R&D Activity for Field Emission and Vertical EP

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Cornell

Vertical EP (Summary)

- Possible benefits: Simpler
  - No large acid barrel, plumbing, valves, acid heat exchanger
  - Fewer places for S accumulation and cavity re-contamination
  - More uniform cooling at cavity due water flow jets
  - More uniform HF flow in cell due to stirring
- Possible disadvantage
  - more exposure to H
  - 600 - 800 C, H degassing required more often?
- Results (& limits)
  - #5: 24 MV/m (quench), return to ACCEL
    - Test for No H Q disease test after 25 µm EP
  - #8: 30 MV/m (quench), 25 MV/m (Qslope, EPerror)
  - #9: 27 MV/m (quench), 26 MV/m (quench)
- Next Steps
  - Continue to push for 35 MV/m
  - We have agreement to transfer Vertical EP to AES company

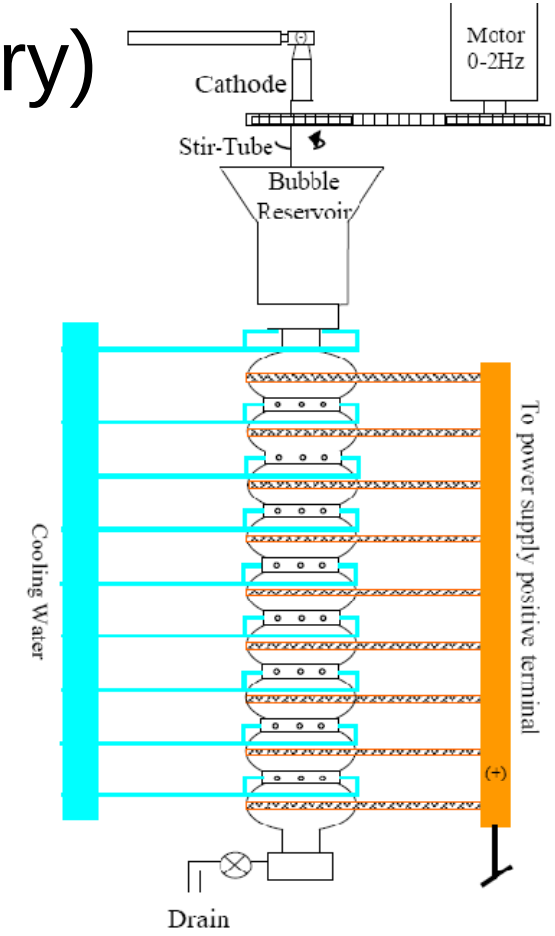


Figure 3. Vertical Electropolish System

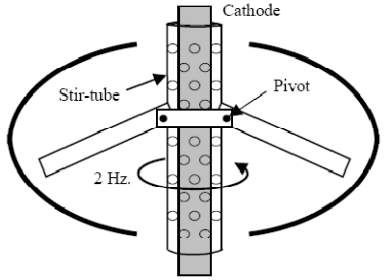


Figure 1. Cathode and stir-tube assembly for one cell. All other cells are identical.

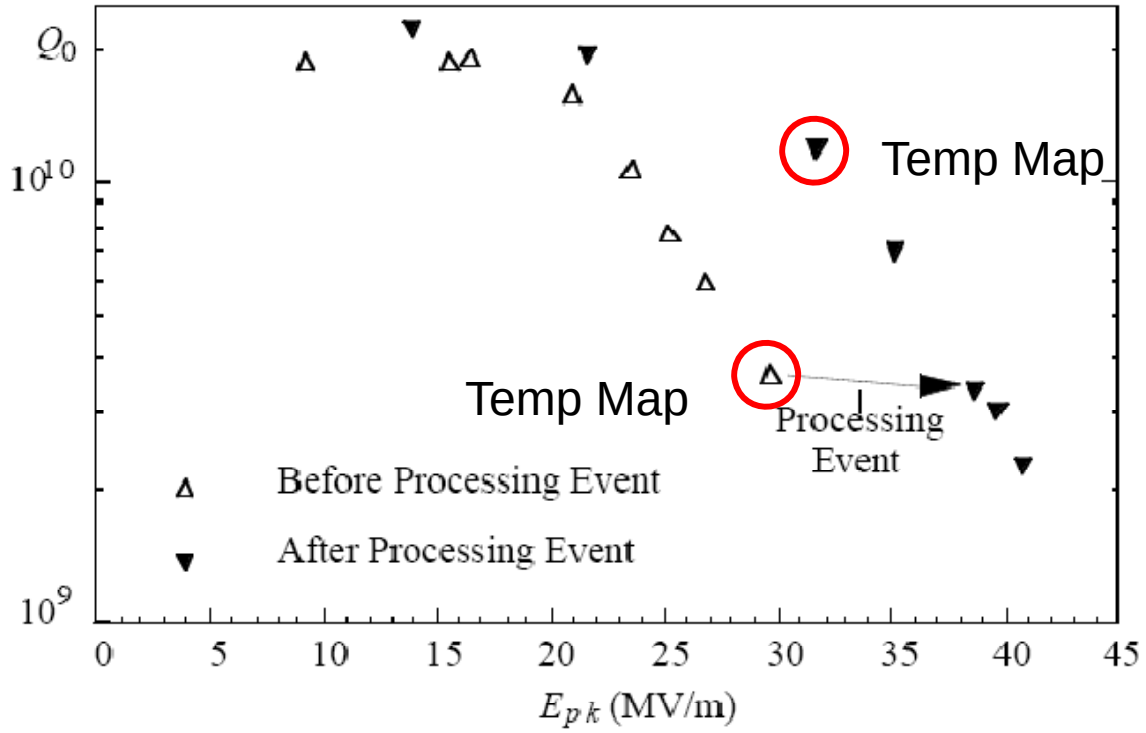
High Pulse Power Processing (HPP)

