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# Better CTC/VTX gas for runs 1b(c), 2, 1st Main Injector?

R. Wagner 4/11/94

## INTRODUCTION:

This note looks at some options for improving CTC and VTX operation at high luminosity and/or shorter bunch spacing by optimizing the gas properties. Basically, two changes to the present gas mixtures are considered:

1. Change the additive to the CTC Argon/Ethane mixture from ethyl to isopropyl alcohol, in order to take advantage of the "expected" better saturated drift velocity with isopropyl and therefore reduce affects from space charge distortions.
2. Change the VTX or CTC mixture to a fast gas, possibly with the addition of 10 to 20% $CF_4$ to a standard mixture. This would allow the chambers to resolve crossings with 396ns spacing and therefore halve the number of interactions the chamber is sensitive to for a particular crossing.

The gas mixtures considered above have, in general, all been shown to have good ageing properties. I think Muzaffer, and perhaps others on CDF, would consider isopropyl to be superior to ethyl alcohol in some cases. Openshaw et al [1] measured that Ar/Et/$CF_4$(48/48/4) ages much more gracefully than Ar/Et(50/50).

Section 1 overviews the accelerator parameters for runs in which the CTC and VTX will be used, with particular attention to the peak luminosities and numbers of interactions per crossing. It will be noted how one could improve chamber operation if gas properties would allow. Section 2 will go over the constraints present for the two chambers which limit the choice of gas. Section 3 will examine the isopropyl alcohol option for the CTC, including the tests which should be done before considering the switch. Section 4 will do the same for the $CF_4$ option. I consider $CF_4$ to be more of academic rather than practical interest, since there is only a very slim chance that the Lorentz angle would be reasonable for the CTC and there does not appear to be a run suitable for its use in the VTX. Section 5 will briefly go over the tests being planned in the B0 clean rooms, including what must be built or purchased to carry them out. This note is hopefully written in enough detail so that I can get some informed feedback as to which measurements are potentially useful and which are a poor use of our resources.

## 1. TEVATRON CONDITIONS FOR 1B, 1C, 2 AND 1ST MAIN INJECTOR.

Tevatron run conditions relevant to CTC/VTX operation are given in Table 1.

Table 1. Tevatron conditions for 1b(c), 2, 1st Main injector

| Parameter | 1B(C) | 2 | 1st Main injector | |
|---|---|---|---|---|
| Bunches | 6 | 36 | 36 | |
| Min Xing spacing | 3500 | 396 | 396 | ns |
| Typical Luminosity | 1.52E31 | 2.15E31 | 8.0E31 | cm-2sec-1 |
| Best Luminosity | 2.25E31 | 3.00E31 | same | cm-2sec-1 |
| Ineractions/Xing (@45mb) | 2.39(typ) | 0.56(typ) | 2.11 | |
| Energy | 900(1000) | 1000 | 1000 | GeV |
| CTC status | In with VTX, SVX' | In with SVX2(straw?) | <-- same? | |
| VTX status | all in | Only forward mods | gone | |

Note that either run 1C or run 2 (36 bunch) will occur, not both. The option of run 2 (6 bunch) is extremely unlikely according to John Cooper, and is not considered here. The luminosities in the table are considered optimistic for 1B, but maybe with the energy improvement (10/9 increase in luminosity from shrinkage in transverse beam size -J.Cooper) and other performance tweaks they are achievable for 1C. Some improvements to chamber performance that could possibly be realized by changing gases are listed below.

Run 1B(C):
CTC: In six bunch operation, a fast gas is of no benefit. However, positive ion distortions in the CTC will likely approach the per cell resolution at 2.25E31, so a gas with a better saturated drift velocity and higher positive ion mobility would help. As will be shown is section 2, adding ispropyl alcohol instead of ethanol to Ar/Et(50/50) has a very good chance of significantly improving the drift velocity saturation. The relative positive ion mobilities are unknown and should be measured.
VTX: I could not think of any gas change which would help at high luminosity and 6 bunch operation.

Run 2:
CTC/VTX:

If not done already, the isopropyl alcohol option for the CTC should again be considered here.

With a 396ns minimum bunch spacing, the number of interactions to which the chamber is sensitive in a particular crossing can be halved by doubling the drift velocity. However, this will not buy you much in run 2 (.56 goes to 1.12, which is a bit worse than 1A conditions but not nearly as bad as run 1B(C)). As will be demonstrated in Section 4, it is very unlikely that a suitable fast gas can be found for the CTC anyway. However, it is likely that a gas with 10 to 20% CF4 would allow the forward VTX modules to resolve crossings, while maintaining reasonable performance. However, with the low number of interactions per crossing expected for run 2, it is probably not worth the bother or expense.

1st Main Injector Run:
CTC: This is the run which is really worrisome. Without a viable fast gas option, the CTC must cope with an average of 4.22 interactions per crossing. While I have not thought about Owen's track imbedding studies or the recent hit count studies in detail, my feeling is that the inner layer hit counts will be too high for a large fraction of interesting events. If there is not enough money for a CTC replacement for this run, we will at least need a "supplement" for the inner layers which can resolve crossings, such as Seog's straw option or an equivalent one with scintillating fibers. Since we may have to remove the CTC anyway to install the new TOF system, we may wish to give some more serious thought about Bob Kephart's inner layer boring option (This makes more sense if run 2 goes away and the TOF system is installed for the first main injector run).

## 2. CONSTRAINTS ON CHAMBER OPERATING PARAMETERS WHICH LIMIT GAS OPTIONS

Below is an attempt to list constraints on the CTC and VTX operating parameters which limit the choice of gas. When the constraints are common, the two chambers are lumped together.

a)Gain (CTC and VTX) In both cases, we cannot significantly increase the operating voltages in order to compensate for a loss of gain with the new gas.

b)Saturated drift velocity (CTC and VTX) This is necessary to give optimal resolution in the presence of electric field variations. An additional electric field variation is introduced at high luminosity due to positive ions distortions.

c)Positive ion mobility (CTC and VTX) We would like to keep this as high as possible in order to minimize drift field distortions at high luminosity.

d)Drift Electric Field (CTC and VTX) Again, this cannot be significantly raised because of the constraints on the operating voltage. We have more than enough troubles where we operate at the moment. In the case of the CTC, this puts severe constraints on accessible Lorentz angles.

e)Lorentz angle (CTC) The CTC was designed to operate with a Lorentz angle (eta) near 45 degrees. For all the gases I came across (see Section 4 for details) when operating between B = 10 and 15kG, sin(eta) = (vB)/kE, where v is the drift velocity and k is a constant that monotonically approaches 1 from smaller values as E approaches 0. At E = 1.3kV/cm, approximately the CTC drift electric field, k is close to 0.80 for this wide variety of gases, including the present CTC mixture. If one wishes to replace the present CTC mixture with a gas having twice the drift velocity, the product kE must also double. The liklihood of of finding a fast gas (or any gas) with k greater than 1 at these magnetic fields appears extremely small - we would require k = 1.6 in order for the electric field to remain completely unchanged.

f)Pulse width and rise time (CTC and VTX) In a multihit system, the pulse width is strongly coupled to the rise time. As the rise time becomes faster, one can clip the pulse narrower without appreciably cutting into the leading edge. In the CTC, the inner layers with the new fast electronics (and no DEDX to worry about), have a discriminated pulse width of about 40ns for high pt tracks, and the outer layers have a somewhat larger width of about 70ns. For the VTX, the rise time naturally becomes slower as the track polar angle increases, so a compromise shaping is used which gives pulse widths of about 90ns at 90 deg. Note that if the rise time of the CTC pulse does not improve with a gas having twice the drift velocity, the two hit resolution degrades by a factor or two (for the inner layers, 40ns*50um/ns=2mm goes to 40ns*100um/ns=4mm). We obviously cannot afford to seriously degrade the two hit resolution of the CTC. The forward VTX modules have large "geometric" widths in any case, so some increase due to the pulse shaping component may be tolerable. For instance, at theta = 30 deg the pulse width would increase by 24% and at 20 deg by 12%.

g)Electron attachment (CTC and VTX) Electron attachment affects the chamber efficiency and position resolution. CF4, like most freons, loves to gobble up electrons.

## 3. ISOPROPYL ALCOHOL OPTION FOR THE CTC.

We are considering a switch from Ar/Et(50/50) bubbling through ethanol at -7.2 degC to bubbling through isopropyl alcohol at 0 degC. The aging behavior of both mixtures were extensively studied [2]. As noted above, the switch is being considered in order to reduce positive ion distortions, In section (a) some general information is given concerning positive ion mobilities, including what little is known about mixtures containing alcohols. Section (b) looks at what we can expect for the drift electric field and drift velocity saturation when operating at 14 kG and eta = 45deg.

