LHC Studies of Twin Higgs Models

Theory: Shufang Su, Xinyu Miao

Exp (ATLAS): Marcel Vos, L. march, E. Ros

(CMS): ??? anyone interested???

Twin Higgs vs. Little Higgs

Little Higgs	Twin Higgs
Higgs is a pseudo-Goldstone boson of spontaneous breaking global symmetry	
collective symmetry breaking	discrete symmetry

Left-right symmetry (left-right twin Higgs models)

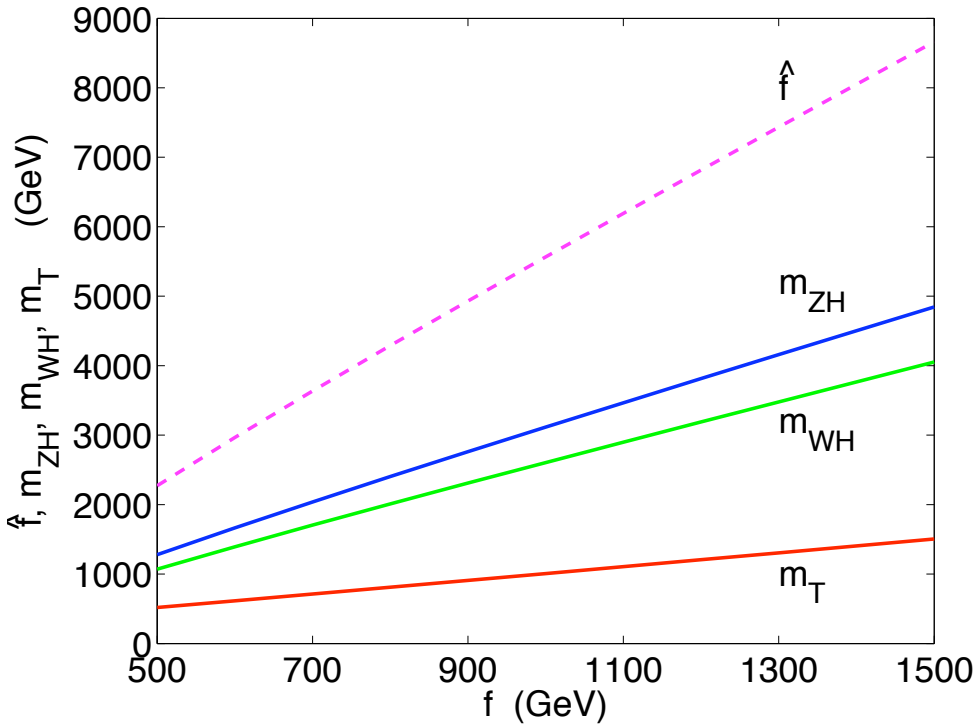
Model: Chacko, Goh, Harnik, hep-ph/0512088

Phenomenology: Goh and Su, hep-ph/0611015

New particles

- Heavy gauge bosons: W_H, Z_H
- Heavy top: t_H
- Other $SU(2)_R$ Higgses: $\phi^{\pm}$

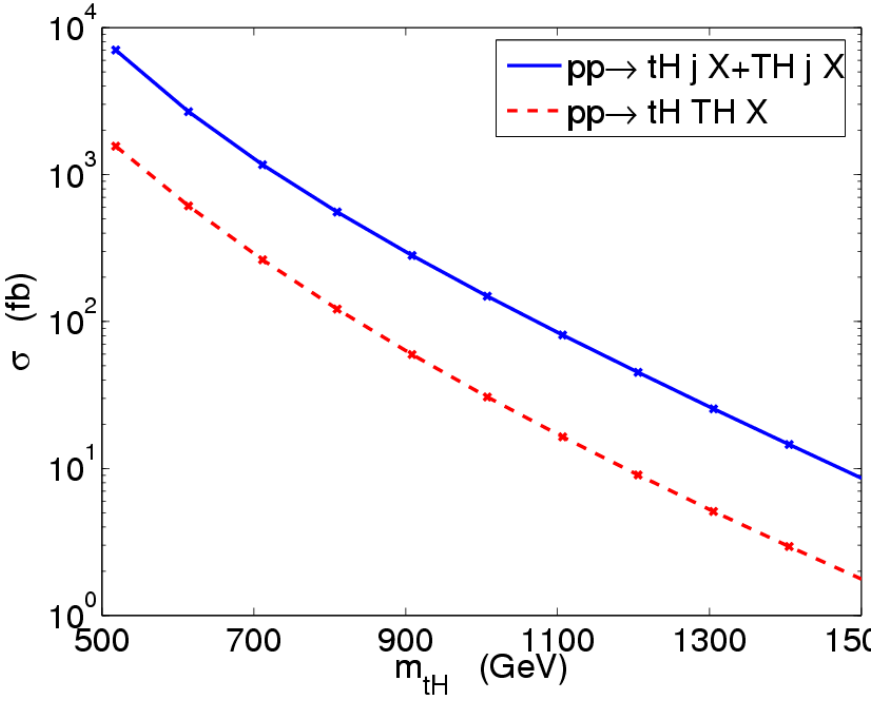
  ϕ^0

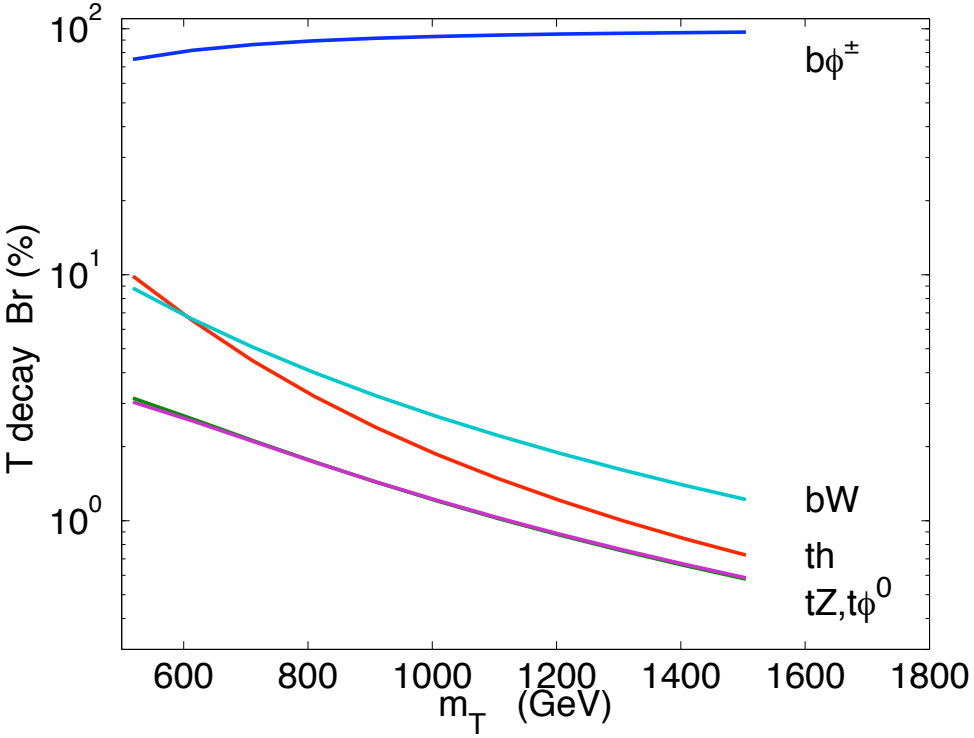


- Model parameters: f, M, (Λ, μ_R)

