GEM TN-92-167

Two Methods to Estimate the Position Resolution for Straw Chambers with Strip Readout

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July 1, 1992

Abstract:

The chambers with cathode readout are a good alternative to the drift chambers of muon detector systems for the future colliders SSC or LHC, due to their high position resolution. The straw chambers with strip readout possess a big advantage over, for example, honeycomb strip chambers: if one chamber is damaged the other chambers continue working due to the external strips. While processing the experimental date we have used only induced signals on three significant strips; for big detectors, it would avoid the storage of a great amount of information per event. The position resolution computing was done with the centroid and charge-ratio methods. In this article we present both methods in connection with the straw chamber particular case.

25 коп.

Редактор Э.В.Ивашкевич. Макет Т.Е.Попеко.
Набор Е.Н.Водоватовой.
Подписано в печать 1.07.92.
Формат 60x90/16. Офсетная печать. Уч.-изд.листов 0,83.
Тираж 450. Заказ 45449.
Издательский отдел Объединенного института ядерных исследований.
Дубна Московской области.

ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ
ДУБНА

E1-92-206

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TWO METHODS TO ESTIMATE THE POSITION RESOLUTION FOR STRAW CHAMBERS WITH STRIP READOUT

Submitted to "Nuclear Instruments and Methods"

1992

1. INTRODUCTION

The chambers with cathode readout are a good alternative to the drift chambers of muon detector systems for the future colliders SSC or LHC, due to their high position resolution. The straw chambers with strip readout possess a big advantage over, for example, honeycomb strip chambers: if one chamber is damaged the other chambers continue working due to the external strips.

While processing the experimental data we have used only induced signals on three significant strips; for big detectors, it would avoid the storage of a great amount of information per event. The position resolution computing was done with the centroid and charge-ratio methods. In this article we present both methods in connection with the straw chamber particular case.

2. EXPERIMENTAL SET-UP

A vaste description of our experimental set-up is given in [1]. The straw chambers 10 mm in diameter were constructed of mylar with a 0.1 μm aluminium film, partially covering the circumference of the tubes. The chosen window had a 36° open angle which was the maximum allowed angle for good behaviour of the chamber. The external cuprum strips were laid on a fiber glass support and were normal to the anode wires. The evaluation of the position resolution was done for 3, 4 and 5 mm strip pitches. Here we present the best results, achieved for the strip pitch of 5 mm; this is in agreement with those reported in [2].

The signals from the three adjacent strips have been fed to CAMAC ADCs (ORTEC) after passing through charge preamplifiers and amplifiers. The information was stored on tape for subsequent off-line processing.

In our testings we have used a gas mixture Ar/CH_4 (50/50) at 1 atm.

The chambers were tested with narrow X-ray beam (8 KeV) with < 100 μm at FWHM, passing through the chamber normal to the anode wire.

3. PROCESSING METHOD

In processing, only those events were taken into account when the induced signal on the middle strip was equal or greater than the corresponding ones from the adjacent strips. This condition was not fulfilled for all the events when the strips were uniformly irradiated, or when the narrow X-ray beam was between two strips.

For position resolution we have used two algorithms: the centroid method [3] and charge-ratio method, improved by H.van der Graff et al. [4].

3.1. Centroid Method

The avalanche position in the centroid method is found fitting a Gaussian curve to the charge induced on the three more significant strips.

$$x = w \frac{\ln Q_L - \ln Q_R}{2(\ln Q_R - 2\ln Q_M + \ln Q_L)}, \qquad (1)$$

where:

w is the strip pitch

Q_M, Q_L and Q_R are the charges induced on the middle, left and right strip; $Q_M \geq Q_R$ (Q_L).

As is shown in [3,5,6], in this method and in other centroid methods (like: center of gravity, Lorentzian curve fitting to the charges, parabolic curve fitting) the computed position of the avalanche, x_c, differs from the real one, x_a. This can be clearly seen in the case of uniform irradiation of the strips with a 5 mm strip pitch (fig.1a).

