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SOME CHARACTERISTICS OF THE LONG STRAW DRIFT TUBES

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1. INTRODUCTION

Wire gas chambers of various types are widely used for tracking in particle physics. Over the last few years, the straw tubes as elements of tracking chambers have evoked a big interest of physicists. Advantages of the straw chambers are :

- the cylindrical geometry gives the optimal timing of the first arriving electrons ;
- the tube configuration provides good protection against crosstalk between neighboring channels, if the straw are terminated with its characteristic impedance /1/. The 0.5 % value of crosstalk is feasible /2/;
- chamber construction is simple.

In this article, we describe our investigation of different straws which can be used as elements of the COMPASS Large Area Tracker /3/, for example.

2. CONSTRUCTION

The straws consist of two layers of polyimide film cut in 8 mm or 12.5 mm strips and are wound spirally at an angle on a mandrel of the permanent diameter ranging from 4 mm to 15 mm. We have produced 2 types of the straws. The type A straws are similar to the ATLAS TRT straws /4/. The inner and external surface of the straws contains a conducting layer of 0.20 μm Al under 7 μm Carbon-loaded Kapton layer. The glued surfaces of the organizing straw strips contain a thermoplastic polyurethane layer of about 5 μm. The wall thickness of these straws is 68 μm, and the straws have conducting layers on both sides.

The B type straws have been assembled using the same inner Kapton strip and the external 40 μm thick Kapton strip without conducting layers. The wall thickness of the B straws is about 85 μm, conductive layers placed on inner surface only.

For testing we have used the 3.0 m long straws. The assembled straws can have some disadvantages :

- the sense wire may have a wrong position and some gravitational sag;

- straw cathode may be neither perfectly cylindrical nor perfectly straight.

The deflection (d) of the wire midpoint can be estimated from the following expression /5/:

$$d = L^2 F / 8 T, \qquad (1)$$

where L is the wire length, T is the tension of the wire and F is the electrostatic force per unit length :

$$F = \frac{2\pi\varepsilon_0 V^2 \delta}{R^2 (\ln (R/r))^2}, \qquad (2)$$

The sense wire potential is V, δ is the wire offset, R is the radius of the straw, and r is the radius of the sense wire. To reach a good spatial resolution of the straw with 50 g wire tension, we have used the wire supports situated 1m away from each other or closer . As wire supports we used the plastic elements with the central hole of 80 μm diameter . The

thickness of the walls is 0.3 mm. We have checked the possibility to organize an insensitive zone of the straw by installing the mylar tube into straw. The scheme of the straw is shown in Fig. 1.

3. PERFORMANCE OF THE STRAWS

The tests performed with the straws are described. We have studied the gas gain, resolution, and the attenuation length. To eliminate the signal reflection, one end of the 30 μm sense wire of the long straw was terminated to ground through a 220 pF capacitor and about 300 Ohm resistor in series. We have studied the insensitive zones close to the wire supports and the special insensitive zones to permit the particles beam to pass through the straws without getting registered .

The γ-source ^{55}Fe and β-source ^{106}Ru were used for the investigation. The high voltage put on the anode wire, the current amplifiers were switched on to the wire through the 220 pF capacitor. The impedance of one was equal 300 Ohm.

The gas for the straw investigation was the mixture Ar - CH_4 (80-20).

The straw gas gain is determined by the electric field value close to the surface of the anode wire. The potential difference (V) ratio of between the anode and cathode of different straws operating with equal gas gain is given by expression:

$$\frac{V_i}{V_j} = \frac{\ln (R_i / r_i)}{\ln (R_j / r_j)}. \qquad (3)$$

Fig. 2 shows the peak of the anode signal amplitudes depending on V for the straws of 4, 10, and 15 mm diameter. Measurements were made by the ^{55}Fe source. As one can see, the expression 2 permits to estimate V for another type of the straw with about a few percents accuracy.

The attenuation length (λ) was measured using the ^{55}Fe source.

