Discovery Potential for the SM Higgs Boson in the H → WW* → 2l2ν channel at LHC

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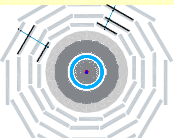
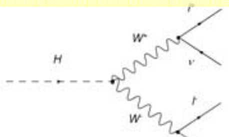
1. Introduction

Prospective search of the SM Higgs boson with the CMS detector. Establishing an analysis strategy for inclusive production of the Higgs boson decaying in WW* pairs in the context of the early LHC data.

Higgs mass region between **120-200 GeV**, in which this signature was proposed as highly sensitive [2], has been studied.

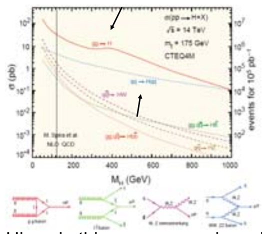
W → ℓν are considered. Final states with **ee, μμ, or eμ**, significant **MET** and **without the presence of jets**.
This study uses MC events with full detector simulation, including limited calibration and alignment precision as expected at the startup.
Sets of **sequential cuts** are applied to each of the three topologies, in order to isolate a signal which exceeds the tt and continuum W^+W^- backgrounds. Alternatively, an artificial neural network (ANN) **multi-variate analysis** technique is used.

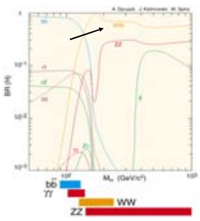




1.1 Decay and production modes

H → W W(*) is the dominant Higgs decay mode in a wide mass range, and for:
$2m_W < m_H < 2m_Z$
the Branching ratio is close to 1 (BR ~1)





SM Higgs in this mass range is mainly produced via:
Gluon fusion (ggH): no hard jet activity
Vector-boson fusion (VBF) (qqH): 2 forward jets, opposite in rapidity, high mass

The leptonic final states of the W bosons give good signature of the Higgs boson

1.2 Signal and background topology

Topology of **the signal**: **H → W W(*) → 2*l* 2ν**
- **2 leptons** (with opposite charge, small opening angle)
- **missing energy** (undetected neutrinos)

m_H [GeV]	σ^{NLO} [pb]	BR(H → WW)	$\sigma^{NLO} \times BR(H \to WW \to \ell\nu\ell\nu)$ [pb]
120	40.31	0.13	0.56
130	35.08	0.28	1.06
140	31.02	0.48	1.58
150	27.55	0.68	1.98
160	24.63	0.89	2.34
170	22.18	0.96	2.26
180	20.17	0.93	1.99
190	18.43	0.77	1.51
200	16.76	0.73	1.30

Table 1: NLO Higgs cross-section, H → WW branching ratio and NLO cross-section times H → WW → ℓνℓν branching ratio for different Higgs boson masses.

Process	WW	ZZ	WZ	W → ℓν	Z → ℓℓ	tt
σ^{NLO} [pb]	114.3	15.3	49.9	61700	5600	840

Table 2: NLO cross-sections for different background processes.

No mass peak (Importance of background control)

Sources of background: multi-lepton final states + Missing ET

Main backgrounds:
Di-boson production, especially **WW** (but also **WZ, ZZ**) ,
ttbar (**tW** and **bb** also),
Drell-Yan, **W + jets** (jets faking electrons)…

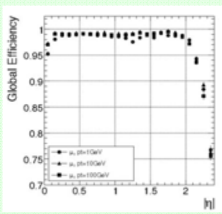
Really big cross-sections when compared with the signal !

2. Event Selection and Analysis

2.1 Trigger and lepton identification

The amount of signal events recorded by the CMS experiment will depend on the trigger efficiency. We consider 9 lepton trigger paths which we plan to use to select pp → H → ℓℓ'νν with high efficiency at luminosities in the range 10^{31} to 10^{33} cm^{-2} s^{-1}.

HLT paths		
μμ	ee	eμ
HLT1MuonIso	HLT1Electron	
HLT1MuonNonIso	HLT1ElectronRelaxed	
	HLT2Electron	HLTXElectronMuon
HLT2MuonNonIso	HLT2ElectronRelaxed	HLTXElectronMuonRelaxed



Standard CMS lepton reconstruction techniques are used.

