Review of Results from Temperature Mapping and Subsequent Cavity Inspections

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DESY, Hamburg, Germany
SRF09

1. Quench locating systems
2. Visual inspection systems
3. Defect investigation methods
4. Examples of defect investigations
   - 4.1. DESY
   - 4.2. Cornell University
   - 4.3. Fermilab
   - 4.4. KEK
5. Conclusion

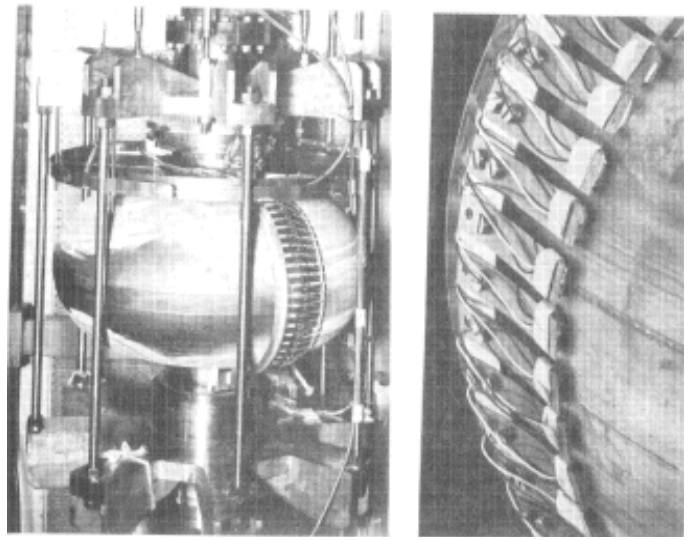
1. Quench locating systems

In a 4K (sub cooled) He bath:

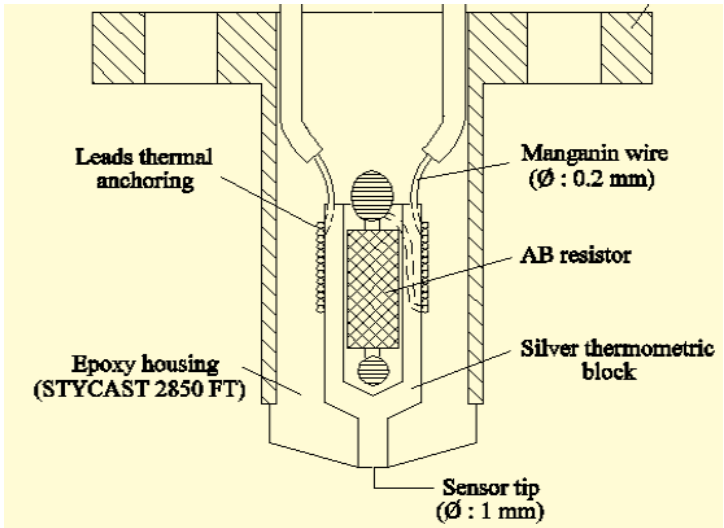
- carbon composition resistors
- rotating and fixed T-maps are in use for a long time

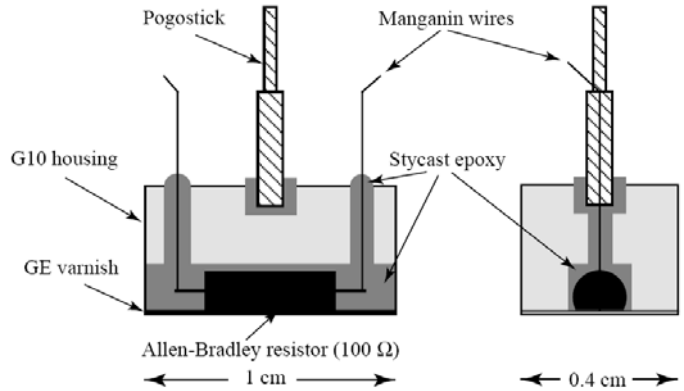
In a 2 K He bath:

- better insulation against the super fluid Helium is necessary
- fixed and rotating systems



H. Piehl, Iniversity of Wuppertal, SRF Workshop, Karlruhe 1980



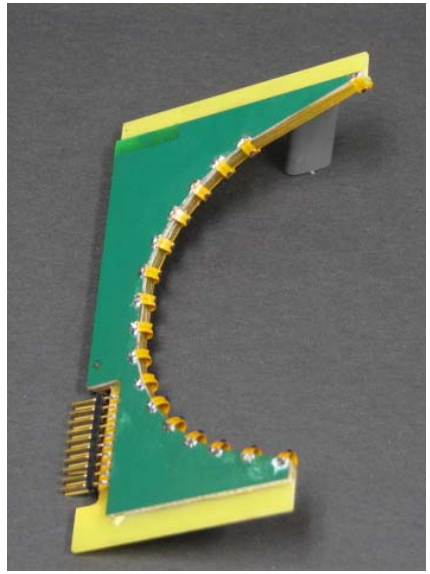


Jens Knobloch, Henry Muller, and Hasan Padamsee
Floyd R. Newman Laboratory of Nuclear Studies
Cornell University, Ithaca, N.Y. 14853

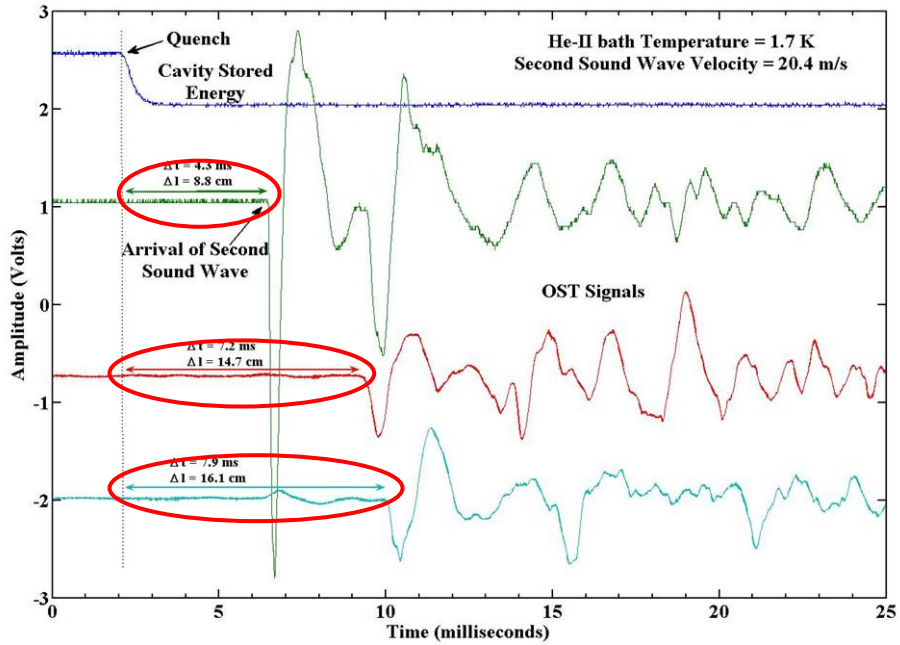
1. Quench locating systems, cont.

