Search for H→WW*→lνlν

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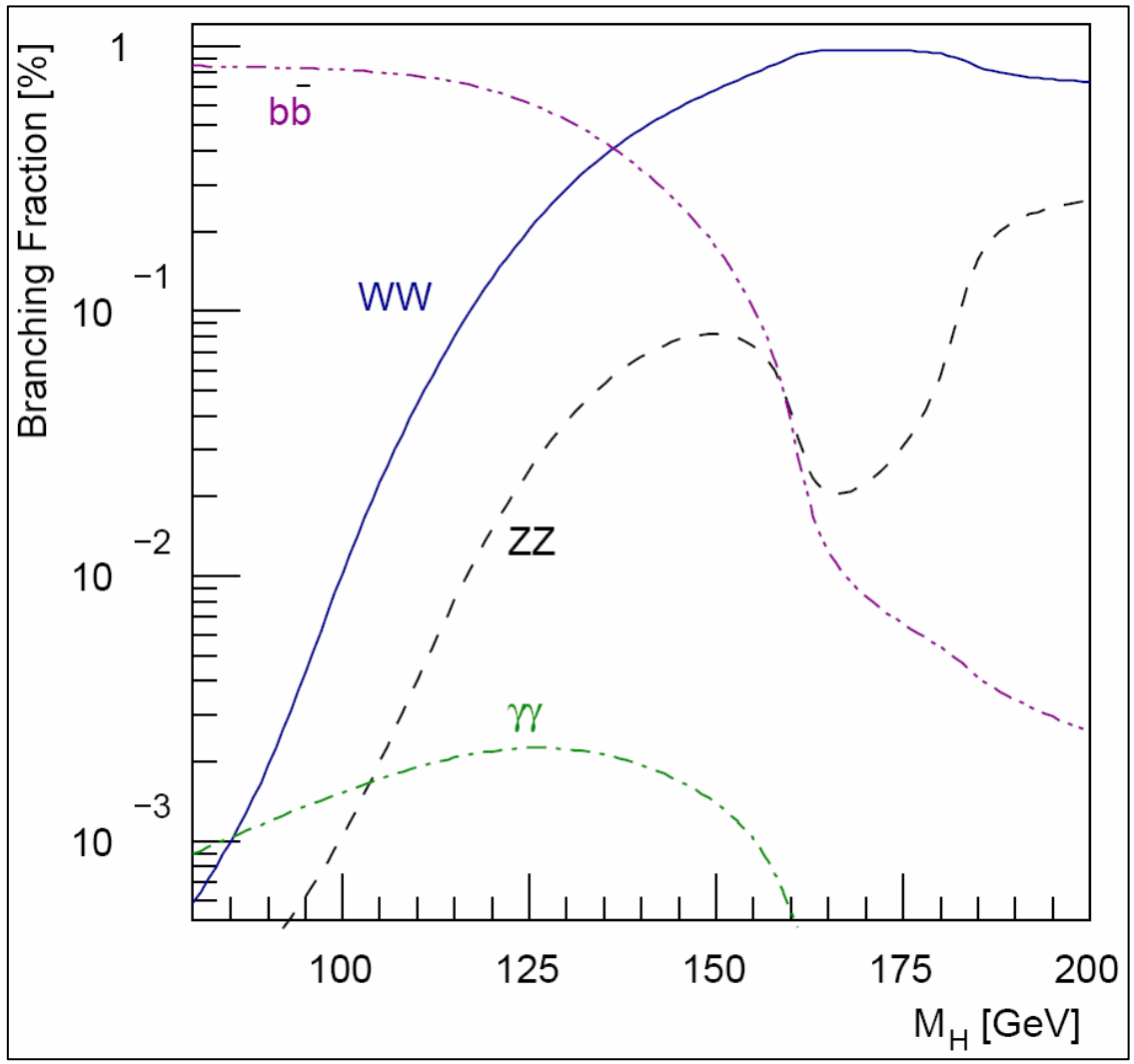