Fig. 3 shows the ratio of the pulse peaks for a different position of the source along the straw in the range of 2 m. The diameter of the straws is 10 mm. Prolongation of this curve makes the attenuation length be equal to 280 cm. However, when measuring the amplitude pulse dependence for 3.0 m long straw (fig. 4), we actually have a smaller pulse attenuation .

The attenuation properties of the straws depend on the cathode and anode resistance. The resistance of the gold plated tungsten wire of 30 mkm diameter is 79 Ohm/m. The thickness of the gold coating of the wire is about 0.25 μm . The resistance of the straw cathode depends on the resistance and width of the polyimide film strips (δ_{str}) and can be estimated by the following expression:

$$R_{cathode} = k_i \frac{R \, R_{coat} \, L}{\delta_{str}^{2}}, \qquad (4)$$

where L is the length of the straw, R_{coat} is the resistance per square of the film coating . The coefficient k_i is equal to 2.6 for the used strips with δ_{str} *of* 12.5 mm width and 4.2 for the δ_{str} *of* 8 mm width, respectively. The resistance of some straws is given in Table 1

Table 1. Cathode resistance of the straw.

Ø straw, (mm)	δ_{str}, (mm)	R_{str}, (Ohm/mm^2)	R_{straw}, (measuring) (Ohm/m)
10	8	3.1	1016
10	8	2.4	773
10	12.5	1.6	133
6	12.5	1.6	81

The losses of the pulse amplitude after transmission along the anode wire depend on the rise time of the pulse because of the skin effect which is inversely proportional to the square root of the frequency. The typical skin depth at the frequency of 100 MHz and 300 MHz is about 12.7 μm and 7.3 μm for our wire, respectively. The frequency properties of the ^{55}Fe pulses is about 300 MHz, when the frequency properties of the pulses from charged particles is less than 100 MHz. So, using the ^{55}Fe source, we increase the resistive loss by nearly 20% over D.C. value /6/.

The article /4/ shows that attenuation properties of the A type straws with the additional Carbon-fibres placed along the straws on the external surface have been improved by the factor of 1.5 ÷ 2. We didn't check this result . However, we compared the attenuation properties of the A and B type straws with 10 mm diameter. Fig. 4 shows the pulse amplitude dependence on the position of the ^{55}Fe source along the straws. The solid curve represents the straws without termination the straws far end. The dashed curve represents the case of the straws far end termination. As one can see the *A* and *B* type straws are rather similar.

We didn't notice any difference of the signal shapes for these straw types. However, using of the straw without termination of the far end entails a greater difference of the pulse rise time for different parts of the straw.

Using the expression to estimate the straw characteristic impedance /4/, we find:

$$Z_0 = 60\, ln\ (R/r), \qquad (5)$$

To compare the *A* and *B* type straws, we terminated them by 230 Ohm resistors.

To organize the insensitive zone for the beam particles, we installed the mylar tube in center of the straw. Radiation length of the tube was 1.4 x 10^{-4} X_0. The thickness of the mylar was 20 μm. Using the γ– and β–sources, we studied the efficiency along of the straw for different ratios of the mylar tube diameter to the straw diameter (from 0.3 to 0.7).

Fig. 5 shows the dependence of the signal amplitude on the position of the ^{55}Fe source along the straw. Fig. 6 shows the efficiency of the β-particles registration for the sensitive and insensitive zones, depending on a straw anode high-voltage. So, the installation of the mylar tube into the straw removes the straw sensibility absolutely.

The installation of the wire supports (spacers) into the straw entails the creation of an insensitive area of the straw. Fig. 7 shows this case for the 10 mm straw. The solid curve is the count curve of the γ-quantum registration vs the displacement of the source from the spacer center. The dashed curve shows the amplitude of these signals. To decrease the spacer influence on the straw sensibility, we should optimize the size of the spacer. The insensitive zone near the spacer can be decreased to the

value that would be equal to the straw radius (about 5 mm in our case) or to 0.5% of the straw length.

4. CONCLUSION

The studying of the straw tubes which we can produce with the diameter ranging from 4 to 15 mm has shown their good quality and a possibility to use them for large area straw chambers. It's possible to use both the A type straws and the B type straws for the large chambers. We believe that the design and construction concepts of the large area straw chambers are more suitable for the large area wire trackers.

