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Author

Olson, S.R.

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S. R. Olson, F. Kirsten, K. L. Lee,
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A MWPC INSTRUMENTATION SYSTEM WITH SMALL DEAD-TIME AND
WITH PROVISION FOR AUTOMATIC TESTING AND CALIBRATION*

S.R. Olson, F. Kirsten, K.L. Lee and D.B. Turner
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

and

A. Grigorian and Z.G.T. Guiragossian
High Energy Physics Laboratory
Stanford University
Stanford, California 94305

ABSTRACT

This paper describes some of the system features of a large array of instrumentation to be used for data collection in an experiment utilizing multi-wire proportional chambers (MWPC) of both the amplifier-per-wire and the delay-line types. The system is designed to uniquely meet special functional requirements for background reduction and dead-time reduction in high counting-rate experiments at FERMILAB.

INTRODUCTION

The instrumentation system to be described is being built for a moderately large-acceptance magnetic spectrometer experiment. The experiment is designed to detect the production of large-angle energetic $\mu^+\mu^-$, e^+e^- , and $\gamma\gamma$ pairs from pion nucleon deep scattering collisions and also to study electron-proton deep inelastic scattering phenomena at FERMILAB (E-192/454).

Multiwire proportional chambers of both the amplifier-per-wire and delay-line types are used in the system. Features are included to provide for automatic testing and calibration, reduction of dead-time, and improved quality of the data transmitted to the computer.

Figure 1(a) shows the experimental layout. Circle-enclosed numbers 1 through 12 indicate the locations of amplifier-per-wire proportional wire chambers. In Figure 1(b) the square-enclosed numbers through 7 indicate the locations of delay-line readout proportional chambers. The distance from the target to the farthest spectrometer is about 40 ft. The cable run distance from the experiment area to the counting room is about 150 ft.

Each spectrometer arm is composed of segments of 30" in diameter Sodium Iodide crystals followed by Pb and Fe absorbers. Delay-line MWPC's are placed between the front NaI segments and the absorbers in order to measure particle coordinates, intercepted electromagnetic shower multiplicity, and pulse profile width above desired threshold levels. Up to four e, μ , γ type particles entering a spectrometer arm can be recorded with know particle-pair space resolution of less than 3 cm. Chambers 1, 2, 3, in Figure 1(b) are set at moderately high threshold, recording the large pulse height of intercepted showers from electrons and gamma-rays. Chambers 4, 5 are used predominantly for hadron identification and rejection and chambers 6, 7 provide muon identification. Pulse height from each NaI segment is recorded and the sum signal is used to provide an energy acceptance in event triggers.

Figure 2 is a block diagram of the instrumentation system. It can be divided into three sections: (1) the Amplifier-per-wire MWPC instrumentation subsystem, (2) the Delay-line MWPC instrumentation subsystem, and (3) the Sodium Iodide detector instrumentation subsystem. Two areas in common between all three sections are the trigger generating subsystem and the automatic testing subsystem.

A Master Event Trigger logic is produced from the subsystems. A trigger signal enables signal processors and readouts to deliver event information to CAMAC readout devices. Features are included to automate testing and calibration of signals from detector pre-amplifiers to signal processors and to reduce the electronics dead-time at a level where the experiment can function in the presence of high background rates.

AMPLIFIER-PER-WIRE MWPC SUBSYSTEM

Charged particle tracking information is obtained by amplifier-per-wire readout MWPC's designated by 1 through 12 in Figure 1(a). Chambers 6, 7, 8 provide x, y, v coordinate information with wires oriented at 90°, 60° and 120° while the remaining chambers provide x, y coordinate information only. Some of the latter chambers are tilted by $\pm 30^\circ$ with respect to others, thus removing coordinate reconstruction ambiguities in high track multiplicity events. Chambers 1 through 8 have successively increasing desensitized central

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zones for the unrecorded passage of beam tracks. Chamber 7 is especially designed to fit inside the magnet providing optimum active detector height between the pole faces. The experiment requires the instrumentation of 12,000 wires of which 4000 channels are being prepared presently.

A typical amplifier-per-wire readout plane is shown in Figure 3(a). Groups of 32 or more high voltage cathode wires are amplified by AC-coupled low input-impedance amplifiers. These cathode signals are used as trigger hodoscope elements, enabling anode write gates and producing prompt timing together with NaI energy acceptance criteria, for the acceptance of anode wire signals.

In order to maintain a channel dead-time of the same order as the chamber avalanche jitter (20 nsec) and the amplifier propagation time, data transmission, reception, and latching circuits are constructed which use no active delays. Instead, the signal delay necessary for twisted pair cable with $\beta = 0.57$. Cable delay can carry the data continuously, while an active one-shot delay carries only a single pulse per delay period. Reasonable attention must be paid in delay cables as to wire tension, twist pitch and dielectric to achieve about 1% propagation variations. If necessary, smaller variations are obtained by trimming the length of each conductor pair. 370 nanosecond of delay are used between the preamplifiers at the chambers and the register cards in the counting room.

Each instrumented anode wire is sufficiently differentiated at the amplifier input to allow for double pulse resolution of less than 40 nsec to exist. The spark protection input drives two stages of MC1035 type linear amplifiers. The last stage of linear gain is biased to achieve additional gain in the desired pulse polarity and suppress non-coincident opposite polarity induced signals. In effect this stage acts as an active rectifier. The linear signal is then sharply differentiated to enhance the discrimination of two closely separated pulses in time. The differentiation is done in a manner which minimizes dead time. Following this, a low threshold discriminator is used to trigger a pulse shaper. The leading edge of the standardized signal is thus referenced to the time when avalanche formations begin. The output stage differentially drives the twisted pair delay cable with a standard pulse at ECL levels with a pulse width of less than 20 nsec.

