Overview Multilayers – RF Results

Sebastian Keckert

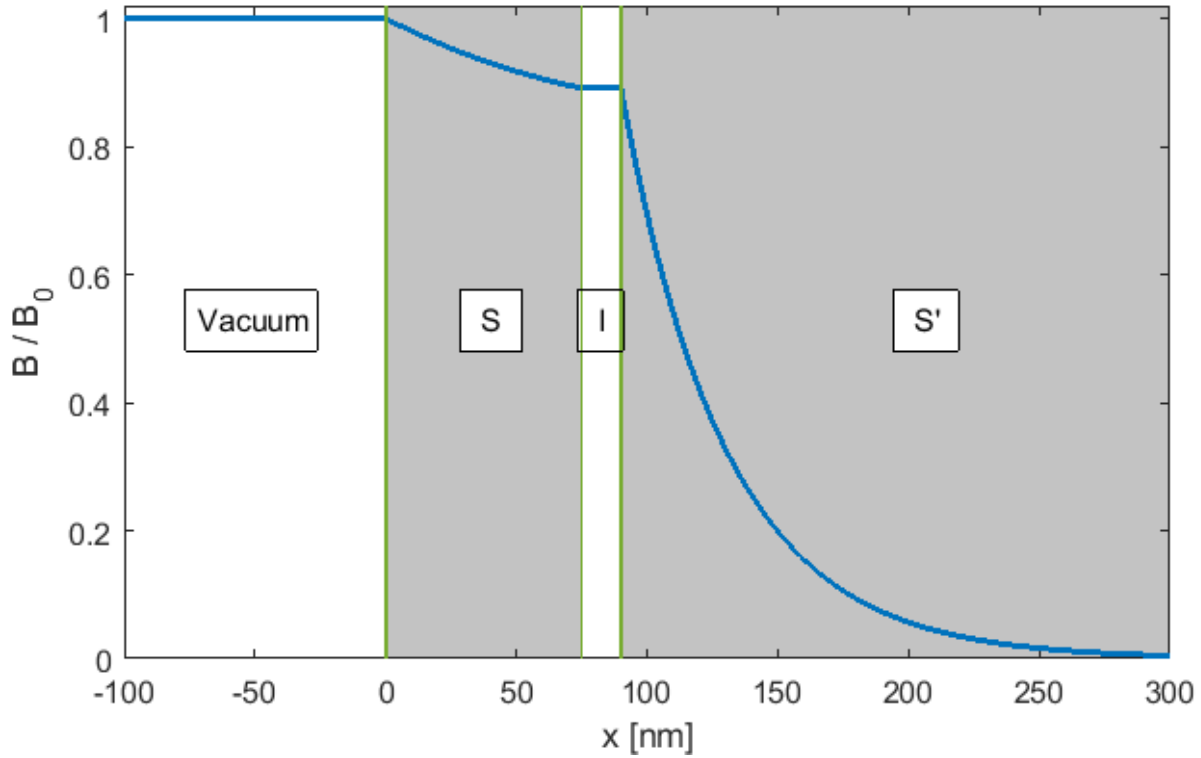
TTC Meeting
5 Feb 2020, CERN

Motivation

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

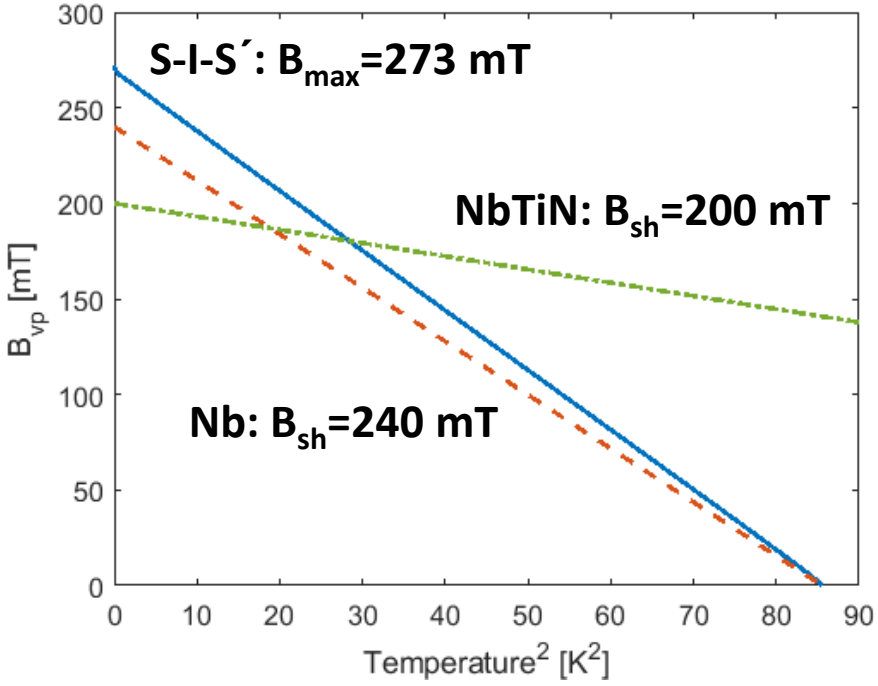


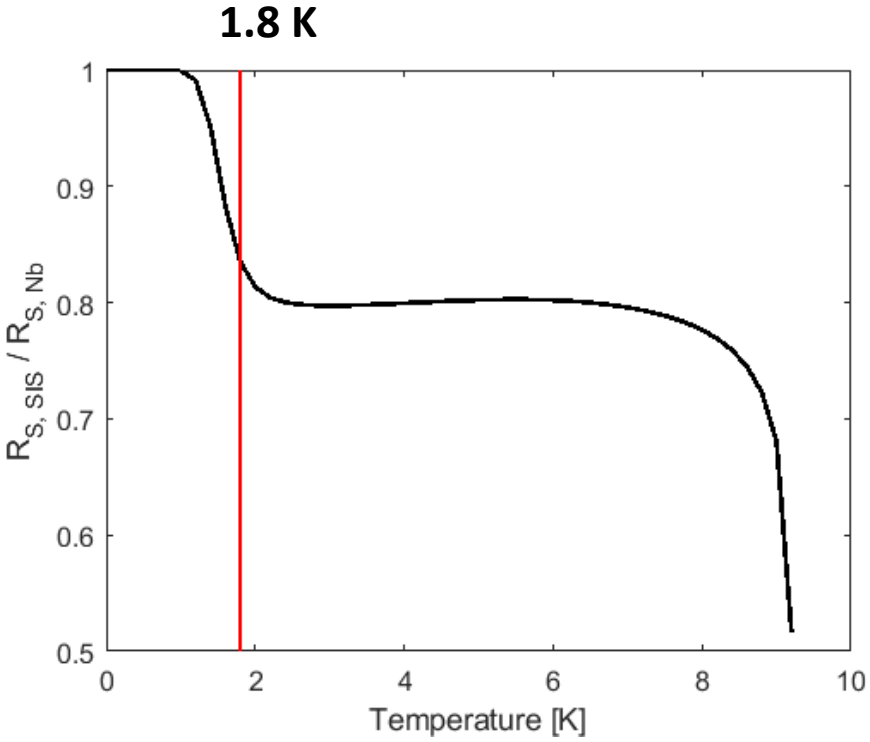
Motivation

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 promises high B_{max}
- More stable w.r.t. early vortex penetration?
- Moderate decrease of R_S
  - Thick films needed for higher operating temperature !

