SUSY effects on Charged Higgs Boson Production at Hadron Colliders

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References:

A. Belyaev, D. Garcia, J. Guasch, J.S., **Phys. Rev. D**65 (2002) 031701 (R); *ibid.* **JHEP** 0206:059,2002)

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GUIDELINES

- Introduction.
  - Motivation
  - Related work and processes
  - SUSY quantum effects on decays involving the top quark and the charged Higgs
- $p\bar{p}(pp) \to tbH^{\pm} + X$ in the MSSM
  - Cross-section computation for the Tevatron II and the LHC energies.
  - Background processes
  - Leading SUSY corrections
  - SUSY K-factor
  - Numerical analysis
- Conclusions.

Introduction and Motivation

- Experimental accuracy reached for the EW precision observables allows to test the SM and its extensions at the Quantum Level.

- When extending the Higgs Sector, we mainly focus on 2HDM's (Type I and Type II) and most particularly on the MSSM.

- The MSSM, being a full Quantum Field Theory, is the most attractive framework for extending the theory of strong and EW interactions.

- Moreover, the MSSM offers a starting point for a successful GUT where a radiatively stable Higgs Sector can survive.

- Although precision observables at LEP have played an important role to test the SM and extensions thereof, future experiments at the Tevatron (II), LHC and LC will be necessary to find out the nature of the SSB.

- The fact that Higgs bosons couple most likely to heavy quarks suggests that the physics of the top quark and of the bottom quark is the natural arena where to try to get a hint of the existence of Higgs particles.

- Once a neutral Higgs boson is found

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  hard work to discriminate its SM or MSSM (or else) nature!!

•However, finding a

charged Higgs boson

would be indisputable evidence of

New Physics

⇓ ⇓

A most preferred production process in hadron colliders like the Tevatron, and specially the LHC, could be

$$p\bar{p}(pp) \to tbH^{\pm} + X \quad \text{(Tevatron)(LHC)}$$

• Distinctive (and large) quantum effects should be able to discriminate its potential SUSY nature!

Other (in general not so favorable) mechanisms for $H^{\pm}$ production in hadron colliders include e.g.:

- One-loop gluon fusion: $g\,g \to H^+\,H^-$;
- Tree-level pair production in bottom quark scattering: $b\,\bar{b} \to H^+\,H^-$;
- Associated production with $W^{\pm}$:
  $b\bar{b} \to W^{\pm}\,H^{\mp}$ (tree-level),
  $g\,g \to W^{\pm}\,H^{\mp}$ (one-loop);
- Drell-Yan type production; $q\bar{q} \to V \to H^+\,H^-$

All of them have been investigated in the literature.

Related work and processes

• The charged Higgs production calculation has been first considered at a preliminary level in:

J.F. Gunion, *Phys. Lett.* B 322 (1994)125; V. Barger, R.J. Phillips, D.P. Roy, *Phys. Lett.* B 324 (1994)236.

• More recently:

J.A. Coarasa, J. Guasch, J. Solà, hep-ph/9909397. Contributed to Physics at Run II: Workshop on Supersymmetry/Higgs: Summary Meeting, Batavia, Ill, 19–21 Nov. 1998 (including preliminary SUSY effects)

A. Belyaev, D. Garcia, J. Guasch, J. Solà, *Phys. Rev.* D 65 (2002)031701(R) (first results with leading SUSY effects); comprehensive study in: *ibid. JHEP* 0206:059,2002.

Related work without SUSY effects: F. Borzumati, J. Kneur, N. Polonsky, *Phys. Rev.* D 60 (1999)115011

NLO-QCD corrections: S-H. Zhu, hep-ph/0112109 (without SUSY); T. Plehn, hep-ph/0206121 (with SUSY).

• To identify the SUSY nature of the Higgs bosons, useful to correlate the charged Higgs production process with the neutral ones

$$p\bar{p}(pp) \to h\, b\bar{b} + X$$

where $h = h^0, H^0, A^0$.

