# Design Considerations for CW SRF Linacs


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# OUTLINE

- **Optimum Gradient**
  - **Scaling Factors**
  - **1989 Cryogenic Optimization of Capital & Operating Costs**
  - **Q-shift across Lambda (1500 & 700 MHz)**
- **Lorentz Detuning and Microphonics**
  - **Steady State**
  - **RF turn on**
- **Superfluid heat transfer as function of temperature and liquid level**
- **Tesla HOM Coupler**
- **Summary**
- **References**

# DESIGN DRIVERS

## ILC

1. Max Gradient
2. $Q_0$
3. Static Heat Loads
4. Packing Factor

## 12 GeV Upgrade / CW SRF Linacs

1. Available Length
2. Packing Factor
3. $Q_0$
4. Static Heat Loads

# POWER DISSIPATION

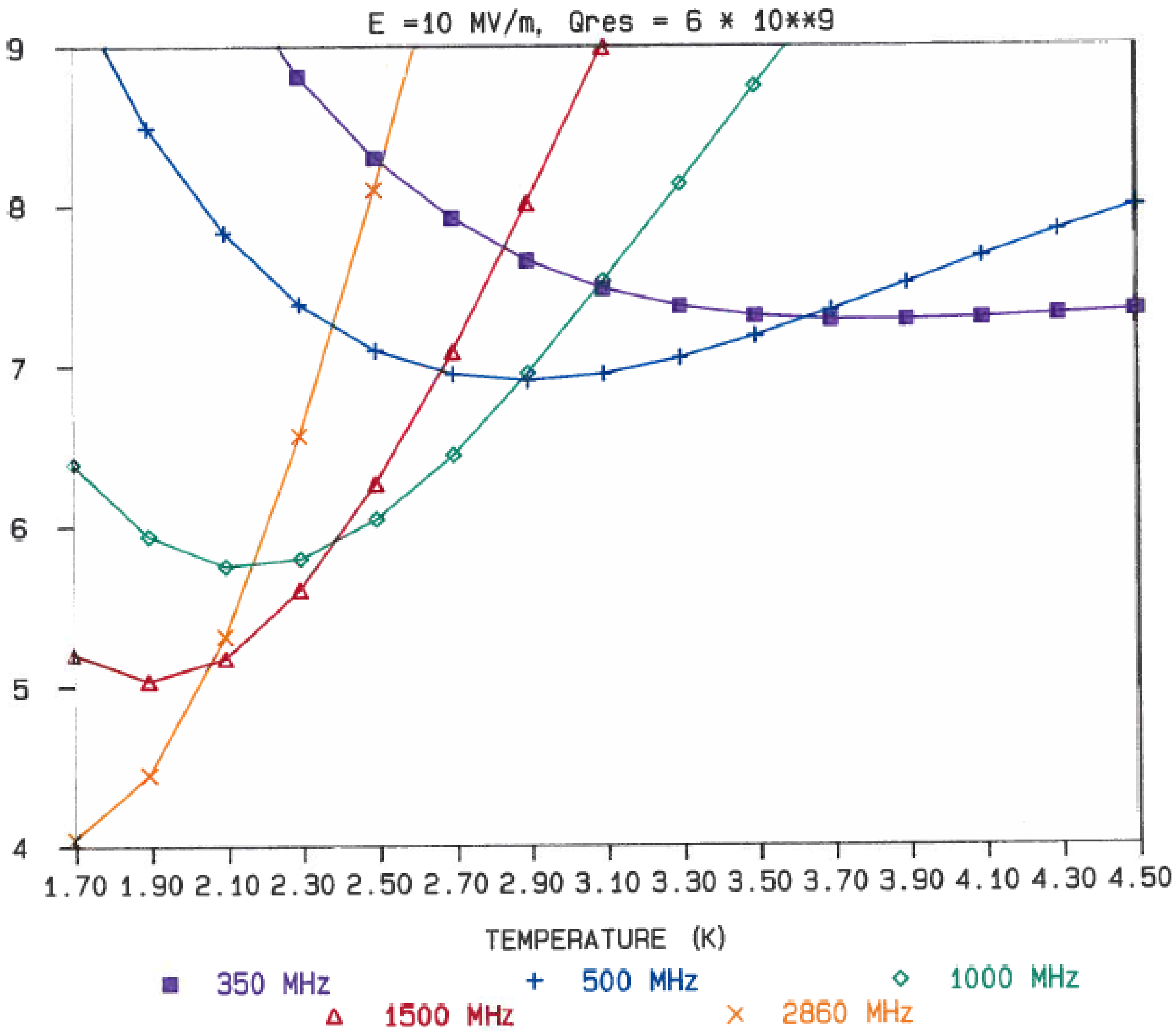
ACCELERATION $\propto \quad G \cdot L$

POWER DESIPATION $\propto \quad \frac{G^2 \cdot L}{Q_0}$

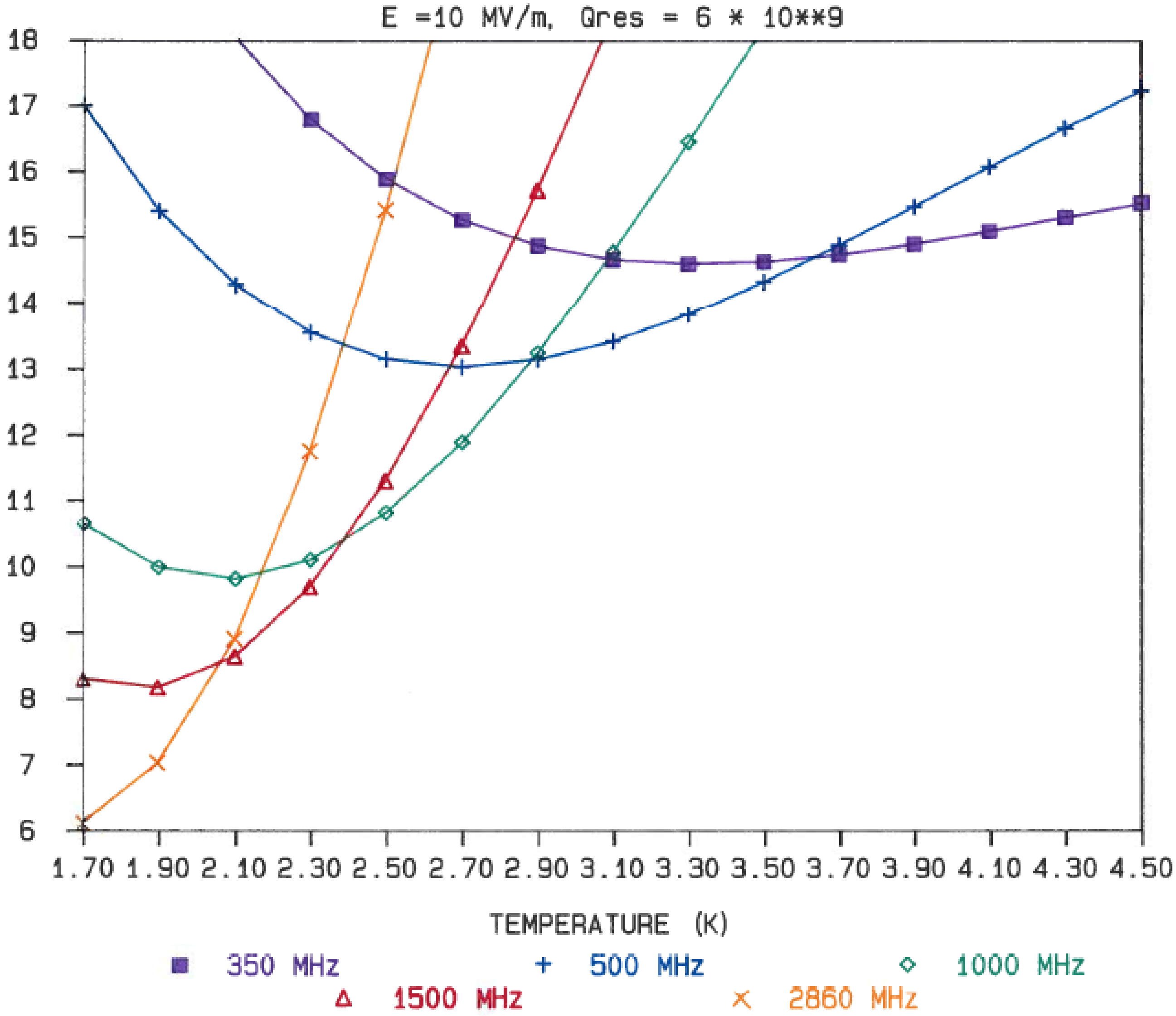
FOR GIVEN ENERGY $\propto \quad \frac{G}{Q_0} \quad \propto \quad \frac{1}{L\, Q_0}$

