ELSEVIER

Nuclear Instruments and Methods in Physics Research A 367 (1995) 92–95

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

The High Momentum Spectrometer drift chambers in Hall C at CEBAF

O.K. Baker[a,b,*], J. Beaufait[b], R. Carlini[b], J. Cha[a], S. Danagoulian[c], A. Johnson[a], B. Kross[b], S. Majewski[b], A. McCauley[a], W. Naing[a], G. Niculescu[a], I. Niculescu[a], T.S. Shin[a], W. Vulcan[b]

[a] *Department of Physics, Hampton University, Hampton, Virginia 23668, USA*
[b] *Physics Division, CEBAF, Newport News, Virginia, USA*
[c] *Department of Physics, North Carolina A&T State University, North Carolina, USA*

Abstract

The multiwire drift chambers to be used in the High Momentum Spectrometer (HMS) at the Continuous Electron Beam Accelerator Facility (CEBAF) have been designed and constructed, and recently employed in initial data-taking runs. These chambers are used to reconstruct scattered charged particle momenta in the HMS using ^{12}C and BeO_2 targets for incident electron energies up to 2.2 GeV. Offline analysis of the data indicate that these drift chambers have spatial resolution (per plane) of about 115 μm (σ) in rates approaching a kHz/wire/mm. It is expected that this performance will improve at higher momenta where multiple scattering contributions are smaller.

The physics program in Hall C at the Continuous Electron Beam Accelerator Facility (CEBAF) will include an exciting and diverse set of experiments in medium and high energy physics. Such a broad program requires a set of highly flexible instruments for charged particle detection and identification [1].

The major instrument built for the initial compliment of experiments in Hall C is the High Momentum Spectrometer (HMS). The HMS will serve as a hadron arm for a subset of the coincidence experiments and as an electron spectrometer for inclusive scattering experiments and for a series of coincidence experiments; it has the capability of analyzing charged particle momenta up to 7 GeV/c [1].

The HMS detector stack is used primarily to identify relatively high energy electrons (and protons) in a modest background of negative (positive) pions and measure their trajectories in the region of the HMS focal plane. Additionally, the detector package provides some π/p separation. To accomplish this, the HMS detector stack employs planar multiwire drift chambers, a gas Cherenkov counter, plastic scintillator hodoscopes and lead-glass shower counters [1–4].

This article reports on the details of the HMS drift chamber design and on first results of the use of these chambers in the spectrometer in the recent experimental runs at CEBAF using a 2.2 GeV electron beam scattering from carbon and beryllium-oxide targets.

The HMS drift chamber is based on a very successful design detailed in Ref. [5] which achieved 140 μm spatial resolution per plane and efficiencies better than 98% even at high rates [5,6]. The layout of the chamber is as follows. There are six planes arranged in the order X, Y, U, V, Y', X' with 1.4 cm spacings between planes (between field wires of the planes). The X planes are orthogonal to the Y planes and the U, V stereo planes are inclined 15° with respect to the X and X' planes. The X' (Y') plane is offset from the X (Y) plane by $\frac{1}{2}$ cell (5 mm). The cell scheme consists of 1 cm × 0.8 cm drift cells with anode planes separated by 2 cm.

The sense wires (anodes) are 25 μm gold-plated tungsten wire, while the field wires (cathodes) are 150 μm gold-plated copper–beryllium. All sense wires reside at ground potential, eliminating the need for decoupling capacitors between the wire and the readout electronics. The tension in the wires after crimping was tested by passing a time varying current through the wires in the presence of a magnetic field [7]. The peak amplitude of the AC induced signal in the wire causes a resonance vibration in the wire according to

$$f=\frac{1}{2L}\sqrt{\frac{T}{\mu}}, \qquad (1)$$

* Corresponding author. Tel. +1 804 727 5820, fax +1 804 249 7363, e-mail baker@cebaf.gov

