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SOLENOIDAL DETECTOR NOTES

MUON CHAMBER GAS AND RELATED ISSUES

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Muon Chamber Gas and Related Issues

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The gas mixture for SDC muon drift chambers has to satisfy the following basic requirements:

- Nonflammable.
- Sparkproof for reliable long time operation.
- Fast drift speed insensitive to changes in the electric field, gas concentration and environmental factors.

The choice of chamber gas has been a critical factor for successful operations in drift chamber's 20 year history. Many chamber gas mixtures have been identified and tried. Unfortunately, none of them is appropriate in all aspects for use in the SDC muon drift chamber.

Almost all the known 'good' drift gas mixtures contain a large fraction of hydrocarbon and, therefore, are flammable. This has increasingly become unacceptable as the scale of muon tracking systems grow bigger and bigger. D0 has abandoned the long tradition of Ar/ethane at Fermilab. They choose Ar:CO_2 (90:10) mixture instead. Both SDC and L* are considering Ar/CO_2 for their muon drift chamber systems based on safety considerations.

The L* group has a active group working on muon chamber gas problems. Their recent results are summarized in their LoI and EoI. The SDC and Empact documents, on the other hand, do not contain any information about this issue.

Flammability

Ar/CO_2 mixture is a inert gas. However, a small amount of hydrocarbon gas may be needed in order to make it more stable against sparking. The HRS gas contains 1% of methane. L* is considering adding 1-2% of iso-propanol (i-C_3H_7OH) into Ar/CO_2 mixture.[1]

Flammability is a very complicated issue which I will not attempt to address. A gas mixture with small amount hydrocarbon concentration can be considered as nonflammable under certain conditions. I will include gas mixtures with less than 10% hydrocarbon in the following discussion although it is not clear if this is an acceptable situation for a SSC experiment.

Many different recipes of this kind mixtures have been studied [2]. Among them, a particularly interesting one studied by L.G. Christophorou et al.[3] at Oak Ridge in 1979 will be discussed in the following sections.

Another example of this kind of non-flammable gas is the 92% CO_2 and 8% i-C_4H_{10} used by SLD group. This is a low diffusion, slow drift and non-saturated gas. Numerous studies have been made in recent years in attempting to find a nonflammable gas mixture for self-quenching streamer tubes. Most of this kind of nonflammable gases are similar to SLD gas. They are CO_2 based containing a small fraction of argon and hydrocarbon gas. These studies are not very useful to us because they do not care about drift properties.

High Voltage Stability

Ar/CO_2 mixtures are know to be unstable against high voltage discharges especially when the CO_2 content is small. By introducing 1% of methane, the HRS gas $Ar:CO_2:CH_4$ (89:10:1) improves this situation. L* is considering adding 1-2% of iso-propanol (i-C_3H_7OH) into Ar/CO_2 mixture. On the other hand, D0 has shown that $Ar:CO_2$ (90:10) can in fact be successfully used in muon drift chambers.

A study by D.M. Lee et al.[4] at Los Alamos in 1987 can help us to better understand this problem. In this study, the high voltage stability problem for many chamber gas mixtures and different anode wire diameters are systematically studied. Small proportional tubes with 0.5" × 1" cross section were used in their study. These tubes were exposed in a 150 MeV electron beam and pulse heights are readout directly using an oscilloscope. 4 wire diameters, 20, 25, 50 and 100μ, and 15 different gas mixtures were tested at both proportional and limited streamer mode. Their observations were shown in fig. 1.

