PROJECT
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TITLE
SEE Evaluation of Pulse Width Modulators UC2843 and UC2845 from ST Microelectronics

EUROPEAN SPACE AGENCY
CONTRACT REPORT

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DOCUMENT CHANGE RECORD

Changes between issues are marked with an outside-bar.

Issue	Date	Paragraphs affected	Change information
1		All	New document
2	2010-06-21	Para 3.1	Add Wafer lot number
		Appendix	Correction of missprint
			Removal of RUAG Proprietary text

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1 ABSTRACT

This report presents the Single Event Effects results on two commercial Pulse Width Modulators manufactured by SGS Thomson Microelectronics in bipolar technology. The study has been performed under ESA contract 11407/95/NL Call-Off Order 11.

2 INTRODUCTION

The tested Pulse Width Modulator (PWM) controllers UC2843 and UC2845 are manufactured by ST Microelectronics and are pin and function compatible with the frequently used controllers UC1843 and UC1845 from Texas Instrument.

The tested devices include functions like error amplifier, oscillator circuit, output circuit, current limiting and internal reference voltage, but no soft start function. The complex nature of the PWM devices makes them usually sensitive to the DC/DC circuit design and the effect of heavy ion can be significant depending on implementation.

The present investigations have been guided by the set-ups and the results from previous tests [1,2]. The circuit design and the test samples have been proposed and provided by ESA [3]. The present investigations include heavy ion tests performed at the Heavy Ion Facilities in Louvain la Neuve/Belgium and Jyväskylä/Finland.

2.1 References

[1] Heavy ion effects in PWM's of the type UCC1806 and UC1825A, ESA_QCA0417S_C, Saab Space report D-P-REP-01388-SE, 2005

[2] Total dose and Single Event Effects in commercial PWMs and gate Drivers
ESA_QCA0822S_C, Saab Space report D-P-RAD-01218-SE, 2008

[3] Input to ST UC2843/45 test board, 10 Feb 2008 issue 3, Sven Landstroem /Estec

3 TEST SAMPLES

3.1 UC2843 / UC2845

UC2843/UC2845 is fixed frequency current mode controllers. Internally implemented circuits include under voltage lockout featuring start-up current less than 1 mA, a precision reference voltage, PWM comparator which also provides current limit control and a totem pole output stage designed to source and sink high peak current. The under voltage lockout threshold for UC2843 and UC2845 are 8.5V and 7.9V, respectively. UC2843 can operate to duty cycles approaching 100%, while UC2845 operate in the range zero to < 50% by addition of an internal toggle flip flop which blanks the output off every other clock cycle.

Part Type	UC2843/UC2845, Current mode controller with fixed switching frequency
Manufacturer	SGS Thomson Microelectronics
Date Code	Unknown, samples supplied by manufacturer
Quality	Prototypes
Bias Cond.	13V used during irradiation
Package	8-pin DIL 300mil

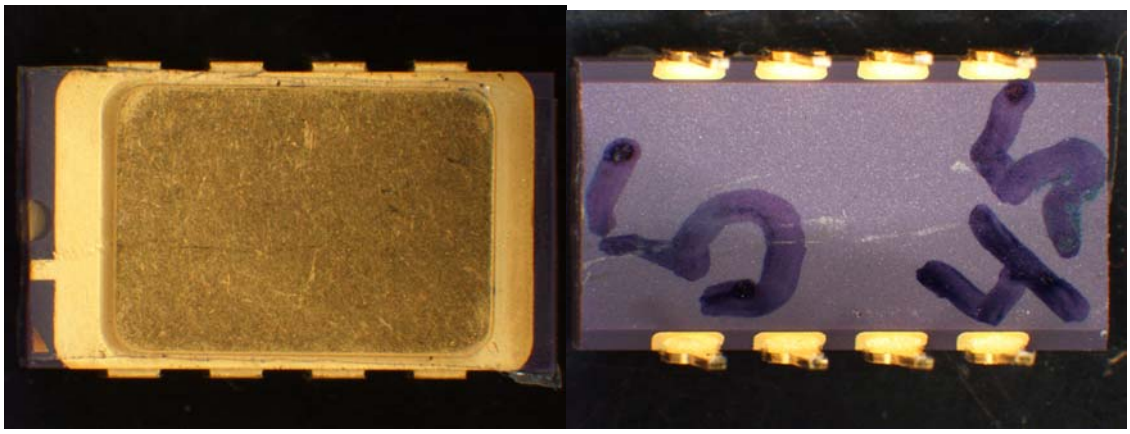

Fig. 3.1.1 Package top & bottom view. The marking on the bottom side indicate serial number #5 and type (UC28)45.

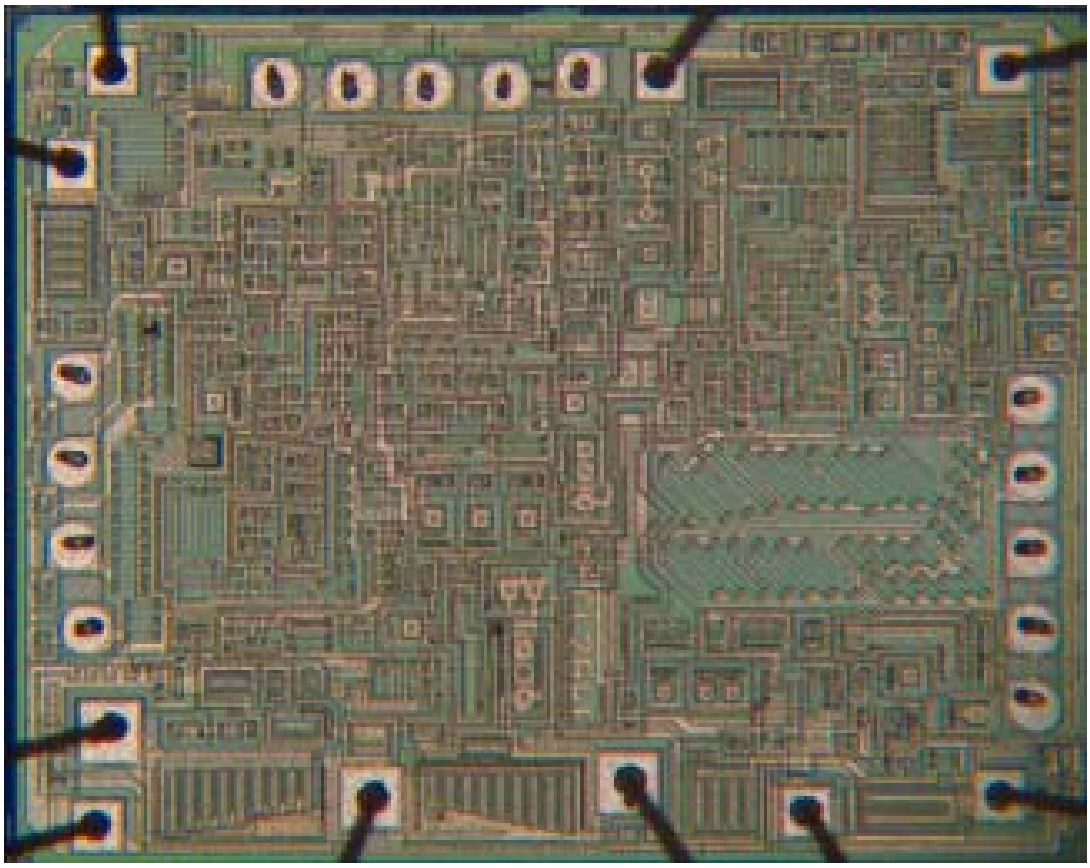

Fig 3.1.2 Overview of the UC2843 die

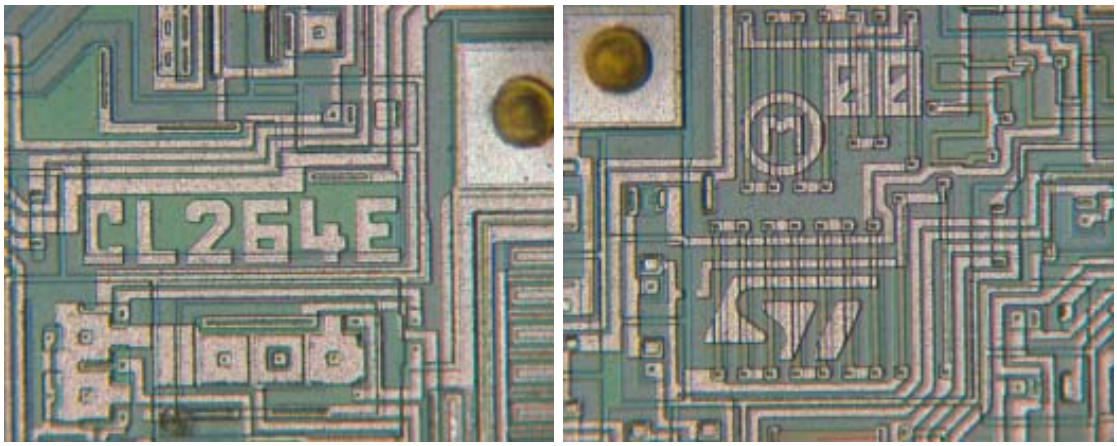

Fig 3.1.3 Close-up picture of the chip marking on UC2843

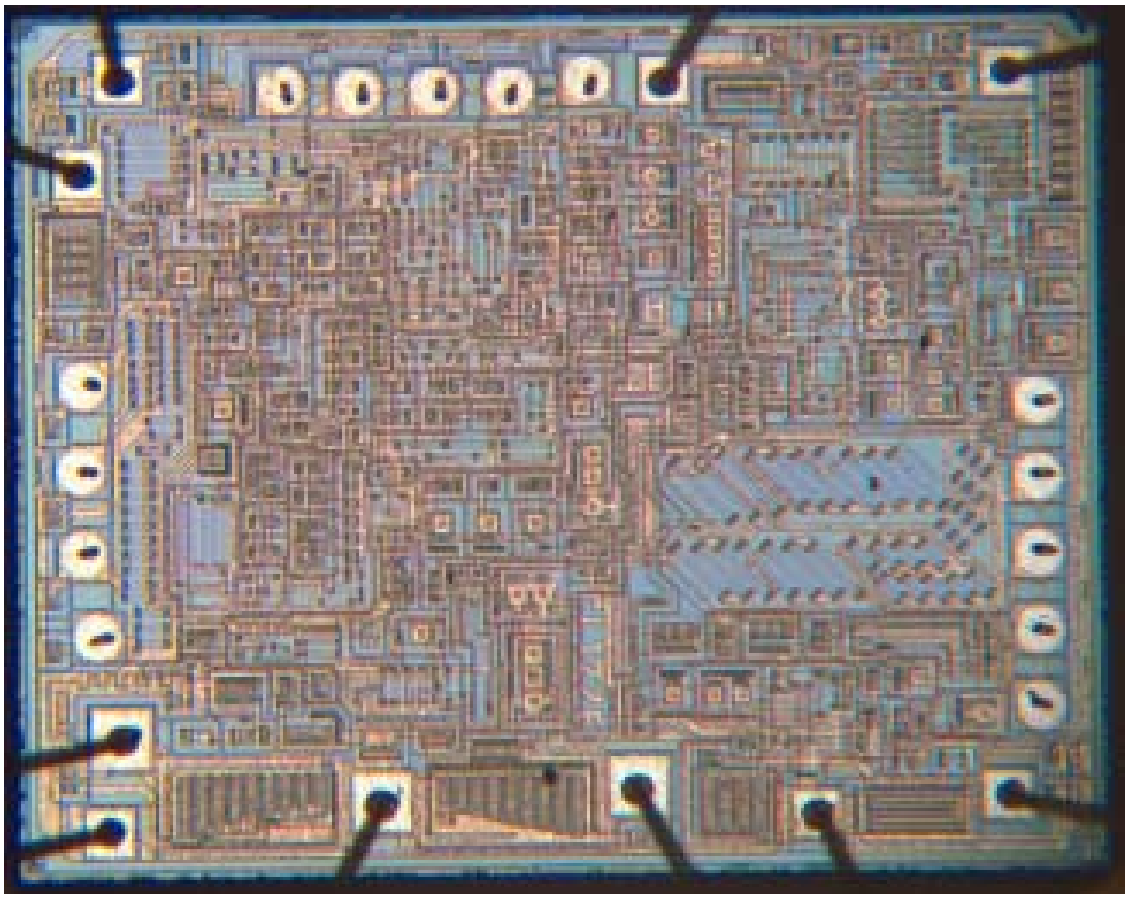

Fig 3.1.4 Overview of the UC2845 die

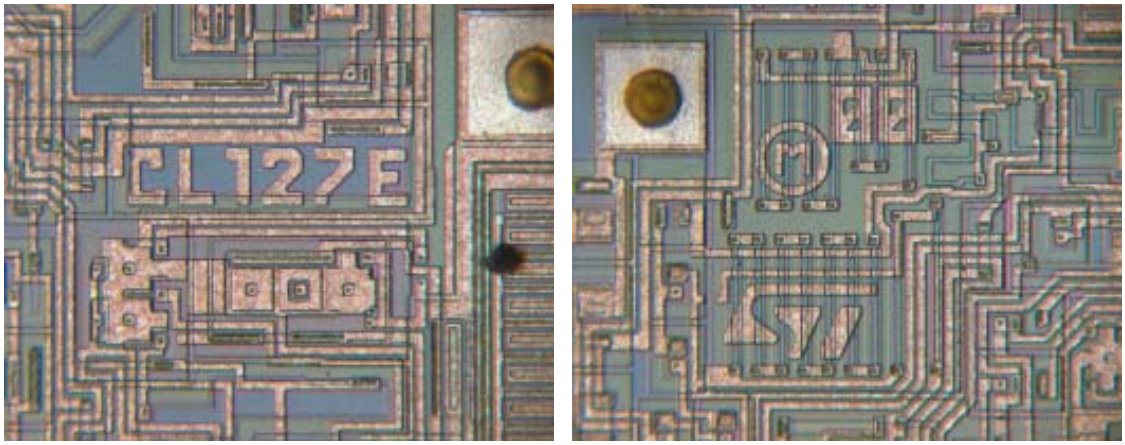

Fig 3.1.5 Close-up picture of the chip marking on UC2845

4 BIAS CONDITION AND TEST SETUPS

Single Event Transients (SET) was measured using two oscilloscopes (Tektronix TDS3054, 500 MHz, 5GS/s) with different trigger conditions given below. The test software was developed by use of “Labview software” for the GPIB communication between the computer and the oscilloscopes and to store all results.

