Fast front-end electronics for COMPASS MWPCs [1]

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Abstract

In the COMPASS experiment, under construction at CERN, about 23000 channels of MWPCs will be used. The very high rate of the muon and hadron beams, and the consequently high trigger rate, require front-end electronics with innovative conceptual design. A new MWPC front-end electronics that fulfills the main COMPASS requirement to have a fast DAQ with a minimum dead-time has been designed. The general concept of the front-end cards is described; the comparative tests of two front-end chips, and different fast gas mixtures, are also shown. The commissioning of the esperiment will start in the summer 2000, and production running, using the muon beam, is foreseen for the year 2001.

I. Introduction

COMPASS [2] is a new experiment under construction at the CERN SPS designed to study the structure and spectroscopy of hadrons with diverse types of high intensity beams. The COMPASS experiment, shown in fig. 1 in the initial set-up configuration, uses a double forward magnetic spectrometer for best momentum resolution. Both spectrometer parts are equipped with RICH detectors, electromagnetic, hadronic calorimeters, and muon filters for particle identification. A large assortment of position sensitive detectors will be used as tracking devices. High precision silicon detectors, new Gas Electron Multiplier and Micromegas gas chambers, straw tubes and scintillating fibers detectors will be exploited in different sectors of the spectrometer. In the phase 1 only RICH1 will be installed and the tracking of charged particles in the small angle spectrometer (SAS) is mainly based on MWPCs placed before and behind the SM2 magnet.

The challenging physics goals of the COMPASS experiment can only be achieved if, at highest possible beam rates, large data statistics can be recorded. The rate of the muon and hadron beam of 100-200 GeV, spans from 5×10^6 up to 10^8 particle/s and the foreseen trigger rate is of the order of 10-100 kHz. With an event size around 30 kB, data rates of 600MB - 6GB per SPS spill will feed the DAQ, leading to 300 TB of data per year on tape. A state-of-the-art read-out system, smart enough to digest these huge data rates, is at the edge of today's digitalization and bandwidth technologies.

Such very tight experimental requirements can be fulfilled by low gap, intrinsically fast MWPCs and/or when high drift speed, not explosive, CF_4 based gas mixtures are used. The bottle-neck of the slowness of standard commercial read-out systems for MWPCs can be overcome by conceptually new, self-triggered, front-end electronics.

The COMPASS approach to the solution of these challenging experimental problems was to minimize the dead time by reading digitized data through pipelines when applicable. The availability and resolution requirements of digitalization units have made this goal not feasible for every detector component.

The read-out architecture of the COMPASS experiment allows data digitalization right at the detector by the front-end electronics wherever possible. In the case of an analog read-out, the pedestal subtraction and zero suppression is performed by the front-end at the detector. To suppress the background for time measurements, only hits correlated with the trigger time are transferred to the data recording system.

II. The COMPASS MWPC

A. Chambers layout

The tracking of charged particles within the acceptance of the second magnetic spectrometer, is performed by MWPCs. Some stations of Sci-fi detectors and GEMs are installed on the beam flight line, where the rate cannot be tolerated by gas detectors. The gain of the chambers in the beam crossing zone, will be dropped down by a proper set of its high voltage.

Three stations of MWPCs are placed before the SM2 magnet, inset between the electromagnetic, hadron calorimeters, and the μwall. The remaining eight are placed behind the SM2 magnet and behind the second calorimeter devices.

The major characteristics of the Large Area Tracking MWPCs are summarized in the right-top part of fig. 1. Essentially two types of chambers, named type A and type B, will be employed. The third one, named type A*, is a variation of type A with an additional plane of horizontal wires. Type A chambers consist of three planes of sensitive wires, one vertical (v) and two tilted at $\pm 10.14^0$ (t) relative to the vertical direction. Type B consists of two planes per chamber, one vertical and one left tilted or one vertical and one right tilted.

The total number of read-out electronic channels in the present COMPASS set-up is about 23000.

