Search of Standard Model Higgs decaying in two b

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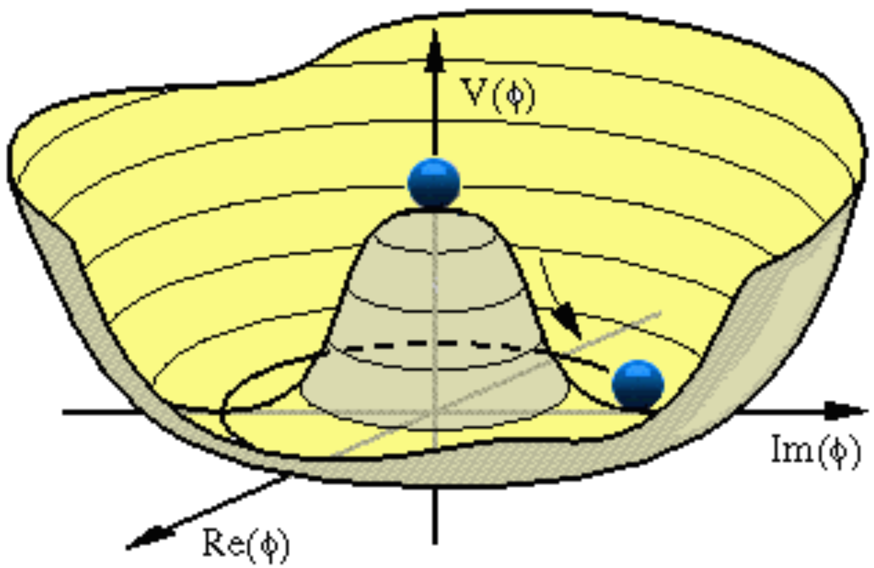
ETH Zurich

29 August 2011

Outline

- Higgs search status
- Low mass Higgs at LHC



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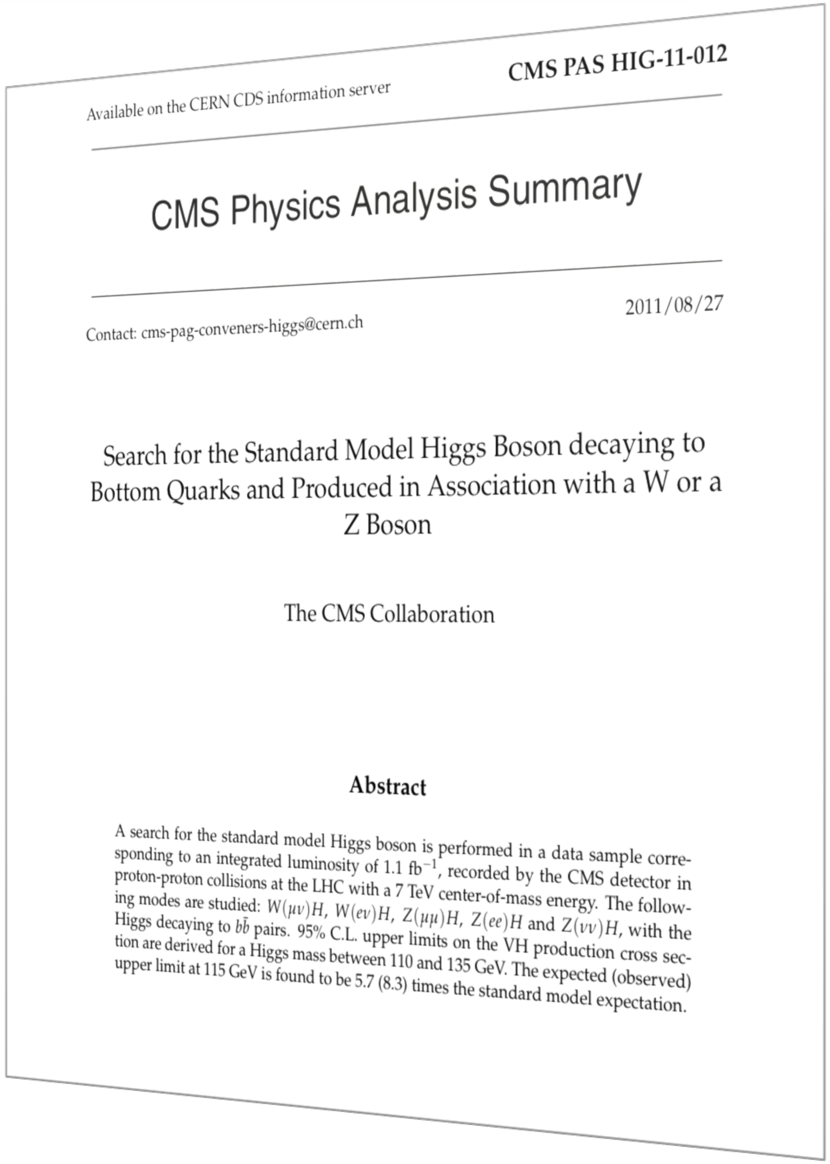
- Low mass Higgs at LHC
- **Analysis strategy**
  - Cut and Count
  - Multi Variate Analysis
- **Control samples**
- **Systematics**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CMS PAS HIG-11-012

CMS Physics Analysis Summary

Contact: cms-pag-conveners-higgs@cern.ch

2011/08/27

Search for the Standard Model Higgs Boson decaying to Bottom Quarks and Produced in Association with a W or a Z Boson

The CMS Collaboration

Abstract

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: $W(\mu\nu)H$, $W(e\nu)H$, $Z(\mu\mu)H$, $Z(ee)H$ and $Z(\nu\nu)H$, with the Higgs decaying to $b\bar{b}$ 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.

HIG-11-012

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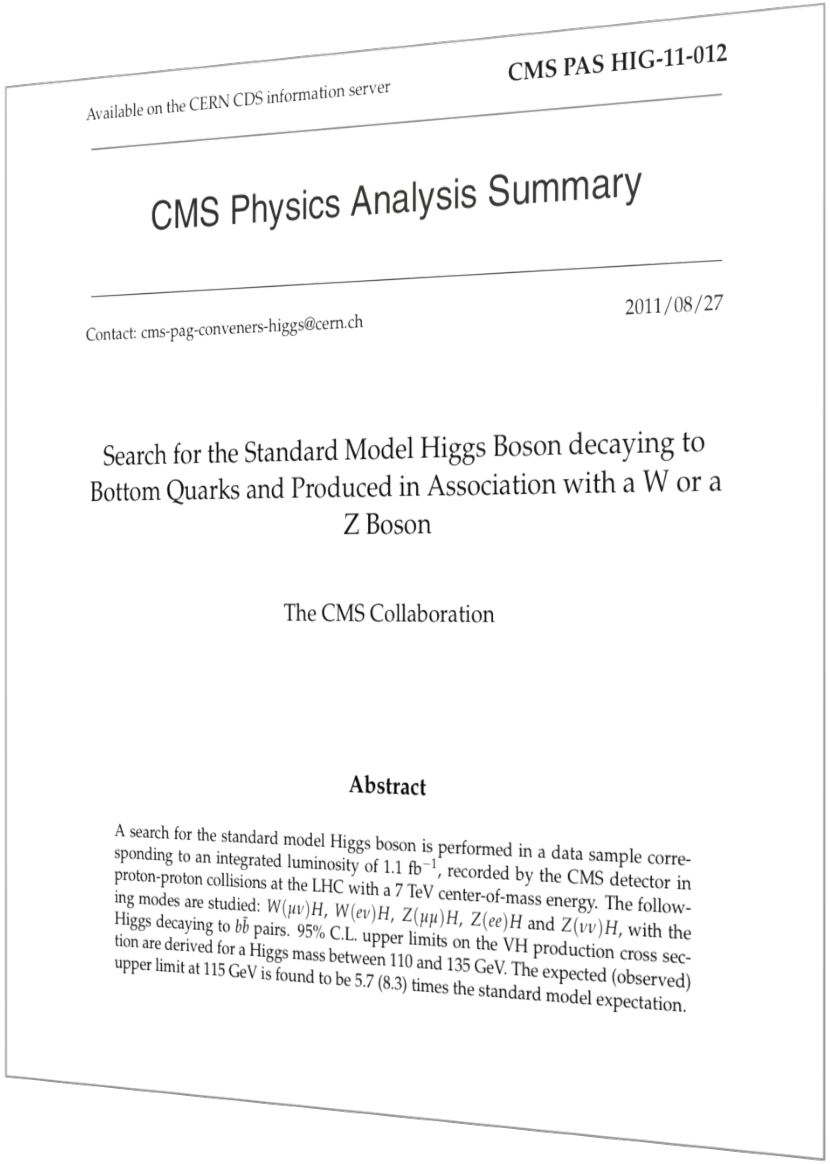
- **Results**
- **Conclusion**



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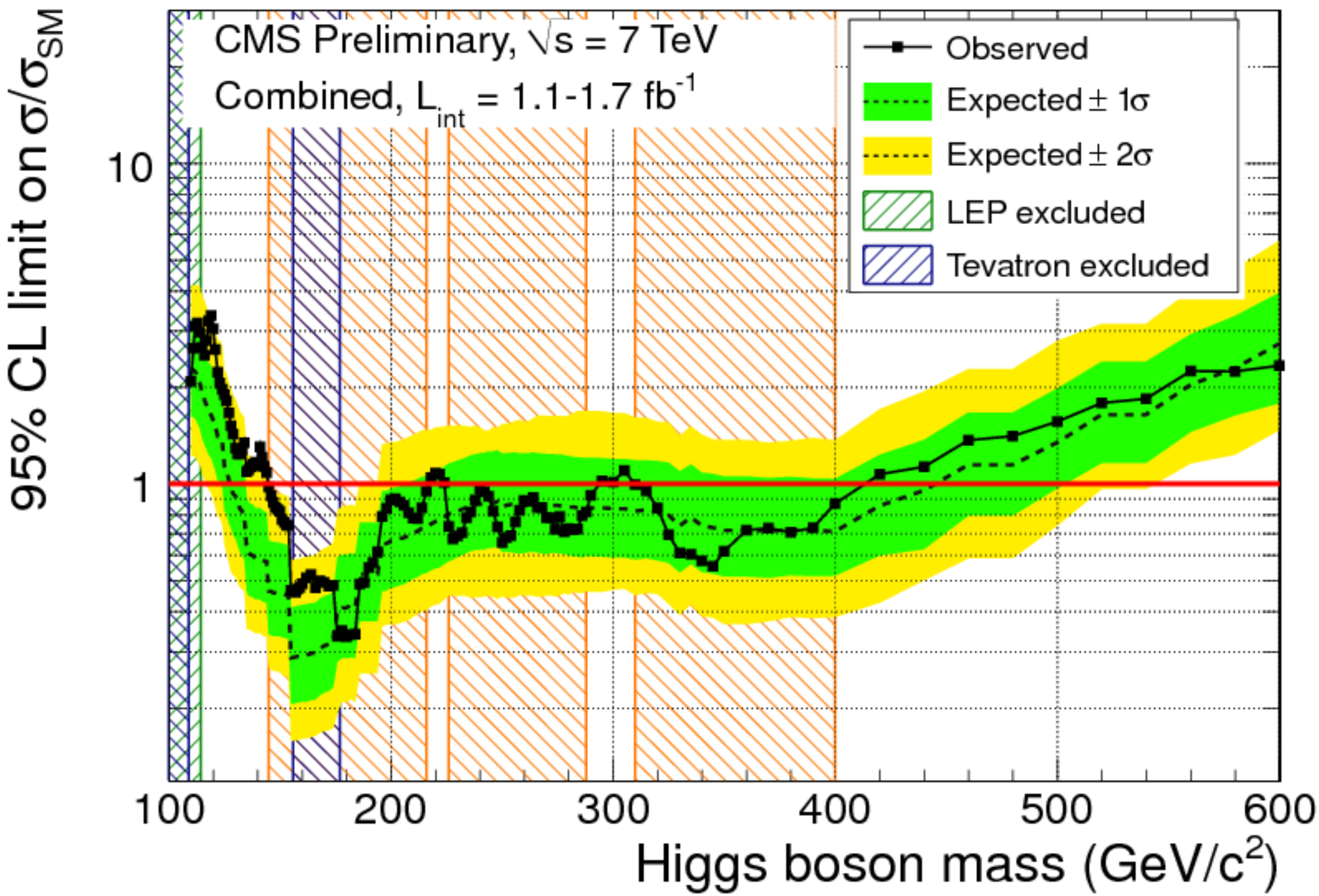
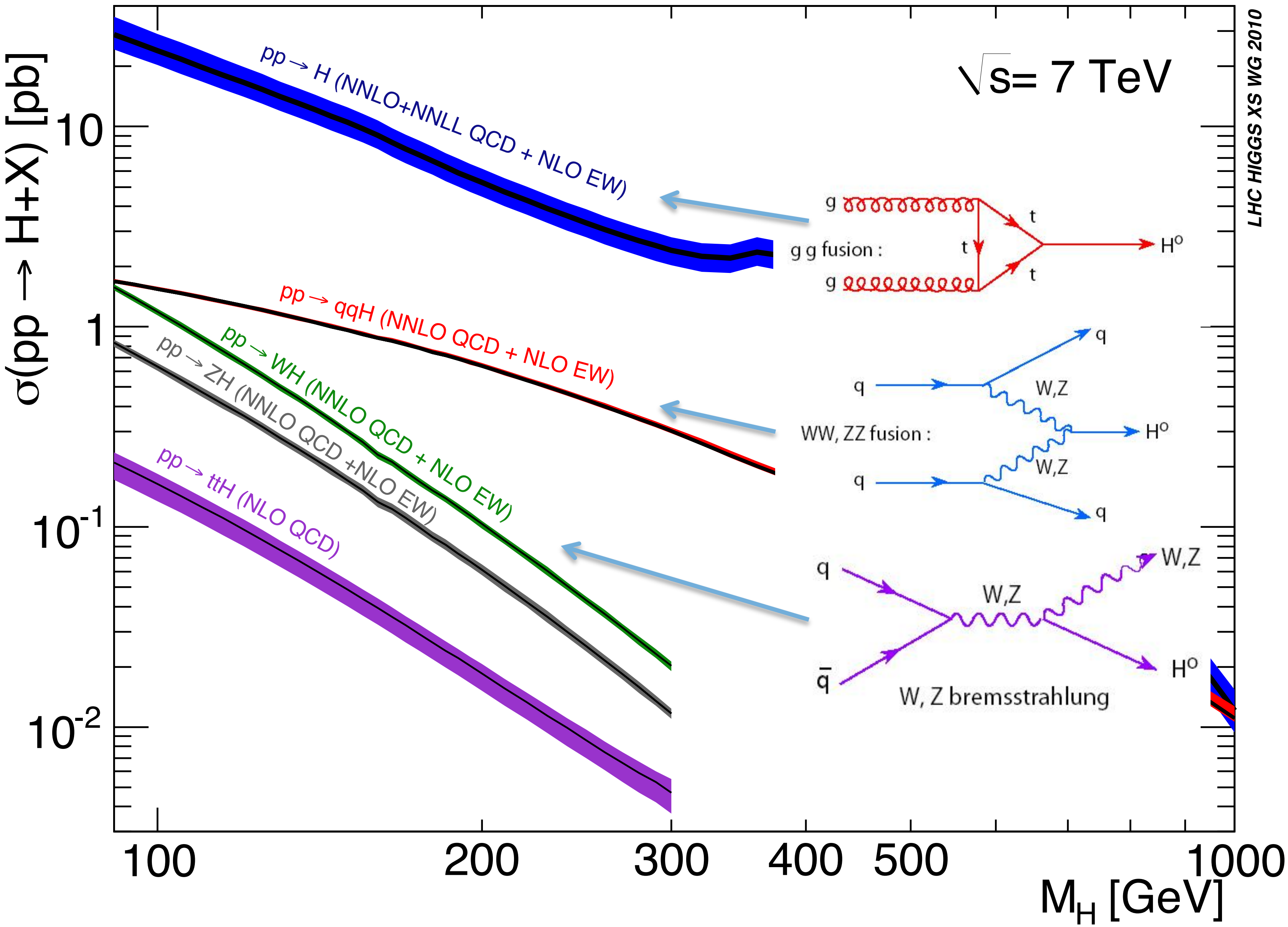
HIG-11-012

