Particle Accelerator Conference

May 4-8 2009
Vancouver, Canada

Progress on Improving SC Cavity Performance for ILC

Rong-Li Geng

Jefferson Lab

PAC09, May 4-8, 2009, Vancouver, Canada

ILC SCRF Cavity Performance Goal

- Operation
  - Eacc 31.5 MV/m
  - Q0 1E10
- Vertical test acceptance
  - Eacc 35 MV/m
  - Q0 8E9
- Gradient choice matters
  - High impact on project cost
  - Energy reach for fixed tunnel length
- 16,000 cavities
  - High yield required
  - Industrialization necessary

ILC Research and Development Plan for the Technical Design Phase

Release 3

February 2009

ILC Global Design Effort

Director: Barry Barish

Prepared by the Technical Design Phase Project Management

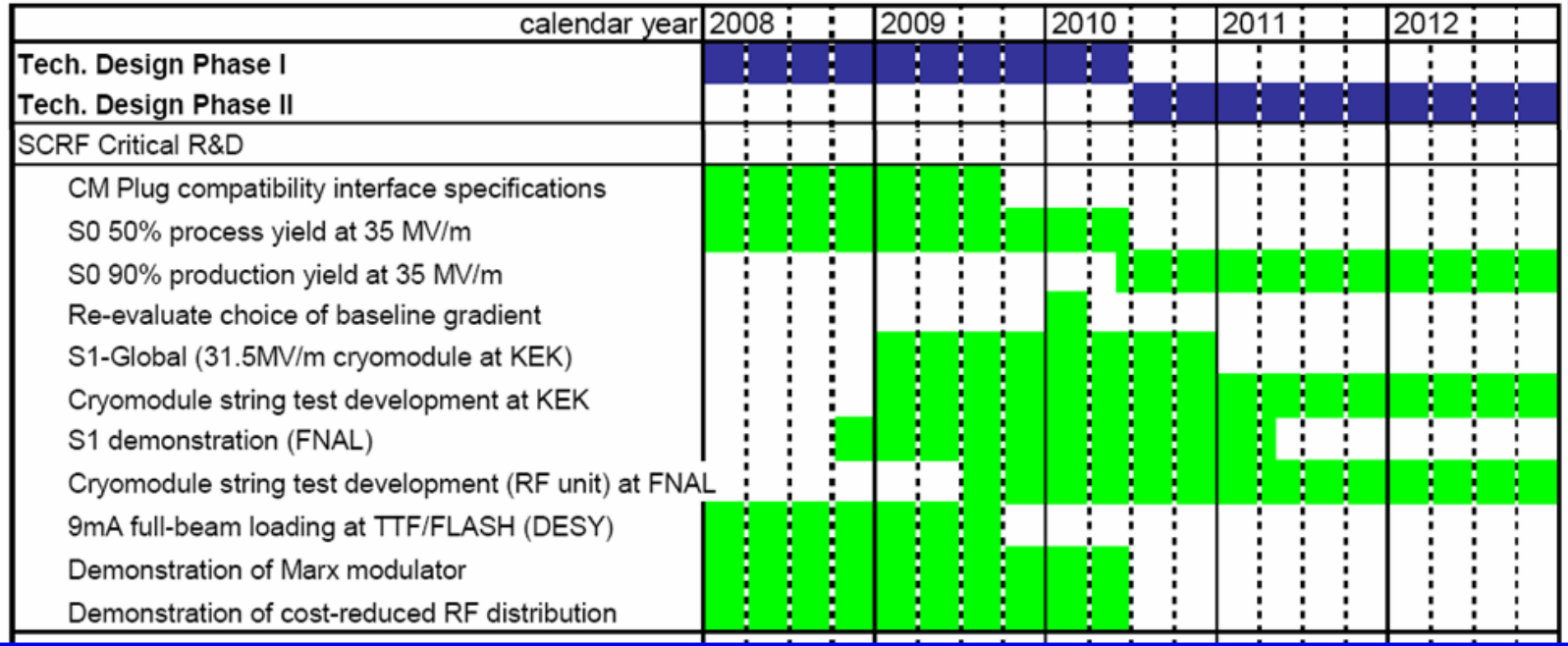
Project Managers:

Marc Ross
Nick Walker
Akira Yamamoto

ILC Research and Development Plan for the Technical Design Phase

Release 3

February 2009



Prepar
Manag

Project

Ro

ILC Research and Development Plan for the Technical Design Phase

Release 3

February 2009

calendar year	2008	2009	2010	2011	2012
Tech. Design Phase I					
Tech. Design Phase II					
SCRF Critical R&D					
CM Plug compatibility interface specifications					
S0 50% process yield at 35 MV/m					
S0 90% production yield at 35 MV/m					
Re-evaluate choice of baseline gradient					
S1-Global (31.5MV/m cryomodule at KEK)					
Cryomodule string test development at KEK					
S1 demonstration (FNAL)					
Cryomodule string test development (RF unit) at FNAL					
9mA full-beam loading at TTF/FLASH (DESY)					
Demonstration of Marx modulator					
Demonstration of cost-reduced RF distribution					

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ILC Research and Development Plan for the Technical Design Phase

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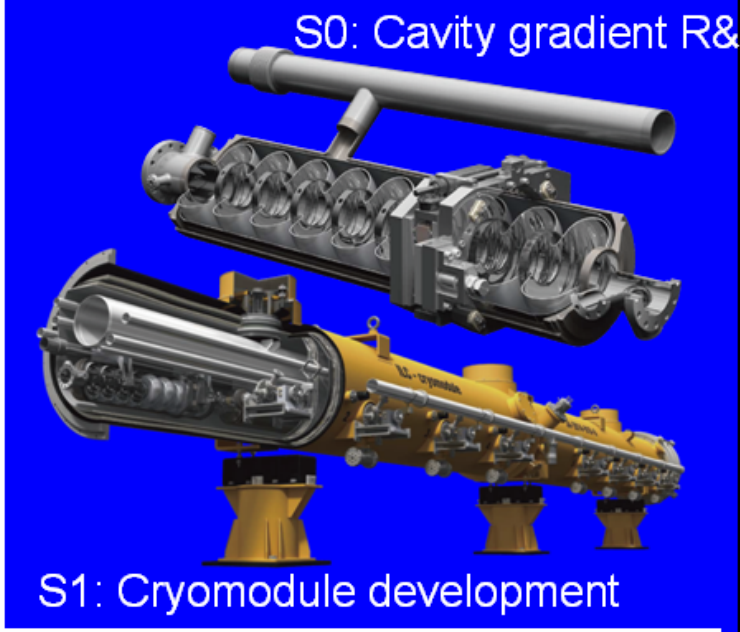

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Globally Coordinated ILC Gradient R&D

Selected highlights

- DESY
  - > 17 cavities reached > 35 MV/m since 2003
  - More cavity (6th production) testing coming…
  - XFEL 800 cavities to be manufactured
- JLAB
  - 7 cavities reached > 35 MV/m since 2006
  - Understand 9-cell limit by T-mapping & optical inspection
  - Large-grain cavity
- FNAL
  - Infrastructure ramp up (EP machine & VTA commissioned)
  - > 20 cavities received from industry, including US cavity vendor
- KEK
  - STF infrastructure ramp up (EP machine & VTA commissioned)
  - Low-loss shape cavity
  - 9-cell cavity T-mapping and optical inspection
- Cornell
  - Quench detection (second sound) instrumentation development
  - Re-entrant shape cavity

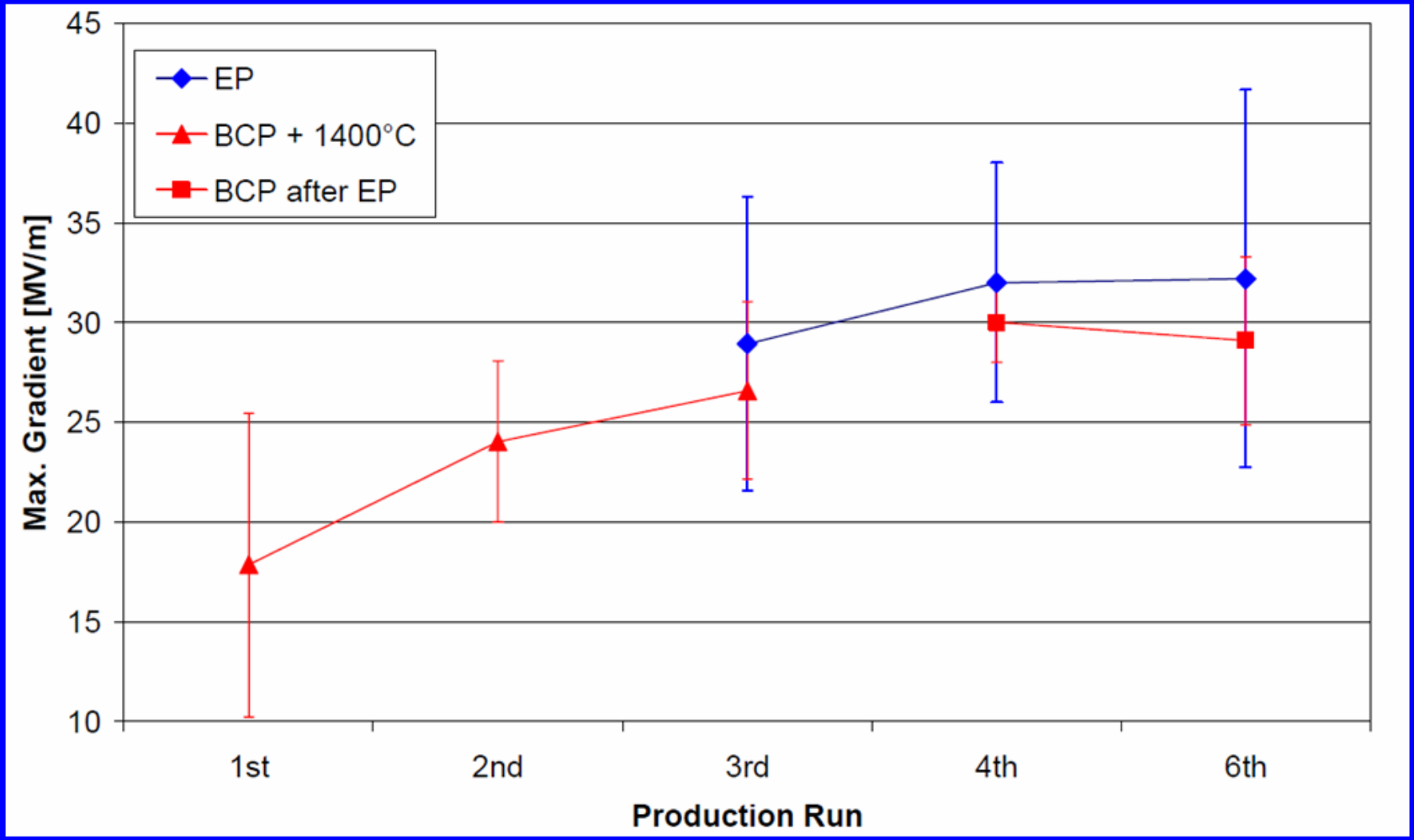
Shape, Material and Processing

- Baseline: TESLA-shape, fine-grain Nb, electropolishing
  - ~ 200 cavities manufactured (mostly DESY)
  - Tested in module and with beam
  - XFEL 800 cavities to be manufactured
  - EP required for 35 MV/m with fine-grain
  - Major global effort is to improve yield
- Alternative: Low-loss & Re-entrant shape, large-grain N
  - LL & RE shapes for higher gradient
  - Large-grain material for 35 MV/m without EP (lowering cost potential)
  - Excellent demonstration with many single-cells
  - 9-cell demonstration under way
- This talk focuses on baseline cavity and processing

Main Processing & Testing Steps

- Heavy EP for damaged layer removal (100-150 μm)
- Cleaning
- Vacuum furnace out-gassing for H removal (600-800 °
- Tune for field flatness and frequency
- Light EP for contamination layer removal (20-50 μm)
- Post-EP cleaning (alcohol or ultrasonic + detergent)
- High pressure water rinsing
- Clean room assembly
- Low temperature bake out (120 °C X 48 h)
- RF test
- Optional T-mapping test → understand gradient limit
- Optional optical inspection