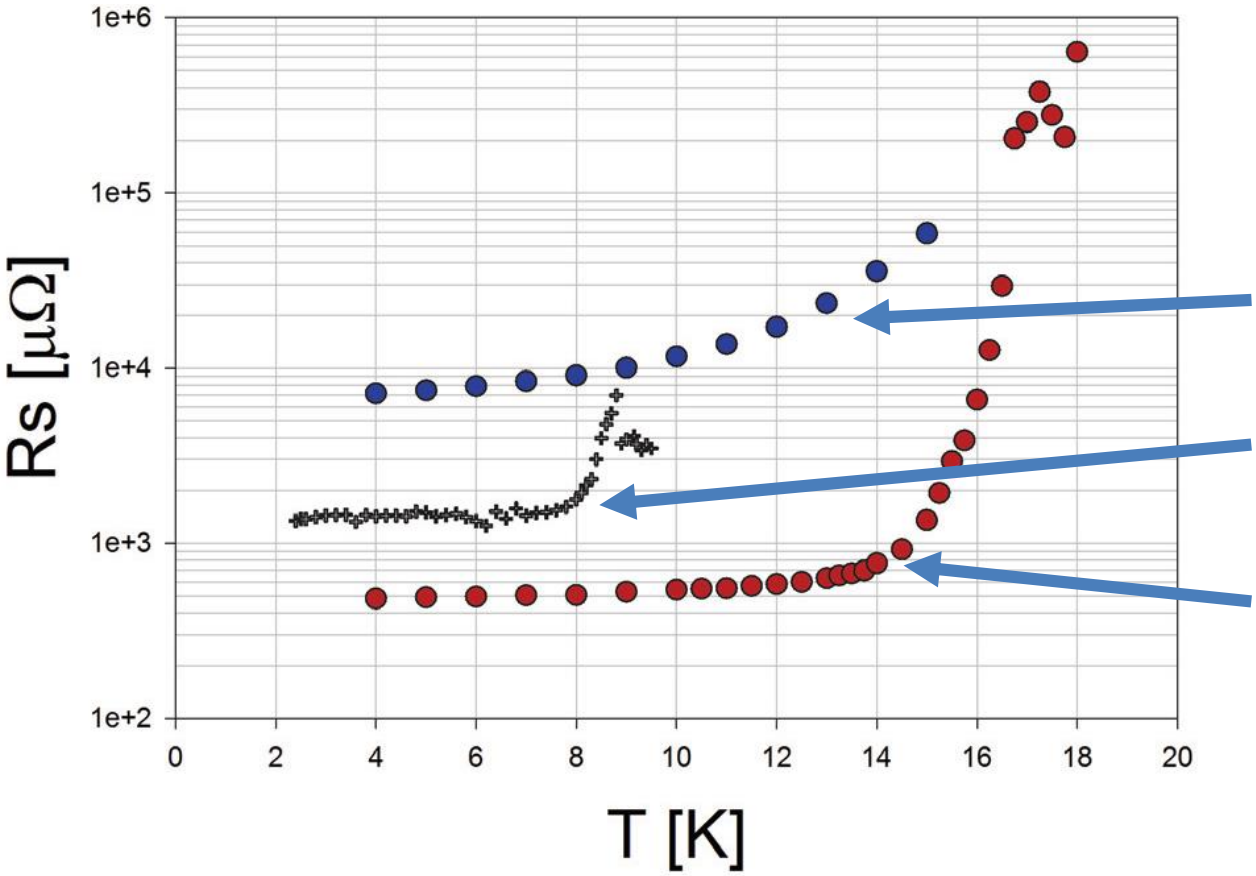




Overview: Multilayer at SRF conferences

Nb_3Sn / Al_2O_3 / Nb @ 7.5 GHz

TE011 sapphire loaded cavity
50mm disk sample



50nm Nb_3Sn / Al_2O_3 / Nb

bulk Nb

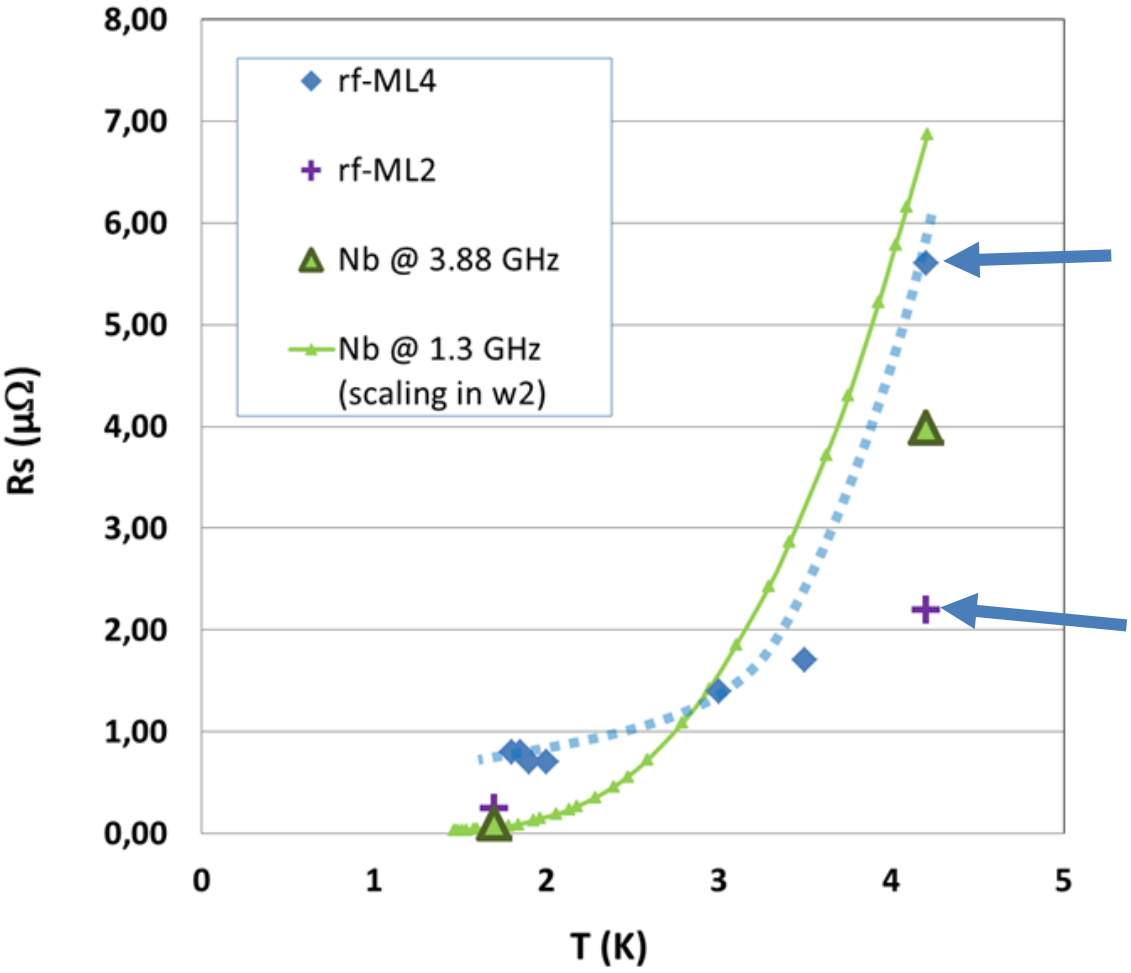
100nm Nb_3Sn / Al_2O_3 / Nb

[S. Sosa-Guitron, SRF'15]

