Progress on CEPC RF System

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2021 CEPC International Accelerator Review Committee Meeting

May 12, 2021

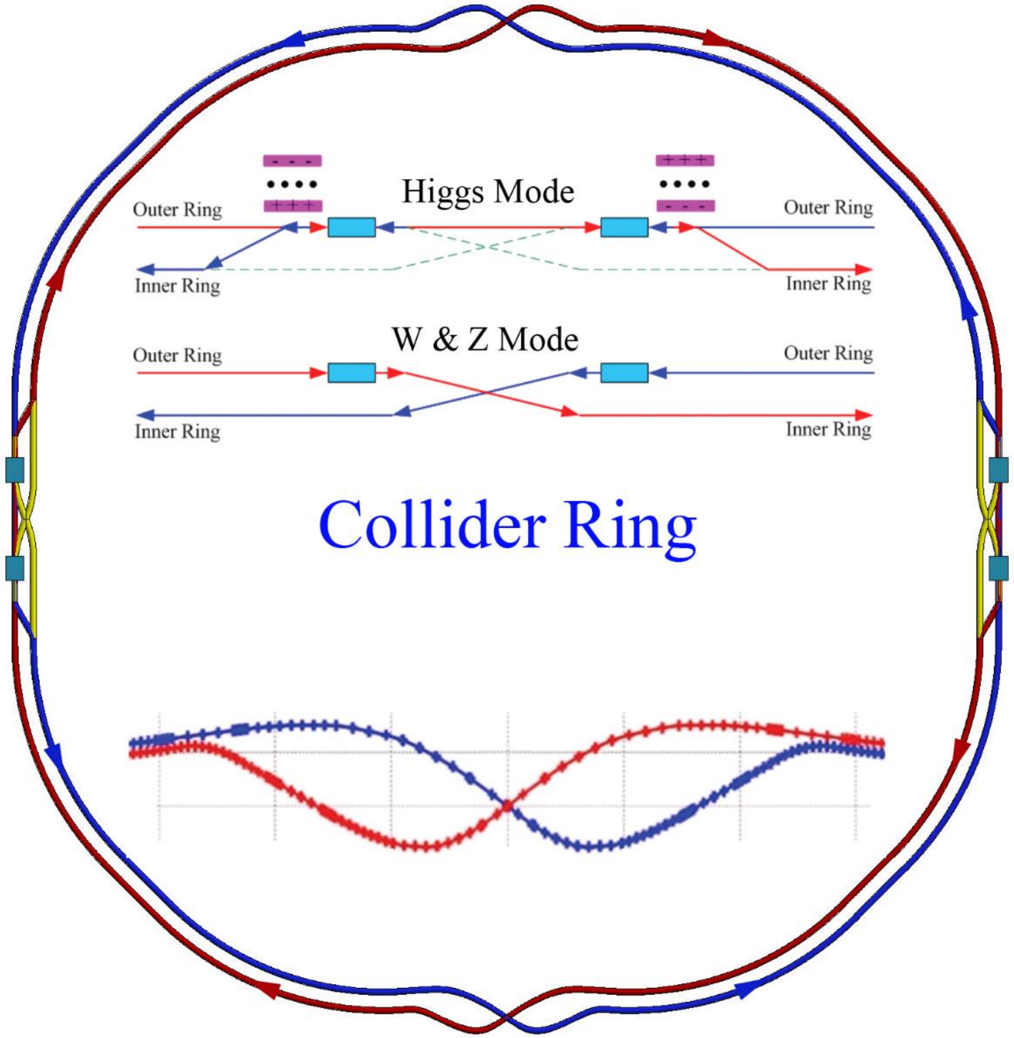
Outline

Update from last CEPC IARC meeting (Nov 2019)

SRF highlights in last 18 months:

1. New RF staging and bypass scheme
2. Beam cavity interaction
3. High Q and gradient cavity (650 MHz & 1.3 GHz, mid-T & EP)
4. High power components (input coupler, HOM coupler & absorber)
5. Cryomodule integration (650 MHz & 1.3 GHz)
6. SRF facility (PAPS)
7. Beam test facility (PAPS)

CEPC CDR SRF Layout and Parameters



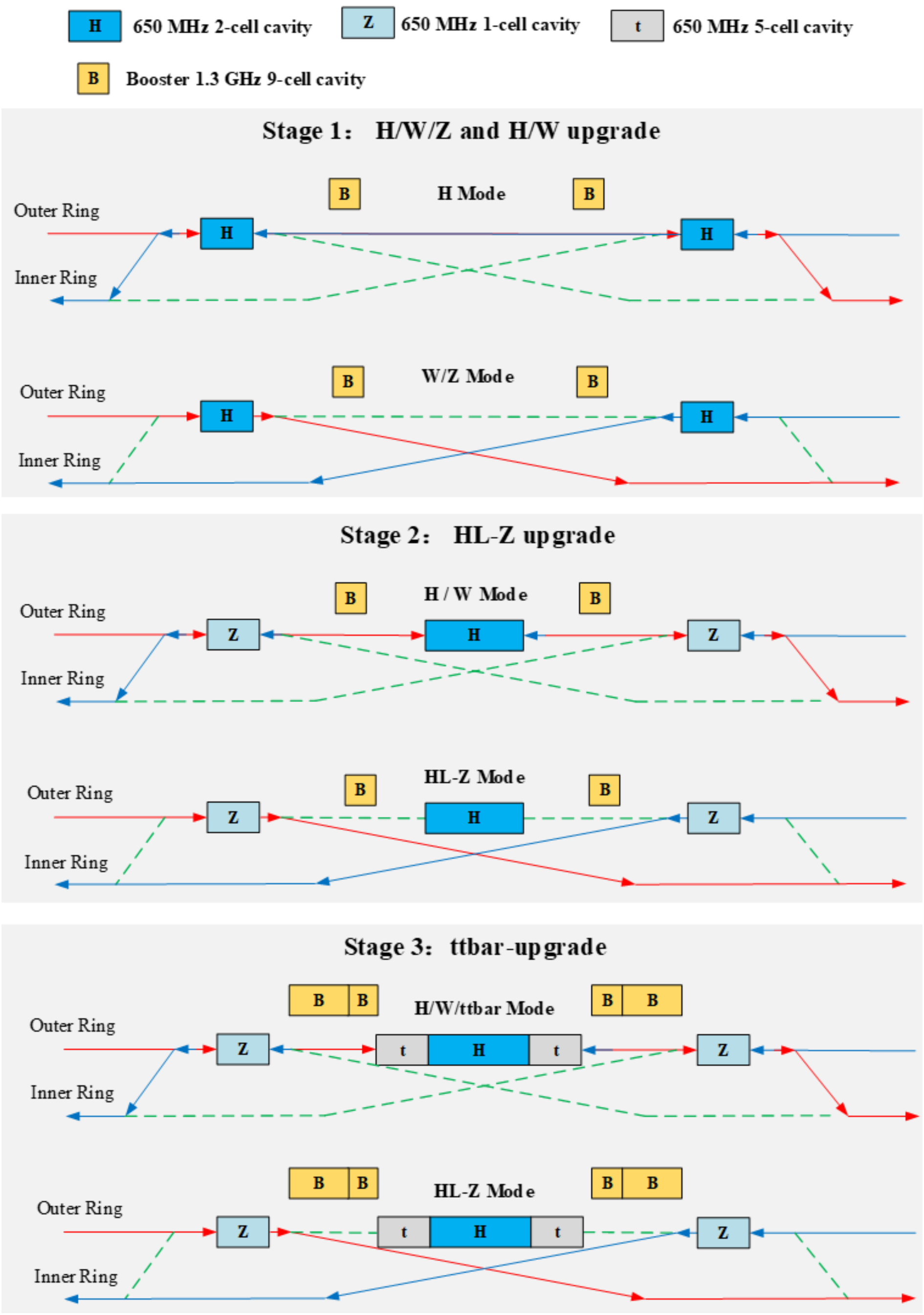
	H	W	Z
Collider Ring	**650 MHz 2-cell cavity**		
Lumi. / IP (10^{34} $cm^{-2}s^{-1}$)	2.93	10.1	16.6 / 32.1
RF voltage (GV)	2.17	0.47	0.1
Beam current (mA)	17.4 x 2	87.7	460
SR power / beam (MW)	30	30	16.5
Cavity number	240	108 x 2	60 x 2
Q_0 at max gradient	4E10 @ 22 MV/m (vertical test) 1.5E10 @ 20 MV/m (long term operation)		
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 (vertical test) 1E10 @ 20 MV/m (long term operation)		

New CEPC Collider Ring Parameters

20210413	ttbar	Higgs	W	Z
Number of IPs	2			
Circumference [km]	100.0			
SR power per beam [MW]	30			
Half crossing angle at IP [mrad]	16.5			
Bending radius [km]	10.7			
Energy [GeV]	180	120	80	45.5
Energy loss per turn [GeV]	9.1	1.8	0.357	0.037
Piwinski angle	1.21	5.94	6.08	24.68
Bunch number	35	249	1297	11951
Bunch population [10^10]	20	14	13.5	14
Beam current [mA]	3.3	16.7	84.1	803.5
Momentum compaction [10^-5]	0.71	0.71	1.43	1.43
Beta functions at IP (bx/by) [m/mm]	1.04/2.7	0.33/1	0.21/1	0.13/0.9
Emittance (ex/ey) [nm/pm]	1.4/4.7	0.64/1.3	0.87/1.7	0.27/1.4
Beam size at IP (sigx/sigy) [um/nm]	39/113	15/36	13/42	6/35
Bunch length (SR/total) [mm]	2.2/2.9	2.3/3.9	2.5/4.9	2.5/8.7
Energy spread (SR/total) [%]	0.15/0.20	0.10/0.17	0.07/0.14	0.04/0.13
Energy acceptance (DA/RF) [%]	2.3/2.6	1.6/2.2	1.2/2.5	1.3/1.7
Beam-beam parameters (ksix/ksiy)	0.071/0.1	0.015/0.11	0.012/0.113	0.004/0.127
RF voltage [GV]	10	2.2	0.7	0.12
RF frequency [MHz]	650	650	650	650
HOM power per cavity (5/2/1cell)[kw]	0.4/0.2/0.1	1/0.4/0.2	-/1.8/0.9	-/-/5.8
Qx/Qy/Qs	0.12/0.22/0.078	0.12/0.22/0.049	0.12/0.22/	0.12/0.22/
Beam lifetime (bb/bs)[min]	81/23	39/18	60/717	80/182202
Beam lifetime [min]	18	12.3	55	80
Hour glass Factor	0.89	0.9	0.9	0.97
Luminosity per IP[1e34/cm^2/s]	0.5	5.0	16	115

CEPC SRF System Design for Higher Luminosity

- **TDR design of CEPC SRF system is aiming to fulfill requirements of improvements over CDR:**
  - higher luminosity at H (5.0×10^{34} vs 2.9×10^{34}) → RF basically no change
  - "high-lumi" for Z (105×10^{34} vs 32×10^{34}) → RF staging and bypass scheme
  - compatible for top-pair production → reserved tunnel space
  - capable to handle 50 MW SR power → reserved tunnel space, RF staging and bypass scheme
- **New RF layout and parameters optimization at each energy with the new by-pass schemes is ongoing.**
- **SRF layout, configuration, parameters, specifications and cost will be upgraded and re-baselined accordingly.**



New RF Staging & By-pass Scheme for CEPC

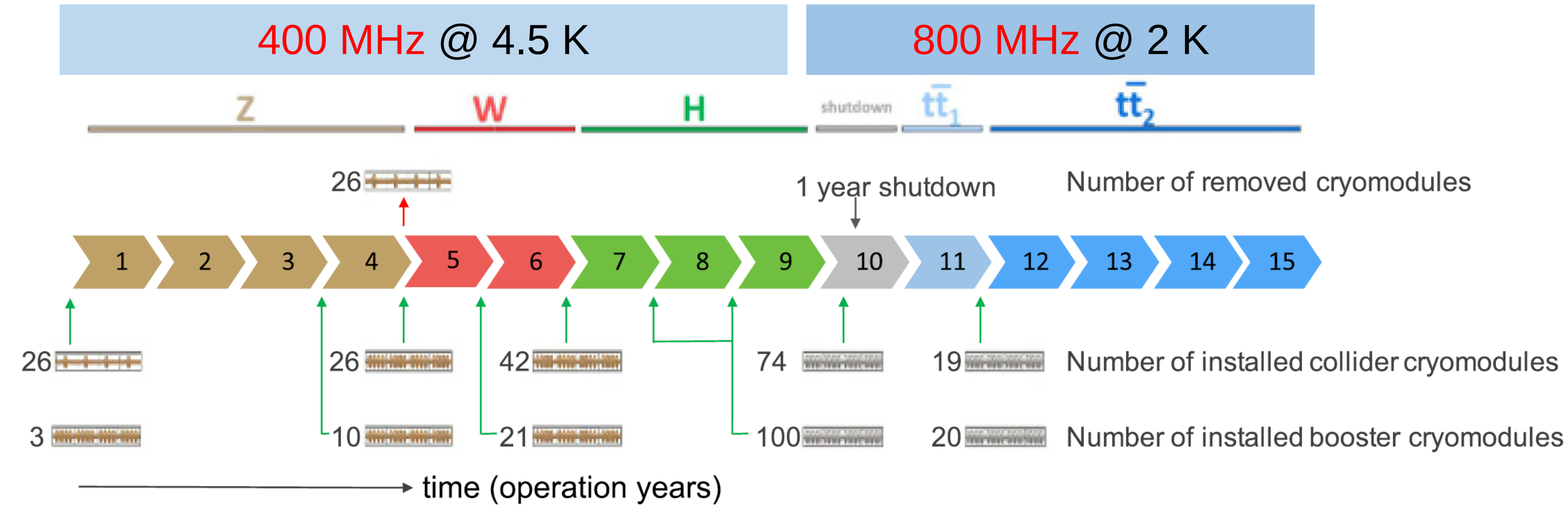
Stage 1 (H/W run for 8 years): keep CDR RF layout for H/W and 50 MW upgrade. Common cavities for H. Separate cavities for W/Z. Z initial operation for energy calibration and could reach CDR luminosity. Minimize first phase construction cost and hold Higgs priority.

