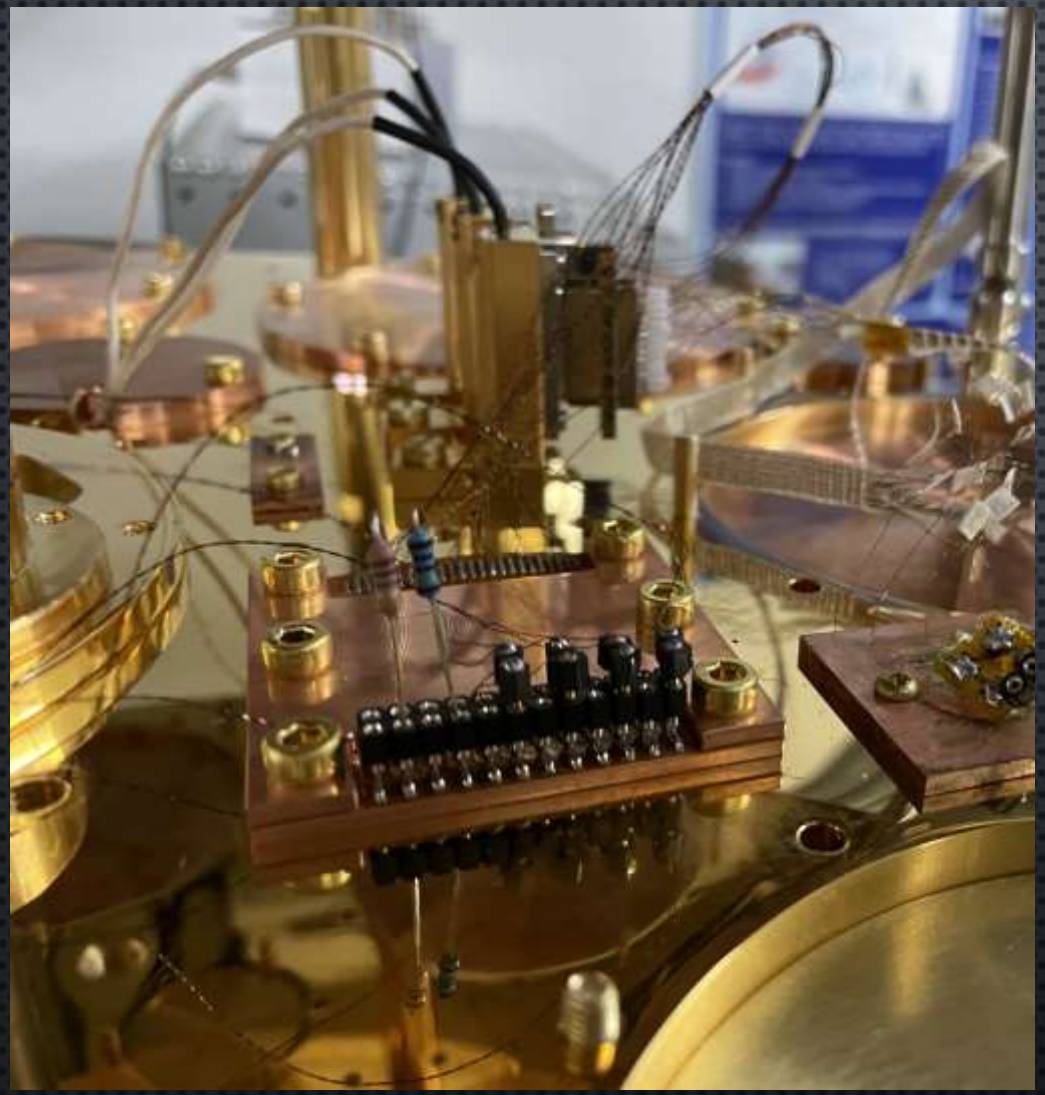
电子学测试

低温下的NTD

Shihong Fu, Long Ma, Xiaozhou Yu

2023/11/10

进行的低温测试

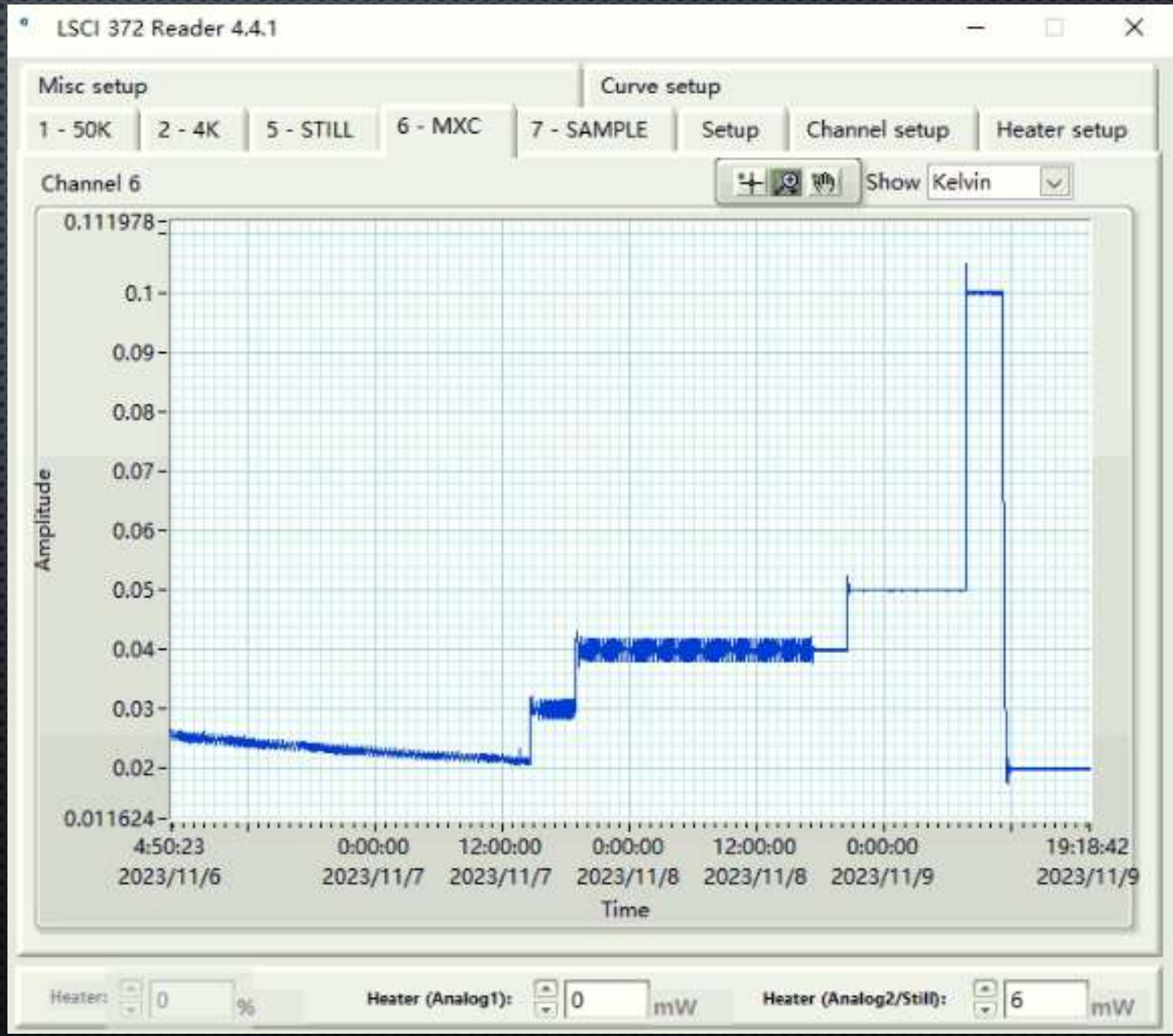


- 3 mm * 3 mm NTD
- 3 mm * 1 mm NTD
- 短接线 （Pin 5- 已经断开）
- 19T20 （USTC提供的参考NTD）
- 1 MΩ
- 10 MΩ

- 用万用表测得NTD加上磷铜线，在常温下阻值约为12 Ω左右
- 再加上从冷盘至室温端读出接口的转接线，合计阻值约为60 Ω左右

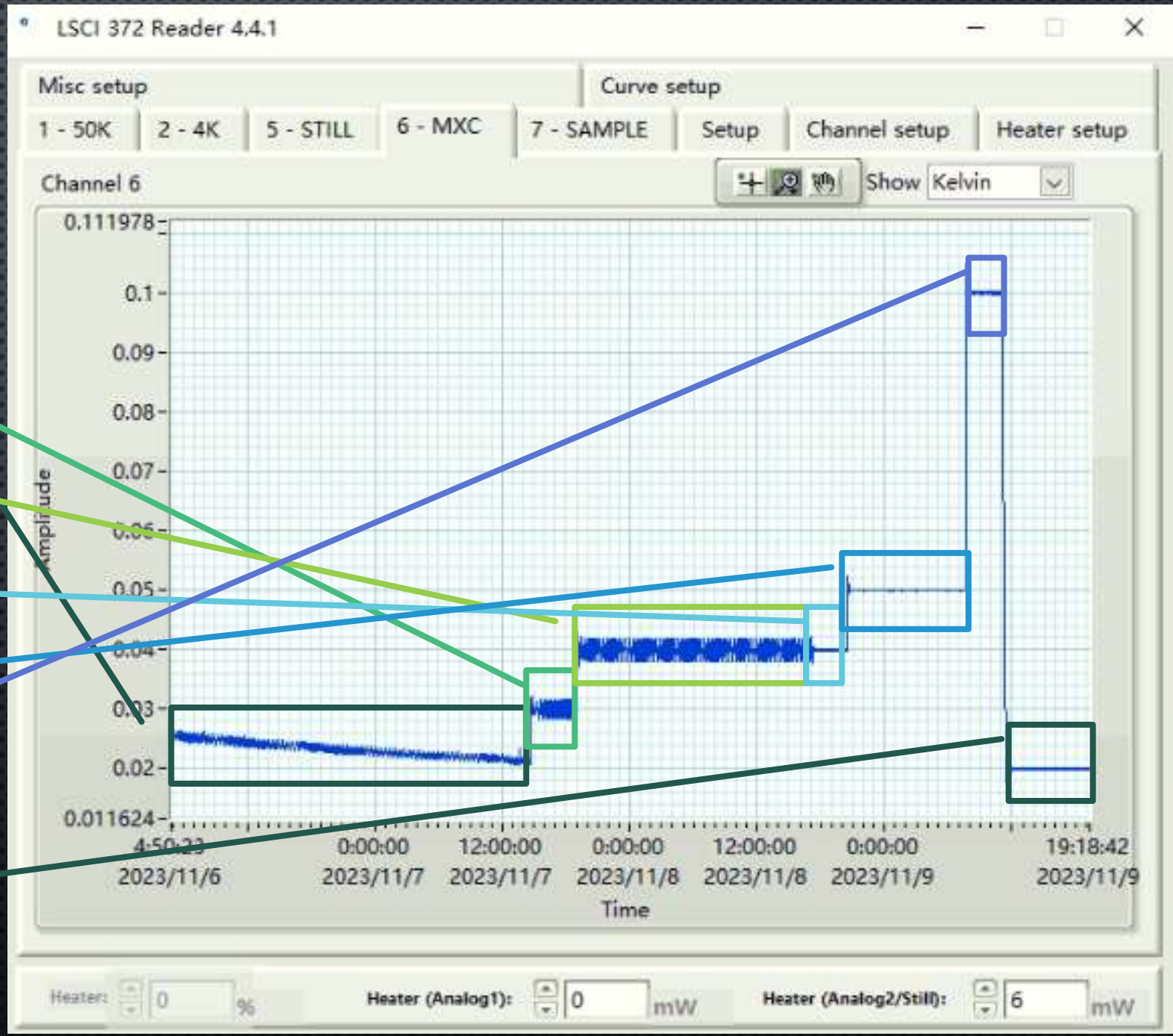
制冷机降温过程

- 初次降温至~20 mK
- 初次控温在~30 mK
- 控温在~40 mK
- 调整PID参数，改善控温的稳定性，仍然在40 mK
- 控温在50 mK
- 控温在100 mK
- 再次回到20 mK控温

