An amplifier for VUV photomultiplier operating in cryogenic environment

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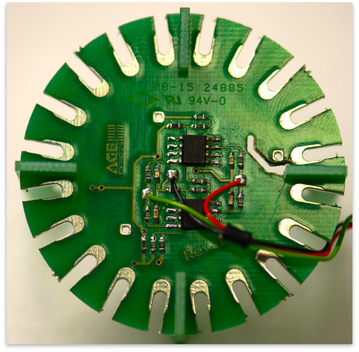
Introduction

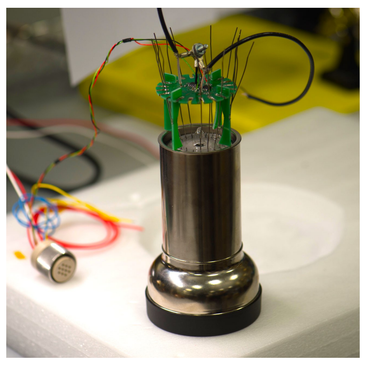
We present an amplifier potentially interesting for noble liquid detectors. The design has been conceived considering the requirements of low power consumption (<30 mW), low noise (250 μV RMS), amplification factor of 10 at 100 MHz and use of commercial components (AD8011). The amplifier has been integrated onto a PCB with a voltage divider to operate an Hamamatsu R11410 photomultiplier tube (used in Xenon1T dark matter experiment). The system has been tested in a controlled bath of liquid nitrogen to investigate its performance at different temperatures. The final prototype looks promising for its use in Liquid Xenon based detectors. Further work is on going to investigate its use at lower temperatures.

Experimental setup

An amplifier circuit has been implemented onto a voltage divider for HAMAMATSU R11410 photomultiplier tube operating in cryogenic environment (i.e. Liquid Argon, LAr, or Liquid Xenon, LXe). The board requires a current supply for the amplifier stage and an high voltage input to power the PMT. 1X and 10X amplified signal outputs are provided.

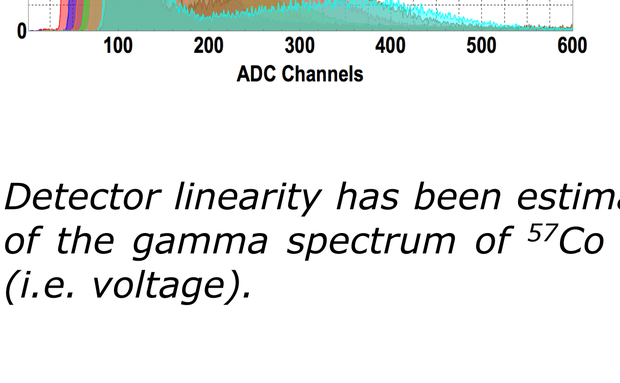


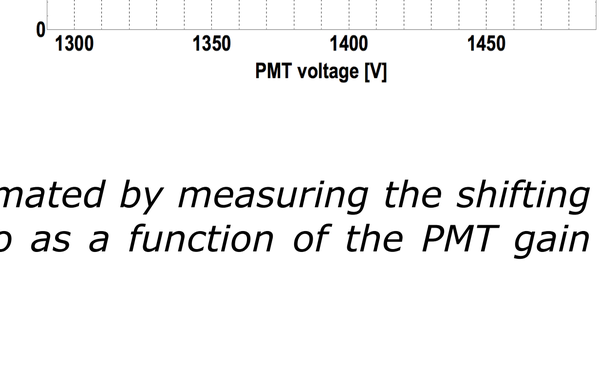
The PMT detects the scintillation light output of an YSO (Yttrium Orthosilicate) crystal irradiated by gammas from a set of sources (^{22}Na, ^{57}Co).
A turbo molecular pump is used to evacuate the vessel. The chamber is kept in a liquid nitrogen bath. An HDO6104 Lecroy oscilloscope has been used to acquire data.



The measurements

To validate the amplification performance, several gamma ray spectra obtained by the integration of 1X and 10X analog outputs have been compared.

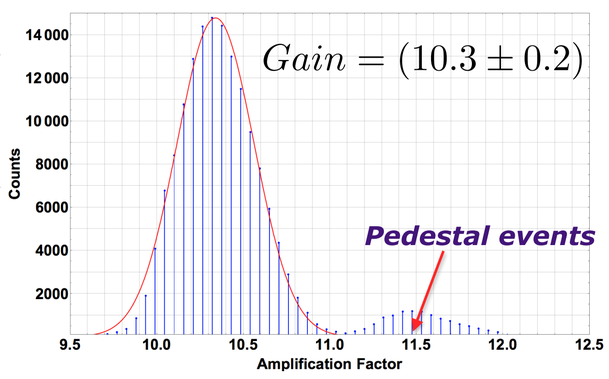


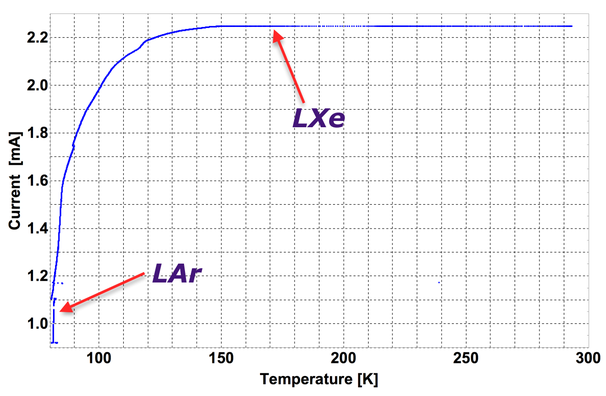


- *Considering a factor 10 of scale, the **spectra superimpose in cold** (173 K, left) **and at room temperature** (293 K, right)*
- *As expected, **low temperature (173 K)** results in a decreasing of the PMT gain (factor **1.94**), while the **amplifier performance is unaffected**.*