Heavy top t_H decay

- **single heavy top production dominate**





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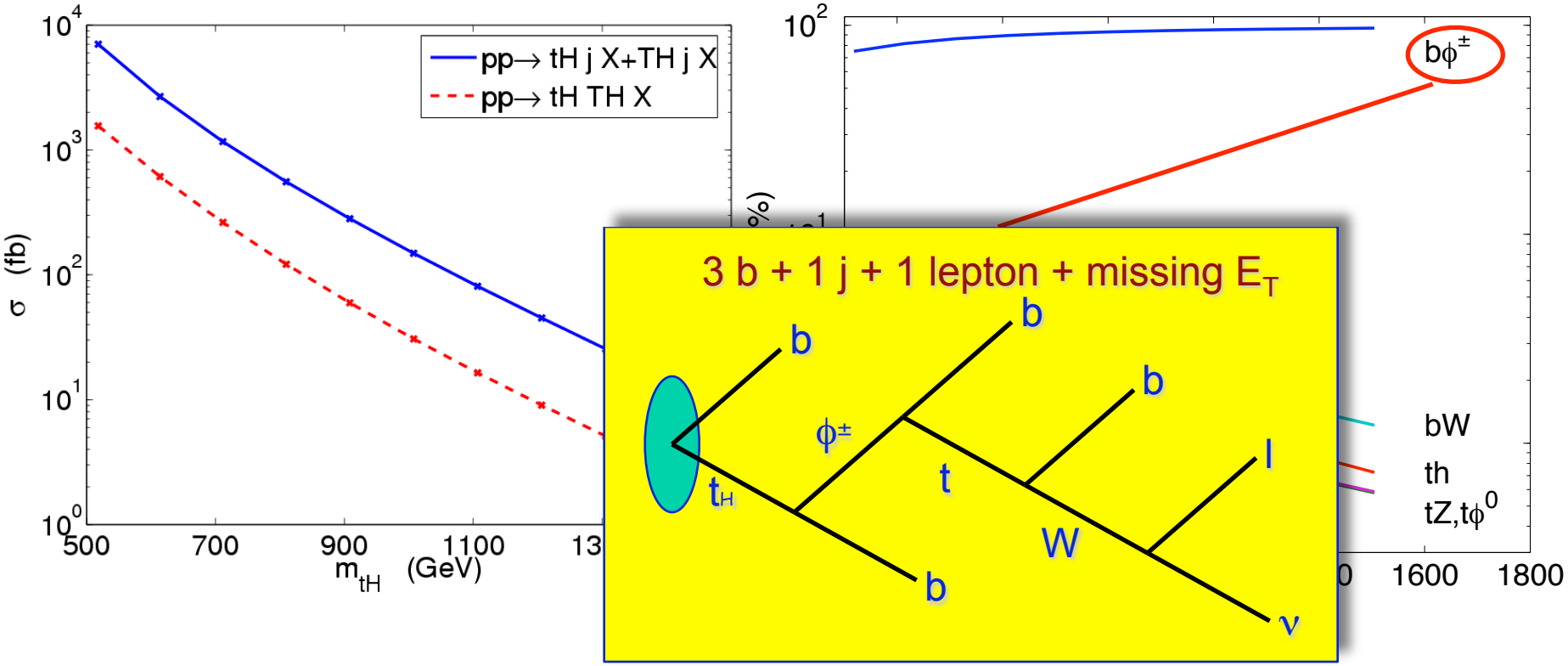

