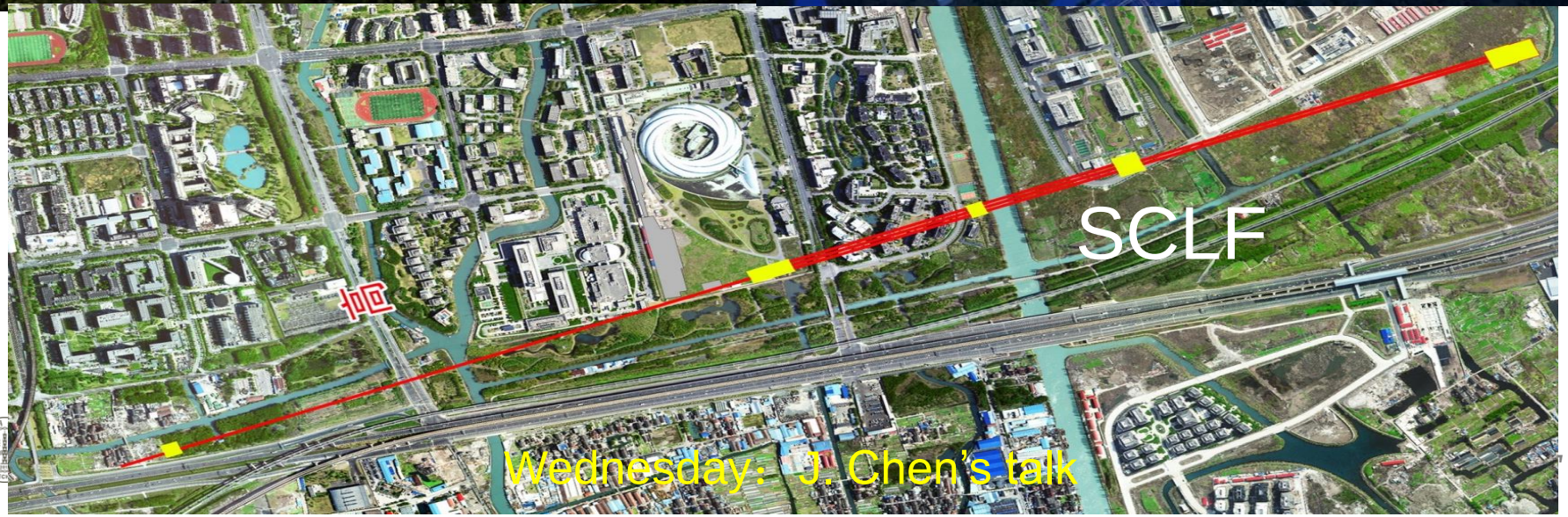
GD: Guangdong Province (near Hongkong)
Cost: rough amount in USD for easy understanding

: heavily SRF

Newly approved large accelerators in China







Maps of new accelerator projects in China

SRF-related features of new projects

	Energy	Current /particle	Mode	SRF Cavities	Key RF-related issues	note
CADS	0.5 GeV	5mA	proton cw-linac	162/325/650 MHz, ~200	High current cw p linac	
HIAF	4.25 GeV / u	1E11u	heavy-ion accelerator	81/162/325 MHz, ~100cav	High current cw i linac	
XFEL	8 GeV	0.2 mA	electron cw-linac	1.3GHzx600 3.9GHzx16	High Q Mass produc.	
HEPS	6 GeV	200 mA	electron cw-ring	166MHzx5 500MHzx2	Low freq. SRF for e ring	

: heavily SRF

SRF R&D Infrastructures: so far

2010-2017

General information of SRF R&D programs

	IMP	IHEP	PKU	SINAP
Driven project	ADS	ADS/ILC	ILC/FEL	SR
Infrastructure locations	Old campus Lanzhou	Old campus Beijing city	Old campus Beijing city	Old campus Jiading
SRF R&D fund	~50M$	~50M$	~10M$	~10M$

SRF Infrastructures in major institutions

	Cryoplant-T	VTS	Space	EP	CM-int./HT	N_dope
PKU	70W@2K	1x2cav	~1000m2	Yes	2-cav	Yes/s
IHEP	100W@2K	1x2cav	~2000m^2	Yes	1-cav	Yes/s
IMP	850W@4K	1x1cav	~2000m^2	Yes	6-cav	No
SINAP	60W@4K	1 cav	~2000m^2	No	1-cav	No

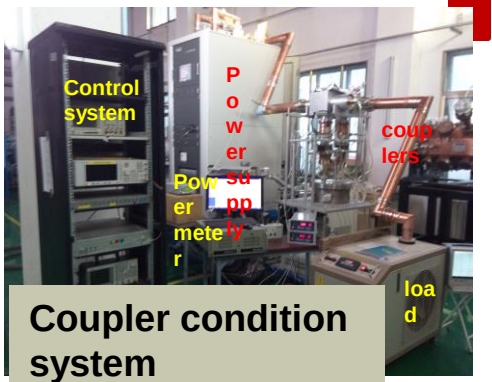
EP/N_dopings are off-site

SRF Infrastructures at IMP (Lanzhou)

