ELQA tests of 11 T series magnet

General remarks

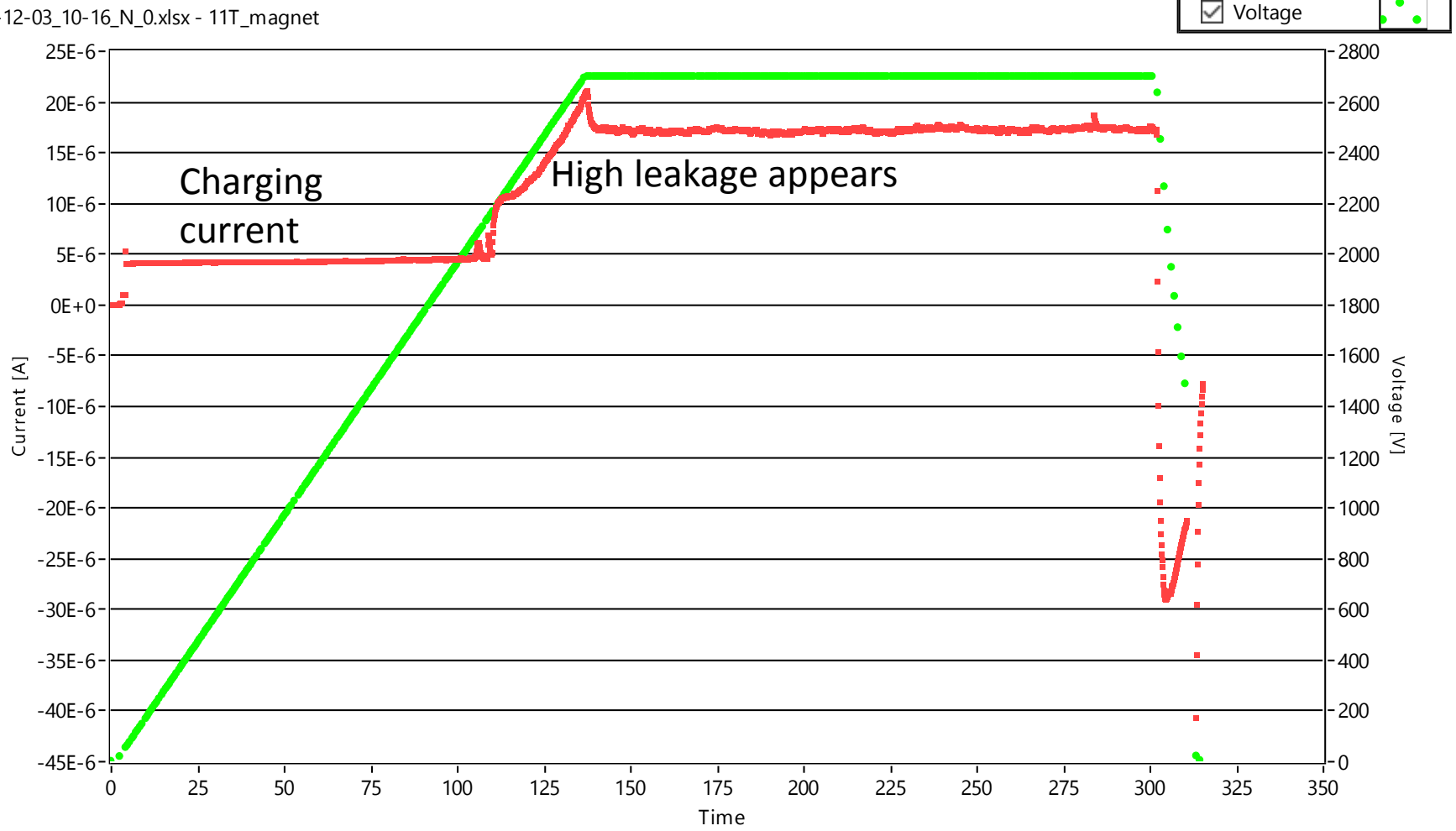
- The V-taps of the corrector magnets are routed in the same capillary as the ones of the main magnet.
- Insulation between main circuit and corrector circuits is OK.
- There is no insulation issue on the corrector circuits (@750 V).

Brief overview of tests

- **2019-11-27:** First tests with the ELQA hardware up to 2.6 kV,
  - The insulation was perfect up to 2.6 kV (leakage current of 200 nA)
  - The test at 2.8 kV was interrupted by a power-cut, during the voltage ramp.
  - DC precision voltage measurements
- **2019-11-28:** Magnet tested up to 2.7 kV,
  - High leakage current first appeared at about 2.74 kV, then the on-set voltage varied
  - DC precision voltage measurements continued
- **2019-11-29:** Magnet tested up to 2.6 kV
  - HV tests mostly below the high leakage current on-set, observation of partial discharges
  - Differential measurements across magnet coils with an oscilloscope
- **2019-12-03:** Magnet tested up to 2.7 kV
  - HV tests mostly below and at the high leakage current on-set, observation of partial discharges
  - Oscilloscope fast measurements of leakage current and voltage to ground between all magnet coils

