Measurement of Muon Lifetime using a Scintillator Detector

Group 5

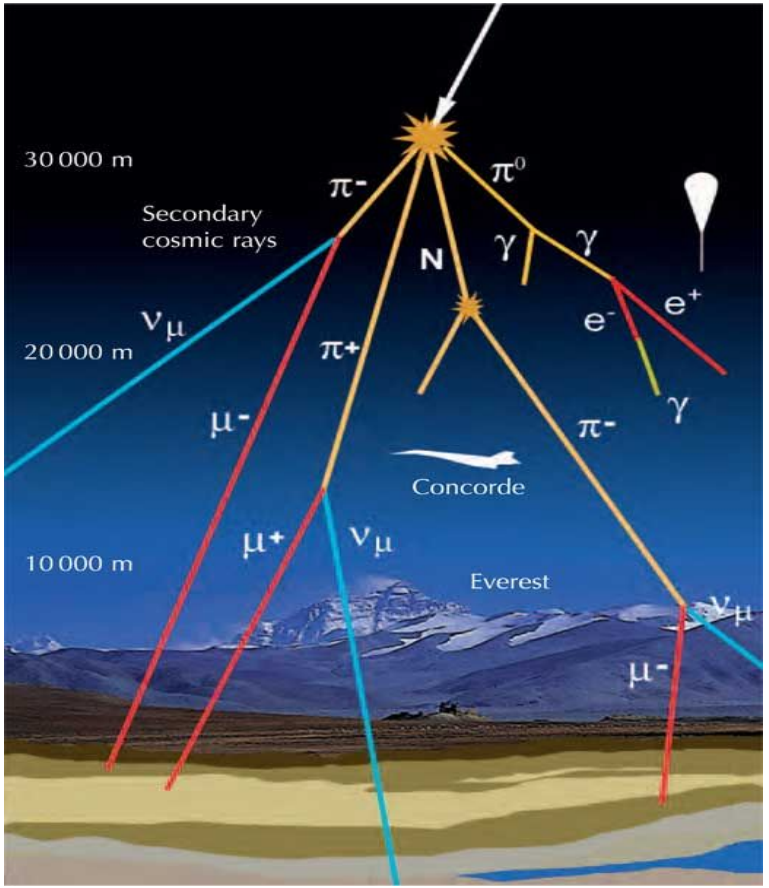
ICFA23 | 25.02.23

Ashish Narayan, Chandra Prakash, Kunal Gautam

Introduction

Motivation

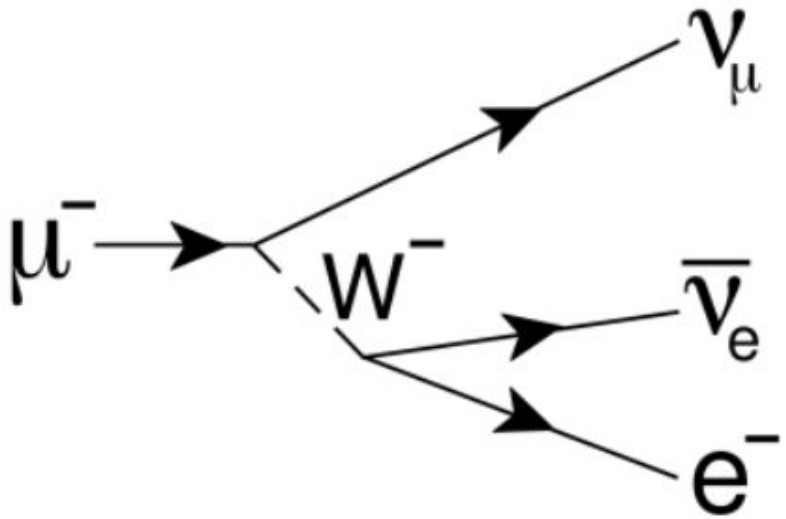
- **Muons** are second-generation leptons.
- Discovered in cosmic rays by **C. Anderson** and **S.H. Neddermeyer** in 1937.
- Generated when **cosmic rays** collide with molecules in the Earth's **atmosphere**.
- Useful in the study of cosmic rays physics and it is a background for most of the experiments related to **Neutrino Physics** and **Astronomy.**
- Fermi Coupling Constant G_F can be measured from the same process.



