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DIGITAL FRONT-END ELECTRONICS FOR COMPASS MUON-WALL 1 DETECTOR

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Алексеев Г. Д., Маджиора А., Журавлев Н. И. E13-2005-37
Цифровая «front-end»-электроника детектора MW1
установки COMPASS

Описывается цифровая «front-end»-электроника детектора MW1 установки COMPASS (ЦЕРН). Цифровая плата разработана на основе микросхемы TDC F1. Плата включает 6 микросхем F1 (192 канала), арбитр шины, схему распределения питания, интерфейс «hot-link». Общее число цифровых плат в системе 44. Они размещены в 5 еврокрейтах (6U) с общим числом каналов считывания 8448. Электроника разработана специалистами ЛЯП (ОИЯИ) и ИНФН (Турин, Италия).

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Digital Front-End Electronics for COMPASS Muon-Wall 1 Detector

The digital front-end electronics for COMPASS Muon-Wall 1 (CERN) detector is described. The digital card has been designed on the basis of the TDC chip F1. One card includes 6 F1 chips (192 channels), bus arbiter, DAC, power supply distribution, hot-link interface. The total number of the digital cards in the system is 44 housed in 5 euro-crates (6U), the total number of readout channels is 8448.
The electronics has been designed by the Dzhelepov Laboratory of Nuclear Problems (JINR) and INFN (Torino, Italy) experts.

The investigation has been performed at the Dzhelepov Laboratory of Nuclear Problems, JINR.

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INTRODUCTION

The first Muon-Wall detector (MW1) is an essential part of the COMPASS spectrometer [1] and is mainly needed for the identification of muons scattered in deep inelastic scattering processes and muons produced in semileptonic decays.

The MW1 detector, shown in Figs. 1 and 2, consists of 2 stations of the proportional tubes, similar to the well-known plastic Iarocci tubes [2, 3] and is located upstream from the magnet SM2 of the COMPASS setup. The stations are placed on both sides of a 0.6-m deep iron absorber wich stops the hadrons. The active dimensions of the detector are 4.86×4.22 m^2. In the beam-crossing zone an empty window of 1.45×1.36 m^2 is used to channel the intense main beam, which reduces the counting rate of the tubes.

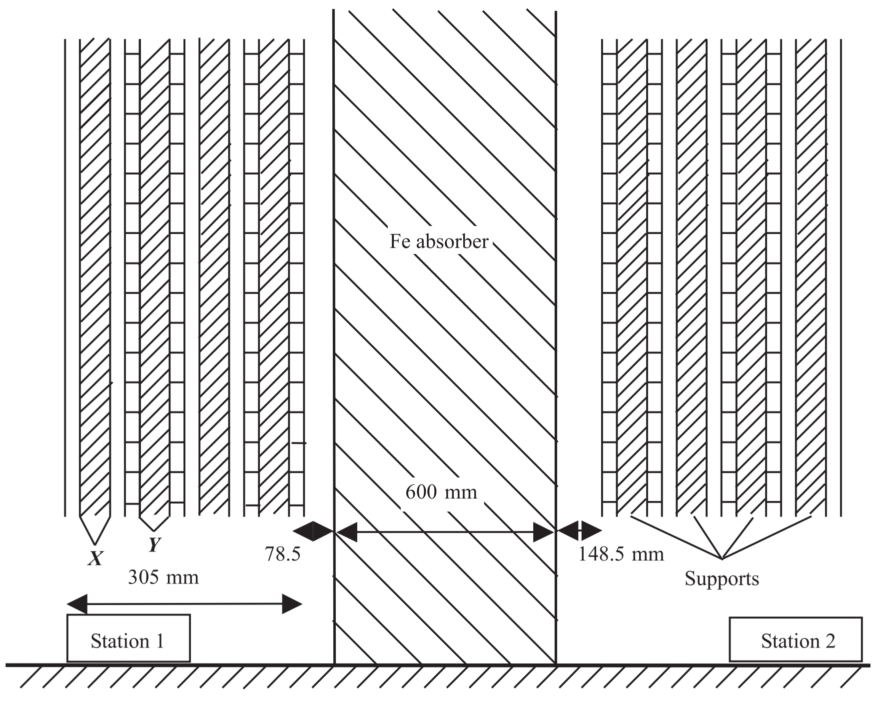

Fig. 1. Schematic side view of the MW1 detector

Each station consists of 8 planes of tubes, 4 planes for the X-axis direction and 4 for the Y-axis direction. The total number of channels (wires) is 8448.

