Search for a Standard Model Higgs boson decaying to b quarks and produced in association with Z/W bosons with the CMS detector

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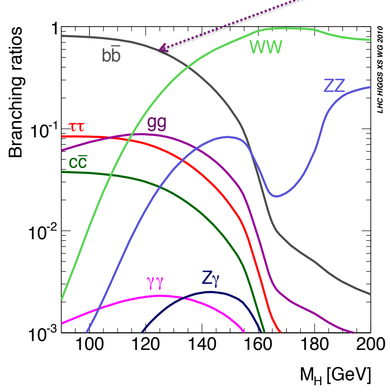
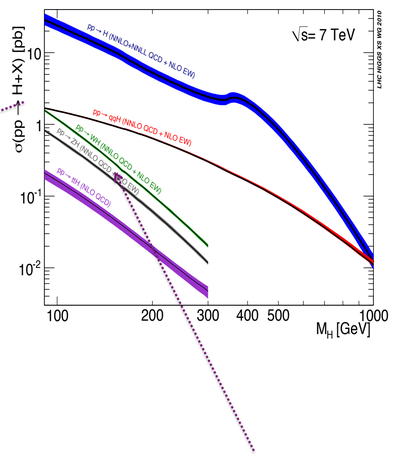
A search for the standard model Higgs boson is performed in a data sample corresponding to an integrated luminosity of 1.1 fb–1, recorded by the CMS detector in proton-proton collisions at the LHC with a 7 TeV center-of-mass energy. The following modes are studied: *W(μν)H, W(eν)H, Z(μμ)H, Z(ee)H* and *Z(νν)H*, with the Higgs decaying to *bb* pairs[*]. 95% C.L. upper limits on the VH production cross section are derived for a Higgs mass between 110 and 135 GeV. The expected (observed) upper limit at 115 GeV is found to be 5.7 (8.3) times the standard model expectation.

Two cut and count analysis performed: mass window (M_{jj} and boosted decision tree (BDT

LHC has delivered ~5 fb^{-1} of integrated luminosity of pp collision data in 2011: benchmark analysis here with 1.1 fb^{-1}

SM Higgs is likely to be at low mass.
In the range [110-135] bb is the predominant BR





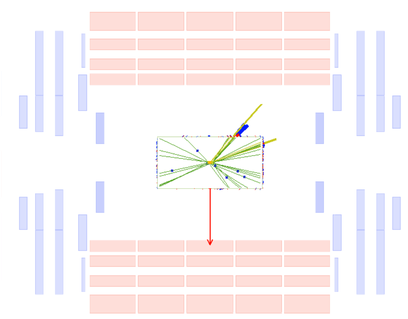
H→bb is overwhelmed by the background.
So we look at associated production with Z/W, paying a price in cross section

Search strategy

Boosted, Topology, QCD rejection

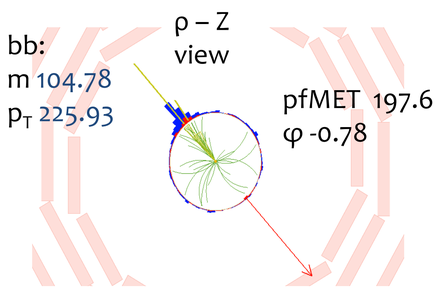
Variable	W($\ell\nu$)H	Z($\ell\ell$)H	Z($\nu\nu$)H
$m_{\ell\ell}$	–	$75 < m_{\ell\ell} < 105$	–
$p_T(b_1)$	> 30	> 20	> 80
$p_T(b_2)$	> 30	> 20	> 30
p_T(jj)	> 165	> 100	> 160
p_T(V)	> 160	> 100	–
CSV1	> 0.898	> 0.898	> 0.898
CSV2	> 0.5	> 0.5	> 0.5
$\Delta\phi$(V,H)	> 2.95	> 2.90	> 2.90
N_{aj}	$= 0$	< 2	–
N_{al}	$= 0$	–	$= 0$
pfMET	> 35(W($e\nu$)H)	–	> 160
pfMETsig	–	–	> 5
$\Delta\phi$(pfMET, J)	–	–	> 1.5
M(jj)(110)	95–125	90–120	95–125
M(jj)(115)	100–130	95–125	100–130
M(jj)(120)	105–135	100–130	105–135
M(jj)(125)	110–140	105–135	110–140
M(jj)(130)	115–145	110–140	115–145
M(jj)(135)	120–150	115–145	120–150

