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A Micro Vertex Detector for Experiment UA1 at the CERN SpS Collider

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Abstract: The design and operation of a small pressurized drift chamber is described. The chamber provides 16 space points between 3 and 8 cm from the beam axis of the CERN proton-antiproton collider.

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1. Introduction

In recent years, precision drift chambers (resolution $\leq 100\mu\text{m}$) mounted close to the interaction vertex, have been used to measure the lifetimes of heavy flavor hadrons and heavy leptons at electron-positron colliders. [1-3] We describe here a vertex detector which has been constructed for the UA1 experiment at the CERN Sp $\bar{p}$ S Collider. The design and operation of the detector and test beam results are outlined below.

2. Chamber Design

The 4π UA1 detector consists of a large cylindrical drift chamber (central detector) surrounded by calorimeters and an outer layer of drift tubes for muon detection [4]. The inner radius of the central detector is 9 cm. The micro vertex detector is a cylindrical jet-style drift chamber [5] which fits between the central detector and a beam pipe of 2.5 cm radius. In order to minimize multiple scattering the beam pipe is fabricated from 1 mm thick beryllium [6]. The chamber wires, which run parallel to the cylinder axis, are strung between two 12 mm thick Stesalit¹ endplates. The chamber is divided into 16 cells which cover 2π in azimuth (figure 1). It is enclosed in an aluminium pressure vessel for which the beam pipe provides the inner wall. Particles produced at 90° to the beam direction traverse 0.56% of a radiation length before reaching the sensitive volume of the chamber. The main parameters of the micro vertex detector are listed in Table 1.

3. Cell Design

Figure 2 shows in detail the geometry of a drift cell. Each cell contains 16 sense wires which alternate with field wires. The sense wires are staggered by $\pm 100\mu\text{m}$ relative to the field wire plane. The staggering is used to resolve the inherent left-right ambiguity. The spacing between field and sense wires and between successive cathode wires is 1.58 mm. The innermost sense wire is 33 mm from the chamber axis. The maximum drift length is 16 mm. The short drift length optimizes the resolution by limiting the longitudinal diffusion of drifting electrons.

The sense wire is a $23\mu\text{m}$ diameter Nicotin wire (see Table 1) strung at a tension of 77 ± 4 gm. The choice of sense wire material was dictated by the following requirements: (i) a high electrical resistivity in order to measure the coordinate along the wire by charge division, and (ii) a suitable diameter to optimize gain without compromising wire stability. The sense wires are held by a three-part pin. The front part is a gold cylinder with a longitudinal notch whose depth is adjusted so that the wire is

¹ Stesalit is the registered tradename for fiberglass/epoxy plates produced by Stesalit AG, Zolwil, Switzerland.

off-center by 100 μm . The wire passes through a tube in the back of the Stesalit endplates and is wedged in place by a cone.

The cathode and field wires are strung at 300 gm tension and are held by crimped copper tubes.

In order to generate and close the electric field at the inner and outer radii of the cells, two field generating circuits were constructed: the inner and outer racetracks (IRT, ORT). The racetracks are cylindrical laminates of (i) Kapton sheets with double-sided printed circuits of gold-plated copper, (ii) Kapton insulating layers, and (iii) a ground plane. The cylindrical racetracks are also used to degrade the high voltage to ground from inside to outside the drift cell in a distance less than 2 mm. The wire tension is completely supported by the outer racetrack cylinder. The thickness of the inner and outer racetracks are respectively 0.29% and 0.93% of a radiation length.

4. Field Mapping

A computer program was used to determine the field, cathode, and racetrack voltages necessary to produce a uniform electric field perpendicular to the field-sense wire plane. This program also provided the charge/length from which the gain on the sense wires could be estimated.

Figure 3 shows the equipotential lines of the optimized field configuration. The high voltage supply with 12 constant voltage taps was constructed to fix the voltage at critical points around the drift cell. It locks the 12 voltages independently of the ionization current.

5. Operating Conditions

The operating conditions summarized in Table 1 were determined by measurements made on two prototype chambers. The gas mixture chosen for this detector is 53%-47% Argon-Ethane. The detector is run at a saturated drift velocity (approx. 50 $\mu\text{m}/\text{ns}$) at an E/P of 1.85 kV/cm-atm. The stability of the wires and uniformity of the electric field permit a maximum pressure of 3 atmospheres. A voltage of -2150 volts is applied to the field wires to enhance the gas amplification. Under these conditions the gain is about 3×10^4 and the average electric fields on the surface of the sense, field, and cathodes wires are 442 kV/cm, 6 kV/cm, and 34.8 kV/cm respectively.

