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Changes in Cavity performance: The Cornell ERL injector

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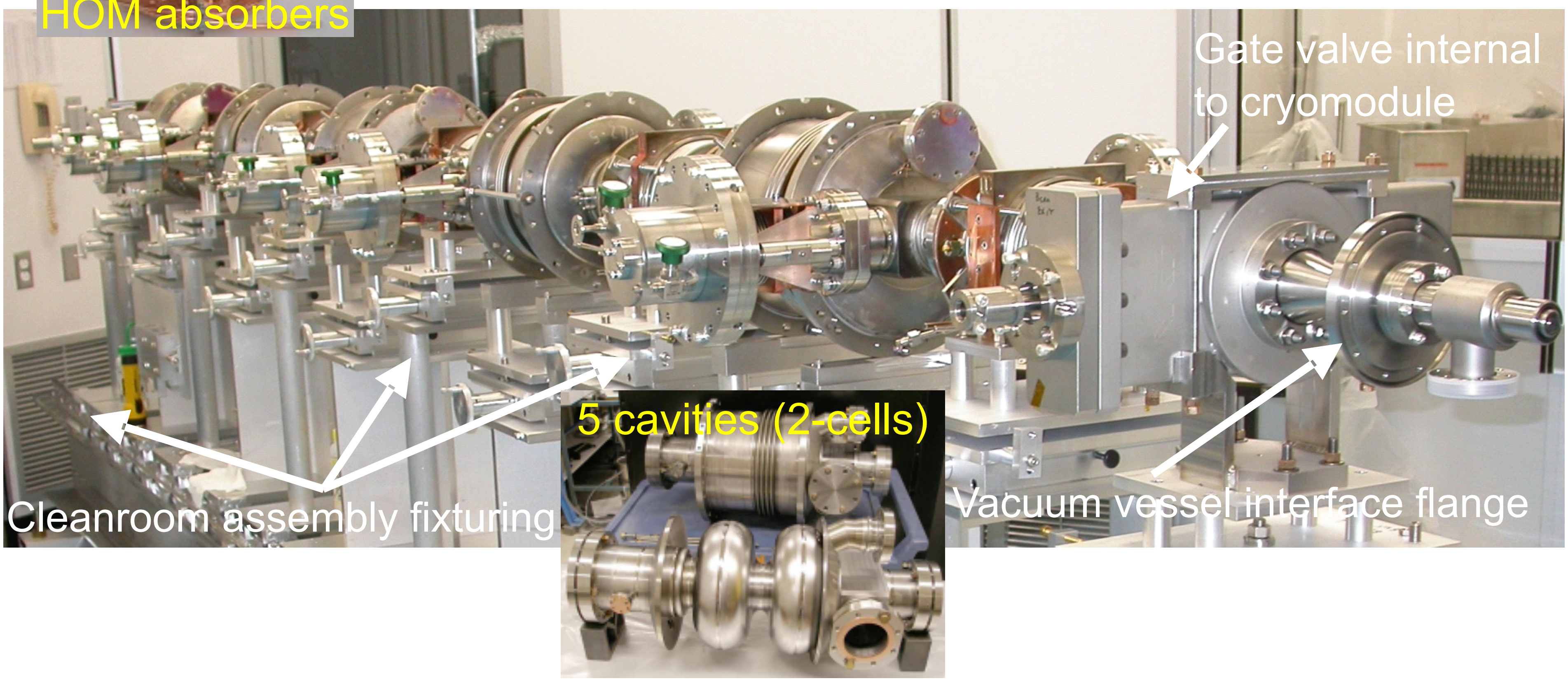
For Cornell's SRF and ERL team



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History of Q0 in the Cornell ERL injector

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There were 4 sets of Q0 test (BCP treated cavities with 120C but no high-T bake):

1. Vertical tests (2008 and 2010)
2. Horizontal tests after installation (2008)
3. Horizontal tests before rebuild to fix HOM absorbers (2009)
4. Horizontal test after rebuild (2010)

