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CM-P00063937

A DRIFT CHAMBER VERTEX DETECTOR FOR
INTERSECTING STORAGE RINGS

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ABSTRACT

A cylindrical drift chamber detector for use in a high p_T experiment at the CERN ISR is described. The sense wires (total of 3444) are grouped in 42 layers at radii between 20 cm and 80 cm and are used to provide determination of 42 space points along tracks passing through all wire layers. The high redundancy of space points provides improved pattern recognition for complex events, good momentum resolution when the detector is placed in a magnetic field, and some particle identification via sampling of dE/dx . Results of tests performed with a smaller chamber are presented. In a direction perpendicular to the sense wires, the accuracy of measurement is given by $\text{FWHM} = 0.5 \text{ mm}$, while $\text{FWHM} = 9 \text{ mm}$ for the coordinate along the wire direction, obtained by the "charge division" method.

Contributed paper for the
Wire Chamber Conference, Vienna, Austria,
14-16 February, 1978

Geneva - 6 March 1977

1. INTRODUCTION

The need for a vertex detector in a large p_T experiment at the CERN ISR, satisfying multiple requirements of large solid angle and low mass density for external detectors, possibility of powerful pattern recognition, good momentum resolution and a reasonable construction time, has led us to consider a cylindrical drift chamber detector with high sense wire density and space point measuring capability. The latter is made possible by the method of charge division¹⁾ for determination of the coordinate along the wire direction simultaneously with the drift-time measurement. In order to study the feasibility of such a design and at the same time determine its operating characteristics, a smaller prototype has been tested.

2. DESCRIPTION OF CHAMBER AND READ-OUT

A schematic view of the full drift chamber system is shown in Fig. 1. The cylinder halves have a substructure consisting of 4° cells. The 42 sense wires in each cell are further divided into three subgroups of 14, 18, and 10 wires with median radii of $r = 26$ cm, 51 cm, and 76 cm, respectively, and 8 mm radial sense wire separation. The tested prototype, seen in cross-section in Fig. 2, contains the outer subgroups of three adjacent 4° cells. The cell boundaries consist of lines of "drift field wires", while the sense wires in each cell are separated by "potential wires". The staggering of the sense wires to the right and left of the radius vector is introduced to resolve the right-left ambiguity. The sense wires are 25 μ diameter non-magnetic stainless-steel wires^{*)}, with a high resistivity (2.8 k Ω /m) essential to the charge division measurement. All other wires are 100 μ diameter Be-Cu wires. The wire positioning accuracy is $\lesssim 50$ μ and is achieved by crimping the wires into tubes of 80 μ inner diameter, located in precisely drilled holes.

The magnetic field measurements were done with a 15 cm long chamber, while the charge division results were obtained with a chamber of the full length, $\ell = 144.0$ cm. The gas mixtures used, Ar-C₂H₆ (54% Ar, 46% C₂H₆) and Xe-C₂H₆ (50% Xe, 50% C₂H₆), are known to show electron drift velocity saturation at drift fields above about 1.2 kV/cm even in a magnetic field²⁾. The operating potentials were chosen accordingly. The gas multiplication was then about 2×10^4 . The voltage distribution along the line of drift field wires was such that the drift field was constant, independent of the radius from the axis of the chamber. The calculated equipotential lines at typical working conditions for the Ar-C₂H₆ mixture ($E_{\text{drift}} = 1.50$ kV/cm) are shown in Fig. 3.

The read-out system is shown schematically in Fig. 4. A fast current pre-amplifier with input impedance 70 Ω is connected to each end of the sense wire.

*) "Stable-Ohm 800" wire, manufactured by the California Fine Wire Co.

The drift time signal is derived from this fast signal (threshold = $0.7 \mu\text{A}$), while the pulse heights in either end of the wire are measured on integrated and shaped signals with peak-sensing ADCs. It is shown in Ref. 1 that the coordinate z along the wire (Fig. 4) can be determined as $z = A/(A + B)$, where A and B are the pulse heights at the two ends of the wire.

