Mass production automated test system for the NEXT SiPM tracking plane

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Abstract—NEXT is a double beta decay experiment that will be operated in Canfranc Underground Laboratory (Spain). It will contain a tracking plane based on ~7000 SiPMs (S10362-11-050P from Hamamatsu) in which every photo sensor must be tested and characterized to ensure detector quality and to perform adequate data corrections. This paper presents the automated system developed for the test and characterization of the SiPMs. The test system is based on laboratory equipment and a custom made board controlled using LabVIEW software, being a concept that can be easily adapted to other experiments.

INTRODUCTION

NEXT is an active project based on a 100-kg high-pressure xenon gas TPC that will search for neutrinoless double beta decay ($\beta\beta_{0v}$) in Xe-136. Such a detector, due to less than 1% FWHM energy resolution and its powerful background rejection provided by the distinct double beta decay topological signature, may become one of the leading experiments of the field [1]. To achieve optimal energy resolution, the ionization signal is amplified in NEXT using the electroluminescence light (EL) in xenon. The chamber will have separated detection systems for tracking and calorimetry [2]. The energy function is provided by a plane of ~ 60 PMTs, while tracking function is provided via ~ 7000 SiPM plane, 10 mm pitch. A small prototype of NEXT is shown in figure 1.

The SiPM plane is based on small boards (see figure 2), called DICE-Boards, with 64 SiPMs sharing same bias supply voltage (cathodes together on 16 SiPMs groups) through 4 tantalum capacitors of 10 $\mu$F and 4 10k$\Omega$ resistors, each ones for 16 SiPMs group. FPC cable is used for signal transmission to the front-end [3], and also for bias supply and temperature sensing readout (based on a NTC termistor on each DICE-Board).

SET-UP & TESTS

The set-up (figure 3) consists of the following electronic devices:

1) A light system, based on a 400 nm emitting LED (HUVL400-520B) controlled by a commercial pulse generator (AGILENT 33250A) able to provide short pulses of about 30 ns.

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2) Keithley 2410 (picoammeter/voltage source), used to provide bias voltage and also to measure the mean value of the current sourced by each SiPM.

3) Oscilloscope LeCroy WaveRunner 64MXi-A (400Mhz) to measure the charge produced by each SiPM signal and provide the Single Photon Spectrum (SPS).

4) Custom board based on 64 relays that allows the selection of the SiPM being tested. The control of the relays is made via LabVIEW and USB through an ATMEAL based microcontroller board. The custom board also includes a 20 dB (x10) gain non inverting amplifier (OPA842) that provides enough amplification to the SiPM signal for being acquired with good resolution using a commercial oscilloscope.

Homogeneous light is provided to the DICE board under test through the reflected LED light over a Teflon surface located in front of the SiPMs. The LED and the DICE boards are placed into a black box (figure 4). The custom board is also inside the box to reduce cabling issues.

Tests and measurements performed to the SiPMs are the following:

Direct polarization: applying a direct voltage of 1 V to the SiPM and checking that the DC current through the SiPM does not exceed certain limits (typically ~38 µA). This test can easily detect damaged or wrong connections in SiPMs.

Dark current: Applying the nominal reverse voltage to the SiPM (~71 V) without applying light and measuring the DC current drained by the SiPM (typically 10-100 nA) obtaining a measurement of the mean dark current.

Photoelectron spectrum: Applying the nominal reverse voltage to the SiPM (~71 V) with light, the histogram of the SiPM charge output is obtained through measuring the amplitude of the signal in the oscilloscope.

The gain of the SiPM is obtained from the histogram [4], as shown in figure 5.

The test system allows the connection of a DICE-Board through FPC cable, performing the test of 64 SiPMs in a sequential mode.

Additionally, the measurements performed will be also done with the SiPM at different temperatures. For this, the DICE-Board will be kept inside a copper container temperature controlled using a Peltier element. This additional system can be easily integrated into the actual LabVIEW system (figure 6).
The Peltier is powered by a current driver (MAX1968) limited at ±1 A, which is controlled with one PWM (Pulse Width Modulation) output of the microcontroller. For the temperature stabilization, a PID controller (Proportional-Integral-Derivative) is implemented in the LabVIEW custom software, to ensure that the temperature of all the SiPMs is homogeneous and stable. The DICE-Boards will be characterized at 5 different temperatures for the SiPMs nominal operation voltage, in a range from 20 °C to 30 °C.

Figure 6: Current driver connected to the custom test board (left) and DICE-Board container aluminium prototype (right).

The control and monitoring system is based on LabVIEW graphical interface that allows the control and monitoring of the whole system (figure 7).

CONCLUSIONS

The test system developed constitutes a simple and fast way for testing and characterizing the SiPMs of the NEXT tracking plane. A basic SiPM functional test is performed, and also important parameters such as gain and dark noise are obtained at different bias voltages. Additionally, a temperature controlled system will be integrated in the test system to characterize the devices as function of temperature. That allows to obtain the gain-voltage and gain-temperature response of each SiPM, in order to compensate the temperature variations during the detector operation and stabilize the SiPM tracking plane gain.

Being the designed system based on laboratory equipment (and therefore independent of the front-end used in the experiment), the system presented can be extrapolated in a short time to other large experiments requiring the test and characterization of massive number of SiPMs.

REFERENCES