# Cornell SRF ILC Effort 2010/2011

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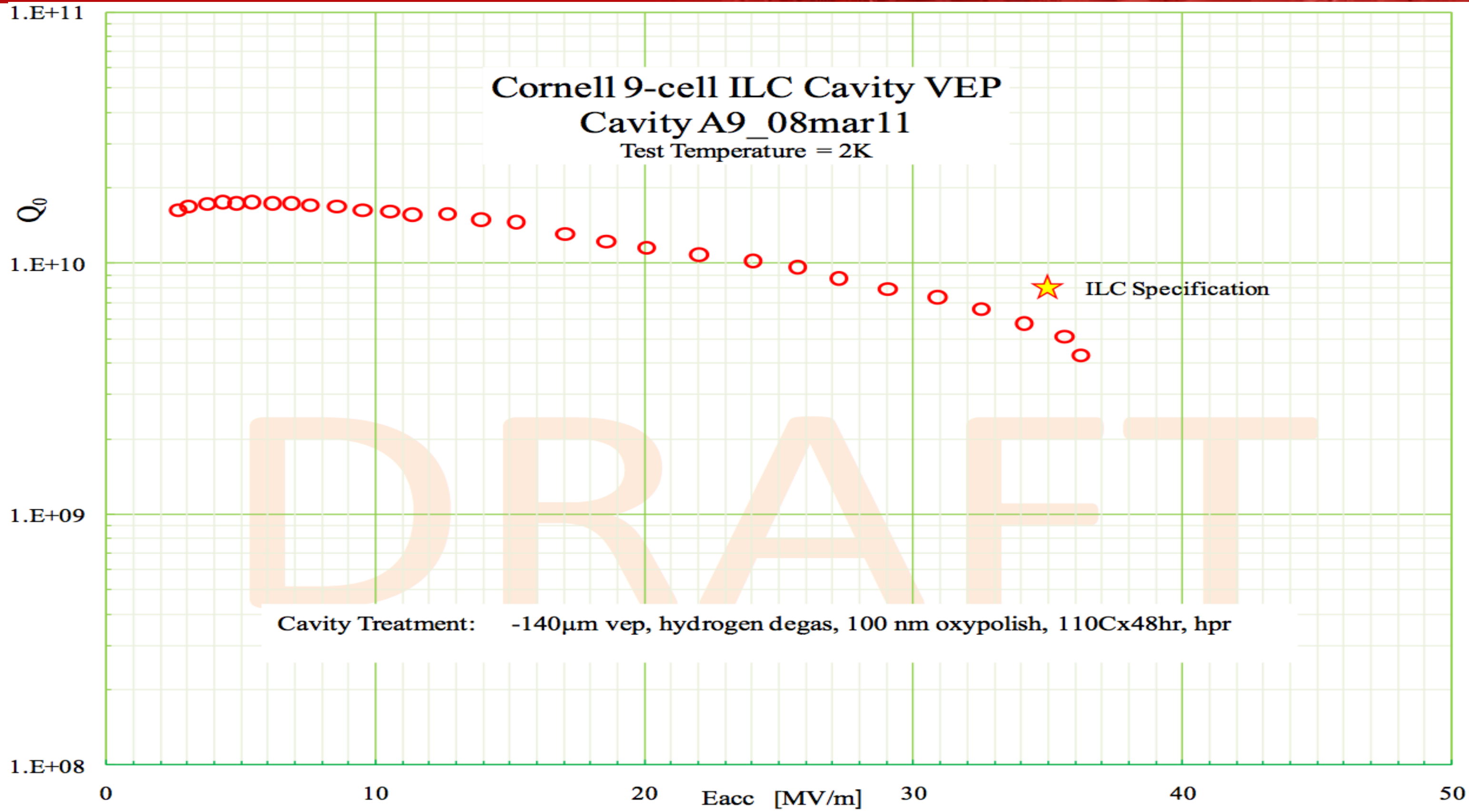
- Optimization of f 9-cell Vertical Electro Polishing (VEP)
- Study of alternative cell shapes:
  re-entrant 9-cell
- 9-cell cavity repair by machine tumbling