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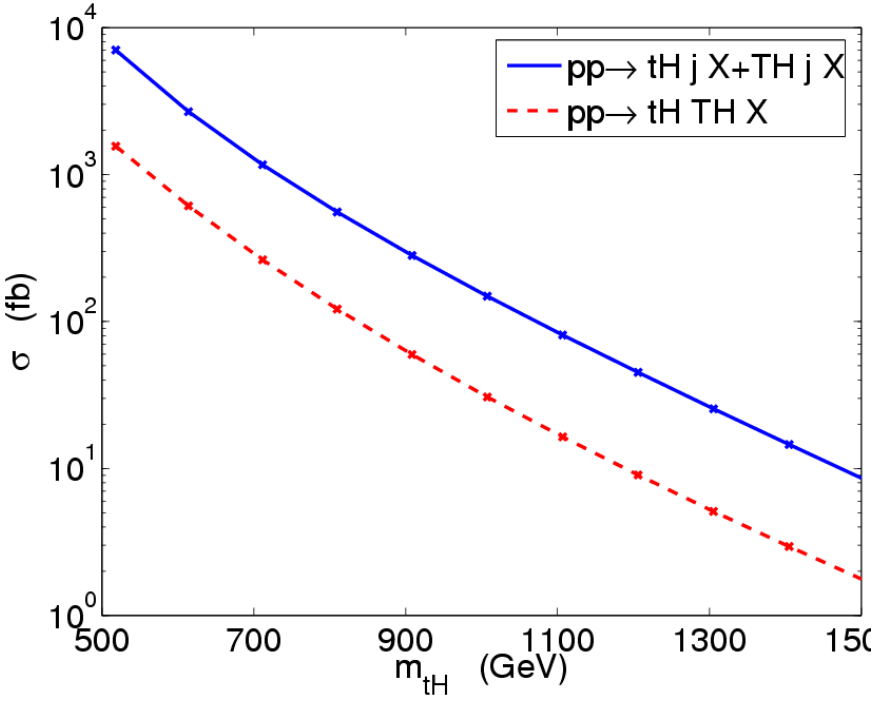
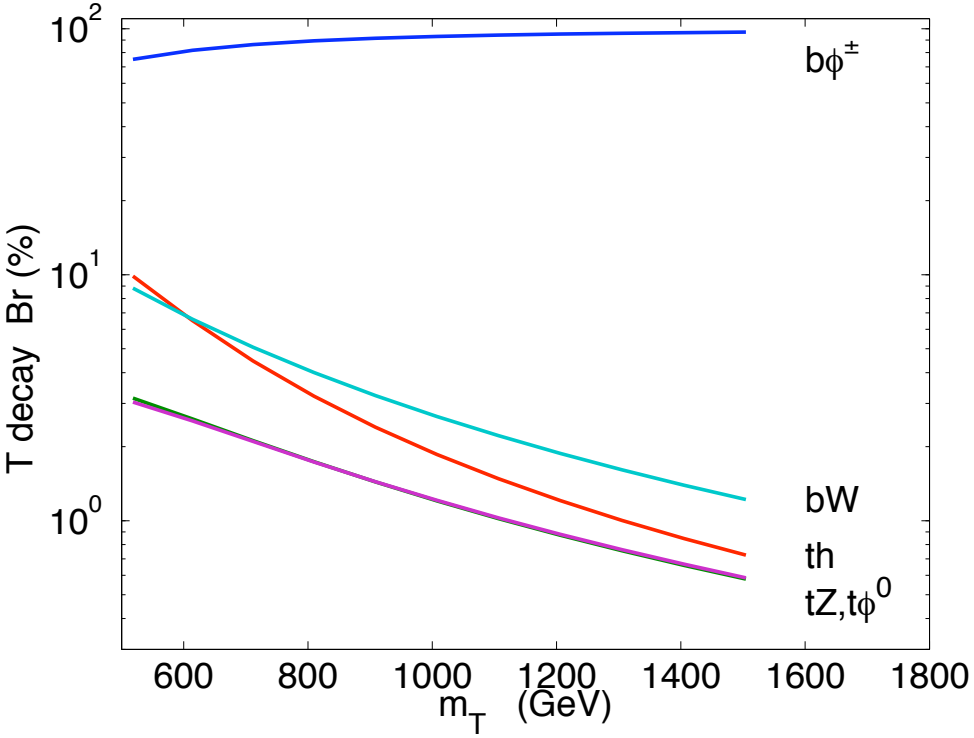
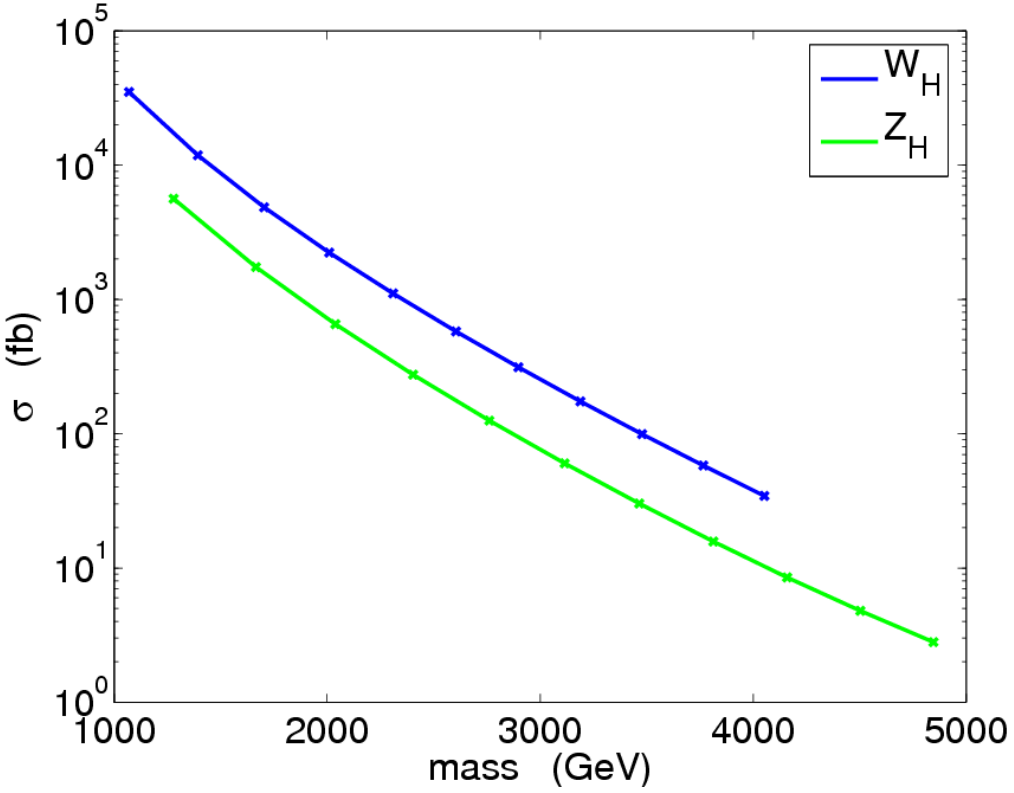




