DTU Nutech, DK-4000 Roskilde, Denmark

Electrometer charge calibration report for file: exp112847

CRC32 file validation = TRUE (ok.lines=43, not.ok.lines=0)

Consistency between index and number of lines in data file = TRUE

> Notes made during the analysis:

42-step procedure

> End of notes.

Electrometer charge calibration: 'KEITHLEYINSTRUMENTSINC.−MODEL6517B−A12/700x'SN1341729 (exp112847)

item	value
File	exp112847
Cal. note	Cal−session−15 XFBK SC1000SN806170
Model (electrometer)	'KEITHLEYINSTRUMENTSINC.−MODEL6517B−A12/700x'
SN (electrometer)	1341729
Range (electrometer)	2e−06
Range of charge supplied (min / max)	−2.0 nC / 2.0 nC (max current = 0.130 nA)
Cable (data file)	'Keithley−triax'
Capacitor id (data file)	'1 nF 1404A−SN−D7−16431384'
Capacitor note (script)	1404A−SN−D7−16431384
Capacitor value (script)	1.000028 nF
Voltmeter data: base value before step	V.ext.read4 V.ext.read5
Voltmeter data: main reading after step	V.ext.read6 V.ext.read7
Electrometer data: base value before step	nC.read4 nC.read5
Electrometer data: main reading after step	nC.read6 nC.read7
Leakage correction model	uniform.leak.model
Voltage burden	0.0 uV
Measurement time: start − stop	'12−07−2018 − 02:56:09' − '12−07−2018 − 04:25:09'
Duration	89.01 min
Lab. temperature	22.15 degC
Lab. humidity	47.0 %RH
Lab. pressure	1014.28 hPa
Ramp time / Wait.before.first.read	15 s / 15 s
Wait.leakage / Wait.between.readings / Total step duration	5 s / 1 s / 98.4 s
Initial charge reading (raw) after reset	−5.5800e−01 pC sd = 1.2400e−01 pC N = 42
End charge reading (raw) after full charge return	1.010 pC sd = 1.423 pC N = 42 Min = −3.1 pC Max = 5.5 pC
Net charge (leakage corrected etc.) for zero−V step	0.115 pC sd = 1.099 pC N = 4
Leakage current (absolute values)	Before: Median= 0.042 pA After: Median= 0.033 pA Max= 0.101 pA
k.elec.all (all data pooled; stat.limit = 25 %)	−1.000474 nC/nC sd = −0.038 % N = 16
k.elec.pos (positive charge only)	−1.000473 nC/nC sd = −0.040 % N = 8
k.elec.neg (negative charge only)	−1.000475 nC/nC sd = −0.039 % N = 8
Polarity ratio: k.pol = k.elec.pos / k.elec.neg	0.999998
Polarity difference : k.elec.pos − k.elec.neg (ANOVA)	0.000002 +/− 0.000197 p = 0.991
Reference polarity for k.non.lin coeff.	Negative (k.elec.neg)
Leakage correction uncert. = u.k.elec.model	−0.0006 %

Uncertainty analysis for electrometer charge cal.: 'KEITHLEYINSTRUMENTSINC.−MODEL6517B−A12/700x'SN1341729 (exp112847)

item	value
File	exp112847
Cal. note	Cal−session−15 XFBK SC1000SN806170
Model (electrometer)	'KEITHLEYINSTRUMENTSINC.−MODEL6517B−A12/700x'
SN (electrometer)	1341729
Range (electrometer)	2e−06
Range of charge supplied (min / max)	−2.0 nC / 2.0 nC (max current = 0.130 nA)
UPARM.charge.u.base.abs	0.000000
UPARM.charge.u.base.pct	0.043000
UPARM.charge.u.minimum.step.abs	0.000000
UPARM.charge.u.minimum.step.pct	0.050000
UPARM.charge.u.voltage.uV	40.000000
UPARM.charge.u.transfer.time.s	5.000000
UPARM.AGGREGATE.charge.u.base.abs	0.000000
UPARM.AGGREGATE.charge.u.base.pct	0.043000
UPARM.AGGREGATE.charge.u.minimum.abs	0.000000
UPARM.AGGREGATE.charge.u.minimum.pct	0.050000
UPARM.charge.u.base.abs	0.000000
k.elec.all (all data pooled; stat.limit = 25 %)	−1.000474 nC/nC sd = −0.038 % N = 16
k.elec.pos (positive charge only)	−1.000473 nC/nC sd = −0.040 % N = 8
k.elec.neg (negative charge only)	−1.000475 nC/nC sd = −0.039 % N = 8
UAGGREGATE.k.elec.all	0.003440 (k=2)
UAGGREGATE.k.elec.pos	0.003447 (k=2)
UAGGREGATE.k.elec.neg	0.003260 (k=2)
Leakage correction uncert. = u.k.elec.model	−0.0006 %

Electrometer charge calibration (3 digits): 'KEITHLEYINSTRUMENTSINC.−MODEL6517B−A12/700x'SN1341729 (exp112847)

Non−linearity correction factors (reference = k.elec.neg; Negative) :

V.select	V.ref	pA.Before	pA.After	nC.adj	nC.net	nC.ref	k.elec.step	N	u.k.elec.step	k.non.lin
−2	−2.001	−0.02	0.02	0.001	2.000	−2.001	−1.000	1	0.001	1
−1.8	−1.801	−0.04	0.01	0.001	1.800	−1.801	−1.000	2	0.001	0.9999
−1.6	−1.601	0.03	0.00	−0.000	1.600	−1.601	−1.001	2	0.001	1.0001
−1.4	−1.401	0.03	0.02	0.001	1.400	−1.401	−1.000	2	0.001	0.9997
−1.2	−1.201	−0.03	0.01	0.000	1.199	−1.201	−1.001	2	0.001	1.0007
−1	−1.000	0.01	0.07	0.001	1.000	−1.000	−1.001	2	0.001	1.0002
−0.8	−0.800	−0.10	0.06	0.001	0.800	−0.800	−1.000	2	0.001	0.9999
−0.6	−0.600	0.04	−0.01	0.001	0.600	−0.600	−1.000	2	0.002	0.9994
−0.4	−0.400	0.01	0.04	0.001	0.400	−0.400	−1.002	2	0.002	1.0013
−0.2	−0.200	−0.01	−0.03	0.000	0.200	−0.200	−1.001	2	0.004	1.0002
0.2	0.200	0.01	0.01	0.001	−0.200	0.200	−1.000	2	0.004	0.9999
0.4	0.400	0.08	−0.03	0.001	−0.401	0.400	−0.999	2	0.002	0.9984
0.6	0.600	−0.06	0.07	0.001	−0.600	0.600	−1.001	2	0.002	1.0007
0.8	0.800	−0.02	0.03	0.001	−0.800	0.800	−1.001	2	0.001	1.0003
1	1.000	0.06	0.08	0.001	−1.000	1.000	−1.000	2	0.001	0.9997
1.2	1.200	0.01	0.03	0.000	−1.200	1.200	−1.000	2	0.001	0.9996
1.4	1.401	0.01	0.01	0.001	−1.400	1.401	−1.000	2	0.001	0.9997
1.6	1.601	0.07	−0.00	0.001	−1.600	1.601	−1.001	2	0.001	1.0001
1.8	1.801	0.04	0.01	0.001	−1.800	1.801	−1.001	2	0.001	1.0001
2	2.001	−0.08	0.05	−0.000	−2.000	2.001	−1.000	1	0.001	0.9997

Electrometer charge calibration (4 digits): 'KEITHLEYINSTRUMENTSINC.−MODEL6517B−A12/700x'SN1341729 (exp112847)

Non−linearity correction factors (reference = k.elec.neg; Negative) :