- Development of a diode based T-map system at Fermilab

- New acoustic defect location system developed at Cornell (localization by time of arrival calculations)

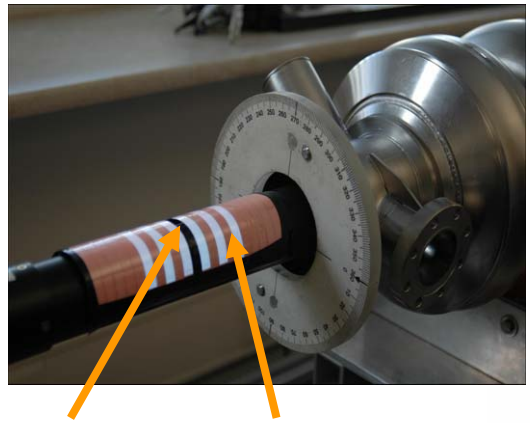


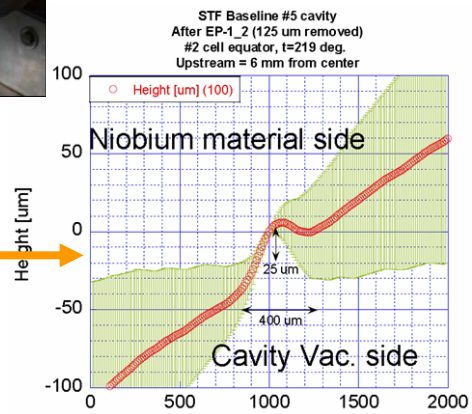
oscillating superleak transducer



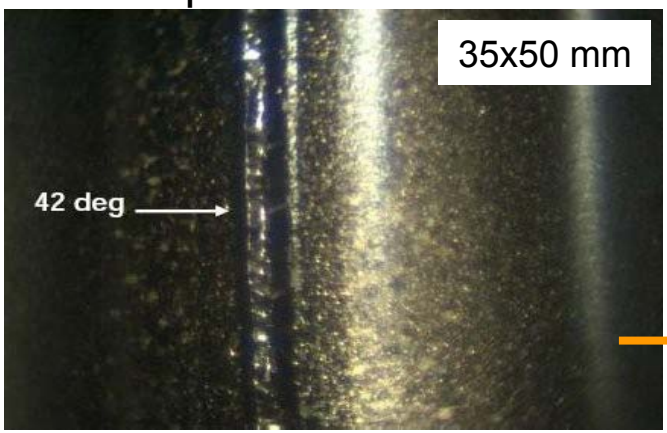
2. Visual inspection systems

- borescope
  - resolution: >0.1 mm
- long distance microscope (Cornell)
  - resolution: 12 µm/pixel (limited by camera)
- University Kyoto and KEK camera system
  - resolution: 7 µm/pixel
  - variable light system for height measurement

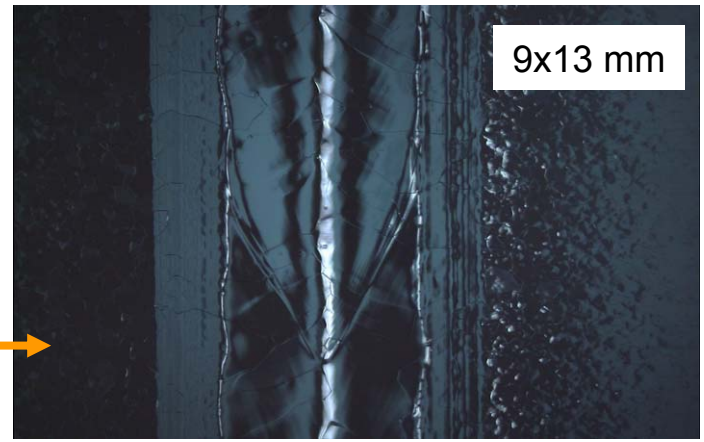




borescope



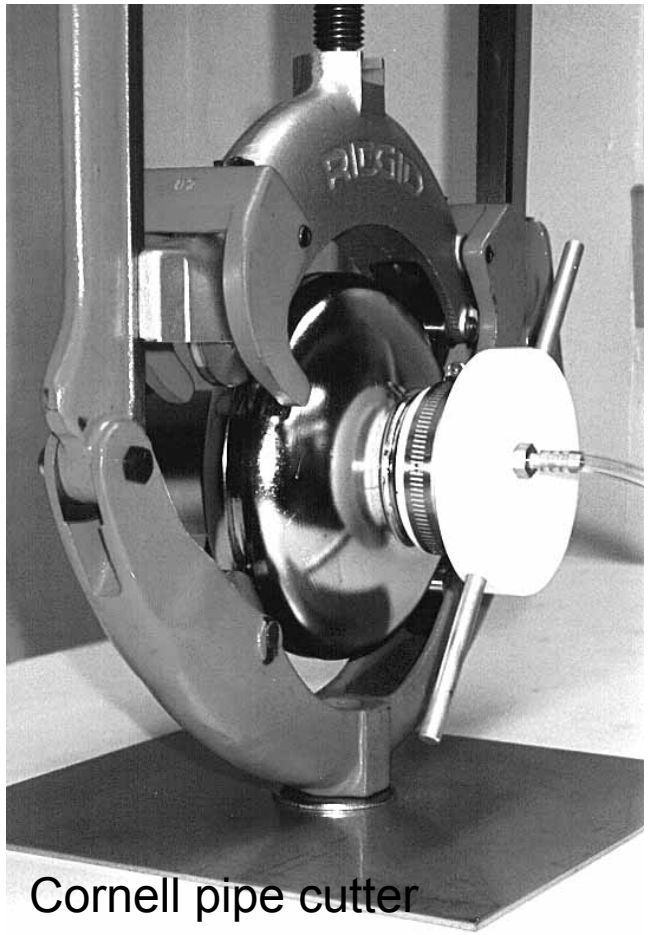
same location inspected with new KYOTO camera system



3. Defect investigation methods

samples have to be cut out of the cavity

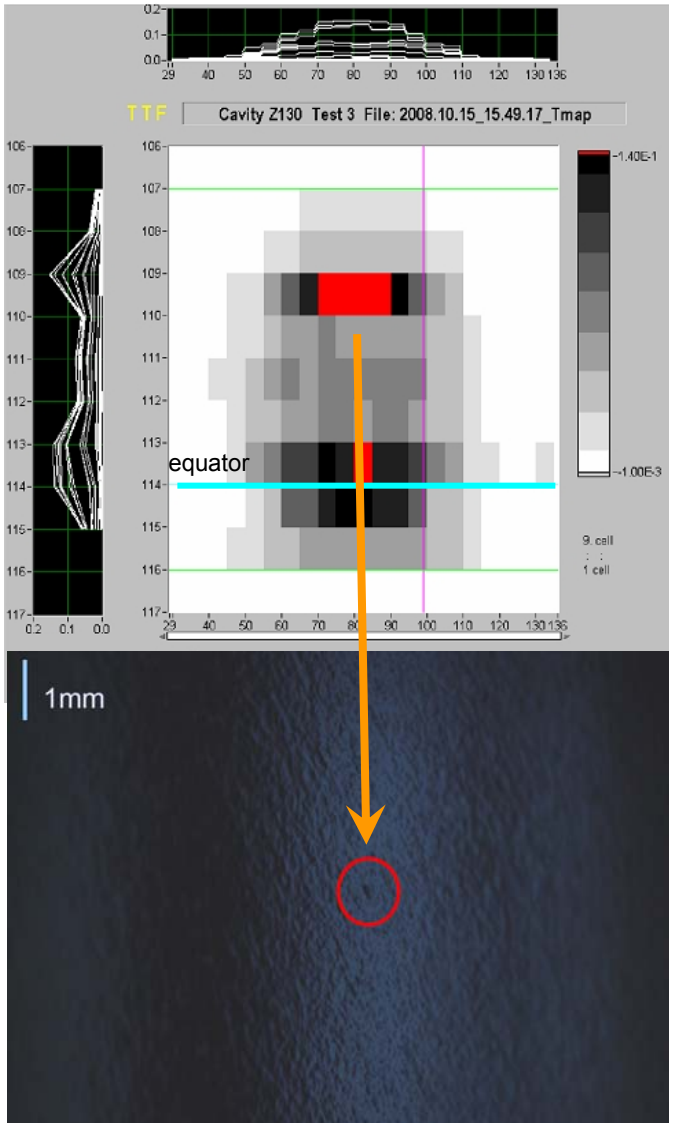
- shape
  - optical microscope
    - resolution: > 1 µm
  - 3D microscope
  - replication and profilometer
  - SEM
    - resolution: few nm
- composition
  - EDX
  - Auger
  - …

