



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

Recent Status of IHEP SRF R&D

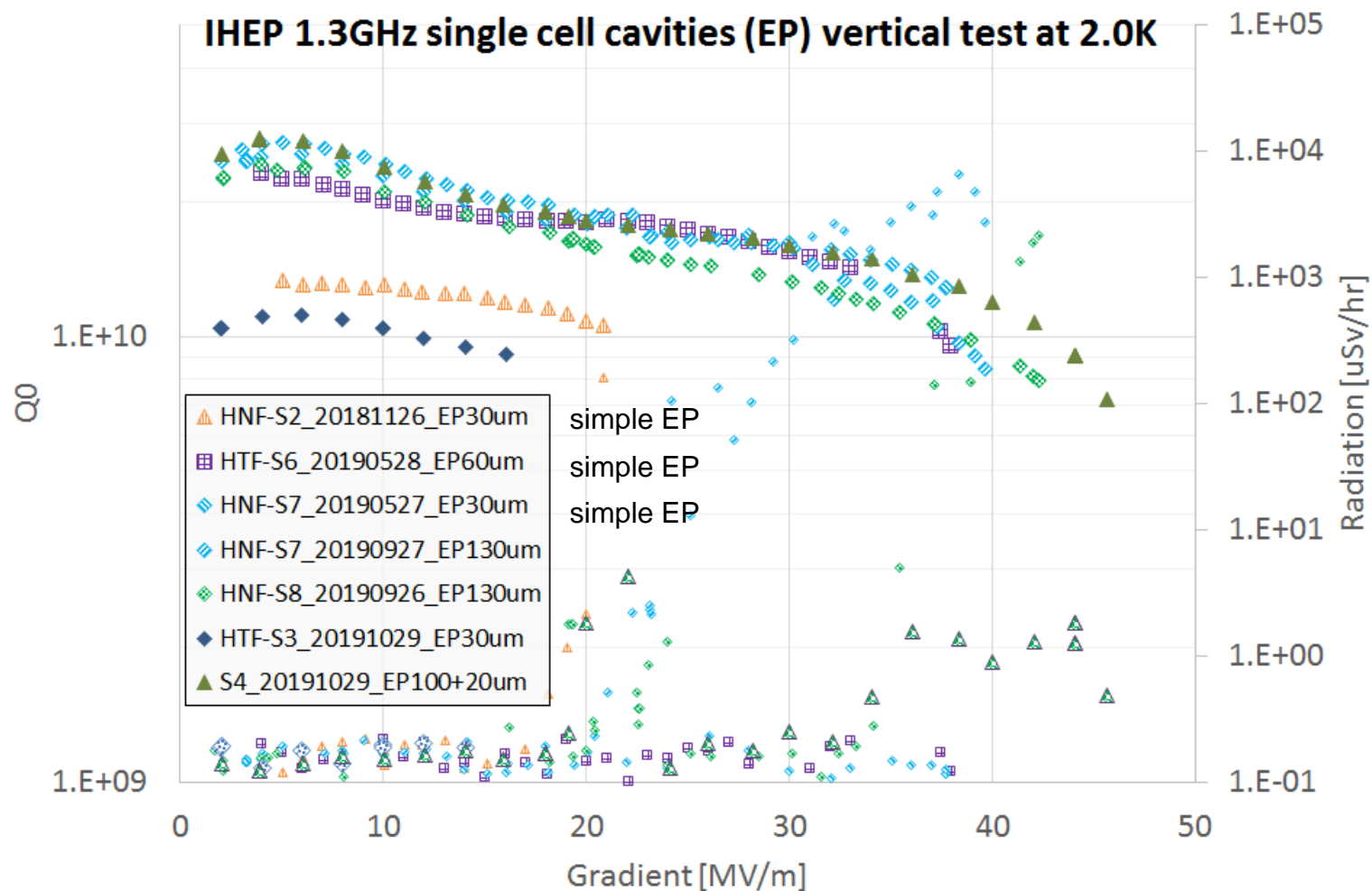
Jiyuan Zhai
IHEP, China

October 31, 2019

Outline

- 1.3 GHz cavity
- 1.3 GHz input coupler
- New SRF lab and facilities

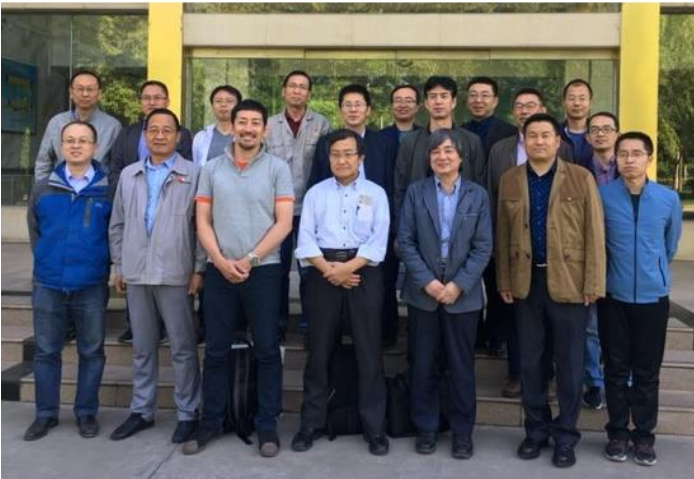
EP FG Single Cells



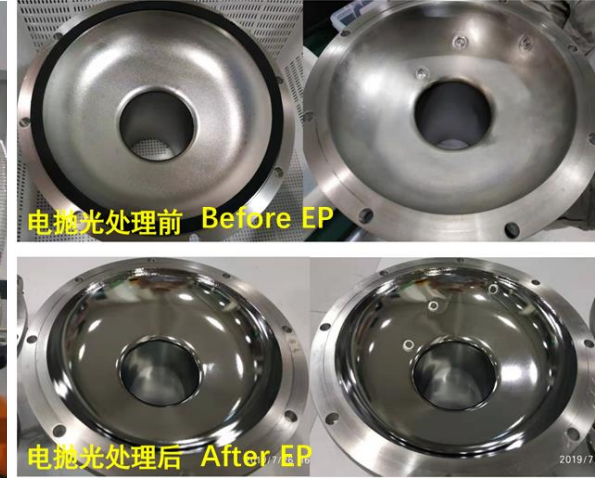
With IHEP's newly developed EP tool (China's first practical EP tool), we are able to get ~ 40 MV/m (without CBP) for FG TESLA single cell cavities.

