Update on High Efficiency High Gradient SRF Cavities

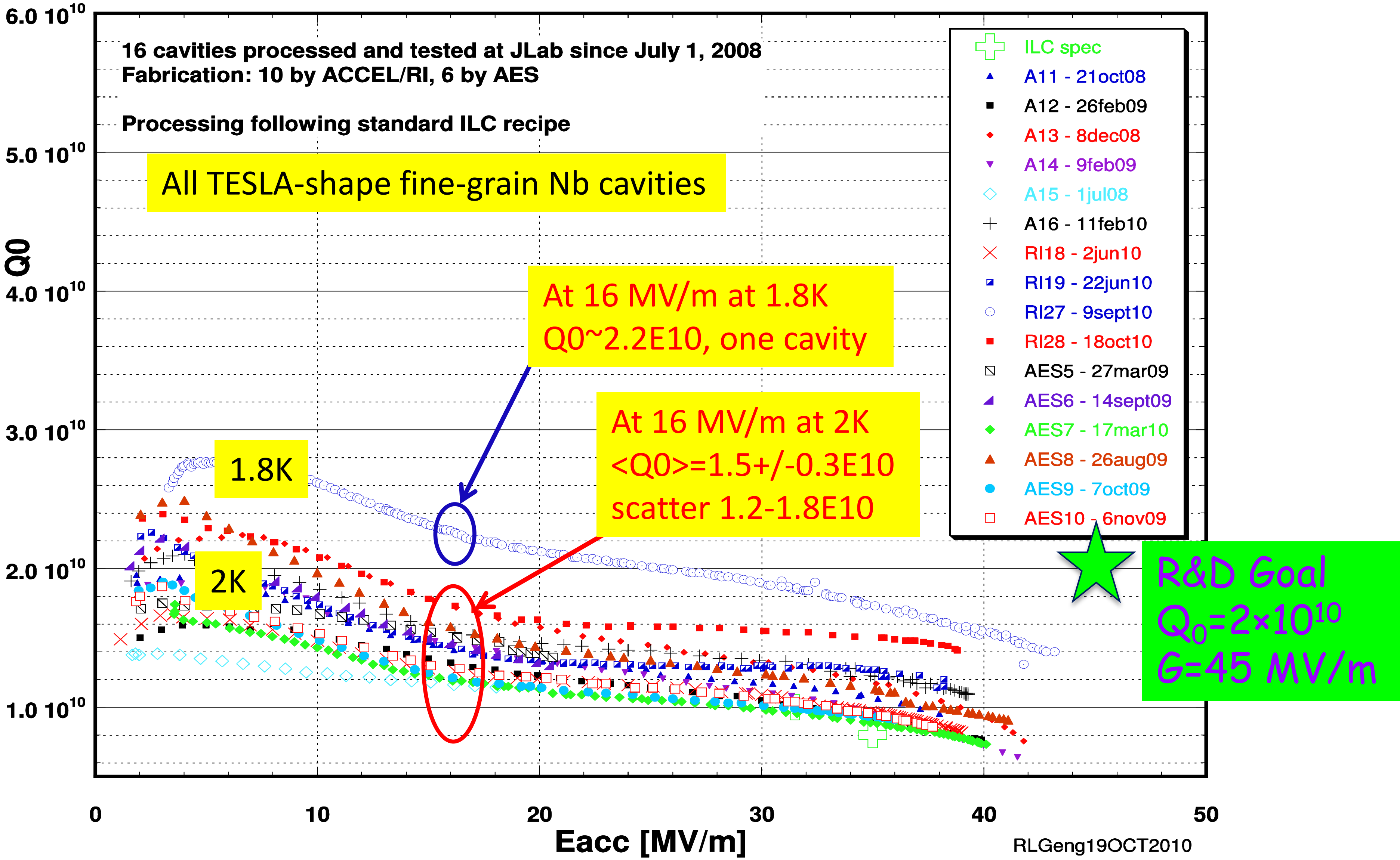
Rong-Li Geng

Jefferson Lab

Benefits of Higher Efficiency Cavities

- Allow longer pulse
  - Higher luminosity
- Less dynamic heat load
  - Smaller cryo plant >>> initial capital cost saving
  - Less AC power consumption >> operation cost saving
- Enable higher gradient for fixed cryo capability
  - Higher energy reach