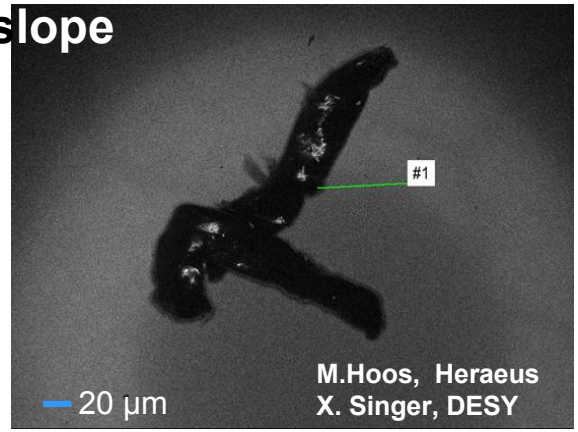


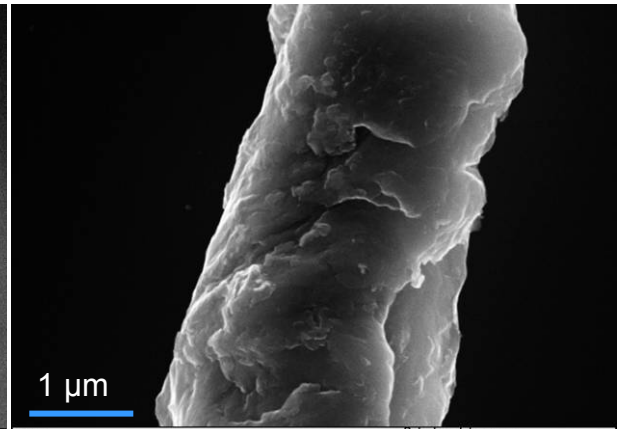
Cornell pipe cutter

4.1. Results from DESY, particle

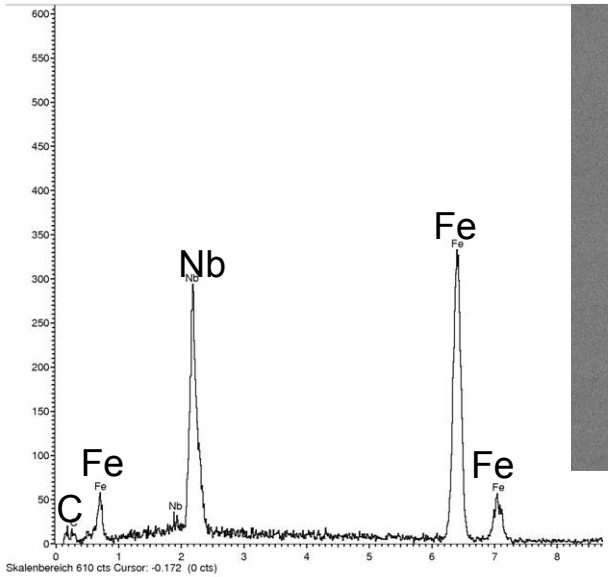
Cell 1, Quench at 16 MV/m at slope

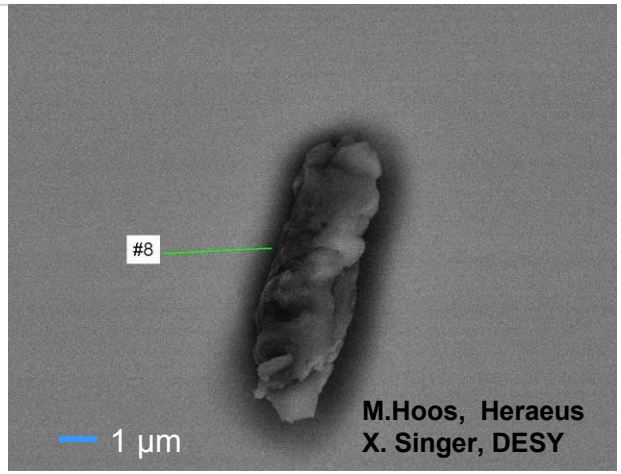






Many spots are detected in the area of the quench.

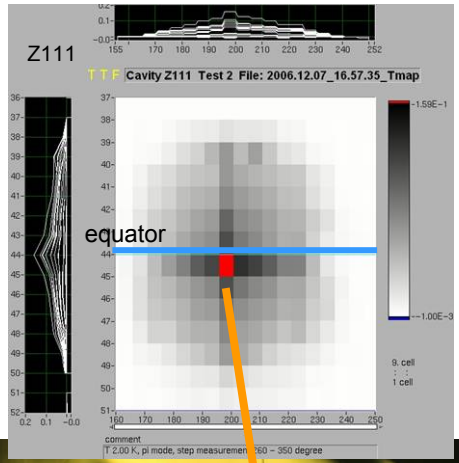




EDX : Fe, C

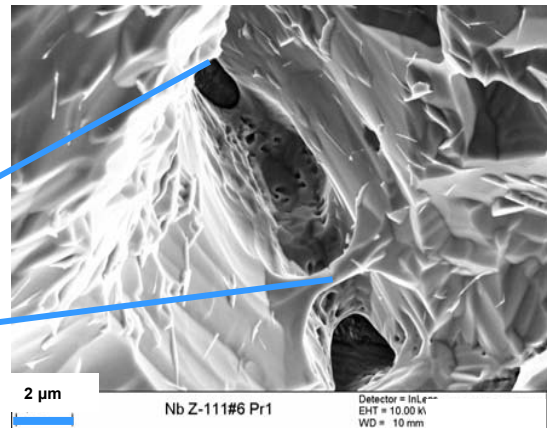
4.1. Results from DESY, holes and pits

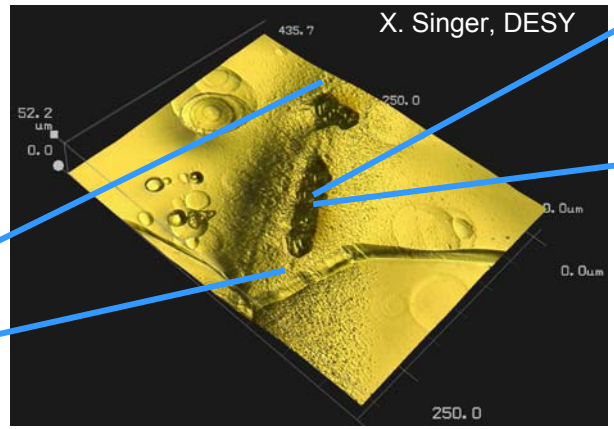
Cell 6, Quench at 16 MV/m on equator

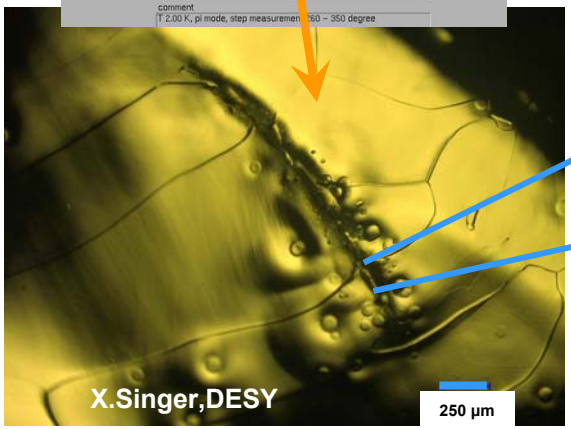


- Holes with sharp edges along the grain boundaries in the equator weld
- Pits around the holes.

