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Results from Duke Wire-Joint Aging Test

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1. Introduction

We present the results from the Duke wire-joint aging test conducted with the second test module. The second test module has 45 straws and two separate gas volumes such that two independent ionization gas mixtures can be used. The straws are inside a 'shell' which is made of plastic frame and mylar windows. CO_2 was flown in the shell to keep the moisture level in the straws low. During the run, the module was placed inside a large radiation shield box which was made of 2 cm thick plastic. In order to reduce the moisture level even further, dry nitrogen was flown inside the radiation shield box. With the two dry volumes, the moisture level in the straw tubes was maintained around 300 ppm throughout the run without a fast gas exchange rate.

The two ionization gas mixtures used in this run were Xe-CO_2 (70-30) and Xe-CF_4-CO_2 (70-20-10). Because of the accuracy of the gas mixing technique, each component may vary a few percent from the nominal values.

Three types of wire-joints were tested; glass wire-joint, encapsulated glass wire-joint and peek wire-joint. In the Xe-CO_2 gas volume, glass wire-joints and encapsulated glass wire-joints were tested and in the Xe-CF_4-CO_2 gas volume, encapsulated glass wire-joints and peek wire-joints were tested.

The radiation sources used in the test were Sr^{90}. Eight 10 milli-curie, and two 50 milli-curie sources were lined in front of the test module every ~10 cm. The two 50 milli-curie sources were positioned near the wire-joint location. One was pointing at the wire-joints and the other was upstream of the wire-joints. The horizontal distance between the straw tubes and the sources was about 7cm. Because of the different distance from the sources to straw tubes, the amount of integrated radiation dosage varied from straw tube to straw tube. Our estimation shows that the integrated charge around the wire-joints in a straw tube is about 2-2.5 times of the average integrated charge quoted for the straw tube.

The current draw in each straw tube was controlled with HV. The current draw per straw tube varied from ~20 micro-amp to ~5 micro-amp for 90 cm of straw length. In order to draw the highest current, the HV settings were ~100-150 volts higher than the nominal voltage setting expected during the full LHC luminosity running period. The aging test experiment lasted for seven weeks.

2. Results

a. Wire-joints

We pulled some of wires from the Xe-CO_2 gas volume and the Xe-CF_4-CO_2 volume. These were the channels which accumulated the most integrated radiation dosage. Because the two strongest sources were positioned near the wire-joints, the area near the wire-joints received higher dosage. We estimate at least of ~ 1C/cm around the wire-joints. The pictures after the radiation are shown in Figure 1 through 4. In all four wire-joint samples, there is no visible degradation noticed under a microscope.

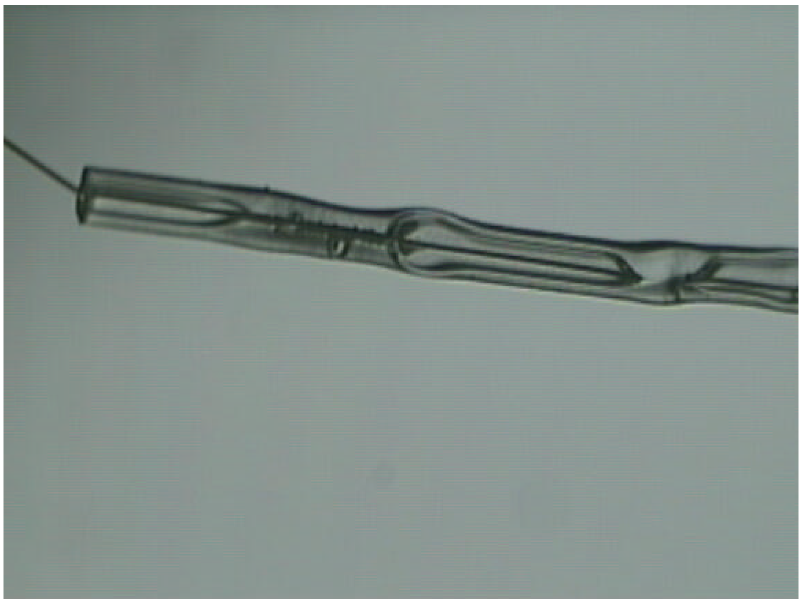


Figure 1. Glass wire-joint after ~1 C/cm radiation. This was in Xe-CO_2 gas mixture.