Test at 2700 V

- Voltage ramp rate 20 V/s
- Increased leakage current appeared at 2170 V

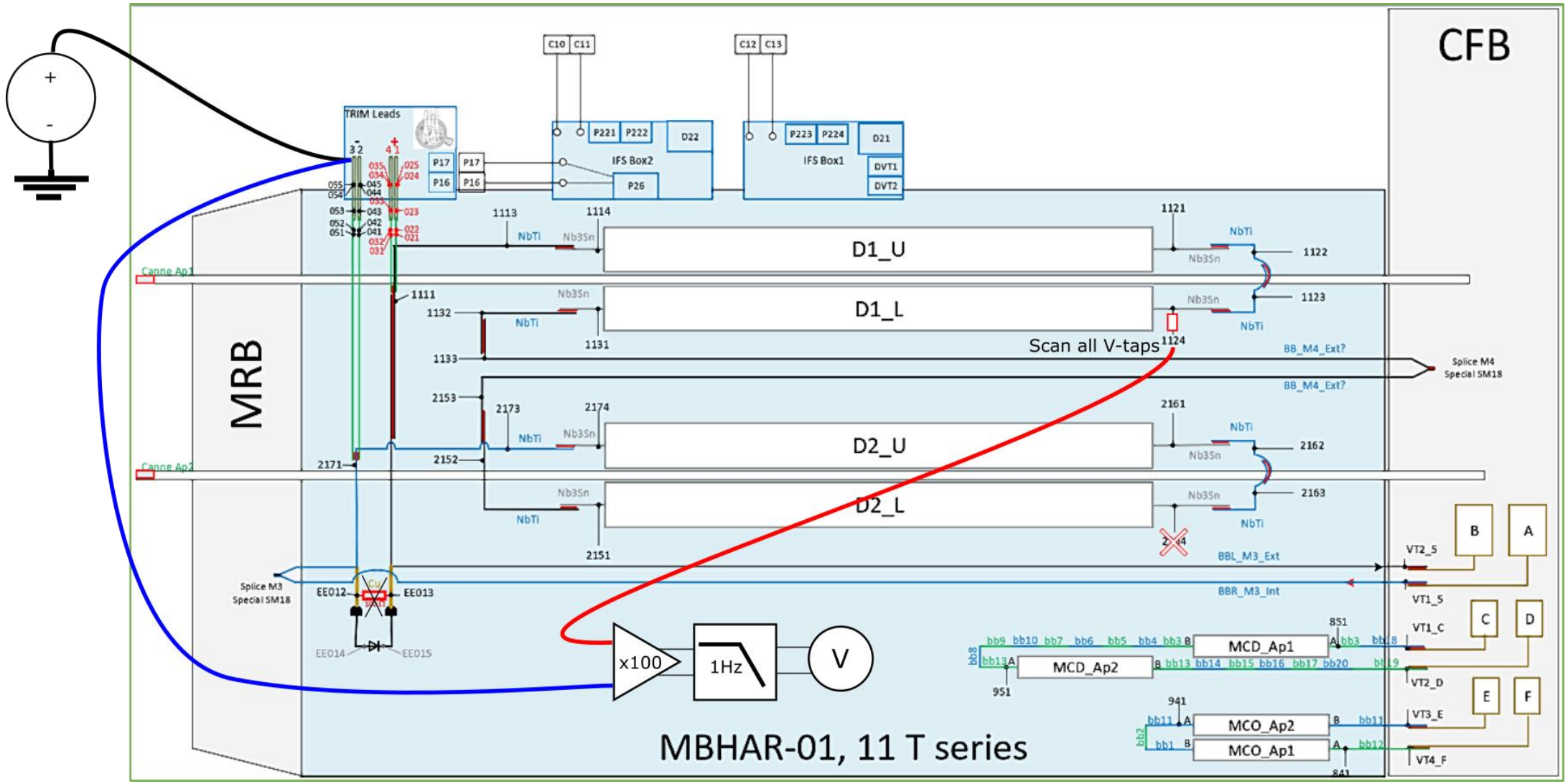


High leakage on-set comparison

- No degradation
- Random behaviour, always between 2 kV and 2.75 kV

Test	start of increased leakage
	V
2019-11-28_10-37	2741
2019-11-28_11-29	2150
2019-11-28_17-29	2440
2019-11-28_17-39	2140
2019-12-29_16-07	2596
2019-11-29_16-23	2200
2019-11-29_16-37	2200
2019-12-03_09-52	2700
2019-12-03_10-16	2160
2019-12-03_10-52	2140