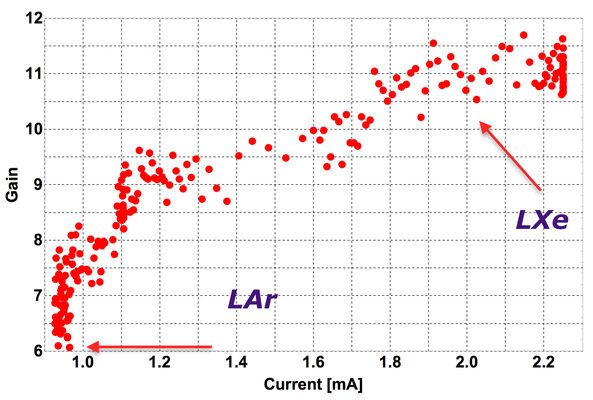
Amplifier Gain

The amplifier gain has been measured over a sample of 200k events taken with ^{57}Co at 173 K. The distribution of the ratio between the amplitude of 1X and 10X waveforms (Gain) is reported in the figure on the right.



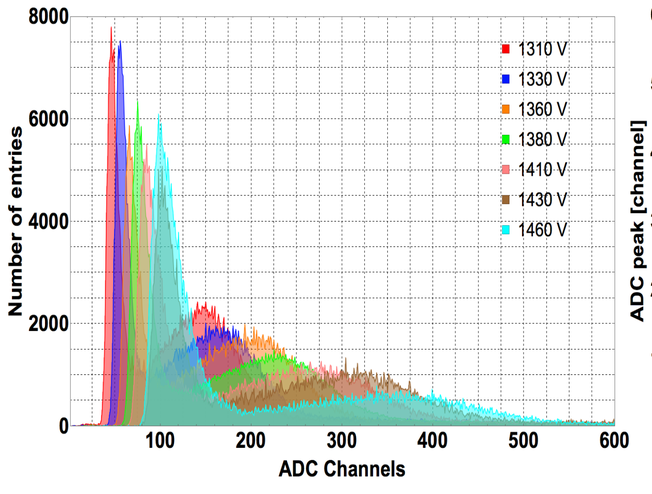


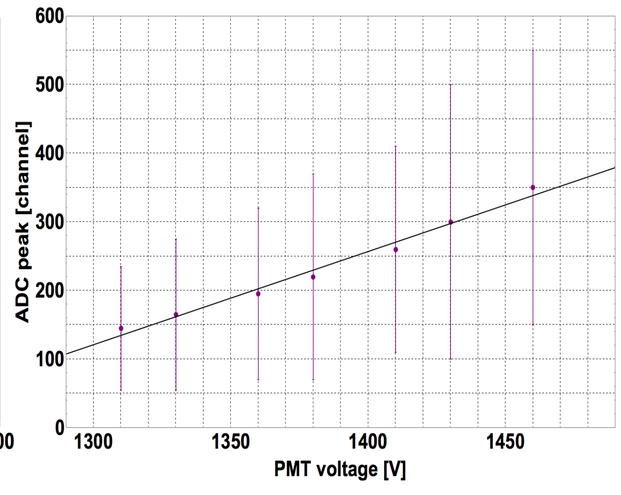
Absorbed current as a function of the temperature. Mean power consumption in the LXe range is 20 mW, in the LAr regime is 10 mW.



Amplification factor as a function of the absorbed current. The gain is about 10 and 7 respectively for LXe and LAr regime.

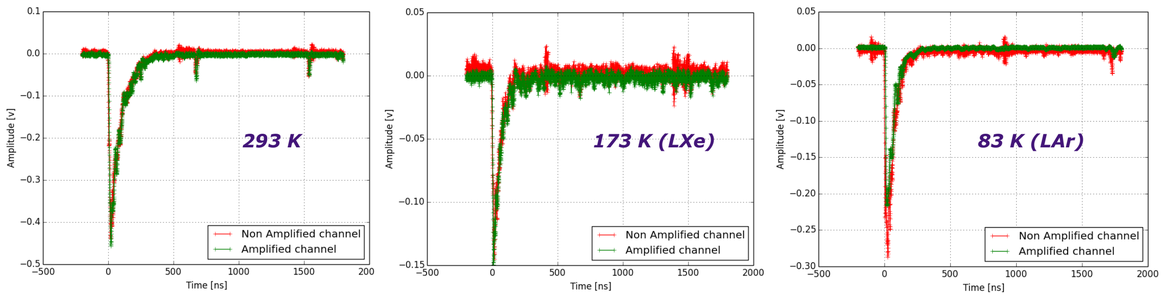
Linearity





Detector linearity has been estimated by measuring the shifting of the gamma spectrum of ^{57}Co as a function of the PMT gain (i.e. voltage).

Waveforms



Pairs of 1X (Red, scaled by a factor 10) and 10X (Green) amplified waveforms. The effect of the temperature becomes visible with the LAr regime (83 K), where the gain deteriorates of about 30% compared to the LXe regime(173 K).