SRF cavities at Peking University

SRF Group

Institute of Heavy Ion Physics, Peking University

October 18, 2011

Outline

1. History of R&D on superconducting cavities
2. SRF cavities fabricated recently
3. Future Plan
4. Summary

History of SRF activities at PKU

Multi-cell cavities technology

SRF Lab founded

1988

1994

2000

2002

2003

2004

2005

2006

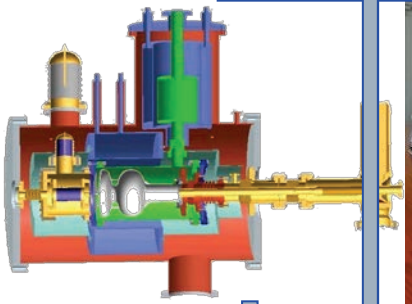
2007

2008

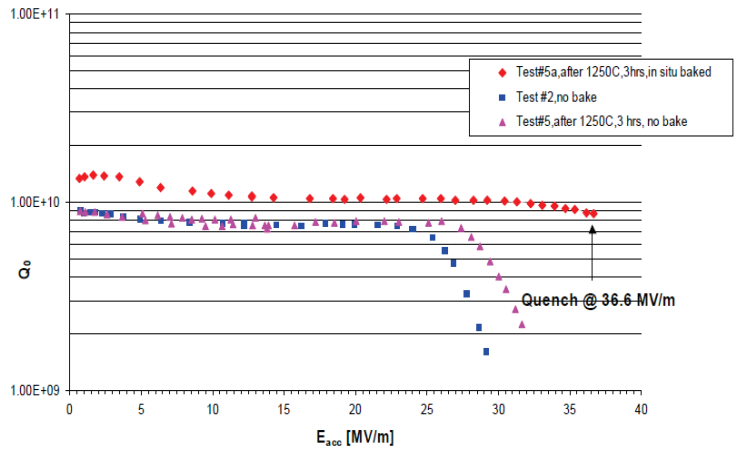
2009

2×3.5cell

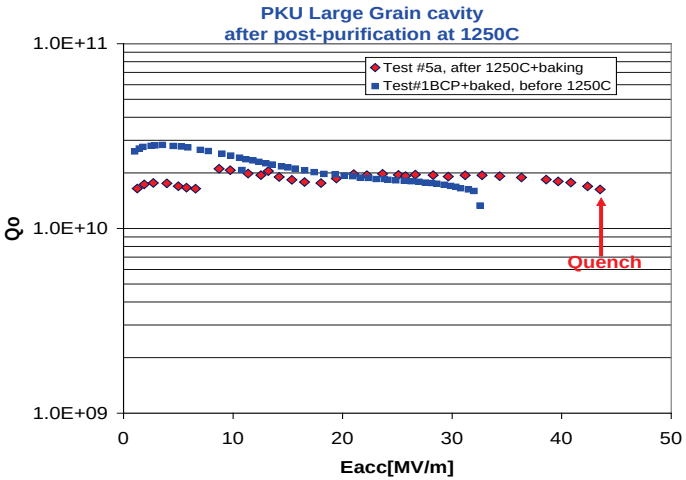
2×9cell



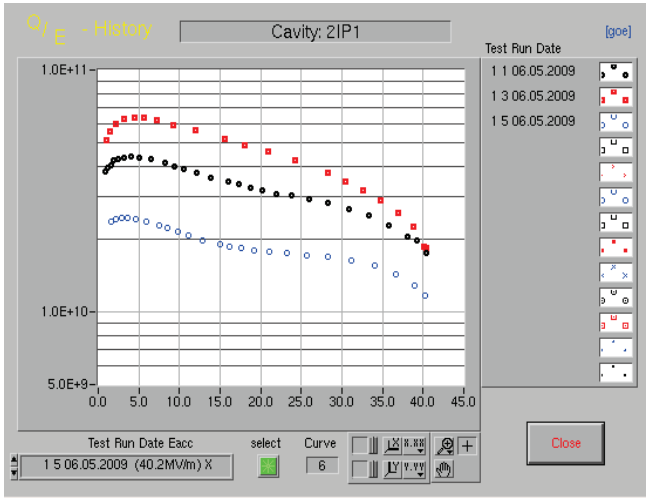
Test results of large grain cavites (high gradient, high Q)



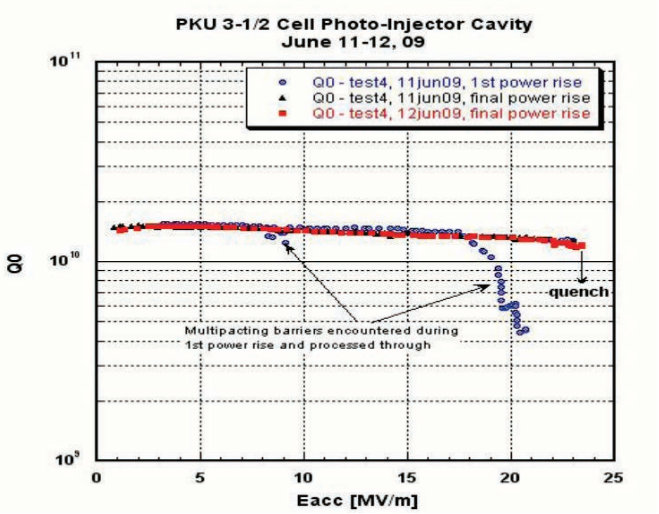
1.5GHz single-cell（36.6 MV/m)



1.3GHz single-cell（43.5 MV/m)



1.3GHz 2-cell （40 MV/m)



1.3GHz 3.5-cell（23.5MV/m)

