IL NUOVO CIMENTO Vol. 27 C, N. 5 Settembre-Ottobre 2004
DOI 10.1393/ncc/i2005-10017-5

Electronics design of the RPC system for the OPERA muon spectrometer

R. Acquafredda(1), M. Ambrosio(1), E. Balsamo(2), G. Barichello(2)
A. Bergnoli(2), L. Consiglio(1), G. Corradi(3), F. Dal Corso(2)
G. Felici(3), C. Manea(2), V. Masone(1), P. Parascandolo(1)
and G. Sorrentino(1)(*)

(1) *INFN and Università "Federico II" - Napoli, Italy*

(2) *INFN and Università di Padova - Padova, Italy*

(3) *INFN, Laboratori Nazionali di Frascati - Frascati, Italy*

(ricevuto il 20 Gennaio 2005)

Summary. — The present document describes the front-end electronics of the RPC system that instruments the magnet muon spectrometer of the OPERA experiment. The main task of the OPERA spectrometer is to provide particle tracking information for muon identification and simplify the matching between the Precision Trackers. As no trigger has been foreseen for the experiment, the spectrometer electronics must be self-triggered with single-plane readout capability. Moreover, precision time information must be added within each event frame for off-line reconstruction. The read-out electronics is made of three different stages: the Front-End Boards (FEBs) system, the Controller Boards (CBs) system and the Trigger Boards (TBs) system. The FEB system provides discrimination of the strip incoming signals; a FAST-OR output of the input signals is also available for trigger plane signal generation. FEB signals are acquired by the CB system that provides the zero suppression and manages the communication to the DAQ and Slow Control. A Trigger Board allows to operate in both self-trigger mode (the FEB's FAST-OR signal starts the plane acquisition) or in external-trigger mode (different conditions can be set on the FAST-OR signals generated from different planes).

PACS 13.15.+g – Neutrino interactions.
PACS 29.40.Cs – Gas-filled counters: ionization chambers, proportional, and avalanche counters.
PACS 84.30.-r – Electronic circuits.

(*) E-mail: giovanni.sorrentino@na.infn.it

© Società Italiana di Fisica

1. – Apparatus description

OPERA [1] is a long-baseline neutrino experiment currently under construction at the Gran Sasso underground laboratories (LNGS). The experiment can perform a ν_τ appearance search due to $\nu_\mu \leftrightarrow \nu_\tau$ oscillation in the parameter region indicated by Super-Kamiokande [2]. It exploits the excellent space resolution of the nuclear emulsion for the unambiguous detection of the decay of the τ produced in ν_τ CC interactions.

The detector design is based on a massive lead/nuclear emulsion target (ECC) complemented by plastic scintillator detectors that allow the location of the event and drive the scanning of the emulsions. This instrumented target is followed by a magnetic muon spectrometer. Each spectrometer consists of a dipolar magnet, the magnetic flux density inside the magnet is 1.55 T. The magnet is made of two arms interleaved by high-resolution trackers. The high-resolution tracker consists of vertical drift tubes [3] with an intrinsic resolution of 0.3 mm in the bending direction. Each arm is made of 12 iron plates 5 cm thick interleaved by Resistive Plate Chambers [4] with 2 mm gas gap. The RPCs contribute to the measurement of charge and momentum of penetrating tracks.

The instrumented target and the spectrometer constitute one "supermodule". OPERA is made up of two supermodules located in the Hall C of LNGS.

The transverse dimensions of the instrumented area of the magnet are 8 m in height and 8.7 m in width. Therefore, the RPCs that instrument the two spectrometers cover a total detector area of 3000 m^2. The total number of read-out channels is about 25000.

2. – The RPC read-out

RPCs are a good choice to instrument the magnetic muon spectrometer given their intrinsic and geometrical efficiency, the low cost, the robustness and the ease of segmentation using proper pickup geometries. A charged particle crossing a RPC produces a quenched spark that induces signals on external pickup electrodes. The induced pulses are collected on two pickup planes made of copper strips with a pitch of 26 mm in the y view and 35 mm in the x view. The strips run in two perpendicular directions providing two-dimensional information. The induced charge is of the order of 100 pC and the pulse has a rise time of few ns.

An overview of the OPERA magnetic spectrometer is shown in fig. 1a, while the RPC layout for a plane is shown in fig. 1b.

3. – The RPC read-out electronics

Because the RPC front-end electronics main task is to provide particle track information, only a digital read-out is foreseen. Moreover, exploiting the excellent RPC timing properties, a prompt signal for precision tracker TDC will be generated.

