ILC Long Term Cavity R&D

Overview

Rong-Li Geng

Jefferson Lab & GDE

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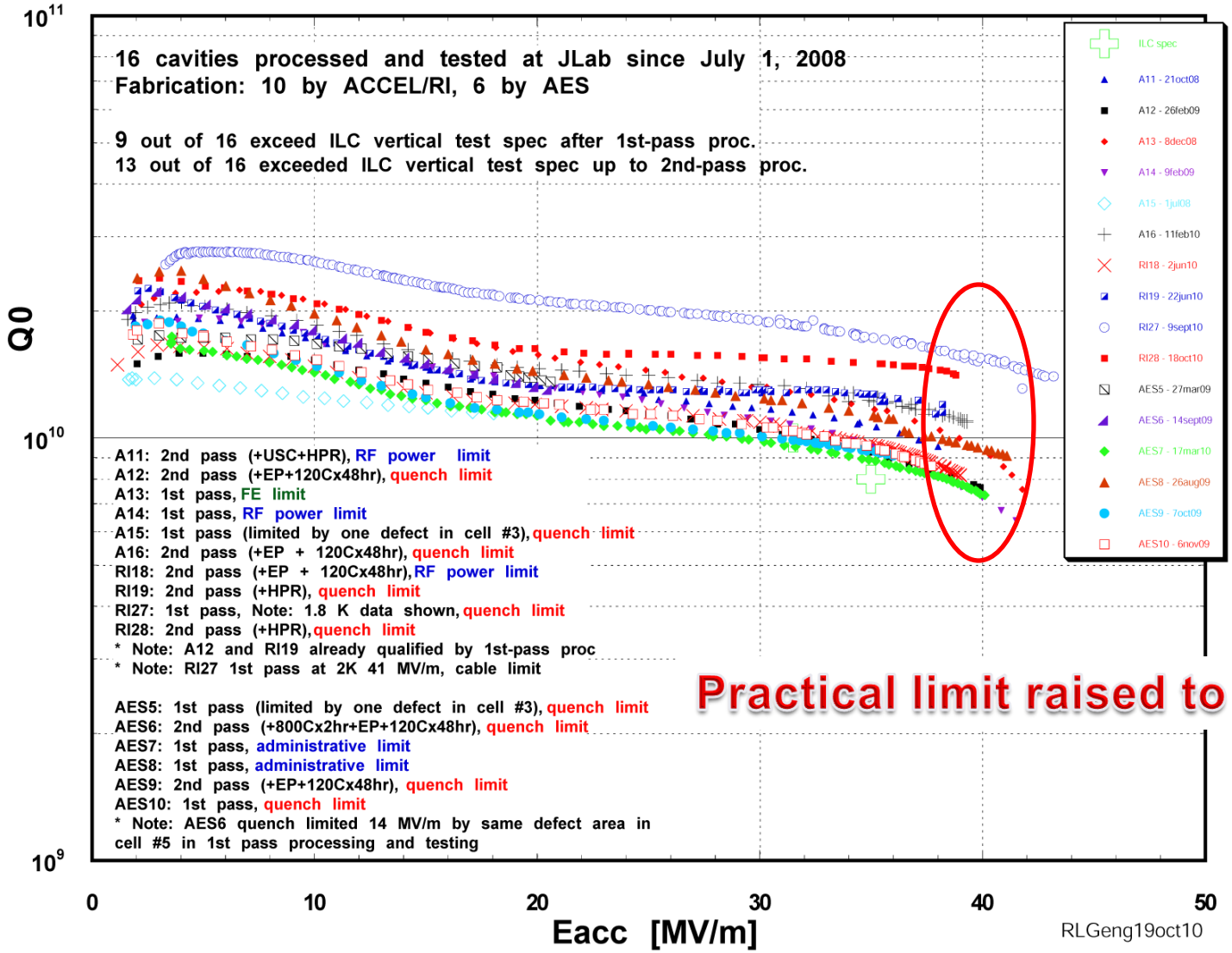
Outline

- Baseline cavity state-of-the-art and near term R&D plan
- Cavity cost reduction or value engineering
  - **Seamless cavity**
  - **Large-grain material cavity**
  - **Vertical EP**
  - **Alternative bulk removal by mechanical polishing, BCP etc.**
- ILC TeV upgrade cavity options
  - **Low-Loss shape cavity**
  - **Re-entrant shape cavity**
  - **LSF shape cavity**
- Very-high-gradient phenomena
  - **Quench**
  - **Sudden field emission turn on**
  - **HOM coupler heating**
- Revolutionary solutions for ultra-high gradient cavities
  - **Atomic layer deposition**
  - **New material cavities**

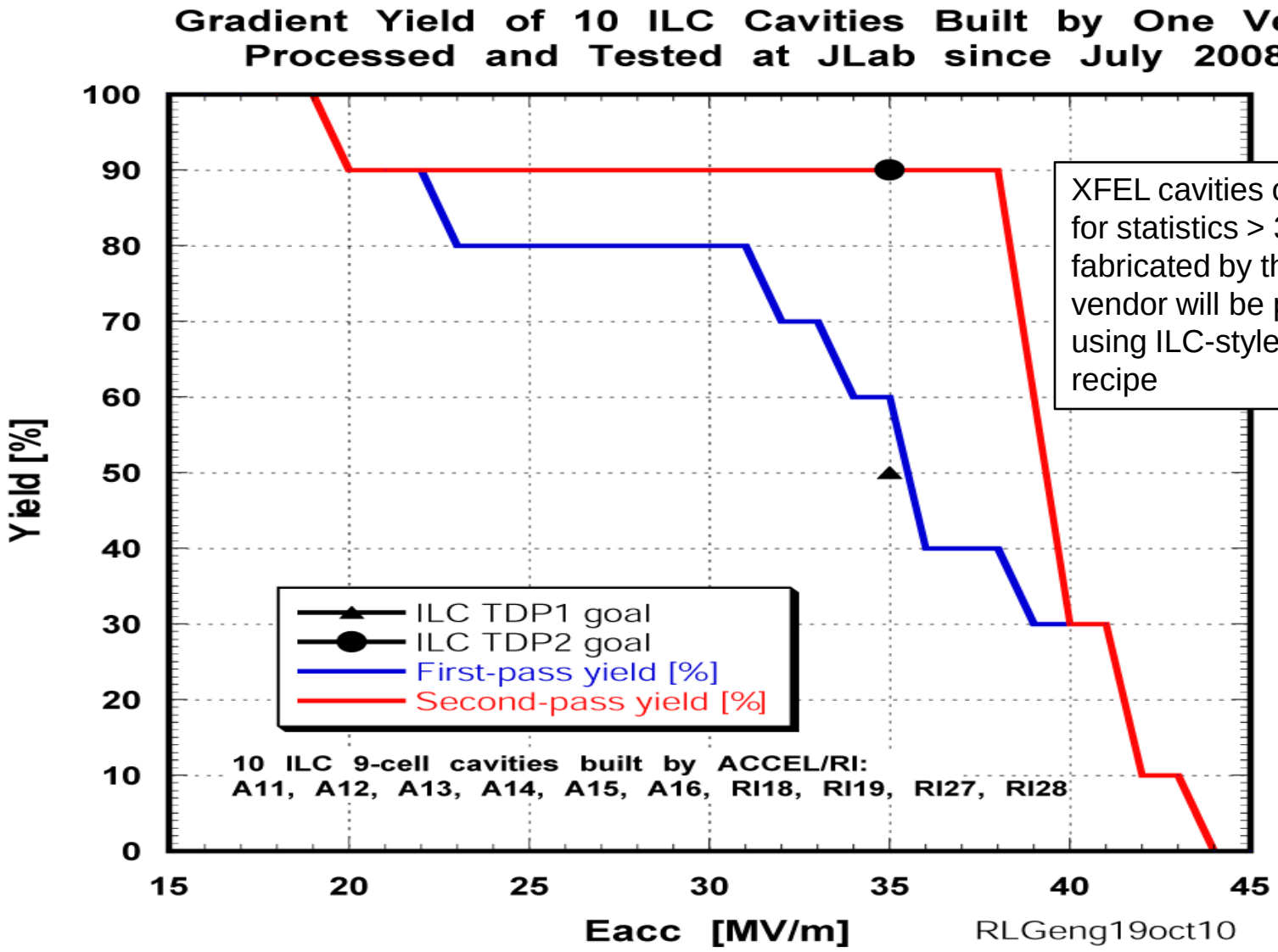
Baseline Cavity State-of-the-art and Near Term Plan

