CEPC SRF System Design and R&D Progress

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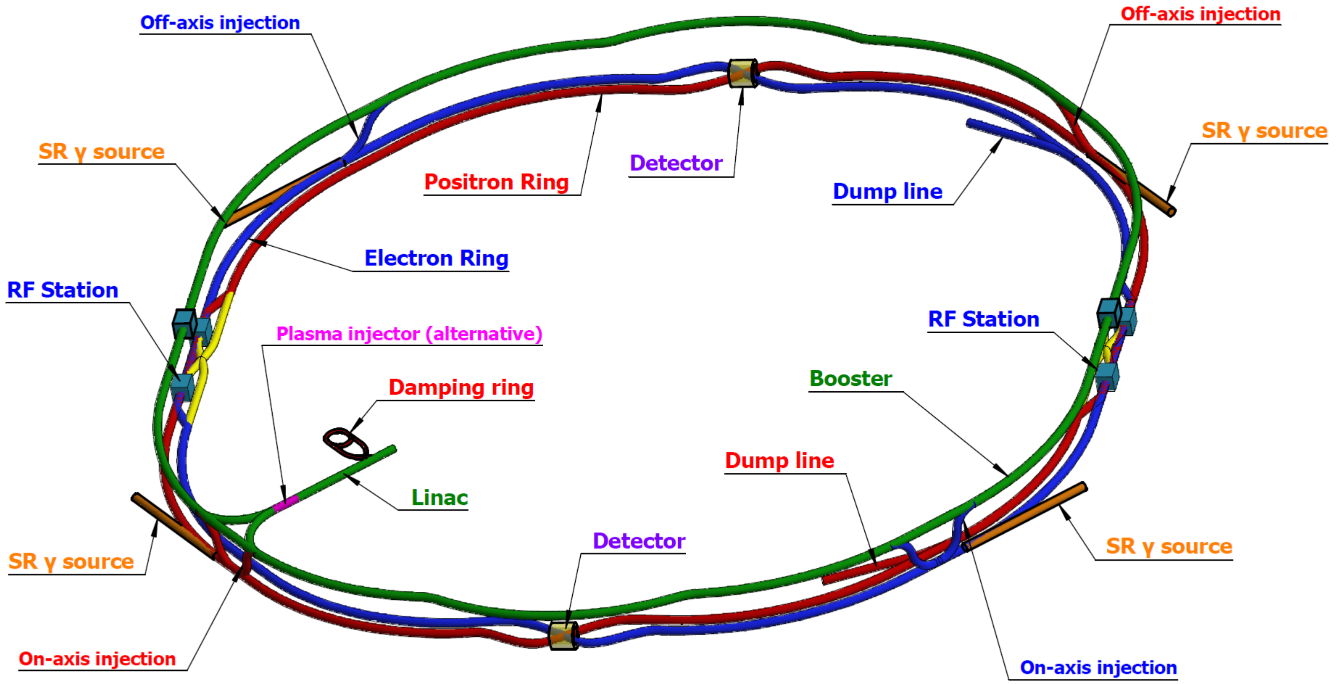
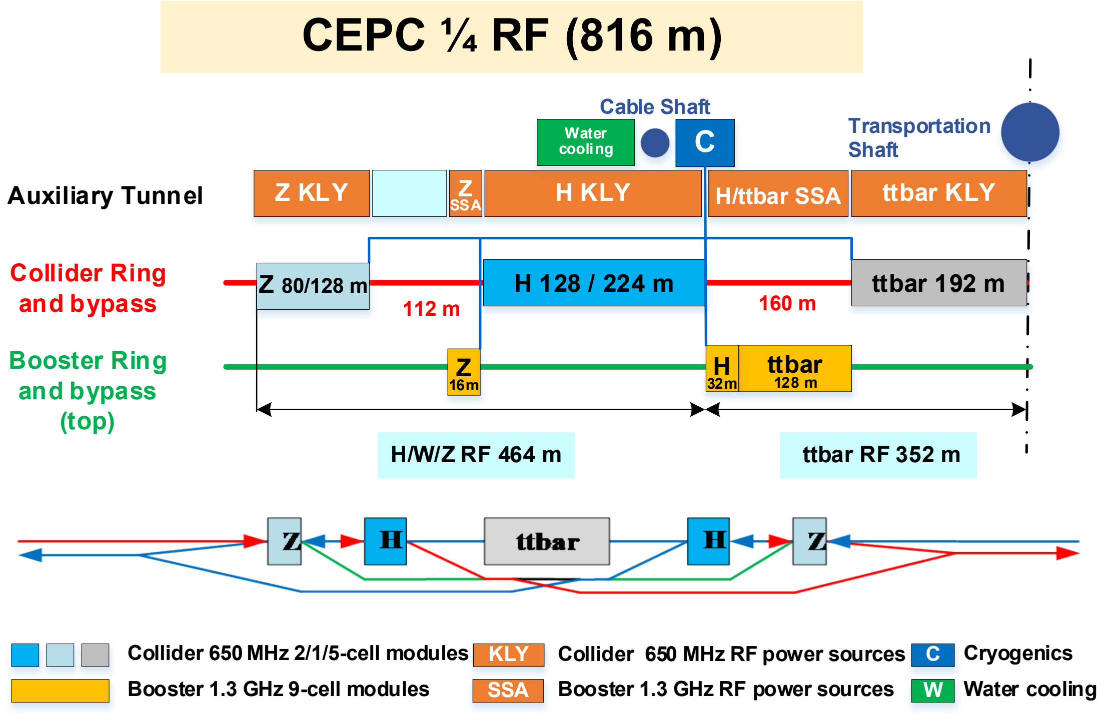
Outline

1. CEPC SRF system design
2. Collider 650 MHz SRF R&D
3. Booster 1.3 GHz SRF R&D
4. Summary

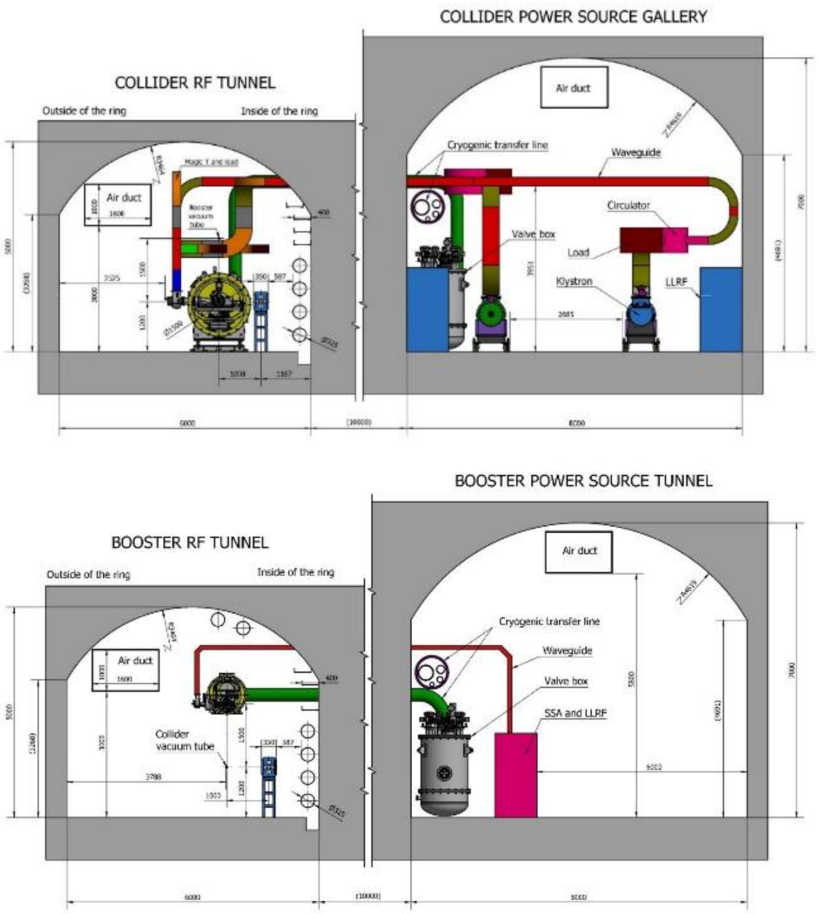


CEPC TDR RF Layout



CEPC 1/4 RF 30 / 50 MW	Collider			Booster		
	H	Z	ttbar	H	Z	ttbar
RF Length / m	128 / 224	80 / 128	192	32	16	128
Cavity & Module	6x2-cell	1x1-cell	4x5-cell	8x9-cell	8x9-cell	8x9-cell
# Module	8 / 14	15 / 25	12	2	1	8
# Cavity	48 / 84	15 / 25	48	16	8	64
Module length / m	88 / 154	40 / 100	132	24	12	96
# Klystron or SSA	24 / 42	15 / 25	12 / 24	16	8	64
RF Power / kW	800	1200	800	25 / 30	25 / 40	10

- Maximize performance and flexibility for future circular electron positron collider.
- Higgs first priority. Mode seamless switching without hardware movement.



CEPC TDR 650 MHz RF Parameters (Collider Ring)

30/50 MW SR power per beam for each mode. Higgs/ttbar shared cavities for the two rings. W/Z separate cavities. HL-Z cavities bypass.	**ttbar 30/50 MW**		**Higgs 30/50 MW**	**W 30/50 MW**	**Z 10 MW**	**Z 30/50 MW**
	New cavities	**Higgs cavities**				
Luminosity / IP [10^{34} $cm^{-2}s^{-1}$]	0.5 / 0.8		5 / 8.3	16 / 26.7	38	115 / 192
RF voltage [GV]	10 (6.1 + 3.9)		2.2	0.7	0.12	0.12 / 0.1
Beam current / beam [mA]	3.4 / 5.6		16.7 / 27.8	84 / 140	267	801 / 1345
Bunch charge [nC]	32		21	21.6	22.4	22.4 / 34.2
Bunch length [mm]	2.9		4.1	4.9	8.7	8.7 / 10.6
650 MHz cavity number	192	336	192/336	96 / 168 / ring	48 / ring	30 / 50 / ring
Cell number / cavity	5	2	2	2	2	1
Gradient [MV/m]	27.6	25.2	24.9 / 14.2	15.9 / 9.1	5.4	17.4 / 8.7
Q_0 @ 2 K at operating gradient	3E10	3E10	3E10	3E10	3E10	2E10
HOM power / cavity [kW]	0.4 / 0.66	0.16 / 0.26	0.4 / 0.67	0.93 / 1.54	1.9	2.9 / 6.2
Input power / cavity [kW]	188 / 315	71 / 118	313 / 298	313 / 298	206	1000
Optimal Q_L	1E7 / 6E6	9E6 / 5.4E6	1.6E6 / 9.5E5	8E5 / 2.7E5	1.4E5	1.5E5 / 3.8E4
Optimal detuning [kHz]	0.01 / 0.02	0.02 / 0.03	0.1 / 0.2	0.7 / 2	7	6.7 / 21.7
Cavity number / klystron	4 / 2	2	2	2	2	1
Klystron power [kW]	800	800	800	800	800	1200
Klystron number	48 / 96	168	96 / 168	96 / 168	48	60 / 100
Cavity number / cryomodule	4	6	6	6	6	1
Cryomodule number	48	56	32 / 56	32 / 56	16	60 / 100
Total cavity wall loss @ 2 K [kW]	12.1	7.1	3.9 / 2.3	1.6 / 0.9	0.1	0.45 / 0.2

- ttbar and Higgs half filled with common cavities for two rings, W and Z with separate cavities for two rings.
- High luminosity Z upgrade use high current 1-cell cavity with RF bypass.
- Add more 2-cell cavities for Higgs 50 MW upgrade.
- Add 5-cell cavities for ttbar while using the original 2-cell Higgs cavities.
- Fundamental mode instability of Z-mode due to large detuning will be suppressed by RF feedback.
- No beam feedback needed for HL-Z because of deep damping 1-cell cavities.

CEPC TDR 1.3 GHz RF Parameters (Booster Ring)

30/50 MW Collider SR power per beam. 30 GeV injection. Higgs & ttbar half filled. Higgs on-axis injection with bunch swapping. Z injection from empty ring.	**ttbar 30/50 MW**		**Higgs 30/50 MW**	**W 30/50 MW**	**Z 30/50 MW**
	New cavities	**Higgs cavities**			
Extraction beam energy [GeV]	180		120	80	45.5
Extraction average SR power [MW]	0.05		0.5 / 0.67	0.02 / 0.04	0.05 / 0.1
Bunch charge [nC]	1.1		0.78 (20.3)	0.73	0.81
Beam current [mA]	0.12 / 0.19		0.63 (1) / 1 (1.4)	3.1 / 5.3	16 / 30
Injection RF voltage [GV]	0.761		0.346	0.3	0.3
Extraction RF voltage [GV]	9.7 (7.53 + 2.17)		2.17	0.87	0.46
Extraction bunch length [mm]	1.8		1.86	1.3	0.75
Cavity number (1.3 GHz 9-cell)	256	96	96	96	32
Module number (8 cavities / module)	32	12	12	12	4
Extraction gradient [MV/m]	28.3	21.8	21.8	8.7	13.8
Q_0 @ 2 K at operating gradient	2E10	3E10	3E10	3E10	3E10
Q_L	4E7	4E7	1.2E7	7.3E6 / 4.4E6	1.2E7 / 6.3E6
Cavity bandwidth [Hz]	33	33	110	178 / 296	111 / 208
Peak HOM power per cavity [W]	0.5 / 0.8		~ 75 / ~ 100	11.8 / 19.6	146 / 272
Average HOM power per cavity [W]	0.2 / 0.32		~ 10 / ~ 15	3.8 / 6.3	80 / 150
Input peak power per cavity [kW]	8.3 / 9.2	5.1 / 5.9	22 / 32	10.9 / 18.1	17 / 32
Input average power per cavity [kW]	0.3	0.2	6.5 / 9.2	0.3 / 0.5	2.5 / 4.5
SSA power [kW] (1 cavity / SSA)	10	10	25 / 30	25 / 30	25 / 40
Total cavity wall loss @ 2 K [kW]	0.36	0.05	0.5	0.02	0.08

- 1.3 GHz 9-cell cavities
- Higgs and ttbar half fill for injection timing with Collider ring.
- Transient beam loading for Higgs on-axis injection tolerable (both at injection and extraction).
- Increased average HOM power of HL-Z requires ERL-type 1.3 GHz cryomodule (HOM absorber at low temperature between cavities). Two cryomodules for Z in each ring with RF bypass to reduce impedance and increase beam current limit.
- High gradient high Q 9-cell cavities for ttbar.
- Narrow bandwidth high gradient cavity voltage ramping through the multipacting region to be studied.
- Still need beam feedback at 30 GeV injection and ramp.

