Status of ILC High Gradient Cavity R&D at Jefferson Lab

Rong-Li Geng
for JLab Team and Collaborators

Jefferson Lab

Linear Collider Workshop of the Americas
March 19-23, 2011, Eugene, Oregon, USA

U.S. DEPARTMENT OF ENERGY
Office of Science U.S. DEPARTMENT OF ENERGY
Jefferson Lab

Content

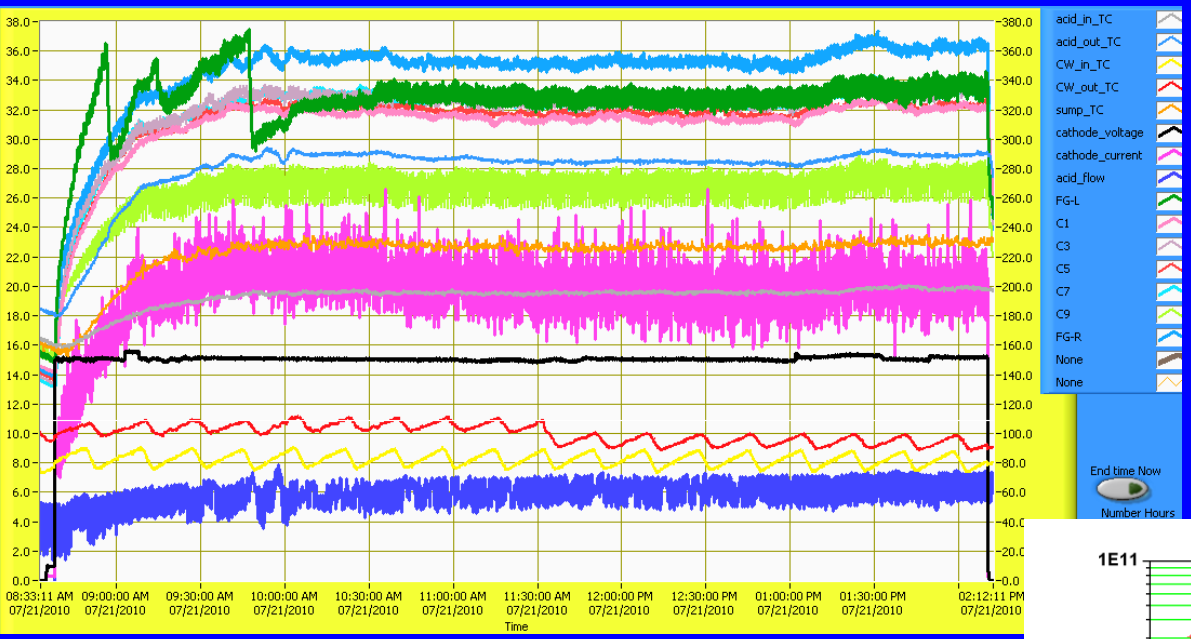
- Brief overview
- Some new results
- Near term plan
- Long term plan

Brief Overview

- Delivered significant 9-cell throughput with resulting simple and reproducible process through correlation, feedback & optimization
  - 107 EP cycles (310 hours voltage-on time)
  - 142 RF tests at cryogenic temperatures
  - 46 distinct 9-cell cavities processed/tested
  - Several Hi-Grade SRF workers trained
    - 4 technicians
    - 2 physicists
    - 1 graduate student (Ph.D. thesis work on quench studies)
  - High gradient procedures in hand for technology transfer
- Added new fundamental understandings (more later)
  - Geometrical defects for quench limit < 25 MV/m
  - EP specific field emitter: niobium oxide granules
- Delivered new gradient and yield results (more later)
  - Practical gradient envelope pushed to ~ 40-43 MV/m (Hpk~180 mT) in TTF-style cavity.
  - Example of 90% gradient yield at 35 MV/m (up to 2nd pass processing, 10 ACCEL/RI cavities)
- Made contribution/impact to external/internal projects
  - Provide feedback to AES and contributed to qualification of AES as first US vendor for ILC
  - Qualified 9-cell cavities for S1-global at KEK and for S1 cryomodule CM2 at FNAL
  - Collaboration with KEK-STF and ANL/FNAL on EP optimization
  - ILC high gradient R&D led to EP of JLAB's CEBAF upgrade cavities (7-cell cavities, total 80).

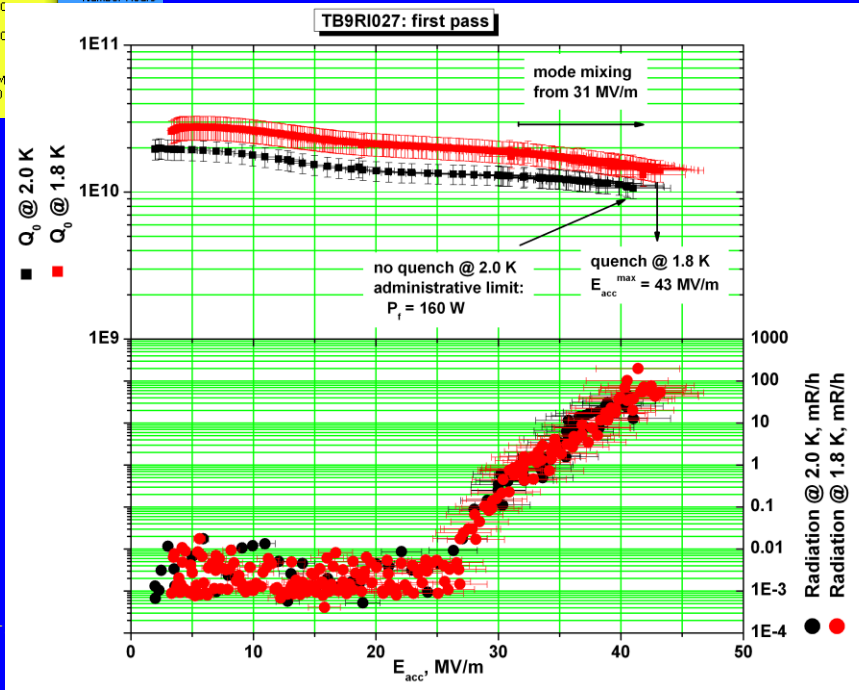
Optimized JLab EP and Cleaning Procedure

