Performance of Xenon as a working gas in an axial field ionization chamber

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Introduction

Radiation detectors generally use the principle of either ionization or scintillation to detect the incident radiation [1]. Gas detectors have successfully used the principle of ionization in various forms depending on the applied electric field and gas pressure. In such applications the choice of the working gas is such that the energy required for ionization is low and the ionization cross-section is high. For ionization chambers generally isobutane has been used due to the above properties [2]. In single wire proportional counters P10 (Methane 4%, Argon 96%) is used because of the quenching properties of CH_4 in Argon at high gain. Timing detectors such as MWPC [3] and PPAC also use isobutane as electron mobility in this gas is much higher than other gases. As such isobutane and P10 are widely used as working gas for charged particle detection. On the other hand the heavy noble gas Xenon is widely accepted as a working gas for detection of photons (particularly X-rays) [4]. Xenon being a high Z material offers a large photoelectric cross-section for energy loss of X-rays. However its response to charged particles has been very rarely studied in the literature.

In this work we comparatively study the response of charged particles to a isobutane and Xenon filled gas detector. We found that using the Xenon gas for a ΔE ionization chamber (where the incident particle is not stopped in the detector volume) would prove to become useful than isobutane as the former shows equivalent performance for both light and heavy charged particles at same gas pressure whereas for isobutane it depends on pressure.

Experiment and Results

The experiment is carried out by using an axial field ionization chamber. The description of the chamber can be found in an earlier work. The experimental setup is shown in fig.1. The chamber is first evacuated by a rotary pump and then charged with research purity isobutane at some pressure. The ionization region is first determined by applying bias in increasing steps until the pulse height saturates. In fig.2 (a) and (b) we show the response of the detector to α-particle and fission fragments from ^{252}Cf source at 205 torr. The source is kept inside the detector and there is no effect of the window thickness in the present measurement. This intermediate pressure is chosen as the resolution for alpha is better at higher pressure and that for fission fragment is better at lower gas pressure. The possible reason is that the α-particle loose much less energy than fission fragments and hence the primary ionization is low at low pressure. In fig. 3 (a) and (b) we show the same α and fission fragments spectra at the same pressure but using Xenon as the working gas.

Fig. 1 Experimental setup.

The spectra of α and fission fragments for various pressures of isobutane and Xenon were recorded between 50 torr and 300 torr. The degradation in fission fragments spectrum becomes systematically poorer from lower to higher pressure. The α spectrum on the other hand shows a reverse trend again systematically.

The axial field ionization detector used in the present work is intended to be used as a ΔE detector for online charged particle identification. In such experiments generally particles with a large variation in Z is required to be measured. The result of our experiment with isobutane shows that the resolution is sensitive to the gas pressure and also varies with the Z of the measured ion.

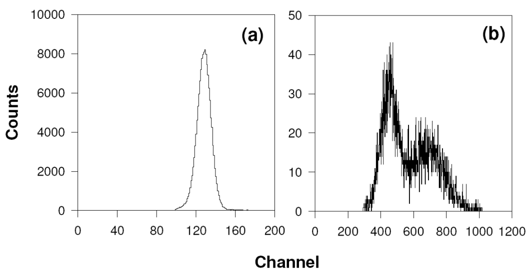

Fig. 2 Spectra of (a) alpha and (b) fission fragments using Isobutane at 205 torr.

Table 1: Energy straggling of fission fragments.

	Isobutane	Xenon
Heavy fragments	0.94 MeV	1.54 MeV
Light fragments	1.38 MeV	1.15 MeV

The repeat experiment with Xenon gas, (not a very common choice in ionization chambers) shows an improvement in performance for both alpha and fission. The resolutions for both low and high Z particles are almost the same.

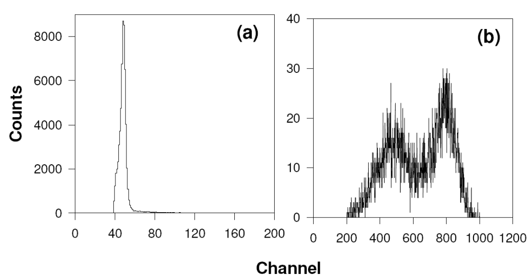

Fig. 3 Same as that of fig.2 (a) and (b) except for Xenon gas.

An interesting aspect observed in the present work is the inversion of energy straggling in the fission spectra in the two gases. Theoretical estimate of energy straggling is obtained from Bohr formula for Xenon and from [5] for Isobutane. The straggling values are given in Table 1. More details of the straggling phenomena will be studied in future.

Conclusions

We have studied the response of Xenon in an axial ionization chamber for light and heavy fragments. The performance of Xenon is more suitable when one measures ions having a wide range Z values. The energy straggling of the heavy ions have been also studied.

References

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