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Stability study and time resolution measurement of straw tube detectors

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Abstract. Straw tube detectors are single wire proportional counters that are widely used as tracking devices. We have carried out R&D activity with a straw tube detector prototype. The aim of this work is to study the stability of the performance in terms of gain and energy resolution of these types of detectors under high rate of radiation. The gain and energy resolution of the detector are studied along with its variation with ambient temperature and pressure. X-rays from a radioactive source are used to irradiate the detector and to monitor the energy spectra simultaneously for calculating the gain. The method followed here is unique as the ageing measurements have been performed without using an accelerated particle beam or any radiation generator. The performance of a straw tube detector has been studied in a laboratory for more than 800 h at a stretch using a single sealed radioactive X-ray source with high intensity. Variation of gain and energy resolution of the straw tube detector under X-ray irradiation in Ar/CO_2 gas mixture (volume ratio 80/20) is discussed in this article. The gain of an aged straw depends on gas flow rate. We have estimated the time required for the gain of a straw tube detector under ageing tests to recover on increasing the gas flow rate. We have also estimated the time resolution of the straw tube detectors by using cosmic rays as the trigger for the Ar/CO_2 gas mixture in 70/30 volume ratio (different gas mixture was used for the measurement of the time resolution). This type of ageing and time resolution measurements in Ar/CO_2 gas mixture has not been reported earlier. The details of the measurement process and the experimental results are presented in this article.

Keywords. Straw tube detector; gain; energy resolution; radiation effect; time resolution.

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1. Introduction

Straw tube detectors such as ATLAS [1] and NA62 [2] experiments at CERN and GlueX [3] in Hall D at JLab are single-wire cylindrical proportional chambers that have been used in many high-energy physics experiments over the decades for tracking charged particles with low material budget. Straw proportional tubes have the potential to be used as tracking devices in future high-energy physics experiments [4–6] involving very high particle density and extremely high interaction rate. Therefore, it is crucial to test their rate handling capability [8] and the effect of prolonged irradiation of these detectors. Earlier studies on straw tubes filled with a $Xe/CF_4/CO_2$ gas mixture have revealed gain degradation [9–12]. This transient ageing phenomenon observed in strongly irradiated straw tubes is because of the change in gas composition due to the production of long-lived and highly electronegative radicals during the avalanche process. This causes a temporary reduction in gain which can be restored by appropriately increasing the gas flow rate. There are more reports on radiation hardness and ageing effects of straw tube detectors [13,14] performed with Xe-based gas mixtures. However, Ar/CO_2 is by far a much more widely used mixture in gaseous particle detectors. As far as CO_2 is concerned, it is believed to be an ageing-resistant gas unlike other organic gases that are mixed with noble ones to quench secondary photons. Pure Ar/CO_2 gas showed stable operation up to ~ 1 C/cm [14–17], while some reports showed unexplained gain reduction with this gas [18,19]. Our goal was to operate the straw tube detector under conditions as close as possible to the real environment of high-energy physics experiments in

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terms of total charge accumulated on the detector over its lifetime. We wanted to study the effect of long-term exposure to radiation of straw tube detectors and to verify if gas ageing phenomena take place or not without imposing accelerated ageing. In this regard, two separate experiments were performed. In the first one, stability tests for the absolute gain and energy resolution of one straw tube under irradiation with X-rays were carried out. The experimental set-up and results are discussed in §2.1 and §2.2 respectively. The influence of temperature and pressure on the gas gain is also investigated. Reduction in gain after continuous operation for a very long time is observed in this experiment. To confirm that this gain reduction is due to ageing phenomena, another experiment using two straw tubes, one as a reference and the other as a test detector, was carried out. The reference straw was under the influence of a low rate of X-ray radiation whereas the other one was under a higher rate of X-ray radiation. A comparison of the gain of both the straws was done at certain time intervals during continuous radiation exposure. A detailed description of the experimental set-up and discussion of the results are included in §3.1 and §3.2 respectively. Time resolution of the detector is another important factor of concern in any tracking system. We have used cosmic rays as the radiation source and measured the time resolution of the straw tube detector. The experimental set-up and results are discussed in §4.

2. Stability test of straws: Experiment I

The main goal of this experiment was to measure the gain of the straw tube detector continuously at finite intervals in order to study its variation with increasing exposure. As the gain of a gaseous detector depend on ambient temperature and pressure [20], we also tried to check their correlation with gain variations.

