Radiation test Campaign at PSI – 24-25-26-27 March 2009

OPTIS beam line - 60 MeV protons

Radiation effects studied : Single Events and Total Dose.

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***DISCLAIMER :***

***"The document is a summary of my personal observations during the above mentioned irradiation campaign. The views expressed in this document do not necessarily represent those of the equipment groups."***

## B. Dehning – BLM tunnel electronics :

1. **Switched mode power supply module for BLM electronics in the LSS**. There are 2 versions of these devices, one gives 5 volts the other is a modified version that gives 2.5 V. These are commercial devices and 4 pcs (2 of each type) were tested. Each time we irradiated the PowerMOS up to doses of 320 Gy without noticing any SEB. The second device was then tested using a load and there we noticed sudden drops in the supply voltage when we irradiated the PowerMOS. This is a reason for concern because these be non destructive (or 'half') latches. They may lead to burn outs if the load is increased or the temperature of the devices increases (for example due to increased current consumption from total dose effects). The proposed solution exists in replacing the powerMOS on all the modules for the tunnel by a higher voltage device with the same functionality (objective is to obtain a derating factor of at least 30 %).

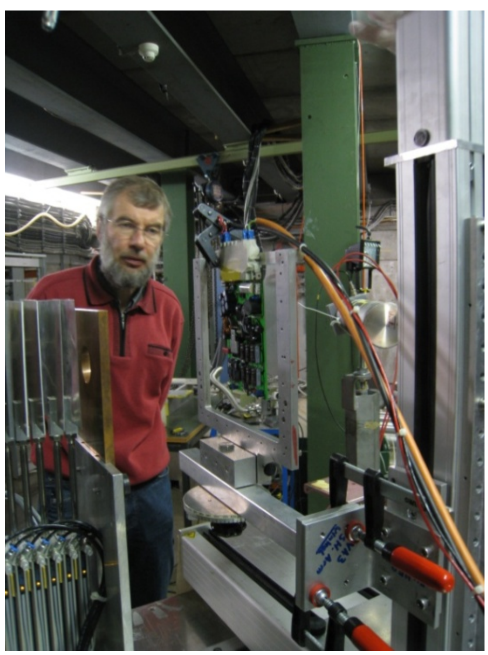
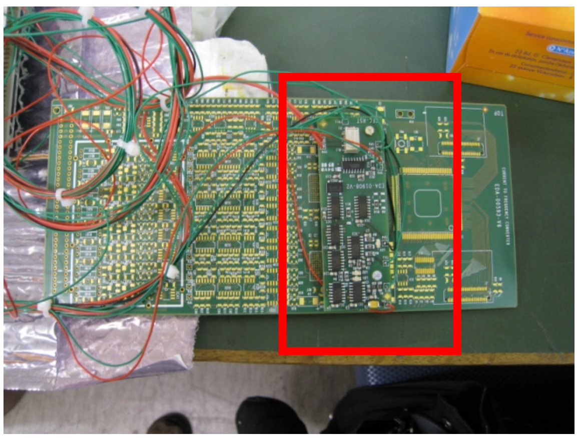


Figure 1 : LHC beam loss expert inspecting the Irradiation setup for the switched mode power supply

The switched mode power supplies are used in the BLM electronics in the RRs and in the UJs. The consequence of a hardware failure of such a power supply is that we dump the beams and access is needed to replace the device.

2. **Mezzanine card for remote reset of the FPGA** – this is a plug on module that is used to reset remotely the RS54SX ACtel antifuse FPGA that does the signal processing in the BLM tunnel crates. The reset can be invoked either via the high voltage supply line or via the worldfip card from the BPM electronics that is located in the same crate. The card has no logic and has a total dose limit of ~300 Gy. The mezzanine card did not cause radiation induced resets. The functionality of the reset was verified during irradiation and at several intermediate stops. The card remained fully functional until the total dose limit was reached.



