中國科學院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

# IHEP ILC Test Cryomodule Status

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On behalf of the ILC SRF R&D team of IHEP

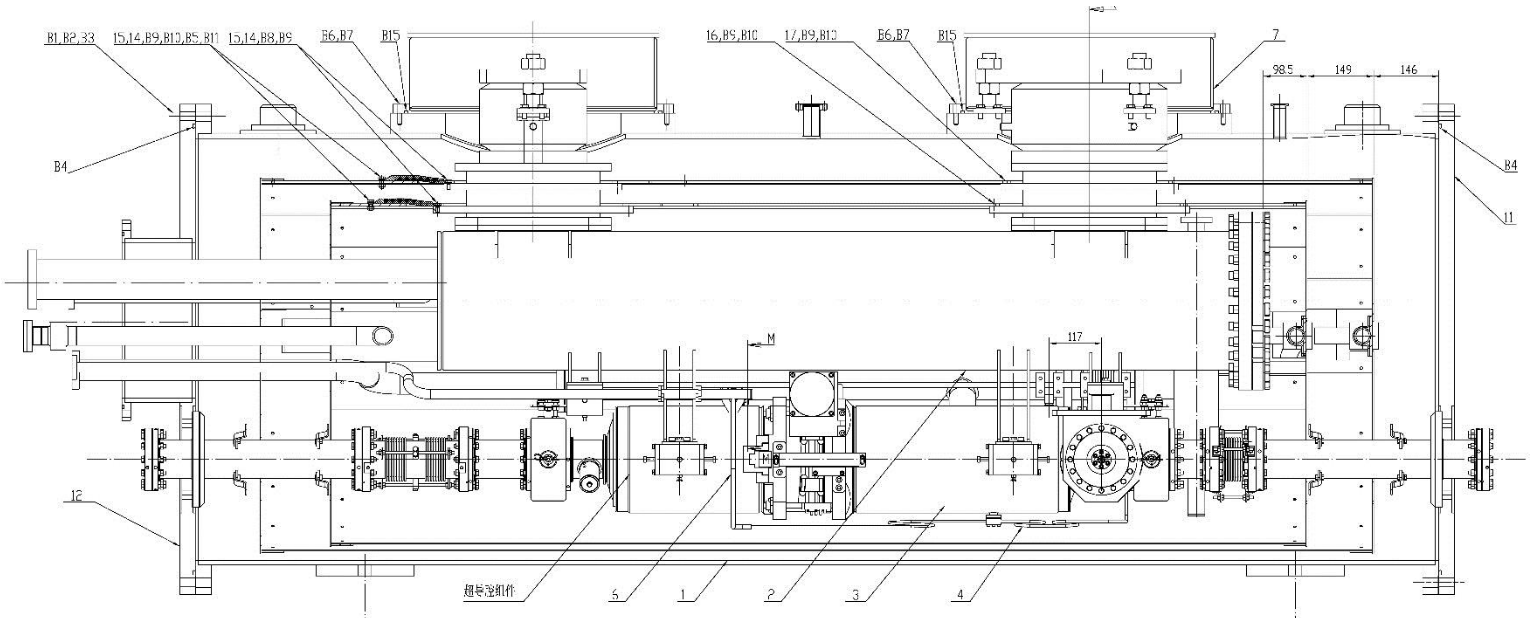
2014 International Workshop on Future Linear Colliders (LCWS14)

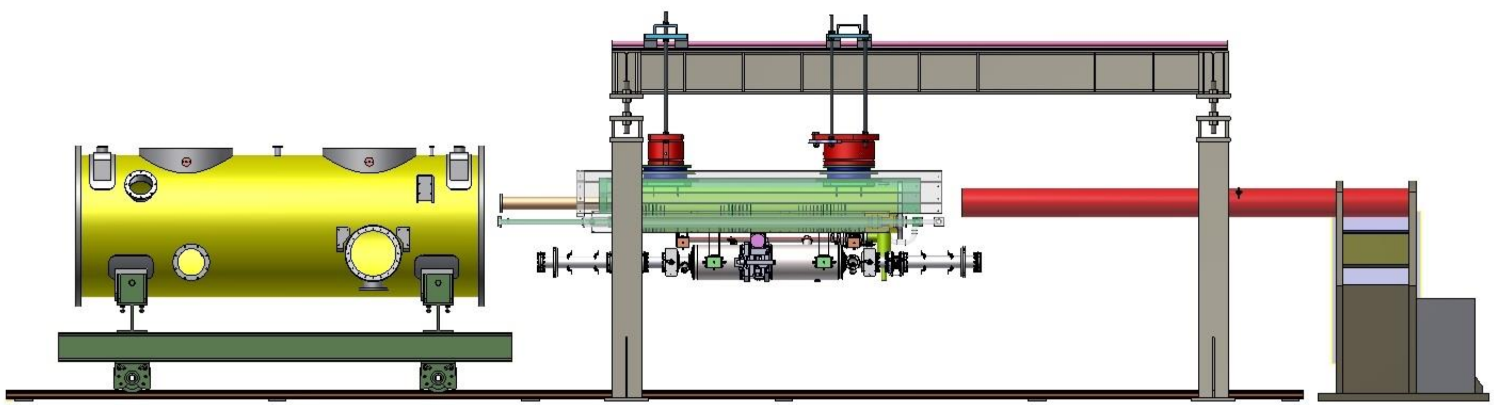
6-10 October 2014, Belgrade, Serbia

# Outline

- Cavity clean room assembly
- Cryomodule assembly
- 80 K cooling down test
- other SRF R&D

