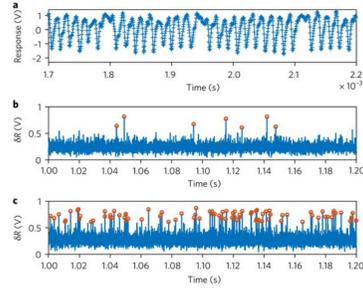# PHOTOMULTIPLIER TUBE GAIN DETERMINATION CONSIDERING TWO RESISTIVE DINODE ARRAY

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Prácticas de Verano SAPHIR-UNAB 2024 January 02 - 19, 2024
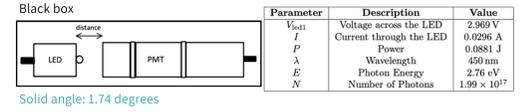
SAPHIR ARM 2024 January 17 - 19, 2024

ABSTRACT

The objective of this project is to measure the gain of two different configuration of the resistive dinode array for the PMT R3998-02. For this, two different LED pulses have been used for the two resisteve array which have the same scale configuration, with different base values, where in one case its highest resistance is 400 kΩ and in the other 200 kΩ.

SETUP

The experiment setup allows measuring the variation of incident photons on the photocathode by changing the values of the generated wave. To achieve this, the PMT under study is positioned at a distance of 90 mm from a blue LED, both enclosed within a lightproof box to shield the setup from ambient noise. The function generator sends signal pulses through the LED, which are captured by the PMT connected to the oscilloscope. This enables the generation of 4 sets of data, 2 for each PMT. A voltage of 1000 V is maintained throughout all measurements, and the amplitude of the generated wave is varied, first to 100 mV and then to 20 mV. From the amplitude setting, voltage for the LED is automatically established. Input signal to the LED.
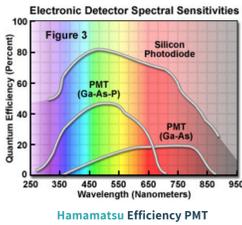

Solid angle: 1.74 degrees

Parameter	Description	Value
V_{LED}	Voltage across the LED	2.969 V
I	Current through the LED	0.0296 A
P	Power	0.0881 J
λ	Wavelength	450 nm
E	Photon Energy	2.76 eV
N	Number of Photons	1.99×10^{17}

PMT R3998-02 First configuration

Parameter	Value
Nominal Resistence	115 [kΩ]
R1	400 [kΩ]
R7	200 [kΩ]
Total resistence	900 [kΩ]
HV Supply	1000 [V]
V_{peak} Conf. 1	100 [mV]
V_{peak} Conf. 2	20 [mV]

PMT R3998-02 Second configuration

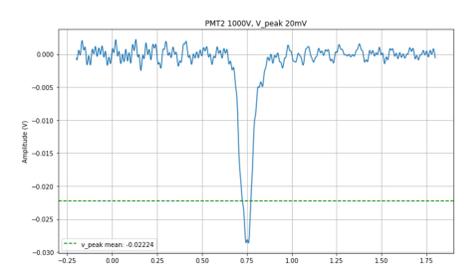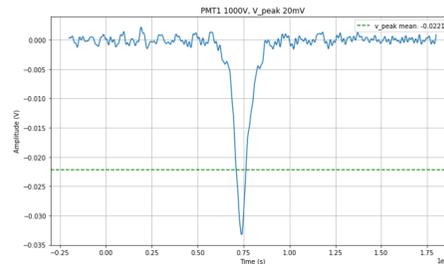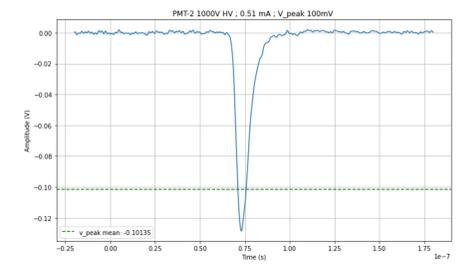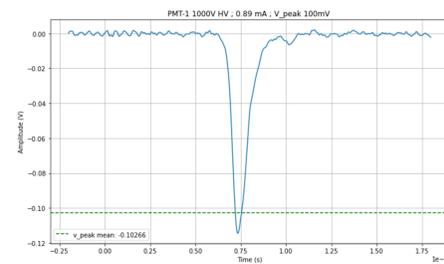| Parameter	Value
Nominal Resistence	66.5 [kΩ]
R1	200 [kΩ]
R7	100 [kΩ]
Total resistence	1950 [kΩ]
HV Supply	1000 [V]
V_{peak} Conf. 1	100 [mV]
V_{peak} Conf. 2	20 [mV]

MOTIVATION

Photomultiplier tubes (PMTs) are highly sensitive photodetection devices. PMTs are used to measure fluorescence and in various measurement systems.

Their high sensitivity makes them indispensable in applications that require the detection of low levels of light or radiation.

Hamamatsu Efficiency PMT

Photodetection efficiency (PDE) is a crucial parameter when evaluating different photomultiplier tubes (PMTs). This parameter is related to the probability that an incident photon generates a detectable electrical signal. The PDE can depend on several factors, such as the wavelength of the incident light, the temperature and structure of the PMT. In the context of research, PDE is critical in determining the sensitivity and performance of PMTs in specific applications, such as low-level light or radiation detection. Therefore, when comparing different PMTs, it is important to consider its photodetection efficiency under the operating conditions relevant to the desired application.
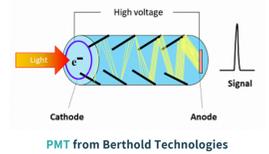
INTRODUCTION

A single photoelectron refers to the detection of a single electron resulting from the interaction of a photon with a photosensitive material, such as a photomultiplier tube.