IHEP EP Facility at Ningxia

- A horizontal EP facility was developed at IHEP in collaboration with KEK.
- Can treat various types of cavities: 500 MHz 1-cell, 650 MHz up to 5-cell, 1.3 GHz up to 9-cell.
- Five TESLA single cell cavities reached 38 ~ 45 MV/m after EP with standard ILC recipe.
- 9-cell cavity EP commissioning will start soon. Target: 40 MV/m for ILC (with 14 R&D 9-cell cavities).



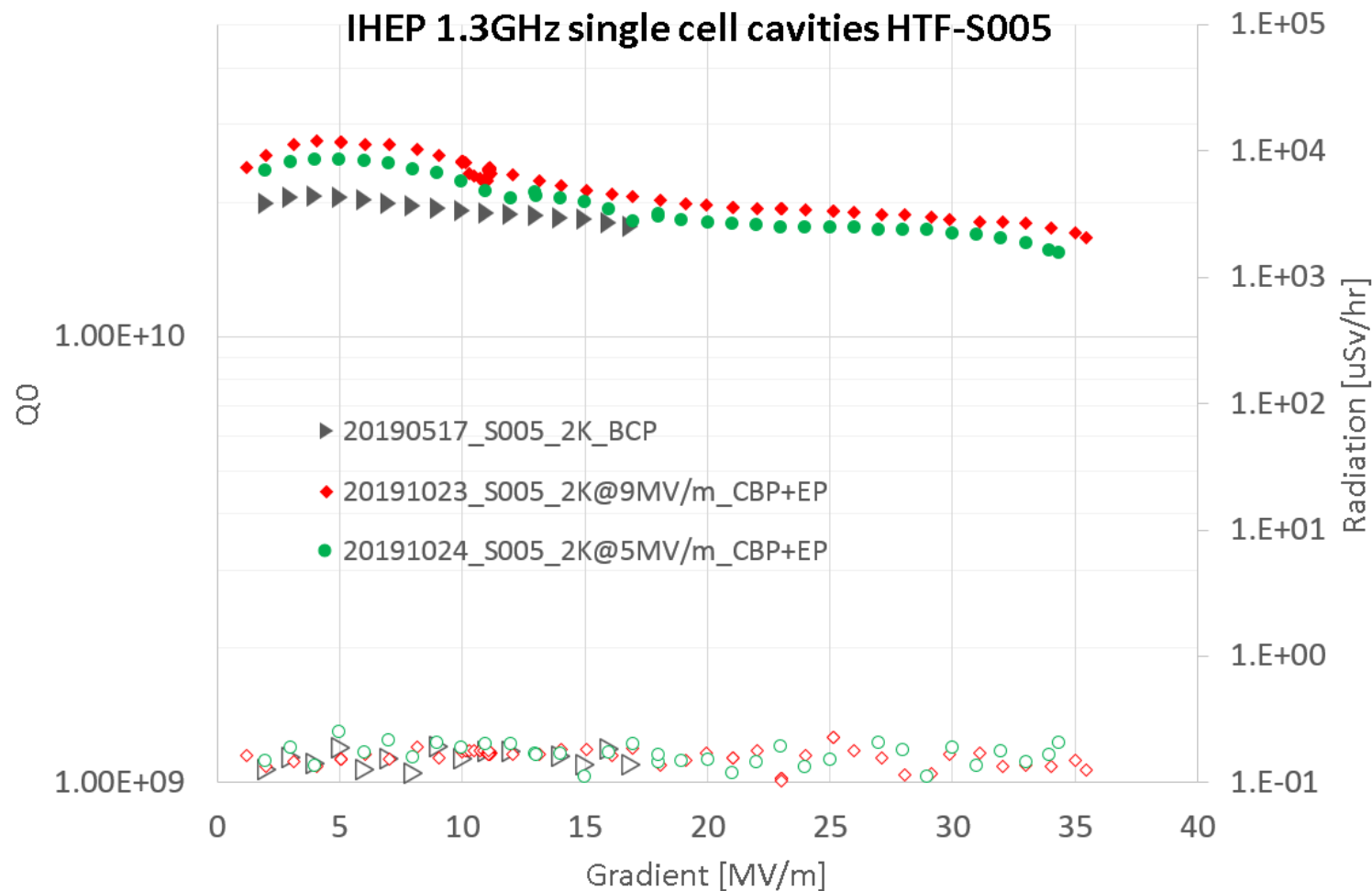
KEK experts joint EP commissioning
at OTIC, Ningxia (May 2019)



