Update on Raising Q0 at Ultra-High Gradient via Large-Grain Niobium Material

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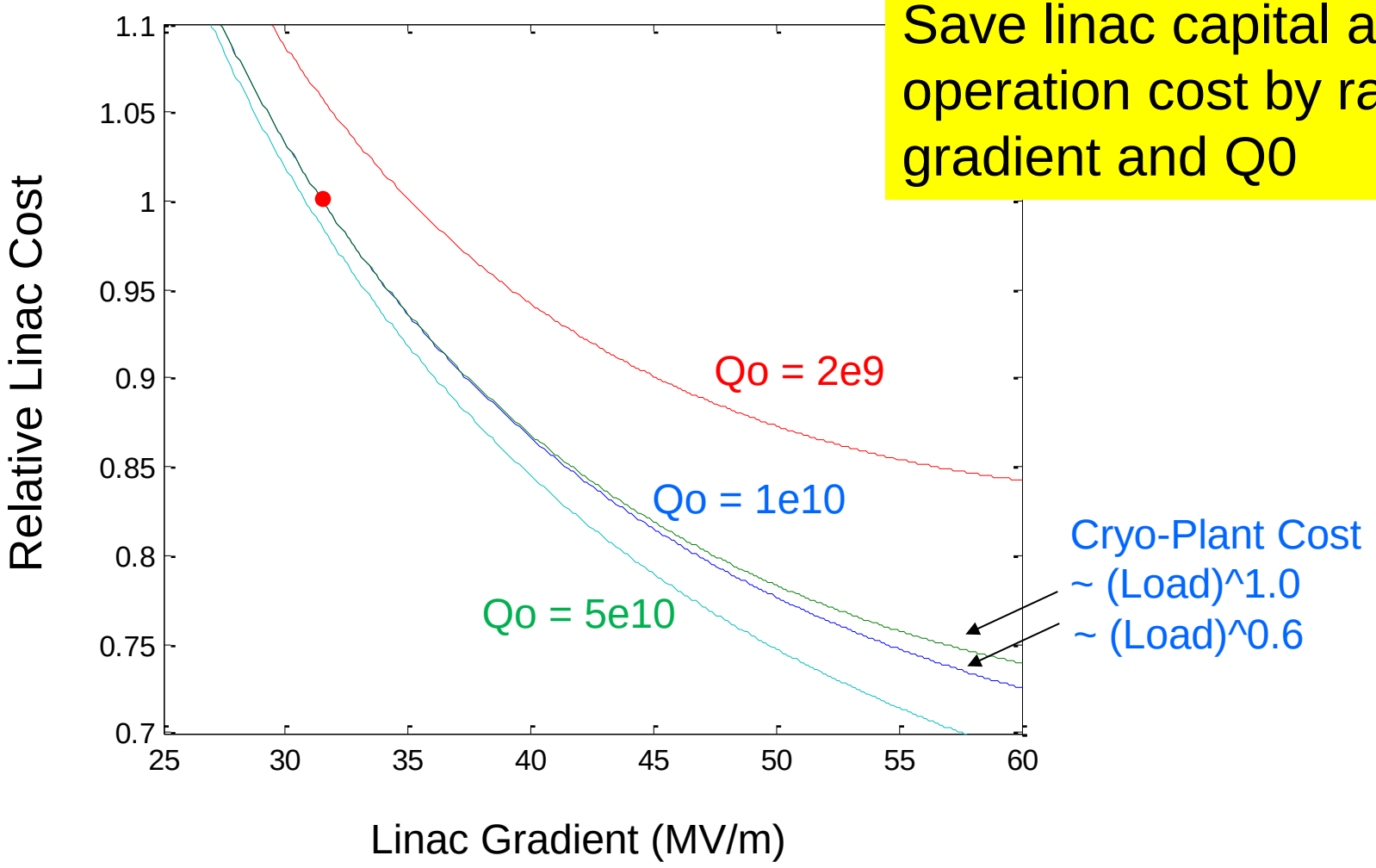
ECFA LC2013, May 27-31, 2013, DESY, Hamburg, Germany

