Aging Studies of CMS Muon Chamber Prototypes under High Doses

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The aging of prototypes for the CMS muon cathode strip chambers under sustained irradiation was studied. The tests were performed with three prototypes with different gas seal designs and for three gas mixtures ($Ar/CO_2/CF_4$ 30:50:20, Ar/CO_2 30:70, and $Ar/CO_2/CF_4$ 40:50:10). The CF_4-containing mixtures showed no or little aging for an accumulated charge per unit of wire length exceeding the high dose of ≈ 13 C/cm. Results of SEM/XEM examinations of the anode wire surfaces for different gas mixtures are presented. In comparison, the performance deterioration in the Ar/CO_2 mixture proved to be very dramatic: the gas gain was falling by a factor of two for each 0.25 C/cm of accumulated charge. The correlation between accumulated charge and the amount of oxygen collected in the anode wire was observed using a Nuclear Reaction Analysis. Aging studies of a full-size CMS Muon Cathode Strip Chamber under global irradiation at the GIF facility at CERN are also presented.

Summary of Talk: The irradiation tests were conducted with three prototypes that were fabricated using materials intended for production chambers. The active area of the prototype chamber was 175×240 mm^2 and reproduced the major local details of the final design. The typical rate of the charge accumulation per day was as follows: about 0.3 C per cm of wire at the center spot, and about 0.004 C/cm^2 for the total charge per entire cathode plane averaged over its surface. The first chamber was tested with $Ar/CO_2/CF_4$ 30:50:20 which was the baseline gas mixture at the time of the test. The CF_4 component is added primarily for its aging-preventing abilities. Indeed, as described below, even in a case of negative influence from the RTV sealing the aging resistance of a chamber with 20% CF_4 mixture did not change up to 13.6 C/cm of accumulated dose. The $Ar/CO_2/CF_4$ 40:50:10 gas mixture was used to see whether this gas is still capable of preventing aging. An SEM/XEM surface examination of the anode wire was done in a few points of the irradiated zone. At the center of the irradiated zone, the gold coverage looked damaged and the wire surface became dark. Although having drastically damaged the gold coverage of the wire with the longtime discharges, we found neither silicon nor carbon-based deposits on the surface. Both $Ar/CO_2/CF_4$ 40:50:10 and $Ar/CO_2/CF_4$ 30:50:20 gas mixtures showed very little signs of aging besides an increase in dark current. The gas gain remained virtually constant up to the end of the test (13 C/cm). Opening of the chambers revealed layers of deposits on the cathode surface. Chemical analysis showed presence of Si, F, and O elements. The intensity of the cathode coating in the test with 10% CF_4 was substantially smaller; however, this is likely due to the change in the chamber sealing design. Wires tested with mixture containing 20% CF_4 appeared to have an etched gold-plated surface. This observation is different from that with 10% CF_4: here the gold plating of wires was observed to crack and the wires were damaged more. However, these damages apparently did not affect the chamber performance. On the outlet edge of the wires we found some tin flakes on the wire surface, very similar to those formed in the 20% CF_4 gas mixture. The tin may come from solder interacting with fluoride. To confirm the crucial role of CF_4, we conducted the second test with Ar/CO_2 30:70 and saw a truly dramatic deterioration. A Nuclear Reaction Analysis was applied to investigate how the light element (oxygen, nitrogen and carbon) distribution along the wire and the depth distribution into the wire surface depend on the accumulated dose. Aging properties of a full-size CMS muon cathode strip chamber (2×1 m^2) were studied at the CERN Gamma Irradiation Facilities (a 0.7 TBq ^{137}Cs source that provided a high flux of 0.66 MeV photons). The chamber studied was from the production line and was flushed with the nominal gas mixture $Ar/CO_2/CF_4$ 40:50:10 at the baseline gas flow rate of 1 chamber volume per day. The total charge per unit of wire length accumulated over the period of 4 months was about 0.4 C/cm, which would correspond to approximately 40 LHC years. The chamber successfully passed the test. A number of chamber parameters was monitored during these studies. The chamber gas gain, efficiency plateau, and anode wire noise did not change. The dark current and resistivity between strips did show signs of deterioration, but still remained well within the specifications throughout the tests.