SUSY 06, Newport Beach

Recent Developments in Little Higgs Searches at LHC

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on behalf of the **ATLAS** collaboration

Outline

- The model
- Heavy gauge boson searches
  - Leptonic decays (Eur. Phys. J. **C39S2**, 13 (2005))
  - Hadronic decays NEW!
  - Higgs decays, m_h=200 GeV NEW!
  - Higgs decays, m_h=120 GeV (Eur. Phys. J. **C39S2**, 13 (2005))
- Summary

Little Higgs model

Effective model adressing hierarchy problem

$\Rightarrow$ larger symmetry, broken at high scale

$\Rightarrow$ *introduce heavy top T, heavy Higgses* ϕ

and ***heavy gauge bosons*** Z_H, W_H, A_H

Littlest Higgs model [Arkani-Hamed et al., JHEP 207(2002)34]

SU(5) $\rightarrow$ SO(5), scale ~10TeV Gauge sector $[SU(2)\otimes U(1)]^2$ SM Higgs

Phenomenology Han et al., Phys.Rev.D67(2003)95004

Gauge sector: parameter θ: mixing angle between W triplets

W_H , Z_H mass degenerate

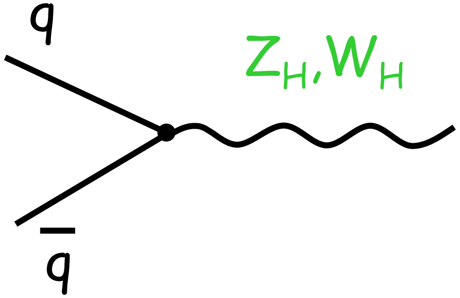
$$M < 6\ \text{TeV} \cdot \left(\frac{m_h}{200\ GeV}\right)^2$$

EW fits $\rightarrow$ strong constraints

Little Higgs realized in several models. Similar particle content.

Z_H, W_H production and decays

$q\bar{q}$ anihilation



Fermionic channels:

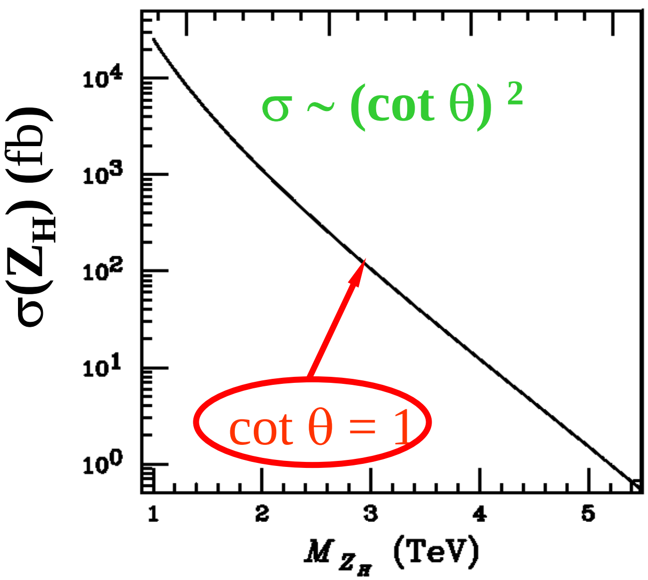
$Z_H \to \ell^+\ell^-, q\bar{q}$

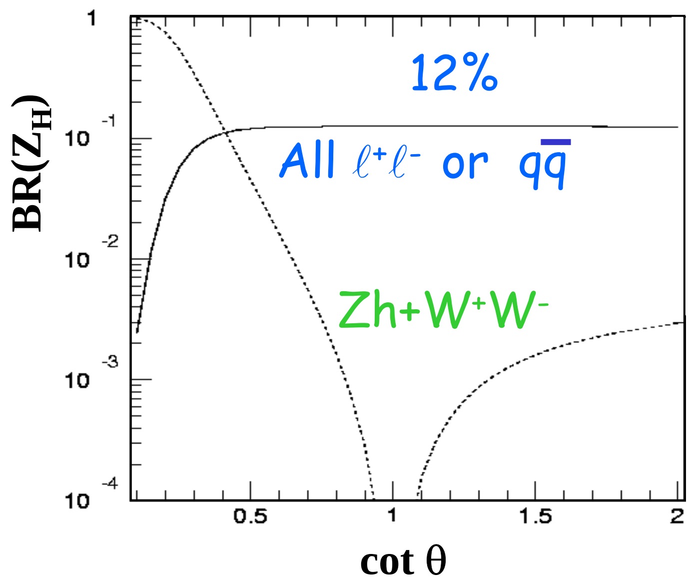
$W_H^{\pm} \to \ell\,\nu,\ q\bar{q}'$

Bosonic channels:

$Z_H \to Zh,\ W^+W^-$

$W_H^{\pm} \to W^{\pm}h,\ W^{\pm}Z$





$BR(Z_H \to q\bar{q}) = 1/8$
$BR(W_H \to q\bar{q}') = 1/4$

$Br(W_H \to t\bar{b}) = 3 \times Br(W_H \to e\nu)$

$\sigma(W_H) = 2\,\sigma(Z_H)$

$\Gamma_{W_H}(Wh+WZ) = \Gamma_{Z_H}(Zh+WW)$

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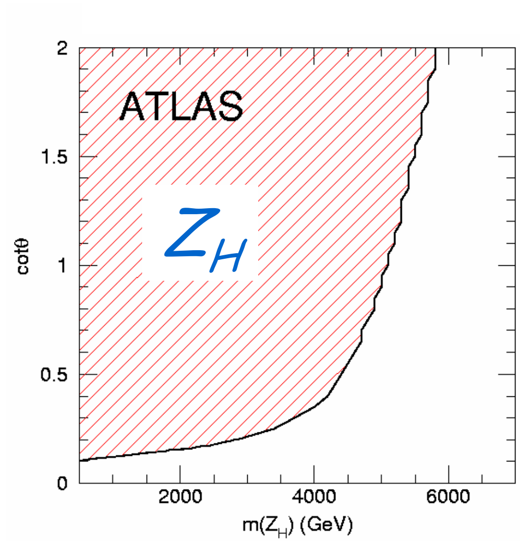
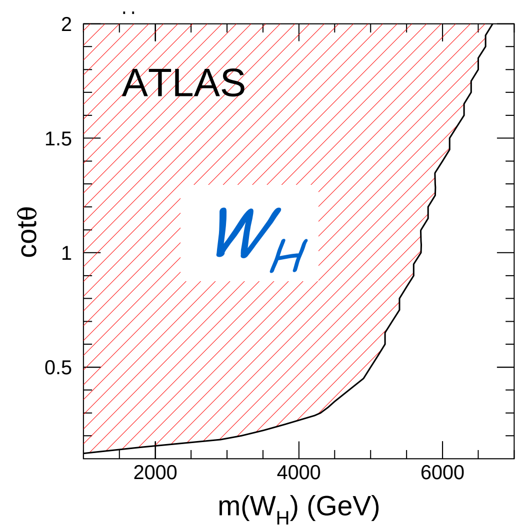
Leptonic V_H decays

$Z_H \rightarrow e^+e^-$
$W_H \rightarrow e\ \nu$

Discovery channel

With 300 fb^{-1} = 3 years of LHC high luminosity:





All analyses performed using a *parameterized* simulation of the ATLAS detector (ATLFAST)

ε(lepton tag) = 90%

Poisson significance ($\sim S/\sqrt{B}$) > 5 + $S \geq 10$
in the mass window → discovery

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Hadronic V_H decays

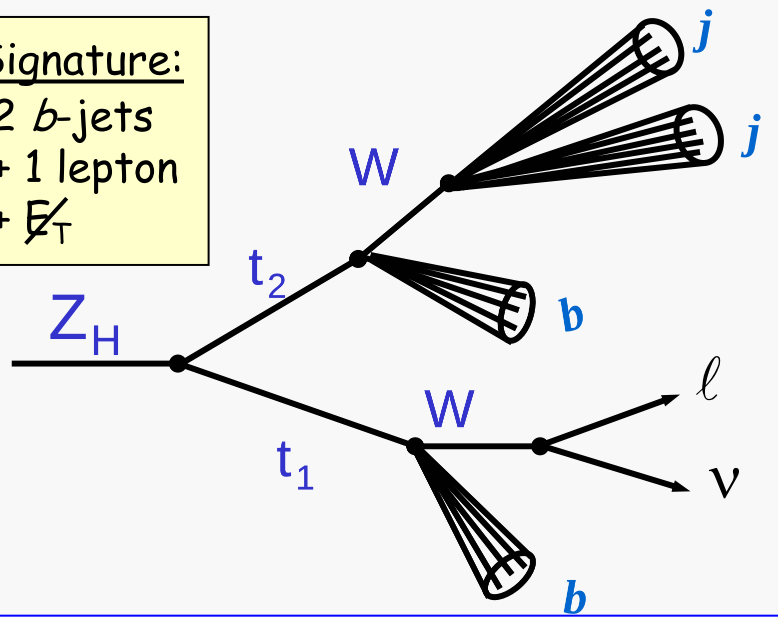
NEW!

$V_H = Z_H, W_H$

$(\Delta R)^2 = (\Delta\eta)^2 + (\Delta\phi)^2$
η=pseudo-rapidity,
ϕ=azimuthal angle

$Z_H \to t_1\bar{t}_2,\ t_1 \to b\ell\nu,\ \bar{t}_2 \to \bar{b}jj$ (ℓ=e,μ)

Signature:
2 *b*-jets
+ 1 lepton
+ $\not{E}_T$



Cuts:
- 1 isol. lepton, p_T>25 GeV
- $\not{E}_T$ > 25 GeV
- 2 b-jets, p_T>25 GeV,
  $\Delta R(b_1\ell)<2$, $\Delta R(b_2\ell)>2$
- $t_1 = b_1 + \ell_1 + \not{E}_T$ (with $\nu // \ell$)
- $t_2 = b_2$ + all jets $\Delta R<2$
- $p_T(b_2+j) > 0.25\ M_{Z_H}$

ε(b tag) = 50 (20)%
Ru = 100 (130) M_{Z_H}= 1 (2)TeV
validated with full simulation

Background: $t\bar{t}$, W+jets,...