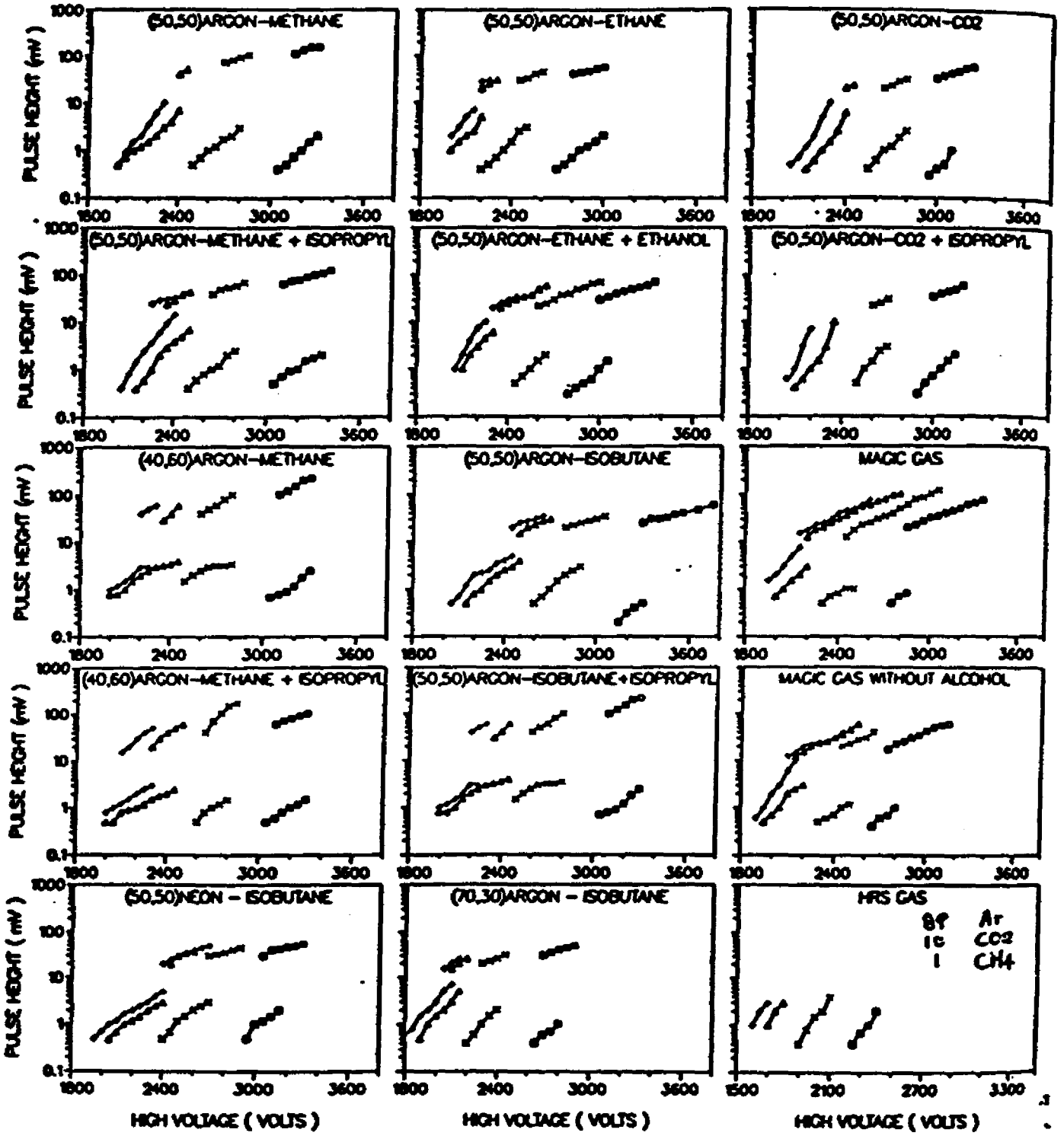

Fig. 1. Pulse height as a function of high voltage for various gases and wire diameters (+: 20 μm; △: 25 μm; ×: 50 μm; □: 100 μm).

Although the added 1% CH_4 should improves the stability against sparking, the HRS gas performed the worst. Its high voltage plateau is short and the streamer mode is completely absence which indicates that sparks occur at low gas gain.

