Beam Test of Scintillation Tiles with MPPC Readout

A. Calcaterra, R. de Sangro, G. Finocchiaro, P. Patteri, M. Piccolo and M. Rama

Laboratori Nazionali di Frascati dell'INFN, Via E. Fermi,40 - I-00044 Frascati (Rome) Italy

This paper [1] describes measurements made using counters composed of a small (3 by 3 by 0.5 cm^3) scintillation tile coupled to a Multi-Photon Pixel Counter (MPPC) and exposed to an electron beam at the Beam Test Facility in Frascati. We show our first results for charge spectra and efficiency, and a very preliminary measurement of device linearity.

1 Introduction and motivation for this study

Silicon photomultipliers [2], often called "SiPM" in literature, are semiconductor photon detectors built from a square matrix of decoupled avalanche photodiodes (APD's) on common silicon substrate. The dimension of each single APD square microcell can vary from 20 to 100 μm. The applications of silicon photon detectors are very wide [3]; in particular, at the ILC, the demands imposed to calorimetry are so stringent that they may be met only with a very fine granularity of individual detection elements; a tile of 30 by 30 by 5 mm^3, and possibly thinner, being typical.

2 The Beam Test Facility in Frascati

The Beam Test Facility [4] exploits by means of a transfer line the DAΦNE ϕ-factory LINAC, and is optimized for the production of electron and positron bunches in a wide range of multiplicities.

The beam profile from the BTF has typical horizontal and vertical dispersions of $\sigma_h = 2$ mm and $\sigma_h \leq$5–10 mm. The BTF equipment includes a Pb-glass calorimeter, placed downstream the user setup. The beam pulse is totally absorbed in the calorimeter, and the integrated signal from the PM gives a measurement of the number of MIPs in every pulse (see Figure 1).

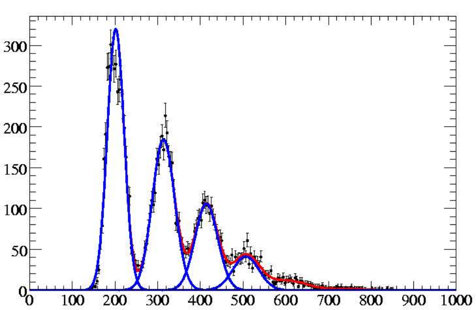

Figure 1: Beam pulse multiplicity. 0-MIPs beam pulses appear at $\sim$ 200 counts.

In most of this work, and unless otherwise stated, only events having a Pb-glass calorimeter signal in the second peak in Figure 1 have been used: those corresponding 1-MIPs beam pulses.

3 Description of the setup and measurements

The setup is composed of 3 counters using MPPC detectors [5] and a 6-layer, two-dimensional tracker made of mechanically-quenched Resistive Plate Counters [6].[a] The trigger is obtained for every beam pulse via a signal synchronous with the LINAC radiofrequency; it is thus unbiased, and completely independent from our measurements.

The counters (one appears in Fig. 2) in these measurements were: n."1", with a scintillation tile made of St. Gobain BC-400 coupled to the MPPC using a 1 mm thick green fiber, inserted into a groove machined along the tile center, and read by an MPPC with 1600 pixels in a square matrix of 1 by 1 mm, and 25 μm pixel pitch; n."2", with a tile made of green-scintillating material, similar to Scionix EJ260, coupled as in n. "1" to an MPPC with 400 pixels, and 50 μm pixel pitch; n."3", with a tile like counter "1", directly coupled without a fiber to a MPPC like the one in counter "2". In all 3 counters the MPPC were biased using a power supply HP6614C, with a stated accuracy of 0.03%, in quadrature with 12 mV.

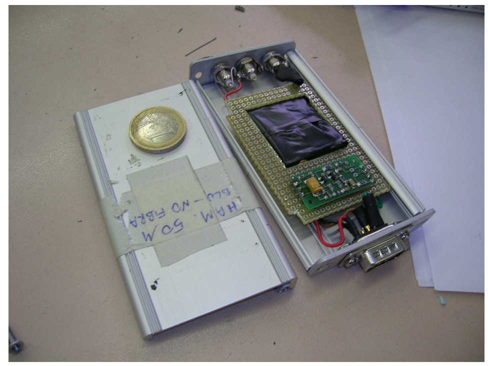

Figure 2: A counter assembly, showing the 3 by 3 cm^2 tile and the preamplifier.

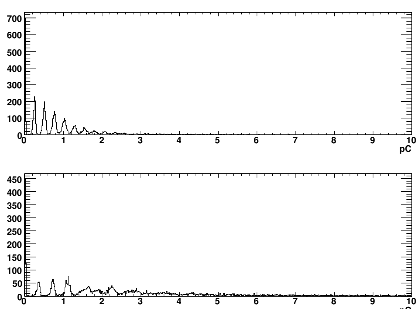

Figure 3: Charge spectra (pC) for counters 2(up) and 3 ($V_bias = 69.5$ V for both).