Achieved ILC Cavity Performance at JLAB (2008-2010)

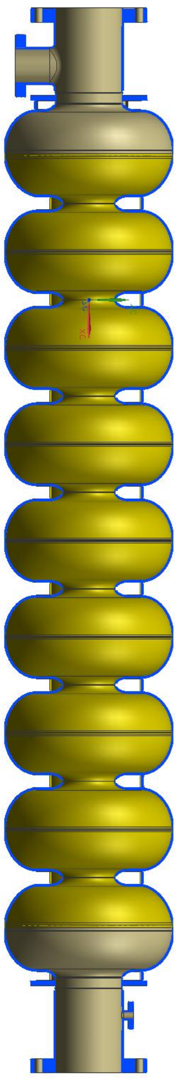


Key Issues

- High efficiency high gradient (HEHG) SRF a fundamental accelerator physics and technology issue with applications to ILC as well as many other machines
  - High efficiency cavity shape
    - "guaranteed" cryo saving
  - Reduce field emission up to Epk ~ 100 MV/m
    - Critical for all SRF machines, in particular stable operation
  - Eliminate Q-slope up to Hpk ~ 200 mT
    - Origins still unclear, even for Nb
    - Key issue to viability of any "new" material
- Recent progress in high Q_0 cavity for medium gradient (Hpk ~ 70 mT) shown good results
  - Can these good results extended to high gradient?

High Efficiency Cavity Shape

		TESLA	Low-loss/ICHIRO	Re-entrant	Low-surface-field
frequency	MHz	1300	1300	1300	1300
Aperture	mm	70	60	60	60
Epk/Eacc	-	1.98	2.36	2.28	1.98
Hpk/Eacc	mT/(MV/m)	4.15	3.61	3.54	3.71
Cell-cell coupling	%	1.90	1.52	1.57	1.27
G*R/Q	Ω^2	30840	37970	41208	36995



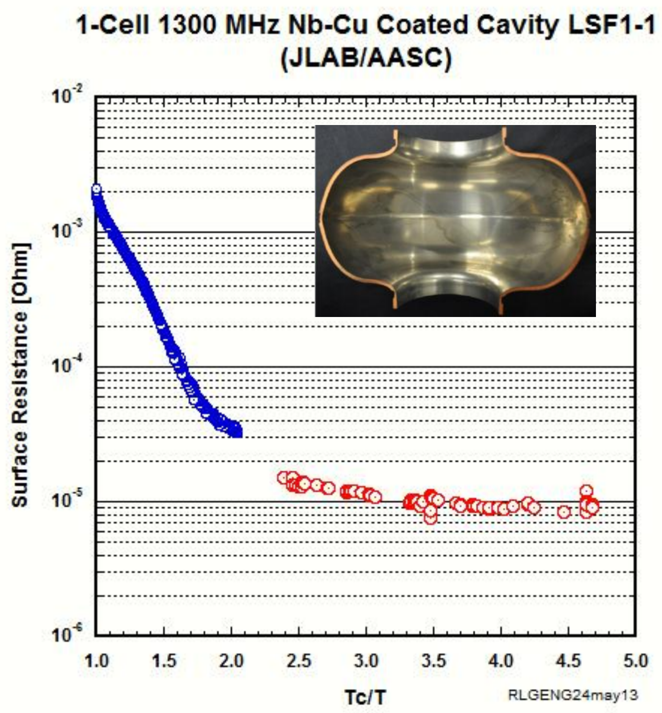
20% more efficient as compared to TESLA shape
Keep peak electric field ratio the same

Z. Li, C. Adolphsen, A New SRF Cavity Shape with Minimized Surface Electric and Magnetic Fields for the ILC, LINAC08 (2008).

