SINGLE EVENT EFFECTS TEST REPORT AD8210S

April 2016

Generic

Radiation Test Report	
Product:	AD8210S
Effective LET:	80 MeV-cm^2/mg
Fluence:	1E7 Ions/cm^2
Die Type:	AD8210
Facilities:	Lawrence Berkeley National Laboratories
Tested:	May 2014

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Test Report for Single Event Latch-up and Single Event Transients Testing of the Analog Devices AD8210 High Voltage, Bidirectional Current Shunt Monitor (5962-12233) for Analog Devices

Customer: Analog Devices PO# 45452874

Aeroflex RAD Job Number: 14-0086

Part Type Tested: High Voltage, Bidirectional Current Shunt Monitor

Lot Number/Date Code: Packages are labeled with: 5962R, 1223301VXA Q 1314A.

Quantity of Parts for Testing: Six AD8210s were available for SEL/SET testing. The serial numbers were: 0039, 0040, 0054, 0088, 0089, and 0166.

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

Electrical Test Conditions: The V_{SUPPLY} and V_S currents were recorded before, during, and after heavy ion exposure and monitored for SELs. The minimum rate of supply current measurements is one complete set of measurements per second.

Bias Conditions: For SEL testing all devices-under-test (DUTs) were biased under the following conditions: $V_{SUPPLY} = 65V$, $V_S = 5.5V$. For SET testing all devices-under-test were biased under the following conditions: $V_{SUPPLY} = 65V$, $V_S = 4.5V$. See the figures and schematics in Appendix B for the details of the bias conditions during irradiation.

Test Software / Hardware: Custom VISA control and monitor software was used for all current measurements. Figure 4-1 shows the test setup. Appendix C, Table C-1 lists the test equipment and calibration dates.

Ion Energy and LET Ranges: Multiple ions from the 10 MeV/n ion beam with LETs between 3.5 and 80 MeV-cm^2/mg were used for all testing. The 10 MeV/n Xe beam has a minimum range of 60 µm in silicon to the Bragg Peak, the shortest range ion used for this test.

Heavy Ion Flux and Maximum Fluence Levels: Testing was conducted with ion fluxes between 10^4 and 10^5 ions/cm^2.

Facility and Radiation Source: Lawrence Berkeley National Laboratories (LBNL) Berkeley, CA using the 88" Cyclotron and the 10MeV/n Cocktail.

Irradiation Temperature: All SEL testing was performed at a worst case package temperature of 125°C (±5°C). All SET testing was at room temperature of approximately 25°C.

SEL Results: The AD8210 is immune to high current latch-up to a LET of 80 MeV-cm^2/mg at a package temperature of 125° C.
SET Results: The AD8210 has a saturation upset cross-section of 1.8×10^{-4} cm^2/events for LETs greater than ~20 MeV-cm^2/mg.

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1.0. Introduction and Test Objective

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). These single event effects (SEE) can lead to system performance issues including degradation, disruption and destruction. This report discusses testing performed on the Analog Devices AD8210 Current Shunt Monitor. The two test standards used to guide this testing are ASTM F1192 and EIA/JESD57.

2.0 Device Description

Six samples of the 5962-12233 (AD8210) were provided in ceramic 10-pin ceramic flatpacks with taped on lids to facilitate access to the bare die during testing. Figure 2-1 shows the block diagram of the AD8210 and the test configuration.

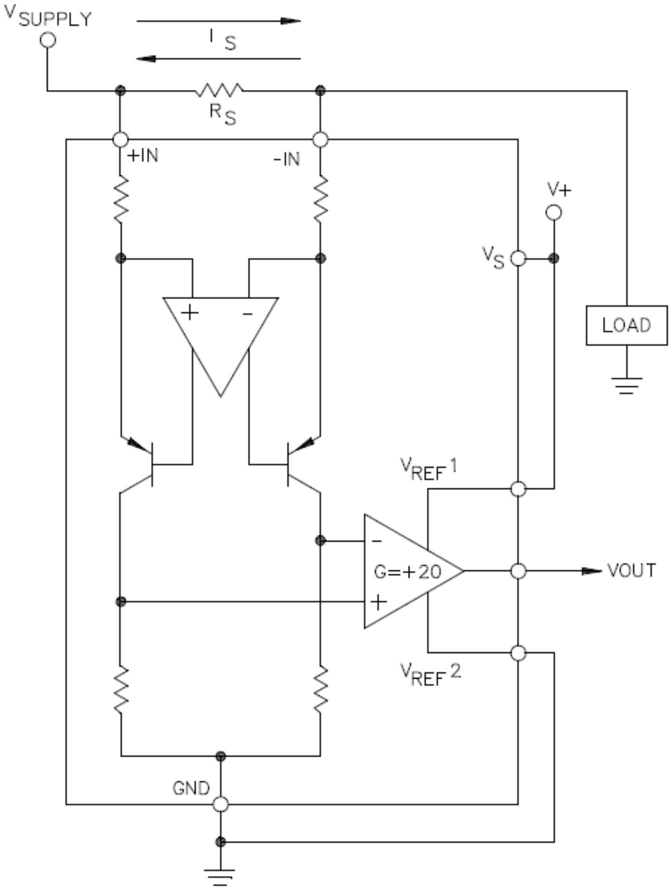


Figure 2-1. AD8210 Block Diagram and Test Configuration.

3.0. Radiation Test Circuit, Test Setup, Test Parameters and Test Conditions

The AD8210 device described in this test report was irradiated at the LBNL cyclotron . For SEL testing, the AD8210 was configured in the ground reference output mode with the V_{REF1} and V_{REF2} inputs held at ground potential. This configuration forced the output voltage to the negative supply voltage (0 volts) when the applied differential input voltage was 0 volts. As tested, the resistive shunt circuit generated approximately 0.13 volts across the differential inputs with a common mode voltage of 65 volts. The resulting voltage measured at the output pin (OUT) of the AD8210 was about 2.6 volts. This output signal was buffered by unity gain amplifier. Figure 3-1 shows the test setup.

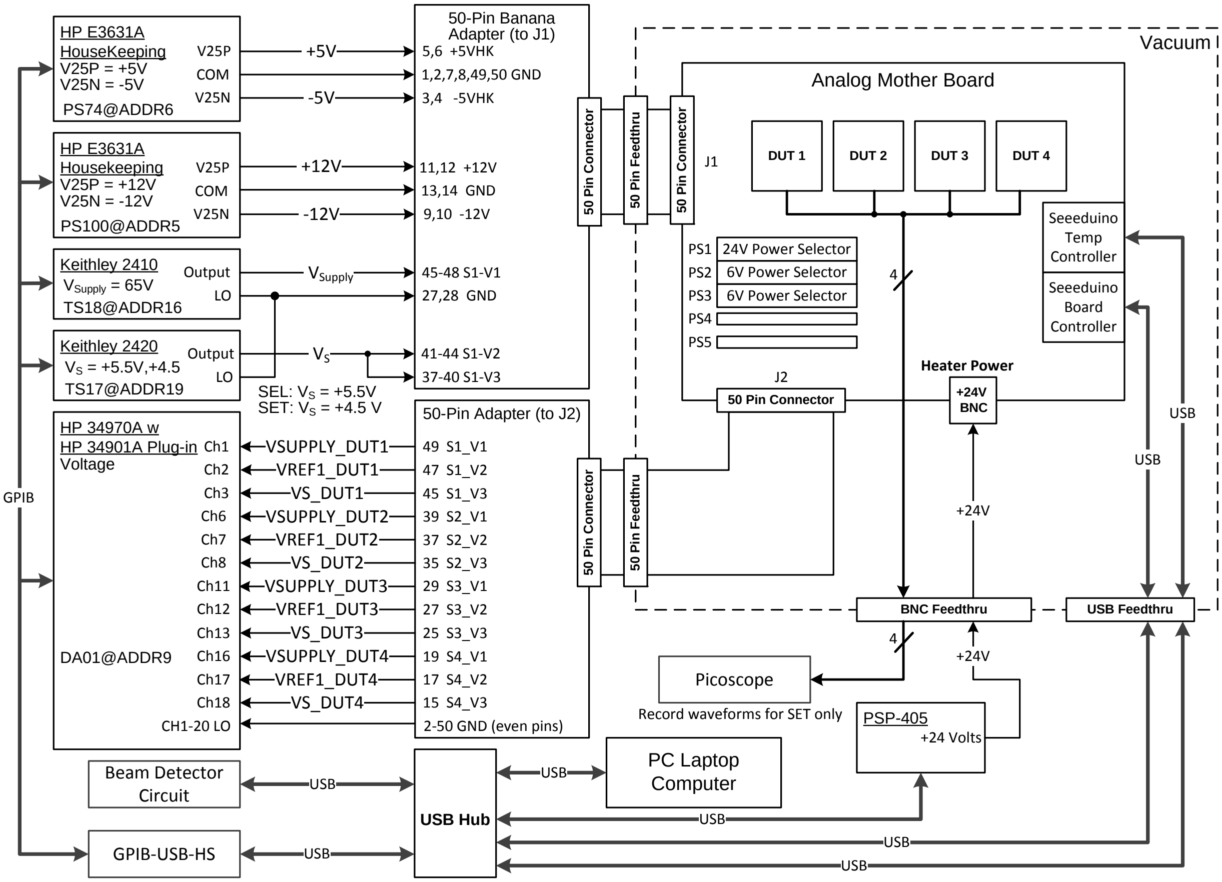


Figure 3-1. AD8210 SEE Test Setup.

All devices-under-test were de-processed 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. See the photograph in Appendix A for a sample of a de-lidded device-under-test.

During the irradiation, the flux was set to be targeted to approximately 10^5 ion/cm^2-s, depending on the ion species and the response of the device-under-test. The irradiation of the devices-under-test was continued until either the minimum fluence is reached or a latch-up event is observed.