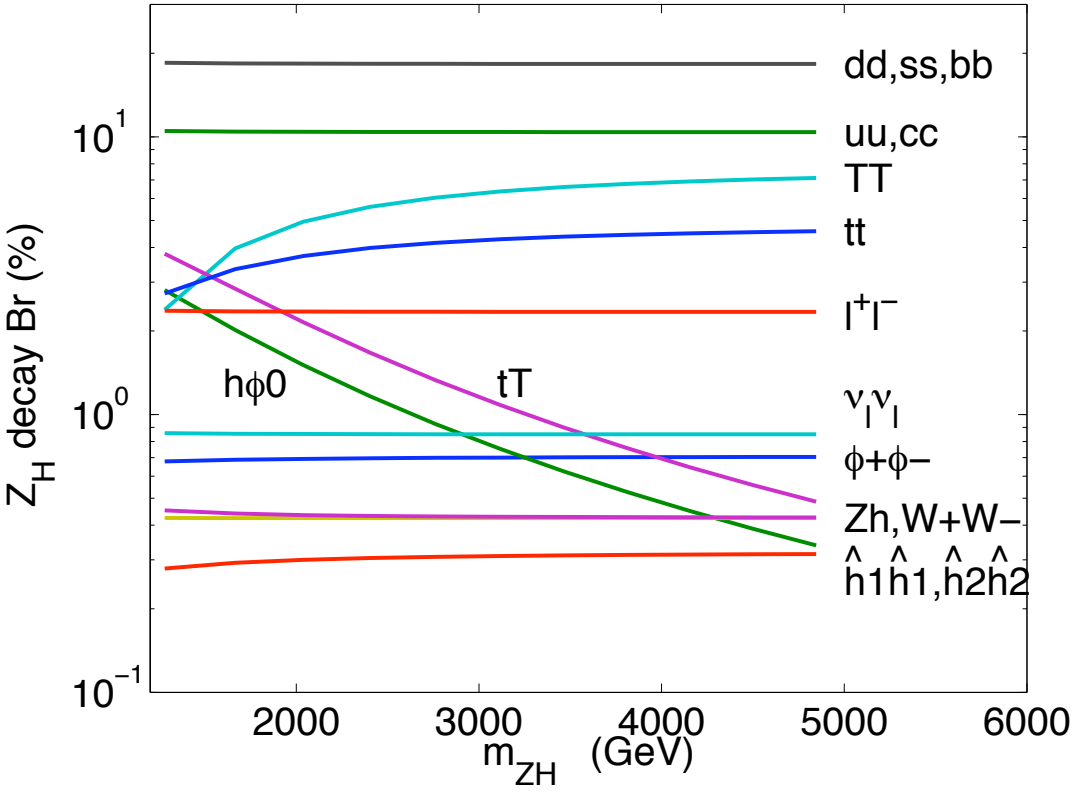
Heavy gauge boson production

- **Drell-Yan process** $q\bar{q}' \to W_H, Z_H$



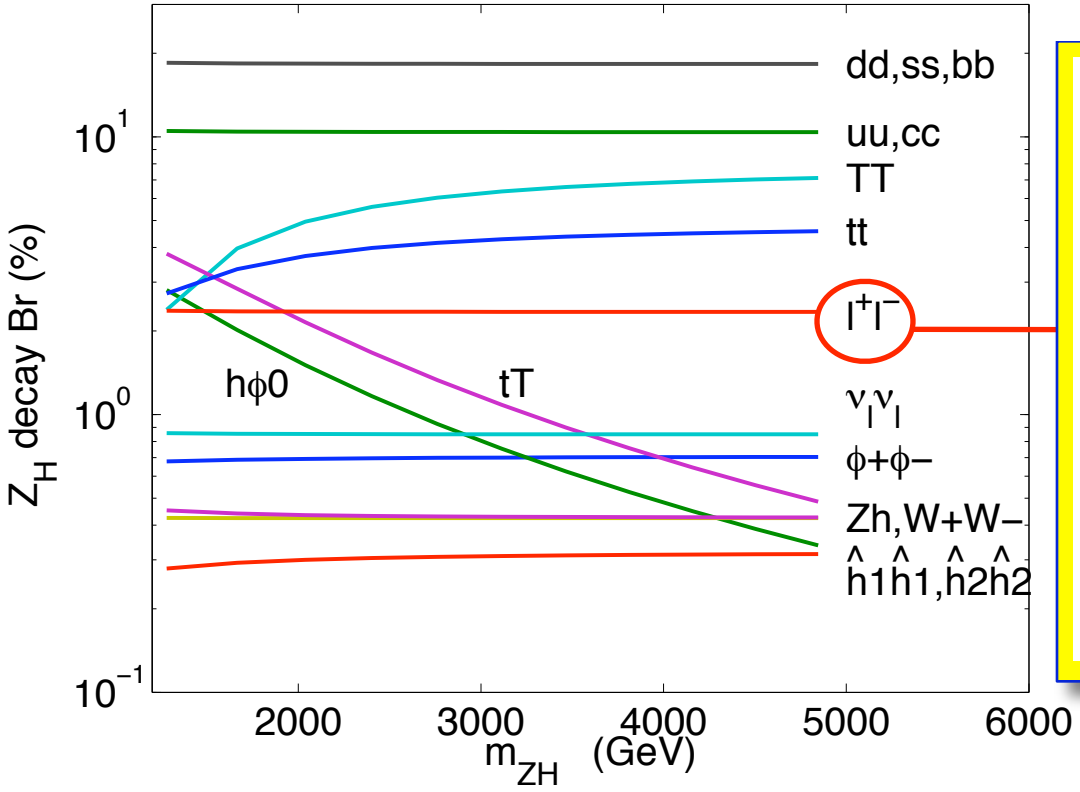
Z_H decay

- Z_H


dd,ss,bb
uu,cc
TT
tt
l+l−
νlνl
ϕ+ϕ−
Zh,W+W−
ĥ1ĥ1,ĥ2ĥ2
hϕ0
tT
ZH decay Br (%)
10^1
10^0
10^−1
2000
3000
4000
5000
6000
mZH (GeV)

Z_H decay

- Z_H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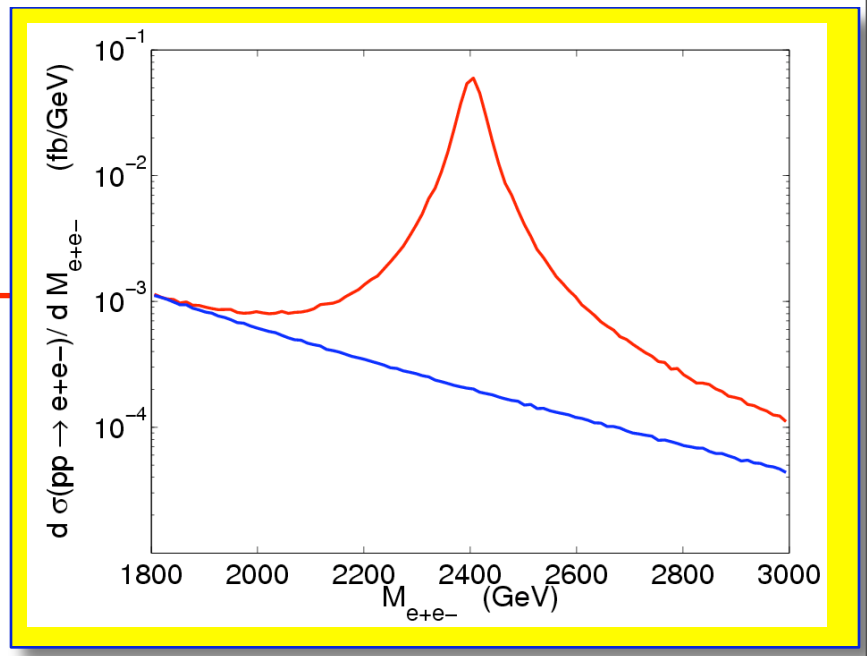
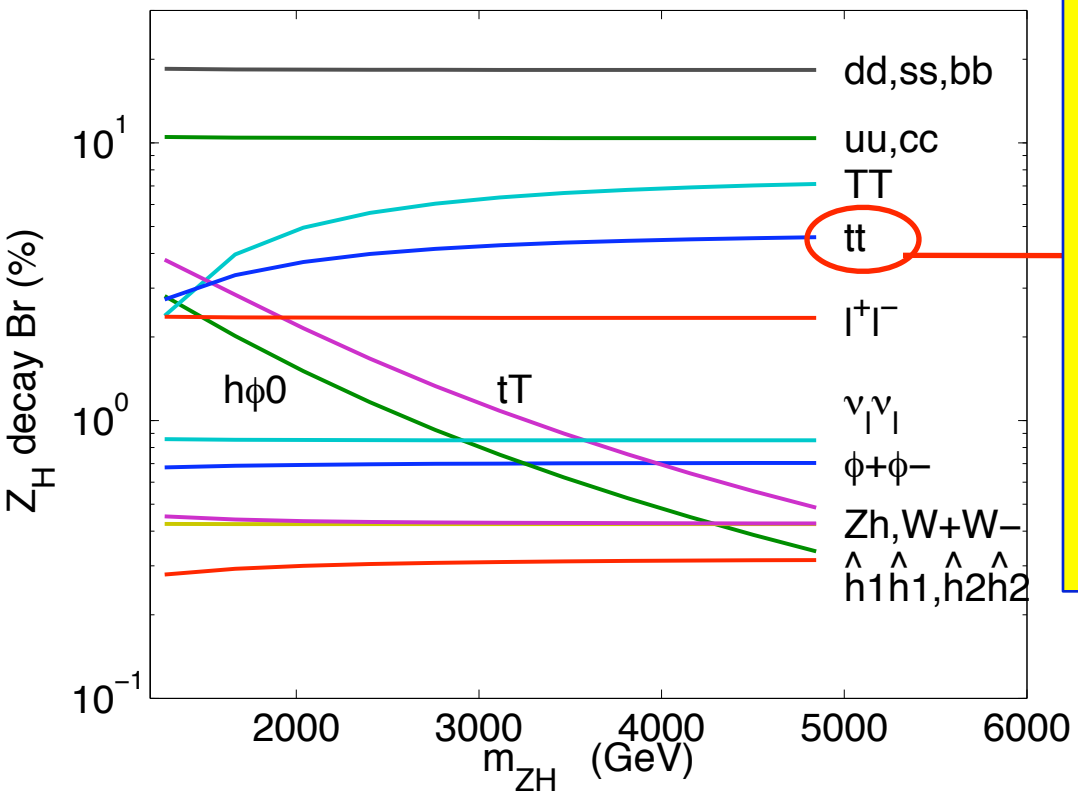

d σ(pp → e+e−)/ d Me+e− (fb/GeV)
Me+e− (GeV)

