E614 Technical Note
Comparison of DME and He-DME (70/30) as Chanber Gases

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The current Michel parameters spectrometer design requires planar drift chambers 4 mm thick, filled with DME gas and separated by gaps of helium. 6 μm aluminized mylar foils will separate He and DME. Keeping these gases separate and monitoring and controlling their pressures and temperature will be both difficult and expensive. For this reason the possibility of using one helium-based gas throughout the spectrometer was considered. While the 6 μm foils would remain in place, the same gas mixture would occupy the drift space in the chambers as well as the gap between chambers. In order to maintain some of the advantages of DME, such as small Lorentz angle and small drift velocity, the gas chosen for this comparison is a 70% He, 30% DME mixture. A 73/27 mix exactly matches the mass in the current two-gas chamber design in the volume including PDCs 1 through 13, thus keeping multiple scattering contributions the same. In what follows, numbers from the 70/30 mix will be used since it is well documented. Relevant parameters of the two gases are shown in Table 1.

	N_c/cm	θ_L ^{o}	v_D(μm/ns)
DME	30	5	2.5
He-DME (70/30)	10	14	10.0

Table 1. Parameters for DME and He-DME (70/30). N_c/cm is the number of primary electron clusters produced per cm [1]. Values for θ_L and v_D are taken at E = 1 kV/cm and B = 2 T.

Two main concerns in comparing gases are chamber efficiency and position resolution, both of which are dominated by the number of electron clusters N_c produced per cm of particle track in the chamber. The intrinsic detection efficiency of a chamber is given by [2]

$$\epsilon = 1 - e^{-xN_c} \tag{1}$$

where x is the track length in the drift cell. This value represents the ideal plateau efficiency of the chamber. For the current chamber design x = 0.4 cm, so that for DME $\epsilon = 0.9999938$ and for He-DME (70/30) $\epsilon = 0.9817$. It is clear that for DME there are more than enough electron clusters produced (by about a factor 2) while for He-DME there are too few to attain good efficiency. Therefore switching to He-DME throughout the spectrometer will require that the width of each PDC be increased to 0.6 cm which will then yield a satisfactory efficiency of $\epsilon = 0.9975$. In order to maintain nearly circular drift contours throughout the bulk of the drift cell, the sense wire spacing will also need to be increased to 0.6 cm, which in turn will reduce the total number of sense wires per chamber.

The position resolution within a drift cell will vary with distance from the sense wire due to electron diffusion and variation in arrival times of the earliest electron cluster. The latter process dominates for cell sizes used in the present detector. An estimate of the size of this effect has been made under the following assumptions: the detection threshold for the pre-amp used is one electron cluster consisting of roughly 2 electrons, the drift velocity is nearly constant throughout the cell except near the avalanche region around the sense wire, and there is no position uncertainty due to chamber construction. If a gas has N_c clusters/cm formed by a track, one cluster could occur with equal probability anywhere along a distance $1/N_c$. Since it is the earliest arriving cluster that determines the timing, it is assumed that the cluster is contained in a segment of length $1/N_c$ which is nearest the sense wire. For tracks normally incident upon the chamber the uncertainty in the cluster's position, and therefore its arrival time, is given by the difference of the distance of closest approach d, and the distance between the sense wire and the end of the segment containing the cluster. For circular drift time contours this difference is

$$\sigma_D = \sqrt{d^2 + (\frac{n}{2N_c})^2} - d \tag{2}$$

where n is the number of electron clusters required to fire the pre-amp. This position uncertainty is plotted versus distance from the sense wire in Fig. 1 for DME and in Fig. 2 for He-DME (70/30). Using n=2 in equation 2 gives good agreement with the chamber measurements presented in [3].

In both figures the position error due to electron diffusion was included, where it is seen to make small contributions over the drift distances of concern here. For He-DME the cluster arrival time uncertainty is dominant throughout the cell. DME, with 3 times the cluster density of He-DME (70/30), has a position resolution of less than 30 μm throughout most of the cell, while He-DME averages from 60 to 100 μm down to a radius of 1mm where the uncertainty grows rapidly.

While DME exhibits by far the least position uncertainty over a larger portion of the cell, He-DME should provide tolerable position resolution, provided the inner portion of the drift cell (d $<$ 0.5 mm) is not used. In this case the resolution of the cell averaged over distance is about 110 μm. To see what this means in terms of momentum resolution, helices without energy loss or multiple scattering were used to generate hits in all 26 drift chambers. A gaussian error with mean 110 μm was attached to each hit and then the tracks were reconstructed using two methods. The first used all 26 planes in the fit. The second mimics the "slide" approach described in the MIG request[4], using only 8 consecutive planes in the fit. Multiple scattering was not included in either method. Both methods were repeated for several energies and angles and the extracted momentum resolutions are shown in Table 2 with the 8-plane (1 slide) results shown in parentheses. The resolutions were found to scale linearly with the input position resolution. For the 26-plane case, in all conditions except for