## 3a) POSITIVE ION MOBILITIES

In general, positive ions from each type of molecule in the gas mixture are produced in the avalanche to the sense wire. Sauli claims that one type of positive ion "quickly" dominates as they collide with molecules while drifting back to the cathode and thus transfer their charges to the molecules with the lowest ionization potential. Table 2 lists the ionization energies of several gases of potential interest [CRC,2]:

Table 2. Ionization energies of some molecules of interest

| Molecule | Ionization Energy (ev) |
|---|---|
| Methylal | 10.0 |
| Isopropyl Alcohol | 10.2 |
| Ethyl alcohol | 10.5 |
| Ethylene ($C_2H_4$) | 10.5 |
| Ethane ($C_2H_6$) | 11.5 |
| Methane ($CH_4$) | 12.6 |
| $CO_2$ | 13.8 |
| Argon | 15.8 |
| $CF_4$ | > hydrocarbons (Yamashita et al.) |

Note that the alcohol molecule will "eventually" be the positive ions when Ar/Et(50/50) is bubbled through either ethyl alcohol or isopropyl alcohol. Some measured positive ion mobilities are given in the Table 3 [3,4,5,6].

Table 3. Positive ion mobilities in some gases of interest

| Ion | In itself | In argon | In $CF_4$ |
|---|---|---|---|
| $CH_4^+$ | 2.23 | 1.87 | 1.07 (cm**2/v/sec) |
| $C_2H_6^+$ | 1.24 | 2.08 | 1.04 |
| $C_3H_8^+$ | 0.79 | 2.07 | 1.05 |
| Iso-$C_4H_{10}^+$ | 0.614 | 1.56 | 1.00 |
| $CO_2^+$ | 1.09 | 1.72 | - |
| Methylal+ | 0.26 | 1.51 | - |
| Isopropyl Al+ | | .86*$C_2H_6^+$? (**) | |

(**)JC's comparison of Ar/Et(98/2) to Ar/Et/Isopropyl (96/4/0.3)

If the positive ion mobilities are measured for each component of a gas mixture, the mobility for the mixture can be calculated via Blanc's law [3]:

$$1/u = f1/u1 + f2/u2 + \dots + fn/un,$$

where u is the mobility, fn is the fraction of gas n in the mixture, and un is the mobility of the positive ion in gas n. Using Ar/Et(50/50) as an example, from Table 2 we see that ethane has the lowest ionization potential and will be the positive ion, and from Table 3 we calculate the mobility to be (.5/1.24 + .5/2.07)**-1 = 1.55 cm**2/v/sec. Yamashita et al [6] verified that the actual positive ion mobility in this mixture agrees with that given above to within 1%.

Unfortunately, mixtures with a small fraction of gas with the lowest ionization potential are more difficult to predict. For example, Sauli and company [3,4,5] measured positive ion mobilities in "magic gas" mixtures containing argon, isobutane and methylal, where the methylal component could be as little as 1%. The measurement was done in a chamber with a 2 cm positive ion drift distance. Definite changes to the mobility were observed with a 1% methylal component, and the mobility essentially reached its "purely methylal" value at 2%. By comparison, the present CTC gas mixture contains about 1% ethanol and the positive ions drift 3.5cm. Bubbling through isopropyl alcohol at 0 degC gives a 0.5% alcohol component.

The only clue I could find as to the mobility of isopropyl or ethyl alcohol ions in either argon or ethane was JC's measurement with the the multistep chamber, which had a positive ion drift of less than 1 cm. The results (the last entry in Table 3) would tend to indicate that the mobility of an isopropyl alcohol ion in argon is 0.86 that of ethane.

It would be interesting to make measurements of the mobility of ethanol and isopropyl alcohol ions in argon and ethane for several positve ion drift distances and several different concentrations of alcohol. At a minimum a measurement should be made for both alcohols at nominal concentrations in Ar/Et(50/50) at a distance of 3.5 cm. Note that a magnetic field is not necessary for this measurement since it has minimal affect on the positive ion drift.

### 3b) DRIFT ELECTRIC FIELD AND VELOCITY SATURATION AT 14KG AND ETA = 45 DEG.

The main motivation for switching to isopropyl alcohol is better velocity saturation to minimize positive ion distortions. From previous measurements with Ar/Et and Ar/Et/ethanol mixtures at B = 0 to 15kG [7], one can make an educated guess as to the expected properties of the Ar/Et/isopropyl mixture, where measurements are only available at 0kG (at least I am not aware of ones at high magnetic fields).

Figure 1 shows drift velocity as a function of electric field at B=0 for Ar/Et(50/50) bubbled through isopropyl alcohol at several bath temperatures, and figure 2 shows the same for ethyl alcohol. It is evident that the "knee" of the distribution compared to Ar/Et(50/50) without alcohol occurs at approximately the same electric field for 0 degC isopropyl alcohol, while it is pushed to substantially higher electric field for -7 degC ethanol. This knee shift of -7 degC ethanol relative to Ar/Et(50/50) without alcohol persists at high magnetic field, as illustrated in figure 3. We would hope that the LACK of a knee shift for 0 degC isopropyl would also persist at high magnetic field, thus allowing operation with a better saturated drift velocity at eta = 45 degrees.

The affect on v .vs. E due to magnetic field for Ar/Et(50/50) is shown in figure 4. The knee is essentially pushed to higher electric field, about 400v/cm higher between B = 0 and 15kG. My guess is that the shift would be about 350v/cm at 14kG, where CDF presently operates. If the v .vs. E curve in figure 1 is shifted by 350v/cm, one can expect to operate at or above the knee with 0 degC isopropyl alcohol for electric fields in excess of about 1.3kV/cm. An estimate of the operating electric field at eta = 45deg for 0 degC isopropyl is not obvious. It is about 1.5kV/cm for pure Ar/Et(50/50) at 14kG, which is higher than we have run the CTC in the past (in 15kG operation in the 88/89 run, the drift electric field was 1.35 kV/cm; in present operation at about 14kG, E = 1.25kV/cm). However, I believe that isopropyl alcohol will lower the electric field for eta = 45 deg by about 1kV/cm (this is a "feeling" based on the behavior in ethyl alcohol and likely wishful thinking.) In any case, we could always run with eta a couple of degrees higher in order to reduce E by about that amount (see figure 3). Clearly a significant increase in E over past operating values is very worrisome.

I propose that we set up the BM106 magnet in B0 and measure drift velocity and Lorentz angle versus E between B = 10 and 15kg for Ar/Et(50/50) bubbled through isopropyl alcohol. As long as the magnet is there, we could measure Lorentz angles for CF4 mixtures or other mixtures in which people are interested.

## 4. CF4 MIXTURES FOR THE VTX AND CTC TO DOUBLE VDRIFT

### 4a) MOTIVATION

When making a drastic change to the gas, all of the operating constraints for the VTX and CTC listed in section 2 must be carefully considered:

a)gain, b)saturated drift velocity, c)positive ion mobility, d)drift electric field, e)Lorentz angle (CTC), f)pulse width and rise time, and g)electron attachment. As was noted in section 2, finding a CF4 mixture for the CTC with the correct Lorentz angle is very unlikely and with adequate pulse width and rise time properties is quite unlikely. For the forward VTX modules, the Lorentz angle constraint is gone, and the pulse width and rise time requirements are much more relaxed, so it is likely that a reasonable CF4 mixture with roughly twice the drift velocity can be found. However, at this time the expected peak luminosity for run 2 does not require a change in gas. In any case, I believe a study of CF4 mixtures is justified for the following reasons:

1.If by some chance there is a way to use it with the CTC, it would alleviate the problem for the first main injector run, where the CTC is sensitive to 4.22 interactions per crossing with it's present gas (see table 1).

2.There is probably a small chance that either run 2 will have higher luminosity or that the forward VTX modules will still be around for the first main injector run.

3.If we are doing the studies with Ar/Et(50/50)+alcohol anyway, there is not much more overhead in testing a few CF4 mixtures. These studies could be useful for other detectors, possibly even some on CDF.

What I have learned about CF4 mixtures that is relevant to the VTX and CTC can probably best be presented by examining the constraints of section 2.

## 4b) GAIN, ELECTRON ATTACHMENT

Most studies with CF4 have logically been directed toward use with proportional chambers (or tubes like straw tubes) which are single hit devices with very short drift distances that are to be used at high rates. In this case, CF4 is chosen not only for its large drift velocity, but because it has about a factor of two higher primary ionization than most gases, such as argon and ethane. The higher primary ionization improves the uniformity of response near the sense wire, which is very important in a small gap, high rate device.

