Test Setup to Measure Gains of the Angra Photomultipliers Using the Single Photoelectron Technique

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Abstract

We report on a setup built to measure gains of the PMT proposed to be used in the Angra Neutrino detector. We illustrate the use of the standard single photoelectron technique supplemented with measurements of rise time in addition to the more conventional methods that measure only amplitude and / or charge of single photoelectron pulses.

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1 Introduction

The measurement of photomultiplier (PMT) gains by sending a short flash of visible or UV light into the PMT photocathode is a simple and well known standard technique. The LED is fed by a fast (a few ns wide) pulse of variable amplitude adjusted to produce in average less than one photo-electron (PE) per pulse. Usually, the charge spectrum of single PE is analyzed either on-line or off-line to measure the mean value of the charge for single PE pulses. However, a practical difficulty arises when the PMT gain is not high enough to make the single photoelectron peak clearly visible in the charge spectrum. Another difficulty comes from the fact that the typical resolution of commercial ADCs (0.25 pC) is inadequate to measure the charge of PMT pulses with only one photoelectron which are, depending on the HV applied to the PMT base, of the order of one pC. These difficulties are more serious as one operates the PMT at relatively low voltages with gains lower than or of the order of $5x10^6$.

In this note we describe a test setup built to characterize PMT, its size was designed to accommodate small PMT like the Hamamatsu H7546 [1], to be used in the muon veto system of the Angra detector [2], up to large ones, like the Hamamatsu R5912 [3], to be used in the neutrino detector of Angra [2]. We also describe a simple method to obtain PMT gains that is free of the inconveniences mentioned in the previous paragraph. This technique makes use of a digital oscilloscope to capture the complete PMT traces into a PC. The voltage traces of thousands of LED-induced PMT pulses are recorded on the hard disk of a PC and subsequently analyzed off-line to extract their charge, amplitude and rise time. Finally, these data are analyzed to measure the charge spectrum of single PE. We illustrate the use of this technique by measuring the gain of a Hamamatsu R5912 PMT operated at 1500 V.

2 Experimental Setup

The experimental setup schematic is shown in Figure 1, with its picture in Figure 2. The R5912 PMT is placed inside a sealed cylindrical chamber [7] consisting of a PVC tube with a thickness of 3mm, an internal diameter of 300mm and a height of 400 mm. The chamber has PVC covers. A schematic view of the dark chamber is shown in Figure 3 while Figure 4 shows the way in which the PMT and LED are placed inside the chamber. The L-shaped bottom is glued to the cylindrical tube while the L-shaped top cover is movable. The tube and covers are internally painted with black seal and externally covered with aluminum foil, totally involving the borders to improve light-tightness and electromagnetic shielding.

This tube is in turn placed inside another cylinder made out of a 2mm thick aluminum sheet (400 mm by 900 mm with its borders tied together by an aluminum profile), with two aluminum covers also 2mm thick, Three rods with hexagonal nuts are used to press the aluminum covers against the cylinder, in addition to reinforcing light-tightness, this structure serves at the same time as a Faraday cage to provide electromagnetic shielding.

A blue LED was placed inside the chamber on top of the photocathode. A cardboard fixed with insulating ribbon to the chamber tube was placed between the LED and the PMT, with a small hole to constraint the photons from the LED to reach only the central region of the photocathode. Cables for LED, PMT HV and PMT signal passed into the chamber through a hole on the chamber tube located near the top, this hole is subsequently sealed with black tape, cooper and insulating ribbons to ensure light tightness. The PMT we used possess a built-in voltage divider in its base.