DESY 6th Production Run Cavities Successful Heavy EP in Industry

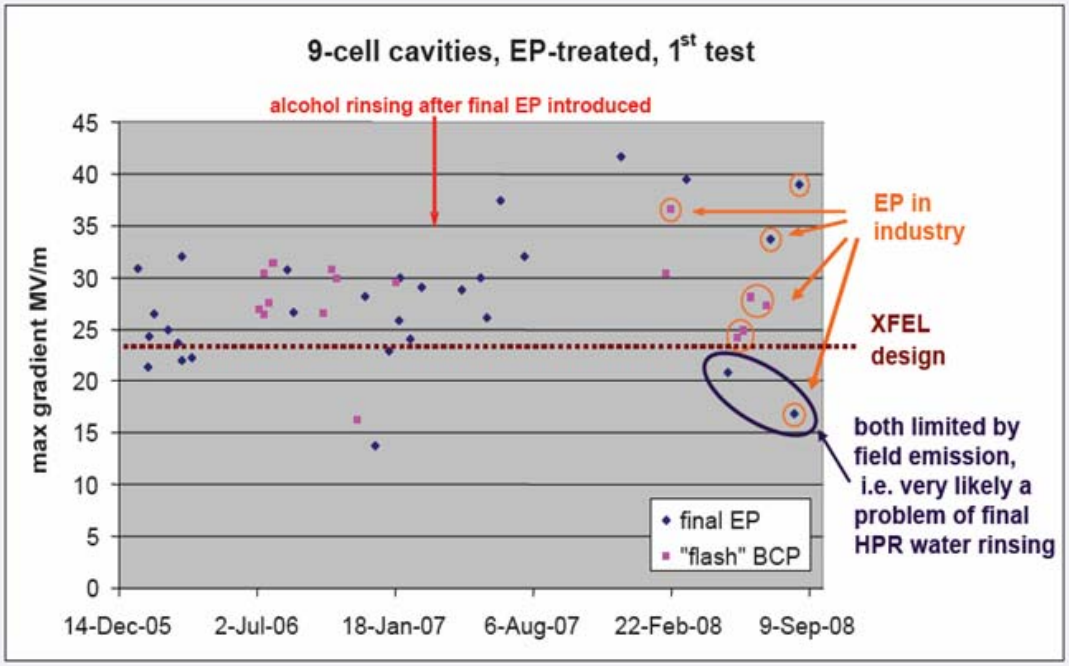


Lilje, Reschke, LINAC08

Alcohol Rinsing after Final EP Reduces Field Emission

The European X-Ray Laser Project XFEL

Cavities since Jan 2006, 1st test



Hans Weise, DESY
TTC Meeting, New Delhi, October 20 - 23, 2008

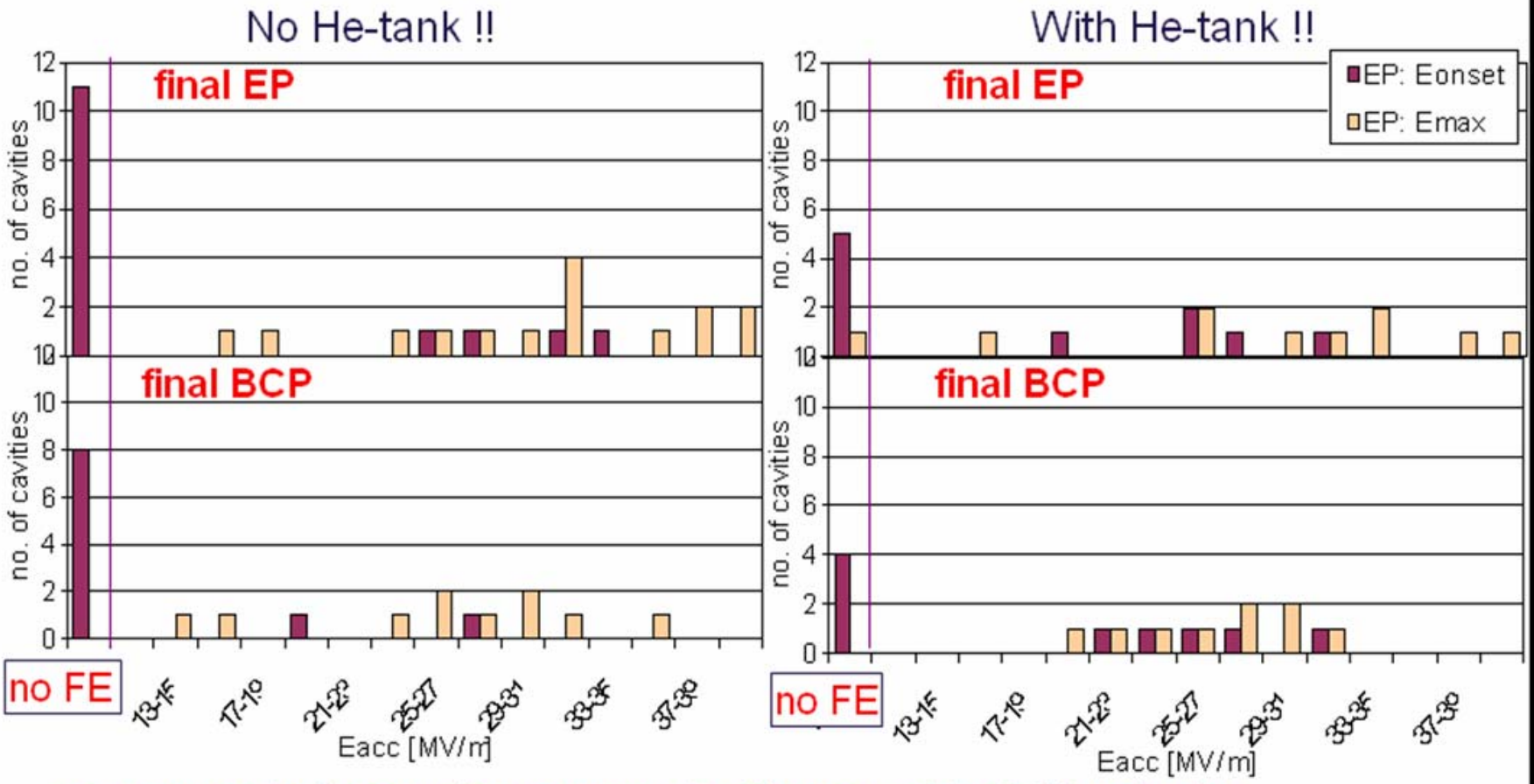
DESY HELMHOLTZ GEMEINSCHAFT 20

Weise, TTC meeting at New Delhi, 2008

Van der Horst et al., SRF20

European XFEL

Final preparation: Analysis of final test



=> as expected: some improvement with respect to field emission

=> "final EP" gives higher E_{max} than "final BCP"

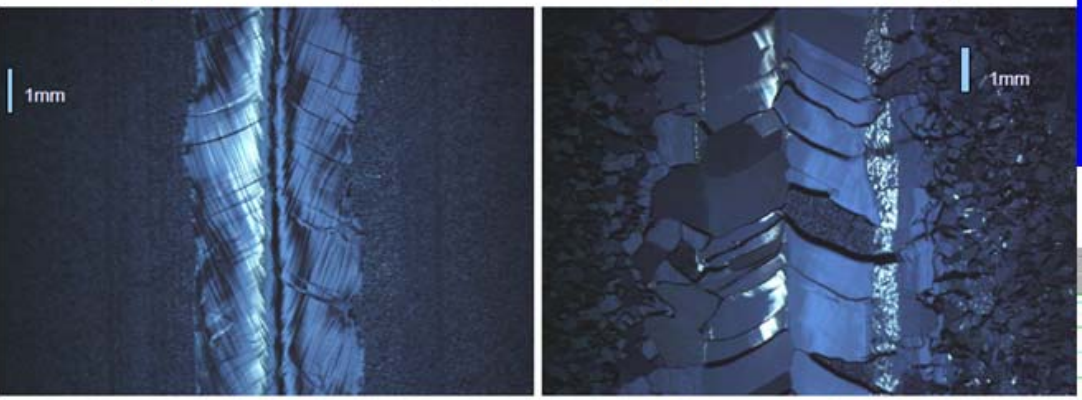
Presented at TILC09 by L. Li

D. Reschke, to be published SRF 2009

DESY 9-cell T-mapping & Optical Inspection

Evolution of defects: Z137

Equator #1 at 23 deg. | Equator #1 at 20 deg.



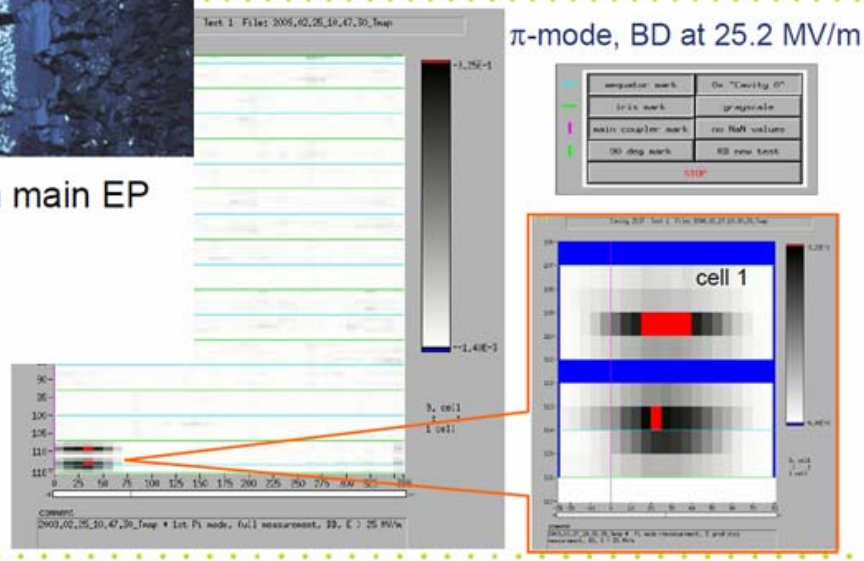
Before treatment | After 108 μm main EP

- Equator #1 shows large steps and rough grains after main EP
- All other equators normal

