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A DRIFT CHAMBER SYSTEM FOR USE IN A HIGH RATE ENVIRONMENT

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Abstract

A system of short drift distance (0.125") drift chambers is described. This system is being built for use in the Brookhaven National Laboratory Multiparticle Spectrometer. These chambers will be able to handle beam rates of several million/pulse and give a spatial resolution of the order of 150 μm. Cathode readout will provide unique 3-dimensional points for each track. The readout will utilize three custom built integrated circuits, a four channel amplifier-shaper, a four channel discriminator and a four channel shift register delay and time digitizer. A summary of test results on a prototype is also given.

Introduction

The recent history of high energy physics has emphasized the importance of being able to study multibody final states that are produced with very small cross sections, e.g. production of charmed particles and baryonium. To make this type of physics feasible, it is essential to have detectors with large solid angle coverage, high rate capability, and good spatial resolution. In order to provide such a facility we are engaged in building a set of short drift space drift chambers for the Brookhaven National Laboratory Multiparticle Spectrometer (MPS).[1,2] Initially the system will consist of 6000 sense wires, but is expected to ultimately have more than 20,000 sense wires. Short drift space drift chambers are the only presently available detectors that offer the capabilities of handling beam fluxes of several million particles per pulse and giving spatial resolution of the order of 150 μm; capabilities that are essential if we are to measure nanobarn cross section in the presence of large backgrounds. Although the system I will describe in the following sections is specifically for the MPS, its basic features are of interest to a wide range of applications, e.g. ISABELLE, FNAL, SPS, etc. I will first describe the chambers themselves, then the electronics being developed, and finally the results from a test chamber.

Chambers

The chambers will be assembled in modules consisting of 5 anode planes. There will be 3X measuring (dispersion plane in the MPS) planes XXX' (X' shifted by the anode to field wire spacing). This arrangement permits us to resolve in the vast majority of cases the left-right ambiguity inherent in multi-wire drift chambers. In addition to resolving the ambiguity, this arrangement gives a slope and a point for each hit, a significant help for pattern recognition. The other 2 planes measure the Y coordinate, only 2 offset Y's are used since there is little magnetic deflection in the Y direction permiting several modules to be used to resolve the up-down ambiguity. One of the Y planes has cathode strip readout, where the strips are at ± 30° to the horizontal; in this way we get three dimensional points on each track, which hopefully will greatly speed up pattern recognition. Table 1 summarizes the chamber parameters.

TABLE 1

Drift Distance	0.125"
Anode to Cathode Distance	0.250"
Anode Wire	0.001" Dia. Tungsten, Gold Plated
Field Wire	0.003" Dia. Nitronic-50 Stainless Steel
Cathode Wire	0.003" Dia. Nitronic-50 Stainless Steel (20/in.)
Frame Material	Pultrusion, Polyester Fiberglass (Composite)

Figure 1 shows cross sections of a module. The frames are assembled from strips made of a polyester-fiberglass composite,[3] which is formed by pulling the resin fiberglass mixture through a heated die in which the material is formed and polmerized. This material has the glass fibers oriented along the pulling direction, which gives it an elastic modulus (perpendicular to the pulling direction) 2-3 times that of G-10, enabling us to have thin nonconducting frames that do not deflect excessively due to the tension in the wires. Another advantage of this material is that it can be formed into a complex cross section incorporating all the required reliefs, glue grooves, and O-ring grooves eliminating all machining except for bolt holes and lap joints. By slightly modifying the forming procedure the manufacturer can produce material with a