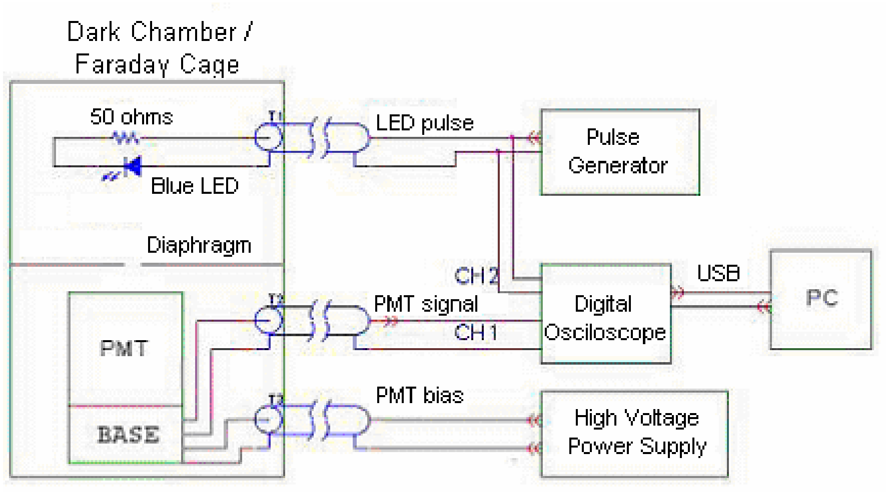

Figure 1 – Setup schematic diagram

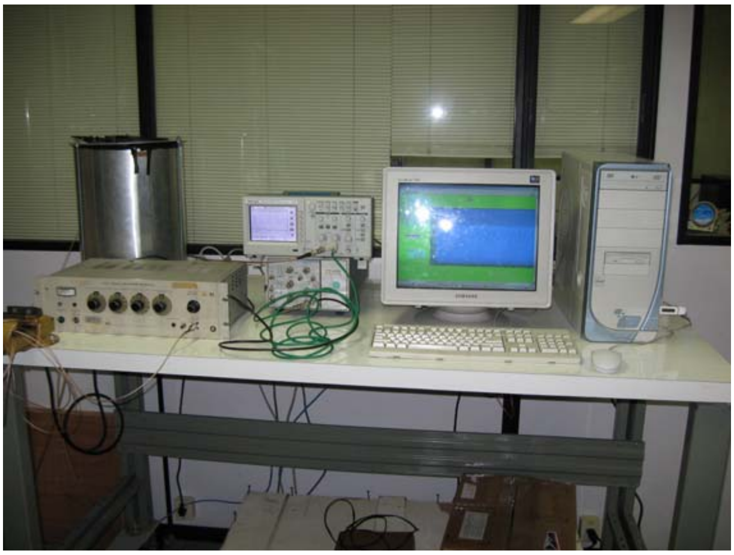

Figure 2: Experimental setup photograph, from left to right: dark chamber with the PMT and LED inside; HV power supply Keithley 246; pulse generator Tektronix PG508; digital oscilloscope Tektronix TDS 1012B; IBM personal computer, with Microsoft Windows XP.

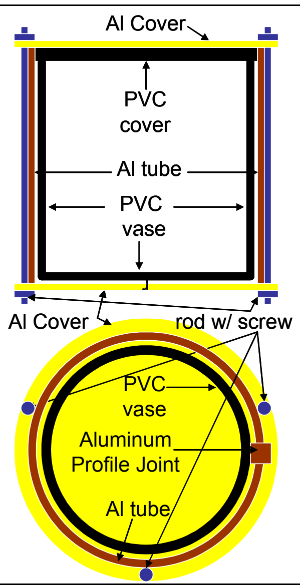

Figure 3a: Schematic view of the dark chamber built to house the PMT and the LED.

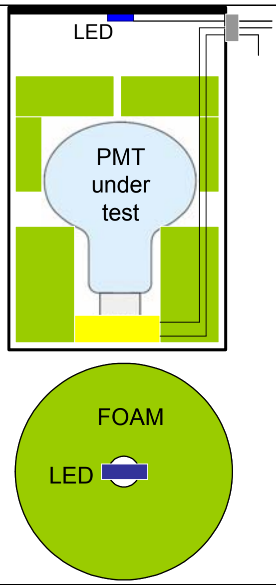

Figure 4: Schematic view of the PMT and LED placed inside the dark chamber.