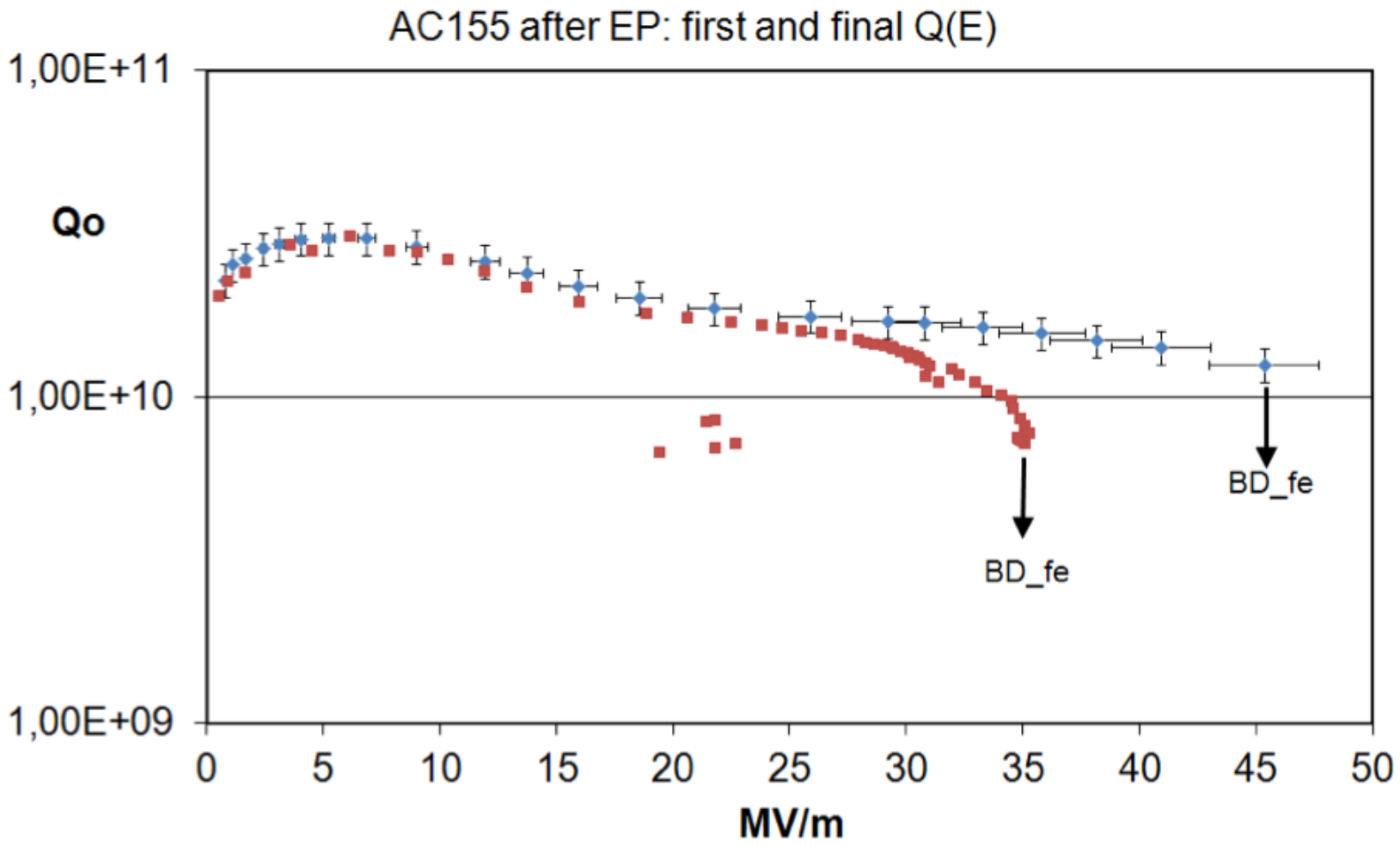
Very High Gradient with High Q0

Save linac capital and operation cost by raising gradient and Q0



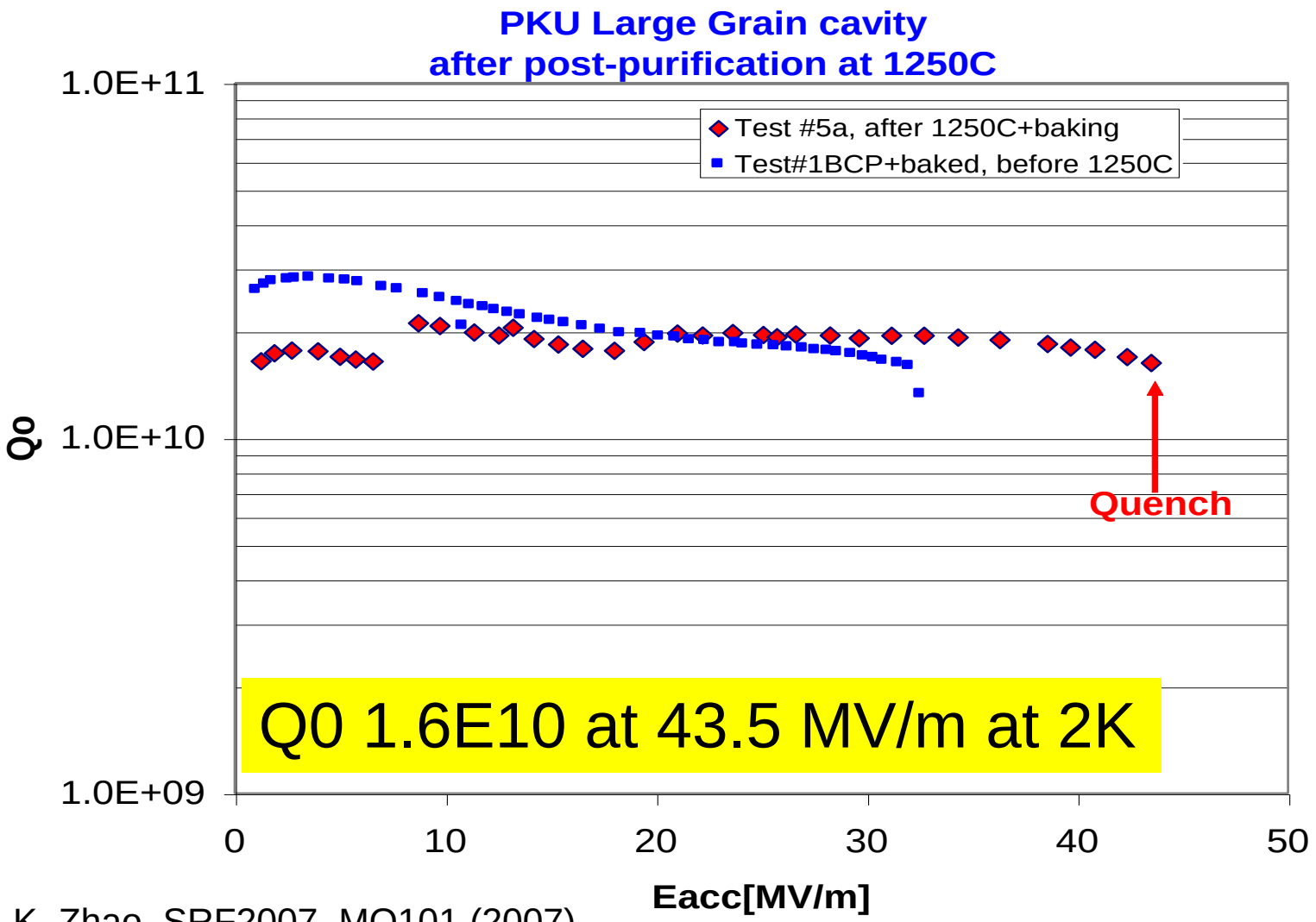
Chris Adolphsen, ALCPG2011.

Record High Gradient 45 MV/m at Q0 > 1E10 by Full-Scale 9-Cell Large-Grain Nb Cavity at DESY



D. Reschke et al., SRF2011, THPO046 (2011).

Record Q0 of 1.6E10 at 43.5 MV/m at 2K by PKU 1-Cell 1300MHz Large-Grain Nb Cavity in collaboration w/ JLAB



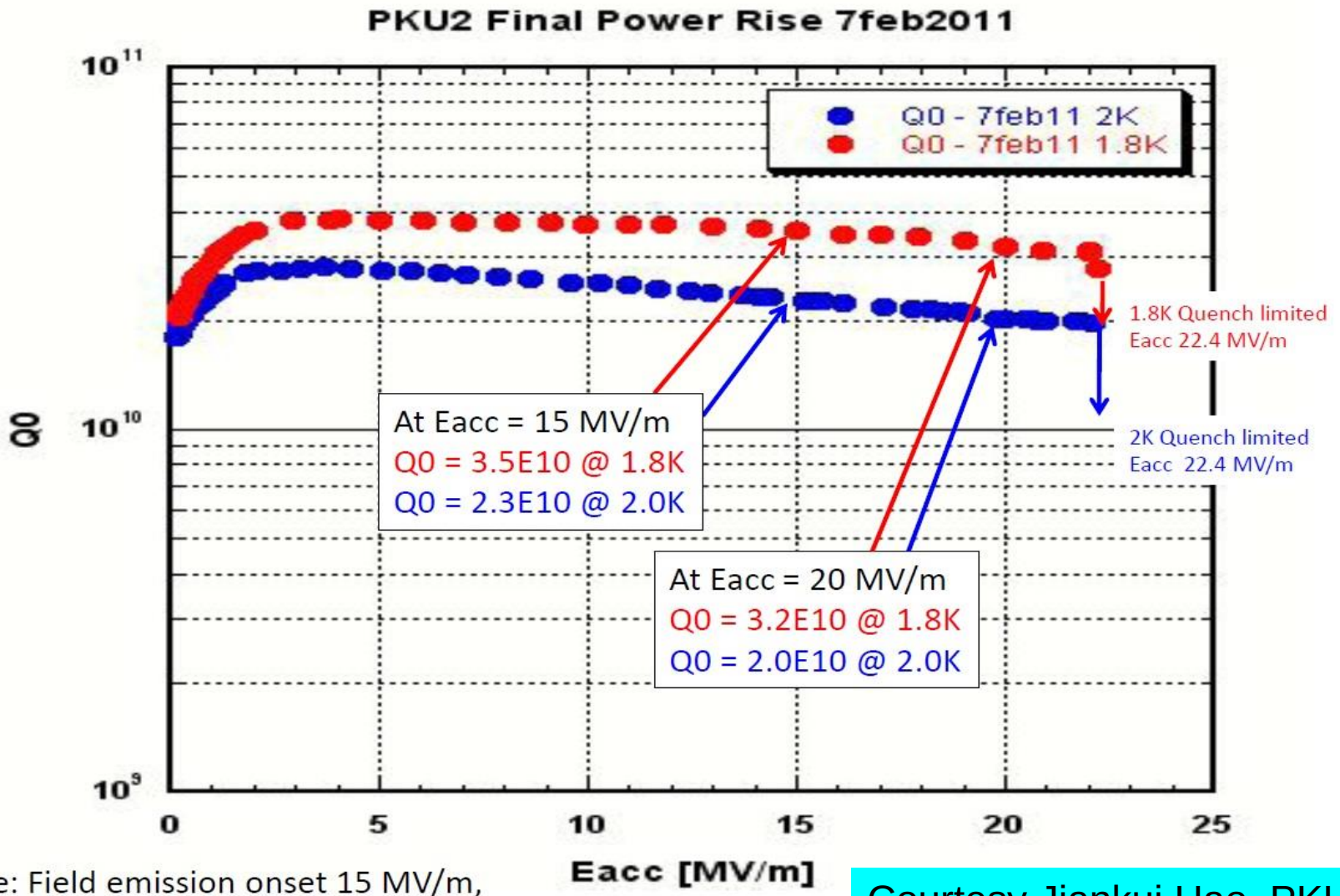
J.E. Chen, K. Zhao, SRF2007, MO101 (2007).

