Available online at www.sciencedirect.com
ScienceDirect
Nuclear Instruments and Methods in Physics Research A 581 (2007) 164–166
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Aging phenomena in the LHCb outer tracker

Tanja Haas

Physikalisches Institut, University of Heidelberg, Germany

On behalf of the LHCb Outer Tracker Group
Available online 31 July 2007

Abstract

The Outer Tracker (OT) consists of 53 760 straw tubes, covering in total an area of $360\,m^2$. The detector is foreseen to operate under large particle rates, up to 30 kHz/cm per straw in the region closest to the beam. Extensive aging tests conducted earlier on with prototype modules indicated excellent gain stability. In contrast, mass production modules show significant degradation under a rather modest level of radiation. This paper presents the observed phenomenon, together with ongoing investigations to both prevent the effect, as well as to recover the gain loss.

PACS: 29.40.Cs

Keywords: LHCb; Outer tracker; Aging; Gaseous detector; Straw

1. The outer tracking system (OT)

The OT is part of the LHCb tracking system [1] and designed as a modular system. The detector modules have a size of $5\,m \times 0.34\,m$. They house 256 straw tubes with an inner diameter of 4.9 mm and a length of 2.5 m. Three stations with a total size of $6\,m \times 5\,m$ per station are constructed from the modules. In total, the OT consists of 264 modules with 53 760 straws.

Panels which also build the gas envelope (materials in contact with the counting gas are aluminum, Kapton [2]) support the straws (built from aluminum, Kapton, KaptonXC [2]). Endpieces and wire locators (Noryl N110 [2]) hold and position the anode wire (25 μm goldplated tungsten wire). Aluminum endblocks, solder points and PCBs are also in contact with the counting gas. The modules are glued together with epoxy (Araldit A110, Hardener AY 991 [3], silica gel).

It is planned to operate the OT at a gain of about 40 000 with Ar/CO_2 (70%/30%) as counting gas. For a luminosity of $2 \times 10^{32}\,s^{-1}\,cm^{-2}$ and an operation time of 10 years, an accumulated charge of 1 C/cm is expected in the most irradiated region of the OT.

E-mail address: haas@physi.uni-heidelberg.de

0168-9002/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2007.07.063

2. High rate irradiation tests during R&D-phase

An intensive test program was performed during the R&D-phase. Test modules with a length of 1 m and 16 straws were used for the irradiation tests. The materials for the modules were taken from the mass production. The modules have undergone tests with highly ionising particles (protons, ionisation up to 3500 mips) as well as tests at an X-ray facility with 9 keV γ's. The main subject of these irradiations were effects appearing at high accumulated charge ($>0.5\,C/cm$). To achieve this numbers, an accelerated irradiation compared to LHCb (7–30) and long irradiation times are required. Even at high irradiation doses no performance degradation was observed. As an example Fig. 1 shows the gain for three different straws during an irradiation up to 3 C/cm. No significant gain drop is observed.

3. Low rate irradiation of production modules

During a test of a 5 m mass production module with a laboratory ^{55}Fe source (maximum rate per centimeter wirelength: 5 kHz/cm, typical width of the intensity profile: 8 mm) a so far not observed aging effect was found.

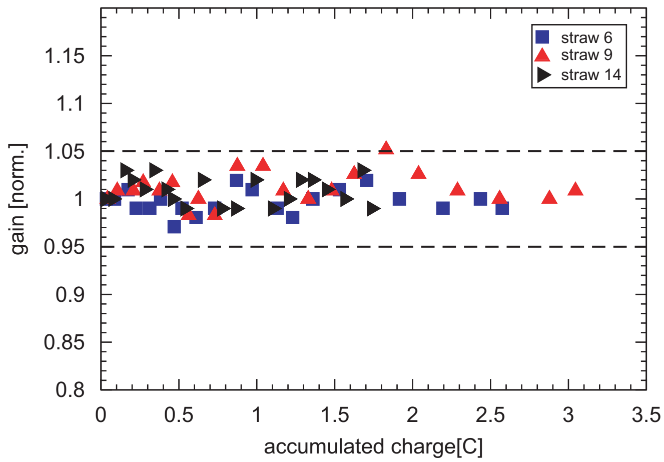

Fig. 1. Example of an irradiation of a test module with 9 keV γ's for three straws. No gain drop appeared up to an accumulated charge of 3 C/cm.