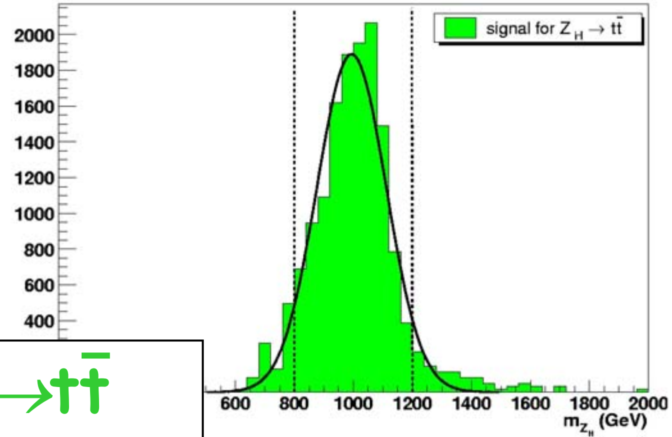
ε_{kine} = 27 (21)%, M=1 (2) TeV

Hadronic V_H decays

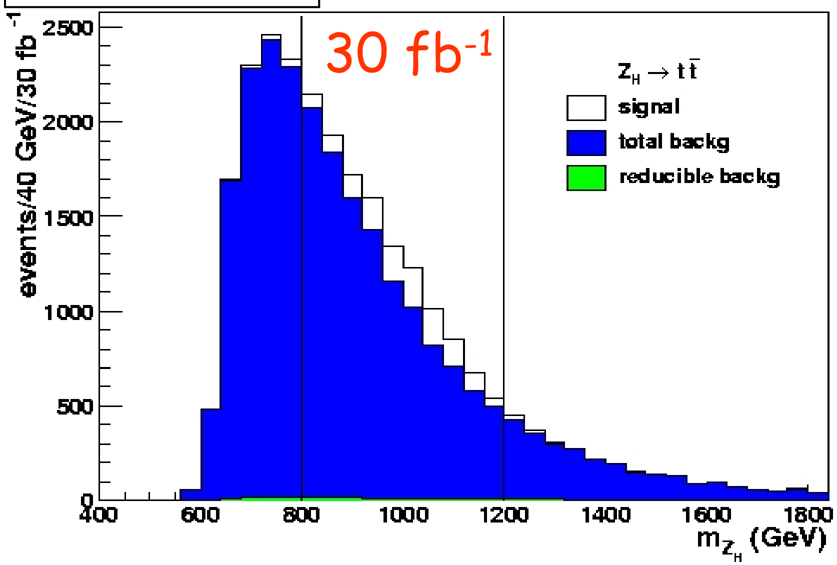
Mass reco. bias: <1%

Mass resolution: ~12%

>> natural width: Γ/M = 2% cotθ



$Z_H \to t\bar{t}$
M=1 TeV

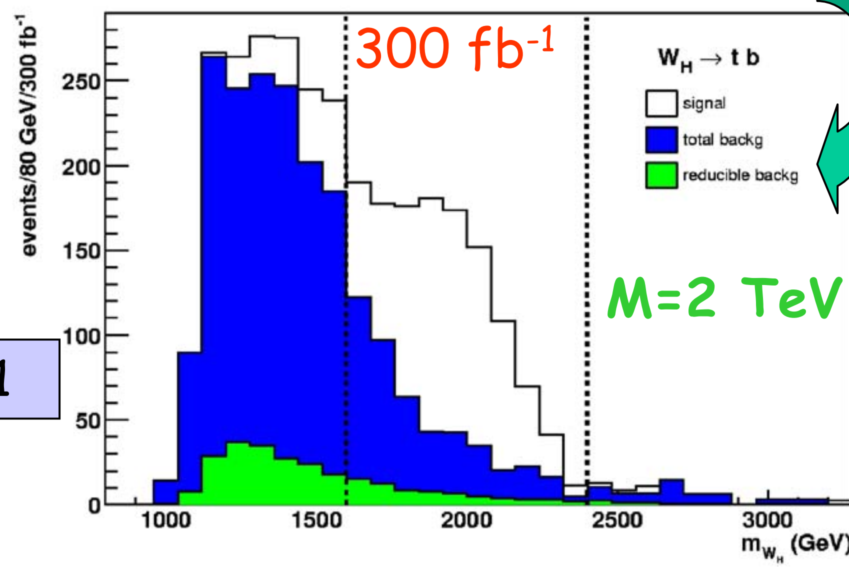


cotθ = 1

Two other modes:

$Z_H \to b\bar{b}$

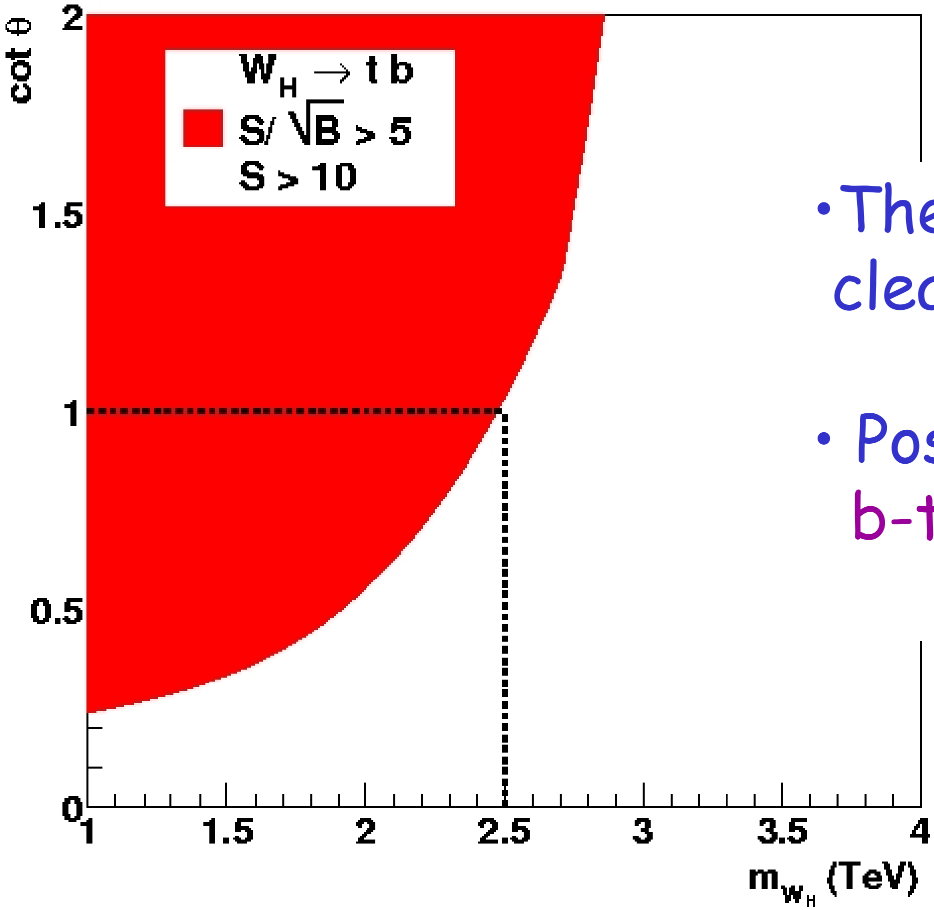
$W_H \to t\bar{b} \to b\, \ell\, \nu\, \bar{b}$