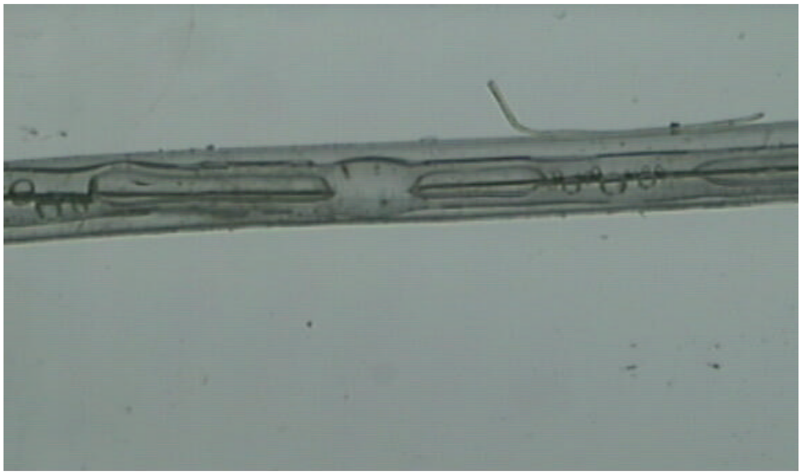


Figure 2. Encapsulated glass wire-joint after the radiation. Shown is the middle part of the wire-joint. This was in Xe-CO_2 gas mixture.

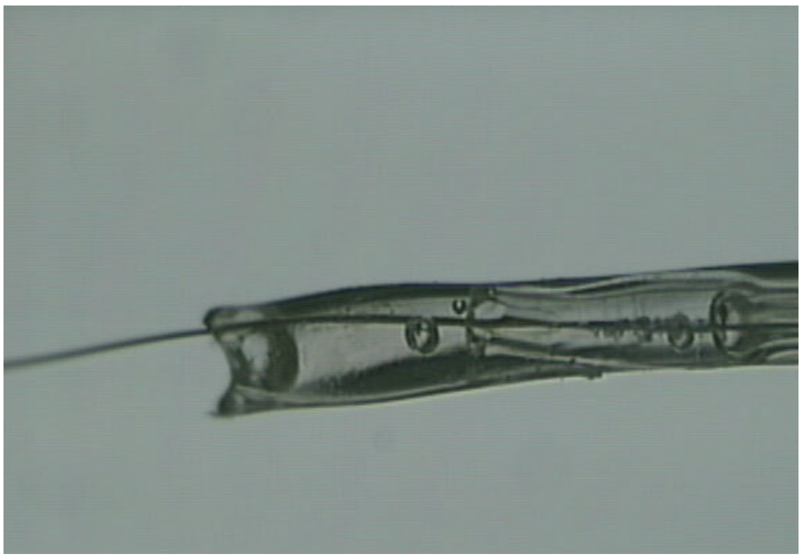


Figure 3. Encapsulated glass wire-joint after the radiation. This was in Xe-CF_4-CO_2 gas volume**.**

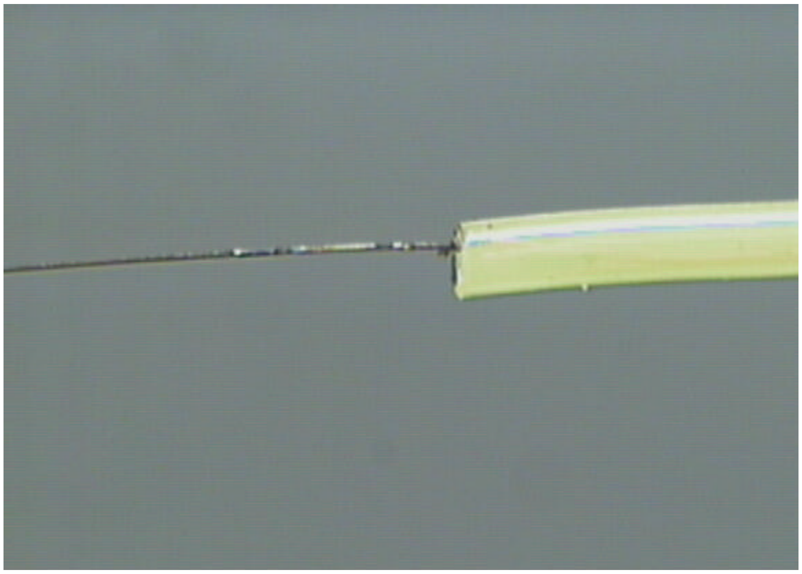


Figure 4. Peek wire-joint after the radiation. This was in Xe-CF_4-CO_2 gas volume.

b. Sense Wire

Contrast to the wire-joints, the sense wires in Xe-CF_4-CO_2 gas volume suffered damage. Figure 5 shows a section of the damaged wire. The damage is pronounced near the two strong sources. SEM scan shows that the gold plating on the wires near the two strong sources was being etched away. Away from the center, there are deposits on the wire.