Cavity assemble

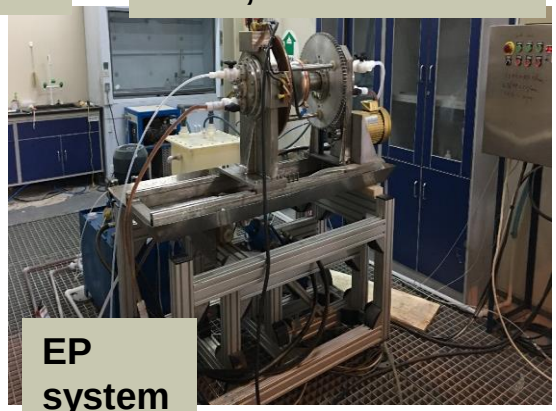
Assemble in clean room

Cryogenic plant, 850W, 4.2 K



Coupler condition system

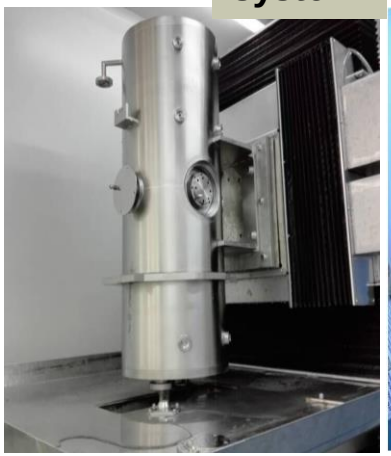
complex acid



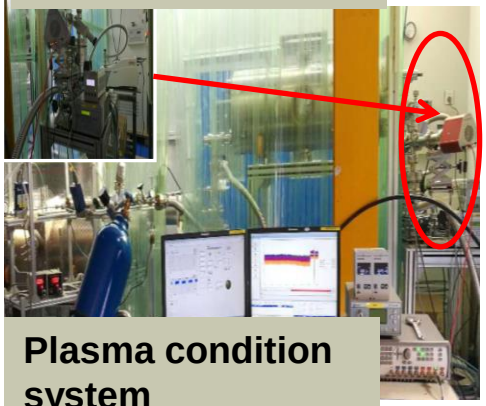
EP system

Ultrapure water system

BCP system



HPR system



Plasma condition system

SRF cavities R&D for ADS at IMP

HWR010

HWR015

CH

Double Spoke

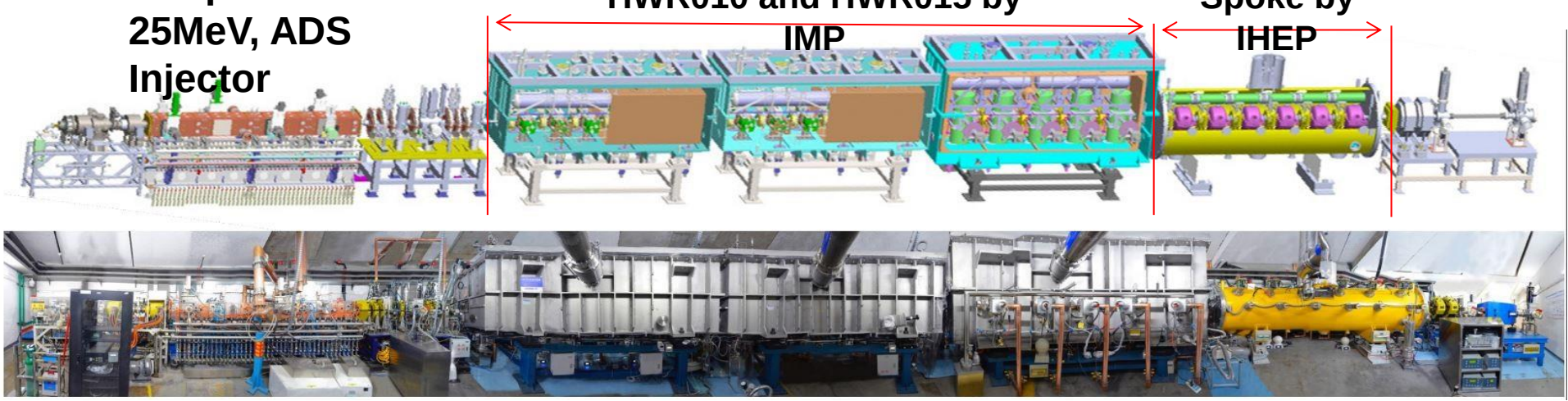
Single Spoke

elliptical

CW proton 25MeV, ADS Injector

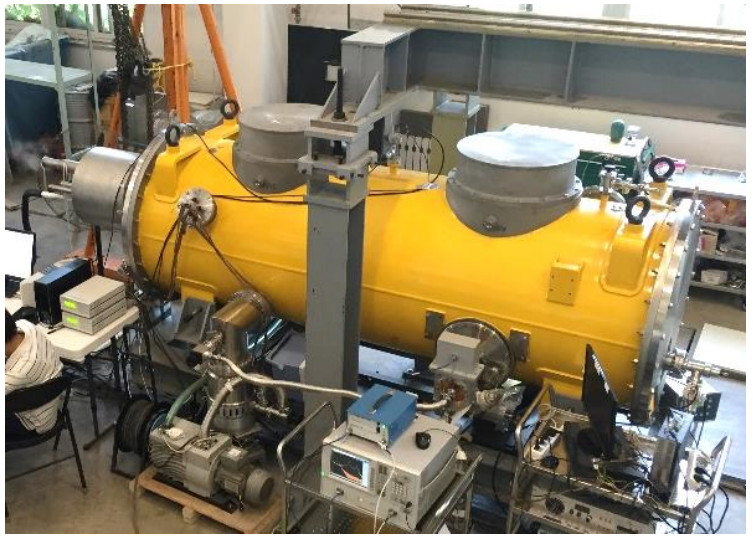
HWR010 and HWR015 by IMP

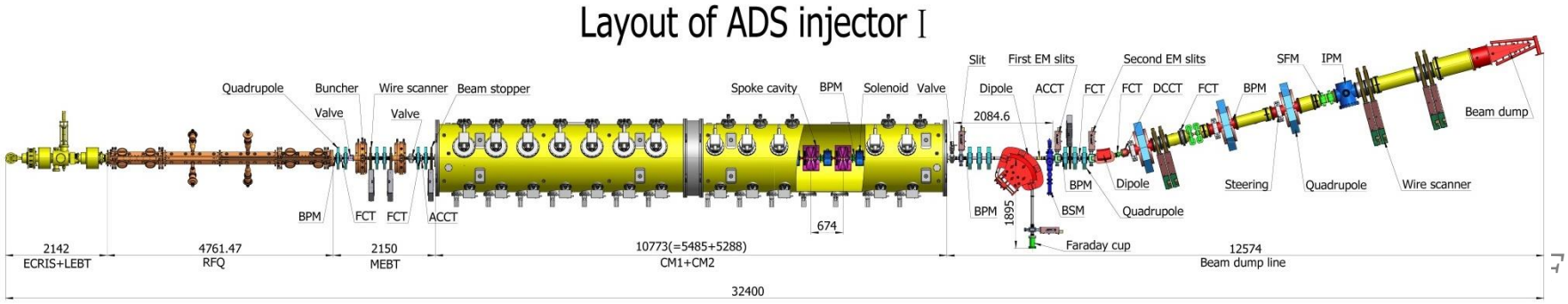
Spoke by IHEP



SRF infrastructure at IHEP

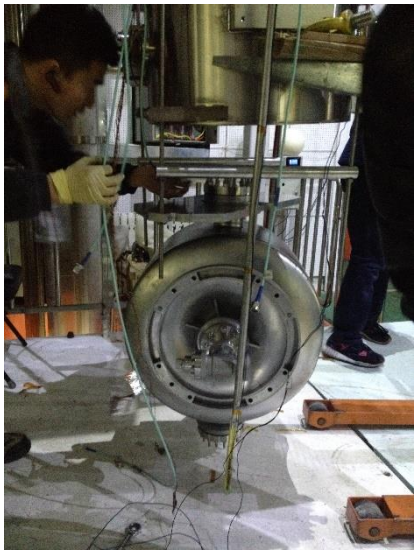
- Complete cryomodules for varies projects have been developed, e.g. BEPC-II (500MHz), C-ADS (325MHz), ILC R&D (1.3GHz)





SRF infrastructure at IHEP

SRF testing



- 2K (100W) VT dewar with refrigerator-close cycle
- One test circle per week (at most 2 x 1.3GHz 9cell cavities at a time)