We found the R5912 PMT signals pretty much noiseless once we operated the PMT inside the dark chamber just described, as can be seen in Figure 4, where in the oscilloscope screen the upper trace is the PMT signal output at 5 mV/div, and the lower trace is the signal send to the LED from a commercial pulse generator (Tektronix PG508) or, alternatively, with a home-made generator which will be described in separate technical note in the near future. Both pulse generators provide very short pulses (widths lower than 10 ns) at a controllable rate of 10 Hz. The stability of the LED pulser is a pre-requisite to obtain a Poisson distribution for the number of photoelectrons for long data-taking periods (usually 5-10 h are enough).The digital oscilloscope we used was a Tektronix TDS 1012B connected to a USB port of the PC. The maximum data acquisition rates obtained with the USB oscilloscope and the LabView-based DAQ system was around 5 Hz to transfer the 2500 point trace data into the PC for every event of driven the LED.

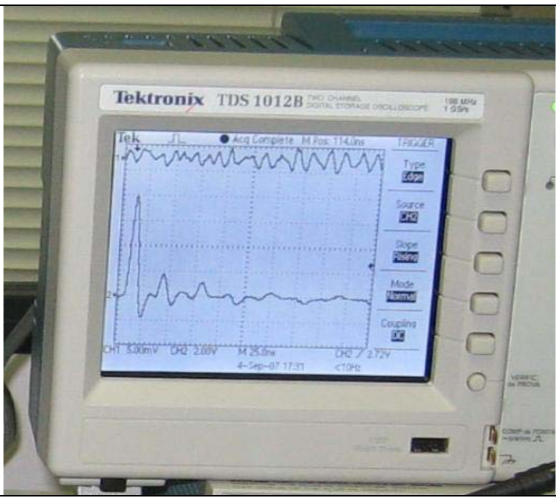	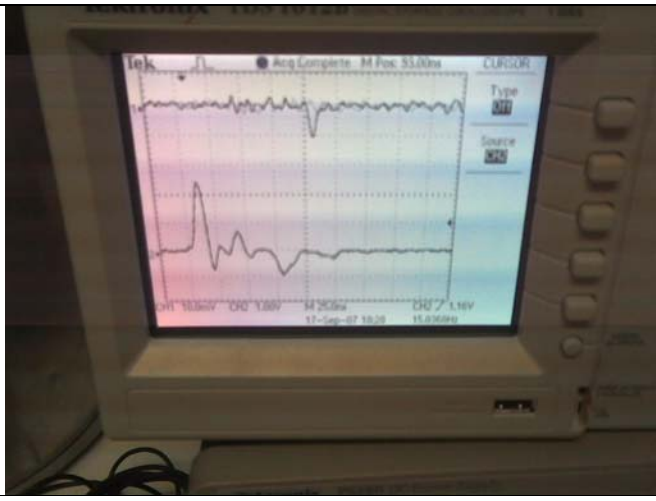
Figure 5a: PMT with no light.	Figure 5b: PMT output signal for one photon.

Figure 5: Digital oscilloscope screen with LED pulse signal below (1 V/div) and above the PMT output signal (5 mV/div), horizontal scale 25 ns/div

The charge, amplitude and rise time from 10 to 90% were subsequently measured off-line for every event by using another Lab View program. These parameters were analyzed and plotted using root [5].

3 Results and Discussion

Figure 6 shows a print-out of the front panel of the Lab View program used off-line to measure charge, amplitude and rise time of the oscilloscope traces previously recorded onto the PC's hard disk. This particular event shows an event with a single PMT pulse. The upper curve is the PMT trace (vertical scale in V) and the lower one the integrated charge (vertical scale in pC).

Likewise, Figure 7 and Figure 8 show events with two and three pulses, respectively.