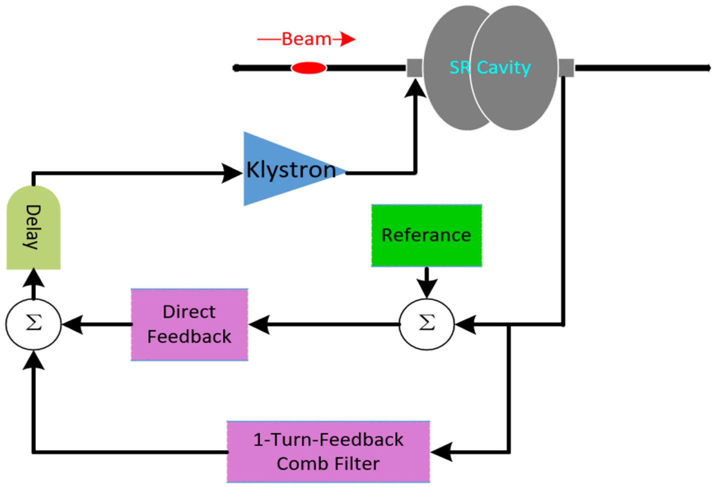
Cavity Cryogenics Heat Load

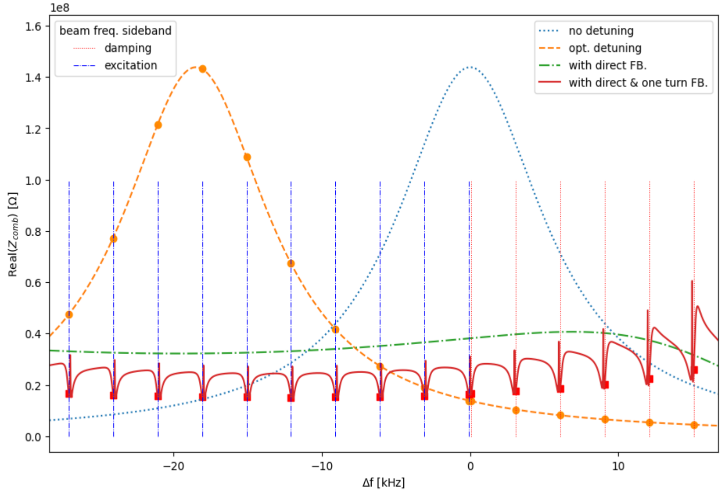
	Collider 650 MHz Cavities				Booster 1.3 GHz Cavities			
	ttbar 50 MW		H 30 MW	H 50 MW	ttbar 50 MW		H 30 MW	H 50 MW
	New	H			New	H		
Cryogenic duty factor	100%	100%	100%	100%	3.4%	3.4%	31%	31%
RF power duty factor	100%	100%	100%	100%	3.9%	3.9%	30%	30%
HOM power duty factor	100%	100%	100%	100%	42%	42%	42%	49%
Operation temperature (K)	2	2	2	2	2	2	2	2
Total number of cavities	192	336	192	336	256	96	96	96
Cell number / cavity	5	2	2	2	9	9	9	9
R/Q (Ω)	532.5	213	213	213	1036	1036	1036	1036
Cavity RF voltage (MV)	31.77	11.61	11.46	6.55	29.4	22.6	22.6	22.6
Q_0	3E+10	3E+10	3E+10	3E+10	2E+10	3E+10	3E+10	3E+10
Input power (peak) / cavity (kW)	315	118	313	298	9.2	5.9	22	26.6
HOM power (peak) / cavity (W)	660	260	400	670	0.8	0.8	74	100
Dynamic heat load @ 2 K / cavity (W)	63.2	21.1	20.6	6.7	1.4	0.6	5.1	5.1
Total cavity dynamic heat load @ 2 K (kW)	12.1	7.1	3.9	2.3	0.36	0.05	0.49	0.49
Dynamic heat load @ 2 K / input coupler (W)	0.6	0.2	0.6	0.6	0.02	0.01	0.33	0.40
Dynamic heat load @ 5 K / input coupler (W)	3.8	1.4	3.8	3.6	0.14	0.09	2.64	3.19
Dynamic heat load @ 40 K / input coupler (W)	15.1	5.7	15.0	14.3	1.4	0.9	26.4	31.9
Dynamic heat load @ 2 K / HOM coupler pair (W)	0.07	0.03	0.04	0.07	0.003	0.003	0.3	0.49
Dynamic heat load @ 5 K / HOM coupler pair (W)	0.4	0.2	0.2	0.4	0.02	0.02	1.9	2.9
Dynamic heat load @ 40 K / HOM coupler pair (W)	0.8	0.3	0.5	0.8	0.04	0.04	3.7	5.9
Static heat load @ 2 K / input coupler (W)	0.05	0.05	0.05	0.05	0.1	0.1	0.1	0.1
Static heat load @ 5 K / input coupler (W)	0.5	0.5	0.5	0.5	1	1	1	1
Static heat load @ 40 K / input coupler (W)	1	1	1	1	2	2	2	2
Static heat load @ 2 K / HOM coupler pair (W)	0.02	0.02	0.02	0.02	0	0	0	0
Static heat load @ 5 K / HOM coupler pair (W)	0.2	0.2	0.2	0.2	0	0	0	0
Static heat load @ 40 K / HOM coupler pair (W)	0.4	0.4	0.4	0.4	0	0	0	0

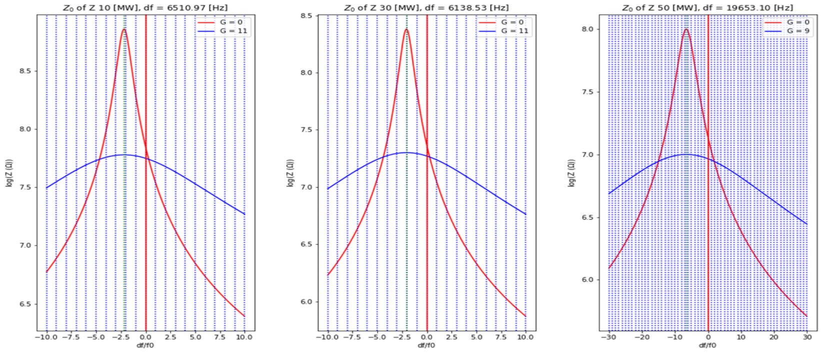
Tianmu XIN, Hang ZHU

RF and Beam Feedback for Fundamental Mode CBI

- Z 10/30/50 MW, damping rate 2.45 Hz.
- Bunch by bunch feedback time 10 Hz.







Mode index	CBM Growth Rate [Hz]					
	10 MW, G=0	10 MW, G=11	30 MW, G=0	30 MW, G=11	50 MW, G=0	50 MW, G=3
-1	116.44	4.52	128.30	4.82	30.77	1.38
-2	495.81	8.53	533.36	9.02	68.11	2.75
-3	237.67	11.42	184.36	11.92	118.38	4.06
-4	68.45	13.04	53.94	13.38	191.05	5.27
-5	28.50	13.50	22.94	13.59	291.00	6.38
-6	14.73	13.08	12.00	12.93	388.09	7.36
-7	8.67	12.11	7.11	11.75	400.55	8.21
-8	5.56	10.87	4.58	10.37	316.83	8.92
-9	3.79	9.56	3.13	8.99	218.89	9.50
-10	2.70	8.29	2.24	7.70	147.65	9.93
-11	2.00	7.14	1.66	6.56	101.81	10.23
-12	1.52	6.13	1.26	5.58	72.58	10.40
-13	1.18	5.26	0.99	4.75	53.45	10.46
-14	0.94	4.52	0.78	4.06	40.52	10.41
-15	0.76	3.89	0.63	3.49	31.48	10.27

- With the help of direct feedback loop, it is possible to reduce the growth rate of the dangerous coupled bunch modes in all cases to the levels which are manageable by the bunch by bunch feedback system.
- To reduce FM impedance of parking 2-cell cavities of 10 MW Z, will try narrow BW (up to Qe 7E6) and symmetric detune … methods.

HOM Damping and Beam Feedback for HOM CBI

Collider 10/50 MW SR power per beam. Higgs/ttbar shared cavities for the two rings. W/Z separate cavities. Z 50 MW cavities bypass. Average beta x/y in RF 30 m.		ttbar 50 MW		Higgs 50 MW	W 50 MW	Z 10 MW	Measured HOM Coupler Qe	Z 50 MW
		New cavities	**Higgs cavities**					
Collider online 650 MHz cavities		**192 5-cell**	**336 2-cell**	**336 2-cel**	**168 2-cell**	**96 2-cell**		**50 1-cell**
Required Qe with only SR damping	TM011	5.4E+06	4.1E+06	1.1E+05	1.0E+04	5.6E+02	2.0E+03	4.8E+02
	TM020	7.0E+06	1.7E+08	4.6E+06	4.3E+05	2.4E+04	7.0E+04	1.4E+04
	TE111	3.4E+05	5.8E+05	2.3E+04	3.6E+03	3.4E+02	1.0E+04	2.3E+02
	TM110	4.2E+05	3.9E+05	1.5E+04	2.4E+03	2.3E+02	7.2E+02	1.3E+02
Required Qe with beam feedback (longitudinal 100 ms, transverse 1 ms).	TM011	-	-	-	-	2.3E+03	2.0E+03	-
	TM020	-	-	-	-	9.8E+04	7.0E+04	-
	TE111	-	-	-	-	2.8E+05	1.0E+04	-
	TM110	-	-	-	-	1.9E+05	7.2E+02	-
Booster online 1.3 GHz cavities		**256 9-cell**	**96 9-cell**	**96 9-cell**	**96 9-cell**	**-**	**-**	**32 9-cell**
Extraction Required feedback time ms. Required Qe for Z 50 MW.	TM011	-	-	-	-	-	5.9E+04	8.8E+03
	TE111	-	-	-	-	-	3.4E+03	5.5E+02
	TM110	-	-	-	61	-	5.0E+04	1.0E+03
Injection Required feedback time ms. Required Qe for Z 50 MW.	TM011	994.8		333.8	82.1	-	5.9E+04	1.7E+03
	TE111	1370		681.7	180.1	-	3.4E+03	1.1E+02
	TM110	174		86.6	22.9	-	5.0E+04	2.0E+02

Collider

- H/W 50 MW: improve HOM coupler design for deeper TE111 damping
- Z 10 MW: rely on beam feedback. Or extreme deep damping HOM coupler?
- Z 50 MW: BEPCII type 1-cell cavity with RT HOM absorber can reach Qe ~ 100

Booster

- ttbar/H/W injection and W TM110 extraction beam FB. Or redesign HOM couplers with deeper damping, or use HOM absorber between cavities.
- Z: HOM absorber for deep damping

HOM frequency spread of cavities will further relax the requirements.