ZννHbb candidate
ρ – Z view



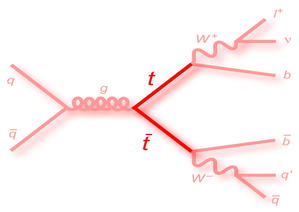
- 2 b-jets
- boosted Z/W (or large MET)
- V and H back to back

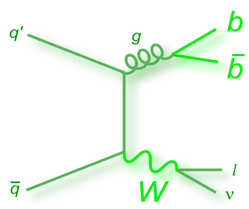
ρ – Z view



Backgrounds

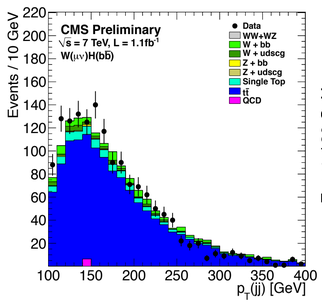
Reducible backgrounds
QCD, V+udscg
ttbar and single top



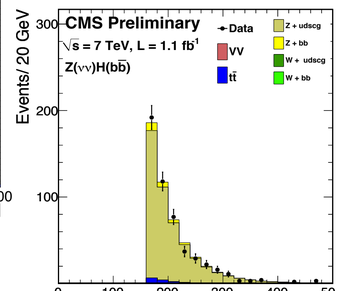


Irreducible backgrounds
V+bb @ high p_T
ZZ(bb), W(lν)Z(bb)

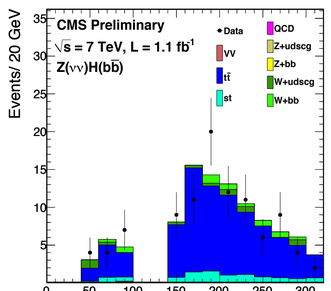
Definition of Control Samples (CS) is crucial
Each CS enriched in different background components,
for example **(2) ttbar** in **WH** analysis: one real b + one fake from W → jj
ZllH: strongly suppressed by Z mass cut
WH: one good btag and additional jet activity
ZinvH: jet activity and presence of leptons
Purity ~90%
data/MC ~1.

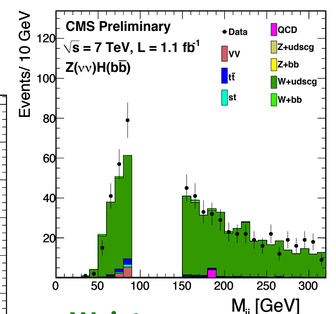


Invisible channel requires special care for CS:
Zνν+jets control:
Use Z → μμ+ jets sample to Re-compute MET



ttbar
ask for one lepton, and b-tag



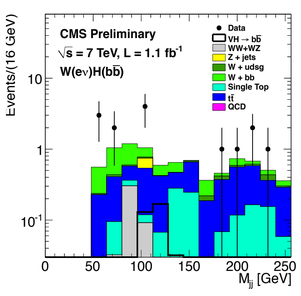


W+jets
ask for one lepton, and no b-tag

M_{jj} and BDT

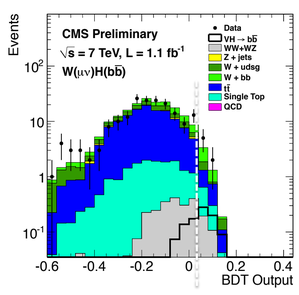
M_{jj} cut and count analysis in the di-jet invariant mass.
Tight selection on most discriminating variables and count events in sliding mass window around the simulated Higgs

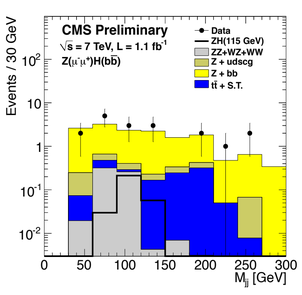
Multivariate Analysis:
Apply looser pre-selection cuts and exploit BDT discriminating power,
count events in enriched signal BDT output region
We use 8 discriminating variables