DC precision voltage measurements



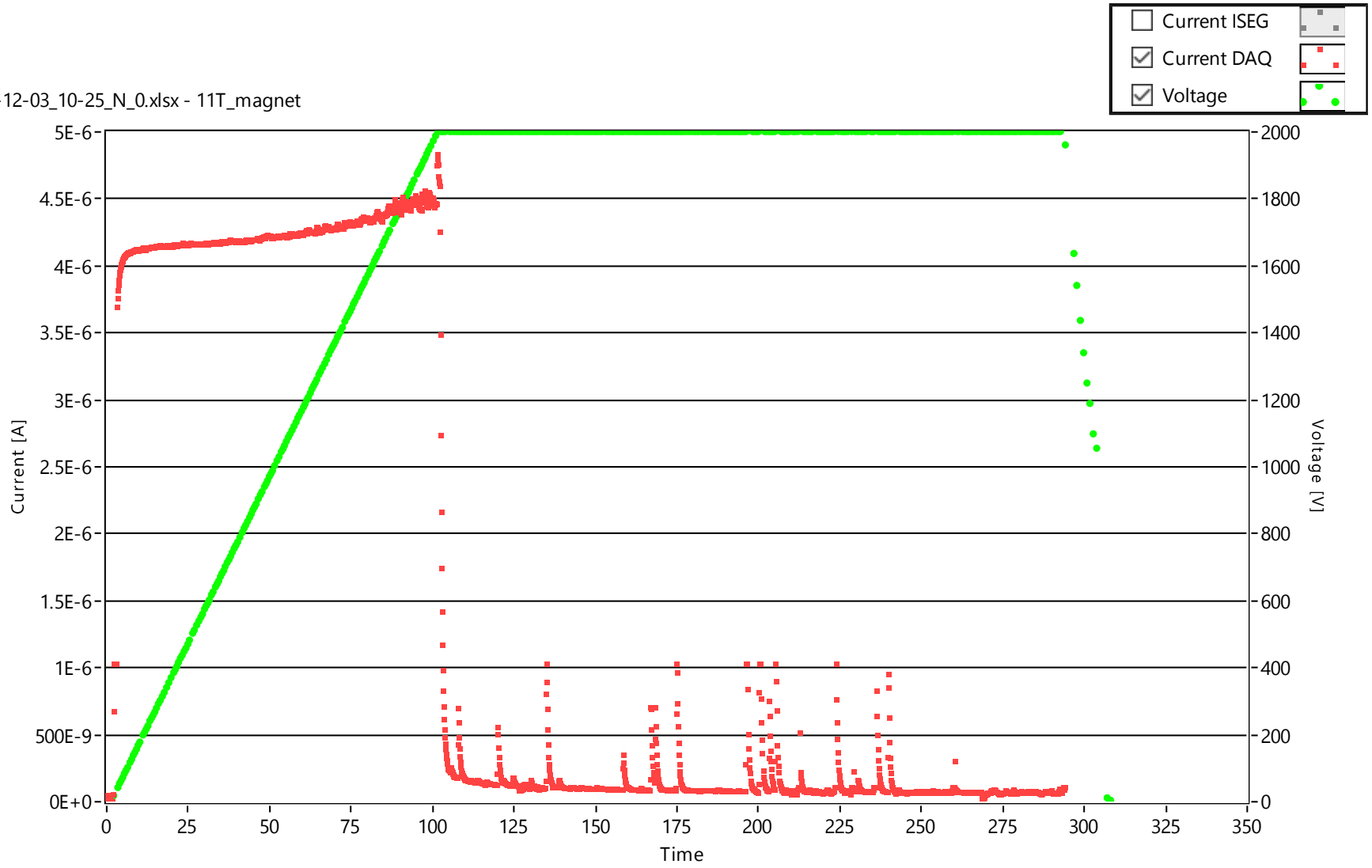
Results

- Not completely conclusive
- Not fully understood
- Grouping of V-taps observed

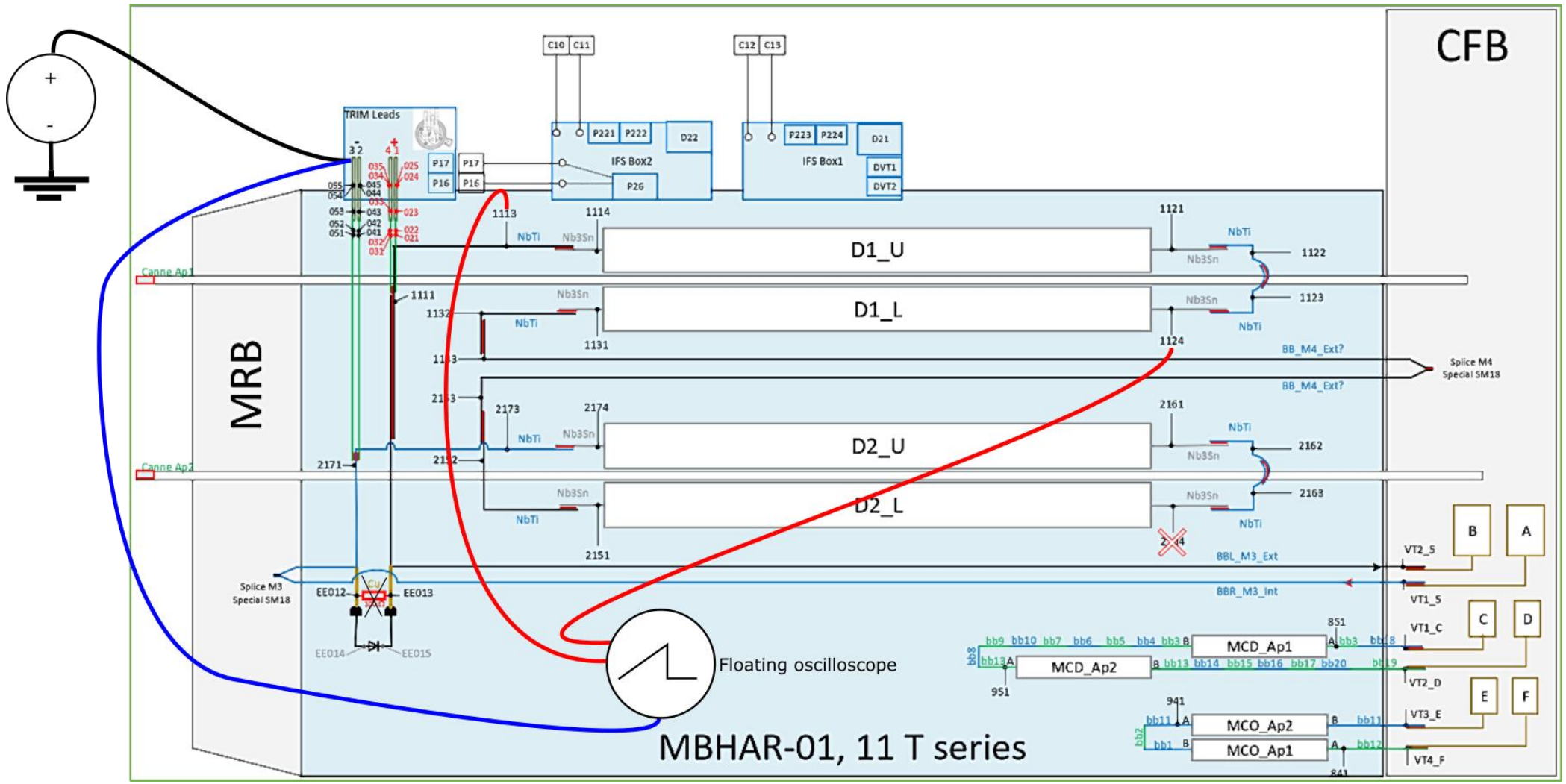
V-tap	0	30	2070	2350	2500	delta
2171	-7.2	-24.5	-32.5	-34.8	-32.5	2.3
2173	-6.8	-46.1	-63	-66.8	-64	2.8
2174	-7.1	-28.5	-42.8	-46.2	-44.3	1.9
2161	-6.9	-10.9	-11.9	-11.6	-8.3	3.3
2162	-6.9	-12	-12.9	-12.7	-9.6	3.1
2163	-6.9	-11.6	-12.6	-12.4	-9.3	3.1
2151	-6.8	-14.4	-19	-19.7	-15	4.7
2152	-6.8	-13.9	-18.3	-19.1	-14.2	4.9
2153	-6.9	-14.6	-18.7	-19.5	-15	4.5
1133	-6.7	-15	-19.5	-20.5	-17.5	3
1132	-6.7	-15.3	-20.1	-21.2	-18	3.2
1131	-6.5	-14.1	-19	-20.1	-17.5	2.6
1124	-6.6	-8.7	-9.4	-9.3	6.6	15.9
1123	-6.5	-9.1	-9.9	-9.8	6.5	16.3
1122	-6.5	-9.1	-9.8	-9.6	6.5	16.1
1121	-6.6	-9.3	-9.9	-9.8	6	15.8
1114	-6.6	-12.5	-13.5	-16.2	0	16.2
1113	-6.6	-13.1	-16	-16.7	0	16.7
1111	-7.1	-13.6	-16.6	-17.3	0	17.3
012	-6.3	-30.9	-38.7	-40.3	-39.3	1
012	-6.4	-30.5	-38.4	-40	-39	1
013	-6.4	-16	-19.5	-20.4	-3	17.4
013	-6.3	-15.8	-19.5	-20.4	-3	17.4
014	-6.4	-59	-78.5	-83.9	-75	8.9
015	-6.4	-12.6	-15.8	-16.4	1	17.4

