Charged Higgs and Top-quark Associated Production with the MSSM Higgs sector extended by dimension six operators

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Introduction

LHC (ATLAS, CMS): $m_H \sim 125$ GeV with SM-like properties

Models with an extended Higgs sector are constrained by

1. the measured mass,
2. CP quantum numbers,
3. and production rates of the new boson.

The discovery of another scalar boson, neutral or charged, would represent unambiguous evidence for the presence of physics beyond the SM.

THDM: Type II (MSSM) h, H, A, H^+, H^-

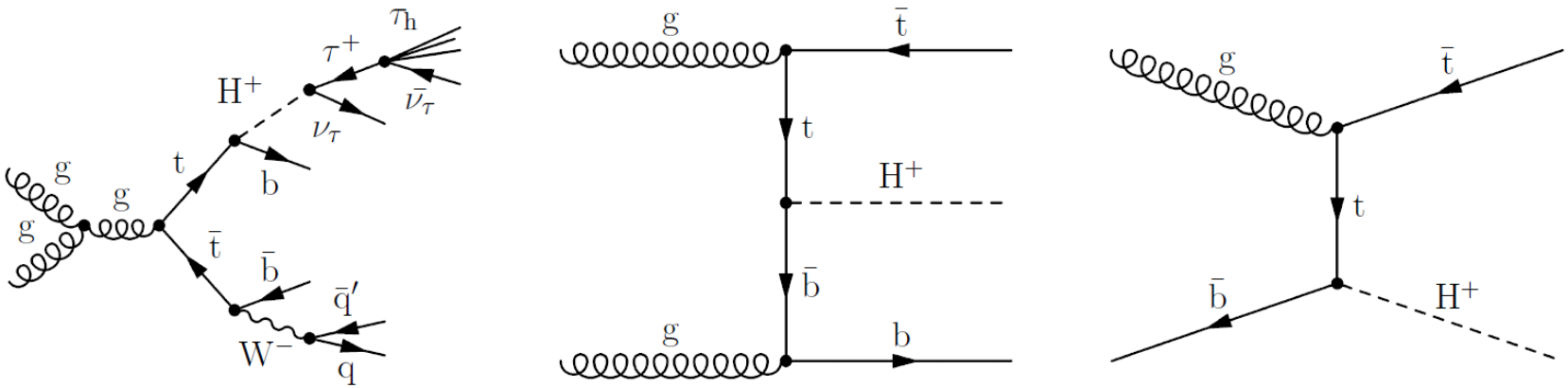
LEP2[1]: $m_{H^\pm} \geq 78.6$ GeV at a 95 % CL

[1] Phys. Lett. B **543** (2012) 1; Eur. Phys. J. C **34** (2004) 399; Phys. Lett. B **575** (2003) 208; Eur. Phys. J. C **72** (2012) 2076.

Production of the charged Higgs boson

The charged Higgs boson is searched[2]

1. for top quark decays for $m_{H^+} < m_t - m_b$,
2. in the direct production $pp \to \bar{t}bH^+$ for $m_{H^+} > m_t - m_b$



Decay mode	Signatures for $m_{H^+} < m_t - m_b$	Signatures for $m_{H^+} > m_t - m_b$
	$pp \to t\bar{t} \to bH^+\bar{b}H^-/bH^+\bar{b}W^-$	$pp \to \bar{t}(b)H^+$
$H^+ \to \tau^+\nu_\tau$	τ_h+jets	τ_h+jets , $\mu\tau_h$, $\ell\ell'$
$H^+ \to t\bar{b}$	—	$\mu\tau_h$, $\ell\ell'$, ℓ+jets

[2]The CMS Collab., JHEP11(2015)018, arXiv:1508.07774v2[hep-ex]