Repeatable process, reproducible result

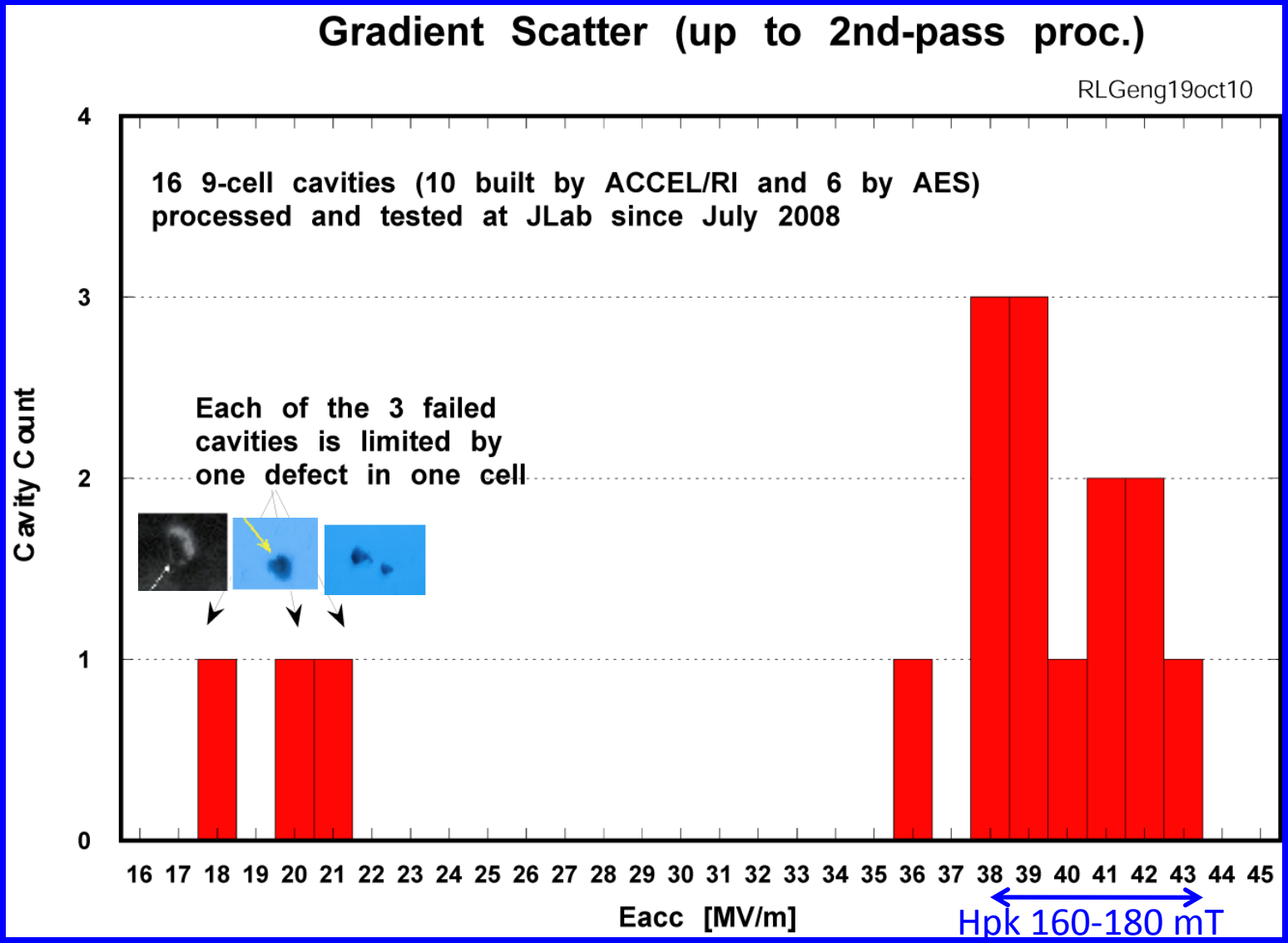


- Cell temperature control
  - ✓ Heavy EP 30-35 °C
  - ✓ Final EP 25-30 °C
- Constant voltage
  - ✓ nominal 14.5 V
  - ✓ allowable range 12-17 V
- Continuous current oscillation
- Auto-polishing
- HOM brushing

RI27 maximum Eacc = 43 MV/m
Hpk = 183 mT



Gradient Scatter (up to 2nd-pass proc.)

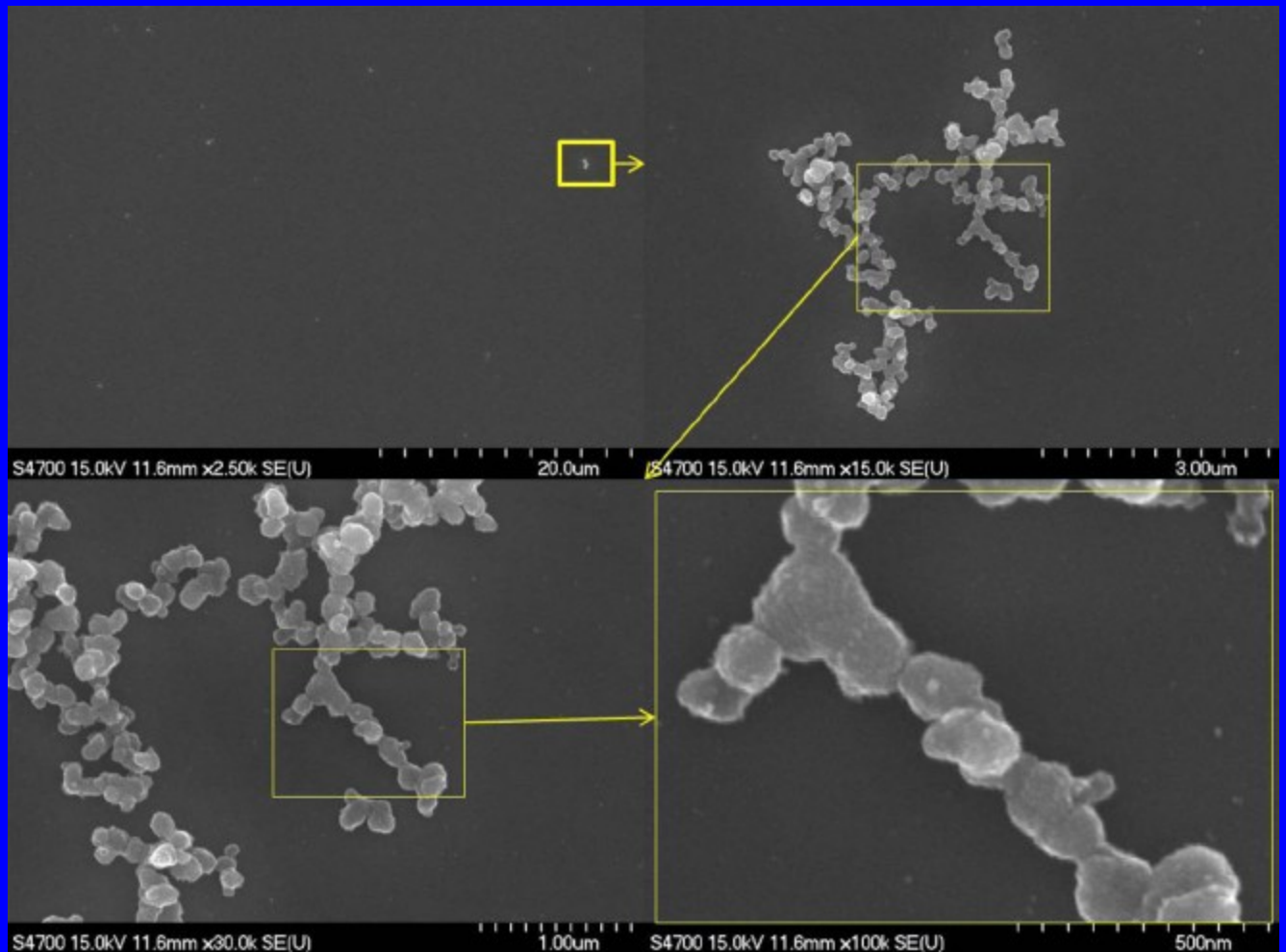


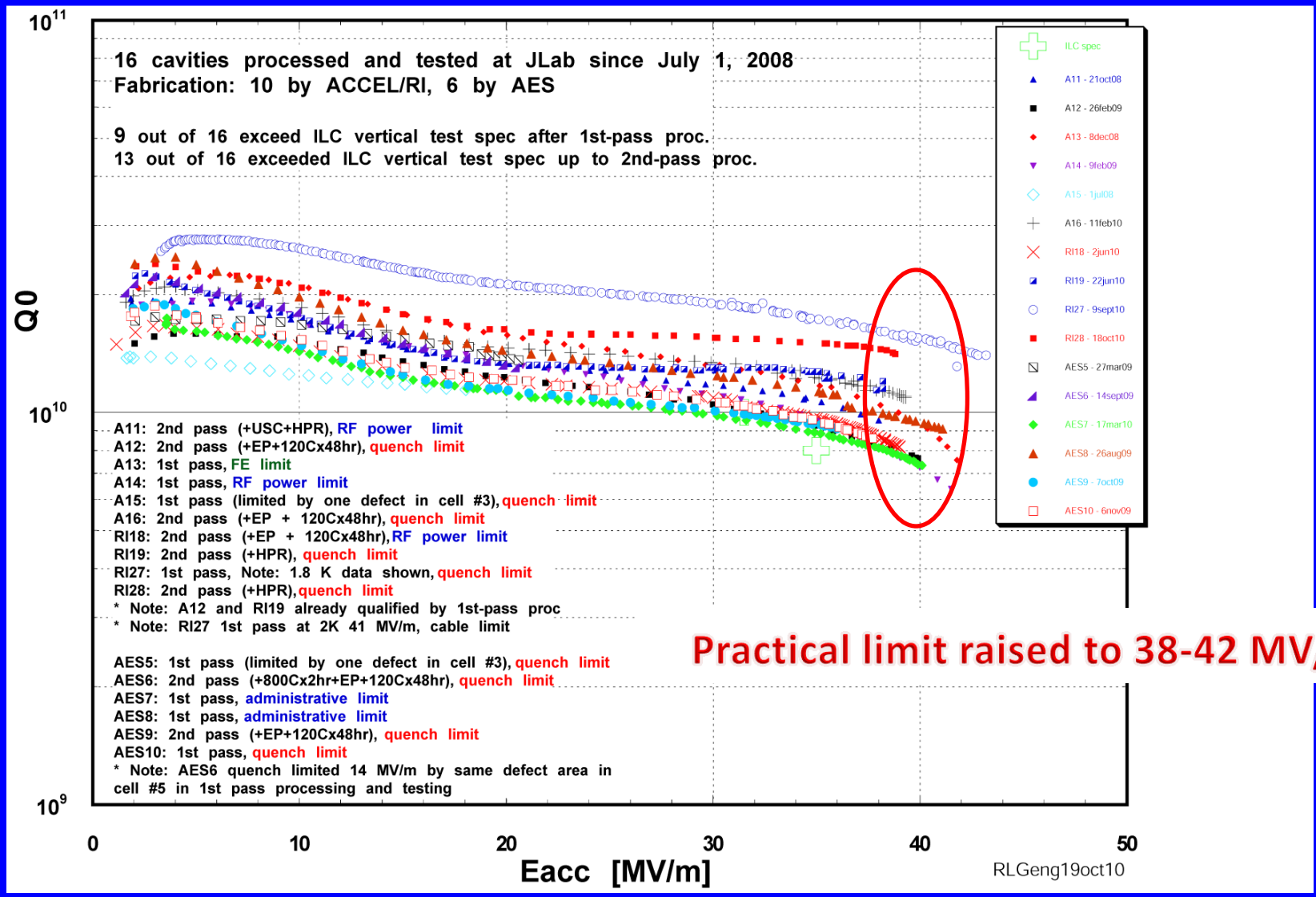
PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS
13, 124702 (2010)