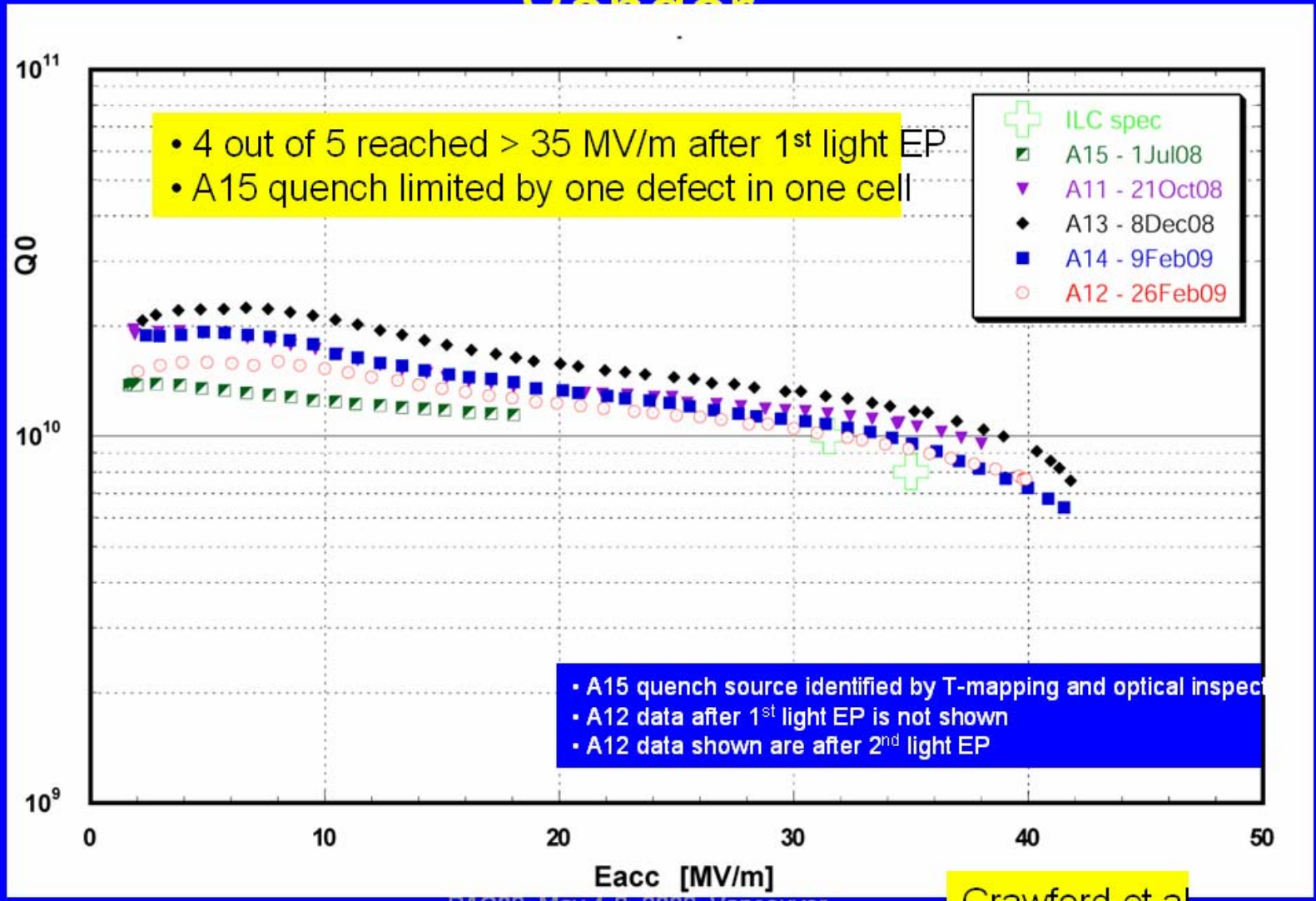
S. Aderhold, TILC09

T-map of Z137

π-mode, BD at 25.2 MV/m

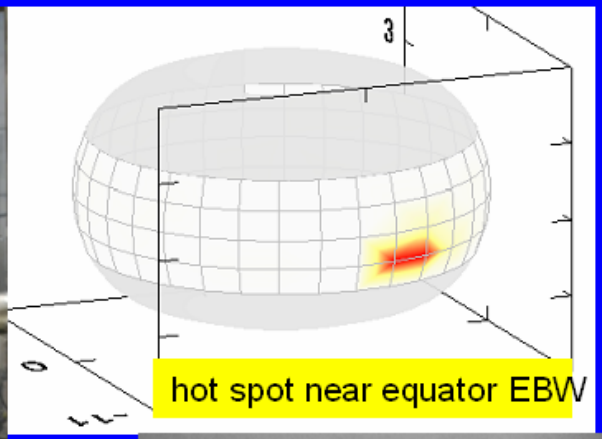


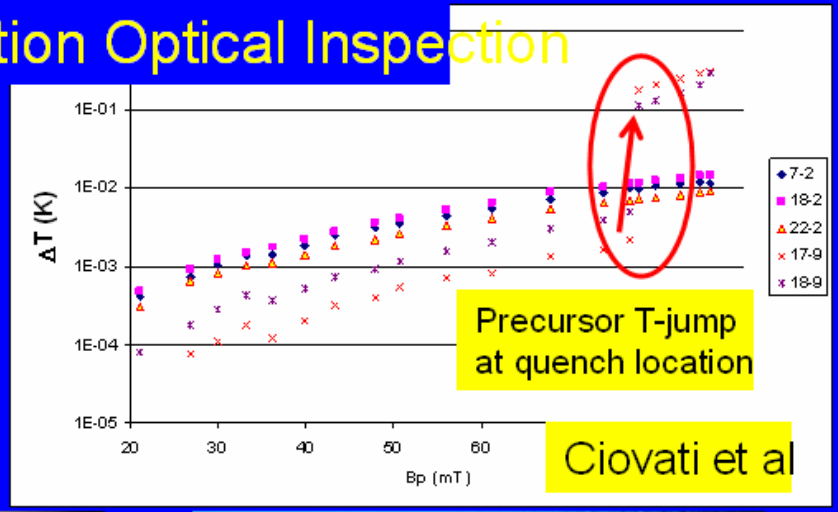
Latest JLab Results of 9-cell from One Vendor

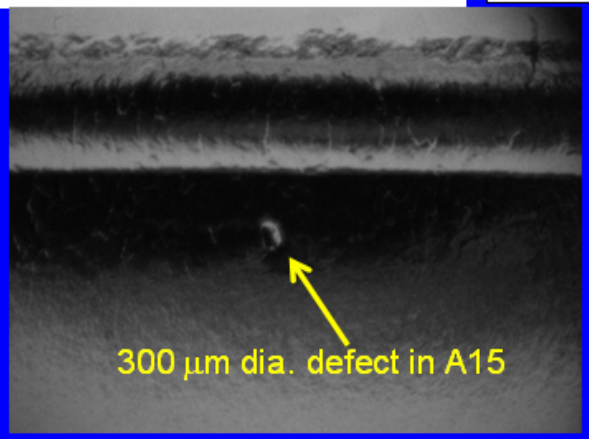


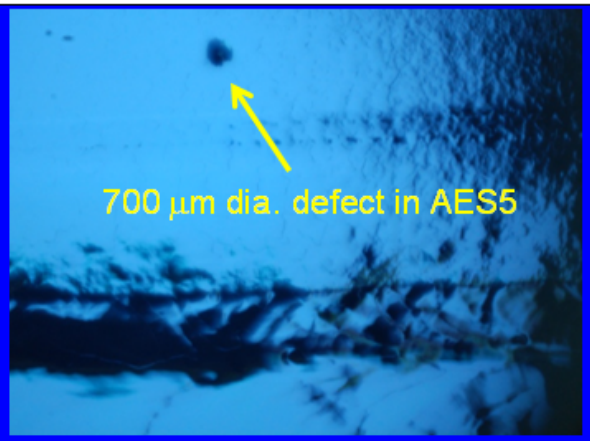
Crawford et al

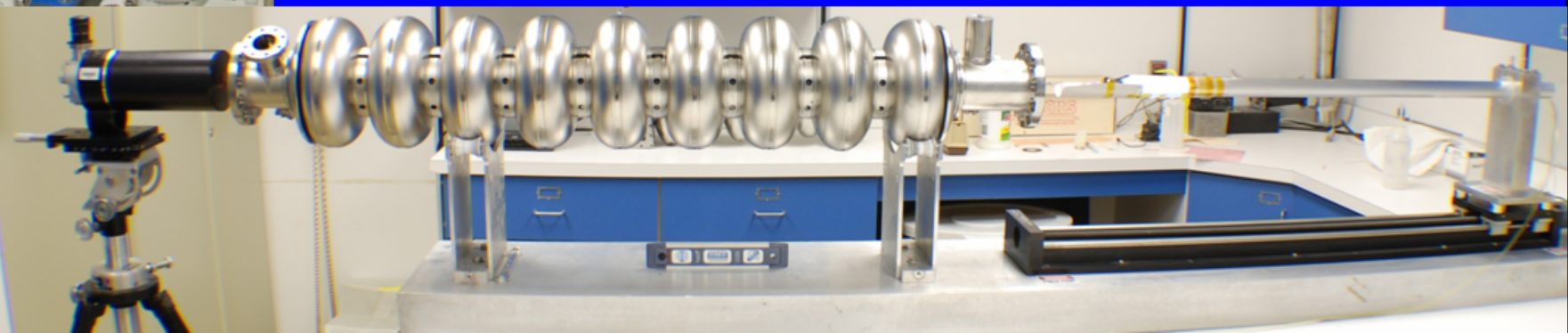
JLab T-mapping and High-Resolution Optical Inspection