Stage 2 (HL-Z upgrade): move Higgs cavities to center, add 2x100 MV 650 MHz high current Z cavities (international sharing for modules and RF sources). By-pass low current H cavities.

Stage 3 (ttbar upgrade): add ttbar cavities (international sharing): Collider + 7 GV 650 MHz 5-cell cavity, Booster + 6 GV 1.3 GHz 9-cell cavity. Both low current, high gradient, high Q. Nb_3Sn@4.2 K or others.

- **Unleash full potential of CEPC with operational flexibility.**
- **Seamless mode switching with unrestricted RF performance at each energy until AC power limit.**
- **Stepwise construction cost, technology risk and international involvement.**

FCC-ee CDR RF Scheme and Alternatives



600/650 MHz 2/5-cell

1.2?/1.3 GHz 9-cell

- 650 MHz for CEPC Collider: synergy with CSNS-II, CiADS, PIP-II, EIC, FCC-ee alternative
  650 MHz @ 2 K more efficient than 4.2 K, high Q technique will apply
- 1.3 GHz natural for CEPC Booster: synergy with FEL and ERL, ILC, FCC-ee alternative

FCC-ee CDR RF Parameters

Table 3.12. Detailed RF configuration of each machine and booster ring.

	Z		WW		ZH		$t\bar{t}_1$		$t\bar{t}_2$	
	per beam	booster booster	per beam	boo-ster	per beam	booster booster	2 beams	booster	2 beams	booster
Total RF voltage [MV]	100	140	750	750	2000	2000	9500	9500	10 930	10 930
Frequency (MHz)	**400**									
RF voltage [MV]	100	140	750	750	2000	2000	4000	2000	4000	2000
E_{acc} (MV/m)	5.1	8	9.6	9.6	9.8	9.8	10		10	
# cell / cav	1	4	4		4		4		4	
V_{cavity} (MV)	1.92	12	14.4	14.4	14.7	14.7	15		15	
# cavities	52	12	52	52	136	136	272	136	272	136
# CM	13	3	13	13	34	34	68	34	68	34
T operation (K)	4.5		4.5		4.5		4.5		4.5	
Dyn losses/cav (W)	14	11	210	26	202	29	210	30	210	30
Stat losses/cav (W)	8		8		8		8		8	
Q_{ext}	4.4×10^4		6.6×10^5		1.9×10^6		4×10^6		4.7×10^6	
P_{cav} (kW)	962		962		368		175		149	
Frequency (MHz)	**800**									
RF voltage (MV)							5500	7500	6930	8930
E_{acc} (MV/m)							19.8	20	19.8	19.8
# cell/cav							5		5	
V_{cavity} (MV)							18.6	18.75	18.6	18.6
# cavities							296	400	372	480
# CM							74	100	93	120
T operation (K)							2		2	
Dyn losses/cav (W)							66	10	66	10
Stat losses/cav (W)							8		8	
Q_{ext}							3.9×10^6		5.6×10^6	
P_{cav} (kW)							176		155	

CEPC Collider Ring SRF Parameters Comparison

	BEPCII 500 MHz 4.2 K	**BEPC3** 500 MHz 4.2 K	**CEPC CDR H** 30 MW 3E34	**CEPC CDR Z** 16.5 MW 32E34	**CEPC TDR Z** 30 MW 105E34	**CEPC TDR H** 30 MW 5E34	**CEPC TDR W** 30 MW 19E34	**CEPC Ultimate Z 50 MW 167E34**
Beam current (mA)	400 (600)	900	2 x 17.4	460	**840**	2 x 16.8	2 x 88.5	1400
Cell number	1	1	2		1	2/1	2/1	1
Cavity number / ring	1	2	2 x 120	60	60	2x(90+60)	2x(90+60)	60
Eacc (MV/m)	6 (1.5 MV)	10 (2.5 MV)	19.7	3.6	**9.4**	**19.7**	4.2	9.4
Q_0 @ 4.2 K / 2 K	1E9	1E9	1.5E10	1.5E10	**1.5E10**	**1.5E10**	1.5E10	1.5E10
Total wall loss (kW)			6.1	0.1	0.35	6.1	0.27	0.35
Input power (kW)	110	150	250	275	**500**	250/125	250/125	**835**
Cavity# / klystron	1	1 SSA	2		1	2/1	2/1	1
Klystron power (kW)	250	150 SSA	800	800	800	800	800	1200
Total KLY number	2	4	120		120	90+120	90+120	120
HOM damper	Absorber	Absorber	Hook+ Absorber		Absorber	Hook+ Absorber	Hook+ Absorber	Absorber
HOM power (kW)	8*	20	0.6	1.9	2.4	0.46 / 0.23	**1.5** / 0.75	**4**

* Bunch length 15 mm, cavity cell HOM loss factor 0.1 V/pC, tapers 0.06 V/pC, absorbers 0.26 V/pC.

CEPC SRF Challenges

- Higgs: high Q at medium gradient
  - Technology frontier today: N-doping, mid-T and other heat treatment
  - Recent breakthrough at IHEP: world's first high Q 1.3 GHz 9-cell cavity with mid-T bake technology
- ttbar: high Q at high gradient
  - Long-term R&D (same with ILC): FE battle, N-infusion, traveling wave, new material (Nb3Sn and other thin film)
  - Recent result at IHEP: world leading high Q 650 MHz cavity at high gradient. First result of Nb3Sn and Nb/Cu cavity.
- W/Z: high current large ring
  - Unprecedented challenges compared to small ring: intense beam spectrum, large detuning compared to the rev. freq, small radiation damping especially for Booster at low energy
  - Input coupler power: high SR power sets the minimum cavity number limited by coupler power capacity
  - HOM damping (power and CBI): relative "high" RF voltage prefers multi-cavity CM (KEKB/BEPCII type cavity as fallback, slot WG cavity and other HOM damping scheme), bunch-by-bunch feedback for booster
  - Fundamental mode CBI (direct RF feedback, counter phasing, raise cavity voltage and input power), gap transient
  - Booster cavity HOM power: ~ 40 W average for HL-Z. "High current" 9-cell cavity (LCLS-II < 1 W, ERL ~ 200 W)

CEPC SRF Hardware Specifications

Hardware	Qualification	Normal Operation	Max. Operation
650 MHz 2-cell Cavity	VT 4E10 @ 22 MV/m HT 2E10 @ 20 MV/m	1.5E10 @ 20 MV/m	2E10 @ 20 MV/m
1.3 GHz 9-cell Cavity	VT 3E10 @ 24 MV/m	1E10 @ 20 MV/m	2E10 @ 23 MV/m
650 MHz Input Coupler (variable)	HPT 300 kW sw	< 280 kW	300 kW
1.3 GHz Input Coupler (variable)	HPT 20 kW peak, 4 kW avr.	< 20 kW peak	20 kW peak
650 MHz HOM Coupler	High power test at RT and 2 K: 1 kW	< 1 kW	1 kW
650 MHz HOM Absorber	High power test at RT: 5 kW	< 5 kW	5 kW
650 MHz Cryomodule (six 2-cell cavities)	static loss 5 W @ 2 K	static loss 8 W @ 2 K	static loss 10 W @ 2 K
Tuner (Collider & Booster)	tuning range and resolution 400 kHz / 1 Hz	300 kHz / 1 Hz	400 kHz / 1 Hz

CEPC SRF System TDR R&D Plan

TDR Phase 1: 2019-2020 (System Design, Components Prototyping)

- ✓ SRF system TDR design for higher luminosity (RF staging and bypass scheme proposed)
- ✓ High Q, high gradient cavity, high power components and other key technology R&D (meet CEPC specs)
- ✓ PAPS SRF facility construction (equipment installation)

TDR Phase 2: 2021-2022 (System Design, Cryomodule Prototyping)

- ☐ SRF system TDR design re-baseline and optimization
- ☐ 650 MHz high Q short cryomodule assembly, operation and improvement (to meet CEPC spec)
- ☐ 1.3 GHz high Q full cryomodule prototyping (to meet CEPC and CW FEL spec)
- ☐ SRF facility (PAPS commissioning, operation and upgrade)

Post-TDR: 2023-2025 (Cryomodule Prototyping, Mass-Production Preparation)

- SRF system Engineering Design, mass-production technology preparation
- 650 MHz full cryomodule prototyping
- 1.3 GHz high Q full cryomodule industrialization and mass production (for FEL projects)
- 650 MHz Z-pole high current cryomodule and ttbar cryomodule concept design
- Nb_3Sn cavity and cryomodule prototyping

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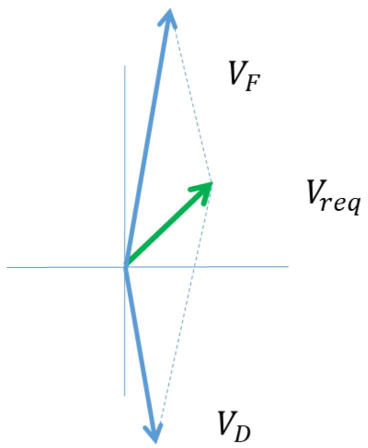
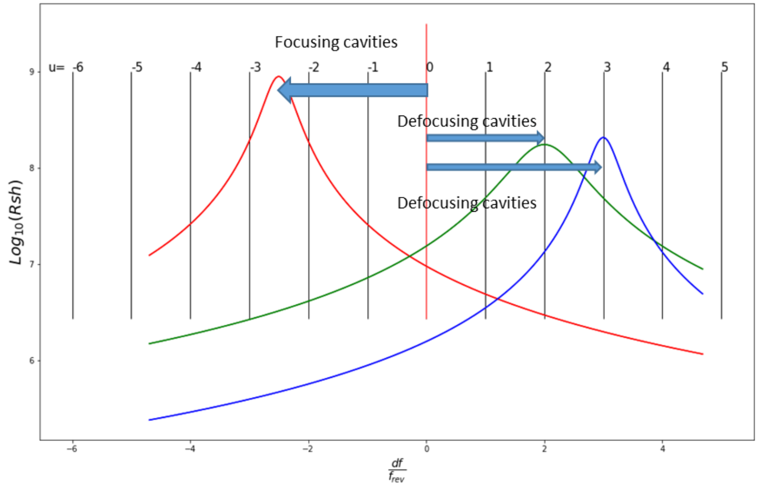
Counter Phasing for HL-Z

- Phasor Diagram
  - Some cavities focus, some defocus.
  - All cavities run at higher voltage.
  - Loaded Q is higher than normal operation.
  - Detune is decreased.
- Approved by the previous tests at KEK
- New spectrum
  - 40 focusing cavities are running at 4.7 MV, QL increased by a order of magnitude.
  - 20 defocusing cavities are positively detuned;
  - Gives us more knobs to turn.
- Potential benifit
  - Sacrifice some antidamping on the “+” modes to get some damping on the “-” modes.
  - Hopefully all modes will be manageable ($Im(\Omega) < 100$ [Hz]).

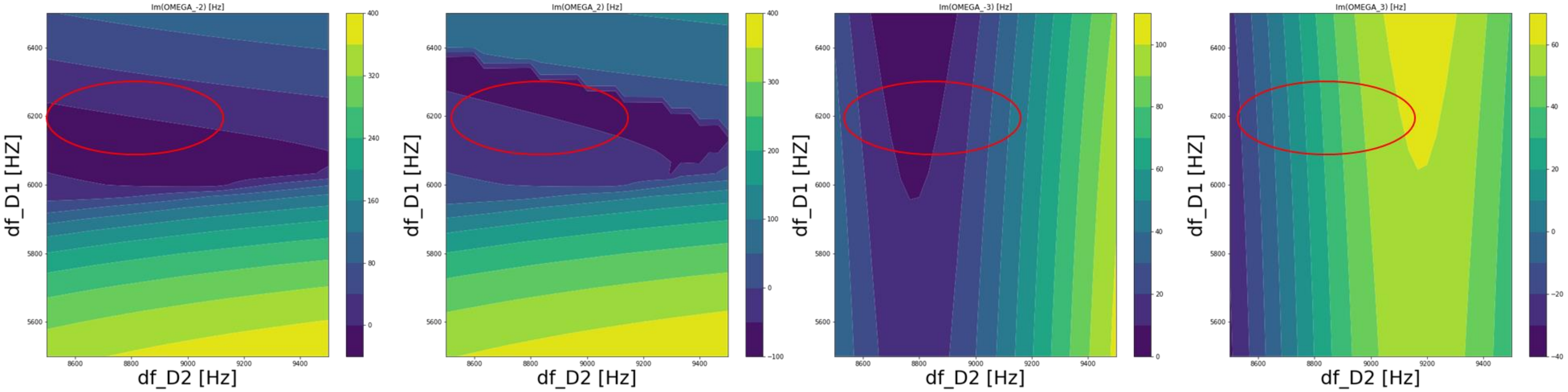




Xin Tianmu

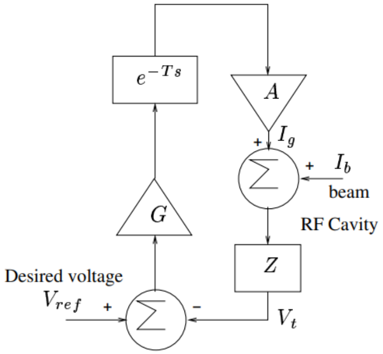
Counter Phasing for HL-Z

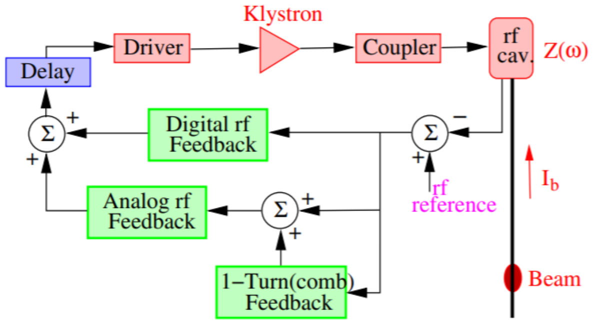
- Stability map
  - Here we showed the growth rate of the most dangerous modes $\mu = \pm 2, \pm 3$.
  - Using 10 cavites to damp the -2 mode and 10 to damp the -3 mode.
  - We noticed the exclusiveness of the stable zone between the modes with same absolute values. But now we might be able to find a region where the growth rates are all less than 100 Hz.
- Further study on power requirement, higher order (m>1) modes, tracking simulation.

