ANALOG DEVICES
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SINGLE EVENT LATCH-UP TEST REPORT ADF4108S

January 2017

Radiation Test Report	
Product:	ADF4108S
Effective LET:	86 MeV-cm^2/mg
Fluence:	1E7 ions/cm^2
Die Type:	R11C
Facilities:	Lawrence Berkeley National Laboratories
Tested:	April 2012

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Single Event Latch-up Testing of the ADF4108 1 GHz to 8 GHz, PLL Frequency Synthesizer

Customer: Analog Devices (PO# 45352065)

RAD Job Number: 11-630

Part Types Tested: Analog Devices ADF4108 1 GHz to 8 GHz, PLL Frequency Synthesizer.

Traceability Information: Manufacturing Code: E195635.1 wafer 11 and E195637.1 wafer 12; see a photograph of a sample device-under-test in Appendix A for traceability information/part markings.

Quantity of Parts for Testing: Two units will be exposed to a fluence of 1E7ion/cm^2 at a maximum LET of approximately 80MeV-cm^2/mg using worst-case bias and temperature (85°C).

Pre-Irradiation Burn-In: Burn-in not specified by the customer.

Referenced Test Standard(s): ASTM F1192, EIA/JESD57

Electrical Test Conditions: Supply current monitored during exposure.

Test Software / Hardware: Aeroflex-RAD's custom GPIB data logging software, See Appendix C, Table C.1 for a list of test equipment and calibration dates.

Bias Conditions: All units-under-test were biased during heavy ion irradiation using a worst-case supply potential. See Section 4 and Appendix B for the details of the bias conditions.

Ion Energy and LET Ranges: Minimum of 10MeV/n Xe beams with an effective LET of approximately 80MeV-cm^2/mg. The 10MeV/n Xe beam has a range of to the Bragg peak of approximately 60µm in silicon. Depending on the response of the unit-under-test additional ions may be used to determine the latchup threshold (using worst-case bias and temperature).

Heavy Ion Flux and Maximum Fluence Levels: Flux of approximately 1 to 2E5 ions/cm2. Minimum 1E7 ions/cm^2 per unit tested when no events are detected.

Facility and/or Radiation Source: Lawrence Berkeley National Laboratories (LBNL) Berkeley, CA (10MeV/n beam).

Irradiation Temperature: Maximum 85°C case temperature as specified as the worst-case operating condition by the datasheet.

SEL Test Result: ADF4108 1 GHz to 8 GHz, PLL Frequency Synthesizer did not exhibit latch up to the maximum tested LET of 86MeV-cm^2/mg. The units-under-test did not latchup, but did suffer SEFI events at an LET of approximately 31MeV-cm^2/mg

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1.0. Overview and Background

It is well known that heavy ion exposure can cause temporary and/or permanent damage in electronic devices. The damage can occur through various mechanisms including single event latch-up (SEL), single event burnout (SEB) and single event gate rupture (SEGR). An SEL event occurs when a parasitic npnp feedback latch structure becomes biased into the on state due to a dense track of electron-hole pairs created along the heavy ion path in silicon. This latch-up is self-sustaining since there is a positive feedback path created and requires a power cycle to reset. A single event latch-up can lead to single event burnout if the current draw from the SEL event is sufficient to damage the junction and/or bond wire. The damage is worse and/or becomes evident with increasing linear energy transfer (LET) and fluence. The two test standards usually used to govern this testing are ASTM F1192 and EIA/JESD57. This destructive testing is usually performed at the maximum datasheet voltage and temperature to a total fluence of not less than 1E7ion/cm^2.

2.0. Single Event Latch-Up Test Apparatus

The single event latch-up testing described in this final report was performed at the Lawrence Berkeley National Laboratories (LBNL) using the 88-Inch Cyclotron. The 88-Inch Cyclotron is operated by the University of California for the US Department of Energy (DOE) and is a K=140 sector-focused cyclotron with both light- and heavy-ion capabilities. Protons and other light-ions are available at high intensities (10-20pμA) up to maximum energies of 55 MeV (protons), 65 MeV (deuterons), 135 MeV (3He) and 140 MeV (4He). Most heavy ions through uranium can be accelerated to maximum energies, which vary with the mass and charge state.

For the SEL testing described in this final report the units-under-test were be placed in the Cave 4B vacuum chamber aligned with the heavy ion beam line. The test platter in the vacuum chamber has full x and y alignment capabilities along with 2-dimensional rotation, allowing for a variety of effective LETs for each ion. For SEE testing Lawrence Berkeley Laboratories provides the dosimetry via a local control computer running a Lab View based program. Each ion is calibrated just prior to use using five photomultiplier tubes (PMTs). Four of the five PMTS are used during the test to provide the beam statistics, while the center PMT is removed following calibration. Figure 2.1 shows an illustration of the LBL facility; including the location of Cave 4B, where the heavy ion SEE testing takes place.

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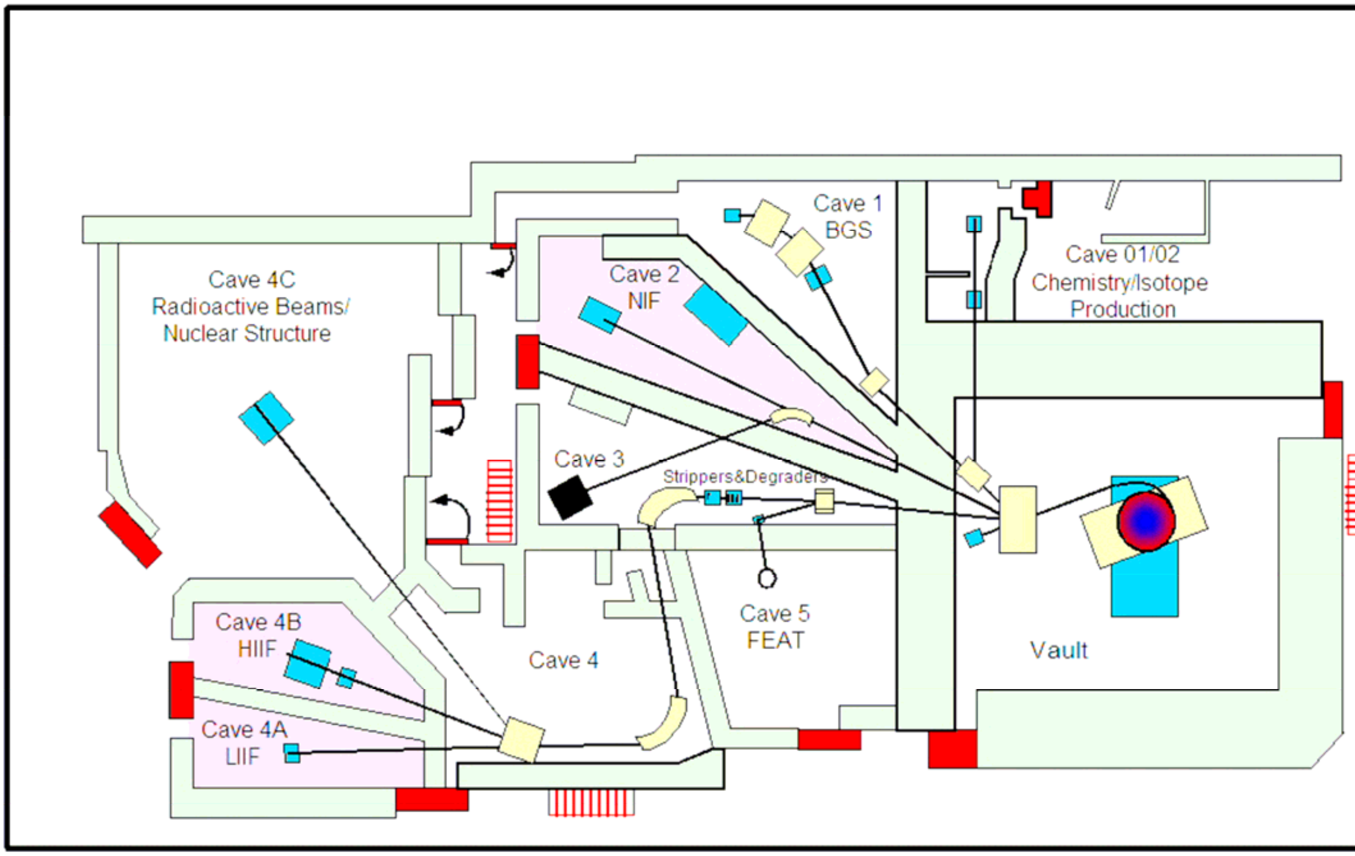

Figure 2.1. Map of 88-Inch Cyclotron Facility showing the location of Cave 4B, where the SEE testing was performed.

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3.0. Radiation Test Conditions

The ADF4108 1GHz to 8.0GHz PLL Frequency Synthesizer described in this final report was irradiated using the 10MeV/n Xe beam at the Lawrence Berkeley National Laboratory. Even though the units-under-test did not exhibit single event latchup, the devices were irradiated using Kr (lower LET) due to the erratic output behavior. All of the runs discussed in this final report were performed using worst-case bias and temperature. The units-under-test were irradiated using a single sided supply voltage of +5.5V to power the Charge Pump and a single sided supply voltage of +3.6V to power both the analog and digital power at the worst-case temperature of 85°C (±5°C). Figure 3.1 shows the test board used for the SEL testing described in this test plan (See the test circuit schematic in Appendix B for the additional details of the bias conditions). The test board was mounted on the test stage at Berkeley and provided 3-axis of motion plus rotation. The board had multiple devices-under-test to allow for sequential testing of the units without having to enter the exposure room and break vacuum during testing.

Additional features of the test board include:

1. DUTs individually powered – power inputs filtered via RLC filters. (See two power inputs V_P and V_{DD} for site 1 schematic in Appendix B).

2. Outputs brought out for monitoring

3. Reference Frequency input held at steady-state 25MHz signal during testing

4. Seeeduino Mega 1280 board used to program DUTs

5. Outputs are buffered with Gain = +2 (Ideal output at scope should range from 1.6V to 3.3V). Range is limited by input signal and system noise floor.

The 10MeV/n beam was used to provide sufficient range in silicon while meeting the maximum LET requirements of the program. The other beams available at Berkeley are the 4.5MeV/n beam and the 16MeV/n beam. The 4.5MeV/n beam does not provide sufficient range for destructive SEE testing while the 16MeV/n beam provides a much smaller selection of ions. Figure 3.2 shows the 10MeV/n beam characteristics for krypton and xenon calculated using SRIM. As seen in the figure, the range to the Bragg Peak for xenon (the shortest range particle used) is approximately 60µm while the surface LET is approximately 58MeV-cm2/mg.

Figure 3.3 shows the characteristics for all the beams available at Berkeley. Note that the units were de-encapsulated prior to testing and all exposures took place from the top surface providing a distance to the active layer in Silicon of approximately 5 to 10µm.

As noted above, the devices were irradiated to a minimum fluence of 1E7ion/cm^2. The flux varied during the testing, but was consistently targeted to approximately 1E5ion/cm^2-s to

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2E5ion/cm^2-s. The irradiation of the units-under-test continued until either the minimum fluence was reached or a latchup event was observed.

For the elevated temperature required for single event latch-up testing an aluminum plate heater fixed to the back of the board and was used to heat the device-under-test (DUT) with an RTD used to monitor the temperature. The case temperature of the DUT was calibrated prior to the testing to the RTD with a thermocouple, allowing the RTD to provide feedback and maintain a calibrated 85°C case temperature throughout the testing. The data monitored during the test (case temperature, supply voltage and supply current) was routed to the control room (approximately 20-feet away) using shielded coaxial cable.

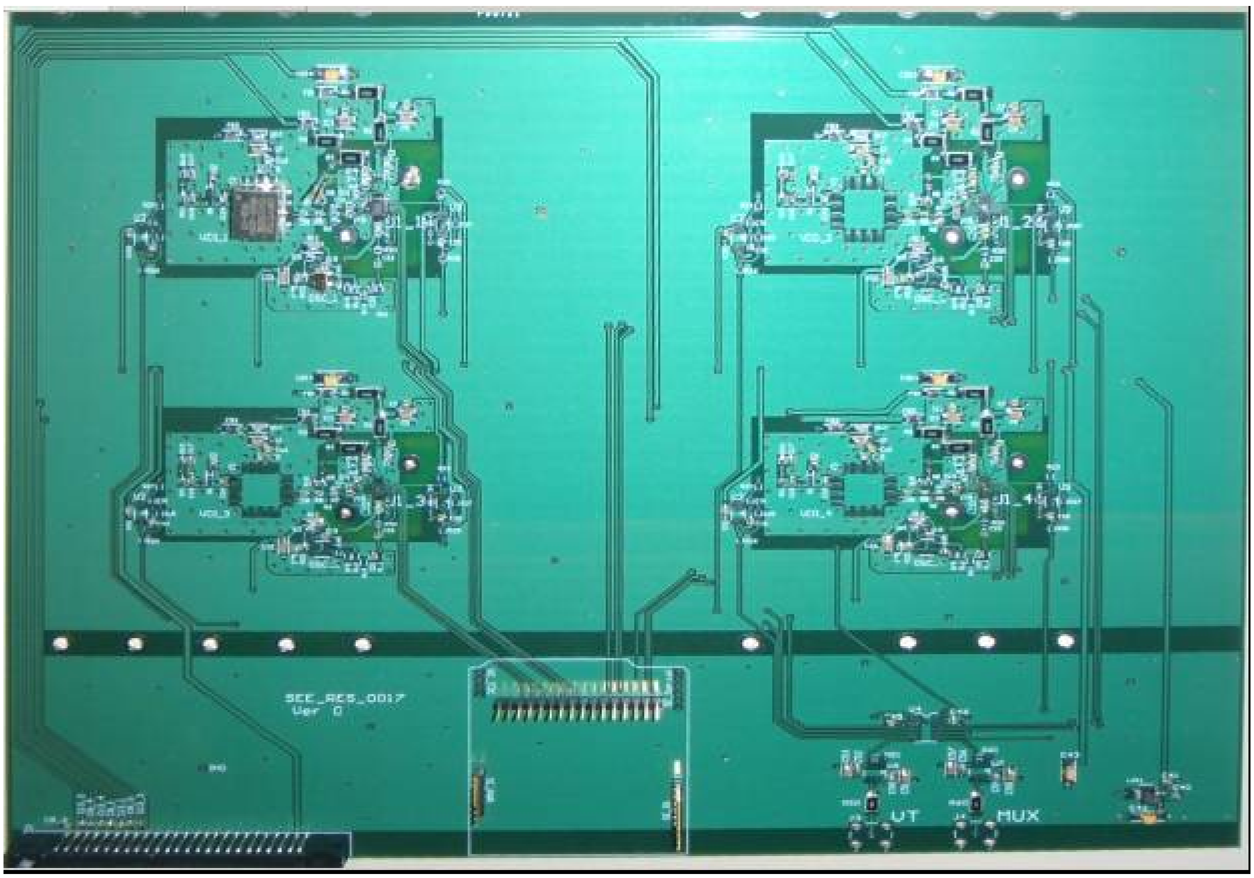

Figure 3.1. Single event test board prepared for mounting on the test stage at Berkeley. The board is designed for testing four devices-under-test (only one shown in this photograph) simultaneously to minimize interruptions during testing. There is also a heater mounted to the backside of the daughter cards to provide the elevated temperature required for this testing.

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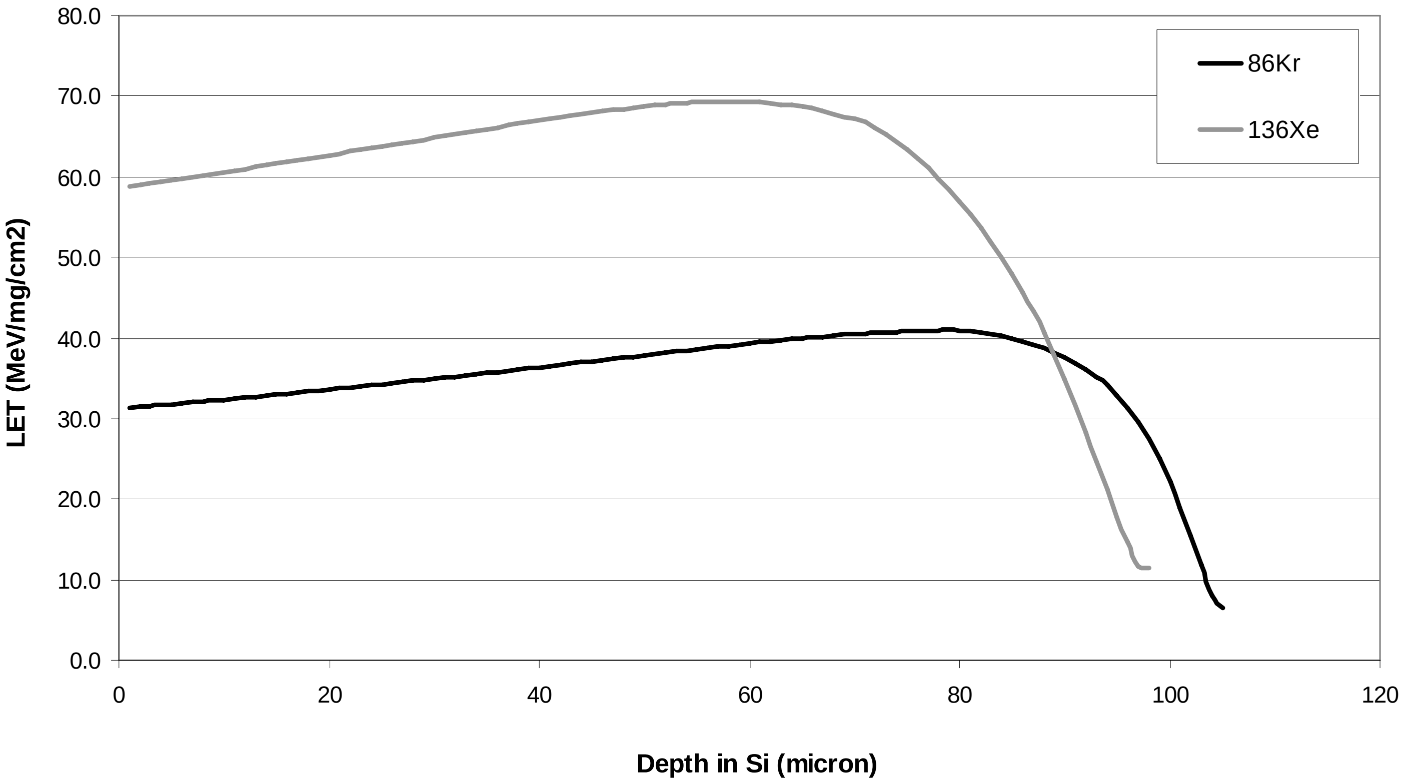

Figure 3.2. Range of the 10MeV/n Kr and Xe beams into silicon. The range to the Bragg Peak for Xe (the shorter of the two particles) is approximately 60µm while the surface LET is approximately 58MeV-cm2/mg.

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Ion	Cocktail (MeV/nuc)	Energy (MeV)	Z	A	Chg. State	% Nat. Abund.	LET 0° (MeV/(mg/cm²))	LET 60° (MeV/(mg/cm²))	Range (µm)	Method
B	4.5	44.90	5	10	+2	19.9	1.65	3.30	78.5	MIVOC
N	4.5	67.44	7	15	+3	0.37	3.08	6.16	67.8	Gas
Ne	4.5	89.95	10	20	+4	90.48	5.77	11.54	53.1	Gas
Si[1]	4.5	139.61	14	29	+6	4.67	9.28	18.56	52.4	Gas
Ar	4.5	180.00	18	40	+8	99.6	14.32	28.64	48.3	Gas
V	4.5	221.00	23	51	+10	99.75	21.68	43.36	42.5	Probe
Cu	4.5	301.79	29	63	+13	69.17	29.33	58.66	45.6	Probe
Kr	4.5	387.08	36	84	+17	17.3	38.96	77.92	48.0	Gas
Y	4.5	409.58	39	89	+18	100	45.58	91.16	45.8	Probe
Ag	4.5	499.50	47	109	+22	48.161	58.18	116.36	46.3	Probe
Xe	4.5	602.90	54	136	+27	8.9	68.84	137.68	48.3	Gas
Tb	4.5	724.17	65	159	+32	100	77.52	155.04	52.4	Probe
Ta	4.5	805.02	73	181	+36	99.988	87.15	174.30	53.0	Probe
Bi	4.5	904.16	83	209	+41	100	99.74	199.48	52.9	Oven
B	10	108.01	5	11	+3	80.1	0.89	1.78	305.7	MIVOC
O	10	183.47	8	18	+5	0.2	2.19	4.38	226.4	Gas
Ne	10	216.28	10	22	+6	9.25	3.49	6.98	174.6	Gas
Si[1]	10	291.77	14	29	+8	4.67	6.09	12.18	141.7	Gas
Ar	10	400.00	18	40	+11	99.6	9.74	19.48	130.1	Gas
V	10	508.27	23	51	+14	99.75	14.59	29.18	113.4	Probe
Cu	10	659.19	29	65	+18	30.83	21.17	42.34	108.0	Probe
Kr	10	906.45	36	84	+24	57	30.23	60.46	113.1	Gas
Y	10	928.49	39	89	+25	100	34.73	69.46	102.2	Probe
Ag	10	1039.42	47	107	+29	51.839	48.15	96.30	90.0	Probe
Xe	10	1232.55	54	124	+34	0.1	58.78	117.56	90.0	Gas
N	16	233.75	7	14	+5	99.63	1.16	2.32	505.9	Gas
O	16	277.33	8	17	+6	0.04	1.54	3.08	462.4	Gas
Ne	16	321.00	10	20	+7	90.48	2.39	4.78	347.9	Gas
Si[1]	16	452.10	14	29	+10	4.67	4.56	9.12	274.3	Gas
Cl	16	539.51	17	35	+12	75.77	6.61	13.22	233.6	Natural
Ar	16	642.36	18	40	+14	99.600	7.27	14.54	255.6	Gas
V	16	832.84	23	51	+18	99.750	10.90	21.80	225.8	Probe
Cu	16	1007.34	29	63	+22	69.17	16.53	33.06	190.3	Probe
Kr	16	1225.54	36	78	+27	0.35	24.98	49.96	165.4	Gas
Xe	16	1954.71	54	124	+43	0.1	49.29	98.58	147.9	Gas
N	30	425.45	7	15	+7	0.37	0.76	1.52	1370.0	Gas
O	30	490.22	8	17	+8	0.04	0.98	1.96	1220.0	Gas
Ne	30	620.00	10	21	+10	0.27	1.48	2.96	1040.0	Gas
Ar	30	1046.11	18	36	+17	0.337	4.87	9.74	578.1	Gas

[1]By Special request

Figure 3.3. Characteristics of all the beams available at Berkeley. For the testing discussed in this report the 10MeV/n beam was used exclusively.

