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TEST OF A LED MONITORING SYSTEM FOR THE PHOS SPECTROMETER

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Abstract

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A prototype of monitoring system for the Photon Spectrometer (PHOS) of the ALICE experiment at LHC is described in detail. The prototype consists of Control and Master modules. The first one is an 8x8 matrix of Light Emitting Diodes coupled with stable generators of current pulses. The system provides an individual control for each of the 64 channels of PHOS prototype based on lead-tungstate crystals. A long term stability of the order of 10^{-3} has been achieved in integral beam test of the monitoring system and PHOS prototypes.

Аннотация

Блик А.М. и др. Испытание мониторной системы спектрометра PHOS: Препринт ИФВЭ 99-50. – Протвино, 1999. – 7 с., 8 рис., библиогр.: 8.

Подробно рассмотрен прототип мониторной системы для фотонного спектрометра PHOS эксперимента ALICE на большом адронном коллайдере LHC. Прототип состоит из двух типов модулей – контрольного модуля и мастер-модуля. На контрольном модуле установлено 64 светоизлучающих диода, соединенных со стабильными источниками импульса тока. Мониторная система обеспечивает индивидуальное управление каждого из 64 каналов мониторной системы для прототипа электромагнитного калориметра, основанного на кристаллах $PbWO_4$. Долговременная стабильность порядка 10^{-3} достигнута при проведении интегрального теста мониторной системы и прототипа калориметра PHOS.

Introduction

PHOS (PHOton Spectrometer) is an electromagnetic calorimeter of high granularity consisting of 17280 detection channels of lead-tungstate crystals (PWO) with 2.2x2.2x18 cm^3 dimensions, which are coupled to large-area PIN-photodiodes with low-noise preamplifiers, see [1]. The calorimeter will operate at a temperature of -25^o C, stabilized with a precision of $\approx 0.3 - 0.4^o$ C. Although the PIN diodes possess high gain stability, with the preamplifiers having their own calibration unit, a Monitoring System (MS) that can test simultaneously all the components of the PHOS channels will be very useful for a set of general tests of the calorimeter. This includes checks of the channel matching and optical contacts between crystals and PIN diodes after assembly and/or before cooling the PHOS modules. The MS will also provide a powerful tool to check the transparency of crystals, the gain factors of the preamplifiers and their stability, the linearity of full electronic chain including preamplifiers, shapers and ADCs for all PHOS channels during physical runs.

In this paper we describe a monitoring system based on an 8x8 matrix of Light Emitting Diodes (LED) coupled with stable generators of current pulses and the current results of integral beam test of the MS and PHOS prototype module, which consists of 8x8 PWO crystals. Compared with the types of MS based on the use of LEDs, see for example [2,3,4,5], the present LED system has several features essential for operation with the PHOS spectrometer in ALICE. The main features are as follows:

- wavelength, duration and intensity of the light flashes are similar to those generated by photons in PWO crystals used in the PHOS;
- minimal power consumption to reduce temperature field distortions in the thermostabilized volume of the PHOS at a temperature of -25^o C;
- high stability of the light flashes.

1. Description and performance of the monitoring system

The MS prototype consists of two modules, the Control Module (CM) and the Master Module (MM). The Master module is located in the control room, and is connected with the Control module, which is inside the PHOS, by a flat cable. The functions of the MS are shared between these modules as follows. The Master module, being connected with a host computer through the CAMAC interface, receives and keeps in memory all the information about the MS operation and, after a special command, transmits it in a digitized form to the Control module. The CM decodes the obtained information and transforms it into a sequence of analog signals which are stored in the analog memory (capacitances) for a short time. After the command "Fire" the given configuration of the LEDs in the CM will be fired.

The Control module of the MS is a two layer printed circuit board with the 8x8 matrix of LEDs positioned centrally over the front face of the crystals. The generators of current pulses as well as control circuits are mounted on the same board. A functional diagram of the Control module is shown in Fig.1. The Control module consists of the decoder of MM commands, four 8-bit Digital-Analog Converters (DAC), 4x2 analog multiplexers and 64 LED drivers coupled with LEDs (the superbright LED L132SG of Kingbright and DAC AD5300BRT of Analog Device with a setting time of 4 μs are used in the prototype). Thus, the operation of each channel of the Control module is performed in a digitized form, and is noiseproof. The analog part for each channel, a LED driver, is spacially dense and located just near the corresponding LED. Therefore, it is also noiseproof. As a result, we obtain a very stable generator of light pulses.