This looks bad enough. However, in our particular application, we only care about the proportional mode and the wire diameter will be at least $50\mu m$. If we look closely, we can see that the HRS gas is actually as good as the AR:C_2H_6 (50:50) for 50 μm diameter wires. The maximum proportional pulse heights are the same in both cases. The magic gas, on the other hand, is only good for $20\mu m$ diameter wires. In terms of the maximum proportional pulse heights, it is actually worse than HRS gas if thinker anode wires are involved.

According to this study, the maximum proportional pulse height is about 2-3 mV (on 50 Ω) for HRS gas which translate to 40-60 μA signals. Normally, the discriminator threshold can be set to as low as 2 μA if high sensitivity amplifiers are used. It should give us enough operation margin even we consider that the average pulse height has to be 10×threshold to ensure full efficiency.[5]

The maximum proportional pulse heights as a function of wire diameter is shown in fig. 2.

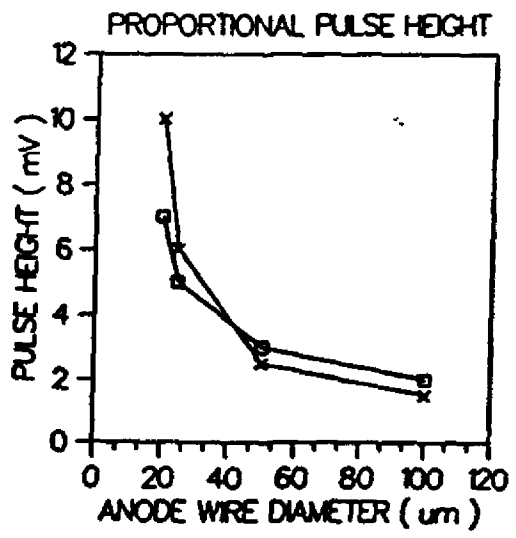

Fig. 2. Proportional pulse height as a function of high voltage at transition [×: (50, 50) argon–ethane; □: (50, 50) argon–ethane + ethanol].

We can conclude that the difference between $50\mu m$ and $100\mu m$ is not very significant. We probably can use any wire within this range. We would like to use thicker anode wires to achieve better electric stability. But this will result larger gravitational sagging because the ratio of strength over weight per unit length is smaller for thicker diameter wires. A optimised solution has to be found.

Drift Speed Stability

The electron drift speed has to be fast. It must not be sensitive to changes in the electric field, gas concentration and environmental factors.

Ar/CO_2

The drift velocity as a function of drift field is given in fig. 3 for different Ar/CO_2 mixtures. The drift velocity is very sensitive to changes in CO_2 concentration if it is less than 16% and drift below about 1.5 kV/cm. This trend is shown in fig. 4 for three different drift field. Data in this figure are from a systematic investigation done at MIT by C.M. Ma et al. in 1982 [6] and also from L* LoI and EoI.