- For gradient recovery from vacuum accidents (and particle contamination)
  - In general there will be many layers of interlocks and protection against vacuum incidents
  - We need to find out if any level of recovery is possible with in-situ method
  - e.g. Question during MAC review
- Particulate contamination may also enter cavity during
  - coupler installation, horizontal test assembly, string assembly or installation into beam line

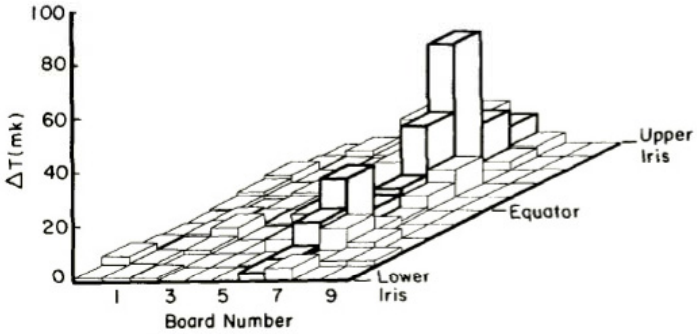
RF Processing Field Emission

With CW Low Power (100- 200 watts)

- How does it work?



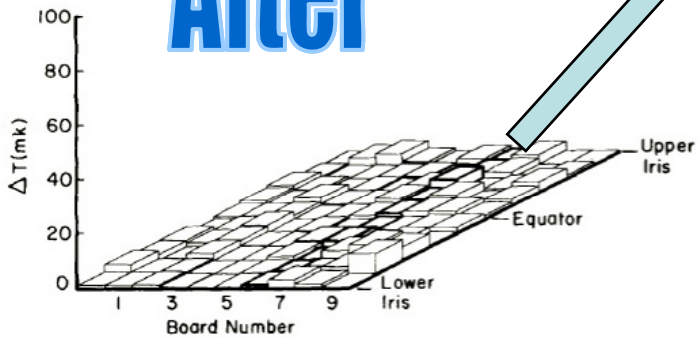
Note that the low field Q value remains above 10^{10} due to processing event



