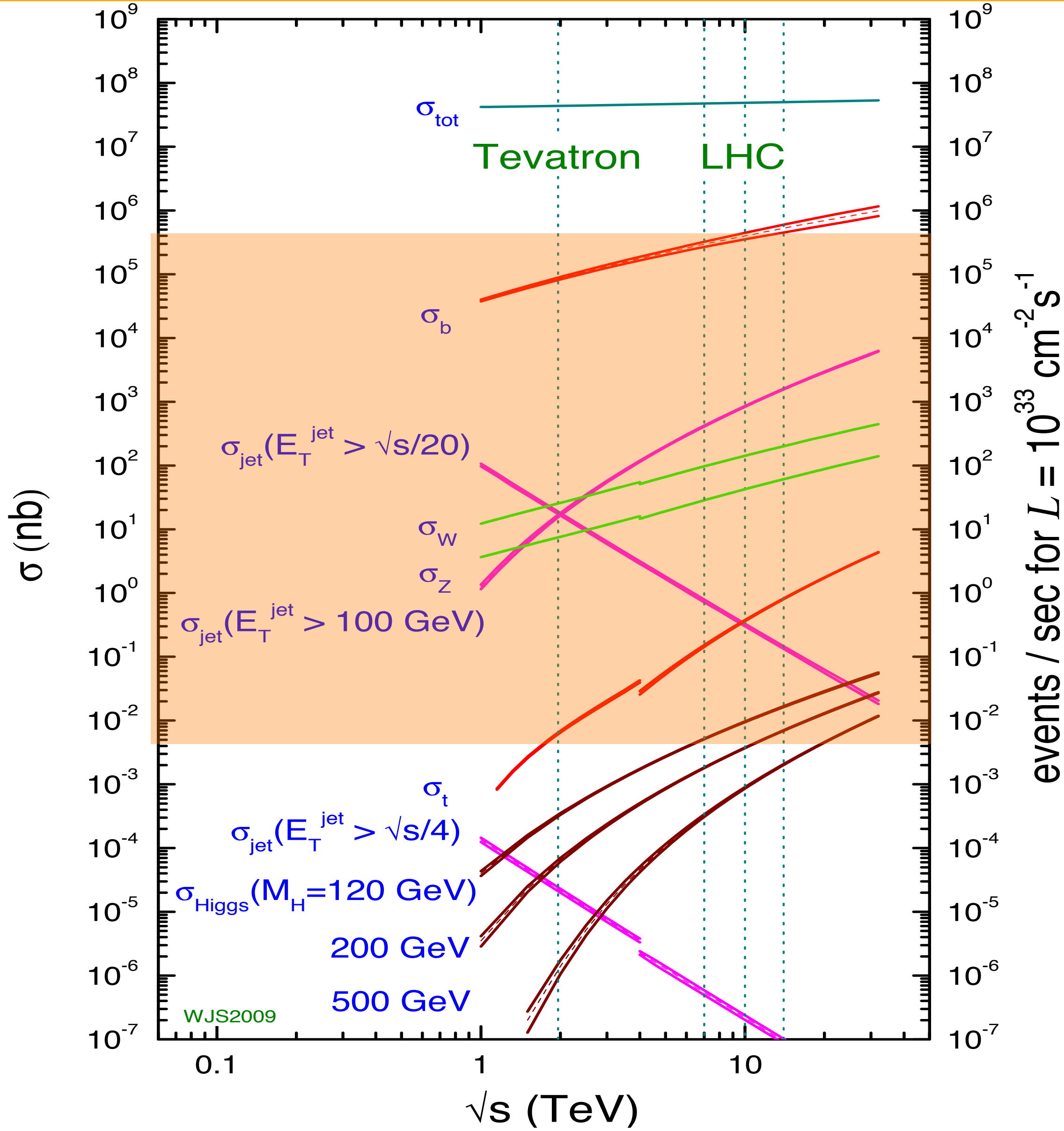
Search For H → $b\bar{b}$ at LHC

Recent LHC Results

Mode	ATLAS	CMS
VH; H → bb	**ArXiv:1207.0210 5 fb^{-1} (7 TeV)**	**PAS HIG-12-025 10 fb^{-1} (7 & 8 TeV)**
ttH; H → bb	Conf-2012-135 5 fb^{-1} (7 TeV)	PAS HIG-12-025 5 fb^{-1} (7 TeV)

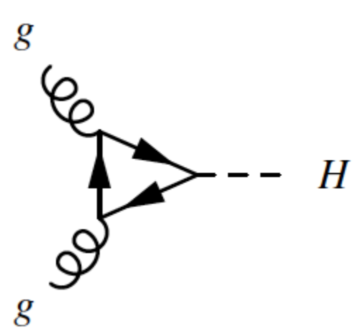
Vivek Sharma, UC San Diego

Digging For Gold Under a QCD Mountain



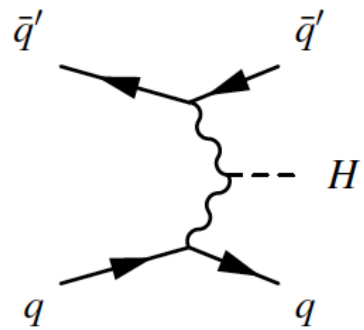
H → bb At LHC

- Production Mechanisms:



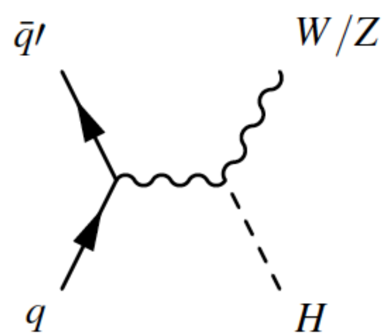
(a) $gg \to H$

No handle against overwhelming background from QCD b-jets



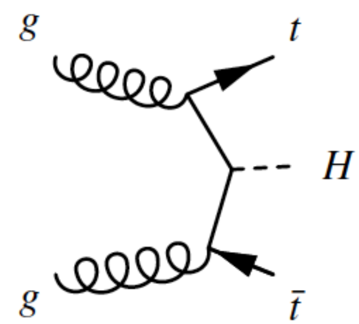
(b) VBF

Less background but still fully hadronic final state



(c) VH

Can use leptons/ MET signature and unique signal topology

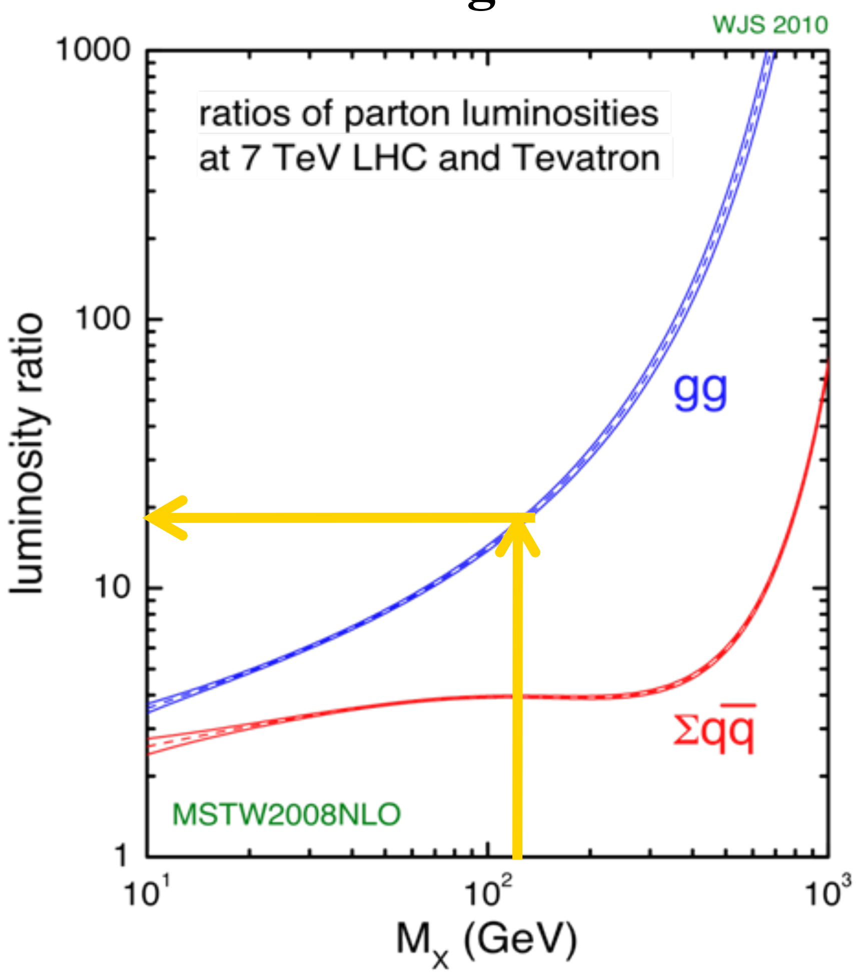


(d) $t\bar{t}H$

Very low rate, Large top background

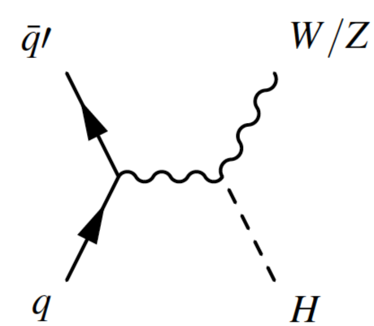
A Word on LHC & Tevatron Comparision

Stirling *et al*



For $M_X \approx 125$ GeV

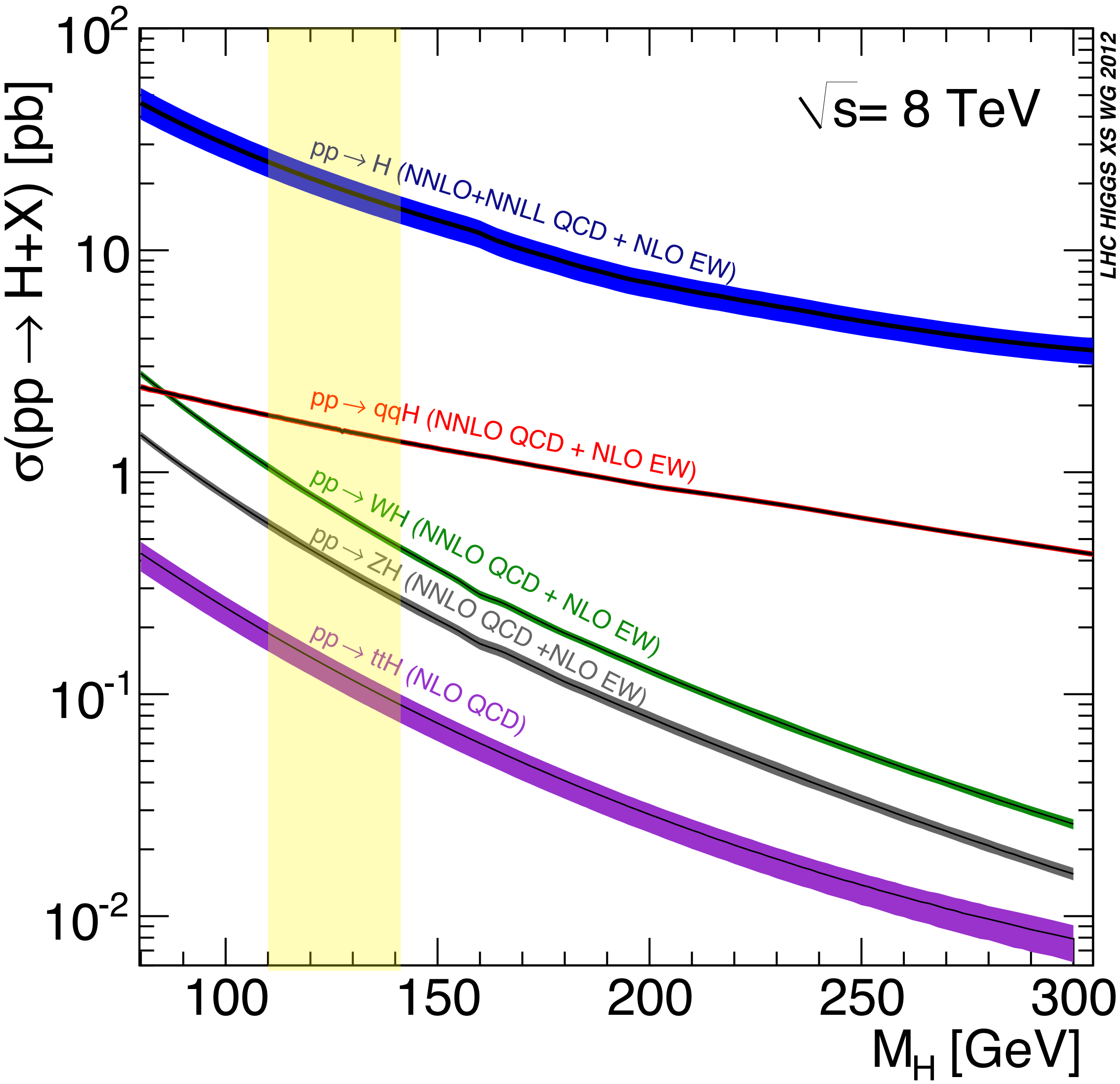
Modest rise in $q\bar{q}$ cross section at 7 TeV, pp → VH production only x3 larger than at 2 TeV



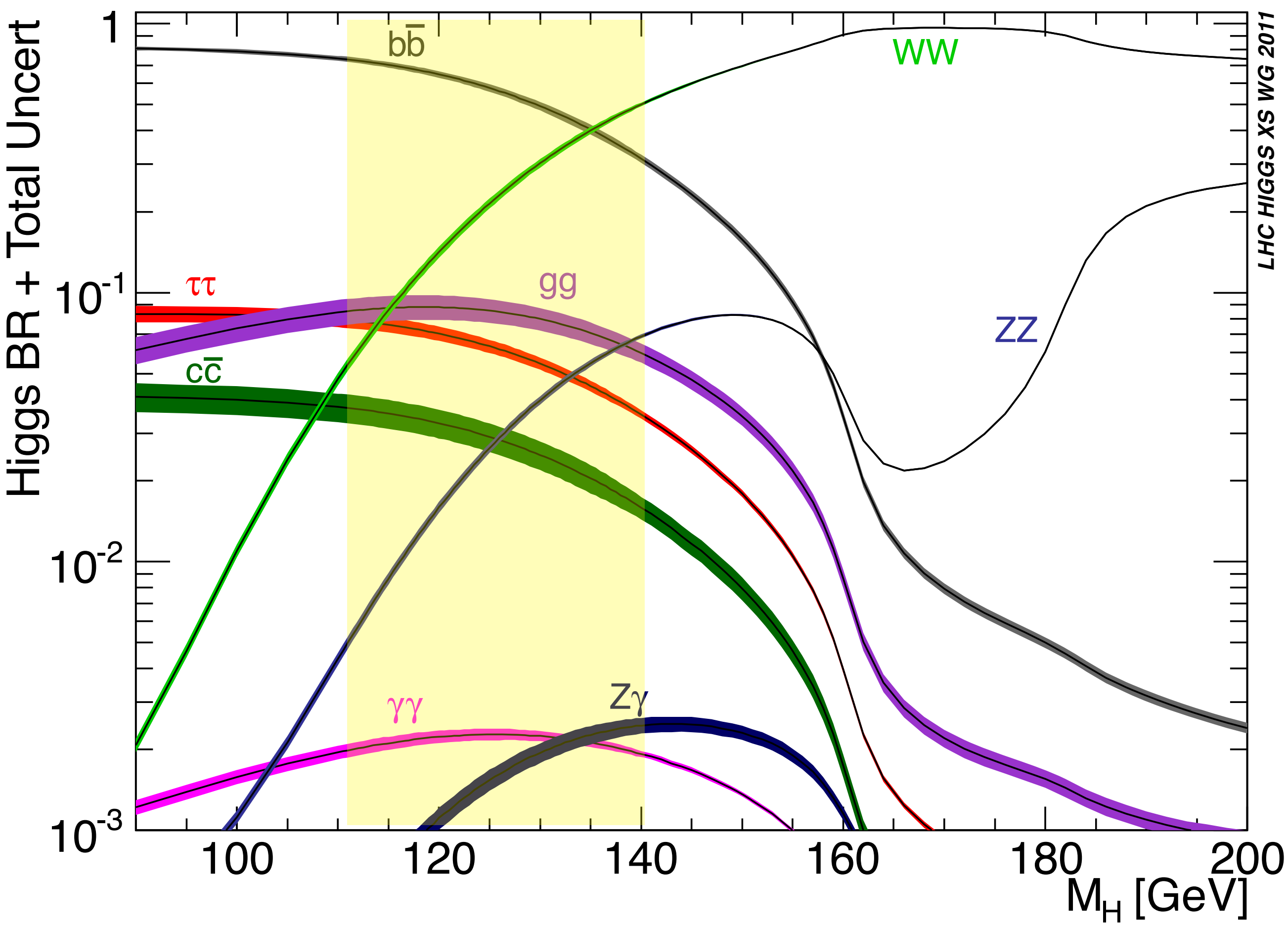
Major backgrounds are $W/Z{+}b\bar{b}$ & $t\bar{t}$ which rises sharply due to rise in gg cross section