# IHEP ILC Test Cryomodule

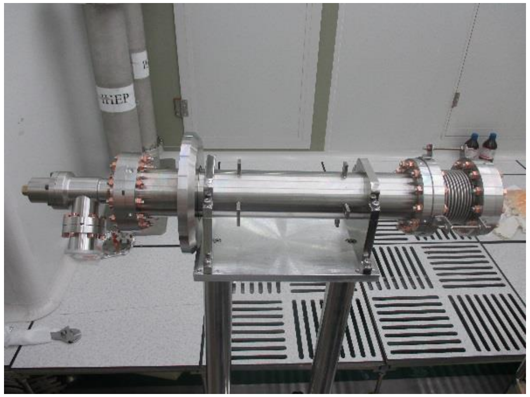


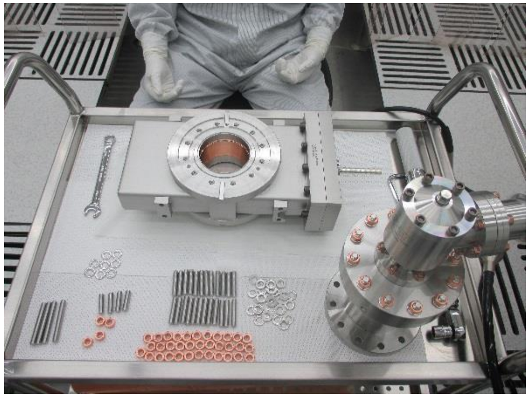



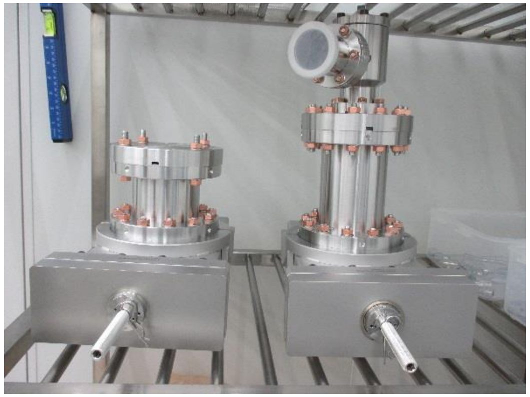

IHEP ILC-TC1

# Clean Room Assembly Preparation

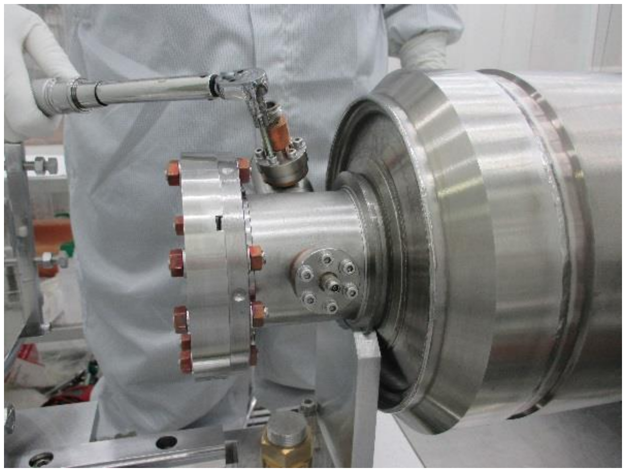
# Particle Free Flange Assembly

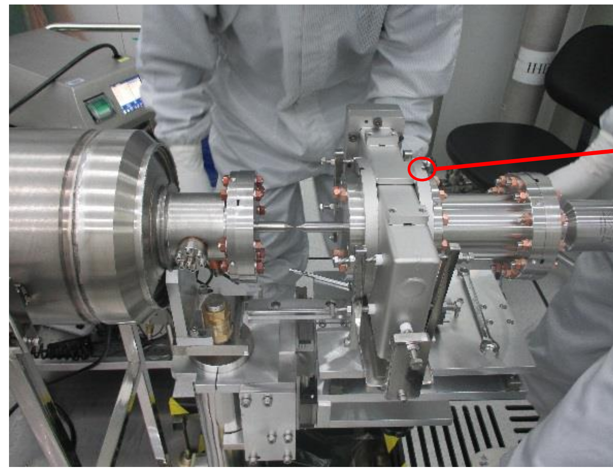


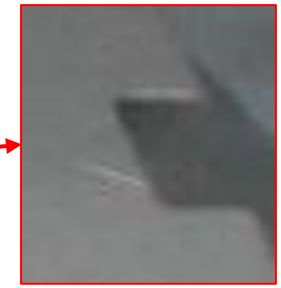




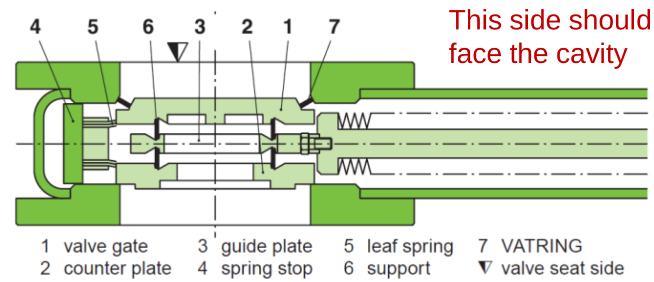
# Gate Valve Assembly





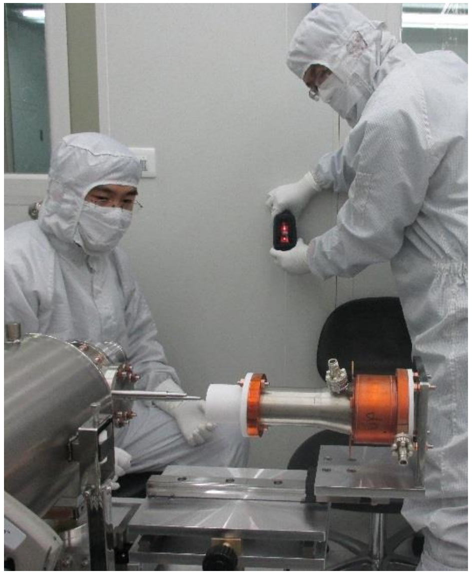


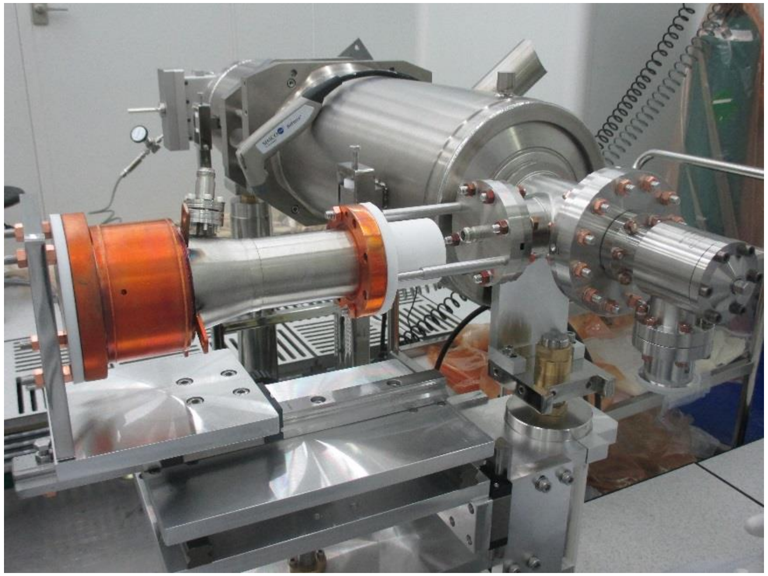
Wrong assembly of the gate valve seat side.



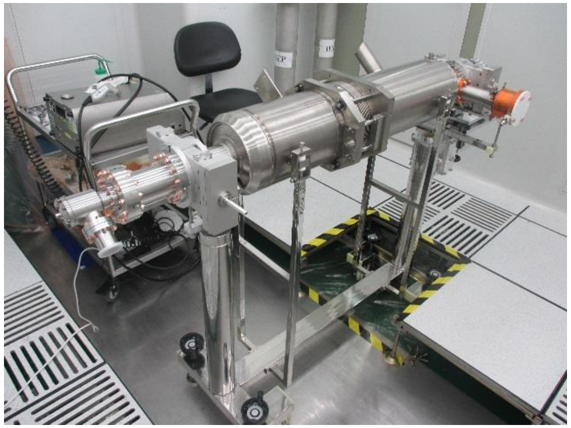

Leak rate will be higher.
Cleanness OK.
Allowable differential pressure 2 bar in either direction.