Latest Progresses in Large-Grain Nb Cavity Development for ILC

- PKU's 9-cell 1300 MHz TESLA shape large-grain Nb cavity PKU4 RF testing in collaboration with KEK.
- IHEP's 9-cell 1300 MHz Low-Loss shape large grain Nb cavity IHEP-02 testing in collaboration with FNAL.
- Series testing of 1-cell large-grain ICHIRO shape cavities at Cornell
- JLAB's 9-cell 1300 MHz ICHIRO shape large grain Nb cavities (two each) testing at JLAB.
- JLAB's 1-cell 1300 MHz TESLA shape mirror-finish large grain Nb cavity testing at JLAB.

PKU Large grain 9-cell cavities: PKU2

RF Testing in Collaboration with JLAB

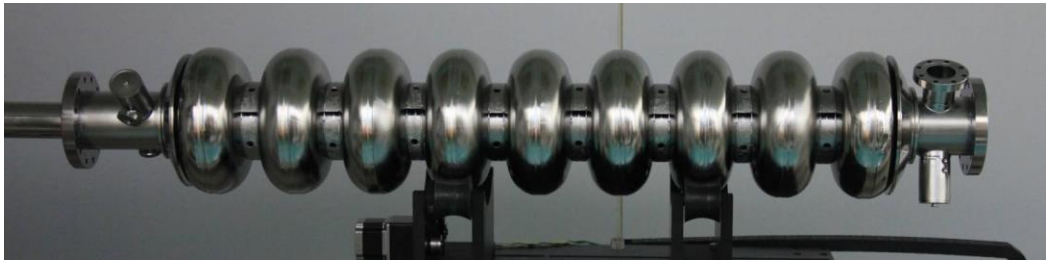


Note: Field emission onset 15 MV/m,
Maximum X-ray dose rate < 100 mR/m. No more mode mixing

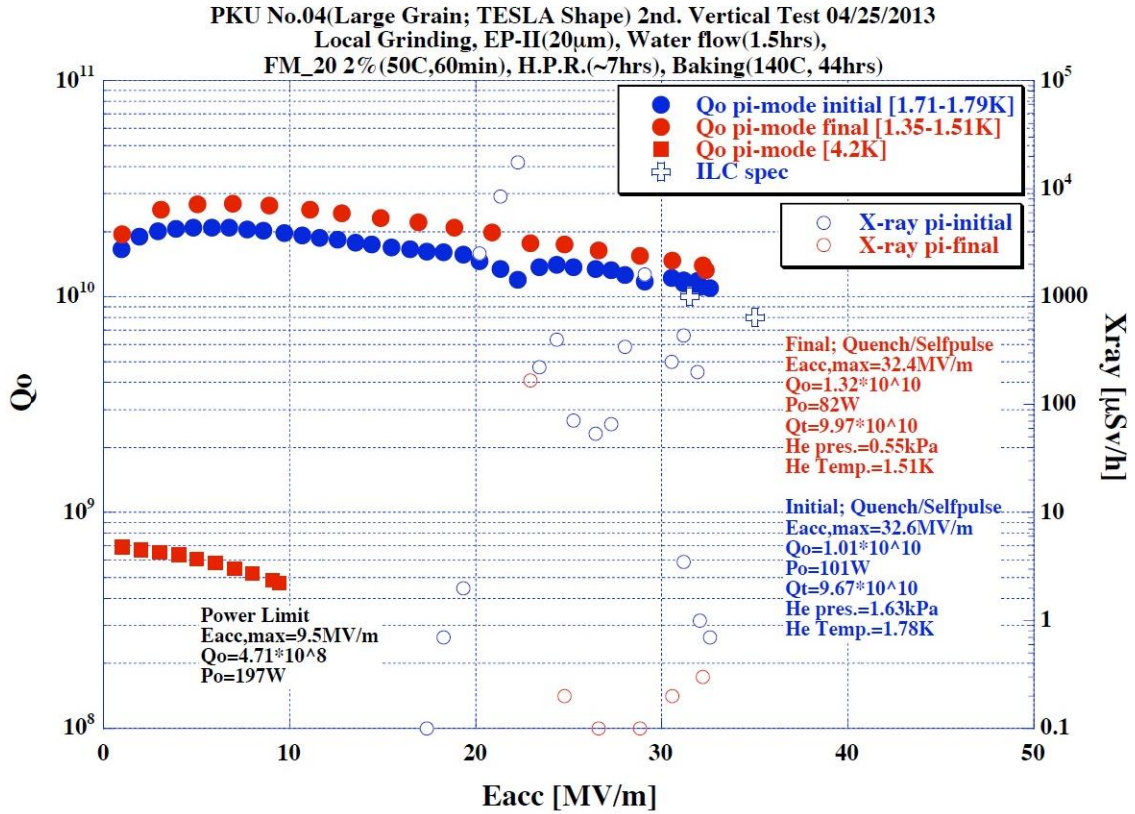
Courtesy Jiankui Hao, PKU

PKU Large grain 9-cell cavities: PKU4

RF Testing in Collaboration with KEK



- Test01 at KEK
  - EP 120 μm, HT 750 °C 3 hr
  - EP 5μm, baking 140 °C 48 hr
  - Eacc 23.8 MV/m, Q_0=6.9E9@Emax
- Test02 at KEK, after local grinding



Latest test April 25, 2013
PKU4 achieved 33 MV/m
At Q0 1E10 at 1.8K

Further processing and testing including local grinding under way

Courtesy Jiankui Hao, PKU

PKU Large Grain Nb Cavities Summary

	1-cell	2-cell	3.5-cell	PKU2	PKU4
HT(°C)	800,1250	800	800,1200	800	750
BCP	✓	✓	✓	✓	--
EP	--	✓	--	Light EP	✓
Eacc,max	43.5	40.2	23.5	22.4	32.6
Q_0@ Eacc,max	1.6E10 @2.0K	1.2E10 @2.0K	1.2E10 @2.0K	2E10 @2.0K	1E10 @1.8K

Researches on large grain niobium superconducting cavities have been carried out at Peking University. A series of large grain TESLA type cavities have been made with Ningxia OTIC material. High gradient and high Q are obtained for single cell, 2-cell and 3.5-cell large grain cavities. Two large grain 9-cell cavities (PKU2 and PKU4) are fabricated. High quality factor have been obtained at maximum gradient for 9-cell large grain

Courtesy Jiankui Hao, PKU

IHEP Large Grain Low-Loss Cavities

- Single cell cavities (in collaboration with KEK, 2007-2008)

made by KEK, EP

made by IHEP, BCP

All single cell and 9-cell large grain niobium material from OTIC, Ningxia, China
All single cell and 9-cell cavities tumbled (CBP).