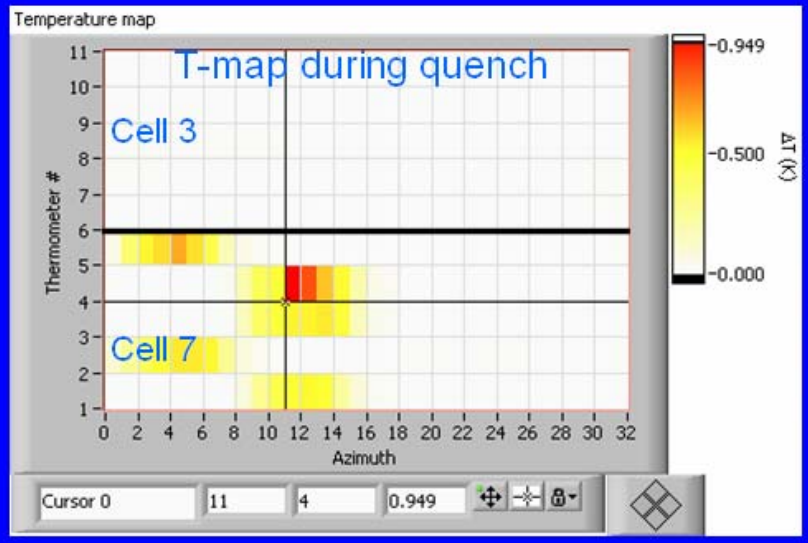


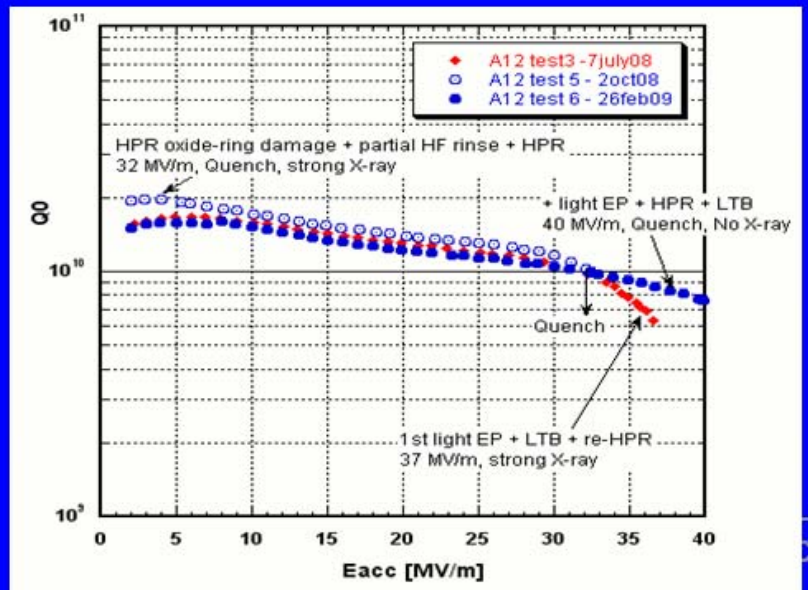






32 MV/m quench (A12) Study and Recover to 40 MV/m by Re-EP

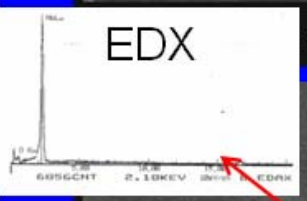




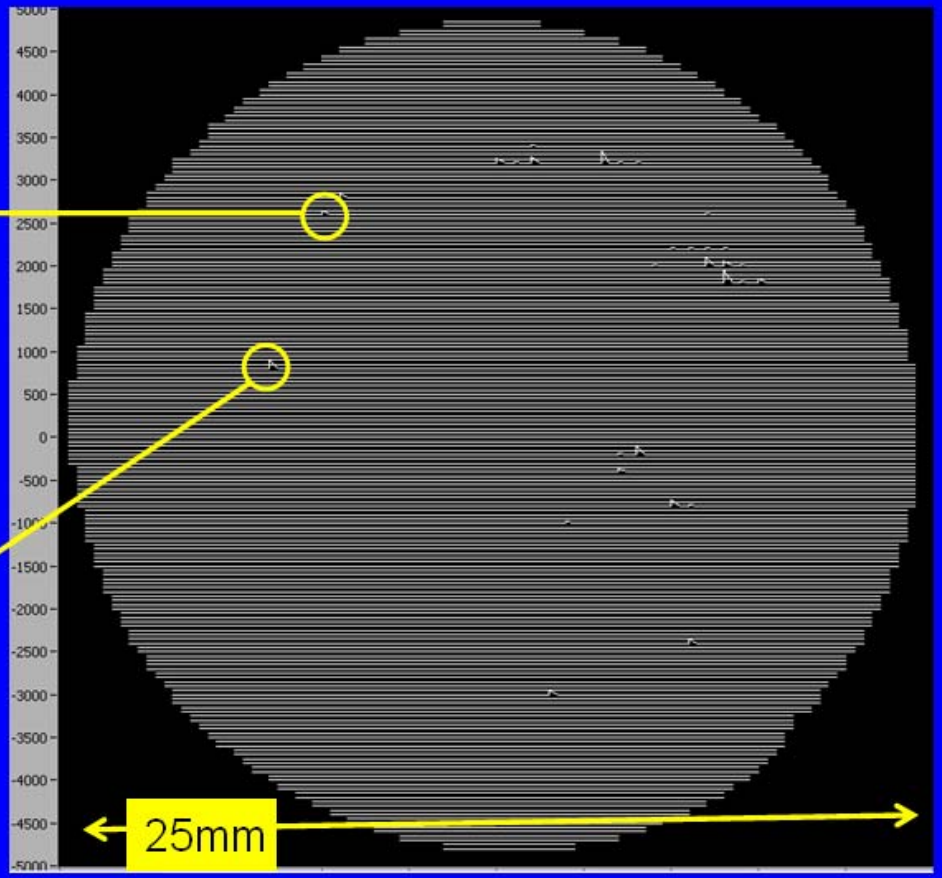
Cell 7 equator EBW seam

No gross defect observed at quench location

ab Surface Studies Reveal Nb-O Granules to be Field Emit

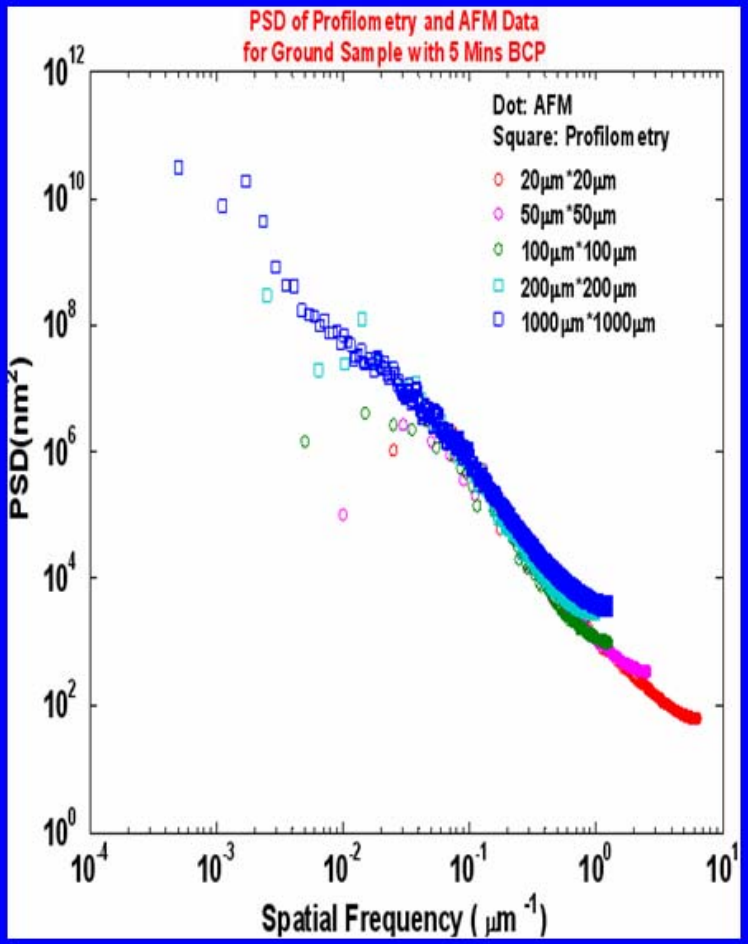


A. Wu

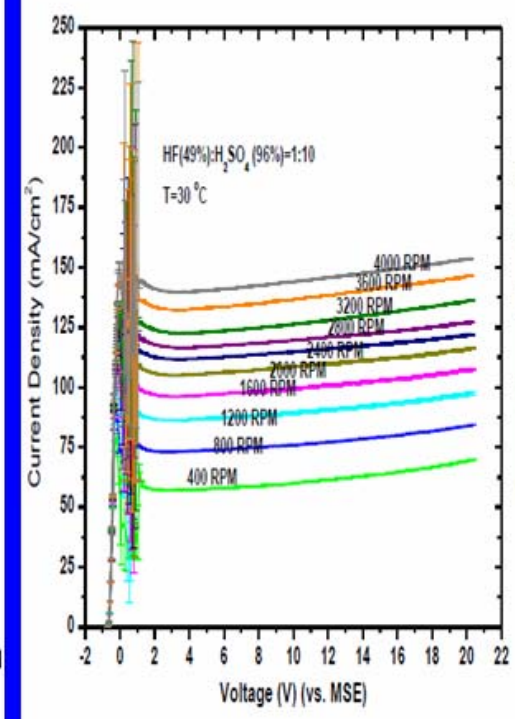


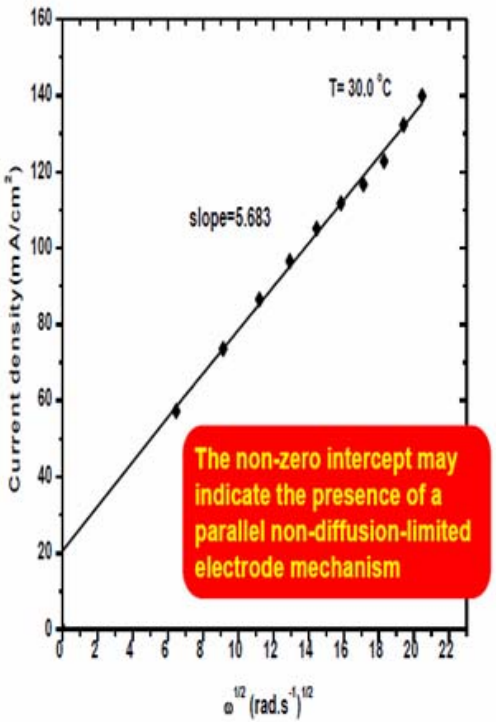
- Nb sample EP'ed together w/ 9-cell cavity
- Now JLab EP lower temp. to reduce Nb-O granul

JLab Basic EP Studies



Rotation Disk Electrode Studies Confirms The Diffusion-Limited Mass Transport Control Mechanism

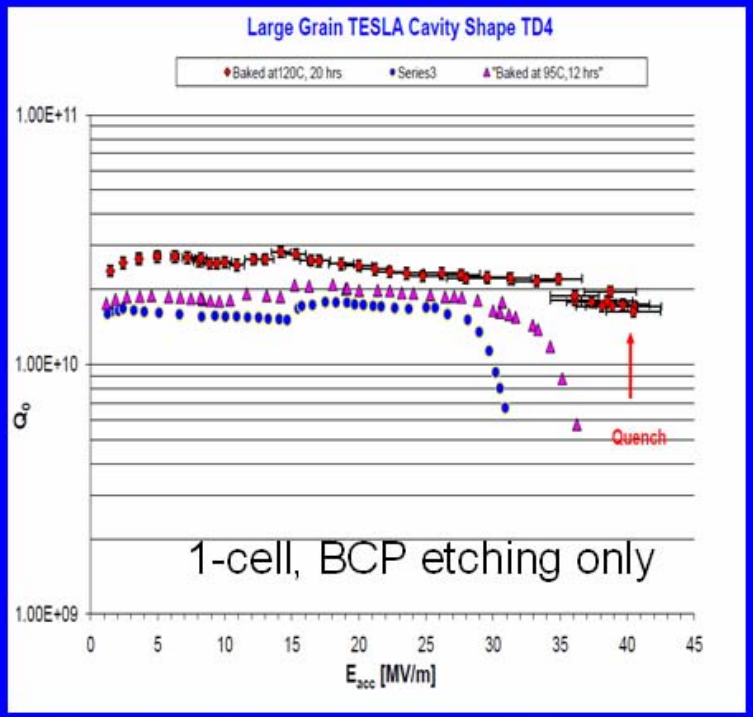




The non-zero intercept may indicate the presence of a parallel non-diffusion-limited electrode mechanism

H. Tian

JLab Large-Grain Nb Cavities



Single Crystal

- A thick sheet of a large crystal from a large grain ingot provided by CBMM has been enlarged at DESY (X.Singer, W.Singer)
- Six sheets could be prepared, large enough to deep draw half cells for TESLA/ILC – type single half cells
- We are in the process of fabricating 3 single cell cavities

Multi-cell Cavities for ILC

- The fabrication of two LL/Ichiro-type 9-cell cavities has started; niobium from CBMM and Tokyo-Denkai will be used
- The 20 sheets of TD material were sliced simultaneously by multi-wires – development done by K.Saito with Japanese Industry – with very good tolerances and surface quality.
- The sheet slicing produced very smooth surface finishes and small deviations in thickness. App. 60 sheets were slice simultaneously in only 40 hrs.

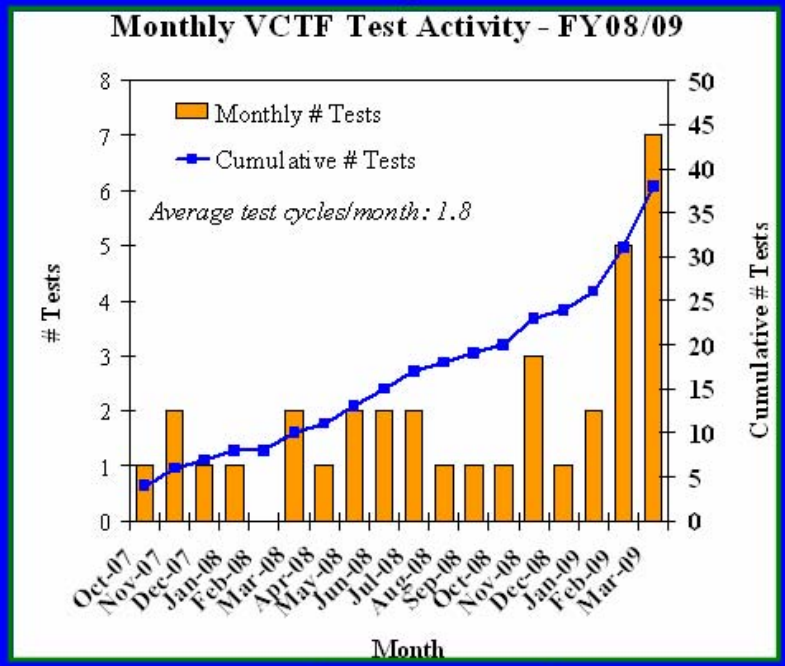
Kneisel, TILC09

FNAL Vertical Cavity Test Facility

- **35 cavity tests in FY08/FY09, where "test" = cryogenic thermal cycle**
  - **9-cell & single-cell 1.3 GHz elliptical cavities and 325 MHz HINS single-spoke resonators**
  - **instrumentation development, variable coupler, thermometry, cavity vacuum pump system, cavity vendor development**
  - **Many cavity tests dedicated to ANL/FNAL CPF commissioning**

Accel 6 w/ variable coupler

TE1ACC001 w/ thermometry
TE1ACC002



C. Ginsburg

ANL/FNAL CPF Updates

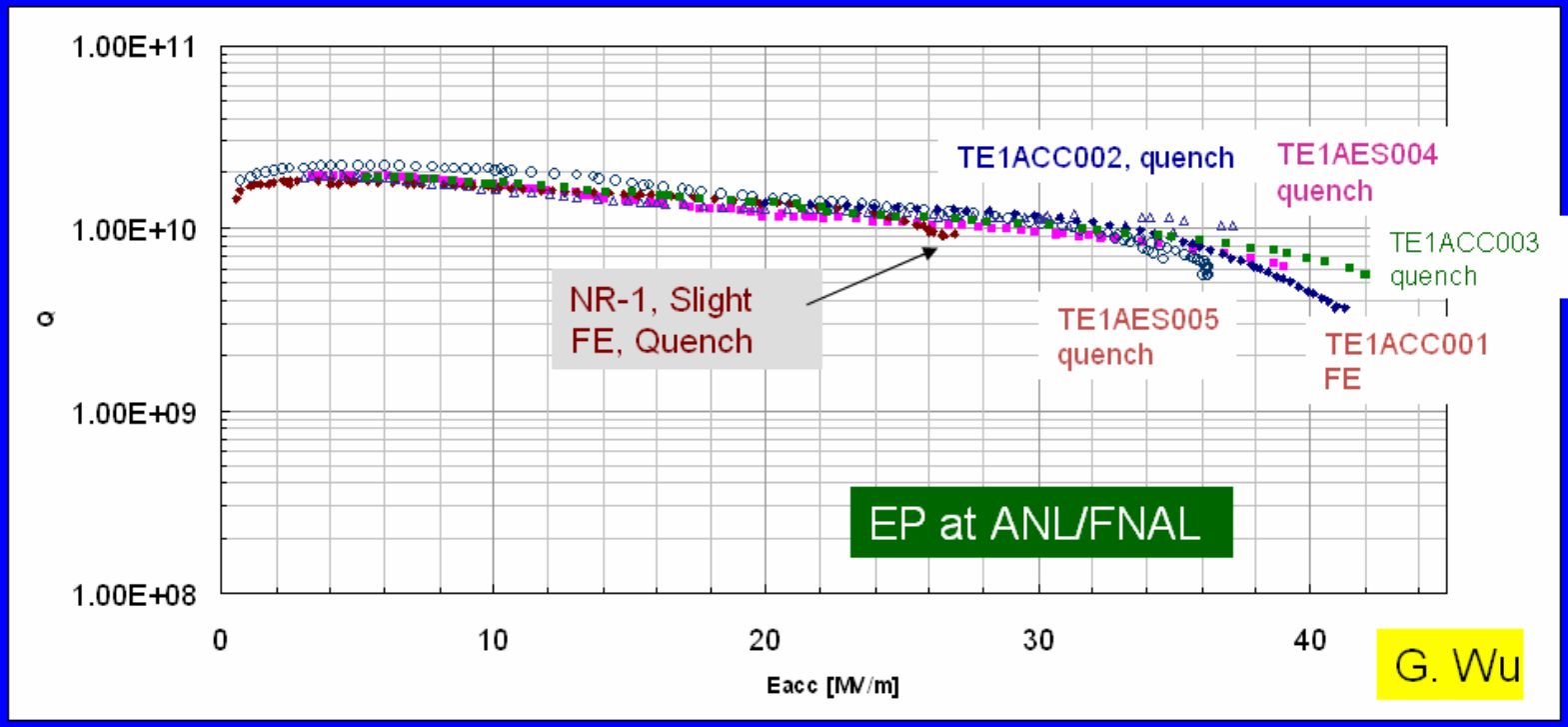
Ultrasonic rinse with gantry crane

High-pressure rinse system with cart

Cavity assembly rail, shown in vertical & horizontal orientation

Cavity vacuum system

FNAL EP single cell cavity performance



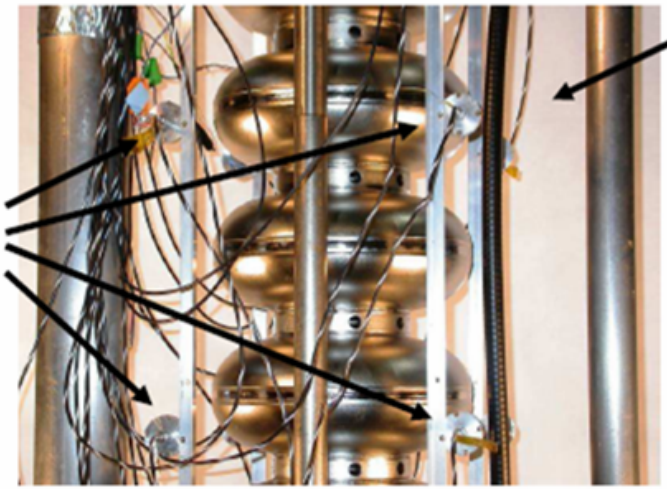
	BCP	EP	Ethanol	Eacc [MV/m]	Notes
NR-1	150	93		26.5	Oxidation by acid residual
TE1AES004	107	65		39.2	Equator large pit present
TE1AES005	104	100	Yes	36.3	Oxidation by HPR water
TE1ACC002		112	Yes on second	37.1	
TE1ACC001		99		41.3	FE appeared after 120°C baking
TE1ACC003		119		42.1	Pit present
TE1ACC004					