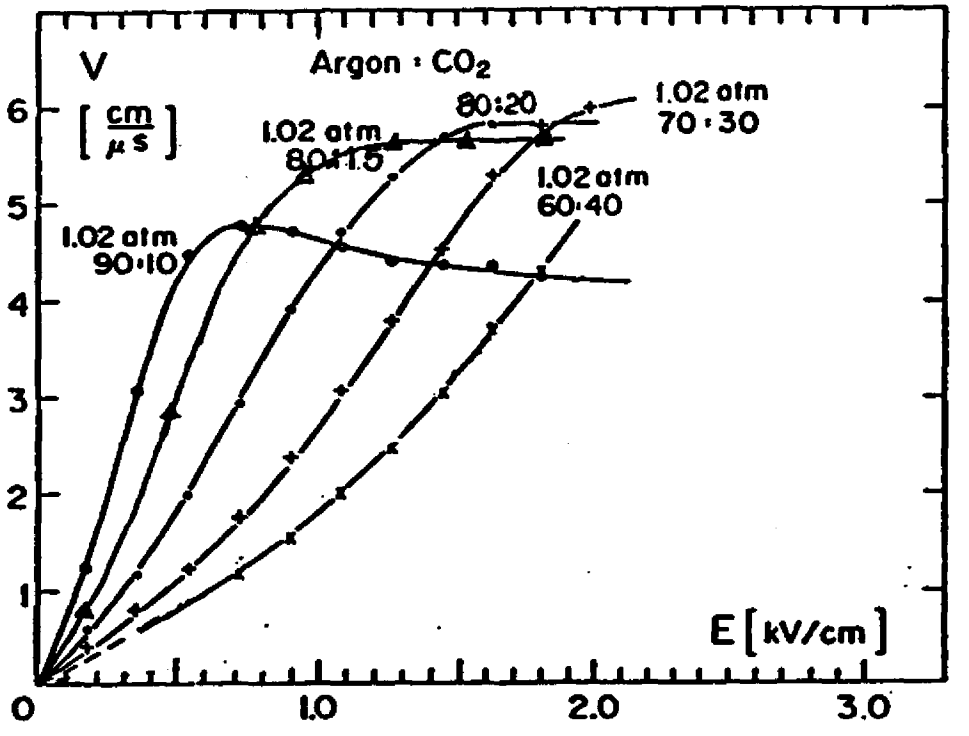

Fig. 3.

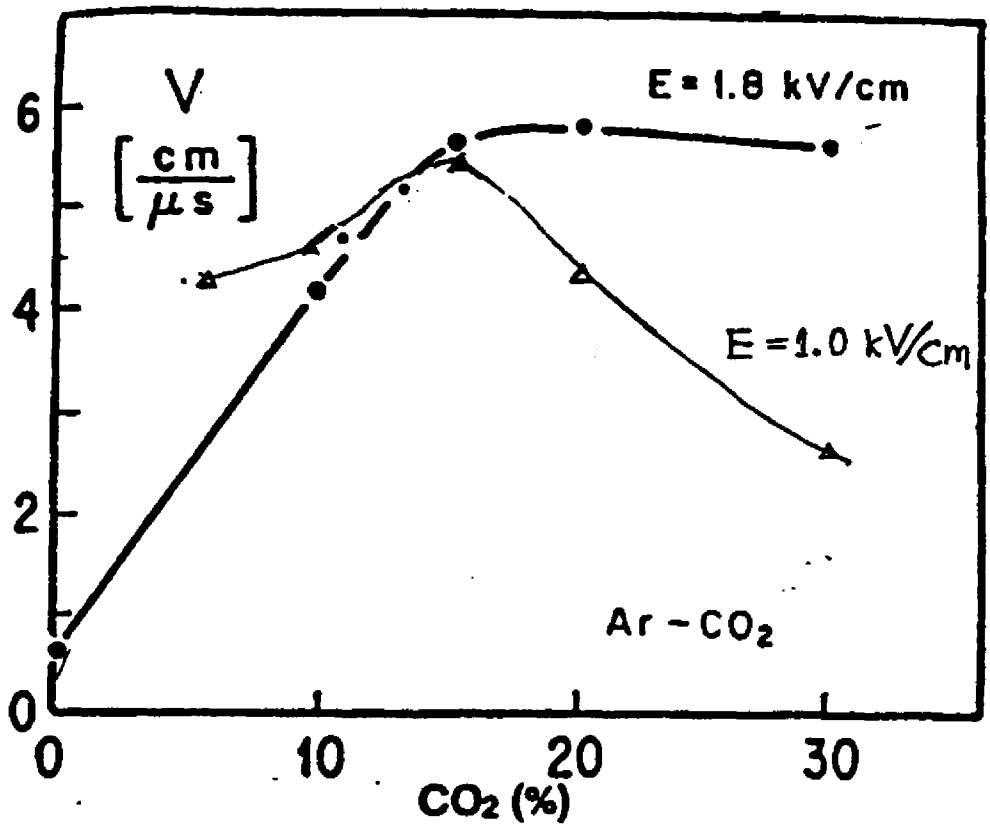

Fig. IV Drift velocity (v) vs CO_2 concentration.

