Implications of naturalness and stringy naturalness for the energy frontier: a Snowmass 2021 EF08 Letter of Intent

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We investigate implications of electroweak naturalness for the Snowmass energy frontier EF08. We clarify several definitions of naturalness: Dirac, 't Hooft, practical and stringy. We comment on several naturalness measures Δ_{HS}, Δ_{BG} and Δ_{EW}. We show how naturalness emerges from the string theory landscape, but with new aspects, namely, a draw to large soft SUSY breaking terms. We propose to build a new computer code which evaluates Δ_{EW} for any SUSY particle mass spectrum listed as a SUSY Les Houches Accord file (SLHA). This will allow comparisons of natural SUSY spectra amongst different spectra generation codes: Isajet, SUSYHit, SoftSUSY and Spheno.

Some physicists declare that the issue of electroweak naturalness is the most important problem in contemporary physics[1], while others maintain that naturalness is completely subjective and hence any discussion of it is to be avoided. Indeed, several definitions of naturalness permeate the HEP community. In addition, several quantitative measures of naturalness are available which seem to be mutually incompatible. For instance, focus point SUSY using the Barbieri-Giudice (BG) log derivative measure Δ_{BG}[2, 3] allows for TeV scale top squarks[4] while the high scale (HS) measure Δ_{HS} seems to require three third generation squarks with mass below 500 GeV[5]. A third measure, Δ_{EW} which measures weak scale fine-tuning[6], allows for higgsino-like electroweakinos in the 100-300 GeV range while all other sparticles may inhabit the (multi-) TeV range.

We have several goals for the Snowmass 2021 EF08 topical subgroup. First, we want to clearly state the several definitions of naturalness, so that coherent discussions may be had to clarify this issue. Second, we also want to present the several quantitative measures of electroweak naturalness and discuss their accompanying virtues and vices. We also want to discuss and make clear their various implications for Physics Beyond the Standard Model, especially for weak scale supersymmetry (WSS).

A fourth notion of naturalness has emerged from the string landscape, which has been invoked to solve the cosmological constant problem. This notion of *stringy naturalness*[7] pertains to the relative likelihood of different *phenomenologically viable* string theory vacua to produce particular values or ranges of observable parameters. We will discuss stringy naturalness[8], and how it is similar to and different from some of the previously mentioned measures.

A thid goal of ours is to make the conservative, model-independent Δ_{EW} measure more readily available for evaluation by the community at large. The Δ_{EW} measure includes over 40 radiative corrections to the magnitude of the weak scale from different particle/sparticle loops. These have been evaluated[9] in terms of the Lagrangian presented in the volume Baer & Tata *Weak Scale Supersymmetry*[10] which differs in certain signs from more conventional Lagrangians. We will re-evaluate these radiative corrections in terms of conventional Lagrangians, and then our goal is to write a computer program to evaluate Δ_{EW} for any SUSY spectrum generated in terms of a SUSY Les Houches Accord (SLHA) file, which is standard output for SUSY particle spectrum calculations. This will allow for comparisons of aspects of natural supersymmetry by different spectra generating codes such as Isajet, SUSYHIT, SoftSUSY and Spheno.

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