Surface characterization of Nb samples electropolished with real superconducting rf accelerator cavities

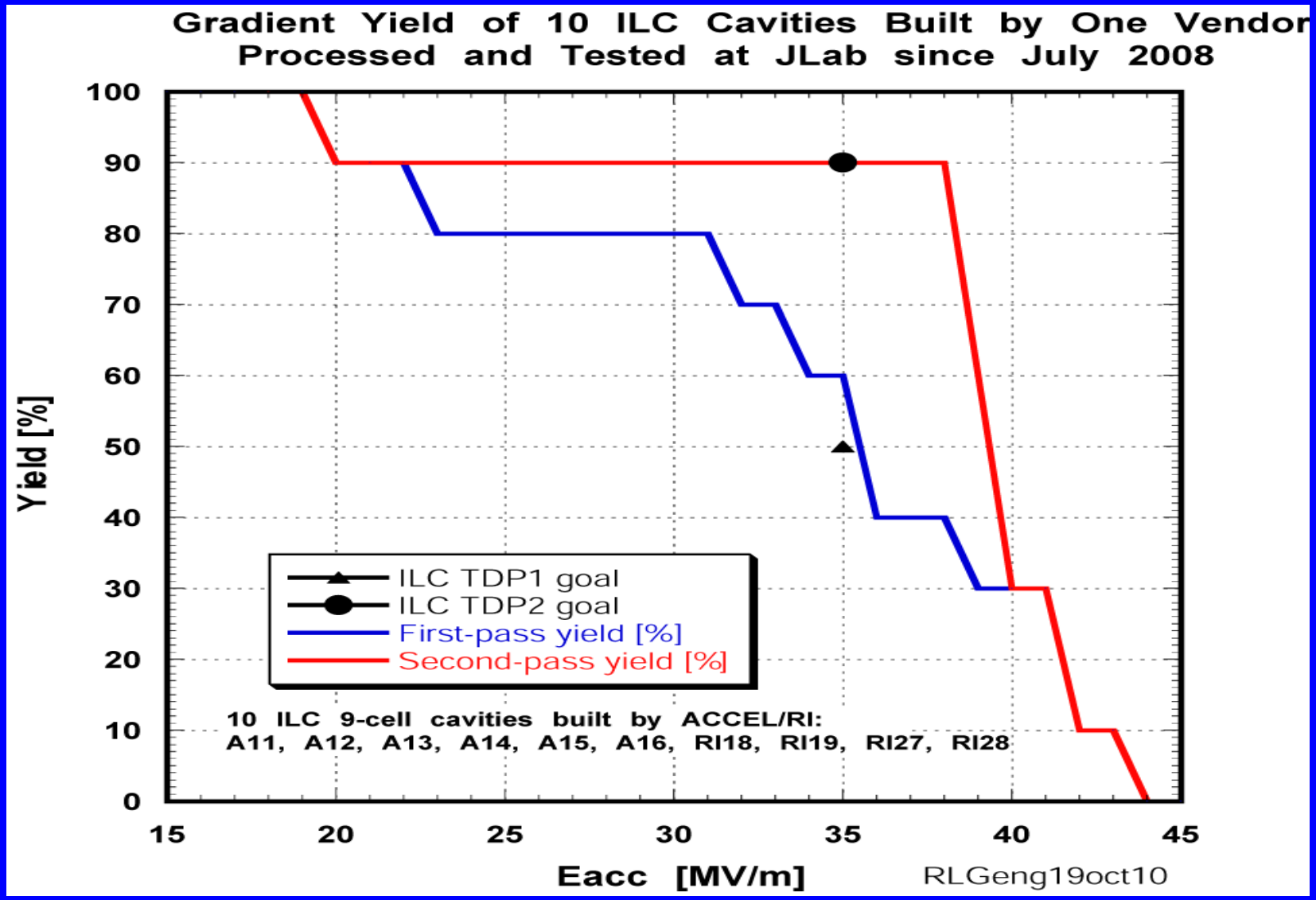
Xin Zhao,[1,*] Rong-Li Geng,[1] P. V. Tyagi,[2] Hitoshi Hayano,[3] Shigeki Kato,[2,3] Michiru Nishiwaki,[3] Takayuki Saeki,[3] and Motoaki Sawabe[3]

[1]*Thomas Jefferson National Accelerator Facility, Newport News, Virginia 23606, USA*
[2]*Graduate University for Advanced Studies, School of Advanced Sciences (GUAS/AS), Ibaraki, Japan*
[3]*High Energy Accelerator Research Organization (KEK), Ibaraki, Japan*
(Received 30 November 2009; revised manuscript received 2 December 2010; published 30 December 2010)





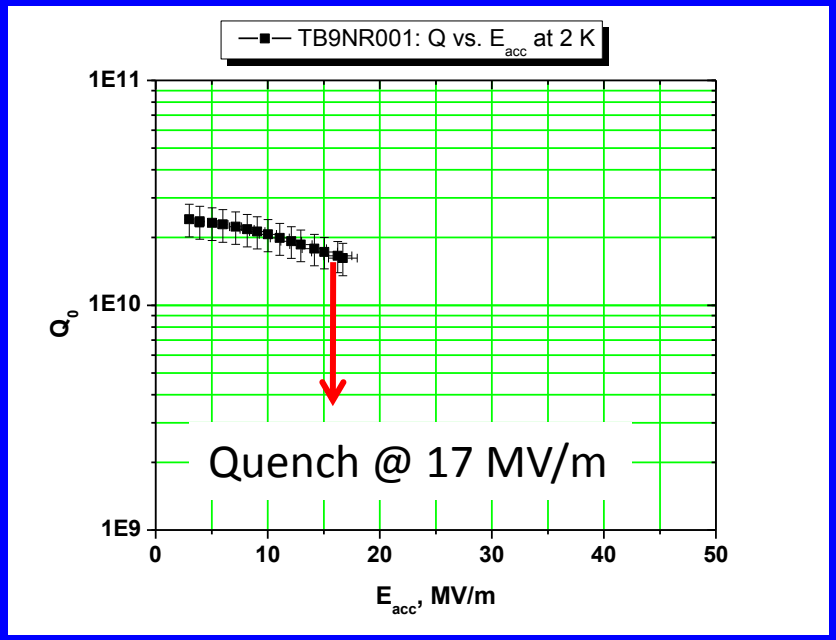
Practical limit raised to 38-42 MV/m

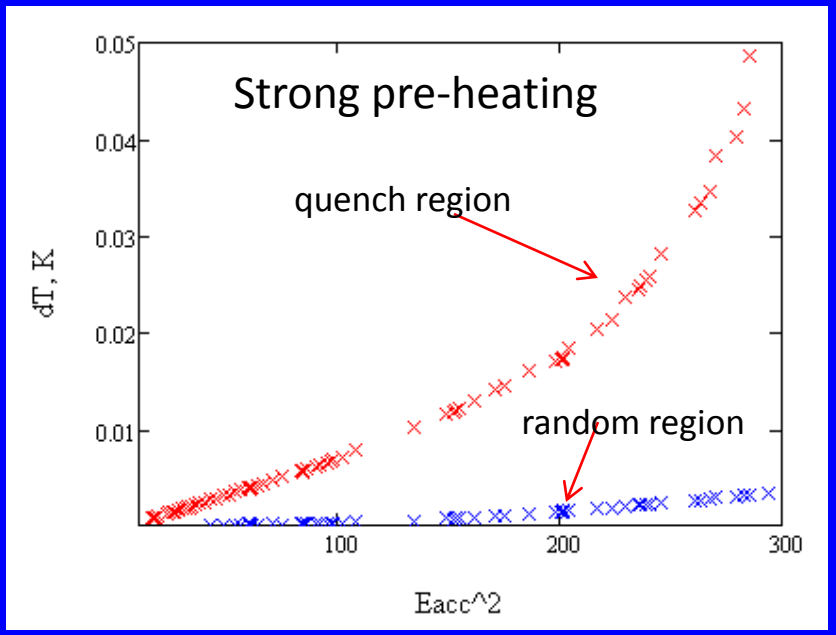

Gradient Yield of 10 ILC Cavities Built by One Vendor
Processed and Tested at JLab since July 2008
Yield [%]
100
90
80
70
60
50
40
30
20
10
0
15
20
25
30
35
40
45
Eacc [MV/m]
ILC TDP1 goal
ILC TDP2 goal
First-pass yield [%]
Second-pass yield [%]
10 ILC 9-cell cavities built by ACCEL/RI:
A11, A12, A13, A14, A15, A16, RI18, RI19, RI27, RI28
RLGeng19oct10