B. Read-out electronics

The block diagram of the read-out electronics under development in Torino is shown in fig. 2

[1]On behalf of the Torino and Dubna LNP groups [1]

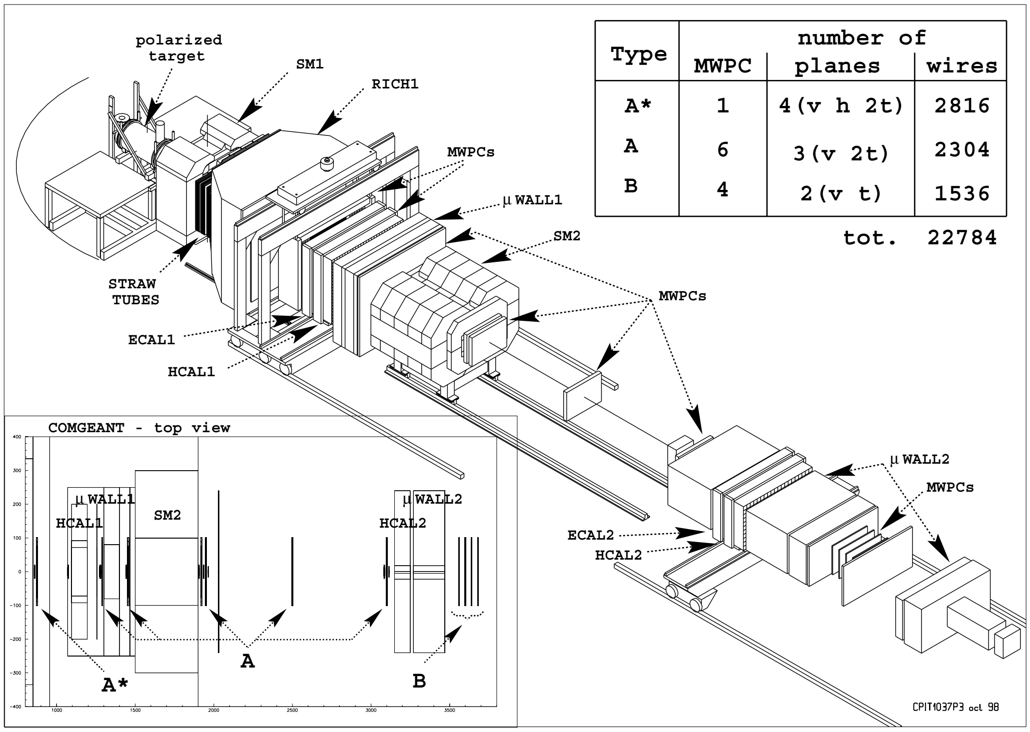

Figure 1: Axonometric and Geant top view (bottom-left) of the COMPASS experimental set-up in the phase 1 configuration. In the initial set-up only the RICH1 will be installed. The major characteristics of Compass MWPCs are also summarized.

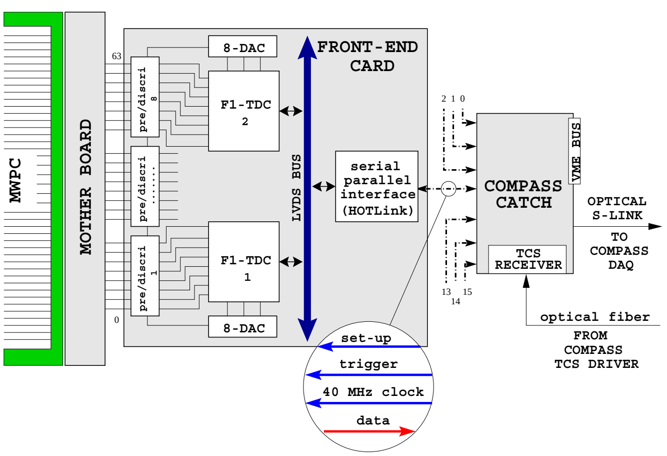

Figure 2: Scheme of the front-end card housing the preamplifier/discriminators, digitizing electronics, and interfaces.

The main components of the system are:

1. mother-board
2. front-end card
3. catch

The “Mother Board” consists of a printed circuit board, fixed to the chamber frame. The main task of the “Mother Board” is the interface between the wires signals and the front-end board. It permits easy card removal without any risk of damaging the chamber’s connectors. A test system capable of injecting into each wire a charge pulse similar to the signal of a minimum ionizing particle crossing the chamber, is also installed on the “Mother Board”. It allows for tests of the front-end cards and of the read-out system, including the input connectors.

The front-end card are the read-out digitizer components. They house the preamplifier/discriminator chips, the digitalizing chips, the threshold DACs, and the parallel-to-serial converter chips that allows for fast transmission of significant data to the “Catch” module.

For noise immunity, the voltages required by the card components is regulated on–board and the ground separation technology between analog and digital grounds is used.