TESLA-Shape EP'ed 9-Cell Cavities



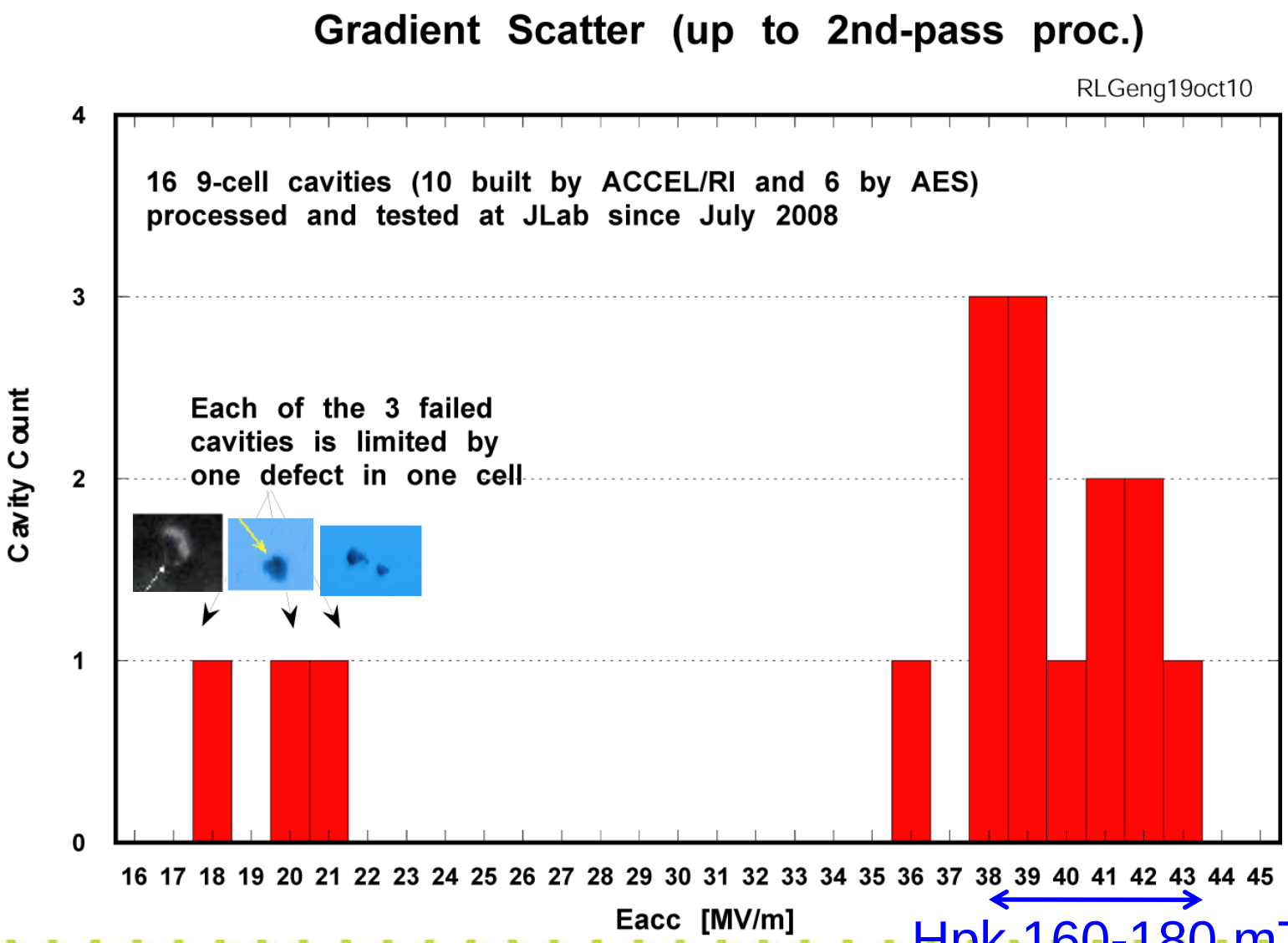
Practical limit raised to 38-42 MV/m

An Example of 90% Yield at 35 MV/m w/ Q0 ≥ 8E9



XFEL cavities opportunity for statistics > 300 cavities fabricated by the same vendor will be processed using ILC-style processing recipe

