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Testing Superconducting RF Cavities of the Highest Field Gradients for the International Linear Collider

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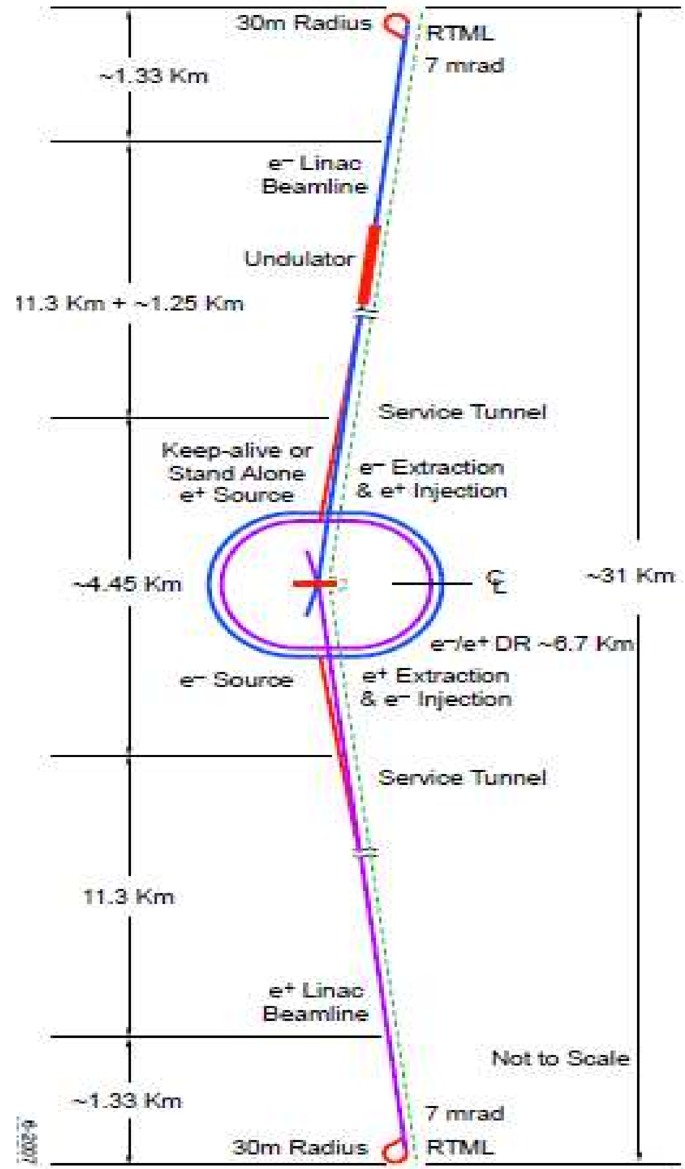
ILC and SRF

- ILC = International Linear Collider
- The ILC is a proposed electron-positron collider that uses **superconducting radio-frequency** (SRF) cavities for acceleration
  – ~16,000 SRF niobium cavities are needed
  – All cavities must reach **accelerating gradients** of E_{acc} = 35 MV/m during tests



Cavity Terminology

- **Q_0** = cavity's **intrinsic quality factor**
  - High Q_0 is desired → indicates efficient performance
  - Great: $Q_0 \approx 10^{10}$ or 10^{11}
- **Quench** = the transition from super- to normal conducting, often caused by unwanted heating
  - It becomes prohibitively harder to excite normal conducting cavities to high E_{acc}
- Good cavity preparation is essential for high quality factors *and* for getting to high E_{acc}

Improving Cavity Performance

- Defects and impurities on the cavity surface can lower Q_0 and cause quenching
  - – Increases the surface resistance of niobium
  - – Causes high RF losses that generate heat
  - – With enough heat, the cavity quenches
- Common procedures to get rid of defects
  - – Chemical treatments
  - – Clean assembly
  - – High pressure rising
  - – Baking

