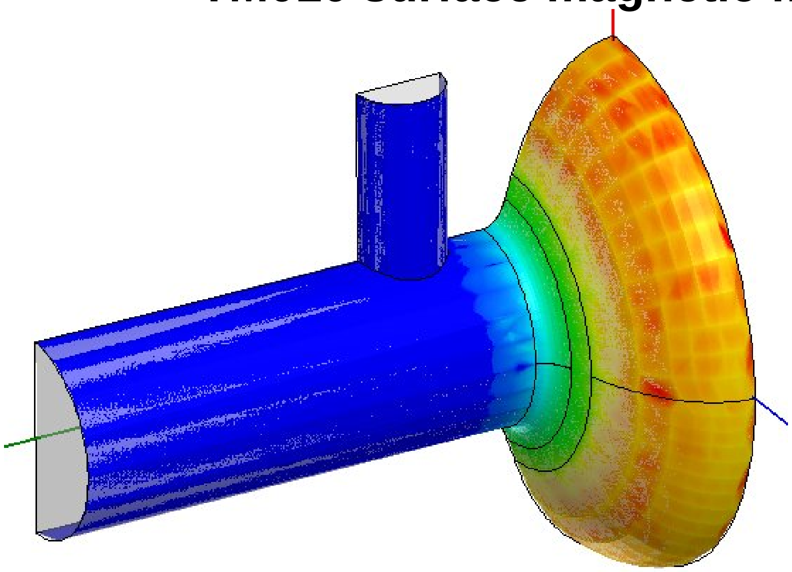
Measurements of the high field Q-drop in TE011/TM010 in a single cell cavity

