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ELECTRON ATTACHMENT OF C_5F_{12} TO BE USED AS GAS RADIATOR
IN THE BARREL RICH DETECTOR OF DELPHI

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ABSTRACT

The performance of RICH detectors is limited by the impurity levels of the drift gas. We report measurements on electron attachment of C_5F_{12} in a CH_4 , C_2H_6 drift gas for drift fields from 0.3 to 1 kV/cm.

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1. INTRODUCTION

Ring Imaging Cherenkov counters [1], as the Barrel RICH detector [2,3] to be installed into DELPHI, measure the angle of the Cherenkov light produced by a relativistic particle traversing the detector, and thus directly the velocity of this particle. The envisaged gas radiator is C_5F_{12} for its superior uv-transparency and high index of refraction. The Cherenkov photons are focussed into TPC like drift tubes, where they are converted into electrons via photo ionisation of TMAE. These electrons drift over a distance of up to 1.5 m to a multiwire proportional chamber, and thus the conversion point of the Cherenkov photons is measured in its three dimensions.

The aim of this study was to analyse the effect of small contaminations of C_5F_{12} in the drift gas on the drift of single electrons. For this purpose a set-up has been realized, to study the drift behaviour of single electrons in tubes similar to the ones later used in the Barrel RICH. A high electron attachment cross section for C_5F_{12} has been found, demanding a superior tightness of the final drift tubes.

2. EXPERIMENTAL SET-UP

The experimental set-up is shown in fig. 1. The essential part is a rectangular drift tube (60 cm long, cross section $18 * 6 \text{ cm}^2$) made out of glass fiber epoxy. The tube is equipped with three sets of quartz windows. To produce inside of this drift tube a homogeneous electrical field the walls are covered inside and outside with kapton sheets with conducting strips as field shaping electrodes. On the windows the equivalent electrode structure has been achieved by wrapping loops of wires around the quartz plates. All electrodes are connected to a linear resistor chain, to produce a drift field of up to 1 kV/cm.

A multiwire proportional chamber has been installed at the end of the drift tube. As shown in fig. 2 it is equipped with 2 planes of field shaping wires and a plane of sense wires. Fig. 2 includes also a typical single electron pulse height spectrum of the detector, from which we deduce an efficiency of $\geq 97\%$. The sense wire signals are amplified in a preamplifier and split to be analysed in a ADC and a TDC. The experiment is controlled by a CAVIAR computer via CAMAC.

The drift gas used was a mixture of 75% CH₄ and 25% C₂H₆, to combine high drift velocity and low diffusion with the possibility to have a gas gain as high as 5×10^5 , needed for the detection of single electrons. The flow rate was 42 l/h. Into the drift gas we injected a stream of 0-40 cm³/min of CH₄ containing 100 ppm of C₅F₁₂. This flow has been controlled by a mass flowmeter. In this way we created concentrations of 0-5 ppm of C₅F₁₂ in the drift gas.

We have generated free electrons in the drift tube using two-photon ionisation along the track of a N₂ laser [4]. The laser beam has been passed through the quartz windows at distances of 5 cm, 32 cm and 60 cm from the detector. To analyse the behaviour of the drift of single electrons, we attenuated the laser beam to a level, where the production efficiency of free electrons was 15% per laser pulse and detector wire. The laser had a pulse to pulse power stability of 10% which gives for 500 laser pulses a variation of ca 1% in the number of generated electrons.

3. RESULTS

The influence of C₅F₁₂ on the drifting electrons is illustrated in fig. 3 for a drift distance of 32 cm. The number of electrons arriving to the detector has been recorded. As shown in fig. 3 this number decreases drastically when some C₅F₁₂ is introduced into the drift gas.

To analyse the data we used the fact that the number of electrons produced follows a Poisson like statistic. The probability of producing k electrons is therefore

$$P^k(n) = (n^k/k!)e^{-n}$$

where n is the average number of electrons generated. Since the detection efficiency of our detector is nearly 100% we get for n

$$n = -\ln(1 - N_e/N_{sh})$$

where N_e is the number of electrons detected per wire and N_{sh} the number of laser pulses. The number of electrons drifting to the detector is reduced by the electron attachment process. Introducing λ for the mean free path of the drifting electron we obtain

$$n(x) = n(0) e^{-x/\lambda}$$

where x is the drift distance. To obtain the mean free path we plotted $\ln(n(0)/n(x \text{ ppm}))$ against the drift distance and fitted a straight line through the experimental data. In fig. 4 the resulting λ 's are shown for different C_5F_{12} concentrations at a drift field of 0.5 kV/cm. From λ we find the electron attachment cross section σ_{AT} by

$$\sigma_{AT} = (N\lambda)^{-1}$$

N being the density of C_5F_{12} molecules.

The measurements have been carried out for different drift fields in the range of 0.3 kV/cm to 1 kV/cm. The results are plotted in fig. 5. The electron attachment cross section decreases smoothly with increasing drift field.

4. DISCUSSION AND CONCLUSION

The electron attachment cross section of perfluoroalkanes has been the subject of a recent, quite detailed study carried out by Hunter and Christophorou [5]. They used high pressure swarm techniques to investigate electron attachment to $n - \text{C}_N\text{F}_{2N+2}$ ($N = 1-6$) in an Ar and N_2 drift gases recording the attenuation of clusters of 2×10^5 electrons produced by α particles from the decay of ^{252}Cf .

Our results differ significantly. A direct comparison of the two experiments is not possible, due to the use of different drift gases. This results in altered electron energy distributions and consequent differences in the electron attachment processes.

It should, however, be pointed out that our results were obtained in experimental conditions similar to the operating conditions of the Barrel RICH. From our results we conclude that a 0.2 ppm contamination of C_5F_{12} in the drift gas will give a mean free path for the drifting electrons of 10 m, which is the actual design figure. This implies a leak tightness for the final drift tubes of better than $10^{-5} \text{ cm}^3/\text{s}$ at atmospheric pressure.

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FIGURE CAPTIONS

- Fig. 1 The experimental set-up.
- Fig. 2 The multiwire proportional chamber layout with a single electron pulse height spectrum.
- Fig. 3 Number of detected electrons for different C_5F_{12} concentrations.
- Fig. 4 The mean free path of a drifting electron for different C_5F_{12} concentrations for a drift field of 0.5 kV/cm.
- Fig. 5 Electron attachment cross section of C_5F_{12} as a function of drift field.

Fig. 1

Fig. 2

No OF ELECTRONS

Fig. 3

Fig. 4

Fig. 5