The design of front-end cards allows the sharing of the same HOTLink serializer/transmitter section between three adjacent cards, using a fast differential LVDS bus. This solution permit a sizeable cost reduction for the marginal boards where the occupancy is low enough to avoid the saturation of the 40 MB/s serial transmitter.

The amplifier/discriminator chips is the new ASIC chip, named MAD4, developed by the INFN section of Padua within the framework of the muon drift tube of the CMS barrel [3]. The main task of this IC is to amplify signals picked up by chamber wires, compare them with an external voltage threshold, and send the differential signals over a long cable.

The chip houses four channels and each of them consists of a wide-band preamplifier stage followed by a shaper and a base-line-restorer. The discriminator stage is followed by a logical shaper that allows the width adjustment of the standard differential LVDS output from 20 to 200 ns. The output buffer is capable of driving long twisted-pairs cables terminated with a 100Ω load.

The last feature of the chip will not fully exploited in our application because the output signals of the preamplifiers are digitized directly on board, i.e. converted into the logical geographic address of the hit wire, by two $\mathcal{F}1$-TDC chips [4]. This chip, developed at the University of Freiburg, will be widely used by several detectors in COMPASS.

In the standard mode the $\mathcal{F}1$ is an eight channel TDC chip with a digitalization uncertainty of 150 ps or 75 ps in the high resolution mode when two adjacent channels are grouped together. When precise timing resolution is not required by the detectors, like in the case of Plastic Iarocci Tubes used in the μwall1/2 or MWPCs, but the low cost per channel is an important parameter, 4 input channels can be read-out by the same TDC channel. In this case the time resolution is lowered to 5.7 ns but each chip can read-out 32 channels. Count rates up to 6 MHz per channel and the double pulse resolution of 22 ns are on the edge of the today's technology. In addition, the $\mathcal{F}1$ can drive an eight-channel, serial-input, digital-to-analog converter AD8842, which can be used for threshold control of the front-end discriminator chips.

The front-end board is connected to the "Catch" module through a standard low cost, four twisted pairs CAT 5+ cable. When the maximum bandwidth is required, the cable length is limited to 20 m. Longer cables can be used at lower read-out speeds.

The 9U VME "Catch" module, developed at the University of Freiburg for the COMPASS experiment [4], performs in hardware the task of the local event builder. It is mainly a data derandomizer and provides enough memory for intermediate storage of several events during the beam spill extraction. It also provides the distribution of the 40 MHz clock required by $\mathcal{F}1$ chips, and the trigger signal to the 16 front-end boards connected to one module. The data down-loading of the $\mathcal{F}1$ internal registers and threshold DACs is also performed by the "Catch" through the same cable. The 16 HOTLink de-serialized receivers chips will be housed on mezzanine cards.

The incoming data are reformatted to 32-bit words, packed with header and trailer data, and finally sent to the superior level of DAQ through S-LINK transmitter at the maximum rate of 100 MB/s.

Although the main data stream goes through the optical S-link, a sub-sample of incoming events can be parasitically picked-up through the VME bus without any penalization of the bandwidth of the main data stream.

III. Front-end chips comparison

In any gas detector the characteristics of the front-end electronics in terms of sensitivity, fastness, and low noise are essential for the overall performances of the detectors.

Some commercial preamplifier and discriminator chips are available but, the high price or low integration represent a real limit to these solutions.

In the framework of modern high energy physics experiments several chips have been designed specifically for gas detectors. Although none of them are in the catalog of electronics components producers, two of them can be find in the experimental physicists community. The first one was designed some years ago, at the University of Pennsylvania [5–7]. It was optimized for straw tube detectors for SSC experiments. The name of the chip is ASD8 and it contains 8 independent channels of the preamplifier, discriminator and output driver in a single chip. The second one, named MAD4, is a new chip, developed by the INFN section of Padua within the framework of the muon drift tube of the CMS barrel [3]. It houses 4 channels of the preamplifier, shaper, discriminator, and output driver.

The main job of our group during the last year was the comparison of the two chips by investigation of the basic MWPC working parameters such as efficiency, cluster size, time jitter, charge, and signal width.

Two 16-channel test cards housing the two or four chips and the associated electronics have been designed. The input and output connectors were compatible with the LeCroy PCOS-III system. Several comparative tests have been done on a small chamber prototype, i.e. a small chamber with the same characteristics of the COMPASS MWPCs in terms of wire pitch, diameter, wire tension, and anode-cathode gap. The length of the 16 sensitive wires is 70 mm with a typical capacity of 11.6 pF.

