The Need To Advance The Intensity Frontier

Jure Zupan[1,*]

[1]*Department of Physics, University of Cincinnati, Cincinnati, Ohio 45221,USA*

Five years from now the LHC will be running at 14 TeV. We may well be fortunate enough that new resonances will have been discovered, giving us the first ideas how electroweak symmetry breaking is realized and how the challenges of the hierarchy problem are resolved. Life will be great. However, it is also possible that we will be facing the nightmare scenario - only the standard model Higgs will have been discovered with no signs of new physics anywhere in the LHC data.

Even in this case there may be a silver lining. If the Higgs mass is found to be low enough, close to the LEP limit of $m_H = 114.4$ GeV, then we will know that new physics needs to kick in well below the Planck scale. The present global electroweak fits point to exactly such a low mass Higgs. Including the direct Tevatron searches, but not the latest LHC Higgs searches, one has $m_H = (120^{+12}_{-5})$ GeV [1]. For example, let us use for illustration the central value $m_H = 120$ GeV. In this case one finds that the Higgs potential is absolutely stable only up to the energy scale between 10^7 to 10^9 GeV (at 90% C.L.) [1] [2]. These energies are well above the reach of the LHC. In contrast they can be probed using high intensity low energy experiments! In fact, for the foreseeable future the precision low energy experiments may be our only chance to understand the structure of physics at the vacuum stability scale.

The precision achieved to date in flavor physics is not far from the benchmarks above. In some cases interesting precision has already been achieved. For instance, the particles giving tree level CP violating contributions to the $K-\bar{K}$ mixing operator Q_4 need to be heavier than $2 \cdot 10^8$ GeV for generic flavor violation with $O(1)$ coefficients. The challenge on both the theoretical and the experimental side is to increase the precision to this level for as many observables, and in as many processes, as possible. How one can achieve this in processes with heavy quarks should be one of the focuses of our “Heavy Quarks Working Group” at the “Fundamental Physics at the Intensity Frontier” workshop. There are a number of improvements that have been in the works for years - the precision of the bag parameters achievable in lattice QCD simulations, including the NP operators, the searches for the CPV in D decays, the improvements in the measurement of the standard CKM unitarity angles, the searches for processes that are extremely suppressed in the SM such as wrong

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[*] Electronic address: zupanje AT ucmail.uc.edu

[1] The spread is due to the errors in m_t, α_S and theoretical uncertainties. It is also possible that the SM vacuum is metastable but long-lived so that it has not decayed yet. In this case the bound on new physics scale has a large spread, $\Lambda < 10^9 - 10^{18}$ GeV. It will be important to improve this prediction in the future and pin down the scale at which the new physics needs to set in to prevent the vacuum decay. This bound would be the equivalent of the unitarity bounds for the LHC, which predict a Higgs or something like it below TeV.

flavor $b \to ss\bar{d}$ decays, rare kaon decays, the description of inclusive and exclusive $\Delta F = 1$ B decays, where further systematic improvements using SCET may be possible, etc. (see, e.g., reviews [5–7]). In many cases we are still far from saturating irreducible theoretical or experimental uncertainties.

There is a long history of first seeing high energy phenomena through rare processes at much lower energies. A celebrated example is nuclear β decay. In 1934 it was explained by Fermi using a four fermion operator [8]. Since this is a dimension 6 operator it is multiplied by a dimensionful coefficient, G_F, whose size points to a scale of new particles at $\mathcal{O}(100)$ GeV assuming their couplings to quarks and leptons are $\mathcal{O}(1)$. It took half a century to produce these new particles, the W and Z bosons, at UA1[9] and UA2 [10]. But the mere presence of β decay and the later discovered related muon and kaon decays enabled to build a successful theory around them — now called the standard model. The advancement of the intensity frontier is our search for the equivalent of the β decay in rare processes.

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