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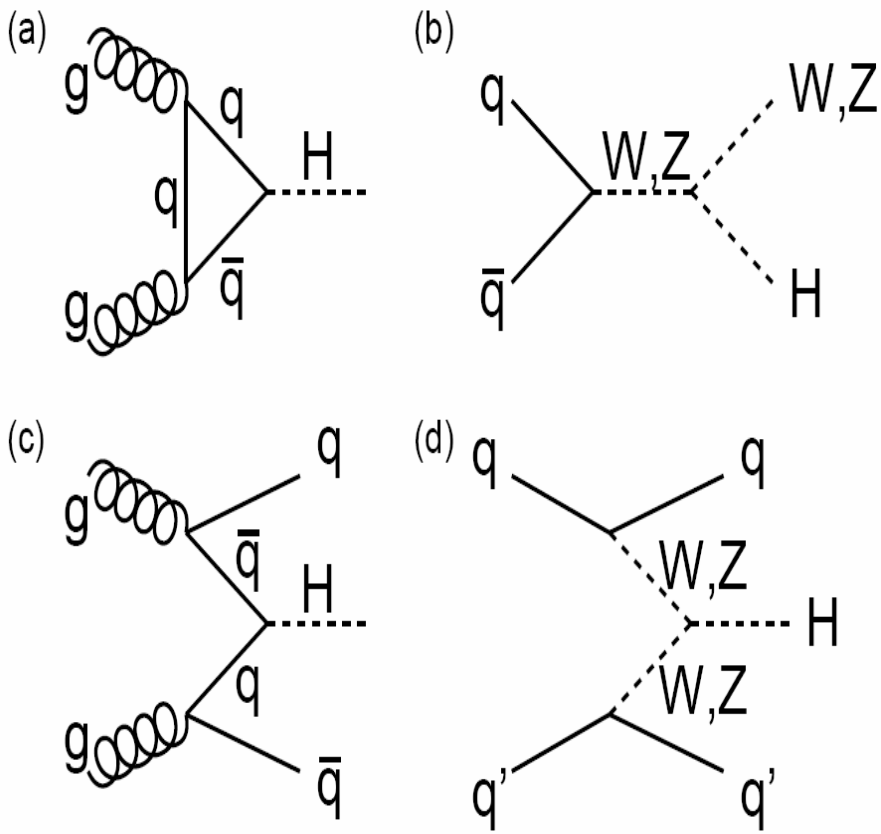
Higgs Production

- Standard Model Higgs
  - Four different processes
  - Gluon fusion (dominant) and Higgstrahlung at the Tevatron
  - NLO predict for M_H~100-200 GeV $\sigma(pp \rightarrow H) \times BR(H \rightarrow WW^*)$ ~11-250 fb
- M_H<135 GeV
  - Higgs decays primarily into bb with branching fraction 70-90% for M_H<125 GeV
- M_H>135 GeV
  - Higgs decays primarily into WW with branching fraction >90% for M_H~160 GeV
- Extensions of the SM including a 4th fermion family predict an enhanced Higgs boson production cross section
  - E. Erik et al., PRD 66, 2002
  - O. Cakir and S. Sultansoy, PRD 65 (2002)



Monte Carlo

- Signal MC for six Higgs masses from 100 to 200 GeV

M_H(GeV)		100	120	140	160	180	200
$\sigma \times$BR (pb)	SM	0.011	0.089	0.207	0.256	0.181	0.101
	4^{th} Gen	0.066	0.471	1.217	2.017	1.471	0.804

- Background MC
  - Vector Boson Pair Production
    - WW, WZ, ZZ
  - Vector Boson Production
    - Drell-Yan: $Z/\gamma^* \rightarrow ee$, $\mu\mu$, $\tau\tau$
    - $W(\rightarrow e$, $\mu)$+Jets, $W(\rightarrow e$, $\mu)+\gamma$
  - Other Backgrounds
    - tt, mult-jet production (from data), $\Upsilon \rightarrow ee$, $\mu\mu$