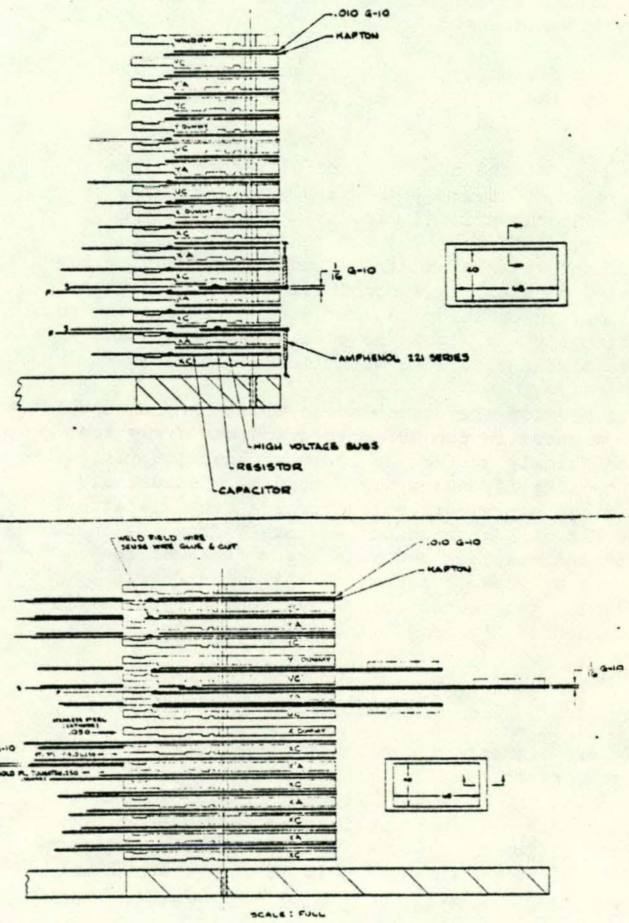

Figure 1 Cross Sections of Chamber Module

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"mirror" smooth surface. Although the tolerance on the absolute thickness is of the order of several mils, the uniformity is excellent, better than 1 mil. This material has already been utilized in the frames of a large trigger proportional chamber, in which the material performed as expected.

Field wires and cathode strips are connected to high voltage distribution buses using thick film resistors (∿ 100KΩ) deposited on the printed circuit. Incorporating the current limiting resistors into the chamber structure itself reduces the stored energy directly connected to the wires and consequently decreases the probability of breaking a wire due to sparking. In an effort to improve the signal transmission properties of the anode wires, we incorporate bypass capacitors into the printed circuit at both ends of the field wires and cathode strips (except for the cathodes that are used to detect induced signals). These capacitors are made by using kapton film with copper laminated on both sides for the printed circuits. Incorporation of the current limiting resistors and the bypass capacitors directly as part of the chamber frames simplifies the construction and structure of the chambers.

We are presently developing an automatic spot welding machine to make the electrical connection between the wires and the printed circuit pads.

Because of the need to carefully control the thickness of the frames, dry film adhesives will be used to bond the printed circuit material to the frame. Dry film adhesives are readily available in 1 to 2 mil thicknesses and are activated by heating for just a few minutes; this combination of characteristics affords us, in addition to very good thickness control, rapid assembly and almost no post assembly cleanup in contrast to the situation with liquid adhesive.

The modules are assembled on aluminum plates which will be mounted in the MPS magnet in such a way that they can quickly be removed and then accurately repositioned to simplify servicing a module. Because of restruction in the vertical clearance, the electronics for the X's will be mounted separately from the anode frame on the upstream and downstream faces of the module and will be connected to the anode frames by short cables and connectors. Electronics for the Y's and the cathode strips will be mounted directly on the frames.

Electronics

We are presently developing three integrated circuits to perform the function of amplifier, discriminator, delay and time digitization. These circuits will give us 4 ns time quantization, ∿ 1 μsec delay and digitization full scale, and a threshold of approximately 0.5 μamps all at a cost of \$6-7/channel in $\geq$ 100,000 quantities.

Separate packages for the amplifier and discriminator were chosen to give better isolation between input and output and to maximize the usefulness of the circuits. These circuits are being developed by LeCroy Research Systems, and prototypes are expected within the next year. Figure 2 shows the configuration of the amplifier and discriminator. Two different ways of using the discriminator are shown; the first is used for straightforward drift chamber use. The second is to be used to give three levels of amplitude discrimination which would permit measurement of dE/dx. Table 2 summarizes the specifications of the amplifier and discriminator.

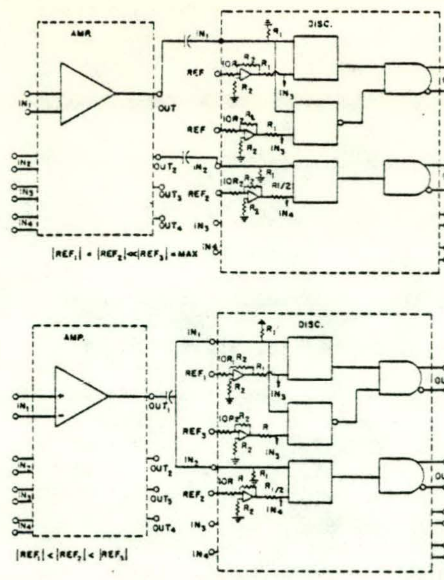

Figure 2 Functional Schematic of the 4-channel amplifier-shaper and discriminator, connected to determine drift time only (top) and the combination of drift time and dE/dx (bottom).

