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Development of a high performance characterization setup for SiPMs and MPGDs towards their integration in mid-large scale systems

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Supported by a common funded project with RD51-CERN, a groundbreaking laboratory for training, development, fabrication, applications and innovation with Silicon Photo-Multipliers (SiPMs) and Micro-Pattern Gas Detectors (MPGDs) and their related technology has been finally commissioned at Universidad Antonio Nariño (UAN) in Colombia. Such devices are featured by their remarkable space and time resolution, high gain, robustness and large stability for a wide range of radiation and particles. The UAN expertise on such kind of devices mainly arises from collaboration with the ATLAS, RD51, NEXT, DUNE experiments worldwide and optical communications industry in Colombia (datLIGHT-VLC). The UAN has developed a dedicated characterization setup and protocol (outside the scope of this work) what ensure a reliable electrical response of SiPMs and MPGDs under predefined conditions by the user at high rate data production. A brief overview of such characterization setup is presented in this work.

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1. Introduction

Strategical agreements and successful cooperation between UAN and European counterparts, made possible the fast-growing commisioning of the UAN Detectors Laboratory for training, development, fabrication, applications and innovation of SiPMs and MPGDs.
The characterization setup for SiPMs and MPGDs designed at UAN consist of a set of hardware and software synchronous modules offering a narrow but precise electrical characterization. In the case of SiPMs [1] it includes: evaluation of photon spectra (gain), current - voltage measurements (breakdown voltage, capacitance, resistance and saturation), noise measurements (optical cross-talk, dark count rate and afterpulsing). Nonetheless, timing properties evaluation, working point optimization, complementary current-voltage measurements, spectral response measurement, linearity, dinamic range, bandwidth and signal-to-noise ratio, are being gradually implemented, as well as evaluation of geometrical parameters (number/size of cells and fill factor). Regarding electrical characterization of MPGDs [2], currently an ongoing work, it is focused on energy resolution, gain and rate capability. Timing resolution, efficiency, spatial resolution and ageing are going to be in turn officially implemented to the characterization protocol.

2. Characterization setup

The big picture of the aforementioned characterization setup is represented in Figure 1.

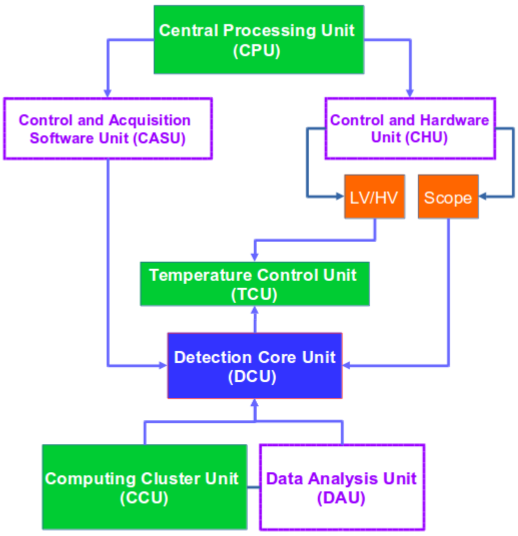

Figure 1: SiPMs and MPGDs characterization setup concept at UAN Detectors Laboratory.

In agreement to Figure 1, the setup is structured in nine units arranged in four main groups: hardware input acquisition and data output (green boxes), GUI programmable execution flow (white boxes), bias and visualization (orange boxes) and detection core (blue box).

2.1 Central Processing Unit (CPU)

By means of the CPU main programmable execution input flows through the CASU and CHU units are enabled via GUI. The CPU (Dell Precision T5600) features by its 2 GHz Intel® Xeon® processor, 8 GB RAM memory, 1 TB storage and 64-bit micro-processor architecture [3], Windows professional operating system and multi-monitor visualization supported by a NVIDIA Tesla® Graphics Processing Unit (GPU) (448 cores, 6 GB memory, 144 GB/sec bandwidth).

