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LHCB PRESHOWER PHOTODETECTOR AND ELECTRONICS

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A comprehensive R&D has been conducted on multianode photomultipliers, leading to the diagnosis of non-trivial problems in the design of the detector Read-out. A major ageing problem has been identified, requiring to define an adequate operation point of the PMT, yielding constraints to the design of the VFE board. The prototype Read-Out electronics, which required a new iteration regarding as the ageing of the phototubes, has been successfully designed, realized and tested. Photomultipliers and electronics Read-Out are about to be produced.

1. Introduction

The first level of trigger of the LHCb experiment is mainly based on the fast response of the calorimetric subsystem, made of four consecutive semi-projective detectors : the Scintillator pads (SPD) and Preshower (Ps) detectors followed by Electromagnetic (ECAL) and Hadronic (HCAL) calorimeters. The first part of the system located in front of ECAL, consists in two and a half radiation lengths lead sheet between two scintillators planes (SPD and Ps plane respectively). Its main task is the validation of the electromagnetic nature of ECAL showers (electron/photon/hadron) at the first level of trigger. Eventually, the Ps energy measurement is also used for offline improvement of the ECAL measurement.

The Ps signals are extracted with wavelength-shifting fibres coupled to 64-anodes photomultiplier tubes, read out with Very-Front-End (VFE) and Front-End (FE) boards that handle and treat with a large and precise dynamics (10-bit) the analogical and digitalized PMT signals, respectively.

The Multianode PhotoMultipliers (Ma-PMT) from the Hamamatsu company have been extensively studied and these studies make the heart of this document. The Ma-PMT performance and qualification will be de-

scribed in the first section of the document. The second section is devoted to the phototube ageing problem, yielding the constraints to the electronics design. The downstream PMT pulse Read Out system by Front-end electronics will then be reviewed and the present achievements (ASIC status and production) summarized in the third section.

2. Performance of the photodetector

The most adequate photodetector to measure the light from the PS and SPD detectors is the 64a-PMT from the Hamamatsu company. About 200 photodetectors will be operated in the experiment. Few prototypes (with 12, 8 and 6 stages of amplification) have been extensively tested at lab with dedicated test benches and the retained photodetector is made of 8 dynodic stages. This section describes the experimental setup of the test bench developed in Clermont ^a and reviews the main measurements and performance of the photodetector.

2.1. *Experimental setup*

The test bench is equipped with a light system intended to mimic the signal issued from the scintillator detector instrumented with the wavelength-shifting fibre. The PMT to be tested is supported by a translation table allowing displacements of the PMT in a plane. The details and the sketch of the experimental setup can be found in ¹. The Ma-PMT signals are read by the Very-Front-End and Front-End (VFE/FE) boards prototypes, described shortly in the last section of this document. A detailed review can be found in ^{2,3}. The whole test bench is monitored with Labview.

2.2. *Measurements*

The main measurements performed thanks to this test bench are the non-uniformity of the anode responses within one Ma-PMT, the linearity along the whole dynamics of the PS, the absolute gain of the Ma-PMT channels and the electronics cross-talk. Specific measurements of the behaviour of the Ma-PMT in magnetic field were conducted as well.

The non-uniformities of the responses between the channels of one photomultiplier have been measured for 5 phototubes. The non-uniformities were

^aAnother test bench has been developed at UA Barcelona but will not be described here.

never measured in a ratio worse than 1 to 3 (min to max). The read-out electronics is designed to correct non-uniformities of such an amplitude.

The linearity of the Ma-PMT channels is an important issue for the PS purpose of the energy measurement. The light has been varied according to the light dynamics of the detector and the linearity of all channels of the tested phototube devices was found to be satisfactory as underlined Figure 1.

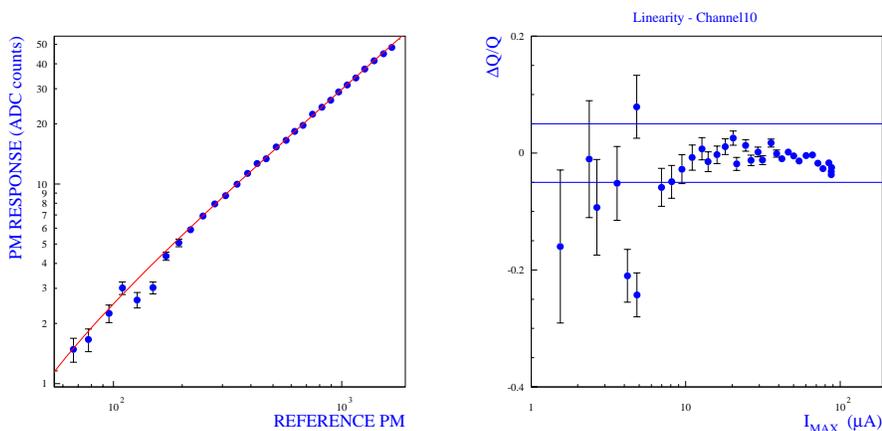


Figure 1. Left: linearity of a typical Ma-PMT channel response along the whole dynamics of the Ps. The abscissa scale stands for the incident light read out by the reference PMT. Right: deviation to the linearity of a typical Ma-PMT channel as a function of the peak PMT current.

Effects of both transverse and longitudinal magnetic field w.r.t the axis of the phototube have been scrutinized. It has been discovered that these phototubes, primarily thought to be structurally robust in magnetic field were significantly sensitive to B fields at the level of 10 Gauss. A dedicated shielding has been designed and a new generation of phototubes is in the process of fabrication by the Hamamatsu company to improve their behaviour.