- 9-cell cavity without HOM couplers (IHEP-01, 2010)

20 MV/m (FE), more process and test in the future

1st process: CBP190μ+BCP110μ+750C.3h +BCP20μ@IHEP, HPR+105C.48h@KEK
2nd process: CBP150μ+BCP60μ+750C.3h+BCP40μ @IHEP, BCP10μ+HPR+120C.48h@JLAB

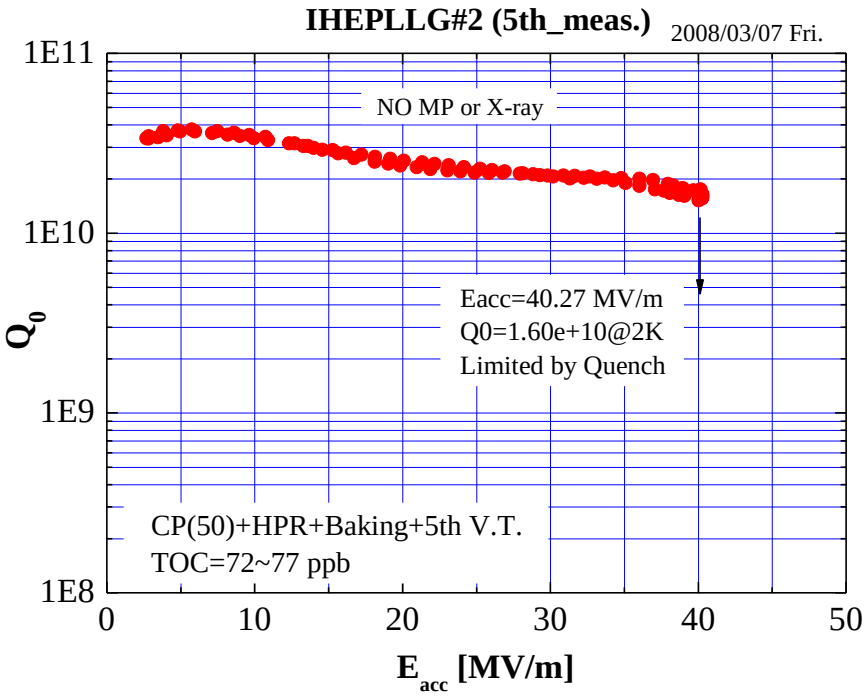
- 9-cell cavity with full end groups (IHEP-02, 2012)

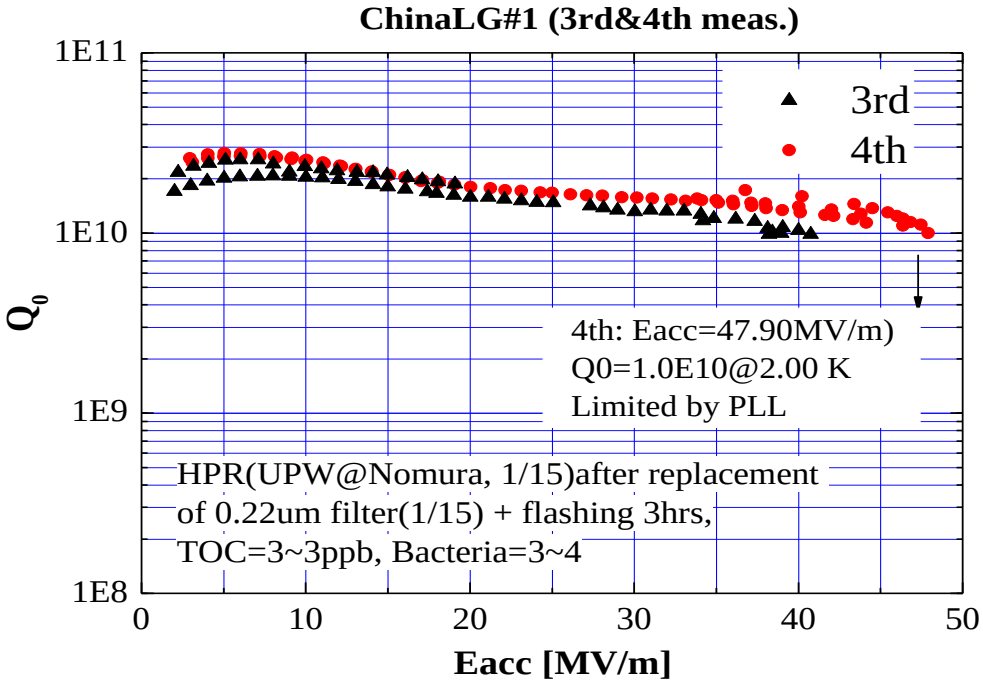
20 MV/m, install to IHEP ILC test cryomodule in 2013