# Most recent Highlight

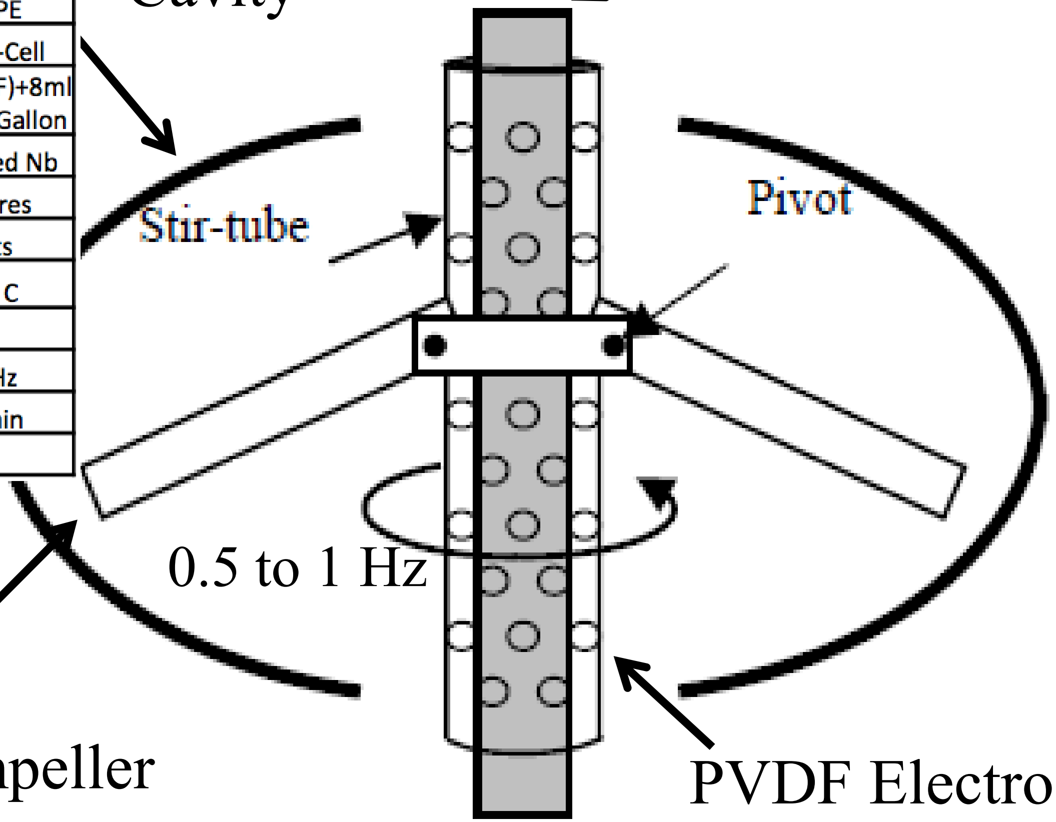



ILC cavity A9 hast surpassed the 35MV/m ILC specification

- It has been repaired by tumbling a single damaged cell
- It had received bulk VEP (140 mm)
- Hydrogen degas (2h at 800C)
- 100nm oxypolish

# What is Vertical Electropolish?

| Parameters for VEP | |
|---|---|
| Cathode | Aluminum > 99.5% |
| Stir-Tube | PVDF |
| Paddles | PVDF |
| Seals | Viton |
| End Groups | PTFE, HDPE |
| Electrolyte | 24 Liters/9 -Cell |
| Electrolyte Composition | 9:1 (H2SO4:HF)+8ml of HNO3 per Gallon |
| Maximum Use | 9 g/l dissolved Nb |
| Current | 250 Amperes |
| Voltage | 14.5 Volts |
| Temperature | 20 to 23⁰ C |
| Stir-Tube Transparency | >50% |
| Stir Frequency | 0.5 to 2 Hz |
| EP Rate at Equator | 0.5 µm/min |
| Ratio EP Rate iris/equator | ~1.5 |

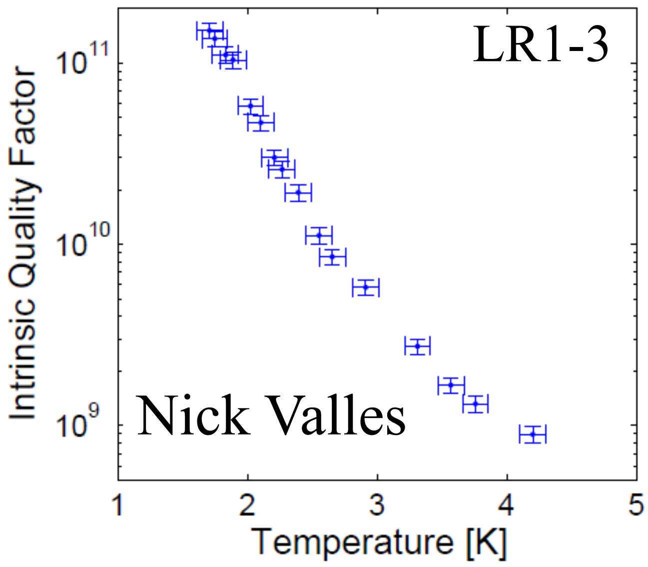


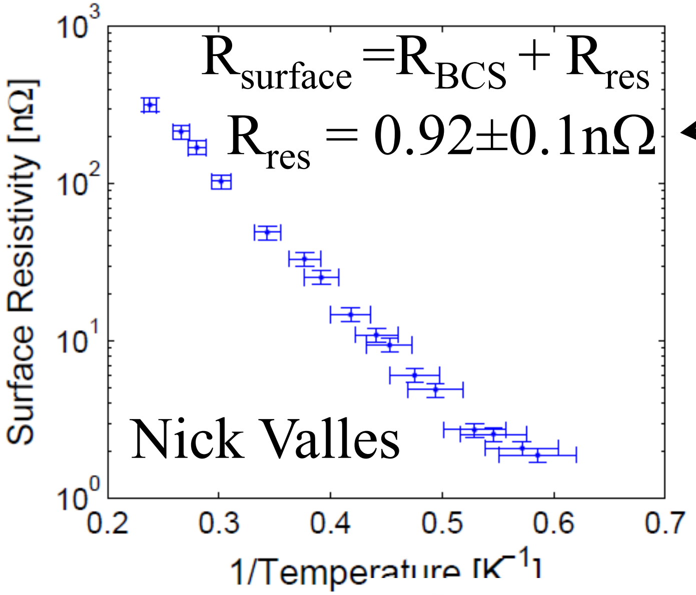

H. Padamsee & A.C. Crawford, PAC07, WEPMS009

# Why Vertical Electropolish?

- Vertical Electropolishing has the Following Benefits:
  - Eliminates rotary acid seals
  - Eliminates sliding electrical contact
  - Eliminates the cavity vertical/horizontal position control fixtures
  - Simplifies the acid plumbing/containment
  - The outside of the cavity is actively cooled, providing better temperature control of the polishing reaction.
- Vertical electropolishing has produced several high performance single cell cavities