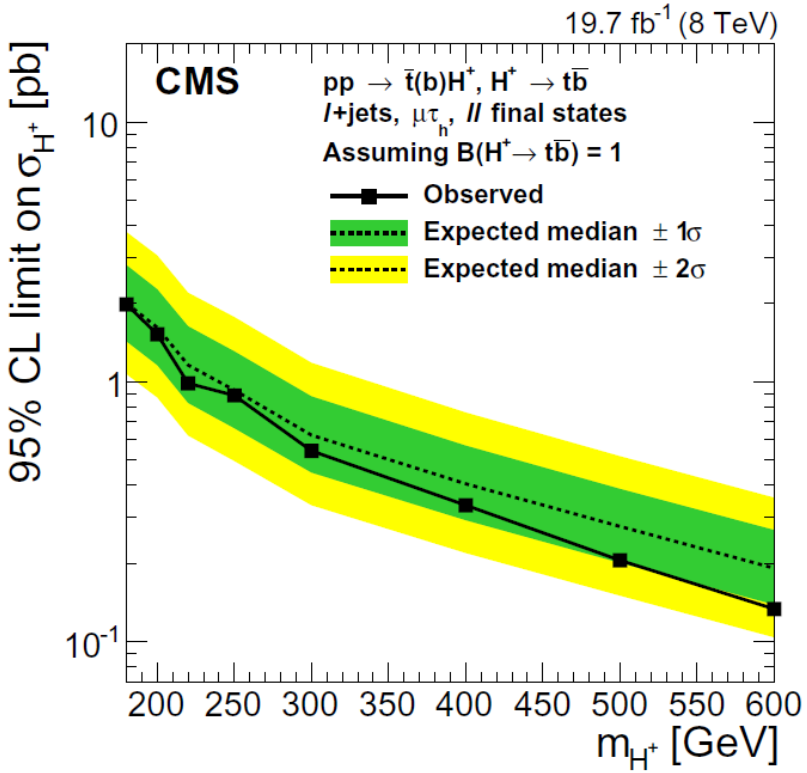
A model-independent upper limits

$\sqrt{s}$=8 TeV

m_{H^+}: 80–160 GeV	180–600 GeV
$B(t \to H^{\pm} b) B(H^{\pm} \to \tau^{\pm} \nu_{\tau})$	$\sigma(pp \to t(b) H^{\pm}) B(H^{\pm} \to \tau^{\pm} \nu_{\tau})$
=1.2–0.5 % CMS	=0.38–0.025 pb CMS
$B(t \to H^{+} b) B(H^{+} \to \tau^{+} \nu_{\tau})$	$\sigma(pp \to t(b) H^{+}) B(H^{+} \to \tau^{\pm} \nu_{\tau})$
=1.3–0.2 % ATLAS	=0.8–0.004 pb ATLAS
if $\tan\beta < 5$ then	if $B(H^{\pm} \to tb)$=1 then
$B(H^{+} \to c\bar{s})$=1	$\sigma(pp \to t(b) H^{\pm})$
$B(t \to H^{+} b)$=5–1 % ATLAS	=2.0–0.13 pb CMS

CMS: JHEP11 (2015) 018, arXiv:1508.07774

ATLAS: JHEP 03 (2015) 088, arXiv:1412.6663; Eur. Phys. J. C 73 (2013) 2465



Expected and observed 95% CL upper limits on $\sigma(pp \to \bar{t}(b)H^+$ for the combination of the $\mu\tau_h, l$+jets, and ll' final states assuming $B(H^+ \to t\bar{b})$=1. The region above the solid line is excluded[3]

[3]The CMS Collab., JHEP11(2015)018, arXiv:1508.07774v2[hep-ex].

MSSM benchmark scenarios

	$m_h^{\max}$	$m_h^{\text{mod}+}$	$m_h^{\text{mod}-}$	light stop	light stau	τ-phobic	low-M_H
m_{top} [GeV]				173.2			
M_S [GeV]	1000	1000	1000	500	1000	1500	1500
μ [GeV]	200	200	200	350	500	2000	varied
$X_t^{\overline{\text{MS}}}/M_S$	$\sqrt{6}$	1.6	-2.2	2.2	1.7	2.9	2.9

Table: Different MSSM benchmark scenarios [4].