V.select	V.ref	pA.Before	pA.After	nC.adj	nC.net	nC.ref	k.elec.step	N	u.k.elec.step	k.non.lin
−2	−2.0008	−0.024	0.020	0.0010	1.9999	−2.0008	−1.0005	1	0.0008	1
−1.8	−1.8007	−0.040	0.008	0.0012	1.8000	−1.8008	−1.0004	2	0.0009	0.9999
−1.6	−1.6007	0.028	0.003	−0.0001	1.5997	−1.6007	−1.0006	2	0.0008	1.0001
−1.4	−1.4006	0.032	0.016	0.0005	1.4004	−1.4006	−1.0002	2	0.0009	0.9997
−1.2	−1.2005	−0.032	0.012	0.0003	1.1991	−1.2006	−1.0012	2	0.0009	1.0007
−1	−1.0005	0.009	0.074	0.0007	0.9998	−1.0005	−1.0007	2	0.0011	1.0002
−0.8	−0.8004	−0.095	0.055	0.0009	0.8001	−0.8004	−1.0004	2	0.0014	0.9999
−0.6	−0.6003	0.040	−0.015	0.0009	0.6004	−0.6003	−0.9998	2	0.0016	0.9994
−0.4	−0.4002	0.007	0.041	0.0011	0.3995	−0.4002	−1.0017	2	0.0024	1.0013
−0.2	−0.2001	−0.006	−0.028	0.0004	0.2000	−0.2001	−1.0007	2	0.0038	1.0002
0.2	0.2001	0.007	0.014	0.0010	−0.2000	0.2001	−1.0004	2	0.0044	0.9999
0.4	0.4001	0.080	−0.034	0.0008	−0.4006	0.4001	−0.9989	2	0.0024	0.9984
0.6	0.6002	−0.063	0.069	0.0007	−0.5995	0.6002	−1.0012	2	0.0017	1.0007
0.8	0.8003	−0.015	0.033	0.0005	−0.7997	0.8003	−1.0008	2	0.0012	1.0003
1	1.0004	0.057	0.075	0.0014	−1.0002	1.0004	−1.0002	2	0.0013	0.9997
1.2	1.2005	0.009	0.031	0.0001	−1.2004	1.2005	−1.0001	2	0.0009	0.9996
1.4	1.4005	0.014	0.010	0.0007	−1.4004	1.4006	−1.0001	2	0.0009	0.9997
1.6	1.6006	0.067	−0.004	0.0006	−1.5997	1.6006	−1.0006	2	0.0009	1.0001
1.8	1.8006	0.042	0.006	0.0009	−1.7997	1.8007	−1.0006	2	0.0009	1.0001
2	2.0007	−0.078	0.047	−0.0001	−2.0003	2.0007	−1.0002	1	0.0008	0.9997

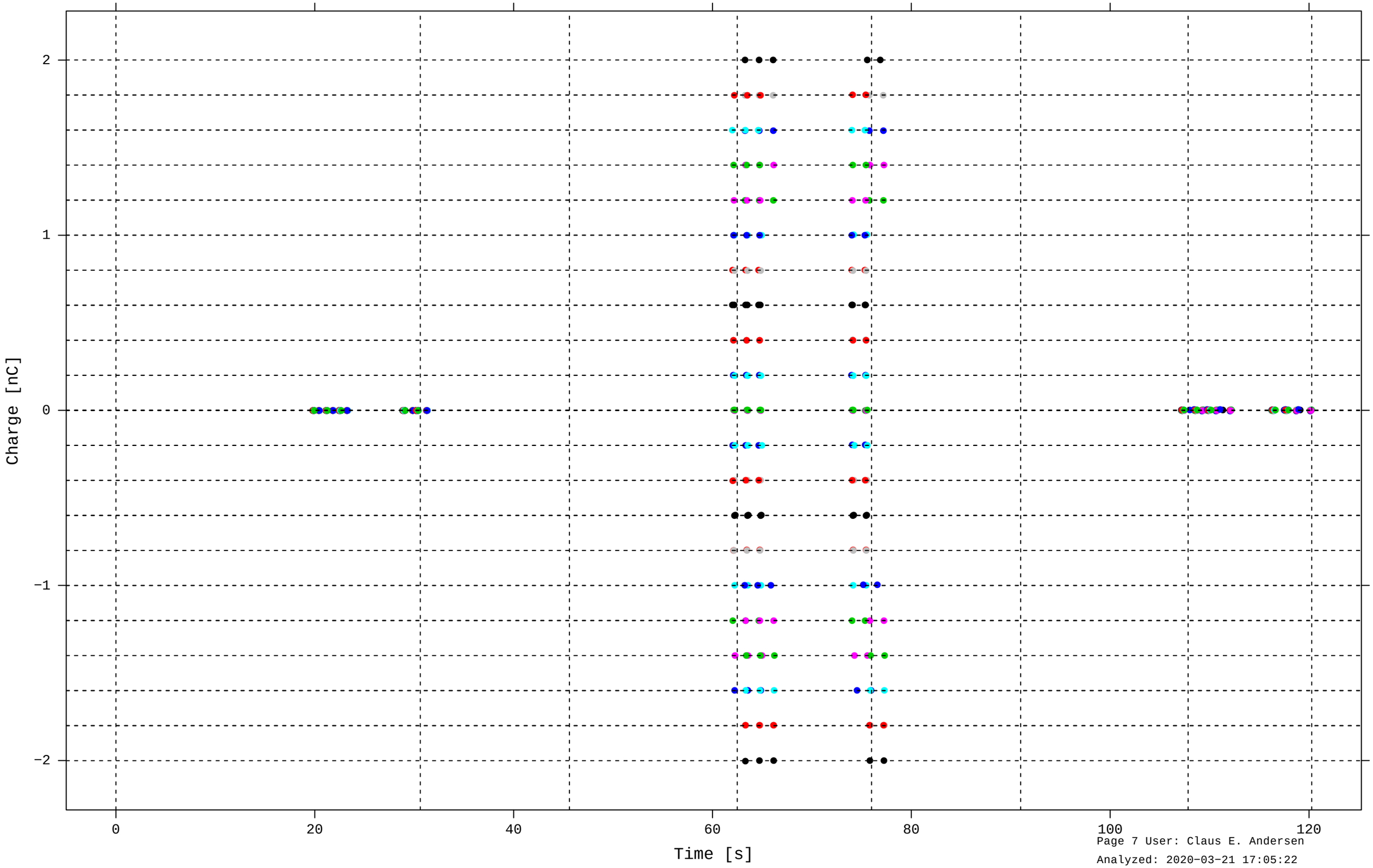
Electrometer charge calibration: 'KEITHLEYINSTRUMENTSINC.−MODEL6517B−A12/700x'SN1341729 (exp112847)
Details for individual steps (electrometer calibration):