The circuitry used for SEE tests is shown in Fig 4.1 and valid for both device types.

Nominal frequency for the irradiation tests has been 100 KHz with nominal ON-time of about 3.5 µs and nominal OFF-time of about 6.5 µs.

Signals and trigger conditions

Signal	Circuit Pin	Description	Trig condition
Vgate	5	PWM Output	Pulse OFF time ≥12 µs
Vgate	5	PWM Output	Pulse ON time ≥5 µs
Vref	8	Reference	Nominal value ± 0.3 V

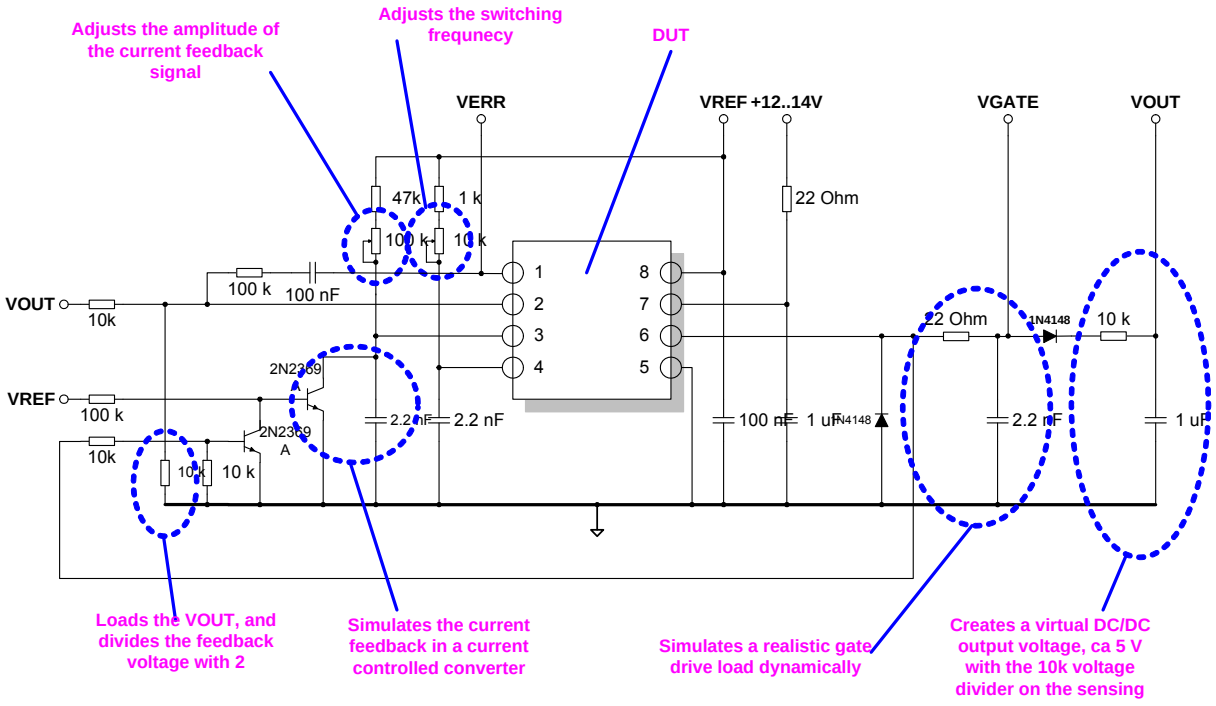

Fig 4.1 Basic Schematic drawing of the biasing of the PWM, the drawing is taken from ref [3]

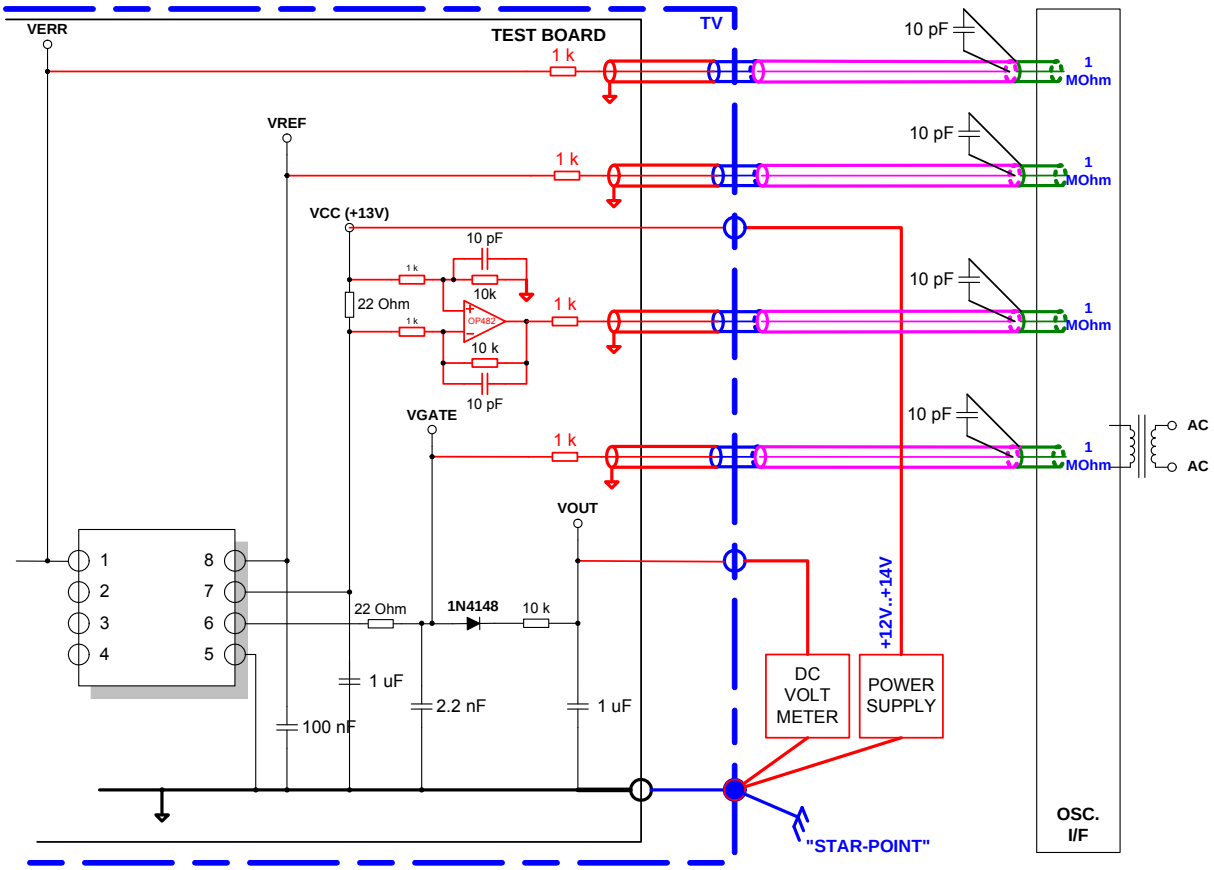

Fig 4.2 Test interface and grounding diagram used for the irradiation tests. The drawing is taken from ref [3].

4.1 Heavy Ion Test Facility

Heavy ion tests were performed at the HIF at Louvain la Neuve/Belgium and at RADEF in Jyväskylä/Finland. The ions used are given in Table 4.1.1. Test data as ion beam, LET, fluence and SET data for the various types are given in Appendix
In this report abbreviation JYKL refer to RADEF in Jyväskylä/Finland and UCL refer to HIF at Louvain la Neuve/Belgium

TABLE 4.1.1

HEAVY IONS USED AT RADEF JYVÄSKYLÄ

Ion	Energy [MeV]	LET^{SRIM} @surface [MeV/mg/cm2]	$Range^{SRIM}$ [microns]
$^{20}Ne^{+6}$	186	3.6	146
$^{40}Ar^{+12}$	372	10.1	118
$^{56}Fe^{+15}$	523	18.5	97
$^{82}Kr^{+22}$	768	32.1	94
$^{131}Xe^{+35}$	1217	60.0	89

HEAVY IONS USED AT LOUVAIN LA NEUVE IN BELGIUM

Ion	Energy [MeV]	LET^{SRIM} @surface [MeV/mg/cm 2]	$Range^{SRIM}$ [microns]
$^{82}Kr^{+17}$	316	34	43
$^{131}Xe^{+26}$	459	60	43

5 RESULTS

No latch-up was detected for UC2843 and UC2845 up to an LET of 85 MeV/mg/cm^2 for a total fluence of 1E+7 ions/cm^2.

No heavy ion strikes resulted in interrupt where the PWM's were out of function longer time than 30µs. The interruption time was independent on used operating frequency.

SET oscilloscope waveforms for both types of typical and worst case pulse profiles for the measured LET values are given in Paragraph 5.2.
SET Cross section curves as a function of LET values are given for specific settings in paragraph 5.3
SET results are presented as histograms of too long "OFF-time" and too long "ON-time" on the PWM output in paragraph 5.4.

The dead time in the recording system is kept low by adjusting the beam flux.

5.1 Test Details

Two devices of each type have been tested. UC2845 have been characterized at all selected LET values, while the SEE behaviour of UC2843 have been verified towards the UC2845 results at about every second selected LET value.

Samples were tested at 100 kHz on output with a duty cycle of about 30%.
The main SET trigger conditions have been on too long OFF -and ON-time on the Output of the PWM.

The oscilloscope waveforms presented below are saved via a GPIB-bus.

For each test run about 100 SET events were collected. The time distributions for too long OFF time and ON time on the Output are given below for various LET values.
The oscilloscope trigger conditions have been:

- Too long "Off time" ; Output signal low > 12µs
- Too long "On time" ; Output signal high > 5µs

For operation in 100 KHz this means one missed pulse for "too long OFF time" and about 30% longer pulse for "too long ON time".

All collected waveforms from the oscilloscope are afterwards analysed and too long "OFF-times" and too long "ON-times" are calculated and presented in histogram. The definition of a true OFF event is given by the oscilloscope trigger conditions, if the pulse height is less than 60% of nominal pulse and if the pulse duration is less than 1.5µs. In Fig 5.1.1 below the total OFF-time is calculated to be 27µs which means that the smaller pulses marked with arrows are filtered out.

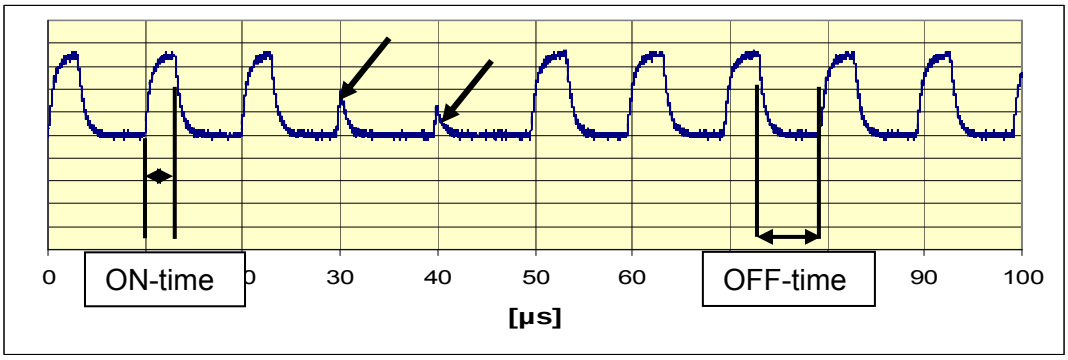

Fig. 5.1.1 Oscilloscope graph from the output of the UC2845 showing the principal for calculating the length of the too long OFF-time.

In those cases where the events are leading to change in the duty cycle the definition of the length of such an event is given if a pulse drop is less than 60% of the nominal drop and if the duration is less than 1.5µs. Such an event will be given as a too long ON-event. A typical event is shown in Fig 5.1.2 below. The drops at the arrows are filtered out.

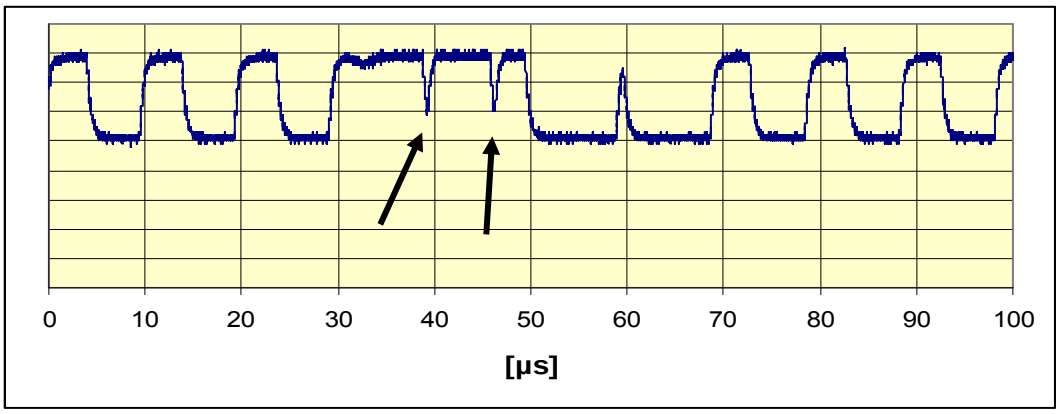

Fig. 5.1.2 Oscilloscope graph from the output of the UC2843. The small pulse drops marked by the arrows are filtered out according to the definitions above and the "ON-time" is here calculated to be 21µs.