2.1 *Experimental set-up*

The straw tube prototype used in this experiment was built in JINR, Dubna, Russia. It consists of 6 straws of 6 mm diameter and 25 cm length which are wound by two Kapton film strips. Carbon-loaded Kapton film of the 160 XC 370 type from DUPONT and aluminised (500 Å) Kapton film of the NH type are used as inner and outer strips, respectively. Both films are covered by a glue layer with a thickness of 7 μm on one side. A gold-plated tungsten-rhenium wire of 30 μm diameter (type 861, Luma) is used as the anode. The wire under 70 g tension is fixed by the crimp pins inserted in the polycarbonate end-plugs. The diameter of the end-plug is 6.0 ± 0.018 mm [6]. The signals from each straw tube are collected

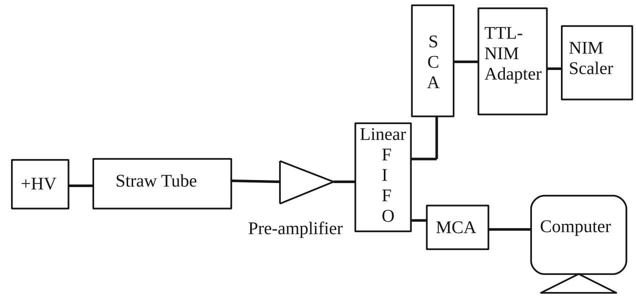

Figure 1. Schematic of the set-up used for the stability tests of the straw tube detector.

using LEMO connectors. A premixed gas composed of argon and CO_2 in 80/20 volume ratio is used in flow mode at a rate of 3 l/h and an overpressure of 1 bar. In these straw tubes, overpressure of the working gas mixture of 1 bar is applied. The gas purity is 99.9% and a polyurethane (PU) tube is used for the gas distribution.

The central anode wires are biased with positive high voltage (HV) using a HV filter box at one end while the signal is collected from the other end after a capacitor. The output signal is fed to a charge-sensitive pre-amplifier (VV50-2 pre-amplifier manufactured by CDT, Heidelberg, Germany) having a gain of 2 mV/fC and a shaping time of 300 ns [7]. The output of the pre-amplifier is sent to a linear fan-in-fan-out (FIFO) module. One output of the linear FIFO is put in a timing single channel analyser (SCA), which is operated in integral mode and the lower level in the SCA is used as the threshold. A NIM-based scalar module is used to measure the counting rate of the detector. A multichannel analyser (MCA) is used to obtain the energy spectra with a ^{55}Fe X-ray source taking another output from the linear FIFO. A schematic of the set-up is shown in figure 1. A typical energy spectrum for ^{55}Fe in Ar/CO_2 80/20 mixture at 1550 V is shown in figure 2.

The gain of the straw tube detector is calculated in the following way. The 5.9 keV peak of the ^{55}Fe X-ray spectrum is fitted with a Gaussian function and from the mean of the fitted peak, the charge after avalanche multiplication (collected charge) is calculated using the gain of the pre-amplifier (PA gain in mV/fC) and the calibration factor (CF in mV/ch) of the MCA to convert the channel number in pulse height (in mV). The small effect of stray capacitances (due to cables, connectors, and so on) on the amplitude of the signal is neglected in the calculation. The expression for gain is given by the ratio of the collected charge and primary charge:

$$\text{Gain} = \frac{\text{Collected charge}}{\text{Primary charge}} = \frac{[(\text{Mean} \times \text{CF})/\text{PA gain}]}{[\text{No. of primary electrons} \times e]}, \quad (1)$$

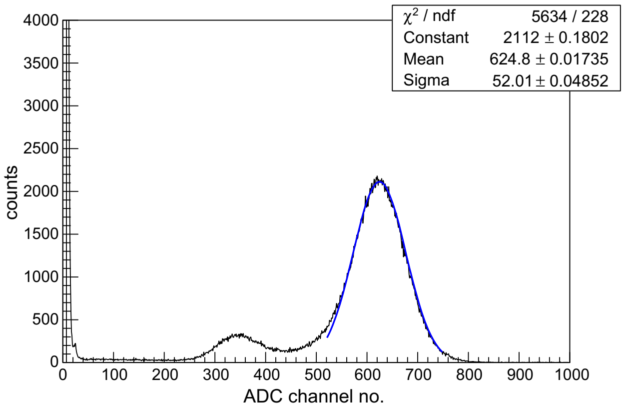

Figure 2. Typical energy spectrum for X-rays from ^{55}Fe source in Ar/CO_2 gas mixture in the 80/20 volume ratio at 1550 V. The main peak is fitted by a Gaussian function shown in blue line.

where e is the electronic charge in Coulomb. The average number of primary electrons produced in the gas is taken as 217 for Ar/CO_2 mixture in the 80/20 volumn ratio assuming full energy deposition of 5.9 keV X-ray in the gas volume and using the average energy required to produce an electron–ion pair. For X-rays in a Ar/CO_2 gas mixture, the primary number of electrons n is calculated using the formula:

$$n = E_X \left(\frac{\%\text{ of Ar}}{W_{Ar}} + \frac{\%\text{ of CO}_2}{W_{CO_2}} \right), \tag{2}$$

where E_X is the energy of the X-ray (for ^{55}Fe $E_X = 5.9$ keV), W_{Ar} and W_{CO_2} are the average energies required to produce an electron–ion pair in Ar and CO_2 gas respectively. W_{Ar} and W_{CO_2} are 26 eV and 33.2 eV respectively. For 80% Ar and 20% CO_2 gas

$$n = 5.9 \times 10^3 \left(\frac{0.8}{26} + \frac{0.2}{33.2} \right) \approx 217. \tag{3}$$