Sample cavity
Roughness (Ra) after EP: 300 nm



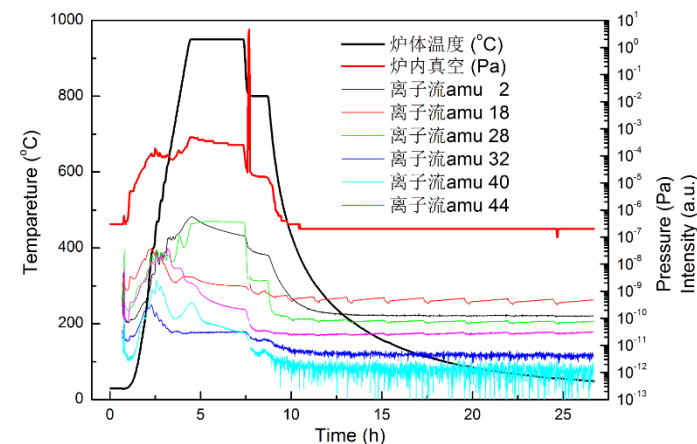
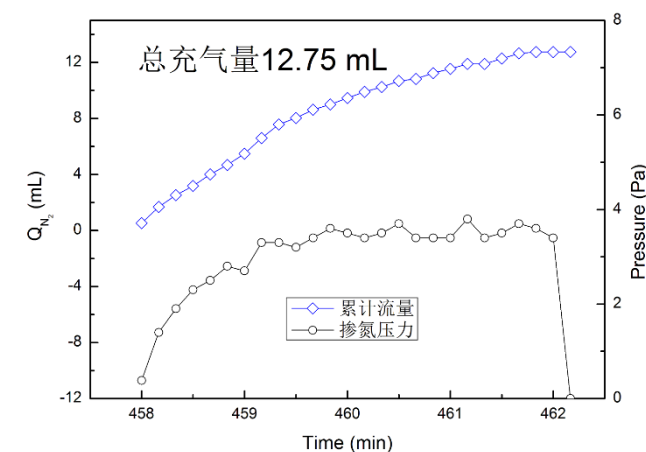
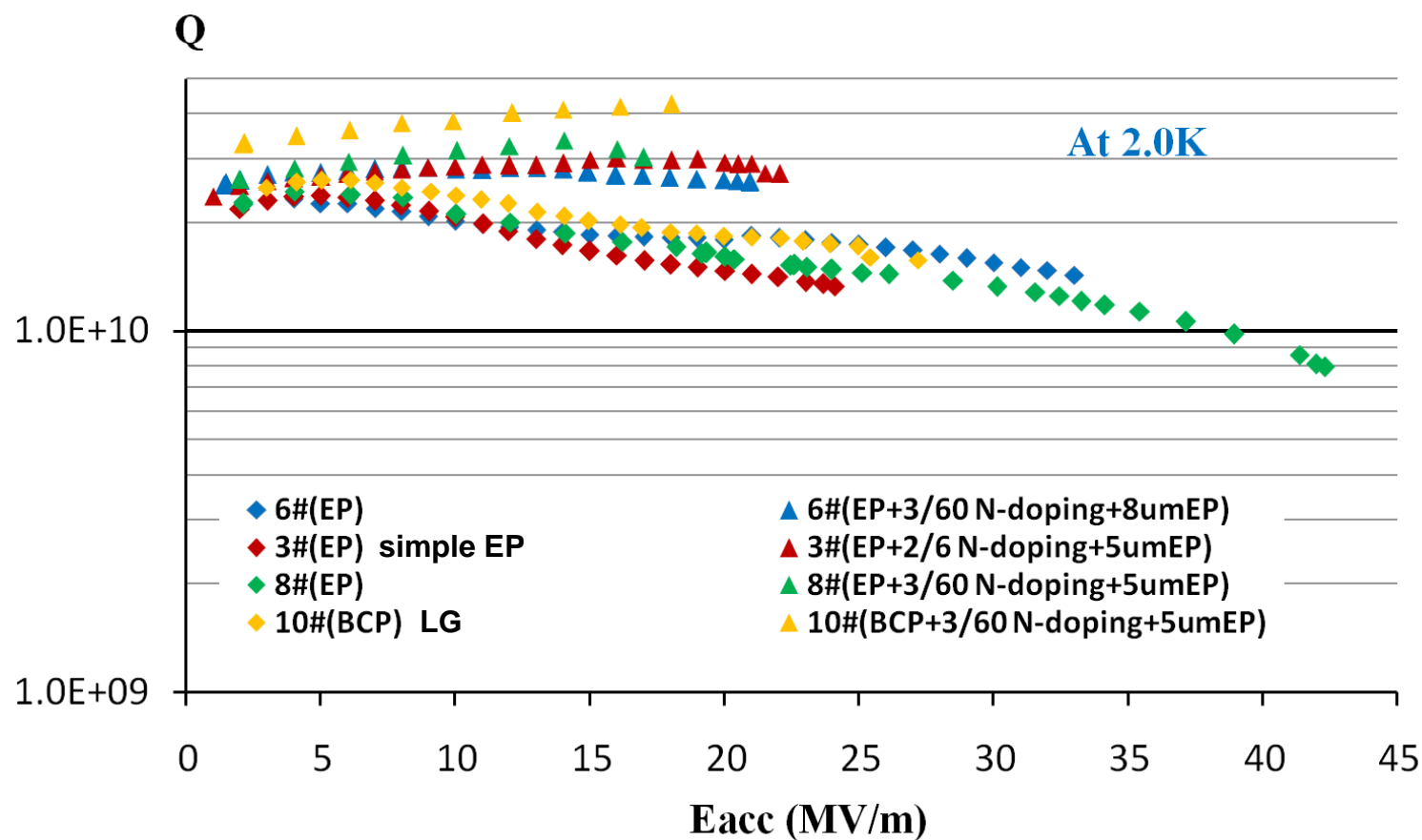
CBP Repair + EP FG Single Cell (S5)