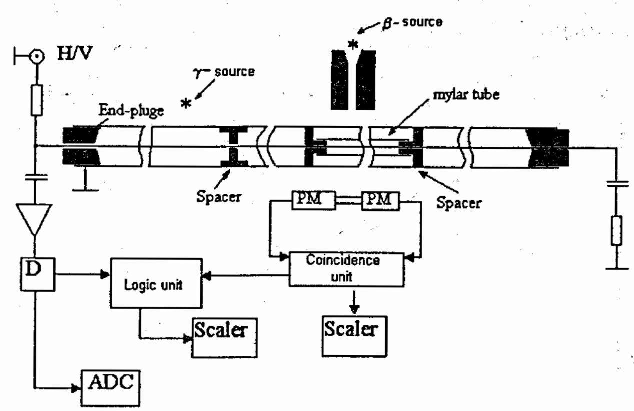

Fig. 1. Schematic representation of the investigated straw.

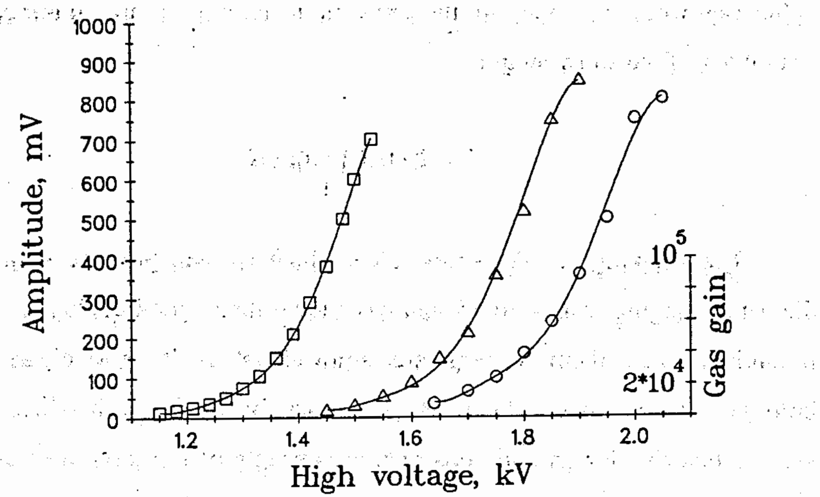

Fig. 2. Gas gain and amplitude of the anode signals depending on high voltage.

( ) - Diameter of the straws is 4 mm,

(Δ) - diameter is 10 mm,

(o) - diameter is 15 mm.

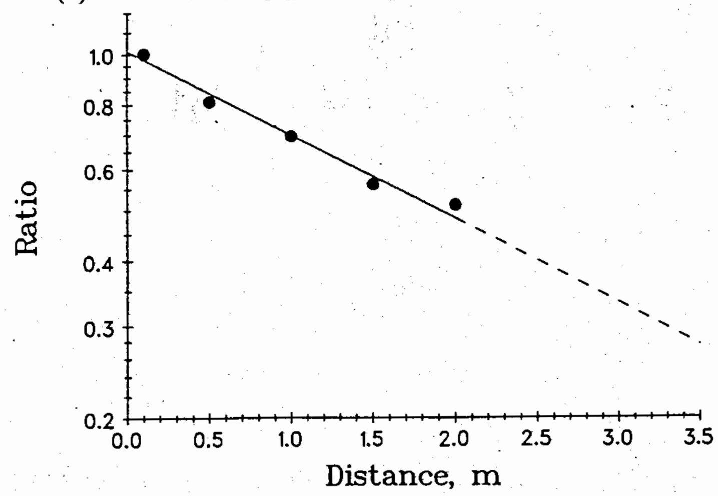

Fig. 3 The attenuation length is obtained from the curve showing the ratio of the amplitude. Width of the strips is 8 mm, R_{str} is 3.1 Ohm / mm^2.

