Discovery potential for the SM Higgs Boson in the $H \rightarrow WW \rightarrow 2l\ 2\nu$ channel at CMS

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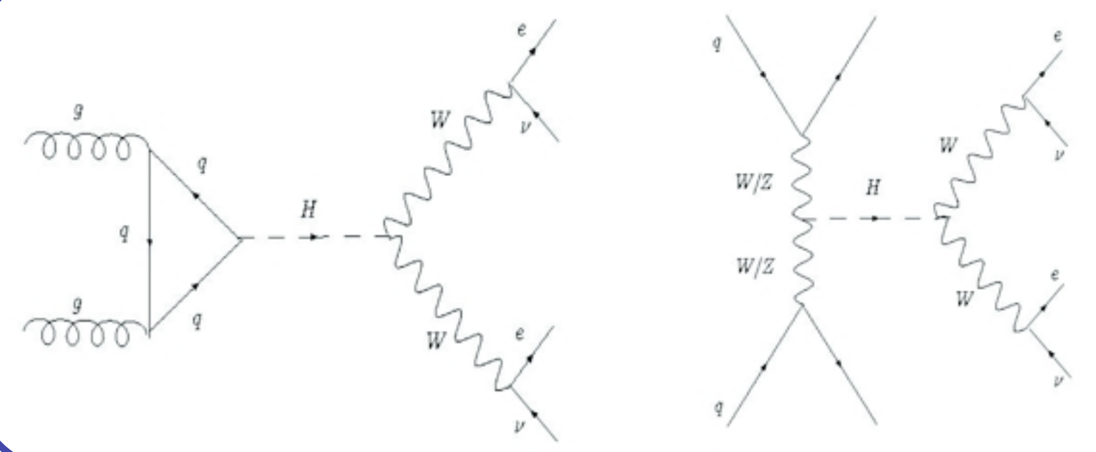
SPLIT08

Introduction

- SM Higgs can be discovered in the H → WW channel over a wide mass range
- most sensitive channel around $m_H \sim 2 \times m_W$
- current limits from Tevatron (CDF & D0)
  - excluding Higgs with m_H = 170 GeV at 95 % CL
- at LHC: cross-section ~ 80 times larger
  - sensitivity expected at a few hundred pb^{-1}
  - discovery potential at a few fb^{-1}

Signal/Background Topology

- Higgs at LHC mainly produced in gluon- and VB-fusion



- **signal topology:**
  - two oppositely charged leptons
  - missing transverse energy (undetected neutrinos)
- **possible background:**
  - all source of real and fake multi-lepton final states + missing E_T
    - e.g. all processes including a W pair (WW, ttbar)

Monte Carlo Datasets

- all samples (except ttbar) are produced using the LO parton-shower Monte Carlo event generator PYTHIA and passed through the CMS detector simulation
  - inclusive reweighting to NLO cross sections for all samples, except:
    - WW continuum background
    - Higgs signal sample
- ttbar produced using the generator TopRex

$pp \rightarrow H \rightarrow WW \rightarrow l\nu l\nu$	
m_H [GeV]	σ_{NLO} [pb]
120	0.56
160	2.34
200	1.30

process	σ_{NLO} [pb]
$qq \rightarrow WW$ (inclusive)	114.3
WZ (inclusive)	49.9
ZZ (inclusive)	15.3
$Z \rightarrow ll$	9640
ttbar (inclusive)	840

Trigger & Lepton Identification

- using 9 different trigger paths:

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

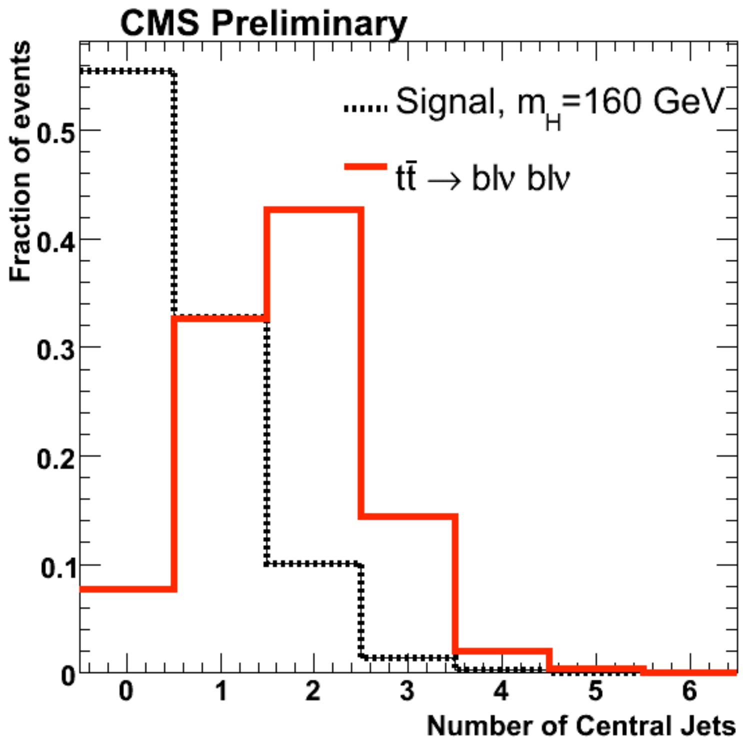
- electron identification:
  - based on matching of charged tracks reconstructed in the central tracker with a supercluster in the electromagnetic calorimeter
- muon identification:
  - matching a track reconstructed in the muon system with a track from the central tracker

Jets & Missing Transverse Energy

- **jet reconstruction:**
  - iterative cone algorithm
  - cone size R=0.5
  - min E_T^{tower} = 0.5 GeV
  - no energy calibration applied
- **jet selection:**
  - $|\eta| < 2.5$ && $p_T > 20$ GeV OR
  - $|\eta| < 2.5$ && 15 GeV < p_T < 20 GeV && $\alpha > 0.2$
  - $\alpha = \Sigma p_T(\text{tracks})/E_T(\text{jet})$ for tracks with
    - ΔR(track-jet) <0.5
    - $|z_{track} - z_{vtx}| < 0.4$ cm
- **MET reconstruction:**
  - vector sum of raw energies in ECAL and HCAL towers
  - correcting for muons

Central Jet-Veto - Why?

- ttbar overwhelming background
- easiest/safest way to reduce this background is a jet-veto



Jet-Selection:
- $|\eta| < 2.5$
- $p_T > 20$ GeV **OR**
- $p_T > 15$ GeV && $\alpha > 0.2$

Jet-Veto:
reject events with any jet fulfilling the selection criteria described before

process	ε_{veto}
tt→bevbev	~ 10 %
H→WW→evev	~ 60 %

Pre-Selection

Lepton Selection:

two reconstructed, isolated and identified leptons fulfilling:
- p_T(lepton 1) > 10 GeV && p_T(lepton 2) > 10 GeV
- p_T(lepton 1) > 20 GeV || p_T(lepton 2) > 20 GeV
- $|\eta|$ (lepton 1) < 2.5 && $|\eta|$ (lepton 2) < 2.5
- lepton 1 and 2 have different electric charge sign

