RF Characterization of an S-I-S' Sample

S. Keckert, O. Kugeler, D. Tikhonov, J. Knobloch (HZB)
A.-M. Valente-Feliciano (JLab)

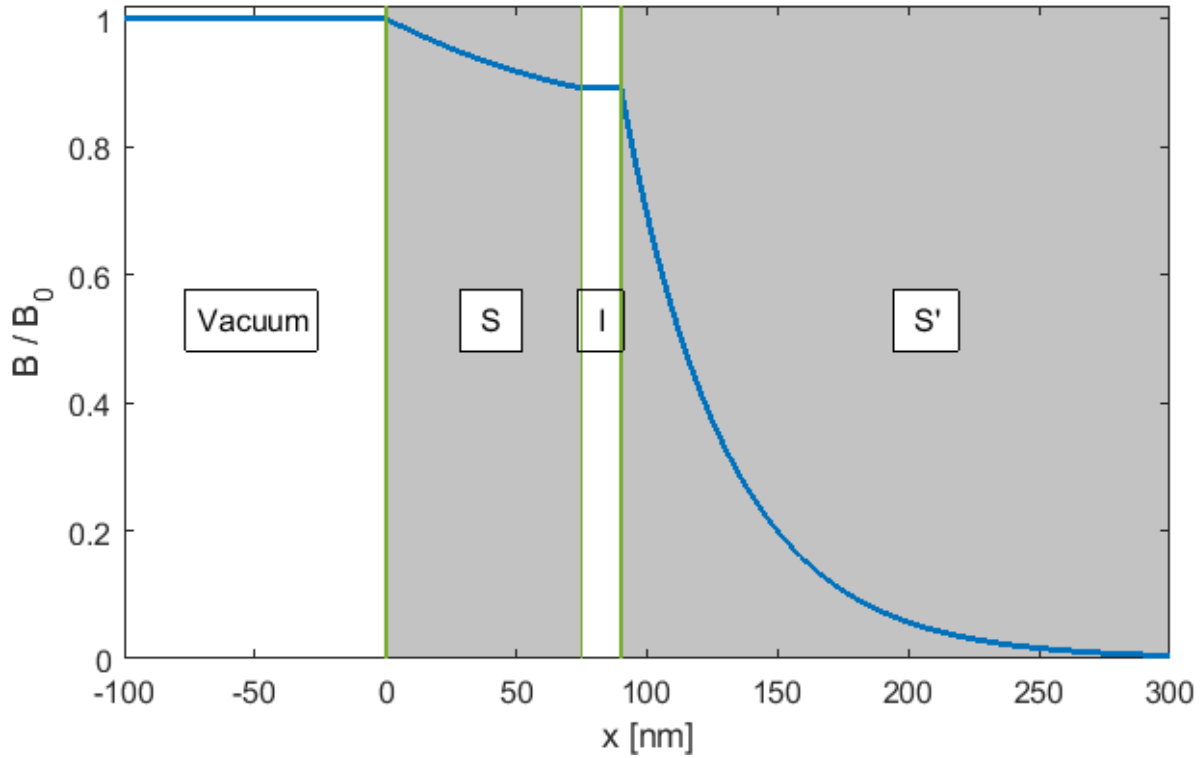
19th International Conference on RF Superconductivity
July 04th 2019, Dresden

HZB Helmholtz Zentrum Berlin

On the way towards high gradient

[A. Gurevich, Appl. Phys. Lett. 88, 012511, 2006]
[T. Kubo, Sc. Sci. Technol. 30, 023001, 2017]

- S-I-S' structure shields bulk superconductor (Nb)
  - $\lambda > \lambda_{\mathrm{Nb}}$
  - B_{vp} can be increased
  - $T_{\mathrm{c}} > T_{\mathrm{c,\,Nb}}$ reduces surface resistance

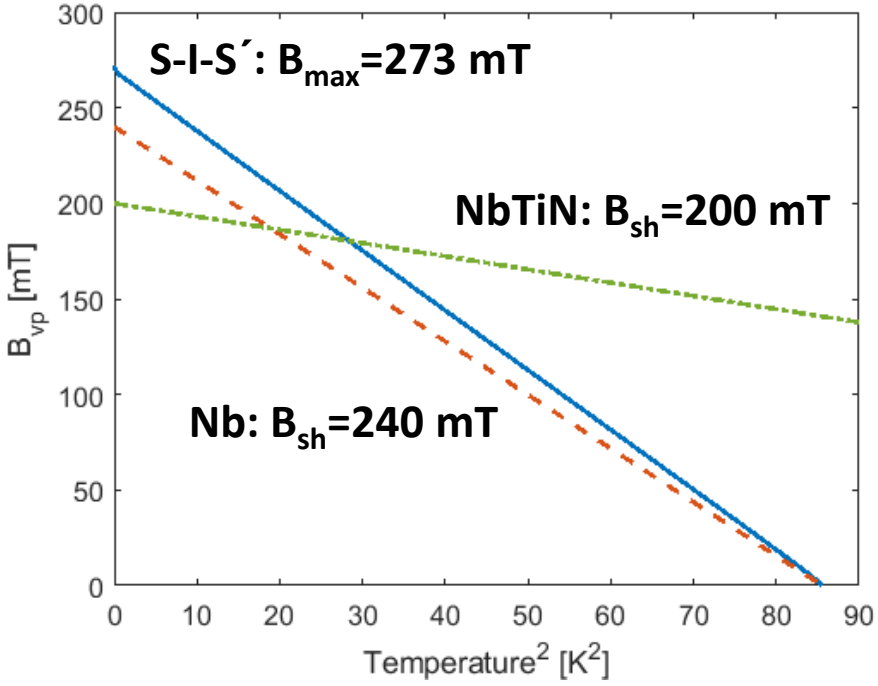


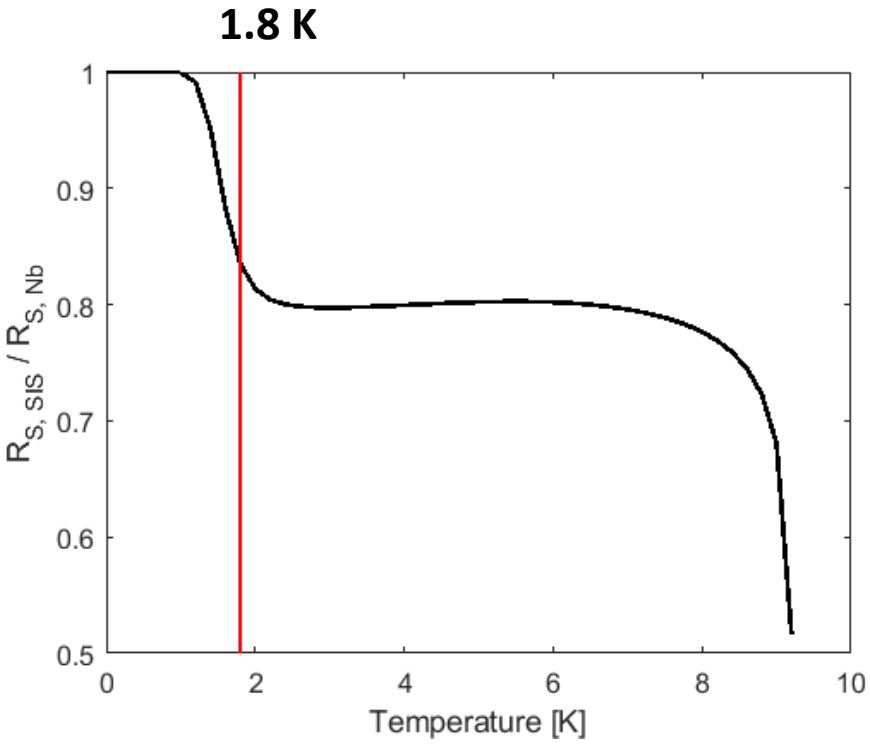
HZB Helmholtz Zentrum Berlin

On the way towards high gradient

[A. Gurevich, Appl. Phys. Lett. 88, 012511, 2006]
[T. Kubo, Sc. Sci. Technol. 30, 023001, 2017]

