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DELAY WIRE CHAMBERS

A USERS GUIDE

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Abstract

The 15 year old blue Delay Wire Chambers are being requested more and more often for short term installations in CERN's secondary and tertiary beam lines. To meet the demand for this type of Multi Wire Proportional Chamber, the mechanics and the electronics, which had been very hard to maintain, have recently been modernised and the present description is meant to guide physicists in the use of these new Delay Wire Chambers.

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1. Introduction

In the early eighties the Delay Wire Chamber, a new type of the Charpak Multi Wire Proportional Chamber [1], was developed in the Beam Instrumentation group at CERN.

In order to improve the space resolution of the classical Multi Wire Proportional Chamber, several interpolating readout techniques had been studied [2]. The chosen technique in the Delay Wire Chamber [3], was to use a delay line to interpolate between the cathode wires. This had the positive side effect of simplifying the data acquisition. The Delay Wire Chambers featured high resolution (0.2 mm), simple mechanical and electronic design, single particle detection at 2×10^5 particles per second and low cost.

These chambers, which are still in high demand by the physicists, have recently undergone an upgrade of their mechanics and local electronics (the latter being obsolete for several years due to special components no longer available on the market).

The design of the Delay Wire Chamber is now simple enough to permit standard series production in industry.

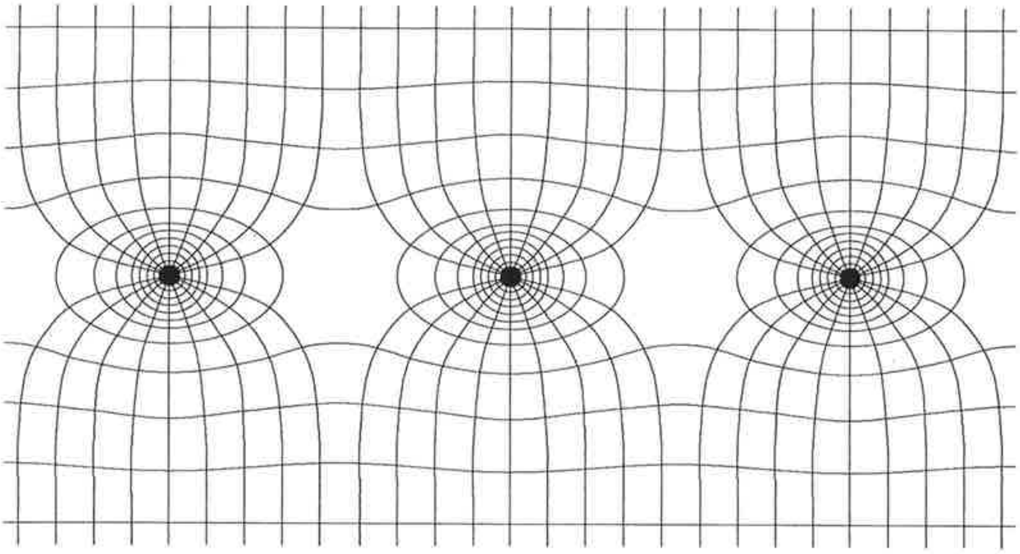

Figure 1. Avalanche is made possible by the strong electrical field around the thin anode wires.

2. How does it work

The Delay Wire Chamber works like any other Multi Wire Proportional Chamber, in the sense that a particle passing through the chamber will ionise the gas and create free electrons and positive holes. The high voltage between anode and cathodes then accelerates the electrons towards the 20 micron anode wires, where avalanche multiplication takes place (figure 1). At the same time an image current is induced in the cathode wires closest to where the anode avalanche took place [5].

Like most Multi Wire Proportional Chambers, the DWC is composed of a sandwich of two cathode planes surrounding a central anode wire-plane. The specificity of the Delay Wire Chamber is that the position information is not taken from the anode wires but from the cathode where individual wires are connected to a tapped delay line (figure 2). In turn the induced signal from the cathode wires builds up two waves in the delay line, one in each direction. These travelling waves are the sum of the contribution from the different cathode wires, added up according to the delay per tap of the delay line (figure 3).