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PKU SRF infrastructure

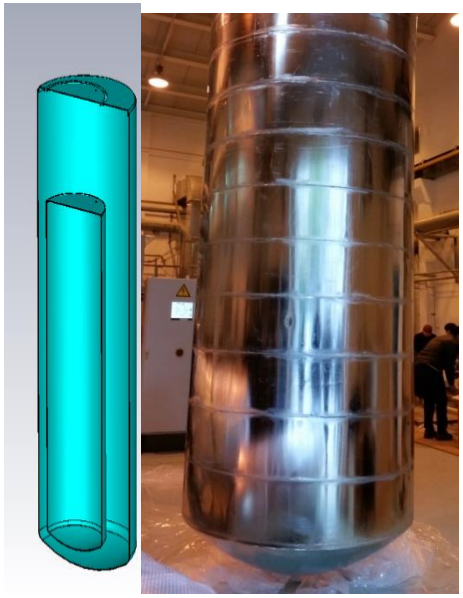
LHe system

2K Pumping system

VTS

VTS Dewar

Insert



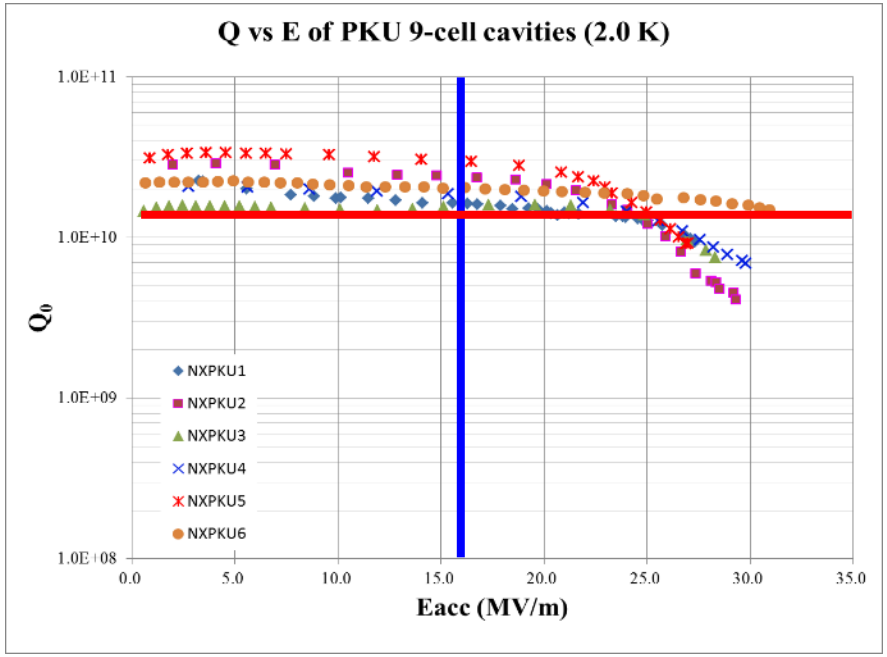
Magnetic shield

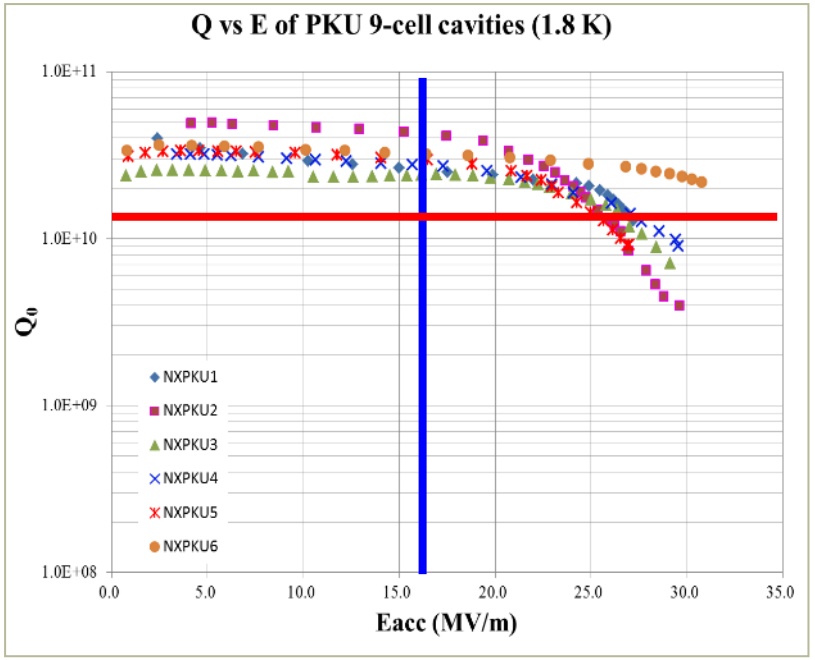
SXFEL project includes sc cavity R&D

6 Large Grain 1.3GHz cavities made in OTIC

Large grain cavities: VT results by PKU

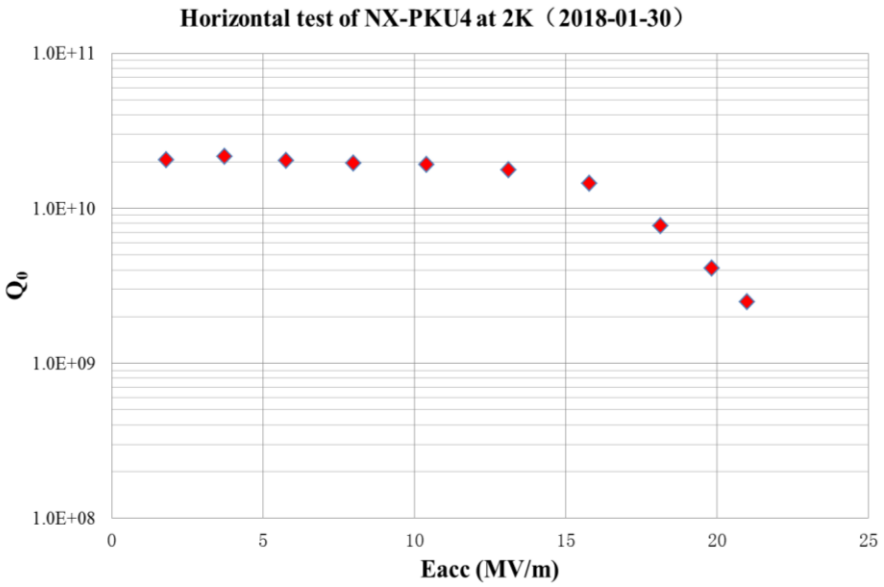
- E_{acc} >25 MV/m (SCLF baseline : 16MV/m , blue)
- Q_0 ~ 1.6-2.4E10 @ 2K , at 16 MV/m, ~3.5E10 @1.8K





- $Q_0(1.8K)/Q_0(2.K)$ = 1.50-1.79 (@~16 MV/m)
- Operation @1.8 K could be an option

Horizontal tests of 1.3 GHz CM (2-LG cavities) at PKU



Horizonal test setup:

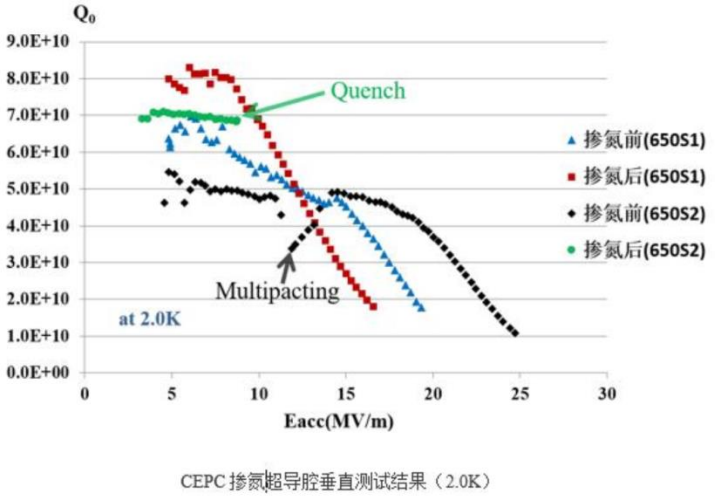
- Pulse mode: 0.5 Hz, 700 ms
- Qe~6×10^8 for Q-E measurement

E_{acc} >20 MV/m without quench

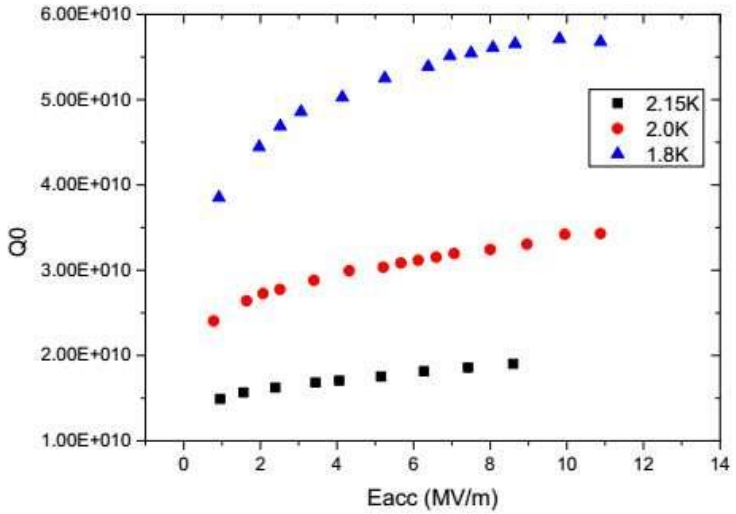
Q-drop after 15 MV/m:

Caused by Cryogenic capacity limitation (~55 W at 2 K for cooling down both 3.5-cell injector and 2×9-cell cryomodule) and probably field emission

