Measuring Q_0 in LCLS-II Cryomodules Using Helium Liquid Level

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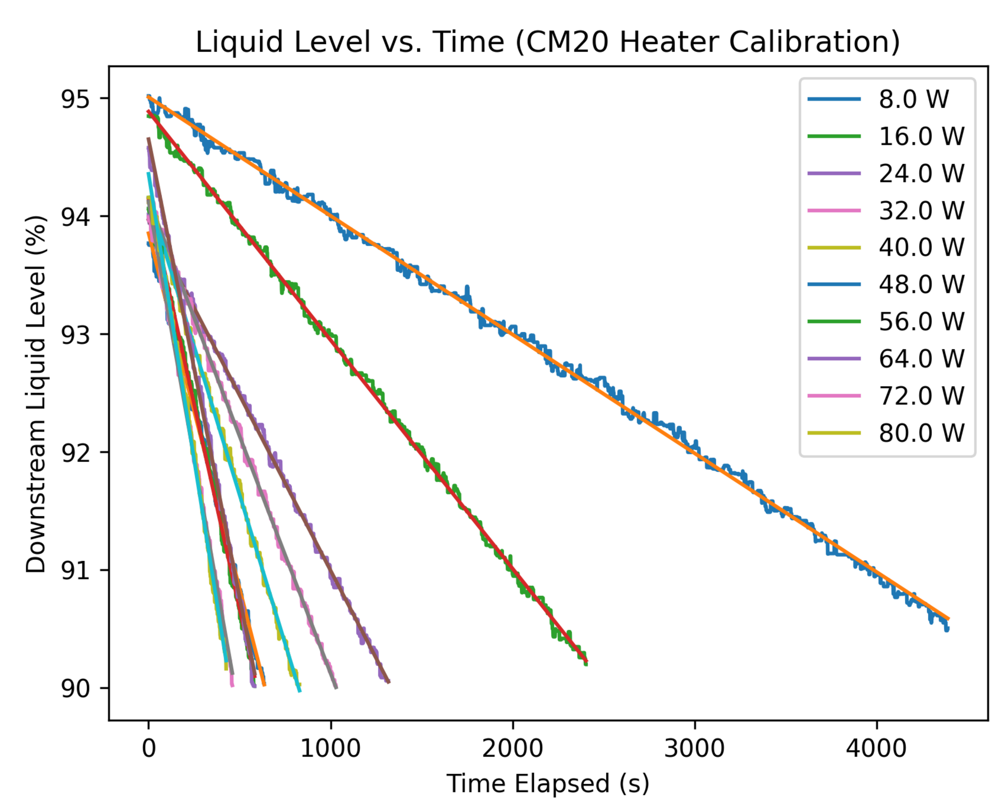
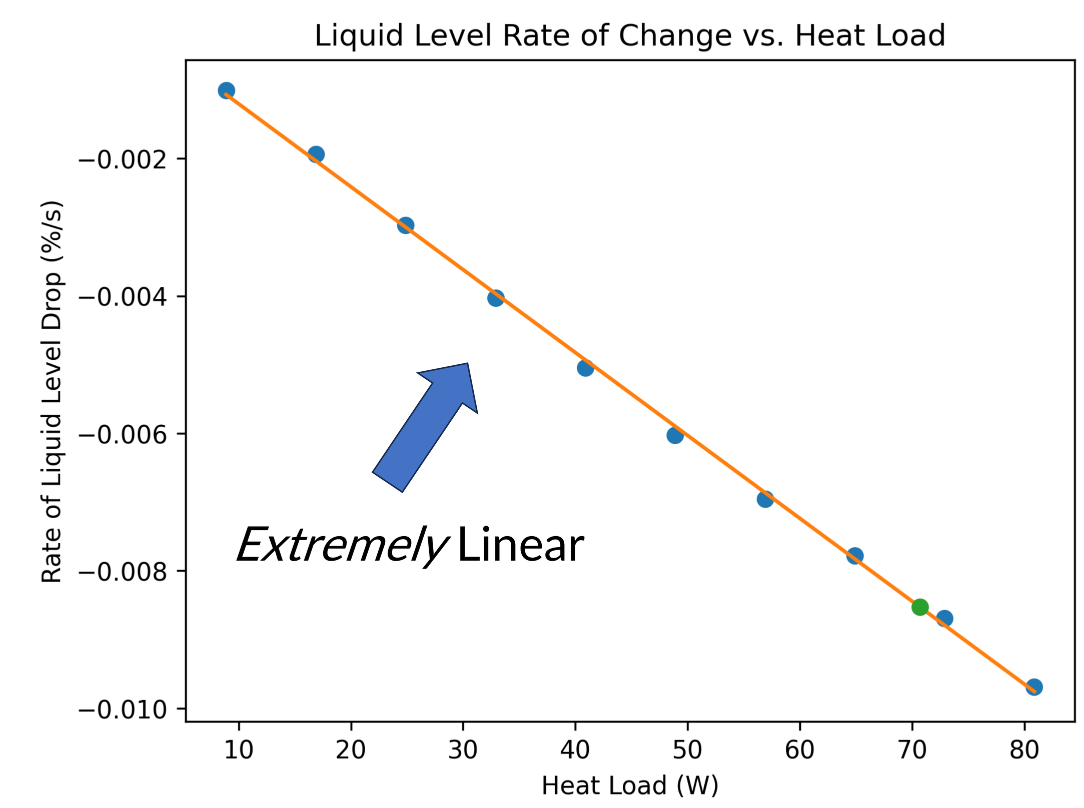
Introduction

