Fabrication, Treatment and Test of Large Grain Cavities

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Outline

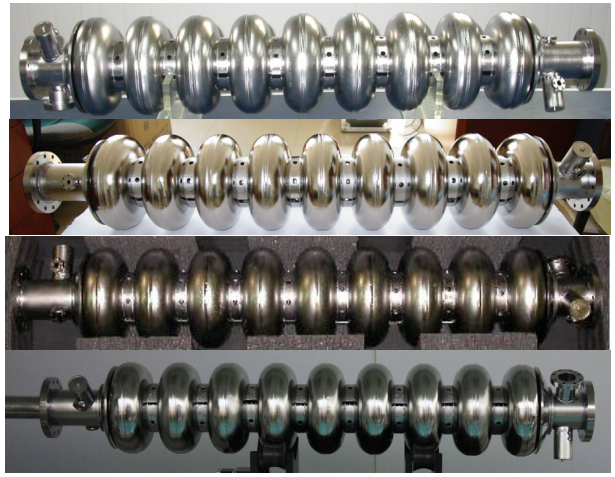
- Motivation and background
- New progress: series production of 9-cell large grain cavities
  - Fabrication
  - Treatment
  - Vertical test
- Summary

Motivation and background

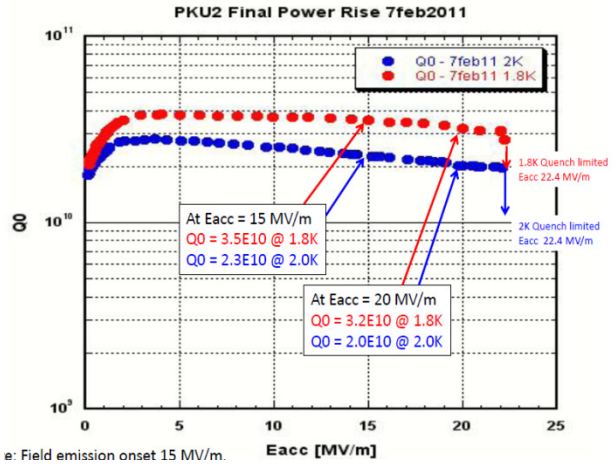
- The development of 1.3 GHz cavity is driven by large projects
- European XFEL and ILC need cavities with high gradient
- CW XFEL needs cavities with medium gradient and high Q, for example, LCLS-II and Shanghai XFEL

Motivation and background

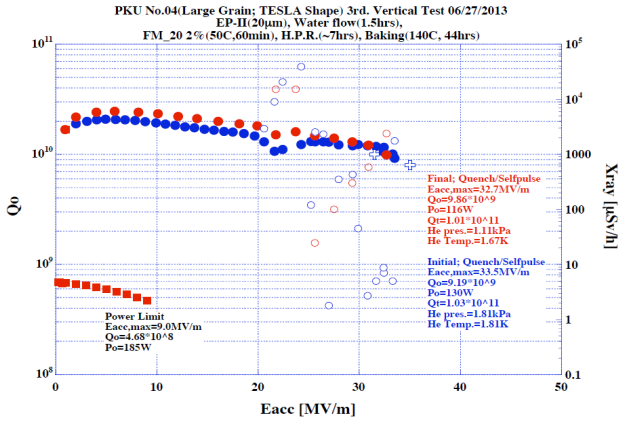
Efforts for 9-cell cavities at PKU (collaboration with HIT)



Cavity	Nb	Eacc (MV/m)	Q @ Emax	Q @ 16MV/m
PKU1	FG	23.0	6.0E09	1.1E10
PKU2	LG	22.4	2.2E10	2.0E10
PKU3	FG	28.6	4.0E09	7.0E09
PKU4	LG	32.6	1.0E10	1.6E10