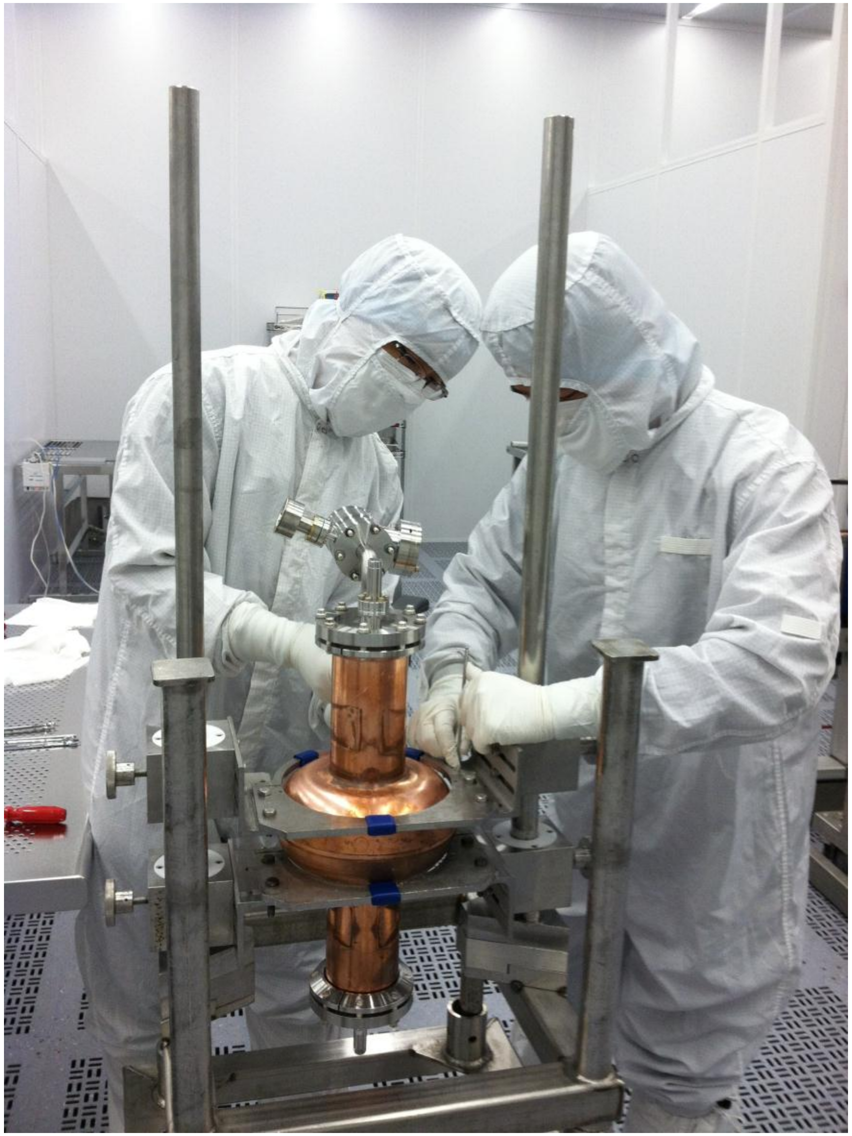
R.L Geng et al., Development of Ultra High Gradient and High Q0 Superconducting Radio Frequency Cavities, IPAC13 (2013).