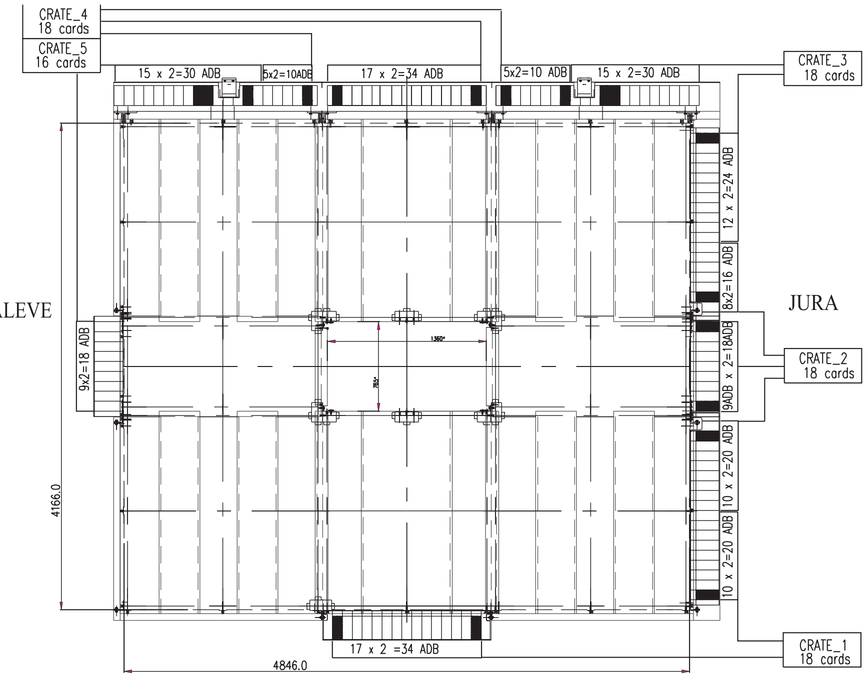

Fig. 2. Front view of one of the MW1 stations. The positions of the front-end boards are shown together with the euro-crates housing the digital cards

A proportional tube consists of a thin-wall (0.6 mm) aluminium profile with 8 rectangular cells of 9.4 $\times$ 9.4 mm^2 inner cross-sections, a stainless steel cover (0.15 mm thick), an envelope made of ABS plastic and 50 μm gold-plated tungsten anode wires stretched in the middle of the cells with an individual signal output from each wire. A negative high voltage is applied to the cathode (aluminium profile and steel cover). The detectors are filled with an Ar + CO_2 gas mixture (70% + 30%).

MW1 FRONT-END ELECTRONICS

The front-end electronics for the MW1 detector consists of an analog and a digital part. The former is located close to the source of the signal, whereas the latter is housed in the euro-crates (6U) around the detector at the maximum distance of 7 m from the analog cards.

Amplifier-Discriminator Board. The analog part is a 32-channel Amplifier-Discriminator Board (ADB) [4] developed on the basis of 8-channel amplifier and discriminator chips of the D0M series (D0M is the abbreviation for the Dubna-D0-Minsk collaboration taking part in the design and production).

The ADB board provides the signal amplification and discrimination within the dynamic range of the input signal (see the Table).

Characteristics of the ADB amplifier/discriminator board

Input signal polarity	negative
Input noise for detector capacitance: CD = 0 pF, rms	40 nA
CD = 60 pF, rms	60 nA
Input signal operation range	60 dB
Input impedance	$\approx$ 50 Ω
Minimal output signal duration	20 ns
Propagation delay at the input operational range 0.2 – 25 μA	28 – 20 ns
Output signal leading/trailing edge	2.2/1.8 ns
Channel-to-channel crosstalk	$<$ –54 dB
Output signal current	4 mA

The differential LVDS output of the D0M chip is able to drive a twisted-pair cable. A short (below 0.5 m) shielded cable connects the sensitive wire to the ADB board. The ADB contains a Test Pulse Generator to produce a current test pulse with the amplitude and duration controlled by a test signal provided by the digital electronics. The common threshold for all 32 channels of the ADB discriminator is set by the analog voltage supplied by the digital card. The ADB requires a double power supply, $\pm$5 V and the power dissipation is about 6 W. The size of the ADB board is 172.6 $\times$ 82.5 mm. Input signals from wires are connected by a 64-pin double-row connector located on the front edge of the ADB, the output and control signals are transmitted through a high density connector at the opposite edge of the ADB. The power supply is connected via a 4-pin connector located near the output connector. ADB input parameters are determined mainly by the characteristics of the transresistance amplifier chip Ampl-8.3.