The following quote from Fisher et al [8] pretty well sums up the problems with using a pure CF4 mixture in this application: "CF4 alone is not sufficiently self quenching as a counter gas for stable operation. It also requires high electric field and exhibits electron attachment" They minimized all three problems by mixing in their favorite quencher, isobutane, which has a considerably higher 1st townsend coefficient than CF4 (thereby allowing a lower operating voltage) and "cools" electron energies below the point (4.5 ev) where they initiate dissociative attachment with CF4. Almost all subsequent studies with CF4 have pointed toward mixtures with with some nicely quenching hydorcarbon. Some interesting electron attachment measurements were made by Anderson et al [9] in a chamber with a 3mm drift space:

| Mixture | Decrease in gain due to attachment |
|---|---|
| 20%CF4/80%Ar | x3 |
| 50%CF4/50%Ar | x5 |
| 50%CF4/50%isobutane | x1.6 |
| 10%CF4/90%isobutane | very small |

If one limits the amount of CF4 and has a reasonable amount of quencher, the electron attachment can likely be kept under control, possibly even with long drift devices like the CTC or VTX.

Unfortunately, the CTC and VTX cannot use CF4/hydrocarbon mixtures because the operating voltage would still be way too high. Rudy Thun [10] and D0 [11] have tried mixing CF4 with "HRS" type mixtures, Ar/CO2/Methane. They found that with 15 to 20% CF4, one could double the drift velocity without too much degradation in performance. Rudy was testing a short drift device and had to raise the voltage when adding CF4 because of the decrease in argon and probably some electron attachment. The D0 result is an "abstract" for an IEEE conference, and I have not yet located a longer paper. It is particularly interesting because they were testing a chamber with even a longer drift distance than the VTX. The abstract did not discuss the increase in operating voltage with the addition of CF4.

## 4c) PULSE WIDTH AND RISE TIME

The rise time of pulses with CF4 may improve somewhat because of the higher drift velocity, but I think it quite unlikely that it is sufficient to allow the the factor of two decrease in pulse width in order to retain the same two-hit resolution in distance. This point was covered adequately in section 2 for both the CTC and VTX, and I have yet found nothing in the literature to help. The pulse shaping with CF4 mixtures can of course be looked at with several different chambers we have in the B0 clean rooms.

## 4d) POSITIVE ION MOBILITY

As indicated in Table 2, the ionization energy of CF4 is higher than that of the hydrocarbons and alcohols we will consider using. Unfortunately, I could not locate the actual value of it's ionization potential (it was not in the CRC handbook or in the other references listed at the end of this report) so at the moment we are stuck with the assertion of Yamashita et al (backed by their data) that it is larger than the hydrocarbons of interest here. I don't know, for instance, if it is larger than that of CO2, which is relevant for use in HRS type mixtures (particularly ones with very little methane, eg 1% or less).

The positive ion mobilities of several hydrocarbon ions in CF4 are shown in Table 3 (data of Yamashita et al [6]). Unfortunately, the mobilities are smaller than those in argon, eg a factor of two less for ethane ions. My guess is that the same trend would hold for alcohol ions, so it is pretty clear that introducing CF4 into your gas mixture will lower the positive ion mobility. As with the constraints of gain and electron attachment, considerations of positive ion mobility confines CF4 to a small fraction of the mixture.

## 4e) SATURATED DRIFT VELOCITY.

The trick is finding a CF4 mixture that saturates at v = 100um/ns at fairly low electric field ( about 1kV/cm at B = 0). This would be fine for the VTX. For the CTC one hopes to "maintain" saturation at B = 15kG for E = 1.3kV/cm or so. Only the B = 0 case is discussed here.

As shown in figures 5 and 6, CF4/CH4(10/90) has sort of a knee at 1.5 v/cm/torr (1.14 kV/cm) with v = 125 um/ns, and CF4/C2H6(10/90) has a nice knee at 1.4 v/cm/torr (1.06 kV/cm) with v = 75 um/ns [6]. These mixtures have too low a gain for the VTX or CTC, but they indicate that relatively low CF4 concentrations can lead to significantly higher drift velocities with saturation at reasonable electric fields.

Some mixtures containing argon (higher gain) have at least demonstrated the potential for high velocities with small CF4 fractions. The D0 abstract [11] and the Thun paper [10] both indicate v = 100um/ns with about 15% CF4 in HRS type mixtures. Unfortunately no v .vs. E information is given in these papers (I will make a better attempt to get more information on the D0 result). Figure 7 shows that CF4/C2H2/Ar(10/10/80) has a nice knee at E = .85 kV/cm with v = 90 um/ns [4,14]. I believe that few people have tried mixing CF4 with Ar/Et or Ar/Methane because there was no motivation. For instance, D0 and Rudy Thun tried mixing it with HRS gas because they normally use HRS gas. For a CDF detector, like the CTC or VTX, it would be more natural to explore mixtures with argon, ethane, and possibly alcohol. A mixture like CF4/Ethane/Ar(15/35/50) may do quite well (at least at B = 0 or for the VTX). It was mentioned in the introduction that Openshaw et al [1] measured that an Ar/Et/CF4(48/48/4) mixture showed far less ageing than Ar/Et(50/50). The authors were also kind enough to measure v .vs. E for this mixture (see figure 8). The drift velocity at the knee is 20um/ns higher than that for Ar/Et(50/50). The saturation, however, could use some improvement.

## 4f) LORENTZ ANGLE AND DRIFT ELECTRIC FIELD (CTC)

As was already explained in section 2e, the constraint that the CTC must operate with eta = 45 deg at about the same electric field as it has now, very likely rules out a fast gas. In this section, the arguments which lead to this conclusion are presented in a bit more detail.

At small electric field, where the electron energy is not significantly increased from the thermal value, the lorentz angle is given by sin(eta) = vB/E. For many gases measured with B between 10 and 15kG, the Lorentz angle follows sin(eta) = vB/kE, where k monotonically approaches 1 from smaller values as E approaches 0. From the results of Daum et al [12] and Atac et al [7], the following list of gases have k = 0.8 +/- .05 for B=15kG and E=1.3kV/cm (about where the CTC presently operates): Ar/Et(50/50), Ar/Et(40/60), Ar/Et/Ethanol(49.5/49.5/1), Ar/CO2/Methane(89/10/1), Xe/CO2(80/20), Xe/Et(60/40), Xe/Et(73/27) and Xe/Et(50/50). The drift velocities at this value of E vary from 33 um/ns for Xe/CO2(80/20) to 52 um/ns for Ar/ET(50/50).

For a gas with double the drift velocity, the product kE must double for sin(eta) to remain fixed. Since we can't raise the electric field in the CTC very much, k must essentially double, way past 1 to 1.6. In other words, instead of k monotonically decreasing from 1 as E increases from small values (as all the gases that I am aware of behave), it would have to increase substantially for the fast gas. My guess is that a clever person with the inclination may actually be able to prove that this is not possible, but unless this happens, I believe it is worth making measurements for a few promising CF4 mixtures in the BM106 magnet.

## 5. GAS TESTS BEING CONSIDERED AT B0

The tests were mentioned in passing in the previous sections. Here they are restated, along with the necessary calculations to be done and equipment to be built or purchased. Since the isopropyl alcohol option for the CTC has a good chance of working and could help matters as early as run 1C, I believe it should be the driving force. However, since tests with CF4 can be added with minimal overhead, I believe it is worth including these as an interesting (and possibly useful) byproduct.

## 5a) VELOCITY AND LORENTZ ANGLE VERSUS E FROM B=0 TO B=15KG.

The necessary equipment for this test is described in detail in Atac et al [7], our original gas tests for the CTC. Muzaffer's little chamber, shown if figure 9, is now operating in the high bay clean room at BO. The experimental setup in the BM106 and the data acquisition system are shown in figure 10 (drift velocity measurements at B = 0 can be done with less fuss). In order to do similar measurements for other gas mixtures: a)the placement/alignment equipment for the chamber must be redesigned and rebuilt (the old equipment was tossed long ago), b)the data acquisition system must be set up, and c)the BM106 magnet with it's Transrex power supply must be installed and made operational in the Assembly Hall. My guess is that we will share the Tranrex with the solenoid test magnet that Bob and Kaori are designing for TOF tests. I will talk to Keith Schuh and possibly Bill Wickenburg about an estimate for the time and expense required to set up the magnet. Jim Welch and Inez Ramos can design and assemble the chamber alignment equipment, and minimal machine shop time is necessary for this.

Previously, Richard used Peter's electrostatics program to calculate the electric field in the drift region (see figure 9). This calculation or a similar one will have to done again.

In order to make tests with CF4 mixtures, we will need to purchase a small volume mixing system. Jim Welch, Muzaffer, and I have had no luck locating one around the lab. Jim and I have looked at systems from Cole-Parmer and MKS. A very versatile system, in term of numbers and ratios of gas components, with adequate accuracy for our needs can be purchased from Cole-Parmer for about $900.

## 5b) MEASUREMENT OF POSITIVE ION MOBILITY

As mentioned earlier in the report, Yamashita et al [6] made very nice measurements of positive ion mobilities using the chamber shown in figure 11. Since it worked well, we could use this as a starting point for our design. Because we will be dealing with positive ions that are a small fraction of the gas, eg 1% ethanol or 0.5% isopropyl alcohol, the positive ion drift distance is critical. Since the CTC and VTX have very close to the same drift distance, a chamber with a fixed distance of 3.5 cm is adequate. However, we may learn alot more using a design where the distance can be varied, say from 1 to 4 cm. Please let me know if you would be interested in designing and building this device (it sounds like fun). Jim and Inez are available to help with the design and do the assembly.

