Questions and answers - Pedro Machado Lecture 1

The following questions were submitted through Zoom Q&A. Some / all may have been answered in the Q&A session already. Nevertheless, we request our lecturers to provide written answers here for the benefit of those who could not attend that session. Thank you!

(1) Apologies if this has already been addressed — I joined a bit late. Just to clarify: is the Heavy Neutral Lepton (HNL) considered a flavor eigenstate or a mass eigenstate? If it's a mass eigenstate, as suggested by the extended 3×4 mixing matrix, how can it interact separately, given that mass eigenstates are typically superpositions? The HNL, in the Lagrangican with non-diagonal mass term, is a flavor eigenstate in the sense that it does not couple to weak interaction. But one needs to be a bit careful here. The flavor eigenstates nue, numu and nutau have flavor labels that distinguish them (as they couple to electrons, muons or taus). For the HNLs there is no label. This is like trying to define flavor eigenstates with only Z interactions: you can do it, but there is some freedom.

(2) Could you please repeat why Higgs mechanism "breaks down" for neutrino? Did not you say there is simply a possibility to add a Majorana mass term because RHN is a SM singlet? Breaks down in the sense that it spoils the main prediction of the Higgs mechanism: the mass of fermions is proportional to their coupling to the Higgs. Invoking a RH neutrino allows for the Majorana mass term which spoils this prediction. More than that, invoking a RH neutrino is postulating a particle that has never been detected, so from a pragmatic point of view why is the answer a RH neutrino? Given the data, a RH neutrino is as good as the scalar triplet in type-2 seesaw or any of the radiative seesaw models. The key of the Higgs mechanism is, IMO, its simplicity: there is only one way to write the mass terms and there is a clear correlation between Yukawa and masses. Neutrinos break that.

(3) What is the difference between delta and psi in the seesaw diagrams? Sorry if this wasn't clear, delta was a scalar triplet and psi was a fermion triplet.

(4) What range of HLN masses can be constrained by meson decay? Direct bounds can be put by observing changes in the kinematics of visible particles. For pion decays, you can typically constrain m_n ~ few-35 MeV or so. For Kaons, the range goes up to a bit above 200 MeV. D mesons allow you to go to the GeV scale. Beyond that is experimentally challenging, but universality still allows bounds for arbitrarily heavy masses: see e.g. 2304.06772 by Hostert and friends.