The Digital MW1 Cards. The logical differential signals generated by the ADB board are converted into coordinate points by the Digital MW1 card (DMW1) (Fig. 3). The connection between the ADB and DMW1 cards is made by using the 80-contact connector and a high density twisted-pair cable [6].

The card has been developed on the basis of the TDC chip F1 [5] in the 160-pin PQFP package with a 0.65-mm pitch. The F1 chip can work either as an 8-channel TDC with the 120 ps time resolution or a 32-channel input register (latch or hit mode) with a 4.6-ns resolution.

The chip includes sixteen 16-bit control registers that load: the mode of the work; the length of the strobe for input signals; trigger latency; trigger window;

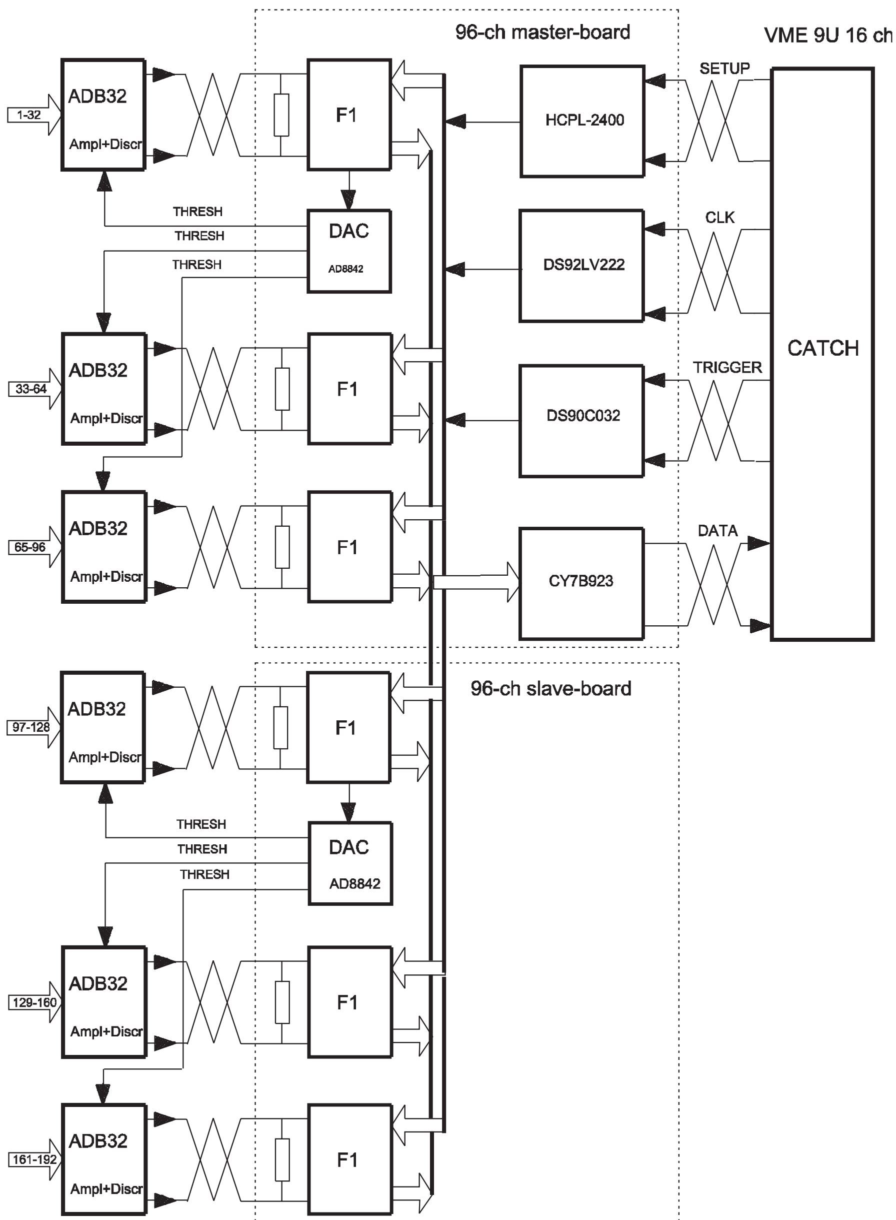

Fig. 3. Block diagram of the digital card

value of the thresholds for external ADC; enable/disable header/trailer word which can be added to the datastream. All those parameters are downloaded in the F1 chip through a 10 Mbaud serial link during the initialization procedure. The structure of the setup data is shown in Fig. 4.

