Aging Studies for the Outer Tracker of HERA–B

HERA–B Outer Tracker Group

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The experimental conditions at HERA–B resemble, in terms of radiation and particle flux, those expected in the LHC. Prototypes of the HERA–B Outer Tracker experienced several aging effects, sometimes after only 10 mC/cm of integrated accumulated dose: Malter effect, anode aging, permanent dark currents, and anode etching. The detector requirements and conditions are summarized. Results of the R&D experiments to find solutions to these problems are given. The conclusions and changes subsequently implemented in the original construction techniques are explained.

Summary of Talk: The HERA–B Outer Tracker is one of the largest trackers ever built. It has in total 8 km^2 of cathode surface and 22 m^3 of gas are flowing through the detector every hour. The experiment collides a proton bunch at an energy of 920 GeV with a fixed target wire at a frequency of 10 MHz and it is designed to produce an average of four proton–Nucleon interaction in every bunch crossing. The high interaction frequency requires a fast drift gas containing CF_4. A high tracking efficiency, together with the noise conditions of the densely packed electronics require the effective gas gain to be at least $2{\cdot}10^4$. This fact, together with the high charged particle flux in the experiment, imposes very strong requirements on the detector, which is designed to receive a maximum accumulated dose of 500 mC/cm of wire per year in the hottest areas. The Outer Tracker has a honeycomb drift tube geometry. The cathode is made from carbon-loaded polycarbonate foil (trademark 'Pokalon-C') that is glued together to form the drift tubes. Gold-plated tungsten wires are soldered into supporting bridges made of bromine-free FR4 material that are installed inside the drift tubes. Material and construction techniques lead to the appearance of different aging effects, some of them after only 10 mC/cm integrated radiation dose: Malter effect, very fast wire aging, permanent dark currents and wire etching were observed. In particular, the Malter effect was observed only in chambers that were irradiated with a hadronic beam. After an intense R&D effort in different radiation facilities, from X-rays to α-beams, solutions have been found for the different problems: the problem of anode aging was solved by exchanging the CH_4 quencher in the originally planned gas mixture ($Ar/CF_4/CH_4$) by CO_2 and carefully selecting "clean" materials and non-outgassing glues. The Malter effect was avoided by coating the cathode foil with a copper-gold layer. The origin of permanent dark currents was traced back to the hygroscopic nature of the FR4 and the wire etching effect can be alleviated by avoiding a gas mixture that is too dry. The last two conditions impose some constraints on the gas system that has to carefully control and monitor the water content inside the drift gas. Long-term aging experiments performed with prototypes that were produced in the same way as the final chambers demonstrated that, after the above mentioned changes, the detector can stand up to 2 C/cm of integrated radiation dose (up to 5 C/cm for some of the effects).