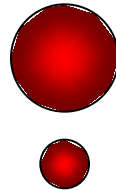


Particle Masses

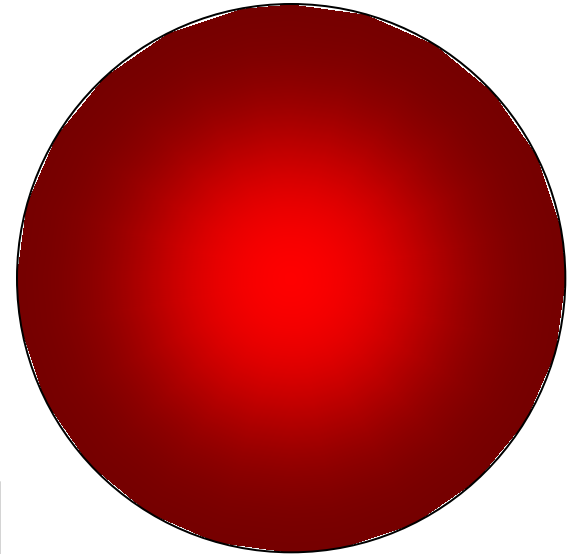
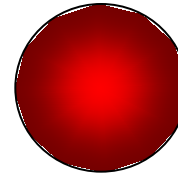
Up Quark
~ 0.002 GeV



Charm Quark
1.25 GeV



Top Quark
175 GeV



Down Quark
~ 0.005 GeV

Strange Quark
~ 0.095 GeV

Bottom Quark
4.2 GeV

These are relative masses not size – they have no measurable size

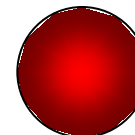
Electron
0.0005 GeV



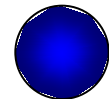
Muon
0.105 GeV



Tau
1.78 GeV



For reference:



Proton
0.938 GeV

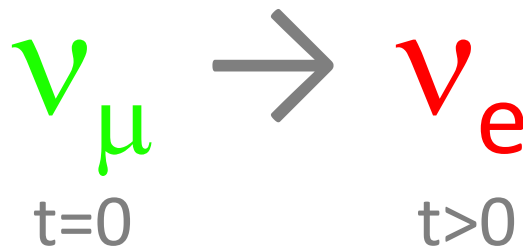
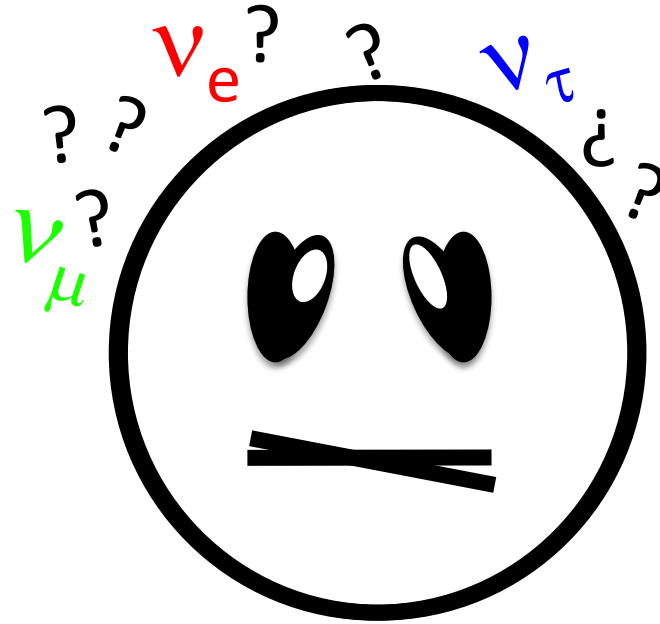
Electron Neutrino
~ 0

Muon Neutrino
~ 0

Tau Neutrino
~ 0

← Originally thought to be massless but now not

The Confused T2K Neutrino



Neutrino Oscillation

$$U = \left(\begin{array}{ccc} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{array} \right) \left(\begin{array}{ccc} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{array} \right) \left(\begin{array}{ccc} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{array} \right)$$