The energy resolution of the straw tube detector is defined as

$$\%\text{energy resolution} = \frac{\text{Sigma} \times 2.355}{\text{Mean}} \times 100\%, \tag{4}$$

where sigma and mean are obtained from the Gaussian fitting of the 5.9 keV peak of each ^{55}Fe X-ray spectrum. The gain of the straw tube is found to be 1.4×10^4 at 1550 V and uniform along the length of the detector.

In order to study the effect of prolonged irradiation of the detector, a collimated X-ray source (activity 3.7 GBq) is placed on top of the detector and a continuous monitoring of the energy spectra is carried out. The collimator is set in such a way that 4 mm length of the straw is irradiated with realistic particle rate in the detector of 40 kHz/mm. The spectra are stored automatically at regular intervals of 10 min. A data logger [21] made in-house is used to record ambient temperature and pressure online.

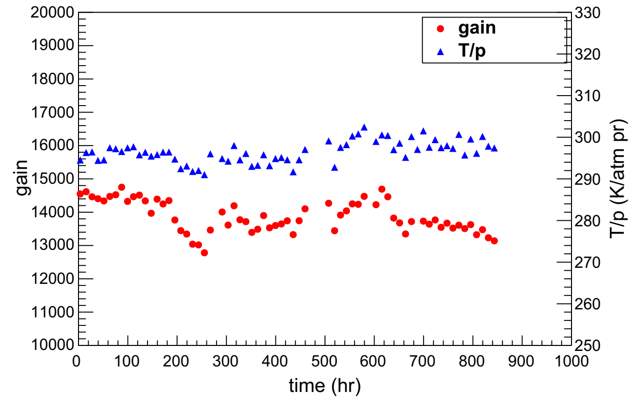

Figure 3. Gain and T/p as a function of time. The bias voltage of the straw tube detector is 1550 V. Error bars are smaller than the marker size.

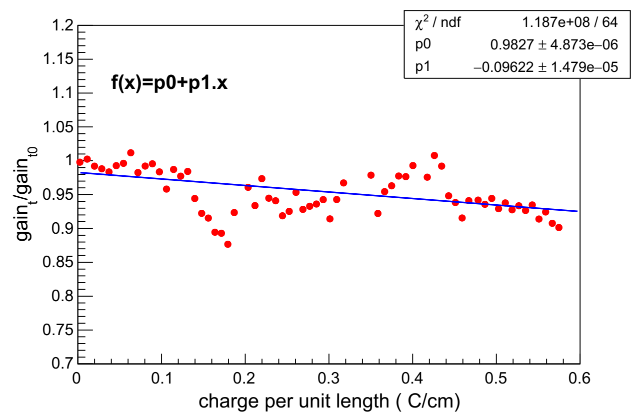

Figure 4. Ratio of instantaneous gain and initial gain (normalised gain) as a function of charge accumulated per unit length.

2.2 *Results*

The gain of the straw tube is measured at regular intervals as mentioned earlier. The gain as a function of time is shown in figure 3 along with the variation of the ratio of ambient temperature ($T = t + 273$ K) and pressure (p) with time. The average relative humidity during the measurement is found to be $\sim 55 \pm 5\%$. From figure 3 it can be seen that during a period of more than 800 h, the gain decreases from 15000 to 13000. This may be the effect of prolonged irradiation. The ageing rate is parametrised as a normalised gas gain loss:

$$R = -\frac{1}{G_0}\frac{dG}{dQ} \times 100\% \text{ per C/cm}, \tag{5}$$

where G_0 is the initial gas gain, dG is the loss of gas gain after collected charge dQ per unit length. To evaluate

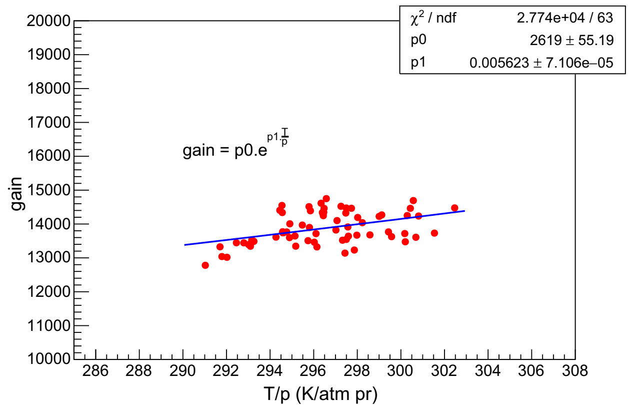

Figure 5. Correlation between gain and T/p. Error bars are smaller than the marker size.