For the single event latch-up testing, the temperature was controlled using a resistive heater and a calibrated electronic temperature measurement device mounted underneath the DUT. The case temperature of the DUT was calibrated prior to the testing using a thermocouple. The temperature was controlled using a PID controller 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 either coaxial cable or ribbon cable. Table F-1 lists the ions, energies, angles, LETs, and ranges used for all testing.

3.1 SEL Test Procedure

During the heavy ion exposure the supply currents of the AD8210 were monitored and recorded at approximately 1-second intervals. The current limit on the power supply was set to 0.2 Amp. Figure 3-1 shows the AD8210 test setup. The oscilloscopes were only used to monitor functionality for SEL testing.

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

1. Power up the selected DUT and wait for it to attain the desired test temperature.
2. Verify the AD8210 generates the correct output.
3. Select the desired ion.
4. Turn on the ion beam, observe/monitor/log device current.
5. If no latch occurs, select the next ion and repeat step 4.
6. If the device latches, shut off the beam and power down the device.
7. Reapply power to the device and check currents for a destructive latch.
8. Test the three remaining DUTs at the highest effective LET in which no latch was observed beginning at step 1.

3.1 SET Test Procedure

During the heavy ion exposure the supply currents of theAD8210 were monitored and recorded at approximately 1-second intervals. Current limit on the power supply was set to 1 Amp. Figure 3-1 shows the AD8210 test setup and the oscilloscopes were used to record the transient waveforms.

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

1. Power up the selected DUT.
2. Verify the AD8210 is generating the correct output.
3. Turn ON ion beam, observe/monitor/log device output and currents.
4. Turn OFF the beam when 10^6 ions/cm^2 or 100 transients have been recorded.
5. If 100 transients were observed, select a lower LET and continue testing at step 2.
6. If less than 10 transients were observed, select a new DUT and continue testing at step 1 until four devices have been tested.

4.0. Single Event Effects (SEE) Test Results

The Analog Devices AD8210 High Voltage, Bidirectional Current Monitors were tested for single event effects at the Lawrence Berkeley National Laboratory Cyclotron Facility on April 15, 2014.

4.1 Single Event Latch-up (SEL) Test Results

For SEL testing, the AD8210 was configured in the ground reference output mode with the V_{REF1} and V_{REF2} inputs held at ground potential. This configuration forced the output voltage to the negative supply voltage (0 volts) when the applied differential input voltage was 0 volts. As tested, the resistive shunt circuit generated approximately 0.13 volts across the differential inputs with a common mode voltage of 65 volts. The resulting voltage measured at the output pin (OUT) of the AD8210 was about 2.6 volts. This output signal was buffered by unity gain amplifier.

The AD8210's were tested using the Analog Mother Board. A photo and the schematics of the DUT board are shown in Appendix B. The SEL run log is shown in Table 4-1. No current latch-ups were observed for LET's ranging between 3.5 to 80 MeV-cm^2/mg for the four devices tested. The current waveforms for each run are shown in Appendix D.

Table 4-1. AD8210 SEL Run Log.

Run #	DUT S/N	Temp. (°C)	Ion	Angle (°)	LET (MeV-cm^2/mg)	Fluence (ion/cm^2)	Comment
50	39	125	Ne	0	3.5	1.18E+07	Pass
51	39	125	Ar	0	9.7	1.01E+07	Pass
52	39	125	Kr	0	30.2	1.01E+07	Pass
53	39	125	Xe	0	58.8	1.01E+07	Pass
54	39	125	Xe	43	80	1.01E+07	Pass
55	54	125	Xe	43	80	1.01E+07	Pass
56	88	125	Xe	43	80	1.01E+07	Pass
57	40	125	Xe	43	80	1.01E+07	Pass

4.2 Single Event Transient (SET) Test Results

As shown in Figure 3-1, the output of the AD8210 was buffered to a PicoScope 6404B for recording of transient pulses caused by a heavy ion strike. Facility noise was present on the signal lines and required the oscilloscope trigger to be adjusted to exclude the noise spikes. The trigger was set for either positive or negative pulses that exceeded 10 millivolts in amplitude for durations in excess of 20 nanoseconds. The events captured for both positive and negative pulses were combined and used in the final upset cross section calculation for a given LET.

During SET testing the supply voltage, V_s, was set to 4.5 Volts. The nominal currents measured for I_{SUPPLY} = ~11.6 mA and I_S = ~2 mA. The SET run numbers, DUT serial numbers, temperature, ion, LET, effective fluence, and the number of transients are listed in Table 4-2.

The AD8210 experienced upsets with each ion, ranging from an LET of 0.9 MeV-cm^2/mg for Boron to 80.4 MeV-cm^2/mg for Xenon. Figure 4-1 shows the cross-section as a function of LET for the three devices tested as well as a Weibull curve for reference. For LETs below 9.7 MeV-cm^2/mg (Ar) the amplitude of the majority of the upsets were less than 0.5 volts for durations less than one microsecond. For an LET of 58.8 MeV-cm^2/mg (Xe) the majority of the upsets were between 0.5 volts and 2.0 volts for durations of one or two microseconds. A significant numbers of transient events were greater than 2.0 volts in amplitude for durations longer than one microsecond with many lasting longer than five microseconds at an LET of 58.8 MeV-cm^2/mg. Figures 4-2 through 4-11 show representative single event transients observed during testing. All the transient events are shown in Appendix E.

Table 4-2. AD8210 SET Run Log

Run #	DUT S/N	Ion	Angle (°)	Effective LET (MeV-cm^2/mg)	Effective Fluence (ion/cm^2)	Transient Type	Number of Transients	Upset Cross Section (cm^2/event)
13	39	Ar	0	9.7	8.57E+05	Negative Pulses	100	1.16E-04
16	39	Ar	0	9.7	8.64E+05	Negative Pulses	100	
18	39	Ne	0	3.5	8.00E+05	Positive Pulses	100	1.06E-04
19	39	Ne	0	3.5	1.08E+06	Negative Pulses	100	
21	39	B	0	0.9	8.90E+05	Negative Pulses	10	1.23E-05
22	39	B	0	0.9	7.32E+05	Positive Pulses	10	
23	39	Kr	0	30.2	6.06E+05	Positive Pulses	100	1.73E-05
24	39	Kr	0	30.2	5.75E+05	Negative Pulses	100	
25	39	Kr	0	30.2	5.80E+05	Negative Pulses	100	
26	39	Xe	0	58.8	1.06E+06	Positive Pulses	100	1.43E-04
27	39	Xe	0	58.8	5.54E+05	Positive Pulses	100	
28	39	Xe	0	58.8	6.15E+05	Positive Pulses	100	
29	39	Xe	0	58.8	5.67E+05	Negative Pulses	100	
30	39	Xe	43	80.4	6.19E+05	Negative Pulses	100	1.63E-04
31	39	Xe	43	80.4	6.07E+05	Positive Pulses	100	
33	40	Xe	43	80.4	5.78E+05	Positive Pulses	100	1.91E-04
34	40	Xe	43	80.4	4.71E+05	Negative Pulses	100	
35	40	Kr	43	42.2	5.49E+05	Negative Pulses	100	1.72E-04
36	40	Kr	43	42.2	6.16E+05	Positive Pulses	100	
38	54	Kr	43	42.2	5.80E+05	Positive Pulses	100	1.84E-04
39	54	Kr	43	42.2	5.06E+05	Negative Pulses	100	
40	54	Ar	43	13.3	1.47E+06	Negative Pulses	100	1.07E-04
41	54	Ar	43	13.3	6.71E+05	Negative Pulses	100	
42	54	Ar	43	13.3	6.61E+05	Positive Pulses	100	
43	88	Ar	43	13.3	6.25E+05	Positive Pulses	100	1.49E-04
44	88	Ar	43	13.3	7.14E+05	Negative Pulses	100	
45	88	Ar	0	9.7	1.09E+06	Negative Pulses	100	1.01E-04
46	88	Ar	0	9.7	8.99E+05	Positive Pulses	100	
47	88	Ne	0	3.5	3.50E+06	Positive Pulses	100	5.37E-05
48	88	Ne	0	3.5	9.22E+05	Positive Pulses	100	
49	88	Ne	0	3.5	1.16E+06	Negative Pulses	100	

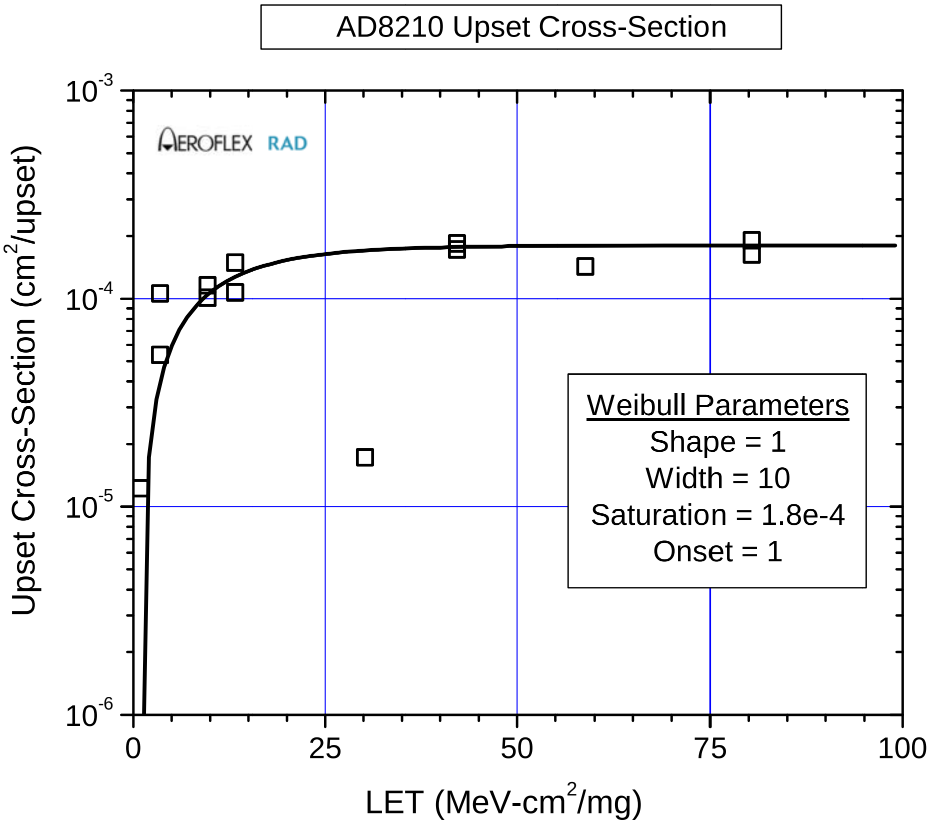


Figure 4-1. Upset cross section of the AD8210 as a function of LET.