LSF Prototype Cavities

- LSF1-1
  - Nb coated Cu cavity



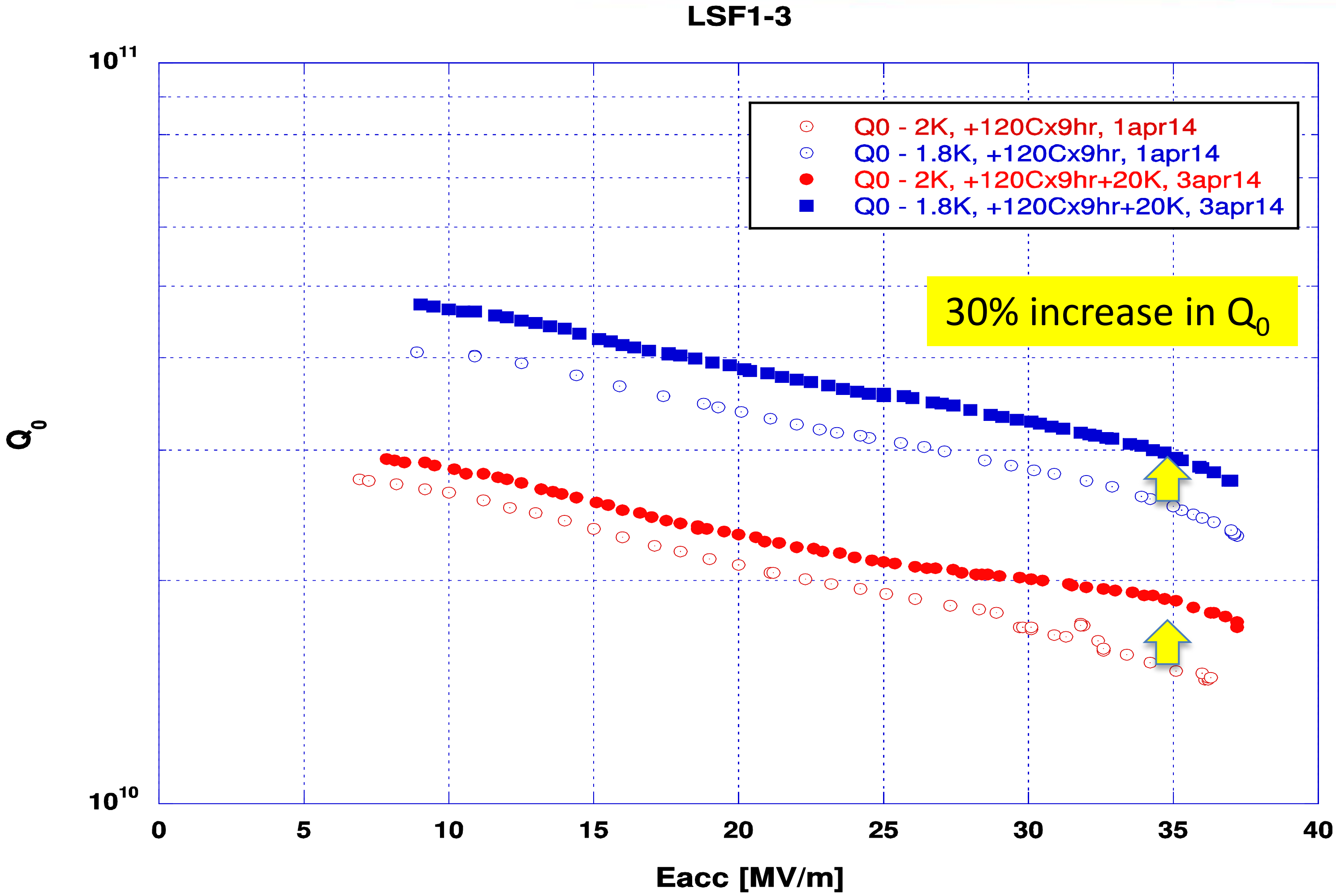
X. Zhao et al., SRF2013, TUP083



LSF Prototype Cavities

- Two single-cell LSF shape cavities built and tested
- Large-grain Nb
- Both reached 37-38 MV/m without field emission
  - BCP so far
  - EP next to raise gradient