Outline

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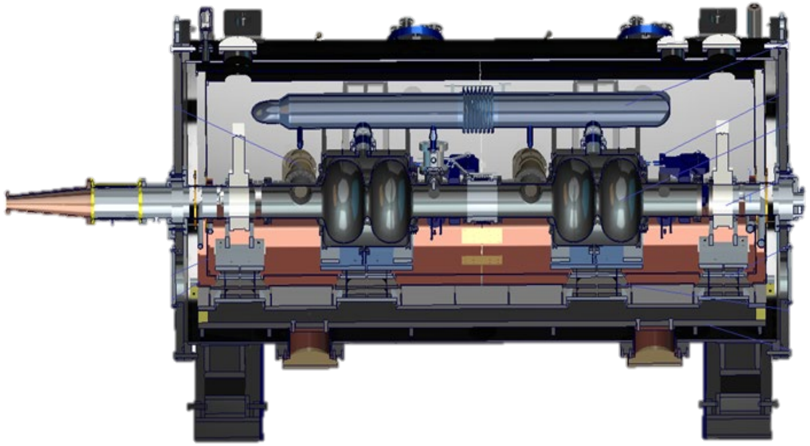
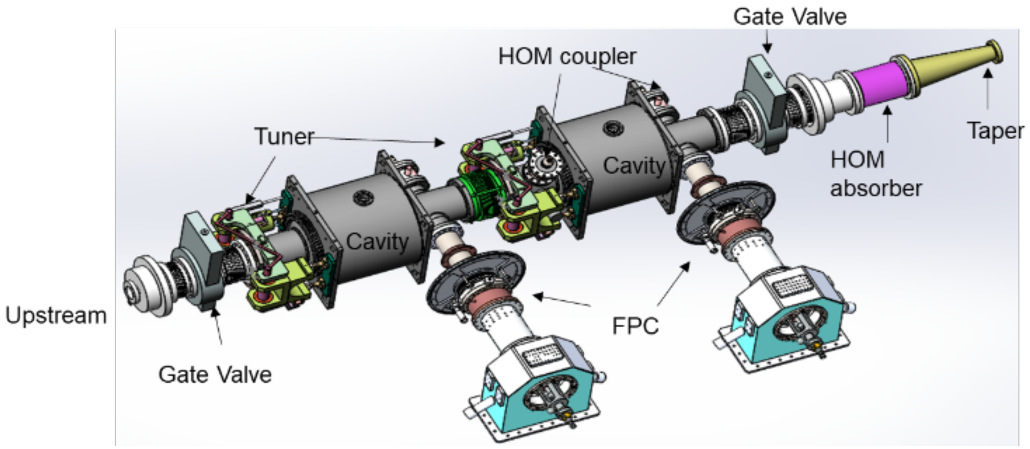
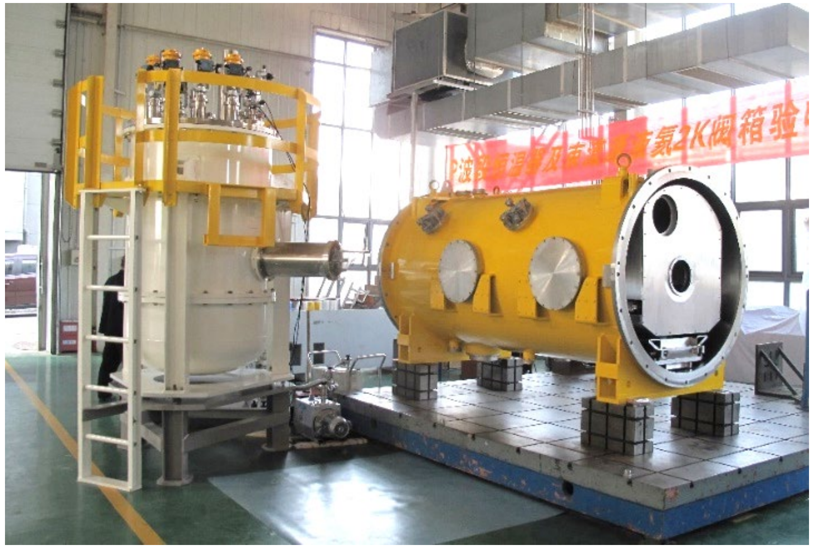
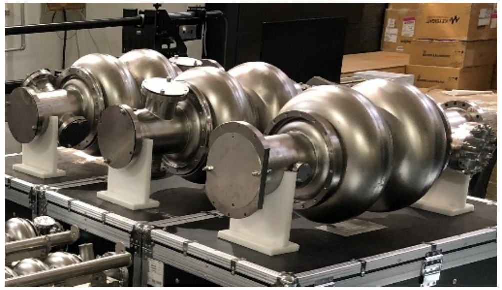
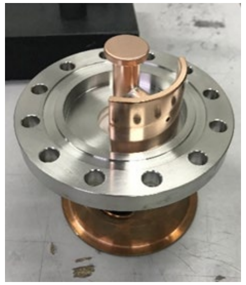
CEPC 650 MHz Test Cryomodule

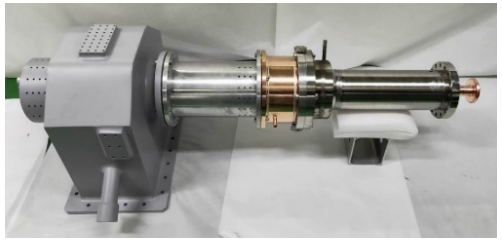


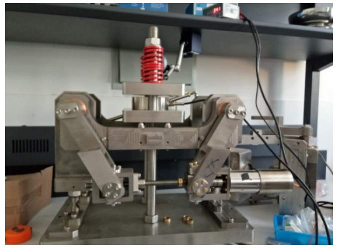


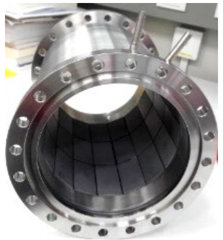




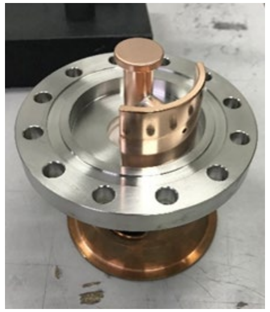


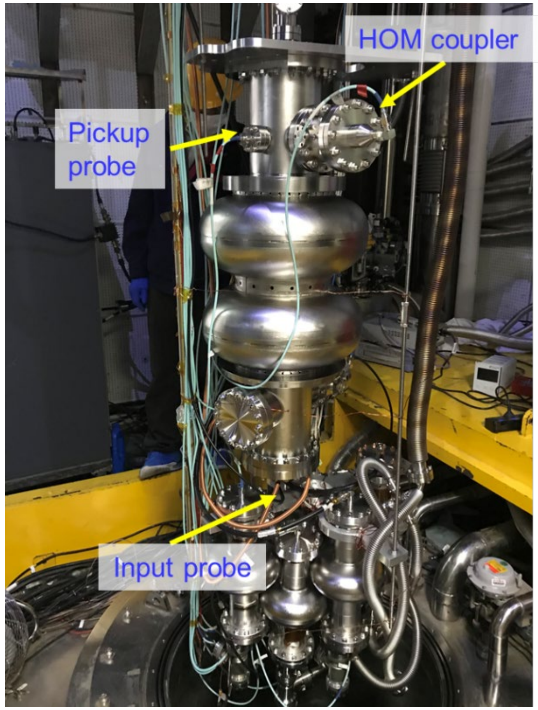


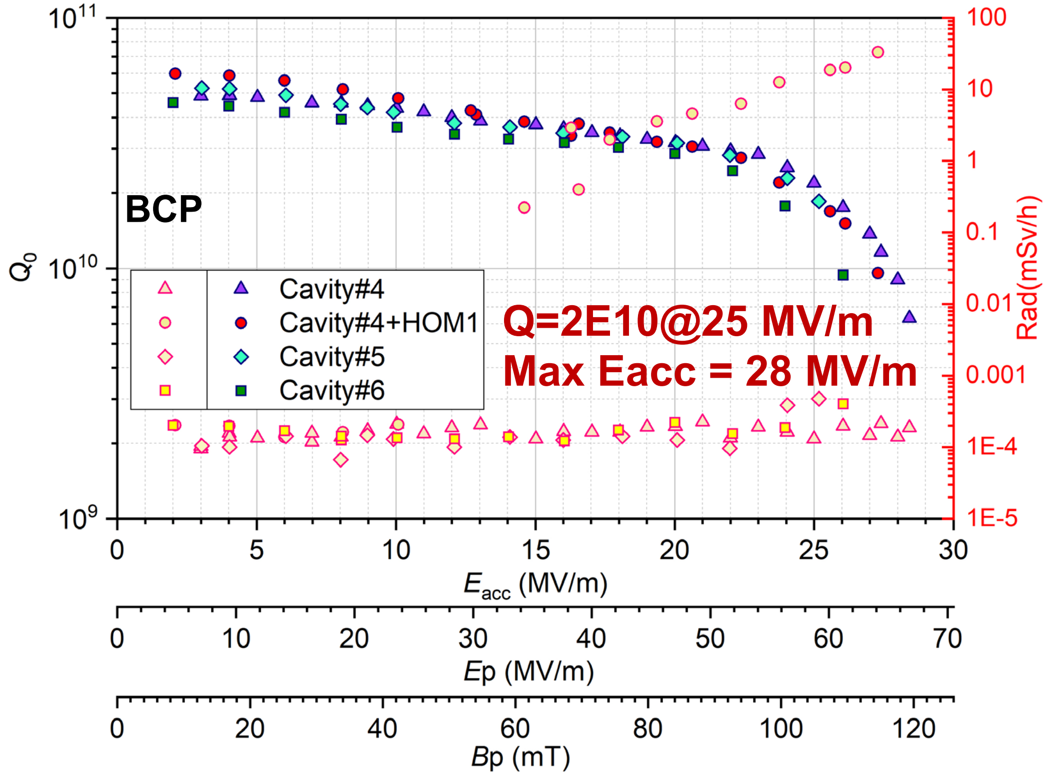




650 MHz 2-cell Cavity Vertical Test with HOM Couplers

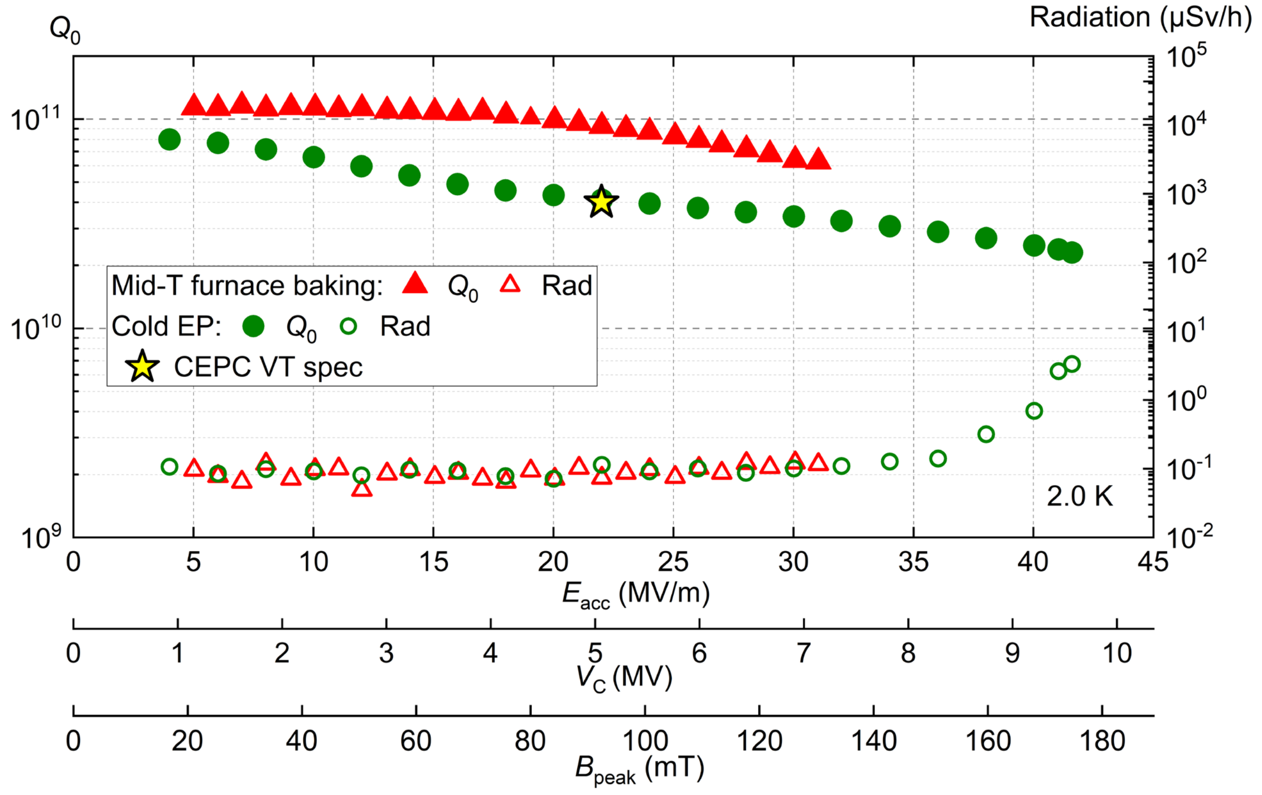




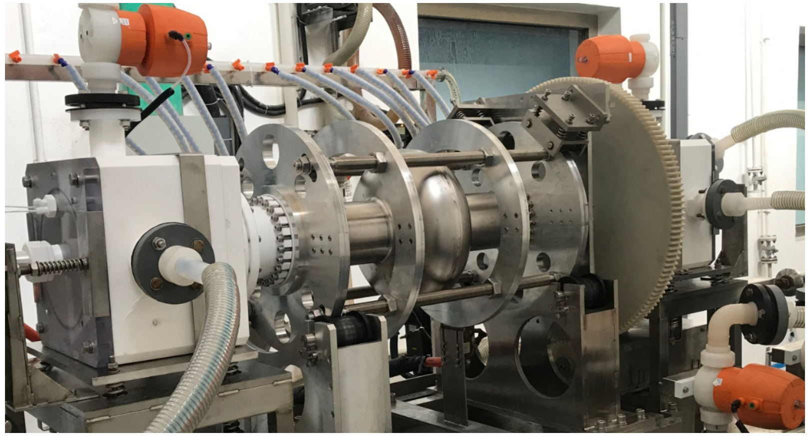


- BCP 650 MHz 2-cell cavities: 2.8E10@22 MV/m (CEPC VT spec: 4E10@22 MV/m)
- Performance no change after install HOM coupler
- EP/heat treatment to further improve gradient and Q

High G High Q 650 MHz 1-cell Cavity

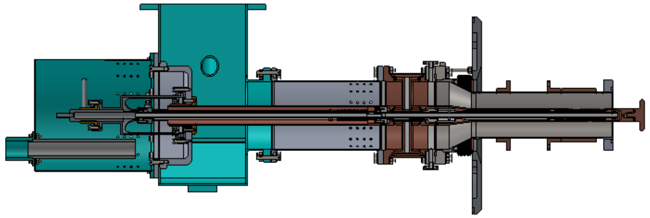


650 MHz 1-cell cavity vertical test
EP treated: 2.3E10@41.6 MV/m@2 K
Mid-T treated: 6.3E10@31 MV/m@2 K

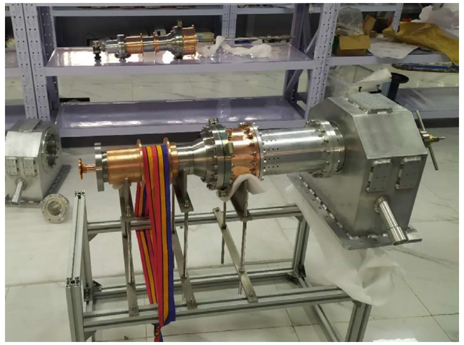


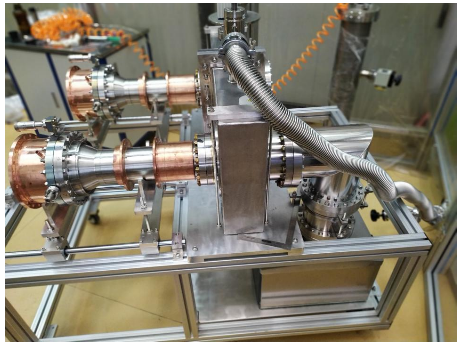
650 MHz High Power Variable Coupler

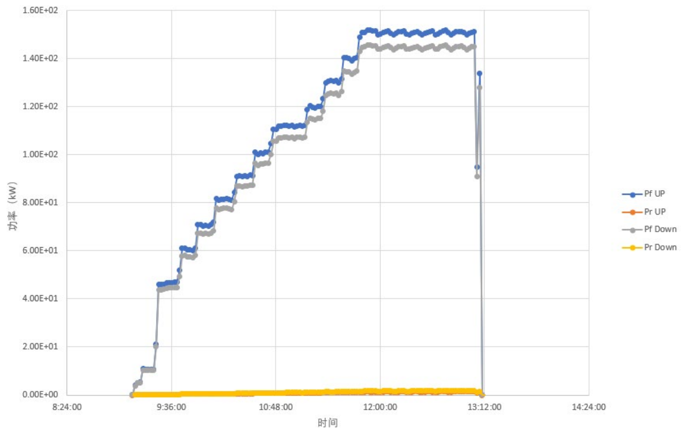
- 650 MHz **variable couplers** tested to CW TW 150 kW (SSA power limit), SW 100 kW (corresponding to 400 kW TW power at the window, exceeds CEPC spec 300 kW). One of the world highest variable couplers.