Z_H decay

- Z_H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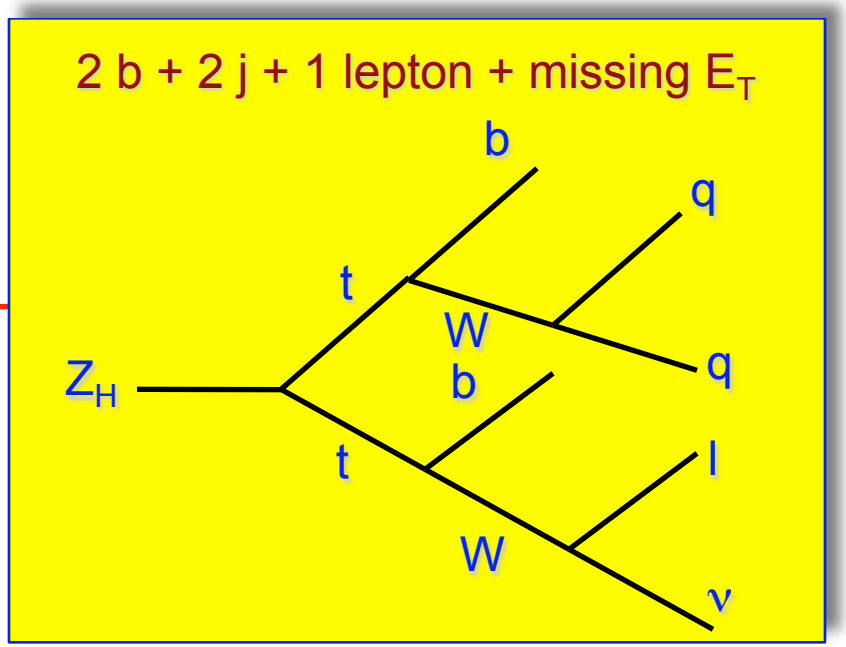
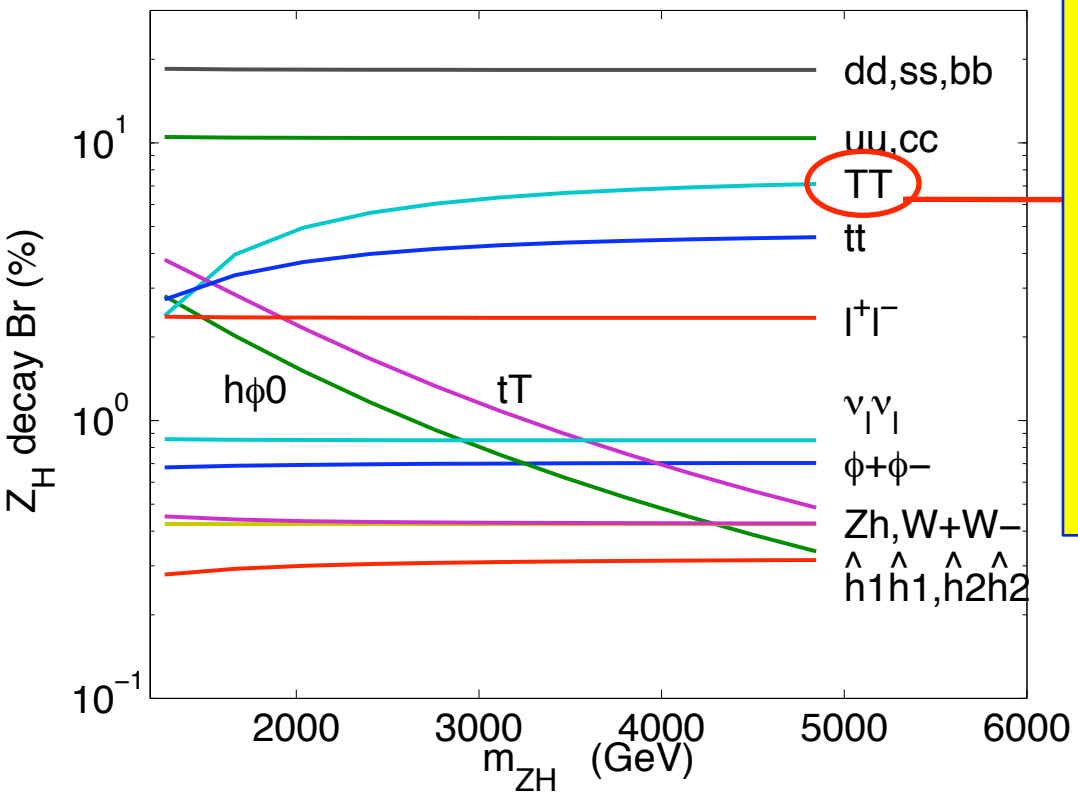