## RERERENCES

When appropriate, comments are made as to what useful information was obtained from the reference. Please let me know if there are other relavant studies. I have copies of these papers in my office, if you wish to make you own copy.

1) R. Openshaw, R. Henderson, W. Faszer, D. Murphy, M. Salomon and G. Sheffer, TESTS OF WIRE CHAMBER AGEING WITH CF4/ISOBUTANE(80/20), AR/ETHANE(50/50), AND AR/ETHANE/CF4(48/48/4), IEEE NS-36 No.1(1989)567.
In addition to some long term, low source intensity ageing tests, this paper also presented curves of v .vs. E at B = 0 for an Ar/Et/CF4 mixture.

2) J. Kadyk (Organizer), PROCEEDINGS OF THE WORKSHOP ON RADIATION

DAMAGE TO WIRE CHAMBERS, LBL-21170, UC-34D, CONF-860162(1986).
This report is the most comprehensive paper on this subject, which unfortunately predates the widespread interest in CF4. However, many studies with ar/ethane/alcohols are presented. It also has some more general information concerning properties of interesting gas components; such as ionization energies and Sauli's discussion of positive ion mobilities.

3) W. Blum and L. Rolandi, PARTICLE DETECTION WITH DRIFT CHAMBERS, Sringer-Verlag (1993).
This book develops the theory for drift chamber properties, such as positive ion mobilities, as well as containing useful data and references.

4) A. Peisert and F. Sauli, DRIFT AND DIFFUSION OF ELECTRONS IN GASES: A COMPILATION, CERN 84-08 (1984).
A compilation of electron drift velocity and diffusion measurements for a wide variety of gases (mostly at B = 0). This paper contains many measurements with Ar/Et and a few with CF4 mixtures, such as the one in figure 7 with Ar/C2H2/CF4.

5) G. Schultz, G. Charpak and F. Sauli, Rev. Phys. Appl 12,67(1977).
It contains the theory of positive ion mobility as well as measurements with magic gas.

6) T. Yamashita et al, MEASUREMENTS OF THE ELECTRON DRIFT VELOCITY AND POSITIVE ION MOBILITY FOR THE GASES CONTAINING CF4, KEK-PREPRINT-91-141 (1991).
This is a very useful paper containing measurements of v .vs. E and positive ion mobilties for CF4/hydrocarbon mixtures. In particular, their technique for measuring positive ion mobilities may be useful to follow.

7) M. Atac, E. Coleman, T. Hessing, R. W. Kadel, M. Pratt, R. L. Wagner, MEASUREMENTS OF DRIFT VELOCITIES AND LORENTZ ANGLES AT 15KG, NIM A249 (1986)265.
This is the original measurements of v and eta for gases to be used by the CTC. Ar/Et/ethanol and HRS gas mixtures both looked reasonable, but we thought that the CTC would have more high voltage problems with the HRS mixture (it has alot more argon).

8) J. Fischer, A. Hrisoho, V. Radeka and P. Rehak, PROPORTIONAL CHAMBERS FOR VERY HIGH COUNTING RATES BASED ON CF4 WITH HYDROCARBONS, NIM A238 (1985) 249.
I believe this is the first experimental application of CF4/hydrocarbon mixtures. It has many nice arguments concerning the problems with using CF4.

9) W. S. Anderson et al, ELECTRON ATTACHMENT, EFFECTIVE IONIZATION COEFFICIENT, AND ELECTRON DRIFT VELOCITY FOR CF4 GAS MIXTURES, NIM A323 (1992)273.
Extremely nice techniques are used to measure electron attachment and the first townsend coefficient for CF4, CF4/Ar, and CF4/hydrocarbon mixtures.

10) R. Thun, TESTS OF SMALL PROPORTIONAL TUBES WITH CF4-HRS GAS MIXTURES, NIM A273 (1988)157.
Particulary nice to see how much the operating voltages change when you start adding CF4 to a "standard" mixture with lots of argon.

11) R. E. Avery, J. Bantly, S. Blessing, D. Buchholz, B. Gobbi, Y. Liu, S. Rajagopalan, STUDY OF FAST GAS MIXTURES (CF4/CO2/AR) FOR THE DO DRIFT CHAMBERS, abstract for the 1992 IEEE meeting but not submitted.
This paper (if I find it) is interesting because it tests CF4 mixtures in a chamber with long drifts. The abstract claims 100um/ns drift velocities with only 15% CF4.

12) H. Daum et al, MEASUREMENTS OF ELECTRON DRIFT VELOCITIES AS A FUNCTION OF ELECTRIC AND MAGNETIC FIELDS IN SEVERAL GAS MIXTURES, NIM 152 (1978) 541.
Electron drift velocity measurements for Ar/Et(50/50) and other gases. It concentrated on higher electric field regions than Atac et al.)

13) A. P. Heinson and D. Rowe, A COMPARISON OF CF4/HYDROCARBON FAST GASES FOR DRIFT CHAMBERS AND STRAW TUBES, NIM A321 (1992)165.
It demonstrates changes in operating voltages when using adding CF4.

14) L. G. Christophorou, D. L. McKorkle, D. V. Maxey, and J. G. Carter, FAST GAS MIXTURES FOR GAS-FILLED PARTICLE DETECTORS, NIM 163(1979)141.
The original paper on CF4 mixtures to speed up drift velocity.

## LIST OF FIGURES

1) Drift velocity .vs. electric field at B = 0 for Ar/Et(50/50) bubbled through isopropyl alcohol at various temperatures (from M. Atac).

2) Drift velocity .vs. electric field at B = 0 for Ar/Et(50/50) bubbled through ethanol at various temperatures (from M. Atac).

3) a)The dependence of v on E at B = 15 kG for Ar/Et(50/50) bubbled through ethanol at various temperatures. b)same for eta (lorentz angle) on E. From [7].

4) The dependence of v on E at B = 0, 10, and 15 kG for Ar/Et(50/50). The curves are the predictions of P. Ramanantsizehena, Thesis, University of Strasbourg, CRN-HE-99-13 (1979). From [7].

5) Electron drift velocity .vs. the reduced field (E/P) for CF4/CH4 with mixing fractions from 50/50 to 10/90 (from [6]).

6) Electron drift velocity .vs. the reduced field (E/P) for CF4/C2H6 with mixing fractions from 50/50 to 10/90 (from [6]).

7) Electron drift velocity .vs. E for CF4/C2H2/Ar(10/10/80) (from [4,14]).

8) Electron drift velocity .vs. E/P for CF4/Iso(80:20), Ar/Et(50/50), and Ar/Et/CF4(48/48/4) (from [1]).

9) a) An elavation view of the drift chamber used for the measurements of v and tan(eta) .vs. E, including a calculation of the equipotential lines for HV = -9.5 kV. b) The calculated electric field in the drift region as function of the y-coordinate. From [7].

10)a)An elevation view of the apparatus used to measure drift velocities and Lorentz angles at high magnetic field. Not shown is the precision slide and stepping motor which drove the u-channel and thereby the drift chamber in the x-direction. In order to move the chamber between its NEAR and FAR y-postions, the aluminum plate was rolled on top of the u-channel on teflon bearings. b)An illustration of the meaurement procedure and data acquisition. From [7].

11) Schematic view of the cross section of the test chamber use for the measurement of positive ion mobility in [6].

20.5 mm = 12 cm [illegible]

