Ayres Freitas – Lecture 1 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 4): The UNCERTAINTIES in predictions are not always reliable. Can we really trust predictions down at fraction of percent level?

A1: Theory uncertainty estimates are indeed not robust numerical predictions. However, their order of magnitude is meaningful. If the uncertainty from unknown higher orders is estimated to be, e.g., 0.1%, then it is conceivable that the true corrections are larger, maybe 0.2%. However, except for exceptional circumstances, I would never expect the true corrections to turn out to be 1%, i.e. a full factor 10 larger. To quote a specific example: the 3rd and 4th order QCD corrections to h->bb are 0.2% and 0.15%, respectively. I seems pretty safe then to assume that the currently unknown 5th order is not larger than any of these, i.e. less than 0.2%. Now you may argue that 0.1% is a better estimate, and I may agree, but 1% or 0.001% are obviously unreasonable estimates.

Q2 (slide 4): Why is the Feynman diagram with the Goldstone boson not important in the 1-loop level (without the Gluon as the second loop)?

A2: Yes, it is important at the one-loop level, for the same reasons, but I did not specifically mention it because all one-loop contributions have been computed, whereas at the 2-loop level only those that are enhanced by the top-Yukawa coupling have been studied.

Q3 (slide 9): Why can we ignore external momenta when finding the corrections in the EFT?

A3: By construction of the EFT (and I did not have time to go into the foundational theory aspects of that), the Wilson coefficient C_{hg} is a constant, i.e. it does not depend on the external momenta. So I can make any choice for the Higgs and gluon momenta when computing C_{hg}, and setting them to zero is the choice that simplifies that calculation the most.
There is also another way to think about it: The effective hGG operator corresponds to the leading terms in an expansion of mh/(2mt) of the full amplitude. The first term in this expansion is the 0th-order of a Taylor series, which corresponds to simply setting mh->0. mh is the energy of the incoming momentum, so setting it zero means that all momenta have to be zero.

Q4 (slide 12): What is the difference between jets and parton shower?

A4: Jets are a collection of hadron observed in the tracker and calorimeter of a detector. The parton shower is one element that is used for simulating jets in a MC event generator, but it is based on approximations (covering only perturbative emissions of soft and collinear gluons, quarks and maybe photons) and it needs to be complemented by other elements (e.g. a description of hadronization) to provide even a crude approximation of observable jets. The showering of partons is not observable in itself, all you can “see” in the detector are the final hadrons.

Q5 (slide 18): How reliable are uncertainties in Lattice QCD calculations?

A5: I am not a top expert on this topic, but there are continuous discussions in the lattice community about identifying and properly estimating all the systematic uncertainties. You can see , for example, that the HPQCD determination of alpha_s from 2010 has a much smaller quoted error than those from more recent years (that have more computing power at their disposal), which reflects the fact that most expert now think that HPQCD underestimated their uncertainties at that time.

Q6 (slide not specified): What exactly is meant by matching and parton showers ?

A6: Both fixed-order perturbative calculations and the parton shower describe, among other things, the emission of additional gluons. The parton shower does that only approximately, but it can generate emissions of multiple gluons in a simple manner. By combining a NLO or NNLO calculation with a parton shower, you can get the emission of the first and/or second gluon exactly, while the parton shower can generate additional gluons approximately. However, if you simply add the fixed-order calculation and the parton shower, you are overcounting the probability for emitting gluons, because the emission of the first gluon is described by both parts.. So you need to implement a procedure that prevents the parton shower from generating the gluons that are already contained in the NLO or NNLO calculation. Such a procedure is generically called “matching”.

Q7 (slide 29): If the Kappa value becomes problematic at higher orders and the QCD correction can go up to 100%, how useful are the results with kappa being similar to 1 in the interpretation of the SM and physics beyond the SM?

A7: That’s very observant! Well, if we introduce a kappa_t for modifying the top Yukawa, and then we use this to compute the decay h->gg, the QCD corrections are in fact still gauge-invariant and well-defined. This is because the Yukawa coupling has nothing to do with QCD. However, you would not be able to consistently compute electroweak corrections in the kappa framework.

Q8 (slide not specified): When we talk about the corrections we usually expect them to be small than LO. Then why are the corrections in case of H > gg are 100%. What it means.

A8: I don't know all the details off the top of my head, but there are several enhancement factors that enter for this specific process. For example, at LO the color quantum numbers of the two gluons must be opposite, because in the incoming Higgs is colorless. However, at NLO you can have three gluons in the final state, and now there are many possible combinations of color assignments that are allowed, so this generates a combinatorial enhancement of the NLO corrections relative to the naive expectation.