• This correlation was proposed in J.A. Coarasa, R.A. Jiménez, J. Solà, *Phys. Lett.* B 389 (1996)312, hep-ph/9511402)

• Recent detailed analyses in:

M. Carena, S. Mrenna, C.E.M. Wagner, *Phys. Rev.* D 60 (1999)075010, hep-ph/9808312

J. Ellis, S. Heinemeyer, K.A. Olive, G. Weiglein, *Phys. Lett.* B 515 (2001)348, hep-ph/0105061.

• In the SM case ($h^0 \equiv H$) with full NLO-QCD effects:

L. Reina, S. Dawson, *Phys. Rev. Lett.* 87 (2001)201804

W. Beenakker, S. Dittmaier, M. Krämer, B. Plümper, M. Spira, P.M. Zerwas, *Phys. Rev. Lett.* 87 (2001) 201805.

Top quark decays in the SM and beyond

- Of course the leading decay is the SM one:

$$t \to W^+ b$$

- BUT –perhaps– the non-SM decay

$$t \to H^\pm + b$$

  is ALSO possible.

◇ The latter is the closest to the SM decay mode. However, it does not mean that $H^\pm$ is SUSY!.

◇ Tree-level effects cannot distinguish whether $H^\pm$ is SUSY or not. Quantum effects– in principle– CAN!!.

(J. A. Coarasa, D. Garcia, J. Guasch, R.A. Jiménez, J.S., *Eur. Phys. J.* **C 2** (1998) 373)

Higgs bosons in 2HDM and MSSM

- An extended Higgs sector can be a source of significant new quantum effects e.g. large FCNC* top or Higgs decays, or large Higgs production cross-sections. At the tree-level, however, the FCNC effects must be avoided.

- Case of 2HDM:

$$H_1 = \begin{pmatrix} H_1^0 \\ H_1^- \end{pmatrix} \ , \ H_2 = \begin{pmatrix} H_2^+ \\ H_2^0 \end{pmatrix}$$

- Possible cures (arrangements of Y.C.):
  - 2HDM I: Only one doublet couples to fermions (due to a discrete symmetry);
  - 2HDM II: H_1 couples to down-quarks and H_2 to up-quarks.
  - $H^\pm$ can then mediate loop induced FCNC: $B(b \to s\gamma) \sim (2-4) \times 10^{-4}$ (CLEO) $\Rightarrow m_{H^\pm} \gtrsim 500\, GeV$!!, and also very rare decays (in the SM context) like $t \to h\, c$, which can be of the same order as the radiative B-decays both in the MSSM and in a general 2HDM II. Specifically, the maximum contributions satisfy*

$$B(t \to g + c) < 10^{-5}(10^{-6}) < B(t \to h + c) \sim \boxed{10^{-4}}$$

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* S. Béjar, J. Guasch, J.S., Nucl. Phys. **B**600 (2001) 21;

J. Guasch, J.S., Nucl. Phys. **B**562 (1999) 3;

"$h \to FCNC$", S. Béjar, J. Guasch, J.S, in preparation.

Physical fields and Goldstone bosons:

$$\begin{pmatrix} G^+ \\ H^+ \end{pmatrix} = \begin{pmatrix} \cos\beta & \sin\beta \\ -\sin\beta & \cos\beta \end{pmatrix} \begin{pmatrix} -H_1^+ \\ H_2^+ \end{pmatrix}$$

$$\begin{pmatrix} G^0 \\ A^0 \end{pmatrix} = \frac{1}{\sqrt{2}} \begin{pmatrix} \cos\beta & \sin\beta \\ -\sin\beta & \cos\beta \end{pmatrix} \begin{pmatrix} -\mathrm{Im}(H_1^0) \\ \mathrm{Im}(H_2^0) \end{pmatrix}$$

$$\begin{pmatrix} H^0 \\ h^0 \end{pmatrix} = \frac{1}{\sqrt{2}} \begin{pmatrix} \cos\alpha & \sin\alpha \\ -\sin\alpha & \cos\alpha \end{pmatrix} \begin{pmatrix} \mathrm{Re}(H_1^0) - v_1 \\ \mathrm{Re}(H_2^0) - v_2 \end{pmatrix}$$

$\tan\beta = \frac{v_2}{v_1}$ $\qquad M_W^2 = \frac{g^2}{2}(v_1^2 + v_2^2)$

Neutral Higgs Couplings:

$$\alpha \to \beta \Rightarrow \begin{cases} (H^0, G^0, G^+) \text{ SM-like} \\ (h^0, A^0, H^+) \text{ enhanced couplings} \end{cases}$$

$$\alpha \to \beta - \frac{\pi}{2} \Rightarrow \begin{cases} (h^0, G^0, G^+) \text{ SM-like} \\ (H^0, A^0, H^+) \text{ enhanced couplings} \end{cases}$$