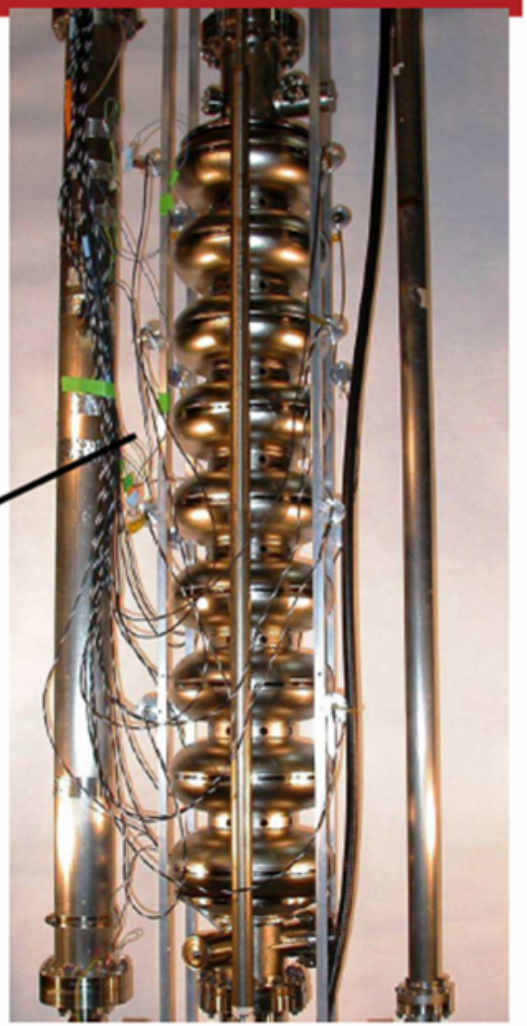
FNAL Cavity Inventory

Tesla-shape nine-cell cavities		
Description	**No. Cavities**	**Status**
AES 1-4	4	tested
AES 5-10	6	received; testing in progress
AES 11-16	6	due Oct 2009
Accel 6-9	4	tested
Accel 10-17	8	received Mar 2008; testing in progress
Accel 18-29	12	due May 2009
Jlab fine-grain 1-2	2	fabrication complete; testing in progress
Niowave-Roark 1-6	6	due Oct 2009
Stimulus Procurement	xx	still in the planning stages; assume first cavities ~April 2010
Total	**48**	
Already Received	24	
Tesla-shape single-cell cavities		
Description	**No. Cavities**	**Status**
AES 1-6	6	tested at Cornell; further testing in progress
Accel 1-6	6	received Dec 2008; testing in progress
Niowave-Roark 1-6	6	received Jun 2008; testing in progress
PAVAC	4	requisition in progress
Total	**22**	
Already Received	18	

2nd Sound Quench Detection

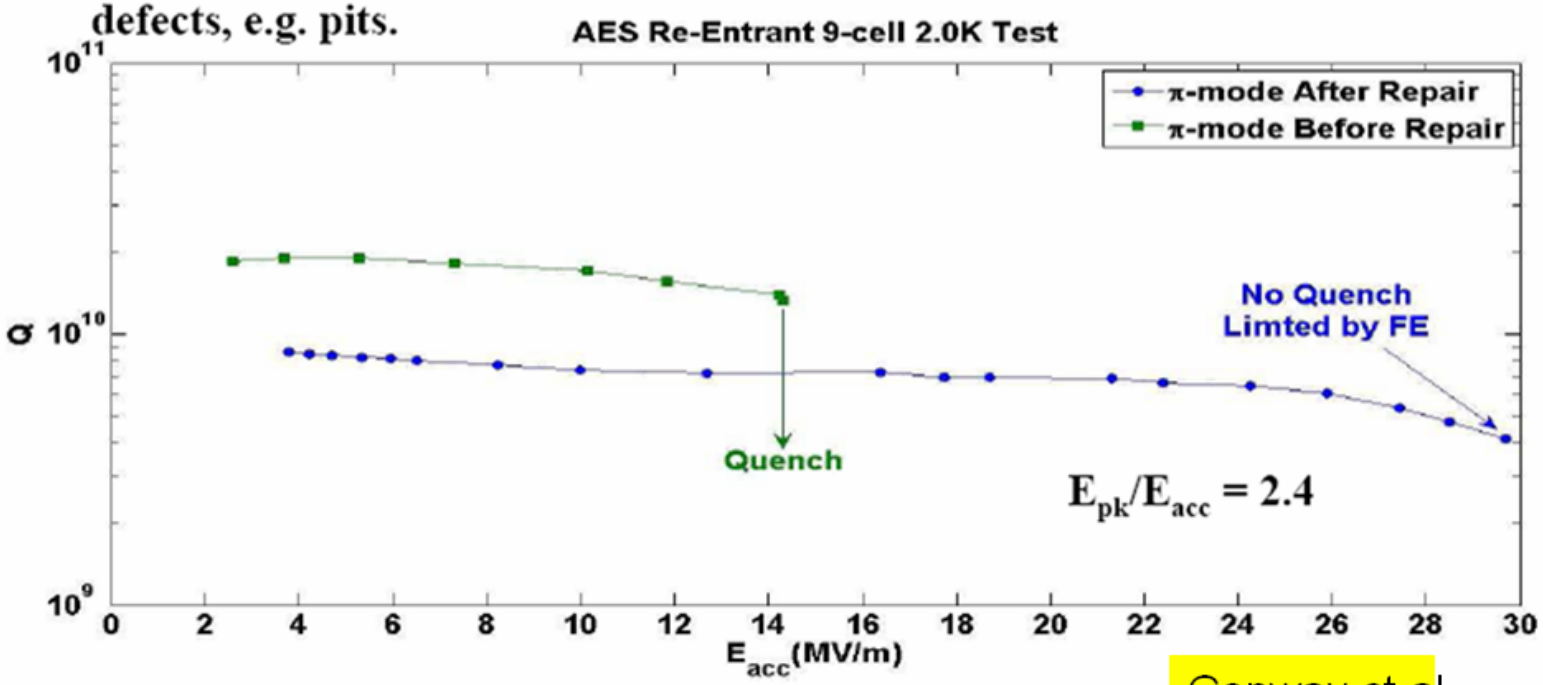
- We have demonstrated that 2nd sound detection can locate multiple quench locations in a single 9-cell cavity cold test
- By exciting different TM_{010} pass-band modes of a 9-cell cavity different cells can be driven to quench.
- This technique is simple, low cost, and quick to implement.





AES Fabricated 9-Cell Cavity Weld Pits Repaired

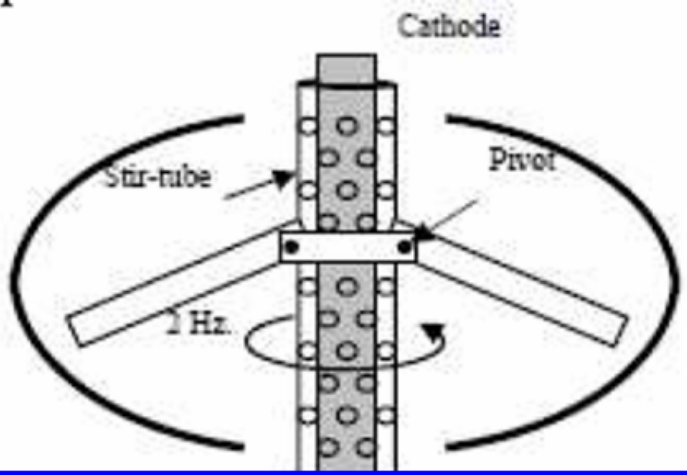
- We have successfully repaired an AES 9-cell cavity with tumbling and VEP.
- This cavity originally quenched at E_{acc} = 15 MV/m at a weld pit in the first cell, after tumbling and reprocessing E_{acc} > 30MV/m.
- When excited in the 5π/9-mode a peak fields of 89 MV/m and 1400 Oe were reached in the center cell. This corresponds to E_{acc} > 37 MV/m.
- This test demonstrates that tumbling is an effective option to repair weld defects, e.g. pits.



Conway et al

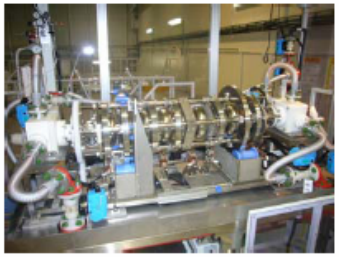
Vertical Electropolish Proven Effective

- We have demonstrated gradients >35 MV/m in individual cells of two 9-cell cavities processed with vertical EP.
- In each test the π-mode was limited by quench.

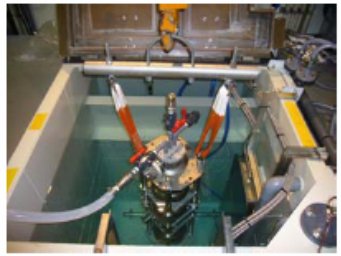


A Cycle of Vertical Test at STF KEK

Flange-CP



EP



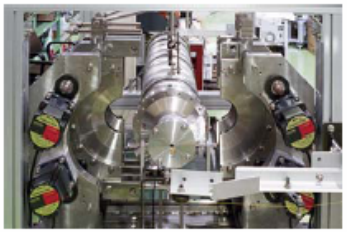
Hot bath Rinsing

HPR

Assembly (Class 10)

Infrastructure in the STF Hall

System check with AES#1 cavity was carried out in Oct., 2008.



Pre-tuning fo adjustment

Inspection of Inner Surface

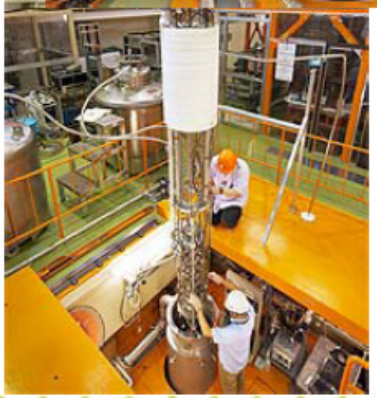
Vertical Test

Hanging Stand

Baking (Class 1000)

Vertical Test at STF KEK

New vertical test system was completed in July 2008.