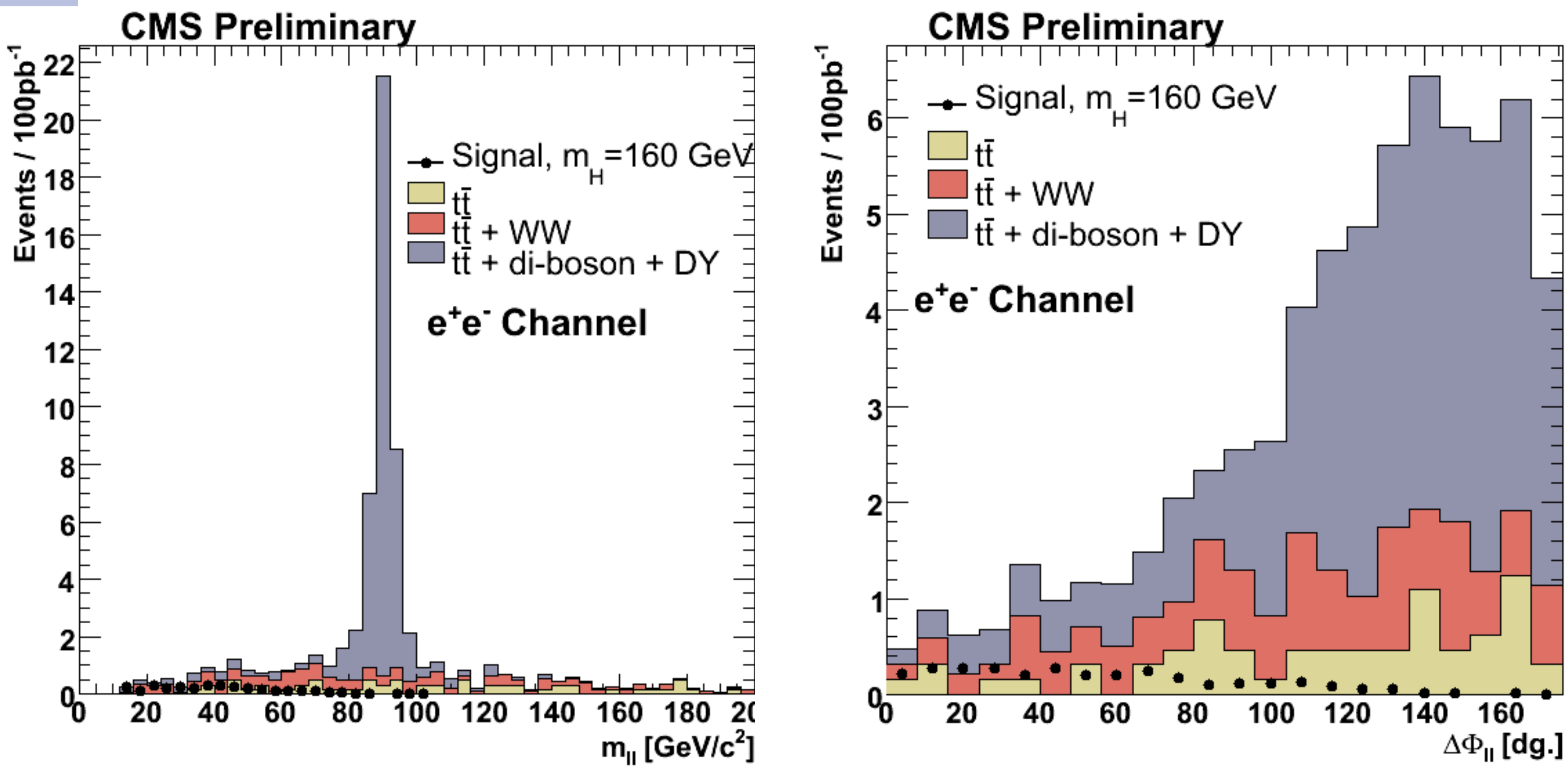
Isolation:

- tracker: sum of track transverse momenta in a cone of R=0.2 (0.3) for electrons (muons)
- calorimeter: sum of ECAL/HCAL energy deposits in same cone

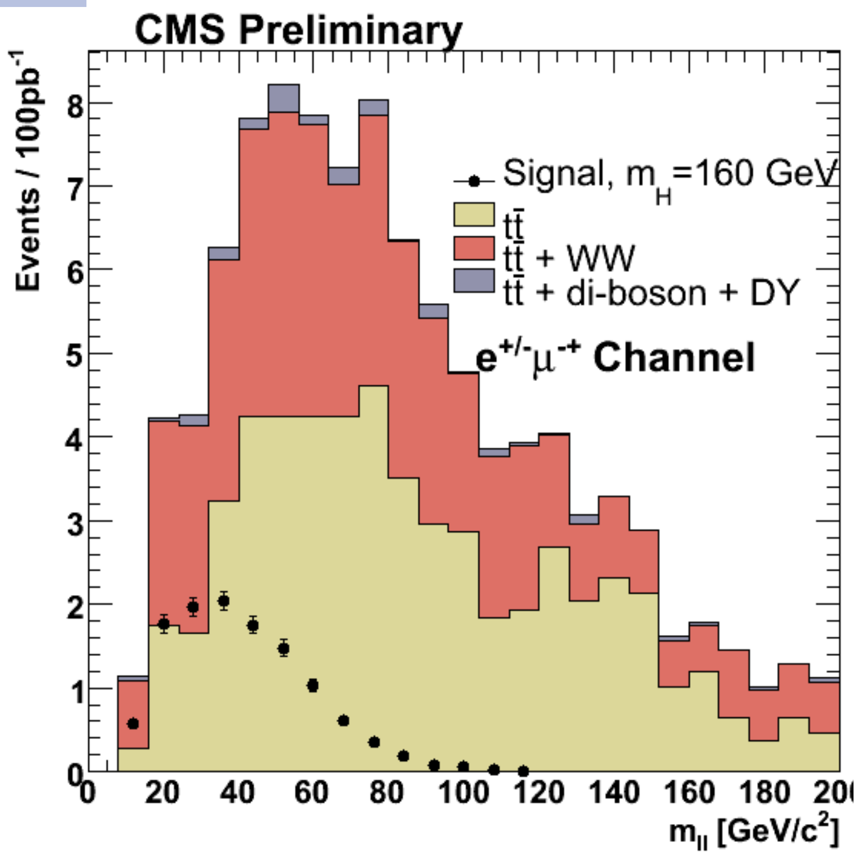
Kinematical Pre-Selection:

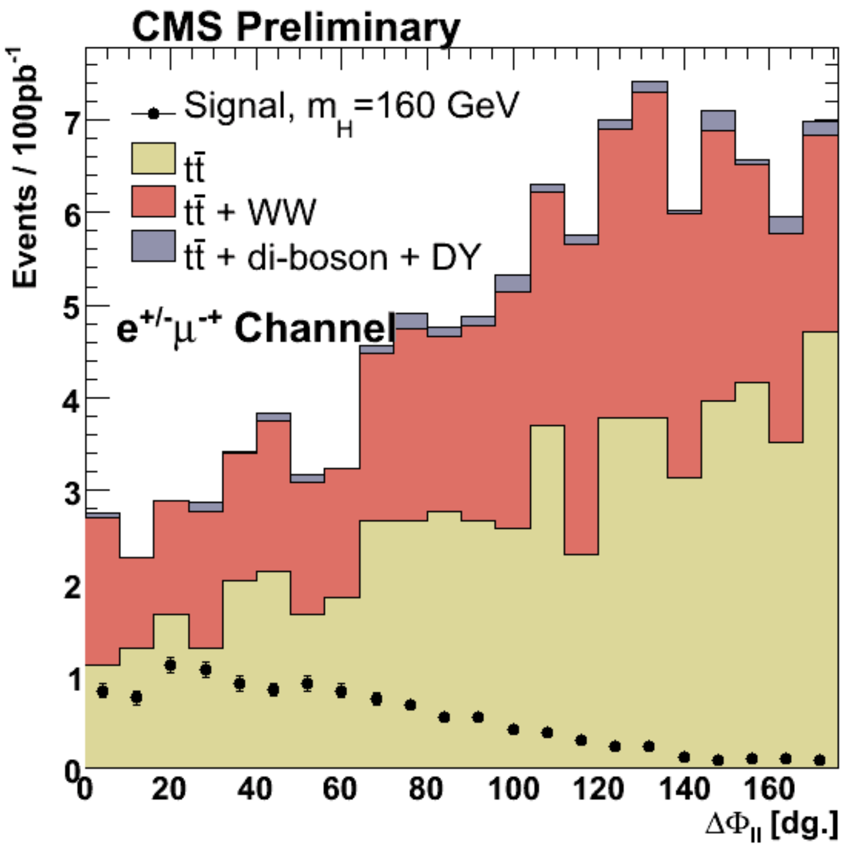
- missing transverse energy E_T^{miss} > 30 GeV
- invariant mass lepton pair m_{ll} > 12 GeV
- # jets passing selection smaller than 3

Distributions after Pre-Selection (ee)

