Results of laser polishing using the field penetration experiment

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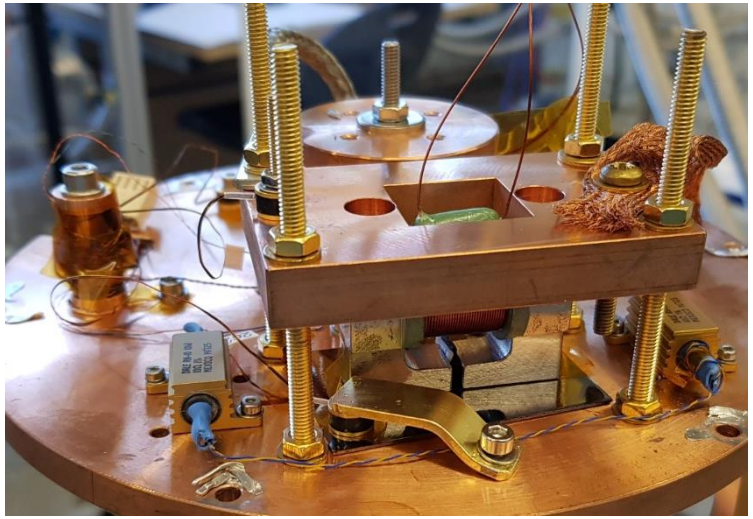
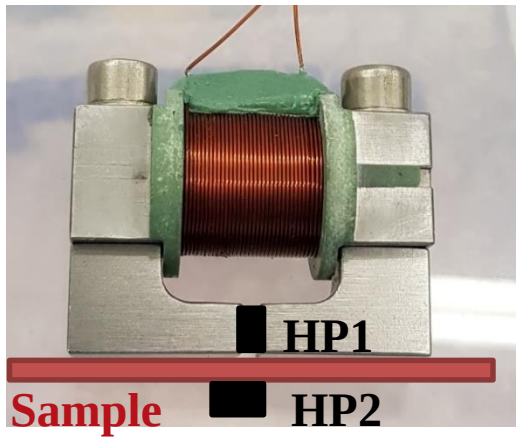
Laser polished samples

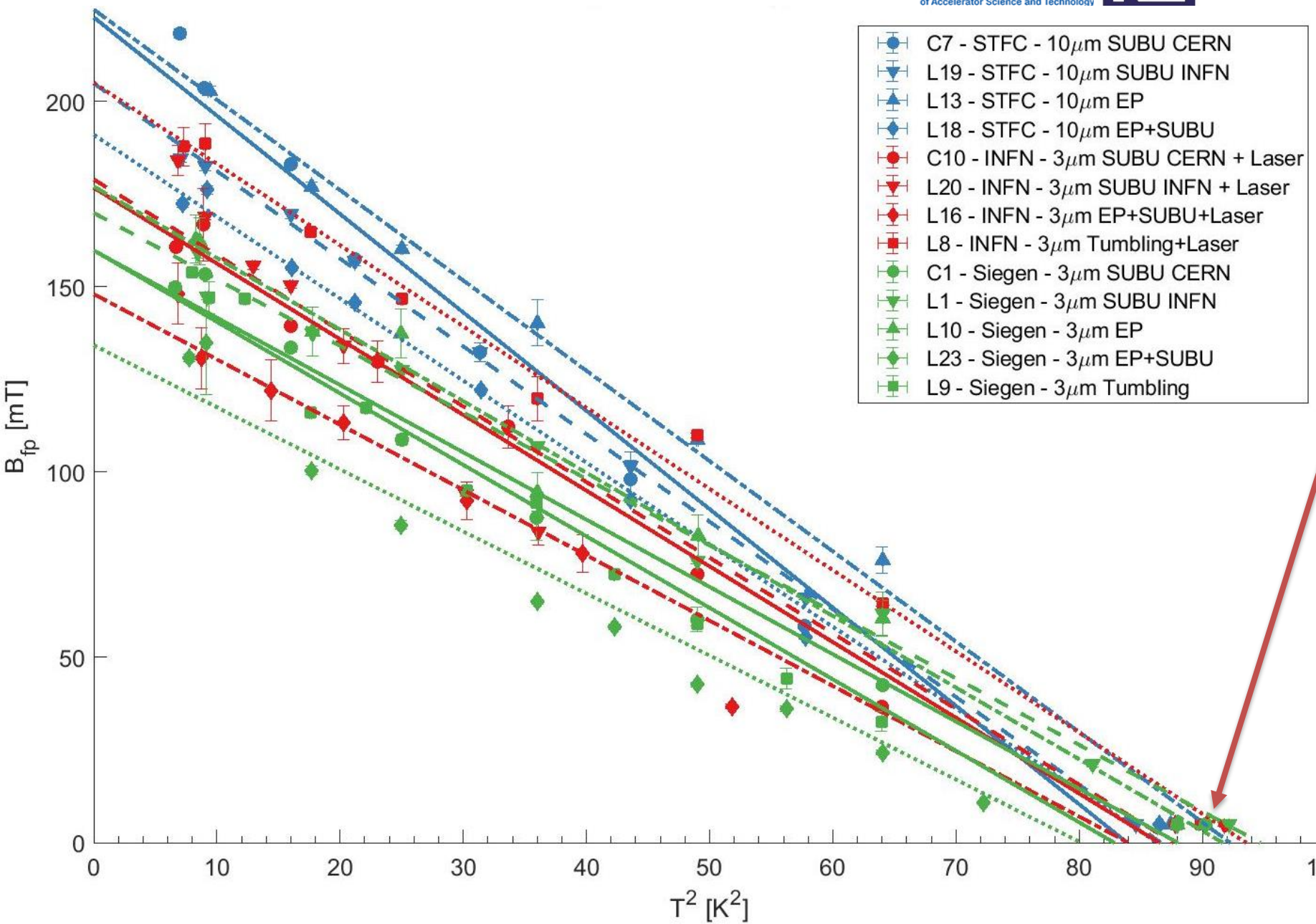
- Nb samples deposited as part of ARIES WP15 sent to RTU for laser polishing.
  - 3 Samples from STFC, and all 5 from Siegen. Samples deposited by INFN not sent as they had already been laser polished in the first test in the field penetration facility.
  - 3/5 STFC samples laser polished
- Samples have been returned, tested, analysed, and compared to the previous results.





Reminder

- DC magnetic field parallel to the surface
- Field local to the sample surface
  - Avoid edge effect.
  - Allow possibility if sample scanning.
- Magnetic field applied from one side of the sample to the opposing side, similar to an SRF cavity.
- Applied and penetrated field measured by Hall probe sensors
- 50×45 mm maximum, or a 50 mm diameter disk.



- New analysis method is now used, so the old data (pre-laser polish) had to be re-analysed, with the data presented to the left.
- Data includes the T_c measurement by Bratislava.
- Assuming a linear fit for B_{fp} as a function of T^2, $B_{fp}(0\ K)$ and T_c is extrapolated.
  - T_c is not as accurate compared to VSM.
- Results are shown by institution at the end of the paper, for both pre and post laser treatment

Effect of substrate polishing on B_{fp}

STFC	Siegen	INFN (with laser polishing sample surface)	
EP (224.7±8.5)	EP (177.0±6.1)		Largest B_{fp}(0 K)
		Tumbling (205.0±7.8)	
SUBU CERN (222.6±0.9)	SUBU INFN (169.9±5.1)	SUBU INFN (178.9±2.2)	
SUBU INFN (204.8±6.9)	SUBU CERN (159.7±1.4)	SUBU CERN (176.7±4.3)	
-	Tumbling (159.8±1.6)		
EP + SUBU (191.0±4.3)	EP + SUBU (134.2±1.1)	EP + SUBU (148.0±3.7)	Lowest B_{fp}(0 K)

Magnetic Field Penetration of Niobium Thin Films Produced by the ARIES Collaboration – (Click link for SRF 21 poster)
Note: These results were analysed using a different technique.