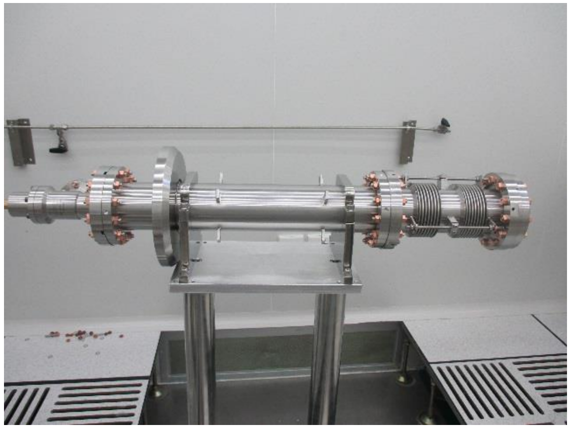
# Coupler Cold Part Assembly

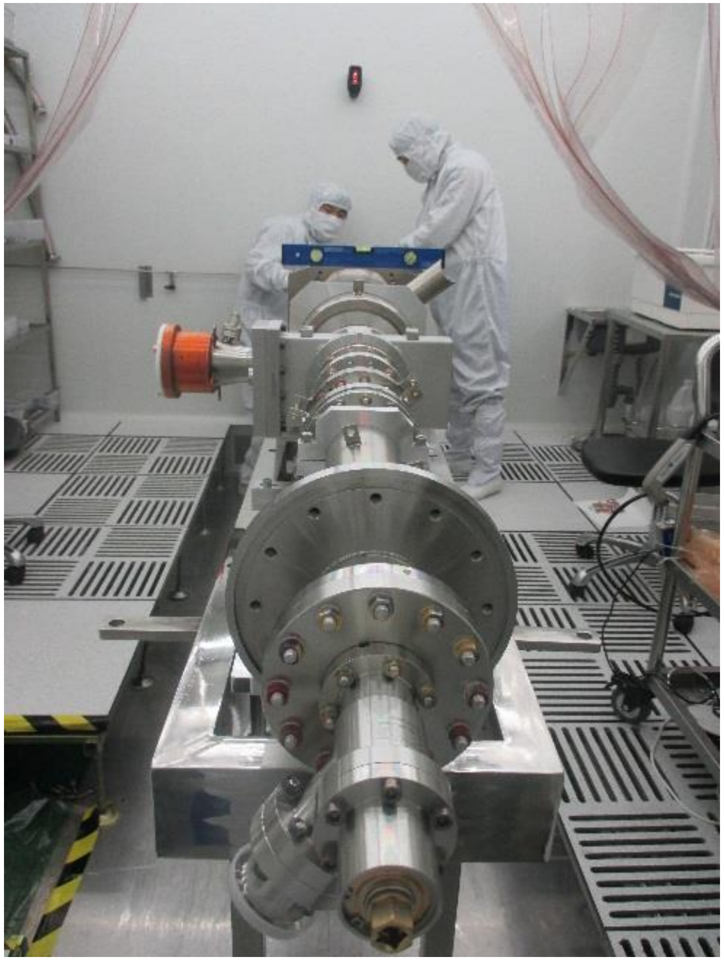


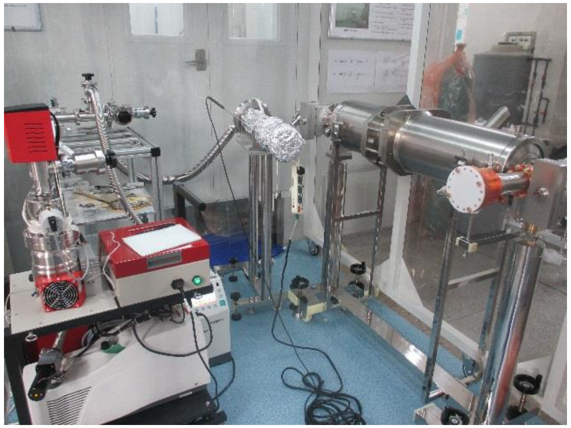


# Clean Room Assembly





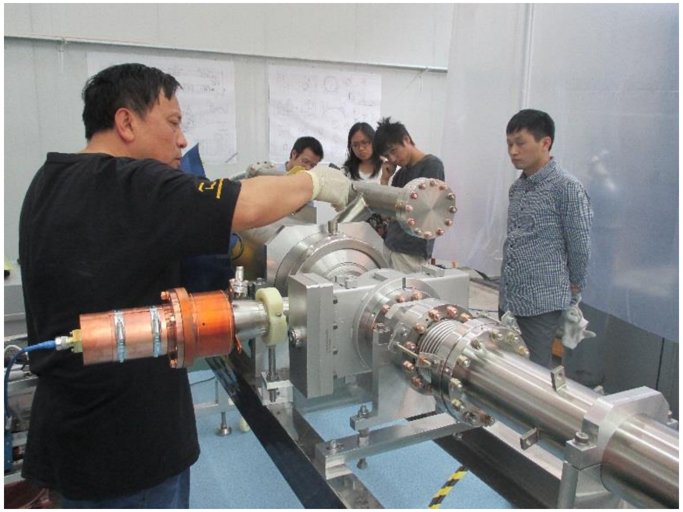
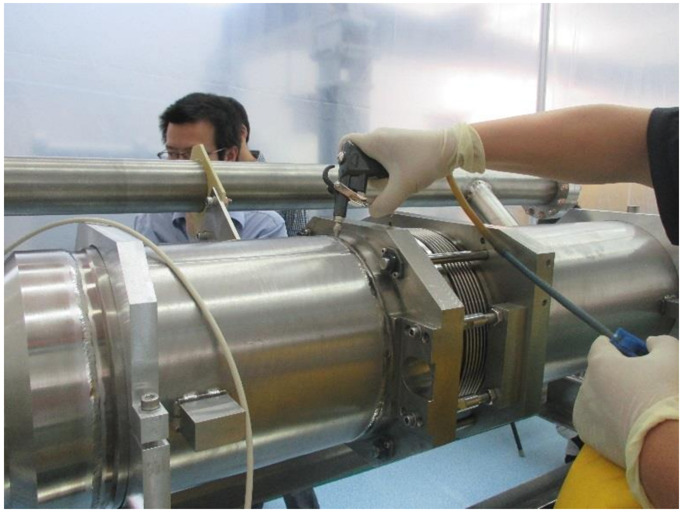




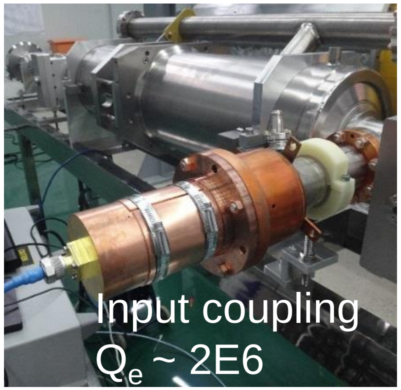

3 m long beamline (large grain low-loss 1.3 GHz 9-cell cavity)

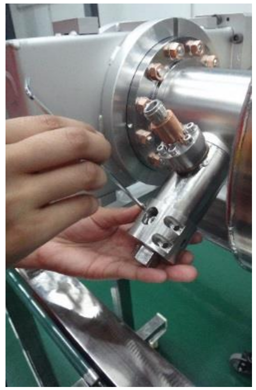
# Two-phase pipe weld and leak check

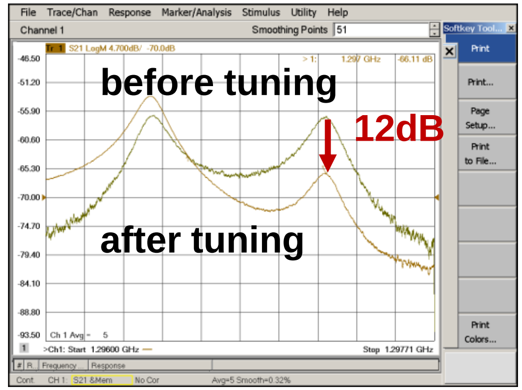


# HOM Coupler Notch Filter Tuning





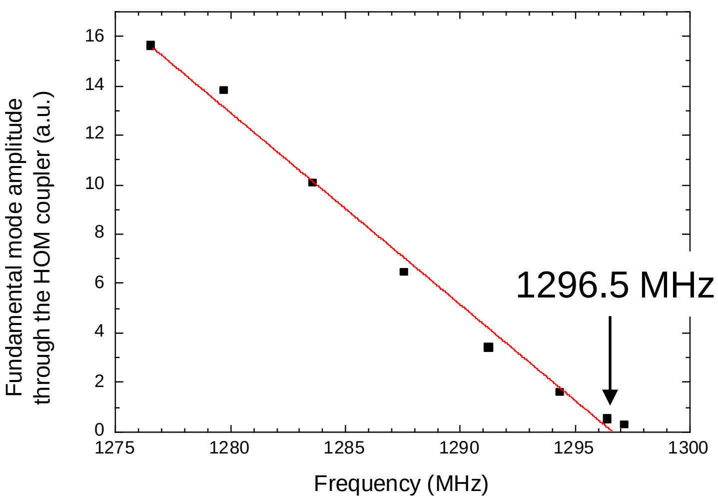

Cavity in Vacuum

Frequency 1297.521 MHz

Input coupler side $Q_e$ = 2E12

(this HOM can cap very soft)

Field probe side $Q_e$ = 3.8E12




Use TM010 passband modes to fit the notch filter frequency (linear near the notch)

Cavity in module iso. vac. (He vessel air) at RT

Frequency 1297.570 MHz

Input coupler side $Q_e$ = **7.5E9**

Field probe side $Q_e$ = 1.5E11

Cavity cool down to 80 K (He vessel 1 atm)

Frequency 1299.945 MHz

Input coupler side $Q_e$ = 2E12 (?)

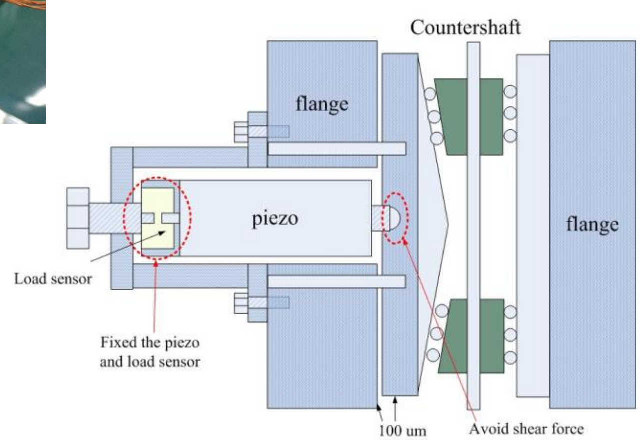
Field probe side $Q_e$ = 2E11

# Tuner Assembly

- After pre-tuning in air: 1297.480 MHz
- After vertical test, cavity in vacuum (free): 1297.439 MHz
- After helium vessel weld: 1297.269 MHz (cavity in vacuum, too low)
- After tuner assembly and add spacer: 1297.521 MHz (1 mm stretch, 64 kg piezo pre-load when hanging on the GRP)

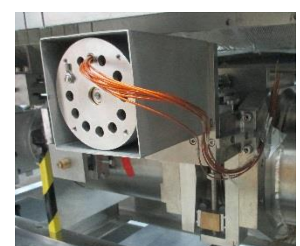
Cryogenic motor
Motor current lead too thin for 1 A current !
Piezo load sensor

