Heavy ion Single Event Effects test on the CMOS operational amplifier LMC6484 from National Semiconductor

Test Report

Christian Poivey
SGT-Inc.

Jim Howard, Hak Kim, Jim Forney
Jackson&Tull

Steve Buchner
QSS

Preliminary

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1 Introduction

This report presents the preliminary heavy ion SET and SEL test data on the LMC6484 CMOS operational amplifier from National Semiconductor.

2 Tested Devices

The tested devices are described in Table 1. The parts have been delidded for testing.

Type	**LMC6484**
Manufacturer	National Semiconductor
Function	CMOS Quad Rail to Rail Input and Output Operational Amplifier
Package	DIP 14
Package marking	"NSC logo"XM106AB LMC6484AIN
Previous SEE testing	No data available

Table 1: description of the tested devices.

3 BNL experiment

3.1 Irradiation facility

The tests have been performed at the Brookhaven National Laboratories in June 2002. The ion beams used are described in Table 2.

Ion	**Energy (MeV)**	**Average flux (#/cm^2-s)**	**Range (μm)**	**LET (MeVcm^2/mg)**
Ni-58	265	~1E+04	42	26.5

Table 2: Ions used at BNL.

3.2 Test set-up

The part has been tested in the voltage follower configuration as shown in Figure 1.

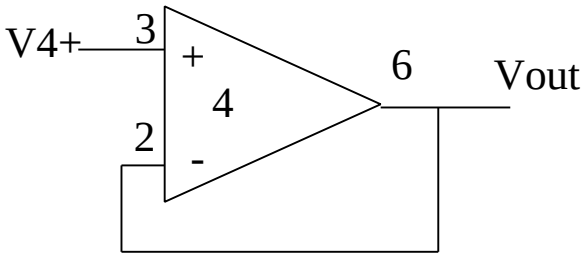

Figure 1: test configuration

The tested bias conditions are described in Table3.

Vsupply (V)	Vin(V)	Vout(V)
+10/0	2	2
	5	5
	8	8

Table 3: Bias conditions.

The device output is monitored by an oscilloscope. As soon as the device output deviates of more than 500 mV from the nominal output, a transient is counted and the transient frame is stored for further analysis.

The device supply current is also monitored. As soon the supply current is larger than a detection threshold, a SEL is counted. The nominal supply current is about 1 mA. The SEL detection threshold has been set to 20 mA.

3.3 Test results

The test results are presented in Table 4. The part is not sensitive to SEL up to the maximum tested LET of 53 MeVcm^2/mg.

Run #	SN #	Vin (V)	tilt	eff. LET (MeVcm^2/mg)	eff. Fluence (#/cm^2)	SEL	SET	Xsection SET (cm^2/dev.)
3	1	2.00	0	26.58	1.32E+06	0	0	7.58E-07
4	1	2.00	45	37.59	9.82E+05	0	0	1.02E-06
9	1	2.00	60	53.16	6.24E+05	0	0	1.60E-06
1	1	5.00	0	26.58	1.47E+06	0	103	7.01E-05
5	1	5.00	45	37.59	8.60E+05	0	107	1.24E-04
8	1	5.00	60	53.16	3.63E+05	0	57	1.57E-04
2	1	8.00	0	26.58	1.65E+06	0	21	1.27E-05
6	1	8.00	45	37.59	1.20E+06	0	52	4.33E-05
7	1	8.00	60	53.16	7.75E+05	0	52	6.71E-05

Table 4: test results.

Figure 2 shows the SET cross section curve. For an input voltage of 2V the part is not sensitive. The part exhibits its maximum sensitivity for an input voltage of 5V.

All the SET are negative going transients with a similar shape. Figure 3 shows a typical transient.