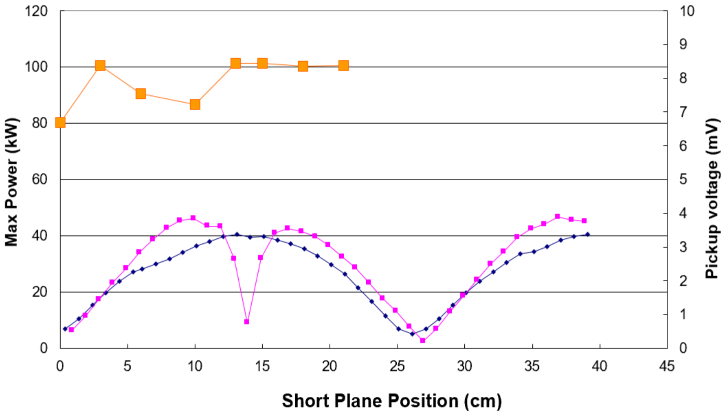
Bellow on inner conductor. Inner conductor water cooling. Outer conductor He gas cooling.



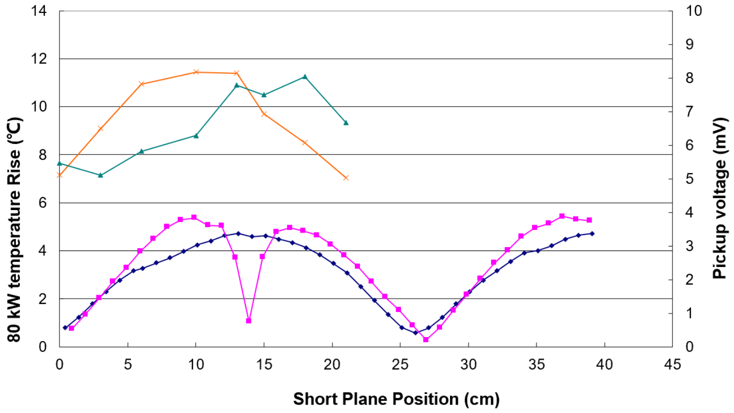




TW high power test to 150 kW

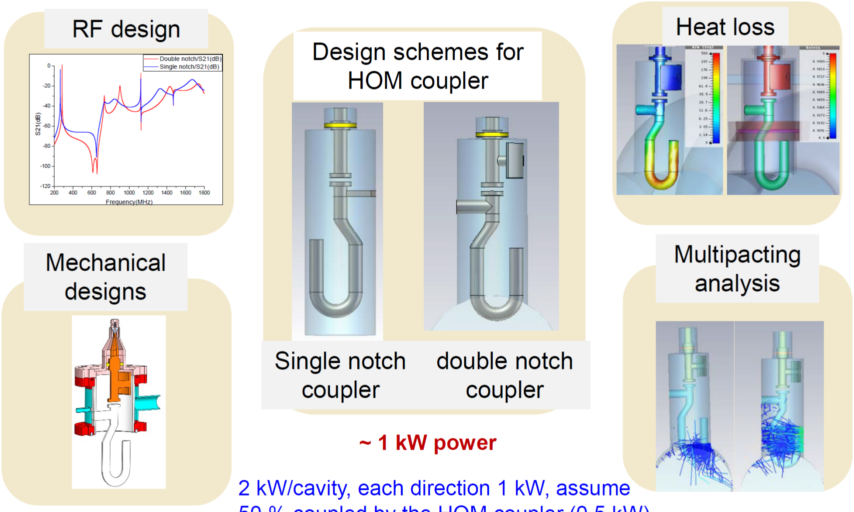


Window SW field and power



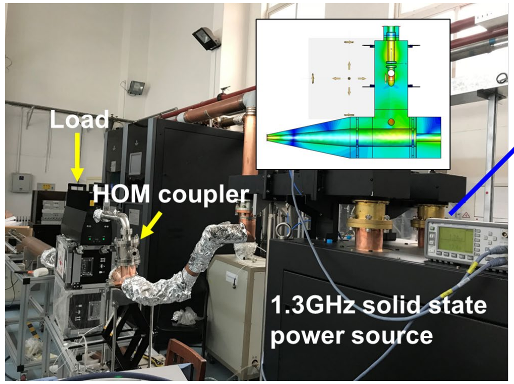
Window SW field and temperature rise

Double Notch HOM Coupler



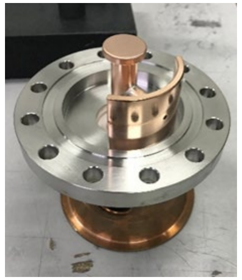
~ 1 kW power

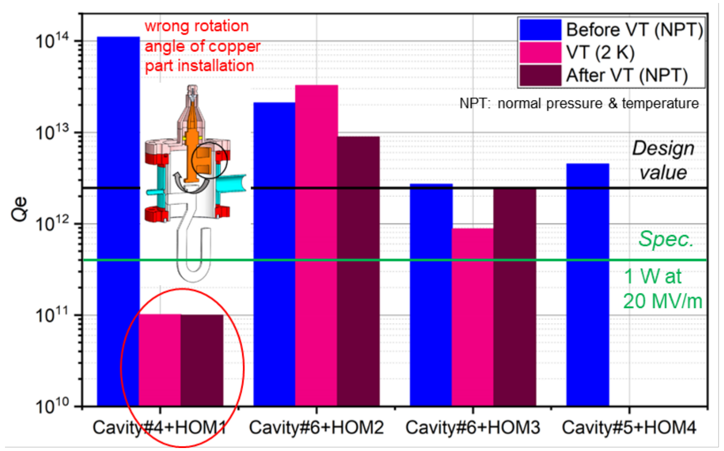
2 kW/cavity, each direction 1 kW, assume 50 % coupled by the HOM coupler (0.5 kW).



- 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.

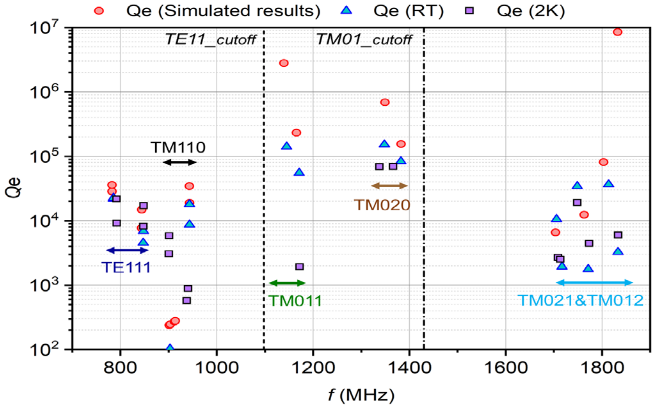
https://doi.org/10.1016/j.nima.2019.163094
https://doi.org/10.1007/s41605-019-0143-x

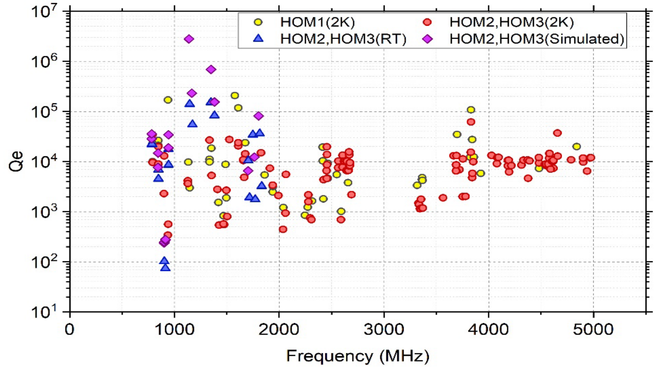




Fundamental mode rejecting Q_e

Test results before and after VT are repeatable if installed correctly. In the module: HOM1 6.8E13, HOM2 1.9E13. HOM3 2.1E12. **No tuning needed.**



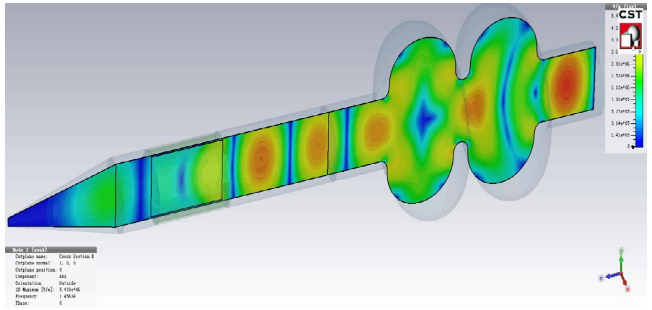


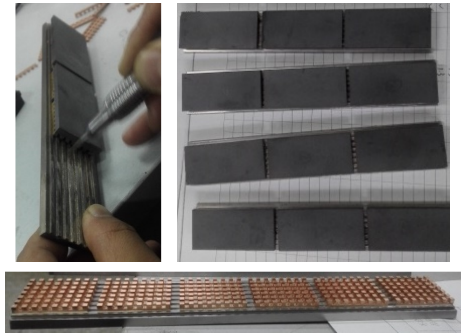
HOM damping Q_e

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

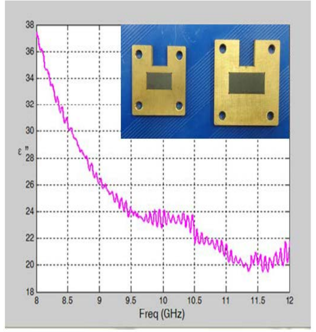
Broadband High Power HOM Absorber

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.

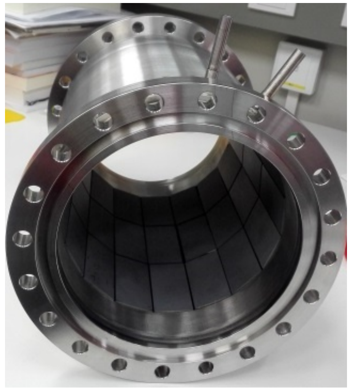


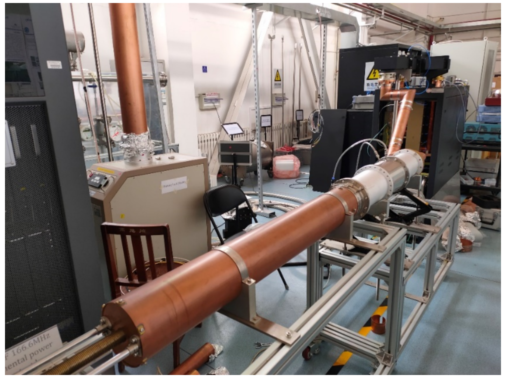


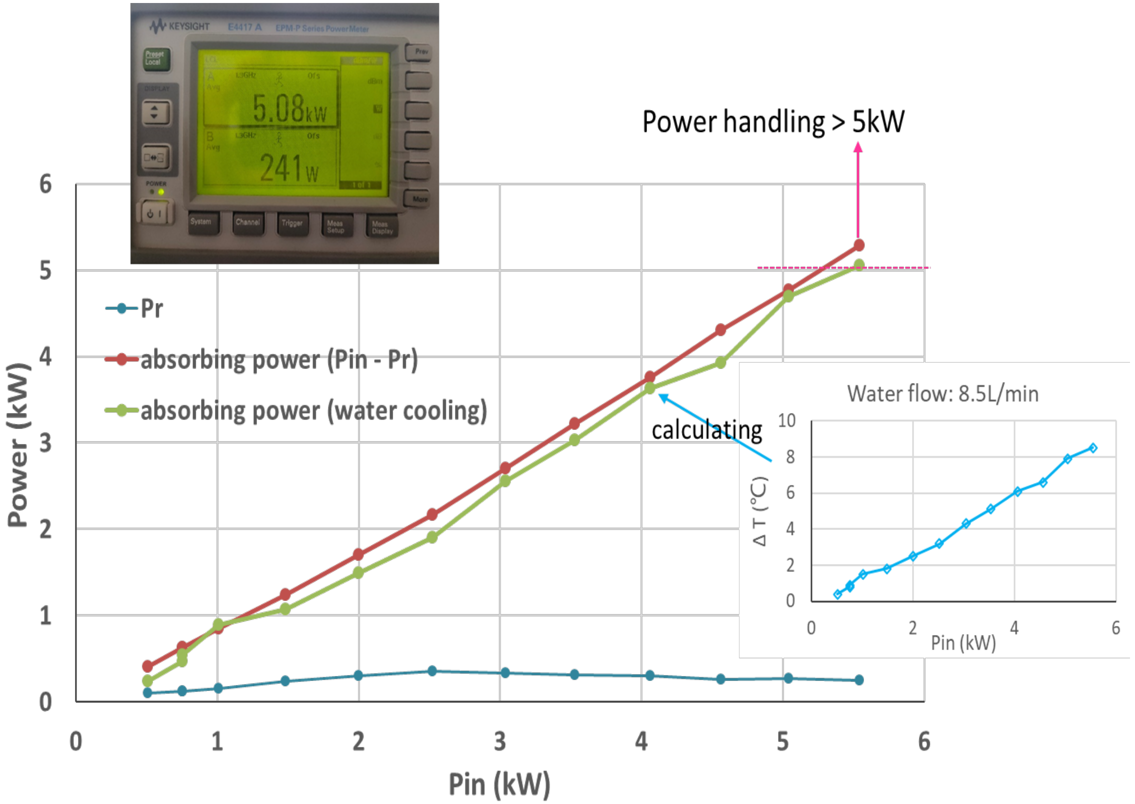
SiC+AlN composite bricks brazed on copper and then on kovar plate



