Frisch and Smith: Time Dilation

Measurement of time dilation by Frisch and Smith, 1963. Compare muon decays from cosmic rays at top of Mt. Washington NH versus sea level. Apparatus is shown in Fig. 1 (Left) Muons that penetrate lead and stop in scintillator have $0.9990 < \beta < 0.995$. Stopped muon lifetime is measured by separation of muon and decay electron scintillation pulses. The muon lifetime of $\tau = 2.2\mu$s is shown in Fig. 1 (Right). They observed an average of $N_0 = 565 \pm 10$ decays per hour on Mt. Washington and $N = 409 \pm 9$ decays per hour at sea level. The height difference is $\Delta x = 1904$ m giving a flight time of $\Delta \mathrm{t} = \Delta \mathrm{x/c} = 6.34\mu$s. Without time dilation, expect $N = N_0 e^{-\Delta t/\tau} = 31.3$ events/hour, τ being the (proper, decay at rest) muon lifetime of 2.2μs. The observed number of sea level events corresponds to a decay $N = N_0 e^{-\Delta t/\tau_{lab}}$ with $\tau_{lab} = \gamma\tau$,

$$\Delta t/\gamma = \tau \ln(565/409) = 0.71\mu\mathrm{s}$$

This gives a $\gamma = 6.34/0.71 = 8.8$. This corresponds to $\tau_{lab} = 19.6\mu$s. The theoretical $\gamma = 10$ based on speed, but they argue in paper that (based on energy measurements) $\gamma = 8.4 \pm 2$.

We see that in the experiment they only observe stopped muon decays. They never directly measure the moving muon lifetime.

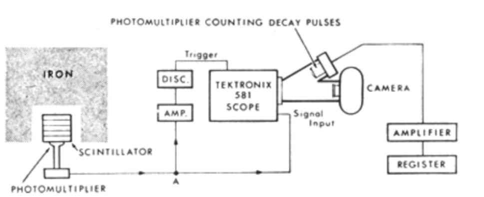

FIG. 2. Scheme of the experiment. The lower parts of the sides of the pile of iron were not as neat as shown, but included wooden supporting beams and some lead bricks in a rather irregular array (see Fig. 3).

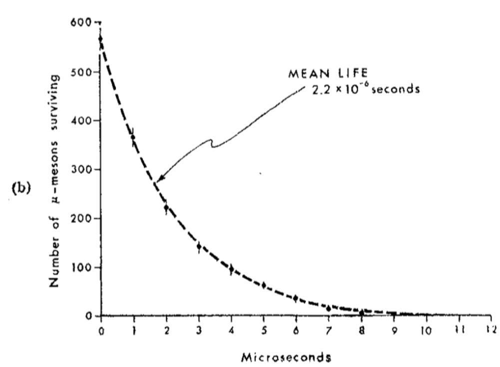

Figure 1: Left: Experiment of Frisch and Smith used to measure muon decays of muons stopped in scintillator. Right: muon lifetime from scintillation pulse time differences between muon stopping in lead and subsequent decay of muon at rest giving an electron.