step.i	V.select	V.ref	pA.Before	pA.After	pA.Return	nC.adj	nC.net	nC.ref	k.elec.step
1	0.0000	−0.0000	−0.096	0.013	0.005	0.0004	−0.0007	−0.0000	0.0155
2	−0.2000	−0.2001	0.069	−0.015	−0.040	0.0002	0.2000	−0.2001	−1.0003
3	−0.4000	−0.4002	0.040	0.026	−0.117	0.0005	0.4008	−0.4002	−0.9983
4	−0.6000	−0.6003	0.046	−0.032	0.048	0.0008	0.6003	−0.6003	−1.0000
5	−0.8000	−0.8004	−0.089	0.072	0.066	0.0012	0.8003	−0.8004	−1.0002
6	−1.0000	−1.0005	−0.014	0.101	−0.083	0.0012	1.0004	−1.0005	−1.0001
7	−1.2000	−1.2005	−0.061	0.043	0.109	0.0006	1.1990	−1.2006	−1.0013
8	−1.4000	−1.4006	0.023	−0.011	0.050	0.0010	1.3999	−1.4006	−1.0005
9	−1.6000	−1.6007	−0.022	−0.016	0.034	−0.0012	1.5998	−1.6007	−1.0006
10	−1.8000	−1.8007	0.046	−0.048	0.052	0.0014	1.7990	−1.8008	−1.0010
11	−2.0000	−2.0008	−0.024	0.020	0.061	0.0010	1.9999	−2.0008	−1.0005
12	−1.8000	−1.8007	−0.125	0.064	0.020	0.0010	1.8011	−1.8008	−0.9998
13	−1.6000	−1.6007	0.079	0.022	0.046	0.0010	1.5997	−1.6007	−1.0006
14	−1.4000	−1.4006	0.041	0.043	0.024	0.0001	1.4008	−1.4006	−0.9999
15	−1.2000	−1.2005	−0.003	−0.020	0.060	−0.0001	1.1992	−1.2006	−1.0011
16	−1.0000	−1.0005	0.032	0.048	0.020	0.0003	0.9992	−1.0005	−1.0013
17	−0.8000	−0.8004	−0.102	0.038	0.003	0.0006	0.7999	−0.8004	−1.0007
18	−0.6000	−0.6003	0.033	0.003	0.045	0.0010	0.6005	−0.6003	−0.9996
19	−0.4000	−0.4002	−0.026	0.056	0.096	0.0018	0.3982	−0.4002	−1.0051
20	−0.2000	−0.2001	−0.081	−0.041	0.029	0.0007	0.1999	−0.2001	−1.0011
21	0.0000	0.0000	0.028	−0.011	0.021	0.0002	0.0006	0.0000	0.0177
22	0.0000	−0.0000	−0.042	0.016	0.060	0.0004	−0.0009	−0.0000	0.0002
23	0.2000	0.2001	0.006	0.007	0.042	0.0011	−0.1991	0.2001	−1.0050
24	0.4000	0.4001	0.177	−0.082	−0.011	0.0004	−0.4003	0.4001	−0.9996
25	0.6000	0.6002	−0.037	0.059	0.063	0.0002	−0.6007	0.6003	−0.9992
26	0.8000	0.8003	0.017	0.033	−0.004	0.0009	−0.7994	0.8003	−1.0011
27	1.0000	1.0004	0.077	0.055	−0.097	0.0002	−1.0001	1.0004	−1.0003
28	1.2000	1.2005	0.043	0.034	0.040	0.0003	−1.2010	1.2005	−0.9995
29	1.4000	1.4005	0.005	−0.020	0.049	0.0006	−1.3994	1.4006	−1.0009
30	1.6000	1.6006	0.066	−0.008	−0.041	0.0008	−1.5993	1.6006	−1.0008
31	1.8000	1.8006	−0.005	0.035	−0.018	0.0017	−1.7994	1.8007	−1.0007
32	2.0000	2.0007	−0.078	0.047	−0.010	−0.0001	−2.0003	2.0007	−1.0002
33	1.8000	1.8006	0.089	−0.022	−0.101	0.0001	−1.7999	1.8007	−1.0005
34	1.6000	1.6006	0.067	−0.001	−0.042	0.0004	−1.6000	1.6006	−1.0004
35	1.4000	1.4005	0.023	0.040	0.003	0.0009	−1.4013	1.4006	−0.9994
36	1.2000	1.2005	−0.026	0.028	−0.103	−0.0000	−1.1998	1.2005	−1.0006
37	1.0000	1.0004	0.036	0.096	0.037	0.0026	−1.0003	1.0004	−1.0001
38	0.8000	0.8003	−0.048	0.034	0.040	0.0001	−0.8000	0.8003	−1.0005
39	0.6000	0.6002	−0.088	0.078	−0.017	0.0013	−0.5983	0.6002	−1.0032
40	0.4000	0.4001	−0.016	0.015	0.059	0.0012	−0.4008	0.4002	−0.9983
41	0.2000	0.2001	0.008	0.021	0.045	0.0010	−0.2009	0.2001	−0.9958
42	0.0000	0.0000	0.046	0.033	−0.004	0.0007	0.0014	0.0000	0.0013

Measurements overview (exp112847)

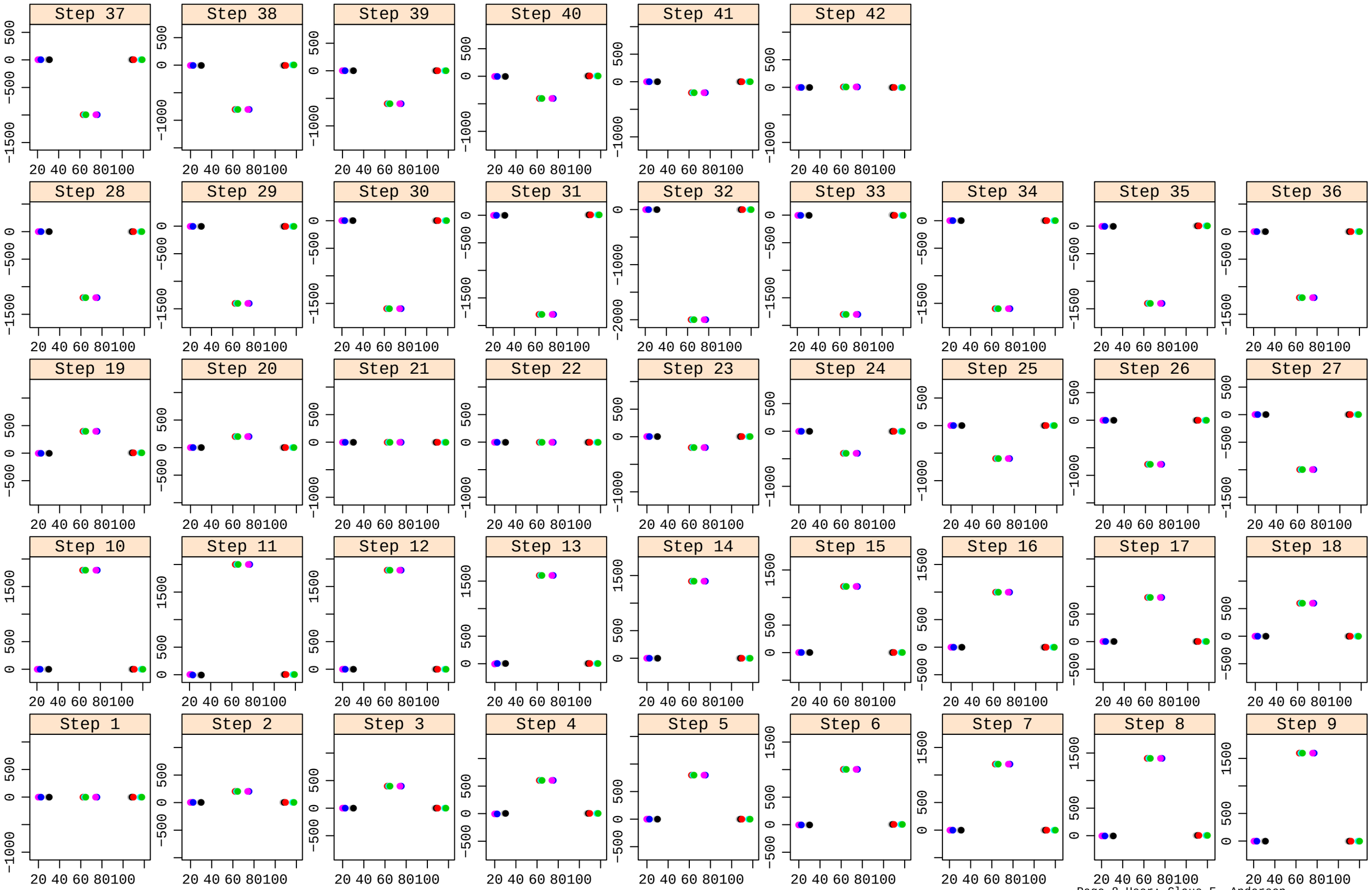
Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Step 7
Step 8
Step 9
Step 10
Step 11
Step 12
Step 13
Step 14
Step 15
Step 16
Step 17
Step 18
Step 19
Step 20
Step 21
Step 22
Step 23
Step 24
Step 25
Step 26
Step 27
Step 28
Step 29
Step 30
Step 31
Step 32
Step 33
Step 34
Step 35
Step 36
Step 37
Step 38
Step 39
Step 40
Step 41
Step 42