LCLS-II cryomodules required a novel method of measuring Q_0 due to hardware incompatibilities with existing procedures, so we developed a method that uses helium liquid level data to estimate the heat generated by cavities. We first establish the relationship between the rate of helium evaporation from known heat loads using electric heaters, and then use that relationship to determine the RF heat load to finally extract Q_0.

Calibration

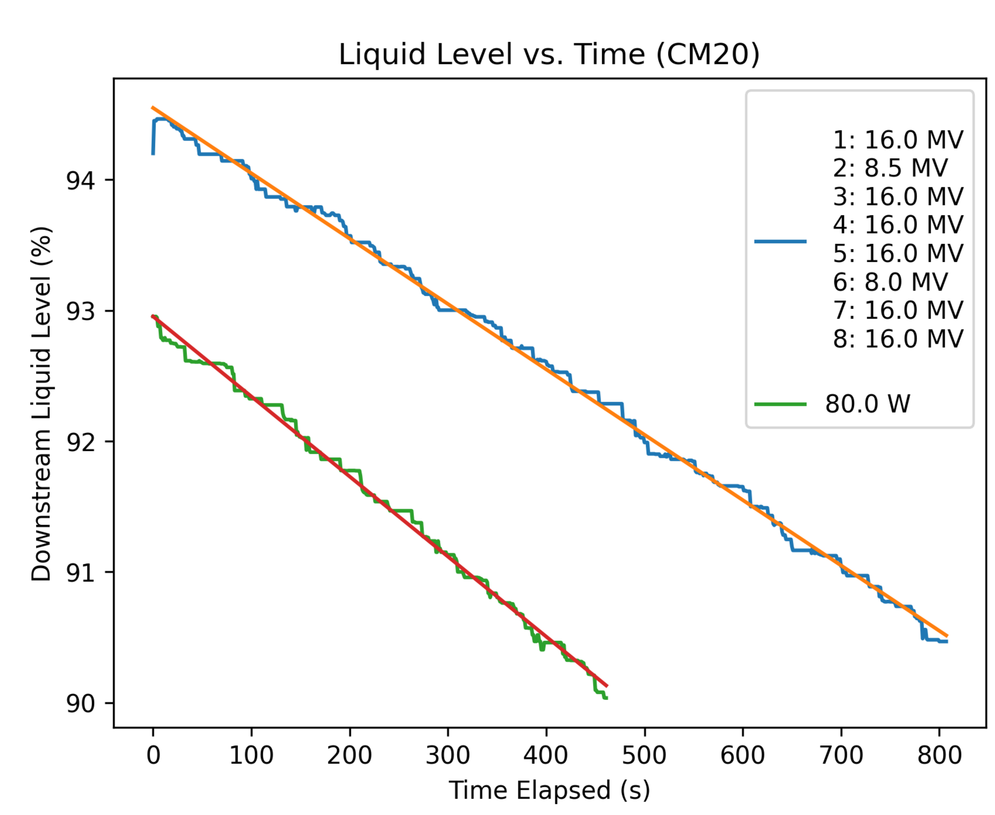
- Set CM heaters to 48 W with no RF load
  - Less than 48 W causes overfilling
- Find JT valve position that holds liquid level steady
- Lock JT valve to that position
- Set heaters to 48 W + various expected heat loads
  - Estimate between 10 and 20 W per cavity
    - 80 to 160 W per CM (8 cavities)
    - 40 to 80 W per rack (4 cavities)
- Extract relationship between *added* heater power and rate of liquid level drop