Gianluigi Ciovati

Jefferson Lab

TE011 vs. TM010 properties

TM010 surface magnetic field



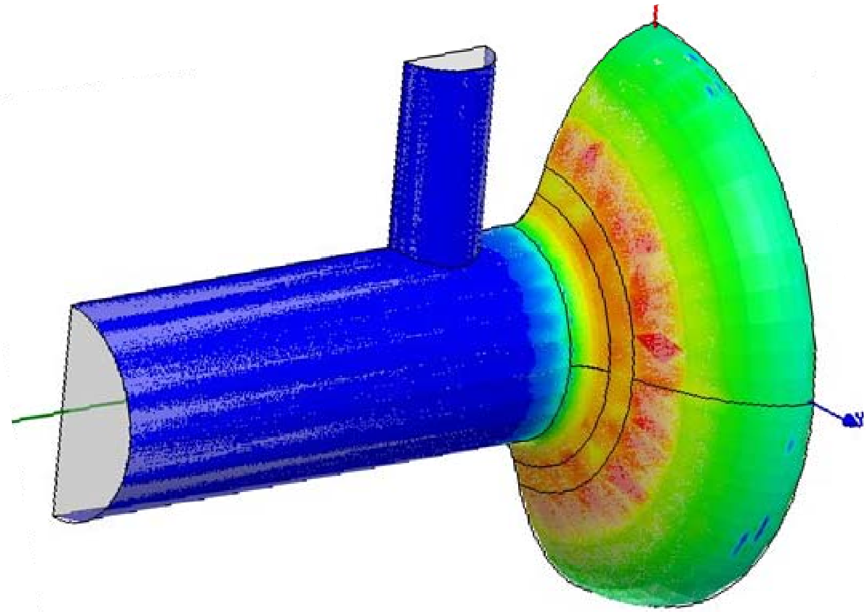
Frequency: 1.467 GHz

Geometry factor: 273 Ω

$B_p/\sqrt{U}$: 60.7 mT/√J

Effective area: 0.0586 m²

TE011 surface magnetic field



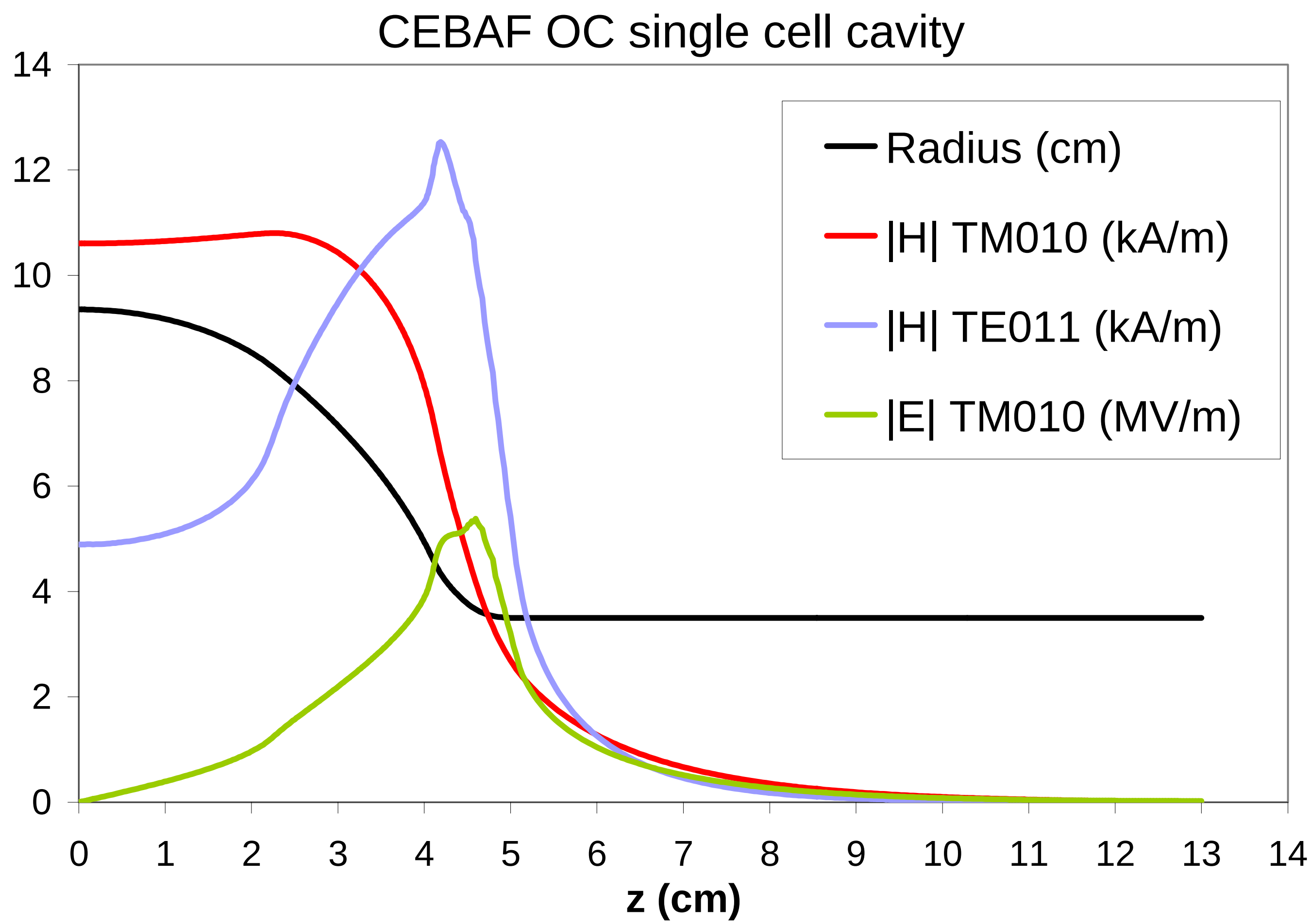
Frequency: 2.824 GHz

Geometry factor: 701 Ω

$B_p/\sqrt{U}$: 50 mT/√J

Effective area: 0.032 m²

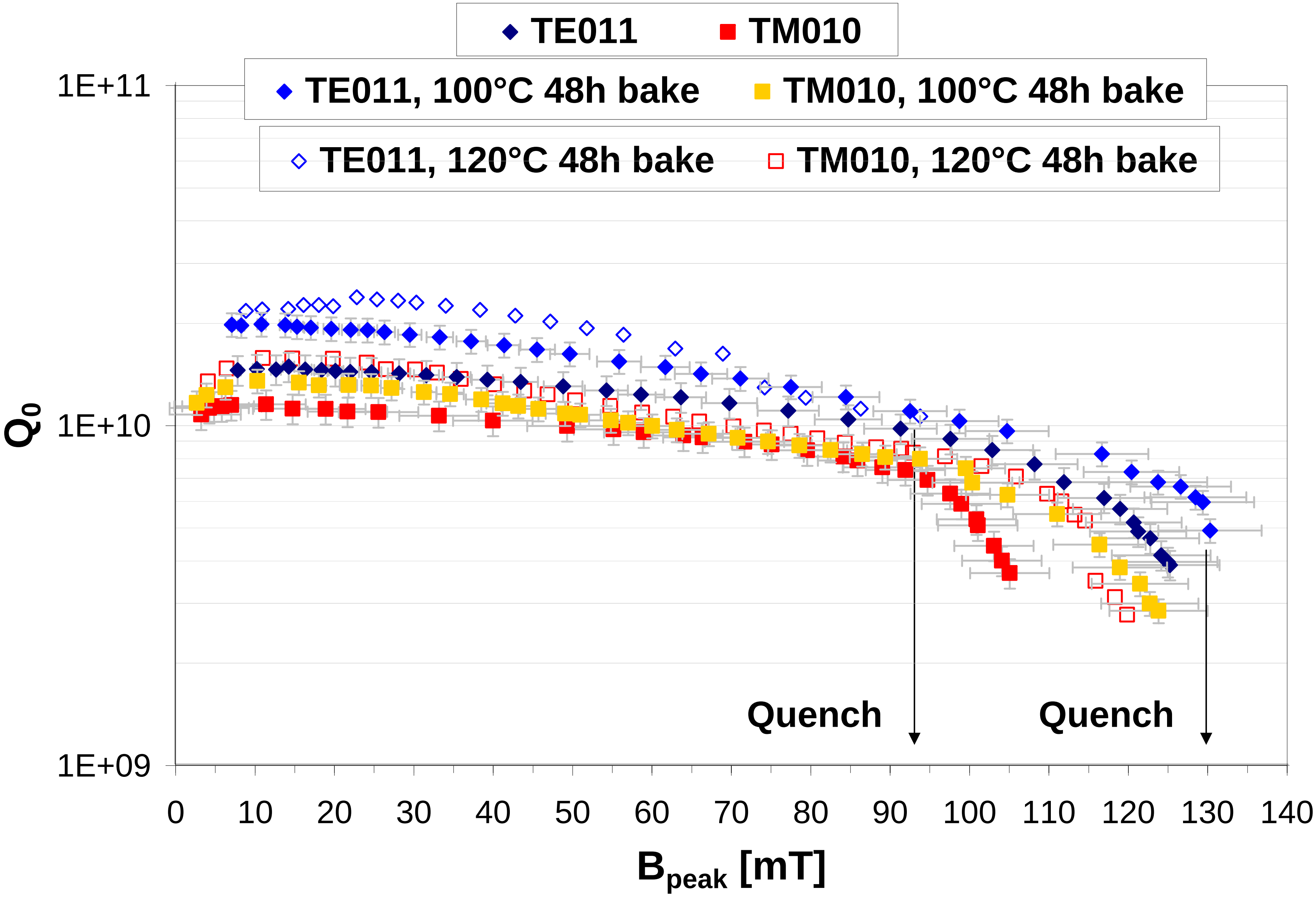
Surface fields distribution



TE011 has no electric field on the cavity surface

Cavity preparation & test

- Degreasing
- 20 μm BCP 1:1:1 or 1:1:2
- 1 h HPR
- Dried overnight in clean room class 10