- Vertical tests looked reasonable (order $2 \cdot 10^{10}$ at 2K. Slightly better for slow cool down)
- Initial horizontal cavity performance not un reasonable ($Q \approx 0.6 \cdot 10^{10}$ at 2K)
- More detailed measurements later showed low intrinsic quality factors Q_0 for all 5 cavities ($Q \approx 0.3$ to $0.5 \cdot 10^{10}$ at 2K)
- HPR cleaning of cavities lead to similar vertical results as initially
- Detailed horizontal measurements ($Q \approx 0.7$ to $1.1 \cdot 10^{10}$ at 2K)

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Q0 vs. Eacc at 2K after 1 year of operation

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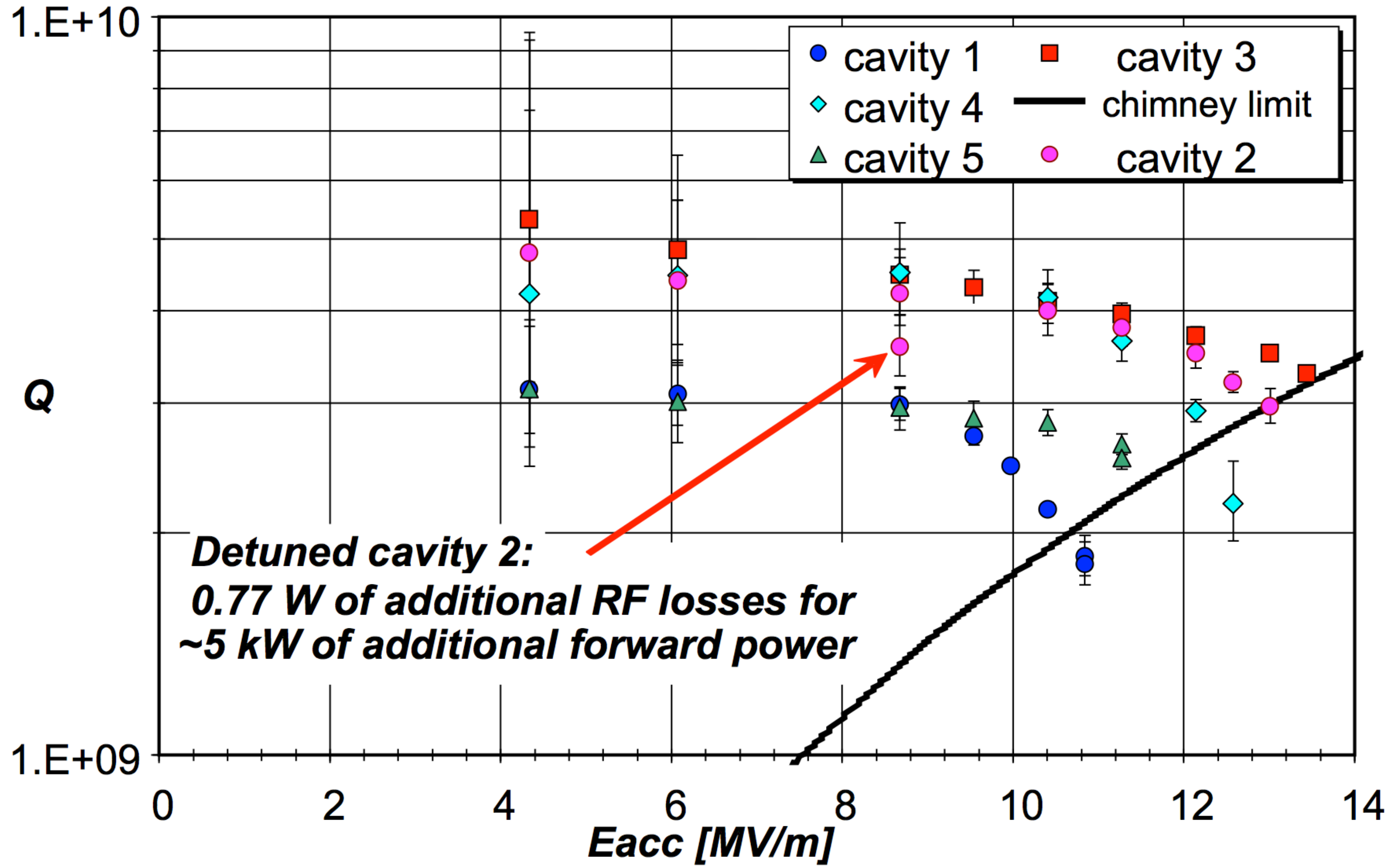

