Community Summer Study 2013 Colloquium Questions

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These questions were compiled by the Cosmic, Energy and Intensity frontiers to be addressed in the colloquium talks and help guide the panel discussions during CSS2013. Some questions overlap.

General Questions

G1. How do we exploit science opportunities at the interfaces between the Frontiers? How do such opportunities receive funding?

G2. How do we exploit connections with nuclear physics in cases where the science questions are related? How do such opportunities receive funding?

G3. How do we ensure a robust program of experiments at different scales?

G4. How do we ensure that new ideas can find fertile ground to germinate?

G5. How do we optimize the global program?

Questions for the Intensity Frontier

IF1. What knowledge is gained by the precision determination of the neutrino mass and mixing parameters? What precision is needed for such measurements in order to compare with predictions? How far will it be feasible to push these measurements? How do these measurements complement the determination of analogous quantities in the quark sector?

IF2. What knowledge is gained from determining the neutrino mass hierarchy?

IF3. How does one frame a convincing and accurate narrative to describe the importance of the PMNS CP violating phase (delta) for understanding the lepton/baryon asymmetry of the Universe?

IF4. Why is it important to measure the Majorana phases in the neutrino sector and are such measurements feasible?

IF5. How important is breadth of program for the next-generation neutrino oscillation experiments? If important, how can this be achieved?

IF6. What is the relative importance of testing the 3-flavor neutrino paradigm and exploring anomalies?

IF7. Is there an experimental floor to the search for neutrinoless double beta decay?

IF8. What should be the neutrino physics strategy beyond the next decade? Have the latest neutrino results been digested into our current plans?

IF9. What role does theory play in neutrino physics? What should be the size of the neutrino theory community? If this community should grow, how is that accomplished?

IF10. What do the neutrino parameters that can be measured over the coming decade (delta CP, hierarchy) tell us? Measuring the quark mixing parameters (which are sometimes overconstrained and testable for consistency) has not yet revolutionized our understanding of flavor structure and the matter-antimatter asymmetry. How might the neutrino sector be different?

IF11. If additional resources can be found to restore some of the scope to LBNE, what is the highest scientific priority: moving underground or improving the beam and/or detectors?

IF12. In the current configuration for Phase 1 of LBNE (assuming no new international support), what 5-sigma discoveries are possible?

IF13. Imagine that one measures the CP violating phase in the neutrino sector to be 85 degrees (for example). What does this imply for the hypothesis that the matter-anti-matter asymmetry is due to leptogenesis? What is the next measurement that one should make to clarify this relation?

IF14. It is especially interesting in studies of rare processes for a discovery of a new physics effect beyond the Standard Model to point to a mass scale that would be the basis for a future accelerator search for new particles. What are the most important rare processes that have the potential to point to a specific mass scale, and how specific can their information be?

IF15. Should searches for proton decay be continued in the absence of a signal? What are the benchmarks for limits on proton decay? Is there a point where such searches are no longer motivated?

IF16. Is the level of predicted rates for neutron-antineutron oscillation in well-motivated models consistent with experimental reach?

IF17. With a grand unification scale at 10^16 GeV as predicted by SUSY-GUTs, the lifetime of the proton to K nu is naively expected to be below 10^33 yr. What are we testing as we push the limits to 10^35 yr.? What are the crucial parameters of GUTs that allow the proton lifetime to be longer? Is the sensitivity to these parameters quartic, as for m_GUT, or, more optimistically, quadratic? Is the expectation for the proton lifetime increased if superpartner masses are heavier than expected, and what is the relation between these quantities?

IF18. Is there a target level of precision for the measurement of heavy quark observables? To what level should such measurements continue to be pursued in the absence of deviations from SM expectations?

IF19. If the LHC does not discover new physics, what can be learned from more precise measurements in the quark flavor sector? What level of precision is desirable for neutron, electron and atomic EDM experiments in this scenario?

IF20. Describe the increase in sensitivity to new particles in loops as a function of time for the g-2, mu-e conversion, tau -> ell gamma, and EDM experiments. There should be separate estimates for SUSY models, in which the flavor-changing effects come from loops, and from models in which the flavor-change comes from a tree-level effective operator. This will facilitate plotting this evolution along with the evolution in sensitivity predicted for direct searches for new particles at the LHC.

IF21. Describe the increase in sensitivity to new particles in loops as a function of time coming from improved measurements of b->s gamma, B and Bs -> mu mu, and related observables. There should be separate estimates for SUSY models, in which the flavor-changing effects come from loops, and from models in which the flavor-change comes from a tree-level effective operator. This will facilitate plotting this evolution along with the evolution in sensitivity predicted for direct searches for new particles at the LHC.