- Assembly in clean room class 10
- Rs vs. T measured from 4.2 K to 1.8 K
- Q_0 vs. B_{peak} measured at 2 K in both modes


TE011
TM010
TE011, 100°C 48h bake
TM010, 100°C 48h bake
TE011, 120°C 48h bake
TM010, 120°C 48h bake
1E+11
1E+10
1E+09
Q0
Quench
Quench
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
Bpeak [mT]

Thermal model

rf surface temperature vs. B_p obtained:

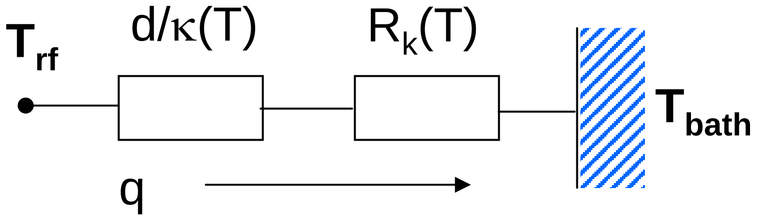
$$R_s(T) = \frac{A}{T}\ln\left(\frac{4kT}{hf}\right)e^{-B/T} + R_{res}$$

A, B, R_{res} from R_s vs. T fit

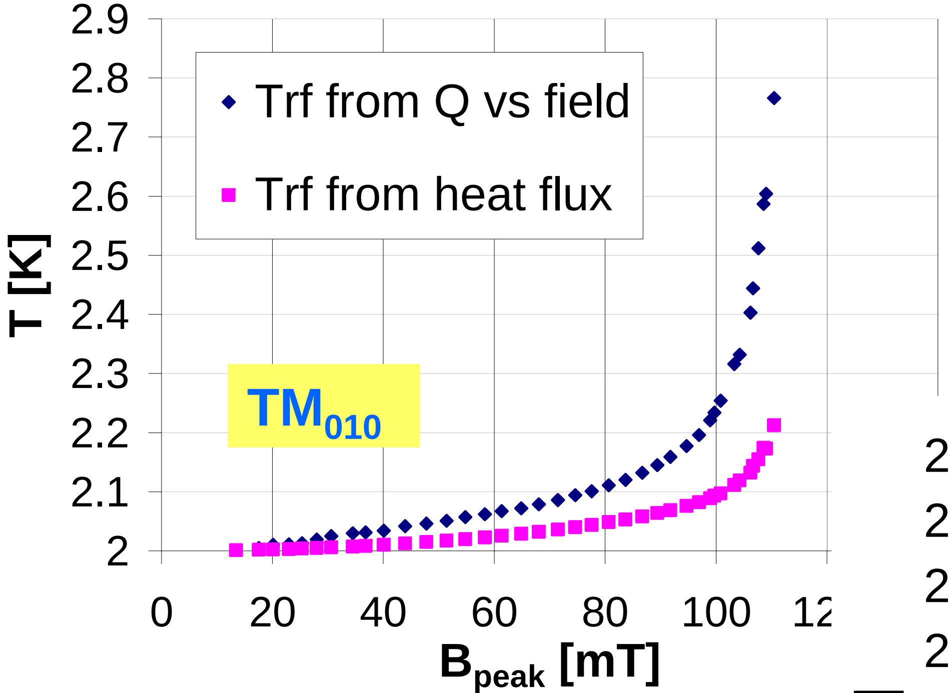
fit with R_s data obtained from high power test