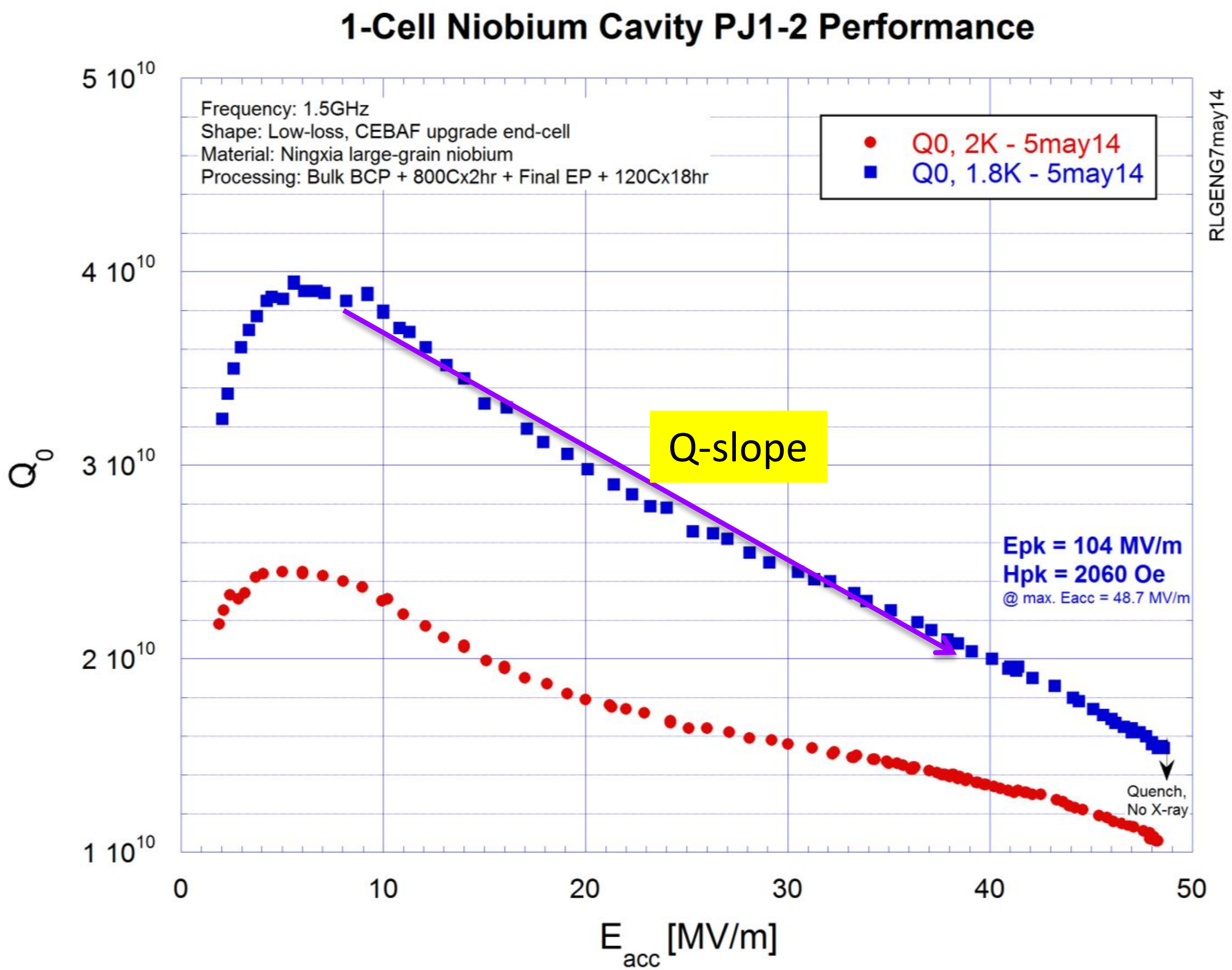
Impact of Cryogenic Thermal Cycling



LSF1-3
1.3 GHz
LSF Shape
Large-Grain Nb

Cavity processing:
BCP 60 um + 800Cx2hr + BCP 20 um + 120Cx9hr

Role of Frozen Flux



1.5 GHz
Low-Loss Shape
Large Grain Nb

