

TTC Delhi Highlights
Mostly on Cavity R&D
in WG3

Introduction to TTC WG3

Charge for our group

Co-Chairs: Hayano, Reschke, Padamsee

- *Status and activities for S0 and S1 of ILC*
 - *give an update on recent progress in this field*
 - *discuss the results and findings especially from the point of view of understanding SC-RF technology in general*
- To focus on the critical S0 and S1 R&D for ILC Baseline we organized the material presented in talks to address the following questions which we also tried to answer in the WG3 final summary report:
 - a) What is the present estimate for the gradient spread and gradient yield due to QUENCH/FIELD EMISSION observed for 9-cell cavities produced by qualified vendors, when these cavities are prepared by the best methods (EP, HPR and bake – baseline ILC preparation method).
 - b) What are the reasons discovered quench in 9-cells?
 - c) What have we learned from 1-cell and sample studies that will guide us to improve the yields for 35 MV/m?
 - d) How does the quench field/location change with repeated preparations?
 - e) What is the progress with developing new vendors for cavities and new vendors for treatments?
 - f) What are the new results for average gradients in cryomodules (S1)?
 - Other topics...

WG3 Program (S0 and S1 for ILC)

Session I (180 minutes)

- 1) Reports on 9-cell and 1-cell cavity test results
 - (20 min) DESY cavity results...Detlef Reschke
 - (15 min) Jlab cavity results including inspection for defects...Bob Rimmer
 - (15 min) Cavity results at FNAL ...Camille Ginsburg
 - (15 min) Cornell: 1-cell test results from new vendor cavities
- 2) Reports on quench location methods, optical exam and results
 - (15 min) "STF T-map results": Yasuchika Yamamoto
 - (15 min) 2nd sound quench detection and results : Cornell
 - (15 min) Update on T-mapping results and surface examination: Tajima
 - (15 min) DESY. T-map and optical inspection results...Detlef Reschke....
 - (15 min) "Recent inspection results by Kyoto-camera": Ken Watanabe
 - (10 min) Marc Ross : ILC GDE S0 summary view
- **(15 min) Discussion**

Session II (180 min)

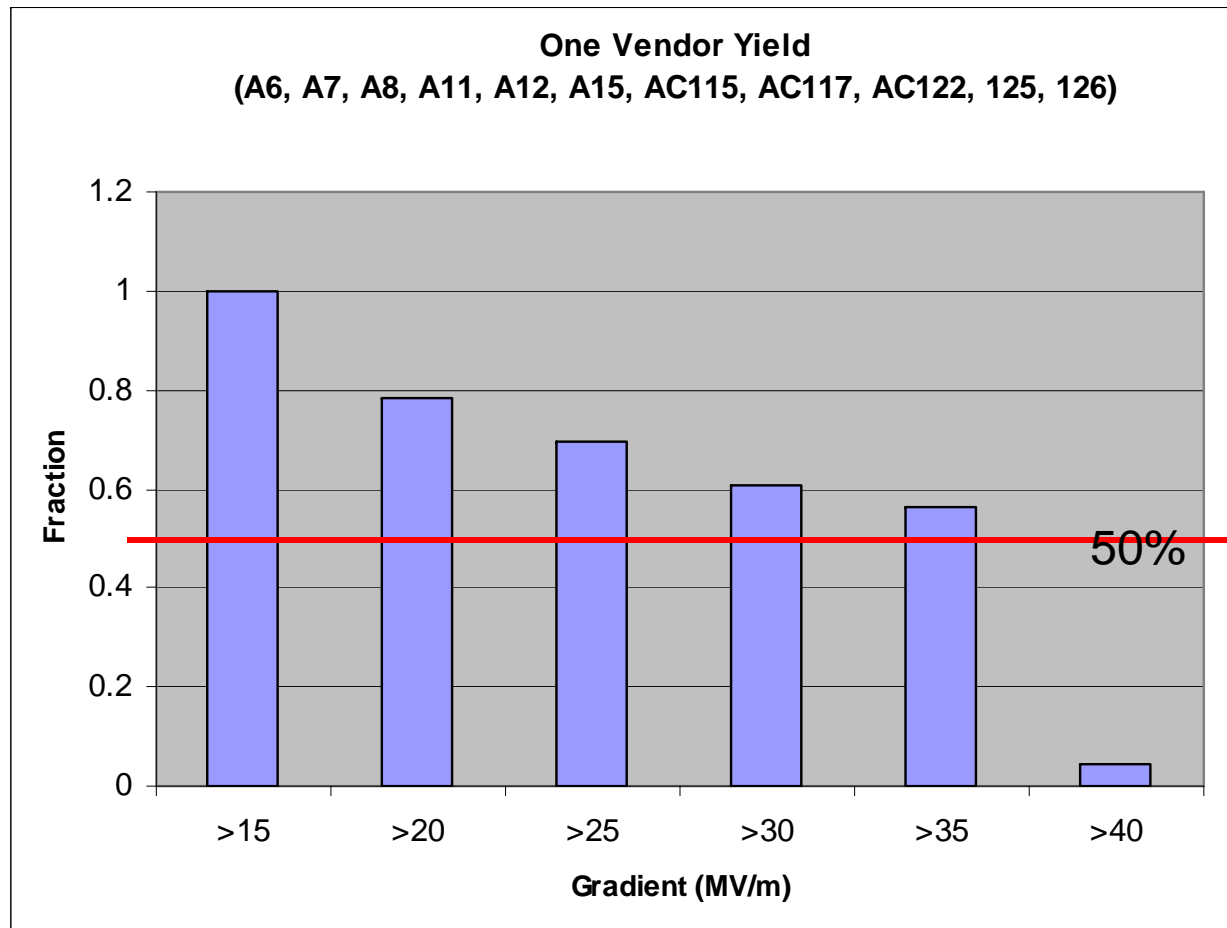
- 3) Reports on basic studies to advance understanding of quench limitations and field emission
 - (10 min) "Surface study by using sample plate": Takayuki Saeki
 - (10 min) "STF new-EP commissioning": Kenji Ueno
 - (15 min) EP studies at Saclay : Fabian Ezenou
 - (10 min) Reproducing pits in the Heat Affected Zone of Welds : Camille Ginsburg (Lance Cooley)
 - (10 min) Artificial defect studies with reactions to BCP, EP and re-melt (Geng/Rimmer)
 - (10 min) Field enhancement factors for pits and bumps: Cornell
 - (15 min) Statistical model for quench distribution leading to defect size distribution: Cornell
 - (10 min) How can large and single grain material help complete the picture? Kneisel
- 20 min discussion
- 4) S1: Status report on new cryomodule tests and lessons learned
 - (15 min) DESY: Module 8, test results and lessons learned: Hans Weise
 - (15 min) "STF cryomodule test": Eiji Kako
- 5) Plans for ILC-cryomodule tests over the coming 1-2 years.
 - (15 min) "STF cryomodule test plan": Norihito Ohuchi(10 min) Fermilab cryomodule test plans : Shekhar Mishra (or Bob Kephart)

Data for Status of S_0

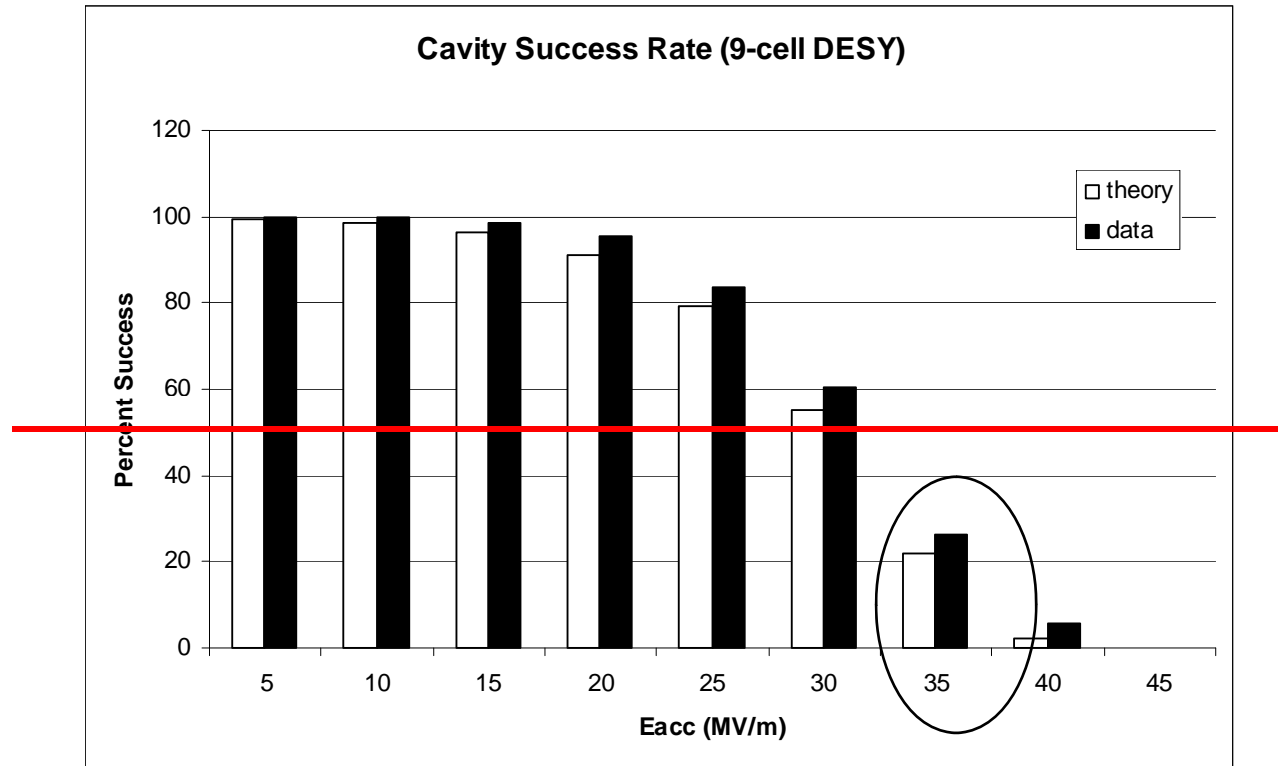
- One of the main objectives was to capture a snapshot estimate of the gradient yield using recent 9-cell cavity test data.

Combined Yield of **Jlab** and **DESY** Tests Reported at TTC Delhi Meeting (October 2008) For One Vendor

23 tests, 11 cavities



Compare to Previous Estimate of Quench Yield (TESLA Note 2008-8)

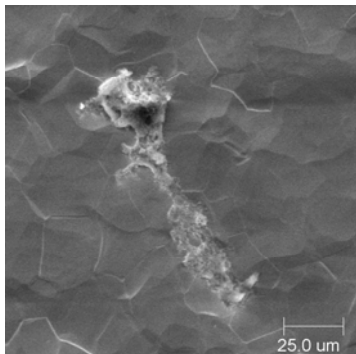


- 66 DESY Tests on 51 cavities 9-cell cavities,
 - Two vendors
- Cavities prepared by EP/HPR/800C/EP/HPR/Bake
- Open bars are yields due to quench modeling

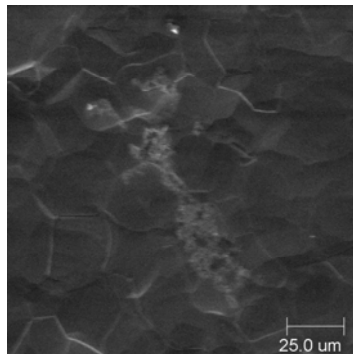
The Overall Yield For Gradient Above 35 MV/M Is > 50% (For Cavities From One Vendor)

- The new yield is about twice as large as previously reported yields on older production runs and tests.
- A large part of the yield improvement is due to field emission reduction from final rinsing
 - with ethanol (DESY)
 - ultrasonic degreasing (Jlab),
 - effective against particles of S that are left behind by EP.
- Nevertheless field emission was still present in a few cases
 - (see further comments on field emission later).