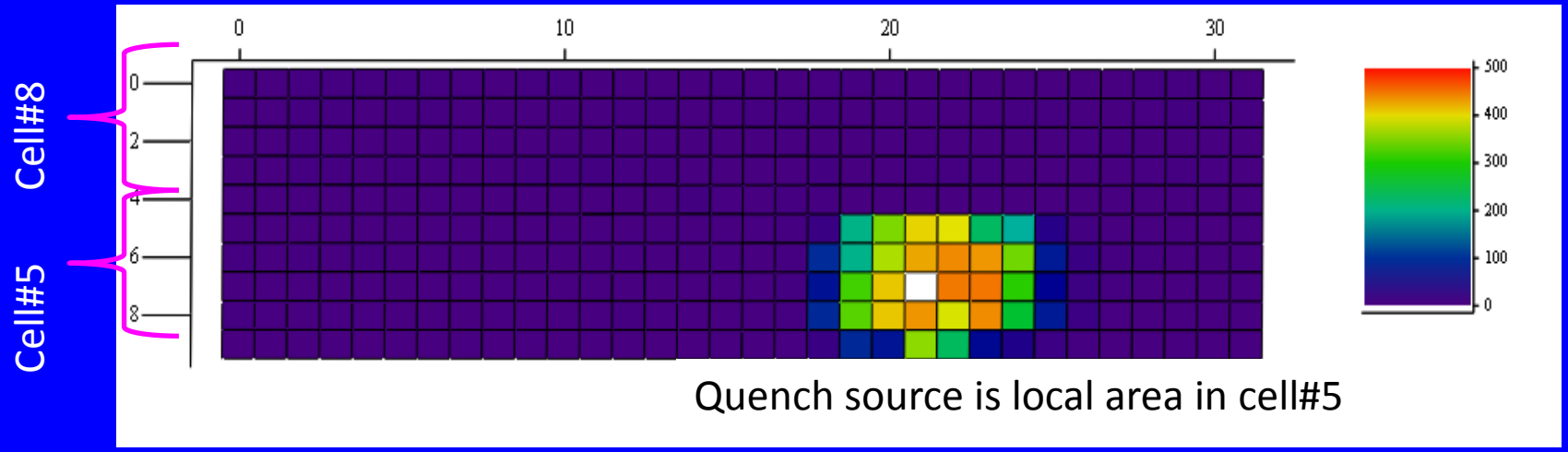
Some New Progress and Results

- New vendor cavity processing and testing in support of America vendor development
  - One of the first two 9-cell cavities made by Niowave/Roark
  - Systematic tracking and study of "genetic defect"
- Cross-region cavity exchanges
  - 9-cell fine-grain and large-grain 9-cell cavities in collaboration with PKU
  - MHI#8 S0 processing and testing in collaboration with KEK
  - JLAB LG#1 local grinding in collaboration with KEK
- Alternate cavity R&D for higher performance and lower cost
  - Low-loss shape cavity ICHIRO7 in collaboration with KEK
  - Seamless 9-cell cavity evaluation in collaboration with DESY
- Capability upgrade
  - Transfer Cornell OST to JLAB
  - Transfer KEK replica to JLAB
  - Upgrade JLAB high-resolution optical inspection machine
- Magneto-Breakdown studies
  - Controlled defect in 1-cell cavity
  - Advanced studies using 9-cell pass-band modes