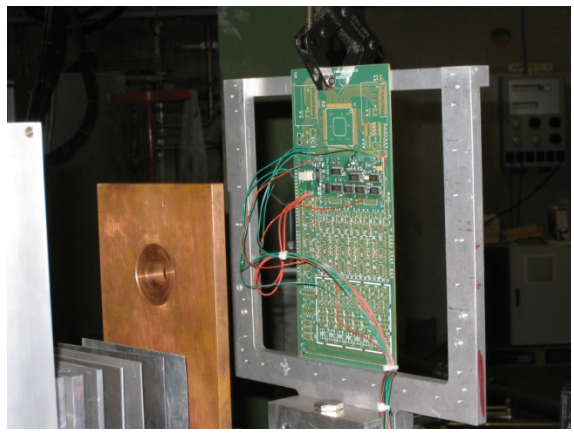


Figure 2 : Mezzanine card for the remote reset of BLM tunnel electronics mounted on a separate PCB (left) to allow individual irradiation in the proton beam (right).

**Summary/conclusions**: the mezzanine card is sufficient radiation tolerant for use in the tunnel. The capability to reset the FPGA of the BLM tunnel electronics via the WorldFIP line still needs to be verified and may be carried out in a complete system test in the CNGS facility later on this year

## P. Dahlen – SIEMENS interlock I/O modules for warm magnet interlocks.

1**. Saftey module of SIEMENS :** SIMATIC S7 6ES7 326-1BK01-0AB0 SC-X2V62351. SM326 part number X|3|4|5|. This module contains 3 ICs with logic, one is the usual Profibus interface, the other is a logic IC that probably controls the 4 individual digital inputs of 6 bits each. The module is 24 Digital Inputs and is divided in 4x6 modules that are all individually powered. The data acquisition rate for the digital inputs is 10 Hz or 1 acquisition every 100 ms.

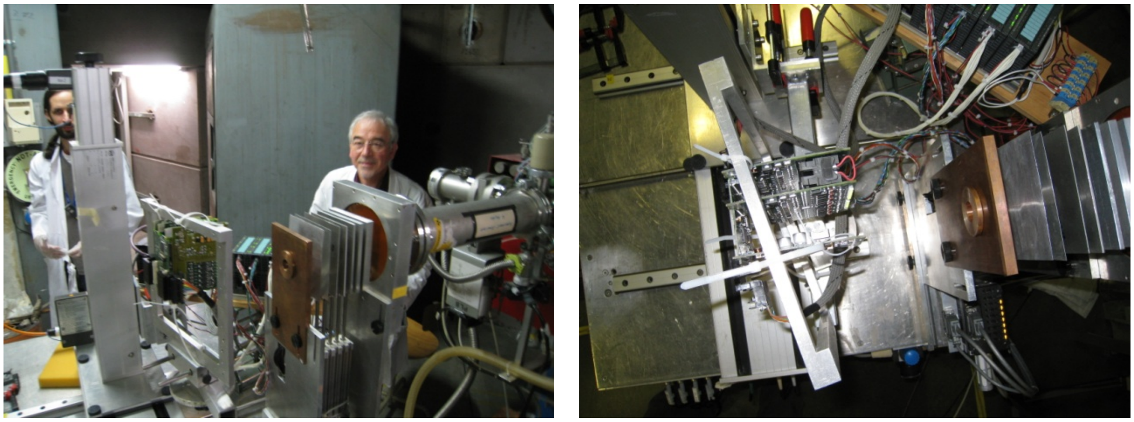


Figure 3 : LHC Interlock expert verifies the irradiation setup (left). SIEMENS remote 24 Digitial Input module in the proton beam (right).

The ICs with the logic were first all individually irradiated up to a total dose of 20 Gy each corresponding to a fluence of 1.5e10 p/cm2 at 60 MeV. We did not observe any functional interrupts of the module. After this test, the collimator was removed and the whole module was irradiated simultaneously. This results in many functional interrupts , that needed to be recovered via soft rests or, in case this did not work, power cycling. For the device cross section of the complete module we computed is $7x10^{-10}$ $cm^{-2}$. After a total dose of 40 Gy on the logic ICs and 20 Gy on the surrounding components, the current consumption increased from 217 to  267 mA.

Figure 4 : Four Single Event Functional Interrupts of the SIEMENS 24 DI remote input module SM326 clearly visible via the on line readout system.

A second identical module was irradiated entirely to have a second estimate of the SEFI cross section. The module was irradiated up to a total dose of 20 Gy after which the device which did not respond any more. The SEFI cross section of the second module is $8.6 \times 10^{-10}$ $cm^{-2}$.