AND…

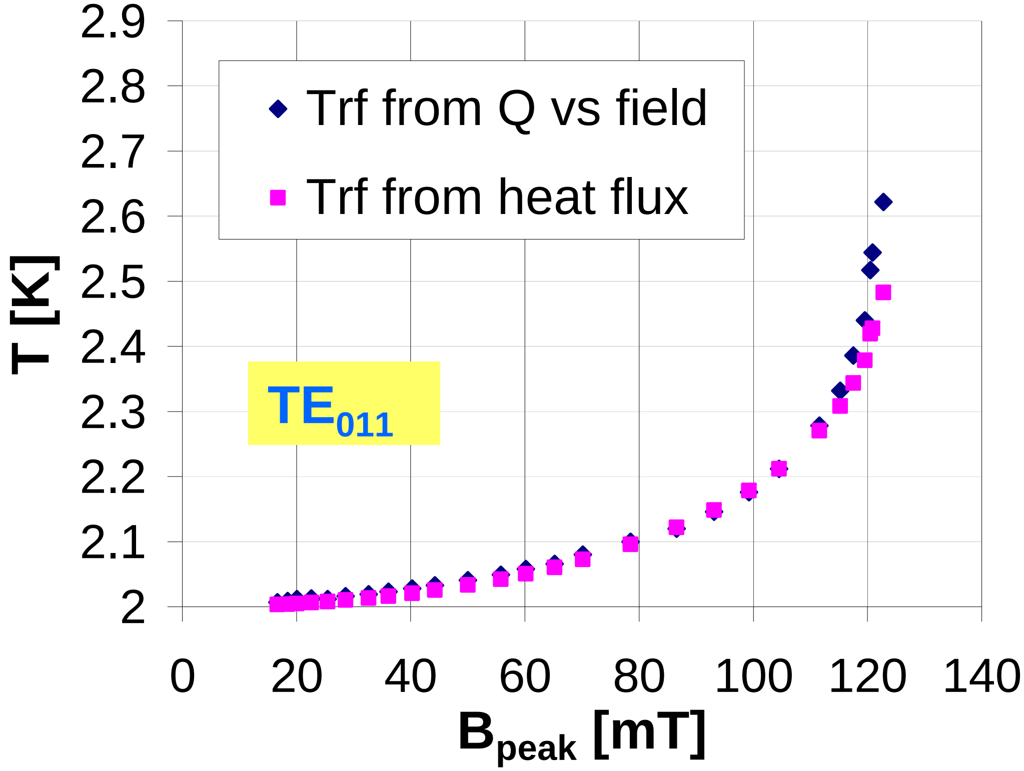
- Heat flux $q = P_c / A_{eff}$
- Thermal conductivity and Kapitza resistance for Nb RRR=200 from published data†



†A. Boucheffa et al., *Cryogenics* **34**, 297 (1994)
S. Bousson, et al, *Proc. 9th Workshop on RF Supercond.,* Santa Fe, USA (1999)