- Eacc: 22.4 MV/m,
- Q_0=2E10 @ 20 MV/m, 2K

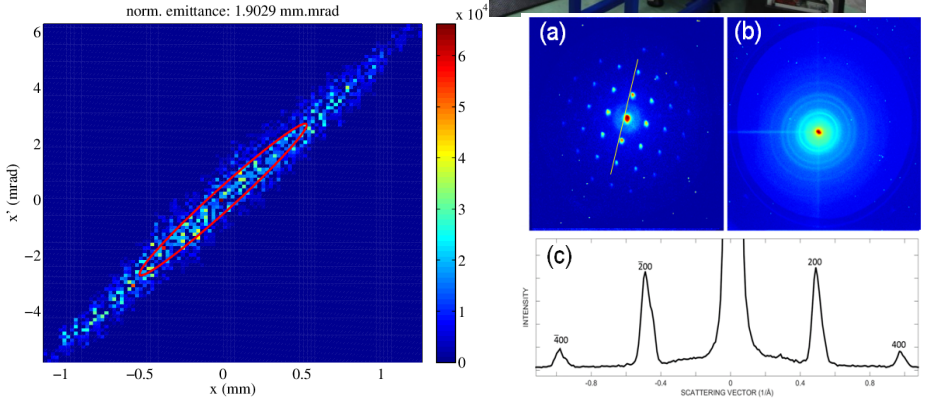


- Eacc: 32.6MV/m, Q_0:1E10 (1.8K)
- Reach ILC requirement

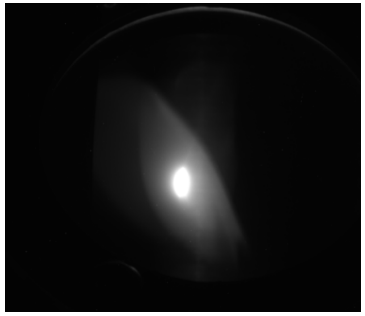
Motivation and background

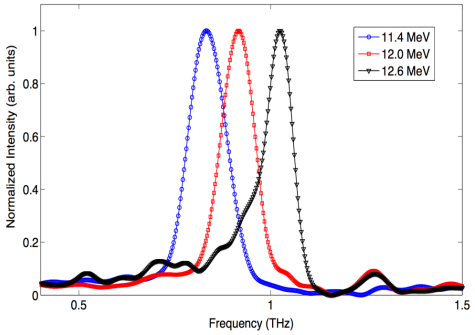
Stable electron beam loading with large grain cavities

DC-SRF injector with 3.5-cell cavity (since 2014)



Cryomodule with 2×9-cell cavities (since 2015)

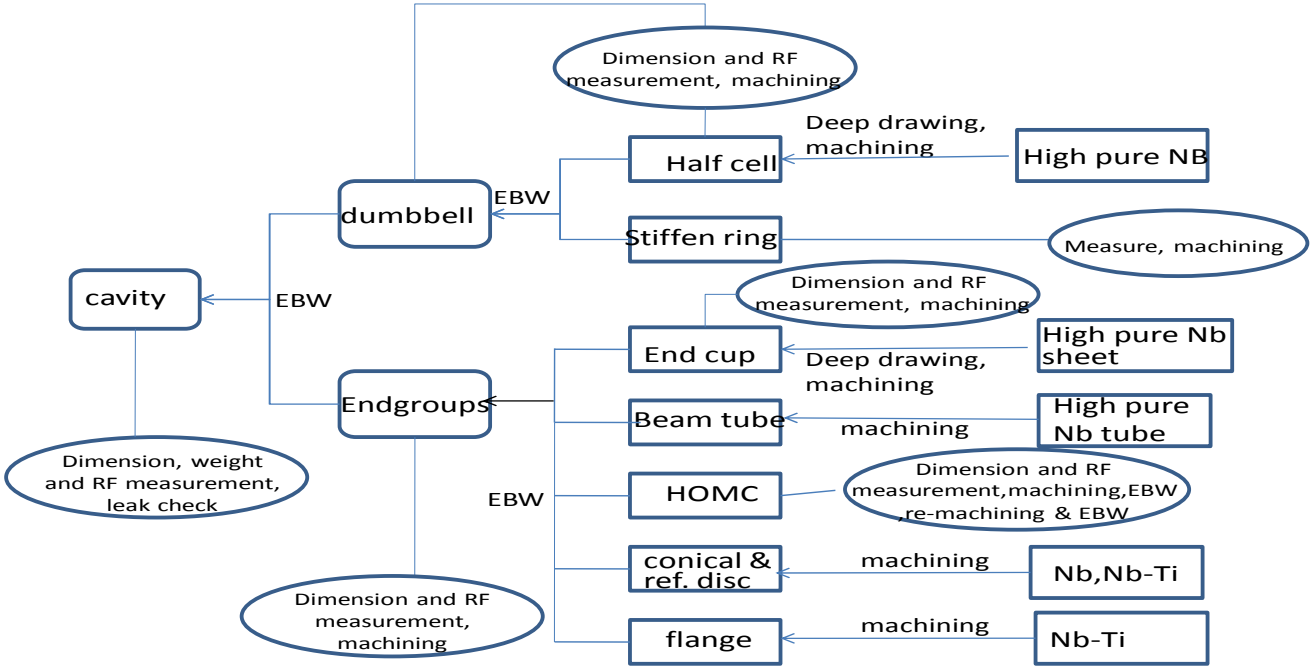




- 10~20 MeV, Ave. current ~1mA (long macropulse)
- Applications: UED, THz radiation