Test at 2000 V

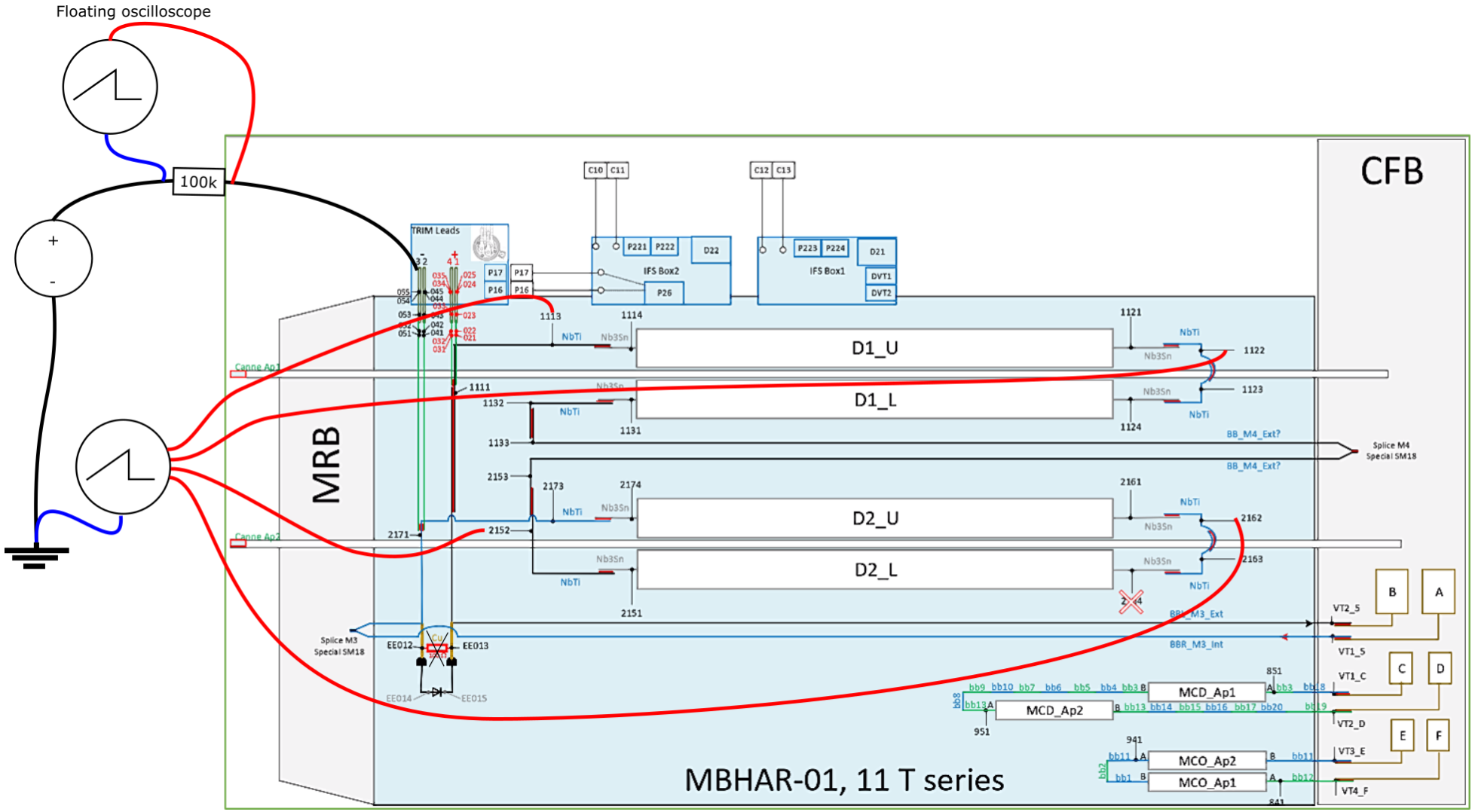
- Partial discharge activity during the ramp and the plateau



Differential measurements across magnet coils with an oscilloscope

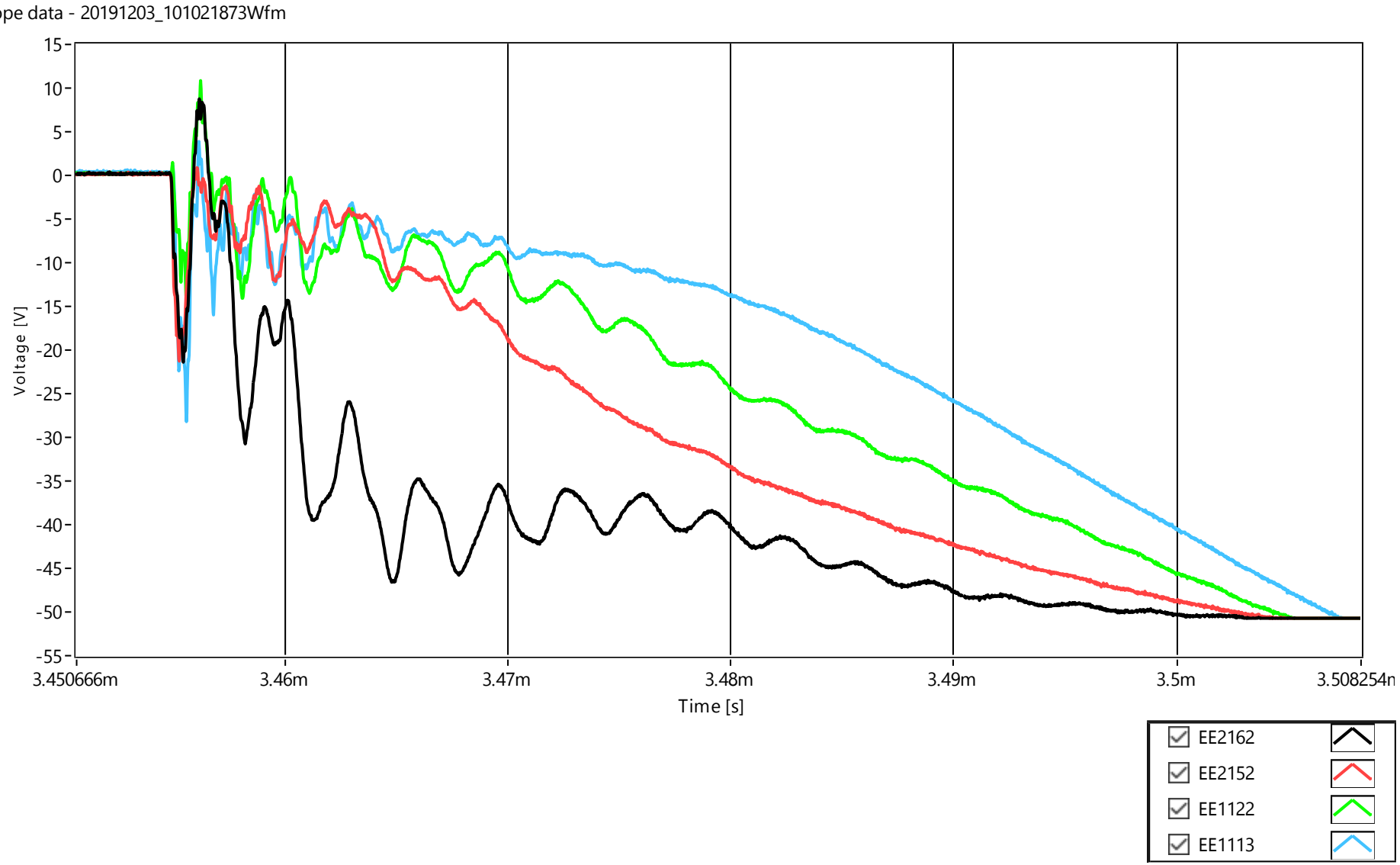


Oscilloscope fast measurements of leakage current and voltage to ground between all magnet coils

