Drift Tube Characterisation

DRD1 School lab group-6
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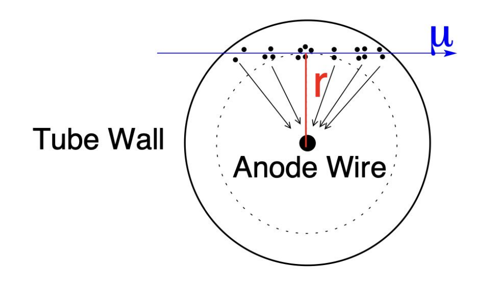
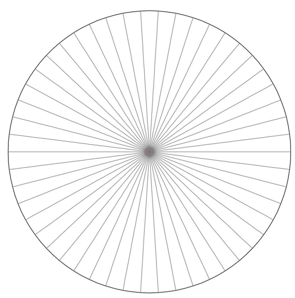
Introduction

- Cylindrical cathode with a tensioned anode wire in the middle of the tube.
- High voltage is applied between anode and cathode.
- Strong electric field is produced near the anode wire.
- Radiation or charge particles passing through the gas creates primary ionization.
- The primary electrons from the ionization, drift radially towards the wire.
- Avalanches occur near the anode wire.
- Avalanches continue till the electrons reach the anode wire.
- Gain of the detector $= \dfrac{Total\ charge\ collected\ in\ anode}{Total\ charge\ due\ to\ primary\ electrons}$



$$E(r) = \frac{V}{\ln b/a}\frac{1}{r}.$$



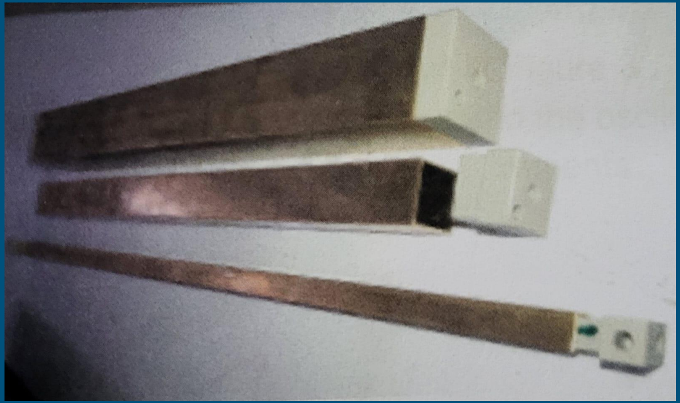
Work plan

In course of characterizing the detector we will-

- ❖ Find a suitable working voltage applied between two electrodes for maximum muon detection efficiency avoiding voltage breakdown.
- ❖ Measure the gain of the detector in two ways-
  - ➢ By measuring the total avalanche charge in a signal peak due to one cluster.
  - ➢ By measuring the total charge over the signal time window due to a single event.

Specification of the Detector under test

- Drift tubes made of brass.
- Square cross section.
- Length 40 cm.
- 1x1 cm^2 cross sectional area.
- Effective half-side size 0.4 cm.
- Gold plated Tungsten(W) wire through the centre of the tube.
- Diameter = 20 μm.



Experimental set-up

- Two scintillators are placed above and below the detector.
- Scintillator area 15x15 cm^2 .
- Scintillators are connected to SiPM.
- SiPM signal is fed to a controller for coincidence counting.
- TELEDYNE Lecroy Oscilloscope with 12 bit ADC resolution and 1 GHz bandwidth is triggered by the coincidence signal from two scintillators.
- Signal from the anode wire is fed to the oscilloscope.
- HV power supply to apply voltage to the tube .
- Gas mixture of 90% Helium- 10% isobutane is flown through the detector.

Working voltage

- Working in proportional region
  - Applied HV in range of 1450 ~ 1520 V (in steps of 20 ~ 30 V)
- Most efficient voltage for cosmic muon detection: 1500 V
  - Efficiency (ratio of tube signals over scintillator signals): ~ 8 to 13%
  - Efficiency after threshold application (next slide): ~ 12 to 13%
- Cosmic muon rate: ~ 0.22 Hz
  - Comparison: expected cosmic muon rate (assumed at sea level and with same tube geometry) of ~ 0.5 Hz

Gain measurement 1

- Whenever there is a trigger and a signal is above noise threshold the signal amplitude is filled in a histogram (lower pink histogram of example picture)
    - The noise threshold is chosen as 3σ of the noise amplitude (here 4.5 mV)
- The histogram gives the average signal amplitude **ΔV'** needed for the gain **G** calculation

Gain calculation 1

$$Q = \Delta V \times C_{\text{tube,eff}} = \Delta V \times \frac{C_{\text{tube}}}{2} = \Delta V \times \frac{2\pi\epsilon_0}{\ln\left(\frac{R}{2r_w}\right)\frac{L}{2}}$$

