RADIATION INDUCED EFFECTS
ON HYDROSTATIC LEVELLING SENSORS

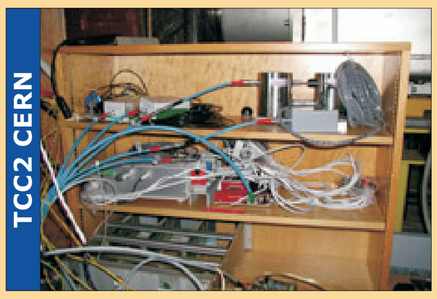
ABSTRACT

In preparation of the permanent alignment system of the LHC low beta quadrupoles, several irradiation tests had been carried out since 2000, in order to validate the use of capacitive HLS sensors. The sensors will be located in areas where significant radiation doses are predicted. Tests have shown perturbing offsets on the sensors' signals as a function of the dose rate. Due to these observations, a theoretical study regarding the HLS senors has been undertaken, showing that at high dose rates, ionization of the air inside the sensors causes charge recombination and this perturbs the position measurement. One model of correction is proposed, and is compared to the sensors' signals monitored during the irradiation tests performed in 2005.

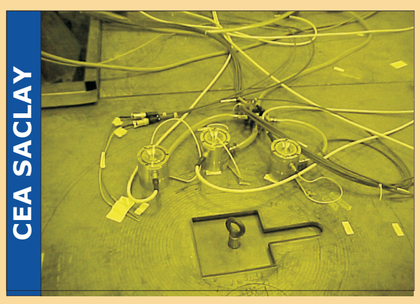
TEST FACILITIES

The TCC2 irradiation test facility has been operated at CERN from 2000 to 2004. It allowed the exposure of equipment to LHC-like radiation types. A radiation exposure of 3 Gy per hour can be achieved with this facility. Over test periods of 15 weeks, total doses between 700 Gy and 2.000 Gy have been cumulated.

TCC2 CERN



CEA SACLAY



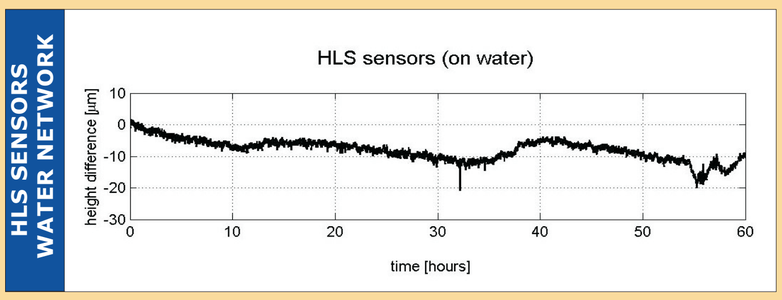
As the LHC low beta magnets will face annual total dose rates of up to 16 kGy, a more powerful test facility was chosen to complete tests. The CEA in Saclay (France) provides such a facility, where dose rates of up to 20 kGy per hour can be achieved. The use of ^{60}Co gamma ray sources does not cause any activation of the tested material. This allows the sensors to be returned to CERN immediatelly after the tests.

TOTAL IONISATION DOSE

Already first tests in the TCC2 facility showed drifts when electronics and sensors were irradiated at the same time. Perturbation of the signal at the relatively low dose rates made a separation of the sensor and the electronic necessary.

Different test series cumulated total doses of up to 180.000 Gy per sensor. The sensors were measuring on fixed targets. The targets were chosen to avoid possible influences of water to the measurements. With the electronics situated outside the irradiation chamber, no degradation of the signal has been observed during constant radiation; the sensors are classified as radiation hard for the LHC. A variation of the signal at the beginning and at the end of those tests will be explained in the chapter dose rate dependence.

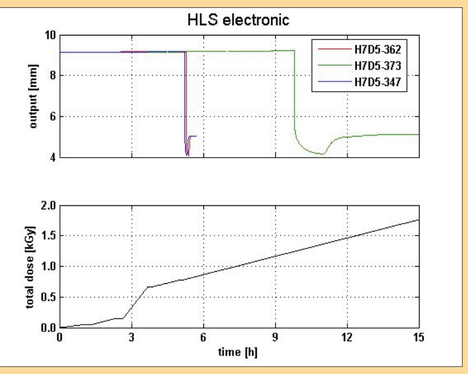
HLS SENSORS WATER NETWORK



In 2005, one of the tests was set up as a total ionisation dose test with two sensors linked by a hydrostatic levelling network. These already previously irradiated sensors did not show any influence due to the water and can be considered to be stable during irradiation, as shown in the figure above.