H→WW* Candidates

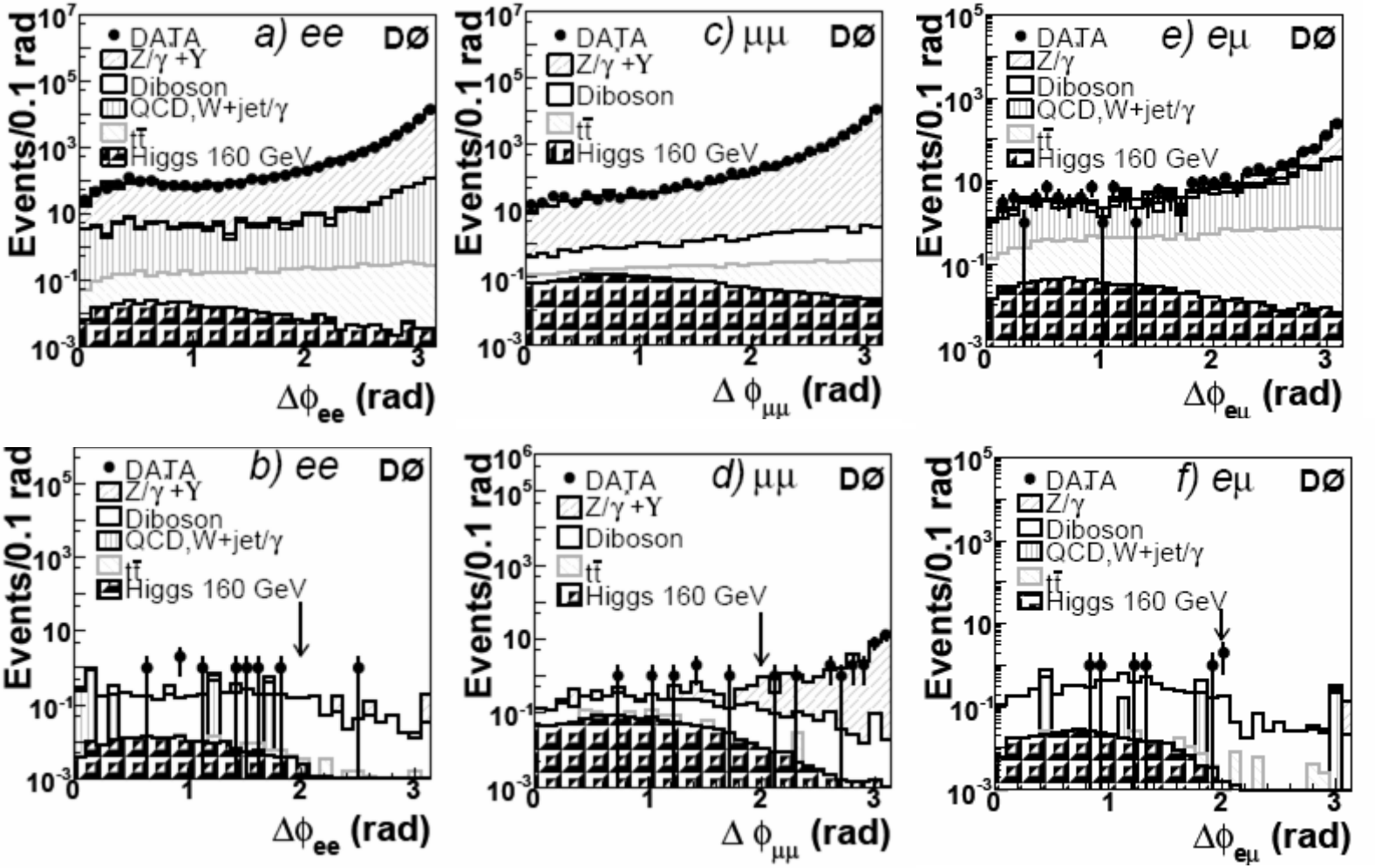
- Search for $H \rightarrow WW^* \rightarrow ll\nu\nu$
  - $l = e, \mu, \tau$
  - Tau decays detected by their leptonic decay modes to electrons and muons
- Data collected by the D0 detector from April 2002 through June 2004
- Integrated luminosities are 325, 318 and 299 pb^{-1} for the e^+e^-, $e^\pm\mu^\pm$, or $\mu^+\mu^-$ final states respectively
- Select events by single or dilepton triggers using three tiered trigger system

- Electrons
  - Isolated EM shower in Calorimeter
  - Spatial track match
  - $|\eta| < 3.0$
- Muons
  - Reconstructed from hits in the wire chambers and the scintillators
  - Match to central track
  - $|\eta| < 2.0$
- Two W bosons
  - Two oppositely charged isolated leptons from same primary vertex with high transverse momentum
  - Large missing transverse energy
  - Some selection cuts are M_H dependent to account for signal kinematic characteristics