FIG 1

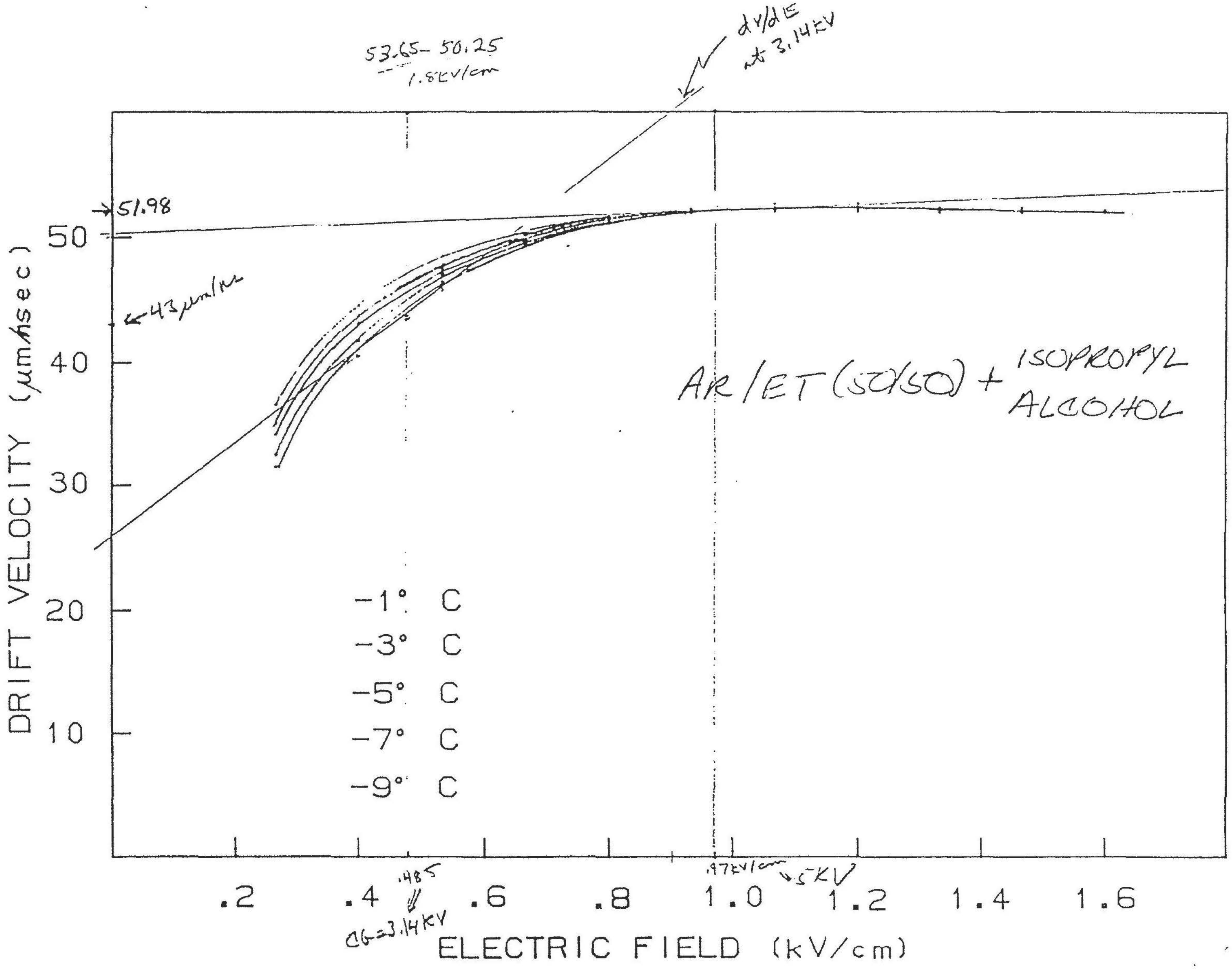


Figure 1

FIGURE 1

FIGURE 2

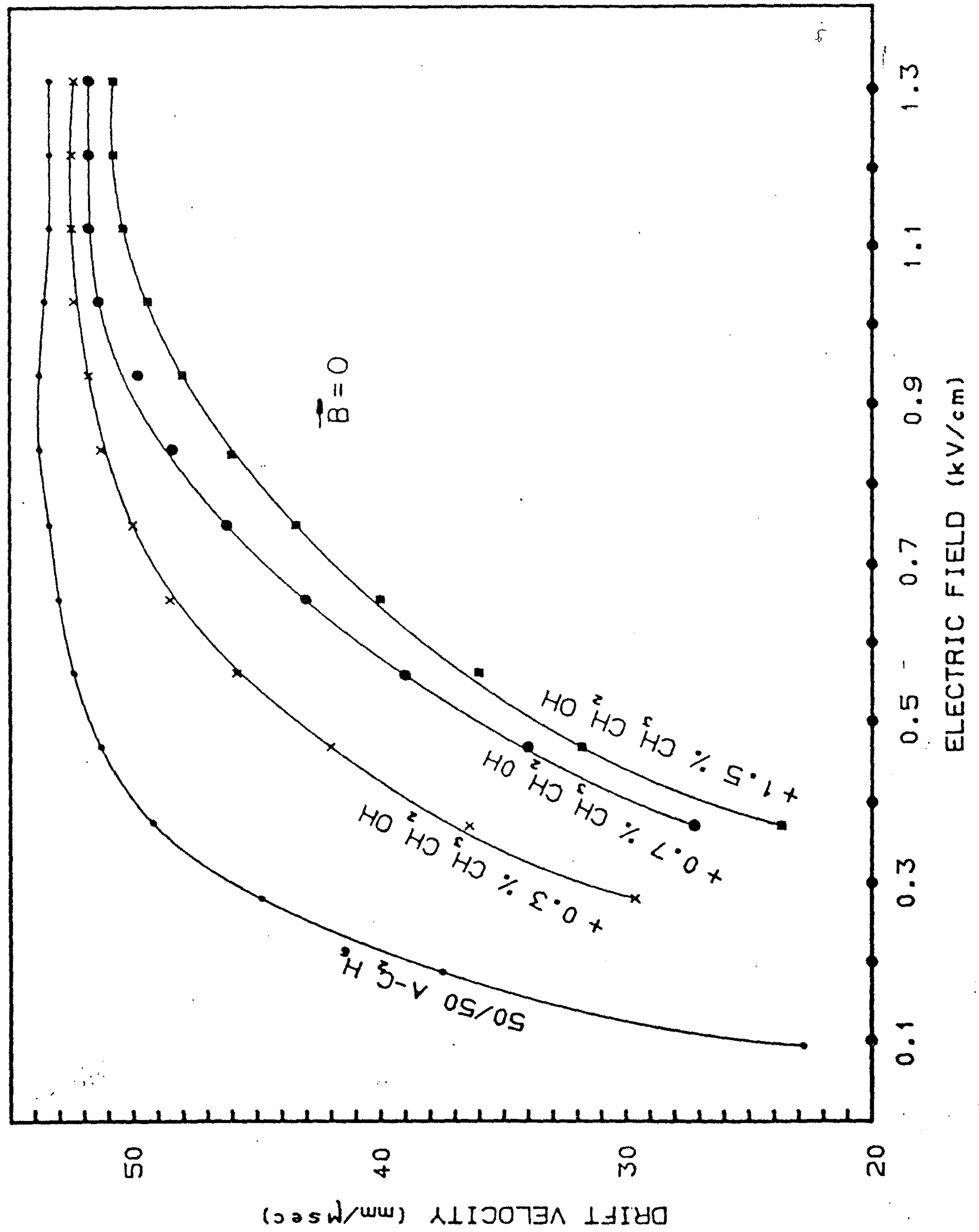
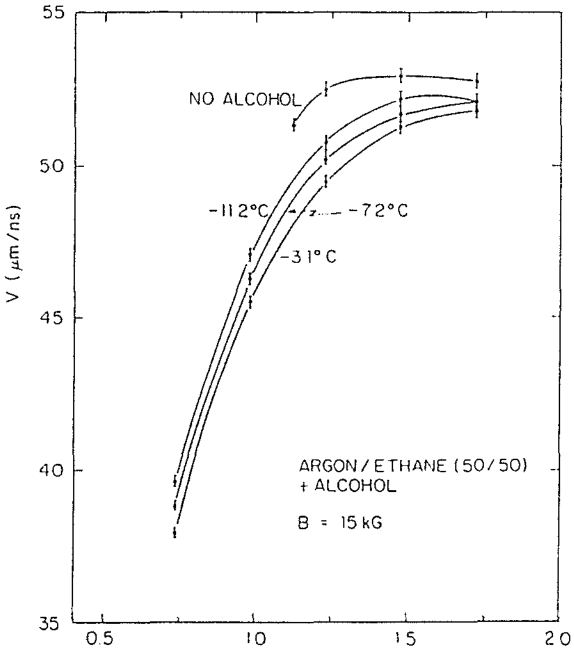
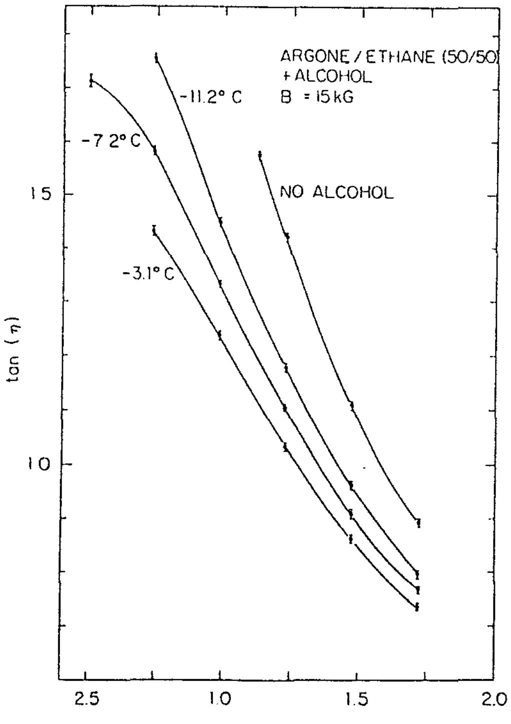