Encapsulated piezo stack and round head to avoid shearing force

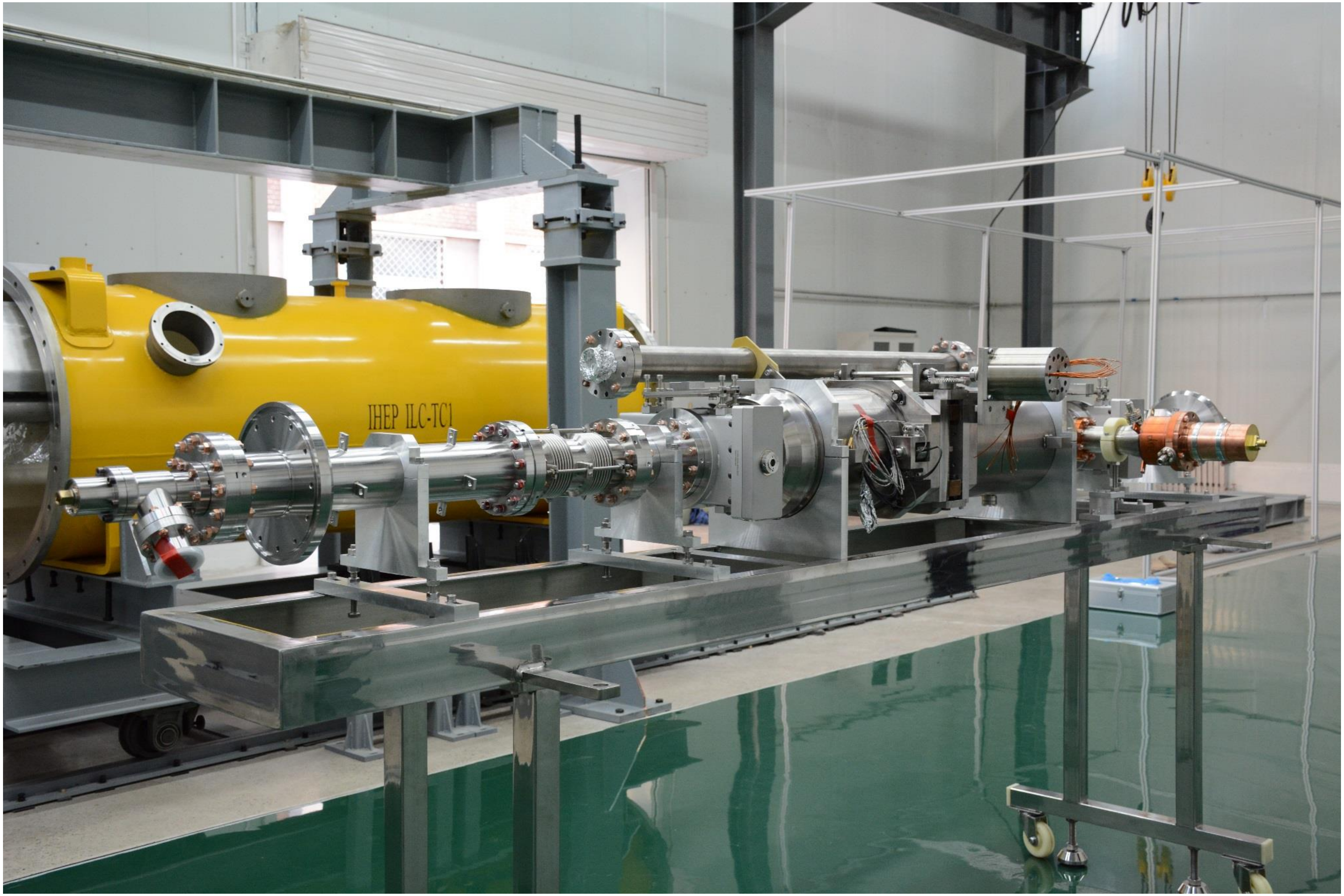



Displacement sensor

Camera and light in the module to monitor the gear



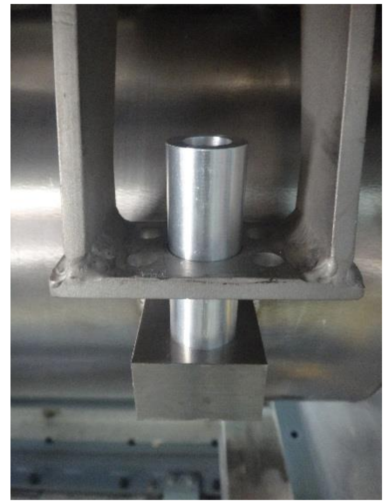
Motor magnetic shield




**Cavity ready to install to cryomodule**

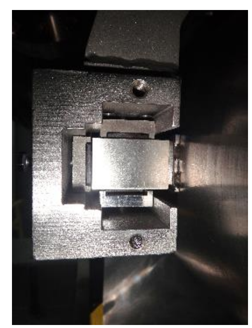
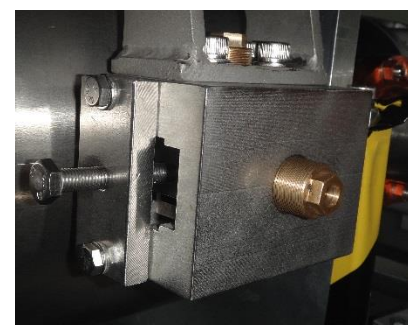
# Cavity Hang on GRP









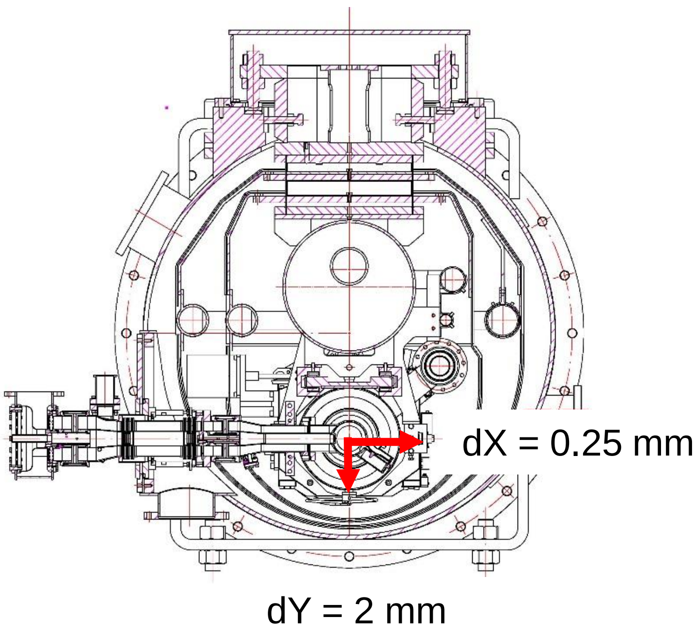



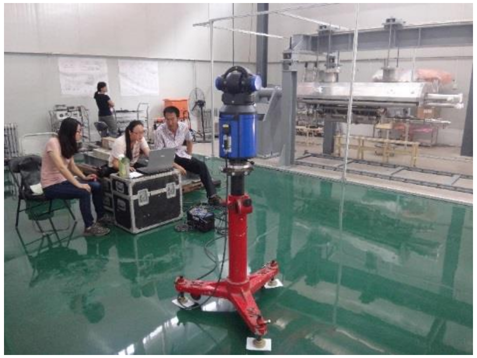
Spring screws (washers)

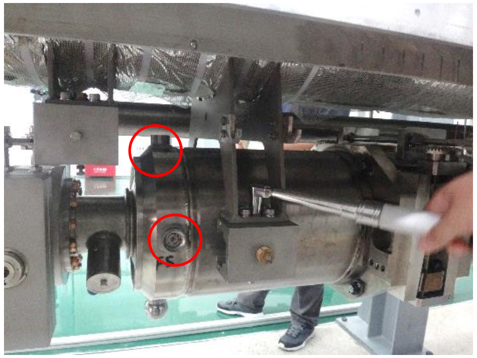
Needle bearings, shells, housings, gauges

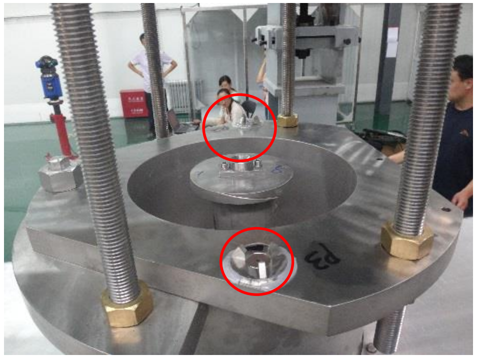
# Cavity Alignment

- Cavity axis 2 mm lower than design for vertical thermal shrink
- Cavity axis 0.25 mm lateral offset to opposite coupler side to compensate different material shrinkage
- Spring washer (SW) tight 6 Nm, then untight upper SW ¼ turn (0.25 mm), untight lateral SW (coupler side)  ¾ turn (0.75 mm)