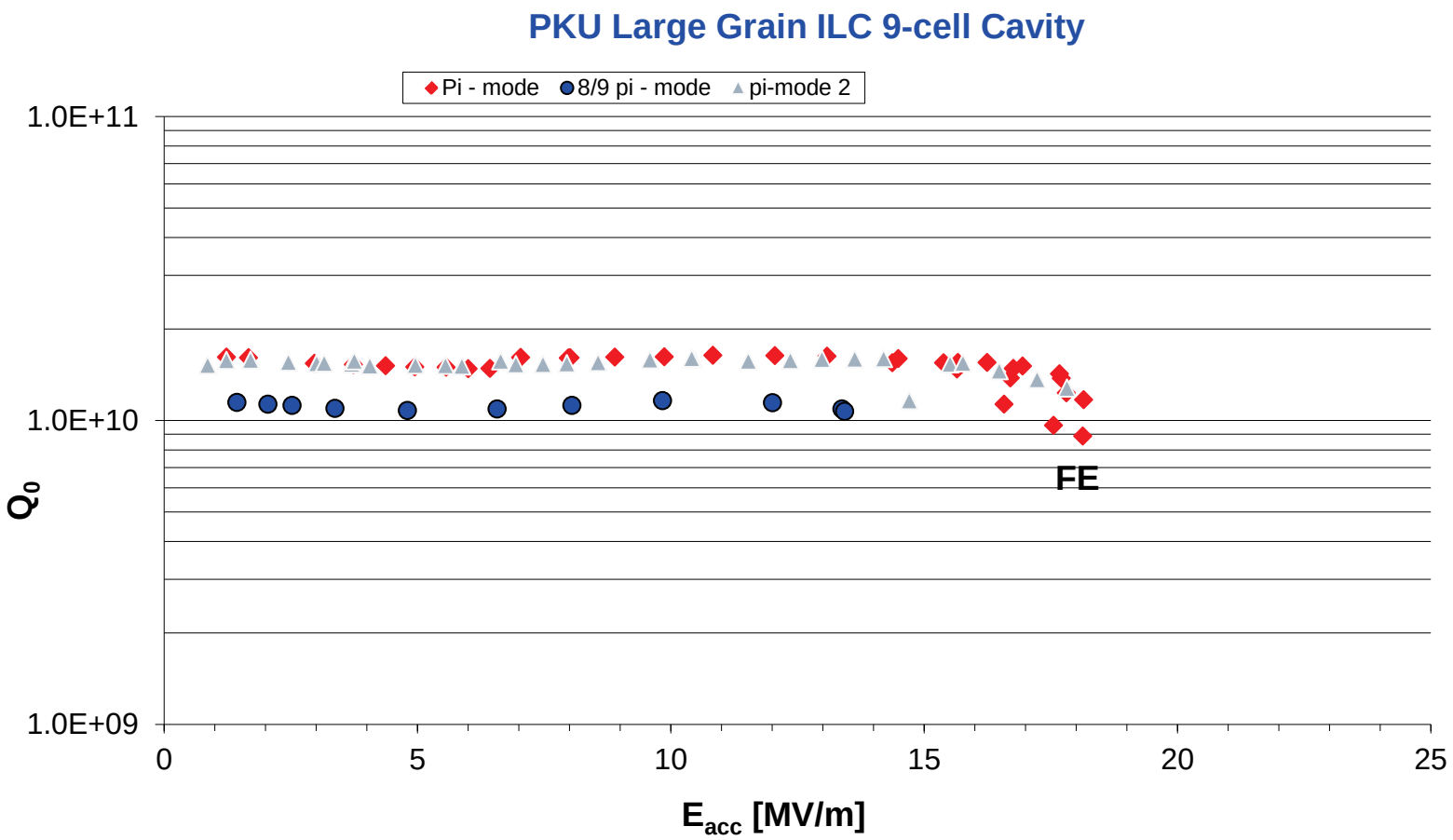
2. SRF cavities fabricated recently

PKU2: large grain 9-cell cavity

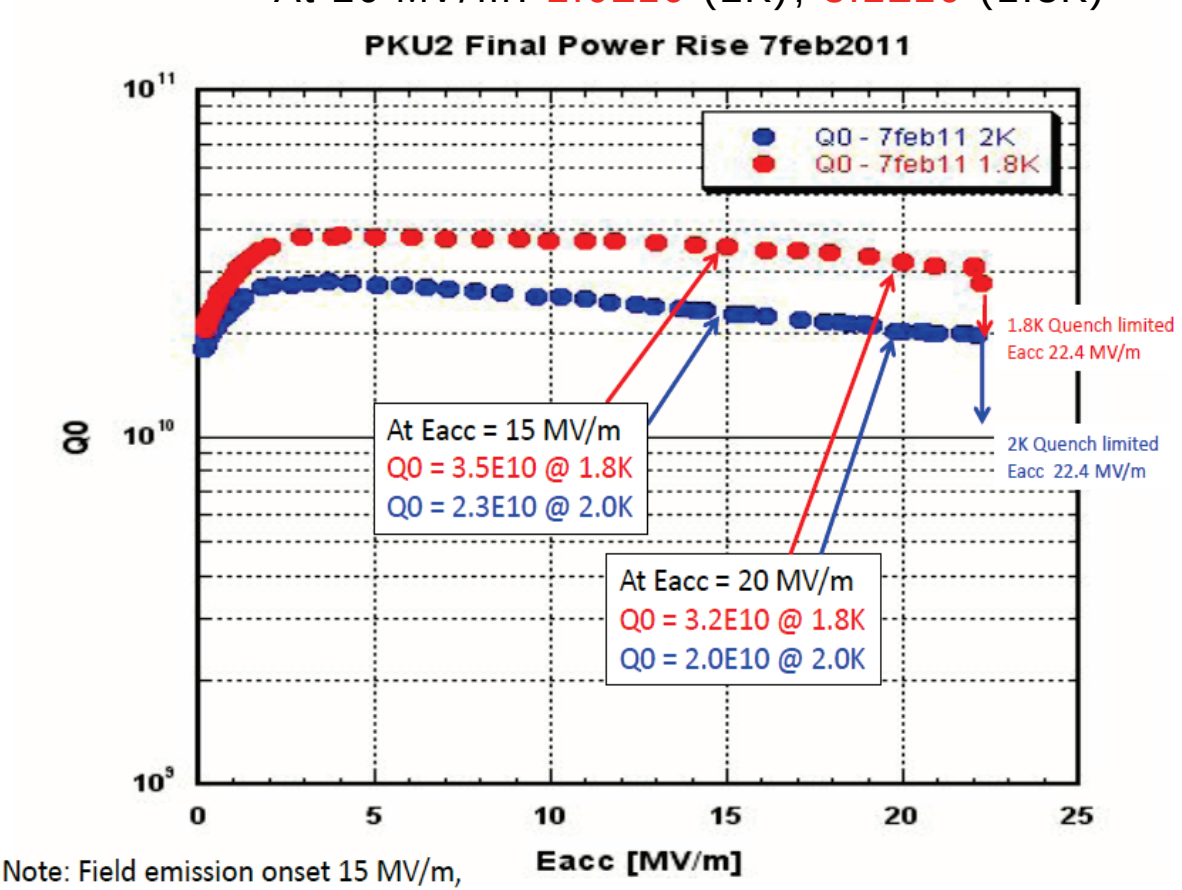
TESLA type, fabricated by Peking University in 2009, tested at Jlab 2010-2011

Test 1

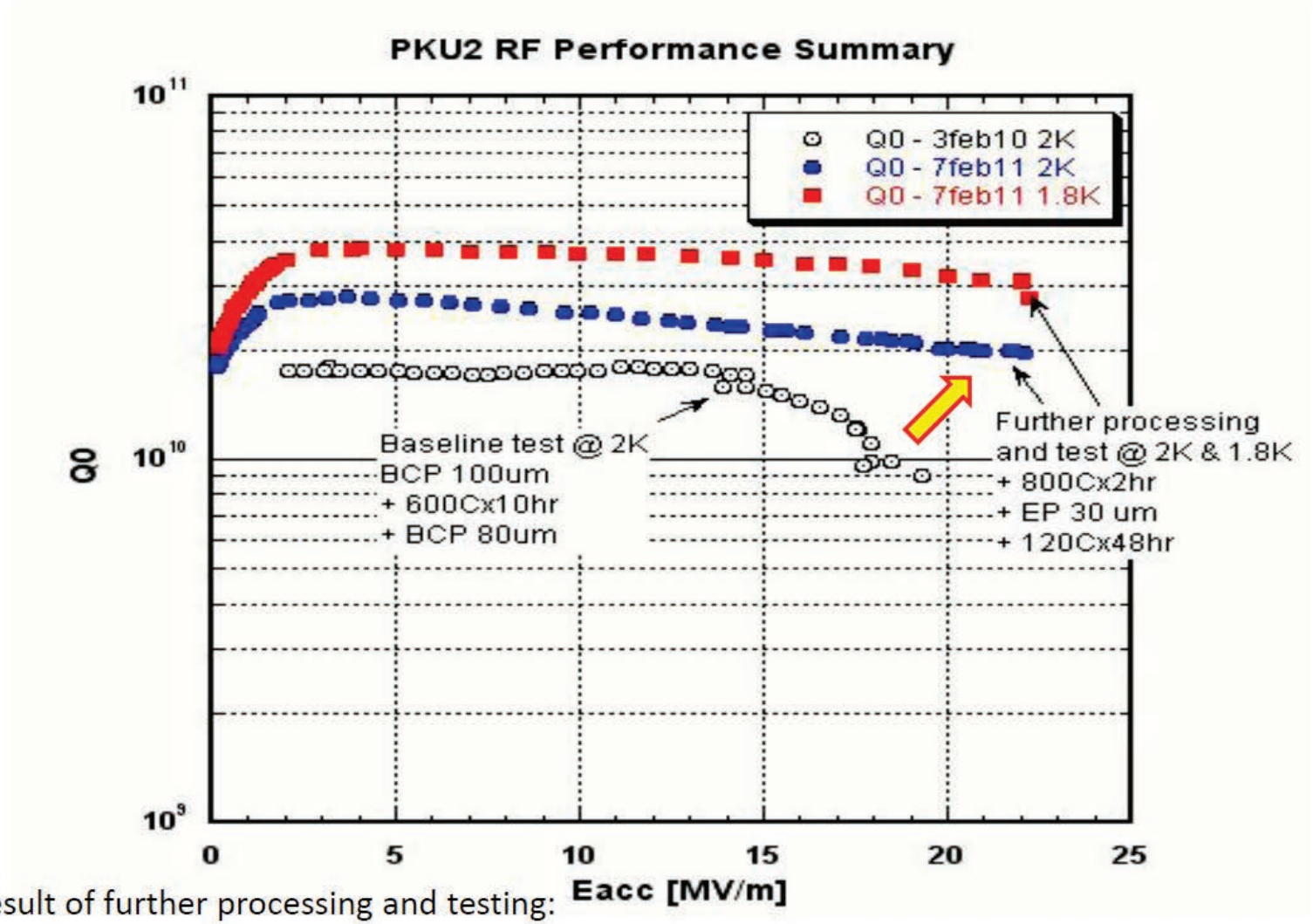
PKU-2(large grain) was tested twice on different days, but same treatment:
80 micron BCP, 600° C 10 hrs hydrogen degassing,50 micron BCP, HPR
RF test at 2K, Eacc 18.5 MV/m with Q_0 9E9, Quench.



Optical Inspection: Defects near Equator EBW
800°C x2 hr + EP 30 μm + 120°C x48 hr
RF test, maximum gradient of 22.4 MV/m
High Q_0 At 15 MV/m: 2.3E10 (2K); 3.5E10 (1.8K)
At 20 MV/m: 2.0E10 (2K); 3.2E10 (1.8K)



Note: Field emission onset 15 MV/m,
Maximum X-ray dose rate < 100 mR/m. No more mode mixing observed during final power rise.