5.2 Typical SET Events for UC2843 / UC2845

The results are shown as oscilloscope pictures of typical heavy ion events. In each figure, the oscilloscope has been triggered by one specific condition (given in the Figure caption) with other signals followed. For each trigger set-up, about 100 SET's have been recorded. The shown pictures are selected as representative SET from heavy ion strikes.

The probabilities for critical transients are closely linked to the implementation of the PWM and the design of the DC/DC converter. The design used in these tests is given in paragraph 4 together with the detailed trigger conditions.

A block diagram of UC2845 is shown in Fig 5.2.1. The two device types UC2843 and UC2845 are in principle build up of identical blocks with the difference that UC2843 can operate to duty cycles approaching 100%, while UC2845 operate in the range zero to < 50% by addition of an internal toggle flip flop which blanks the output off every other clock cycle. The monitored signals are indicated in the block diagram.

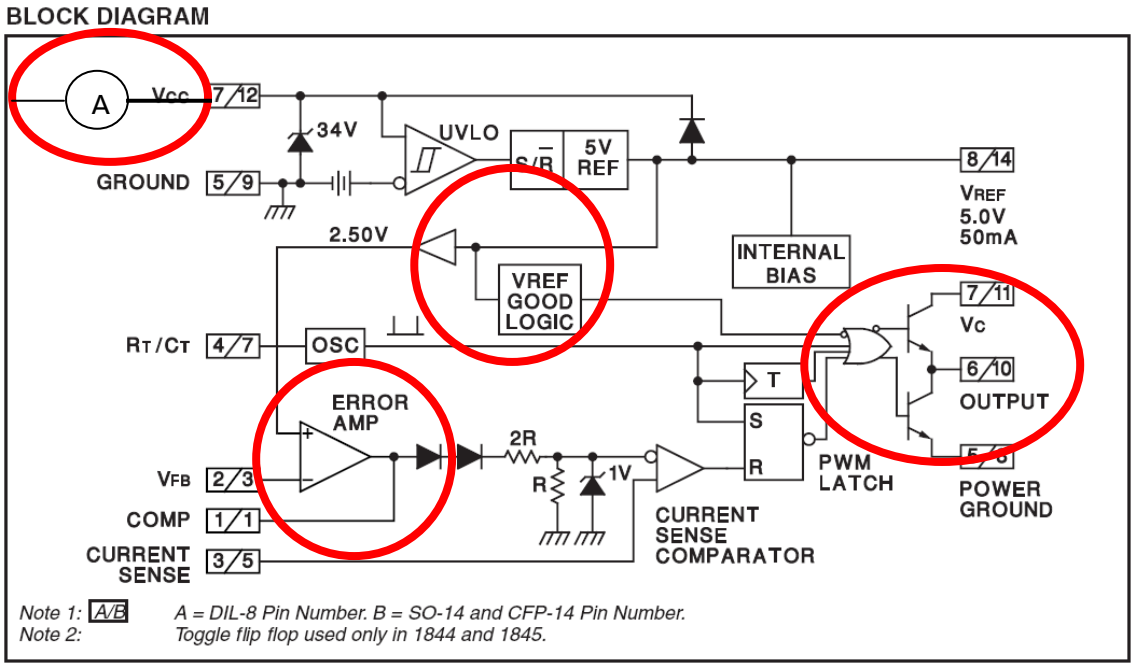

Fig 5.2.1 Block diagram of UC2845. The different functions monitored during irradiations are marked with red circles.

In all tests the shape of the signals Output, Error Amplifier (E.A.), Voltage Reference (Vref) and Supply Current (Supply Curr.) were recorded for each event.
In general, the oscilloscopes were set to trigger on SET on the Output signal while the Vref, Supply Current and E.A. were monitored. Verification runs with trigger conditions on Vref and Supply Current were performed but no type of events were observed that were not observed when triggering on the Output.

The most abundant SET with “too long OFF time” in UC2845 results in the loss of one output pulse as shown in Fig 5.2.2. In this SET all other signals have also been upset as well. The upset of Error Amplifier (E.A.), Voltage Reference (Vref) and abnormal Supply Current (Supply Curr.) is depending on where on the chip the SET is initiated. In the present investigations it seems as the Output always are affected, while the other signals may vary. Different SET scenarios are shown in Figs 5.2.2-5.2.5 with the same effect on the Output. In the figures the trigger has been on the Output with the other signals following. In verification tests triggering on E.A, Vref and Supply Current no difference in SET behaviour on the Output could be observed.

A representative picture of the worst case SET is shown in Fig 5.2.6. The maximum OFF time measured was about 25 µs. The UC2845 was tested at both half and double frequency and the total OFF time seem to be independent on operating frequency.

Typical “too long ON time” is shown in Fig 5.2.7. In a majority of all registered too long ON time, a too long OFF time is followed as shown in Fig 5.2.7. A few events have the Output shape shown in Fig 5.2.8 where the ON time is more or less correct but the duty cycle in one period has been changed. The maximum ON time measured is about 8µs.

An example of triggering on Vref is given in Fig 5.2.9. In the picture it can be seen that the trigger-start of Vref give rise to a too long OFF time which is shorter than the 12µs requirement used for the Output trigger. However, a majority of short OFF times seem to be followed by a long OFF time (>12µs) generated by the “swing-in” of the E.A or/and Vref.

Various verification tests with modified design and bias set-up were performed with Xe ions. Results from running the set-up in double frequency are given in Figs 5.2.11 and 5.2.12 where a worst case example of SET is shown. The OFF time were found to be more or less independent on frequency while the ON time showed more repeating of pulses without proper period in between.

Change of current feedback to maximum specified values where not possible with the selected design and set-up.

The SET behaviour of UC2843 resembles the results from UC2845 very much. Worst case UC2843 events are shown in figure 5.2.10-5.2.12 operating the PWM at 100 kHz and 200 kHz. The shift in duty cycles seem to be doubled by the frequency but the total ON or OFF time seem to stay constant.

To operate the devices on 20V operating voltage instead of the 13V, used in all other runs, had no effect on the SET behaviour. Results from a test run on 20V are shown in Fig 5.2.13.

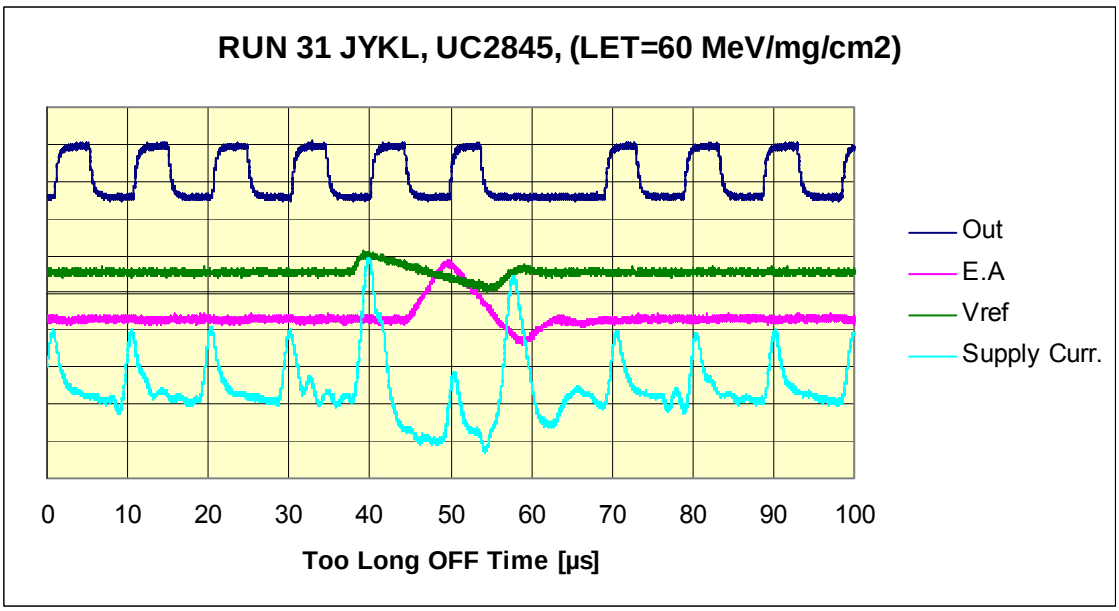

Fig 5.2.2 UC2845, Too long OFF time triggered by Output with E.A, Vref and Supply Current effected by the event.

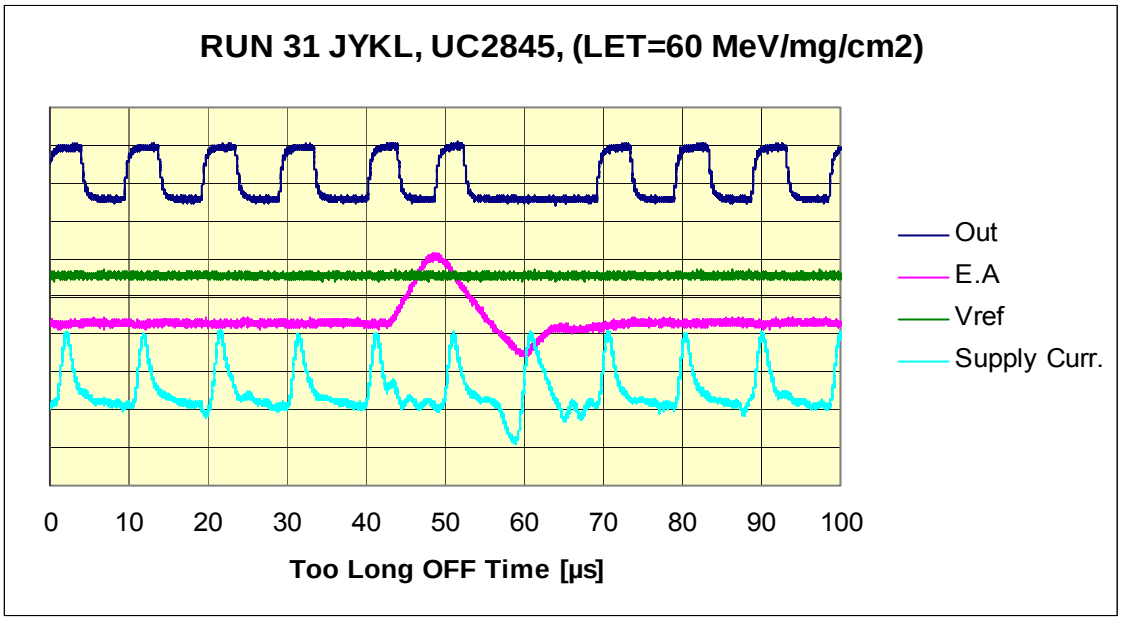

Fig 5.2.3 UC2845. Too long OFF time triggered by Output with EA effected

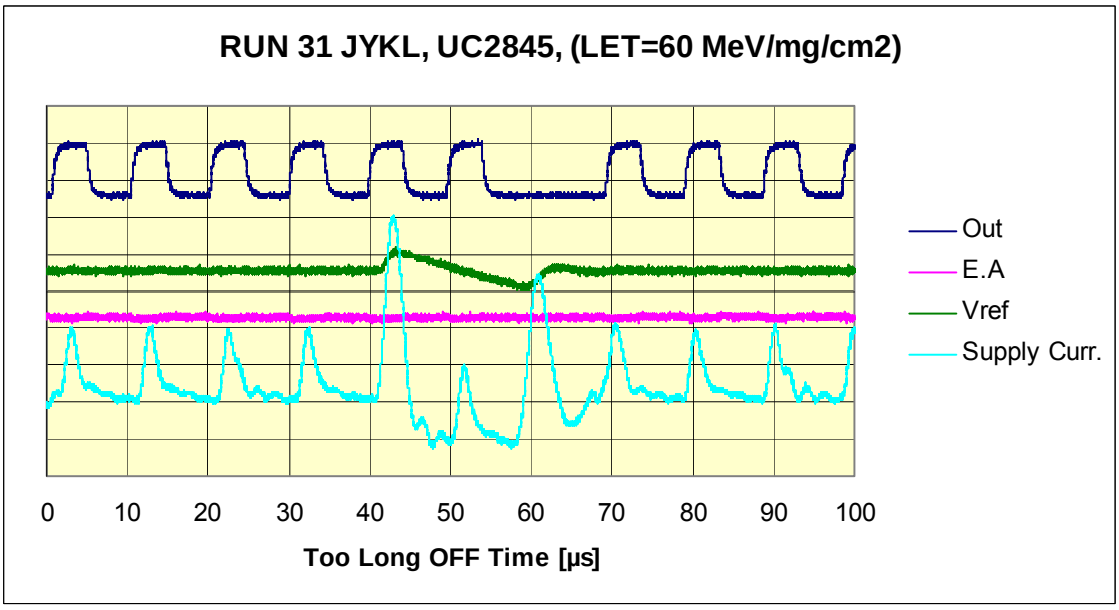

Fig 5.2.4 UC2845. Too long OFF time triggered by Output with Vref and Supply Current effected

