Wolfgang Altmannshofer – Lecture 1 Questions

Questions marked in green were answered during the Q&A session. Original questions listed without correction for grammar/spelling. Where a slide number was given it is shown.

Q1 (slide 3) Are there models where there is only one generation of fermions before EWSB, and its the breaking of the symmetry that introduces the 3 generations somehow? Can it be consistent with cosmology with just 1 generation?

(I might have misunderstood that question during the Q&A)
I can in principle imagine a scenario in which in the early universe 2 generations are for some reason completely decoupled and become dynamical after some phase transition (but I would not know how to do that in practice...). We have a good understanding of the number of light degrees of freedom during big bang nucleosynthesis. As long as the phase transition happens sufficiently early it should be OK with regards to cosmological constraints.

Q2 (slide 9/10) Are the right-handed rotation matrices analogous to those going into the LH CKM physical in the SM?

The right-handed rotation matrices are unobservable in the Standard Model. They belong to the set of parameters that can be removed by the flavor symmetry. The right-handed rotations can become physical in extensions of the Standard Model.

Q3 (Spurions?) Can you explain again what spurions are?

The term spurion is used to refer to a non-dynamical object that is promoted to an auxiliary field with symmetry transformation properties that restore a symmetry of the system. In the example, it is the Yukawa couplings that are promoted and that are assigned transformation properties such that the SU(3)^5 flavor symmetry of the SM Lagrangian is restored.

Q5 (slide 5) Does the Standard Model REQUIRE exactly three families? For example, is there any prohibition to have four (or five)?

There is no theory reason for having three families. The Standard Model with four or five families would be completely self consistent. However, from the experimental side, additional chiral families of quarks and leptons would drastically change properties of the Higgs boson, in particular the couplings to gluons and photons. The LHC Higgs rate measurements exclude additional chiral families.

Q6 (slide 18) Could you please explain why amplitude is proportional to product of Yukawas?

The idea is to find combinations of Yukawa couplings that have the correct transformation properties under the flavor symmetry. A single down-type Yukawa has the right transformation properties, but it does not lead to any flavor change. To get flavor change one needs both up-type and down-type Yukawa couplings. The simplest combination that has the right transformation properties is Yu.Yu^t.Yd

Q7 (slide 20) CKM elements are more or less intuitive. Can you motivate why the ratios have the factors of 16-pi? And why does one ratio depends on (m_s/m_b)^2?

The flavor changing processes are all 1-loop induced. For a loop you get a 1/16pi^2 in the amplitude. At the level of the branching ratio that gives a factor (1/16pi^2)^2. The ratio (ms/mb)^2 shows up, because I have normalized all branching ratios to h->bb. The decay rate of h->bb is proportional to mb^2, while h->sd is proportional to ms^2.

Q8 (slide 26) Are these constraints independent of the model?

The shown constraints are as model independent as possible. Contributions to flavor changing processes are estimated by only taking into account the presence of flavor changing couplings of the 125 GeV Higgs. The physics that leads to the flavor changing Higgs couplings will likely also contribute directly to the flavor changing processes. The main assumption of the constraints is that there are no accidental cancellations of different contributions.