Elsevier Science B.V.
SSDI 0168-9002(95)00737-7

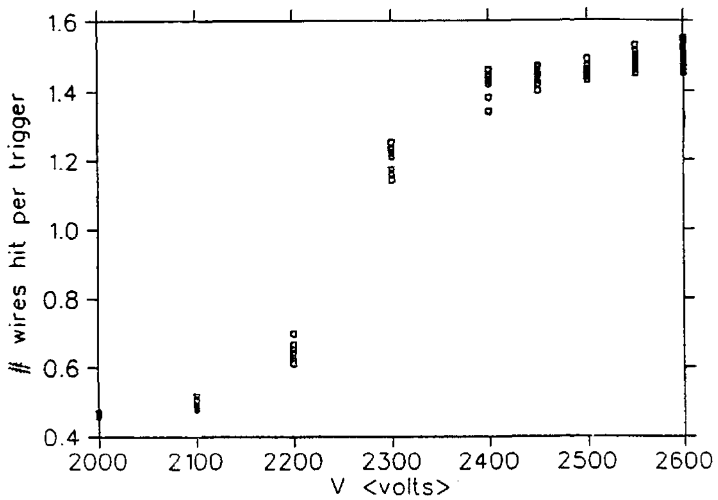

Fig. 1. The number of drift chamber wires hit per triggered event as a function of the high voltage on the field wires in the drift chamber. A triggered event is defined to be at least three out of four scintillator planes in the HMS detector stack. The plateau is about 200 V wide. The operating voltage during most of the data taking runs was 2500 V.

where f is the resonance frequency (in Hz), L is the wire length, μ is the mass per unit length of the wire, and T is the applied tension. This method has been shown to provide a very sensitive measure of the wire tension [7]. This resonance feedback method was used to demonstrate that all the wires received the same tension to within ±5%.

A 50:50 mixture (by weight) of argon and ethane was used for filling the chamber [8]. This gas mixture was passed through an isopropyl alcohol bubbler at 0°C, thus doping the mixture with about 1% alcohol. Previous studies indicate that this procedure is preferable in a high incident particle rate environment [6]. The gas flow through the chamber was varied during the course of the test runs from 80 to 200 cm^3/min. The exhaust gas was bubbled through a low viscosity oil. The chamber was operated at just a fraction above atmospheric pressure.

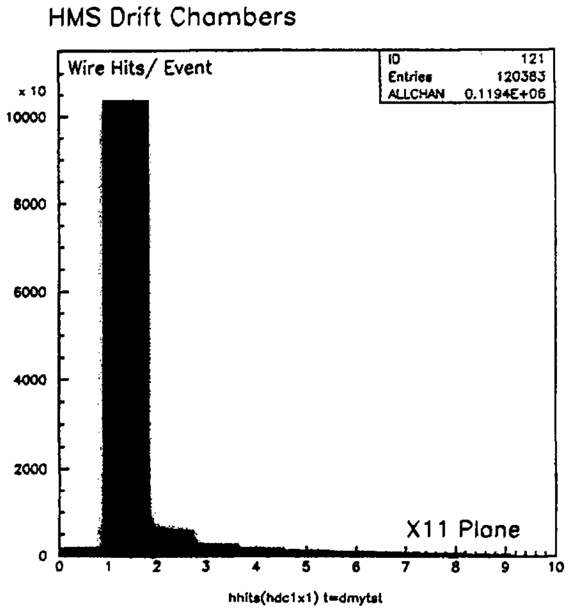

Fig. 2. The number of drift chamber wires hit per triggered event, where a triggered event is defined in the caption of Fig. 1. As can be seen, there is usually a single drift chamber hit registered per event.

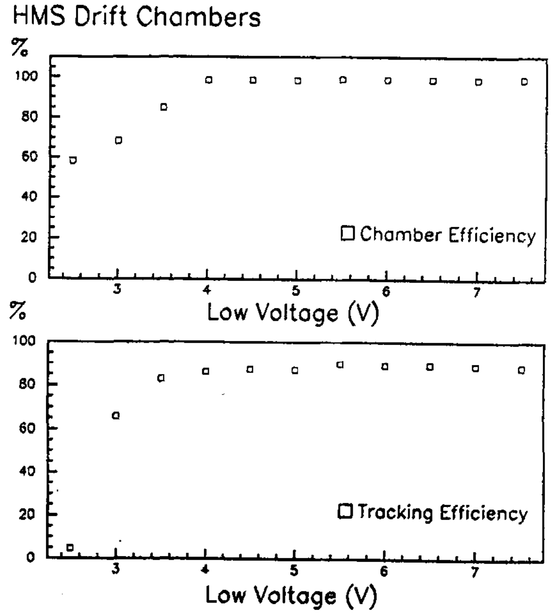

Fig. 3. The drift chamber efficiency (upper half) and the tracking efficiency (lower half) versus the threshold voltage (low voltage) applied to the digitizing electronics.

The drift chambers described were tested in the HMS spectrometer at CEBAF. Electrons with energies 0.75, 1.21, and 2.17 GeV were incident on the solid targets listed above. Scattered electrons were momentum analyzed in the HMS at 12° and 27° with respect to the incident beam direction.