Note: The effect of polishing has slightly changed compared to previous report due to the change in analysis method

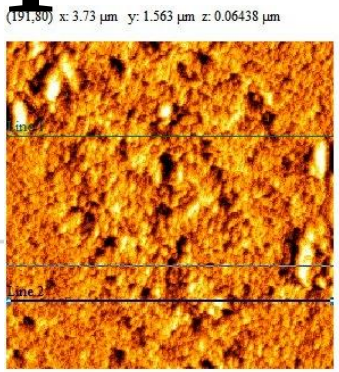
Laser treatment parameters

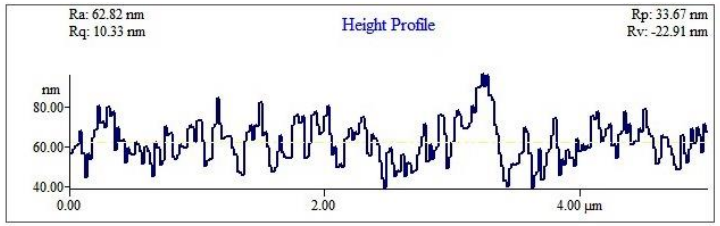
- All samples sent for laser polishing had the same parameters for treatment:
  - Wavelength: 1,063 mk
  - Intensity: 70 MW/cm^2
  - Pulse duration: 6nm
  - Dose: 66 J/cm^2
  - Step: 5 mk
  - Frequency: 10 Hz
  - Beam diameter: 3mm

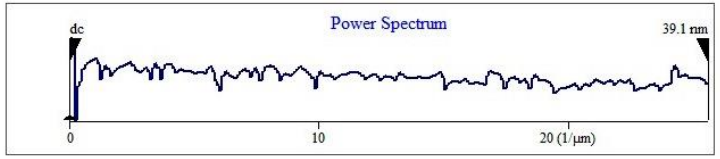
- Samples treated:
  - STFC: C7 - SUBU CERN, L13 – EP, L18 – EP + SUBU
  - Siegen: C1 – SUBU CERN, L1 – SUBU INFN, L10 – EP, L23 – EP + SUBU, L9 - Tumbling
- Surface characterisation by Artur has been reported at the last IFAST meeting, and are shown again over the next few slides

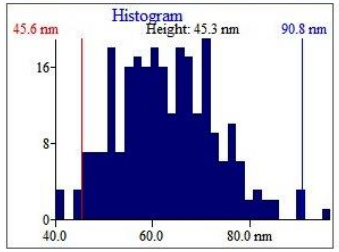
C1 Siegen - SUBU CERN

Nonirradiated



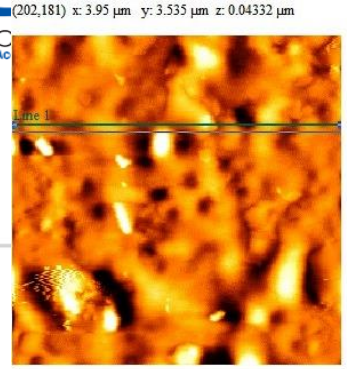


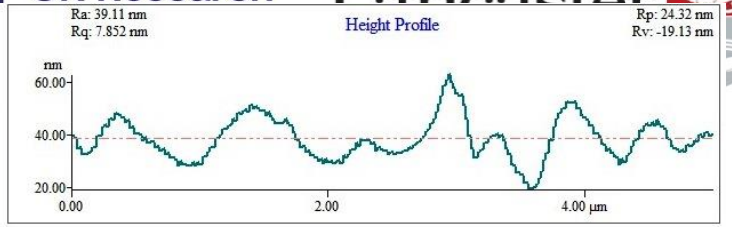


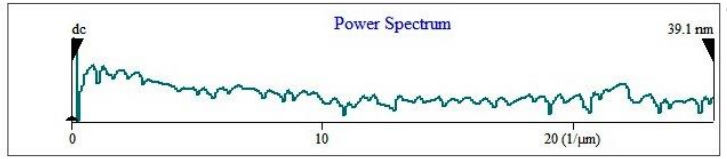


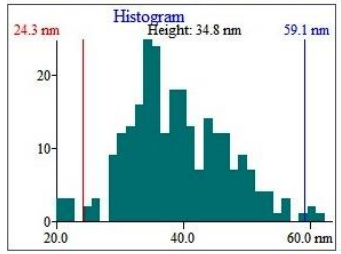
	Rp-v	Rms Rough (Rq)	Ave Rough (Ra)	Mean Ht	Median Ht	Arc length	Bearing Ratio
Line 1	55.41 nm	10.93 nm	8.856 nm	62.82 nm	63.08 nm	5.474 µm	@30.0% 69.45
Line 2	**56.58 nm**	**10.33 nm**	**8.309 nm**	**62.82 nm**	**61.74 nm**	**5.388 µm**	**@30.0% 68.00**
Delta [,]							

Irradiated



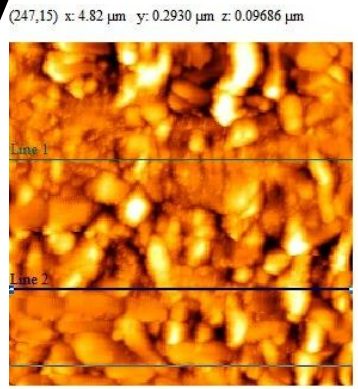


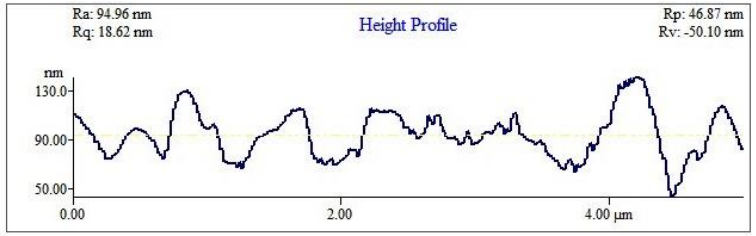


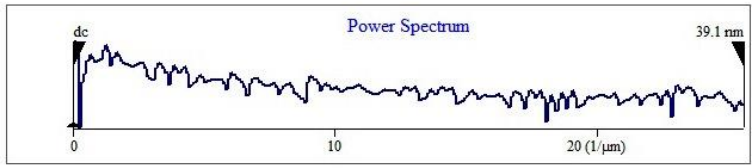


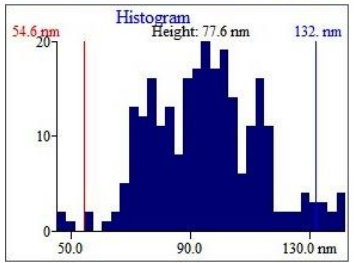
	Rp-v	Rms Rough (Rq)	Ave Rough (Ra)	Mean Ht	Median Ht	Arc length	Bearing Ratio
Line 1	**43.46 nm**	**7.852 nm**	**6.272 nm**	**39.11 nm**	**38.34 nm**	**5.145 µm**	**@30.0% 43.42**
Delta [,]							

C7 STFC - SUBU CERN

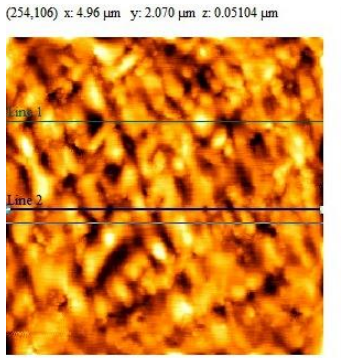


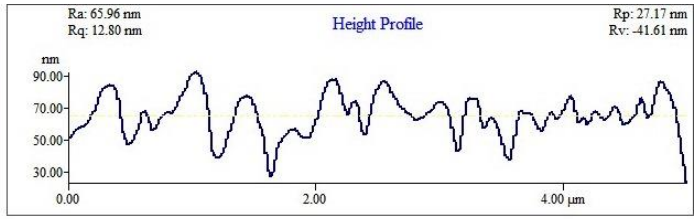


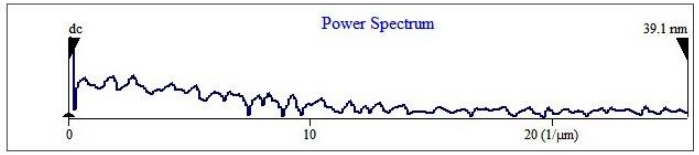


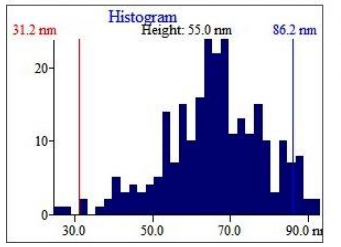


	Rp-v	Rms Rough (Rq)	Ave Rough (Ra)	Mean Ht	Median Ht	Arc length	Bearing Ratio
Line 1	77.50 nm	11.17 nm	7.904 nm	94.96 nm	95.03 nm	5.124 µm	@30.0% 99.40
Line 2	**96.98 nm**	**18.62 nm**	**14.67 nm**	**94.96 nm**	**94.59 nm**	**5.152 µm**	**@30.0% 102.87**
Delta [,]							