FIGURE 2



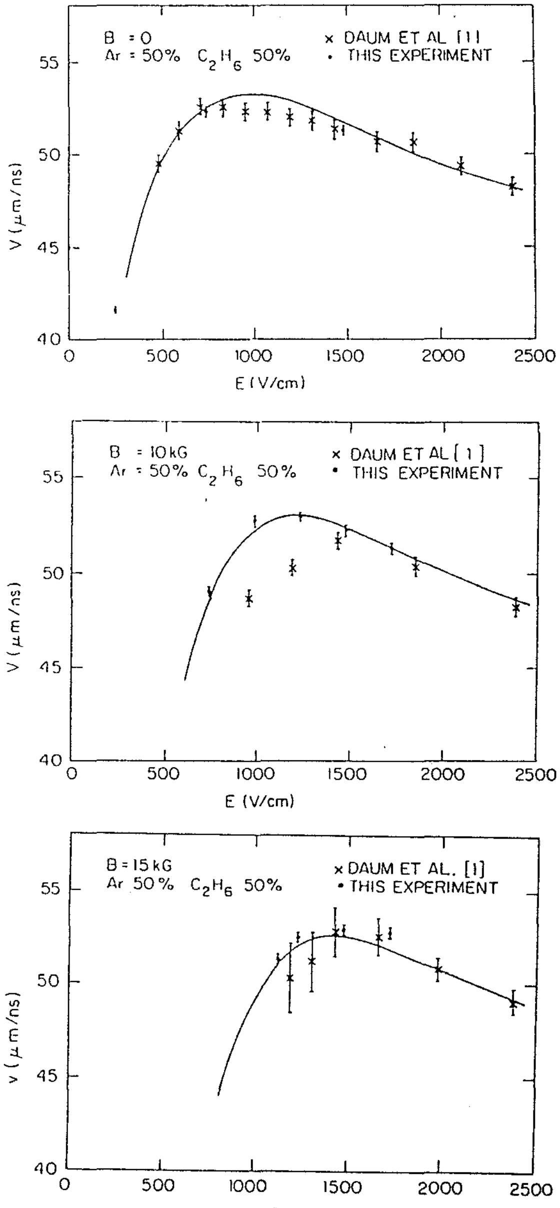
3a

Fig. The dependence of $v$ on $E$ at $B = 15$ kG for AR/ET(50/50) with several alcohol concentrations. The curves were drawn to guide the eye.



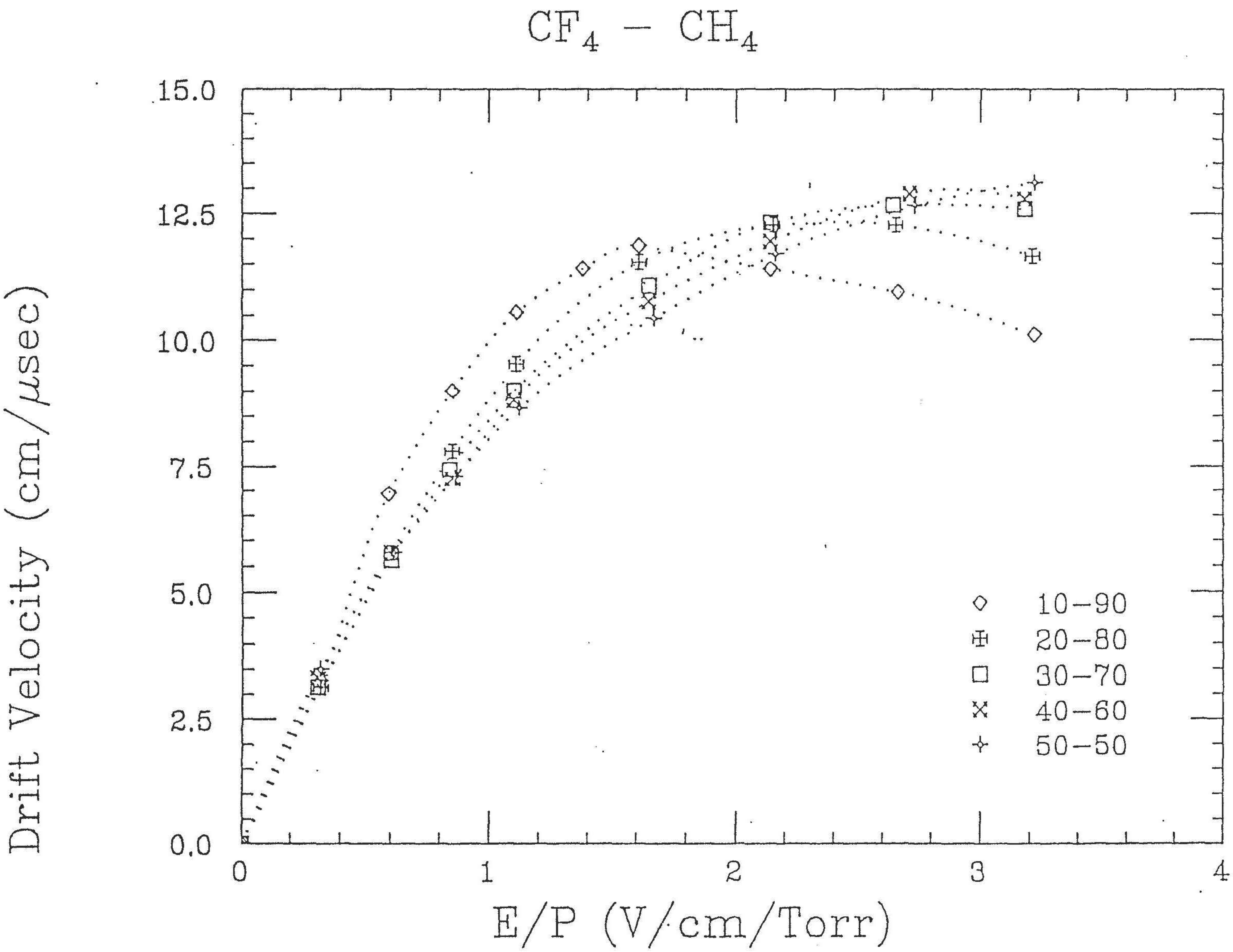
3b

Fig. The dependence of $\tan(\eta)$ on $E$ at $B = 15$ kG for Ar/ET(50/50) with several alcohol concentrations. The curves were drawn to guide the eye.



4

Fig. The dependence of $v$ on $E$ at (a) $B = 0$, (b) $B = 10$ kG, and (c) $B = 15$ kG for AR/ET(50/50). The curves are the predictions of ref. [6].



$CF_4$ – $CH_4$
Drift Velocity (cm/μsec)
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
1
2
3
4
E/P (V/cm/Torr)
◇ 10–90
⊞ 20–80
□ 30–70
✕ 40–60
✧ 50–50