	H^0uu	H^0dd	h^0uu	h^0dd	A^0uu	A^0dd
Model I	$\frac{\sin\alpha}{\sin\beta}$		$\frac{\cos\alpha}{\sin\beta}$		$\frac{1}{\tan\beta}$	
Model II	$\frac{\sin\alpha}{\sin\beta}$	$\frac{\cos\alpha}{\cos\beta}$	$\frac{\cos\alpha}{\sin\beta}$	$\frac{\sin\alpha}{\cos\beta}$	$\frac{1}{\tan\beta}$	$\tan\beta$

• Charged Higgs couplings:

$$\mathcal{L}^{(j)}_{Htb} = \frac{g\,V_{tb}}{\sqrt{2}\,M_W}\,H^+\bar{t}\,\left[m_t\cot\beta\,P_L + m_b\,a_j\,P_R\right]\,b + h.c.$$

$a_I = -\cot\beta$ and $a_{II} = +\tan\beta$.

• MSSM case corresponds to $a_{II} = +\tan\beta$. At high $\tan\beta$ (typically > 20) the $H^\pm$-production process under consideration is optimized and then one gets the effective interaction

$$\mathcal{L}_{\text{eff}} = \frac{gV_{tb}}{\sqrt{2}\,M_W}\,\frac{\overline{m}_b(\mu_R)\tan\beta}{1+\Delta m_b}\,H^+\bar{t}_L\,b_R + h.c.$$

where we have included the extended form

$$h_b = \frac{m_b}{v\cos\beta}\frac{1}{1+\Delta m_b} \to \frac{m_b}{v}\frac{1}{1+\Delta m_b}\tan\beta$$

for the bottom quark Yukawa coupling, which involves the resummation of all corrections of order $(\alpha/4\pi)^n\tan^n\beta$ ($\alpha = \alpha_S, \alpha_W$) encoded in the supersymmetric parameter $\Delta m_b \sim \alpha\,\tan\beta$ (see later).

• It turns out that most of the SUSY correction to the associated charged Higgs production with the top quark comes from this effective interaction at high $\tan\beta$.

• $\tan\beta$ can be defined in many ways, and there can be some gauge dependence in a given definition (not in the observables!) when extended at higher orders. For the $t\,b\,H^\pm$ vertex we could use a "physical definition" of $\tan\beta$ (no gauge dependence) – as we did in top and charged Higgs decays. But since we checked that the main corrections come from finite threshold effects, the differences between definitions give subleading corrections at high $\tan\beta$.

$$\boxed{p\bar{p}(pp) \to tbH^{\pm} + X}$$

◇ At large $\tan\beta$ this is the leading process for Higgs boson production.

◇ At the parton level it proceeds through:

$$q\bar{q} \to H^+ \bar{t}\, b, \quad gg \to H^+ \bar{t}\, b,$$

and

$$\bar{b}g \to H^+ \bar{t}$$

◇ Appropriate subtraction of the gluon splitting term required:

$$\sigma(g\bar{b} + gg \to H^+\bar{t} + X)_{real} = \sigma(g\bar{b} \to H^+\bar{t}) + \sigma(gg \to H^+\bar{t}b) - \sigma(g \to b\bar{b} \otimes g\bar{b} \to H^+\bar{t}).$$

◇ Examples of background processes:

Tevatron			**LHC**		
$\sigma(qq \to t\bar{t}b\bar{b})$	=	6.62 fb	$\sigma(qq \to t\bar{t}b\bar{b})$	=	0.266 pb
$\sigma(gg \to t\bar{t}b\bar{b})$	=	0.676 fb	$\sigma(gg \to t\bar{t}b\bar{b})$	=	6.00 pb
$\sigma(gb \to t\bar{t}b)$	=	1.22 fb	$\sigma(gb \to t\bar{t}b)$	=	4.33 pb
Subtr. term	:	0.72 fb	Subtr. term	:	2.1 pb
Total	:	7.80 fb	Total	:	8.50 pb

◇ Crucial statistical parameter is the significance of the signal:

$$\boxed{S/\sqrt{B}}$$

◇ Standard discovery limit is

$S/\sqrt{B} = 5$ (99.999957% $C.L.$).

Exclusion limit is defined as:

$S/\sqrt{B} = 2$ ($\sim$ 95% $C.L.$).