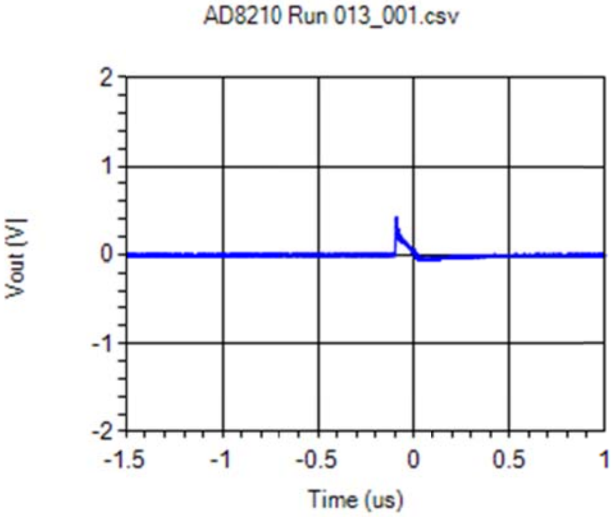


Figure 4-2 (Figure E-1.) AD8210 Output, Run # 013, Frame # 001

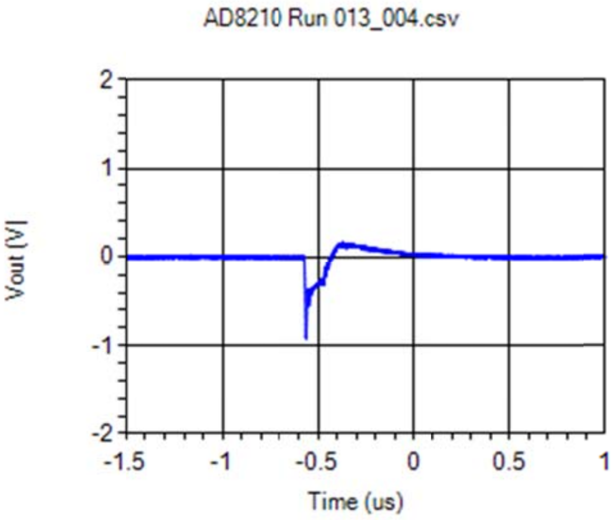


Figure 4-3 (Figure E-4). AD8210 Output, Run # 013, Frame # 004

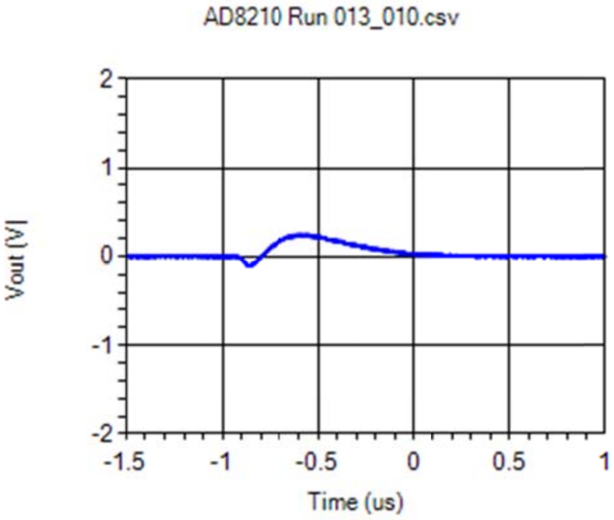


Figure 4-4 (Figure E-10). AD8210 Output, Run # 013, Frame # 010

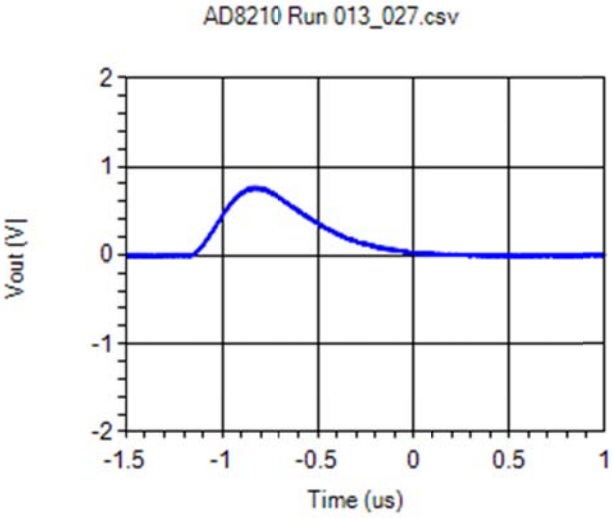


Figure 4-5 (Figure E-27). AD8210 Output, Run # 013, Frame # 027

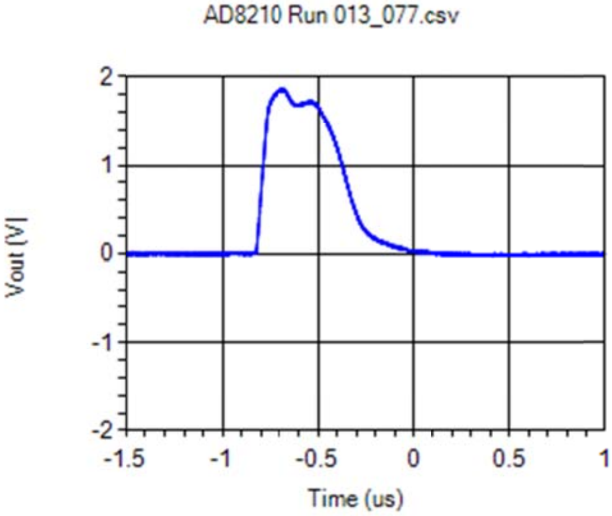


Figure 4-6 (Figure E-77). AD8210 Output, Run # 013, Frame # 077

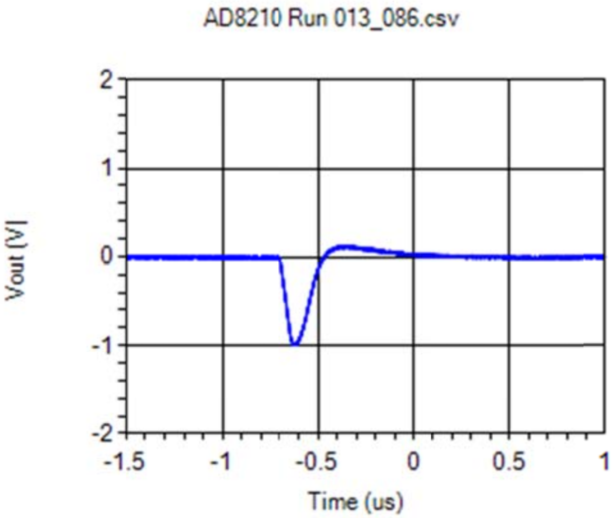


Figure 4-7 (Figure E-86). AD8210 Output, Run # 013, Frame # 086

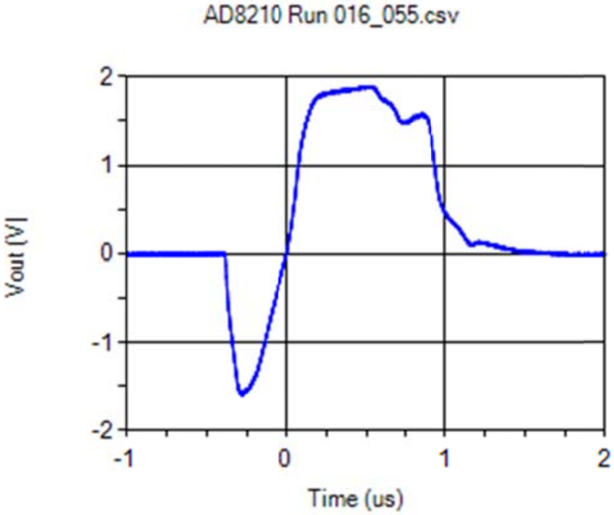


Figure 4-8 (Figure E-155). AD8210 Output, Run # 016, Frame # 055

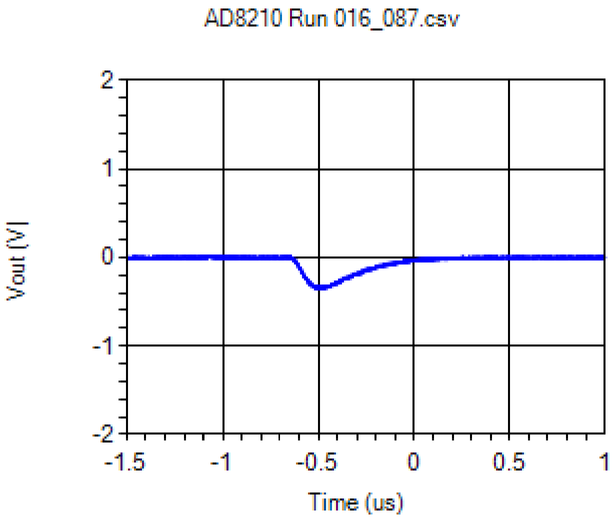


Figure 4-9 (Figure E-187). AD8210 Output, Run # 016, Frame # 087

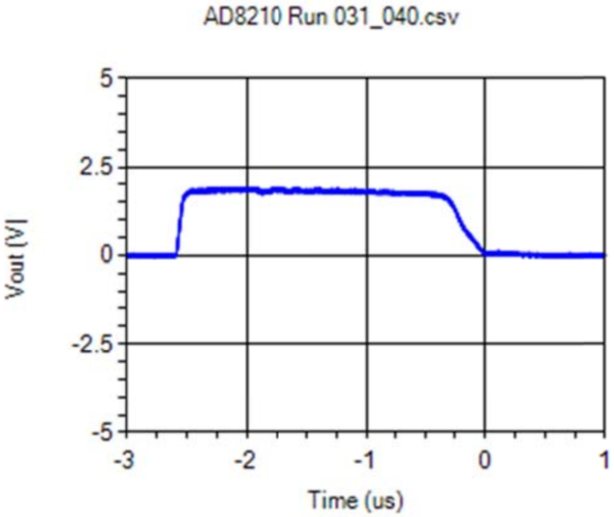


Figure 4-10 (Figure E-1260). AD8210 Output, Run # 031, Frame # 040

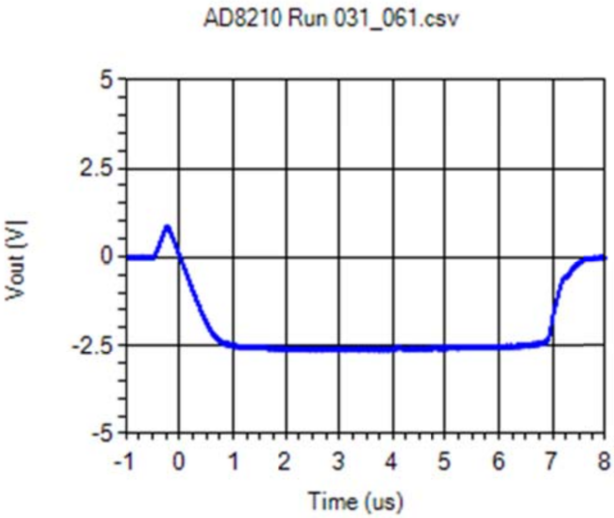


Figure 4-11 (Figure E-1281). AD8210 Output, Run # 031, Frame # 061

5.0. Summary/Conclusions