Overview: Multilayer at SRF conferences

100nm NbN @ 3.88 GHz, 1 mT

TE011 cavity
130mm disk sample



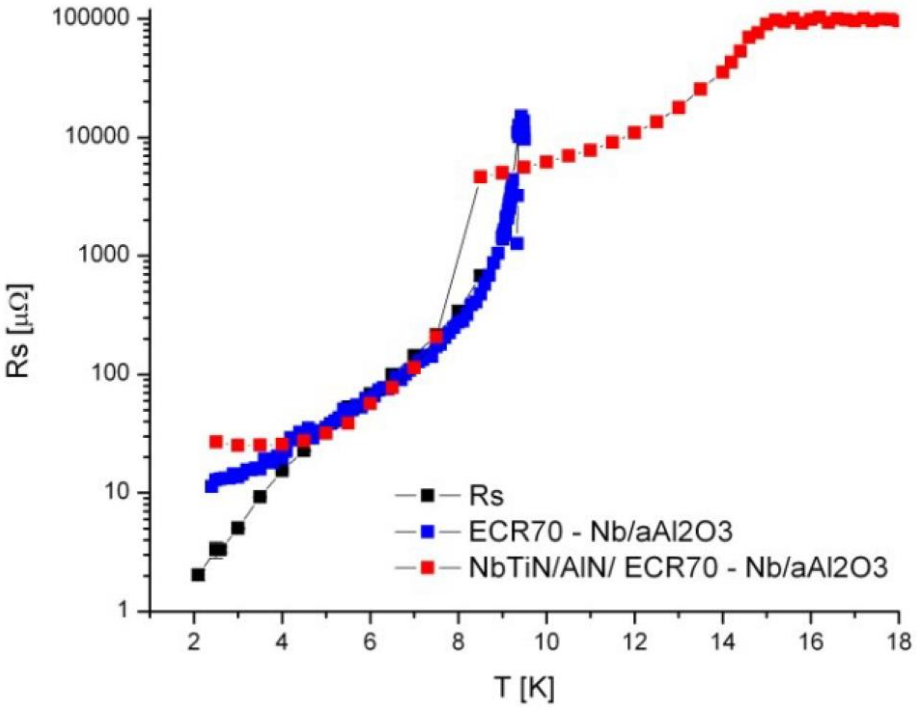
4x 25nm NbN / 14nm MgO
+ 5nm MgO top layer
Substrate: rough PC Nb

2x 50nm NbN / 14nm MgO
+ 5nm MgO top layer
Substrate: smooth LG Nb

[C. Baumier, SRF'13]

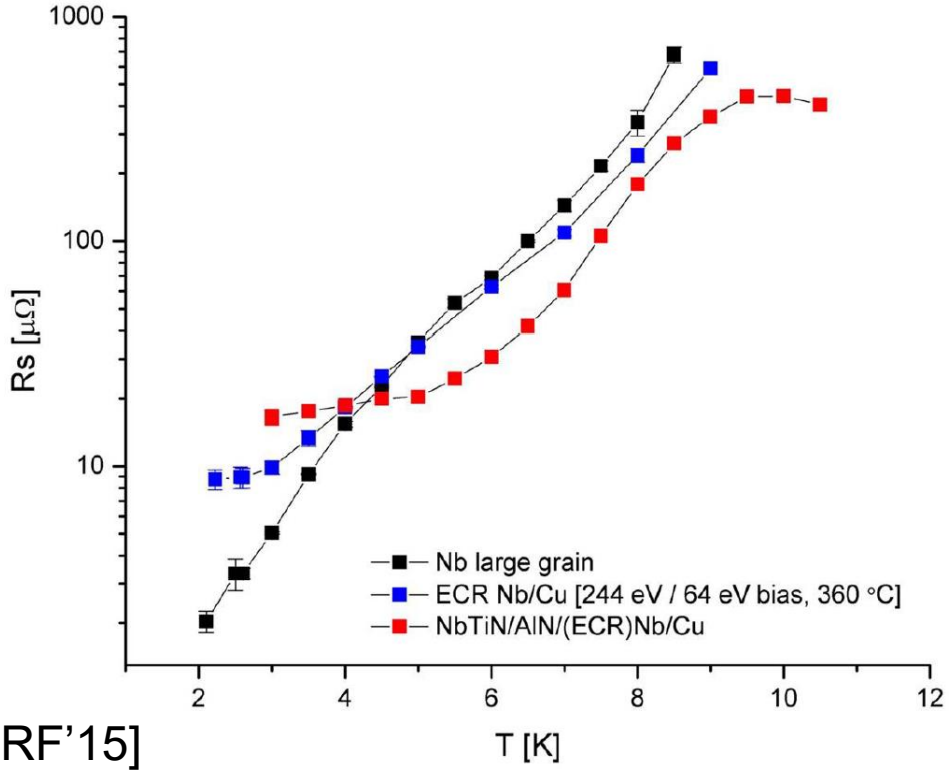
Overview: Multilayer at SRF conferences

NbTiN / AlN / Nb @ 7.5 GHz



TE011 sapphire loaded cavity
50mm disk sample

[A.-M. Valente-Feliciano, SRF'13]