Figure 8 shows raw data for charge vs rise time for a set of events taken on August 31th, 2007 for the Hamamatsu R5912 PMT operated at 1500 V. Throughout this note, this rise time is defined as the time it takes for the charge to go from 10% to 90% of its final value using an integration window of 150 ns; this window may contain zero, one o more single PE pulses. The accumulation of points on the lower left side region corresponds to events which contain only one

PE. Figure 9 shows the distribution of amplitude versus rise time for the same data. Figure 10 shows the distribution of rise time for events with amplitude greater than 5 mV. The single peak between 0 and 15 ns corresponds to single photoelectron pulses, the flat distribution above 15 ns up to around 120 ns is due to our using a slow LED, i. e., the probability for a second PE pulse to occur within 100 ns after a first PE pulse is approximately constant.

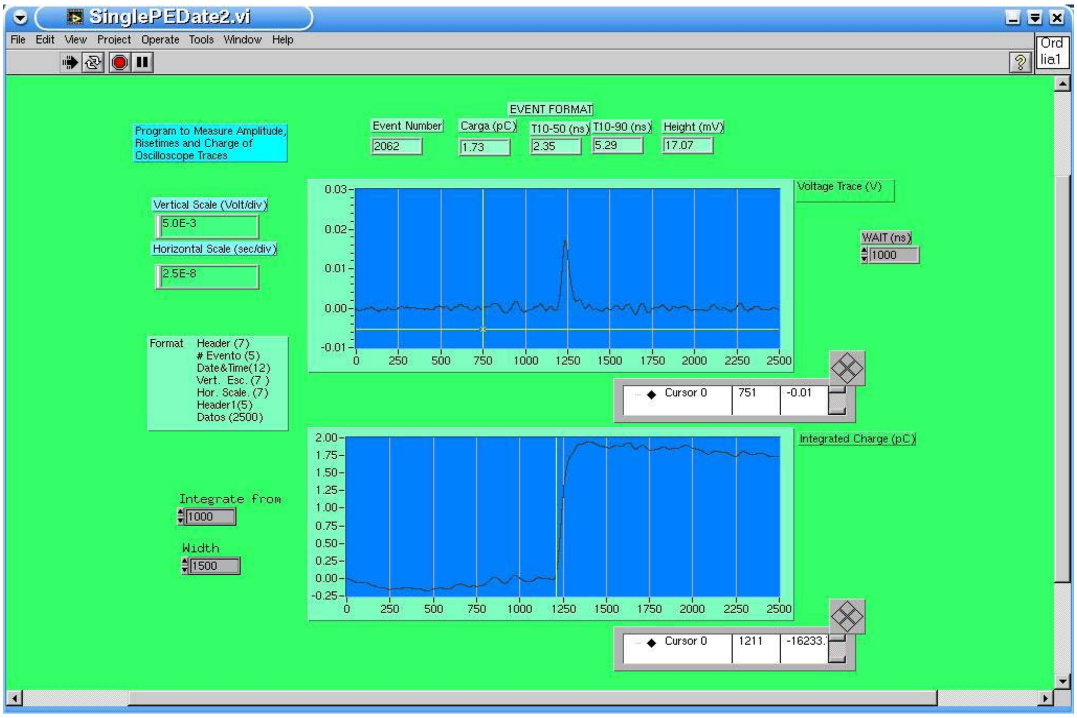

Figure 6: Event with a single isolated PMT pulse. The upper curve is the PMT trace in V and the lower one the PMT output charge in pC. The horizontal scale is 25 ns/div.

Figure 7: Event with two isoated PMT pulses. The upper curve is the PMT trace in V and the lower one the charge in pC. The horizontal scale is 25 ns/div. are measured. Therefore, the technique illustrated in this note can be applied to PMTs with gains well below 107, where it would be impossible to measure gains with a commercial ADC because the typical 0.25 pC resolution is inadequately coarse.

