RCU2 testing and design

Inge Nikolai Torsvik

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Department of Physics and Technology
University of Bergen

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4 Testing at Oslo Cyclotron Laboratory(OCL)

4.1 About OCL

Oslo cyclotron Laboratory is located at the Department of physics at the University of Oslo, and was opened in 1978. The cyclotron is of the type MC-35 and was made by Scanditronix AB from Sweden. This is the only accelerator in Norway for ionized atoms used in basic research. The cyclotron can accelerate protons, Deuteron, ^{3}He and ^{4}He, with energies and intensities as seen in the table 1 bellow. A drawing of the lab can be seen bellow in figure 1. The laboratory is divided in tree the control room, the inner experimental hall and the outer experimental hall. The cyclotron is placed in the inner hall, and a beam is sent through pipes to the outer hall. There is vacuum inside the cyclotron and the pipes that leads to the test area so that you should not suffer energy loss from collision with air molecules. With magnet you are able to regulate the beam, so that you are able to get the beam to your desired pipe exit. There are also several cups put on the pipeline, that you are able to block the beam. These can be used to stop the beam during an experiment, so you are able to go into the experimental area and do changes on your setup. When the cyclotron is running and the beam is on, you are not allowed to enter the inner experimental area.

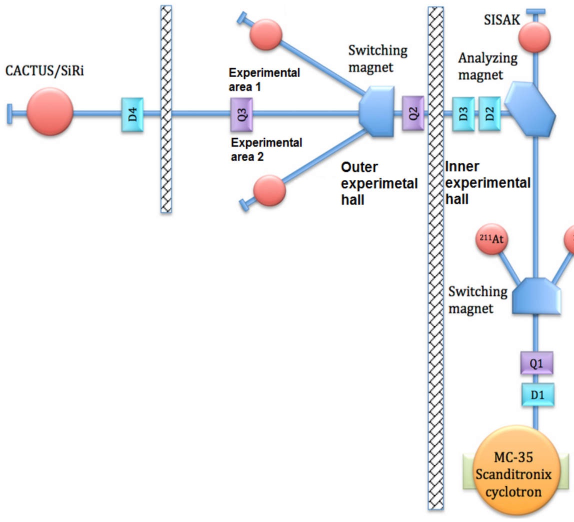

Figure 1: Out-lay of the OCL

Ionized beam particle type	Energy(MeV)	Intensity(μA)
Proton	2-35	100
Deuteron	4-18	100
^{3}He	6-47	50
^{4}He	8-35	50

Table 1: Ionized beam particle data table

4.2 Experiment setup and equipment

The experiment setup was placed in the outer experimental hall in ”experimental area 2”. The setup that was used as well as the equipment used can be found in the figure and table bellow: The equipment was kept in close to the same height around 140-150cm. Beam exit was in a height of 141.5cm.