The signals from the left and right sides of the sense wires are read out by preamplifiers (Laben VV35) outside the pressure vessel endplates. The preamplifier was developed at Physikalisches Institut Heidelberg and produced by Laben Milano in a hybrid package. The main characteristics

of the Laben VV35 are its low noise, 40 dB gain, < 2 ns rise-time, small dimensions, and low power consumption. A minimum ionizing particle perpendicular to the sense wire produces an average signal of 80 mV at the output of the preamplifier; one mV corresponds to one primary electron produced in the gas. Figure 4 shows the path of the left and right pulses after they are split. One pair of pulses is summed and clipped to produce a 20 ns wide signal and then sent to a discriminator and TDC for drift time measurement. The other pair of pulses is input to charge division electronics to obtain the coordinate along the wire. The discriminator is based on a fast high precision voltage comparator, the LeCroy MVL407. Since the drift velocity is $50 \mu\text{m}/\text{ns}$, a double-track resolution of 1 mm is possible.

6. Test Beam Results

The microvertex detector was tested in a 10 GeV pion beam at the CERN PS. The drift time information was digitized using a LeCroy 2228A single-hit TDC with a precision of 0.25 ns/bin. The charge division information was digitized on charge-time-digitizers (CTD's) first developed for the UA1 central detector [7]. The discriminator thresholds were set at 5 mV throughout most of the test beam run.

The single wire resolution was calculated from a straight line fit to the drift time coordinates of beam particles passing perpendicular to the chamber axis. Figure 5 shows a trajectory at the center of the chamber. Figure 6 exhibits the expected linear relationship between drift distance and the square of the resolution. The average single wire resolution close to the sense wire is $36 \mu\text{m}$.

The sense wires are staggered by $\pm 100 \mu\text{m}$ relative to the cell axis (figure 2). In addition, the electric field produces a bowing of the sense wires with maximum displacement at the center of the wire. The total displacement can be measured by treating it as a variable in track-fitting. For standard operating conditions (Table 1) the net displacement at the center of the wire (as for the results in figure 5) was found to be $530 \mu\text{m}$, in agreement with calculations.

The drift velocity was calculated to be $51 \pm 1 \mu\text{m}/\text{ns}$ from the difference in width of the drift time spectra of the 16 wires within a drift cell.

7. Conclusions

A drift chamber operating at 3 atmospheres pressure has achieved an average single wire resolution of less than $50 \mu\text{m}$. The small spacing of 1.58 mm between field and sense wires provides 16 space coordinates over a 5 cm radial distance.

8. Acknowledgements

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Table 1: Parameters of the micro vertex chamber

Inner radius	25 mm
Outer radius	89 mm
Wire length	800 mm
Maximum drift distance	16 mm
Number of cells	16
Number of sense wires per cell	16
Total number of sense wires	256
field wires	272
cathode wires	528
Radial position of first sense wire	33 mm
last sense wire	80 mm
Spacing between field/sense wires	1.58 mm
Staggering	100 μ m
Sense wire material	23 μ m (Nicotin a Ni-Co-Cr-Mb-Fe alloy)
Field/Cathode wire material	150 μ m (Cu-Be)

Running Conditions:

Drift Field	1.85 kV/cm-atm
Field wire voltage	2.15 kV
Gas mixture	Argon-Ethane (53%-47%)
Pressure	3 atm
Drift Velocity	51 μ m/ns

Figure Captions

- Figure 1: The arrangement of the 16 drift cells on the Stesalit endplate. The wire/pin positions are shown in detail for one cell.
- Figure 2: A single drift cell in detail.
- Figure 3: Computer display of the equipotential lines in a single drift cell. The potentials on the wires and racetracks produce a uniform electric field throughout the cell.
- Figure 4: Block diagram of the readout electronics.
- Figure 5: A cosmic ray muon passing through opposite drift cells. The figure is expanded in the horizontal direction.
- Figure 6: The average resolution squared as a function of the drift distance shows the effect of longitudinal electron diffusion.

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6