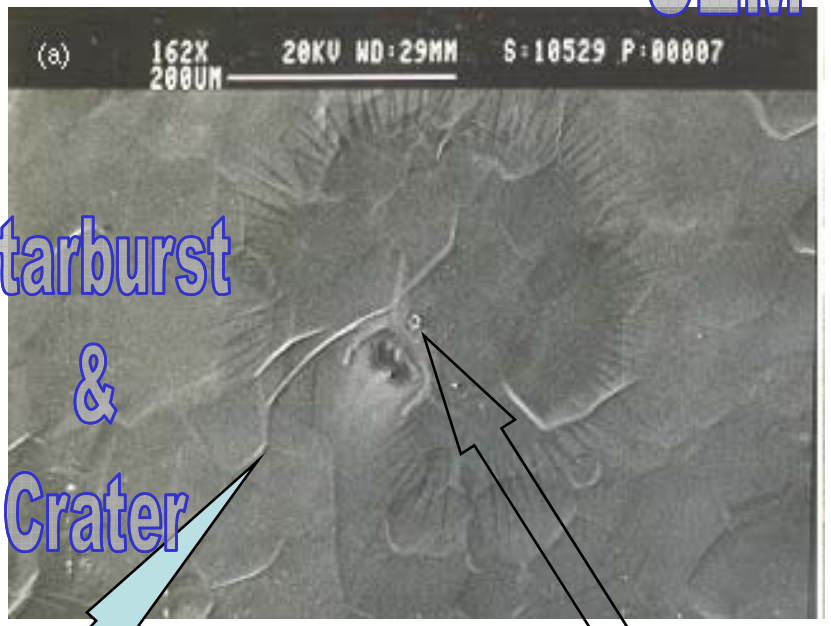
Before Processing

Temperature Maps

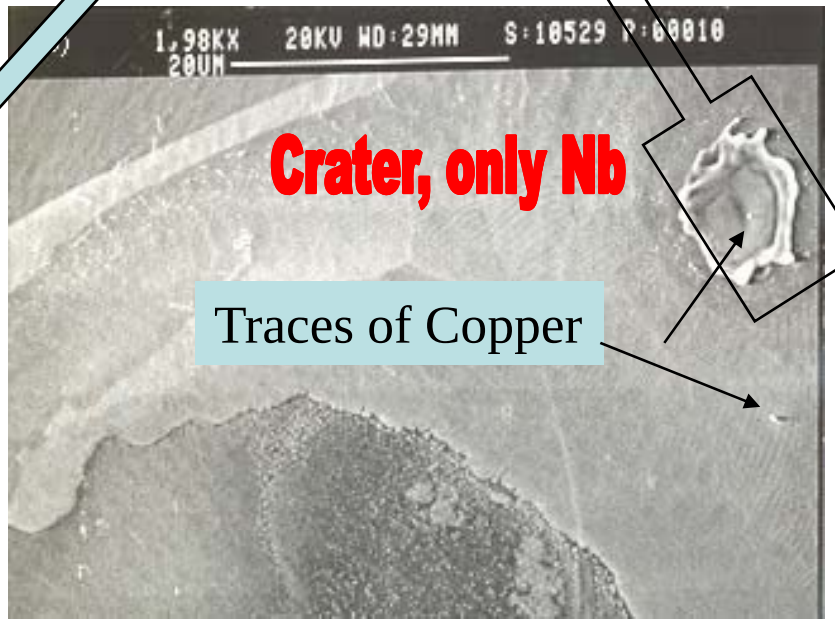
After



SEM



Starburst & Crater



Crater, only Nb

Traces of Copper

CORNELL UNIVERSITY

CW RF Processing of Planted Emitter

- Deliberately introduce SiO2 particle in high field region of 6 GHz cavity
- Reach RF voltage breakdown at 75 MV/m
- Examine region

Before

After

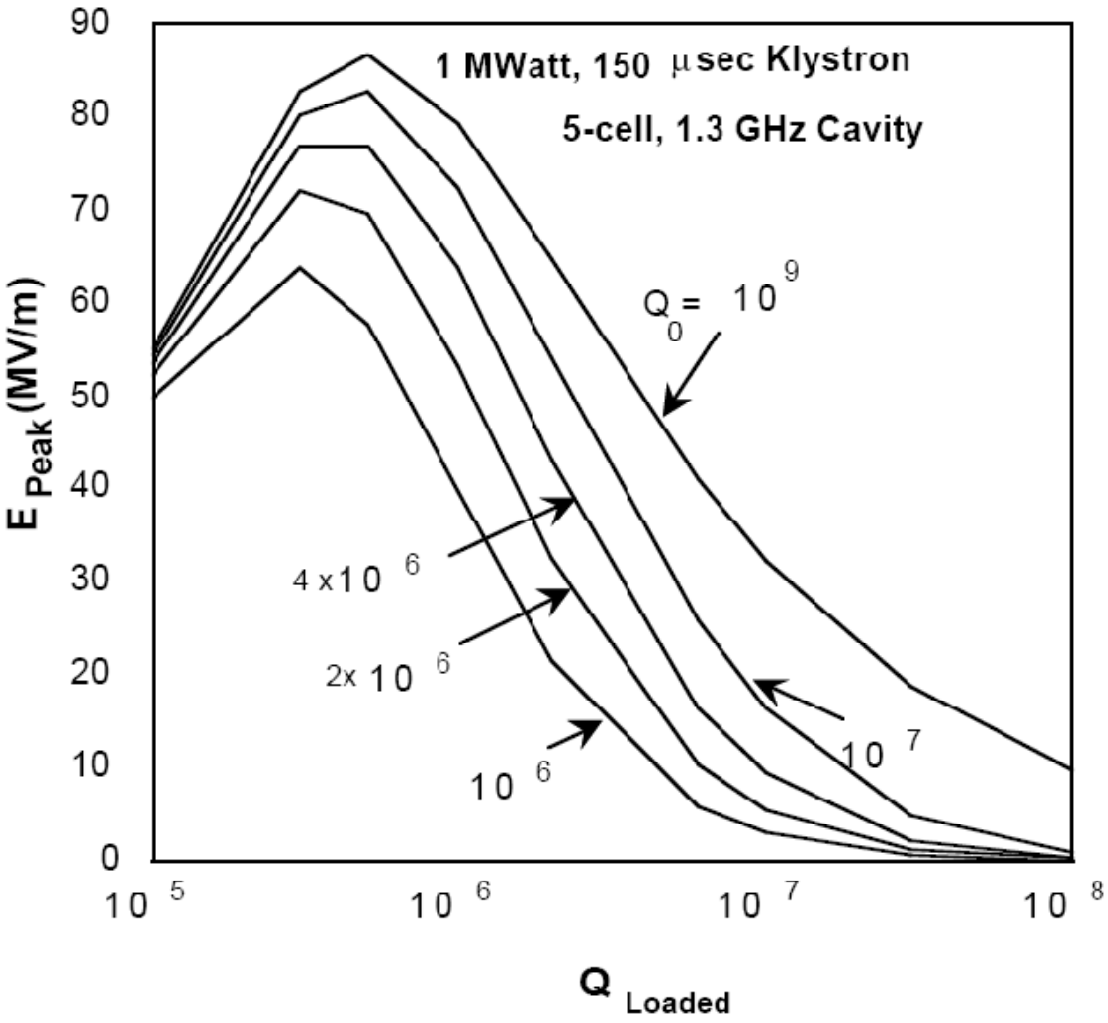
Understand the Physics of Emitter Processing