1. Surface Inspection System

2. Temperature Mapping System

3. Passband-modes Measurement

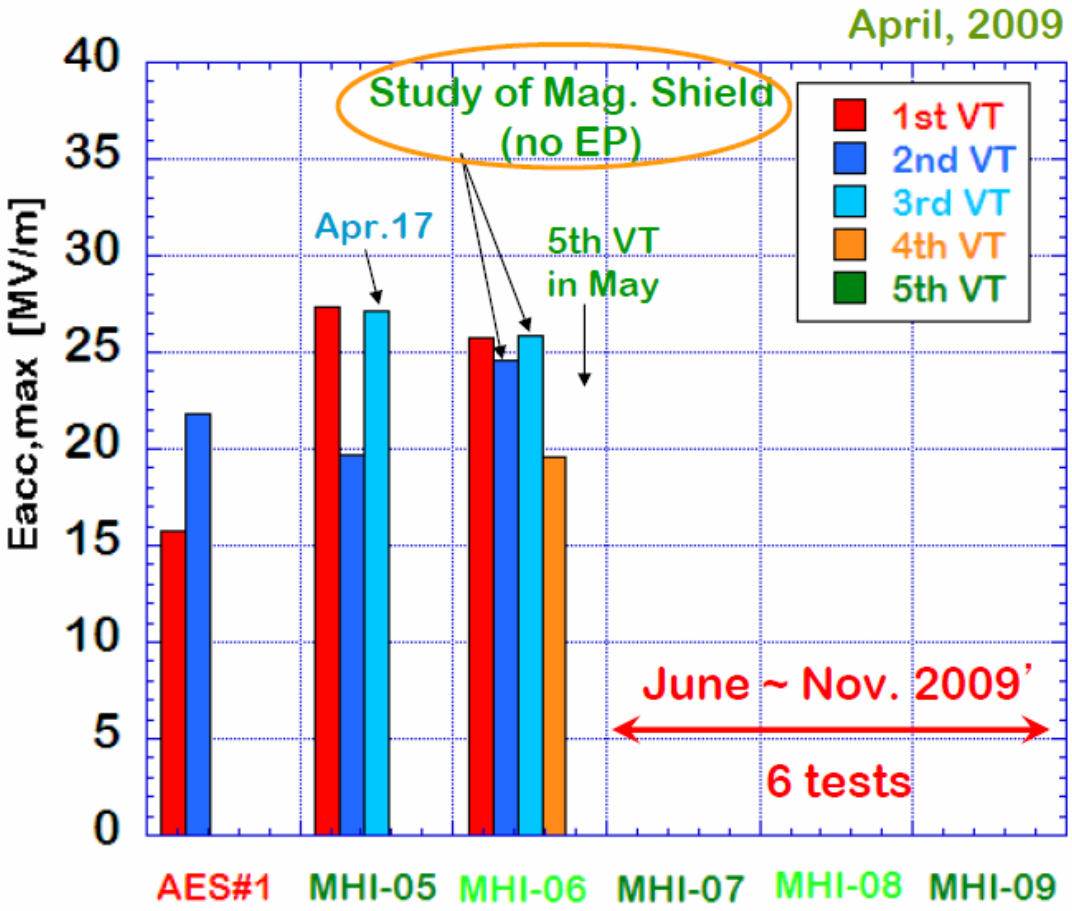
E. KAKO (KEK)
2009' April 18

TILC'09 @Tsukuba
Global Design Effort

E. Kako

4

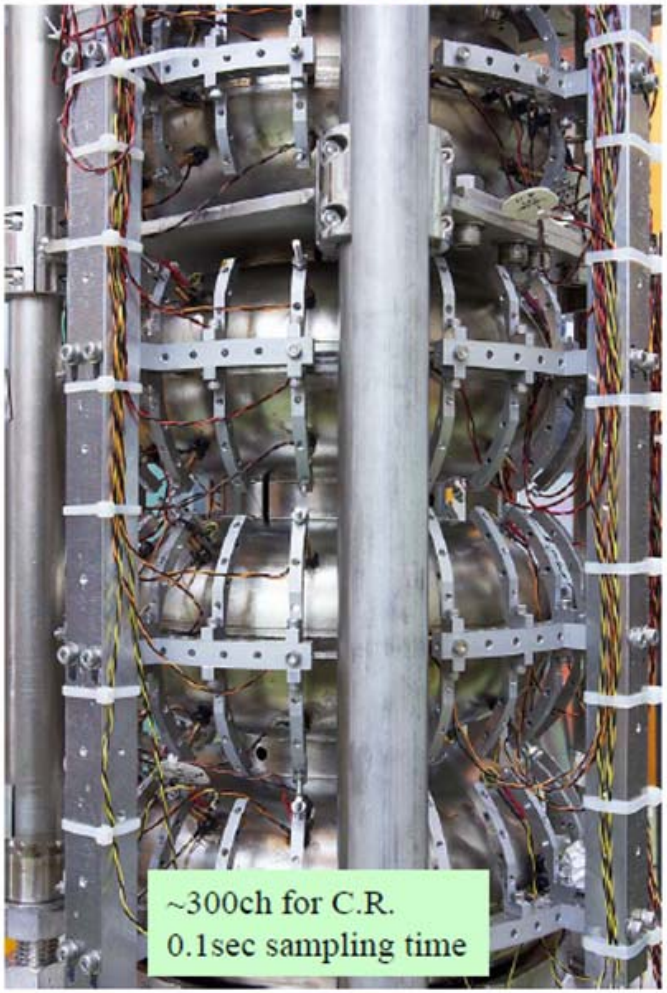
Summary of V.T Results at STF

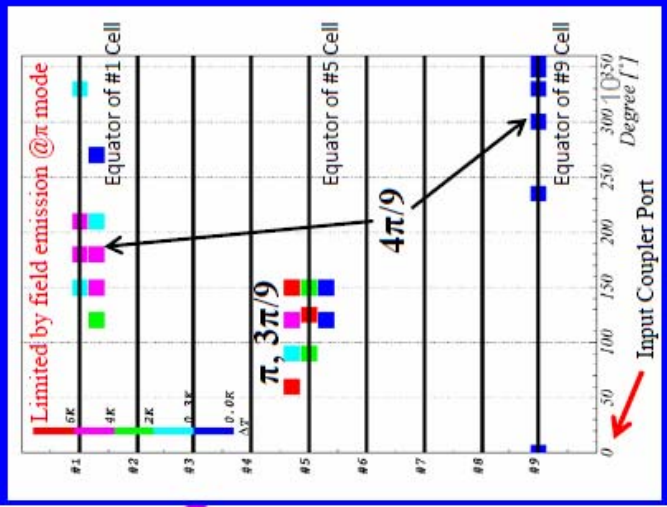


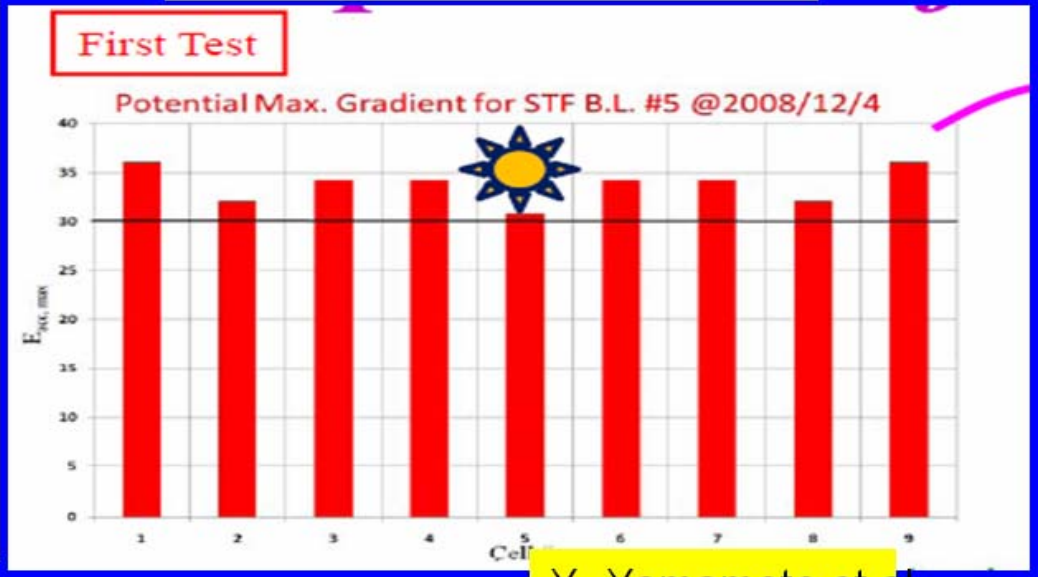
E. Kako

KEK T-mapping New 9-cell Cavities

Fish-bone structure



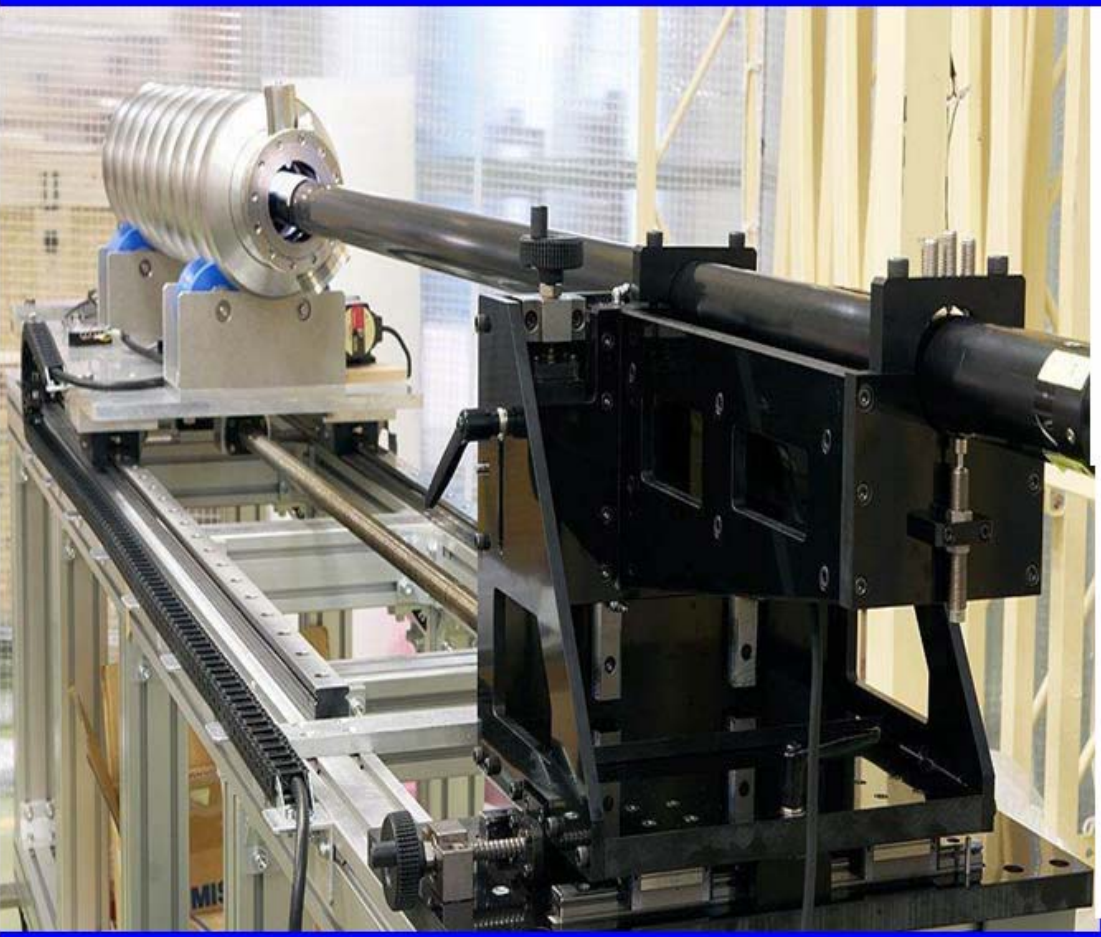


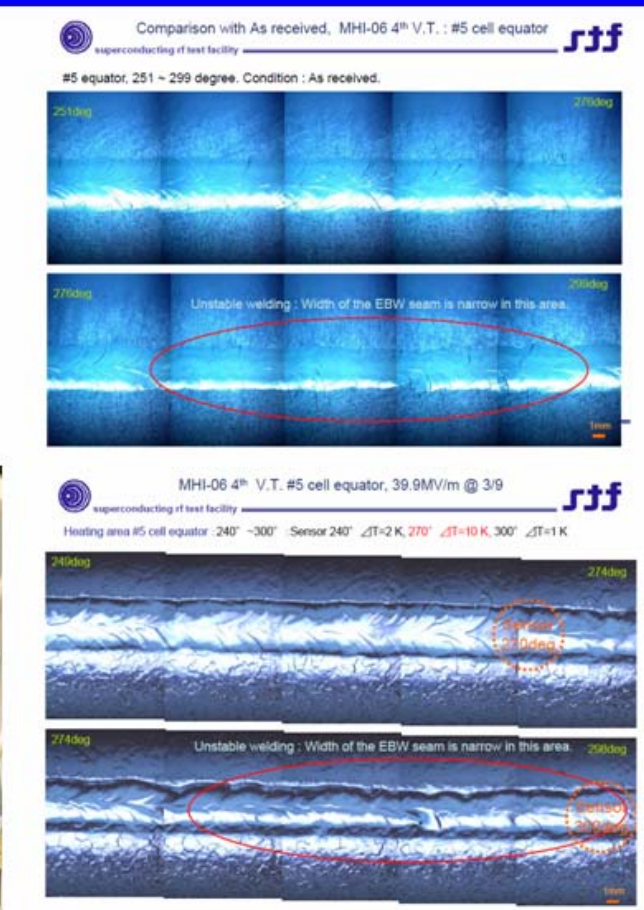


Y. Yamamoto et al

KEK Optical Inspection new 9-cell Cavities

Before & after EP – reveals unstable weld possible cause for quench