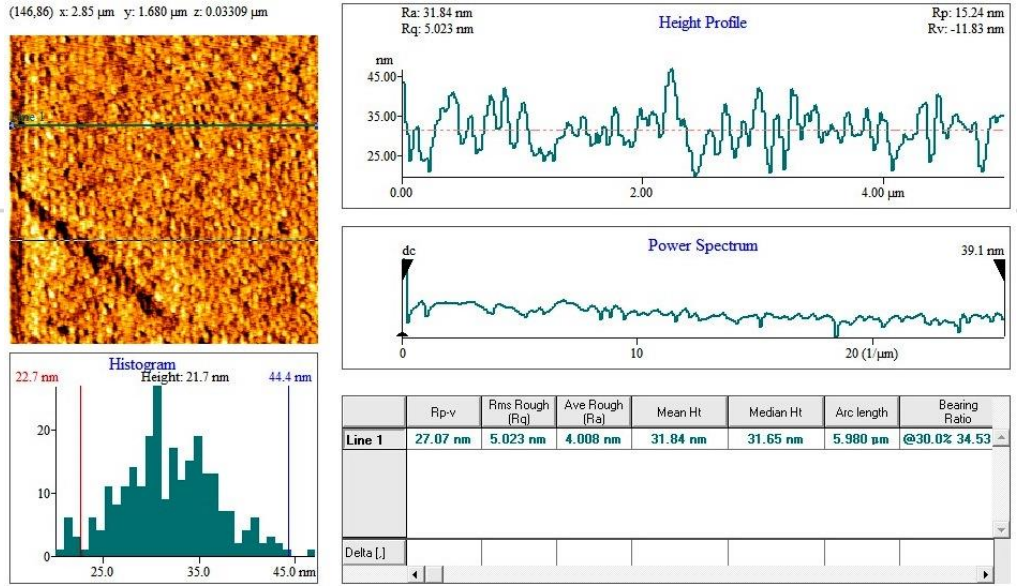




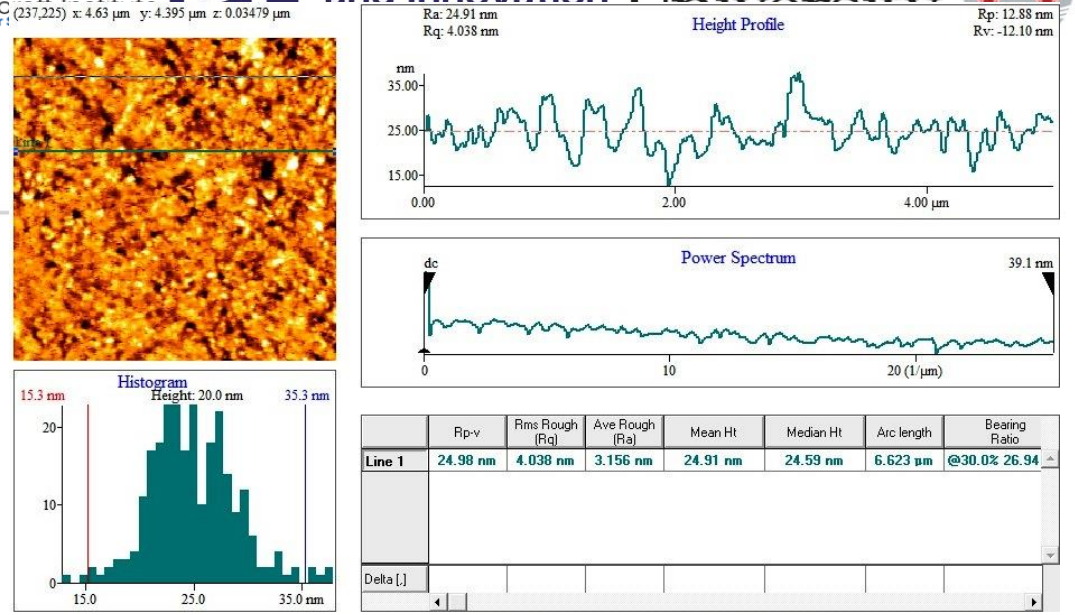
	Rp-v	Rms Rough (Rq)	Ave Rough (Ra)	Mean Ht	Median Ht	Arc length	Bearing Ratio
Line 1	95.06 nm	18.59 nm	14.22 nm	65.96 nm	67.51 nm	5.347 µm	@30.0% 75.68
Line 2	**68.78 nm**	**12.80 nm**	**9.820 nm**	**65.96 nm**	**66.36 nm**	**5.407 µm**	**@30.0% 72.67**
Delta [,]							

