Medium Field Q slope & 4K

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Motivation

- Know very little about low β cavities
- On FRIB committee
- Why is there so much Q slope?
- Can it be better?

- Q is very important especially for cw - period

Low β cavities - choose low freq

- What temperature is really best
- What Q performance should one expect
- What should one be satisfied with
- Do we understand the limitations and where they come from
- What preparation steps do what, and which are best
- If one is doing a project, it is essential to try to optimize the performance vs cost. (there aren't that many projects)
- It helps to understand the limitations

Q Components

- Design G
- R_{bcs}
- R_{resid}
- Thermal properties, ΔT
  - in Nb,
  - Helium to Nb

1.5 GHz Gianluigi Ciovati
120 bake, 2.2K above λ

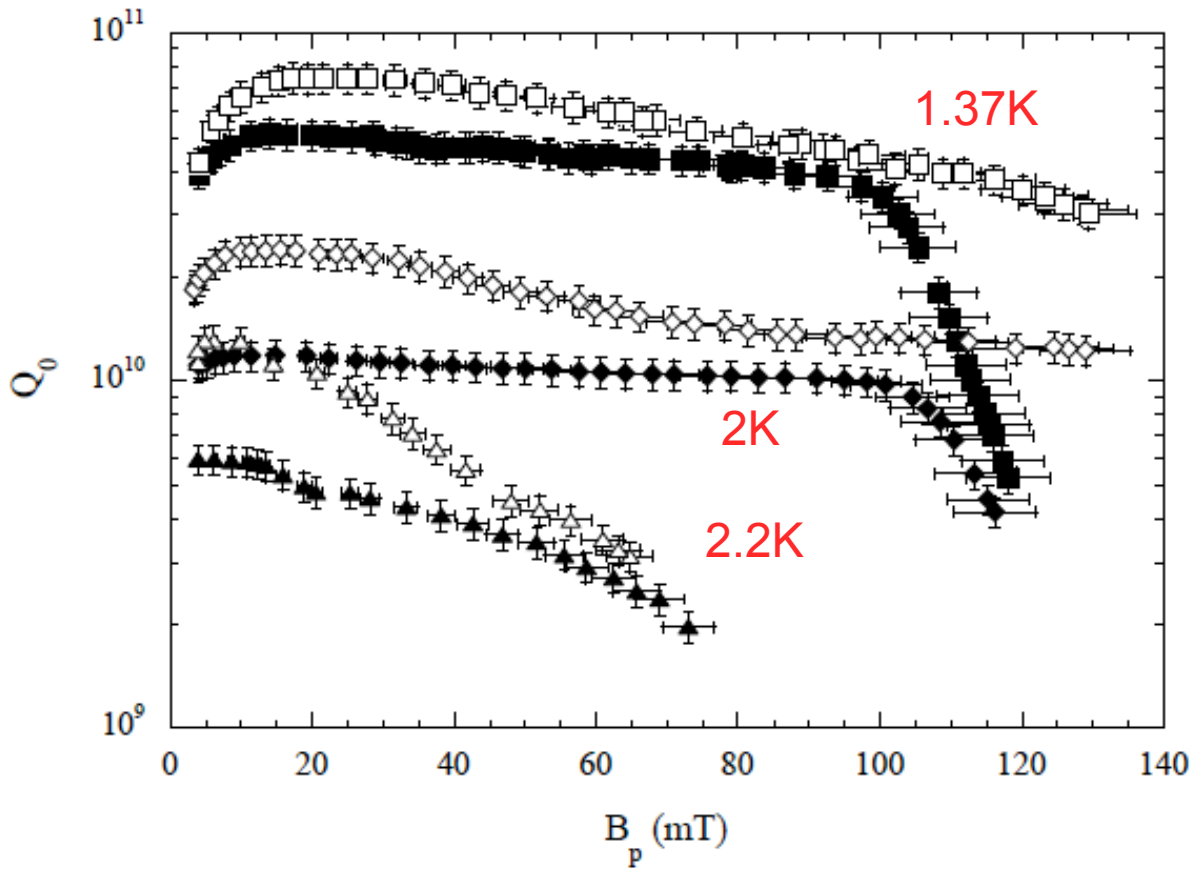


FIG. 51. Q_0 vs. B_p before (solid symbols) and after 120 °C, 48 h baking (open symbols) at three different temperatures: 1.37 K (squares), 2 K (diamonds) and 2.2 K (triangles).