DTU



Charge transfer readings for each voltage step (exp112847)

nC.read1 nC.read10 nC.read11 nC.read12 nC.read13 nC.read14 nC.read15 nC.read2 nC.read3 nC.read4 nC.read5 nC.read6 nC.read7 nC.read8 nC.read9



Before−currents at each voltage step (exp112847)

nC.read1 nC.read10 nC.read11 nC.read12 nC.read13 nC.read14 nC.read15 nC.read2 nC.read3 nC.read4 nC.read5 nC.read6 nC.read7 nC.read8 nC.read9

Step 37: 2: 0.036 +/− 0.004 pA
Step 38: 2: −0.048 +/− 0.005 pA
Step 39: 2: −0.088 +/− 0.007 pA
Step 40: 2: −0.016 +/− 0.004 pA
Step 41: 2: 0.008 +/− 0.010 pA
Step 42: 2: 0.046 +/− 0.006 pA

Step 28: 2: 0.043 +/− 0.003 pA
Step 29: 2: 0.005 +/− 0.001 pA
Step 30: 2: 0.066 +/− 0.003 pA
Step 31: 2: −0.005 +/− 0.003 pA
Step 32: 2: −0.078 +/− 0.002 pA
Step 33: 2: 0.089 +/− 0.004 pA
Step 34: 2: 0.067 +/− 0.002 pA
Step 35: 2: 0.023 +/− 0.001 pA
Step 36: 2: −0.026 +/− 0.002 pA

Step 19: 2: −0.026 +/− 0.002 pA
Step 20: 2: −0.081 +/− 0.001 pA
Step 21: 2: 0.028 +/− 0.004 pA
Step 22: 2: −0.042 +/− 0.008 pA
Step 23: 2: 0.006 +/− 0.006 pA
Step 24: 2: 0.177 +/− 0.005 pA
Step 25: 2: −0.037 +/− 0.002 pA
Step 26: 2: 0.017 +/− 0.008 pA
Step 27: 2: 0.077 +/− 0.002 pA

Step 10: 2: 0.046 +/− 0.007 pA
Step 11: 2: −0.024 +/− 0.001 pA
Step 12: 2: −0.125 +/− 0.005 pA
Step 13: 2: 0.079 +/− 0.007 pA
Step 14: 2: 0.041 +/− 0.005 pA
Step 15: 2: −0.003 +/− 0.007 pA
Step 16: 2: 0.032 +/− 0.001 pA
Step 17: 2: −0.102 +/− 0.004 pA
Step 18: 2: 0.033 +/− 0.002 pA

Step 1: 2: −0.096 +/− 0.005 pA
Step 2: 2: 0.069 +/− 0.003 pA
Step 3: 2: 0.040 +/− 0.003 pA
Step 4: 2: 0.046 +/− 0.001 pA
Step 5: 2: −0.089 +/− 0.001 pA
Step 6: 2: −0.014 +/− 0.003 pA
Step 7: 2: −0.061 +/− 0.005 pA
Step 8: 2: 0.023 +/− 0.003 pA
Step 9: 2: −0.022 +/− 0.007 pA

Charge [pC]

Time [s]

After-currents at each voltage step (exp112847)

nC.read1 nC.read10 nC.read11 nC.read12 nC.read13 nC.read14 nC.read15 nC.read2 nC.read3 nC.read4 nC.read5 nC.read6 nC.read7 nC.read8 nC.read9

Step 37: 2: 0.096 +/- 0.006 pA
Step 38: 2: 0.034 +/- 0.002 pA
Step 39: 2: 0.078 +/- 0.002 pA
Step 40: 2: 0.015 +/- 0.001 pA
Step 41: 2: 0.021 +/- 0.000 pA
Step 42: 2: 0.033 +/- 0.001 pA

Step 28: 2: 0.034 +/- 0.003 pA
Step 29: 2: -0.020 +/- 0.003 pA
Step 30: 2: -0.008 +/- 0.007 pA
Step 31: 2: 0.035 +/- 0.002 pA
Step 32: 2: 0.047 +/- 0.002 pA
Step 33: 2: -0.022 +/- 0.004 pA
Step 34: 2: -0.001 +/- 0.005 pA
Step 35: 2: 0.040 +/- 0.004 pA
Step 36: 2: 0.028 +/- 0.006 pA

Step 19: 2: 0.056 +/- 0.000 pA
Step 20: 2: -0.041 +/- 0.007 pA
Step 21: 2: -0.011 +/- 0.009 pA
Step 22: 2: 0.016 +/- 0.004 pA
Step 23: 2: 0.007 +/- 0.002 pA
Step 24: 2: -0.082 +/- 0.005 pA
Step 25: 2: 0.059 +/- 0.004 pA
Step 26: 2: 0.033 +/- 0.008 pA
Step 27: 2: 0.055 +/- 0.005 pA

Step 10: 2: -0.048 +/- 0.008 pA
Step 11: 2: 0.020 +/- 0.003 pA
Step 12: 2: 0.064 +/- 0.002 pA
Step 13: 2: 0.022 +/- 0.001 pA
Step 14: 2: 0.043 +/- 0.006 pA
Step 15: 2: -0.020 +/- 0.005 pA
Step 16: 2: 0.048 +/- 0.002 pA
Step 17: 2: 0.038 +/- 0.005 pA
Step 18: 2: 0.003 +/- 0.007 pA

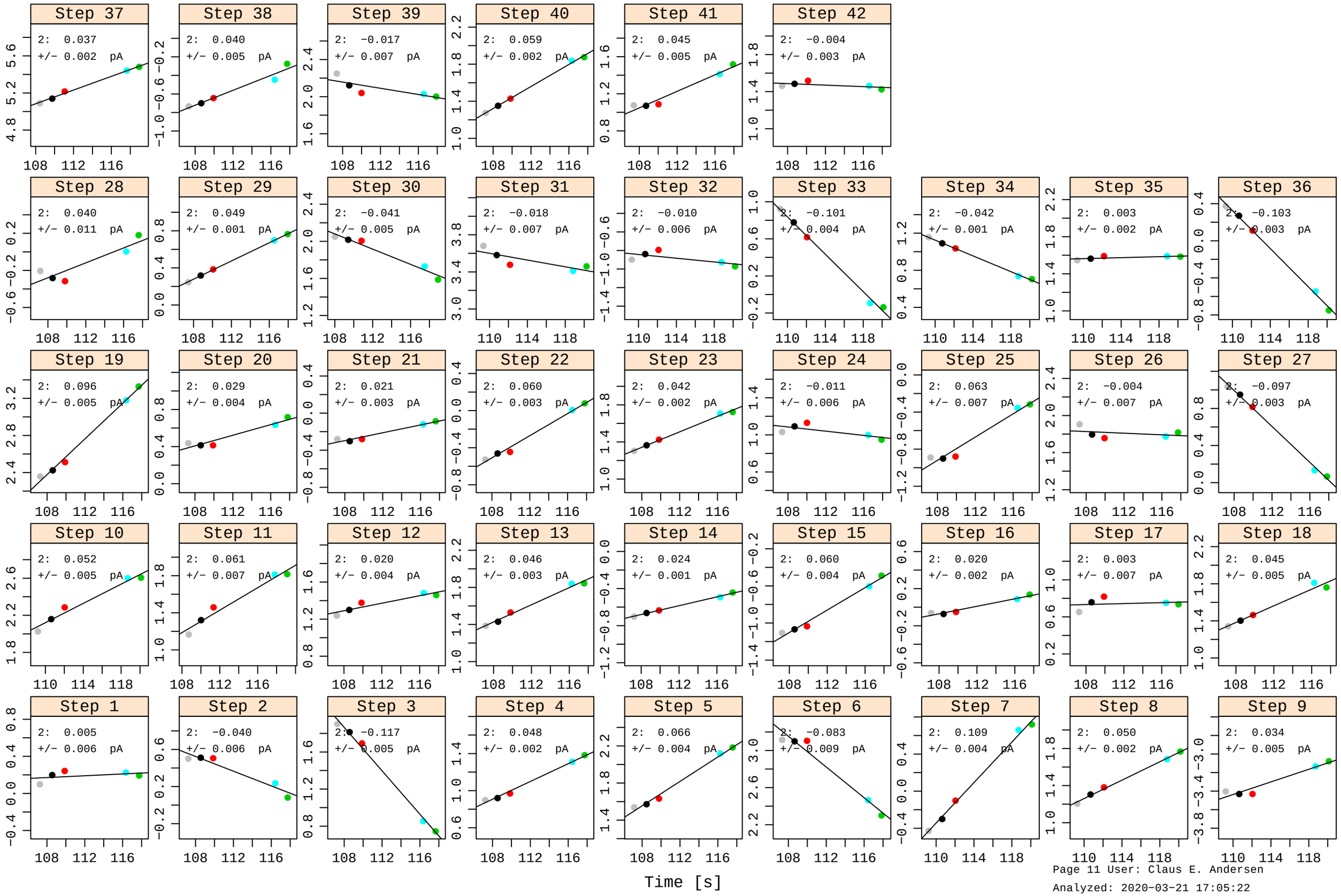
Step 1: 2: 0.013 +/- 0.003 pA
Step 2: 2: -0.015 +/- 0.004 pA
Step 3: 2: 0.026 +/- 0.001 pA
Step 4: 2: -0.032 +/- 0.002 pA
Step 5: 2: 0.072 +/- 0.004 pA
Step 6: 2: 0.101 +/- 0.002 pA
Step 7: 2: 0.043 +/- 0.007 pA
Step 8: 2: -0.011 +/- 0.005 pA
Step 9: 2: -0.016 +/- 0.004 pA