The electronics requirements are: self-trigger mode acquisition, single-plane read-out capability and precise time information to be added to each signal for the off-line event reconstruction.

The read-out electronics chain is made of three main stages: the Front-End Board (FEB) system, the Controller Board (CB) system and the Trigger Board (TB) system.

3˙1. *The Front-End Board.* – Each plane (fig. 1b) is read-out by nine FEBs. Each board collects the signals from 64 strips providing signal discrimination and shaping and produces a FAST-OR output that contributes to build the plane FAST-OR signal.

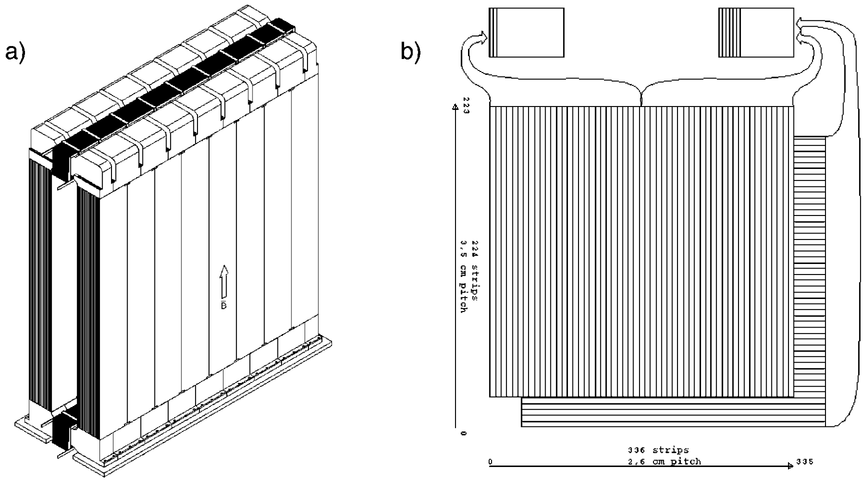

Fig. 1. – a) Spectrometer layout; b) RPC layout.

If a plane FAST-OR is detected, the CB generates a LOAD command to store input signals (shaped to 2 μs) in a parallel-input serial-output 64 bits shift register device. Then a clock sequence is generated by the CB board to transfer FEB shift register data into the CB board memory (fig. 2). Signals from FEBs are collected by means of twisted-pair cables connected to special boards (Transition Boards), in order to match FEBs and CBs cables to the crate backplane. LVDS standard is used in the data link. Both FEB and CB crates will use the same backplane to simplify maintenance.

3˙2. *The Controller Board.* – The Controller Board has been developed in order to manage the RPC front-end electronics. The block diagram of the board is shown in fig. 2.

The Controller Board is the interface between the FEB system and the spectrometer DAQ. Each CB manages the nine FEBs required to acquire an entire RPC plane, providing the read-out of digital signals stored in the FEBs shift register chain and managing the SLOW CONTROL data exchange. The CB receives the nine FAST-OR input signals from FEBs and generates the plane FAST-OR output for trigger purpose.

When an OR signal from one or more FEBs is detected (FAST-OR), the CB sends a common trigger (LOAD) to the FEBs (eventually in coincidence with an external trigger), performs the shift register readout through a serial interface, implements the data zero suppression and organizes data in a FIFO for data acquisition.

The CB can operate in 2 modalities: auto-trigger (*i.e.* the plane acquisition starts if a FAST-OR signal from that plane is detected) and external trigger (*i.e.* the plane acquisition starts in the occurrence of an external trigger). When the CB operates in auto-trigger mode an individual FAST-OR starts the acquisition of the entire plane, while in the external trigger mode, the acquisition starts only if the selected trigger conditions among different RPC planes occur. When the trigger conditions are satisfied, the CB enables a BUSY signal to indicate that the acquisition procedure is in progress and sends a LOAD signal to the FEBs starting the plane read-out. The LOAD signal is followed by a train of 64 clock signals at 10 MHz frequency to perform the readout of the 64 bit shift register of each FEB.

