E614n18.wpd
Feb 20, 2001
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Cathode Foil Failure and Some Recommendations

Introduction

The E614 dense stack was bench tested from Jan 19, 2001 to Jan 30, 2001. The configuration of the dense stack, starting from the bottom and working up was: V1, U1, V2, U2, U3, V3, U4, V4, Cathode Only. During that time several planes failed. On Jan 22, plane V3 failed to hold high voltage. On Jan 25 plane U4 failed. By Jan 30 plane U2 also showed problems holding high voltage. At first it was assumed that the problem was due to broken or loose wires. But in fact when the detector was opened up it was found that no wires were broken but rather five of the nine cathode planes had failed. The cathode planes had all failed by ripping along the inner edge of the cathode frame. The rips occurred in various places around the circumference of the frame with no obvious position correlation from plane to plane. However all the planes that failed were adjacent to each other and were internal to the chamber. They were the cathode foils between wire planes V2 and V4. I have been looking into possible causes of the foil failure.

All the foils that failed had several things in common. They were all from the dense stack. They were all adjacent to one another. They had all failed an initial leak test and had been sealed with optical epoxy. However there is no one factor that can be pointed to that caused the foils to fail.

The failure of these foils is hard to understand for the following reasons. Of the nine foils mounted in UV modules, none failed in this manner. All foils in use in detector modules have been stretched by the same amount, 0.8%, and all foils have come from the same roll of aluminized polyester film. While not all foils have been sealed with optical epoxy, there are many foils that have been sealed with optical epoxy that have not failed. The foils that did fail came from two different stretching dates - Aug 2, 2000 and Sept 5, 2000. The oldest foil stretched by 0.8% was stretched on Mar 17, 1999 and was sealed with optical epoxy. It is much older than the foils that failed. It was set aside for long term testing and has not yet been installed in a chamber module.

Suggested Failure Mechanisms

Three possible mechanisms have been proposed for the failure of the cathode foils. They are foil damage during sealing, shrinkage in dry gas, and creep.

One suggestion was that the people sealing the foils with optical epoxy scraped the surface of the foil with the dispensing needle causing it to be damaged and fail at that point. There is evidence of something that looks like a scrape mark in some locations on the edge of the failed foils. However the foils did not fail until they had been operating in the detector for 3 days or longer. They had survived on the bench for 4 to 5 months before that without failing. They had also survived a leak test without failing. It should also be noted that the top cathode only foil has been sealed with optical epoxy, and shows this scrape mark, and so far has not failed.

A second suggestion was that the foils in the dry chamber gas lost moisture and as they dried out shrank resulting in increased tension. Robert Openshaw, using the top cathode only foil from the dense stack, measured this tension increase in dry helium. It was found to be 3% which is close to the value predicted from data sheets for mylar. This increase in tension is thought to be too small to cause a foil failure.

A third possibility we considered is creep failure. Robert Openshaw tested the tension of the dense stack top cathode foil and found it to be 1.5 lb/in instead of the expected 1.4 lb/in. Back in 1999 I did some creep tests on this material. A sample subjected to a linear tension of 1.6 lb/in developed a small tear along the clamping bar after 6 days, which slowly propagated. The foil then failed completely after 4 months. The sample also showed a strain mark along the clamping bar very similar to the scrape we see along the edge of the failed foils. This test is not very reliable however because it was done in an area where other people could have bumped the foil and also it represents a sample of only one. But it does suggest that some of our foils may be stretched uncomfortably close to the breaking point.

Recommendations

A discussion group meet to decide what to do for subsequent cathode foil production. The group consisted of Wayne Faszer, Dave Gill, Robert Henderson, Robert Openshaw, and Grant Sheffer. We decided to make the following changes to subsequent batches of foils:

- Reduce the foil tension by 25% to give a wider safety margin in foil tension.
- We will not initially seal leaky foils with optical epoxy and will instead try to use them as internal foils. Only the windows need to be leak tight, and they are only 50% of the foils in the experiment.

We also have another batch of about a dozen foils stretched by 0.8% which have just been completed. We decided to use them in the existing modules and dense stack because not using them will set back production by about one month. We will see if they get into trouble.