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POSITION-SENSITIVE GAS PROPORTIONAL CHAMBERS

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Summary

A number of multiwire, position-sensitive, gas proportional chambers have been constructed which use fast delay line (2.5 ns/cm) readouts to provide trajectory position and angle information for particles near the focal planes of the Energetic Pion Channel and Spectrometer (EPICS) and High Resolution Spectrometer (HRS) at the Clinton P. Anderson Meson Physics Facility (LAMPF). These chambers are two dimensional with anode wires in one direction and cathode wires in the other direction. When operated as ordinary delay line chambers, position resolution of 0.5 mm (FWHM) can be obtained in the cathode direction for short cathode wire lengths. If the drift information from the anodes is used, resolution of less than 0.35 mm (FWHM) can be obtained in this direction. The chambers can be operated at count rates of 5×10^5 pulses/sec with live times of greater than 90%. Efficiencies, measured at lower counting rates, are typically greater than 99%.

Delay Lines

The delay lines are microstrip[1] delay lines printed on copper teflon-glass laminate.[2] The properties of a 30-cm length of delay line are summarized in Table I.

Table I. Delay Line Properties

Length	30.0 cm
Width	7.6 cm
Thickness	0.8 mm
Conductor Width	0.5 mm
Conductor Length	20.0 m
Inductance	9.0 μH
Capacitance	680.0 pF
Attenuation (100 MHz)	3.0 db
Delay	2.5 ns/cm
Delay/Risetime	19:1
Impedance	110 Ω
Resistance (D.C.)	40 Ω
Resistance (100 MHz)	80 Ω

The delay per unit length of 2.5 ns/cm compares with delays of 80 ns/cm, 40 ns/cm, 11 ns/cm, and 2.2 ns/cm, in previously reported work.[3-6] The rise time/delay time and attenuation for this delay line is worse than in some others reported in the literature. However, a correction which restores some of the degradation in position resolution due to these effects is described later in this paper.

Construction

The active cathode and the anode for each chamber are mounted on one side of an 8.25-mm thick "window frame" constructed from aluminum tooling plate, which is cut down to accommodate the cathode. The inactive cathode is mounted on a similar opposing frame. The wire planes are insulated from the aluminum by the delay line on one end and by a 0.78-mm thick piece of epoxy fiberglass board (G10) on the other end. For the anode plane, the G10 and the teflon of the delay line are allowed to overhang the edge of the aluminum, providing the necessary high voltage insulation. Gas windows of 25 μm aluminized mylar are taped and grounded to the outsides of the aluminum frames. A gas seal is made around the edge of the assembled chamber using plastic tape. The anode to cathode gap is typically 4 mm.

The cathode planes are wound with 80 μm copper clad aluminum wire with 1-mm spacings and the anodes are wound with 20 μm gold-plated tungsten wire with 2-8 mm spacings. The wires in both planes are soldered directly into their delay lines. Signals from the anode, which is run at high voltage, are capacitively coupled from the ends of the delay line.

Chambers with active areas of 60 cm x 10 cm, 30 cm x 20 cm and 90 cm x 30 cm have been constructed and are in routine use at LAMPF.

Electronics

The fast rise time signals (shown in Fig. 1) from the ends of the delay line are transported, though short, up to 2 m, 93 Ω cable to leading edge discriminators.[7]