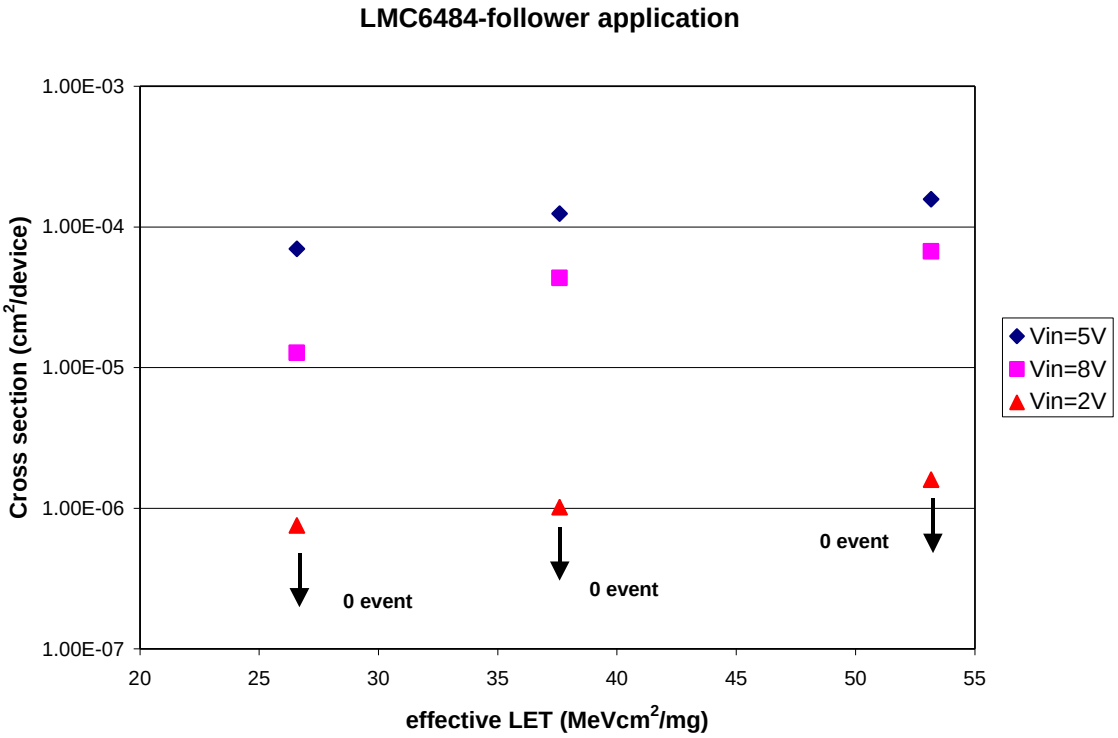

Figure 2: SET cross section curve

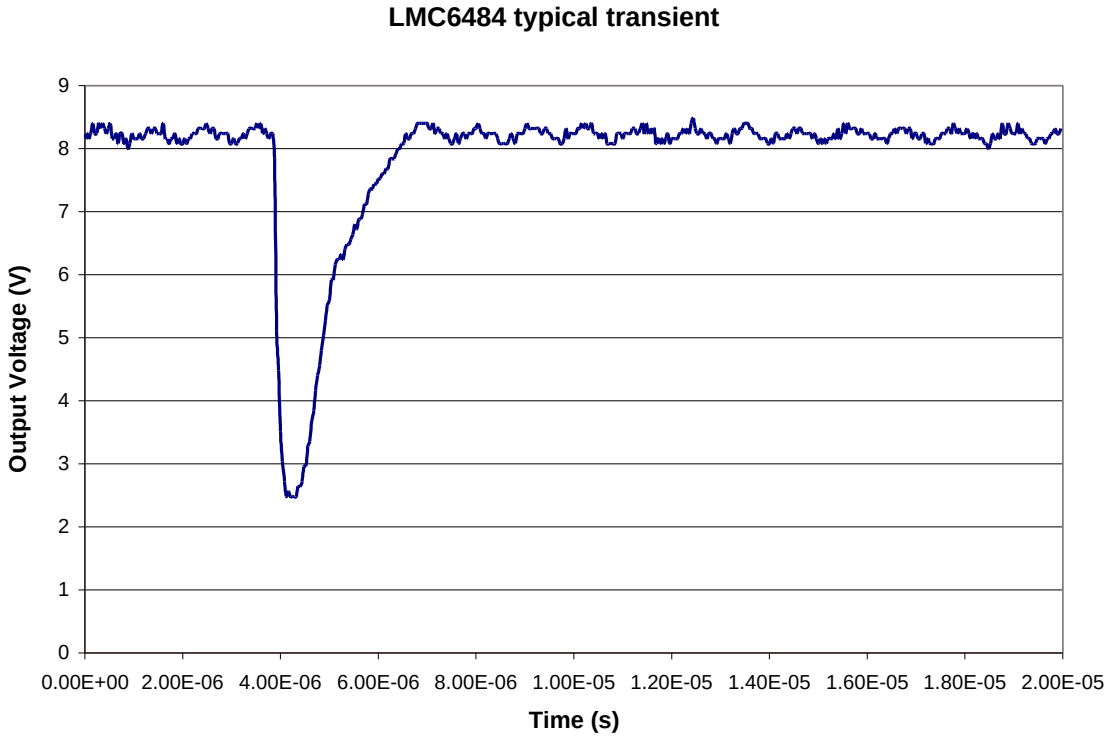

Figure 3: typical transient waveform

4 TAMU experiment

4.1 Irradiation facility

The tests have been performed at the TEXAS A&M cyclotron in October 2002. The ion beams used are described in Table 5.

Ion	Energy (MeV)	Average flux (#/cm^2-s)	Range (µm)	LET (MeVcm^2/mg)
Ne	264	~2E+05	258	2.8
Ar	496	~6E+04	174	8.7

Table 5: Ions used at TAMU

4.2 Test set-up

The part has been tested in the non inverting gain x3 configuration as shown in Figure 4.

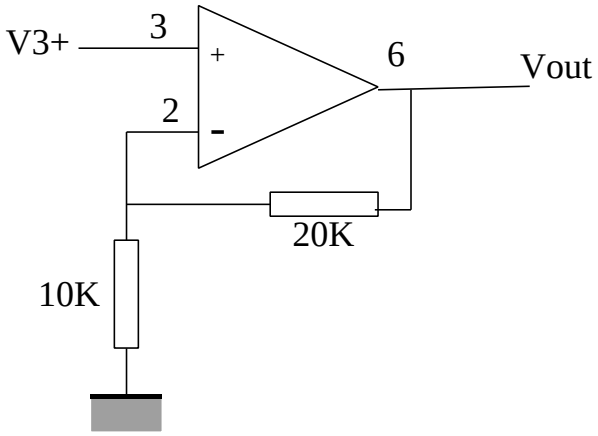

Figure 4: test configuration

The tested bias conditions are described in Table6.

Vsupply (V)	Vin(V)	Vout(V)
+10/0	1	3.2
	1.5	4.75
	2.5	8.1
+5/0	0.5	1.5
	1	3.2

Table 6: Bias conditions.

The device output is monitored by an oscilloscope. As soon as the device output deviates of more than 500 mV from the nominal output, a transient is counted and the transient frame is stored for further analysis. The DUT is connected to the oscilloscope with an active FET probe.

4.3 Test results

The test results are presented in Table 7. The part is not sensitive to SEL up to the maximum tested LET of 15 MeVcm^2/mg.
Figure 5 shows the SET cross section curve. The part seems more sensitive for high input voltages. We can also see that the experiment data obtained with a tilted beam do not fit with the curve.