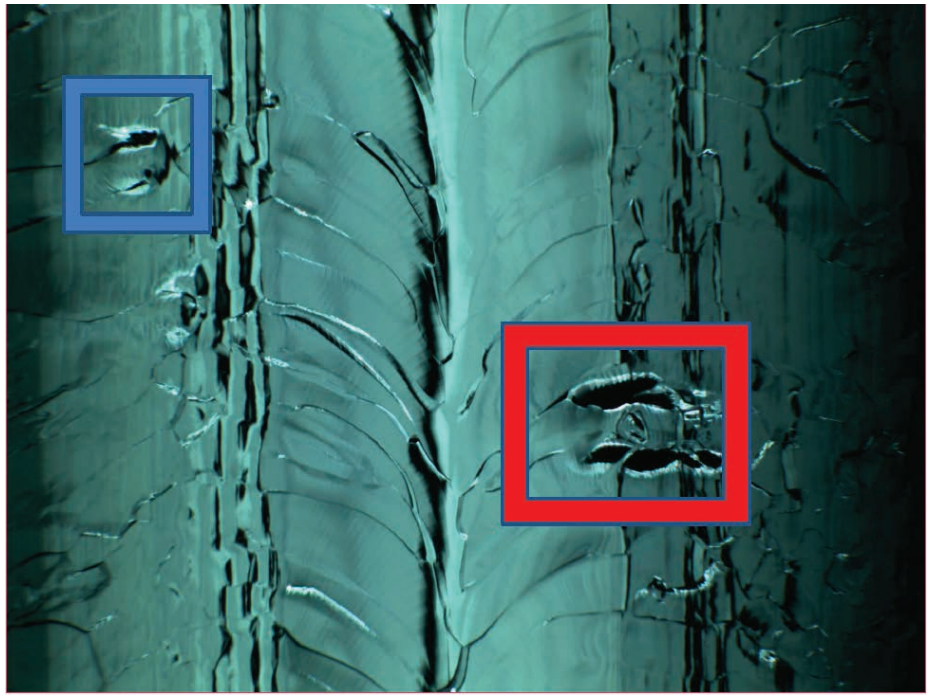
Result of further processing and testing:

- 16% improvement in Eacc
- More than a factor of 2 improvement in Q0 at Eacc > 19 MV/m

Optical inspection

Where are they from?

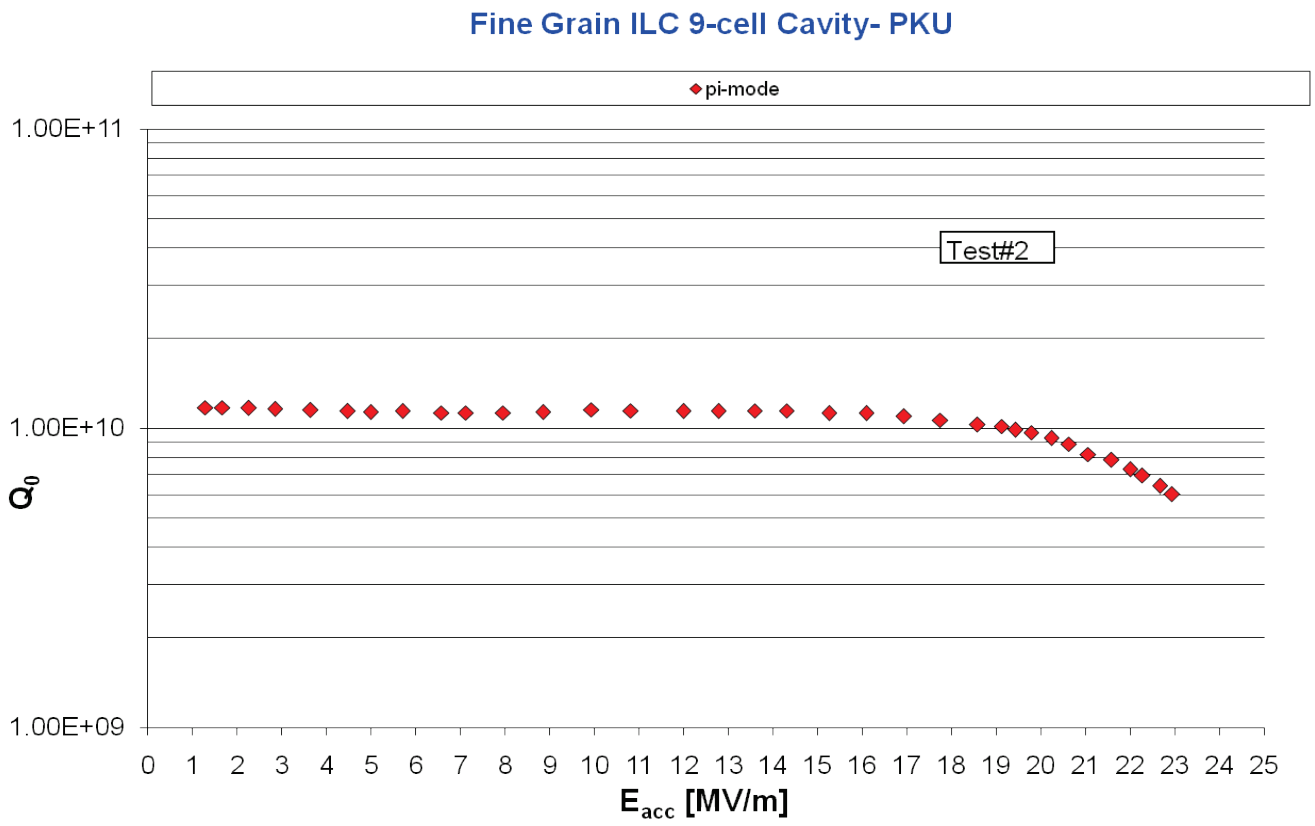
- Tuning?
- EB welding?



- 2 new LG cavities are being fabricated
  - ➢ Improve machining and EB welding
  - ➢ Post-treatment