L1 Siegen - SUBU INFN

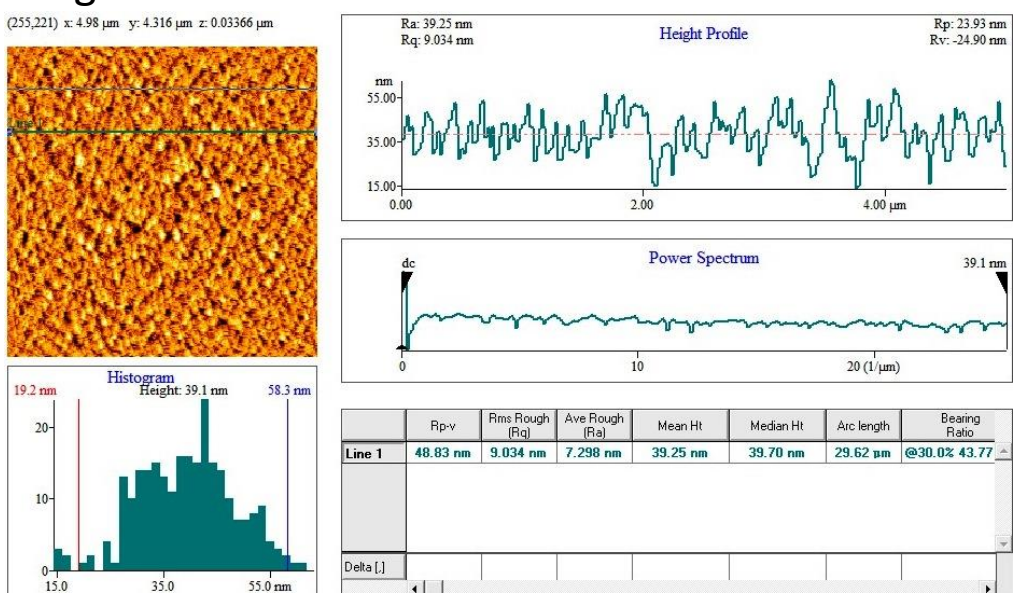
Nonirradiated

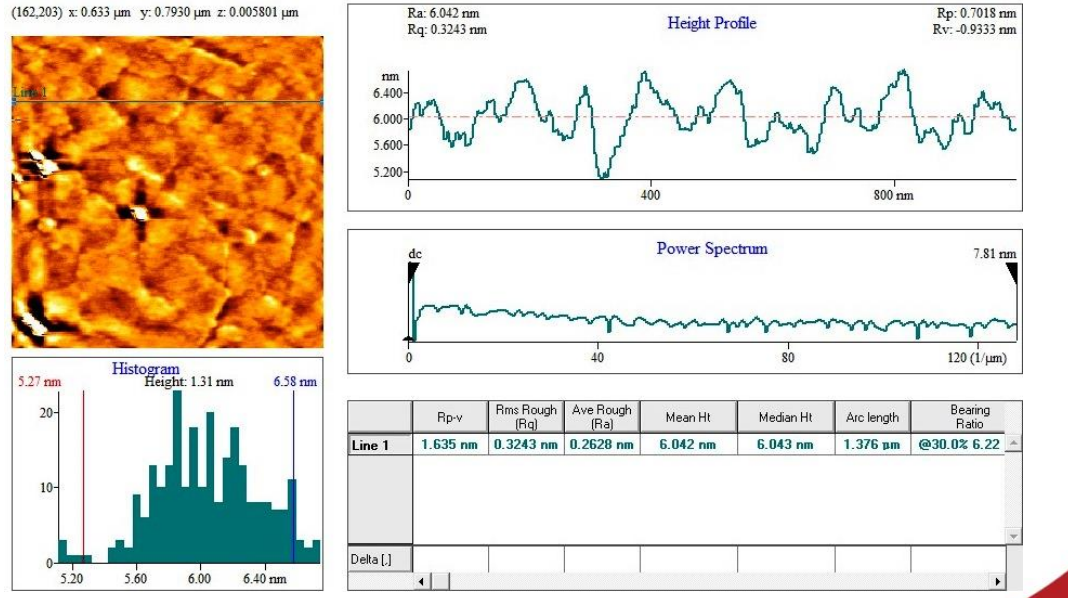


Irradiated



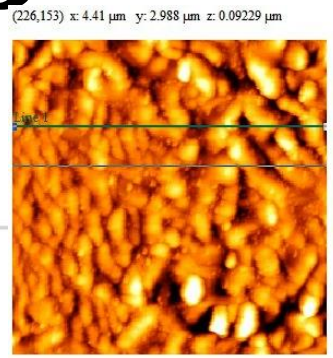
L10 Siegen - EP

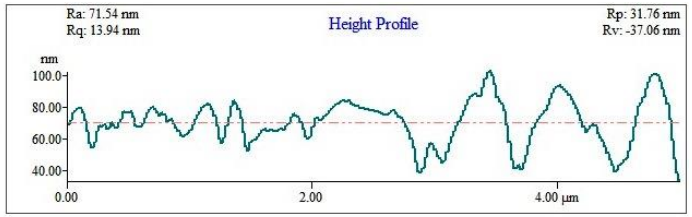


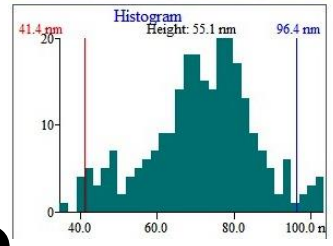


L13 STFC - EP

Nonirradiated

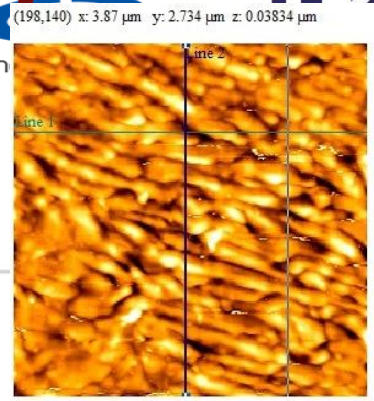


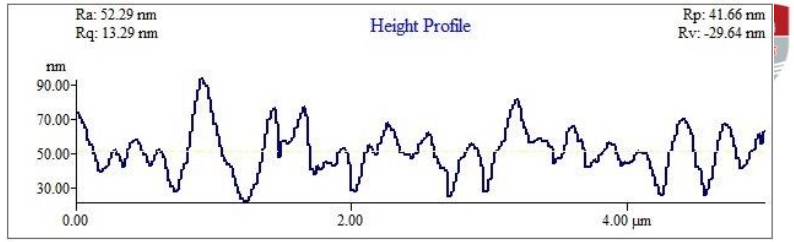


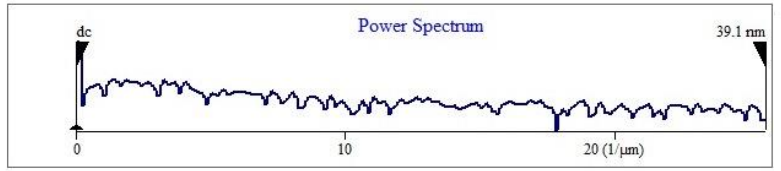


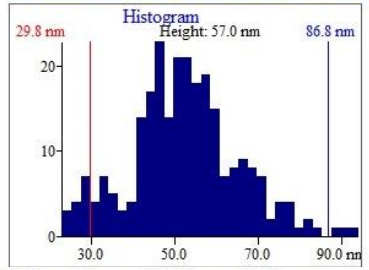
	Rp-v	Rms Rough (Rq)	Ave Rough (Ra)	Mean Ht	Median Ht	Arc length	Bearing Ratio
Line 1	68.82 nm	13.94 nm	10.92 nm	71.54 nm	72.99 nm	5.168 µm	@30.0% 78.82
Delta [.]							

Irradiated





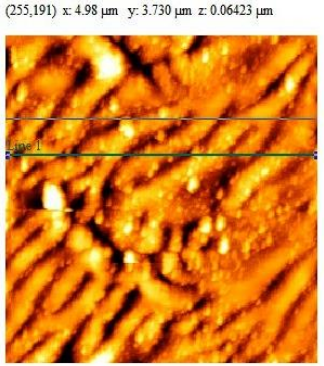


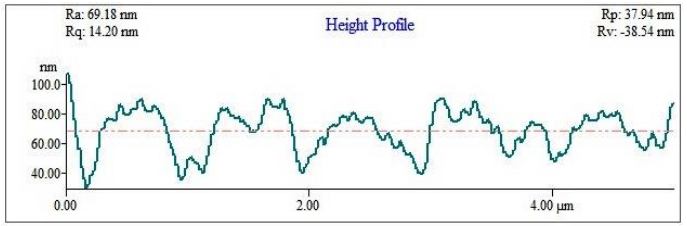


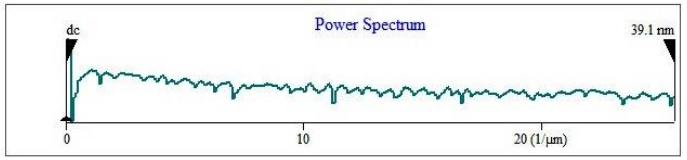
	Rp-v	Rms Rough (Rq)	Ave Rough (Ra)	Mean Ht	Median Ht	Arc length	Bearing Ratio
Line 1	51.45 nm	13.35 nm	11.31 nm	52.24 nm	54.90 nm	5.494 µm	@30.0% 62.00
Line 2	71.30 nm	13.29 nm	10.20 nm	52.29 nm	51.75 nm	5.613 µm	@30.0% 57.74
Delta [.]							

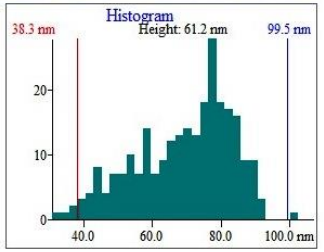
L18 STFC – EP + SUBU

Nonirradiated



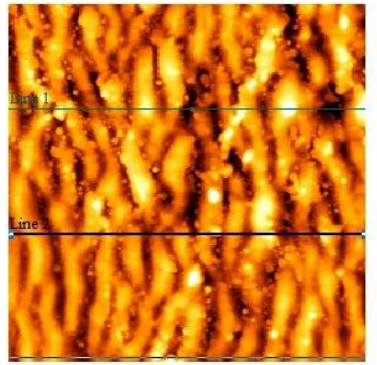


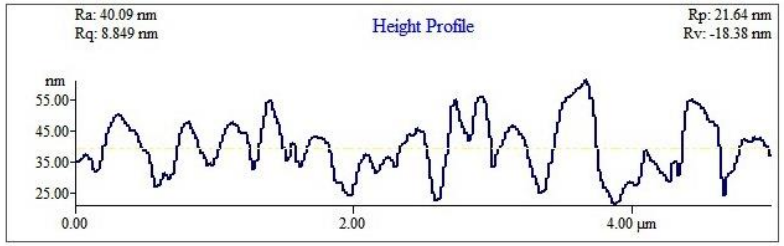


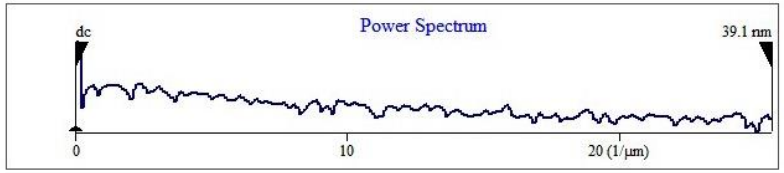


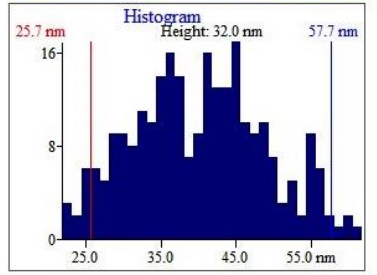
	Rp-v	Rms Rough (Rq)	Ave Rough (Ra)	Mean Ht	Median Ht	Arc length	Bearing Ratio
Line 1	76.47 nm	14.20 nm	11.76 nm	69.18 nm	72.36 nm	6.371 µm	@30.0% 78.19
Delta [.]							