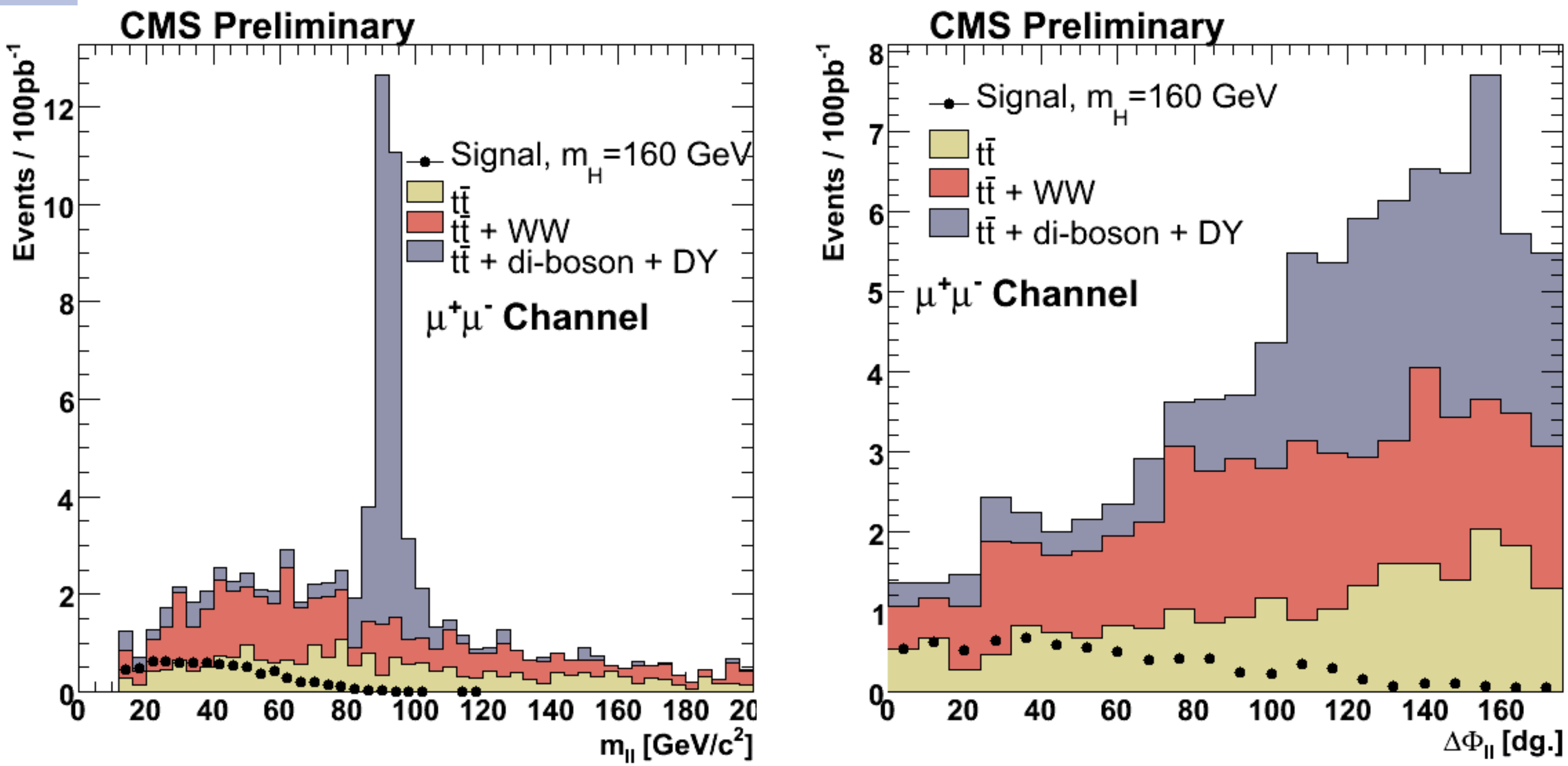


Distributions after Pre-Selection (eμ)





Distributions after Pre-Selection (μμ)