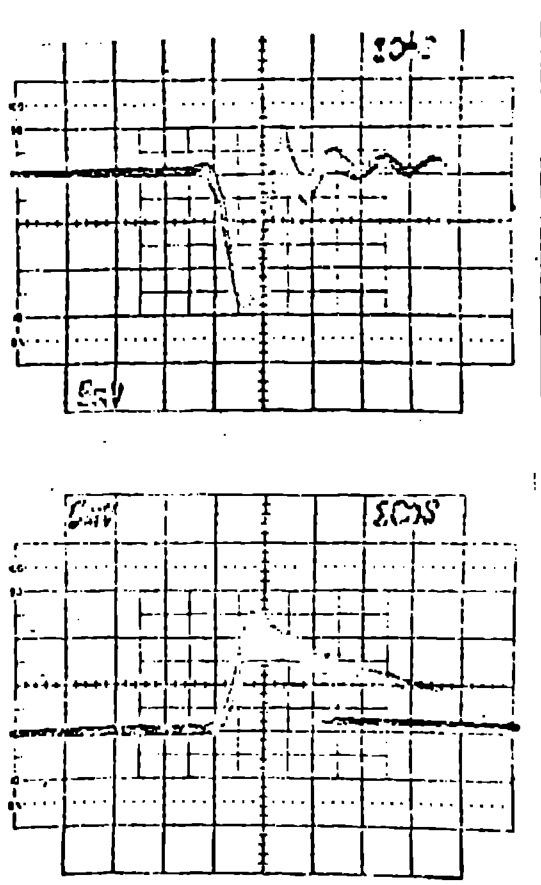

Fig. 1: Direct pulses from a chamber obtained using an ^{55}Fe source. Top (anode). Bottom (cathode).

Threshold levels, referenced to the input, of 0.5 to 1.0 mV are typically used. The NIM level logic signals from the discriminators are transported through up to 200 m of 50 Ω coaxial cable to counting houses where they are regenerated and used in trigger logic and as steps for a multichannel CAMAC time-to-digital converter, TDC.

Computer Processing

The digitized time information is read into a computer where time sums (t_s) and time differences (t_d) are formed from the signals from each delay line. Time differences are used to measure the position and time sums are used to measure the drift time for each event.

Count rate losses and inefficiencies can be monitored by subtracting the anode t_s from the cathode t_s to form the time sum check, t_c. A typical histogram of this quantity is shown in Fig. 2 below.

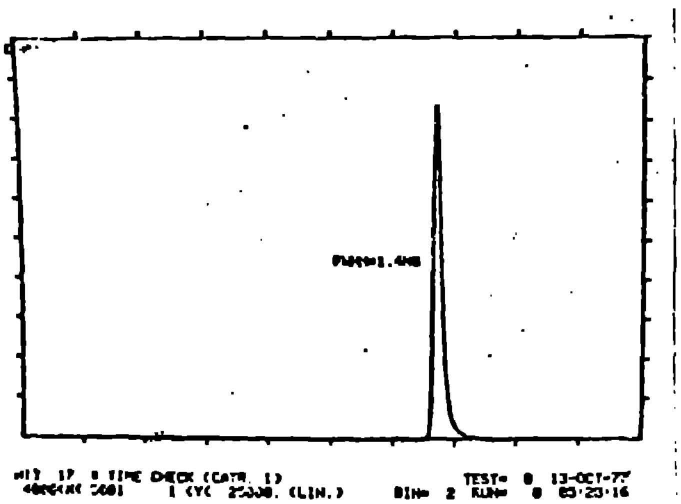

Fig. 2: Time sum check for a 60 cm x 10 cm delay line chamber.

This procedure cancels drift time and uncertainties in the starting time for the TDC, providing a sharp time peak (about 1-2 ns FWHM) at a time equal to the difference in the anode and cathode delay line lengths.

The time sum check can also be used to correct the time difference (position) for effects due to linear attenuation and dispersion in the delay lines. In this approximation, the time sum and consequently the time sum check do not depend on the position of the event in the chamber but only on the pulse height. Consequently, the time sum check can be used to correct the time differences for the effects of time walk for pulses away from the center of each delay line. The form of this correction is illustrated in Figs. 3 and 4. The improvement in resolution near the edge of the chamber is nearly a factor of 2.

Drift Chambers

Position information can be obtained from the anode direction of a chamber by using the drift time information.[8,9] For each event, the wire number is obtained from the t_d and the drift time can be obtained from t_s if a prompt scintillator signal is used as the start for the TDC. A histogram of the t_s for a chamber is shown in Fig. 5.