Fig. 5

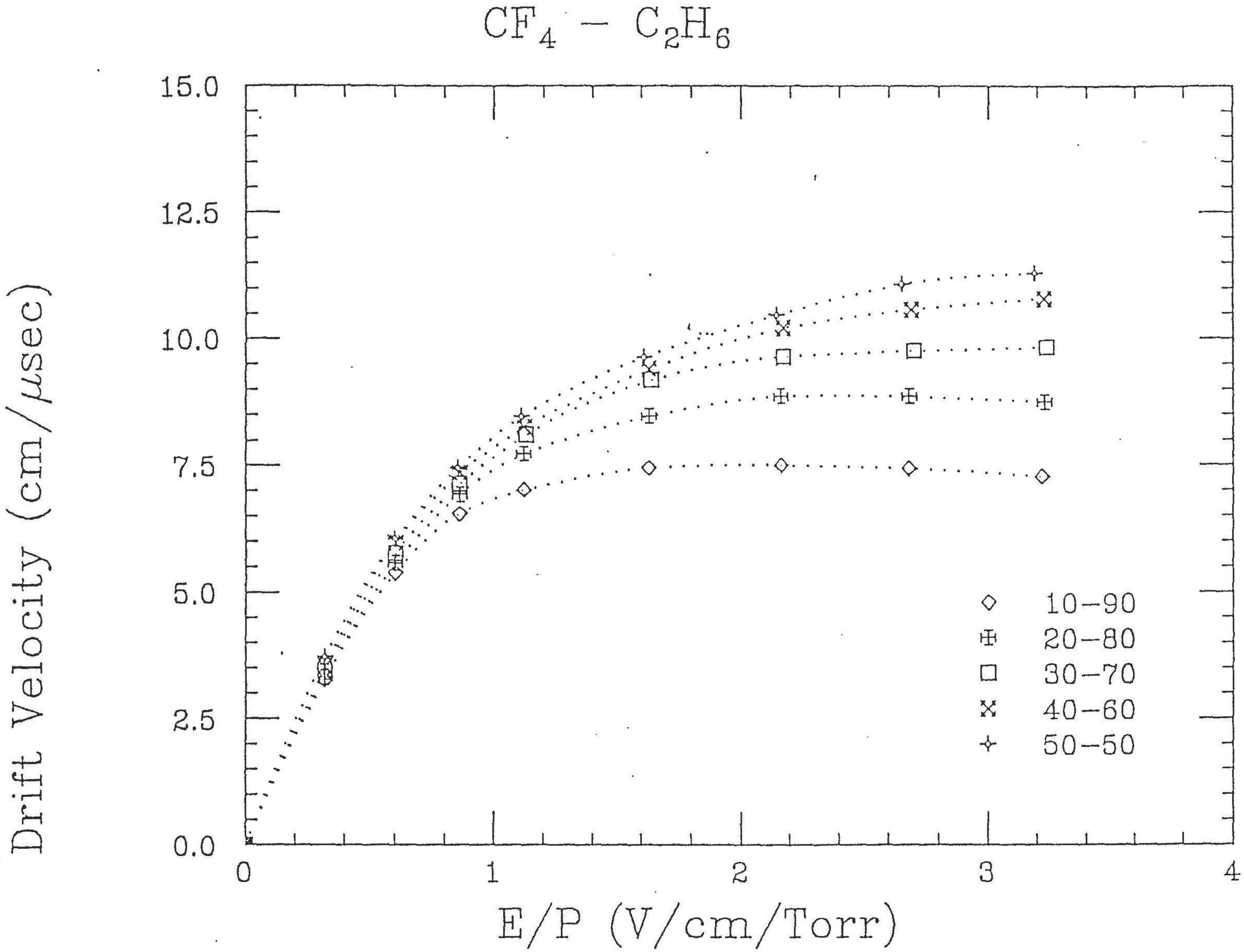

$CF_4 - C_2H_6$
Drift Velocity (cm/μsec)
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
1
2
3
4
E/P (V/cm/Torr)
◇ 10–90
⊞ 20–80
□ 30–70
⌧ 40–60
✧ 50–50

Fig. ~~5(b)~~ 6

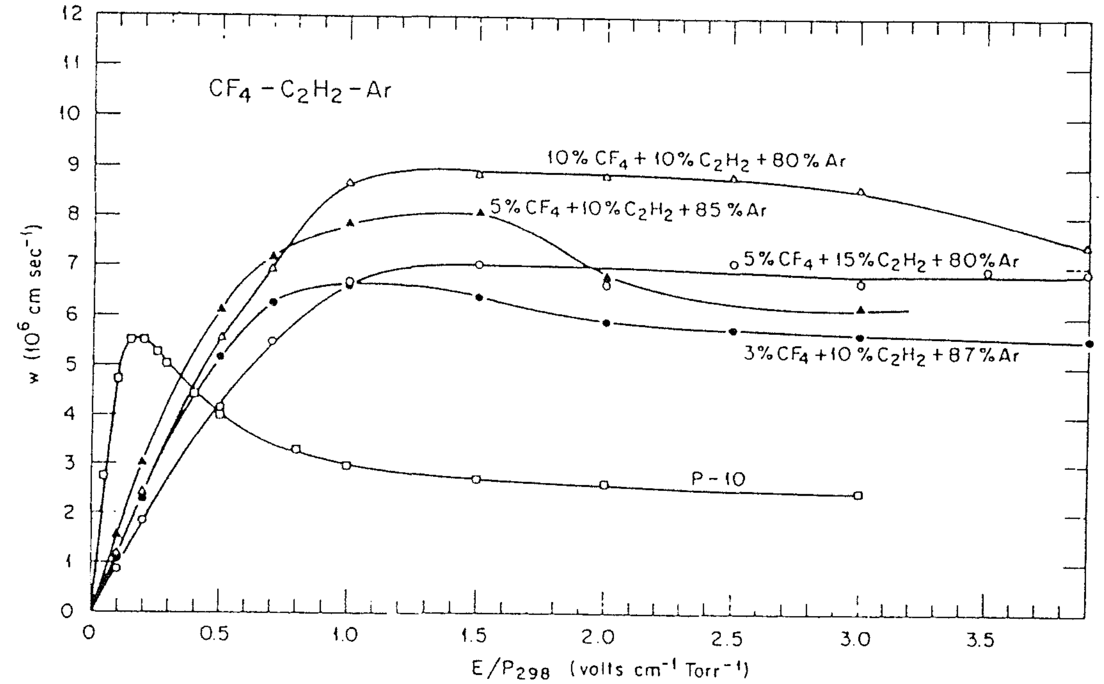


Fig. 7 Christophorou et al. (1979)

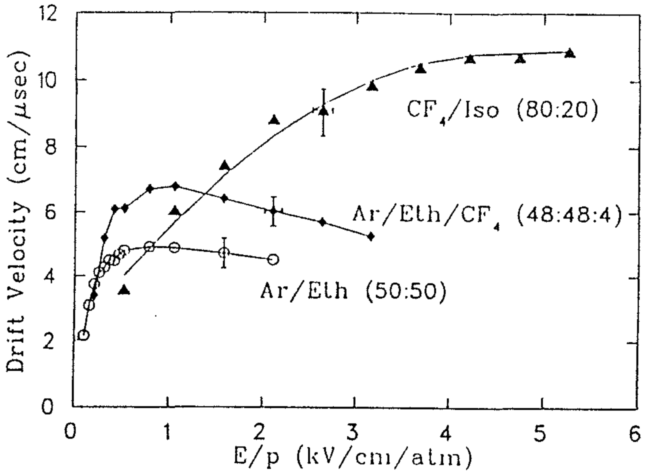


Figure 8. Drift velocity vs E/P for CF$_4$/Iso (80:20), Ar/Et (50:50), and Ar/Et/CF$_4$ (48:48:4).