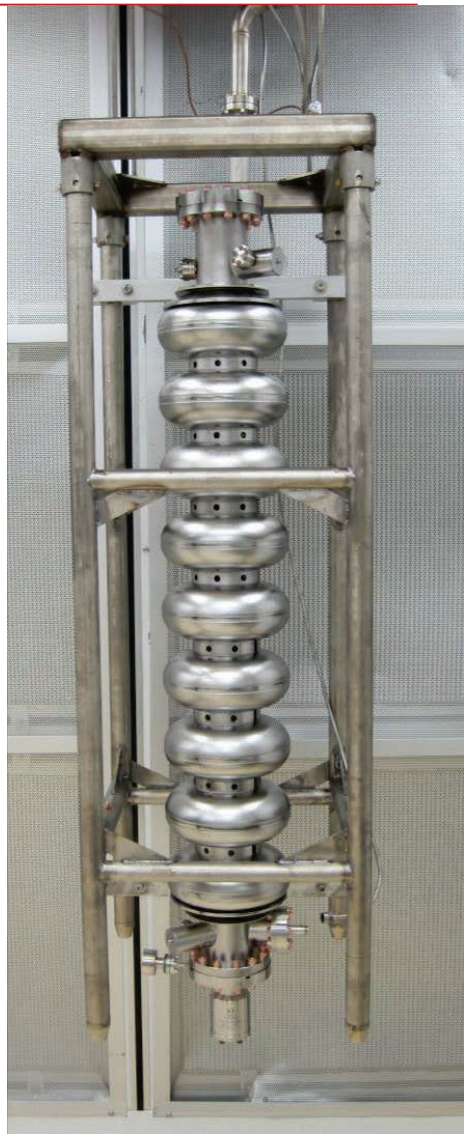
Fine grain 9-cell cavities

First 9-cell cavity PKU1: 23 MV/m

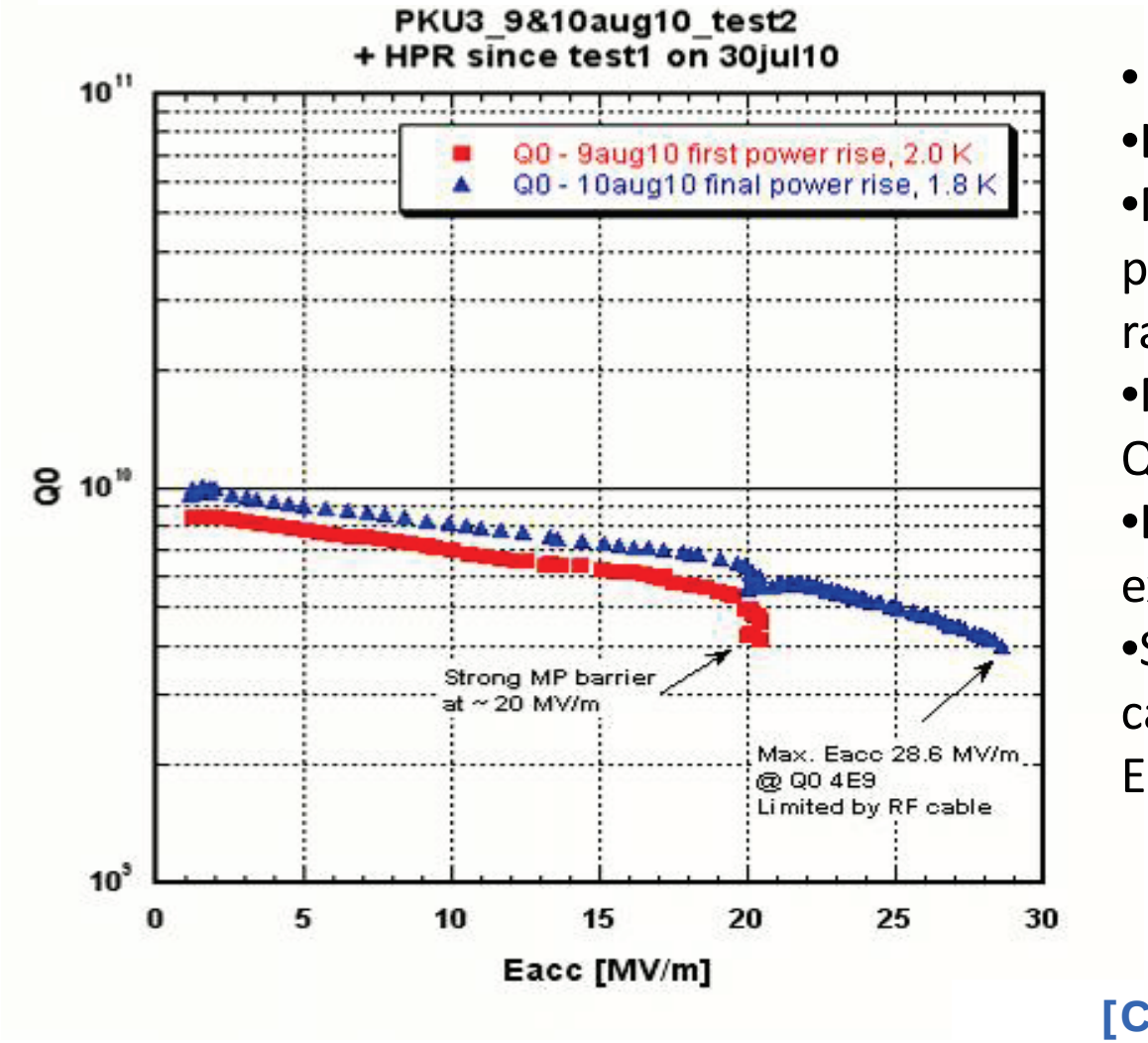


PKU3: fine grain 9-cell cavity

- Fabricated at PKU 2009, tested at Jlab in 2010
- 120 μm EP+800 °C x2hr+Light EP 25 μm+120°C x 48 hr
- 1st test max. Eacc 20 MV/m @ Q_0=2.3E9, limited by FE



Second RF Test



- Re-HPR 2 times
- Low field Q_0=8.4E9 at 2K
- Max Eacc 20.5 MV/m during first power rise at 2K, limited by radiation.
- Max Eacc reached 28.6 MV/m at Q0 4E9,1.8K, limited by RF cable.
- Low field Q 2-3 time lower than expected -due to the material?
- Strong field emission- maybe caused by sharp edges in the iris EBW regions

[Coutesy Rong-Li Geng]

- First 9-cell cavity with end groups in China reaching a gradient usable for ILC
- A milestone in SRF technology in China

http://newsline.linearcollider/readmore_20100909_atw.html

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China reaching the target gradient

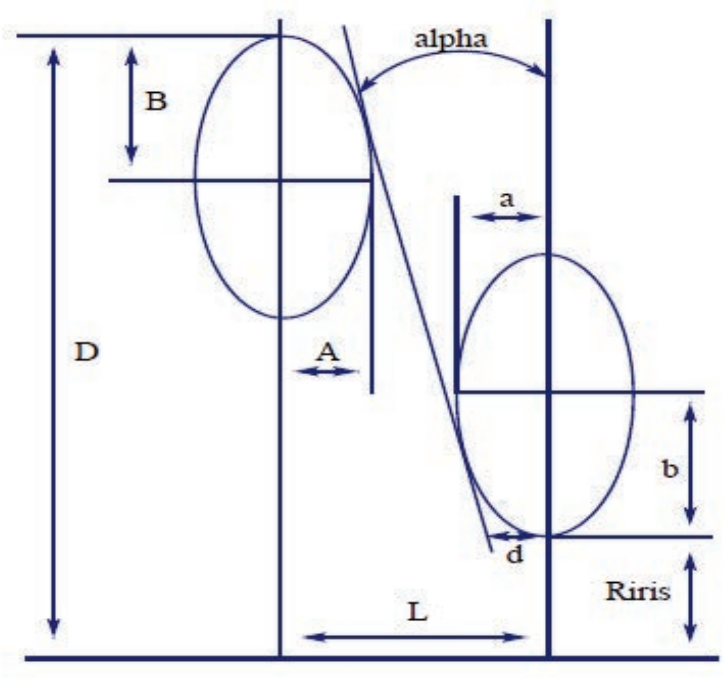
A 1.3-gigahertz TESLA-type nine-cell niobium superconducting cavity, named PKU3, as the third nine-cell cavity fabricated by the superconducting radiofrequency (RF) group at Peking University, Beijing, China, achieved an accelerating gradient of 28.6 megavolts per metre (MV/m) at an unloaded quality factor of 4×10^9 in its second vertical test at Jefferson Lab (JLab), USA on 9 August 2010. This cavity is the first nine-cell cavity with end group components in China reaching a gradient usable for the ILC.

The cavity is made of high-purity niobium from Orient Tantalum Industry Corp. (OTIC), Ningxia, China. The fabrication of the cavity was finished in the middle of 2009. After field flatness pre-tuning with the Peking University tuning facility, PKU3 was sent to JLab in April 2010 for performance evaluation.

High current cavity

5-cell high current cavity (Collaboration with ANL)

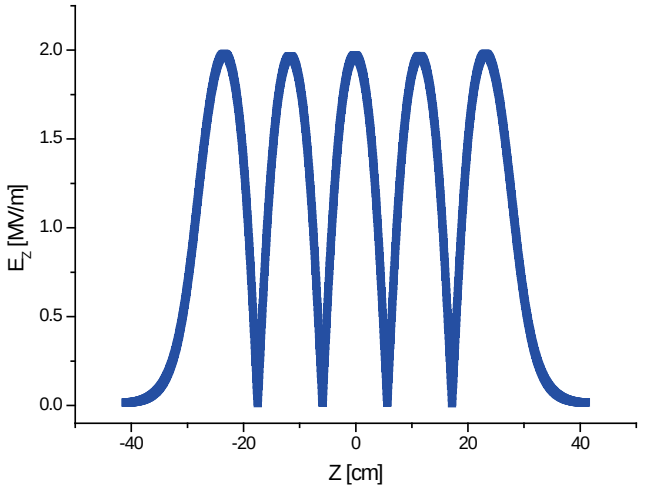
parameters	mid-cell	end cell
L	115.4	115.4
Riris	41.2	48.7
A	38	35.7
B	23.8	23.8
a	10.8	16.9
b	16.3	16.3
D	104	104



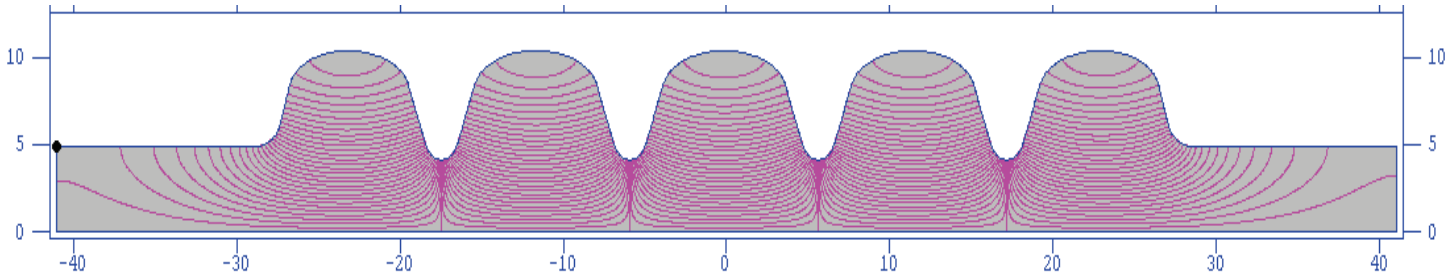
Simulations

Parameters

Frequency(MHz)	1300
Number of cell	5
R/Q (ohm)	466
Epk/Eacc	2.43
Bpk/Eacc mT/(MV/m)	4.6
G Factor	276
coupling coeffcient(%)	3.62
K// for $\sigma_z = 1mm$ (V/PC)	5.52
k⊥ for $\sigma_z = 1mm$ (V/PC/m)	7.56
Riris(mm)	41.2
Rpipe(mm)	48.7