COST OF OPTIMUM GRADIENT FOR 1300 MHz ≈15MV/m

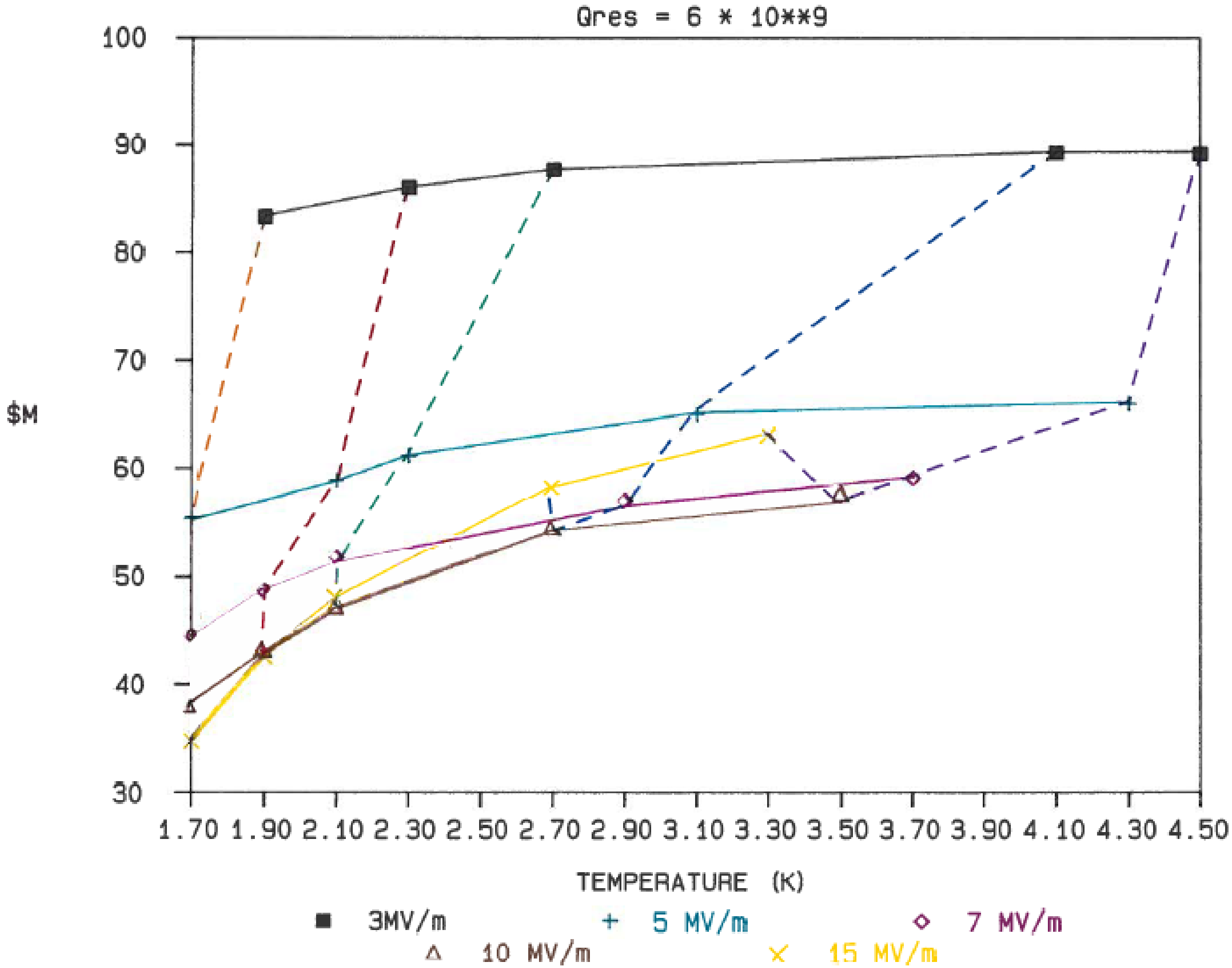
# NORMALIZED CAPITAL COSTS



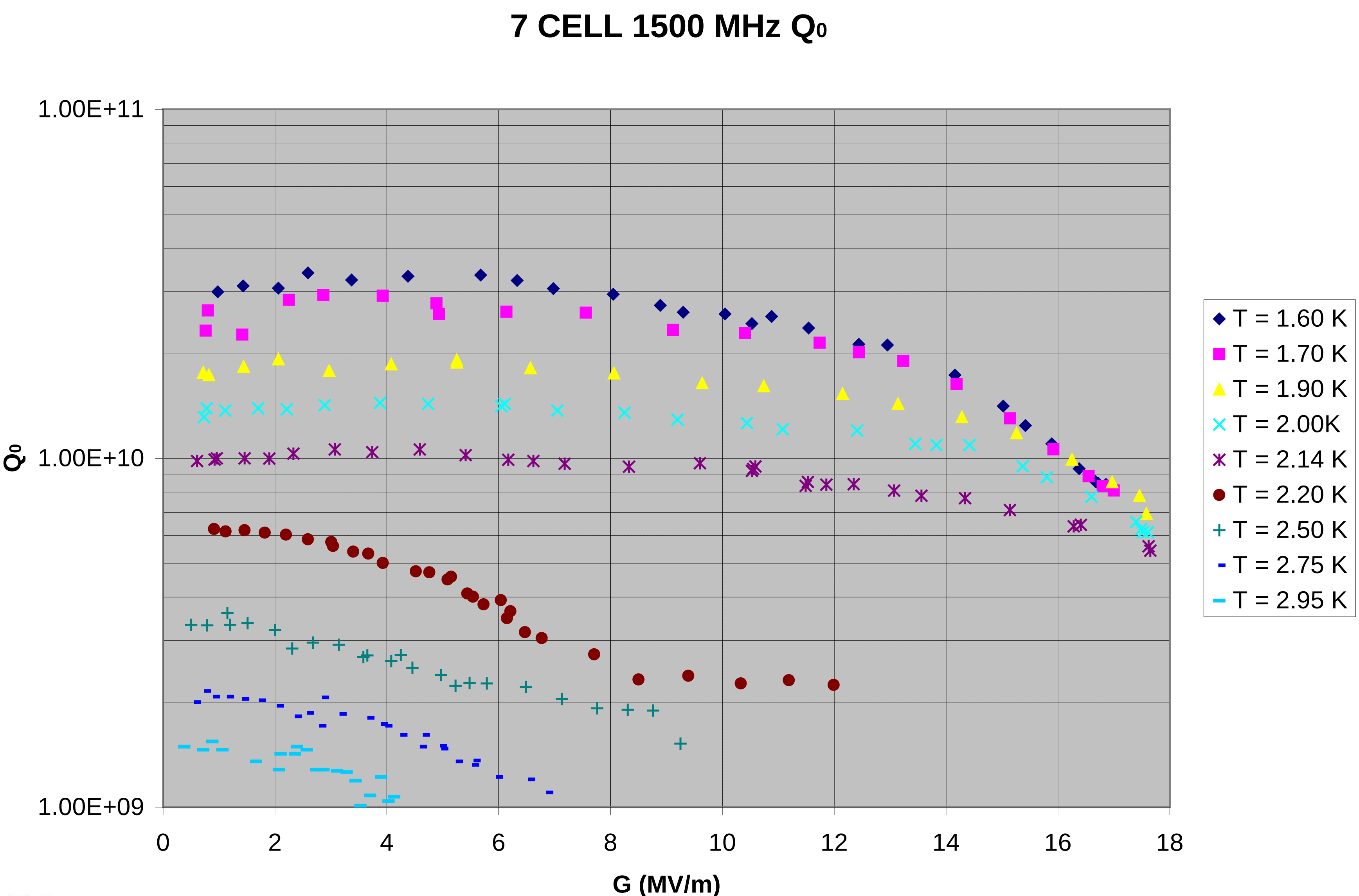