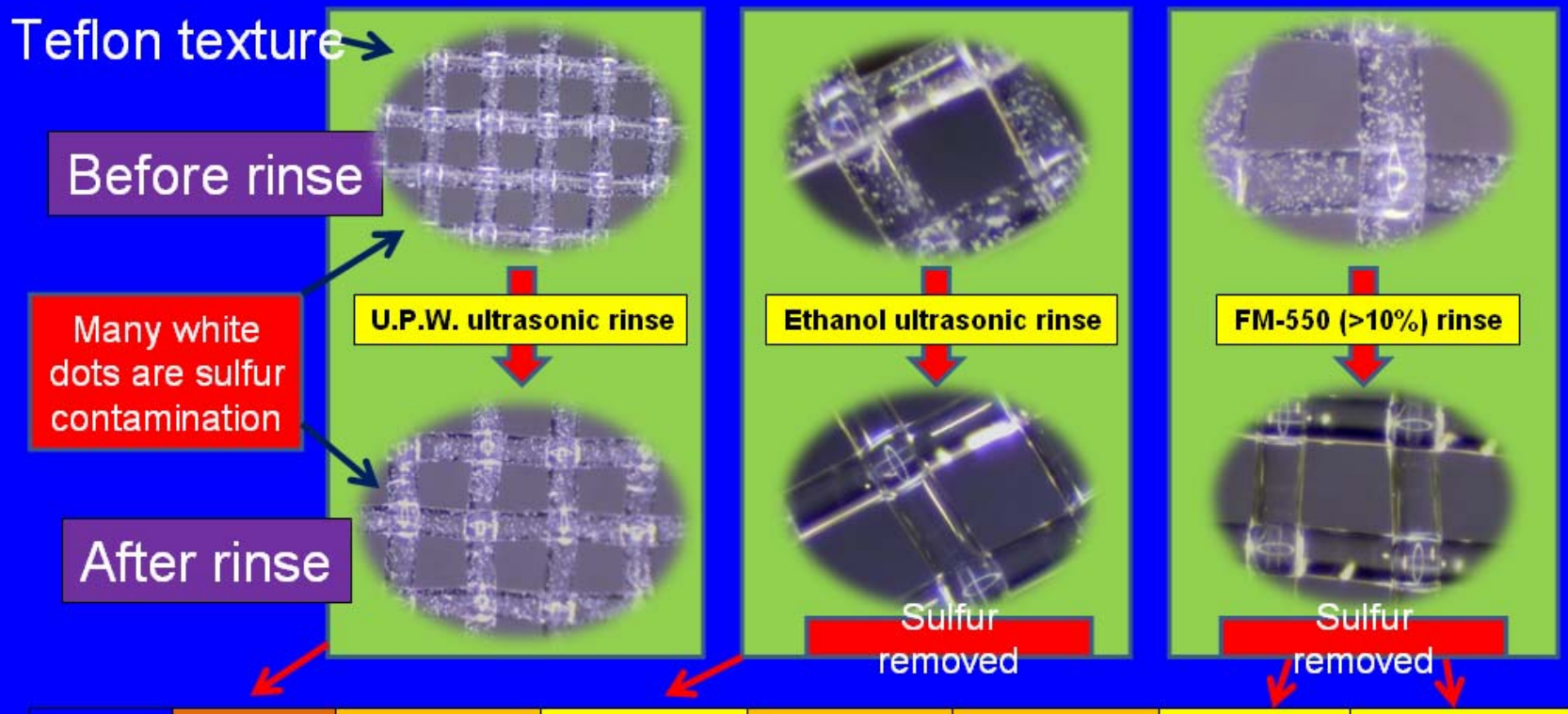




K. Watanabe et al

KEK Rinse Effect to Remove Sulfur precipitation/contamination

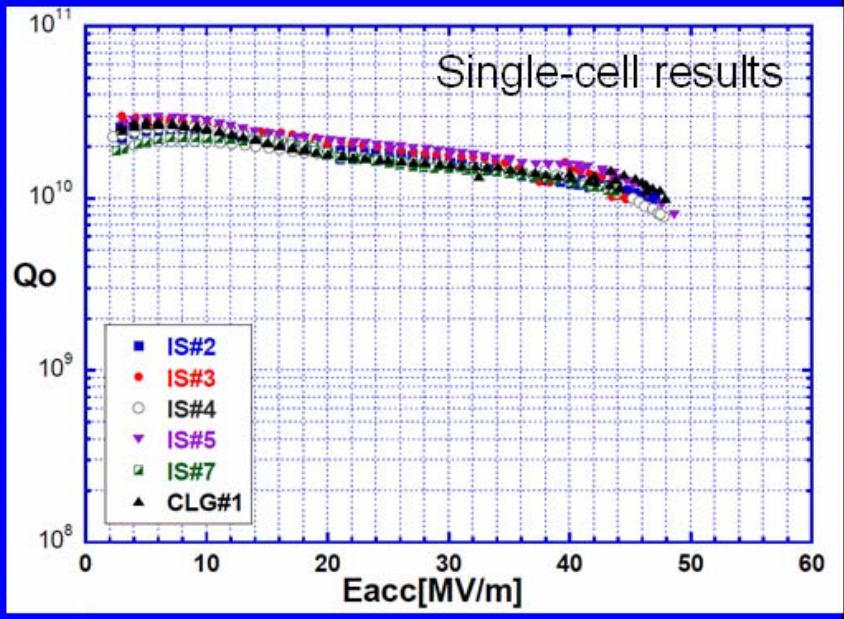
T. Saeki



	U.P.W. ultrasonic rinse	Ethanol rinse (vibration)	Ethanol ultrasonic rinse	Detergent FM-550 2 %	Detergent FM-550 5 %	Detergent FM-550 10 %	Detergent FM-550 20 %
Cleaning Result	×	□	○	□	□	○	○

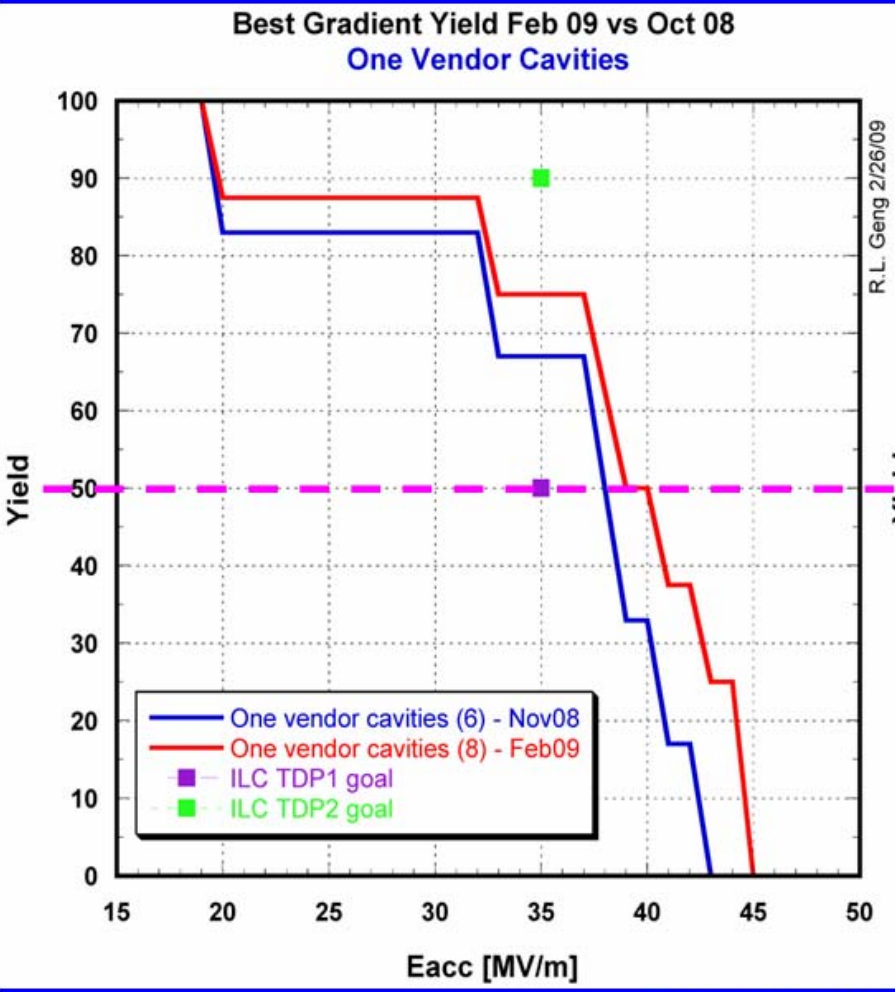
KEK New ICHIRO 9-cell Cavities

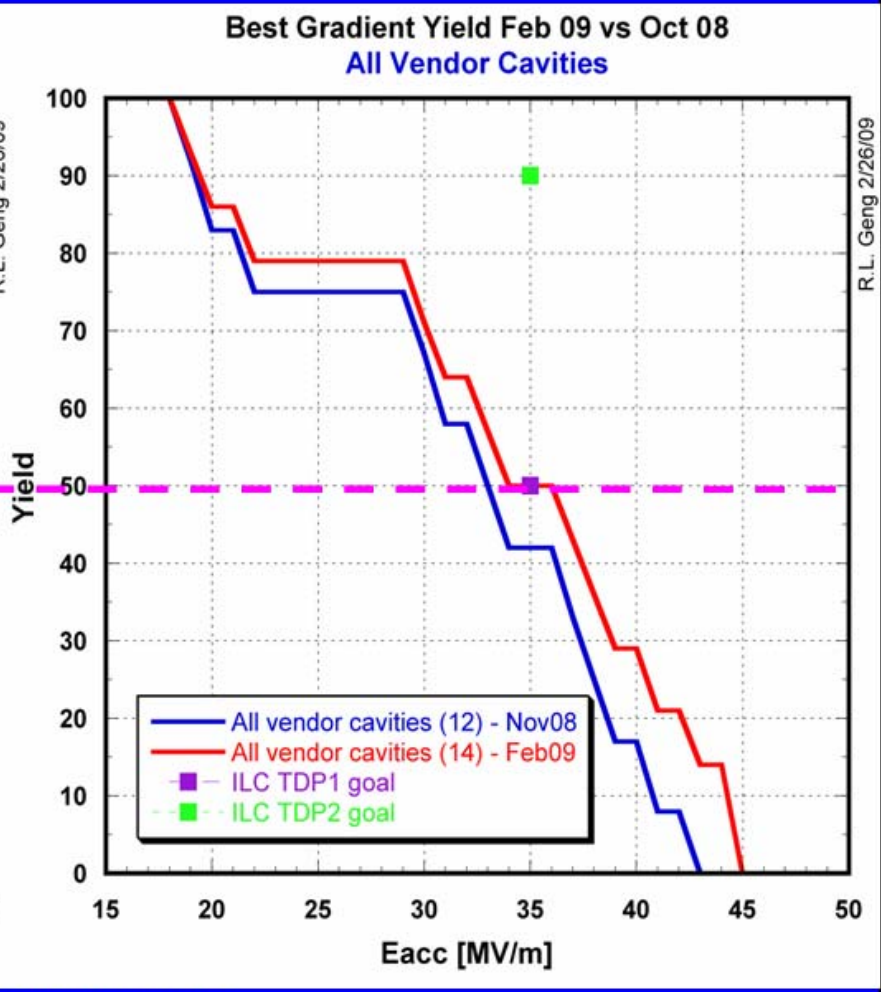
- Two bare cavities tested
- One reached 36.5 MV/m so far (KEK/JLab collal
- Two full cavities fabricated (one sent to JLab)
- One full cavity fabricated with large-grain Nb



