Tesla Technology Collaboration Meeting

Working Group 1:
β=1 , Gradients, Reproducibility, Procedure Refinement
Summary

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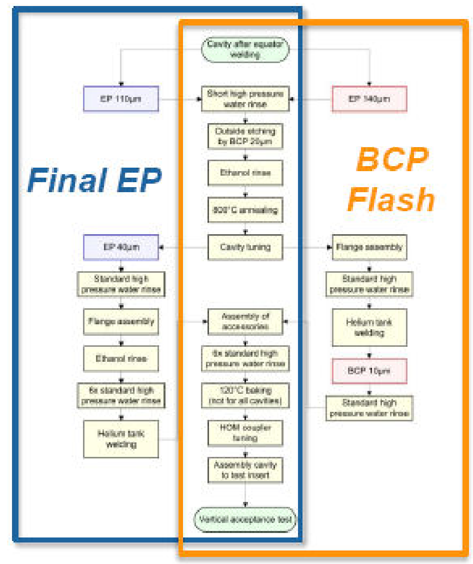
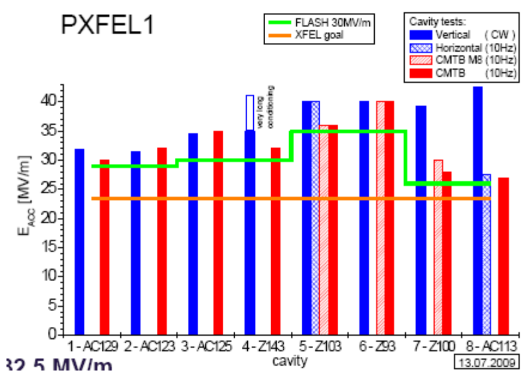
Tesla Technology Collaboration Meeting
Fermilab, April 2010

Needs for β=1 cavities: XFEL

- Initial cavity call for tender July 2, 2009 led to a second one with modifications, notably removal of performance guarantee
- Total number of cavities etc. reduced to 80%
  - From the 1st XFEL MAC: With realistic assumptions on lower beam emittance, linac energy reduction by 20% to 14 GeV appears as a reasonable compromise between cost aspects and scientific potential of the facility. CW mode remains an interesting future option, but: If CW mode is realized, this should go along with re-establishing the full (TDR) linac length to permit ~7GeV.
- Cavity surface preparation strategy
  - Two schemes for the final surface treatment (Final EP and BCP Flash) will be used for cavities from two different vendors
- Cavities contracts to be placed asap; delivery in 2012-2013



- Excellent results from Chinese cryomodule
  - After string and module assembly only 5% gradient reduction
  - Average max gradient 32.5 MV/m
  - Operation in FLASH 30 MV/m

