Lorentz Angle Effect in Gas Mixtures

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1 Introduction

Resolution degradation of the CSC's have contributions from two major sources (i) due to tracks inclined from the normal to the face of the chamber, and (ii) due to the Lorentz angle of the gas mixture which is dependent on the gas mixture chosen for the tracking detectors. Therefore, the gas choice must be made with great care. In addition to the Lorentz angle there are other properties of the gas one should keep in mind. These include:

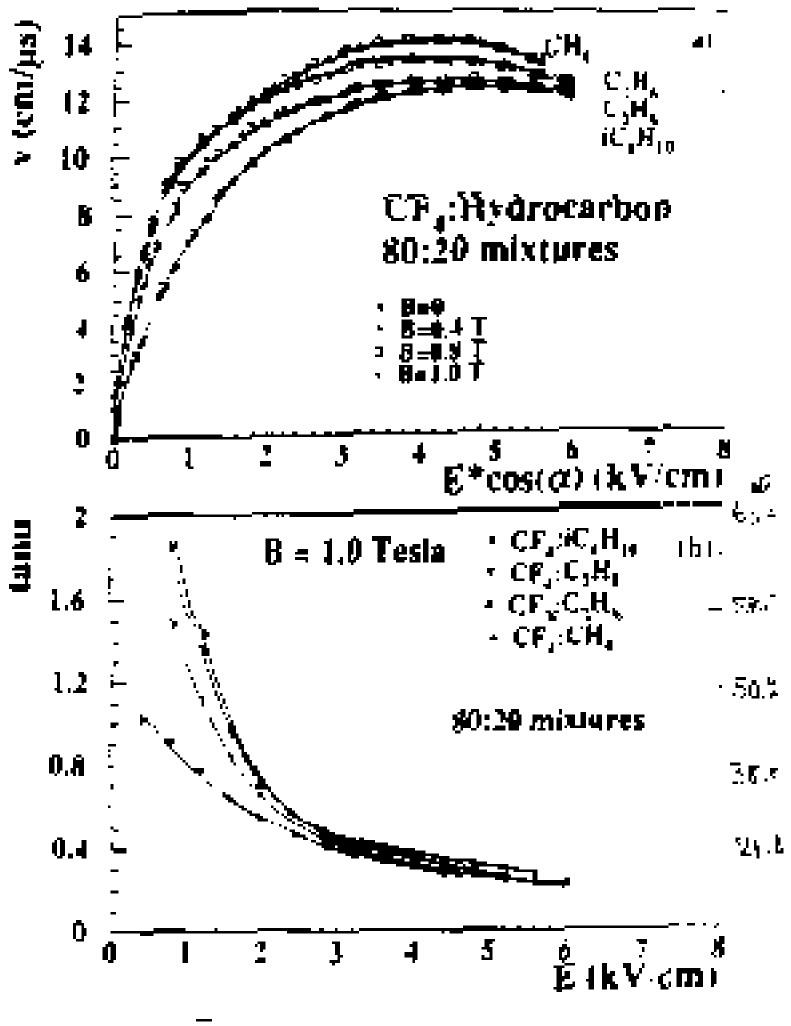
- The gas should possess fairly good electron drift velocity
- Diffusion of electron should be low
- The gas should have a stable operating plateau
- The gas mixture should be nonflammable and chemically not aggressive
- The CSC aging effect should be small

2 Previous Studies

There have been many studies carried out in the recent past which focused on finding a suitable gas mixture for drift and CSC chambers. Y.H. Chang etal [1] of the MIT group and O. Kiselev etal [2] of the PNPI group have extensively studied gas mixtures for CSC chambers and this report reviews their work and looks for a probable gas to be used in PHENIX trackers.