Choices

- Temperature ~2K- 4K
  - Low freq , $R_{BCS} \alpha f^2$ should be low at higher K
  - Q(T) vs Cryo cost 2K vs 4.x K
  - Gradient (or B) operation limit - potential for upgrade or higher performance
- Processing BCP-EP
- 600-800C out gas- softer structure vs Q disease
- Mag field shielding- how much R_{resid}
- Low temp ~120C bake with low R_{BCS} does it help, could it hurt

Slope parameter

- Do we really understand 4K cooling
  - Nucleate boiling, convection, film boiling, thermal conductivity
  - Is R_{resid} really constant with T & B
  - Is R_{BCS} dependent on B

$$R_S\left(T, B_P\right) = R_{S0}\left(T\right)\left[1 + \gamma\left(T\right)\left(\frac{B_P}{B_c}\right)^2\right]$$

$$R_{S0}\left(T\right) = R_{BCS0}\left(T\right) + R_{res}$$

  - The γ can include both surface and thermal properties
  - Treat it as a performance parameter
  - If γ=4: B=50mT, R/R_0=1.25; B=100mT, R/R_0=2

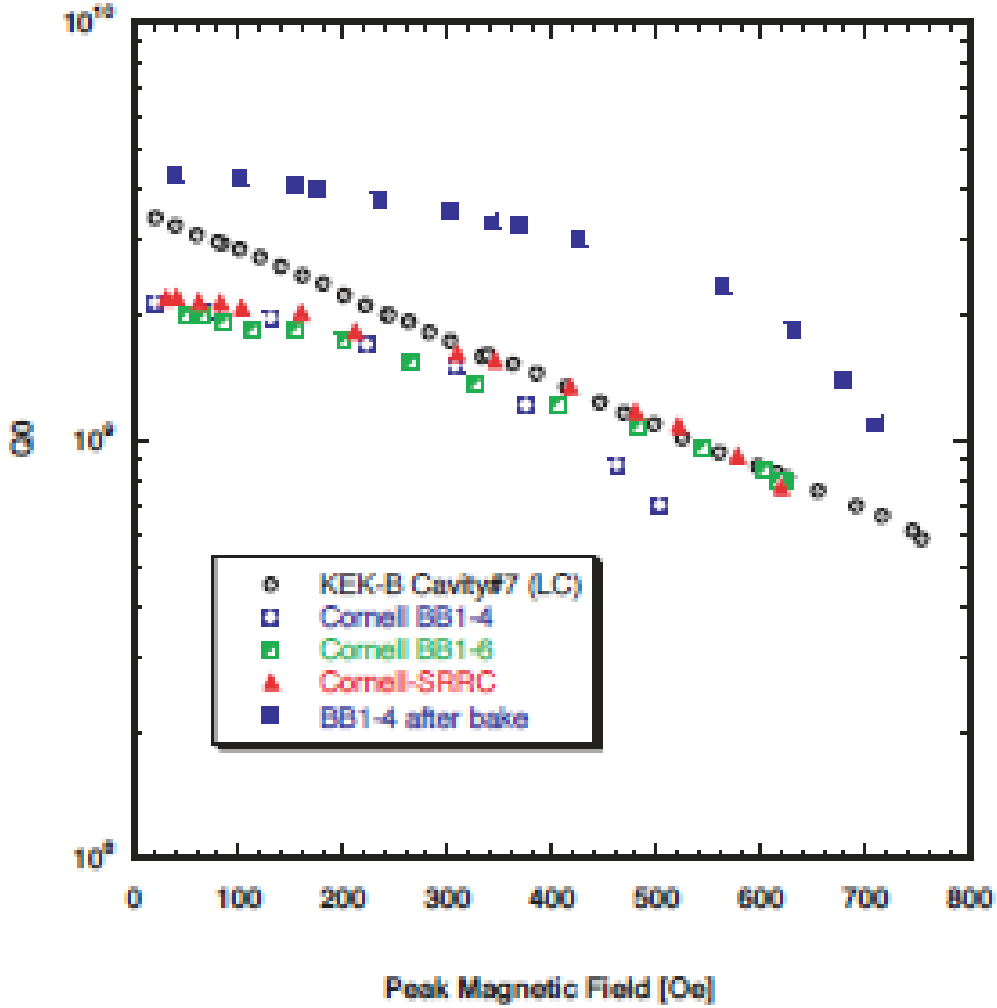


Figure 6: The measurement results for cavities with different surface treatment. There is a strong effect of surface treatment on the low-field Q-slope.