WH ele: M_{jj} final numbers

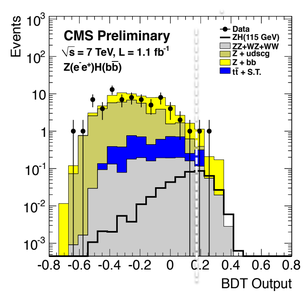
Process	110 GeV	115 GeV	120 GeV	125 GeV	130 GeV	135 GeV
W + udscg	0.036 ± 0.015	0.01 ± 0.004	0.011 ± 0.004	0.013 ± 0.005	0.012 ± 0.005	0.027 ± 0.011
Wbb̄	0.442 ± 0.120	0.344 ± 0.093	0.375 ± 0.102	0.370 ± 0.100	0.32 ± 0.087	0.265 ± 0.072
Z+jets	0.204 ± 0.146	0.204 ± 0.146	0	0	0	0
tt̄	0.767 ± 0.193	0.543 ± 0.136	0.543 ± 0.136	0.503 ± 0.126	0.568 ± 0.143	0.403 ± 0.101
ST	0.076 ± 0.030	0.122 ± 0.049	0.181 ± 0.072	0.283 ± 0.113	0.32 ± 0.128	0.385 ± 0.154
VV	0.134 ± 0.053	0.065 ± 0.026	0.045 ± 0.018	0.042 ± 0.017	0.033 ± 0.013	0.029 ± 0.012
B_{exp}	1.66 ± 0.299	1.288 ± 0.242	1.155 ± 0.206	1.211 ± 0.217	1.253 ± 0.228	1.109 ± 0.209
WH	0.263 ± 0.074	0.296 ± 0.083	0.203 ± 0.057	0.201 ± 0.056	0.142 ± 0.040	0.123 ± 0.034
ZH	0.004 ± 0.001	0.002 ± 0.001	0.003 ± 0.001	0.002 ± 0.001	0.002 ± 0.001	0.001 ± 0.001
N_{obs}	4	4	1	1	0	0





ZllH μ: M_{jj} final numbers

Process	110 GeV	115 GeV	120 GeV	125 GeV	130 GeV	135 GeV
Z + udscg	0.110 ± 0.064	0.110 ± 0.065	0.110 ± 0.065	0.110 ± 0.065	0.150 ± 0.069	0.110 ± 0.065
Zbb̄	1.930 ± 0.337	2.050 ± 0.396	1.650 ± 0.373	1.740 ± 0.378	1.660 ± 0.375	1.600 ± 0.361
tt̄ + ST	0.030 ± 0.031	0.090 ± 0.036	0.140 ± 0.044	0.140 ± 0.044	0.190 ± 0.053	0.190 ± 0.127
VV	0.260 ± 0.100	0.160 ± 0.064	0.070 ± 0.033	0.030 ± 0.023	0.020 ± 0.021	0.010 ± 0.011
B_{exp}	2.330 ± 0.363	2.410 ± 0.358	1.970 ± 0.348	2.020 ± 0.348	2.020 ± 0.351	1.910 ± 0.356
S	0.218 ± 0.057	0.195 ± 0.051	0.152 ± 0.040	0.128 ± 0.033	0.102 ± 0.027	0.077 ± 0.020
N_{obs}	3	3	3	3	2	3



Systematics and limits

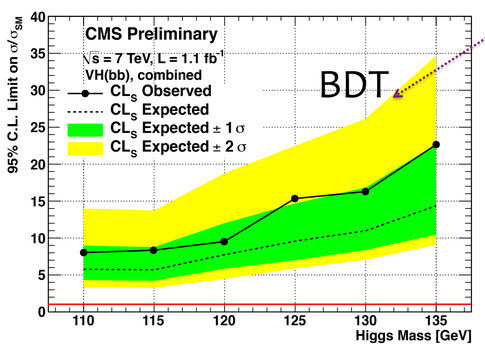
The total yield uncertainty on the signal prediction is around 26% for ZH and WH production.

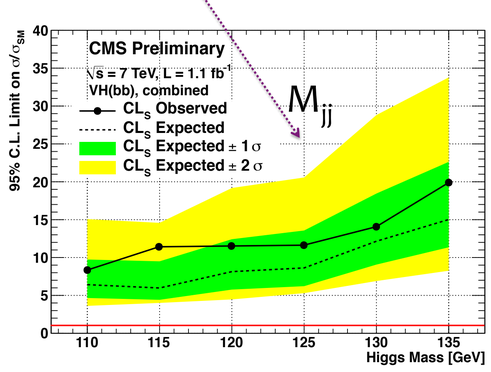
Background yield uncertainties range from 12% to 20% depending on mode and mass point.