CBP200μ(mirror finish)+EP40μ+800C.3h +EP30μ+HPR+120C.24h@FNAL

Courtesy Jiyuan Zhai, IHEP

Single Cell Test Results





40 MV/m, Q_0 = 1.6 x 10^{10} @ 2K

CBP150μm+BCP200μm(total)
750C 3h, 120C 48h

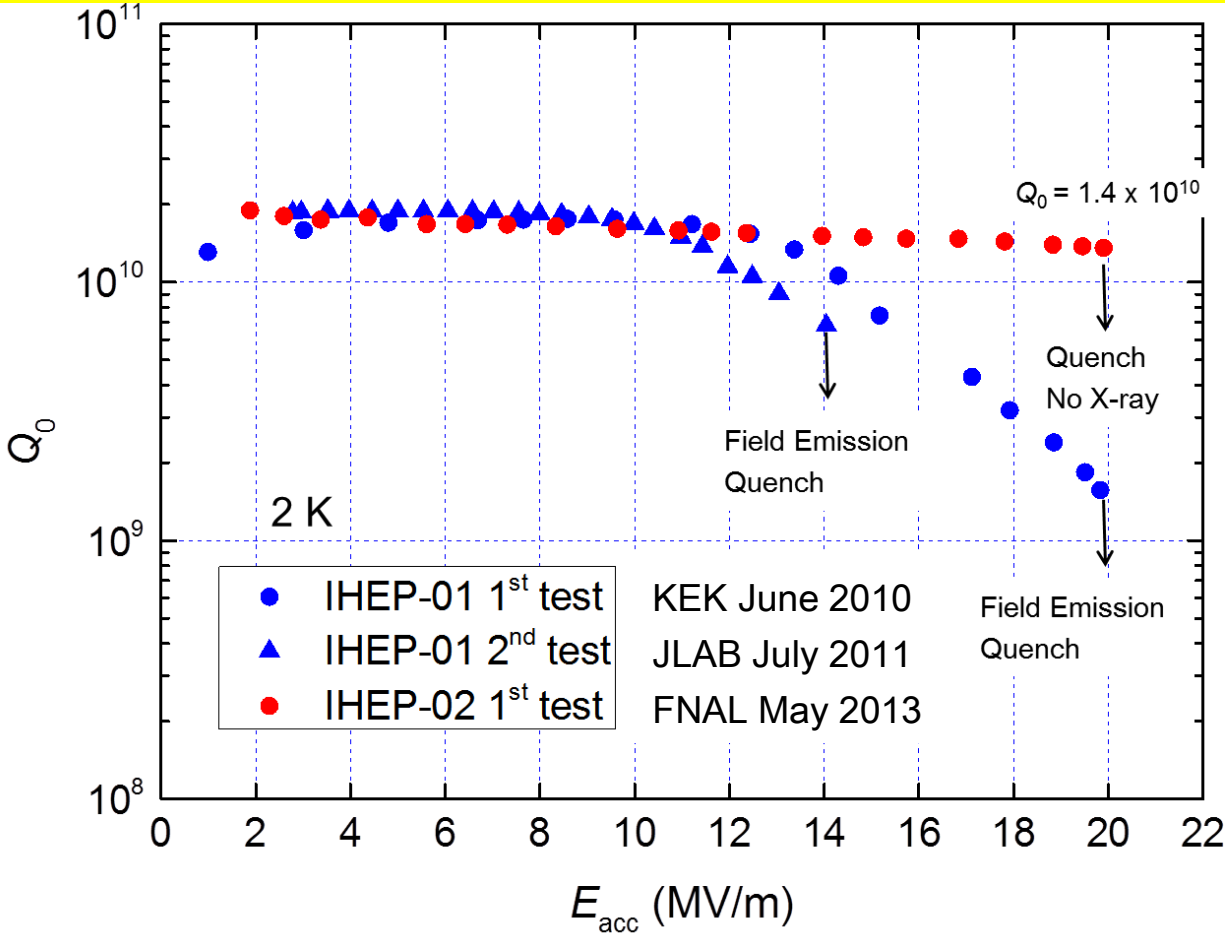
48 MV/m, Q_0 = 1.0 x 10^{10} @ 2K

CBP90μm+BCP10μm+EP100μm(total)
750C 3h, 120C 48h (12h bake causes high field Q-slope)

Courtesy Jiyuan Zhai, IHEP

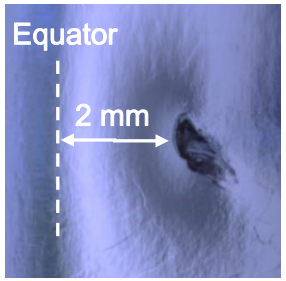
9-cell Test Results and Limitation

IHEP-02 latest test done this month



Courtesy Jiyuan Zhai, IHEP

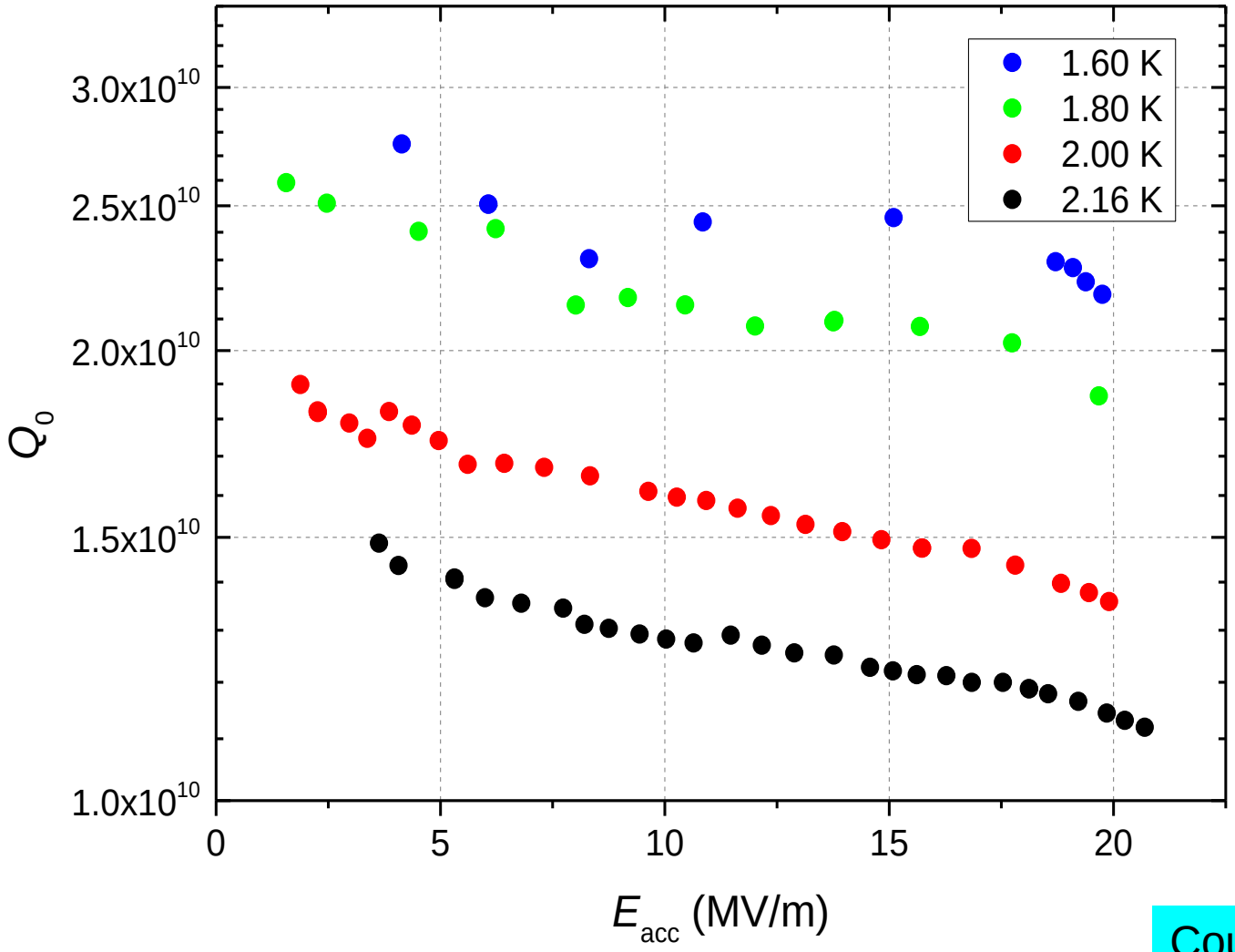
A pit on the iris and possible contamination may be the reason of strong field emission of IHEP-01.



IHEP-02 quench defect (detected by second sound and thermometry). The quench location has sharp and deep grain boundary step made during half cell pressing.