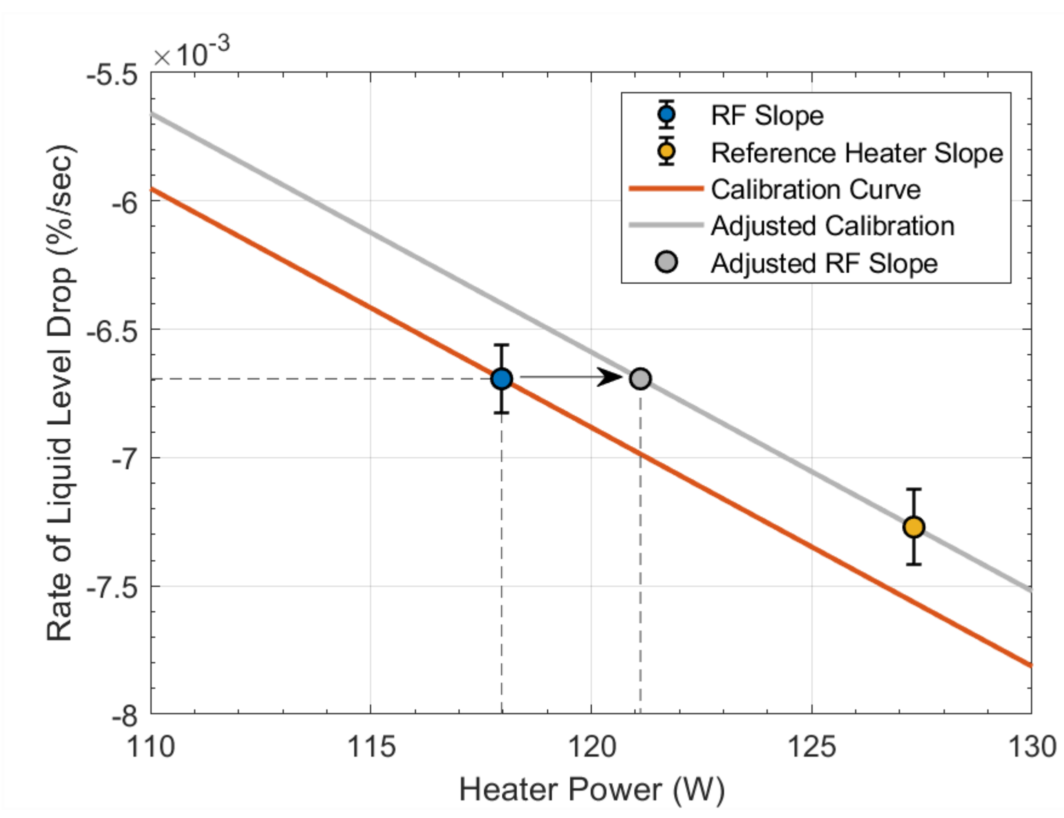




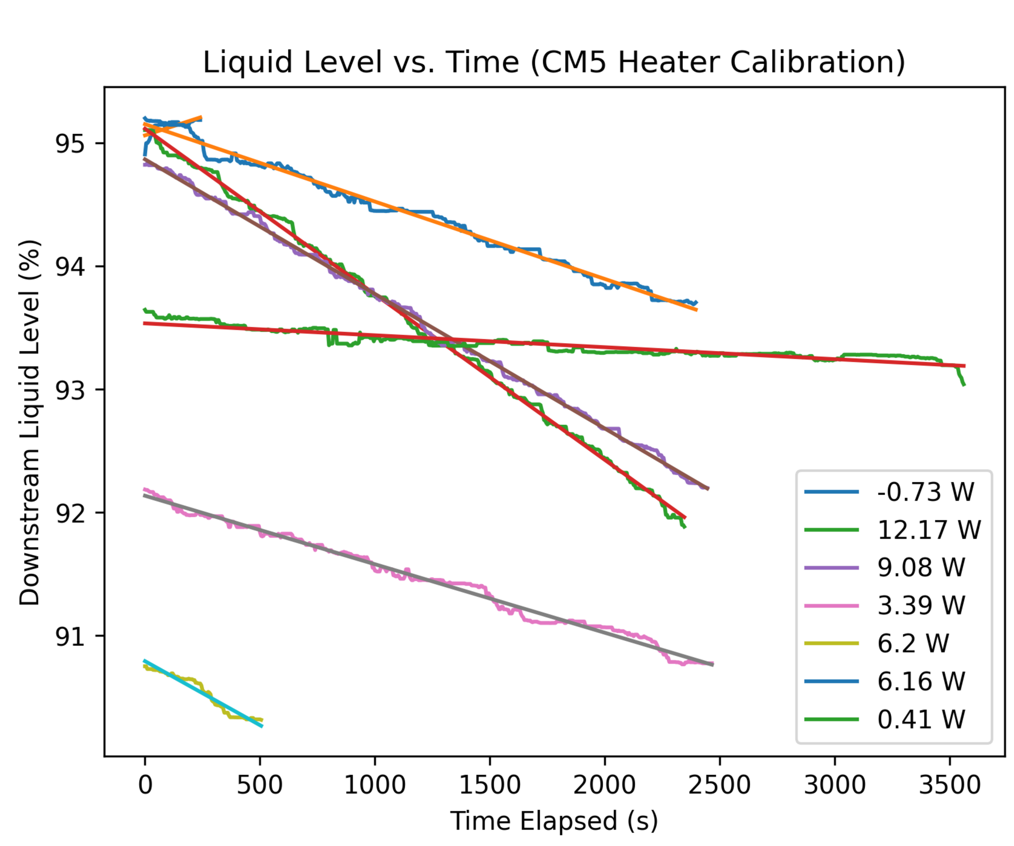
RF Measurement

- Set CM heaters to 48 W
- Lock JT valve at position found in calibration
- Set subset of cavities to typical operating amplitudes
  - Usually no less than four cavities
- Take heater measurement to adjust calibration curve for potential drift in static heat load