The signals from each individual anode were amplified and digitized in Nanometrics [9] and LeCroy 2735DC drift chamber cards [10]. The delayed discriminated signal formed the stop of LeCroy 1879 Time-to-Digital Converters (TDCs); the fast signals form S1 and S2 formed the TDC starts. The data was stored to disk with a Hewlett-Packard 735/125 computer [11] for data acquisition.

The efficiency, ϵ, of each plane was checked as a function of field wire voltage and scattered particle rate. The efficiency is related to the number of wire chamber hits registered normalized to the number of events where an event was a three-fold scintillator hodoscope coincidence. The curve, in Fig. 1, shows a 200 V wide plateau with just over one wire hit (on average) per trigger. As can be seen in Fig. 2, for most of the scintillator triggers, there is one drift chamber hit.

It is advantageous to run with the threshold voltage on the electronics cards as low as possible to achieve a particle detection efficiency as near to 100% as possible, consistent with tolerable dead time corrections. During the

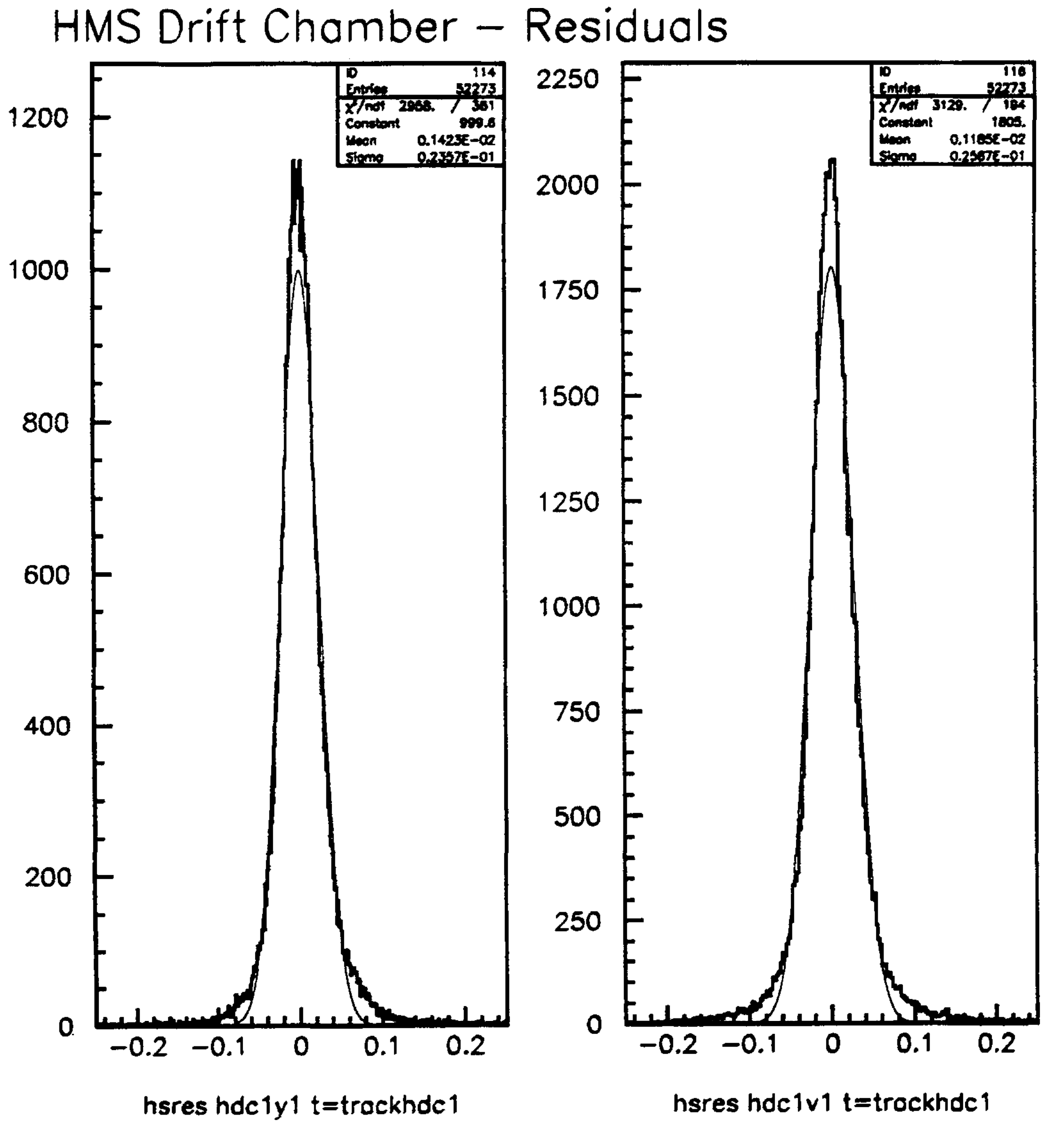

Fig. 4. The spectrum of values for the difference between the measured and calculated tracks through the chamber. This data (the residuals) is used to determine the intrinsic resolution of the drift chamber. Shown are the residuals for the Y-plane (left half) and the V-plane (right half) of one of the HMS drift chambers.