By passband mode test, 5 cells of IHEP-01 ≳ 30 MV/m, 7 cells of IHEP-02 ≳ 40 MV/m, both Pi modes quench at 20 MV/m in cell#9 300 deg equator.

IHEP-02 Q_0 at Different Temperatures



Enormous hydrogen outgassed during 800C heat treatment after intensive CBP (200μm) and light EP(40μm).

Relatively low Q and Q-slope may be caused by remained hydrogen or defects heating up (?) . About 5 defects similar to the quench defect in IHEP-02.

Courtesy Jiyuan Zhai, IHEP

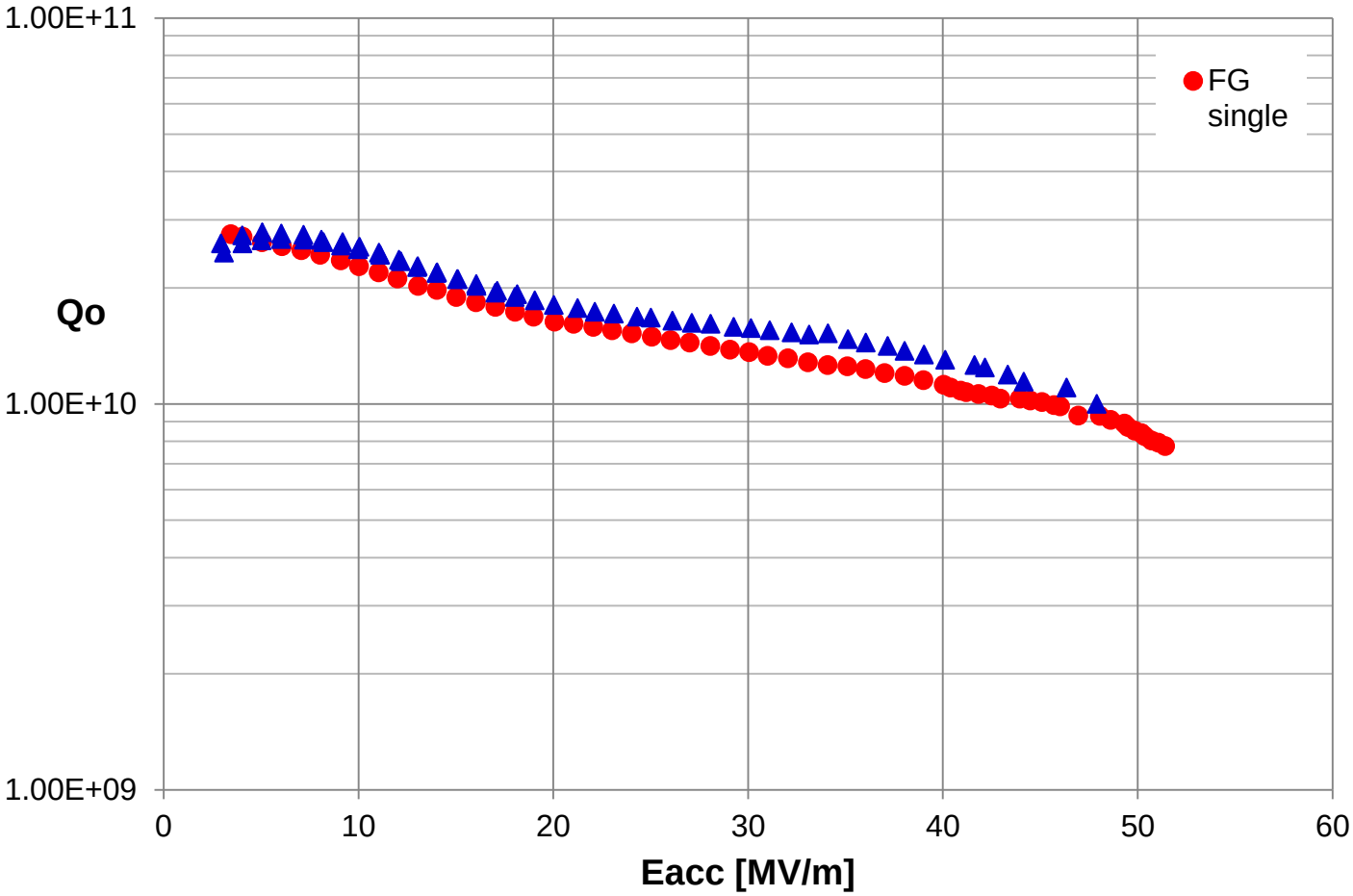
R&D on LG single-/multi-cell cavity w/ ICHIRO (KEK low-loss) shape

Notes

- LL shape+BCP+LG seems promising for high voltage with high Qo, and flat Qo(E)-curve.
- Most benefit of LG cavities seems to be capability of BCP for high voltage with high Qo.
- Optimization of total BCP removal is required because too much removal has degraded cavity performance.

Courtesy Fumio Furuta, Cornell

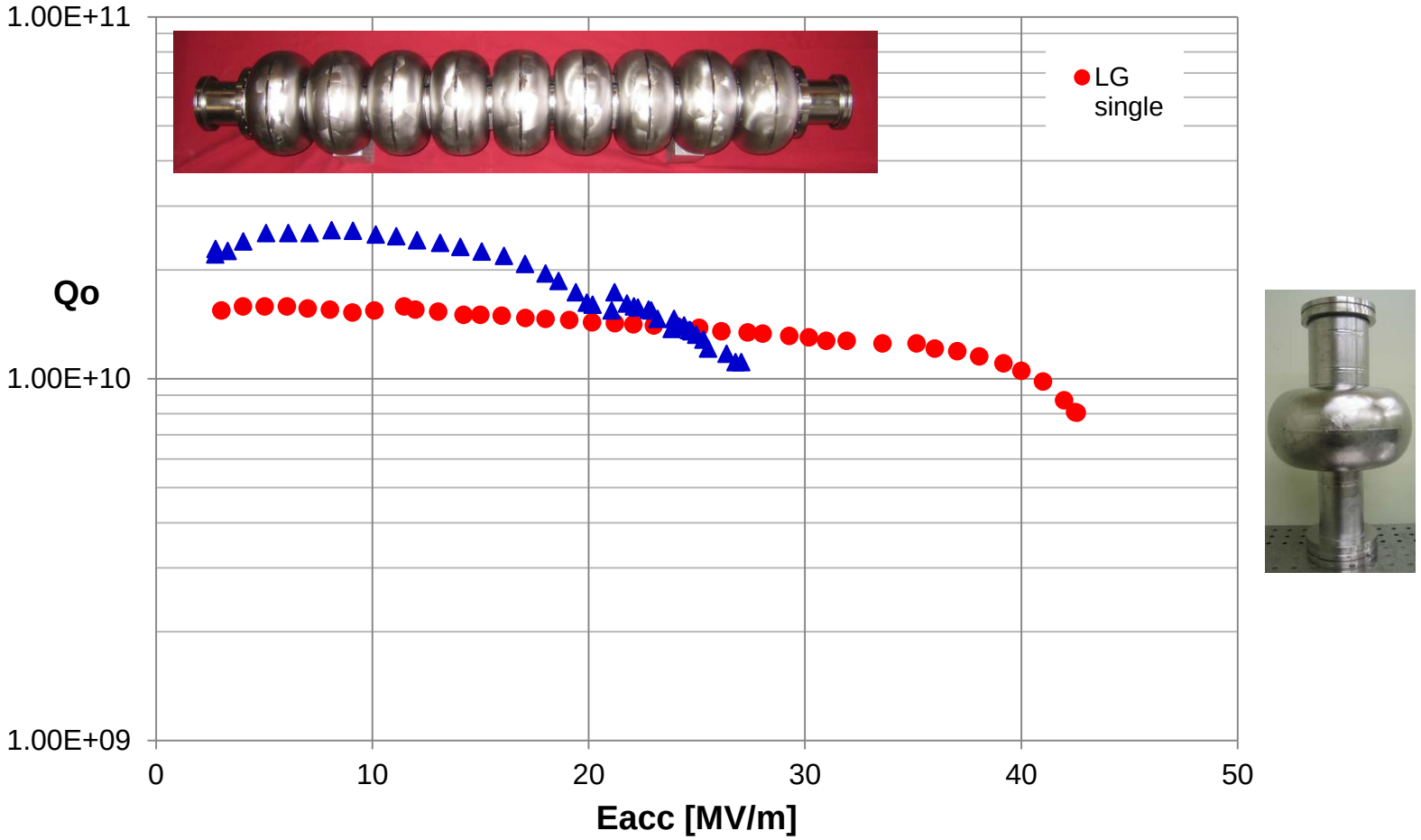
Comparison of EP'ed LG & FG ICHIRO singles



