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Executive Summary Charged Leptons

The enormous physics potential of the charged lepton experimental program was very much in evidence at the Workshop. There are discovery opportunities in experiments that will be conducted over the coming decade using existing facilities and in more sensitive experiments possible with future facilities such as Project X. Exquisitly sensitive searches for rare decays of muons and tau leptons, together with precision measurements of their properties will either elucidate the scale and dynamics of flavor generation, or limit the scale of flavor generation to well above 10^4 TeV.

The crown jewel of the program is the discovery potential of muon and tau decay experiments searching for charged lepton flavor violation with several orders-of-magnitude improvement in sensitivity in multiple processes. This is an international program, with experiments recently completed, currently running, and soon to be constructed in the United States, Japan, and Europe. These include the completion of the MEG experiment at PSI, an upgrade of MEG, the proposed mu3e search at PSI, new searches from muon to electron conversion (Mu2e at Fermilab, COMET at J-PARC), SuperKEKB, and over the longer term, experiments exploiting megawatt proton sources such as Project X.

Over the next decade gains of up to five orders-of-magnitude are feasible in muon-to-electron conversion and in the $\mu \to 3e$ searches, while gains of at least two orders-of-magnitude are possible in $\mu \to e\gamma$ and $\tau \to 3\ell$ decay and more than one order of magnitude in $\tau \to \ell\gamma$ CLFV searches. The question of which of these processes is the more sensitive was addressed in some detail at the Workshop; the answer is that the relative sensitivity depends on the type of new physics amplitude responsible for lepton flavor violation. Thus the pattern of violation that emerges yields quite specific information about new pysyics in the lepton sector. Existing searches already place strong constraints on many models of physics beyond the standard model; the contemplated improvements increase these constraints significantly, covering substantial regions of the parameter space of many new physics models. These improvements are important regardless of the outcome of new particle searches of the LHC; the next generation of CLFV searches are an essential component of the particle physics road map going forward. If the LHC finds new physics, then CLFV searches will confront the lepton sector in ways that are not possible at the LHC, while if the LHC uncovers no sign of new physics, CLFV may provide the path to discovery.

In general, muon measurements have the best sensitivity over the largest range of the parameter space of many new physics models. There are, however, models in which rare tau decays could provide the discovery channel. It was clear from the discussion that as many different CLFV searches as feasible should be conducted, since the best discovery channel is model-dependent and the model is not yet known. Should a signal be observed in any channel, searches and measurements in as many CLFV channels as possible will be crucial to determining the nature of the underlying physics, since correlations between the rates expected in different channels provide a powerful discriminator between physics model.

The new muon g–2 experiment will measure the anomaly to close to 100 parts per billion precision with different experimental techniques. This will be an important measurement whether or not the LHC sees new physics. If the LHC sees SUSY-like new physics, g–2 will be used as a constraint in determining which model we see. The LHC will be particularly sensitive to color super-partners, while g–2 can pin down the flavor sector. The sensitivity of g–2 to $\tan\beta$ will provide a test the universality of that parameter. If the LHC does not see new physics, then g–2 can be used to constrain other models, such as theories involving dark photons and extra dimensions. Any new physics model will have to explain the discrepancy between the theoretical and experimental values of g–2. The reduction of theory errors in the calculation of g–2 is thus also of great importance, particularly the contribution of light-by-light scattering. New data from the KLOE and BES-III experiments will put the candidate models on firmer ground, as will lattice calculations to be undertaken by, among others, the USQCD collaboration. A Super B Factory with a polarized electron beam can measure, for the first time, the anomalous moment of the τ, using new variables involving the polarization.

The search for EDMs will also play an important role in new physics searches. The achievable limit on the electron EDM is the most stringent, but searches for muon and tau EDMs are nonetheless of interest, since new physics contributions scale as the lepton mass. These can be important: if an electron EDM were to be found, the value of second and third generation EDMs would be of great interest. Parasitic measurements with the new Fermilab $g-2$ experiment will improve the μ EDM limit by two orders of magnitude. Improvement of this limit would also help to rule out the possibility that the muon EDM is the cause of the current discrepancy in the g–2 measurement. New dedicated experiments now being discussed could bring the limit down to the 10^{-24} $e$cm level, making it competitive with the electron EDM constraints. In the same vein, a Super B Factory with a polarized electron beam can reach a sensitivity below 10^{-21} $e$cm. Additional symmetry tests will also be possible, including sensitive searches for CP violation in τ decay and tests of electroweak parity violation using electron scattering and e^+e^- collisions.

An exciting program of sensitive searches for new physics using the large samples of μ and τ decays in experiments at the intensity frontier awaits us. These experiments will likely be central to our understanding of physics beyond the Standard Model.