Geng, Padamsee
500MHz, 4.2K
Cornell, KEK cavities
Note low temp bake

Dominated by R_{BCS}
Conclude R_{BCS} field dependent

Grassellino, et al, Triumf f=141 MHz

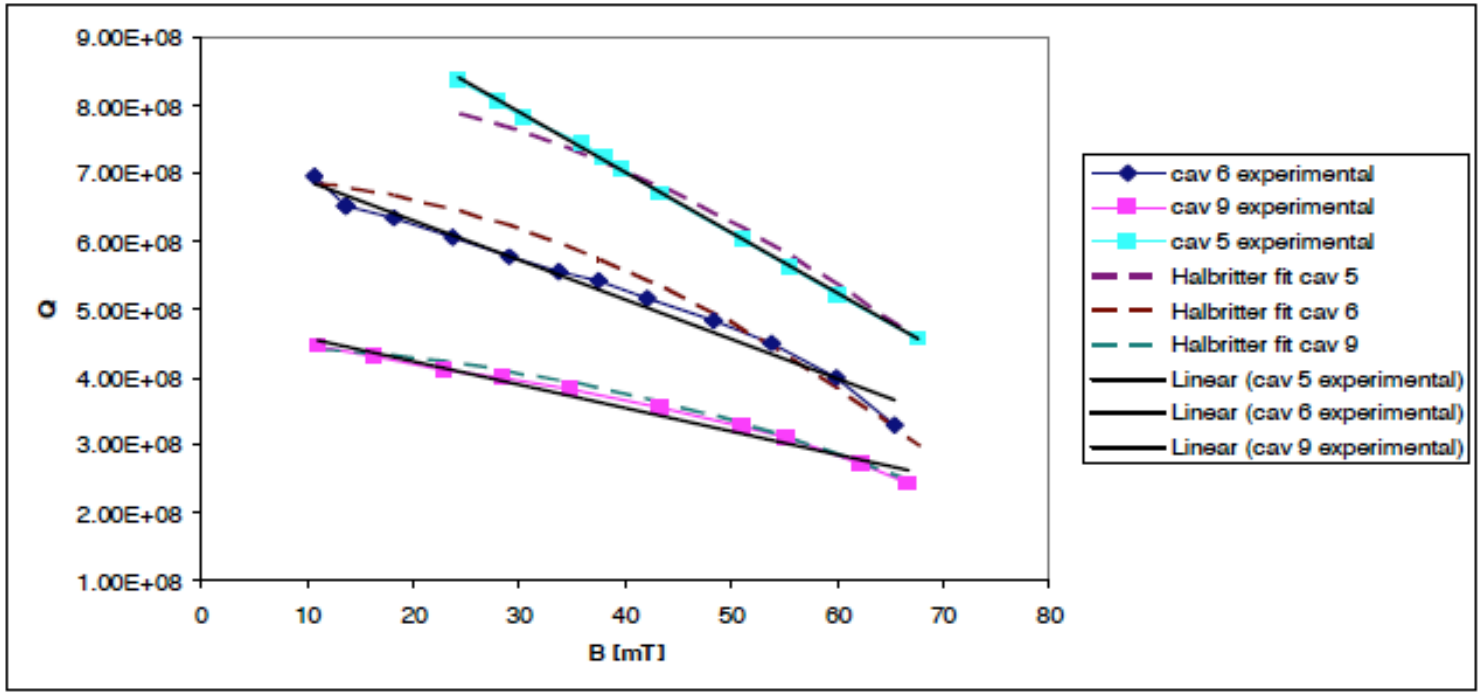
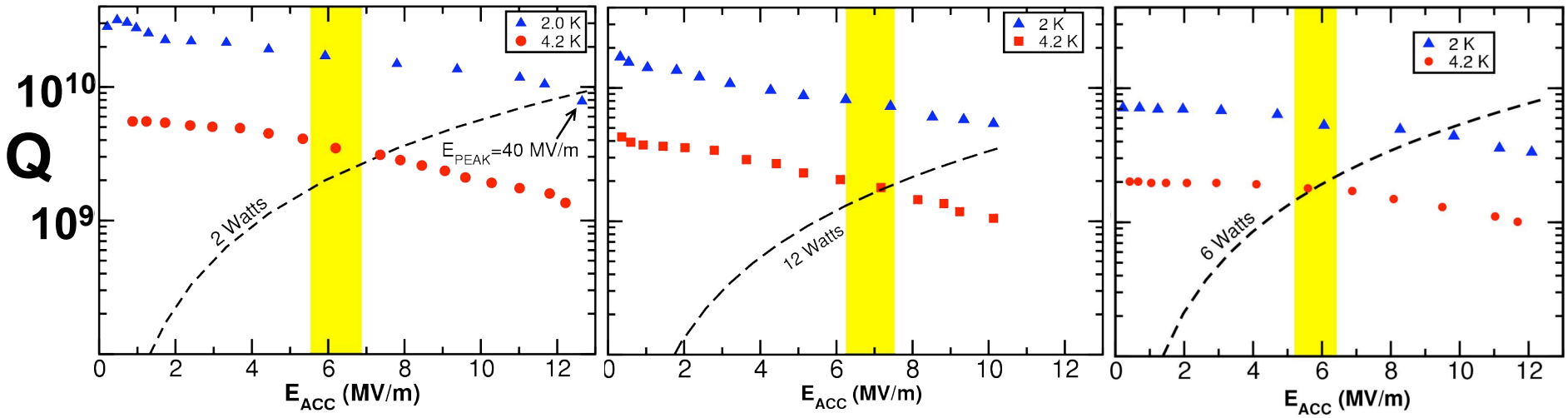