3. MEASUREMENTS AND RESULTS

3.1 Drift time

To study the resolution and linearity of the coordinate measured by the electron drift time, a $4 \text{ GeV}/c$ negative beam (mostly π^-) of narrow width ($\text{FWHM} \approx 1.5 \text{ mm}$) in the direction of drift was used. The measurements were performed by displacing the drift chamber with respect to the constant beam profile (see Fig. 5). The setting error in positioning the chamber was $\lesssim 50 \mu$. A magnetic field parallel to the sense wires and of variable strength could be applied.

Figure 6a demonstrates how the construction using staggered sense wires solves the right-left ambiguity. The "wrong" track solution contains deviations of $\pm 0.8 \text{ mm}$ (twice the sense wire staggering) from a straight line fit and can therefore easily be rejected.

A simple track-finding routine fitting straight lines to the hits on six pre-selected wires was employed to study the resolution in the drift coordinate measurement. The difference for a certain wire between the measured and the fitted coordinate is depicted in Fig. 7 for tracks of inclination $\alpha = 0^\circ$. The accuracy is given by $\text{FWHM} = 0.5 \text{ mm}$, both when $B = 0$ and when a magnetic field of 6 kG is applied.

The efficiency of a single wire, defined by demanding a hit within $\pm 1 \text{ mm}$ of the fitted track, is $\geq 99.4\%$ with the potentials and thresholds used.

In the event shown in Fig. 6b no track was found. In this case, a magnetic field of 6 kG along the wire direction was applied, and the angle of inclination of the track was $\alpha = 30^\circ$. The track appears as two segments that do not join at the cell boundary. The explanation of this effect can be found in Fig. 8. Because of the magnetic field, the electron drift is deflected by an angle θ from the direction of the electric field. The drift velocity projected onto the electric field direction is $V_{\text{drift}} \cos \theta$. One way of treating this effect is then to apply a correction of $d' \tan \theta \tan \alpha$ to the measured projected drift distance d' , where $d' = (V_{\text{drift}} \cos \theta) \cdot t_{\text{drift}}$ (see Fig. 8).

For large angles α the correction is quite large (several mm) and has to be done by iteration. However, for high p_T tracks, $p_T \gtrsim 1 \text{ GeV}/c$, where accuracy is most important, α is limited to $\alpha \lesssim 5^\circ$ and the correction is at the 2% level. It can be seen from Ref. 2 that a $\text{Xe-C}_2\text{H}_6$ gas mixture from this point of view is preferable to an $\text{Ar-C}_2\text{H}_6$ mixture because of the smaller deflection angle θ . It should

be pointed out that because of this magnetic deflection, double hits or missing hits (as in Fig. 6b), depending on the sign of α , can occur when tracks cross the cell boundaries.

The space-time relationship in a magnetic field for tracks with $\alpha = 0^\circ$ is shown in Fig. 9 for a single wire in the drift cell of Fig. 2. The drift time has here been represented by the mean value of a Gaussian fit to the raw time distribution. The relationship is linear, even in the presence of a 6 kG field.

3.2 Charge division and pulse-height measurements

The determination of the coordinate along the sense wires by charge division was studied with the full-length prototype. Linearity and resolution was again measured by displacing the chamber with respect to the fixed beam of width 1.5 mm along the wire direction. The result is shown in Fig. 10. The resolution in the middle of the chamber, given by $\text{FWHM} = 9 \text{ mm} = 0.6\%$ of the wire length, is consistent with that expected from electronics noise. On the contrary, the resolution close to the wire ends, $\text{FWHM} \approx 20 \text{ mm}$, is considerably worse. This effect has been traced to a non-optimized layout of the return signal path, and various electrical solutions have been found which result in improved performance.

The dependence of the pulse height ($A + B$) on the radius (wire number) and on the coordinate along the drift direction are shown in Fig. 11. The 20-30% difference in pulse height on a wire at $y = -0.4 \text{ mm}$ between tracks at positive and negative y is caused by the wire staggering. The smaller pulse height for tracks at positive y is due to a smaller multiplication near the wire for avalanches from that side.