Chemical Treatments

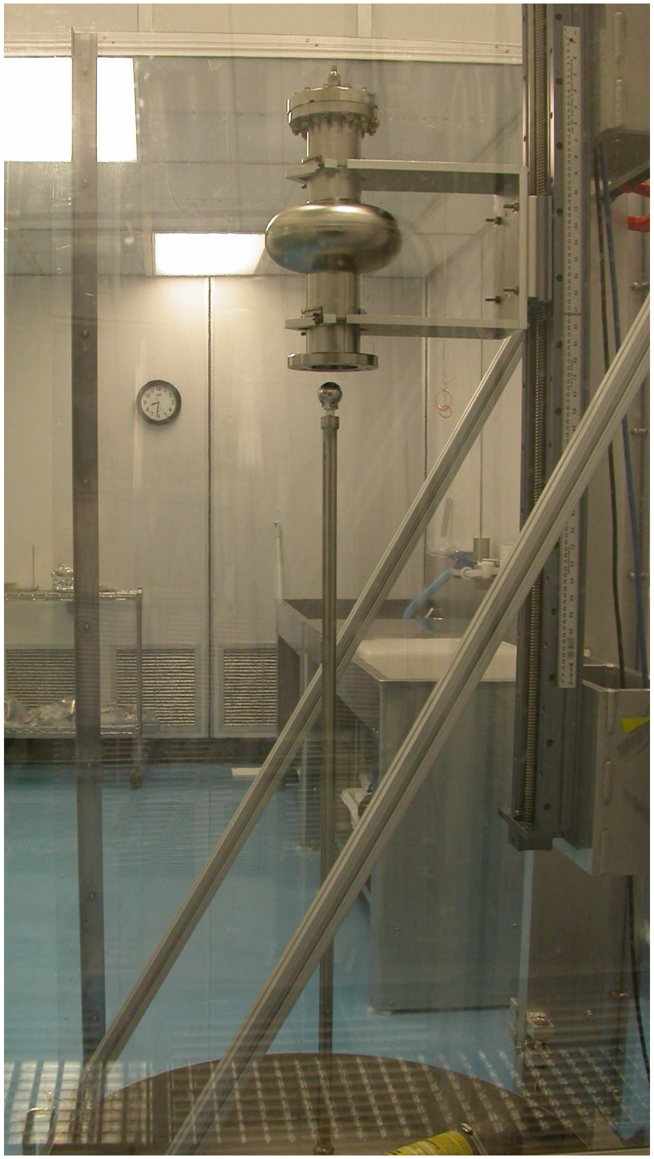
- **Chemical treatments** use acid solutions to etch away the outer layers of niobium
  - **Buffer chemical polish (BCP)** is a rough etch
  - **Electropolish (EP)** is a finer, smoother etch

- There exists a proposal that only BCPs are needed for large grain cavities

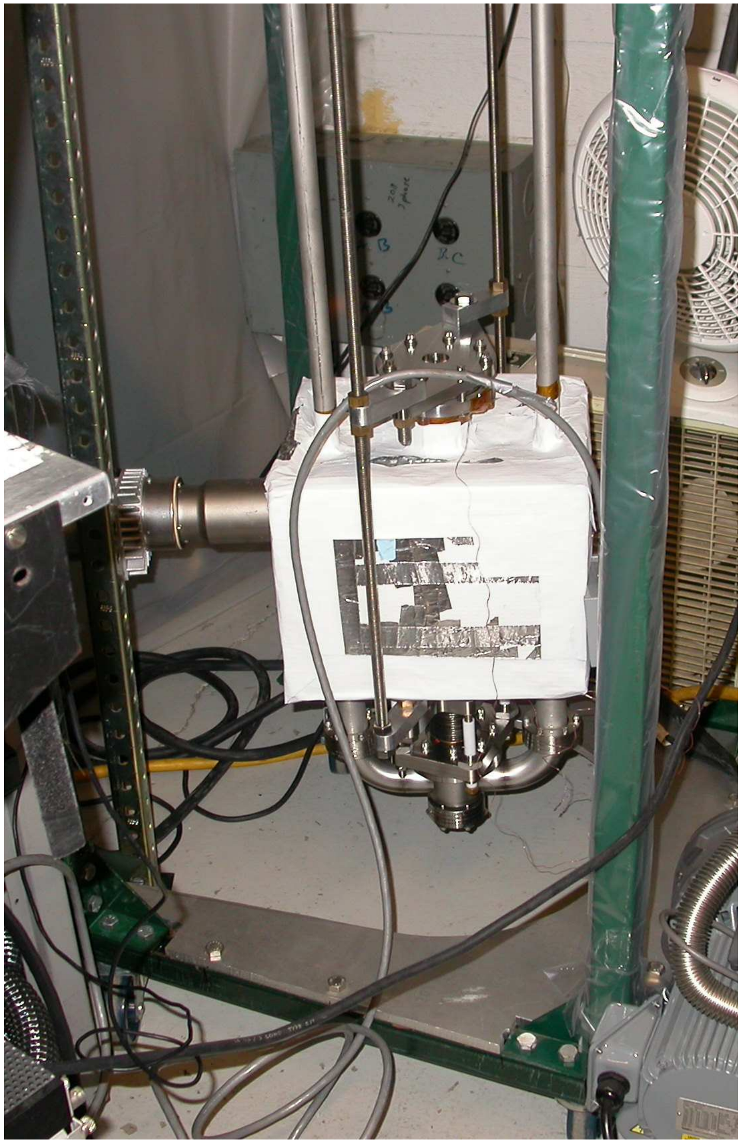
- BCPs and EPs use Hydrofluoric Acid
  → undergraduates must stay away!