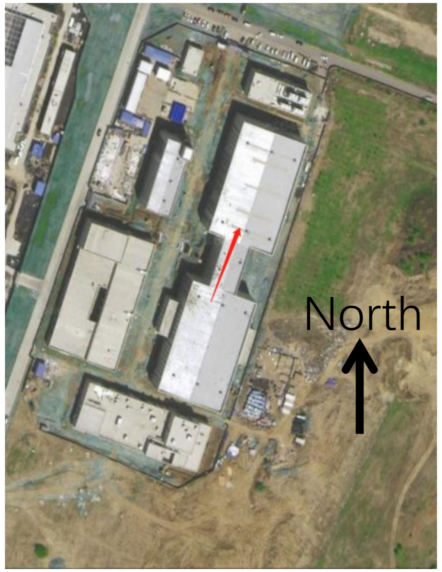
Measured permittivity of SiC+AlN composite (for broadband microwave absorbing)

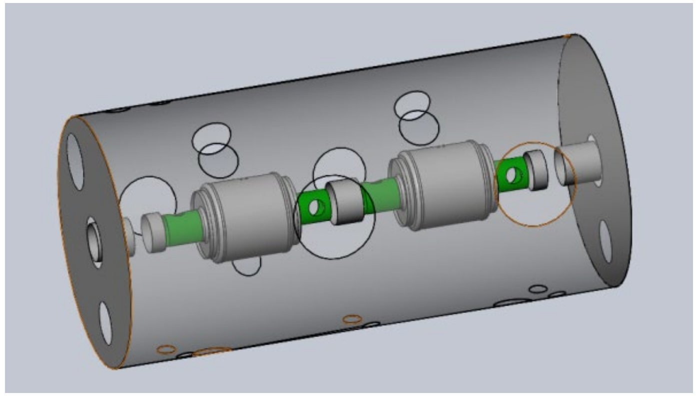




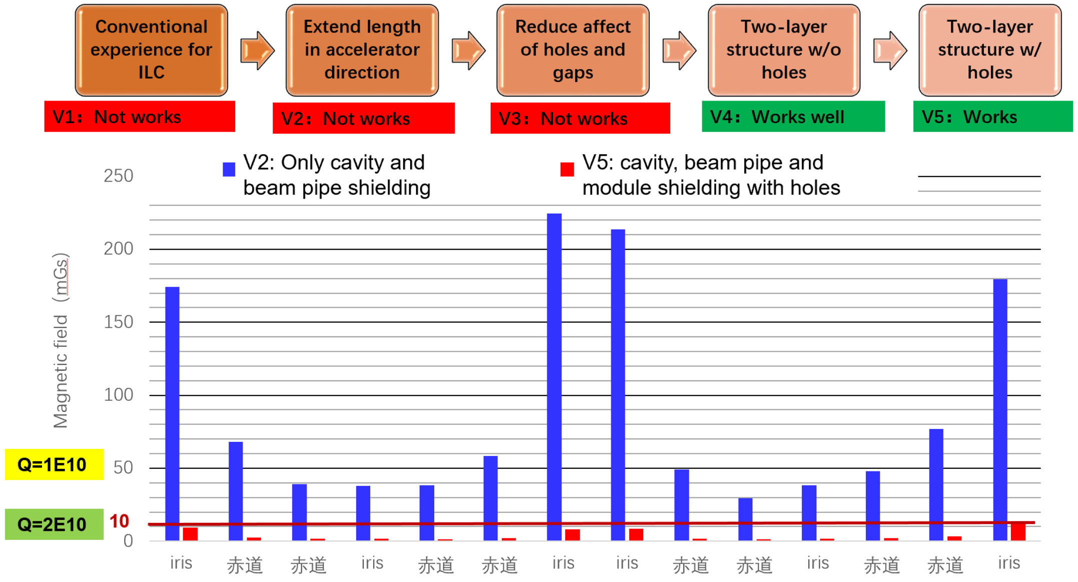


Global and Local Magnetic Shielding



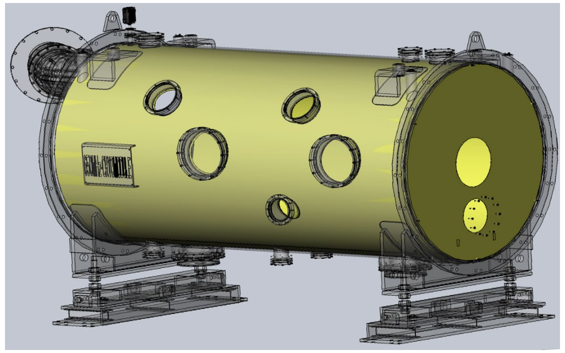


Because of beam direction and larger beam pipe than 1.3 GHz, **only two shieldings** can reach the magnetic field requirement of high Q 650 MHz cavity: **cavity (2 K local) shield and module (RT global) shield**.

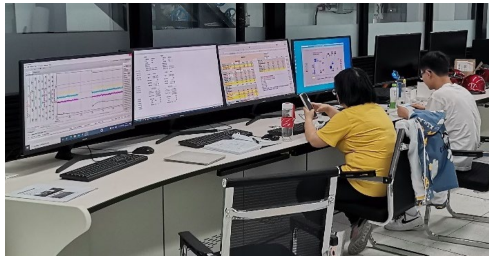


$$R_{mag} = \eta \cdot S(l) \cdot (B_{ext}+B_{tc})\sqrt{f}$$

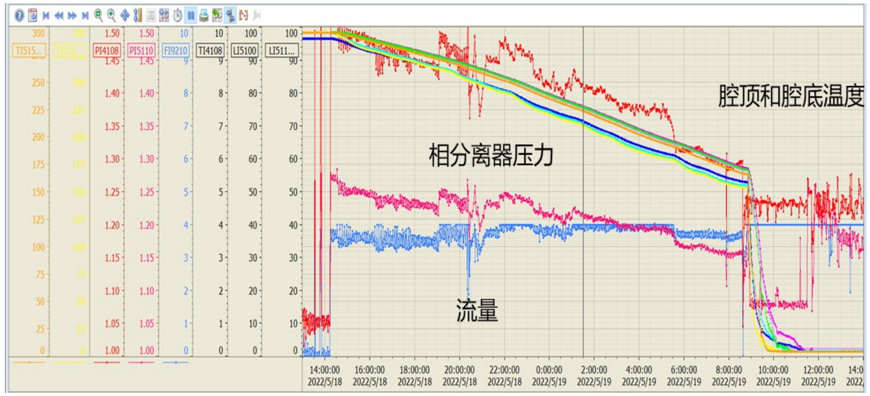
1. Flux trapping ratio: grain size, high-T annealing, fast cold down
2. Magnetic sensitivity: mean free path and other
3. Remnant magnetic field: demagnetization, magnetic shield, magnetic compensation
4. Thermocurrent induced magnetic field



650 MHz Cryomodule Cool Down and Testing



- DC photo-cathode gun voltage conditioned up to 400 kV
- Cavity frequency, HOM coupler double notch filter, tuner, vacuum, cryogenics perform well
- Cavity magnetic field at 2 K < 2 mG (large beam pipe North to South)
- LLRF system commissioning and high power test ongoing
  - Optimizing the outer conductor helium gas cooling of the input coupler. Cavity early quench (8 MV/m) if with poor coupler cooling.



Module automatic cool-down experiment

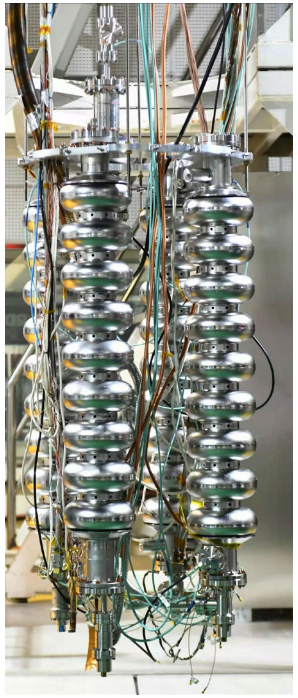
1. 300 to 150 K: < 10 K/hr. Cavity top and bottom ΔT < 20 K
2. 150 to 4.5 K: Cavity surface > 1 K/min
3. 4.5 to 2 K

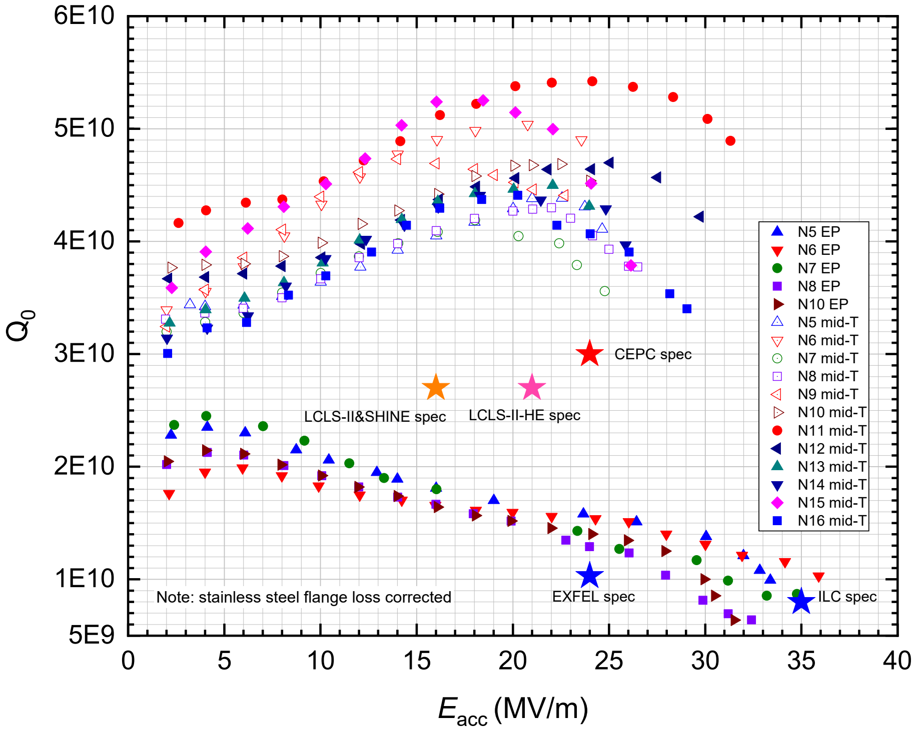
Outline

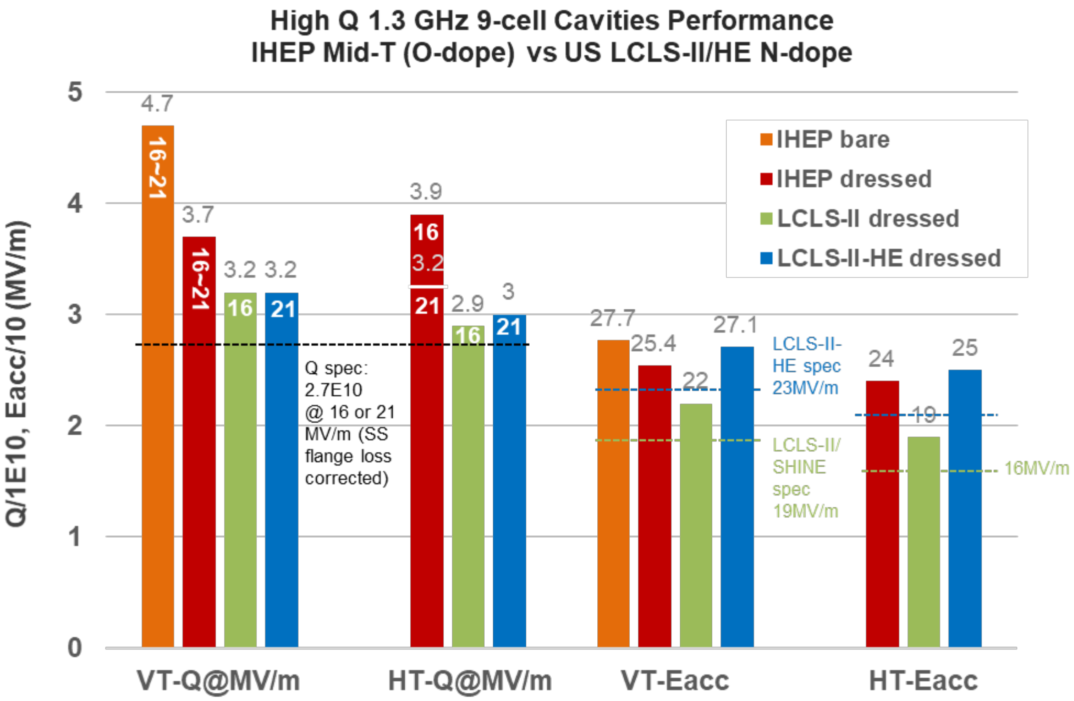
1. CEPC SRF system design
2. Collider 650 MHz SRF R&D
3. Booster 1.3 GHz SRF R&D
4. Summary

World Leading Mid-T High Q 1.3 GHz 9-cell Cavity

- Mid-T (O-doping) supremacy over N-doping: higher G & Q, simple process (oxidation in air vs N_2 injection), less EP (1 vs 3), not sensitive to light EP (no light EP).
- Best mid-T 9-cell cavity (N11): 5.4E10@21 MV/m, 4.9E10@31MV/m (ss flange loss corrected)
- Mid-T is the best choice for future high Q cavity? Now demonstrating in IHEP’s 8x9-cell cryomodule.