N-doping: initial results by IHEP and PKU



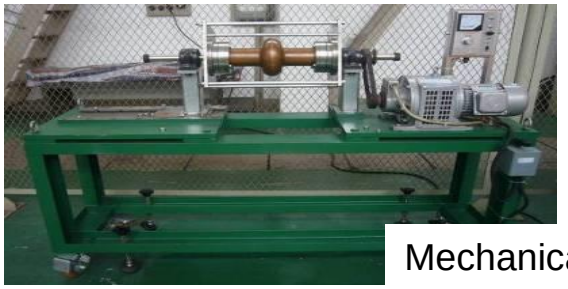
IHEP 650MHz single-cell cavity N-doping



PKU N-doped 1.3GHz cavity

IHEP/PKU/SINAP to have 9-cell cavity EP/N-doping in 2018

Infrastructure on SRF at SINAP



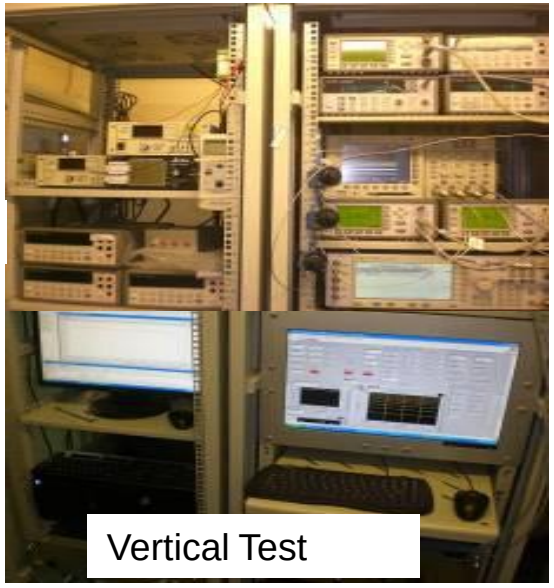
Mechanical Polish

Clean-room

Buffered Chemical Polishing

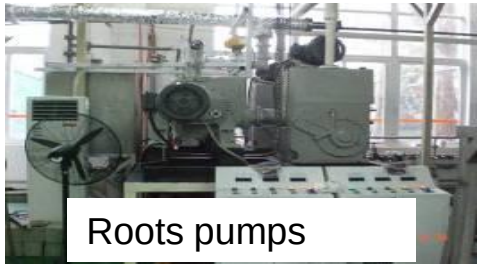
Ultra-Pure Water

High Pressure Rinsing



Vertical Test

Annealing



Roots pumps

SRF Infrastructure and R&D so far

- Proton cw linac machine:
  ADS R&D made significant advances in past years by IMP/IHEP teams
  foundations for CADS/HIAF projects

- Electron cw linac :
  R&D / infrastructure much underfunded.
  huge efforts needed to take new challenges facing us on Hard XFEL at Shanghai

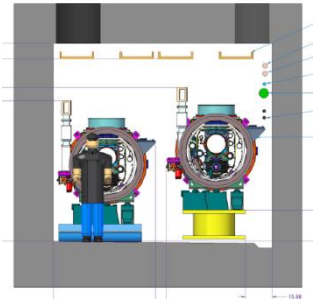
2017 is turning point as Shanghai XFEL and HEPS projects(prototyping and construction) got funded.

New projects: huge challenges

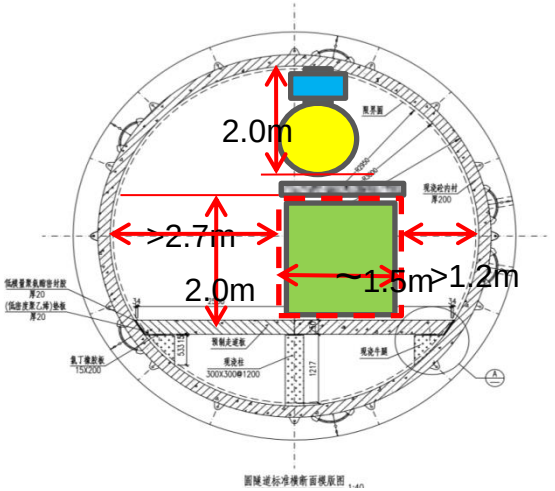

N
S
Shanghai Hard X-ray FEL
Injector
Linac
Switchyard
SINAP
STU
Far Hall
SARI
Near Hall
Beam Dump
Undulator

