Determination of the Muon Lifetime

Using Cosmic Ray Muon

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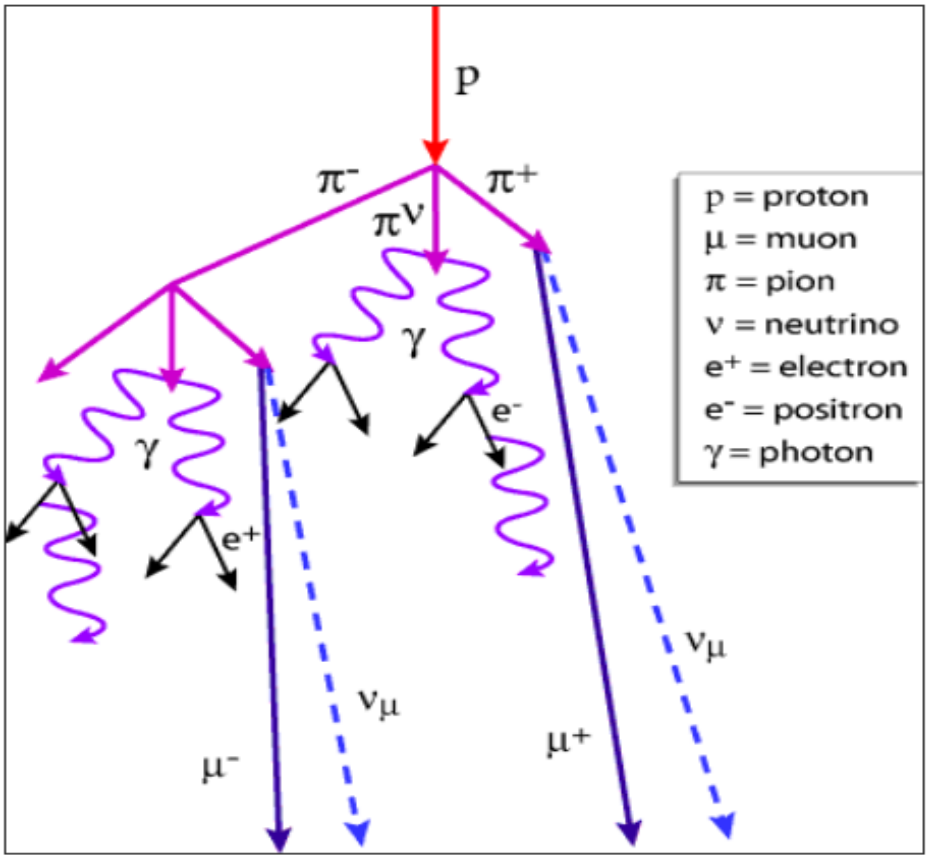
Introduction

- Muons were discovered by Carl D. Anderson and S. Neddermeyer at Caltech in 1936, while studying cosmic radiation; named "mesotron"
- Muon was confirmed in 1937 by J. C. Street and E. C. Stevenson.



- Cosmic ray muons are created when cosmic rays enter earth's atmosphere
- Elementry particle(i.e.no sub-structure)
- mass 105.66 MeV
- Interact weakly
- $\mu^- \rightarrow e^- + \upsilon_\mu + \upsilon_e bar$
  $\mu^+ \rightarrow e^+ + \upsilon_\mu bar + \upsilon_e$
- lifetime $\tau_\mu = 2.197 \mu s$

Objectives

Objectives

Determination of Muon life time

Motivation

- Natural Source: flux at sea-level muons $\sim 1 min^{-1} cm^{-2}$
- In 1941: Rossi–Hall experiment muons were used to observe the time dilation for the first time.
- Gain practical skills in data acquisition