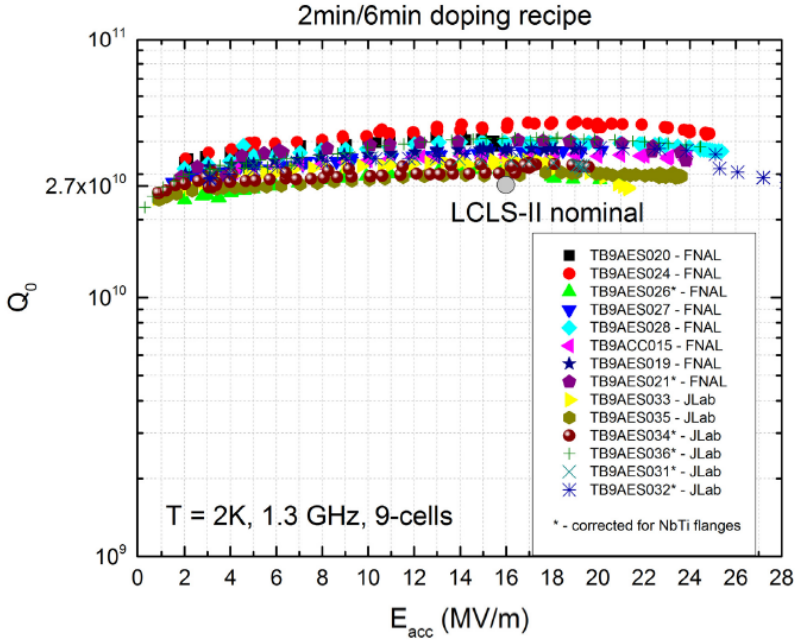
Motivation and background

- Driven by the needs of Chinese CW XFEL plans: 1.3 GHz cavities with ~16 MV/m, 2-3×10^{10}
- Production study of 9-cell cavities
  - Series production following the standard specification at PKU
  - Test of repeatability and consistency



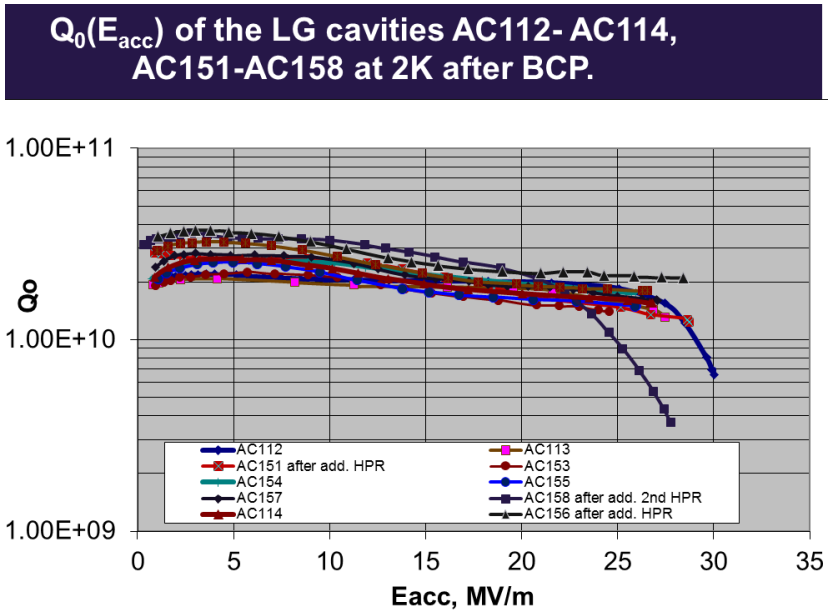
Methods to reach high Q for 1.3 GHz cavities

High Q tech.: N-doping



A. Grassellino, SRF2015

Optional tech.: Large Grain



W. Singer, TTC2011, Beijing

Methods to reach high Q for 1.3 GHz cavities

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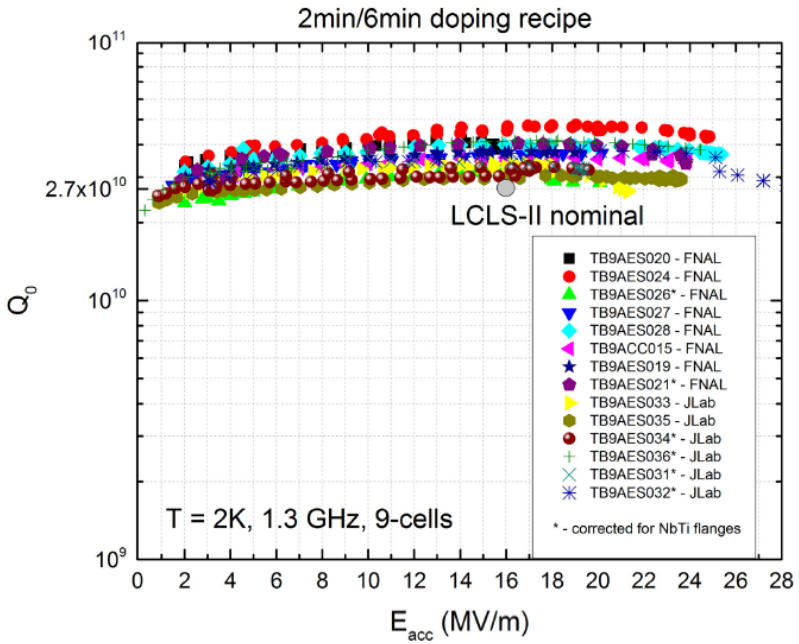