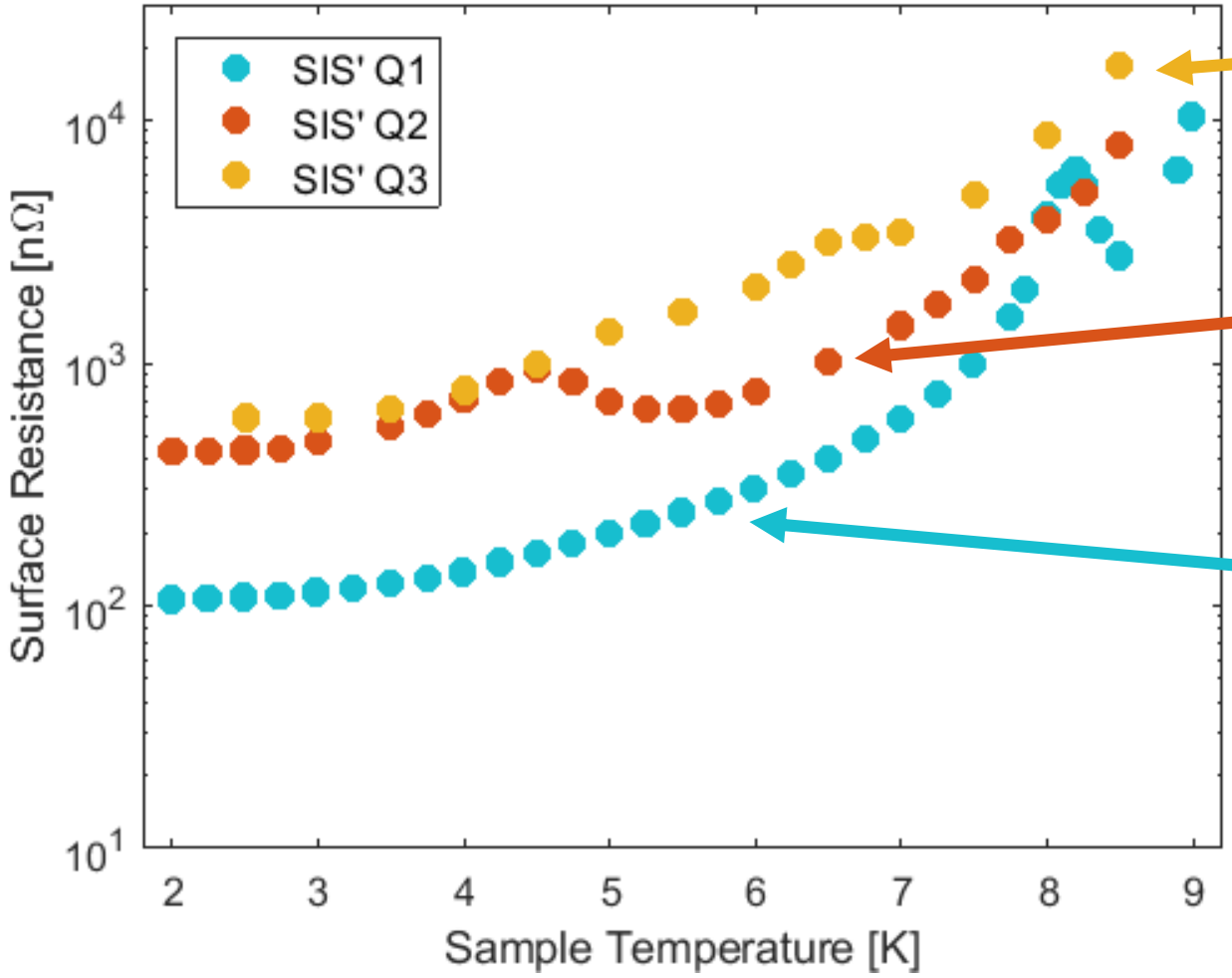


[A.-M. Valente-Feliciano, SRF'15]

Overview: Multilayer at SRF conferences

75nm NbTiN / 15nm AlN / Nb @ 10 mT

HZB QPR, 75mm disk sample



1286 MHz

845 MHz

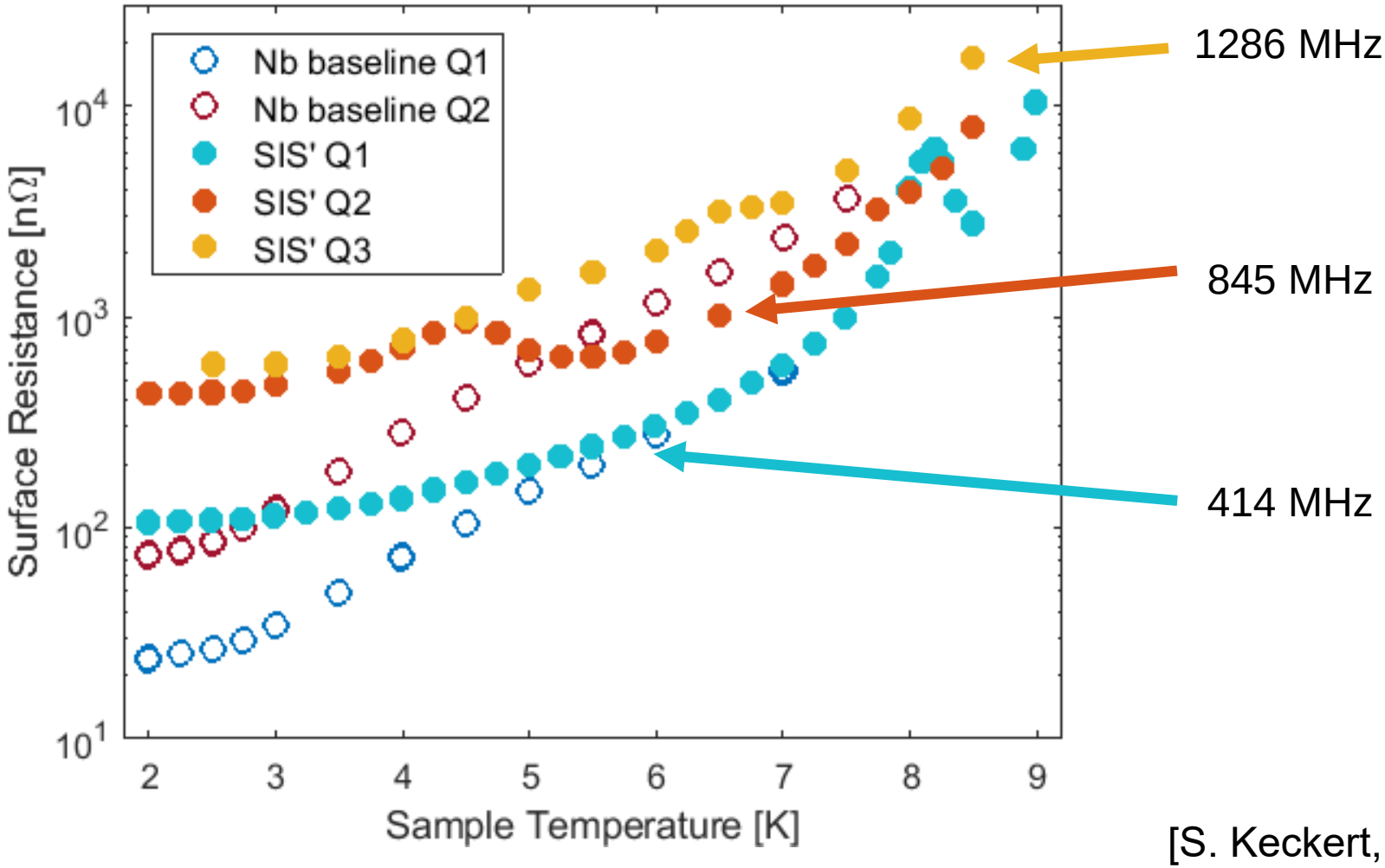
414 MHz

[S. Keckert, SRF'19]

