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APD Power Control for the ALICE PHOS Prototype

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Introduction

PHOS is the Photon Spectrometer for the ALICE experiment at the Large Hadron Collider (LHC) at CERN.

The PHOS consists of 17920 detection channels, segmented in 5 modules. Each detection channel consists of a lead tungstate crystal PWO of dimension $180 \times 20 \times 20 \text{ mm}^3$, equipped with an Avalanche Photo Diode (Hamamatsu S8664-55 APD) coupled to a low noise preamplifier. The crystals and photo-detectors are operated at $-25 \text{ }^\circ\text{C}$. At this temperature, the light yield is about a factor of three larger than the light yield at room temperature. The performance and energy resolution of the detectors have been investigated with a 256-channel PHOS prototype see Figure 1, Figure 2 and ref. [1].

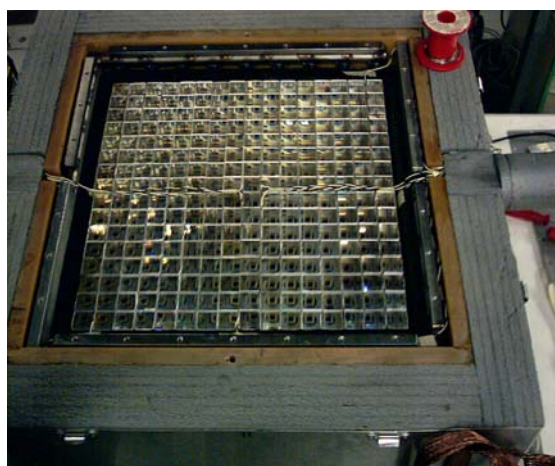


Figure 1. The 256-channel PHOS prototype

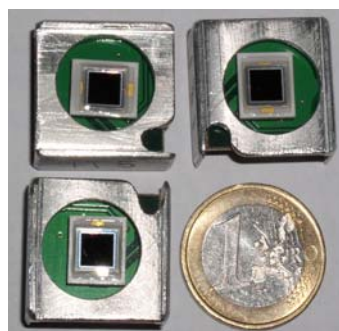


Figure 2. APDs mounted on preamplifiers

APD is a semi-conductor device. The intrinsic gain factor is very sensitive to the applied bias voltage (350-400V) and to the temperature, especially at the PHOS operating temperature [2]. In addition several other factors contribute to the effective gain factor: the light yield of the PWO crystal, the optical coupling between the crystal and APD, aging effects, and gain factor fluctuation spread of the preamplifiers and analog shapers.

A distribution of the gain measured for the 256 channels of the prototype, with the same bias voltage $\sim 400V$ applied to all APDs, is shown in Figure 3. The wide measured distribution does not comply with the PHOS requirement to deliver a partial analog sum for a PHOS energy trigger to the L0/L1 logic.

Since the effective gain factors can be controlled by a channel-by-channel APD bias setting, it was decided at an early stage of the PHOS electronics development to implement an APD bias control system. With this system the distribution of the gain value can be reduced to less than 5%. Each channel can be individually calibrated by means of the PHOS LED monitoring system.

The LHC CMS experiment, which uses similar APDs for the ECAL detector [3], presorts the APDs in batches according to gain factors. However, this method is not applicable for PHOS, because it is required that the PHOS delivers a rather precisely determined energy trigger to the L1/LO logic, and needed precision can't be reached with just presorting APD's.

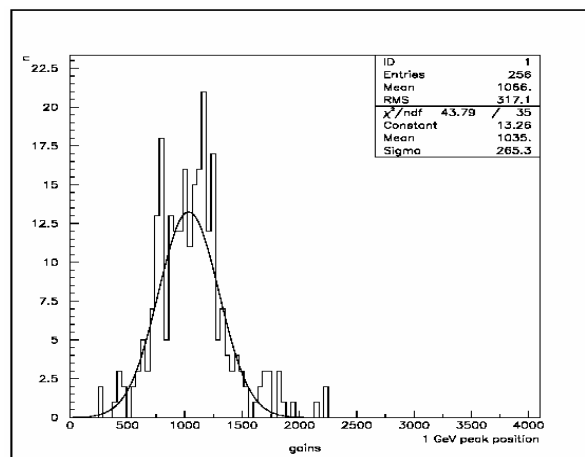


Figure 3. Channel gain distribution measured with the PHOS-256 prototype

System requirements and design

The operating requirements for the APD bias control system are the following:

- Computer controlled regulation of bias voltage in the 250-400V range;
- Voltage step resolution equal to 0.5V for gain = 100 and $T = -25^\circ C$, i.e. a 2% accuracy in matching the APD gains;
- Noise on bias voltage line $< 25mV$ in order to keep stability better than 0.1%.