The drift velocity stability against environmental factors is not very well know. Presumably the above conclusion is also true that the drift velocity is sensitive to changes of factors such as temperature and pressure if the CO_2 concentration is < 16%.

A D0 study [7] has reached different conclusion. It showed that the drift velocity is relatively insesitive to changes in CO_2 concentration and to water contamination. Clearly further investigation is needed.

Fig. 2 shows that the drift field has to be as high as 1.5kV/cm in order to reach the drift velocity plateau for Ar:CO_2 (85:15). The required high voltage on the I-beam cathode will have to be as high as −6kV for drift tubes with 4 cm drift distance. If we follow L*'s advice by using 18% CO_2 concentration and drift field 1.8 kV/cm, we would have to run cathodes at −7.2kV. This will create some difficulties for the drift tube design and operation.

$Ar/CF_4/CO_2$

The problem discussed above may be eased by introducing a third component. D. Green et al. propose [7] to use $Ar/CF_4/CO_2$ gas mixture. A variety of mixing ratios were studied. Their conclusion is that $Ar:CF_4:CO_2$ (88:10:2) is a good choice for fast drift application. The average drift velocity in this mixture is 8.7 cm/sec under their test conditions.

They did not measure drift velocity as a function of drift field. But fig. 5 from D0 paper shows that the drift velocity saturation property of $Ar:CF_4:CO_2$ (88:10:2) is definitely better than the standard $Ar:CO_2$ (90:10).