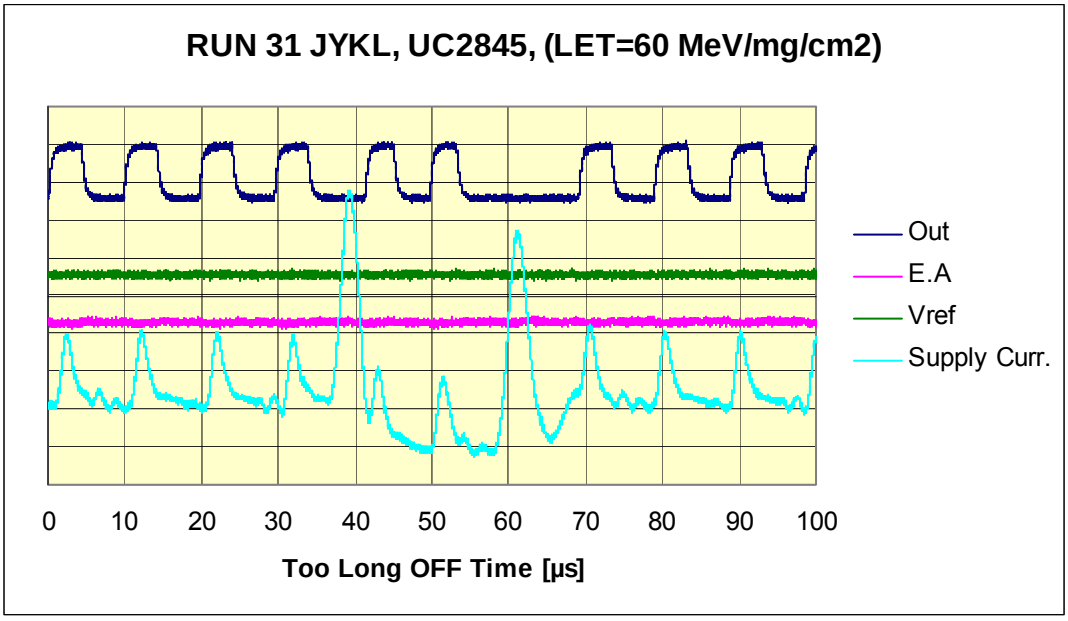

Fig 5.2.5 UC2845. Too long OFF time triggered by Output with Supply Current effected

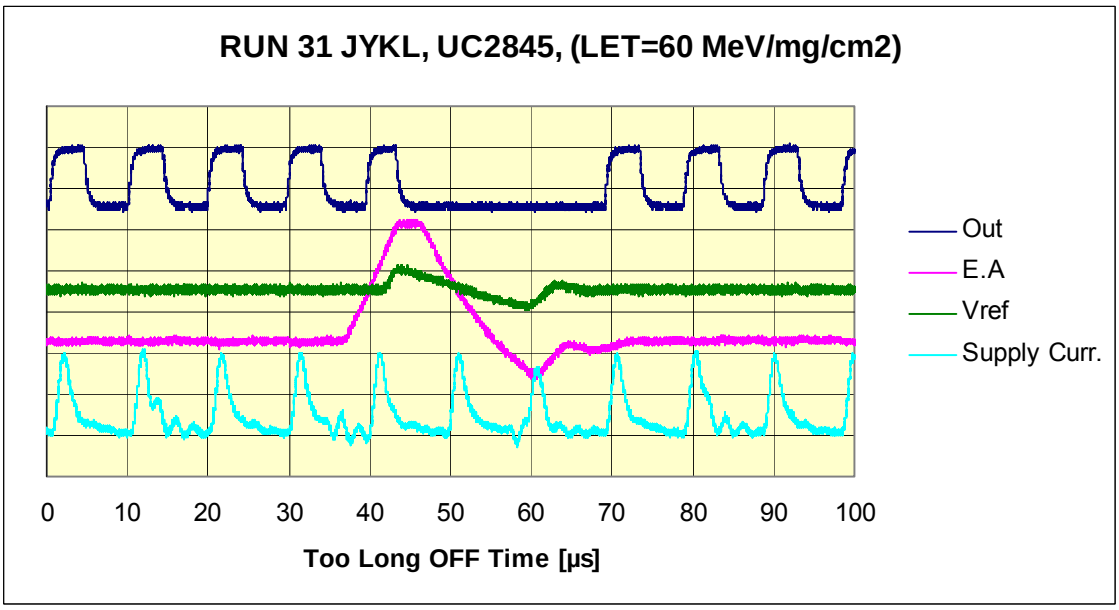

Fig 5.2.6 UC2845. Too long OFF time triggered by Output where two pulses have been missed. This oscilloscope picture represents typical SET with OFF time around 25µs.

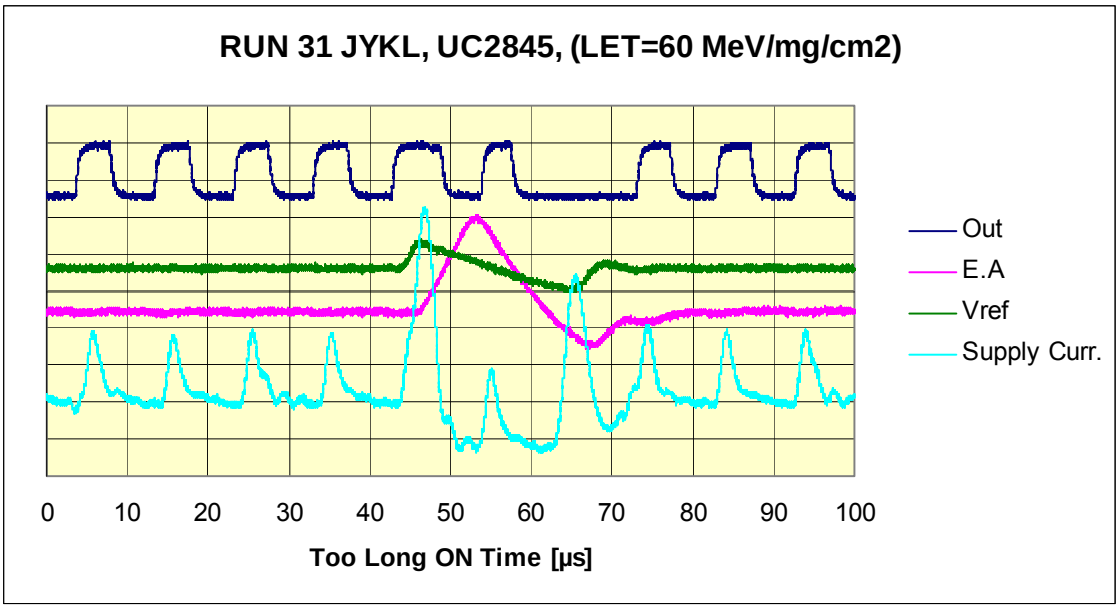

Fig 5.2.7 UC2845 Too long ON time triggered by Output. Too long ON time pulses were often followed by a too long OFF time.

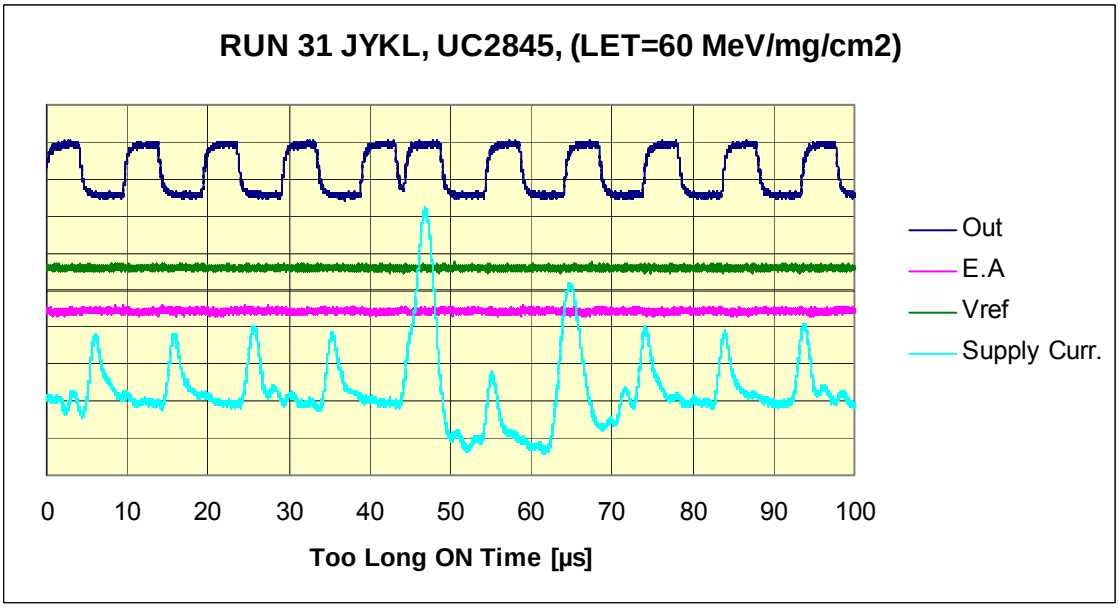

Fig 5.2.8 UC2845 Too long ON time triggered by Output. This type of event indicates a change in duty cycle for one period only.

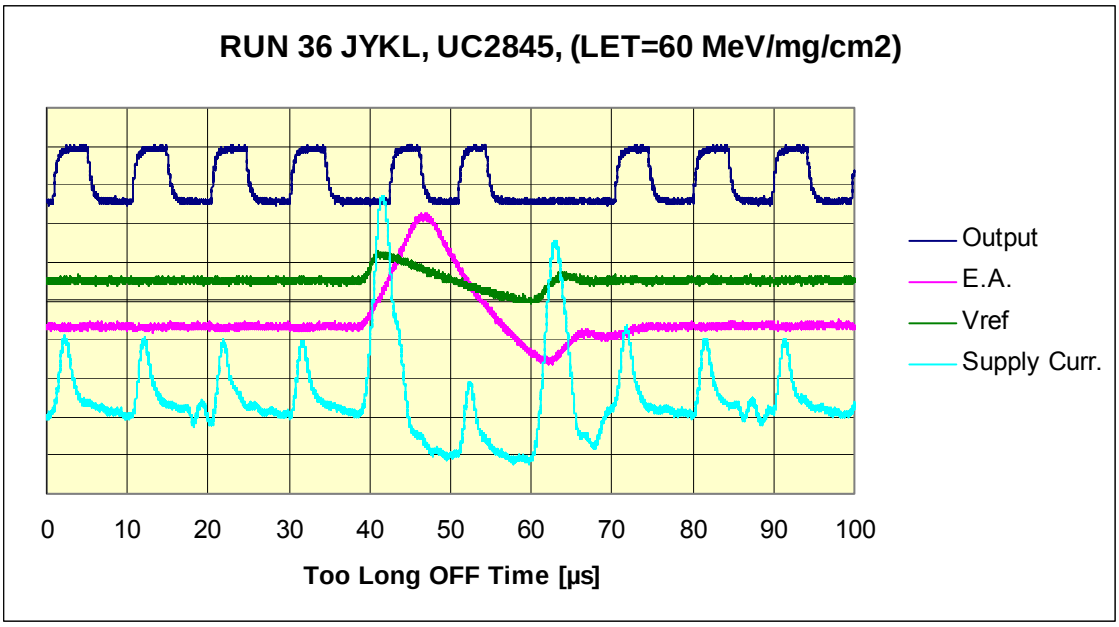

Fig 5.2.9 UC2845 Example of SET triggered by Vref

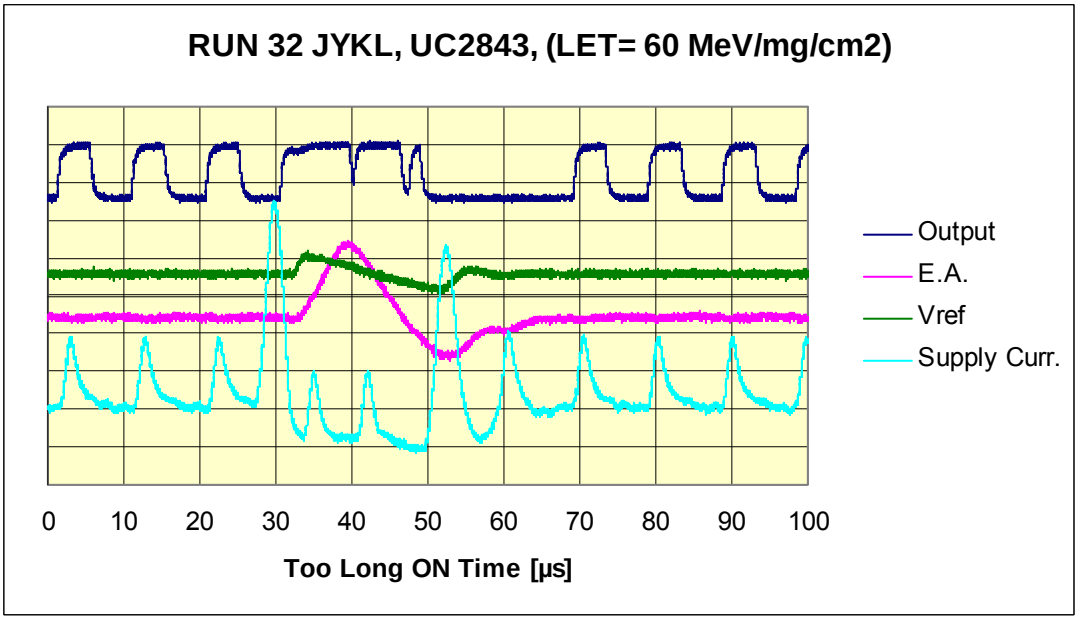

Fig 5.2.10 UC2843 @ 100kHz; Worst case SET triggered by the Output.