The bandwidth limitation of the twisted pair cable requires differentiation at the receiver, so that a pulse pair resolution of less than 40 nsec is achieved. A simplified function diagram of a transmission/reception channel is shown in Figure 3(b).

Cathode wire group signals are sent by fast coaxial cable ($\beta = 0.84$) to the counting room where they serve the function of providing early hodoscope element information in the making of event trigger decisions. These participate in the formation of enabling wire gates for anode signals, with acceptance windows of less than 40 nsec, consistent with the anode signal pulse-pair resolution in time. This is an essential precaution for high background rate experiments; otherwise the confusion created by 'stale' tracks becomes prohibitive. The system is therefore matched with the space-charge limitations in the operation of MWPC's. Cathode group signals are also latched in registers for computer readout along with anode signals.

The delay cable carrying the anode signals is a relatively inexpensive flat array of 16 twisted pair conductors "sandwiched" between layers of PVC. The differential mode signals are received on register cards, at a comparator with an adjustable threshold bias. Other than the elimination of the one-shot multi-vibrators the operation of the register and readout systems is essentially similar to the system described at the 1973 NSS¹. All circuits are on modular type circuit cards which plug into modular mother boards to facilitate changes in configuration and repair as well as to minimize cost. These mother boards are housed in powered cabinets which service 2500 channels. The data output is bit-parallel, word-serial via a daisy chain cable interconnecting all the mother boards holding the register cards. The daisy chain cable terminates at a CAMAC module which does wire address translation before transmitting the data to the computer at a rate of up to 1 word per microsecond. Time is required only for reading data from register cards having "hits" recorded, thus minimizing "readout dead time". A more detailed description of this look-ahead readout sequence is contained in the previously mentioned paper.¹

Computer-controlled testing capability is provided for this part of the system in the way illustrated² in Figure 4. Chamber wires are divided into eight test groups. This arrangement provides a means for testing the response of each channel in regard to both signal amplitude and position by cycling through the test groups. Since the test pulse enters the system between the chamber wire and the preamplifier, it provides a check of essentially the entire signal path including the addressing and readout electronics. Although not intended for a high resolution test of the electronics, the amplitude of the test pulse can be programmed and thus provides a "sensitivity map" of the array of wire channels.

DELAY LINE MWPC SUBSYSTEM

Figure 1 also illustrates how the proportional chambers with delay-line type readout are utilized in the two spectrometer arms of the experiment. They are interleaved with the NaI crystal segments. These chambers and the associated electronics provide a particularly good means for obtaining information from intercepted electromagnetic showers.

Figure 5 shows the delay line MWPC instrumentation. The delay lines are mounted on the low-voltage cathode planes. The terminated delay line output drives a linear amplifier with dynamic range of 100:1. The high voltage anode planes are grouped into eight sections. Each anode group is AC-coupled to a low input-impedance high gain amplifier.

The delay-line chamber apertures are 30.4 x 30.4 inches with a wire spacing of 0.1 in. The delay-line input taps are time-spaced 5 nanoseconds apart and thus with a digitizer having 0.5 nanosecond resolution they provide an inherent spatial resolution of 0.01 in. Figure 6 shows a photograph of one of the delay lines before assembly into the chamber. The input taps are on the top edge and the taps on the bottom edge are used for the inputs to a "Hazard Signals Inspector" and for injecting test and calibration signals.

Details of the design and function of the Hazard Signals Inspector will be covered in another paper

(Delay Line MWPC Hazard Signals Inspector) at this conference.⁴ It is a vital part of the system in that it very effectively reduces the number of background and non-trigger particle signals which would otherwise overload the charge and time digitizers causing undesired "dead time". For economic reasons these digitizers must be limited in the number of inputs they can handle within a given time span. Essentially, the Hazard Signals Inspector divides a MWPC delay-line into eight independent signal monitor and control segments, analyzes the signals from these segments, controls the digitizers, and also passes resultant information to the computer. This segmented control effectively reduces the delay-line occupation time by a factor of eight and greatly reduces the number of background and non-trigger particle signals processed by a Charge, Time, Pulse-Width Discriminator which is also described in another paper at this conference.⁵ This module is designated as 4XQT in Figure 5.

Just as with the amplifier-per-wire subsystem a provision for testing and calibration is made for this part of the system also. In this case, however, the test pulses in addition to being computer-controlled for amplitude and point of application also can be programmed for variable delay thus providing a check not only of the delay-line amplifiers but of the Hazard Signals Inspector and digitizers as well. The entire test and calibration operation is controlled from one CAMAC module and can be run very conveniently as often as the experimenters consider it necessary.

Since the Tester Module also provides signals to the Trigger Logic section when the system is in "test mode" (in lieu of signals from the NaI detectors) a very comprehensive checkout of the system is possible either with or without the beam present.

The system features we have described, particularly those which facilitate testing and calibration and reduction of dead time, provide the experimenters with a high degree of confidence in the validity and accuracy of the data collected.

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Fig. 1(a) FERMILAB Experiment E-192.

Fig. 1(b) Spectrometer Arm for electron/gamma-ray/hadron detection.

Fig. 2 Experiment Instrumentation for FERMILAB E-192/454.

Fig. 3(a) Amplifier-per-wire subsystem signal flow diagram.

Fig. 3(b) Transmission/reception of anode or cathode channel.

Fig. 4 Computer controlled testing capability for amplifier-per-wire channels.

Fig. 5 Delay Line readout MWPC Instrumentation

Fig. 6 Delay line for readout of MWPC.

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