# NORMALIZED OPERATING COSTS



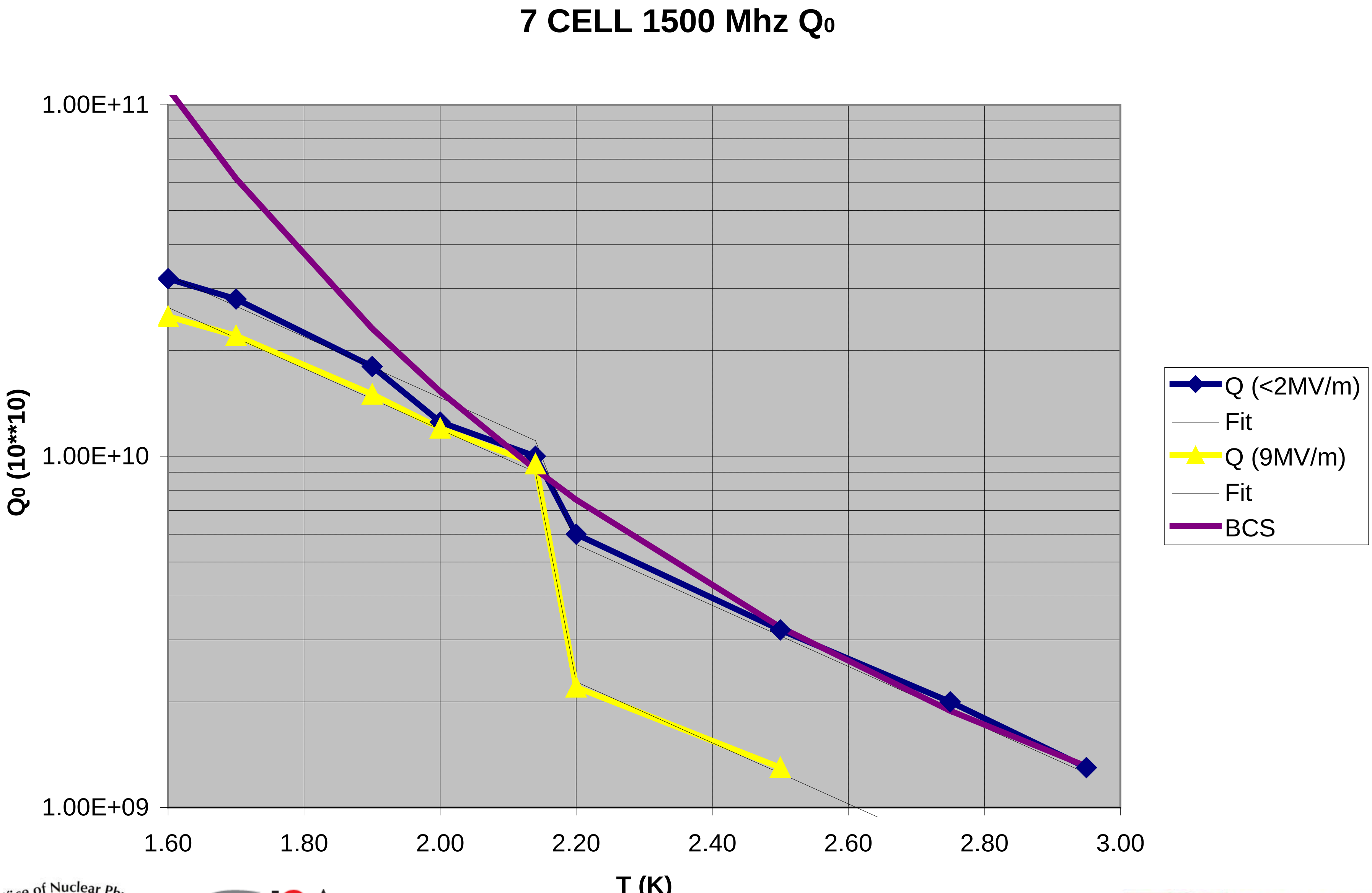
# TEN YEAR TOTAL COSTS



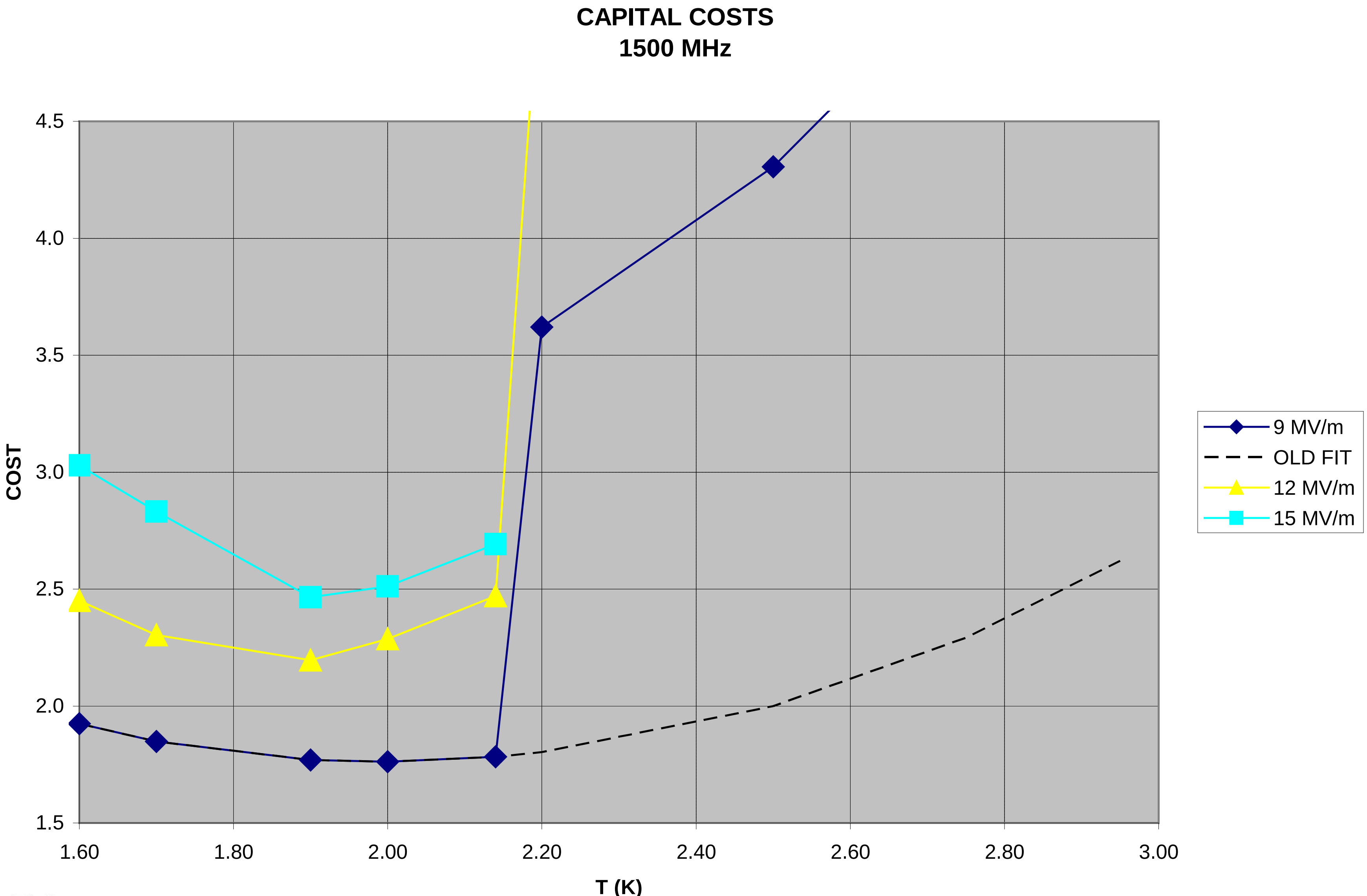