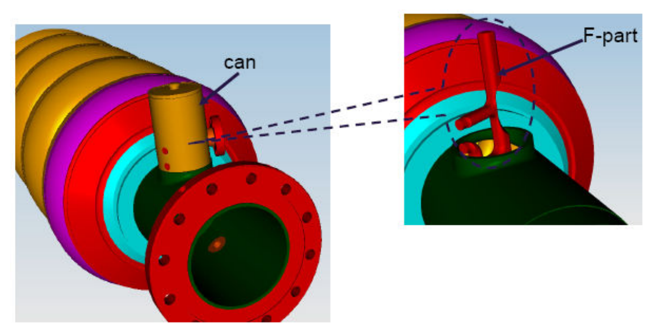


- Many lessons to be learned from XFEL experience for future projects

Weise

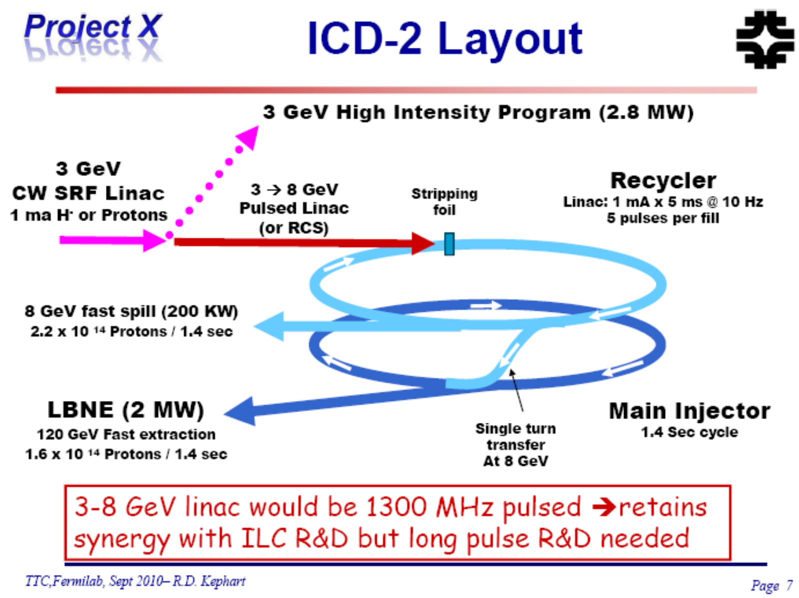
Needs for β=1 cavities: XFEL

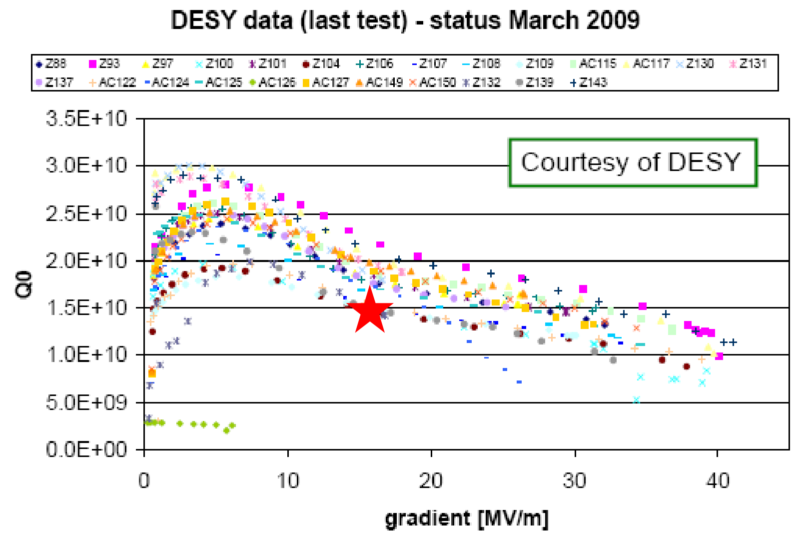
- The cw acceptance test for XFEL cavities with assembled HOM feedthroughs has been proposed to lower the production cost, but it may lead to:
  - Rejection of cavities, which are good for the XFEL operation
  - Contamination of sc cavities with the evaporated soldering material used in the HOM feedthroughs
- Summary of the Pulsed Tests
  - Cavities without HOM feedthroughs demonstrated in vertical test the same performance as for the cw test.
  - Cavities with good HOM feedthroughs demonstrated in vertical test even higher Eacc. RF on-time can be too short to quench the cavity.
  - Cavity with HOM feedthroughs demonstrated in horizontal test the performance observed in vertical test without the feedthroughs.
- Pulsed acceptance tests
  - Pros:
    - Production less expensive.
    - Less LHe for the acceptance tests of at least 640 cavities.
    - Less probability for the contamination with soldering material
  - Cons:
    - Cavity conditioning, if needed, will take longer.
    - Additional effort for automation of the acceptance test needed



Sekutowicz

Needs for β=1 cavities: Project X



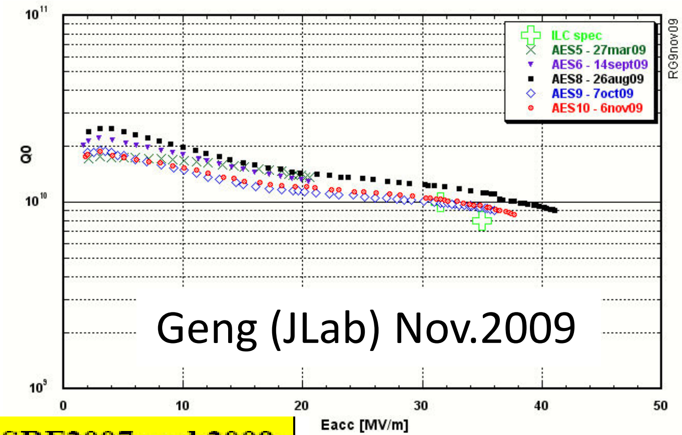


- 2-3 GeV contains ~65 Tesla-like cavities: ~17 MV/m, Q0=1.5E10@2K
- Future 3-8 GeV = <u>either</u> a pulsed linac (Tesla-like cavities) or a rapid cycling synchrotron
  - Linac: 200 Tesla-like cavities in 25 cryomodules operating at 25 MV/m

Kephart

Cavity gradient highlights

Integration of improved cavity fabrication, improved EP and post-EP cleaning and other clean cavity assembly is pushing gradient yield up to >35 MV/m by the 1st or 2nd pass tests



Geng (JLab) Nov.2009

ILC activity @ JLAB

by R.L.Geng et al., SRF2007 and 2009

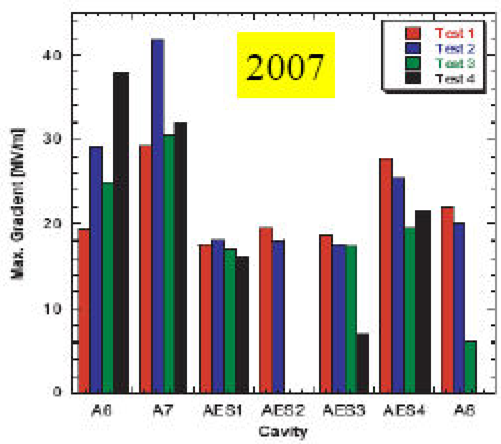


Figure 2: Maximum gradients achieved by 9-cell cavities.

