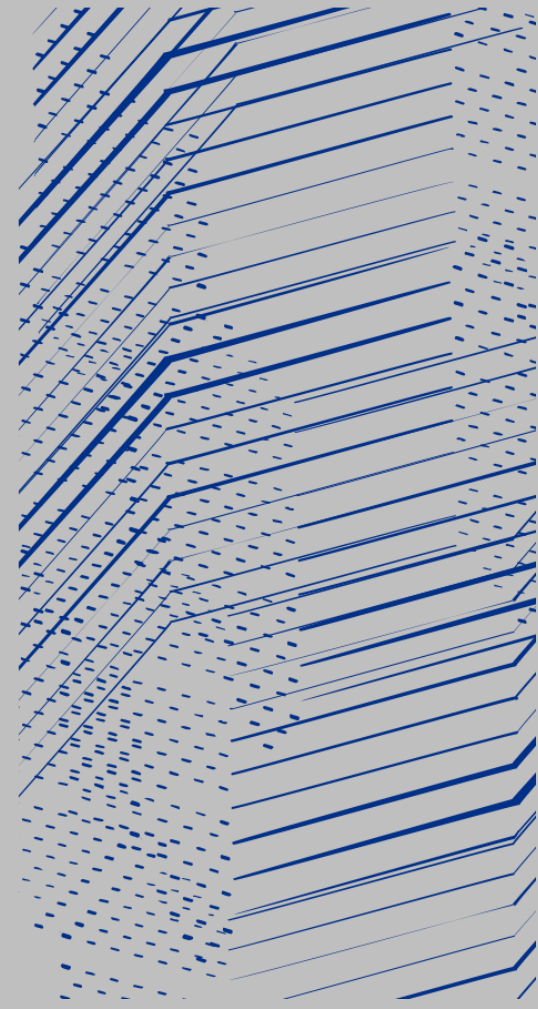


Magnetic Field Penetration Facility: Testing facility for the Characterization of Thin Film and Multi-Layers.

Author's: Liam Smith, Oleg Malyshev,
Dan Seal.



Magnetic Field Penetration Facility (MFPP).

- A testing facility to characterise Superconducting properties' of A15 Thin Film and Multi-layer structures, for RF cavity development.

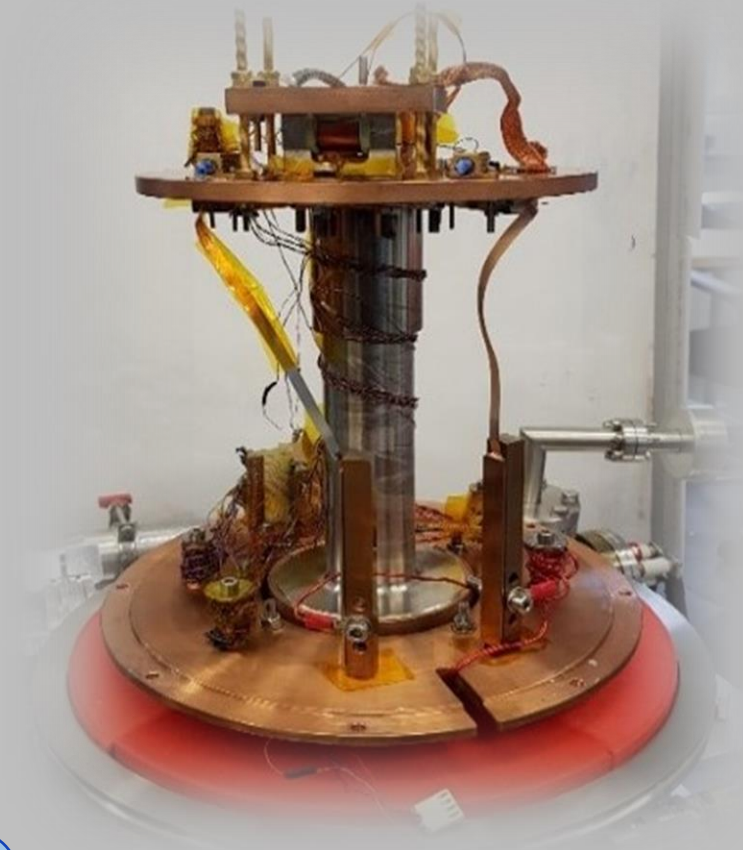
Outline.

Function of the MFPP:

- Structure and testing parameters of the facility.
- Operation.

Results and Analysis:

- Tc Analysis method.
- Bfp Analysis method.



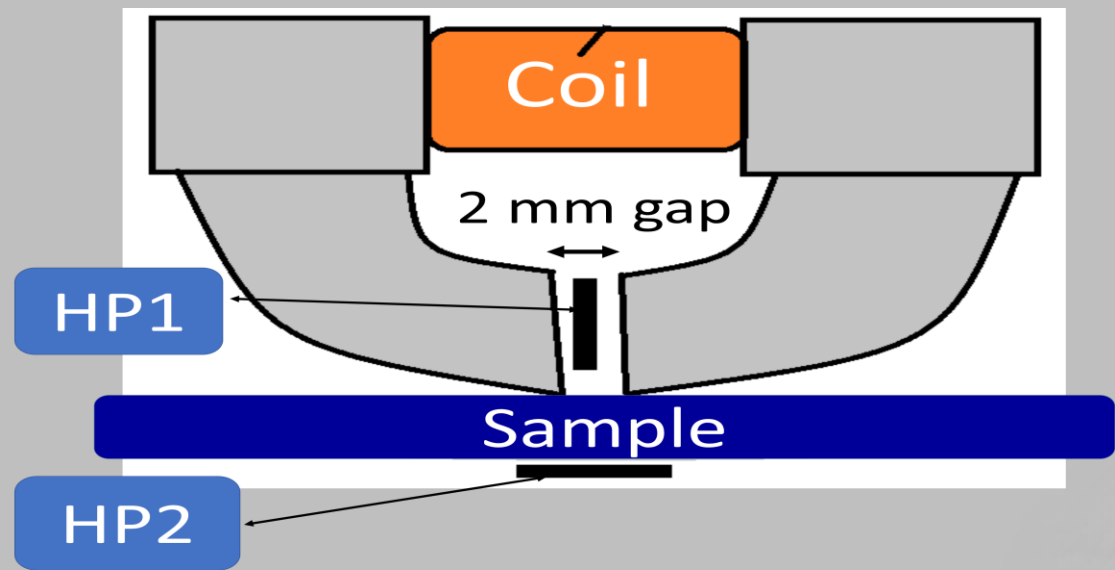
Introduction:

- Facility is stationed at Daresbury Laboratory.
- allows a practical and time efficient technique for testing TF for SRF applications.
- In operation since 2020.



Magnetic Field Penetration Concept

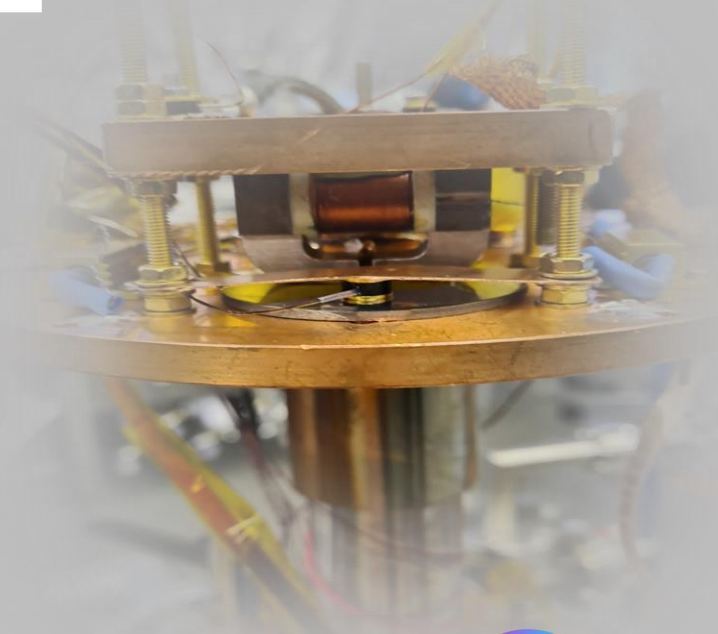
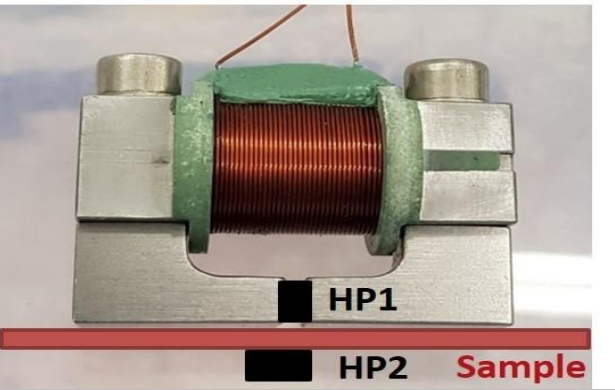
- The point of full flux penetration (B_{fp}) is defined using two Hall probes, Hp1 and Hp2. Hp1 is situated between the yoke dipoles, directly above the sample, and measures the maximum applied magnetic field B_1 , while Hp2 sits in a carved out trench, directly below the sample and measures B_{fp} .



Facility operates within the temperature range of 2.6 and 30 K.