Hadronic V_H decays

- The Z_H to $t\bar{t}$ and $b\bar{b}$ decays are difficult to detect

300 fb^{-1}



- The W_H to $t\bar{b}$ decay might yield a signal clearly separable from background
- Possible improvement by optimizing b-tagging at very high p_T

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V_H decays to Higgs (m_h=200 GeV)

NEW!

Assume Higgs discovered

m_h=200 GeV

BR($h \to W^+W^-$) = 74 %
BR($h \to ZZ$) = 26 %

SM Higgs→usual BR

$$V_H \to V_1 h \to V_1 V_2 V_3 \qquad V = Z,W$$

Studied channels: ◈ $V_H \to$ 3 leptonic V (→ leptons only)
✷ $V_H \to$ 2 leptonic V + 1 V → jj

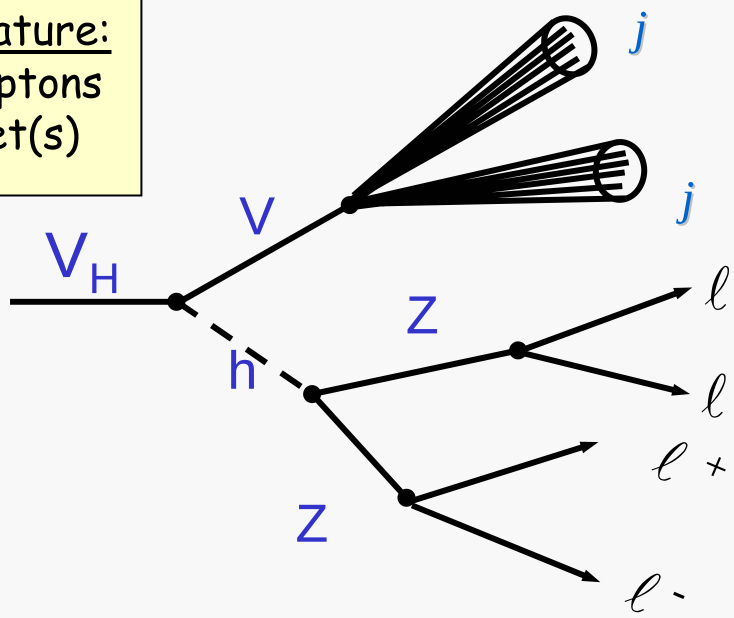
"A" modes: ✷ ($V_1 \to jj$) and ◈ ⇒ isolated leptons
"B" modes: ✷ (V_2 or $V_3 \to jj$) ⇒ lepton in jet

Branching fractions = 4 10^{-5} - 7 10^{-4} ($\cot\theta$=0.5)

V_H decays to Higgs (m_h=200 GeV)

$V_H \to Vh \to jjZZ \to jj\ \ell^+\ell^-\ell^+\ell^-$ (ℓ=e,μ) very clean

Signature:
4 leptons
+ jet(s)



Cuts:
- 2 isol. leptons (1,2) $M_{12}= M_Z \pm 15$ GeV
- 2 isol. leptons (3,4) $\Delta R_{1,2-3,4}<1.5$
- $p_T(1+2+3+4)>0.25\ M_{V_H}$
- 1 or 2 jets, $p_T>$ 0.25 M_{V_H} ($\Delta R_{1-2}<1$)
- $m(4l+j)=M_{V_H} \pm 15\%$

$\cot\theta$=0.5

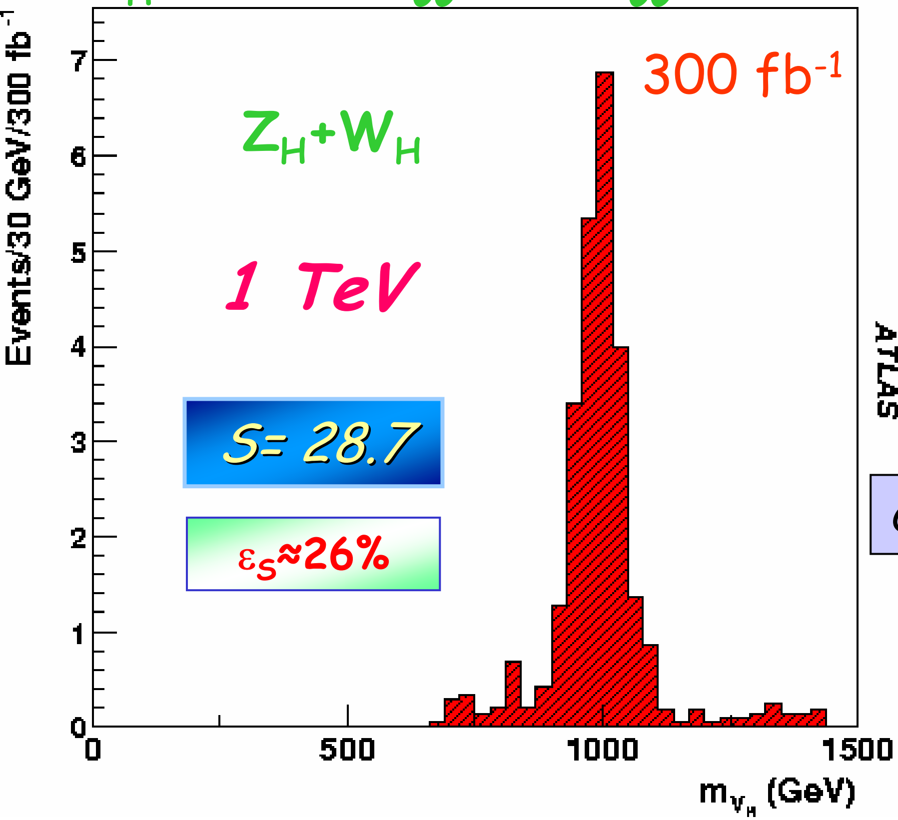
$M(Z_H)$	σ.BR (fb)
1000	0.177
2000	0.009