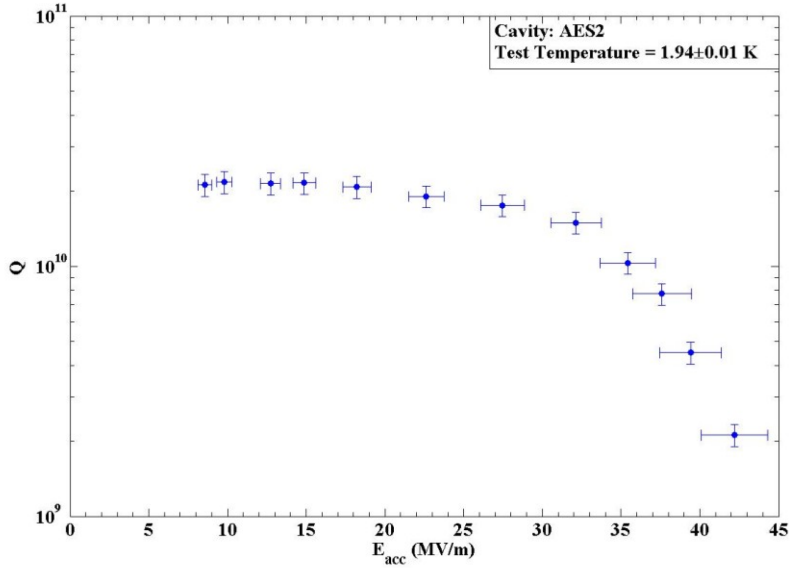
# Single Cell VEP




- Extremely low residual resistances
- CW field performance approaches theoretical limit

- We reduced the temperature at which we polish to 20-25 C, was 30-40 C.
- We reduced the agitation of the electrolyte during the polish.
- We have had several good single cell results, e.g. one cavity had a Q higher than we could measure.



# 9-Cell Vertical Electro-Polish Status

- We have processed and tested 5 different 9-cell cavities with vertical electropolish. Sometimes more than once.
- We have processed single cell cavities with VEP to very high Q0 repeatedly.
- Highest field for an ILC cavity is 36MV/m.
- We have repaired defective cavities via tumbling, followed by VEP.
- Successful tumbling achieved for full cavity as well as for individual cells in 9-cell cavitites.