Field Flatness:98%



Field distribution of foundamental mode

Simulations

Parameters

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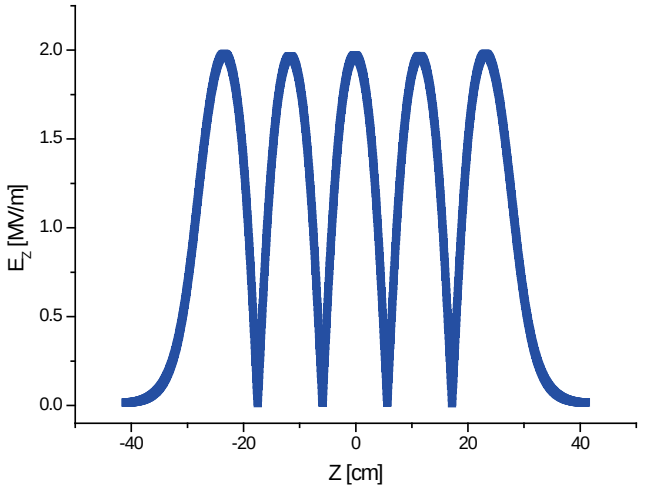
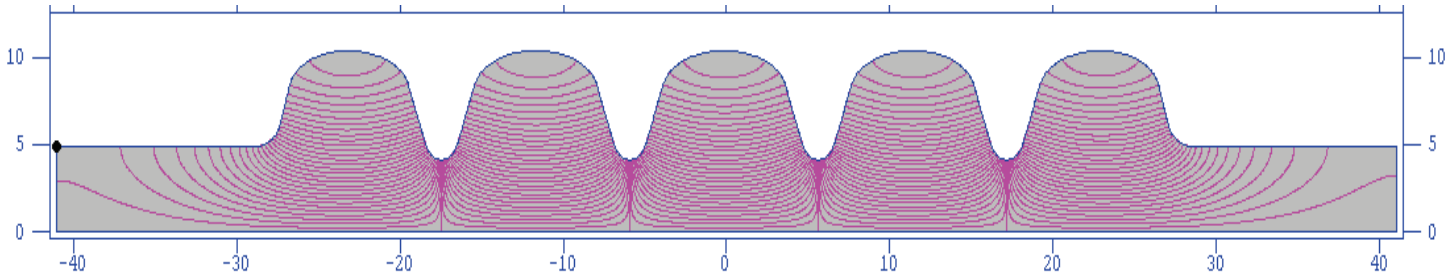
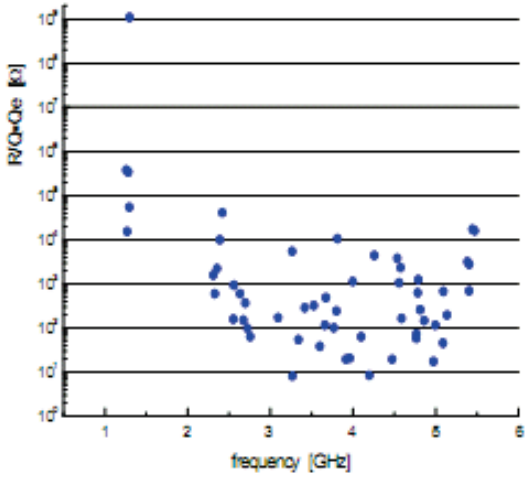


Field Flatness:98%



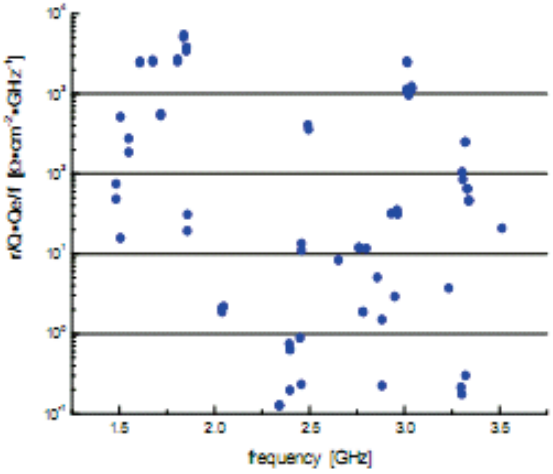
Field distribution of foundamental mode

Simulations



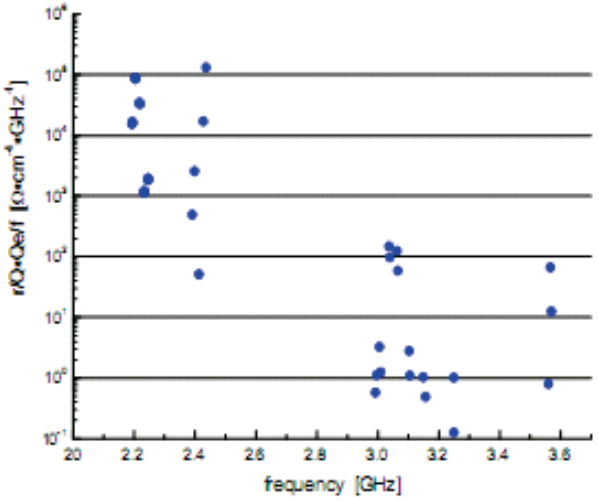
Monopole mode

$$R/Q*Q_e < 10^4\ \Omega$$



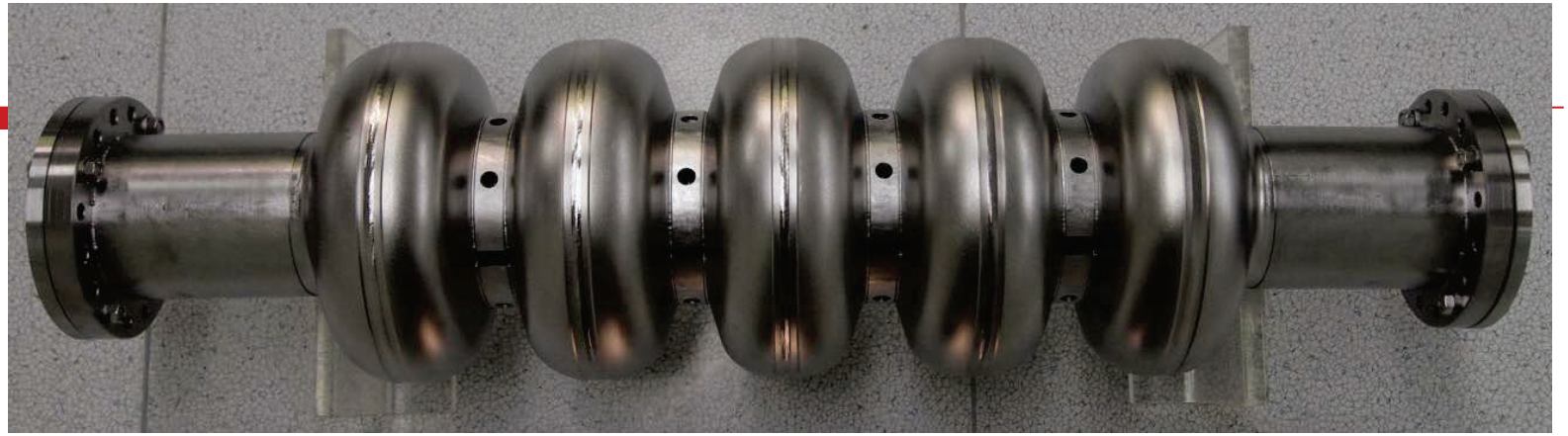
Dipole mode

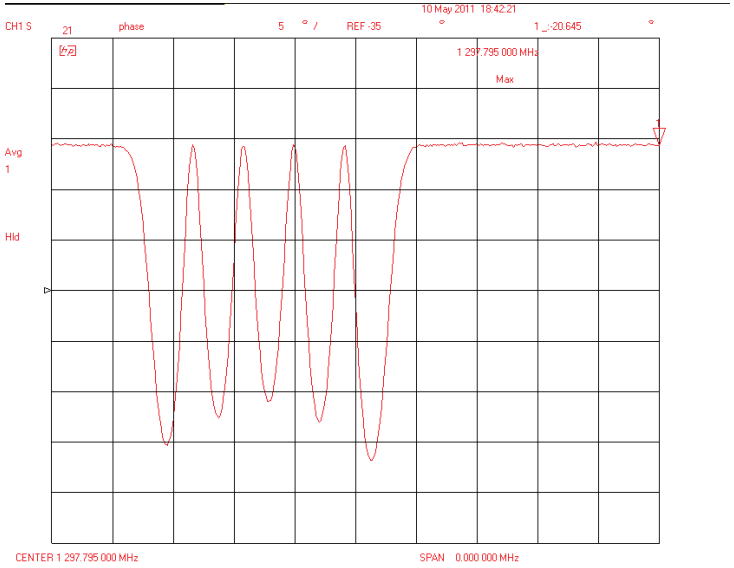
$$R/Q*Q_e/f < 1.4*10^5\ \Omega/(cm^2 \cdot GHz)$$