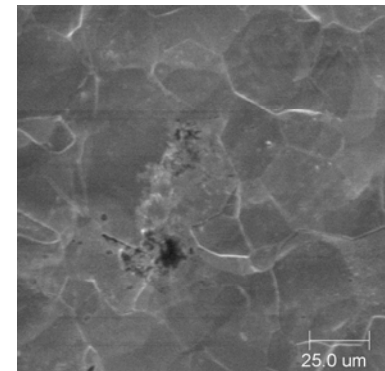
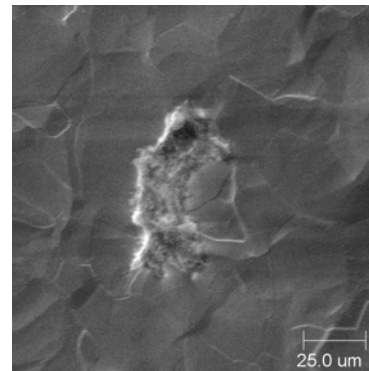
S particles deposited
on sample during EP



After Ethanol
rinsing



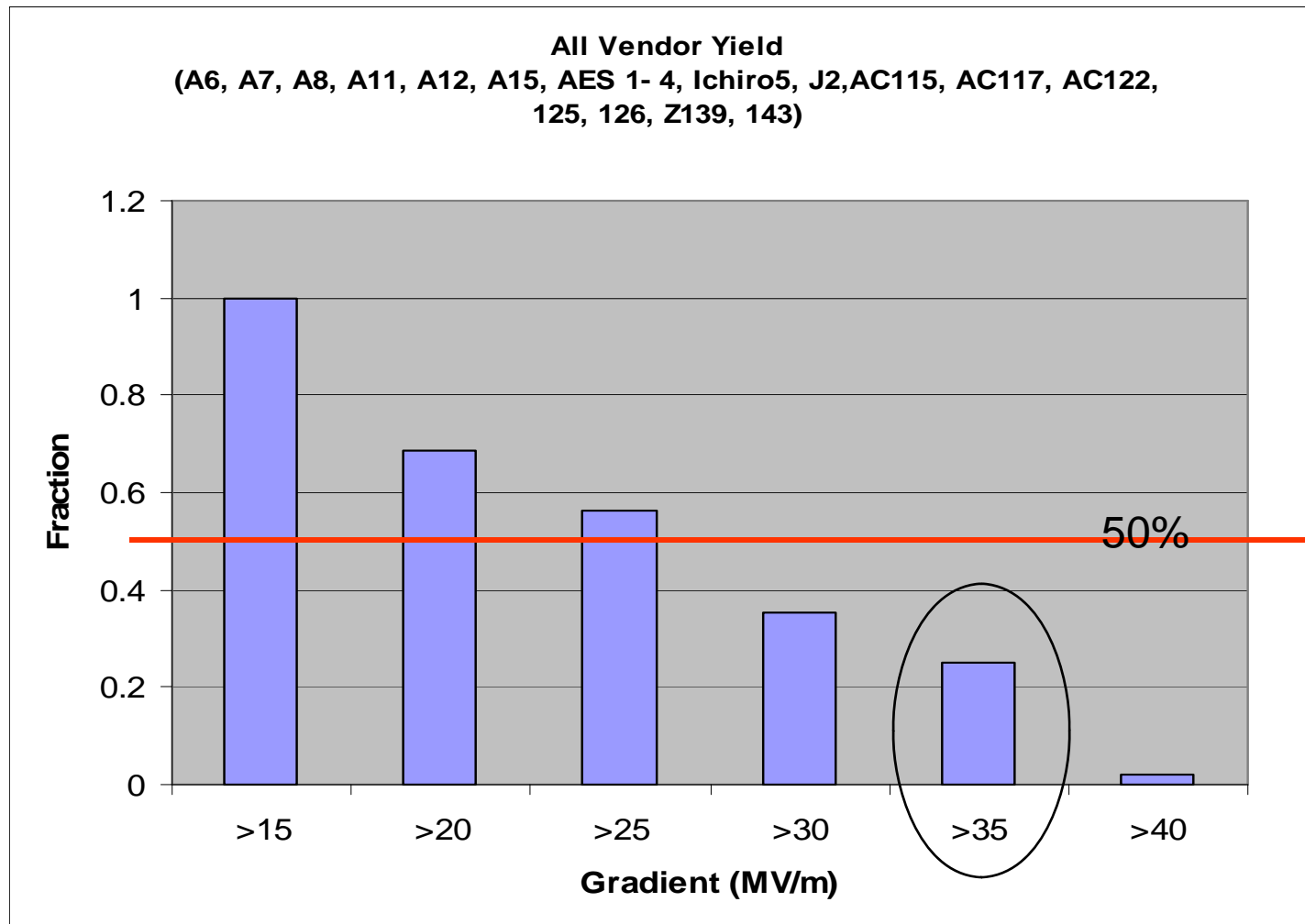
Dissolved particle, but leaves an
imprint, Possible quench site?



(Cornell
Basic
R&D)

Multiple Vendor Yield

48 Tests, 19 cavities, including ACCEL, AES, Zanon, Ichiro, Jlab



Clearly there are many more variables to bring under control when dealing with many vendors.

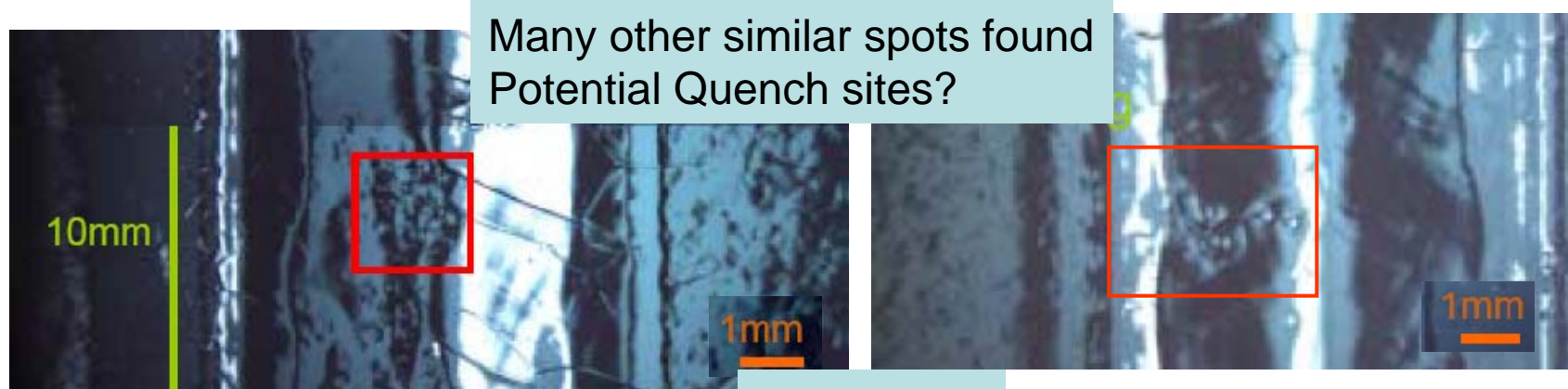
Important Progress since Last TTC Meeting.

- Sources for quench **below 25 MV/m** have been identified
- Thermometry first used to locate quench regions
- Followed by optical inspection.
- Quench sites are predominantly **bumps and pits** on the equator e-beam weld
- Or in the heat affected zone of that weld.
- Many pictures available

Thermometry Systems for 9-cells

- DESY
 - Rotating system sensitive to quench
- Jlab (With FNAL)
 - Cernox thermometers placed on equator of candidate cells after modal analysis
 - Large-scale system (1000 thermometers) for 2 culprit cells identified by modal analysis
- Cornell
 - 2nd sound system with 8 transducers
 - Large scale system (5000) under development
- Under Development
 - LANL (large scale system 5000 thermometers)

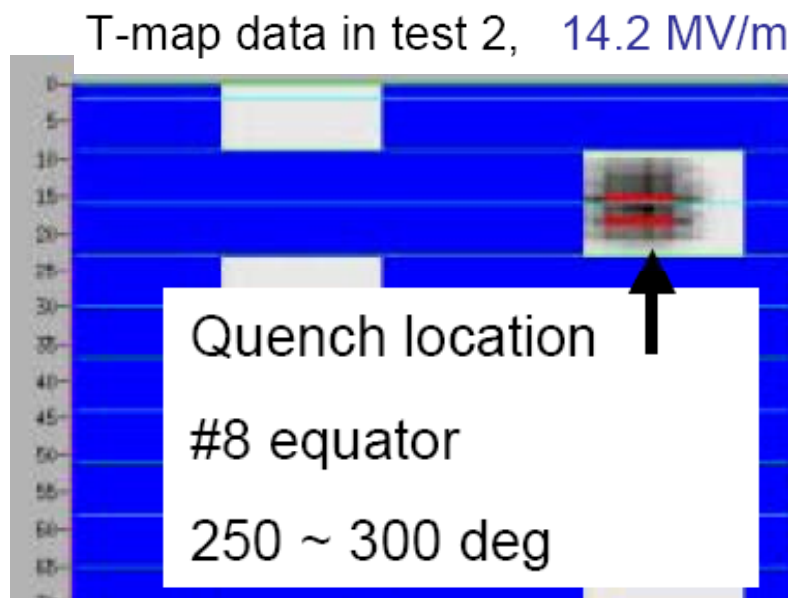
Comparison Between Temp Map Quench Spot and KEK Optical Camera Exam