- Many experiments (both RF and DC) to understand emitter processing
- Computer simulation models using MASK and OOPIC-Pro to simulate processing
  - Theses: J. Knobloch, G. Werner
  - Main result : Need to raise local E for a short time (< μsec) so that field emission current reaches a threshold value for local discharge (spark) which destroys emitting particle
- CW power generally not enough to reach high E and high current to destroy emitters, especially when field emission current is strong

DC processing

High Pulsed Power Allows High E

- Use 1 MW and 150 μsec with Qext between 10^5 and 10^6 to reach 90 MV/m in the presence of field emission
- With longer pulse length, less power and high Qext is OK to reach 100 MV/m

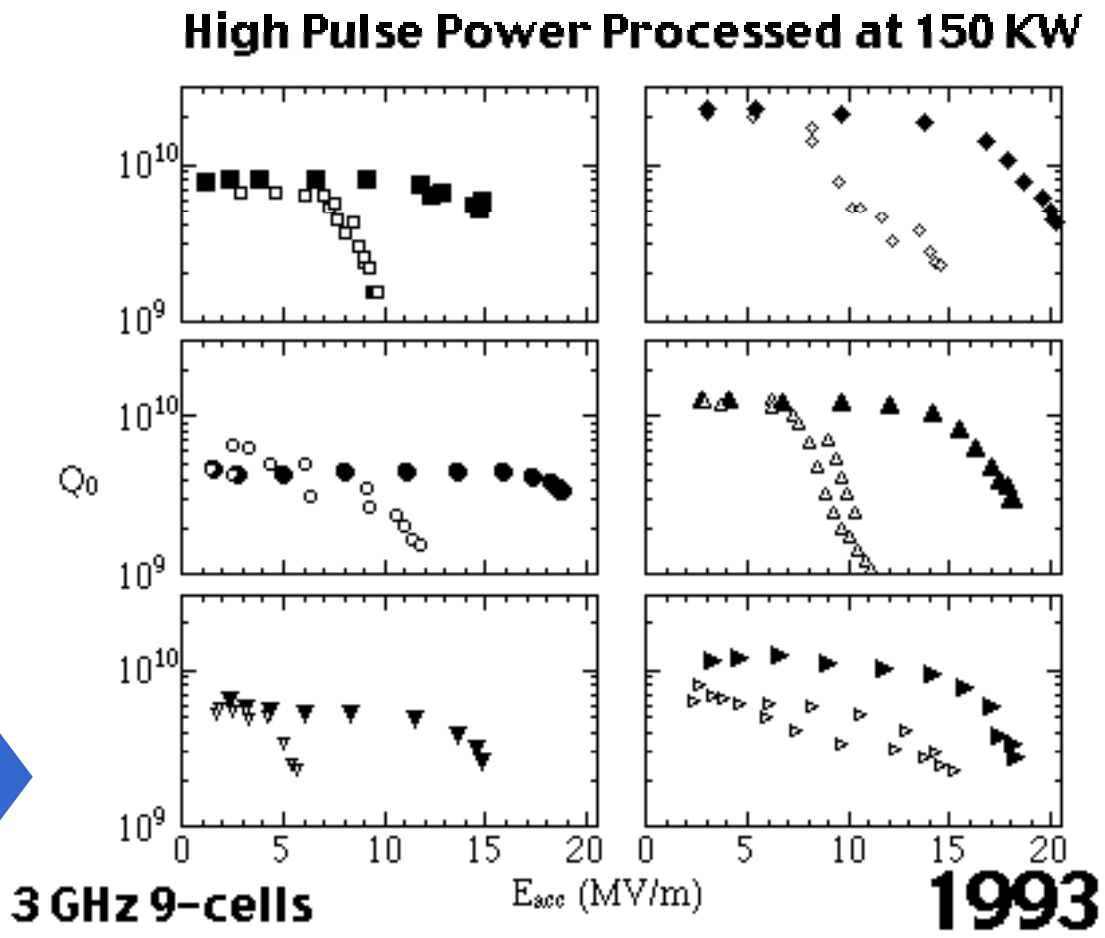


HPP at 3 GHz

- In 1993 Cornell proved that HPP works for 9-cell, 3 GHz cavities.
- The maximum power available was 150 kW (500 usec pulse length, 1 Hz rep rate)
- Hence max field reachable was 20 MV/m
- Field emission was successfully processed in most tests.
- In 1993, HPR was not used, yet many field emitters could be processed.
- (Publications available)