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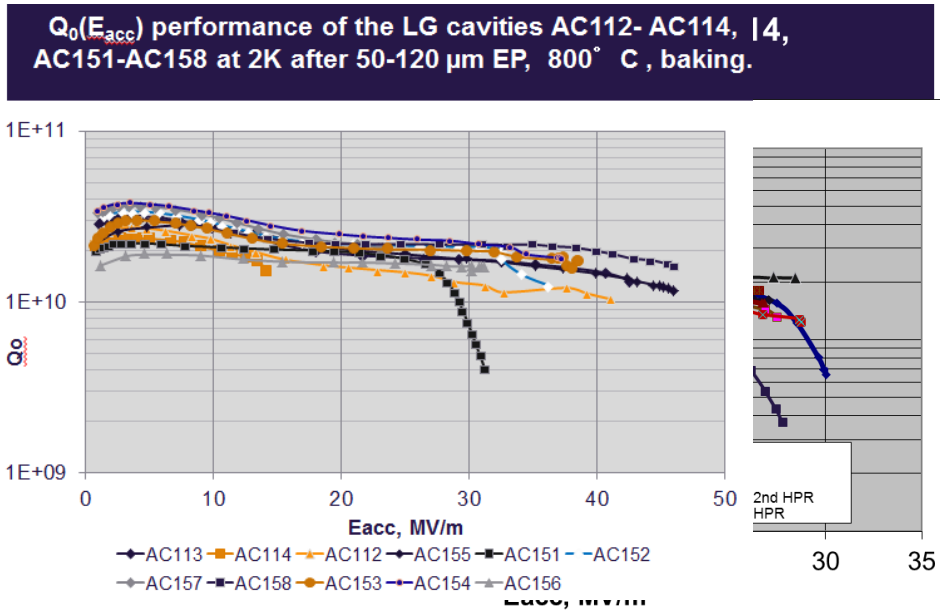

W. Singer, TTC2011, Beijing

We choose large grain material for series production study to test the possibility of using LG cavities to get high Q for CW XFEL

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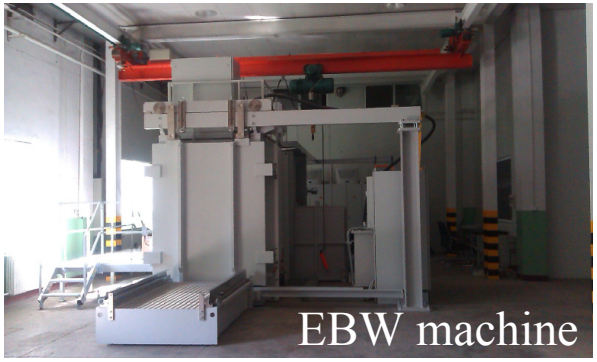
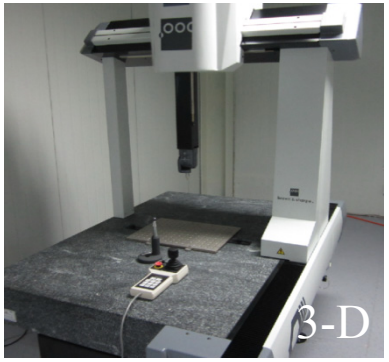
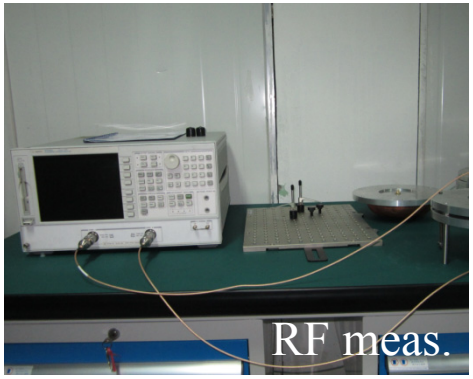
Series production of 9-cell large grain cavities

Ningxia Orient Superconductor Technology Co., Ltd (OSTEC) (Founded by OTIC and PKU, 2011)