$M(W_H)$	σ.BR (fb)
1000	0.338
2000	0.018

Background: ~ none

V_H decays to Higgs (m_h=200 GeV)

$V_H \rightarrow Vh \rightarrow jjZZ \rightarrow jj\ \ell^+\ell^-\ell^+\ell^-$

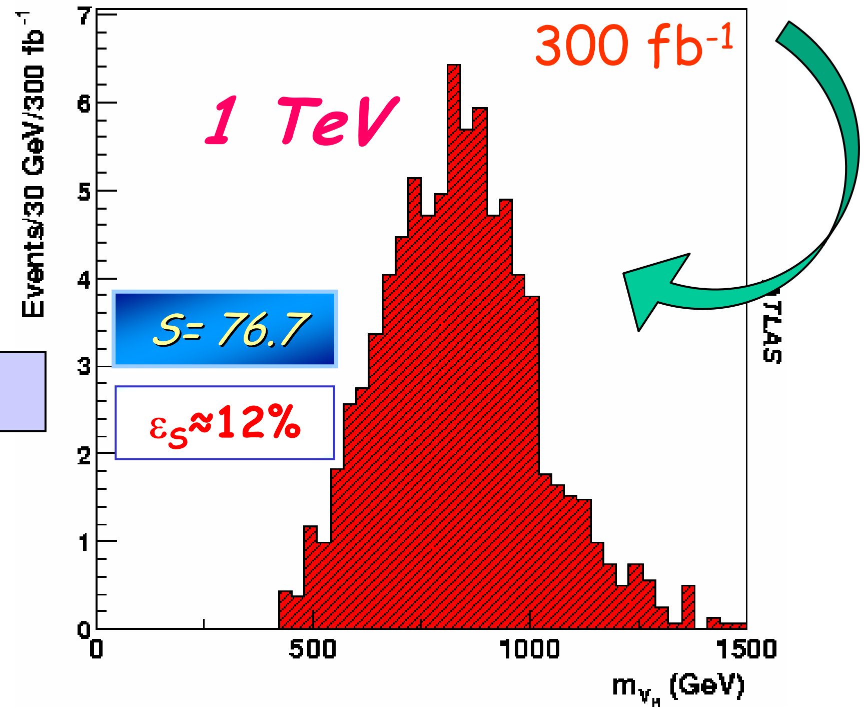


cotθ = 0.5

Two other modes:

$Z_H \rightarrow Zh \rightarrow \ell^+\ell^- W^+W^- \rightarrow \ell^+\ell^-\ell^+\nu\ell^-\nu$

$W_H \rightarrow Wh \rightarrow \ell\nu W^+W^- \rightarrow \ell\nu\ell^+\nu\ell^-\nu$



Mass reco. bias: 1%

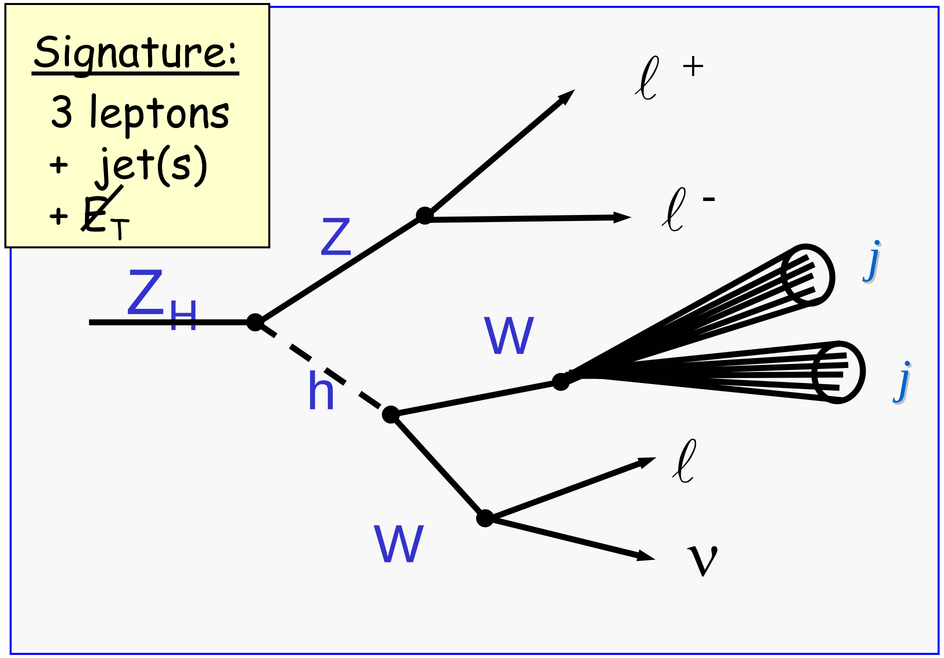
Mass resolution: 4%

Assume $\vec{\not{p}} = \vec{\not{p}}_T \Rightarrow$ bias, poor resolution

V_H decays to Higgs (m_h=200 GeV)