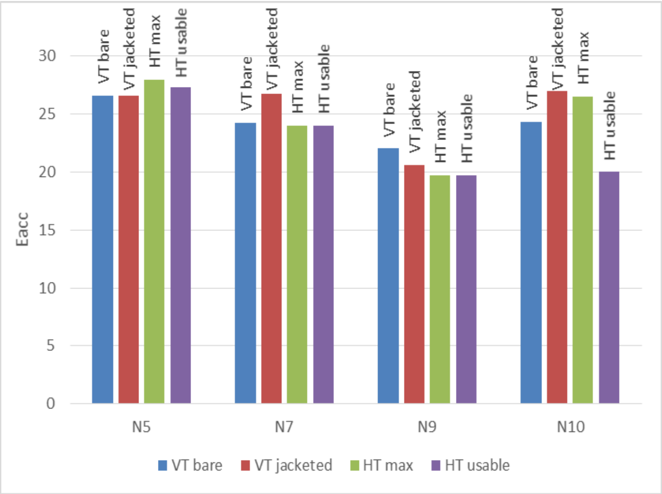


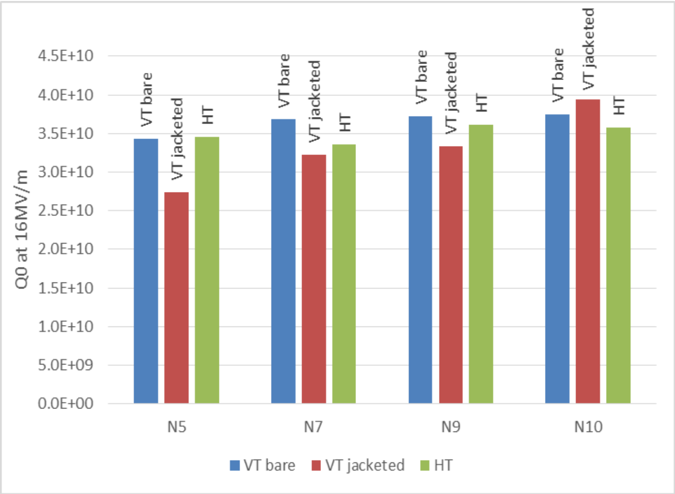


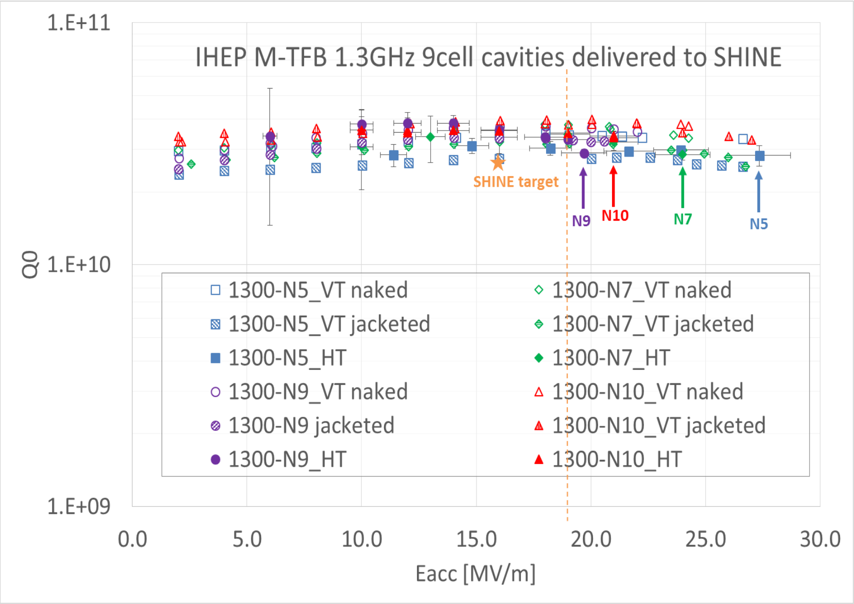


ss flange loss corrected for Q_0

Horizontal Test of Mid-T 9-cell Cavities





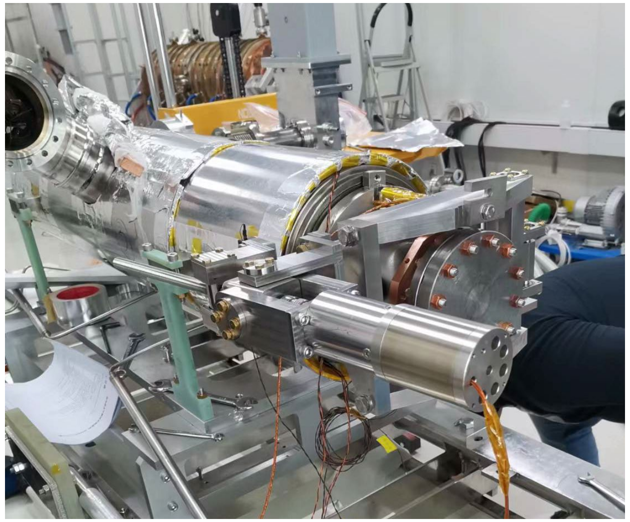


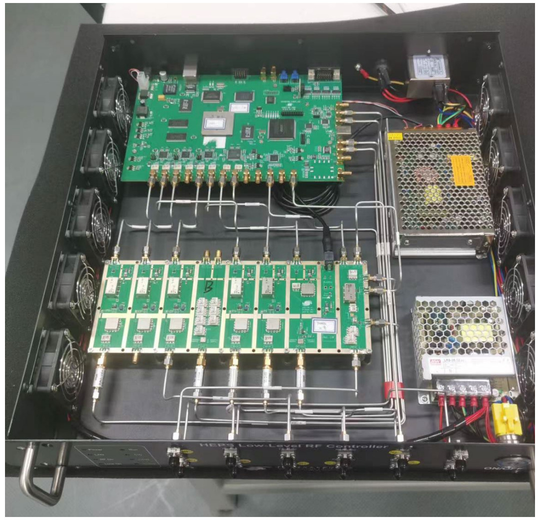
CAV#	Cavity VT with helium vessel			Cavity horizontal test				
	$E_{acc.max}$ (MV/m)	$Q_0/10^{10}$ @ 16 MV/m	$Q_0/10^{10}$ @ 21 MV/m or $E_{acc.max}$	$E_{acc.max}$ (MV/m)	$E_{acc.use}$ (MV/m)	FE onset (MV/m)	$Q_0/10^{10}$ @ 16 MV/m	$Q_0/10^{10}$ @ 21 MV/m or $E_{acc.max}$
N5	26.6	2.7	2.8	28	27.3	none	3.5	3.3
N7	26.7	3.2	3.1	24	24	none	3.4	3.2
N9	20.6	3.3	3.2	19.7	19	none	3.6	2.9
N10	27	3.9	3.9	26.5	20	none	3.6	3.1
Average	**25.2**	**3.3**	**3.3**	**24.6**	**22.6**	/	**3.5**	**3.1**

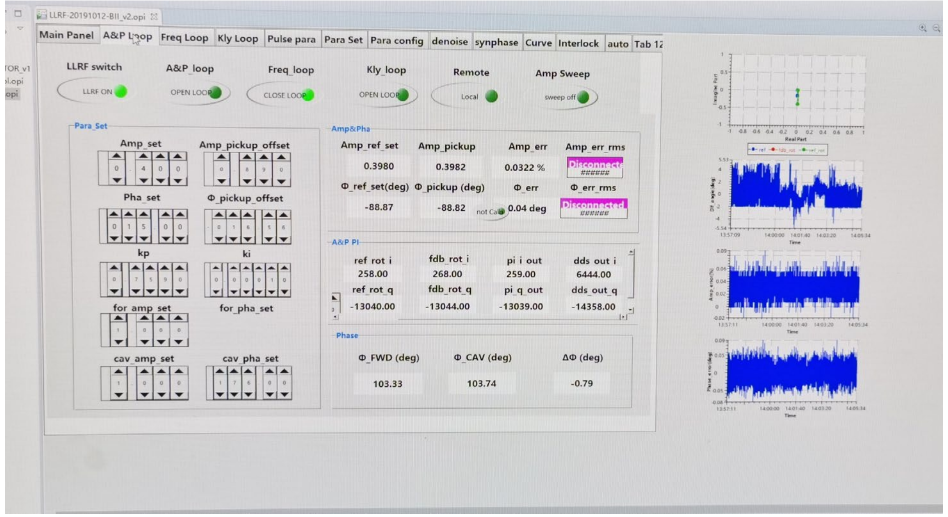
9-cell cavity with power coupler, self-excited horizontal test (not GDR mode, w/ tuner)
Usable gradient: radiation < 0.5 mSv/h, 0.5 MV/m below Eacc.max, one hour stable operation

ss flange loss not corrected for Q_0

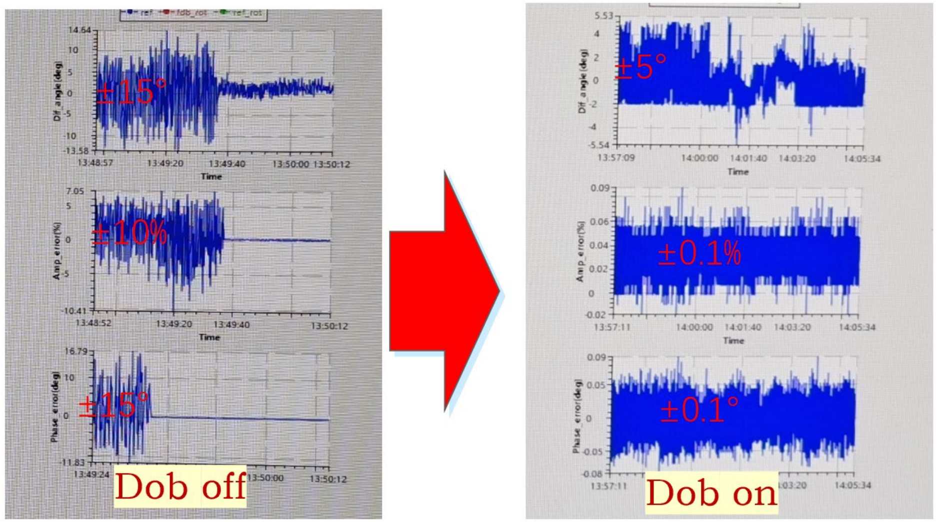
Horizontal Test of Mid-T 9-cell Cavities



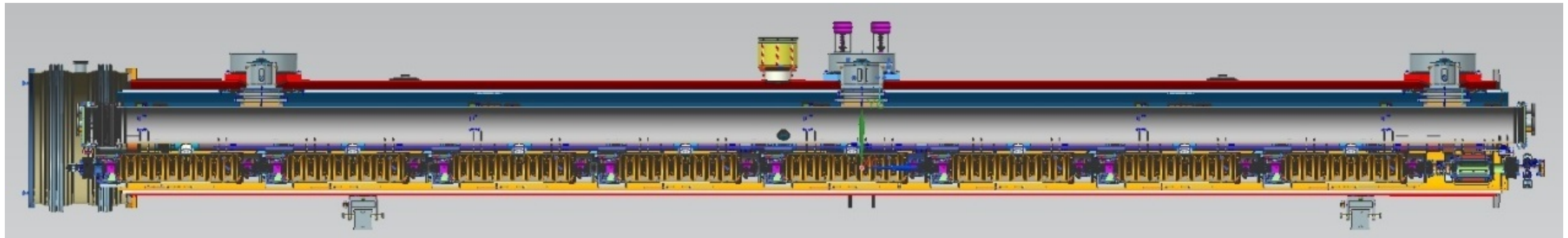




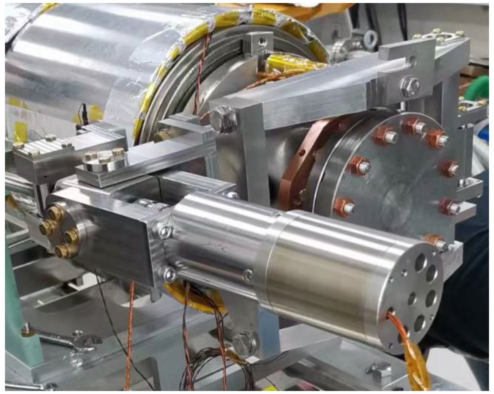
- **Tuner test at 2 K**
  - motor tuning range: 420 kHz (design 400 kHz)
  - piezo tuning range: 3 kHz (design 1 kHz)
  - tuning resolution: < 1 Hz
- **LLRF commissioning**
  - SEL & GDR mode
  - DOB (disturbance observer based) better than PI controller
  - optimizing loop parameters to improve field stability