For an accurate estimation of the position resolution, we corrected this shift using an empirical transformation which maps the estimated centroid x_c onto the avalanche position x_a [6]. This transformation was obtained in the following way: for the uniform irradiation of the strips, $dN/dx = 1/k$, the experimental distribution, (fig.1a), is

$$\frac{dN}{dx_c} = \frac{dN}{dx_a} \cdot \frac{dx_a}{dx_c}. \qquad (2)$$

Taking into account that at the edges of the strips $x_c = x_a = \pm w/2$ and from (2) one can get:

$$x_a = k \int_{-w/2}^{x_c} (dN/dx_c)\, dx_c - w/2 \qquad (3)$$

with

$$k = \frac{w}{\int_{-w/2}^{w/2} (dN/dx_c)\, dx_c}. \qquad (4)$$

This transformation was computed for the three kinds of strips used in our experiment and for every signal/noise ratio. In our measurements no significant dependence of this transformation on the signal/noise ratio could be observed.

Figure 2 shows the relation between x_a and x_c, obtained by fitting the results from (3) with a polinomial of degree six for the signal/noise ratio of 50 and 5 mm strip pitch. Figure 1b gives the distribution dN/dx_c after correction.

Figure 3 gives the dependence of the position resolution on the signal/noise ratio after correction for the 5 mm strip pitch.

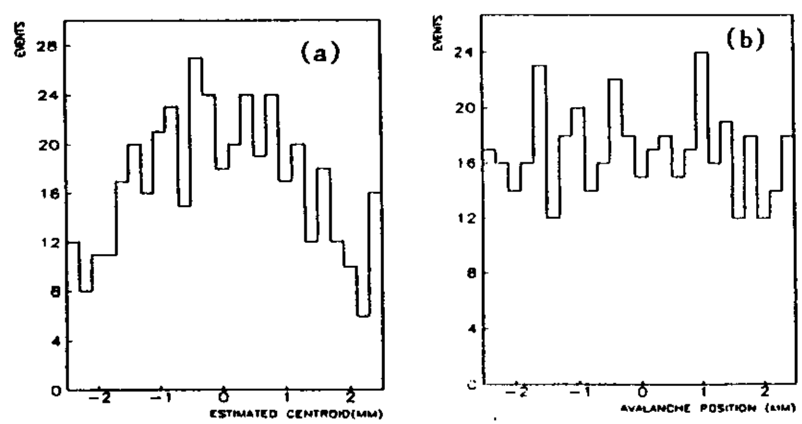

Fig.1. Events distribution for uniform irradiation of the strips before (a) and after (b) empirical transformation.

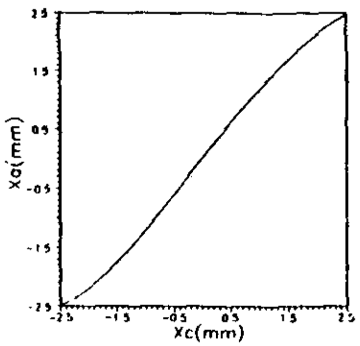

Fig.2. Relation between estimated centroid and avalanche position.

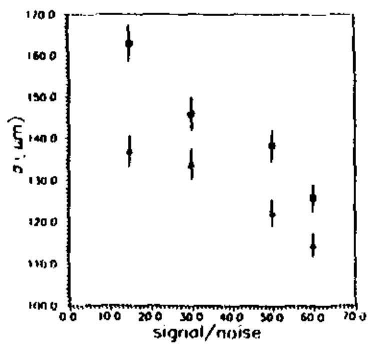

Fig.3. Position resolution dependence on the signal/noise ratio for □ centroid method and Δ charge ratio method at $x_a \simeq 2$ mm.

For strips with a 3 mm pitch, the maximum signal/noise ratio was about 20 ÷ 25 and $\sigma \simeq 250$ μm.

3.2. Charge-Ratio Method

When strips are uniformly irradiated, the ratio Q_R/Q_M depending on Q_L/Q_M is given in figure 4a, for 5 mm strip pitch and S/N = 60 ÷ 65, and in figure 4b, for narrow X-ray beam.