⇒ Small signal, worse S/N

Higgs Production in pp collisions: √s = 8 TeV



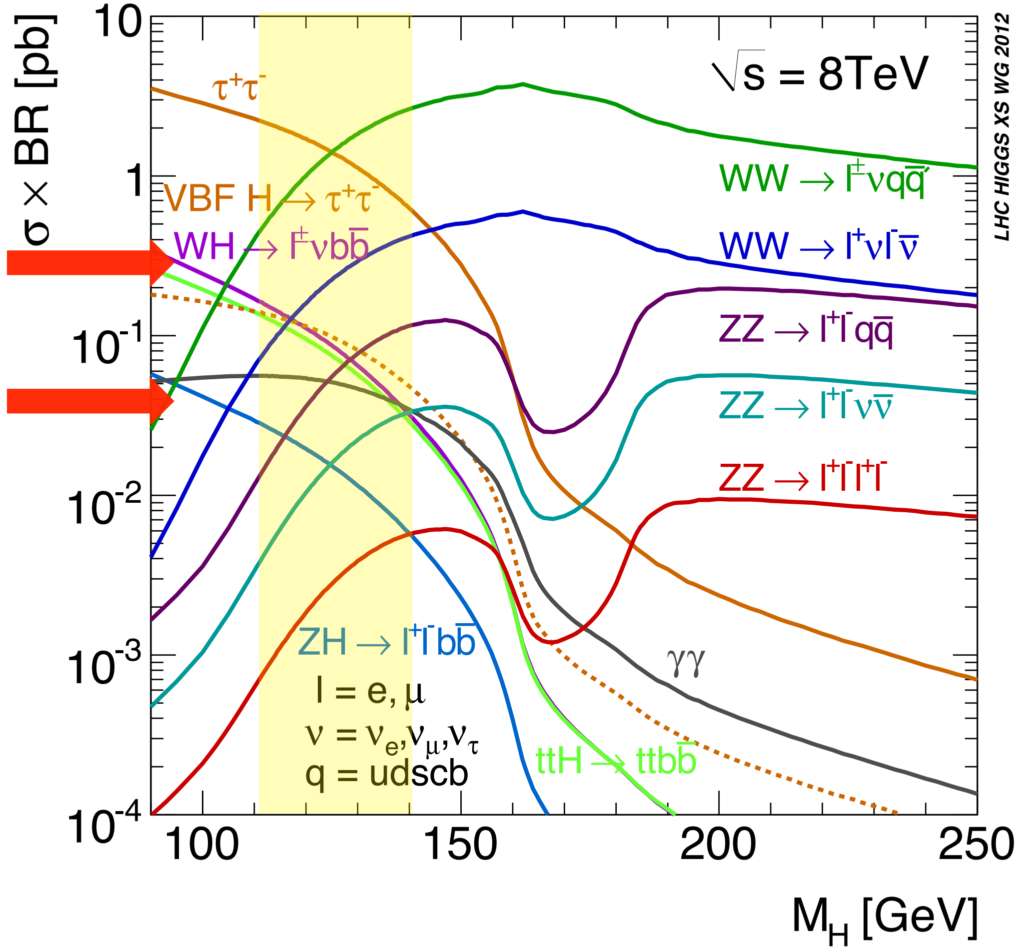
Higgs Branching Ratio At Low M_H



@ 125 GeV:

$\mathrm{BR}(h \to b\bar{b}) = 58\%$, $\mathrm{BR}(h \to WW^*) = 21.6\%$, $\mathrm{BR}(h \to \tau^+\tau^-) = 6.4\%$,
$\mathrm{BR}(h \to ZZ^*) = 2.7\%$, $\mathrm{BR}(h \to gg) = 8.5\%$, $\mathrm{BR}(h \to \gamma\gamma) = 0.22\%$,
$\mathrm{BR}(h \to c\bar{c}) = 2.7\%$

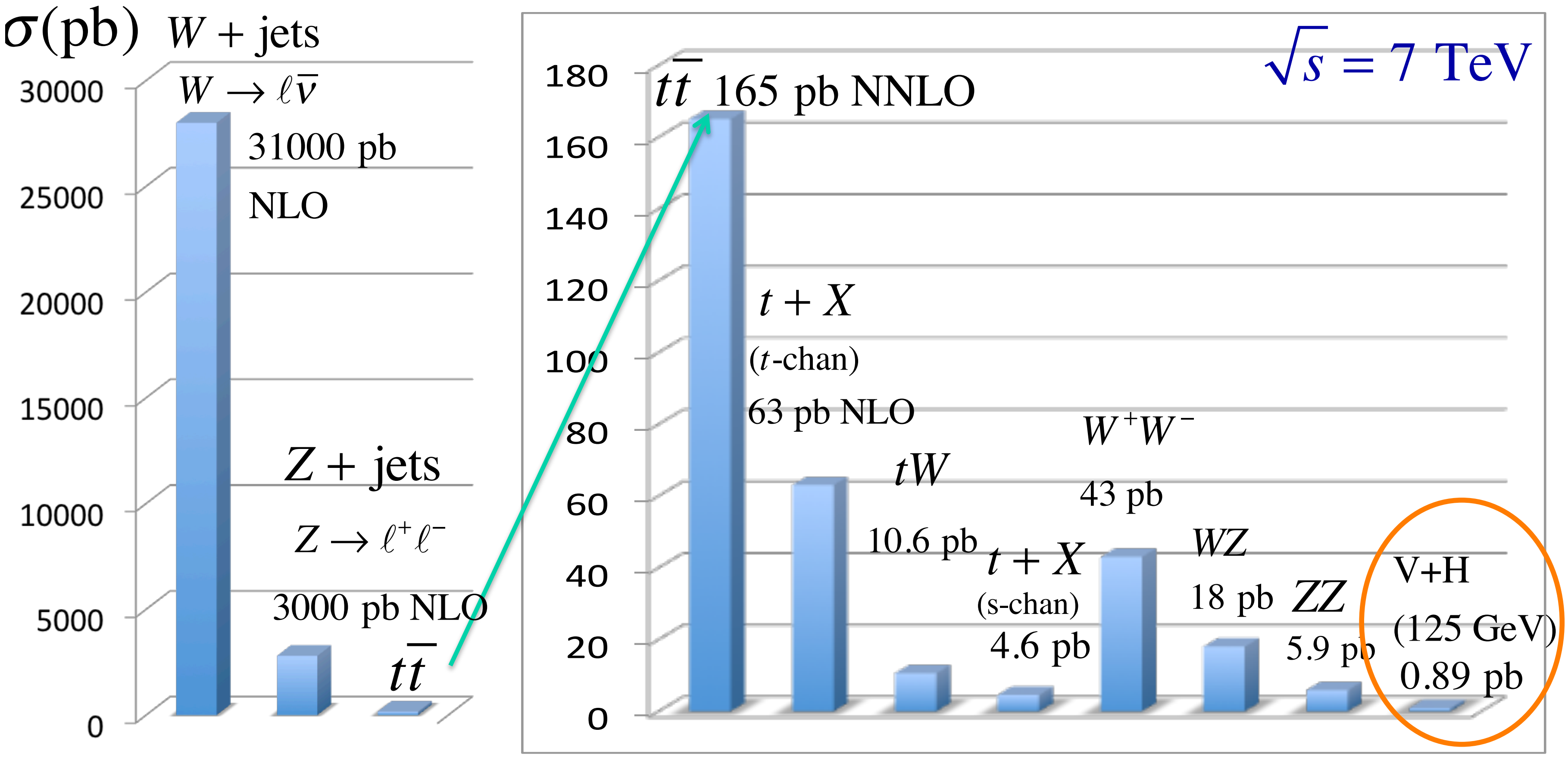
[Cross section × Branching Ratio] Vs M_H



Significance of an observation depends on ability to restrict background processes that mimic Higgs signature

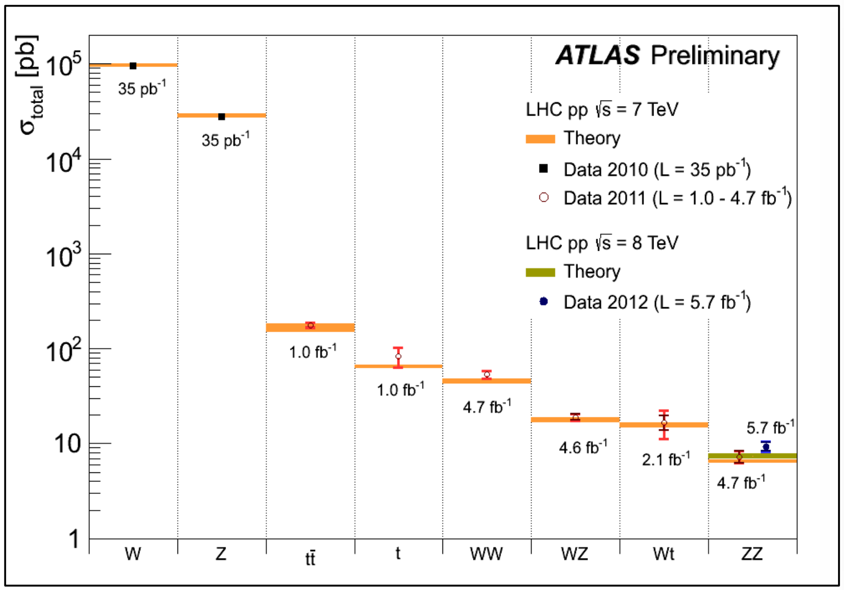
Cross Sections for Background SM Processes

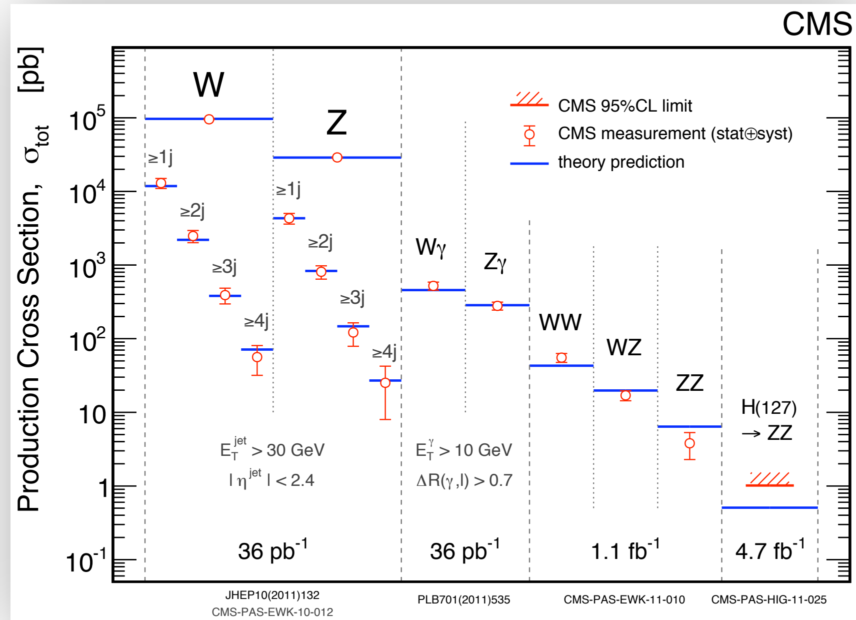
Backgrounds up to 5 orders of magnitude larger than signal !



Need to measure them as we search !

Measurements Of Key Background Processes



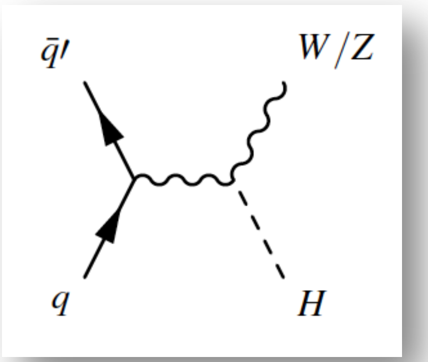


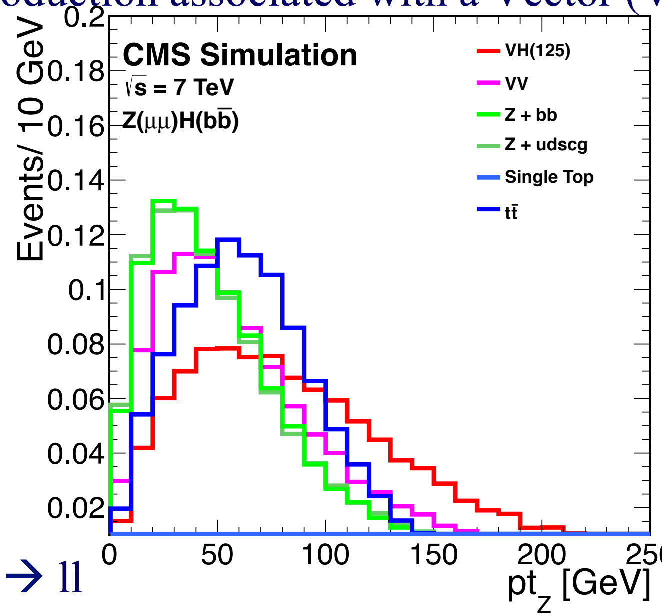
Good agreement between theory prediction and exptal measurements

Decades of precise theory effort comes to fruition !

CMS H→ bb Search In a Nutshell

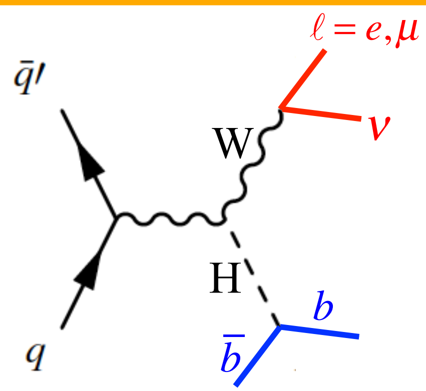
- H → bb production via gluon fusion and VBF are quite large but are buried (10^7) under QCD production of b bbar pairs
- Most promising channel is H → bb production associated with a Vector (V=W or Z) boson

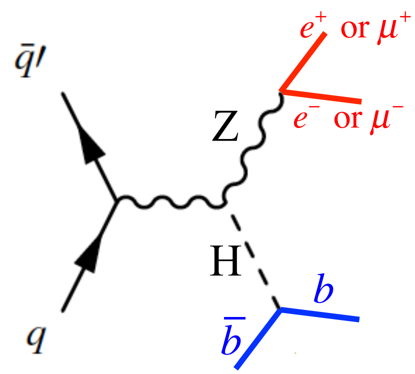


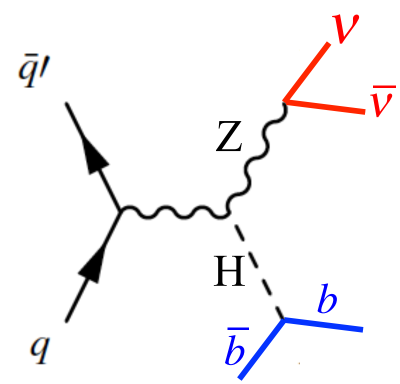


- V reconstruction: W → l ν, Z→ νν, Z → ll
- H→ bb reconstructed as two b-tagged jets recoiling against a high P_T W/Z boson
  - Large W/Z P_T → smaller background & better di-jet mass resolution
  - Use b-jet energy regression → improved H → bb mass resolution
- Events separated into categories , based on S/N (5 channels x 2 P_T(V) bins = 10)
- Use data control regions to constrain major backgrounds (V + jets, ttbar etc)
- Use MVA methods to discriminate between signal & background.

pp→VH; H → bb Triggers





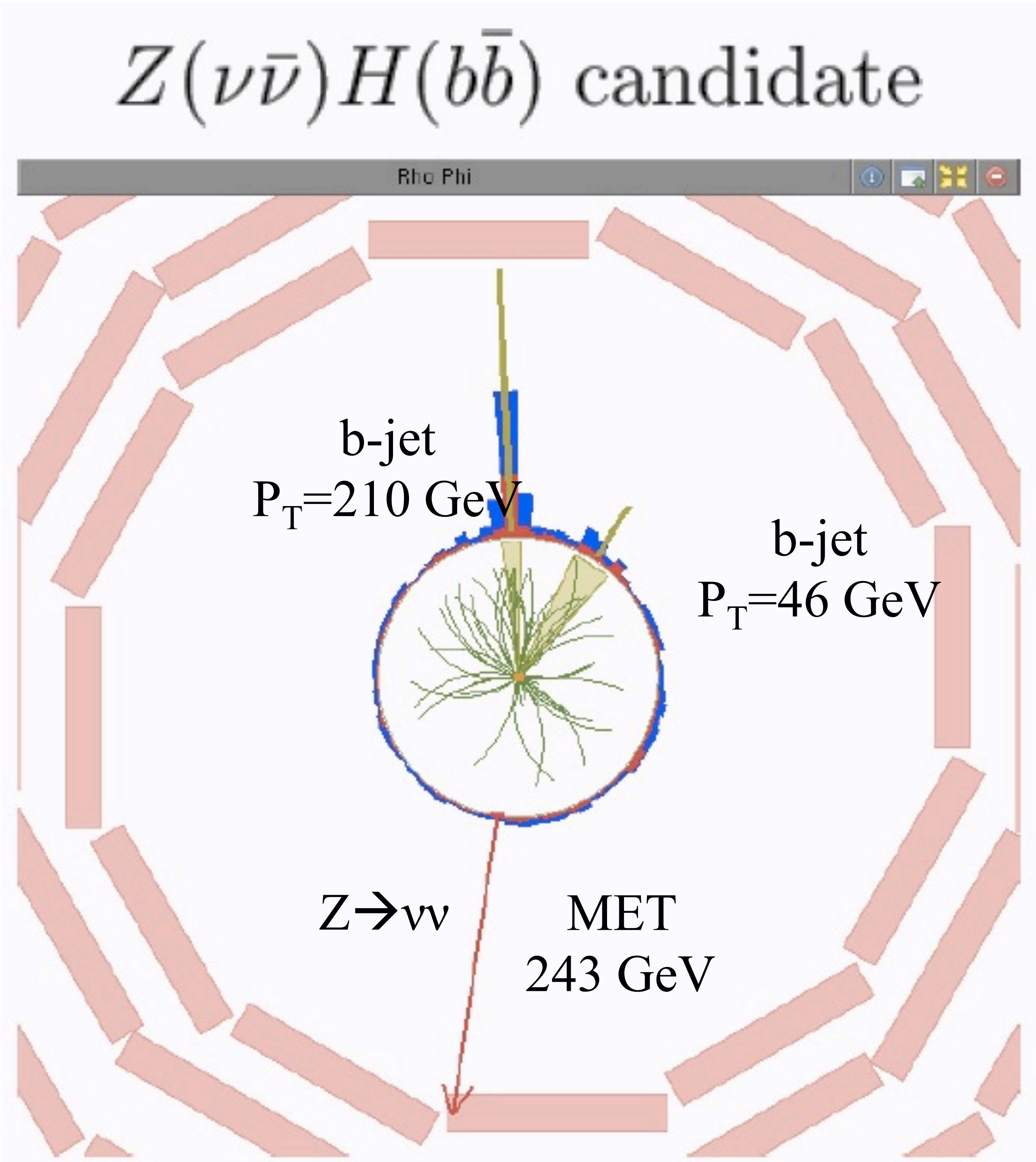


2011, 5 fb-1 @ 7 TeV

Mode	Lepton Trigger	Cross-Trigger (Jet, MET)
$W(\mu\nu)H$	(Isolated) muon, 17-40 GeV	-
$Z(\mu\mu)H$	(Isolated) muon, 17-40 GeV	-
$W(e\nu)H$	Isolated electron, ID cuts, 17-32 GeV	2 jets (25-30 GeV) + MHT (15-25 GeV)
$Z(ee)H$	Di-electron, 17-8 GeV	-
$Z(\nu\bar{\nu})H$	-	MET (80-100 GeV) + 2 jets (20 GeV) OR MHT (150 GeV)