By using the anode signal as a common start and measuring the time delays for the integrated waves to reach the amplifiers at each end of the delay line, the impact point (where ionising took place) can be determined with a resolution about ten times better than the wire spacing.

A second sandwich of cathodes and anode placed orthogonally in the same housing, constitutes the other plane to give a full two dimensional position reading.

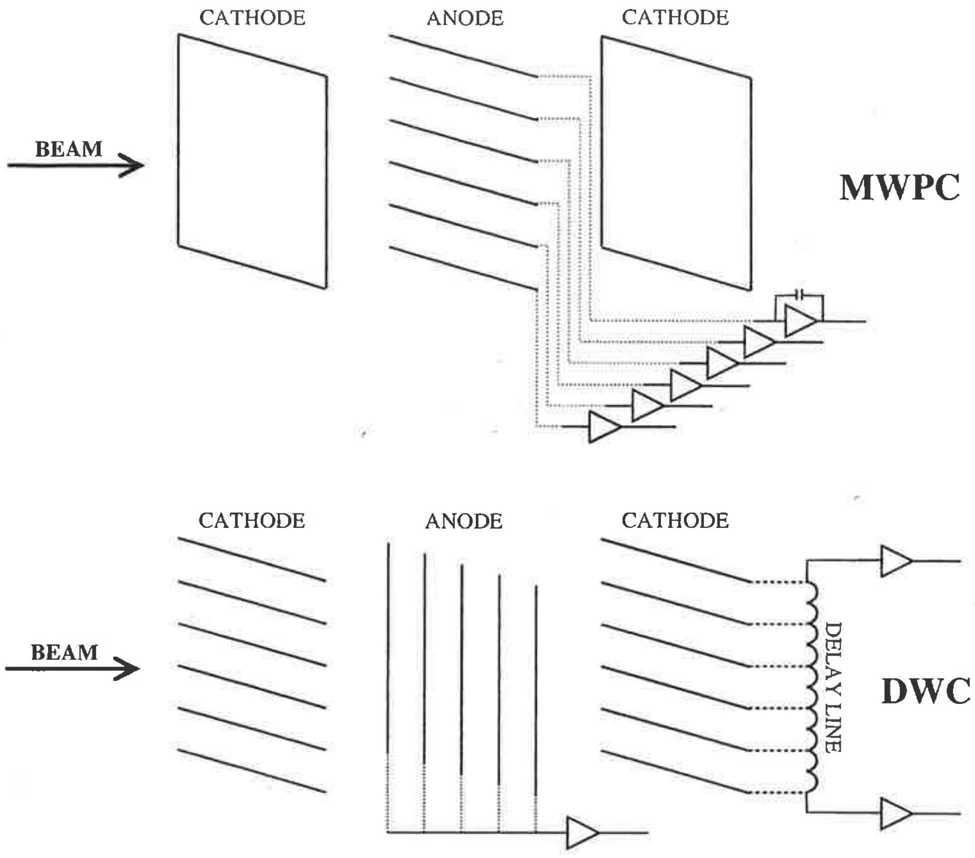

Figure 2. Standard MWPC read out against DWC read out.

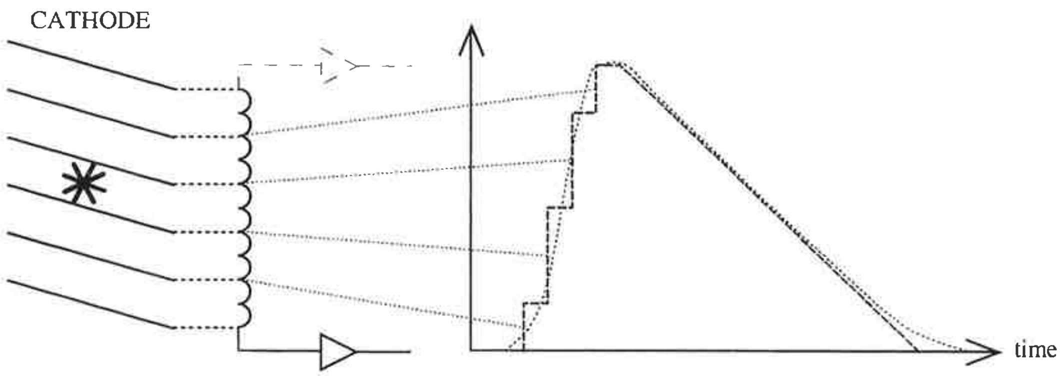

Figure 3. The travelling wave is built up by adding up the single inputs in the delay line.