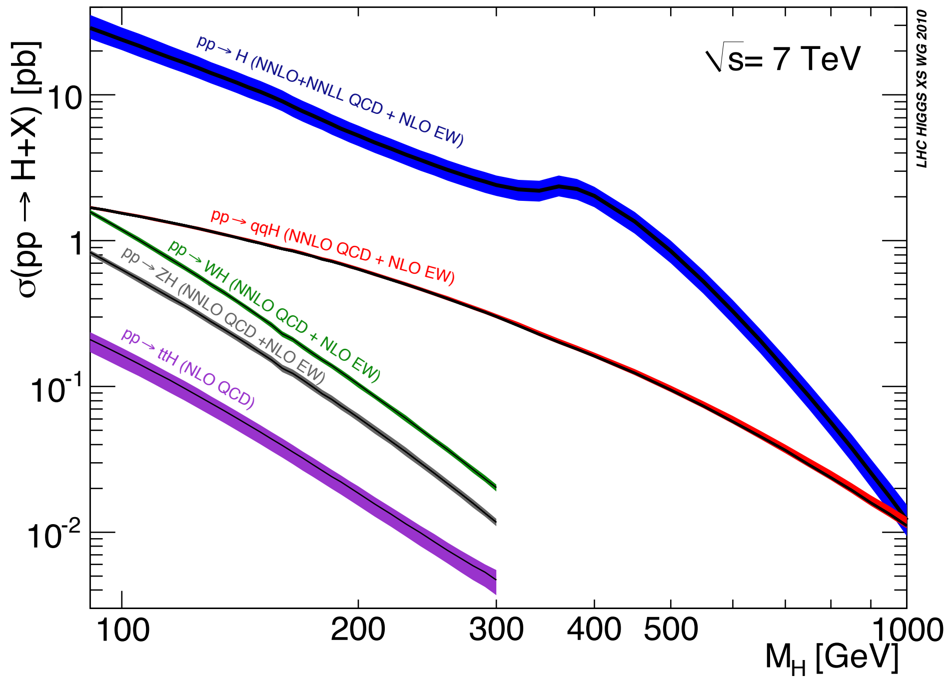
Higgs search status

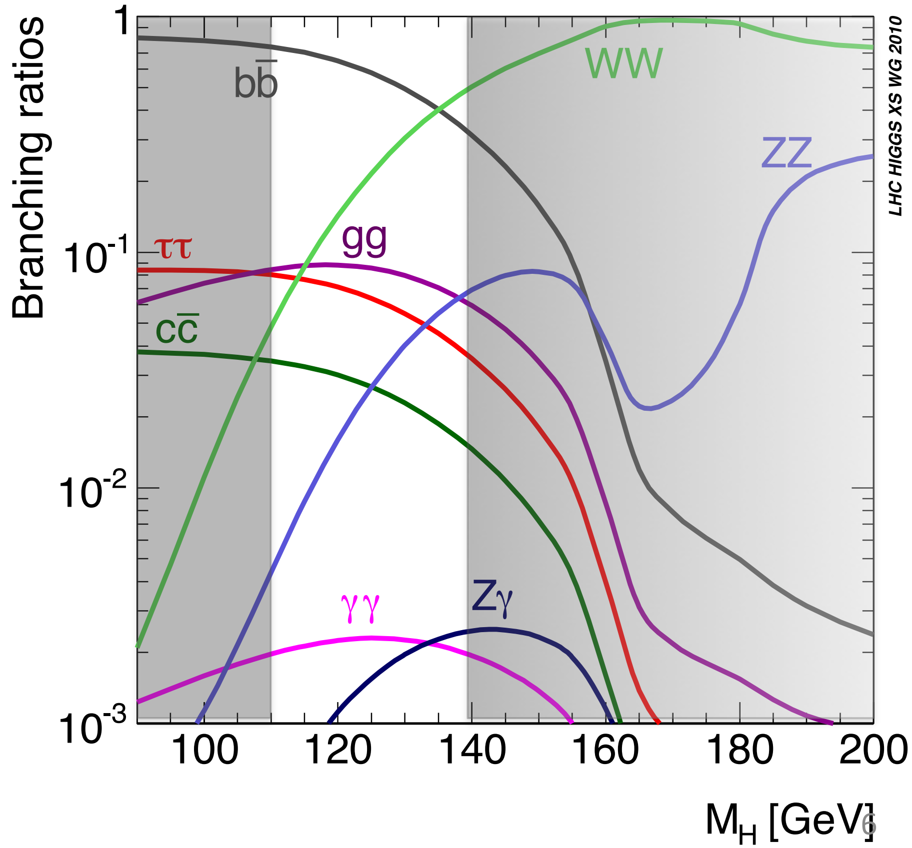


Low mass Higgs at LHC

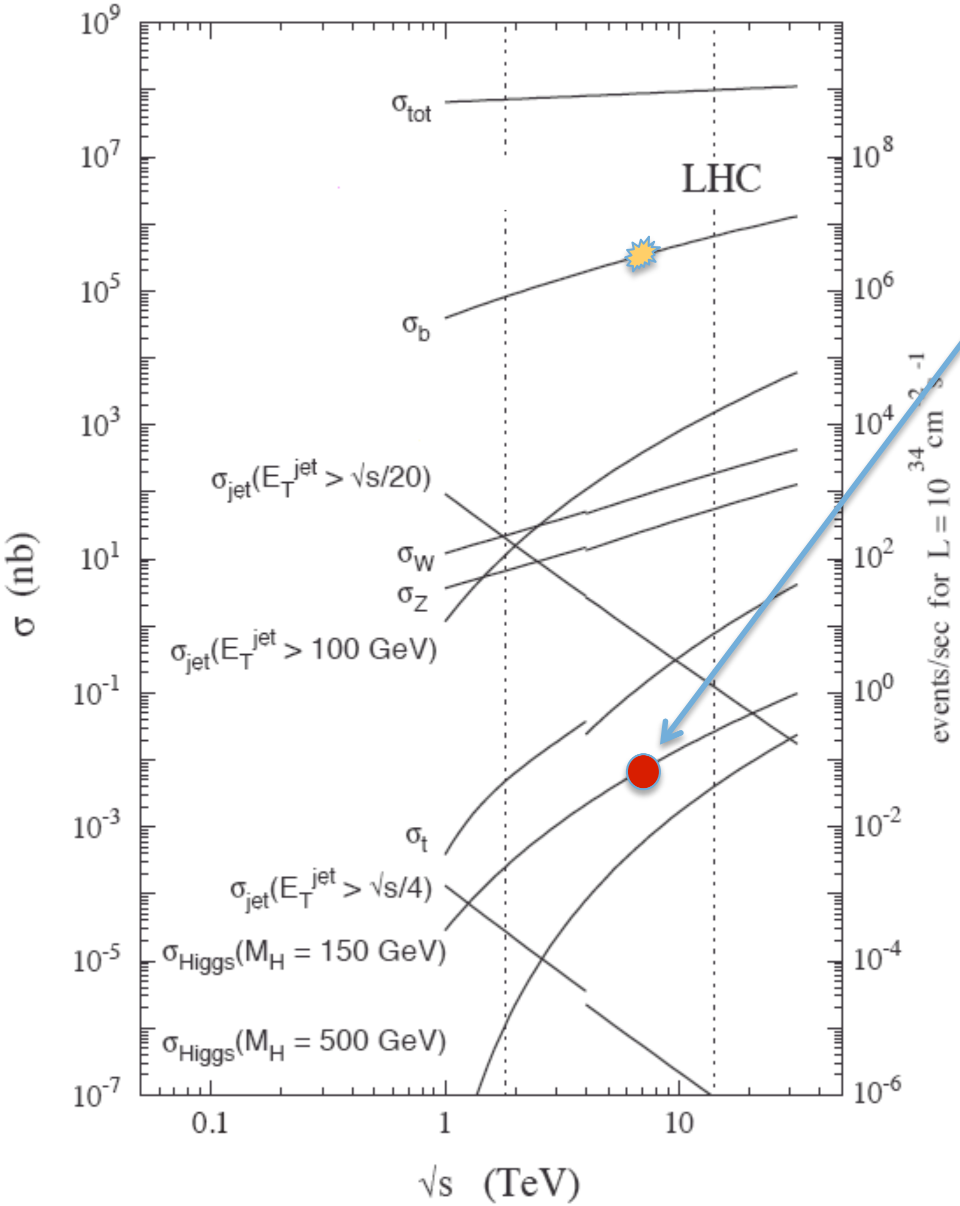


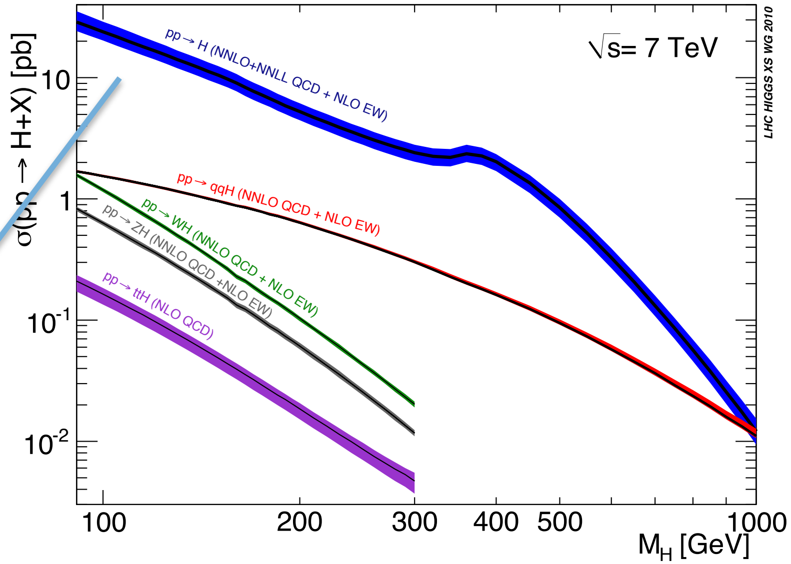
Low mass Higgs at LHC

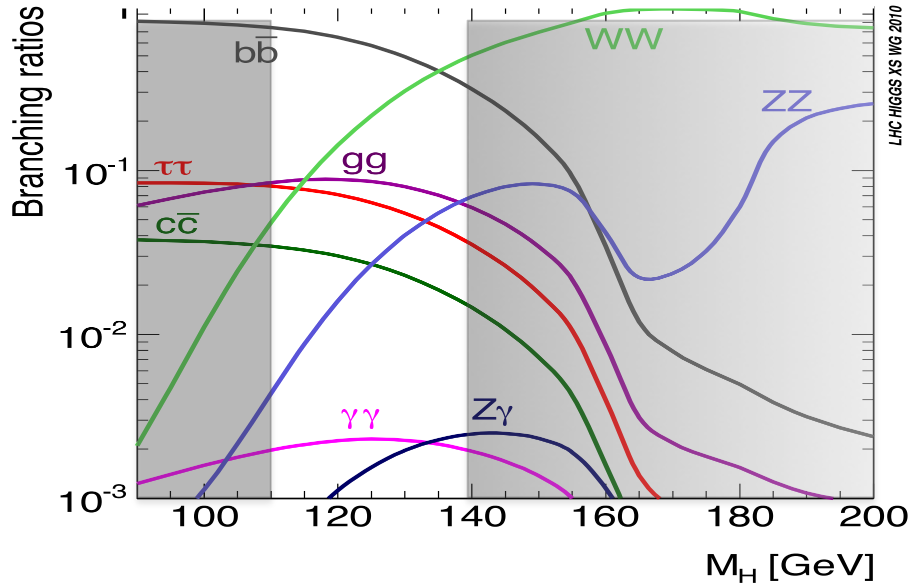




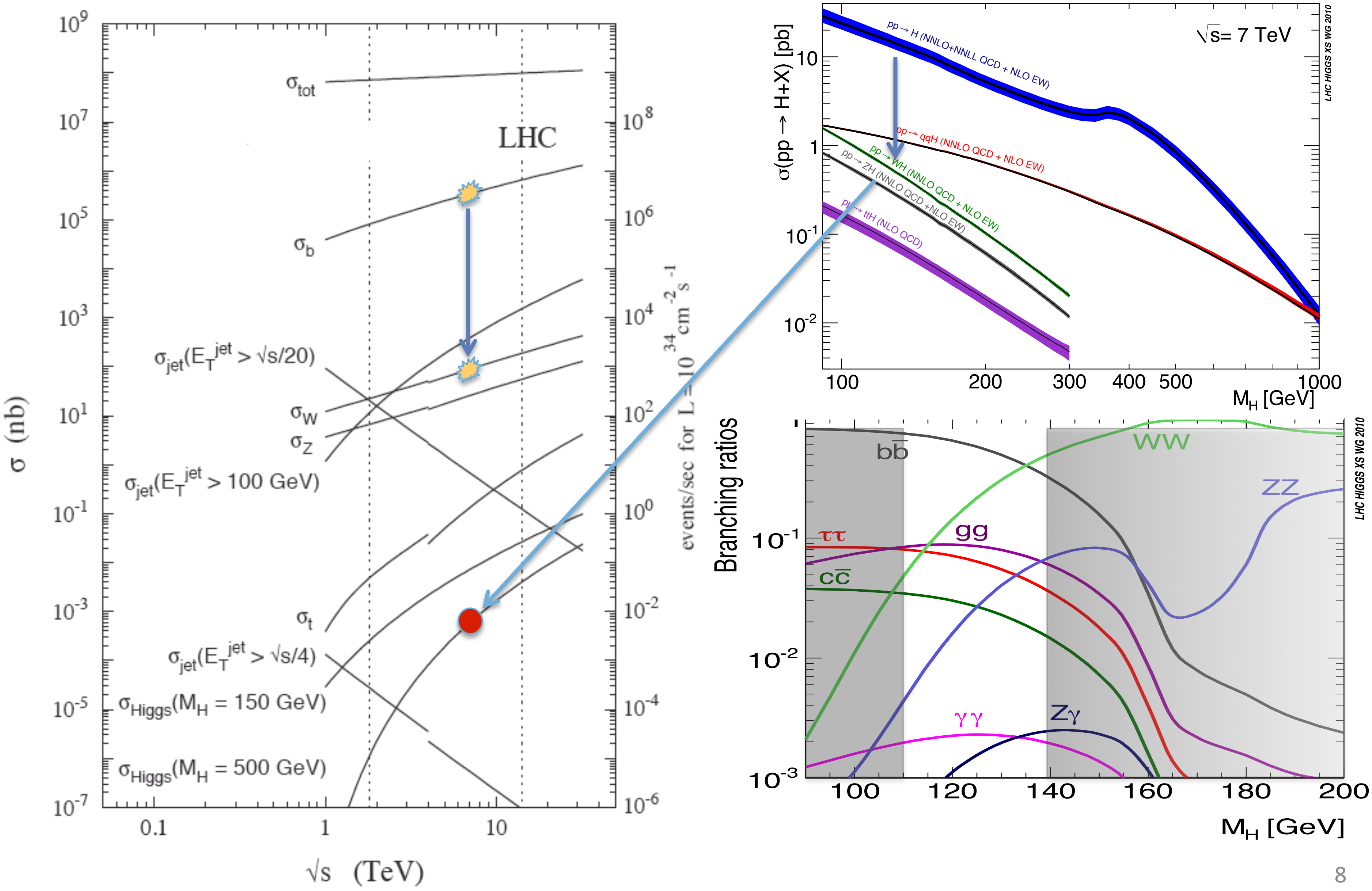
Low mass Higgs at LHC



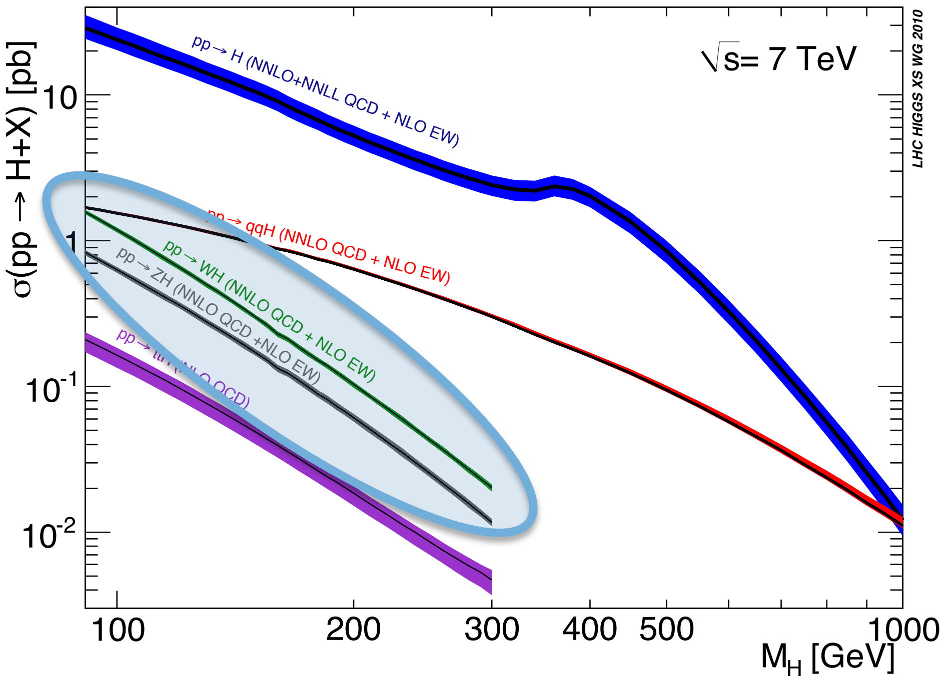


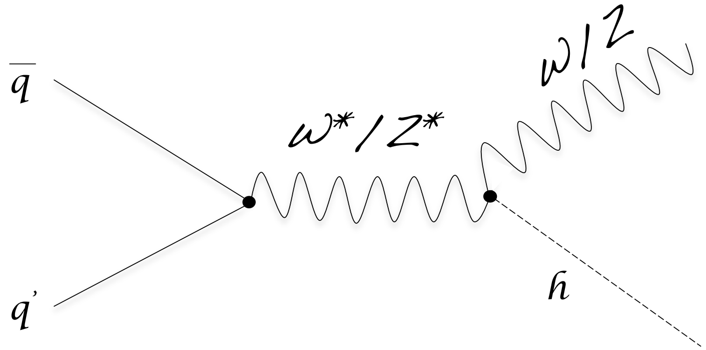


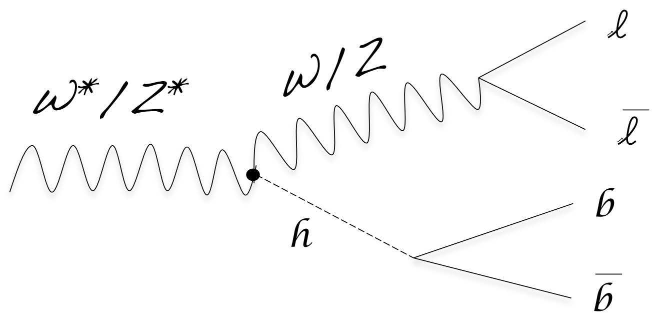
Low mass Higgs at LHC

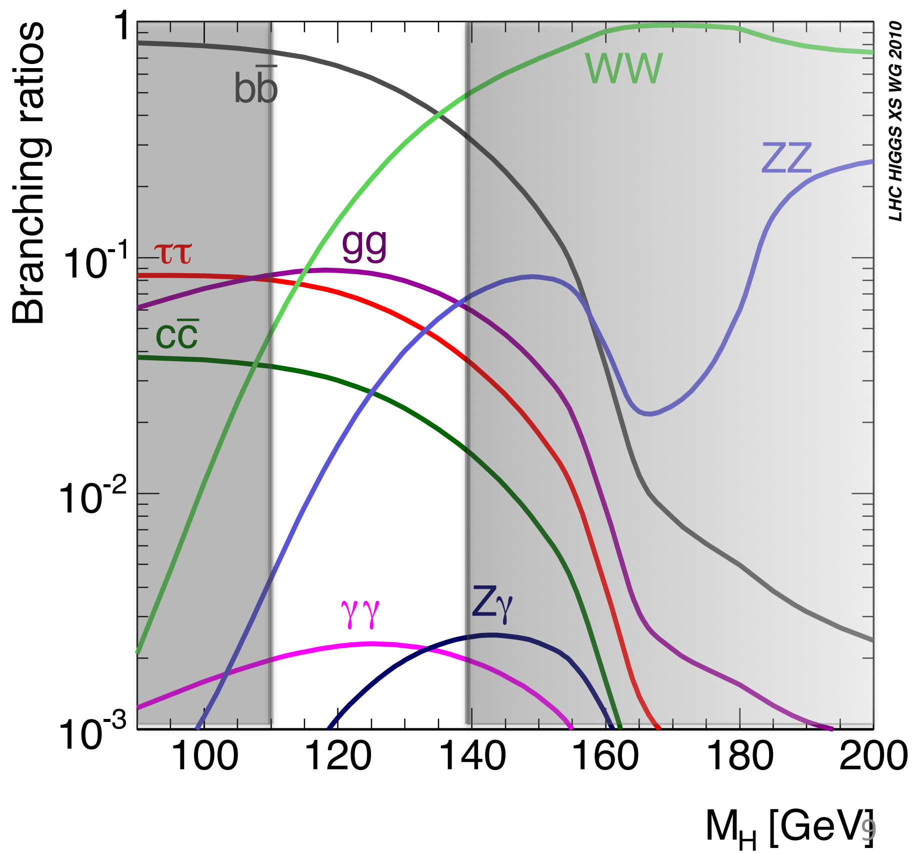


Low mass Higgs at LHC



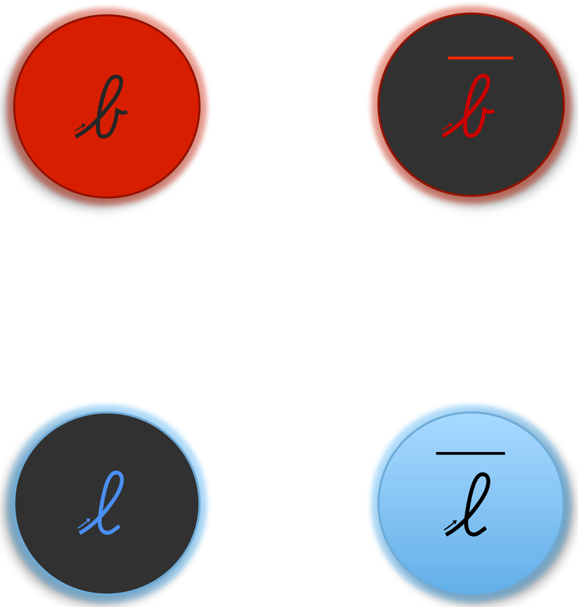




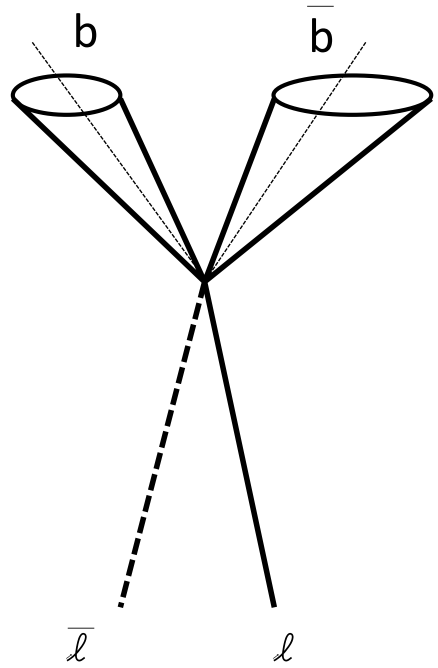


Analysis techniques

Ingredients

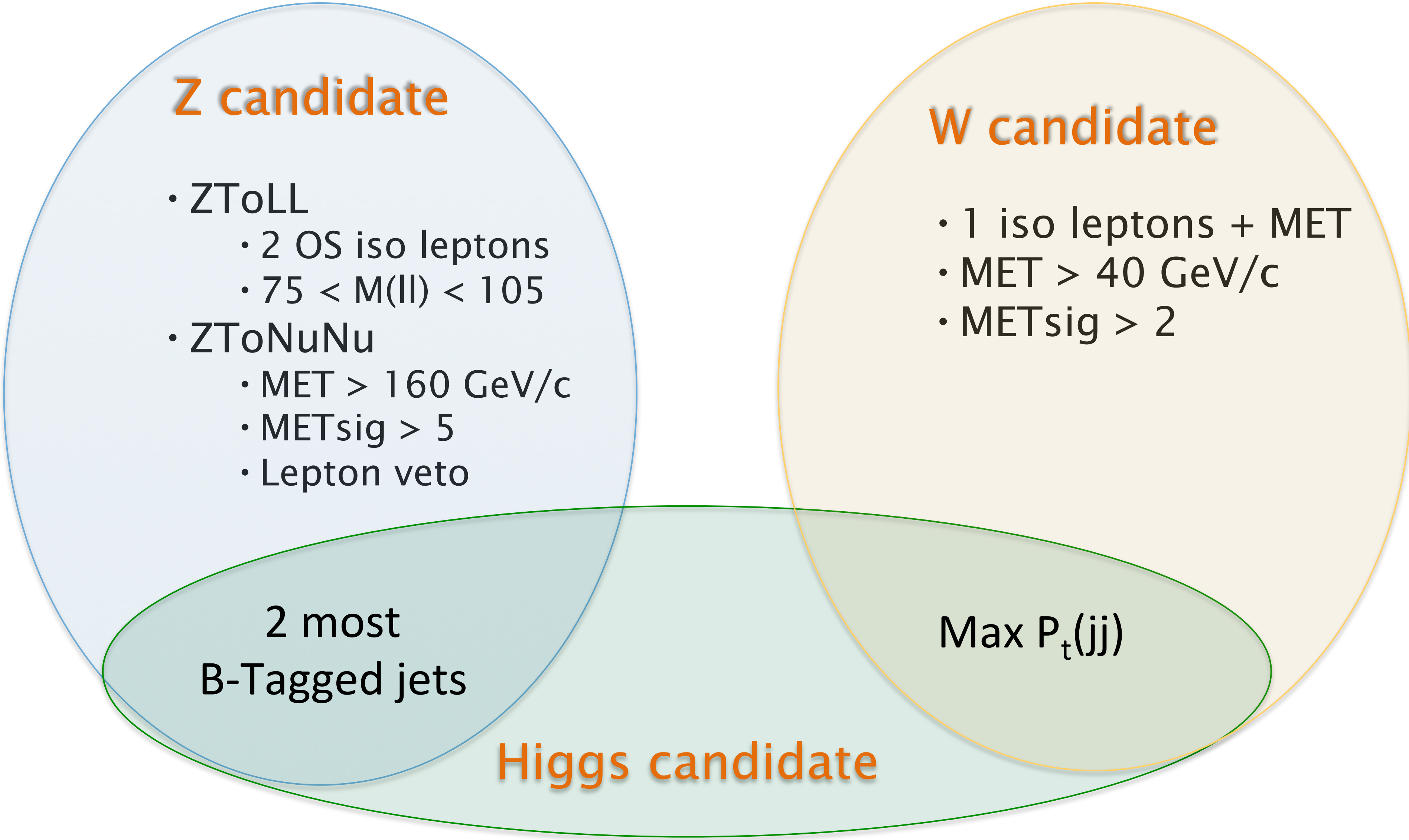


$H \longrightarrow bb$

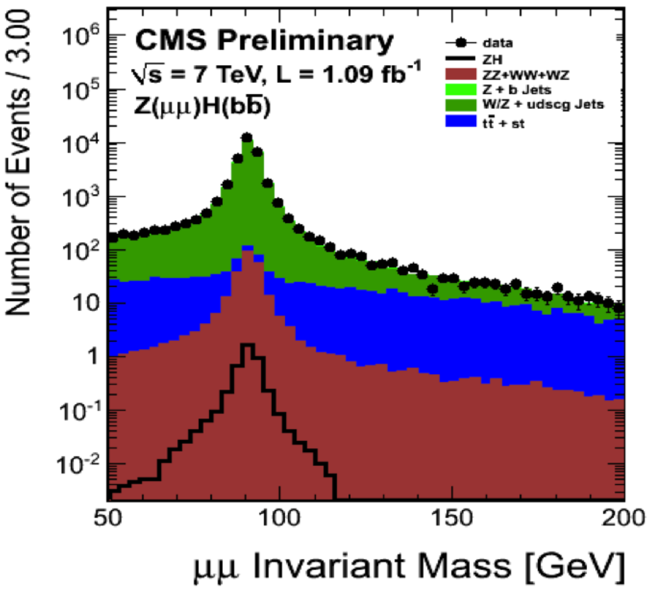


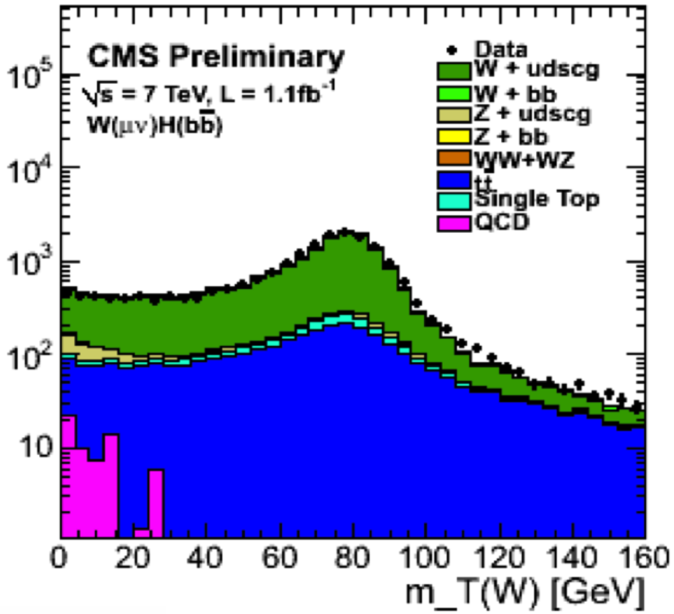
$W \longrightarrow l\nu$; $Z \longrightarrow l^+l^-$; $Z \longrightarrow \nu\nu$

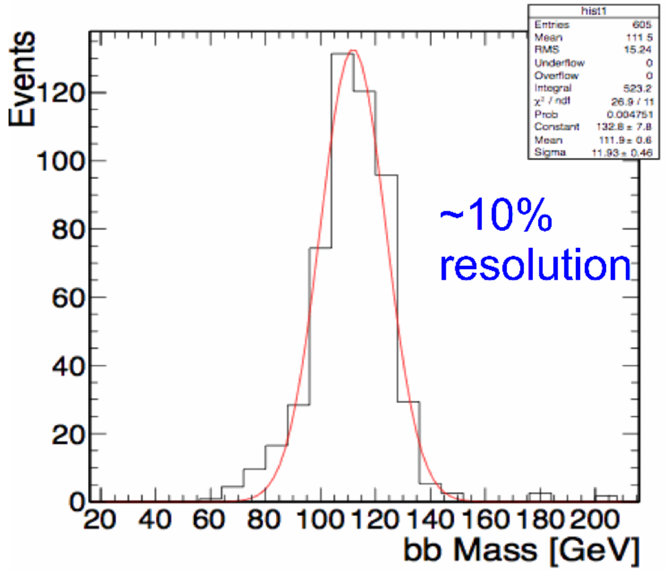
Higher level object



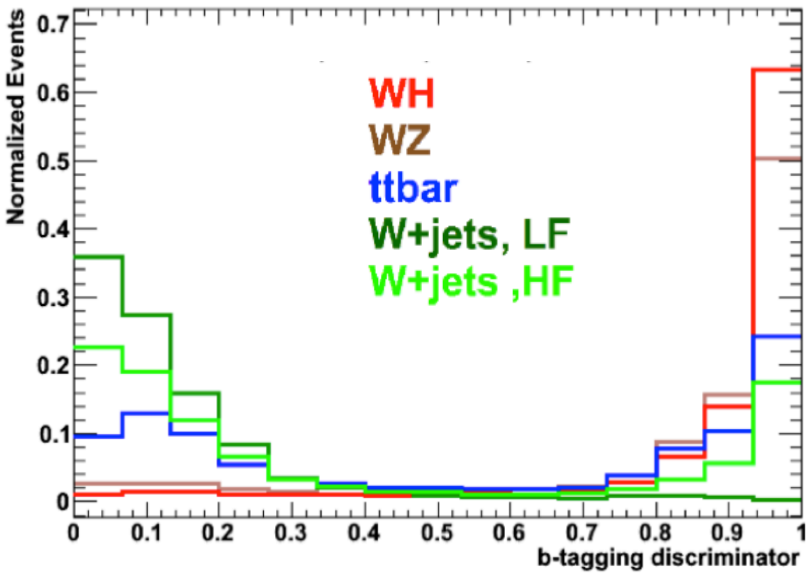
Mass resolution

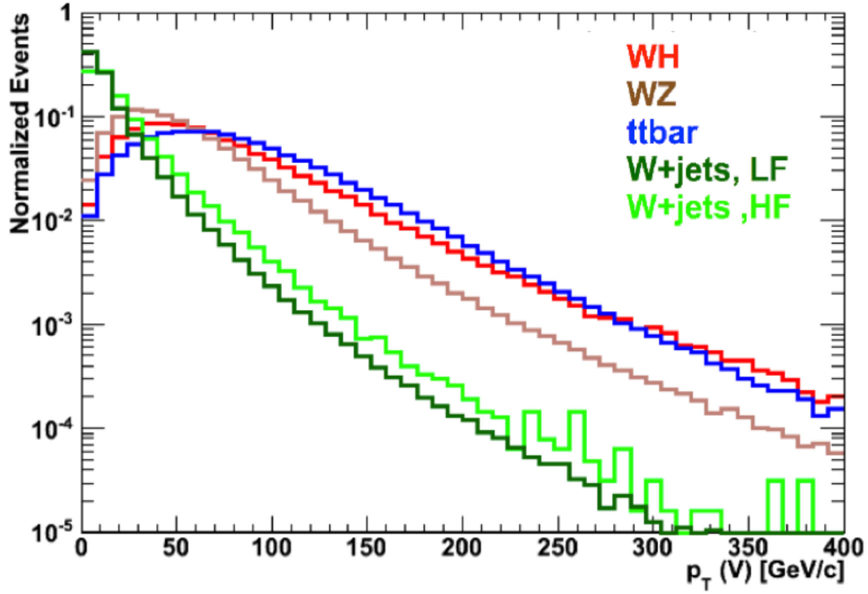


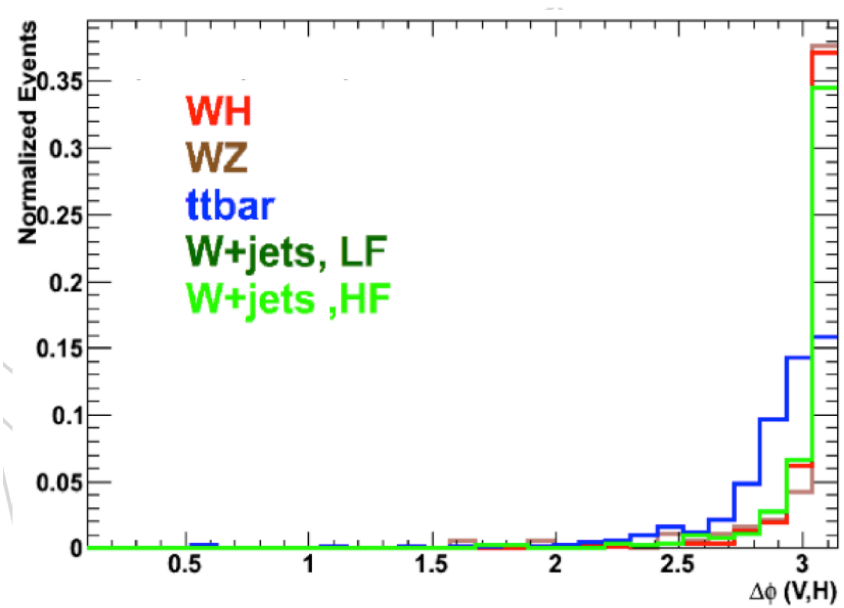


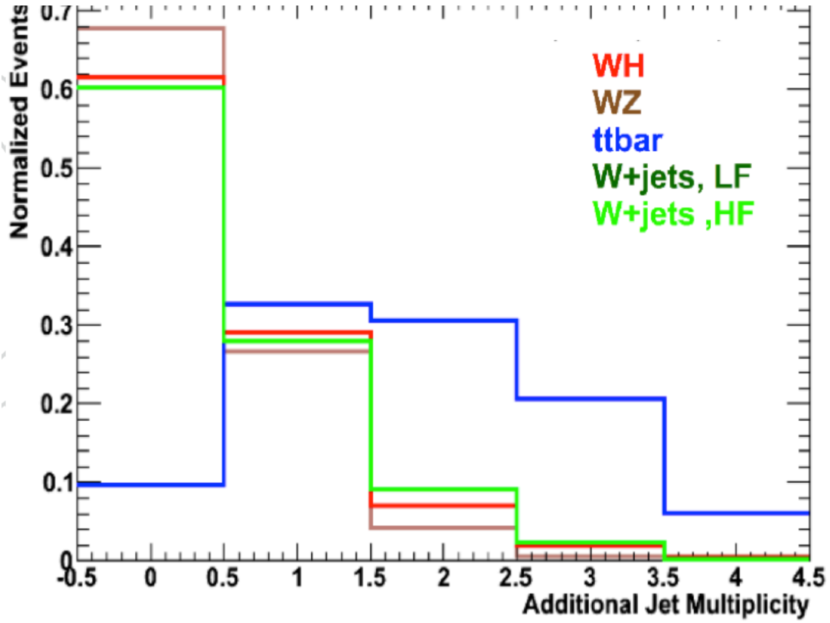


Discriminating variables









Analysis strategy

Cut and Count

Variable	$W(\ell\nu)H$	$Z(\ell\ell)H$	$Z(\nu\nu)H$