Cornell Laboratory for
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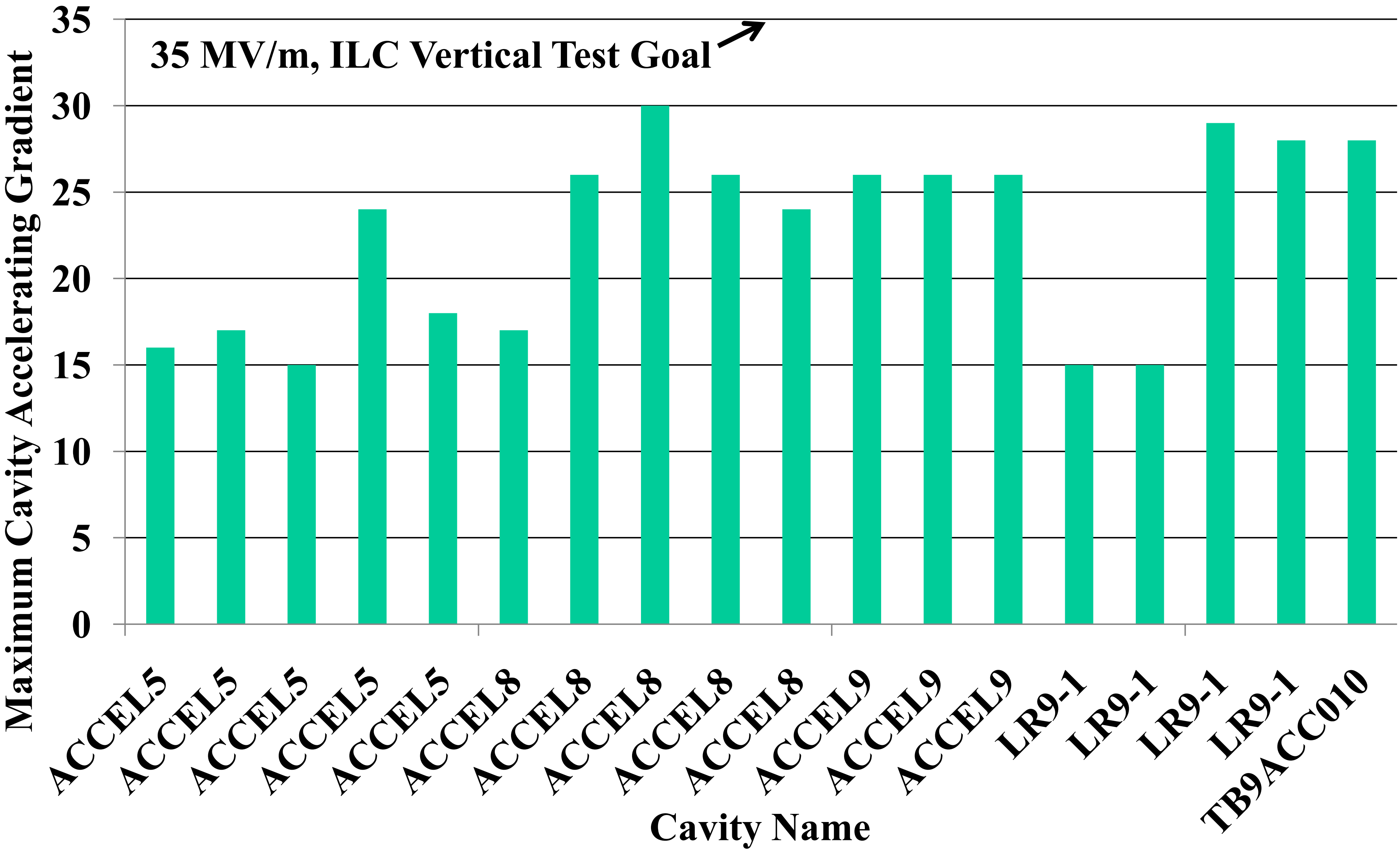
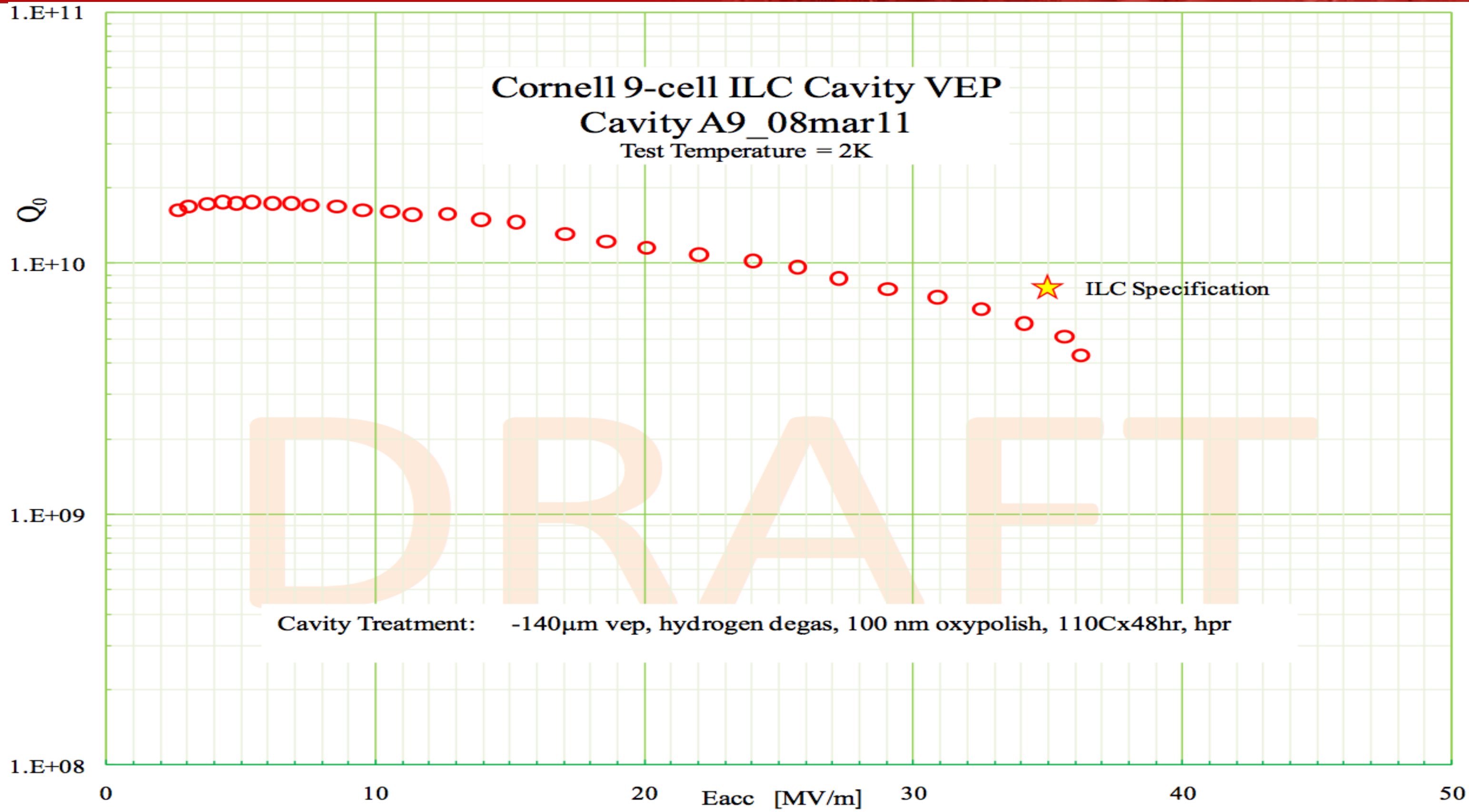
# 9-Cell Vertical Electro-Polish Status before last year



