5th School on Cosmic Rays and Astrophysics

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Instrumentation and Calibration of a Muon Telescope Based on the Cherenkov Effect

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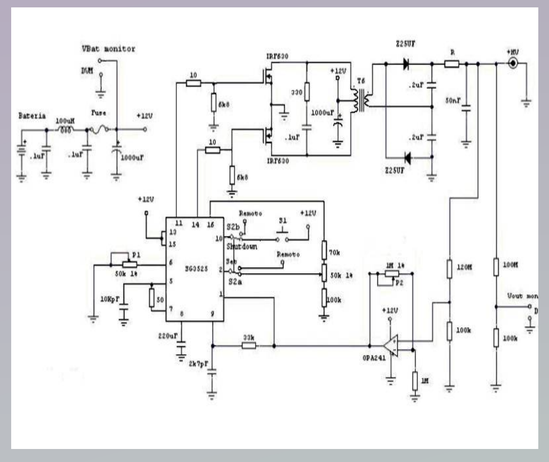
Abstract

Cherenkov tanks are charged particles detectors, also sensitive to gamma rays (by decay in an electron-positron pair). The height of the water column that the particles cross determines its sensitivity to gamma rays, thus decreasing this column (below 40 cm.) allows us to have a detector sensitive mainly to muons. Muon telescopes for space weather studies have been developed using a plastic scintillator. These detectors are expensive and also must develop an optical coupling between the scintillator and the light detector. Cherenkov tanks allow us to obtain the energy spectrum of the particles that pass trough them (80 to 160 MeV range in telescope mode for muons) which makes this detectors appropriate for space weather studies. The present work shows the instrumentation and calibration of a muon telescope built using two Cherenkov tanks.

High Voltage Power Supply

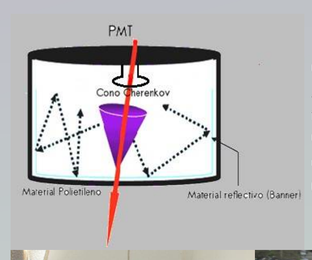
Developed for the experiment it is a source that has a topology Push - Pull, being able to feed 3 PMTs, with a power of 2 watts. The HV is acquired through multiplication of voltage, that depend function steps of stages to rectify the voltage. It is is modular, can be powered by batteries and is inexpensive



Outline of the high-voltage source

Cherenkov Detector

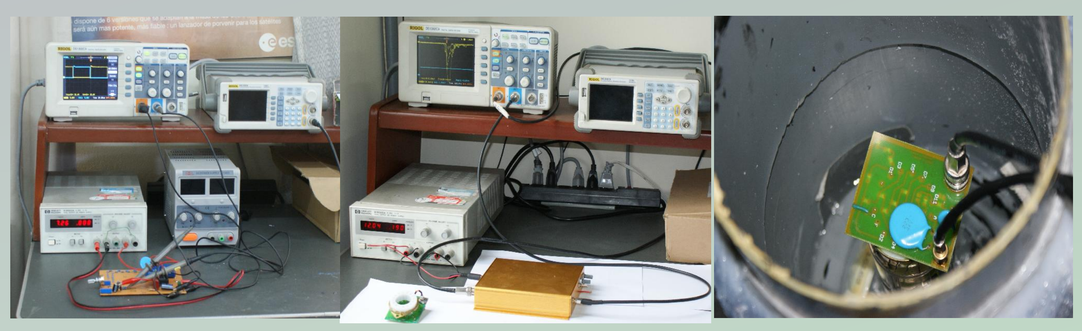
The tank is based on the Cherenkov effect. This effect is produced by charged particles which have a velocity greater than the speed of light in the dielectric medium (water), Cherenkov radiation is a type of shock wave which produces a bluer luster.



Outline of operation of the tank: A charged particle to passing through the tank produces cone Cherenkov light , the light reflects off the walls to reach the lightsensor (photomultiplicador).

Commercial tanks used to construct Cherenkov tanks. It shows the external coating of polyethylene and the coating of blue plastic mesh for protection against the environment.

System Calibration Equipment

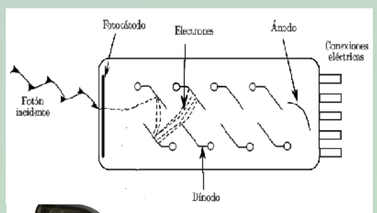


The pictures show: The bench test of the high voltage supply source without load (left). Full module operation: high voltage source, voltage divider and Cherenkov tank (center). The connections of the voltage divider in the Cherenkov tank (Right).