Selection Criteria

- Preselection cuts
  - Trigger, Object ID, oppositely charged leptons
  - p_T>15 (10) GeV for leading (trailing) lepton
- $\not\!\!E_T$>20 GeV
  - Suppresses dominant Z/γ* bkg
- Scaled $\not\!\!E_T$>15 GeV
  - Remove bkg due to large contributions from mismeasured jet energy
- Invariant mass cut
  - m_{ee}< min(80 GeV, M_H/2)
  - 20 GeV < $m_{\mu\mu}$< M_H/2
    - Remove J/Ψ, Y, Z/γ*
- Sum of p_T of the leptons and $\not\!\!E_T$, and the transverse invariant mass cuts
  - Rejects W+jets/γ and WW events, and further reduces Z/γ*
- Scalar sum of the transverse energies of the jets, H_T<100 GeV
  - p_T>20 GeV, |η|<2.5
  - Suppresses bkg from tt production
- Azimuthal opening angle between the two leptons $\Delta\varphi_{ll}$< 2.0
  - Remove remaining Z boson and multijet bkg which exhibit back-to-back topology
  - Not the case for Higgs boson decays because of spin correlations

Data & MC Azimuthal Opening Angle



- Top: After initial transverse momentum cuts
- Bottom: After final selection except for $\Delta\varphi_{ll}$ criteria

Efficiencies

M_H (GeV)	ee	$e\mu$	$\mu\mu$
100	0.56 ± 0.05	1.02 ± 0.06	0.44 ± 0.03
120	1.18 ± 0.09	2.0 ± 0.1	1.02 ± 0.06
140	1.55 ± 0.08	2.9 ± 0.2	1.34 ± 0.08
160	2.1 ± 0.1	3.9 ± 0.2	2.0 ± 0.1
180	2.1 ± 0.1	3.9 ± 0.2	1.68 ± 0.09
200	1.57 ± 0.09	3.2 ± 0.1	1.53 ± 0.07

- Overall detection efficiencies include statistical & systematic uncertainties in quadrature (in %)
  - $H \rightarrow WW^* \rightarrow ll\nu\nu$ events determine using PYTHIA 6.2 event generator with GEANT-based simulation of the D0 detector
  - Trigger, reconstruction and identification derived from data.
  - Kinematic acceptance efficiency derived from MC

Signal and Background

M_H (GeV)	100	120	140	160	180	200
$H \to WW^{(*)}$	0.007 ± 0.001	0.125 ± 0.002	0.398 ± 0.008	0.68 ± 0.01	0.463 ± 0.009	0.210 ± 0.004
Z/γ^*	7.9 ± 1.1	7.5 ± 1.0	3.8 ± 0.6	4.0 ± 0.7	6.6 ± 0.9	9.9 ± 1.1
Diboson	4.4 ± 0.2	8.1 ± 0.2	11.7 ± 0.3	12.3 ± 0.3	11.6 ± 0.3	9.6 ± 0.3
$t\bar{t}$	0.03 ± 0.01	0.11 ± 0.02	0.29 ± 0.02	0.47 ± 0.03	0.66 ± 0.05	0.72 ± 0.05
W+jet/γ	16.9 ± 2.2	14.2 ± 2.1	5.8 ± 1.2	2.8 ± 0.9	0.7 ± 0.5	0.7 ± 0.5
Multi-jet	0.6 ± 0.3	0.3 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.3 ± 0.1	0.3 ± 0.1
Background sum	29.9 ± 2.5	30.1 ± 2.3	21.8 ± 1.4	19.7 ± 1.2	19.8 ± 1.1	21.2 ± 1.2
Data	27	21	20	19	19	14