# Most recent VEP test at Cornell




ILC cavity A9 hast surpassed the 35MV/m ILC specification

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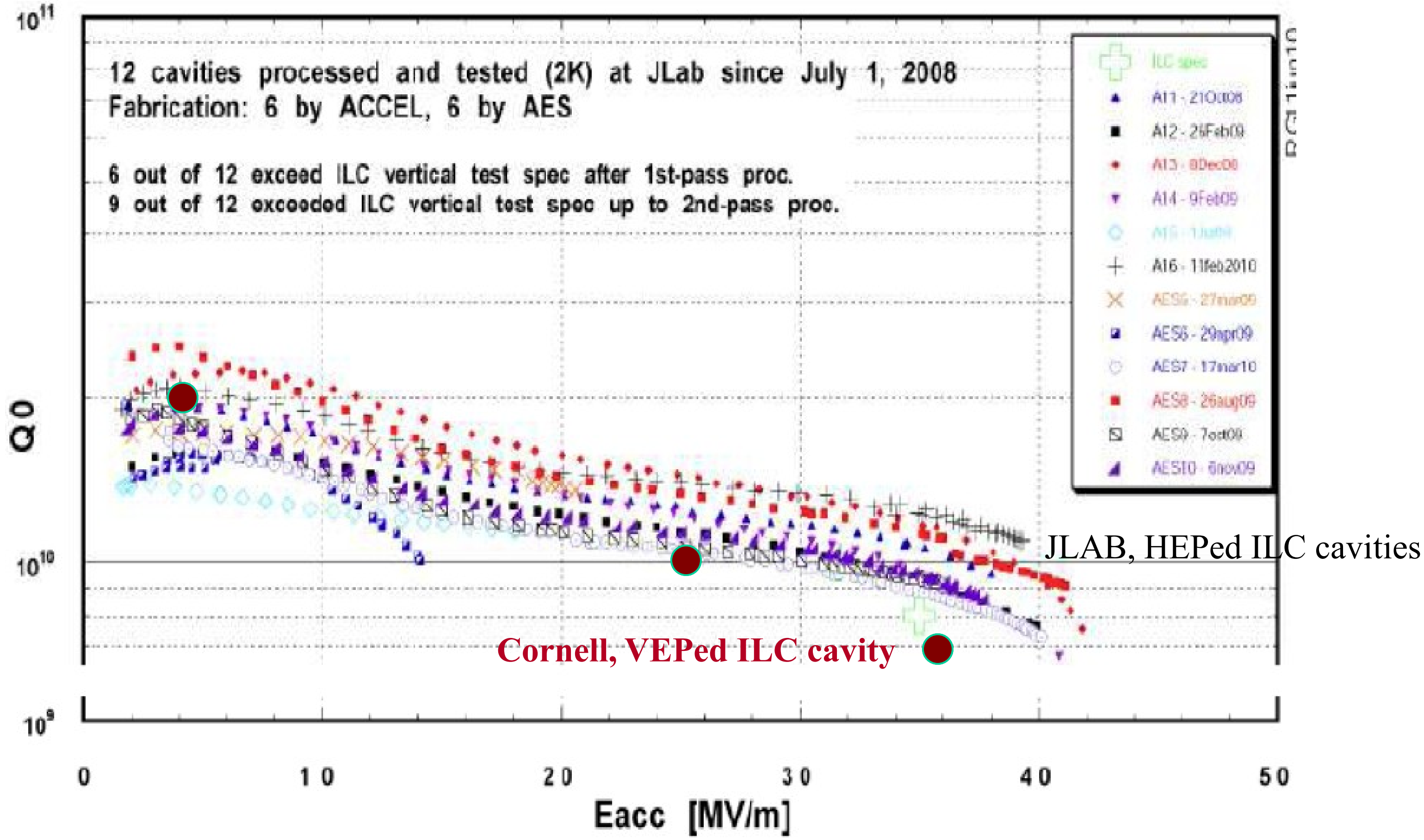
# Comparison to HEP performances