EXFEL，LCLS-II(HE) and Shanghai XFEL

European XFEL

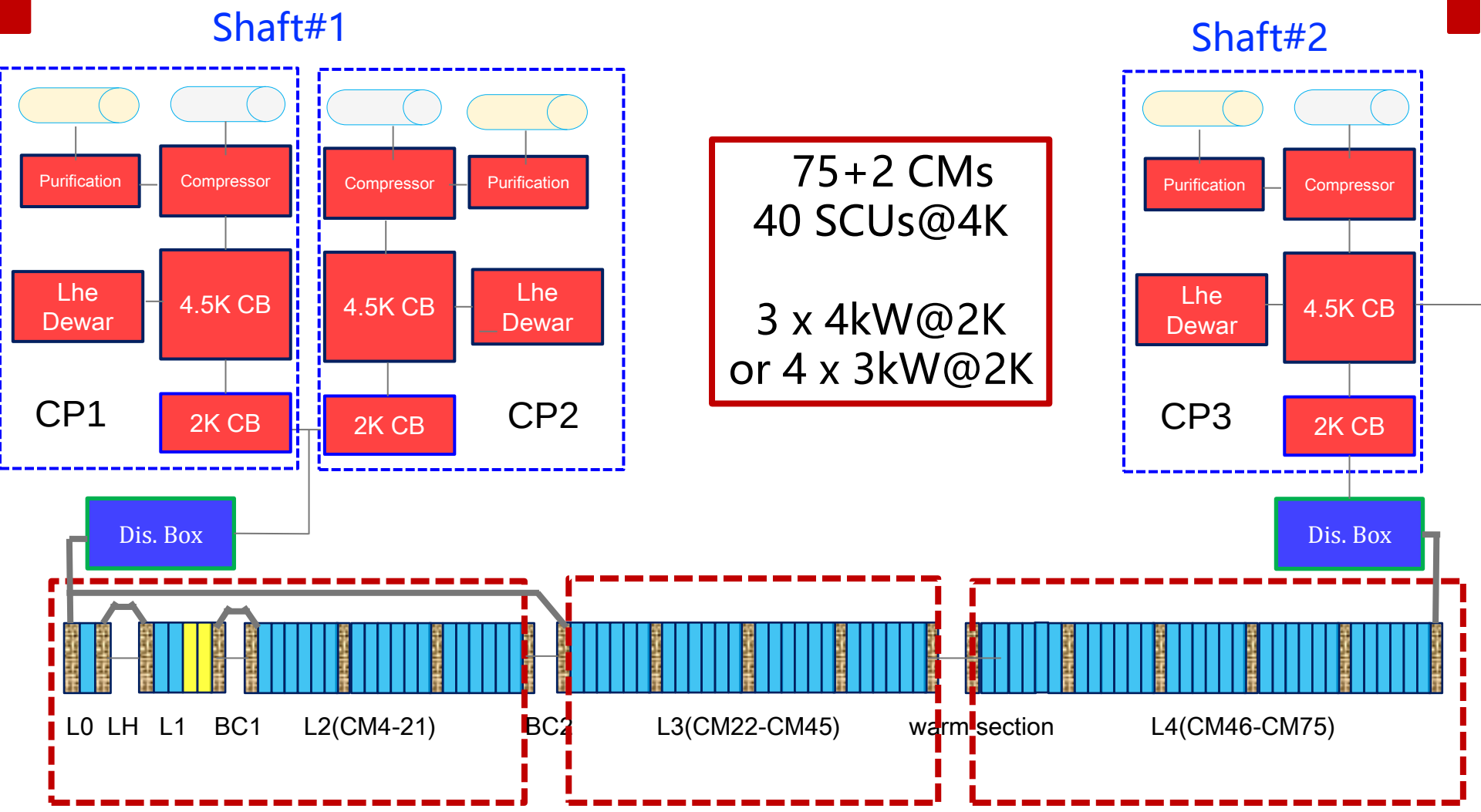


LCLS-II



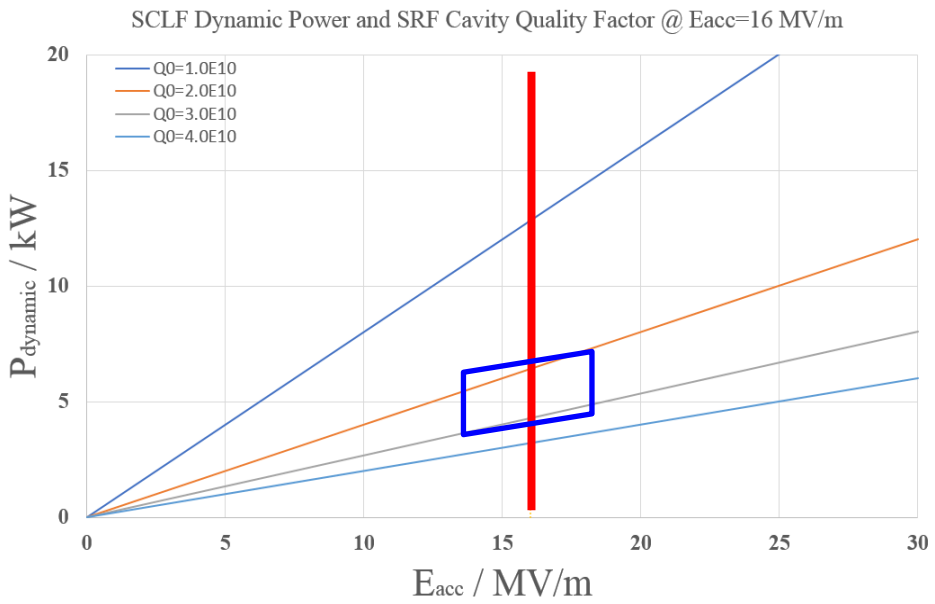
	EuropeanXFEL	LCLS-II (HE)	Shanghai XFEL
RF mode	Pulsed	CW	CW
Power source	Klystron	SSA	SSA
Install	Single ac Tunnel	Tunnel + Gallery	Single ac Tunnel
2K heat load/CM	~20w/CM	~80w/CM	~80w/CM
Tunnel slope	~	0.5%	~
N of modules	~100	~35 (+19)	~75
2K capability	~3kW	~ 2 x 4kw	~ 3x4 or 4x3 kw

CMs and cryogenic system



6CMs

Cryogenic plant: ~12kW@2K total



Operating points in considerations

Gradient: 14~18MV/m
Qo: 2.0~3.0E10
Load_d: 4~8kW@2K
Plant: ~12 kW@2 K

- For Q0 ≥3E10 @ 16 MV/m

Surface treatment : N-doping, infusion

Lots prototyping ahead

- For Q0 ≥2E10 @ 16 MV/m

State-of-art non-doping cavities

Large grain materials

2.0 K→1.8K operating

TESLA 9-cell 1.3GHz cavity

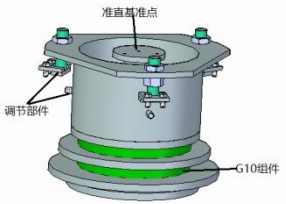
Cryomodule

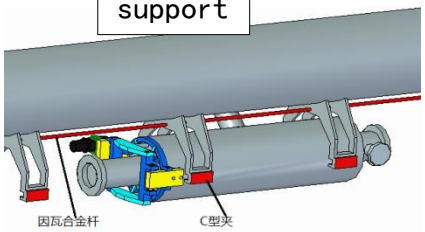
based on EXFEL&LCLS-II type

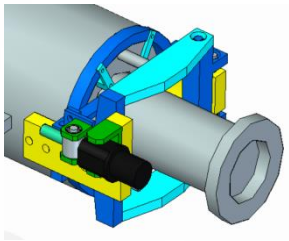
support

post

tunner

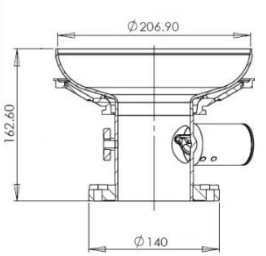




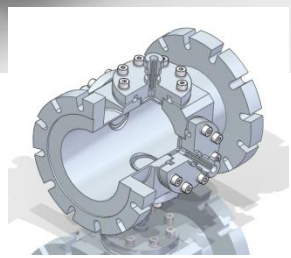


Quad

cavity



Coupler



BPM

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SCLF strategy on SRF

- TESLA type cavity/cryomodule technology are well established, thanks to the continues global efforts especially by TTC and EXFEL/LCLS-II project.
  - join and cooperate with community, hopefully make contributions
- Major components have been industrialized.
  - multi commercial suppliers (to deal with tendering/bidding procedures of funding agencies)
- Novel technologies (N-Doping, infusion, etc.) are of great importance to project for cost-effective performance and future potentials.
  - all for it since now, while keep other options going
- CM Integration/SRF Testing need to be taken care of on-site to a large extent unless good partners found
  - build-up full capabilities while look for collaborating institution/industry

SRF R&D Infrastructures: next

2018-2019 (fully funded, ongoing)