- Field emission at higher E_{acc}
- Voltage limit due to the chimney heat flux transfer, not quench
- Cavities on either end of the module show lowest Q

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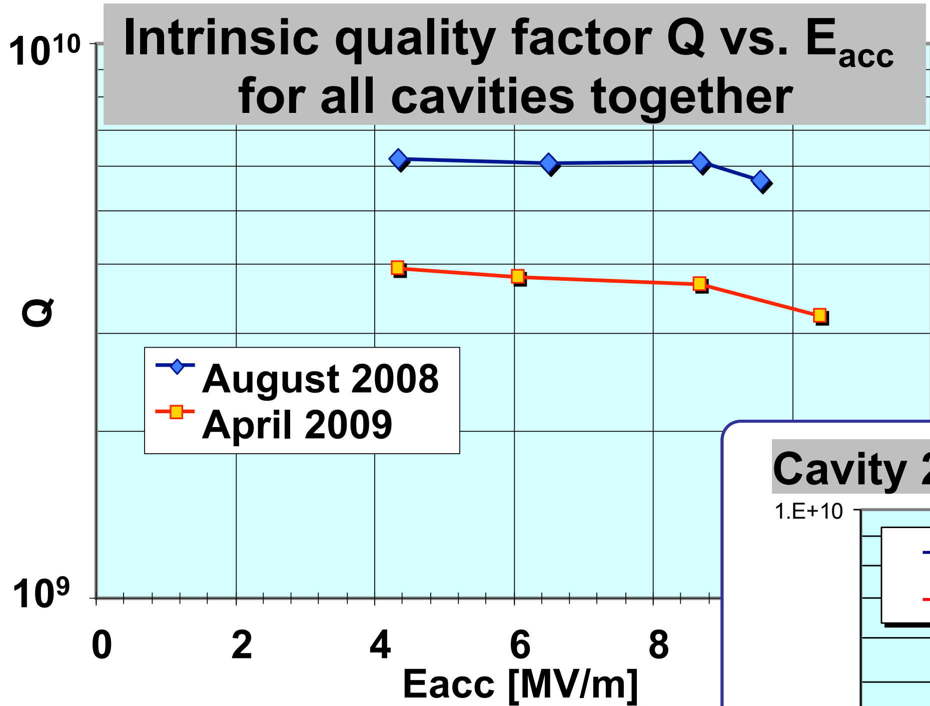
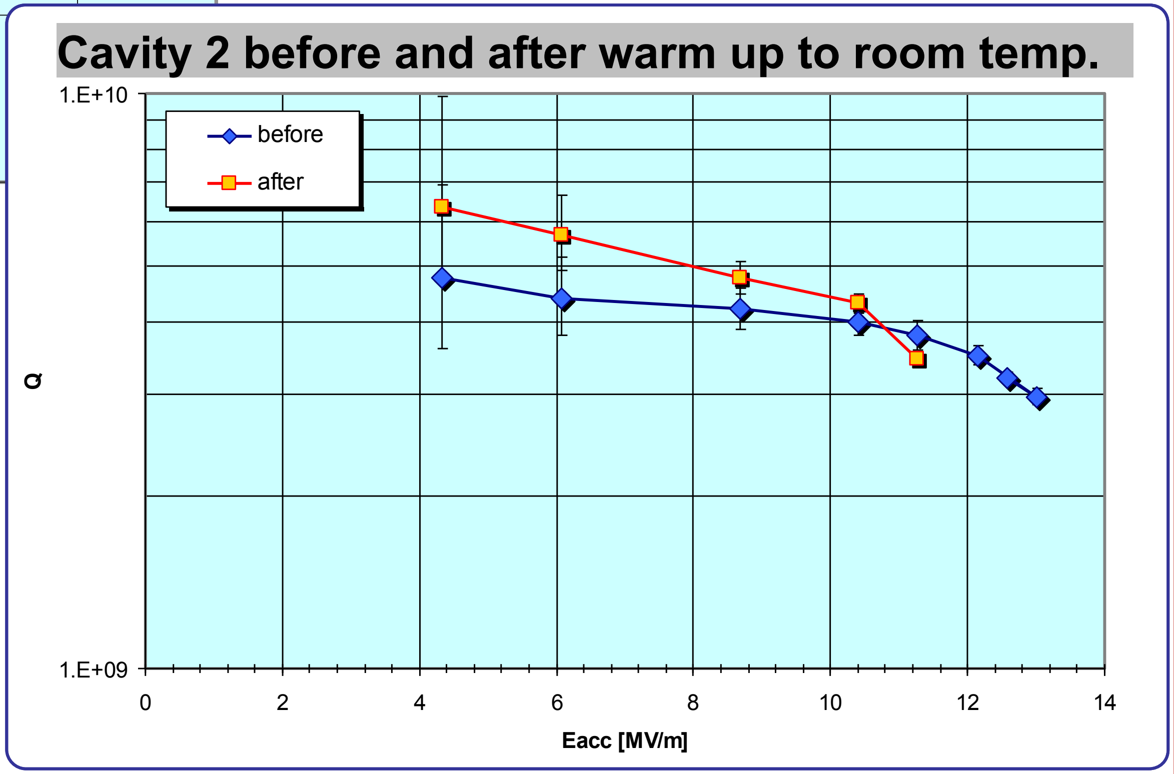