Experimental Setup

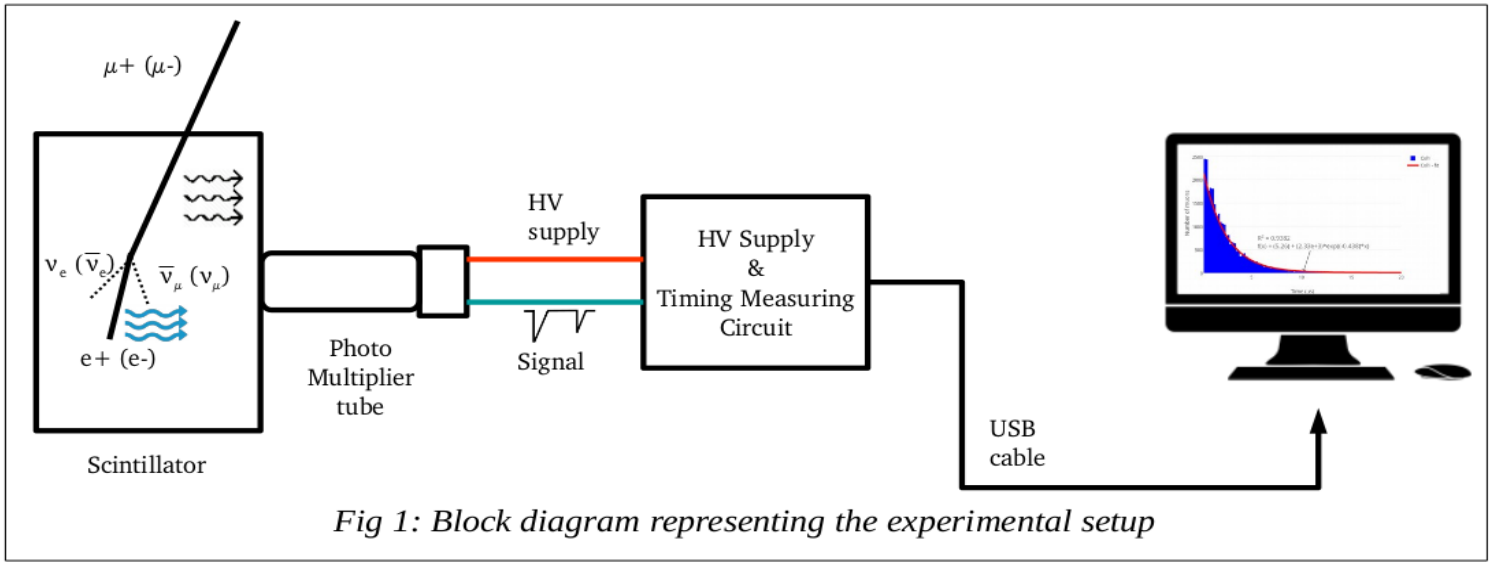


Fig 1: Block diagram representing the experimental setup

- Consist of plastic scintillator, photomultiplier tube, a timing measuring circuit and high voltage supply
- Dimension: $25cm \times 25cm \times 15cm$

Probability of decay in time interval dt:

$$dP = \Gamma dt \text{ where decay rate } \Gamma = 1/\tau_\mu$$

$$dP(t) = \Gamma e^{-\Gamma t} dt$$

Results: Life time measurement

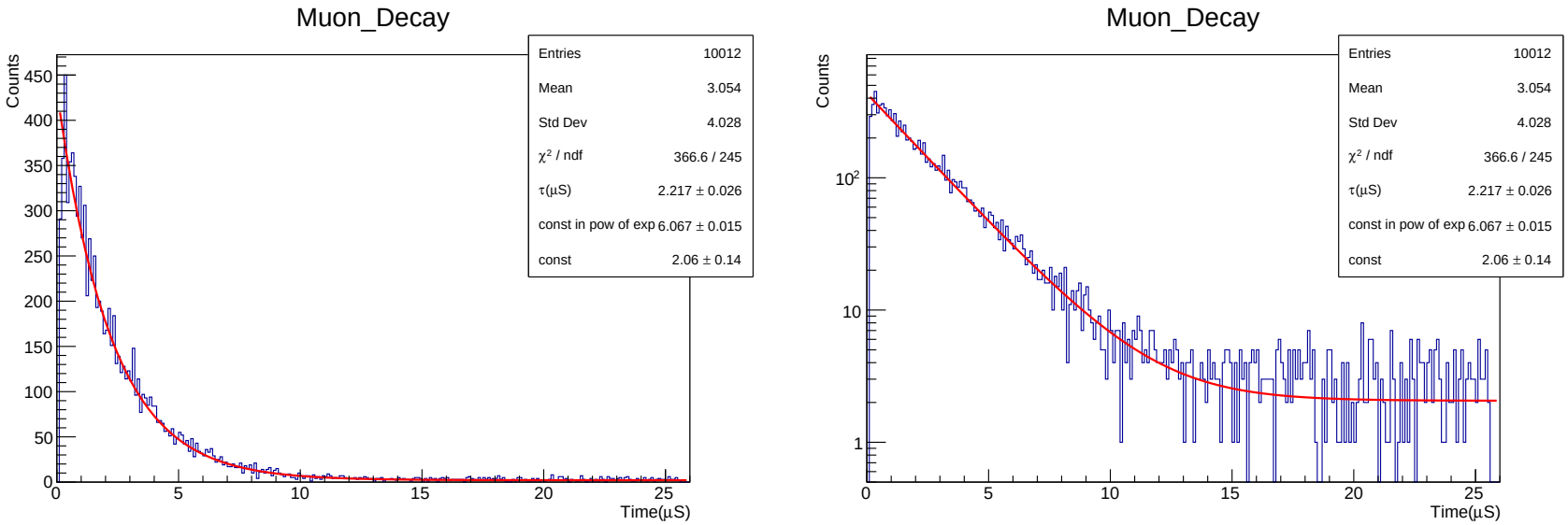
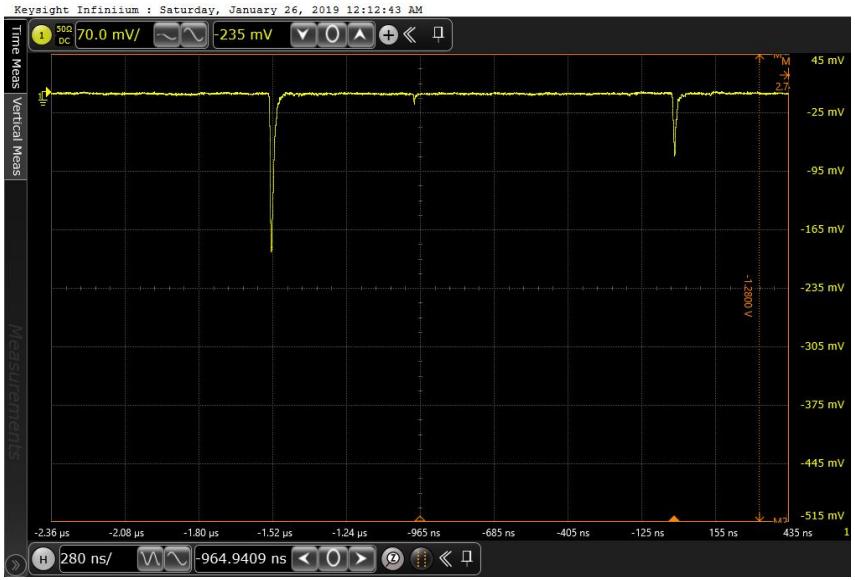