TABLE 2

Number of Channels/package	- 4
Amplifier Transresistance	- 50 KΩ
Input Impedance	- < 50Ω
Input Noise	- < 0.25 μa rms
Risetime	- < 4 ns
Overload Recovery	- < 40 ns for 30 ns wide 100 μA pulse
Input protection	- discharge of 100 pf capacitor charged to 3 KV
Discriminator time slewing	- < 4 ns for 2X-20X threshold
Hysteresis	- 6 mv
Threshold	- 0 to 500 mv
Threshold match	- ± 5 mv
Crosstalk between channels	- > 40 db down
Output	- low: 1.5 volt high: 3.5 volt 3 ns risetime

The digital delay and time digitizer is made from a static 256 bit (effective) shift register, which can be clocked at an effective speed of 250 MHz. In this system the output of the discriminator is continually shifted down the register until an appropriately timed trigger is generated which stops the clock; the data in a segment of the register is read out and then the clock is restarted to shift in new data. In order to maximize the versatility of the circuit, the length of the segment that can be read out will be controlled by an external device and could, if desired, include the entire register. This circuit is being built by RCA using CMOS/SOS technology which offers high speed, low power consumption, high density, and low cost; prototype delivery is approximately one year.

CMOS/SOS is not presently capable of operating at 250 MHz, but by using a four-phase clocking system, each clock being 62.5 MHz and having 90° relative phase shift, clocking four 64 bit shift registers, we achieve the same effect. External to the package the only difference between a one-phase and four-phase system is the necessity to provide the additional two clock inputs; all other inputs and outputs are the same.

Readout speed is restricted by the ability of the output device to drive a capacitive load to approximately 25 MHz. Table 3 summarizes the specifications of the digital delay.

TABLE 3

Channel/package	- 4
Maximum clock speed	- > 65 MHz
Maximum readout speed	- > 20 MHz
Data setup time variation within a channel	- ± 1 ns
Data Input	- Differential
Clock Input	- C_1, $\bar{C}_1$, C_2, $\bar{C}_2$
Logic Levels (except data)	- Low 0.5 ± 0.5 volts High 4.5 ± 0.5 volts
Data Logic Levels	- Low - 1.5 volts High - 3.5 volts

Figure 3a shows the logic diagram for a single channel; Figure 3b is the diagram for a package. Only 2 clocks are drawn because $C_3 = \bar{C}_1$ and $C_4 = \bar{C}_2$. Also

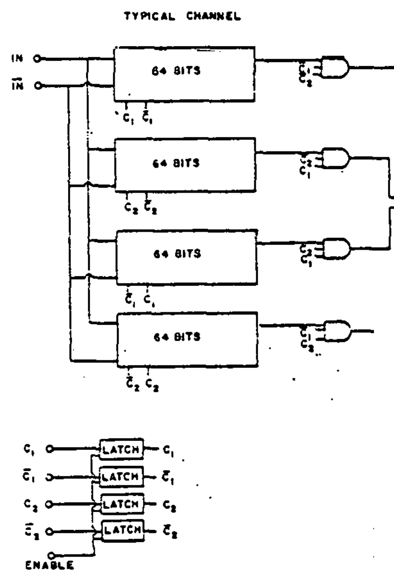

Figure 3a

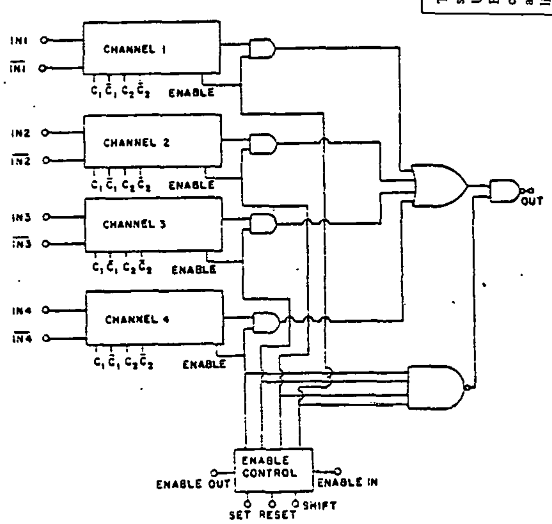

Figure 3b

Figure 3
Functional schematic of digital delay and encoder:
a. Single channel
b. 4-Channel package.

it is assumed that it will be possible to gate the clock to the first stage of the shift register and maintain the setup time variation specification; otherwise it will be impossible to read out the first bit in each register which is not a serious restriction. An open drain (or its equivalent) output will be used so that several packages (up to 32) can be wire or'ed together for readout.