- Use adjusted calibration curve to get total heat load from rate of liquid level drop during RF measurement
- Use calculated heat load to get *effective* Q_0:
  - $Q_{eff} = \frac{\sum_i E_i{}^2 L^2}{[R/Q] * P_{tot}}$
  - $P_{tot} = \sum_i P_i$
  - $P_i = \frac{E_i{}^2 L^2}{[R/Q] * Q_{eff}}$
- Optional: repeat to extract single cavity heat using simple matrix math

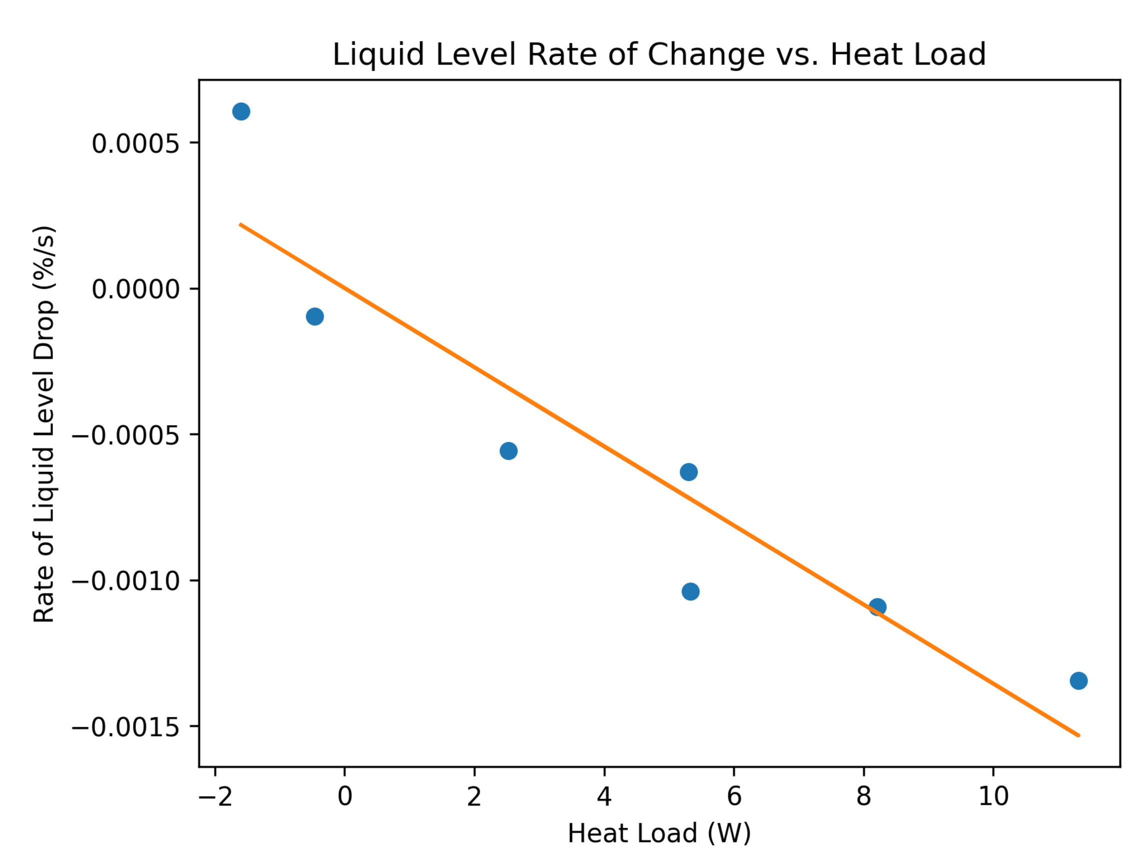




Why Not Single Cavity?