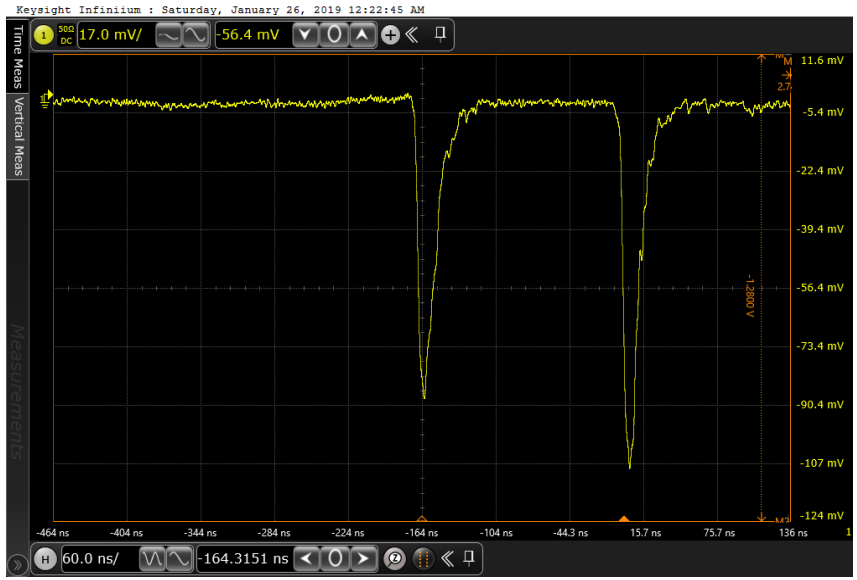
Figure: Histogram of muon lifetime

- $N = N_0 e^{-t/\tau} + b$
- $N_0 = 414.46 \pm 20.36$
- $b = 2.06 \pm 0.14$
- $\tau(\mu s) : 2.217 \pm 0.025$

Results: Time Measurement



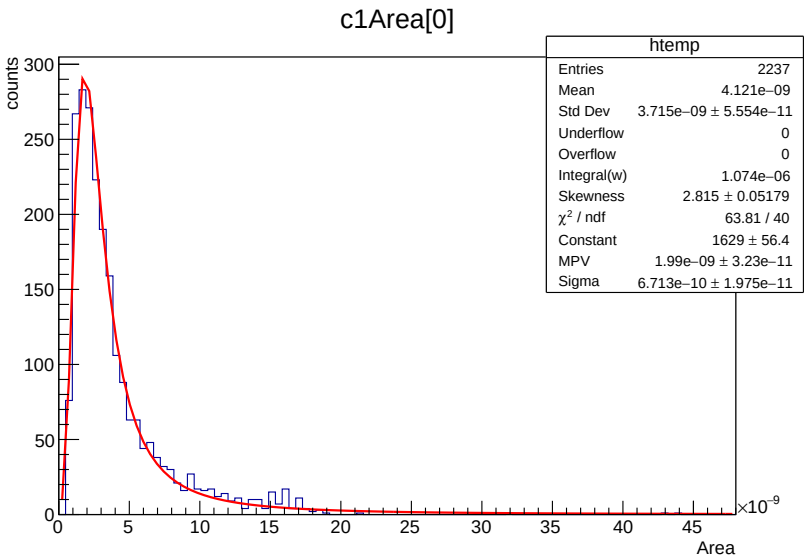
(a) Bigger Muon Pulse



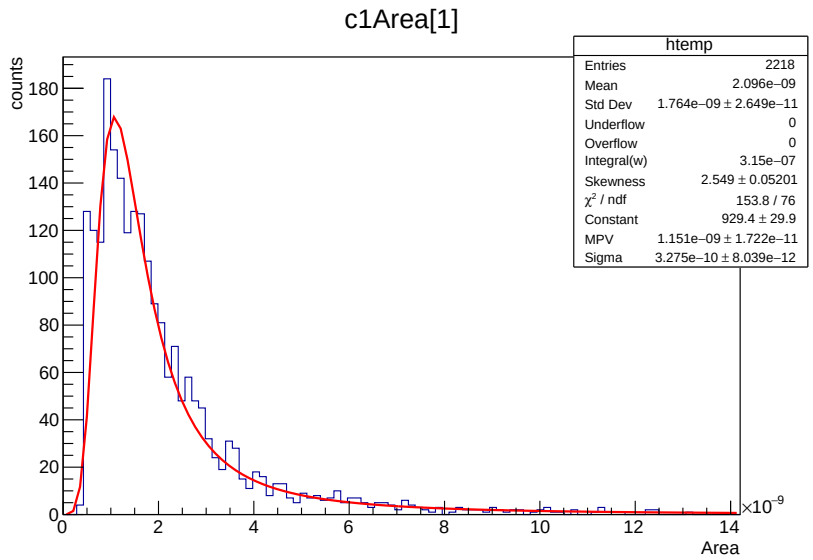
(b) Bigger Electron Pulse

- Sampling rate: 50ps
- Frequency : 10MHz ; Resolution: $0.1\mu s$
- Count: $2^8 - 1 = 255$ ie. if a second pulse is not received within 25.5 μs counter will reset.