*pdg

Basics of Muon Decay

- Mass of the muon is **105.7 MeV**, about **200 times** the mass of the **electron**.
  - m_μ = 105.6583755±0.0000023 MeV*
- Interactions similar to those of the electron.
- The mean lifetime of a muon is about **2.2 microseconds**.
  - τ_μ = 2.1969811±0.0000022 μs*
- $\mu^- \rightarrow e^- + \nu_\mu + \nu_e$
- Probability of decay in time interval from t to t+dt:
  - $dP(t) = \Gamma e^{-\Gamma t} dt$, where $\Gamma = 1/\tau$



Objective

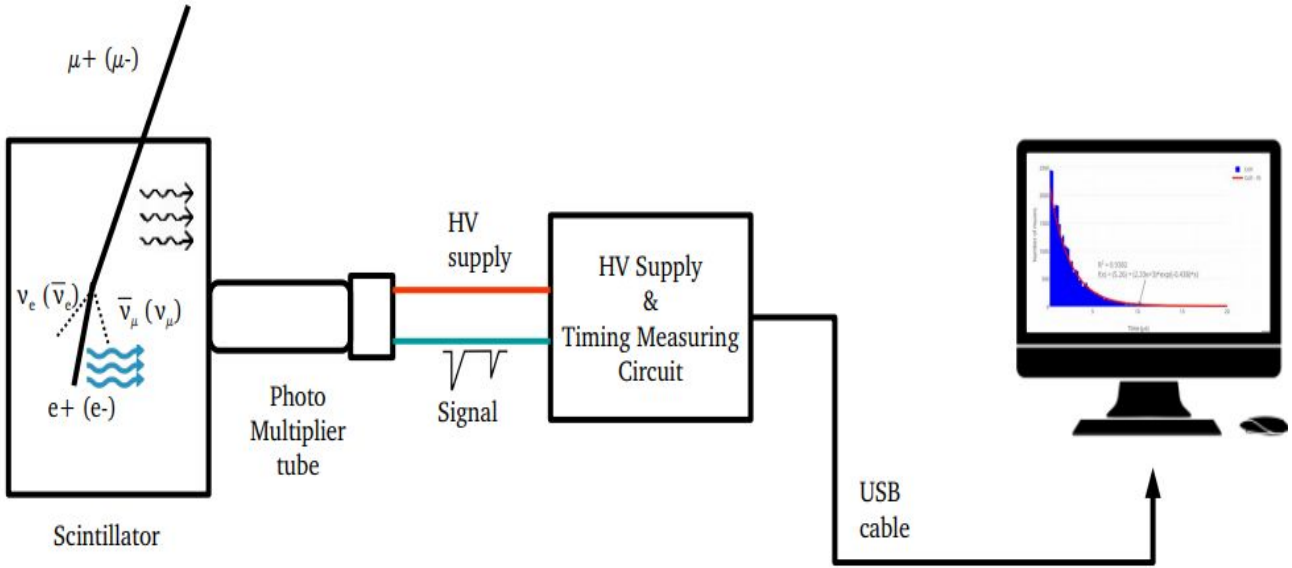
- Measure the lifetime of muons, which requires:
  - Detecting the muon
  - Detecting the daughter electron
  - Measuring the time difference between the signals from the two.
- Here, we are only interested in muons that decay inside the plastic scintillator.