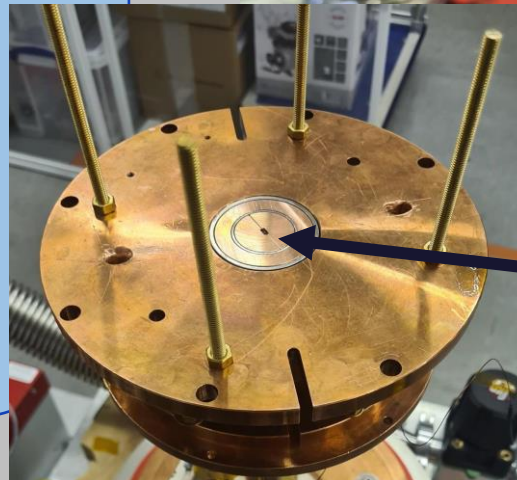
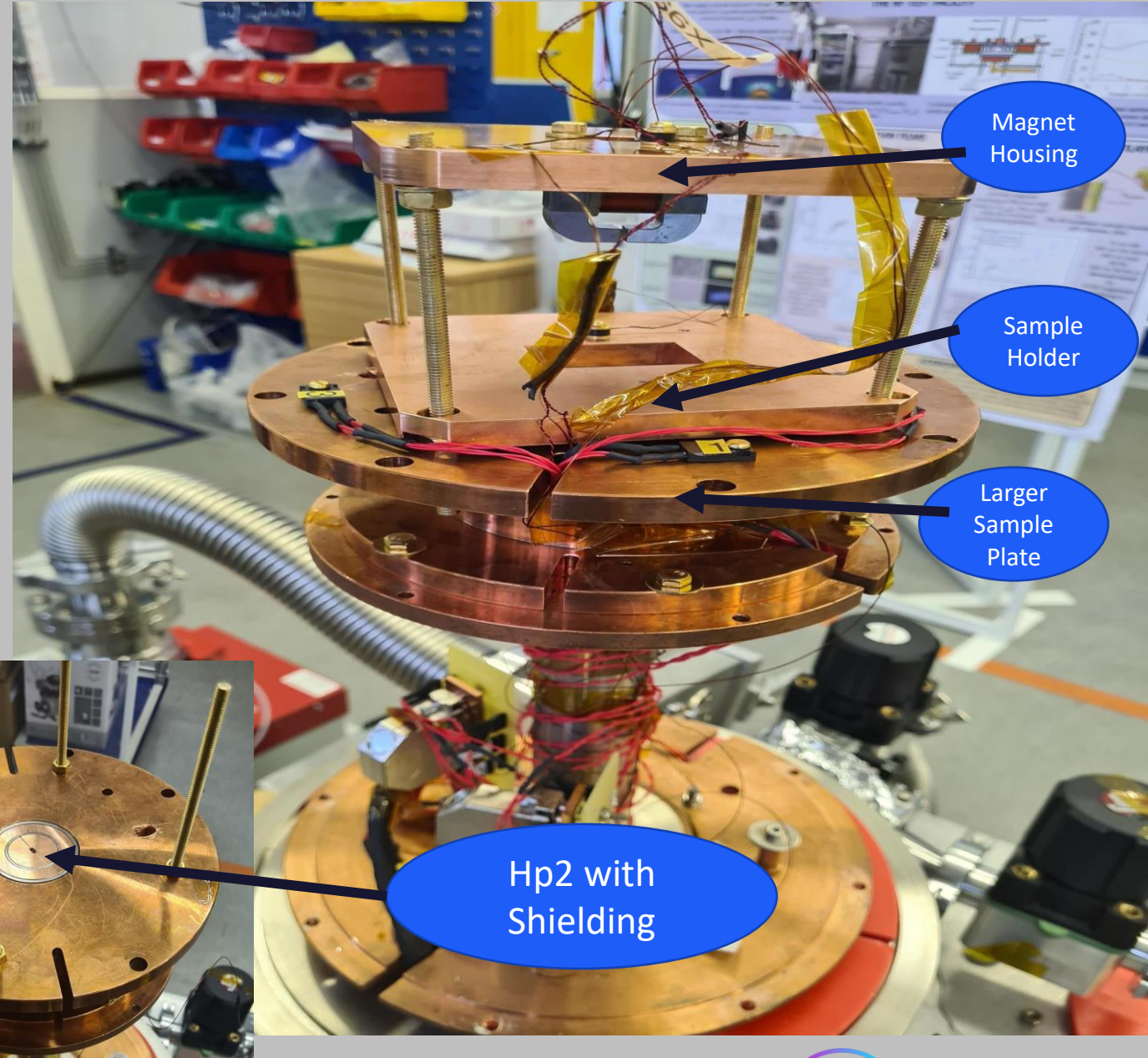
Maximum applied magnetic field (B_1) = 600 mT.

- NbTi coil produces a DC magnetic field, through a 2 mm gap in a carbon based, steel, yoke magnet, parallel to the surface of a flat sample, to replicate the conditions met by the cavity wall.



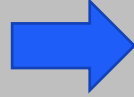
Cryogenics System

- LHe free Cryocooler
- Sample plate accommodates samples $\varnothing = 100 \text{ mm} - 30 \text{ mm}$.
- Sample holder sits around edges of the sample, to avoid film damage.
- Ability to test 6 GHz Cavity.
- New Hall probes (Paragraf sensors) with higher resolution have been installed. (Previous resolution = 0.4 – 0.7 mT, aiming for 1 order of magnitude lower).
- Hall probe Shielding has been installed:
 - $d = 30 \text{ mm}$, $w = 1 \text{ mm}$ and $L = 50 \text{ mm}$
 - $d = 50 \text{ mm}$, $w = 2 \text{ mm}$ and $L = 50 \text{ mm}$



Operation 1: T_c measurement

Chamber is pumped down to $3.5E-7$ mbar.

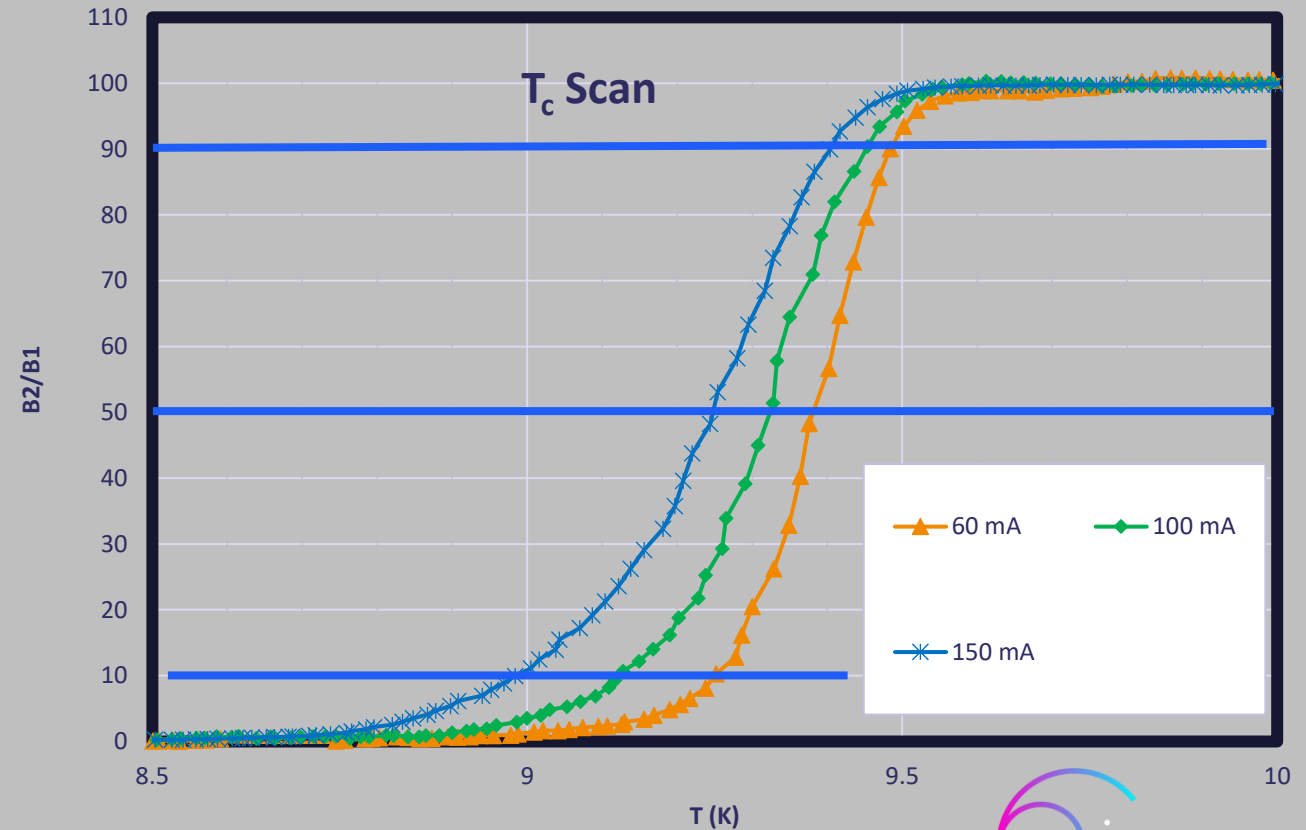
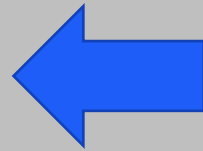


System cooled by Helium fed compressor. (2.6 K)



Temperature scan measurement applied to identify T_c .

Penetration measurement carried out based on temperature set points established from T_c measurement.

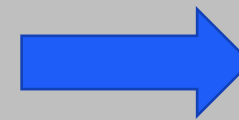


Operation 2 Penetration Field Measurements at Fixed Temperature

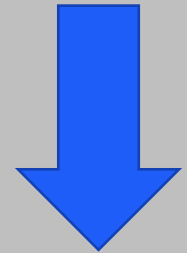
Temperature set point in the range between:
2.6 K – 10 K



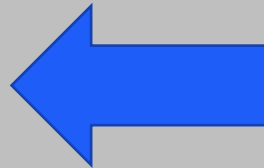
Ramp up B_1 until at least
 $B_2 > 4 \text{ mT}$



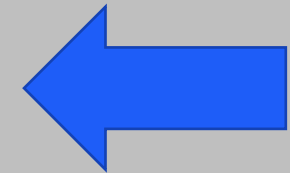
Degauss magnet



Ramp down to next
Temperature Set Point.

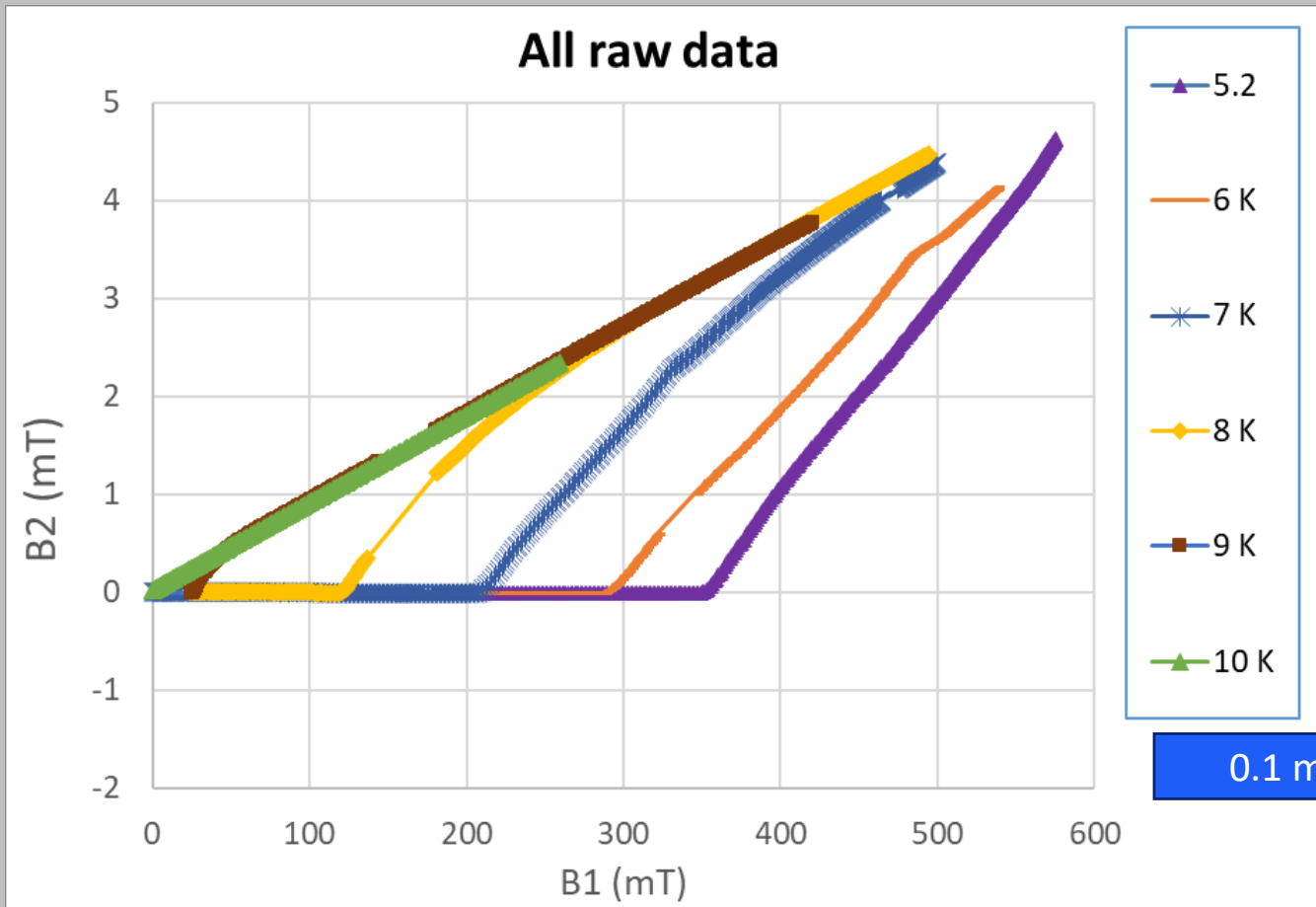


Temperature ramp up
to $T > T_c$
(Demagnetise
sample.)