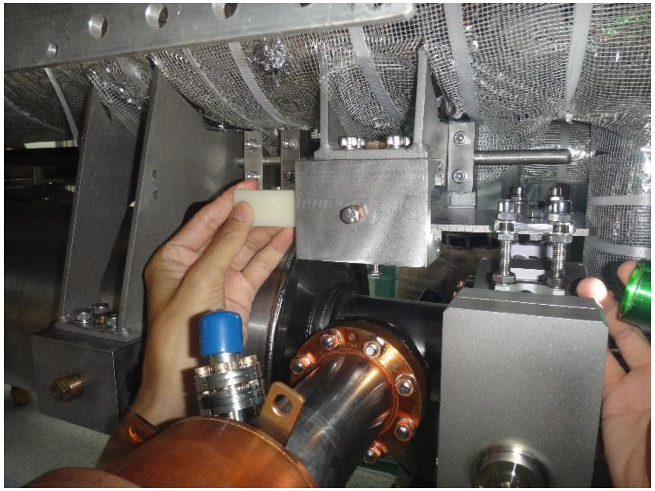




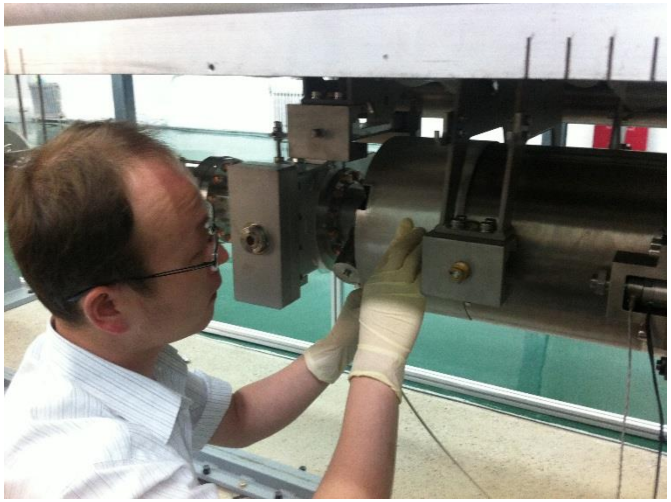


# Cold Mass Assembly

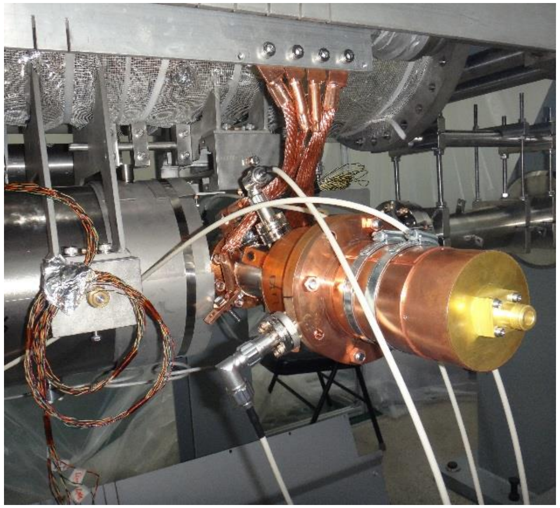


Gate valve supporting

Pre-cooling line



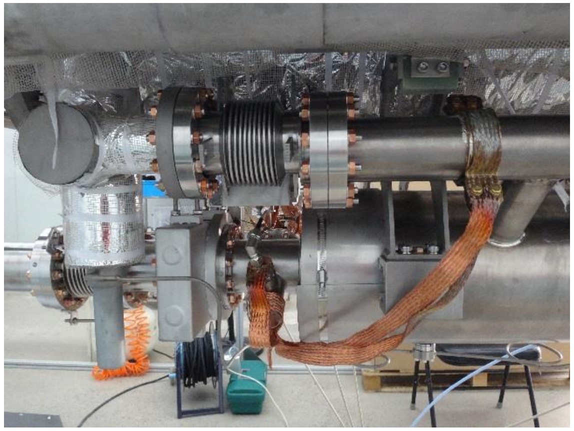
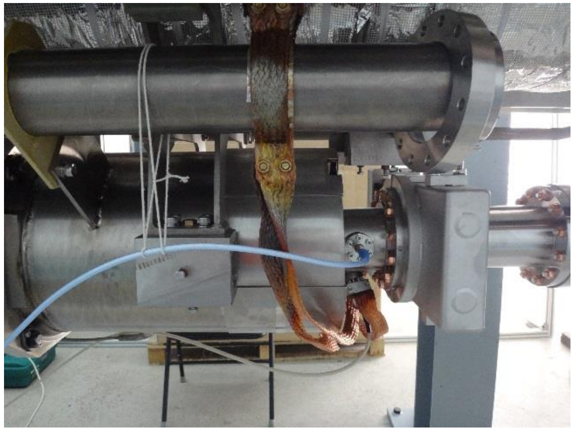
Magnetic shield cap



Thermal anchors

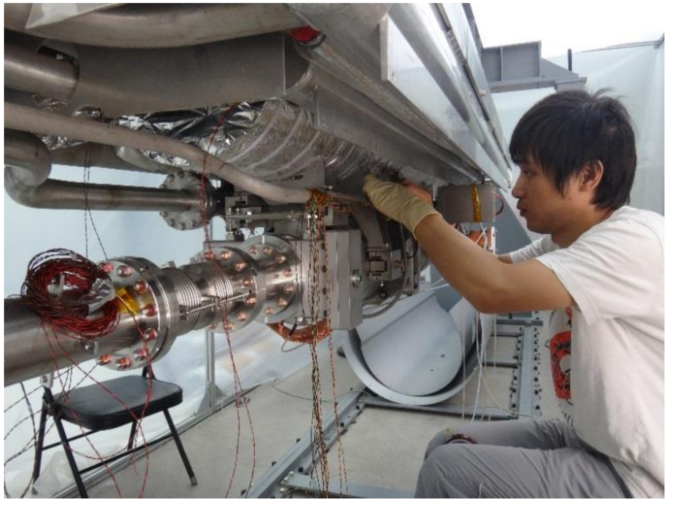
Tuner and piezo test and preload

# Cold Mass Assembly

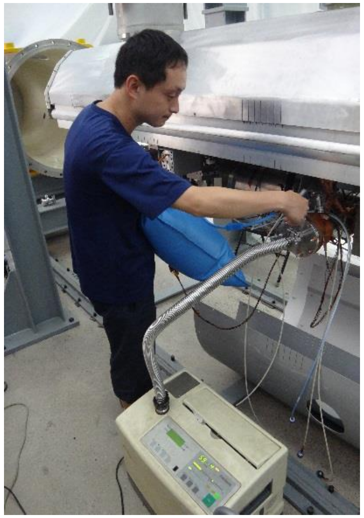
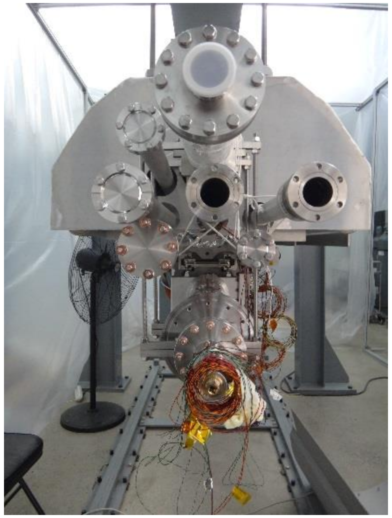

HOM coupler and feedthrough thermal anchors

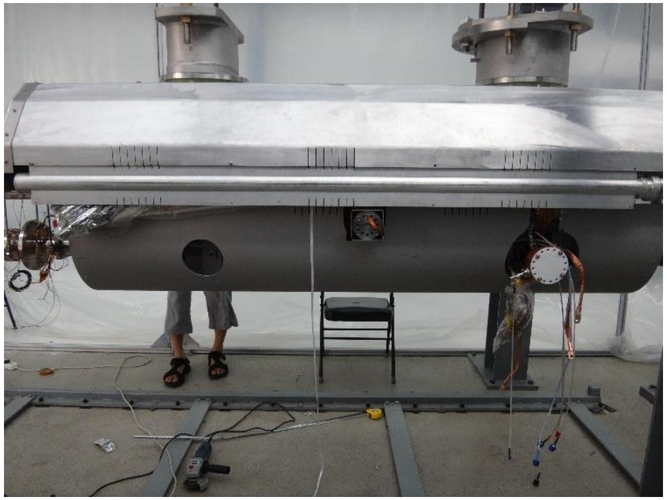

2K, 5K, 80K cryogenic lines leak check



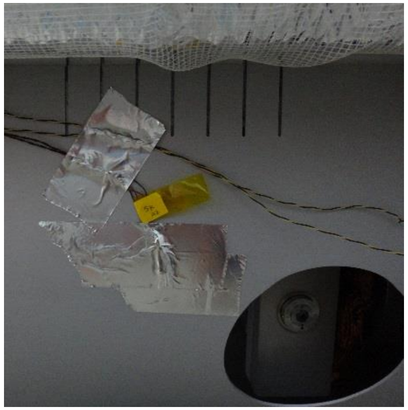
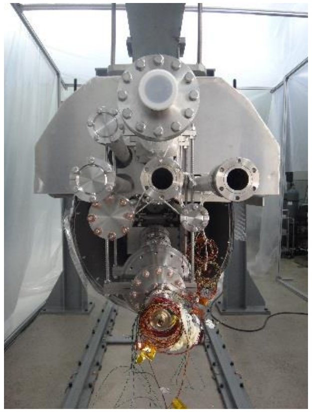
Thermometers and cables