CBP (with fine polishing step) 120 um + EP 20 um + annealing + EP 20 um

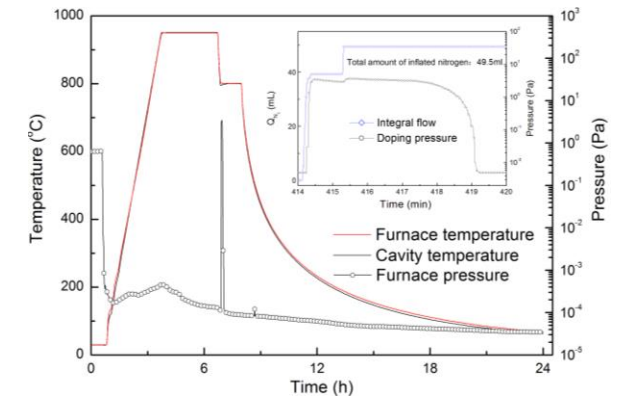
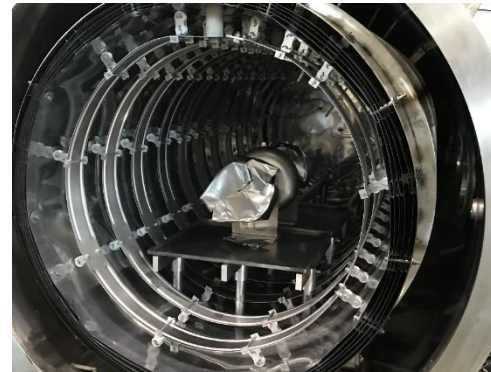
N-Doping Single Cells

Need to improve N-doping and light EP process to increase gradient and Q.



S10 N-doping process

Vacuum Furnaces for N-doping and Infusion



Small dual vacuum furnace.

300 mm diameter and 500 mm length. Heater placed in the outer vacuum, very high vacuum ($< 2E-7$ Pa)

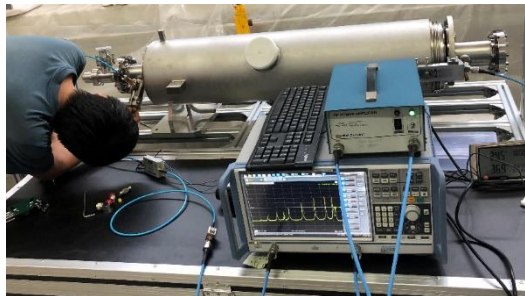
Big furnace with cryo-pump.

1.3 GHz 9-cell Cavities

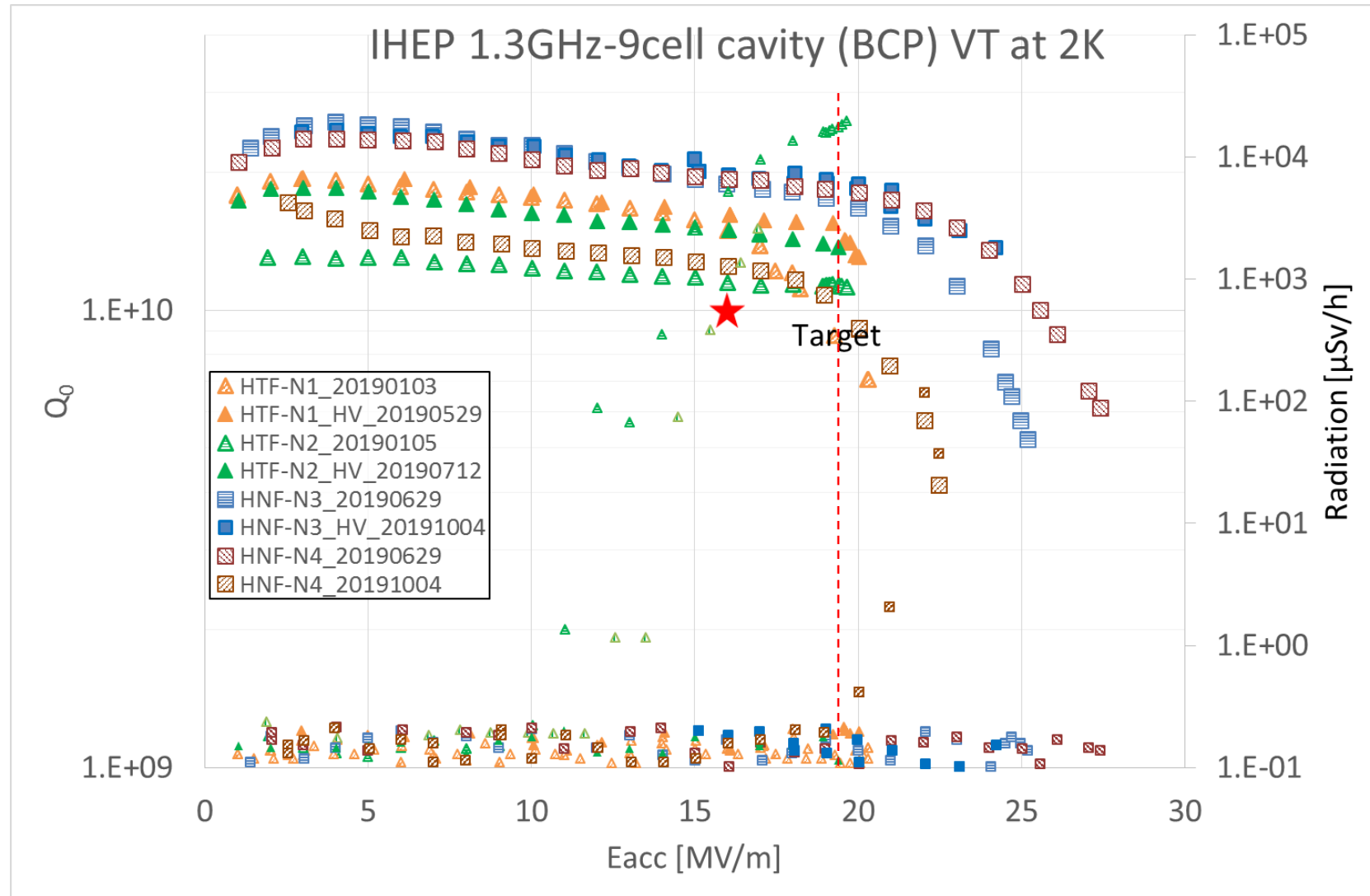


北京高能锐新科技有限责任公司
Beijing HE-Racing Technology Co., Ltd.