dut#	Vcc (V)	V+ (V)	Angle	Eff LET (MeVcm2/mg)	Eff. Fluence (#/cm2)	SET#	Cross Section (cm2/dev)
1	**+10/0V**	1	0	2.80	9.93E+06	2	2.01E-07
1	**+10/0V**	1	0	2.80	1.00E+07	3	3.00E-07
1	**+10/0V**	1	45	3.96	1.00E+07	1	9.96E-08
1	**+10/0V**	1	60	5.60	9.95E+06	69	6.93E-06
1	**+10/0V**	1	0	8.69	7.39E+06	878	1.19E-04
1	**+10/0V**	1	45	12.29	1.73E+06	374	2.16E-04
1	**+10/0V**	1	55	15.15	8.09E+05	230	2.84E-04
1	**+10/0V**	1	60	17.38	1.00E+07	121	1.21E-05
1	**+10/0V**	1.5	0	2.80	9.94E+06	1	1.01E-07
1	**+10/0V**	1.5	45	3.96	7.85E+06	247	3.15E-05
1	**+10/0V**	1.5	60	5.60	9.95E+06	65	6.53E-06
1	**+10/0V**	1.5	0	8.69	2.36E+06	410	1.74E-04
1	**+10/0V**	1.5	45	12.29	1.96E+06	459	2.34E-04
1	**+10/0V**	1.5	55	15.15	6.94E+05	245	3.53E-04
1	**+10/0V**	2.5	0	2.80	9.96E+06	5	5.02E-07
1	**+10/0V**	2.5	45	3.96	1.00E+07	154	1.53E-05
1	**+10/0V**	2.5	60	5.60	1.00E+07	57	5.70E-06
1	**+10/0V**	2.5	0	8.69	3.37E+06	519	1.54E-04
1	**+10/0V**	2.5	45	12.29	1.73E+06	403	2.34E-04
1	**+10/0V**	2.5	55	15.15	7.86E+05	237	3.02E-04
1	**+5/0V**	0.5	0	2.80	1.00E+07	0	1.00E-07
1	**+5/0V**	0.5	45	3.96	9.97E+06	2	2.01E-07
1	**+5/0V**	0.5	60	5.60	9.95E+06	3	3.02E-07
1	**+5/0V**	0.5	0	8.69	2.89E+06	281	9.72E-05
1	**+5/0V**	0.5	45	12.29	2.08E+06	313	1.51E-04
1	**+5/0V**	0.5	55	15.15	1.21E+06	219	1.81E-04
1	**+5/0V**	1	0	2.80	1.01E+07	3	2.97E-07
1	**+5/0V**	1	45	3.96	1.00E+07	5	4.98E-07
1	**+5/0V**	1	60	5.60	9.95E+06	54	5.43E-06
1	**+5/0V**	1	0	8.69	2.72E+06	302	1.11E-04
1	**+5/0V**	1	45	12.29	1.99E+06	329	1.66E-04
1	**+5/0V**	1	55	15.15	1.21E+06	226	1.87E-04

Table 7: test results.