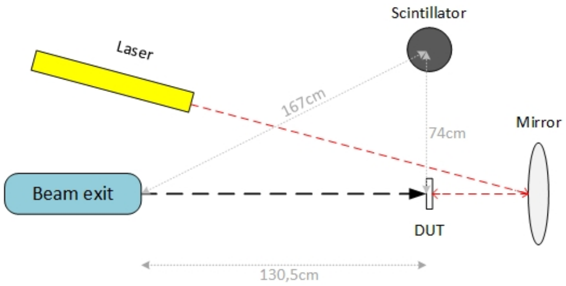

Figure 2: Experimental setup seen from above

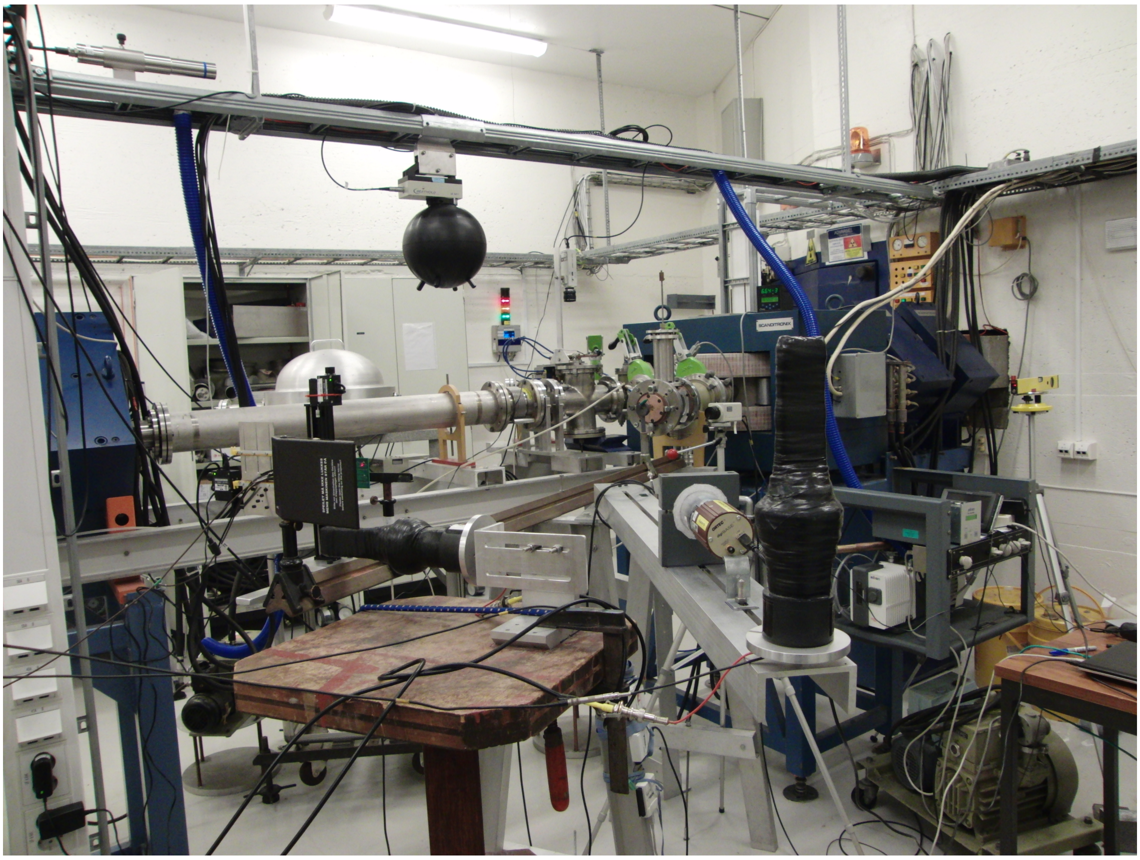

Figure 3: Picture of the experimental area

Equipment	Explanation
Scintillator	A plastic scintillator with photomultiplier, that was used to measure relative radiation. We had two of these, one that was placed right under DUT and one that was placed 75cm away from DUT. We only used one during the experiment.
High voltage regulator	Voltage for the photomultiplier. 800V was used
8 test boards	TPS51200, MIC69302WU, SN74AVCB16245, SN74AVC2T245, QS3VH257, SY89831U, ADN2814 and MAX3748
SRAM-board	A PCB board with 4 SRAM cells, that was used to characterise the beam and to measure scintillator counts
Computer	A VPN connection was set on a computer inside the experimental hall, so we where able to control the experiment outside the experimental hall. The computer was running LabView to control the experiment, data was also saved on the computer
USB DAQ	Used to get analog and digital connection to the test boards and send data to the computer.
Radiation film	A film that reacts when radiated with protons. Used to identify the beam.
Counting controller	a device that counts rising or falling edges
leveled laser	This was used to pinpoint the center of the beam.
Mirror	Reflecting the laser beam to the backside of the test boards.
XY-controller	Connected to the computer so we can do minor changes to the placement of the test boards outside the experimental area

Table 2: Equipment used in the experiment

4.3 Measurement equipment and test boards

4.3.1 SRAM

The SRAM board consist of several SRAM chips and a flash based FPGA and some connections and supporting electronics. When a SRAM chip is exposed to radiation a Single Event Upset(SEU) can occur. The method of detecting an Single Event Upset (SEU) in a SRAM is rather straight forward, as can be seen in the flow diagram of figure 4. There is an initial startup phase where a known pattern is written to all the addresses in the SRAM. When the startup phase is done, the value from the first address is read back and compared to a known value by xoring the known value with the read. If they are not alike a SEU has occurred, and a 1 will return from the xor and be added to a SEU counter. The correct value is then written back to the address and the system moves on to the next address.