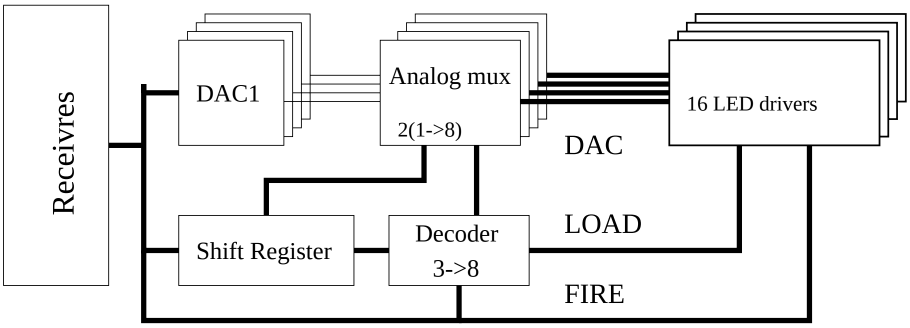

Fig. 1. Functional diagram of the Control module.

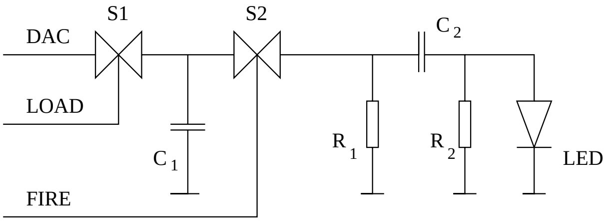

Fig. 2. Scheme of the LED driver.

The scheme of the LED driver is shown in Fig.2. At the first stage of the CM operation the specific code is loaded in the DAC by the Master module (once the DAC has been already loaded and the code should not be changed, this stage is omitted). At the second stage the capacitance C_1 is charged by the DAC through the connected analog switch $S1$ of the 74HCT4066 type, and a bit later the switch $S1$ is disconnected. Thus the capacitance C_1 is used as an analog memory and should have a low leakage current and high stability. At the last stage the switch $S2$ is connected, and the capacitance C_1 is discharged through the LED. The duration of the leading edge of the LED flash is determined by the speed of the switch $S2$, the trailing edge is determined mainly by the C_1R_1 time constant (~ 1 μs in our case), and the C_2R_2 chain shapes the pulse. The whole amount of light is defined by the charge kept at the capacitance C_1 and can be adjusted by the DAC.

For the temperature and time stability we used capacitances with the NPO dielectric. The leakage current for such type of capacitance is about 100 pA. An additional decrease of the leakage current is achieved due to the low temperature of analog switches. These features ensure a charge stability of $\sim 10^{-3}$ during about 1 ms. A typical light pulse is shown in Fig. 3. The pulse duration ($\sim 100\ ns$) is of the same order of magnitude as that from PWO crystals of the PHOS.

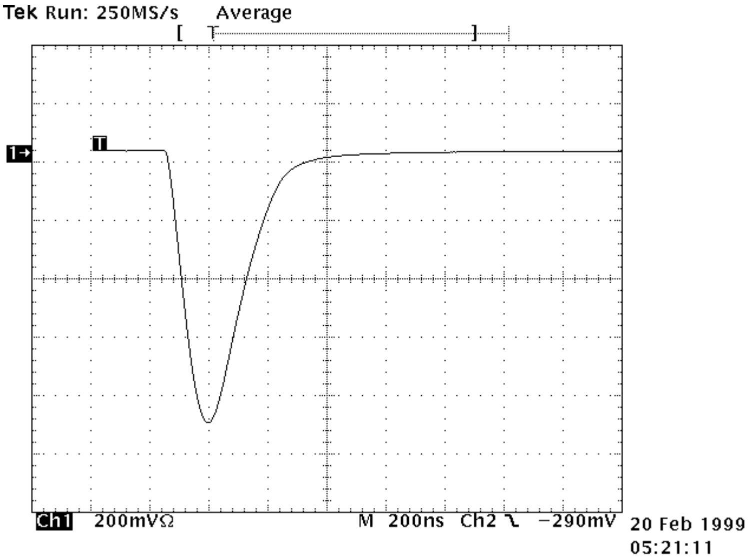

Fig. 3. The light flash from LED viewed by fast photomultiplier 56AVP and digitized by the oscilloscope TDS724.