Overview: Multilayer at SRF conferences

75nm NbTiN / 15nm AlN / Nb @ 10 mT

HZB QPR, 75mm disk sample



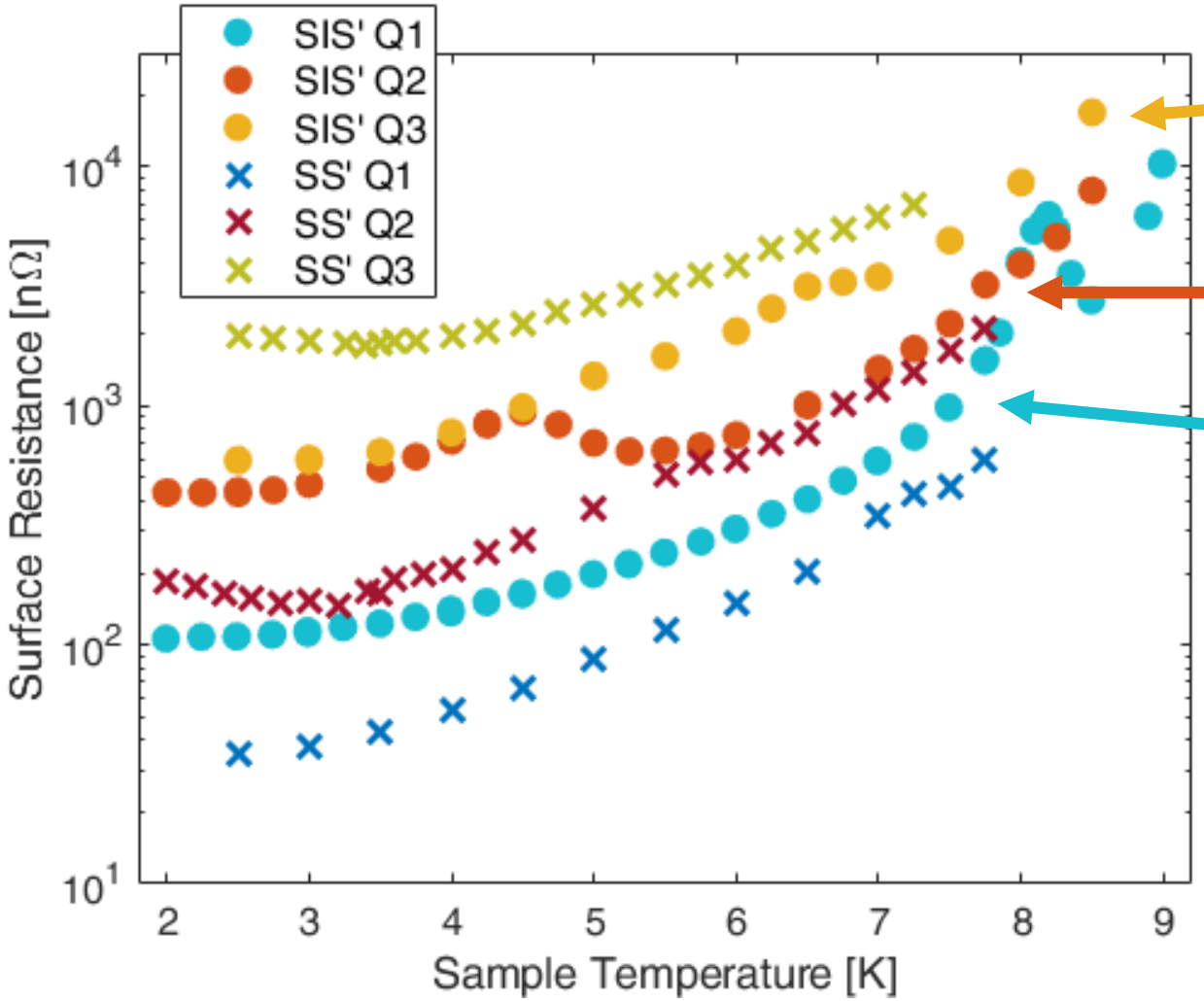
[S. Keckert, SRF'19]

Overview: Multilayer at SRF conferences

S-I-S´ : 75nm NbTiN / 15nm AlN / Nb

S-S´ : 70nm NbTiN / Nb

HZB QPR, 75mm disk sample



1286 MHz

845 MHz

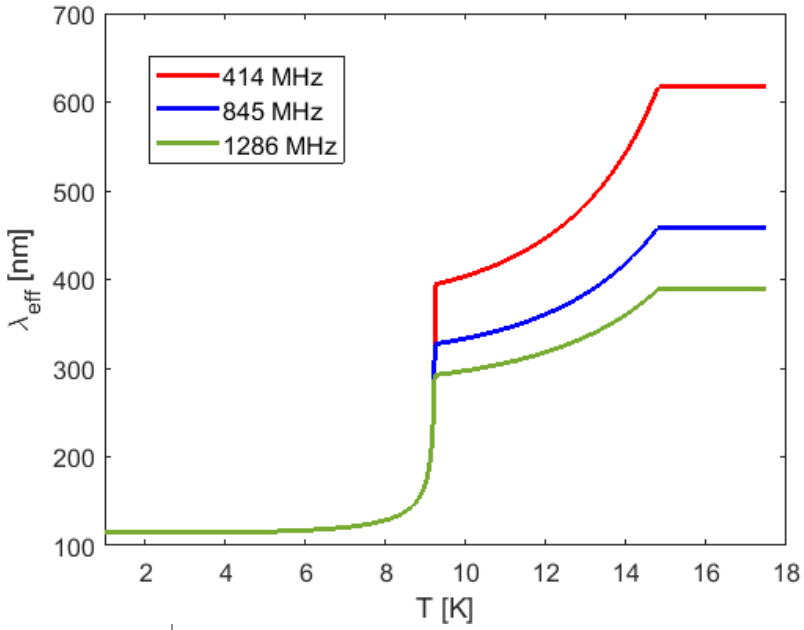
414 MHz

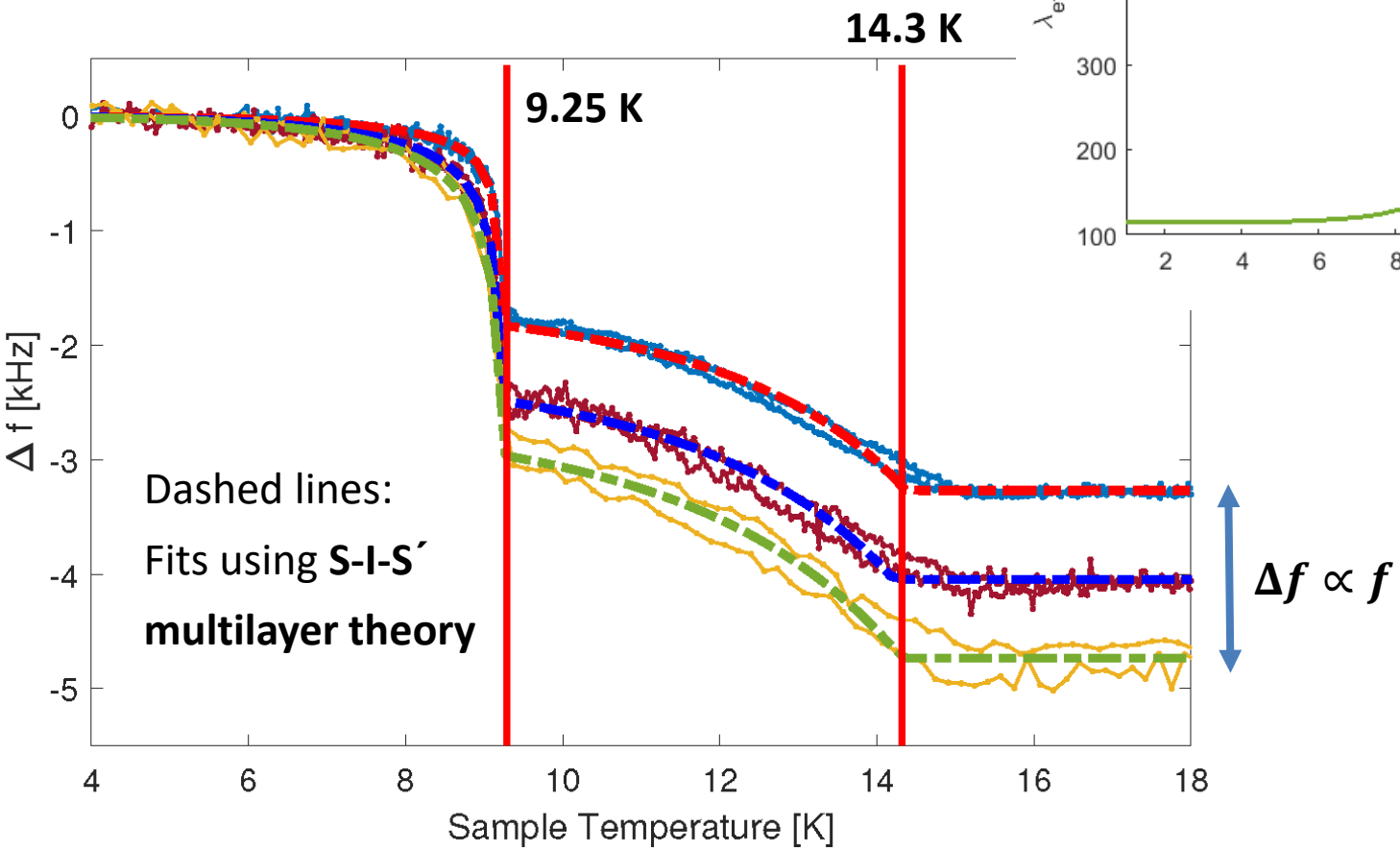
[D. Tikhonov, SRF19]