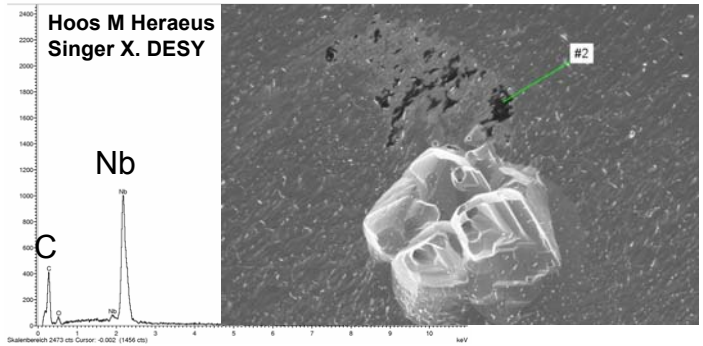
SEM





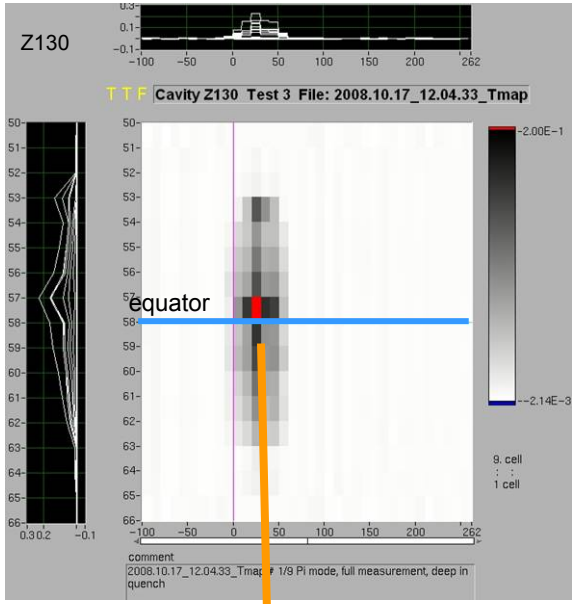


- Auger analysis: no foreign material
- EDX analysis: increased content of carbon in black spots