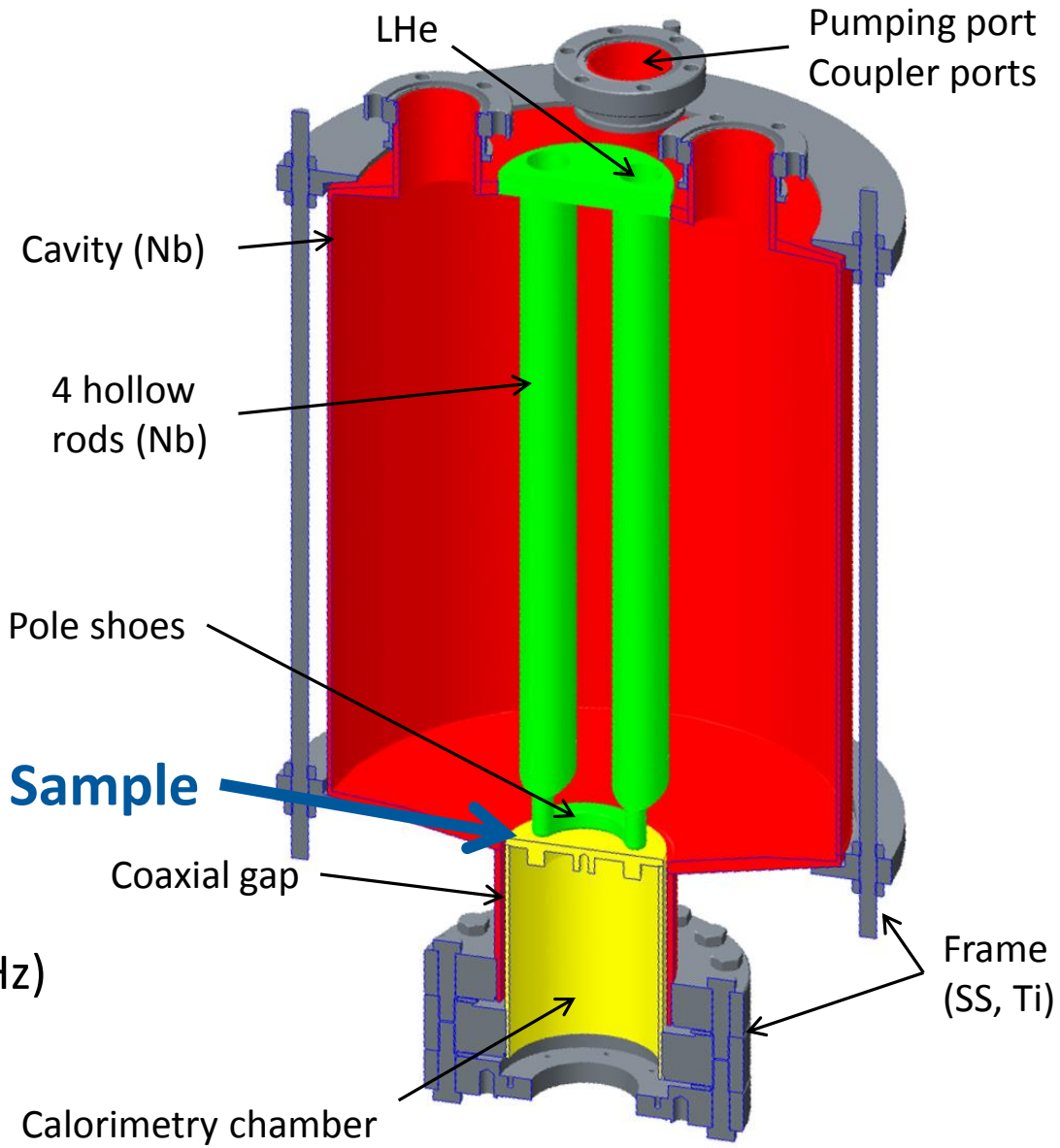
- S-I-S' structure shields bulk superconductor (Nb)
  - $\lambda > \lambda_{\mathrm{Nb}}$
  - B_{vp} can be increased
  - $T_{\mathrm{c}} > T_{\mathrm{c,\,Nb}}$ reduces surface resistance





The Quadrupole Resonator (QPR)

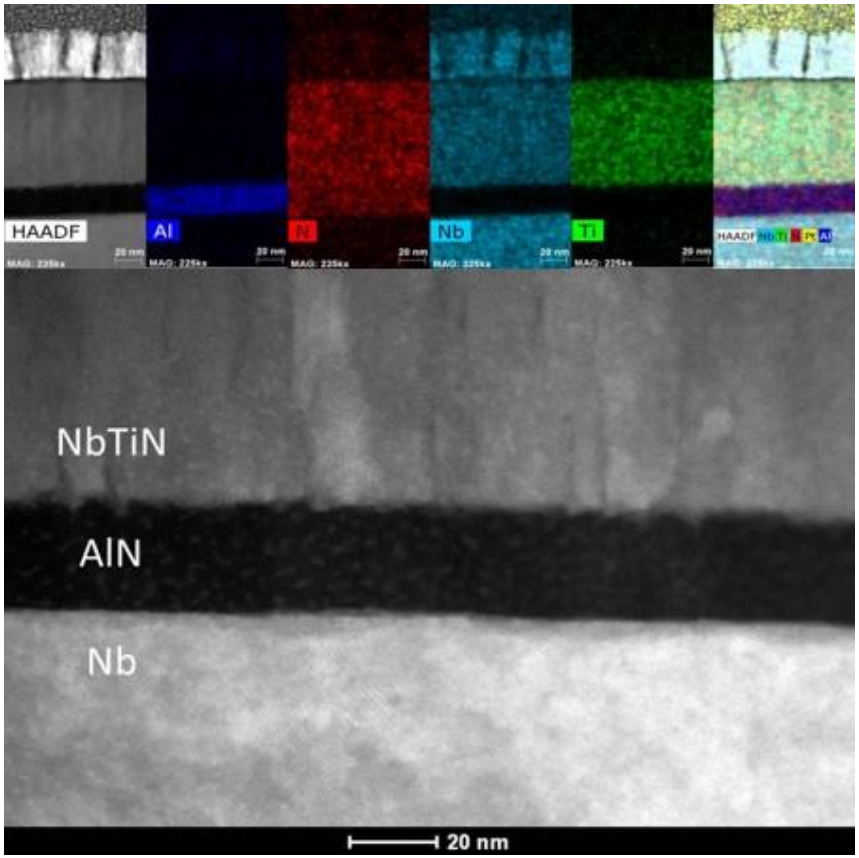
- Quadrupole modes at ≈ 415, 845, 1286 MHz
- Operated in vertical cryostat → LHe bath at 1.8 K
- Coaxial structure → thermal decoupling
- Calorimetric measurement of surface resistance
- $B_{Sample,\ max}$ ~ 120 mT (415 MHz) ~ 30 MV/m (TESLA)