$p_T(b_1)$	> 30	> 20	> 80
$p_T(b_2)$	> 30	> 20	> 30
$p_T(jj)$	> 165	> 100	> 160
$p_T(V)$	> 160	> 100	–
CSV1	CSVT	CSVT	CSVT
CSV2	> 0.52	> 0.5	> 0.5
$\Delta\phi(V,H)$	> 2.95	> 2.90	> 2.90
N_{aj}	$= 0$	< 2	–
N_{al}	$= 0$	–	$= 0$
pfMET	–	–	> 160
pfMETsig	–	–	> 5
$\Delta\phi(\text{pfMET},J)$	–	–	> 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

Boost decision tree

Variable
$M(jj)$: dijet invariant mass
$Z(\ell\ell)$: dilepton invariant mass; in
$p_T(jj)$: dijet transverse momentum
$p_T(V)$: vector boson transverse momentum
CSV1: max(CSV1,CSV2)
CSV2: min(CSV1,CSV2)
$\Delta\phi(W,H)$: azimuthal angle between V and dijet
$\Delta\eta(J1,J2)$; different in η between Higgs daughters
N_{aj}: number of additional central jets (in WH and $Z(\nu\nu)H$)

Preselection

Variable	$W(\mu\nu)H$	$W(e\nu)H$	$Z(\mu\mu)H$	$Z(ee)H$	$Z(\nu\nu)H$
$p_T(b_1)$	> 30	> 30	> 20	> 20	> 80
$p_T(b_2)$	> 30	> 30	> 20	> 20	> 20
$p_T(jj)$	> 150	> 150	–	–	> 160
$p_T(V)$	> 150	> 150	–	–	–
CSV1	> 0.40	> 0.40	> 0.50	> 0.50	> 0.50
CSV2	> 0.40	> 0.40	> 0.50	> 0.50	> 0.50
N_{aj}	–	–	< 2	< 2	–
N_{al}	$= 0$	$= 0$	–	–	$= 0$
$\Delta\phi(V,H)$	–	–	> 2.4	> 2.4	–
$\Delta\phi(\text{pfMET},J)$	–	–	–	–	> 0.5
pfMETsig	–	> 2	–	–	> 5
BDT	> 0.05	> 0.06	> -0.25	> 0.10	> -0.17