Subtraction Term

• Overlap arises because the b-density in the $\bar{b}g$ amplitude receives contributions from gluon splitting already counted in the gg amplitude, so we have to avoid double counting by subtracting the gluon splitting term.

$$\sigma(\bar{b}g + gg \to H^+\bar{t} + X)_{net} = \sigma(g\bar{b} \to H^+\bar{t}) + \sigma(gg \to H^+\bar{t}b) - \sigma(g \to b\bar{b} \otimes g\bar{b} \to H^+\bar{t}).$$

$$\frac{df_{b/h}(x,Q^2)}{d\ln Q^2} = \frac{\alpha_S(Q^2)}{2\pi}\int_x^1 \frac{dz}{z}\left\{P_{b\leftarrow b}(z)\, f_{b/h}(\frac{x}{z},Q^2) + P_{b\leftarrow g}(z)\, f_{g/h}(\frac{x}{z},Q^2)\right\}$$

• The subtraction term can be approximated by integrating the gluon-splitting part $g \to b$ of this equation at the leading order in $\alpha_S(Q^2)$ $\Rightarrow$ the modified b-density is:

$$\tilde{f}_{b/h}(x,Q^2) = \frac{\alpha_S(Q^2)}{2\,\pi}\ln\left(\frac{Q^2}{m_b^2}\right)\int_x^1 \frac{dz}{z}\left[\frac{z^2+(1-z)^2}{2}\right] f_{g/h}\left(\frac{x}{z},Q^2\right),$$

where $P_{b\leftarrow g}(z) = (1/2)\left[z^2+(1-z)^2\right]$ is the gluon splitting function.

• Thus the modified b-density contains the collinear log and splitting function $P_{b\leftarrow g}$ convoluted with the g-density $\Rightarrow$ the expression for the subtraction term is:

$$\boxed{\text{Subt.term}(AB \to H^+\bar{t}b)} \quad =$$

$$\int dx_1 dx_2 \left\{ \begin{array}{c} \tilde{f}_{b/A}(x_1,Q^2) f_{g/B}(x_2,Q^2)\sigma(\bar{b}g \to \bar{t}H^+) \\ +f_{g/A}(x_1,Q^2)\tilde{f}_{b/B}(x_2,Q^2)\sigma(g\bar{b} \to \bar{t}H^+) \end{array} \right\}$$

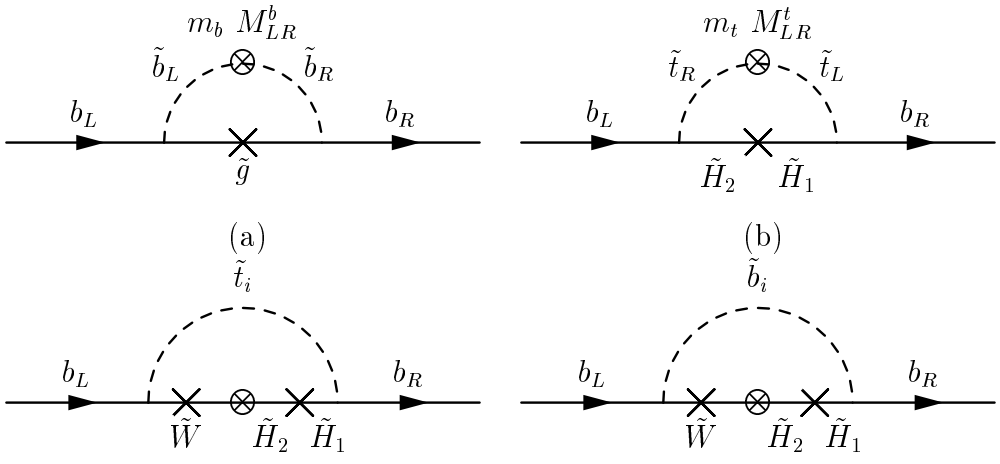
Leading SUSYcorrections

$$(\Delta m_b)_{\text{SUSY-QCD}} = -C_F \frac{\alpha_S(M_{\text{SUSY}})}{2\pi} m_{\tilde{g}} M^b_{LR} I(m_{\tilde{b}_1}, m_{\tilde{b}_2}, m_{\tilde{g}})$$
$$\to +\frac{2\alpha_S(M_{\text{SUSY}})}{3\pi} m_{\tilde{g}} \mu \tan\beta I(m_{\tilde{b}_1}, m_{\tilde{b}_2}, m_{\tilde{g}})$$