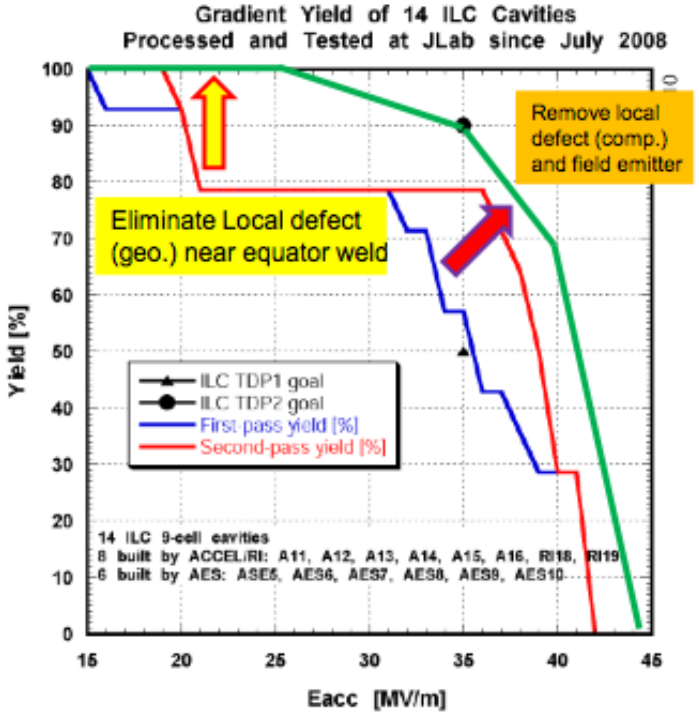
Main Issue: quench limit ~ 20 MV/m due to local geometrical defect (near equator EBW sub-mm dia.)



Near Term Plan: Improve Fabrication

Gradient Improvement Plan

Based on Recent Understanding due to Globally Coordinated S0 Program



- Highest priority is to push yield up near 20 MV/m – the yield drop due to local (geometrical) defects near equator weld.
  - **Fabrication QA/QC**
  - **Mechanical polish prior to heavy EP**
  - **Post-VT local targeted repair**
  - **Seamless cavity**
  - **Large-grain mat. from ingot slicing**
  - **Fine grain mat. optimization**
- Also high priority is to suppress field emission at high gradient (up to 42 MV/m) – and quantify its effect on cryogenic loss and dark current.

- XFEL >600 production Cavities
- FNAL > 40 cavities from ARRA fund

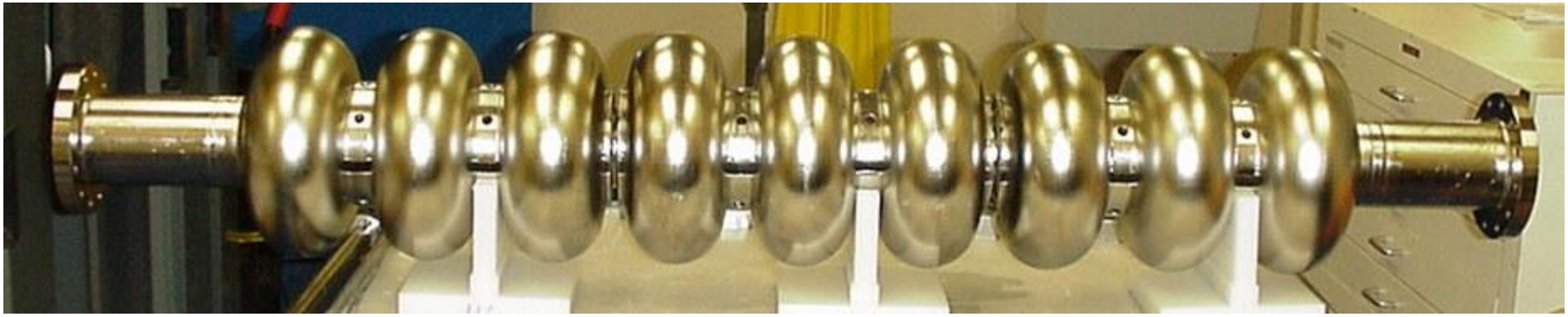
Reliable and reproducible EP essential. Example now exists.
Pursuit is continuing in some facilities.

Cavity Cost Reduction or Value Engineering

Seamless Cavity

- Elimination of equator EBW may improve fabrication yield
- Potential of cost saving
- New progresses being made, talk by Waldemar Singer
- Level of efforts increasing at FNAL – talk by Andy Hocker

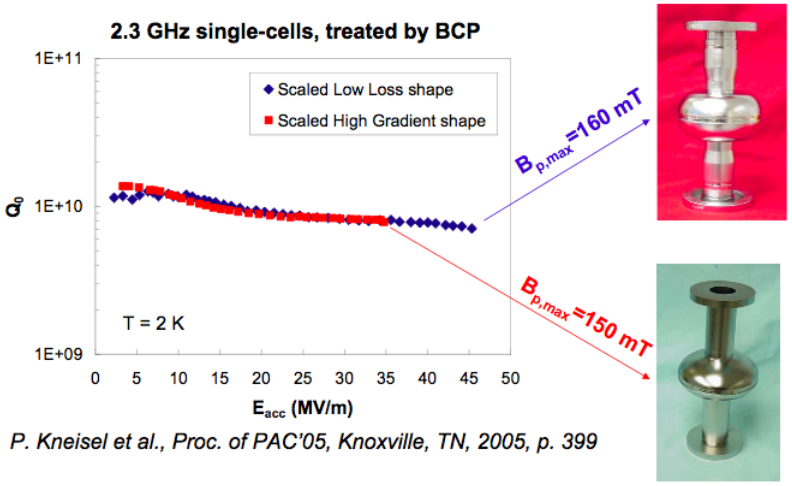
Courtesy of W. Singer



Courtesy of P. Kneisel

Large-Crystal/Single-Crystal Cavity

Single-crystal cavities(2)



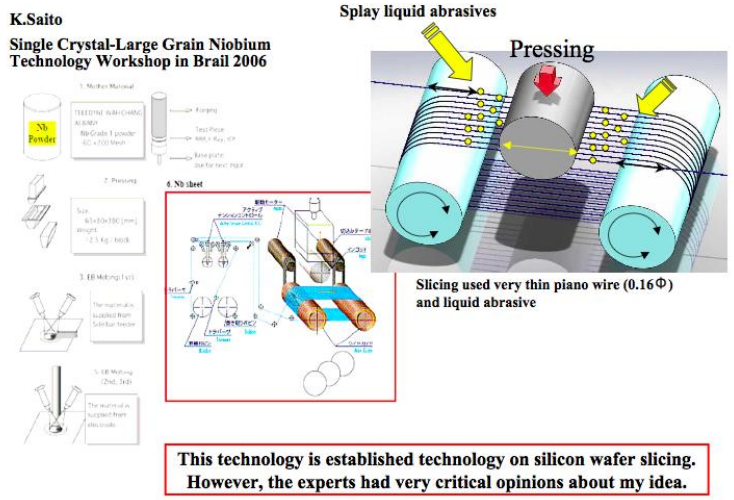
P. Kneisel et al., Proc. of PAC'05, Knoxville, TN, 2005, p. 399