Irradiated





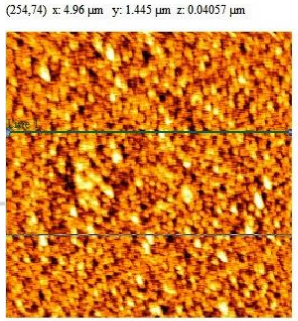


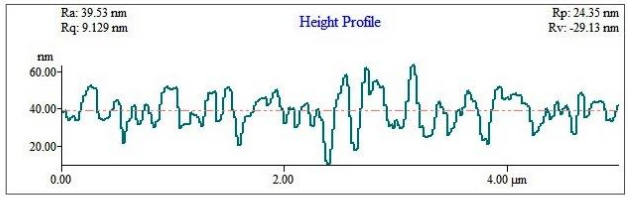


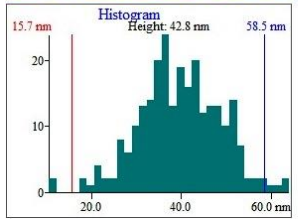
	Rp-v	Rms Rough (Rq)	Ave Rough (Ra)	Mean Ht	Median Ht	Arc length	Bearing Ratio
Line 1	88.14 nm	14.99 nm	11.63 nm	40.08 nm	38.19 nm	5.505 µm	@30.0% 46.36
Line 2	40.02 nm	8.849 nm	7.282 nm	40.09 nm	40.15 nm	5.524 µm	@30.0% 44.66
Delta [.]							

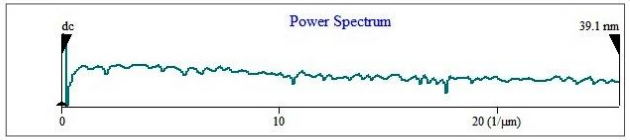
L23 Siegen – EP + SUBU

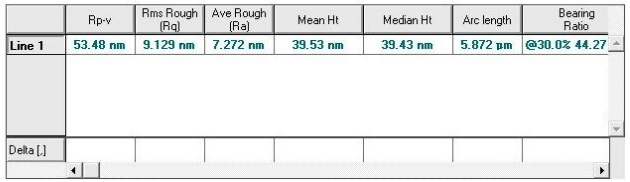
Nonirradiated





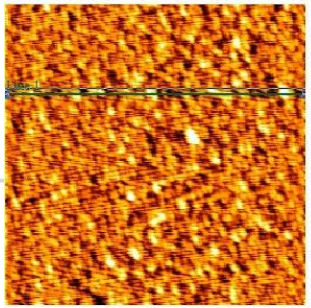


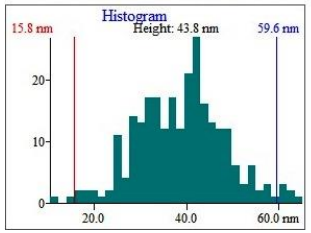


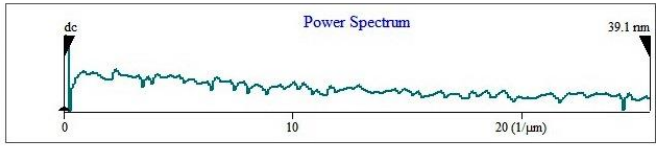


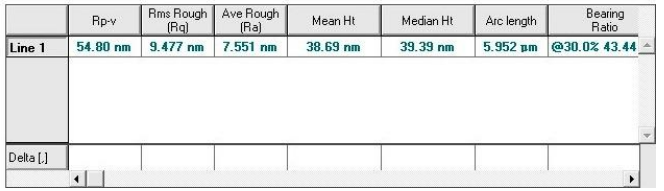
	Rp-v	Rms Rough (Rq)	Ave Rough (Ra)	Mean Ht	Median Ht	Arc length	Bearing Ratio
Line 1	53.48 nm	9.129 nm	7.272 nm	39.53 nm	39.43 nm	5.872 µm	@30.0% 44.27
Delta [.]							

Irradiated







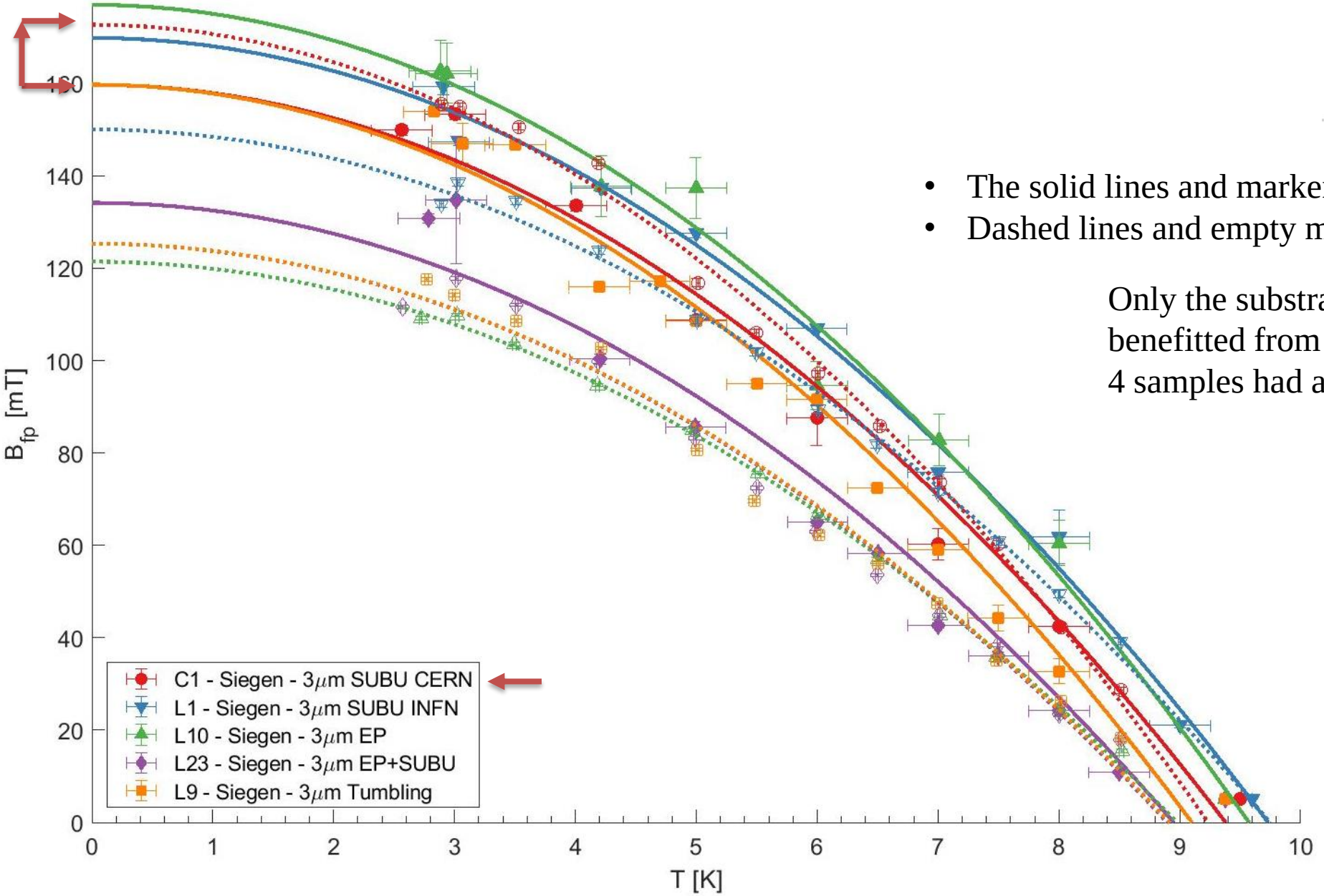


	Rp-v	Rms Rough (Rq)	Ave Rough (Ra)	Mean Ht	Median Ht	Arc length	Bearing Ratio
Line 1	54.80 nm	9.477 nm	7.551 nm	38.69 nm	39.39 nm	5.952 µm	@30.0% 43.44
Delta [.]							