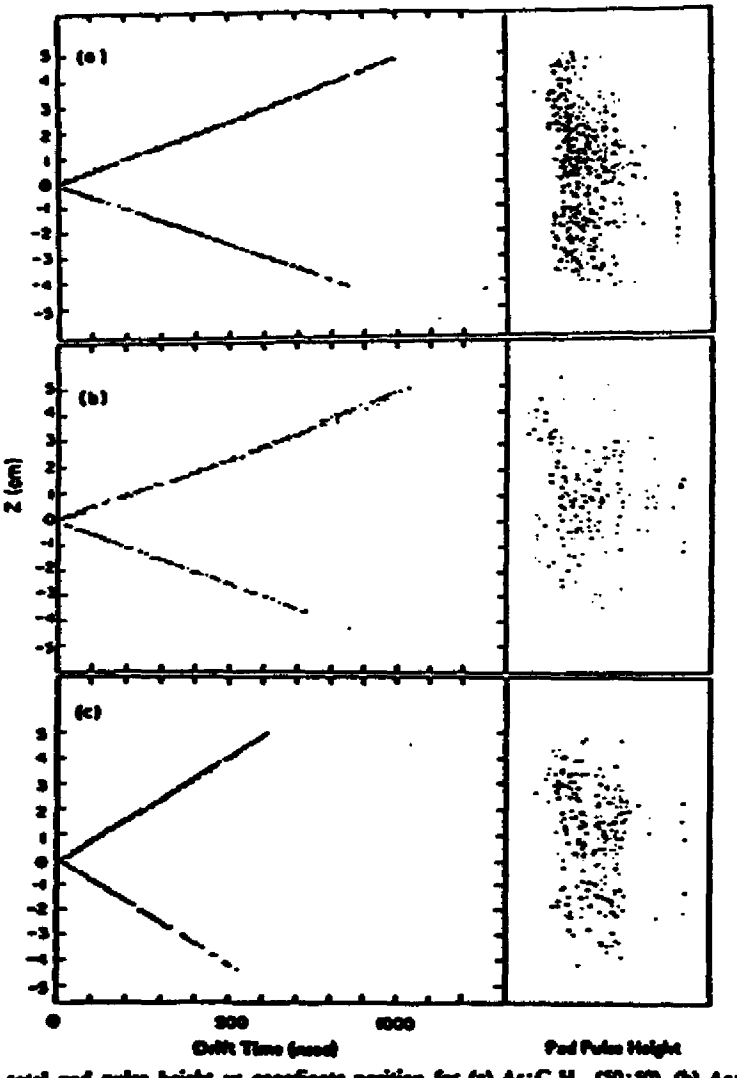

Fig. 5. Drift time and total pad pulse height vs. coordinate position for (a) $Ar:C_2H_6$ (50:50), (b) $Ar:CO_2$ (90:10) $Ar:CO_2:CF_4$ (88:2:8).

It is clear that the relationship between the drift speed and drift field can be tuned by varying the ratio of the three components. Small amount of CF_4 (a few percent to about 10%) in argon not only can significantly increase the drift speed but also can speed up the drift at low field. Increasing the CO2 content (more than the 2% that D0 proposed) extends the drift speed plateau to higher drift field region. But it also slows the drift speed on the plateau. It is very likely that a optimized solution can be found.

$Ar/CF_4/C_2H_2$

Another interesting gas was studied by Christophorou at Oakridge in 1979. In fig. 6 taken from their paper, gas mixtures $Ar/CF_4/C_2H_2$ clearly show nice drift velocity saturation properties. One particular mixture 80:10:10 shows that the drift velocity plateau extends from about 1 kV/cm to 2 kV/cm at almost 9 cm/sec. The 10% of C_2H_2 not only can suppress sparks, it may in fact make the streamer operation possible. Other hydrocarbon gases such as ethane and isobutane should have similar effects as C_2H_2.

For comparison, Fig. 7 shows the drift property of CO_2/CF_4 without hydrocarbon.

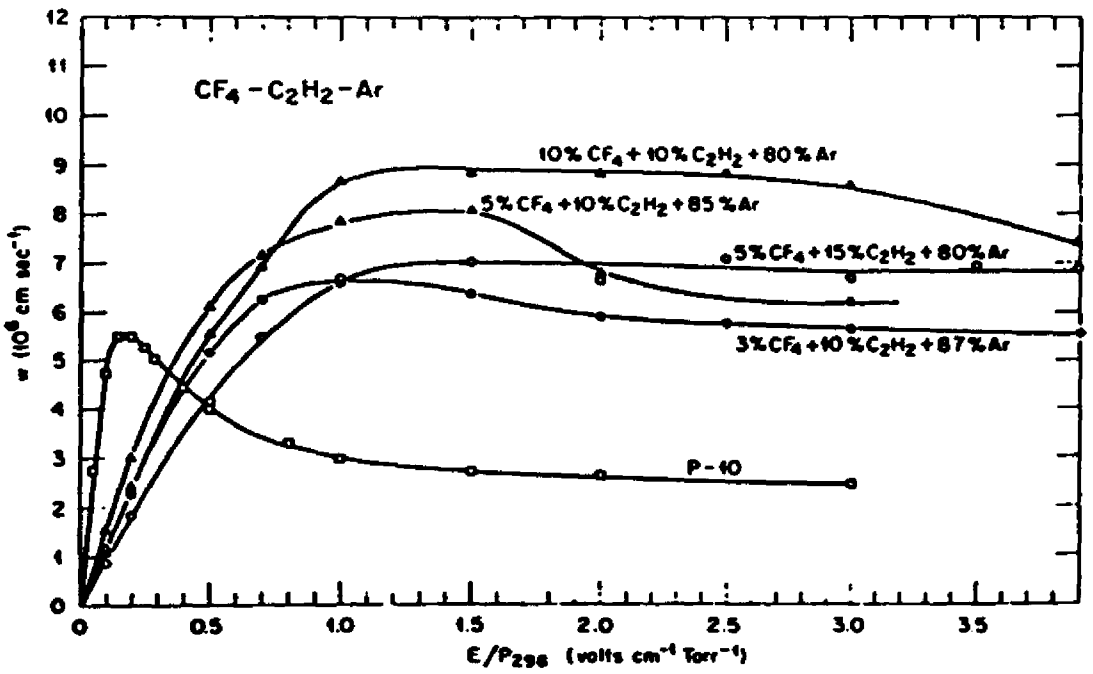

Fig. 6 Christophorou et al. (1979)

