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MEASUREMENTS OF ELECTRON DRIFT IN FAST GASES WITH CROSSED ELECTRIC AND MAGNETIC FIELDS†

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Abstract

Results are presented from theoretical and experimental studies of electron drift in gas mixtures which aim for high drift speed and good X-ray detection. Implications for the design of an Intermediate Track Detector at a supercollider are briefly considered.

Introduction

This paper reports progress in establishing the optimum gas mixture for an intermediate angle gaseous chamber system at an experiment at a future proton supercollider (SSC or LHC). The detector (Intermediate Track Detector ITD) will be designed to reconstruct charged tracks, and possibly also to identify electrons by means of transition radiation (TR) detection in the pseudo-rapidity range $1.2 < \eta < 2.2$ [1]. The foreseen technique follows closely that of the forward track detector at the H1 experiment at HERA [2,3,4,5]. An essential ingredient for the proper design of an ITD is an understanding of the electron drift properties of potentially suitable gas mixtures.

Preliminary Considerations

Theoretical and experimental studies of various gas mixtures are under way. Interaction rates at a proposed luminosity (10^{33} cm^{-2} s^{-1}) of future supercolliders together with the nature and configuration of drift cells in an ITD at a "magnetic detector" (e g the SDC experiment at SSC [6]) pose the following minimum set of requirements on choice of gas mixture if optimal drift chamber operation is to be possible:

- high drift velocity for minimal cell occupancy with minimal drift Lorentz angle;
- good spatial accuracy in proportional mode;
- minimal depreciation with radiation exposure;
- manageable physical and chemical properties;
- X-ray sensitivity for efficient TR detection.

Figure 1 shows a compilation of measurements of the electron drift velocity as a function of drift field for the six fastest known pure gases [7]. When mixed with noble gases for comfortable HV operation (Ar for cheapness, He for low density, Kr and Xe for TR X-ray absorption), high drift speed is still to be expected. Other components may also be included as quenchers, ionization increasers, or fillers.

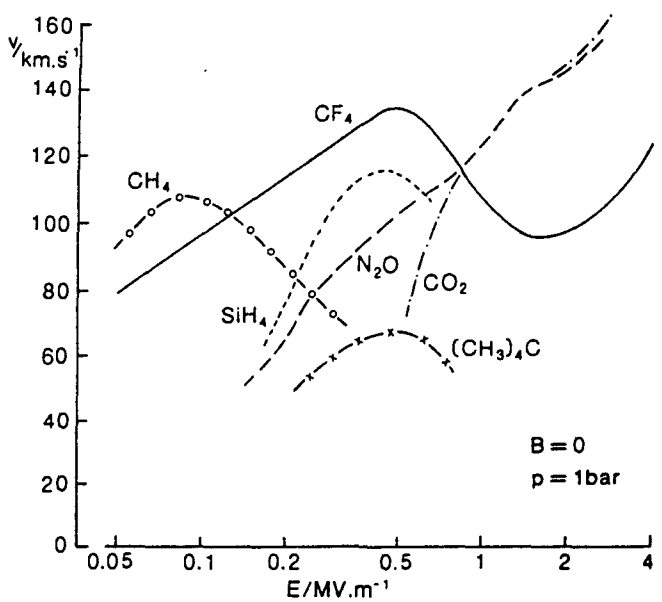

Fig 1: Electron drift velocities in fast polyatomic gases.

Admixtures of the gases of figure 1 to the noble gases also cool electron drift by virtue of their (inelastic) vibrational degrees of freedom. Nitrous oxide (N_2O) and neo-pentane ($(CH_3)_4C$) have further good properties. For example N_2O contains no C atoms, so can never polymerize, while $(CH_3)_4C$ absorbs the UV emission of Kr or Xe better than iso-C_4H_{10} or other quenchers. Kr or

In choosing a particular mix we try of course also to minimize the toxicity and explosion risk. In what follows, we present first\ measurements of mixtures containing the cheapest noole gas (Ar) and the fastest pure gas (CF_4).

Experiment

A multi-wire drift cell designed and constructed specifically for the purpose is used to measure drift velocity and Lorentz angle. The chamber follows closely the design of Atac et al [8]. Drift time in a constant electric field is measured over perpendicular distances of a 16, 32 or 48 mm from a sense wire. Drift direction is measured using the known position of irradiation by a collimated ^{90}Sr source (β end-point energies 0.55 MeV ^{90}Sr, 2.23 MeV ^{90}Y) and the position of gas avalanche along the sense wire by means of the induced signal on adjacent cathode strips. The chamber itself is operated in the uniform magnetic field of a C-magnet ($B \leq 2$ T) with the plane of ionisation drift and sense wire perpendicular to the magnetic field direction.