Much improved

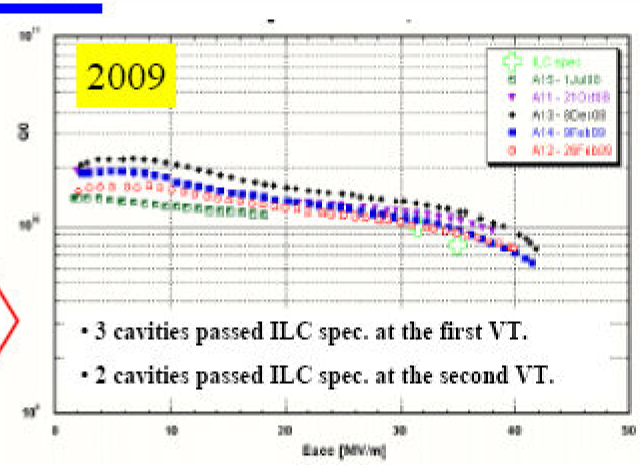
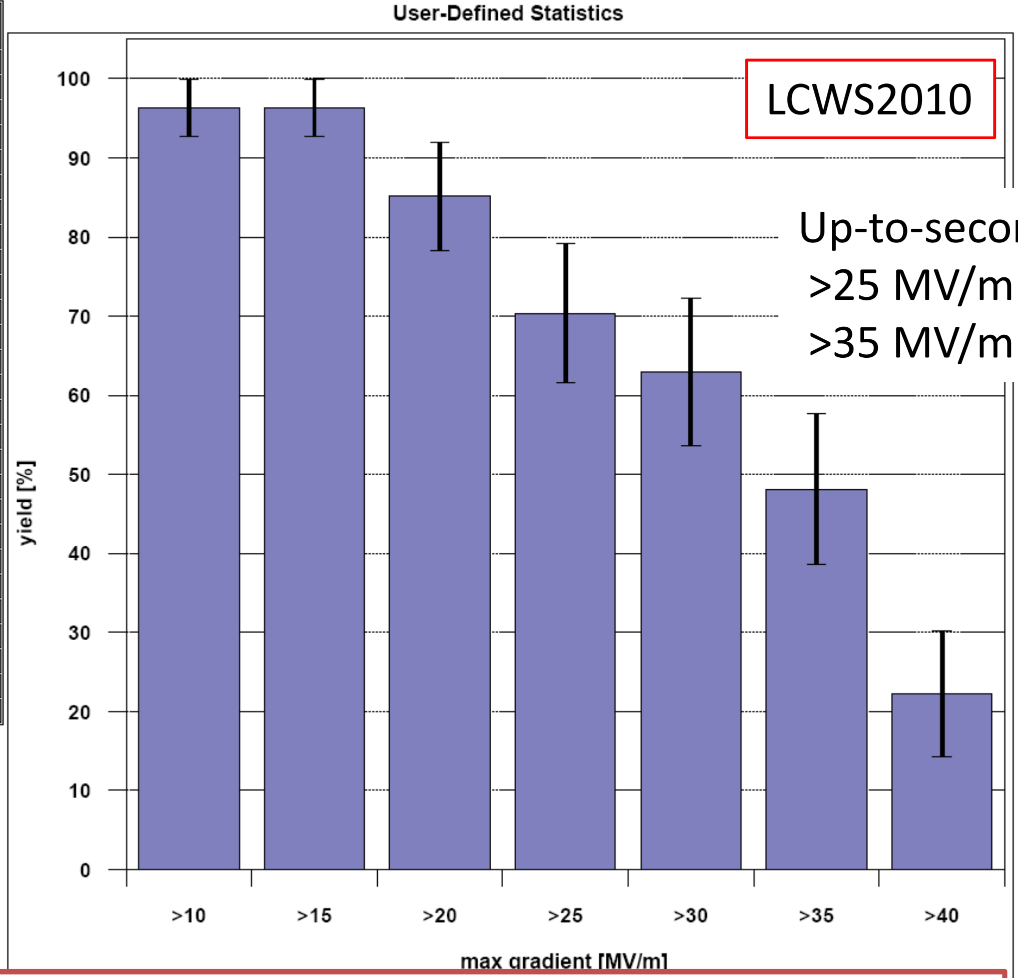


Figure 3: Performance of 5 new cavities manufactured by ACCEL and EP processed and tested since July 2008 at JLab. Error bars are not shown for clarity.