The AD8210 High Voltage, Bidirectional Current Monitor were immune to single event latch-up for LET’s ranging from 3.5 to 80 MeV-cm^2/mg at a temperature of 125 °C while operating at a supply voltage of 5.5 volts.

Single event transients were observed at all LETs from 0.9 to 80 MeV-cm^2/mg with a saturation cross-section of ~1.8x10^{-4} cm^2/event.

Appendix A: Photographs of sample devices-under-test prior to de-processing for traceability and post de-processing to show the die and bond wires in the package.

Figure A-1. AD8210 DUT SN 0089 with Package Markings.

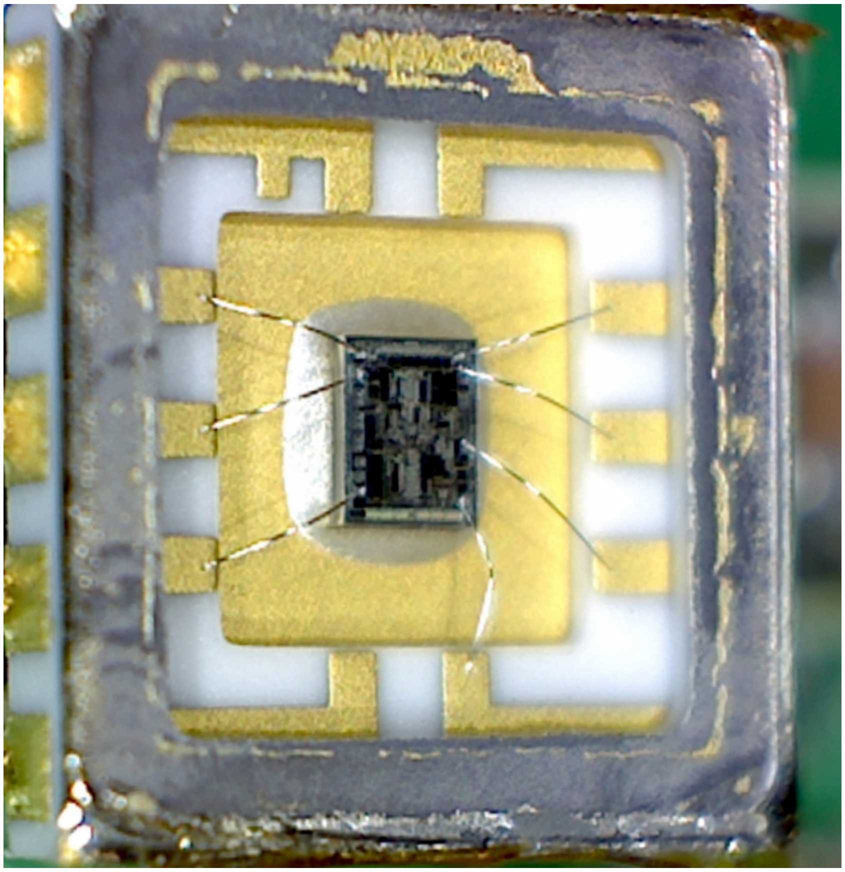


Figure A-2. De-processed AD8210 DUT SN 0039

Appendix B: Photograph of the Test Boards and Electrical Schematics.

Figure B-1. DUT Test Board.

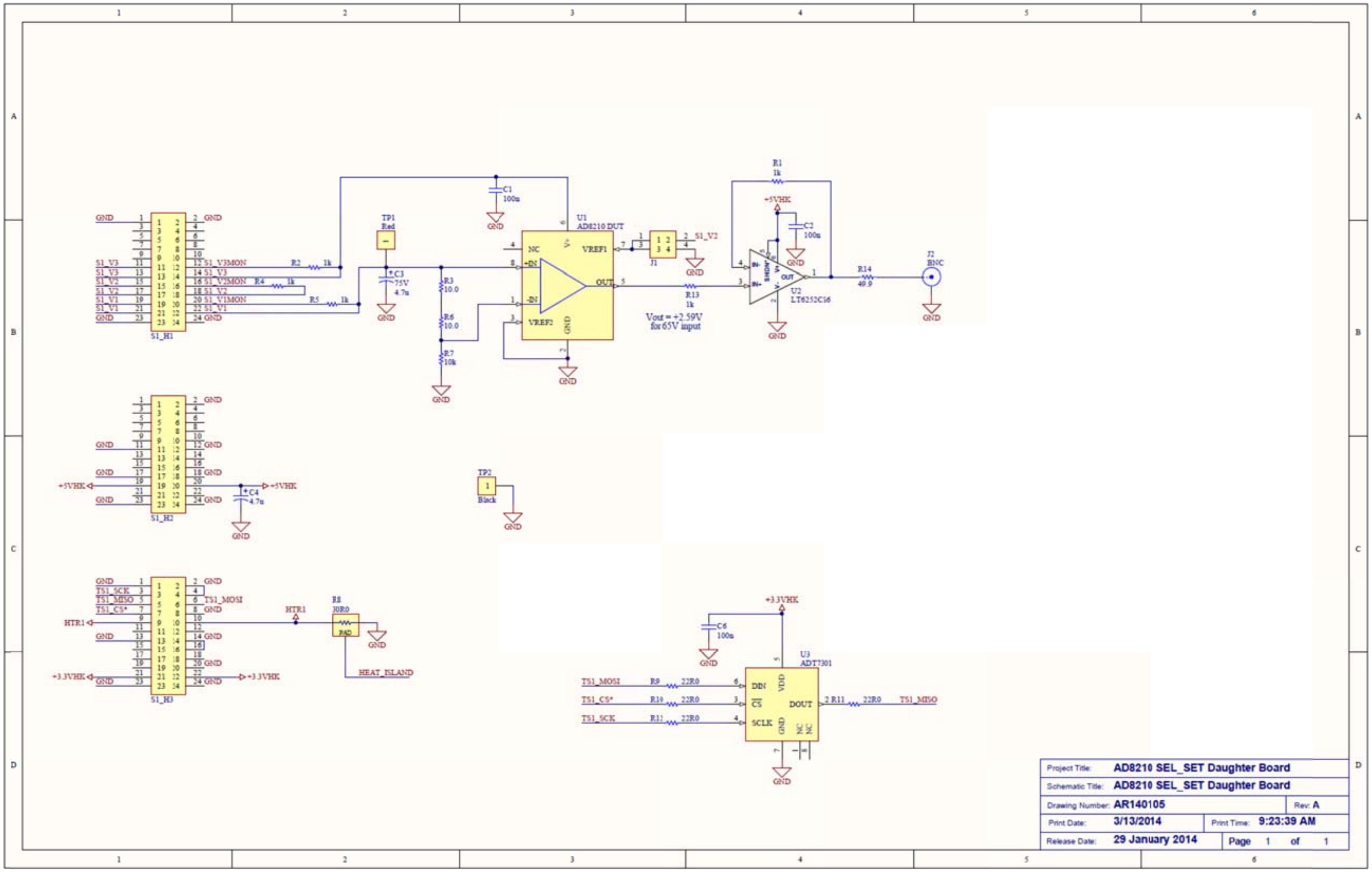


Figure B-2. AD8210 DUT Test Board Schematic

Appendix C: Electrical Test Parameters and Equipment List:

Table C-1 lists the equipment typically used during the testing as well as the calibration dates and the date the calibration is due.

Table C-1. Test Equipment List and Calibration Dates.

