

## SSI15 Projects

1. A SLAC physicist has received approvals to procure a crystal ball. Using it to look into the future, he has learned that 10 years from now all the attention in the neutrino field will be focused on resolving the discrepancy between two or more different datasets. What are these datasets? What are the implications of this discrepancy for new physics?
2. Detection of neutrinos from core-collapse Supernova blasts is a key goal of the current and next round of neutrino experiments. This detection can be accomplished with a number of detector technologies (water-Cherenkov, liquid argon, scintillator, Icecube). Which technology is best suited for the task and why? What detector characteristics are desirable? What considerations are relevant for designing the Trigger and Data Acquisition Systems? Does it make sense to have more than one type of detector online? Does it help if the detectors are in different parts of the globe?
3. Construct a model where the properties of a new neutrino would make it a possible DM candidate while evading the current experimental constraints. How could such a model be experimentally tested?
4. How can the CP-violating phase in the neutrino mixing matrix,  $\delta$ , possibly be related to leptogenesis? Can you make a model where this is transparent and has testable predictions?
5. Although neutrinos are electrically neutral they might still have some electromagnetic interactions. For example, Dirac neutrinos can have magnetic and/or electric dipole moments while Majorana neutrinos can have 'transition' dipole moments connecting the various neutrino mass eigenstates. What are the current constraints on such interactions and how would they modify the usual expectations for the determination of neutrino properties? How would the roles of cosmological, astrophysical & reactor/accelerator neutrinos be modified if such interactions existed?
6. The KATRIN experiment is sensitive to neutrino masses at the  $\sim 0.2$  eV level. Outline the design improvements that would be necessary to be able to probe neutrino masses with a factor of  $\sim 5$ x greater sensitivity. How feasible would such modifications be?

7. In the Lambda-CDM model the sum of the neutrino masses is now determined to be less than  $\sim 0.25$  eV. How sensitive is number this to the various model assumptions, i.e., determine if there is a model-independent constraint on the neutrino masses from cosmology.
8. Future neutrino experiments will place tight constraints on the minimal 3-neutrino 'SM-like' picture. What experiment or combination of experiments would conclusively exclude this simple scenario? How could other experimental results be used to clarify the true nature of the neutrino sector in this case and what would be the simplest scenario describing this?
9. The on-surface Collider Experiment Hall (CEH) at SLAC was once considered as a far detector site for a long baseline neutrino experiment with NUMI-like beam from FNAL. If the NOvA detector were placed here at CEH, how would you optimize the NUMI beam tune for that experiment and how well that experiment might do compared to NOvA in its current location? The main physics goal in both cases is the measurement of the neutrino mass hierarchy. Discuss the possible utility of seeing the 2nd oscillation maximum if the NUMI beam line pointing angle can be adjusted.
10. The advantage/disadvantage of a particular type of neutrino detector varies as a function of neutrino energy and type. Make a chart showing the optimal regions for each type of neutrino detector. What's the prospects for improving the coverage?
11. Devise a way to measure the 2 Kelvin Cosmic Neutrino background.
12. It is possible that the small neutrino masses may be generated by a see-saw mechanism where the heavy neutrinos lie close to the electroweak scale. Explain how such heavy neutrinos have avoided detection so far, what signals we might expect from them at the LHC and what signal rate we might observe, that could include missing  $E_T$ , or the Higgs boson in the decay.
13. If neutrinoless double-beta decay is observed are there further measurements that one can perform to tell us the nature of the underlying physical process?
14. Design a neutrino cross section experiment in which a subtraction technique (for example, measurements on D<sub>2</sub>O and H<sub>2</sub>O, or C and a hydro-carbon molecule) is used to measure the total CC single pion production cross section on free nucleons at  $\sim 5$  GeV to within 5% statistical uncertainties. What are the implications of this accomplishment to the neutrino oscillation program ?

15. Under what conditions are neutrino beams of pure mass eigenstates produced? Are there terrestrial neutrino beam experiments in which this would become a concern? Could such a beam be produced artificially?
16. The Pentagon wishes to communicate with submarines that are submerged along the coast of North Korea by using a neutrino beam located in Washington DC. This is a bit stream with the presence/absence of pulsed neutrinos at 1 second intervals. If the desired bit rate is 1 bit/s with <1% error rate, how intense must the initial neutrino beam be? What type of neutrino beam would you prefer and what is the most practical design for the submarine's detector?
17. Discuss the optimization of an accelerator-based neutrino beam for an on-axis, long-baseline experiment with a near detector. Consider such factors as baseline, beam intensity, hadronic production uncertainties, decay volume length, Far Detector sensitivity etc. If we fix the baseline as FNAL->SLAC (as in question 9), discuss the beam optimization.
18. If the di-boson/dijet excess possibly observed by both ATLAS and CMS at  $\sim 2$  TeV is real, what potential implications could there be for neutrino physics? Construct a model to demonstrate this. Even more generally, what discovery could be made during LHC Run 2 that would have the greatest impact on neutrino physics and why? Provide a detailed example.
19. Design a new generation of solar neutrino experiment and discuss its prospect in advance our insight of the neutrino sector, and shed light into the inner secret of the sun ?
20. Dark matter experiments distinguish between energy deposits that result from scattering off electrons and the nucleus. How can this feature be used to learn about the neutrino properties ?