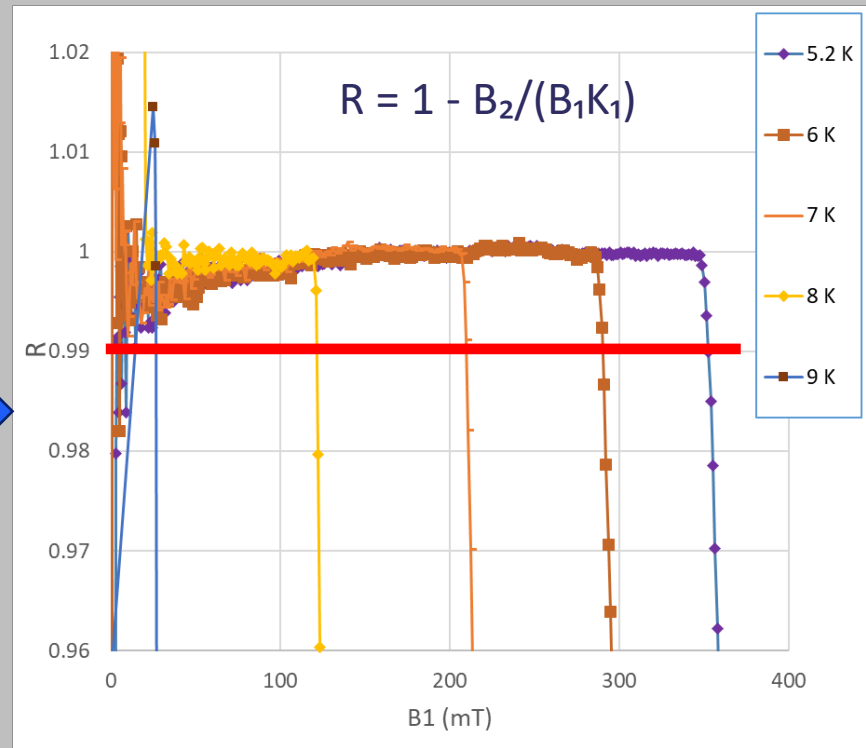


Analysis Method

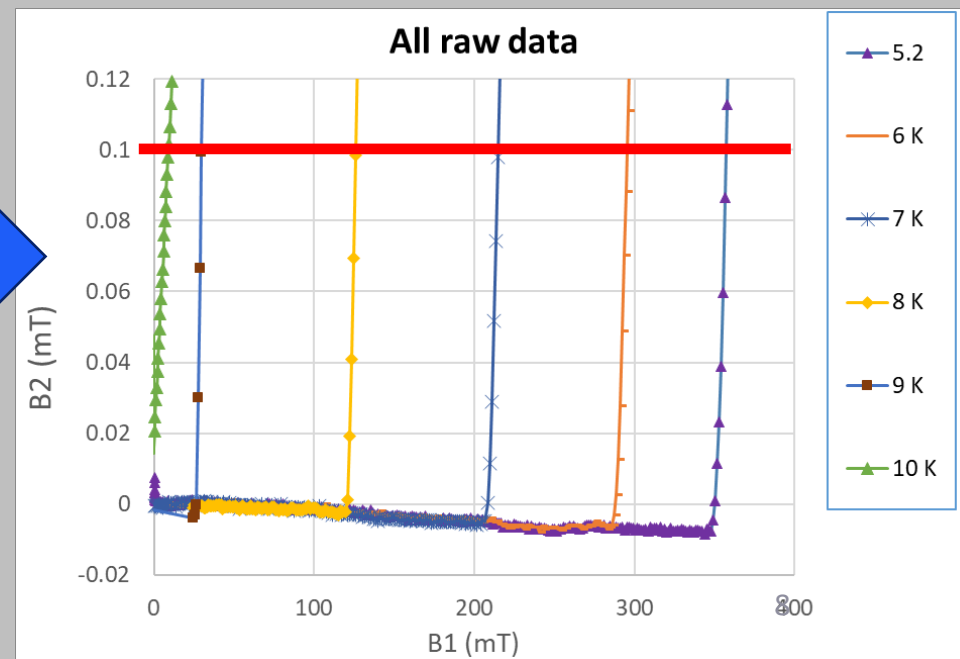
Bulk Nb



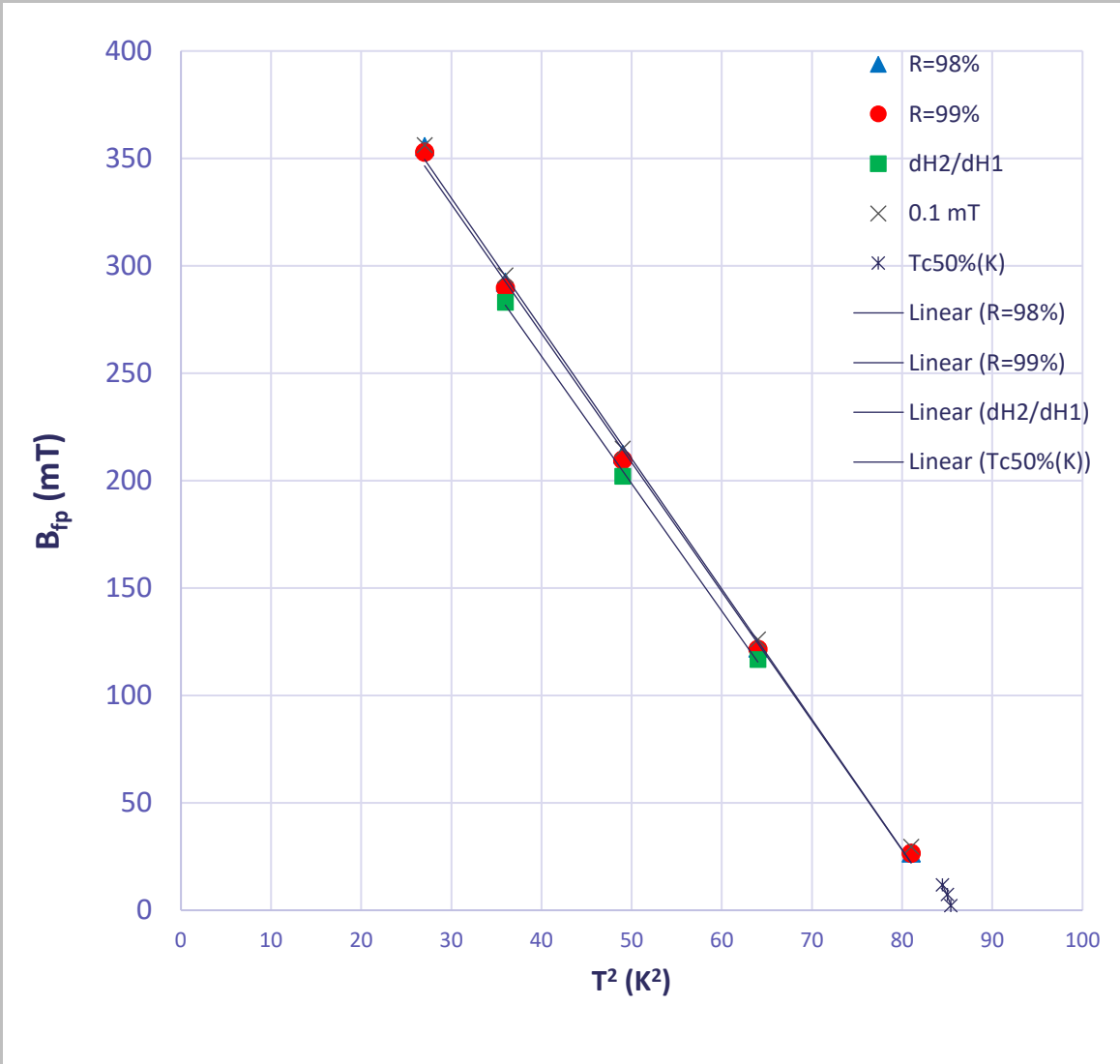
R method



0.1 mT method



Bulk Nb results

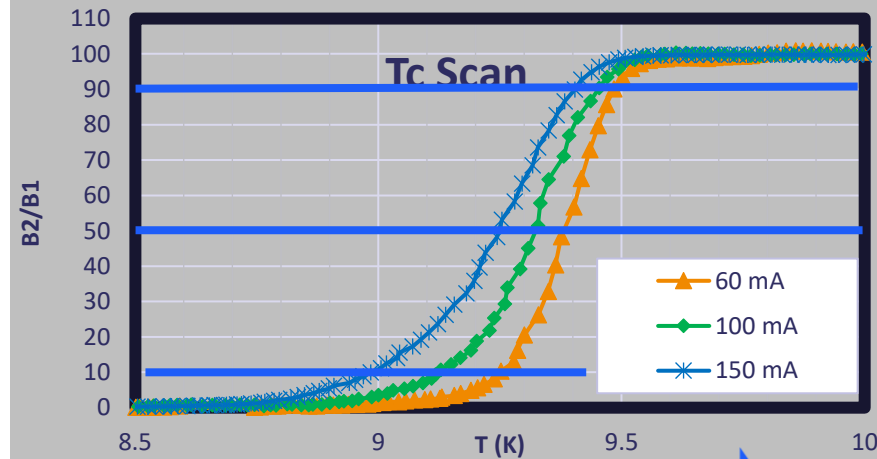


Extrapolation from MFP runs

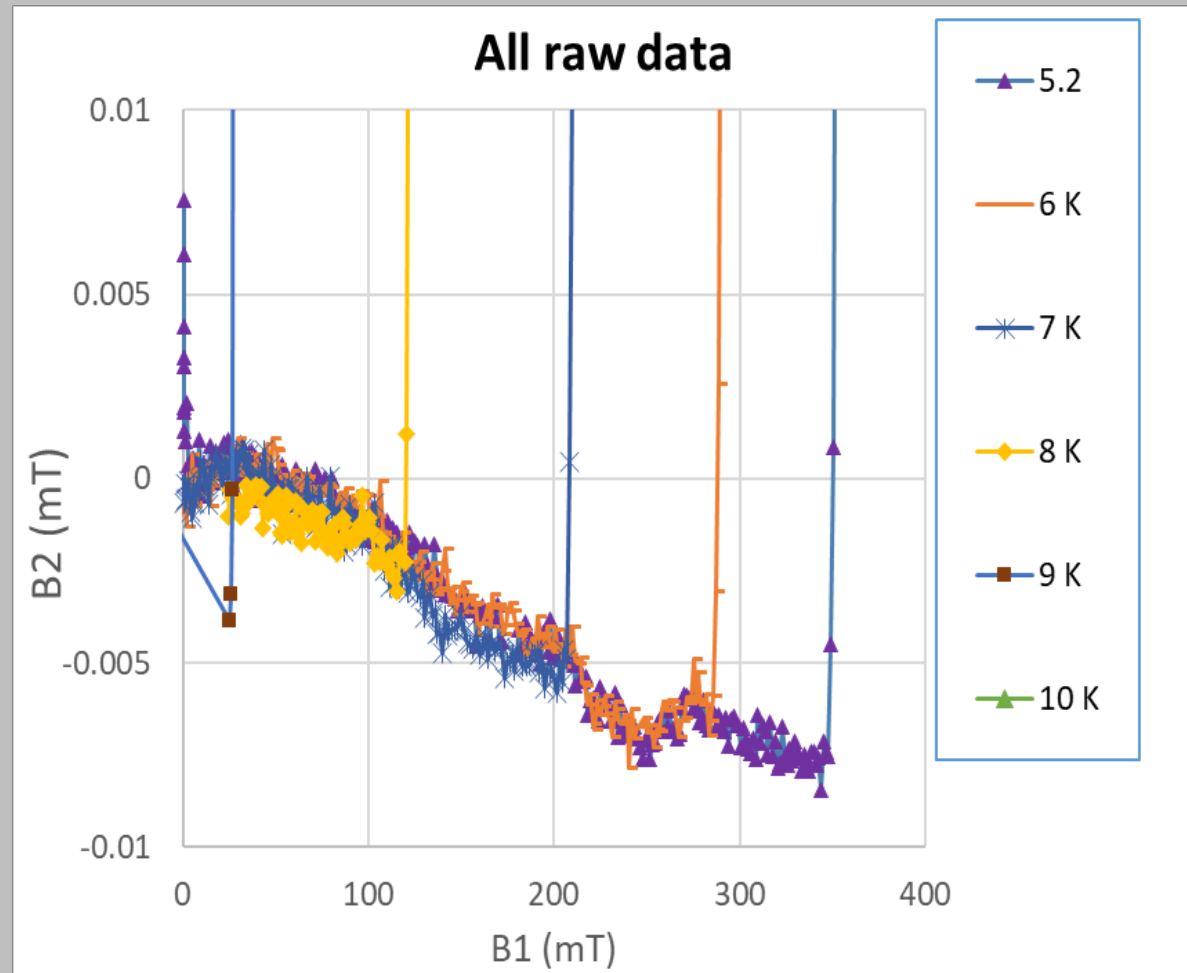
	98%	99%	dB2/dB1	0.1 mT
a	-6.07	-6.01	-6.13	-6.03
B _{fp} (0K)=	513.55	509.12	506.37	514.58
T _c (0mT) =	9.20	9.20	9.09	9.23
B _{fp} (4.2K)=	406.55	403.06	398.17	408.15

