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SDC
SOLENOIDAL DETECTOR NOTES

SOME FACTS CONCERNING THE ELECTRICAL RESISTANCE OF STRAW TUBE CHAMBERS

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Some Facts Concerning the Electrical Resistance of Straw tube Chambers

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I. The Cathode Resistance

The resistance is determined by the thickness and composition of the coating. We have always used aluminum for the coating material. Early in our experience with straw tubes we found that we could not use standard aluminized mylar because the coatings were too thin and the material was usually coated on both sides. We wanted to obtain as much electrical conductivity as we could but we found that we could not obtain coatings on mylar or polycarbonate that were thicker than about 1000 Angstroms. This limit is apparently set by the amount of heating that the plastic film can withstand during the metalization process. The resistance of these coatings is about 1 ohm/sq.

There is no conductivity across the gaps in the spiral wound straws as far as we know. The effective length of the straw when calculating the total resistance is therefore the length of the strip that forms the inside layer. It is about 0.45 in wide and perhaps 15% longer than the length of the tube itself. Thus a 1 meter long tube has a resistance of about 100 ohms. This is confirmed by measurements on the tubes.

The new Kapton material has 2500 Angstroms of aluminum and the measured resistance is 0.25 ohms/sq. This is 4 times lower than the resistance of the old material but the thickness is only 2.5 times thicker. This is probably because the coating is not uniform at a microscopic level and with the thicker coating there are more connections between islands of aluminum.

A copper coating was proposed by Kirk McDonald as something that could be applied more thickly to mylar and polycarbonate but the study was never done.

II. The Wire Resistance.

We have several possibilities for wire material and wire size as well as for coating the wire with a different material. Moreover the losses to the pulse amplitude after transmission along the wire depend on the rise time of the pulse because of the skin effect

Cu	1.75 microhm-cm	7.1 micron
Au	2.4	8.3
Al	2.6	8.5
Mo	4.8	11.8
W	5.6	12.7
Be-Cu 25 Alloy	7.7	15

Resistivities and skin depth at 100MHz for a few materials.

Our standard gold plated tungsten wire with 0.00100 in diameter has a measured resistance of 113 ohms/m. The amount of gold is 3 to 5% by weight which is the same as 3 to 5% of the area because the densities of gold and tungsten are about equal. This corresponds to 1.5 to 2.5% of the radius being gold so that the gold coating is about 1/4 micron thick on the 25 micron wire. Using a radius of 12.5 micron and the resistivity in the table the tungsten part of the wire has a resistance of 115 ohms/m. A gold wire with 4% of the area of the tungsten has a resistance of 1230 ohms/m and the parallel combination of the two is 105 ohms/m. This is in fair agreement with the measured value. The resistivity of the very thin drawn wire may differ from the bulk value quoted in the tables of resistivity. The gold lowers the resistance of the wire by only a small amount.

A reduction in the resistance of the wire can be achieved by increasing the size of the wire or by using a material with lower resistivity. Be-Cu of the type with high tensile strength has a higher resistivity and so is not desireable. Molybdenum wire has sometimes been used for chamber sense wires and has about a 15% lower resistivity than tungsten. Its Z is 42 as compared to 74 for tungsten which reduces the radiation length somewhat. Its tensile strength is about half that of tungsten. We can easily increase the diameter of the sense wire to 0.0015 in or 0.002 in. This will reduce the resistance of the wire by a factor of 2 or 4. A factor of 4 would match the resistance of the sense wire to that of the new kapton film.

The skin depth is inversely proportional to the square root of the frequency. As the table shows the typical skin depth at the typical frequency of 100 MHz is of the same order as the wire radius. Although the exact form of the dependence of the resistance on the frequency is complicated, a simple approximate relationship can be used. For values of the wire radius r and skin depth d such that r/d is less than or equal to 1, the effective resistance is within a few per cent of the D.C. value. For r/d = 1.5 the effective resistance is about 10% larger than the D.C. value. For r/d more than or equal to 2 the ratio of the effective resistance to the D.C. resistance is 1/4+r/2d.

For pulses from charged particle tracks where the rise time corresponds to a frequency of 100 MHz or less, the ratio r/d is about 1 so that we can just use the D.C. resistance. For pulses from the Fe-55 source (frequency of about 300 MHz) there is an increase in the resistive loss by 15-20% over the D.C. value. Losses will still scale inversely with the area of the wire. The gold plating on the wires is too thin to change the current distribution at high frequency.