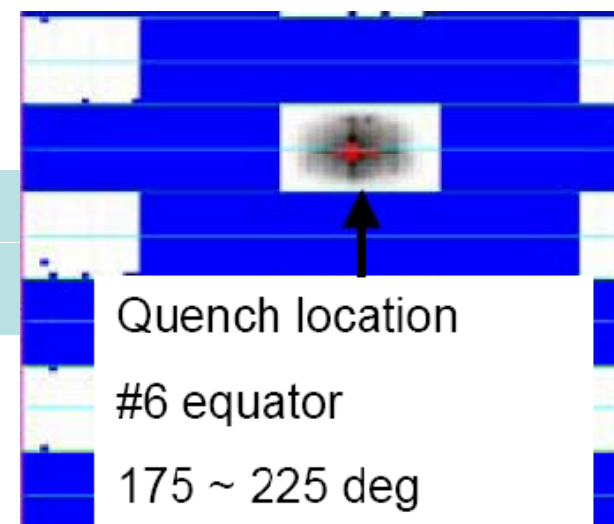
Z110 #8 equator, $t=288 \sim 299$ deg

KEK
Optical
Inspection

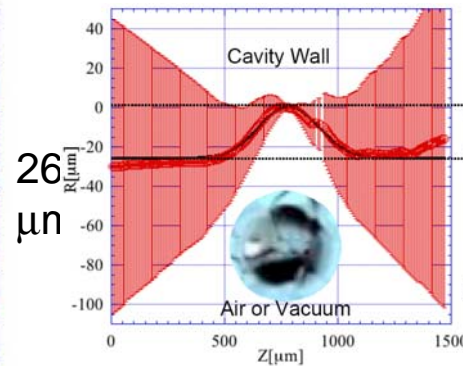
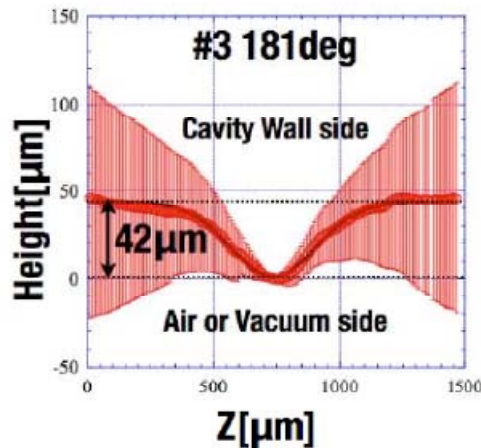
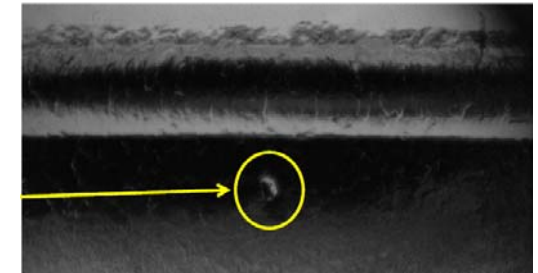
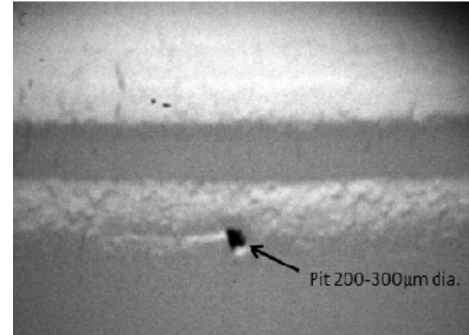
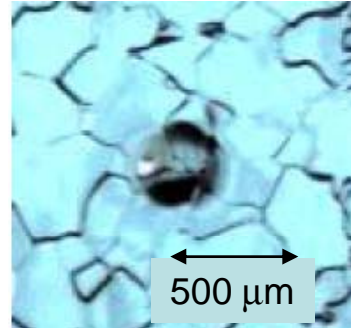
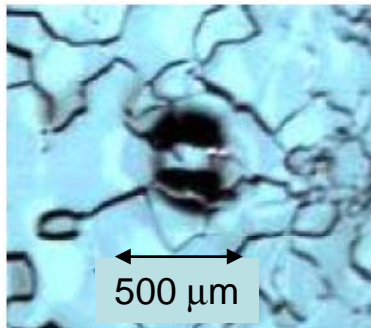
Z111 #6 cell equator
16.0 MV/m



DESY
T-Maps

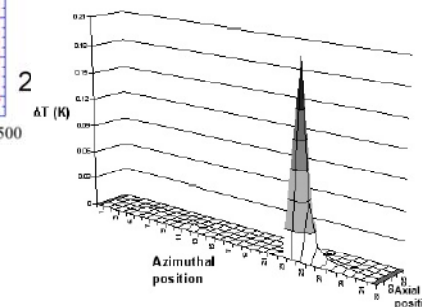


Museum of Identified Sources of Quench Below 25 MV/m (Pits and Bumps)



Pit found by Jlab in
A15, Quench
at 17 MV/m

100 μm pit near weld
Quench at 18 MV/m
Jlab quench
location and
optical
inspection
With remote
Questar



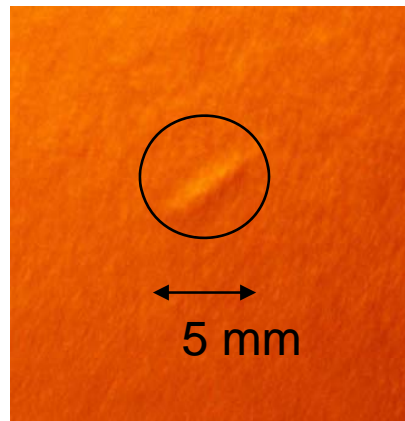
T-map of pit
quench

Bump found by KEK Optical
Inspection with CCD camera in
AES 9-cell cavity with
thermometry (Jlab and FNAL)
Quench at 18 MV/m

Pit found by KEK
optical inspection
with CCD camera
in AES #1 cavity
Quench at ~ 18
MV/m

Two Examples of Quench Above 25 MV/m

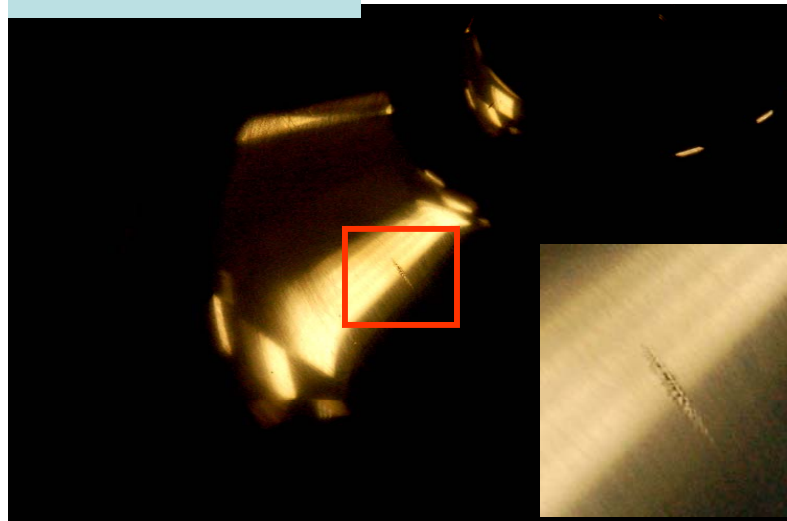
Quench at 29 MV/m



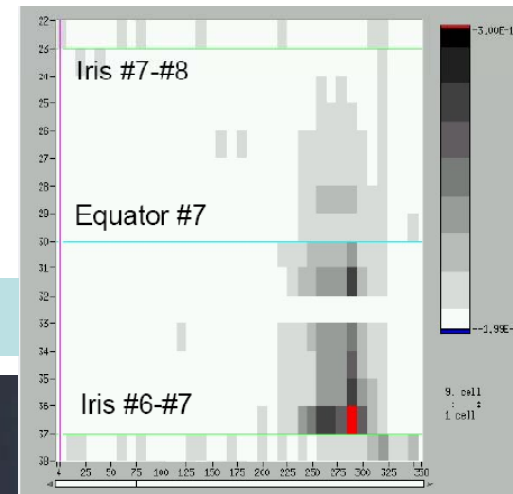
Bump found at
Quench location on
Niowave/Roark 1-cell
cavity (Cornell)

Deep scratch
subsequently found on
Cavity Forming Die

Cornell



BD at 27.9 MV/m with very low FE



DESY

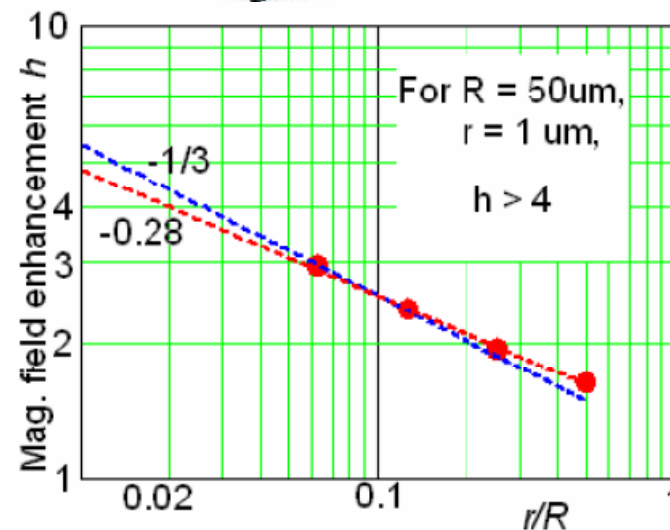
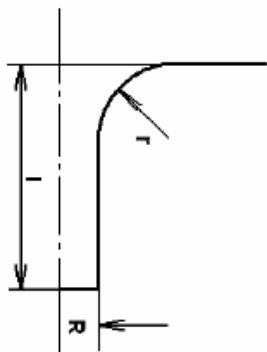
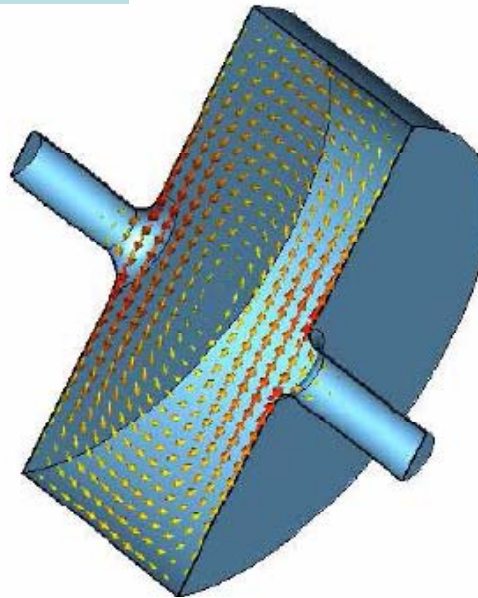
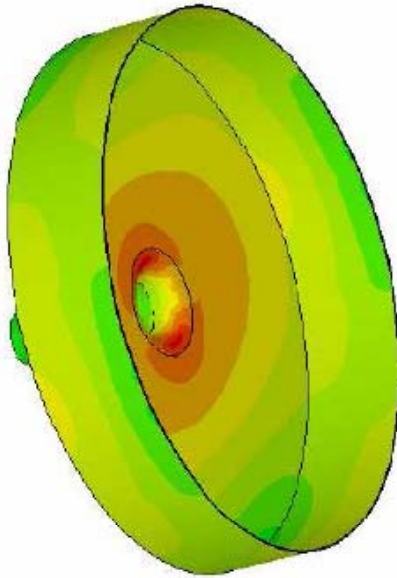
Single spot at 288 deg near iris

Theoretical work

- At Cornell and Saclay, calculations show that field enhancement at **bumps** can be as high as a factor of 2 depending on the aspect ratio of the asperity.
- The situation for a pit is more serious.
- The field enhancement depends on the ratio of the edge radius (r) to the pit radius (R), increasing as $r^{-1/3}$.
- For an extreme case, the enhancement can be a factor of 5.5 !
 - 1 μm edge radius on a 100 μm diameter pit
 - Need High Resolution microscopy to resolve such features (see example later)