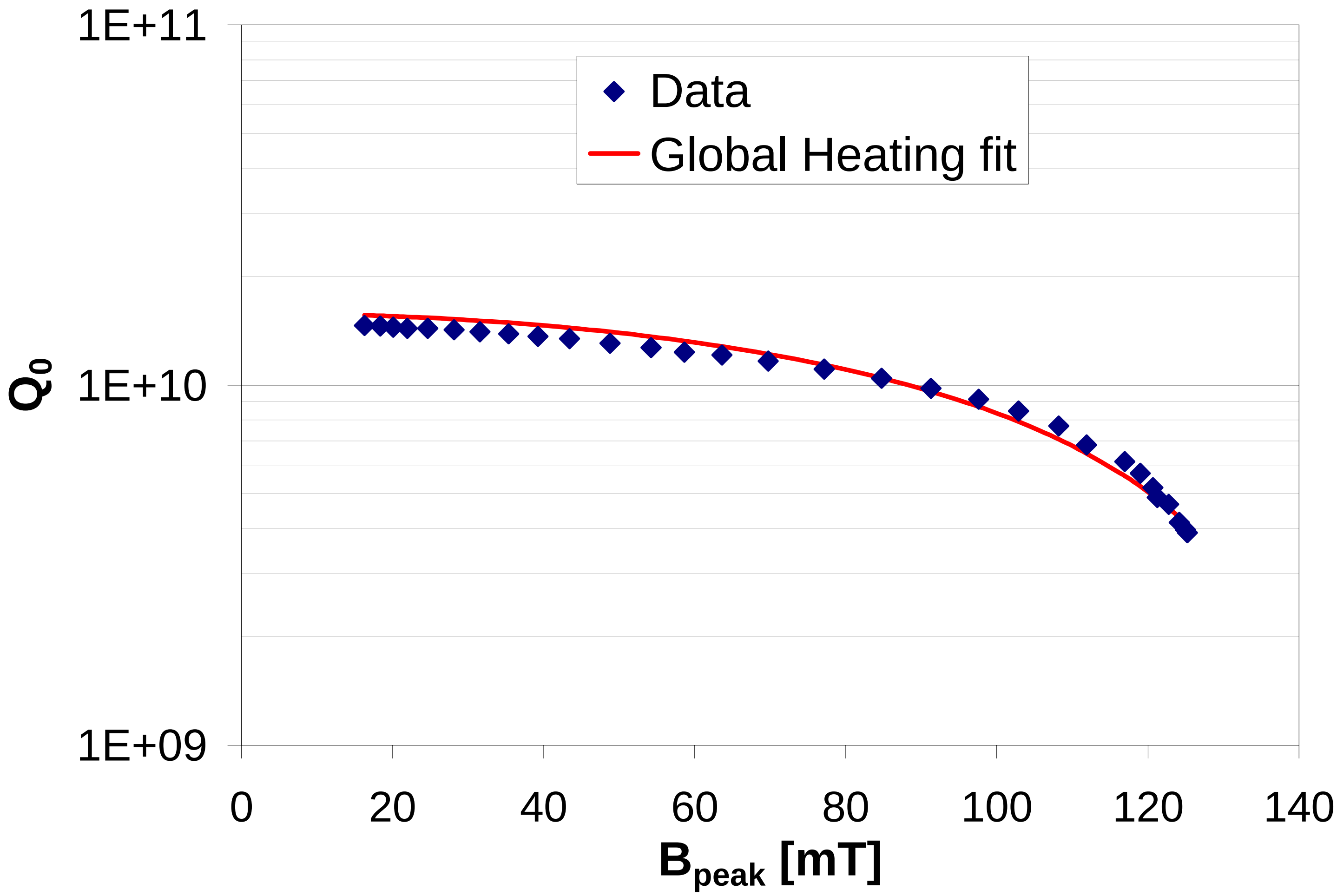


Before baking



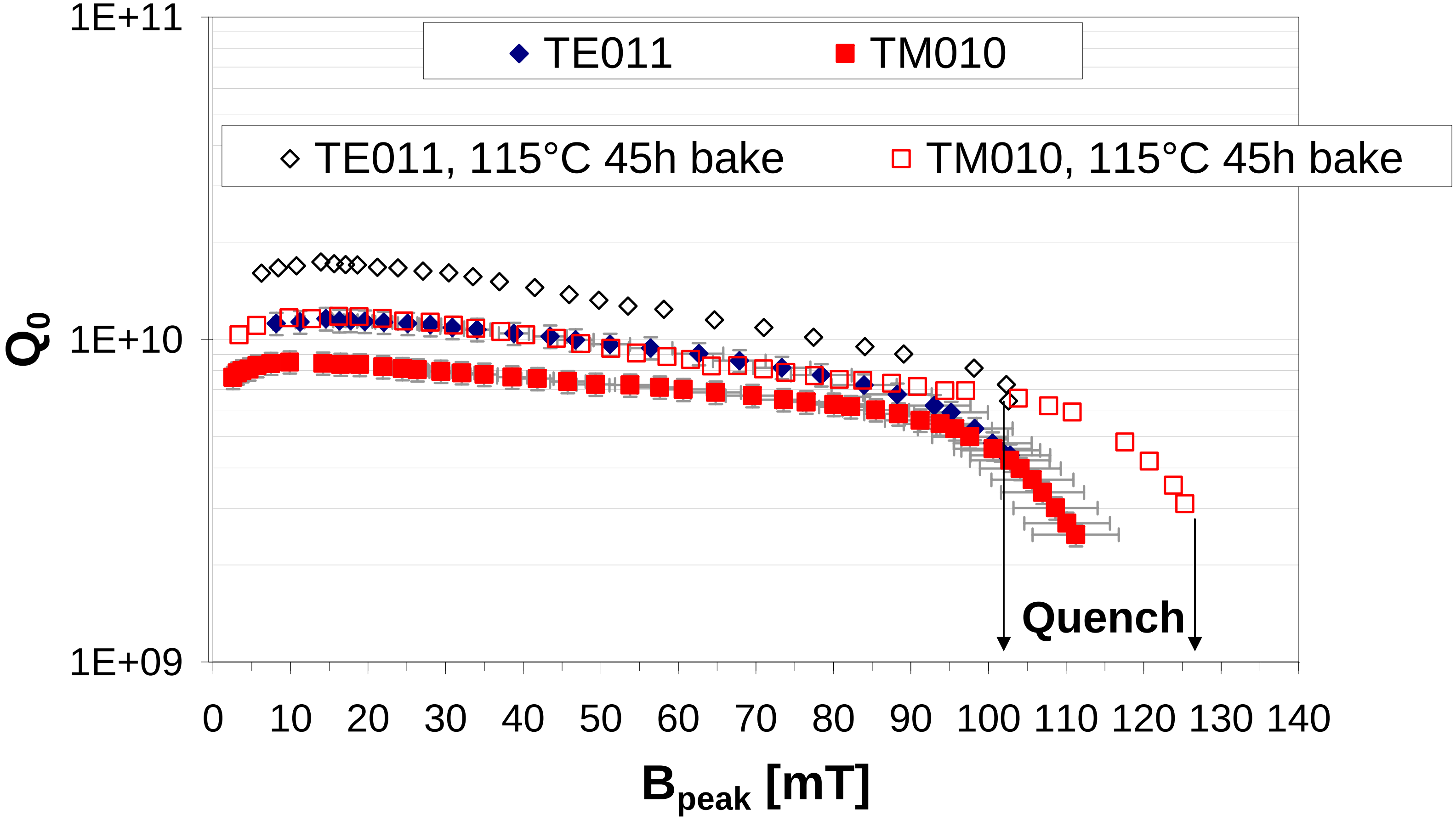
Good agreement on data after baking in TE011 mode if Kapitza resistance is increased by about a factor of 2