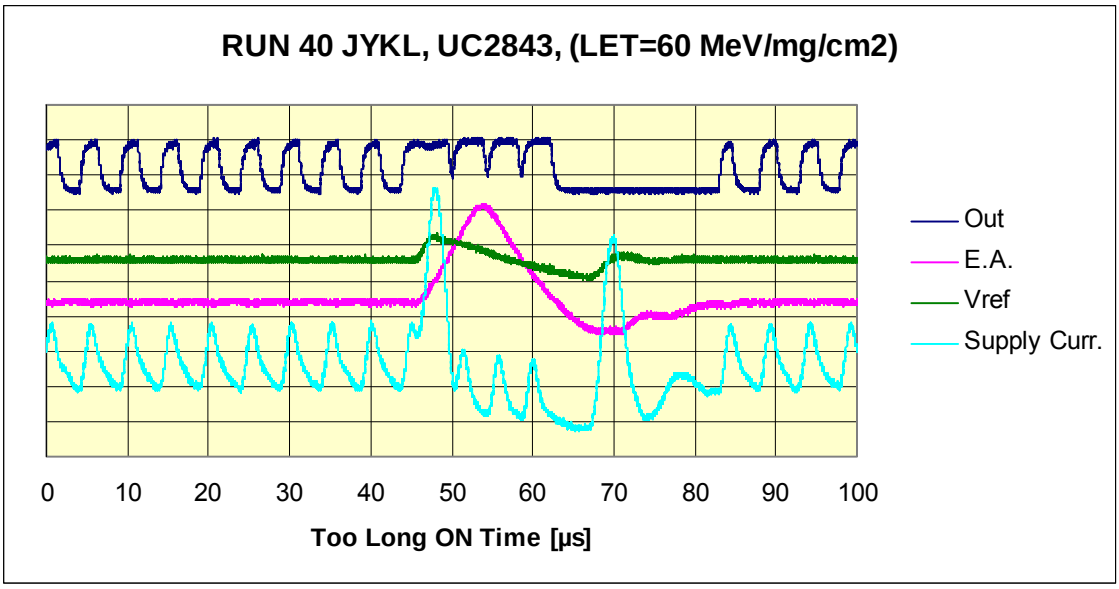

Fig 5.2.11 UC2843 @ 200 kHz; Worst case SET triggered by too long ON time on the Output. Doubling of the frequency only seem to double events affecting the duty cycle while the observed ON and OFF times are about constant in length.

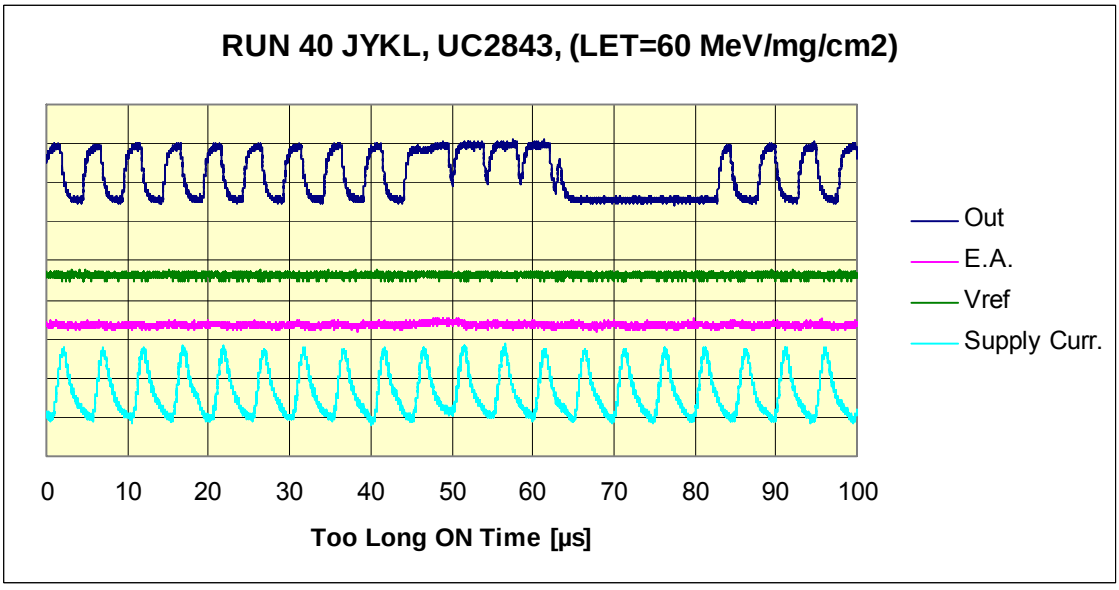

Fig 5.2.12 UC2843 @ 200 kHz; same type of Output pulse as in Fig 5.2.11 but all other signals are unaffected.

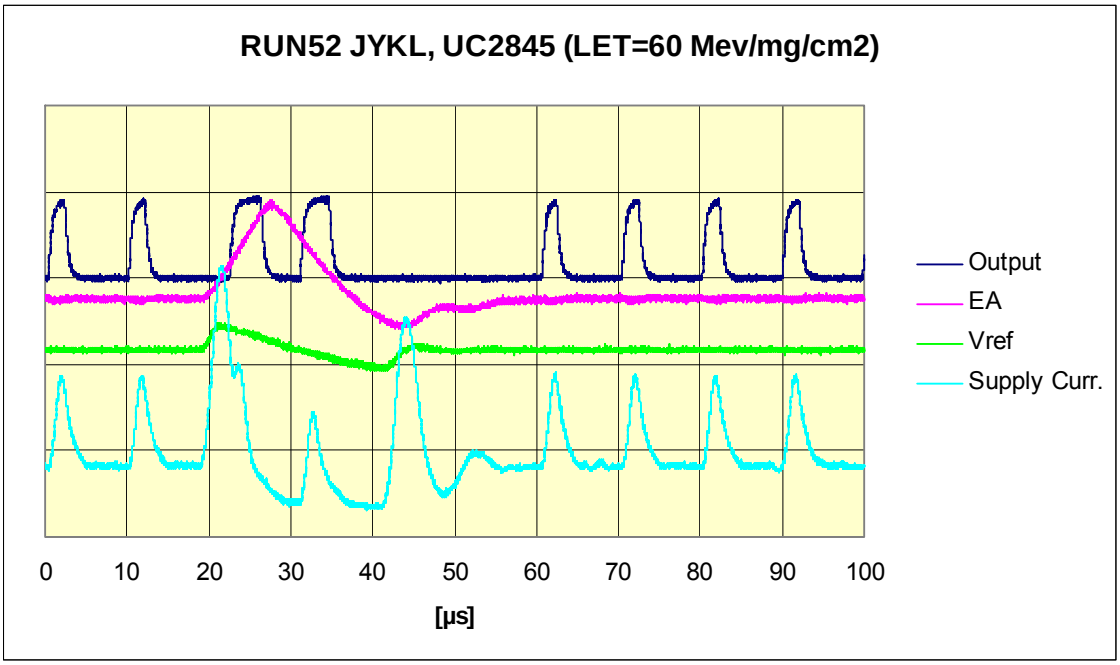

Fig 5.2.13 Oscilloscope picture of SET in UC2845 triggered by Output with 20V supply voltage.

5.3 Cross Sections

Cross sections for various SET pulses for both too long ON and OFF times are given below. The cross sections are determined from data given in Appendix 1 and the defined pulse interpretations given in paragraph 5.1

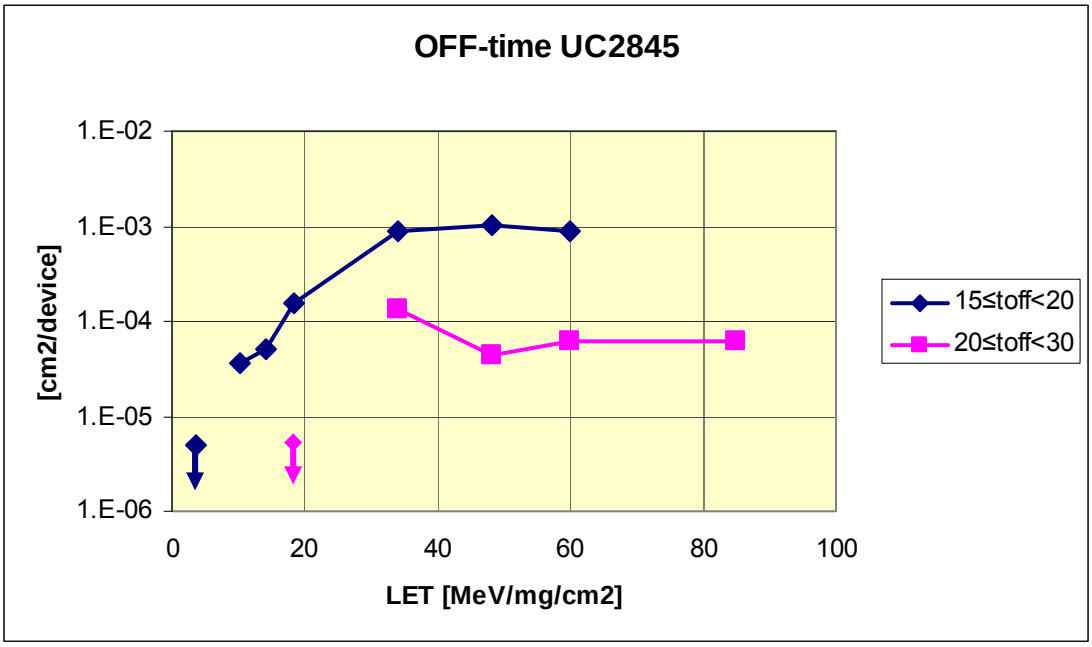

Fig 5.3.1 Too long OFF time cross sections as a function of LET for UC2845.

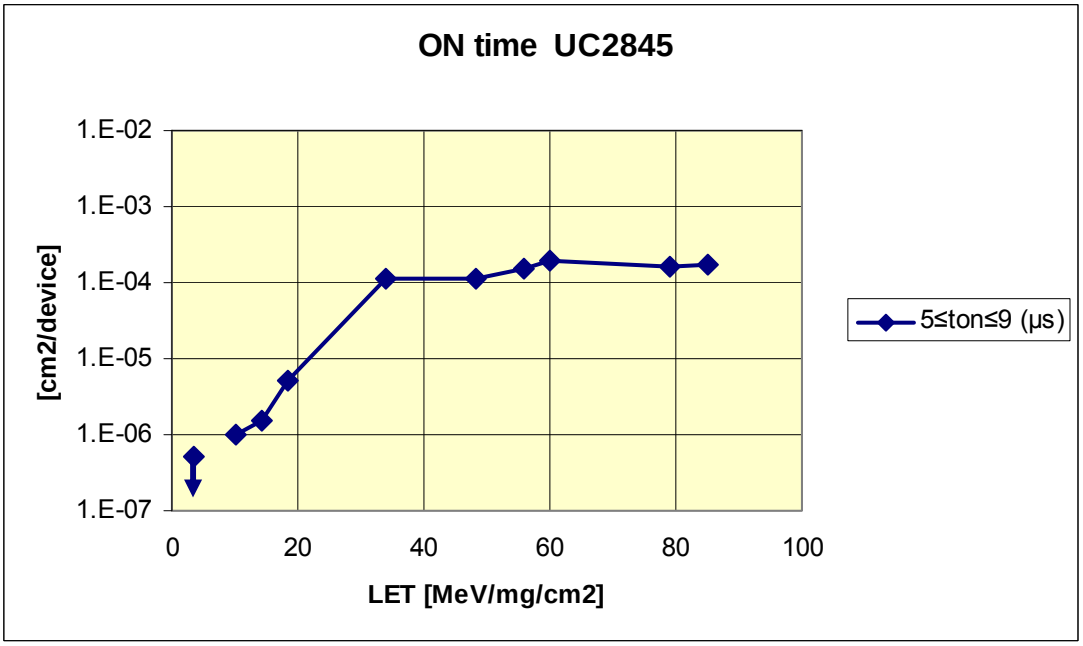

Fig 5.3.2 Too long ON time cross sections as a function of LET for UC2845.

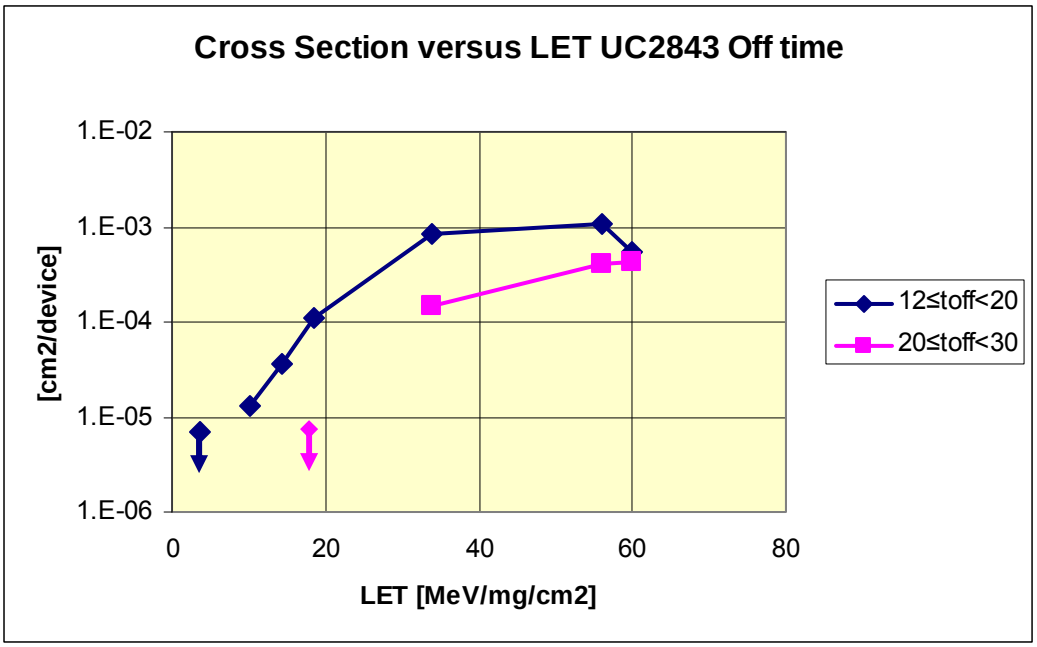

Fig 5.3.3 Too long OFF time cross sections as a function of LET for UC2843.