Figure 1: TRIUMF quarter wave cavities characterization curves and relative fit using Halbritter quadratic model and linear fit.

Linear and quadratic dependence on Bp
Suggestion of correlation with reduction of Tc with Bp
Temp dependent component of Rs carries the field dependence

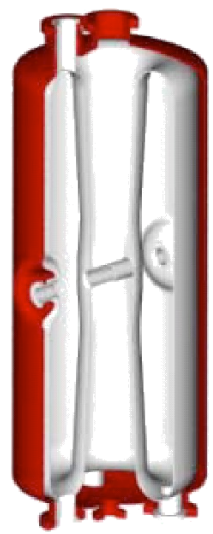
Kelly 2004 Test Performance of the RIA Mid-beta Cavities EP



β=0.1 → β=0.5

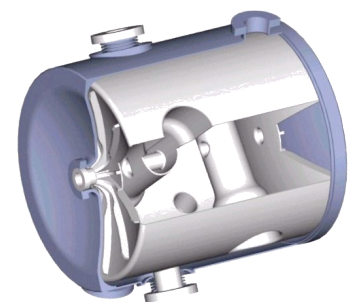
115 MHz β =0.15

Quarter-wave



172 MHz β =0.25

Half-wave



345 MHz β =0.4

Double-spoke

Kelly 2004 Surface Resistance in SRF Drift-tube Cavities EP "Lower rf losses and less "Q-slope" at 4 K"