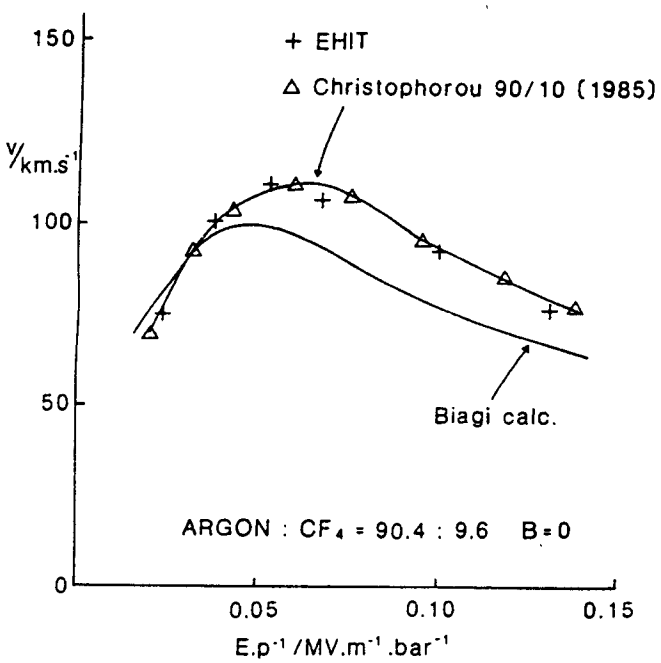

Fig 2: Drift velocity measurement in an Ar:CF_4 90:10 mixture with B=0; previous measurements and calculation are also shown [9,11,12].

Results of drift velocity measurements for CF_4:Ar mixtures in zero magnetic field are shown in figure 2 together with preliminary calculations [9,10]. In zero field our drift velocity measurements agree with previous measurements [11,12]. Systematic errors of measurement are of order 10%, and may be reduced after further study.

In finite applied magnetic fields (examples are shown in figures 3 and 4), where our measurements are unique, there is however some discrepancy of drift speed and angle with calculation. These calculations involving CF_4, and the parametrisations of input cross sections which they use, are new so the discrepancies should not yet be regarded as established.

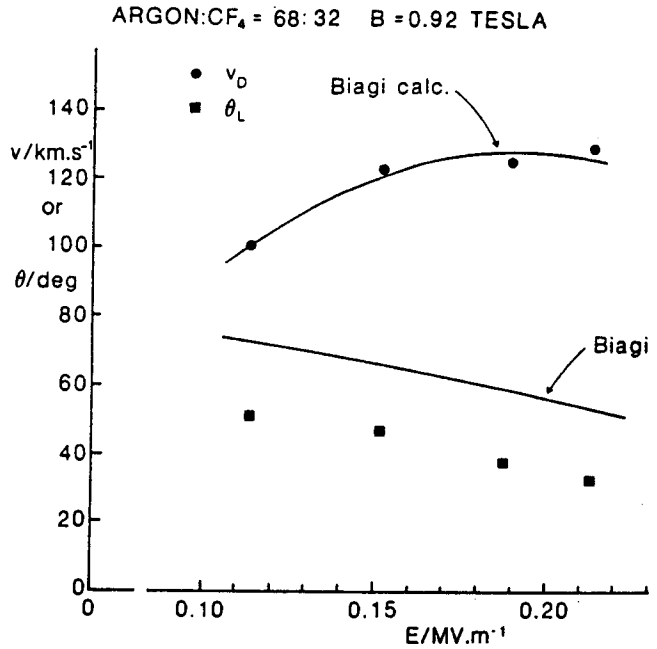

Fig 3: Drift velocity and angle measurements in an Ar:CF_4 68:32 mixture and crossed B field of 0.92 T; theoretical calculation is also shown [9].