2.1 Y.H. Chang Studies

Y.H. Chang studied 34 CF_4 gas mixtures in the magnetic fields of 0-1 T. Measurements of drift velocity of electrons in gas mixtures of CF_4 and hydrocarbon gases, CF_4 and CO_2 mixtures and $CF_4 + CO_2 + hydrocarbon$ gas mixtures were done. Figure 1 shows the CF_4 + different hydrocarbon mixtures, such as methane, ethane, propane and isobutane mixtures for drift velocity vs. electric



v (cm/μs)
CF_4:Hydrocarbon
80:20 mixtures
E*cos(α) (kV/cm)
B = 1.0 Tesla
80:20 mixtures
E (kV/cm)

Figure 1:

field and the behavior of the Lorentz angle with electric field. The drift velocity has been plotted against the electric field component parallel to drift direction. The above measurements shown are for a mixture of 80:20 at a B field of 1 Tesla. One can note that as the molecular weight of the hydrocarbon increases (as one moves from methane to butane) the drift velocity of the electron decreases and the Lorentz angle also decreases for such mixtures. However, the Lorentz angle is affected significantly in the lower E field regions. Figure 2 shows thebehavior of $CF_4+ibutane$ for different mixtures, the behavior of drift velocity and tangent of Lorentz angle as a function of E field. As the composition of CF_4 mixture decreases the electron drift velocity in the mixture decreases. The addition of a third component gas such as CO_2 reduces the Lorentz angle drastically. This is evident from Figure 3. The electron drift velocity also decreases. At B=1 T, gas mixtures $CF_4 + CO_2 + ibutane$ of ratios 20:60:20 and 30:60:10 seem to show a Lorentz angle α of around 6° and the electron drift velocity are around 7cm/μs. These are gas mixtures also exhibit a behavior of almost linear dependence of tan α with E field.

There have been studies of drift velocity and Lorentz angle in othermixtures such as $CF_4 + Ar + ibutane$, $CF_4 + Ar + CO_2$, and $CF_4 + Ar + C_2H_6$. Some of these mixtures have a lower breakdown voltage and most of them have a Lorentz angle greater than those gas mixtures discussed earlier. Figures 4 and 5 show the plot of defection figure of merit (C) for a gas with the electric field component parallel to drift velocity. The gas deflection figure of merit is defined as:

$C = \frac{vB}{Esin\alpha}$ v: Velocity
B: Magnetic Field Strength
E: Electric Field Strength
α: Lorentz Angle

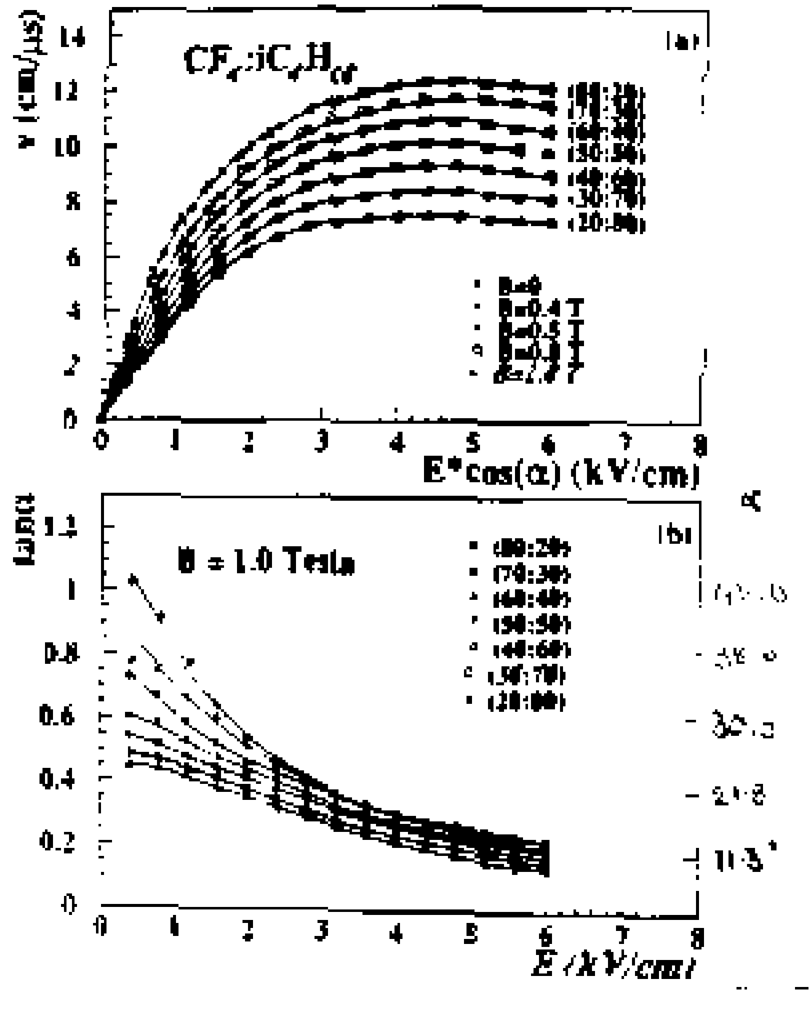
For a good gas mixture one would expect C to be a constant as a function of E. If this were to be the case one can assume a linear scaling to obtain the value of α at different B fields. Note for $CF_4 + hydrocarbon$ mixtures thefigure of merit is fairly constant, however, the influence of a magnetic field on the microscopic drift process leads to small effects only, as seen from the scatter of the points.