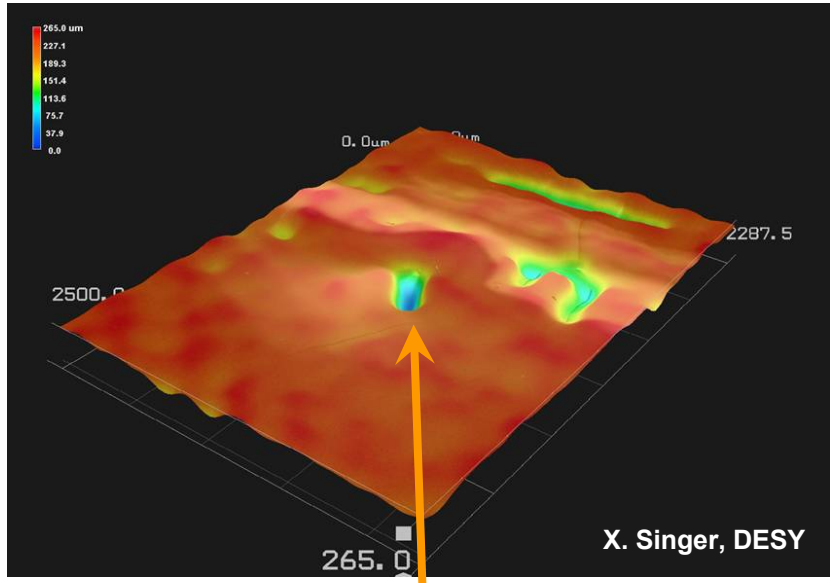


4.1. Results from DESY, hole and bump

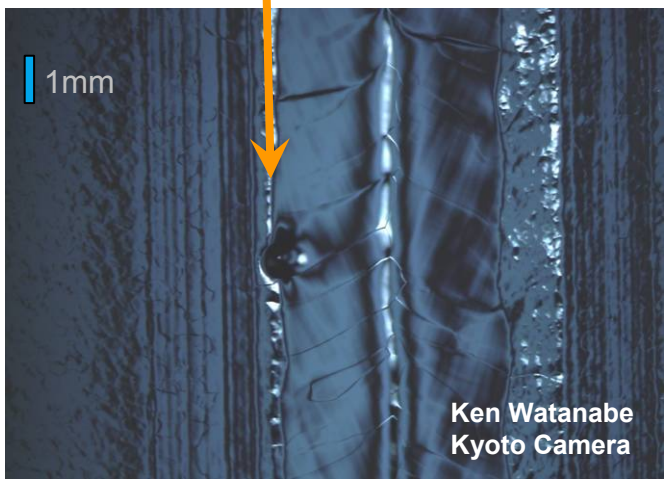
Cell 5, Quench at 23 MV/m on equator

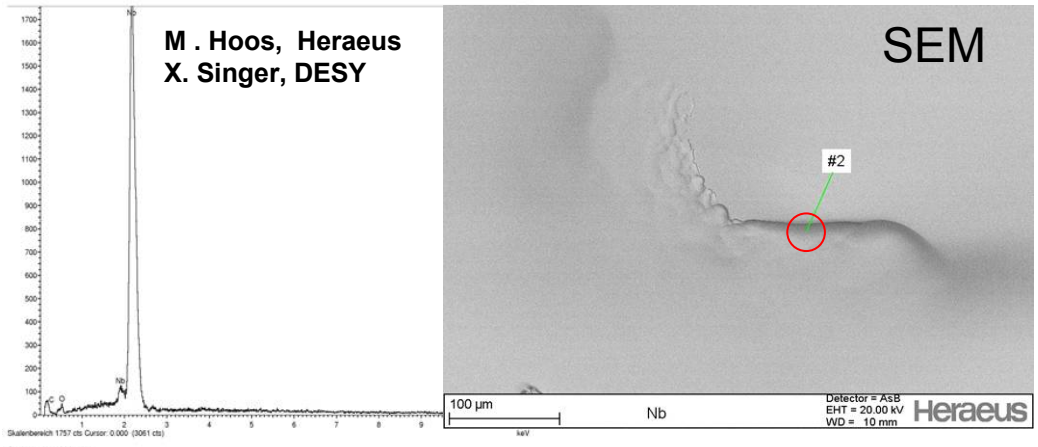


hole in the equator weld



3D image, bump and hole up to 200 µm deep



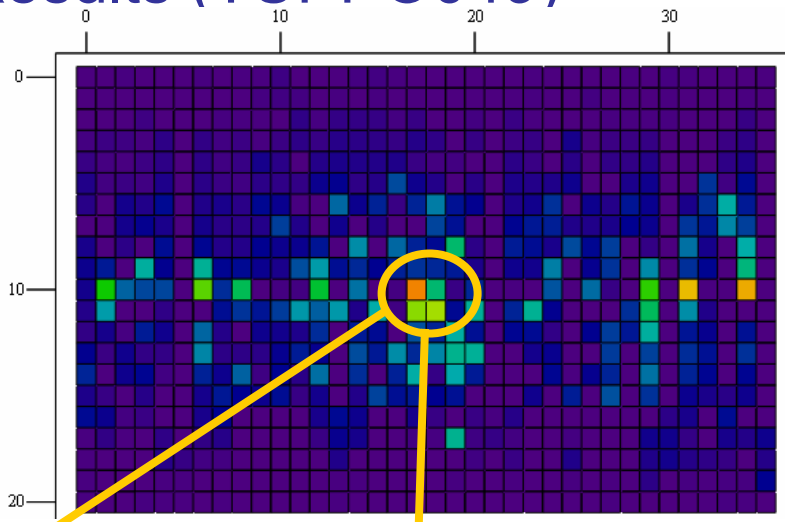


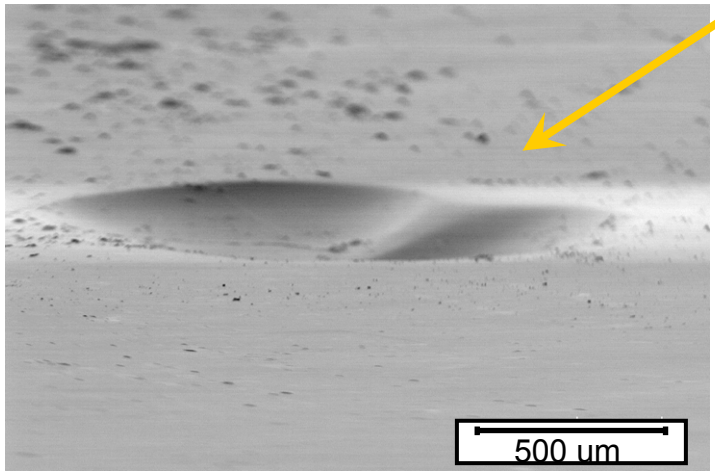
No foreign material inclusions detected by EDX

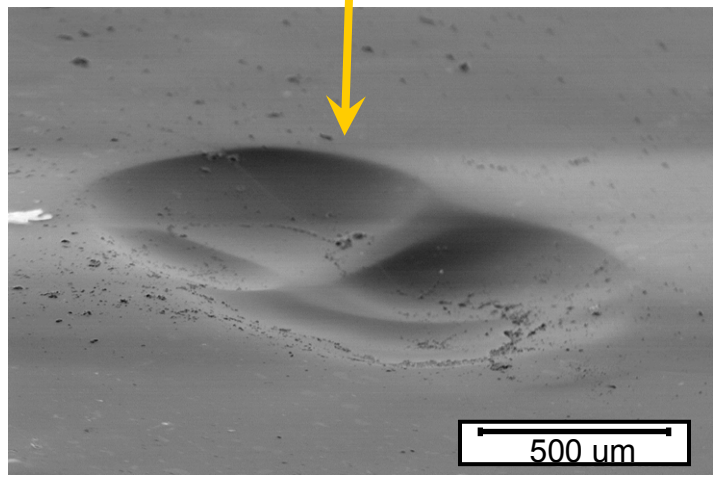
4.2. Results from Cornell University, pits

T-Map System and SEM Results (TUPPO049)

- many interesting details with SEM
- These details do not show up with optical inspection.
- Optical inspection can only serve as a rough, but useful, guide





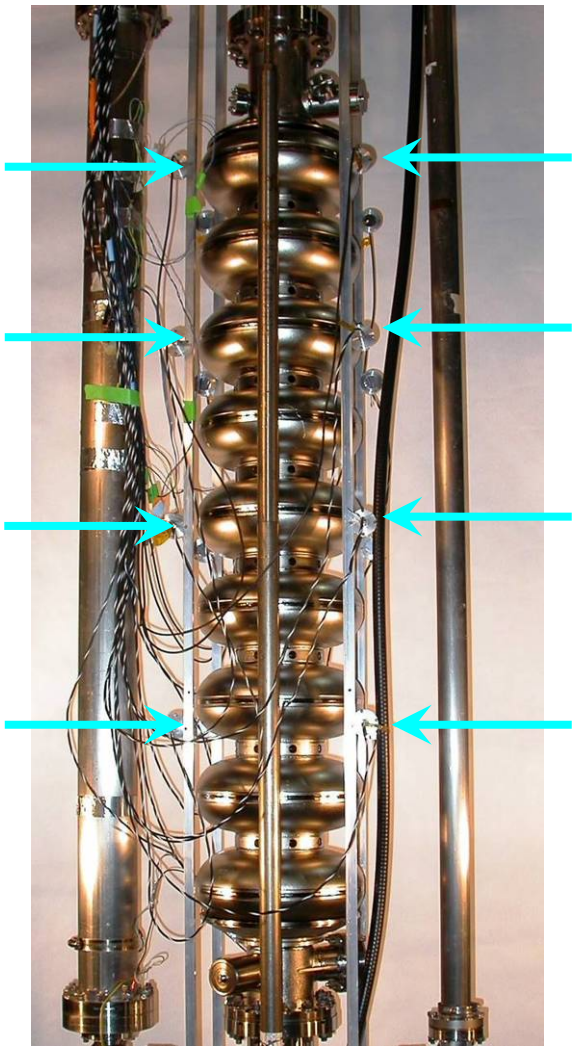


Same pit-defect, SEM images taken from different angles

Zack Conway at all, Cornell University

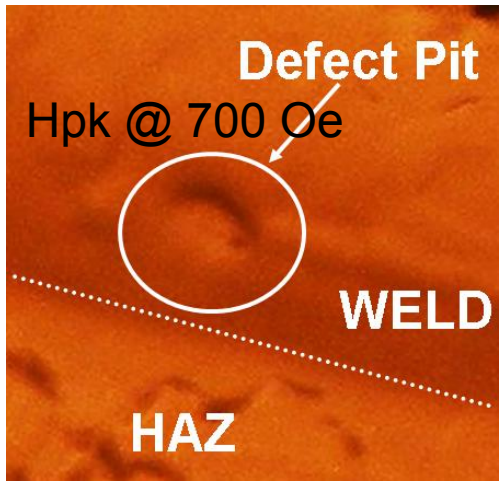
4.2. Results from Cornell University, pits cont.