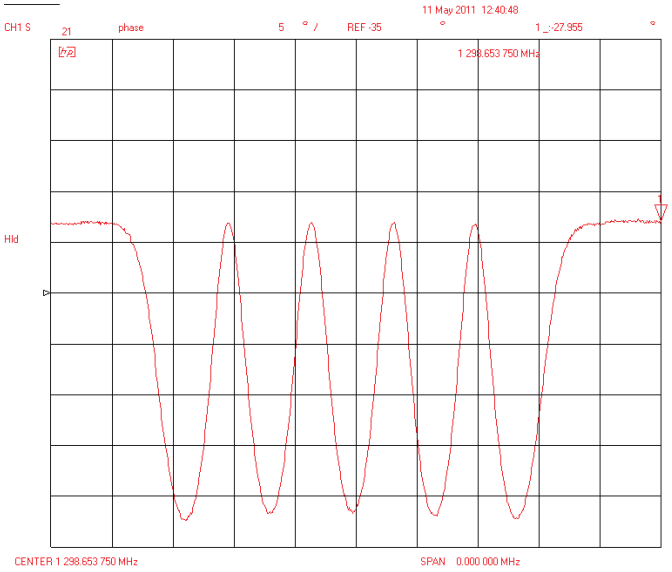


Quadrupole

$$R/Q*Q_e/f < 4*10^6\ \Omega/(cm^4 \cdot GHz)$$



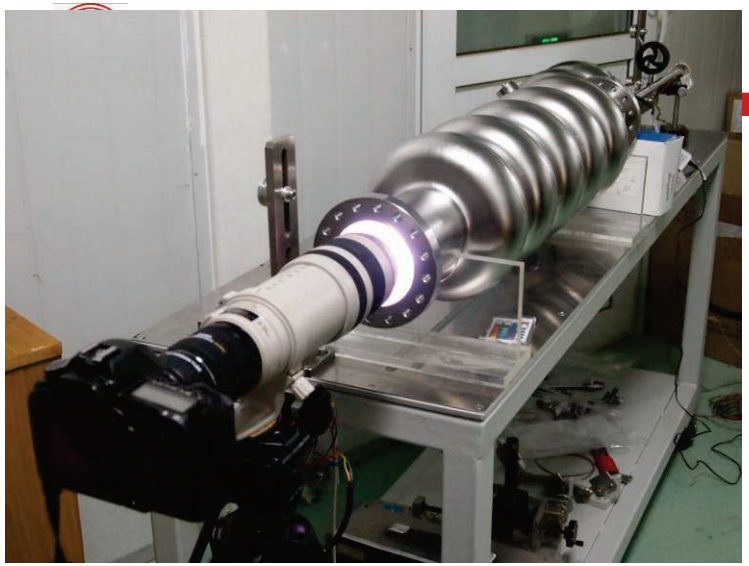


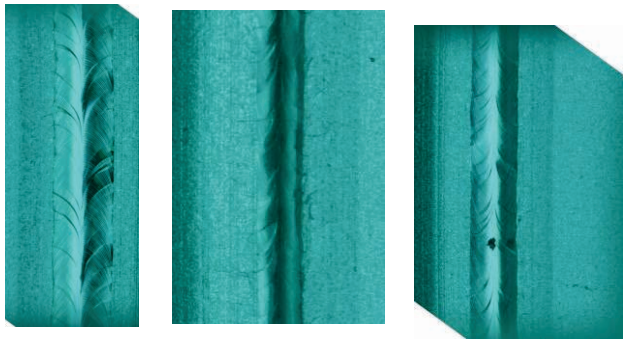


After fabrication, 87%，
1297.80MHz，(goal:1298.6MHZ)

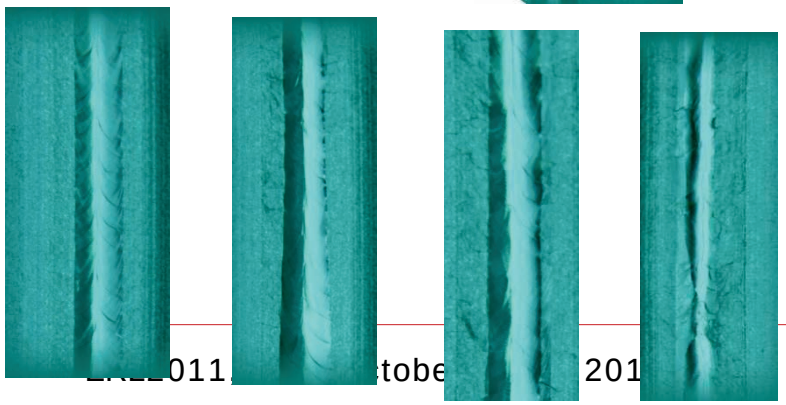
After tuning: 98.6%，1298.65MHz

Optical inspection of EBW

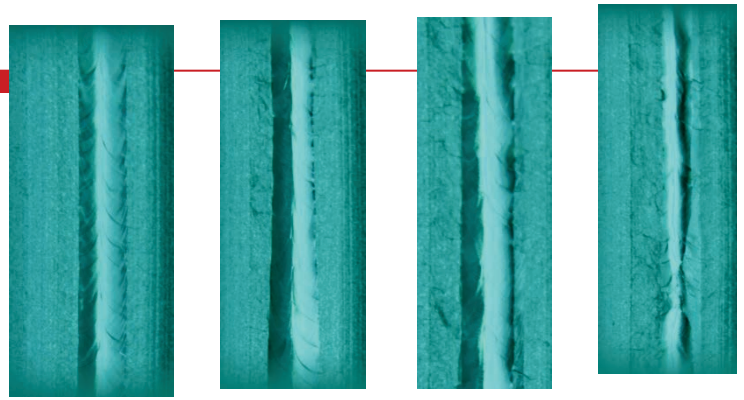




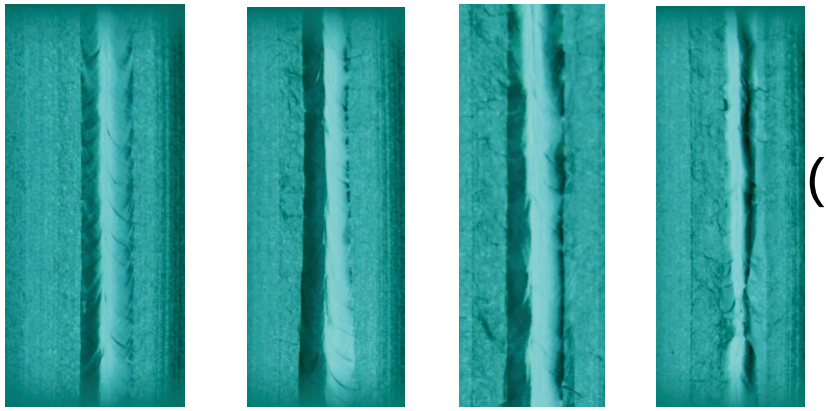
(1)



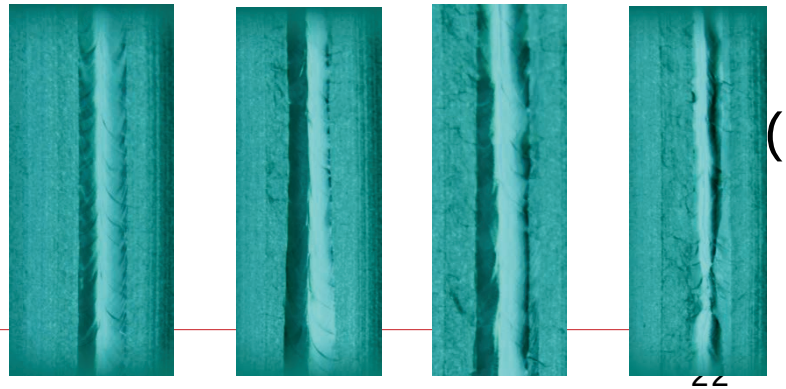
(2)