Equipment	**Entity #**	**Calibration Date**	**Calibration Due**	**Purpose**
Keithley 2420 High Current Source Meter	TS18	12/23/2013	12/23/2014	V_{SUPPLY} Power Supply and I_{SUPPLY} Measurement
Keithley 2410 High Voltage Source Meter	TS17	10/14/2013	10/14/2014	V_S Power Supply and I_S Measurement
Agilent 34970A Data Acquisition Unit	DA01	07/26/2013	07/26/2014	Voltage Monitoring
Agilent 34901A Multiplexer	MP03	01/30/2014	01/30/2015	Voltage Monitoring
Fluke 115 True RMS Multimeter	HM12	12/06/2013	12/06/2014	Voltage Measurements
Omega Handheld Thermometer	TM02	07/15/2013	07/15/2014	Temperature Calibration
Type K Thermocouple	TC01	07/29/2013	07/29/2014	Temperature Calibration
PicoScope 6404B	OS11	09/05/2013	09/05/2014	Output Waveform Measurements
Instek PSP-405 DC Power Supply	PS12	N/A	N/A	Heater Power
Agilent E3641A DC Power Supply	PS74	N/A	N/A	+5.0 VDC, and -5.0 VDC
Agilent E3641A DC Power Supply	PS100	N/A	N/A	+12 VDC and -12 VDC

Appendix D: SEL Current Waveforms

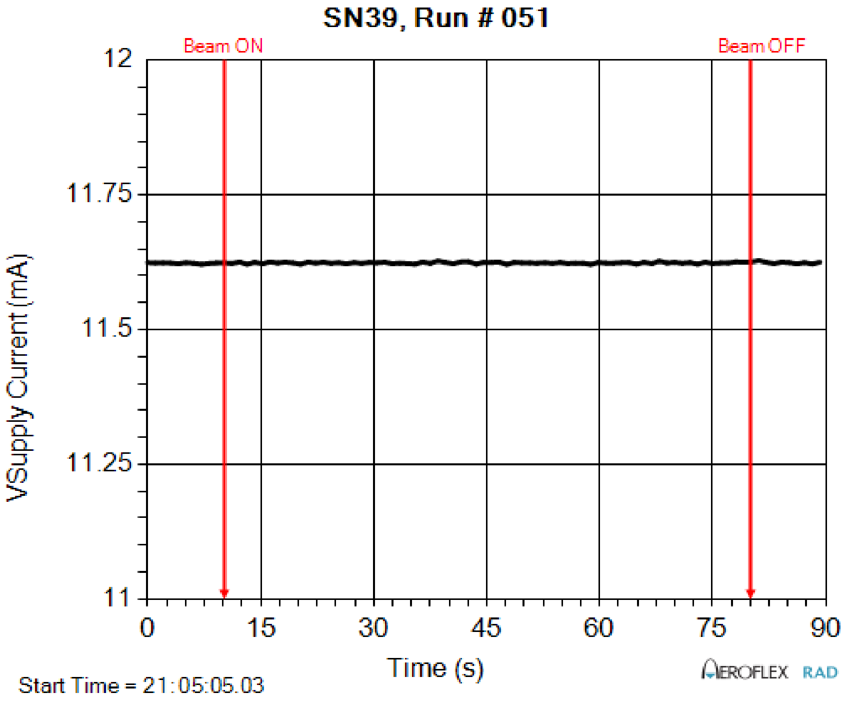


Figure D-1. AD8210 SN39, Run #51, VSupply Current (mA).

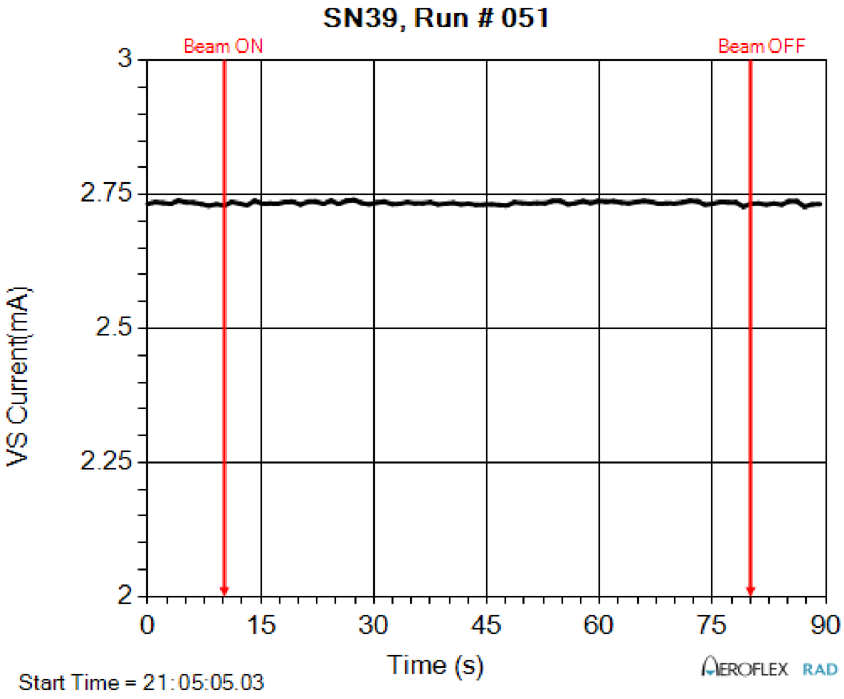


Figure D-2. AD8210 SN39, Run #51, VS Current (mA).

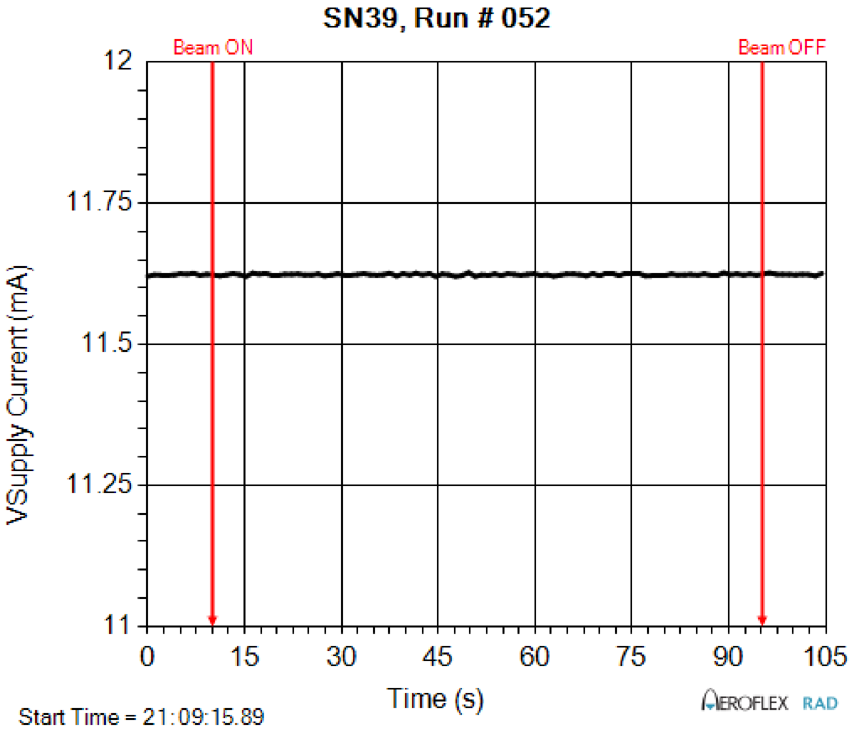


Figure D-3. AD8210 SN39, Run #52, VSupply Current (mA).

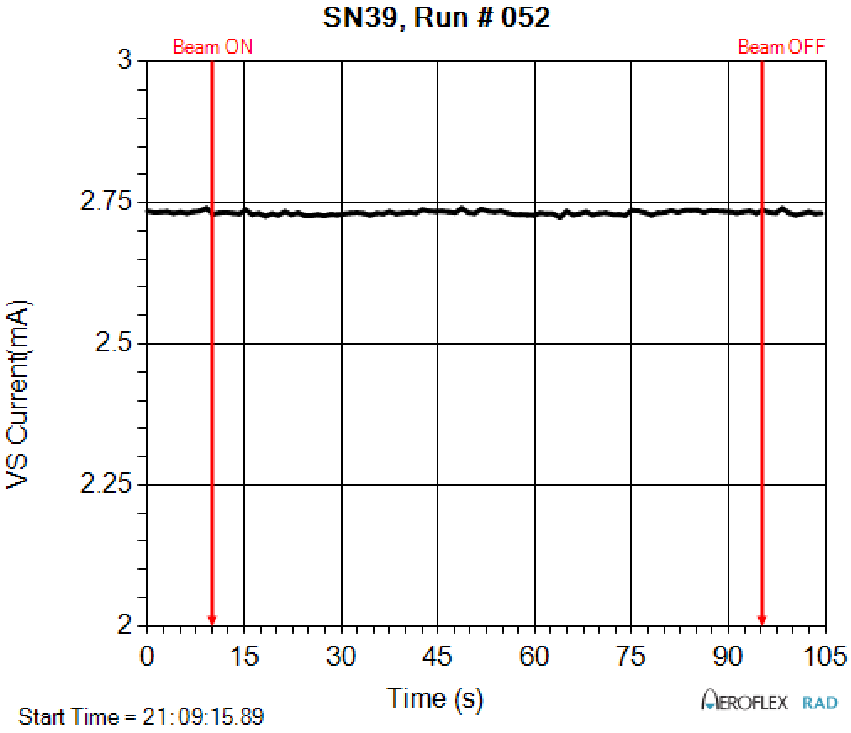


Figure D-4. AD8210 SN39, Run #52, VS Current (mA).