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4.0. Tested Parameters

During heavy ion exposure the current from the two positive supplies to the devices-under-test will be measured and recorded in approximately 1-second increments. In addition to the supply currents, the output of the units-under-test (e.g., V_{OUT}, see the functional block diagram of the device-under-test in Appendix B) will be measured for proper operation/output signal. The units-under-test will be operated using a 25MHz reference clock signal generated using CMOS clock oscillators mounted on the test motherboard. The units-under-test are configured in a closed loop with a Crystek CVCO55BE-1650-2150 Voltage Controlled Oscillator (VCO). The tuning voltage (filtered charge pump) and digital lock indicator outputs were captured on a digitizing oscilloscope. The primary metric for determining SEL is a significant increase in supply current. However, for the SEL portion of the testing discussed in this test plan we will verify proper operation and/or recovery of the device using an oscilloscope that triggered whenever there is a significant distortion in the tuning voltage or the digital lock signal.

Table 4.1 summarizes the single event transient tests performed for the ADF4108 1 GHz to 8 GHz, PLL Frequency Synthesizer. Note that the SET results are recorded in a separate report entitled: “Single Event Transient Testing of the ADF4108 1 GHz to 8 GHz, PLL Frequency Synthesizer.” Table 4.1 records the total effective fluence, the average flux, the run time, the beam energy, the ion and the effective LET. As noted above, the SEL testing occurred at three case temperatures of approximately 85°C (±5°C).

In general the following minimum criteria must be met for a device to have considered passing the SEL test for a given ion, LET and/or temperature: during the heavy ion exposure the DUT’s supply current must remain within the unit’s specification limit without cycling power. If this condition is not satisfied following the heavy ion testing, then the SEL testing could be logged as a failure. Note that during heavy ion testing a substantial amount of total dose can be absorbed by the devices-under-test. If a functional failure occurs during or following the testing, it is important to separate TID failures from destructive single event effects. Also, a single event latch-up may not be a “destructive” event since it is still functional, however a unit which experiences an SEL (i.e., a high sustained supply current requiring a power cycle to recover) is considered to have failed this test even if the units are functional and meet parametric limits following the testing.

For the testing described in this plan the following general test procedure was used:

1. Turn on board power (DUT power = +5.5V, board power = ±5V)
2. Turn on DUT charge pump (V_P) power (DUT V_P power = +5.5V)
3. Turn on DUT Analog and Digital (V_{DD}) power (DUT V_{DD} power = +3.6V)
4. Select Site 1 outputs by setting Analog MUX inputs A0 and A1 to logic 0
5. Program the DUT to operate at 1.80GHz with a Phase Detector frequency of 500kHz)

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6. Program the DUT MUXOUT to output the digital lock detect signal
7. Observe the tuning voltage and the MUXOUT signals (J2 and J3, respectively) using scope or multimeter
8. Adjust temperature to +85°C
9. Turn ON ion beam, observe/monitor/log device current
10. Repeat process with different ion energies as device response dictates
11. After site testing is completed, reposition test board to irradiate the next DUT to be tested.
12. Repeat steps 2& 3.
13. Select the site outputs by changing Analog MUX inputs A0 A1
14. Repeat steps 5 through 10
15. Repeat steps 11 through 14 for remaining DUTs

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Table 4.1. Summary of the single event latchup tests performed for the ADF4108 1 GHz to 8 GHz, PLL Frequency Synthesizer.

Run#	Test Date	Serial Number	Temp (C)	Total Eff Fluence	Run Time (sec)	Ion	Eff LET
10	4/5/2012	SN 1	85	1.05E+06	18.7	Xe 58.78	86.19
11	4/5/2012	SN 1	85	1.01E+07	140.62	Xe 58.78	86.19
12	4/5/2012	SN 1	85	1.01E+07	91.07	Xe 58.78	86.19
13	4/5/2012	SN 1	85	1.01E+07	80.81	Xe 58.78	67.87
14	4/5/2012	SN 1	85	1.01E+07	69.05	Xe 58.78	58.78
15	4/5/2012	SN 1	85	1.01E+07	78.96	Kr 30.86	30.86
16	4/5/2012	SN 1	85	1.01E+07	109.65	Kr 30.86	43.64
17	4/5/2012	SN 3	85	1.01E+07	108.62	Kr 30.86	43.64
18	4/5/2012	SN 3	85	1.01E+07	86.99	Xe 58.78	86.19
19	4/5/2012	SN 3	85	1.01E+07	82.25	Xe 58.78	86.19

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5.0. Single Event Latch-Up Test Results

Using the criteria established for pass/fail of this single event latchup test, the Analog Devices ADF4108 1 GHz to 8 GHz, PLL Frequency Synthesizer (of the lot date code identified on the first page of this test report) PASSED. The units-under-test did not appear to suffer from any definitive latchup events to the maximum tested LET of approximately 86MeV-cm^2/mg (and at a case temperature 85°C). However the units-under-test did suffer single event effects that caused improper operation of the device that persisted until a power cycle was completed. All of the units returned to proper operation after a power cycle. The single event effect response on the operation of the ADF4108 1 GHz to 8 GHz, PLL Frequency Synthesizer are discussed in a separate report entitled: "Single Event Transient Testing of the ADF4108 1 GHz to 8 GHz, PLL Frequency Synthesizer."

Table 5.1 show a summary of the single event latch-up data acquired. The table shows the run number, serial number of the part irradiated, the case temperature during testing, the ion species, the effective fluence, the effective LET and whether or not an SEL event was recorded in either of the power supplies (i.e. V_{DD} or V_P).

Figure 5.1 shows VDD and IDD versus time during run 10 while Figure 5.2 shows VP and IVP versus time during run 10 for the ADF4108 1 GHz to 8 GHz, PLL Frequency Synthesizer. The complete set of data plots for runs 10 through 19 can be seen in Appendix D. As seen in these figures, the units-under-test exhibit single event effects that cause the supply currents to move higher and/or lower during the beam run. In our opinion, none of these effects are due to single event latchup, but related to single event upset or transients that cause the device to temporally malfunction. Proper operation of the device occurs either spontaneously or via a power cycle.

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Table 5.1. Summary of the SEL test runs and results for the ADF4108 1 GHz to 8 GHz, PLL Frequency Synthesizer.

Run#	Test Date	Serial Number	Temp (C)	Total Eff Fluence	Run Time (sec)	Ion	Eff LET	SEL
10	4/5/2012	SN 1	85	1.05E+06	18.7	Xe 58.78	86.19	No
11	4/5/2012	SN 1	85	1.01E+07	140.62	Xe 58.78	86.19	No
12	4/5/2012	SN 1	85	1.01E+07	91.07	Xe 58.78	86.19	No
13	4/5/2012	SN 1	85	1.01E+07	80.81	Xe 58.78	67.87	No
14	4/5/2012	SN 1	85	1.01E+07	69.05	Xe 58.78	58.78	No
15	4/5/2012	SN 1	85	1.01E+07	78.96	Kr 30.86	30.86	No
16	4/5/2012	SN 1	85	1.01E+07	109.65	Kr 30.86	43.64	No
17	4/5/2012	SN 3	85	1.01E+07	108.62	Kr 30.86	43.64	No
18	4/5/2012	SN 3	85	1.01E+07	86.99	Xe 58.78	86.19	No
19	4/5/2012	SN 3	85	1.01E+07	82.25	Xe 58.78	86.19	No

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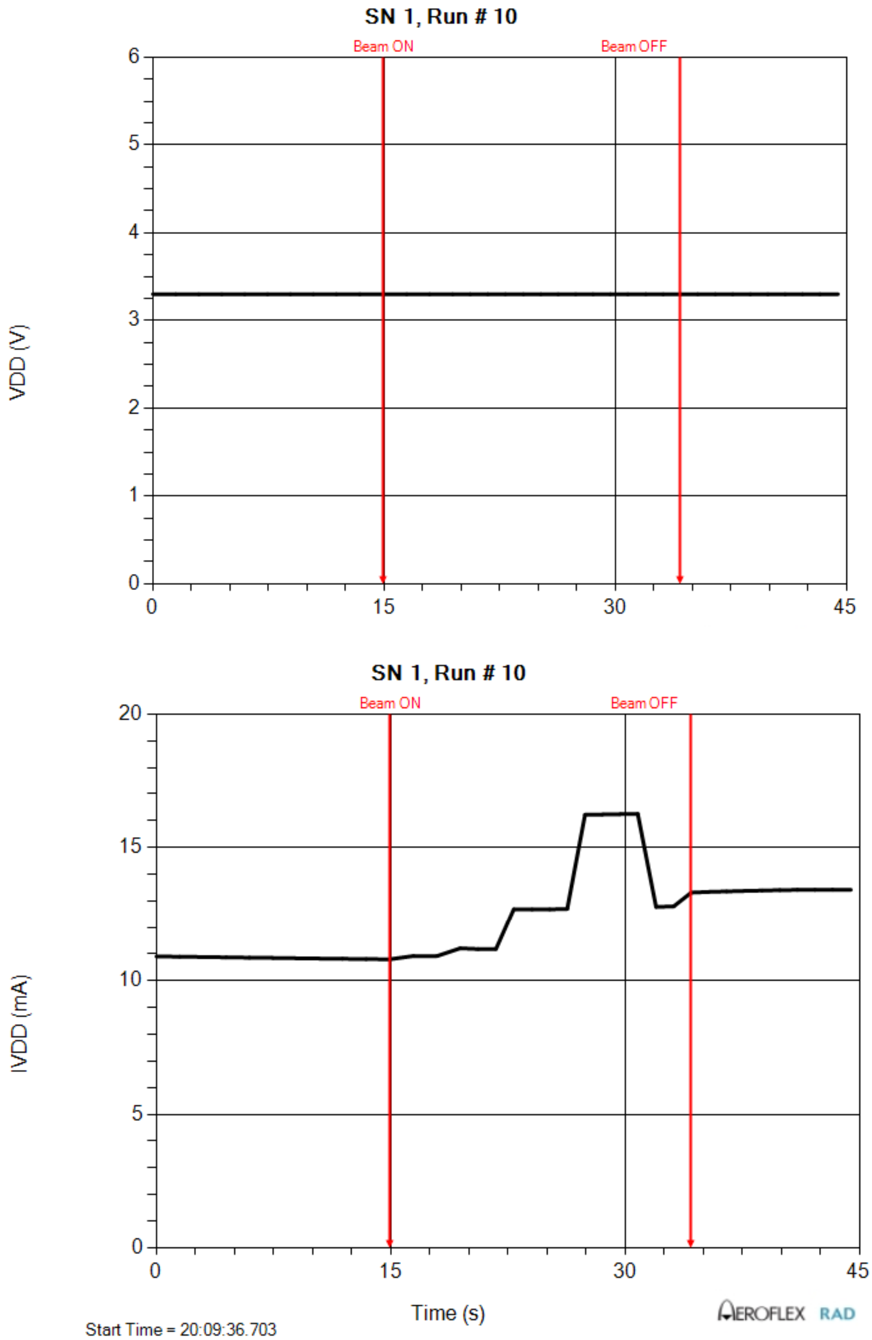

Figure 5.1. VDD and IDD versus time during run 10 for the ADF4108 1 GHz to 8 GHz, PLL Frequency Synthesizer. See Table 4.1 for the details about the run.

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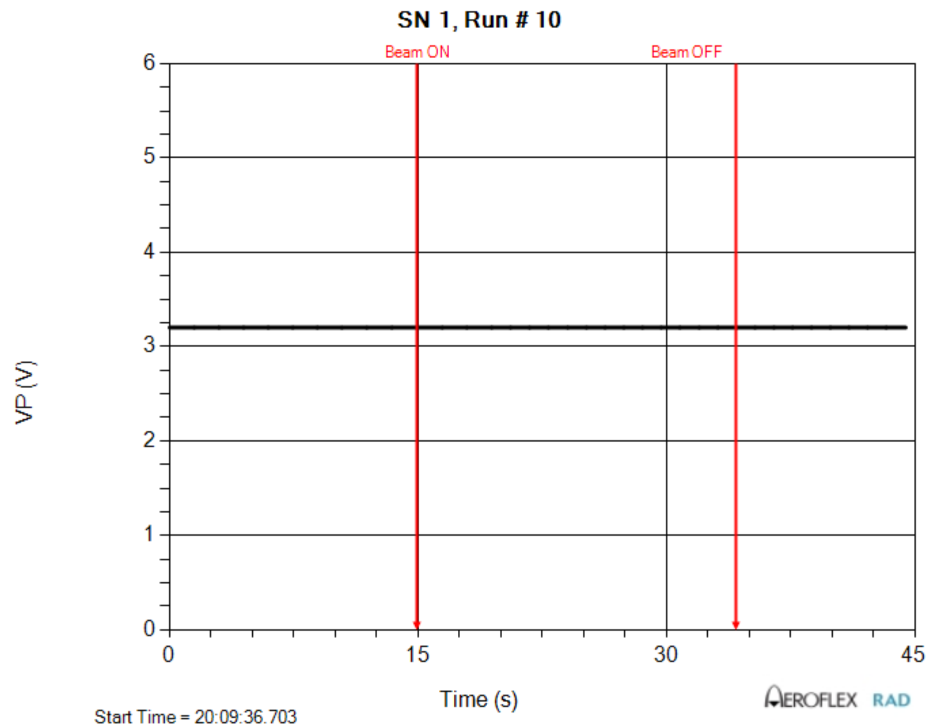

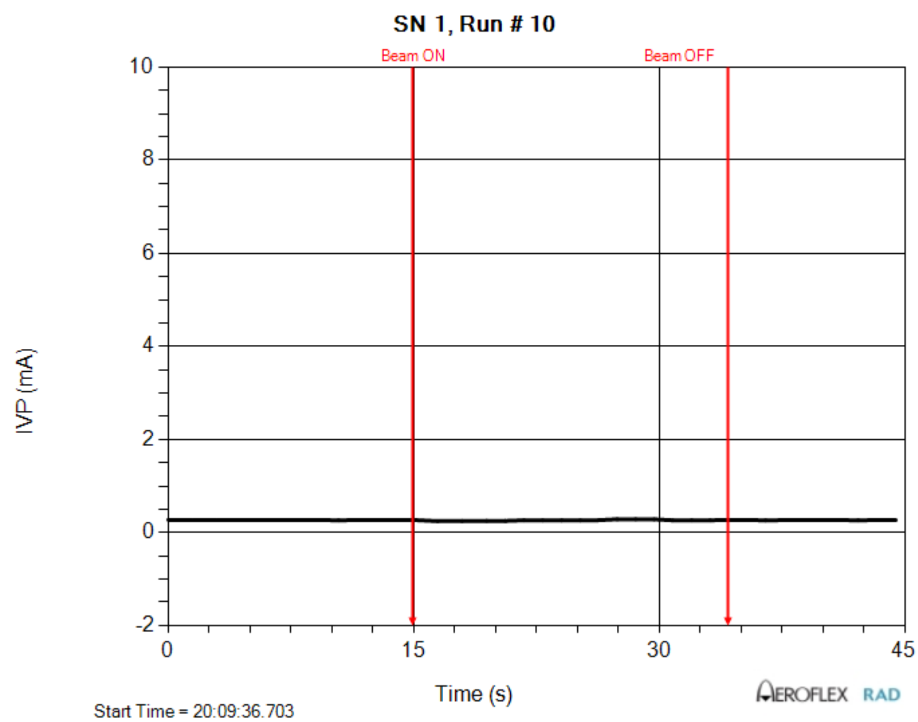

Figure 5.2. VP and IVP versus time during run 10 for the ADF4108 1 GHz to 8 GHz, PLL Frequency Synthesizer. See Table 4.1 for the details about the run.

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6.0. Summary/Conclusions

The single event latch-up testing described in this final report was performed at the Lawrence Berkeley National Laboratories (LBNL) using the 88-Inch Cyclotron on December 7th, 2011. The 88-Inch Cyclotron is operated by the University of California for the US Department of Energy (DOE) and is a K=140 sector-focused cyclotron with both light- and heavy-ion capabilities.

The ADF4108 1GHz to 8.0GHz PLL Frequency Synthesizer described in this final report was irradiated using the 10MeV/n Xe beam at the Lawrence Berkeley National Laboratory. Even though the units-under-test did not exhibit single event latchup, the devices were irradiated using Kr (lower LET) due to the erratic output behavior. All of the runs discussed in this final report were performed using worst-case bias and temperature. The units-under-test were irradiated using a single sided supply voltage of +5.5V to power the Charge Pump and a single sided supply voltage of +3.6V to power both the analog and digital power at the worst-case temperature of 85°C (±5°C).

The devices were irradiated to a minimum fluence of 1E7ion/cm2. The flux varied somewhat during the testing, but was approximately 1E5ion/cm^2-s to 2E5ion/cm^2-s. During the testing the irradiations continued until either the minimum fluence was reached or a latchup event was observed. In general the following minimum criteria must be met for a device to pass SEL testing: During the heavy ion exposure the DUT's supply current must remain within the unit's specification limit without cycling power. If this condition is not satisfied following the heavy ion testing, then the SEL testing could be logged as a failure.

Using the criteria established for pass/fail of this single event latchup test, the Analog Devices ADF4108 1 GHz to 8 GHz, PLL Frequency Synthesizer (of the lot date code identified on the first page of this test report) PASSED. The units-under-test did not appear to suffer from any definitive latchup events to the maximum tested LET of approximately 86MeV-cm^2/mg (and at a case temperature 85°C). However the units-under-test did suffer single event effects that caused improper operation of the device that persisted until a power cycle was completed. All of the units returned to proper operation after a power cycle. The single event effect response on the operation of the ADF4108 1 GHz to 8 GHz, PLL Frequency Synthesizer are discussed in a separate report entitled: "Single Event Transient Testing of the ADF4108 1 GHz to 8 GHz, PLL Frequency Synthesizer."

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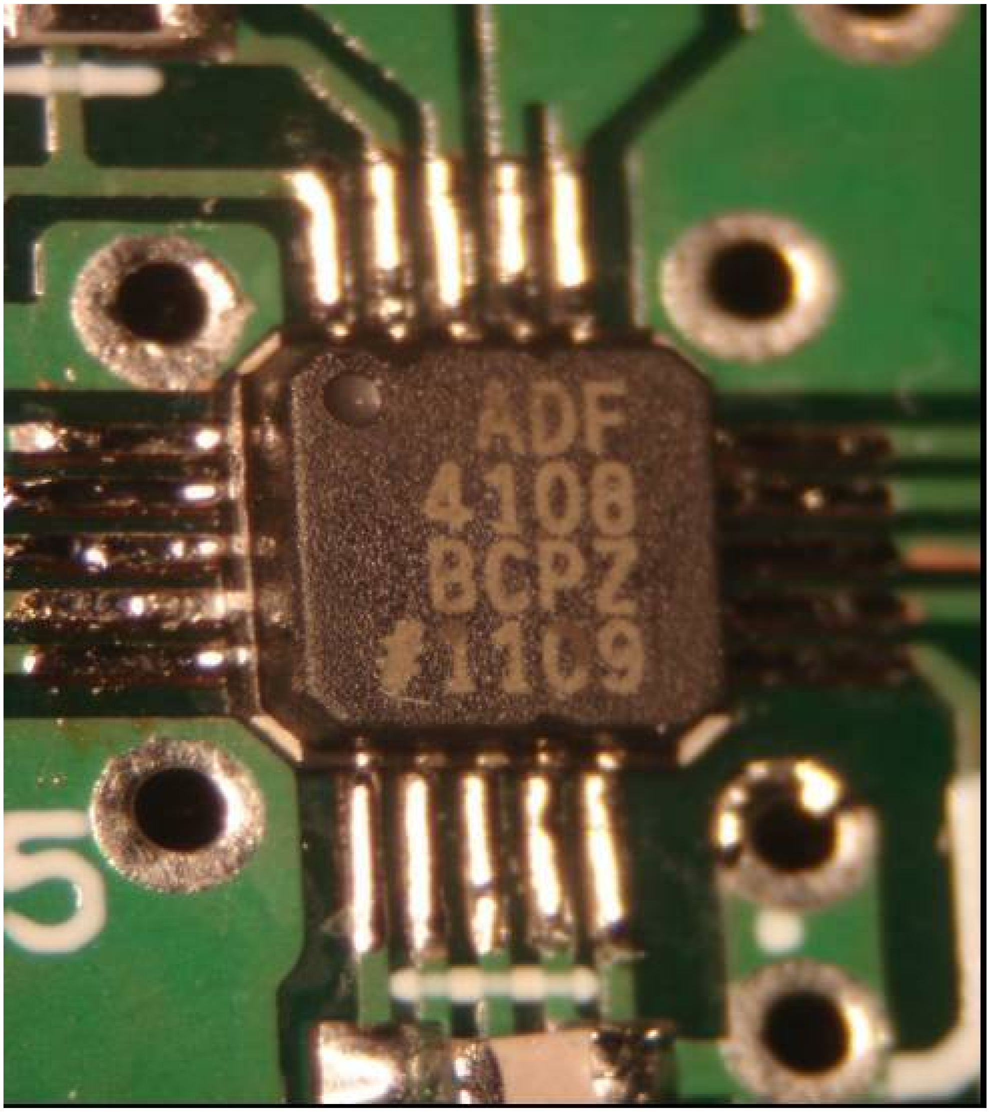
Appendix A: Photograph of a Sample Device-Under-Test for Device Traceability and a decapsulated Unit Prepared for SEL Testing