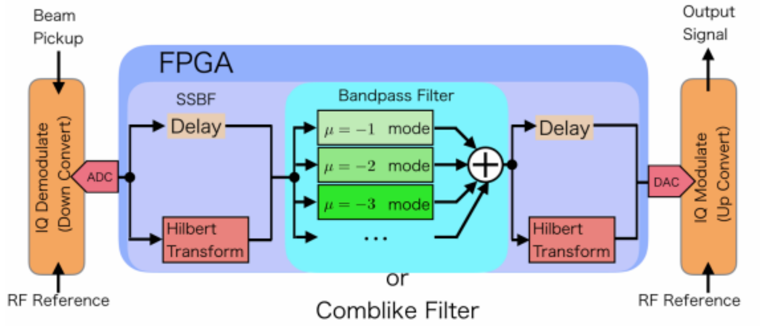


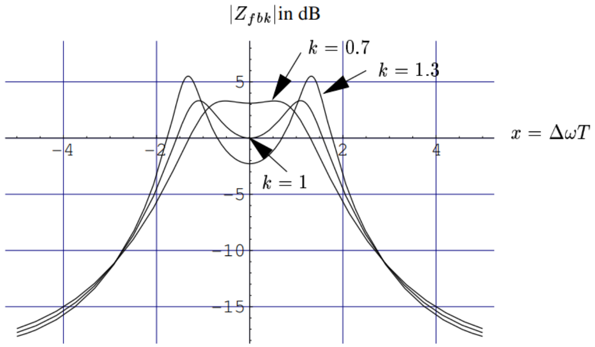
RF Feedback Methods to Damp FM CBI

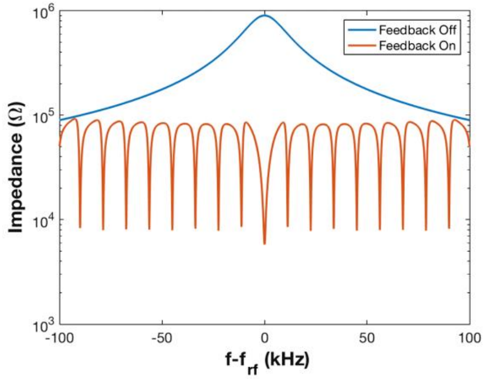
- Direct RF feedback: peak shunt impedance and the Q has simply been reduced. Unavoidable loop delay T limits the achievable impedance reduction.
- OTFB (one turn delay feedback) in LHC: RF feedback and comb filter to reduce the effective impedance of the cavity at the vicinity of the revolution frequency harmonics $f_{rf} + nf_{rev}$
- Mode by Mode feedback in SuperKEKB: single-sideband filter to filter the excitation mode sideband which is the lower sideband of transmit signals.

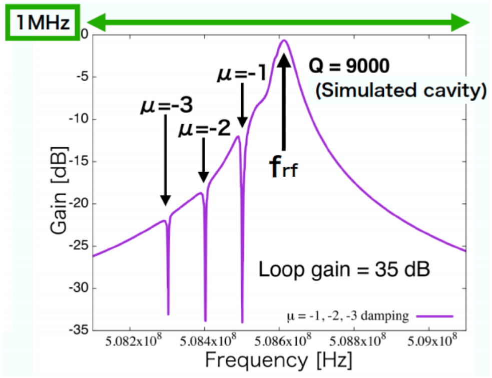












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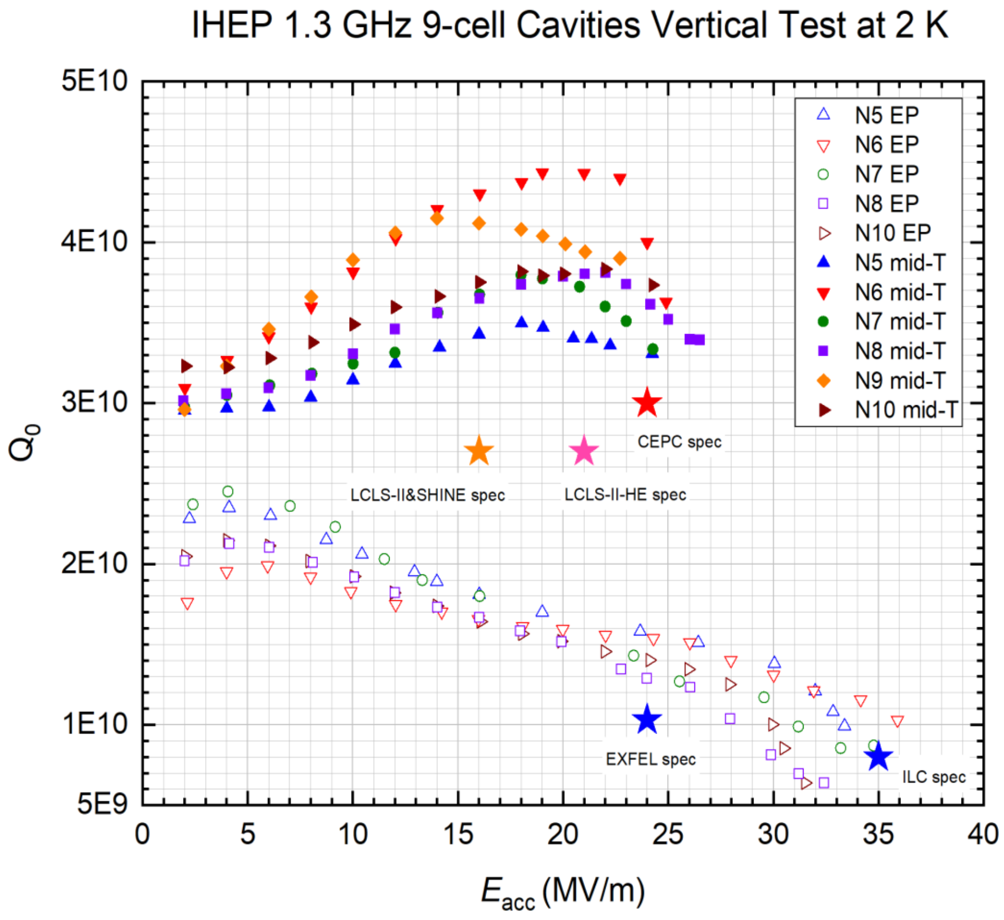
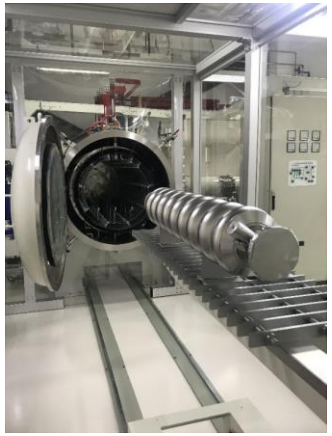
High gradient High Q 1.3 GHz 9-cell Cavity



9-cell EP facility commissioning started in April 2020, reached 36 MV/m in August, Mid-T high Q in October.

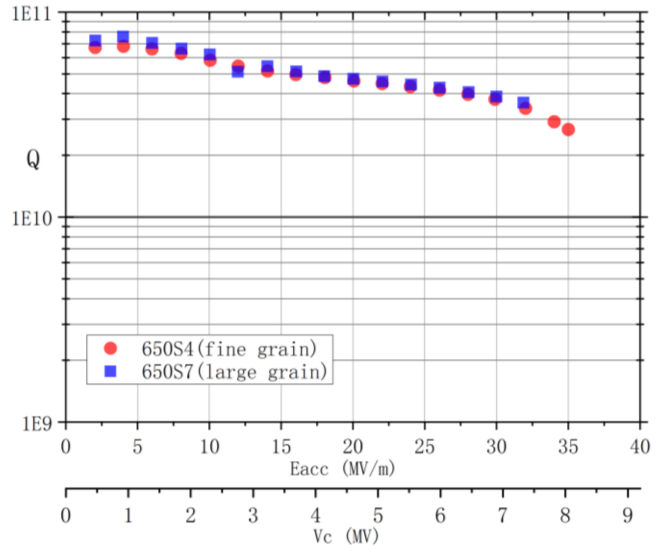


- Five EP 9-cells > 30 MV/m, max 36 MV/m, reach ILC spec.
- Six Mid-T Furnace Bake 9-cells: 3.4~4.5E10@16~22 MV/m, beyond CEPC, LCLS-II and LCLS-II-HE spec. World leading results comparable to LCLS-II-HE cavities.
- Aiming for 3E10@45 MV/m.

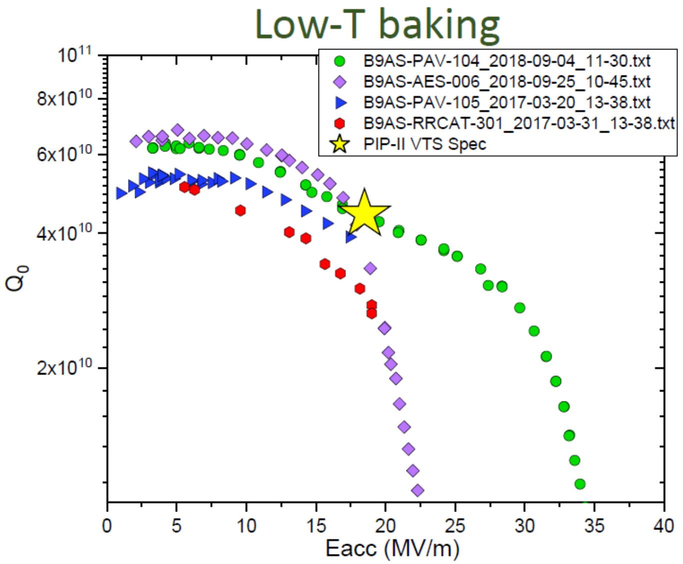
Pre-print https://arxiv.org/abs/2012.04817v1
TTC https://indico.desy.de/event/27572/contributions/94299/
LCWS https://indico.cern.ch/event/995633/contributions/4267322/

High gradient High Q 650 MHz 1-cell cavity

- 650 MHz 1-cell cavities reached 2.7E10 @ 35 MV/m after bulk BCP or FP (flexible polishing) 150 um + 950 C annealing + light EP 20 um + low-T bake. FP can replace bulk chemistry (BCP or EP).
- World record of 650 MHz cavity Q above 30 MV/m. Aiming for 3E10@40 MV/m.
- Bulk EP may further increase the gradient and Q. Novel heat treatment for even higher Q.