2 b + 2 j + 1 lepton + missing ET
b
q
t
W
q
ZH
b
t
l
W
ν

Z_H decay

- Z_H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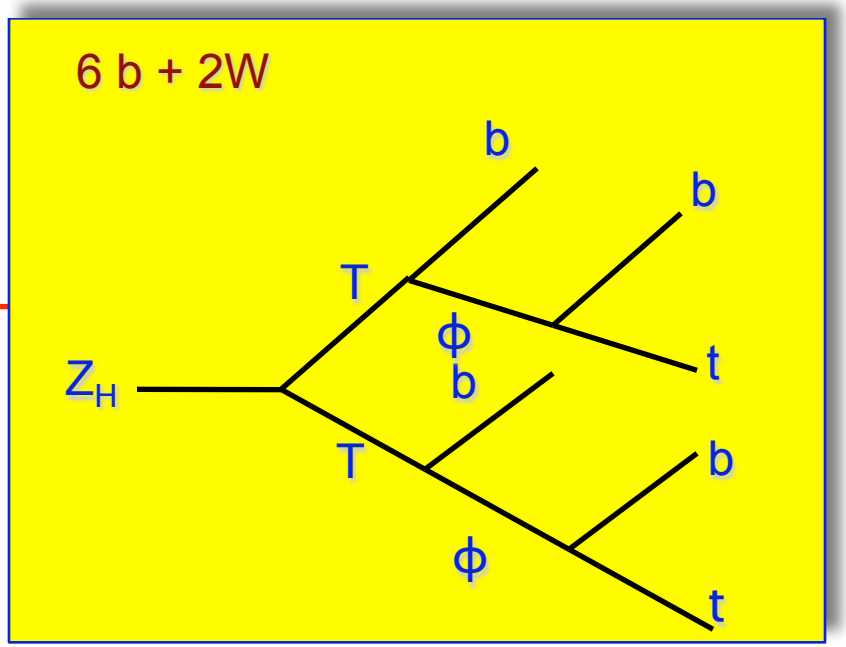
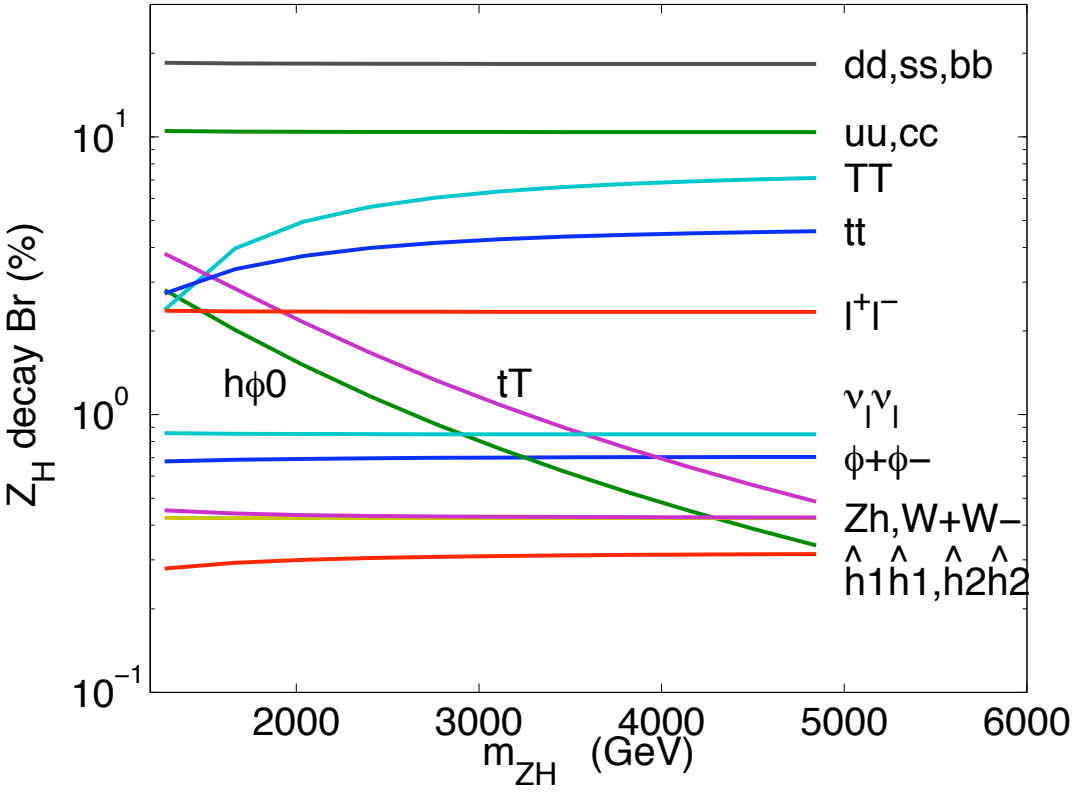

6 b + 2W
b
b
T
ϕ
t
ZH
b
T
b
ϕ
t

Z_H decay

- Z_H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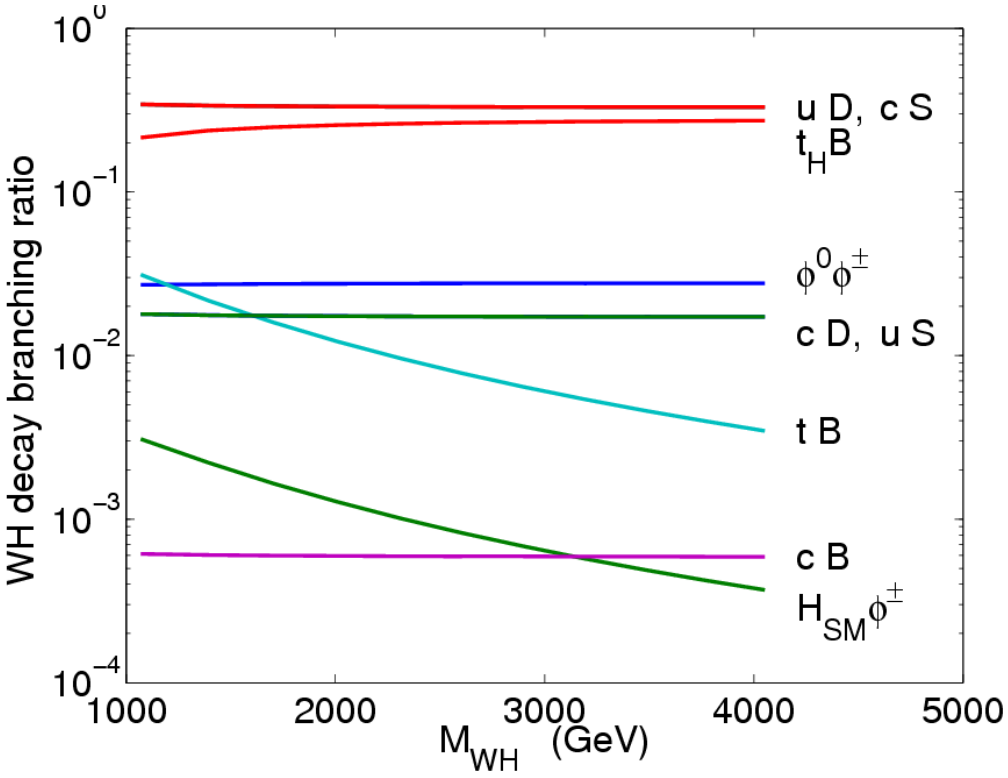
W_H decay

