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SDC
SOLENOIDAL DETECTOR NOTES

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Abstract

Pure argon (Ar) gas and a mixture of 99% Ar + 1% CH_4, both at a pressure of 100 atm, have been exposed to approximately 16 Mrad of radiation from a ^{60}Co gamma source. The ionization produced in each gas by an ^{241}Am alpha source has been measured before and after irradiation. No significant radiation damage is observed.

1. Introduction

The most severe problem associated with the forward (θ=5.7° to 0.3° or η=3 to 6) calorimetry of SSC collider detectors is the extremely high radiation levels. The radiation dose expected from p-p collisions alone, at a polar angle of 1° and at the electromagnetic shower maximum position of the forward SDC calorimeter (about 12 meters from the interaction point) is about 12 Mrad for one year of SSC operation at a luminosity of 10^{33} cm^{-2} sec^{-1}. At 0.3° the dose is 444 Mrad per year. One technology that has the potential to survive these huge radiation doses is high pressure gas ionization calorimetry [1]. This technology uses high pressure gas as sampling medium. To measure the effect of large doses of radiation on high pressure gasses, we have exposed argon gas and a mixture of 99% Ar + 1% CH_4, both at 100 atm, to about 16 Mrad of gamma radiation from a ^{60}Co source at the Phoenix Laboratory of the University of Michigan. In the following we describe the experimental setup, present the results of our measurements and finish with our plans for the future.

2. Experimental setup

The gas is contained in a high pressure vessel, a schematic diagram of which is shown in Fig. 1. The vessel is made out of stainless steel and its volume is about one liter. It has two high-pressure electronic feedthroughs, one connected to the anode and the other not in use. The gas is inserted in the vessel through piping not shown in Fig. 1. The vessel is evacuated to about 10 mTorr before filling with gas. The gas is monitored by the signal produced by an ^{241}Am alpha source implanted at the center of a 2 cm diameter cathode. To measure this signal, a positive high voltage is applied to an equal size metallic plate opposite the cathode. The electronic readout chain is shown in Fig. 1. No voltage was applied to the anode during the irradiations discussed

in this paper. The following materials inside the high pressure vessel are also exposed to radiation and are in contact with the gas: stainless steel (vessel walls), aluminum (cathode), copper (feedthrough pin, anode and wire from anode to feedthrough pin), glass (feedthrough insulator) and ceramic (anode support frame). To measure the total dose two FWT-00-60 films, made by Far West Technologies, Goleta, CA, were placed on the outside surface of the vessel, facing the source, and two more on the opposite side. During irradiation the dose rate was also measured with a Reuter-Stokes ion chamber model RS-C4-1606-207 placed at a distance of about 10 cm from the gas volume. The two methods have given very different results, the film dose being several times larger than the ion chamber one. The doses quoted in this paper were extracted from the ion chamber measurements. We are still trying to understand the difference between the ion chamber and the film doses.

3. Measurements and results

At first, argon gas at 100 atm was irradiated from October 5 to October 16, 1991 with a half hour total interruption. The total dose on the gas was at least 16 Mrad. This gives an average dose rate of about 100 Krad per hour. The alpha source signal before and after irradiation vs. the electric field is shown in Fig. 2. The "after" measurement was done two days after the end of the irradiation. At an electric field value of 1 kV/mm the signal after irradiation is about 6% less than before irradiation. After the exposed gas was purged and the vessel refilled with new argon gas, the alpha source signal recovered exactly its value before irradiation.The electron drift velocity was also measured before and after irradiation at a fixed value of the electric field. The drift velocity after irradiation was almost 50% larger. A small amount of vessel wall outgassing, caused by the intense radiation, can explain the observed small decrease in signal and increase in drift velocity. Similar effects are caused by introducing a small percentage of CH_4 in argon gas at 100 atm [1].

A second exposure to the same ^{60}Co source took place from December 5 to December 21, 1991. This time the vessel was filled with a mixture of 99% Ar + 1% CH_4 at 100 atm. The total dose received by the gas, as extracted by the ion chamber measurements, was again at least 16 Mrad. Therefore the average dose rate was about 65 Krad per hour. The alpha source signal before and after irradiation vs. the electric field is shown in Fig. 3. At an electric field value of 1 kV/mm the signal after irradiation is about 8% larger than before irradiation. No change in the electron drift velocity was observed. We are not sure if the 8% signal increase is real or is due to experimental uncertainties (the whole electronic chain response could drift by about +-5%). If

the effect is real, it could be explained if the radiation dissociates a small fraction of CH_4 molecules. This effect, called radiolysis, has been studied by R. Holroyd [2]. A small decrease in the CH_4 concentration can explain the increase in signal and the fact that the drift velocity remained the same [1]. The vessel pressure was measured after irradiation and found to be the same within the uncertainties of the gauge reading.