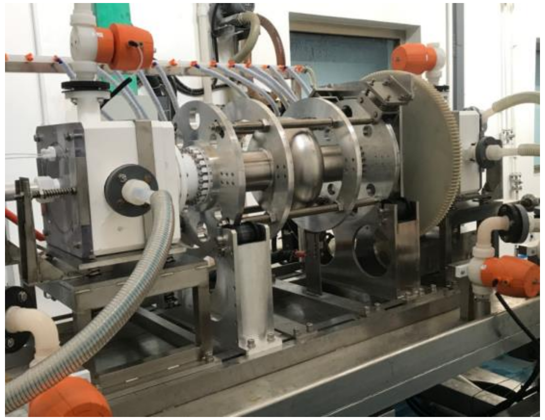


IHEP CEPC 1-cell



FNAL PIP-II HB650 1-cell in 0 B field

Courtesy of M. Martinello (FNAL)

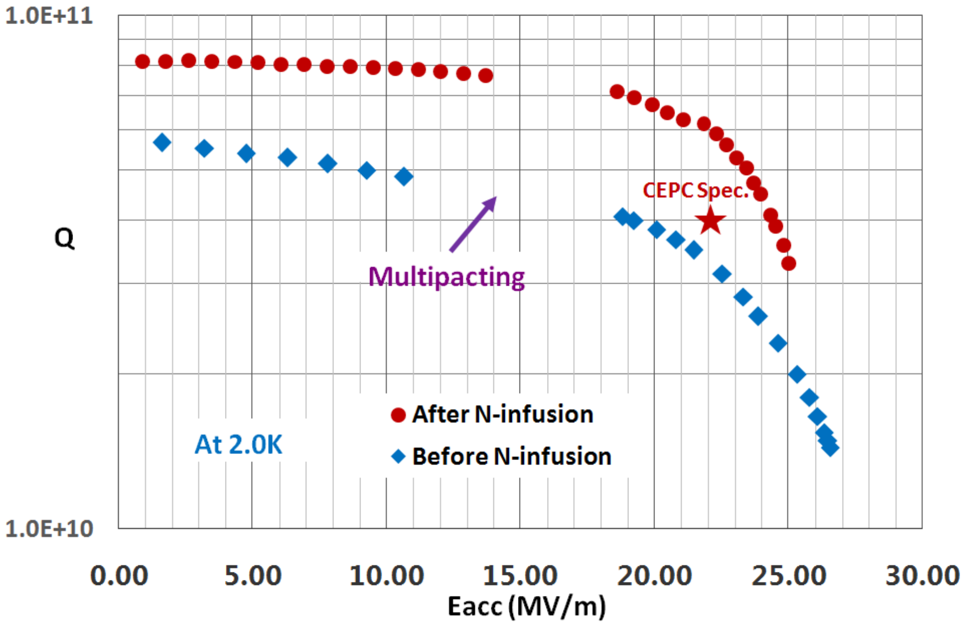


Compared to the 1.3 GHz cavities EP studied for years, 650 MHz cavities have different radial sizes, interior surface, volumes and so on, which require a lot of EP parameters optimization work.

PIP-II HB650, beta=0.9, G=260 ohm, Epeak/Eacc=2, Bpeak/Eacc=3.9 mT/(MV/m)
CEPC 650MHz 1-cell, beta=1, G=284 ohm， Epeak/Eacc=1.9, Bpeak/Eacc=4.2 mT/(MV/m)

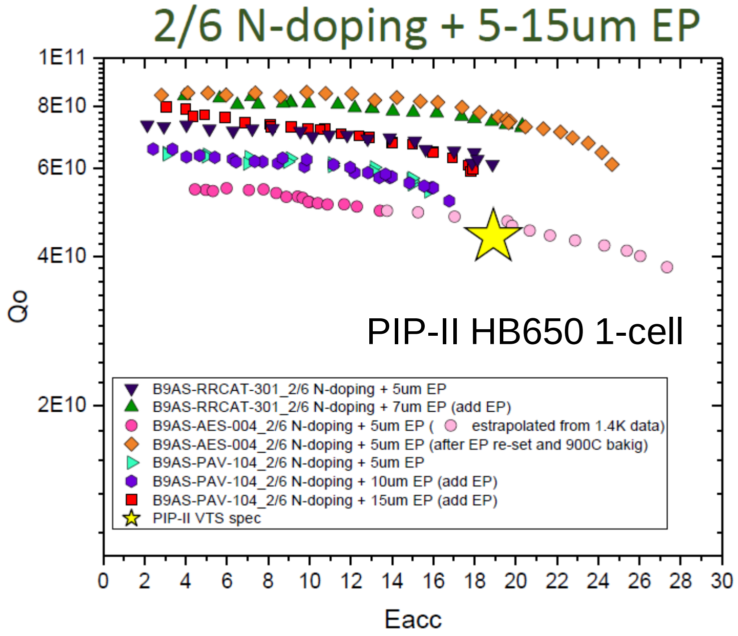
High Q N-infusion BCP 650 MHz 2-cell Cavity

- Nitrogen-infusion of the BCP cavity: 6E10@22MV/m, exceeds CEPC spec (4E10@Eacc=22MV/m)
- World record Q in BCP cavity. Q at 20 MV/m close to the N-dope+EP cavity.
- EP+N-infusion to further improve the gradient and Q.



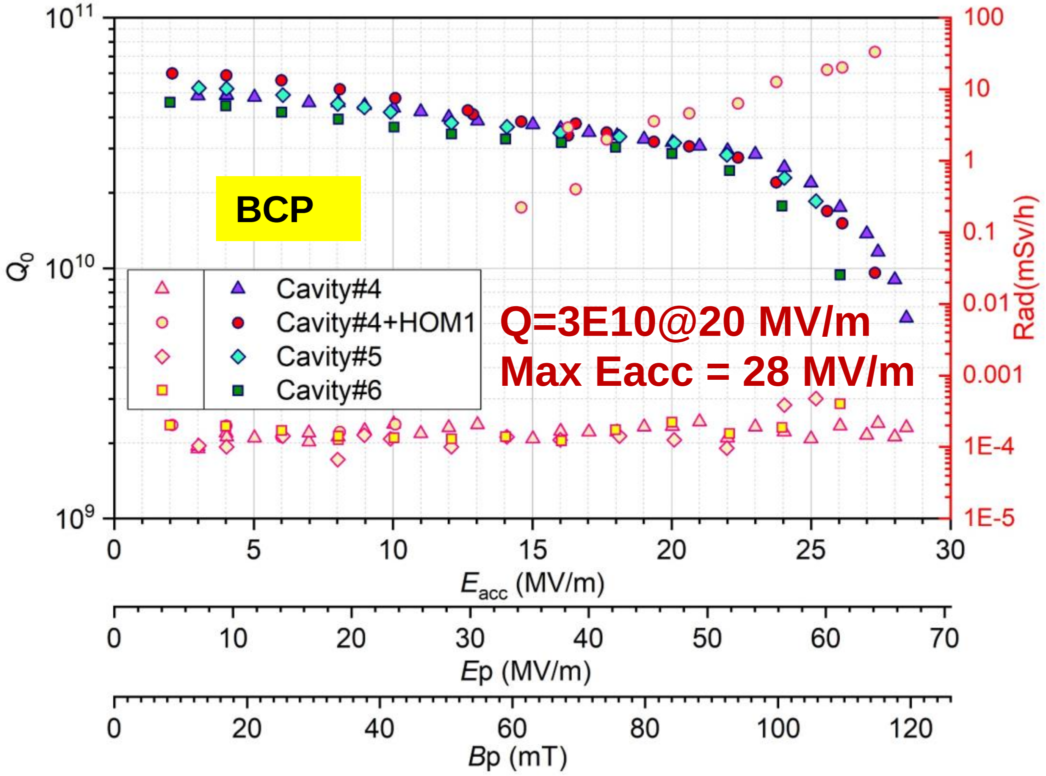
Courtesy of Jiankui Hao (PKU)

https://doi.org/10.1007/s41365-021-00881-3



Courtesy of M. Martinello (FNAL)

650 MHz 2-cell Cavity Vertical Test with HOM Couplers



- BCP 650 MHz 2-cell cavities: 2.8E10@22 MV/m (CEPC VT spec: 4E10@22 MV/m)
- Performance no change after install HOM coupler
- EP/heat treatment to further improve gradient and Q

https://doi.org/10.1016/j.nima.2021.165093

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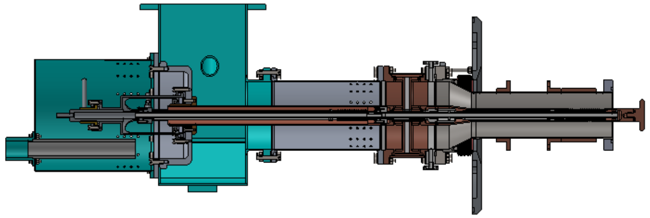
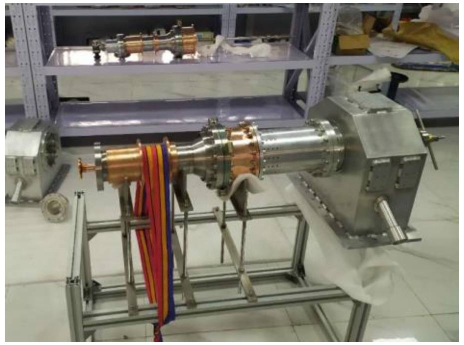
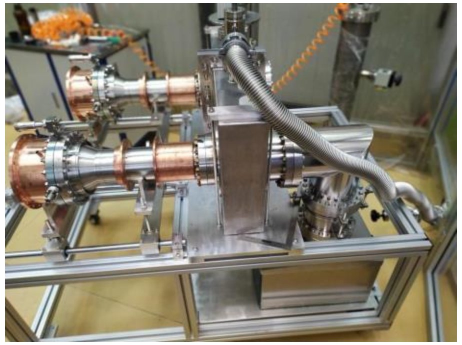
CEPC 650 MHz High Power Variable Coupler

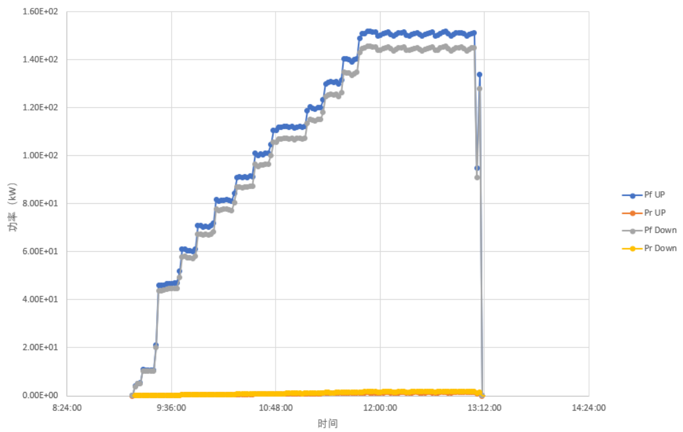
- 650 MHz **variable couplers** tested to CW TW 150 kW (SSA power limit), SW 100 kW (corresponding to 400 kW TW power at the window, exceeds CEPC spec 300 kW). One of the world highest variable couplers.
- High power test with CEPC 800 kW klystron soon (need high power circulator)



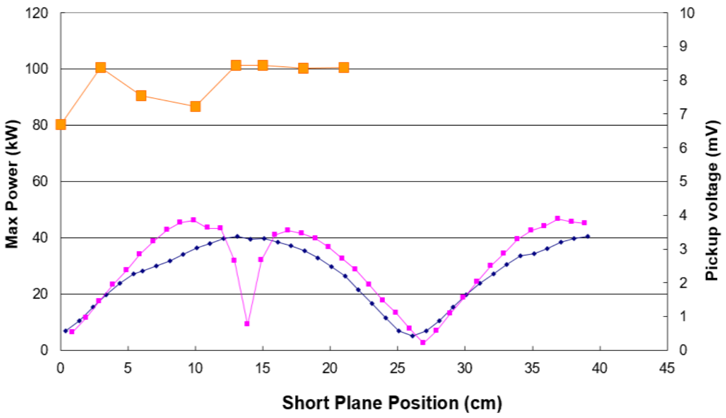
Bellow on inner conductor. Inner conductor water cooling. Outer conductor He gas cooling.