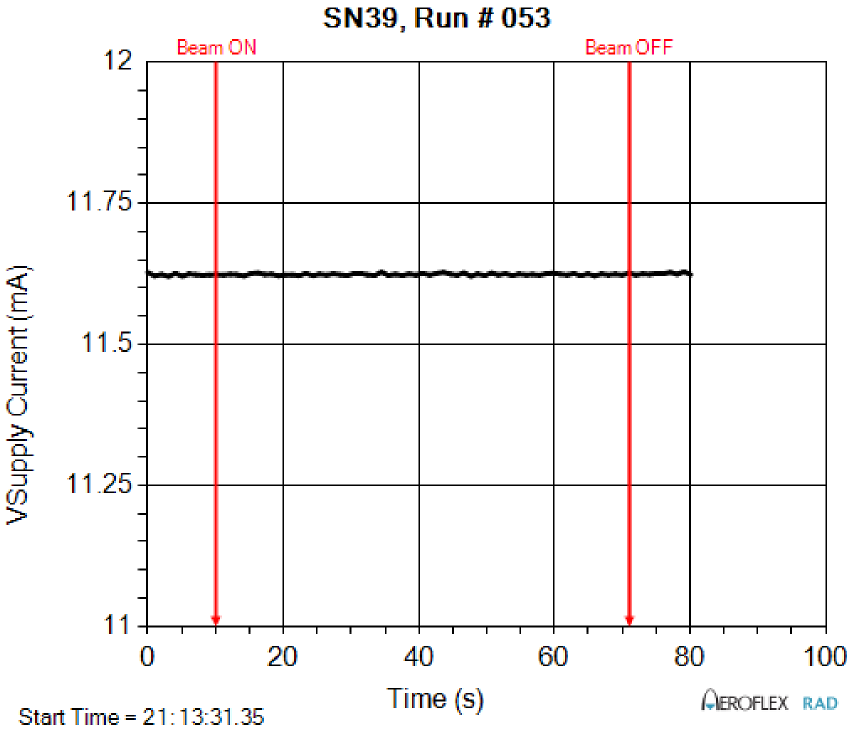


Figure D-5. AD8210 SN39, Run #53, VSupply Current (mA).

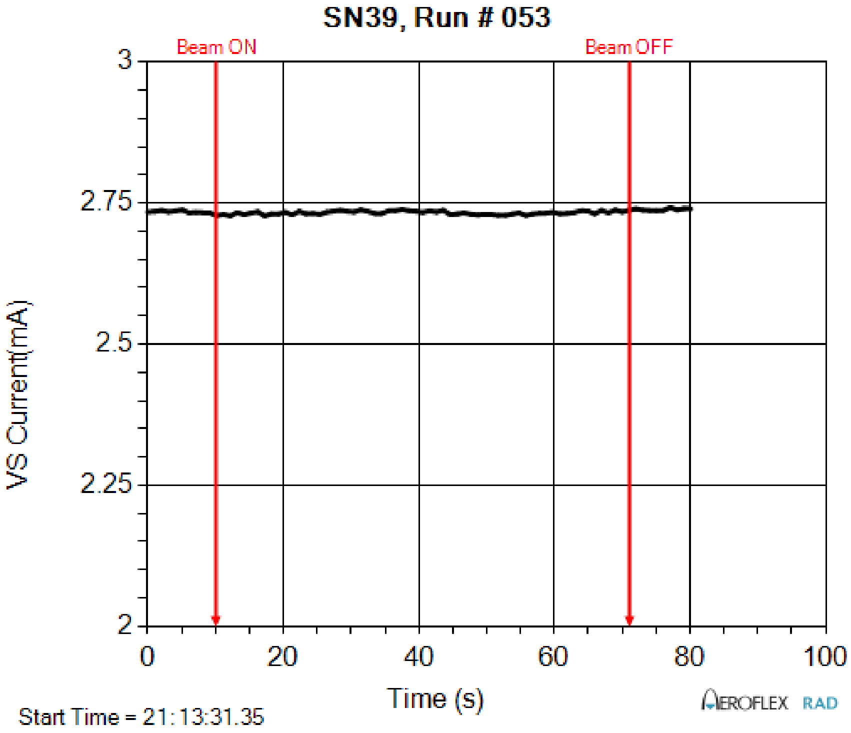


Figure D-6. AD8210 SN39, Run #53, VS Current (mA).

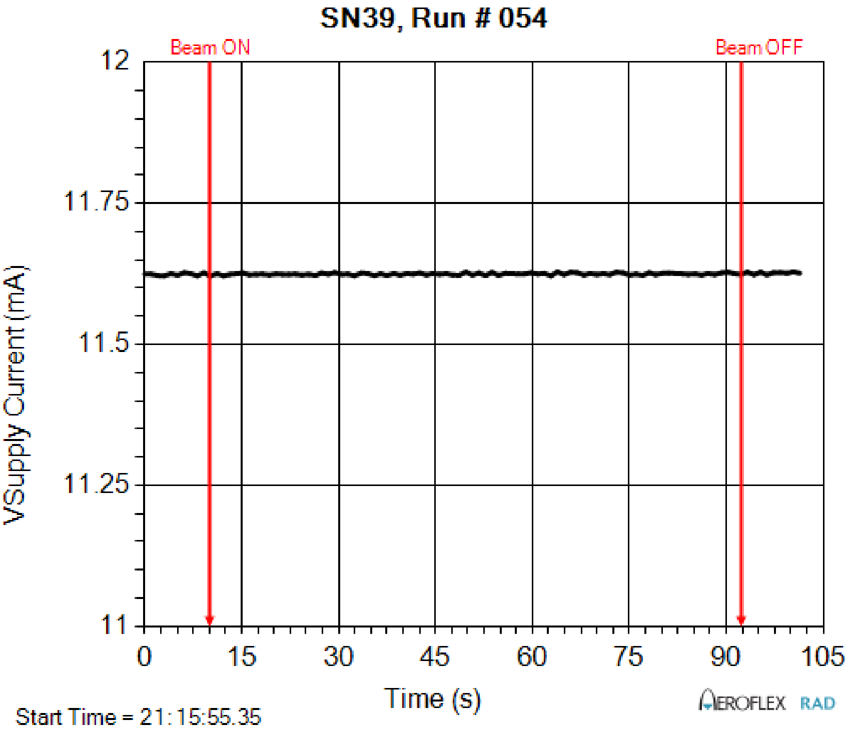


Figure D-7. AD8210 SN39, Run #54, VSupply Current (mA).

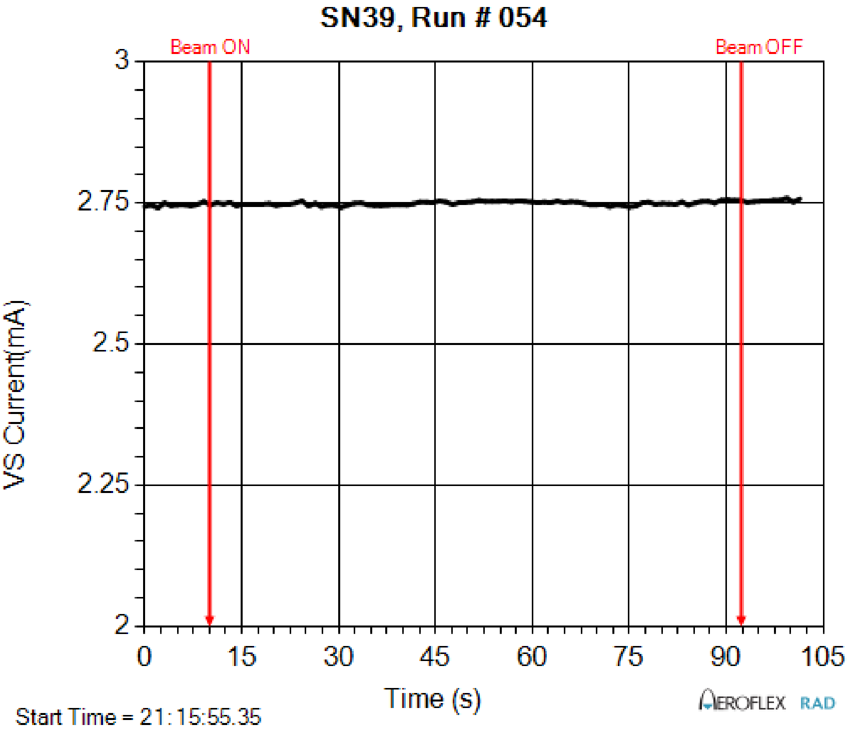


Figure D-8. AD8210 SN39, Run #54, VS Current (mA).

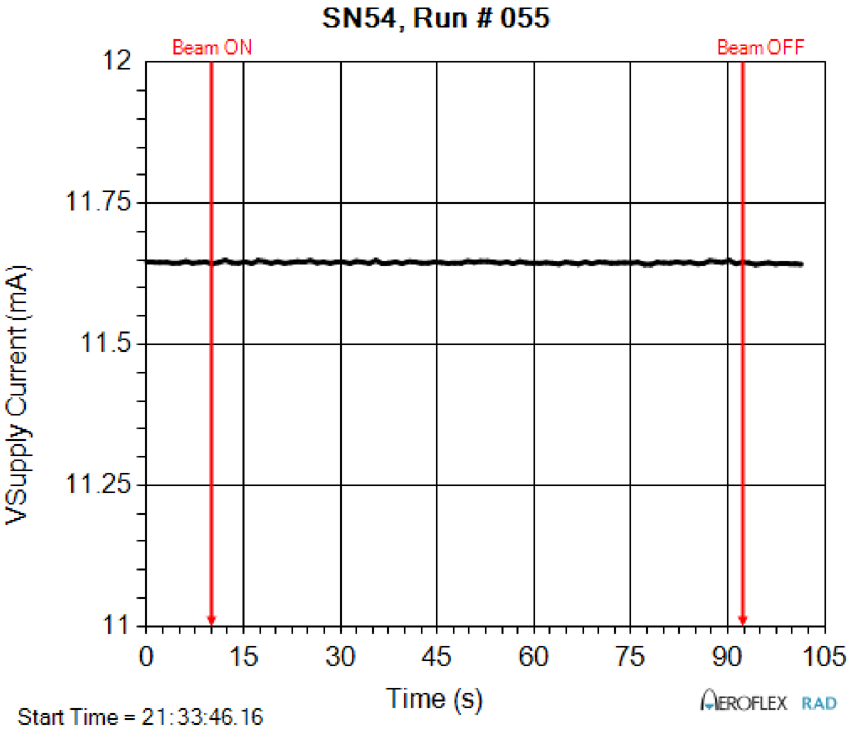


Figure D-9. AD8210 SN54, Run #55, VSupply Current (mA).