Saito

Cavity gradient tracking

No.	Cavity	Test Date	Max. Eacc [MV/m]
1	TB9ACC013	01.Dec.08	41.80
2	TB9ACC014	09.Feb.09	41.50
3	ACCEL7	18.Jan.07	41.20
4	TB9AES008	26.Aug.09	41.10
5	Z143	12.Nov.08	41.00
6	TB9AES007	16.Mar.10	41.00
7	TB9ACC016	11.Feb.10	39.30
8	AC122	26.Aug.08	38.88
9	AC115	11.Dec.07	38.60
10	TB9AES010	06.Nov.09	37.70
11	TB9ACC011	21.Aug.08	37.00
12	TB9AES009	07.Oct.09	36.00
13	TB9ACC012	07.Jul.08	35.10
14	AC150	08.May.09	33.23
15	Z139	20.Oct.08	32.75
16	Z106	27.Feb.07	31.50
17	AC124	19.May.09	30.93
18	ACCEL6	23.Jan.07	29.00
19	AC127	11.Jun.09	27.85
20	AC149	05.May.09	23.27
21	TB9AES006	11.Sep.09	22.20
22	Z141	14.May.08	20.70
23	TB9AES005	09.Apr.09	20.50
24	TB9ACC015	14.Jul.08	19.00
25	Z131	25.Nov.08	17.96
26	Z130	15.Oct.08	16.60
27	AC126	21.Oct.08	6.14



Up-to-second-pass cavity yield at
>25 MV/m is (70 +- 9) %
>35 MV/m is (48 +- 10) %

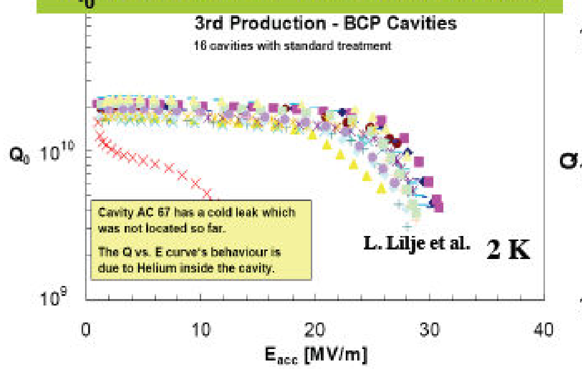
Improved reliability of yield estimates with ILC database
+ may be used for process and fabrication R&D

Ginsburg

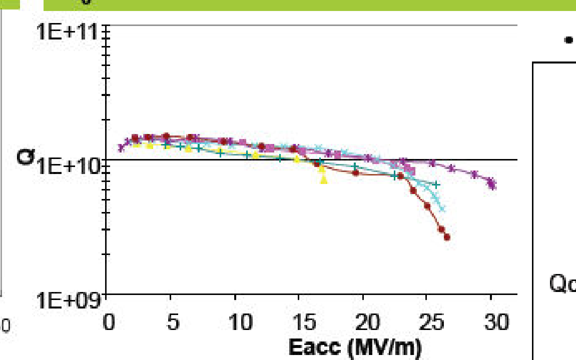
Quantification of Q0

- Exceptionally high Q0 values of 5E10 – 1E11 have been achieved in a few cavities in vertical tests
- In larger samples
  - Significant variation in medium field Q0 values
  - Poor repeatability of high-Q0 results
  - No systematic understanding
  - Low (~120C) and high temperature (800C-1400C) heat treatments impact residual resistance and medium field Q-slope, but no coherent picture
- Cavity Q0 at operating gradient has high impact on cost
  - Q0 of 2E10 at 1.8K is currently realistic

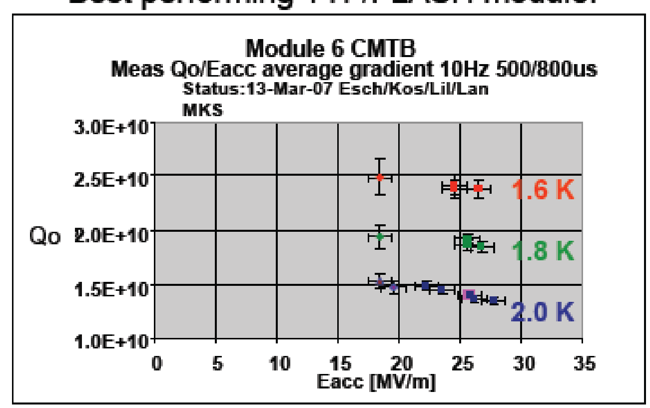
Q_0 versus Eacc: TTF 9-cell cavities



Q_0 versus Eacc: Cornell 9-cell cavities



- Best performing TTF/FLASH module:

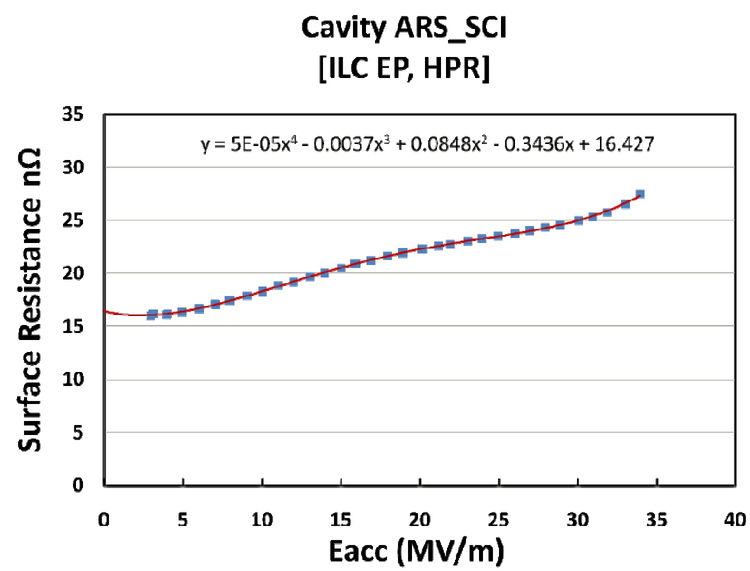


(Courtesy of R.Lange et al. DESY MKS)

Hoffstaetter

Q0 Phenomenological Modeling

- Fit cavity surface resistance vs. Eacc with parametrization and look for common features
- 25 ILC 9-cell cavity curves have been fit with this technique
- Look for fundamental significance in the features
- Work in progress



$$R_s = T + S \times E + \{R_o - T\} \times \{1 - (E/U)\}^2 \times \{1 - (E/V)\}^2$$

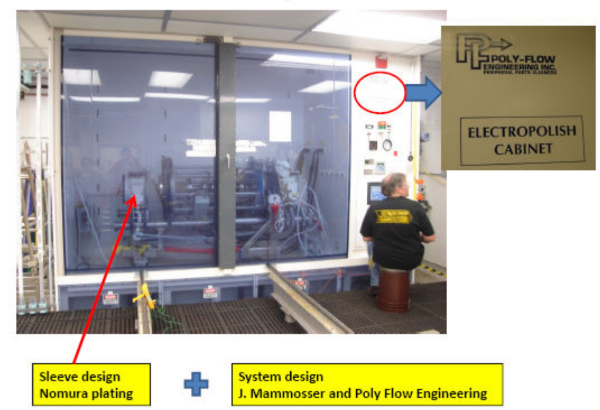
where

- R_s is the surface resistance at $E_{acc} = E$
- S is the slope of the straight line
- T is the intercept of the straight line on the R axis
- R_0 is the value of the surface resistance at $E_{acc} = 0$
- U and V are the values of E where the straight line touches the fourth order polynomial fit to the data

Coba

Standard Cavity Processing

EP facility at JLab

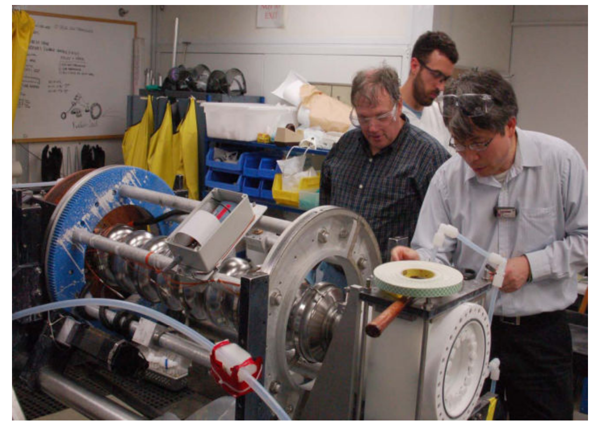


- Extremely useful to have in-person visits of experts to other laboratories to compare notes
- Variations found, some effect still unclear:
  - Facility
    - EP acid tank capacity and acid volume
    - EP acid flow rate
    - EP and water rinsing atmosphere (nitrogen vs. air)
    - EP acid temperature
    - EP voltage and current
  - Operation
    - Rotation after EP
    - Flow rate of water rinse
    - Rinse flow route
    - Rinse time
    - #fill/dumps
- No substitute for in-person on-site interaction; additional visits anticipated
- When results are reproducible, anticipate updating TTC technical board recommendation for cavity processing

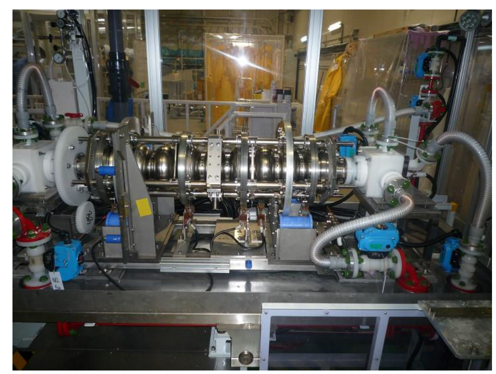
Saeki

Cavity surface processing reproducibility

- Monitor/control of parameters at JLab [Reece]
  - Stability improving at JLab over time
  - Cavity performance too