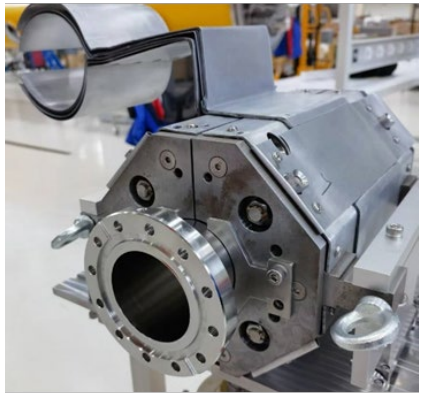


1.3 GHz High Q Module with Mid-T 9-cell Cavities



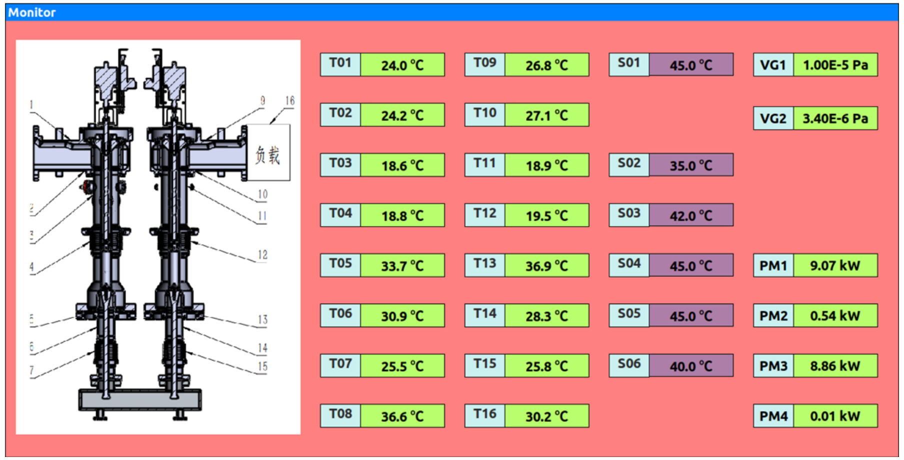
8 cavities, input couplers, tuners, SC magnet, BPM, cryostat, module cart, feed/end-cap, volve-box …



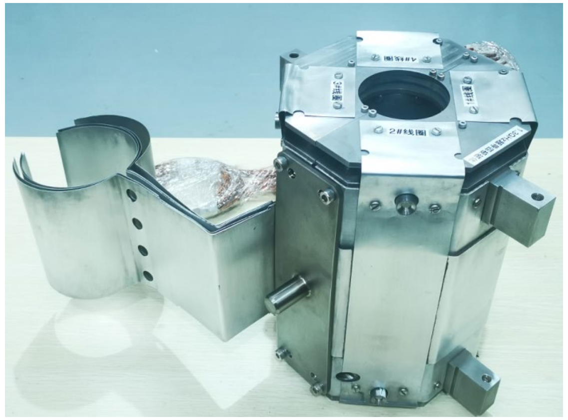


1.3 GHz Input Couplers

1.3 GHz Input Coupler Conditioning						
Coupler	Travelling Wave			Standing Wave (10 mm step)		
	Conditioning Time (h)	Max Power (kW)	Interlocks	Conditioning Time (h)	Max Power (kW)	Interlocks
1# & 2#	30	10	1	84	5	0
3# & 4#	49	10	2	93.5	7	0
5# & 6#	41	9.5	2	107	6	36
7# & 8#	9.5	8	62	62	6.2	12



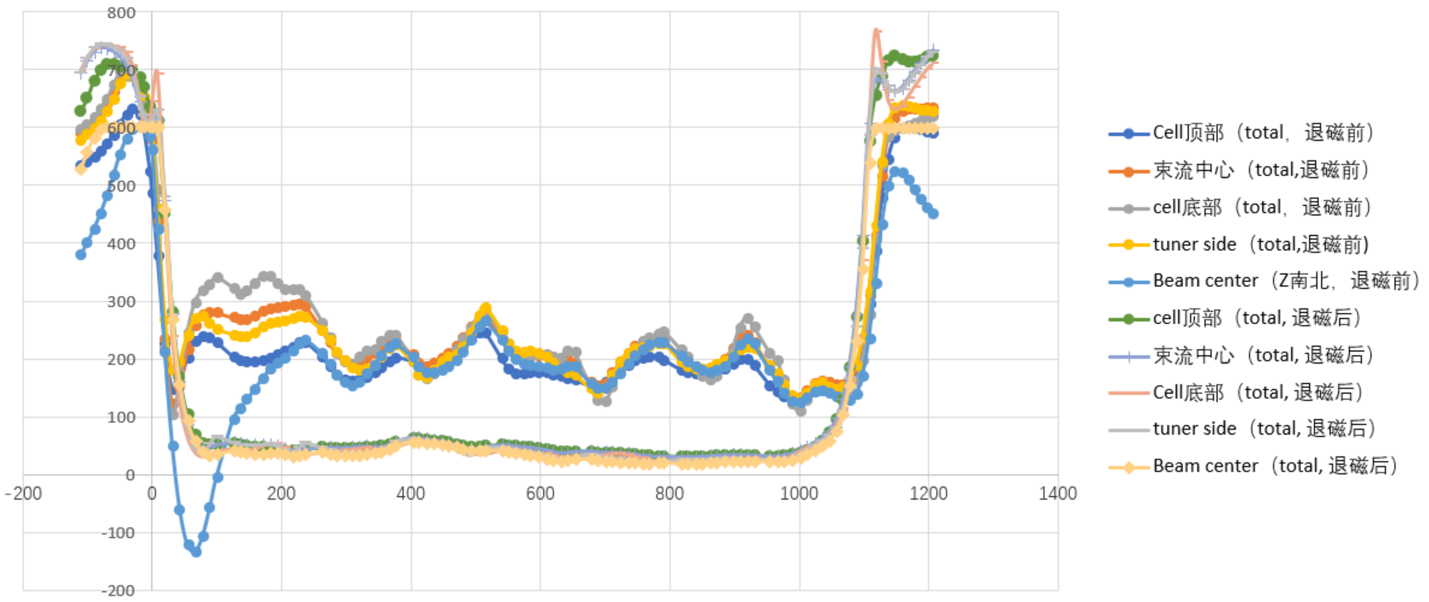
Superconducting Magnet and Degaussing



- The magnet includes one set of quadrupole coils, two sets of correction coils and one set of heating coils with power source and quench protection system.
- Conducting cooling excitation and magnetic field test in liquid helium was done. All coils can run stably at 35 A. The magnetic field results meet the design values.
- Remnant field at 0 A is over 20 Gs at a distance of 400 mm from the end of the magnet (cavity position). After a dedicated degaussing cycle, the remnant field is less than 50 mGs. Need to degauss before each warm up of the module.

	Parameter	Unit	Design value	Measured value@20A
Quadrupole coil@5mm	Peak integral field gradient	T	2.0	2.6381
	Peak field gradient	T/m	8.67	11.6090
	Higher-order field components		0.3%	<0.1%
	Gradient stability (r=5mm)		0.5%	<0.1%
Correction Coil	The integration of the bipolar field	Tm	0.005	HC：0.018 VC：0.017
	Effective length	mm	230	HC：238 VC：234

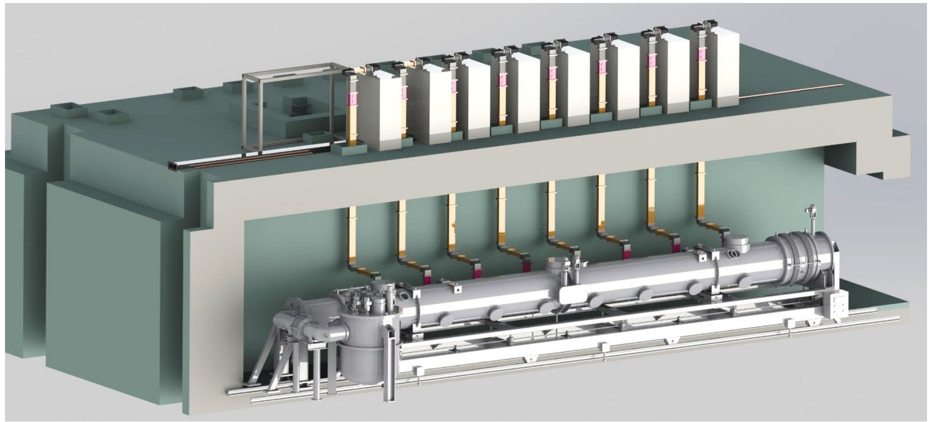
Cryomodule Vacuum Vessel Degaussing

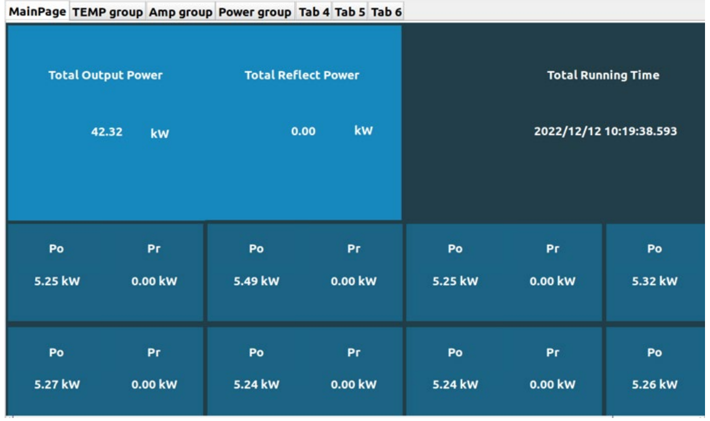


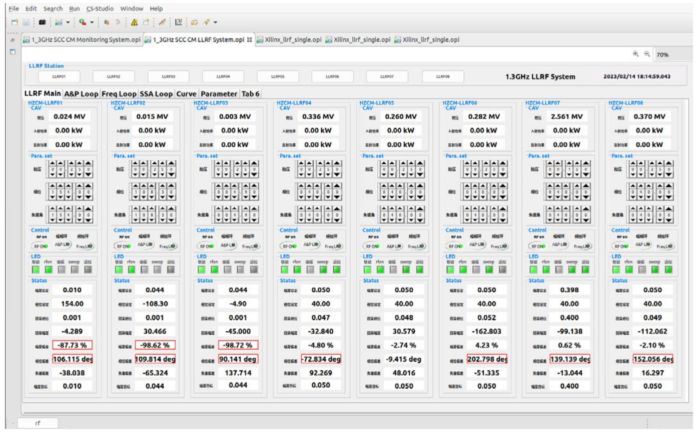
- Module north to south
- Before degaussing ~ 200 mG
- After degaussing < 40 mG, nearly 0 mG with online compensation
- Remnant magnetic field will be very small with two-layer magnetic shielding of the cavity

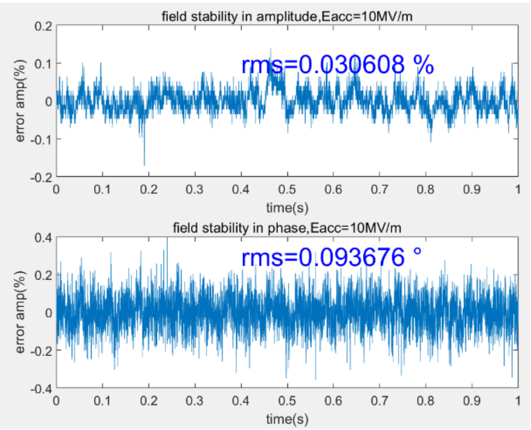
HLRF and LLRF System

- 8 x 5.2 kW SSA. 8 x LLRF systems.



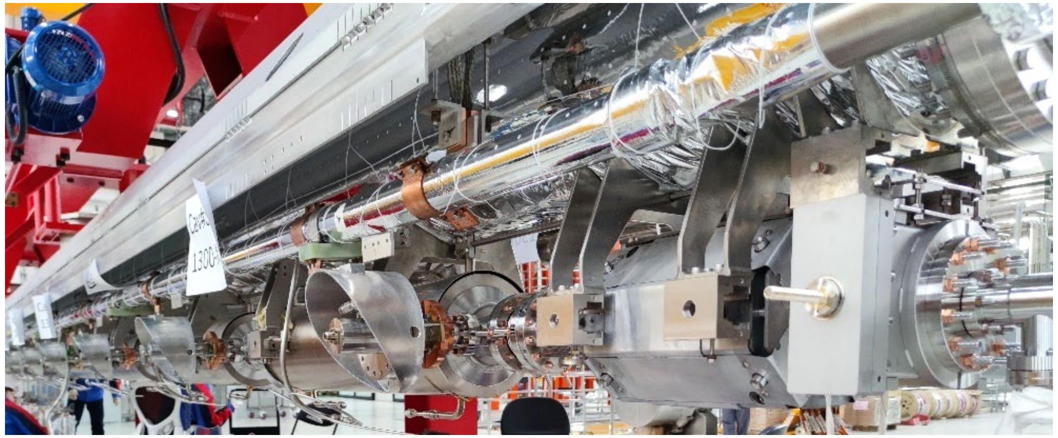


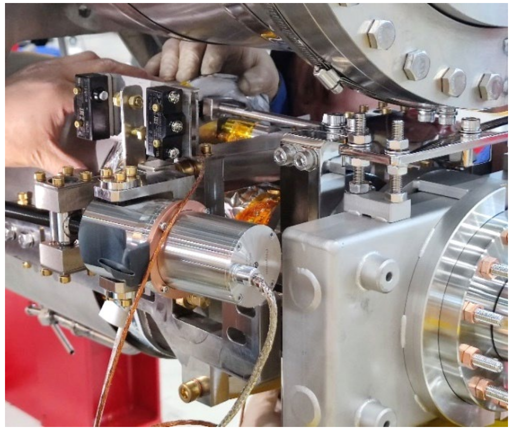


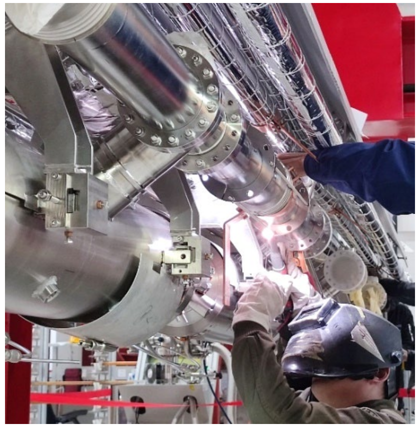


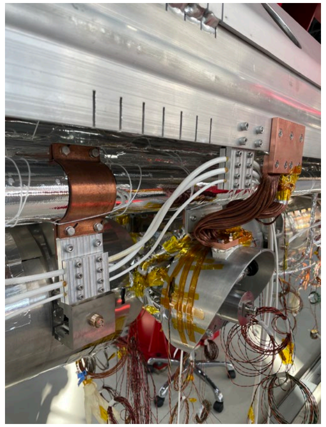
Cavity String and Cryomodule Assembly

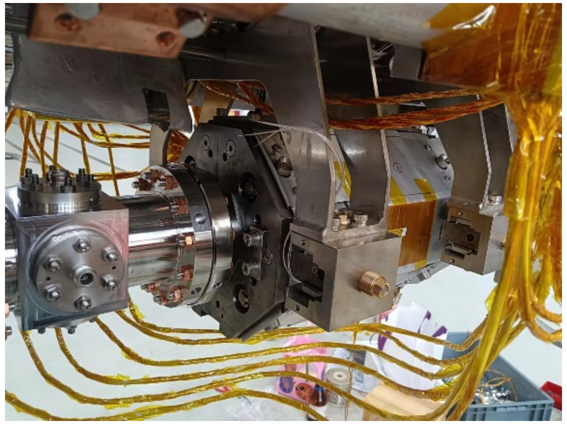
- Cavities HPR before string assembly.
- Cavity string keeps in vacuum all the way to module testing.