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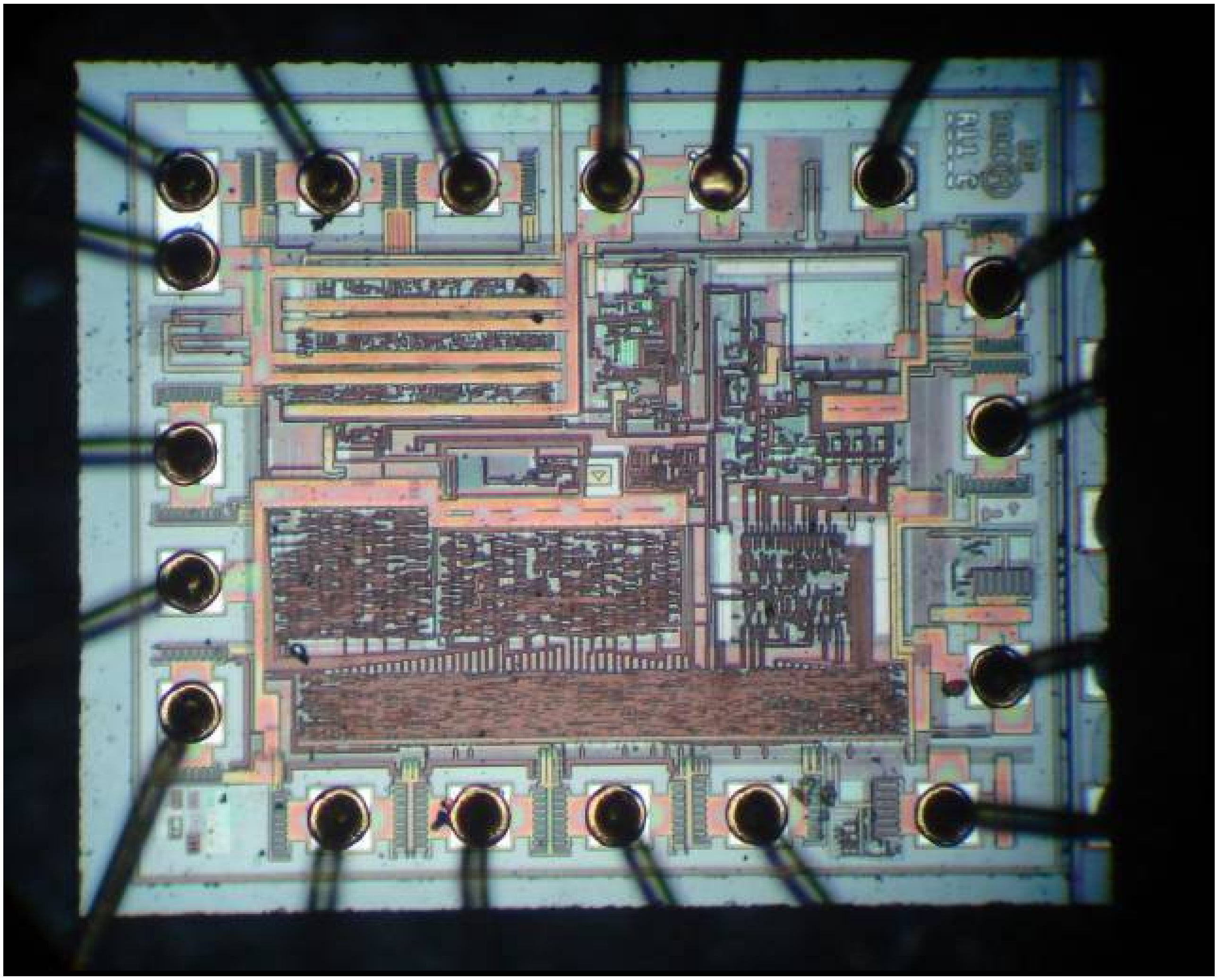

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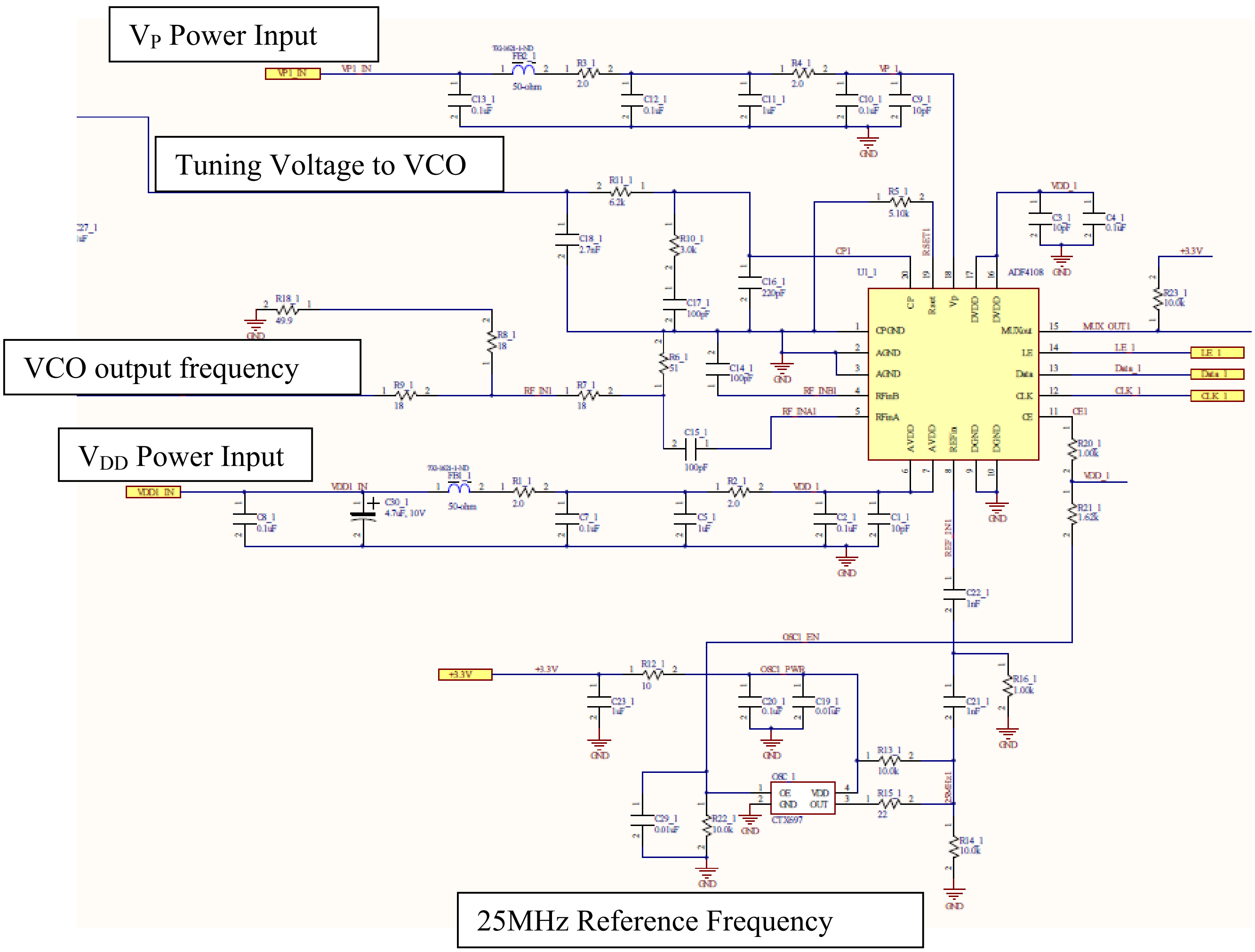
Appendix B: Schematic of Test Board (Single Test Site) and Photograph of Test Board Used During Heavy Ion Exposure and Functional Block Diagram of the Device-Under-Test



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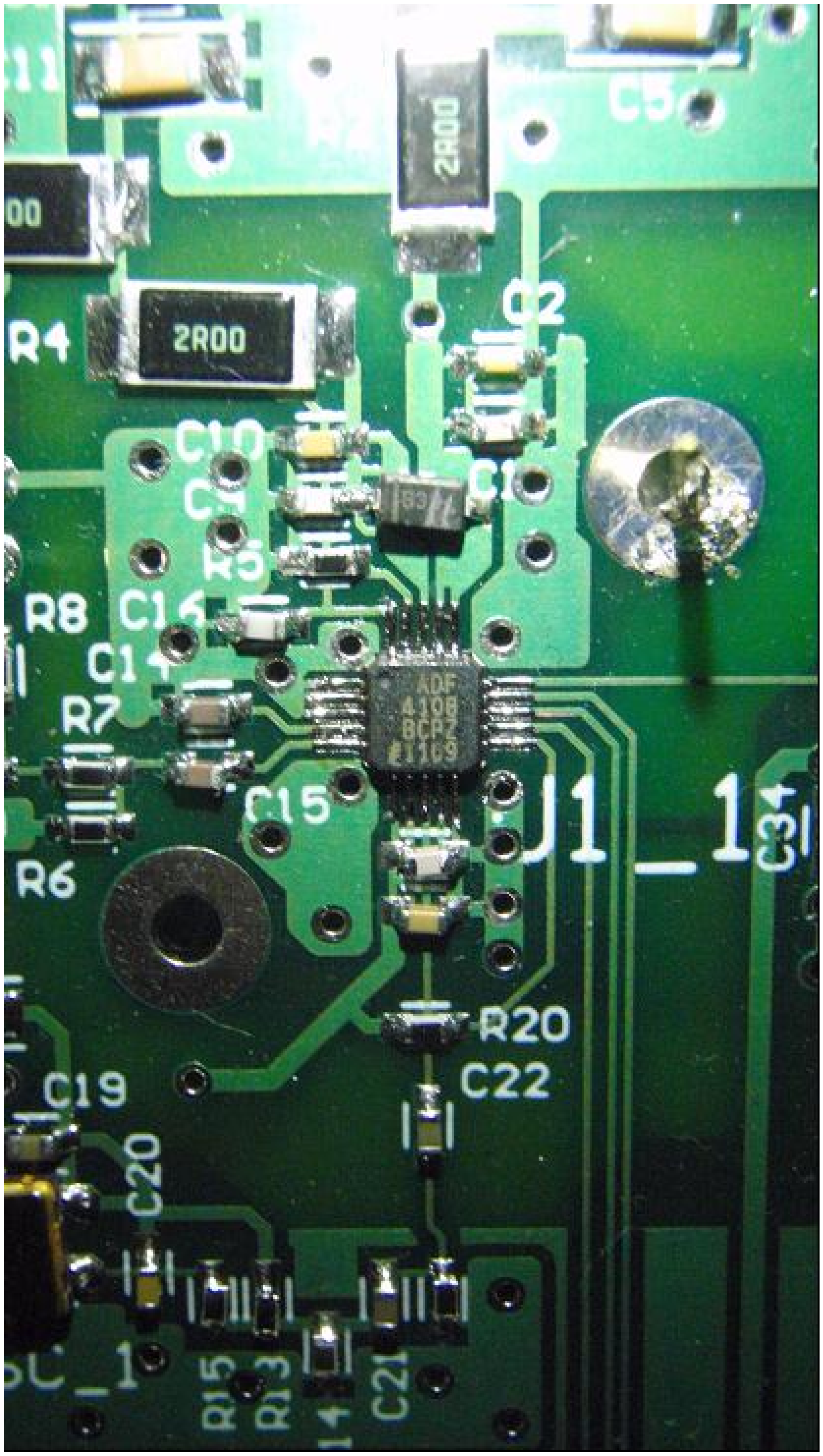

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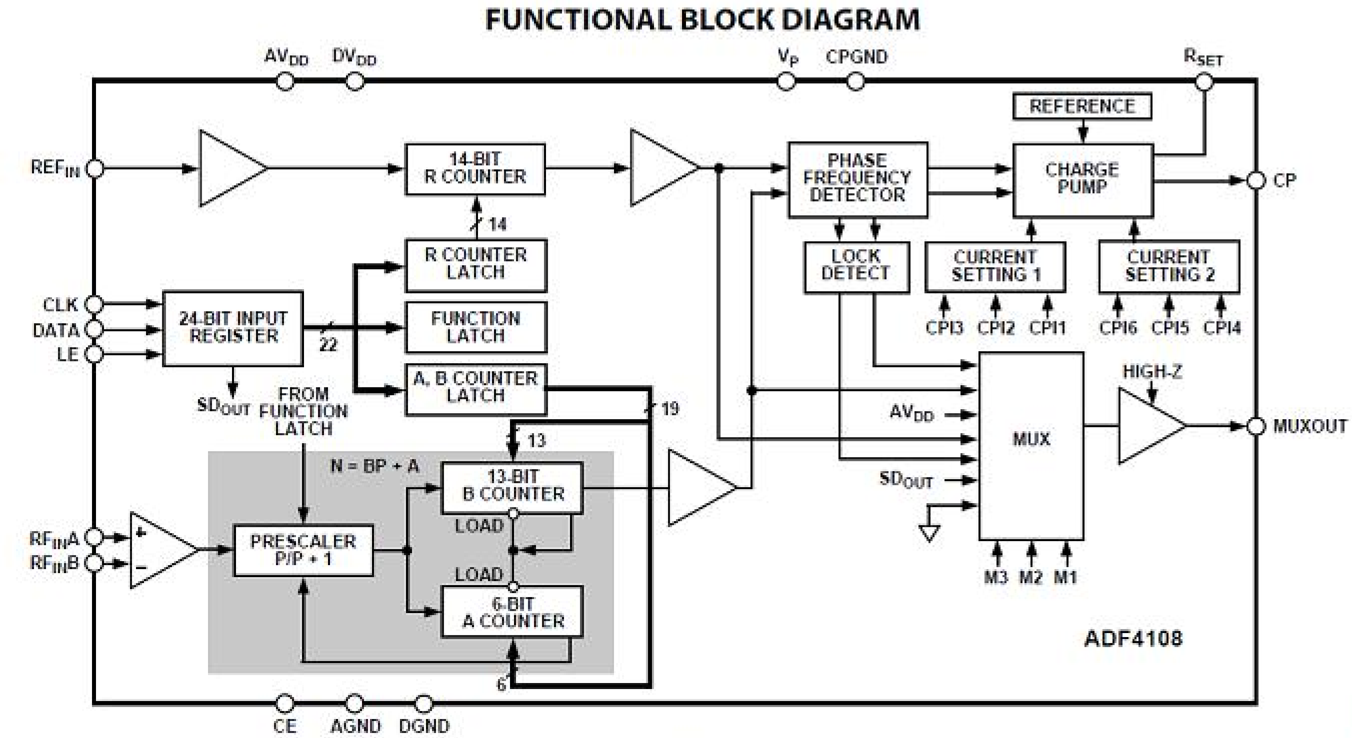

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Appendix C: Electrical Test Parameters and Equipment List

The single event latch-up testing described in this testy plan will be performed at the Lawrence Berkeley National Laboratories using the 88" Cyclotron. The testing will be performed in vacuum using the 10MeV/n beam. This beam was selected since it provides plenty of range for de-encapsulated or delidded die being irradiated from the top surface and offers a wide selection of ions and LETs. The beam characteristics and dosimetry were provided by the Berkeley heavy ion test facility. Berkeley can deliver the beam with a high degree of uniformity over a 2-inch diameter circular cross sectional area using the in-line test system. Uniformity is achieved by magnetic defocusing and by thin foil scattering. The beam uniformity and flux are determined using an array of five plastic scintillators coupled to photo multiplier tubes, located in the diagnostic chamber adjacent to and upstream from the target.

The devices will be irradiated to a minimum fluence of 1E7 ion/cm2, if no events are detected. The flux may vary during the testing, but will be consistently targeted to approximately 1E5 ion/cm^2-s, depending on the ion species and the response of the device-under-test. Table C.1 shows the test equipment that will be used for this testing.

Table C.1. Test equipment and calibration dates for testing the ADL5513 1 MHz to 4 GHz, 80dB Logarithmic Detector/Controller

HP 34401A Multimeter	3146A65284	5/15/11	5/15/12	I_{CC} measurement
Agilent E3642A DC Power Supply	MY40004345	N/A	N/A	Test power supply-Positive Supply
Agilent E3631A DC Power Supply	K920920312	N/A	N/A	Test power supply-Negative Supply
Fluke Model 77 Multimeter	38301747	2/19/12	2/19/13	Vcc measurement at the DUT
Omega HH12 Handheld Thermometer	233126	2/19/12	2/19/13	Temperature Calibration
Tektronics TDS5104B Oscilloscope	B011044	10/22/11	10/22/12	Output Waveform Measurements

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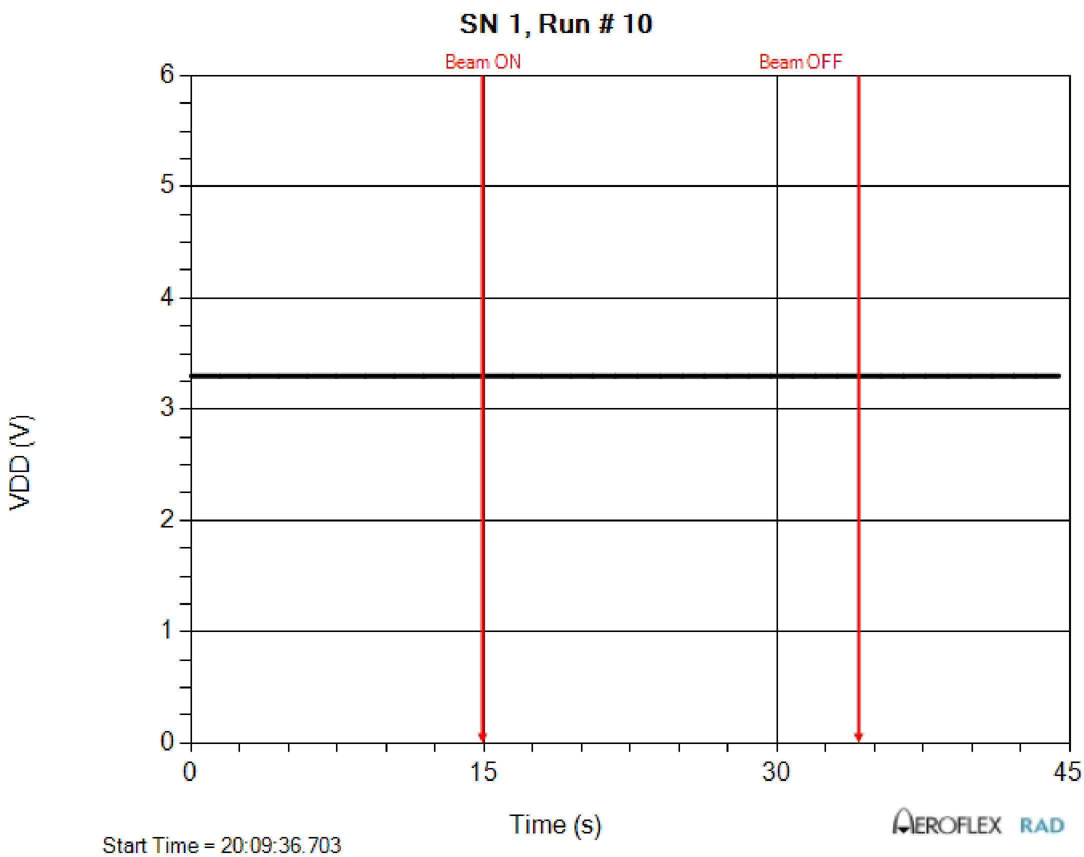
Appendix D: Supply potential and supply current (for both the VDD and VP supplies) versus time for all of the SEL test runs discussed in this report.