Lifetime Measurement

Using Plastic Scintillator Detector

Experimental Setup

- Plastic Scintillator
  - 25x25x20 cm^3
- Photomultiplier Tube (PMT)
- Time-measuring Circuit
- High-voltage Supply



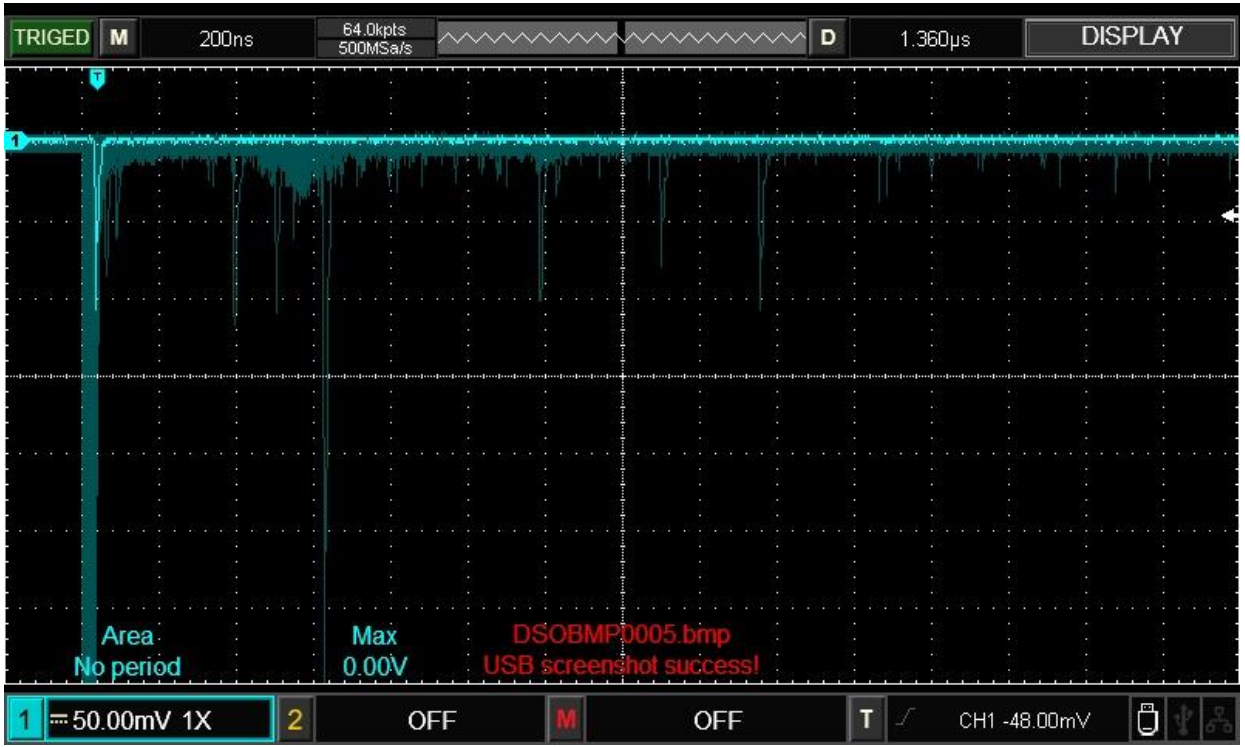
Signal from Muon Decay

Muon Signal

Delayed Electron Signals

Signal From Muon Decay

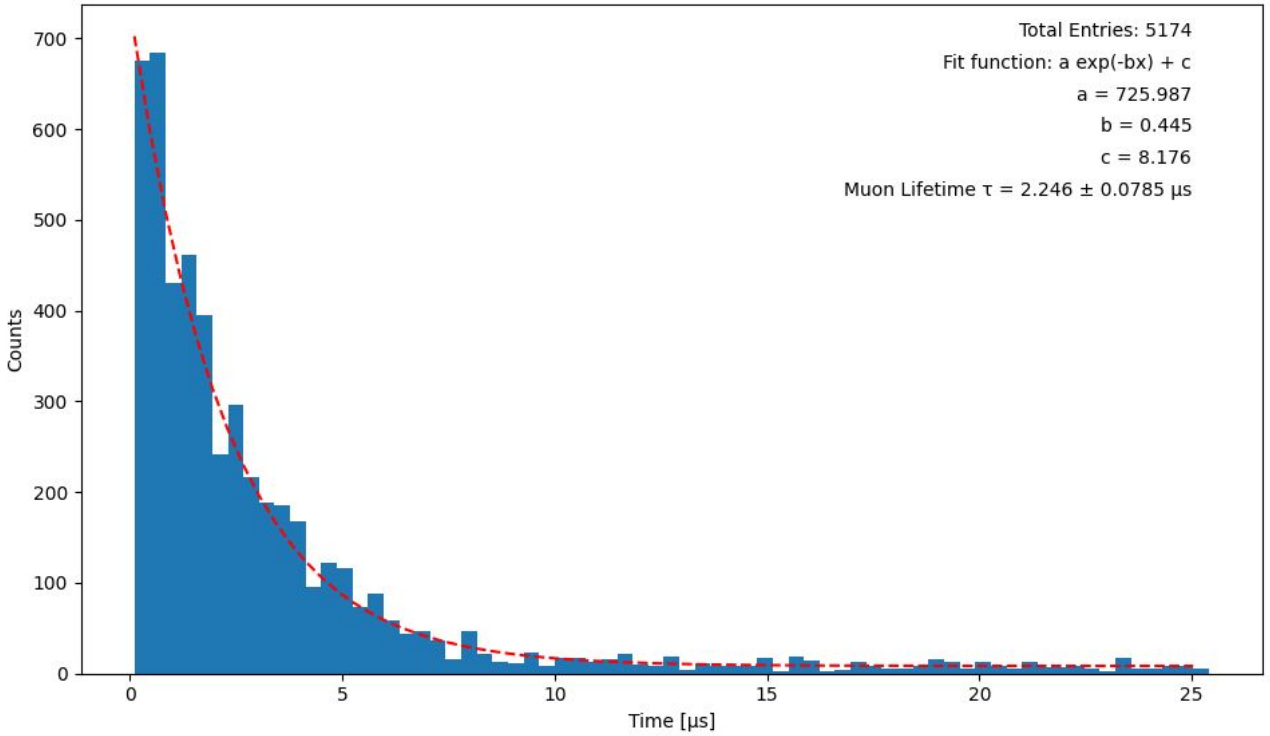
- 8-bit counter with a 10 MHz clock.
  - Range of 0-25.5 µs
  - Steps of 0.1 µs