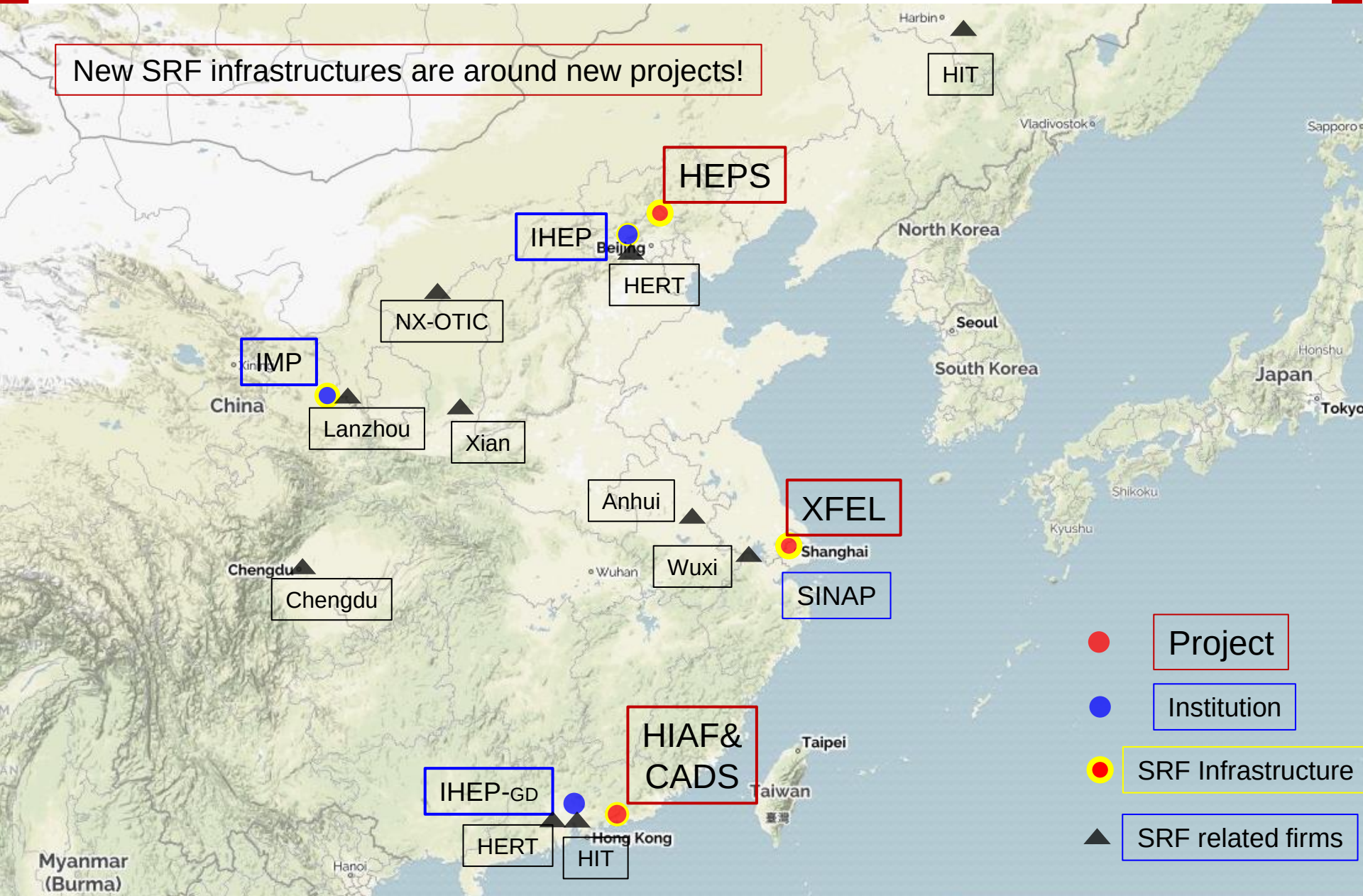
General information of SRF R&D programs

	IMP	IHEP	PKU	SINAP
Driven project	HIAF/ADS	HEPS/CEPC/ ILC/ADS	XFEL	XFEL
Infrastructure locations	HIAF site Huizhou	HEPS site Huairou	Same location	XFEL site Zhangjiang
SRF R&D fund	TBD	~50M$	~10M$	~100M$

SRF Infrastructures in major institutions

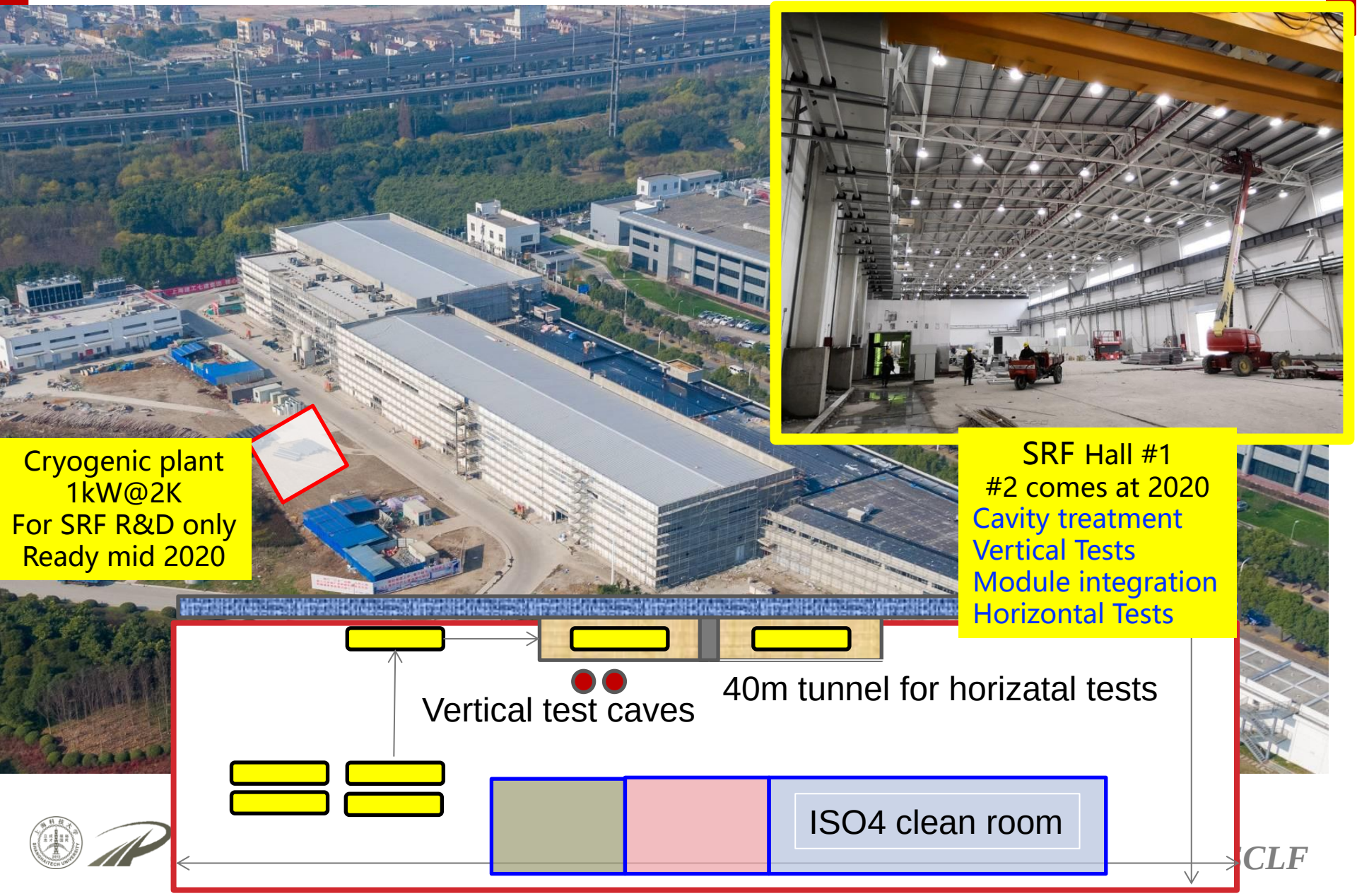
	Cryoplant-T	VTS	Space	CM-int./HTS	EP/N_doping
PKU	70W@2K	1x2cav	~2000m^2	2-cav CM	Yes/9-cell
IHEP-HR	300W@2K	3x4cav	~4500m^2	8-cavCM/2HT	Yes/9-cell
IMP-GD	TBD	yes	~TBD m^2	Yes	yes
SINAP	1000W@2K	4x4 cav	~8000m^2	8-cavCM/4HT	Yes/9-cell

Locations of SRF infrastructure / Industry




SSRF
3.5GeV Light Source
Soft XFEL User Facility
1.5GeV e- / ~1keV x-ray
532m, 2 FEL lines/5 stations
Hard XFEL
8 GeV SC, 3.1km
3 FEL lines, 10 stations
Photon science complex at Shanghai

SRF R&D Halls and cryogenic plant at SINAP



New SRF infrastructure at SINAP

- 2 SRF Halls + CM storage : total 8000m^2
- SRF treatments/CM integrations
- 1kW@2K cryogenic plant
- 4 VT caves
- 2x40m bunkers: 4 HTS

Different scenarios envisioned

- 4x4-cavity and 4xCM tests
- 2-CMs HT with interconnect
- gun + 1-2 CMs = beam test
- SXFEL wide tunnels for several CMs (~ a SC VUV FEL)

Domestic & international collaborations on prototypes & R&D

- at least 5 prototype CMs (CM#-5 to CM#-1)
  - component R&D and supply chain
  - cavity VT and component tests (use PKU/IHEP VTS until 2020)
  - CM integrations
  - HT (1kW CP ready in 2020)