The sense wire in Xe-CO_2 gas volume did not suffer damage. There is no dis-coloration on the wire unlike the sense wires from Xe-CF_4-CO2 gas volume. No obvious damage is observed from the SEM scan. The detail of the wire damage, including SEM images, is presented elsewhere.

c. Pull test

The pull test is to check the strength of the wire-joints after irradiation. In the plot below (Figure 6), the breaking tension is plotted for the three types of joints. The breaking tension of wire is about 200 grams. The failure of the peek wire-joints is likely due to the manufacturing defect rather than the irradiation effect. For other cases, the wire-joints are stronger than wire itself, i.e., wire breaks first rather than the wire-joints.

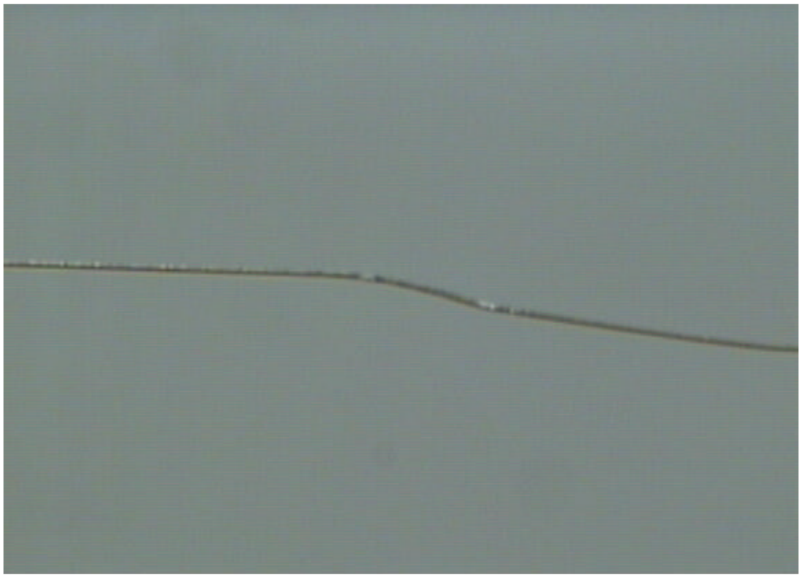


Figure 5. A picture of wire with gold etched away. This was in Xe-CF_4-CO_2 gas volume.

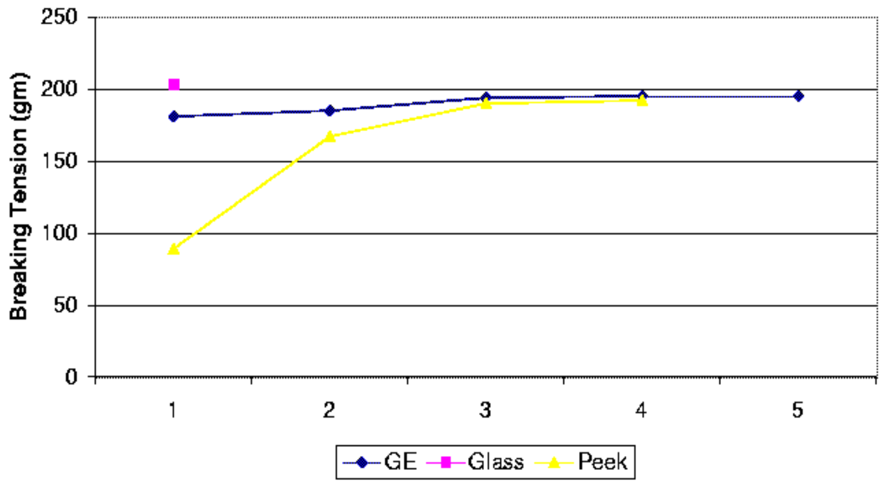


Figure 6. The tension when a wire segment with wire-joint fails. When the breaking tension is near 200 grams, the failure mode is the broken wire rather than the wire-joint failure.

d. Gain study

The gain is measured along each straw tube length at 26 equally spaced points four times a day throughout the run. The straws with wire-joints are read out from both ends. Because the wire-joints are not exactly center, the number of measurement is fourteen for one end and twelve for the other end. During the gain measurement, the SR^{90} sources are closed and high voltage is set at near the nominal operating voltage (1570 V). A Fe^{55} source is moved along the straw length and the charge is measured using a LeCropy ADC. Each ADC distribution (there are about 1500 distributions from one set of measurement) is fitted using a gaussian function and the mean value (called the average gain) is obtained.