From T_c measurements

T _c	" $+\Delta T$ "	" $-\Delta T$ "
9.254	0.032	0.032

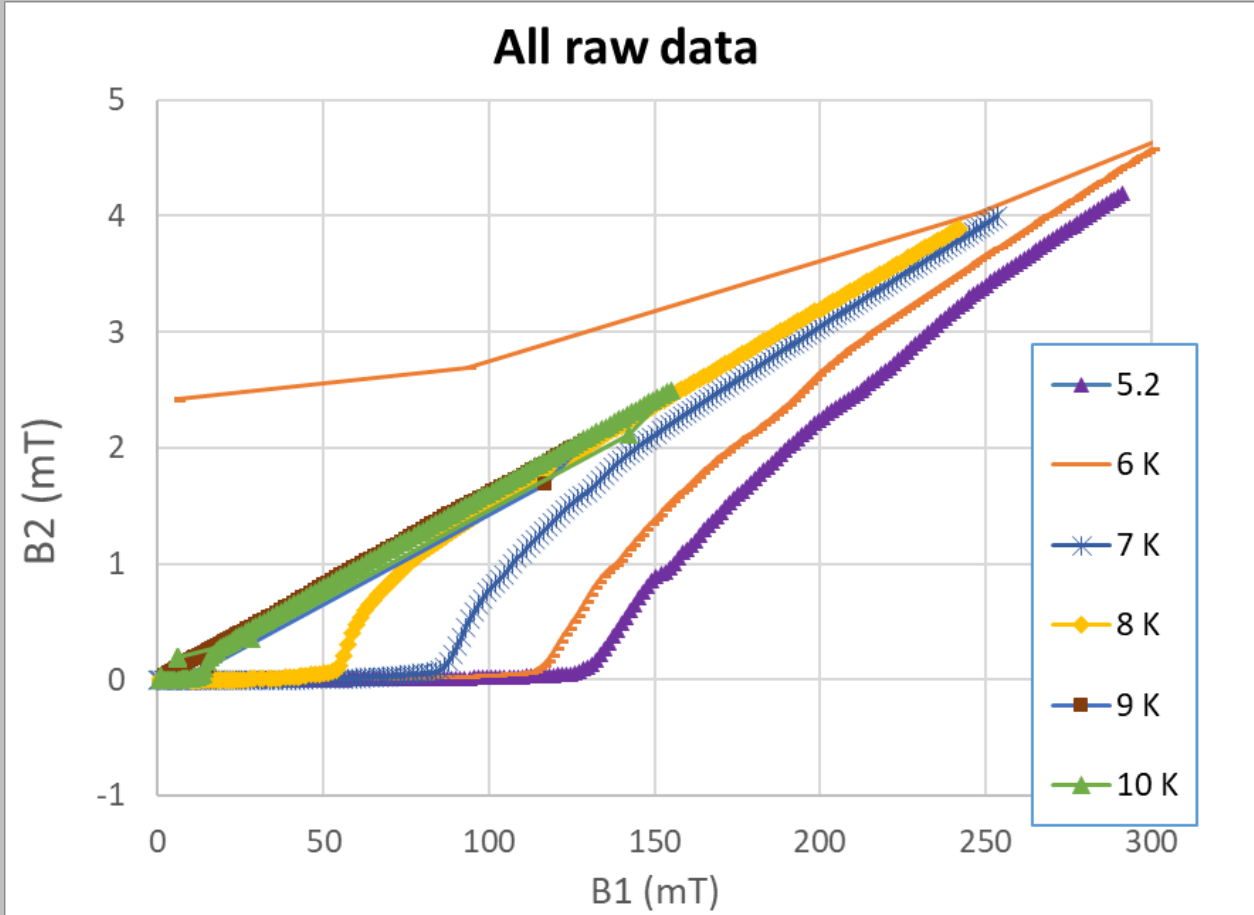


Negative slope on Bulk Nb

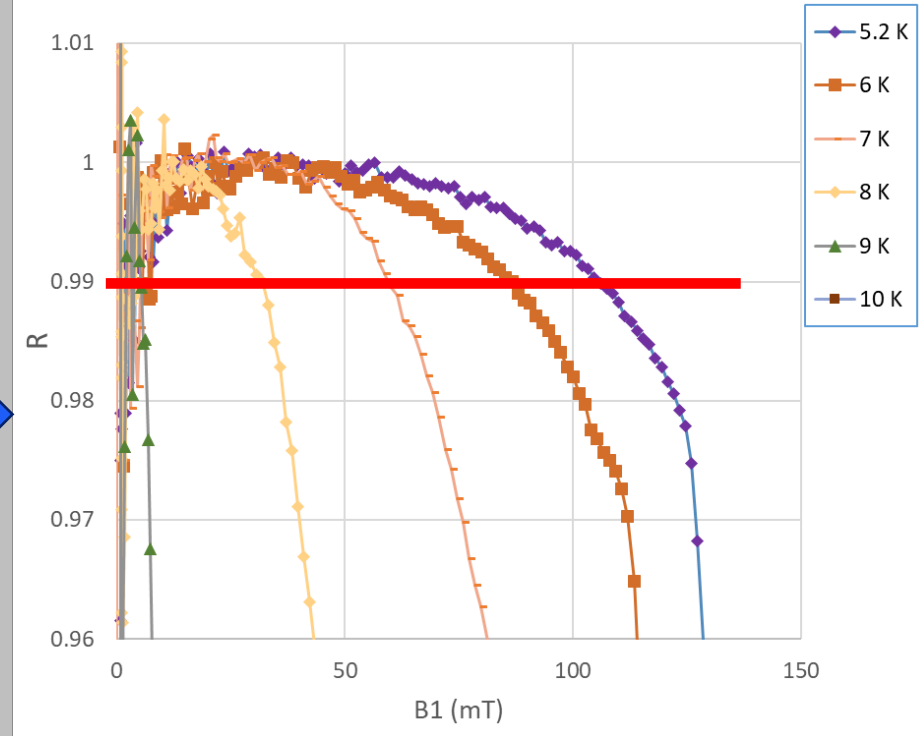


Thin film: Nb L19

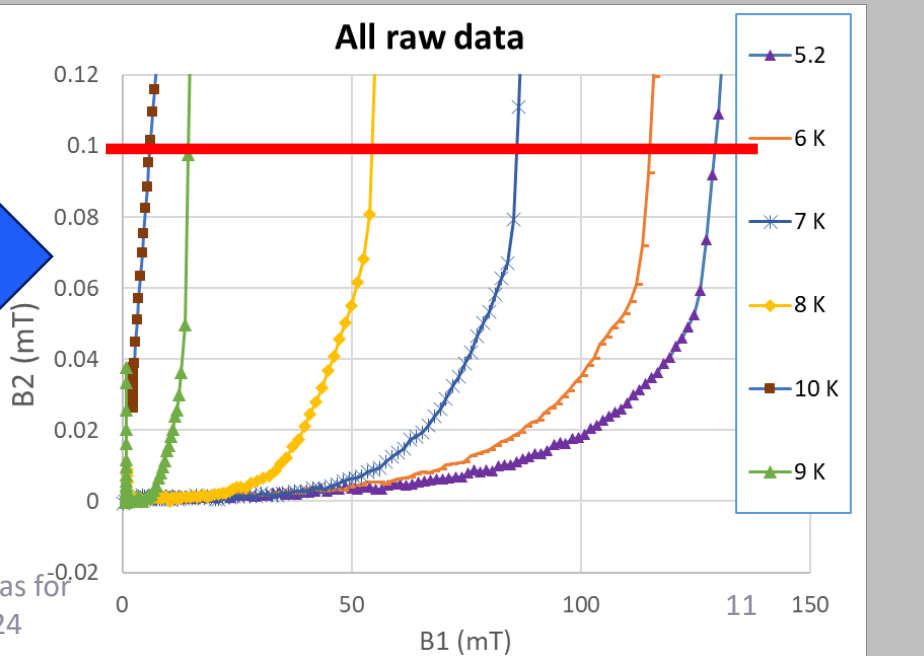
All raw data



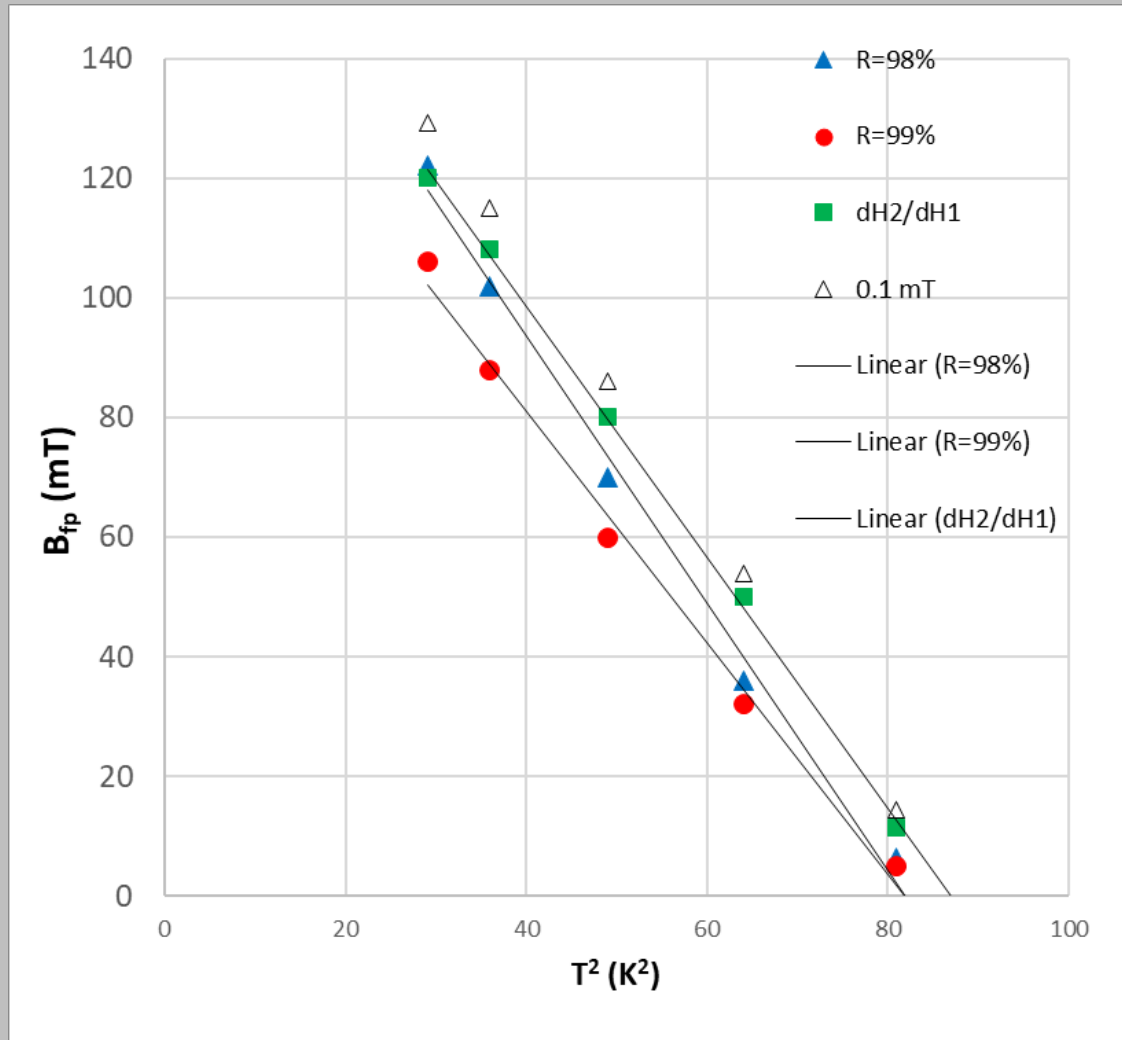
R method



0.1 mT method