Mixtures of $CF_4 + CO_2 + ibutane$ doesn't seem to have these effects whereas in the Ar mixtures it is the worst.

Making use of thefigure of merit data one could calculate the Lorentz angle for mistures of $CF_4 + CO_2 + ibutane$ of composition 20:60:20 and 60:20:20 at different B.

Gas Mixture	α at E= 4 kv\cm		
$CF_4 + CO_2 + ibutane$	B=0.3T	0.4T	0.5T
(a) 20:60:20	2.03	2.7	3.4
(b) 60:20:20	3.77	5.03	6.3
$CO_2 + Ar + CF_4$[1]			5.6

[1]Mixture studied by O. Kiselev etal.



CF$_4$:iC$_4$H$_{10}$
(a)
v (cm/μs)
E*cos(α) (kV/cm)
B=0
B=0.4 T
B=0.5 T
B=0.8 T
B=1.0 T
(80:20)
(70:30)
(60:40)
(50:50)
(40:60)
(30:70)
(20:80)
(b)
B = 1.0 Tesla
E (kV/cm)
α

Figure 2:

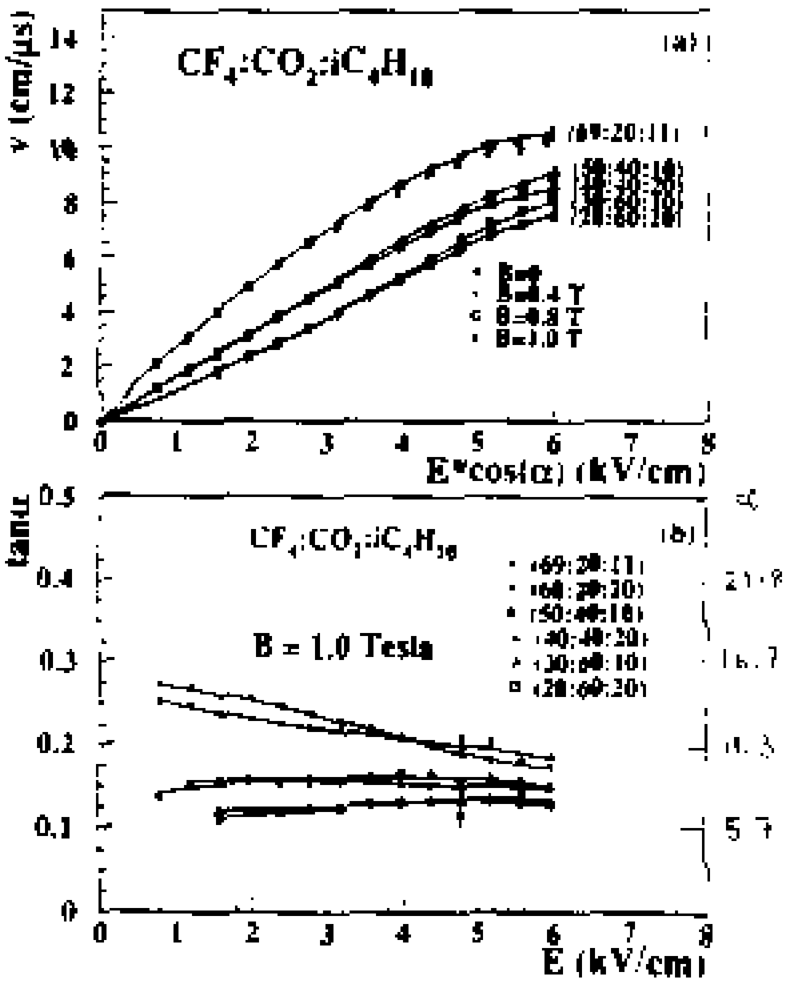

v (cm/μs)
CF4:CO2:iC4H10
(a)
(69:20:11)
B=1.0 T
E*cos(α) (kV/cm)
tanα
CF4:CO2:iC4H10
(b)
(69:20:11)
(60:20:20)
(50:40:10)
(40:40:20)
(30:60:10)
(20:60:20)
B = 1.0 Tesla
E (kV/cm)

