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TITLE: DELAY LINE READOUT OF ANODE PLANES IN PROPORTIONAL CHAMBERS

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1. Introduction

Electromagnetic delay line techniques for reading out one position coordinate of charged particle tracks in multiwire proportional counters have proved to be very successful¹⁻³). Generally, these techniques have been applied to reading out the position of the positive pulse induced on the cathode plane, and hence yield the particle coordinate parallel to the anode wire direction¹⁻³). In order to obtain the perpendicular coordinate one must, in general, determine which anode wires were active in producing the signal. In the past this has been done usually by individual readout of each anode wire by means of a separate circuit attached to each anode wire. This generally leads to complex and expensive anode readout systems. The application of delay line techniques to reading out the anode signals is an obvious way of simplifying anode readout problems. With such techniques most of the instrumentation necessary for readout can be assembled from standard CAMAC and NIM electronic modules.

We have developed an extremely simple type of delay line for reading out anode signals and which requires extracting signals at only two points, at each end of the delay line. Signals are then processed in the same way as has been done with monofilar helical cathodes³). Hence, the time difference between these two signals is proportional to the active anode wire position, and can be measured with standard time digitization techniques.

2. Qualitative design considerations

The scheme we have adopted is illustrated in fig. 1. The anode delay line is a cylindrical helix and the anode wires are soldered directly to the

helix at regular intervals. The anode wires behave like lumped capacitances so the net result is a distributed parameter delay line periodically loaded with lumped capacitances to ground and to the cathode helix. In order to avoid excessive dispersion, the lumped capacitances must not be large compared to the total distributed capacitance between anode wire connections.

The delay line, although cylindrical, is designed to simulate a flattened helix which, in the ideal case, has no dispersion³). This is done by making the spacing between the helix and the conducting tubular core small compared to all other dimensions. We have used a thin (127 μ m) polyethylene sheet insulator for this purpose. The grounded aluminum tube simulates the ground plane of the flattened helix.

The helix was wound with copper wire thick enough so that the frequency dependent resistance due to skin effect did not unduly degrade the pulse rise time. For the same reason, we found that it was very important to use a low-loss dielectric such as polyethylene to separate the helix from the conducting core. An attempt to use wire insulated with polyvinyl chloride yielded a helix whose pulse rise time was excessively degraded during propagation through one pass of the delay line.

Even though, in principle, a flattened helix has a frequency dependent characteristic impedance, that of the helix described here is essentially independent of frequency over the frequency range of interest³). The reason is the low value of a/p , where a is the spacing between helix and ground and p is the helix pitch. For small values of a/p , the characteristic impedance is given approximately by ³⁾

$$Z_0 \approx 377 a/p \Omega.$$

Because of the constant value of Z_0 for our delay lines, the lines are easily terminated in simple resistances in contrast with the monofilar cathode helices described in ref. 3.

As shown in fig. 1, we have made our chambers with helical cathodes in order to provide two-dimensional readout. There is capacitive coupling between the cathode helix and the anode wires and consequently some of the positive cathode signal is coupled capacitively to the anode wires. This signal appears on the output of the anode delay line as a small positive signal which begins promptly and last as long as there is a signal on the cathode helix. Since the anode signal is negative and we use negative leading edge timing, the positive signal has very little effect on the operation of the chamber.

3. Construction details

We have constructed and tested chambers of two different types, both with monofilar helical cathodes. One was of the type shown in fig. 1, with the anode plane on the midplane of the cathode helix. The other was designed for detection of low energy α particles, and required an entrance side unobstructed by a helical cathode. Hence, the entrance side had a simple planar cathode consisting of a sheet of aluminized mylar 6 μm thick plus 1 μm of aluminum on both sides. One side of a flattened helix wound around a solid aluminum ground plane comprised the other cathode, as is shown in fig. 2.

In both cases the anode helices were wound from 0.644-mm-diam tinned copper wire with a pitch of 1.5 mm onto aluminum tubes but insulated from

the tubes with sheets of polyethylene 0.127-mm-thick. The tube for the first chamber was 3.8 cm-diam and that for the α chamber was 5.1 cm-diam. The anode wires were directly connected to the helices by soldering connecting wires with uniform spacings. The delay per anode wire was 1.27 ns in the first chamber and 1.7 ns in the α chamber. Before connecting the anode wires, the measured impedance of each delay line was approximately 100 Ω . After connecting the anode wires, the impedance of both lines dropped to approximately 50 Ω . Each chamber assembly was placed in an aluminum box with entrance and exit windows consisting of mylar foils, and the aluminum tube was electrically connected to the aluminum box.