- Measure the time-difference between two signals.



Result

- $N = N_0 e^{-t/\tau} + c$
  - $N_0 = 725.987$
  - $c = 8.176$
- $\tau = 2.246 \pm 0.078\ \mu s$

In agreement with the current PDG value.



Conclusion

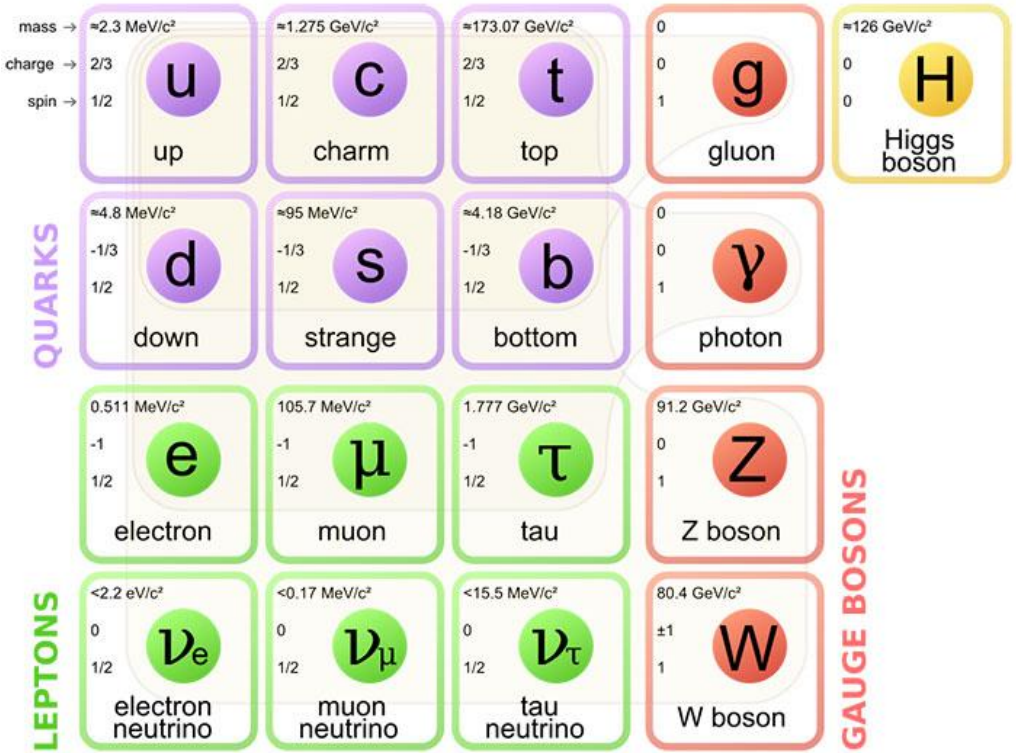
- Once upon a time, there was a muon 🤩
- Suddenly, it decayed into an electron 😱
- We detected both of them with a very cost effective table-top detector 🥳
- And now we are particle physicists 😎