We consider a simplified scenario with following assumptions

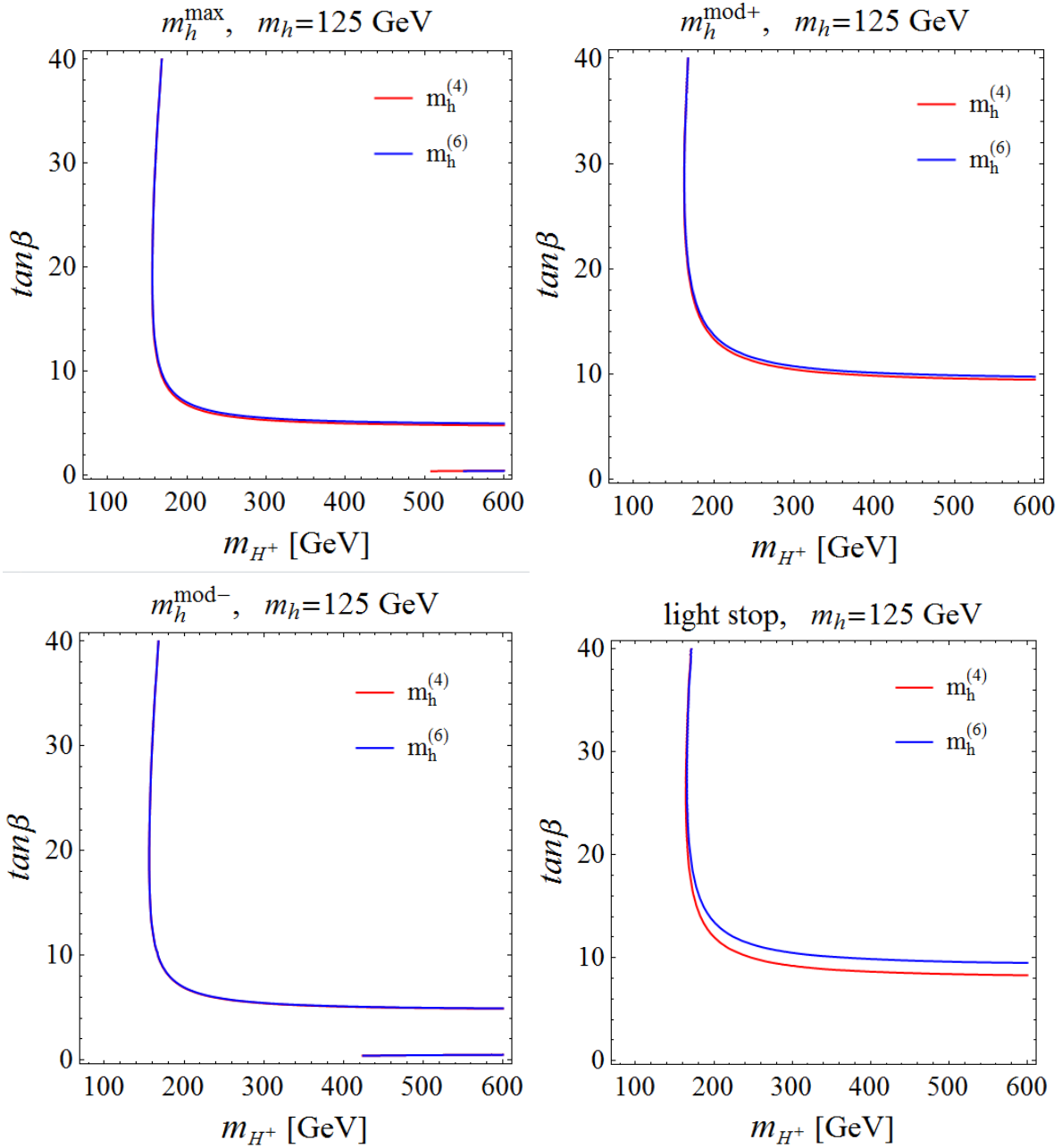
1. RGE's contributions and 1,2 generations of squarks are neglected,
2. the main contributions come from threshold effects and two-loop

