Theoretical Motivation
Decay of the Higgs boson to invisible final states is predicted by many theories that aim to describe phenomena beyond the standard model. Some of these theories allow final states to be dark matter particles.

Experimental Motivation
The visible decays of the Higgs boson are used to constrain the invisible branching fraction (indirect searches) since beyond the standard model Higgs decays affect the total width of the Higgs boson.

However, large uncertainties might accommodate beyond the standard model properties. The standard model branching ratio $H(\text{inv})$ is $0.12\%$ for $H(Z(4\nu))$.

Direct Searches
Considering Higgs boson production mechanisms, direct searches can be performed.

The gluon-gluon fusion (ggH) channel has the highest production cross-section. However, it is possible not to have visible products in the final states.

The vector boson fusion (VBF) channel is the most sensitive even though it has a large background and it is hard to trigger on. The jets have a large pseudo-rapidity gap and there is no colour connection between them.

The vector boson associated production (VH) channel has a low rate and its final states contain leptons that could be missed. However, VH with $V \rightarrow \ell\ell$ gives well isolated leptons to trigger on.

VBF Higgs to Invisible Searches
Signal topology:
- two jets with large pseudo-rapidity separation ($\Delta y_j$);
- large dijet invariant mass ($m_{jj}$);
- MET well separated from any jet.

Expected backgrounds:
- $Z \rightarrow \nu\nu$ + jets;
- $W \rightarrow \ell\nu$ + jets;
- Top quark, diboson, and QCD multi-jet.

Two different approaches used:
- cut-and-count, results directly translated into a limit on the visible cross-section in a model independent way;
- shape, improves the sensitivity for a SM-like H($\text{inv}$).

Control Regions
Most backgrounds come from misreconstructed jets and/or missed leptons. These backgrounds are estimated using control regions where leptons are identified.

To estimate the background in the signal region:

The V-jets represent the largest backgrounds in this search ($\approx 95\%$), and are determined through a simultaneous maximum-likelihood fit across four control regions and the signal region.

Signal Region
Assuming the standard model production cross-section, an observed (expected) upper limit on the invisible branching fraction of the 125 GeV Higgs boson is found to be 0.53 (0.27) for the cut-and-count and 0.28 (0.21) for the shape analyses at 95% confidence level, using the 2016 13 TeV dataset of 35.9 fb$^{-1}$.

Combination and Dark Matter Interpretation
The combination of searches for Higgs decays to invisible final states can be used to probe the compatibility of the Higgs boson found at CMS with the standard model prediction. The searches target the ggH, VBF, and VH production modes, using 2016 13 TeV datasets.

The results indicate that the relative contributions between the different production mechanisms are consistent with their standard model predictions within the uncertainties. The combination yields an observed (expected) upper limit on the invisible branching fraction of the 125 GeV Higgs boson of 0.24 (0.18) at 95% confidence level assuming standard model production rates.

The $\mathcal{R}(H(\text{inv}))$ can be translated into DM-nucleon spin-independent cross-section limits as a function of dark matter mass, using Higgs-Portal models and assuming scalar/fermion dark matter candidate.

The LHC limits are complementary to direct detection experiments.