Taking this effect into account, the pulse height information on the wires can be used to calculate dE/dx for a found track. We have measured a dE/dx resolution of 28% FWHM for 2 GeV/c pions in $\text{Ar-C}_2\text{H}_6$. This was obtained by calculating the average of the 10 smallest pulse heights on 14 wires in the full-length prototype (9 mm samples).

4. CONCLUSIONS

- 1) The construction using staggered sense wires resolves the right-left ambiguity.
- 2) The space-time relationship for tracks of zero inclination is linear, even in the presence of a magnetic field.
- 3) A correction must be applied to the drift-time measurements for inclined tracks. The correction can be substantial when a magnetic field is present, but for the important class of high p_T tracks, where accuracy is most important, it is at the 2% level. In the zero field case, the inclined track correction is smaller.
- 4) The coordinate along the wire direction can be obtained by charge division.

The authors would like to thank P. Quéro and his group for constructing the test chambers, and Ph. Dam and G. Trouiller for assistance during the tests.

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Figure captions

- Fig. 1 : A view of the drift chamber vertex detector. The assembly from three separate rings is shown for the left half cylinder. The chamber is subdivided into identical 4° drift cells.
- Fig. 2 : Cross-sectional view of one of the three adjacent 4° cells of the test module (ring 3). There are 10 active sense wires in each cell, since the first and last wires are not read out. The sense wire spacing is 8 mm and the staggering with respect to the radius vector is ± 0.4 mm. The potentials $-V_n$ were chosen in the tests to give a constant potential difference between the field-shaping wires.
- Fig. 3 : Equipotential lines in one cell of the test chamber at typical working conditions. The drift field is 1.50 kV/cm. The first and last sense wires, where the field is less uniform, are not in use.
- Fig. 4 : Schematic diagram of the read-out system. Each sense wire provides a drift-time measurement and pulse-height measurements in both wire ends. The discriminator threshold is 0.7 μ A.
- Fig. 5 : Test chamber set-up in the beam line. The beam width in the chamber was about 1.5 mm. The chamber could be moved across the fixed beam, and rotated with respect to the beam. S1, S2, and S3 are scintillator trigger counters.
- Fig. 6 : a) On-line event display demonstrating the resolution of the right-left ambiguity. The open squares indicate the sense wires (10 active in the upper cell, only 6 in the lower), while the crosses indicate the hits.
b) Event display of an inclined track in a magnetic field as in Fig. 5. The track segments in the two adjacent cells do not join at the cell boundary.
- Fig. 7 : Typical difference between drift coordinate measured with a single wire and coordinate interpolated from a fit to six other wires in the drift cell. In this case, the inclination $\alpha = 0^\circ$.
- Fig. 8 : Illustration of the influence of a magnetic field along the wire direction. The electron drift is deflected by an angle θ from the direction of the electric field. The correction to the measured projected drift distance d' is

$$d - d' = d' \tan \theta \tan \alpha .$$

- Fig. 9 : The space-time relationship in a drift cell for tracks with inclination $\alpha = 0^\circ$. A constant correction of 4 nsec (0.2 mm) has been applied to the data on the side of the wire where the pulse height is low owing to the staggering (see Fig. 11).
- Fig. 10 : a) The charge ratio $A/(A + B)$ as a function of beam position along the wire.
b) Typical charge division spectrum close to the wire middle. The beam width along the wire direction was 1.5 mm.
- Fig. 11 : a) Dependence of pulse height $(A + B)$ on wire number in cell when $y_{\text{track}} > 0$ (in this case $y_{\text{track}} = 12$ mm).
b) Dependence of pulse-height $(A + B)$ on track position for wire number 5. The even-odd effect caused by the sense wire staggering of ± 0.4 mm is clearly seen.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

a)

b)

Fig. 6

Fig. 7

• $\bar{B}$

Fig. 8

Fig. 9

Charge division
 54% Ar, 46% C₂H₆
 B = 0
 Wire number 5

Fig. 10

Fig. 11