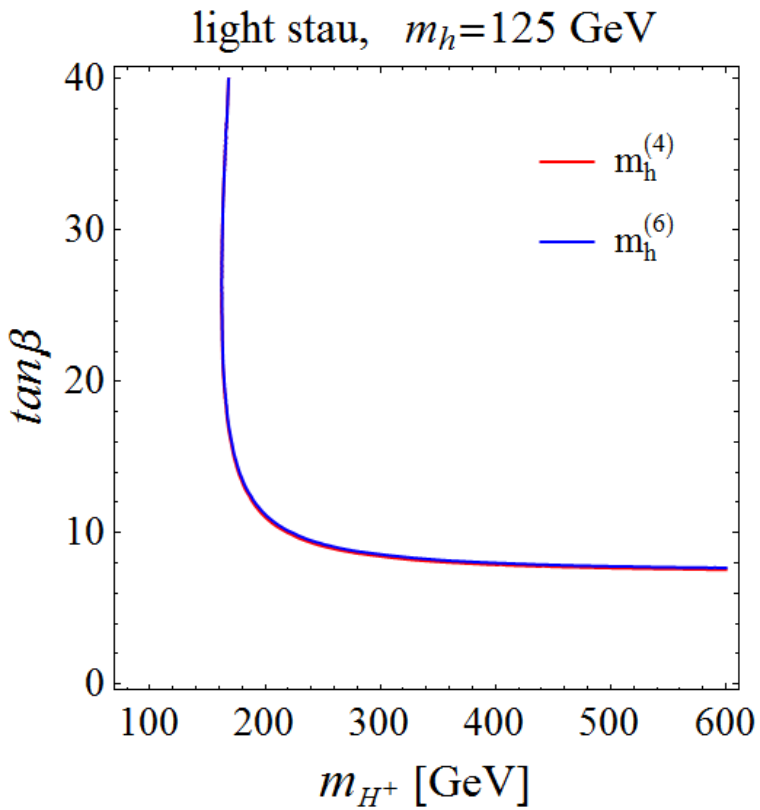
$$\Delta\lambda_i = \Delta\lambda_i[1-\texttt{loop}]+\Delta\lambda_i[2-\texttt{loop}], \qquad \Delta\lambda_i[1-\texttt{loop}] = \Delta\lambda^{\text{eff.pot}}-\Delta\lambda^{\text{fiel}}$$

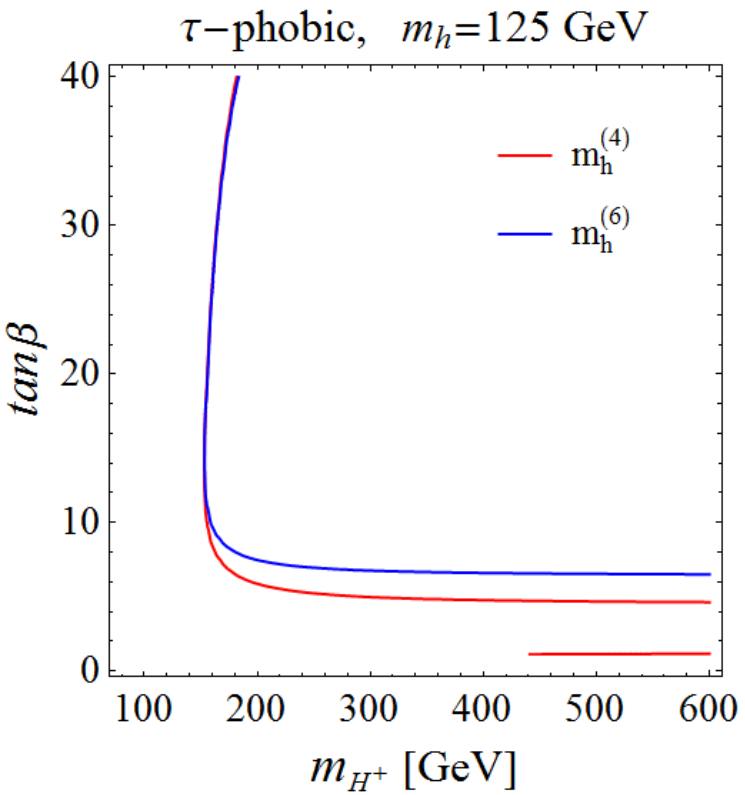
3. the additional one-loop contributions of the dimension-six operators may be included.