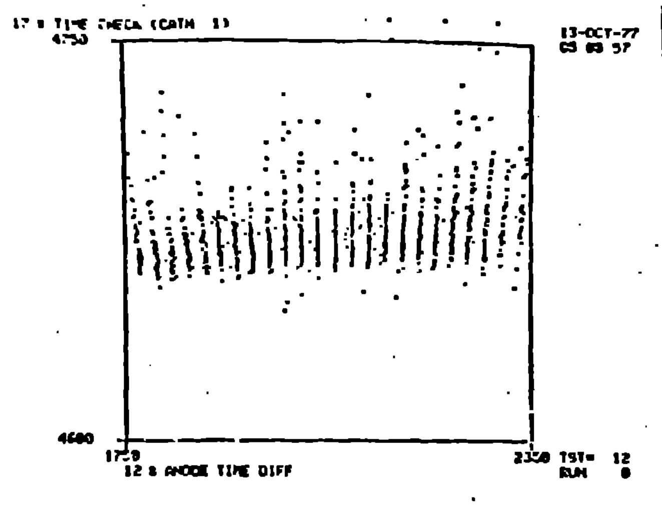

Fig. 3: A scatter plot of t_c vs t_d for the anode of a 60 cm x 10 cm chamber. The vertical axis is t_c and the horizontal axis is the anode t_d.

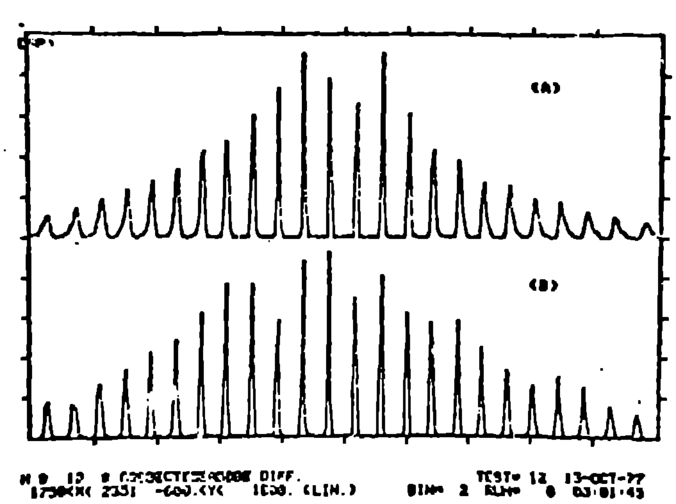

Fig. 4: Top: A histogram of the projection of t_d from the previous scatter plot. Bottom: A histogram of the corrected $t_d' = t_d(1.+k(t_c-t_{c0}))$ where k and t_{c0} are constants which have been adjusted to give the best resolution for wires away from the center of the delay line.

This time information can be calibrated to give position information by uniformly illuminating the chamber, and by assuming the t_s spectrum represents a uniform position distribution with a width of half the anode wire spacing. A drift distance histogram results as seen in Fig. 6.

Deciding whether to add or subtract the drift distance from the wire location requires the use of two closely spaced offset anode planes. Also, if the trajectory divergence is large, it is necessary to use angle information to avoid having ambiguous regions near the wires. The focal plane region of the EPICS spectrometer includes two chambers with 8-mm anode wire separation, offset by 4 mm, and separated by 8 mm, and a third chamber located 50 cm downstream for measuring angles. Each chamber has an active area of 90 cm x 30 cm.

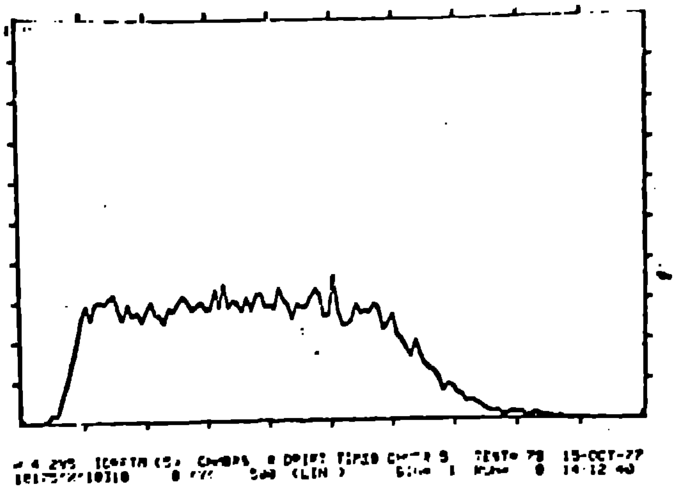

Fig. 5: A histogram of the time sum for a chamber with a 90-cm length with 8 mm anode wire spacing (112 anode wires).