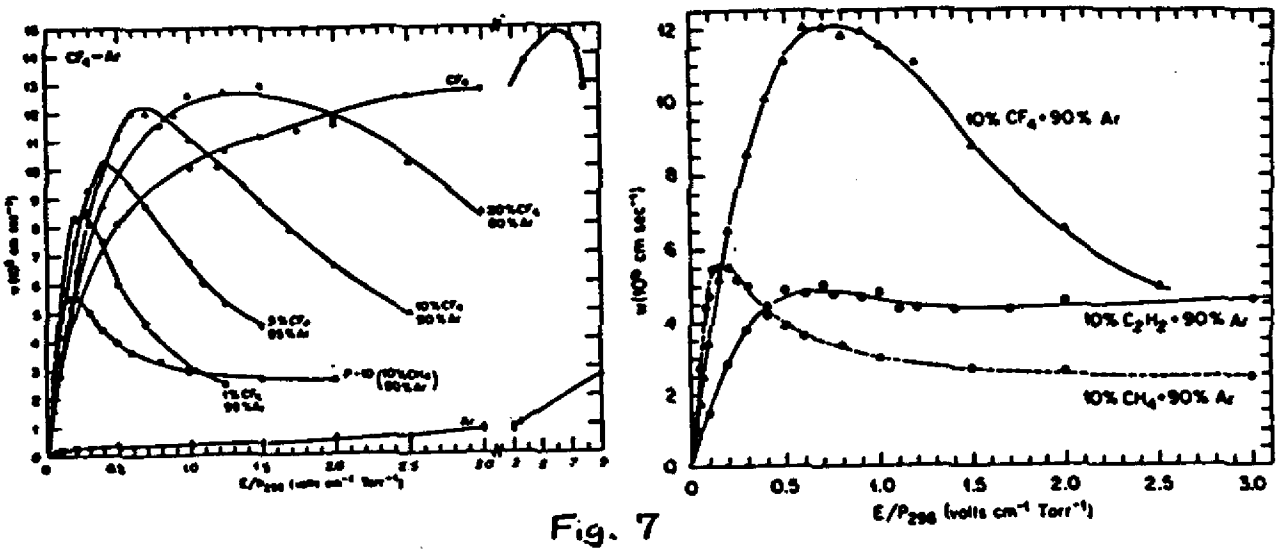

Fig. 7

Summary

- Ar/CO_2 mixture is a good candidate gas for SDC muon drift tube. Much more studies are needed to investigate its properties before we can determine that it can indeed satisfy all our requirements.
- $Ar/CF_4/CO_2$ is a very promising mixture. Again, studies are needed to optimize the mixing ratio and investigate its properties.
- $Ar/CF_4/C_2H_2$ mixture is another good candidate if 10% of C_2H_2 is tolerable.

References

[1] L* LoI and EoI.

[2] *Anna Peisert and F. Sauli. 'Drift Chamber Gas', CERN 84-08, 1984.*

[3] L.G. Christophorou et al., 'Fast Gas Mixtures', NIM 163 (1979) 141.

[4] D.M. Lee, R. Bilskie and H. Sanders, NIM A256 (1987) 329.

[5] F. Sauli, 'The Wire Chamber Bible', CERN 77-09.

[6] C.M. Ma et al, MIT Technical Report 129 and 130 (1982), to be published.

[7] J.M. Butler et al., 'Fast Gas in D0 Muon System', NIM A290 (1990) 122.