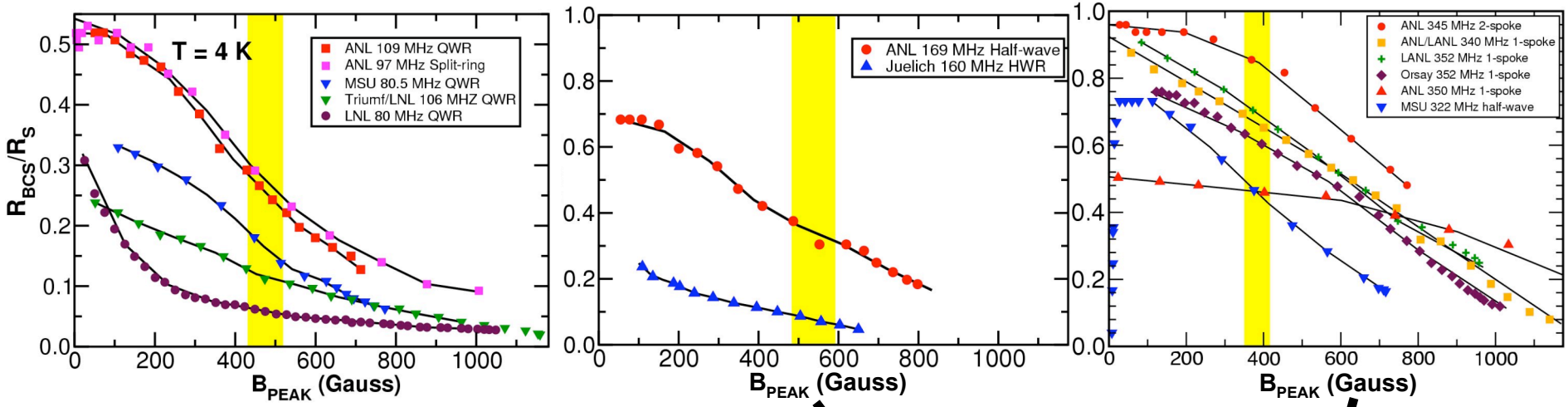


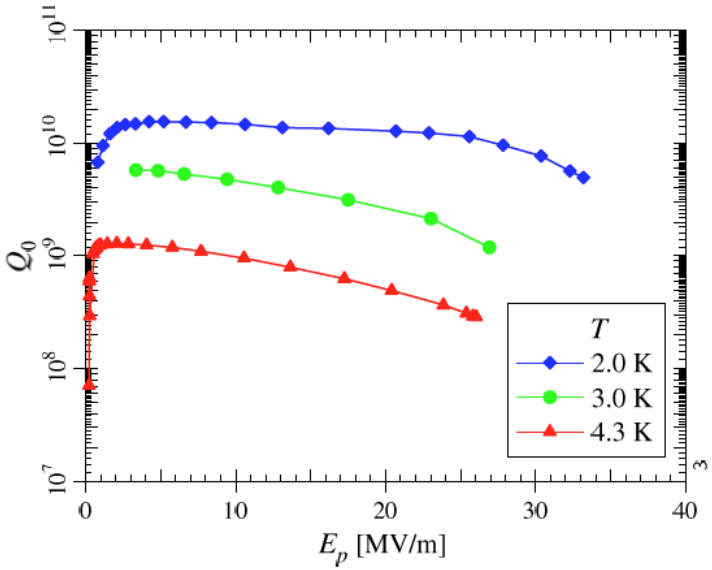
	Figure 1.	Figure 2.	Figure 3.
Frequency	80 - 109 MHz	160 - 169 MHz	322 – 352 MHz
Geometrical Factor	15 – 18 Ω	26 - 58 Ω	61 – 101 Ω
BCS Resistance	2 – 3.5 nΩ	8.7 - 11.3 nΩ	31 – 39 nΩ

Hartung MSU

F= 322MHz

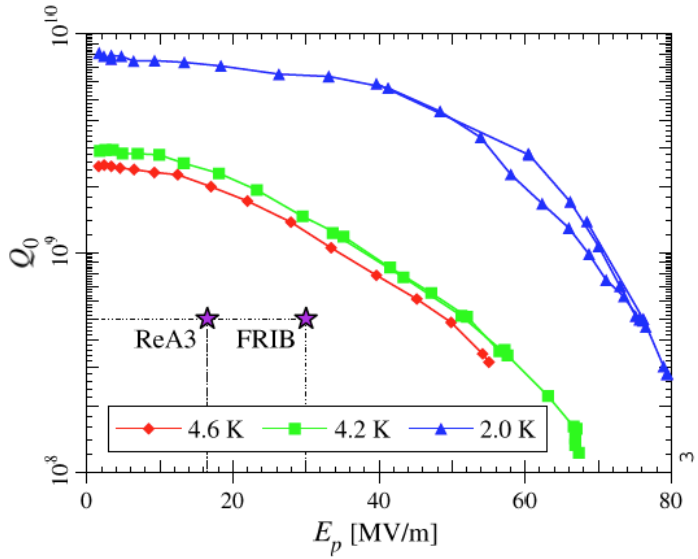
F= 80.5 MHz

Operating Temperature (R22)