So long,

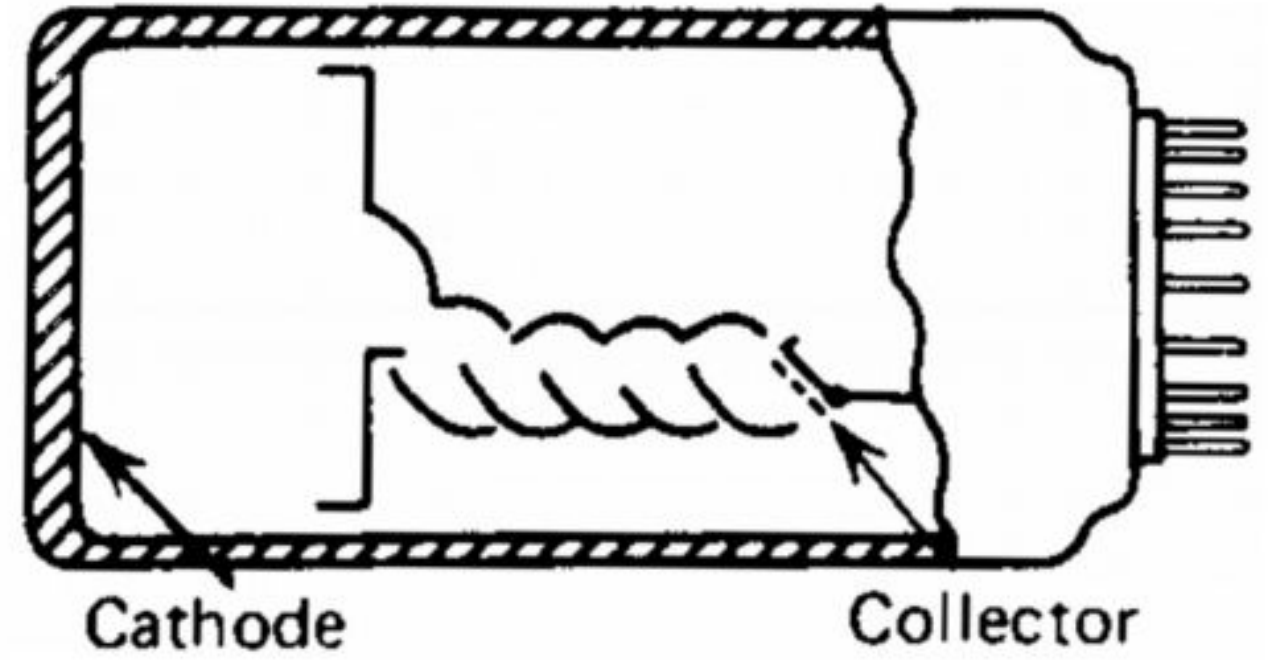
and **thanks** for all the fish

Back-up

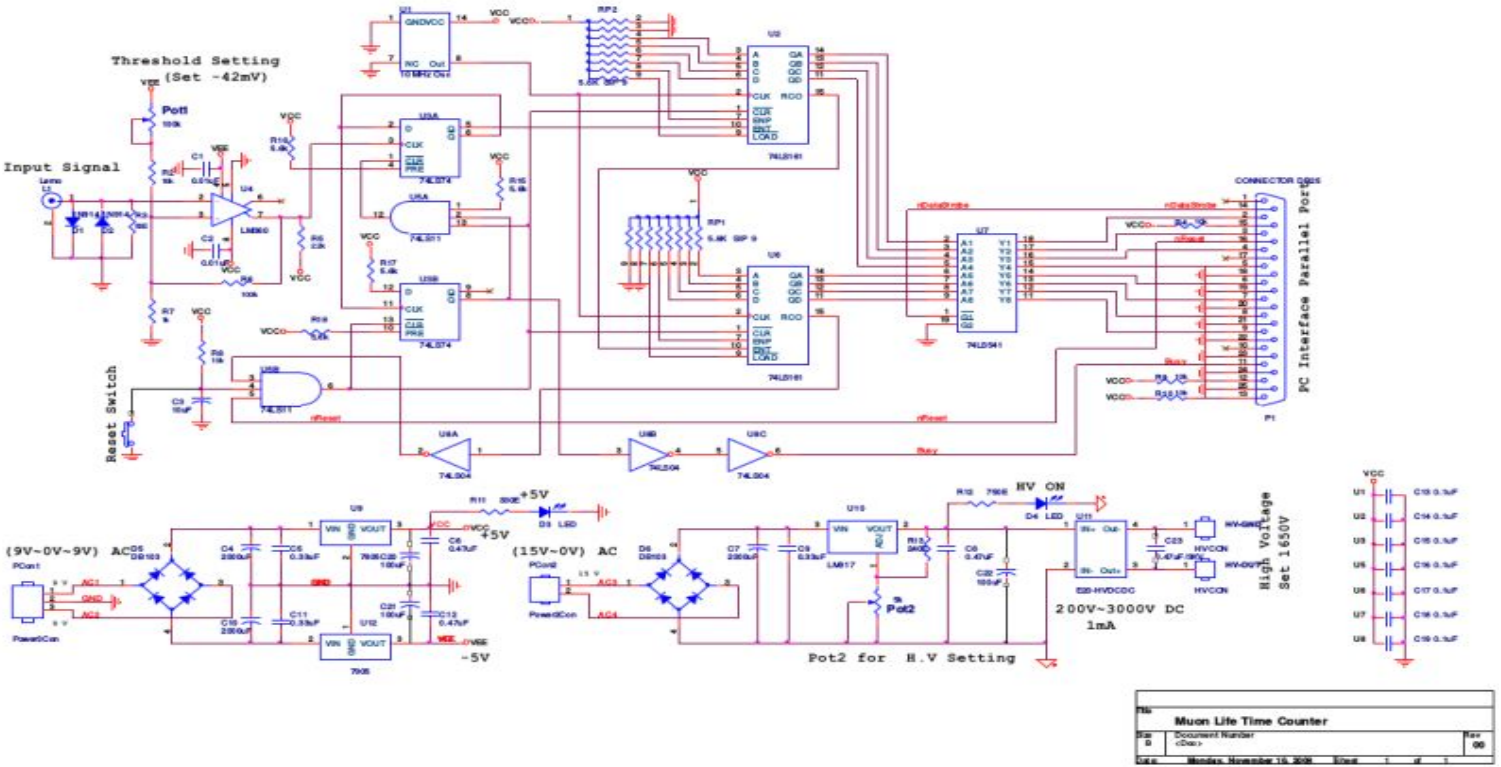