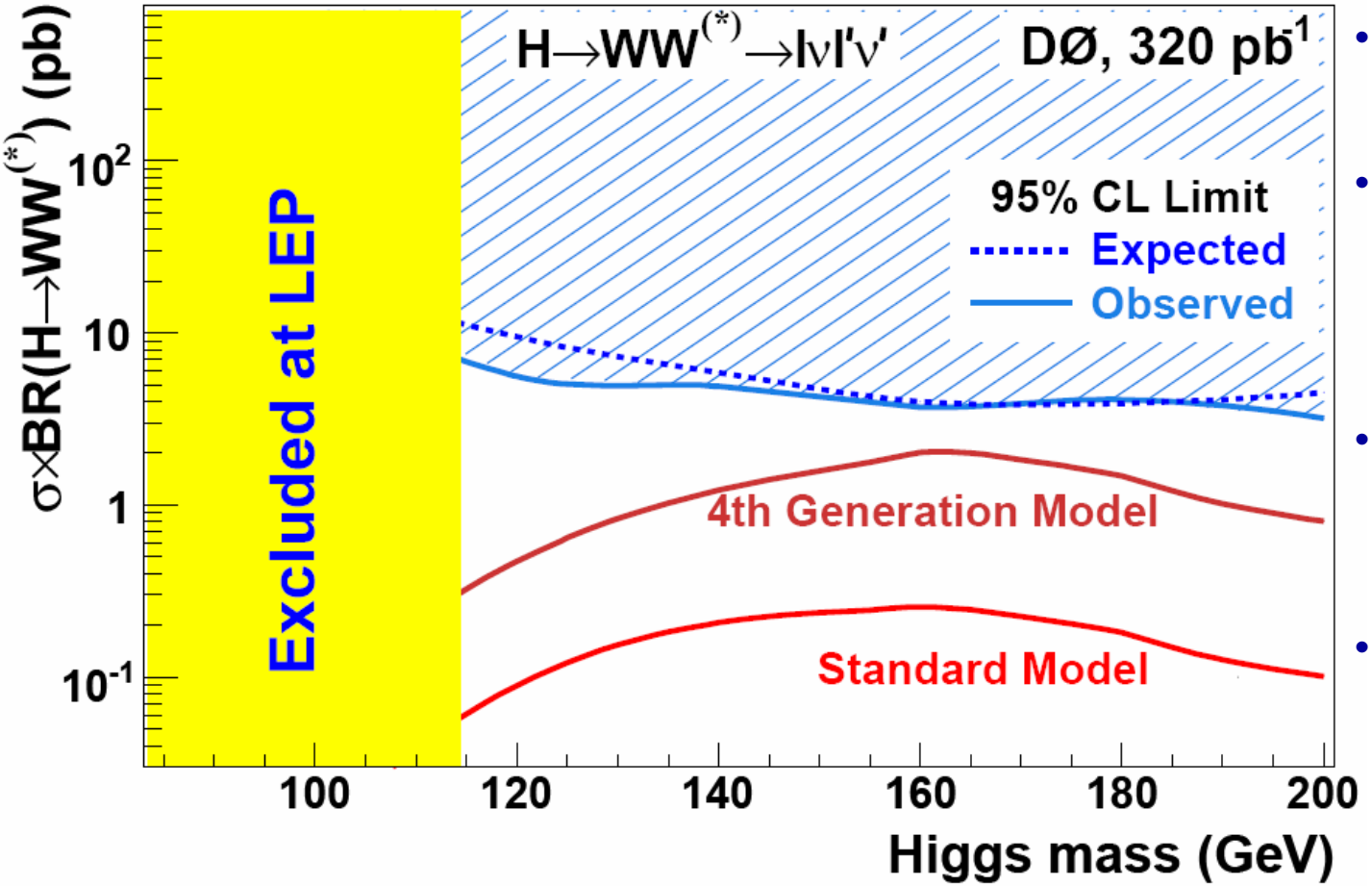
- After all selections, with only statistical uncertainties given
- Using the NLO cross sections calculated with HIGLU (M.Spira hep-ph/9510347) and HDECAY (A. Djouadi et al., CPC108,1998), and the branching ratio of 0.1068±0.0012 for W→lν (all three channels combined)
- Z/γ*, W+jets/γ, tt, WW, WZ, ZZ estimated using PYTHIA normalized to NLO cross sections
- W+jets/γ contributions verified using ALPGEN
- Background due to multi-jet production determined from data using a sample of like-sign di-lepton events with inverted lepton quality cuts