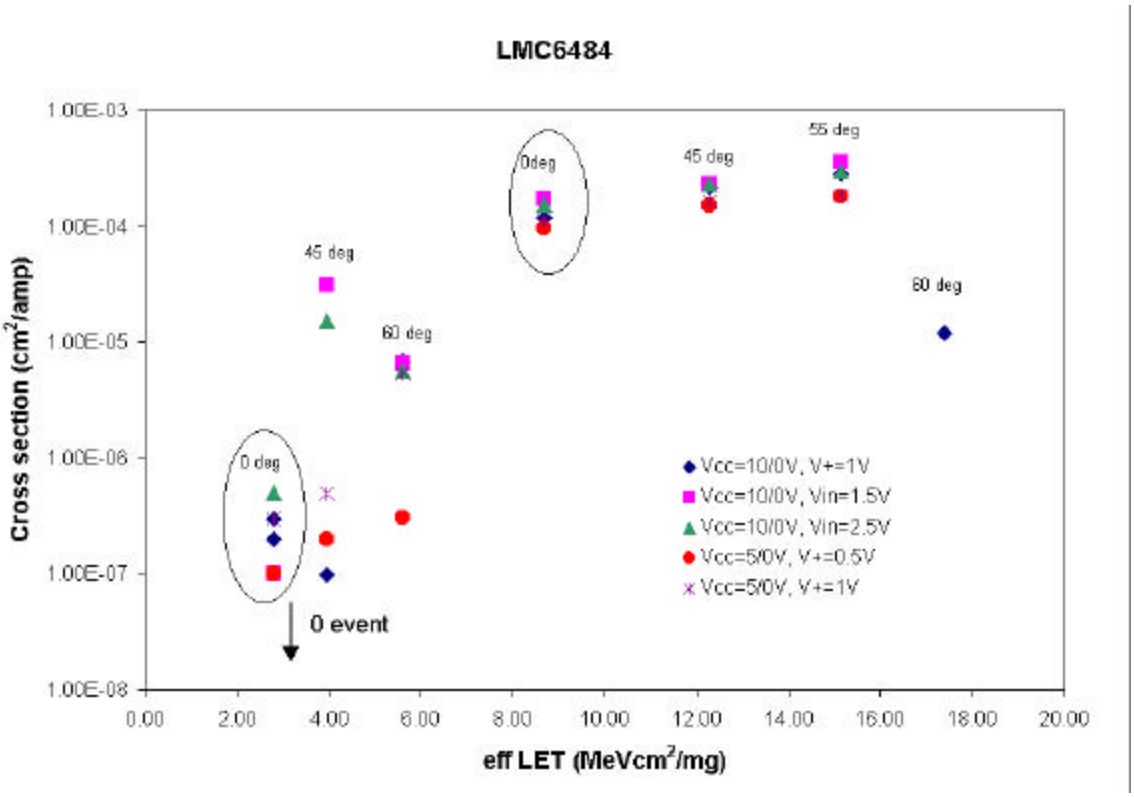

Figure 5: SET cross section curve.

Two different classes of transients have been observed. Typical waveforms are shown in Figures 6 and 7. All transients observed during this experiment have a small amplitude.