Global Heating* in TE011: $R_s = R_0/(1-CB_p^2)$

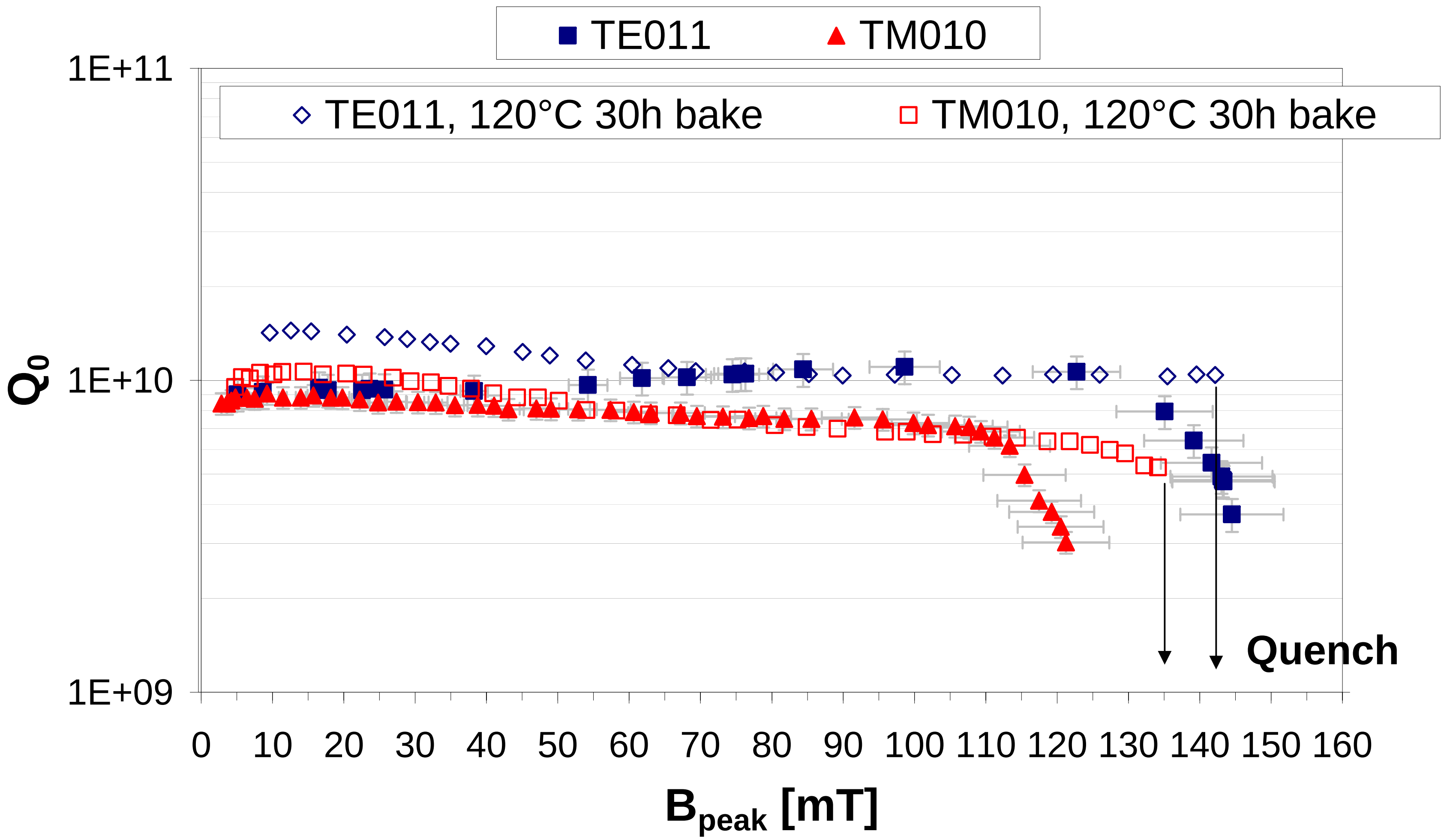


*B. Visentin et al, *Proc. 9th Workshop on RF Supercond.,* Santa Fe, USA (1999)