Control samples

Three different control samples

V + LIGHT FLAVOUR

Variable	W(ℓν)H	Z(ℓℓ)H
$p_T(b_1)$	> 30	> 20
$p_T(b_2)$	> 30	> 20
p_T(jj)	> 150	> 100
p_T(V)	> 150	> 100
CSV1	.not.CSVM	.not.CSVL
CSV2	.not.CSVM	.not.CSVL
N_{aj}	< 2	< 2
pfMETsig	> 2.5	–

TTBAR

Variable	W(ℓν)H	Z(ℓℓ)H
$p_T(b_1)$	> 30	> 20
$p_T(b_2)$	> 30	> 20
p_T(jj)	> 100	> 0
p_T(V)	> 100	> 0
CSV1	CSVT	CSVT
N_{aj}	> 1	> 1
pfMET	–	> 50
$M_{\ell\ell}$	–	> 120

V + HEAVY FLAVOUR

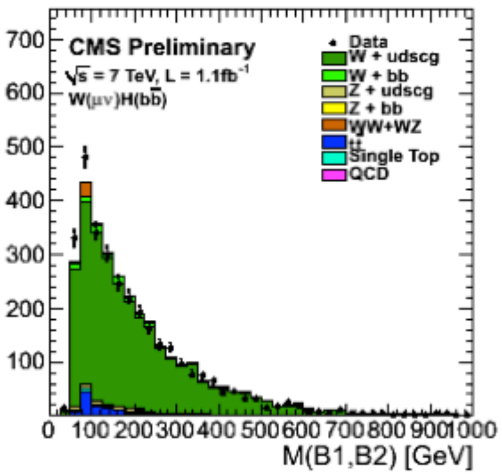
Variable	W(ℓν)H	Z(ℓℓ)H
$p_T(b_1)$	> 30	> 20
$p_T(b_2)$	> 30	> 20
p_T(jj)	< 150	–
p_T(V)	< 150	–
M_T	[40, 120]	–
CSV1	CSVT	CSVT
CSV2	–	CSVT
$\Delta\phi$(V,H)	–	> 2.9
N_{aj}	= 0	< 2
pfMET	–	< 30
pfMETsig	> 2.5	–
M(jj)	–	< 100 || > 140

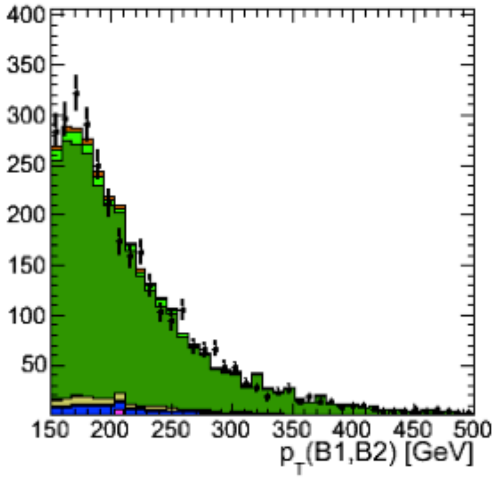
ZNuNu CASE

- remove muons from ZMuMu data and re-reconstruct the event
  - reweighted for branching ratio and acceptance
- Z+HF
  - Veto higgs mass 100-140
- Ttbar
  - require btag
- W+jets
  - veto bjets

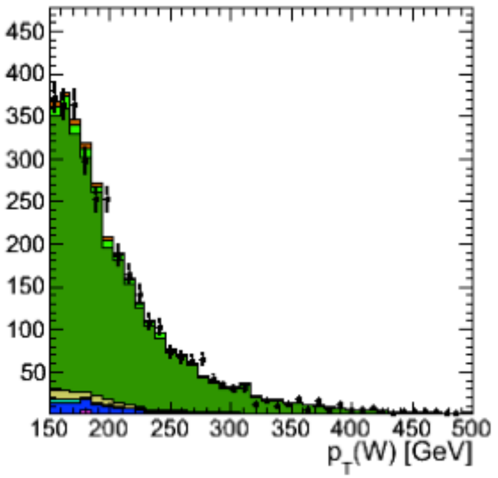
Control samples

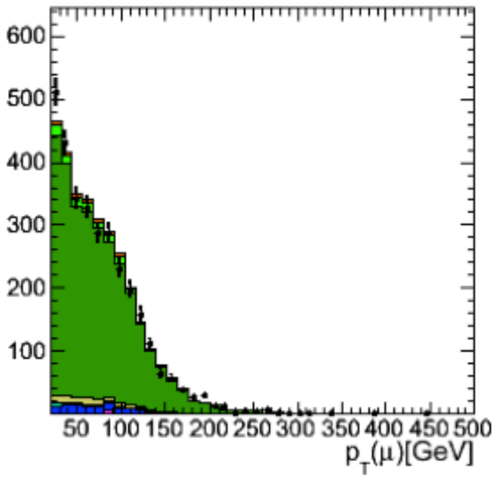
V + LIGHT FLAVOUR

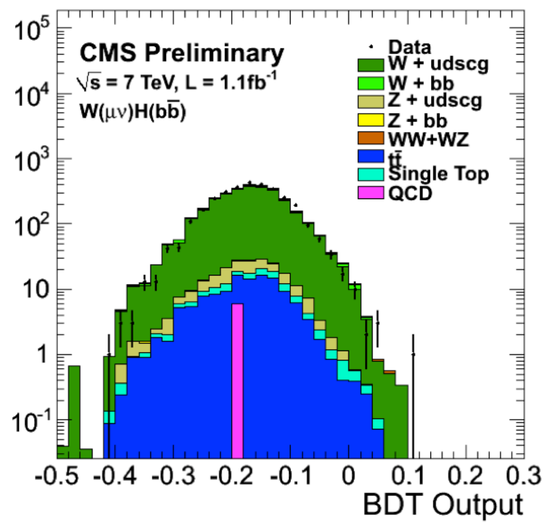




Process	W($\mu\nu$)H	W($e\nu$)H	Z($\mu\mu$)H	Z(ee)H
W + udscg	3188.9	2428.4	0	0
$Wb\bar{b}$	123.0	110.1	0	0
Z + udscg	84.5	64.8	1306.0	1014.7
$Zb\bar{b}$	3.8	3.1	10.0	37.0
$t\bar{t}$	139.4	112.6	0.3	0.6
Single Top	33.8	25.8	–	–
VV	62.2	53.6	14.8	11.3
QCD	6.9	0.9	0	0
Purity	87.5%	86.8%	98.1%	95.4%
Total MC	3642.5	2798.6	1331	1063.5
Total Data	3157	2451	1242	977
Data/MC	0.867 ± 0.058	0.876 ± 0.060	0.933 ± 0.028	0.919 ± 0.037

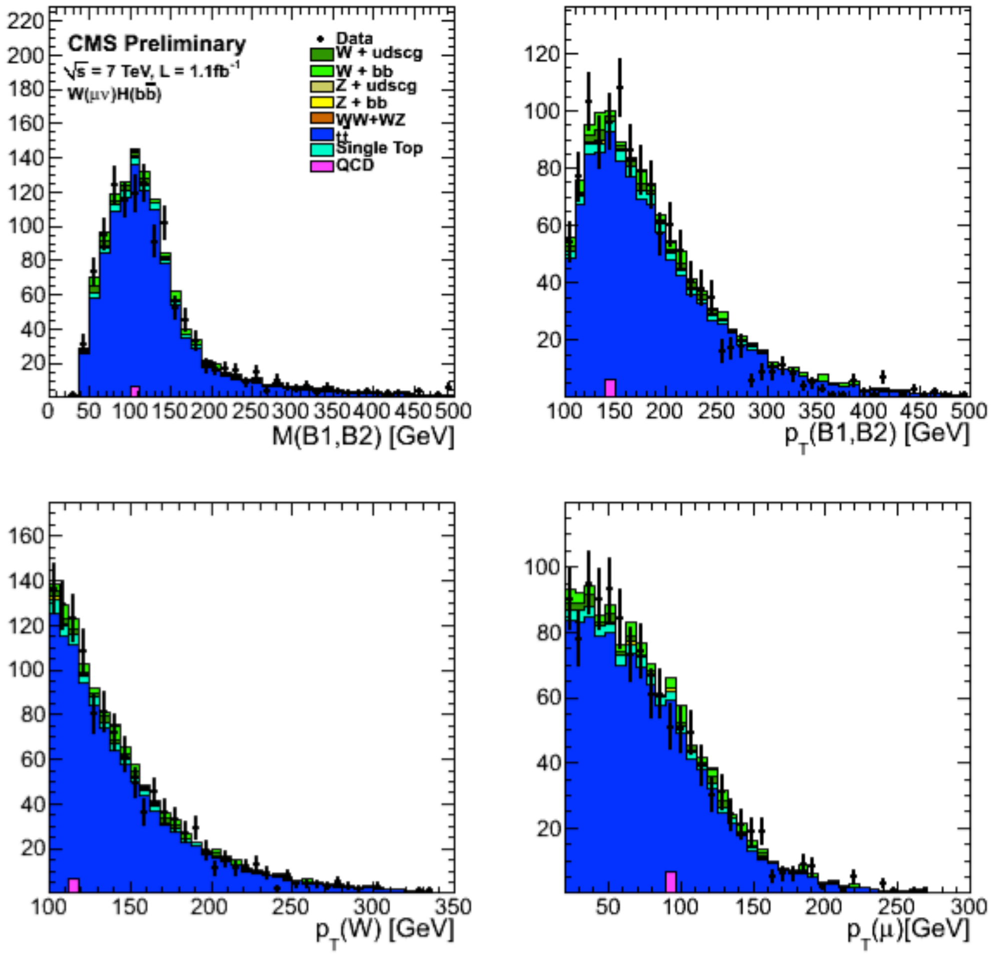




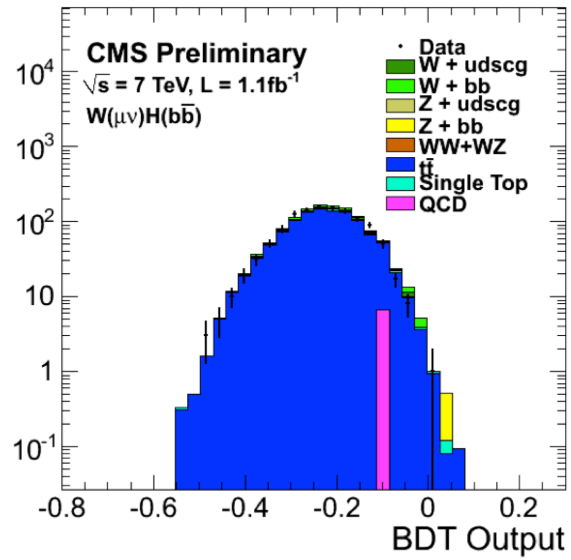


Control samples

TTBAR



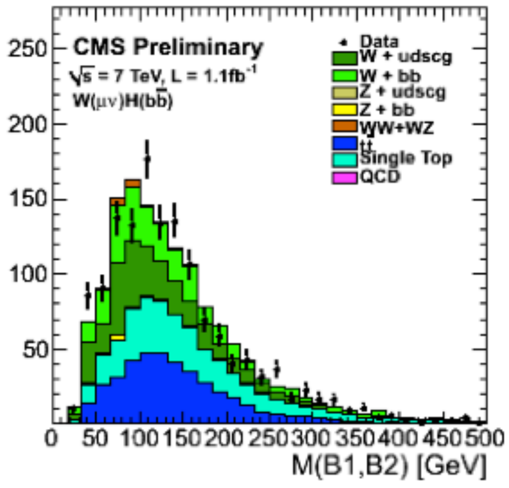
Process	$W(\mu\nu)H$	$W(e\nu)H$	$Z(\mu\mu)H$	$Z(ee)H$
W + udscg	25.2	21.1	0	0
$Wb\bar{b}$	53.3	34.4	0	0
Z + udscg	0.5	0.7	6.4	1.6
$Zb\bar{b}$	6.0	7.1	0.7	0.3
$t\bar{t}$	1085.8	865.3	227.1	155.9
Single Top	47.9	37.4	–	–
VV	1.9	1.6	5.3	3.3
QCD	6.7	0.8	0	0
Purity	88.5%	89.3%	90.0%	96.8%
Total MC	1227.3	968.6	239.7	161.1
Total Data	1170	997	241	170
Data/MC	0.953 ± 0.064	1.029 ± 0.061	1.01 ± 0.08	1.06 ± 0.08

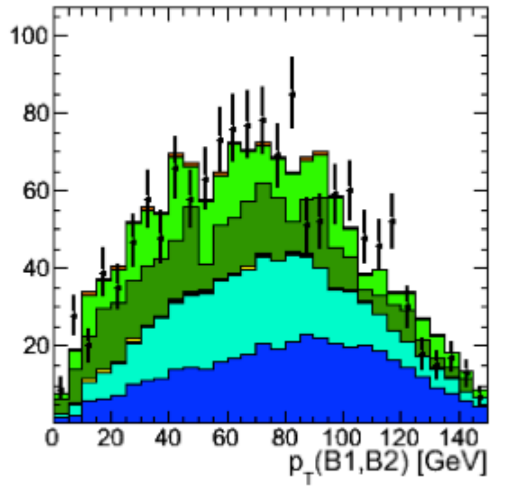


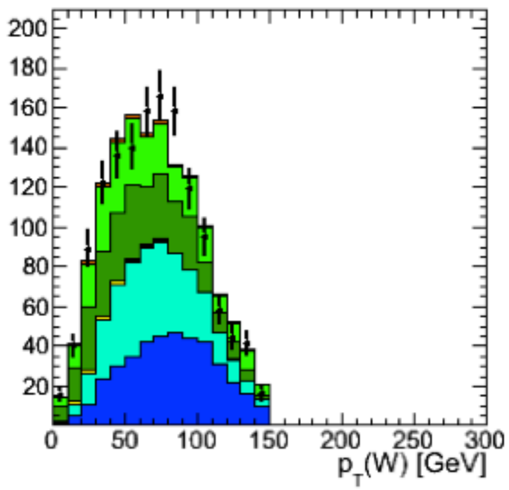
Control samples

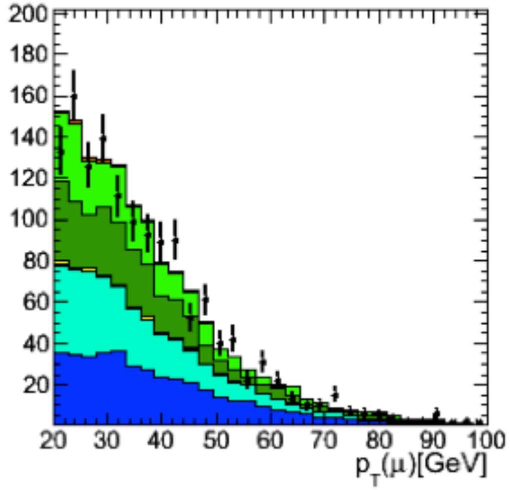
V + HEAVY FLAVOUR

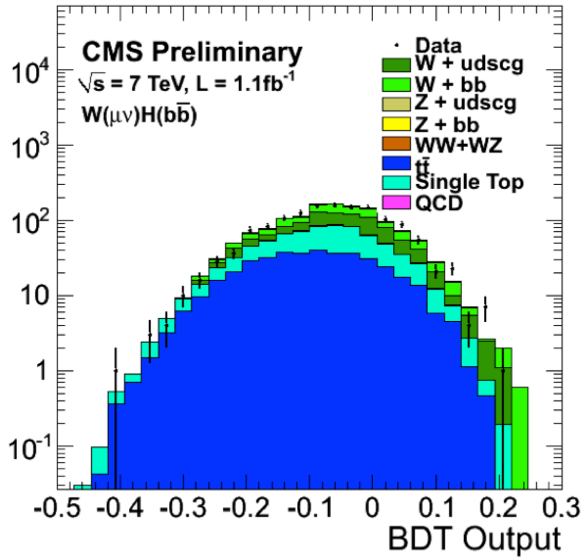
Process	$W(\mu\nu)H$	$W(e\nu)H$	$Z(\mu\mu)H$	$Z(ee)H$
W + udscg	282.9	127.4	0	0
$Wb\bar{b}$	247.8	134.8	0	0
Z + udscg	4.0	0.7	0.5	0.6
$Zb\bar{b}$	9.8	0.9	31.7	24.2
$t\bar{t}$	365.7	239.5	4.3	4.4
Single Top	333.1	172.3	–	–
VV	14.5	8.0	0	0.9
QCD	0	0	0	0
Purity	19.7%	19.7%	84.4%	80.7%
Total MC	1257.9	683.6	37.6	30.0
Total Data	1397	734	40	37
Data/MC	1.11	1.07	1.06 ± 0.19	1.23 ± 0.24
Scale Factor	1.78 ± 0.28	1.44 ± 0.31	–	–











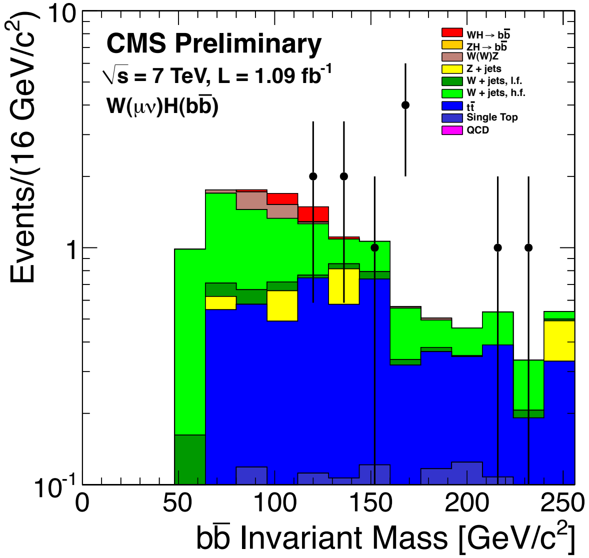
Main Systematics

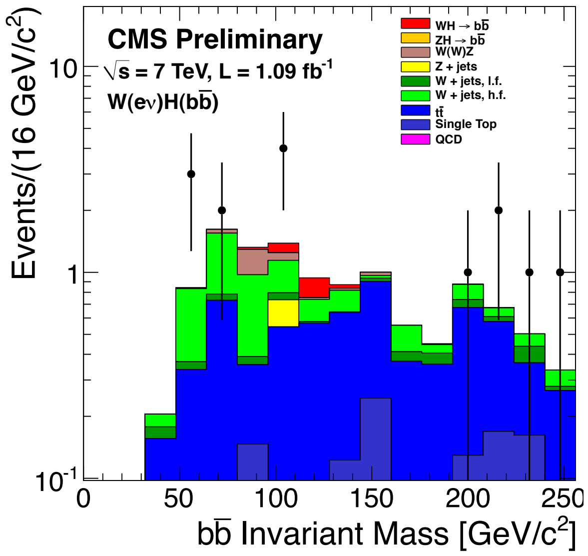
- Luminosity : 4.5%
- Backgorund estimate :
  - VHbb 20%
  - singleTop, VV 30%
- Btagging : 10% / jet
  - Two btagged jet : 20 % total
- MET + Jets trigger : 5%
- Jet energy resolution : 10%
- Signal QCD corrections: 10%
- Higgs Pt shape : 10%