Calculations of Field Enhancement for

Pits



Bumps

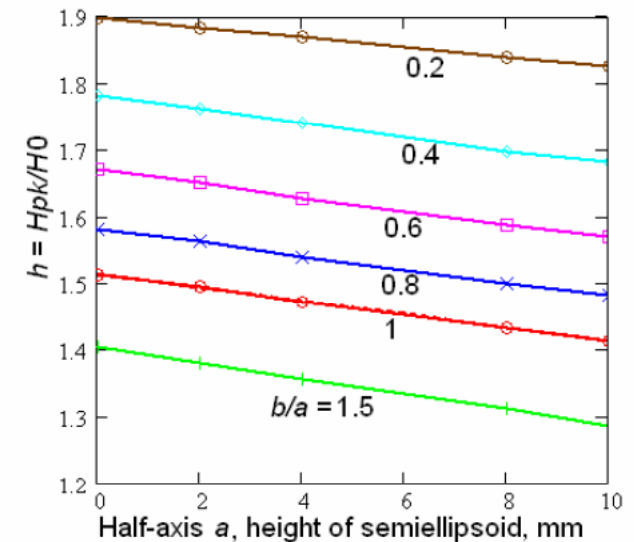
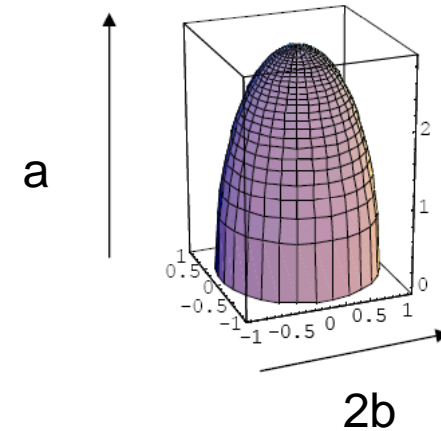
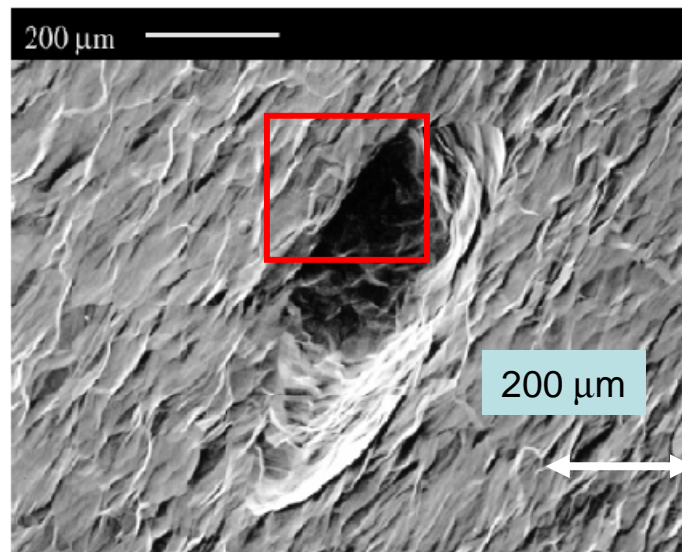


Figure 11. Magnetic field enhancement at the semiellipsoidal protrusion on a plane.

High Resolution Microscopy of Pit

- SEM picture of the pit supports possibility of sharp edge which becomes normal conducting, behaving like a defect.

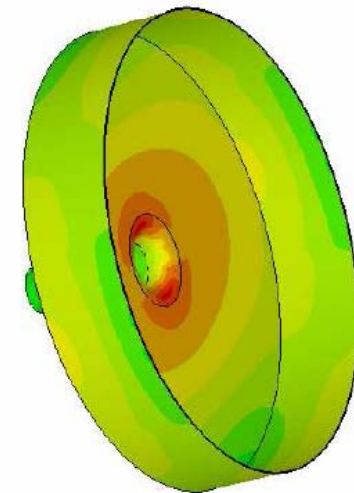


Pit with sharp edges

Reported in Thesis
of J. Knobloch
(1997)

Quenched at 93 mT

$E_{acc} = 21 \text{ MV/m}$

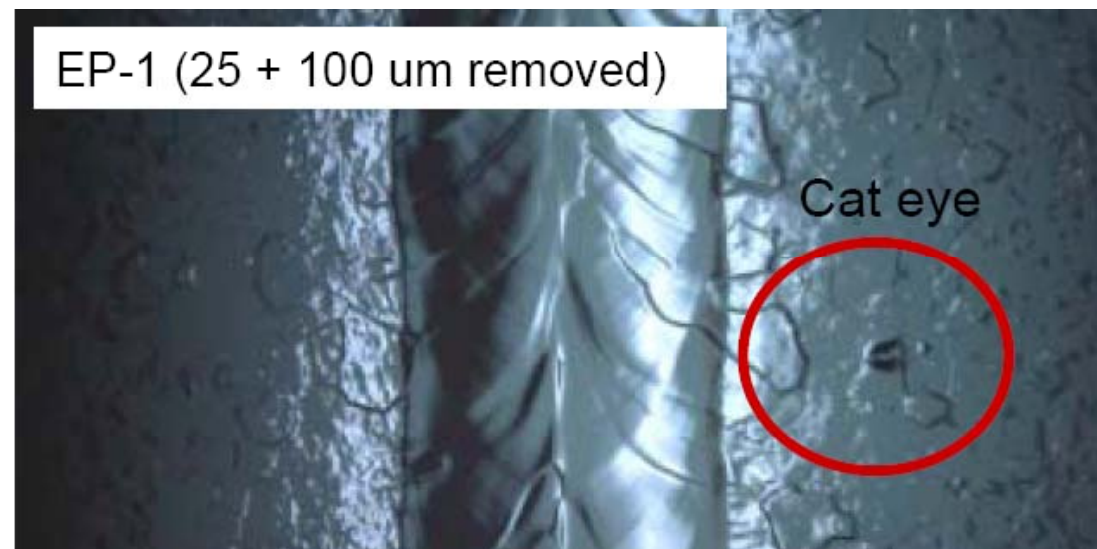


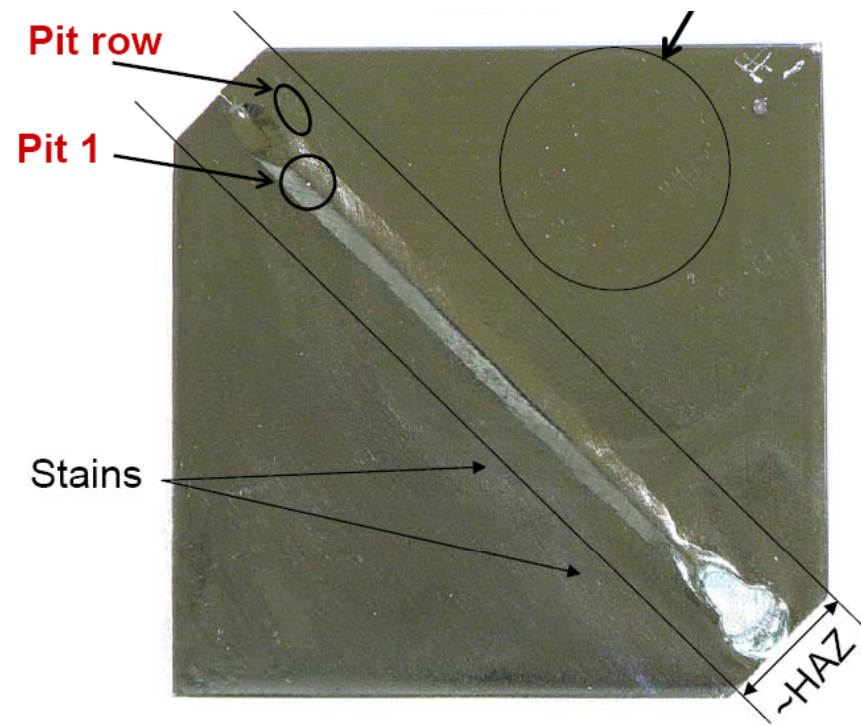
Model for current
density enhancement
at pit edge

Studies to Understand the Origin of Pits and Bumps

- KEK: tracking the growth of pits in cavity with EP
- FNAL: similar study, with welded samples
- Jlab : Effect of BCP and EP on pits
 - Try to repair pits with e-beam welding

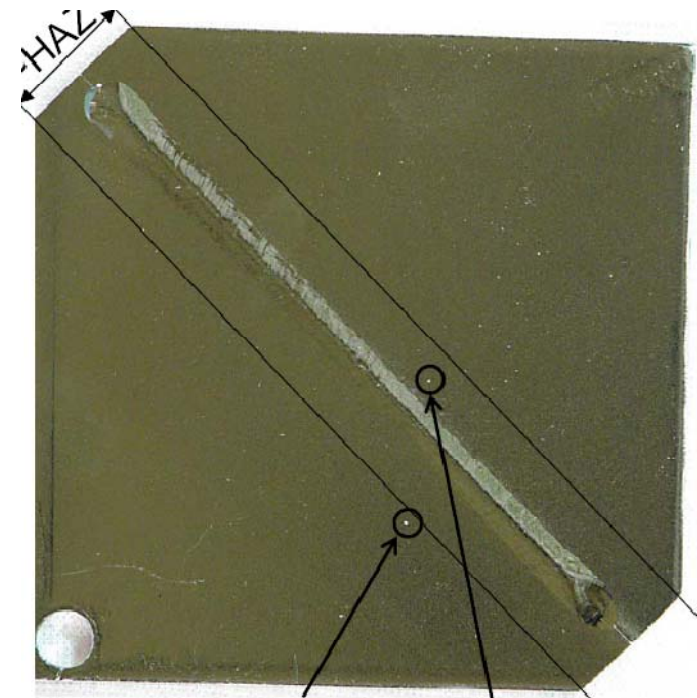
KEK



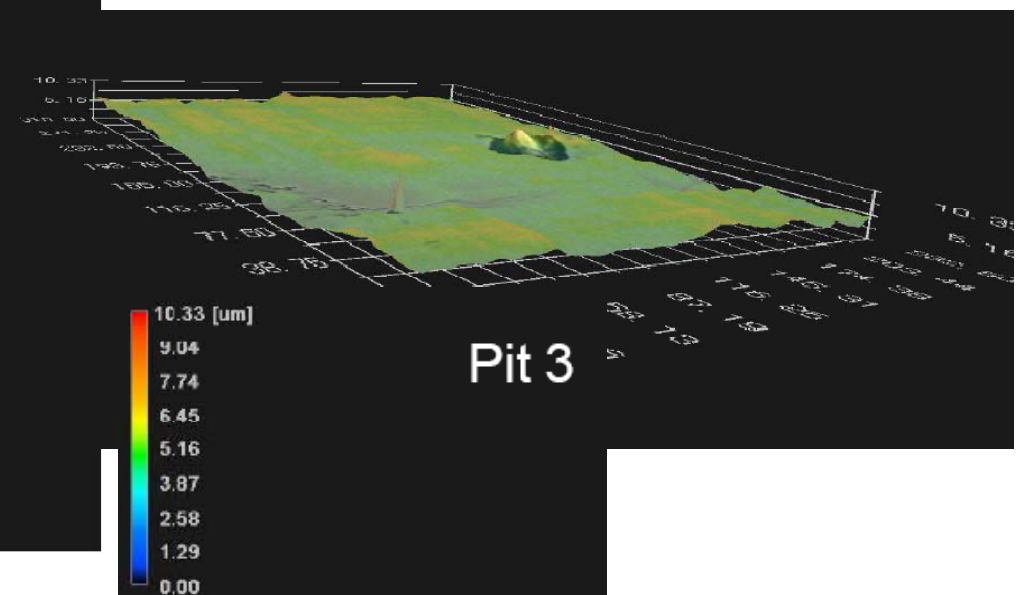
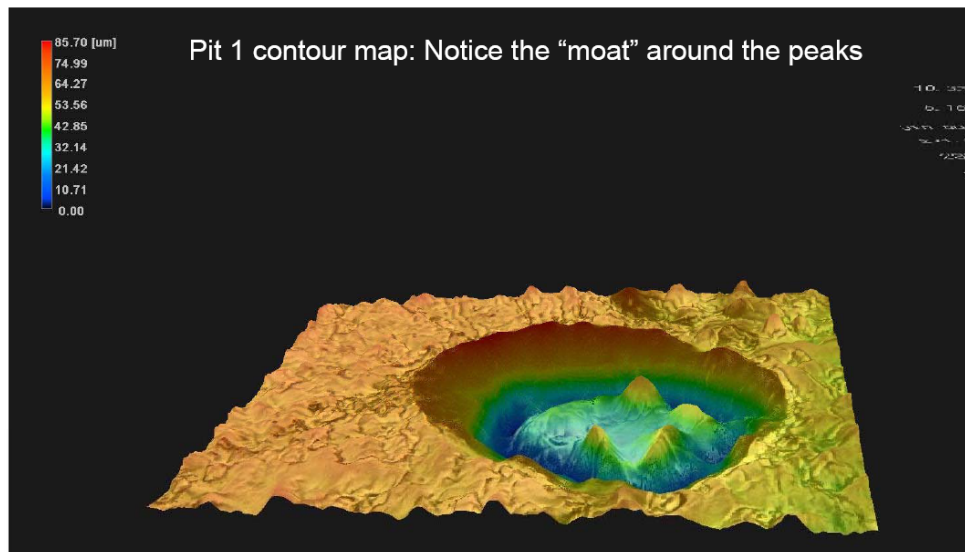