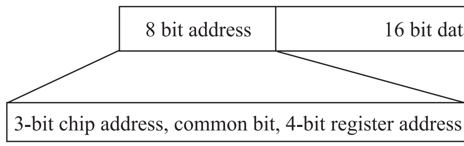

Fig. 4. Structure of the setup data format

Diring the initialization phase, simultaneously with the loading of the control registers of the F1 chip the readout of the geographic address of the individual digital card is carried out. The geographic address is set with the help of jumpers on the card. The initialization phase is started either at the power-up or after the setting of the corresponding bit of one of the control registers.

The signals from the ADB cards in LVDS levels are accepted by the F1 during the internal strobe signal and are stored in the internal hit buffer.

The data readout from the F1 is started after the trigger signal arrives from the trigger logic. Only the hits related to this specific trigger and located inside the trigger window are transmitted to the data acquisition system for further processing (Fig. 5).

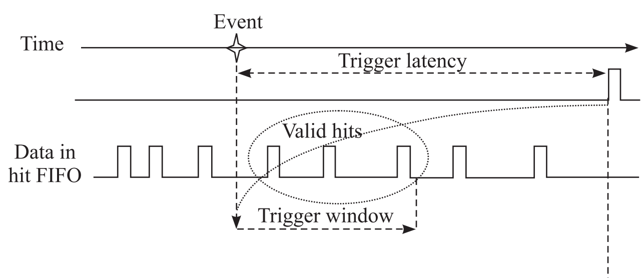

Fig. 5. Search of valid data in hit FIFO

The trigger latency and the trigger window are the same for all channels of the TDC chip.

The data from the digital cards are transmitted via a high speed serial hot-link (40 MB/s) to the standard COMPASS catch cards (VME, 9U) [7]. The data readout from F1 chips in each card is carried out sequentially according to the chip number. For each hit a 24-bit data word is sent (Fig. 6).

The possibility of using 12 bit time in the data word allows the space resolution of the detector to be substantially improved.

One DMW1 card consists of the two boards. The first board (master-board) has the dimension of a VME 6U card, whereas the second one (slave-board) is a

23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	Chip address			Channel address			Time												Wire address			

Fig. 6. Data word (hit mode)

piggy-back of the first one. The master-board houses three input connectors, three F1 chips (96 channels in total), an 8-channel DAC AD8842 (separate channel per one ADB), a bus arbiter, a hot-link interface and a power supply distribution. The slave-board is simpler and houses only three input connectors, three F1 chips, the DAC and a local bus to connect the F1 bus to the hot-link chip on the master-board.

The digital cards can be housed in a standard VME crate, but because only power supply lines are used by the cards, we use a cheaper dedicated crate with a simple backplane (only with power supply distribution lines).

The power dissipation of one card is about 7.5 W.

The total number of DMW1 cards in the MW1 system is 44 and they are housed in 5 euro-crates (see Fig. 2).

The MW1 detector and its electronics have been functioning since 2001 and have demonstrated very good and reliable technical performance. The examples of the hits and drift time distributions for one of the planes of the MW1 detector are shown in Figs. 7, 8. The histogram in Fig. 7 has three peaks due to peculiar

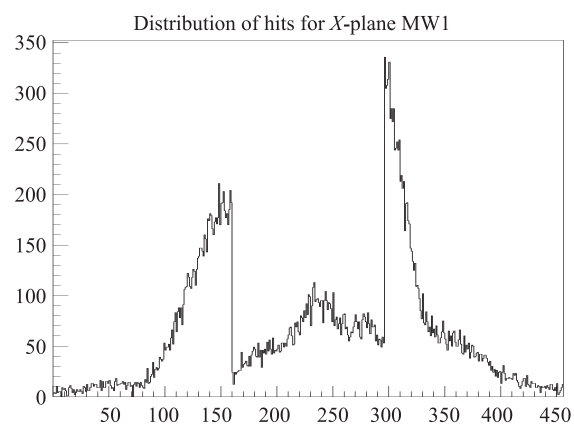

Fig. 7. Particle flux profile along the horizontal (X) axis: the scale is in number of channels