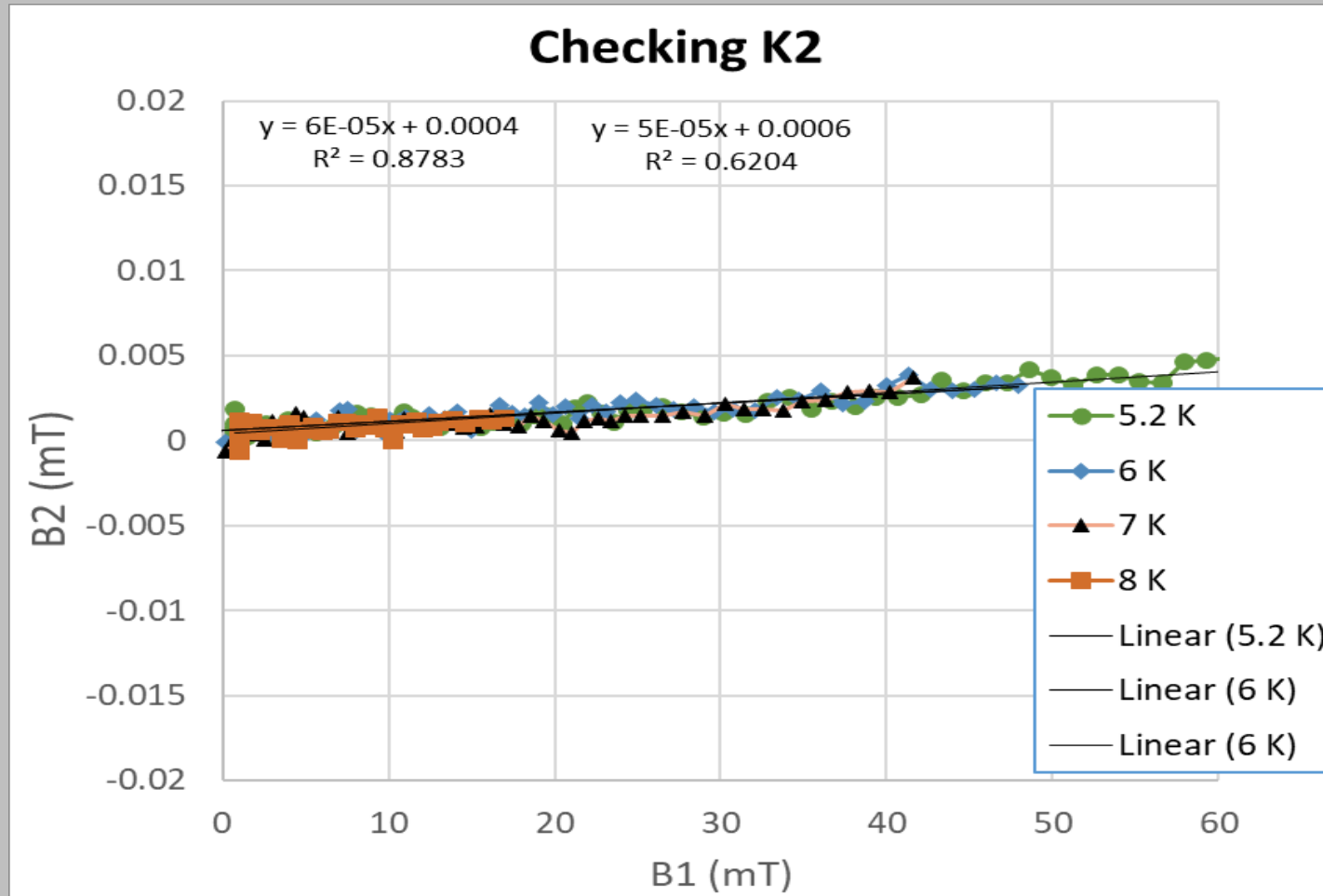


Nb L19 results

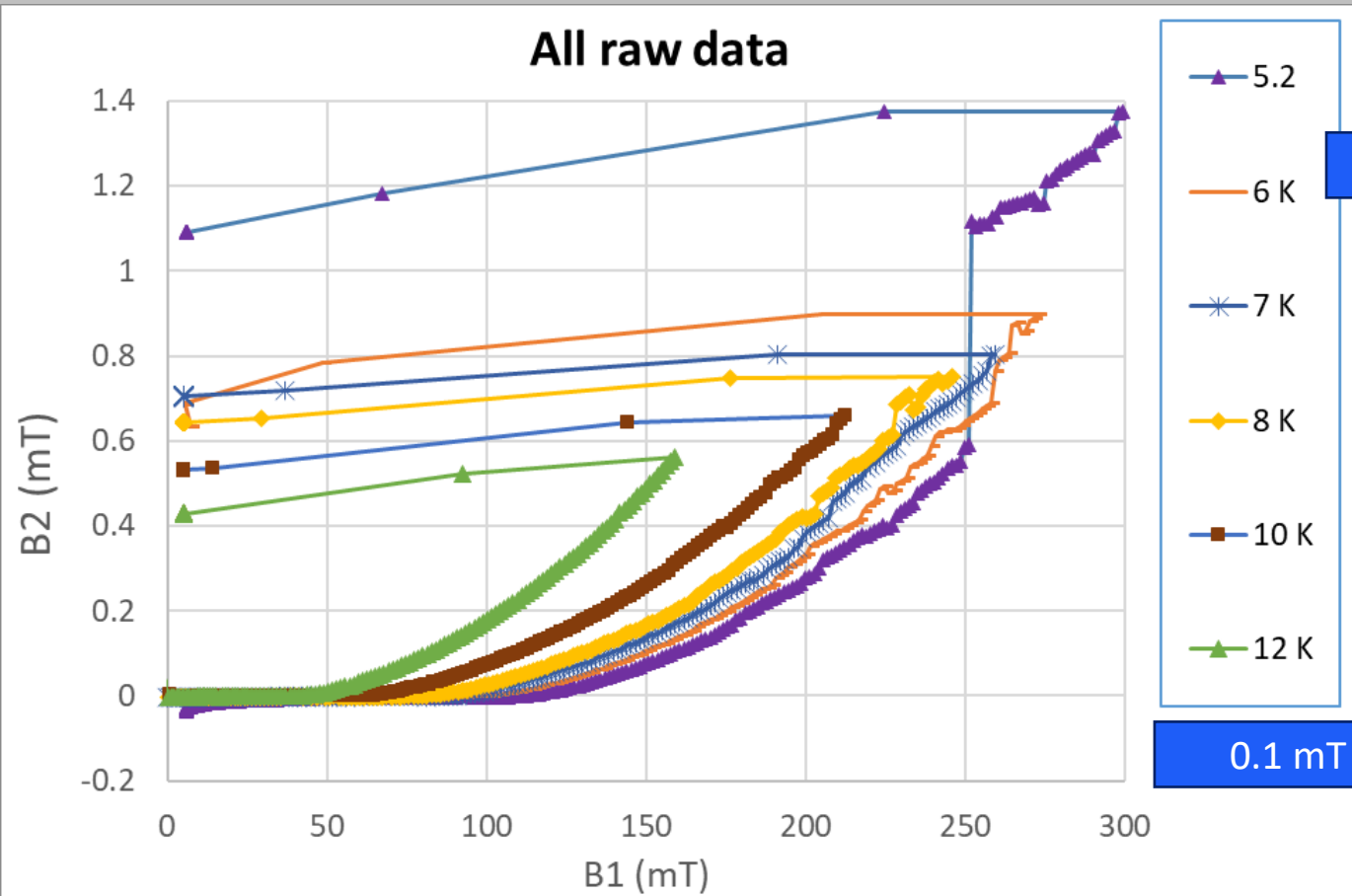


Summary for B _{fp} measurements				
	98%	99%	dB2/dB1	0.1 mT
a	-2.23054	-1.93519	-2.09606	-2.20908
B _{fp} (0K)=	182.9131	158.5247	182.5431	194.2412
T _c (0mT) =	9.055613	9.050796	9.332127	9.377015
B _{fp} (4.2K)=	143.5665	124.388	145.5685	155.273