$Z_H \rightarrow Zh \rightarrow \ell^+\ell^- WW \rightarrow \ell^+\ell^- jj\, \ell\nu$ (ℓ=e,μ)

Signature:
3 leptons
+ jet(s)
+ $\not{E}_T$



Cuts:
- 2 isol. leptons (1,2) $M_{12} = M_Z \pm 15$ GeV
- 1 isol. lepton, $W_1 = \ell_3 + \not{E}_T$, $p_T > 50$ GeV
  apply M_W constraint or assume $\nu \,//\, \ell_3$
- 1 or 2 jets, $M_j = M_W \pm 15$ GeV
- $p_T(\ell_1+\ell_2+W_1+j) > 100$ GeV

cotθ=0.5

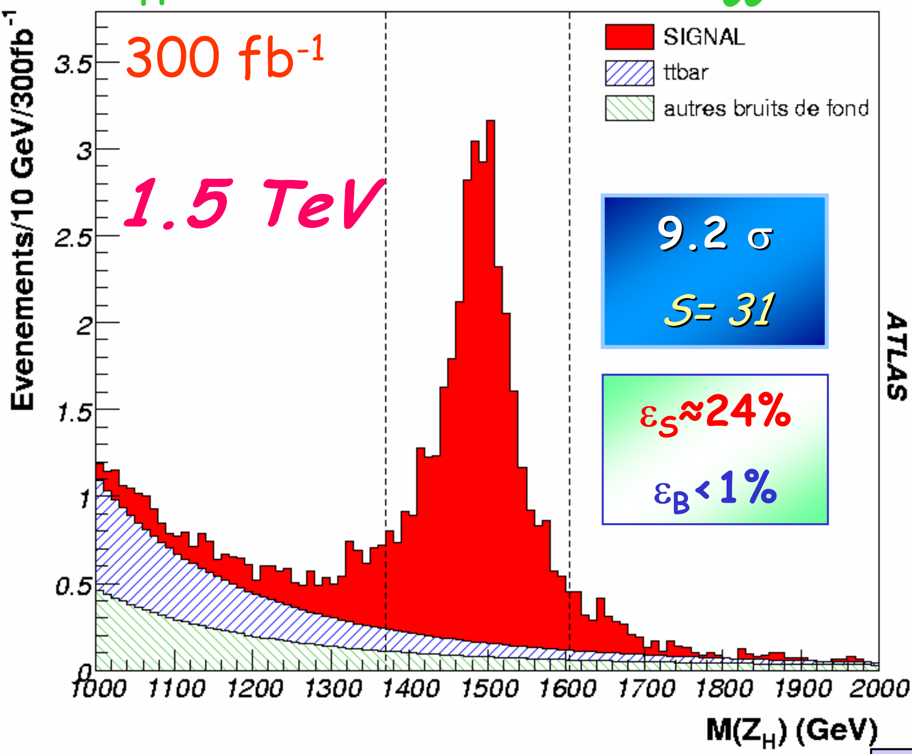
$M(Z_H)$	σ.BR (fb)
1000	3.064
1500	0.645
2000	0.145

Background: $t\bar{t}$, Zh, WZ, ZZ, h
σ.BR (fb)= 3376, 2, ...

Lack of statistics on background → extrapolated

V_H decays to Higgs (m_h=200 GeV)

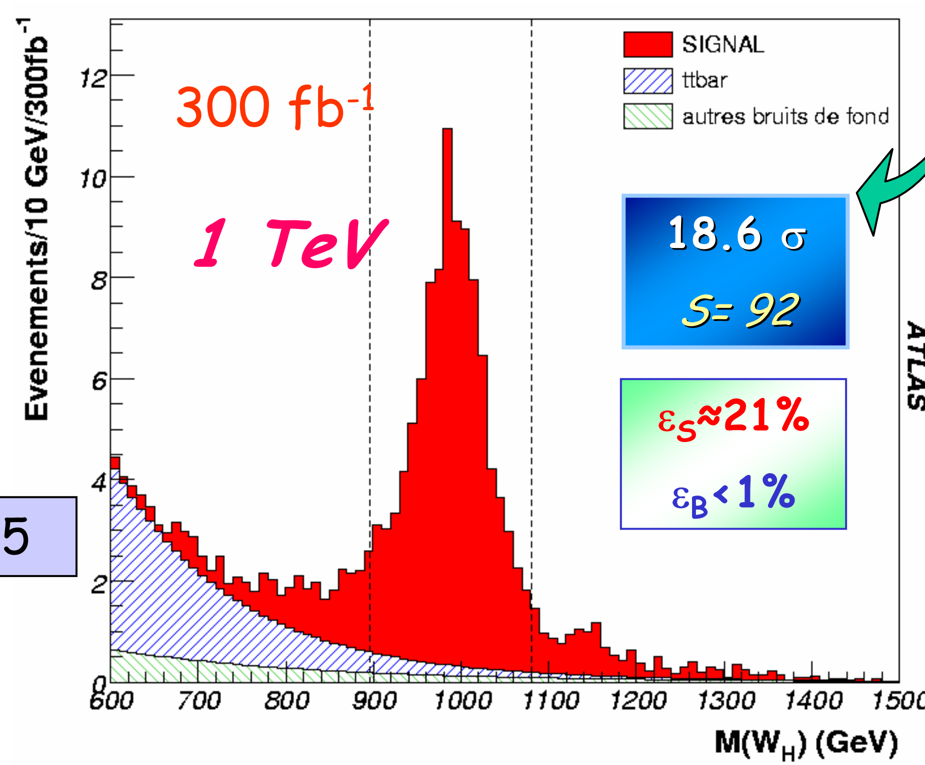
$Z_H \rightarrow Zh \rightarrow \ell^+\ell^- WW \rightarrow \ell^+\ell^- jj\ \ell\nu$