2012, 5 fb-1 @ 8 TeV

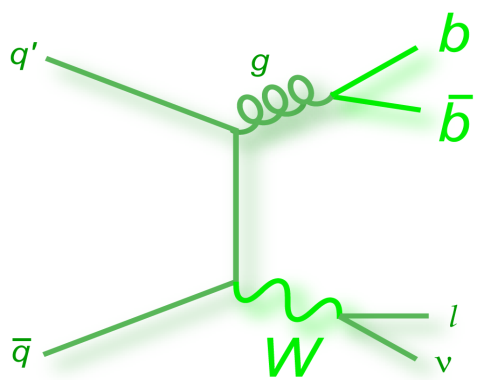
Mode	Lepton Trigger	Cross-Trigger (Jet, MET)
$W(\mu\nu)H$	(Isolated) muon, 24-40 GeV	-
$Z(\mu\mu)H$	(Isolated) muon, 24-40 GeV	-
$W(e\nu)H$	Isolated electron, ID cuts, 27 GeV	-
$Z(ee)H$	Di-electron, 17-8 GeV	-
$Z(\nu\bar{\nu})H$	-	MET (80 GeV) + 2 jets (25-60 GeV), $\Delta\phi$ cuts OR MHT (150 GeV)



Two clean b-jets
M_{bb} = 120 GeV
$P_{T,bb}$ = 248 GeV

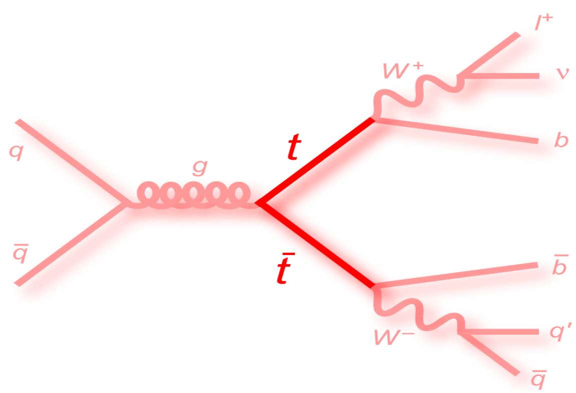
Recoiling against
Z→νν
➔ Large MET

Backgrounds in H→ bb Search



Reducible backgrounds:

- QCD (strongly suppressed by lepton isolation and Pt)
- V+udscg,V+bb @ low p_T and mass
- W(lν)W(jj)
- ttbar and single top (→Wb)



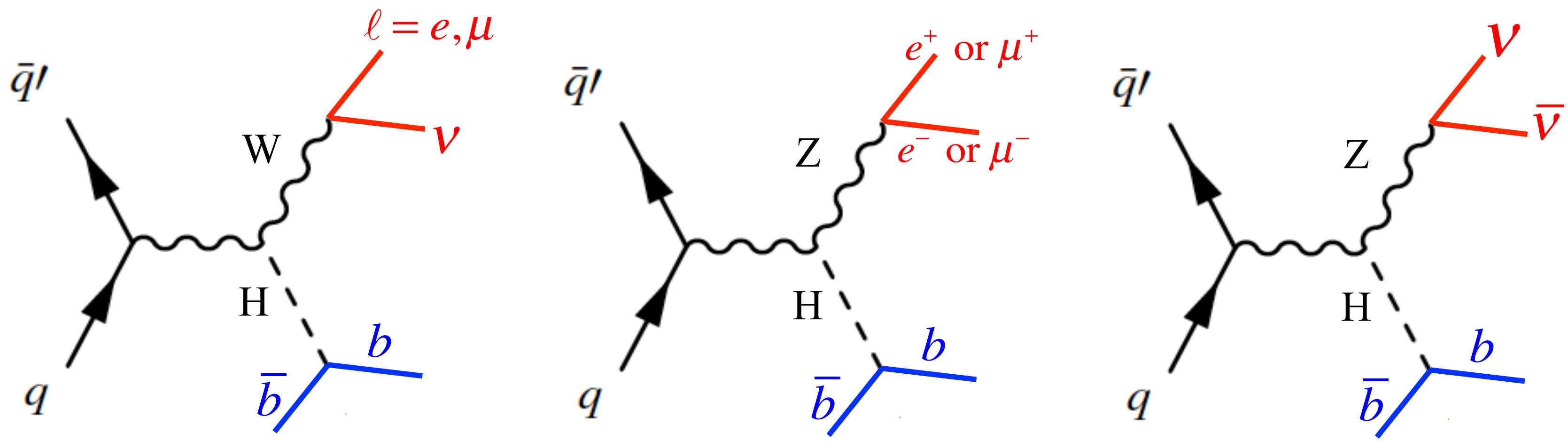
Irreducible backgrounds:

- V+bb @ high p_T and mass
- ZZ(bb), W(lν)Z(bb)

Important discriminating variables

- Mass resolution (separation of VH from VV)
- b-tagging ➔ suppression of V+light quarks
- Back-to-back topology
- Additional jet activity in the event (ttbar)

pp→VH; H → bb Search



To distinguish events with different S/N

➔ further catagorization by the p_T of the associated Vector boson

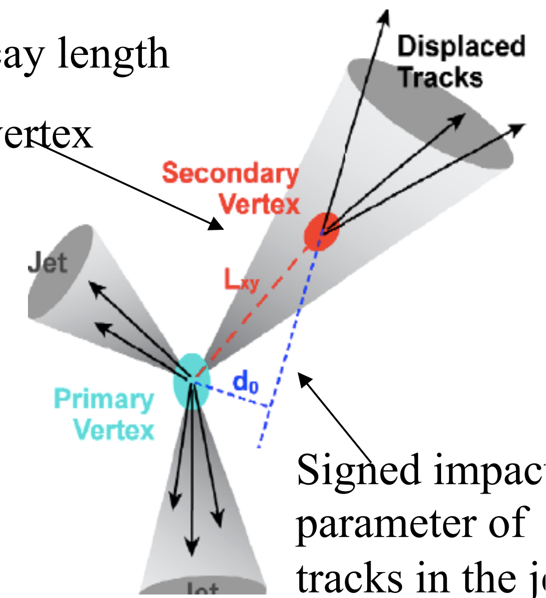
Channel	"Low " p_T (V)	"High" p_T (V)
Z → ll + H→ bb	$50 < p_T < 100$	$p_T > 100$
Z → νν + H→ bb	$120 < p_T < 160$	$p_T > 160$
W→ lν + H → bb	$120 < p_T < 170$	$p_T > 170$

➔ Total of 10 catagories & 2 run periods

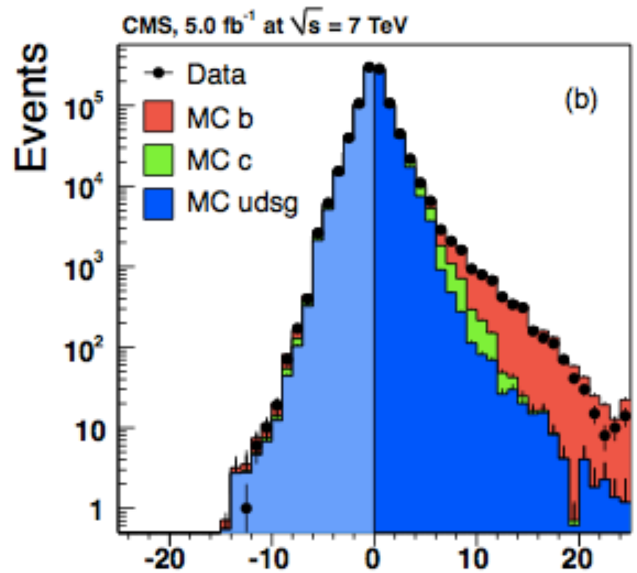
b-Jet Identification Crucial

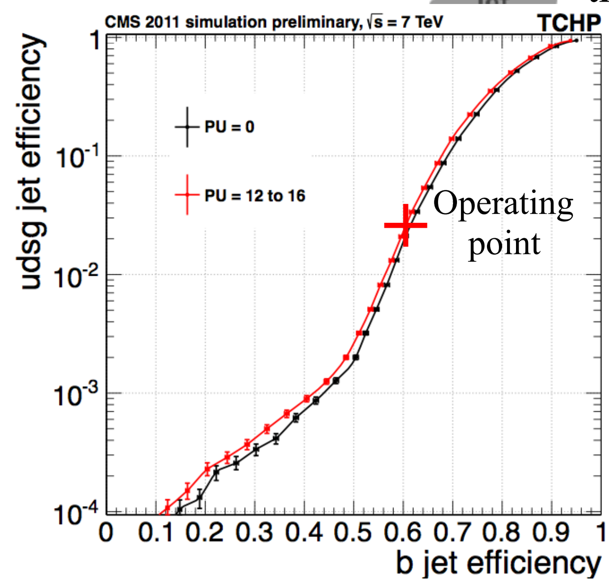
- b-hadron lifetime ≈ 1.5ps, <βγcτ> ≈ 1800μ
- Tracks from b-hadron decay have large P_T
- Average B-track multiplicity ≈ 6
- b-taggers based on
  - Large signed impact parameter significance
  - Secondary vertex with large decay length
- Mistag rate measured from "negative tags"

Signed decay length of B vertex



Signed impact parameter of tracks in the j



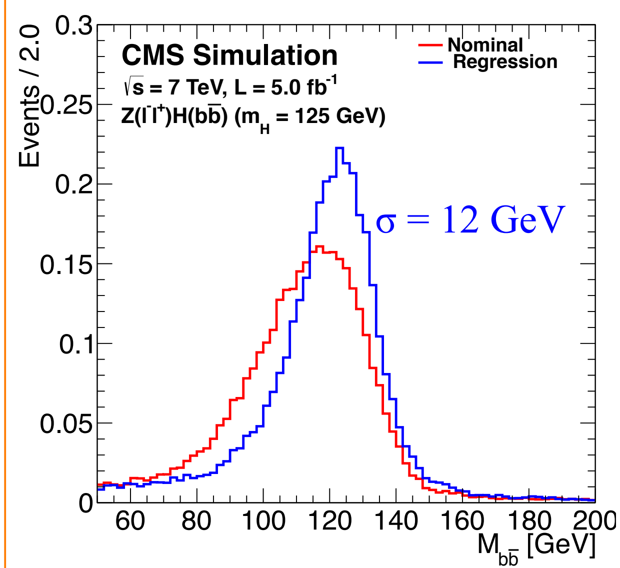


Improved b-Jet Energy Measurement

Mass resolution and bias improved using algorithm developed at CDF for b-jet energy corrections http://arxiv.org/pdf/1107.3026.pdf

A Regression trained on VH signal events using several jet variables:

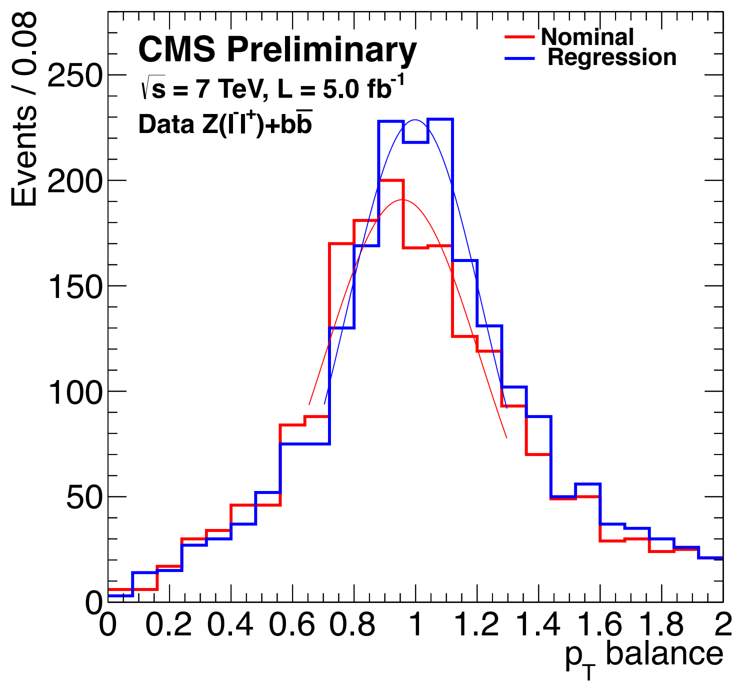
- raw p_T – transverse momentum of the jet before corrections;
- p_T – transverse momentum of the jet after corrections;
- E_T – transverse energy of the jet after corrections ($Z(\ell\ell)H$ uses E instead);
- M_T – transverse mass of the jet after corrections;
- η – pseudorapidity of the jet;
- ptLeadTrk – transverse momentum of the leading track in the jet;
- vtx3dL – 3-d flight length of the jet secondary vertex;
- vtx3deL – error on the 3-d flight length of the jet secondary vertex;
- vtxMass – mass of the jet secondary vertex;
- vtxPt – transverse momentum of the jet secondary vertex;
- Chf – fraction of jet constituents that are charged;
- Nch – number of jet constituents that are charged;
- Ntot – total number of jet constituents;
- $\rho25$ – energy density calculated within $|\eta| < 2.5$;



➔ Improvements in M_{bb} mass resolution of about 20% for Z(ll)H, 15% for W(lν)H and Z(νν)

b-Jet Energy Regression Validation

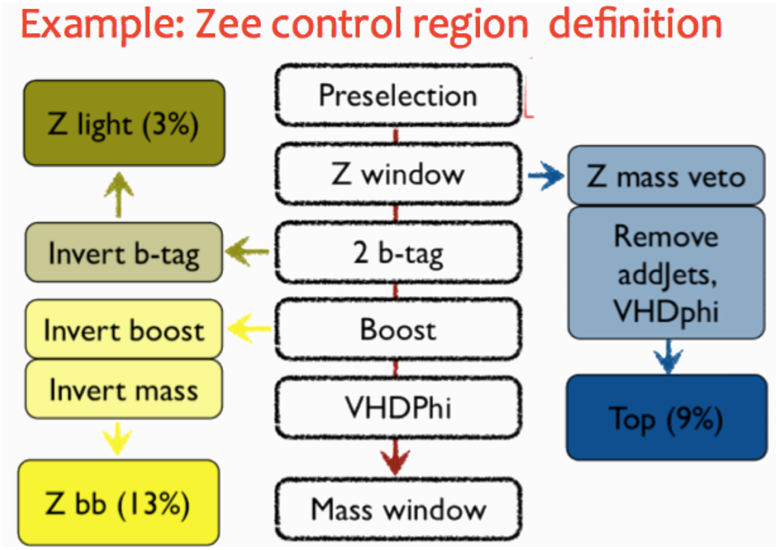
Extensively validated on simulation and Data Control Regions
→ check of data/MC agreement of variables input to the regression in all control regions
→ p_T balance in Z(→ll)+bb
→ full reconstruction of top mass in ttbar and Single Top samples



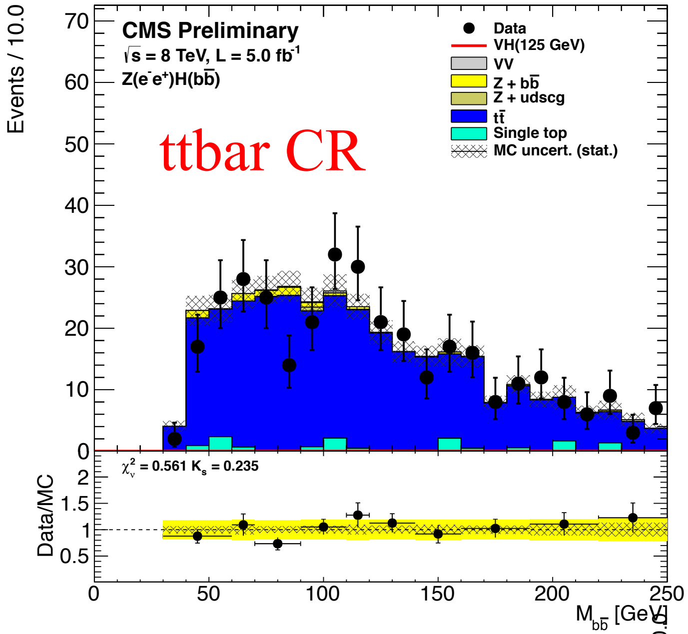
Background Estimate From Control Regions