[S. Keckert, SRF'19]

S-I-S´ penetration depth

75nm NbTiN / 15nm AlN / Nb
HZB QPR, 75mm disk sample
414 MHz, 845 MHz, 1286 MHz

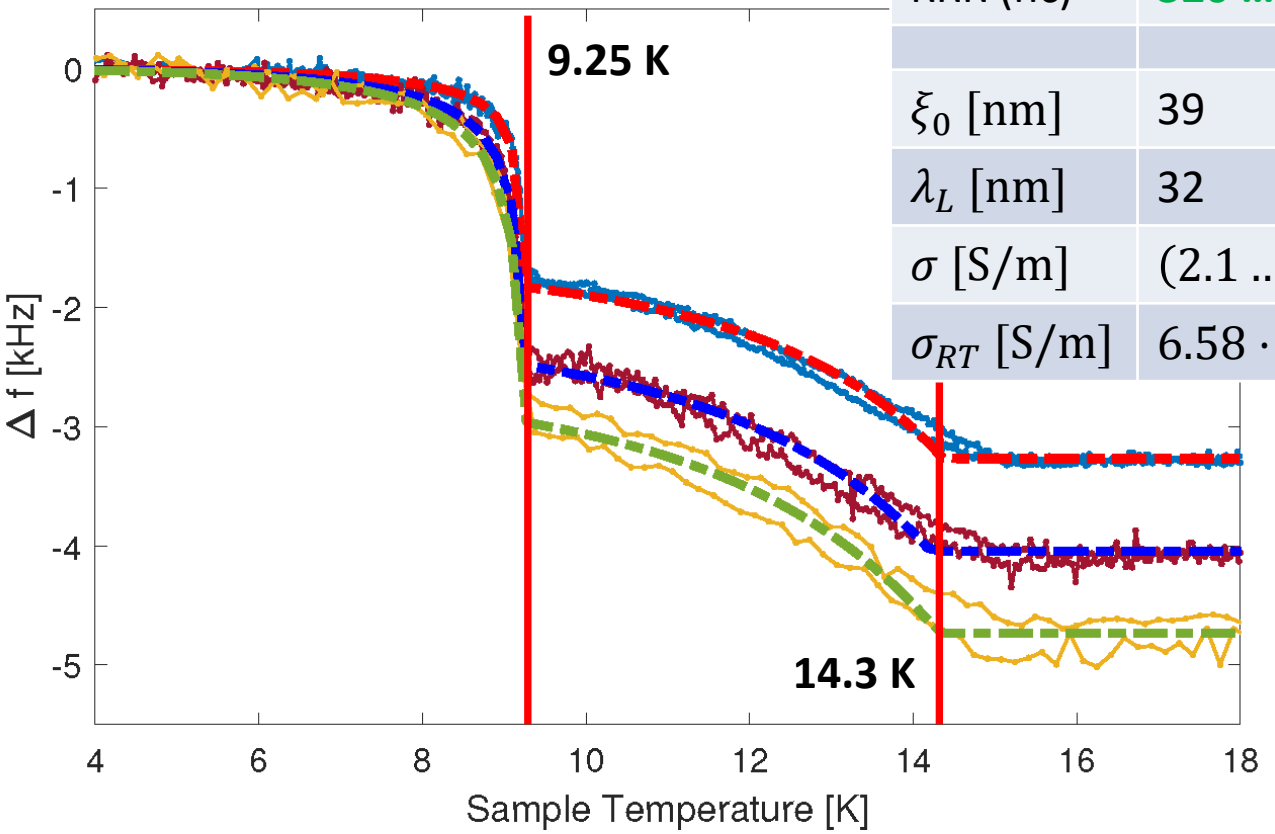




S-I-S´ penetration depth

75nm NbTiN / 15nm AlN / Nb
HZB QPR, 75mm disk sample
414 MHz, 845 MHz, 1286 MHz

	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]	$6.58 \cdot 10^6$	



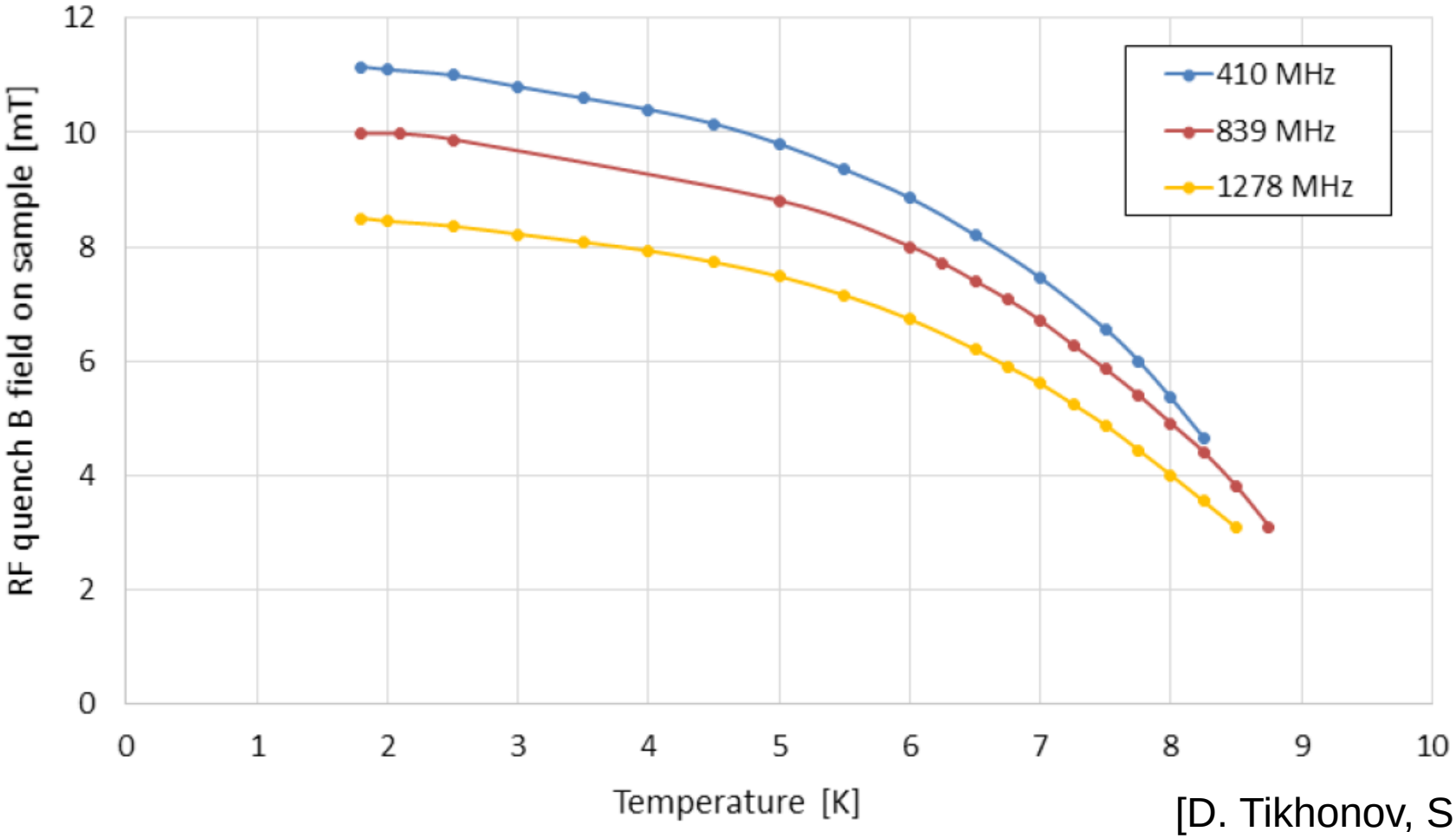
Dashed lines: Fits using
S-I-S´ multilayer theory