The set-up system used for the tests performed on chamber prototype is shown in fig. 3.

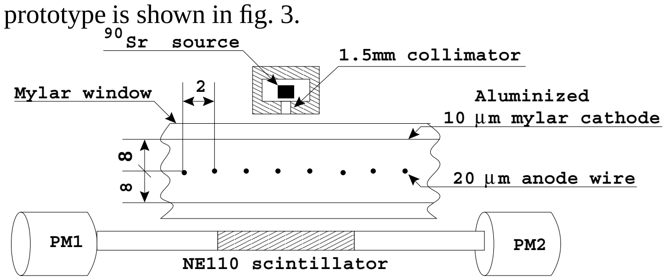

Figure 3: Test set-up. The β^- emitted by a collimated ^{90}Sr source are detected by the coincidence of two photomultipliers faced to the same small scintillator beneath the chamber.

The DAQ system, previously developed for Disto experiment at Saturne [8], has been used during the tests.

At the same time several laboratory tests have also been performed in order to characterize the two chips. Finally, performance of the two chips have been compared using a fully refurbished Ω chambers used in the experimental set-up and two different fast gas mixtures.

The efficiency measurements of the ASD8 and MAD4 chips are shown in fig. 4. The efficiency vs. voltage potential is plotted for pure CF_4 and a mixture of Ar(74%),CO_2(6%),CF_4(20%).

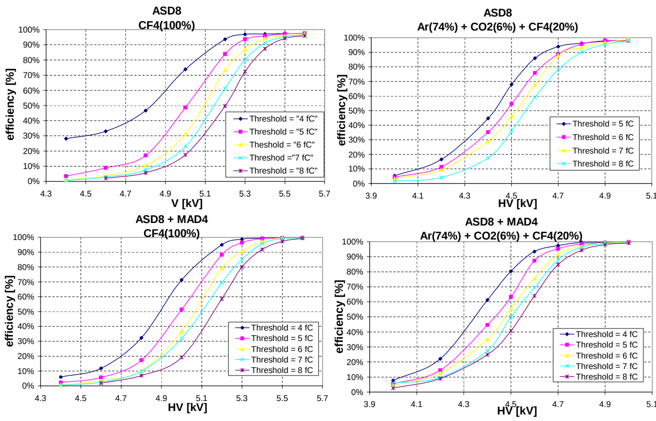

Figure 4: Efficiency of MAD4 and ASD8 chips vs. chamber potential using two fast gas mixtures and several thresholds. The tests were performed on the Ω chambers used in the experiment.

The performance of the two chips are quite similar and satisfactorily good. High detector efficiency can be obtained with the two chips at the same voltage potential. The main difference is the noise pick-up which is relatively higher for ASD8 than MAD4.

Also the cluster size, shown in fig. 5, are similar. The probability to have one hit per event is plotted as function of the chamber potential. No relevant differences are shown.

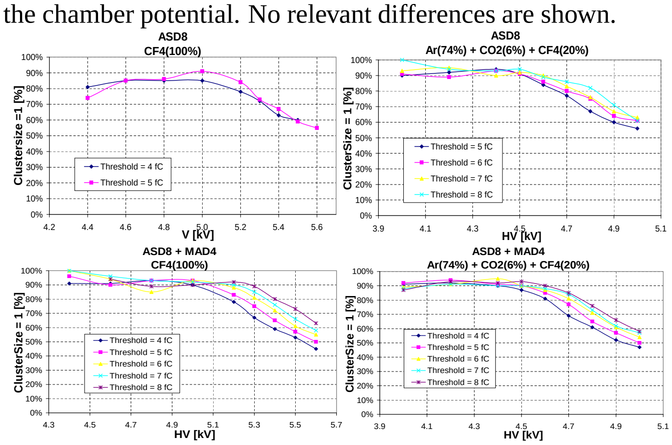

Figure 5: Cluster-size of MAD4 and ASD8 chips using two fast gas mixtures and several thresholds. The tests were performed on the Ω chambers used in the experiment.

IV. Conclusions

A conceptually new design of MWPCs front-end electronics has been used in order to fulfill the high rate requirements of the challenging Compass physics program.

The most relevant results of comparative tests done so far for the selection of the most proper chip for COMPASS MWPCs have been shown.

The performance of the two chips on Compass MWPCs, where time resolution is not a relevant parameter, are similar and satisfactory. The MAD4 will be used on our front-end electronics mainly for costs reason, better stability and less noise pick-up.

V. Acknowledgments

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VI. References

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