- N-Doping, infusion R&D
  - infrastructure

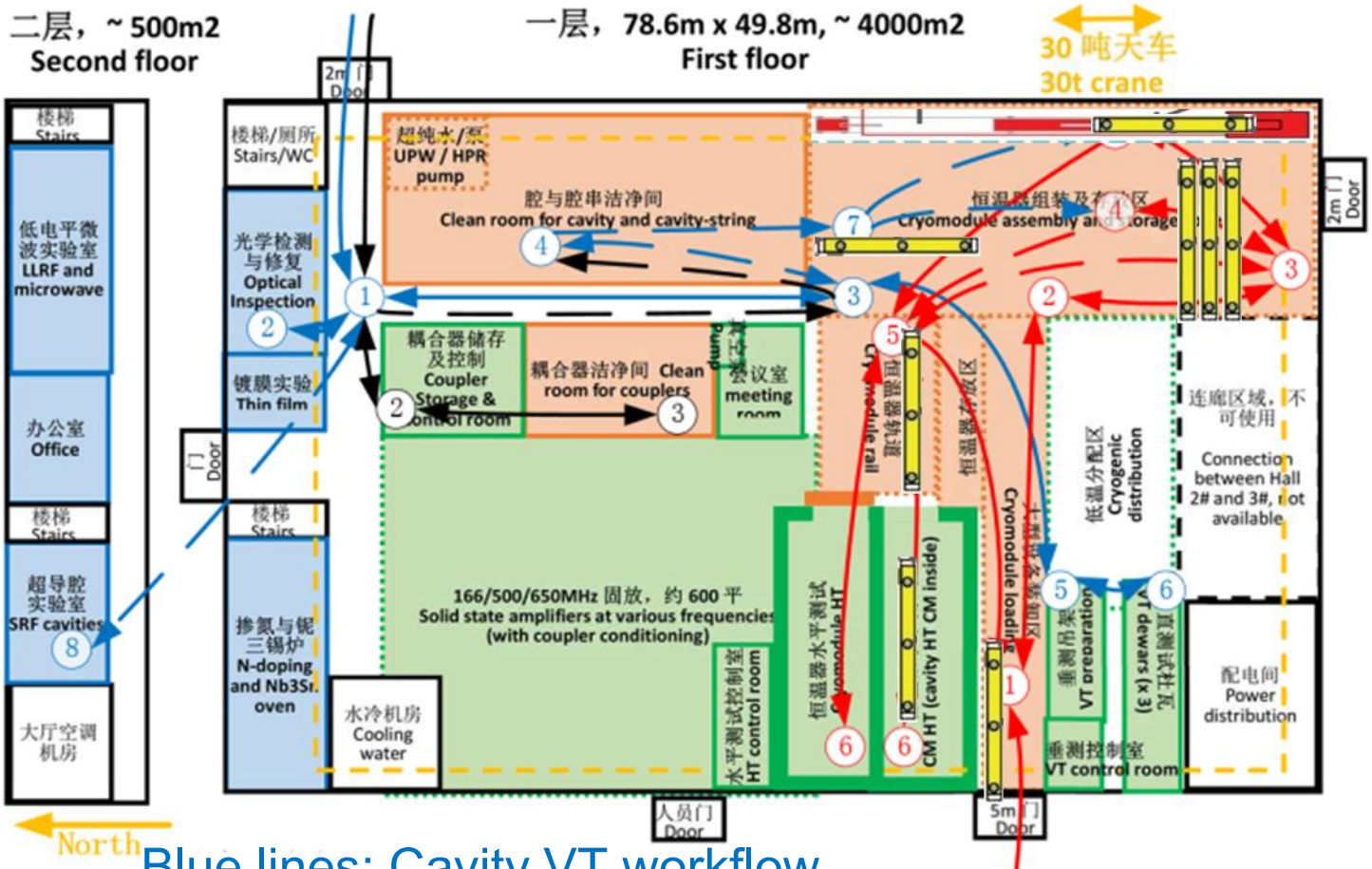
  - above all, build up a good team (& collaborations)
  - recruiting both experienced & young people
  - reviews/workshops/committees ahead

IHEP's new infrastructure: PAPS

- "Platform of Advanced Photon Source Technology R&D", to provide infrastructure for construction of future project.
- Budget: 500M CNY funded by Beijing Gov.
- Construction: 2017.5-2020.6
- Consist of 7 systems:
  - **RF system**
  - **Cryogenic system**
  - Magnet technology
  - Beam test
  - X-ray optics
  - X-ray detection
  - X-ray application

Layout of the SRF facility at IHEP's PAPS

- 3 VT dewars
- 2 HT caves
- 500m^2 CR
- FPC aging in CR ISO7
- Optic inspec.
- Pre-tuning
- Furnace
- Nb_3Sn oven
- Nb-Cu sputtering
- T-mapping
- Second sound
- ……



Blue lines: Cavity VT workflow

Black lines: FPC conditioning workflow

Red lines: CM assembly and test workflow

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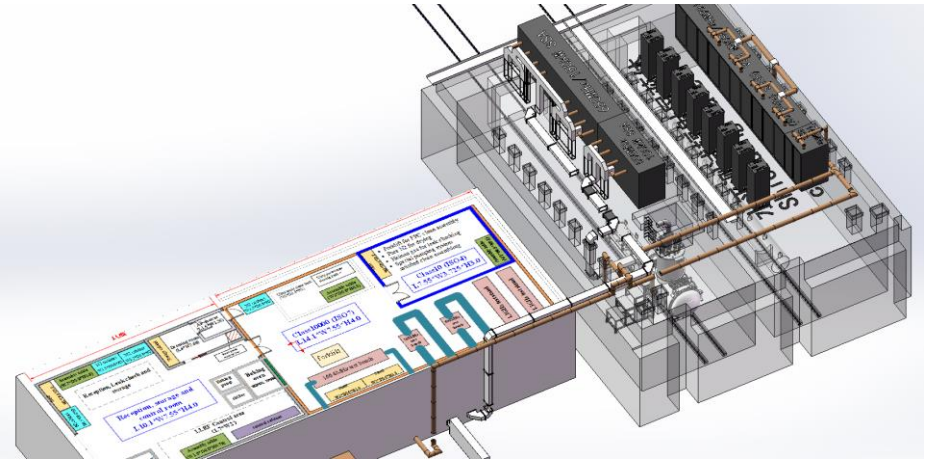
New infrastructure at HEPS campus

- SRF facility construction
  - Civil construction is on going, and will be finished by Oct. 2018.
  - Purchase on equipments is on going, and installation will be finished by Mar. 2019.
  - Commissioning of the cryogenic system will be finished before Oct. 2019.
- R&D activities
  - N-doping study has started: samples were analyzed; baseline cavities were tested; more cavities were under fabrication.
  - Tunable FPC for CEPC has been designed.



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SRF related industry: a glance

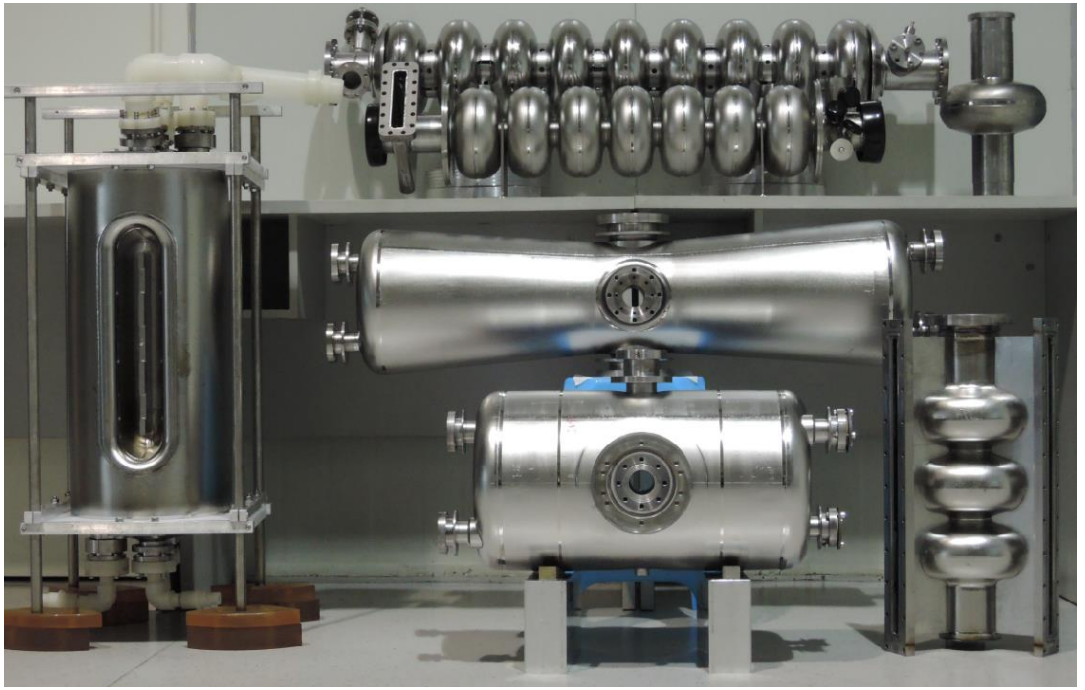
Domestic suppliers of major SRF components (incomplete)