4. Conclusions

Argon gas and a mixture of 99% Ar + 1% CH_4, both at 100 atm, have been exposed to at least 16 Mrad of radiation from a ^{60}Co gamma source. The ionization produced in each gas by an ^{241}Am alpha source was measured before and after irradiation. No significant radiation damage was observed. These results indicate that a high pressure forward calorimeter filled with 99% Ar + 1% CH_4 gas could operate for at least one year at SSC (with nominal luminosity), even without gas circulation.

5. Future plans

We plan to expose a mixture of 95% Ar + 5% CH_4 (the most likely mixture if this technology is finally chosen by SDC [3]) to an even larger dose (50 to 100 Mrads). During this exposure we plan to connect the cathode and the anode to the poles of a battery (the use of high voltage during irradiation is very difficult because of practical considerations). We also plan to expose a fill with the same gas mixture to a very high flux of neutrons from a nuclear reactor.

Acknowledgements

We would like to thank Brian Kross for designing and constructing the high pressure vessel used in the studies described in this paper. Many thanks also go to Dr. Robert Blackburn of the Phoenix Laboratory of the University of Michigan for actually performing the irradiations.

References

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[2] R. A. Holroyd, Effects of radiation damage to ionization chamber liquids, IEEE Trans. Nucl.Sci. NS-37 (1990).

[3] L. Demortier et al., " Test Beam Results of a Prototype Parallel Plate Electromagnetic High Pressure Gas Calorimeter", SDC-92-183.