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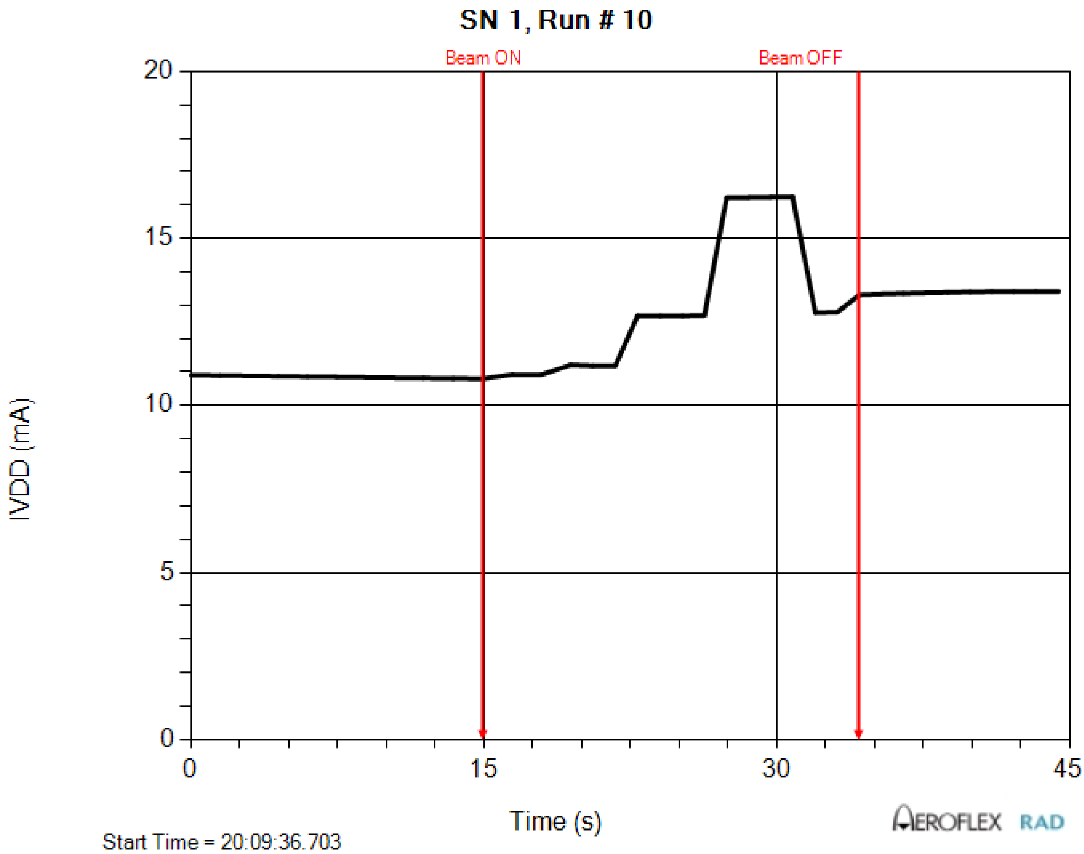

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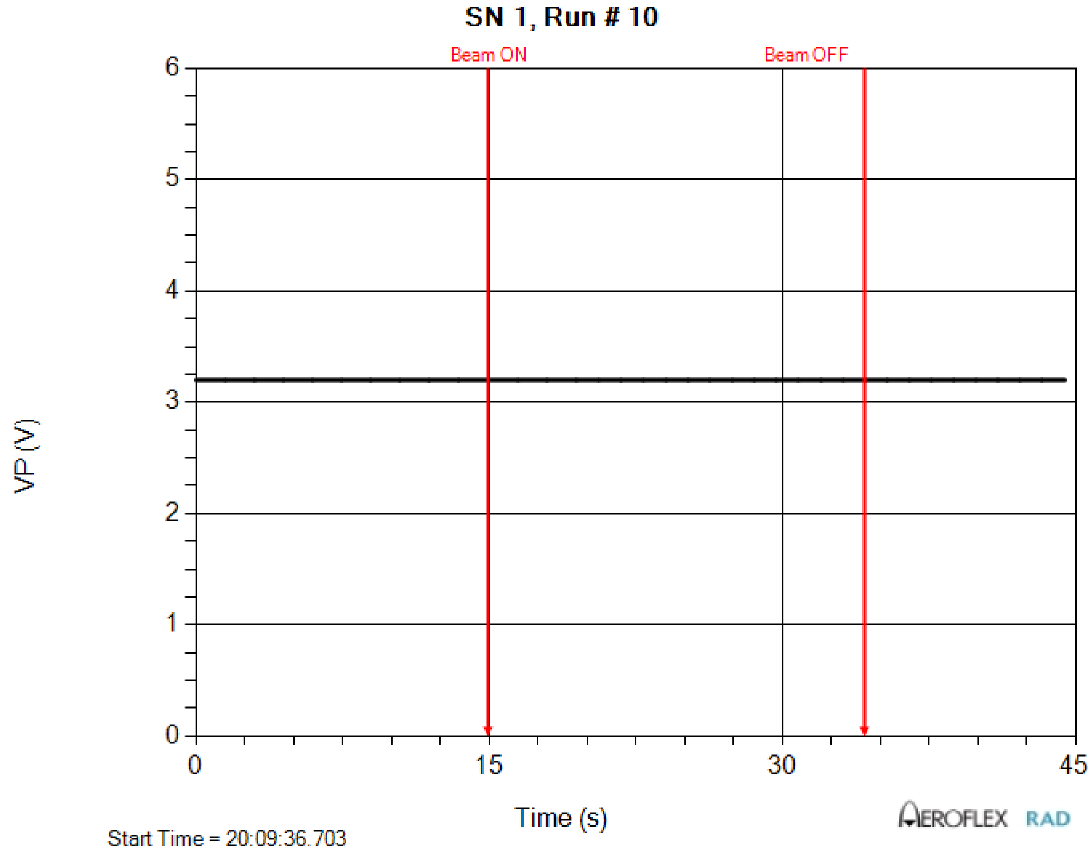

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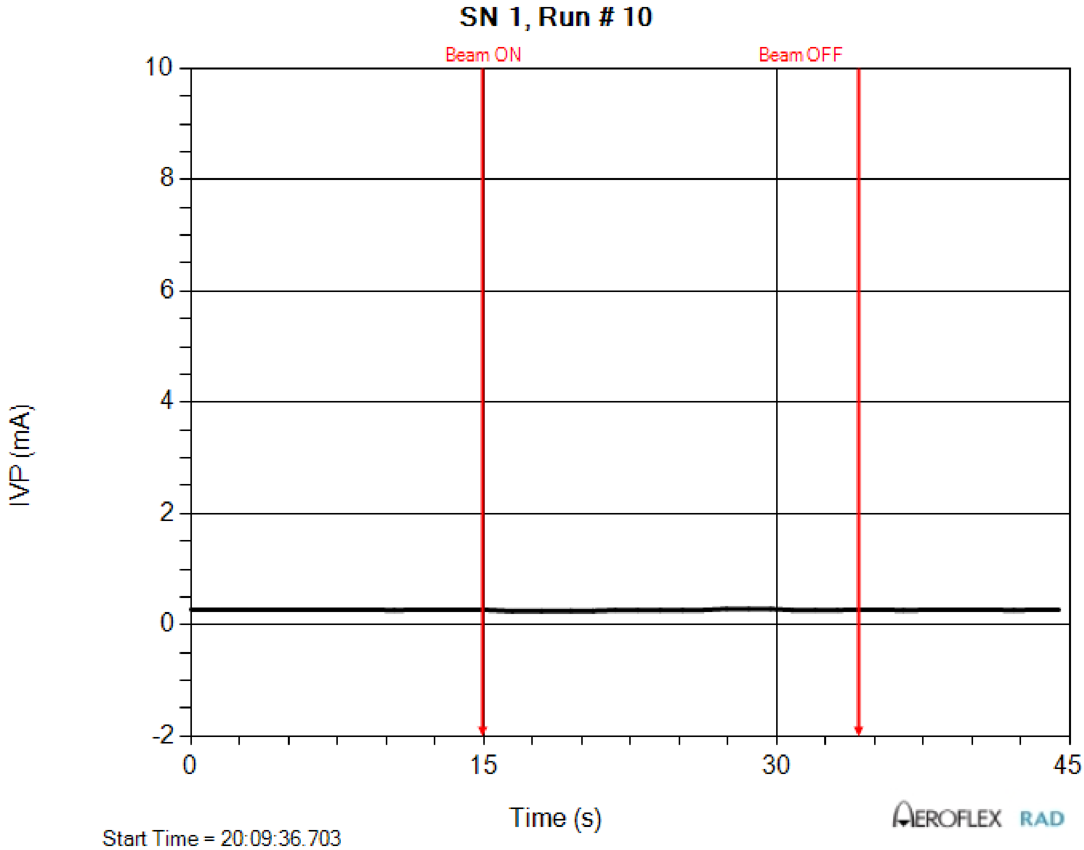

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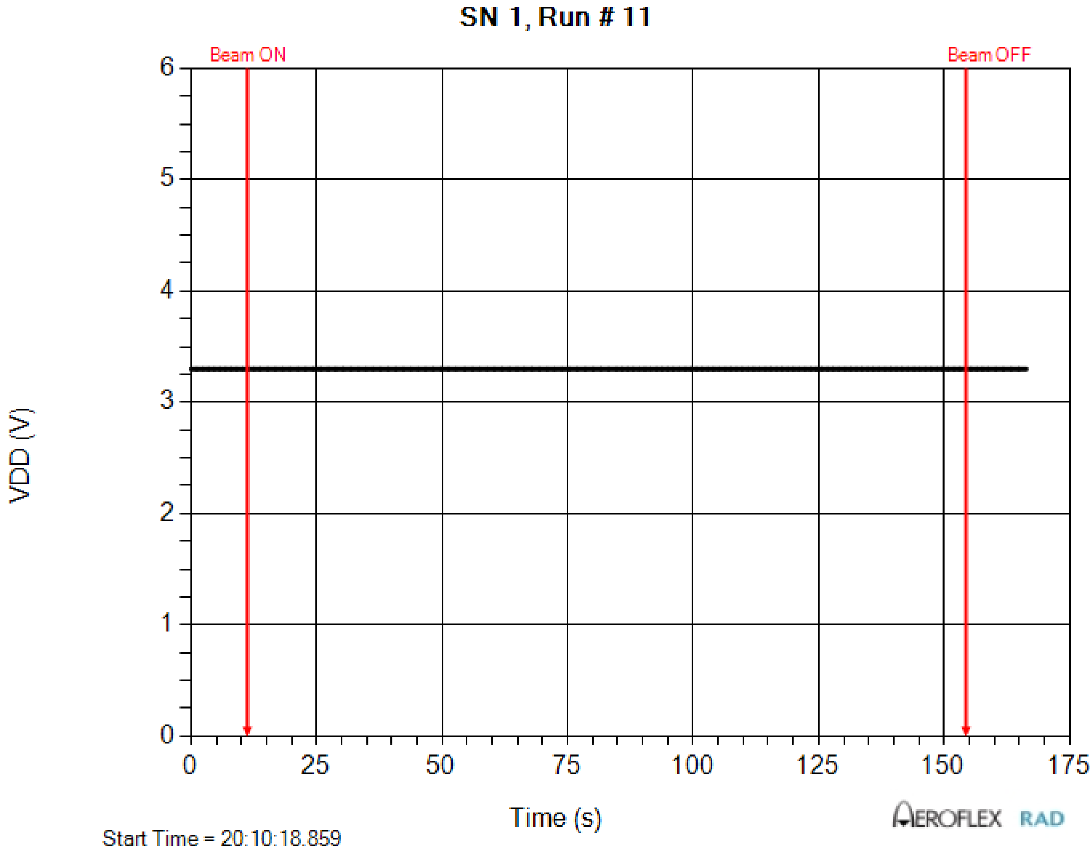

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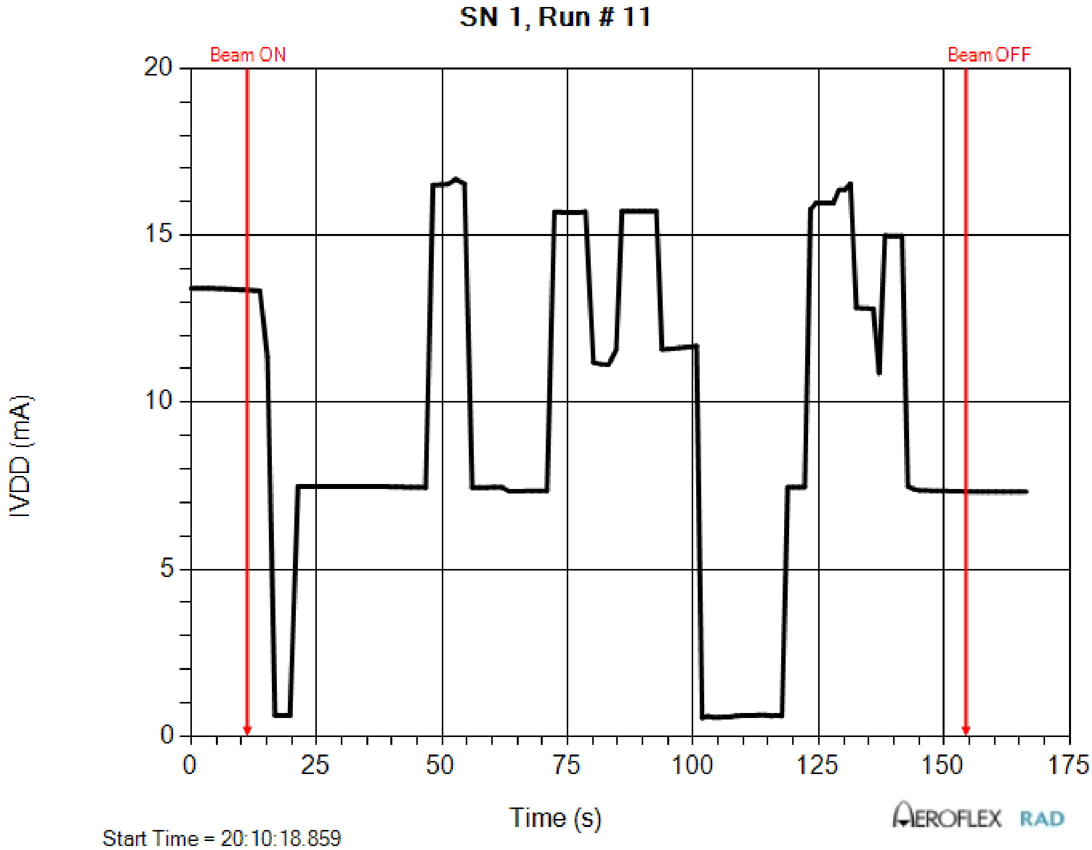

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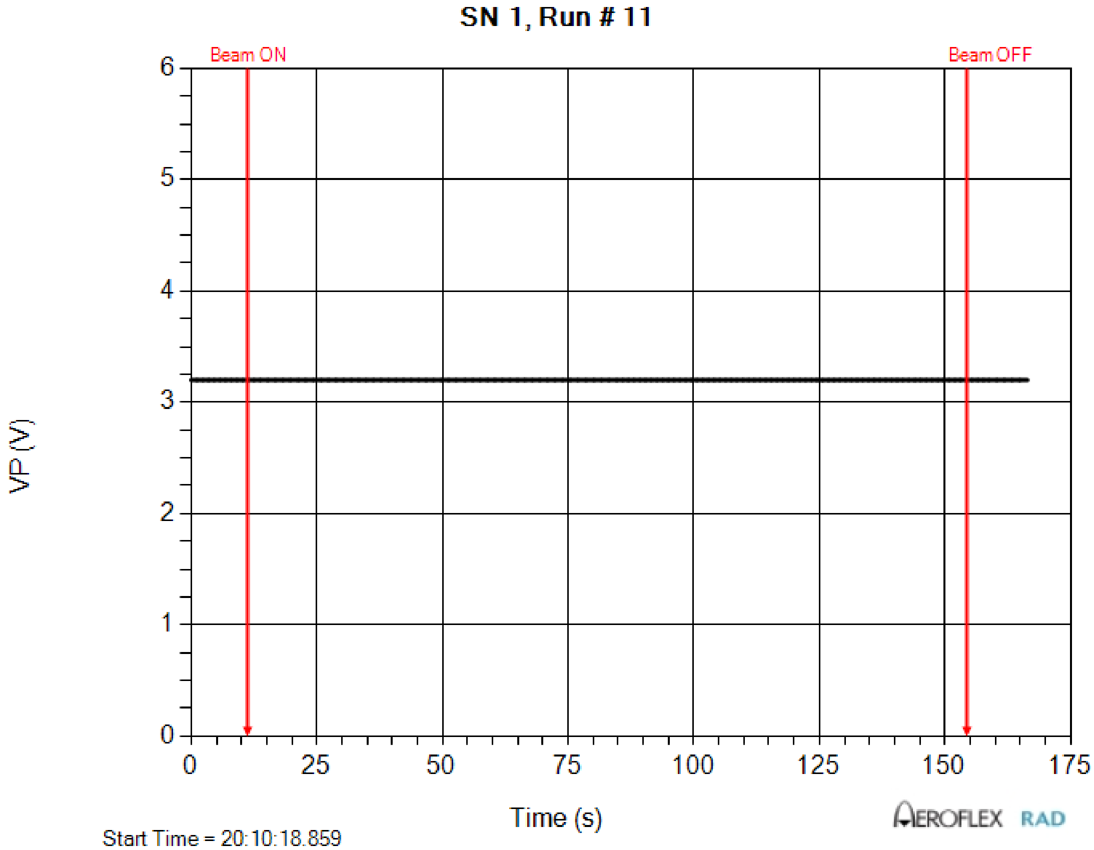

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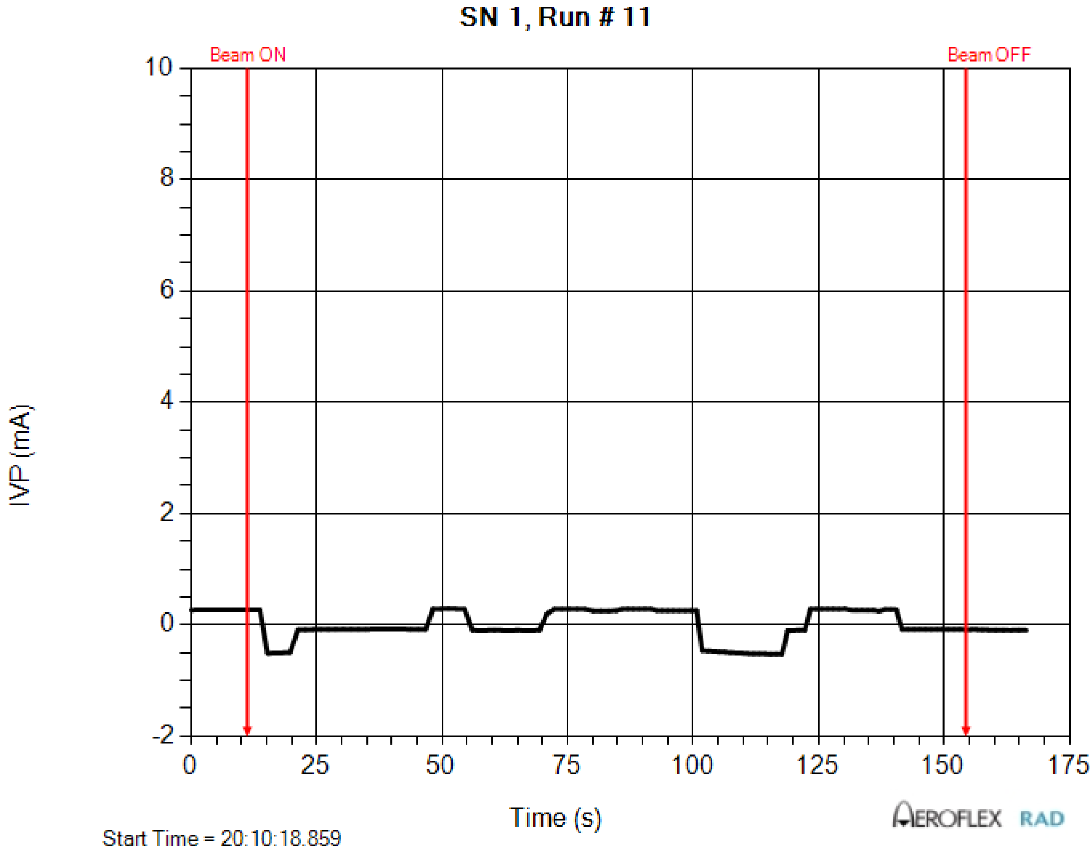

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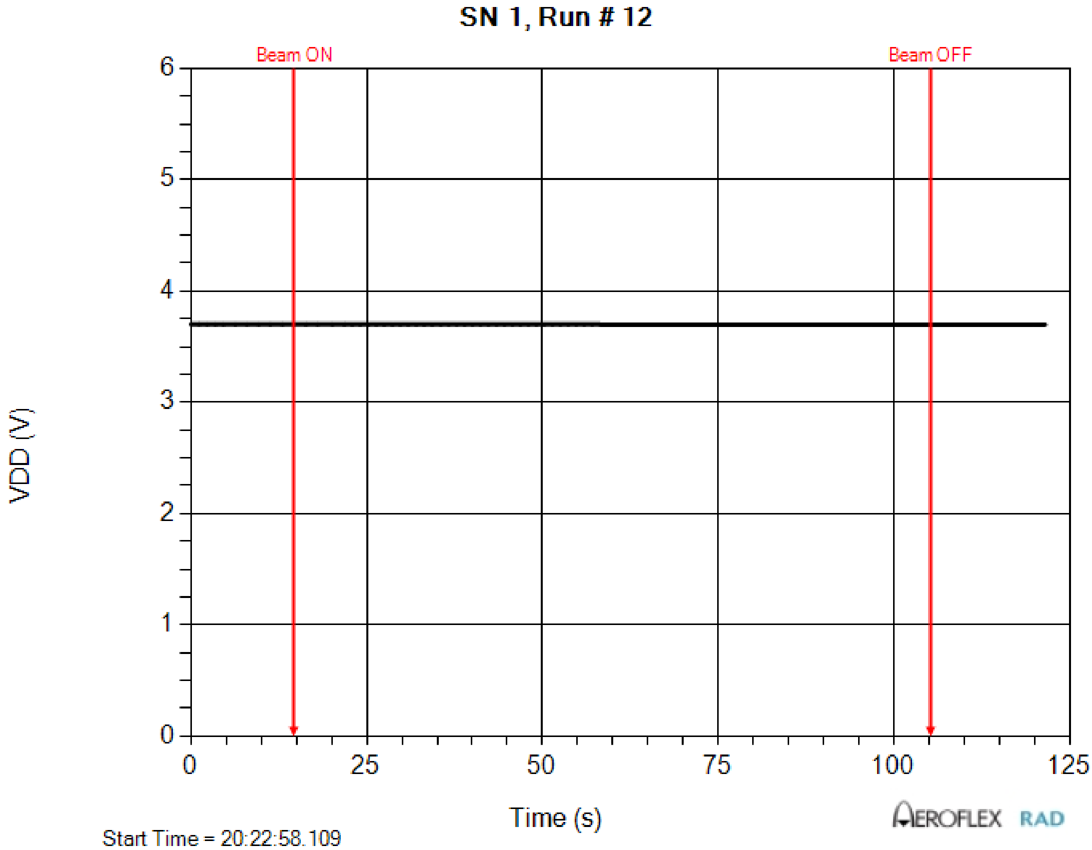