- Q Degradation over time?

- Slightly improved Q_0 by warm-up /cool down?



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Possible reasons for reduced Q_0

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- Possible reasons:
  - Coupling-dependent losses in the beam tube and coupler regions

    (cavity flanges are thermally anchored to a "4.5K" cooling circuit, which was actually at 6K because of inefficient heat exchanger in cold box and unbalanced flow with HOM absorbers $\Rightarrow$ increased $R_{BCS} \propto \exp(T)$ in beam tube sections.)
  - Cryo-pumping of residual gases: degradation over time, end cavities have lower Q factors.
  - Ferrite contamination

    (Cracked ferrite tiles were observe in HTC test and in the ERL injector.)
  - Dust contamination from the outside

    (The end cavities have lowest Q.)
  - Cavity preparation (temp during BCP,…)?
  - Hydrogen Q-disease: No

    (no indication during subsequent vertical tests, no Q-reduction after keeping module at 80 K for hours).

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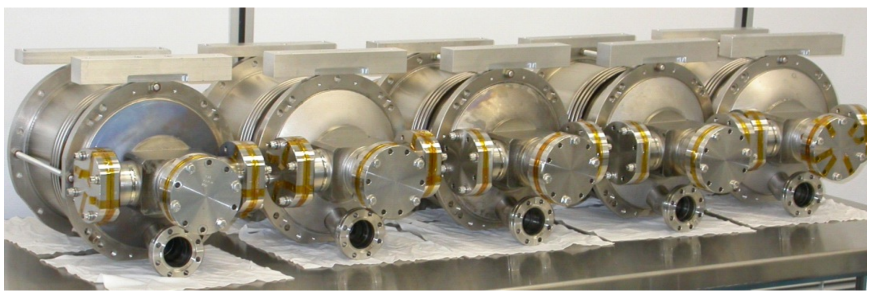
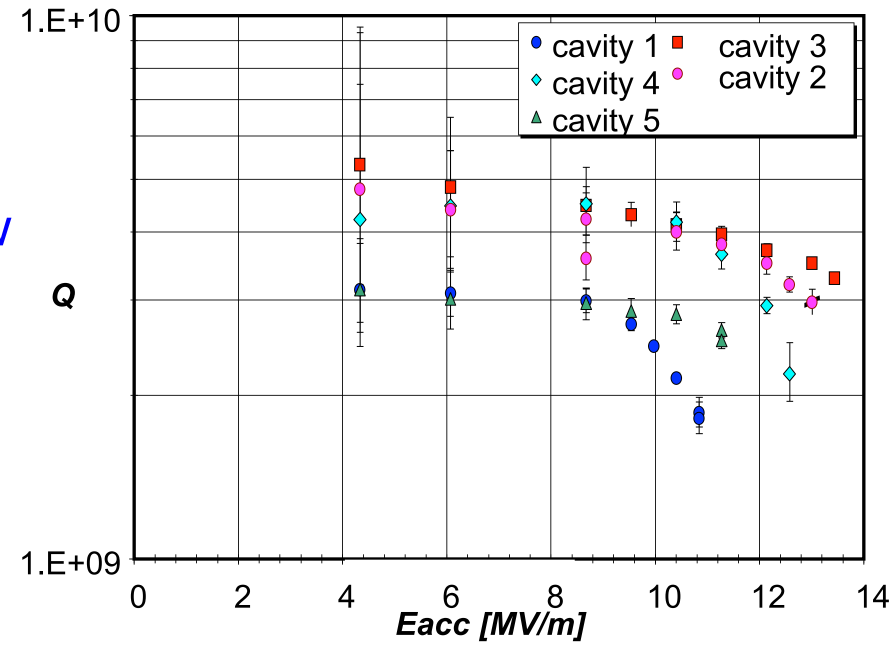
Before:

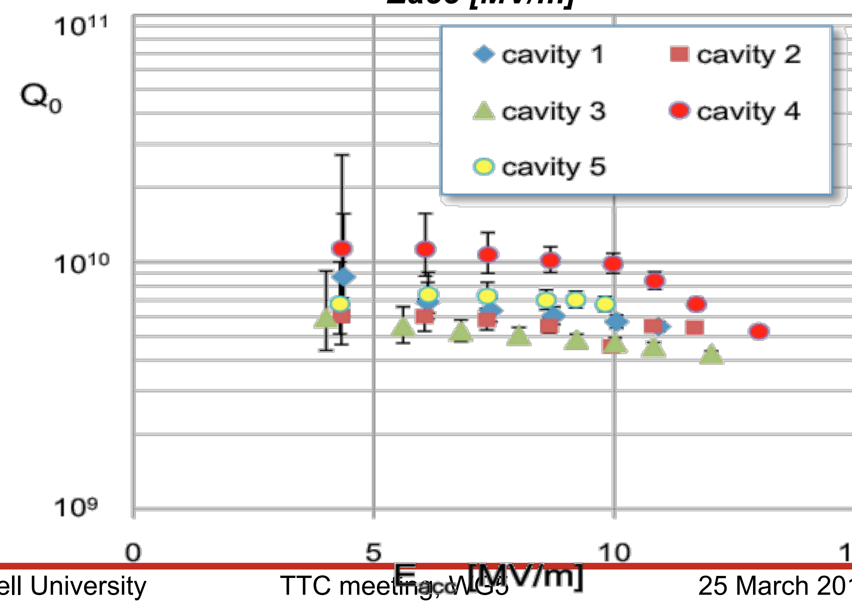
- Cavities met gradient specs, but had low intrinsic quality factors Q_0 ($Q \approx 0.3$ to $0.5 \cdot 10^{10}$ at 2K)
- Q_0 degradation over time?





After module rebuild:

- Intrinsic quality factors improved ($Q \approx 0.5 \cdot 10^{10}$ to $1.1 \cdot 10^{10}$ at 2K)



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Statistical analysis of Q variations

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If Q in several cavities is from contamination, then

(a) The average Q drop is from the average number of particles (of a certain size and material)

(b) The spread in Q drop is from the counting statistics of these particles.

