First results on proton irradiation of the associated electronics of tilt and proximity sensors.

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Abstract

Tilts and optical proximity sensors are devices appropriate to measure with high precision angles and short distances, respectively, in the future LHC experiments. Damages on the sensor electronics due to radiation environment may occur. These devices are components of the Link Alignment system, that relates the muon chambers with the central tracker of CMS.

At the CYClotron of LOuvain-la NEuve (CYCLONE) of the Université Catholique de Louvain, we have irradiated up to a total fluence of 1.53x10^10 protons/cm^2 two commercial electronics: the tilt sensor signal conditioner (model 83162 from Applied Geomechanics), and the proximity sensor signal conditioner (model Z4M-W100 from Omron). No damage was observed in the proximity sensor signal conditioner. Small variations on DC output voltage was observed on the tilt sensor signal conditioner.

I. INTRODUCTION

The proton irradiation of the tilt and proximity sensor electronics was performed on 19 March 2003 at the CYClotron of LOuvain-la NEuve (CYCLONE) of the Université Catholique de Louvain, in Belgium. This facility supplies a 60 MeV protons beam with intensity from 10^7 p/cm^{2}s to $4x10^8$ p/cm^{2}s. The main purpose was to make a board-level testing of two commercial electronic boards: *the tilt sensor signal conditioner* (model 83162 from Applied Geomechanics), *and the proximity sensor signal conditioner* (model Z4M-W100 from Omron).

These electronic boards will be placed at the experimental hall of the CMS experiment, above the barrel (Z=3, R=10). With a proton fluence comparable to the estimated neutron fluence in CMS for this location (1.53x10^{10} protons/cm^2) [1], we deposit a total ionizing dose of 21 Gy aprox (about 50 times greater than the expected one during 10 years).

Three units of the tilt sensor signal conditioner and two of the proximity sensor signal conditioner was tested. A sensor head of the proximity sensor was also tested. The sensor head is composed of a position sensitive detector (PSD), a laser source and an amplifier to drive analog signals. Sensor head will be placed inside barrel (MABs) of the CMS experiment.

II. EXPERIMENTAL SET-UP

Three tilt sensor signal conditioners (named T1, T2 and T3) and two proximity sensor signal conditioners (named OMRON I and OMRON II) were exposed, one by one, to a 10 cm diameter 60 MeV proton beam. Each of them absorbed a TID of 21 Gy (Si) and received 1.53x10^{10} protons/cm^2, except T2 and OMRON I that received double TID and fluence in two independent steps. The set up is shown in Figure 1.

Figure 1: Experimental set-up

To measure analog output signals and currents power supply of the signal conditioners, we use a remote data acquisition module from Advantech (ADAM 4017). It is an 8-channel analog input module that includes a 16-bits analog to digital converter. The module uses RS-485 serial communication, to send data to PC. A transparent RS-485 to RS-232 converter (ADAM 4520) is used to interface with PC serial port. A block diagram of the data acquisition system is shown in Figure 2.

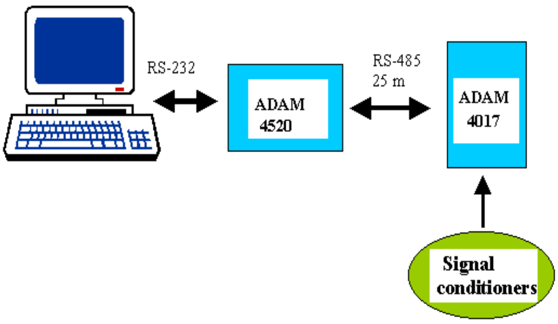

Figure 2: Data acquisition block diagram

III. THE TILT SENSOR SIGNAL CONDITIONER

The tilt sensor signal conditioner is a printed circuit board assembly that is used for signal conditioning of the tilt sensors. It provides simultaneous excitation of two electrolytic tilt transducers and conditions the returned signals in two analog DC voltages. It provides both single-ended and differential output on each of its two tilts channels. We selected differential output for our application. Two different gains can be selected (x1 and x10) with a switch. The signal conditioner has two single-pole RC low-pass filters (integrators) selected by a switch. The time constants for each filter are 0.05 and 7.5 s. After an instantaneous change in tilt, the output signal settles to 90% of its final value after three time constants, and 98% of this value after four time constants.

The board is 10 cm diameter round (exactly the same size that protons beam!).

Tilt sensor behaves as a variable resistor and is excited with an AC signal. In order to have an output stable signal during the irradiation test, we emulate tilt sensor with two series 2KΩ, +/- 0.01%, resistors, with a temperature coefficient < 0.6ppm/ºC. These resistors emulate tilt sensor with no tilt, i.e. with the tilt sensor perpendicular to the gravity vector. With this condition, DC output signal must be around 0V.

Board is powered with +/- 12 V DC, 12 mA per side.

Analog DC output signals and power currents of the two power voltages were measured during irradiation test, in order to measure variations over the typical values.

IV. THE PROXIMITY SENSOR SIGNAL CONDITIONER

The laser proximity sensor that will be used in the link alignment system is a commercial system (OMRON, model Z4M-W100) [3] composed of two parts:

- Sensor head
- Signal conditioner (amplifier).