Figure 3:

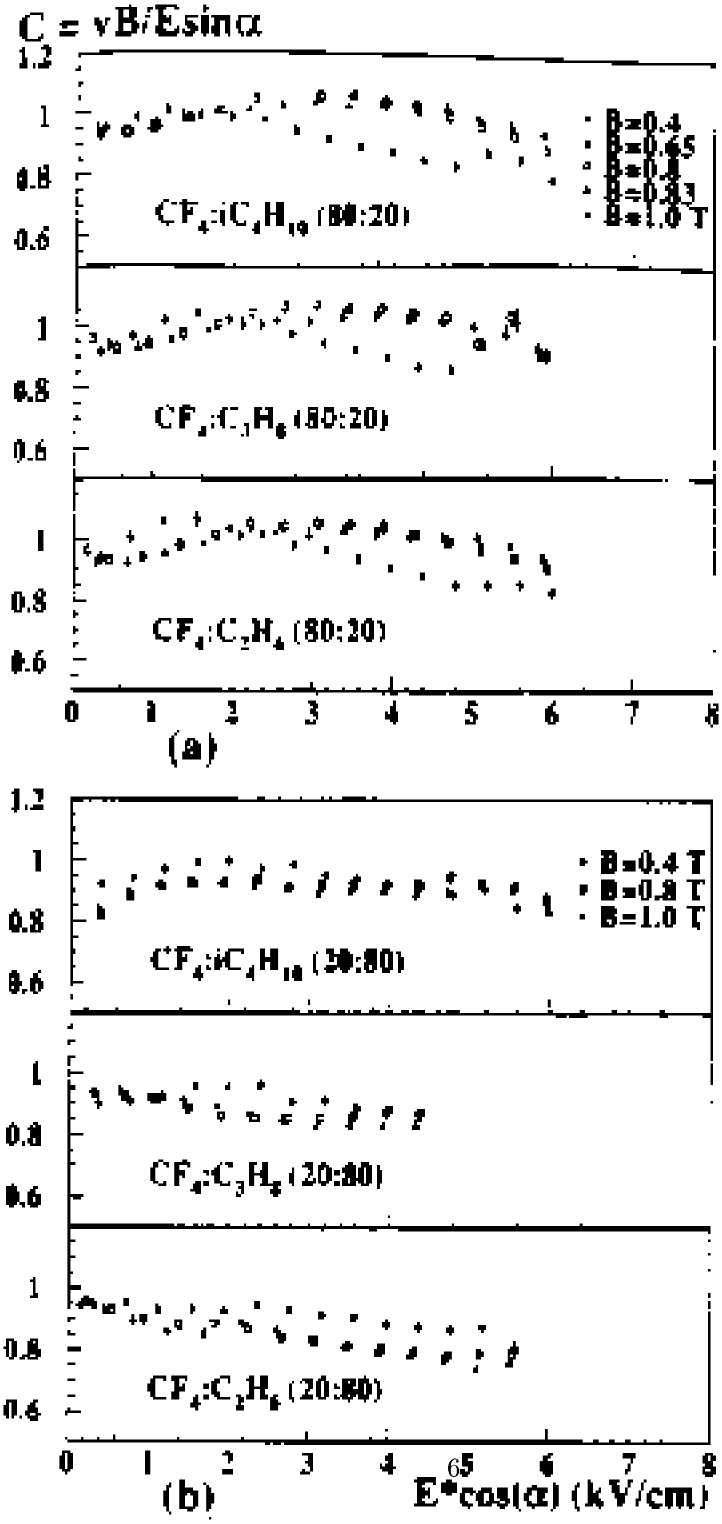

C = vB/Esinα
CF4:iC4H10 (80:20)
CF4:C3H8 (80:20)
CF4:C2H6 (80:20)
B=0.4
B=0.65
B=0.8
B=0.83
B=1.0 T
(a)
CF4:iC4H10 (20:80)
CF4:C3H8 (20:80)
CF4:C2H6 (20:80)
B=0.4 T
B=0.8 T
B=1.0 T
(b)
E*cos(α) (kV/cm)