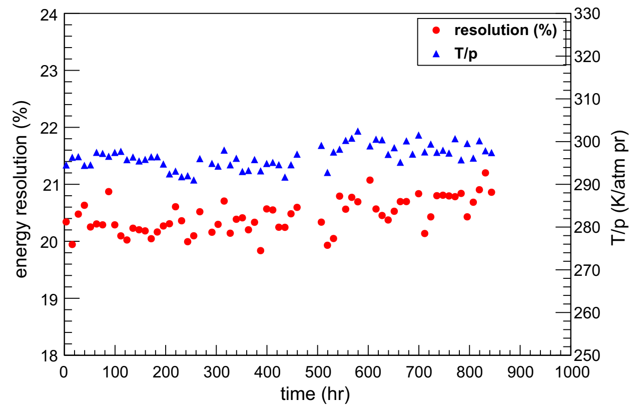

Figure 6. Energy resolution and T/p as a function of time. The bias voltage of the straw tube detector is 1550 V.

the ageing rate, we normalised the instantaneous gain (gain_t) by the initial value of the gain (gain_{t0}) and plotted it against charge accumulated per unit length of the straw tube detector as shown in figure 4. The accumulated charge over the straw tube is calculated using the relation

$$\frac{\mathrm{d}Q}{\mathrm{d}l} = \frac{r \times n \times e \times G \times \mathrm{d}t}{\mathrm{d}l}, \tag{6}$$

where r is the measured rate (in Hz) in a particular area of the detector, n is the number of primary electrons for a single X-ray photon, e is the electronic charge, G is the gain of the detector, $\mathrm{d}t$ is the time in second and $\mathrm{d}l$ is the irradiated length of the straw. In this case, the straw tube is continuously irradiated for more than 800 h leading to a charge accumulation of 0.6 C/cm. As shown in figure 4, the normalised gain is fitted by a first-order polynomial function. The slope $p1$ of this function corresponds to the ageing rate which is 9.6% per C/cm. However, this observation needs a confirmatory test to ensure that this is purely due to the irradiation and not due to other external effects. It can be seen from figure 3 that the variation of gain depends on variation in T/p. Although there is not much variation in T/p throughout the experiment, we still tried to find a correlation of gain with T/p which is shown in figure 5. It is seen from figure 5 that the points are scattered and so the χ^2/NDF of the fit is bad. Therefore, it can be said that in addition to T/p, other parameters also are responsible for the variation of gain.

It is known that ageing of gaseous detectors strongly depend on total accumulated charge [22]. Apart from that, the ageing rate is affected by macroscopic parameters such as high gas gain, radiation intensity and gas flow rate. In that direction, the next experiment is carried out with high radiation intensity and low gas flow rates to observe ageing rates for the straw tube in a practically lesser time.

Figure 6 shows the variation of energy resolution with time. In this experiment, it is observed that the energy resolution increases from an initial value of 20% to a final value of 21% at the end of the measurement.

3. Stability test of straws: Experiment II

The goal of the second experiment was to verify whether the degradation in the gain of the straw tube detector is purely due to high irradiation or not. To this end, gain and energy resolution measurements with two straws are carried out. The detectors are positioned adjacent to one another. The idea is to use one straw as a reference detector (marked as R) and the other one (marked as A) for the study of ageing effects due to a much higher amount of accumulated charge with respect to the reference detector. To study the performance, gain and energy resolution of both the straws are measured continuously and simultaneously at equal intervals of time.

3.1 *Experimental set-up*

An identical experimental set-up as mentioned in §2.1 is used to measure the gain and the energy resolution of both the straws. The detectors are connected to the same gas line such that any external factors affecting the performance of the straws cancel out when we take the ratio of any measured quantity of the two straws such as gain or energy resolution. The same ^{55}Fe X-ray source is used to irradiate both the straws. The radiation over straw R is purposely kept at low rates just to use it as a reference detector to monitor the gas gain continuously and compare at fixed time intervals with the gain of straw A. The counting rates in the straw tubes A and R, adjusted by using a perspex collimator, amount to 35 kHz/mm and 0.09 kHz/mm, respectively. The biasing voltages of the detectors A and R are kept at 1550 V and 1450 V respectively. The reference detector R is operated at low gains ∼6000 and lower radiation, whereas the straw tube A is operated at high gains ∼13000. This is done to achieve a higher amount of accumulated charge on straw A in comparatively lesser amount of time and to minimise the amount of charge accumulation on R. So the expectation is that the ratio of the gains of the two straws normalises all the effects due to external factors such as ambient temperature, pressure, relative humidity and gas flow rate. The energy spectra from both detectors are simultaneously stored at regular intervals of time through two separate MCA modules. The detector characteristics such as gain and energy resolution are extracted from the ^{55}Fe X-ray spectra using the same method as discussed in §2.1.