Charge [pC]

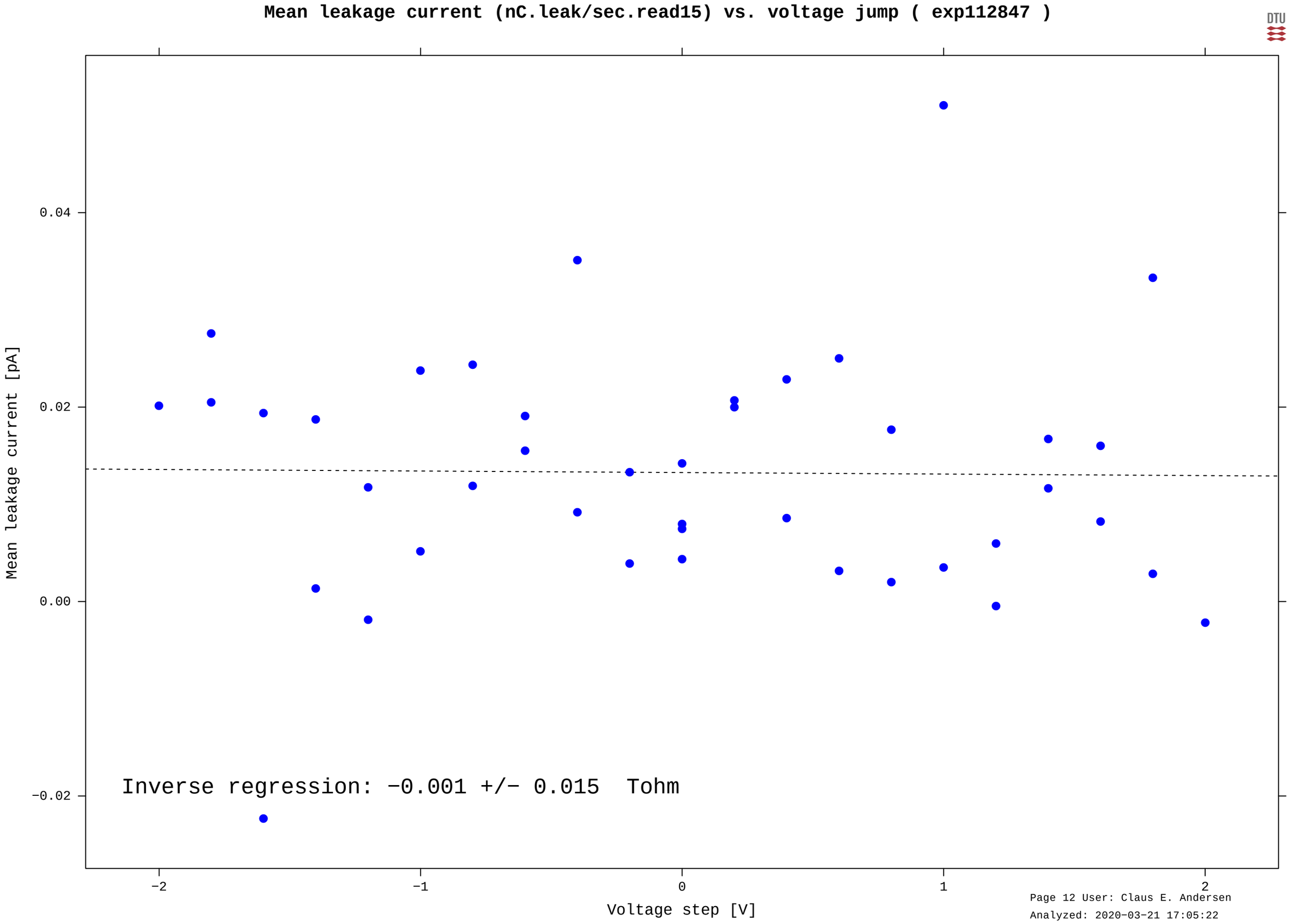
Time [s]

Return-currents at each voltage step (exp112847)

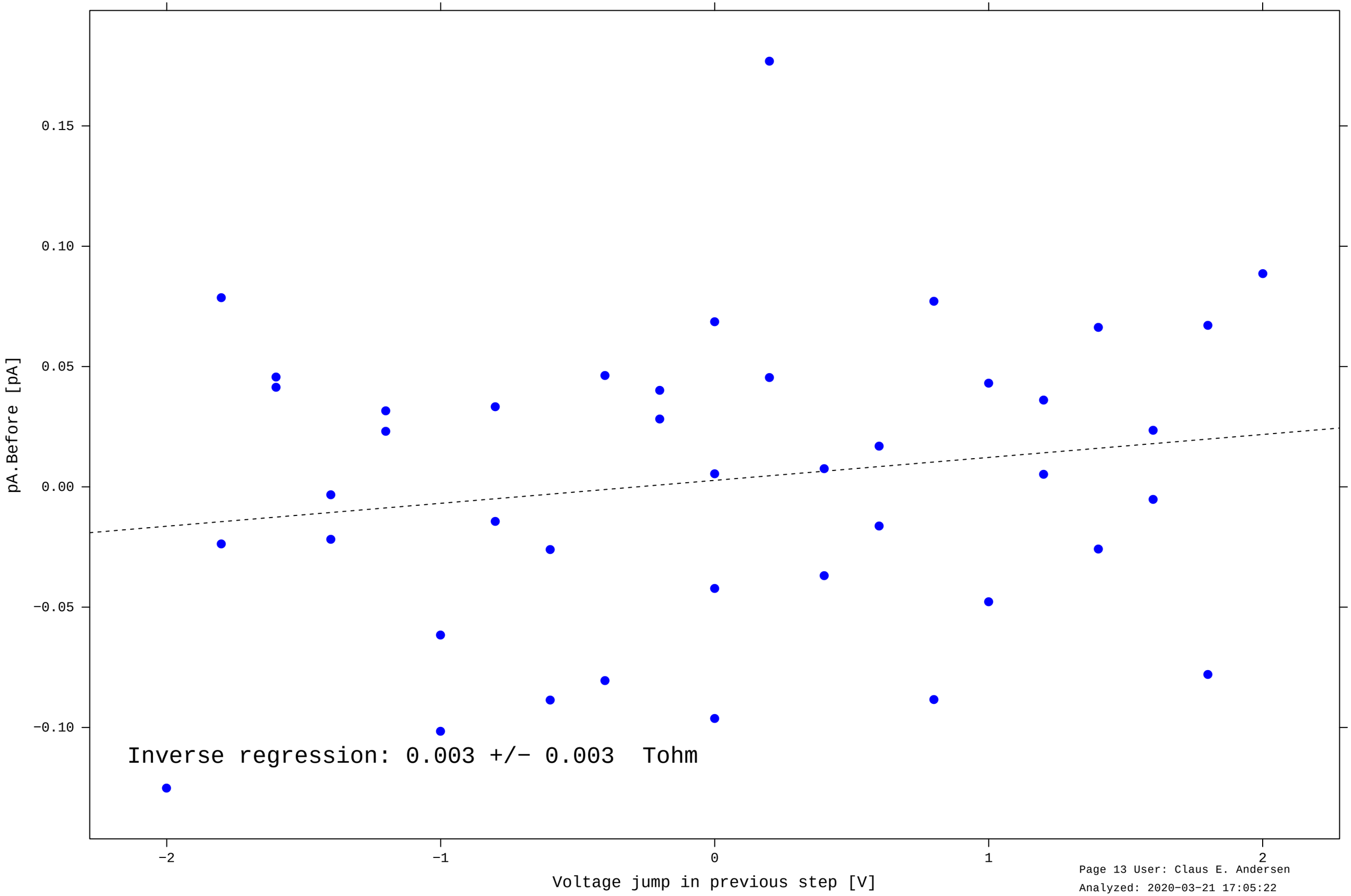
nC.read1 nC.read10 nC.read11 nC.read12 nC.read13 nC.read14 nC.read15 nC.read2 nC.read3 nC.read4 nC.read5 nC.read6 nC.read7 nC.read8 nC.read9