Figure 4:

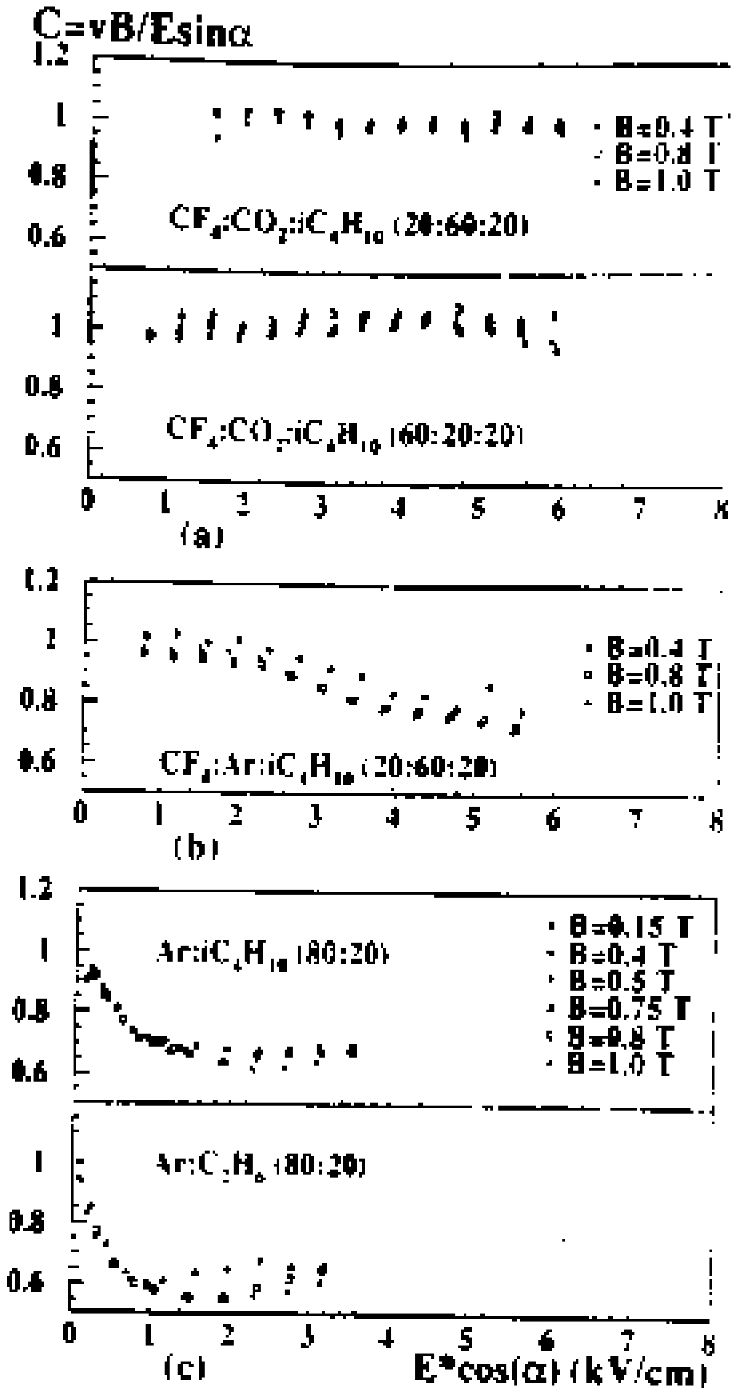

C=vB/Esinα
B=0.4 T
B=0.8 T
B=1.0 T
CF4:CO2:iC4H10 (20:60:20)
CF4:CO2:iC4H10 (60:20:20)
(a)
CF4:Ar:iC4H10 (20:60:20)
(b)
Ar:iC4H10 (80:20)
B=0.15 T
B=0.4 T
B=0.5 T
B=0.75 T
B=0.8 T
B=1.0 T
Ar:C2H6 (80:20)
(c)
E*cos(α) (kV/cm)

Figure 5:

These studies suggests that some of these gas mixtures used could be probable candidate gases for use in the drift and CSCs. However, further studies of the gas mixtures must be done in order to evaluate their behavior as far as gas multiplication, electron diffusion, efficiency, and stable operation are concerned.