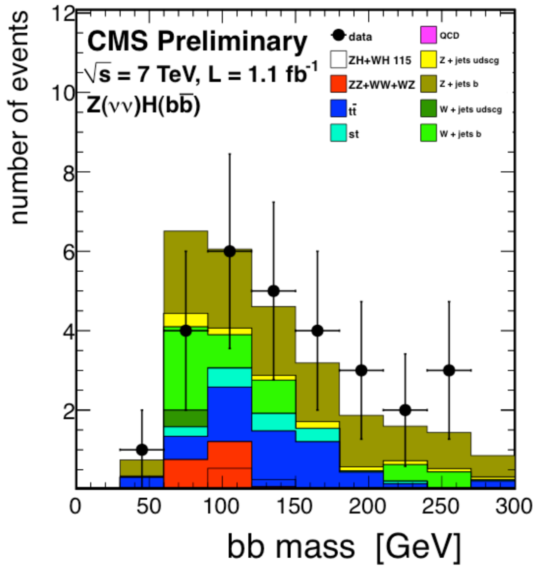
TOTAL:

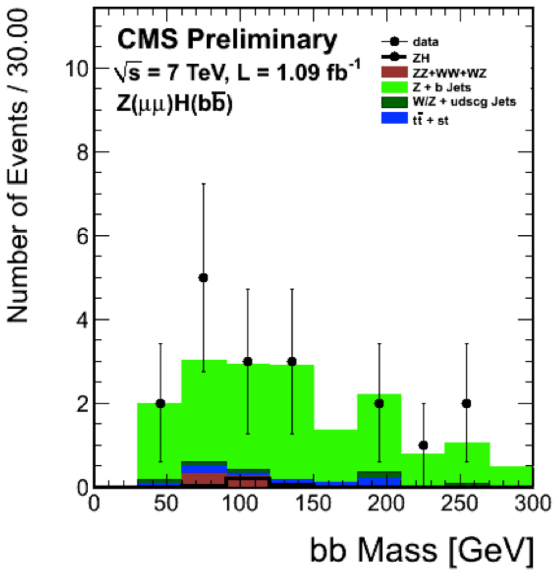
- signal : 27%
- background : 20%

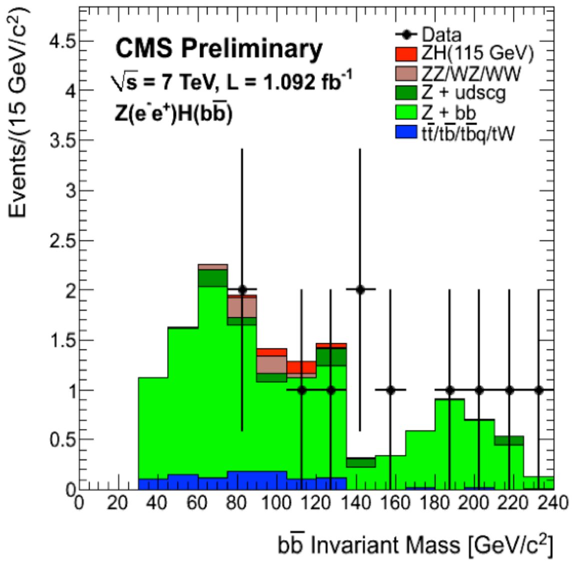
Results


CMS Preliminary
√s = 7 TeV, L = 1.09 fb-1
W(μν)H(bb̄)
Events/(16 GeV/c2)
bb̄ Invariant Mass [GeV/c2]

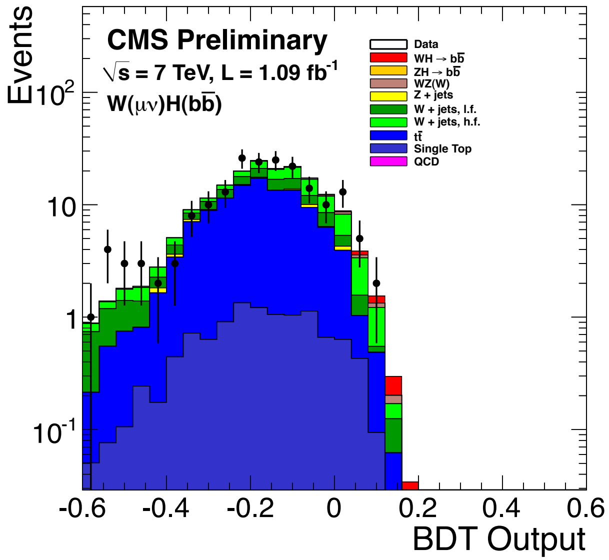

CMS Preliminary
√s = 7 TeV, L = 1.09 fb-1
W(eν)H(bb̄)
Events/(16 GeV/c2)
bb̄ Invariant Mass [GeV/c2]


CMS Preliminary
√s = 7 TeV, L = 1.1 fb-1
Z(νν)H(bb̄)
number of events
bb mass [GeV]

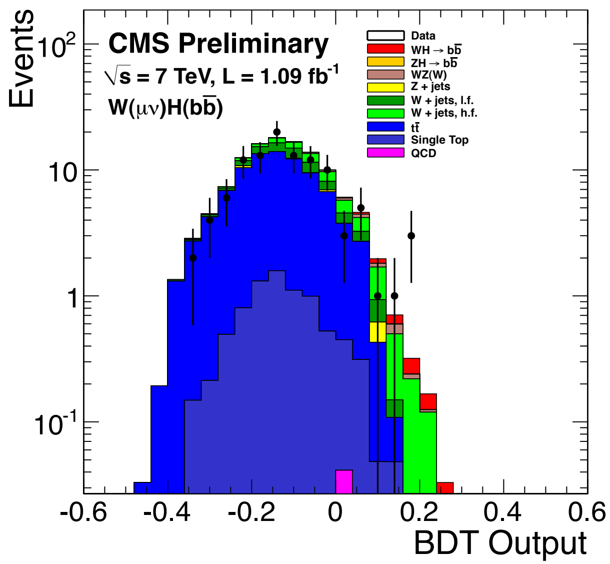

CMS Preliminary
√s = 7 TeV, L = 1.09 fb-1
Z(μμ)H(bb̄)
Number of Events / 30.00
bb Mass [GeV]


CMS Preliminary
√s = 7 TeV, L = 1.092 fb-1
Z(e-e+)H(bb̄)
Data
ZH(115 GeV)
ZZ/WZ/WW
Z + udscg
Z + bb
tt̄/tb̄/tb̄q/tW
Events/(15 GeV/c2)
bb̄ Invariant Mass [GeV/c2]

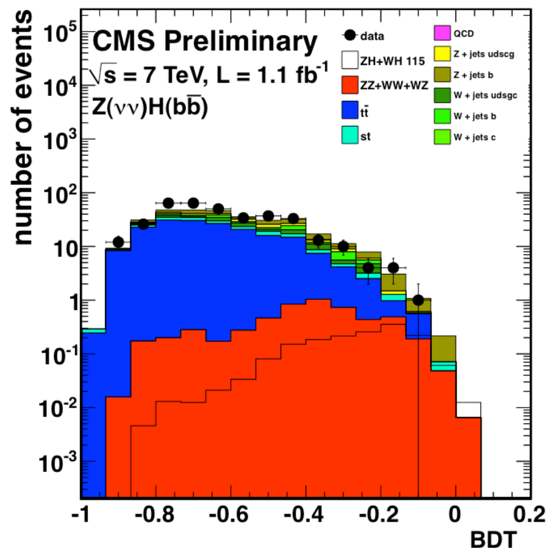
Results



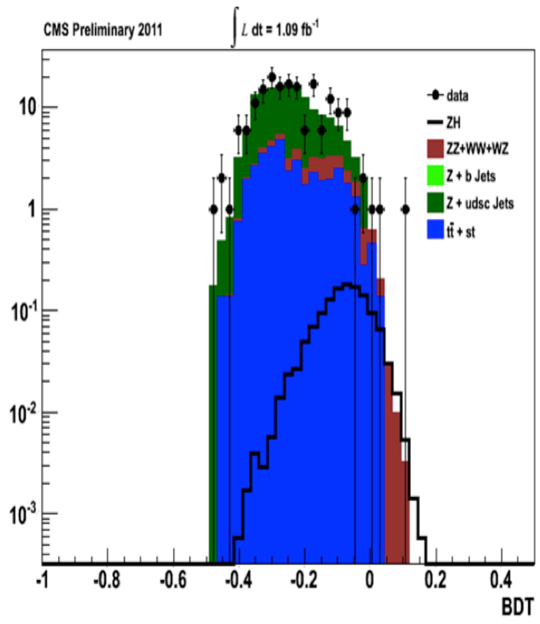
CMS Preliminary
$\sqrt{s}$ = 7 TeV, L = 1.09 fb^{-1}
W(μν)H(b$\bar{b}$)
Data
WH → b$\bar{b}$
ZH → b$\bar{b}$
WZ(W)
Z + jets
W + jets, l.f.
W + jets, h.f.
t$\bar{t}$
Single Top
QCD
Events
BDT Output



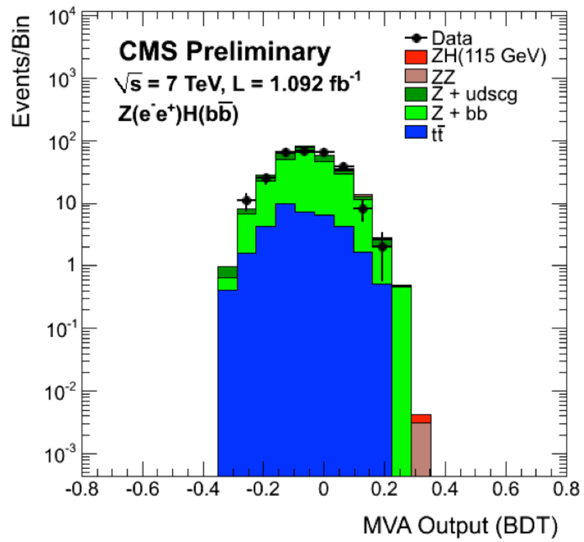
CMS Preliminary
$\sqrt{s}$ = 7 TeV, L = 1.09 fb^{-1}
W(μν)H(b$\bar{b}$)
Data
WH → b$\bar{b}$
ZH → b$\bar{b}$
WZ(W)
Z + jets
W + jets, l.f.
W + jets, h.f.
t$\bar{t}$
Single Top
QCD
Events
BDT Output



CMS Preliminary
$\sqrt{s}$ = 7 TeV, L = 1.1 fb^{-1}
Z(νν)H(b$\bar{b}$)
data
ZH+WH 115
ZZ+WW+WZ
t$\bar{t}$
st
QCD
Z + jets udscg
Z + jets b
W + jets udsgc
W + jets b
W + jets c
number of events
BDT



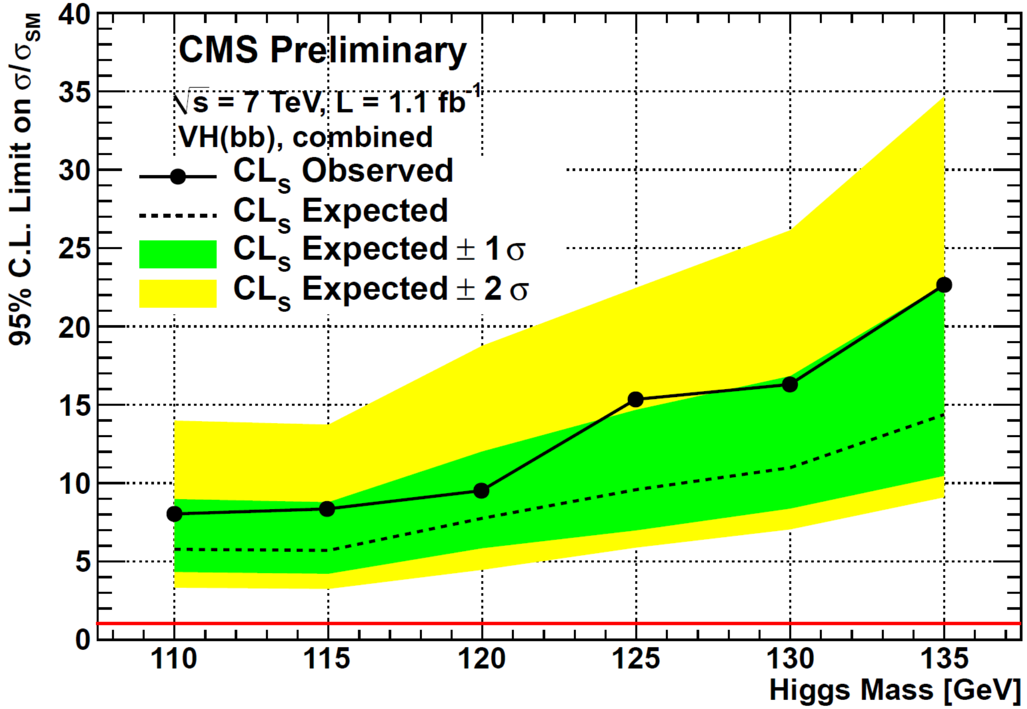
CMS Preliminary 2011
$\int L\,dt$ = 1.09 fb^{-1}
data
ZH
ZZ+WW+WZ
Z + b Jets
Z + udsc Jets
t$\bar{t}$ + st
BDT



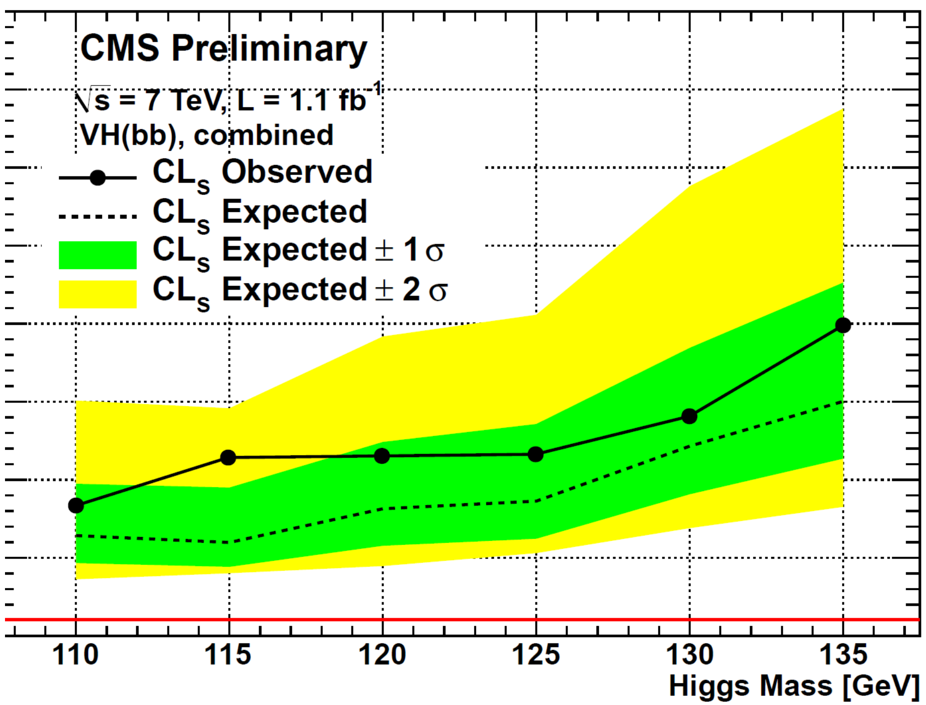
CMS Preliminary
$\sqrt{s}$ = 7 TeV, L = 1.092 fb^{-1}
Z(e$^-$e$^+$)H(b$\bar{b}$)
Data
ZH(115 GeV)
ZZ
Z + udscg
Z + bb
t$\bar{t}$
Events/Bin
MVA Output (BDT)

Results

BDT Analysis

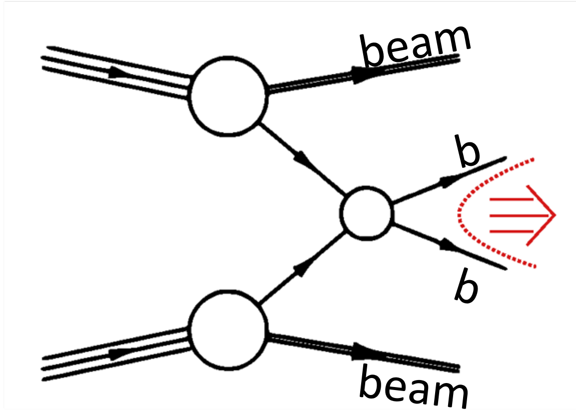


Cut and Count Analysis



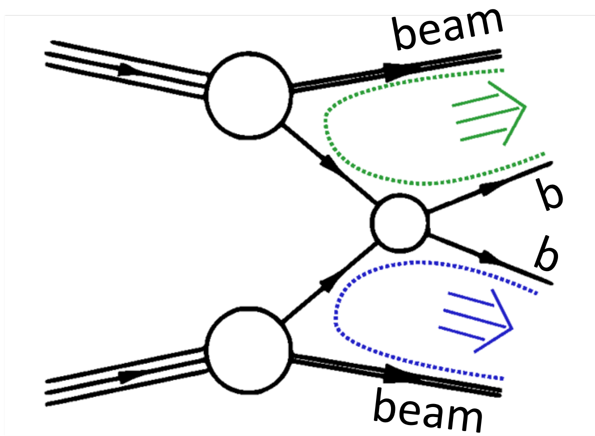
Colour connection

- Dominant background ZHbb channel is Zgbb
- Signal ZHbb:
  - Higgs colour singlet object
  - Γ(H) << Γ(QCD)
    - The bs of the Higgs can "*talk*" ONLY between each other



Gallicchio, Schwartz PRL 105, 022001 (2010)

- Background Zgbb:
  - Gluon coloured object
    - The bs of the gluons "*talk*" with all the event (beams)



Gallicchio, Schwartz PRL 105, 022001 (2010)

Pull vector

Pull vector and angle:

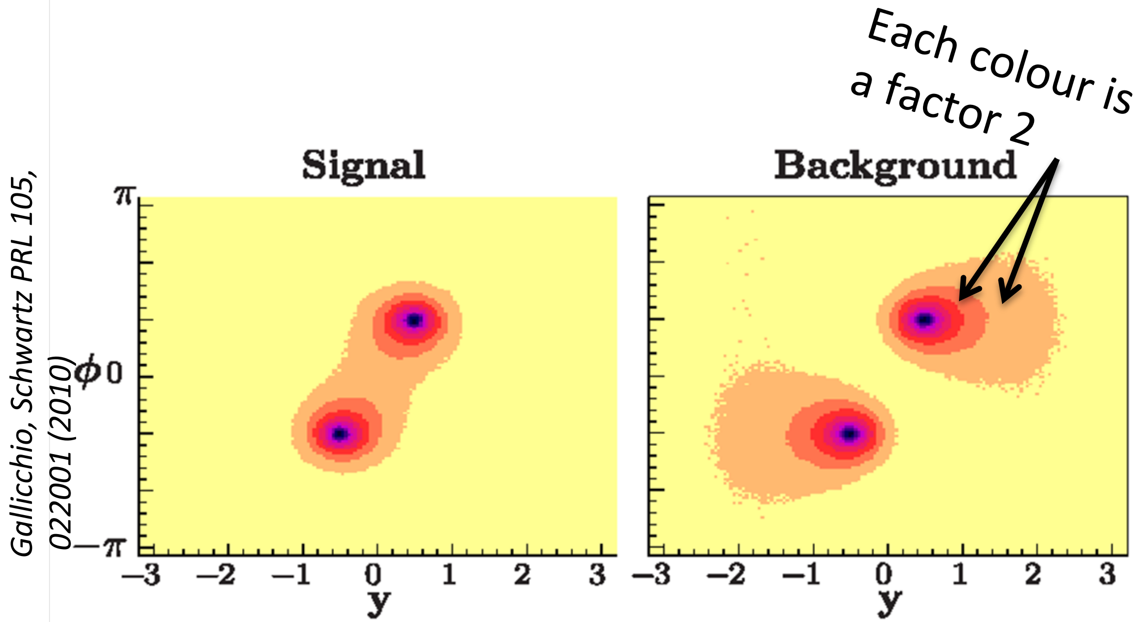
– Vector in $\langle y,\phi \rangle$ plane:

$$\vec{t} = \sum_{i \in jet} \frac{p_T^i \cdot |\vec{r}_i|}{P_T^{jet}} \cdot \vec{r}_i$$

$$\vec{r}_i = (\Delta y_i, \Delta \phi_i) = \vec{c}_i - \vec{J}$$
$$\vec{J} = (y_{jet}, \phi_{jet})$$

– Angle wrt JJ dir:

$$\Delta\theta_t = \theta_t - \theta_{JJ}$$

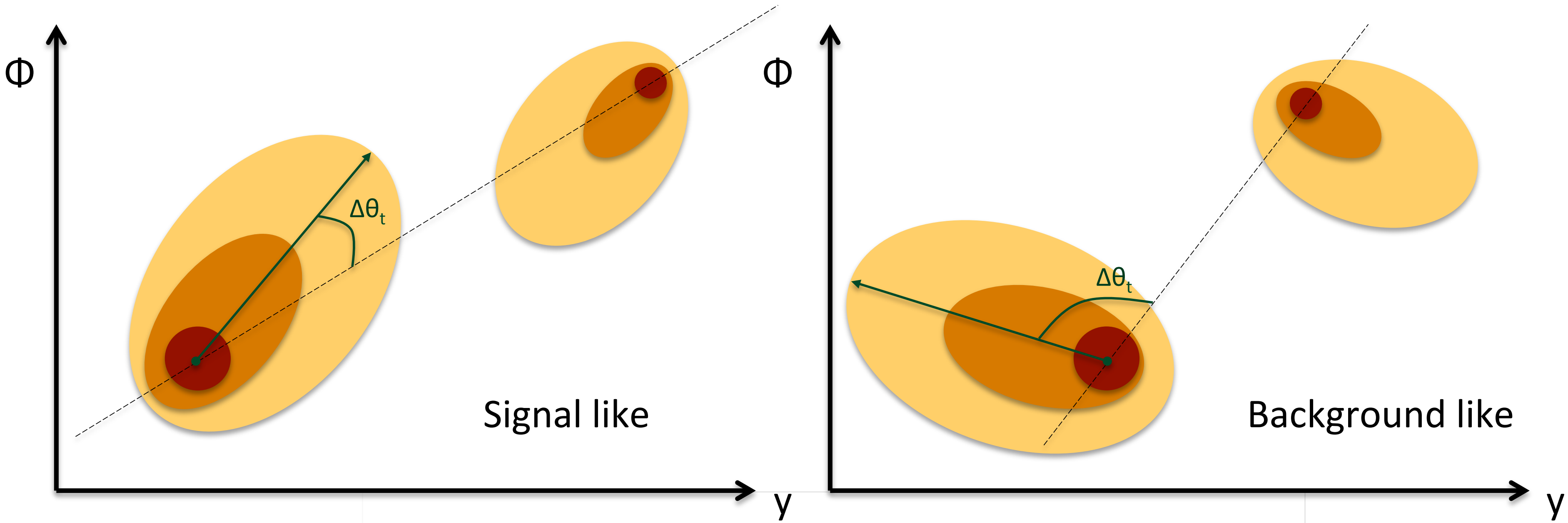


One point of the phase space showered 10E5 times

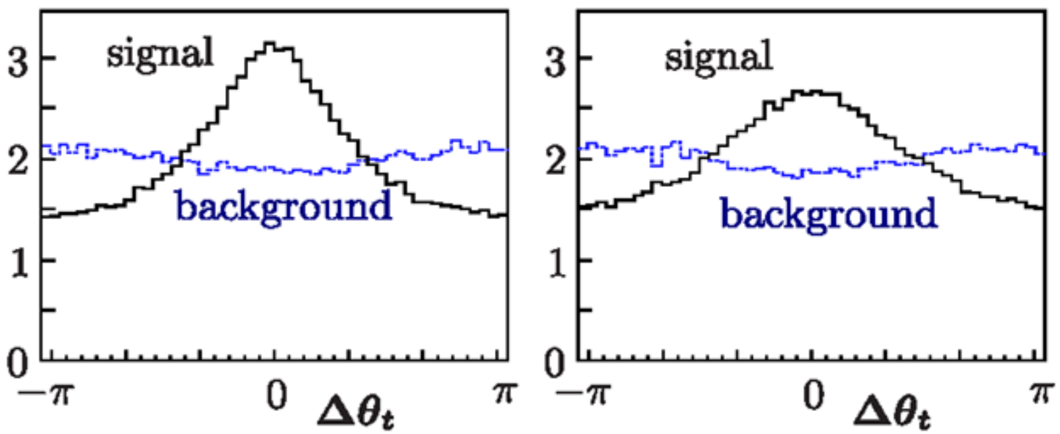
Properties of pull:

- Infrared safe
- Collinear safe
- Boost invariant

Pull angle



Leading jet　　Second leading jet



Gallicchio, Schwartz PRL 105, 022001 (2010)

Higgs mass window [100,140]

Conclusion

- Low Higgs search at LHC is feasible… actually done!
- Good control on backgrounds for all channels with CS
- Very conservative approach on systematics
- No significant excess found (yet…)

IMPROVEMENTS

- Add more discriminating variables:
    - Colour flow
    - Good Ideas…?

Conclusion

- Low Higgs search at LHC is feasible… actually done!
- Good control on backgrounds for all channels with CS
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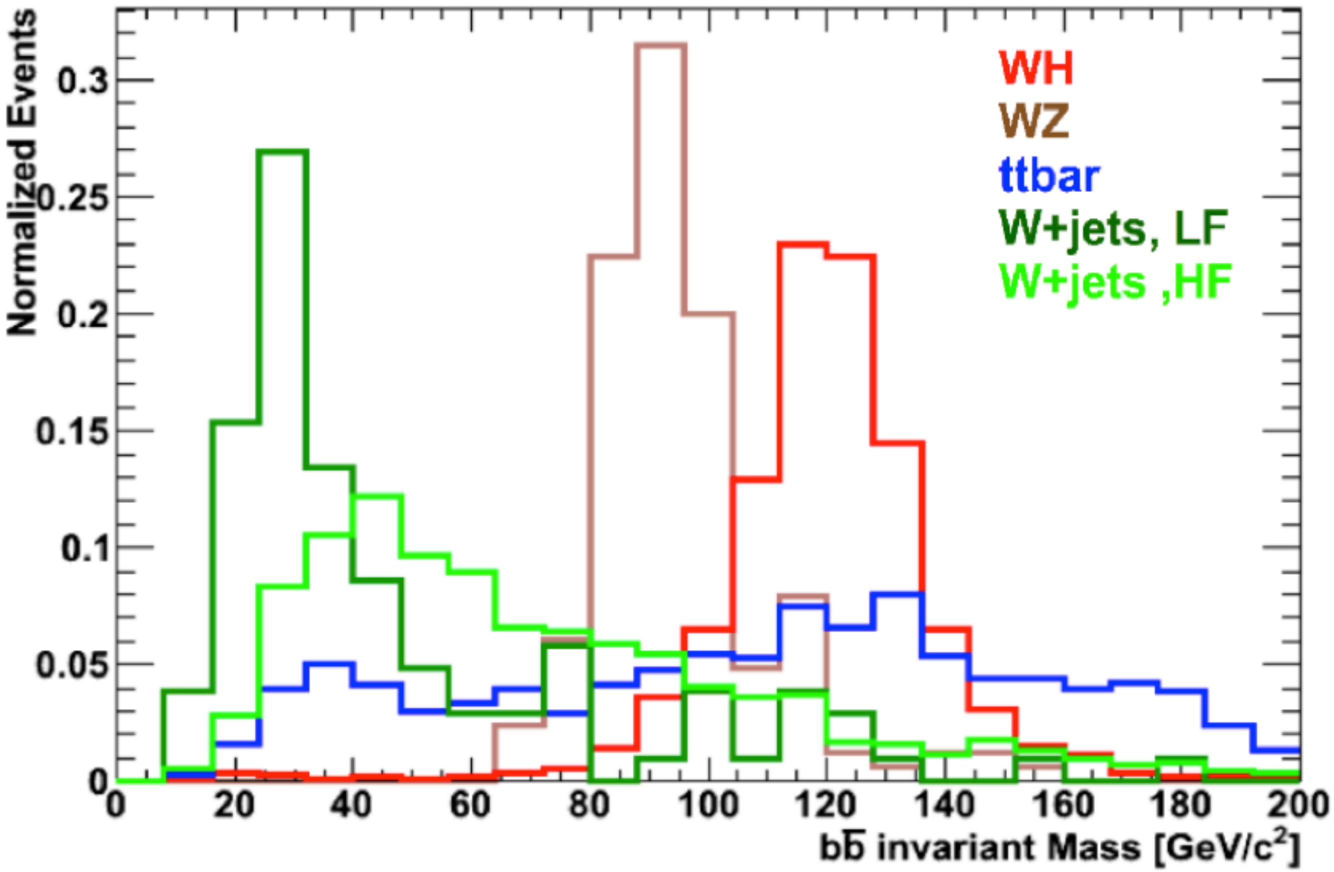
IMPROVEMENTS

- Add more discriminating variables:
  - Colour flow
  - Good Ideas…?

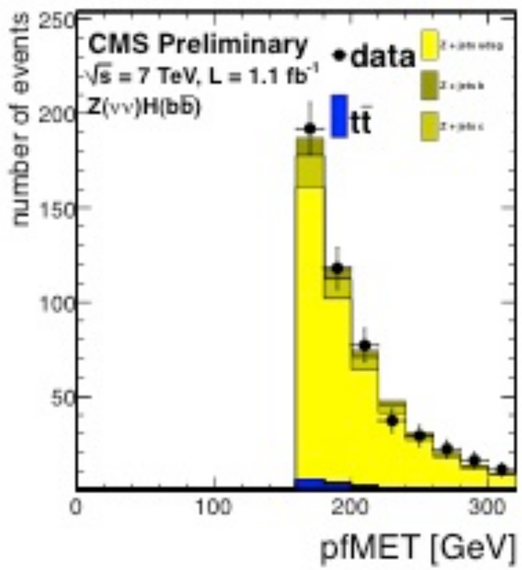
Thanks

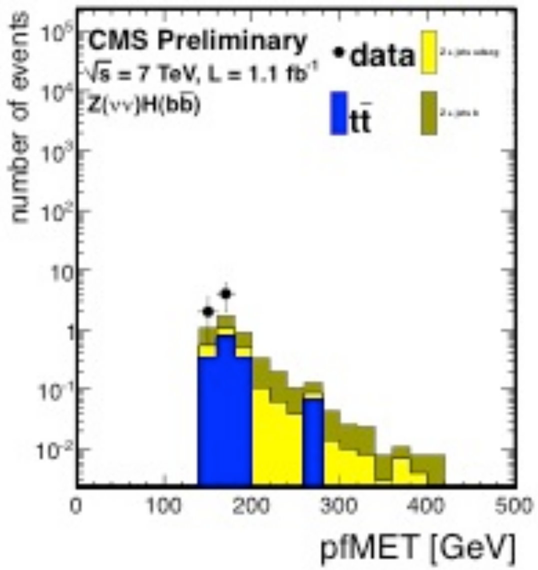
Backup

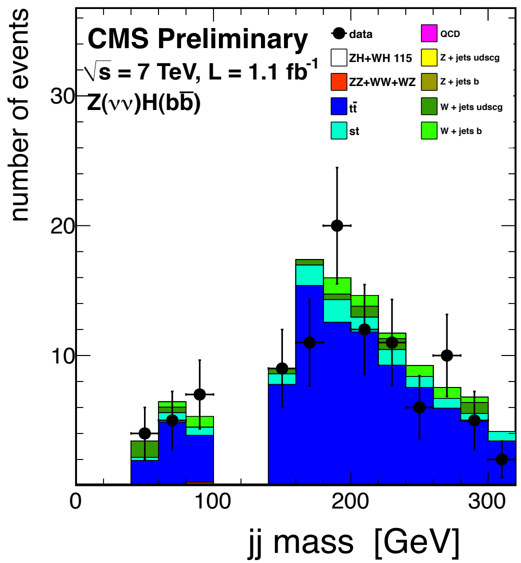

WH
WZ
ttbar
W+jets, LF
W+jets ,HF
Normalized Events
0.3
0.25
0.2
0.15
0.1
0.05
0
0
20
40
60
80
100
120
140
160
180
200
$b\bar{b}$ invariant Mass [GeV/c^2]

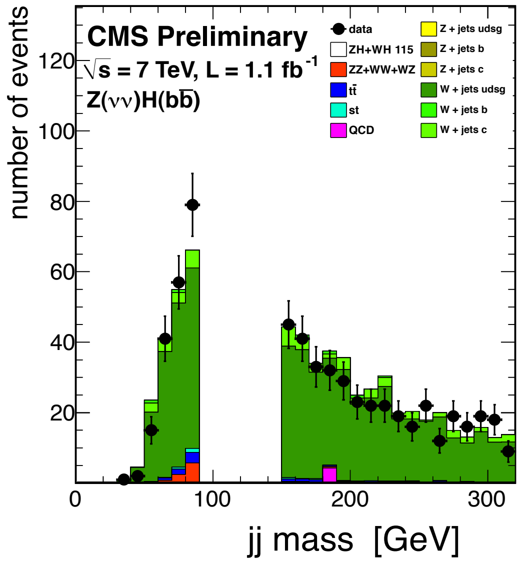
Control samples

ZNuNu case



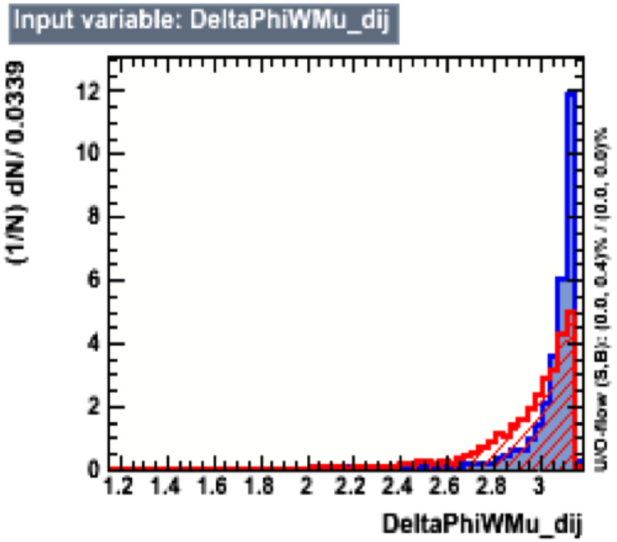


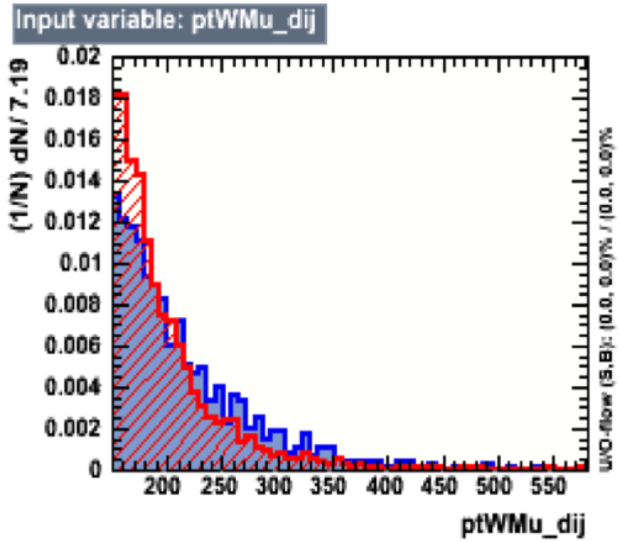


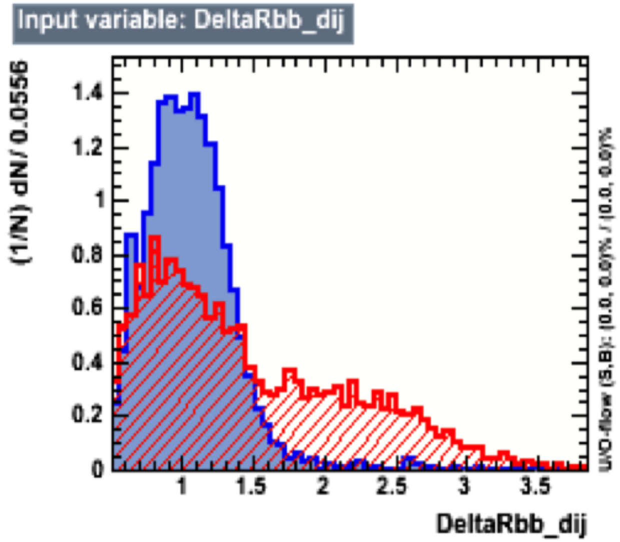


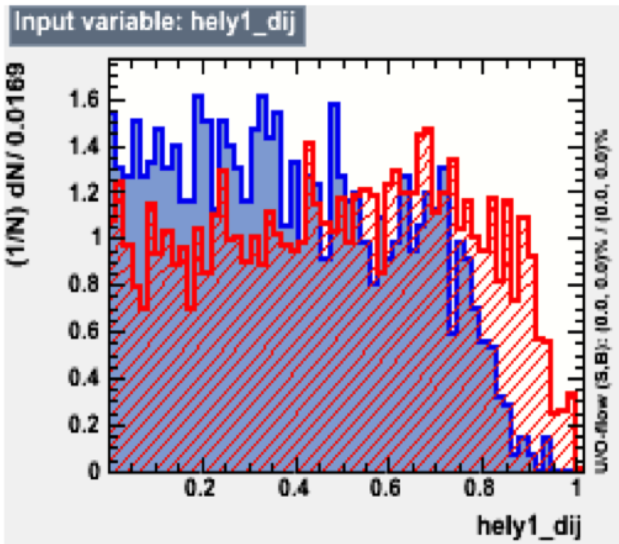
Process	Z + udscg	Zbb̄	tt̄	W + jets
W + udscg	0	0	3.77	1033.47
Wbb̄	0	0	18.4	106.65
Z + udscg	482.7	0.92	0	0
Zbb̄	25.0	2.15	0	0
tt̄	14.6	1.51	148.3	19.65
Single Top	0	0	14.1	6.9
VV	0	0	1.0	24.7
QCD	0	0	0	0
Purity	93%	44%	89.9%	86.4%
Total MC	522.3	4.58	185.90	1195.42
Total Data	517	6	172	1135
Data/MC	0.99 ± 0.02	1.2 ± 0.3	0.92 ± 0.07	0.95 ± 0.04