A first version of the APD bias control system has been developed for the PHOS-256 prototype. The basic detector unit is a row of 8 crystals with APDs and preamplifiers connected to the external electronics through an adapter card (T-card). The PHOS crystal volume is cooled to $-25^\circ C$.

The principle of the APD bias control system is to feed individual bias voltages to APDs from a single 400V supply through a LV-HV regulator circuit using 8-bit DACs.

Bias control system layout is shown in Figure 4. A program, running on PC, retrieves information of the APD bias values for each PHOS prototype channel from a data base. The program has two options: 1) EDIT a data base of the bias values and 2) WRITE the bias values into the DAC register.

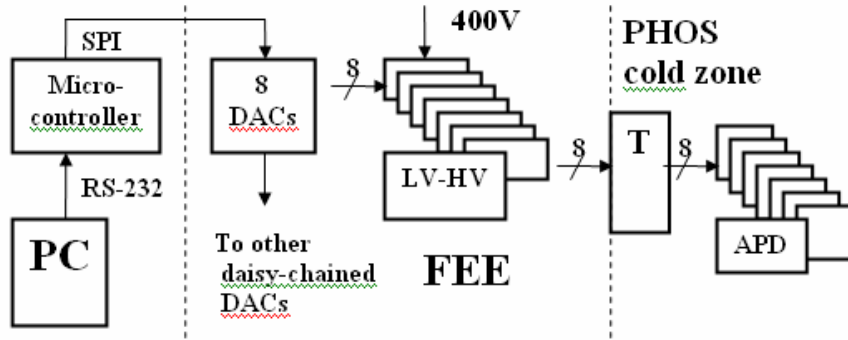


Figure 4. The APD bias control system layout

When the WRITE option is being fulfilled the data base of the bias values is loaded from PC into the microcontroller (ATMEL AT90S8515) intrinsic memory. The microcontroller is used for storing the data base as well as for writing the bias values into DAC register. The voltage from DAC output is converted to the APD bias voltage by a LV-HV regulator which is shown in Figure 5. A DAC chip is the octal 8-bit MAX5258 with Serial Peripheral Interface (SPI) for daisy-chaining interconnection. A regulation curve for the LV-HV regulator is shown in Figure 6. The LV-HV regulator is an amplifier with the negative feedback and the gain equal to 80. The amplifier consists of two parts: a comparison element and a regulation one. The comparison element is the operational amplifier AD8544 and the regulation element is opto-coupler KPC452. The opto-coupler insulates the low voltage circuits from high voltage circuits safely.