(3)



(4)

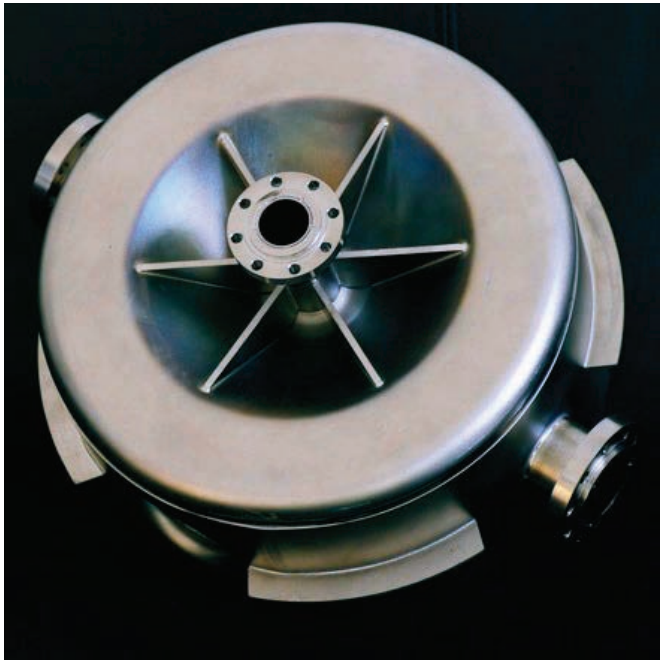


(5)

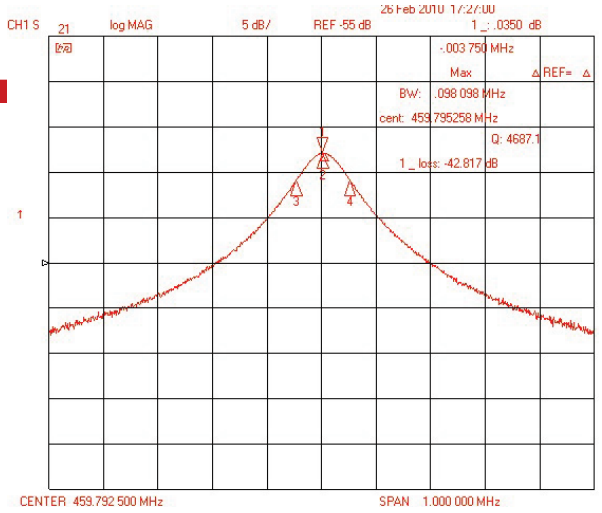
low beta cavities

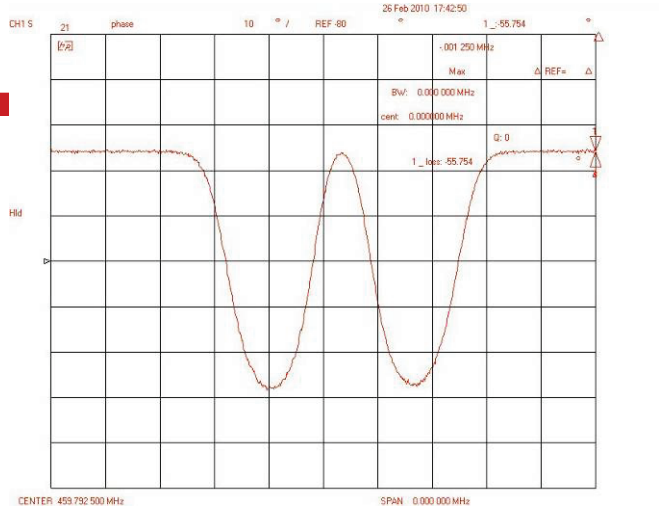
Single Spoke Cavity for proton accelerator

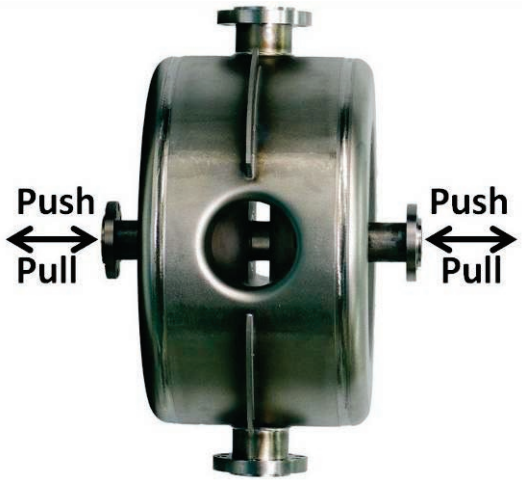
	PKU SSC	PKU SSC Mark II
Frequency [MHz]	450	450
Beam pipe diameter [mm]	30	30
Geometrical beta	0.2	0.2
Transit time factor	0.80	0.80
G [Ω]	73	88
R/Q_0 [Ω]	179	211
E_{peak}/E_{acc}	2.65	2.86
B_{peak}/E_{acc} [mT/(MV/m)]	5.22	3.90

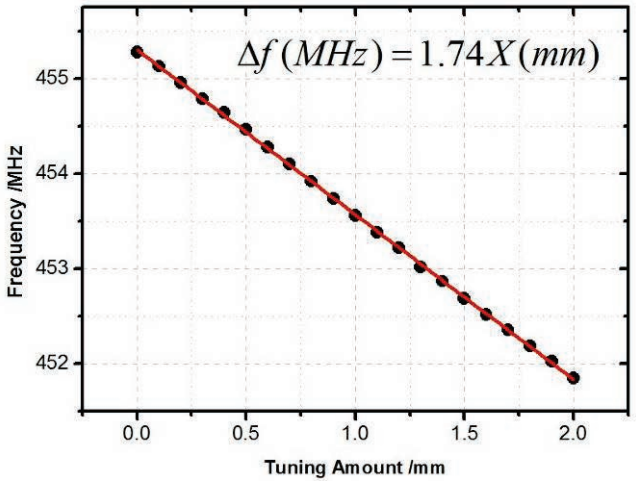


The stiffening ribs structures of PKU SSC.









Preliminary cold test: 3 MV/m
[at Jlab, P. Kneisel]

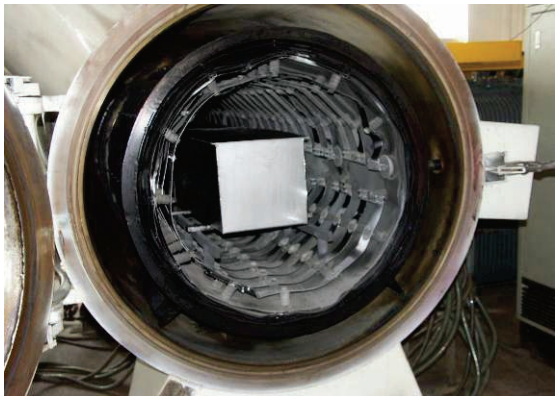
3. Future plan

Current Facilities for SRF researches

Clean room

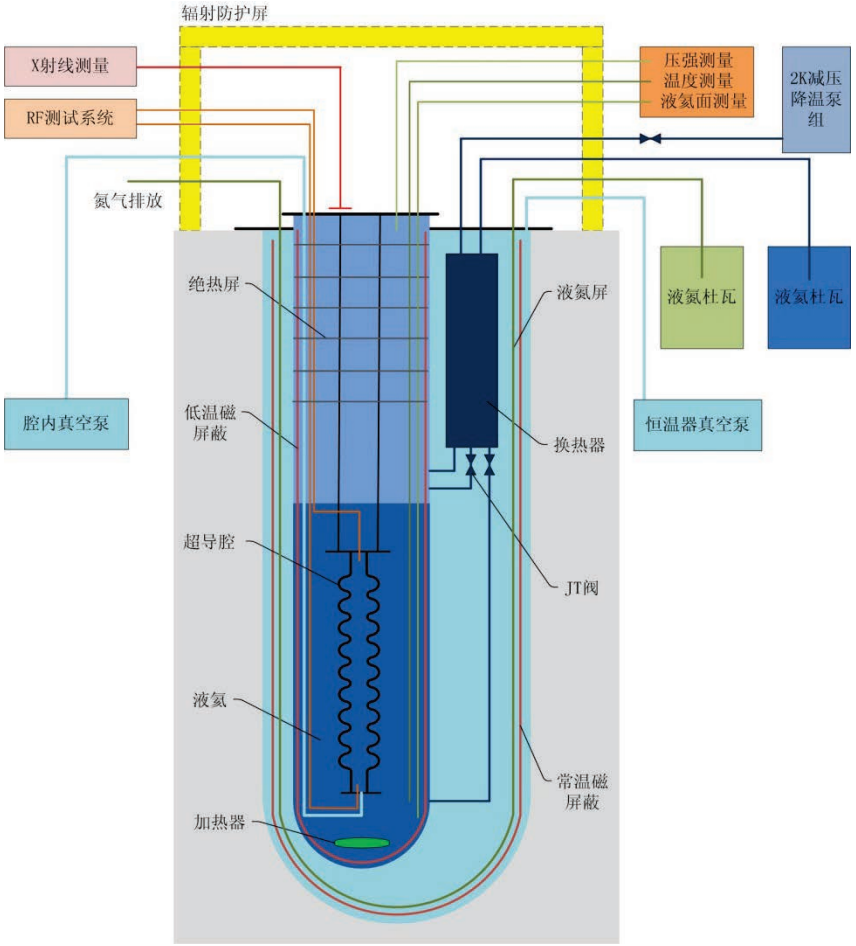
Pure water

Tuning sys.