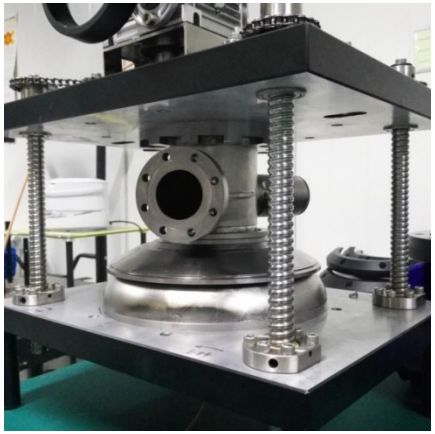






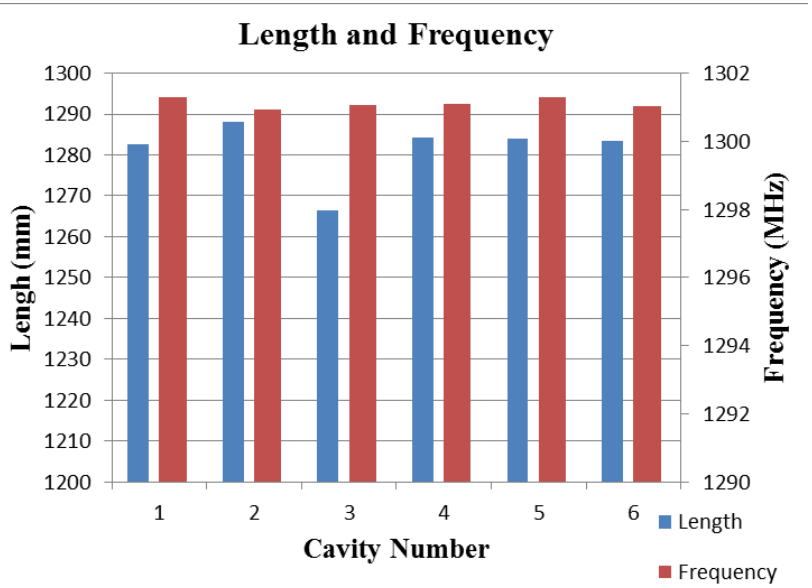
Series production of 9-cell large grain cavities

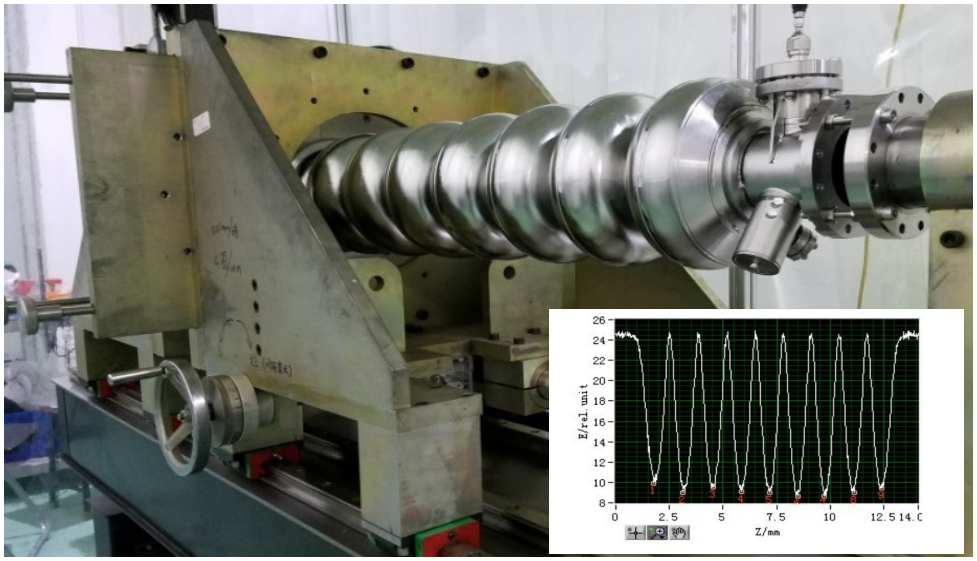
Strict quality control for every step



Series production of 6 LG 9-cell cavities (2016-2017)

Length, frequency and flatness





- $L \pm \sigma_L = 1284.5 \pm 2.1$ mm (cavity #3 excluded)
- $f \pm \sigma_f = 1301.12 \pm 0.14$ MHz
- within the tolerance
  - σ_L : ± 3 mm
  - σ_f: ± 0.5 MHz

Flatness before and after tuning

Cavity #	original	after tunting
1	69.9%	96.6%
2	57.3%	94.6%
3	66.7%	95.1%
4	75.6%	95.0%
5	63.0%	95.3%
6	60.0%	96.6%

Post processes

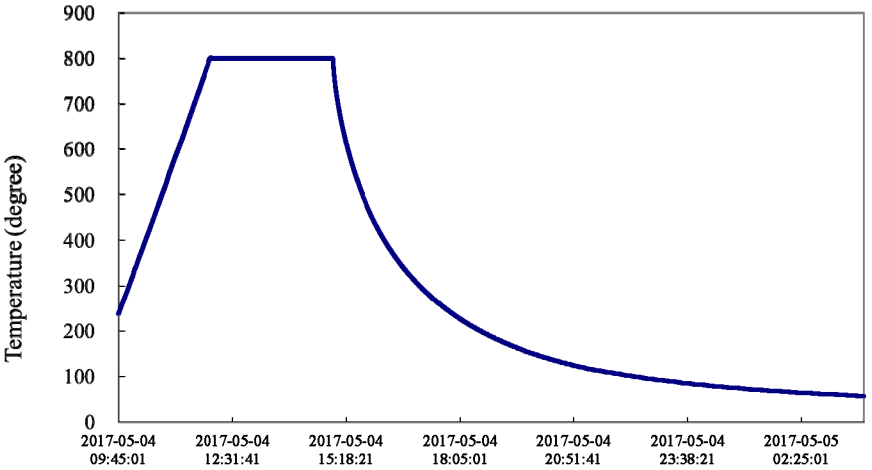
- BCP (180 μm)
- HPR
- 800 °C degasing/annealing
- BCP (30 μm)
- Field flatness tuning
- Ultra sonic cleaning
- HPR
- Assembly
- HPR
- VT Assembly
- Vertical Test