Fig. 3 shows the pedestal-subtracted charge spectra (in pC) for counters 2(up) and 3 biased at 69.5 V, about 1 V above the MPPC breakdown voltage; the RMS noise, estimated by fitting with a Gaussian the peak at 0 pC, is 2–3 fC and the gain, measured by fitting the peak pitch, is $\sim 1.6\times10^6$ for counter 2 and $\sim 2.2\times10^6$ for counter 3. Since the preamplifiers for all counters were identical, the gain difference indicates that the working points for the 2 MPPCs were actually different: the scintillator material and the coupling geometry would have affected the peak populations, creating a bigger or smaller "average number of peaks". Some deterioration of the charge signal beyond $\sim$ 1.5 pC for counter n.3 seems not attributable to channel electronics, the RMS noise figure (width of the peak at 0 pC) being about the same for both.

We use Fig. 4 to measure the efficiency of counters 2 and 3, where we plot the signal from counter 2 along the horizontal axis and the signal from counter 3 vertically.

[a]The tracker is meant to measure the beam impact point on the counters but, as this paper does not address the issue of pulse height vs impact points, its information was not used.

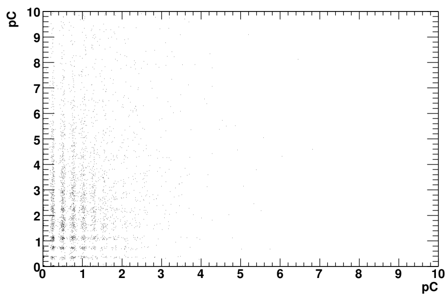

Figure 4: Integrated charge from counter 2 (horizontal axis) and 3.

Due to the very close proximity of the 2 scintillating tiles, we select events $\sim 4\sigma$'s above the pedestal for one of the two, and evaluate the efficiency of the other one as the ratio of counts above-pedestal to the total. These proximity-defined efficiencies are of $(91 \pm 1)\%$ and $(84 \pm 1)\%$ for counters 2 and 3 respectively. We judge that the difference in efficiencies is due to the different working point of the 2 MPPC's, that were identically biased at 69.5 V.

In Fig. 5 (top, and bottom left) one may see the charge spectrum for counter 1, biased at 72.0 V, in units of "pixels", for 1, 2, and 3-MIPs events. Fitting these data to Landau distributions we obtain the Most Probable Values (MPV's) plotted in the bottom right part of Fig. 5 against the number of MIPs. The points lie very close to the fitted line, with an intercept close to 0. The most probable number of pixels per MIP is 14.

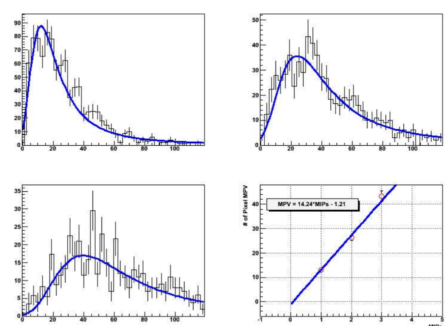

Figure 5: Linearity of counter 1 readings.

The results described in this paper, although still in an initial stage, encourage us to proceed with the study of the performance in a beam test and in cosmic rays of complete counters, employing a SiPM as detection element: with a small and relatively fast assembly we have obtained charge spectra and efficiency, and a first very preliminary measure of linearity. We plan to increase the number of counters studied by an order of magnitude to gather more statistics and to implement a measure of temperature in our setup.

The authors of this paper wish to express their thanks to G. Mazzitelli and P. Valente, and all operators of the BTF facility for successful and time-efficient running, and to L. Daniello for his skill and dedication in the assembling of the MPPC counters.

References

[1] Slides at this link:
`http://ilcagenda.linearcollider.org/contributionDisplay.py?contribId=381&sessionId=108&confId=1296`

[2] Dolgoshein B. *et al.* Nucl. Instrum. Meth. A5632006368, and references therein.

[3] for a recent review, see N. Otte in Proceedings of the SNIC April 2006 Symposium, SLAC, Stanford, available online at `http://www-conf.slac.stanford.edu/snic/default.htm`

[4] Mazzitelli G. *et al.* Nucl. Instrum. Meth. A515/32003516. See also the web page `http://www.lnf.infn.it/acceleratori/btf/publications.html`

[5] The present paper is about devices S10362-11-050U and S10362-11-025U, for a description of these and other devices see `http://www.hahamatsu.it`.

[6] Calcaterra A. *et al.* Nucl. Instrum. Meth. A565/22006444.