The LED is fired in the forward direction by a low-voltage pulse with an amplitude up to 5 V. This soft mode of LED operation decreases the effect of LED ageing. The voltage variation at the C_1 capacitance using an 8-bit DAC changes the light intensity by two orders of magnitude and overlaps the whole dynamical range of the PHOS. The dependence of the LED light intensity on the DAC code is of exponential type. It has been measured with a 11-bit ADC in a special test run with the PHOS prototype (see below) and is shown in Fig. 4. A power consumption of the Control module is of the order of 0.3 mW/channel in an idle state, whereas in the active state it is about two times higher. This is negligibly small compared with the heat penetrating through the walls of thermostabilized volume of the PHOS.

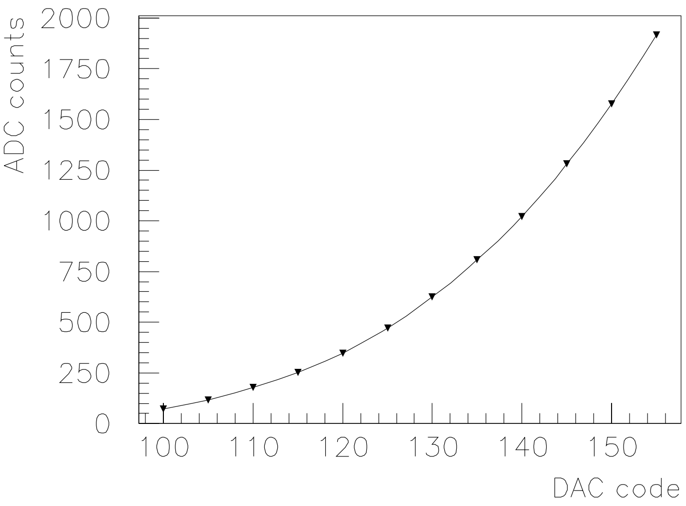

Fig. 4. LED amplitude dependence in a PHOS channel on the DAC code. The measurements were performed with 11-bit ADC. The curve is an interpolation of the measured points.

The operation of the LED monitoring system is defined by the Master module. There are four operational modes:

- ”Stand-by” mode, i.e no LED signals, minimal power consumption by the CM.
- ”Fast” mode, i.e. the mode when the channel pattern is sent to the CM without DAC loading. This mode is main in a physical run for channel monitoring.
- Amplitude scan and different channel pattern loading. The main purpose of this mode is a total test of the cable connections, quality of the optical contacts and the electronics chain. This mode is intended for an installation stage of the PHOS and for periods between runs for checking the PHOS performance.
- Loading of the *shower pattern* and *physical event image.* In this mode the physical performance of the PHOS based on the Monte-Carlo minimum bias events (which are loaded into the CM) can be estimated. The performance of PHOS will be checked ”in vitro” without beams.

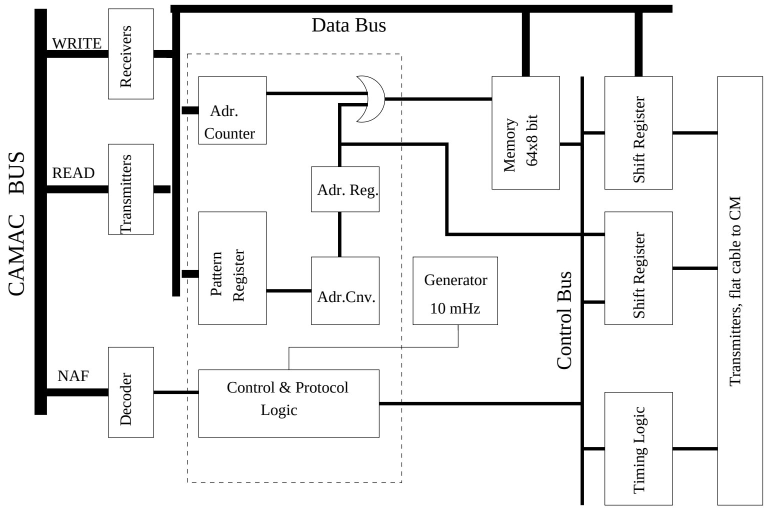

Fig. 5. Functional diagram of the Master module. The part marked by the dashed line is realized with ALTERA.