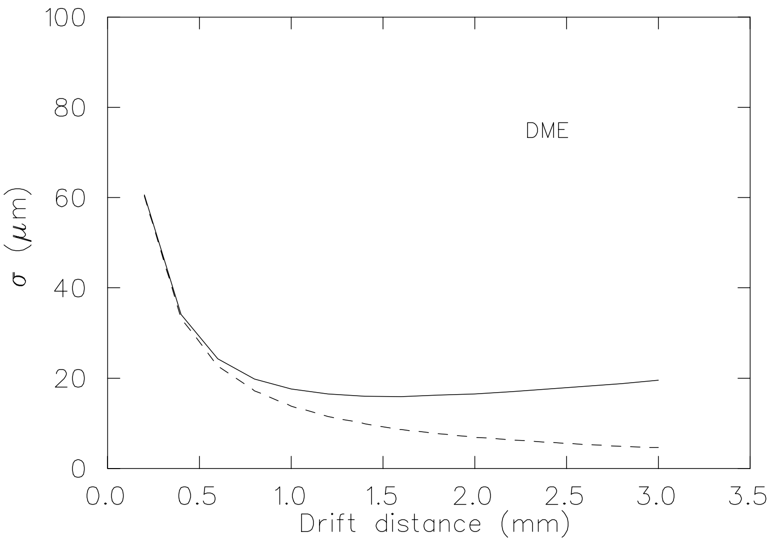

Figure 1: Position uncertainty within drift cell using DME gas. Solid curve: sum in quadrature of cluster statistics error and diffusion error. Dashed curve: cluster statistics only.

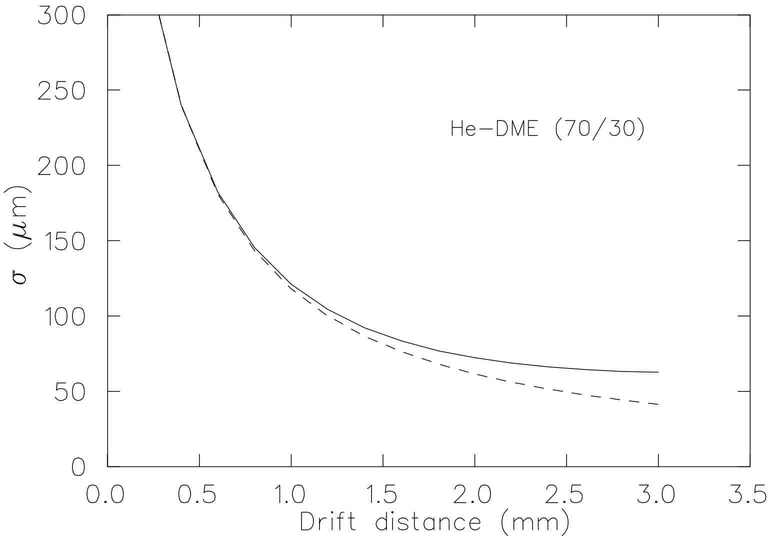

Figure 2: Position uncertainty within drift cell using He-DME (70/30) gas. Solid curve: sum in quadrature of cluster statistics error and diffusion error. Dashed curve: cluster statistics only.

$p \geq 50$ MeV/c and $\theta \geq 15^o$, the resulting momentum resolution (σ) is quite small, less than 100 keV. For the 8-plane case the resolutions agree with those shown in curve 4 of Fig. 13 of the Appendix of the MIG request once they are scaled by the input position resolutions (50 μm / 110 μm).

Theta(degree)	20 MeV/c	30 Mev/c	50 MeV/c
10	36 (158)	64 (355)	180 (1150)
15	24 (99)	40 (232)	117 (736)
20	19 (67)	26 (161)	80 (521)
30	14 (35)	16 (86)	42 (290)
45	14 (26)	16 (36)	18 (119)
60	18 (30)	18 (30)	19 (42)
75	19 (35)	19 (33)	19 (34)

Table 2. Momentum resolution (σ) in keV as a function of p and θ with all 26 planes used in fit. Numbers in parentheses were obtained using only 8 consecutive planes (1 slide) in fit. A position uncertainty of 110 μm is assumed for each drift chamber plane. Momentum resolution scales linearly with position uncertainty.

Also shown in Fig. 13 is the momentum resolution as a function of angle for 50 MeV positrons with multiple scattering included and handled using the slide method. For the worst case, $\theta = 10^o$, the total momentum resolution (σ) is 770 keV. In the vacuum case (no multiple scattering) it is 480 keV. From this, the extracted multiple scattering effect is 600 keV. Combining this in quadrature with the result in Table 2 (50 MeV/c, 10^o, 110 μm) yields a total resolution of 1300 keV or about 70% higher than that obtained when a 50 μm position resolution is used. For 45^o the corresponding increase is 23% and for 60^o it is only 6%.

To summarize, if it is decided to use a single gas (He-DME 70/30) rather than pure DME separated by gaps of He, the drift chamber cell width must be increased to 6 mm in order to attain good efficiency. This would also mean increasing the sense wire spacing to 6 mm which in turn means fewer sense wires. It is possible that the expense caused by these changes to the chamber design may offset the savings from going to a simpler gas monitoring and handling system. The position resolution in the cell will deteriorate from less than 30 μm for DME to an average of 110 μm for He-DME. The result of this change would be to broaden by about 70% the momentum resolution for 50 MeV/c positrons at 10^o. For larger angles and lower momenta the effect is less, as small as 6% for 50 MeV at 60^o. Such an increase is acceptable for large angle tracks but for small angle tracks it may pose a problem. If more planes are included in the slide, the small angle errors can be reduced significantly.

References

[1] W. Farr et al., Nucl. Instr. and Meth. **154**, 175 (1978).

[2] J. Fischer et al., Nucl. Instr. and Meth. **A238**, 249 (1985).

[3] V. Cindro et al., Nucl. Instr. and Meth. **A309**, 411 (1991).

[4] D.R. Gill et al., Major Installation Grant request to NSERC (1996).