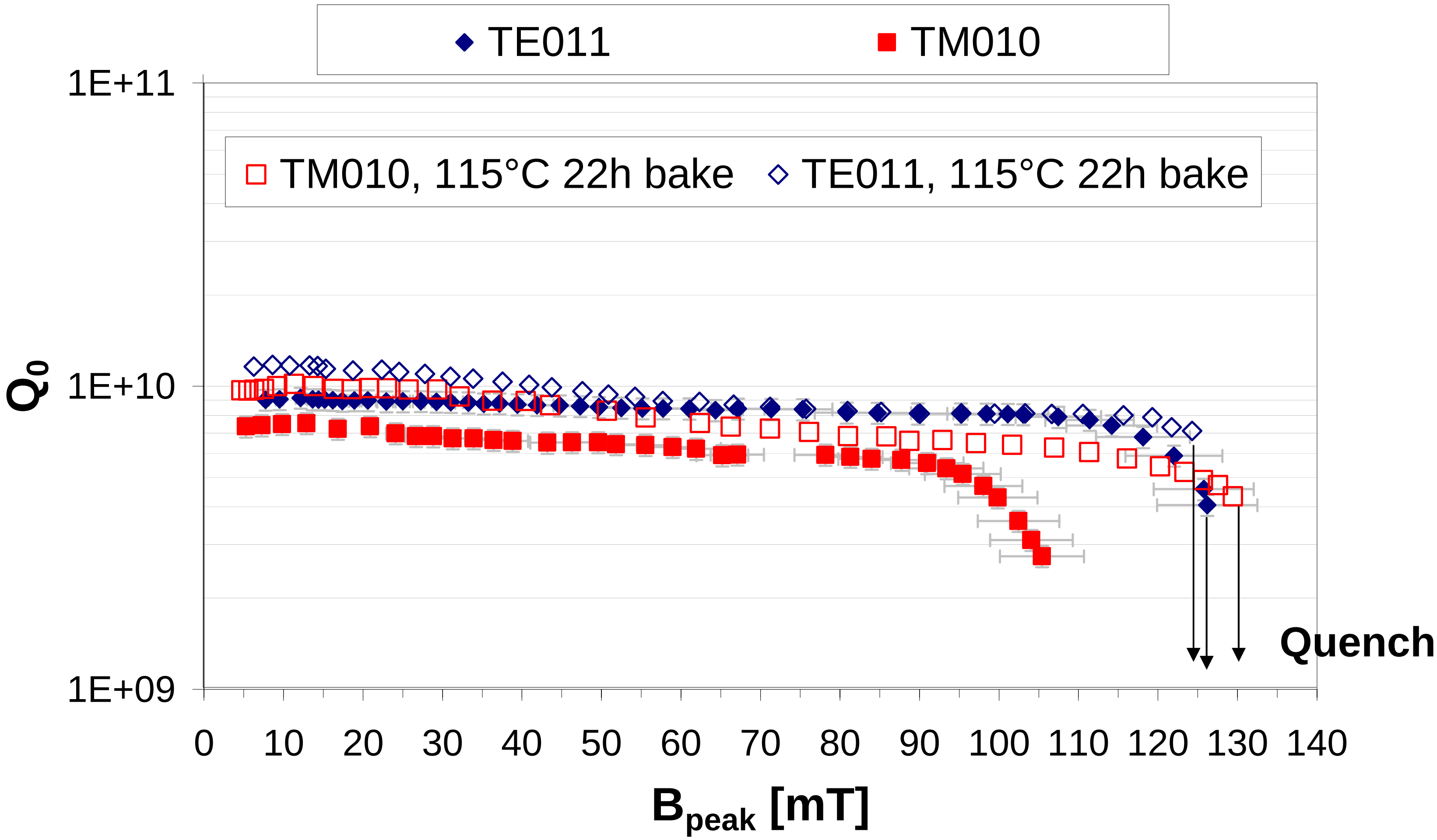
Anodization: 90 nm thick oxide layer growth after chemical etch



