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. (Page 4) About helicity, what is its importance, or for what reason was it introduced the first time? And why do we like to relate it to chirality for massless particles ?

Helicity is useful because it helps us understand the spins in decay processes (e.g., the momentum provides an axis for us to talk about "spin up" or "sping down") and it is an "easy" thing to think about conceptually and mathematically. The correspondence between helicity and chirality for massless particles is very handy, and probably is the reason that chirality or "handedness" got its name in the first place: the right-handed chiral state is exclusively in a right-handed helicity state for massless particles, so it makes chirality an easier thing (I would claim!) to think about.

2. (Page 9) Why do these two interactions never happen?

The simple answer is that the weak interaction violates parity: it doesn't couple to left-handed positrons or right-handed electrons. It is a deeper question to ask why does the Weak interaction violate parity? The mathematical answer is that the weak interaction has a "V-A" form, which of course we figured out by seeing that it violated parity. The deeper answer is: I don't know, and I don't think anyone knows, why parity is violated.

3. (Page 14) Why can't we consider an anti-beta decay as a proton decay process?

I think I may not have been clear: protons in nuclei can decay to positrons, neutrons, and neutrinos. When we usually talk about "proton decay" (as a non-Standard Model process), we mean for free protons, for which is energetically not possible (and in which we mean baryon number is not conserved). In proton beta decay, the proton is in a nucleus and can borrow binding energy to make the heavier neutron, so baryon number is conserved.

4. (Page 12) Why is it important to be out of thermal equilibrium? Alternatively, why does it not work if it is in thermal equilibrium?

If you're in thermal equilibrium, any process that might lead to a baryon asymmetry happens forwards-and backwards at the same rate. If you are out of thermal equilibrium, then the baryon violating process can happen and then when you move to another point in phase space, the rate for the backwards process is different, and so you can generate an asymmetry.

5. (Page 19) Concerning the difference between the right-handed neutrino and antineutrino, can't we simply say it's that the first interacts via week interaction while the second doesn't? (We only differentiate two particles by the way they interact with SM fields, so isn't that difference a big deal?)

   Ah, yes—the question I am asking is more "How does the weak interaction know it is a different particle?" The weak interaction distinguishes nu_L and nu_R because they have different handedness. What does the anti-nu_R have that the nu_R doesn't? We can say they have different weak hypercharge, or that the nu_R is a SU(2) singlet, but that is something we put into the theory to make it behave the way we see (up to the discovery of neutrino mass).

6. (Page 17) If we can accept that the electron has mass and is only produced left-handed in weak interactions. Why can't we do the same for neutrinos, but we must conclude that they are massless?

We conclude they are massless because what we measure in the lab is (effectively) the helicity, and we infer the chirality from that. Since we never see the neutrino with the "wrong" helicity, we think it is massless. Right-handed (chiral) electrons are never made in weak interactions but what we measure is both right- and left-handed helicities for the electrons, and to have both they must be massive.

7. (Page 49) Can you explain the two light signal vs heat signal plots? Why are there two distinct classes of events?

   One class are gamma-rays, which look like the anticipated beta-beta signal, and the others are alphas, which are backgrounds. The clear separation between them shows that the scintillation light gives them excellent particle ID to eliminate backgrounds.

8. (Page 58) How can the square of the mass difference be negative?

   Ah, I should defined this: m^2_ij = (m^2_i - m^2_j) so if m_j > m_i, this is negative.

9. (Page 55 left figure) m_beta-beta has a range of O(5x) for each case. What is the prospect of narrowing down this range? How much has this range changed in the last ten years for example?

   The y-axis on this figure shows the range to which experiments are sensitive. As experiments become more sensitive, they probe further down the y-axis. The best so far is KamLAND-Zen that probes down to 40 meV, and the top of the "inverted hierarchy" region is about 50 meV. Future experiments will probe down below 10 meV. The spread in each band is because of uncertainties on the mixing angles and mass differences as measured by existing oscillation experiments.

10. Do we confirm neutrino only have weak interaction? Do we have other possibilities?

Neutrinos presumably interact via gravity, but there is no good way to verify this (probably cosmology can ultimately provide limits). It is possible they have a very very tiny charge and therefore interact electromagnetically, but it would have to be extremely small. They can't have any color charge or we'd have seen that in experiments. Can there be other, non-Standard Model interactions? Yes, and this is a place where people are actively looking for such "non-standard interactions."

11. Is the Majorana phase constrained by the Katrin experiment?

Unfortunately, no. They measure the neutrino mass independent of its Majorana nature, and so the phases don't enter into the expression for that mass. Combining this and BB experiments also doesn't help, because in mbb the phases are getting squared and so you can't extract them from the mbb itself.

12. What are the implications that double beta decay hasn't found anything for the inverted hierarchy? Will not find anything for any hierarchy?

We have only just started probing the inverted hierarchy, so we may yet see something. Of course, we don't yet know what the hierarchy is, but if the experiments that probe to the bottom of the inverted hierarchy band don't see anything, and we know the hierarchy is inverted, we can see neutrinos are Dirac particles. If not, we will have to push lower, perhaps down to the "normal hierarchy" region and, of course, there is a possibility that the CP phases will be such that they cancel and make this rate very low.