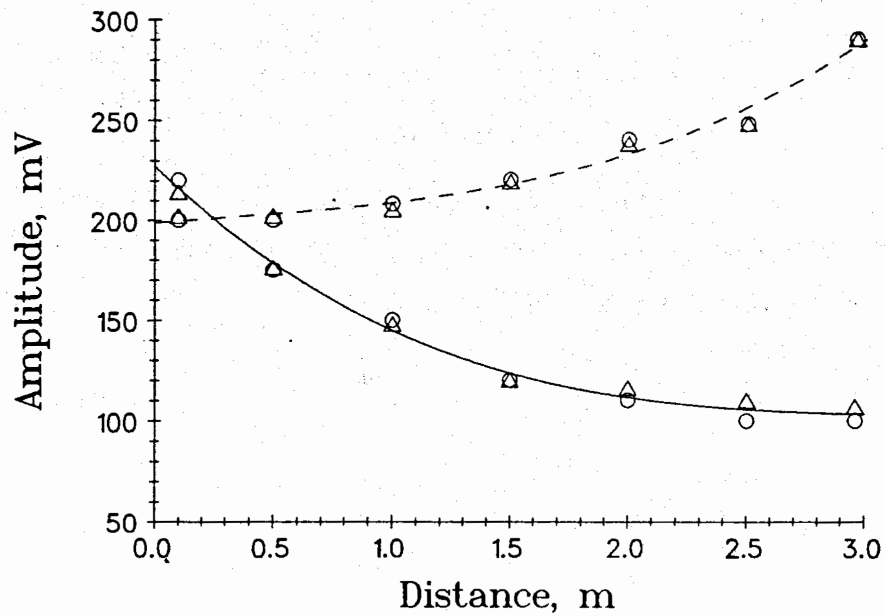

Fig. 4 Ratio of anode amplitudes vs the position of the ^{55}Fe source along the straw. Solid curves represent the terminated straws (R = 230 Ohm), dashed curves represent the non terminated straws (R = ∞). Width of the strips is 8 mm, R_{str} is 3.1 Ohm/ mm^2.

(A) - A type of the straw,

(O) - B type of the straw.

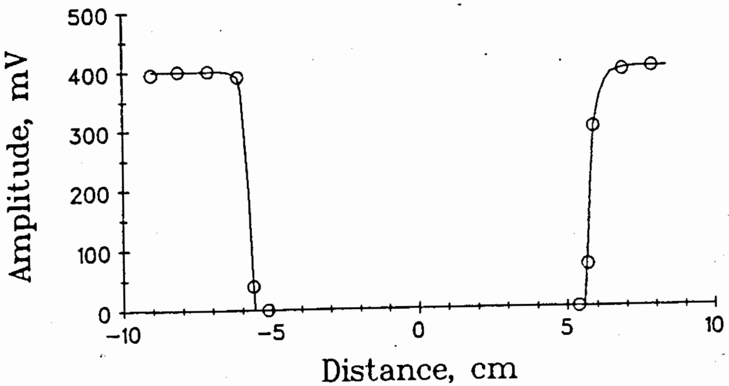

Fig. 5 Amplitude of the pulses vs the position of the ^{55}Fe along the straw. The straw with the diameter of 10 mm contains the inner mylar tube with the length of nearly 10 cm.

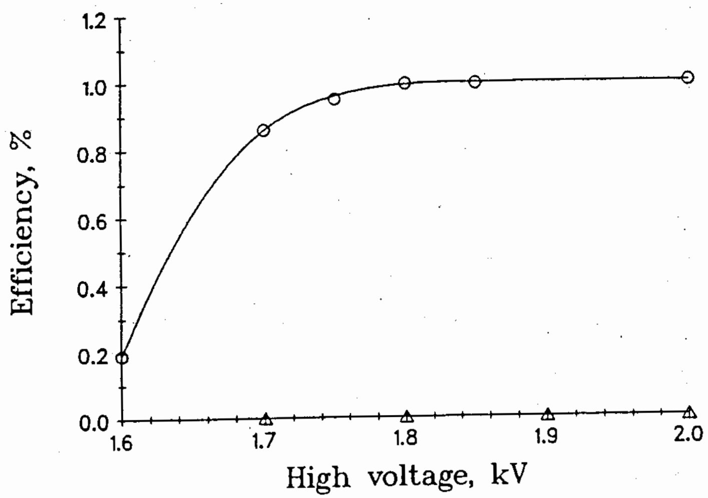

Fig. 6 Efficiency of the β - particles registration by the straw with the inner mylar tube.