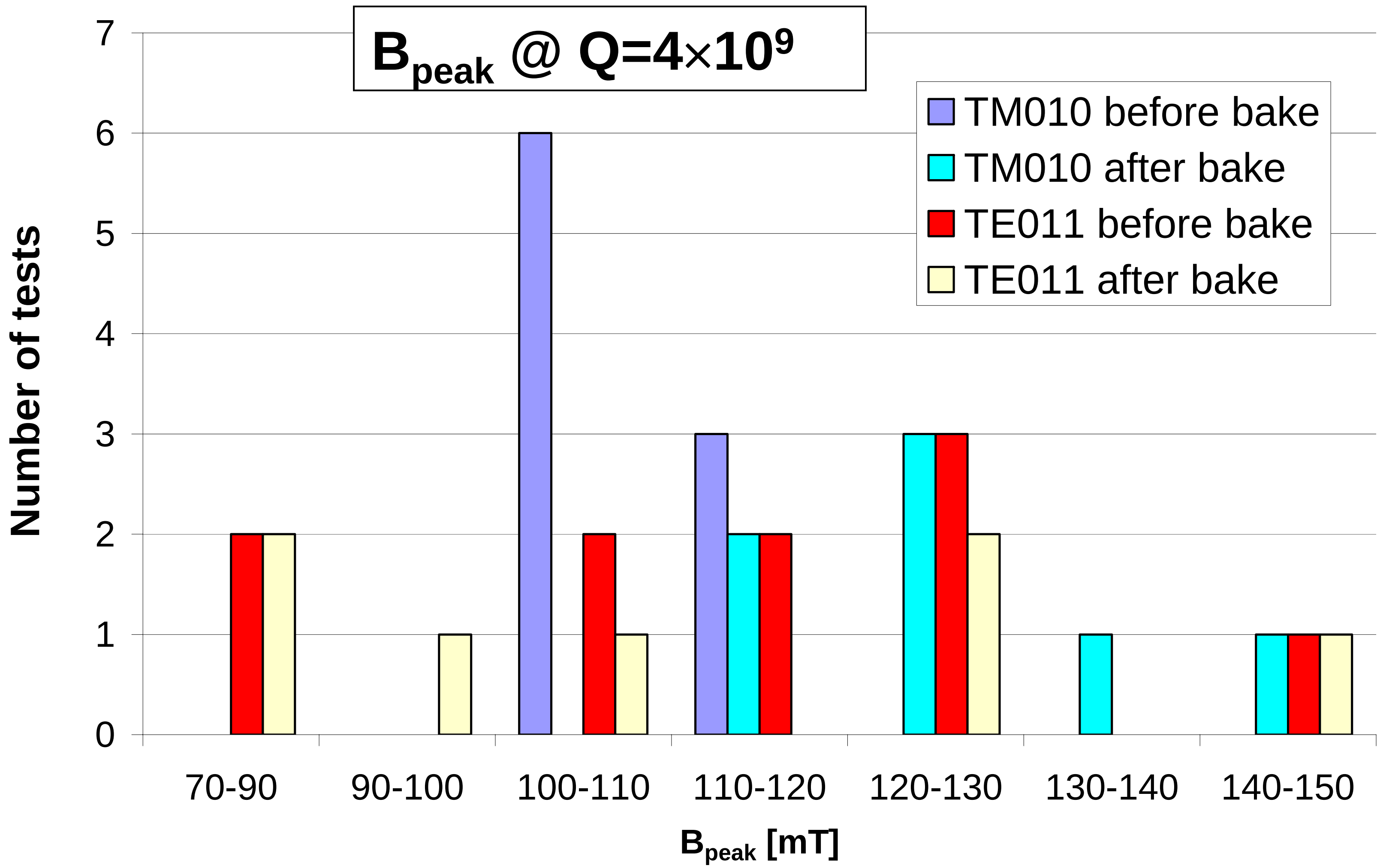
Heat treatment: 1250°C, 12h ramp down to 1000°C in 20h. RRR improved from 320 to 725 measured on sample



- Global heating model less accurate in describing high field Q-drop after heat treatment in TE mode.
- Surface resistance increases exponentially as in TM mode



Summary of Q vs. B_p results



Influence of treatments on Q-drop

- Baking at 120°C
  - Same Q-drop improvement for 48, 30, 22, 12h
- After HT (larger grains, higher thermal conduct.):
  - No changes in Q-drop features in TM mode
  - Exponentially decreasing Q appears in TE mode (as in TM mode)
- After anodization:
  - Smoother Q-drop in TM mode
  - Max field in TE mode < TM mode

Medium field Q-slope results

	γ values	TM010	TE011
Before HT	Before bake	2.5	2.6
	After bake*	3.1	3.3
After HT	Before bake	1.0	0.6
	After bake*	1.9	1.8

* After baking the R_s vs. B_p dependence change from quadratic to linear

Material parameters results

After baking:

- Small increase (< 5%) of Δ
- Decrease of m.f.p. l to ~ 25-40 nm
- Increase of R_{res}

	TM010	TE011
before bake	6 nΩ	9 nΩ
after bake	12 nΩ	11 nΩ

Q-drop discussion

- Magnetic field enhancement model (MFE) [1]

  Q-drop due to surface roughness yielding magnetic field enhancement ⟹ local quenches lowering Q

- Interface tunnel exchange model (ITE) [2]

  Q-drop due to exponentially increasing surface resistance due to e^- tunneling from localized states at Nb-oxide interface under E field

(1) J. Knobloch et al, *Proc. 9th Workshop on RF Supercond.,* Santa Fe, USA (1999)

(2) J. Halbritter, *IEEE Trans. On Appl. Superc.,* 11 No 1, 1864 (2001)

- Max. field before baking is higher in TE mode than TM mode
  - MFE model: B-field in TM mode is high in the equator weld area where there are larger steps
  - ITE model: Q-drop in TM mode is dominated by the E-field
- Q-drop improvement after baking, limited by quench
  - MFE model: increase of B_{sh} due to O diffusion (not supported by measurements)
  - ITE model: reduction of density of localized states for TM mode, no explanation for TE mode

Conclusion

- The same dependence R_s vs. B_p as seen in TM010 mode above 90mT was observed in TE011 mode at higher field, once the thermal conduc. was decreased by HT
  - Q-drop is more probable to be a magnetic field effect
  - None of the present models explain all the experimental results