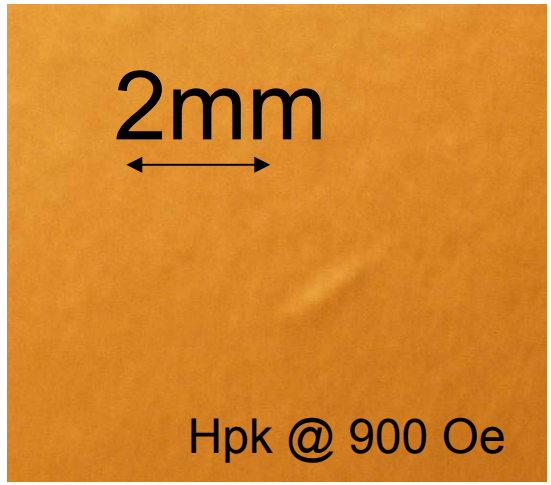
Example pits found with acoustic defect location system (TUOAAU05)

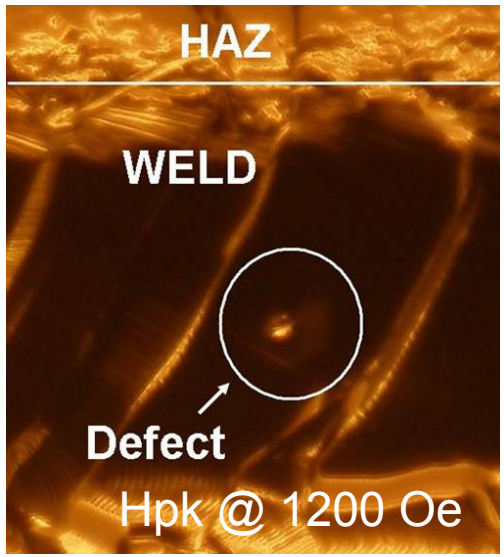


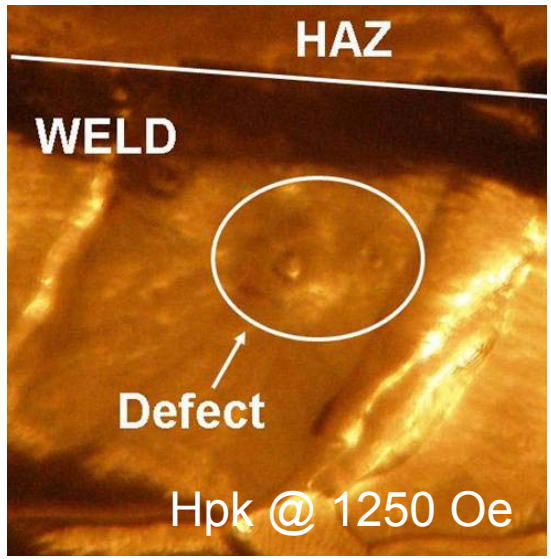
8 superleak transducers used

quench limitations are noted as Hpk





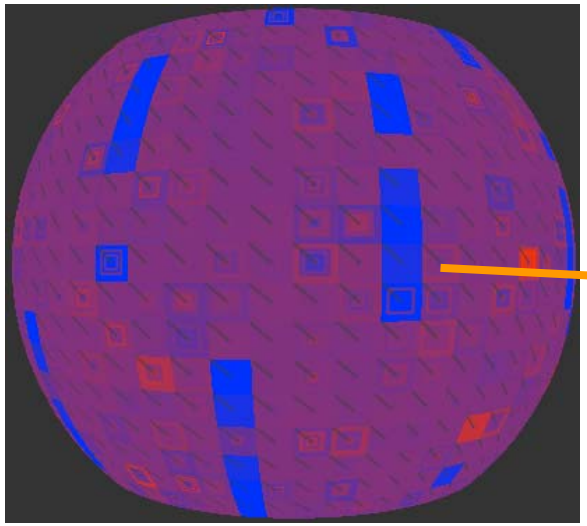




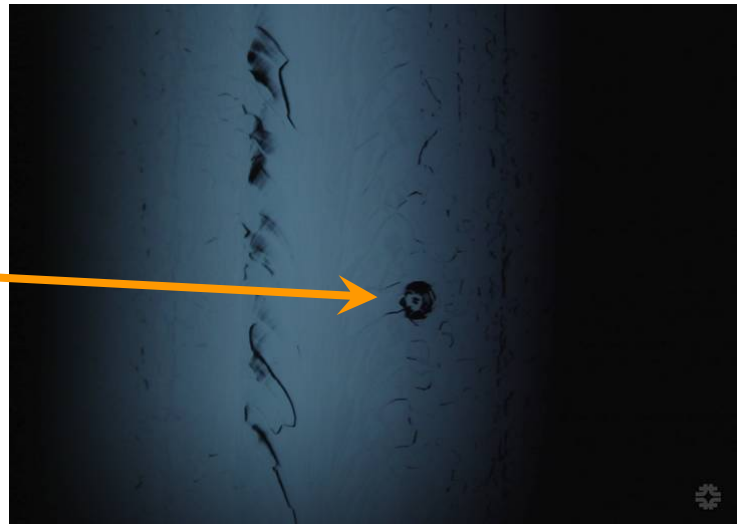
Zack Conway at all, Cornell University

4.3. Results from Fermilab, pits

Single Cell, quench at 39 MV/m

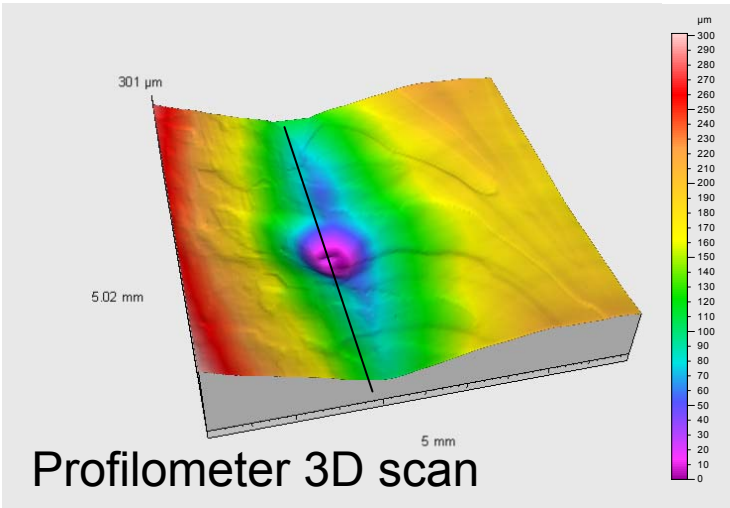


Diode T-map

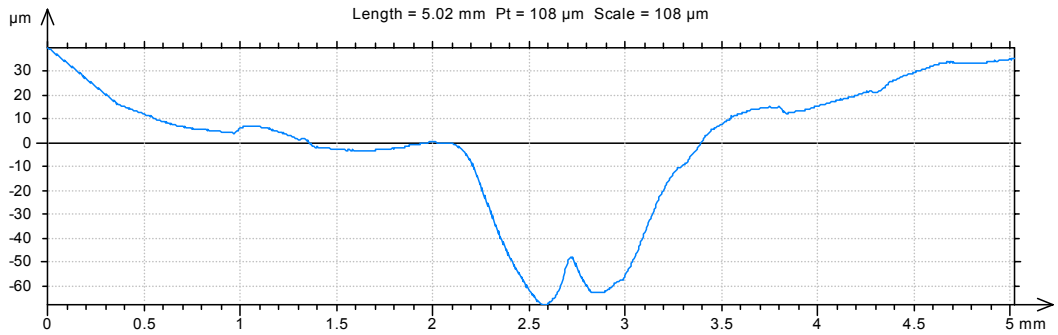


Camera inspection

see Genfa's talk on Thursday THOBAU03



Profilometer 3D scan



Profilometer line scan: pit is ~70 µm deep

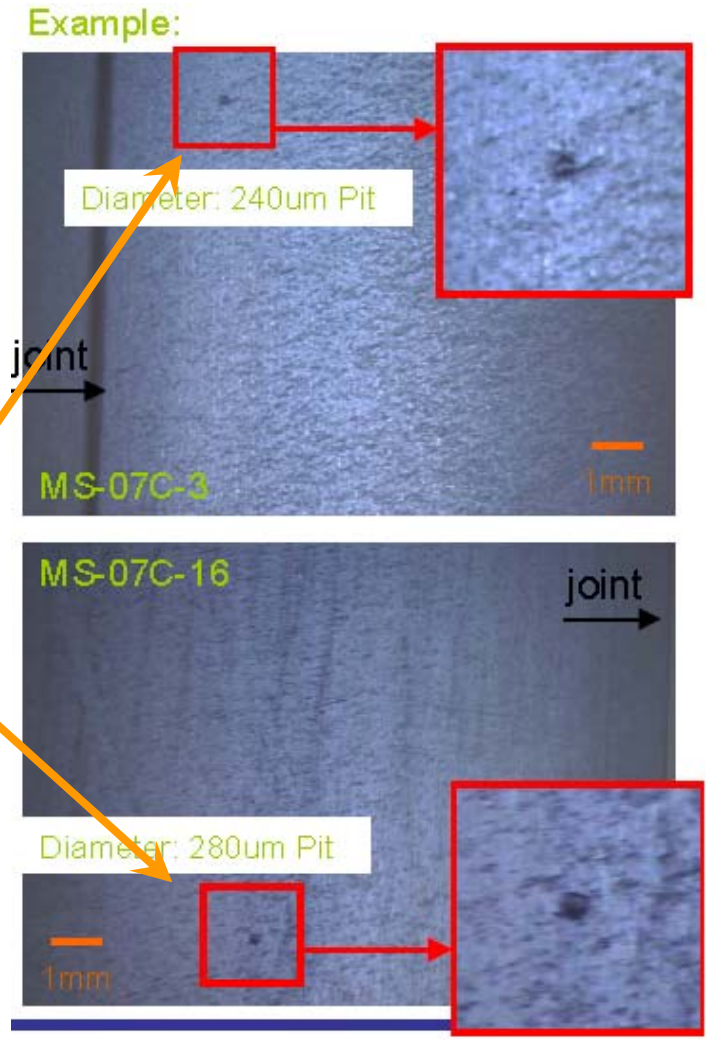