2.2 Control and Acquisition Sofware Unit (CASU)

SiPM is coupled to the CAEN SP5600B Evaluation Kit [4] purchased with a `LabVIEW`-based control software with basic functionalities. UAN slightly tuned (only for academic purposes) such `LabVIEW` code (over primitive functions and invoking nodes) doing possible flexible automation tests by combining Power Supply Amplifier Unit (PSAU) and digitization parameters, and temperature monitoring among others. `LabVIEW` tool developed at UAN is in turn adaptable to MPGD characterization unit requirements when invoked.

2.3 Control and Hardware Unit (CHU), LV/HV and Scope Units

The CHU consist of 2 well defined tools for control and instrumentation local configuration of LV/HV sources (`UANGTracer`) and scope (`UANGScope`). `UANGTracer` allows to configure the number of started sessions for controlling of a GPIB (IEE 488.2) source in a basic mode (voltage, current and safeguards) and advanced mode (lineal and logarithmic scanning, data buffer reading, Service ReQuest, data saving and plots sketch). `UANGScope` was designed for "mimic" the scope interface. It uses National Instruments (NI's) libraries for GPIB or Ethernet conection, it couples pad, canvases and windows in a modern frame and easily playable graphical data per channels, configure scope triggers and get signals coming from all the channels at once.

2.4 Temperature Control Unit (TCU)

The TCU is a hybrid homemade and manufacturer device that allows the temperature control (close loop scheme) of the environment (20-35°C) by using a conventional Peltier Cell, thermal dissipators and a temperature controller (HTC 1500). The control is carried out by a thermoregulation function based on analytical approaches on radiation, conduction and convection on the cell surroundings. The TCU can be set for acquisition in background light intensity (0-200 lx), pulsed light intensity (0-150 lx) and frequency (0-40 MHz), current across the Peltier Cell (0-15 mA), Bias Voltage (0-1000 V) and Duty Cycle (0-100%) conditions.

2.5 Detection Core Unit (DCU)

The DCU is the backbone of the characterization setup where the SIPM and MPGD work as a very different standalone module: design, structure and functionality.

SiPMs are essentially a matrix of avalanche photodiodes with a common output where each photodiode operates in a Geiger regime. The GEM ionization chamber is mainly featured by its charge multiplication electrode (foil) and the HV bias commonly connected as an electrically dependent circuit of the patterned readout board.

SiPM setup consist of an ultra fast LED driver, PSAU and digitizer integrated into the CAEN Evaluation Kit. The kit has a pair of SiPM holders specially designed to fit Hamamatsu Photonics reference, but slightly homemade tuned fitting other references (e.g., SensL, ST Microelectronics).

For GEM case, the data and pulse online acquisition is carried out with a high performance scope featured by its advanced triggers and fast viewing modes in time and frequency domains controlled by GPIB. A structured pre-amplification/amplification Scalable Readout System (SRS) is actually the option for GEM multi-channel readout [5].

2.6 Computing Cluster Unit (CCU)

The high rate data flow output coming from the hardware modules chain are proccessed, analyzed, filtered and sorted by means of the DAU, a structured algorithms and framework running through the CCU. CCU is linked in a such a way that the full data output stream undergo a programable data analysis routine on parameters explained in Section 1. CCU is a batch system workstation formed by 11 CPUs featured by its large storage capability ($\sim$ 3 TB), multi-core technology, and close to 3 GHz of frequency for a whole 8-core CPU, ensuring powerful processing, stability and advanced multi-tasking [3].

2.7 Data Analysis Unit (DAU)

As previously commented, the DAU runs fast algorithms for SiPMs and MPGDs electrical properties evaluation. Interface is a `MATLAB` and `Java` environment with inner coding of well known physics - engineering languajes and tools as `ROOT` and `MATLAB` itself. For SiPMs case (similar concept for GEM), there are several pads inset into a friendly canvas, with acquisition configuration over the DCU chosen, as well as statistical data analysis options for data stream coming from pre and post acquisition stages, data quality and delivery report of the characterization routine.

3. Outlook

A high performance characterization setup for SiPMs and MPGDs has been finally commisioned at the UAN Detectors Laboratory. The constant growing improvements on hardware, software, computing and human resources situates UAN as an appreciable partner on scientific and technical cooperation on radiation and particle detectors research, development and technology transfer.

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