3. How to read it out

For the permanently installed Delay Wire Cambers on the beam lines, the relevant data can be accessed through the physicist TREE-program [6] currently written in Nodal.

The cathode signals from these chambers can also be obtained via separate NIM outputs from the local discriminator in the black box directly on the chamber support. In this case the data acquisition should be accomplished by your own Time to Digital Converter (TDC) after reshaping the signals in the users barrack. The Lecroy LRS4208 (for Camac) or the CAEN V488 (for Vme) can be recommended, but other TDC's with a time resolution better than 1ns can also be used.

In the case of a 'private' self installed chamber (chapter 5), a discriminator with a threshold of –30mV should be inserted in between the chamber and the TDC, and it should be located close to the chamber if the latter is more than 30 metres away from your electronics. The use of a differentiating zero crossing discriminator may slightly enhance the precision of the position measurement at the extremities of the chamber.

For the TDC you need a common start signal, typically derived from a scintillator trigger, an anode signal or an interesting event from your experiment. Once the four time delays: from the common start to the left; right; up and down stop-signals, have been measured by the TDC, the absolute position of the incident particle can easily be calculated from the following formula:

X-position = (timeRight – timeLeft) x horizontalSlope + horizontalOffset

Y-position = (timeUp – timeDown) x verticalSlope + verticalOffset

The absolute position is indicated in millimetres from the centre, the times are in nanoseconds, the slope is approximately 0.2 mm/ns and the offset is close to zero. The slope is a constant given by the delay line, whereas the constant offset is determined by the propagation delay (difference in cable length) and the properties of the chamber electronics.

To know the slope and the offset with precision for a given set-up, a calibration is needed.

4. How to calibrate it

In order to calibrate a Delay Wire Chamber, three calibration inputs have been foreseen. A test signal, simulating a spill of particles at the same position, can in this way be applied from a portable or a fixed test generator. A portable DWC test generator can be borrowed from the SL/BI group. This dedicated test generator supplies a trigger signal at NIM level, to be used as a common start for the Time to Digital Converter, as well as the beam-simulating signal. This test signal has a triangular positive shape with a rise time of 10 ns, a flat top of 20 ns and a fall time of 60 ns. The amplitude should be 40 mV in 50 ohms and the repetition rate some 10 kHz. The battery operated DWC test generator switches on automatically when the trigger output is loaded with 50 ohms. This excitation results in six negative 80 mV output pulses from the chamber, four of which are from the cathodes and two from the anodes.

Three series of data acquisitions with the TDC, while exciting the chamber at: –30 mm; the centre and at +30 mm, give you three reference points (figure 4). The best linear fit through these three points along with a good coefficient of determination, gives you the slopes and the offsets, which for a given set-up are constant over time.

The theoretical 0.2 mm/ns slope and the zero offset can now be replaced by the measured values in the position formula above.

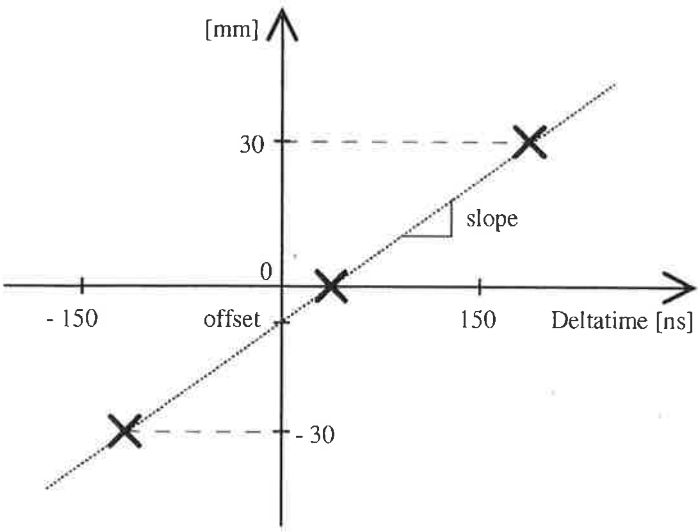

Figure 4. Calibration principle.