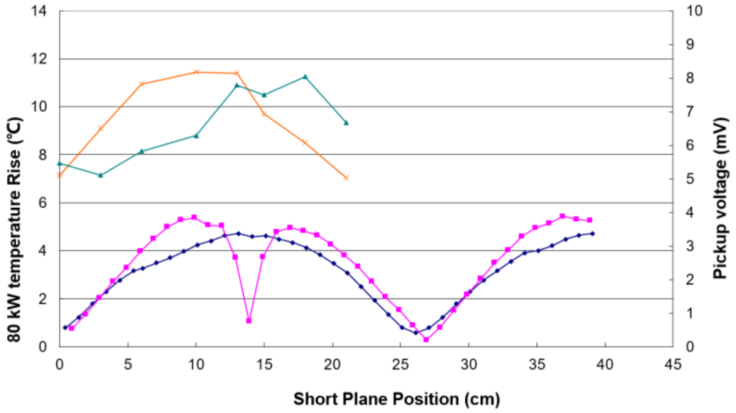




TW high power test to 150 kW

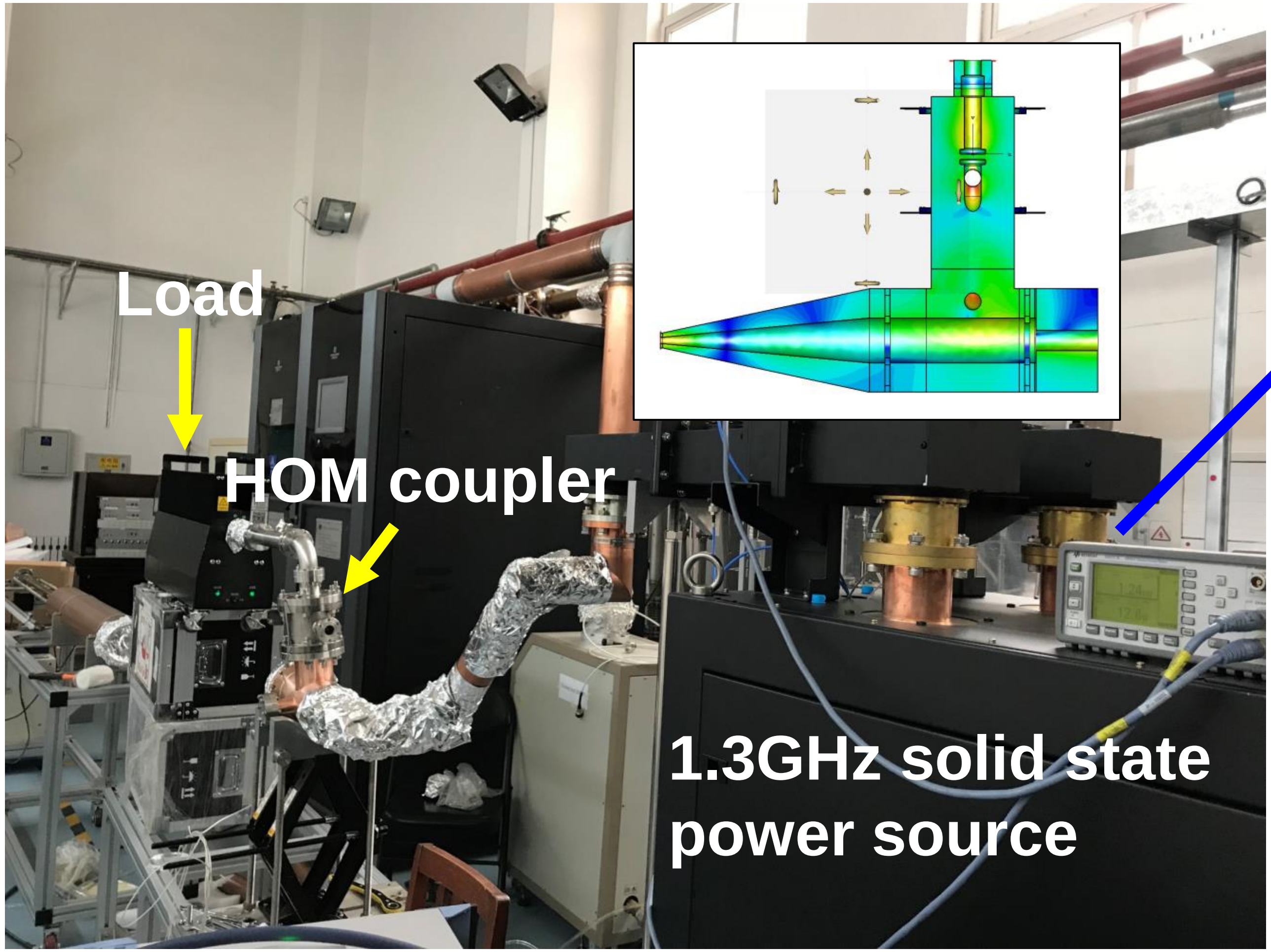


Window SW field and power



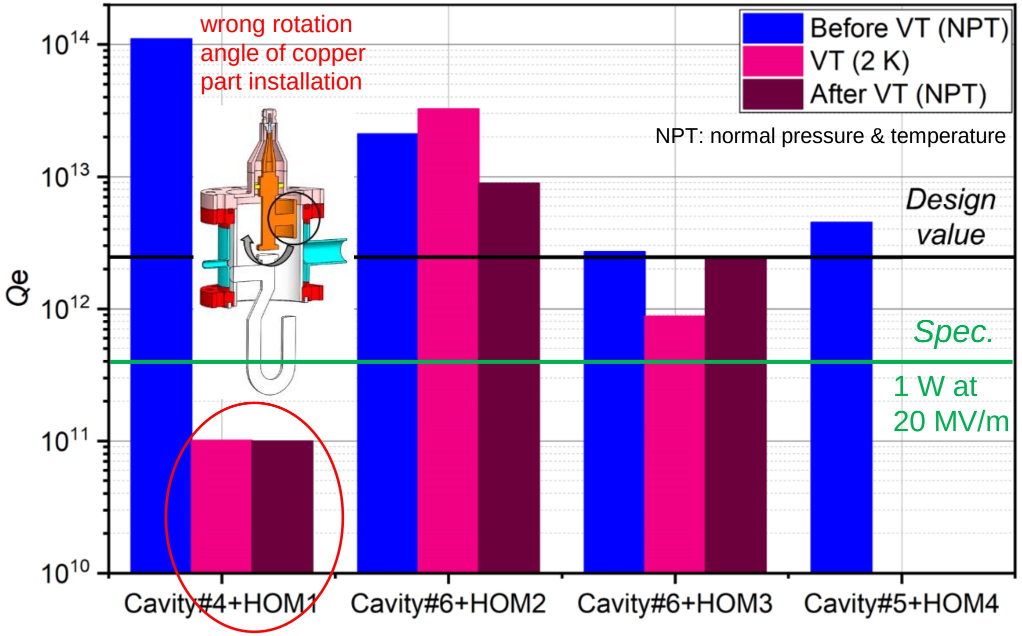
Window SW field and temperature rise

HOM Coupler High Power Test



- Input power: 1.3 kW
- Reflection power: 8.6 W
- Room temperature: 20.5℃
- Temperature on HOM coupler pick up: 29.4℃
- Meet CEPC spec. Cold test planned.

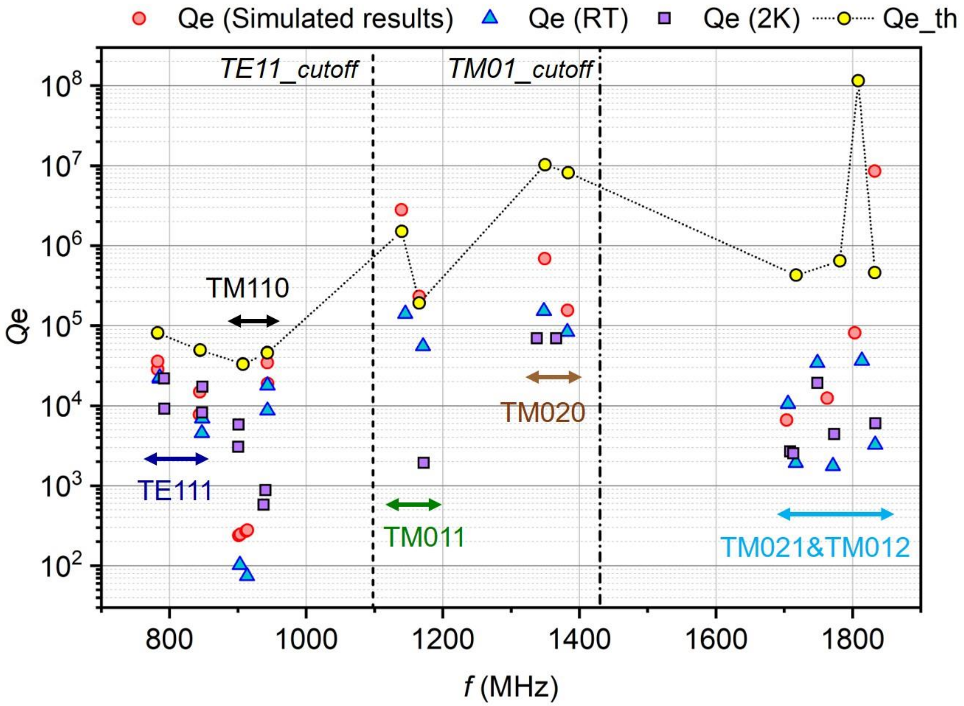
HOM Coupler RF Performance



Fundamental mode rejecting Q_e

Near or larger than 1×10^{12} at 2 K. Test results before and after VT are repeatable if installed correctly.

https://doi.org/10.1016/j.nima.2019.163094
https://doi.org/10.1007/s41605-019-0143-x

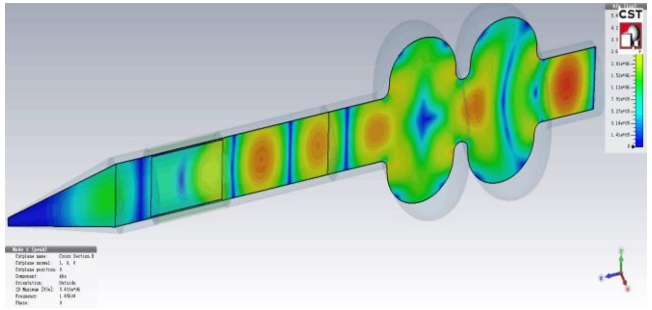


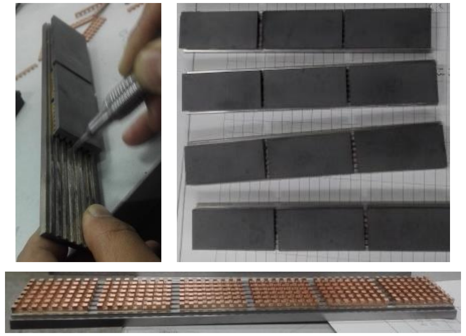
HOM damping Q_e

Fulfill Higgs CBI requirement. Need beam feedback for Z. Further damping optimization is under way.

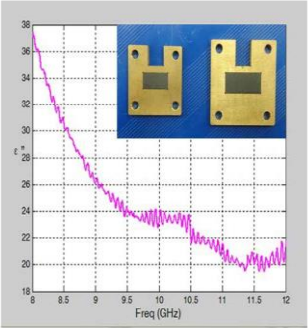
HOM Absorber High Power Test

Due to short bunch length thus wide HOM frequency range, **SiC+AlN** composite is chosen for cavity HOM absorbing material. 5 kW high power test show high absorbing efficiency, meet CEPC spec.

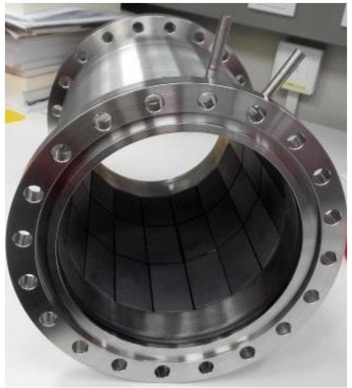


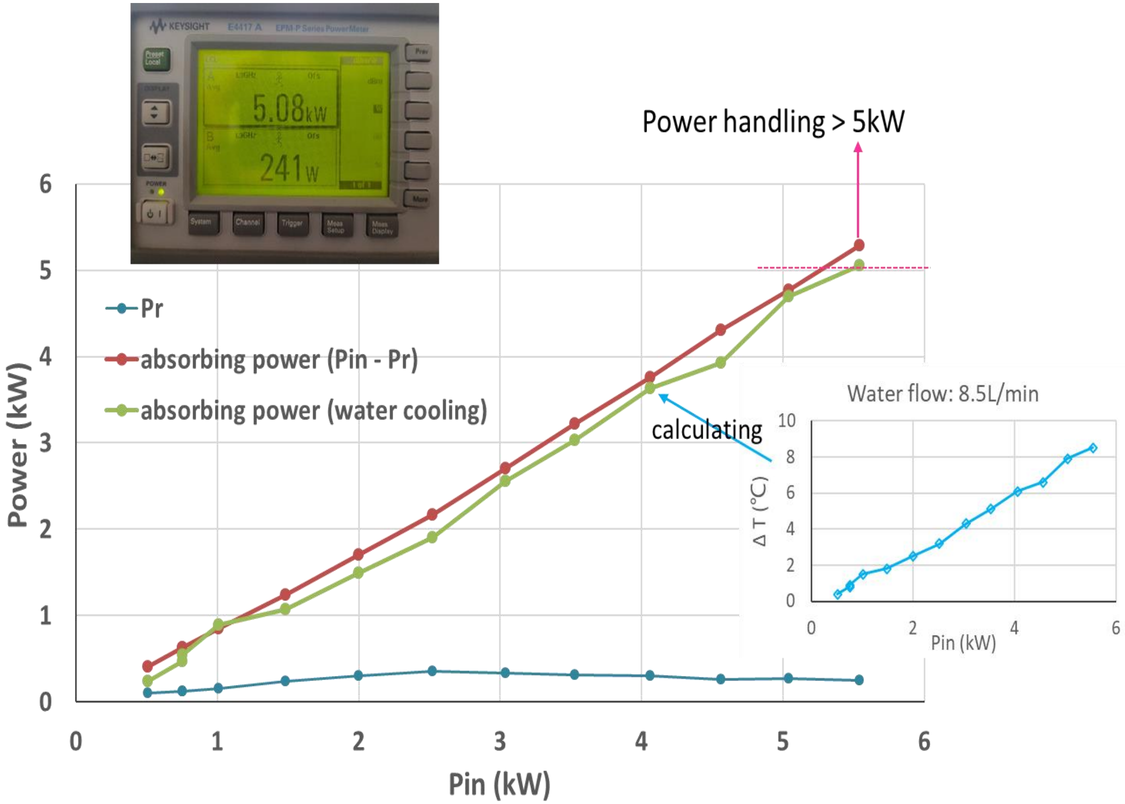


SiC+AlN composite bricks brazed on copper and then on kovar plate



Measured permittivity of SiC+AlN composite (for broadband microwave absorbing)





Outline

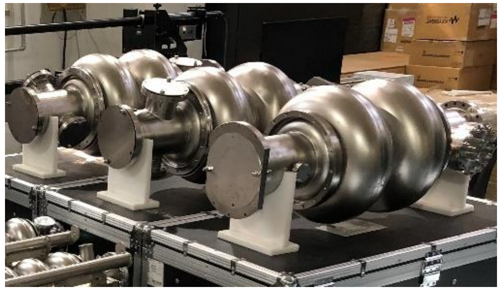
Update from last CEPC IARC meeting (Nov 2019)

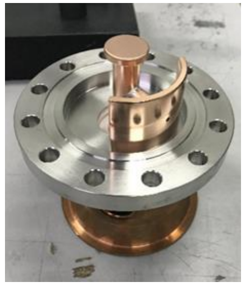
SRF highlights in last 18 months:

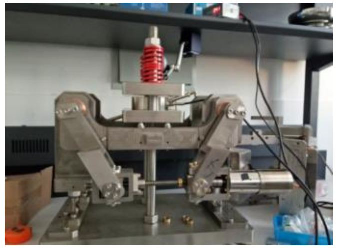
1. New RF staging and bypass scheme
2. Beam cavity interaction
3. High Q and gradient cavity
4. High power components
5. **Cryomodule integration**
6. SRF facility
7. Beam test facility

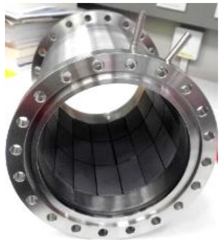
CEPC 650 MHz Test Cryomodule

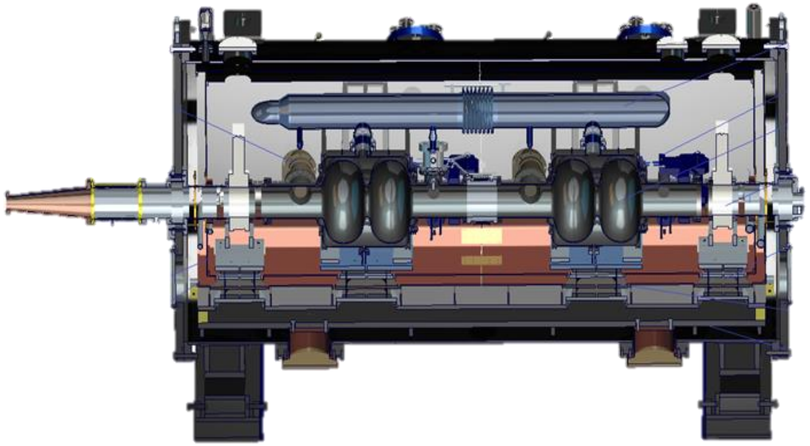
- Cavity string and module assembly in March to May 2021.
- Horizontal and beam test at PAPS in summer.
- Demonstrate 650 MHz cavity high Q operation.