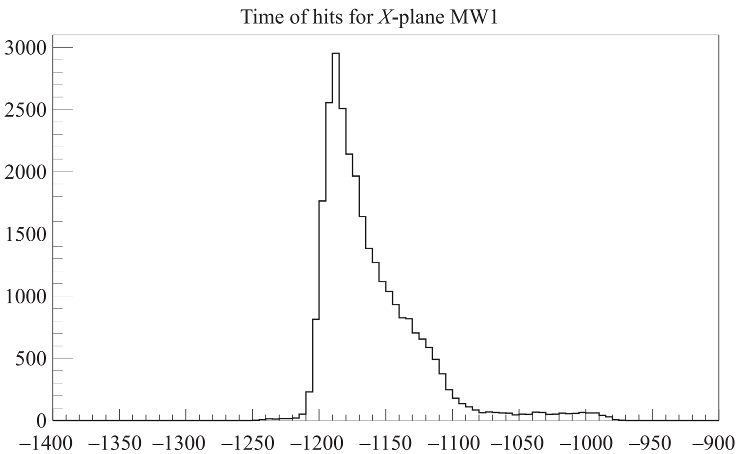

Fig. 8. Drift time spectrum: the scale is in ns

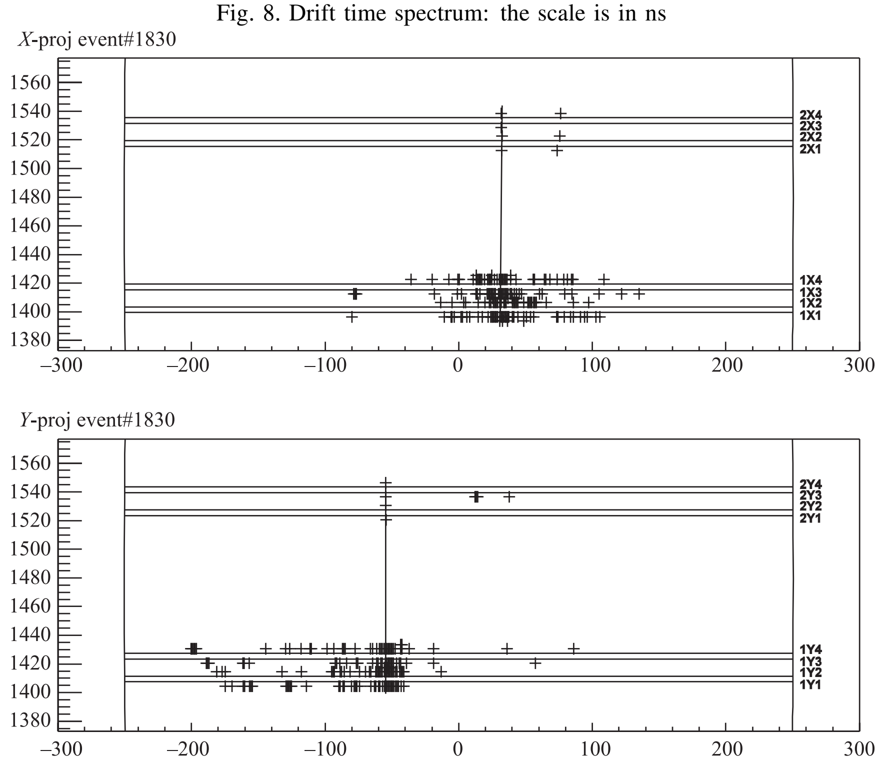

Fig. 9. Example of the COMPASS event as seen by the MW1 detector

geometry of the MW1 detector (the big hole in the center of the plane). Each bin in the histogram represents an individual wire of the MDT. The histogram is «noiseless» – no sharp peaks due to electronics noise are present.

Figure 8 demonstrates the drift time spectrum of the MDT (peak correlated with trigger signal) as well as a flat uncorrelated background due to the spurious hits in the aperture of the detector.

Figure 9 gives an interesting example of the COMPASS event where the muon is seen clearly as four hits on both coordinates in the second MW1 station in the presence of big shower punchthrough from the hadron calorimeter. This low-energy stuff is intercepted by an iron filter (60 cm thick) in between the MW1 stations.

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