A checkerboard pattern, a pattern of alternating ones and zeros, is used when writing to the SRAM. To check for stuck bits, the bit pattern in the whole address space is inverted after each read. The cross section for SEU and particles is known through earlier experiment with the SRAM-board, and is found to be 1.14×10^{-6} cm^2. The FPGA on the SRAM PCB is designed with RS485 two-way communication which makes it possible to edit firmware as well as sending data out. Through the experiment the SRAM PCB was connected with RS485 to a ‘en box som arild hadde‘ that could be connected to a computer. On the computer we run a LabVIEW program, that made us able to monitor data, as well as doing some settings. The SRAM board also had an input for scintillator counts, so we could monitor scintillator counts by the use of this board.

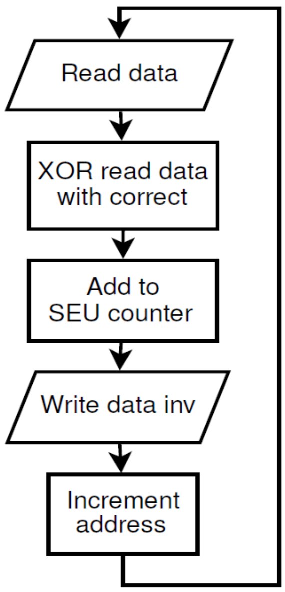

Figure 4: Flowchart for SEU detection

4.3.2 Scintillator

The detection of ionizing radiation by the scintillation light produced in certain materials is one of the oldest techniques on record. In Geiger and Marsdens famous scattering experiment of a-particles off Gold nuclei, the scattered as were observed via the scintillation light they produced when they hit a ZnS-screen. ZnS produced light flashes, called scintillation light, when hit by an α. The scintillation process remains one of the most useful methods available for the detection and spectroscopy of a wide assortment of radiation.