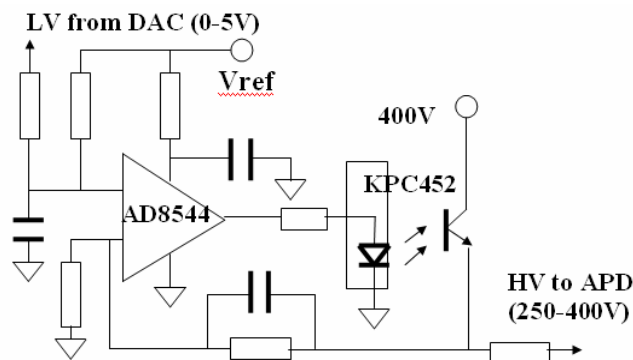


Figure 5. LV-HV regulator schematic

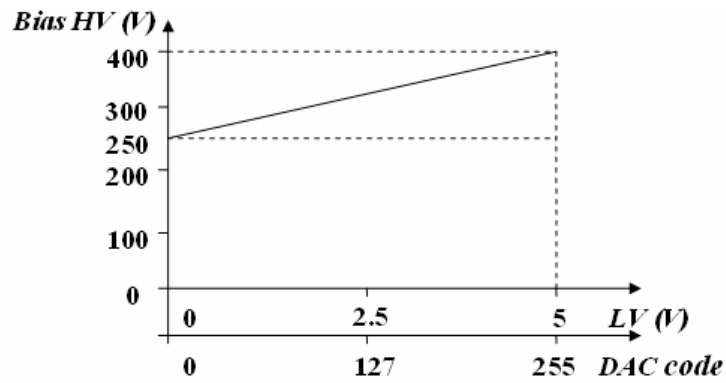


Figure 6. LV-HV regulation range for APD bias control

Results

The APD bias control system has been implemented on the front-end electronics card developed for the PHOS-256 prototype, Figure 7.

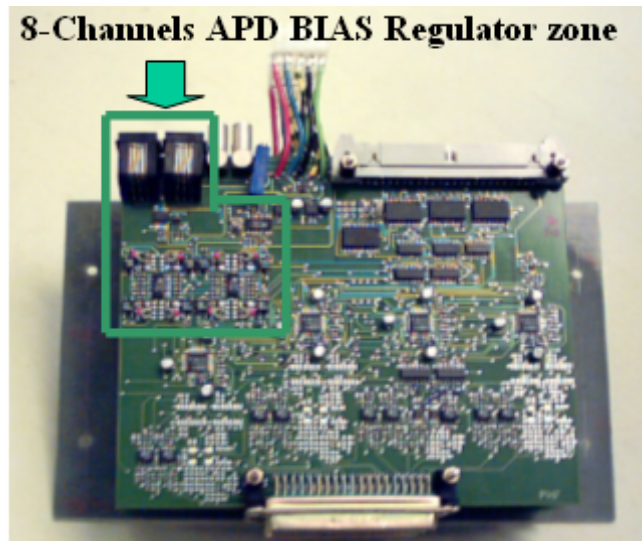


Figure 7. APD bias control board for PHOS-256 FEE

Tests of the system show very good long term and temperature stability of the HV output ($<0.1\%$), as well as good accuracy of the APD bias setting ($<1V$) and PHOS channel gain regulation ($<4\%$). It should be noted that the gain regulation accuracy is limited by the accuracy of the used 8-bit DAC chip, and it can be improved by using a 10-bit chip.

In Figure 8 results from PHOS beam test during summer 2003 beam test are displayed for 9 central channels irradiated with 2 GeV wide electron beam. The spectra were recorded after all channel gains were adjusted by the APD bias control system.

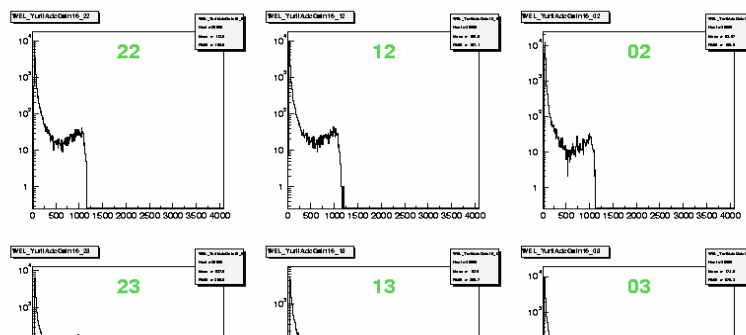


Figure 8. Wide electron beam (2 GeV) spectra for nine channels of the PHOS-256 prototype with individual APD bias settings. The spread in gain factors is within 4%.

Conclusion

An APD bias control system, providing individual bias voltage feeding of APD's, has been developed. It is characterized by a handy control method and rather simple LV-HV regulator schematics. The prototype system was realized for the PHOS-256 prototype and tested in beam at the CERN PS accelerator. It was demonstrated that, when applying the APD bias control system, the spread of the overall gain factors of different detector channels is within 4% as compared to about 30% spread without the system. The developed system meets the specification of the PHOS detector. Moreover, the accuracy of the channel gain factors can be further improved by using a 10-bit DAC chip in the PHOS detector instead of the 8-bit DAC chip, which was used in the prototype.

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