Clean Room Procedures

- **Cavity assembly**
  - Always done in the clean room to minimize the number of particulates that enter the cavity
- **High pressure rinsing** (HPR)
  - Performed in clean room
  - Spray interior of cavity with jets of ultrapure water at 1000 psi
  - This dislodges loose particulates in the cavity



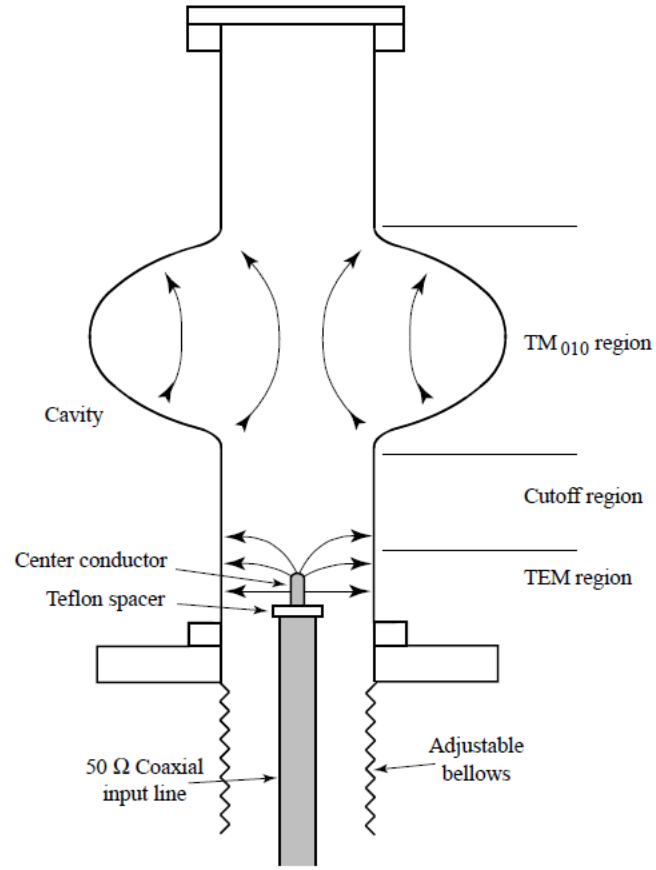
Cavities Bakes



- Bakes are performed for freshly electropolished cavities
  - Baking reduces the surface resistance of niobium
  - All bakes performed for this project were at 110ºC, but higher-temperature bakes at ~800ºC are also common

Cavity Testing

- Cavities are tested in a liquid helium bath
- Measurements are made through input and output power couplers
  - The output power probe is coupled to the cavity very weakly
  - We want the input power probe to be unity coupled to the cavity for tests
  - Probe length is semi-adjustable during tests
- Q_0 values are obtained at various E_{acc} values to create a Q-curve



Results from Cavity Tests

- Three single-cell cavities were tested
  - AES-2
  - NR1-2
  - LR1-5
- All tests suggested high Q's, but the only Q-curve obtained was from AES-2
- Difficulties with coupling prevented us from obtaining Q-curves for NR1-2 and LR1-5