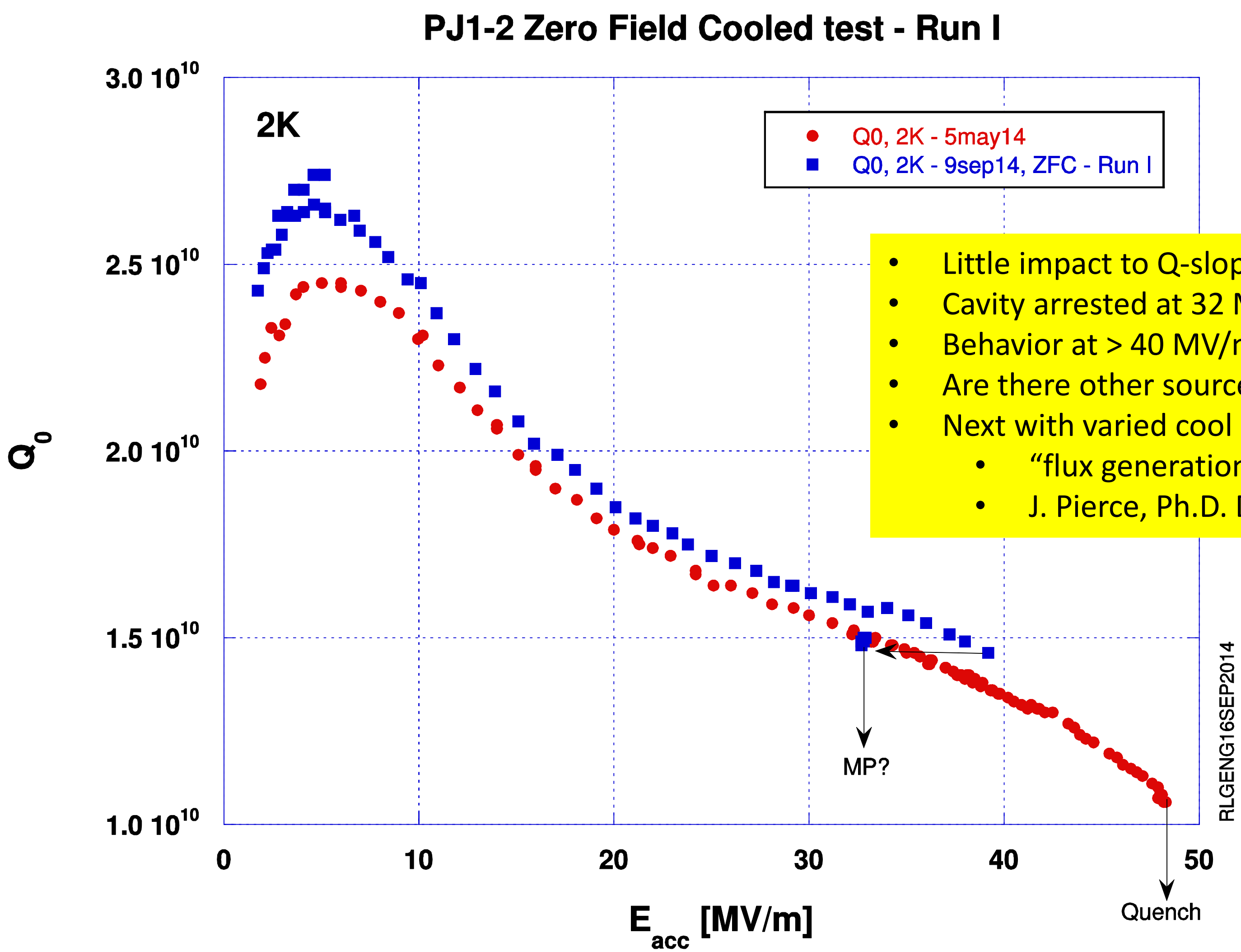
Cavity processing:
Bulk BCP + 800Cx2hr
Final Processing:
EP 30 um + 120Cx18hr
+ EP 10 um + 120cx18hr.

"Zero Field Cooling" Test

Bare cavity
Standard test configuration
Typical ambient field at cavity equator 2-5 mG