MVA analysis





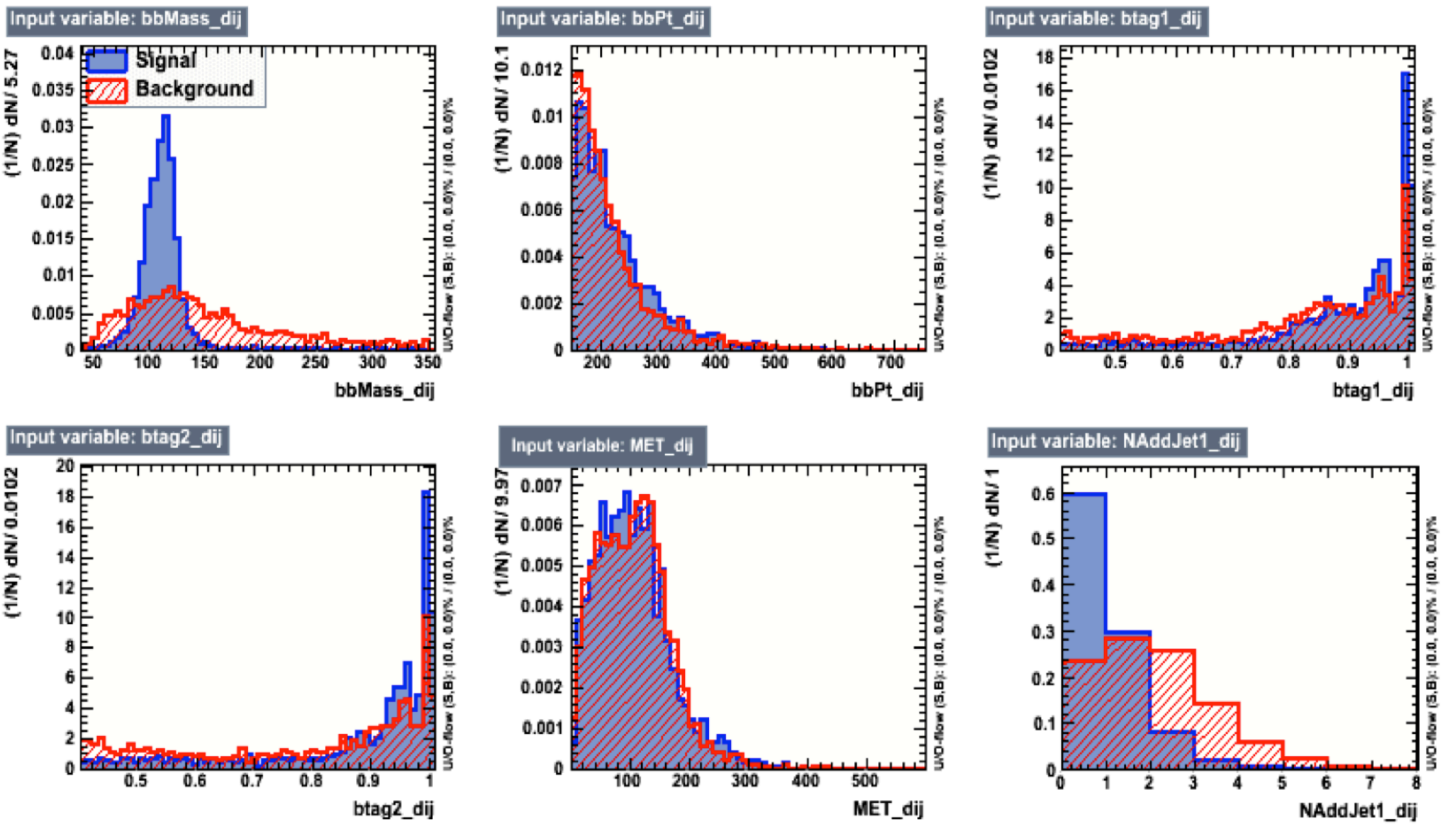




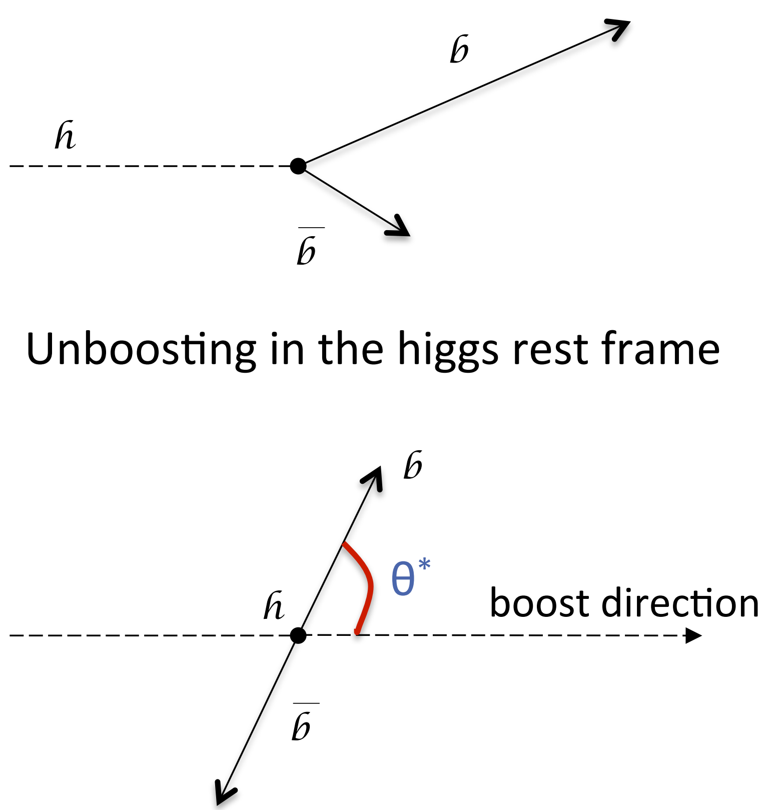
Preselection:

- Boosted region: pt(H,V) > 150
- Min bTag(j1,j2) CSV > 0.4

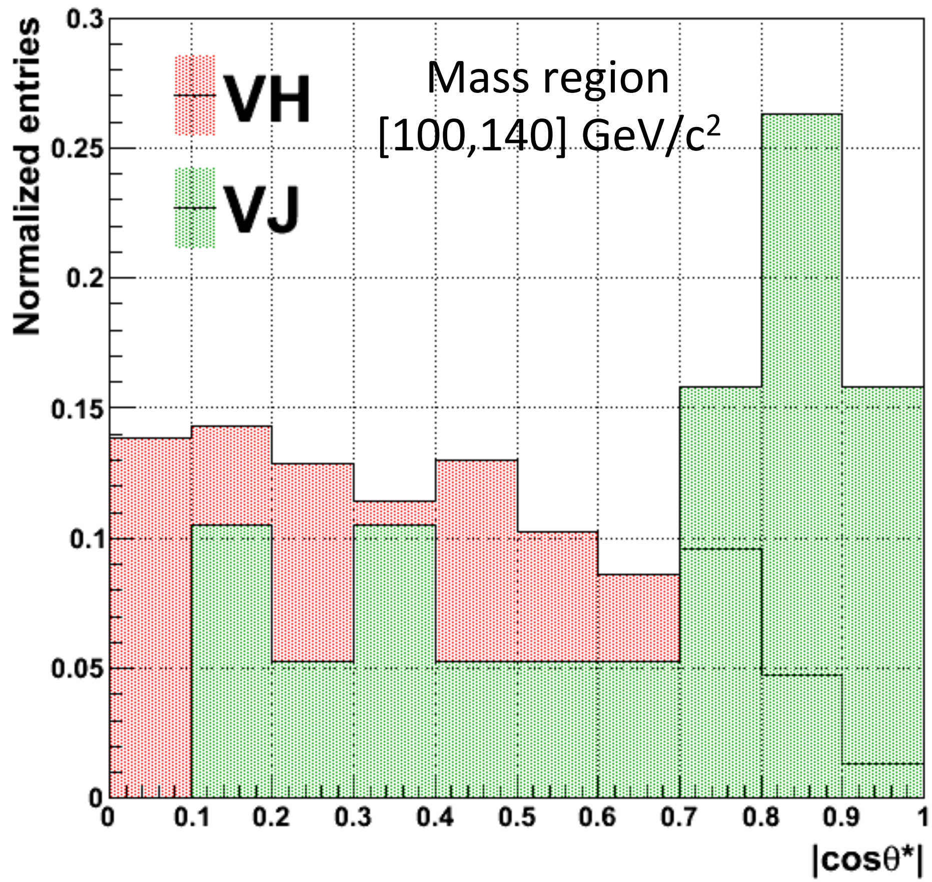
MVA analysis



Helicity angle CMS simulation

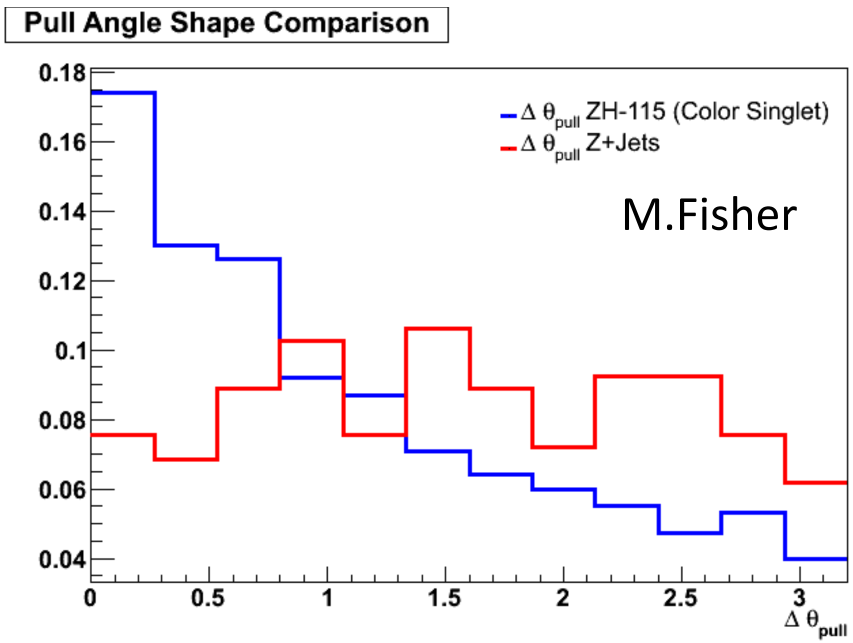


Signal-background shape comparison



MVA analysis

ZtoLL channel



TMVA output
After preselection

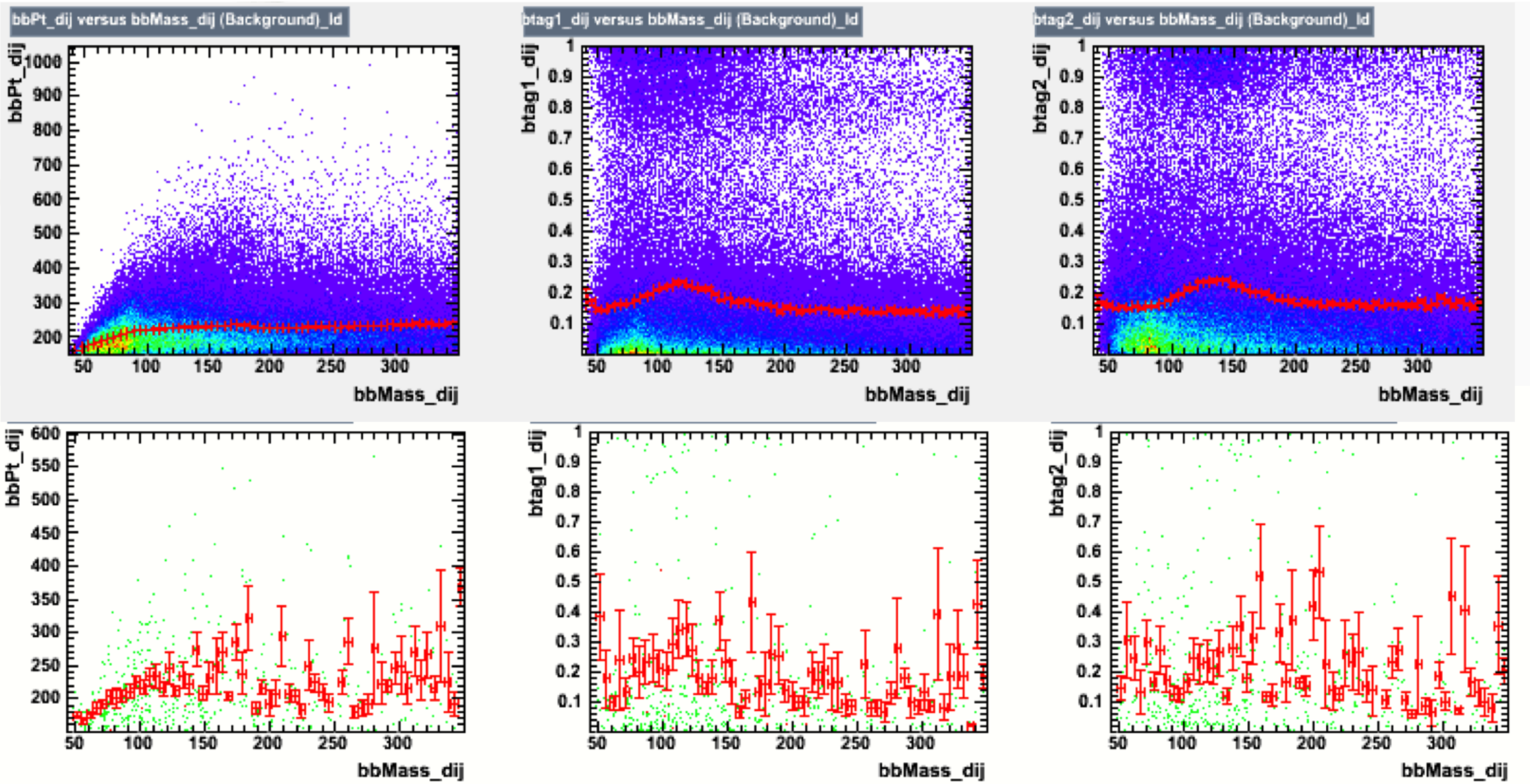
M.Fisher

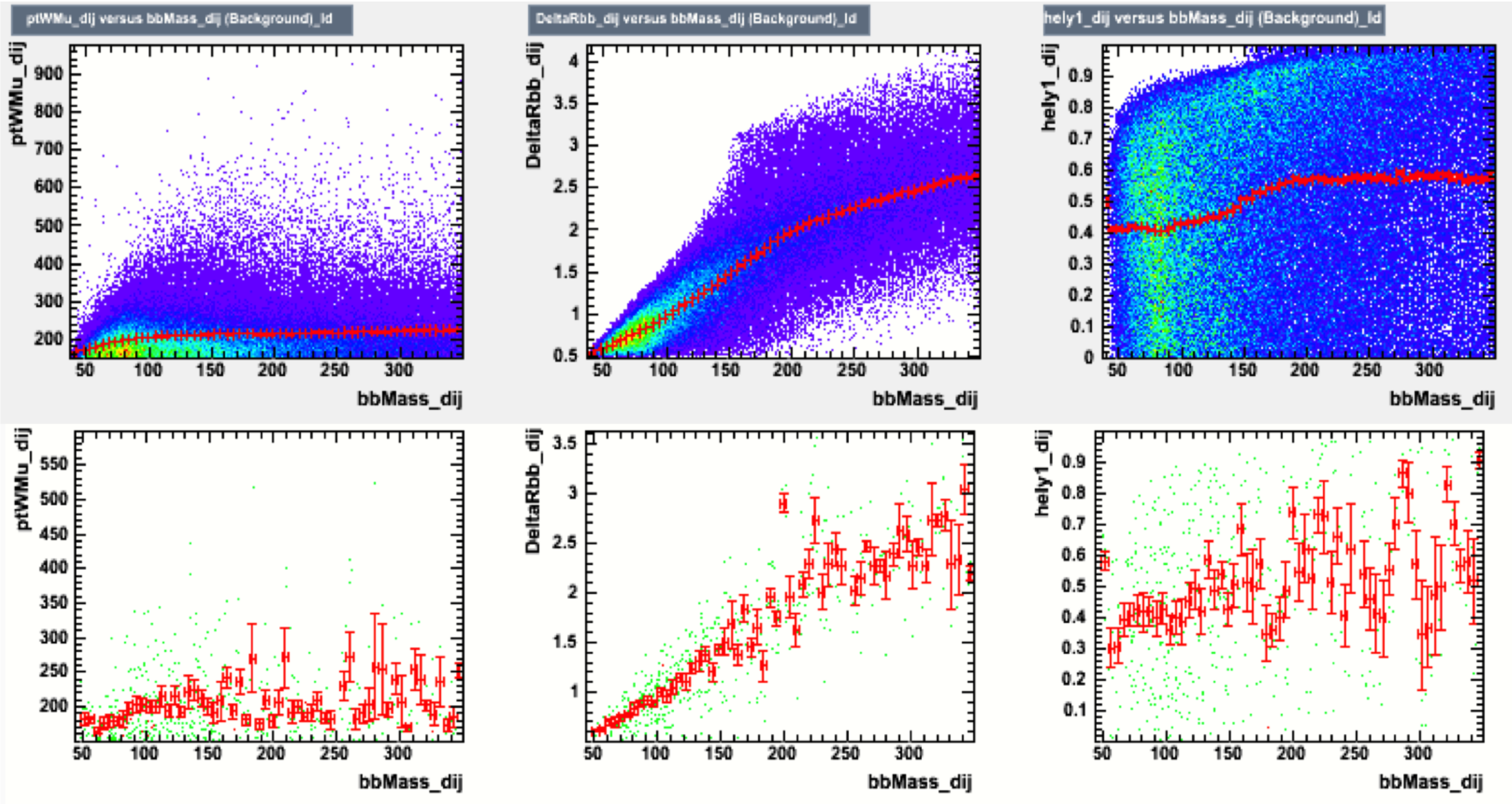
Rank	Variable	Separation
1	DTheta_{Pull}	4.538e-01
2	H Mass	4.357e-01
3	JJ DR	4.334e-01
4	CosRest	3.988e-01
5	J2 PT	3.423e-01
6	J1 PT	3.328e-01
7	CSV 1	2.859e-01
8	Z PT	2.771e-01
9	H-Z DPhi	2.766e-01
10	CSV 2	2.750e-01
11	Z Mass	2.626e-01
12	H PT	2.375e-01