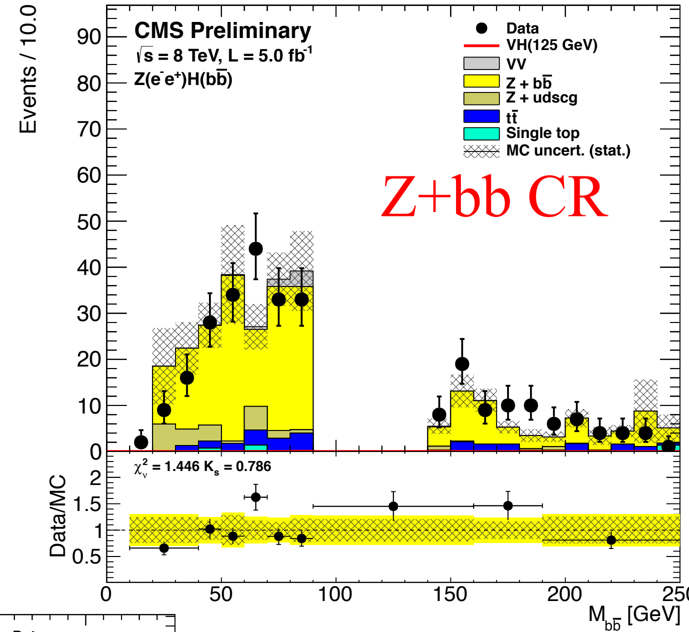
- Main backgrounds are the usual suspects:
  - Reducible: W/Z + jets (light and heavy flavor jets) & ttbar
  - Irreducible : WZ, ZZ and single top (taken from simulation)
- Background yields determined from several signal-depleted control regions (CR) using kinematic selection close to signal region (SR)
- Scale factors (SF) for V+udscg, ttbar V+bb/cc determined simultaneously in each mode from likelihood fits in control regions
- Renormalize background estimate in signal region based on these SF

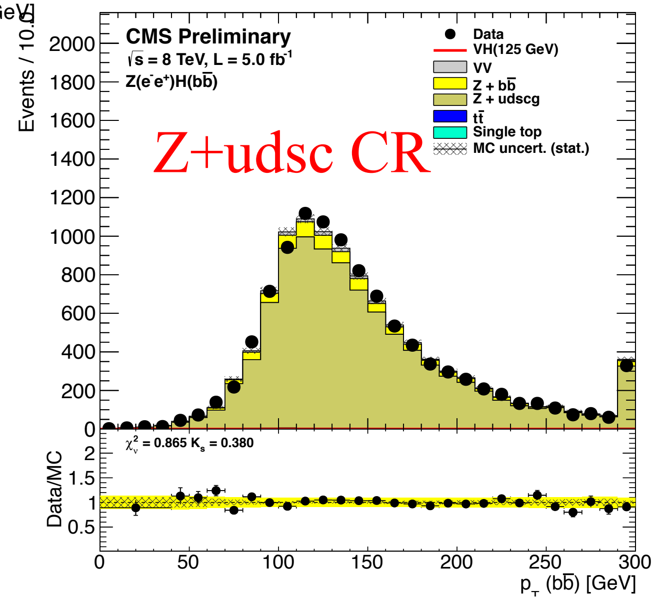
$$\text{Bkgnd(SR)} = \text{SF(CR)}*\text{Bkgnd}_{MC}\text{(SR)}$$



Example Control Regions In Data: (Z → *ee*)+ H Mode





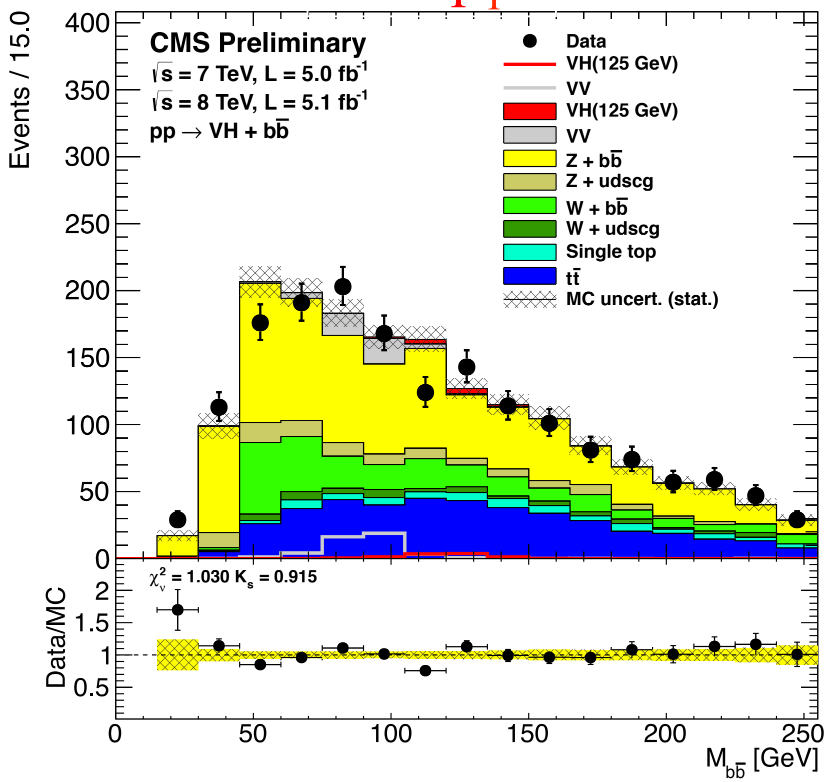


Reasonably pure control samples

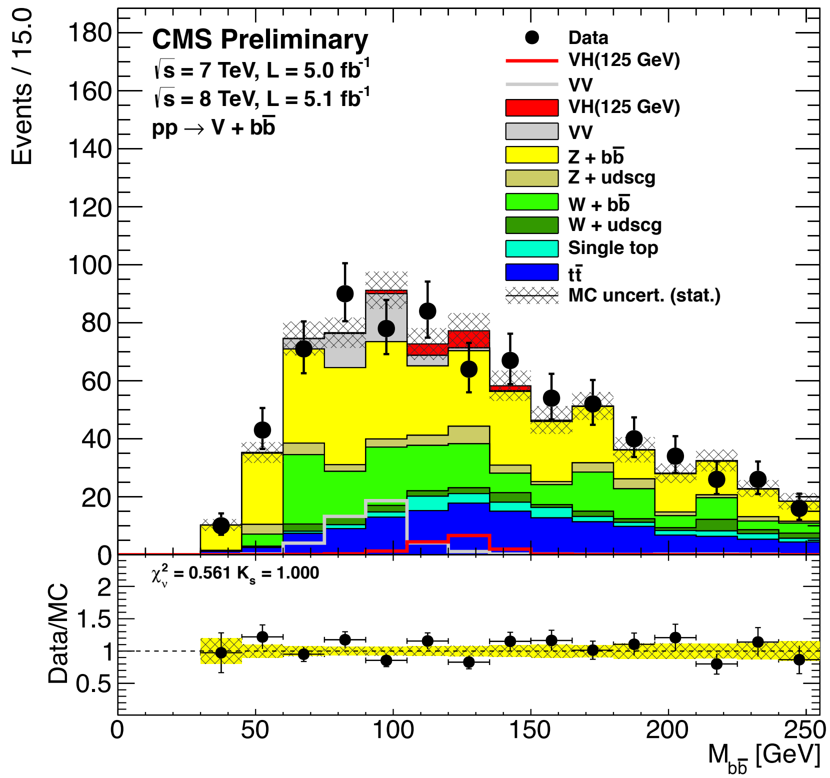
M_{bb} Mass Distribution : All Channels Combined

Distribution of events that pass a selection optimized for M_{bb} variable

Low p_T^V



High p_T^V



Good agreement between data and background prediction

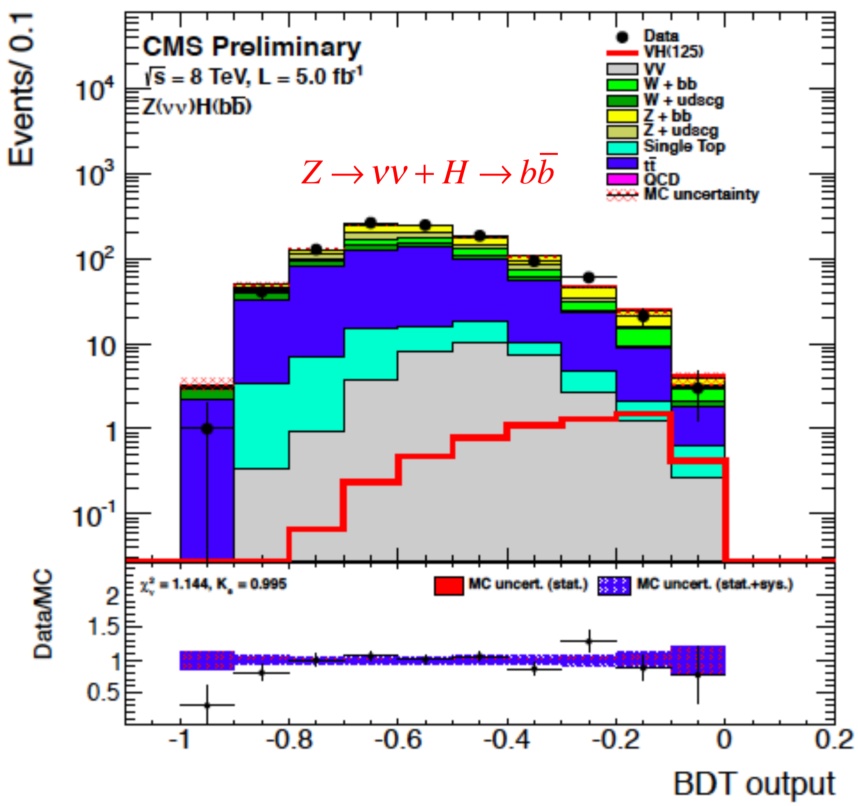
Further Separating Signal From Backgrounds

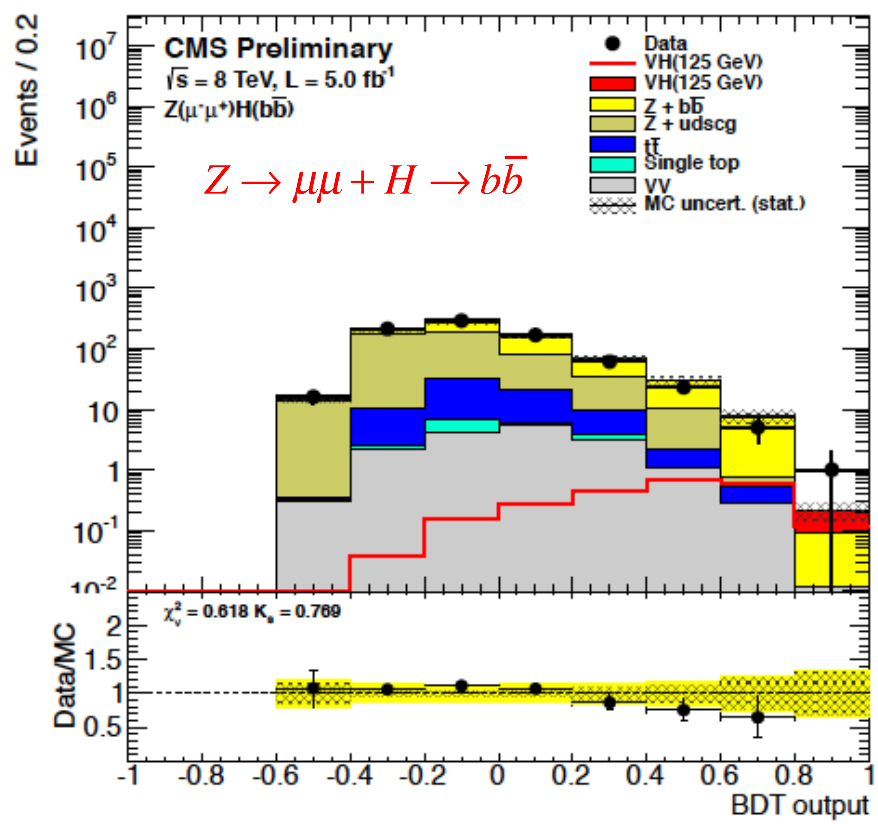
- A multivariate (BDT) algorithm trained at each Higgs mass hypothesis
- Several kinematic and topological variables used to separate Signal from background

Variable
$p_{\mathrm{T}j}$: transverse momentum of each Higgs daughter
$m(\mathrm{jj})$: dijet invariant mass
$p_{\mathrm{T}}(\mathrm{jj})$: dijet transverse momentum
$p_{\mathrm{T}}(\mathrm{V})$: vector boson transverse momentum (or pfMET)
$\mathrm{CSV}_{\mathrm{max}}$: value of CSV for the b-tagged jet with largest CSV value
$\mathrm{CSV}_{\mathrm{min}}$: value of CSV for the b-tagged jet with second largest CSV value
$\Delta\phi(\mathrm{V},\mathrm{H})$: azimuthal angle between V (or $E_{\mathrm{T}}^{\mathrm{miss}}$) and dijet
$\lvert\Delta\eta(\mathrm{jj})\rvert$; difference in η between Higgs daughters
$\Delta R(\mathrm{j1},\mathrm{j2})$; distance in η–ϕ between Higgs daughters (not for $\mathrm{Z}(\ell\ell)\mathrm{H}$)
N_{aj}: number of additional jets ($p_{\mathrm{T}} > 30\,\mathrm{GeV}$, $\lvert\eta\rvert < 4.5$)
$\Delta\phi(\mathrm{E}_{\mathrm{T}}^{\mathrm{miss}},\mathrm{jet})$: azimuthal angle between $E_{\mathrm{T}}^{\mathrm{miss}}$ and the closest jet (only for $\mathrm{Z}(\nu\nu)\mathrm{H}$)
$\Delta\theta_{\mathrm{pull}}$: color pull angle [62] (not for $\mathrm{Z}(\ell\ell)\mathrm{H}$)

Shapes of Signal & Background BDT Distributions

- A Higgs signal in the mass range [110-135] GeV is searched for as an excess in MVA classifier using predicted shapes for signal & bkgnd





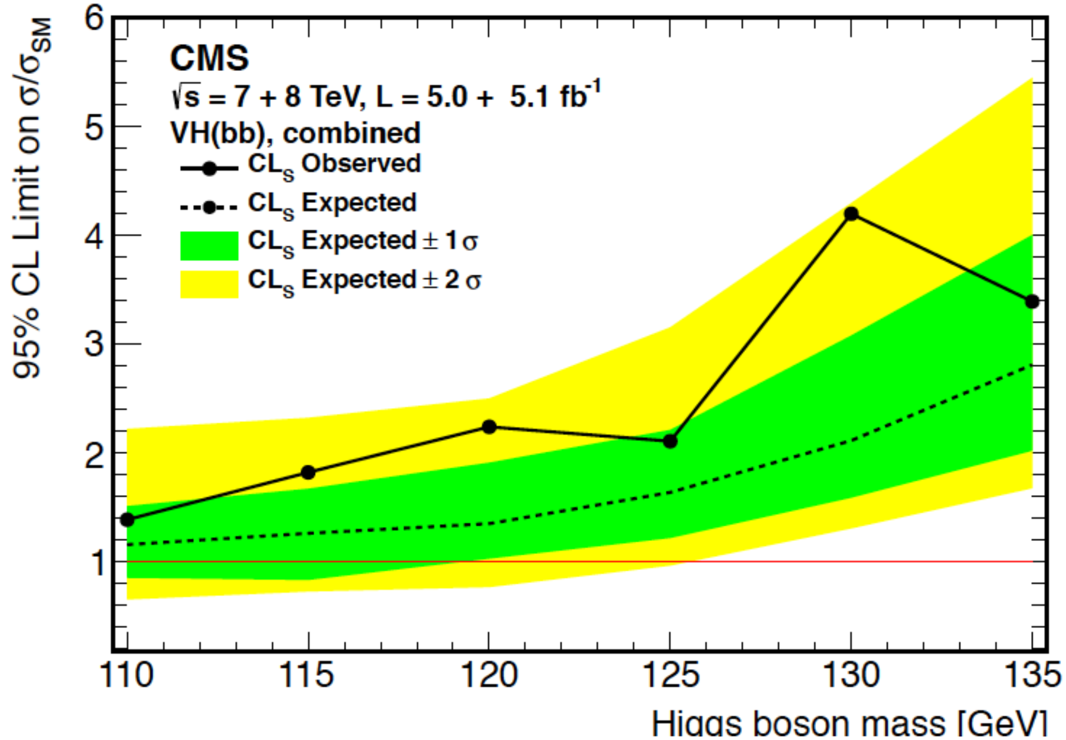
No significant excess seen over predicted background yields in these or other channels

Systematic Uncertainties in VH Analysis

Source	Range
Luminosity	2.2-4.4%
Lepton efficiency and trigger (per lepton)	3%
$Z(\nu\nu)H$ triggers	2%
Jet energy scale	2–3%
Jet energy resolution	3–6%
Missing transverse energy	3%
b-tagging	3–15%
Signal cross section (scale and PDF)	4%
Signal cross section (p_T boost, EWK/QCD)	5–10% / 10%
Signal Monte Carlo statistics	1-5%
Backgrounds (data estimate)	$\approx$ 10%
Diboson and single-top (simulation estimate)	30%

CMS Limits: VH, H → bb Searches (10 fb^{-1})