S-I-S´ Sample

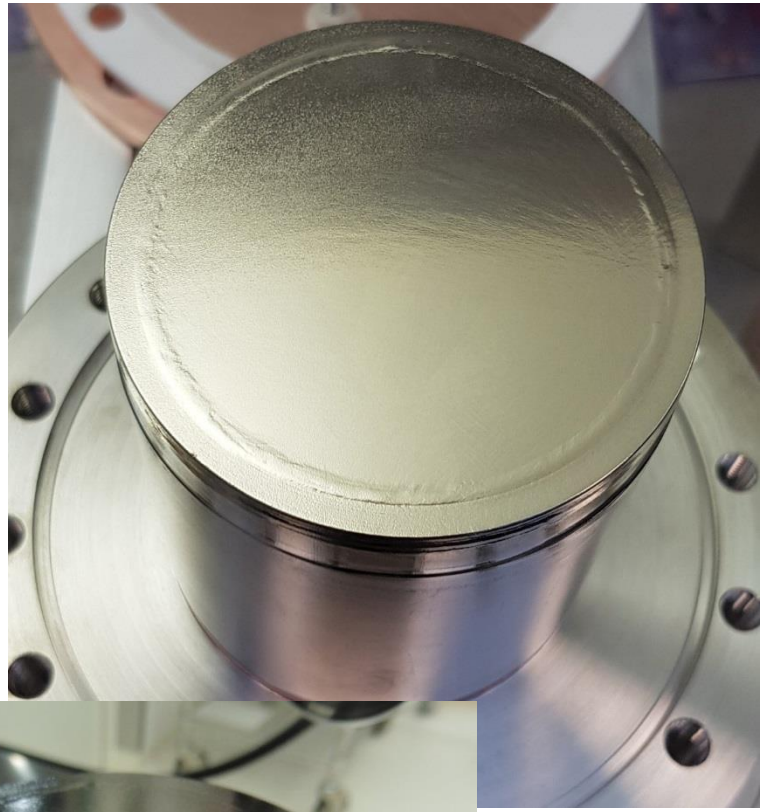
HZB Helmholtz Zentrum Berlin

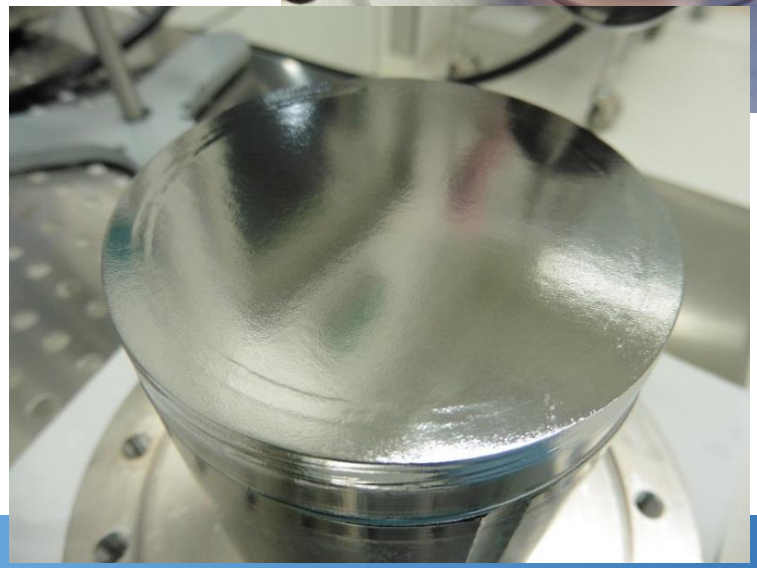
75 nm NbTiN – 15 nm AlN – bulk Nb



[Courtesy of Anne-Marie Valente-Feliciano]

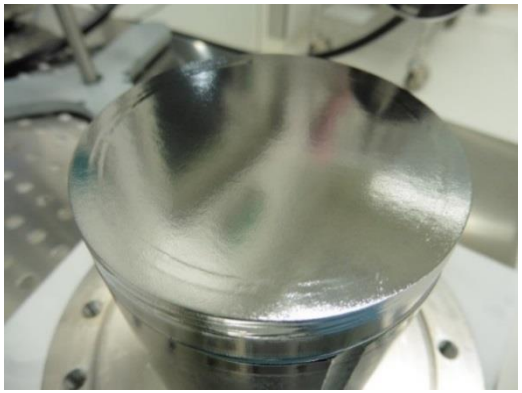
THFUA3 talk by A-M. Valente-Feliciano

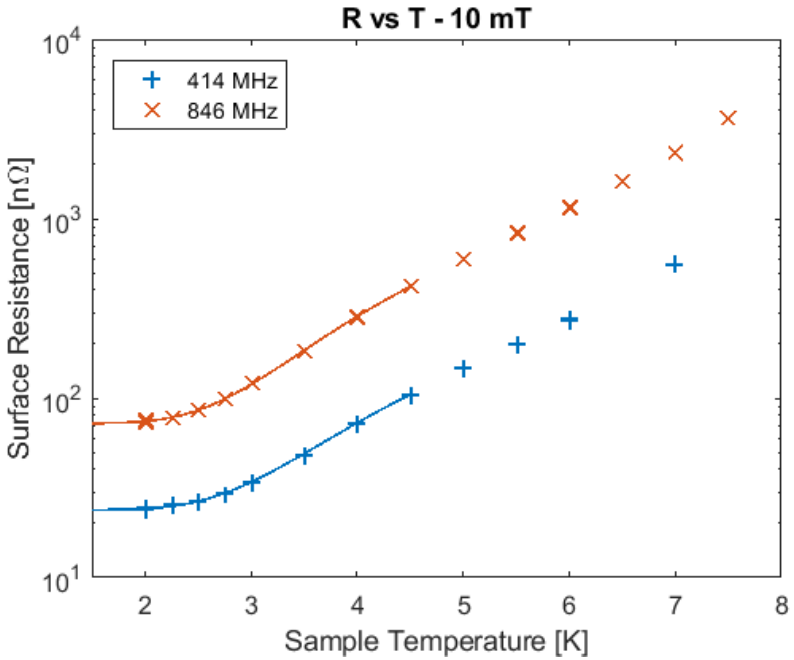


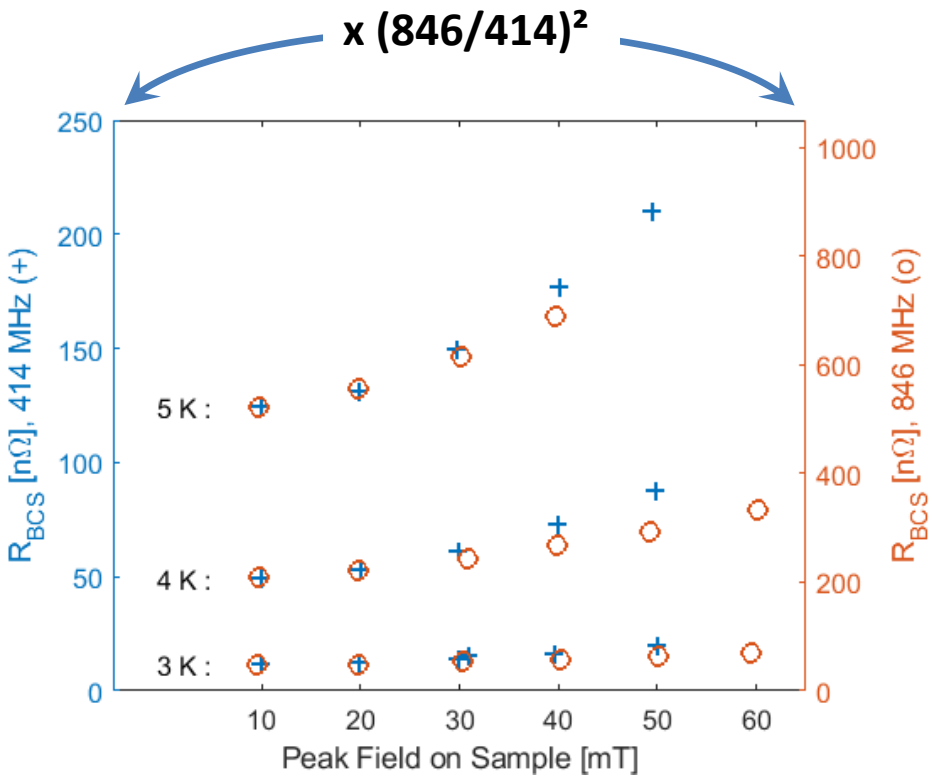


Baseline measurement – surface resistance

- Bulk niobium, RRR 300
- Sample manufactured at JLab
- nano-polish and EP
- Residual resistance
  23 nΩ (414 MHz)
  73 nΩ (846 MHz)