5. How to install a 'private' chamber

The following description of the possibility to install a 'private' Delay Wire Chambers, can not be taken for granted as a service function of the SL/BI group. However, the groups responsible for the beam instrumentation infrastructure may, as a secondary priority, be willing to lend out some of the equipment mentioned below.

Although many of our fixed target beam lines are already equipped with Delay Wire Chambers with permanent read out facilities, a request can be made for a chamber on loan for a specific short term installation. To install such a chamber you typically need: a support; a gas supply; a chamber; a high voltage supply and a low voltage supply.

We normally use the standard purple support and the standard Argon/Carbon-dioxide gas mixture supplied for other Multi Wire Proportional Chambers by the SL/EA group. For the Delay Wire Chamber itself, a limited number are available on loan from the SL/BI group. Finally the Danfysik 3 kvolts high voltage supply and the bipolar 6 volts supply may be obtained on lease from the ECP/ESS electronics pool.

The use of the non-explosive Argon (50 %) / Carbon-dioxide (50 %) gas mixture, makes the chamber very safe to handle. Other 'magic' gas mixtures may be used to enhance the chamber gain, but the Argon/CO2 is a good compromise between inoffensive gases and the gain [4]. In principle a Multi Wire Proportional Chamber using inorganic quenchers like our Delay Wire Chamber does not consume the gas, but to be sure that air does not enter a small gas flow of a few cubic centimetres per minute is recommended. A differential pressure monitor with an alarm contact, indicating the correct flux of the gas in the chamber, can be supplied with the chamber if needed. Care should be taken not to block the gas exhaust from the chamber, as this will cause the kapton windows to blow up.

When putting a chamber into operation, certain procedures must be followed. Primarily the chamber should be left several hours under gas flow before applying the high voltage. Then the high voltage can be gradually increased to 2900 volts while observing that the current remains below 1 microampere. It is healthy for the chamber to limit the high voltage supply to 3000 volts and 100 microampere. Otherwise destructive sparking may occur inside the chamber.

A high voltage scan, using an external scintillator trigger, can now be performed. Starting at 2600 volts and progressing in steps of 50 volts will reveal the high voltage plateau. The optimum working voltage is typically in the region from 2800 to 2900 volts, where the efficiency should be better than 98 %.

In the past many chambers have been damaged by incorrect connection of the bipolar 6 volts supply. Although the new chambers are protected against inversed polarity, the following cabling convention (figure 5) for the two-pin Lemo connector must be observed: the minus 6 volts to pin 1 zero-volt to the shielding and the plus 6 volts to pin 2. The power supply must be stable to within 5 %.

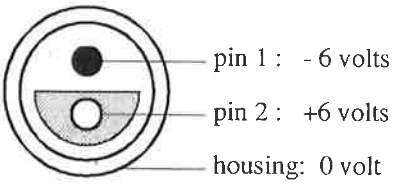

Figure 5. Cabling convention for the cable to be used for the bipolar 6 volts supply.

6. The DWC used as a Spectrometer

In several beam lines a system of four Delay Wire Chambers surrounding a bending magnet constitutes a spectrometer (figure 6). By measuring the trajectory of a particle upstream as well as downstream to the bending magnet, and knowing the field integral, the energy of individual particles can be calculated. The energy spectrum of a particle beam can in this way be observed with the Delay Wire Chamber Spectrometer.