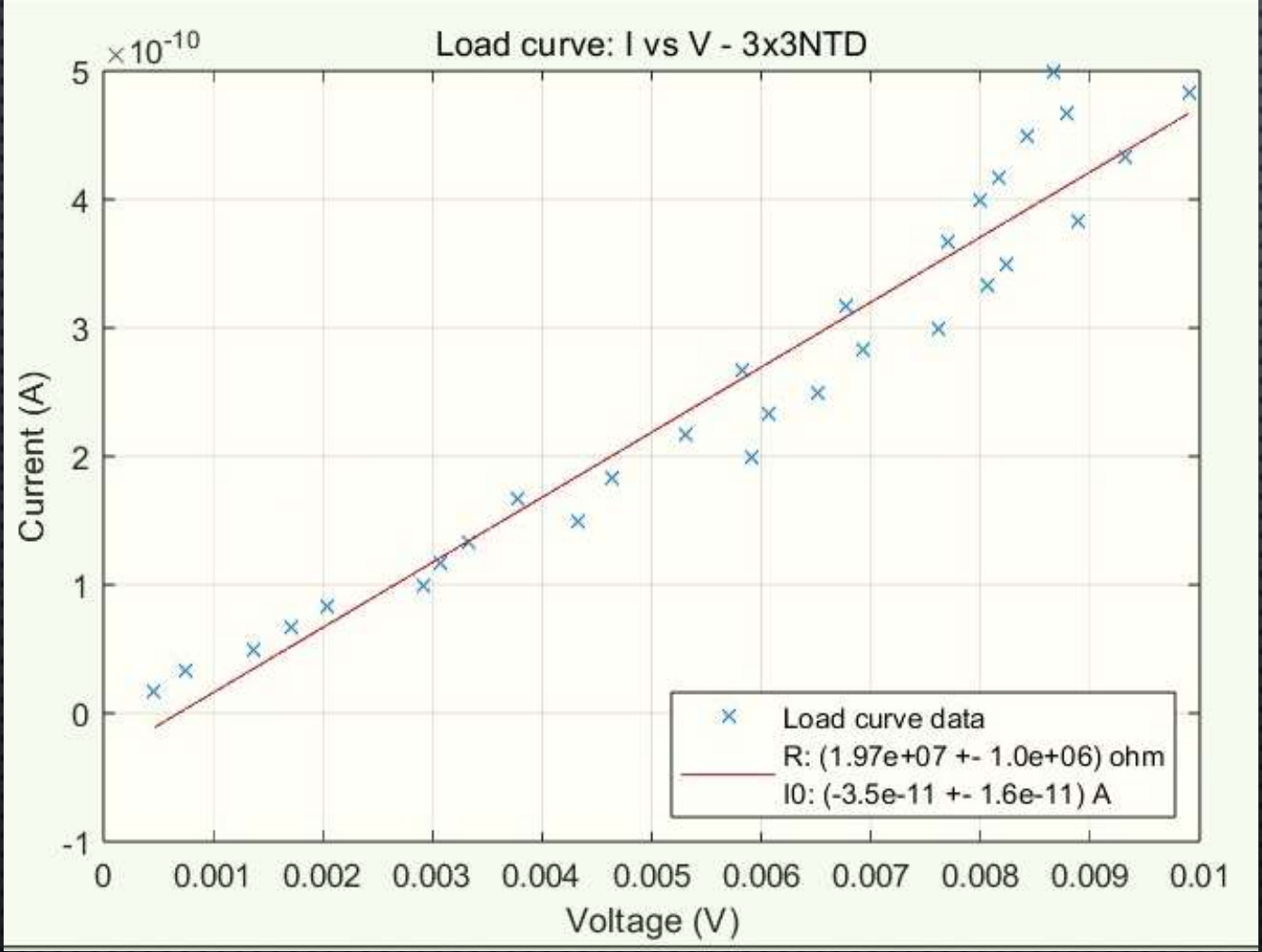


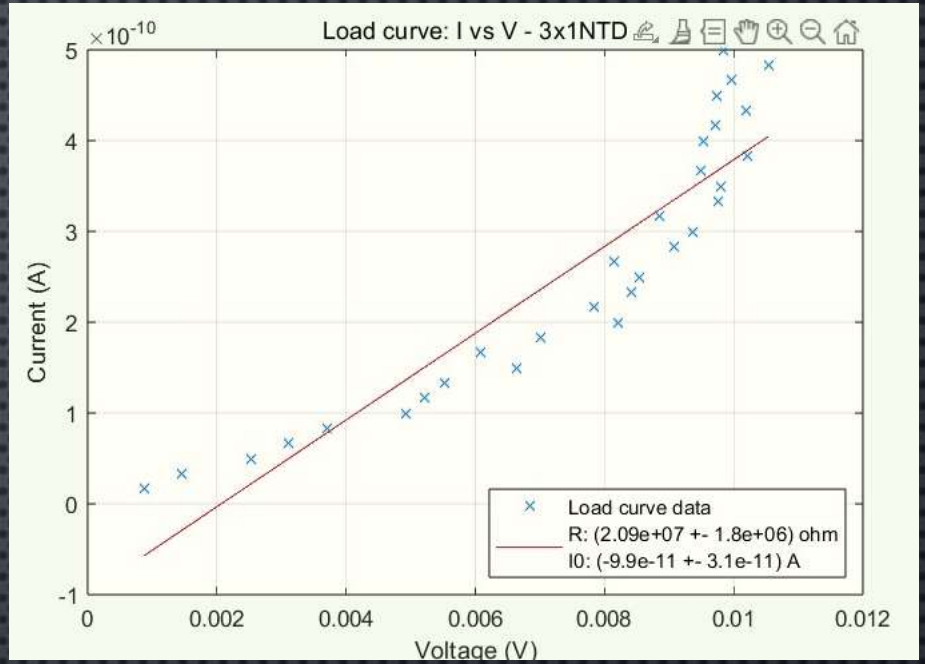
制冷机降温过程

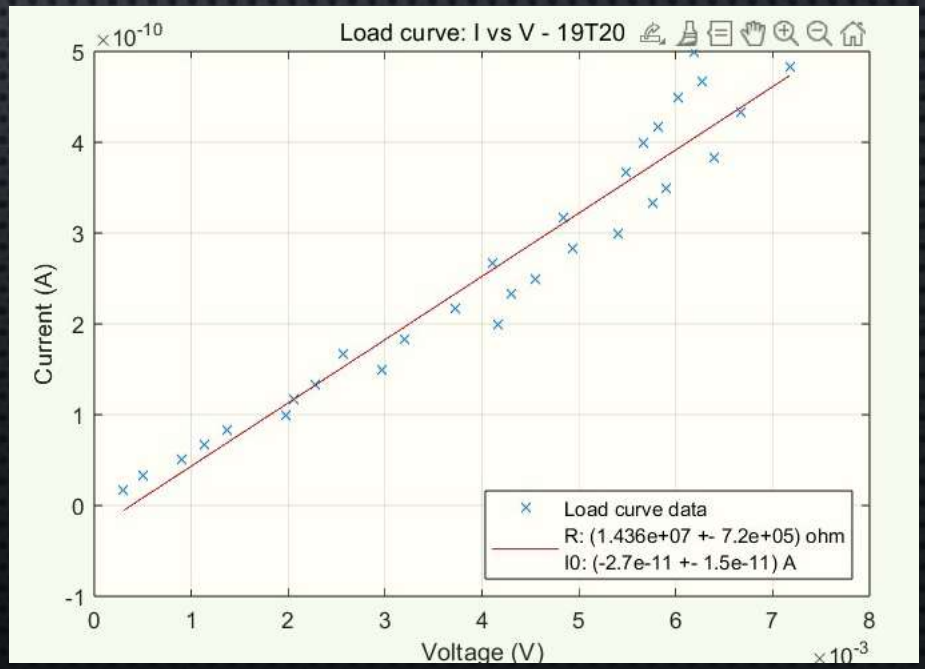
- 初次降温至~20 mK
- 初次控温在~30 mK
- 控温在~40 mK
- 调整PID参数，改善控温的稳定性，仍然在40 mK
- 控温在50 mK
- 控温在100 mK
- 再次回到20 mK控温



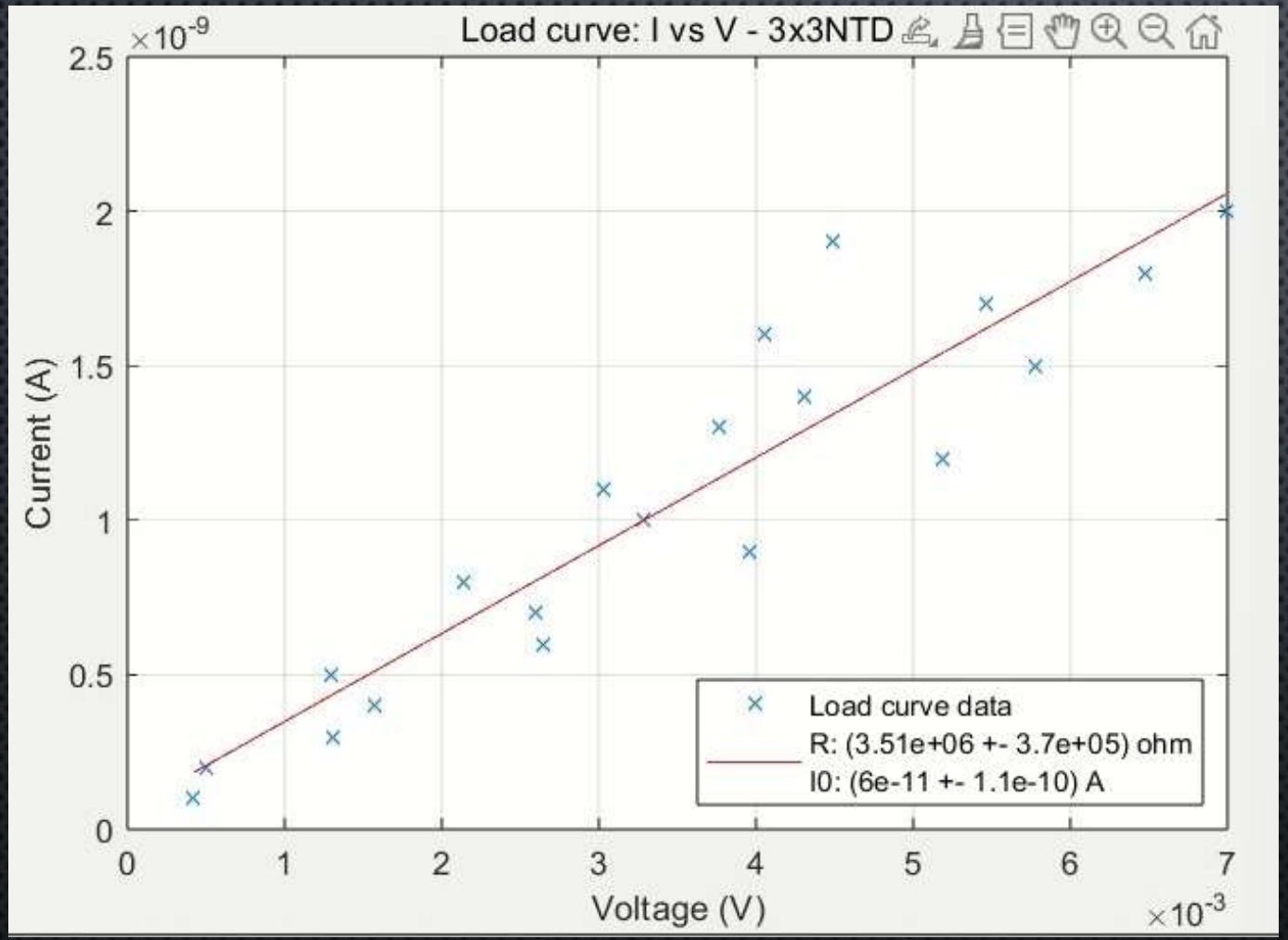
初次降温至~20 mK

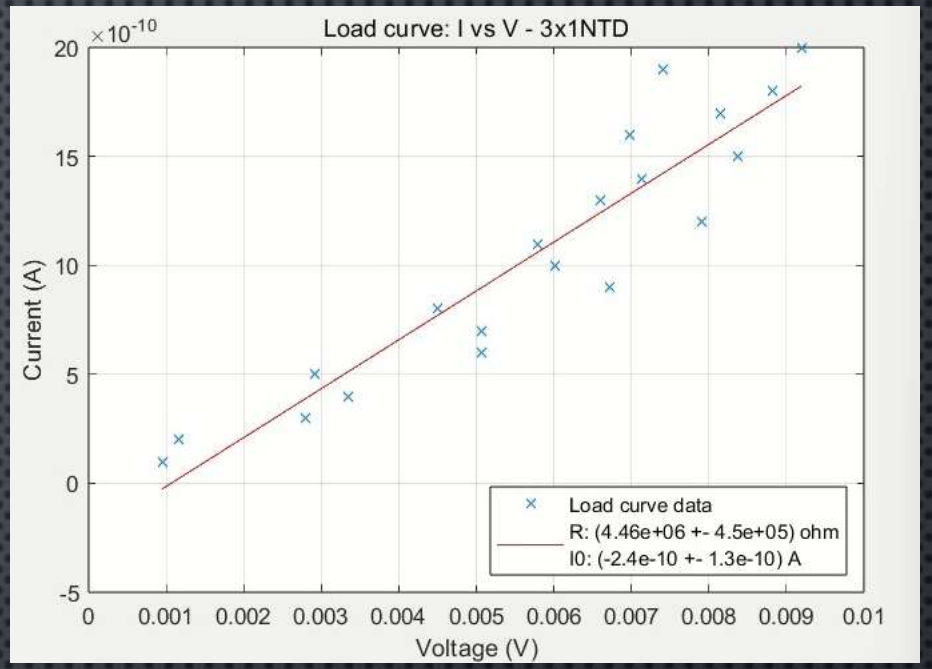

Load curve: I vs V - 3x3NTD
×10^-10
Current (A)
Voltage (V)
Load curve data
R: (1.97e+07 +- 1.0e+06) ohm
I0: (-3.5e-11 +- 1.6e-11) A