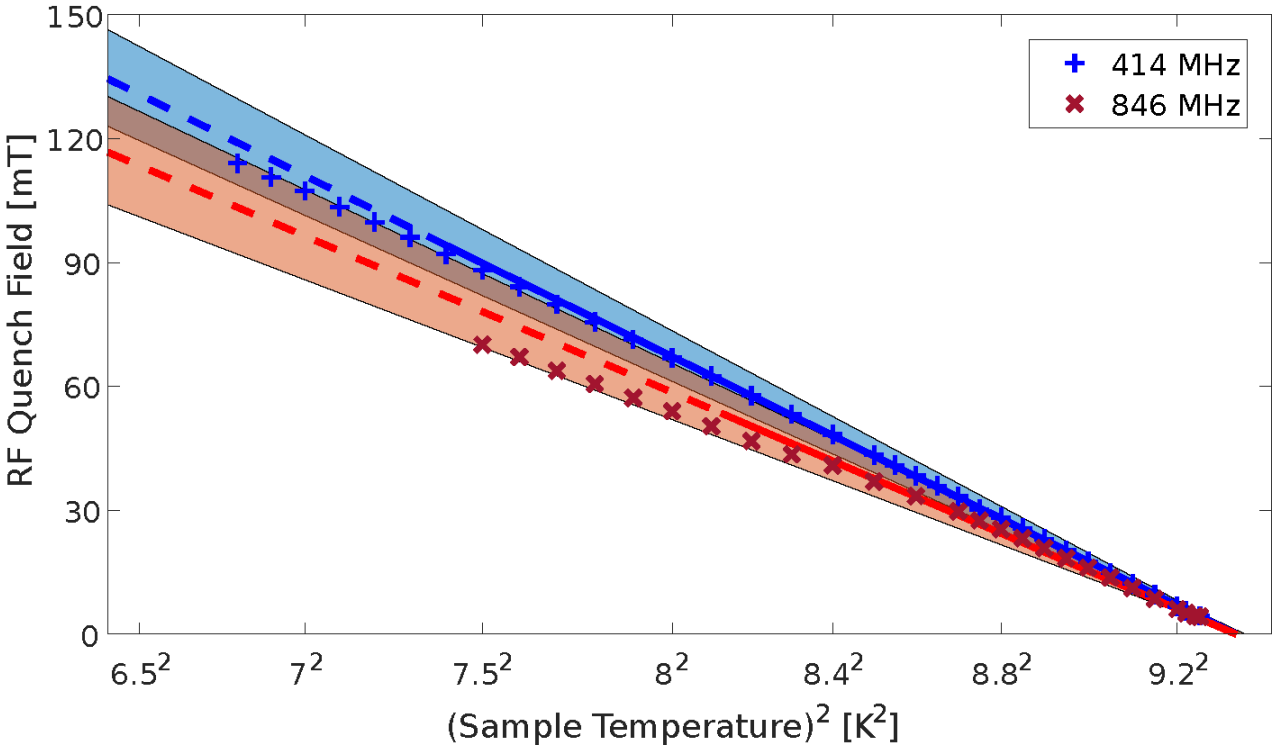






Baseline measurement – RF quench field

- Low stored energy in QPR: $U \approx 0.1$ J @ 100 mT
- Pulsed measurement with few 100 W and fast power meter
- High RF quench field
  254 mT (414 MHz)
  220 mT (846 MHz)



Solid lines: Linear fit

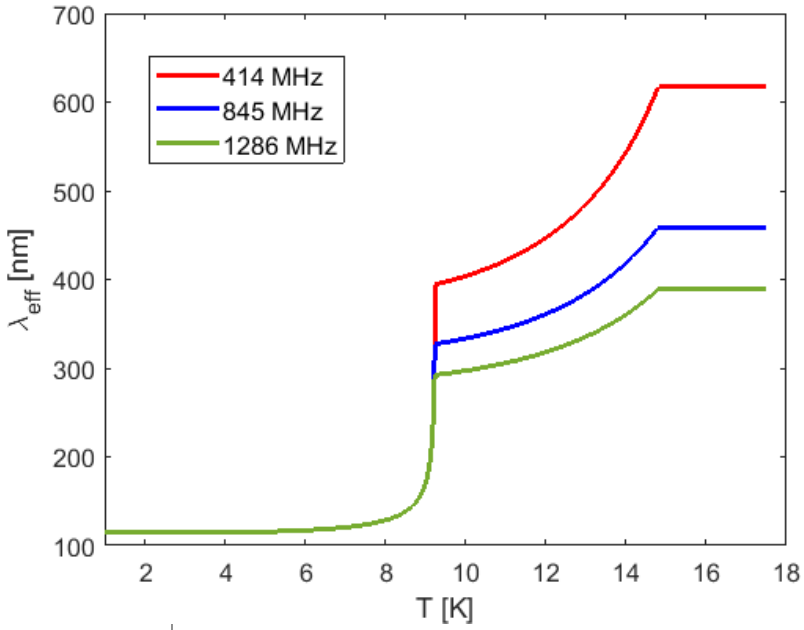
Dashed lines: Extrapolation

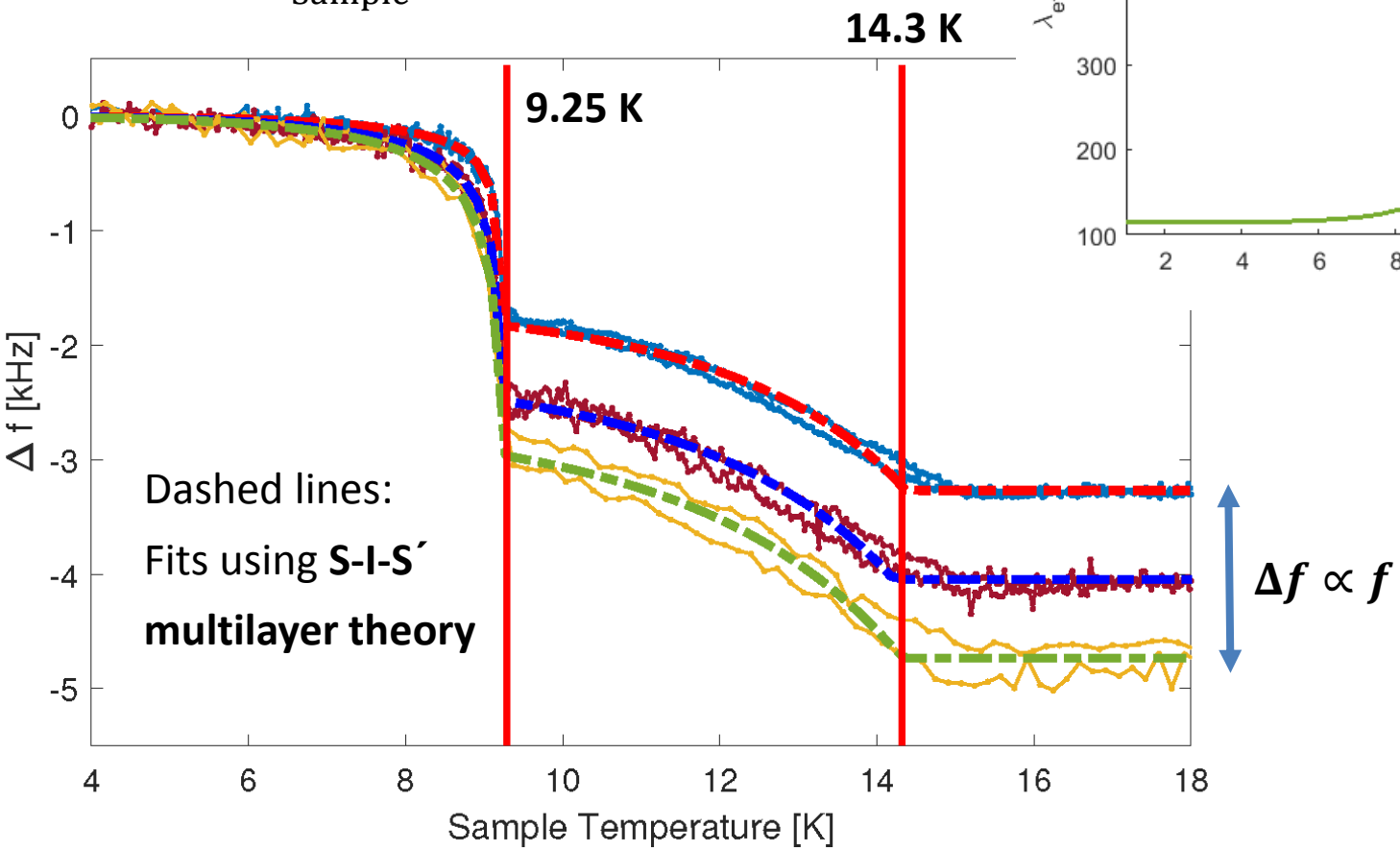
$$B_q(T) = B_0\left(1 - \left(\frac{T}{T_c}\right)^2\right)$$