2.2 O. Kiselev Studies

O. Kiselev's is a more comprehensive study as it was performed in order to test suitability of gas for GEM CSCs. Their studies have recommended $Ar - CO_2 - CF_4$ triple gas mixture for the GEM Muon System. This triple gas mixture exhibited a Lorentz angle of about $8.5°$ at 4kv/cm fields at 0.8T. The other gas mixtures O. Kiselev studied appeared to not have satisfied the criteria of gas amplification, etc. One cannot rule out the possibility of using $Ar - CO_2 - CF_4$ mixture, as at lower magnetic fields of $\alpha \sim 5.6°$ at about 5.7 (assuming linear scaling). The other prospective gas mixture one could study is $CO_2 + CF_4$ (50:50) which seems to have a lower Lorentz angle when compared to the triple mixture. Figures 6 and 7 show the behavior of the triple mixture and the $CO_2 + CF_4$ mixture.

Assuming that one of these gases would be suitable for the PHENIX detector with a Lorentz angle of approximately $5°$ at 0.5 T, one can estimate the resolution degradation due to the Lorentz angle effect. These estimates project a figure of 45 μm for degradation due to Lorentz angle. However, one has to keep in mind that the degradation of resolution due to other sources may serve to worsen the estimated figure.

3 Conclusion

Probable gas mixtures for the PHENIX Muon Tracker could be

(i)	$CF_4 + CO_2 + ibutane$	of	20:60:20, 30:60:10, or 60:20:20
(ii)	$CF_4 + CO_2$	of	50:50
(iii)	$CO_2 + CF_4 + Ar$	of	50:30:20 or 50:20:30

The suitability of the gas mixtures (i) and (ii) for CSCS have to be tested for other qualities mentioned earlier. Gas mixture (iii) may not need that rigorous of a study as it was the gas mixture selected for the GEM Muon System.

References

[1] Y. H. Chang etal., NIM A 339 (1994)

[2] O. Kiselev etal., GEM TN-93-417, June (1993)