Oct. 30 – Nov. 2, 2006 Single Crystal Workshop

Courtesy of P. Kneisel

- Large-crystal/single-crystal material critical field comparable to fine-grain
- Still need EP for reproducible high gradient
- Multi-wire slicing developed by Tokyo Denkai/KEK increases cost saving perspective of large-crystal material cavity

Courtesy of K. Saito



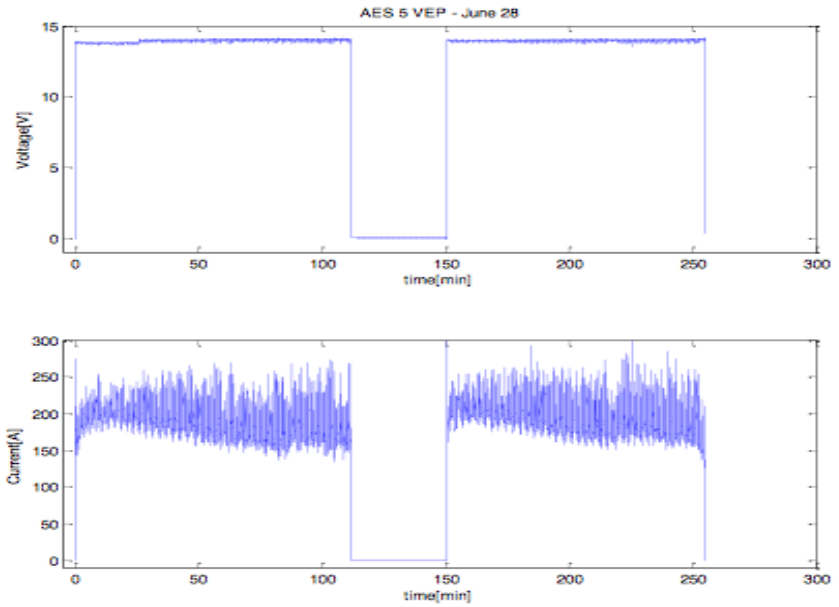
Vertical EP

- Way to go for mass-production style cavity processing
- New development at Cornell increases attractiveness of VEP
- More cavity data expected in FY11 from Cornell

Cornell SRF

TB9AES005 VEP 28jun10

- Material removal: 70 μm
- Temperature: 22 C
- Slow stirring speed: 0.8 Hz
- Current oscillations with good modulation depth were achieved, similar to the JLab horizontal system
- Electropolished surfaces have similar appearance to JLab horizontally polished cavities
- VEP System is ready for two new AES cavities.

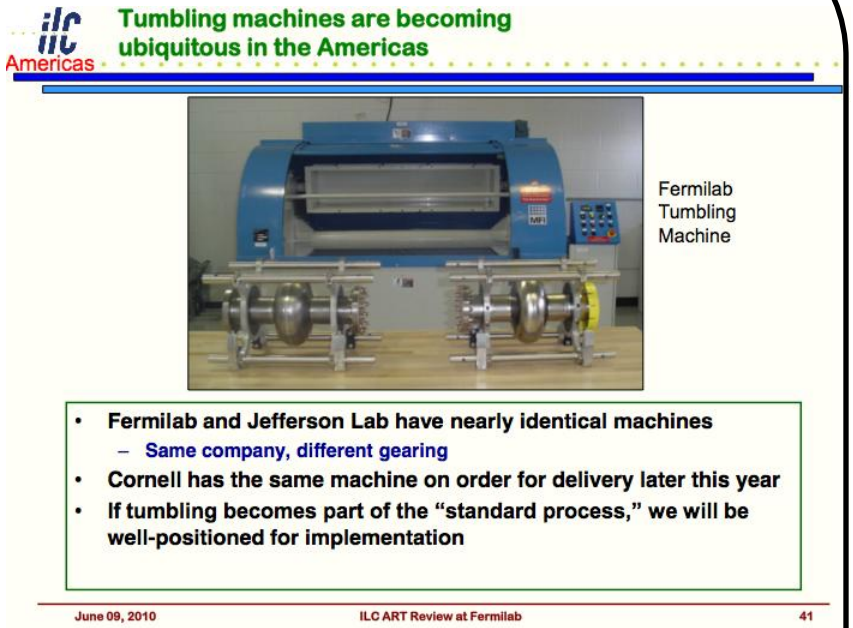


ACrawford 20jul10

Courtesy of A. Crawford

Alternative Bulk Removal (+final light EP)

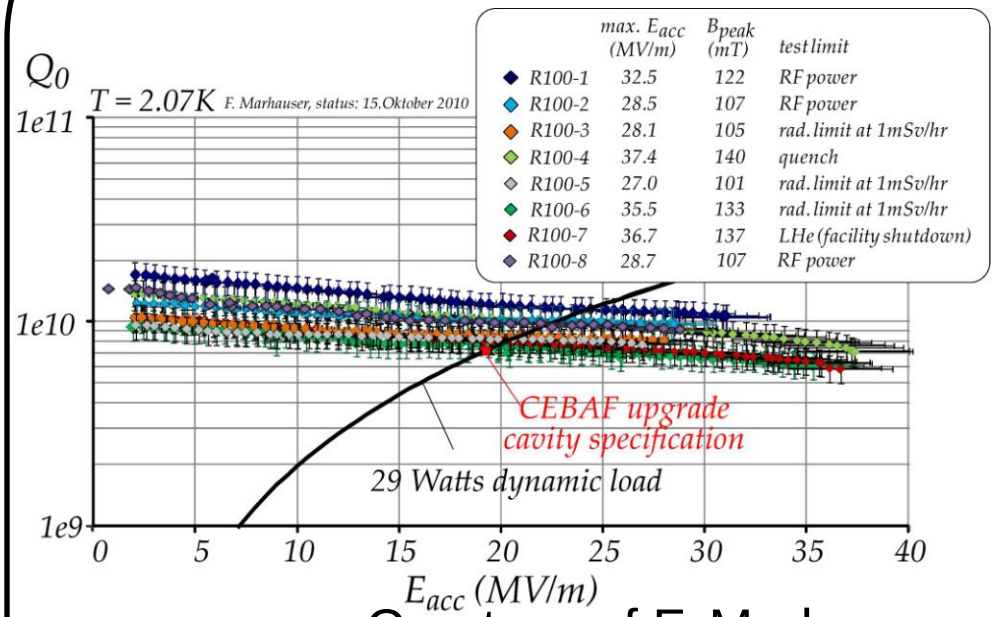
Mechanical Polish



Courtesy of M. Champion

- Effectively eliminate geometrical flaws due to fabrication
- Save cost by reduced EP
- Level of effort in America region increasing

Buffered Chemical Polish

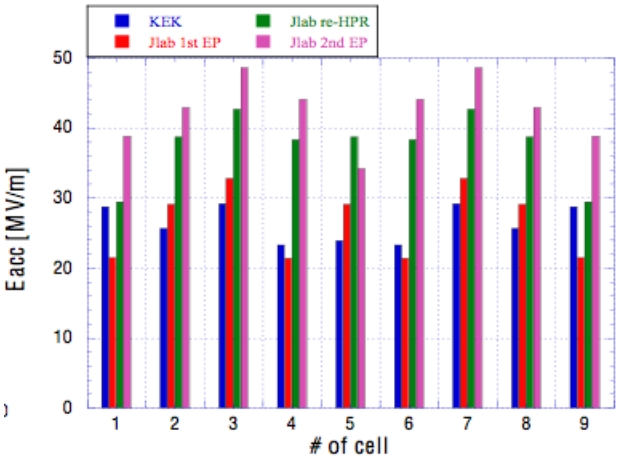


Courtesy of F. Marhauser

- Prof of principle established 1997-2002
- Successful application to CEBAF 7-cell cavities due to availability of in-house EP expertise; more than 80 7-cell cavities will be processing using this method

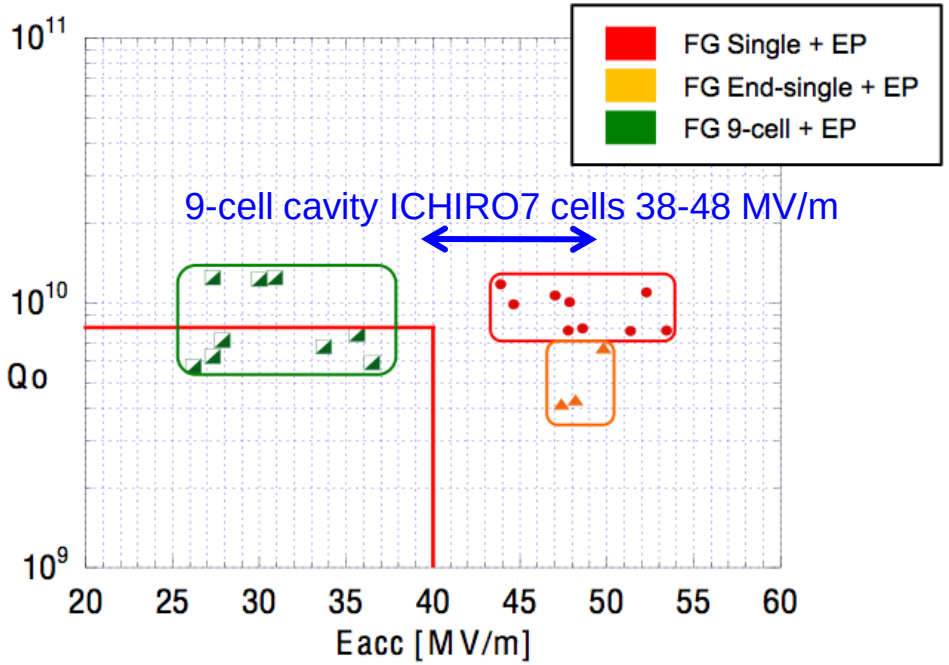
ILC TeV Upgrade Cavity Options

Low-Loss/ICHIRO Shape Cavity



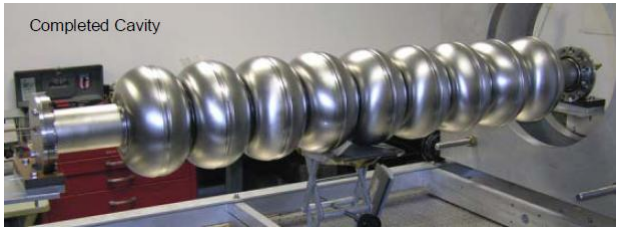
- Intensive push by KEK in collaboration with JLAB toward 9-cell demonstration
- Level of effort should increase
- Talk by F. Furuta and J. Gao

Current status of ICHIRO + EP



Courtesy of F. Furuta

Re-entrant Shape & LSF Shape Cavities

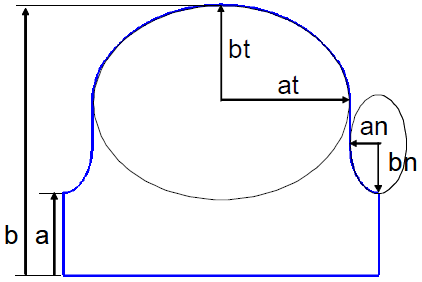


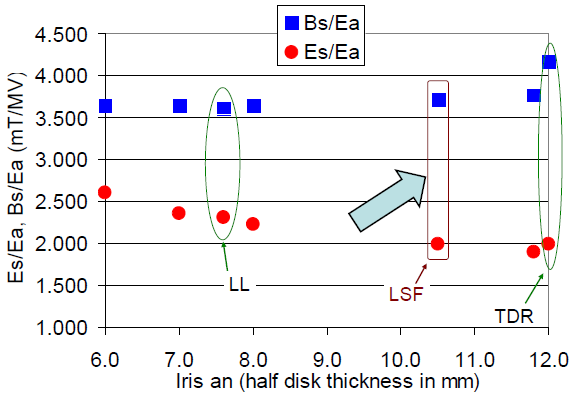
- 30-mm aperture 1-cell re-entrant cavity demonstrated 59 MV/m gradient
- 9-cell re-entrant cavity work needs to increase effort
- Talk by G. Hoffstaeter

Cell Shape Optimization

THP038

- LSF a new addition with further improved characteristics
- Multi-cell prototyping should start as soon as possible
- JLAB has interest but unable to start due to resource limit – opportunity in FY11 due to program re-prioritization



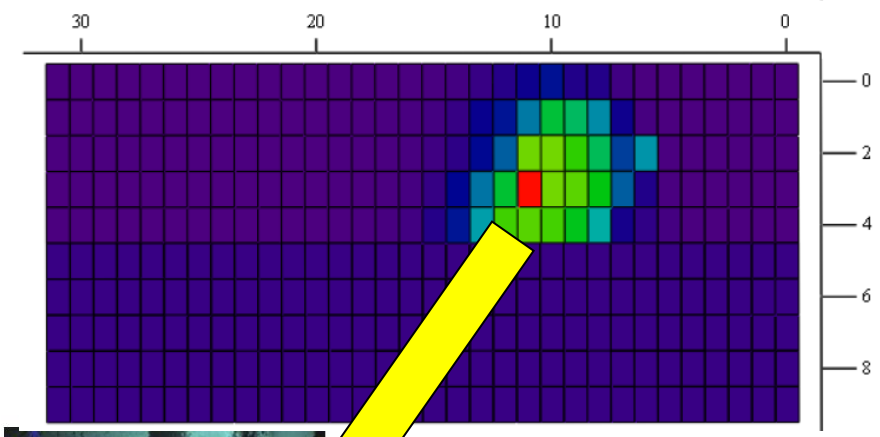


- **Cell contour: two ellipses connected with straight lines**
- **Given *an*, *bn* and *bt* optimized to minimize Es and Bs**
- **Low Surface Field (LSF) Design**
  - **Iris radius of 30-mm**
  - **an=10.5 mm**

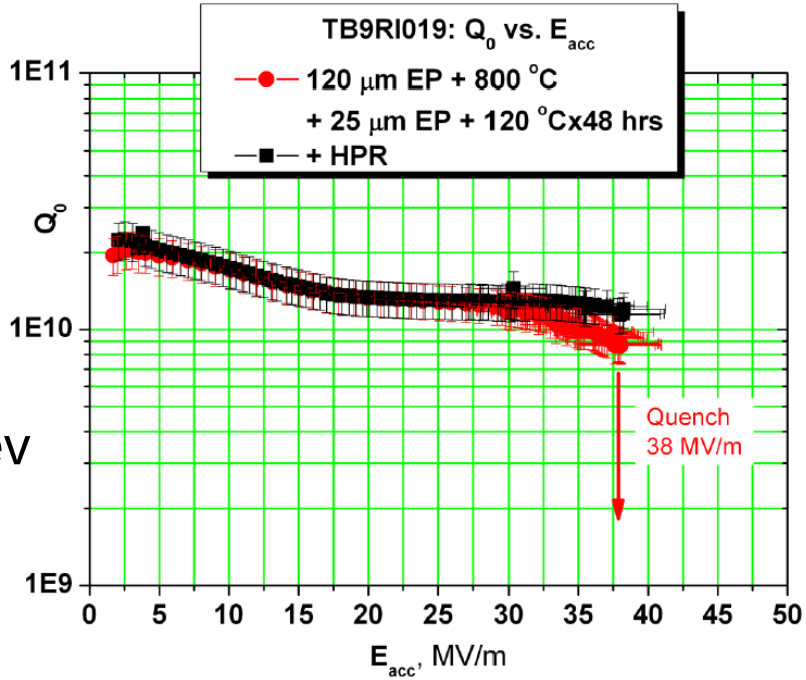
Courtesy of Z.H. Li

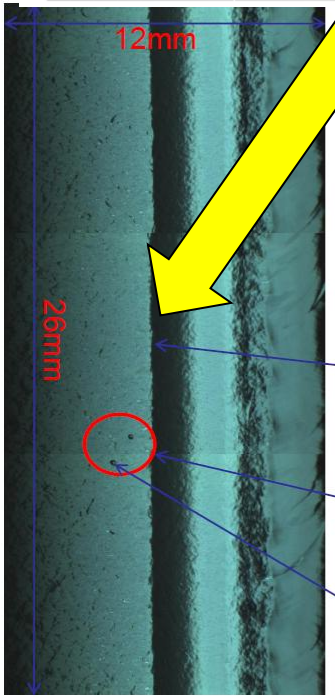
Very-High-Gradient Phenomena

Quench in Gradient Range of 35-45 MV/m



Courtesy of G. Eremeev





Center of quench area predicted bt T-maaping

Two outstanding defects observed
~ 5mm away from predicted quench location

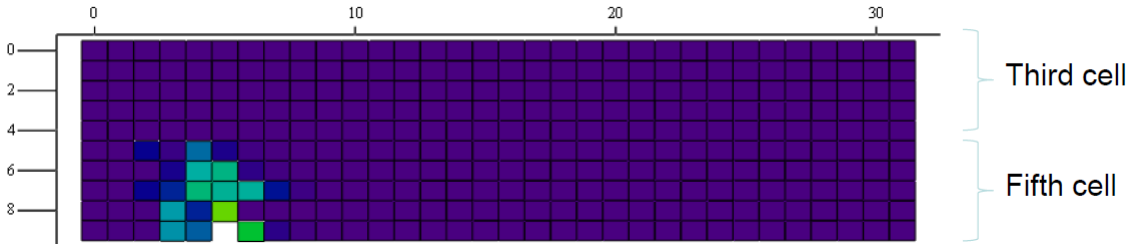
Defect diameter 200um

Courtesy of J. Dai

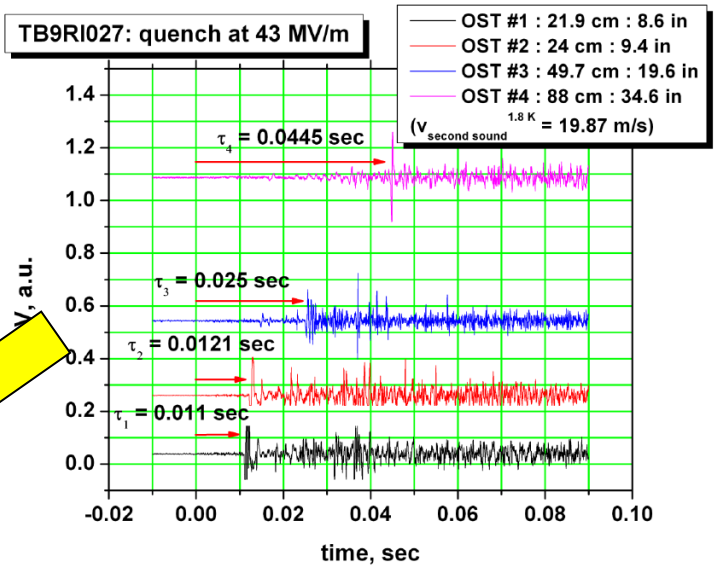
- No observable defect at predicted quench site (unlike quench limit ~ 20 MV/m, which is correlated with sub-mm sized geometrical defects)
- Further spatial resolution improvement in T-mapping and inspection required