FNAL

- 210 total μm removed



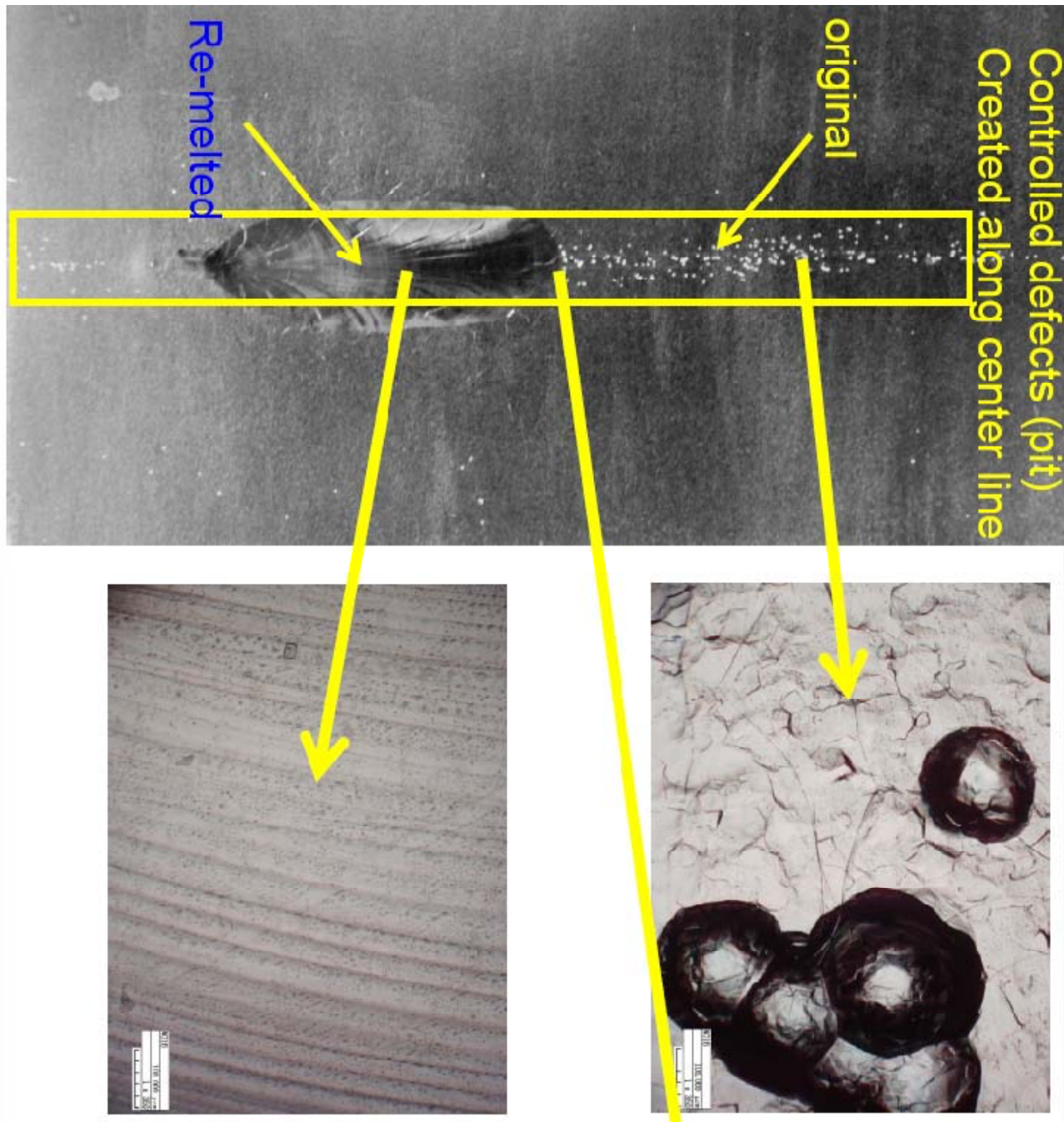
- 110 total μm removed (total)



- Preliminary experiments show a pit can not be removed by BCP or EP, even after heavy ($\sim 150\mu\text{m}$) removal.
- This is true for pits of various sizes (sub-mm in diameter, up to $200\mu\text{m}$ in depth).
- Preliminary profiling of pits show geometric features that could cause local magnetic field enhancement of $\sim X2$.
- Preliminary experiments show encouraging results of removing localized pits by using the E-beam re-melting method.
- Further studies under way to characterize relationship between pit features and quench behavior.

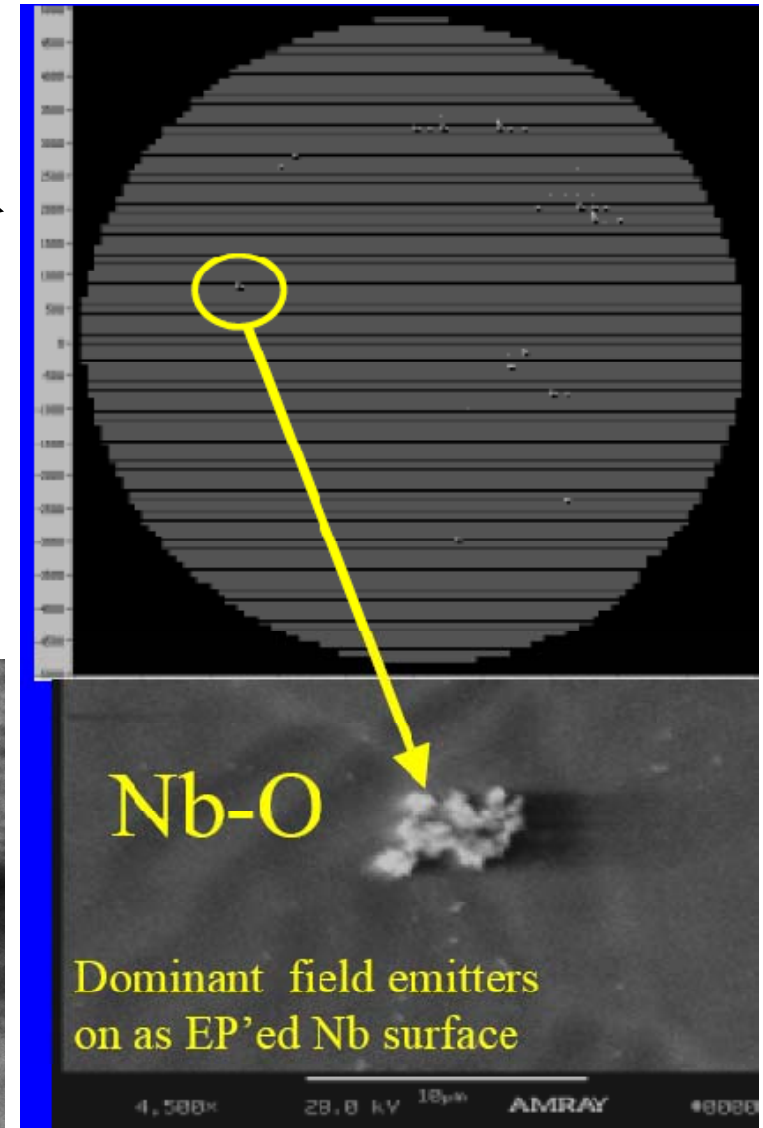
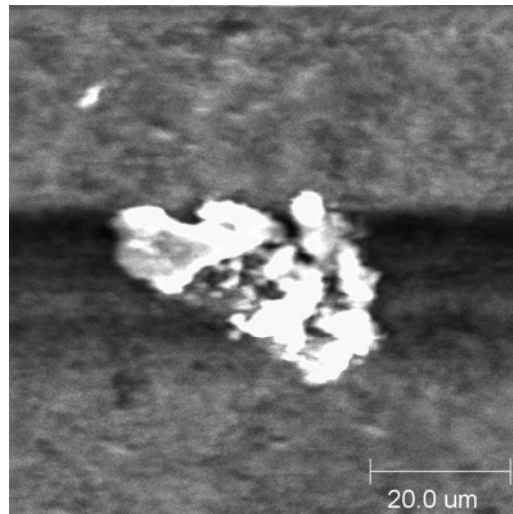
Jlab

- E-beam melting to repair pits
- Try this on a single cell ?



Some Open Questions for Field Emission

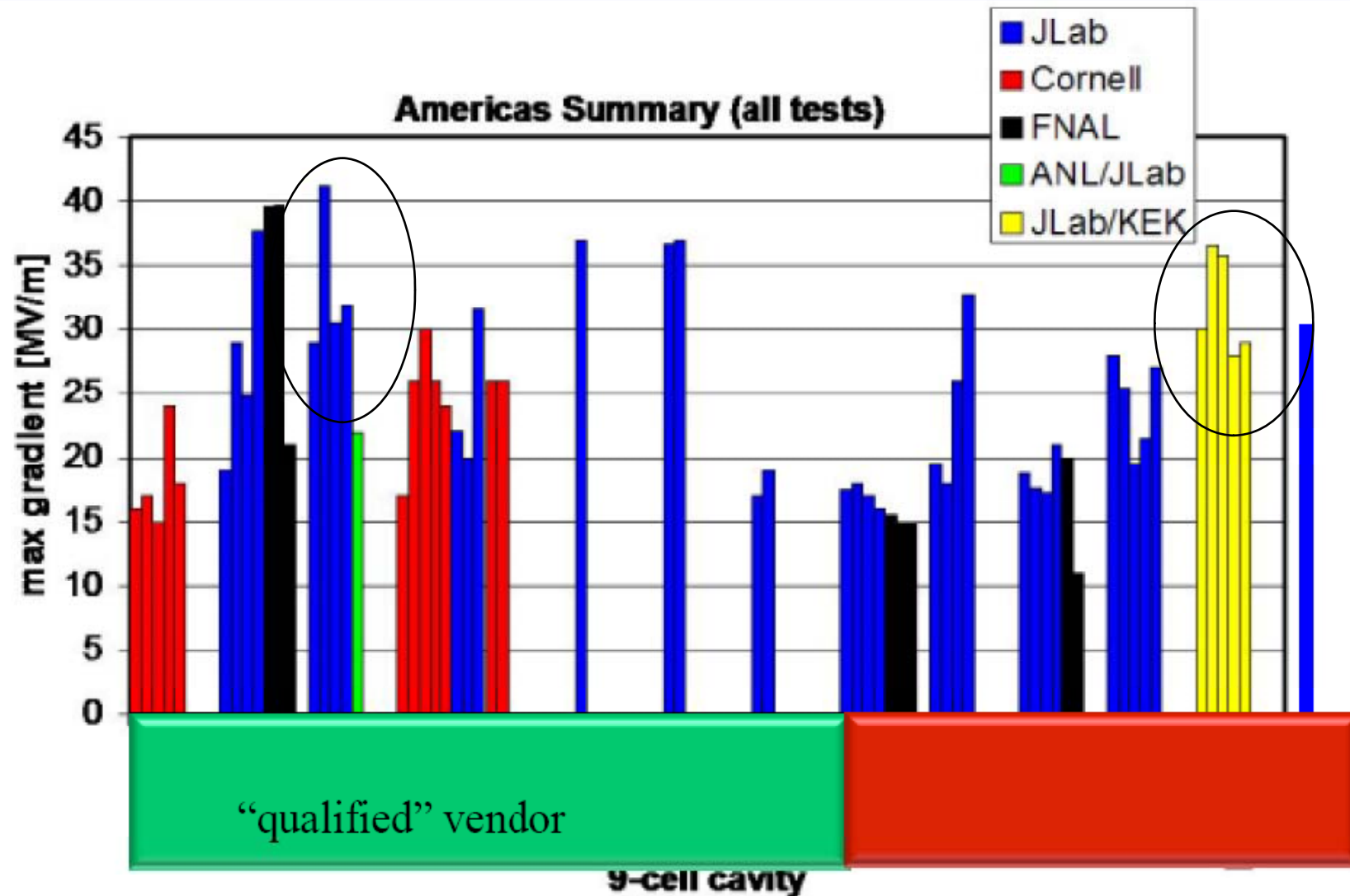
- Jlab confirmed niobium-oxide particles reported by Cornell (PAC-07) to be field emitters
- Probably not Nb₂O₅
- R&D needed to determine stoichiometry (XPS)
- Nb-O particle found in previous Cornell study