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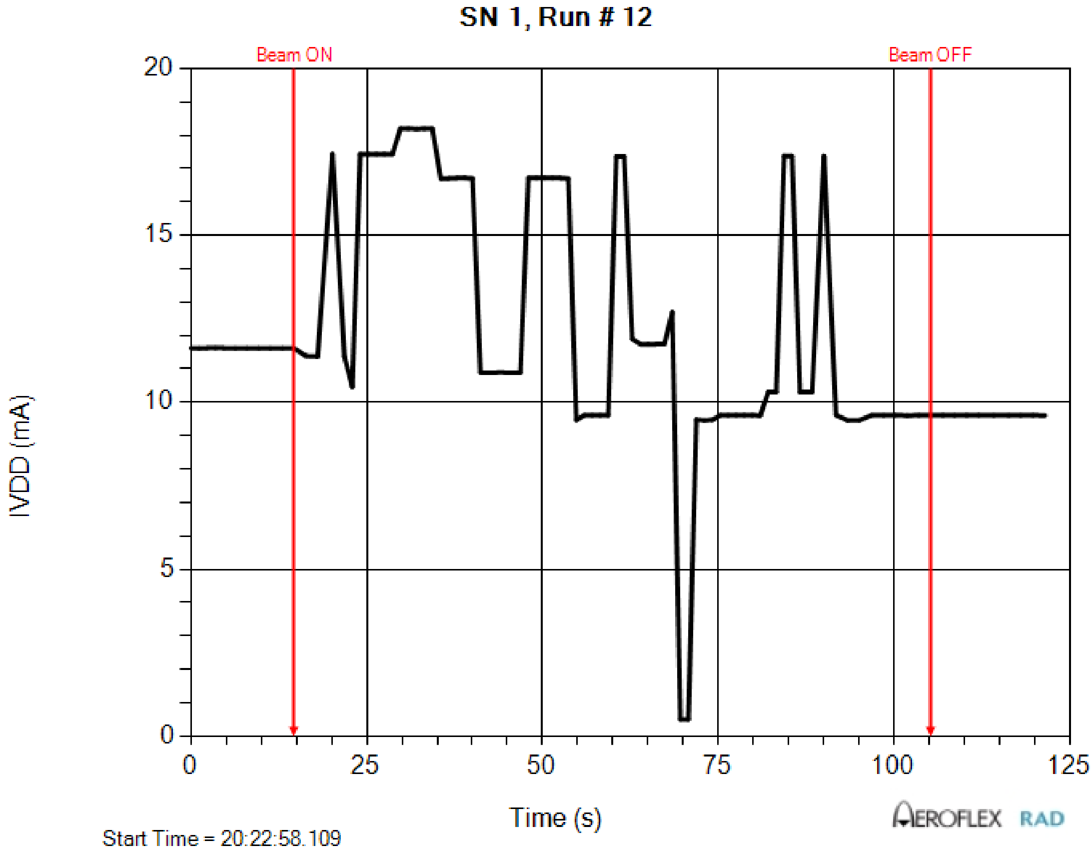

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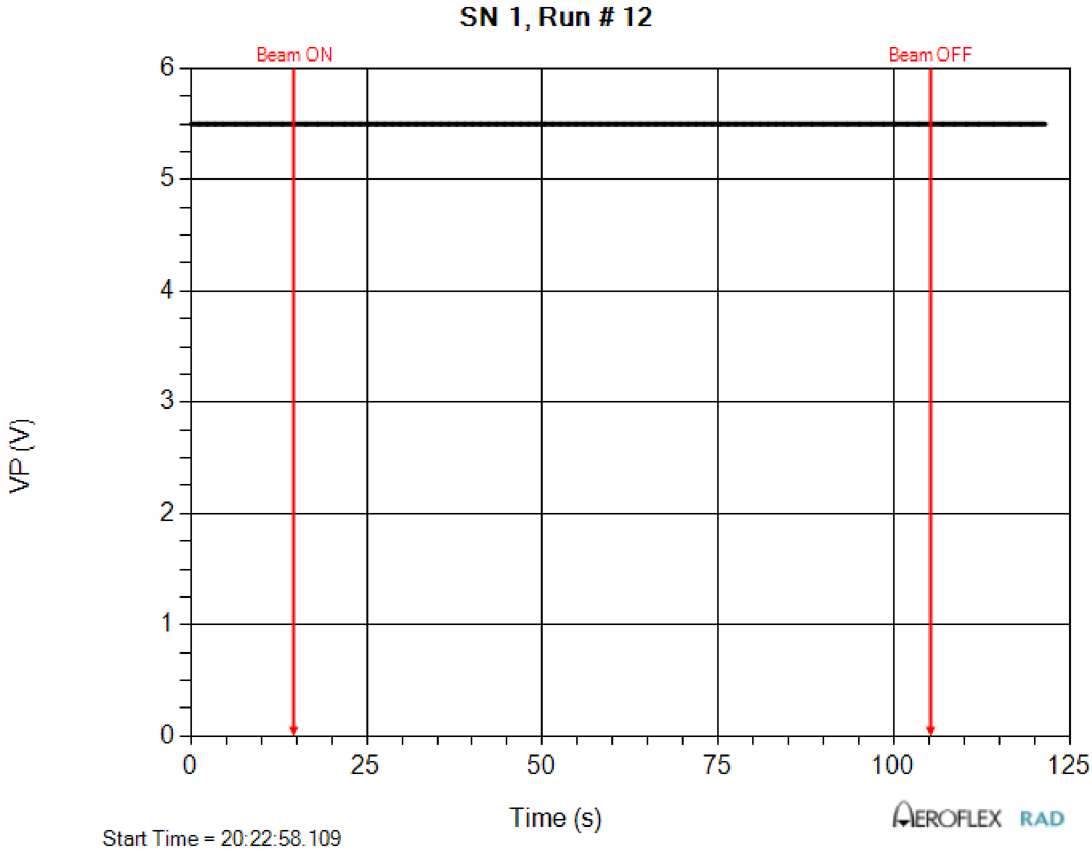

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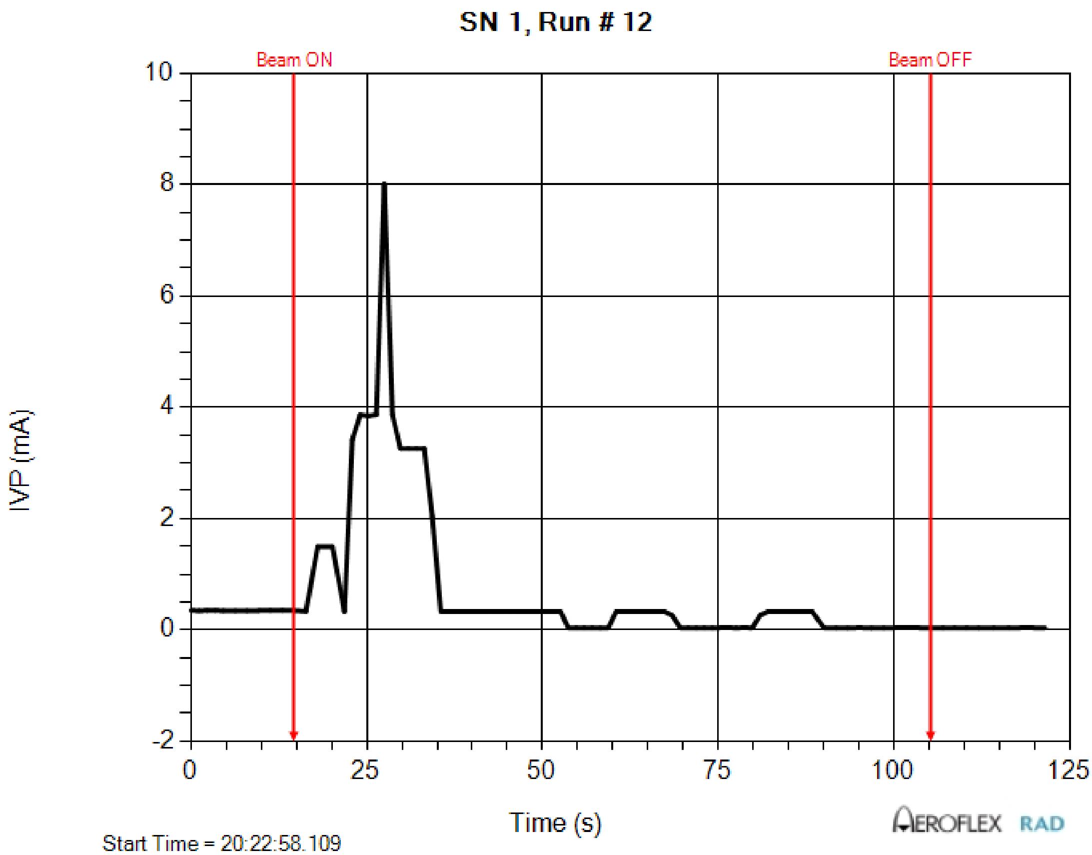

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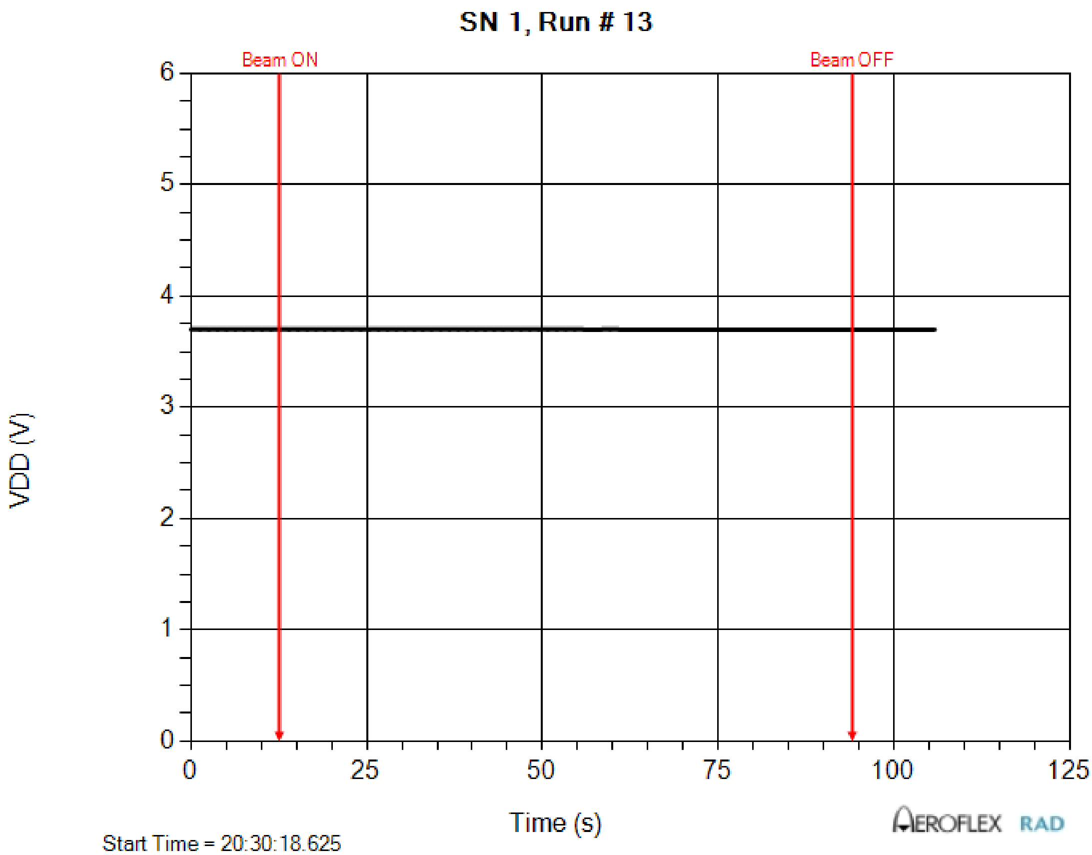

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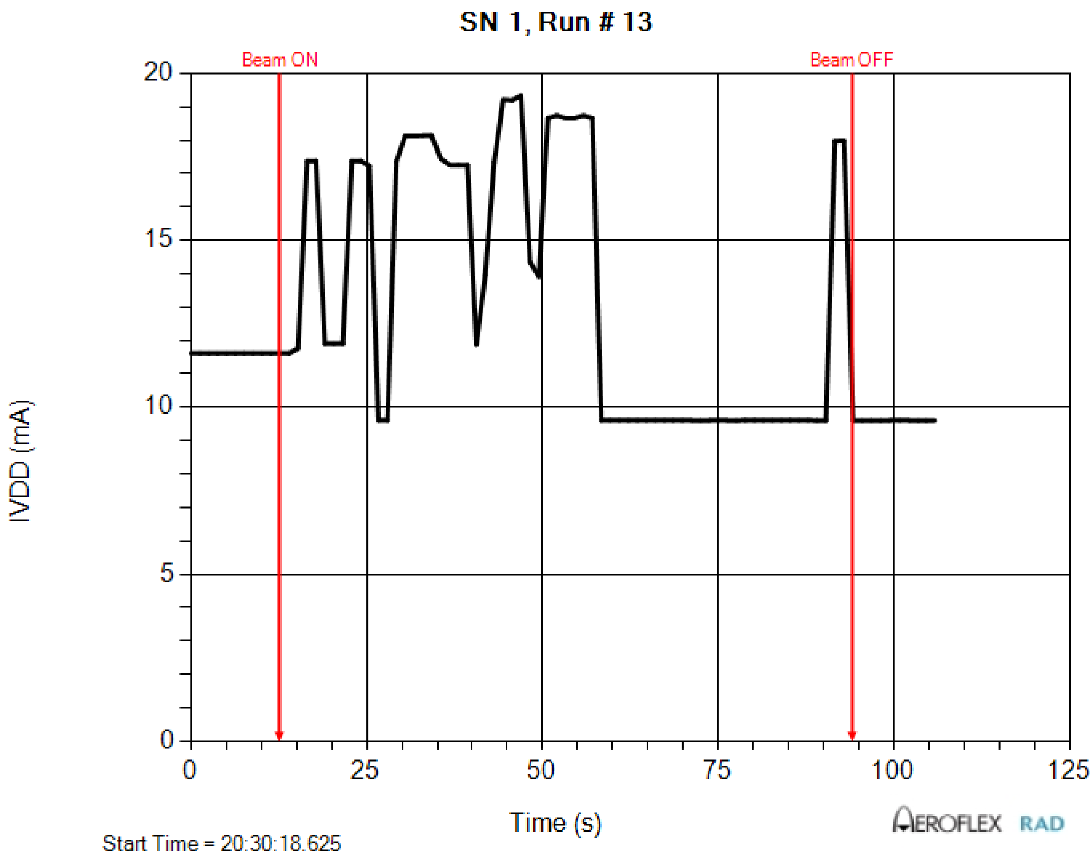

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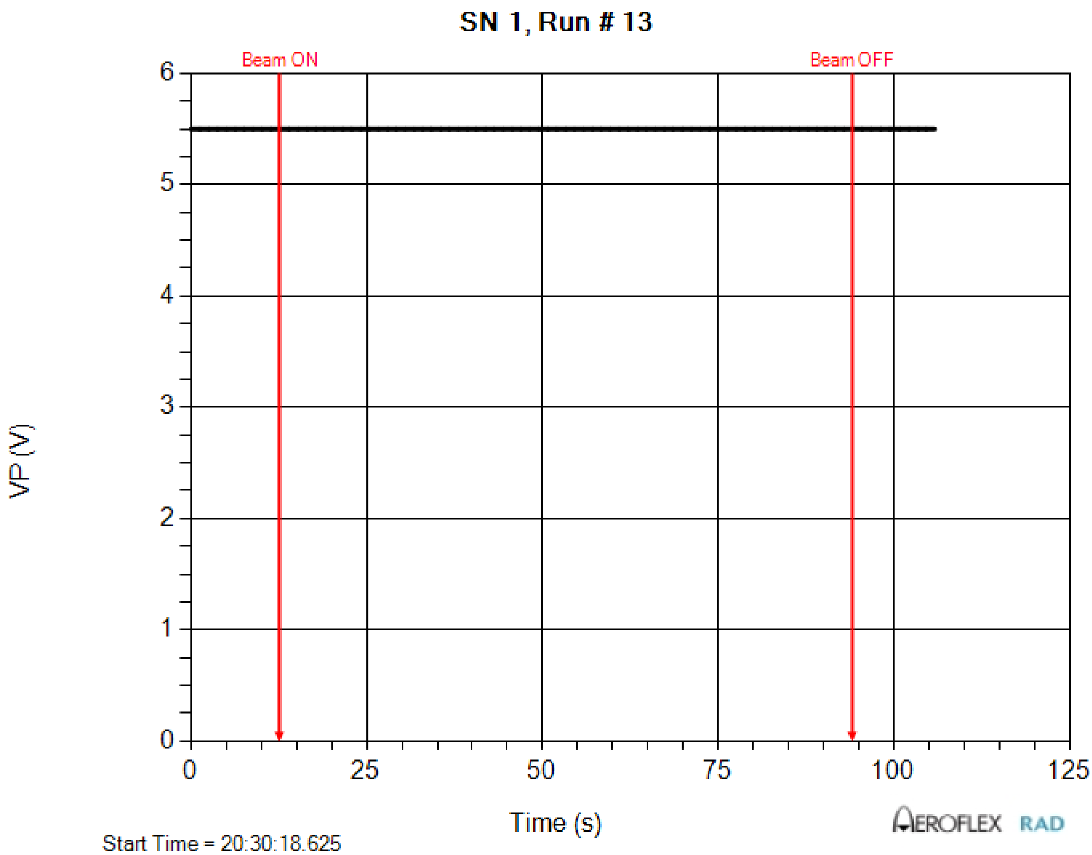

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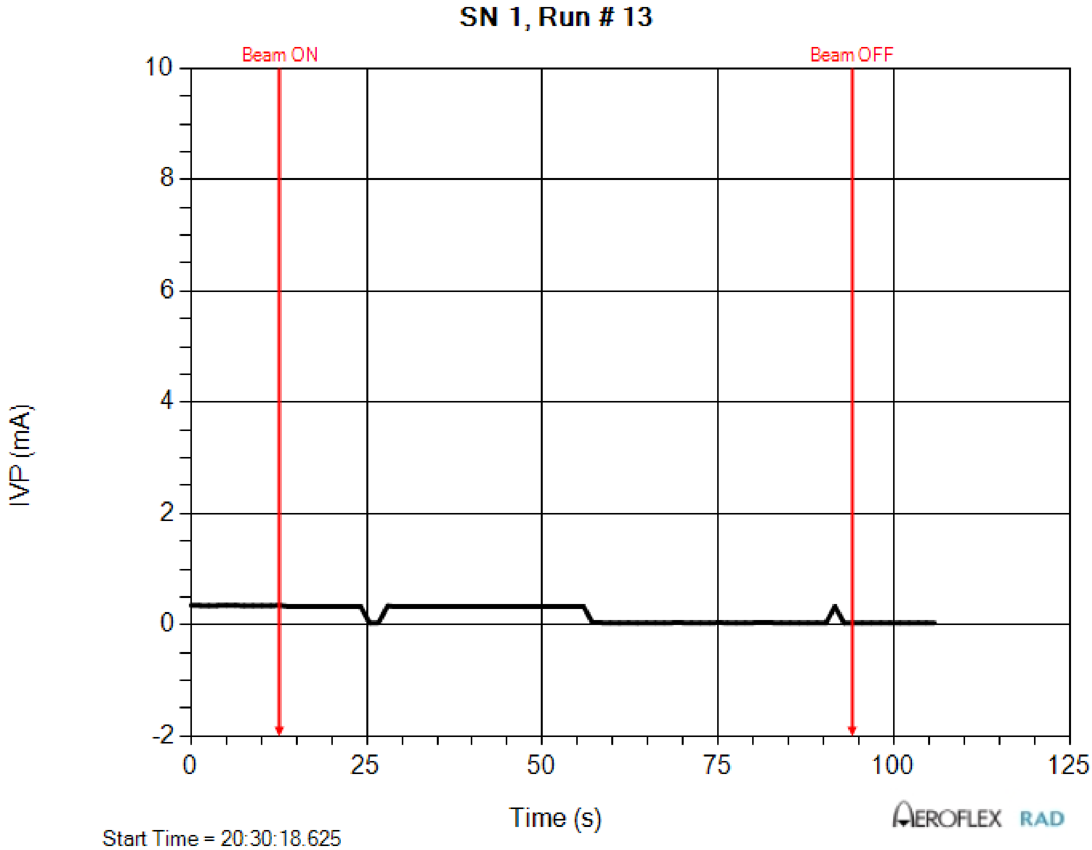

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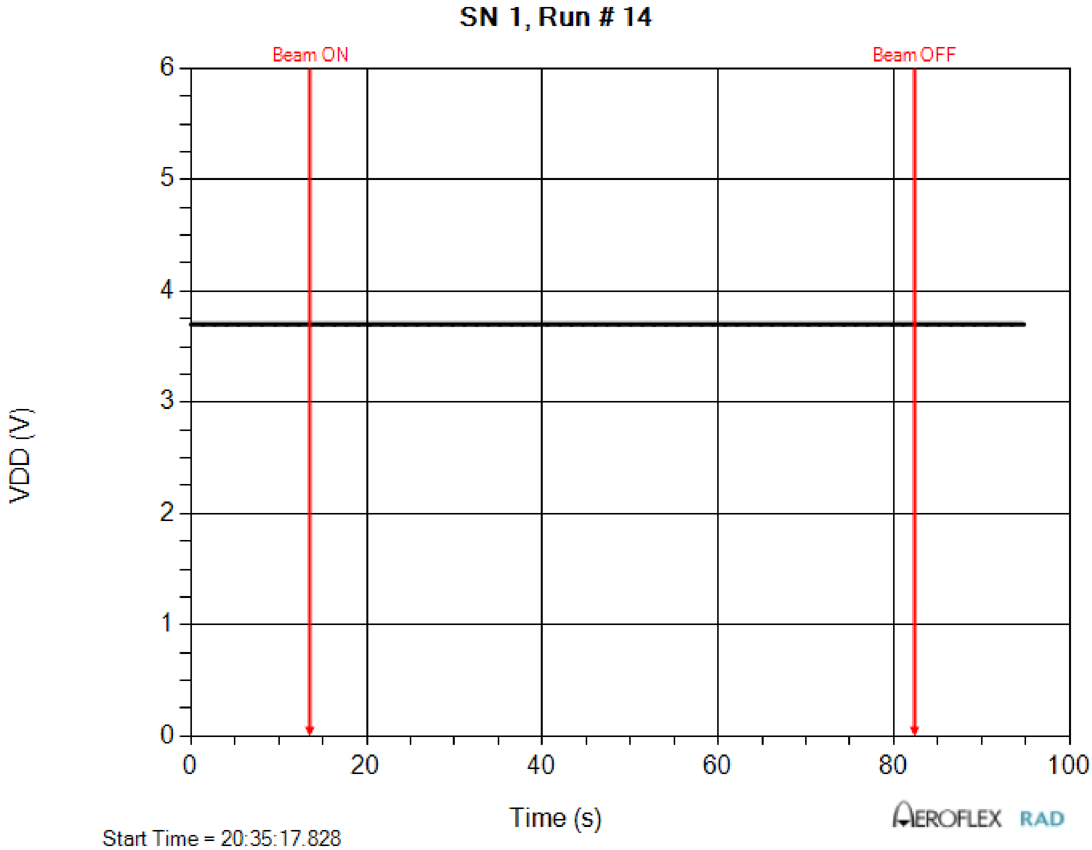