- Monitor/control of parameters at KEK [Sawabe]
  - EP electrolyte
  - EP temperature, current, cooling
  - Detergent
  - Waste water



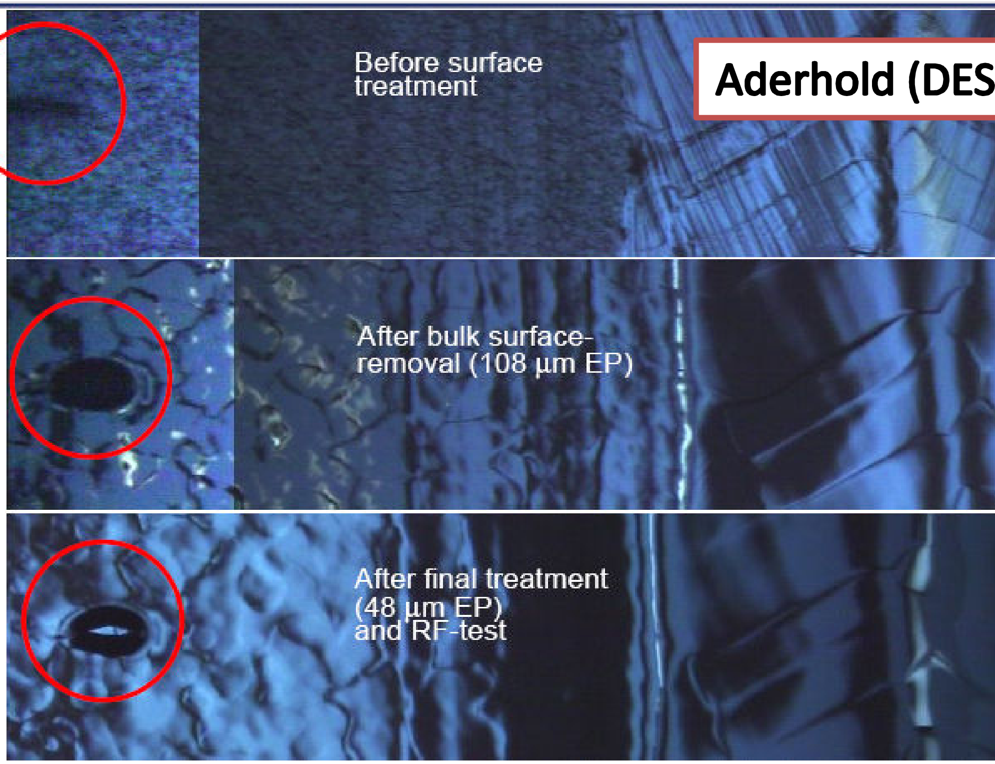
Cavity Understanding: optical inspection

- Mode measurements + thermometry + optical inspection usually reliable method to locate cavity limitation for substantially limited cavities
- Kyoto/KEK method convenience permits inspection at multiple steps
- Further automation, especially for movement and data acquisition, in progress; automated feature detection difficult