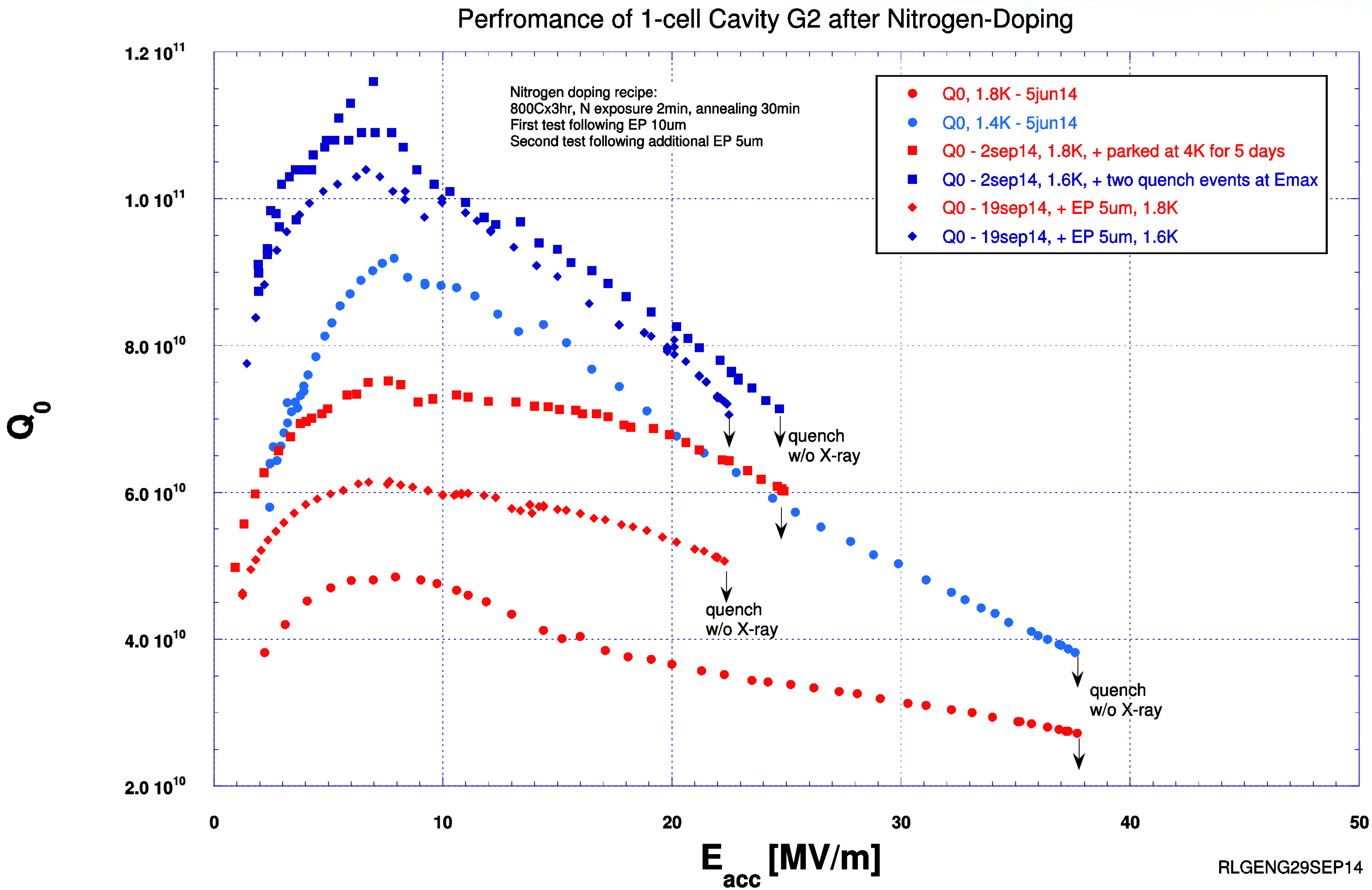
Magnetic shielding added for vertical test
Shielding factor ~ 100
Ambient field at cavity equator ~ 20 μG

First Result of ZFC



- Little impact to Q-slope up to 40 MV/m
- Cavity arrested at 32 MV/m, nature TBD
- Behavior at > 40 MV/m TBD
- Are there other source of flux?
- Next with varied cool down profile to test
  - "flux generation by thermalelectrocity"
  - J. Pierce, Ph.D. Dissertation, Stanford, 1967

Extending High Q0 from Impurity Doping to High Gradient?