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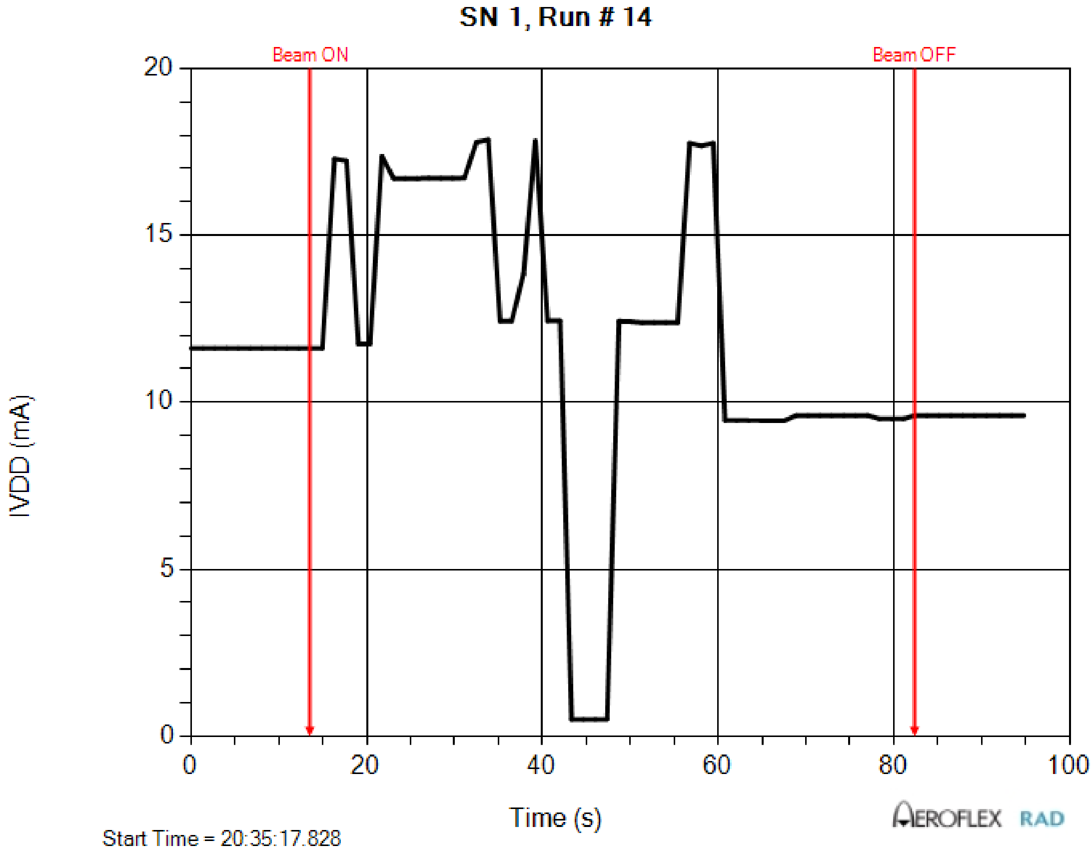

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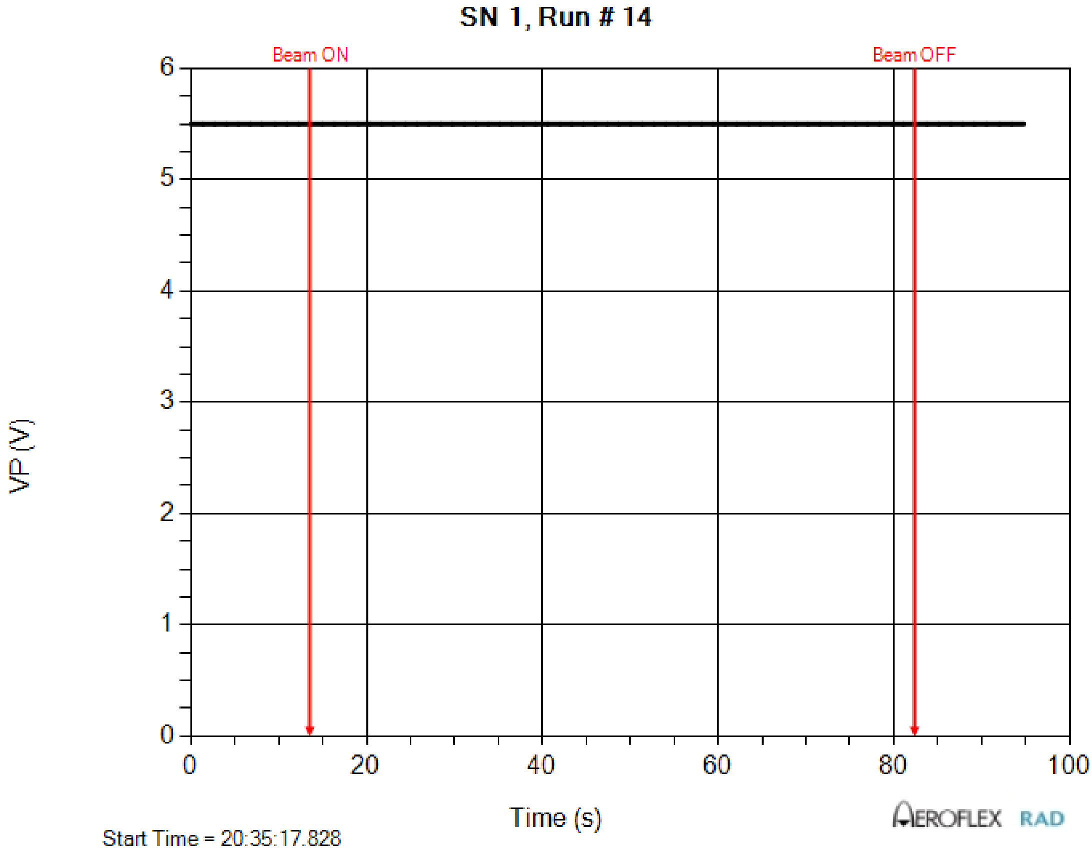

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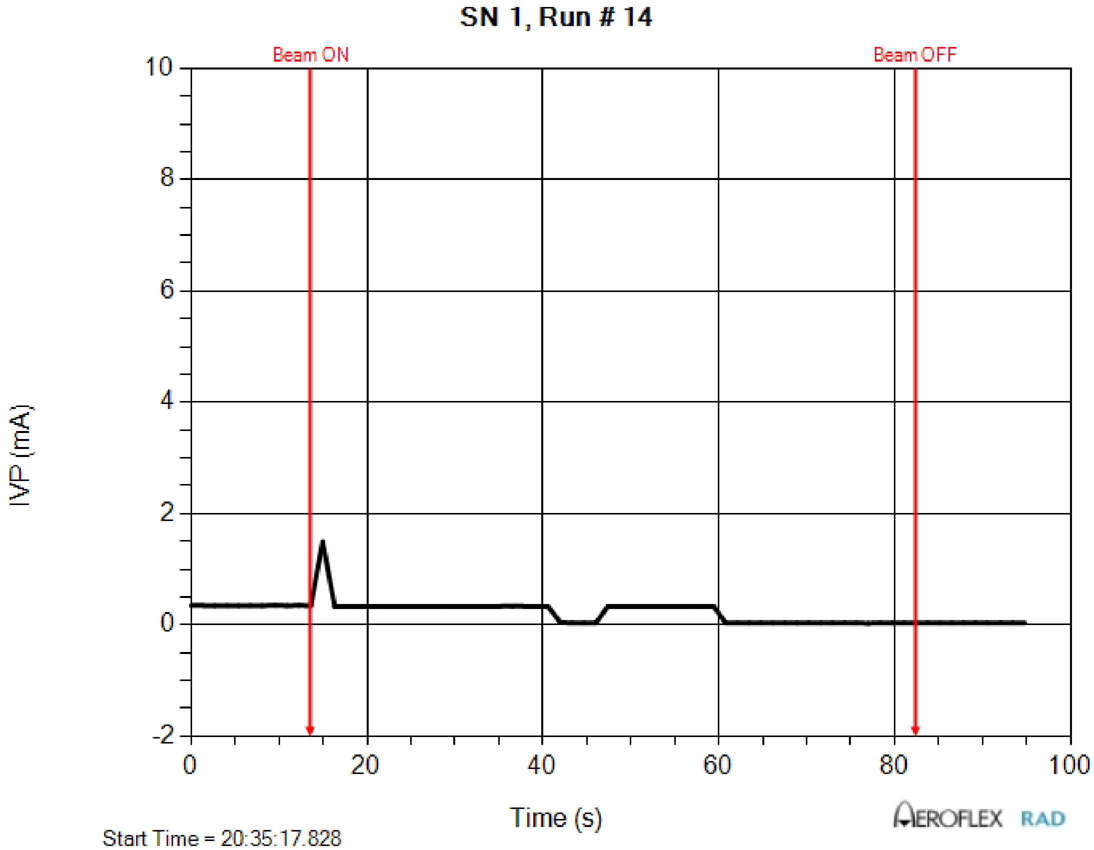

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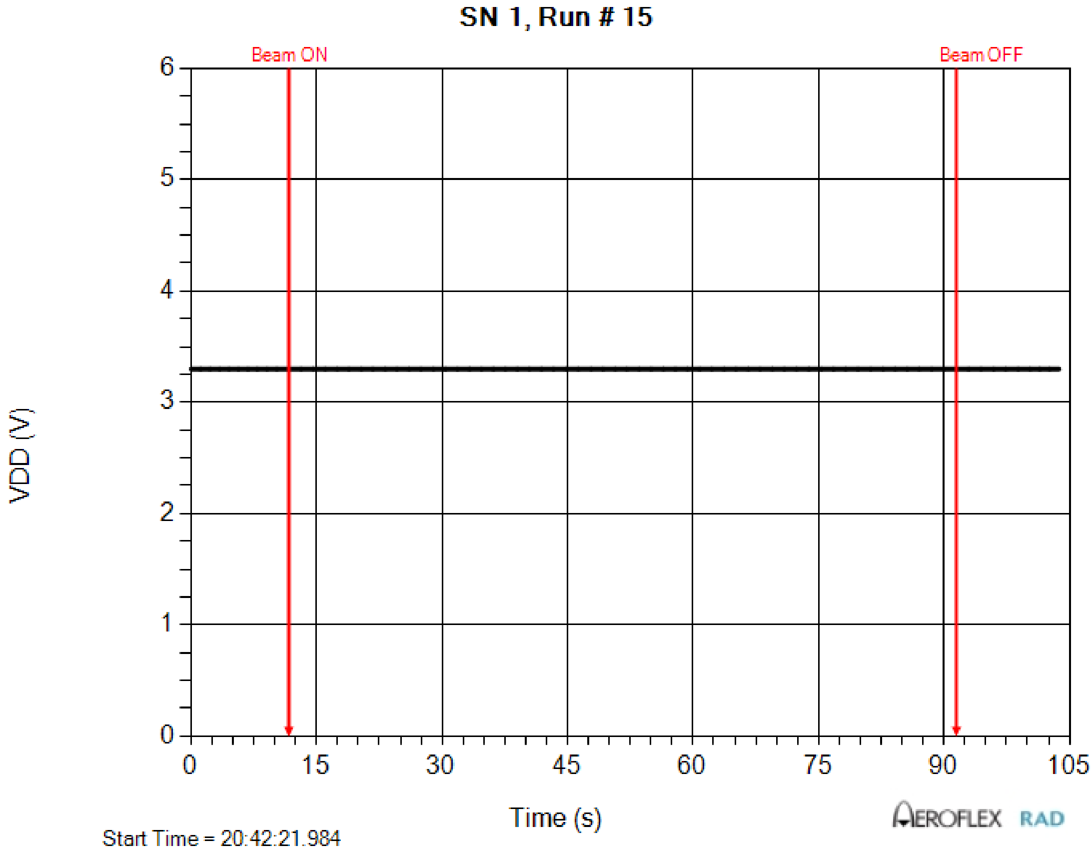

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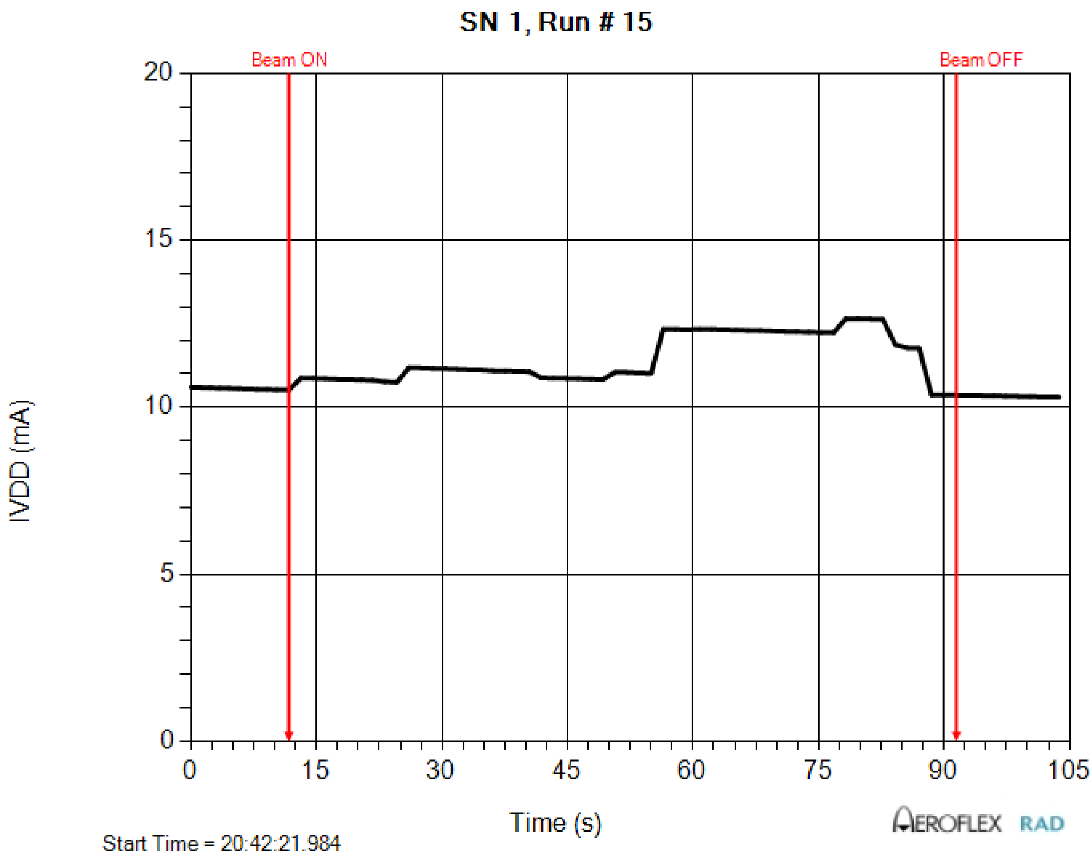

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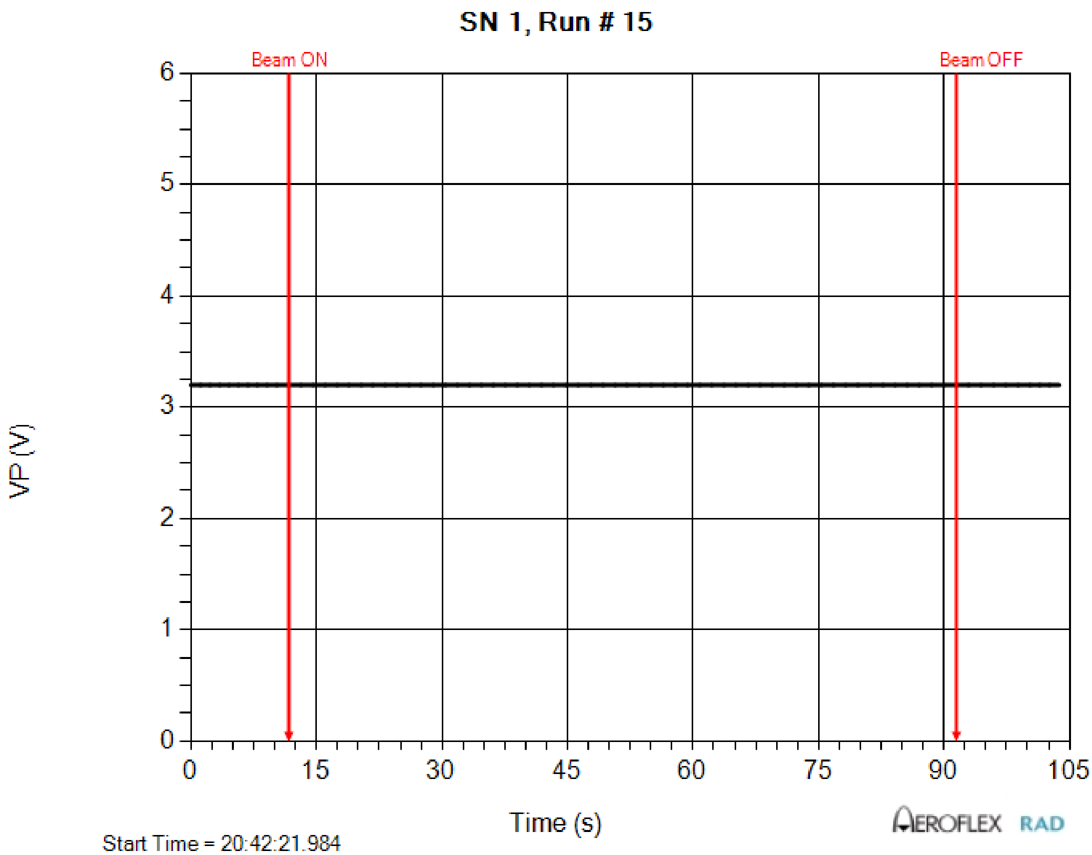

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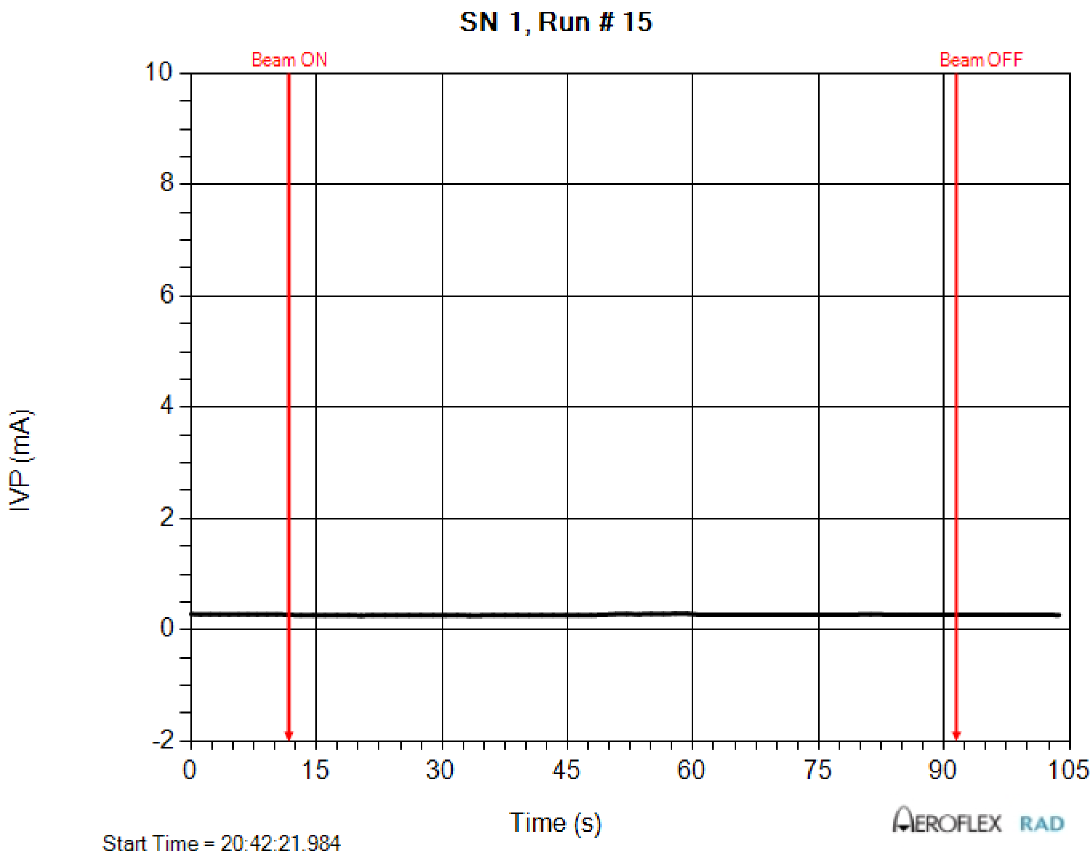