Atmospheric
CP Violation
Solar

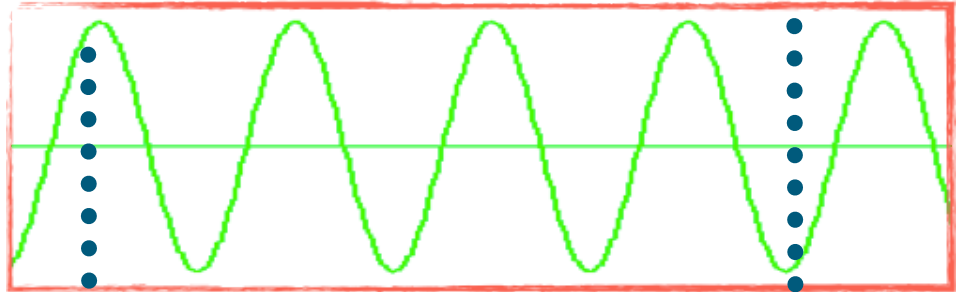
$$P(\nu_l \rightarrow \nu_l) = \sin^2 2\theta_{ij} \sin^2 \left(\frac{1.27 \Delta m_{ij}^2 L}{E} \right)$$

Solar $l = e$ and
Atmospheric $l = \mu$

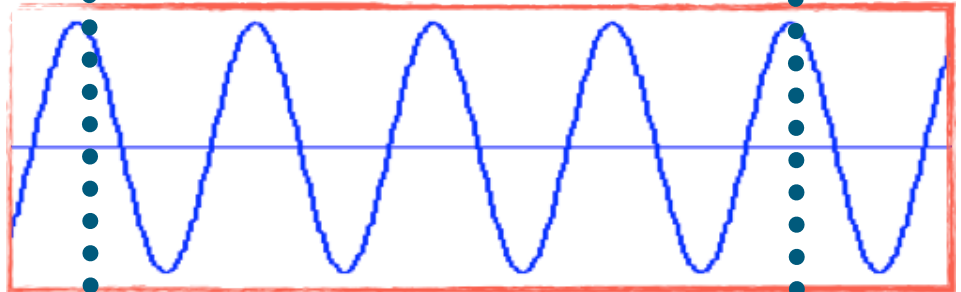
eV² → Δm_{ij}² km → L
GeV → E

The Brilliant Disappearing Neutrino

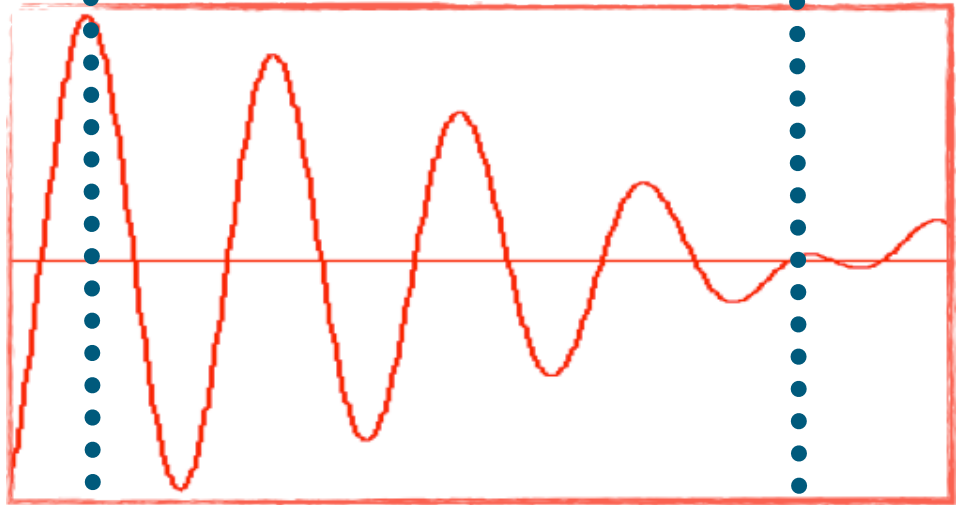
Sound 1



Sound 2



Sound 1+2





Impressionistic Science



- Particle physics is probabilistic.
- Need to view particles in situations many times.
- Need to view them in many different situations to understand their true Nature.
- Are the die loaded or true?