S-I-S´ penetration depth

$$\lambda_{eff}(T) = \frac{1}{B_0}\int_0^{\infty} B(x,T)\,\mathrm{dx}$$

$$\Delta f = -\frac{\pi\mu_0 f^2}{G_{\mathrm{Sample}}}\Delta\lambda_{eff}$$

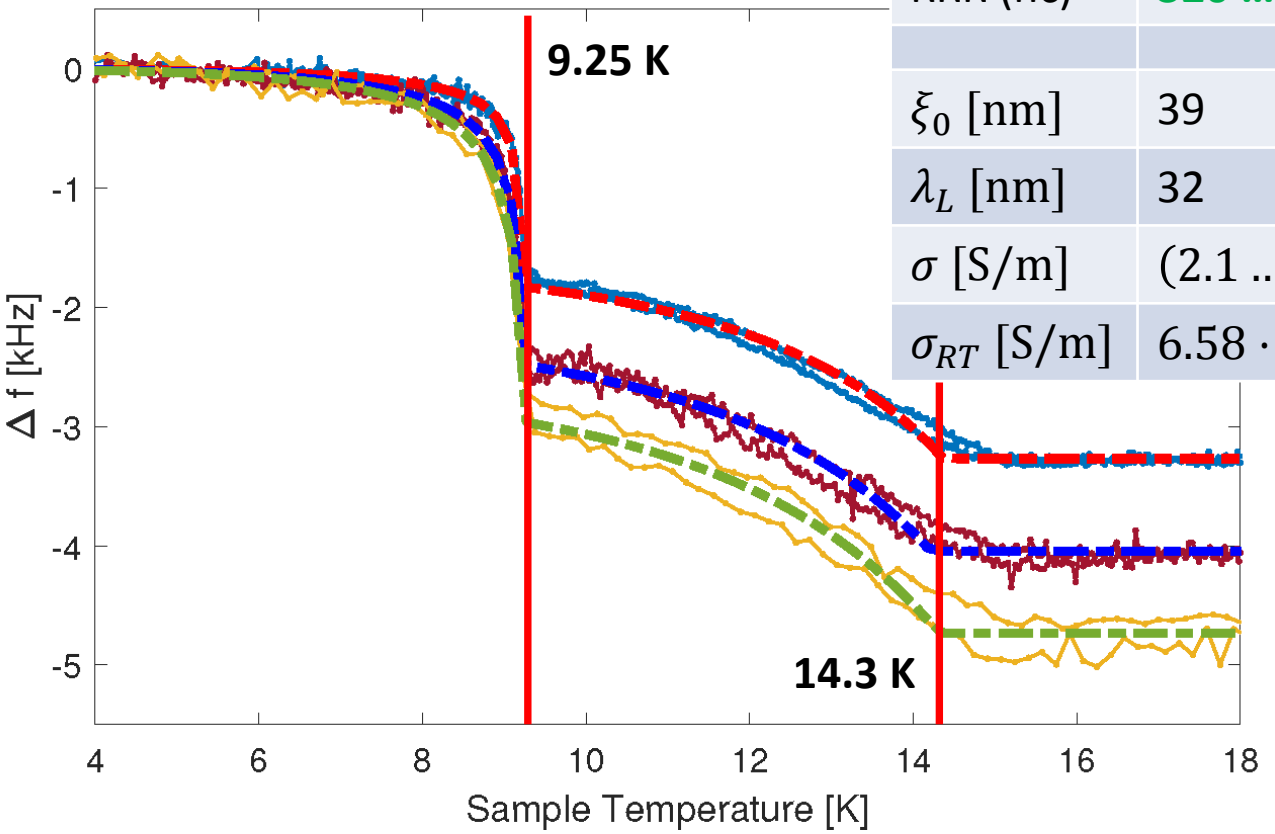




S-I-S´ penetration depth

$$\lambda_0(l) = \lambda_L \sqrt{1 + \frac{\pi \xi_0}{2l}}$$

	Nb	NbTiN
T_c [K]	9.25	14.3 (Lit: 17.3)
λ_0 [nm]	44 … 46	240 … 250
RRR (sc)	15 … 25	
RRR (nc)	320 … 350	
ξ_0 [nm]	39	(5)
λ_L [nm]	32	(150 … 200)
σ [S/m]	$(2.1 \ldots 2.3) \cdot 10^9$	$2.86 \cdot 10^6$
σ_{RT} [S/m]	$6.58 \cdot 10^6$	



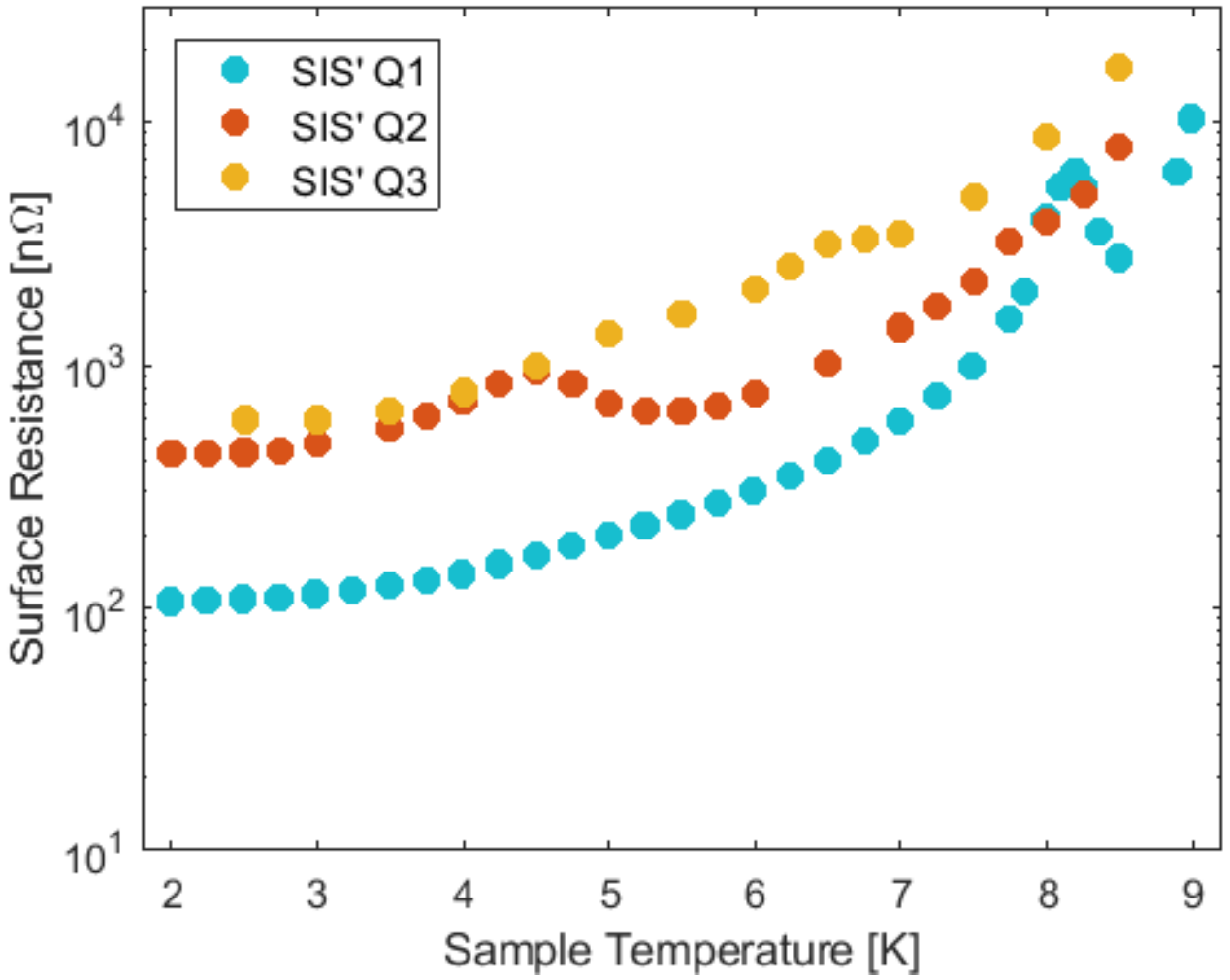
Dashed lines: Fits using
S-I-S´ multilayer theory