- ILC cavity A9 hast achieved 36MV/m
- It had received bulk VEP (140 mm)
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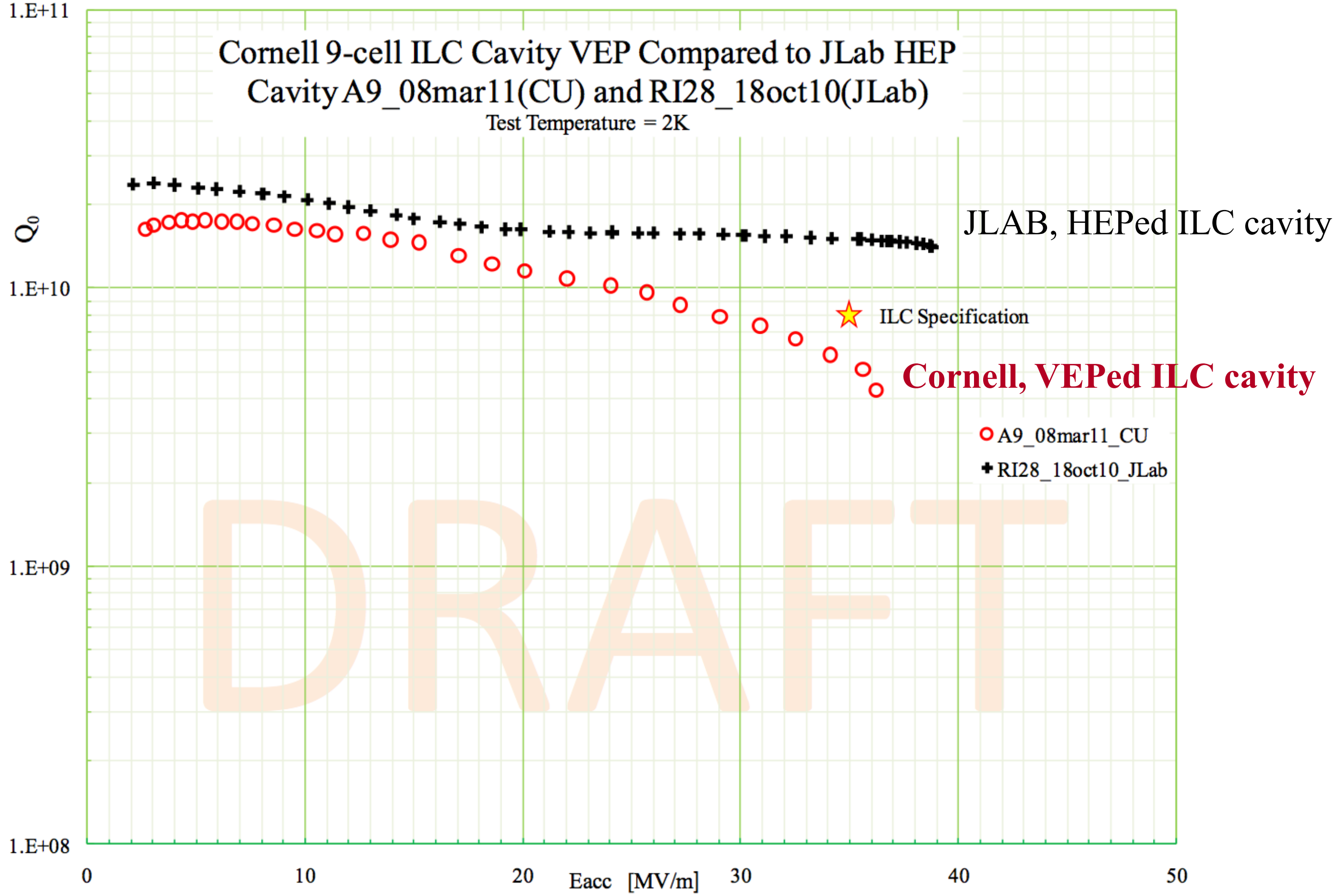
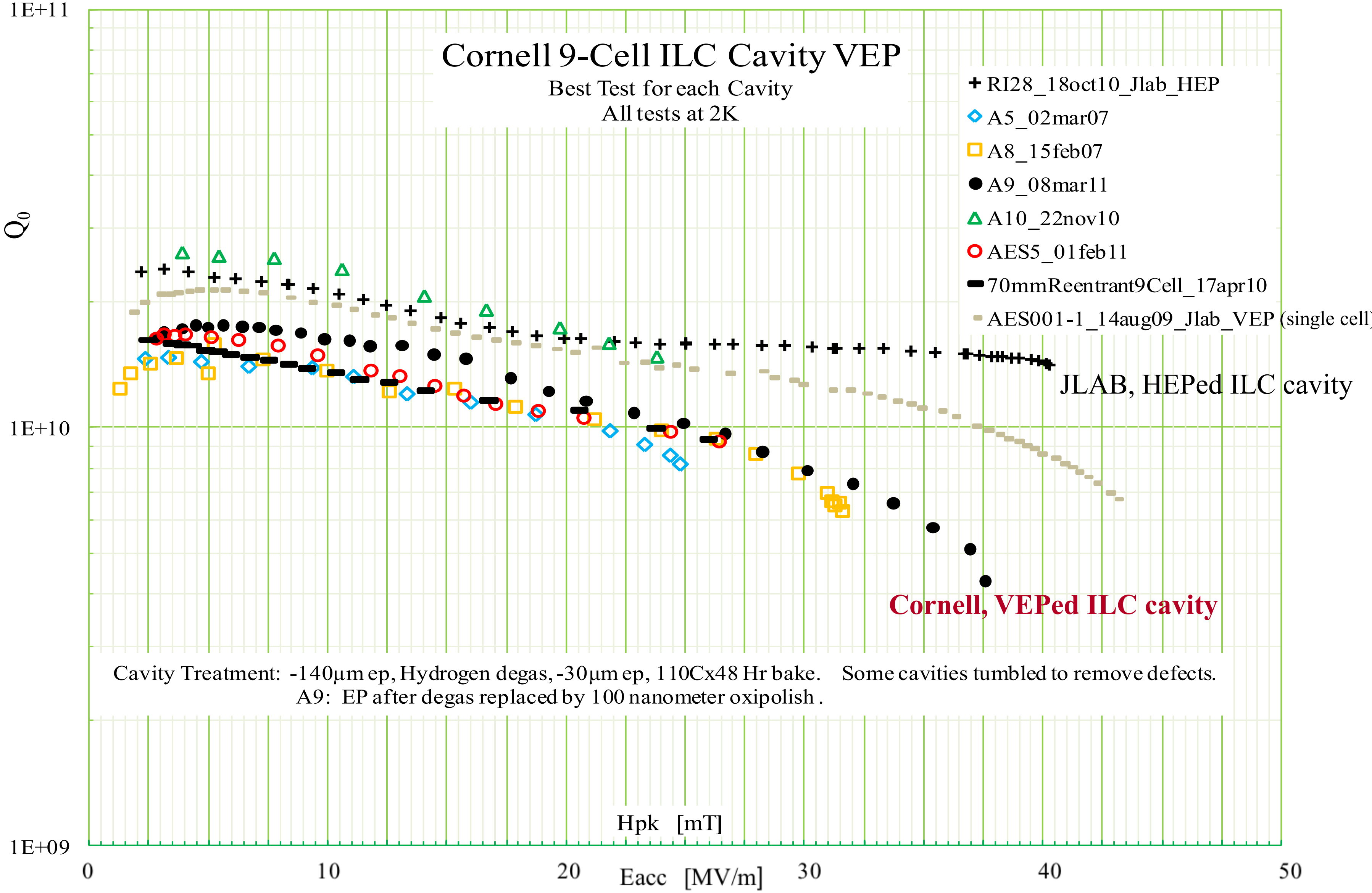
# Good VEP vs. good HEP