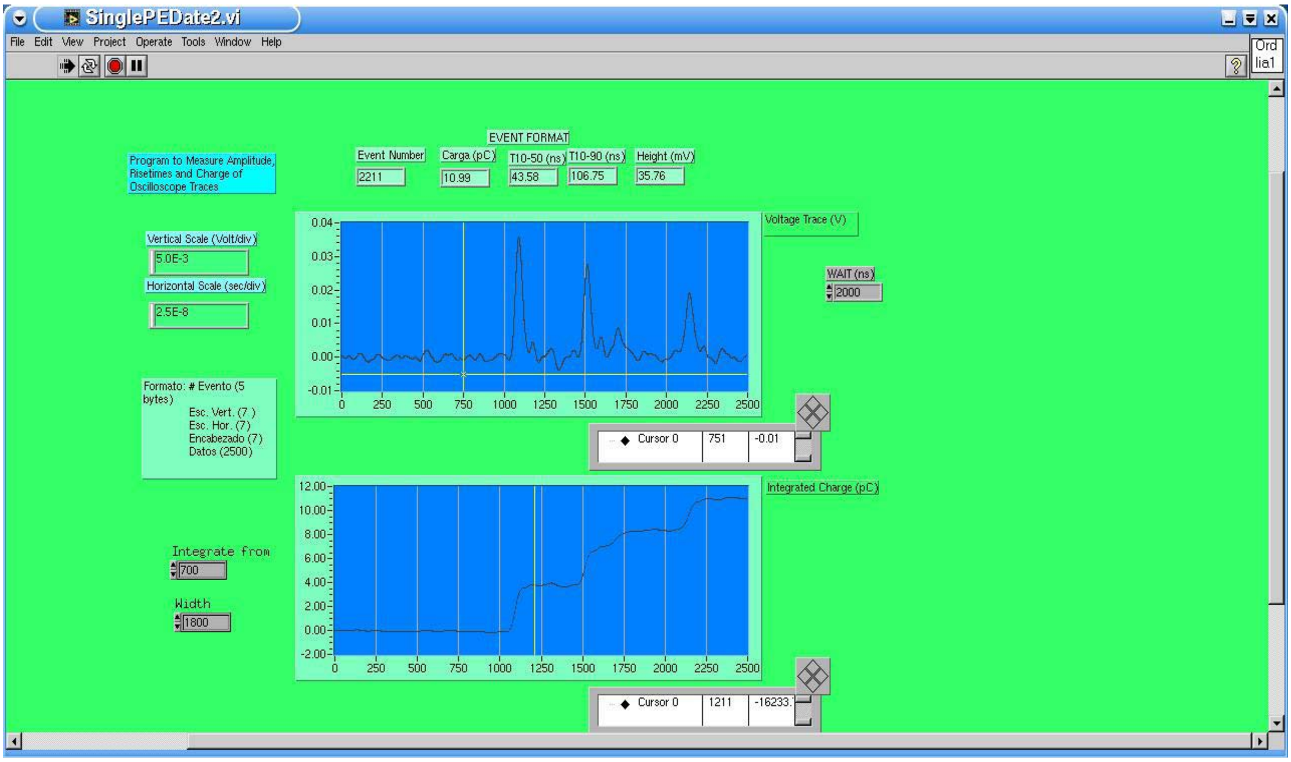

Figure 8: Event with three isolated PMT pulses. The upper curve is the PMT trace in V andthe lower one the charge in pC. The horizontal scale is 25 ns/div.

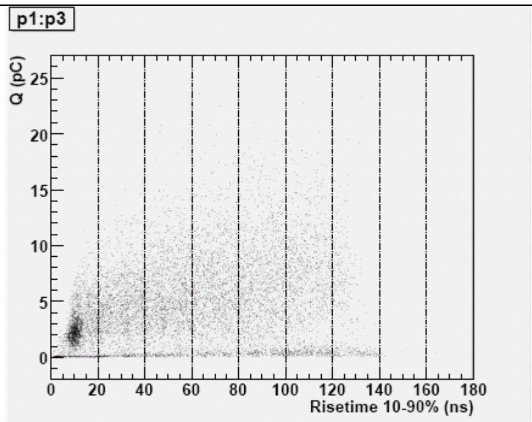

Figure 9: Charge vs risetime from 10 to 90% for a set of events taken on August 31th., 2007.