Electronics are more sensitive to radiation influences. They broke typically down at a total ionisation dose of approximatelly 800 Gy. They have to be protected in places with low dose rates, like for example the survey galleries in the experimental area.

RADIATION HARDNESS OF HLS ELECTRONIC



DOSE RATE DEPENDENCE

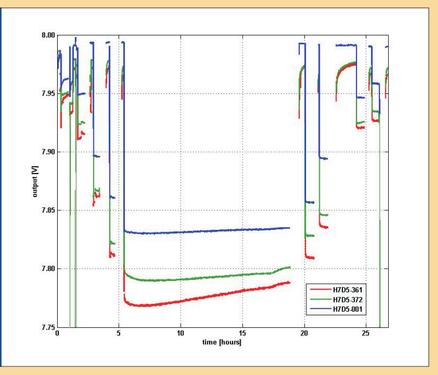
Tests in 2004 at high dose rates showed a possible influence of the radiation dose on the measurements. Similar observations were made in 1999 during measurements on the LEP spectrometer.

An additional HLS test series in 2005 with dose rates between 50 Gy/h and 1.500 Gy/h confirmed this hypothesis and a model for compensation of this influence has been derived.

The sensor interprets a change in the capacitance ΔC as a change in the distance between the electrode of the sensor and the target

$$\Delta C = \frac{\varepsilon_o \cdot \varepsilon_r \cdot S}{\Delta h} \qquad (1)$$

HLS SENSORS AT DIFFERENT DOSE RATES



with ε_0 as the absolute permittivity in vacuum, ε_r the dielectric constant of air, S the surface of the electrode and Δh the variation of the distance between the electrode and the target. This change occurs during irradiation when ionisation in the HLS sensor is created.

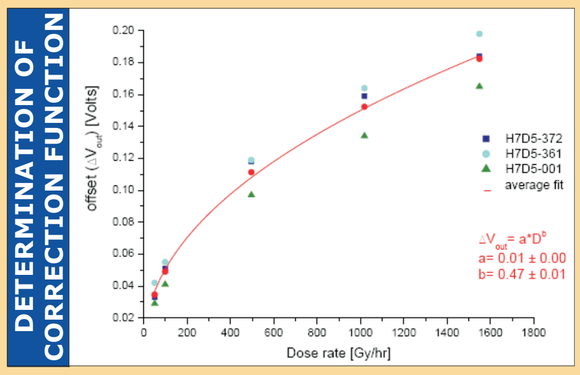
$$V_{out} = (V_{offset} + \frac{1}{C_e} \cdot V_e \cdot C_{ref}) \cdot G \qquad (2)$$

$$I_{ion} = \frac{D \cdot m \cdot S_g}{W \cdot S_w} \qquad (3)$$

Equation 2 describes the corresponding change in the output voltage with the main parameters C_e as the measured capacitance and V_{out} as the output voltage.

The link between HLS and condenser chamber is the fact that they are built as capacitors. As the Bragg-Gray conditions are met with this assumption, one can calculate the ionization current by equation 3, with the main parameters I_{ion} as the induced ionization current and D as the dose rate in the air inside the vessel.

DETERMINATION OF CORRECTION FUNCTION



The hypothesis and model were confirmed and influences on measurements in a radiation environment can now be corrected. The influence during LHC runs will be much less as dose rates are not that high as during irradiation tests.

CONCLUSIONS

Irradiation test for HLS sensor validation were carried out at different facilities at CERN and at CEA. Modifications on the sensor design have been carried out in order to get radiation hard equipment for the LHC. Remote electronics, cable lengths of 30 m for the transport of the primary signal and a new electrode design were introduced. Ionisation of the air inside the vessel at high dose rates lead to investigations on a compensation model.

Three major conclusions can be drawn from the tests in the last five years. First, the modification of the sensors and the development of remote electronics were necessary with respect to the dose rates of the LHC. The sensors can provide reliable measurements within some microns if the electronics are installed in a radiation safe environment. Second, the 2nd (ceramic) and 4th (stainless steel) generation of hydrostatic levelling sensors have passed the total ionization dose test. The simulated test period was ten years of LHC operation. Third, ionization in the air between sensor and water surface occurs and can be compensated with a model that has been determined.

These extensive tests were essential to prepare the survey group for the online monitoring and alignment of the LHC final focusing magnets. Modifications on HLS alignment sensors had been done to customise them to the high radiation doses expected in this and future particle accelerators.

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