# 1999 TEMPERATURE OPTIMIZATION



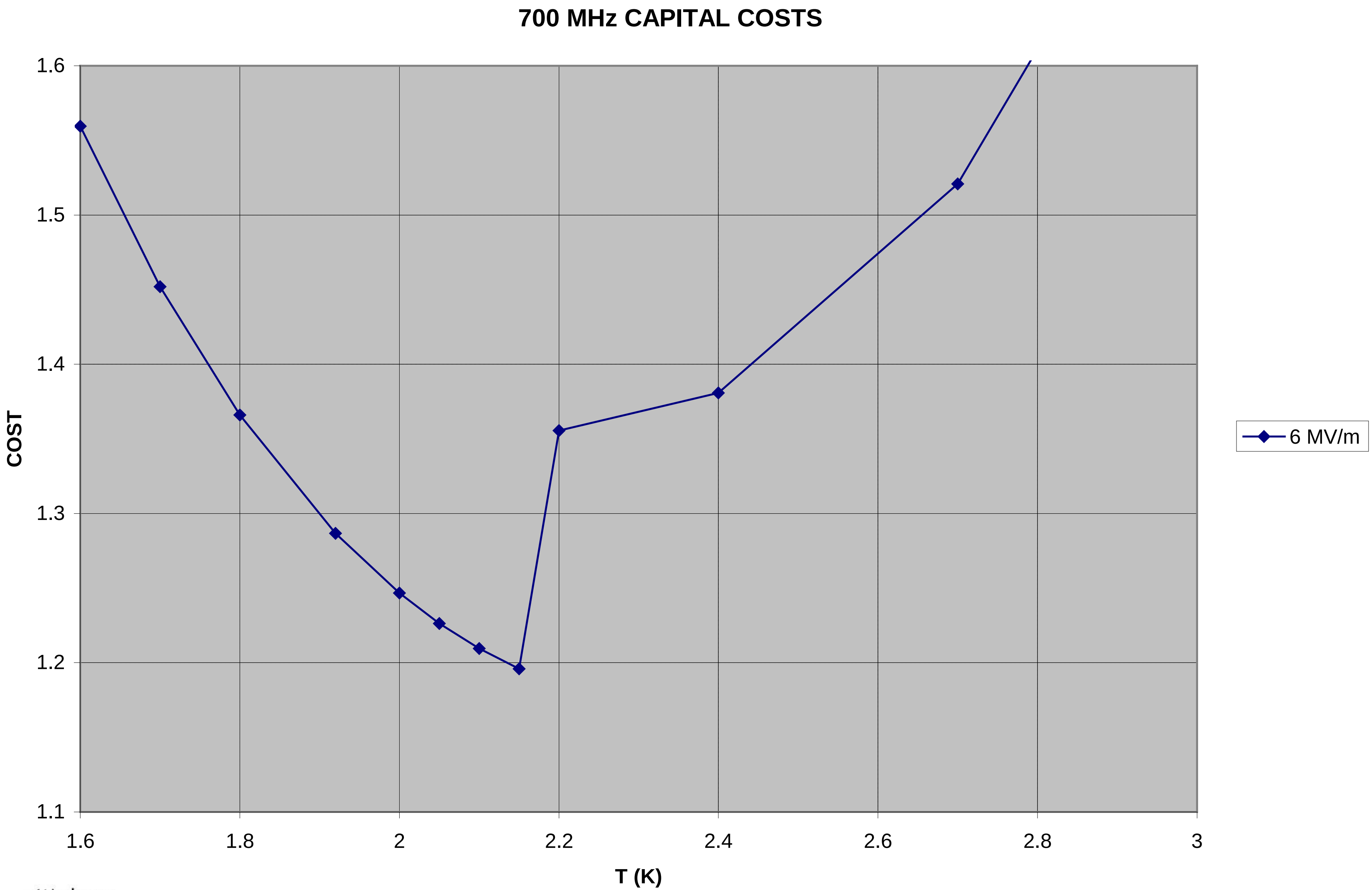
# 7 CELL 1500 MHz CAVITY



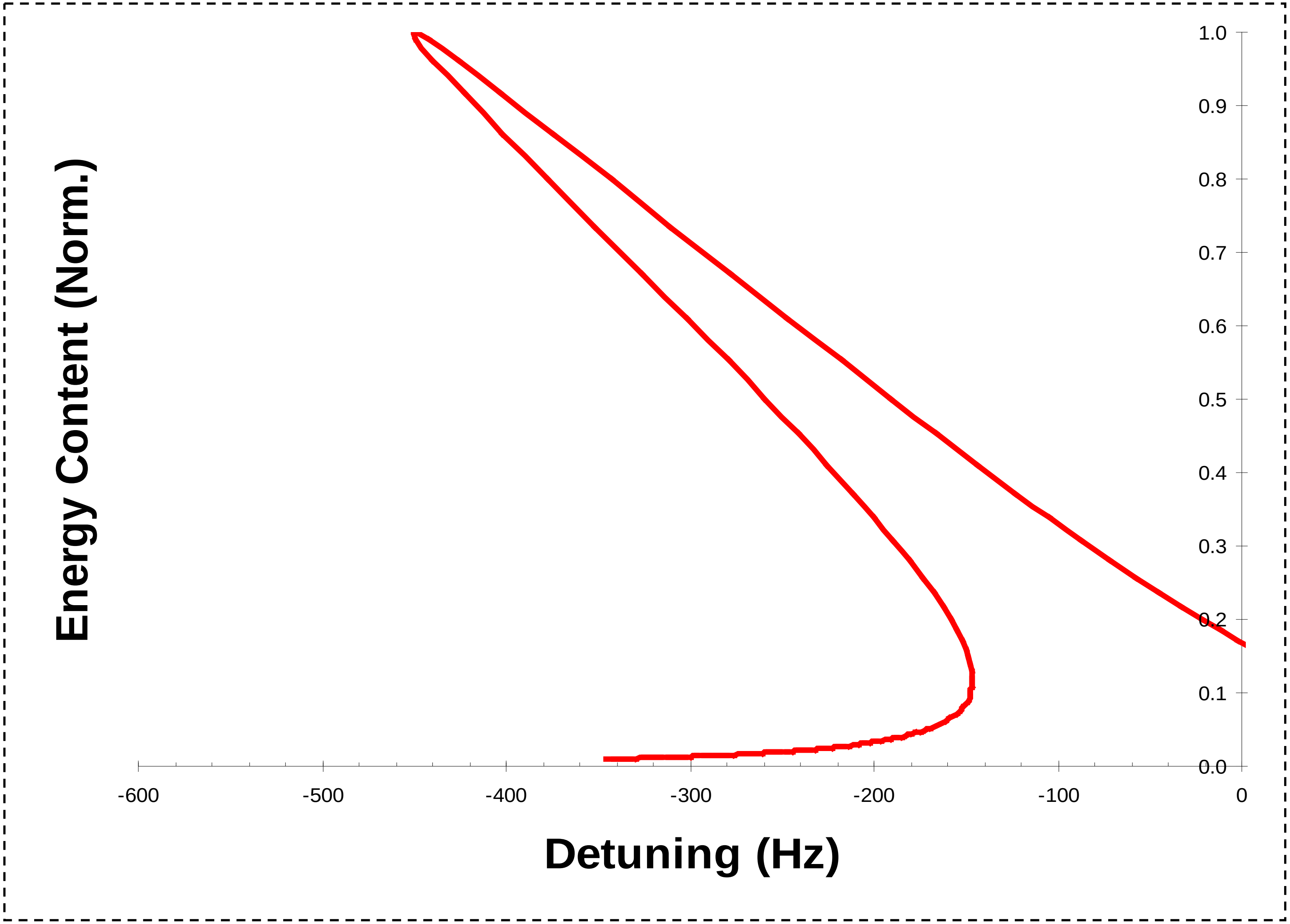
# 1500 MHz REFRIGERATION CAPITAL COSTS



# 700 MHz REFRIGERATION CAPITAL COSTS



# 12 GeV LORENTZ DETUNING CURVE



# STIFFING RINGS & PIEZO-ELECTRIC TUNER

## Stiffing Rings

- Improve detuning curve
- Raise the structure resonate frequencies
- Increase require tuner forces
- Do not eliminate need for fast tuner

