

RCU2 testing and design

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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, 3He and 4He , 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.

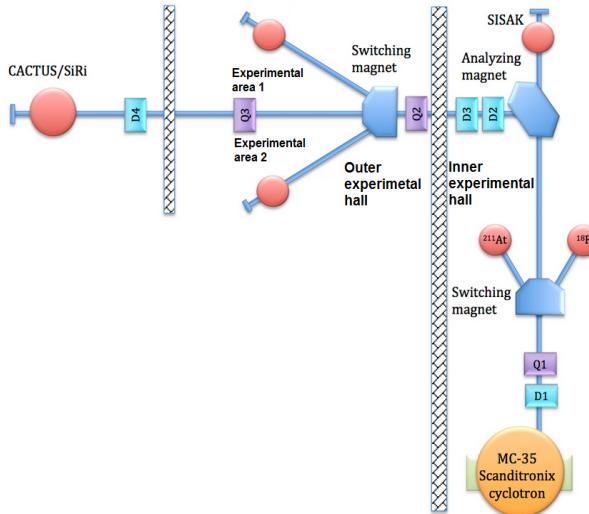


Figure 1: Out-lay of the OCL

Ionized beam particle type	Energy(MeV)	Intensity(μ A)
Proton	2-35	100
Deuteron	4-18	100
3He	6-47	50
4He	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.