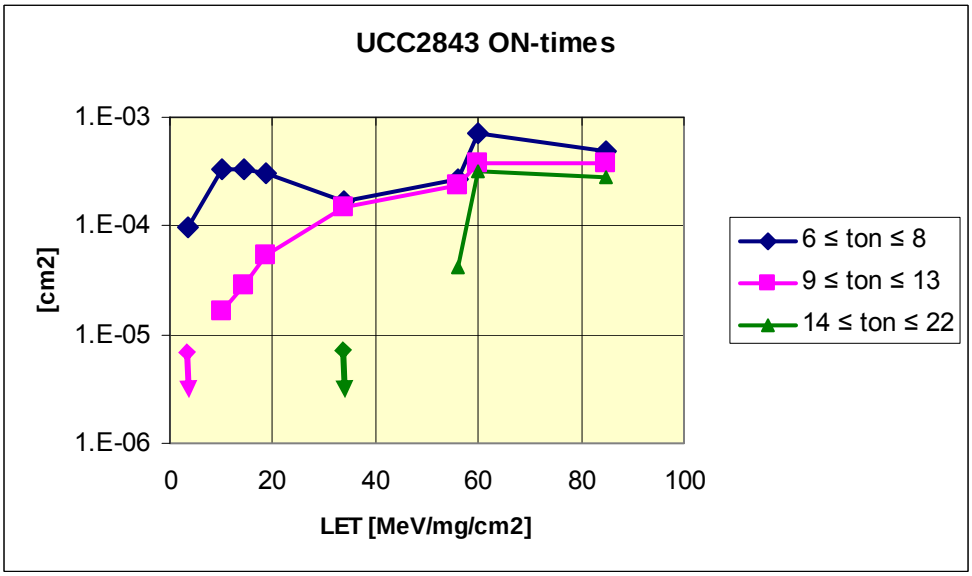

Fig 5.3.4 Too long ON time cross sections as a function of LET for UC2843.

5.4 SET Pulse Length Histograms

Too long OFF time pulses are more frequent than too long ON time pulses and also the too long ON time only change with a few µs, while the OFF time have been detected up to 28µs.
For UC2845 and UC2843 too long OFF time histograms are shown in Figs 5.4.1-5.4.9 for the LET range 14 - 60 MeV/mg/cm2. In Figs 5.4.10 and 5.4.11 too long ON time histograms for ^{131}Xe (LET=60 MeV/mg/cm2) are presented. Figs 5.4.12 and 5.1.13 shows good statistic of too long OFF time histograms, when the oscilloscope trigger condition was set to ≥22µs, which means a minimum of 2 lost pulses at 100 KHz.
Irradiations have been performed at both JYKL and UCL. In Figs 5.4.8 and 5.4.9 histograms showing the results for UC2843 and ^{131}Xe from the two facilities are compared.
Histograms showing the distribution for 20V bias condition are given in Figs 5.4.14 and 5.4.15.
In all histograms below the headings “JYKL” refer to RADEF in Jyväskylä and “UCL” refer to HIF in Louvain la Neuve.

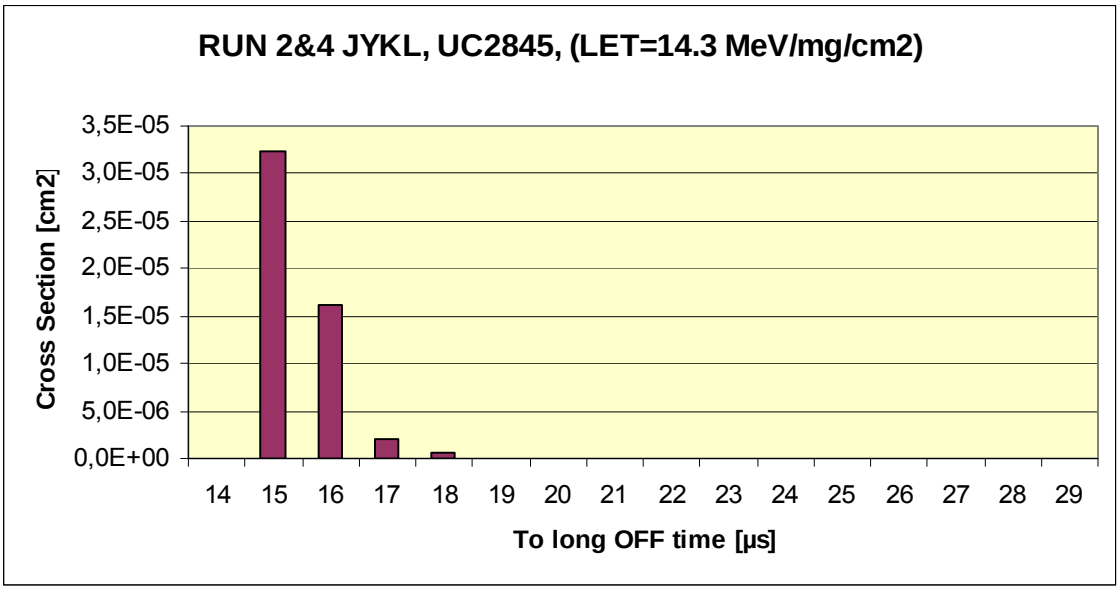

Fig 5.4.1 UC2845 histogram of too long OFF time as a function of the cross section. Irradiation in JYKL with ^{40}Ar at 45° (LET=14.3 MeV/mg/cm2).

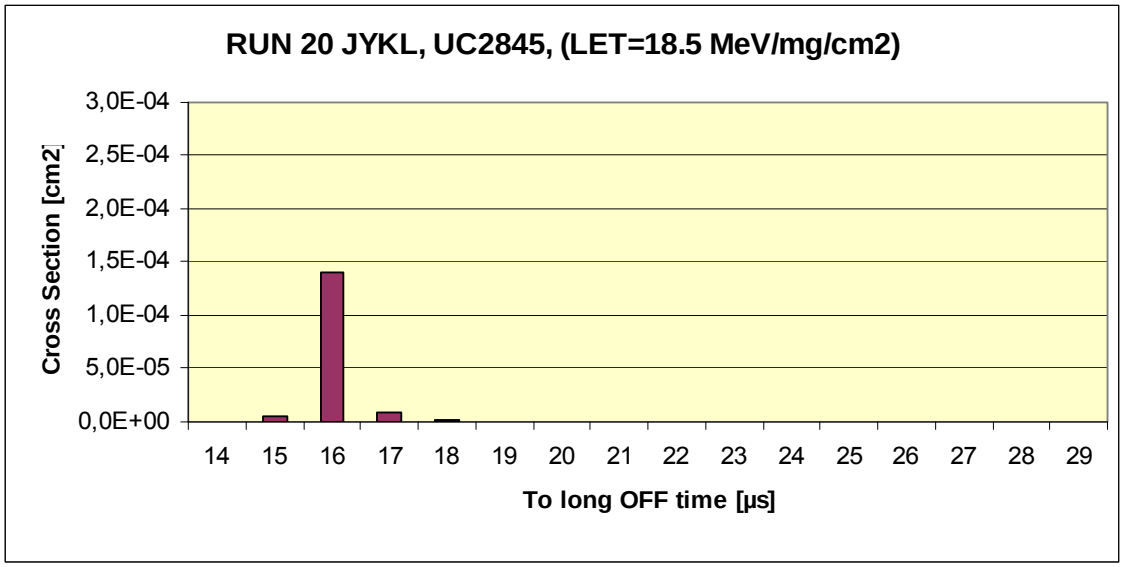

Fig 5.4.2 UC2845 histogram of too long OFF time as a function of the cross section. Irradiation in JYKL with ^{56}Fe at 0° (LET=18.5 MeV/mg/cm2).

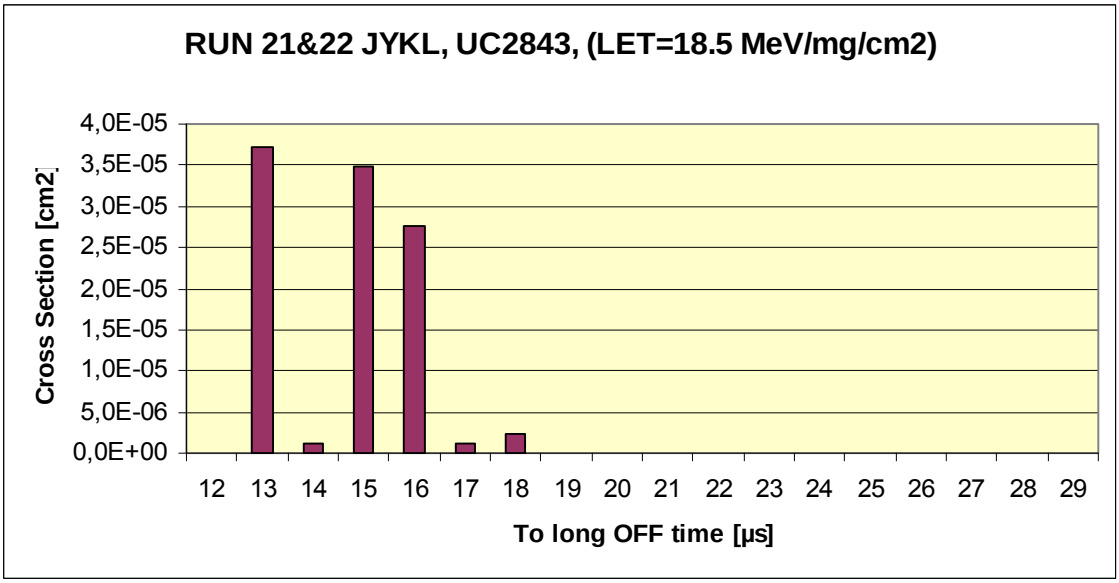

Fig 5.4.3 UC2843 histogram of too long OFF time as a function of the cross section. Irradiation in JYKL with ^{56}Fe at 0° (LET=18.5 MeV/mg/cm2).

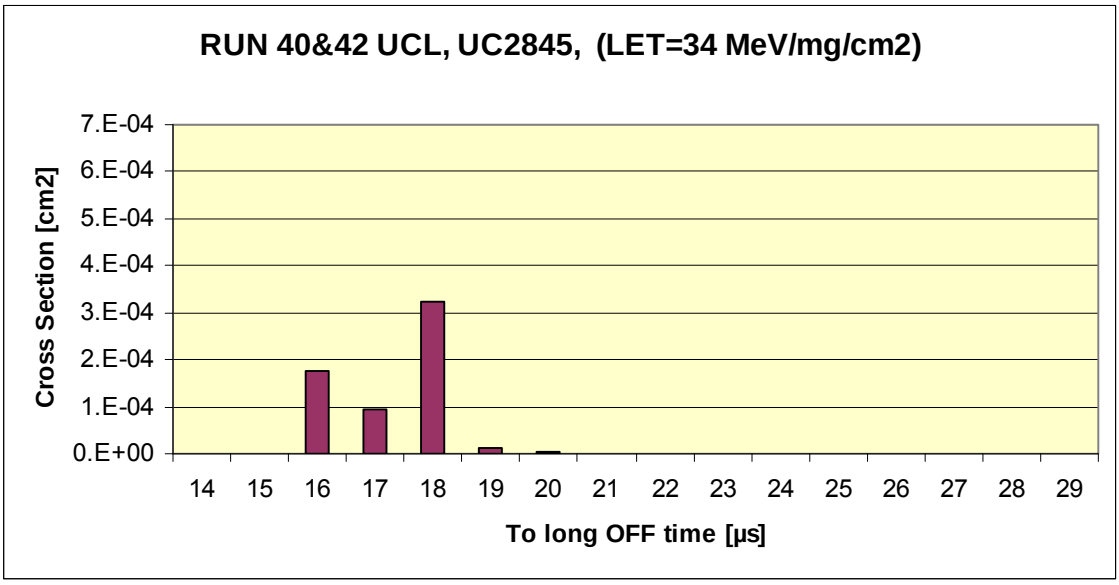

Fig 5.4.4 UC2845 histogram of too long OFF time as a function of the cross section. Irradiation at UCL with ^{82}Kr in 0° (LET=34 MeV/mg/cm2).

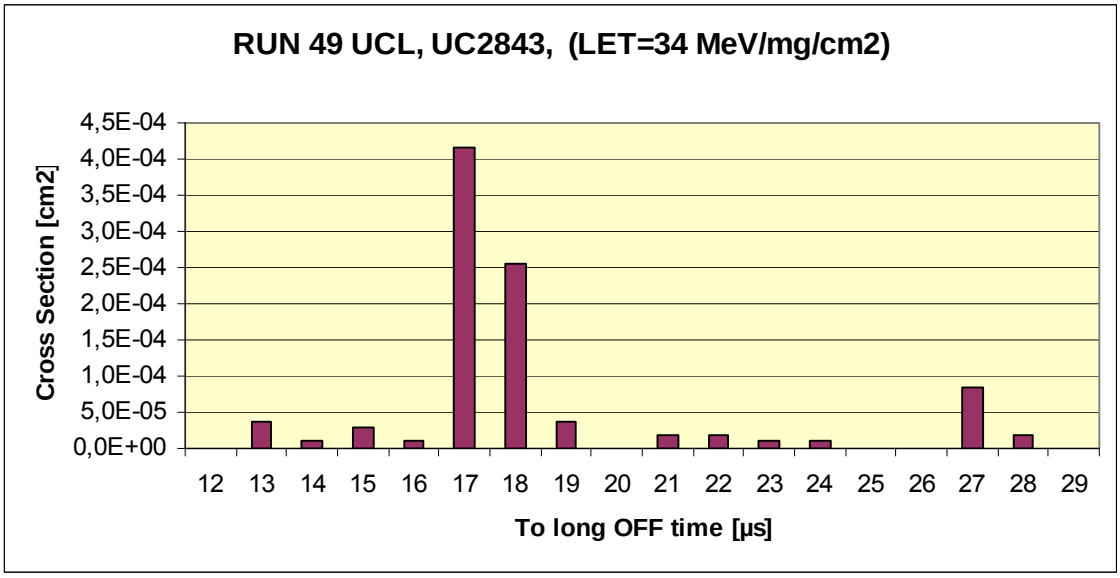

Fig 5.4.5 UC2843 histogram of too long OFF time as a function of the cross section. Irradiation at UCL with ^{82}Kr in 0° (LET=34 MeV/mg/cm2).