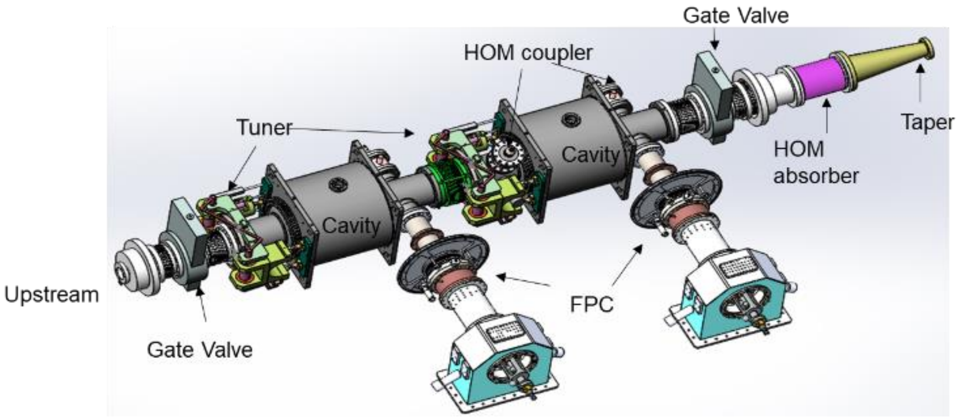




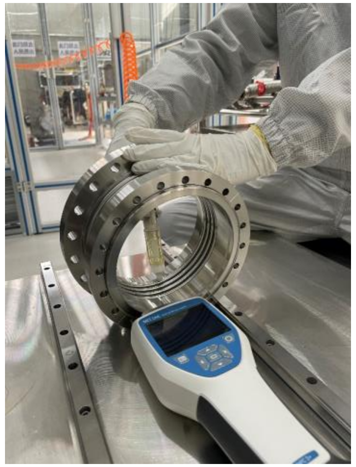
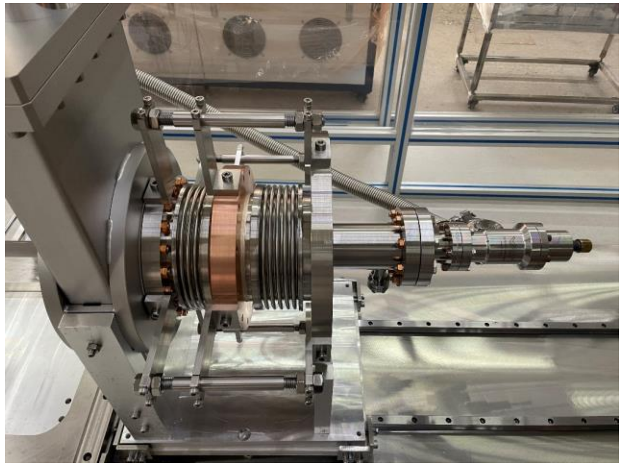


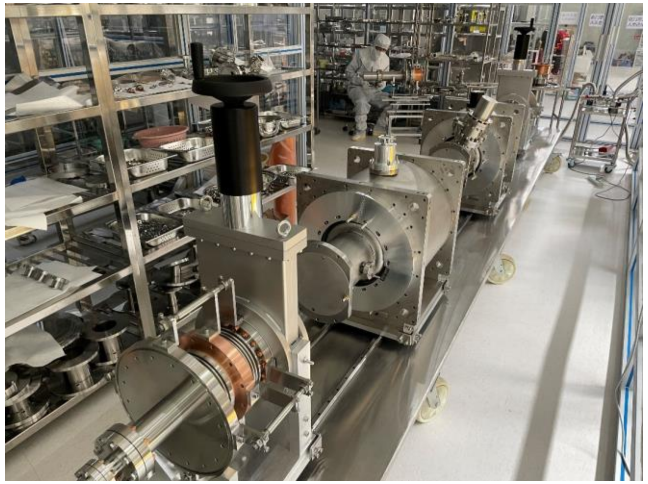


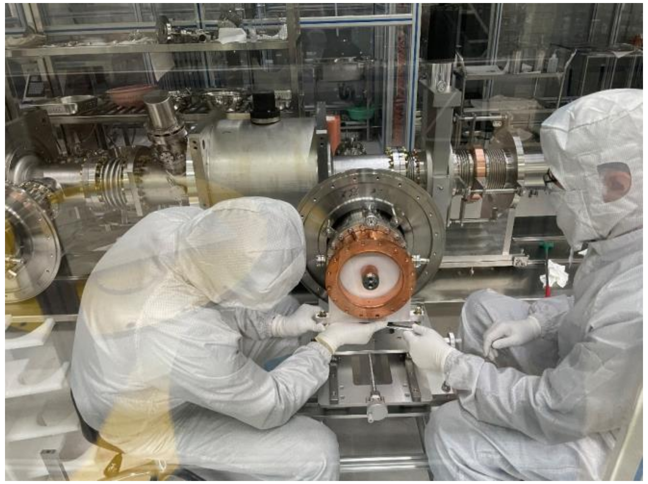




650 MHz 2 x 2-cell Cavity String Assembly

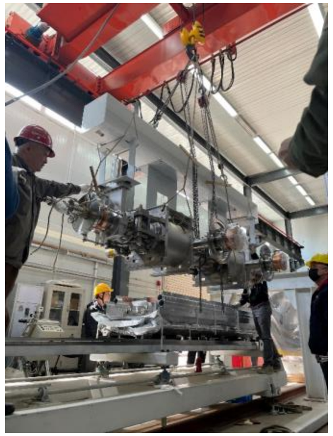




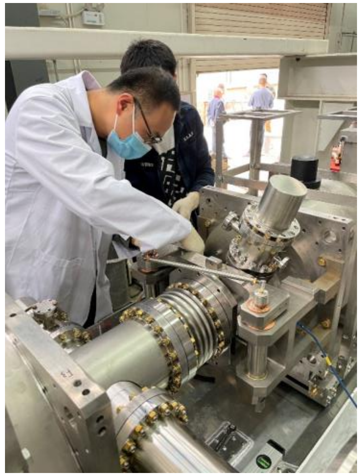



650 MHz Test Cryomodule Assembly

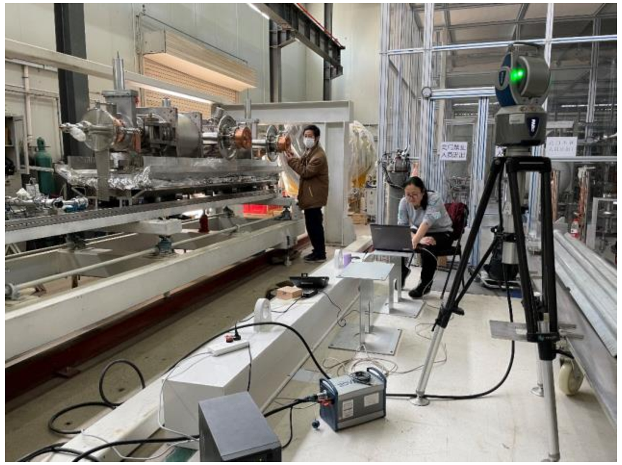
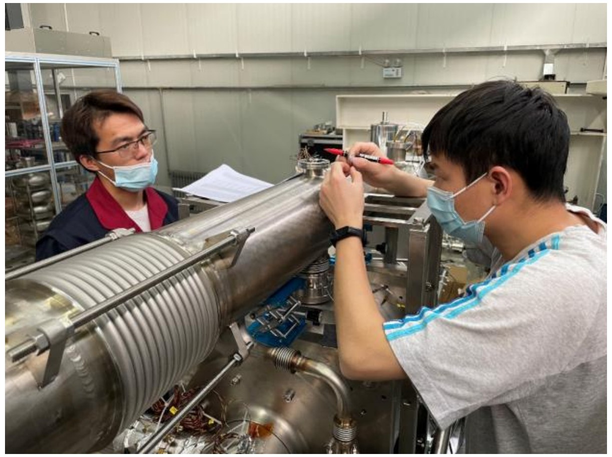
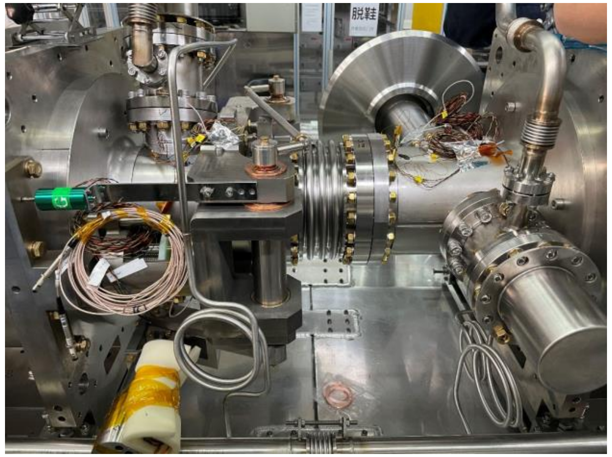
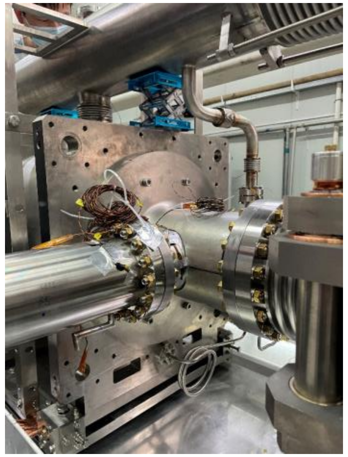


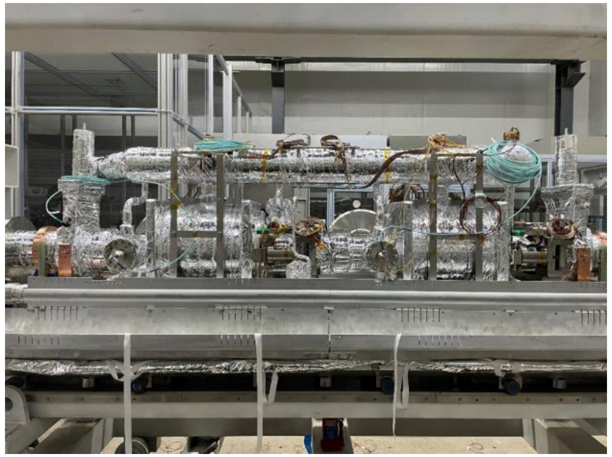
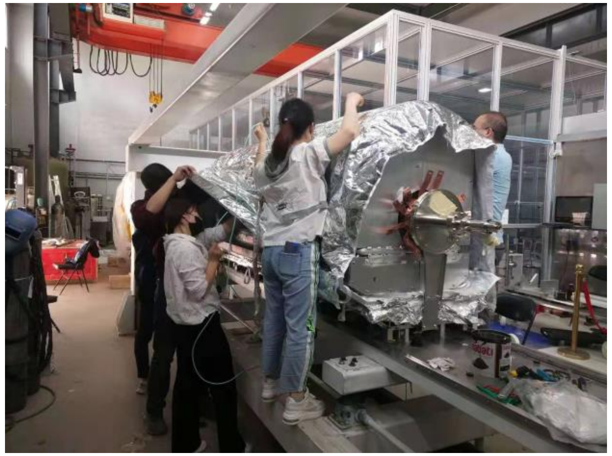