IF22. What is the impact of higher precision measurements processes that determine the CKM angles, such as sin 2beta, sin 2 beta_s, and V_{ub}. Can uncertainties be improved sufficiently that tensions between parameters can demonstrate the presence of new physics?

IF23. What is the impact of measurements of direct CP violation in charm decay on the search for new physics? In what processes is the Standard Model prediction sufficiently well understood, including perturbative and nonperturbative effects, to allow a strong conclusion of a deviation from the Standard Model?

IF24. Improvements in the muon g-2 measurement need to be accompanied with improvements in the Standard Model prediction for the term involving the hadronic vacuum polarization. What are the prospects for improvement of the current estimate, including via lattice gauge theory? To reach the parts per billion level in the error, the contribution from light-by-light scattering must also be improved with input from low-energy data. How can this be done?

IF25. Why should g-2 be measured more precisely when the theoretical error is so large and uncertain? How will lattice calculations evolve and what cross-checks of them will be available?

IF26. Does the strong upper limit on the mu $\rightarrow$ e gamma branching ratio from MEG preclude an observable signal of lepton flavor violation in mu-e conversion experiments in nuclei? What new physics could such a signal reveal?

IF27. What new experiments or techniques are required to more deeply probe the effective mixing-mass plane for new light weakly coupled particles?

IF28. Dark matter explanations for the positron excess that invoke light ultra-weakly interacting particles are severely constrained from a variety of observations. In light of that fact, is there a motivated parameter space to aim for? Does it make sense to look at a next generation of experiments?

IF29. What are some qualitatively interesting thresholds for EDM constraints? (For example, one might be the predictions of SUSY models with very heavy scalars, but sub-TeV gauginos and Higgsinos.) What experimental program is required to reach these thresholds in the coming 5, 10, 20 years?

IF30. The best current limits on the electron EDM come from experiments using polar molecules such as YbF in which atomic physics effects enhance the influence of an electron EDM. How can we check or calibrate the atomic physics calculations that go into the interpretation of these experiments?

Questions for the Cosmic Frontier

CF1. What criteria could be used to prioritize activities across the Cosmic Frontier? The size of the communities? The connection to other key questions in particle physics and astrophysics? The variety of possible funding sources?

CF2. With the significant change of plans involving DUSEL, what are the needs for underground floor space for low-background experiments, and are those needs met in current planning?

CF3. For direct detection, when is the right time to move from small projects toward larger ones?

CF4. Dark matter direct detection will reach the neutrino background at some stage. Although this background is not formally irreducible, is it realistic to think that one could go beyond this? What experiments would make this possible in a cost-effective way?

CF5. To what level should we continue to search directly for WIMP dark matter in the absence of a convincing signal? Is there a technique, or a motivation, to search beyond the neutrino floor? Is there a natural stopping point for direct DM searches?

CF6. Suppose direct detection experiments using one target are significantly more sensitive than those using another target in terms of sigma_SI. Is there a compelling rationale for continuing funding for experiments using the non-leading targets?

CF7. How important is it to carry out direct search experiments with different nuclei versus performing more than one experiment with the same material for cross-checks?

CF8. How do large dark matter detectors convincingly demonstrate that their efficiency for detecting low-mass WIMPs is well understood?

CF9. How can the conflicting results at low WIMP mass be resolved? What is the next step if a positive signal is convincingly observed?

CF10. What can we learn about dark matter properties from direct detection experiments? How important is it to pursue directional dark matter detection experiments?

CF11. Can dark matter be convincingly discovered by indirect searches given astrophysical and propagation model uncertainties? Do indirect searches only serve a corroborating role?

CF12. Given large and unknown astrophysics uncertainties (for example, when observing the galactic center), what is the strategy to make progress in a project such as CTA which is in new territory as far as backgrounds go? How can we believe the limit projections until we have a better indication for backgrounds and how far do Fermi data go in terms of suggesting them? What would it take to convince ourselves we have a discovery of dark matter?

CF13. Clarify the uncertainties in the expected axion detection rates: Particle physics: for a given mass, what is the lowest possible coupling? If there is no lower bound, are there values beyond which the models get qualitatively more fine-tuned and the search becomes less motivated? Astrophysics: can there be large variations local density? If so, how do these modify the experimental reach?

CF14. What is the target range for axion mass and coupling, and how are those determined?

CF15. What are the most promising techniques to extend searches for non-WIMP dark matter?

CF16. Can astrophysics reveal some specific properties of dark-matter particles, for example, their self-interaction or primordial velocity distribution?

CF17. Is cold dark matter in good agreement with observations of structures on all scales? Can baryonic astrophysics simultaneously rectify the discrepancies on all length scales?

CF18. What would it take to convince ourselves that we have: a discovery of dark matter? Discovered two different species of DM? Discovered ALL of the dark matter? a false signal of a dark matter discovery?