Standard Model

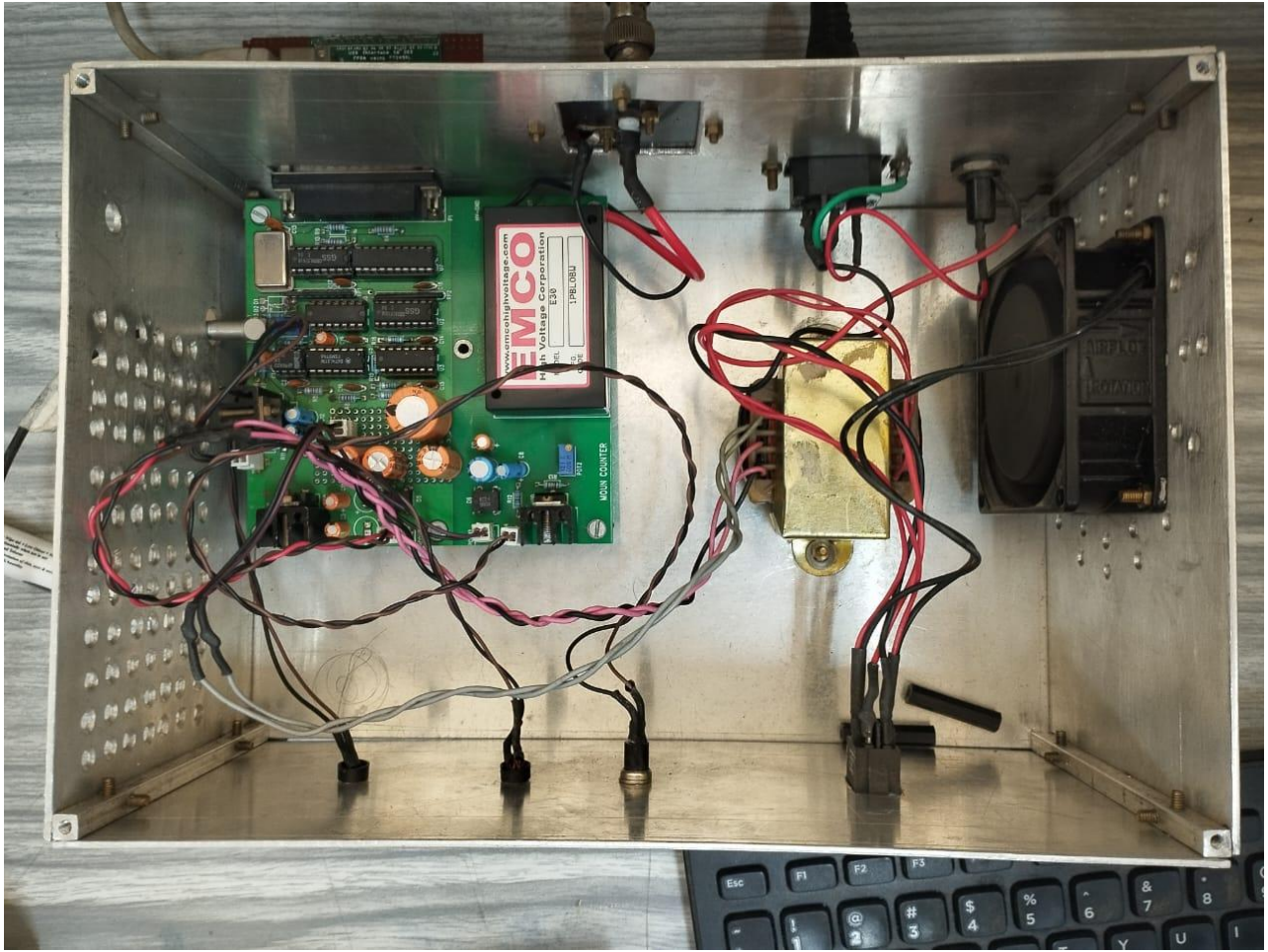


Photomultiplier Tube (PMT)



Time-measurement Circuit




EMCO
High Voltage Corporation
www.emcohighvoltage.com
MODEL
E30
SERIAL
19BEL0BU
DATE
MUON COUNTER
POT1