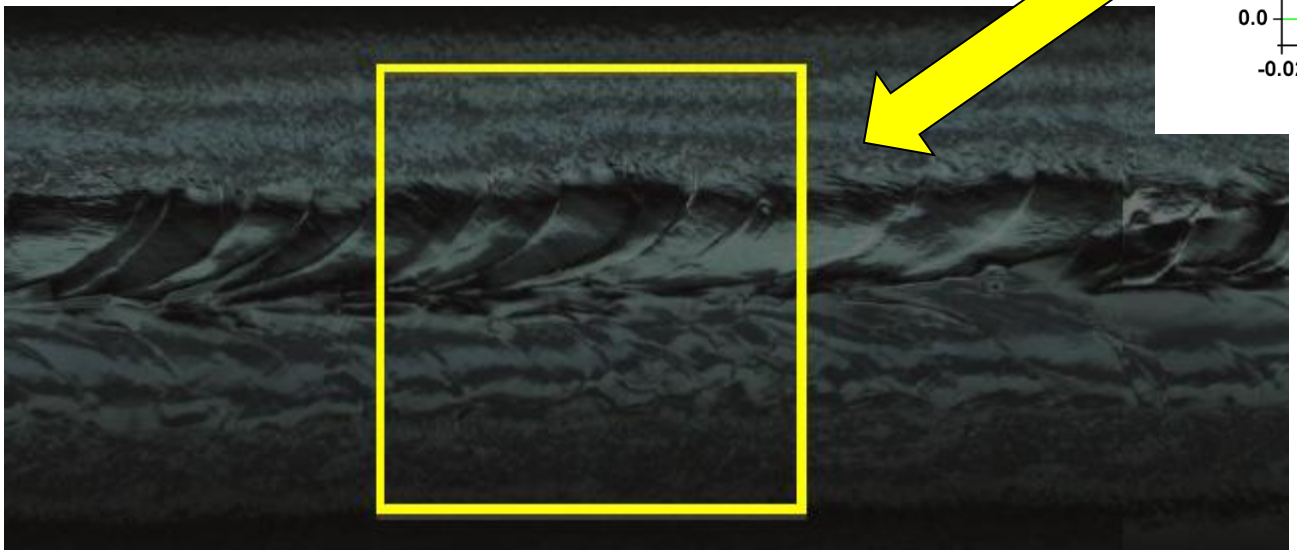
Quench in Gradient Range of 35-45 MV/m

Cavity RI27 quench at 43 MV/m



Courtesy of G. Eremeev



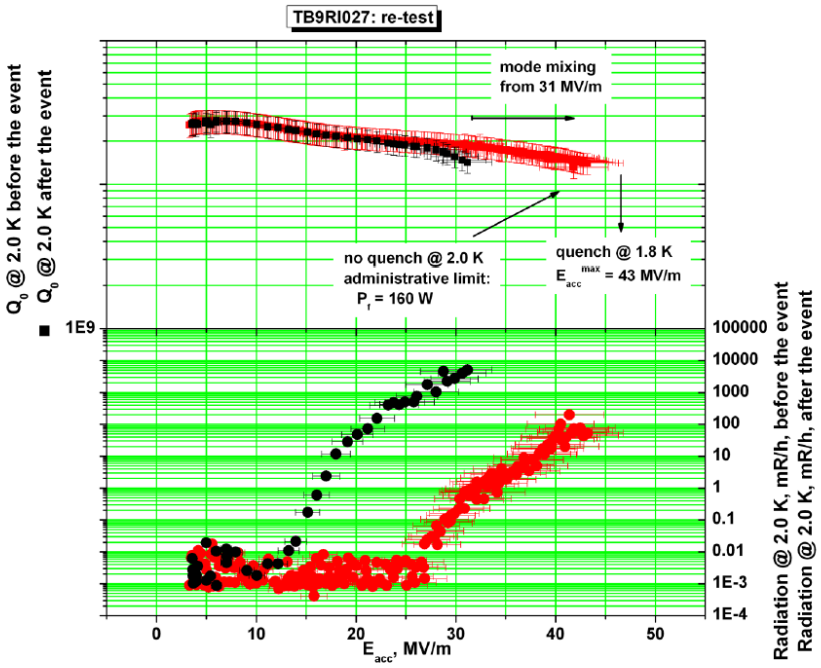


- OST predicted quench area shown in box
- No observable feature on site
- Predicted quench site coincides with weld overlap
- Improved material characterization needed
- Material talk by T. Bieler

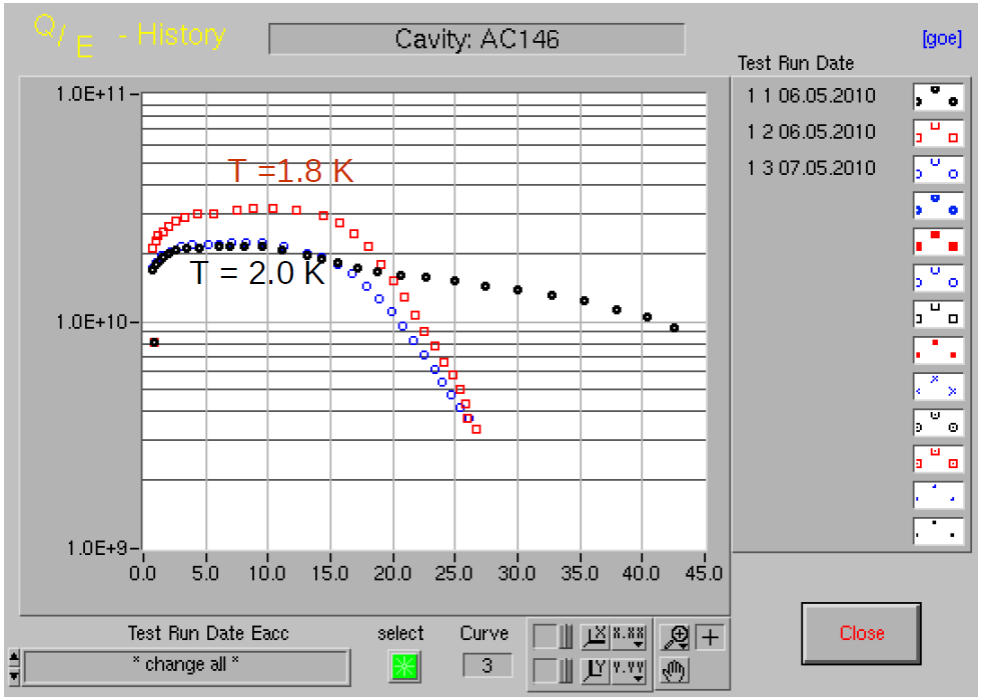
Sudden Turn-on "Event" at VHG

- Phenomenon observed in several occasions (two examples shown)
- Event followed by severe performance loss
- re-HPR recovers RI27 to 35 MV/m with Q0 8E9
- There may be some emitter can not be removed by HPR – alternative cleaning method worth exploring – [talk by D. Reschke]

