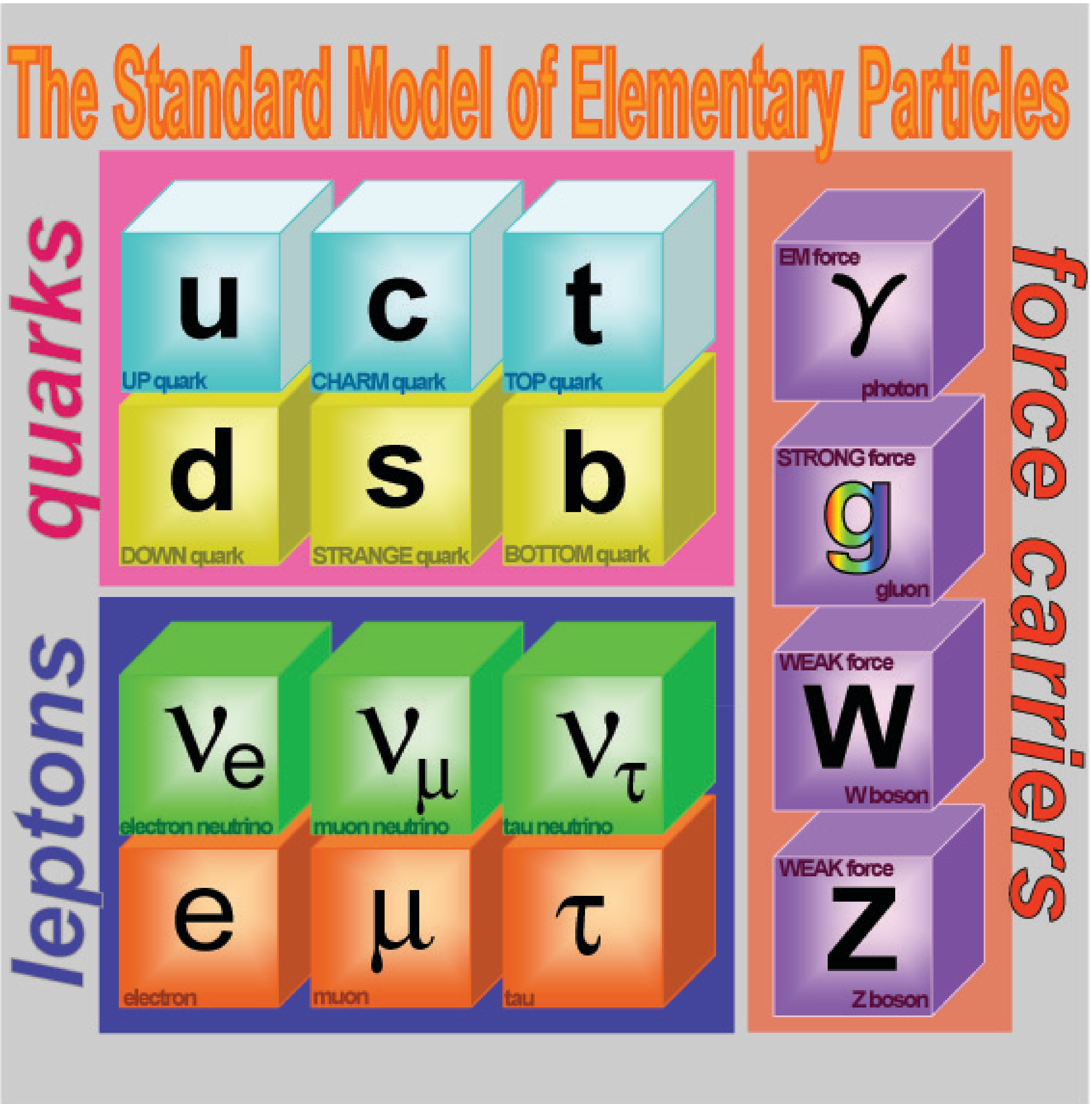
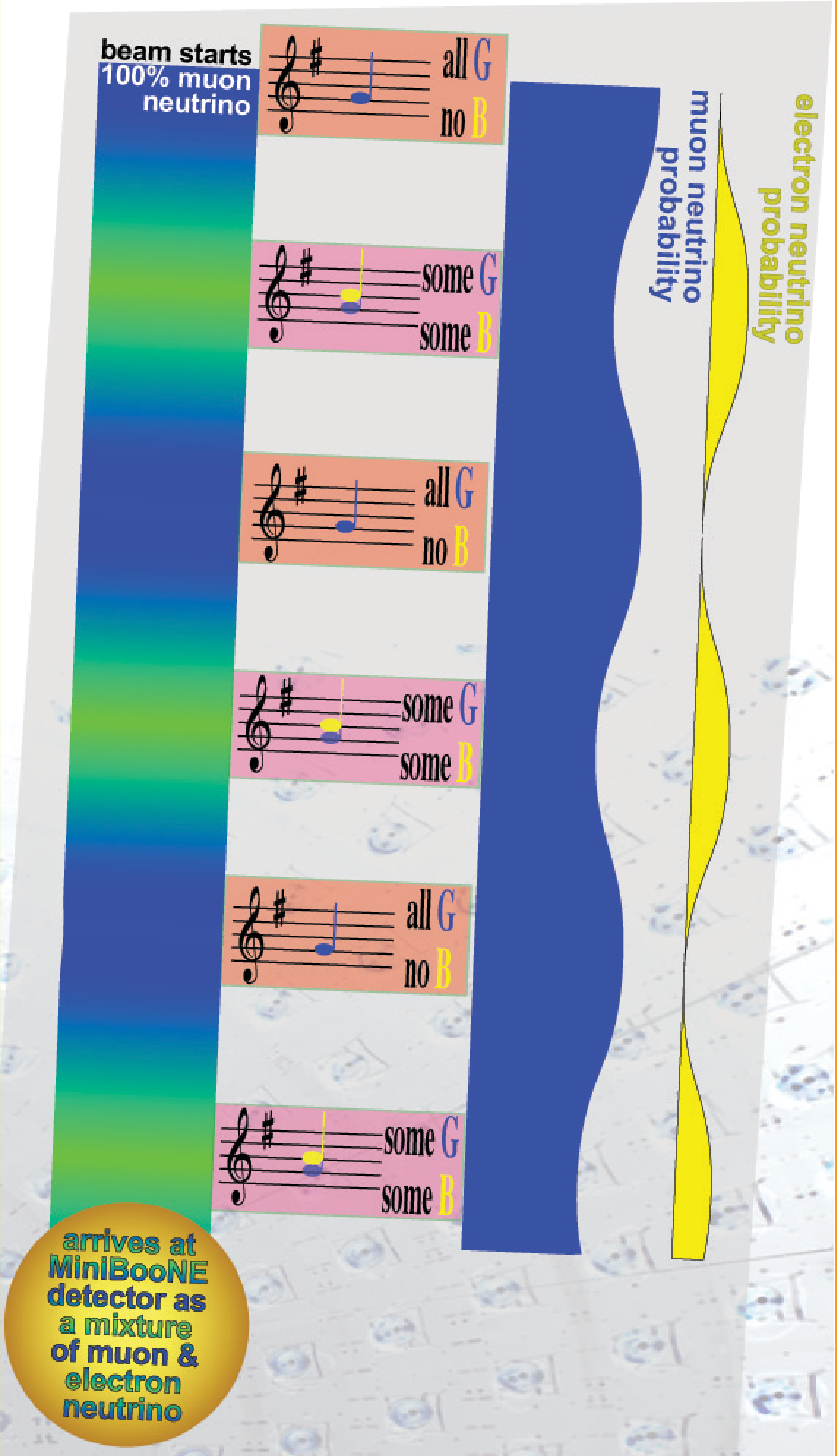
Of neutrino mass, and oscillation