Free parameters: $m_{H^\pm}$, M_S, $\tan\beta$, μ, $A_t = A_b = A$

[4] M. Carena et al, Eur. Phys. J. C 73, 2552 (2013)


m_h^{max}, m_h=125 GeV
m_h^{mod+}, m_h=125 GeV
m_h^{mod-}, m_h=125 GeV
light stop, m_h=125 GeV
$m_h^{(4)}$
$m_h^{(6)}$
tanβ
m_{H^+} [GeV]
0
10
20
30
40
100
200
300
400
500
600


light stau, m_h=125 GeV
40
30
20
10
0
$tan\beta$
100
200
300
400
500
600
m_{H^+} [GeV]
$m_h^{(4)}$
$m_h^{(6)}$


$\tau-$phobic, m_h=125 GeV
40
30
20
10
0
$tan\beta$
100
200
300
400
500
600
m_{H^+} [GeV]
$m_h^{(4)}$
$m_h^{(6)}$

Cross sections $\sigma(gg, q\bar{q} \to \bar{t}bH^+)$

$\sqrt{s}$=13 TeV

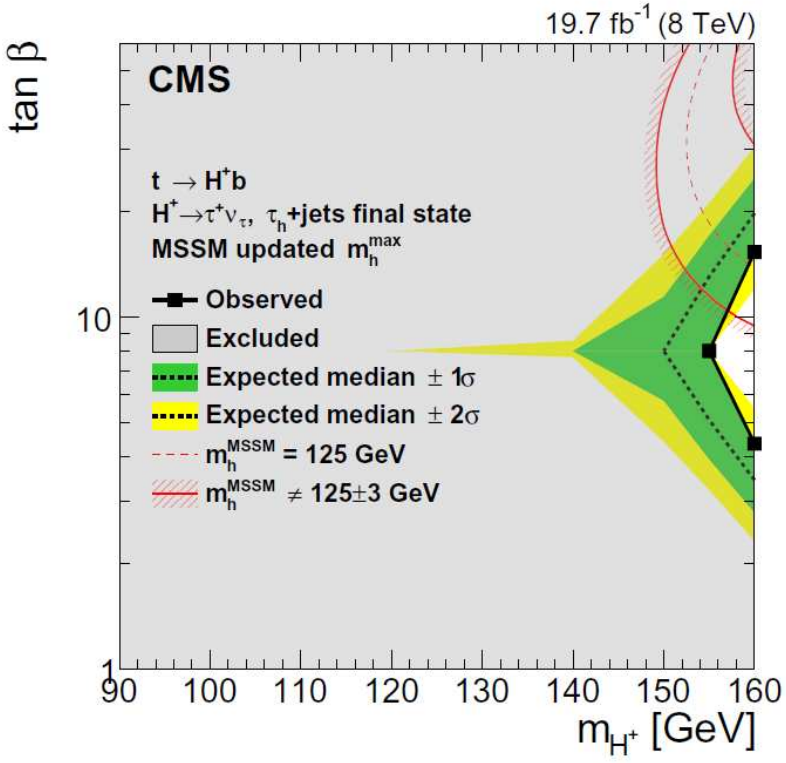
Computations are performed in CompHEP

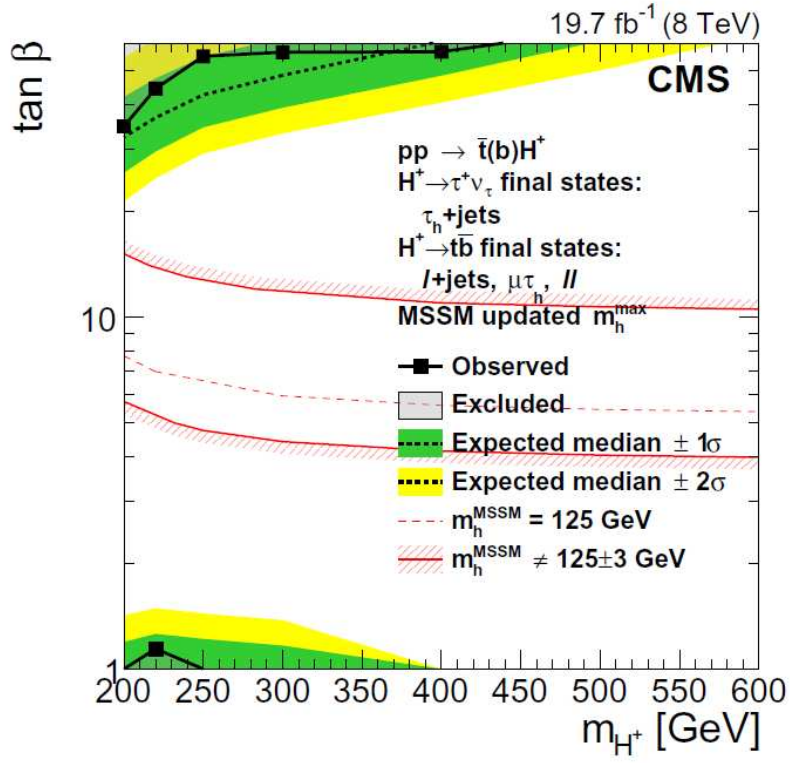
Scenario	$m_{H^\pm}$	$\tan\beta^{(4)}$	$\tan\beta^{(6)}$	$\sigma^{(4)}$, fb	$\sigma^{(6)}$, fb
$m_h^{\max}$	200	6.790	7.020	101.200 ± 0.350	102.420 ± 0.040
	400	4.990	5.180	27.749 ± 0.080	24.895 ± 0.300
	600	4.800	4.980	18.394 ± 0.033	30.853 ± 0.021
	600	0.453	0.428	549.860 ± 0.006	617.160 ± 9.380
	800	0.488	0.468	155.520 ± 1.410	173.660 ± 1.300
	800	4.730	4.920	2.289 ± 0.008	2.224 ± 0.007
	1000	4.705	4.890	0.873 ± 0.003	0.863 ± 0.003
	1000	0.501	0.482	56.356 ± 0.197	61.848 ± 0.184
$m_h^{\text{mod}+}$	200	13.310	13.690	258.710 ± 0.676	268.470 ± 0.895
	400	9.460	9.740	34.013 ± 0.179	38.232 ± 0.300
	1000	9.258	9.553	1.139 ± 0.005	1.224 ± 0.006
	1000	0.405	0.403	85.792 ± 0.328	87.799 ± 0.304
$m_h^{\text{mod}-}$	200	6.896	6.938	97.456 ± 0.286	99.564 ± 0.256
	600	4.890	4.920	6.686 ± 0.025	7.015 ± 0.038