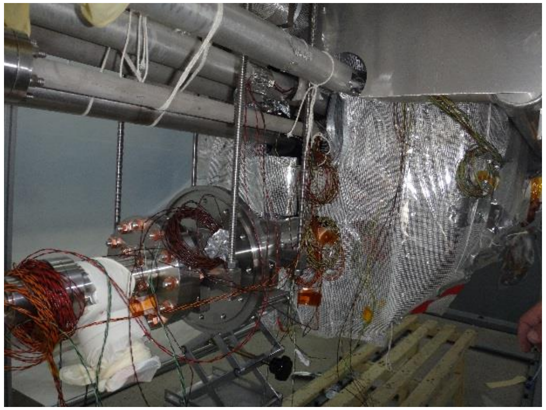
# 5 K Thermal Shield and Multi-layer Isolation

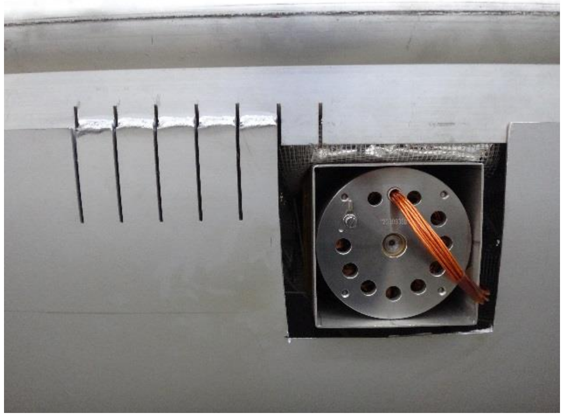



# 5K and 80K Shield

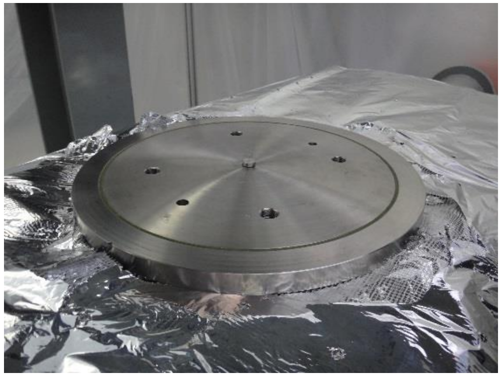



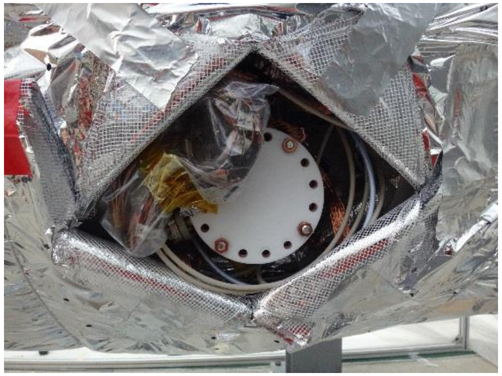


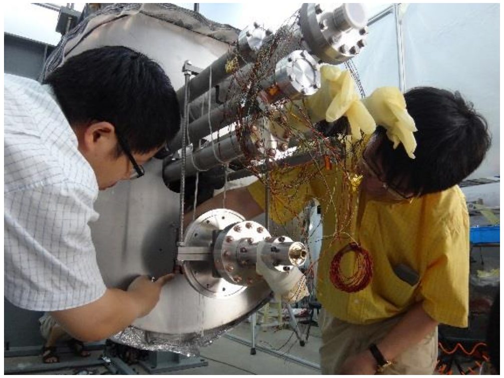
Due to lack of welding operation space, 5 K lower shield screwed to the 5K upper shield and Omega pipe; 80 K shield TIG weld

# 80 K Shield and Multi-layer Isolation

Due to thick beam pipe, we connect the beam tube 5K thermal anchor to the 80K shield to prevent frost.





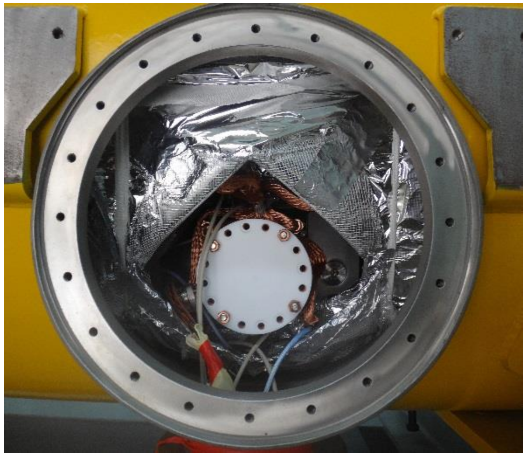


# Cold Mass to Vacuum Vessel, Alignment

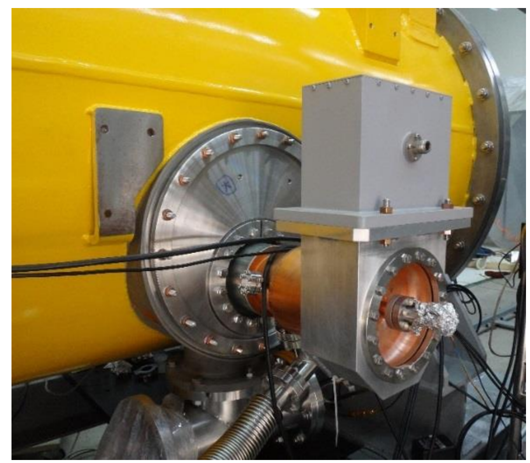




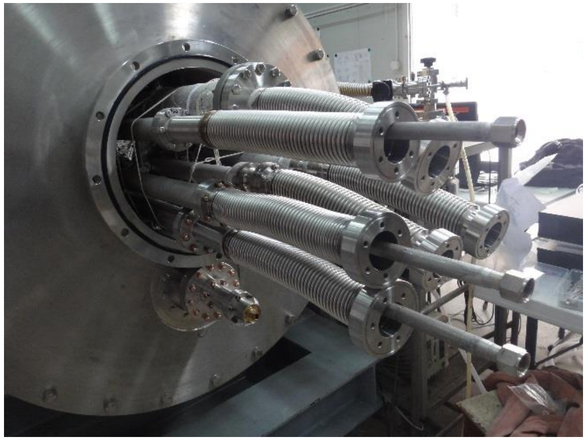

# Coupler Warm Part and Doorknob Assembly

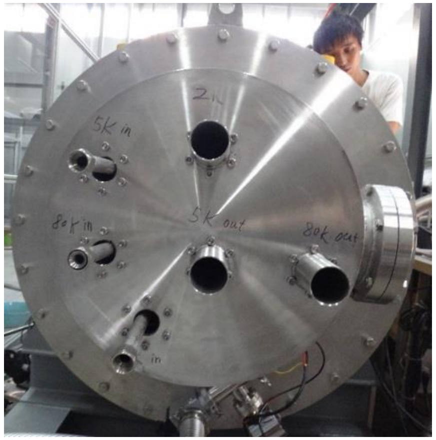


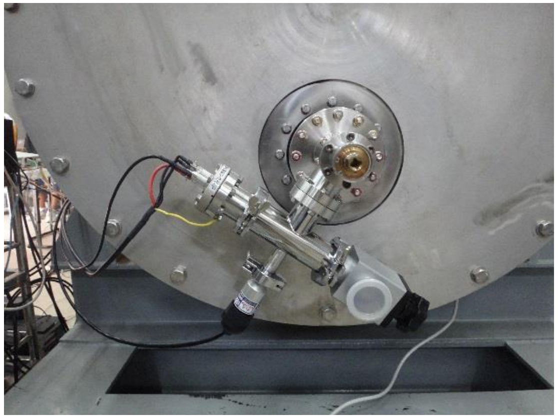


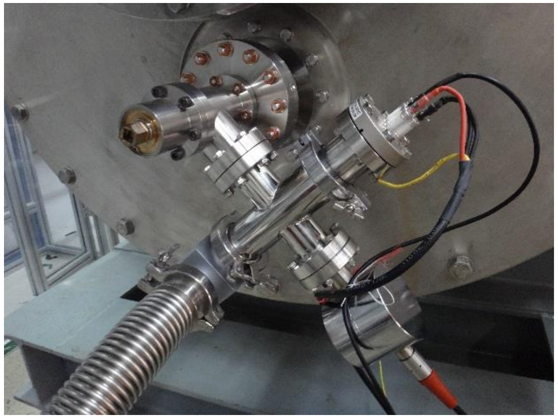



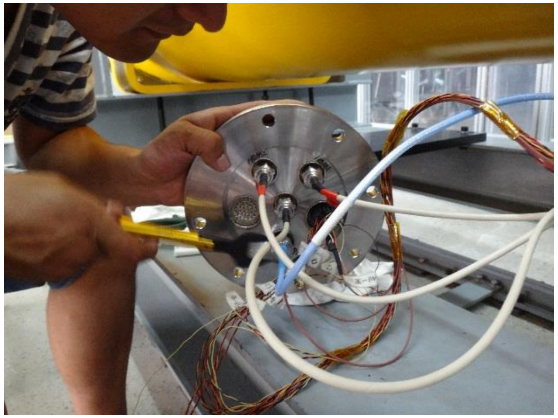
# Cryogenic, Vacuum and Signal Connection