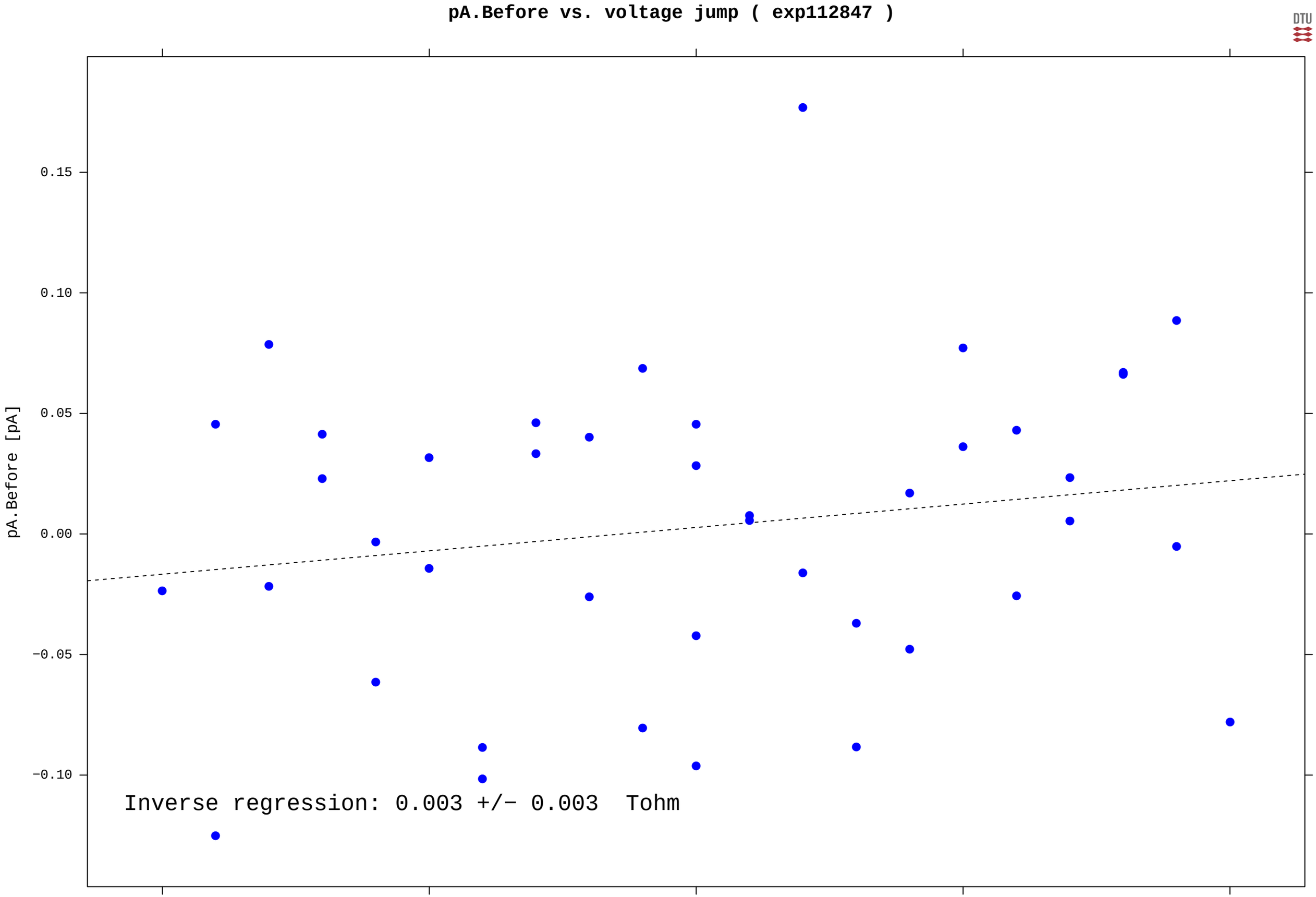
Mean leakage current (nC.leak/sec.read15) vs. voltage jump (exp112847)



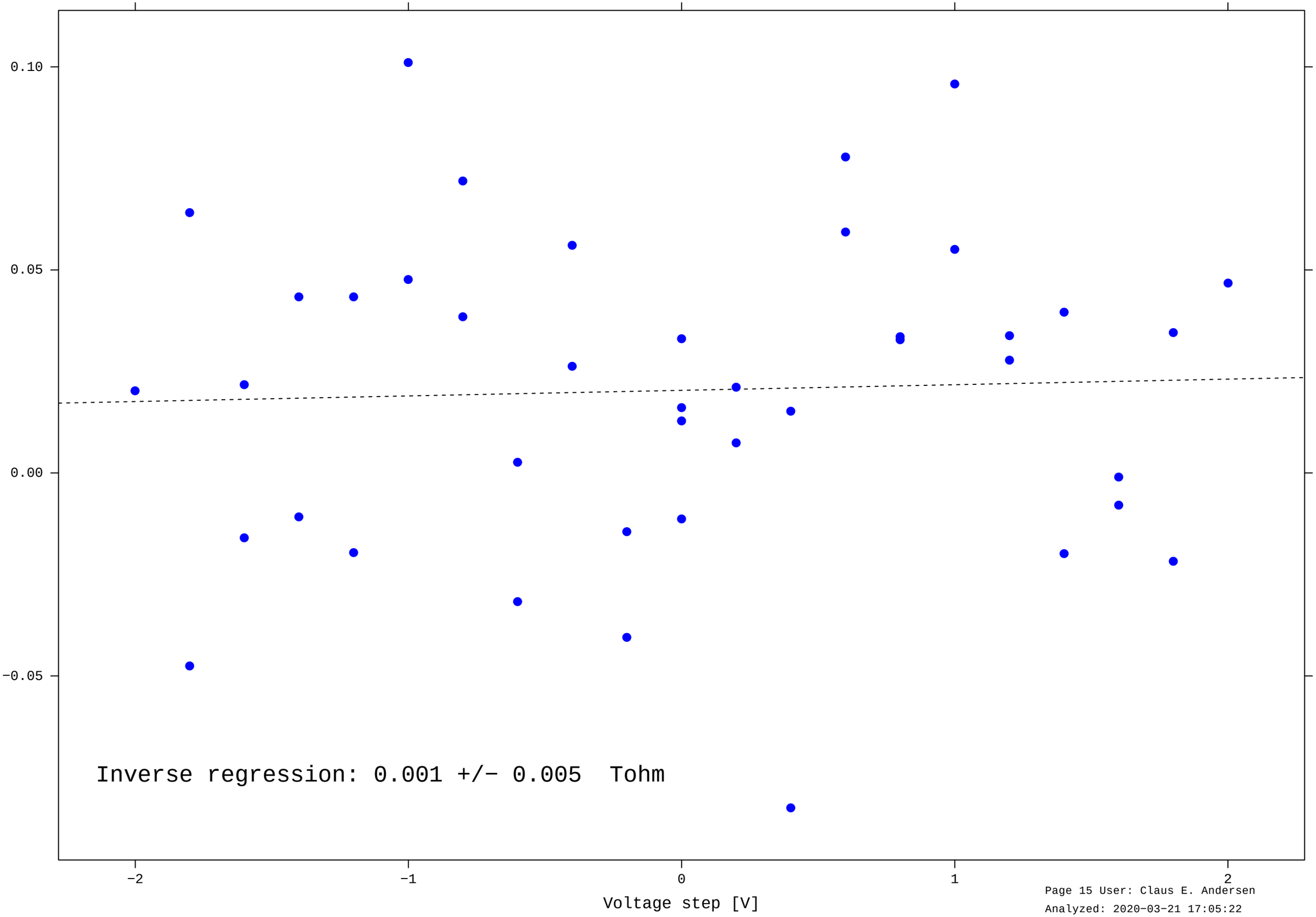
pA.Before vs. voltage jump in the preceeding step (exp112847)
This is a test for any memory effect in the system