Dewar test
β = 0.285 r

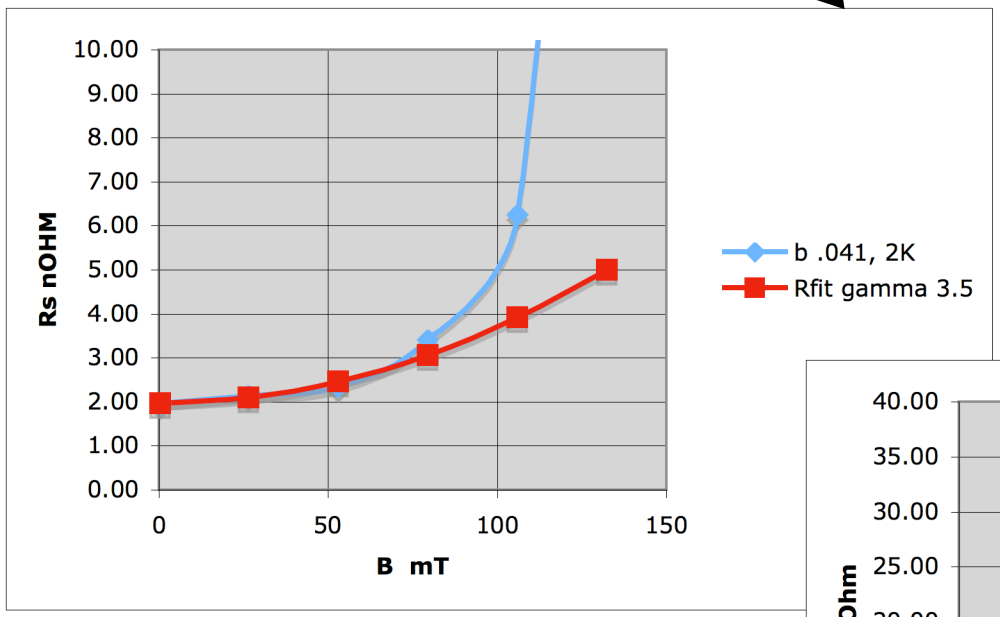
Operating Temperature (R22)