Push for High Gradients
15 - 20 MV/M
3 GHz 9-cells

1993



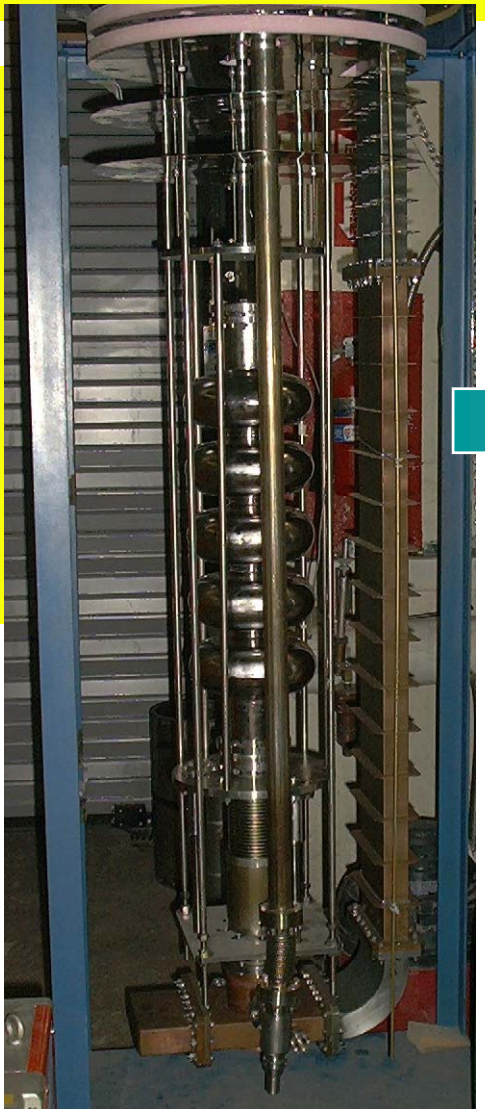
1.3 Ghz, 5-cells (1995)

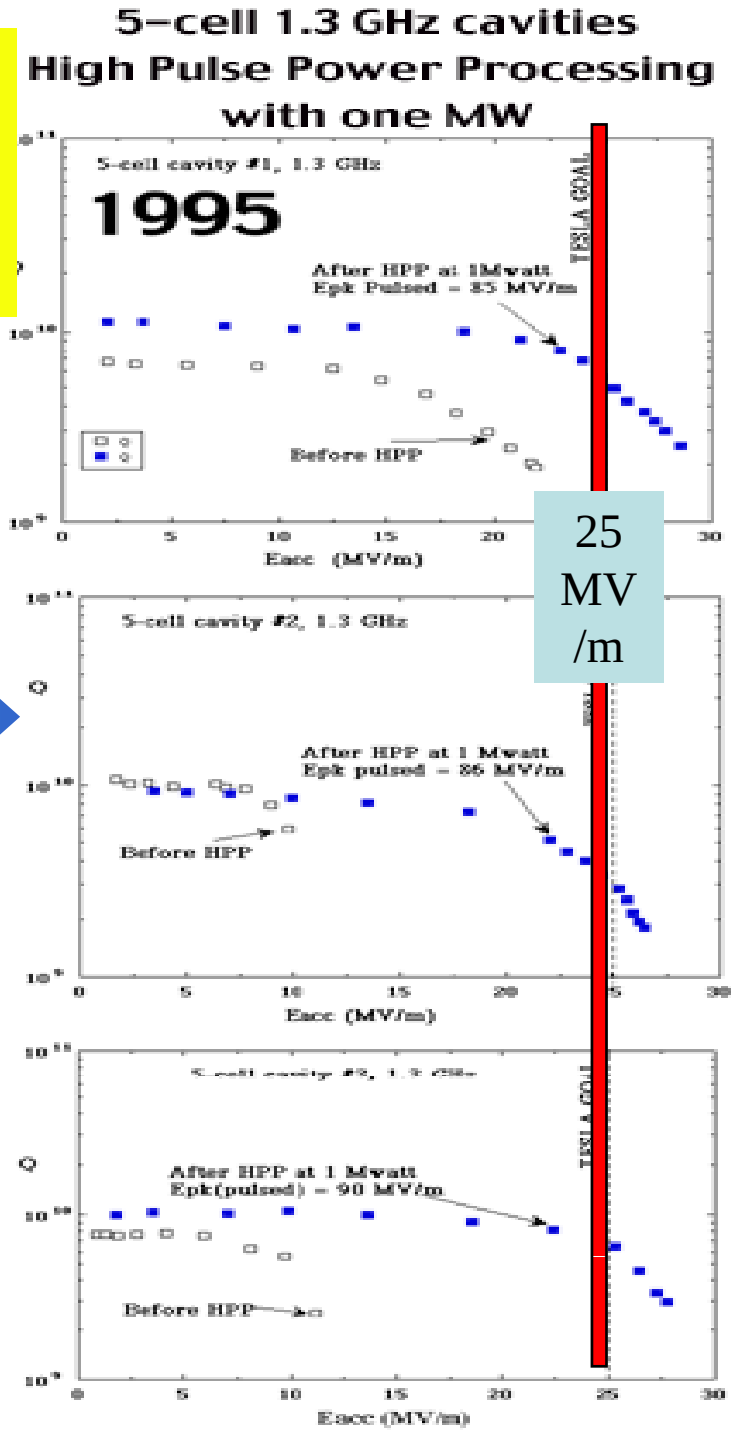
- Cornell-Fermilab-DESY collaboration prepared and processed three 5-cell cavities at 1.3 GHz
- No HPR was applied
  - HPR process was not yet developed
- => Strong field emission was seen in every test
- Gradients limited between 10 – 20 MV/m by field emission
- HPP successfully processed emission in every test using about 1 MW, 250 usec, peak field 90MV/m
- 26 – 27 MV/m reached with all 3 cavities
- Q values of 10^10 and greater were reached, showing that there is no significant damage during HPP
- (Publications available)