We have no enough information about components inside sensor head and signal conditioner, so we only made a board-level test.

The laser proximity sensor electronics produce a DC output voltage (from -4 to 4 V) proportional to the distance (60 to 140 mm) from sensor head to a target. Power supply is 12 VDC with a current consumption of 120 mA maximum.

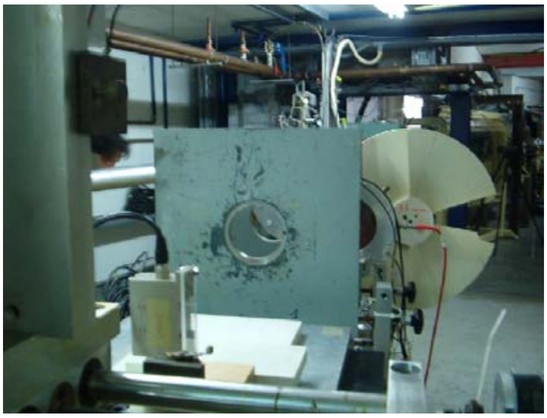

Figure 3: Proximity sensor signal conditioner

Analog DC output signal and power current were measured during irradiation test, in order to measure variations over the typical values.

A. *The sensor head*

The sensor head is composed of a position sensitive detector (PSD), a laser source and an amplifier to drive analog signals.
In order to get a maximum cross-section we placed PSD and laser source with their greater surface perpendicular to the protons beam. Proximity sensor signal conditioner was placed out of beam, but near sensor head (3 m).

The set sensor head and target was mounted on an optical rule (see Figure 4), in order to guarantee a known stable distance.

Figure 4: Sensor head and target

B. *The signal conditioner*

The signal conditioner was placed with its greater surface perpendicular to the protons beam, in order to get a maximum cross-section (Figure 3). When signal conditioner was irradiated the sensor head was placed out of the protons beam (3m). We never irradiate sensor head and signal conditioner at the same time.

V. RESULTS OF THE TESTS

A. *Tilt sensor signal conditioner*

CMOS and bipolar technologies are mixed in the integrated circuits placed on the tilt sensor signal conditioner board. Linear devices and some simple CMOS logic integrated circuits are the main components. Analog DC outputs and power currents were measured during irradiation to notice variations over the typical values. A small drift on DC output was observed during irradiation after 1 Gy dose. Variations on DC output signals of 5-6 mV, that affect system specifications, were observed after 4 Gy dose. Figure 5 shows the analog signals from the three tilt sensors before and after start irradiation period.

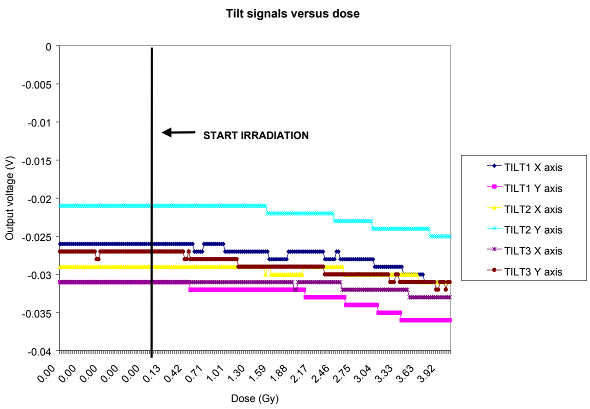

Figure 5: Tilt signals versus dose

Very small changes were observed on the power currents during all irradiation period (10 microamps over 10 miliamps).

B. *Proximity sensor signal conditioner*

No valuable changes on DC output signal (Figure 6) and power current (10 microamps over 70 miliamps) was observed during irradiation of the sensor head and signal conditioner.

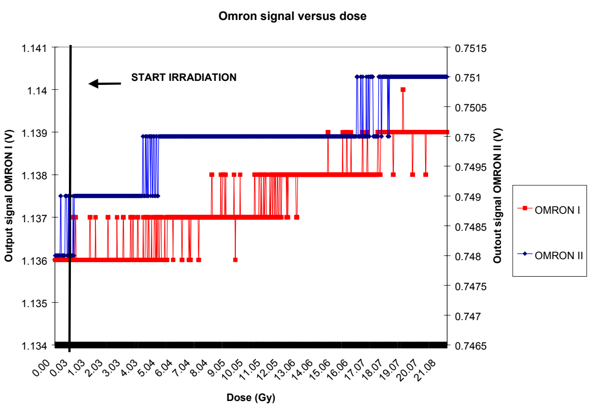

Figure 6: Omron signal versus dose

VI. CONCLUSIONS

The levels reached during proton test have exceeded the radiation tolerance criteria, including safety factors. No damage was observed in the proximity sensor signal conditioner. Small variations on DC output voltage was observed on the tilt sensor signal conditioner after ten times the expected dose. New tests must be done to understand the observed effects.

VII. REFERENCES

[1] "A global radiation test plan for CMS electronics in HCAL, Muons and Experimental Hall", Updated Draft 17/12/1999.

[2] Model 83162 Board Level Signal Conditioner. User´s Manual. Applied Geomechanics. www.geomechanics.com

[3] www.omron.com. OMRON, model Z4M-W100 data sheet.