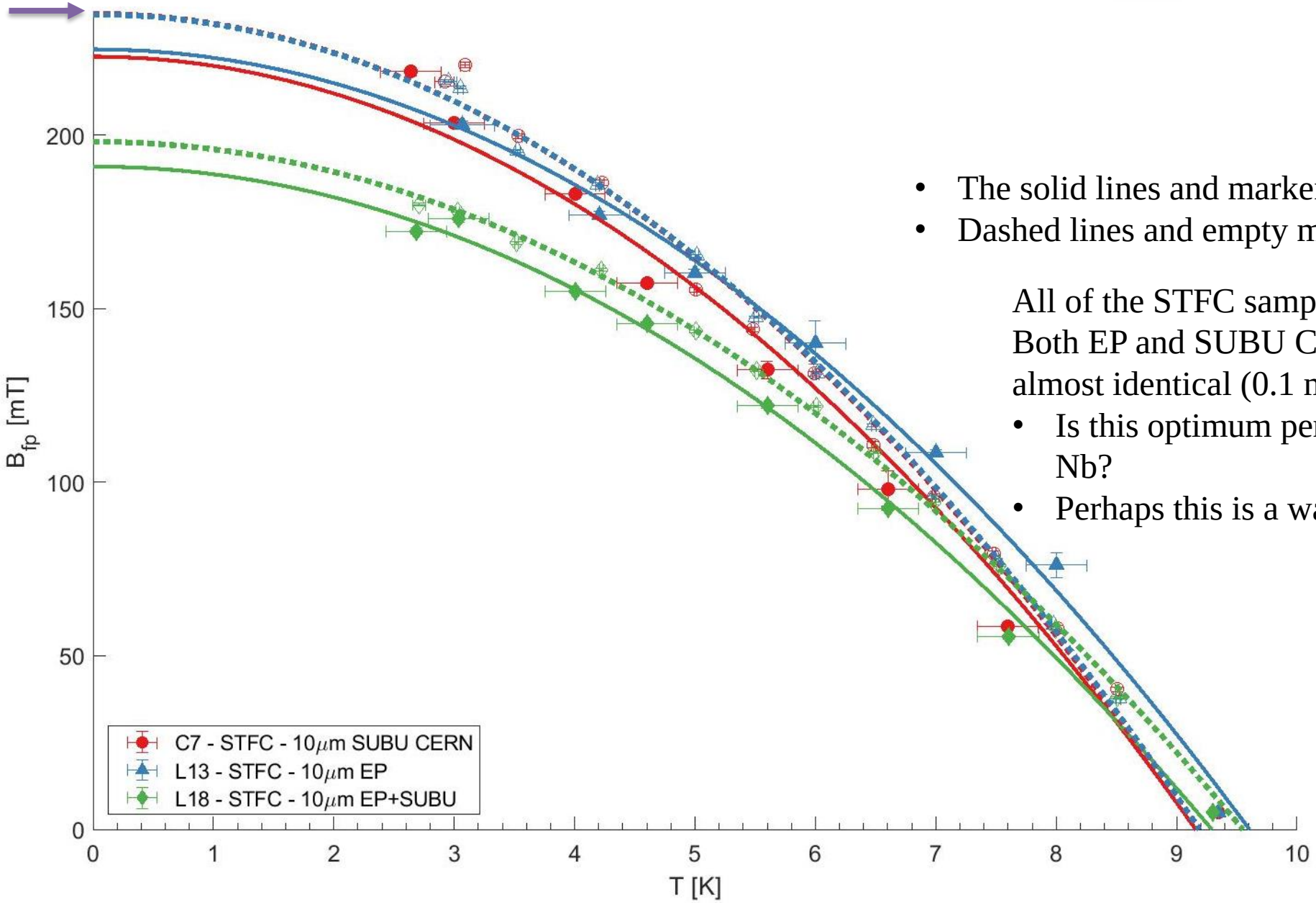
Siegen samples

- The solid lines and markers are pre laser polishing.
- Dashed lines and empty markers are post laser polishing

Only the substrate polished by SUBU CERN benefitted from the laser polishing. The other 4 samples had a reduction in $B_{fp}(0\ K)$.



C7 and L13 behave very similar after laser polishing



STFC samples

- The solid lines and markers are pre laser polishing.
- Dashed lines and empty markers are post laser polishing

All of the STFC samples saw an increase in B_{fp}(0 K). Both EP and SUBU CERN polished substrates are almost identical (0.1 mT difference).

- Is this optimum performance for B_{fp} of 10µm of Nb?
- Perhaps this is a way to improve bulk Nb cavities?

Effect of laser polishing the Nb

STFC	Siegen	INFN (with laser polishing sample surface)	
SUBU CERN (234.9 ± 1.3)	SUBU CERN (152.7 ± 2.5)	Tumbling (205.0 ± 7.8)	Largest B_{fp}(0 K)
EP (234.8 ± 2.4)	SUBU INFN (150.1 ± 2.1)	SUBU INFN (178.9 ± 2.2)	
	Tumbling (125.4 ± 0.9)	SUBU CERN (176.7 ± 4.3)	
	EP + SUBU (125.3 ± 2.1)		
EP + SUBU (198.1 ± 6.0)	EP (121.4 ± 2.1)	EP + SUBU (148.0 ± 3.7)	Lowest B_{fp}(0 K)

Note: Samples deposited at INFN only underwent 1 round of laser polishing, so the data in this table is the same as first – Just here for comparison.

Full comparison

STFC	Siegen	INFN	
SUBU CERN + LP (234.9)	EP (177.0)	**Tumbling + LP**(205.0)	Largest B_{fp}(0 K)
EP + LP(234.8)	**SUBU CERN + LP** (152.7)	**SUBU INFN + LP**(178.9)	
EP (224.7)	SUBU INFN (169.9)	**SUBU CERN + LP**(176.7)	
SUBU CERN (222.6)	SUBU CERN (159.7)	**EP + SUBU + LP**(148.0)	
SUBU INFN (204.8)	Tumbling (159.8)		
EP + SUBU + LP (198.1)	**SUBU INFN + LP**(150.1)		
EP + SUBU (191.0)	EP + SUBU (134.2)		
	Tumbling + LP(125.4)		
	EP + SUBU + LP(125.3)		
	EP + LP (121.4)		Lowest B_{fp}(0 K)

Note: There are differences between each institute such as sample thickness, therefore each institute must be compared individually.

Conclusion

- Laser polishing increased the performance for the samples deposited at STFC, and the SUBU CERN sample deposited at Siegen.
- Reduction in field penetration performance in the samples deposited at Siegen.
- Reza currently has the laser treated samples from STFC and Siegen for surface analysis.
- **Questions to Artur:**
  - Was the laser polishing consistent for each sample? Any change in intensity or time taken etc? This information is now included in the presentation
  - Have you performed surface characterisation on these samples?
    - Surface after irradiation is in Artur's previous IFAST (3rd) presentation, which includes AFM and optical images
  - Would you like these samples returned once Reza has finished?