1995
Gradients 26 - 27 MV/m reached in
Three 5-cell structures

Cornell
DESY
Fermilab

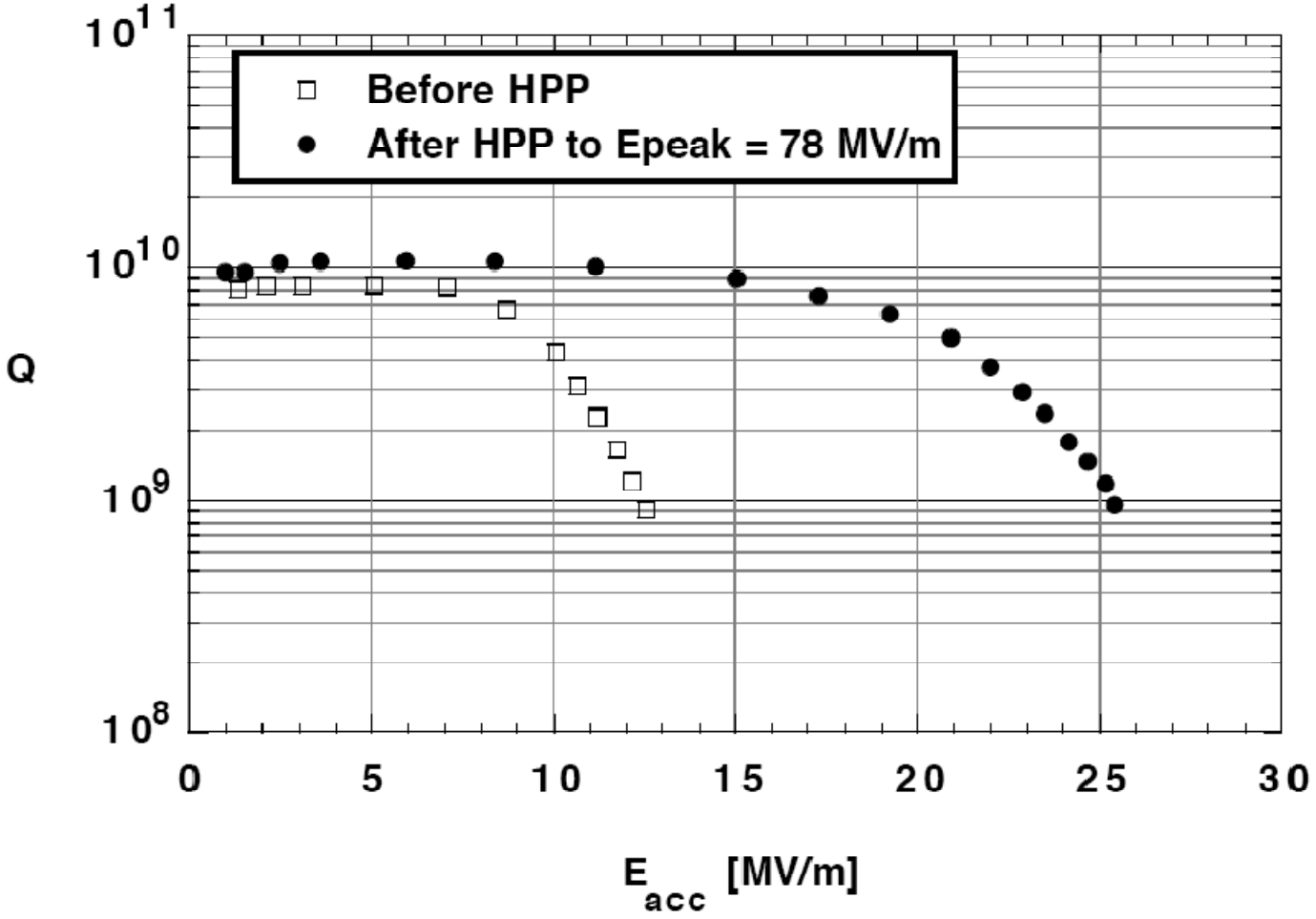
Collaboration





25 MV /m

4-cell, 1.3 GHz Russian Nb cavity

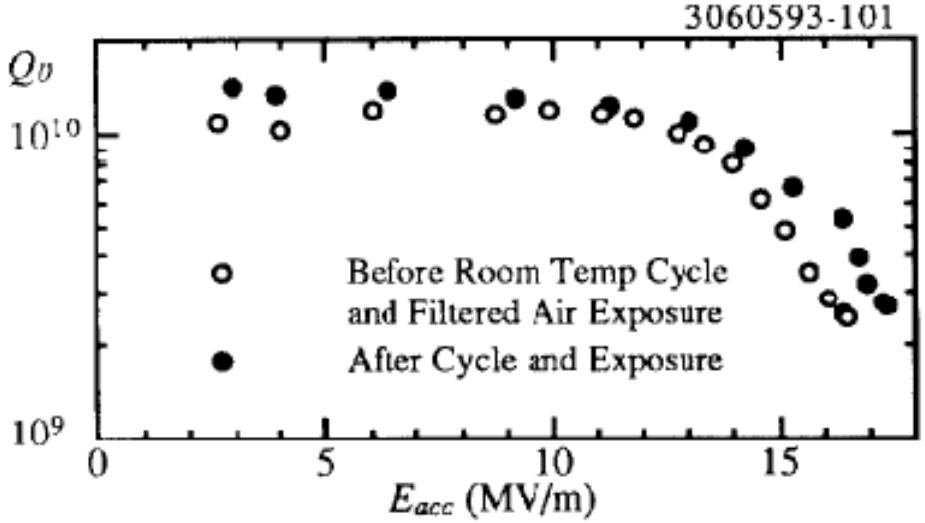


Recovery from Vacuum Accidents

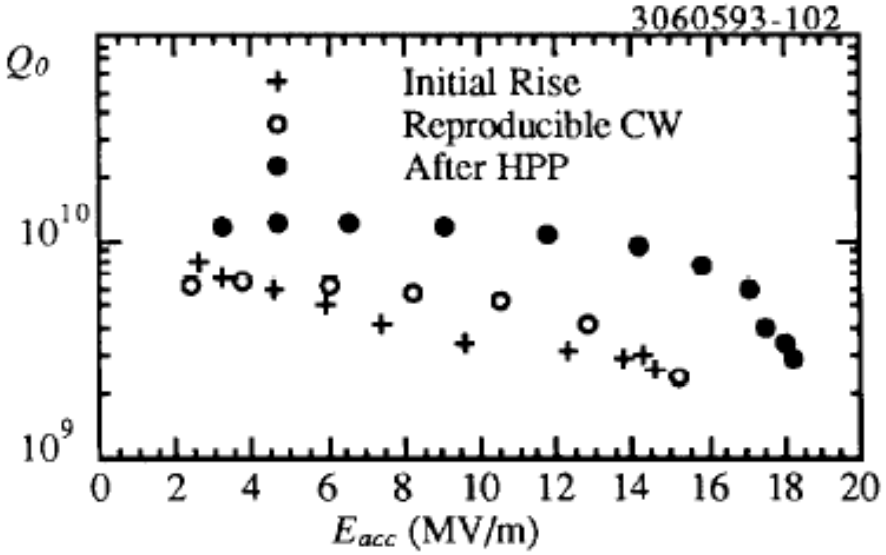
- HPP was also used to recover gradient after vacuum accidents increased field emission
- Accident 1 : few torr exposure to cold cavity, pump-out, HPP - recover
- Accident 2: one atmosphere room air exposure to cold cavity, warm up, pump-out, cool down, HPP-partial recovery