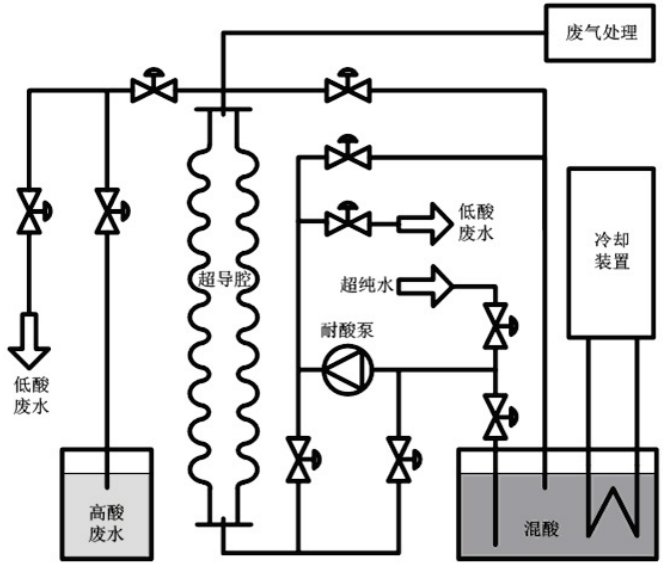


High temp. furnace

Planed Facilities for SRF researches



VTS



BCP

Cavities in future projects

- High accelerating gradient cavity: 9-cell TESLA type
- High current cavity: 5cell or 7 cell
- High power main coupler
- Low beta cavities: spoke, QWR

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

- More and more requirment for SC cavities (ADS,XFEL,ILC,...)
- Industrialization is necessary
- Ningxia OTIC and PKU cooperate for many years
  - Nb material (since 2002)
  - Large grain cavity (since 2005)
  - Multi-cell SRF cavities (since 2006)
- Establish a Company

Ningxia Orient Superconductor Technology Co., Ltd.

- OTIC
  - material preparation
  - Deep drawing, machining
  - EB welding
  - High temperature treatment
- PKU
  - RF measurements
  - quality control
  - Surface treatment
  - Cold test

Summary

- Progresses on SRF cavities have been made at Peking University in recent years
  - 9-cell TESLA type cavites are fabricated, max. gradient 28.6 MV/m
  - A 5-cell prototype cavity for high current is fabricated for ANL
  - Sing-spoke cavities are fabricated for proton acceleration
- Promote the industrialization process in China
- More cavities will be design and fabricated

Acknowledgements

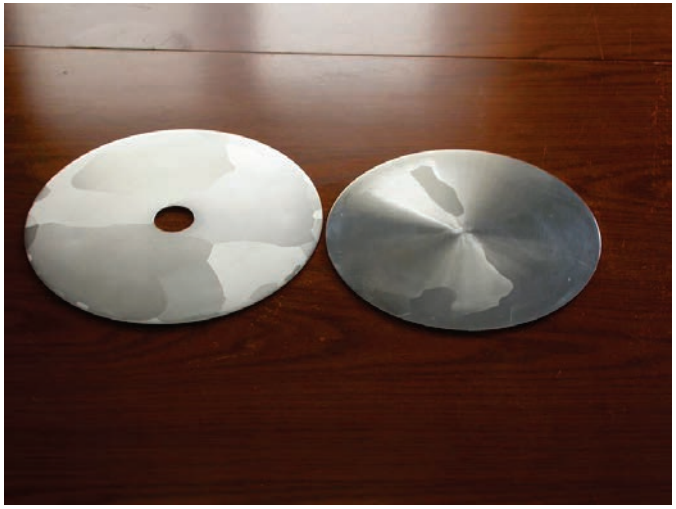
We give great thanks to the colleagues who help us continuously

- P. Kneisel (Jlab)
- R.-L. Geng (Jlab)
- R. Rimmer (Jlab)
- D. Proch (DESY)
- Ningxia OTIC colleague
- J. He (HIT)
- ……

Thank you for your attention!

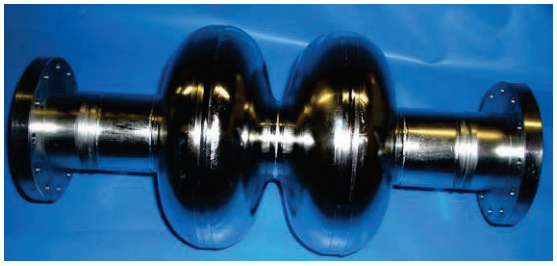
- single-cell cavities, QWR (before 2005)
- Since 2005,TESLA-type multi-cell SRF cavities with Chinese niobium (Ningxia OTIC)
  - Development of SRF technique
  - Setup of facilities for fabrication of SRF cavities
  - SRF specialists
- High current cavity
- Spoke cavity

Large Grain Nb

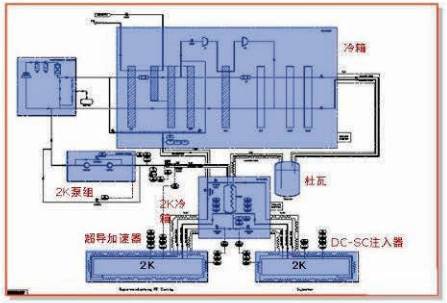


Researches on Large Grain Nb Cavity (Collaboration with OTIC and Jlab)

- 2002, researches on high pure niobium
- 2005, start researches on large grain niobium cavities
- Ningxia OTIC LG niobium



Cryogenic System

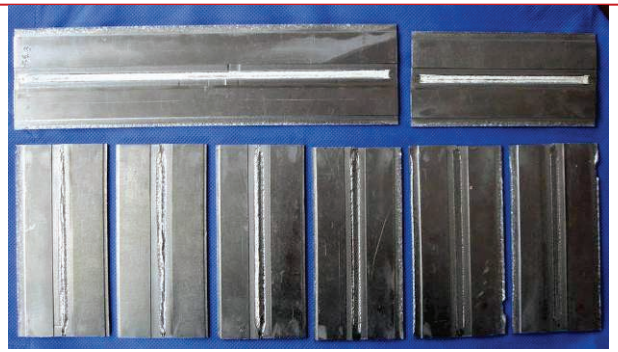


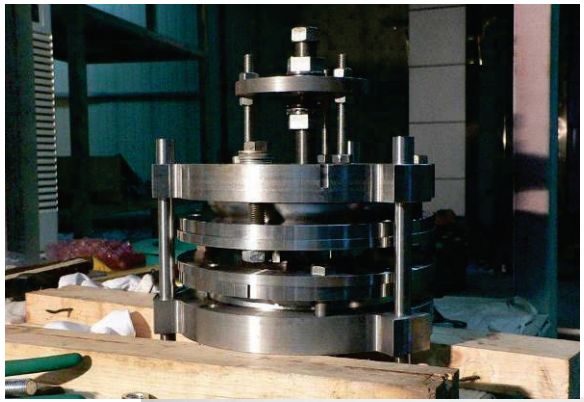
北京大学2K低温系统

(1) 4.2K系统 (2) 2K系统 (3) 缓存罐
(4) 冷却水 (5)超导加速器和注入器

- Commissioning of Cryogenic system: March – June 2010
- Commissioning of Cryogenic system with DC-SC injector (w/o beam): Jan-April 2011
- Lequefaction rate: 120 l/h
- Cooling capacity: 58W @ 2 K
- Upgrade is necessary for vertical test stand

Accumulated Key techniques for fabrication of cavities





Fitting stiffening ring tool

A new hall in Ningxia