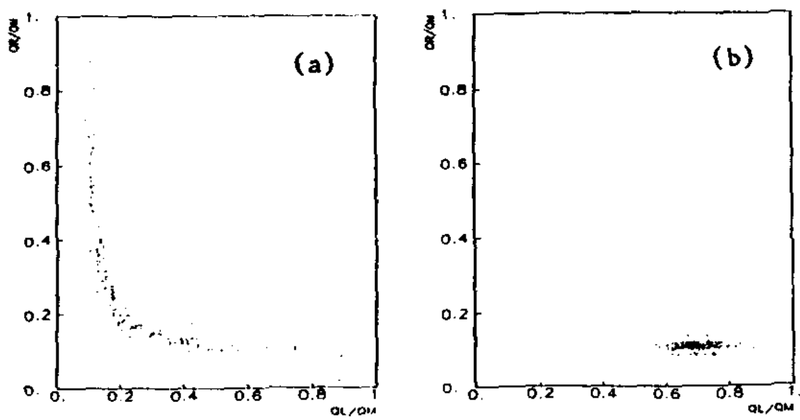

Fig.4. The ratio Q_R/Q_M depending on Q_L/Q_M for (a) uniform irradiation and (b) narrow X-ray beam.

It is possible to relate the points in the precedent scatter plots to the avalanche position. The angle

$$\alpha = \mathrm{arctg}\,\frac{(1 - Q_R/Q_M)}{(1 - Q_L/Q_M)} \qquad (5)$$

depends on the avalanche position x_a. The induced charge along the X-axis (normal to the strips) is of the form [5]:

$$Q = Q_a\, g\, f(x,x_a), \qquad (6)$$

where Q_a is the avalanche charge; g, a geometrical factor; f, the profile of the induced charge. The charge induced on the i-th strip is given by the following equation:

$$Q = Q_a\, g \int_{x_i}^{x_i+w} f(x,x_a)\, dx. \qquad (7)$$

If function f is known, then it is possible to find numerically or analytically the relation between α and x_a using relations (5) and (7). It was the case shown in [6], but geometrical factor g was changed to obtain the minimum position resolution. In our case, we could not apply this method because we did not accurately know function f.

One more way to determine the position resolution is to use an empirical relation $\alpha = \alpha(x_a)$ [3]. We have used the following expression for the 5 mm and 3 mm strip pitches

$$x_a = A\,\mathrm{arctg}\,[B(\alpha - \pi/4)] \qquad (8)$$

with A = 2.4065, B = 2.0995 for the 5 mm strip pitch respectively A = 1.4439, B = 2.0995 for 3 mm. In processing, the uniformity test described in 3.1 was used.

This method has two advantages over the first one [6]:

- it does not depend on the common bias-level substraction
- it does not strongly depend on the cross talk.

Figure 5a shows the avalanche distribution for the narrow X-ray beam estimated with the relation (1); and 5b, the corresponding one computed with the relations (5) and (8) after uniformity test. The dependence of the position resolution on the signal/noise ratio computed with the charge-ratio method, is given in figure 3.

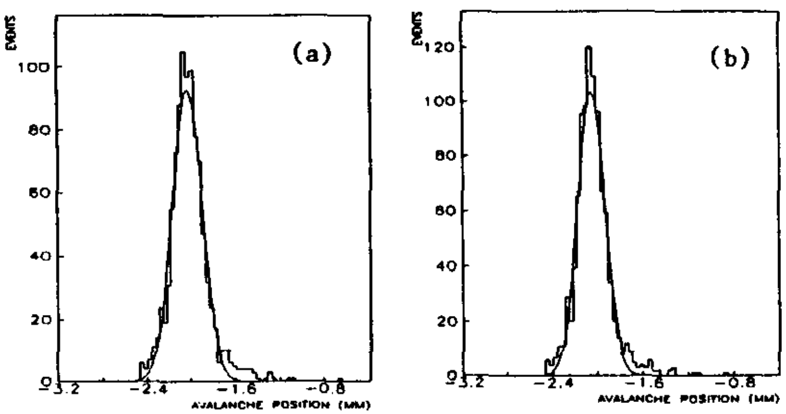

Fig.5. Avalanche distribution estimated with (a) centroid method, σ = 135 µm (b) charge/ratio method, σ = 121 µm.

Along the strip (X-axis) the position resolution estimated with the charge-ratio method, gives almost the same results as the centroid method, excepting the points near the edges of the strips where the position resolution is smaller by ≈ 10% than the position resolution estimated with the centroid method.

4. CONCLUSIONS

The centroid and charge-ratio methods can be applied to estimate the position resolution for the straw chambers with strip readout. The second method gives ≈ 10% better resolution than the first one at the edges of the strip. Its advantage: it is not sensitive to the pedestal substraction or to the cross talk between strips. It means that the charge-ratio method is more suitable for data processing of big detectors having straw chambers with strip readout.

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Received by Publishing Department
on May 13, 1992.