- VEP at Cornell has surpassed 35MV/m voltage specifications for the ILC
- 70% of Q0 specifications for ILC
- Performs similar to HEPed cavities except for the flattening of Q0 above about 20MV/m that optimized HEP has yield

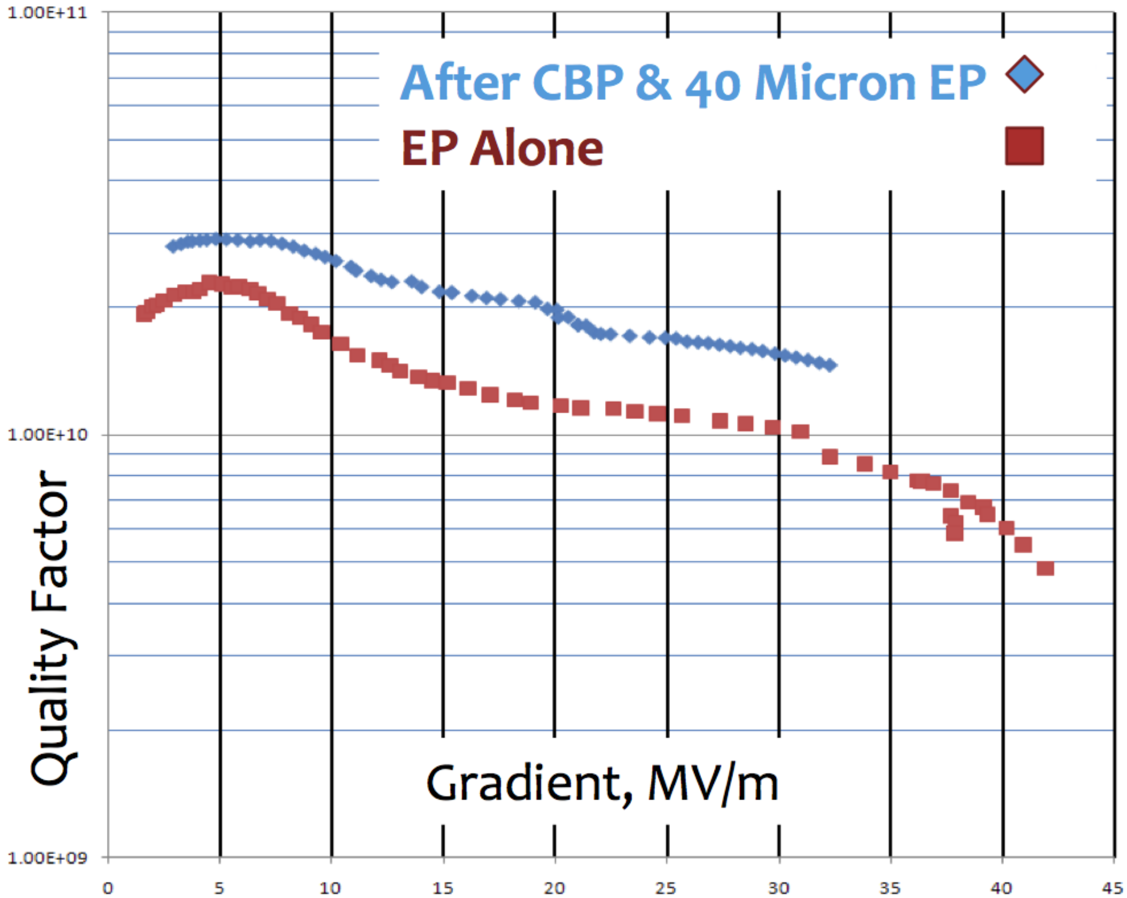
# Cornell 9-cell ILC Cavity VEP



# Recent VEP tests at Cornell

- One cavity (A10) has high initial $Q_0$ . It was tested after hydrogen degassing without any material removal. The rest of the cavities have suppressed initial $Q_0$ .
- All cavities do not show the leveling off for the Q vs. E curve that optimized HEPed cavities have above 20 MV/m
- The performance is similar for a large range of EP parameters such as electrolyte mixture (with or without nitric Acid), electrolyte temperature, electrolyte velocity and electro-polish voltage.
- Results from FNAL indicate that electro polishing at too low a voltage may cause enhanced Q slope. Cavity A9 was electro polished at 14 V. We will repeat at 17 V.
- Most cavity tests have field emission, but a similar amount to a typical horizontally electropolished cavity at Jlab. Cavity A8 had no field emission below 28 MV/m and only a minimal amount at fields above this.

# Centrifugal Barrel Polishing to high Q0




From TTC March 2011 presentation of Charlie Cooper

- Centrifugal Barrel Polishing (CBP) and EP have shown to increase Q0 in ILC cavity ACC001 at FNAL.
- Cornell has the same CBP machine as FNAL.
- VEP and CBP should bring cavities beyond the ILC specification for Q0

# Open VEP questions

- It is troubling that the start of degradation in $Q_0$ coincides with the two point multipacting band for ILC cavities. There was no indication of multipacting during these tests.

- It is possible that Cornell's coaxial input coupler has heating problems at 20 MV/m power levels. Cooling of the center conductor is known to be problematic.