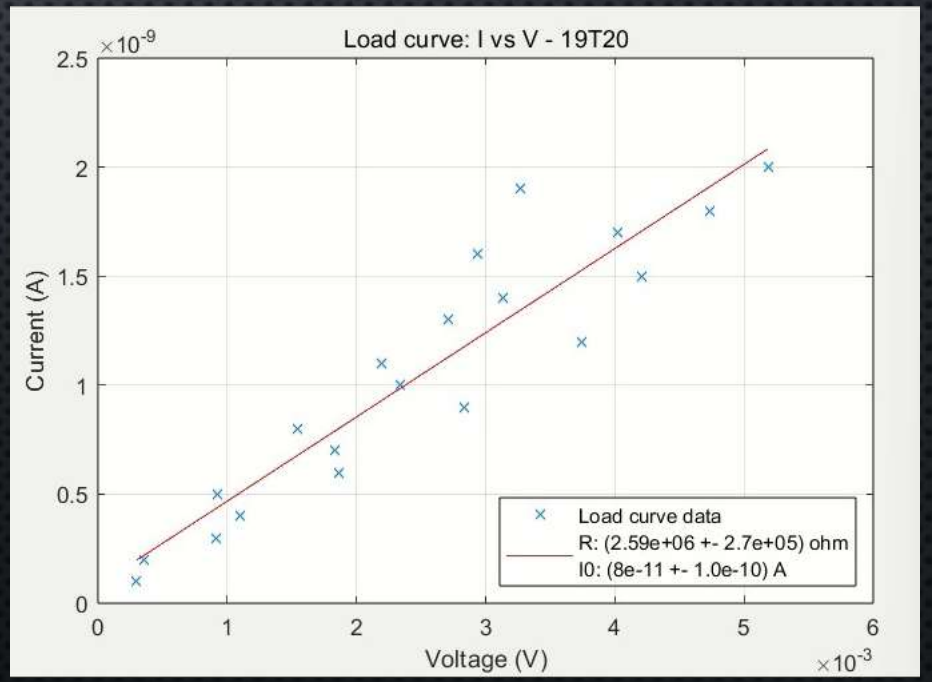

Load curve: I vs V - 3x1NTD
×10^-10
Current (A)
Voltage (V)
Load curve data
R: (2.09e+07 +- 1.8e+06) ohm
I0: (-9.9e-11 +- 3.1e-11) A


Load curve: I vs V - 19T20
×10^-10
Current (A)
Voltage (V)
×10^-3
Load curve data
R: (1.436e+07 +- 7.2e+05) ohm
I0: (-2.7e-11 +- 1.5e-11) A

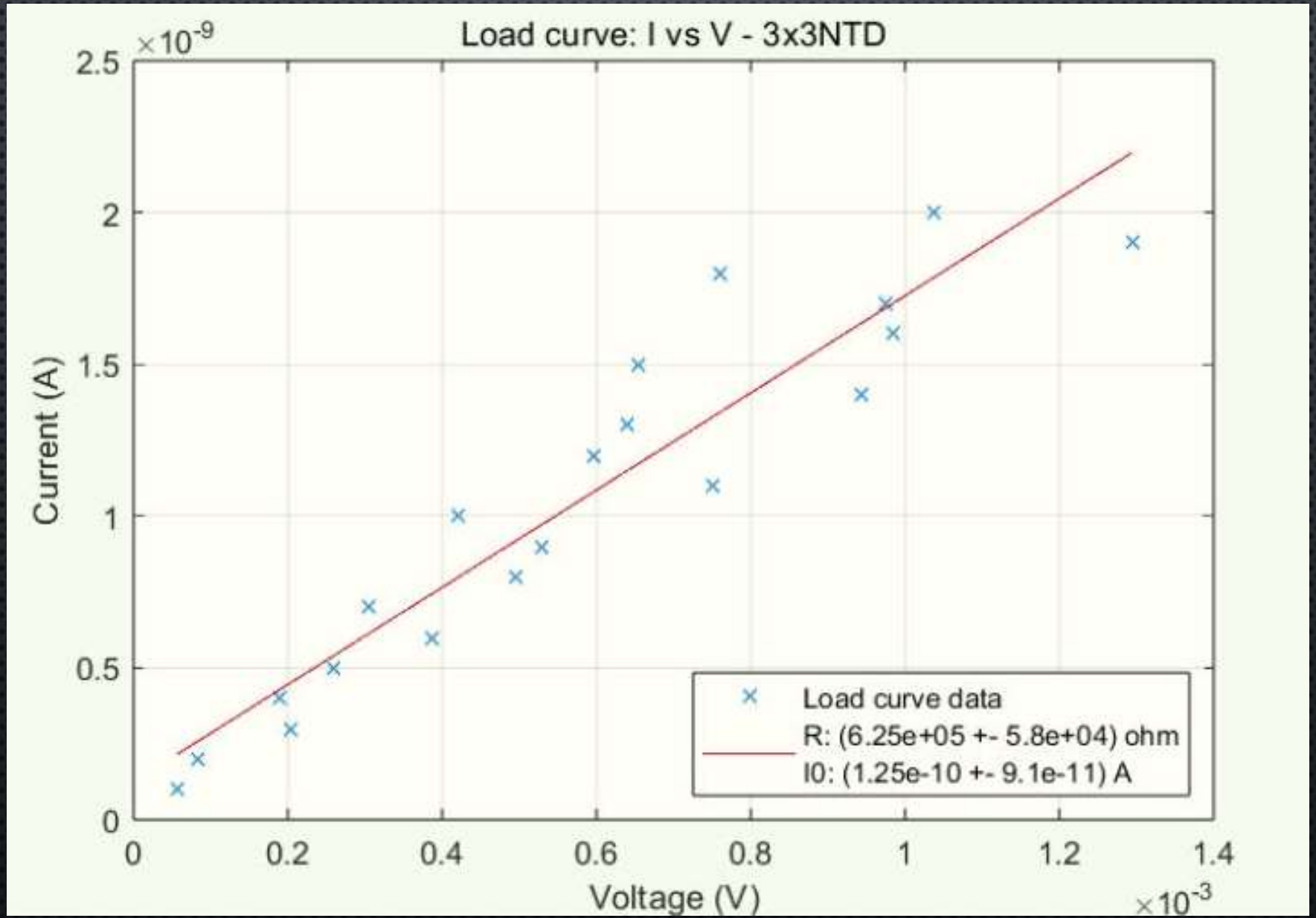
初次控温在~30 mK


Load curve: I vs V - 3x3NTD
×10^-9
Current (A)
Voltage (V)
×10^-3
Load curve data
R: (3.51e+06 +- 3.7e+05) ohm
I0: (6e-11 +- 1.1e-10) A

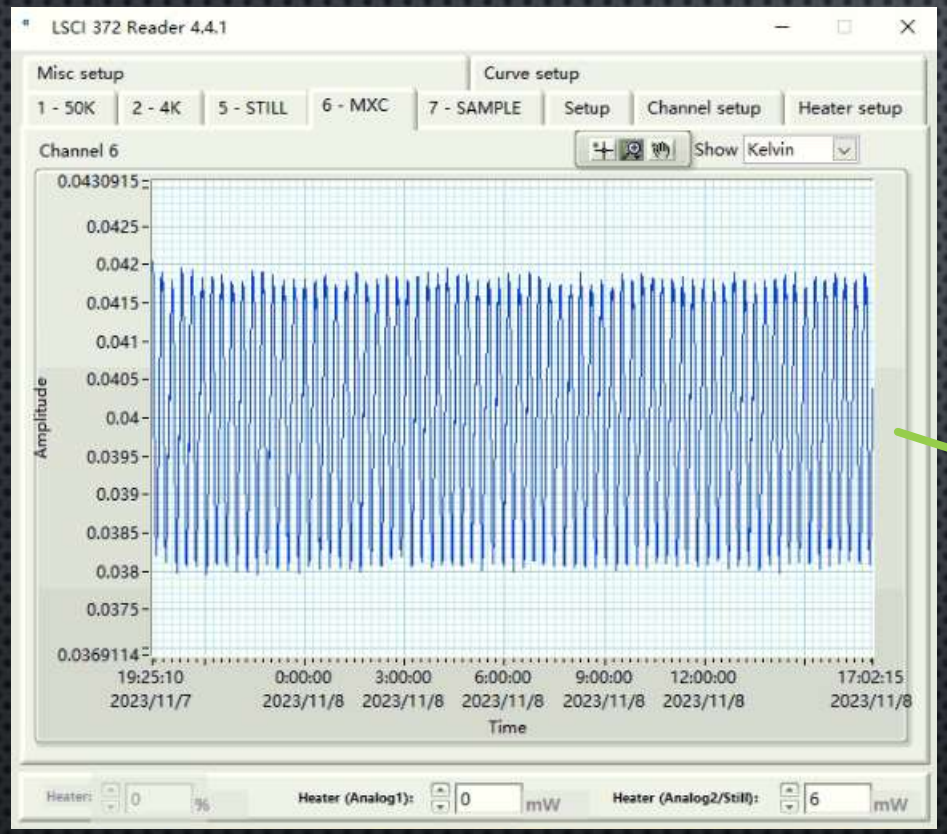

Load curve: I vs V - 3x1NTD
×10^-10
Current (A)
Voltage (V)
Load curve data
R: (4.46e+06 +- 4.5e+05) ohm
I0: (-2.4e-10 +- 1.3e-10) A


Load curve: I vs V - 19T20
×10^-9
Current (A)
Voltage (V)
×10^-3
Load curve data
R: (2.59e+06 +- 2.7e+05) ohm
I0: (8e-11 +- 1.0e-10) A

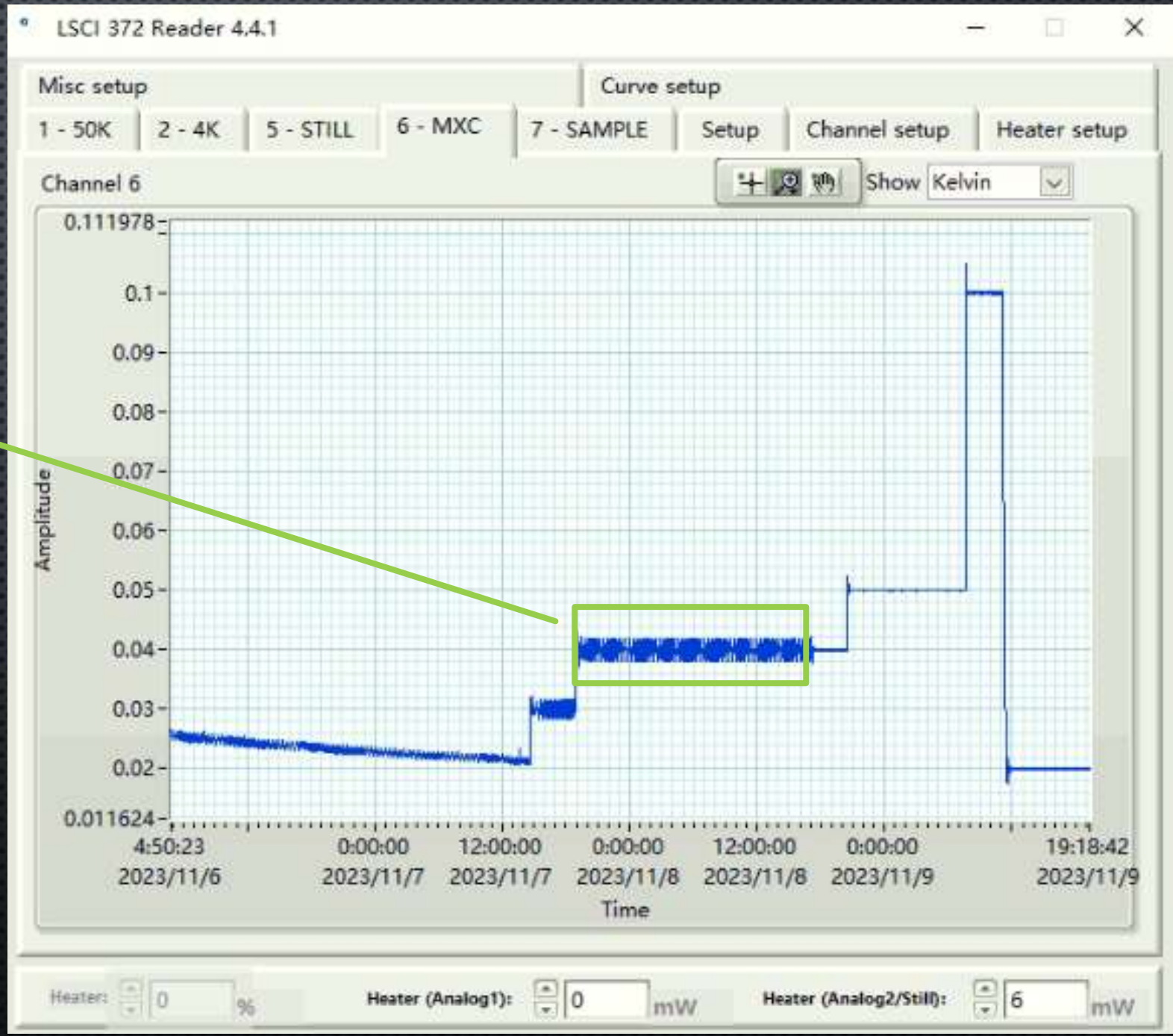
控温在~40 mK


Load curve: I vs V - 3x3NTD
×10^-9
2.5
2
1.5
1
0.5
0
Current (A)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
×10^-3
Voltage (V)
Load curve data
R: (6.25e+05 +- 5.8e+04) ohm
I0: (1.25e-10 +- 9.1e-11) A