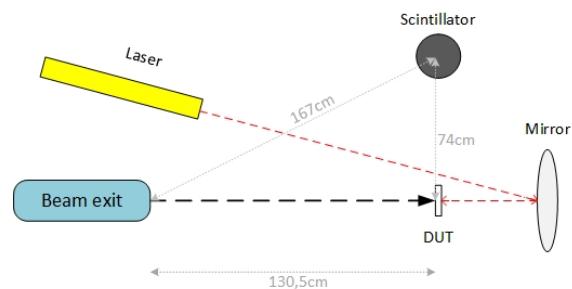


Figure 2: Experimental setup seen from above

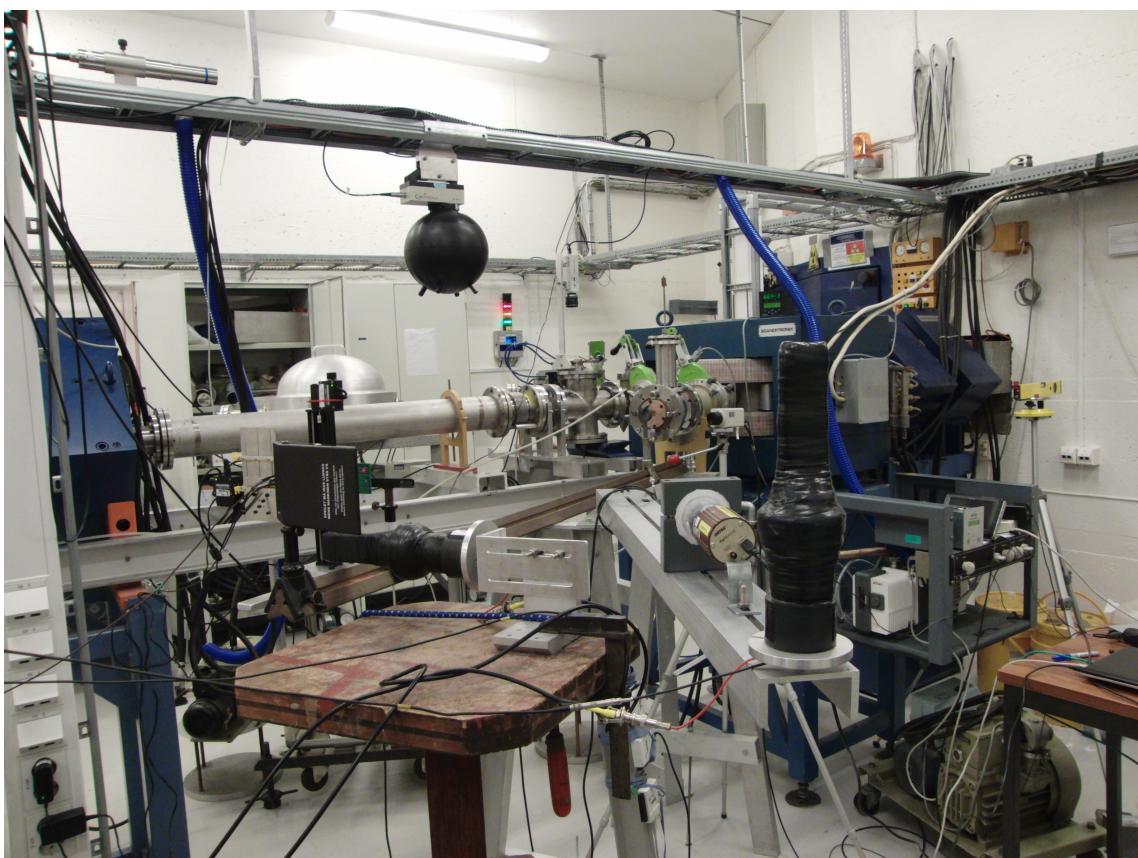


Figure 3: Picture of the experimental area

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 were 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

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 xorring 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 $1.14 \times 10^{-6} \text{ cm}^2$

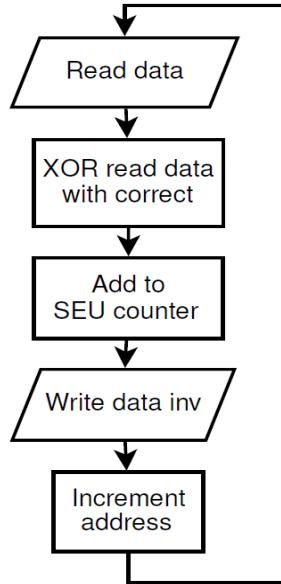


Figure 4: Flowchart for SEU detection

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 α -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.

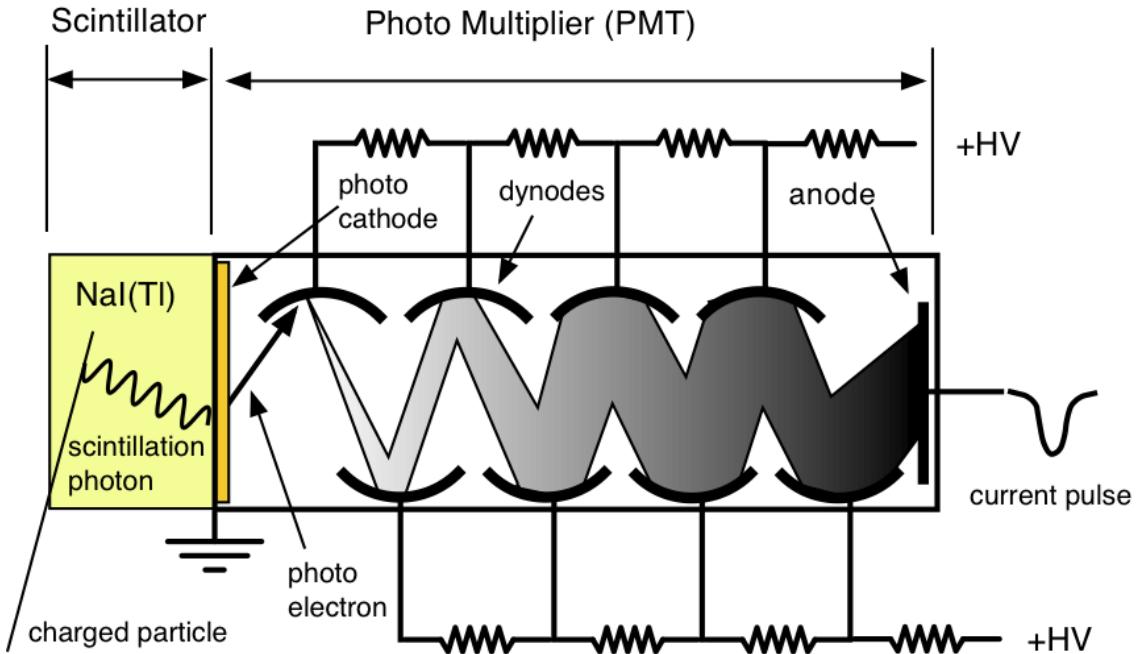


Figure 5: Concept drawing of scintillator

4.4 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 fixed, 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 outside 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 chip 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 each day we should do tests, because the beam are never the same two days at a row. When the beam center is found and everything is looks fine, we could start the testing. We were able to control the intensity of the beam freely inside the limitation of the beam (for protons that is up to $100\mu\text{A}$). This way we could control the dose of radiation we was giving to the test boards. The beam intensity on our experiment area could be measured with a Faraday Cup(FC), by putting this in front of the beam, but this had to be removed when we were doing tests, since it will block the beam.

5 Results and calculations from beam test at OCL