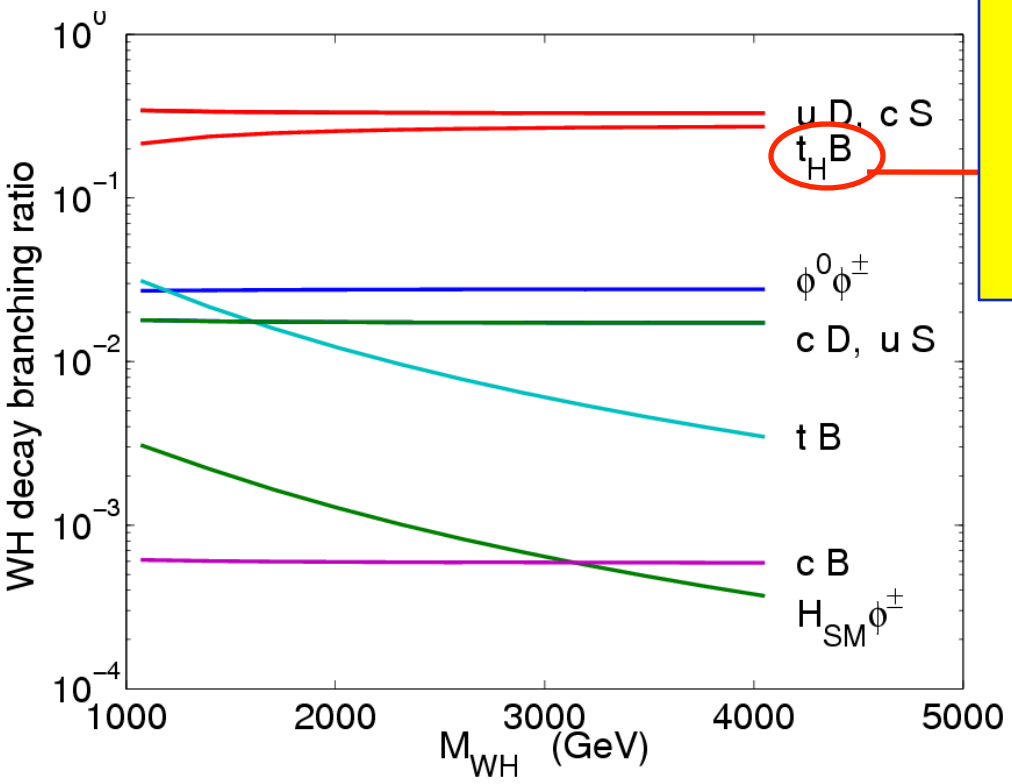
- W_H ($m_{\nu R} > m_{WH}$)



- W_H ($m_{\nu R} < m_{WH}$), $W_H \rightarrow l\ \nu_R$, Br ~ 9%

W_H decay

- W_H ($m_{\nu R} > m_{WH}$)



$t_H \rightarrow b\phi^\pm$: 4b + 1 lepton + missing E_T

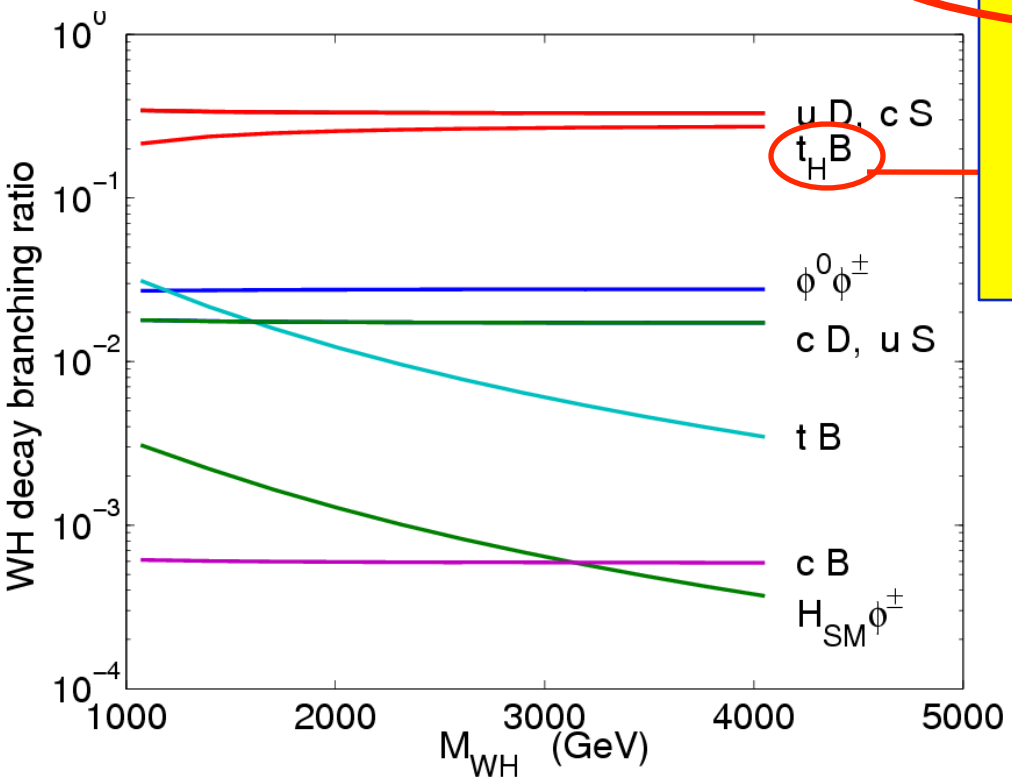
$t_H \rightarrow bW$: 2b + 1 lepton + missing E_T

$t_H \rightarrow tZ$: 2b + 3 lepton + missing E_T

- W_H ($m_{\nu R} < m_{WH}$), $W_H \rightarrow l\ \nu_R$, Br ~ 9%

W_H decay

- W_H ($m_{\nu R} > m_{WH}$)



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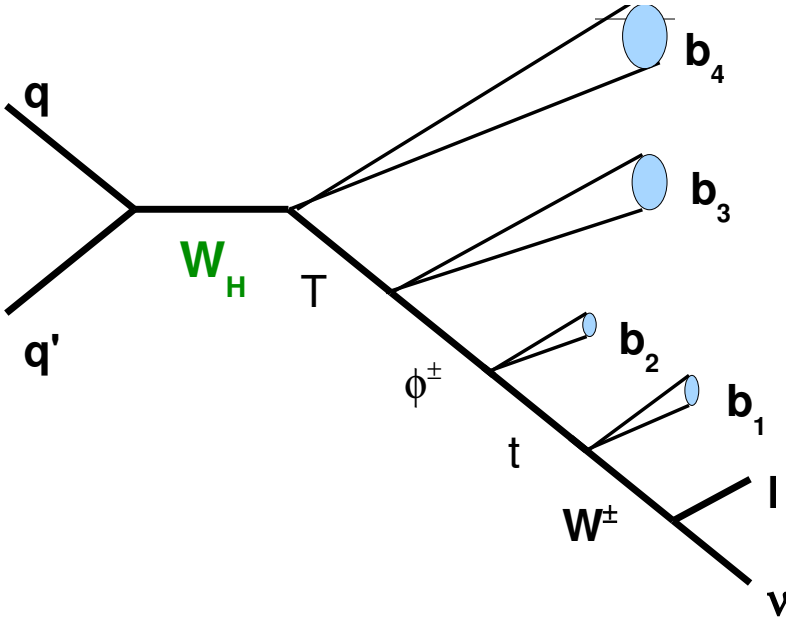
$t_H \rightarrow bW$: 2b + 1 lepton + missing E_T

$t_H \rightarrow tZ$: 2b + 3 lepton + missing E_T

- W_H ($m_{\nu R} < m_{WH}$), $W_H \rightarrow l\ \nu_R$, Br ~ 9%

$W_H \rightarrow t_H b$ channel (1 TeV)

