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Basic Information Relating to Use of PDT's: Specification for Wire/Wall a-Concentricity

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Abstract:

The use of cylindrical drift tubes without support bridges for the wire is discussed. Basic formulae for calculating the electric field and the induced tracking errors for this configuration are presented.

GEM MEMO

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The PDT option for the barrel muon chambers of GEM would involve the use of pressurized, cylindrical drift tubes. Wires would be strung down the tube centers and would have their ends fixed at precision end plates. PDT's would not involve the use of wire bridges to reduce wire sag. This strategy is based on the following philosophy:

1) Bridges involve additional complications in the mechanical design and alignment of the muon chambers; it would be desireable to eliminate these if they were not necessary;

2) Allowing the wires to sag over the chamber length of approximately 4 meters should be acceptable if the wire position were calculable based on knowledge of the tension, and if deviation of concentricity of the wire center from the tube center did not compromise chamber resolution; it might be added that for the voltages and tube diameters anticipated for the PDT option, issues involving electrostatic instability do not present serious concerns.

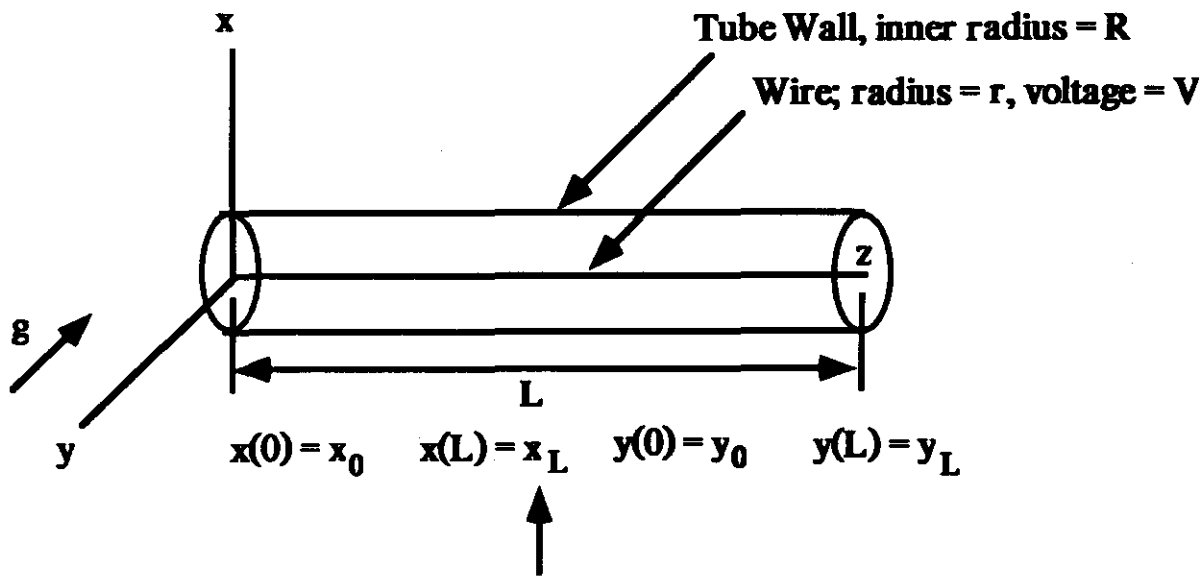
In this memo, we present some basic information relating to the use of cylindrical drift tubes which will be useful as reference material for future memos in this series of memos.

Fig. 1 illustrates the basic components of a drift tube, and formulae for wire displacement due to gravity and electrostatic forces are also given. At the bottom of the figure the formula for the critical voltage at which electrostatic instability sets in, V(critical), is also given. As an example, if R = 2 cm, r = 25 microns, L = 4m, and T = 300 g, V(critical) = 24 kV, which is much larger than would be required for PDT operation (about 4 kV).