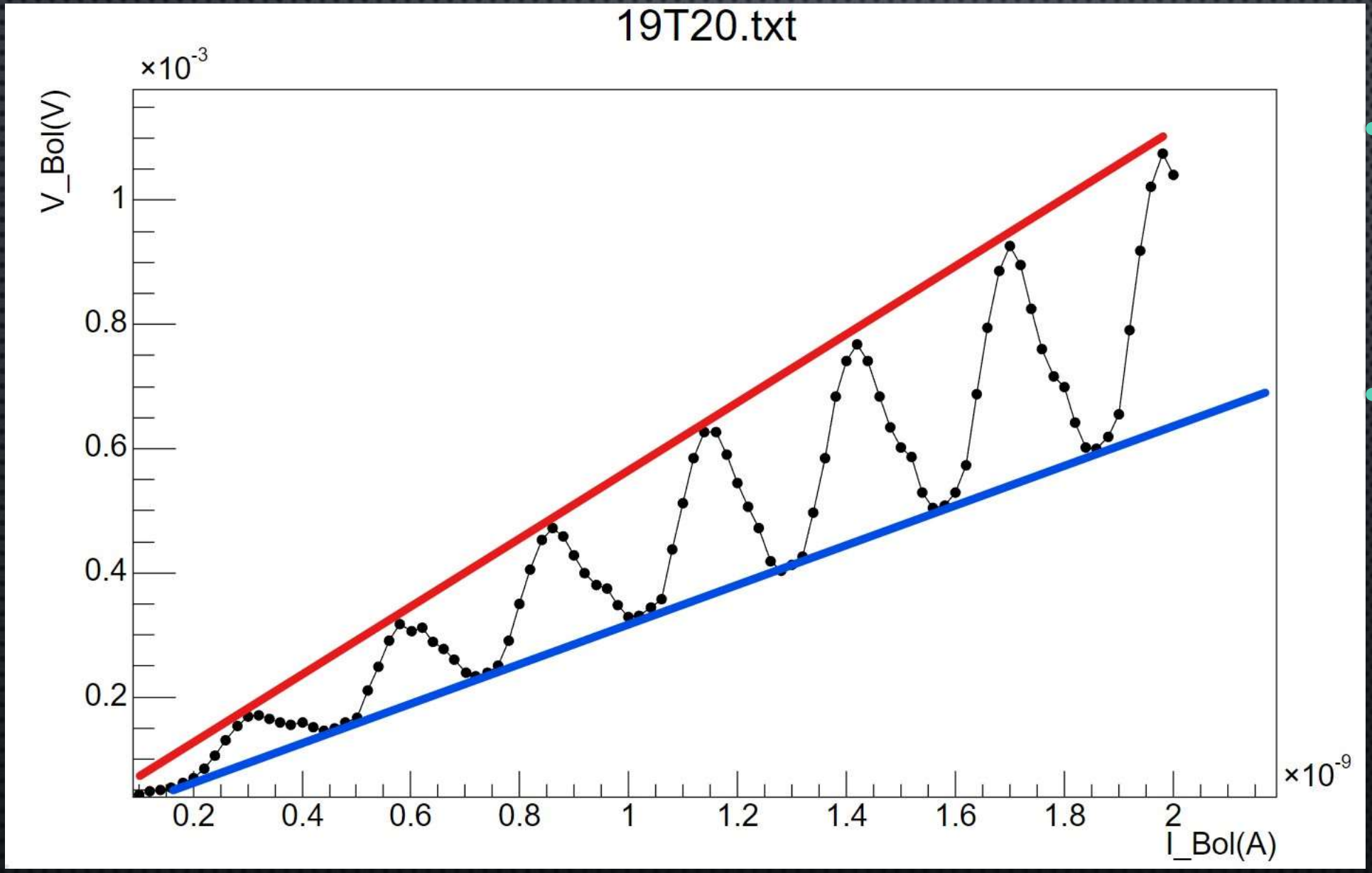
控温在~40 mK



- $T_{\min} \approx 38$ mK
- $T_{\max} \approx 41.7$ mK
- $\Delta T \approx 3.7$ mK



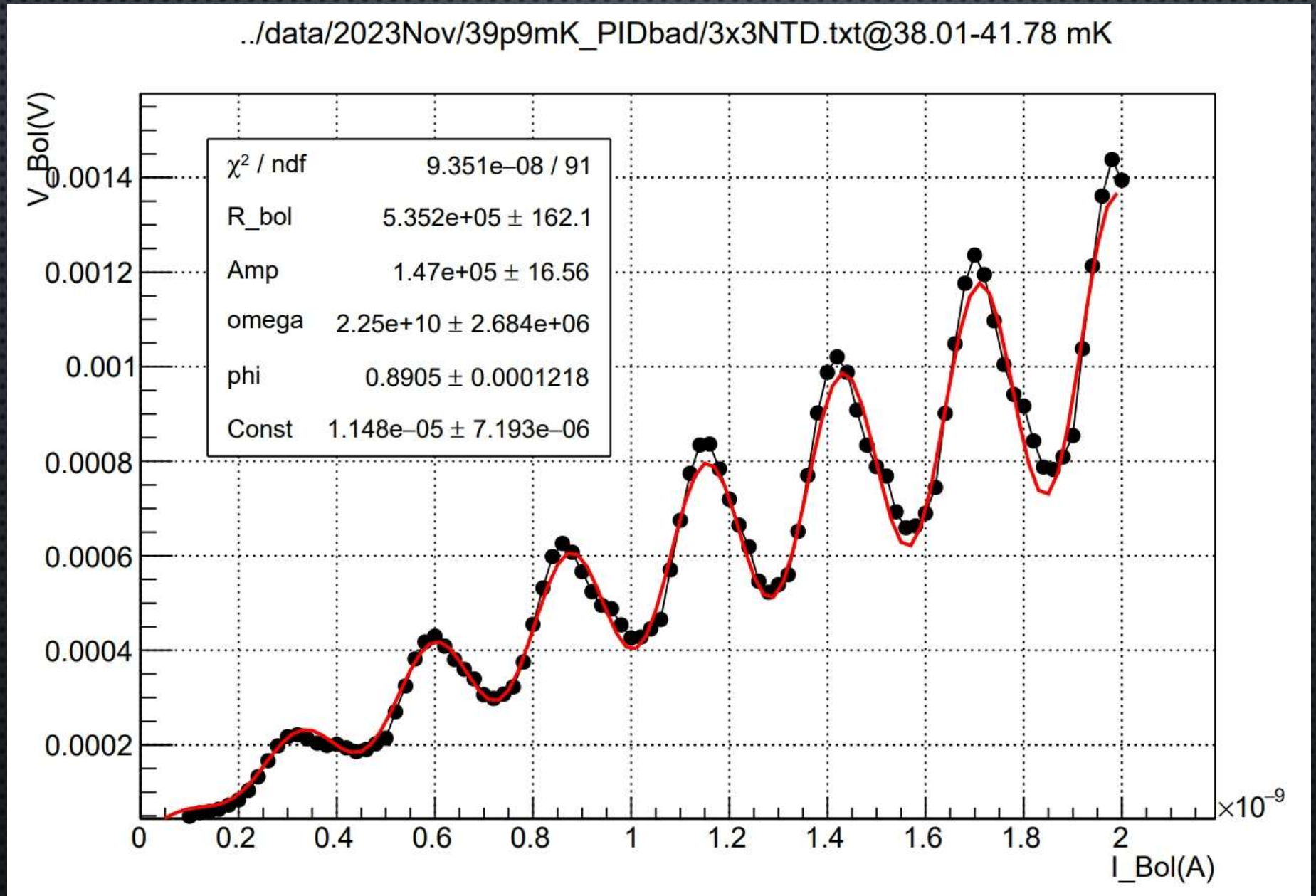
控温在~40 mK



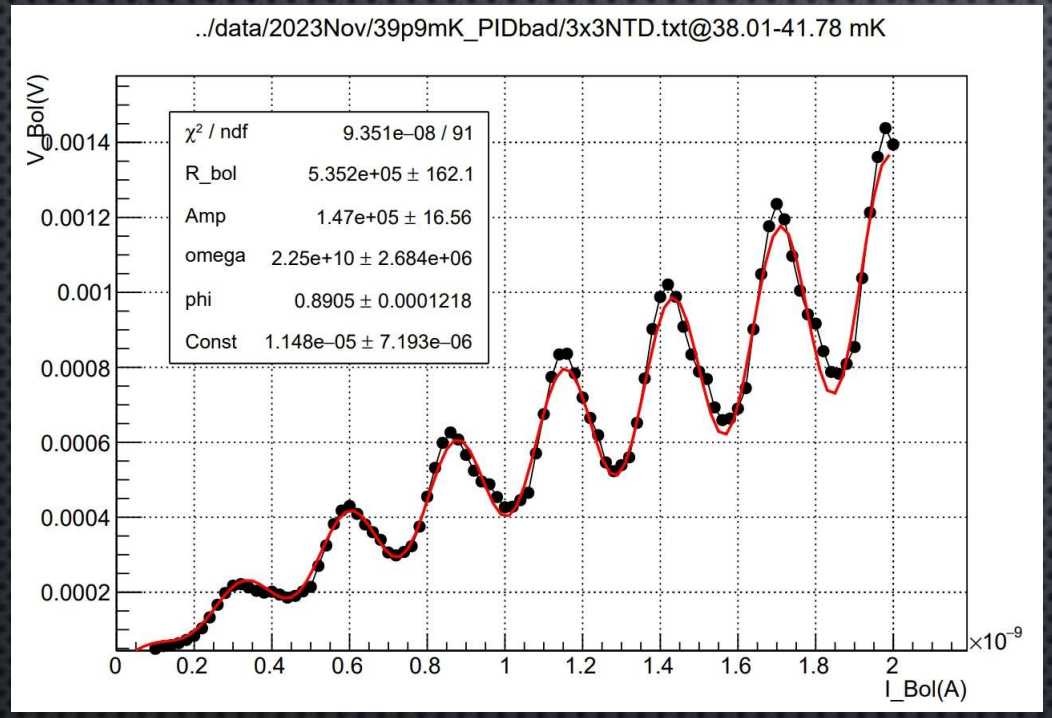
- $T_{\min} \approx 38\ \mathrm{mK}$
- $T_{\max} \approx 41.7\ \mathrm{mK}$

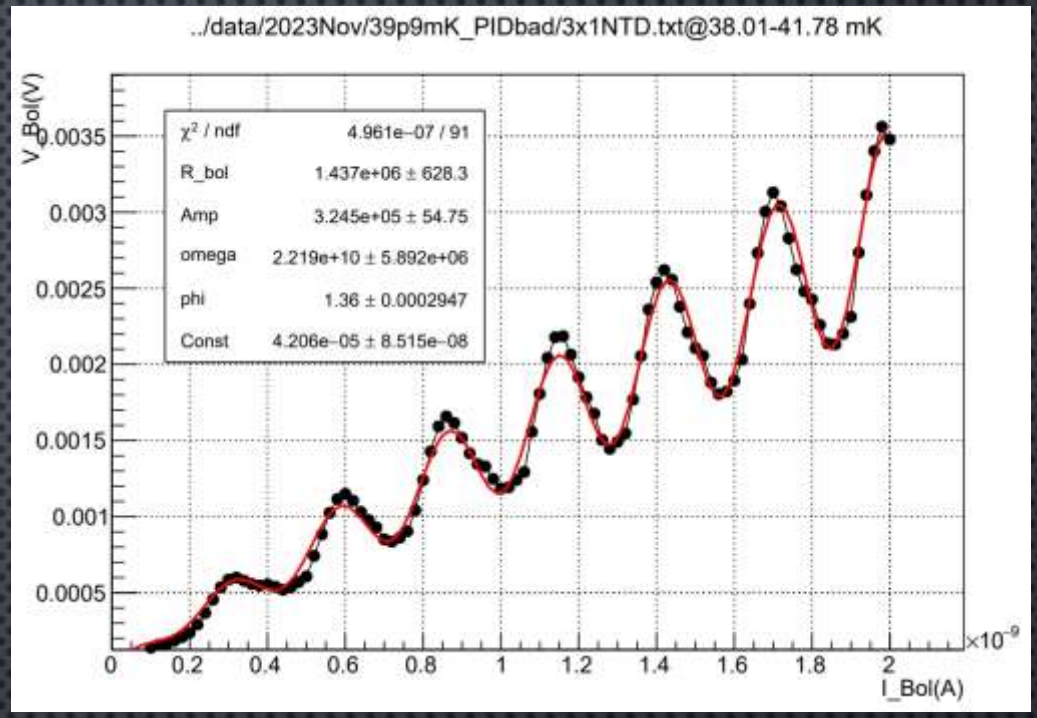
控温在~40 mK

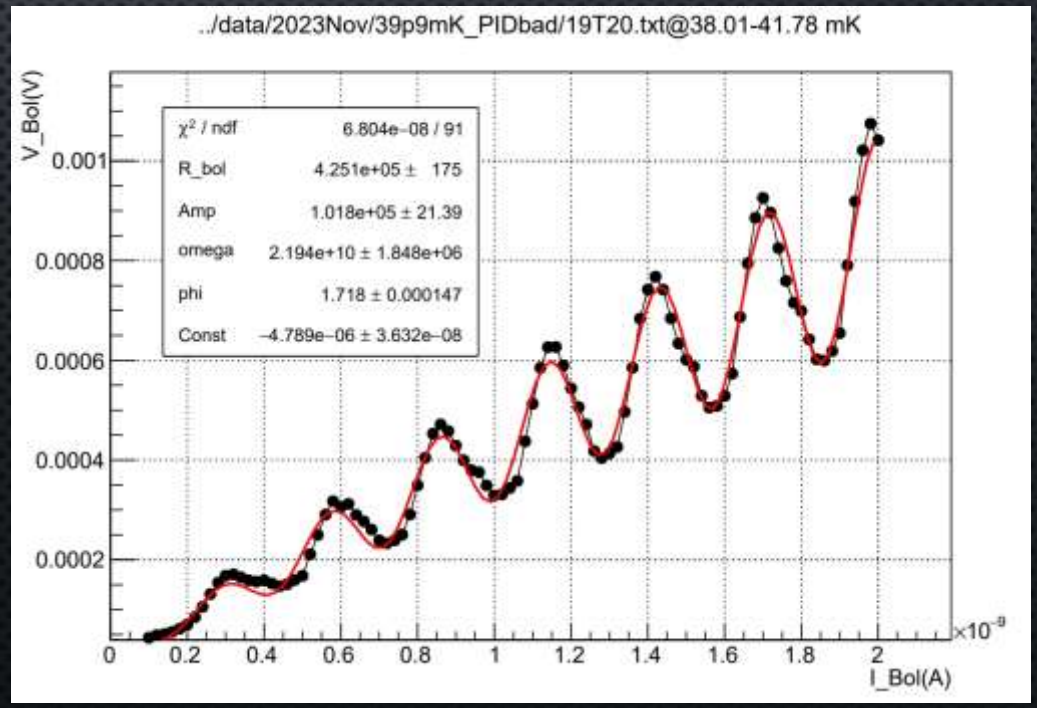
$$V(I) = R_{\mathrm{bol}} \cdot I + Amp \cdot I \cdot \sin(\omega I + \varphi) + C$$