S-I-S´ surface resistance

R(T) at constant B

Q1, Q2: 10 mT

Q3: 8.8 mT

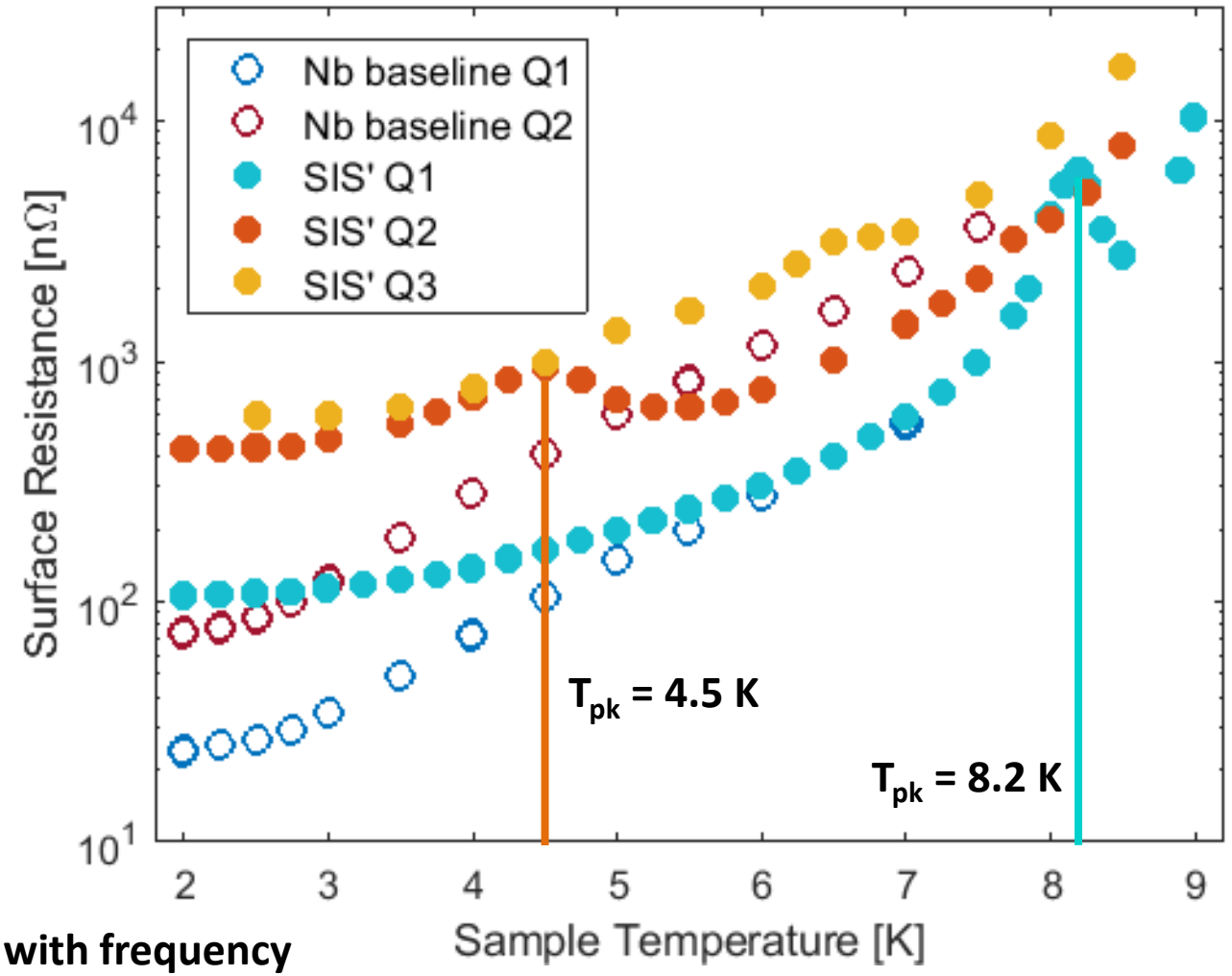


S-I-S´ surface resistance

R(T) at constant B

Q1, Q2: 10 mT

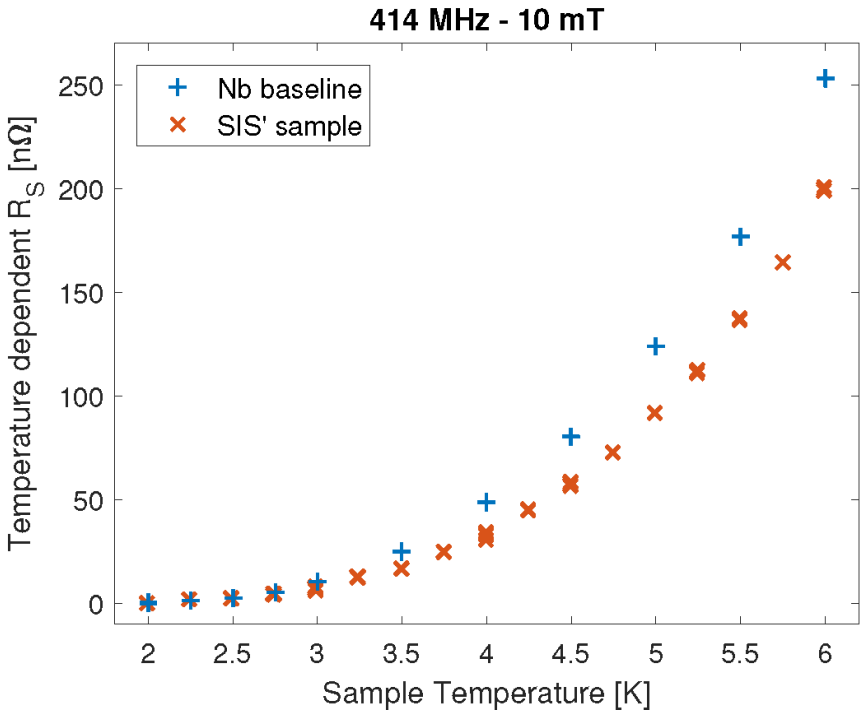
Q3: 8.8 mT

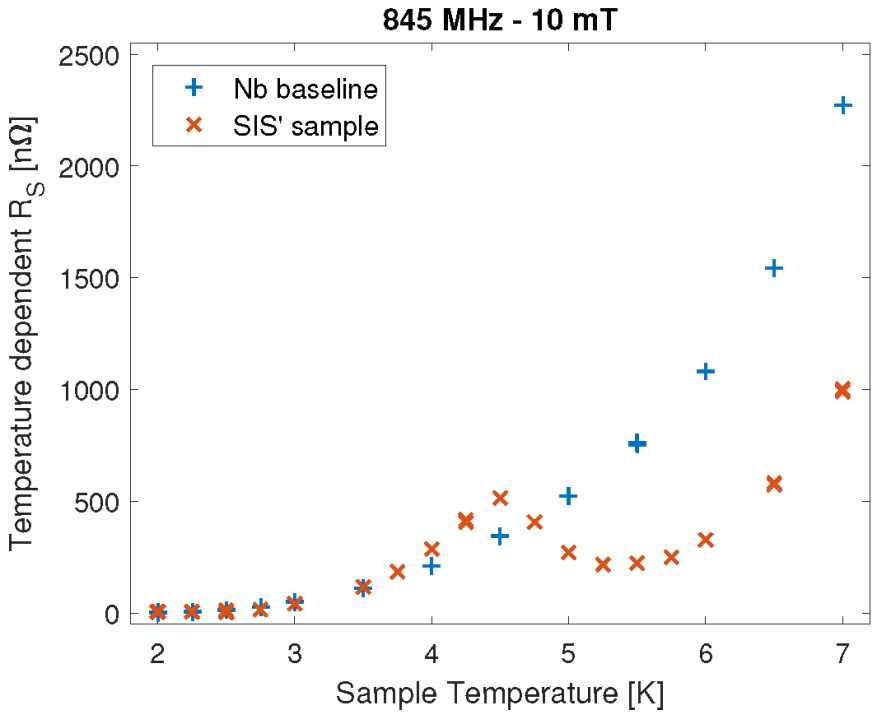


1

➔ T_{pk} changes with frequency

S-I-S´ vs. Baseline – R(T)