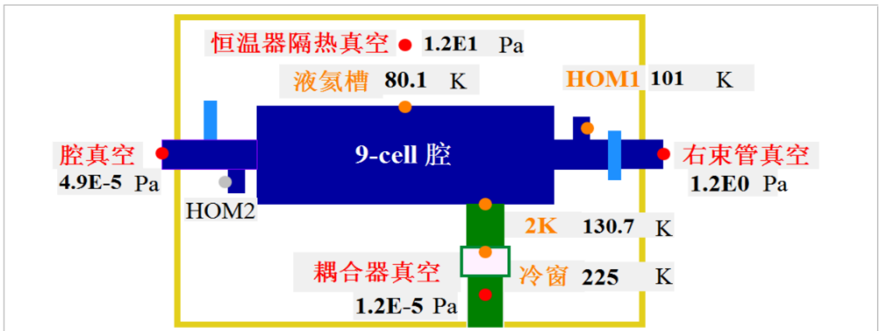



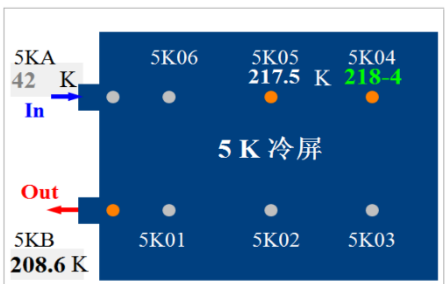


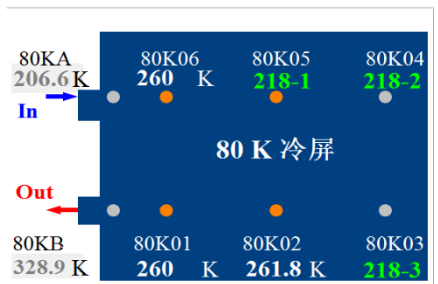


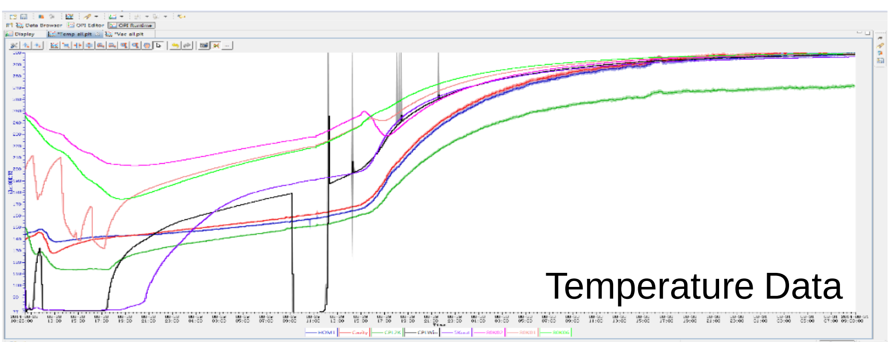
# $LN_2$ 80K Cool Down Test

# Vacuum and Temperature Reach



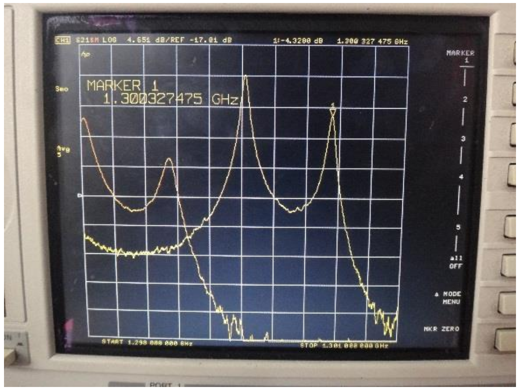



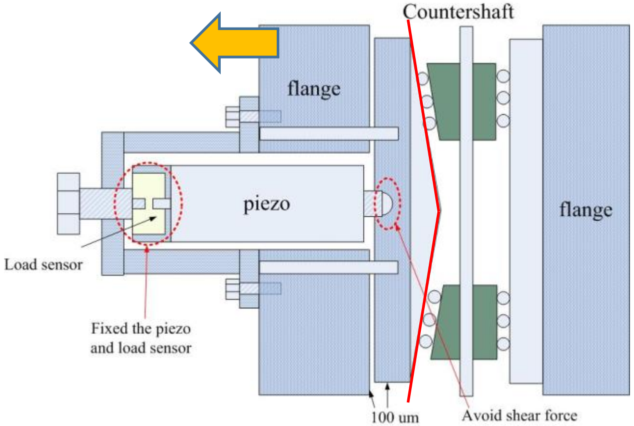



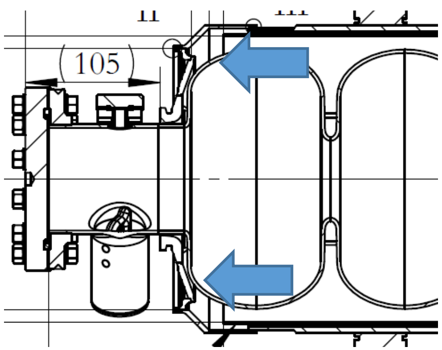

- Cavity and coupler cold window cooled to 80 K ( < 40 K/h), cavity vacuum 4E-5 Pa (small ion pump), coupler vacuum 5E-6 Pa.
- Some thermometers did not work
- Due to leak of the cryogenic line connection, outgassing and small pumping rate, isolation vacuum was only 1~10 Pa after cooling down. Thus, 5 K and 80 K shield reached 140 K at lowest.
- We will solve the isolation vacuum leak problem and do 80 K cool down test again in November.
- 2 K high power horizontal test next year (cryo-plant OK, klystron deliver early next year)

# Cavity and Tuner

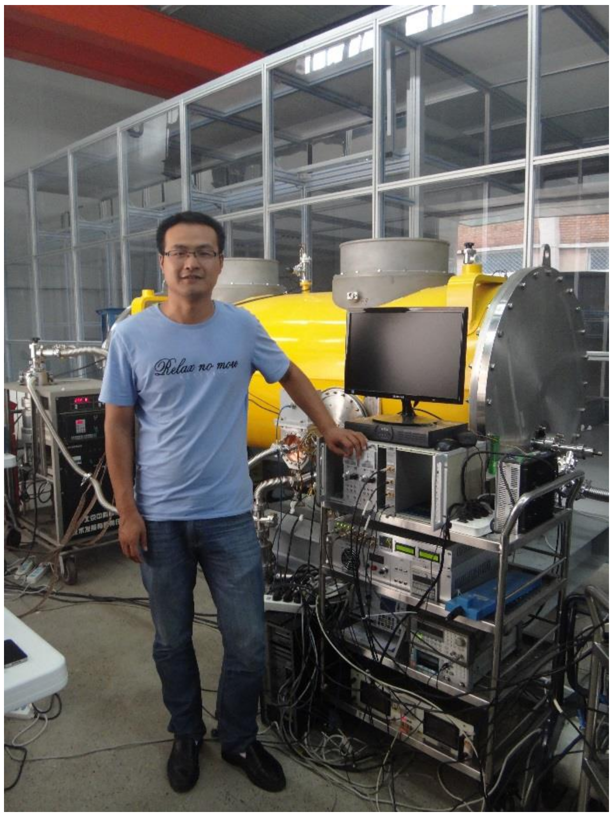
- Cav. vac. HV vac. iso vac. BT air: 1297.570 MHz (1297.521 MHz for HV&iso air)
- Cav. vac. HV air. iso vac. BT vac.: 1298.431 MHz
  - df = +861 kHz, dL = +2.9 mm, tuner roller and taper block detached
  - HV ID 230 mm, 415 kg atm force => 143 kg/mm, similar to piezo load sensor measurement: 133 kg/mm (cavity very soft)
- Cool down to 80 K, helium vessel and cavity shrink 1.4 mm, tuner gap 1.5 mm.
  Cav. 1300.335 MHz (HV 1 atm). When 2 K (HV 30 torr), cavity will be shorter.
- After warm up. Cav. vac. HV air. iso air. BT vac.: 1297.785 MHz
  Cav. vac. HV air. iso air. BT air.: 1297.9 MHz (permanent elongation 1.3 mm)
- Tuner stretch 1.2 mm, then touch the cavity. Piezo test.
- If cool down to 2 K: 1297.9 + 2.43 (RT=>4K & iso.vac.) - 0.83 (4K=>2K pump down) + 0.5 (tuner stretch 1.6 mm) = 1300 MHz