HPP for Recovery from Vacuum Accidents

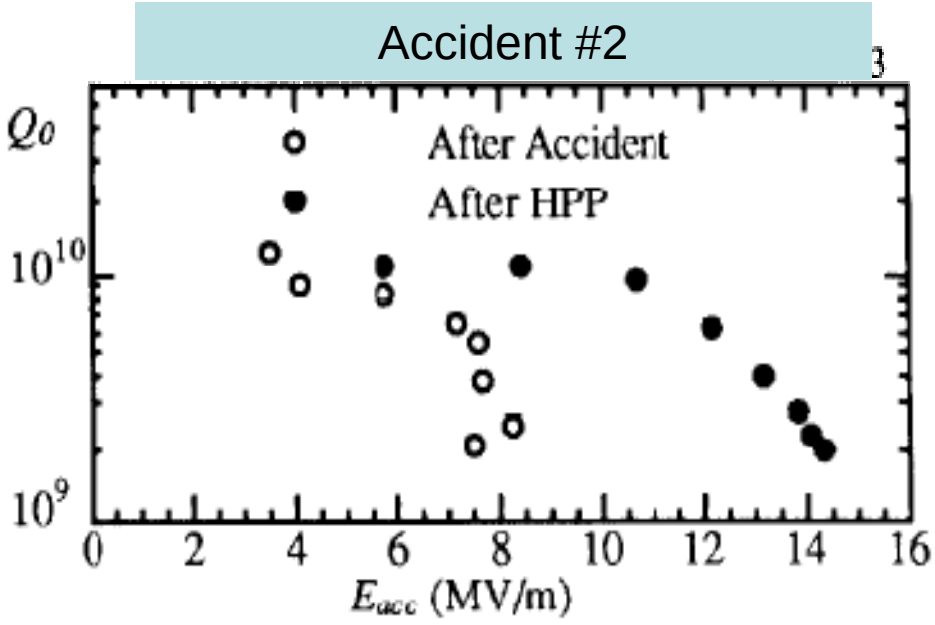
Baseline and
Clean Air Exposure



Accident #1



Accident #2



Summary of Possible Benefits of HPP

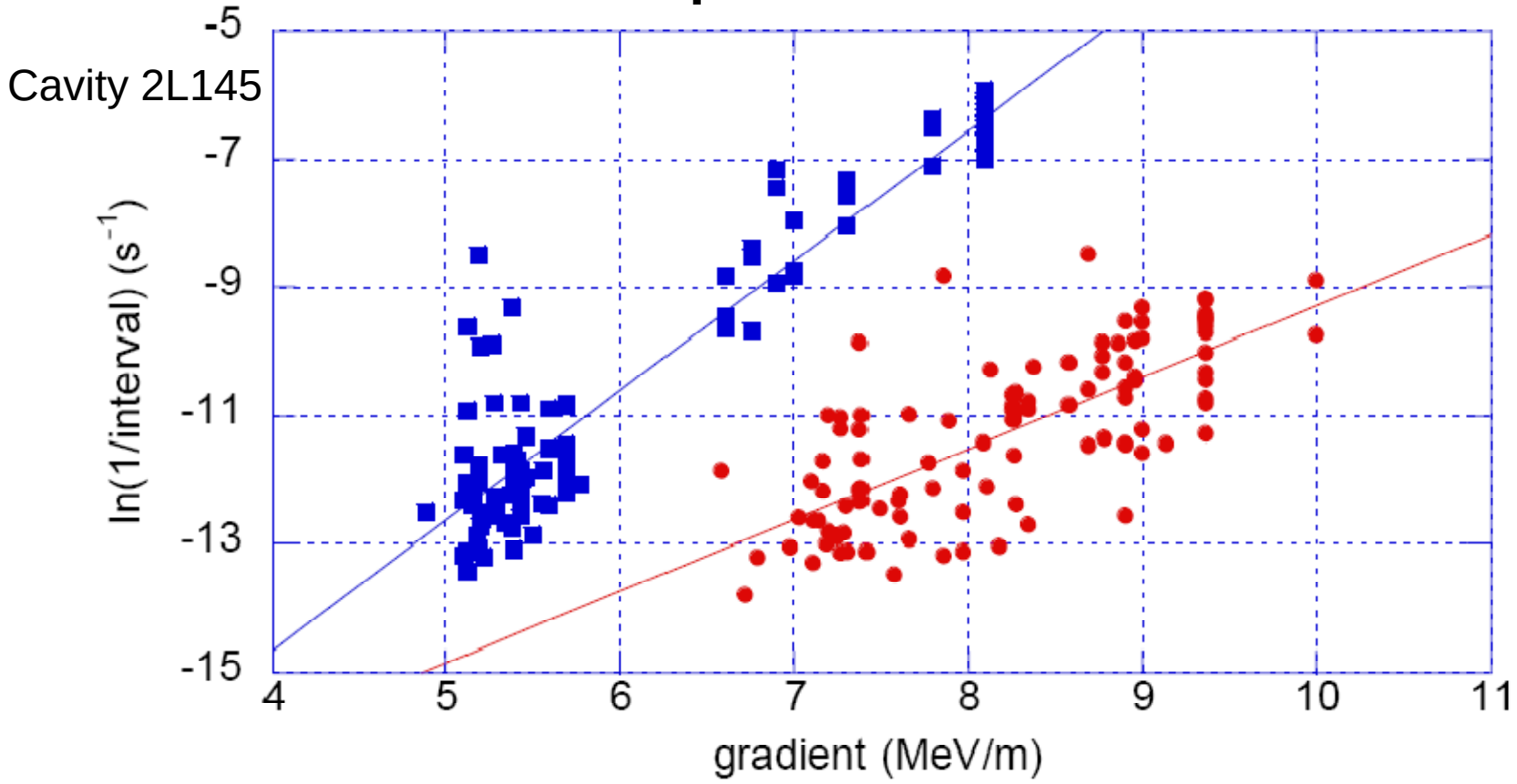
- Explore processing field emission for 9-cells
- Explore parameters for horizontal tests and final cryomodule performance
- Combination of HPR and HPP could be very effective against field emission.
- Recovery (or partial recovery) from vacuum accidents
- End

Field Emission Onsets During Accelerator Operation

- CEBAF reports activation of emitters
- 8 cavities per year show new onset field emission (latest 13 cavities per year)
- Drop of gradient average 1 – 2 MV per year (about 1% per year)
- These drops are NOT due to vacuum incidents…suspected : particle motion
- Needs serious attention !

Courtesy of
Jay Benesch

Example of "Event"



Red circles are before 04:40 on 9/21/2004; Blue squares are after

At 8.1 MV/m, interval changed from ~80,000 seconds to ~500 seconds