For the last two decades, the X5 and the X7 beam lines at CERN have been equipped with spectrometers based on the classical Multi Wire Proportional Chamber. These chambers with amplifiers on each of the 96 anode wires had a resolution of about one millimetre. As the electronics of this system was completely obsolete, we had the choice either to rebuild the complete data acquisition for this high number of channels or to develop a new spectrometer based on the Delay Wire Chamber. Given the better resolution and the simpler data acquisition of the DWC's, it was decided to equip these two beam lines with new spectrometers based on the updated Delay Wire Chamber, in spite of their lower rate capability.

The functional diagram of the new spectrometer is showed in figure 7. The common start for the TDC is derived from a complex coincidence of the scintillator triggers, anode signals and beam timing signals. The Time to Digital Converter has a FIFO type of memory, making it possible to acquire data with very little dead time and to process the data for a profile or an energy spectrum off-line. After each spill the data is accessible via the Nodal TREE-program [6]. Notice also the user output foreseen on the discriminator installed on the chamber support (figure 7).

The functional diagram for all our other permanently installed Delay Wire Chambers, supplying profiles for beam diagnostics, will be identical to the ones of the new spectrometers as from the 1999 start up.

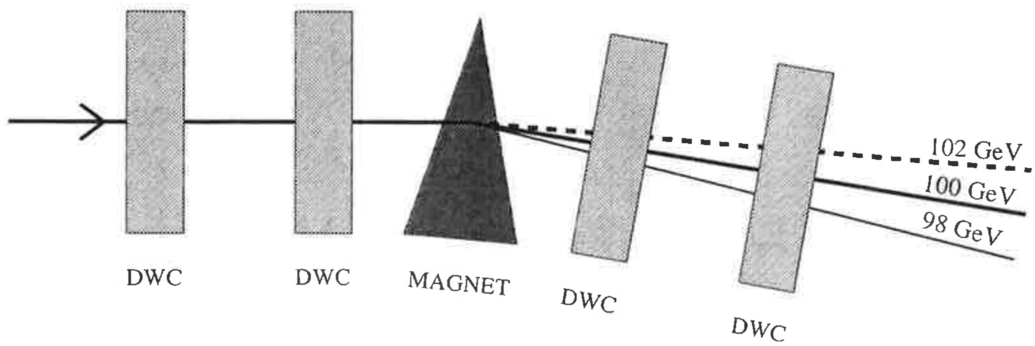

Figure 6. The effect of a bending magnet on particles with different energies.