Equipment used to characterize the high-voltage source are: Hewlett Packard DC Power Model E3620A, Digital Oscilloscope Rigol DS1302CA 2 channel model.

Photomultiplier tube (PMT) - Instrumentation

It is a vacuum tube with a photocatode, dynodes and anode, its operation is based on the photoelectric effect an a cascade multiplication; it has a fast response, high stability and gain at high frequencies, and these detectors can work for many years with low maintenance cost.



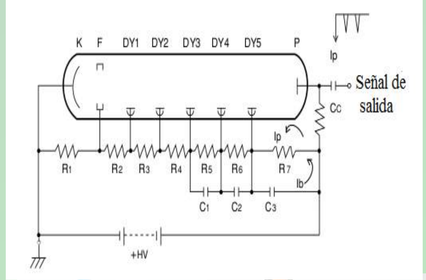
Outline of operation of a PMT, a photon strikes the photocathode releases an electron which is accelerated and is multiplied in the dynodes due to a constant potential difference between them.

Photo EMI 9530A PMTof dynodes 11.

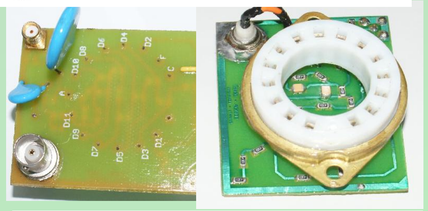
Voltage divider

Is an array of electronic devices based on resistors and capacitors used for dividing an input high voltage(HV), generating constant Potential differences that are Applied to each dynode to ensure the gain and stability these potential differences should be kept constant.

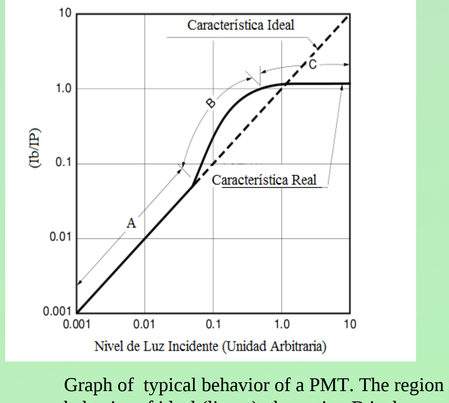
The gain of the PMT must be linear for proper operation. To extender the linearity to the B region (see figure 7) decoupling capacitors (C1, C2, C3) are connected .



Typical diagram of the operation of a voltage divider: the voltage drop in the resistor R7 generated by the current Ip (due to light pulses) is offset by the decoupling capacitor C3, a similar situation occurs in R6 and R5



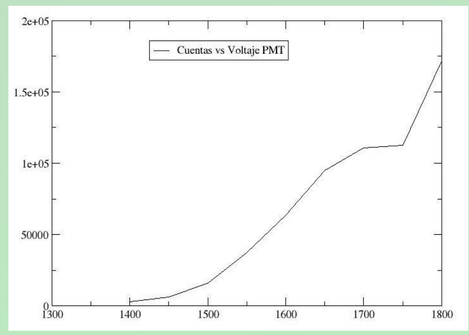
Voltage divider circuit assembly with surface components for the EMI 9530 PMT A.

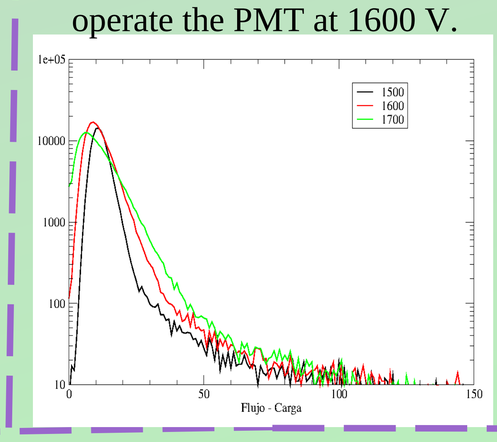


Graph of typical behavior of a PMT. The region A is the behavior of ideal (linear), the region B is the non-linear region and the C region is the region of saturation.

Results

The calibration curve (Plateu) of the Cherenkov detector .Shows the three regions: linear (1500-1650 V), saturation (1650-1750), overload (1750-1800). We operate the PMT at 1600 V.





Flux at different voltage values used for the energy calibration of the Cherenkov detectors. The peak corresponds to a vertical muon that deposited 80 MeV.

Conclusions and Future work

- Intrumentation for registration of rays cosmic in telescope mode is under developed (voltage divider - high voltage source - tank Cherenkov). For this purpose several cards test for good performance of each of the modules were designed.
- The electronic system developed is a prototype , we obtained the saturation curve and calibration of equipment.

Acknowledgements

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