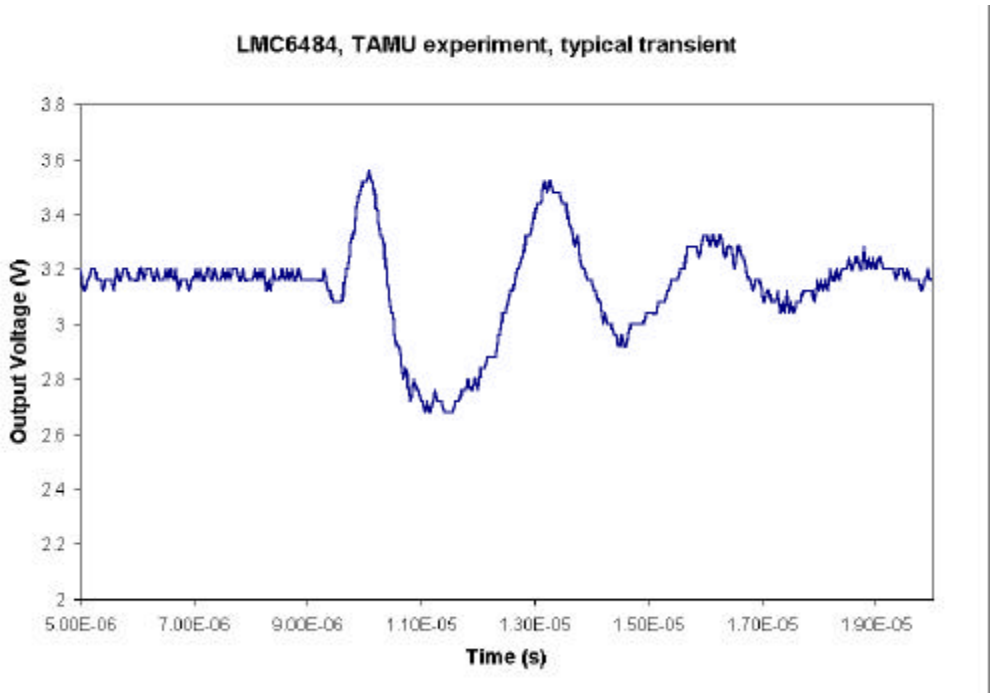

Figure 6: typical transient waveform 1

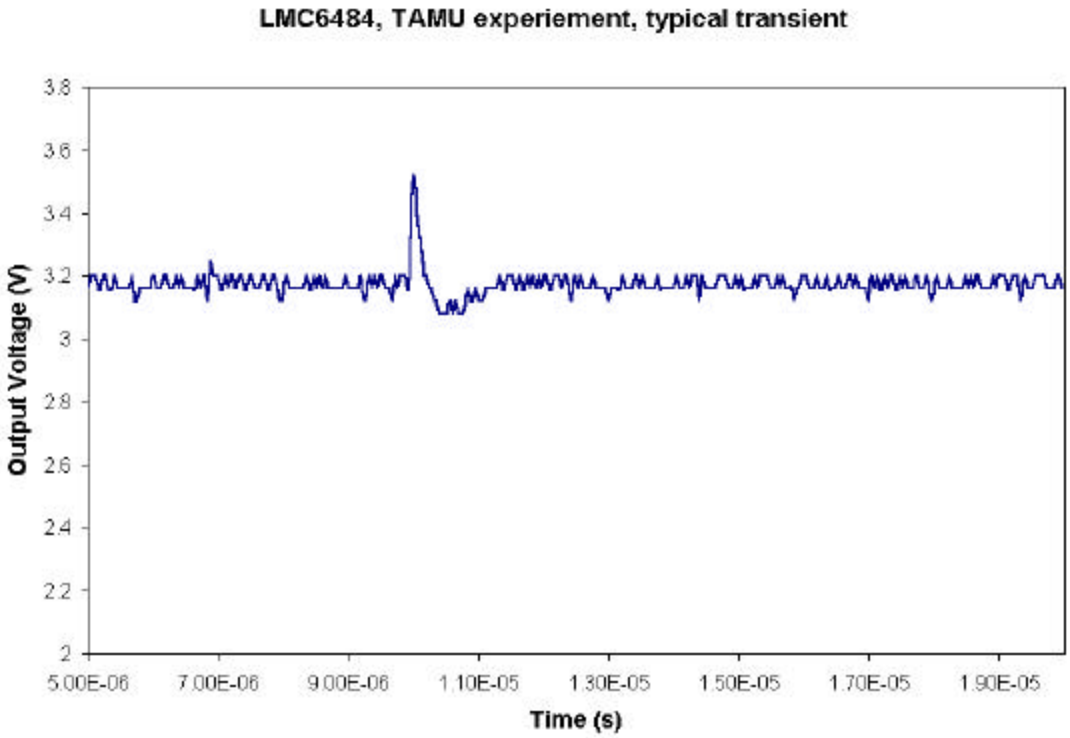

Figure 7: typical transient waveform 2

5 Laser experiments

5.1 Irradiation facility

Tests were performed at NRL in October 2002.

5.2 Test setup

The part has been tested in the voltage follower configuration as shown in Figure 1. Power supply voltage was +10/0V and the input voltage was 8V.
The device output is monitored by an oscilloscope. As soon as the device output deviates of more than 500 mV from the nominal output, a transient is counted and the transient frame is stored for further analysis. The DUT was connected to the oscilloscope with and without an active FET probe.

5.3 Test results

Different sensitive regions have been identified, but one large region is significantly most sensitive than the others. This is the only sensitive region at low energy.
Figure 8 shows the SET waveform obtained on this most sensitive region for different laser energies with and without the active FET probe. We can see that the set-up in this case does not have a significant effect on the waveforms. When the energy is increased the transient amplitude and duration increase.
At the energy corresponding to a 14 mV reading on the silicon diode (maximum tested energy), the SET amplitude is 8V and the duration is about 2 µs.
At the energy corresponding to a 7 mV reading on the silicon diode, we get a transient similar to the one obtained at BNL and shown in Figure 3.

