Questions and answers - Loukas Gouskos Lecture 2

The following questions were submitted through Zoom Q&A. Some / all may have been answered in the Q&A session already. Nevertheless, we request our lecturers to provide written answers here for the benefit of those who could not attend that session. Thank you!

(1) Can we experimentally distinguish H and A? Will they generate different distributions of some kinematic parameters?

We can experimentally distinguish between H (CP-even) and A (CP-odd) using spin-sensitive observables, especially in the H/A→ttbar channel. Top quarks decay before hadronizing, so their spin information is preserved in the angular distributions of their decay products.

(2) We talked about various BSM scenarios such as 2HDM. Limits are set. Is it (in principle) possible to exclude such models altogether? It seems like HL-LHC will give stronger limits on cross section times branching ratio, but the case can then be made for 100 times more data than HL-LHC.

Models like the 2HDM are frameworks with many free parameters (e.g. masses, couplings, decay modes), so we can only exclude specific slices of their parameter space, not the entire model. There's no "no-lose theorem" guaranteeing that new states must be observable at the HL-LHC or even future colliders. We should also remember they are theoretical models - nature could be different.

(3) Page 29. Can you explain the two lower figures some more? In the figure of "w/o toponium", the red line represents data well. Why do we focus on the other figure and conclude observing toponium? Also, there are several points near 600 GeV that no fit describes well. This discrepancy is not so different from the sum of all differences put together between with and w/o toponium. Comment?

The "with toponium" fit incorporates a QCD-predicted pseudoscalar ttbar bound state that modifies m(tt) precisely at threshold, producing a characteristic shape and rate consistent with non-relativistic QCD expectations. We cannot exclude the possibility that this excess originates from a new elementary pseudoscalar, such as the A. However, the absence of corresponding hints in other decay channels makes this interpretation less favored. In any case, further dedicated studies are needed to establish the true origin of the excess.

The deviations near m(tt)~600 GeV are not statistically significant and consistent with statitstical fluctuation.

(4) Question about p 61 figure. Should we expect 5% of the black points to be beyond the 95% yellow band? Looks like we are very much short. Can you comment? [Comment / interpretation of the question. We expect one in 20 points to be outside the 95% band, without needing to know what the probability distribution looks like in detail. I did not count the points in detail, but it is many more than 100. On the other hand, it's hard to find even one or two points outside the yellow band.]

The total number of generated signal points is ~200, after which an interpolation technique is applied to increase the number of points for the interpretation (as shown in Fig. 61). Before interpolation, we find ~35 points outside +/-1σ and ~4 outside +/-2σ, compared to the ~66 and ~10 expected by statistics. This indicates that a somewhat conservative approach has been followed, though not dramatically so. In the case of Fig. 61, the interpolation introduces strong correlations between neighboring points, so the statistical expectations no longer apply; i.e., we expect fewer fluctuations than if all points were independent.

(5) Typo? Near the bottom of slides 33 and 34, should "b" be "t" in Feynman diagram?

No, the diagram is correct. One gluon splits to t tbar, whereas the other one to b bar. The t (+2/3) interacts with the b (+⅓) and produces the H^+.