New 9-cell Cavity by Niowave/Roark

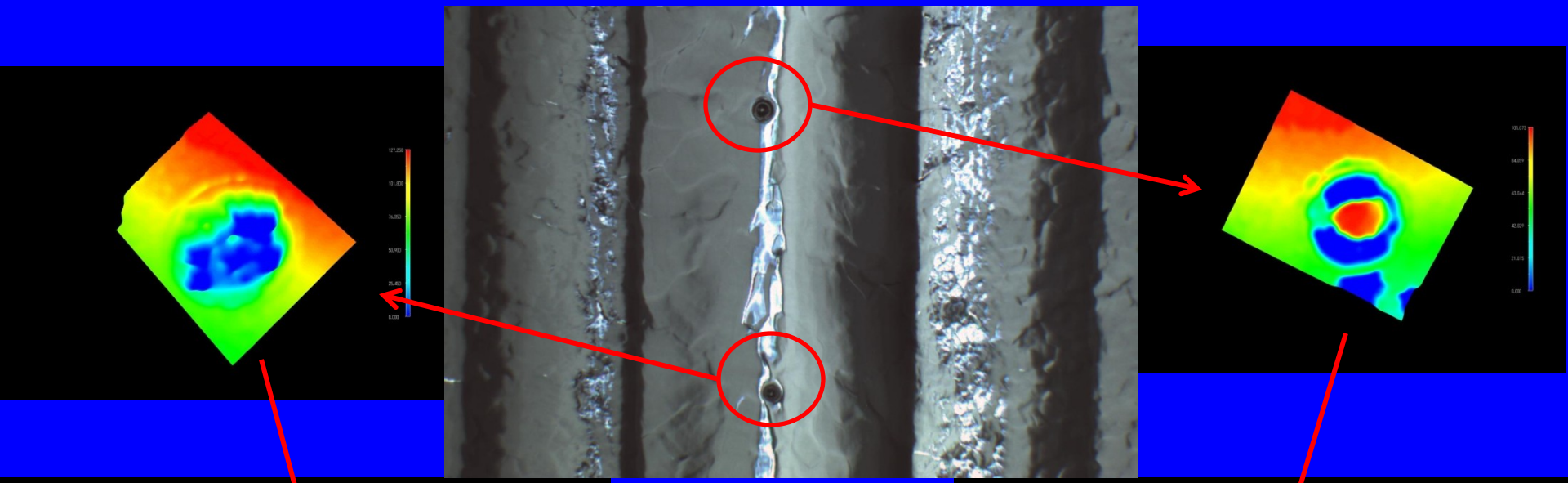




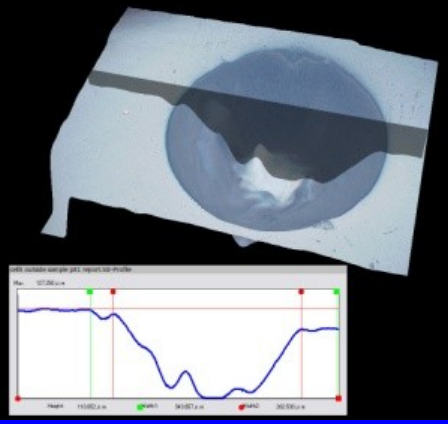


Quench source is local area in cell#5

Profiles of Defect(s) Limiting NR1 to 17 MV/m



Width: 262um
Height: 127um

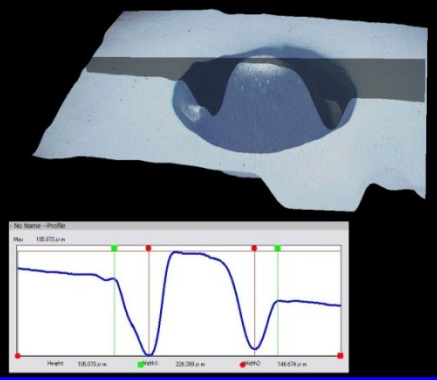


Geometric defects at quench location in cell #5 of NR1

Inside fusion region of equator EBW

Defects are suspected to be disclosed welding pockets

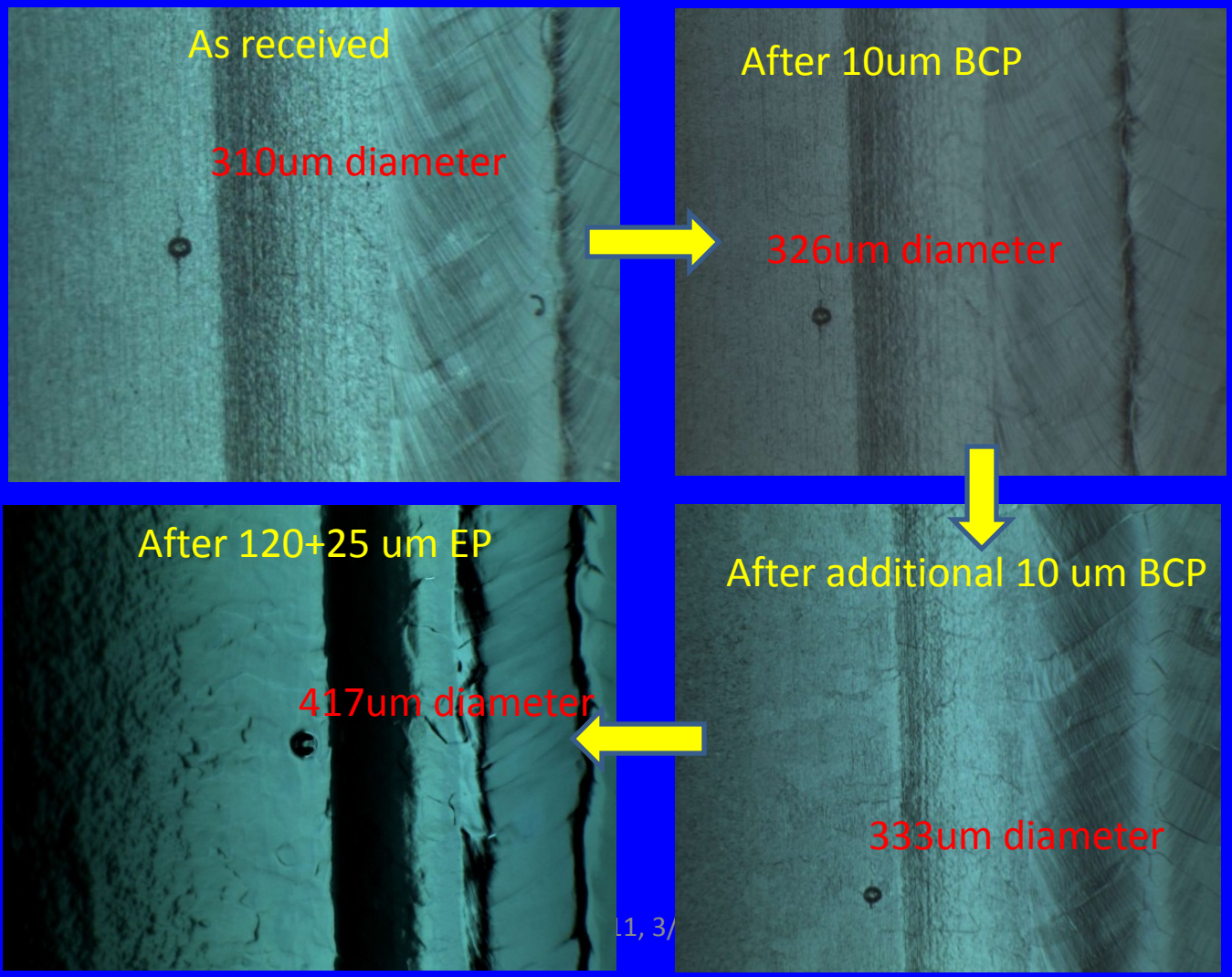
Width: 226um
Height: 105um



Tracking for Outstanding Features in NR1

Cell#4 (51mm, 175Degree), near equator EBW

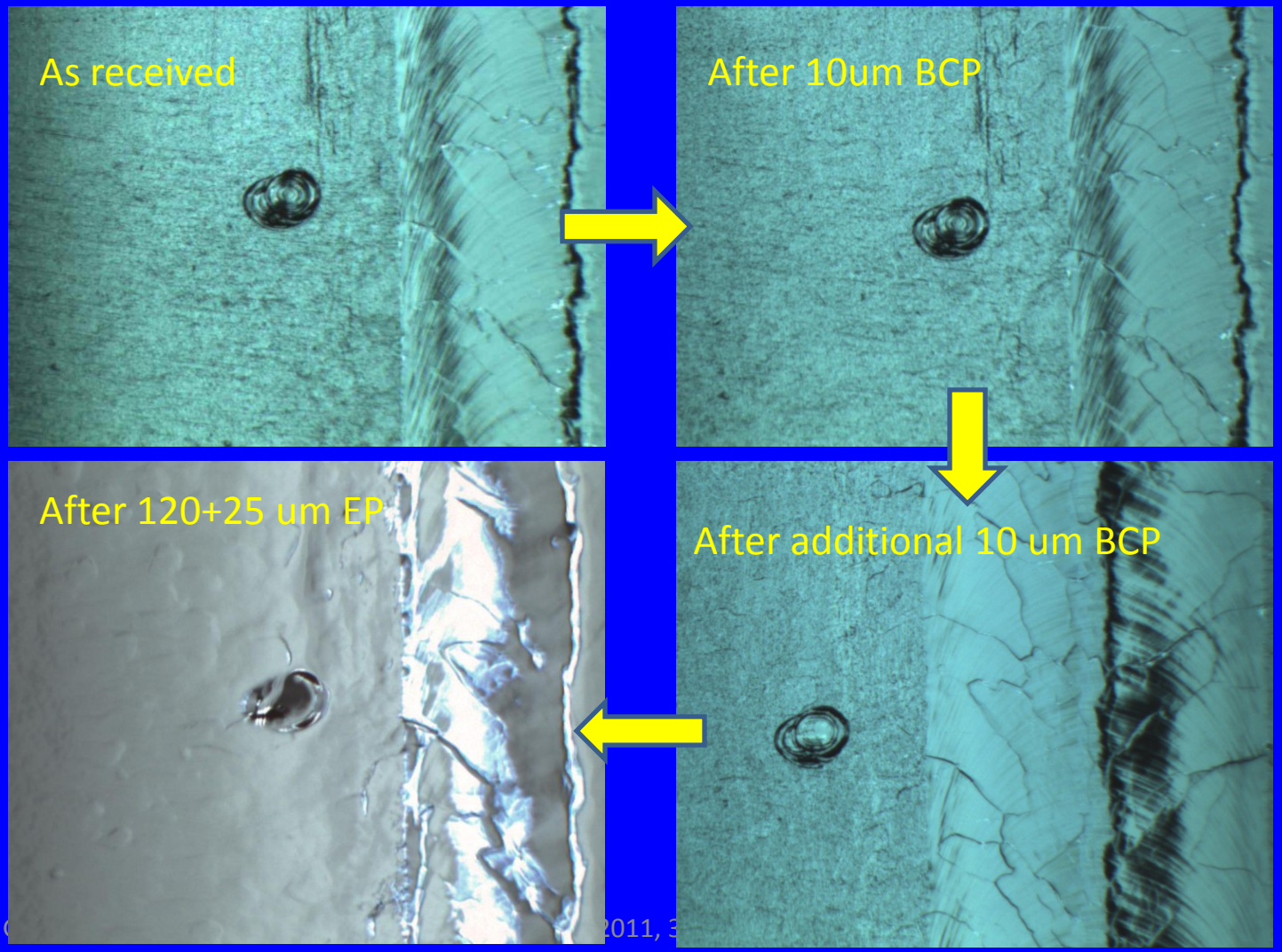
Cell#4 quench reached a surface magnetic field of 1022 Oe, corresponding to 24 MV/m



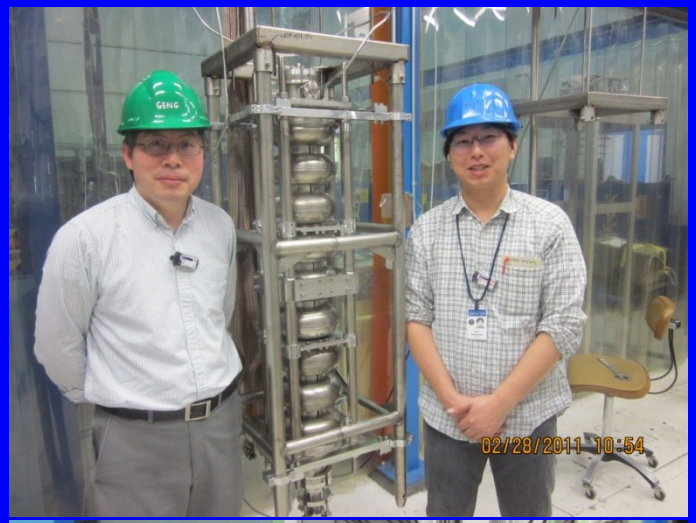
Tracking of Outstanding Features in NR1

Cell#4 (51mm, 175Degree), near equator EBW

Cell#4 quench reached a surface magnetic field of 1022 Oe, corresponding to 24 MV/m