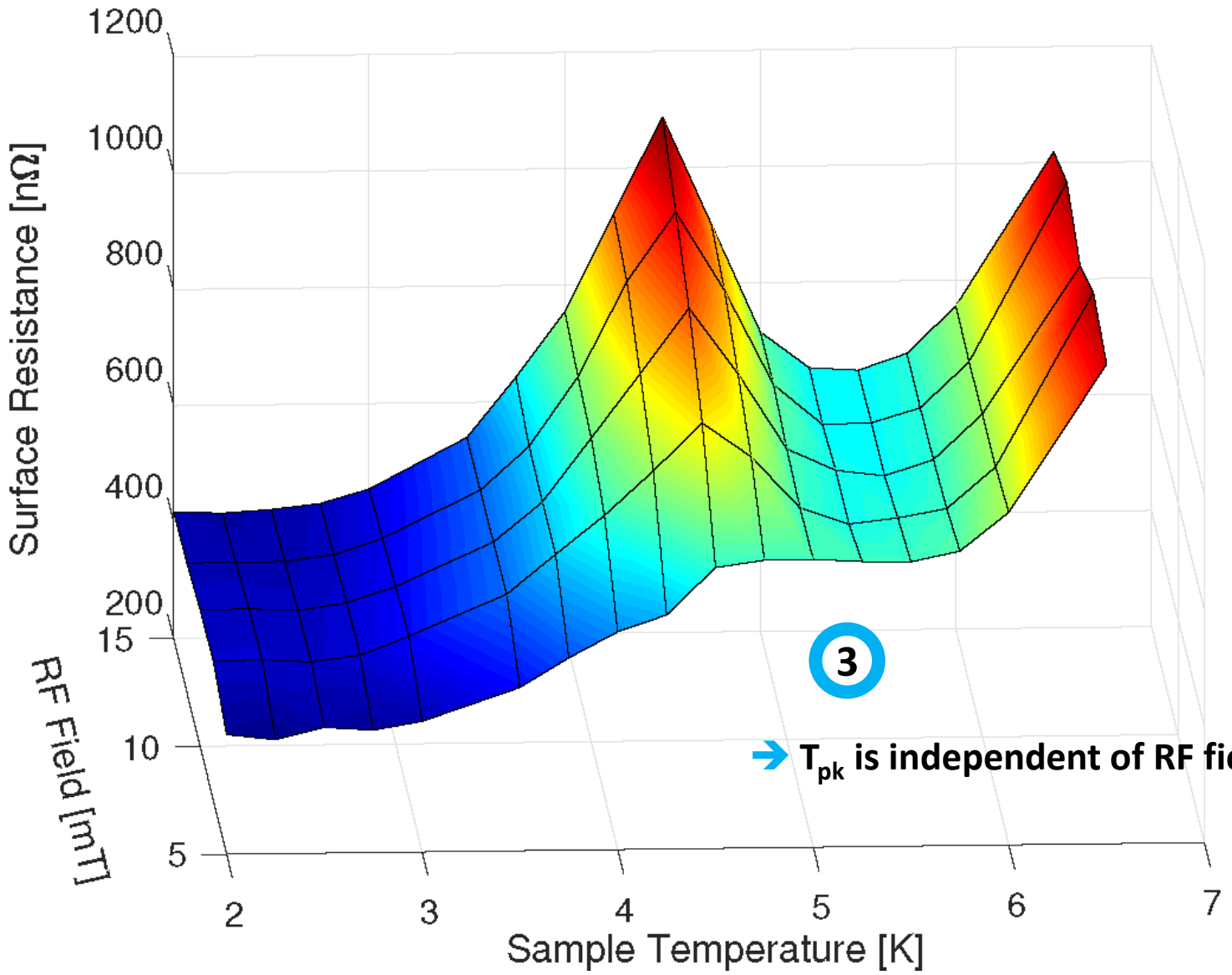




2

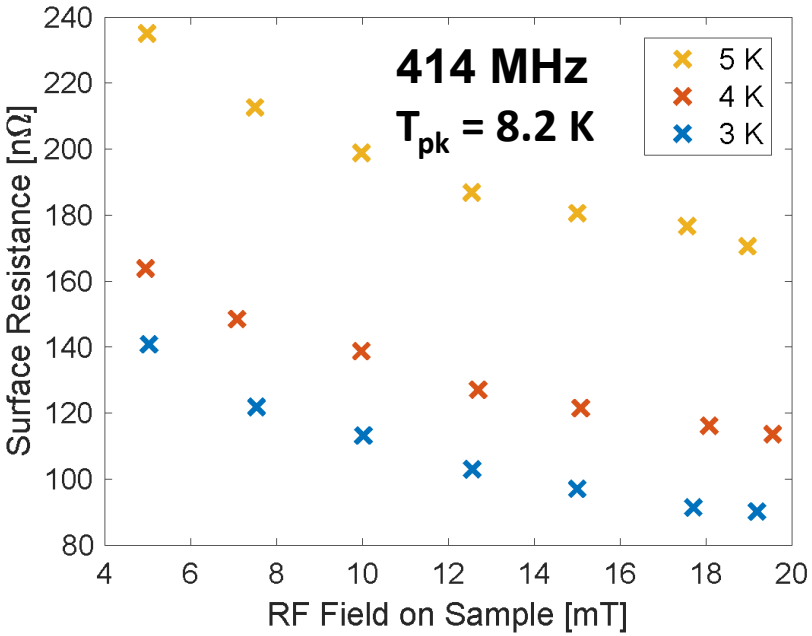
➔ non-monotonic R(T) due to **increased surface resistance near T_{pk}**

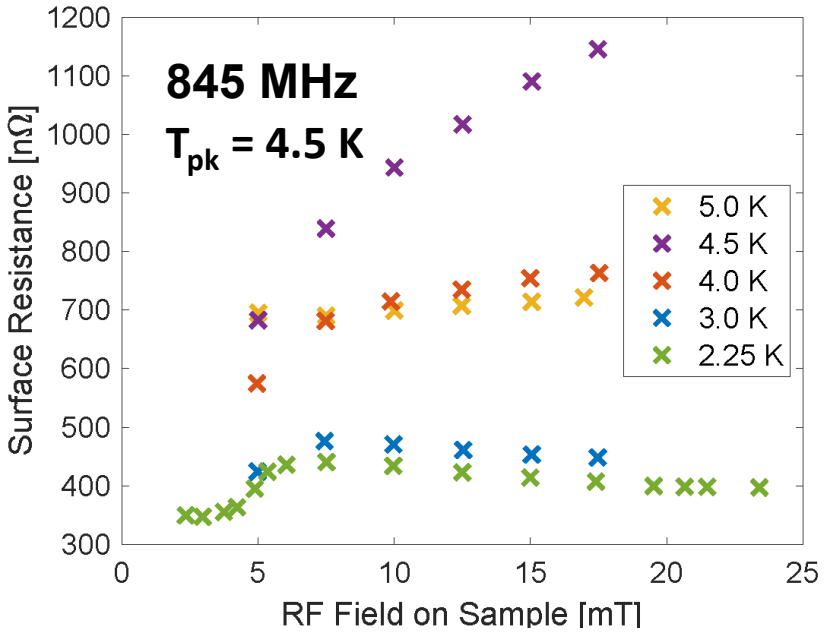
S-I-S´ – R(T,B) – 845 MHz



→ T_{pk} is independent of RF field

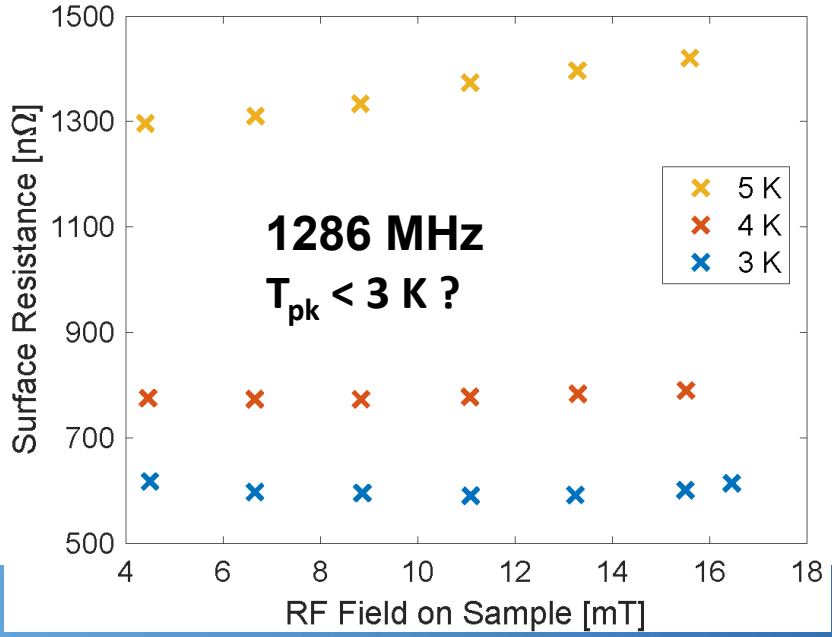
S-I-S´ – R(B)