K. Saito

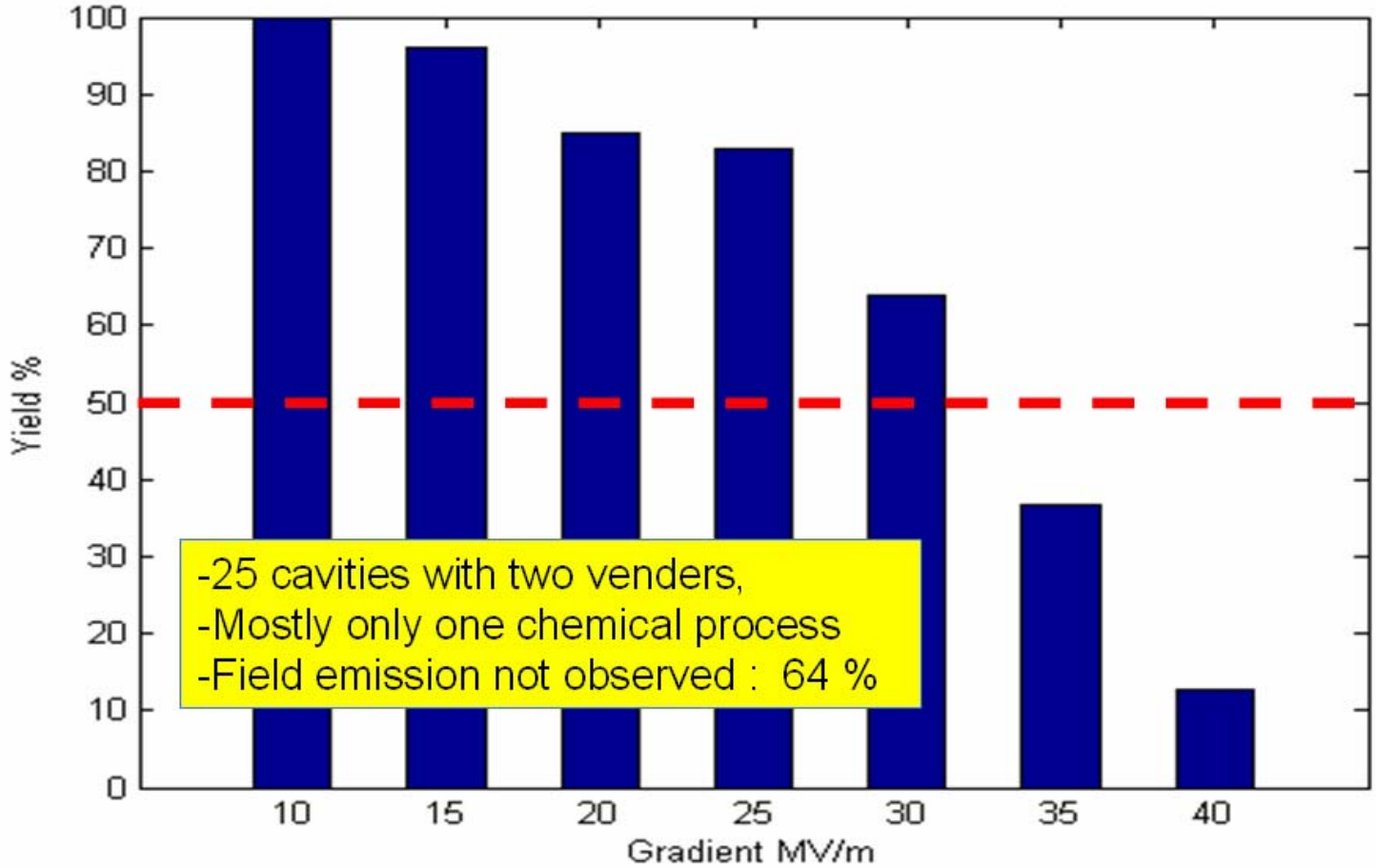
Recent Gradient Yield Progress at JLab



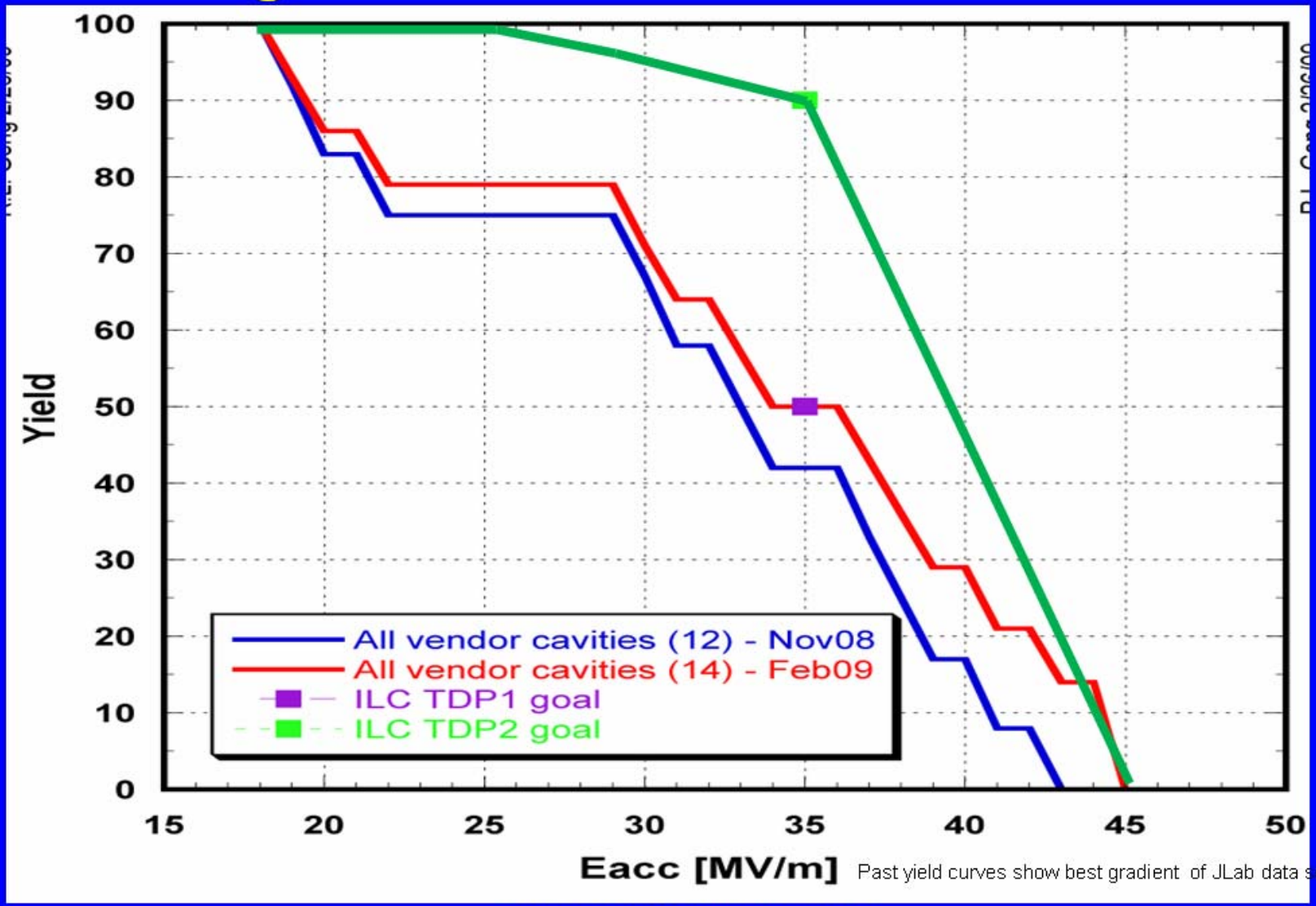


Recent Progress in Yield at DESY

Data provided by D. Reschke, and reassembled by M. Ross

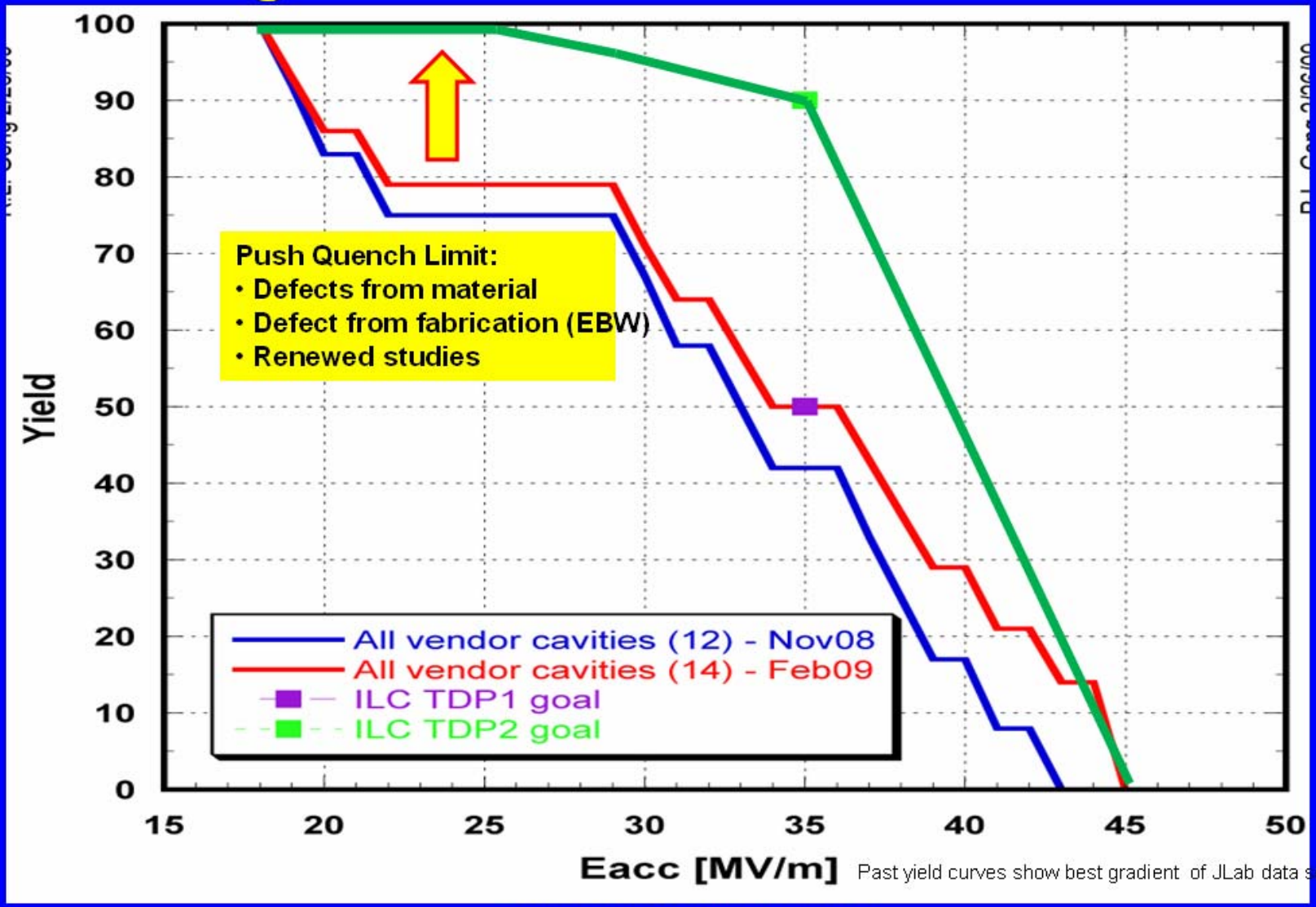


Two Big Pushes Ahead…



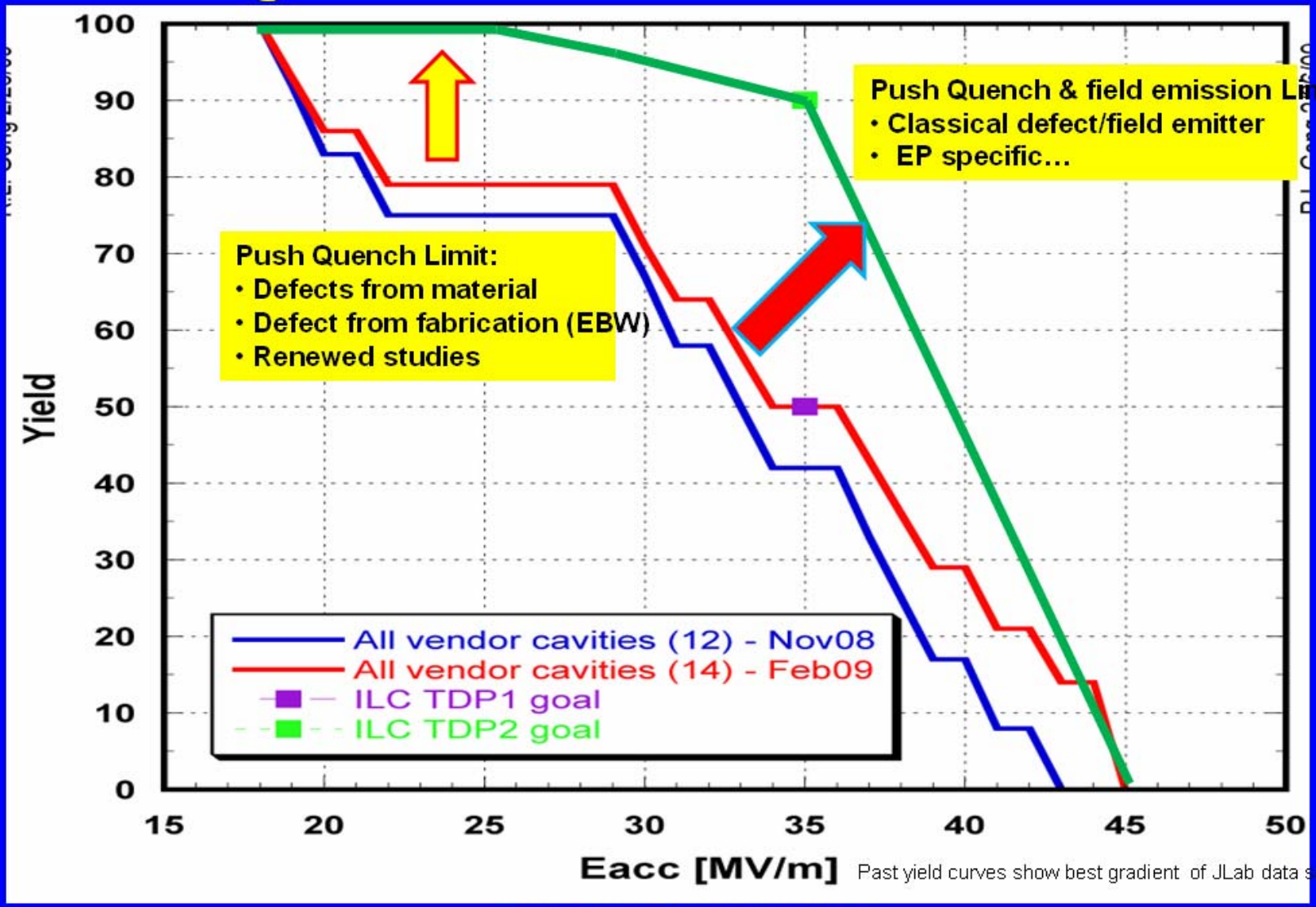
Past yield curves show best gradient of JLab data set

Two Big Pushes Ahead…



Past yield curves show best gradient of JLab data set

Two Big Pushes Ahead…



Past yield curves show best gradient of JLab data set

Summary

- Progress being made pushing yield curve
  - Shown by both DESY data and JLab data
  - Several cavities demonstrated > 35 MV/m after first light EP
  - Expect more statistics (> 60 cavities) 2009-2010
- Field emission much reduced
  - Shown at DESY (alcohol rinsing) and at JLab (ultrasonic + detergent)
  - 1st demonstration of 40 MV/m w/o detectable Bremsstrahlung X-ray
  - Further understanding needed for further improvement
- Quench understanding improved
  - Yield drop 15-20 MV/m partly due to defect in equator EBW HAZ
  - Most cases at JLab: one defect in one cell; other cells 32-44 MV/m
  - Local repair seems to be the way to go for raising yield (besides QA)

Summary (cont.)

- Global effort ramping up
  - FNAL infrastructure (EP, VTA) commissioned; excellent 1-cell results
  - KEK STF infrastructure commissioned
  - > 60 cavities expected 2009-2010
- Laboratory-Industry collaboration ramping up
  - European industry heavy EP demonstrated
  - First America cavity vendor meeting at FNAL – feedback info to cavity vendor
  - ILC PM's visit to ACCEL, ZANON, MHI, AES, NIOWAVE/ROARK, PAVAC
- Outlook encouraging
  - Further progress along base line seems possible
  - Great potential along alternative line

A Canadian company to be visited during PAC09