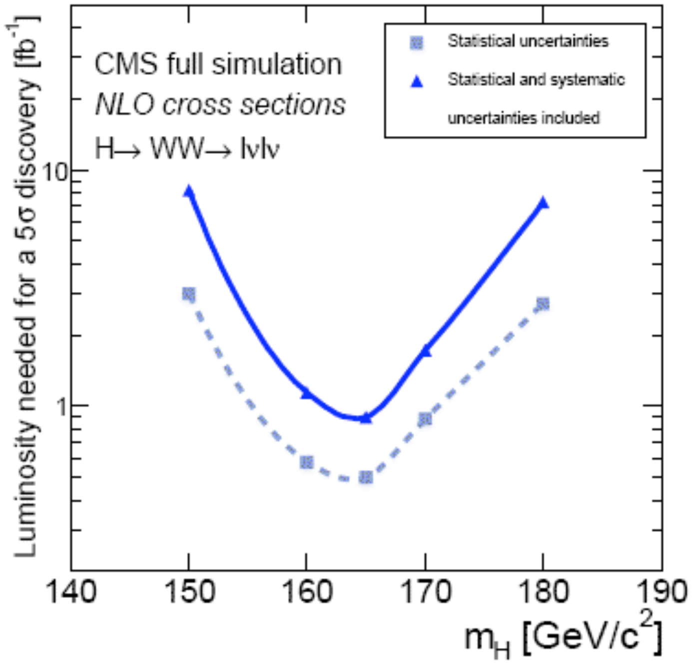


Final Selection Variables

- **jet-veto:**
  - powerful against ttbar background
- **max $\Delta\varphi_{ll}$ (angle between leptons in transverse plane):**
  - powerful against WW continuum background, due to scalar character of the Higgs boson (spin-correlations)
- **max m_{ll} (invariant mass of lepton-pair)**
  - especially in ee/μμ case powerful against contamination of lepton-pairs coming from Z decays
- **min/max E_T^{miss} (missing transverse energy)**
- **max p_T^{min} (transverse momentum softer lepton)**
- **min/max p_T^{max} (transverse momentum harder lepton)**
- all these cuts (except jet-veto) are either tuned for each mass-hypothesis and each lepton-channel or are the variables used in the MV analysis

Cut Based Analysis

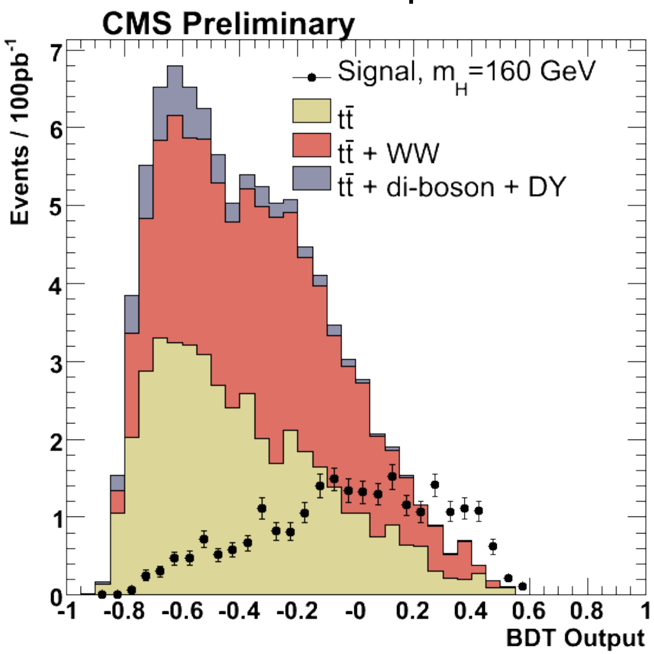
- splitting sample in three different final state lepton configurations
  - ee, eμ, μμ
- for each Higgs mass hypothesis cut-values are tuned in order to maximize
  - **$n_\sigma(cuts) = N_S / Sqrt(N_B + \Delta N_B^2)$**
    - N_S: signal events
    - N_B: background events
    - ΔN_B: expected error
      - here $\Delta N_B = 0.2 \times N_B$



- Plot from PTDR analysis
  CMS Collaboration,
  "CMS Physics Technical Design Report (Vol II),"
  J. Phys. G: Nucl. Part. Phys. 34,995-1579 (2007

Multivariate Analysis

- used Boosted Decision Tree (BDT) and Neural Networks (NN)
  - Higgs mass hypothesis dependent
  - all final state lepton configurations considered simultaneously
  - lepton- and pre-selection applied, additional cuts:
    - $m_{ll} < 80$ GeV, $\Delta\varphi_{ll} < 160°$
  - 60% of samples used to train classifier, 40% for limit computation



- BDT classifier output normalized to L=100 pb^{-1} after
  - HLT/skimming
  - lepton-, pre-selection
  - central jet-veto
- similar results for NN analysis

Conclusions

- the $H \rightarrow WW \rightarrow l\nu l\nu$ analysis has been performed within the CMS software /simulation environment in the Higgs mass range m_H=[120,200] GeV
  - lepton (e,μ) and jet reconstruction and selection, E_T^{miss} reconstruction
  - HLT as well as kinematical pre-selection cuts applied
  - Analysis covering all Higgs mass hypothesis using
    - cut-base, lepton-flavour separated analysis
    - multivariate techniques
  - expected 95% CL exclusion-sensitivity for a wide Higgs mass range for an integrated luminosity of a few hundred pb^{-1}
- ongoing studies:
  - measuring fake rates and background contamination from data
  - understanding systematic uncertainties from data