Signals were taken from both ends of the anode helix and fed through 50 Ω cables to fast amplifiers, fast discriminators, and then to a time-to-amplitude converter and multi-channel analyzer. Preamplifiers were not necessary because of the 50 Ω impedance of the helix. All of the electronics were noncritical commercial items.

4. Results

Photographs of anode delay line pulses taken from both chambers, with an ^{55}Fe source, are shown in fig. 3. The pulses from the symmetrical chamber were taken directly from the anode helix since the high voltage was applied to the helical cathode. However, the α chamber had high voltage applied to the anode because the cathode consisted on one side of an aluminized mylar film to which it would have been inconvenient to apply high voltage. Consequently, the anode helix signals were obtained through coupling capacitors which differentiated the signals. This resulted in a pulse risetime which was shorter from the α chamber than from the symmetrical chamber, as can be

seen in fig. 3. The initial risetime as measured with the active anode wires at one end of the anode helix for the symmetrical chamber is approximately 8 ns while that from the α chamber is approximately 5 ns. After delays of 40 ns, the risetimes have been degraded to approximately 12 ns and 9 ns, respectively.

Fig. 3 also shows clearly the effects of the cathode-to-anode coupling by the presence of the precursor signals arriving prior to the main pulse. These are oscillatory but with a positive bias so the discriminators can easily be made to trigger only on the negative-going main pulses. The precursor from the alpha chamber is only about half as large as that from the symmetric chamber. This is a consequence of the cathode helix surrounding the anode in the latter case but not in the former, as was discussed above.

The overall performance of the chambers was measured using an ^{55}Fe source which illuminated many anode wires simultaneously. The spectrum of differences between the arrival times of the pulses at the two ends of the anode helix then determines the active anode wire location within the resolution of the system. Such spectra are shown in figs. 4 and 5. The symmetrical chamber had 53 anode wires but only 50 peaks in the spectrum were recorded, the three peaks at the upper end being missing in this particular spectrum. The α chamber had 31 wires and all peaks were recorded.

In the α chamber spectrum of fig. 4, the peak separation is 3.4 ns and the best resolution is 0.435 ns fwhm. In the symmetrical chamber spectrum of fig. 5, the peak separation is 2.54 ns while the best resolution is 0.50 ns, slightly worse than that of the α chamber. Furthermore, the resolution of the symmetrical chamber is degraded more severely at the ends of the spectrum than that of the α chamber. This is presumably due to the slightly

longer risetimes of the pulses from the symmetrical chamber together with the larger precursor signals.

The extreme simplicity in simultaneous readout of both cathode and anode planes using delay line techniques leads to economical and convenient two-dimensional readout. They were developed for use in the high resolution pion spectrometer at the Los Alamos Meson Physics Facility (LAMPF). One of the first applications of such chambers however, has been in tuning up secondary particle beams at LAMPF, where they have been used for obtaining two-dimensional beam profiles. Delay line readout of the anode planes should simplify proportional chamber systems in most other applications as well.

Figure Captions

1. Sketch of cylindrical anode delay line with anode wires directly connected. Also represented is the cathode helix for two dimensional delay line readout.
2. Cross-section of α chamber. A flattened helix serves as the exit cathode plane while the entrance cathode plane consists of a thin foil of aluminized mylar. The anode delay line is not shown, but is similar to that in fig. 1.
3. Oscillograms of the pulses from the anode helix using an ^{55}Fe source. Horizontal scale, 10 ns/division. Vertical scale, 5 mV/division.
 - a) Symmetrical chamber, source near readout end of helix.
 - b) Symmetrical chamber, source away from readout end.
 - c) Alpha chamber, source near readout end.
 - d) Alpha chamber, source away from readout end.
4. Alpha chamber anode time difference spectrum.
5. Symmetrical chamber anode time difference spectrum.

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DELAY LINE READOUT OF ANODE PLANES IN
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Simple delay lines have been developed for reading out active anode wire locations in multiwire proportional chambers. Anode wire positions are readout using commercial fast logic and time digitization apparatus with no special electronics required.

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