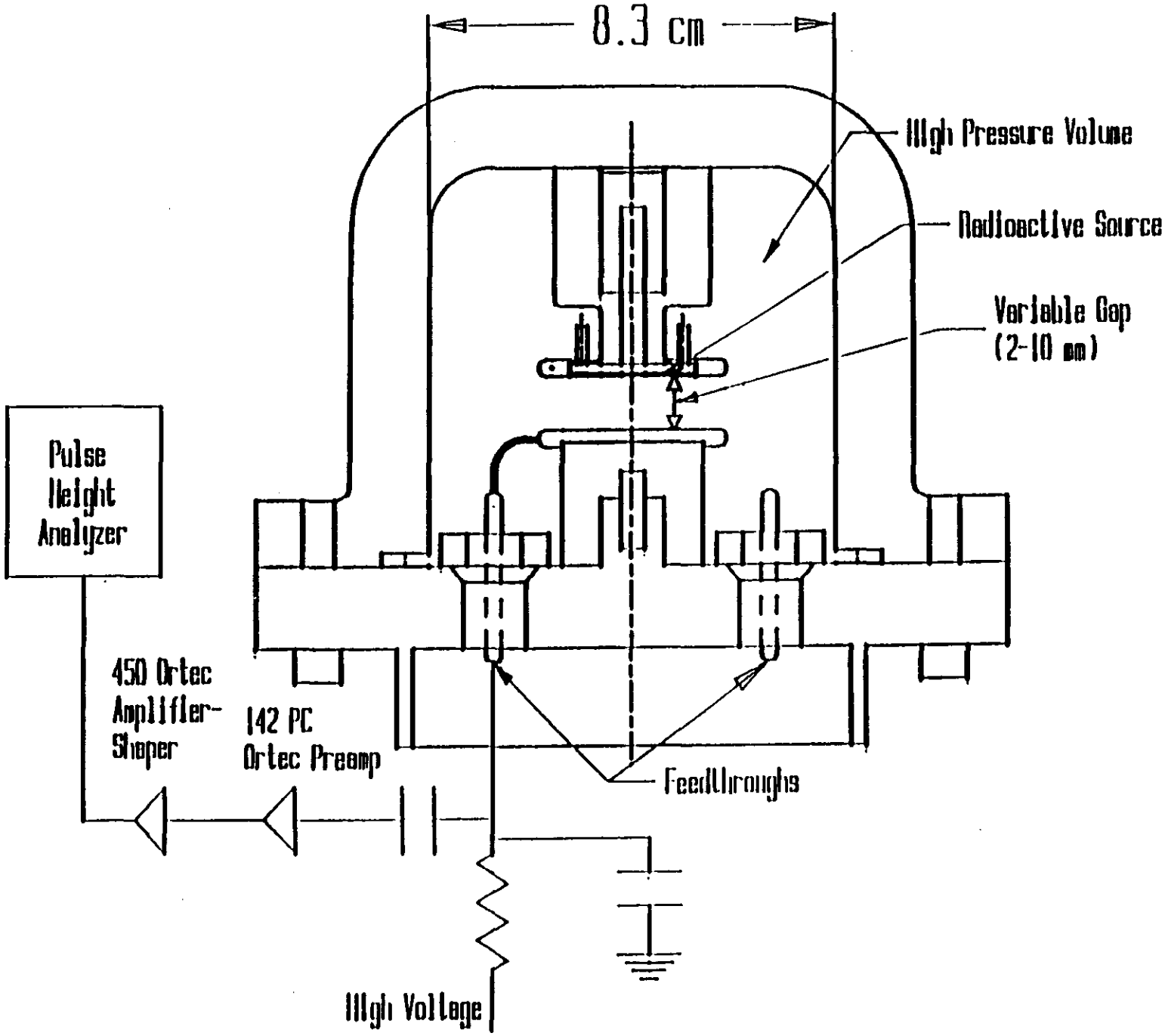

Fig. 1. Schematic diagram of the vessel used for the radiation damage studies.

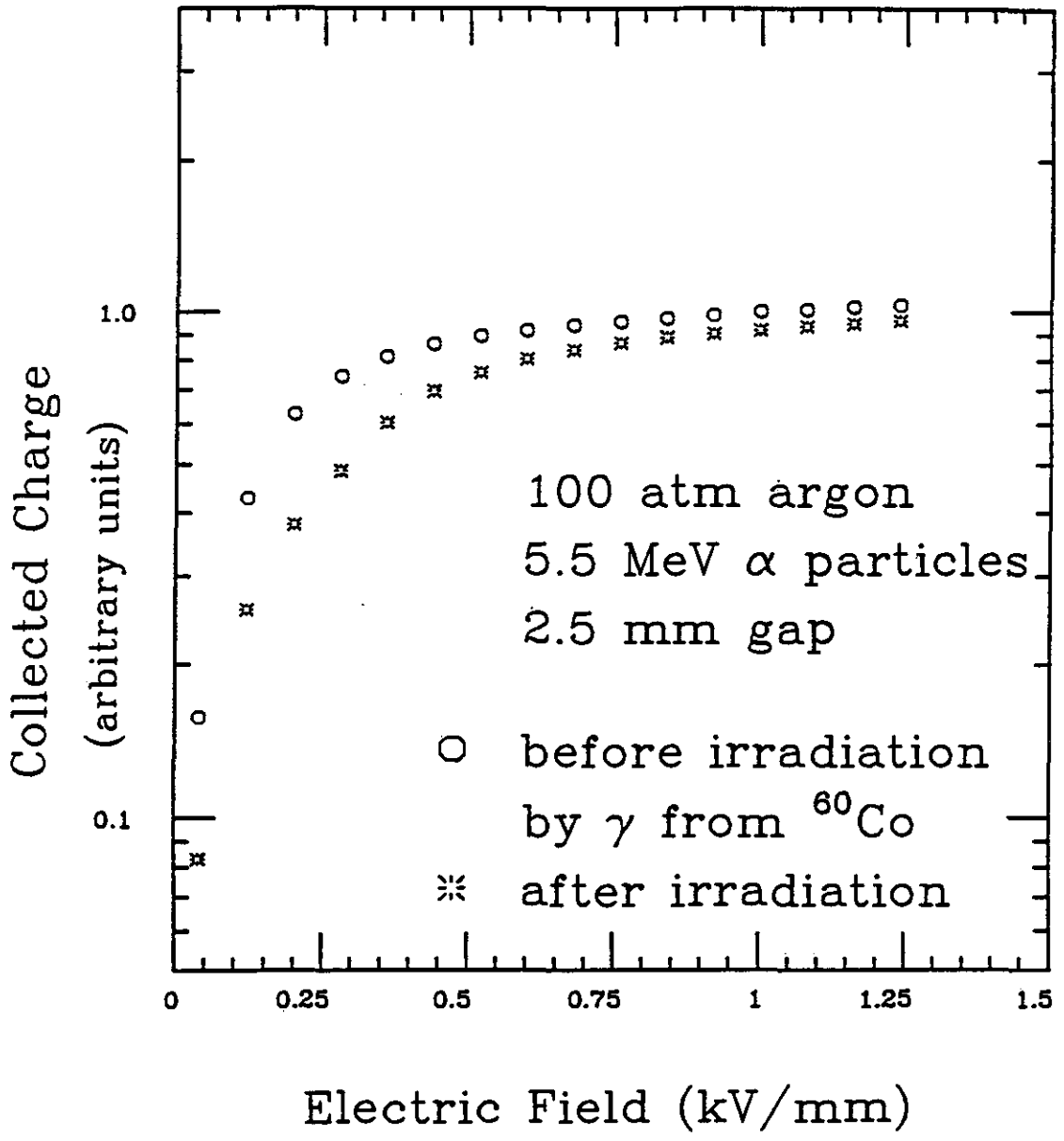

Fig. 2. Collected charge versus electric field before and after irradiation.

