Restoring Contaminated Wires, Removing Gas Contaminants and Aging Studies of Drift Tube Chambers

D0 Collaboration

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The original muon detection system of the Fermilab D0 colliding beam experiment contained 12,000 drift cells 5 cm by 10 cm in cross section and up to 580 cm in length. There was one recycling gas system for all the chambers. During the first year of running, it was discovered that inefficient cells, all in regions of high radiation, had a contaminating shell of crud coating their wires. The source of the contaminant was found to be outgassing of the cathode pads which were made from a laminate of fiberglass and epoxy/polyester resin, with a copper cladding on one surface. The vapor formed a brittle sheath on the wires, but only in regions of high current discharge due to radiation from the accelerator and colliding beams. A method for cleaning the wires in place was devised. By heating the wire quickly to a temperature close to the melting temperature of gold, the sheath was ripped to shreds and blown away. The procedure for "zapping" wires and for removing the contaminating vapor will be presented. The upgraded D0 experiment now uses Iarocci-type mini-drift tubes for the forward muon system. The results of aging tests for these chambers will also be presented.

Summary of Talk: The Fermilab D0 experiment is a large, general-purpose collider detector. It consists of three systems: tracking, calorimetry and muon detection. The central muon detection system (WAMUS) is made up of a set of proportional drift tube chambers which surround large magnetized iron toroids. All of the WAMUS PDT chambers are made of the same 10 cm by 5 cm aluminum tubes, but vary from 330 cm to 580 cm in length. Each drift cell has top and bottom cathode pads, which are made of either G-10 (25%) or Glasteel (polyester and epoxy based plastic sheets with a glass fiber mat)(75%). Only the cathode surface has copper cladding. The aluminum tube is grounded while the potentials of the sense wire and pads are kept at +4.6 and +2.3 kV respectively. The gas mixture was Argon/Freon/CO_2 90:6:4 during the first run, and is Argon/Freon/Methane 84:8:8 for the upgraded detector. All PDTs share a recycling gas system. The forward muon tracking detector (FAMUS) consists of three layers of Iarocci-type mini-drift tubes (MDTs) covering large toroid magnets. Each tube has eight 1 cm by 1 cm cells up to 583 cm in length, with a 50 micron (W-Au) anode wire in the center. The tubes are made from aluminum extrusion combs with stainless steel cover foil and inserted into plastic (PVC) sleeves. The anode wire is grounded at the amplifier while the cathode potential is -2.3kV. The fast gas mixture is CF_4/CH_4 90:10. The MDTs also have their own gas recycling system. Although most of the hadrons and electrons are filtered out by the calorimeters before they reach the muon system, at small angles the background particle flux is rather high. Another large source of radiation during the first run was from the main ring accelerator, which passed, with very little shielding, right through the detector. During the first year of running we realized that the drift cells in regions of high level radiation were becoming very inefficient. We extracted and replaced several wires that were in the region of high radiation. The bad news was that the exposed wires were covered with a thick brittle sheath of crud. The good news was that the wall and pads of the drift cells were not damaged. Since changing the 500 plus wires that were affected was not a possibility, we searched for a cure that would clean the wires in place, and could be completed in a matter of days during an extended shutdown. A sample of the wire crud was taken to Argonne's chemical physics lab. Meanwhile, we performed our own studies and discovered a number of crud facts and attributes:

- The crud scrapes off easily, and dissolves in ammonia and in water.
- The source of the crud is from the vapors of the Glasteel of the cathode pad. The crud can be created quickly by flowing gas through Glasteel ground up into a powder and then into a test cell running at 1 microamp per inch of wire. The test cell has the same geometry as the PDTs. Crud formation is not dependent on the percentage of Freon in the gas mixture.
- The crud can be removed by increasing the cell voltage to create currents of 10 microamps/inch, but this process takes several days and is not a practical way to clean thousands of 500 cm or longer wires.

The Argonne analysis seemed to confirm our results, identifying the crud as similar to CASCAMITE 14, a powdered resin glue, using styrene. We made several attempts at renewing dirty wires inside drift cells, but only succeeded in forming an insulating layer of aluminum oxide on the cell walls and copper oxide on the pad surfaces. In our attempt to exploit the high current cleaning effect, however, we discovered that if the wire is heated quickly to a temperature close to the melting point of gold, the sheath of crud shatters and blows away! If the heating is too slow, the crud cooks into a coating which is hard to remove and is insoluble. If the temperature is too high, the gold melts and beads up (later tests showed that drift cells still worked if the gold was beaded up or even completely removed from the Tungsten wire). We were able to clean over 5000 wires during a two week shutdown using a "zapping" probe. One end of a cell sense wire was grounded to the chamber. A 1.55 microfarad capacitor is charged up between 3500 volts for a 190 cm long wire and 6300 volts for a 580 cm wire. This corresponds to a stored energy of 9.5 to 31 joules. The zapping probe is touched to the other end of the grounded wire and the capacitor is discharged through it in less than 2 millisec. The signals from the "zapped" wires are as good as newly replaced wires. We also discovered two ways to trap out the evil vapor. During the first run a cold trap operating slightly above the freezing point of CO_2 (Argon and CF_4 have even lower liquification temperatures) was added to the gas recycling system, and reduced the aging rate by a factor of ten. For the present run we are simply using a large activated charcoal filter. It has removed the contaminants without changing the gas mixture ratio. The famous MDT's have replaced the forward PDTs which would not have survived the present run which will reach an integrated luminosity of 2 inverse femtobarns. Aging tests of MDTs have been performed at Dubna, where the tubes were built. Several detectors made in the style finally used in the D0 detector were illuminated by a ^{90}Strontium source. A comparison was done between the radiated MDT and a non-irradiated MDT, using the signals from an ^{55}Fe source. All studies were performed with the CF_4/CH_4 90:10 mixture. No deterioration in the detector performance was seen with an accumulated charge up to 5 C/cm. The estimated charge accumulated on the anode wires during Run II is about 0.02 C/cm. These studies demonstrate that the MDTs can run for many years at expected Tevatron luminosities without aging.