Two other modes:

$Z_H \rightarrow Zh \rightarrow \ell^+\ell^- ZZ \rightarrow \ell^+\ell^- jj\ \ell^+\ell^-$

$W_H \rightarrow Wh \rightarrow \ell\nu\ ZZ \rightarrow \ell\nu\ jj\ \ell^+\ell^-$



$\cot\theta = 0.5$

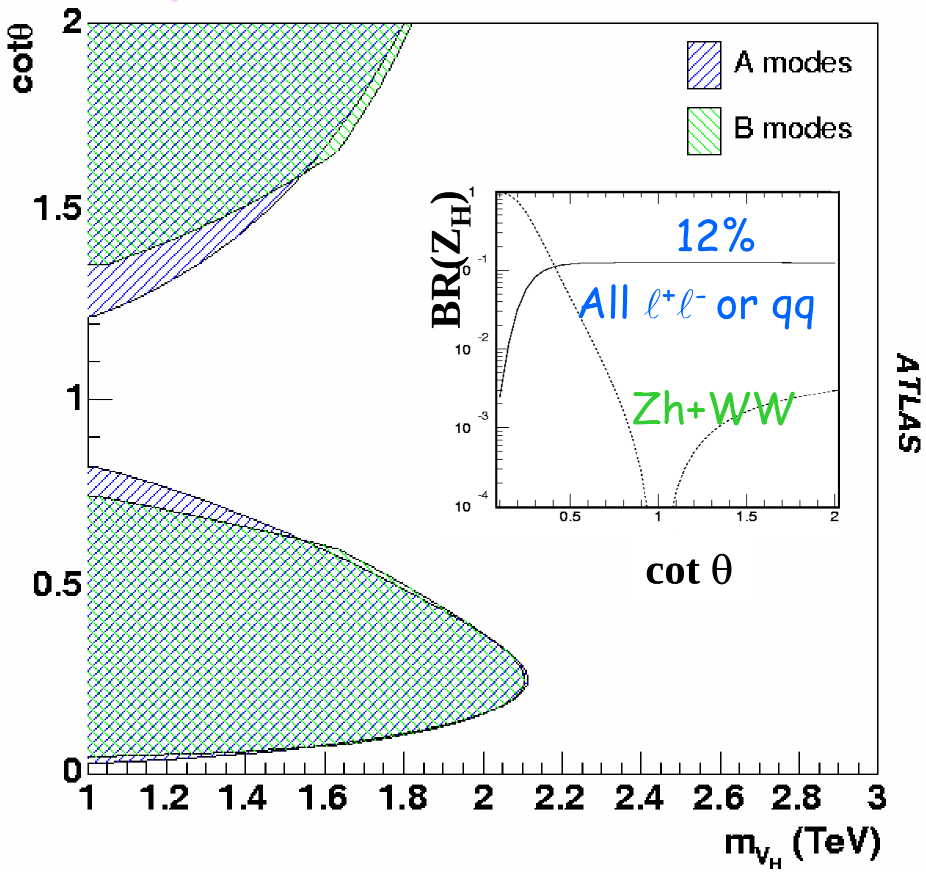
Mass reco. bias: 1%

Mass resolution: 4%

~same all modes

V_H decays to Higgs (m_h=200 GeV)

$\int Ldt$ = 300 fb^{-1}



Mass reach about 2 TeV, except when cotθ ~ 1

Although ATLFAST lepton isolation criteria were especially tuned (B modes), needs validation with full simulation

M_{V_H} < 6 TeV for m_h = 200 GeV (avoid fine tuning)