Cross-Region Cavity Exchange



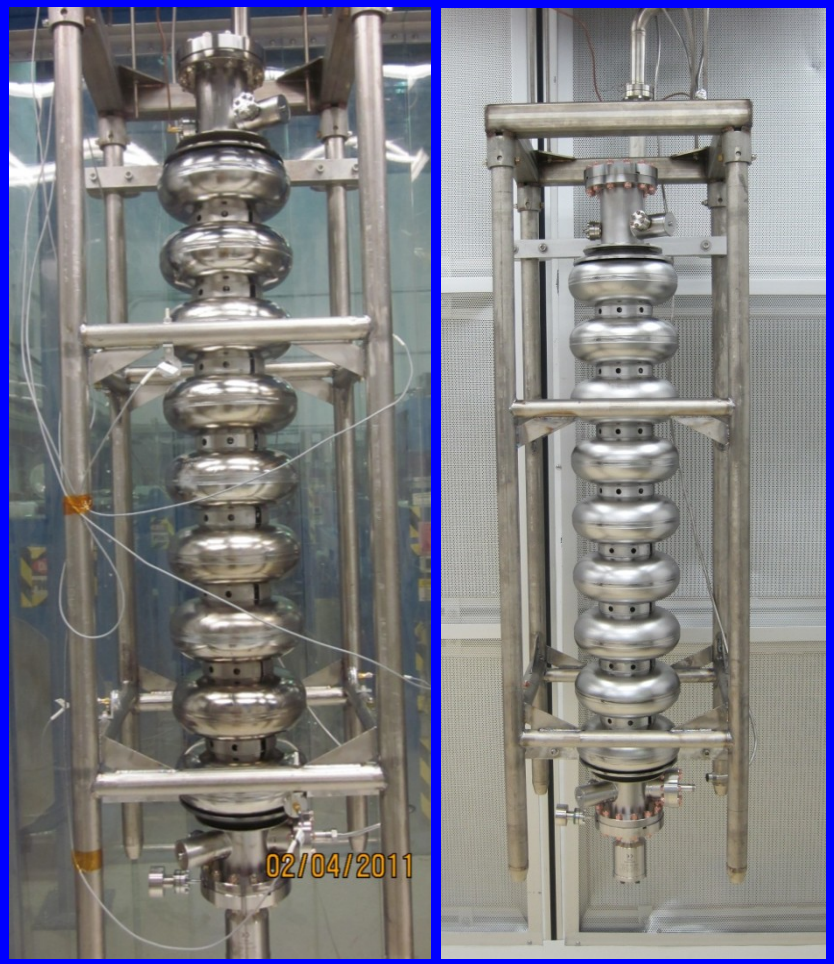
KEK scientists, Kirk Yamamoto and Ken Watanabe, visited JLab

- Cavity processing procedure exchange
- At-cavity field emission monitoring and cross-checking
- KEK replica technology transfer to JLab
- A mini-plug-compatibility test

Cross-Region Cavity Exchange (cont)

PKU2

- First TTF-style 9-cell large-grain cavity with end group component
- Cavity reached quench field of 22.4 MV/m
- Cavity achieved very high Q_0
  - 2E10 at 20 MV/m, 2K
  - 3.2E10 at 20 MV/m, 1.8K

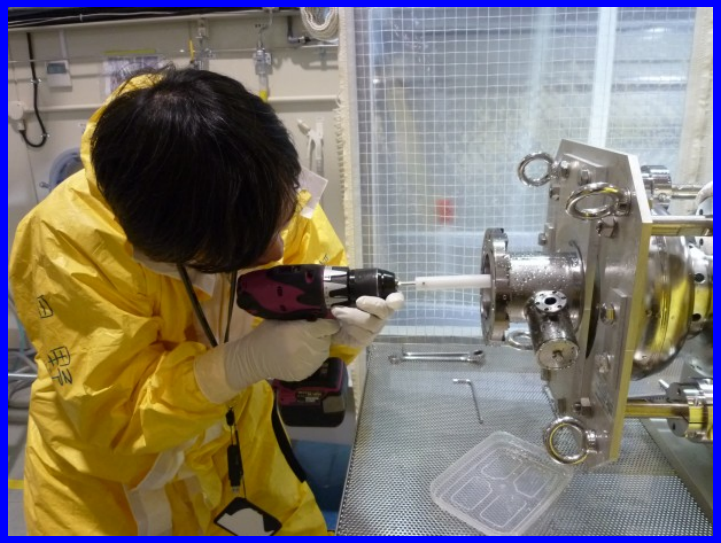


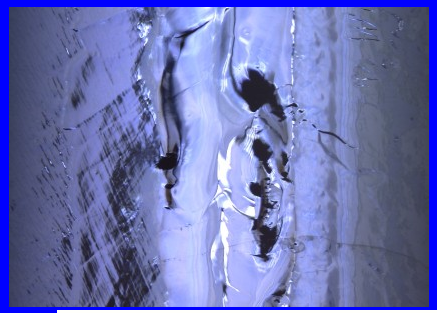
PKU3

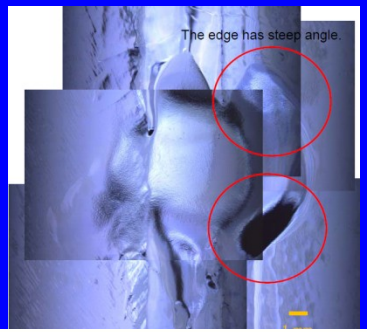
- First TTF-style 9-cell fine-grain cavity with end group component built in China to reach a gradient usable for ILC
- Cavity reached quench field of 28.3 MV/m

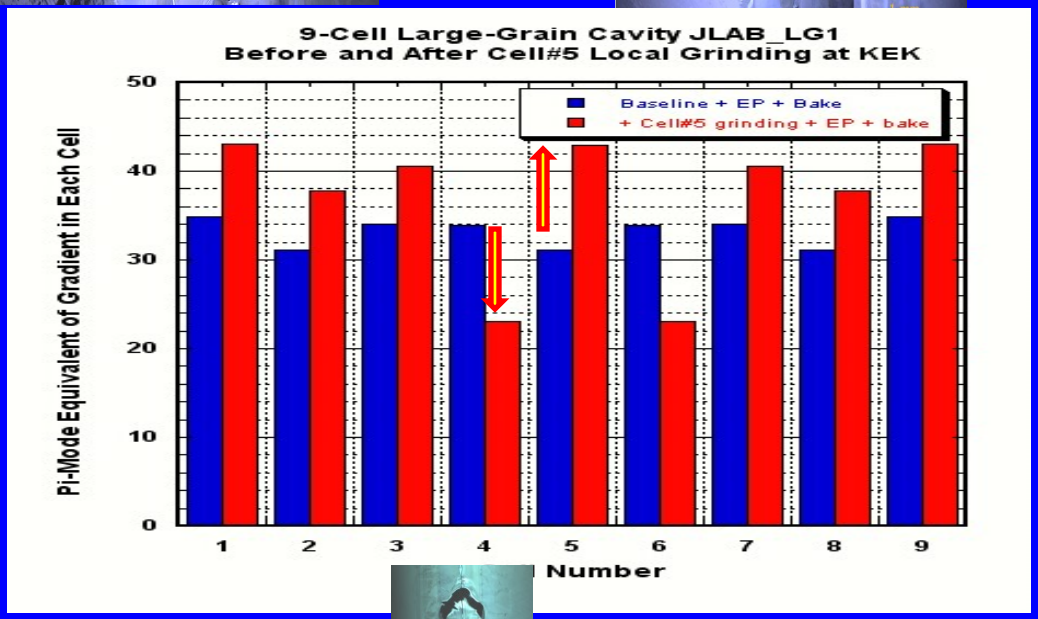
Cross-Region Cavity Exchange (cont)

JLAB LG#1 quench defect (a weld hole repair) in cell#5 has been successfully removed by local grinding at KEK.
The repaired cell is improved from 1320 Oe (31 MV/m) to 1832 Oe (43 MV/m).