3.2 *Results*

The variations over time of the gain and the energy resolution, as well as the ones of T/p, are plotted in figures 7 and 10 respectively. As one can see in figure 7, a gradual decrease in the gain of straw A with time is observed with respect to the straw R. After the first 100 h of measurement, a decrease of 11% in absolute gain is observed at a gas flow rate of 0.02 l/h. Then the gas flow rate is increased up to ∼0.13 l/h to check if the gain restores to its original value or not. In figure 8, the normalised gain of straw A, viz. the instantaneous gain (gain) over the initial gain (gain_{t0} = 13000) and T/p are plotted as a function of time from the time instant in which the gas flow rate is increased. The time-varying normalised gain is fitted by the function

$$f(t) = p_0(1 - p_1 e^{-t/p_2}), \tag{7}$$

where p_0, p_1 are constants, t is the time in h and p_2 is the time constant of the function. From this fit, one can see that the gain restores to 96% of its initial value in 3.62 h of continuous gas flow at a rate of 0.13 l/h. T/p was constant throughout this time as can be seen from figure 8 and so the gain was not needed to be normalised by the T/p effect. After a few hours, the gas flow rate is again reset to ∼0.03 l/h and the measurement is continued. The high voltage is kept ON and the source is not removed from its original position. We can see that the gain of straw A continuously decreases from 13000 to 10000, viz. 77% of the initial value. If we again increase the gas flow rate to a value of 0.8 l/h after ∼600 h, we can see an increase in the normalised gain as shown in figure 9. The normalised gain is fitted with the same function as in eq. (7). From the fit it is found that the gain increases from about 80% to 87% of its initial value in a time duration of 3.15 h, but the gain did not restore to its original value even after flowing the gas at

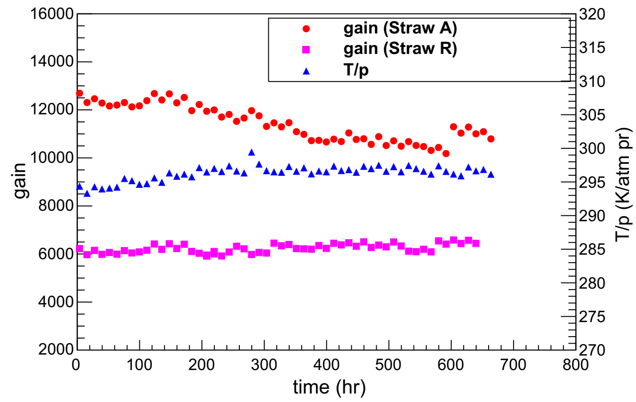

Figure 7. Gain and T/p as a function of time of the straws A and R biased at 1550 V and 1450 V respectively.

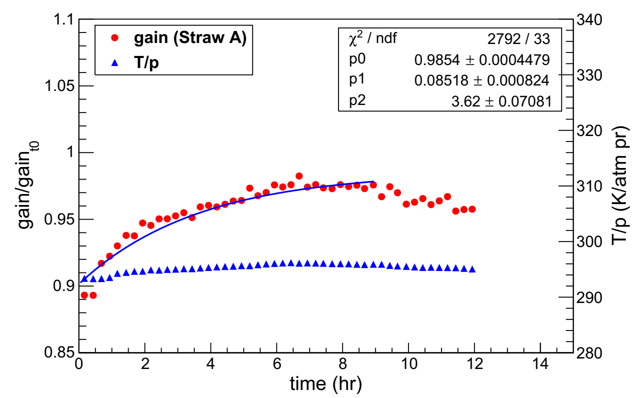

Figure 8. Normalised gain and T/p as a function of time (here $t = 0$ h means $t = 100$ h of the actual measurement).

a high rate for more than 10 h. The effect of changing the gas flow rate is also observed for straw R, but this effect is more prominent for straw A. There is an overall slight increase in the gain of straw R which is due to the increase in T/p with time. For the same reason, there is a decrease in the energy resolution value of straw R from 25% to 23% as shown in figure 10. However, it can be seen from figure 10 that the energy resolution of straw A increases from 29% to 34% (which is 17% increment). It should also be noted here that the energy resolution of straw A does not improve by increasing the gas flow rate. This may indicate the performance degradation of the straw at high radiation environment.

To understand the effect of prolonged irradiation on the degradation of the gain of the straw tube detector, the ratio of the gains of the straws is taken and normalised by the ratio of the initial gains. As changes in temperature, pressure, relative humidity and gas flow rate will affect both the straws similarly, the ratio of the two gains can properly express the long term effect of the radiation only on the straw under ageing study.