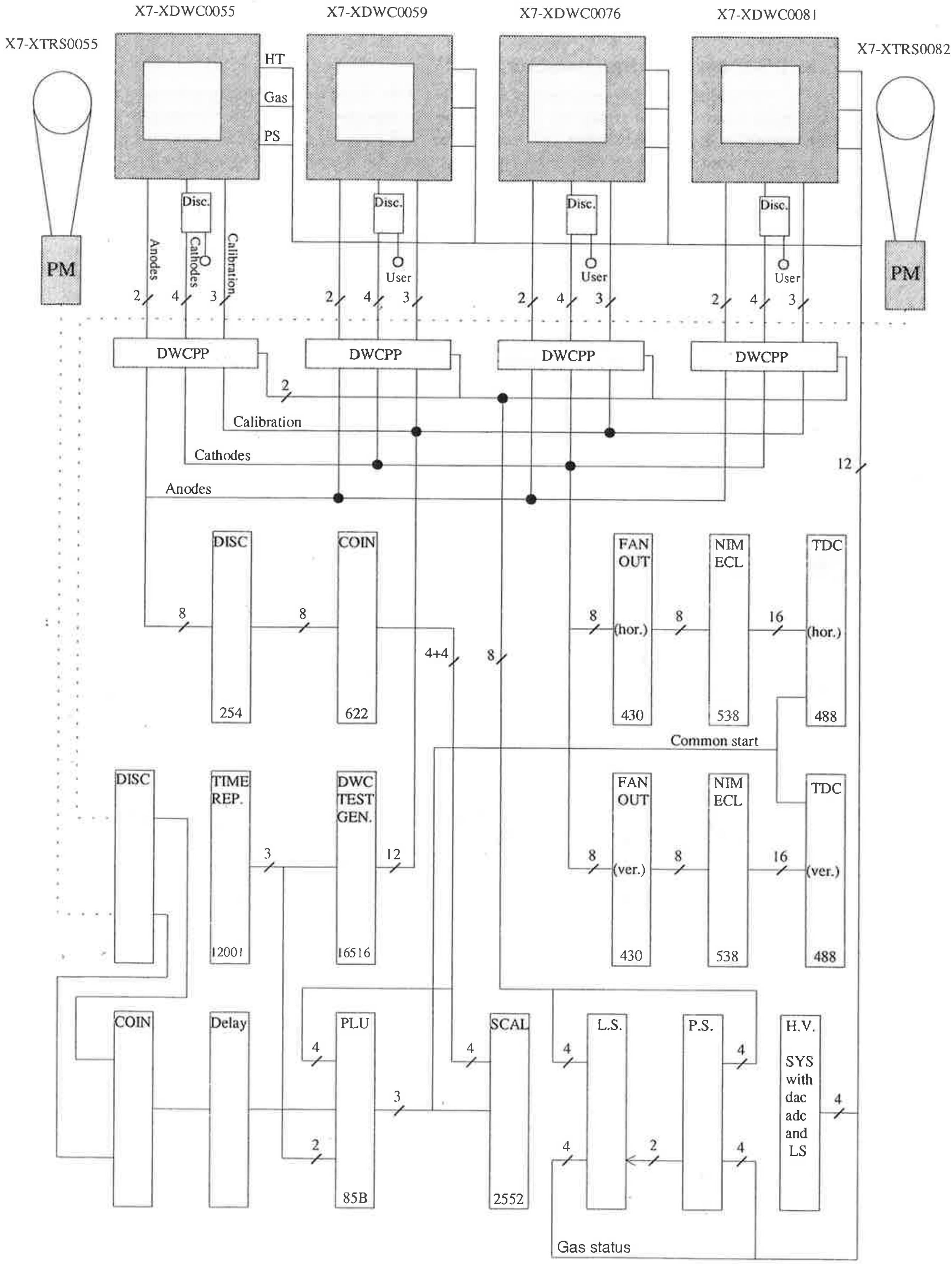

Figure 7. Block diagram of the Delay Wire Chamber Spectrometer on the X7 beam line.

7. Chamber mechanics

The Delay Wire Chamber is built in an aluminium case measuring 220 x 220 x 56 mm^3, with two kapton windows of 110 x 110 mm^2 and a thickness of 25 microns. It contains a sandwich of two (x and y) times three insulated frames (PCB), each 5 mm thick (figure 8) [3]. Fifty-five bronze-beryllium wires of 100 microns, with 2 mm spacing make up the cathode planes, whereas the anode has twenty-eight tungsten gold-plated wires spaced by 4 mm. These wires, only 20 microns thick, are responsible for the avalanche that sets the gain of the chamber.

The two cathode planes, which are perpendicular to the anode, have their wires interconnected via a 60-pin flat band cable in order to double the weak cathode signal and to extend the high voltage plateau by 180 volts. Fifty-one out of these fifty-five double wires are connected to the electronics via the tapped delay line. The last four double wires, at the extremities of the chamber, are connected to ground in order to extend the uniform region of electrical field.