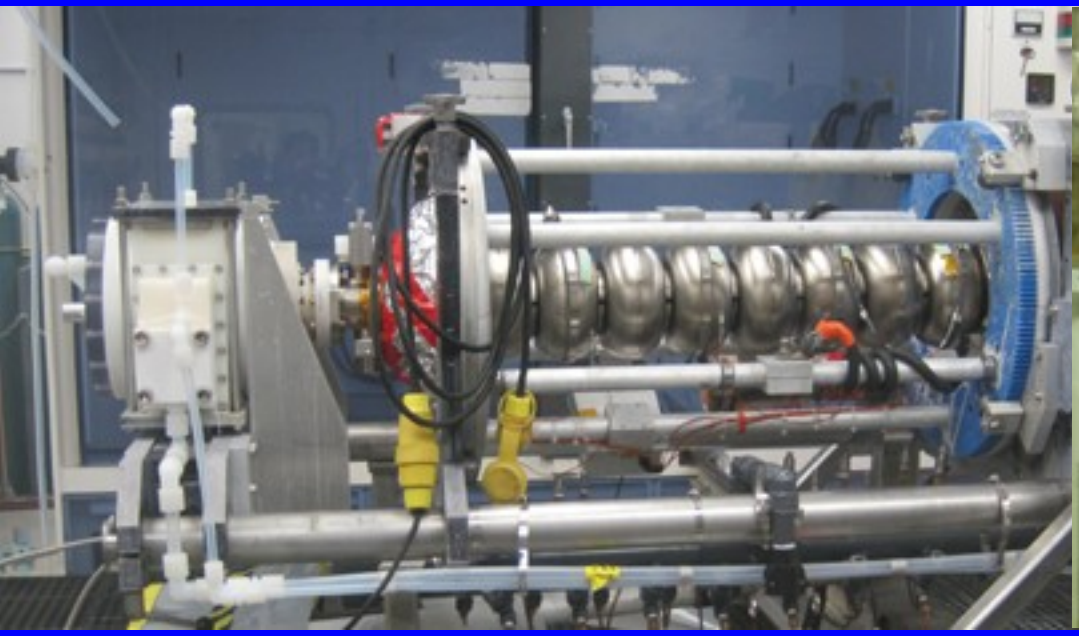






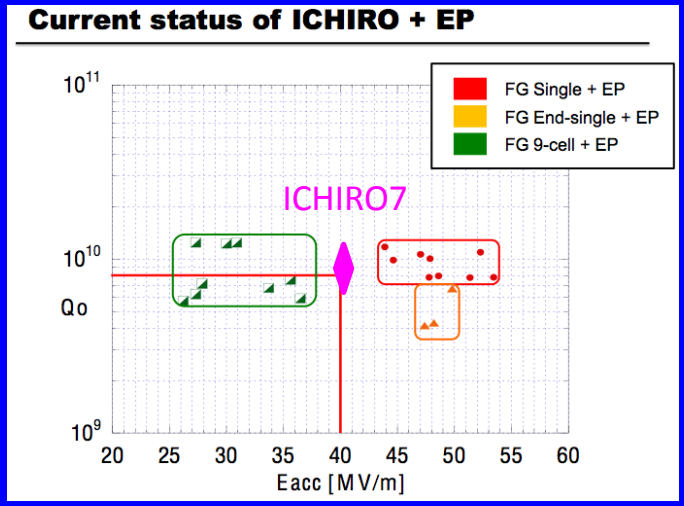
Note: Cell4 degraded due to another defect

Alternate Cavity R&D for > 45 MV/m



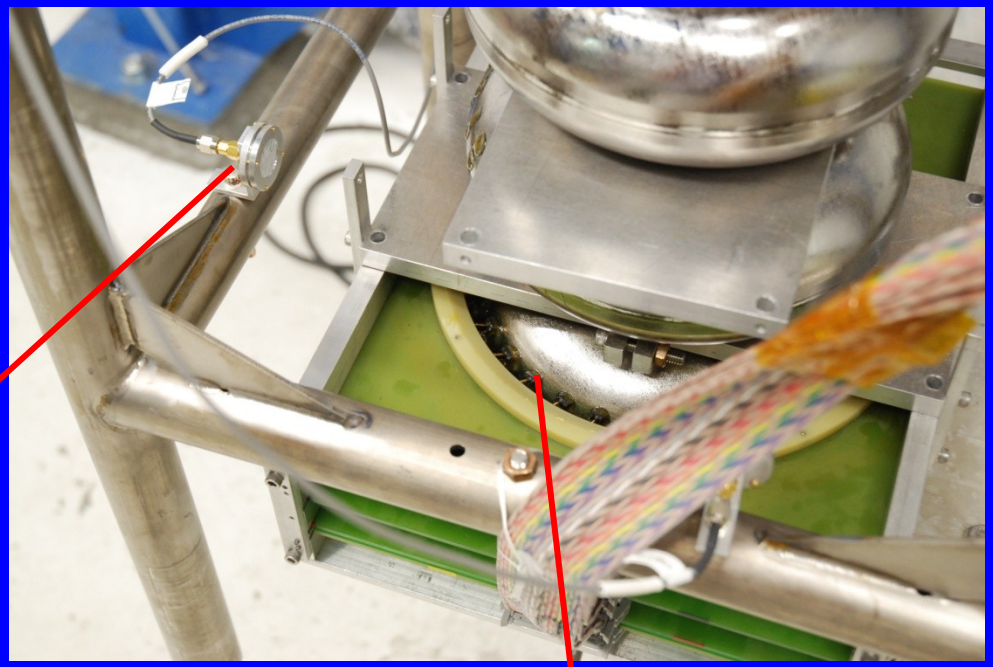
ICHIRO7 processing and testing in collaboration with KEK

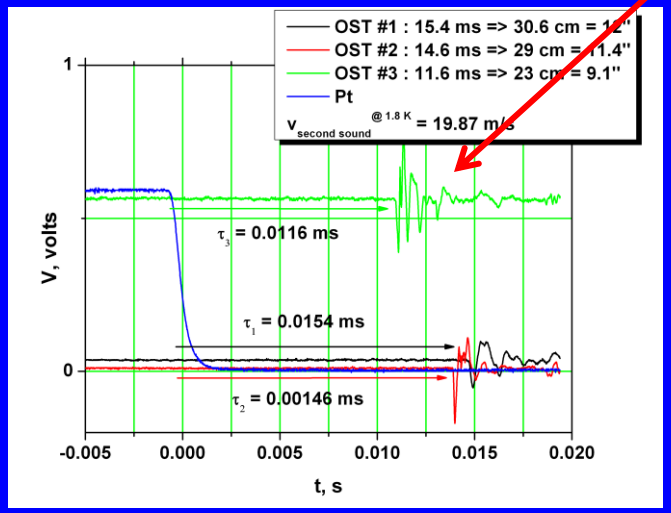
- KEK scientists Fumio Furuta and Kenji Saito visited JLab
- Collaboration aims for > 45 MV/m demonstration in a 9-cell cavity
- ICHIRO7 recently reached 40 MV/m with Q_0 8E9

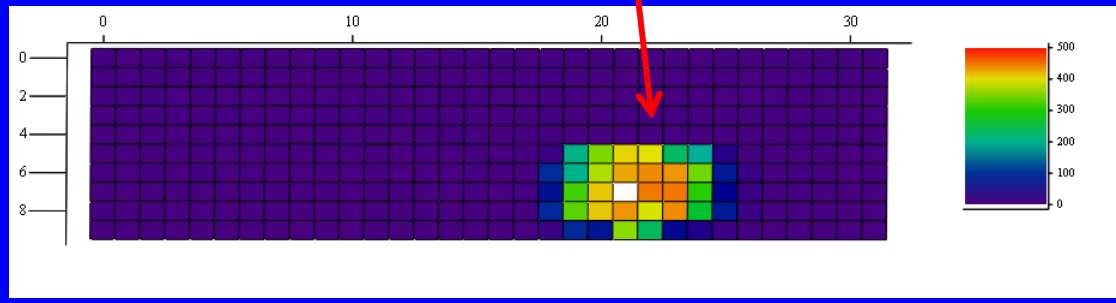


Capability Enhancement/Upgrade

Cornell OST transfer to JLab for cross-checking and routine quench location detection