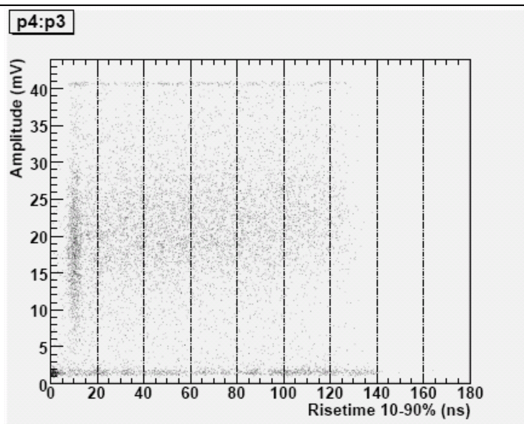

Figure 10: Amplitude vs risetime (from 10% to 90%) for the same data shown in Figure 9.

Figure 11 shows the raw distribution of charge (integrated off-line as illustrated in Figure 6, the termination resistor used to match impedances is 50 -, as usual). Likewise, Figure 11 shows the distribution of pulse amplitudes for events with Q > .1 pC and risetime > 15 ns. In order to select 1-PE pulses we cut on risetime lower than 15 ns, as shown in Figure 7 and Figure 9. The result is shown in Figure 13 where the peak for a single PE is clearly visible at a charge of 2.2 pC as indicated by the gaussian fit superimposed (this not so good fit is only meant to show the position of the most probable value for the charge duistribution). We can also exclude 1-PE events by requiring the risetime to be greater than 15 ns, this is shown in Figure 14. The mean value of this peak is twice the charge value for single PE events; this means that two photoelectron events dominate in this plot.

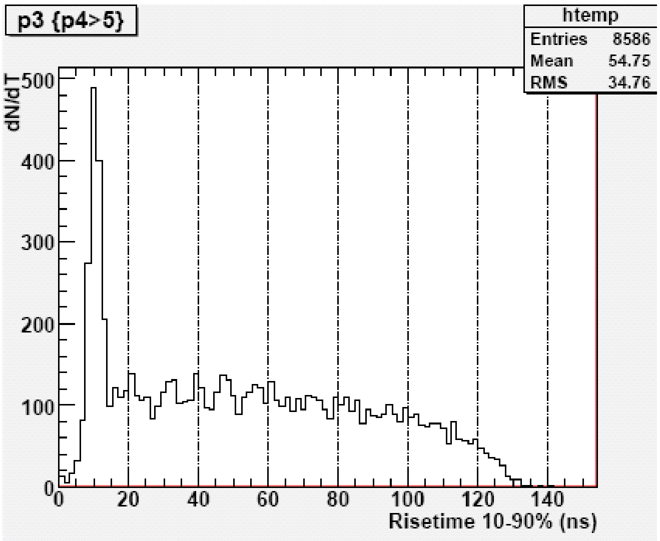

Figure 11: Risetime for events with $V > 5$ mV. The single peak between 0 and 15 ns corresponds to single photoelectron pulses, the flat distribution above 15 ns is due to our using a slow LED.

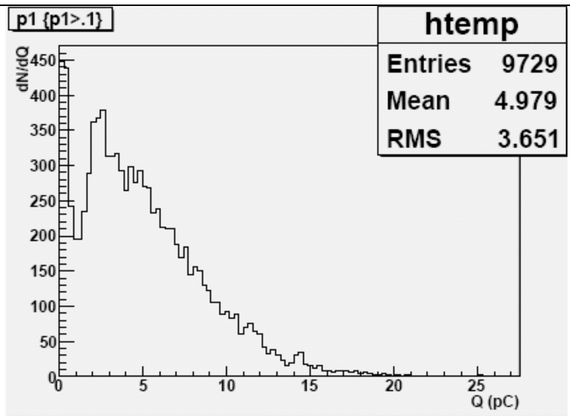

Figure 12: Pulse amplitude for events with $Q > .1$ pC and *risetime* > 15 ns.