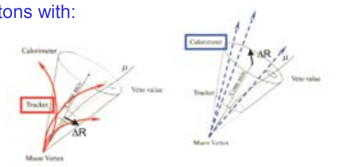
The effective selection of e and μ should show high efficiency for true isolated leptons from W boson decays, while at the same time effectively suppressing leptons from heavy quark decays or fake leptons produced by other objects.

The identification of electrons is tight (to reduce contamination by W+jets), based on the matching of a charged track reconstructed in the central tracker with a supercluster in the electromagnetic calorimeter [3][4].
Muon candidates are identified by matching a track reconstructed in the muon detectors with a track reconstructed in the central tracker[4][5].

2.2 Lepton selection

Events are required to have exactly two leptons with:

- **opposite electric charge sign**
- **|η| ≤ 2.5**
- **p_T ≥ 10, 20 GeV**
- **isolated with tracks**
- **isolated in the calorimeter**



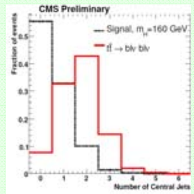
If more than two are found, the event is rejected (against WZ and ZZ backgrounds)

2.3 Jet Veto and Missing ET

No hard jet activity in the central region is expected for signal, which can be used against **ttbar** background.

Jets reconstructed using iterative cone algorithm with ΔR=0.5. **If an event contains any jet with p_T >15 GeV and |η| < 2.5, it is rejected** (also against: **Wtb, QCD, Z+jets, W+jets**).

A significant missing energy is expected due to the neutrinos in the final state, and is computed from the raw tower energies.



The **MET cut** is specially useful against **Drell-Yan** background after mll cut

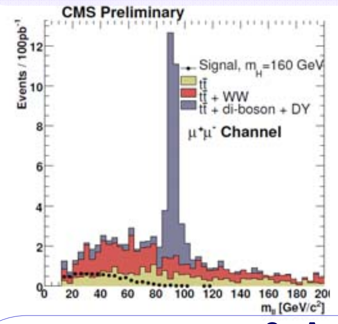
2.4 Kinematic variables

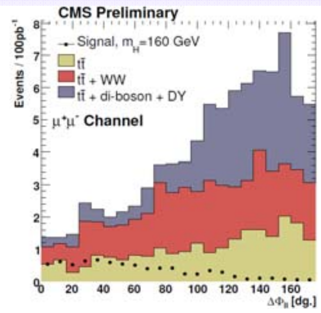
To optimize the signal event selection against the main backgrounds:

- angle between the leptons in the transverse plane $\Delta\Phi_{\ell\ell}$.
For **WW** events this angle is expected to be large (leptons back-to-back), for the scalar SM Higgs boson this angle tends to be small (spin correlations).

-invariant mass of the lepton pair $m_{\ell\ell}$.
An upper cut is applied in the case of e^+e^-, $\mu^+\mu^-$ final states to reduce the contamination by leptons coming from **Z-boson** decays.

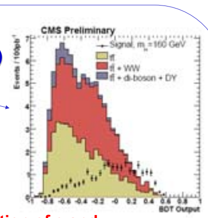
- transverse momenta of the harder ($p_T^{\ell,max}$) and the softer ($p_T^{\ell,min}$) lepton
upper/lower limit applied in order to reduce the background further.





3. Analysis

Split in three complementary topologies **(e^+e^-, $\mu^+\mu^-$ and $e^\pm\mu^\pm$)**
Two approaches: Sequential cuts and multivariate.



Common for all the final states

Skimming — Reduce data volume, Select interenting events

Pre-selection — Define common objects for the analysis/select events

Final state cuts ee, eμ, and μμ
- **Experimental differences in the identification of e and μ**
- **Some bckg. processes do not equally affect all the final states**

Jet Veto

Multivariate Analysis | Sequential cuts

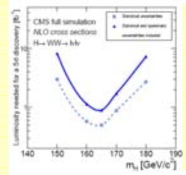
Cuts on sensible variables:
Missing E_T
ΔΦ
Inv. Mass
P_T leptons

The combination of the analyses improves CMS discovery potential

4. Results

Physics TDR [1] conclusion:
SM Higgs boson could be discovered in the H → WW → lνlν channel with less than $1fb^{-1}$ if its mass is around 165 GeV

Progress has been made toward a search for the Higgs boson in this channel. The selection of events with leptons, missing energy, and no central jets is a good starting point for this search.



5. References

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