	Nb-materials	Cavity-FPC	Cryostat	SSA
NX-OTIC(-PKU)	int. supplier	Cavity		
HERT(-IHEP)		Cavity/FPC		
HIT(-IMP)		Cavity		
RuiYuan(-IMP)		Cavity		
WUXI-inno.			yes	
Wanrui-			yes	
BG-electronics				yes
CD				yes

SRF cavity supplier- Ningxia OSTEC

#	Cavity type	Number
1	1.5GHz single cell	1
2	HWR β=0.29 For FRIB	7
3	1.5GHz 7cell	2
4	β=0.085 162.5MHz QWR	2
5	325MHz HWR	2
6	1.3GHz 3cell slot cavity	1
7	162.5MHz Taper HWR015	2
8	Spoke012	5
9	Spoke021	5
10	1.3G single cell	12
11	650MHz single cell/2-cells	3 / 2
12	162.5MHz Taper HWR009	2
13	Large grain 1.3GHz 9cell	6
14	Deflection cavity	1

Ningxia Orient Superconductor Technology Co., Ltd (OSTEC)



HERT by IHEP

北京高能锐新科技有限责任公司
Beijing HE-Racing Technology Co., Ltd.

- Beijing HE-Racing Technology company is experienced in production of jacked SRF cavities, FPC couplers, and other NC accelerator components
- A new post processing facility is to be built in 2018.


Press Machine


CNC Turning Center


Vertical Machining Center


WEDM


CMM Machine

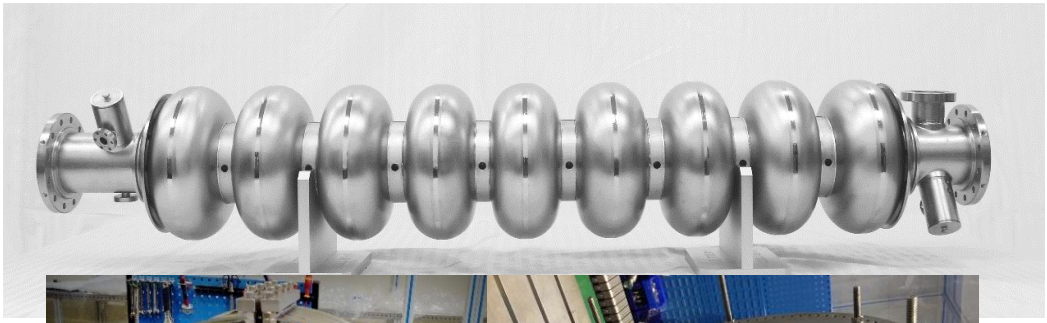

Vacuum Furnace

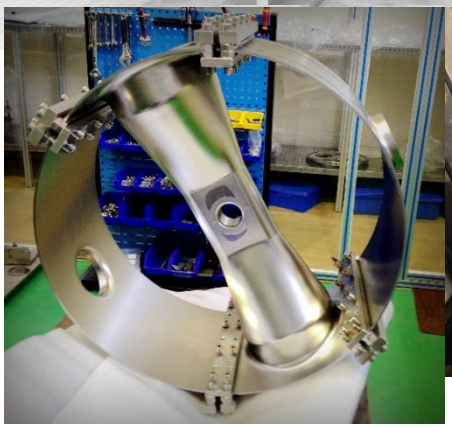

EBW Machine

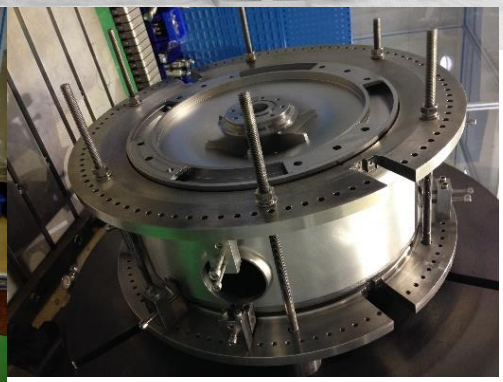

Helium Leak Detector

HERT (SRF cavities)

- 14 SRF cavities have been fabricated, including spoke cavities, elliptical cavities, and QWRs.
- More elliptical and spoke cavities are in progress
- Capability: ~80 cavities per year.







Cavity type	Freq.(MHz)	Time	Status
C-ADS Spoke012	325	2015	Beam commissioned
C-ADS Spoke021	325	2015	Beam commissioned
ILC 9cell TESLA	1300	2016	Vertical tested
HEPS-TF QWR	166.6	2017	Vertical tested

HERT (FPC couplers)

- More than 60 FPCs have been fabricated
- Capability: ~100 FPC couplers per year

Project	Freq. MHz	Power (kW)
BEPCII	500	Test: CW, 420 kW Oper.: CW, 150 kW
C-ADS	325	Test: CW, 10 kW Oper.: CW, 10 kW
C-ADS	162.5	Test: CW, 10 kW Oper.: CW, 10 kW
ILC R&D	1300	Test: 1 MW, 1.5 ms, 5 Hz
C-ADS	325	Test: CW, 105 kW Oper.: CW, 100 kW
C-ADS	162.5	Oper.: CW, 80 kW

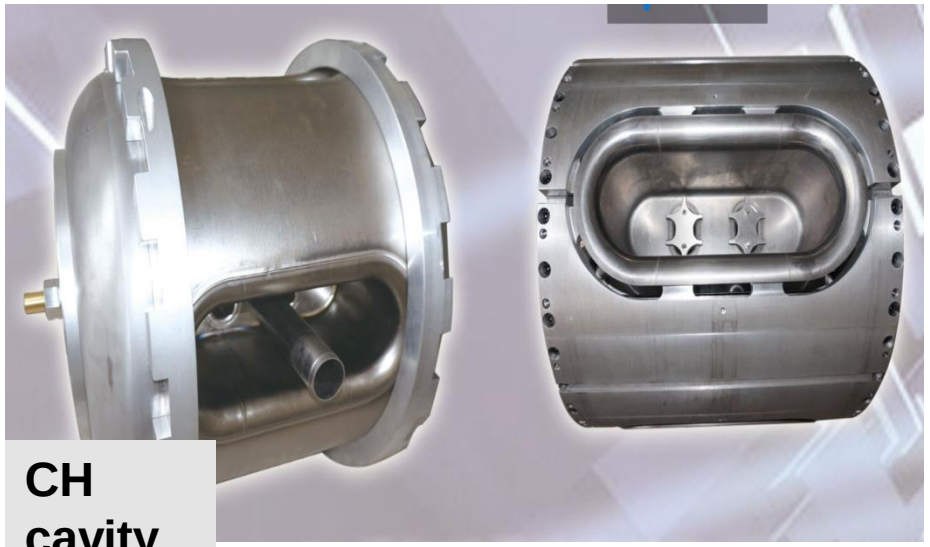
Industry: SRF Cavity (HIT)

Build more 50 cavities
Planning to expanded production
Planning 1000 cavities/year

SCLF

SRF cavity supplier- RuiYuan

Lanzhou Ruiyuan Machinery and Equipment Co., Ltd.(LRME) is a private high-tech enterprises founded on the basis of a group working on military technical production. The company is major in the designing and manufacturing of high technology, scientific research and production equipment, such as modern physics equipment, superconductivity, electrical, magnetic and application of ultra high vacuum technology.



CH cavity

HWR helium vessel

Kiker

Permanent magnetic high charge state ion source

SCLF

Wuxi-inno. for cryostat

Outlook

- Large accelerator projects got a boost in past 2 years, in which most of them are SRF-based.
- SRF R&D were far from enough so far. Domestic SRF industries are limited yet growing steadily.
- New funding for infrastructures and prototyping will help greatly in next few years.
- Fairly long way to go for the new projects. We are at the starting point. Collaborating is essential.