

Proper lifetime of the muon

Preparatory questions

The muon is an elementary particle and one of the fundamental constituents of matter. Muons are very similar to electrons, apart from the fact that a muon has about 200 times more mass than an electron. Muon decay is governed by the charged weak interaction. Take a textbook on particle physics, for example D.H. Perkins, Introduction to High Energy Physics, to study muon decay in detail.

1. The muon has a lifetime of $2.197 \mu\text{s}$. According to classical physics, what is the distance that a muon would travel at the speed of light during its lifetime? Why do muons produced in the upper atmosphere, say at 10 km, reach the sea level before they decay? What is the speed of a muon with an energy of 2 GeV? How far will the muon travel before disintegrating?
2. Describe how a scintillation counter works, starting from the entrance of an energetic charged particle into a scintillator, and ending with an electrical pulse at the output of the photomultiplier.
3. Describe the function and operation of each of the following elements of the measurement apparatus
 - a) discriminator
 - b) coincidence unit
 - c) scaler
 - d) Time to amplitude converter
 - e) multichannel analyzer
4. How many ‘accidentals’ (i.e. pulses from unrelated particles) will you observe during one hour of measurement from a scintillation counter if the accidental event rate is 10^4s^{-1} ? Assume the time window for determining coincidence to be 100ns. How will these accidentals be distributed in your spectrum of ‘counts vs. time’?
5. Sending pulses down coaxial lines introduces a delay. Explain why this is so. How does the delay depend on the length of the cable? What is the delay introduced by a 50Ω coaxial cable, 2 meters long. (hint: read about coaxial cables in the “basic measurement apparatus” section of the course webpage)