Fig. 2 gives the formulae for calculating the electric field inside a drift tube, for the general case of a wire which is offset from the tube center. It is important to note that exact formulae exist for this general situation. By using these formulae, it is possible to calculate tolerances acceptable for wire/tube a-concentricity (which contribute to tracking resolution errors due to deviation of the true time-space function from that assuming the wire and tube wall to be concentric). Fig. 3

shows the drift time error for the case of an offset of 1 mm, for a 2 cm radius tube, a 25 micron radius wire, using HRS gas (89% argon, 10% carbon dioxide, 1% methane) at 1 atm and 2500 V. Fig. 4 shows the resulting tracking error. Fig. 5 shows the tracking error for a 0.5 mm offset, which amounts to an average error of less than 25 microns. Since this error is likely to be random, and is small compared to the 100 micron goal for single wire resolution, it is acceptable:

In conclusion then, the specification on wire/wall a-concentricity is 1/2 mm.



Coordinates of fixed ends of wire; tube center is along z axis

ρ = mass density of wire
T = tension of wire

$$K = 2\pi\varepsilon_0 V^2 / [R \ln(R/r)]^2$$

$$y_g = \rho \pi r^2 g / K$$

$$\omega^2 = K/T$$

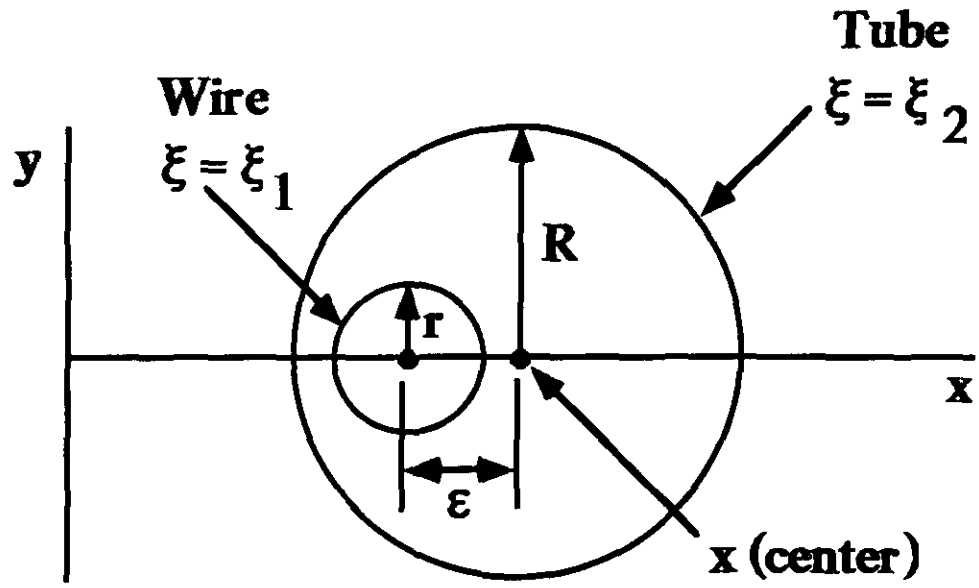
$$\boxed{y(z) = (y_0 - y_g)\cos(\omega z) + y_g + [y_L + (y_g - y_0)\cos(\omega L) - y_g]\sin(\omega z)/\sin(\omega L)}$$

$$\boxed{x(z) = x_0 \cos(\omega z) + [x_L - x_0 \cos(\omega L)]\sin(\omega z)/\sin(\omega L)}$$

$$\boxed{V(\text{critical}) = 3611\ V\,(T/300\ g)^{0.5}\,(R/2\ \text{cm})\,(4\ m/L)\ln(R/r)}$$

Fig. 1

ELECTRIC FIELD IN DRIFT TUBE CAN BE EASILY CALCULATED PRECISELY



BIPOLAR COORDINATES

$$x = a \sinh(\xi) / (\cosh(\xi) + \cos(\theta))$$

$$y = a \sin(\theta) / (\cosh(\xi) + \cos(\theta))$$

$$\varepsilon = (R^2 + a^2)^{1/2} - (r^2 + a^2)^{1/2}$$

$$x\,(\text{center}) = a \coth(\xi_1)$$

$$r = a / \sinh(\xi_1)$$

$$R = a / \sinh(\xi_2)$$

$$E_x = -V (\cos(\theta) \cosh(\xi) + 1) / [a (\xi_1 - \xi_2)]$$

$$E_y = V (\sin(\theta) \sinh(\xi)) / [a (\xi_1 - \xi_2)]$$

Fig. 2

Effect of Tube Wall Placement on Time-Space Function: Epsilon = 1 mm; R = 2 cm, r = 25 microns, V = 2500 volts, HRS gas, 1 atm