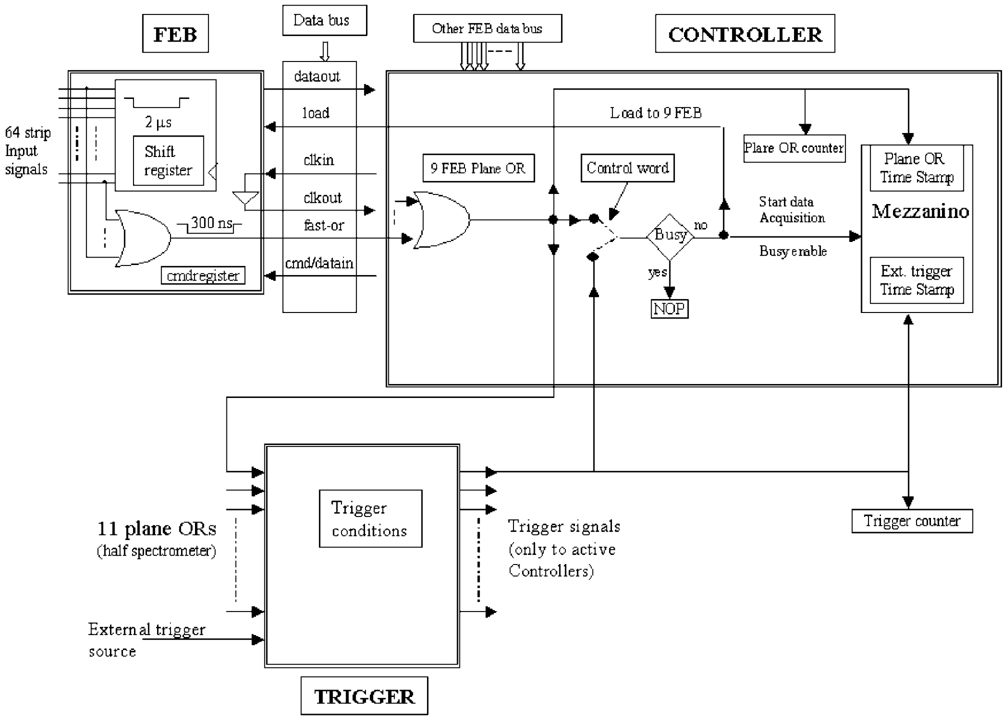

Fig. 2. – The layout of RPC readout system.

The nine FEBs required to fully read-out a plane are acquired in parallel, while the data shift register chain of each FEB is read through a serial interface. About 8 μs are required to acquire an entire plane, which ensures a maximum acquisition rate of 100 kHz/plane.

Plane FAST-OR signals and Trigger signals occurring during the data acquisition process are counted and time stamped in order to evaluate the trigger efficiency and to identify lost triggers.

The CB hosts the DAQ interface (Mezzanino) and the Node Card for the event time-stamp. The Mezzanino (developed in Lyon) [5] is hosted on the CB as a daughter card. It performs a simple formatting of the data and provides a precise measurement (10 ns) of the event time, adding the time stamp of the event (generated by the Global Position System (GPS) through the Pulse Per Second (PPS) clock). Event information is trasmitted to the DAQ system through an Ethernet protocol. Furthermore the Mezzanino allows the setting of SLOW CONTROL parameters at the start-run time. An independent serial allows to manage the CB for test purpose.

3˙3. *The Trigger Board.* – The Trigger Board has been developed to minimize the effects of the apparatus noisy sections by imposing coincidences between planes of the spectrometer and, eventually, other components of the detector. Every Trigger Board manages the acquisition of a full arm of the spectrometer (figure 2). Up to eight conditions of trigger to the 16 input channels (11 from RPC planes and 5 coming from other detectors) can be selected.

The Trigger Board reacts to any input configuration within 175 ns, well below the 300 ns of the LOAD generated from the Controller Board.

The elaboration of trigger signals is implemented through a Look Up Table (LUT) technique.

Also the Trigger Board allocates the DAQ interface Mezzanino and the Node Card for the time stamp. This allows the acquisition of trigger conditions, trigger time and plane pattern conguration for each triggered event.

4. – Conclusion

The OPERA spectrometer RPC read-out electronics has been defined according to the detector characteristics and the experimental requirements.

Signals are processed in free running mode on the basis of self-triggering conditions or using the trigger validation signal.

Data are time stamped to allow the off-line event reconstruction. A first prototype of the FEB and CB have been realized. The test of complete electronics chain is in progress using a RPC horizontal telescope built in Naples.

* * *

We thanks the electronic service of INFN, Sect. of Naples and Sect. of Padua, the IPNL, the IN2P3-CNRS and the Université C. Bernard Lyon I of Lyon for their involvements in the development of specific parts of the whole system.

REFERENCES

[1] CERN-SPSC-2000-028, LNGS-exp-30-2001-ADD-1 (2001).
[2] Fukada Y. *et al.*, *Phys. Rev. Lett.*, **81** (1998) 1562.
[3] Becker U., CERN-EP/80-154 (1980).
[4] Santonico R., *Nucl. Instrum. Methods A*, **263** (1988) 20.
[5] Girerd C. *et al.*, LYCEN, 2000-109.