CF19. If the dark matter particle is detected through non-collider experiments, what can we learn about its properties? (e.g., can we learn its spin?) Would we be able to learn whether it interacts with SM matter only through the "Higgs portal"?

CF20. Suppose there is a 10 GeV WIMP or a 100 GeV WIMP with direct detection cross section just below current limits. This is the best case for understanding the particle nature of the dark matter. What is the full set of measurements that we are likely to make on such a particle from Cosmic Frontier probes alone?

CF21. If there is more than one type of dark matter particle, how can we discover this in Cosmic Frontier experiments? Can we measure the dark matter fraction from different sources?

CF22. In some indirect detection searches for dark matter, it is notoriously difficult to rule out all hypotheses that a signal is of astrophysical origin. But perhaps other knowledge from particle physics can help. Would it be helpful, for example, to know the mass of a dark matter candidate? What accuracy is needed? Can direct detection provide sufficient accuracy?

CF23. What are the constraints on theories in which dark matter has no SM interactions stronger than gravitational? In such a case are there prospects for discovering its particle nature?

CF24. It has turned out that missing transverse energy is a very effective signature for discovery at the LHC. So, have we ruled out WIMP dark matter with mass below 500 GeV?

CF25. What are the roles of optical and CMB observations for particle physics?

CF26. What are the intrinsic uncertainties in cosmic surveys that limit extractions of the properties of dark energy?

CF27. Dark energy experiments are proposed to measure w+1 to higher and higher precision. Suppose we find w = -1 at Stage IV sensitivity. What are the motivations to plan beyond Stage IV? Is there a value at which improved precision becomes drastically more difficult to obtain?

CF28. What is the target level of precision for measurements of w and w'? What do increasingly precise measurements teach us? What is next if w is consistent with -1 and w' with 0?

CF29. What is the evidence for inflation as the origin of cosmic structure? Is inflation uniquely preferred as a model? A major goal of CMB studies is to improve the search for the gravity wave component of the CMB fluctuations by two orders of magnitude. But the observable depends on the inflation scale to the fourth power, so is this improvement significant for the theory of Inflation?

CF30. The study of cosmic structure may allow us to measure neutrino masses sufficiently accurately to determine the hierarchy. How realistic is this, what assumptions are needed, and when is this likely to happen?

CF31. What is the projected accuracy of the sum of neutrino masses & N_{eff} from the cosmic frontier in ~2020 and ~2025 and ~2030?

CF32. For a long time, there have been indications that the number of light degrees of freedom required in cosmology is greater than 3. Recent measurements from the CMB and other sources have given more precise information on this question. What are the prospects for establishing that this number of degrees of freedom is indeed greater than 3, or, alternatively, for providing an upper bound well below 4?

CF33. What expertise can HEP experimentalists deploy in telescope-based experiments? Where are the overlaps?

CF34. What are the roles of cosmic-ray, gamma-ray, and neutrino experiments for particle physics? What future experiments are needed in these areas and why? Are there areas in which these can have a unique impact?

CF35. What will it take to identify the mechanism for baryogenesis or leptogenesis? Are there scenarios that could conceivably be considered to be established by experimental data in the next 20 years?

CF36. What are the leading prospects for detecting GZK neutrinos? What experimental program is required to do this in the next 5 years, 10 years, 20 years, and how important is this?

Questions for the Energy Frontier

EF1. What is the physics case for a dedicated Higgs factory? How does this change if the properties of the Higgs boson discovered at the LHC remain consistent with SM expectations? What is the ultimate reach for the LHC at each of its anticipated stages in terms of precision Higgs, top, and other electroweak measurements?

EF2. Is there a realistic scenario in which the US has an onshore energy frontier machine in the coming 20 years? If there is, what actions should be taken in the next 5 years? If there is no such scenario, how should this impact plans for the coming 20 years? Please list specific options and some scenarios that might lead to selection of specific options.

EF3. What is our relationship with CERN for the foreseeable future? Would increasing in-kind contributions (hardware built and managed centrally in the US), be important, and at what level?

EF4. What are the key questions involving the Higgs boson that the ILC can answer whereas hadron colliders cannot? What do we learn about new physics scenarios from percent-level Higgs couplings measurements?

EF5. The message from the LHC seems to be that with data in hand, we consistently outperform expectations for extraction of Higgs properties. In that case, what would an ILC contribute? What key assumptions are we making now that we could relax with ILC inputs?

EF6. Given that LHC results are not yet pointing at a new energy scale, can we, at this point in time, make an informed decision about the next large, energy-frontier machine? Must we have a well-defined physics target to build the next accelerator? Must we have a well-defined physics target to double the LHC energy?

EF7. Can new particles or interactions be discovered at the ILC that were missed by the LHC? How compelling are such scenarios?