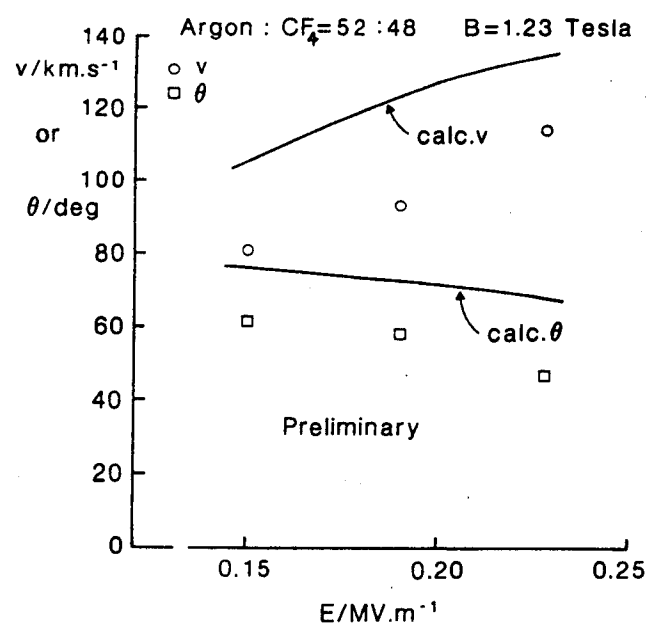

Fig 4: Drift velocity and angle measurements in an Ar:CF_4 52:48 mixture and crossed B field of 1.23 T; theoretical calculation is also shown [9].

It is already clear however that the use of CF_4 as a major component of drift chamber gas for the purpose of

increasing ionisation drift velocity to at least 100 $\mu m\ ns^{-1}$ is confirmed and for the first time demonstrated in substantial crossed magnetic field. Nevertheless its use in a magnetic field of ~1.8 T (likely in the SSC experiment SDC) with a suitable drift electric field may involve Lorentz angles substantially greater than 45° unless the chamber can be operated with a high drift field ≥ ~2 kV cm^{-1}.

A major problem associated with the use of CF_4 is the chemical effect it has on materials familiar to us in the construction of low mass drift chambers, e g foam, phenolic and epoxy based composites. At least one of our insulating materials, probably phenolic-bonded fabric ("Tufnol"), and perhaps also epoxy-bonded fabric ("G10"), had shrunk significantly due to absorbing CF_4.

We are therefore now carrying out measurements of mixtures with N_2O, which on paper looks also to be a suitable gas for drift velocities of 100 $\mu m\ ns^{-1}$, as quencher while we prepare a new prototype using CF_4 resistant materials. To date it is not yet clear that we can achieve adequate avalanche gas gain in the externally applied magnetic field for the hitherto possible electric drift fields.

Implications for ITD Chamber Design

The requirement of high drift field and thus acceptable Lorentz angle (~ 45°) is easily achieved with modest applied voltage for the small chamber aperture which is essential at high rate supercollider experiments. Any significant Lorentz angle increases the memory time of a drift cell and thus increases the occupancy. One possible way of reducing this effect is to string the ITD sense wires to follow as closely as possible to equiangular (logarithmic) spirals (figure 5).

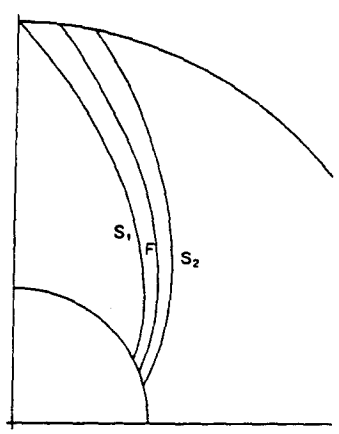

Fig 5: Equiangular spirals for 45°.

The problems experienced with the deformation, chemical and/or physical, of the construction materials used dictate the following:

- pre-shrinkage by long immersion in CF_4 gas, or perhaps other CFCs
- identification and use of low mass, inert materials which also have the necessary mechanical properties, e g Teflon (PTFE)

and they are being pursued.

Conclusions

First measurements have been made of electron drift characteristics in substantial crossed magnetic fields with gas mixtures which appear suitable theoretically for gaseous drift chambers at high rate supercolliders. It is possible to achieve acceptable drift velocities (>~100 km s^{-1}) in Ar:CF_4 mixtures, but with the disadvantage of substantial drift angles for values of drift electric fields used hitherto (~0.12 MV m^{-1}). At higher drift field (> ~0.3 MV m^{-1}) the drift angle can probably be reduced to 45° or less. Present theoretical calculations of drift velocity and angle for these mixtures are not yet of adequate precision for chamber design.

A serious drawback of the mixtures so far investigated is their deleterious effects on the materials traditionally used for low mass construction.

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