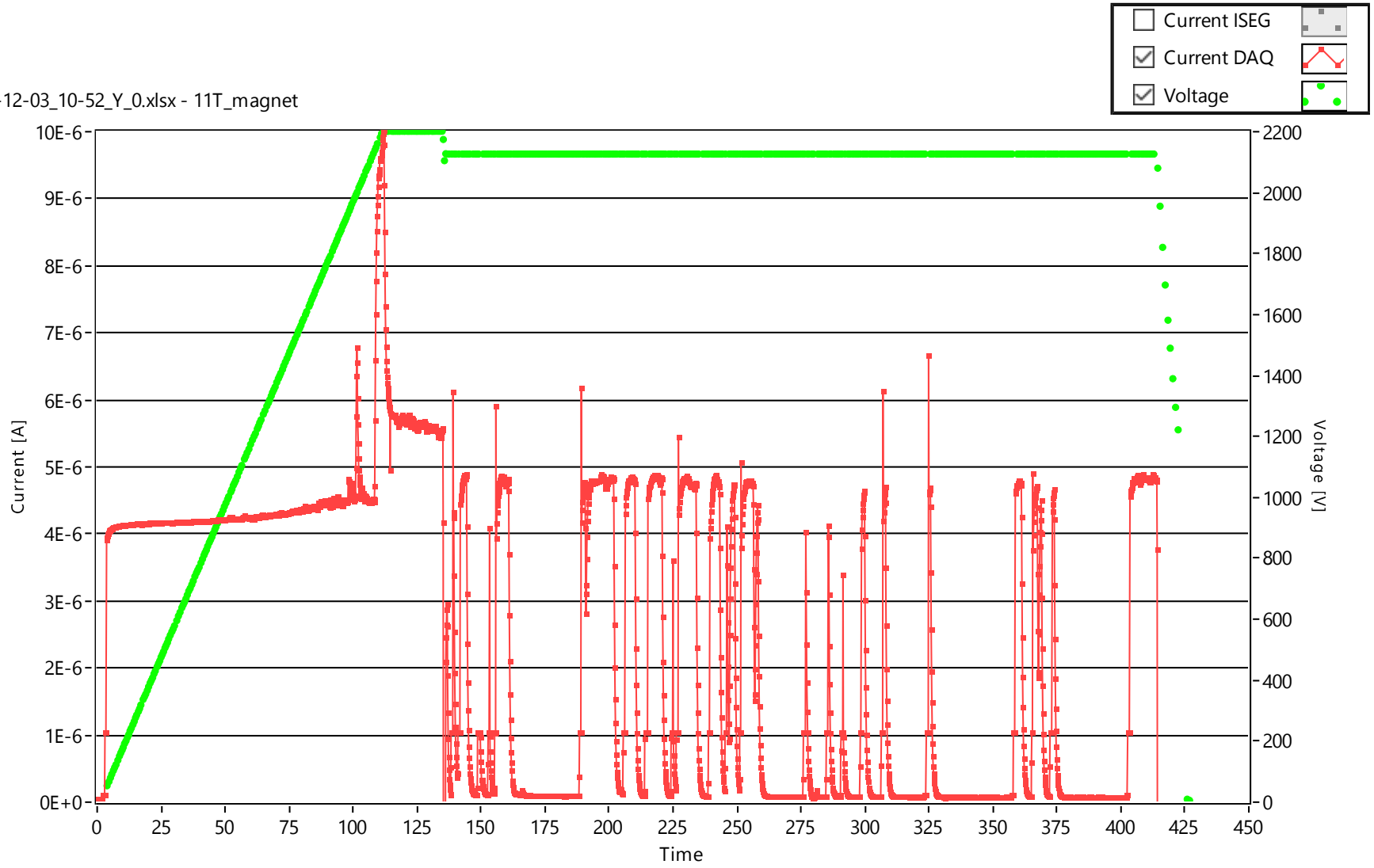


Scope data – reference, short on trim lead 3

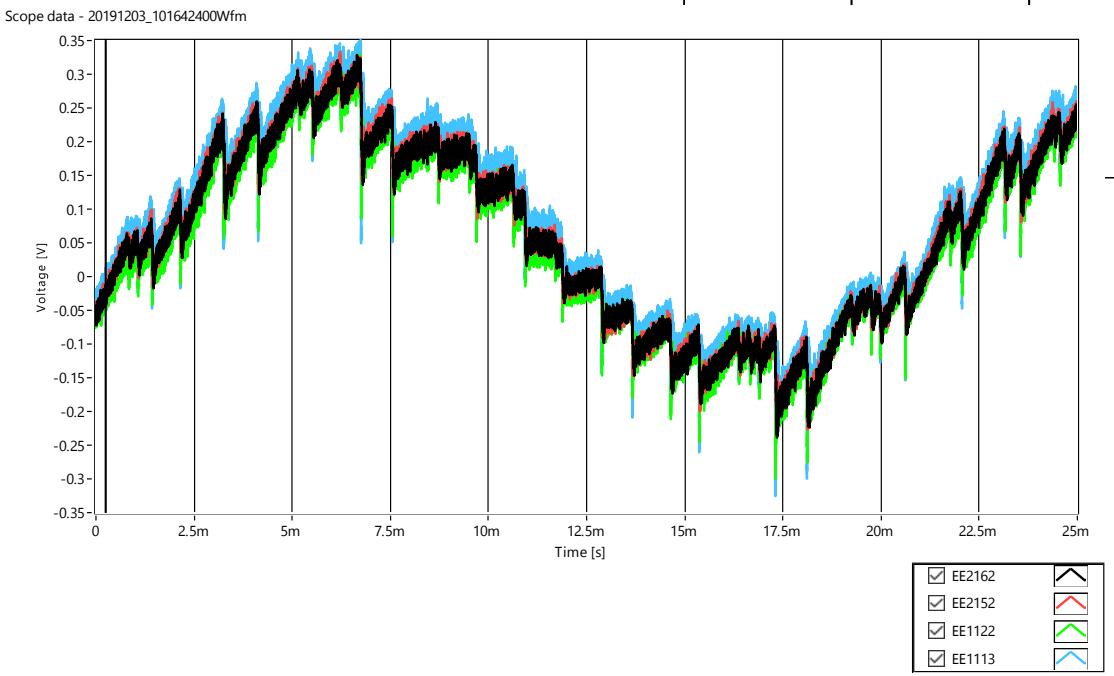
Short provoked at the trim lead 3, this is the expected behaviour of the circuit. The fault can be easily localised.