EF8. Given the very large size of the LHC collaborations, is there room for growth in the energy frontier? What is the plan for growth if the ILC does not move forward? Is growth necessary?

EF9. What is the typical number of students and post-docs involved in producing a single publication at the LHC? Over the lifetime of the experiments, what fractions of the students receive significant hardware experience? If this number is low, what is the plan for training people to be able to design and build the next generation energy frontier machines and detectors?

EF10. What is the physics motivation for the high-luminosity LHC run? Do we need to be involved in both ATLAS and CMS experiments? What should we do next if LHC13 does not find new physics?

EF11. What steps are needed to demonstrate that a muon collider is feasible? If it were feasible, how limiting is the experimental environment for performing measurements?

EF12. What do we gain from measurements of triple-gauge-couplings (TGC) in light of other precision electroweak data? Do theories exist where we expect to naturally have SM-like precision measurements, but large deviations in the TGCs?

EF13. The current data seem to put large amounts of MSSM parameter space in an uncomfortable position. Clearly some interesting regions remain. When do we expand to alternatives, such as the NMSSM? Which ones do we choose? Are there new paradigms?

EF14. How do we determine experimentally the symmetry protecting the DM lifetime?

EF15. Precision measurements at colliders require tools to model and account for nonperturbative effects. The most common such tools, e.g., PYTHIA, require extensive tuning to data. How do we estimate the errors from this method of accounting nonperturbative contributions? It is possible that systematic effects from the modeling could give much larger effects? Is it possible that we are tuning away subtle but novel effects from new physics?

EF16. Given that, so far, there are no strong hints for BSM effects in flavor and CP violation, what is the expectation that new particles discovered at colliders can have flavor or CP violating couplings? How heavy must new particles be to have large flavor or CP violating couplings?

Questions for Education-Outreach

EO1. Do we perform enough outreach? Should we spend more resources on education and outreach? Do we take full advantage of opportunities to advertise the excitement and benefits of particle physics? How can we do better?

EO2. What synergies exist between particle physics and other fields of science? How do we better capitalize on these synergies and proposed applications of HEP?

EO3. What technologies arising directly from HEP, e.g., from accelerator, detector and computational designs, are relevant for fields beyond fundamental science? How do we better advertise this contribution to society?

EO4. How do we convince society and our government that our science is worth funding? Why is it that the HEP budget continues to decrease, when others (including nuclear physics) go up?

EO5. Our field is increasingly focused on precision measurements in all frontiers. How do we convince ourselves and others that this constitutes discovery science?

Questions for the Computing Frontier

COMF1. Theoretical physics requires increasingly more significant computing resources. How is this being incorporated into computing plans? EF-Computing: To what extent is high-energy physics still generating the world's largest randomly-accessed databases? Can we claim to be a world leader in data science? Along what dimensions?

COMF2. The Grid was commissioned along with the LHC detectors. ESnet traffic has increased 10x every four years throughout the LHC lifetime. Will improvements in networking infrastructure, QoS, monitoring, etc. continue to keep up with LHC demands for distributed computing? In what directions are new enabling technologies required and when must they mature to again keep up with the LHC machine and detector upgrades?

COMF3. How do the different physics frontiers--and associated theory and physics simulation--differ in their needs for future computing technology evolution? In what respects can they benefit from common computing technology evolution?

COMF4. Proposed very high statistics experiments at the Z resonance require large rates -- many kHz -- at which data is written to storage. What are the limits?

COMF5. What are the requirements and opportunities for cosmological computing -- in both theoretical simulations and data analysis -- to enable the extraction of new particle physics information from astrophysical observations over the coming decade?

Questions for the Instrumentation Frontier

InF1. High luminosity running at a hadron collider will depend on efficient triggering in a difficult environment. Isolation requirements will likely be compromised, and, as a result, triggering on leptons may need to depend heavily on tracking. What are the most promising enabling technologies for electron/photon/tau triggers in this environment, considering luminosities up to 10^{35} cm^{-2}s^{-1}? What are likely R&D paths to realizing these technologies?

InF2. In the context of proposals of large tunnels that could host both pp and e+e- colliders, it is interesting to ask whether it is possible to design 4 pi detectors that can be used both for pp and e+e- experiments (perhaps with some interchangable inner tracking layers). Is there an optimal design of such a multi-purpose detector? What are the most important compromises required?

InF3. In a hadron collider environment, the ability to recognize displaced vertices and to trigger on them at level 1 would be a transformative technology. Can this be realized?

InF4. In some studies for ILC and CLIC, the sophistication of particle flow calorimetry approaches the ability to resolve single hadrons. At what point does the evolution of particle flow calorimetry give a qualitative, rather than just a quantitative, boost to experimental capabilities? Can the technologies of proposed detectors reach this point?