- Given: L = 0.4 *m* ; R = 4 *mm* ; r_w = 10 *μm* ; Z_{scope} = 50 *Ω*
- Charge defined as: Q
  - with ΔV = **ΔV'** / $((2*Z_{scope})/(Z_{scope}+Z))$
  - and Z = $sqrt(L_{tube}/C_{tube})$ including $L_{tube} = 2*10^{-7}$ *H/m* * $\ln(R/(2r_w))$ * L
- The gain is calculated using: G = Q / $(<n_{ele/cl}> * -1.6*10^{-19}$ *C*) with $<n_{ele/cl}>$ = 1.6
- With **ΔV' = -14.379 mV** from the measurement the gain is

$$G = 4.4*10^5$$

Gain measurement 2:

Obtain G from the average signal total charge:

- $$Q_{tot} = \frac{|\int(\text{abs}(\text{signal amplitude}(t))dt)|}{Z}$$

  Z is the characteristic impedance of the tube.

- $G = Q_{tot}[C]/(<n_{eleprimary/event}>)*1.6*10^{-19}[C]$

  As done for gain calculation one, integral needs to be corrected for the coefficient F

- $<n_{eleprimary/event}> = n_p * <L_{track}> * <n_{ele/cl}> * f_R$

n_p is number of primary ionisation per cm, $n_{phelium}$ is 4.8 and n_{pisob} is 84 per m.i.p.

➔ If we consider that not all cosmics which arrives on the tube are m.i.p.s, f_R is 1.3.

Gain Calculation 2:

Substituting values for the gain calculation:

- Q_{tot}= 65pWb/317.68=2.05*10^{-13}C

n_p is 0.9 and L_{track} is 0.8

- $<n_{eleprimary/event}> = n_p*<L_{track}>*<n_{ele/cl}>*f_R = 21.2$
- $G= Q_{tot}[C]/(<n_{eleprimary/event}>)*1.6*10^{-19}[C] = 2.05*10^{-13}C/21.2*1.6*10^{-19}C$

Final obtained value of Gain is:

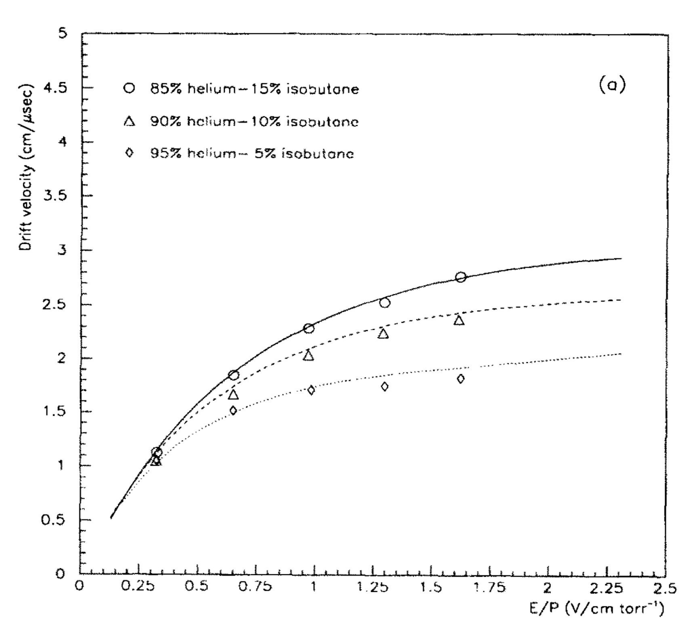
- $G= 6*10^4$

Conclusion

- The Gain value we calculated using two methods are not same.
- Which may be due to the reason due to small statistics of the event.

Thank You !

Back-up



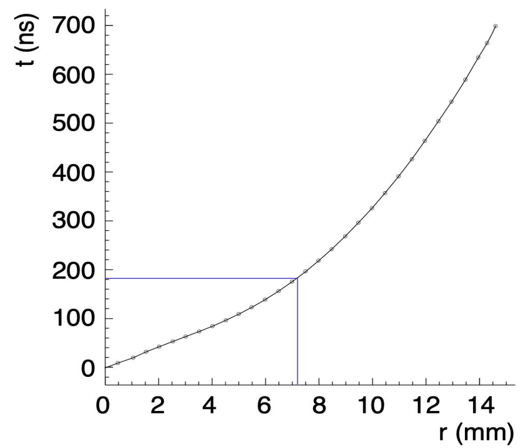


Figure 4: Space-to-drift time relation of 30 mm diameter drift tubes. If the tube diameter is reduced to 15 mm, the maximum drift time is reduced from 700 ns to about 200 ns (blue lines).