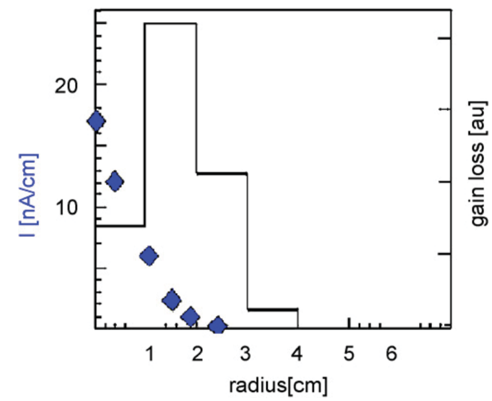

Fig. 3. Gain drop in dependence of the distance from the source (black lines). The intensity profile of the source is superimposed (grey dots). The maximum damage occurs at $2-5\,\mathrm{nA/cm}$.

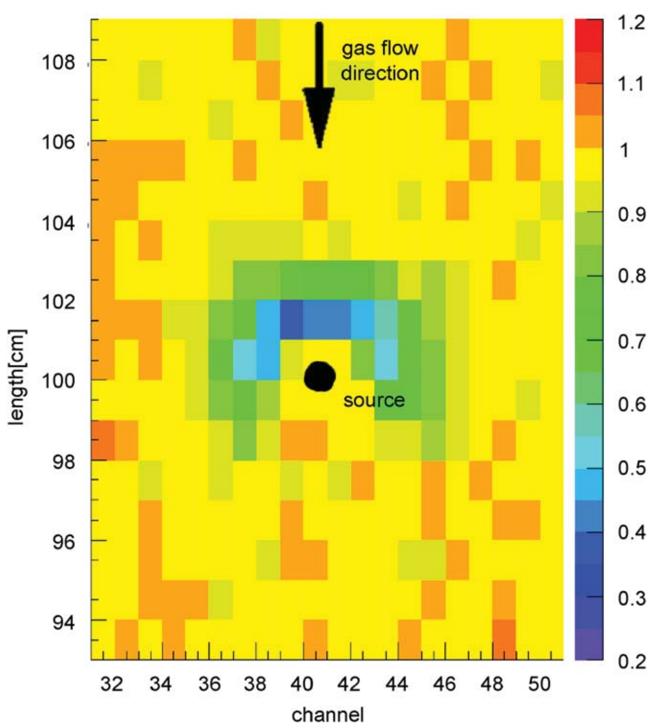

Fig. 2. Affected area of a 5 m module after an irradiation with an ^{55}Fe source. After 144 h a gain drop of 40–50% is measured in direction of the gas flow. Typical is the half moon shape of the area with aging.

Fig. 2 shows a small area of an irradiated 5 m module. After an irradiation with the above ^{55}Fe source for 144 h a gain drop of 40% to 50% is measured. The graduation of shading illustrates the signal height after irradiation normalized to the signal height before irradiation (corrected for pressure effects).

Typical for this aging phenomenon is the halfmoon shape of the affected area and the dependence of the gas flow direction (Fig. 2). There is no gain drop directly beneath the source. In Fig. 3 the gain drop is shown in dependence of the distance from the source (black lines, arbitrary units). The intensity profile of the source (blue dots) is superimposed. The maximum gain drop appears at an anode current of $2-5\,\mathrm{nA/cm}$. Similar results (gas flow dependence, dependence on irradiation strength) are obtained with an ^{90}Sr source and with an irradiation in X-ray facility (with an irradiated area of $3000\,\mathrm{cm}^2$ compared to $50\,\mathrm{cm}^2$ for a laboratory source) with 9 keV γ's at comparable anode currents.

An irradiated production module was opened to analyse the degradated wires. Different tools were used to check for deposits on the wire. An Analysis with an *Optical microscope* shows light interferences on the wire surface indicating deposits of a typical thickness in the order of the wavelength of light (a few hundred nanometer). The inspection with a *Scanning electron microscope (SEM)* points to insulating deposits. With an *Energy dispersive X-ray spectroscope (EDS)* carbon deposits with a thickness of a few hundred nanometer are found. Hydrogen is probably also part of the deposits but not detectable with this spectroscope. There is no indication for silicon.