- 7 9-cell cavities already made for SHINE R&D. 4 cavities BCP and vertical tested. 11 cavities in fabrication.
- Four cavities laser welded with helium vessel. Will deliver to Shanghai for test module assembly.



BCP 9-cell Cavities w/o&w Helium Vessel



RF and Mechanical Quality Control

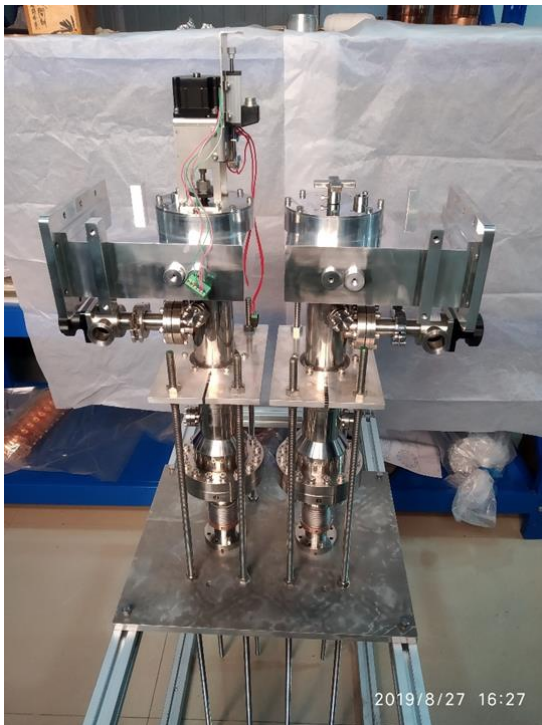
	Specification	1300-N001	1300-N002	1300-N003	1300-N004
Dumbbell shape error	$\leq \pm 0.5$ mm	± 0.4	± 0.4	± 0.4	± 0.4
Cavity length (after pre-tuning)	1283.40 \pm 3.0 mm	1284.55 mm	1283.19 mm	/	/
Cavity length in helium vessel	1283.40 \pm 3.0 mm	1283.56 mm	1282.30 mm	1280.94 mm	to be measured
Eccentricity (radius)	≤ 0.4 mm	no adjustment	no adjustment	no adjustment	no adjustment
Frequency bare cavity (vacuum, RT)	1298.2 \pm 0.1 MHz	1298.210 MHz	1298.160 MHz	1298.162 MHz	/
Frequency bare cavity (2K)	1300.2 \pm 0.1 MHz	1300.252 MHz	1300.199 MHz	1300.318 MHz	1300.280 MHz
Frequency dressed cavity (2K)	1300.2 \pm 0.1 MHz	1299.870 MHz	1300.018 MHz	1300.062 MHz	1300.200 MHz
Field flatness bare cavity	≥ 95 %	95%	98%	97%	96%
Field flatness dressed cavity	≥ 90 %	85%	94%	98%	98%
Leak rate	$\leq 1.0\text{e-}8$ Pa l/s	OK	OK	OK	OK
HOM coupler FM Q_e (2K)	$> 2.7\text{E}11$	1.5E12, 3.5E13	3.7E12, 4.7E11	1.6E11, 2.1E12	to be measured
Dressed cavity gradient (BCP)	> 19 MV/m	20 MV/m	19.5 MV/m	23.2 MV/m	to be measured
Dressed cavity Q_0 (BCP)	$> 1.0 \times 10^{10}$ @16 MV/m	1.50E+10	1.40E+10	1.90E+10	to be measured
Dressed cavity gradient (EP+N-dope)	> 19 MV/m	/	/	/	/
Dressed cavity Q_0 (EP+N-dope)	$> 2.7 \times 10^{10}$ @16 MV/m	/	/	/	/

1.3 GHz Variable Coupler



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- Two 1.3 GHz TTFIII-type variable input couplers. Modified for 7 kW CW power. Can be used for ILC.
- High power conditioning at Shanghai soon (14 kW TW, 7 kW SW).



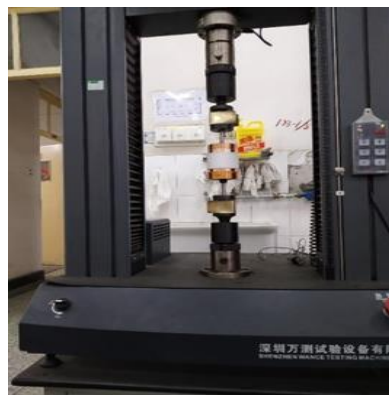
1.3 GHz Variable Coupler



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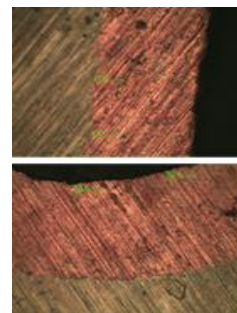
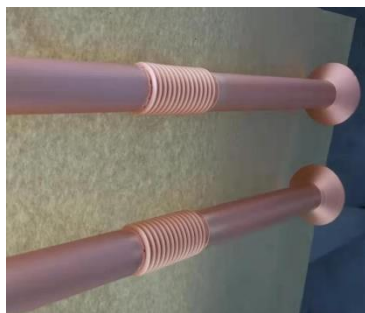


Ceramic Brazing



Strength Test (>100 MPa)

	Specifications	Test Results	Notes
Thickness of inner conductor Cu plating	$150 \pm 20 \text{ } \mu\text{m}$	150 – 190 μm	bellow 30 %
Thickness of outer conductor Cu plating	$30 \pm 20 \text{ } \mu\text{m}$	30 – 40 μm	bellow 30 %
RRR	30 - 80	24 - 26	
Thickness of TiN Coating	10 nm (7-15 nm)	20 - 40 nm	