S-S´ RF quench field

70nm NbTiN / Nb

No insulator

HZB QPR, 75mm disk sample



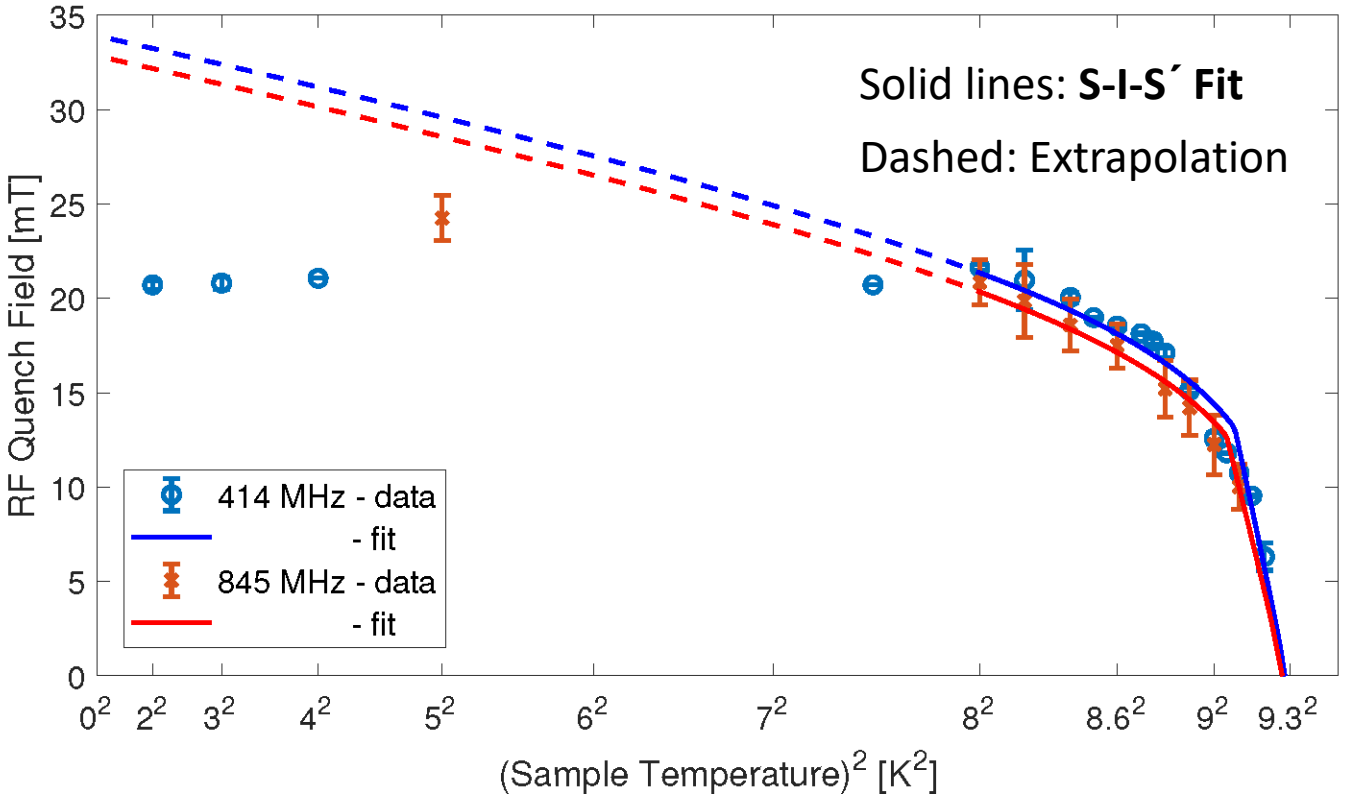
[D. Tikhonov, SRF19]

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**

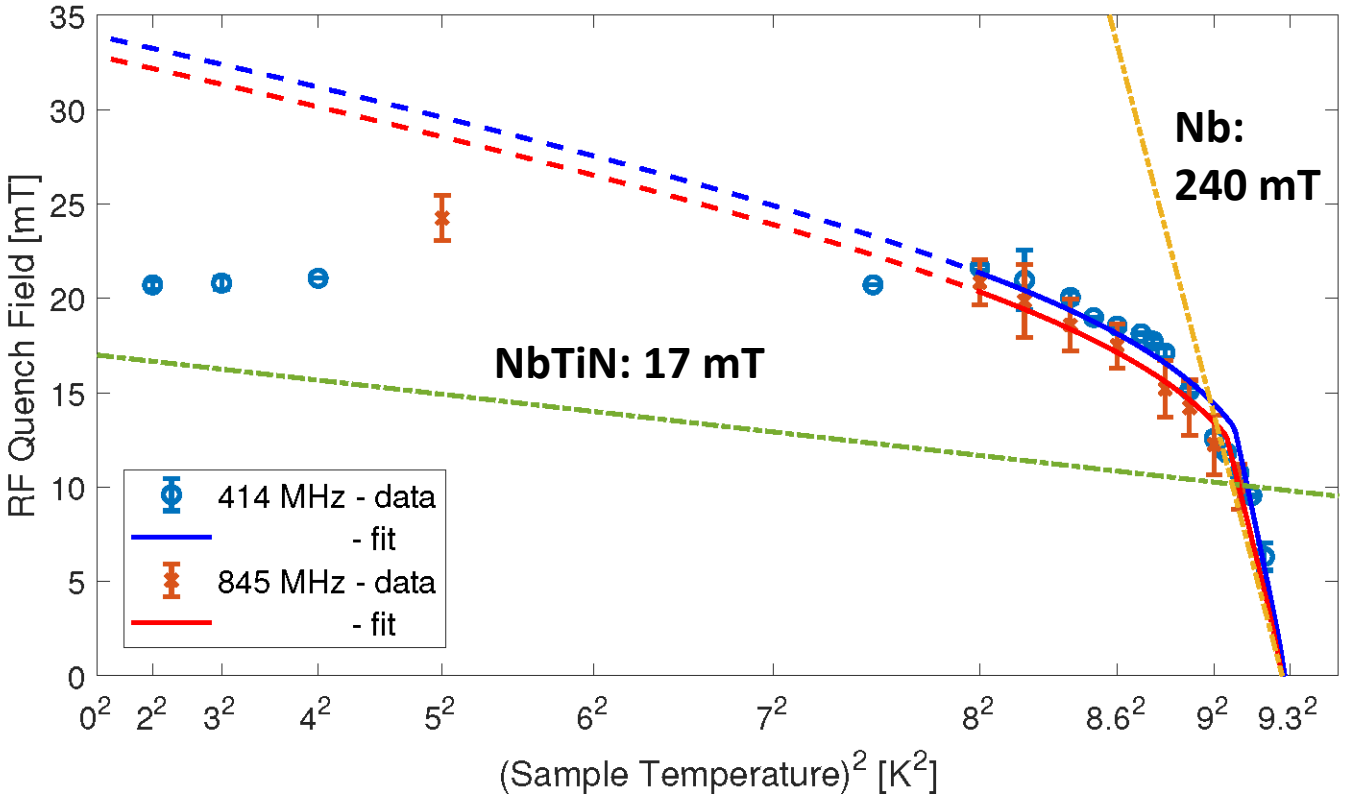


S-I-S´ RF Quench field

- 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 multilayer structures with sample test cavities