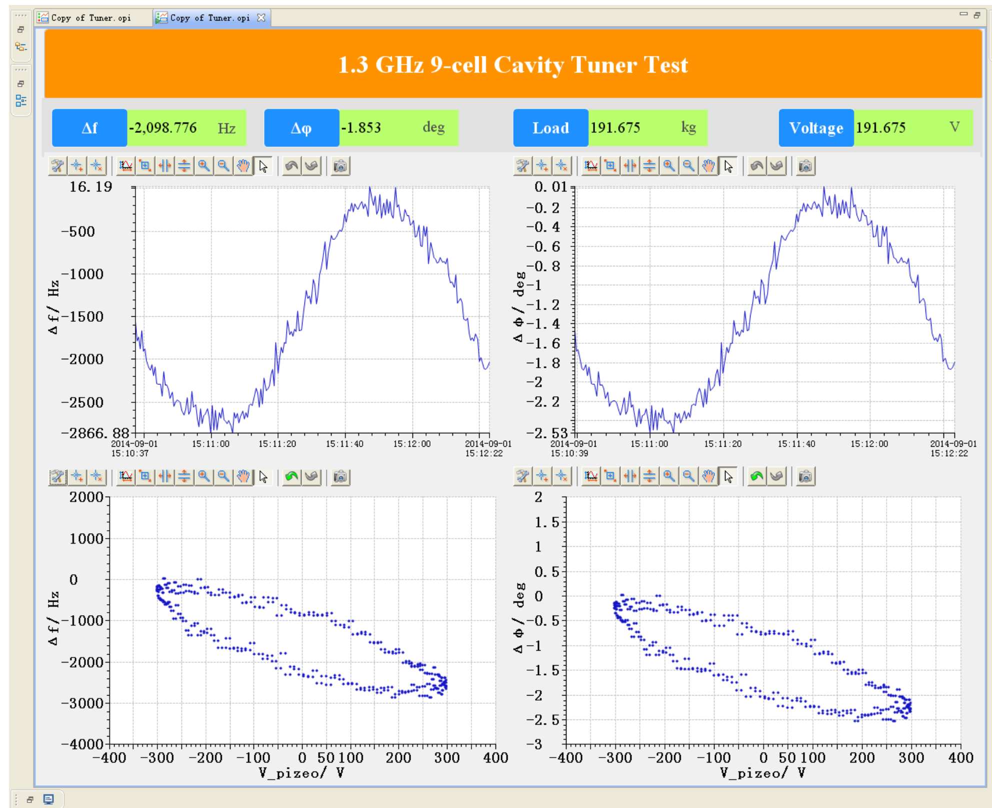


# Piezo Test at RT

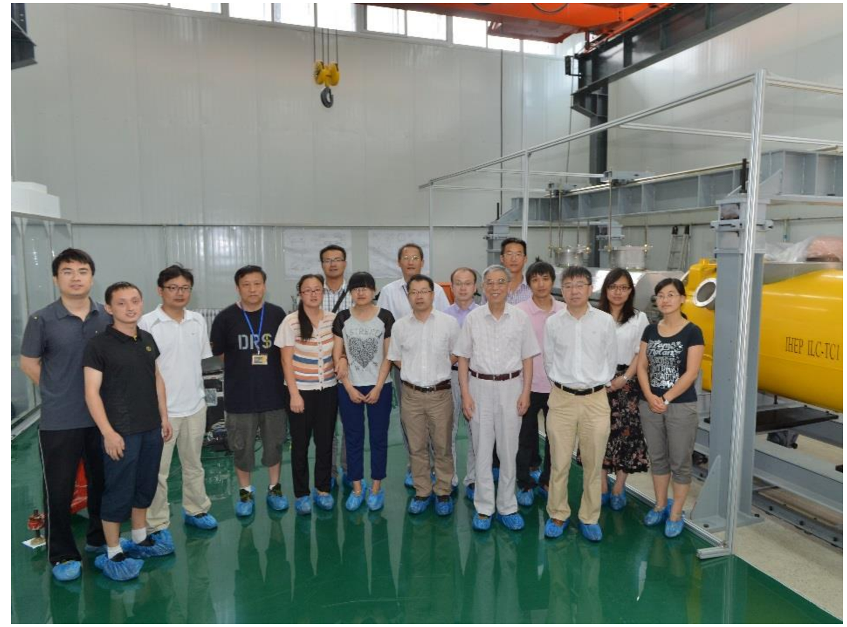


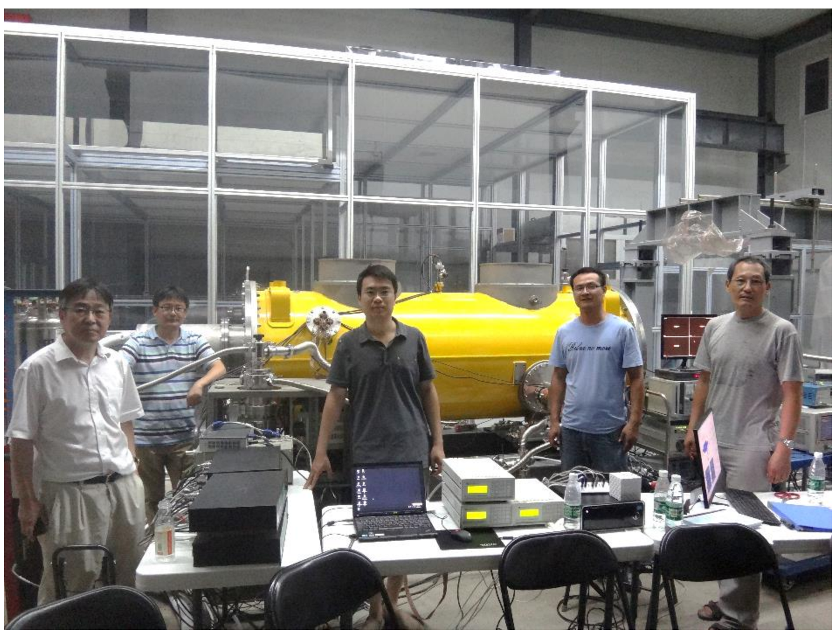



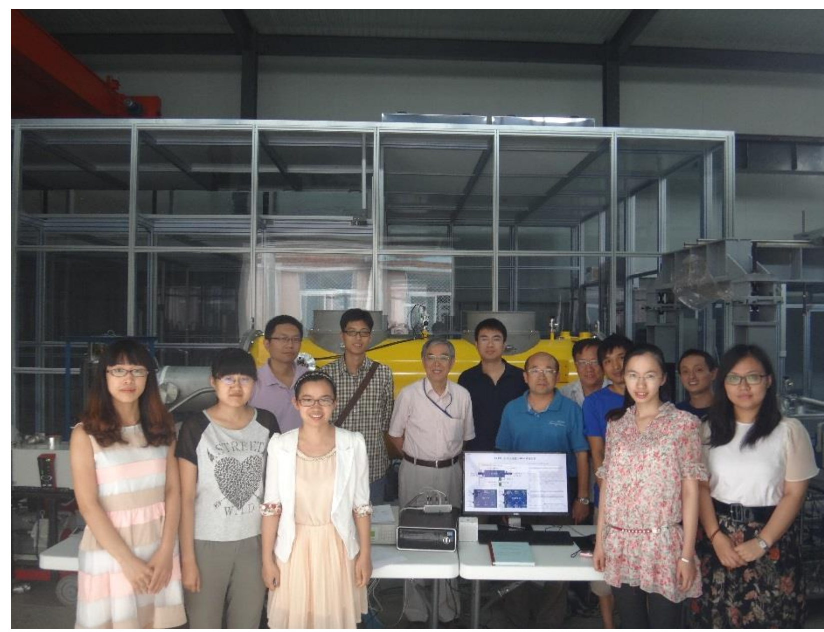

Piezo pressure 38 kg, offset 400 V, scan ±200V

# Other SRF R&D

- Fine grain TESLA-like 9-cell cavity (IHEP-03)
  - Dumbbells and end groups welding done
  - Dumbbell equator welding test ongoing. Blowing holes sometimes due to fit-up variation of the step mating
- Other SRF R&D Plan (ILC and CEPC)
  - TESLA 9-cell cavity by HE-racing company (IHEP workshop)
  - 1.3 GHz 9-cell cavity will be used for CEPC booster (256 cavities, 5 GeV RF voltage) and possible for injector linac (289 cavities, 6 GeV)
    - CW 20 MV/m, $Q_0$ > 2E10 (nitrogen-doping) => high $Q_0$ at medium $E_{acc}$
    - Gradient could be > 30 MV/m if without Q drop => high $Q_0$ at high $E_{acc}$
    - R&D on thin film ($Nb_3Sn$) of usable gradient and high $Q_0$ at 4.2 K
  - Extensive development of SRF key technology, personnel, infrastructure and industrialization needed in 2016-2020 for CEPC. Make most use of ILC technology and synergy with ILC.


IHEP ILC-TC1





# Thank you