The data and theory about the fundamental particles and forces of nature were assembled in the 1970's into what has become known as the Standard Model [see the chart, to the right]. This model says that all three kinds (or flavors) of neutrino – electron, muon, and tau – are massless. It's not so unusual for a particle not to have a mass; after all, the carrier particles of the electromagnetic force (the photon, symbolized by a γ) and the strong force (the gluon, g) are both massless.



In the Standard Model, not only are neutrinos massless, they also abide by clannish lepton family rules. When neutrinos interact or are produced in a decay, the number and flavor of leptons must be the same, before and after. That's why, as we saw before, nuclear decays producing an electron always make an electron ANTI-neutrino; pions decay to muon neutrinos and ANTI-muons.



The peculiar phenomenon of neutrino oscillations runs contrary to both these Standard Model tenets: observing oscillations shows that neutrinos are NOT massless, and they CAN change flavor. Understanding the details of neutrino oscillations requires a trip into the sometimes counter-intuitive world of quantum mechanics; the musical analogy in the box below may be helpful.

MiniBooNE's beam starts out as 100% pure muon neutrinos. If, when it arrives at the tank, signals from electron or tau neutrinos show up, we'll have seen oscillations! Neutrinos oscillating means neutrinos with mass, and that opens many new doors on our understanding of how particles – and galaxies, and universes – work.

Suppose you could only hear one pitch (or frequency) of sound at a time – your "sound detector" could only tell, "That note was a G," or "That was a B." The Standard Model says, "If a note starts out as a G [or a B], it stays that way forever; hearing a note as a G means it was made by a process that only generates Gs." Oscillations play by different rules, and admit the possibility that a note originating as a G (a muon neutrino, say) can "de-tune" as it travels, developing a B component (electron neutrino). Does this mean that you would hear chords in neutrino beams? No – remember, you can only hear one pitch at a time. What it *does* mean is that if you had a beam created purely of 1000 G's, and set up a listening post some distance away, you might get 990 G's – and 10 B's. What oscillates in neutrino oscillations is the *probability* – the likelihood that a neutrino created of one kind stays of that kind permanently, or if it has some chance of changing its kind.