Some Open Questions About Quench

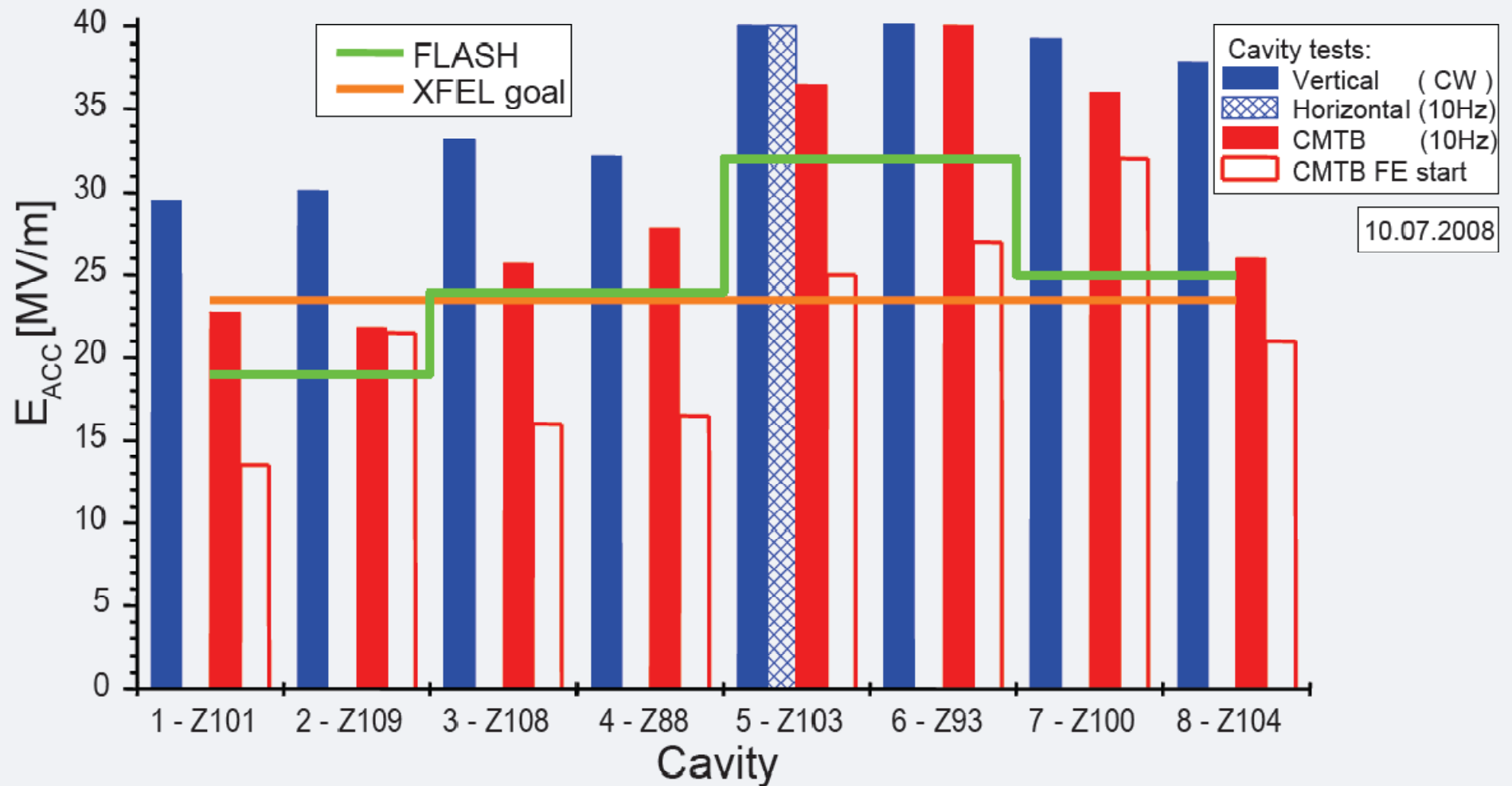
- What is the nature of quench sources for $E > 25 \text{ MV/m}$?
- Why does the quench field drop from 35 – 40 MV/m to 30 MV/m on re-treatment?
- Does a pit cause pre-heating below quench?
 - See latest Cornell result at end of this talk

Test to test variation, why?



S1 Results TTC Highlights

Module #8 test results



Module 8: Lessons learned

- Module 8 was a test vehicle for an out-sourced module assembly
- The two groups of four cavities each were assembled by two different teams
- Findings:
 - The actual work was done with slightly different ,respect‘
 - We were unable to identify or describe obvious differences
 - There is the suspicion that the single cavity venting was done with either different care or just different due to an aged venting equipment; we are going to replace the system
 - cav 8 probably suffered from a too fast venting of the string during a quick repair / exchange of an HOM feed-through
- Xrays of Z103 at 35 MV/m
 - vertical 0.1 mGy/min top plate, i.e. pick-up end of cav.
 - horizontal 0.08 mGy/min coupler end
 - module 0.1 mGy/min end of module and coupler end
 - 0.01 mGy/min beg. of module and pick-up end

KEK CM Test Results



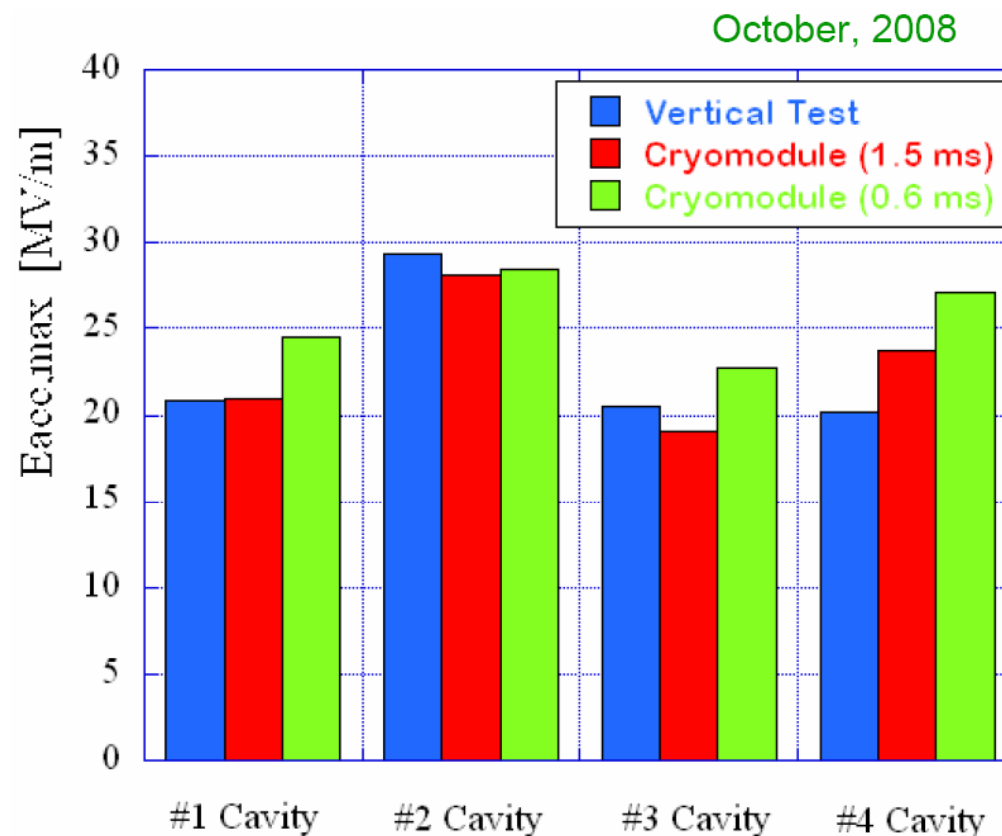
- Ceramic disk coupler
- Slide-jack tuner



