PHYS3710 Short experimental projects I
Department of Physics
The Chinese University of Hong Kong, Hong Kong
Topic: Cosmic Muon Lifetime Measurement

designed by

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Topics you should know first:

1. Muon properties (mass, charge, decay, half-life (at rest & at high speed))
2. Muon in cosmic rays (generation, energy, muon flux ≈1 particle/min/cm^2 on earth surface) (See Ch. 4 of Ref. 1 & Ref. 2)
3. Particle detectors (See Ref. 5 for principle of Geiger counter & scintillation counter)

Objectives:

1. Measure cosmic muon flux.
2. Confirm high penetration power of cosmic muons.
3. Measure muon half-life.

Check-list for the project:

(A) ***Preparation:***

1. Review muon physics (refer to modern physics textbooks).
2. Get some idea about cosmic rays (Ref. 1 & 2).
3. Learn detector principle (Ref. 5).
4. Instrumentation: In the lab we will introduce the required instrumentation. Get familiar with each of them one by one with the help of Tektronic CRO & pulser.
   (a) Detectors: Geiger Muller (GM) counter & plastic scintillation counter
   (b) Electronics: Tektronic CRO, NIM module, pulser, high voltage power supply, preamplifier, amplifier, SCA (single channel analyzer), MCA (multichannel analyzer), MSA (multiscaler analyzer), …

(B) ***GM counter experiments:***

1. Read p. 25 of Ref. 1 for penetration of 4 cm gold block and p. 45 of Ref. 2 for penetration of 25 cm – 1 m lead bricks:
2. Set up one Aware GM counter with a PC (http://www.aw-el.com/).
3. Use a β source to check each GM detector.
4. Set up two Aware GM counters with a coincidence circuit. Clamp the GM counters with a lead brick in between as shown in Fig. 1.
5. Count for about 1 week. (Note: If the total count is N, then the error is $\sqrt{N}$.)
6. Remove carefully the lead brick without disturbing the two GM counters.
7. Count for another week. Compare the two count rates.
8. Estimate the muon flux.

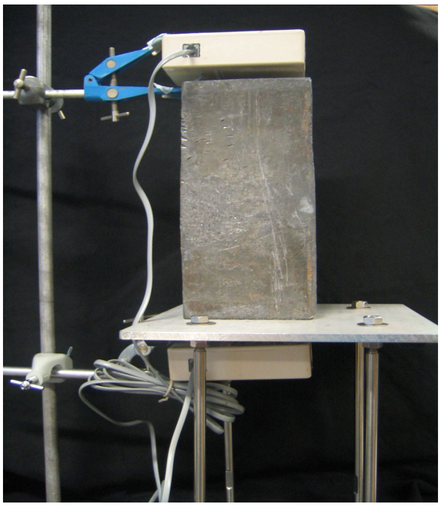

Fig. 1 Setup for muon flux measurement.

(C) *Muon half-life:*

1. Read Ref. 5 to learn the steps of assembling a scintillation counter.
2. Assemble the plastic scintillation counter.
   (Be careful! Expensive components: e.g., > $ 10K for the plastic scintillator).
3. Use a pulser to check preamplifier, amplifier, SCA (single channel analyzer), MCA (multi-channel analyzer). Pay attention to the pulse width of each output signal.
4. Use a gamma source to check operation of the plastic scintillation counter
5. Set up detector as shown in Fig. 2 and repeat experiment described in Ref. 4.
6. Set up detector as shown in Fig. 3 and convert the MCA to work as MSA. Set SCA as a discriminator (select a lower level) and collect data for at least one week (the longer the better). You get $N(t)$.
7. For large t, $N(t) \approx$ constant $\equiv N_0$. This is the background.
8. Subtract this background from all data & then plot Log (N-N_0) vs t.
9. Get muon half-life from the slope of this plot.
10. Estimate the muon flux using the cross-sectional area of the scintillator and compare with the expected value.

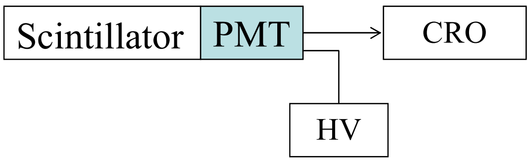

Fig. 2 Muon half-life measurement with Tektronic CRO

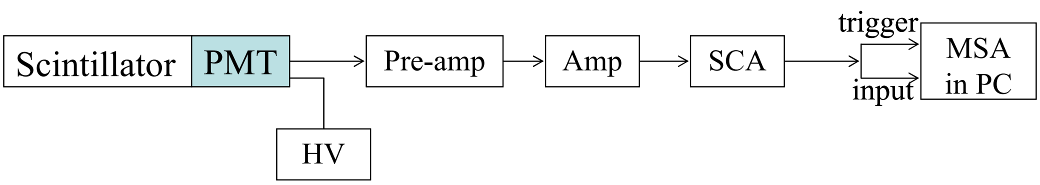

Fig. 3 Setup for muon half-life measurement

References:

1. F. Close, M. Marten & C. Sutton, *The particle odyssey: a journey to the heart of the matter*. (QC793.2C56 2002)
2. B. Rossi, *Cosmic rays*, (QC485R66 1996a)
3. C.R. Gould & R.L. Ives, Am. J. Phys. **43**, 918 (1975).
4. H. Mühry & P. Ritter, "Muons in the classroom", The Physics Teacher **40**, 294 (2002).
5. W.R. Leo, *Techniques for nuclear and particle physics experiments : a how-to approach* (QC793.46 .L46 1994)

*** A collection of references is available in the lab.