控温在~40 mK



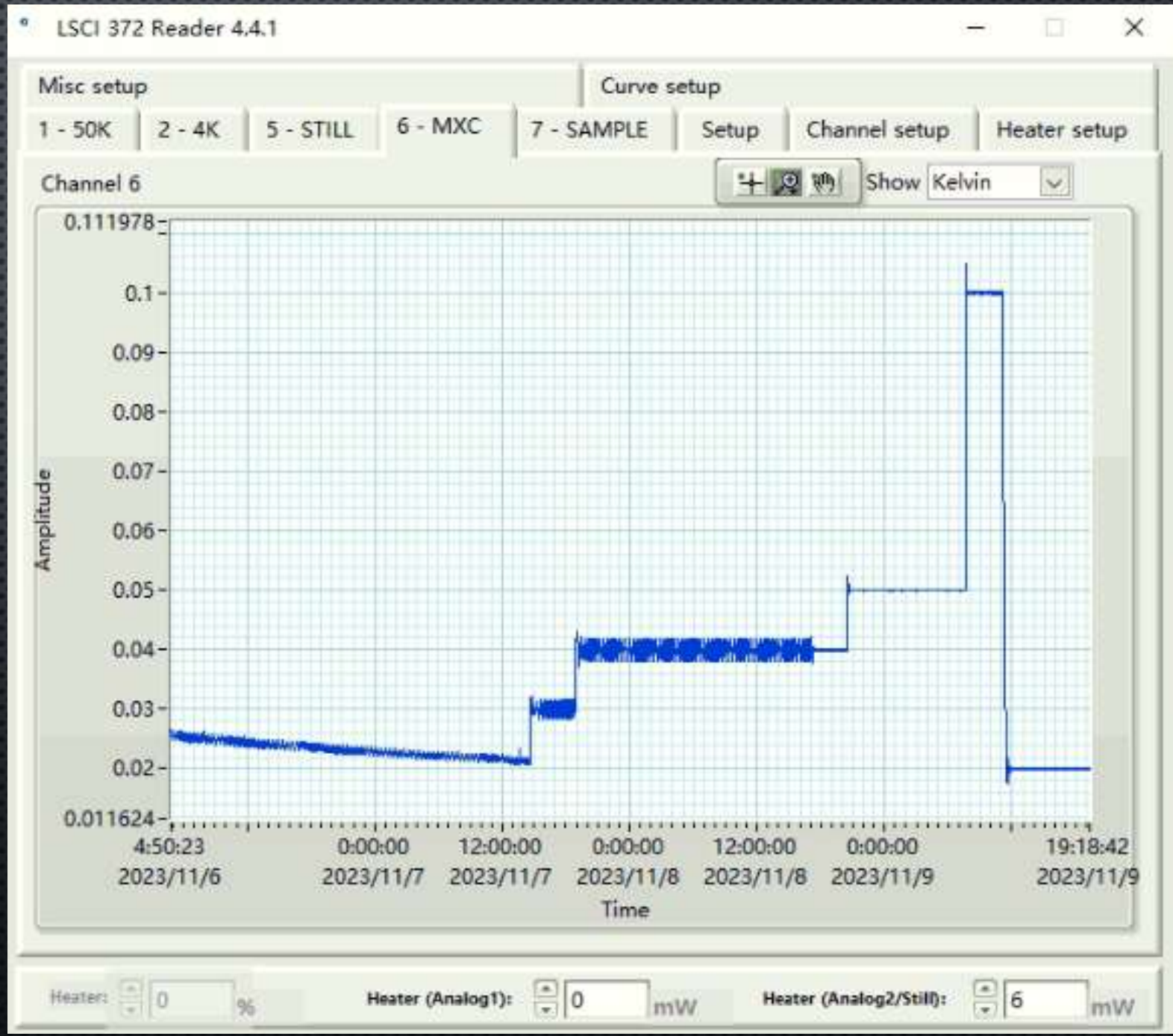




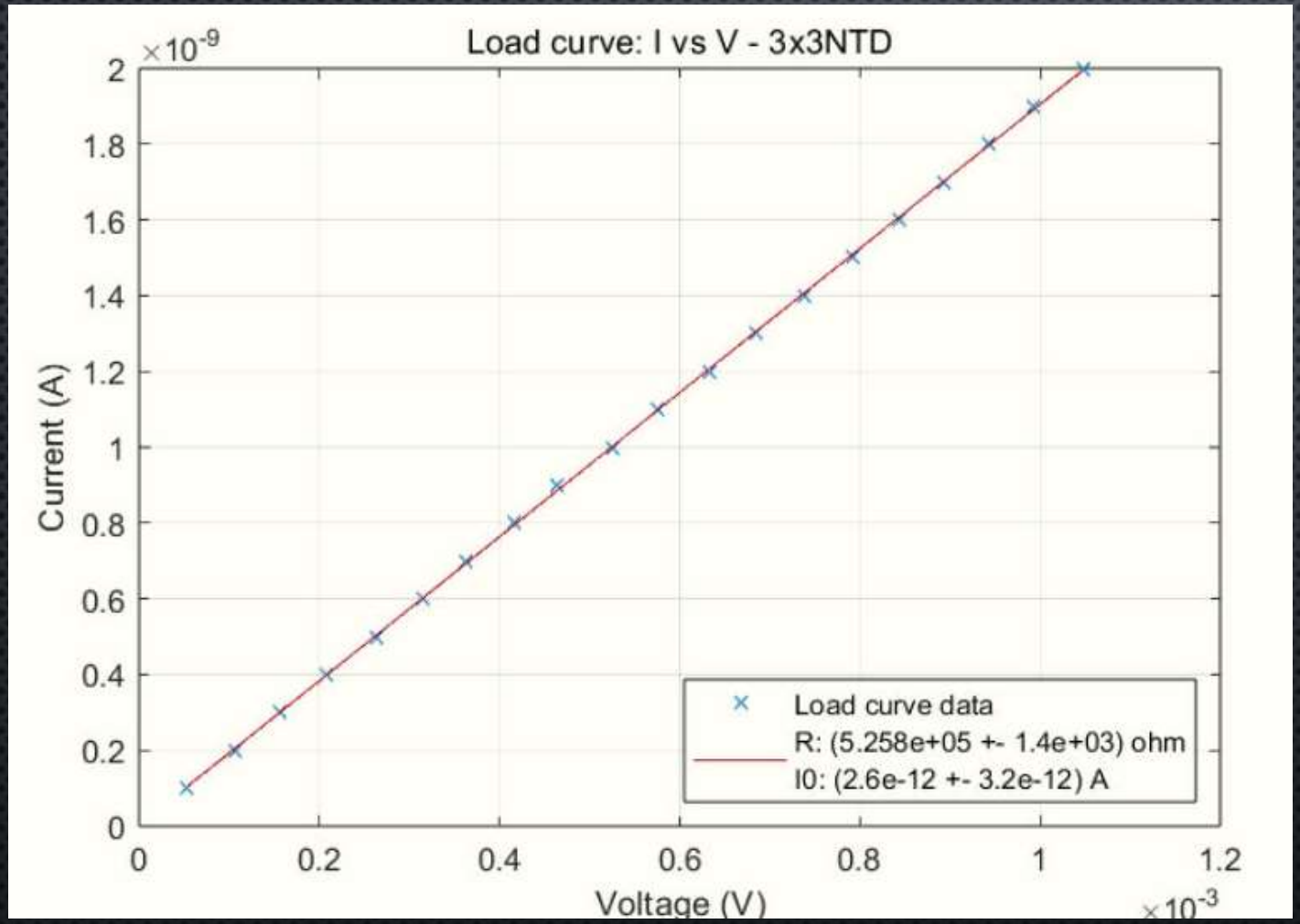
- $V = R_{\mathrm{bol}} \cdot I + Amp \cdot I \cdot \sin(\omega I + \varphi) + C$
- $\max R_{\mathrm{bol}} = R_{\mathrm{bol}} + Amp \ @ \ T_{\mathrm{min}}$
- $\min R_{\mathrm{bol}} = R_{\mathrm{bol}} - Amp \ @ \ T_{\mathrm{max}}$

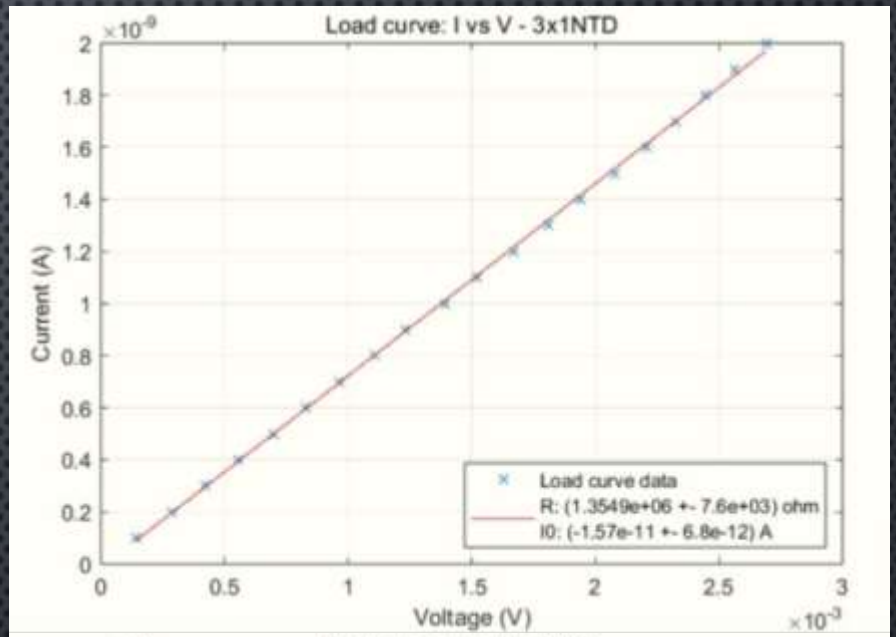
制冷机降温过程

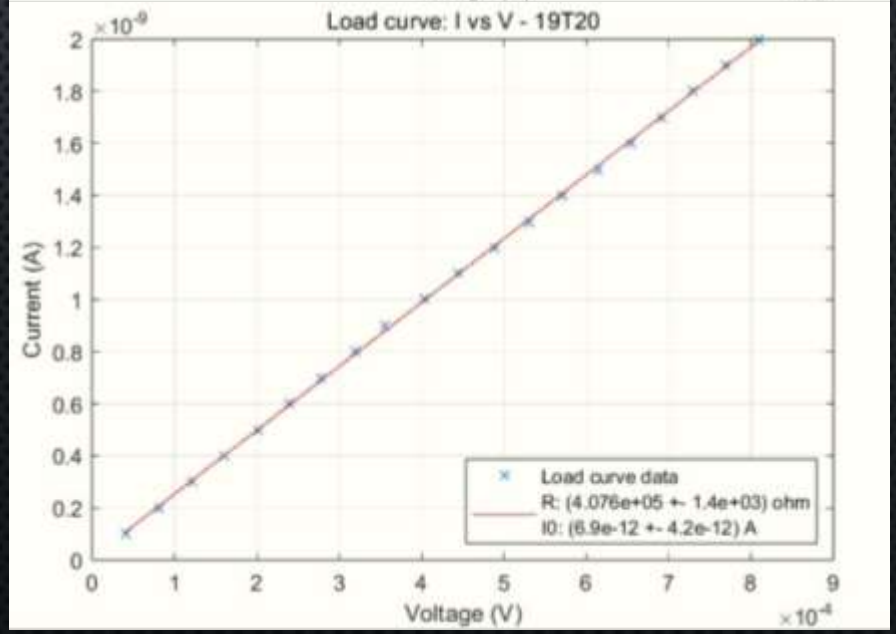
- 初次降温至~20 mK
- 初次控温在~30 mK
- 控温在~40 mK
- 调整PID参数，改善控温的稳定性，仍然在40 mK
- 控温在50 mK
- 控温在100 mK
- 再次回到20 mK控温