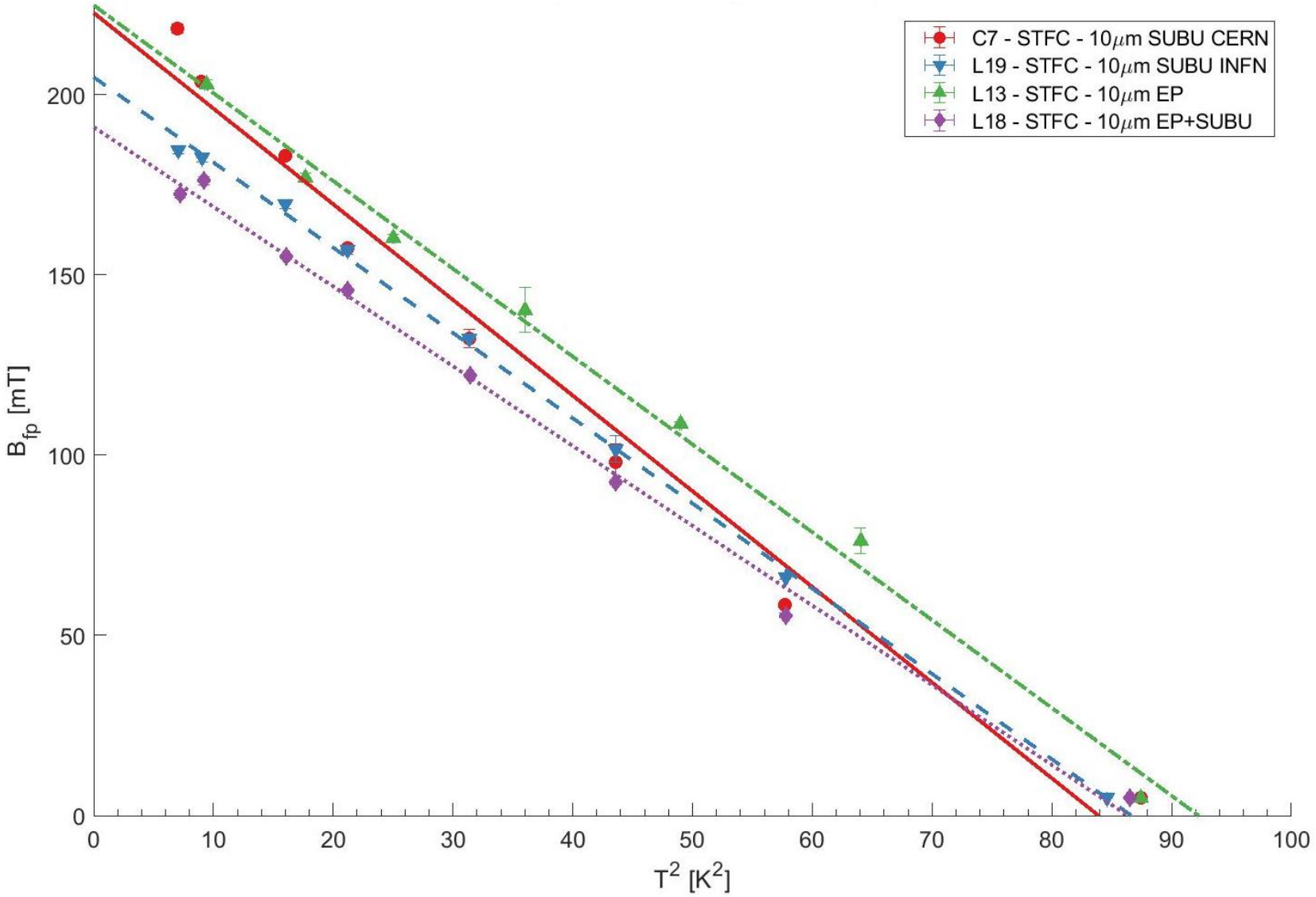
Everyone: Should I begin a draft of this paper? Would be beneficial?

Thank you for your attention, I am happy to answer any questions.

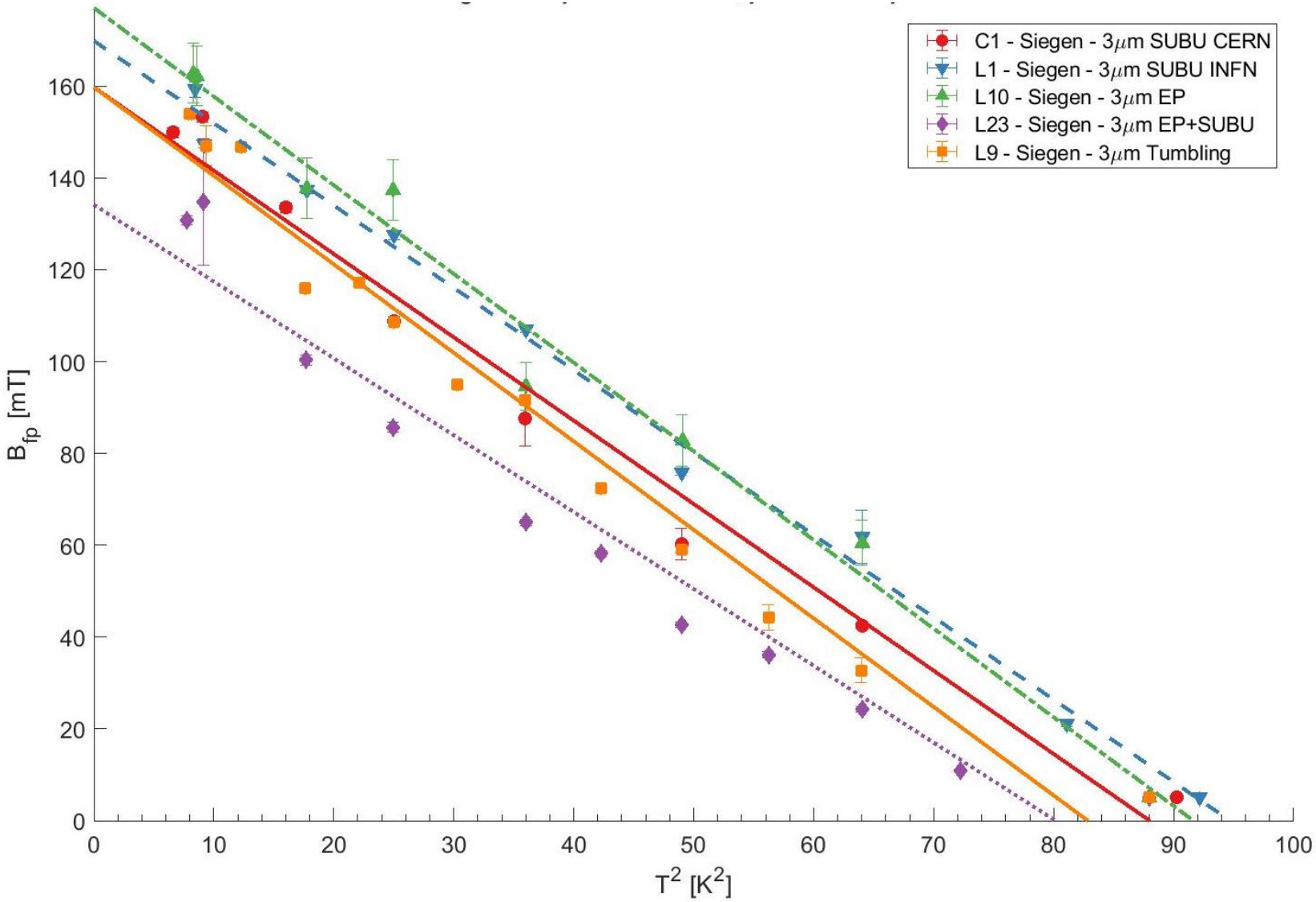
Results comparison

				Results from Bratislava VSM					Field penetration experiment							
				Pre laser polishing			Post laser polishing		First test				Second test - post laser polishing			
Origin	Material	Thickness	Substrate Treatment	Bperp(4.2 K) [mT]	Bpara(4.2 K) [mT]	Tc(5 mT) [K]	Bperp(4.2 K)[mT]	Bpara(4.2 K) [mT]	Tc (K)	ΔTc (K)	Bfp(0 K) (mT)	ΔBfp(0 K) (mT)	Tc (K)	ΔTc (K)	Bfp(0 K) (mT)	ΔBfp(0 K) (mT)
STFC	Nb	10µm	SUBU CERN	24.1	150.1	9.35	0	0	9.2	0.3	222.6	0.9	9.17	0.04	234.90	1.10
STFC	Nb	10µm	EP	22	100.3	9.35	0	0	9.6	0.4	224.7	8.5	9.19	0.09	234.80	2.40
STFC	Nb	10µm	EP + SUBU	17.7	61	9.3	0	0	9.3	0.3	191.0	4.3	9.55	0.29	198.10	6.00
STFC	Nb	10µm	SUBU INFN	17.3	73.2	9.2	0	0	9.3	0.4	204.8	6.9				
Siegen	Nb	3µm	SUBU CERN	15.5	49.6	9.5	0	0	9.4	0.3	159.7	1.4	9.24	0.13	172.70	2.50
Siegen	Nb	3µm	SUBU INFN	14.5	38	9.6	0	0	9.7	0.4	169.9	5.1	9.75	0.14	150.10	2.10
Siegen	Nb	3µm	Tumbling	16	38.6	9.38	0	0	9.1	0.2	159.8	1.6	8.92	0.06	125.40	0.90
Siegen	Nb	3µm	EP	15.5	32.7	9.38	0	0	9.6	0.4	177.0	6.1	8.98	0.15	121.43	2.10
Siegen	Nb	3µm	EP + SUBU	15	24.5	9.38	0	0	9.0	0.3	134.2	1.1	8.90	0.15	125.30	2.10
INFN	Nb	3µm	SUBU5 CERN	12	0	9.37	17	50.2	9.3	0.3	176.7	4.3				
INFN	Nb	3µm	Tumbling	18	0	9.48	19.1	42.5	9.7	0.4	205.0	7.8				
INFN	Nb	3µm	EP + SUBU5	14	0	9.37	15.5	47.2	9.2	0.3	148.0	3.7				
INFN	Nb	3µm	SUBU5 INFN	20	0	9.58	23.7	45	9.4	0.3	178.9	2.2				
INFN	Nb	3µm	EP	18	0	9.28	18.8	45.2	0.0	0.0	0.0	0.0				