In the MPS system we expect to have a readout controller for each group of 500 wires, which when reading out 32 bits/wire at 25 million bits/second with all controllers operating in parallel gives a total readout time of 650 μs. These controllers will initialize the system by setting the enable controls so that all channels can read in data and turn on the fast clocks. When a preliminary trigger is generated, the controller will stop the fast clocks, holding the data until a final trigger is formed and the readout cycle started. A readout cycle consists of resetting all the enable controls, shifting a one into the first enable control shift register and starting the readout clock, which reads out the first channel. When the desired number of bits (32 for the MPS) have been read from the first channel, encoded and stored in cache memory, the one is shifted to the next channel, enabling the readout of channel 2; this process is repeated until all channels in a given subsystem have been read into the controller. Data from the cache memory is transferred to main data storage, and the system is ready to be reinitialized. If, on the other hand, no final trigger was formed, the fast clock would be restarted.

Although these three integrated circuits are being developed as a complete system, they should as individual components prove useful generally in high energy physics experiments.

Test Results

As an initial step in the development of this system, we have built a small prototype chamber with 3 planes X'XX to test different gases and prototype electronics constructed utilizing existing circuits. The test chamber is similar to the proposed chambers except it has a drift distance of 0.1 inches and 0.0007 inch diameter anode wires.

Since this system will be incorporated into a major facility that is often operated by physicists with limited experience with the system, it is essential that the gas used in the chambers be chosen to give stable operation, safety, long chamber life, and ease of data processing. Measurements of efficiency and drift time vs. distance and a preliminary estimate of the spatial resolution have been made for mixtures of 80% Ar/15% C_4H_{10}/6% Dimethoxymethane, 80% Ar/20% CO_2, and 78% Ar/15% CO_2/5% C_4H_{10}/2% Dimethoxymethane.

Efficiency measurements were made in a high energy pion beam that was uniform over the one inch wide active region defined by scintillators. A typical high voltage plateau curve for the Ar-C_4H_{10}-Dimethoxymethane mixture is shown in Figure 4a and for Ar-CO_2-C_4H_{10}-Dimethoxymethane in Figure 4b; similar curves are obtained for a wide range of field wire high voltages. An efficiency of ∿ 100% is obtained over a many hundred voltage range of cathode voltage, a significant operating convenience. Ar-CO_2 has a very small plateau ∿ 100V, a distinct limitation in our system. Measurements made in conjunction with those of drift time vs. distance indicate that the efficiency is uniform across the drift cell.

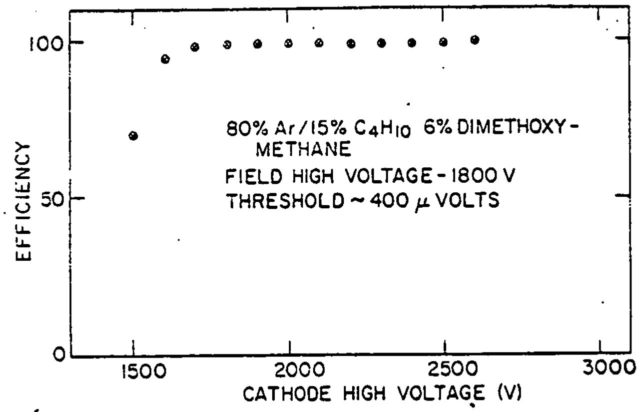

Figure 4a

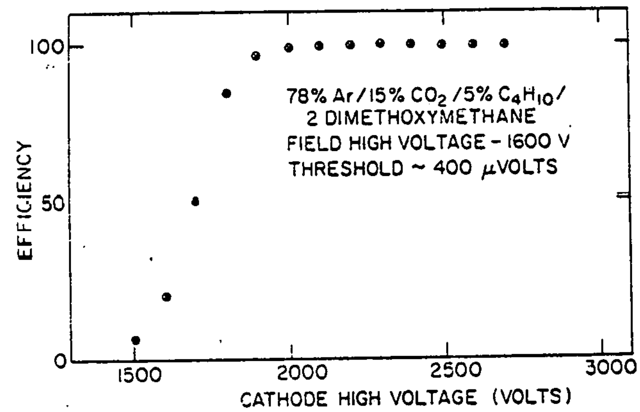

Figure 4b

Figure 4

High voltage plateau curves using:

a. 80% Ar/15% C_4H_{10}/6% Dimethoxymethane

b. 78% Ar/15% CO_2/5% C_4H_{10}/2% Dimethoxymethane

In order to measure the drift time vs. distance relationship we used a single wire proportional chamber mounted on a translation stage to define a narrow beam (~ 350 μm FWHM). Drift time was measured using a LeCroy "QVT" multi-channel analyzer started by the coincidence between scintillators, single wire chamber, and the drift chamber and stopped by the drift chamber output. Figure 5 shows the results for the Ar-C_4H_{10}-