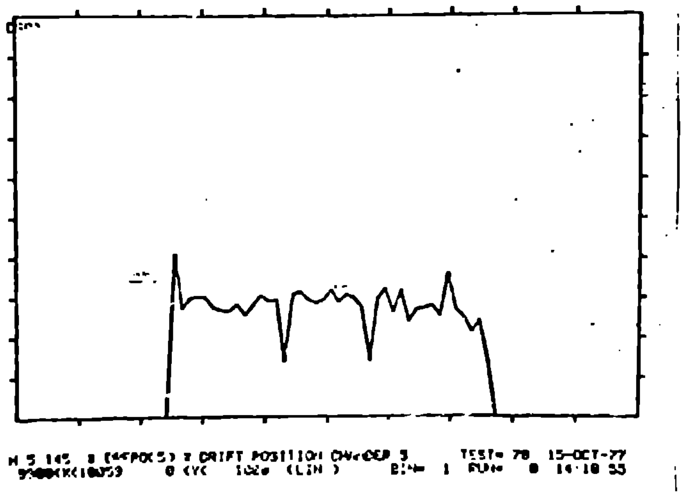

Fig. 6: Drift distance histogram. This figure shows a uniform position distribution of 4 mm width.

Using the drift information from the first two chambers, and the full beam exiting from the spectrometer (90 cm x 200 mrad x 20 cm x 100 mrad) results in the position error histogram shown in Fig. 7. The FWHM resolution is the distribution of the difference between the projections of the positions from the two chambers to a plane lying between them. Included in this resolution of 0.5 mm are timing uncertainty (which is correlated between the two chambers and enters with a factor of two), angle uncertainty, and nonlinearities in the drift time to distance conversion, all averaged over the full extent of the beam. When the known angle uncertainty is removed, the single chamber resolution is better than 0.34 mm, a figure which is close to that obtained from drift chambers with individual wire readouts.

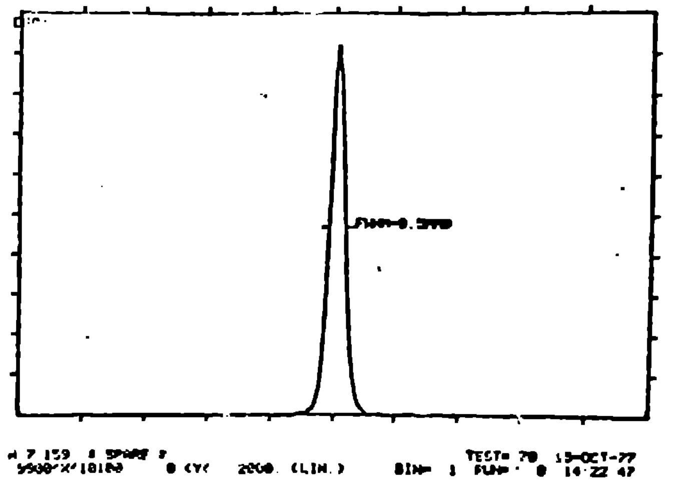

Fig. 7: Error histogram obtained between two drift chambers near the EPICS focal plane.

Conclusions

Chambers which provide inexpensive, accurate, and reliable position information with resolving times comparable to the intrinsic resolving times of multiwire chambers where each wire is independently read out by its own discriminator have been constructed. The position resolution obtainable from the anode plane of the chambers is better than 0.3 mm (FWHM) when the drift time is used. For the cathode direction, position resolution better than 0.5 mm (FWHM) has been obtained for cathode wire lengths less than 30 cm. For cathode wire lengths of 90 cm, position resolution of less than 3 mm (FWHM) has been obtained.

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