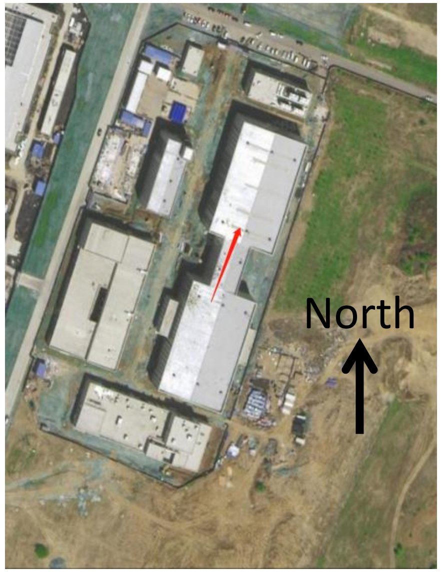
650 MHz Test Cryomodule Assembly

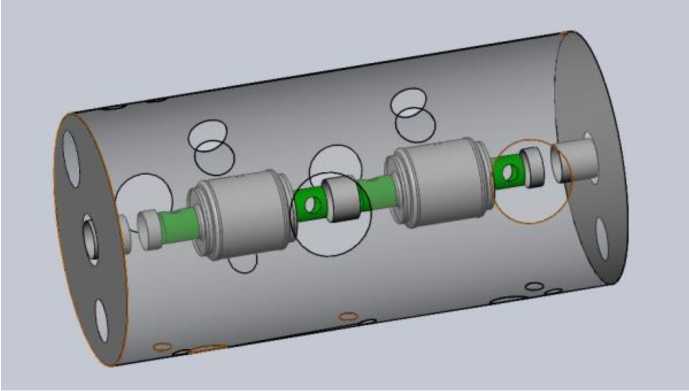





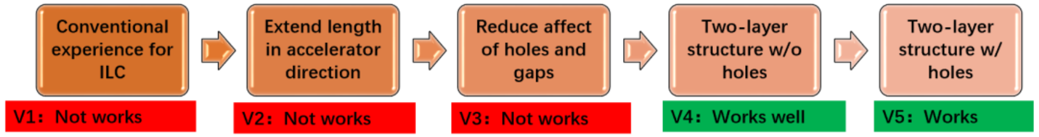

650 MHz Test Cryomodule Assembly

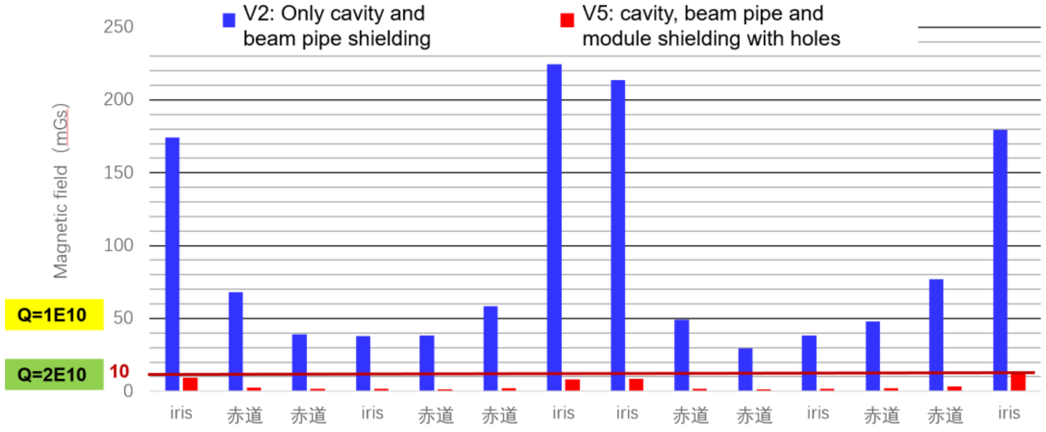
Preserve Q_0 in Module: Magnetic Shielding and Compensating





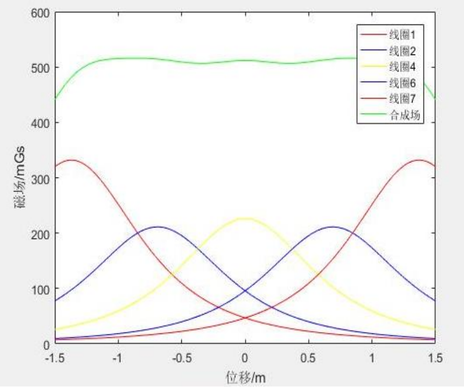
Because of beam direction and larger beam pipe than 1.3 GHz, **only two shieldings** can reach the magnetic field requirement of high Q 650 MHz cavity: **cavity (2 K local) shield and module (RT global) shield**.





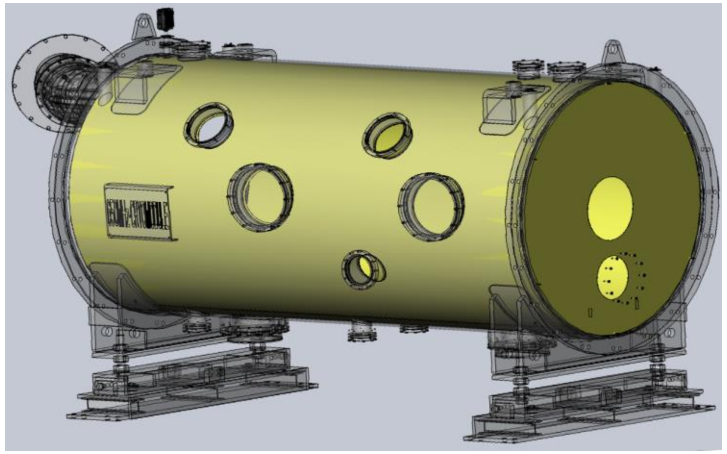
$$R_{mag} = \eta \cdot S(l) \cdot (B_{ext} + B_{tc})\sqrt{f}$$

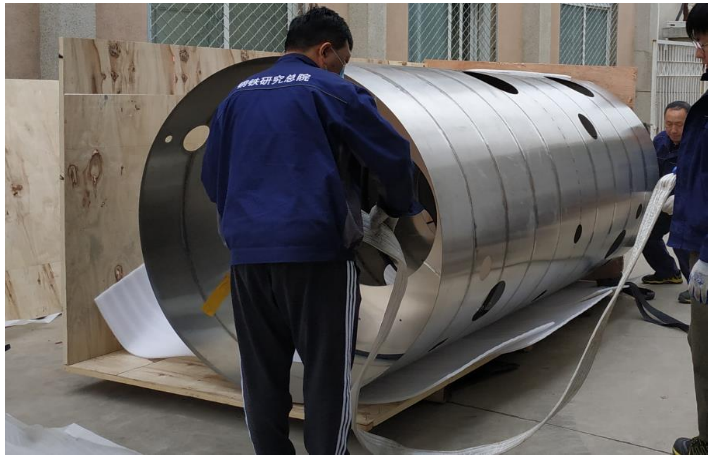
1. Flux trapping ratio: grain size, high-T annealing, fast cold down
2. Magnetic sensitivity: mean free path and other
3. Remnant magnetic field: demagnetization, magnetic shield, magnetic compensation
4. Thermocurrent induced magnetic field



Magnetic compensation with coils

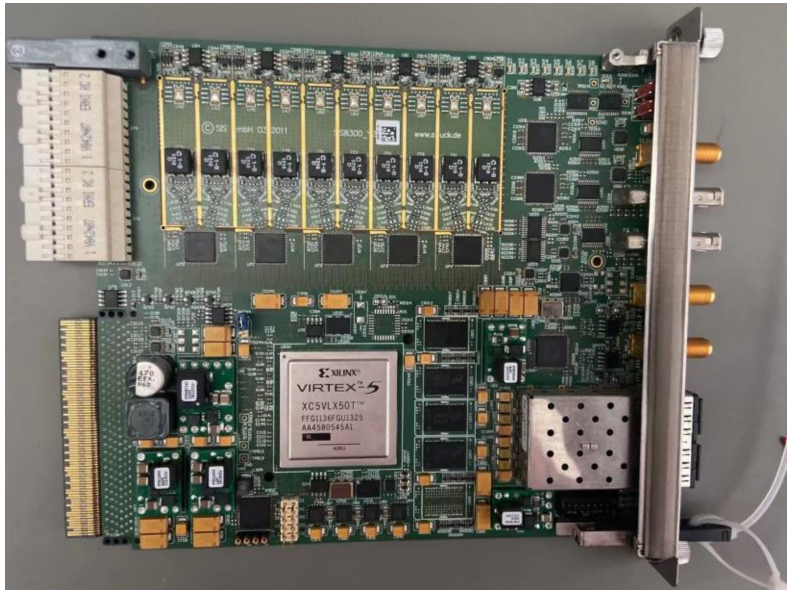
Global Magnetic Shield of the 650 MHz CM





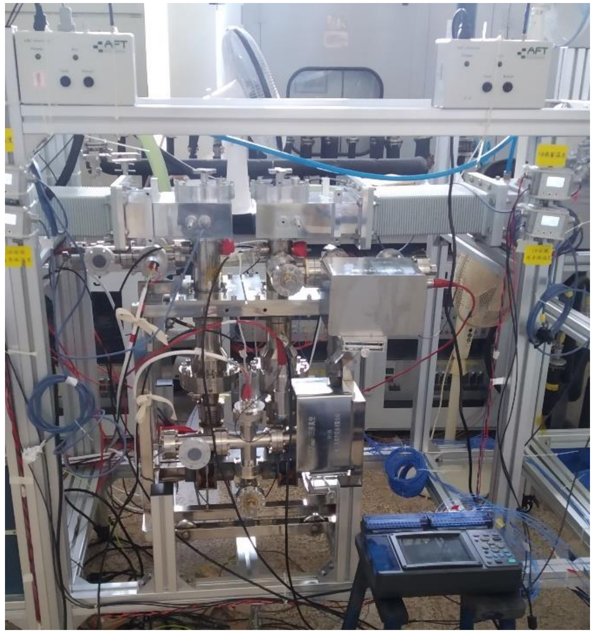
650 MHz HLRF and LLRF

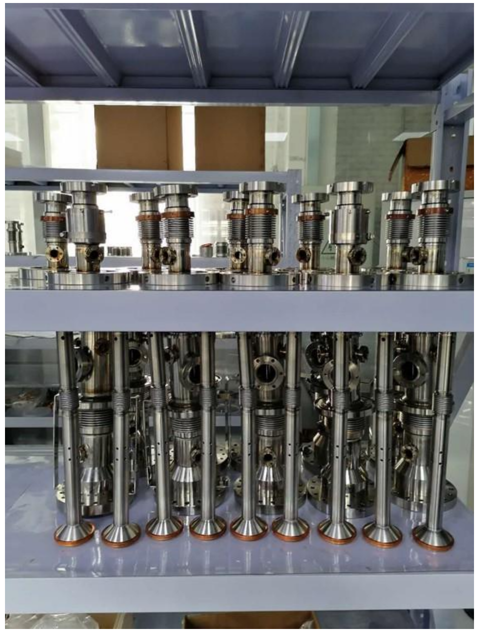
- 650 MHz 150 kW (total) solid state amplifier
- 650 MHz 800 kW klystron (Zhou Zusheng’s talk)
- 650 MHz LLRF



1.3 GHz Input Coupler

- 1.3 GHz variable input couplers high power tested to CW 14 kW TW, 7 kW SW.
- Another six couplers under fabrication.
- Ceramic window TiN sputtering and coupler copper plating (especially bellow) meet the specifications.

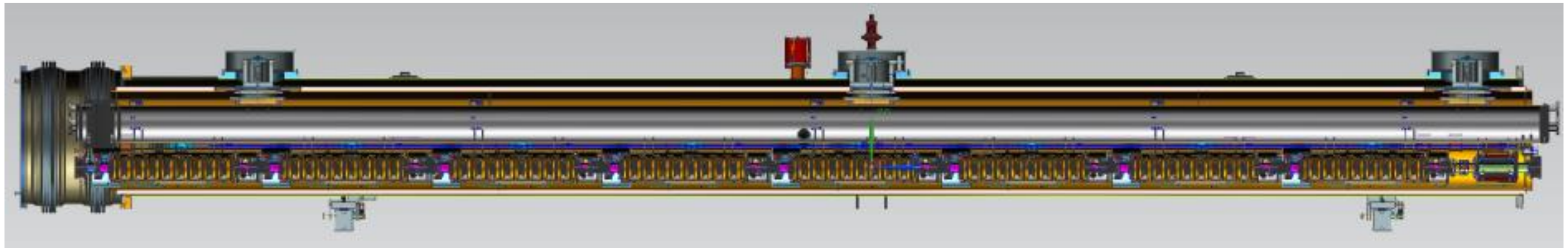


1.3 GHz Cryomodule

CEPC booster 1.3 GHz SRF technology R&D and industrialization in synergy with domestic CW FEL projects (2017-2027, ~1000 9-cell cavities).