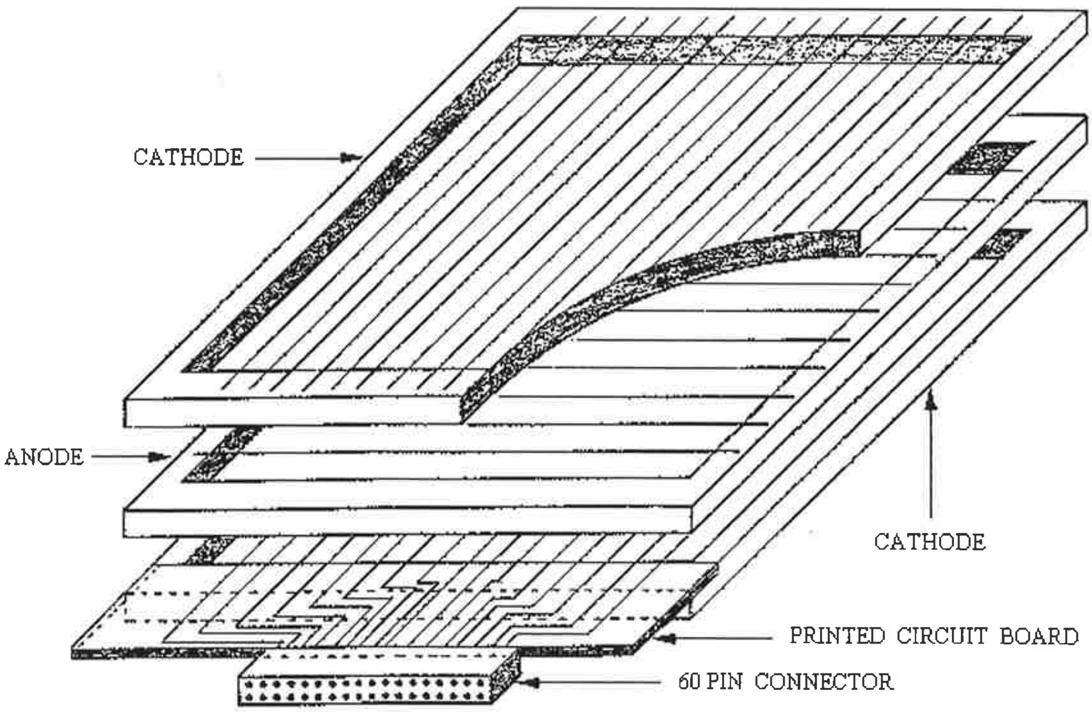

Figure 8. Sandwich construction of one plane of the Delay Wire Chamber.

8. Local electronics

The main element of the electronics (figure 9) located inside the chamber is the lumped delay line. This delay line is composed of five standard ten-tap SMD delay lines connected in series. The total 250 ns delay contains fifty 5 ns cells with a characteristic impedance of 200 ohms. The delay line is terminated at each end by a low noise amplifier with a bandwidth of 20 MHz.

The anode wires are connected together on the main frame PCB and the collected signal is fed through a high voltage decoupling capacitor to the local electronics.

Inside the chamber, one printed circuit board per plane provides you with the analog anode signal and the two cathode signals already at a comfortable level (50-200mV) for discrimination. Attempts to implement a fast discriminator inside the chamber have been abandoned because the wires act like electromagnetic antennas and pick up the fast digital output signal introducing oscillations.

As mentioned in chapter 4, three calibration inputs allow you to check and calibrate a complete set-up.