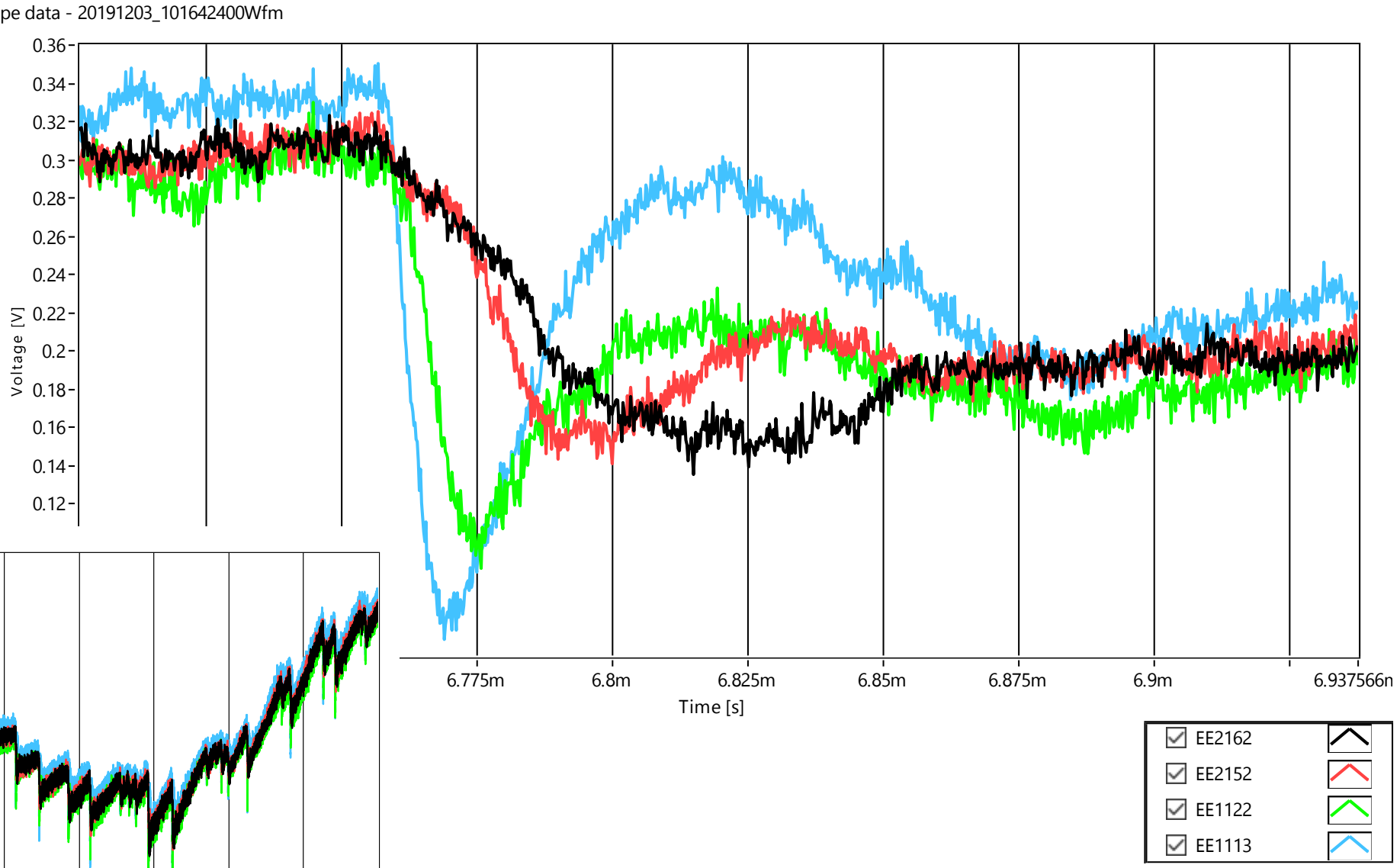


Strange activity at 2124 V



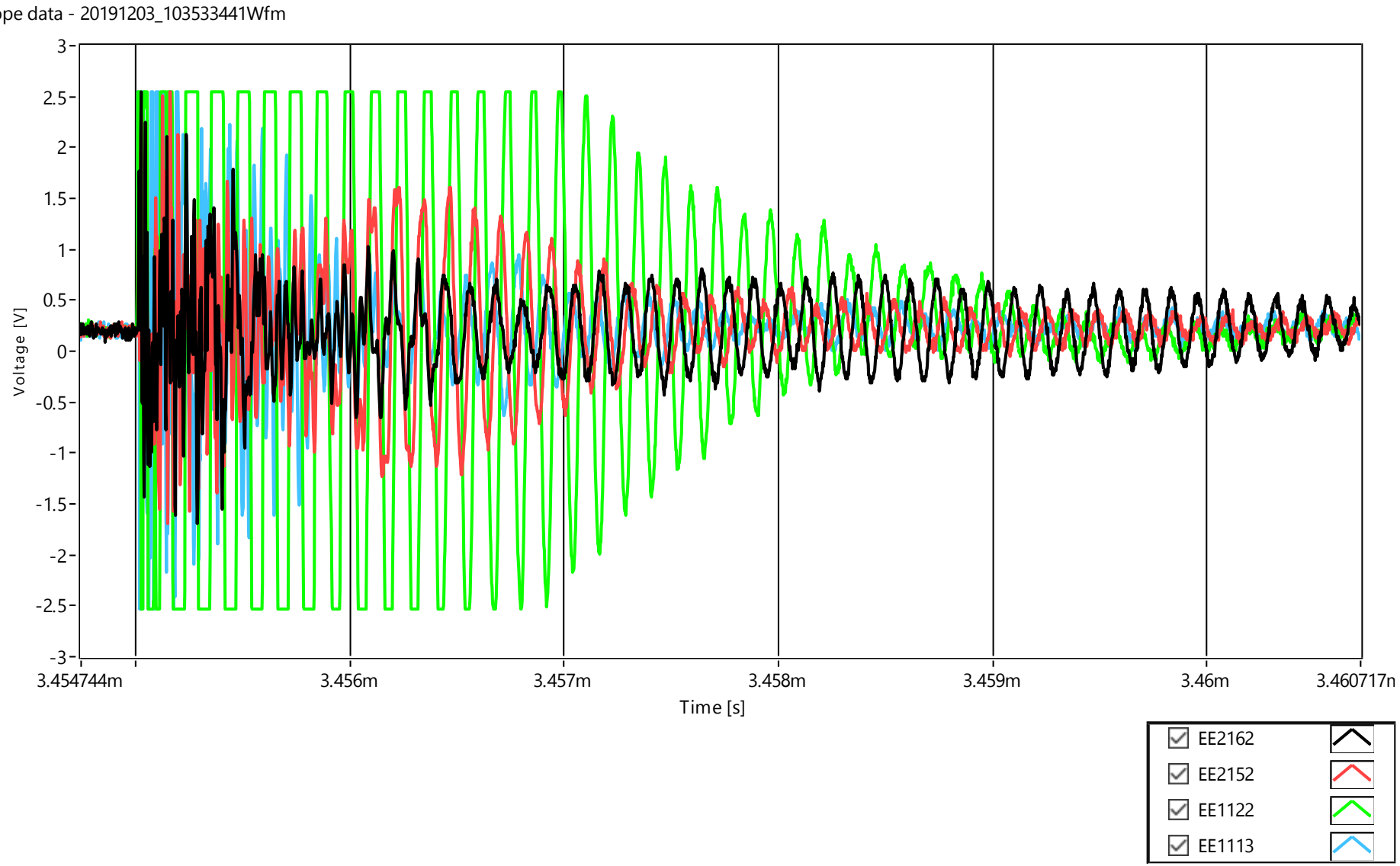
50 Hz noise chopped with fast transients, unknown origin, most likely external to the magnet