Aderhold

Cavity Understanding: optical inspection

Evolution of defect in Z142

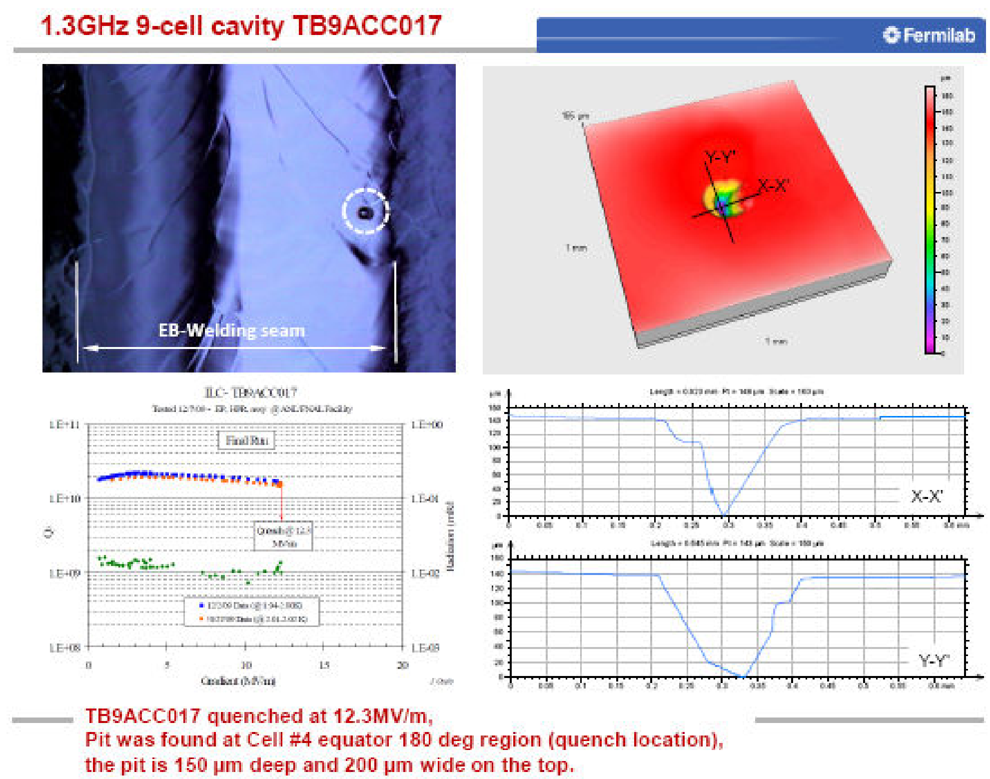


Aderhold (DESY)

Sergatskov (FNAL)

Cavity understanding: replicas+3D geometry measurement

- FNAL [Ge]
  - Combined with thermometry and profilometry

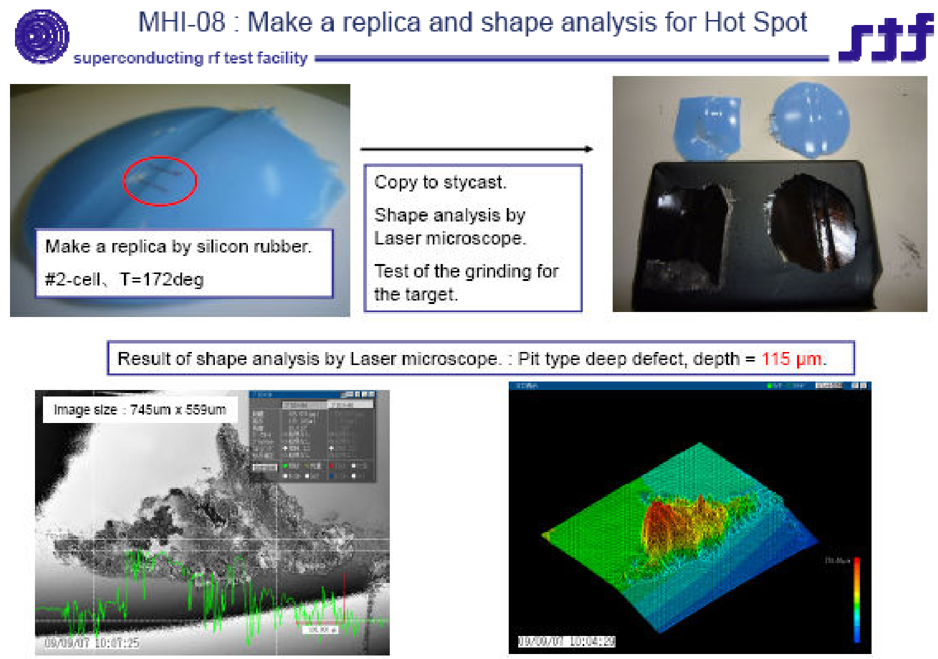


Cavity understanding: replicas+3D geometry measurement

- KEK [Hayano]

Labs	Method	Cavity name	Results
DESY	Local Grinding (KEK)	AC71	26MV/m (string???) -> 30 MV/m
FNAL	Local Grinding (KEK)	AES-03	20 MV/m (Bump, scratch) -> 34 MV/m
JLAB	Local Grinding (KEK)	JLAB LG-01	30 MV/m (Pit) -> will be tested.
KEK	Local Grinding(KEK)	MHI-08	16 MV/m (Pit) -> 27 MV/m

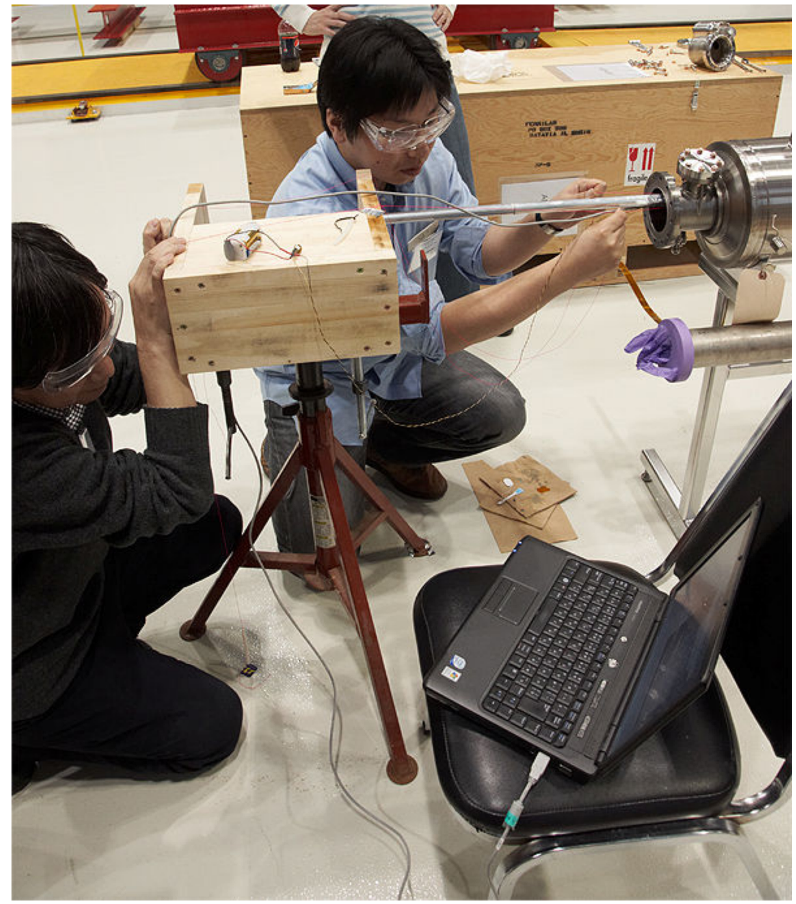
- Combined with thermometry, 3D microscopy, grinding repair