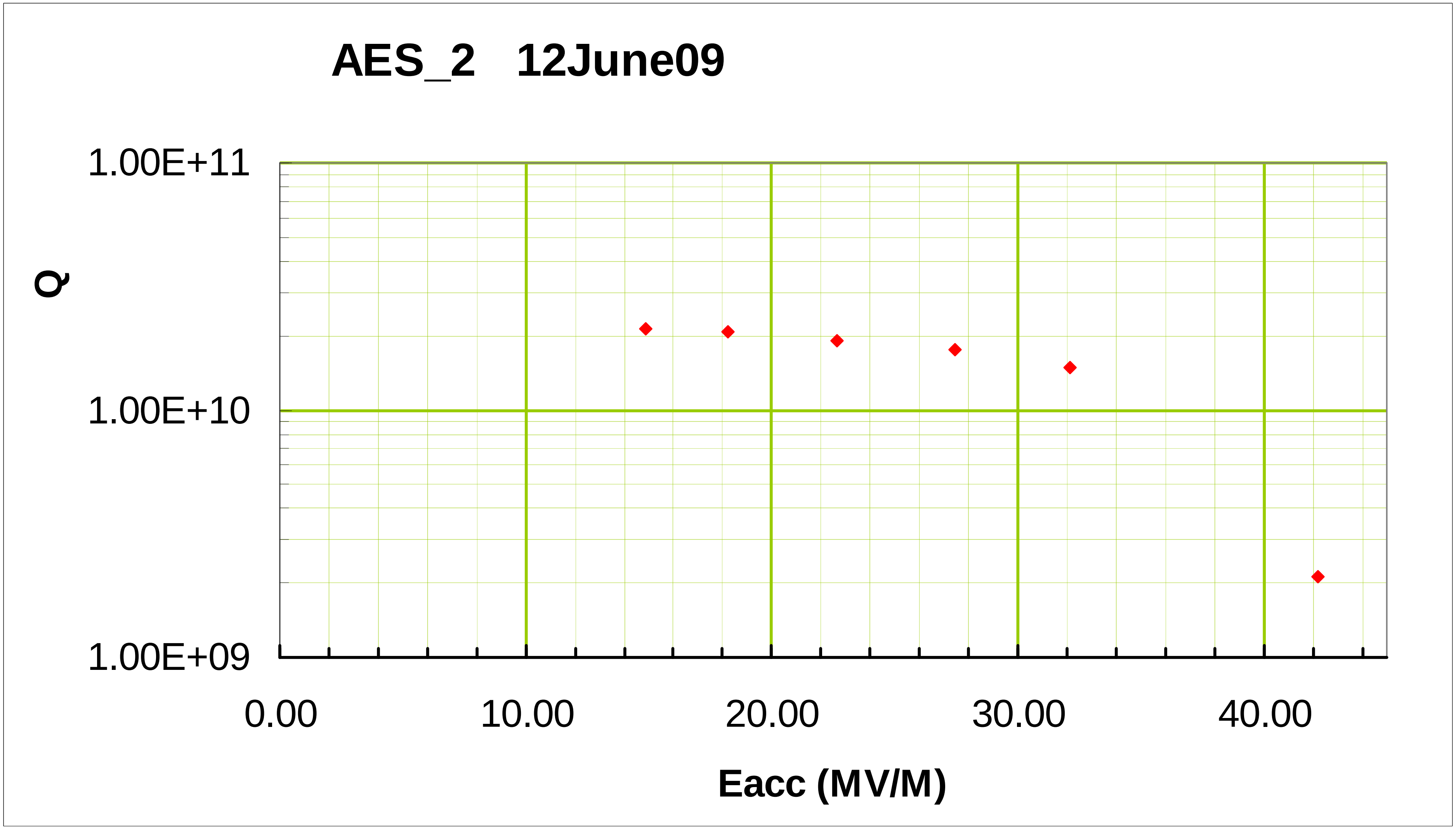
Notes on the Tests

- **NR1-2 Cavity Test:**
  - Input coupler's probe length was too long → cavity was always overcoupled
  - Estimated a low-field Q of over 8×10^{10}
- **LR1-5 Cavity Test:**
  - Could not unity couple to the cavity
  - Measured Q-value were: 2.4×10^{10} and 8.9×10^{9}
  - This was a large-grain reentrant cavity that had only received a BCP

Notes on the Tests

- **AES-2 Cavity Test:**
  - Q curve looked good: Q-values around 10^{10}
  - We were able to get above E_{acc} = 42 MV/m
  - Not enough liquid helium to finish the Q slope

AES-2 Q-Curve


AES_2 12June09
Q
1.00E+11
1.00E+10
1.00E+09
0.00
10.00
20.00
30.00
40.00
Eacc (MV/M)