## 12 GeV Cavity

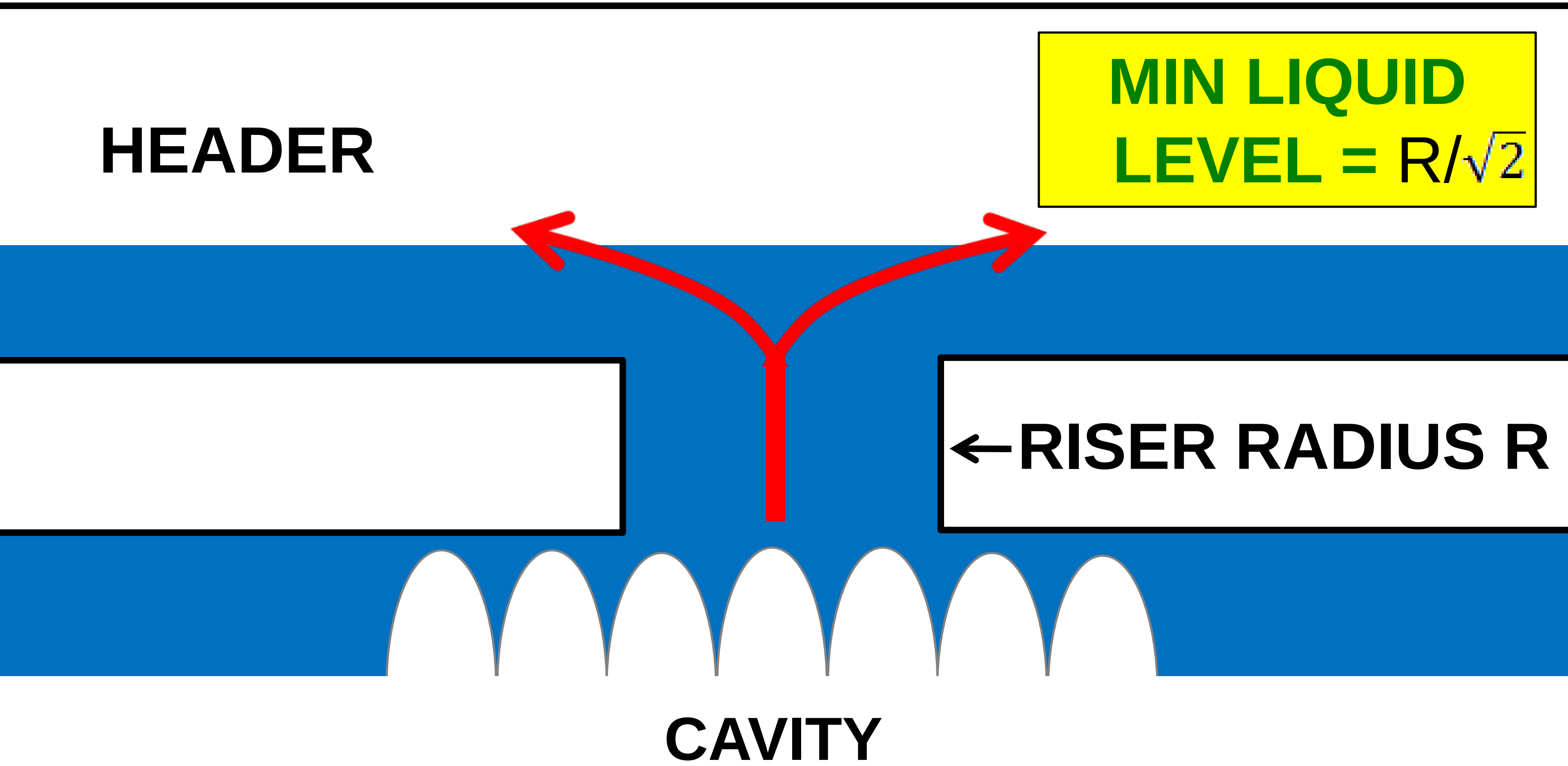
- Elected not to pay for stiffing rings
- Fast tuner required:
  - To eliminate slow tuner microphonics
  - For fast cavity turn on (or LLRF self-excited-loop)

# CW PERFORMANCE LIMITERS

- **Lambda**
- **Super fluid heat conductance: ~1.0W/cm$^2$**
- **Super fluid liquid – gas vaporization: <<1.0W/cm$^2$**
  - **Single JLab CM Experiment**

**NET EFFECT: GRADIENT IS FUNCTION OF LIQUID LEVEL**

# HEAT CONDUCTION THRU VERTICAL RISER



# TESLA HOM COUPLER

# TESLA HOM COUPLER

- **Matched to ILC needs; also used for:**
  - **SNS**
  - **12 GeV Upgrade**
  - **JLAB FEL (10KW)**
- **Cooling**
  - **Hook: Through two attachments welds to can**
  - **Probe: Through ceramic feedthrough PROBLEM**
- **Thermal limited by:**
  - **Duty factor**
  - **RF coupling**
  - **Beam current**
- **Limited work-a-rounds:**
  - **Improved feedthrough heat transfer; including sapphire**
  - **Nb probe tips**
  - **2K heat straps**

# TESLA HOM COUPLER

- **TESLA HOM coupler is optimized for**
  - **Pulsed Operation**
  - **Low Currents**
- **CW requires cooling modification**
- **JLab has had a great deal of trouble adapting this design for other applications:**
  - **SNS (???Multipacting???)**
  - **High Current CW FEL (requires SC probe tip)**
- **Fermi Lab had trouble adapting this design for 2600 MHz**
  - **Weld failure**

# SUMMARY

- **CW operation requires integrated design effort**

- **Just scaling pulsed design will get you into trouble**

# REFERENCES

C. H. Rode and D. Proch, “Cryogenic Optimization for Cavity Systems,” Proceedings of the IEEE Particle Accelerator Conference, March 1989, p. 589.

C. H. Rode, “Temperature Optimization for Superconducting Cavities,” Proceedings of ASC 98, IEEE Transactions on Applied Superconductivity, June 1999, p. 873-876.

C. H. Rode, “Jefferson Lab 12 GeV CEBAF Upgrade,” to be published in the Proceedings of the Cryogenics Engineering Conference, June 2009.