- Judging by optical inspection, the recent series of Vertical EP procedures, on A9, A10 and AES5 have surfaces as good or better than the best Horizontal EP finishes from any laboratory. So it is difficult to assign the Q slope to surface roughness.

- Perhaps there is a significant difference in RF surface quality due to the physical orientation of the surface during EP. Is there a difference in a surface that was "up" compared to a surface that was "down"?

# VEP discussion and plans

- Cornell would like to certify its rf test system by testing a horizontally electropolished, 35 MV/m cavity from another laboratory. This would be done in a manner similar to rf test cross checks between Jlab and FNAL. Cornell would modify its rf test stand to accept a vacuum sealed cavity with a fixed input coupler.

- If the rf certification indicates no problems with the Cornell equipment and procedure, then Cornell would like to perform a 30 μm VEP on the test cavity in order to check if the VEP process degrades a known good srf surface.

- A sample EP program that is designed to measure the difference in surface quality with respect to physical orientation of the sample during the EP procedure would be of high value. Samples could be tested in Cornell's new "mushroom" cavity that has maximum magnetic fields at the sample surface.

# Alternative cell shapes: 9-cell re-entrant cavity

- Re-entrant cavity shapes, including those with 70mm iris diameter lack the mechanical rigidity of the TESLA cell shape

- Cavity AES_LR9-1 has experienced detuning at the 20% level, with respect to field flatness, during handling and RF test

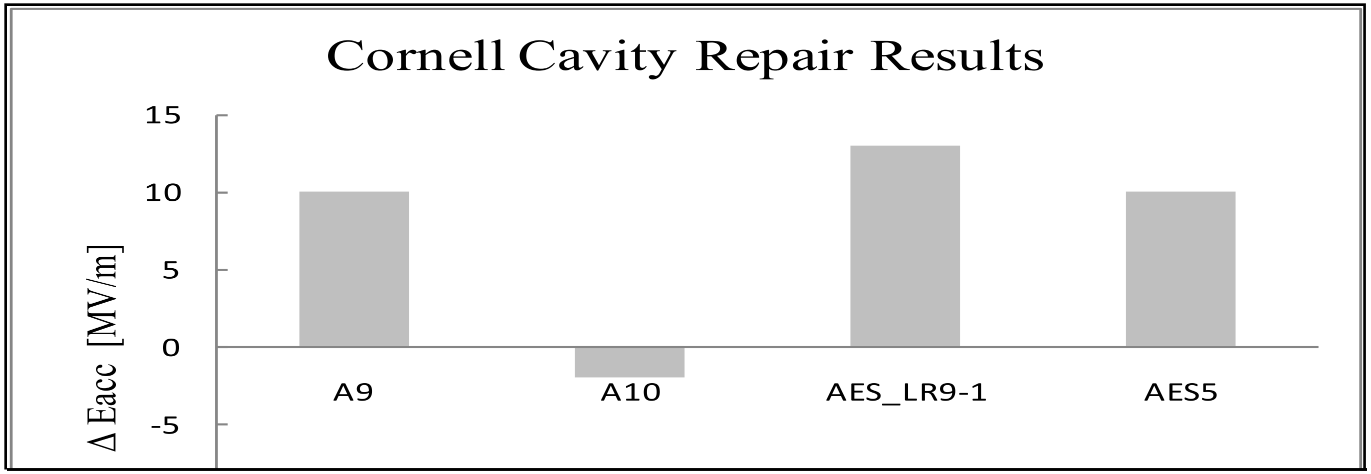
- AES_LR9-1 is having strengthening ribs added, including both end half-cells. It is expected that this will prevent detuning in the future.

- AES_LR9-1 used to be limited to 15MV/m by quench in one cell. It was improved by tumbling and is now limited to 28MV/m by quench in another cell.

- This cell will be tumbled and the cavity will be re-processed and tested.

# Cornell cavity repair: Tumbling and CBP

| | Original Limit | After Tumbling | Process |
|---|---|---|---|
| AES_LR9-1 | 15 MV/m | 28 MV/m | all cells (pit removal) |
| AES5 | 21 MV/m | 31 MV/m | 1-cell (pit removal) |
| A9 | 26 MV/m | 36 MV/m | 1-cell (no pit visible) |
| A10 | 27 MV/m | 25 MV/m | all cells (no pit visible) |




Tumbling a cell that has a clear indication of a quench, while leaving other cells undisturbed, is a viable way of increasing cavity performance. This technique can be applied to both tumbling and centrifugal barrel polishing.

# Summary

- Vertical Electro Polish has surpassed ILC parameters for voltage (35MV/m)
- ILC Q0 requirements reached to 70% at full voltage
- Q0 can be as high as top performing horizontally electro-polished cavities up to about 20MV/m
- Optimally HEPed ILC cavities have a flattening of Q0 at higher voltages, which VEPed cavities do not yet have (even for single cells).
- Parameter changes (e.g. lower voltage) for HEPed cavities also leads to Q0-drop below the flattened curve above 20MV/m
- We plan to further improve VEP through optimal parameters, e.g. Voltage
- We will try to understand influence of surface orientation
- We will drive hydrogen bubbles out of the cavity through acid flow
- We wish to test our equipment and directly compare VEP to HEP by treating an HEPed 35MV/m cavity
- We are stiffening a re-entrant 9-cell cavity to study alternative cell-shapes
- We have repaired several cavities by tumbling individual cells of 9-cell cavities