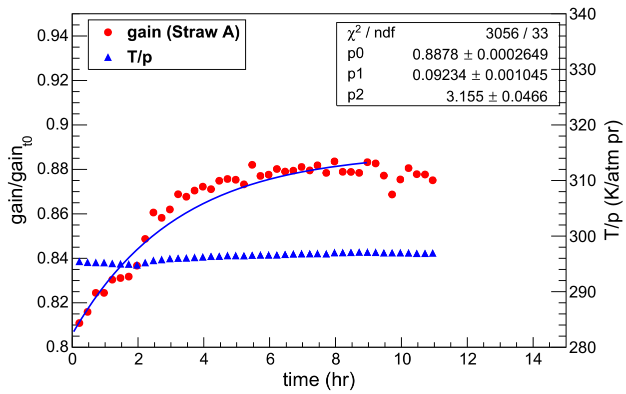

Figure 9. Normalised gain and T/p as a function of time (here $t = 0$ h means $t = 600$ h of the actual measurement).

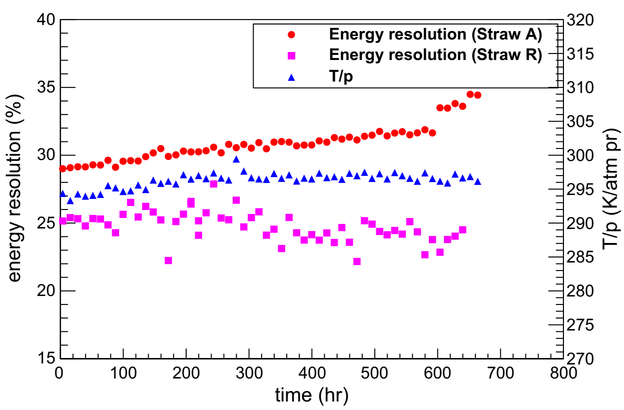

Figure 10. Energy resolution and T/p as a function of time for both the straws. The bias voltage of straws A and R are 1550 V and 1450 V respectively.

The normalised ratio is calculated as

$$\text{Ratio}_{\text{normalised}} = \frac{\frac{\text{Gain}_{\text{straw A}}(t)}{\text{Gain}_{\text{straw R}}(t)}}{\frac{\text{Gain}_{\text{straw A}}(0)}{\text{Gain}_{\text{straw R}}(0)}}, \tag{8}$$

where $\text{Gain}_{\text{straw A}}(0)$ and $\text{Gain}_{\text{straw R}}(0)$ are the initial gains in straw A and straw R respectively. The normalised ratio is fitted by a first-order polynomial function as shown in figure 11. Here also a negative slope of −1.15 clearly may indicate a degradation of the gain in straw A because of the high rate of radiation.

4. Measurement of time resolution

Since straw tubes may be used for tracking in several upcoming high-energy physics experiments, it is also important to study their timing properties. The time resolution of a gaseous detector depends on the gas mixture and the applied voltage or electric field of the detector. It is actually the measure of the fluctuation in the time

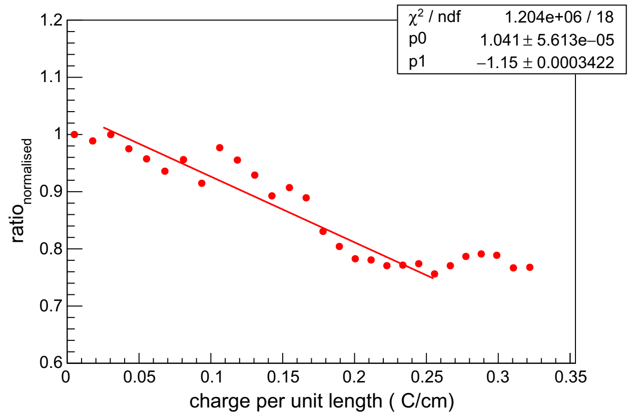

Figure 11. Normalised ratio of gains of straws A and R as a function of charge accumulated per unit length of straw A.

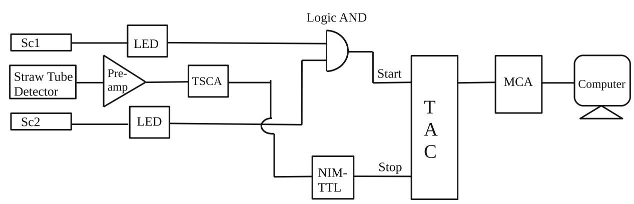

Figure 12. Schematic of the electronics set-up for time resolution measurement of the straw tube detector.

required for the electrons to drift along the electric field lines towards the anode wire. For wire chambers, the time resolution is usually of the order of a few ns.

The time resolution of the straw tube detector is measured with a premixed Ar/CO_2 gas in the 70/30 volume ratio. Two plastic scintillator detectors are used to generate 2-fold trigger signals with cosmic rays. The photomultipliers coupled to the scintillators are biased with a voltage of +1550 V. The signals from the scintillators are fed to a leading edge discriminator (LED) with a threshold of −50 mV. The 2-fold coincidence signal is used as the 'start' signal for the time to amplitude convertor (TAC). The TAC is set at 10 μs full scale range. The straw signal after passing through the pre-amplifier is fed to a timing single channel analyser (TSCA) which gives a TTL logic output. This TTL signal is converted to NIM signal using TTL-NIM adapter module and the NIM output signal is used as the 'stop' signal for TAC.