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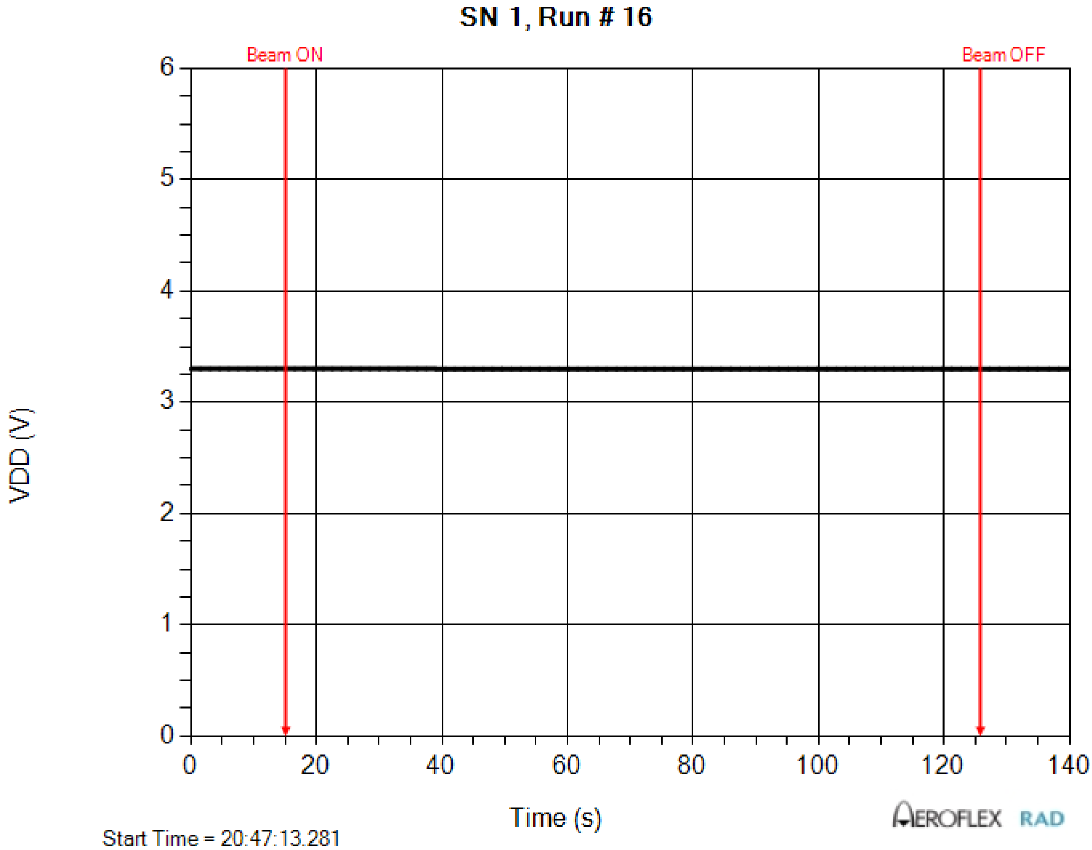

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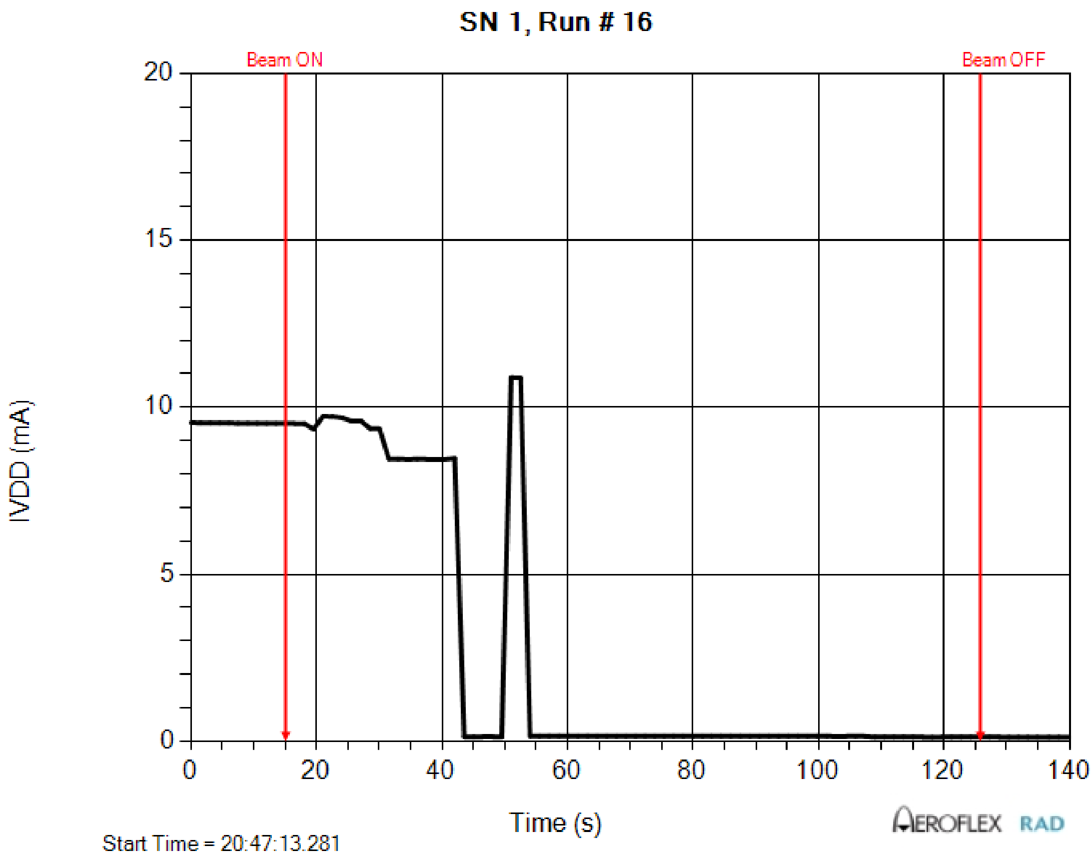

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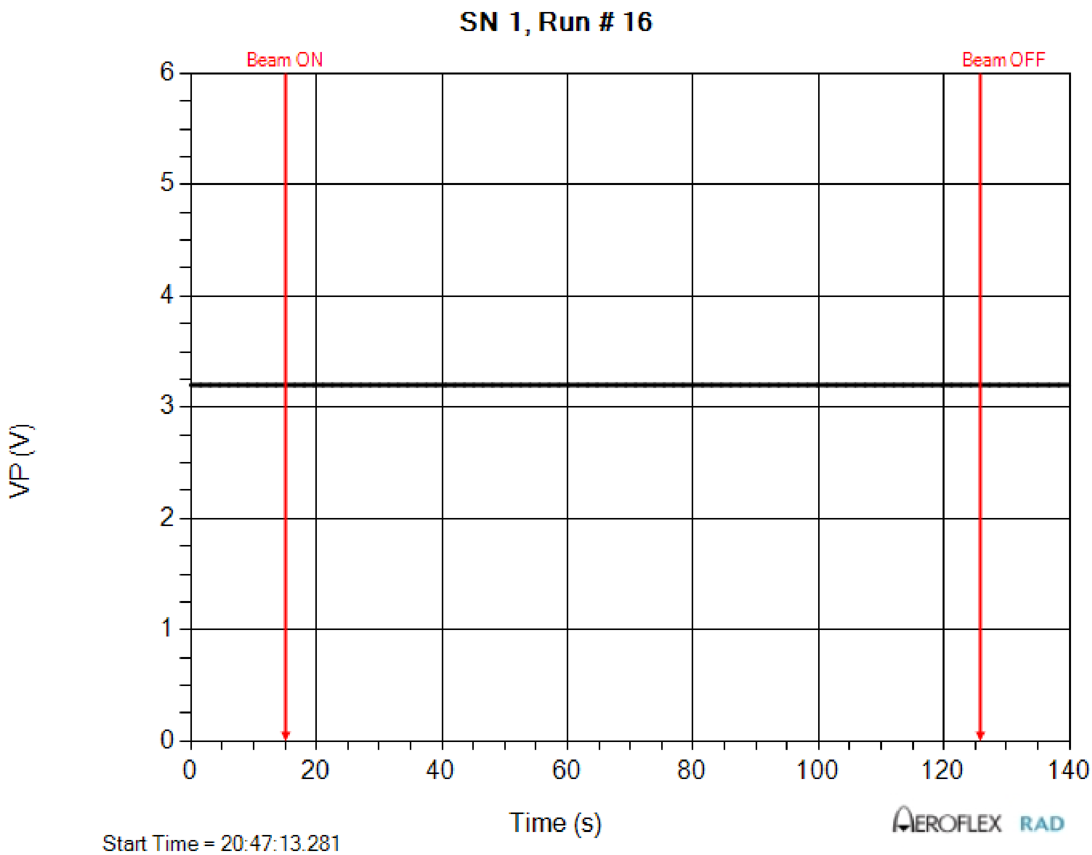

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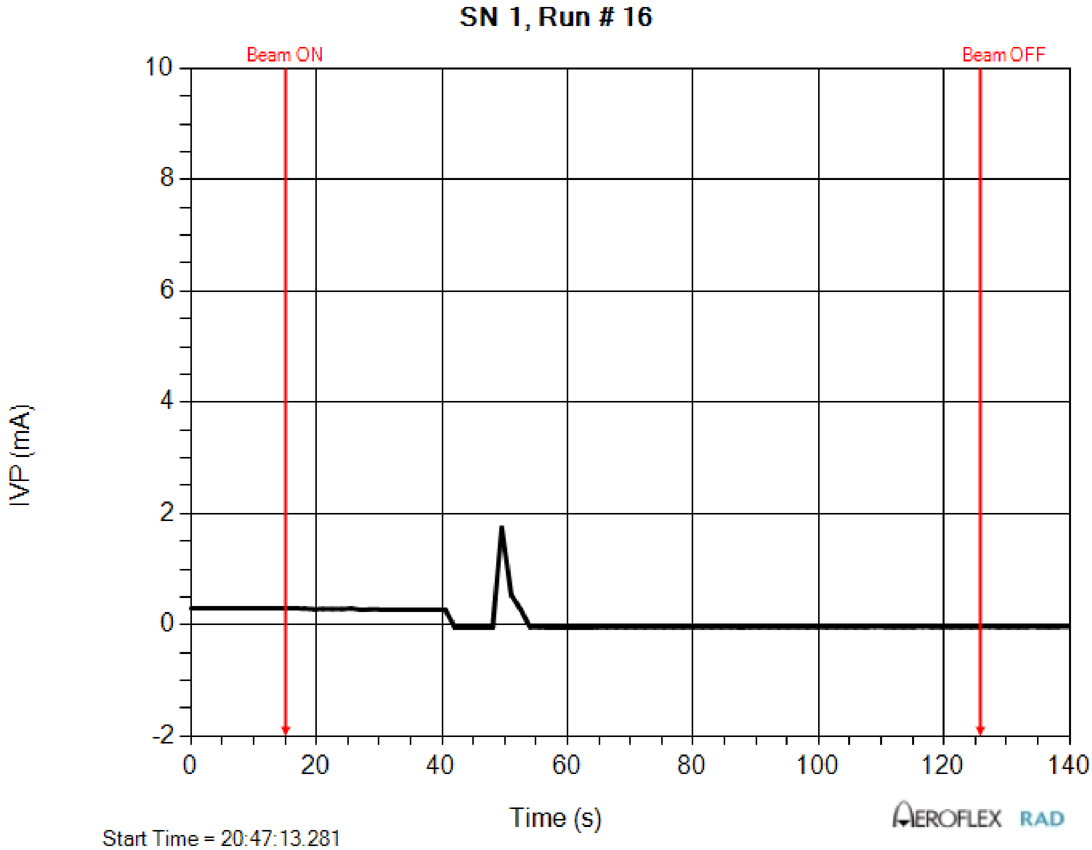

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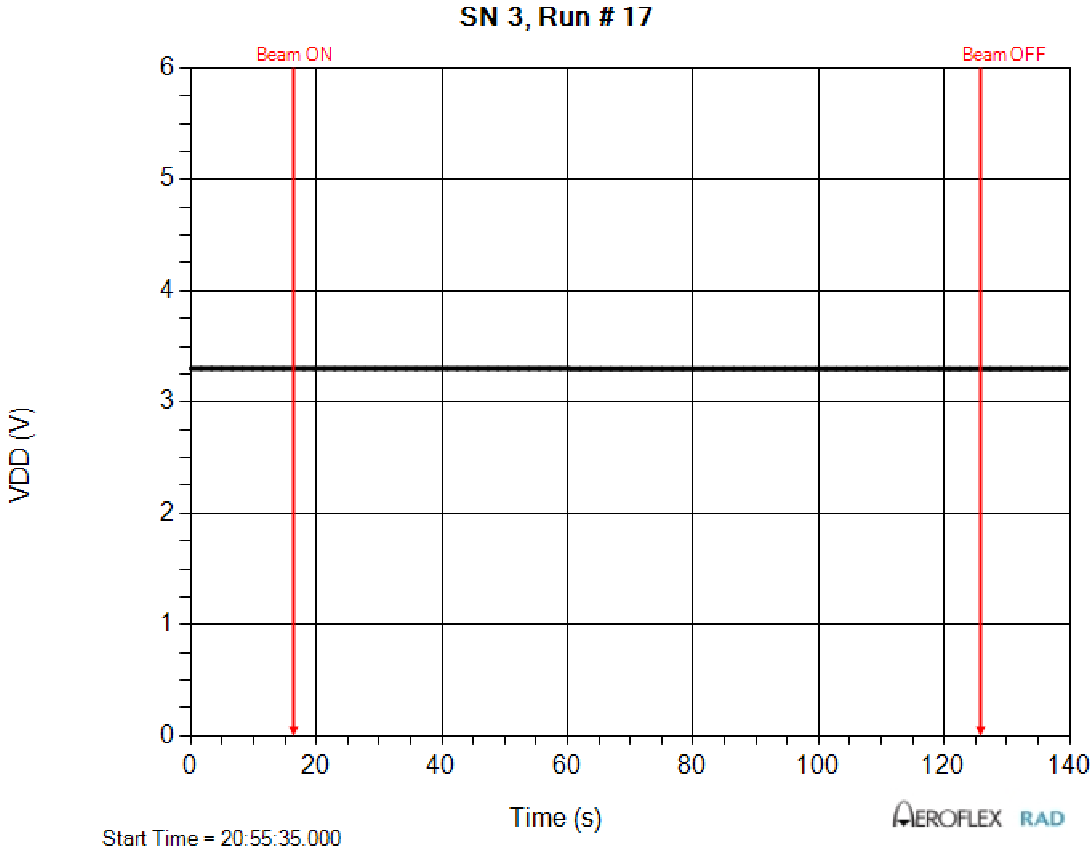

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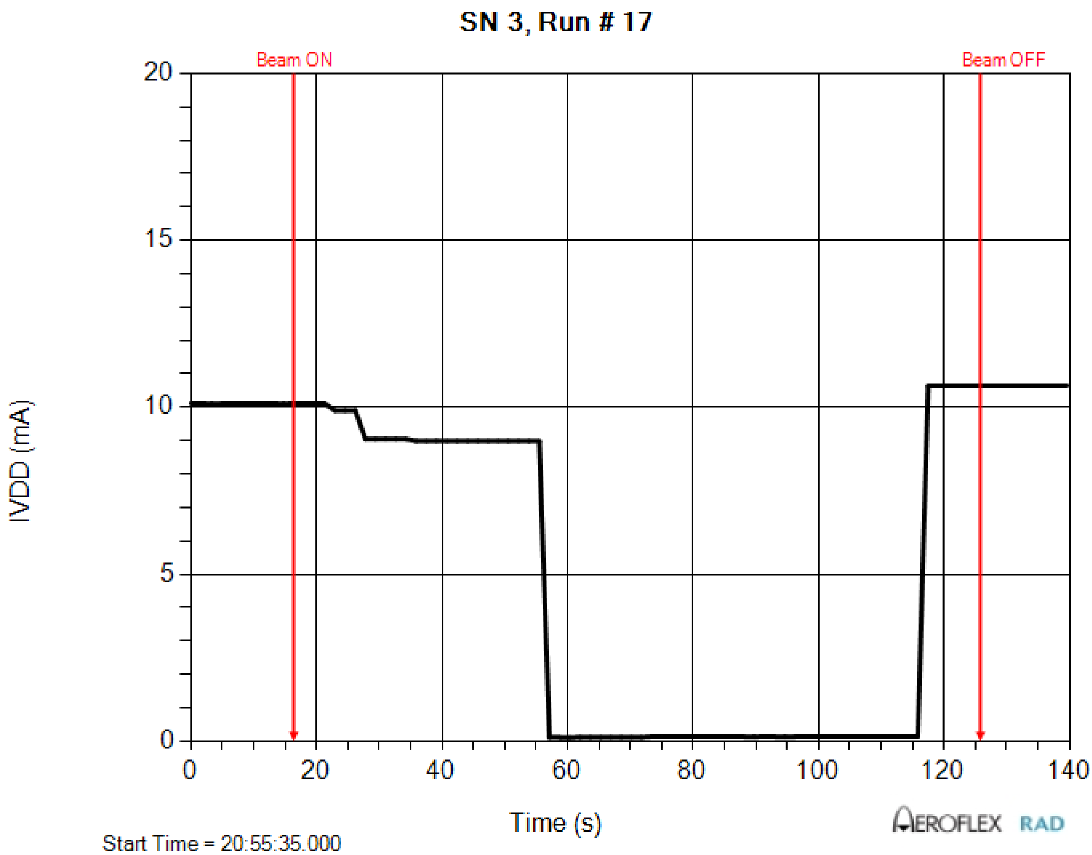

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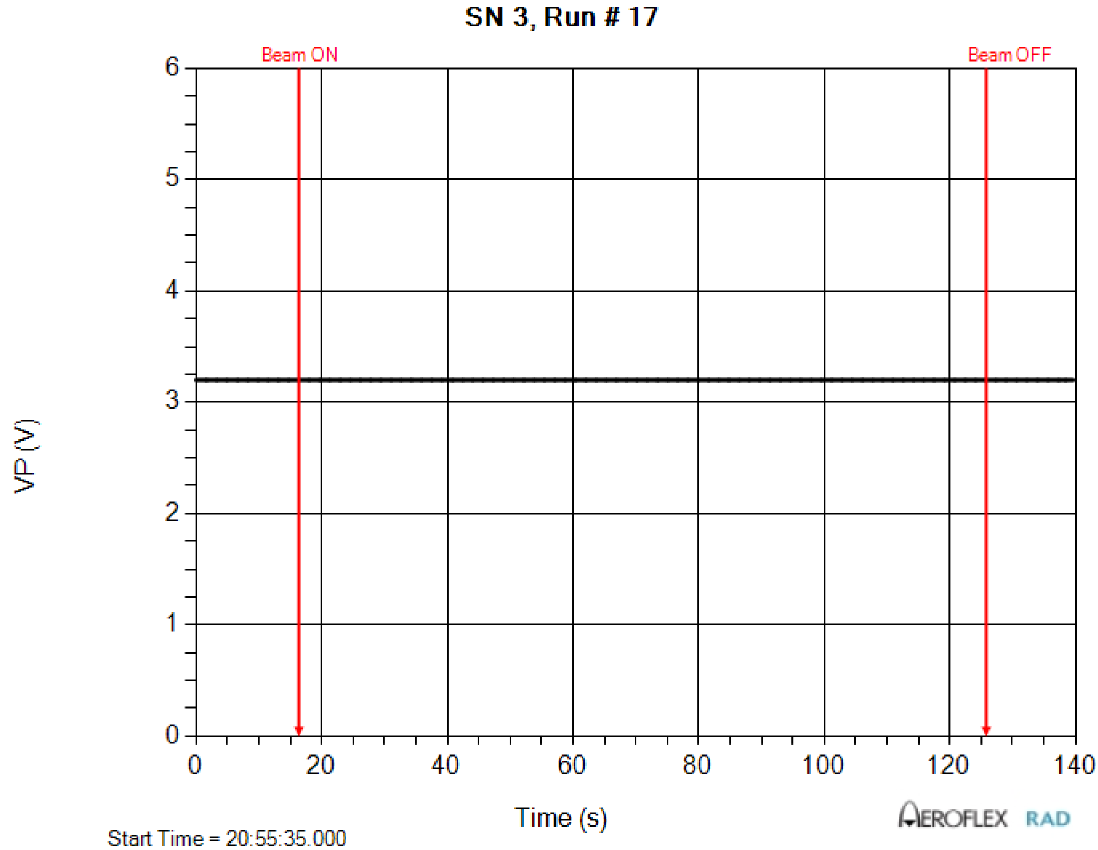

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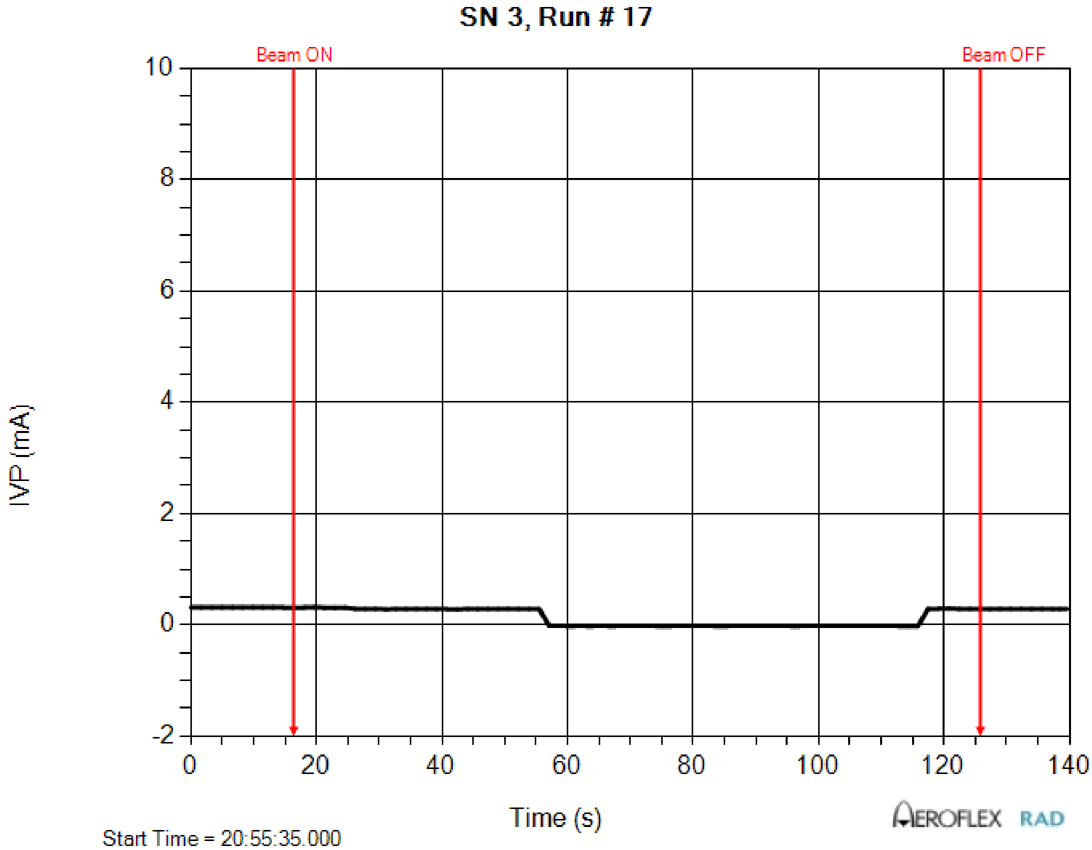