course of the experiment, the threshold voltage was set at about 3 V output on the preamplifier/discriminator card power supply. This corresponded to about 3 mV actual threshold. In Fig. 3 is shown the chamber efficiency (upper half of the figure) versus threshold (low) voltage and the tracking efficiency (lower half of the figure) also versus low voltage. The tracking efficiency is the number of good tracks found versus the number of triggered events where a trigger is defined in the caption of Fig. 1.

The ultimate performance criterion studied for this chamber is the charged particle track position resolution through the chamber. The drift chambers in the HMS detector stack will be used to calculate the momentum of each detected particle at any point on its trajectory and in particular, at the vertex (the point of interaction in the target).

The approximation to the charged particle track is a straight line through the six planes of the chamber. A hit is predicted at a point on one of the six planes based upon the calculated straight line. This is compared to the actual measured intersection point in that plane [12]. The calculated position in the U plane for example can be expressed as

$$\mathrm{PU}(x, y) = (x \cos(\theta_U), y \sin(\theta_U)) \tag{2}$$

with

$$x = x_0 + \left(\frac{X' + X}{Z_{X'} - Z_X}\right) Z_U \tag{3}$$

and similarly for y. In these equations θ_U is 15°, x and y are the positions along the horizontal and vertical directions in the chamber, X (X') correspond to the positions in the X (X') planes and $Z_X - Z_{X'}$ is the distance between the X and X' planes (along the beam direction).

The measured position in the plane is obtained from the difference in time between the TDC start and stop and making use of Eq. (2). The difference between the measured and calculated position gives the estimate of the spatial resolution in that plane [13,14]. An example of this quantity (difference between measured and calculated position) is shown for the Y-plane (left half) and the V-plane (right half) in Fig. 4. The width of this distribution is equal to the sum of the square of the uncertainty in the calculated and measured position for the five planes used to make the calculation. The resolution for the example shown is 259 μm (σ) for the V plane which includes contributions from five planes. The resolution is then taken to be 115 μm (σ) for this plane. (Both curves shown in Fig. 4 include the resolution, added in quadrature, from the five planes used in the calculation.) The uncertainty in the FWHM estimation is approximately 50 μm. Thus the resolution per plane (for the V plane here) is 115±11 μm (σ).

In conclusion, the High Momentum Spectrometer of Hall C at the Continuous Electron Beam Accelerator Facility uses planar drift chamber with horizontal, vertical, and stereo planes and drift cells of dimension 10.0 mm × 8.0 mm. A discussion of the HMS drift chambers design, construction, and testing has been reported on in this article. The chamber resolution is relatively constant up to about 1 kHz wire^{-1} mm^{-1}. The use of these chambers in reconstruction of charged particle momenta in the HMS yields momentum resolution in the spectrometer of about 0.1%. This performance is expected to improve at higher energies (where errors due to charged particle multiple scattering is reduced) and with optimized running conditions in Hall C at CEBAF.

References

[1] CEBAF Conceptual Design Report (1990).
[2] CEBAF Summer Workshop (1988).
[3] O.K. Baker et al., PANIC XII Conf. Proc. (1990) XVII-18.
[4] O.K. Baker et al., Va. J. Sci. 143 (1990) 45.
[5] R. Bolton et al., Nucl. Instr. and Meth. A 292 (1983) 571.
[6] R. Bolton, private communication (1990).
[7] M. Atac and M. Mishina, Fermilab TM-1125 2562.000 Internal Report (1988).
[8] B. Jean-Marie et al., Nucl. Instr. and Meth. 159 (1979) 213.
[9] Nanometrics System Inc., Oak Park, IL, USA.
[10] LeCroy Corporation, 700 Chestnut Ridge Road, Chestnut Ridge, NY 10977, USA.
[11] Hewlett-Packard Co., Santa Clara, CA, USA.
[12] R.K. Bock et al., Data Analysis Techniques for High-Energy Physics Experiments (Cambridge University Press, 1990).
[13] J.C. Lassalle et al., Nucl. Instr. and Meth. 176 (1980) 371.
[14] T. Chen et al., Nucl. Instr. and Meth. A 290 (1990) 390.