The time difference between the 'start' and the 'stop' signal gets converted to amplitude in the TAC and the output is fed to the MCA for obtaining a timing spectrum. The schematic electronics set-up for timing measurement is shown in figure 12. Figure 13 shows a typical time spectrum at 1750 V which is fitted with a Gaussian function. The mean of the distribution gives the time difference of the trigger and the straw tube signal. The sigma of this distribution is the effective/combined time resolution of the straw tube

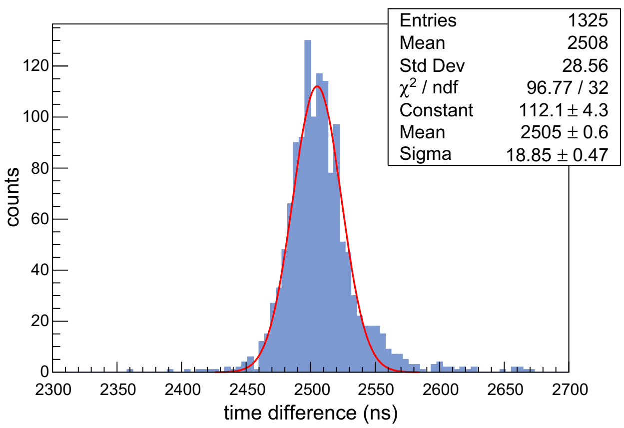

Figure 13. Time spectrum of the straw tube detector at 1750 V with Ar/CO_2 in the 70/30 volume ratio.

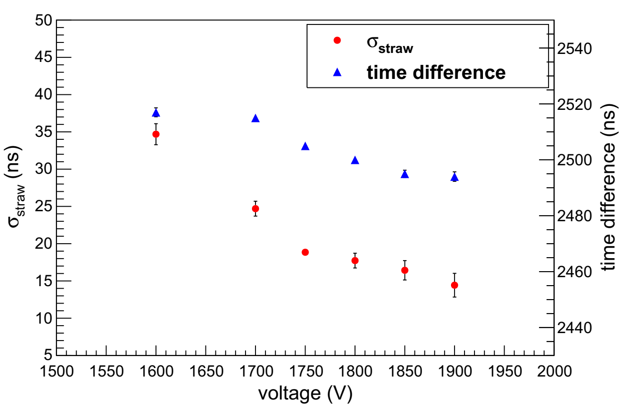

Figure 14. Time resolution (σ_{straw}) of the straw tube and time difference as a function of voltage.

and trigger detectors. The time resolution of the straw tube is extracted from the relation:

$$\sigma_{\text{eff}}^2 = \sigma_{\text{straw}}^2 + \sigma_1^2 + \sigma_2^2, \quad (9)$$

where σ_{eff}^2 is the effective time resolution of the combined detector set-up, σ_1 and σ_2 are the time resolution of the trigger scintillators Sc1 and Sc2 respectively. The time resolutions of the trigger scintillators are independently measured and the values of σ_1 and σ_2 are found out to be (0.38 ± 0.01) ns and (0.56 ± 0.01) ns respectively. The time resolution of the straw tube is measured for different voltage settings. The variation of the time resolution (σ_{straw}) of the straw tube and the time difference between the start and stop signal, as a function of voltage is shown in figure 14. As one can see, the time resolution decreases with the increase in voltage. The best achieved time resolution for the straw tube is found to be (14.4 ± 1.6) ns at 1900 V.

5. Summary and outlooks

From the first experiment, we concluded that the gain reduction by 9.6% per C/cm after a total charge accumulation of 0.6 C/cm wire on the straw might be due to continuous and high radiation. The observed ageing rate is small but not negligible. In the second experiment, we confirmed that the occurred ageing was due to the high radiation intensity and also have drawn a conclusion on the dependence of this ageing rate on the gas flow rate. It takes about 3 h for the gain of a continuously irradiated straw to partially restore after increasing the gas flow rate. The transient nature of ageing is proven by the fact that the gain tends to restore as one increases the gas flow rate. After a very long exposure to radiation, one can observe that the gain degrades continuously and it did not restore. The gain did not restore to its initial value even after we allow the gas to flow at a very high rate for a long time. This means that there is some ageing due to long term operation of the straw tube detectors which is not observed in the case of accelerated ageing measurements reported in refs [9,10]. Therefore, this needs further detailed investigation. For Ar/CO_2 gas mixture operated at high rates over long time periods, a gradual decomposition of CO_2 can occur and the resulting pure carbon can be deposited at the cathode [23]. An important observation in both the experiments is that the gain degradation of the straw tube detector starts immediately from the time of operation under high intensity radiation. The degradation is slow and gradual. The difference between the first and the second experiments was that, the latter was conducted at relatively lower gas flow rates. Another conclusion that can be drawn from our experiment is that the straw tubes can be safely operated at low radiation intensities ($\sim$0.1 kHz/mm) and at low gas flow rates ($\sim$0.02 l/h) (as no ageing is observed in straw R of experiment 2) and at high radiation intensities ($\sim$40 kHz/mm) at high gas flow rates (>3 l/h) (as slight gain reduction is observed even after 800 h of operation of the straws in experiment 1).

