MEAN LIFETIME PART 2: COSMIC MUONS
STUDENT GUIDE

In chemistry class, you learned about nuclear decay and described this decay by determining the half-life of the nucleus by analyzing an exponential decay curve.

The *half-life* of the nucleus is the time for ½ the sample to decay according to the mathematical model

$$N = N_0 2^{-t/T_{1/2}}$$

where N is the number of nuclei in the sample, N_0 is the initial number of nuclei, t is time, and $T_{1/2}$ is the half-life of that nucleus.

Particle physicists prefer to describe the decay of fundamental particles using mean lifetime. The *mean lifetime* of a particle is the time for 1/e of the sample to decay according to the mathematical model
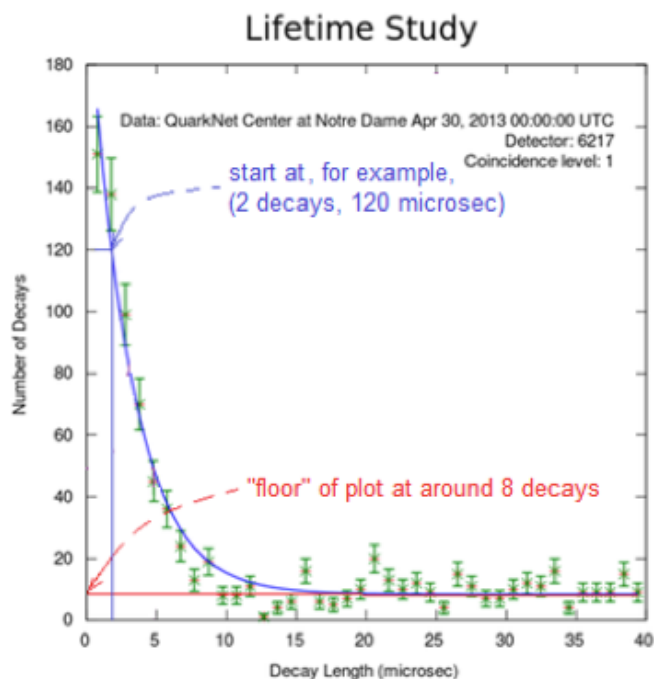
$$N = N_0(e^{-t/\tau})$$

where N is the number of muons in the sample, N_0 is the initial number of muons, t is time, and τ is the mean lifetime.

OBJECTIVES:
 Explain the difference between mean lifetime and half-life.
 Describe how to analyze a plot when the time chosen to start the analysis is not zero microseconds.
 Describe how to analyze a plot when the asymptote of the curve is not at zero decays.
 Determine the mean lifetime of cosmic ray muons.

DATA ANALYSIS
The image below is an example of a mean lifetime study from the Cosmic Ray e-Lab. Your plot will not have the mean lifetime calculation shown in blue at the top of the plot.

Your teacher will give your group a lifetime study plot. Determine the half-life and mean lifetime for your plot. Record the class data:

Half-life	Mean Lifetime

Make a histogram of class data for Half-life and a second histogram for Mean lifetime.

DISCUSSION QUESTIONS:
1. How well does each plot fit using 2 half-lives? With 2 mean lifetimes? What does this say about the reliability of the plot?
2. Using a decay curve describe how to use half-life and mean lifetime to explain how particles decay randomly yet decrease in number in a predictable way.
3. Explain the difference in the mathematical models used to determine half-life and mean life-time.
4. Provide evidence to refute the claim that "All particles of a particular type decay in exactly a time described by the particle's mean lifetime."