Figure 7 shows the average gain from four channels (Xe-CO_2 volume) as a function of time. For each horizontal value, there are fourteen data points corresponding to the fourteen (or twelve) measurements. There is no obvious gain change over the period of the experiment.

Figure 8 shows the same but these are from Xe-CF_4-CO_2 volume. Unlike the plots in Figure 7, the average gain has decreased in some of the plots. The degree of the gain reduction depends on the irradiation dosage. The area with the most gain reduction is around the wire-joints where the two strong sources were located. We should note that the bottom two plots are from the straw tubes where thinner gold plated wire was used (0.3-0.4 micron thickness compare to 0.5-0.7 micron thickness for the baseline wire). The area with the gain drop is also consistent with the damage observed on wire.

Figure 7. Average gain as a function of time. From Xe-CO_2 volume.

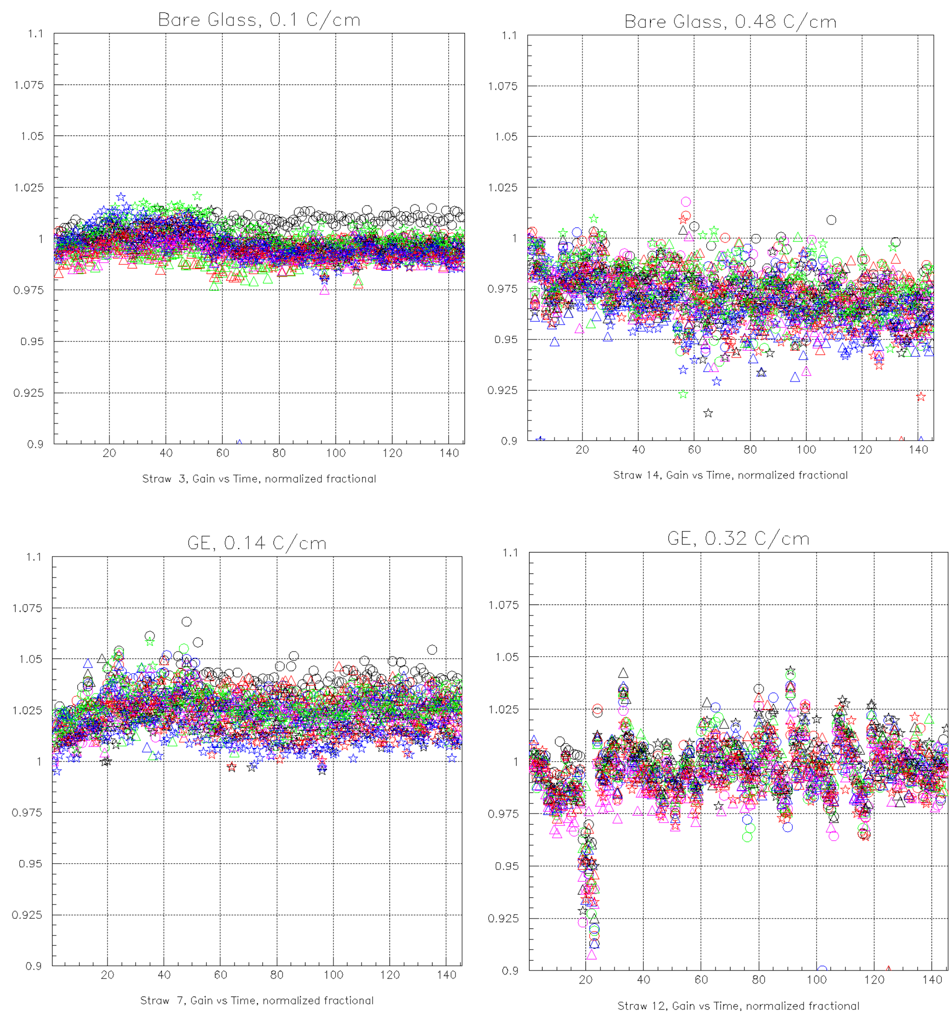
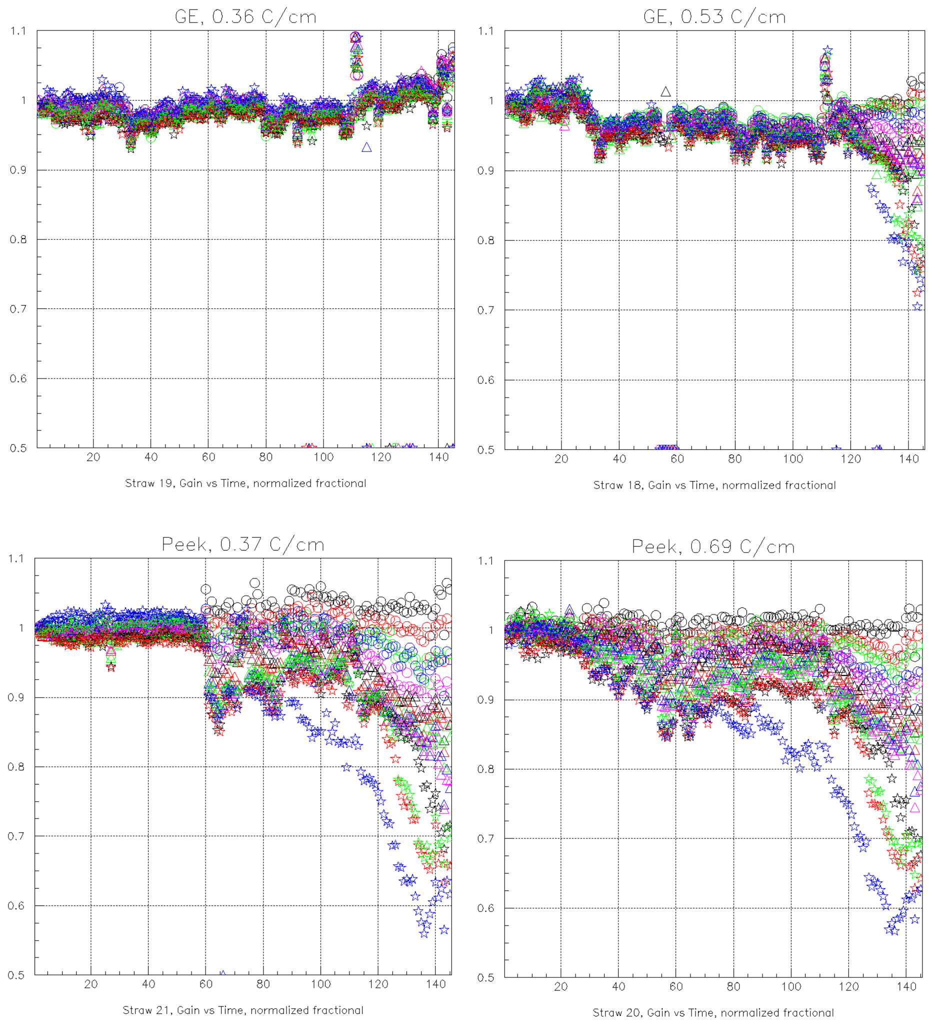


Figure 8. Average gain as a function of time. From Xe-CF_4-CO_2 volume.



3. Conclusion and Plan

Our measurement shows that the encapsulated glass wire-joint and peek wire-joints survived ~1 C/cm radiation dosage without any visible damage in Xe-CF_4-CO_2 and glass wire-joint and encapsulated wire-joint survived ~1 C/cm radiation dosage in Xe-CO_2 mixture as well. The moisture level in the straws was maintained around 300 ppm throughout the run.

However, the sense wire located near the high radiation in Xe-CF_4-CO_2 gas mixture suffered damage. SEM scan shows that in some areas, the gold plating is removed, and in some other areas there are deposits.

The wires pulled out were replaced and the test module was put back for operation in the second week of March. With about two weeks of running, we have not observed any gain change in all wires. The running parameters are very similar to the previous run. The plan is to continue the irradiation while taking the gain data four times a day until the integrated charge of ~2-3 C/cm is accumulated around the wire joint.