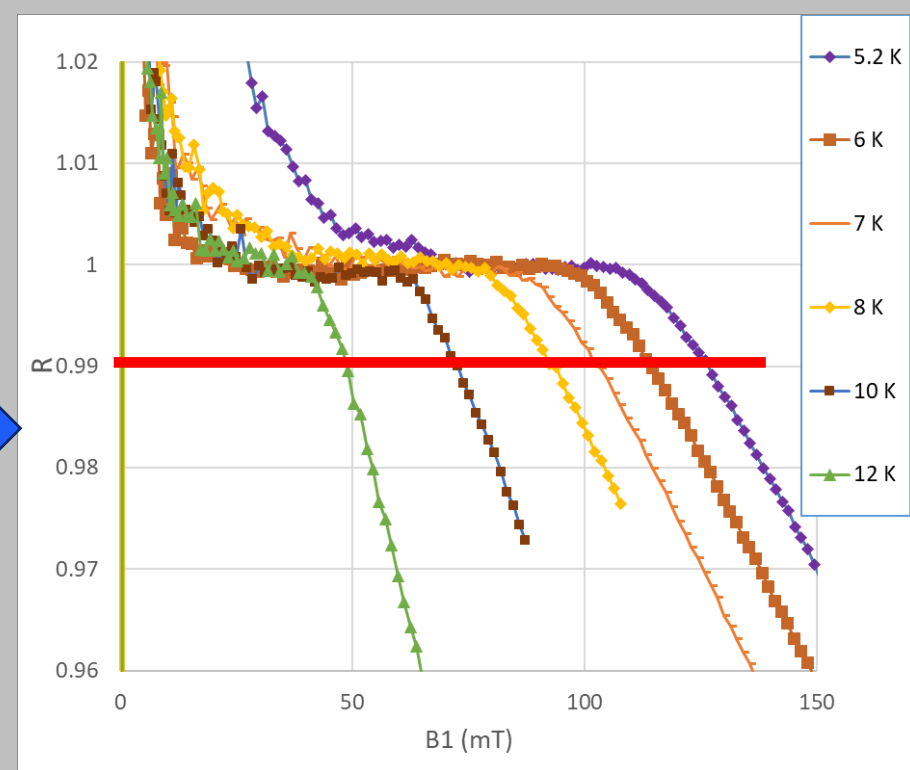
Weak positive slope on Nb L19



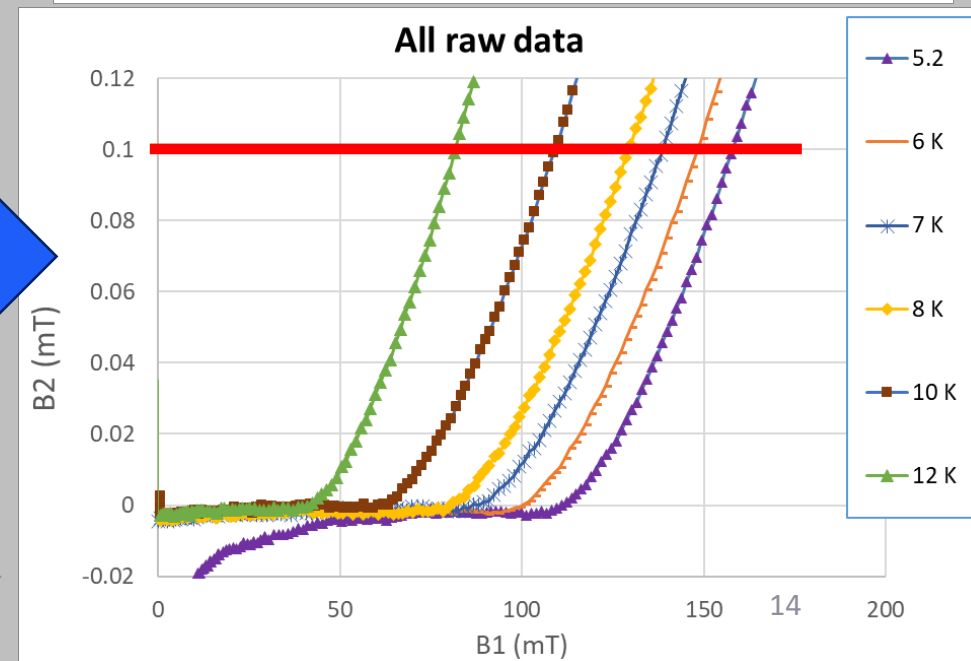
Nb₃Sn/Sapphire



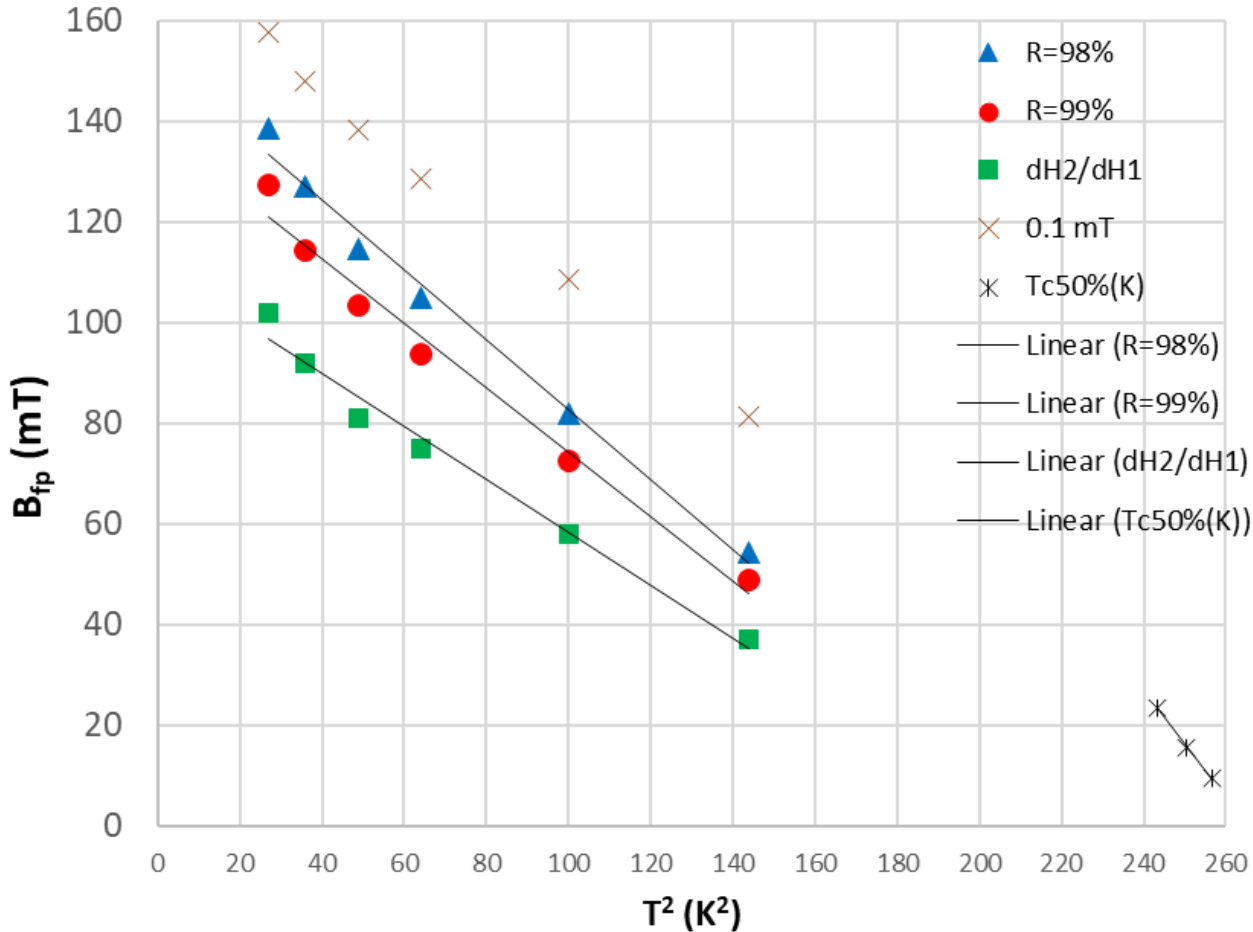
R method



0.1 mT method



Nb₃Sn/Sapphire results



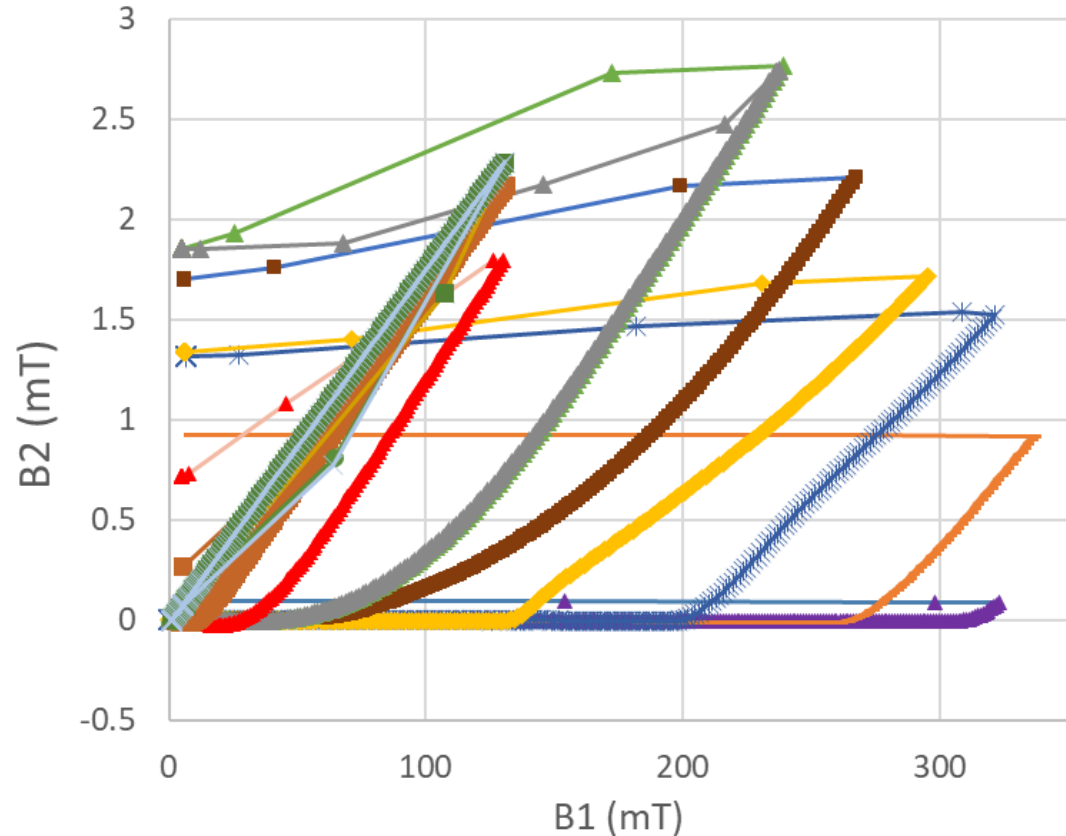
Summary for B_{fp} measurements

	98%	99% dB2/dB1	0.1 mT	
a	-0.69	-0.64	-0.53	-0.63
B _{fp} (0K)=	152.05	138.24	111.01	171.10
T _c (0mT) =	14.82	14.70	14.52	16.50
B _{fp} (4.2K)=	139.84	126.96	101.72	160.01

Summary for T_c measurements

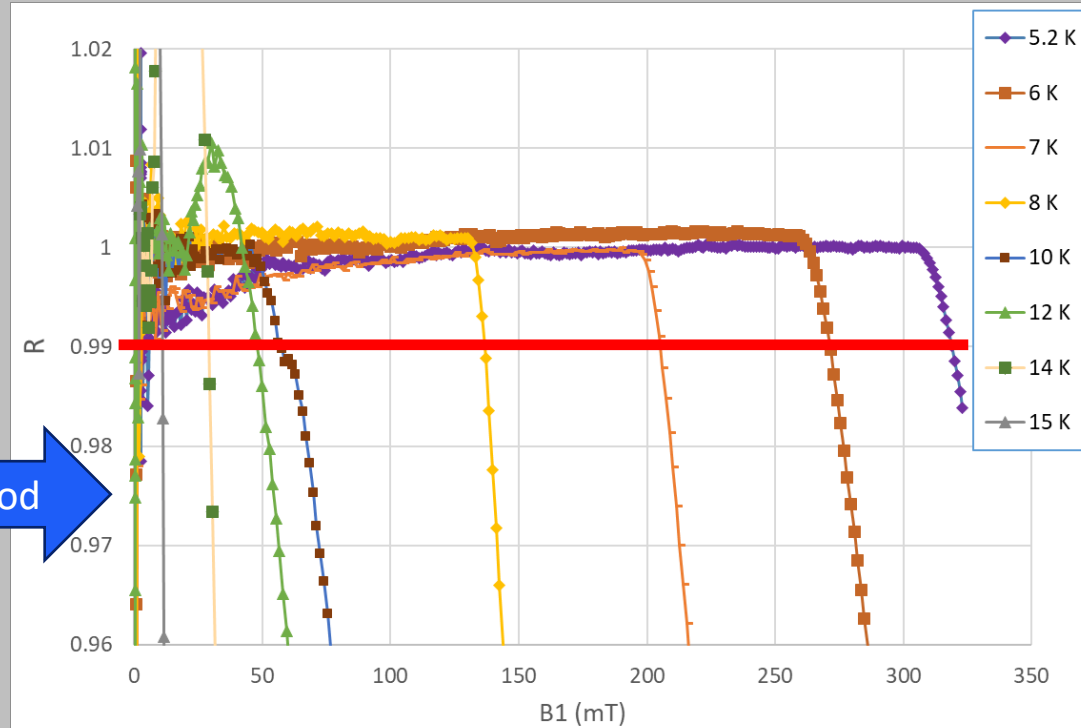