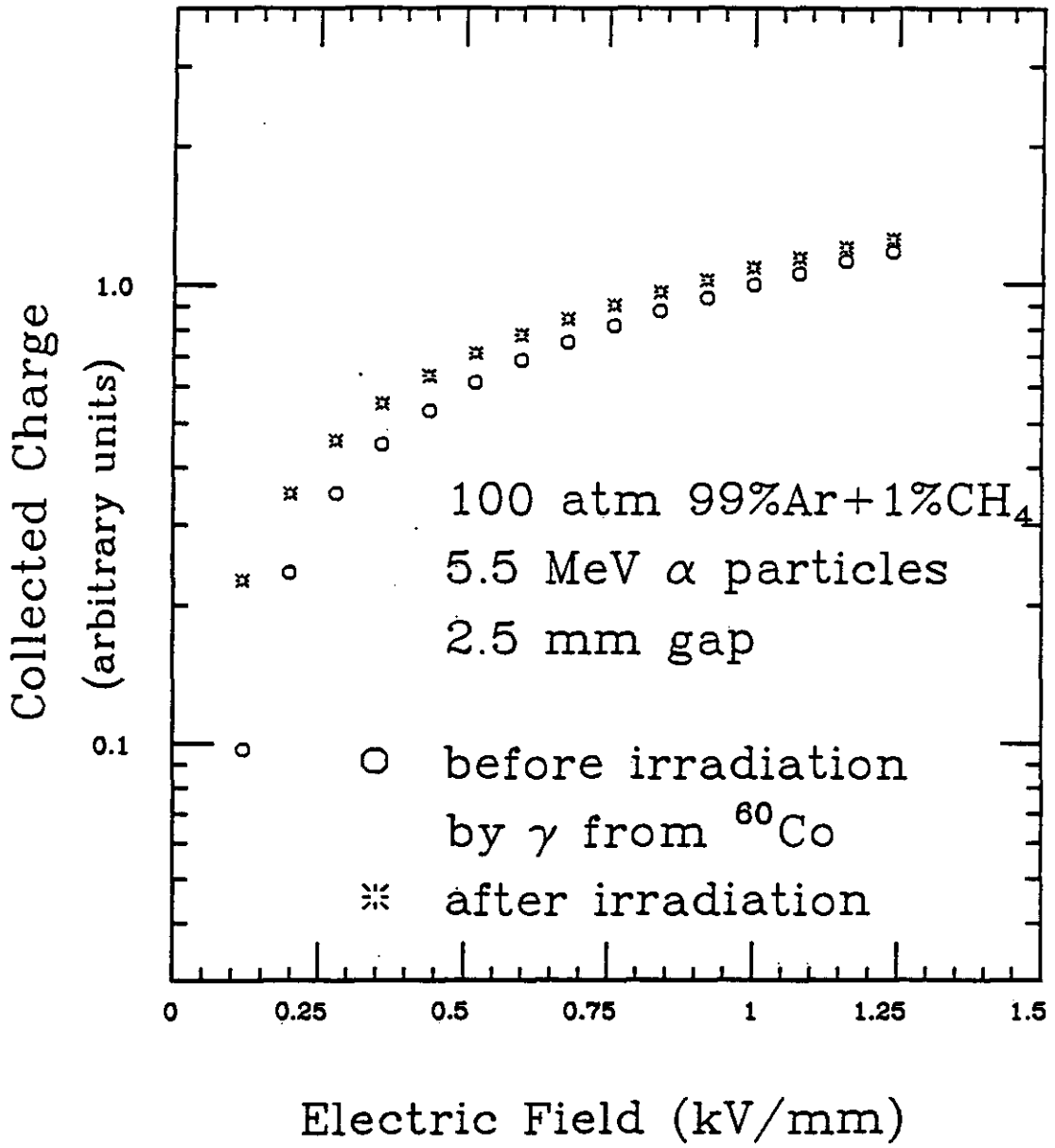

Fig.3. Collected charge versus electric field before and after irradiation.