4

➔ Q-slope behavior changes at T_{pk}

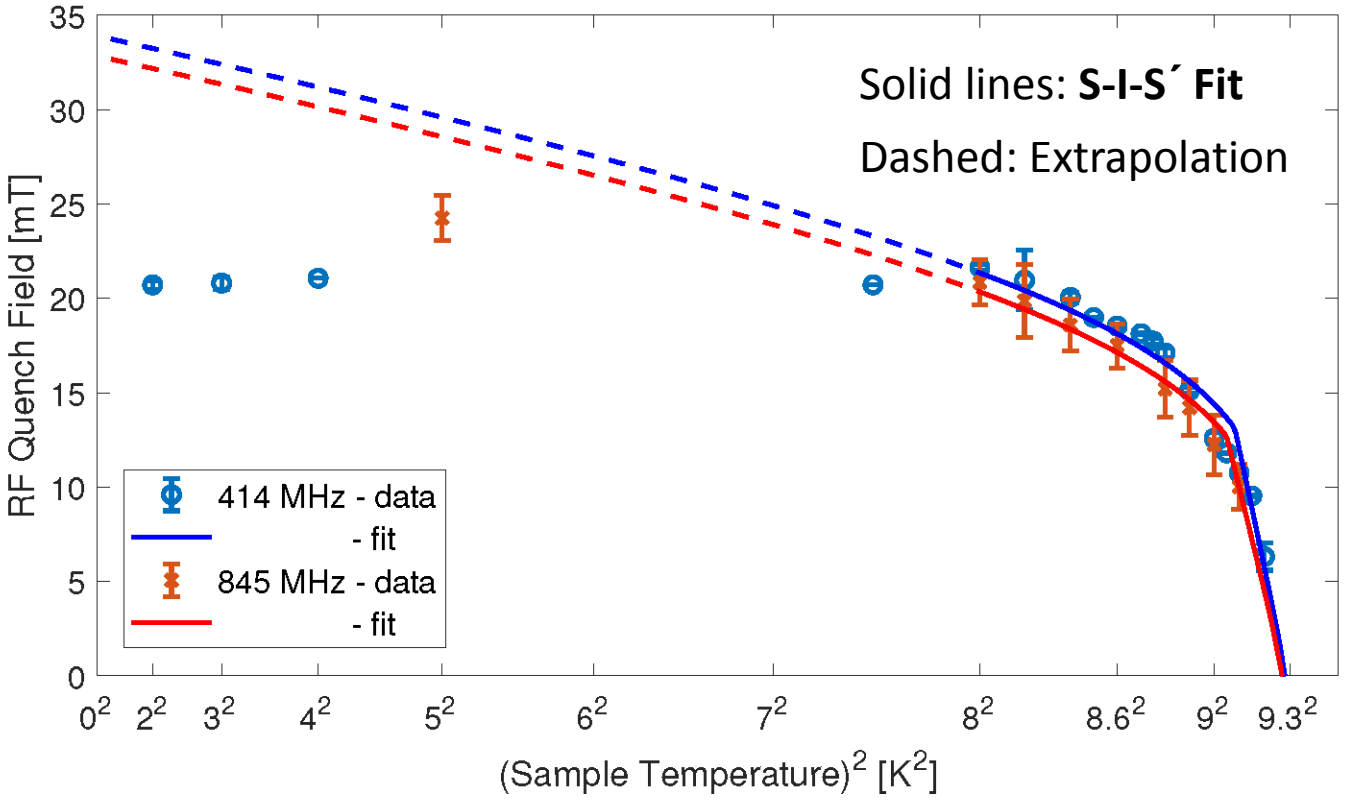


S-I-S´ RF Quench field

- Hard magnetic quench limit at 20-25 mT
- **Fit** according to S-I-S´ **multilayer theory**

➔ **S-I-S´ allows increase of bulk limit**

	Nb	NbTiN
T_c [K]	**9.3**	**14.3** (Lit: 17.3)
$B_{\max}$ [mT]	**220 … 250**	**17**

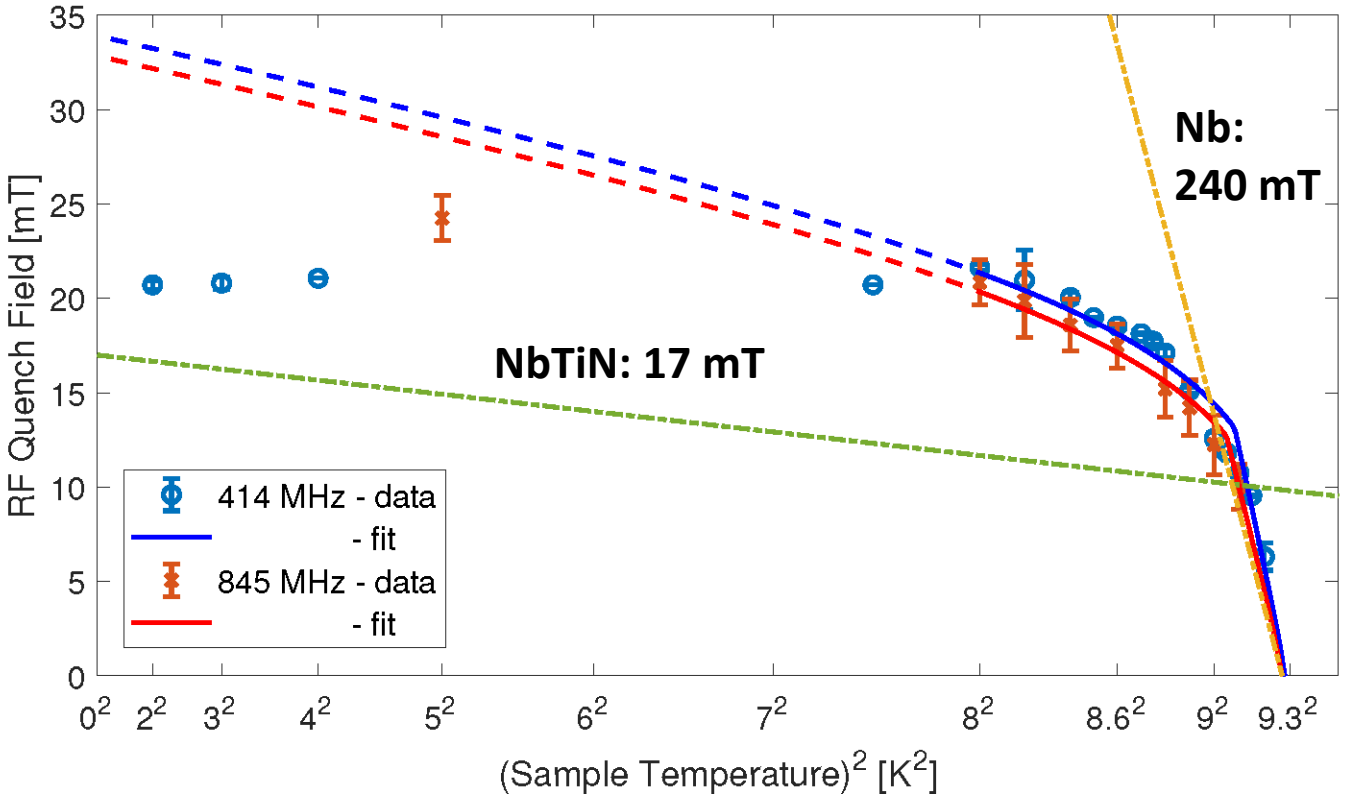


S-I-S´ RF Quench field

- Hard magnetic quench limit at 20-25 mT
- **Fit** according to S-I-S´ **multilayer theory**

➔ **S-I-S´ allows increase of bulk limit**

	Nb	NbTiN
T_c [K]	**9.3**	**14.3** (Lit: 17.3)
B_{max} [mT]	**220 … 250**	**17**



Conclusion

HZB Helmholtz Zentrum Berlin

SRF characterization of NbTiN – AlN – Nb sample at HZB

- Penetration depth measurement consistent with S-I-S´ multilayer theory
- First RF critical field measurement of an S-I-S´ structure
- Demonstrated increase of quench field
- Non-monotonic surface resistance vs. temperature
  - Coupling?
  - … ?
- To be continued: Study of R_s vs. thickness

TUP073, poster by D. Tikhonov (HZB)

Thank you for your attention!