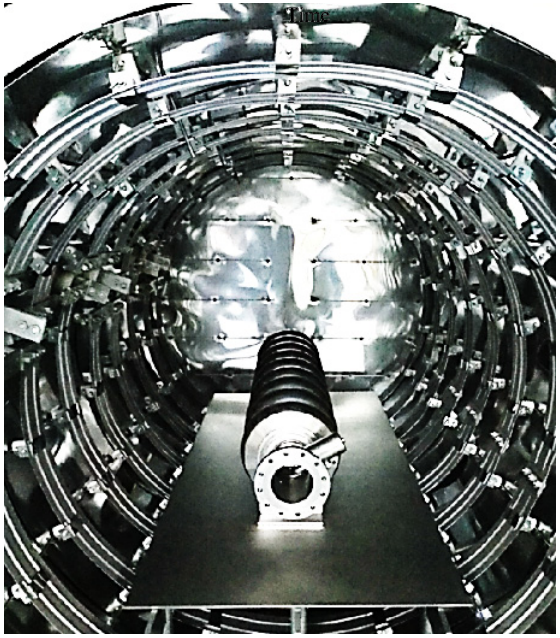
Without EP

BCP

HPR

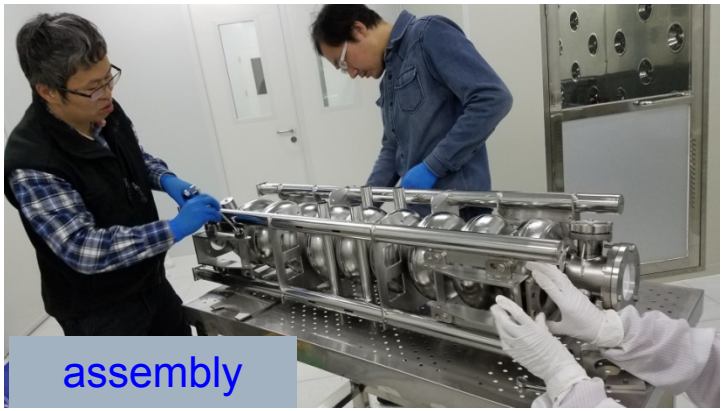
800°C heat treatment (3 hours)





Clean room assembly + HPR


US cleaning

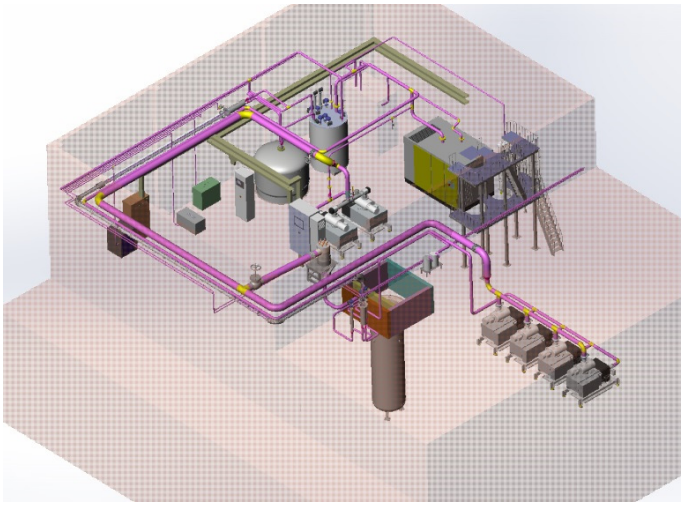

assembly

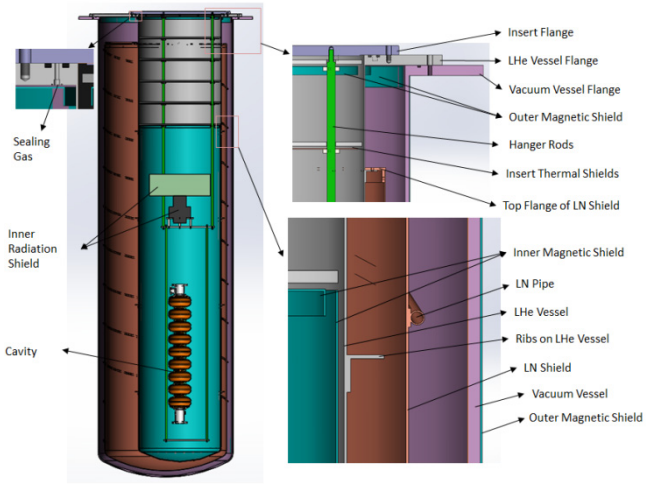

components cleaning


HPR


leak check

Setup of Vertical Test System (VTS)