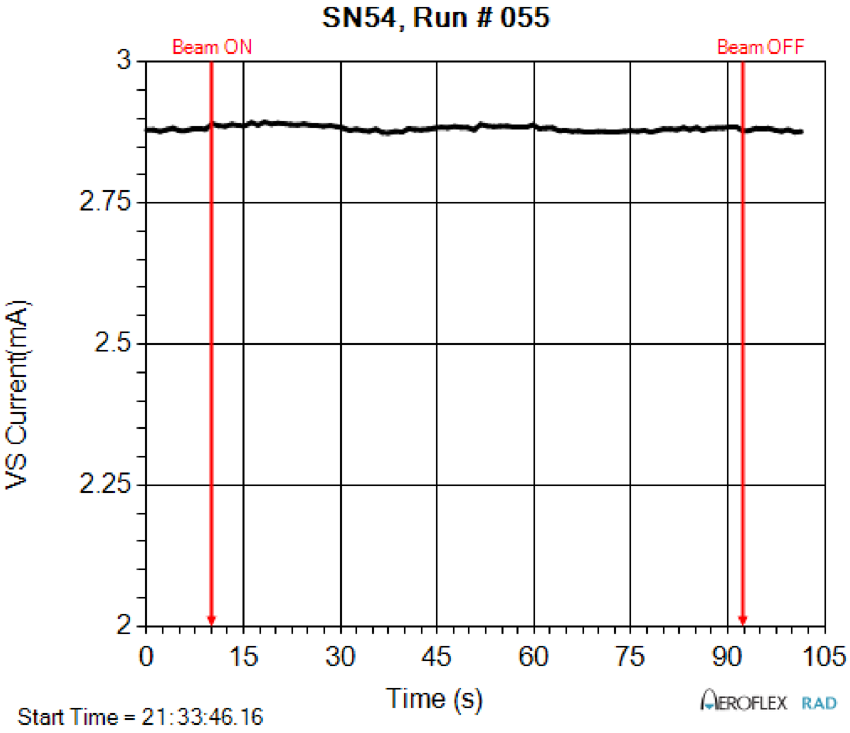


Figure D-10. AD8210 SN54, Run #55, VS Current (mA).

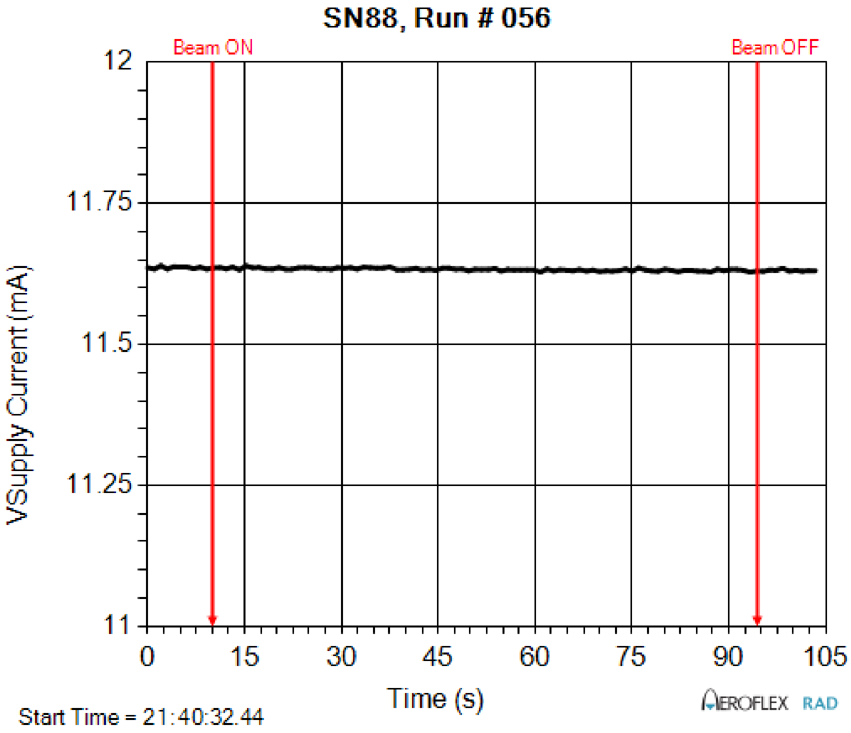


Figure D-11. AD8210 SN54, Run #56, VSupply Current (mA).

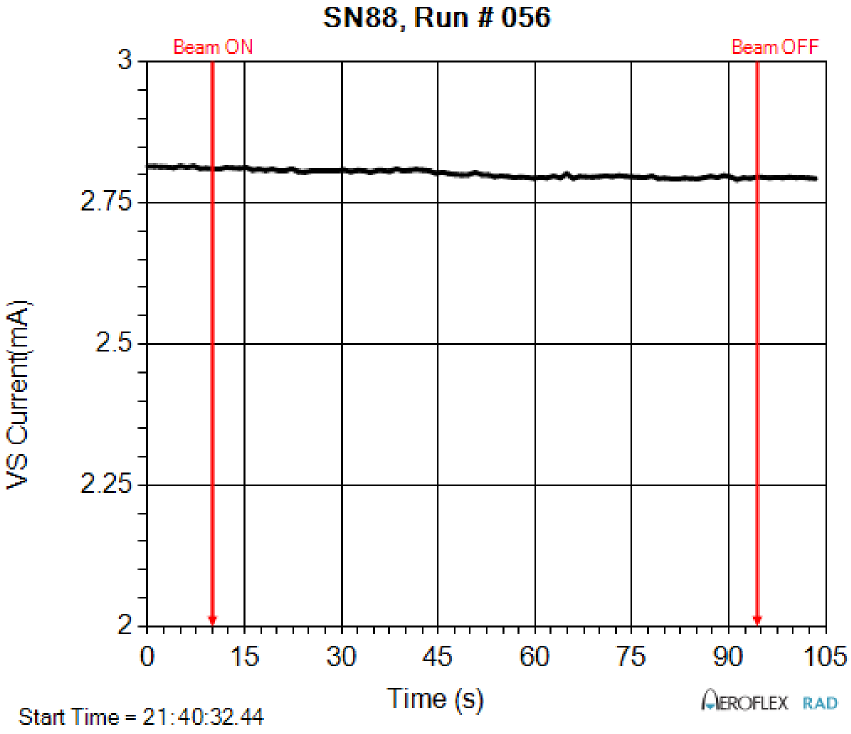


Figure D-12. AD8210 SN54, Run #56, VS Current (mA).

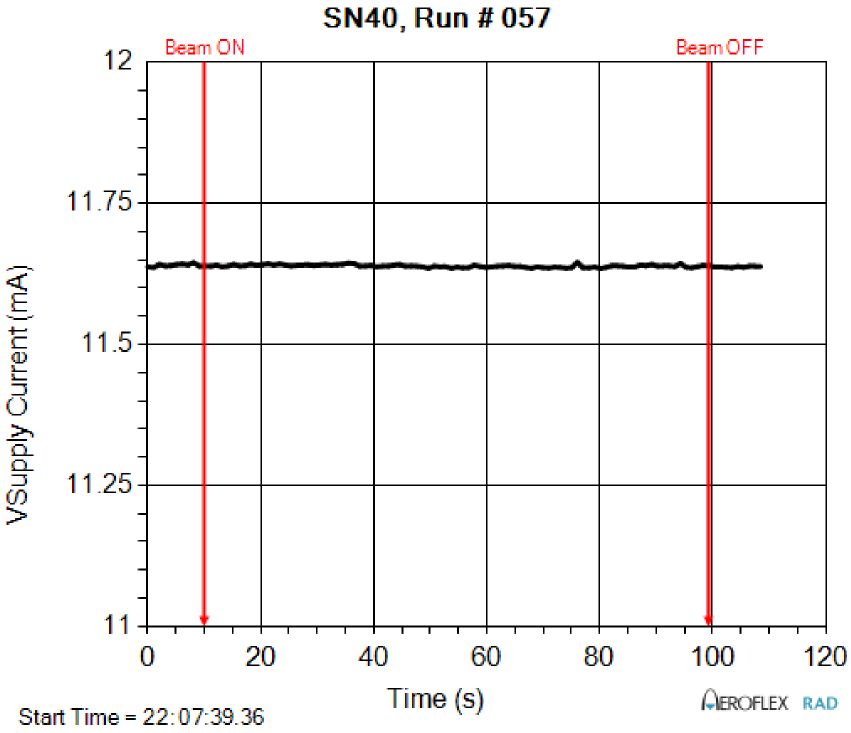


Figure D-13. AD8210 SN40, Run #57, VSupply Current (mA).