The MM prototype is realized as a CAMAC module. Its functional diagram is shown in Fig.5. The decoding circuitry, ancillary logic and memory counters are realized on the Field Programmable Gate Array (FPGA) ALTERA EPM7160SLC84-10 [6]. The current configuration of loaded channels is saved in the MM memory and then can be sent to the Control module at any time. The SPI protocol is used to link the Master and Control modules. In the MS prototype the rate of pattern loading has been limited by a 10 MHz clock pulse.

The Master module has the following CAMAC functions:

- Reset of the MM memory address pointer,
- Read/Write the pattern configuration in the MM memory,
- Read/Write the address pointer in the MM memory,
- Read/Write the DAC code in the MM memory,
- Direct Write the DAC code to the CM,
- Load the pattern and DAC memory in the CM,
- Load the pattern and DAC memory in the CM and ”Fire” it,
- Send the command ”Fire” to the CM.

2. Prototype beam test

The prototype of the monitoring system was tested simultaneously with the 8x8 PHOS prototype in 1999 in the T10 beam of the PS CERN accelerator. The CM was housed in front of the PHOS prototype inside the thermostabilization volume at -20^o C. The temperature stabilization was provided with accuracy of $\pm 0.2^o$ C. The signals from the PHOS channels (PWO crystals in junction with PIN-diodes, preamplifiers and shapers) were measured with an 11-bit LeCroy ADC. The stability of the preamplifier and shaper chains was checked in special pulser runs, when calibrated signals were transmitted to the inputs of preamplifiers. The LED monitoring runs followed just after the pulser runs. During the monitoring the Master module was controlled by an autonomous host computer which also initiates the special monitoring trigger to collect the monitoring data. The LED trigger rate was 0.3 kHz. In average a monitoring run takes 5-10 min of real time.

Typical examples of the amplitude spectra in one PHOS channel are shown for pulser and monitoring runs in Fig. 6. As is seen from the figure, the widths of the pulser and LED spectra are similar. Thus, we can conclude that the light flash fluctuations are small compared with the noise level in the electronics chains of the PHOS.

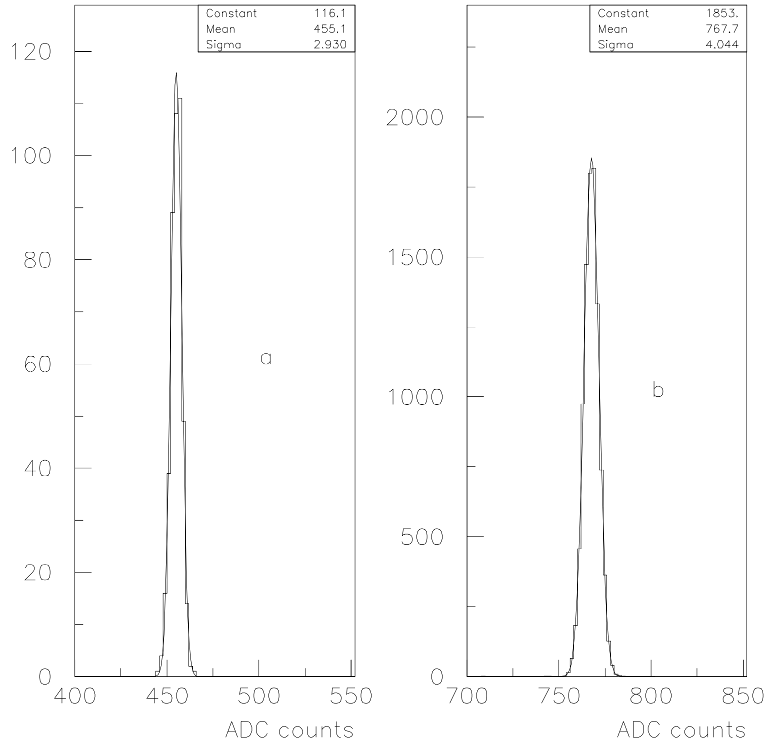

Fig. 6. Amplitude spectra in the same PHOS channel: a) pulser run, b) LED monitoring run.

As for the quality of channel monitoring, it is useful to distinguish long and short term instabilities. The latter means the LED signal variation during a monitoring run. It can be characterized by variation of the LED signal ratio for two different PHOS channels. Measurements of the short term instability have been performed for several monitoring runs. The typical results are presented in Fig. 7, where the LED signals from two different PHOS channels averaged over 16 triggers (one measurement) as well as their ratio are shown. The deviation of two signal ratio to its average value is $\sigma_R/\langle R\rangle = 1.2\cdot 10^{-3}$ during a monitoring run. No systematics in the variation of the ratio was found (see Fig. 7c) where a linear fit of the distribution gives a value of $\sim 3\cdot 10^{-7}$ for the slope.