TESLA

Cavity understanding: replicas+3D geometry measurement

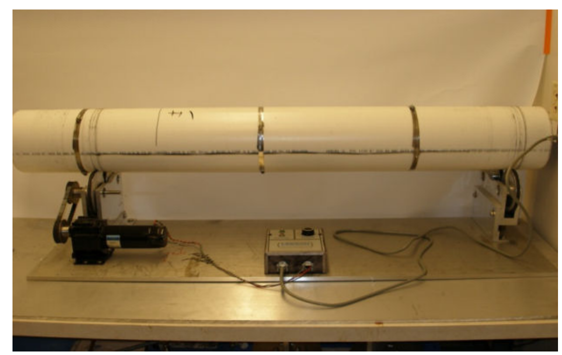
- Collaborative effort!
- KEK replica of dressed cavity AES001 at FNAL 4/21



Improving the Cavities (1)

- FNAL Tumbling [Cooper]
  - Good results on 1-cell, limited statistics

- Cornell Tumbling [Hoffstaetter]
  - Repair of LR9-1 (AES 9-cell re-entrant) from 15 to 28 MV/m



TESLA

Improving the Cavities (2)

- Laser remelting [Ge]
  - Good result on single-cell (TE1ACC003, 36->39 MV/m, was already a pretty good cavity), to be expanded to 9-cell


The Pit before re-melting

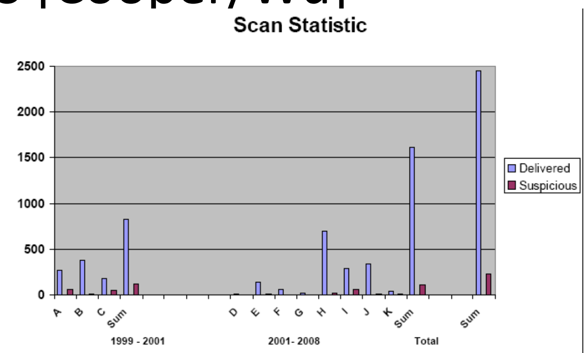

After re-melting

Images was taken from Kyoto Optical Inspection machine

- Grinding [Hayano] (shown earlier)
  - Several examples of improvement shown

Zoo of weird stuff

- We still don't understand very well the effect of the surface geometry
  - Examples of ugly tumbled cavity and bad ECS [Cooper/Wu]



DESY Eddy Current Scanning Statistic

- Comment on ECS from DESY [W.Singer/Lilje]
  - Surface profile peculiarities
    - May be harmless
  - defects like foreign material inclusions
    - Definitely harmful (if after treatment they are close to the surface)
    - Are rare these days, in particular because of DESY careful analysis and feed back to niobium producers
    - Eddy current statistics (shown). The suspicious sheets does not mean definitely bad sheets, but they can harm the performance. We use the sheets for less critical applications or rework the surface
      - Fraction of suspicious sheets reduced over time

More stuff

- Possibility of dressed EP “necessity is the mother of invention” [Mammosser] [Hoffstaetter]
- Realization that the unexpected will happen [Kim] and we have to be prepared for remedial work at any step

Summary of Issues

- Current issues with projects
  - Performance requirements to vendors
  - Optimizing commissioning
- Shared problems that need solving
  - Q-slope understanding and reproducibility, hot topic for Project X
- Updates on problems solved
  - Maybe not solved, but steady and excellent progress on cavity investigation and repair. More data needed and forthcoming.
- Performance and reliability topics
  - Although many excellent results, cavity processing overall is not stable or reproducible enough. Improved monitoring and stability should help
- New techniques and discoveries
  - Features studies and repair
- Progress on understanding technical issues
  - Substantial expansion of investigation techniques used regularly to study cavities, especially development of features
- Needed developments
  - Repairing cavities down the chain, e.g., EP on dressed cavities, possibility of FE in installed cavities