(O) - the ^{106}Ru source placed into the sensitive zone of the straw,

(Δ) - the source placed into the insensitive zone.

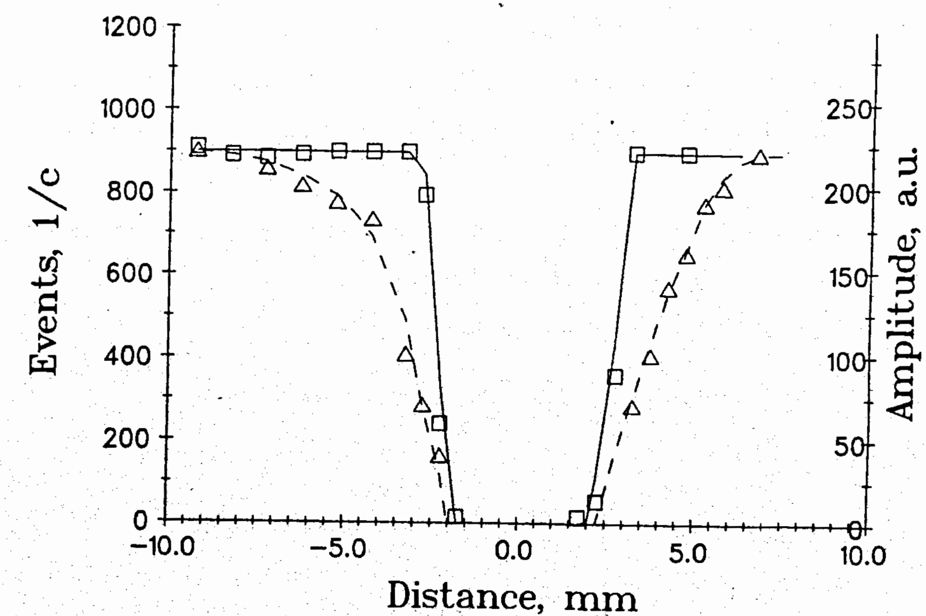

Fig. 7 Count curve (solid curve) dependence on the displacement of the source position from the center of the spacer installed in the straw with the diameter of 10 mm. The ^{55}Fe source was collimated. The width of the collimator was about 3 mm.

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Бычков В.Н. и др. E13-98-209
Некоторые характеристики тонкостенных дрейфовых трубок большой длины

Показана конструкция и результаты испытаний длинных тонкостенных дрейфовых трубок (строу) различного типа. Диаметр трубок достигал 15 мм, а длина 3 м. Резистивность катода этих строу имеет величину около 100 Ом/м, что обеспечивает достаточно небольшое ослабление сигналов по их длине. Установка спейсеров (поддержек анодных проволок) приводит к уменьшению эффективной длины строу не менее 0,5 % на метр.

Работа выполнена в Лаборатории сверхвысоких энергий ОИЯИ.

Сообщение Объединенного института ядерных исследований. Дубна, 1998

Bytchkov V.N. et al. E13-98-209
Some Characteristics of the Long Straw Drift Tubes

This article represents the construction and testing of the long straw drift tubes of different types. The diameter and the length of each straw were equal to 15 mm and 3 m respectively. The cathode resistance of these straws has a small value, i.e. about 100 Ohm/m. Thus, they do not have a large attenuation length. Installation of the spacers reduces the effective straw length by 0.5 % per meter, at least.

The investigation has been performed at the Laboratory of Particle Physics, JINR.

Communication of the Joint Institute for Nuclear Research. Dubna, 1998