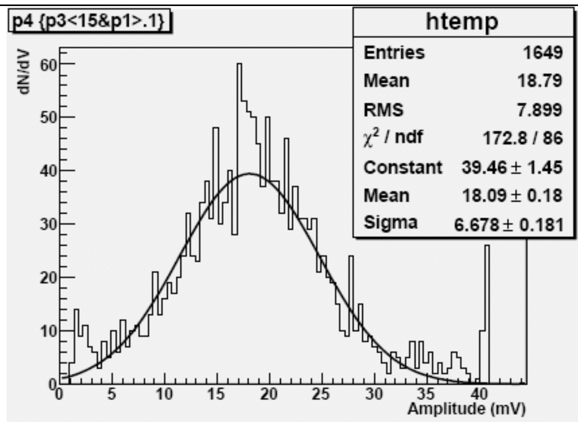

Figure 13: Pulse amplitude for events with $Q > .1$ pC and *risetime* > 15 ns.

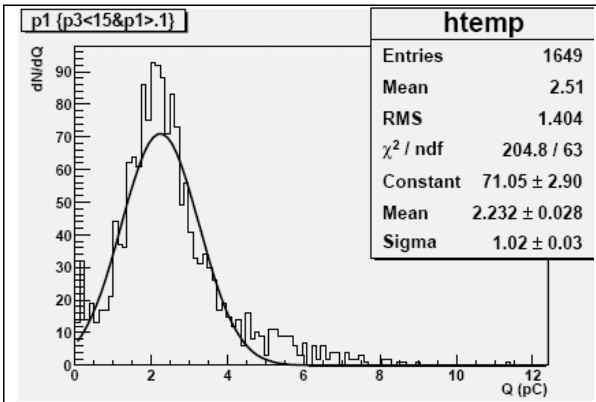

Figure 14: PMT charge for events with $Q > .1$ pC and *risetime* < 15 ns.

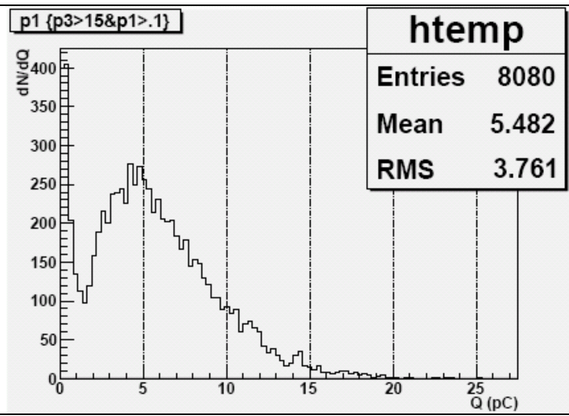

Figure 15: PMT charge for events with $Q > .1$ pC and *risetime* > 15 ns. The most probable value is twice that of a single PE.

4 References

[1] See *http : //www.sales.hamamatsu.com/en/products/electron − tube − division/detectors/photomultiplier − modules/part − h*7546*b* − 200*.php*
[2] J. C. Anjos et al., Braz. J. Phys. vol.36 no.4a So Paulo Dec. 2006.
[3] See *http : //www.sales.hamamatsu.com/en/products/electron − tube − division/detectors/photomultiplier − tubes/part − r*5912*.php*
[4] See *http : //www.ni.com/labview/*
[5] *http : //root.cern.ch/*
[6] *http : //www.tek.com/products/oscilloscopes/tds*1000*tds*2000*/index.html*
[7] Vaz, Mario - Class notes on Basic Instrumentation in High Energy Physics, CBPF, May 2007