TB9RI027 : Before and after the event

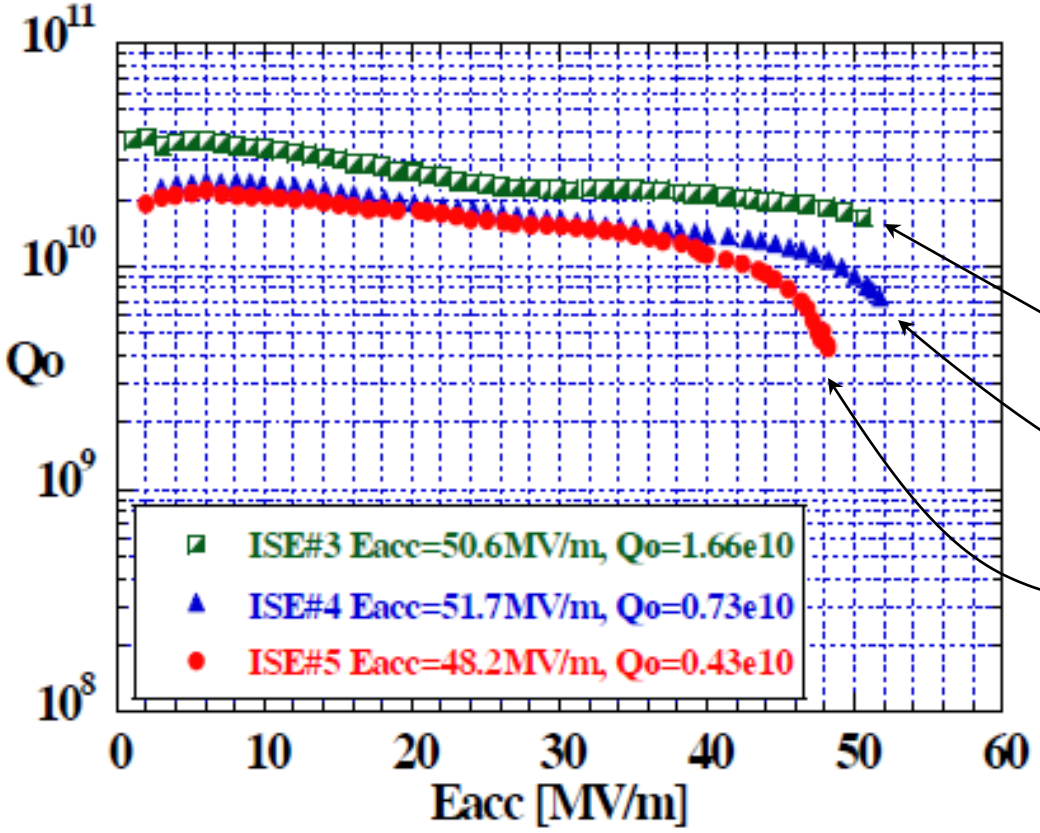


Courtesy of G. Eremeev



Courtesy of S. Aderhold

HOM Coupler Heating at VHG



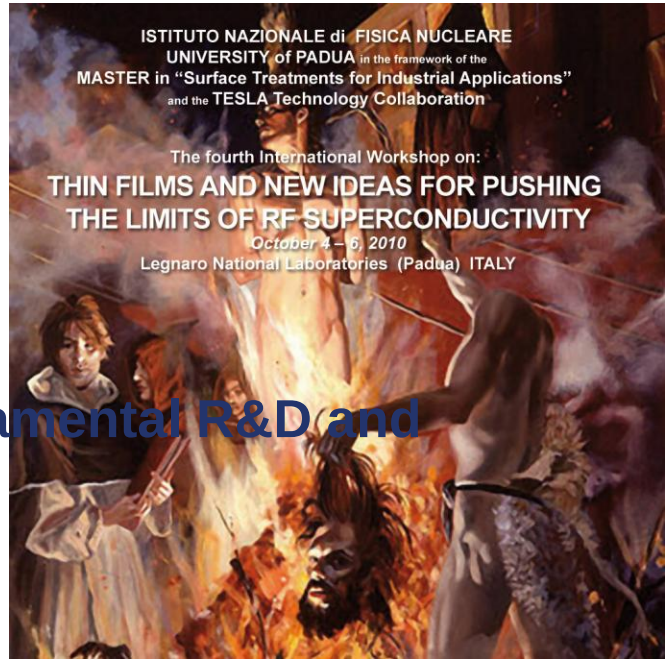
Courtesy of F. Furuta, K. Saito

- It appears some heating occurs in HOM coupler at ~ 50 MV/m
- Further studies and new design studies are important
- Talk by T. Konomi

Revolutionary Solutions for Ultra-High Gradient Cavities

Beyond Niobium Material

- Niobium
  - **35-40 MV/m for TESLA shape cavities**
  - **40-55 MV/m for LL, RE, LSF shape cavities**
    - 60 MV/m seems upper limit w/ further material optimization
- Material beyond niobium
  - **Many candidates on table**
  - **Growing interest**
    - See talks from latest Thin Film Workshop
    - Youtube link http://www.youtube.com/watch?v=vrI9H1AajqI
  - **Need to gap bridge between material fundamental R&D and cavity system development**
  - **Today we will hear two talks**
    - ALD talk by Th. Prolier
    - New material cavity talk by G. Eremeev



Final Remarks

- Baseline cavity technology R&D a success
  - **TDP-1 gradient R&D milestone of 50% yield at 35 MV/m on "global" bases delivered.**
  - **Gradient advanced – practical gradient limit in 9-cell cavity raised to 38 – 42 MV/m.**
  - **An example of 90% yield at 35 MV/m w/ Q0 8E9 set based on 10 cavities built by one vendor and processed at one lab without bias.**
  - **TDP-2 gradient goal of 90% yield at 35 MV/m on global bases can be expected.**
- Alternative shape cavity work should increase
  - **Important for ILC TeV upgrade.**
  - **9-cell demonstration of 45-50 MV/m can be expected by end of this year.**
- Very-High-Gradient issues & countermeasures need studies
  - **What is the nature of quench at 35 – 55 MV/m?**
  - **What is the nature of sudden turn on "event" at > 40 MV/m?**
  - **What HOM coupler design changes are needed for VHG cavities?**
- Focused material R&D important for SRF based LC
  - **60 MV/m seems within reach of niobium material.**
  - **New material is the future for > 60 MV/m.**
  - **Likely path is thin film coated cavities.**