Systematics

	ee		$e\mu$		$\mu\mu$	
M_H (GeV)	Signal	BG	Signal	BG	Signal	BG
100	8.3	9.5	6.4	11.4	7.8	7.2
120	8.3	8.6	6.7	13.6	7.3	7.5
140	6.4	6.7	6.9	13.6	7.2	8.3
160	6.6	7.3	6.7	12.0	7.1	8.3
180	6.9	10.3	6.6	13.0	7.3	14.6
200	6.8	10.6	6.1	12.3	6.9	18.1

- Total systematic uncertainties (in %)
  - Excludes 6.5% contribution from luminosity uncertainty
- Largest contributions
  - Background
    - Jet energy scale for low Higgs masses due to the large W+jet/γ background, and W boson pair production for high Higgs masses
  - Signal
    - Parton distribution function

Expected & Observed Upper Limits



- Modified frequentist method - T. Junk, NIM A434, 1999.
- Combination of three decay channels for six different Higgs boson masses
- Different values are due to different bkg expectations & signal efficiencies
- Best limits achieved for large Higgs masses as S↑ & B↓

M_H (GeV)	100	120	140	160	180	200
Expected limits (pb)	20.3	9.5	5.9	4.0	3.9	4.5
Observed limits (pb)	18.5	5.6	4.9	3.7	4.1	3.2

Summary

- Searched for the Higgs boson in the $H \rightarrow WW^* \rightarrow ll\nu\nu$ decays in e^+e^-, $e^\pm\mu^\pm$, and $\mu^+\mu^-$ final states
  - Integrated luminosity ~ 300-325 pb^{-1}
- Data is consistent with the expectation from background
- No excess has been observed
  - 95% CL Limits on the production cross section times branching ratio have been derived for six different Higgs boson masses
- Observed and expected cross section limits are compared to predictions from the SM and from an extension including a fourth fermion family
- With this analysis, we are a factor of 2 below expected sensitivity per Higgs sensitivity report
  - See talk by Gregorio Bernardi
- For Winter/Spring 2006 conferences
  - Increased lepton efficiency
  - Improved calorimetry, tracking, Monte Carlo
  - Increased luminosity by factor of ~3

Selection Criteria

	Selection criterion	Value
Cut 1	Preselection	Trigger, ID, leptons with opposite charge and $p_T^{\ell 1} > 15$ GeV and $p_T^{\ell 2} > 10$ GeV ($m_{\mu\mu} > 20\,\mathrm{GeV}$)
Cut 2	Missing transverse energy $\not\!\!E_T$	$\not\!\!E_T > 20\,\mathrm{GeV}$
Cut 3	Scaled $\not\!\!E_T^{Sc}$	$\not\!\!E_T^{Sc} > 15$ (for $N_{Jet} > 0$)
Cut 4	Invariant mass $m_{\ell\ell}$	$m_{\ell\ell} < \mathrm{M_H}/2\,\mathrm{GeV}$ (80 GeV)
Cut 5	Sum of $\mathrm{p_T}$ and $\not\!\!E_T$	$\mathrm{M_H}/2 + 20(10)\,\mathrm{GeV} < p_T^{\ell 1} + p_T^{\ell 2} + \not\!\!E_T < \mathrm{M_H}$
Cut 6	Transverse mass $m_T^{\ell\ell}$	$\mathrm{M_H}/2 < m_T^{\ell\ell} < \mathrm{M_H} - 10\,\mathrm{GeV}$
Cut 7	H_T (scalar sum of p_T^{Jet})	$H_T^{Jet} < 100\,GeV$
Cut 8	Lepton opening angle $\Delta\phi_{\ell\ell}$	$\Delta\phi_{\ell\ell} < 2.0$

$$\not\!\!E_T^{\mathrm{Sc}} = \frac{\not\!\!E_T}{\sqrt{\sum_{\mathrm{jets}} \left(\Delta E^{\mathrm{jet}} \cdot \sin\theta^{\mathrm{jet}} \cdot \cos\Delta\phi\,(\mathrm{jet}, \not\!\!E_T)\right)^2}}$$

$$m_T^{\ell\ell'} = \sqrt{2 p_T^{\ell\ell'} \not\!\!E_T (1 - \cos\Delta\phi(p_T^{\ell\ell'}, \not\!\!E_T))}$$