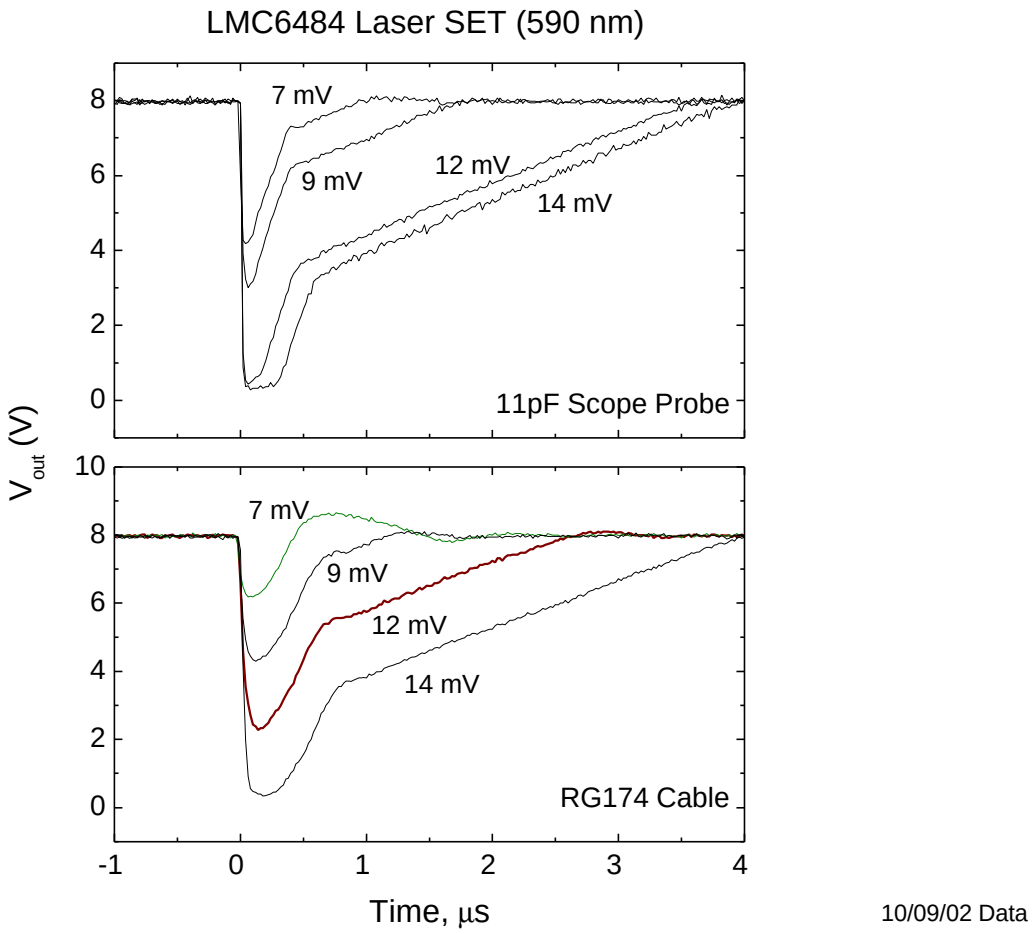

Figure 8: SET waveforms obtained with the laser on the most sensitive region.
Data collected with a 11pF scope probe (top curve) and without (bottom curve)

6 Conclusions

This preliminary heavy ion SEE test on LMC6484 shows that the part is not sensitive to SEL up to the maximum tested LET of 53 MeVcm2/mg.

BNL experiments show a moderate SET sensitivity for the test configuration (voltage follower). The part is not sensitive for a low input voltage close to the low supply voltage rail. The part shows its highest sensitivity for an input voltage at midway between the supply voltage rails. Then the sensitivity decreases for an input voltage close to the high supply voltage rail. All the SET are negative going transients.

The TAMU experiment data at lower LET values show only small amplitude SETs. The SET waveforms are significantly different to the ones obtained at BNL.

The large negative SET obtained at BNL have been reproduced by the laser. Laser experiment data show the strong effect of energy on the SET characteristics. They also show that the set-up does not have a significant effect on the waveform for this part.