-Both cavities were processed by CBP+EP+120Cbake
-FG+EP achieved Eacc of 51MV/m w/ Qo of 7.8e9.
-LG+EP achieved Eacc of 48MV/m w/ Qo of 1.0e10.
-EP processes show same results on FG and LG single cells.

Courtesy Fumio Furuta, Cornell

Results of BCP'ed ICHIRO single-/9-cells



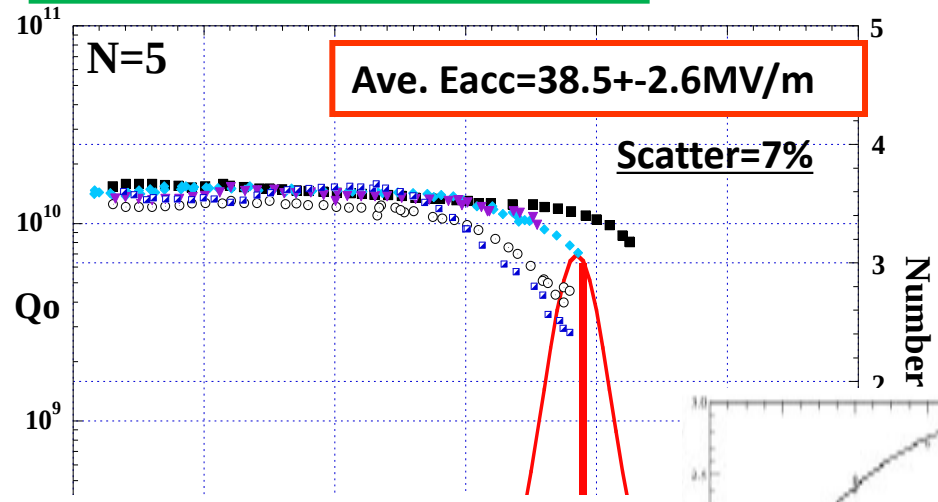
-Cavities were processed by CBP+BCP+120Cbake
-BCP+LG single achieved Eacc of 42.6MV/m w/ Qo of 8.0e9 at 1st VT.
-BCP+LG 9-cell achieved Eacc of 27MV/m w/ Qo of 1.1e10 so far.
-Horizontal BCP was applied on 9-cell to make uniform removal.

Courtesy Fumio Furuta, Cornell

Series test of BCP+LG ICHIRO single

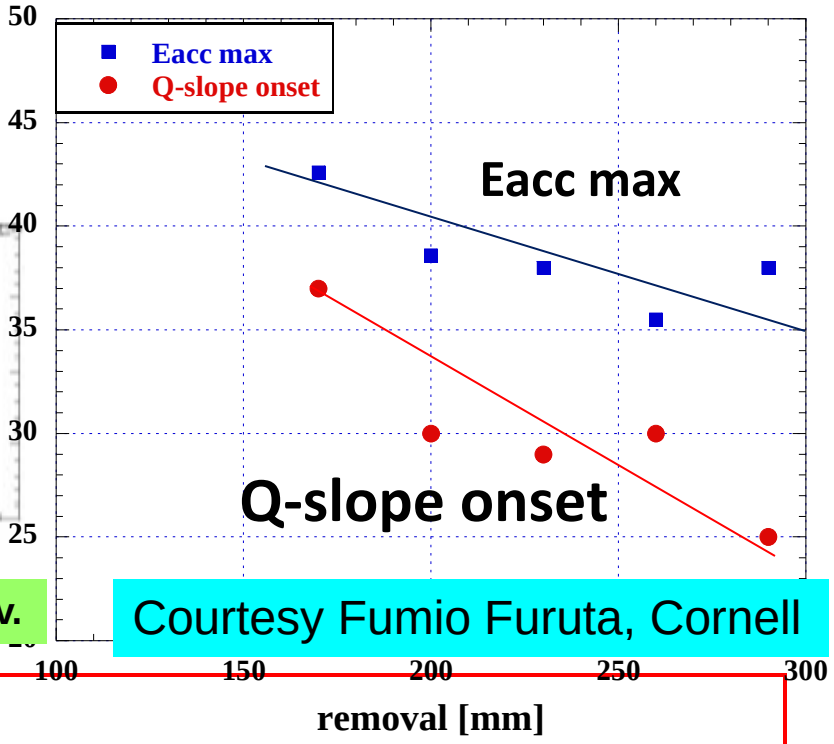
CBP+AN+BCP(170μm) +HPR+Baking → 1st VT → +BCP(30μm) +HPR +Baking → VT

repeat



By J. Knobloch, Cornell Univ.