Lower level objects

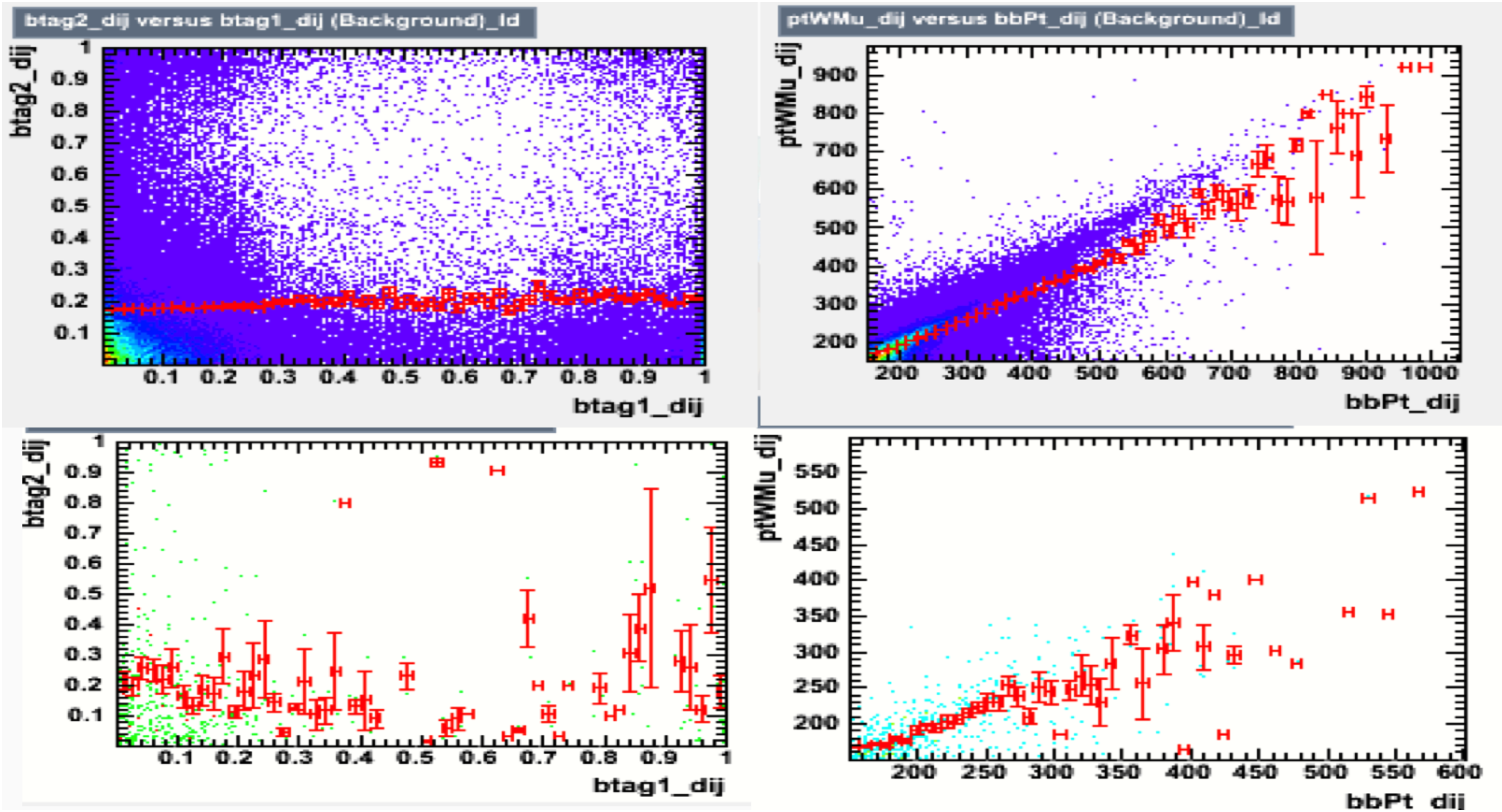
Full particle flow analysis

- PV and PU treatment
  - DA algo used for PV
  - PFnoPU (CHS)
  - Fastjet subtraction
- Electrons
  - Isolated
  - Zee:
    - WP95
    - $P_t > 20$ GeV/c
  - Wenu
    - WP80
    - $P_t > 30$ GeV/c
  - $|\eta| < 2.5$ (gap regions excluded)
- Muons
  - Isolated
  - $P_t > 20$ GeV/c
  - $|\eta| < 2.4$
- Jets
  - AK5 clustering algo
  - ZLL
    - $P_t > 20$ GeV/c
  - WLNu / ZNuNu
    - $P_t > 30$ GeV/c
  - $|\eta| < 2.5$
- B-Tagging
  - Combined secondary vertex tagger (IP+SV info)
    - CSVT : 0.898
    - CSVM : 0.679
    - CSVL : 0.244
- MET

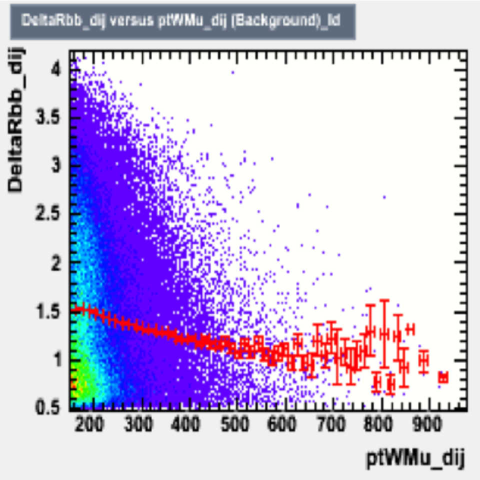

bbPt_dij versus bbMass_dij (Background)_ld
btag1_dij versus bbMass_dij (Background)_ld
btag2_dij versus bbMass_dij (Background)_ld
bbPt_dij
btag1_dij
btag2_dij
bbMass_dij

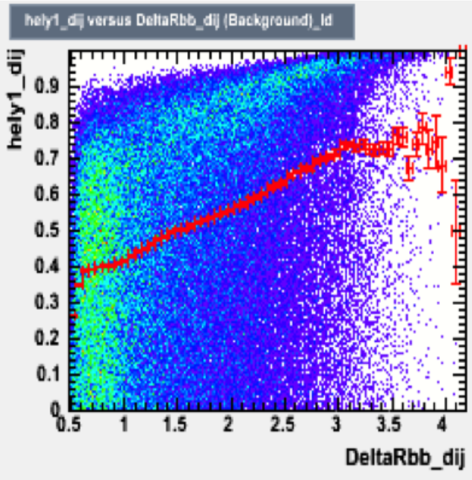


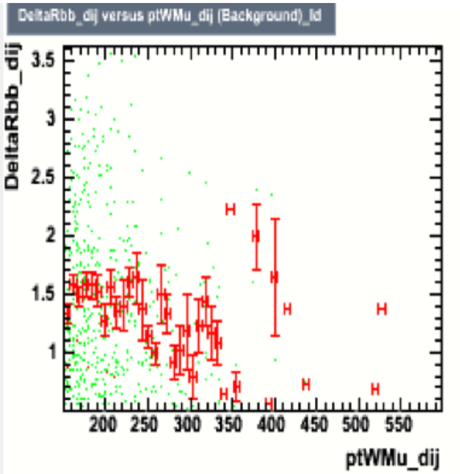
ptWMu_dij versus bbMass_dij (Background)_ld
ptWMu_dij
bbMass_dij
DeltaRbb_dij versus bbMass_dij (Background)_ld
DeltaRbb_dij
bbMass_dij
hely1_dij versus bbMass_dij (Background)_ld
hely1_dij
bbMass_dij
ptWMu_dij
bbMass_dij
DeltaRbb_dij
bbMass_dij
hely1_dij
bbMass_dij

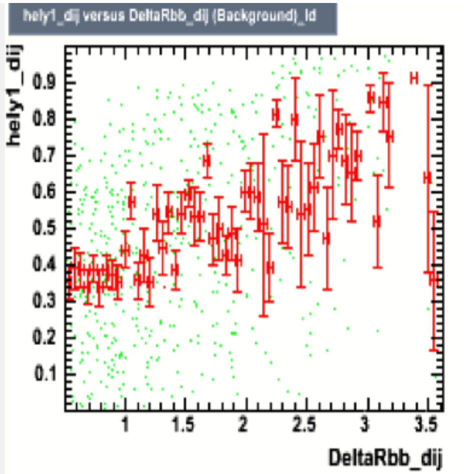


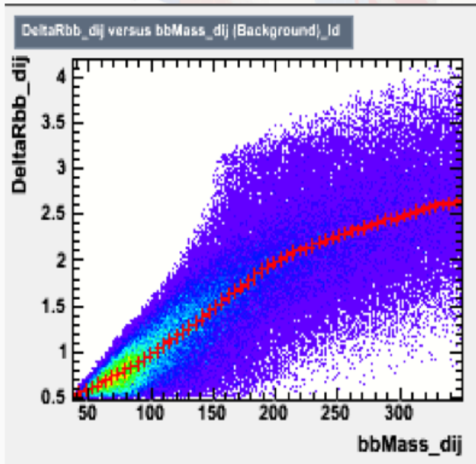
btag2_dij versus btag1_dij (Background)_ld
btag2_dij
btag1_dij
ptWMu_dij versus bbPt_dij (Background)_ld
ptWMu_dij
bbPt_dij
btag2_dij
btag1_dij
ptWMu_dij
bbPt_dij

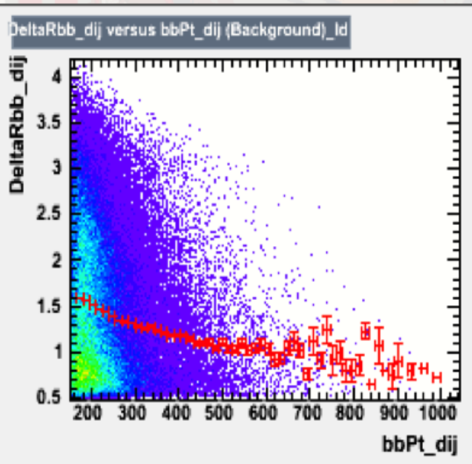

DeltaRbb_dij versus ptWMu_dij (Background)_ld
DeltaRbb_dij
ptWMu_dij

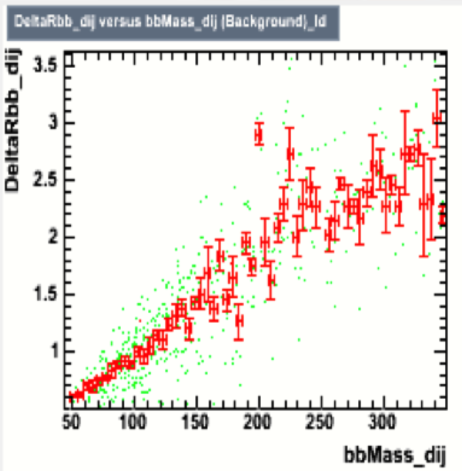

hely1_dij versus DeltaRbb_dij (Background)_ld
hely1_dij
DeltaRbb_dij

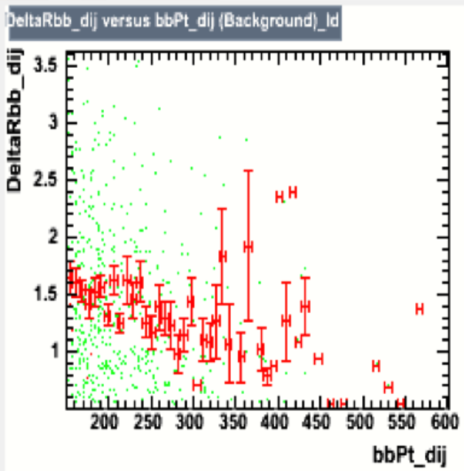

DeltaRbb_dij versus ptWMu_dij (Background)_ld
DeltaRbb_dij
ptWMu_dij


hely1_dij versus DeltaRbb_dij (Background)_ld
hely1_dij
DeltaRbb_dij


DeltaRbb_dij versus bbMass_dij (Background)_ld
DeltaRbb_dij
bbMass_dij


DeltaRbb_dij versus bbPt_dij (Background)_ld
DeltaRbb_dij
bbPt_dij


DeltaRbb_dij versus bbMass_dij (Background)_ld
DeltaRbb_dij
bbMass_dij


DeltaRbb_dij versus bbPt_dij (Background)_ld
DeltaRbb_dij
bbPt_dij

Results

WMuNu

Process	110 GeV	115 GeV	120 GeV	125 GeV	130 GeV	135 GeV
W + udscg	0.095	0.071	0.058	0.045	0.061	0.095
$Wb\bar{b}$	1.047	0.989	0.951	0.846	0.733	0.671
Z+jets	0.168	0.174	0.006	0.238	0.238	0.238
$t\bar{t}$	0.981	0.928	1.068	1.095	0.982	1.012
Single Top	0.202	0.173	0.194	0.201	0.234	0.152
VV	0.247	0.155	0.040	0.021	0.018	0.009
B_{exp}	2.740	2.490	2.316	2.446	2.266	2.176
S	0.384	0.367	0.307	0.242	0.193	0.146
N_{obs}	2	3	4	4	3	3

ZNuNu

Process	110 GeV	115 GeV	120 GeV	125 GeV	130 GeV	135 GeV
W + udscg	0.02	0.02	0.02	0.02	0.01	0.01
$Wb\bar{b}+t\bar{t}$	1.99	1.37	2.15	2.41	2.48	2.23
Z + udscg	0.15	0.17	0.14	0.13	0.12	0.12
$Zb\bar{b}$	1.88	1.99	1.70	1.71	1.70	1.73
Single Top	0.51	0.47	0.52	0.42	0.58	0.42
VV	1.31	1.20	0.22	0.12	0.08	0.07
B_{exp}	6.15	6.05	4.75	4.80	4.87	4.61
S	0.70	0.53	0.51	0.44	0.35	0.26
N_{obs}	6	6	5	5	6	5

WENu

Process	110 GeV	115 GeV	120 GeV	125 GeV	130 GeV	135 GeV
W + udscg	0.068	0.030	0.032	0.014	0.012	0.038
$Wb\bar{b}$	0.507	0.403	0.367	0.361	0.312	0.259
Z+jets	0.192	0.191	0	0	0	0
$t\bar{t}$	1.015	0.744	0.802	0.884	1.030	0.843
Single Top	0.125	0.088	0.106	0.150	0.186	0.273
VV	0.145	0.069	0.049	0.043	0.045	0.041
B_{exp}	2.052	1.525	1.355	1.451	1.585	1.453
S	0.297	0.329	0.231	0.216	0.158	0.140
N_{obs}	4	4	1	1	0	0

BDT

Process	$W(\mu\nu)H$	$W(e\nu)H$	$Z(\mu\mu)H$	$Z(ee)H$	$Z(\nu\nu)H$
W + udscg	0.659	0.692	0	0	0.00
$Wb\bar{b}$	2.516	2.08	0	0	0.01
Z + udscg	0	0	2.21	2.20	0.07
$Zb\bar{b}$	0.006	0.191	15.1	11.7	1.19
$t\bar{t}$	1.052	1.979	2.21	2.18	0.61
Single Top	0.526	0.267	–	–	0.47
VV	0.376	0.518	1.23	0.71	0.50
QCD	0	0	0	0	0
B_{exp}	5.136	5.731	20.75	16.79	2.39
$S(110)$	0.604	0.485	0.73	0.54	0.60
$S(115)$	0.640	0.519	0.64	0.47	0.49
$S(120)$	0.484	0.407	0.55	0.40	0.39
$S(125)$	0.345	0.330	0.43	0.31	0.33
$S(130)$	0.245	0.236	0.32	0.22	0.23
$S(135)$	0.149	0.160	0.22	0.15	0.16
N_{obs}	7	9	26	10	1

ZMuMu

Process	110 GeV	115 GeV	120 GeV	125 GeV	130 GeV	135 GeV
Z + udscg	0.08	0.09	0.08	0.08	0.08	0.08
$Zb\bar{b}$	2.51	2.55	2.71	2.61	2.51	2.61
$t\bar{t}$ + ST	0.06	0.12	0.16	0.16	0.22	0.21
VV	0.27	0.17	0.08	0.04	0.02	0.01
B_{exp}	2.93	2.93	3.05	2.89	2.84	2.92
S	0.26	0.23	0.19	0.16	0.13	0.09
N_{obs}	3	3	3	3	2	3

ZEE

Process	110 GeV	115 GeV	120 GeV	125 GeV	130 GeV	135 GeV
Z + udscg	0.08	0.17	0.08	0.17	0.17	0.25
$Zb\bar{b}$	1.92	2.03	1.92	2.14	2.03	1.58
$t\bar{t}$ +ST	0.28	0.23	0.23	0.22	0.17	0.17
VV	0.22	0.16	0.09	0.06	0.04	0.02
B_{exp}	2.50	2.59	2.33	2.59	2.40	1.74
S	0.22	0.19	0.15	0.13	0.10	0.08
N_{obs}	1	2	2	2	3	4

Combining all the channels

M_H(GeV)	Expected	Observed
110	8.1	7.4
115	8.0	8.3
120	10.1	10.8
125	12.2	13.0
130	17.3	19.1
135	25.2	29.0