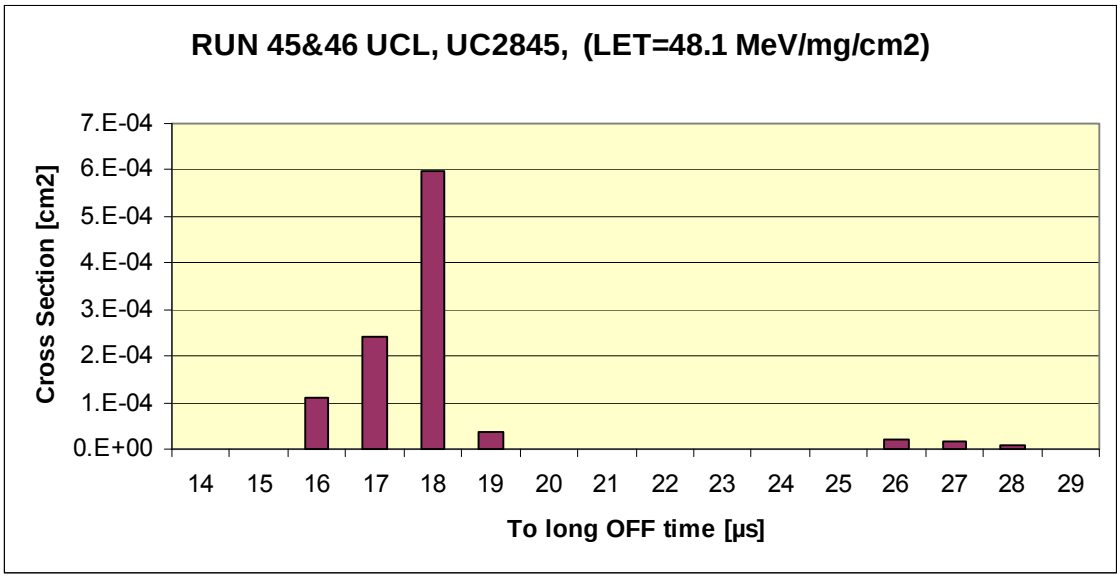

Fig 5.4.6 UC2845 histogram of too long OFF time as a function of the cross section. Irradiation at UCL with ^{82}Kr in 45° (LET=48.1 MeV/mg/cm2).

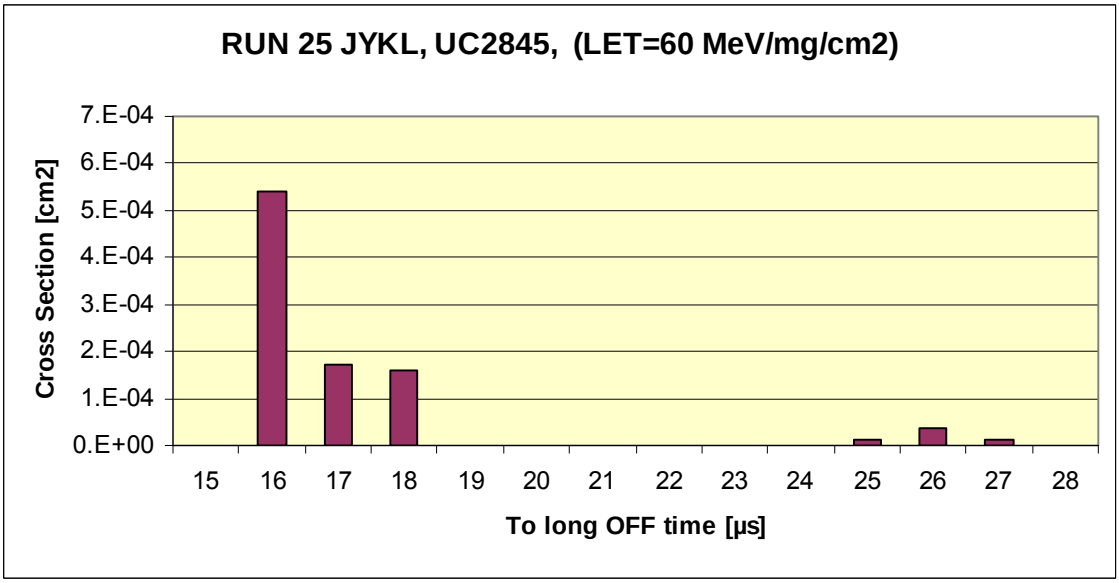

Fig 5.4.7 UC2845 histogram of too long OFF time as a function of the cross section. Irradiation in JYKL with ^{131}Xe at 0° (LET=60 MeV/mg/cm2).

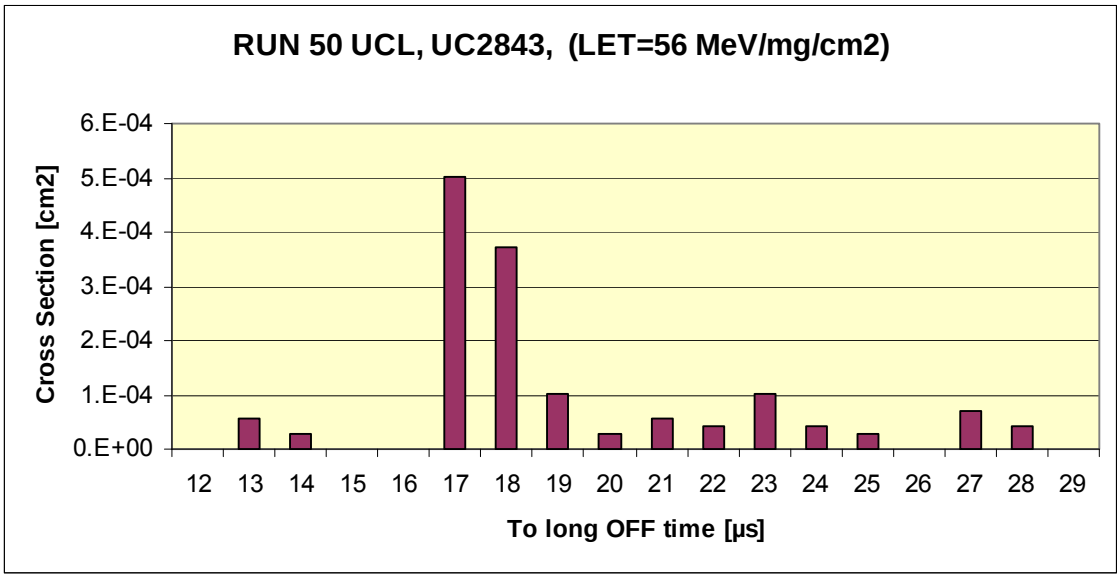

Fig 5.4.8 UC2843 histogram of too long OFF time as a function of the cross section. Irradiation at UCL with ^{131}Xe at 0° (LET=56 MeV/mg/cm2).

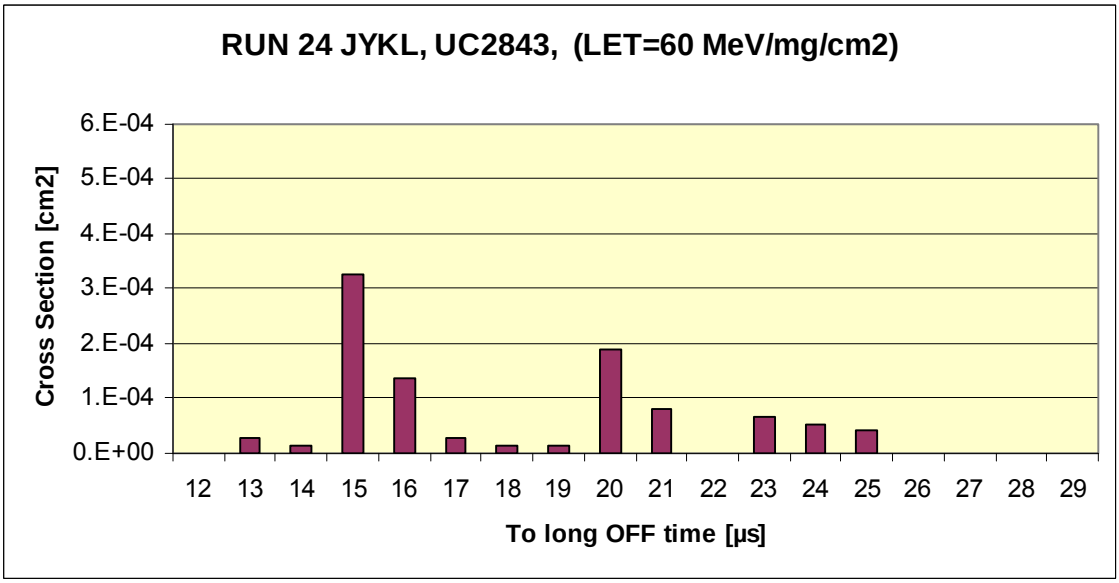

Fig 5.4.9 UC2843 histogram of too long OFF time as a function of the cross section. Irradiation in JYKL with ^{131}Xe at 0° (LET=60 MeV/mg/cm2).

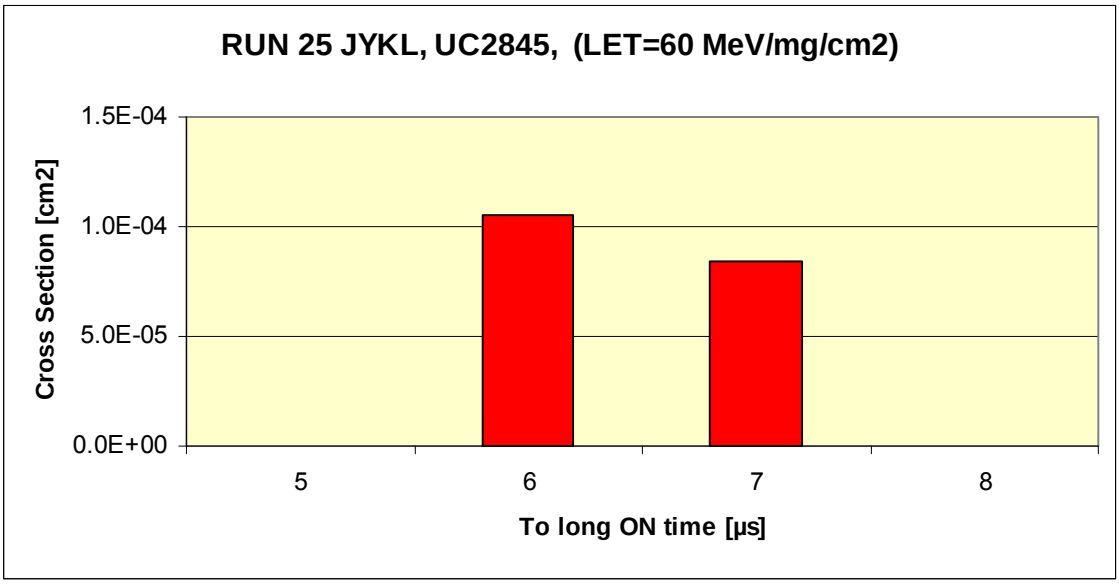

Fig 5.4.10 UC2845 histogram of too long ON time as a function of cross section.

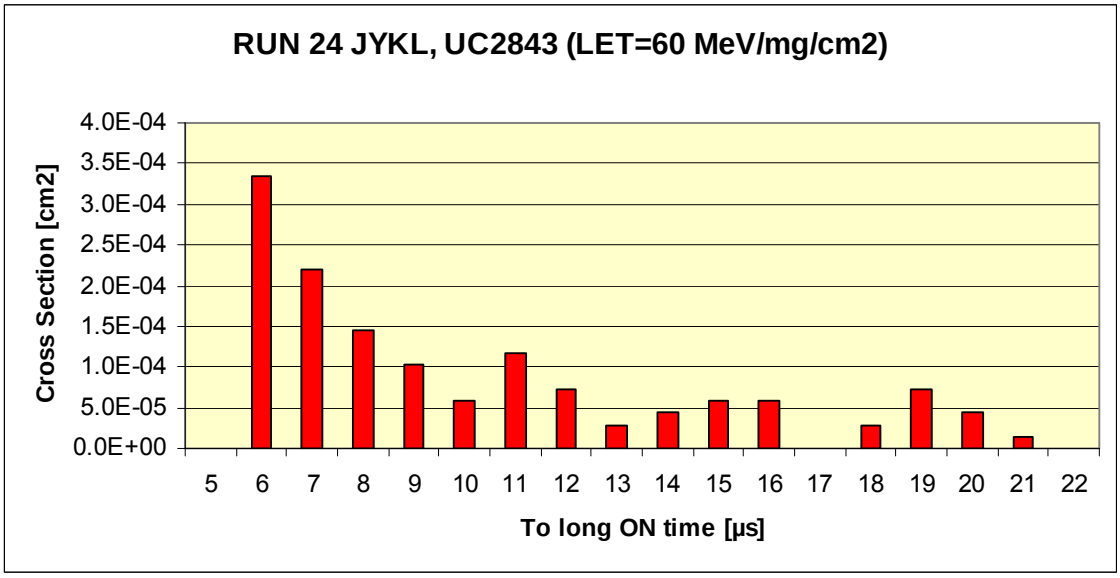

Fig 5.4.11 UC2843 histogram of too long ON time as a function of cross section.