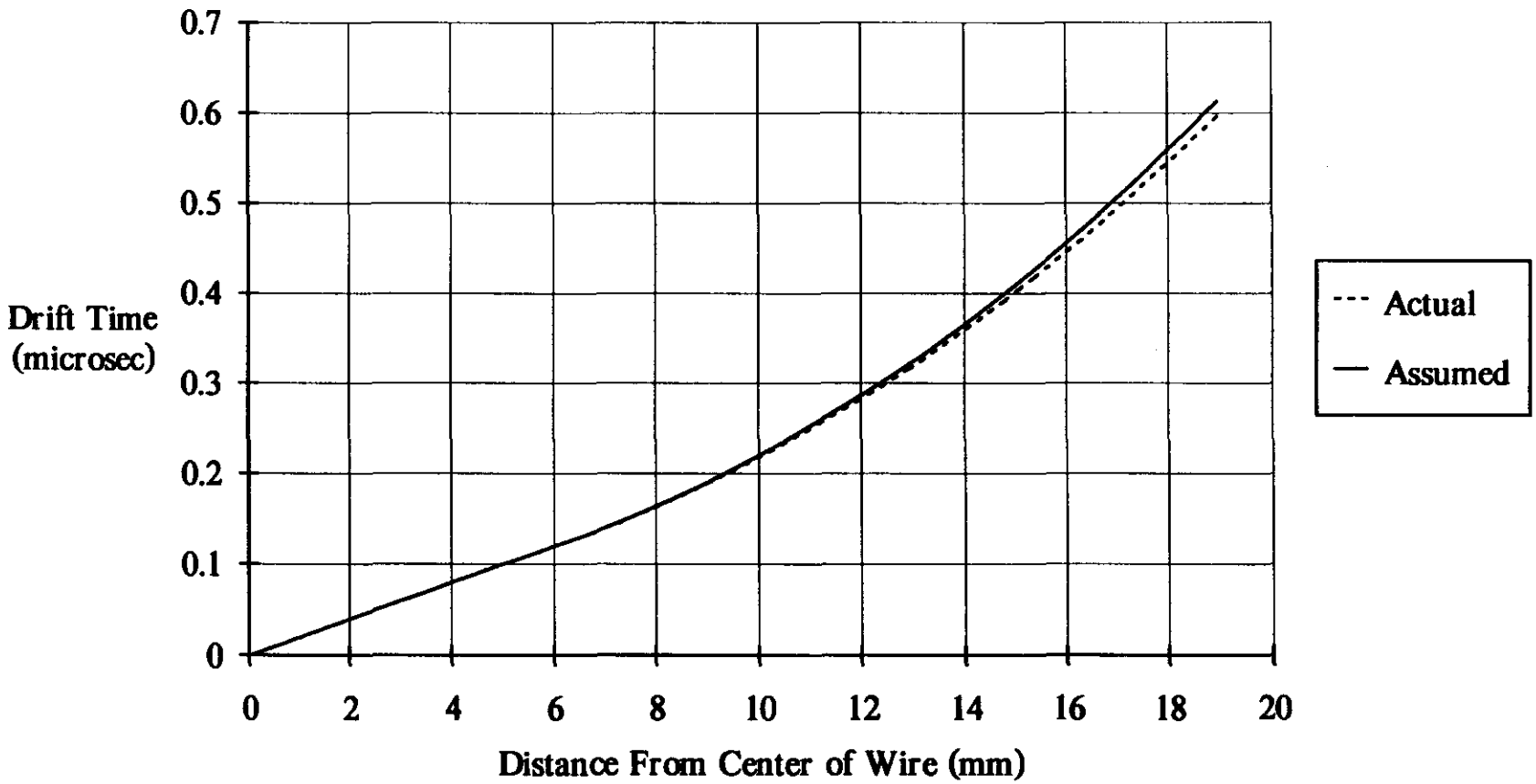


Fig. 3

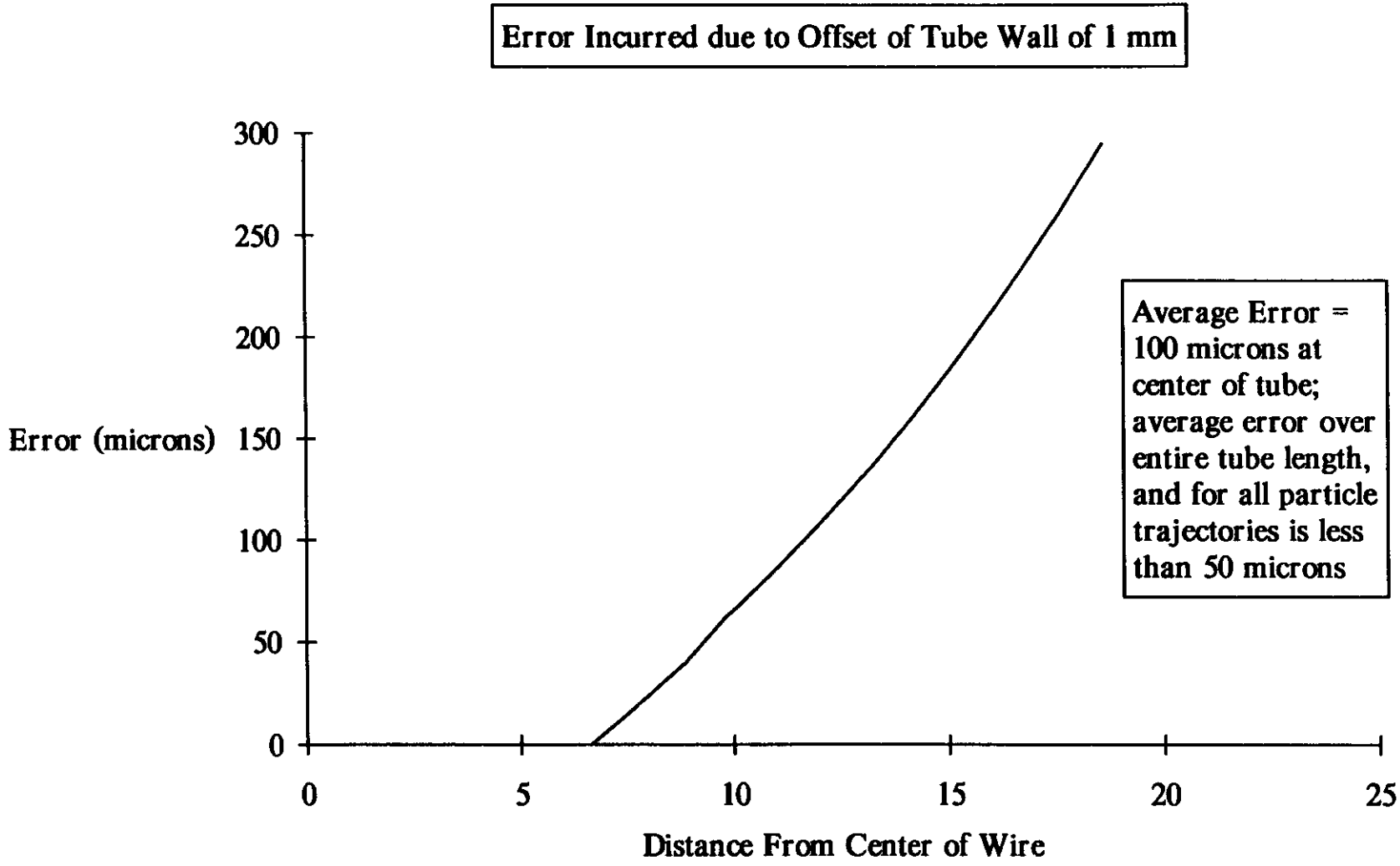
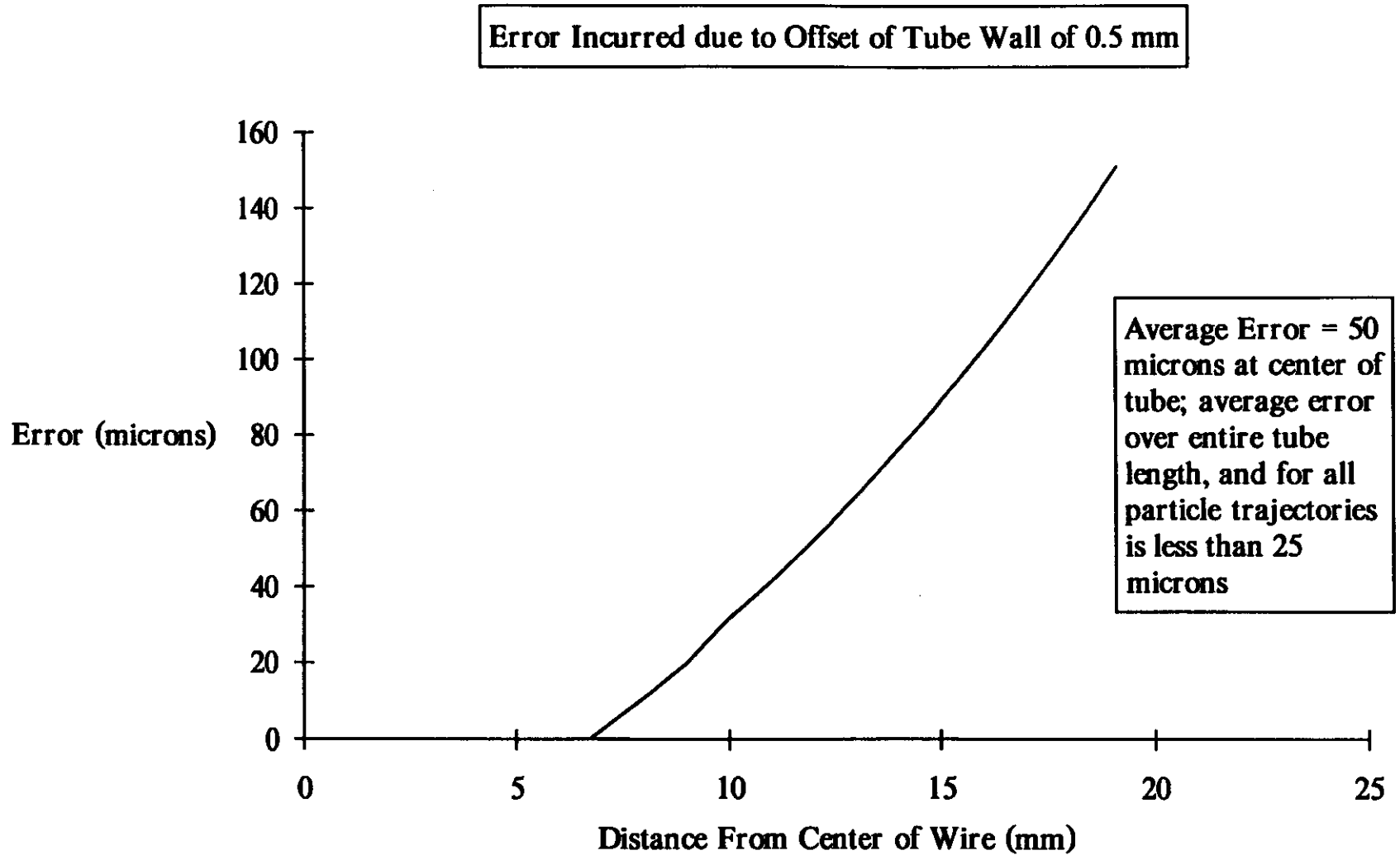

Error Incurred due to Offset of Tube Wall of 1 mm
Error (microns)
300
250
200
150
100
50
0
0
5
10
15
20
25
Distance From Center of Wire
Average Error = 100 microns at center of tube; average error over entire tube length, and for all particle trajectories is less than 50 microns

Fig. 4

Fig. 5


Error Incurred due to Offset of Tube Wall of 0.5 mm
Error (microns)
160
140
120
100
80
60
40
20
0
0
5
10
15
20
25
Distance From Center of Wire (mm)
Average Error = 50 microns at center of tube; average error over entire tube length, and for all particle trajectories is less than 25 microns