On the other hand, it is well known that the Ar/CO_2 mixture is very robust and does not produce deposits on the wire. So an alternative reason of gain degradation in both experiments might be the use of a gas mixture of low purity (99.9%) and of a polyurethane tube. There might be diffusion of water vapour through the walls of PU tube. Water vapour does affect the gain, as it modifies the Townsend coefficients slightly, but this effect, if due to leakage, should plateau at some point, and in addition it should not affect the energy resolution. A residual, true degradation is observed, which can only be due to contaminants in the gas, e.g. from material outgassing. To check this in the near future, the measurements will be repeated with gas having higher purity and using stainless tube for the gas distribution. A systematic study of the ageing rates at different radiation intensities, gas gains and gas flow rates will also be carried out in future to fix the operating conditions of the straws in the real experiment.

The time resolution of the straw tube detector is also measured with cosmic rays. The best achieved time resolution is found to be 14.4±1.6 ns at a biasing voltage of 1900 V.

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References

[1] https://atlas.cern/discover/detector/inner-detector
[2] https://home.cern/news/news/experiments/new-straw-trackers-na62
[3] Y Van Haarlem *et al.*, *The GlueX central drift chamber: Design and performance*, *Nucl. Instr. and Meth. in Phys. A* **622** (2019) 142.
[4] http://www.fair-center.eu/for-users/experiments/cbm.html
[5] http://www.fair-center.eu/
[6] V Peshekhonov *et al*, *Phys. Particles Nucl. Lett.* **9**(**2**), 172 (2012)
[7] CDT CASCADE Detector Technologies GmbH, Hans-Bunte-Str. 8-10, 69123 Heidelberg, Germany. www.n-cdt.com
[8] S Roy, N Nandi, R P Adak, S Biswas, S Das, S K Ghosh, S K Prasad and S Raha, *Nucl. Instrum. Methods Phys. Res. A* **936**, 488 (2019)
[9] V G Bondarenko, B A Dolgoshein, V A Grigoriev, A A Kruglov and I S Markina, *Nucl. Phys. B* **44**, 577 (1995)
[10] M Capeans, C Garabatos, R Heuer, R Mackenzie, T Meyer, F Sauli and K Silander, *Ageing properties of straw proportional tubes with* $Xe/CF_4/CO_2$ *gas mixture*, CERN-PPE/93- 136 (1993)
[11] M Capeans, *IEEE Trans. Nucl. Sci*. **51**(**3**), 994 (2004)
[12] E Abat *et al*, *JINST* **3**, P02013 (2008)
[13] T Akesson *et al*, *Nucl. Instrum. Methods Phys. Res. A* **361**, 440 (1995)
[14] J A Kadyk, J Va'vra and J Wise, *Nucl. Instrum. Methods Phys. Res. A* **300**, 511 (1991)
[15] J Va'vra, *Nucl. Instrum. Methods Phys. Res. A* **252**, 547 (1986)
[16] A Dwurazny, Z Hajduk and M Turala, Ageing effects in gaseous detectors and search for remedies, *Proceedings of the Workshop on Radiation Damage to Wire Chambers* **LBL-21170** (1986) p. 113
[17] E Conti and F Gasparini, *Nucl. Instrum. Methods Phys. Res. A* **465**, 472 (2001)
[18] V Blinov, Influence of materials and sense wire surface quality on aging with DME and other gases, *Proceedings of the International Workshop on Aging Phenomena* (DESY, Hamburg, Oct. 2–5, 2001)
[19] T Kowalski, A study of aging effect in gas monitoring proportional counters of the BAC calorimeter of the ZEUS experiment, *Proceedings of the International Workshop on Aging Phenomena* (DESY, Hamburg, Oct. 2–5, 2001)
[20] M C Altunbas, K Dehmelt, S Kappler, B Ketzer, L Ropelewski, F Sauli and F Simon, *Nucl. Instrum. Methods Phys. Res. A* **515**, 249 (2003)
[21] S Sahu, D Nag, S Rudra, S Swain, S Biswas, S Das and P K Sahu, *JINST* **12**, C05006 (2017)
[22] J A Kadyk, *Nucl. Instrum. Methods in Phys. Res. A* **300**, 436 (1991)
[23] V Pashhoff, *Studies on ageing and reanimation of drift tubes for the ATLAS muon spectrometer*, Dissertation (University Freiburg, 1999) CERN-THESIS-99-083