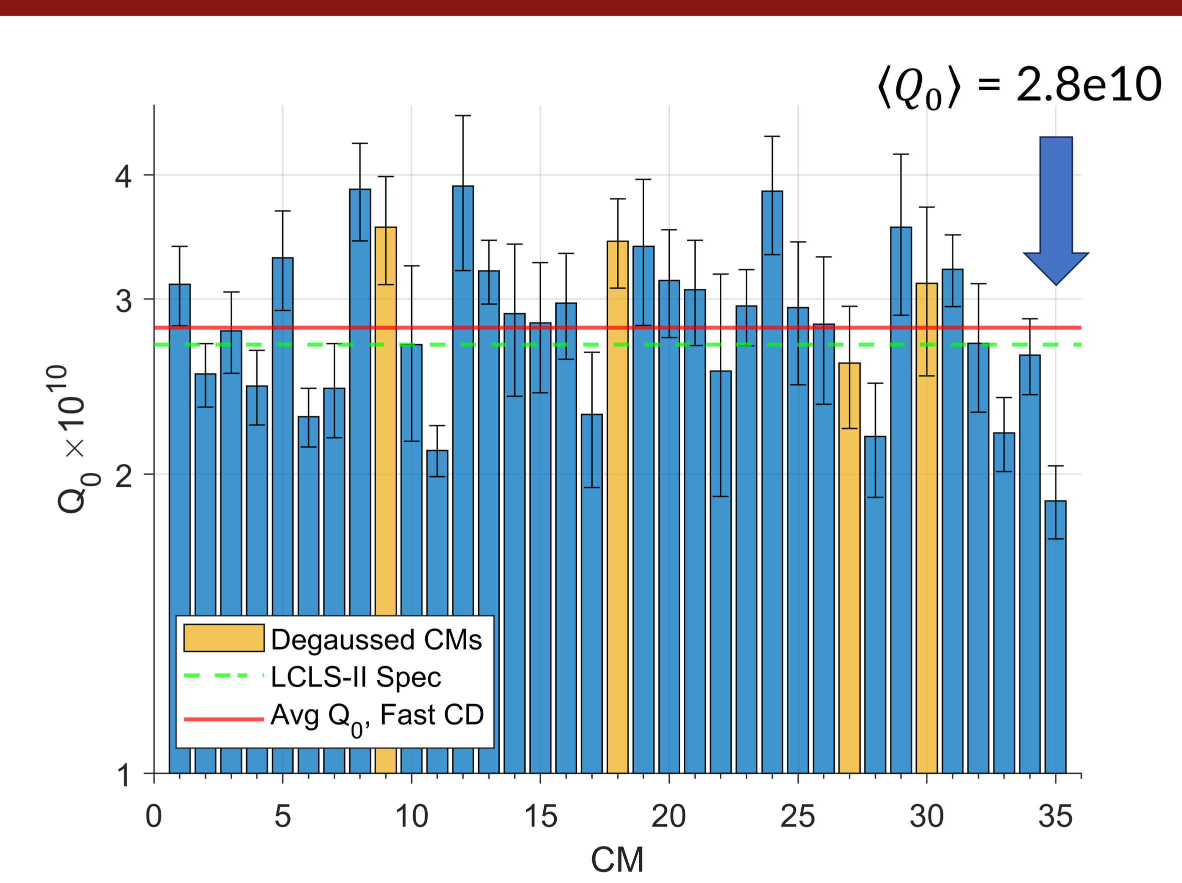


- Time constraints
  - Lower heat = slower evaporation
  - 8 measurements vs 1
- Increased liquid level line fit error for < 20 W



- Single cavity heat extraction method works well
  - Caveat: cavities generating less than 4 W at measurement amplitude fall within noise

Results



- Average measured Q_0 exceeds spec of 2.7e10
- Error analysis indicates ~20% error
- Method validates doping in installed linac
- Method has now been fully automated