Results:Charge Measurement



(a) Muon



(b) Electron

- MPV(most probable value):
  1. Muon : 1.99×10^{-9}
  2. Electron : 1.151×10^{-9}
- Charge:
  1. Muon : $0.0397 \times 10^{-9} C$
  2. Electron : $0.0230 \times 10^{-9} C$

Summary:

Remark

- Our measurement of muon life time 2.217 ± 0.025 agrees with PDG value (2.1969811 ± 0.0000022).
- Understand charged particle detection mechanisms in scintillation detectors;
- Understand light detection in photomultipliers

Source of Error

- Background Noise(i.e. radioactive source)
- Other through going muons
- Satistical uncertainty

References

Acknowledgement

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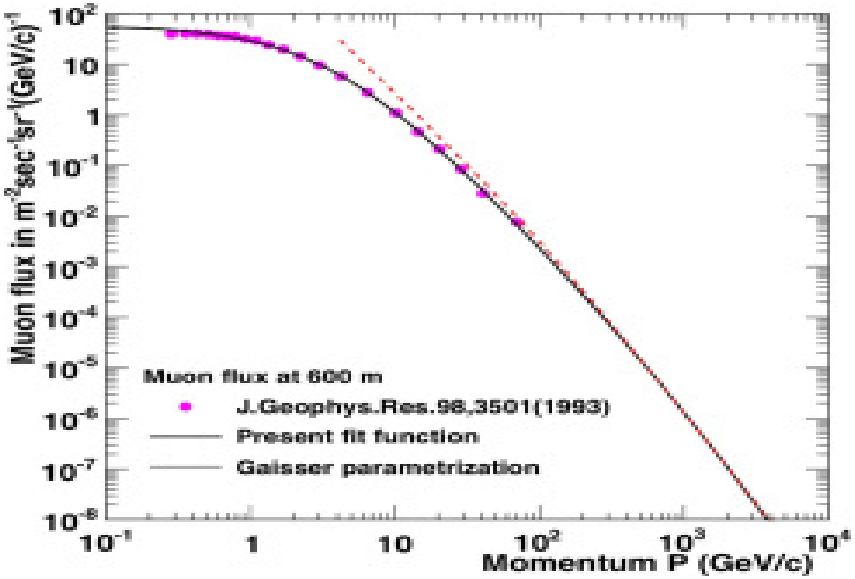
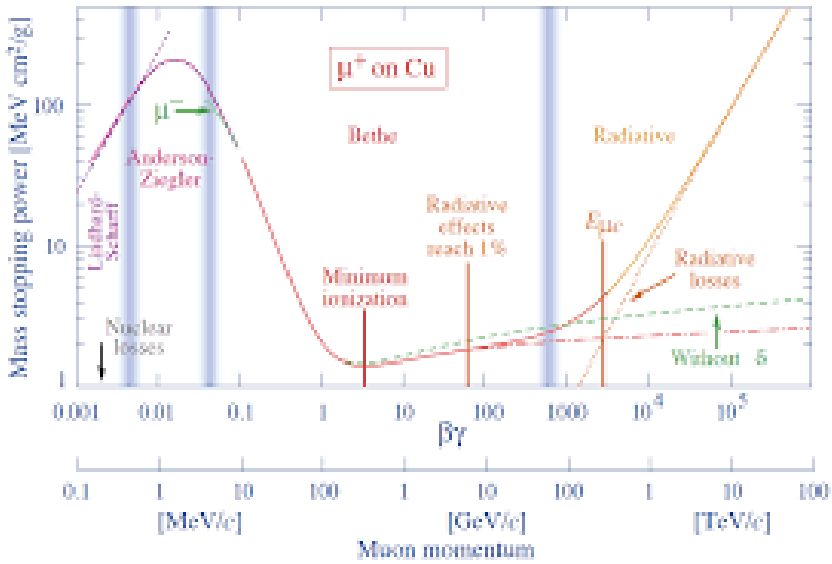
References