Genfa Wu, for Fermilab team

4.4. Results from KEK, pits and bumps in MHI - cavities

- intensive inspection on two cavities near (±15mm) and on equator weld (with Kyoto camera)
  - before dumbbell welding
  - cavity as received
  - after pre EP
  - after 100 m EP
  - after annealing
  - after final EP
  - after vert. test + T-map
- many suspicious spots were found before second EP typical
- typical pits:
  - diameter: 200 - 500 µm
  - depth: 10 - 30 µm
- typical bumps:
  - diameter: 800 µm
  - height: 50 µm

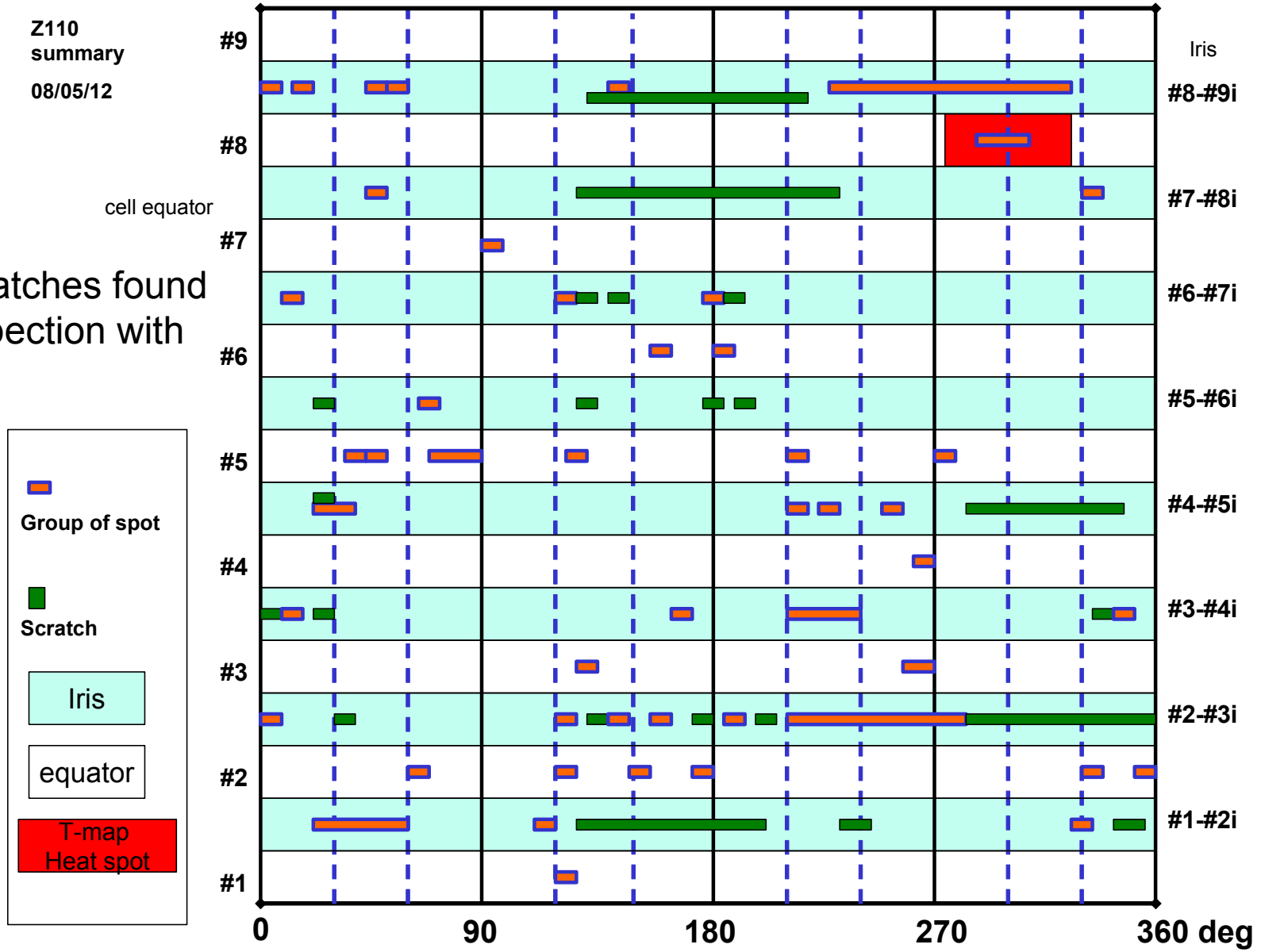
‘The spots were observed on the surface even in the dumbbells stage.’

‘However, heating at similar spots is not detected in the V.T. for MHI-05 and MHI-06’