Limit based on S & B shape analysis of BDT output

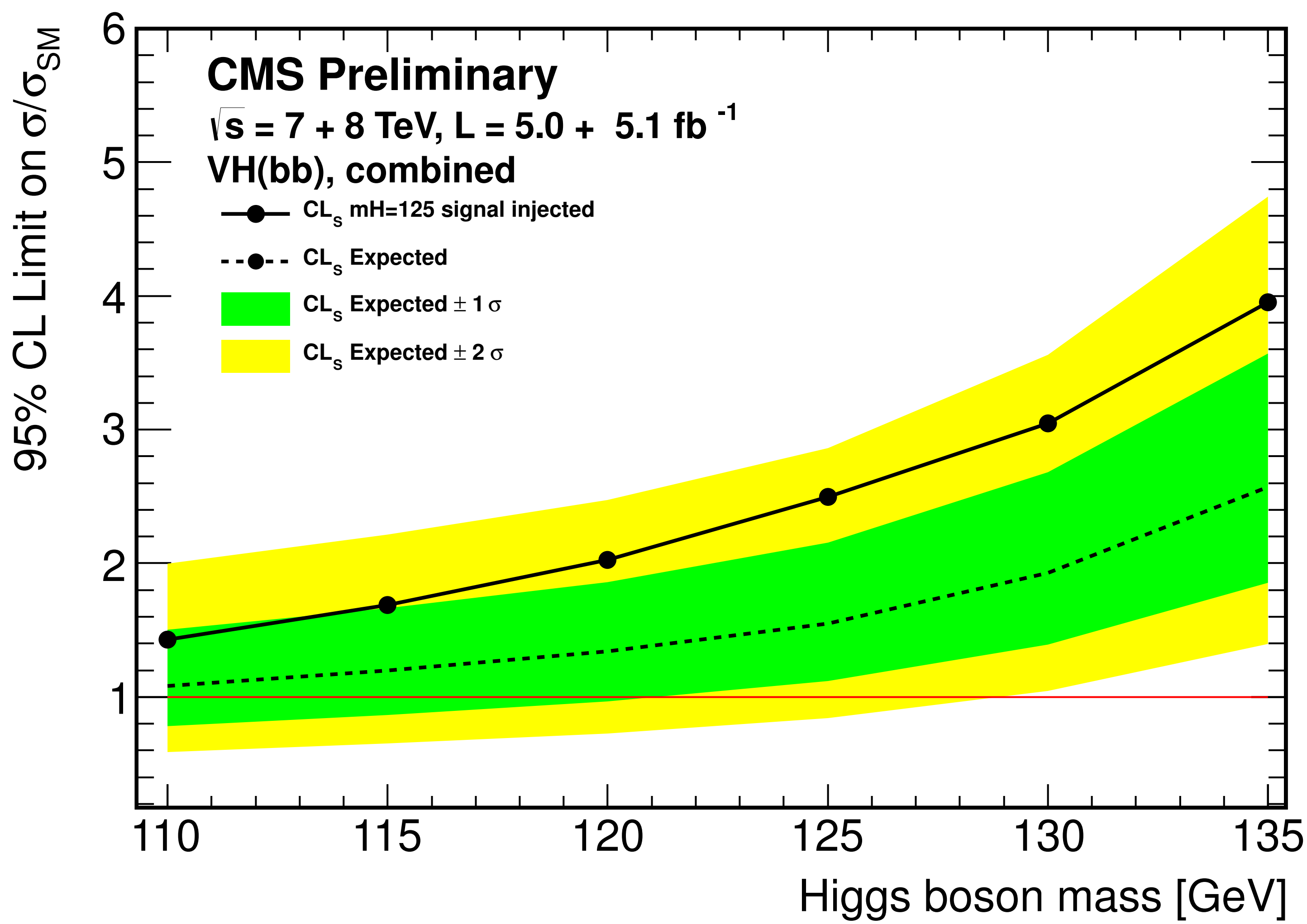


m_H(GeV)	110	115	120	125	130	135
Exp.	1.16	1.26	1.35	1.64	2.12	2.81
Obs.	1.39	1.82	2.24	2.11	4.20	3.39

Approaching SM Higgs Sensitivity

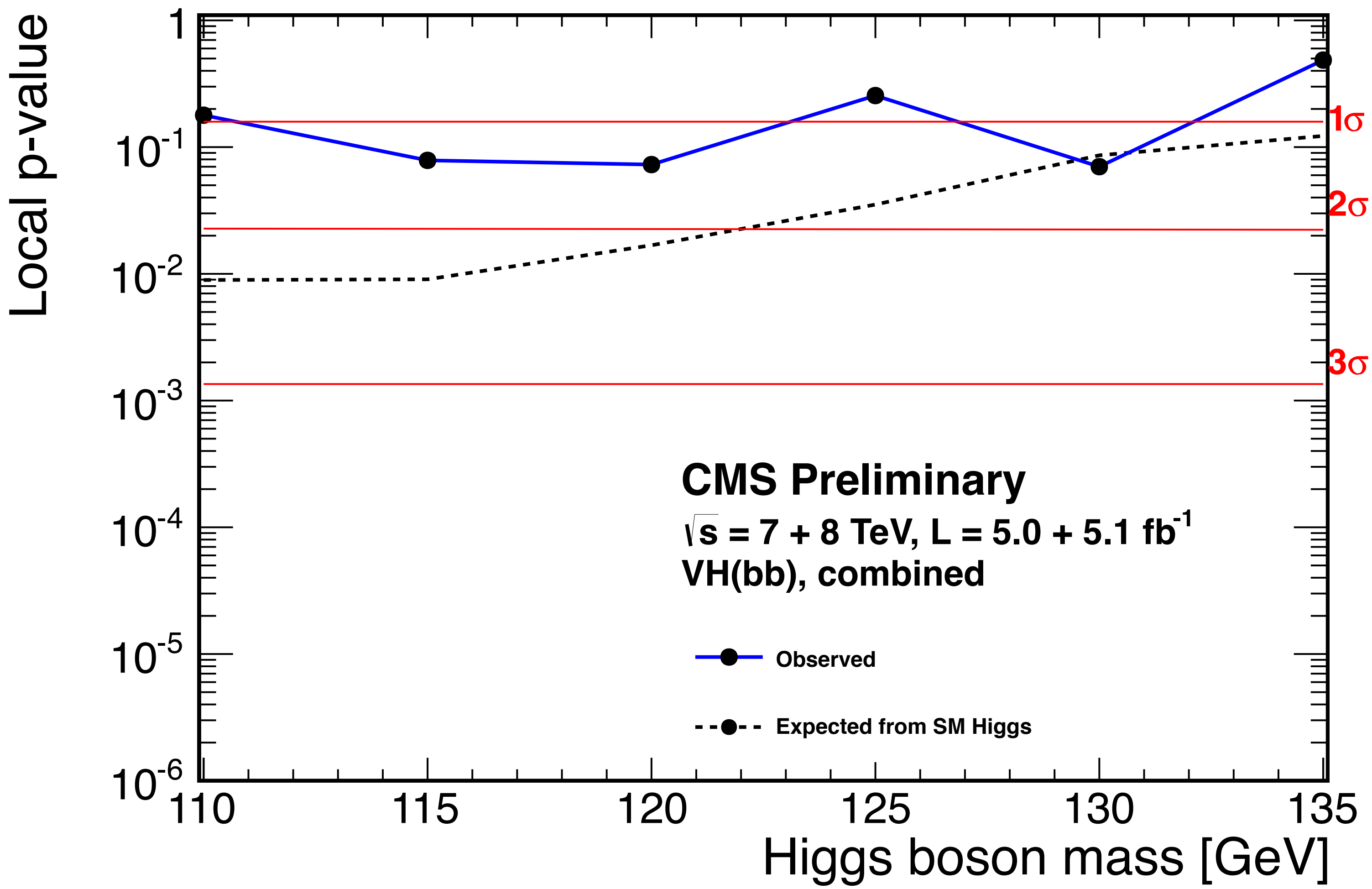
What Would A M_H = 125 GeV Signal Look Like

- Inject Signal pseudo-data corresponding to SM $\sigma \times$ Br



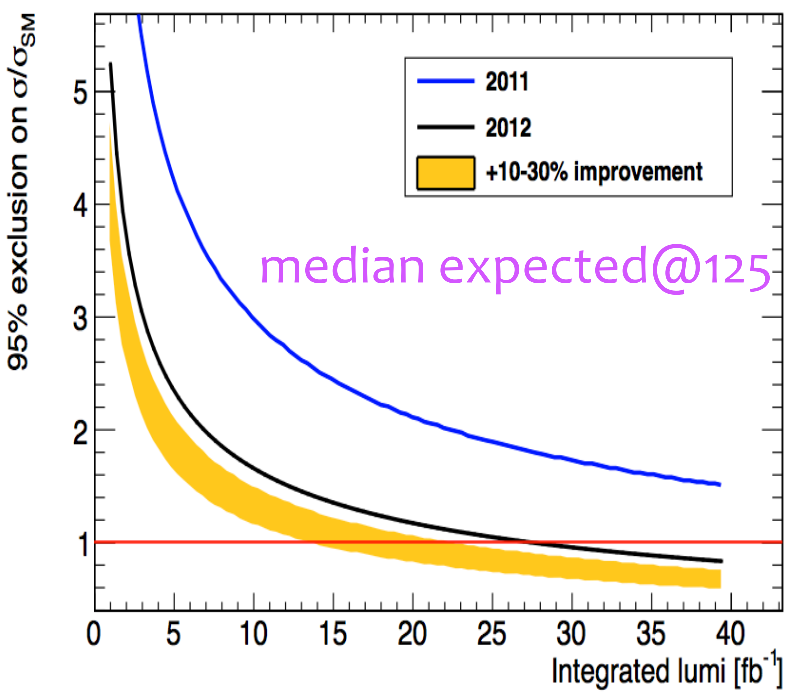
p-Value Distribution: CMS

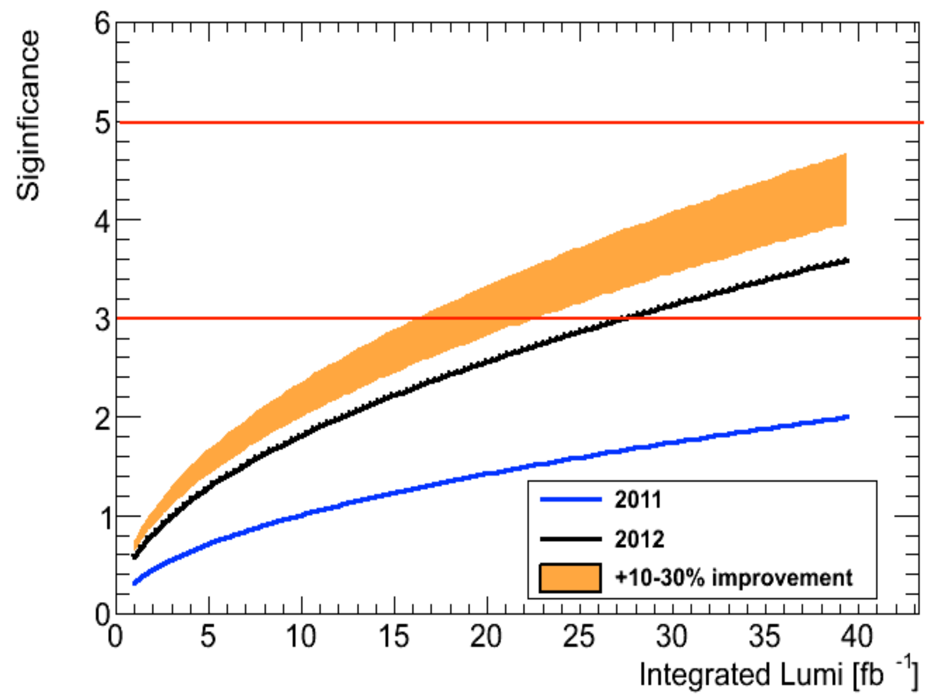
p-value: chance of background fluctuating as high as or higher than what is observed in data at a particular mass



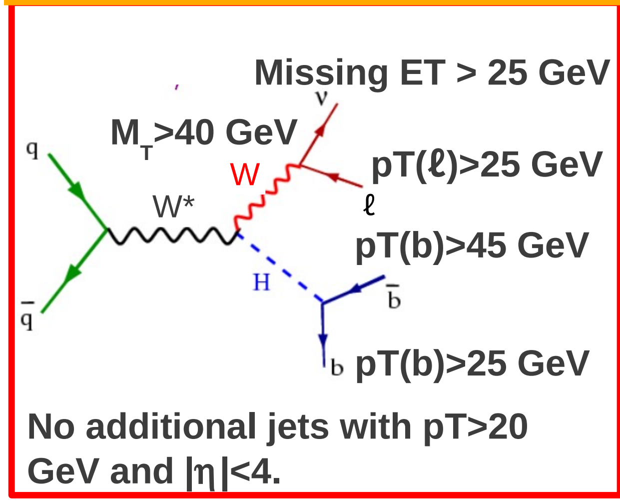
CMS Sensitivity With More Data & Improvements

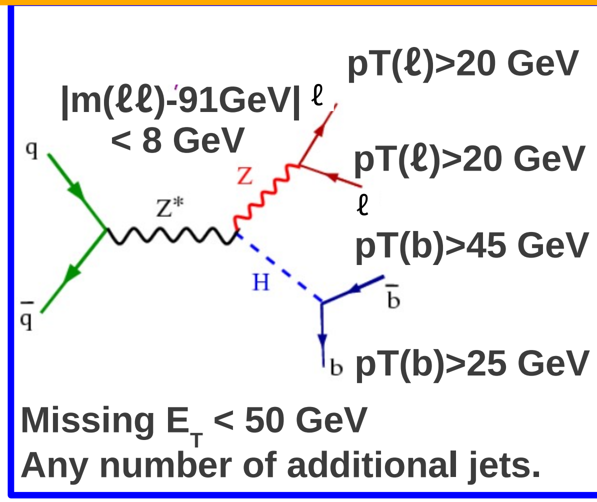
- Further plans to improve sensitivity by ≈ 10-30% :
  - increase signal reconstruction efficiency, add V → τ final states
  - improve M_{bb} mass resolution when b decays semileptonically
  - improved characterization of backgrounds

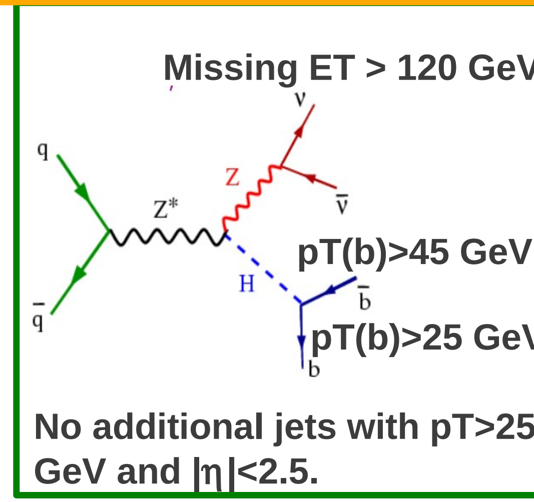




ATLAS Search For VH, H → bb (4.7 fb^{-1} at 7 TeV)

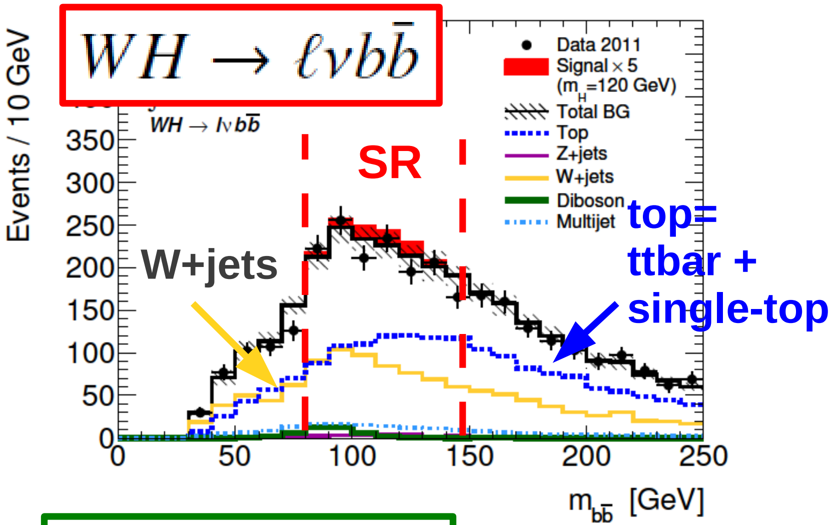


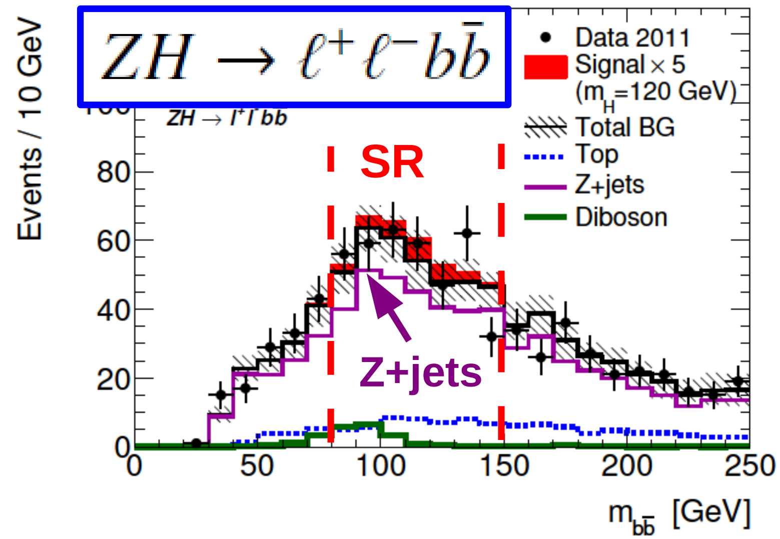


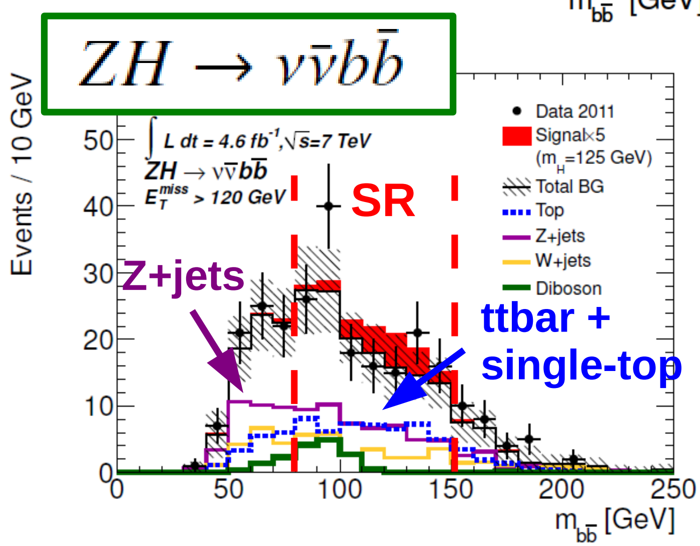


- Each channel subdivided into bins in $p_T(V)$ to take advantage of varying S/B and background composition → 11 subchannels
- Cut based analysis → look for an excess in M_{bb} distribution
- M_{bb} shapes for signal and major backgrounds (V+jets, ttbar..) taken from simulation, determine scale factors from signal-free control regions in data
  - scale factors in different CRs vary between 0.8 -2.4
  - minor backgrounds (WZ, WW etc) taken from theory calc.