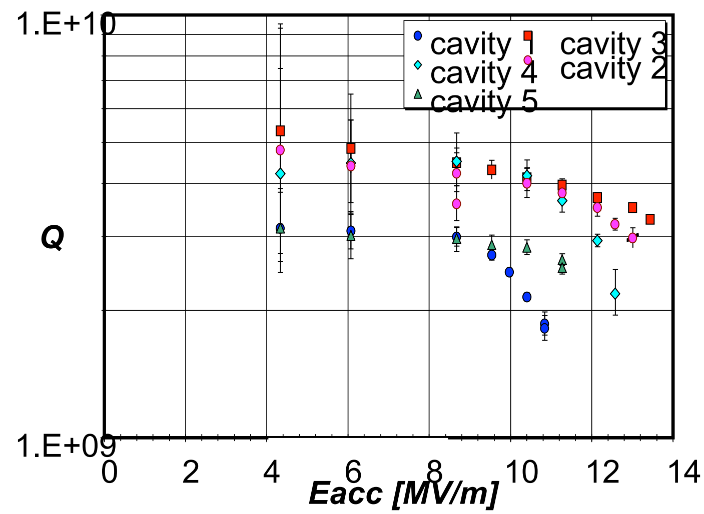
In counting statistics for the number of particles i_n, the average is related to the spread:

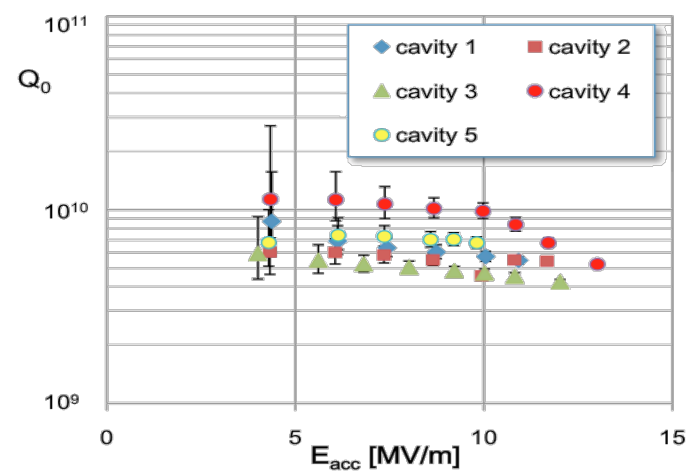
$$\mathrm{rms}(i_n) = \sqrt{\langle i_n \rangle}$$

Consistency of the Q-drop with contamination can therefore be checked:

- Is the average Q-drop suitably related to the spread in Q-drop for reasonable assumptions for material and size of particles?

Q drop in several cavities





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Statistical analysis of Q variations

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If all particles have the same size V_0, then the average loss per particle is given by the loss per particle kV_0 and the average number of particles $<i_n>$.

The spread in loss is given by the spread in the number of particles.

From average Q-drop and spread in Q-drop, the number of particles i_n in and their size V_0 can therefore be computed.

$$\langle i_n \rangle = \left[\frac{\left\langle \frac{1}{Q_n} \right\rangle - \frac{1}{Q_0}}{\mathrm{rms}\left(\frac{1}{Q_n} \right)} \right]^2$$

$$V_0 = \frac{1}{k} \cdot \frac{\mathrm{rms}\left(\frac{1}{Q_n} \right)^2}{\left\langle \frac{1}{Q_n} \right\rangle - \frac{1}{Q_0}}$$

In Cornell's injector Q dropped between vertical and horizontal tests and we obtained

(1) The Q-drop statistics leads to an average of 30 particles per cell.

(2) The loss per particle is consistent with Ferrite particles of 30micron diameter.

(3) It is, for example, not consistent with small particles from nylon.

If V. Shemelin, G.H. Hoffstaetter, Influence of foreign particles on the quality factor of superconducting cavities, Proceedings of SRF2011, Chicago/IL (2011)

Start of Discussion