3. The ageing problem

A dedicated test bench has been designed to evaluate the long term behaviour of the phototubes in the conditions of the largest illumination expected from the complete simulation of LHCb events. Two phototubes were

tested and 14 channels were measured. The Figure 2 shows a typical PMT response under two operation conditions. An unexpected spectacular exponential drop occurred in the former experiment for one month of illumination showing the working point to be inadequate. Based on an extrapolation of these results to lower gain, it has been checked experimentally that dividing the PMT gain by 10 would offer acceptable conditions of operation (right plot of Figure 2). The main consequence is that the former VFE electronics shall be redesigned to improve its gain accordingly.

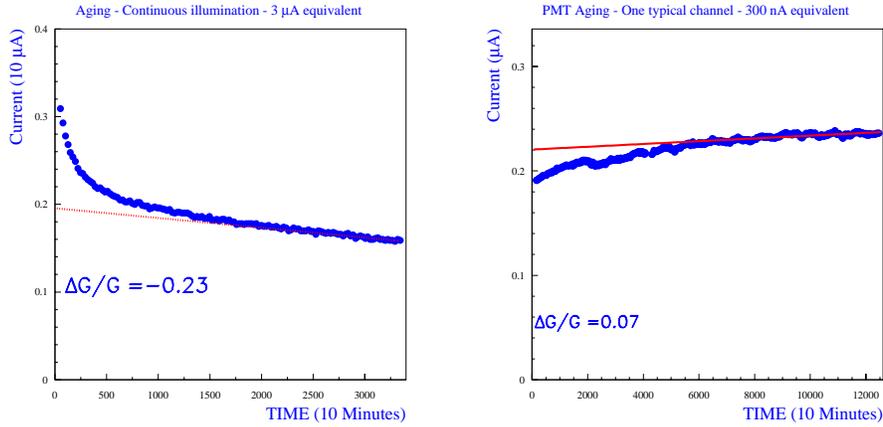


Figure 2. Left: PMT responses for one month of continuous illumination in the initial expectation of the PMT operation. Right: PMT response under an illumination divided by ten (one LHCb year equivalent).

4. The electronics architecture and performance

The Front-End Read Out system is made of a Very Front-End board, directly connected to the 64-anodes PMT, and a Front-End board, displaced, receiving the 6 000 output analog signals from the VFE by means of 20 meters long Ethernet differential cables. Sixteen chips per board, each handling 4 channels, perform the signal shaping of the 64 signals of a PMT. The large fluctuations of MIP signal do not allow a "classical" shaping. Therefore, a mixed analog/digital shaping method has been retained based on two interleaved fast integrators, each working at 20 MHz, one being in integrate mode while the second one is digitally reset ². The basic architecture

of one channel Read Out is shown on Figure 3.

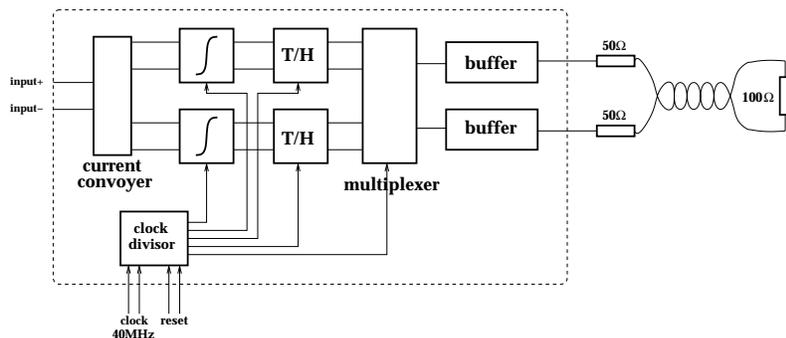


Figure 3. Basic architecture of one channel Read Out including switched integrator, track and hold, multiplexer and cable push-pull driver.

The ageing problem mentioned in section 3 has been solved by designing a fully balanced current conveyer as input, restricting the changes to the previously defined electronics at the first stage only. The main challenge there is to deal with extremely small currents, the typical signal from a MIP being a $1 \mu\text{A}$ peak current. A prototype of this electronics has been successfully designed, realized and tested, the measurements and the simulation being in excellent agreement. Those chips satisfactory fulfill the PS requirements.

The FE board is a fully synchronous device, in which the signals are digitized with 10-bit ADCs. The pedestals and residual pulse from preceding 25 ns cycle are subtracted and the sub-channels gains are corrected. After subtraction, a precision on the 5 MIPs (the trigger threshold) signal of $\sim 6\%$ is achieved. Signals are then stored in a FIFO pipeline until Level-0 and Level-1 trigger decision^b. A detailed review of the FE electronics can be found in³.

5. Conclusion and perspectives

A comprehensive R&D has been conducted on multianode photomultipliers, leading to the diagnosis of non-trivial problems in the design of the detector Read-Out. A major ageing problem has been identified, requiring to define

^bThe preshower trigger data are computed, combined with 64 trigger bits coming from SPD, and sent to an ECAL validation board as the complete preshower trigger information

an adequate operation point of the PMT, yielding constraints to the design of the VFE board. New process of phototube fabrication was also demanded to improve their behaviour in magnetic fields.

The prototype Read-Out electronics, which required a new iteration regarding as the ageing of the phototubes, has been successfully designed, realized and tested. PMTs and electronics Read-Out are about to be produced.

References

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