Signal & Control Regions



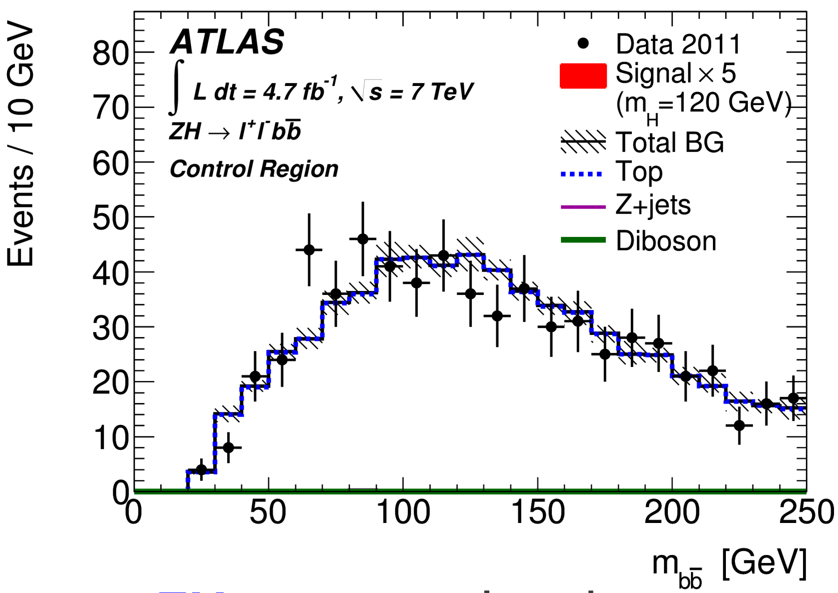


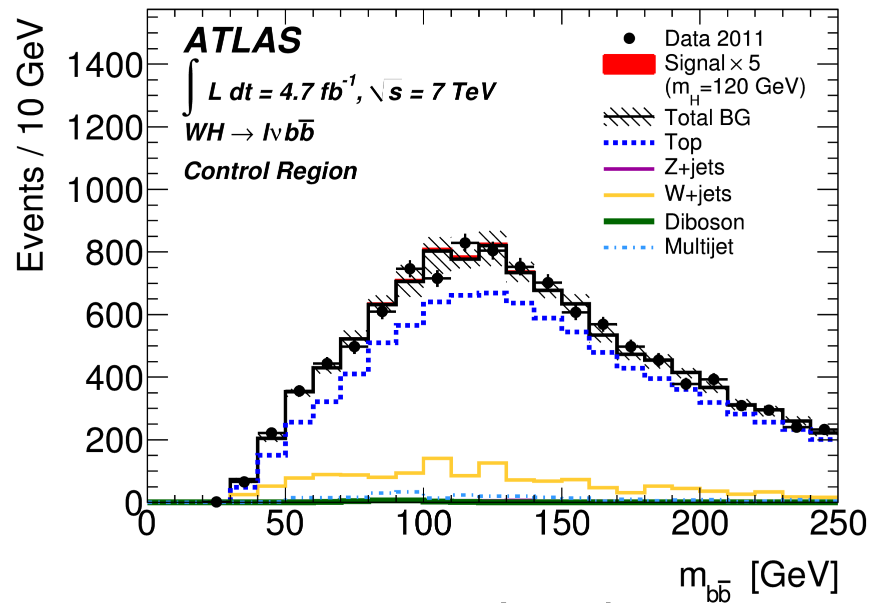


+ **resonant background** from diboson

- M(bb) shape from MC, normalization of main backgrounds from data (excluding **SR**)
- $WH \rightarrow \ell\nu b\bar{b}$: Top and W+jet scale factors from m(bb) sidebands + WH top control region
- $ZH \rightarrow \ell^+\ell^- b\bar{b}$: Top and Z+jet scale factors from m(bb) sidebands + ZH top control region
- $ZH \rightarrow \nu\bar{\nu} b\bar{b}$: take scale factors from other channels, after cross-checking in dedicated control regions.

Top Background Control Regions

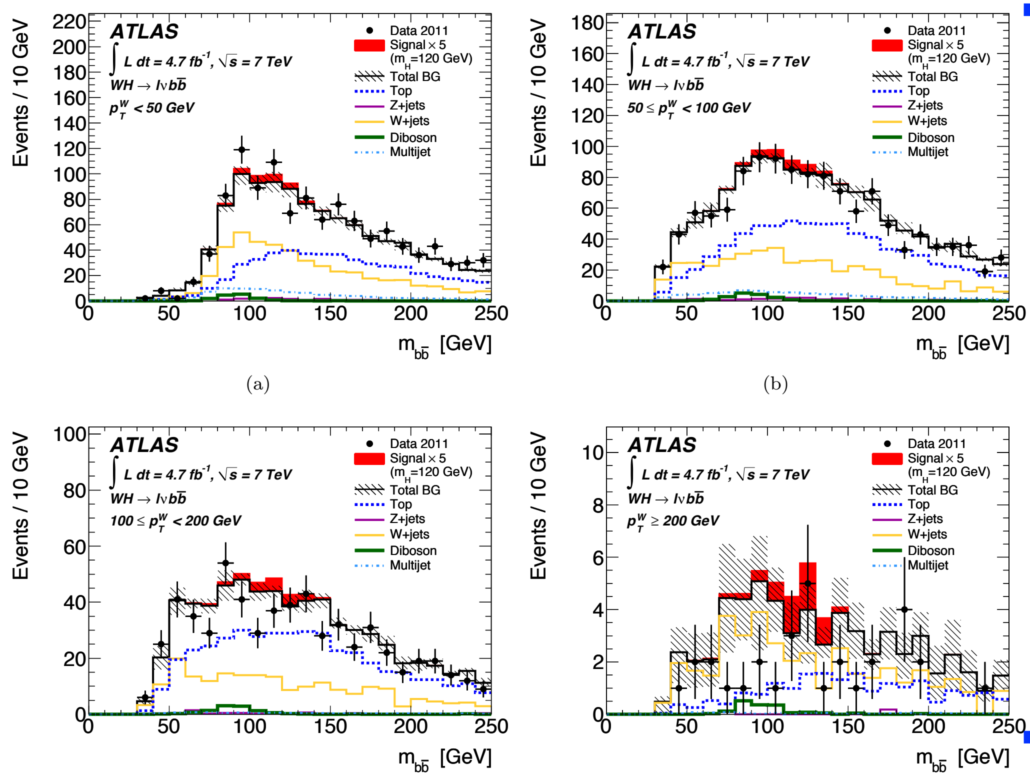




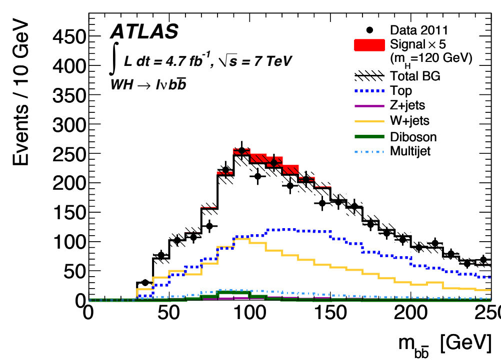
- **ZH** top control region:
  - |m(ℓℓ)-91GeV|>15 GeV
  - ETmiss > 50 GeV
- **WH** top control region:
  - Require 3 instead of 2 jets in the events

Very good agreement in m(bb) shape after simultanous fit to top and W+jet backgound normalizations. Normalization for W+jet background in 3 jet bin determined independently from W+jet in 2 jet bin.

ATLAS Search For WH, H → bb

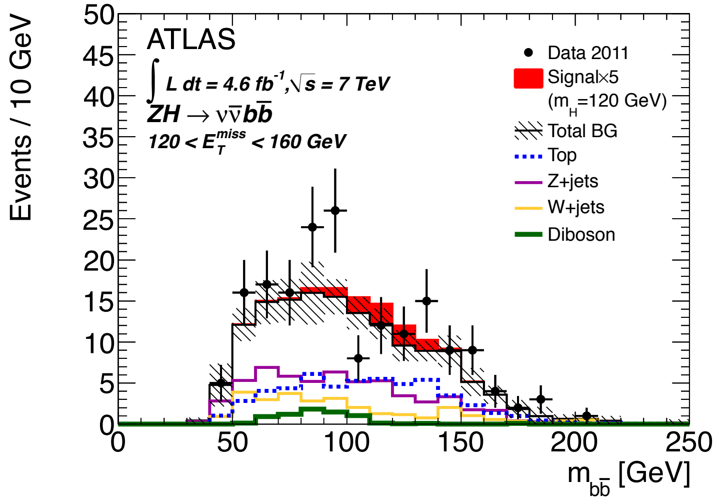


4 W p_T bins

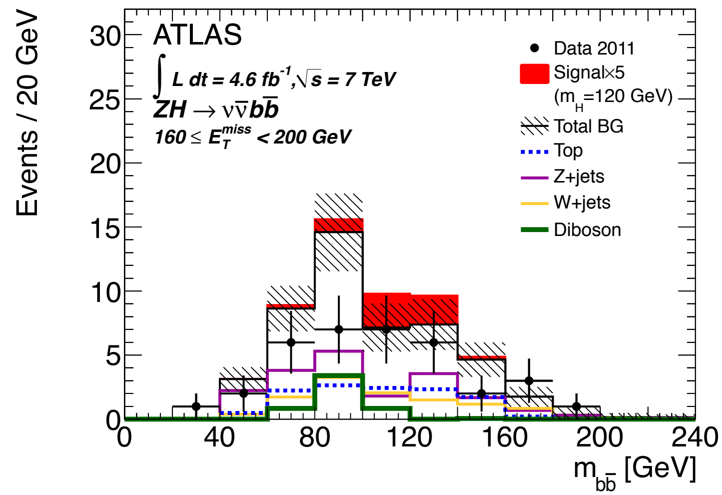


Combined

ATLAS Search For Z→νν + H, H → bb

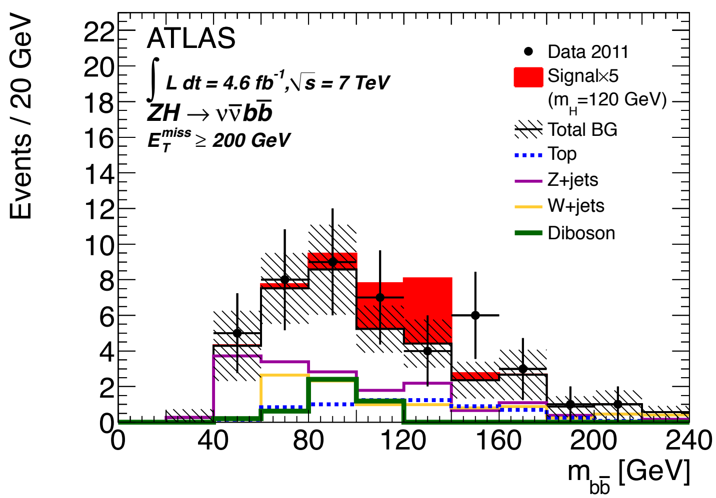


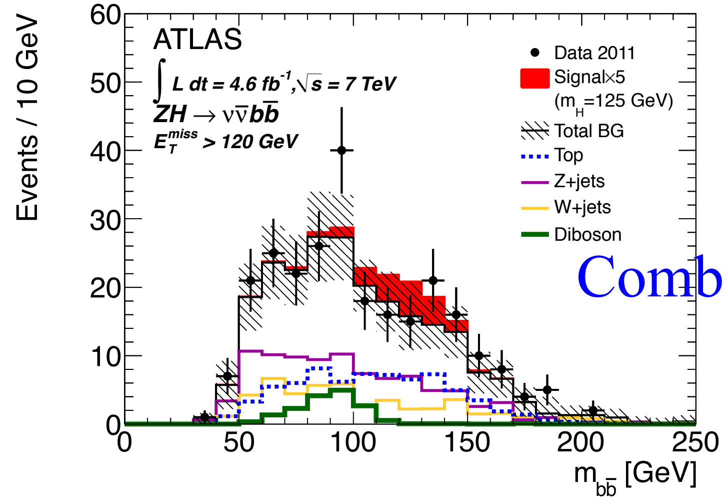
(a)



(b)

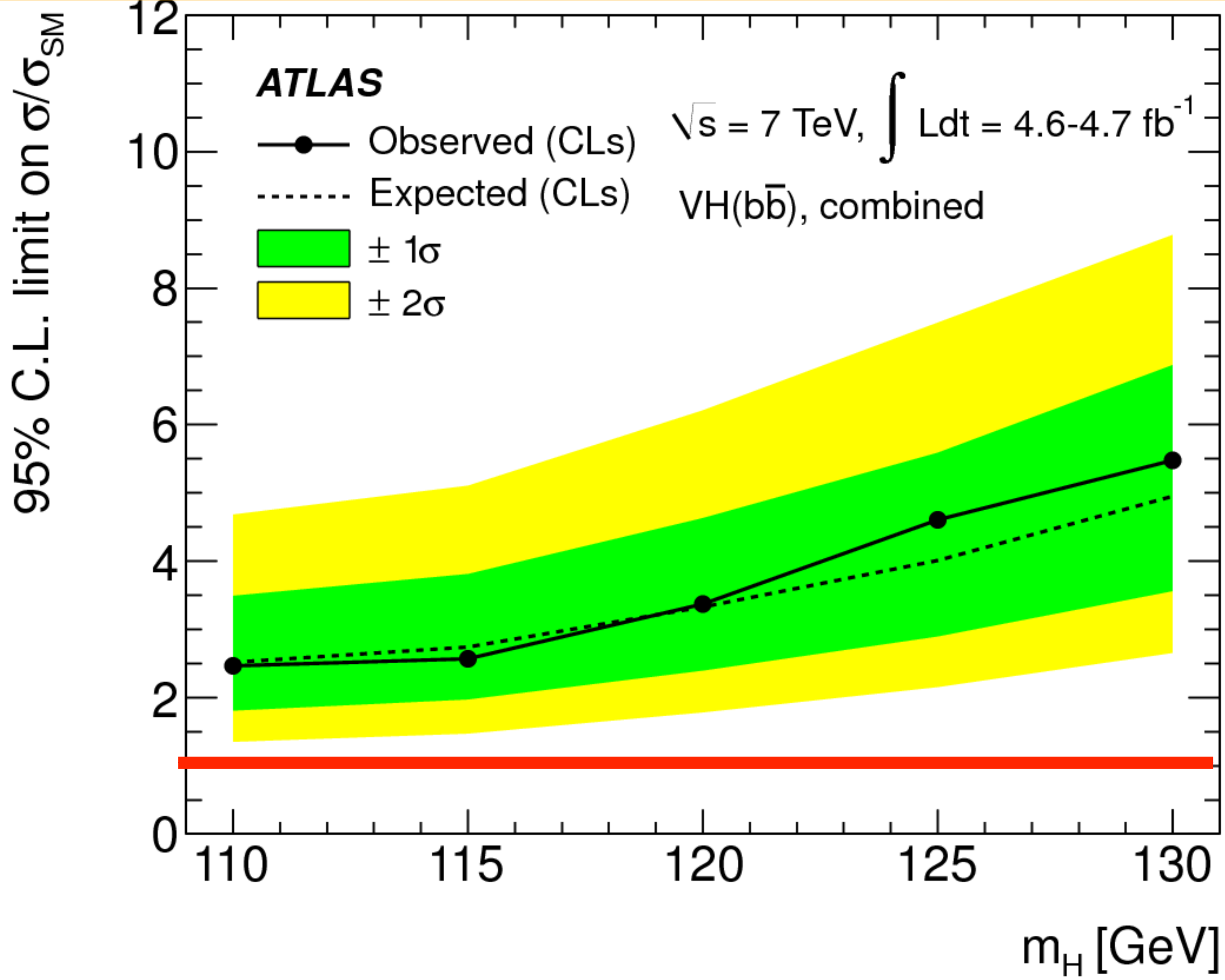
3 Z → νν MET Bins





Combined

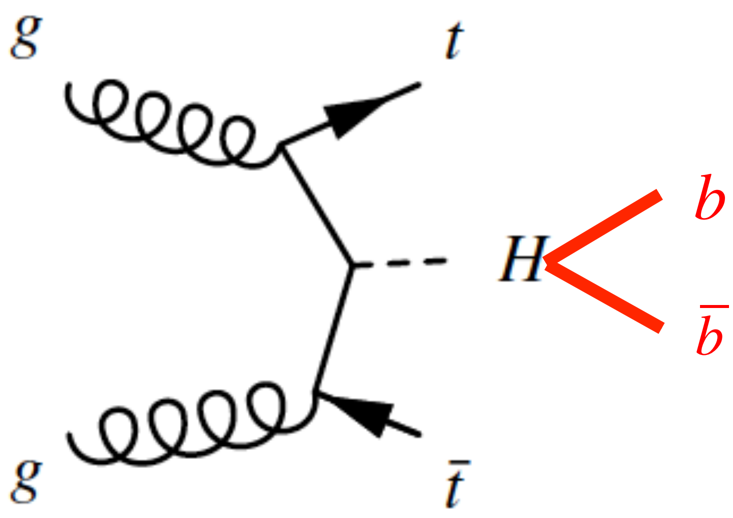
ATLAS Limits For VH, H → bb Searches (4.7 fb^{-1})