Other Related Recent JLab Results

P. Dkakal et al., ASC2014, 1LOr1B-05

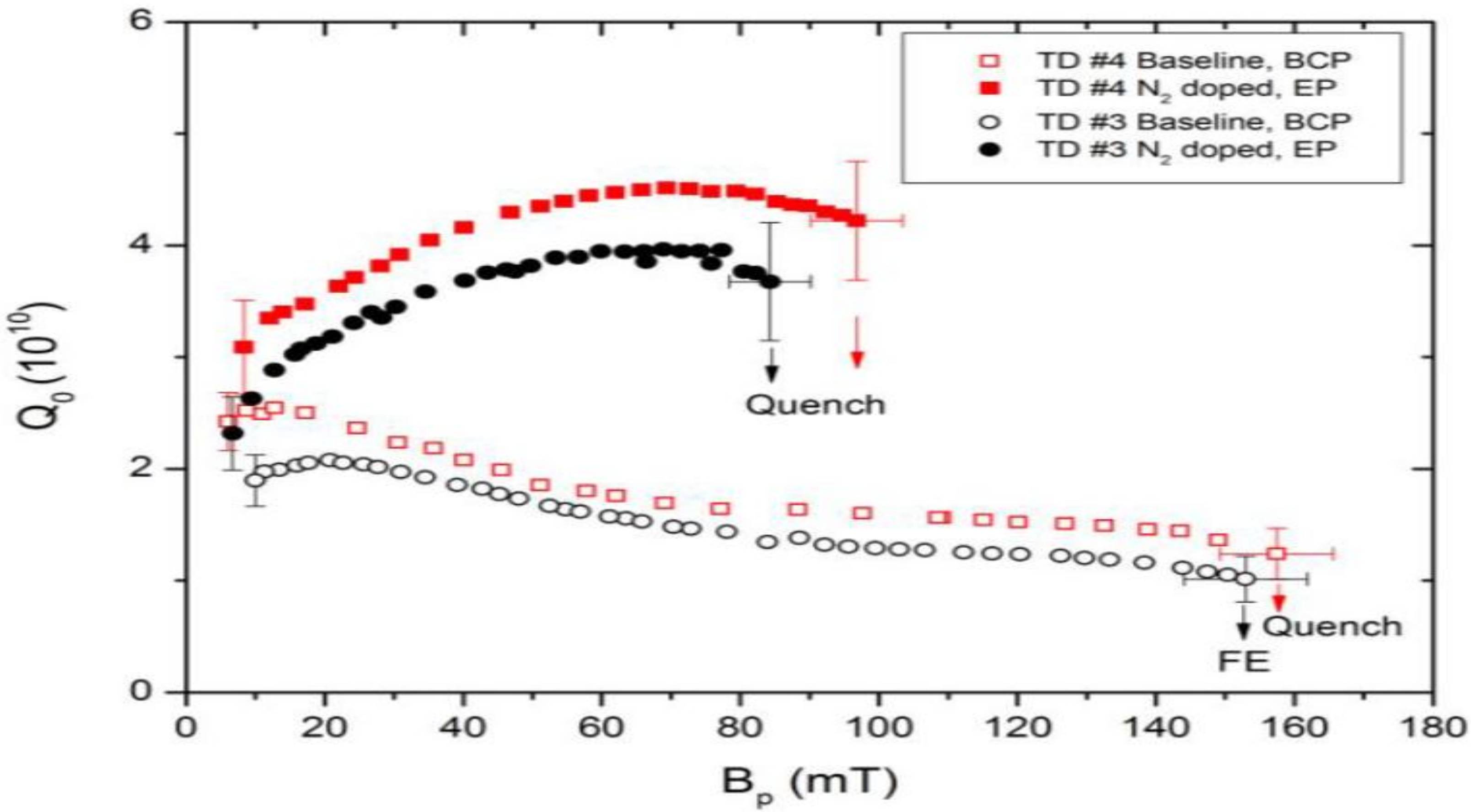


Fig. 3. Q_0(2 K) vs B_p for ingot Nb with RRR>300 1.3 GHz (B_p/E_{acc} = 4.33 mT/(MV/m)) cavities heat treated in the presence of nitrogen gas followed by ~10 μm EP.

Conclusion

- High Efficiency High Gradient (HEHG) SRF an accelerator science and technology topic of fundamental importance.
- HEHG cavity has unique applications for ILC in (1) higher ILC luminosity; (2) 1 TeV energy reach; (3) cost saving in construction and operation.
- HEHG cavity enables higher gradient for CW machine.
- Now after an extensive period (2006-2012) of ILC high gradient SRF cavity R&D program and more than a year of interruption for SRF infrastructure upgrade (2012-2013), we are back to high gradient SRF R&D at JLab. Excellent initial result on HEHG cavities confirms the upgraded SRF facilities have unique capabilities.
- “Field emission free” up to Epk=100 MV/m achieved in 1-cell.
- Series of testing carried out to study origins of “Q-slope”.
- Excellent results in LSF shape + large-grain Nb cavities achieved.
- Extension of these work to 9-cell requires funding support.