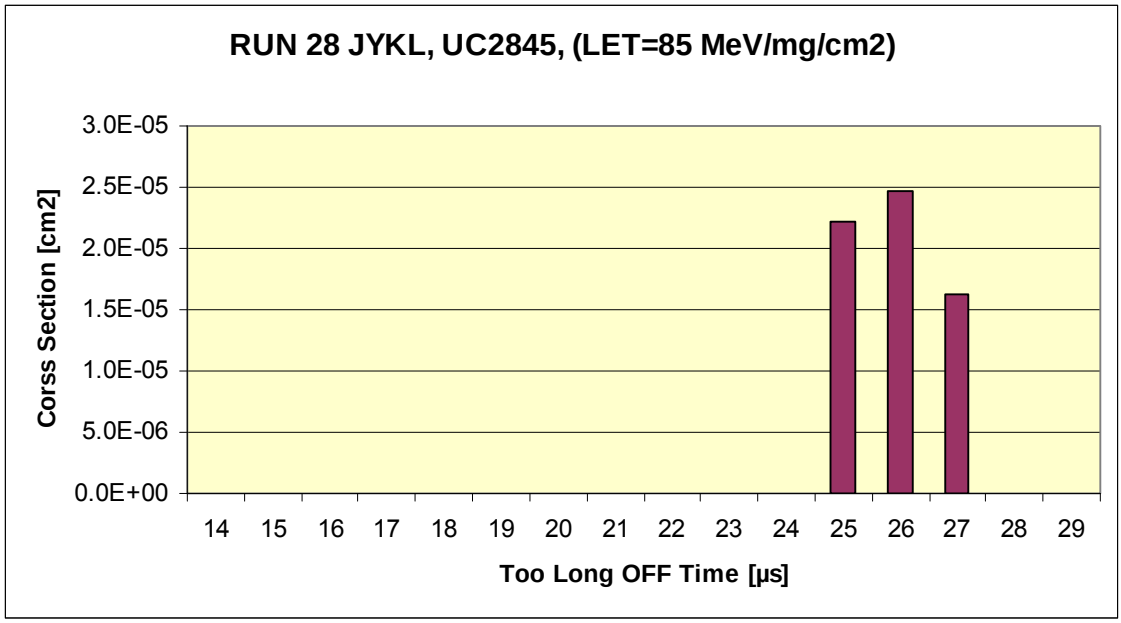

Fig 5.4.12 UC2845 histogram of too long OFF time as a function of the cross section with oscilloscope trigger conditions >22µs. The test was performed to collect better statistics on the longer OFF times. Irradiation in JYKL with ^{131}Xe at 45° (LET=85 MeV/mg/cm2).

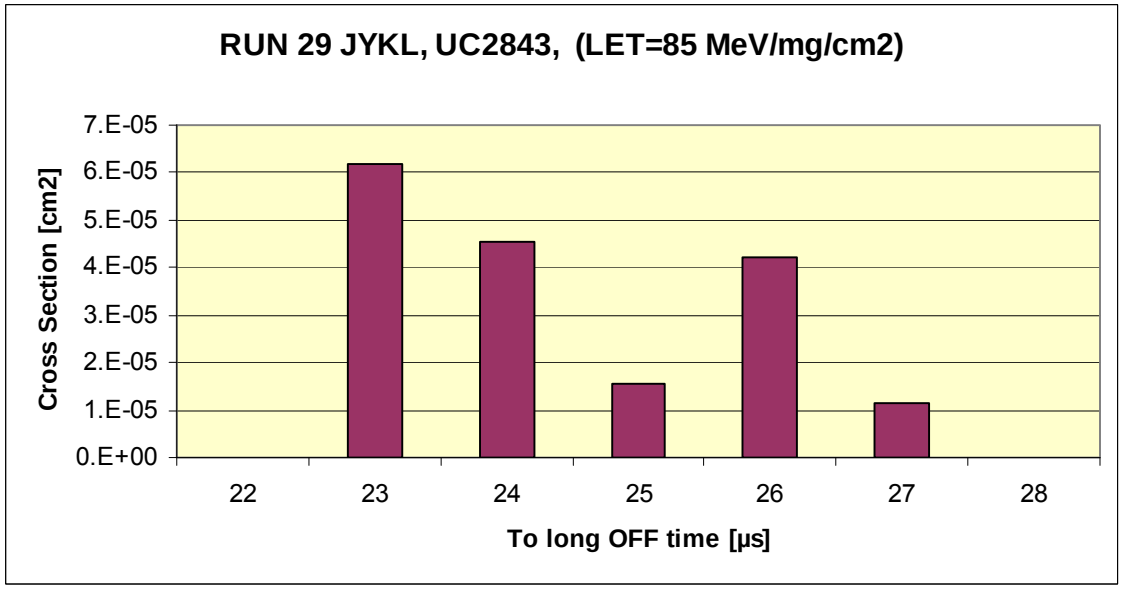

Fig 5.4.13 UC2843 histogram of too long OFF time as a function of the cross section with oscilloscope trigger conditions >22µs. The test was performed to collect better statistics on the longer OFF times. Irradiation in JYKL with ^{131}Xe at 45° (LET=85 MeV/mg/cm2).

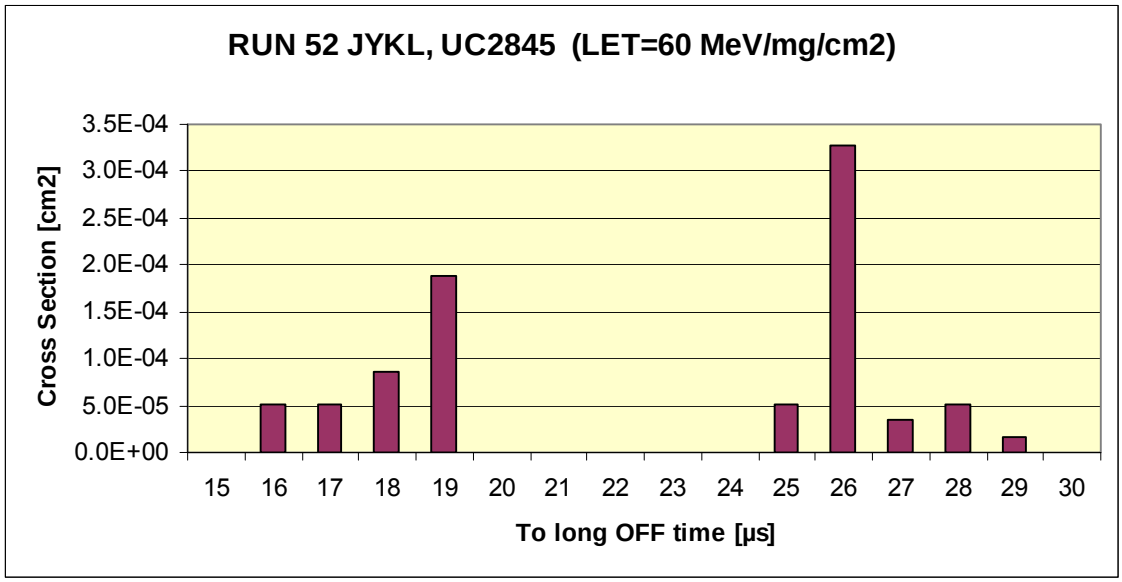

Fig. 5.4.14 UC2845 Too long OFF time, Supply voltage = 20.

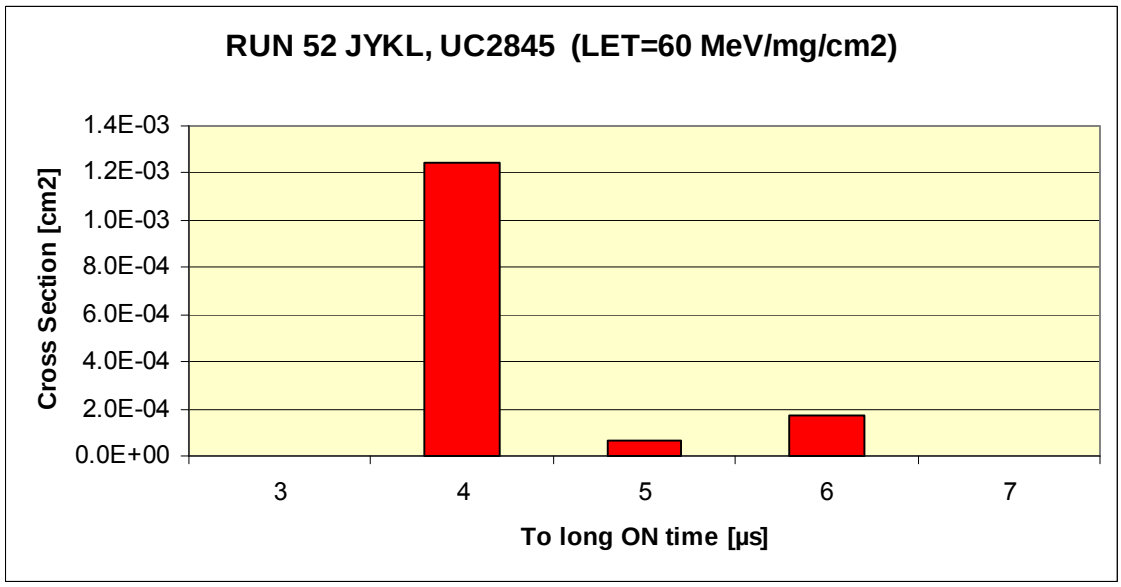

Fig. 5.4.15 UC2845 Too long ON time, Supply voltage = 20V

6 CONCLUSION

Two devices of each type have been tested of UC2843 / UC2845 manufactured by SGS Thomson Microelectronics. UC2845 have been characterized at all selected LET values, while the SEE behaviour of UC2843 have been verified towards the UC2845 results at about every second selected LET value.
Samples were tested in an application like bias circuitry operating at 100 kHz on output with a duty cycle of about 30%. The main SET trigger conditions have been on too long OFF- and ON-time on the Output of the PWM.
No significant differences between the two device types were observed.

No latch-up was detected for UC2843 and UC2845 up to an LET of 85 MeV/mg/cm^2 for a total fluence of 1E+7 ions/cm^2.
No heavy ion strikes resulted in interrupt where the PWM's were out of function longer time than 30µs. Testing with 200kHz has demonstrated that the interruption time is independent on the operating frequency.
The characteristics of the transients are closely linked to the implementation of the PWM and the design of the DC/DC converter. In this work only one implementation solution has been evaluated. It is believed that another implementation would result in different characteristics of the transient events.

7 Appendix

Test data on which the cross section figures and histograms have been based on. All Latch Up test runs were performed with high beam flux. All other runs were performed with adjusted low beam flux due to the dead time in the recording system.

Raw data from Jyväskylä

RUN #	Device	Ion	LET (MeV/mg/cm2)	trig	Fluence	Too long OFF events	Too long ON events
1	UC2845-1	Ar	10.1	OFF/ON	1.00E+06	30	2
2	UC2845-1	Ar	14.3	OFF/ON	1.00E+06	49	3
4	UC2845-2	Ar	14.3	OFF/ON	1.00E+06	58	0
5	UC2845-2	Ar	10.1	OFF/ON	1.00E+06	4	0
7	UC2843-2	Ar	10.1	OFF/ON	5.10E+05	13	190
8	UC2843-2	Ar	14.3	OFF/ON	3.00E+05	10	114
9	UC2843-1	Ar	14.3	OFF/ON	2.00E+05	8	79
10	UC2843-1	Ar	10.1	OFF/ON	3.00E+05	11	88
12	UC2843-1	Ne	3.6	OFF/ON	7.16E+05	0	50
13	UC2843-1	Ne	3.6	OFF/ON	7.16E+05	0	44
14	UC2843-2	Ne	3.6	OFF/ON	3.00E+05	0	41
16	UC2843-2	Ne	3.6	OFF/ON	7.00E+05	0	98
17	UC2845-2	Ne	3.6	OFF/ON	1.00E+06	0	0
20	UC2845-2	Fe	18.5	OFF/ON	1.00E+06	155	5
21	UC2843-2	Fe	18.5	OFF/ON	1.00E+06	106	341
22	UC2843-2	Fe	18.5	OFF/ON	1.82E+05	13	
24	UC2843-2	Xe	60	OFF/ON	1.00E+05	99	84
25	UC2845-1	Xe	60	OFF/ON	1.00E+05	93	140
27	UC2845-1	Xe	60	LU-test	1.00E+07		19
28	UC2845-1	Xe	85	LU-test	1.00E+07		
29	UC2843-2	Xe	85	LU-test	1.00E+07		
30	UC2843-2	Xe	60	LU-test	1.00E+07		
31	UC2845-2	Xe	60	LU-test /ON	1.00E+07		1644
32	UC2843-1	Xe	60	LU-test	1.00E+07		
34	UC2843-1	Xe	60	Vref	5.00E+04		
36	UC2845-2	Xe	60	Isupply	1.00E+05		
37	UC2845-2	Xe	60	Isupply	1.00E+05		
38	UC2843-1	Xe	60	Isupply	1.00E+05		
40	UC2843-1	Xe	60	OFF/ON, 200kHz	1.00E+05		
41	UC2845-2	Xe	60	OFF/ON 200kHz	1.00E+05		
43	UC2845-2	Xe	60	Isupply 200kHz	1.00E+05		
45	UC2845-2	Xe	60	OFF/ON, 50kHz	1.00E+05		
48	UC2845-2	Xe	60	E.A	1.00E+06		
49	UC2843-1	Xe	60	Isupply	4.10E+04		
50	UC2843-1	Xe	60	OFF/ON, Vin=20V	1.00E+05		
51	UC2843-1	Xe	60	OFF/ON, Vin=11V	1.00E+05		
52	UC2845-1	Xe	60	OFF/ON, Vin=20V	1.00E+05		

Raw data from UCL

RUN #	Device	Ion	LET (MeV/mg/cm2)	trigg	Fluence	to long OFF events	To long ON events
40	UC2845-1	Kr	34	OFF/ON	1.00E+06	123	
42	UC2845-1	Kr	34	OFF/ON	1.00E+06	30	
45	UC2845-1	Kr	48	OFF/ON	1.00E+06	251	28
46	UC2845-2	Kr	48	OFF/ON	1.00E+06	175	17
48	UC2845-2	Kr	34	OFF/ON	5.10E+05	161	19
51	UC2843-2	Xe	79.2	LU-test	3.00E+05		
52	UC2845-1	Xe	79.2	LU-test /ON	2.00E+05		1625
54	UC2845-1	Xe	56	ON	3.00E+05		13
55	UC2845-2	Xe	56	ON	7.16E+05		8
57	UC2845-2	Xe	59.2	LU-test	7.16E+05		