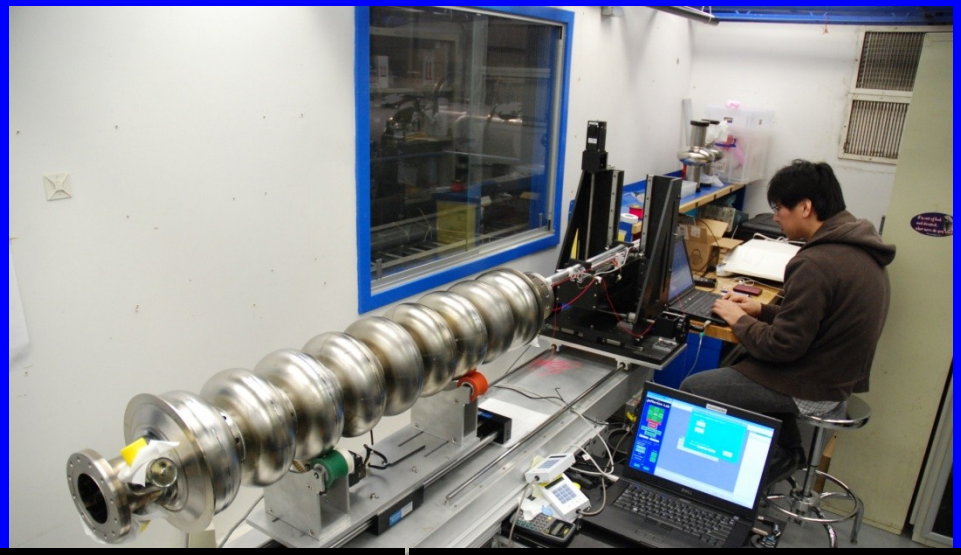


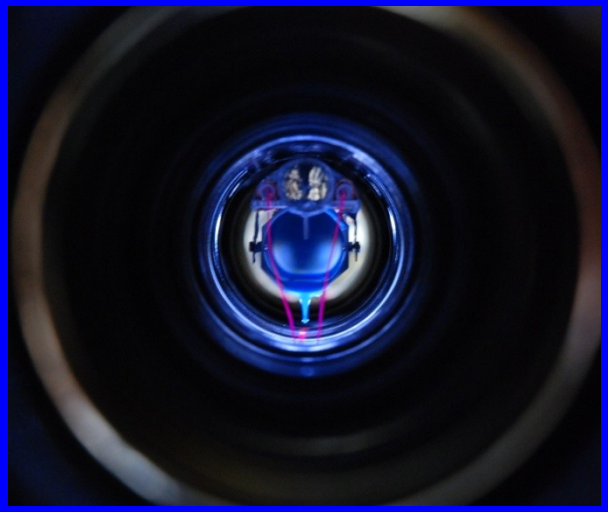


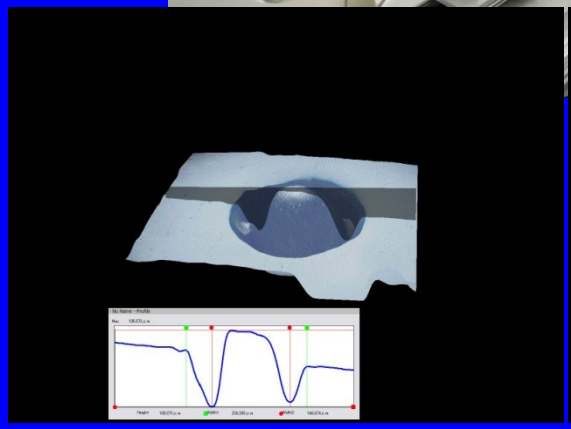


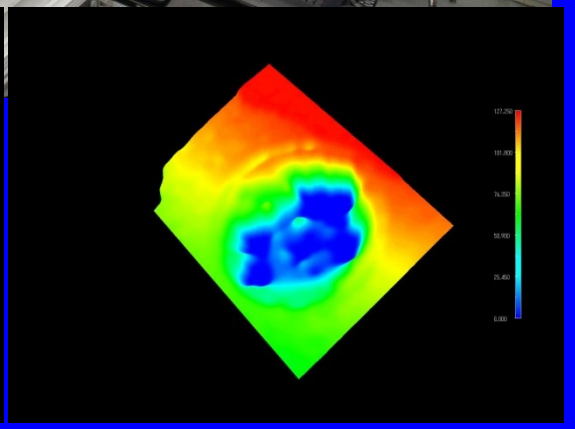
Capability Enhancement/Upgrade (cont)

KEK replica technology transfer to JLab for 3D defect profiling and sduties









Capability Enhancement/Upgrade (cont)

A dual-mode high-resolution optical inspection machine at JLab

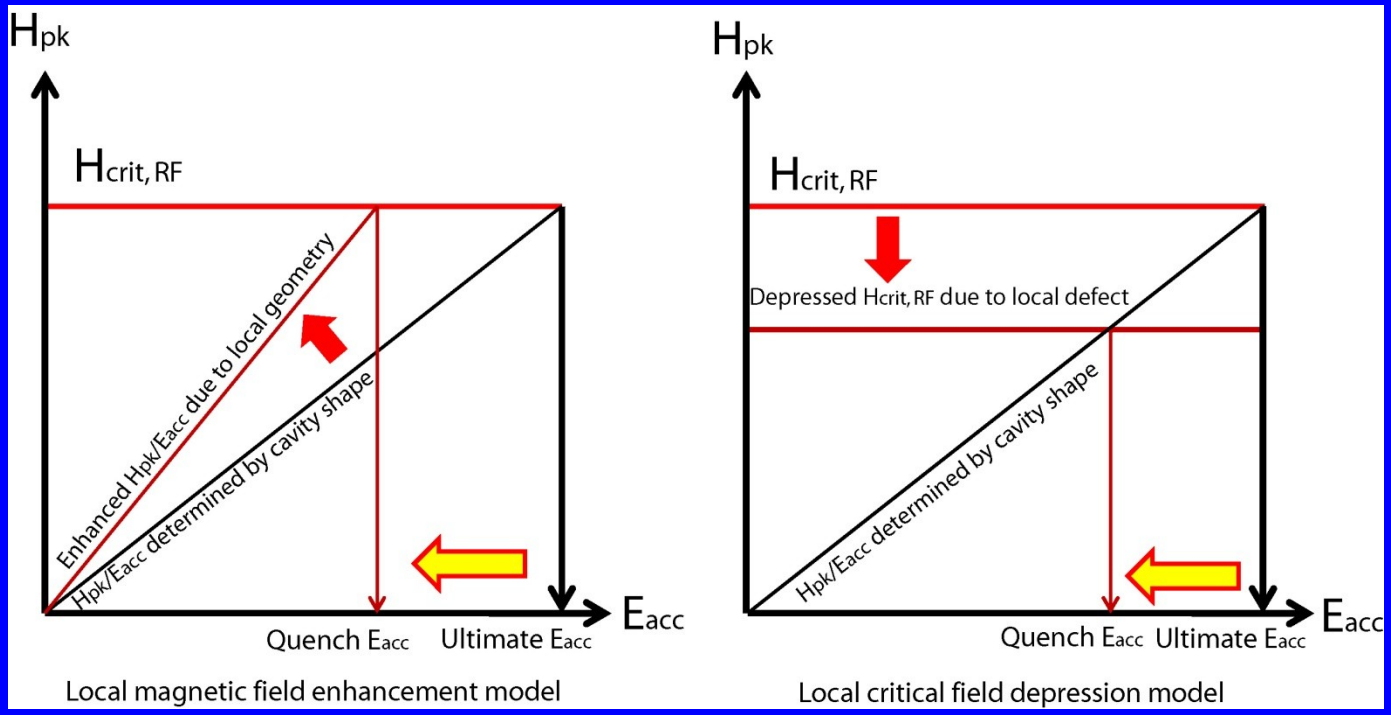
Kyoto-KEK camera on loan from KEK

Optimized for ILC cavity

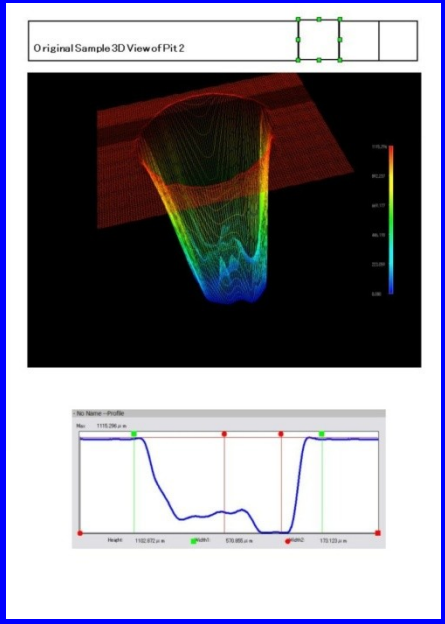
Quastar Based system with a rotatable mirror inserted into Cavity

Small (down to 50 mm) or large aperture cavities can be inspected

Magneto-Breakdown Studies



Controlled geometric defect planted in 1-cell cavity



Advanced 9-cell measurements using OST and pass-band modes
First measurements clearly show non-thermal breakdown

Near Term Plan (2011-2012)

- Continue S0 processing and testing using JLab's established procedure to support global cavity gradient yield analysis
  - Throughput will be adjusted
    - 12 GeV 7-cell cavity EP work impacts facility availability
    - US program evolving (9-cell hydro-forming; 9-cell mechanical polishing)
  - Manual labor to be done by trained production staff

- Breakdown studies to support new vendor qualification (low field quench) and to push gradient envelope (high field quench)
  - High-resolution local thermometry
    - First prototype being built
    - First test is NR1 twin defects which are 3.8 mm apart
  - Advanced studies of magneto-breakdown
  - Controlled geometric defect in 1-cell cavity
  - Local electron-beam re-melting for defect removal technique development

- Field emission studies and countermeasure developments
  - At-cavity X-ray monitoring and X-ray mapping
  - Optical observation of cavity inner space
  - In-situ processing techniques such as glow-discharge cleaning

Long Term Plan (beyond 2012)

- Continue alternate shape cavity work to push gradient toward prototype 9-cell bulk Nb cavity at 45-50 MV/m
  - ICHIRO cavity processing and testing in collaboration with KEK
  - Develop prototype LSF shape cavity in collaboration with SLAC
- Develop Nb/Cu composite material cavity toward 90% yield at 45 MV/m
- Develop solution for Q_0 1-2E10 at 40 MV/m
  - Optimized surface removal and heat treatment
  - Encouraging evidence already observed in recent 9-cell studies at JLab inspired by on-going JLab high-Q program
- Develop technology prototype via cavity system development using new materials in collaboration with surface and thin film experts
  - ALD
  - Energetic deposition