Copper Plating

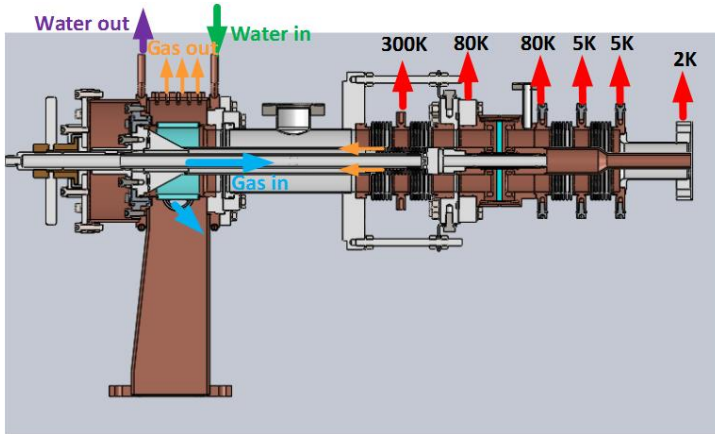


TiN Sputtering device and SEM section

High Power 1.3 GHz Variable Coupler



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- Design for 70 kW CW power. Can be used for CEPC booster cavity (< 20 kW peak).
- High power conditioning in a resonance ring (up to 10 times of the 8 kW SSA power). Forward CW power **30 kW for 1 hour**. Max power above **50 kW**.

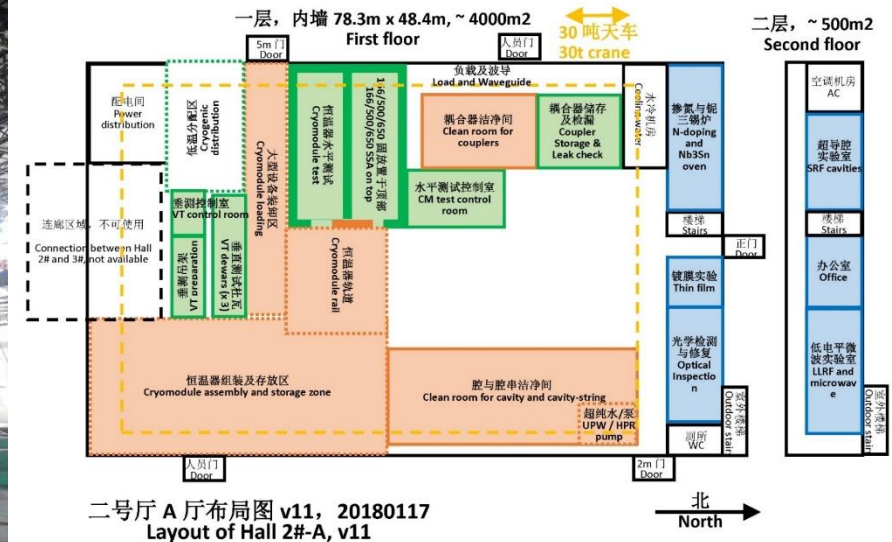


New SRF Lab and Facilities

1. New SRF lab
2. EP facility
3. Vacuum furnaces for N-doping
4. Nb₃Sn furnace
5. Tuning machine
6. Inspection camera
7. TX-mapping
8. Second sound

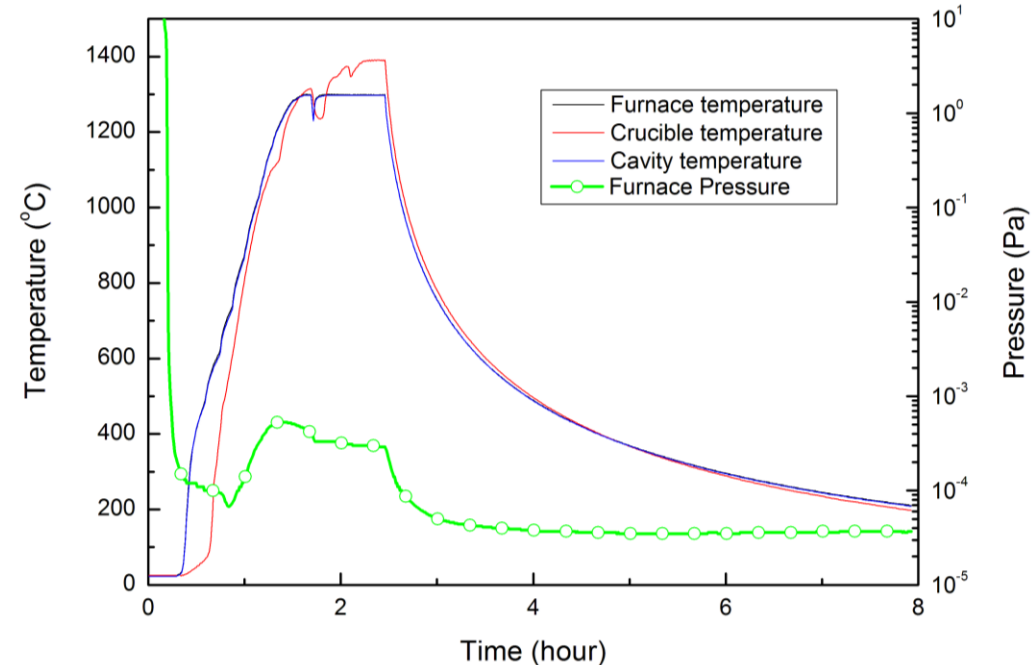
IHEP New SRF Lab at Huairou

- 4500 m² SRF lab in PAPS, Huairou Science Park, north Beijing.
- Civil construction completed in summer.
- Test stands, clean rooms and other facilities installation and commissioning by mid 2020.
- 200 ~400 cavities (couplers) tests, 20 cryomodules assembly and horizontal tests per year.