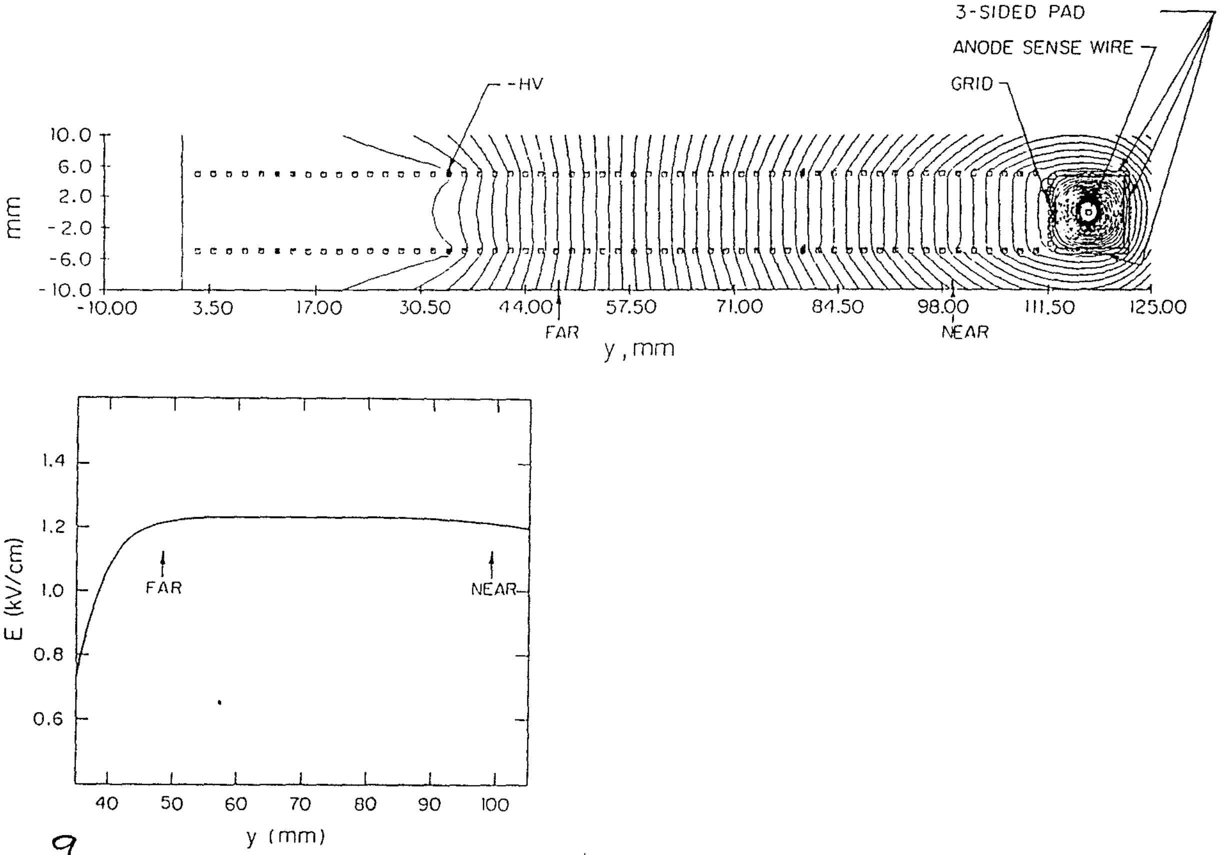
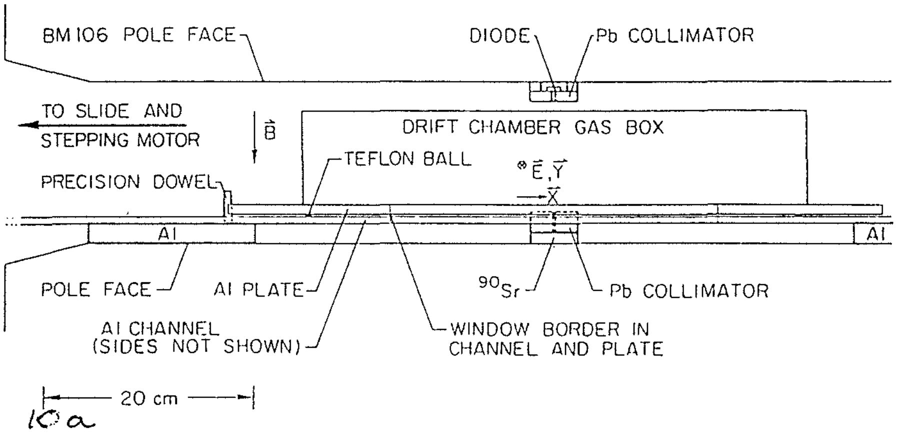
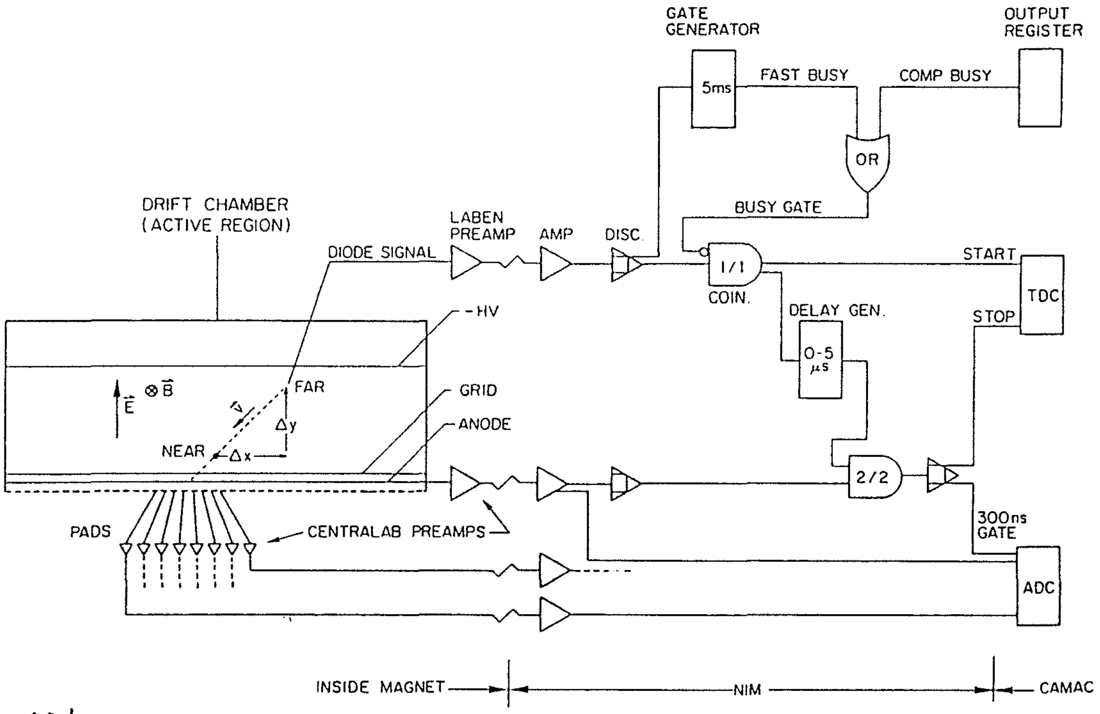


Fig. 9. (a) An elevation view of the drift chamber used for the measurements of $v$ and $\tan(\eta)$, including a calculation of the equipotential lines for hv = −9.5 kV. (b) The calculated electric field in the drift region as a function of the $y$-coordinate for hv = −9.5 kV.



10a

Fig. [illegible] An elevation view of the apparatus used to measure drift velocities and Lorentz angles at high magnetic field. Not shown is the precision slide and stepping motor which drove the u-channel and thereby the drift chamber in the $x$-direction. In order to move the chamber between its NEAR and FAR $y$-positions, the aluminum plate was rolled atop the u-channel on teflon balls.



10b

Fig. [illegible] An illustration of the measurement procedure and data acquisition.

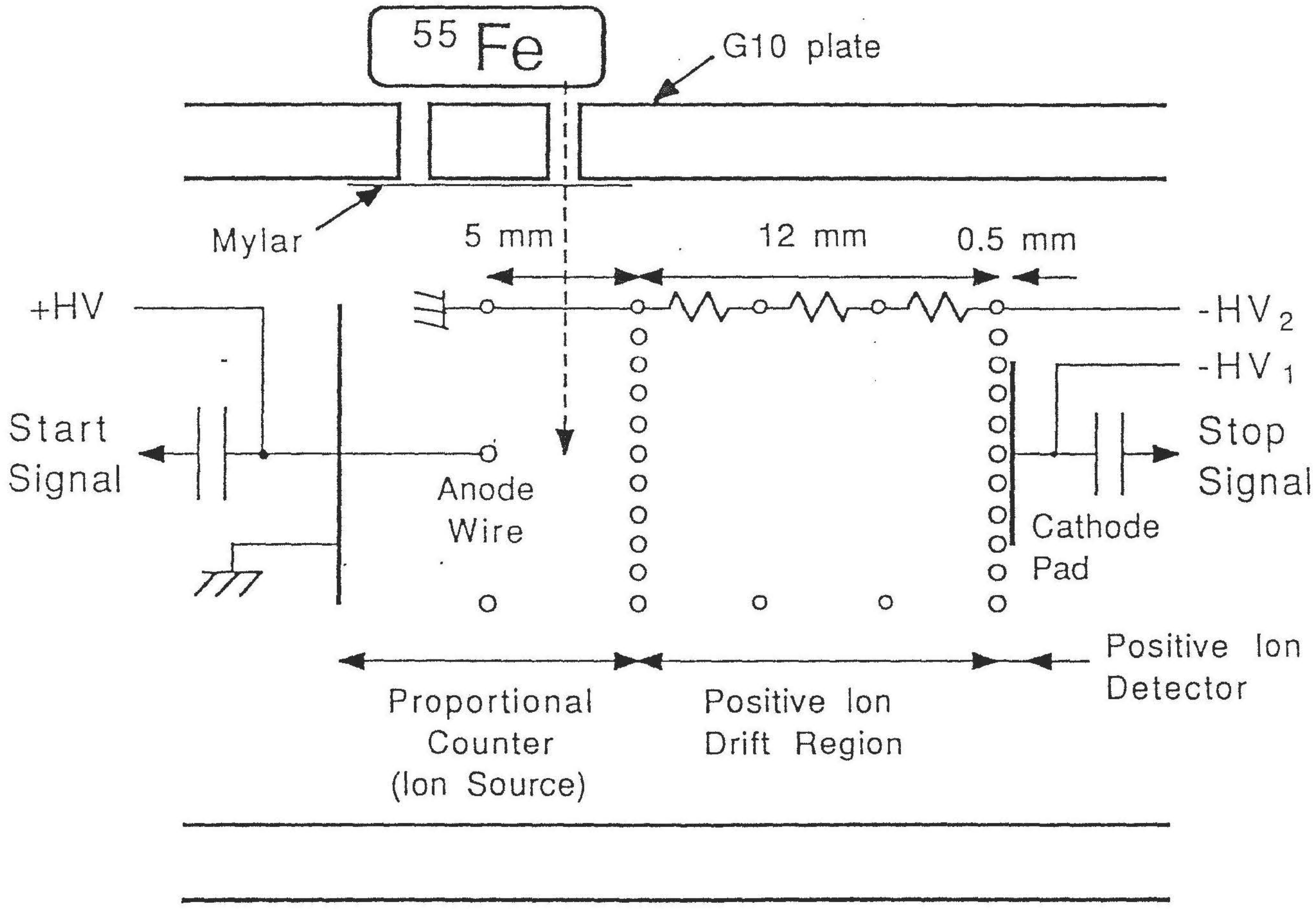

55 Fe
G10 plate
Mylar
5 mm
12 mm
0.5 mm
+HV
-HV 2
-HV 1
Start Signal
Stop Signal
Anode Wire
Cathode Pad
Proportional Counter (Ion Source)
Positive Ion Drift Region
Positive Ion Detector

Figure 11