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The ultimate measurements of the Higgs boson mass and width in Run 3, the HL-LHC and beyond

Since the discovery of the Higgs boson, the focus in Run 2 (2015–2018) of the LHC has shifted from observation to precision measurements of its properties. The couplings of the Higgs boson to other elementary particles can be predicted by the standard model of particle physics only when its mass is known. This motivates precise measurements of the mass of the Higgs boson. These measurements are carried out in the two high resolution channels, which are the H→γγ and the H→ZZ→ 4l channels respectively.
The most precise measurement of the Higgs boson mass till date was published recently by the CMS collaboration with mH=125.38 ± 0.24 (0.12(stat.) ± 0.08 (syst.)) GeV, a precision of nearly 0.1%. This was obtained by combining the measurements in the high resolution channels performed with the 2016 dataset and in Run 1. The precision obtained was made possible by a dedicated effort to mitigate the systematic uncertainties associated with such a measurement. In the immediate future both the ATLAS and CMS collaborations are updating the mH measurements with the full Run 2 dataset. Once these results are combined together the measurement will tend to get limited by the systematic uncertainty of the measurement.
The width of the Higgs boson of the Standard model is 4.1 MeV. The typical experimental resolution of mH is ~1.5 – 3 GeV. Hence direct measurements of the width of the Higgs boson are limited severely by the experimental resolution in both H→γγ and H→ZZ→ 4l channels. In the H→ZZ→ 4l channel indirect measurements utilizing off-shell Higgs boson production in combination with the on-shell signal strength measurements have constrained the width to 0.08 < ΓH< 9.16 MeV. In the H→γγ channel, the interference between Higgs boson production via gluon fusion and the continuum QCD diphoton production leads to a mass shift compared to what is measured in the H→ZZ→ 4l where this interference effect is absent. A measurement of this mass shift can be translated to a constraint of the Higgs boson width.
By the end of the HL-LHC, with a dataset nearly 10 times of the current one the statistical precision of the mH measurement will improve to ~20 MeV (0.01%). However if we continue with the current strategy it is unlikely that we can achieve a systematic precision of better than ~ 0.07%, which is based on the precision with which we can measure the lepton and photon energy scales. A new strategy needs to be developed to benefit from the large HL-LHC dataset and measure the mass of the Higgs boson to a precision of better than 0.05%. With such precision, effects such as the mass shift in the diphoton decay channel due to interference can be measured and tested against the standard model prediction. The width of the Higgs boson is expected to measured in the H→ZZ→ 4l channel with a precision of ~25 % using the off-shell technique.
In this oral presentation the authors will summarize the currently available measurements of the Higgs boson mass and width. An estimate of the ultimate precision possible for these measurements in the future will also be presented with a focus on the key challenges that need to be met to achieve the same. In future we shall explore the feasibility of these measurements in FCC(hh) machines.

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