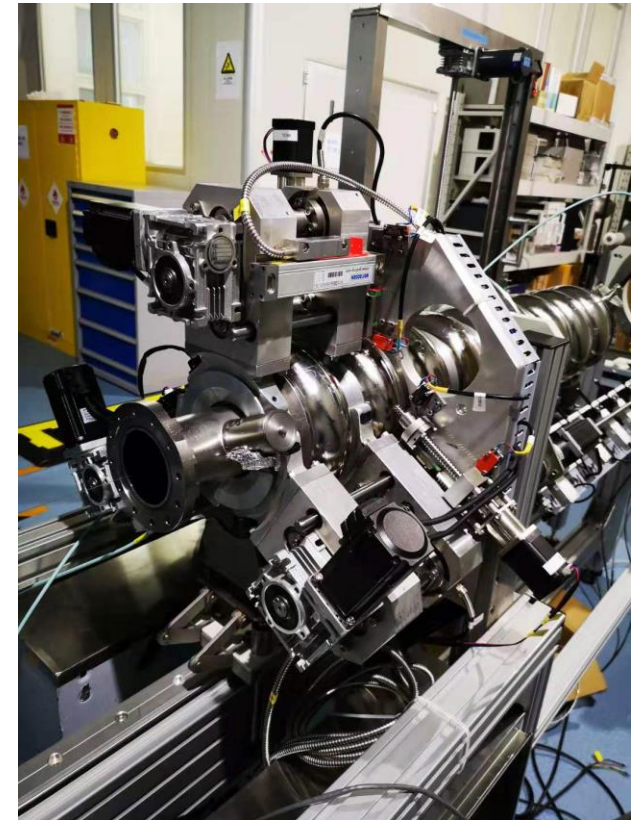
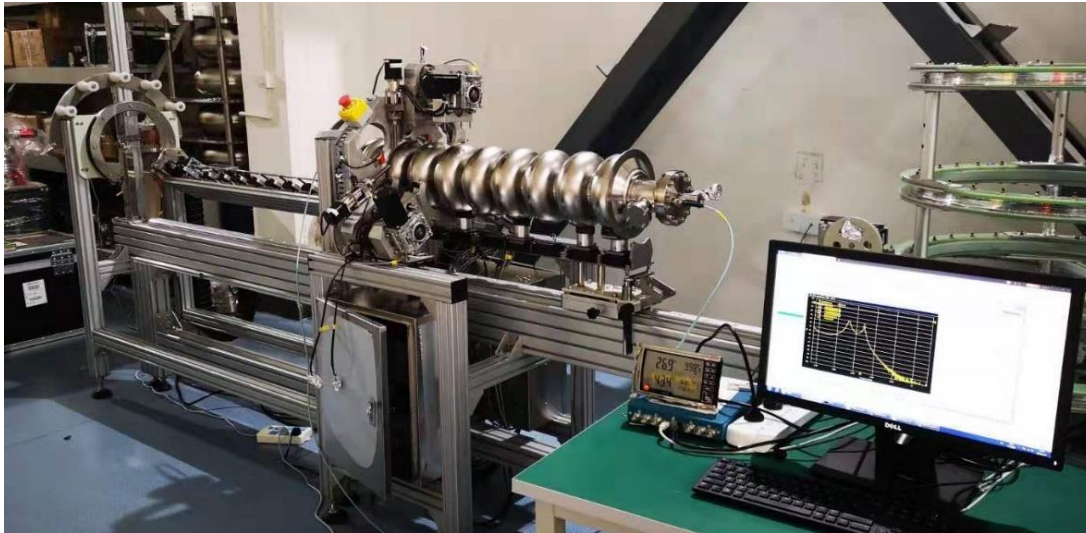
Nb₃Sn Furnace

- 300 mm diameter, 500 mm height (for single-cell 1.3 GHz cavity studying)
- Heated to 1300 C for Nb₃Sn film growing
- Coating pressure and temperature precisely controlled and measured
- Special rotating structure to improve the Nb₃Sn film quality



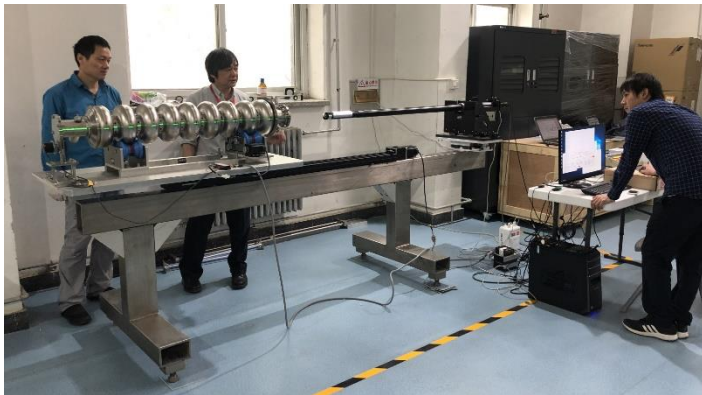
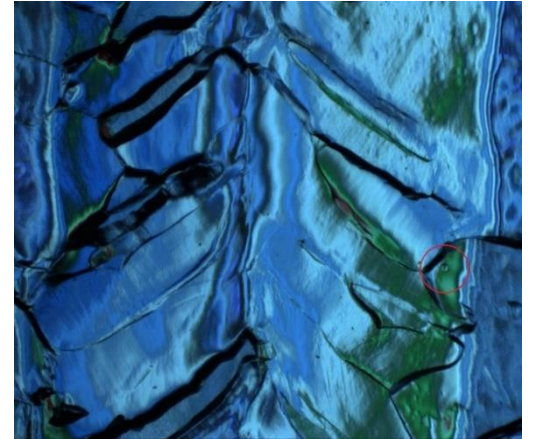
IHEP New Tuning Machine (by PKU)

- Cavity frequency tuning and field flatness, length and eccentricity adjustment. Similar to DESY's design for XFEL.
- Need to improve automatic tuning procedure for higher efficiency (target: half day a cavity).