**Summary/conclusions**: The SM326 safety module from SIEMENS with 24 digital inputs is much more complex as compared to the ET200M and ET200B modules that are presently in use in the transfer lines and in US85. The device is very sensitive to single events, the estimated cross section is $8.6 \times 10^{-10}$ $cm^{-2}$. Once the device is in “system failure” mode, it can be recovered with a soft reset. Occasionally, a power cycle was needed. <u>These devices are should not be used in areas with radiation.</u>

2**. ET200 M Communication Module :** SIMATIC S7 6ES7 153-1AA03-0XB0 ET200M x|17|18|19. This module allows the communication of the data from the I/O modules over the profibus fieldbus connection and is thus of high importance. Near Identical devices have been tested in 2001, 2003 and 2007.

Under irradiation (flux 1e8 p/cm2/s) this module showed bus errors but the module managed to recover without external intervention provided the beam was stopped. These kind of events were reproduced six times for a total fluence of $1.8 \times 10^{11}$ $p/cm^2$ giving a cross section of $3.3 \times 10^{-11}$ $cm^{-2}$.

The next (identical module) was irradiated under the same conditions and noted a cross section of 6 $\times 10^{-11}$ $cm^{-2}$. When we investigated the device in the state where it “hangs” it was found that the address of the Profibus address of the module was changed. By reinitializing the module, the correct hardware address is loaded in SRAM memory on the chip and the device works normally again.

**Summary/conclusions**: The ET200 M Communication module shows occasional functional interrupts. Power cycles of the module restore the correct functionality. We strongly suspect that the functional interrupts are due to the corruption of the hardware address in the module. Once the address is modified, the PLC does not recognize the module anymore.

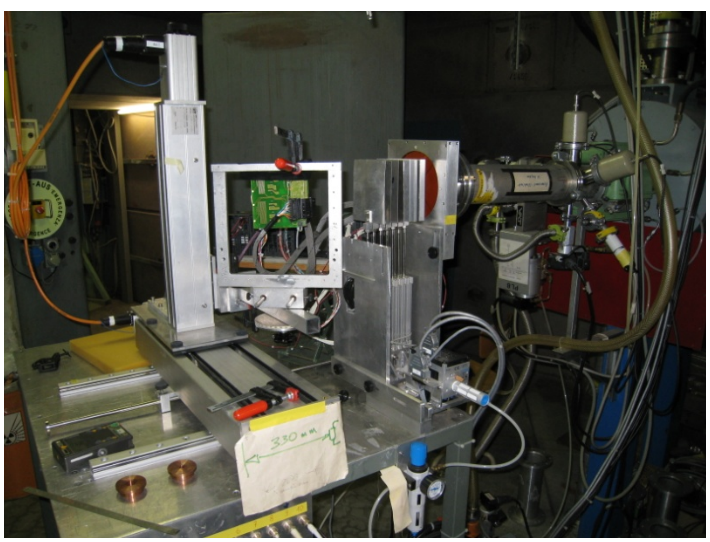


Figure 5 : The SM322 8 bit digital output module under radiation.

3. **SM322 output module** SIMATIC S7 6ES7 322-**1HF**10-0AA0 ET200M x|3|4|5 - 8 DO bit digital output with Electrostatic Relays. This module has partially no logic on board apart from the IC that drives the communication with the ET200M slave module mentioned here above.

This module showed no sensitive to single events, we stopped irradiation after a total dose of 500 Gy because the LEDs did not work anymore (but the module worked fine).

**Summary/conclusions**: The SM322 8 DO (1HF version) 8 bit digital output works extremely well under radiation.

4. **SM322 output module** SIMATIC S7 6ES7 322-**5HF**10-0AA0 ET200M x|3|4|5 - 8 DO bit digital output with Electrostatic Relays AND control logic (ATMEL FPGA visible on PCB board) This module is nearly identical the one mentioned here above.

We decided to irradiate the entire card without the use of a collimator because there was no much beam time left (several problems with the test set up occurred). After a fluence of 4e11 protons cm2 (equivalent to 560 Gy total dose) we observed no SEEs

**Summary/conclusions**: The SM322 8 DO (5HF version) 8 bit digital output with digital control also works extremely well under radiation.