KEK 4-cavity module test

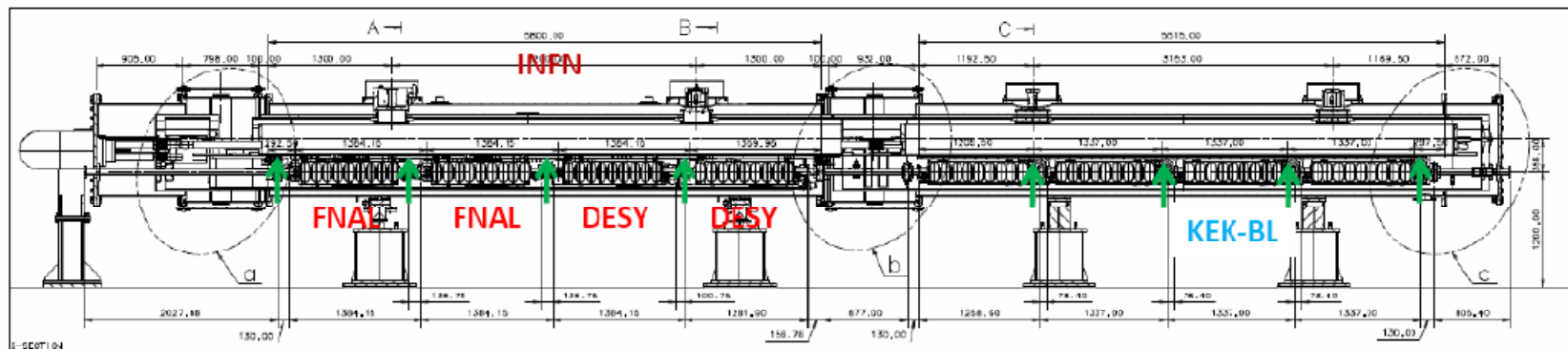
Ave. Eacc,max (V.T.)
= 22.7 MV/m

Ave. Eacc,max (Cryo.)
= 23.0 MV/m



S1 Global Plans

Composite Module at KEK



Cryogenic system

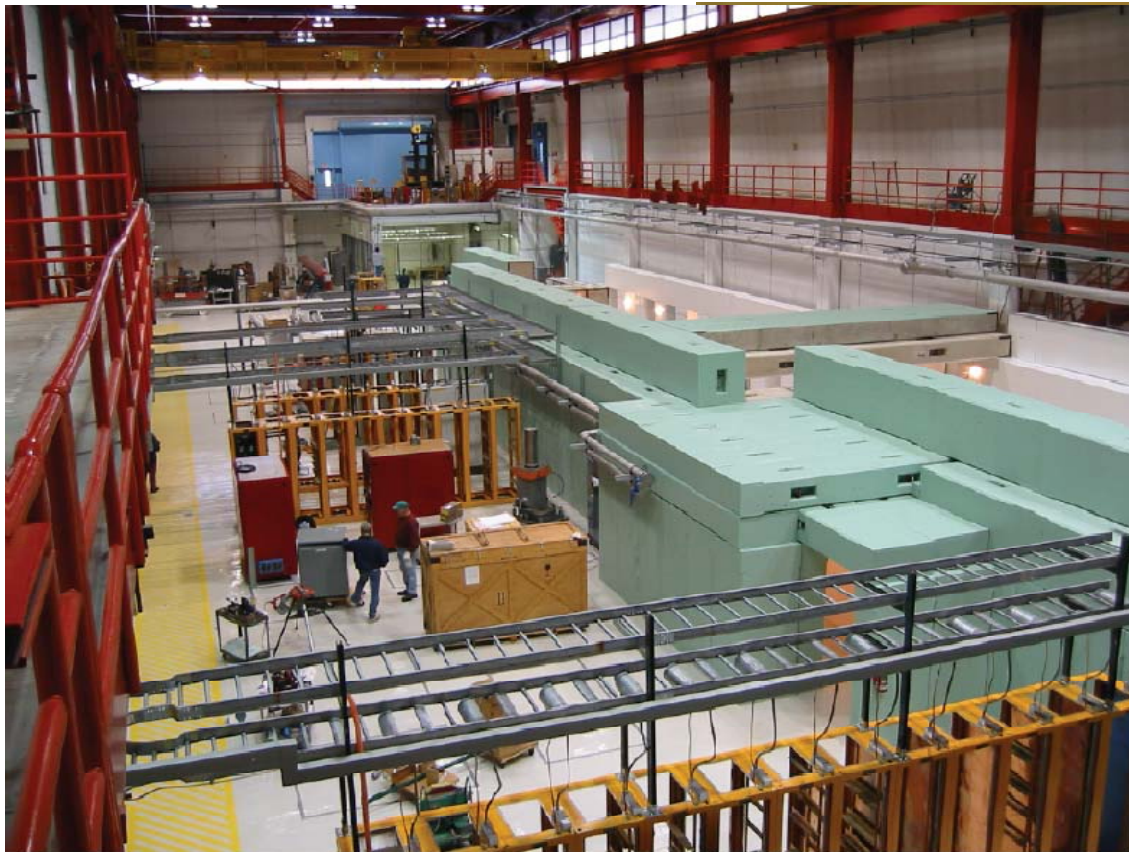
Module C

Module A

2008/10/21

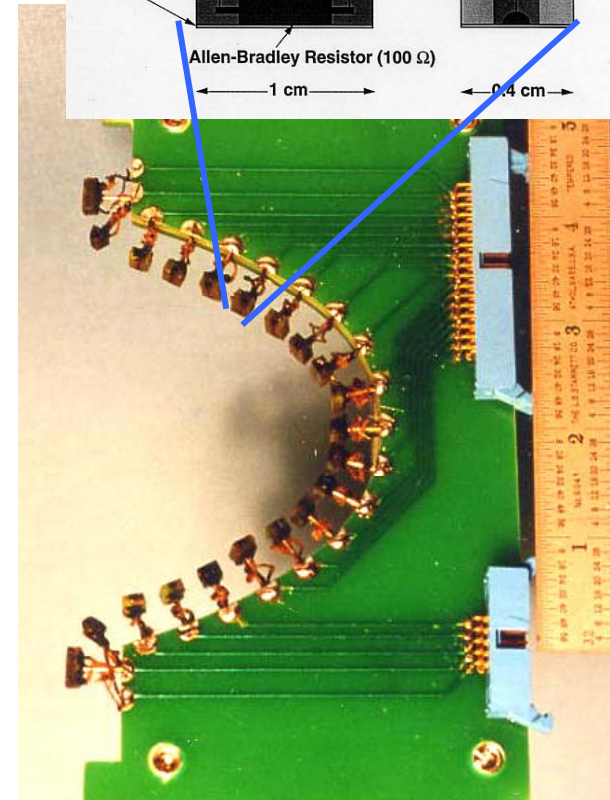
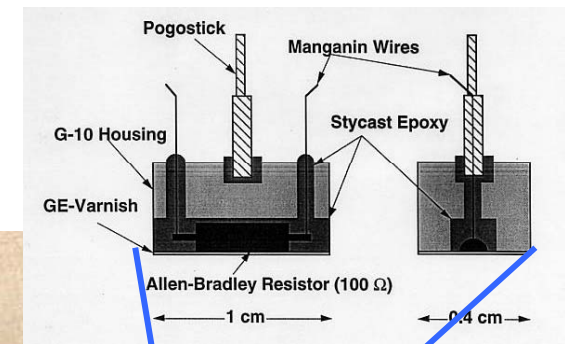
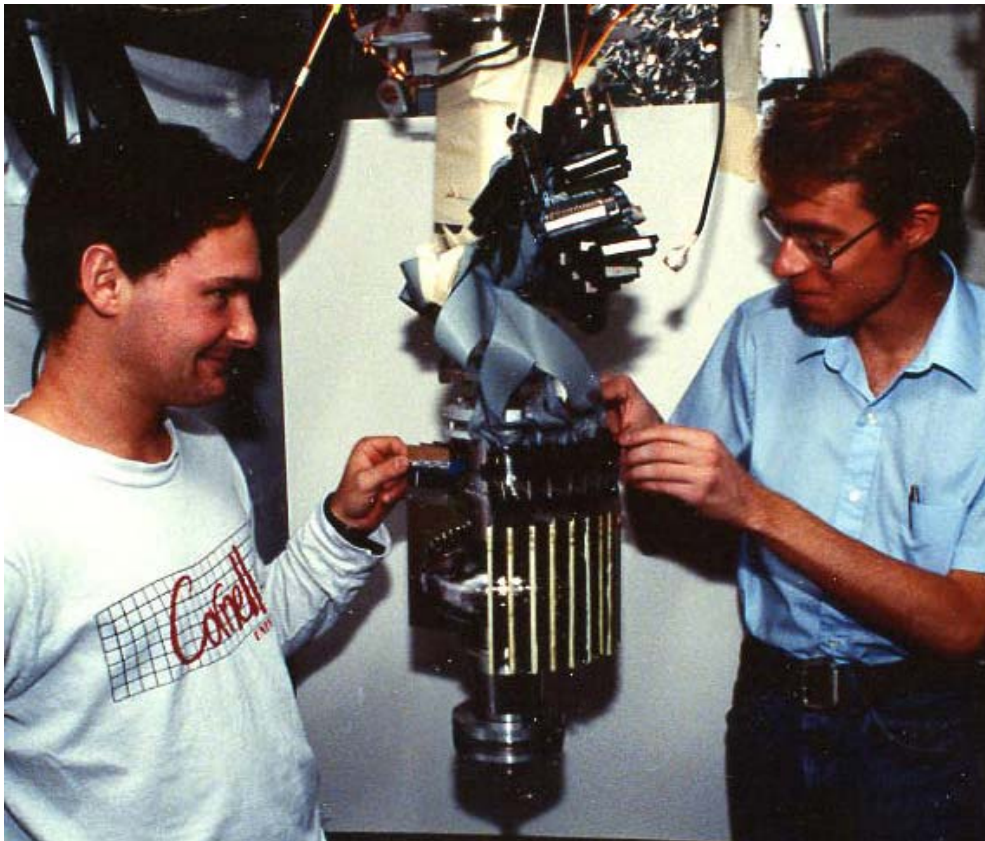
TTC-India-Delhi

Module Assembled with DESYkit Getting Ready to Test at FNAL

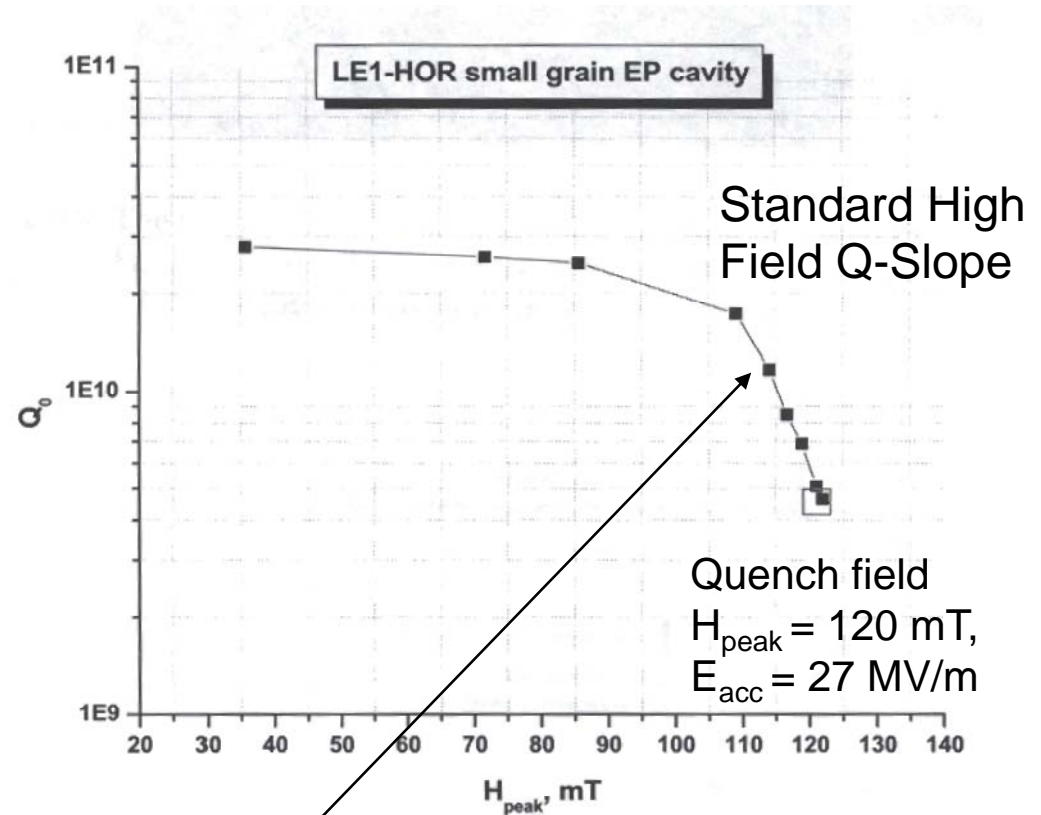
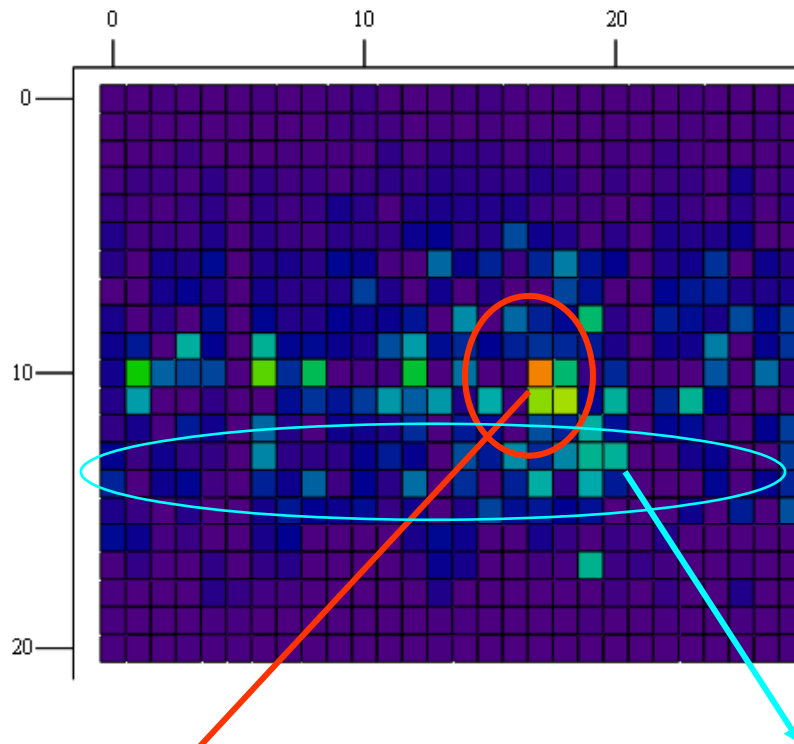