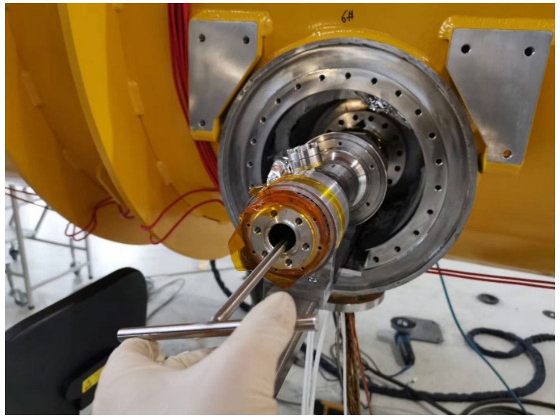


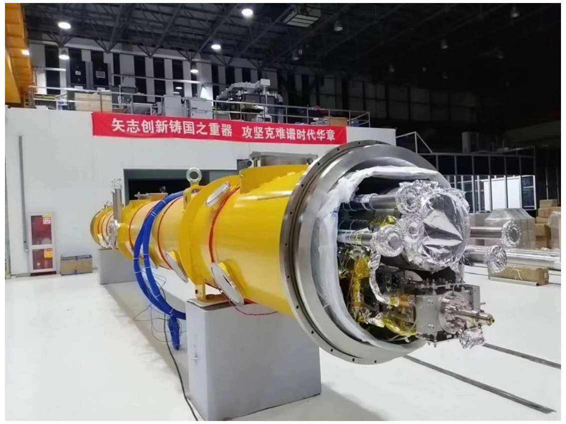








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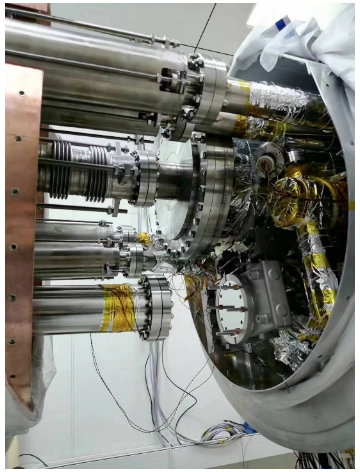
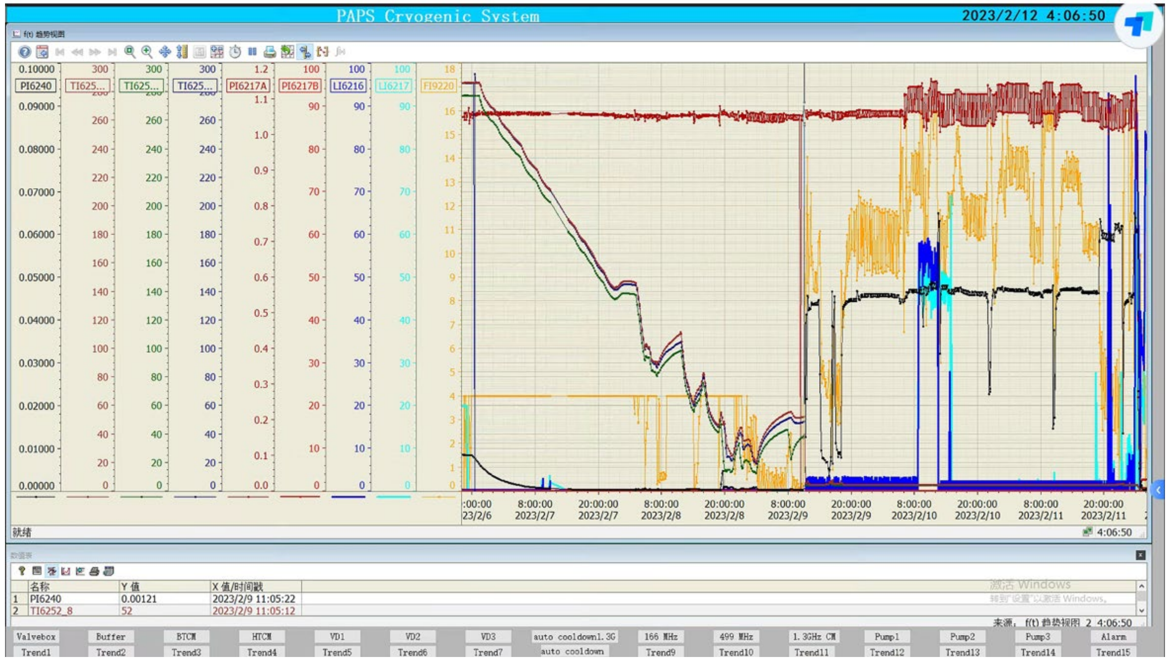
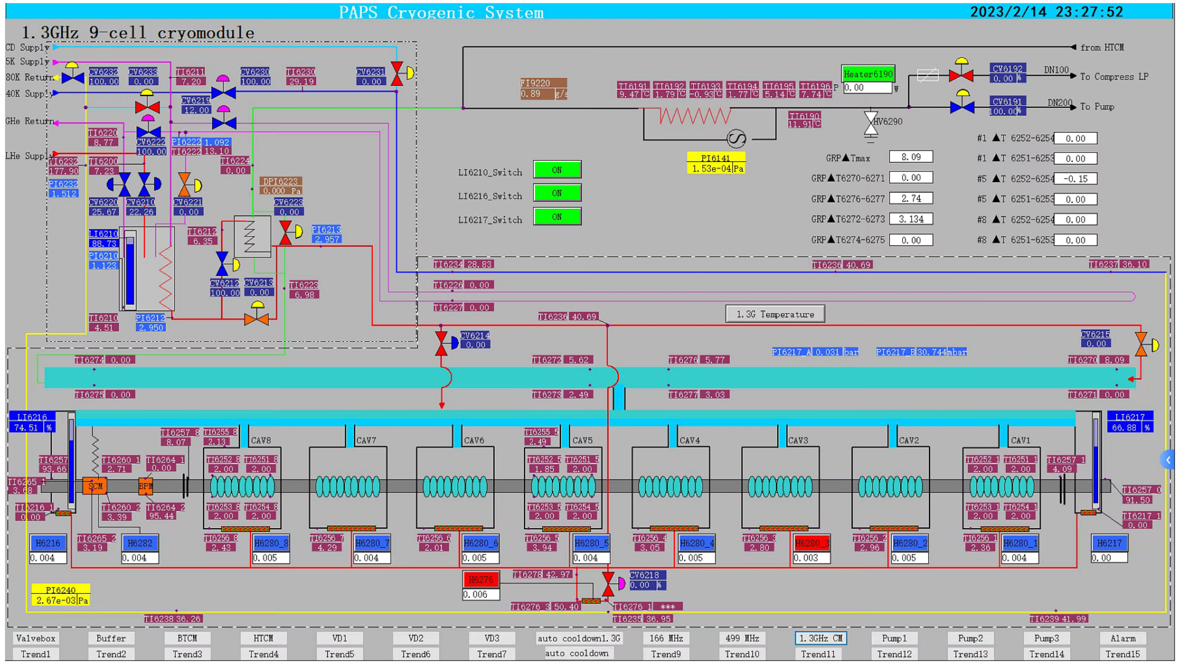
Cryomodule Installation in Horizontal Test Stand



2 K Cool Down and Cavity High Power Test

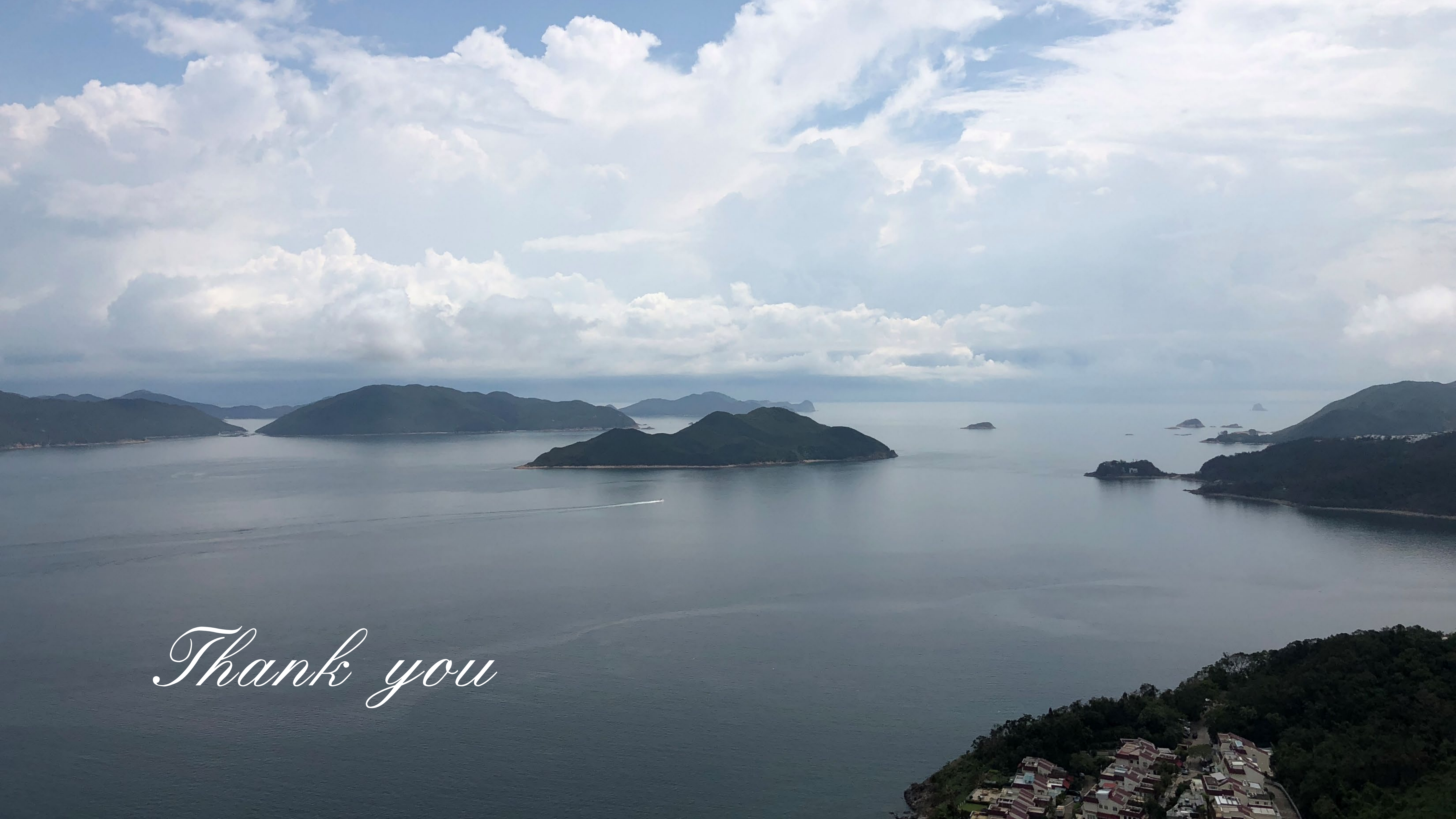
- ✓ Fast cool down between 40 K to 4.2 K to expel magnetic flux.
- ✓ Cavity, coupler and cryomodule isolation vacuum OK.
- ✓ Cavity frequency, tuner, piezo, input coupler QL adjustment, HOM coupler FM Qe OK.
- ✓ Preliminary individual cavity test at 16 MV/m show high Q.
- ✓ LLRF system commissioning, unit test, microphonics measurement, data analysis … ongoing.
- ✓ Faraday cups to be installed to measure dark current in next cool down and test.





Summary

- CEPC SRF layout and parameters are fixed for TDR. Consistent with CEPC physics run requirement (Higgs first, mode-switching), different from FCC-ee.
- Both 650 MHz and 1.3 GHz Mid-T high Q cavities achieved world leading performance. High performance demonstration of the prototype cryomodules is the next major goal. Mid-T is promising for high Q application.
- Post TDR (EDR) task: Focus on optimization of the Higgs cavity and cryomodule design. Develop high current HL-Z and high gradient high Q ttbar cavity/module concept. Speed up Nb_3Sn and other new material cavity R&D for CEPC with their huge spin-off for society.


Thank you