Similar sensitivity as CMS cut based 7 TeV analysis

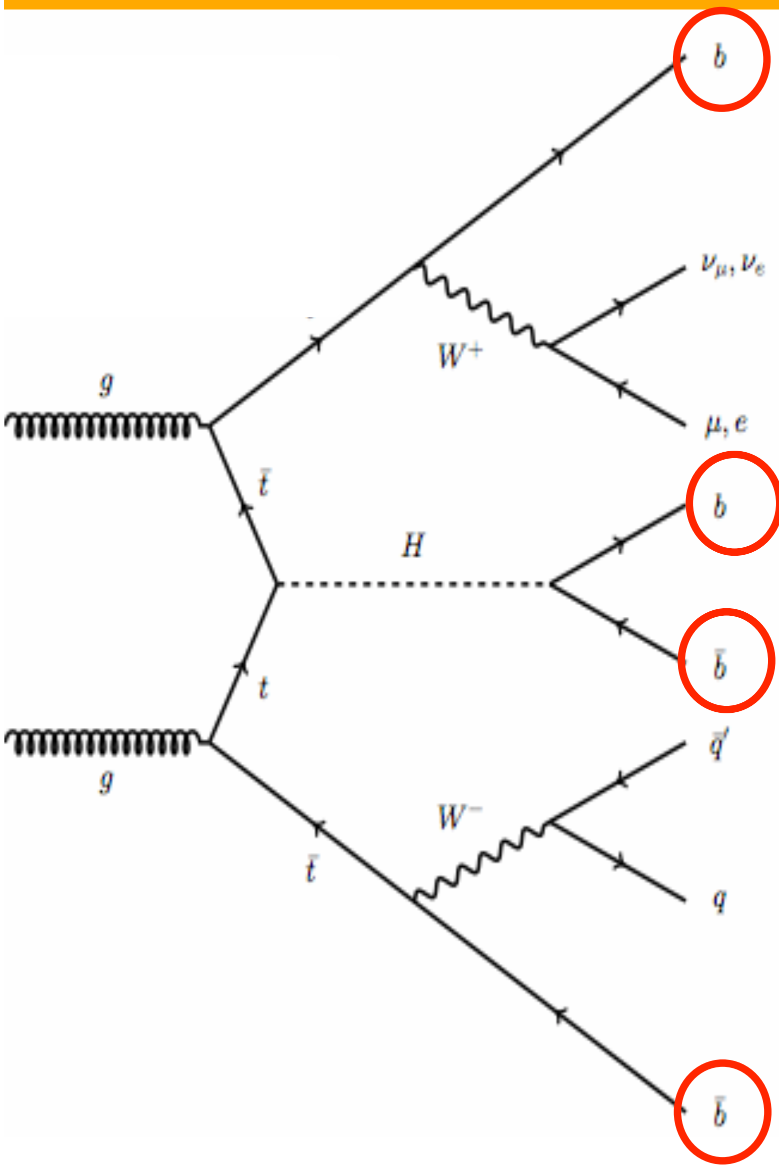
MV based analysis with better M_{bb} resolution coming soon

$t\bar{t} + (H \rightarrow b\bar{b})$



Simultaneously sensitive to Yukawa coupling between Higgs and the top & H → bb branching ratio

pp→ ttH, H → bb Analysis Overview:



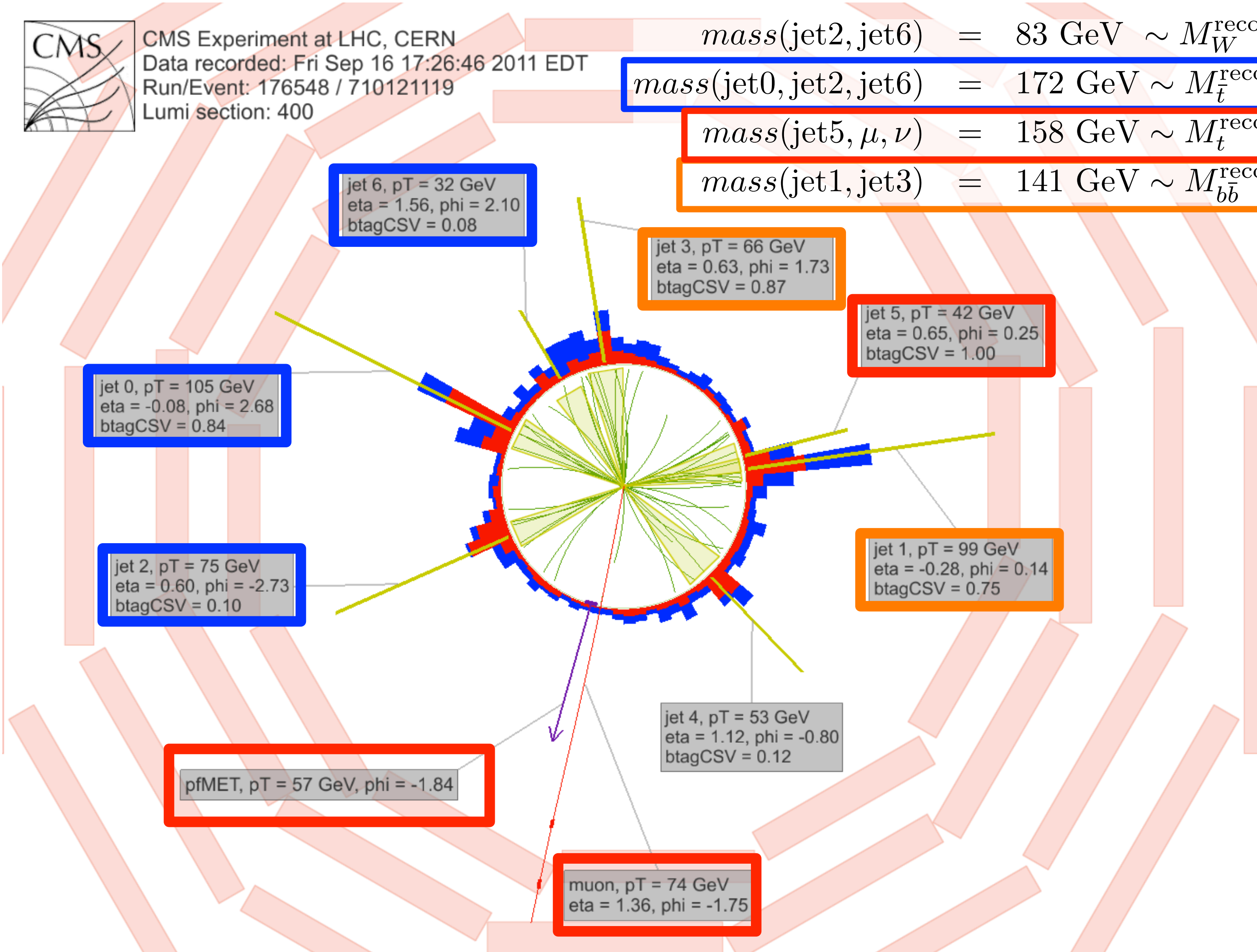
- Ideally, search for events with :
  - $[t \to bl^+\nu + \bar{t} \to \bar{b} + W^- \to l^-\bar{\nu}] + H \to b\bar{b}$

    $\Rightarrow (l^+l^-) + MET + 4bjets$
  - $[t \to bl^+\nu + \bar{t} \to \bar{b} + W^- \to q\bar{q}'] + H \to b\bar{b}$

    $\Rightarrow (l^+) + MET + 4bjets + 2\,jets$
- Reality→ Efficiency, Mistag, misreco
- Major background: $pp \to t\bar{t} + X$
  - Irreducible background $t\bar{t} + b\bar{b}$
- Split events by type of top decay and by # of reconstructed jets and the # of tagged b-jets
- Devise method to distinguish

  $t\bar{t}$ from $t\bar{t}H$
- ATLAS & CMS search differently

pp→ ttH, H → bb Candidate Event



$$mass(\text{jet2}, \text{jet6}) = 83 \text{ GeV} \sim M_W^{\text{reco}}$$

$$mass(\text{jet0}, \text{jet2}, \text{jet6}) = 172 \text{ GeV} \sim M_{\bar{t}}^{\text{reco}}$$

$$mass(\text{jet5}, \mu, \nu) = 158 \text{ GeV} \sim M_t^{\text{reco}}$$

$$mass(\text{jet1}, \text{jet3}) = 141 \text{ GeV} \sim M_{b\bar{b}}^{\text{reco}}$$

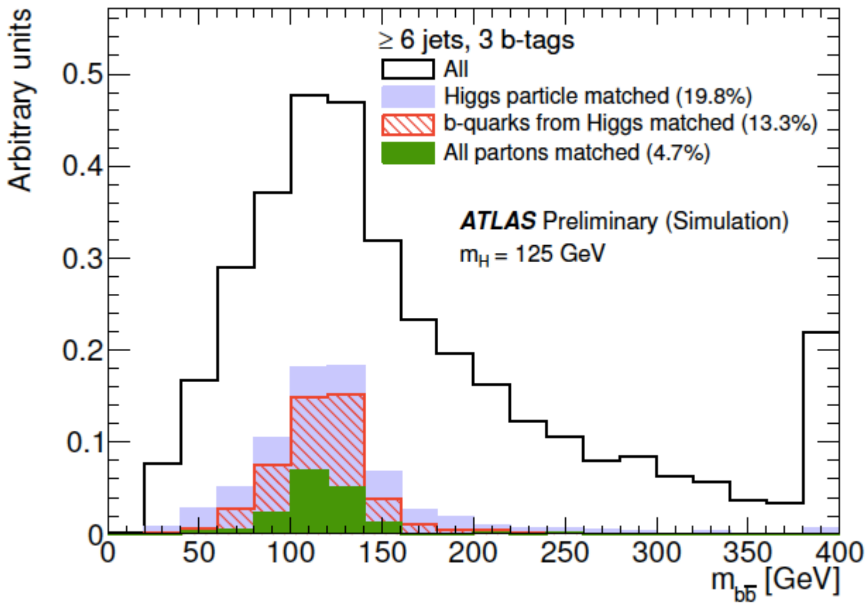
ttH Search in 7 TeV Data: ATLAS Approach

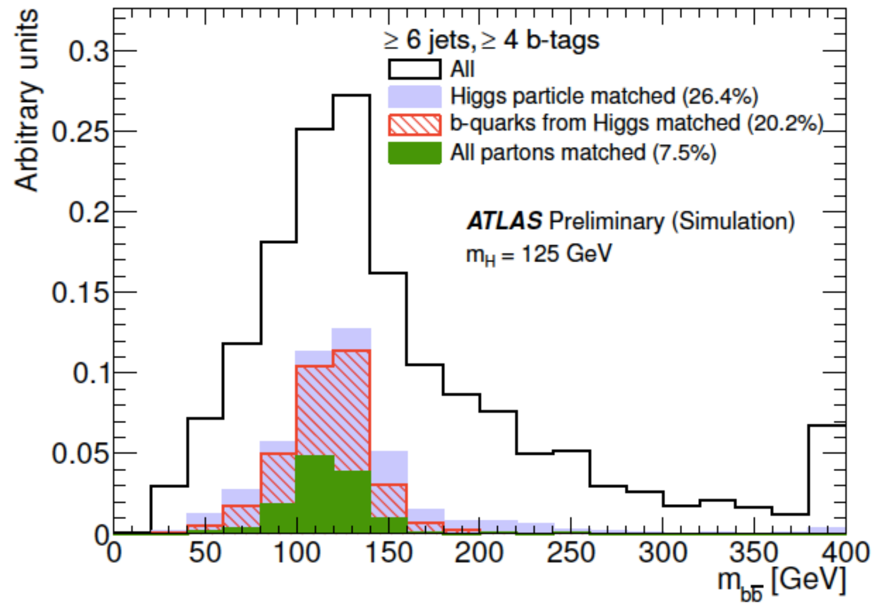
- Target lepton+jet events with at least 4 reconstructed jets
- Catagorized into 9 topologies based on # of jets, # of tagged b-jets
- A **single** discriminant employed to distinguish between S & B
  - Catagories with ≥ 6 jets (≥3 b-jets) have best S/N
    - **Kinematic fit to select 4/6 jets to ttbar decay in the event**
    - **M_{bb} of remaining two jets used to search for H → bb**
  - Catagories with < 6 jets (<3 b-jets) dominated by backgrounds
    - **use H_T = scaler sum of jet p_T**
      - H_T primarily sensitive to jet reconstruction & measurement uncertainties & modeling of tt+jets backgrounds
- Perform simultaneous fit to background-dominated catagories and those with signal to get improved background prediction with reduced uncertainties → better search sensitivity

Too Many b-jets In Event → A Combinetorial Problem

Reconstucted H → bb mass after kinematic fit in ttH simulation

Correct b-jet pair identified as coming from H → bb with a probability of 26% (≥ 4 tagged b-jets) & 20%(3 tagged b-jets)