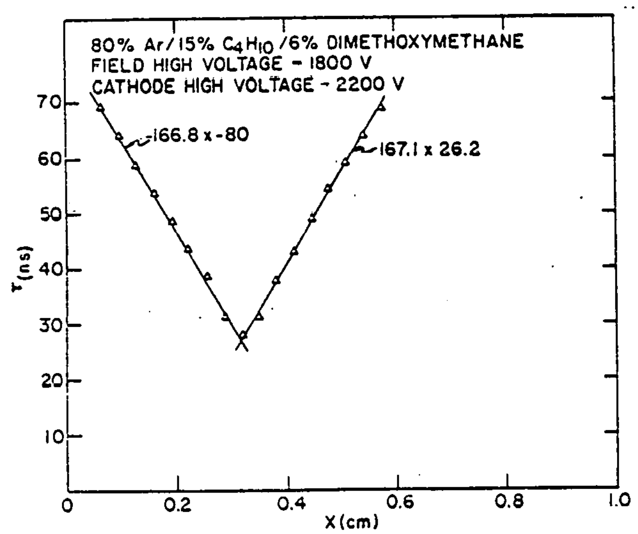

Figure 5a

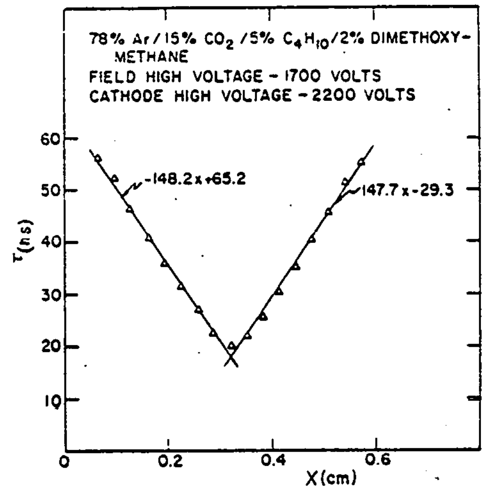

Figure 5b

Figure 5

Drift time vs. distance using:

a. 80% Ar/15% C_4H_{10}/6% Dimethoxymethane

b. 78% Ar/15% CO_2/5% C_4H_{10}/2% Dimethoxymethane.

Dimethoxymethane and Ar-CO_2-C_4H_{10} Dimethoxymethane mixtures, from which we see that both gases have reasonably saturated drift velocity over the drift space (the deviation at the anode wire in the Ar-CO_2-C_4H_{10}-Dimethoxymethane corresponds to only ~ 100 μm). Both gases have satisfactory linearity for use in this system, in addition the Ar-CO_2-C_4H_{10}-Dimethoxymethane has a significant safety advantage.

An estimate of the resolution was obtained by starting a coincidence of the output from one drift chamber plane and the scintillators and stopping the "QVT" with the output of one of the other planes. This method is limited by the uncertainty in the time resolution of the coincidence (estimated 1 ns rms), divergence of the beam, and misalignment of the beam and the chamber. Table 4 gives the estimated resolution for the three gases along with the average inverse drift velocity.

TABLE 4

Gas	Ar/C_4H_{10} Dimethoxymethane	Ar/CO_2/C_4H_{10} Dimethoxymethane	Ar/CO_2
σ	50 μm	80 μm	120 μm
dt/dx ns/mm	16.7	14.8	14.1

In conclusion we are building a drift chamber system that will not only significantly improve the ability of the MPS to measure small cross sections in the presence of large backgrounds, but will also serve as a prototype of the type of detectors required at ISABELLE. In building this system we are developing new chamber materials and are developing three custom integrated circuits that perform all detection functions. Preliminary gas mixture tests indicate that an Ar-CO_2-C_4H_{10}-Dimethoxymethane mixture offers a satisfactory combination of properties.

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3. Creative Pultrusions, Bedford, Pennsylvania.