Fast transients, provoked by partial discharges.

Green curve measured between the coils of aperture 1



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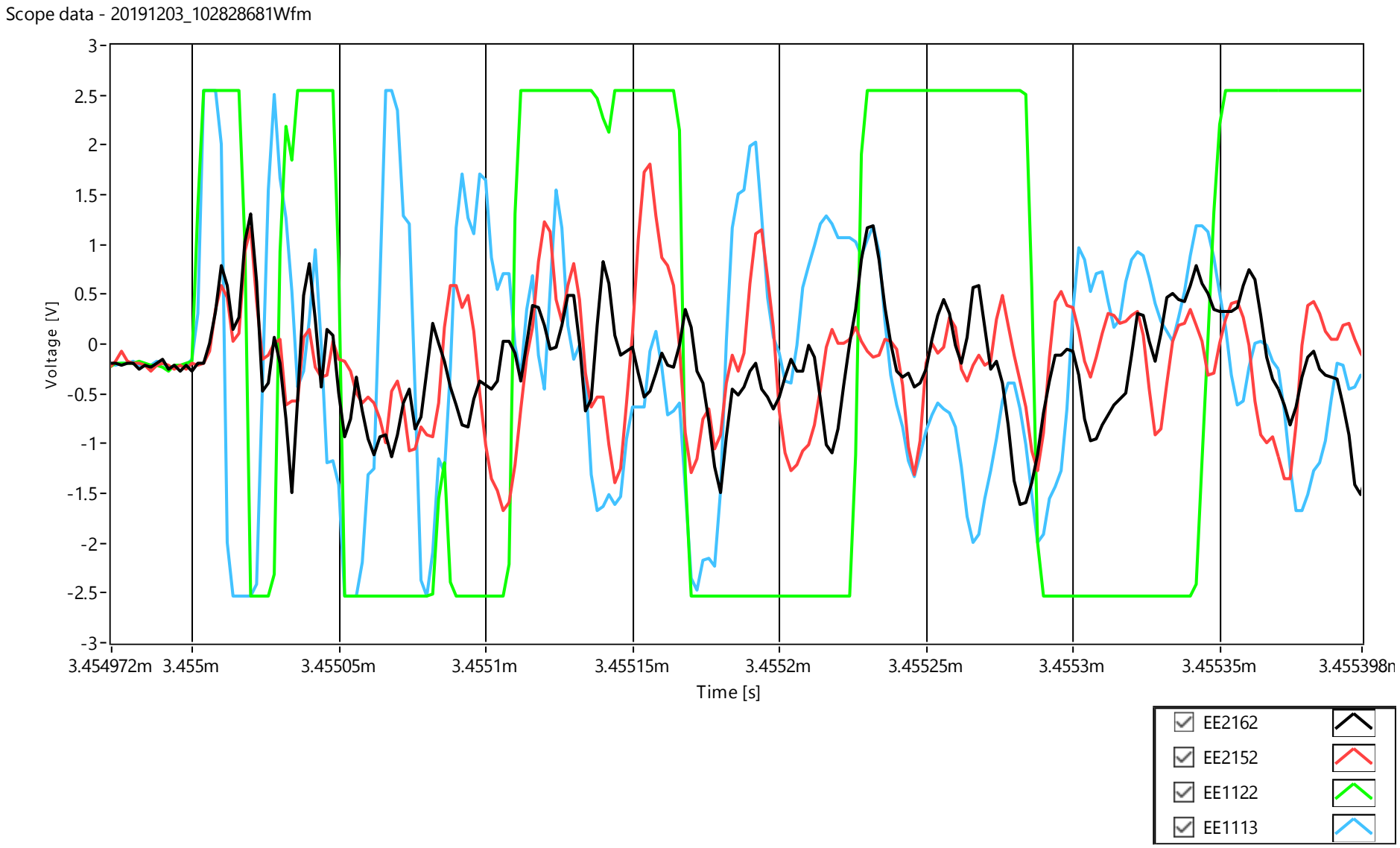
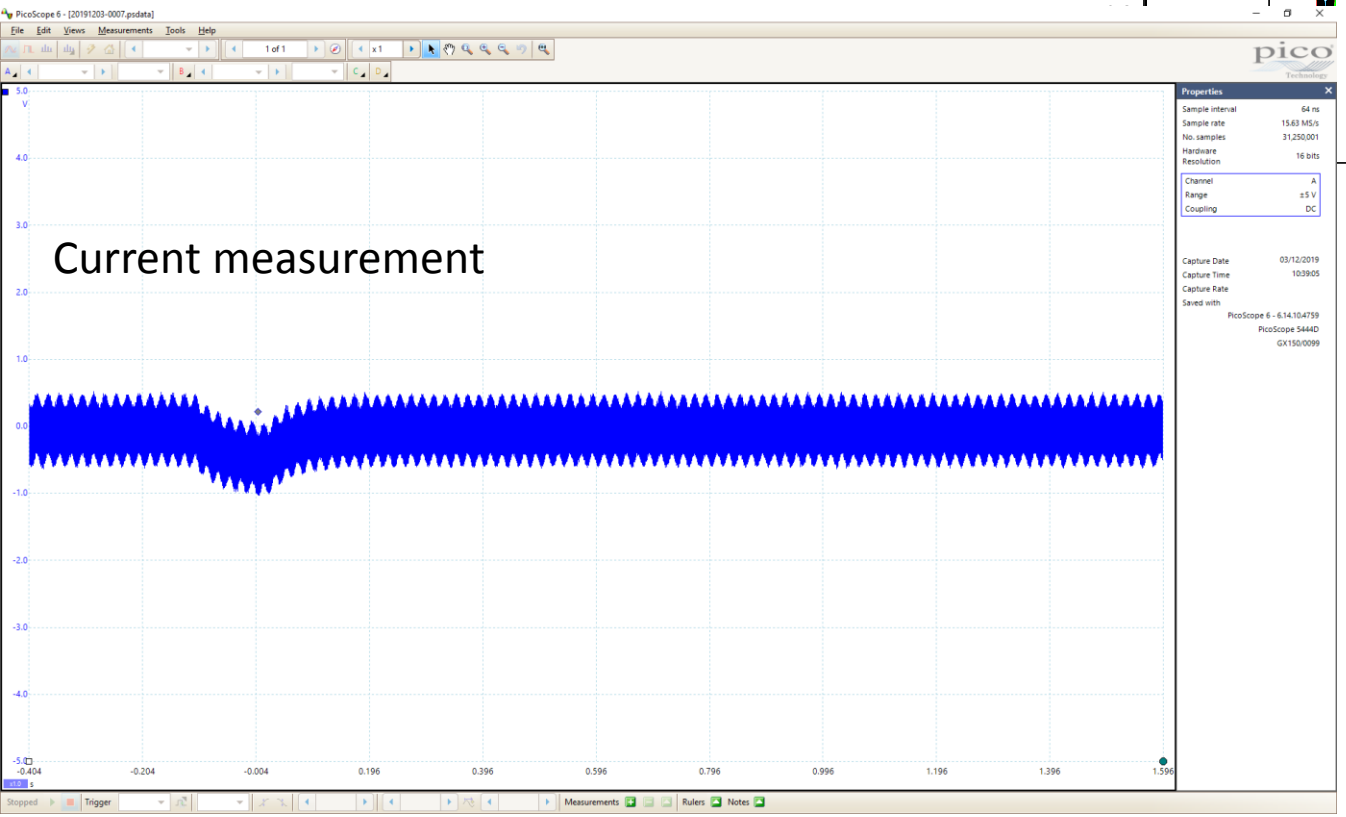
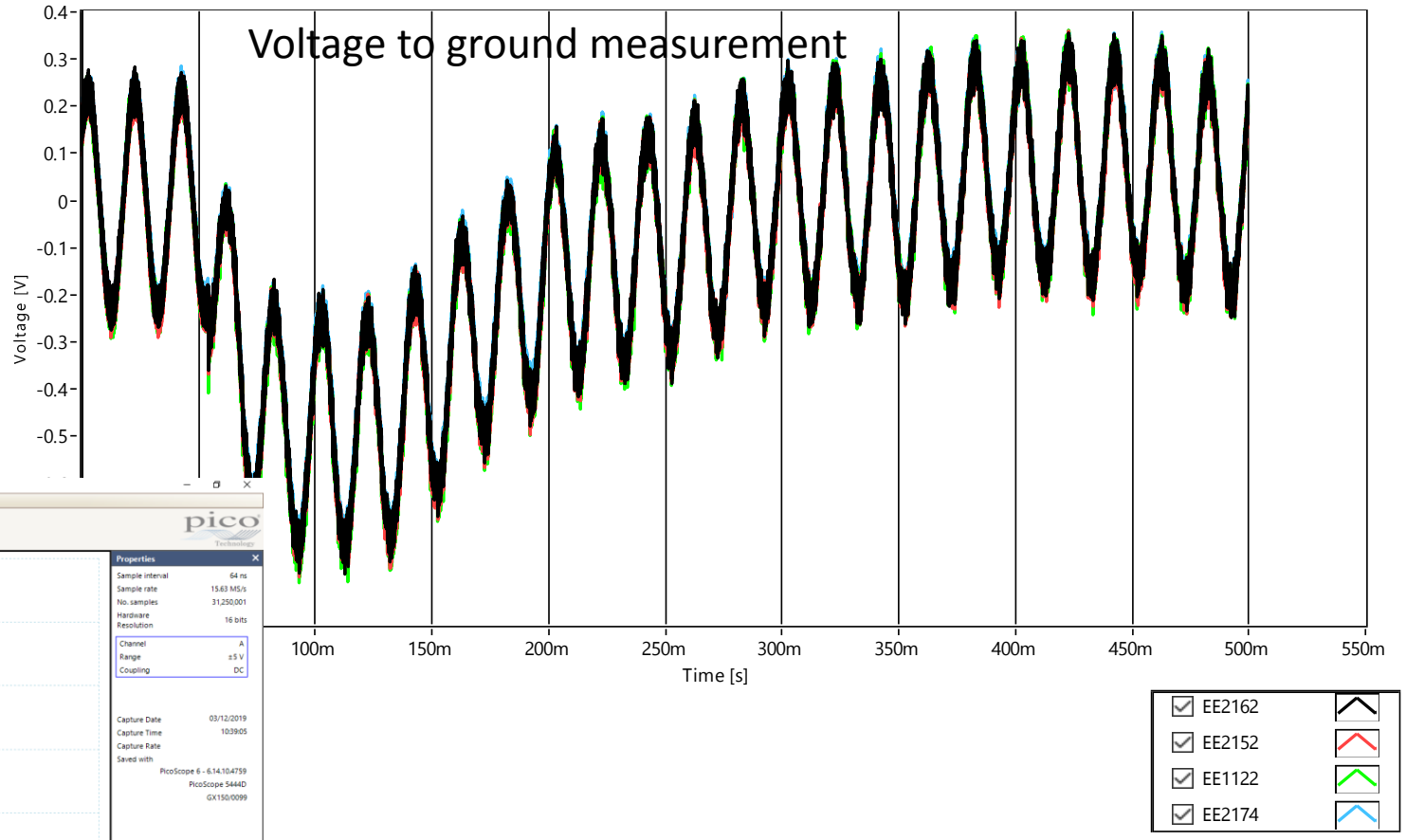


On-set of high leakage current is a slow process





Conclusions

- High leakage current that appears at about 2 kV during the HV test was observed with both instruments (SM18 and ELQA)
- The high leakage current is not acceptable for the installation in the RB magnet chain
- Multiple measurements were performed testing various scenarios
- Very difficult to localise this kind of fault, especially in a superconducting magnet
- The fault location cannot be clearly identified
- If the fault persists at warm, the fault localisation will be much easier
- The capillary has to be kept for future studies
  - Confirming or excluding the fault in the capillary will be very useful for the magnet
  - If the fault is in the capillary, it is a very good study-case
  - The capillary has to be handled with particular care during and after the removal from the magnet