K. Watanabe at. all. Recent Results of Cavity Inspection for the SC Cavity at KEK-STF, PAC09,

4.4. Results from TTF cavity, inspection at KEK

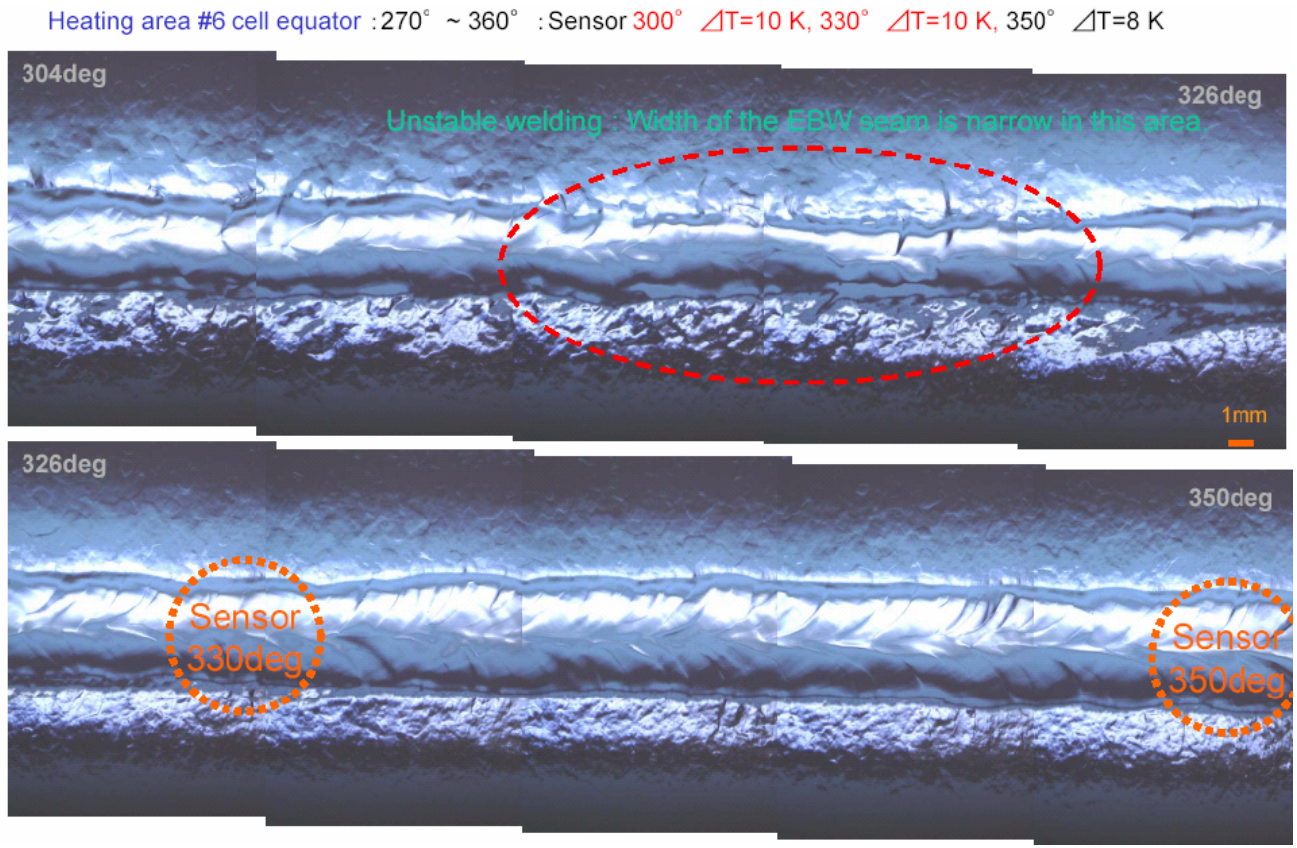


spots and scratches found by optical inspection with Kyoto camera

4.4. Results from KEK, welding seams, MHI-06

Quench location investigations:

- "The observed suspicious spots (…) are not reason of limitation of cavity performance at this moment."
- heating area at 33 MV/m was 304° - 350°
  - a non-uniform weld seam was found



more in Ken's talk TUOBAU01

Defect size and achievable gradient

Zack Conway, Cornell:

- ‘At accelerating gradients above ~30 MV/m I cannot find the defects with long-distance optical microscopy. Below ~30 MV/m, I find defects at the quench-spot 95% of the time with long-distance optical microscopy.’

Ken Watanabe, KEK:

- ‘The heating at the suspicious spots was not detected by T-map.’
- ‘Heating locations at accelerating mode were inspected, but there were no visible defect.’

more next talk: David Meidlinger
TUOAAU05

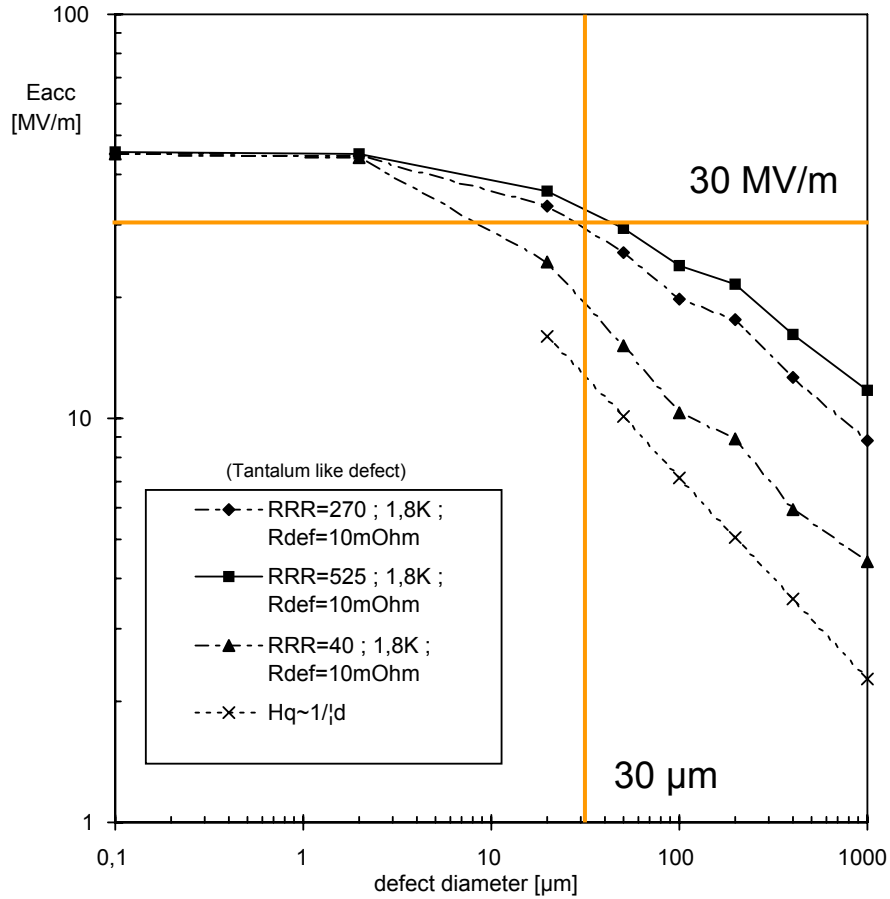


Fig.2: Calculated breakdown field for RRR=525, RRR=270 and RRR=40. The analytical Hq~1/¦d is shown as comparison.

THERMAL MODEL CALCULATIONS FOR 1.3 GHZ TTF ACCELERATOR CAVITIES, Detlef Reschke

Summary and Conclusion

- Big improvement in Cavity fabrication and treatment
  - less foreign materials found (at limitations <20MV/m only)

- New visual inspection systems are available (Kyoto/KEK)
- Long distance microscope with the same resolution
  - much improved resolution: about 10 µm/pixel depending from camera

- Many irregularities in the cavity surface are found with this systems during and after fabrication and treatment
  - pits and bumps
  - weld irregularities
- Some correlations are found with quench limitations at higher fields
  - But often no correlation between suspicious pits and bumps and quench location
- At gradient limitations in the range >30 MV/m defects are often not identified

- Investigations are necessary for
  - classification of defects
  - what causes the defects → intensive inspections at different fabrication and processing states are done at KEK

Acknowledgements

Thank you for providing me with the information and the material:

Zachary Conway and his team at Cornell University
Xenia and Waldemar Singer, Sebastian Aderholt at DESY
Ken Watanabe and his team at KEK
Genfa Wu and his team at Fermilab

I was not able to include all the work done at the different institutes. There is much more interesting and important work done – see the next talks.