1. Street, J.; Stevenson, E. (1937). "New Evidence for the Existence of a Particle of Mass Intermediate Between the Proton and Electron"
2. http://www.ino.tifr.res.in/bsn/INO/muonlife-meghana.pdf

Backup



(a) Muon Flux



(b) Energy Deposition in Cu

Backup

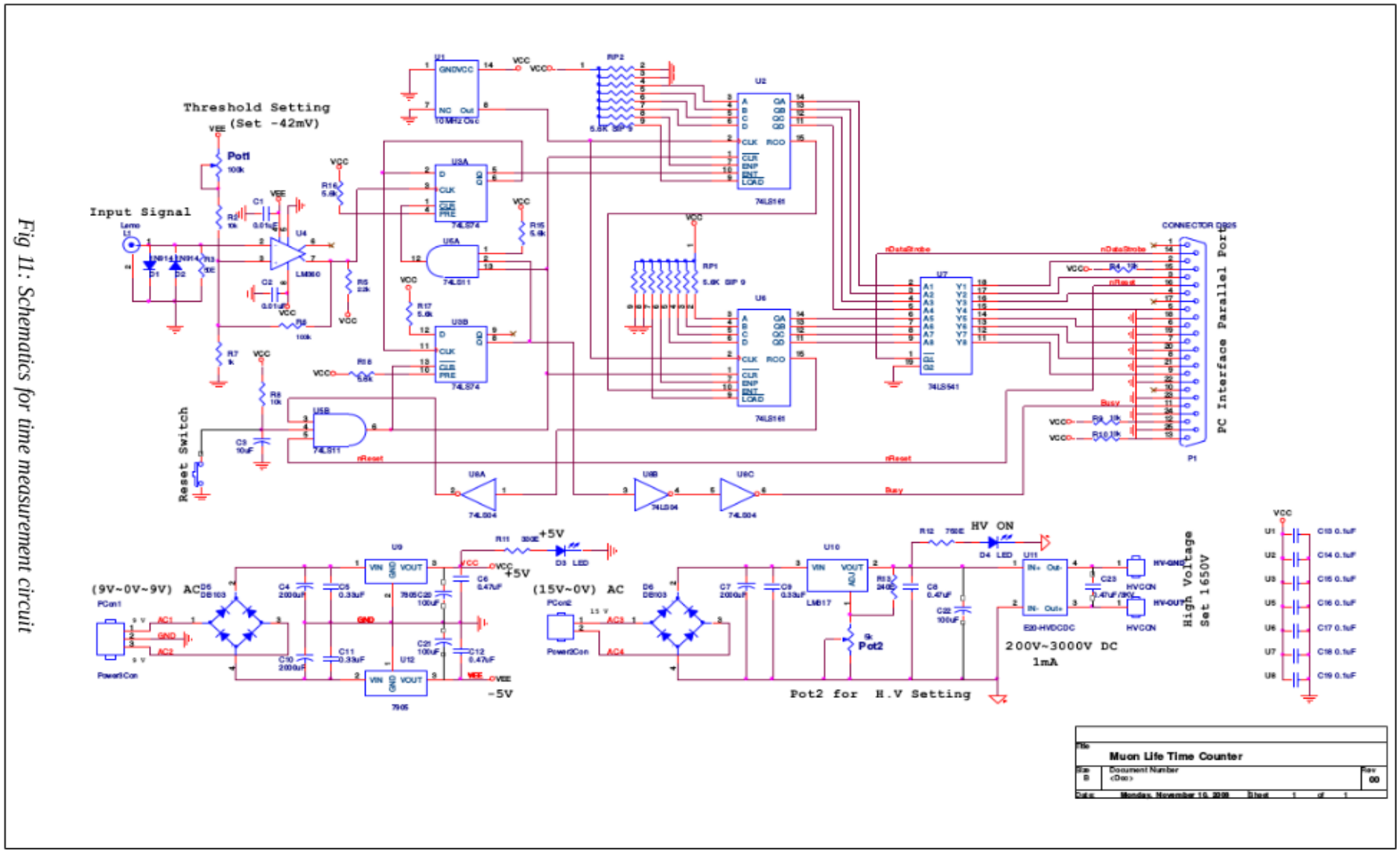
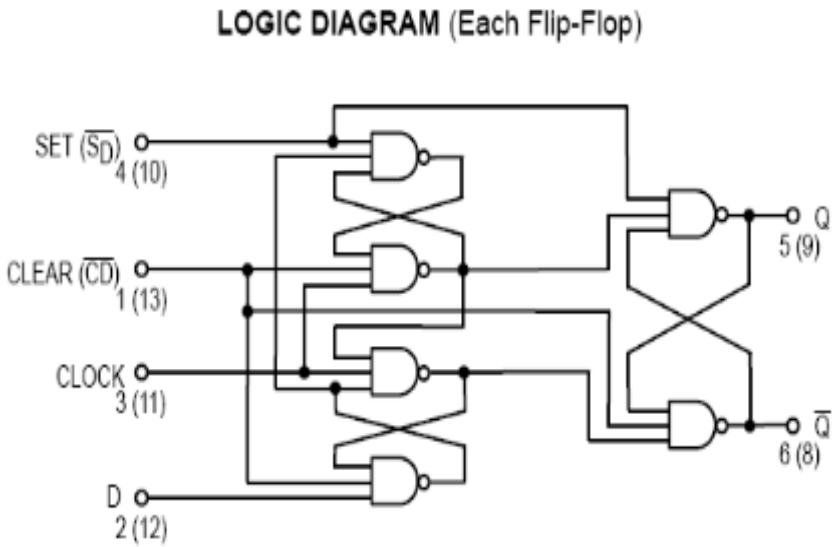