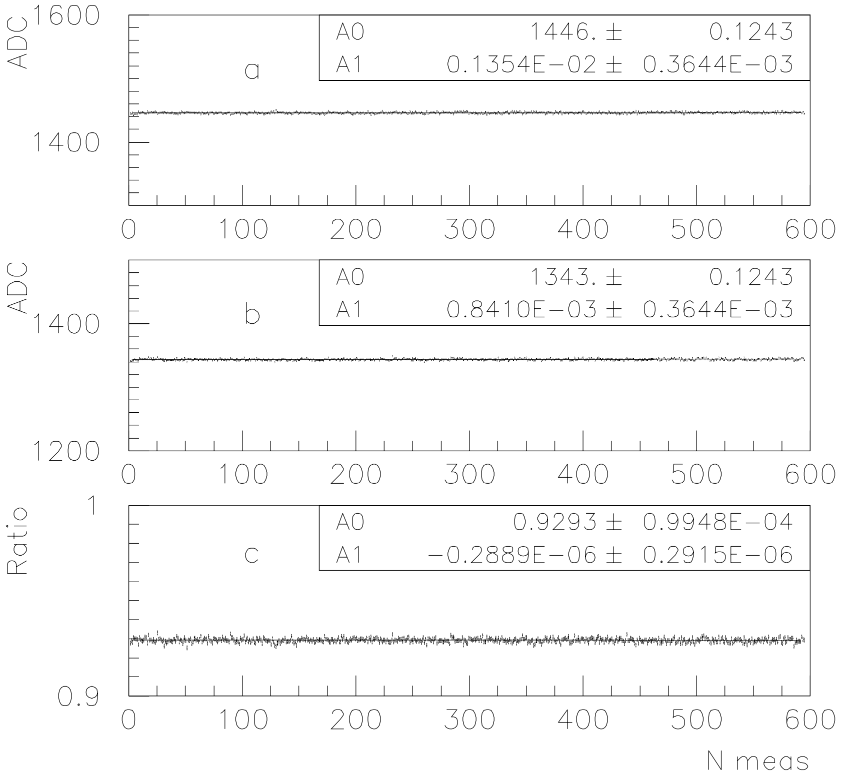

Fig. 7. The short term instability of LED monitoring system: a) channel A, b) channel B, c) the ratio A/B. Each point is an average over 16 ADC values. The A0 and A1 are parameters of linear fit $F(N) = A0 + A1\cdot N$. The time covered in the figure is 10 min.

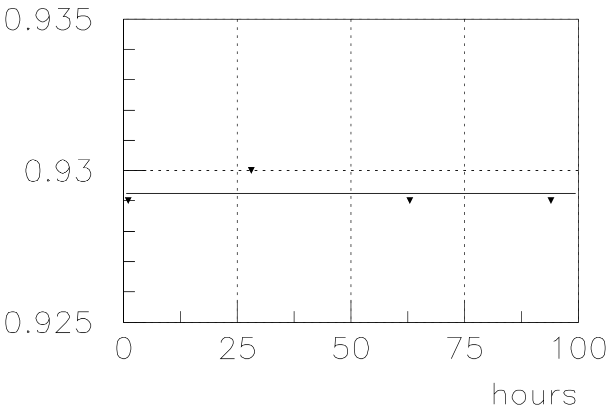

Fig. 8. The long time stability of two channels ratio, the line is the fitting constant.

The long term instability is characterized by the deviation of the average value of LED ratio from one monitoring run to another. The measurements are presented in Fig. 8. As is seen the relative deviation from the average value is equal to $\sigma_R/\langle R\rangle = 10^{-3}$, which is in good agreement with the value obtained for short term measurements. Thus, we conclude that the general instability of the LED monitoring system prototype is of the order of $\sim 10^{-3}$.

Conclusion

The prototype of LED monitoring system for the PHOS spectrometer of the ALICE has been tested simultaneously with PHOS prototype in T10 beam of the PS accelerator in CERN. The system provides an individual control of each of the 64 channels of the PHOS prototype. It is based on the very stable generators of the current pulses which were used for the LED excitation. The achieved stability of the system is of the order of 10^{-3} during ≈ 100 hours.

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