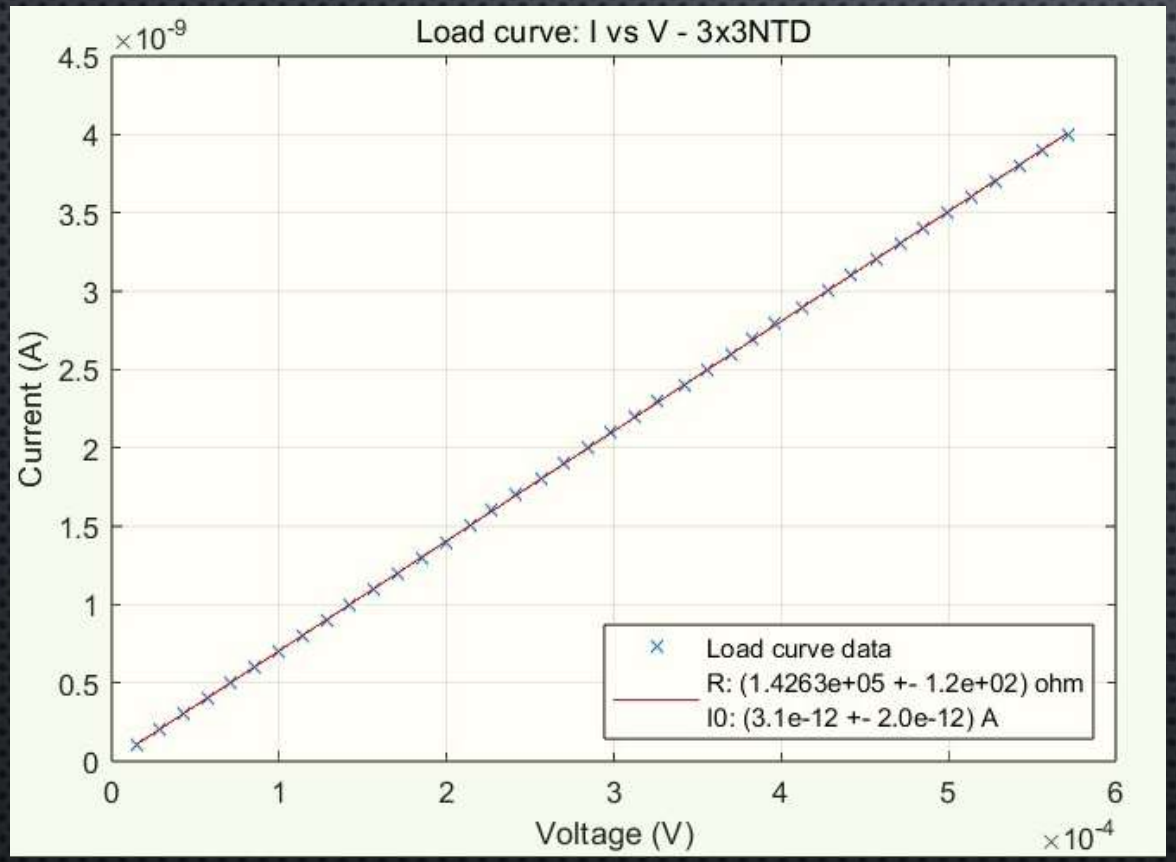
调整PID参数，改善控温的稳定性，仍然在40 mK

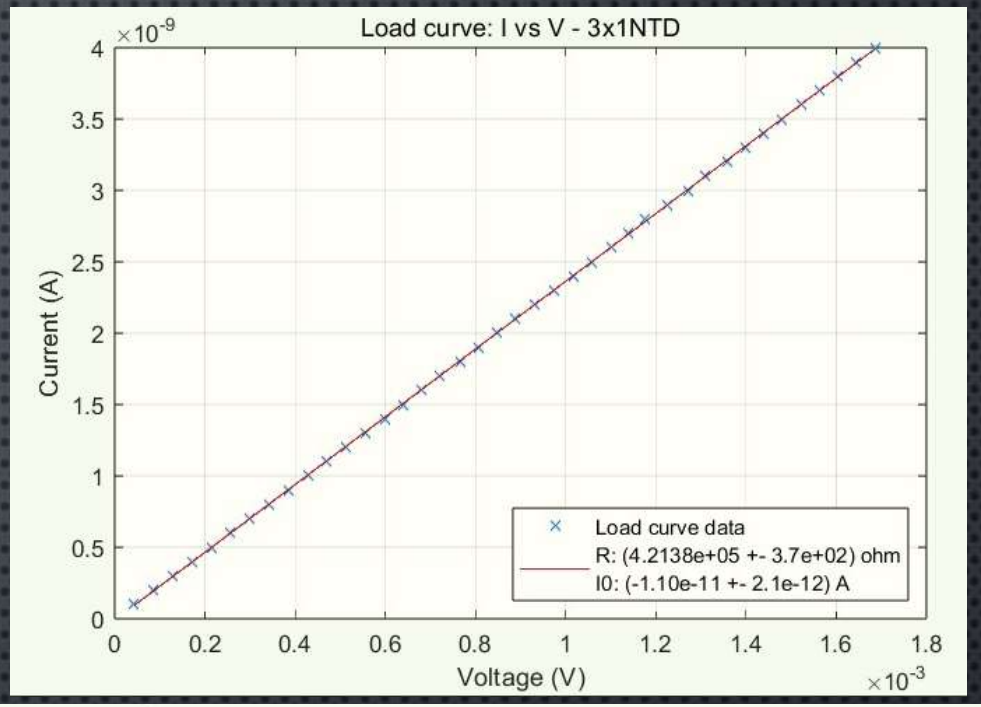


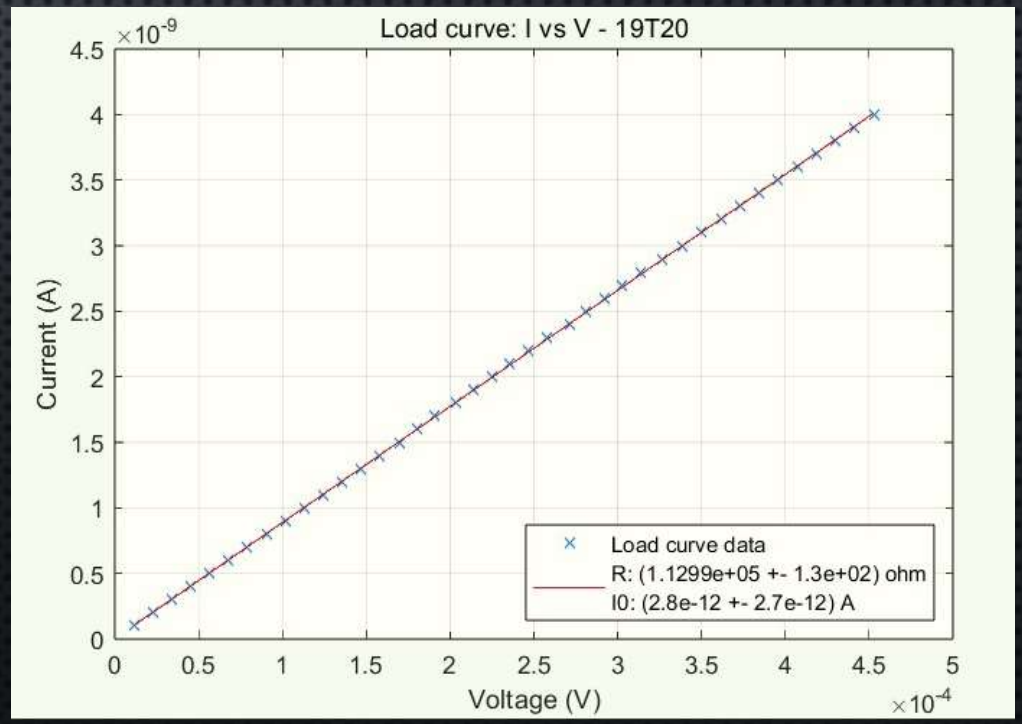




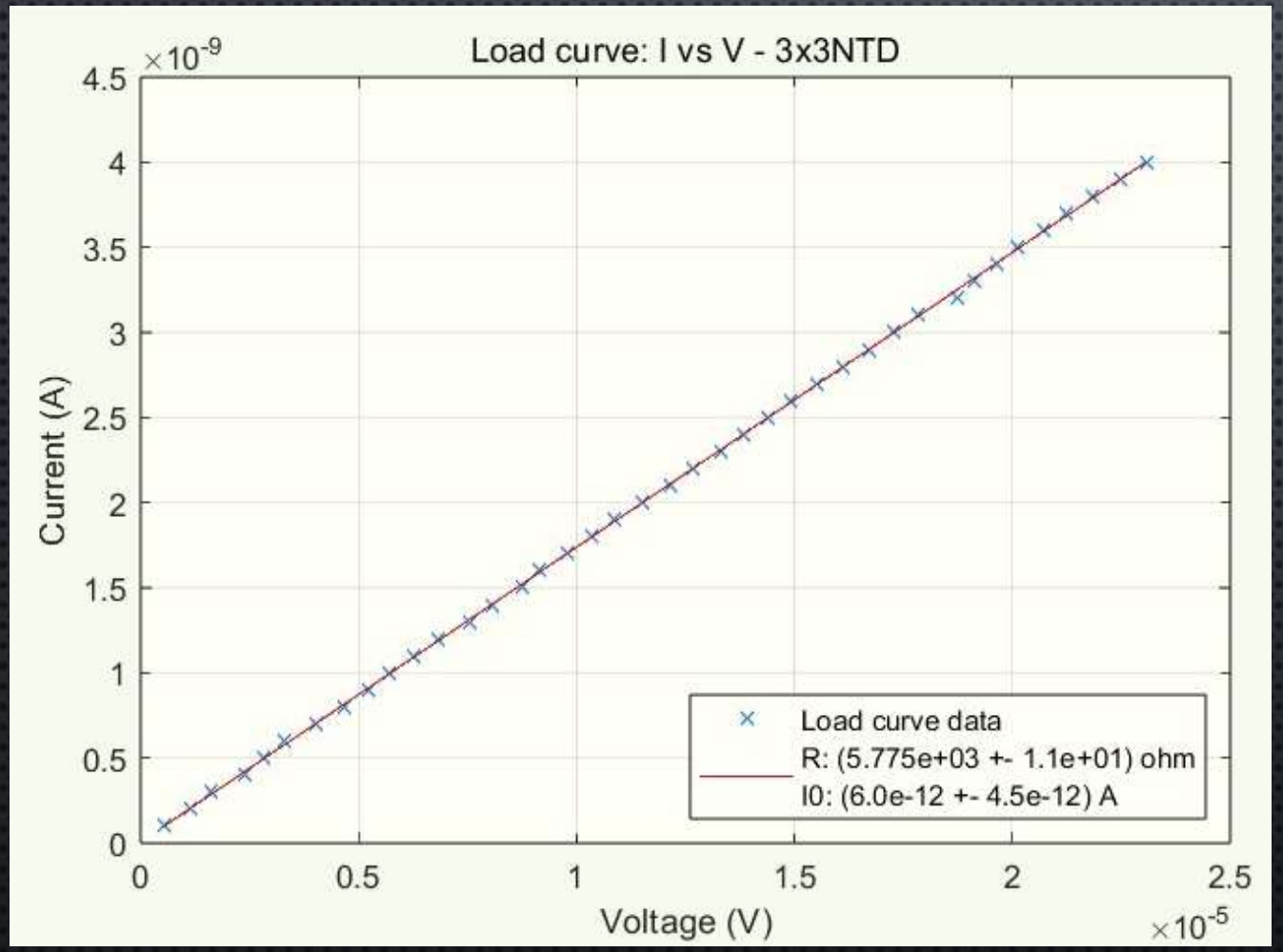
控温在50 mK

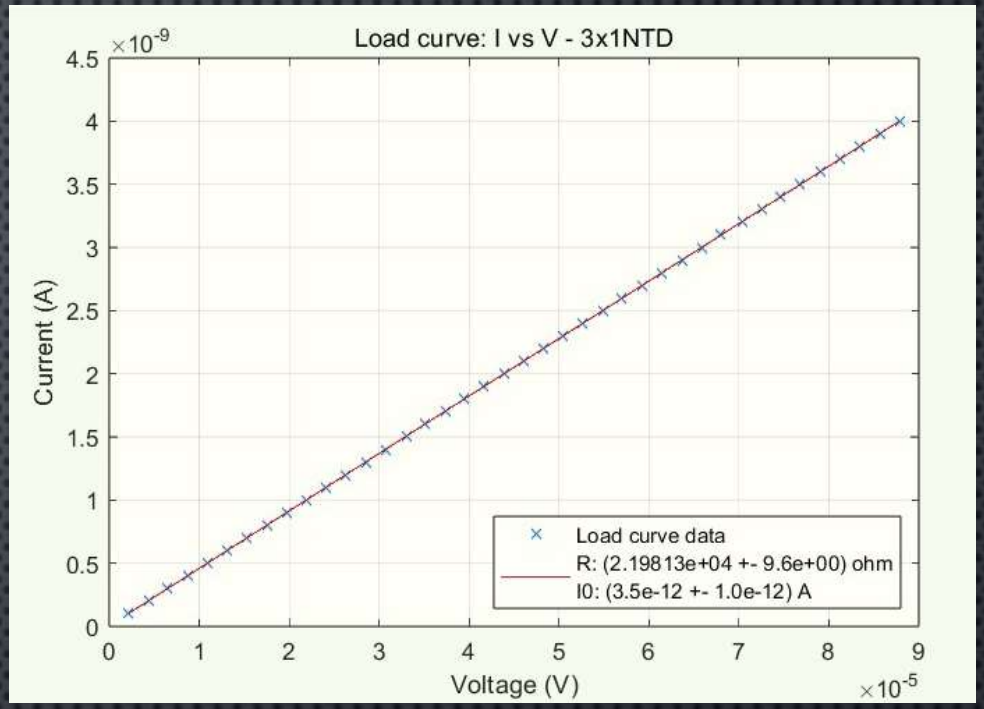

Load curve: I vs V - 3x3NTD
×10^-9
Current (A)
Voltage (V)
×10^-4
Load curve data
R: (1.4263e+05 +- 1.2e+02) ohm
I0: (3.1e-12 +- 2.0e-12) A