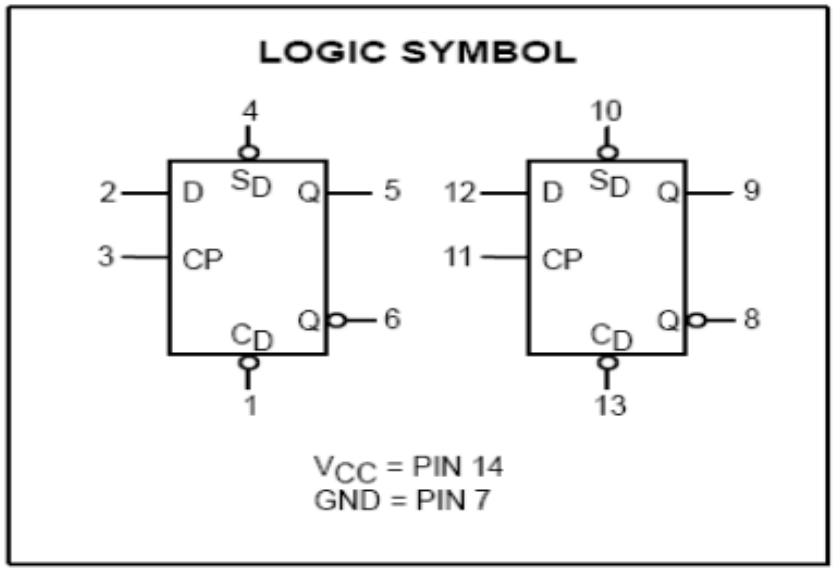


Fig 11: Schematics for time measurement circuit

Backup





Inputs				Outputs	
PR	CLR	CLK	D	Q	$\overline{Q}$
L	H	X	X	H	L
H	L	X	X	L	H
L	L	X	X	H (Note 1)	H (Note 1)
H	H	↑	H	H	L
H	H	↑	L	L	H
H	H	L	X	Q_0	$\overline{Q}_0$

X = LOW or HIGH Logic Level
H = HIGH Logic Level
L = LOW Logic Level
↑ = Positive-going Transition