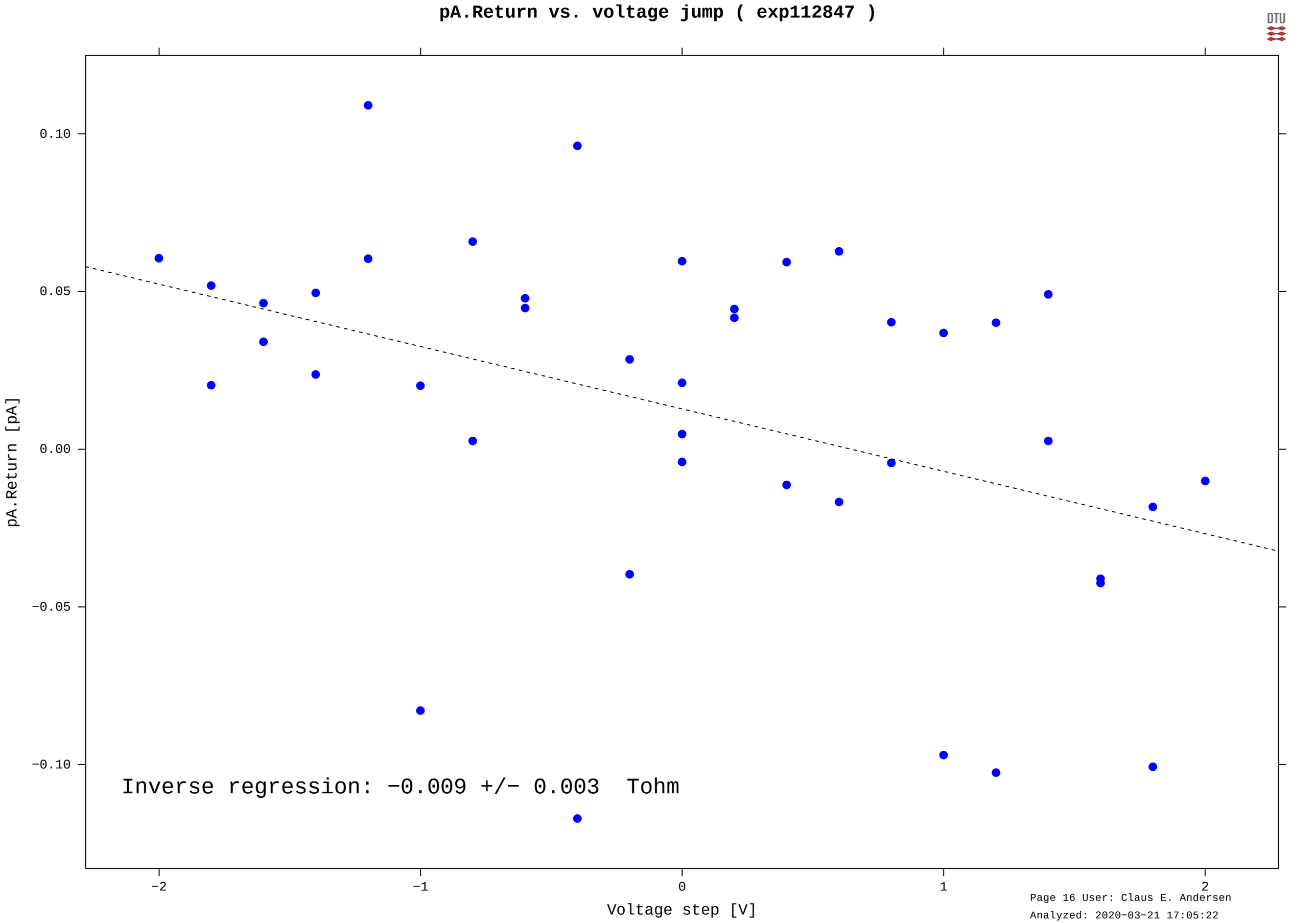
pA.Before vs. voltage jump (exp112847)



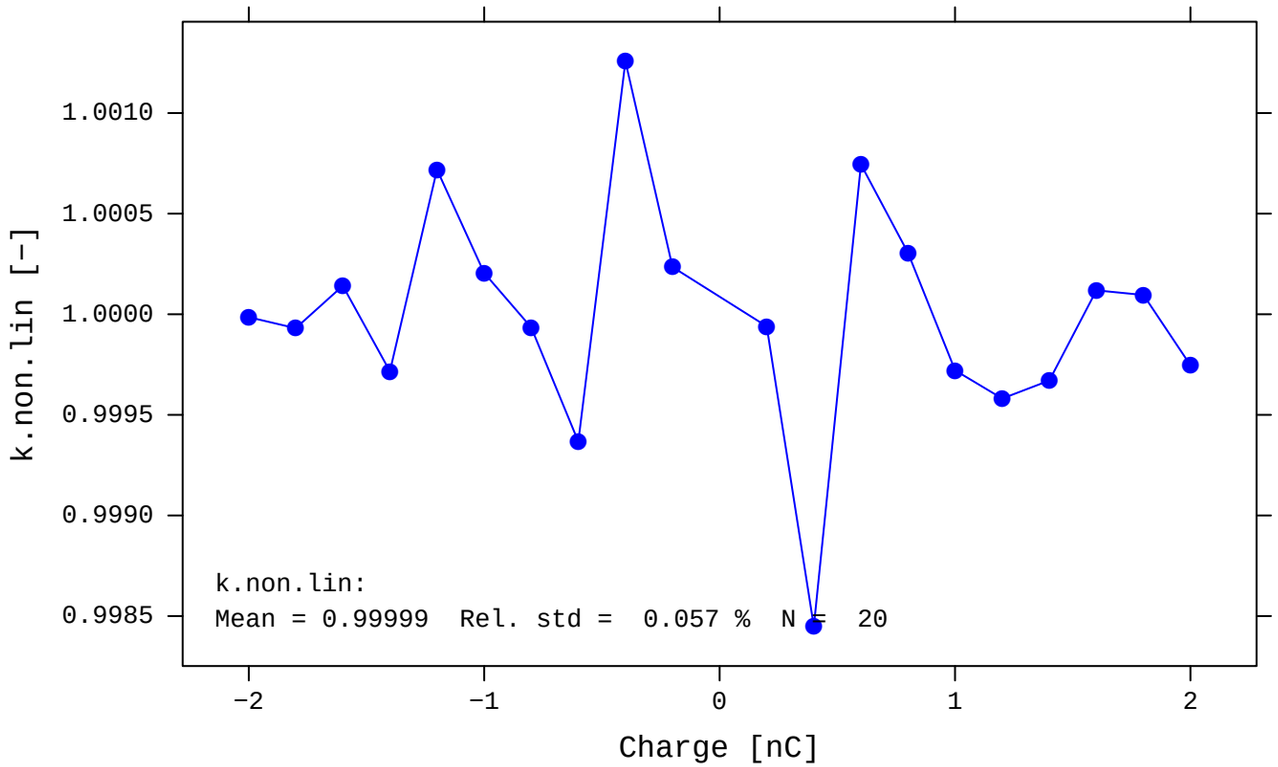
pA.After vs. voltage jump (exp112847)