- ~ 20 high Q 9-cells in 2021
  - optimize heat treatment (balance between Q and magnetic sensitivity)
  - horizontal test (flux expulsion, fast cool down, magnetic shield and compensation, LLRF and microphonics)
  - some undressed cavities go through EP baseline high gradient test first
- 1.3 GHz 8x9-cell high Q cryomodule prototype in 2021-2022
  - cavity, coupler, tuner, magnetic shield and hygiene, superconducting magnet, BPM, beam line HOM absorber, copper plated beam pipes and other vacuum components, cryostat, HLRF, LLRF, tooling
  - clean room and test stand commissioning, drawings, clean room and assembly procedures, training, transportation …
- 1.3 GHz 9-cell high Q cavity and cryomodule mass production in 2022-2026



Outline

Update from last CEPC IARC meeting (Nov 2019)

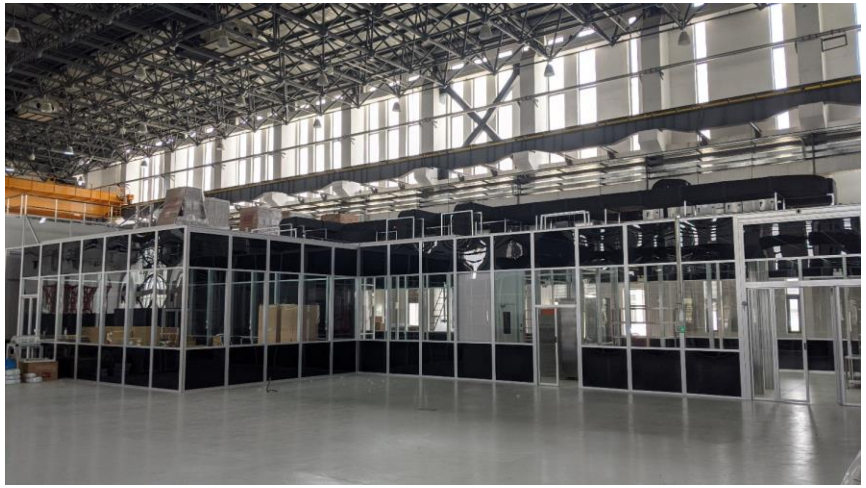
SRF highlights in last 18 months:

1. New RF staging and bypass scheme
2. Beam cavity interaction
3. High Q and gradient cavity
4. High power components
5. Cryomodule integration
6. **SRF facility**
7. Beam test facility

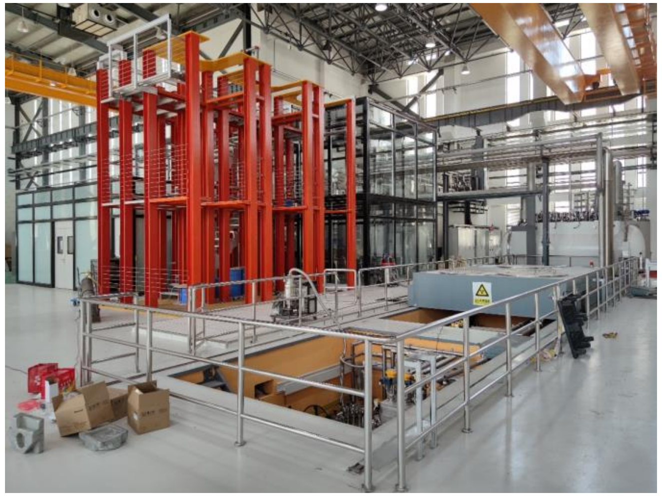

PAPS

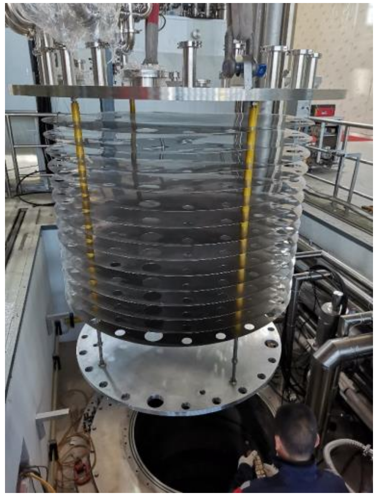
New SRF Facility



New SRF Facility





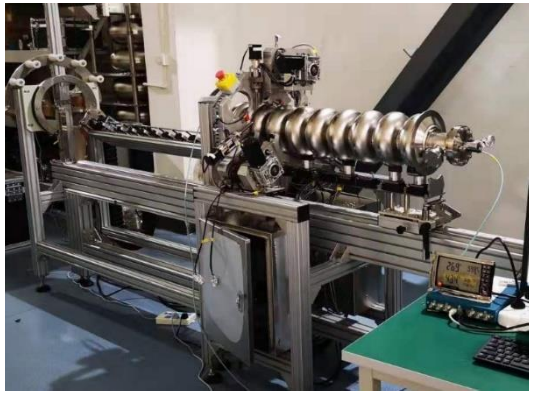
New SRF Facility

Vacuum furnace (doping & annealing)

Nb3Sn furnace

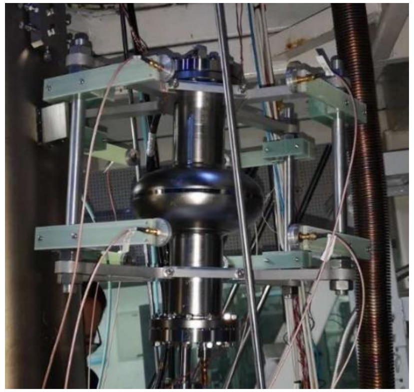
Nb/Cu sputtering device

Cavity inspection camera and grinder

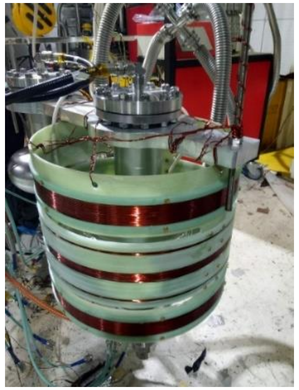


9-cell cavity pre-tuning machine

Temperature & X-ray mapping system



Second sound cavity quench detection system



Helmholtz coil for cavity vertical test

SSA

LLRF for cavity & coupler testing

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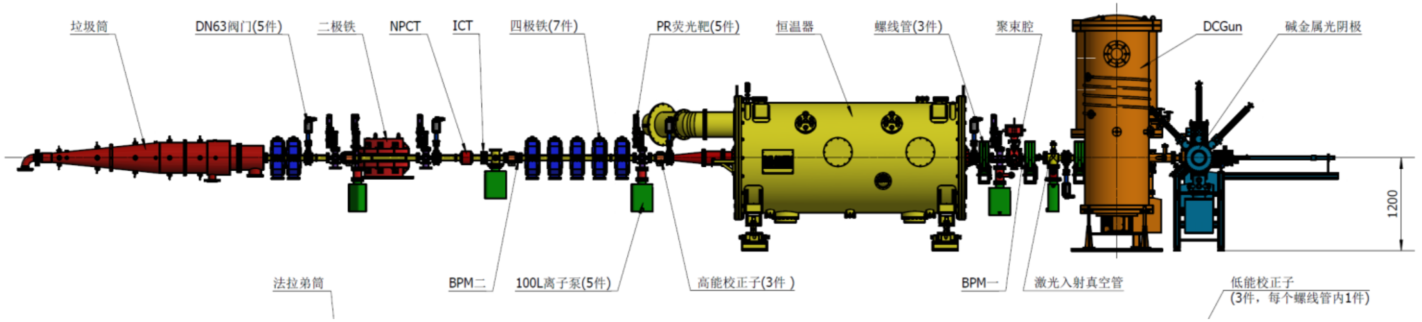
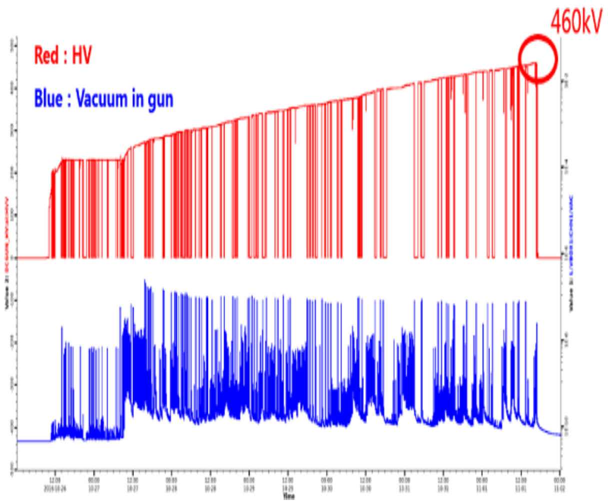
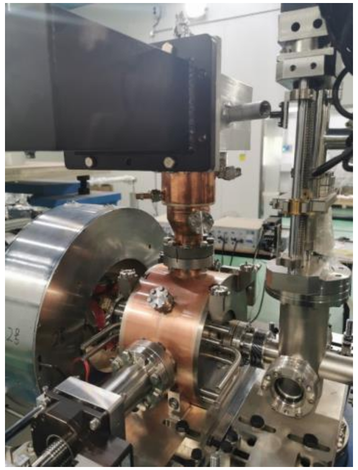
Beam Test Facility

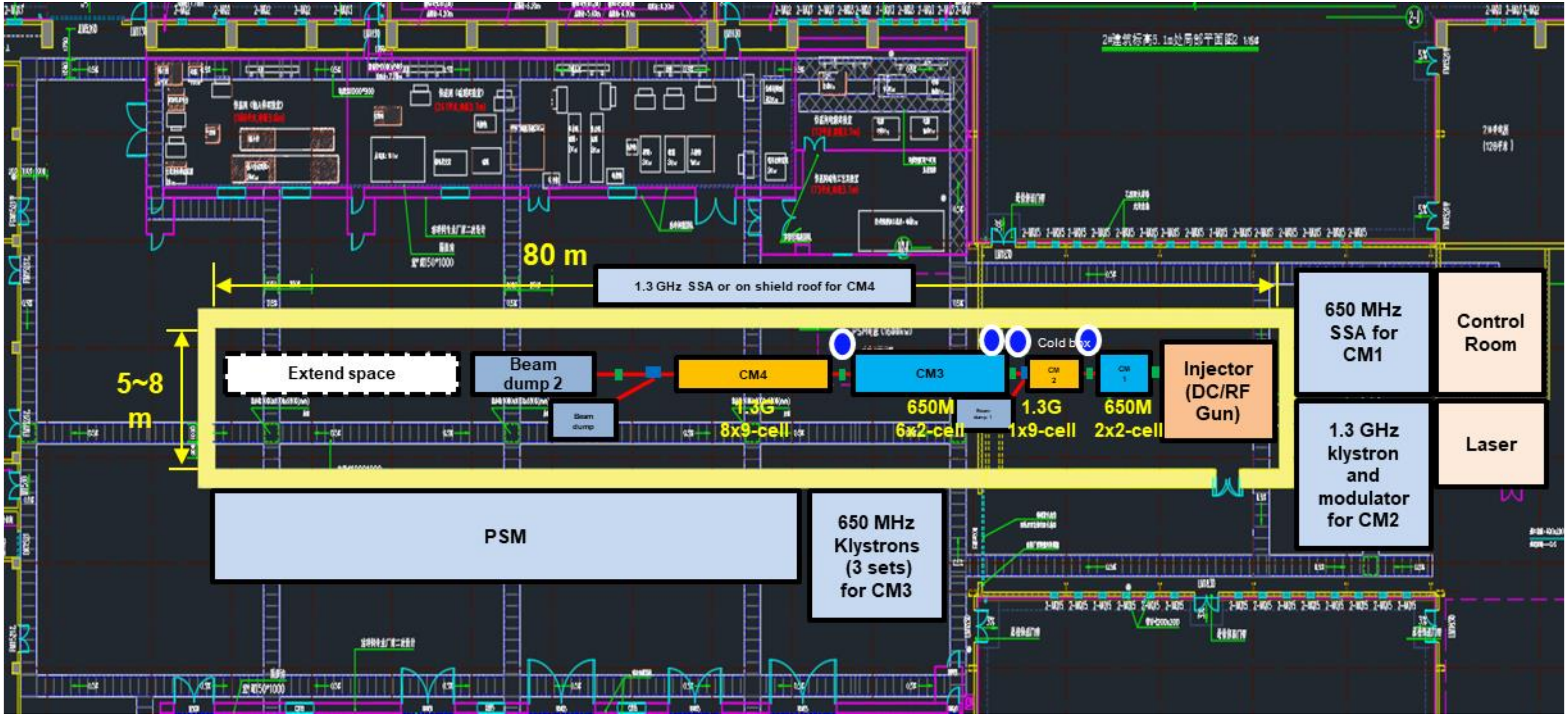
- Succeed to have 5 mA CW 460 keV electron beam from DC photo-cathode gun
- 15 MeV energy boost by the 650 MHz 2x2-cell cavities.







Beam Test Facility (future extension)



Summary

- CEPC RF system design towards TDR is aiming to match the RF parameters, layout, configuration, specifications and cost to the new machine baseline parameters improved over CDR.
- RF staging and by-pass scheme is proposed to unleash full potential of CEPC with operational flexibility, enable seamless mode switching with unrestricted RF performance at each energy, and stepwise RF system construction cost, technology risk and international involvement.
- Priority is given to the cryomodule prototyping and industrialization required for CEPC construction. Good progress include 650 MHz and 1.3 GHz high Q high gradient cavities, high power input couplers, high power HOM couplers and absorbers. CEPC Collider Ring prototype 650 MHz 2x2-cell test cryomodule has completed construction and will have horizontal test and beam test. A high Q 1.3 GHz 8x9-cell cryomodule will be constructed in 2021-2022 as the CEPC Booster cryomodule prototyping.
- PAPS SRF infrastructure at Huairou will start operation soon to support the future R&D.
- Plan to strengthen the SRF technology R&D and production collaborations with PKU, SHINE and other Chinese superconducting FEL projects, and hopefully FCC, EIC and ILC. International in-kind contributions for CEPC RF system could be high current cryomodules for high luminosity Z-pole and high gradient high Q cryomodules for ttbar, which will need continuous pushing of the SRF frontiers. We expect quite a lot of potential international high-tech suppliers for the CEPC RF system construction and upgrade.

Thanks to our great colleagues from RF, Cryogenics, Vacuum, Alignment, Linac, AP groups.