The single photoelectron calibration method focuses on estimating the mean and variance of the single photoelectron distribution at the output of the PMT.

The single photoelectron charge distribution for a typical PMT is often represented by a Gaussian fit. Methods for analyzing the single photoelectron spectra and measuring the time spread of single photoelectrons in fast photomultipliers have also been developed.

A photo multiplier tube (PMT) receives incident electrons where their energy causes the emission of a greater number of secondary electrons.

Photomultiplier Tube (PMT)

PMT from Berthold Technologies

The current and voltage in PMT are related to its ability to convert photons into an amplified electrical current. The voltage applied to the PMT influences its current amplification capacity. Therefore, the voltage controls the sensitivity and dynamic range of the PMT, while the current is related to the intensity of the detected light and the efficiency of the photoelectric conversion.

Photocollection efficiency refers to the ability of a device to collect incident light and convert it into electrical current.

SIGNAL AND CHARGE DISTRIBUTIONS

EXPERIMENTAL DESIGN

To obtain the photodetection efficiency for different PMTs, the PMT model R3998-02 will be used, which has a voltage divider which will allow the input voltage to be reduced in order to work at an adequate level. In an ideal case each dynode consumes less current compared to its input due to the efficiency in electron multiplication, since each electron that impacts the first dynode produces a constant number of electrons in the next, which means that the current of plate is proportional to the incident photon current, resulting in a high amplification factor and therefore low current consumption at the dynode.

This PMT model has the following distribution of resistances and supply voltage.

VOLTAGE DISTRIBUTION RATIO AND SUPPLY VOLTAGE

Electrodes	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	P
Radio	3	1	1	1	1	1	1.5	1	1	1	1	1

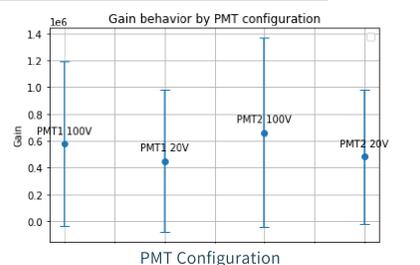**Supply Voltage:** 1000 V, **K:** Cathode, **Dy:** Dynode, **P:** Anode, **G:** Grid

For this model there is a maximum input voltage of 1500 V, where its nominal voltage (which guarantees that the PMT works correctly) is 1200 V. Due to this, 3 values will be selected for the input voltage which will fall within this range. Due to the resistance distribution presented above, two configurations will be selected, one where its largest resistance is 400 kΩ and the other 200 kΩ.

PMT 1

VOLTAGES AND RESISTANCES

800 V
i11 = 0.8 mA
i12 = 0.4 mA

1000 V
i21 = 1.1 mA
i22 = 0.5 mA

1200 V
i31 = 1.3 mA
i32 = 0.6 mA

EXPECTED GAIN

800 V   G = 3 x 10^5

1000 V   G = 1 x 10^6

1200 V   G = 4 x 10^6

PMT 2

Your paragraph text

CONCLUSIONS, RESULTS AND PERSPECTIVES

The PMT is exposed to a set of LED pulses, and the output signals are recorded, forming a distribution. A Gaussian distribution is then fitted to this data to extract the mean (μ) and standard deviation (σ). The GAIN is calculated as GAIN = <Q>/<N>, where <Q> is the average charge per pulse (calculated as μ/e, where e is the electron charge) and <N> is the average number of photoelectrons per pulse (calculated as $(\mu/\sigma)^2$).

Summary Table

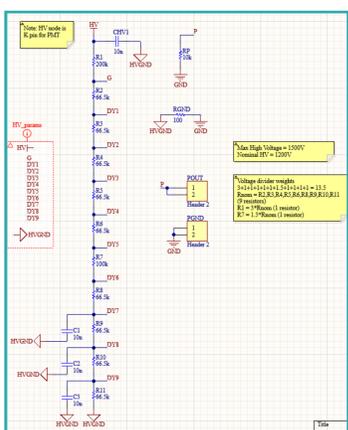| Element	Configuration	Mean	χ^2/ndf	Sigma	Gain
PMT 1	100 mV	$2.1e{-}12 \pm 8.9e{-}15$	427.1/509	$4.4e{-}13 \pm 1.5e{-}14$	$5.8e5 \pm 0.4e5$
PMT 1	20 mV	$4.3e{-}13 \pm 3.9e{-}15$	229.1/256	$1.8e{-}13 \pm 1.6e{-}14$	$4.5e5 \pm 0.8e5$
PMT 2	100 mV	$1.9e{-}12 \pm 9.0e{-}15$	466.8/520	$4.4e{-}13 \pm 1.6e{-}14$	$6.6e5 \pm 0.4e5$
PMT 2	20 mV	$3.8e{-}13 \pm 4.0e{-}15$	266.3/260	$1.7e{-}13 \pm 4.2e{-}15$	$4.8e5 \pm 0.2e5$

The purpose of the study involves comparing the gain for different resistance values. Values are obtained within an order of magnitude compared to what is stipulated by the manufacturer (G = 1 x 10^6). However, it is possible to observe compatibility among the gain values, which can be represented on the error graph. In general, the PMT2 configuration yields higher gains under the same conditions.