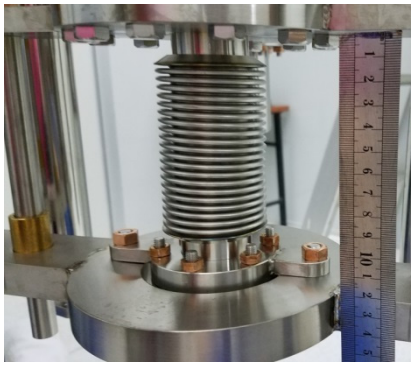




- Double magnetic shield, < 10 mGs
- He mass flow @ 30 mbar: 10 g/s
- Cooling capacity: >200W @ 2 K

Poster
Dejun ZHOU
TUPB099

Vertical Test

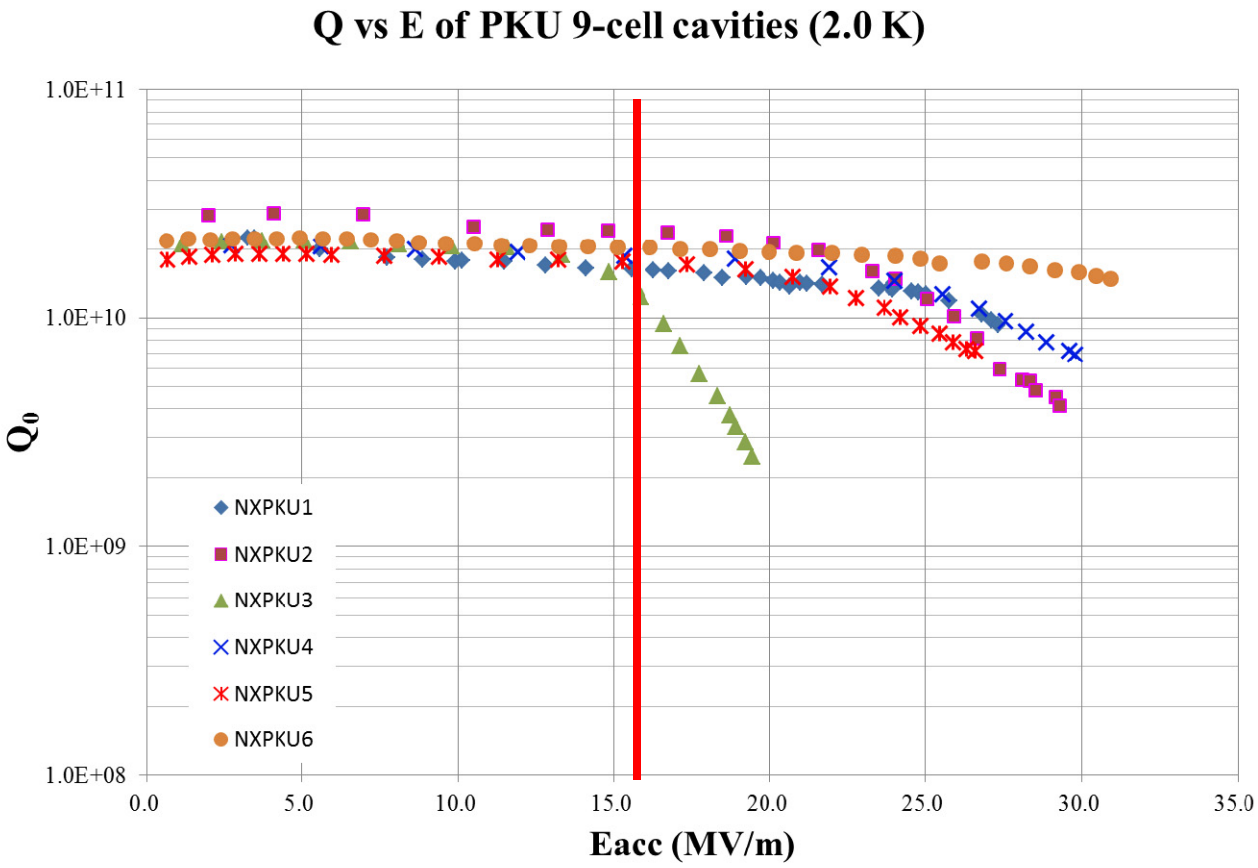


Vertical test of 6 large grain 9-cell cavities (April ~ June, 2017)

Q vs E curves of 6 large grain cavities at 2 K

- All cavities follow the same procedure
- #1,3,4,6, 1st test
- #2,5, 2nd test, with additional HPR