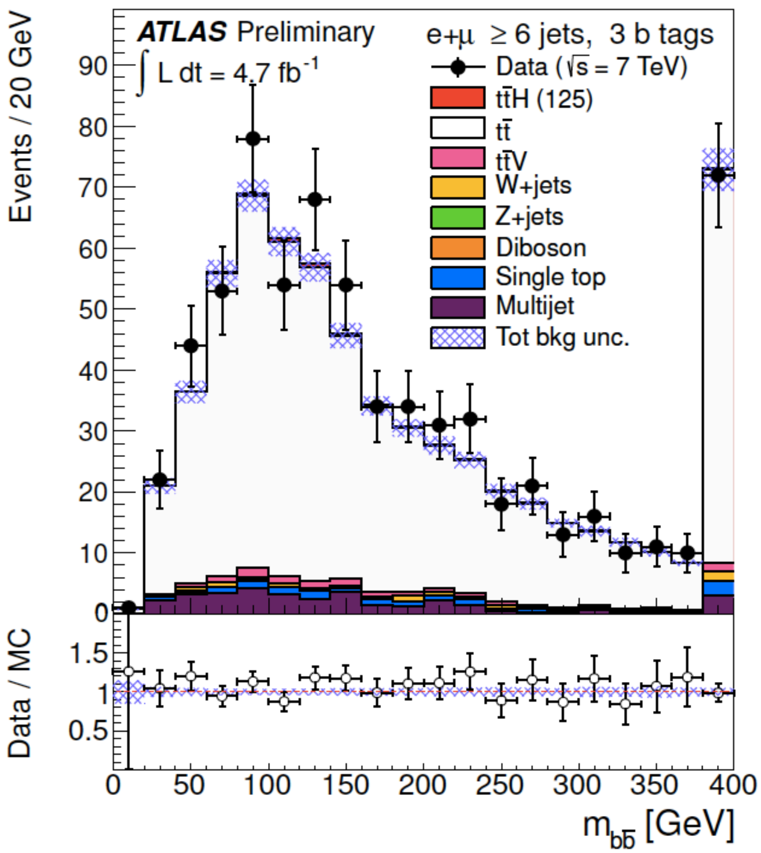




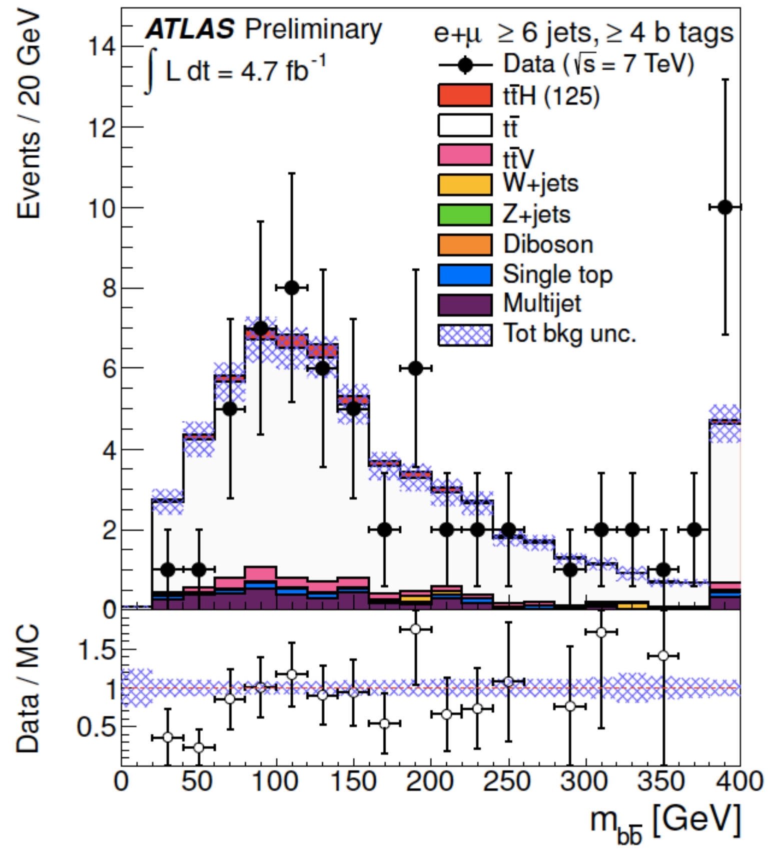
Leads to dilution in search sensitivity

Signal "Rich" Catagories

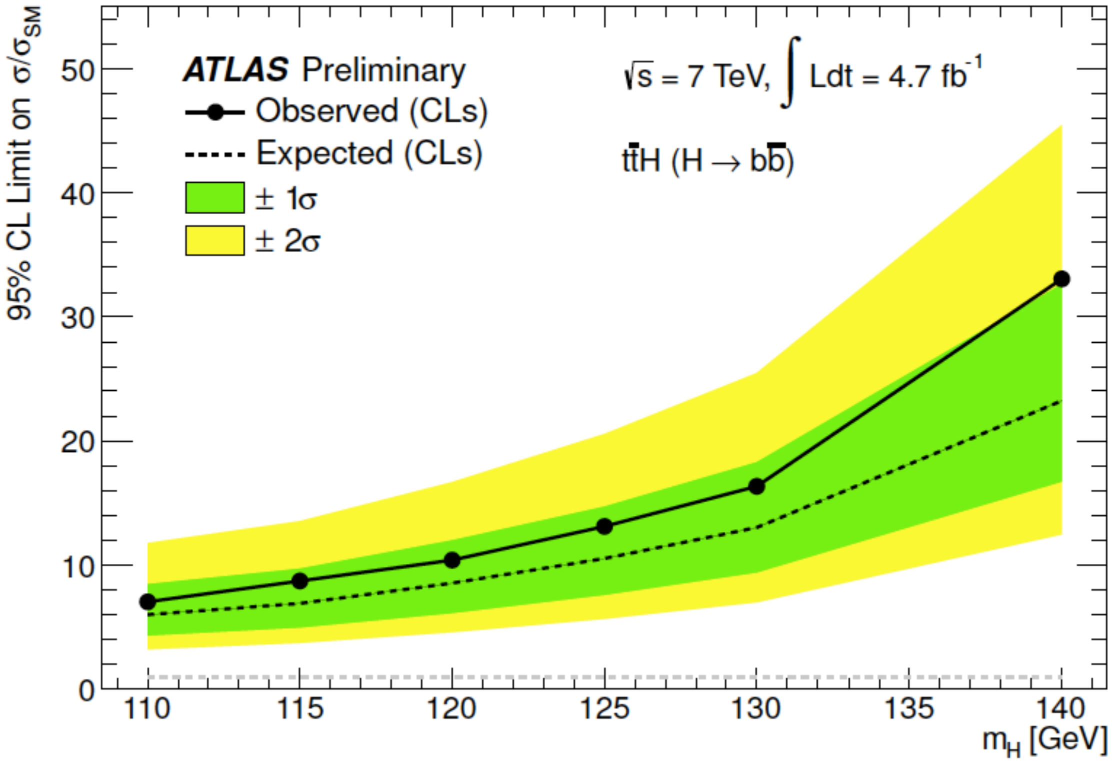
lepton + ≥ 6 jets (3 b-jets)



lepton + ≥ 6 jets (≥4 b-jets)



Expected & Observed Limits From ttH Search :ATLAS



m_H (GeV)	observed	-2 s.d.	-1 s.d.	median	+1 s.d.	+2 s.d.	stat only
110	7.0	3.2	4.3	6.0	8.5	11.8	3.5
115	8.7	3.7	5.0	6.9	9.7	13.6	4.0
120	10.4	4.6	6.2	8.5	12.0	16.7	4.9
125	13.1	5.7	7.6	10.5	14.7	20.6	6.1
130	16.4	7.0	9.4	13.0	18.3	25.5	7.8
140	33.0	12.5	16.7	23.2	32.7	45.5	14.2

CMS Approach : Think Different

- In ttH events with H →bb, presence of two additional *b-quarks* in the event creates **combinatoric issues** that prevents the reconstruction of a clear resonant peak. So don't rely on it
- Instead, employ host of **kinematic variables** that show separation between the dominant *tt+jets* background and the *ttH* signal
- These variables fall in two catagories:
  - those that discriminate between events containing four *b-quarks* from those containing fewer
  - those that distinguish between events containing top quark pairs plus an additional heavy object versus those that do not contain an additional heavy object
- Although none of these variables individually is as powerful as M_{bb} would be if the Higgs peak could be resolved, combining these variables using a MVA technique can yield sufficient separation to set sensitive limits in this channel

CMS Analysis : 5 fb^{-1} at 7 TeV (2011)

- Catagorize dilepton or lepton+ jets events by multiplicity of jets & # of b-tags ➔ total of 9 exclusive catagories

leptons	jets	b-tags	$t\bar{t}H$	$t\bar{t}$	others	data
1ℓ	4	3	3.5	981.6	60.1	1214
1ℓ	4	≥ 4	0.5	18.6	1.4	18
1ℓ	5	3	4.7	637.3	29.6	736
1ℓ	5	≥ 4	1.2	30.8	1.0	37
1ℓ	≥ 6	2	6.3	2160.3	95.4	2137
1ℓ	≥ 6	3	4.4	391.0	13.9	413
1ℓ	≥ 6	≥ 4	1.7	38.4	1.0	49
2ℓ	2	2	0.7	3354.1	951.9	4401
2ℓ	≥ 3	≥ 3	2.9	164.3	27.7	192

For M_H=120 GeV

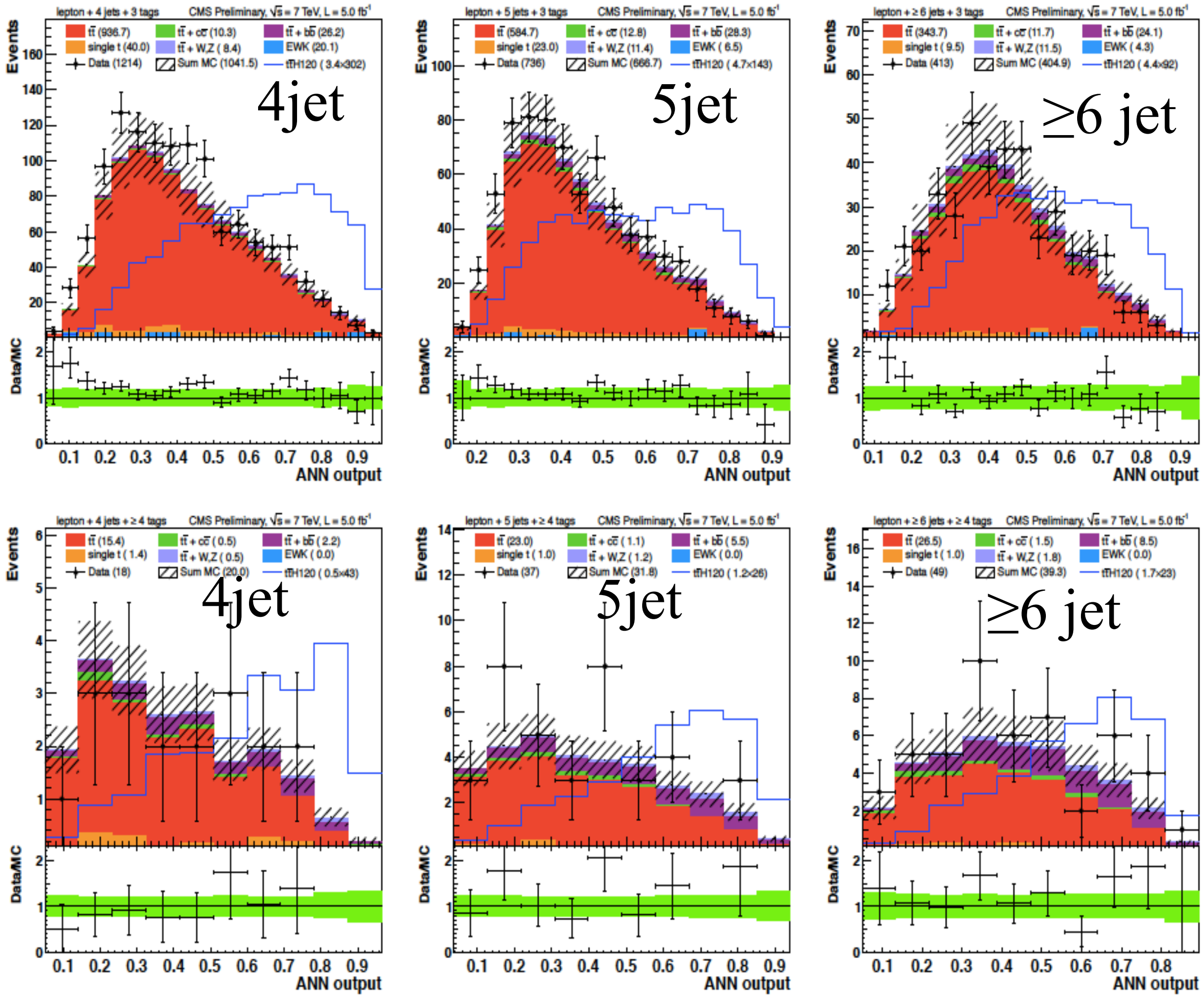
- To further distinguish between signal & bkgnd, use ANN with input based on **information in the entire event to separate S from B:**
  - kinematic info of leptons, jets, MET, event shape
  - discriminant output from b-tag algorithm (average b-tag value)
  - minimal angular seperation ΔR between 2 b-jets (tt+bb Vs ttH)
  - Choice of variables optimized for each category

ttH ANN Inputs

Variable	Description
aplanarity	Event shape variable equal to $\frac{3}{2}(\lambda_3)$, where λ_3 is the third eigenvalue of the sphericity tensor as described in [15].
ave CSV (tags)	Average b-tag discriminant value for b-tagged jets
ave ΔR(tag,tag)	Average ΔR between b-tagged jets
ave mass(untag,untag)	Average of the invariant mass of all pairs of jets that are not b-tagged
ave mass(tag,tag)	Average of the invariant mass of all pairs of jets that are b-tagged
best higgs mass	A minimum-chi-squared fit to event kinematics is used to select two b-tagged jets as top-decay products. Of the remaining b-tags, the invariant mass of the two with highest E_t is saved.
closest tagged dijet mass	The invariant mass of the two b-tagged jets that are closest in ΔR
dev from ave CSV (tags)	The square of the difference between the b-tag discriminant value of a given b-tagged jet and the average b-tag discriminant value among b-tagged jets, summed over all b-tagged jets
highest CSV (tags)	Highest b-tag discriminant value among b-tagged jets
H_0, H_1, H_2, H_3	The first few Fox-Wolfram moments [16] (event shape variables)
$\sum p_T$(jets,leptons,MET)	The sum of the p_T of all jets, leptons, and MET
jet 1, 2, 3, 4 p_T	The transverse momentum of a given jet, where the jet numbers correspond to rank by p_T
lepton p_T	The transverse momentum of the lepton (LJ channel)
lowest CSV (tags)	Lowest b-tag discriminant value among b-tagged jets
mass(lepton,jet,MET)	The invariant mass of the 4-vector sum of all jets, leptons, and MET
mass(lepton,closest tag)	The invariant mass of the lepton and the closest b-tagged jet in ΔR (LJ channel)
M3(1 tag)	The invariant mass of the 3-jet system with the largest transverse momentum where one jet is b-tagged and the other two are not.
MHT	Vector sum of transverse momentum for all jets with $p_T > 20\,\text{GeV}/c$
MET	Missing transverse energy
min ΔR(lepton,jet)	The ΔR between the lepton and the closest jet (LJ channel)
min ΔR(lead lepton,jet)	The ΔR between the highest p_T lepton and the closest jet (DIL channel)
min ΔR(tag,tag)	The ΔR between the two closest b-tagged jets
second-highest CSV (tags)	Second-highest b-tag discriminant value among b-tagged jets
sphericity	Event shape variable equal to $\frac{3}{2}(\lambda_2 + \lambda_3)$, where λ_2 and λ_3 are the second and third eigenvalues of the sphericity tensor as described in [15]

Table 9: Event variables used in ANN training and their descriptions.

ANN Distribution For Some Lepton+ Jets Catagories



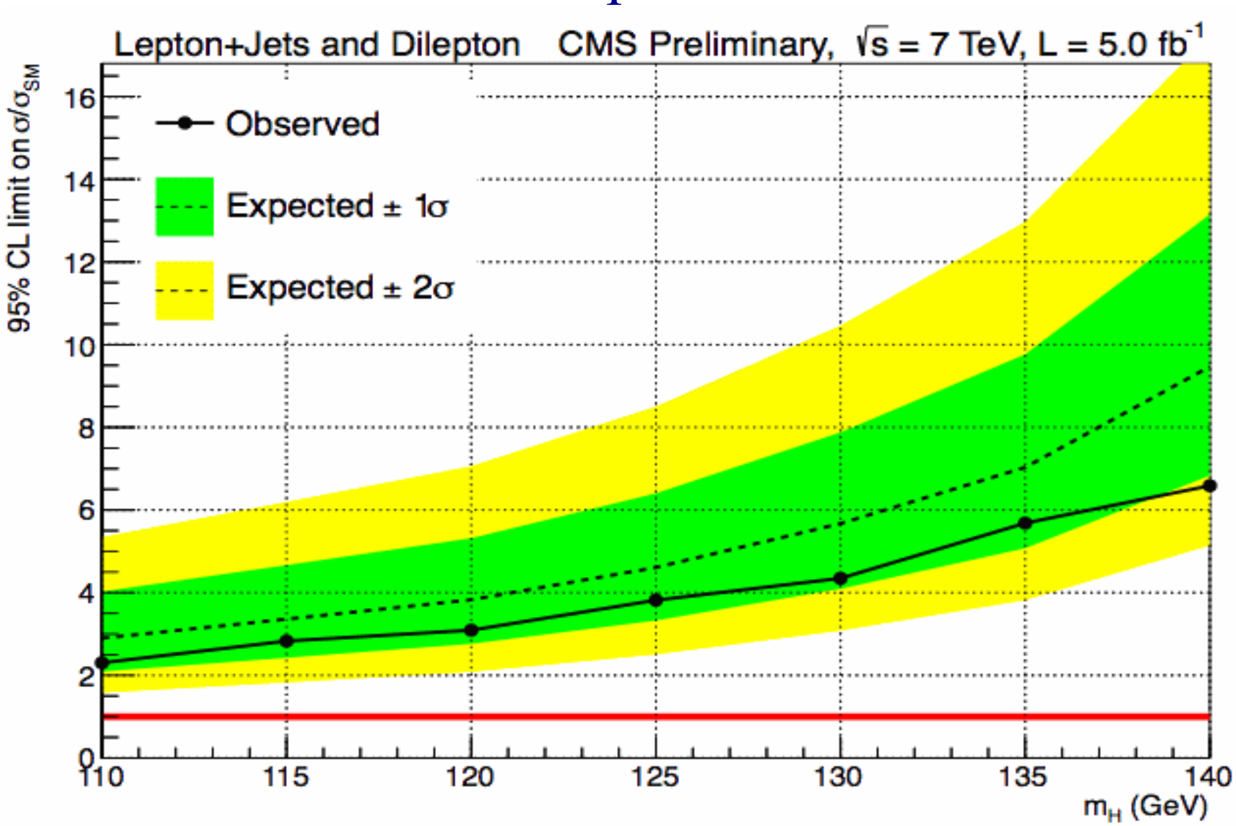
3 b-jet tags

≥4 b-jet tags

Red = ttbar , Blue = ttH, (M_H) = 120 GeV, normalized to total bkgnd

CMS Limits From ttH Search

Simultaneous fit to NN output of 9 catagories to set limits on Higgs production cross section



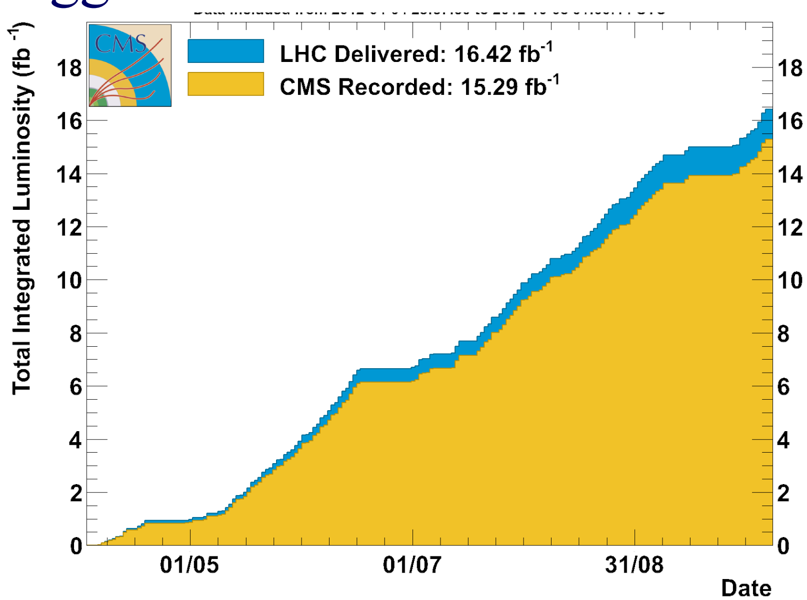
95% CL Limits
5 fb^{-1} , 7 TeV data

Mass	Exp.	Obs.
110	2.90	2.30
115	3.36	2.83
120	3.83	3.09
125	4.61	3.82
130	5.67	4.35
135	7.03	5.68
140	9.47	6.59

- Search sensitivity dominated by lepton+jet mode,
- 5-10% improvement from di-lepton mode
- No excess seen, expect 4.6 x σ_{SM} at 125 GeV, observe 3.8 x σ_{SM}

Summary

- Search for H → bb at LHC is not just an analysis but a full research program. New ideas are adding drops in the sensitivity bucket
  - rapid progress
- With ≥ 25 fb^{-1} data each by end of 2012, ATLAS & CMS should be sensitive to SM Higgs in the VH channel



- First attempts at search for ttH, should reach ≈ $2.5\times\sigma_{SM}$ sensitivity with 2012 data assuming background shapes can be kept under control