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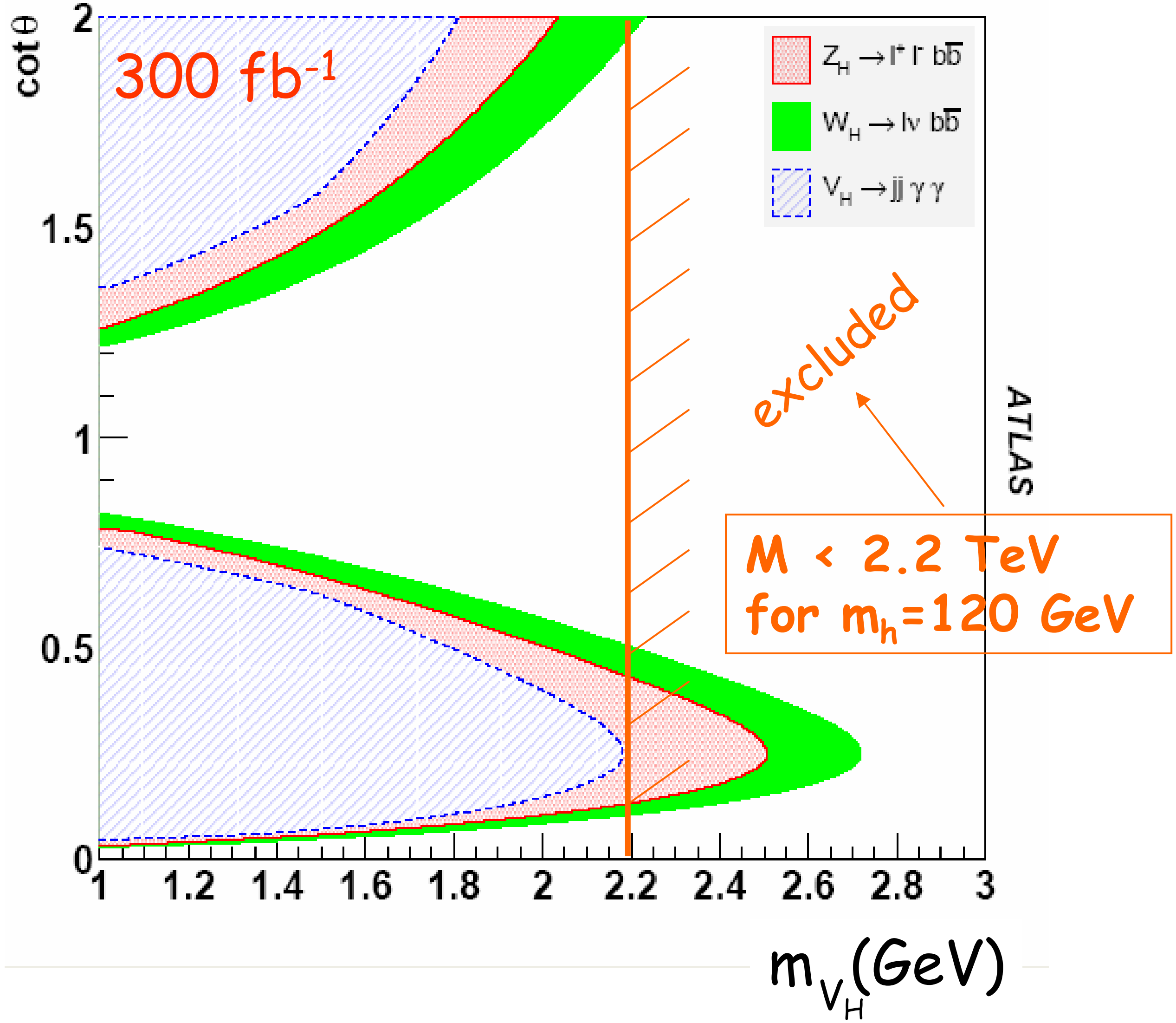
V_H decays to Higgs (m_h=120 GeV)

Earlier results:

BR($h \to b\bar{b}$) = 66 %
BR($h \to \gamma\gamma$) = 0.2 %

$Z_H \to Zh \to jj\gamma\gamma,\ \ell\ell\ b\bar{b}$
$W_H \to Wh \to jj\gamma\gamma,\ \ell\nu\ b\bar{b}$
(ℓ=e,μ)



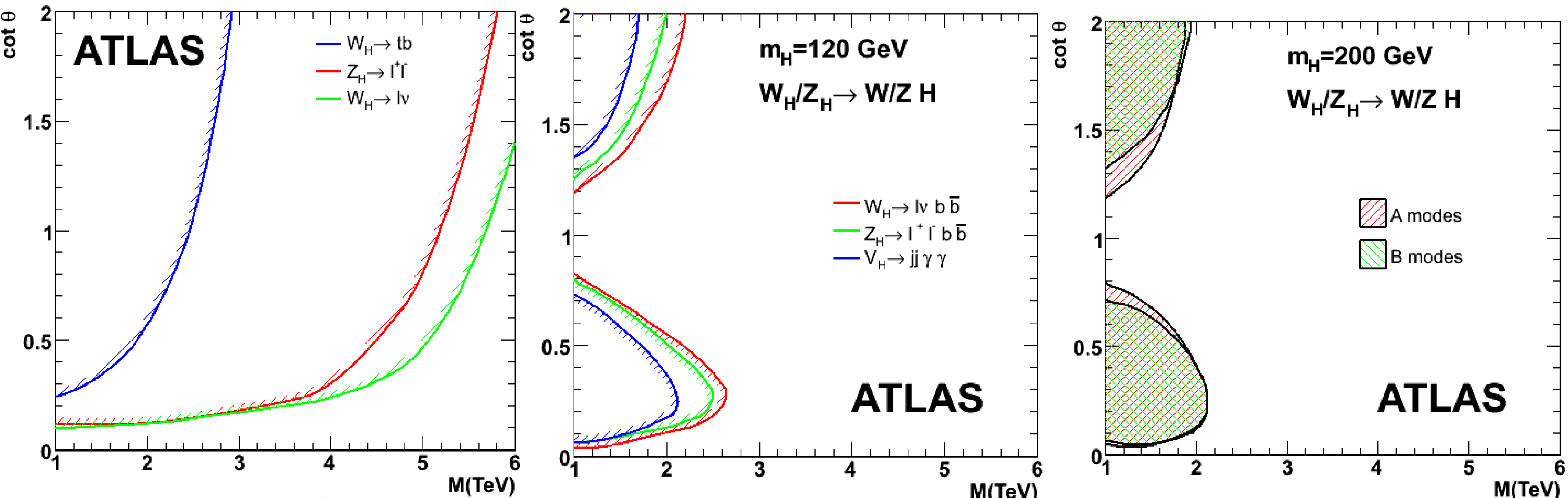
ε(b tag) = 40-50% Ru = 100
ε(γ tag) = 80%

Summary

The Z_H, W_H can be discovered up to 5-6 TeV if $\cot\theta$ large

It may be possible to probe the model up to ~ 2 TeV

- using the $W_H \to t\bar{b}$ decay ($\cot\theta > 0.25$)
- using the $V_H \to Vh$ decay ($\cot\theta \notin [0.8,1.2]$)



Fermionic decays

Bosonic decays

References:
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S. Gonzales de la Hoz *et al.*, ATL-PHYS-PUB-2006-003
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