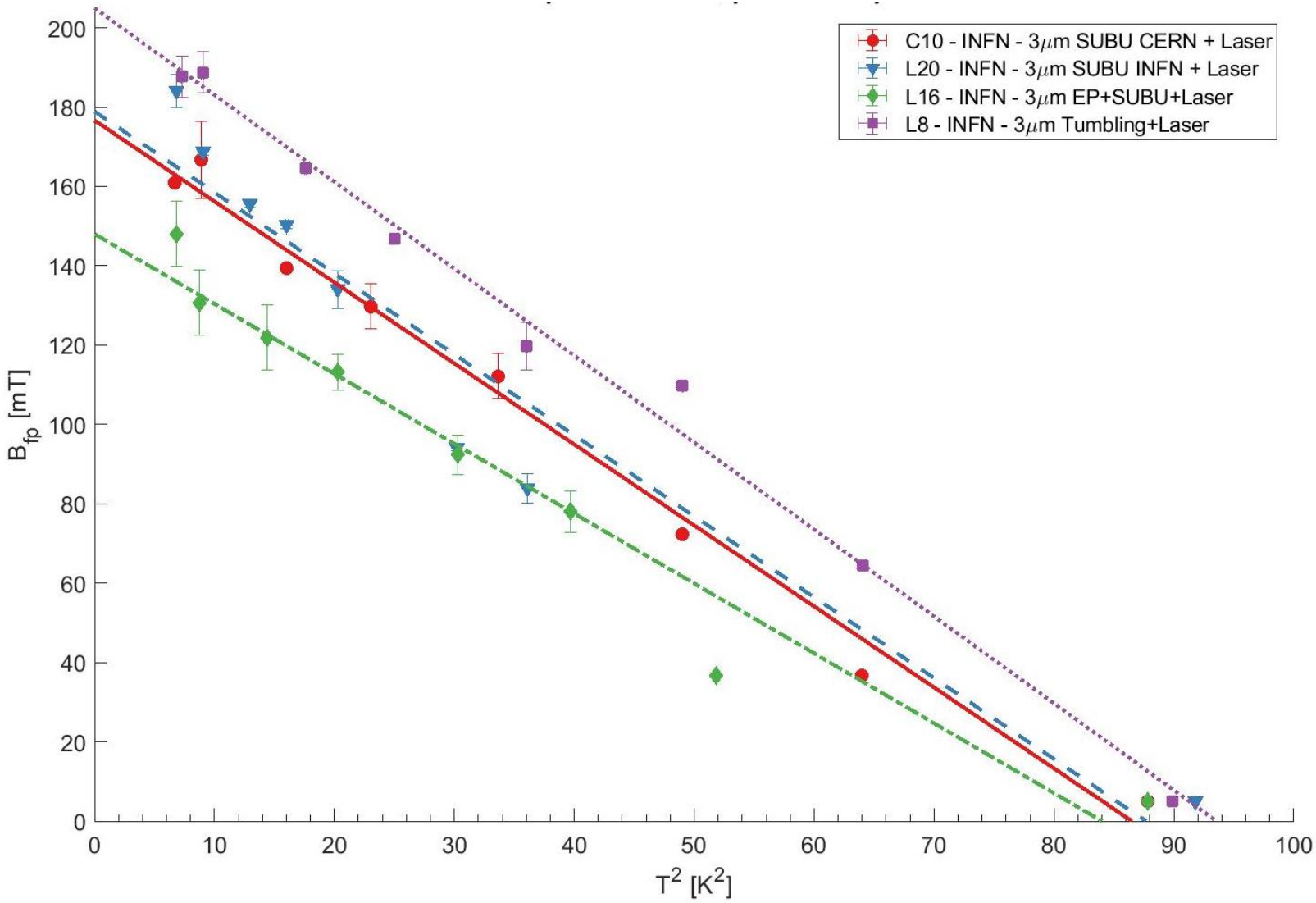
STFC Samples, Pre – Laser treatment



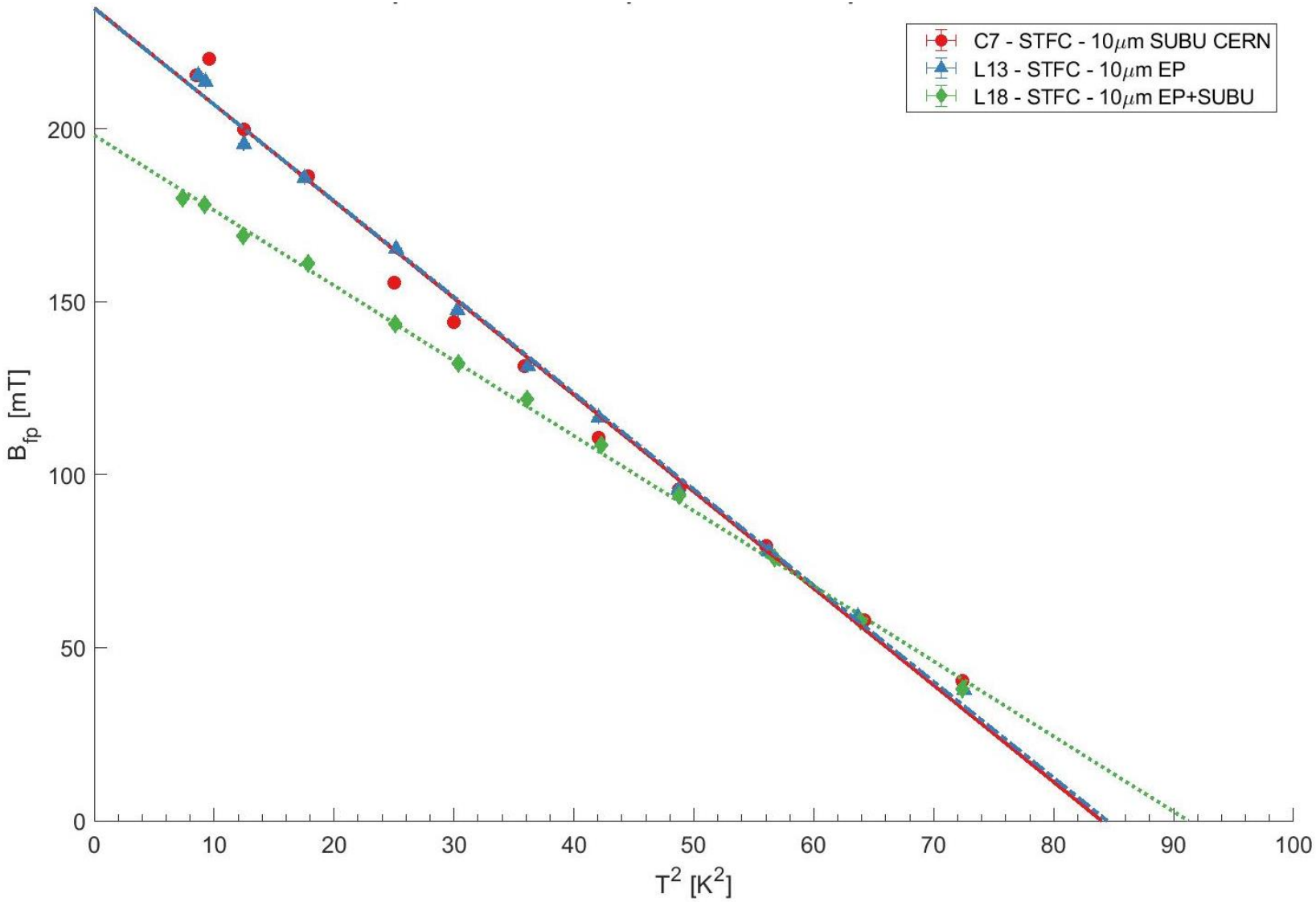
Siegen samples, pre laser treatment



LNL samples, 1 round of laser treatment



STFC Samples, Post – Laser treatment



Siegen samples, post laser treatment