T _c	" $+\Delta T$ "	" $-\Delta T$ "
16.289	0.252	0.280

All raw data



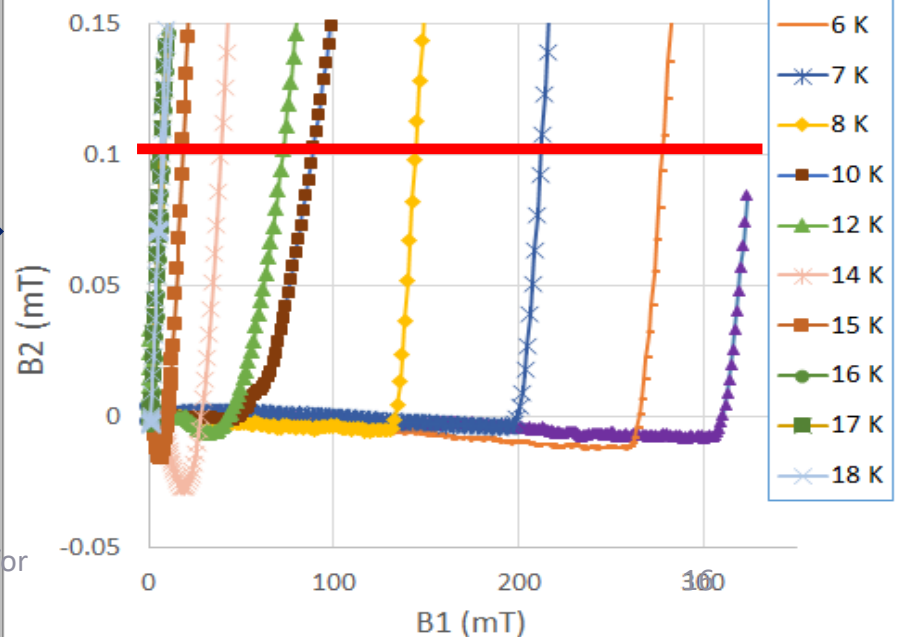
- 5.2 K
- 6 K
- 7 K
- 8 K
- 9 K
- 10 K
- 12 K
- 14 K
- 15 K
- 16 K
- 17 K
- 18 K

R method

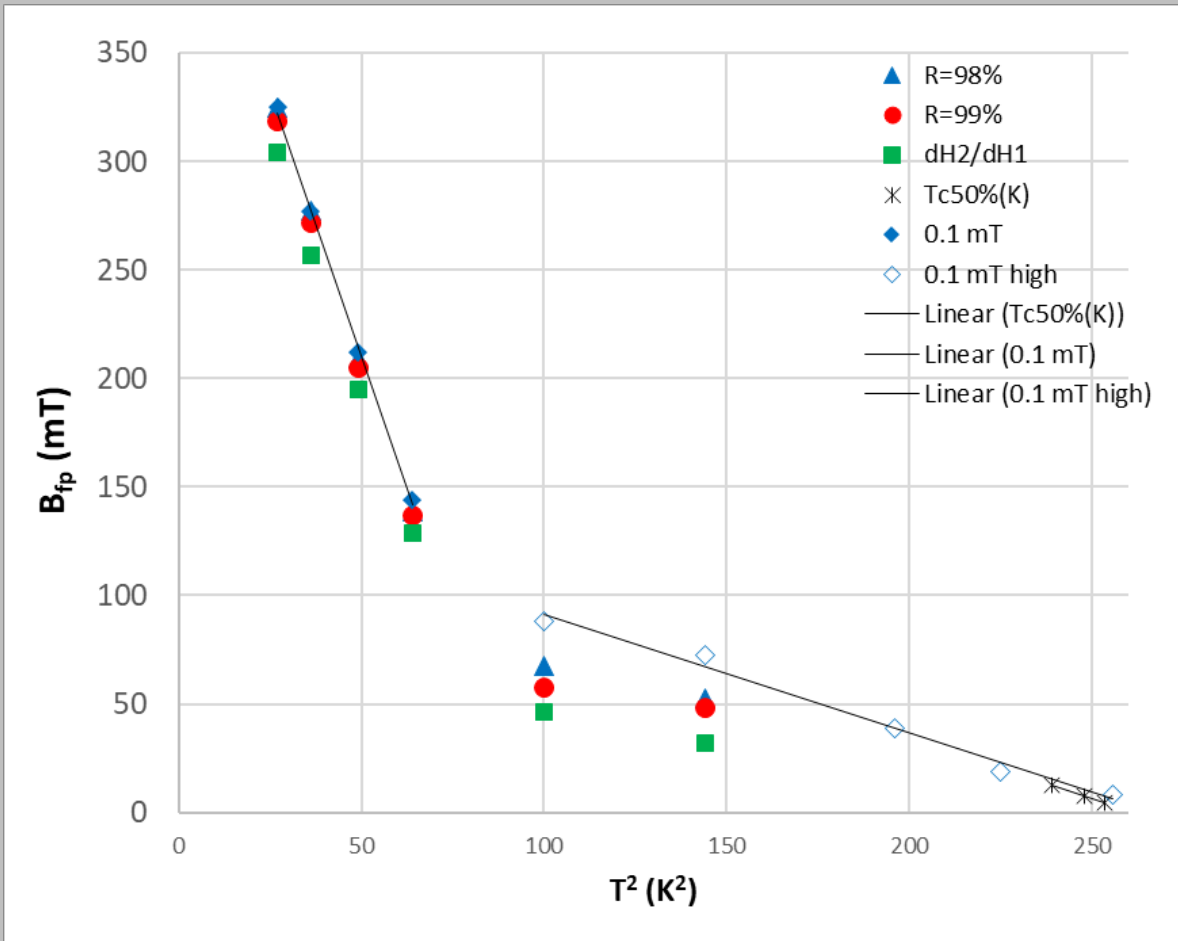


0.1 mT method

All raw data



Nb₃Sn on Bulk Nb - results



Summary for B _{fp} measurements					
	98%	99%	dB2/dB1	0.1 mT low	0.1 mT high
a	-5.04	-4.92	-4.72	-5.14	-0.54
B _{fp} (0K)=	459.21	449.72	428.97	463.12	145.30
T _c (0mT) =	9.55	9.56	9.53	9.50	16.37
B _{fp} (4.2K)=	370.34	362.89	345.71	372.53	135.73