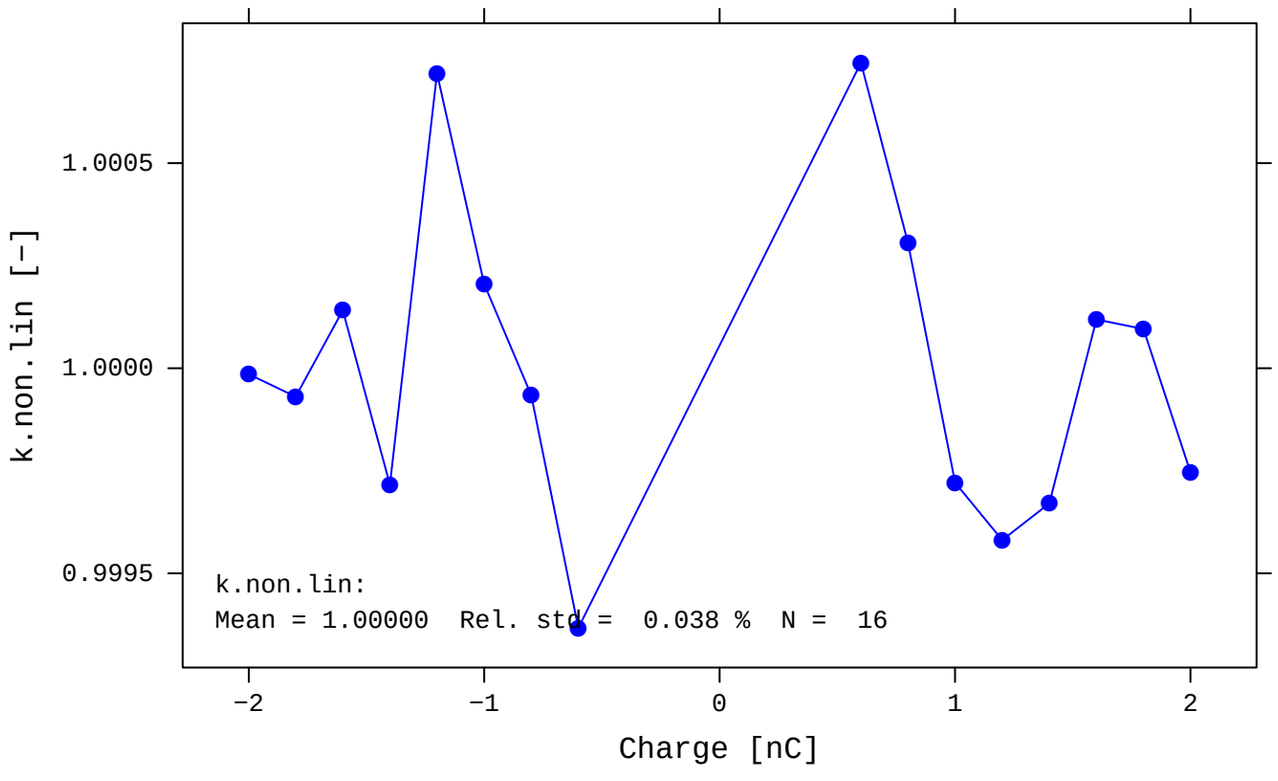
pA.Return vs. voltage jump (exp112847)



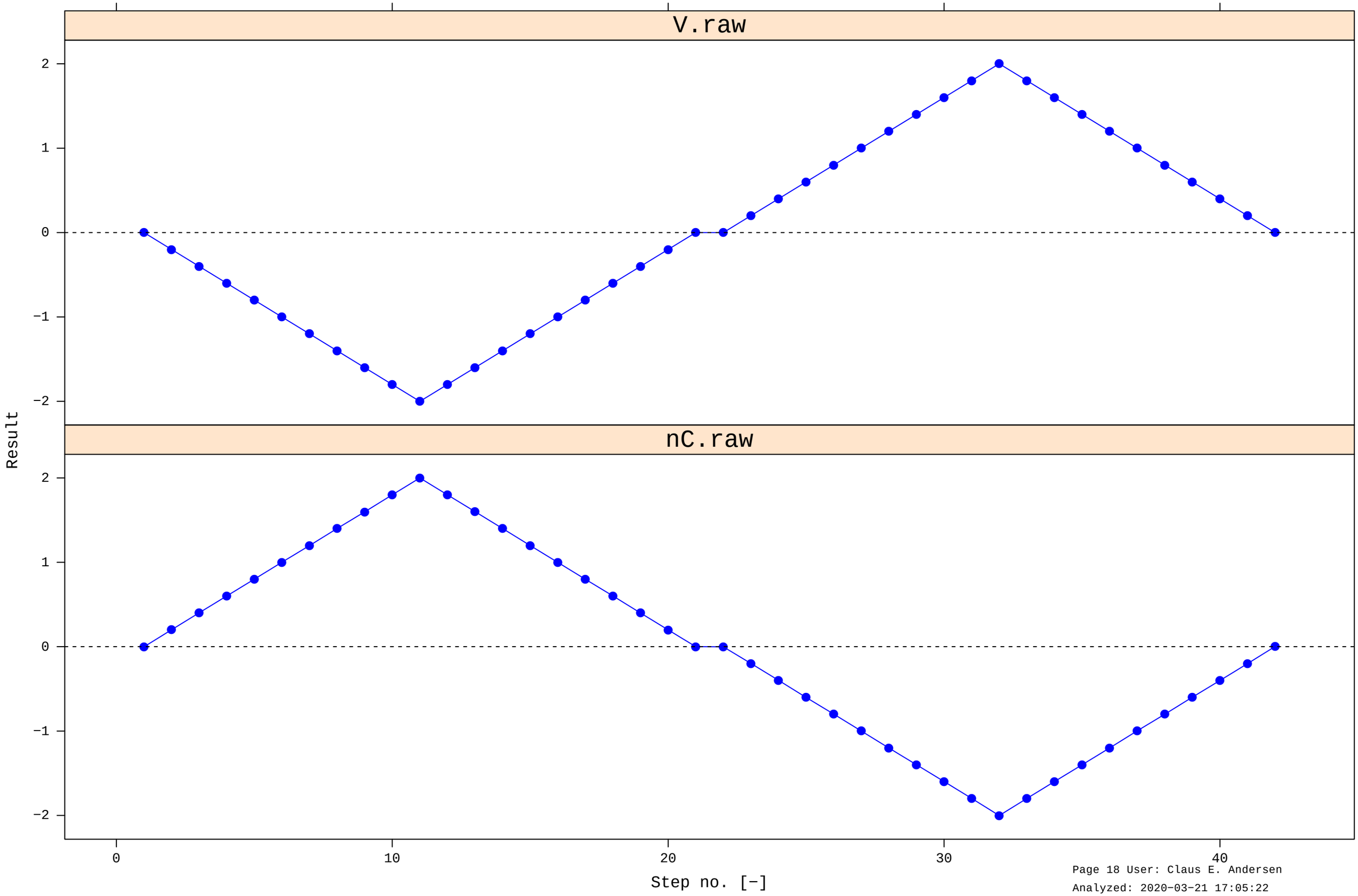
k.non.lin vs. charge (exp112847)



k.non.lin vs. charge (exp112847) with k.elec.stat.limit = 25 %



Raw readings from the voltmeter (V.raw) and the electrometer (nC.raw). (exp112847)
A positive V.raw means that positive charge is sourced into the electrometer.



This is the final page of the Electrometer charge calibration report for file: exp112847