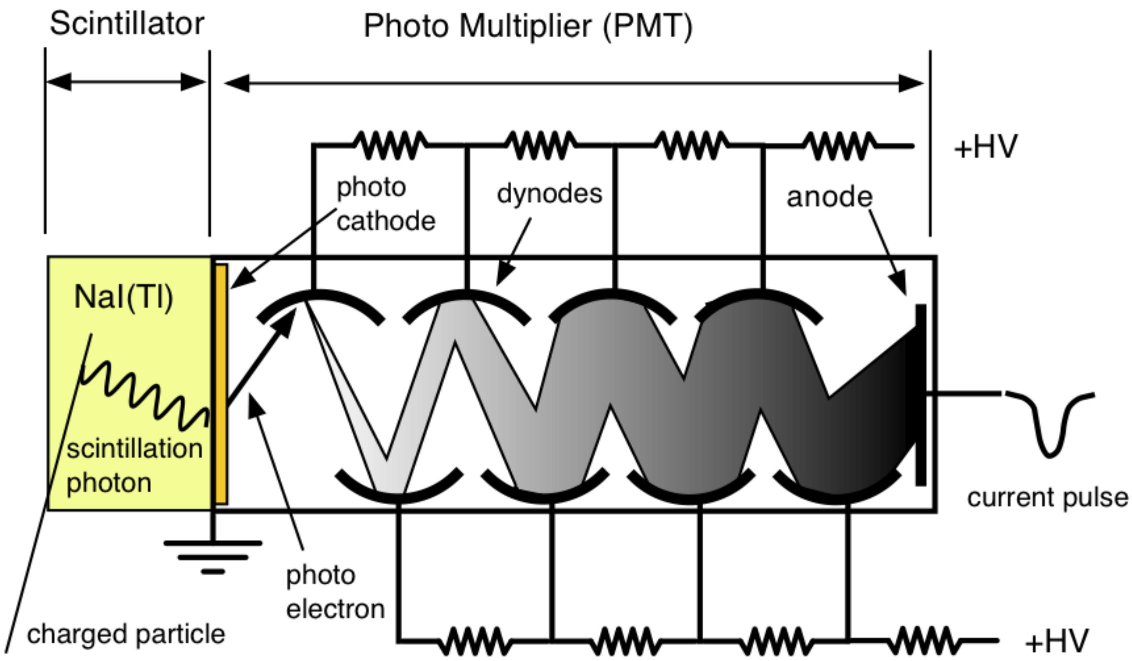

Figure 5: Concept drawing of scintillator

4.3.3 The test boards

TPS51200 - A Sink/Source DDR termination regulator. Used to power DDR RAMs. We are going to use this for 0.75V DDR3 RAM.
MIC69302WU - This is a high current low voltage regulator. Is going to be used to produce a 1.2V voltage.
SN74AVCB16245 - This is a 16-bit noninverting bus transceiver, with configurable voltage transceiver and 3-state outputs.
SN74AVC2T245 - This is a dual-bit noninverting bus transceiver ,with configurable voltage transceiver and 3-state outputs
QS3VH257 - This is a Quad 2:1 multiplexer/demultiplexer with high bandwidth bus switch
SY89831U - This is a high speed, 2GHz differential LVPECL 1:4 fanout buffer optimized for ulta-low skew applications
ADN2814 - This i a clock and data recovery IC with integrated Limiting amplifier. works in rate of 10Mb/s to 675 Mb/s.
MAX3748 - This is a limiting amplifier. works in rate of 155Mb/s to 4.25Gb/s.

4.4 Preparation and characterization of the beam

Before we could start testing the test boards, the cyclotron had to be made ready for a proton beam and the magnet controlling the direction had to be put in the right position to get the beam out in experiment area 2. This was done by the experienced lab personnel.

4.4.1 purpose of tests

The purpose of testing these board is to see if they are able to survive in a highly radiated area. Every IC that has been tested, are IC's that are going to be used in creation of the new RCU2 board, that is going to be placed in ALICE at CERN.

4.4.2 Beam setup

When the beam was set, we could start the characterization of the beam. The first thing to do is to get an understanding of the beam, too see that it is centered and that it hits around the area that we expect. This was done by using radiation films that turns black when exposed to radiation. We put one of these right in front of the beam exit and one in front of DUT-area to see how the beam looks like at the two places. This gave us a hunch of where the beam goes. A more precise calibration was done by the use of the SRAM board and the scintillator. By measuring the relation between scintillator counts on the scintillator which was in a locked position and SEU on the SRAM that was connected to a XY-controller(which made the SRAM freely to move), we were able to find a more precise position of the beam center by seeing which position gives most SEU compared to scintillator counts.

This had to be done everyday at startup before we could start the tests. When the beam center is found and everything looks fine, the laser was placed in a position so the laser points to where we have found the center of the beam to be. After that we could switch out the SRAM board with the PCB that we were going to test. We were able to control the intensity of the beam freely from the control room inside the limitation of the beam (for protons that is up to 100μA). This way we could control the dose of radiation we were giving to the test boards. The beam intensity could be measured with a Faraday Cup(FC), by putting it in front of the beam. But the FC had to be removed when we were doing tests, since it will block the beam.

4.4.3 The test procedure

Before the test day I had made simple test program in LabVIEW for each PCB that we were going to test. Each PCB had a mark on the back indicating the center of the IC. The PCB picked out for testing was placed in so that the laser pinpoint this mark, then the IC should be in the center of the beam. We were running 3 labVIEW programs through the experiment, one for controlling the XY-controller, one for SRAM PCB(for scintillator counts) and one program for each of the test boards. The SRAM and test board programs were constantly saving data on the disk.