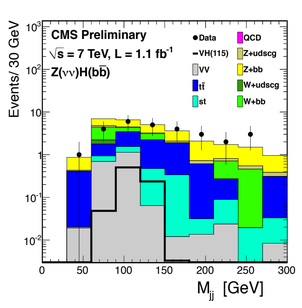
Efficiencies:
Lepton momentum scale and calib (2.0%)
Lepton identification and trigger: 1%,2%
MET triggers: 5%
MET resolution: 3%
B-tagging: 10%/jet
Luminosity: 4.5%
JER and JEC: Evaluate impact of jet scale on di-jet mass resolution and efficiency; JEC (~1%) JER (~10%)

Signal: **Higgs cross-section**: 4% using NNLO from LHC WG, **p_T spectrum** in the analysis regime: 5(10)% for Z(W)H due to electroweak corrections [**] and 10% from QCD (NNLO vs NLO [***])

Background:
Shapes are checked in appropriate control regions, corresponding systematic ttbar (8%), V+jets (light: 7%, heavy: 30%), VV (theory:4%, efficiency 30% as VH), single top (30%)
MC statistics: 1-4%
Everything goes in data-card to get limits

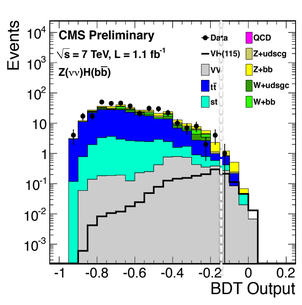






ZννH: M_{jj} final numbers

Process	110 GeV	115 GeV	120 GeV	125 GeV	130 GeV	135 GeV
W + udscg	0.024 ± 0.007	0.023 ± 0.007	0.022 ± 0.007	0.019 ± 0.006	0.014 ± 0.004	0.012 ± 0.004
Wbb+ tt̄	2.030 ± 0.609	1.780 ± 0.534	2.050 ± 0.615	2.360 ± 0.708	2.420 ± 0.726	2.110 ± 0.633
Z + udscg	0.180 ± 0.039	0.180 ± 0.039	0.140 ± 0.030	0.130 ± 0.028	0.120 ± 0.026	0.130 ± 0.028
Zbb	1.970 ± 0.603	1.890 ± 0.578	1.790 ± 0.548	1.710 ± 0.523	1.780 ± 0.545	1.810 ± 0.554
ST	0.460 ± 0.174	0.460 ± 0.174	0.410 ± 0.155	0.410 ± 0.155	0.460 ± 0.174	0.400 ± 0.152
VV	0.770 ± 0.292	0.460 ± 0.174	0.410 ± 0.155	0.110 ± 0.042	0.080 ± 0.030	0.070 ± 0.027
B_{exp}	5.434 ± 1.069	4.793 ± 0.938	4.822 ± 0.958	4.739 ± 0.969	4.874 ± 0.998	4.532 ± 0.918
S	0.669 ± 0.174	0.593 ± 0.154	0.417 ± 0.108	0.442 ± 0.115	0.326 ± 0.085	0.245 ± 0.064
N_{obs}	6	5	5	5	6	5



M_H(GeV)	BDT Expected	BDT Observed	M(jj) Expected	M(jj) Observed
110	5.8	8.0	6.4	8.2
115	5.7	8.3	6.0	11.3
120	7.7	9.5	8.1	11.4
125	9.6	15.3	8.6	11.6
130	11.0	16.3	12.1	14.0
135	14.4	22.5	15.0	19.9

BDT ~10% better than M_{jj} analyses

CLs method currently recommended by the LHC Higgs Combination Group.
The expected (observed) upper limit at 115 GeV is found to be 5.7 (8.3) times the Standard Model expectation

Observed data consistent with background expectation!

LHC will likely provide more than 10 fb^{-1} by the end of 2012: VHbb will help at low mass to find or ruled out a Standard Model Higgs.
In order to do that: improve analysis (BDT especially) and beat experimental systematics related to (b)jets and background subtraction!!!

[*] CMS PAS IG-11-012, "Search for the Standard Model Higgs Boson Decaying to Bottom Quarks and Produced in Association with a W or a Z Boson", CMS Collaboration" http://cdsweb.cern.ch/record/1376636
[**] http://arxiv.org/abs/0710.4749
[***] http://www.arxiv.org/abs/1107.1164