Bulk Nb

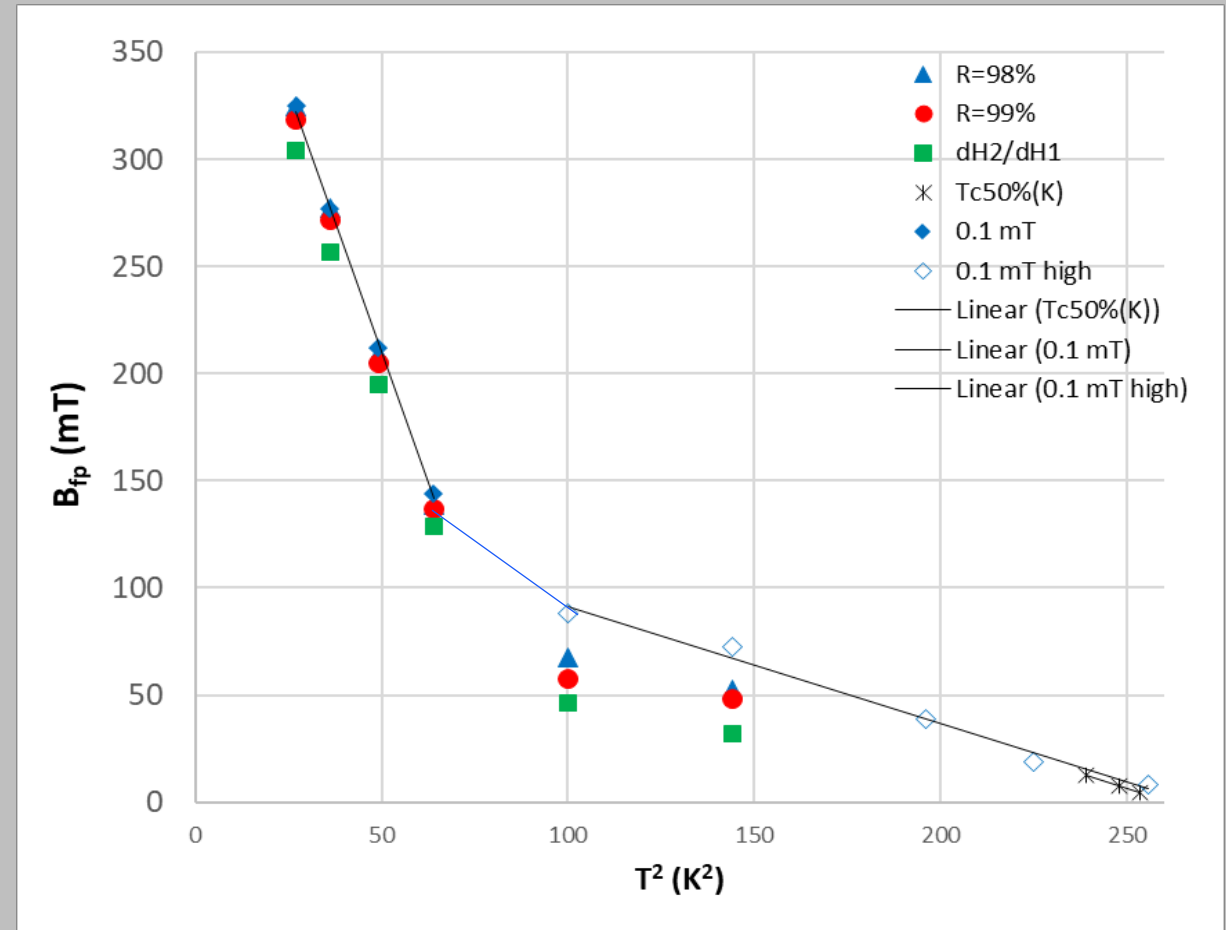
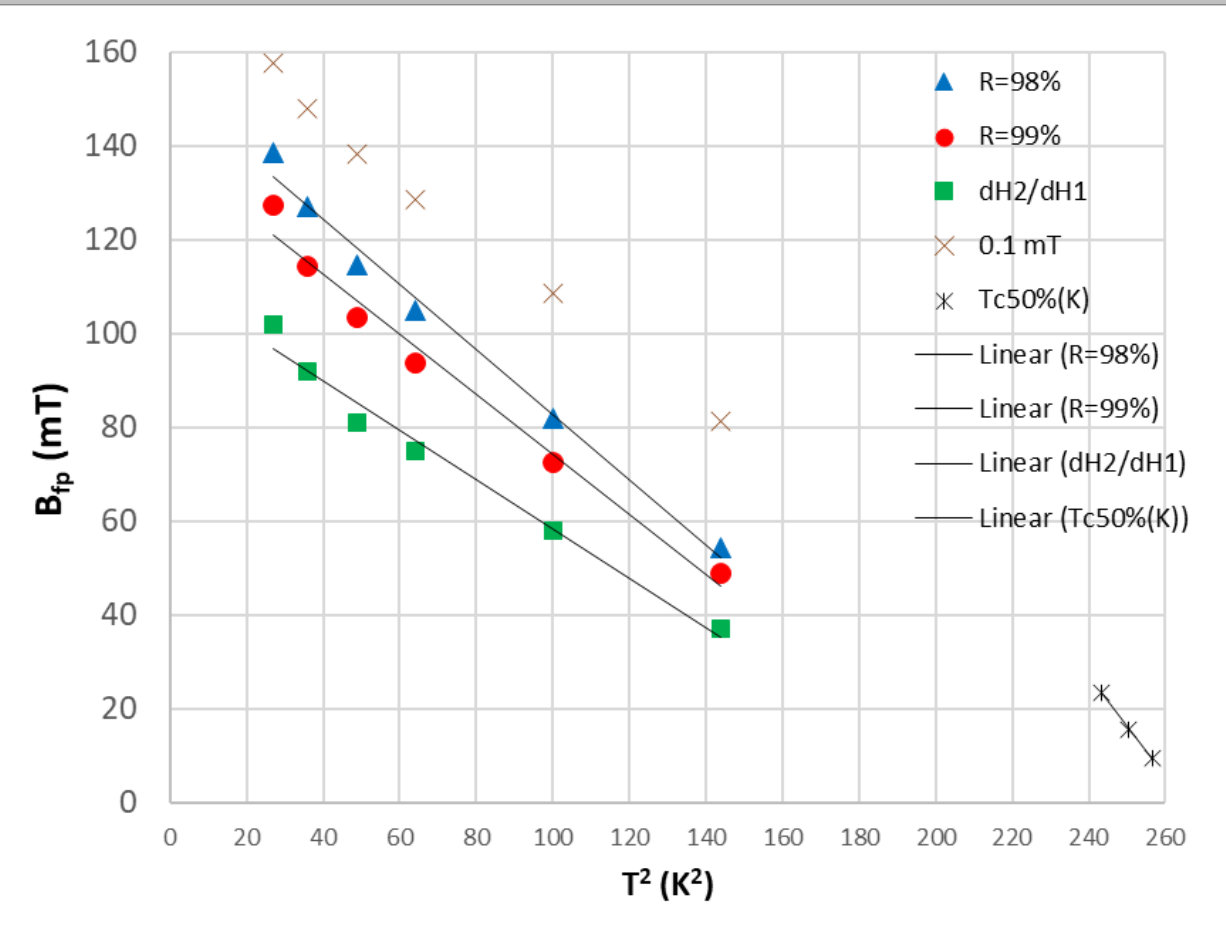
Nb₃Sn

Summary for T_c measurements

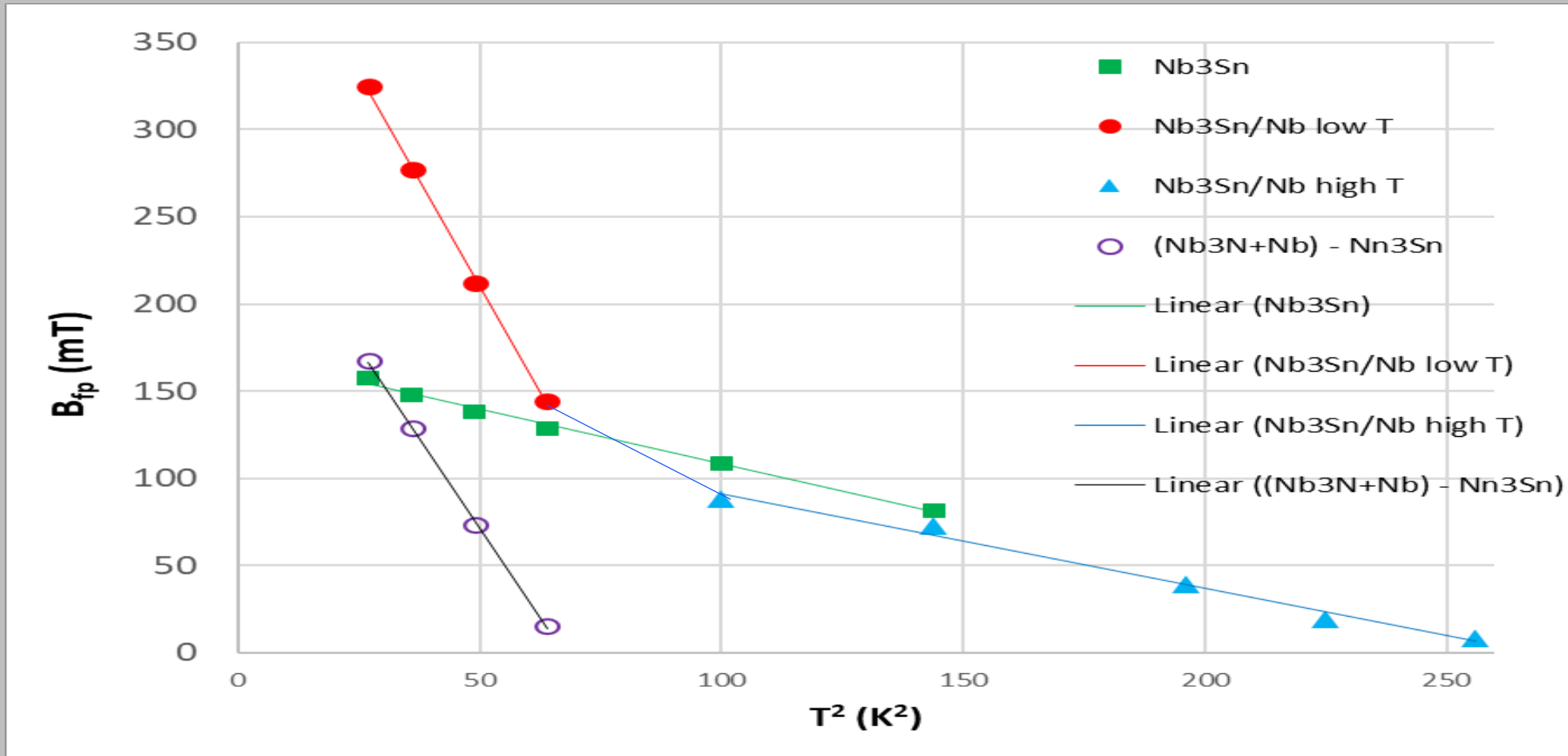
T _c	" $+\Delta T$ "	" $-\Delta T$ "
16.201	0.360	0.261

Nb₃Sn/Sapphire

Nb₃Sn/Nb



Summary for Nb₃Sn/Sapphire and Nb₃Sn/Nb



Conclusion

- A testing facility to characterise Superconducting properties' of A15 Thin Film and Multi-layer structures, for development of SRF cavity.
- Allows a practical and time efficient technique to evaluate screening efficiency of strong magnetic field of STF: B_{fp} and T_c .
- Results and Analysis have been demonstrated.



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