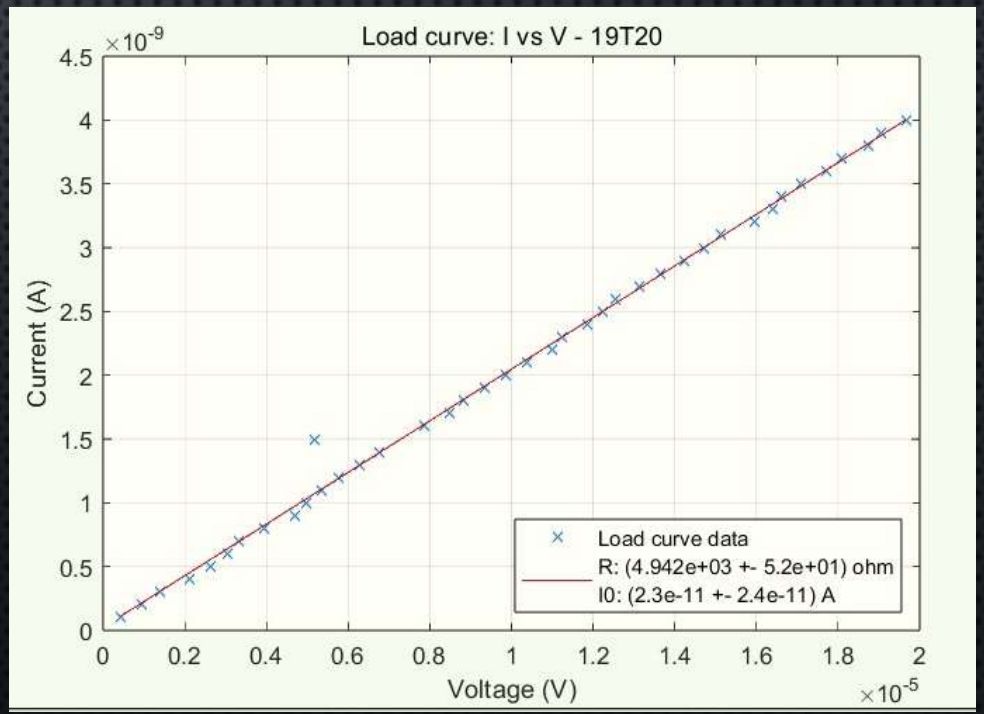

Load curve: I vs V - 3x1NTD
×10^-9
Current (A)
Voltage (V)
×10^-3
Load curve data
R: (4.2138e+05 +- 3.7e+02) ohm
I0: (-1.10e-11 +- 2.1e-12) A


Load curve: I vs V - 19T20
×10^-9
Current (A)
Voltage (V)
×10^-4
Load curve data
R: (1.1299e+05 +- 1.3e+02) ohm
I0: (2.8e-12 +- 2.7e-12) A

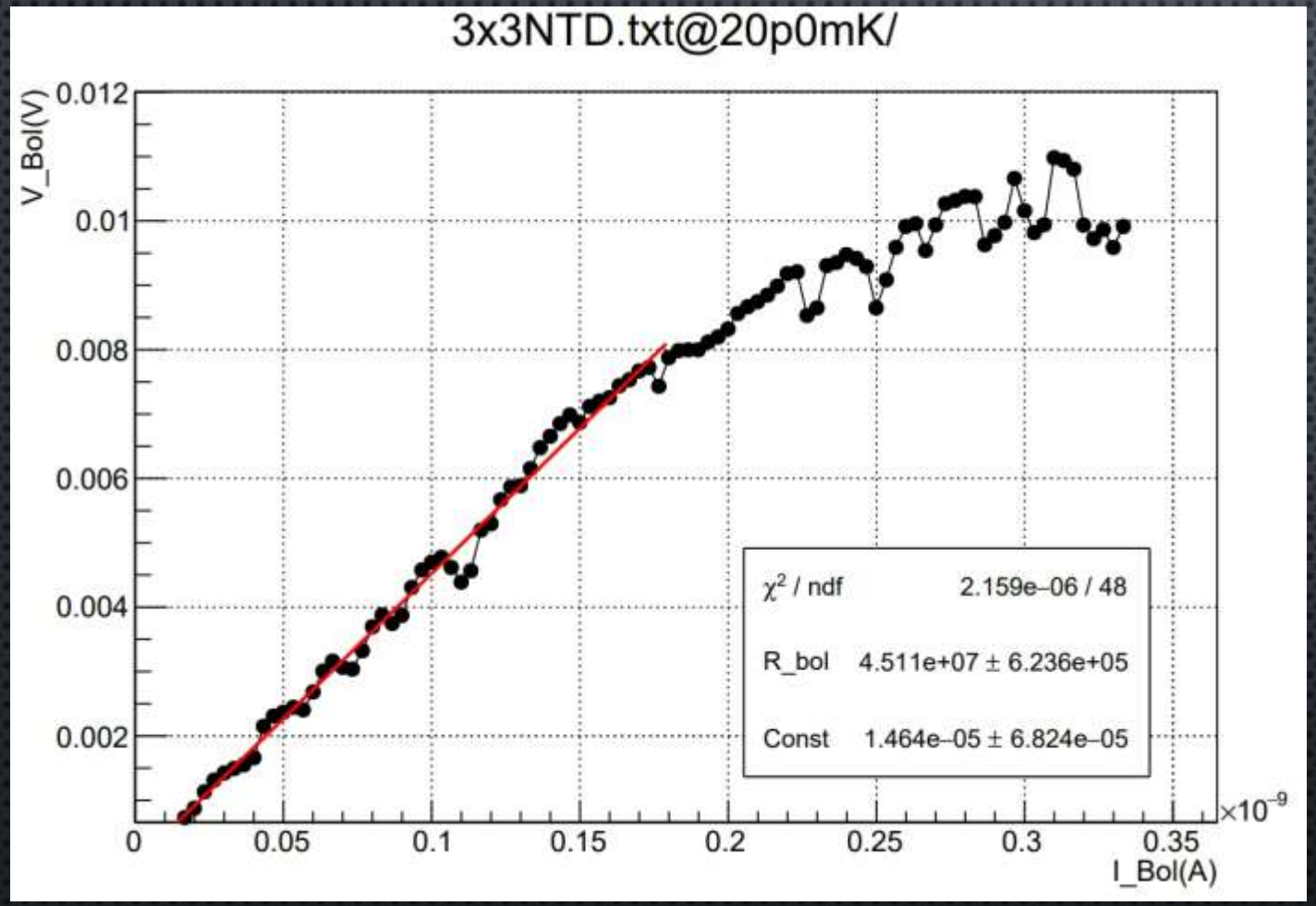
控温在100 mK

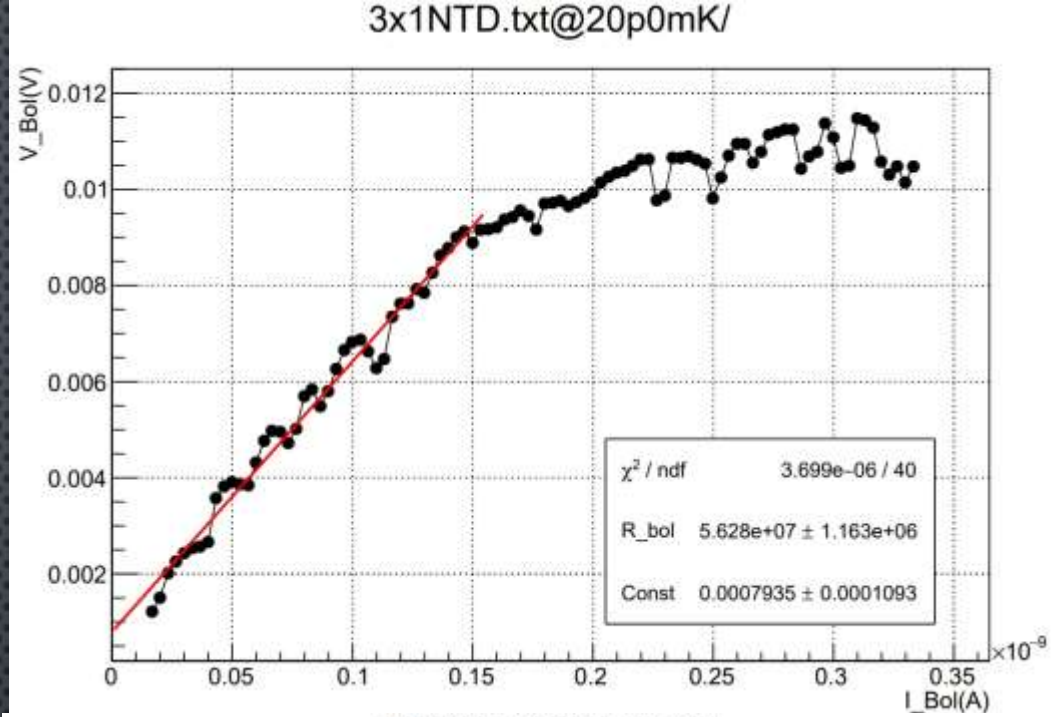

Load curve: I vs V - 3x3NTD
×10^-9
Current (A)
Voltage (V)
×10^-5
Load curve data
R: (5.775e+03 +- 1.1e+01) ohm
I0: (6.0e-12 +- 4.5e-12) A

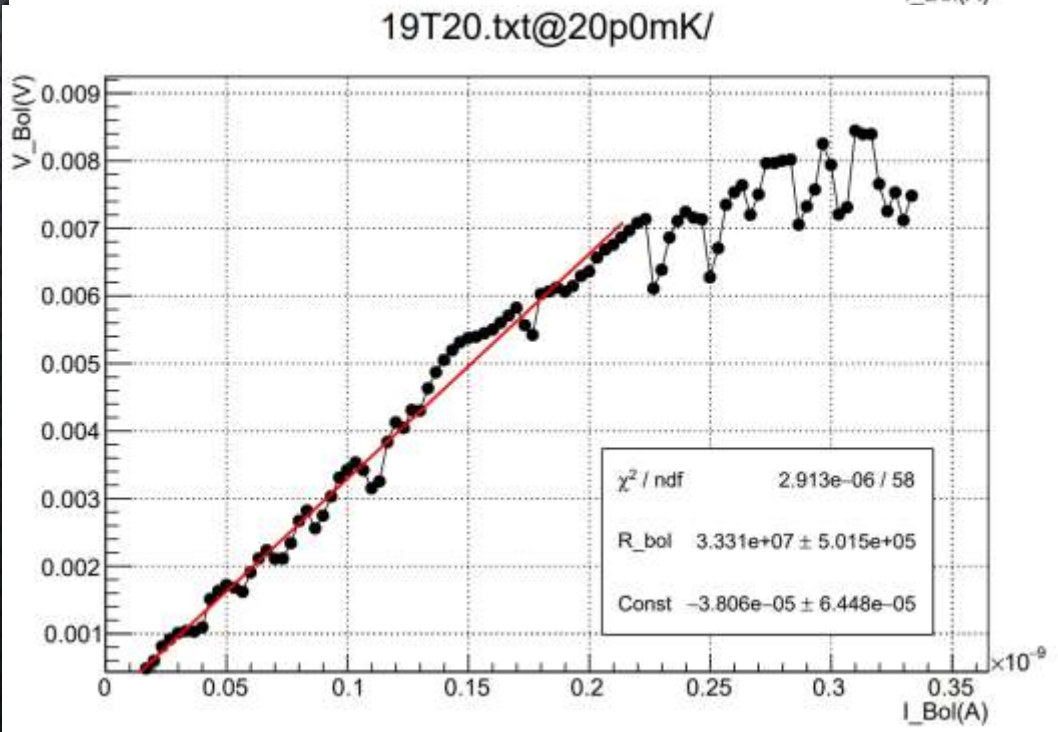

Load curve: I vs V - 3x1NTD
×10^-9
Current (A)
Voltage (V)
×10^-5
Load curve data
R: (2.19813e+04 +- 9.6e+00) ohm
I0: (3.5e-12 +- 1.0e-12) A