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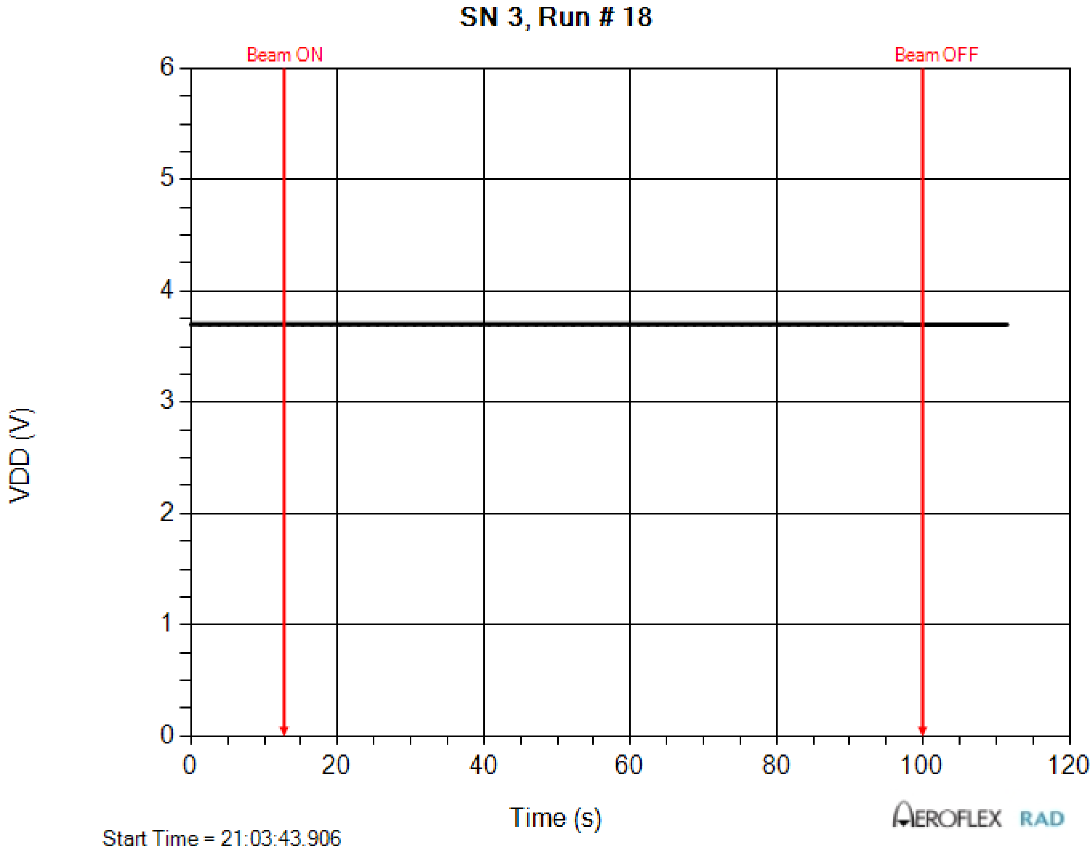

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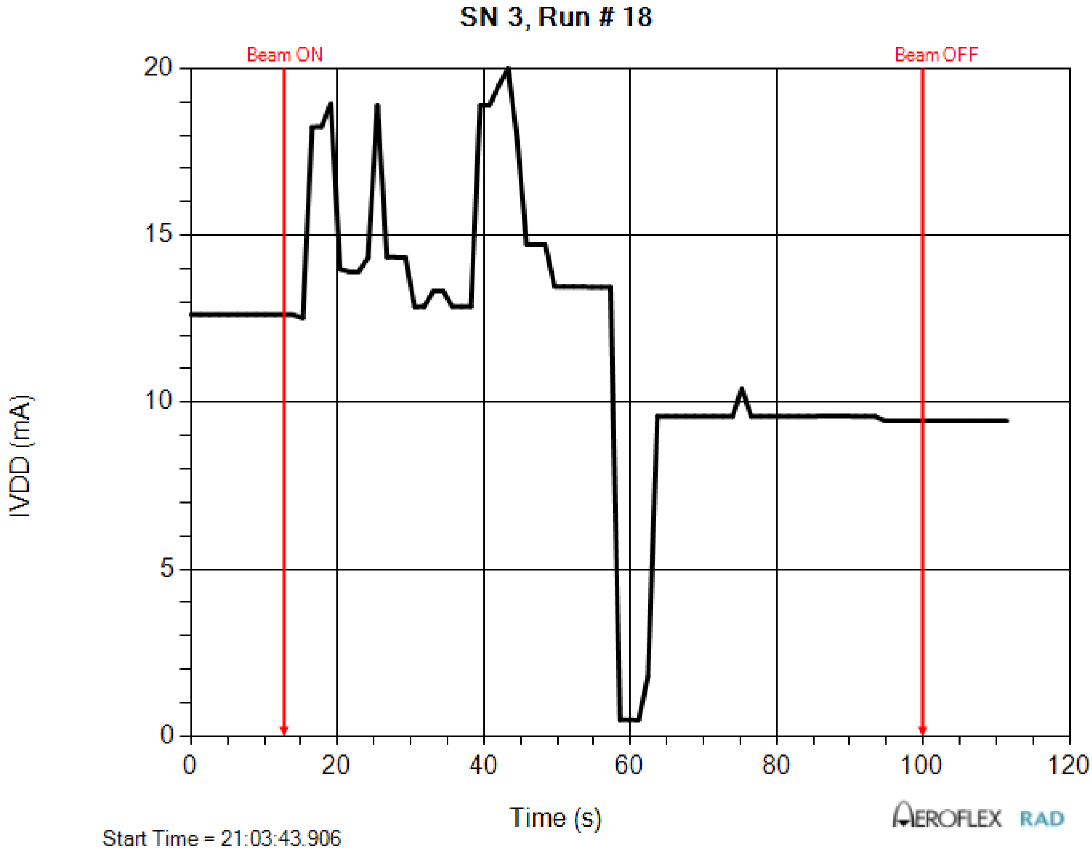

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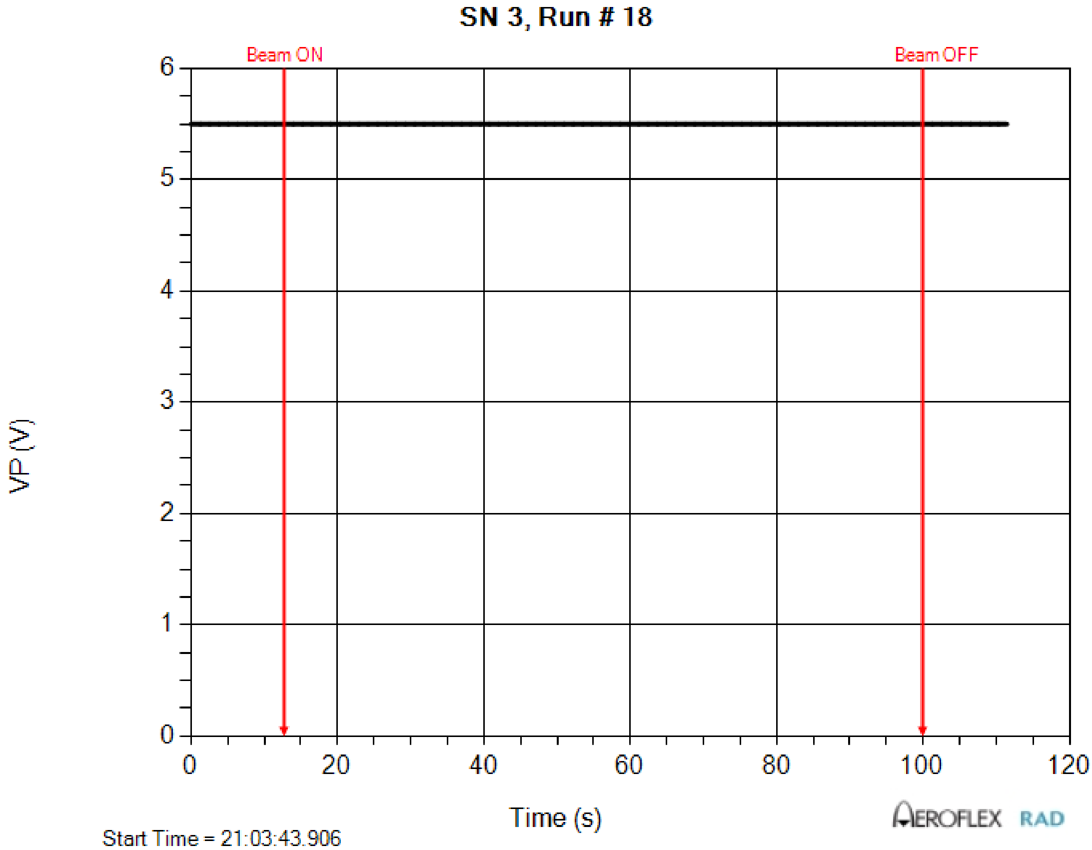

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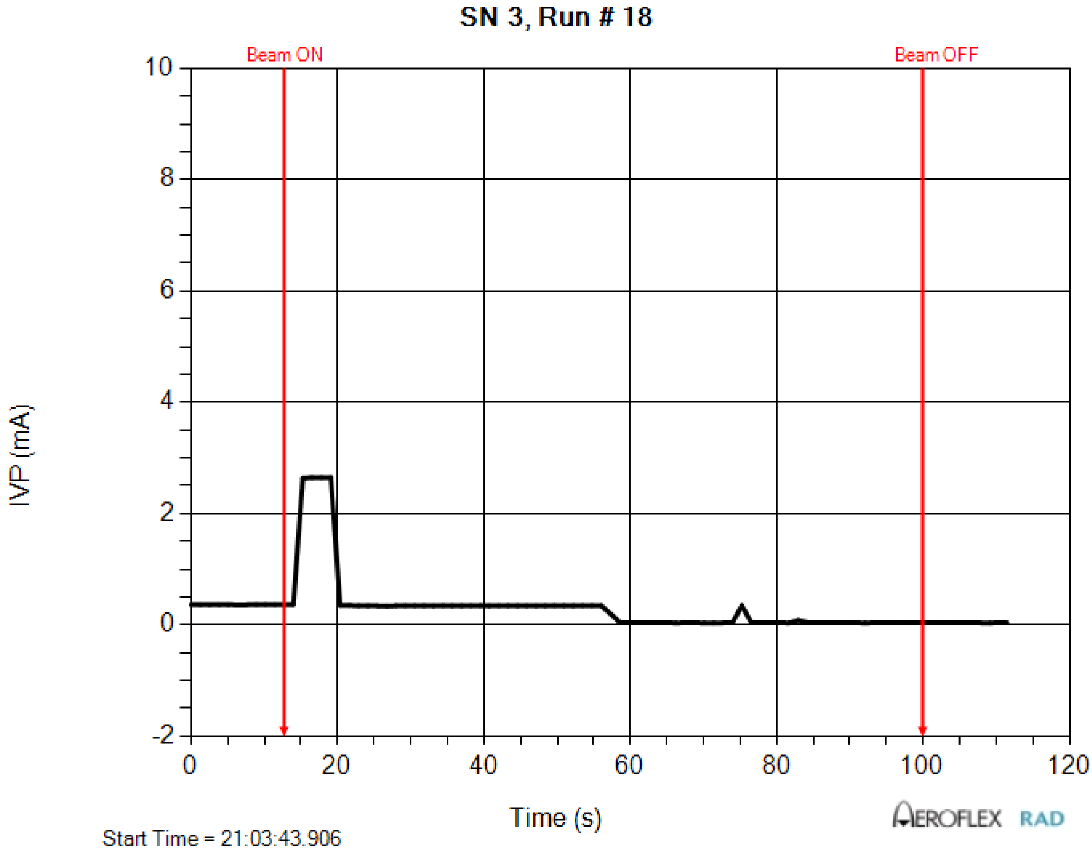

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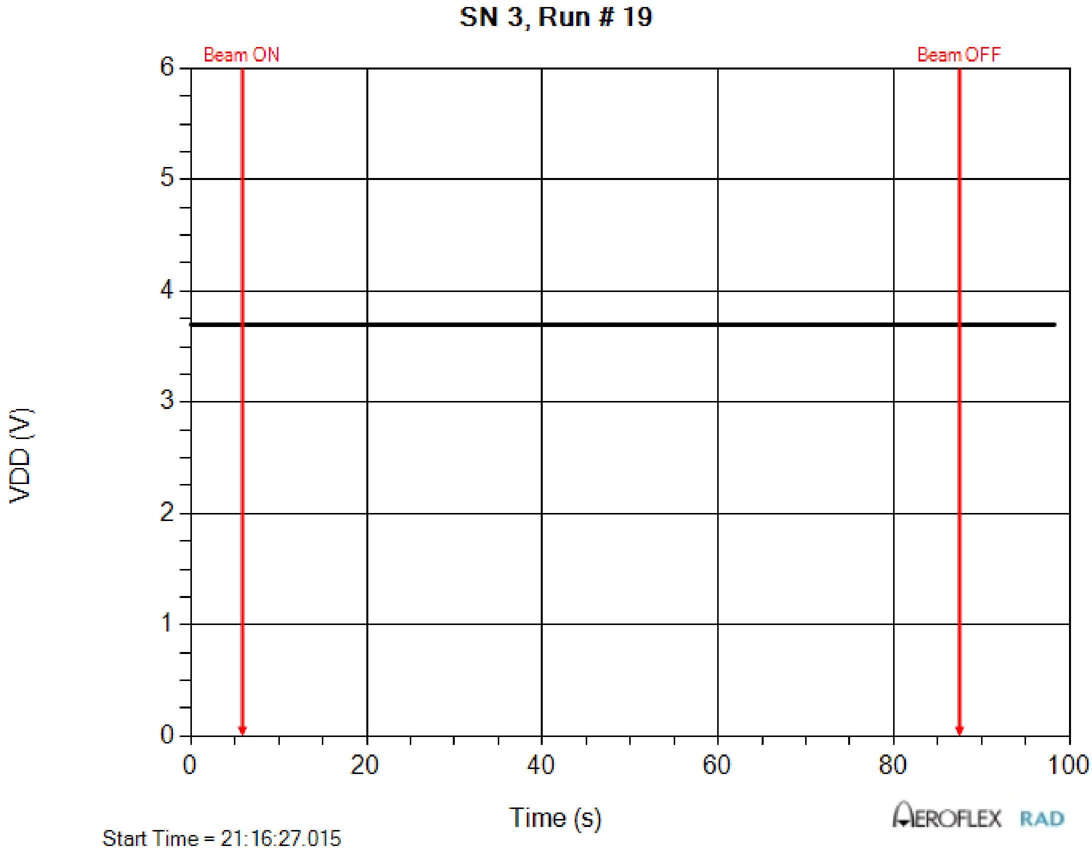

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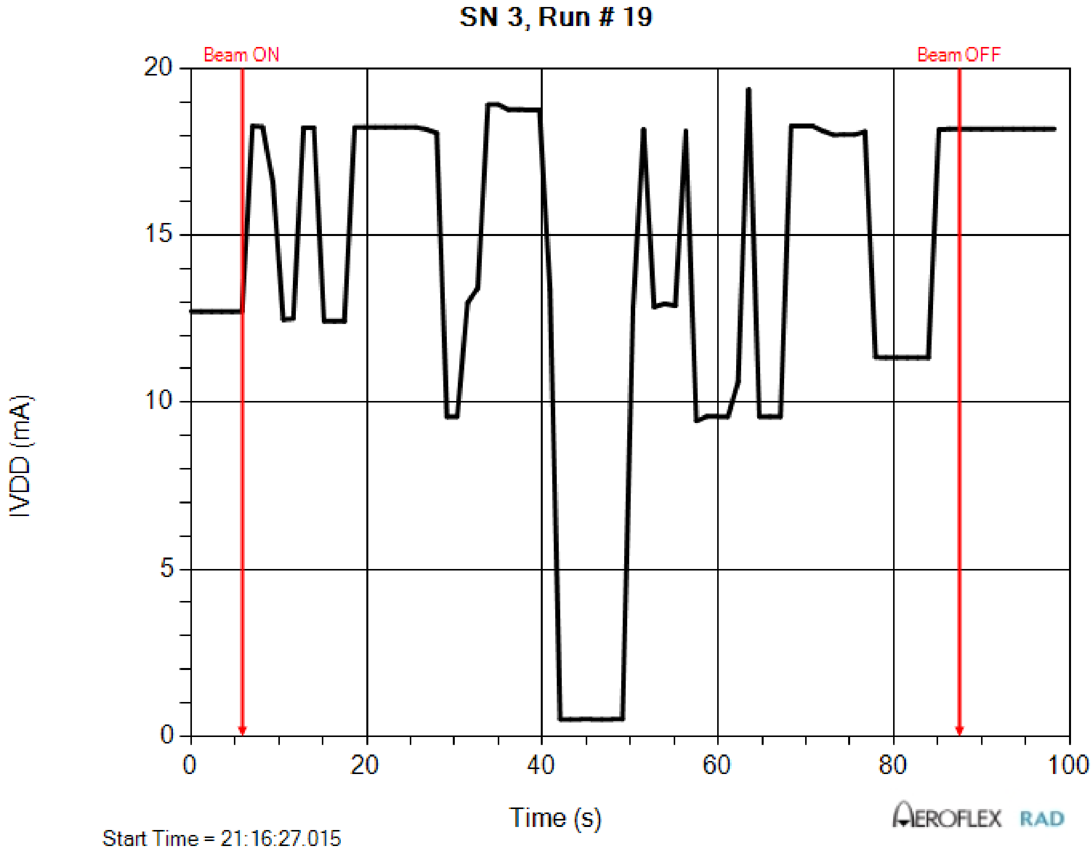

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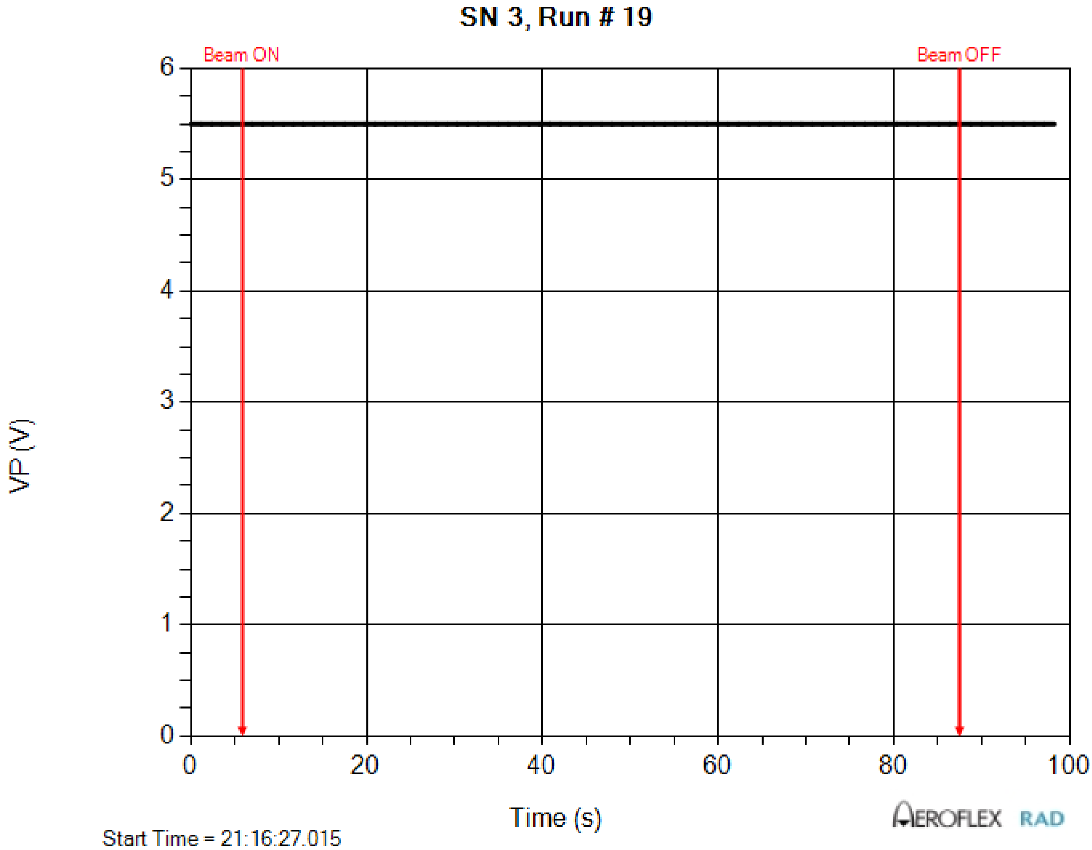

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