	600	0.489	0.488	468.680 ± 1.910	461.71 ± 2.32
	1000	4.798	4.828	0.891 ± 0.004	0.882 ± 0.004
	1000	0.521	0.520	53.482 ± 0.242	51.946 ± 0.229

Scenario	$m_{H^\pm}$	$\tan\beta^{(4)}$	$\tan\beta^{(6)}$	$\sigma^{(4)}$, fb	$\sigma^{(6)}$, fb
light stop	200	12.018	13.488	216.170 ± 0.415	265.680 ± 0.442
	600	8.280	9.492	7.254 ± 0.015	8.655 ± 0.015
	1000	8.119	9.320	0.953 ± 0.004	1.995 ± 0.002
light stau	200	11.032	11.208	194.050 ± 0.287	198.870 ± 0.348
	600	7.550	7.665	12.191 ± 0.012	12.339 ± 0.012
	1000	7.399	7.512	1.528 ± 0.001	1.547 ± 0.002
τ-phobic	200	5.865	7.465	96.952 ± 0.280	106.650 ± 0.371
	600	4.626	6.495	7.355 ± 0.048	6.749 ± 0.049
	600	0.397	–	702.540 ± 3.430	–
	1000	4.563	6.449	0.932 ± 0.004	0.932 ± 0.006
	1000	1.161	–	10.738 ± 0.057	–

Scenario	$m_{H^\pm}$, GeV	μ, GeV	$\tan\beta$	$\sigma^{(6)}$, pb
low-m_H	148.9	4660	4	3.684 ± 0.024
	146.4	4400	4.5	3.691 ± 0.022

Table: Cross sections for $gg, q\bar{q} \to \bar{t}bH^+$ where m_H=125 GeV.





The CMS Collab., JHEP11(2015)018, arXiv:1508.07774v2[hep-ex]

Summary

Exclusion limits in the $(m_{H^+}, \tan\beta)$ parameter space in different MSSM benchmark scenarios are considered with taken into account new radiative corrections induced by dimention-six operators of one-loop resummed MSSM Higgs potential.

1. New areas of parameter spase with low $\tan\beta$ appear.

2. Relative large values of cross sections for extremely small $\tan\beta$ or $m_{H^\pm} \geq 500$ GeV as a rule are forbidden by model independent upper limit.

Thanks for your attention