New Result from Cornell After TTC on **Pre-Heating** at Large Pit (lots of EP)

- Cornell 1-cell with large-scale thermometry system
- Works in superfluid to detect heating **BELOW** quench
- 760 thermometers for 1-cell, 1500 MHz cavity
- Grain size 1 mm (after HT1350C), preparation:
 - EP, 800 C, EP, HPR (no bake)



Temperature Map & Q vs E



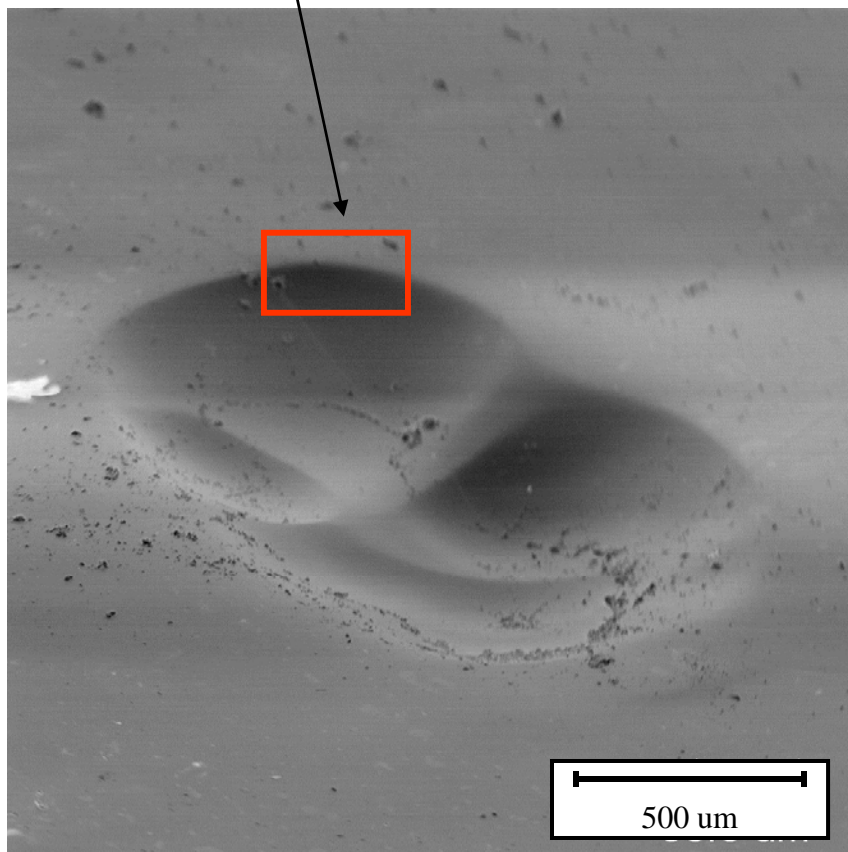
- General heating due to high field Q-slope
- Defect heating at pit at field BELOW quench
- Cavity prepared by EP and flash BCP (no bake)

Extract Samples from Cavity to Study High Field Q-slope and Defect Regions



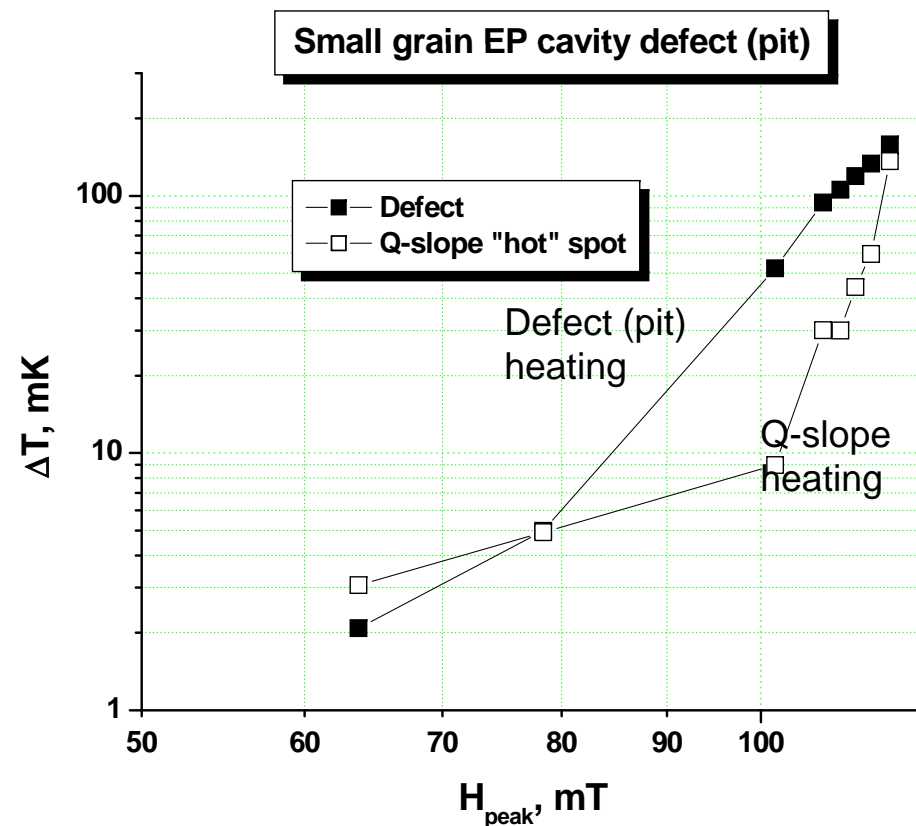
Defect Heating Surpasses Q-slope Heating Above 800 Gauss

Possible region of high field enhancement and quench may be only 10 μm



SEM back-scattered image

Individual thermometer responses

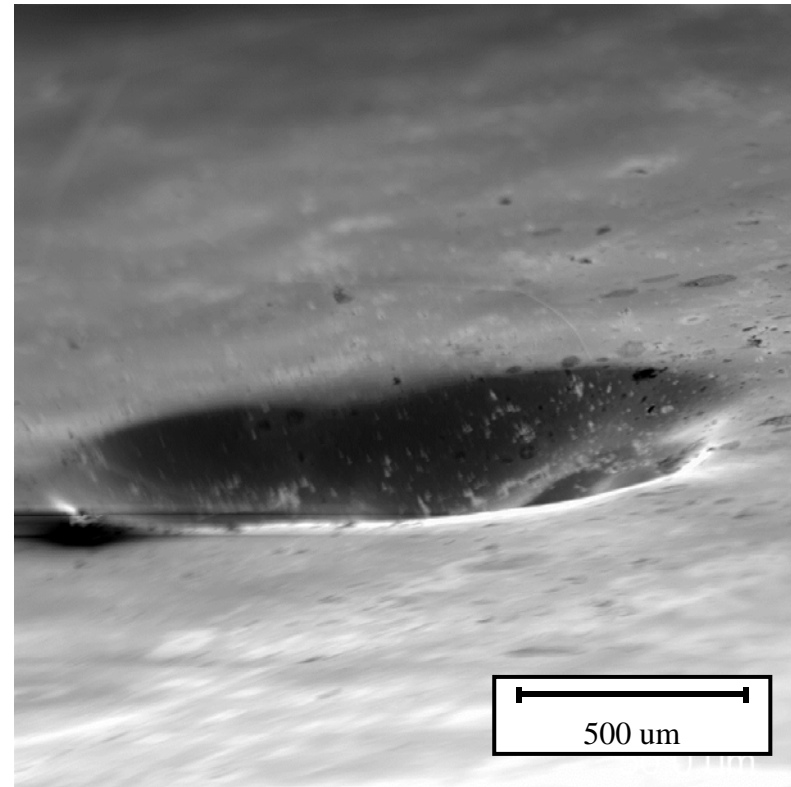
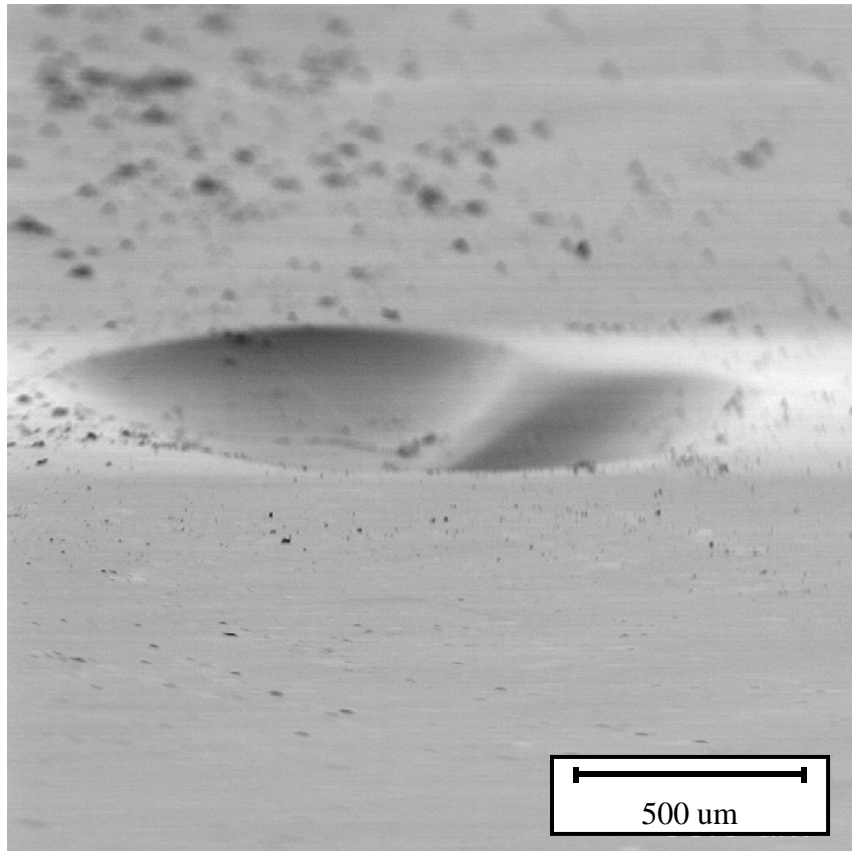


SEM

Quench field

$H_{\text{peak}} = 120 \text{ mT}$,

$E_{\text{acc}} = 27 \text{ MV/m}$



- $H_{crit} (T= 0 \text{ K})= 2000 \text{ Gauss}$