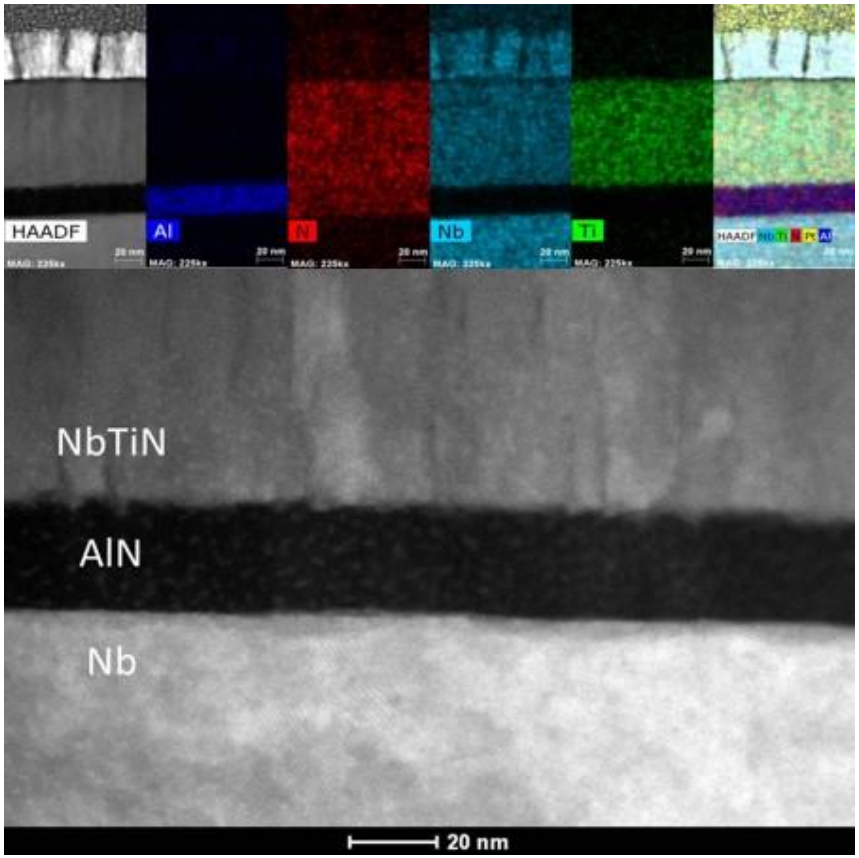
- So far: Mostly surface resistance data at high frequency and low field
- Consistently: Lower R_S than for Nb at higher temperature
  So far: Severe limitations by residual resistance
- Penetration depth measurement agrees with S-I-S´ multilayer theory
- First RF critical field measurements of S-I-S´ and S-S´ structures show low-field quenches
- We need more data on the RF quench field !

Thank you for your attention!

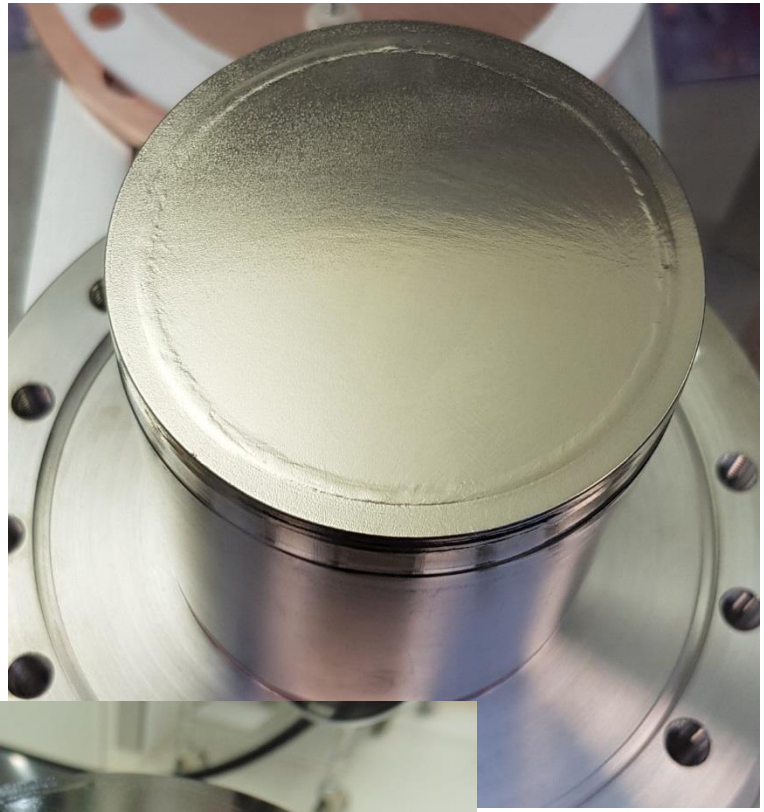
S-I-S´ Sample

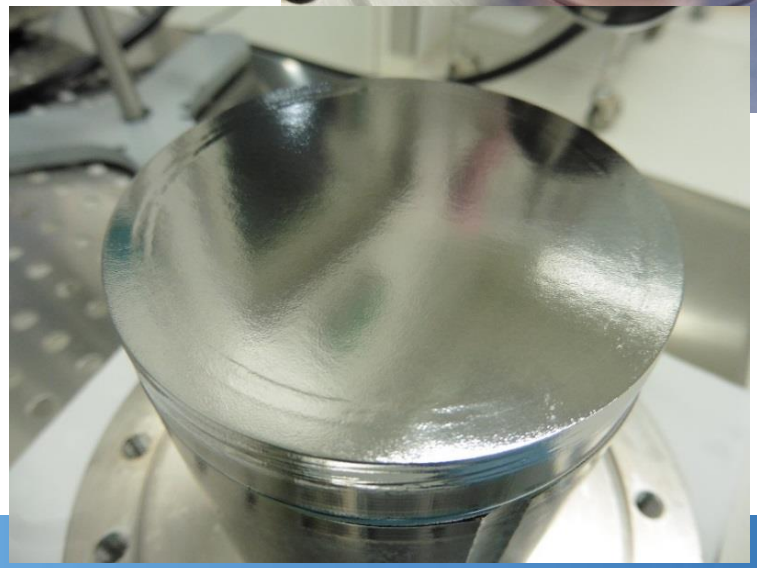
HZB Helmholtz Zentrum Berlin

75 nm NbTiN – 15 nm AlN – bulk Nb



[Courtesy of Anne-Marie Valente-Feliciano]





S-I-S´ – R(T,B) – 845 MHz