Variation of gain and energy resolution with temperature and pressure of straw tube detector

S. Roy[1],* N. Nandi[2], R. P. Adak[1], S. Biswas[1], S. Das[1], S. K. Ghosh[1], S. K. Prasad[1], and S. Raha[1]
[1]*Bose Institute, EN-80, Sector V, Kolkata-700091, INDIA and*
[2]*Raja Peary Mohan College, West Bengal- 712258, INDIA*

Introduction

The straw tube detector is a single wire gas chamber operated in proportional region. The details of this detector and its principle of operation are described in Ref. [1, 2]. Straw tubes are currently being used in large High Energy Physics (HEP) experiments as tracking detector with low material budget [3]. We are exploring the possibility of using straw tubes for the 3^{rd} and 4^{th} stations of CBM Muon Chamber (CBM-MUCH) [4] at the future Facility for Antiproton and Ion Research (FAIR) [5] in Darmstadt, Germany.

A systematic study on the basic characteristics of a prototype straw tube detector is performed using conventional NIM electronics and Ar/CO_2 gas mixture in 70/30 and 90/10 volume ratio. The gain and energy resolution are measured from the energy spectrum using Fe^{55} X-ray source [6]. The variation of gain and energy resolution with temperature and pressure are measured with Ar/CO_2 gas in 70/30 ratio and presented in this report.

Experimental method

The gain of the detector is calculated as ratio of the 5.9 keV peak of Fe^{55} X-ray spectrum (fitted with a Gaussian) converted in charge using the gain on the ADC and preamplifier and the average number of electron produced in the gas (respectively 212 and 222 for the Ar/CO_2 70/30 and 90/10 mixture). The energy resolution is defined as the FWHM of the 5.9 keV peak of Fe^{55} X-ray spectrum fitted with a Gaussian function. In this report, the result of current measurements is presented.

*Electronic address: shreyaroy2509@gmail.com

Results

It is well known that the gain of any gaseous detector depends significantly on the ratio of temperature and pressure, (T/p). The dependence of the gain (G) of a gaseous detector on absolute temperature and pressure is given by the relation [7]

$$G(T/p) = Ae^{(B\frac{T}{p})} \quad (1)$$

where the parameters A and B are to be determined from the correlation plot.

In this study the detector is biased with 1650 V and is exposed to X-rays from the Fe^{55} source at a rate of 53 kHz and the energy spectra are recorded. Simultaneously the temperature (t in $^{\circ}C$) and pressure (p in mbar) are also recorded using a data logger, built in-house. The measurement is done for a time period of $\sim$ 340 minutes.

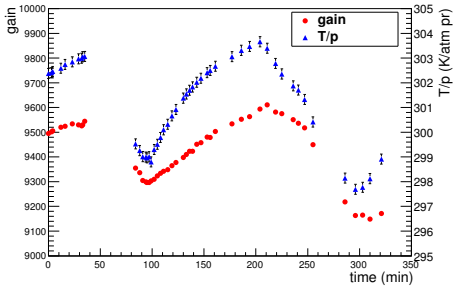

FIG. 1: Variation of the measured gain and T/p as a function of the time.

The variation of the measured gain and T/p are plotted as a function of period of operation in FIG. 1, where T (= t+273) is the absolute temperature in Kelvin and p (p in mbar/1013) is in the unit of atmospheric pressure.

The gain vs. T/p correlation plot is fitted with the function given by equation 1 and is shown in FIG. 2 (in FIG. 2 the parameters A and B are marked as p0 and p1 respectively). The values of the fit parameters A and B obtained, are 854.7 ± 3.305 and 0.0079 ± 1.284 × 10^{-5} atm pr/K. Using the fit parameters, the gain is normalised by using the relation:

$$gain_{normalised} = \frac{gain_{measured}}{Ae^{(B\frac{T}{p})}} \quad (2)$$

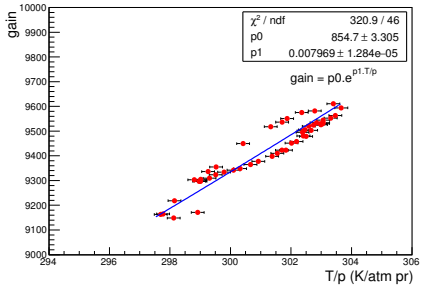

FIG. 2: Correlation plot: Variation of the gain as a function of T/p.

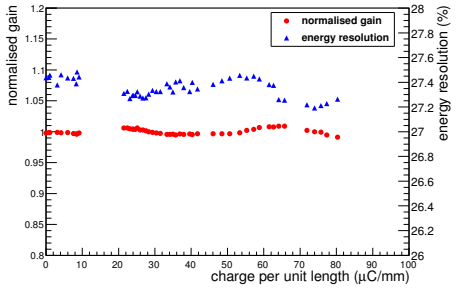

FIG. 3: Variation of the normalised gain and energy resolution as a function of the charge per unit length i.e. dQ/dL.

To check the stability of the detector, the normalised gain is plotted against the total charge accumulated per unit irradiated length of the detector which is directly proportional to time. The charge accumulated at a particular time is calculated by

$$\frac{dq}{dL} = \frac{r \times n \times e \times G \times dt}{dL} \quad (3)$$

where, r is the measured rate in Hz incident on a particular length of the detector, dt is the time in second, n is the number of primary electrons for a single X-ray photon, e is the electronic charge, G is the gain and dL is the irradiated length. The normalised gain as a function of the charge accumulated per unit length is shown in FIG. 3.

The energy resolution as a function of charge accumulated per unit length is also shown in FIG. 3. The mean energy resolution is found to be 27.36% with a sigma of 0.09.

Summary and outlooks

To check the effect of temperature and pressure on the gain and energy resolution, a continuous measurement is performed. Same Fe^{55} X-ray source is used to irradiate the detector and to obtain the spectrum. The gain is normalised for the T/p effect. The normalised gain is found to be stable with an average value of 1.002 with a sigma of 0.006 for a duration of ∼ 340 minutes which is equivalent to an accumulation of charge per unit length of ∼ 80 μC/mm.

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