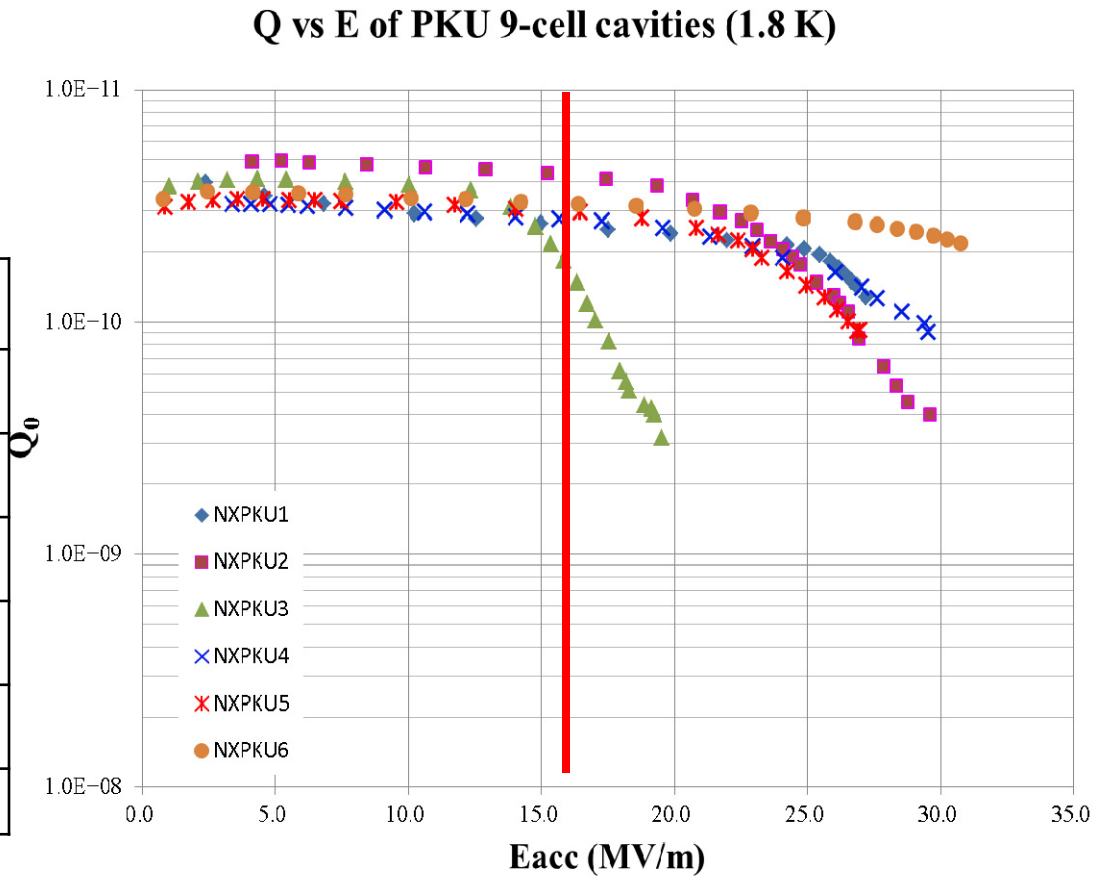
- E_{acc} of 5 cavities larger than 25 MV/m
- Q_0~1.6-2.4E10 @ 16 MV/m
- #3, strong FE due to HPR accident



Q vs E at 1.8 K

- Q_0(1.8K)/Q_0(2.K) = 1.50-1.79 (@~16 MV/m)
- Advantage of running at 1.8 K when the ratio >1.33

Cavity	Q_0(2.K)	Q_0(1.8K)	Ratio
#1	1.6E10	2.6E10	1.63
#2	2.4E10	4.3E10	1.79
#3	1.2E10	1.8E10	1.50
#4	1.8E10	2.7E10	1.50
#5	1.7E10	3.0E10	1.76
#6	2.0E10	3.2E10	1.60



Operation at 1.8 K with large grain cavity has obvious advantage

Future Plans

- Understand and reduce field emission;
- Further improve Q_0 by EP, N-doping;
- Horizontal test of the six 9-cell cavities;
- Further improve the performance of cryomodule with large grain cavities;
- ……

Summary

- Six 1.3 GHz large grain 9-cell cavities have been fabricated, treated and tested at PKU.
- Only with BCP, five cavities reach gradient larger than 25 MV/m, the intrinsic Q values are about 2×10^{10} at 16MV/m and 2.0 K.
- Repeatable production of 1.3 GHz large grain 9-cell cavities is realized with industry.
- Large grain cavities which show high Q_0 and high stability in this study provide an viable option for CW linac.

Acknowledgements

We give great thanks to

- colleagues of international collaboration for cavity treatments and tests,
- colleagues of IHEP for discussion and construction of vertical test system,
- colleagues of OSTEC for the collaboration on fabrication of 9-cell superconducting cavities.

Thank you for your attention !