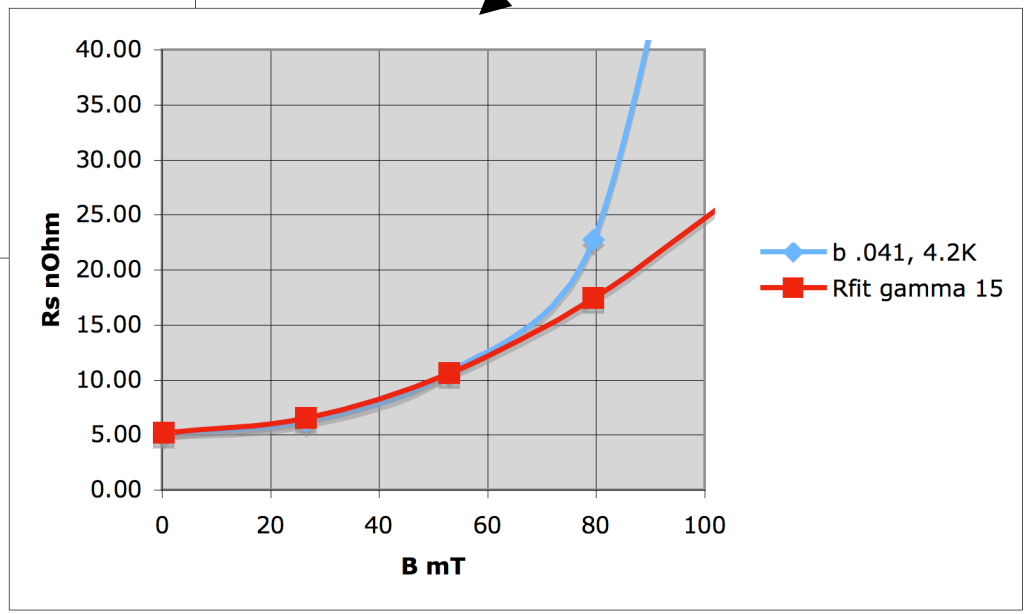
Dewar tests
β = 0.041 resonator

FRIB β=.041, f= 80.5 MHz

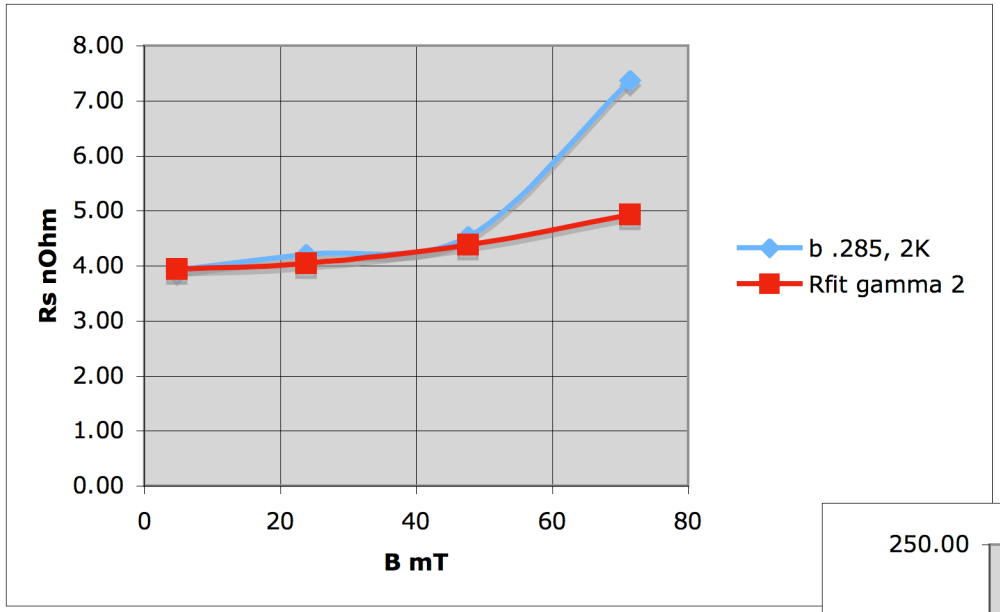
2K, R_{s0}~2nOhm
γ~3.5



4.2K, R_{s0}~5nOhm
R_{bcs}~2nOhm
γ~15

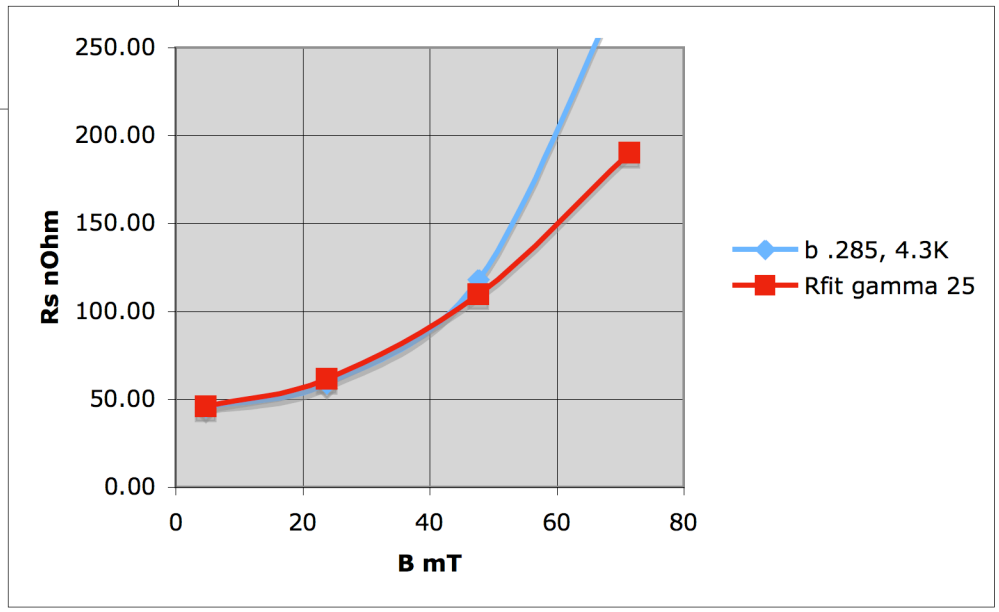


FRIB β=.285, f= 322 MHz



2K, R_{s0}~4nOhm
γ~2

4.2K, R_{s0}~46nOhm.
R_{bcs}~35nOhm
γ~25



Measurements

- I have a hard time calculating a substantial dT from thermal effects at ~100MHz freq if the cavity surface is cooled
- Measure
  - Q vs T at different B levels to try to sort out R_{resid} from R_{BCS}
  - More measurements around 2.2 K
  - Try to identify different cooling regimes

Summary 4K low freq

- The γ is a nice way to characterize medium Q slope (independent of its interruption)
- It is important to understand how much of large γ is from thermal dT
  - Is some part of the surface not cooled by helium?
- Processing alternatives appear to be important, but needs to be sorted from cavity design differences
- Best processing and benefits need to be determined
- Is there good understanding of all this, and I just don't know about it?
- If not we need to pay more attention
- What would be good measurements, calculations?
  - Q vs T at different B
- Hope this will lead to corrections, comments, discussion