Many (all) the questions have been answered during the Q&A period. Nevertheless, we ask that you provide written answers below so students can come back to read them again. Thanks!

1. "How can this arise from an SU(2) invariant UV completion". What is UV completion?

The Majorana mass term as written down in the lecture does not respect SU(2) invariance. The neutrinos share an SU(2) doublet L with the charged leptons, so an SU(2)-invariant Lagrangian should involve only L, not its individual components separately. I'm calling a theory that satisfies this requirement a UV completion because it involves heavier particles (in this case the Higgs). "UV" refers to higher energy, that is, heavier.

2. After discovery of neutrino mass by Super-K in 1998, Pierre Ramond made a statement (see https://physics.aps.org/focus/supplement/neutrinoquotes.html) that the Super-K results provide "additional" evidence for low-energy supersymmetry. If he is right why haven't we seen evidence for SUSY at the LHC? or alternately if he is right at what masses will super-partners be discovered at LHC? Or is he right?

I believe the argument Pierre had in mind is that the "natural" scale for the right-handed N_R fields is similar to the GUT scale, so neutrino masses provide circumstantial evidence that new physics exists at this scale. But Grand Unification of gauge couplings doesn't work in the Standard Model. It does work in the MSSM, though. Today we know that the GUT scale has to be somewhat higher (~10^{16} GeV) than the maximum mass of the N_R, 10^{14} GeV. (If the N_R were heavier, the predicted neutrino masses would be too small as m_D can't be made much larger than 100 GeV without the Yukawa couplings becoming larger than O(1) and violating unitarity.) So the direct connection between the mass of N_R and the GUT scale is no longer there. And moreover, there is lots of non-SUSY possibilities to achieve Grand Unification. And even is SUSY helps with Grand Unification, it wouldn't necessarily need to be discoverable at the LHC (though the SUSY scale would then probably not be too far above the reach of the LHC).

3. When we diagonalize to arrive at m(neutrino) ~ 0.1 eV, we assumed mD ~ 100 GeV and mM ~ 10^14 GeV. Why are these assumptions reasonable? Otherwise, won't we be predicting very different m(neutrino)?

These were choices I made for illustration. m_D can't be much larger than 100 GeV, otherwise the Yukawa coupling would need to be larger than O(1) (and therefore violate unitarity). But it could be much smaller, depending on what values of the Yukawa coupling y we are comfortable with. In a sense, once we fix m_D, the observed neutrino masses provide a *measurement* of m_M. There is, however, no theoretical guidance as to the scale of m_M.

4. Mentioned the SM neutral current 'preserves' the neutrino, while the charged current does not. Could you clarify that you meant by this?

The Feynman diagram corresponding to a NC interaction vertex involves a Z boson and two neutrino lines, so it describes processes in which a neutrino comes in and a neutrino goes out. The CC vertex, on the other hand, involves a W boson, a neutrino, and a charged lepton. So it describes processes with an incoming neutrino/outgoing charged lepton, or vice-versa. In other words, it changes one fermion species into another.

5. Does string theory predict the seesaw mechanism (or conversely is seesaw mechanism a natural outcome of String theory?)

No, string theory does not predict the seesaw mechanism. String theory isn't a specific model, but rather a toolbox for constructing models. It should certainly be possible to construct string models that involve at least the particle content required for the seesaw mechanism. (Beyond the particle content, it is difficult to make concrete predictions from string models.)

6. at the start neutrinos were introduced to conserve energy (by Pauli) could the particle we call neutrinos now be more than Pauli thought may be energy is not totally conserved and this particle do something else?

A violation of energy conservation would be a far more profound paradigm shift than anything we're discussing in our everyday lives as physicists. By Noether's theorem, a violation of energy conservation would imply that physical processes are not invariant with regard to translations in time. And I don't see any reason / any indication for this being the case.

7. Since m_M is very large, what can the seesaw mechanism make some testable differences from SM except for the neutrino mass problem?

Excellent point, the seesaw mechanism is indeed very, very difficult to verify. (I'm not aware of any practical way.) There are, however, variants of the seesaw mechanism, that are more easily testable.

8. Why cannot neutrino mass be explained with Higgs mechanism?

They can. A Dirac mass term does precisely that. It arises from a Yukawa coupling between the Higgs doublet, a charged lepton doublet, and the RH neutrino singlet after the Higgs is replaced by its vev.

9. Cosmology gives upper bound on SUM of neutrino masses, or an AVERAGE of the three masses?

The limit is on the *sum* of neutrino masses, assuming that the cosmological abundance of each neutrino species is that predicted in the standard ΛCDM model. If for whatever reason neutrino abundances were different, the limit would need to be re-interpreted.

10. Is there a reason there is a negative sign when introducing the mass term in the seesaw mechanism but not while doing the same in Dirac and Majorana mass term?

This was a typo in my lecture notes, which I have now fixed. Thanks for spotting this!

11. In seesaw we need heavy right handed neutrinos to explain the smallness of neutrino mass. Can we have light right handed neutrinos and still explain the smallness of neutrino mass.

The RH neutrinos can be lighter (~ TeV) if we choose m_D similar to the electron mass rather than similar to the top quark mass. Making m_D and m_M even lighter is possible, but then the Yukawa coupling required for such small m_D may again be considered unnatural.