The impact of the gas properties on the aging was studied. A decrease of the gas flow exchange rate from 1 to $\frac{1}{4}$ Vol/h also decreases the gain drop by a factor 2–3 for similar irradiation times. The influence of different admixtures to the counting gas was tested. Adding *Tetrafluoromethane* ($Ar/CO_2/CF_4$ 75%/10%/15%) as well as adding water (50–2500 ppm) does not lead to an improvement of the module behavior. The addition of 2.5% oxygen ($Ar/CO_2/O_2$ 70%/27.5%/2.5%), however, reduces the aging by a factor 2–3.

Further investigations were done whether the deposits which lead to the gain loss can be removed. An reirradiation of a damaged area at higher intensities (typical anode currents $>50\,\mathrm{nA/cm}$) was able to reestablish the original gain in the damaged spots. Likewise the effect of an HV training at large positive voltages ($1800-1900\,\mathrm{V}$, about 300 V higher than the nominal operation voltage) and at negative anode voltage ($1300-1400\,\mathrm{V}$) was studied. In both cases significant anode currents have been observed.

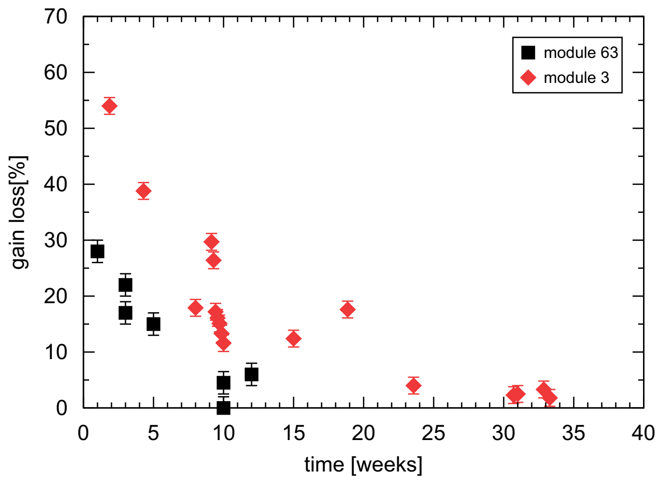

Fig. 4. Example for the effect of long term flushing on irradiations. There is a clear decrease of gain loss with flushing time. Each point corresponds to an irradiation with an gas exchange rate of 1 Vol/h (500 l/day).

A treatment for several hours (20−80 h) again reestablished the original gain of the treated wires.

The influence of long-term flushing on the modules was also studied. Fig. 4 shows the observed gain loss for two affected modules obtained after different flushing times (each point corresponds to a test for similar irradiation times with Ar/CO_2 as counting gas). The gas exchange rate was chosen to 1 Vol/h (about 500 l/day). A clear decrease of gain loss with flushing time is observed. This behaviour is an indication of volatile impurities outgassing from module components. As the temperature could have an influence on possible outgassing, the flushing at an increased temperature (40−45 °C) was also studied. Although these studies are not yet completed, there are indications that a higher temperature could accelerate the improvement of the aging behavior.

4. Summary

The module design of the LHCb Outer Tracker has undergone an intensive test program focussing on long-term aging effects at high irradiation doses. Prototype modules have been studied up to an anode charge deposit of 3 C/cm without observing any significant aging effect. Modules from the mass production, however, show at a very modest irradiation level significant gain loss created by very thin insulating deposits. With typical anode currents of 2−5 nA/cm effects are seen already after one day. Irradiations with significantly larger anode currents ($>$ 20 nA/cm) do not lead to a gain loss. So far the origin of the "low rate" aging effect has not been identified. But the observed improvement of the module behaviour after long-term flushing points to an outgassing of module components.

References

[1] LHCb Outer Tracker, Technical Design Report CERN/LHCC 2001-024.
[2] J.A. Kadyk, Nucl. Instr. and Meth. A 300 (1991) 436.
[3] M. Capeans, Aging of gaseous detectors: assembly materials and procedures, ICFA Instrumentation Bulletin 24, 2002.