Performance study of Straw tube detector prototype for future heavy Ion collision experiment

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I. INTRODUCTION

Straw tube detectors are widely used in High Energy Physics (HEP) experiments as tracking device for their low material budget. In the upcoming Compressed Baryonic Matter (CBM) experiment at the Facility for Antiproton and Ion Research (FAIR) at Darmstadt, Germany, possibility to use such detectors are under consideration for the 3^{rd} and 4^{th} stations of CBM Muon Chamber (MuCh) [1–4]. Extensive R&D are performed on the stability and rate handling capability of straw tube prototype [5, 6]. In the present study the gain, energy resolution and count rate of a straw tube prototype are measured using a ^{55}Fe X-ray source. The dependency of the gain on ambient parameters such as temperature (t), pressure (p), and humidity (RH) are also studied.

II. STRAW TUBE DETECTOR AND EXPERIMENTAL SETUP

A straw tube is a thin-walled (∼60 μm) Kapton cylinder with an inner carbon-loaded conductive layer and a central anode wire. The prototype module, contains six straws of 6 mm diameter and 25 cm length, operated with Ar/CO_2 gas mixture in volumetric ratio 70/30 at a flow rate 3 l/h. Positive high voltage (HV) (1340–1450 V) is applied to the anode. A ^{55}Fe X-ray source is placed on one of the straws using a G-10 collimator. The signals from the anode is fed to a charge sensitive pre-amplifier of gain 2 mV/fC and shaping time of 300 ns via a LEMO cable. The signals are further analysed using standard NIM electronics (preamplifier, FIFO, SCA, MCA, NIM-TTL and scaler), while t, p, and RH are simultaneously recorded using a data-logger built in-house as described in detail in Refs. [5, 6].

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III. RESULTS AND DISCUSSION

In this work, keeping the ^{55}Fe on one straw the applied voltage is increased and the signals are counted. The count rate as a function of applied high voltage is shown in Fig. 1. A plateau region is observed after 1400 V onwards indicating the saturation of count rate with radioactive source or in other words saturation of efficiency.

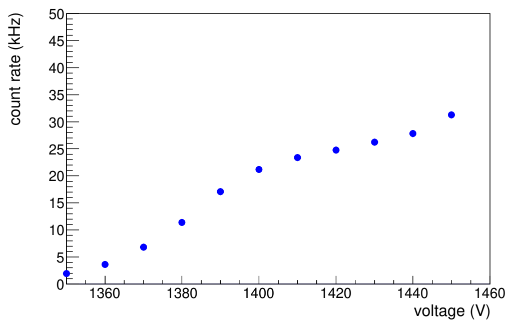

FIG. 1: The count rate as a function of voltage. Error bars are smaller than the marker size.

The gain and energy resolution of the straw tube prototype is calculated using a Double Gaussian function. A typical ^{55}Fe spectrum at 1450 V is shown in Fig. 2.

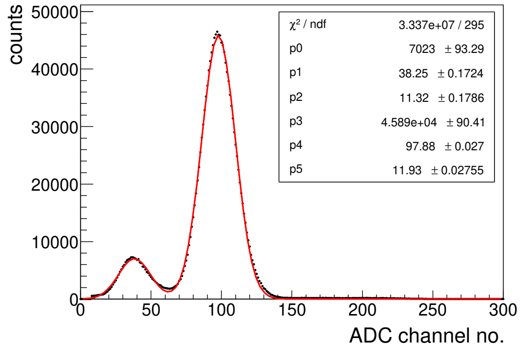

FIG. 2: ^{55}Fe X-rays spectrum at 1450 V.

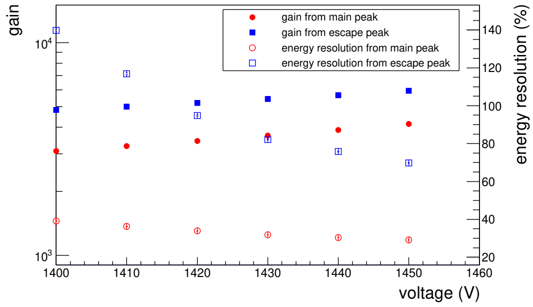

FIG. 3: Gain and energy resolution as a function of voltage.

The gain is calculated using the formula,

$$gain = \frac{output\ charge}{input\ charge} = \frac{\frac{mean\ pulse\ height}{2\ mV} fC}{no.\ of\ primary\ electrons\ \times\ eC} \qquad (1)$$

whereas, the full width at half maxima (FWHM) of the Gaussian fitted spectrum is used to define the energy resolution of the chamber using the formula,

$$Energy\ resolution = \frac{sigma \times 2.355}{mean} \qquad (2)$$

where the *sigma* and the *mean* are obtained from the Gaussian fitted 5.9 keV main peak and Argon escape peak of $\sim$ 2.9 keV of ^{55}Fe X-ray spectrum. The no. of primary electrons for 5.9 keV and 2.9 keV X-ray is calculated to be 212 and 104 respectively with Ar/CO_2 mixture in 70/30 ratio. For the first time the gain and energy resolution are measured using both the main peak and escape peak of ^{55}Fe spectrum. The gain and energy resolution, extracted for both the main and escape peak as a function of voltage are presented in Fig. 3. For both the cases the gain increases exponentially with voltage, while the energy resolution improves with increasing voltage.

It is well known that the gain of any gaseous detector depends significantly on temperature and pressure. In fact the gain increases with (T/p) exponentially following the relation [6]

$$gain(T/p) = A\, e^{B\,(T/p)}, \qquad (3)$$

where A and B are parameters determined from the correlation curve between gain and (T/p). This relation highlights the importance of normalised gain calculation against variation for the ambient environmental parameters in order to assess the stability of gaseous detector. The variation of gain and energy resolution with (T/p) is also studied.

IV. ACKNOWLEDGEMENTS

We thank Late Prof. Vladimir Peshekhonov (JINR, Dubna) and Dr. Christian J. Schmidt (GSI Detector Laboratory) for providing the straw tube prototype and valuable discussions.

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