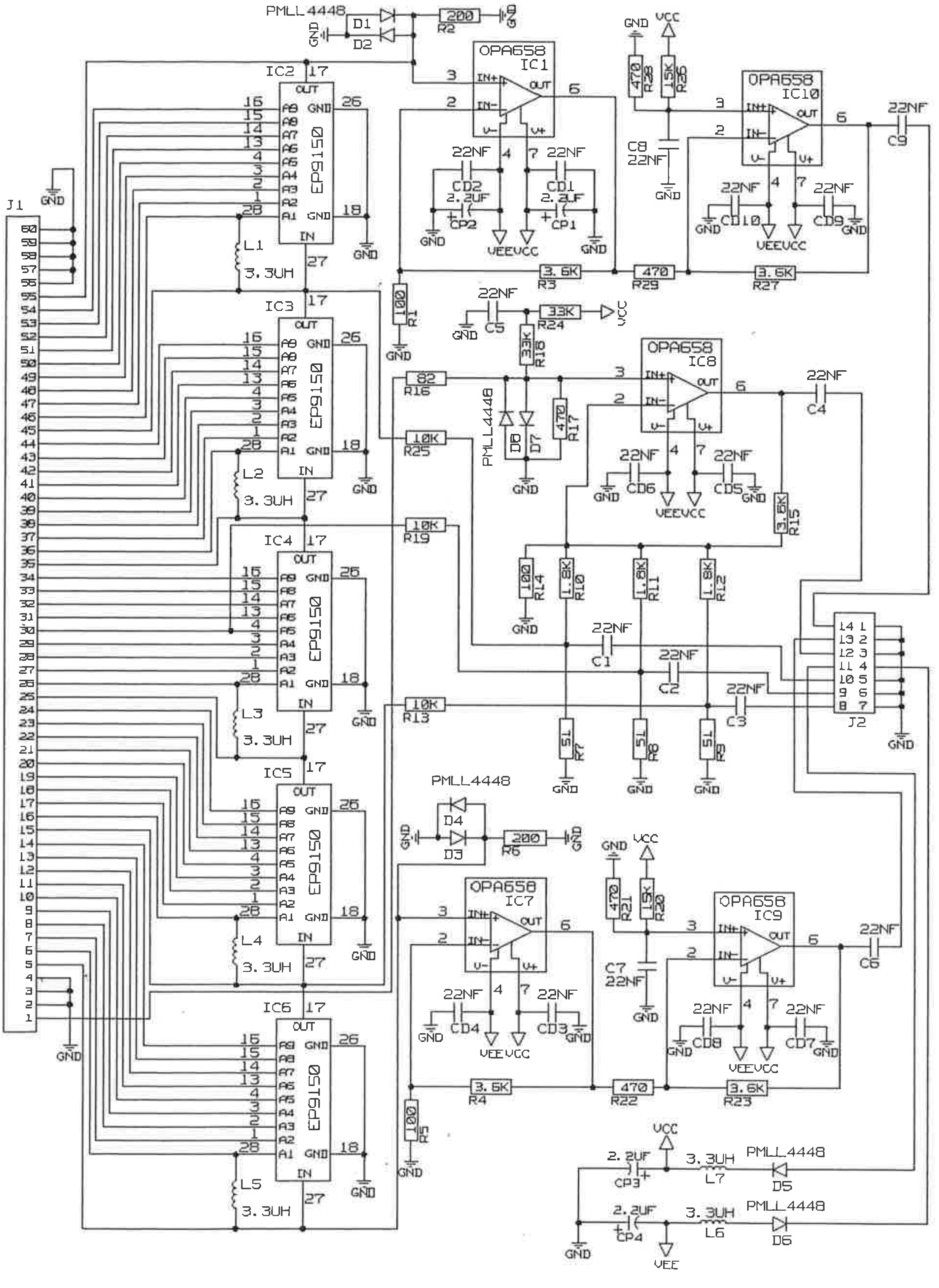

Figure 9. Local electronics diagram.

9. Specifications

Overall dimensions	:	220 x 220 x 56 mm^3
Active area	:	100 x 100 mm^2
Linear region	:	80 x 80 mm^2
Cathode wires	:	55 beryllium-bronze 100 microns wires
Anode wires	:	28 tungsten gold-plated 20 microns wires
Windows	:	2 x 25 microns Kapton
Spatial resolution	:	better than 200 microns
Integral linearity	:	< 1 % in the linear region
Differential linearity	:	< 7 %
Power supply	:	bipolar 6 volts / 50 milliampere
Maximum output amiplitude	:	-3500 mV in 50 Ω
Operational high voltage	:	2800 to 2900 volts
Maximum high voltage	:	3100 volts
High voltage plateau	:	> 200 volts
Dark current	:	< 50 nanoampere
Detection efficiency	:	> 99 %
Chamber dead time	:	250 ns
Maximum beam rate	:	2 x10^5 particles per second for a rejection < 10 %
Gas mixture	:	Argon / Carbon-dioxide 50/50
Gas Flux	:	10 cubic centimetres per minute

10. Acknowledgments

Je voudrais remercier M. G. Vismara pour ses explications et suggestions constructives et aussi M. J. L. Pasquet et M. A. Boldi d'avoir partagé leur compétence avec moi pour la réalisation de la chambre.

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