Conclusion and Scope

A search for the SM Higgs boson has been carried out, using 7, 8 & 13 TeV data collected by the CMS detector, in the associated production mode where the Higgs boson is produced along with a W boson and decays to a pair of τ leptons, and W boson decays to a highly energetic μ. Two different analyses are performed,

- $WH \rightarrow \mu \tau_h \tau_h$: In this channel the associated W boson decays to a μ and both the τ leptons from the Higgs boson decay hadronically ($\tau_h$), giving rise to one μ and two opposite sign $\tau_h$ in the final state. The Higgs mass is reconstructed by the two $\tau_h$ candidates. This analysis is performed using data corresponding to integrated luminosity of 5, 19.5 and 2.1 fb$^{-1}$ at $\sqrt{s} = 7, 8$ and 13 TeV proton-proton collisions respectively. The final state is dominated by mis-identified or fake
background events. A novel data-driven fake rate technique has been developed
and fake background is estimated by a $Jet \rightarrow \tau_h$ fake rate method. No excess
in event yield has been observed over the predicted background and a confidence
limit is set on the SM Higgs cross section. The expected limit at 125 $GeV/c^2$ for
the combined 7 & 8 TeV analyses is $12 \times SM$. Evidently, more data is needed to
increase sensitivity of the channel. The observed limit is compatible both with
SM Higgs and background only (no Higgs) hypotheses. At $\sqrt{s} = 13$ TeV, the cross
section of the WH process should increase by a factor of $\sim 1.8$ with respect to
$\sqrt{s} = 7$ TeV and the expected limit at 125 $GeV/c^2$ extracted from 2.1 fb$^{-1}$ data at
13 TeV is roughly equivalent to the 7 TeV results.

- $WH \rightarrow \mu\mu\tau_h$: In this channel, one of the $\tau$ leptons from the $H \rightarrow \tau\tau$ mode decays
to a $\mu$. Though $H \rightarrow \tau\tau \rightarrow \mu\tau_h$ branching ratio is much smaller than that of
$H \rightarrow \tau\tau \rightarrow \tau_h\tau_h$, the presence of two muons in the final state increases the event
yield since reconstruction efficiency of $\mu$ in CMS is much higher than $\tau_h$. The
visible mass of the Higgs boson is reconstructed by the sub-leading $\mu$ and the $\tau_h$
candidate in the final state. This analysis has been performed using the 2.1 fb$^{-1}$
integrated luminosity at $\sqrt{s} = 13$ TeV. Like the other analyses discussed above,
the final state is dominated by fake background events which is estimated above,
the analysis in this semi-leptonic channel to improve the overall sensitivity and
coverage of the search. The expected limit at 125 $GeV/c^2$ is $\sim 20 \times SM$ for $\sqrt{s} = 
13$ TeV data, which is very similar to what has been seen using the 5.0 fb$^{-1}$ of $\sqrt{s} =$
7 TeV data. Clearly, more data is needed to improve sensitivity of the channel.

Both the analysis channels are dominated by fake background events in the final
state, where one or more particles are mis-identified as real particle. The data-driven
fake estimation technique developed for the analyses complements each other. In the process of performing the analyses, several other studies like measuring the muon trigger, identification and isolation efficiencies are performed. Studies have also been performed on tau isolation to mitigate the pile-up effect using Monte Carlo events of different pile-up and bunch crossing scenarios. With more data, it is expected to show some hint of the SM Higgs particle to establish the fermionic coupling in associated production mode. In future dedicated studies can be performed to identify the property of the boson and its resemblance with the SM Higgs.

CMS is also preparing for several upgrades to meet its physics goals for future LHC running. The LHC is scheduled for a luminosity upgrade (High Luminosity LHC, HL-LHC) during 2022 and expected to deliver an instantaneous luminosity of \(5 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}\) which is \(\sim 5\) times higher than the current value. To meet the challenges posed by the HL-LHC, several sub-detector components of the CMS detector will be upgraded. In this context, a trigger algorithm for electrons has been designed including the tracker information at Level-1 to reduce the enormous event rate expected during HL-LHC. This will enable CMS to retain similar physics performance at the low mass range even at the high luminosity environment. The analysis has been carried out in two different ways, by using the stub information and tracklet based track information. Once the matched object is found a L1Track based isolation variable is exploited, which performs way better than a L1Calo based isolation. The results obtained justify the usefulness of a L1 Track Trigger for electron and are described in the Phase II Technical Proposal. Performance of the algorithm has also been studied for couple of other outer tracker geometries which are a modified version of the proposed baseline design.

This study can be further extended by exploiting the crystal level calorimeter object which promises a finer position resolution to understand whether it is possible to achieve
a better performance than the tower level object. It is also possible to carry out the analysis using tracks reconstructed by some other methods that are available now.

The thesis also presents a study of track reconstruction at Level 1 using the Associative Memory based pattern recognition. AM-based tracking is expected to play a major role for the Phase-II upgrade of the CMS detector. An emulation of a Principal Component Analysis induced track fitting algorithm has been performed for floating and fixed point representations. The response of the fitter does not degrade for integer based fixed point representation which is supposed to be implemented on FPGA hardware.