Marcel group: pythia + ATLASFAST



Reconstruct masses

$l+\nu \rightarrow W$ $\quad p_T(l) > 25$ GeV/c,

$E_T^{miss} > 25$ GeV/c

assume p_z^{ν} // p_z^{l} to reconstruct W

$\varepsilon_l = 90\%$ (trigger + lepton ID)

$W+b_1 \rightarrow t$ $\quad 25 < p_T(b_1) < 200$ GeV/c

$t+b_2 \rightarrow \phi^{\pm}$ $\quad 25 < p_T(b_2) < 100$ GeV/c

$\phi^{\pm}+b_3 \rightarrow T$ $\quad p_T(b_3) > 100$ GeV/c

$T+b_4 \rightarrow W_H$ $\quad p_T(b_4) > 150$ GeV/c

$|\eta| < 2.5$ for all leptons and jets

Additional cuts

$m(t) < 250$ GeV/c^2

$m(\phi^{\pm}) < 250$ GeV/c^2

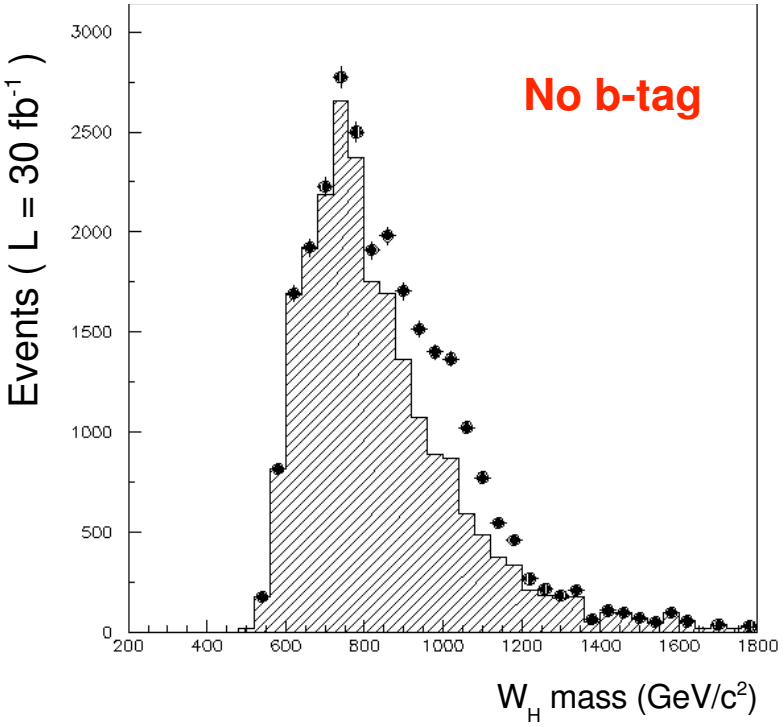
$m(T) < 700$ GeV/c^2

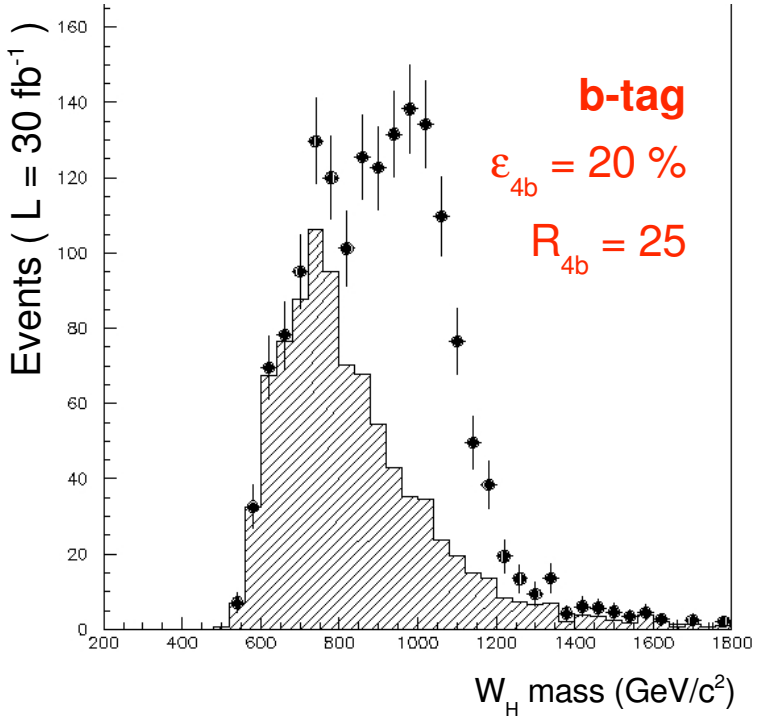
$p_T(T) > 150$ GeV/c (jacobean peak)

Efficiency (kin. cuts only):

$\varepsilon_{kin} \sim 12\ \%$

b-tag





N_{sig} = 3253

N_{tt} = 9427

N_{wj} = 319

$N/\sqrt{B}$ = 33

N_{sig} = 651

N_{tt} = 377

N_{wj} ~ 0

$N/\sqrt{B}$ = 33

$W_H \rightarrow t_H b$ channel (up to 4 TeV)

Shufang group: madgraph (+pythia)

- Dominant background tt (one W → lν, one W→ qq), Wjjjj,Wbbjj,Wcjjj
- Cuts
  - lepton (e or μ) with $p_T > 30$ GeV, $|\eta|<2.5$
  - at least three jets with $p_T > 50$ GeV
  - one jet with $p_T > 350$ GeV
  - reconstructed mt mass: mt ± 10 GeV
  - reconstructed $m_{\phi\pm}$: $150 < m_{\phi\pm} < 550$ GeV
  - reconstructed m_{tH}: 500 GeV < m_{tH} < 2000 TeV
  - b-tag two lowest p_T jets

f (m_{tH})	σ_{before} (fb)	σ_{after} (fb)	s/√B (L=30 fb^{-1})
600 GeV	642	2.4	28
1000 GeV	32	2.4	28
1500 GeV	2.9	0.13	1.5 (could be improved)

background	σ_{after} (fb)
tt	0.045
Wjjjj	~0
Wbbjj	0.10
Wcjj	0.07
Wbbbb	small
QCD	. . .

Working in progress and future work

- Other Channels:
  - $Z_H \rightarrow l^+l^-$ (dilepton)
  - $Z_H \rightarrow tt$ (tt resonance)
  - $Z_H \rightarrow t_H t_H$ (6b+2W)
  - $W_H \rightarrow \phi^0\phi^\pm$ (Marcel's group already studies this)
  - $W_H \rightarrow l\, \nu_R$
  - $t_H \rightarrow tZ \rightarrow 2b+3l+\nu$
- small M case, $\phi^\pm \rightarrow \tau\nu_\tau$, cs instead of tb, possibility for discovery?
- Define and study a set of benchmark points: f, M, (μ_R)

exp: High p_T b-tagging

madgraph model file