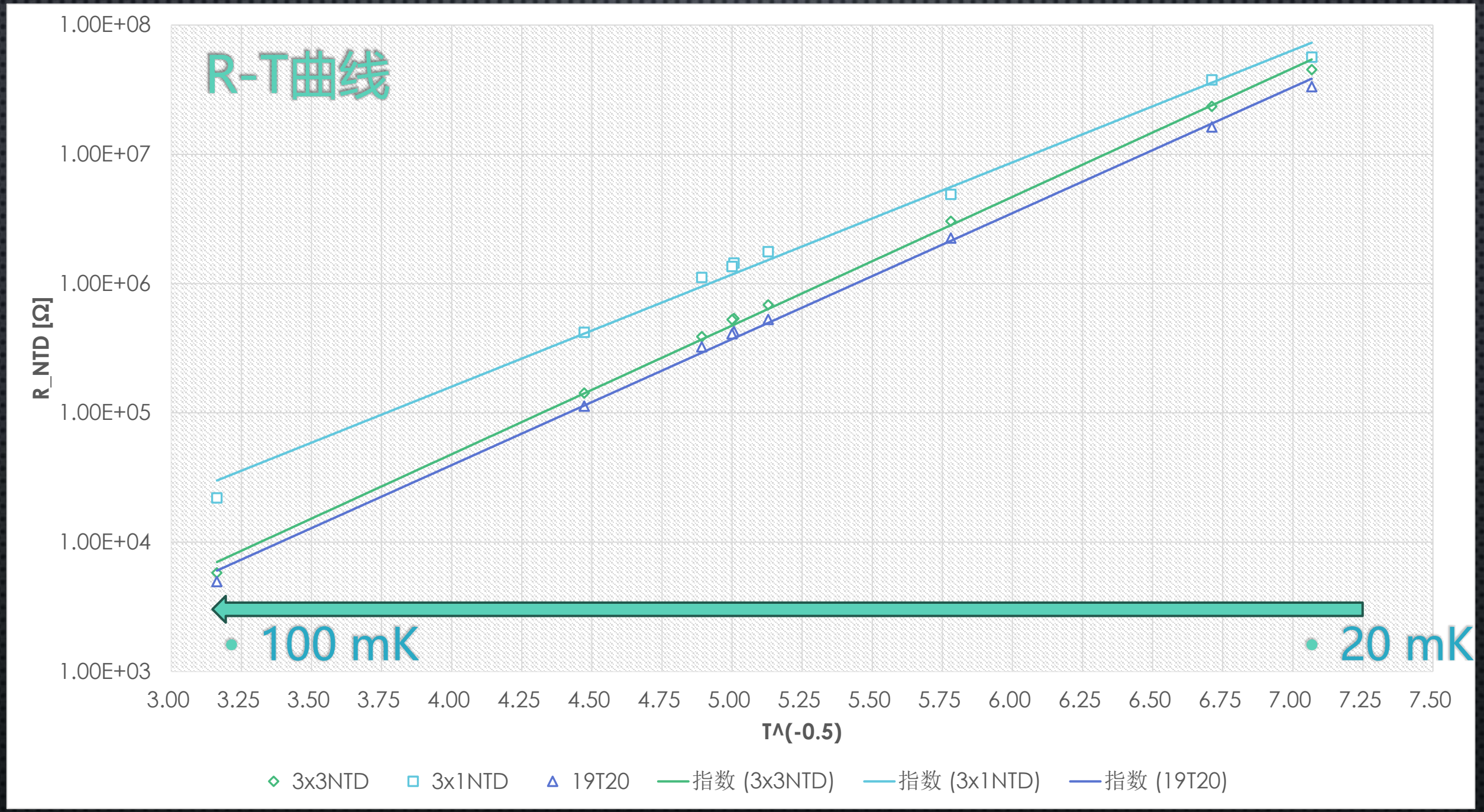

Load curve: I vs V - 19T20
×10^-9
Current (A)
Voltage (V)
×10^-5
Load curve data
R: (4.942e+03 +- 5.2e+01) ohm
I0: (2.3e-11 +- 2.4e-11) A

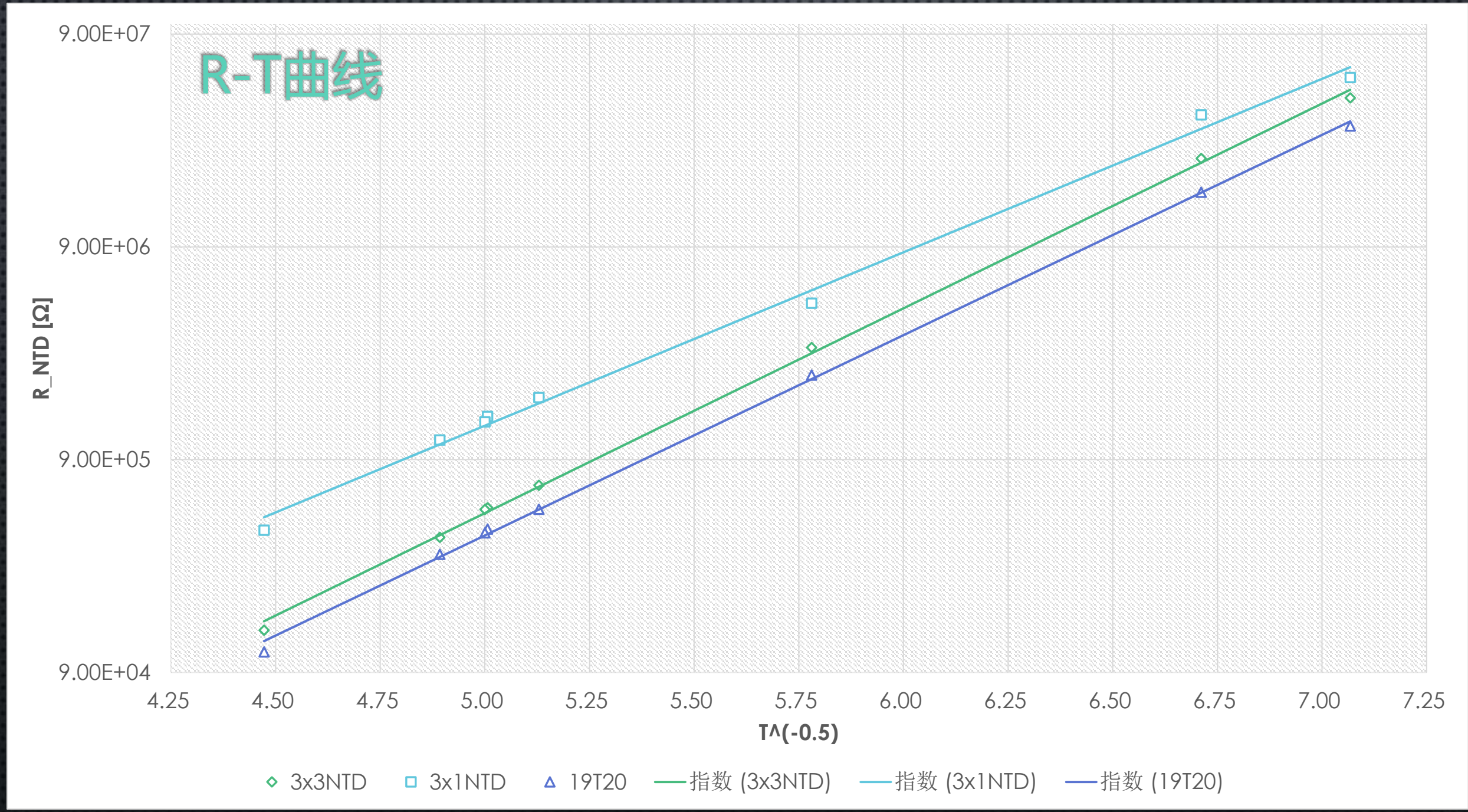
再次回到20 mK控温

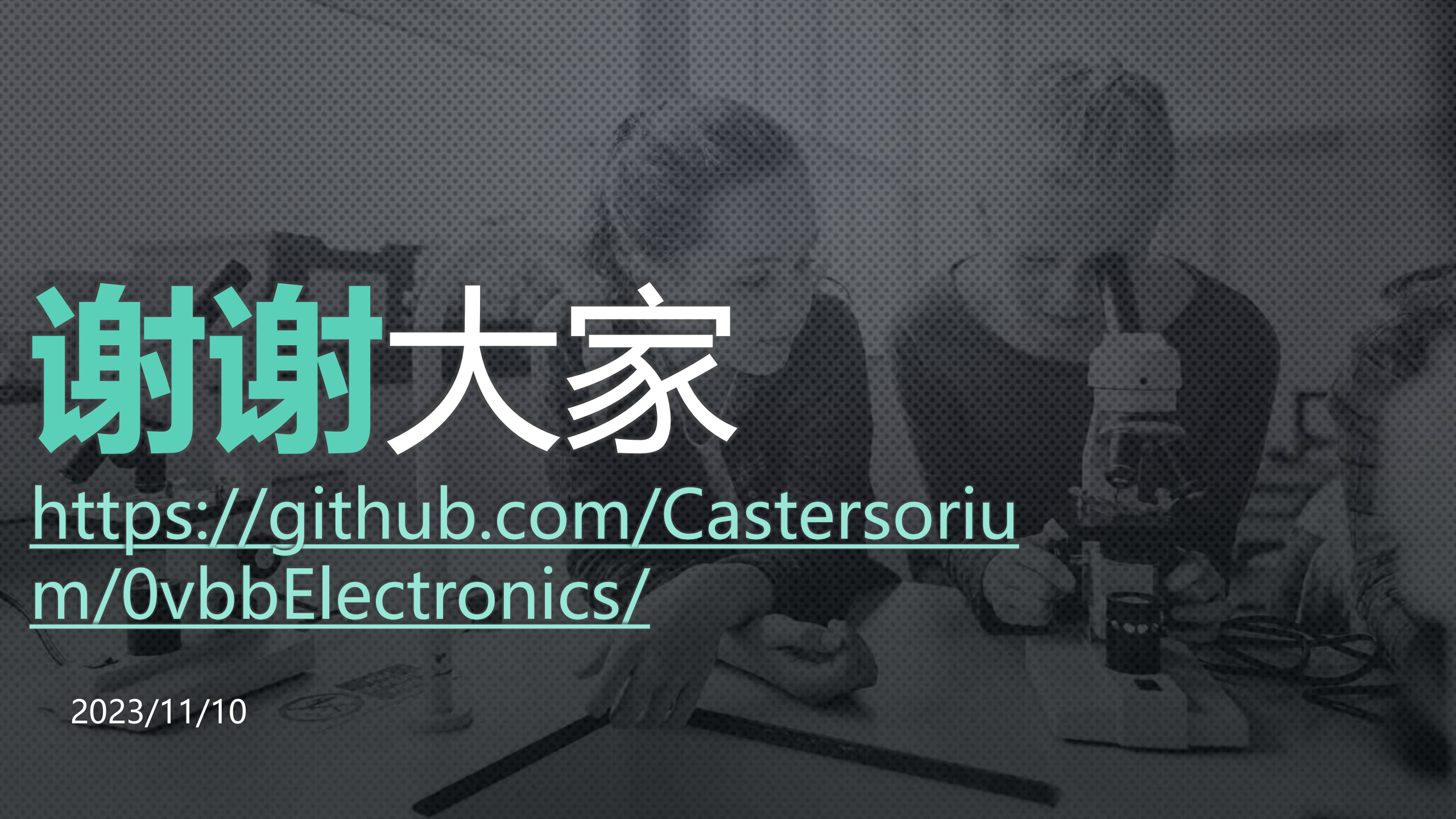

3x3NTD.txt@20p0mK/
V_Bol(V)
I_Bol(A)
×10⁻⁹
χ² / ndf 2.159e−06 / 48
R_bol 4.511e+07 ± 6.236e+05
Const 1.464e−05 ± 6.824e−05


3x1NTD.txt@20p0mK/
V_Bol(V)
I_Bol(A)
×10⁻⁹
χ² / ndf 3.699e−06 / 40
R_bol 5.628e+07 ± 1.163e+06
Const 0.0007935 ± 0.0001093


19T20.txt@20p0mK/
V_Bol(V)
I_Bol(A)
×10⁻⁹
χ² / ndf 2.913e−06 / 58
R_bol 3.331e+07 ± 5.015e+05
Const −3.806e−05 ± 6.448e−05


R-T曲线
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
R_NTD [Ω]
3.00
3.25
3.50
3.75
4.00
4.25
4.50
4.75
5.00
5.25
5.50
5.75
6.00
6.25
6.50
6.75
7.00
7.25
7.50
T^(-0.5)
100 mK
20 mK
3x3NTD
3x1NTD
19T20
指数 (3x3NTD)
指数 (3x1NTD)
指数 (19T20)


R-T曲线
9.00E+07
9.00E+06
9.00E+05
9.00E+04
R_NTD [Ω]
4.25
4.50
4.75
5.00
5.25
5.50
5.75
6.00
6.25
6.50
6.75
7.00
7.25
T^(-0.5)
3x3NTD
3x1NTD
19T20
指数 (3x3NTD)
指数 (3x1NTD)
指数 (19T20)



谢谢大家

https://github.com/Castersorium/0vbbElectronics/

2023/11/10