Measurement of the electron drift velocity in DME gas

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We have developed a photoelectric tracking type gas X-ray polarimeter using a time projection chamber technique for cosmic X-ray polarimetry.[1)] We select dimethyl ether (DME) as target gas of the polarimeter because the electron drift velocity in DME is relatively slow. The polarimeter chamber, filled with DME gas under a pressure of 190 Torr, consists of three components: drift plane, gas electron multiplier (GEM), and readout strips. When an X-ray interacts with a DME gas atom, a photoelectron is ejected in a direction according to a cosine probability distribution aligned with the electric field vector of the incident X-ray. Secondary electrons produced by photoelectron ionization are drawn by the electric field to the GEM, amplified by a factor ∼3000 with the strong electric field in the GEM hole, and then collected by readout strips. The 2-d image of the photoelectron track created by the readout strip position and timing enables measurement of the polarization degree of incident X-rays. In order to square the pixel size of the 2-d image, the electron drift velocity is optimized to be 0.242 cm/μs, which is derived from a strip pitch of 121 μm over a sampling rate of 50 ns. Thus, we accurately measure the electron drift velocity in DME gas under a pressure of 190 Torr as a function of applied electric filed.

Figure 1 shows a schematic view of experimental setup. We generated X-rays with a modulated X-ray source (MXS), whose X-ray radiation can be controlled by a switching LED[2)] with a pulse generator. Generated X-rays were collimated and directed parallel to the GEM foil. The drift distance of electrons to the GEM foil changed by moving it up and down the chamber using the Sigma Koki Z-stage. We measured the time interval between the leading edge of the pulse, which turned on the LED, and a discriminator signal created by charges induced on the GEM cathode. The drift velocity can be determined by dividing the X-ray beam position difference by the time interval difference. Figure 2 shows time interval as a function of stage position. The drift velocity was calculated by the slope of this plot.

The observed drift velocities, $v_{\rm obs}$, at various electric field are listed in Table 1. The drift velocities are determined with an accuracy of $< 0.5\%$, and are consistent with the Magboltz prediction[3)], $v_{\rm sim}$, under the DME gas condition of 190 Torr and 25°C. We determined that the electric field, where the drift velocity is 0.242 cm/μs, is 196.3 V/cm by interpolating the observed values. Reproducibility of the results should be checked in further experiments.

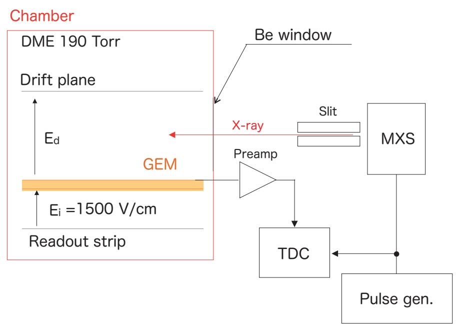

Fig. 1. Experimental setup to measure the electron drift velocity in DME gas.

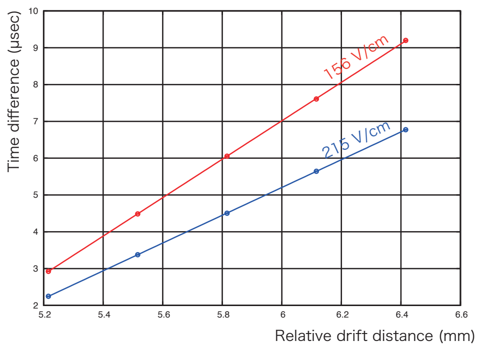

Fig. 2. Time difference as a function of stage position. The drift velocity is calculated by the slope of this plot.

Table 1. Comparison of simulated drift velocity and measured velocity.

E_d (V cm^{-1})	$v_{\rm obs}$ (cm μs^{-1})	$v_{\rm sim}$ (cm μs^{-1})
156	0.1918(6)	0.1916(2)
176	0.2161(10)	0.2158(2)
186	0.2291(8)	0.2285(3)
196	0.2405(8)	0.2411(3)
205	0.2525(9)	0.2532(3)
215	0.2650(8)	0.2651(3)

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References
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