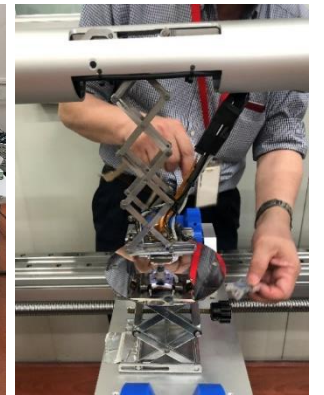
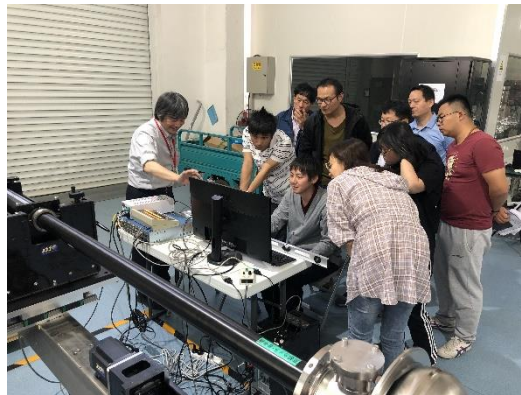


Inspection Cameras

- One 1.3 GHz Kyoto camera rent from KEK. Already inspected seven 9-cells and tens of single cells.
- One 650 MHz / 1.3 GHz inspection camera and grinder purchased from Japa (1.3 GHz camera head and grinder head will deliver soon).



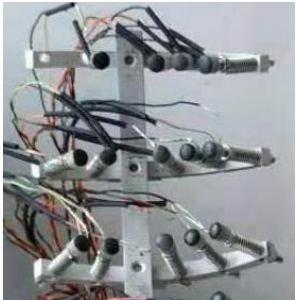
Hayano-san helped to install
KEK's 1.3 GHz camera and train IHEP people



Iwashita-san and Hayano-san helped to commission
650 MHz camera and grinder, and train IHEP people

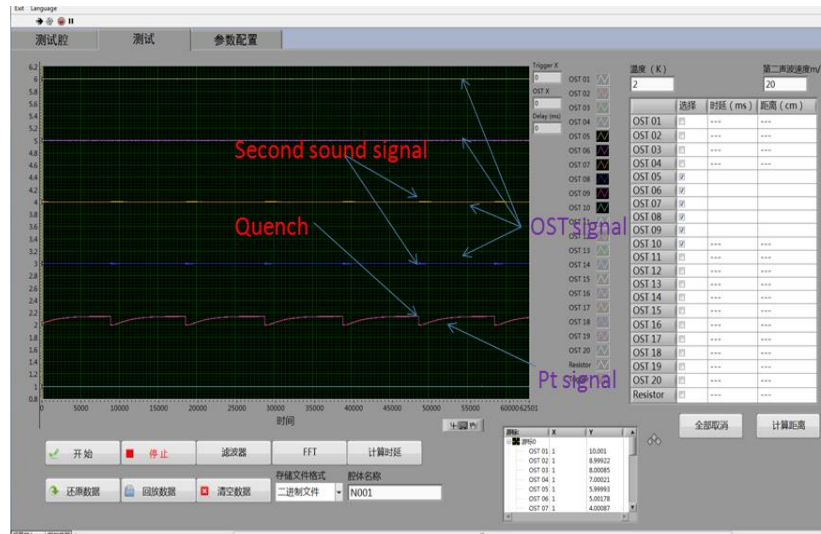
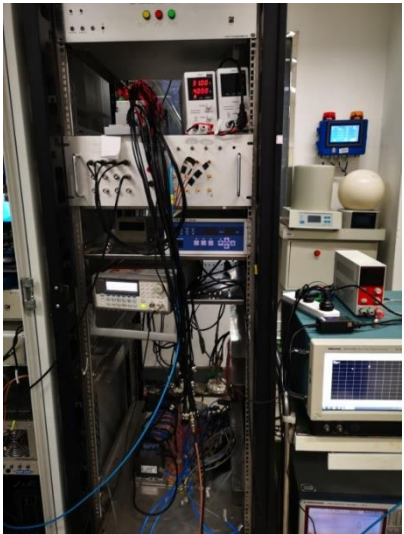
TX-Mapping System

- For 9-cell cavity: 400 carbon resistor temperature sensors, 200 PIN photo diodes X-ray sensors
- System integration completed. Will commission in PAPS SRF lab in 2020.
- Thanks for the help of Kirk Yamamoto-san of KEK.



Second Sound Quench Detection System

- 20 OSTs will be used for the 1.3 GHz 9-cell cavity and 8 OSTs for single cell.
- Second sound signals from OST are amplified by two 12-channel amplifier. Acquisition system: NI9222 and NI9402. LabVIEW for data saving and quench position calculation.
- Thanks for the help of Carlo and colleagues of INFN-LASA.



Summary

- Most single cells achieved ~ 40 MV/m with improved fabrication techniques and newly developed EP tool. High gradient high Q 9-cell cavities expected next year.
- Rapid industrialization of cavities and input couplers for SHINE project (600 cavities). Cost reduction and mass production (200~300 cavities/couplers) preparation next year.
- IHEP's new SRF lab and infrastructures enable future ILC cavities, couplers and cryomodules mass production in China, as well as various fundamental and frontier research.
- We thank KEK for collaboration on SRF technology and infrastructures.