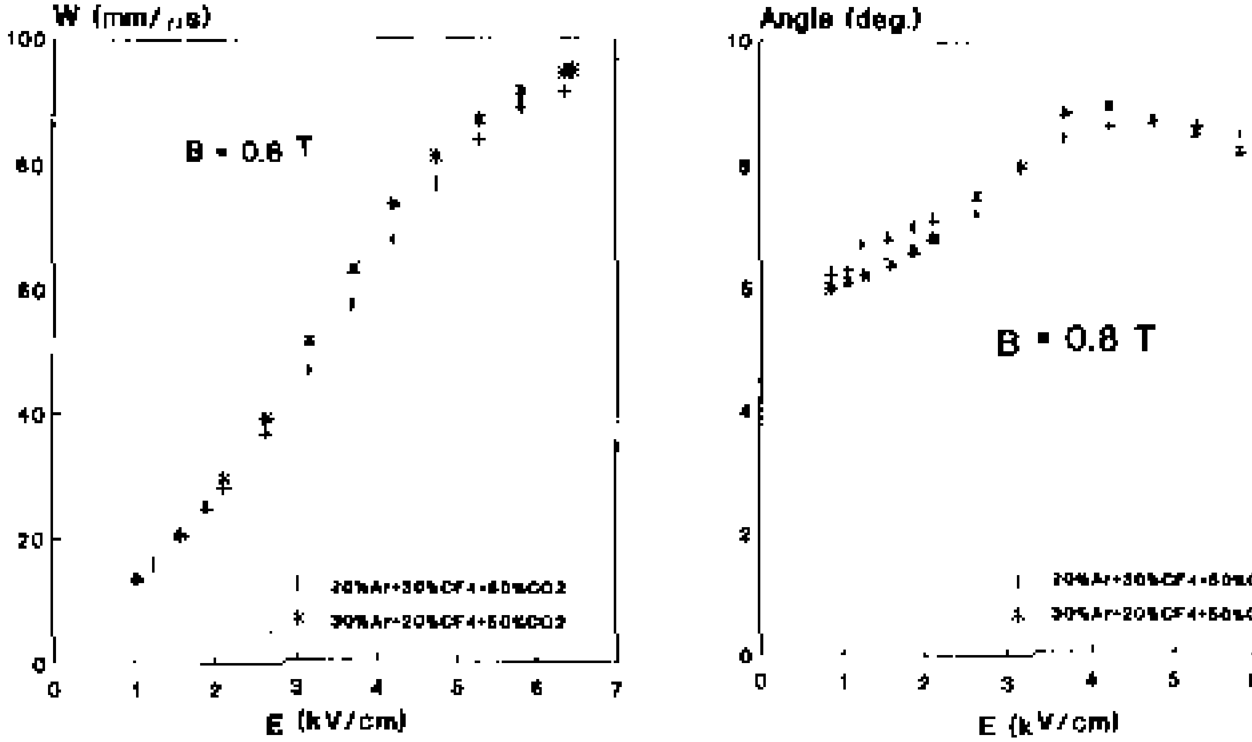


Fig-14 Our measurements of parallel electron drift velocity and Lorentz angle in $50\%CO_2 + 30\%CF_4 + 20\%$ Ar and $50\%CO_2 + 20\%CF_4 + 20\%$Ar for $B = 0.8$ T.

Figure 6:

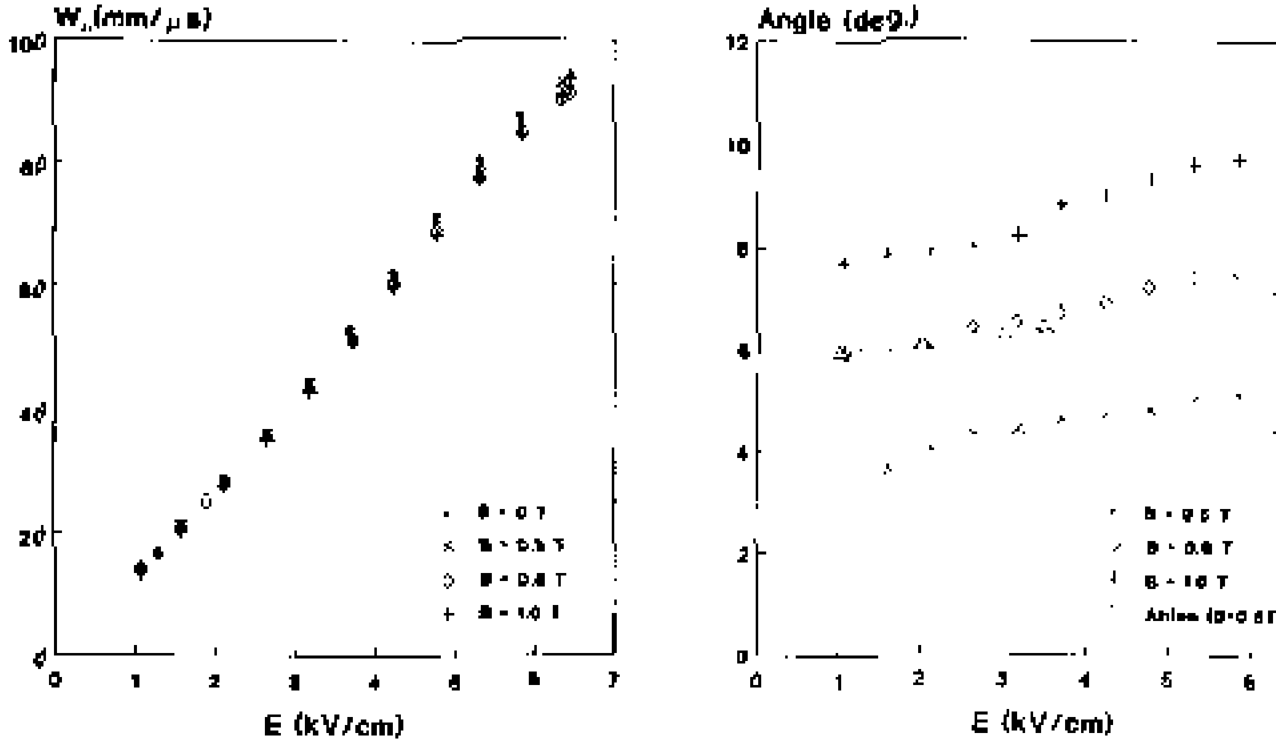


Fig.13 Our measurements of parallel electron drift velocity and Lorentz angle in 50%CO_2 + 50%CF_4 for B = 0, B = 0.5, B = 0.8 and B = 1.0 T. For B = 0.8 T comparison to the data of S.Ahlen [12].

Figure 7: