Wolfgang Altmannshofer – Lecture 2 Questions

Questions marked in green were answered during the Q&A session. I haven't tried to correct grammar/spelling. Where a slide number was given it is shown.

Q1 (slide 10): I have the feeling that the models that try to explain the mass hierarchy of the quarks just transfer the problem to something else. For example in slide 10, then the question becomes why are the fermions located in different places in this extra dimension. Why are these model preferable over just accepting the mass hierarchy?

A1: It is true that these models do not predict the precise values of the fermion masses. But they do predict that the spectrum should be hierarchical. Random O(1) differences of the location in the extra dimension will be mapped onto exponential differences in the masses.

Q2 (slide 11): If particles can gain mass via loop couplings to Higgs, why don't e.g. gluons have mass?

A2: The SU(3) gauge symmetry is unbroken in the Standard Model and ensures that the gluons remain massless to all loop orders. Same is true for the photon, where the relevant unbroken gauge symmetry is U(1)_em.

Q3 (Slide 14): Agustin Romero: Great talk, thanks! Can you explain why the singlet does not contribute to electroweak symmetry breaking?

A3: The term singlet means that the field is uncharged under the SM gauge symmetry. In particular it has no SU(2)_L or U(1)_Y charges. That implies that these symmetries are not broken when the singlet develops a vacuum expectation value.

Q4 (Slide 20): why each Yukawa terms has the Left-handed with Right-handed fields combined

A4: (I might have misunderstood the question when I answered yesterday during the Q&A) The reason why the Yukawa interactions connect left and right handed fields is Lorentz-invariance. Terms in the Lagrangian need to be Lorentz scalars. Combining a left-handed and right-handed field does give a scalar. (Combining two fields with the same handedness gives a Lorentz vector, which can be contracted with a derivative leading to the usual kinetic terms)

Q5 (Slide 20): If we add right-handed neutrinos, How do the doublets couples with neutrinos in each case? In the same way as down-quarks?

A5: The right handed neutrinos can in principle couple to either of the two doublets. That means that for each of the 2HDM types, one finds 2 “sub-types” with the neutrinos coupled either to H1 or to H2

Q6 (Slide 21): Something special about Type-2 for this scheme, or other 2HDM types can also work similarly ?

A6: Experimentally we know that the top mass is much larger than the bottom mass and the tau mass, while the bottom and tau mass are similar. In order to get 3rd generation Yukawa unification we therefore need a setup that treats the top differently than the bottom and tau. This is exactly what happens in the type 2 model.

Q7: (Slide 24): Why is there a tail in the plots for type-II, X, and Y?

A7: The tails in the those plots correspond to regions or parameter space where some of the Higgs couplings to fermions have opposite sign but the same magnitude as the Standard Model prediction. The LHC measurements are only weakly sensitive to the sign of the couplings and currently cannot rule out such scenarios.

Q8: (Slide 28): The ratio of BR(B->tau-nu) to SM looks like it can be one, depending on the value of tangent(beta). Is there some physics significance for such a value?

A8: In the type 1 and type 2 models there are indeed regions of parameter space where the new physics amplitude is non-zero, but the branching ratio is Standard Model like. Those regions correspond to rather small charged Higgs masses and very large (or very small) values of tan(beta). Those regions or parameter space are excluded by other flavor transitions, for example D_s -> tau nu or K -> mu nu.

Q9 (Slide 30): if assuming the higgs boson do not coupling to light quark, Is the constrain on H+ from the meson decay still valid?

A9: The constraints that are shown hold in the models with natural flavor conservation. In models with different Higgs couplings most of the constraints will change. Some constraints might go away, some might get more stringent. It depends on the details of the model.