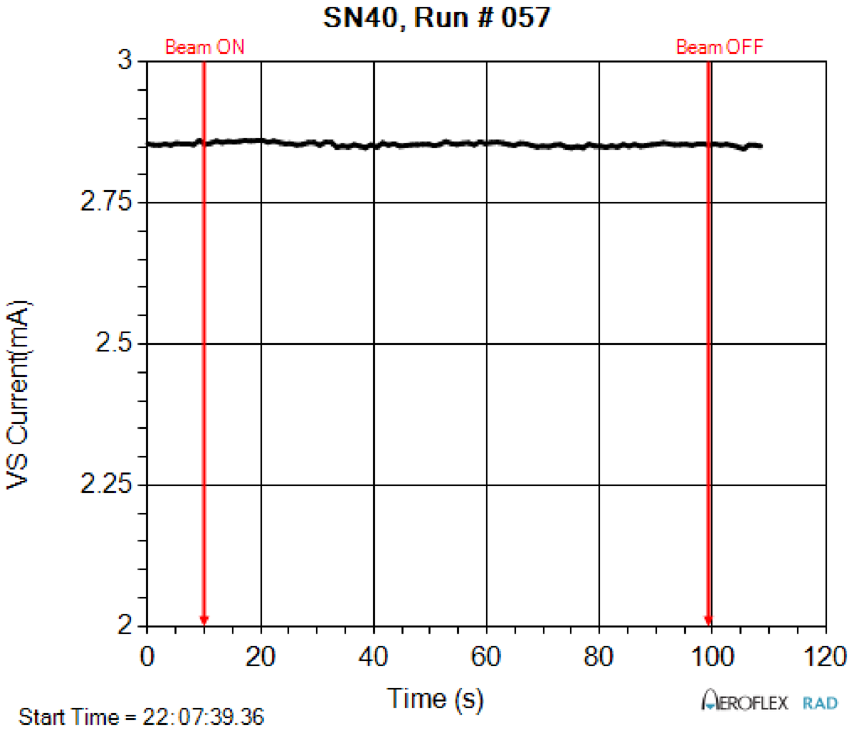


Figure D-14. AD8210 SN40, Run #57, VS Current (mA).

Appendix E: SET Transient Waveforms

Published in a separate file do to file size considerations.

Appendix F. Test Facility Description

The non-destructive single event effects testing discussed in this test plan was performed at the Lawrence Berkeley National Laboratories (LBNL) Cyclotron Facility using their 88-Inch Cyclotron. The 88-Inch Cyclotron is operated by the University of California for the U.S. 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 (10-20 pμA) up to maximum energies of 55 MeV (protons), 65 MeV (deuterons), 135 MeV (^{3}He) and 140 MeV (^{4}He). Most heavy ions through uranium can be accelerated to maximum energies, which vary with the mass and charge state. For the single event transient testing performed at LBNL the devices will be placed in the Cave 4B vacuum chamber aligned with the heavy ion beam line. The test platter in the vacuum chamber has full horizontal and vertical 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 F-1 shows an illustration of the LBNL facility; including the location of Cave 4B, where the heavy ion SEE testing takes place. Table F-1 shows the beam characteristics available at Berkeley.

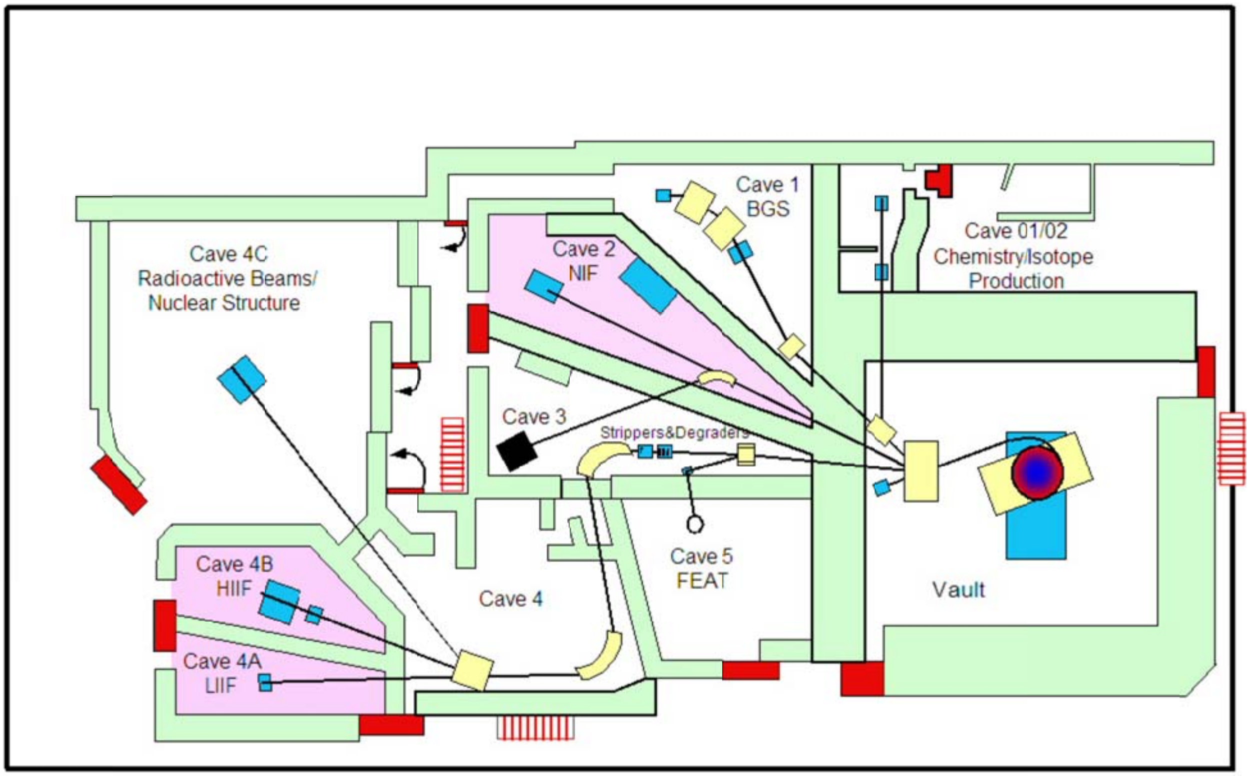
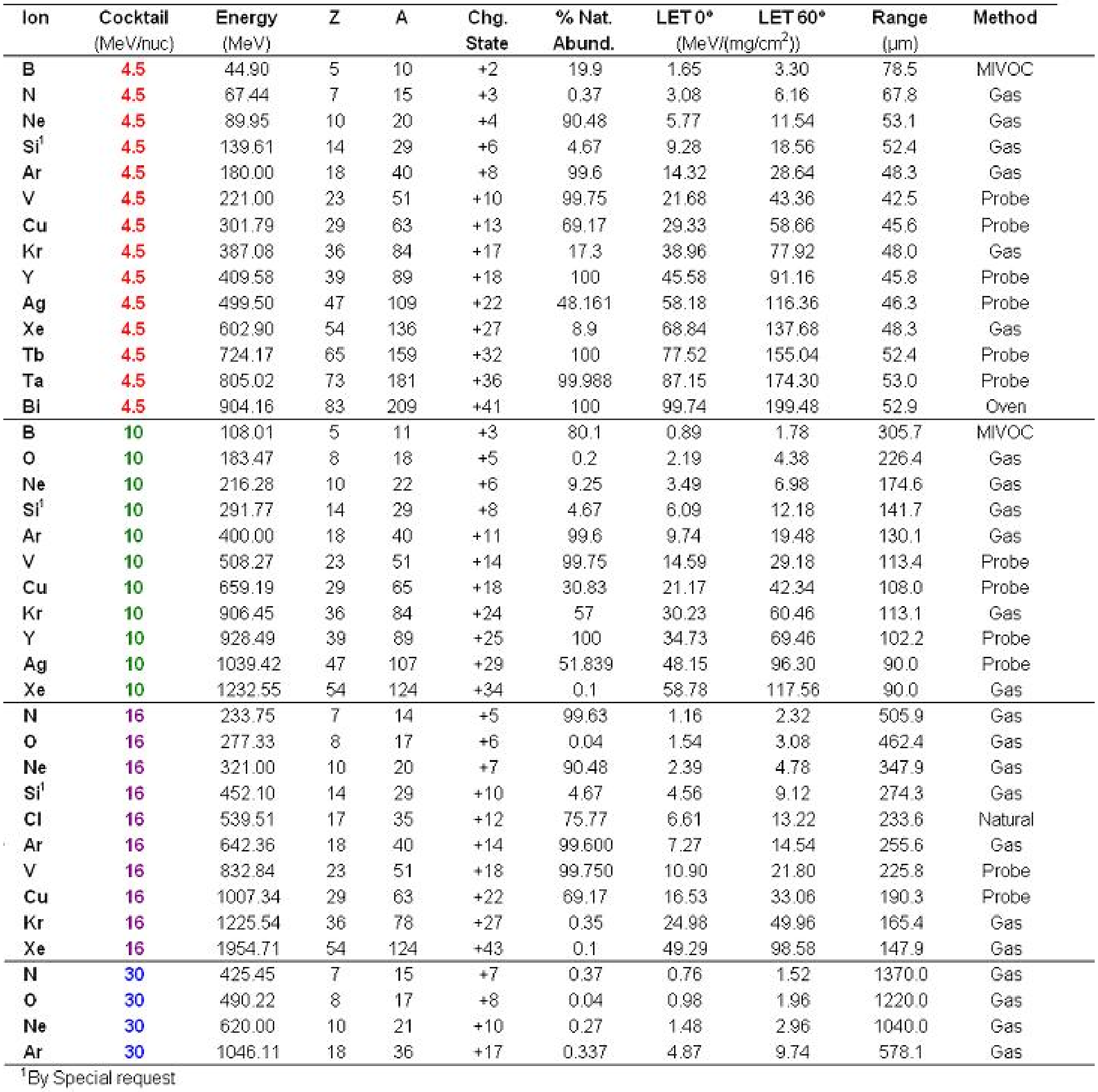


Figure F-1. Lawrence Berkeley National Laboratory 88" Cyclotron Facility Layout. Cave 4B is used for heavy ion testing.

Table F-1. Characteristics of all the beams available at Berkeley. The 10 MeV per nucleon beam will be used for all testing discussed in this report.



Ion	Cocktail (MeV/nuc)	Energy (MeV)	Z	A	Chg. State	% Nat. Abund.	LET 0° (MeV/(mg/cm^2))	LET 60° (MeV/(mg/cm^2))	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