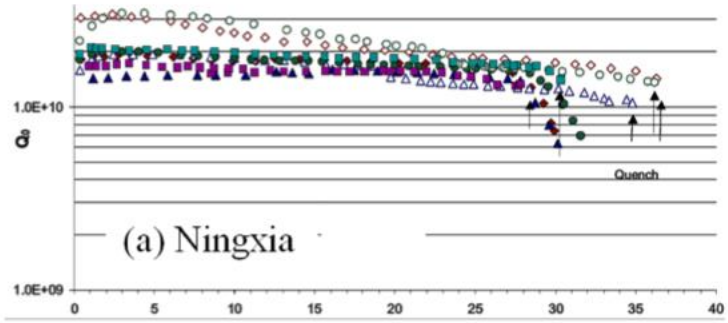
-LG single cell cavity-

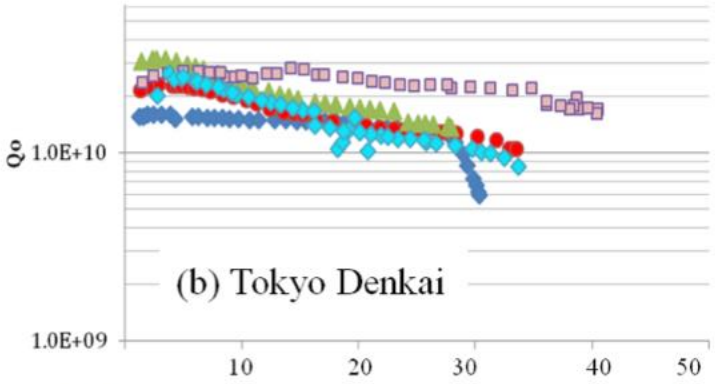


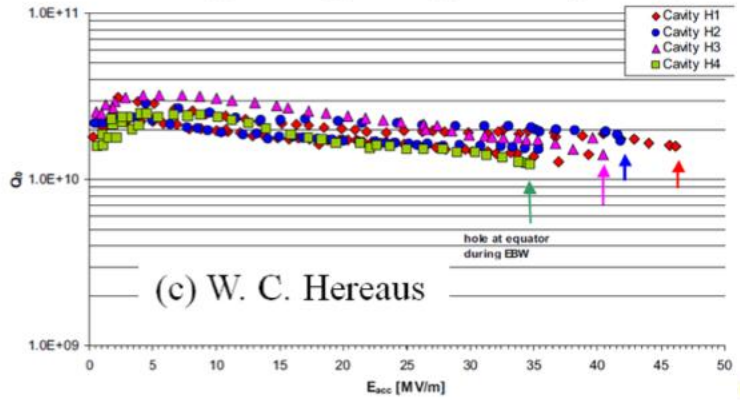
Courtesy Fumio Furuta, Cornell

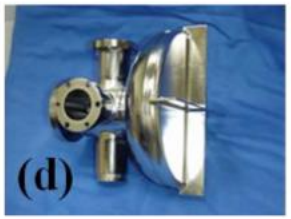
Additional BCP degraded field and Q-slope onset.
Step of grain boundary might be enlarged by BCP -> Magnetic field enhancement?

JLAB Large-Grain Nb Cavities





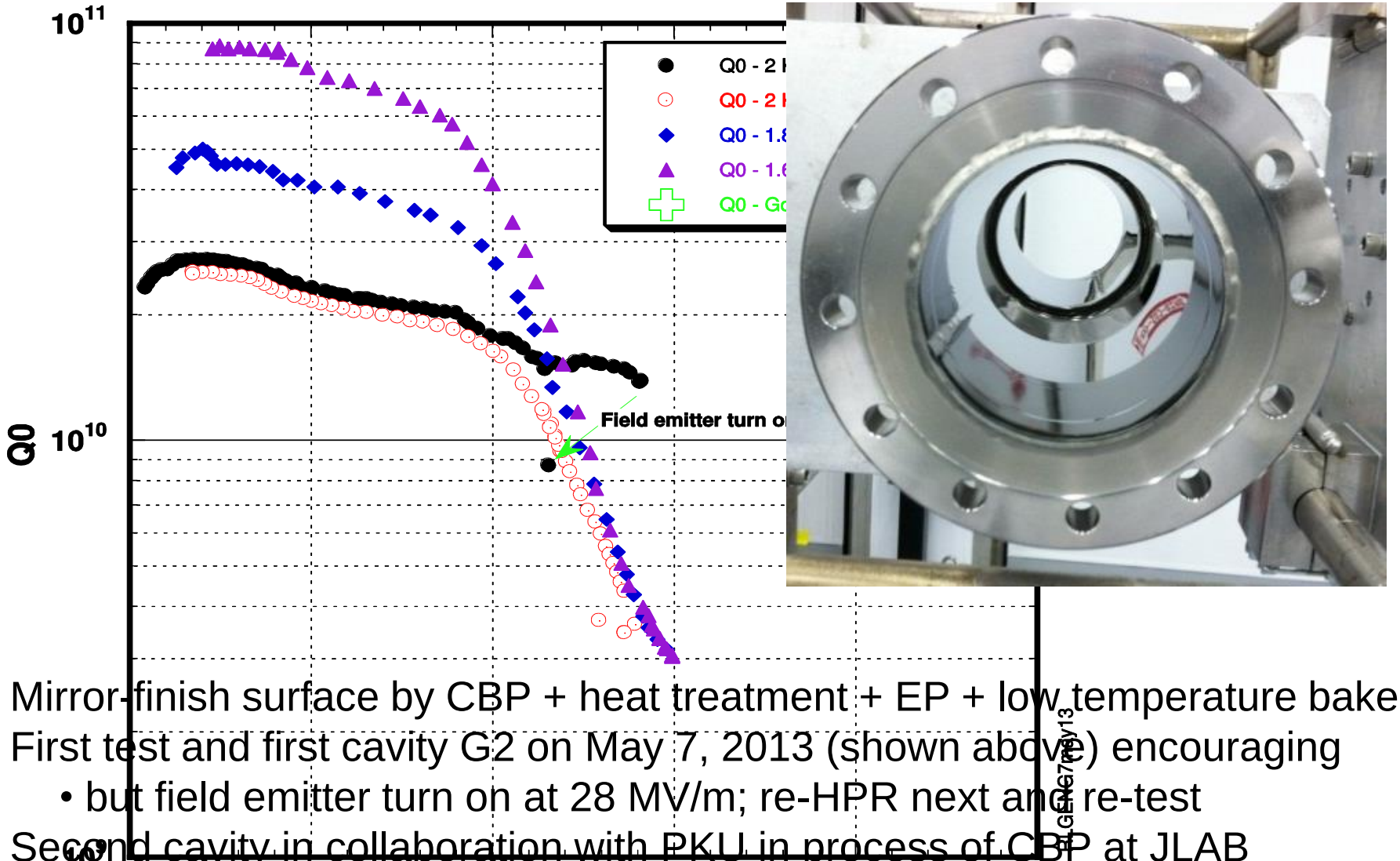




Two new 9-cell 1300 MHz ICHIRO shape large grain Nb cavities completed and first RF test this week.

A new review paper on large grain Nb material and cavity by Peter Kneisel et al.,
http://arxiv.org/abs/1304.1722

JLAB 1-Cell Large-Grain Nb Cavity for High Q0 at Ultra High Gradient



- Mirror-finish surface by CBP + heat treatment + EP + low temperature bake
- First test and first cavity G2 on May 7, 2013 (shown above) encouraging
  - but field emitter turn on at 28 MV/m; re-HPR next and re-test
- Second cavity in collaboration with PKU in process of CBP at JLAB

DESY Large Grain Nb Cavities

- Record gradient in a full-scale 9-cell cavity by AC155 (previous slide).
- Two large grain cavities incorporated in cryomodules operating in FLASH accelerator
- No new update on large grain cavity R&D
- But "…plans to use a full cryomodule of 9-cell cavities made from ingot niobium into its XFEL accelerator."

Conclusion

- There is continued interest in developing large-grain niobium cavities for higher performance in gradient and in Q0
- Incorporation of large grain niobium cavities in cryomodules operating in FLASH and XFEL helps settle the pressure vessel code concern and provides further encouragement for large grain cavity development in other regions
- There is a special interest currently in developing large grain Nb cavity for high Q0 at medium gradient for CW applications. These activities are not covered by this talk despite possible synergies.