5 Results and calculations from beam test at OCL

The radiation was done in 5 days divided in two periods 13.11-15.11 and 28.11-29.11. I have made two version of most of the boards, the exception is ADN2814 and MAX3748 which I only made one version of. The boards that where tested the first time are $TPS51200_1, MIC69302WU_1, SN74AVCB16245_1, SN74AVC2T245_1, QS3VH257_1 andSY8$
tested in that order. The first time at OCL we where given an beam of 28MeV, but the second time, the lab personnel manage only to produce a beam of 25MeV.

5.1 Calculation of dose

After we have run a test, we know the time it has run and relativistic scintillator counts 74cm from DUT. But from the calibration we know the relation between scitillator counts and SEU on the SRAM, and Cross section of the SRAM is known. By using this data we can calculate the fluence at DUT. By the use a program called FLUKA. That is a simulation program that could be used to simulate protons in air. We are able to simulate a proton beam of 28MeV/25MeV and enter our position for DUT. Then the Fluka simulation results give us how many protons we will find at DUT area for each proton coming out of the beam exit, and what dose each proton produce at DUT area. By dividing fluence on protons at DUT per protons from the BE(beam exit). We are able to find the fluence at BE. And then we can multiply by the dose we receive per proton at the BE. And then we get the Dose at DUT area.

A complete result of the tests can be found in one of the appendix.

Calibration test nr.:	x	y	Scint rel	sram3	SRAM/SC
1	0	0	23813	1971	8,28E-02
2	0	-0,5	37930	3867	1,02E-01
3	0	-1	27527	2817	1,02E-01
4	0	-1,5	34413	3360	9,76E-02
5	0	-2	32713	2763	8,45E-02
6	0,5	0	38753	2709	6,99E-02
7	-0,5	0	23420	2483	1,06E-01
8	-1	0	20611	2232	1,08E-01
9	-1,5	0	21014	2410	1,15E-01
10	-1,5	0	20676	2260	1,09E-01
11	-2	0	35787	3776	1,06E-01
12	-2,5	0	27847	2512	9,02E-02

Table 3: Calibration tests 14.11.2013

Calibration test nr.:	x	y	Scint rel	sram3	SRAM/SC
1	-0,8	-1	27798	1463	5,26E-02
2	-1,3	-1	17721	1239	6,99E-02
3	-1,8	-1	12904	1203	9,32E-02
4	-2,3	-1	13361	1276	9,55E-02
5	-2,8	-1	12786	1238	9,68E-02
6	-3,3	-1	12342	1156	9,37E-02
7	-2,5	-1	11696	1223	1,05E-01
8	-2,5	-1,5	11027	1075	9,75E-02
9	-2,5	-2	11835	1063	8,98E-02
10	-2,5	-0,5	15593	1540	9,88E-02
11	-2,5	0	12620	1034	8,19E-02
12	-2,5	-1	65280	5999	9,19E-02
13	-2,5	-1	52752	4803	9,10E-02
14	-2,5	-1	57229	5250	9,17E-02

Table 4: Calibration tests 15.11.2013

Device	Exposed time[s]	Dose[Rad]	Error
$TPS51200$	2065	41800	No
$MIC69302WU_1$	2240	164000	No
$SN74AVCB16245_1$	967	65200	No
$SN74AVC2T245_1$	860	4600	Yes
$QS3VH257_1$	795	52800	No
$SY89831_1$	1251	93500	No

Table 5: Tests at OCL 15.nov 2013

Device	Exposed time[s]	Dose[Rad]	
$ADN2814/_run1$	1273	20200	Yes
$ADN2814/_run2$	2286	324900	Yes
$MAX3748$	2384	442200	No
$TPS51200_2$	-*	-*	-*
$MIC69302WU_2$	1385	383800	No
$SN74AVCB16245_2$	526	201400	No
$SN74AVC2T245_2$	478	161600	No
$QS3VH257_2$	264	110300	No
$SY89831U_2$	921	165800	No

*The board wouldn't work at test time

Table 6: Tests at OCL 27-28.nov 2013