where $C_F = (N_c^2 - 1)/2N_c = 4/3$ is a color factor (with $N_c = 3$). Moreover we have $\alpha_S(M_{\text{SUSY}}) \simeq 0.09$, $M^b_{LR} = A_b - \mu \tan\beta$ and the last expression holds only for sufficiently large $\mu \tan\beta \gg A_b$. Here μ is the higgsino mass parameter in the superpotential and A_b is the bottom quark trilinear coupling in the soft-SUSY-breaking part of the superpotential. As for the electroweak effects on Δm_b they stem from similar loops involving mixed LH and RH-stops and mixed charged higgsinos $\tilde{H}_1 - \tilde{H}_2$ and read

$$(\Delta m_b)_{\text{SUSY-Yukawa}} = +\frac{h_t h_b}{16\pi^2} \frac{\mu}{m_b} m_t M^t_{LR} I(m_{\tilde{t}_1}, m_{\tilde{t}_2}, \mu)$$
$$\to +\frac{Y_t}{4\pi} A_t \mu \tan\beta I(m_{\tilde{t}_1}, m_{\tilde{t}_2}, \mu)$$

Here A_t is the top quark trilinear coupling; $Y_t \equiv h_t^2/4\pi \simeq 1/4\pi$ and $M^t_{LR} = A_t - \mu \cot\beta$.



(c)

Vertex SUSY corrections

• We have concentrated on the calculation of the one-loop effects on the $tbH^{\pm}$ vertex using CompHEP. Although it is designed for tree-level calculations, we have managed to add the SUSY corrections to the $tbH^{\pm}$ vertex and fermion propagators.

• Computed the full set of one-loop SUSY diagrams for the relevant $tbH^{\pm}$ vertex $\Rightarrow$ similar bunch of diagrams as in the on-shell case, but we have to account for the off-shell external lines, which is a non-trivial task.

• Procedure: i) Modified CompHEP's Feynman rules to allow for the most general $tbH^{\pm}$ vertex; ii) CompHEP reckons the squared matrix elements and dumps the result into REDUCE code; iii) at this point, inserted expressions for the coefficients of the off-shell $tbH^{\pm}$ vertex that include the one-loop off-shell SUSY corrections to the vertex itself and to the off-shell fermion propagators and fermionic external lines; iv) the subsequent numerical computation of the one-loop integrals has been done using LoopTools.

• The upshot is that the approximation of neglecting vertex and propagator corrections in the cross-section computation of our process and the use of the effective Lagrangian ("improved Born approximation") is justified in the relevant region of parameter space. The bulk of the one-loop corrected cross-section is just

$$\boxed{\sigma \to \sigma(1 - 2\Delta m_b)}$$

For $\mu < 0,\ A_t > 0 \Rightarrow \Delta m_b < 0$, preferred situation!

• Effects entering Δm_b at high $\tan\beta$ are of the type $\alpha_S \tan\beta$ or $Y_t \tan\beta$ whereas those from the most relevant 3-point EW vertices are of the type

$$\frac{1}{4\pi}\left(\frac{g\, m_b \tan\beta}{M_W}\right)^2 \sim \frac{h_t^2}{4\pi} = Y_t$$

and so they are down by an extra power of $\tan\beta \Rightarrow$ they are subleading effects on equal footing to the previously dismissed SUSY corrections to pure QCD vertices.

• In principle both the SUSY-EW and SUSY-QCD contributions to Δm_b can be sizeable; naively one could think that the first one (induced by higgsino-gaugino exchange) is suppressed with respect to the gluino-induced part by a factor of $\alpha_W/\alpha_S \sim 10^{-1}$, but this is not necessarily so. The I-functions are slowly varying, and (if similar) then the ratio is

$$\left(\frac{\text{QCD}}{\text{EW}}\right)_{SUSY} \sim \frac{8}{3}\left(\frac{\alpha_S}{Y_t}\right)\left(\frac{m_{\tilde{g}}}{A_t}\right) \gtrsim 3\left(\frac{m_{\tilde{g}}}{A_t}\right)$$

where $Y_t \sim 1/4\pi$ and $\alpha_S(m_t) \simeq 0.11 \Rightarrow$ for $A_t \gg 3\, m_{\tilde{g}}$ the EW effects could be dominant!!

• However, the vacuum stability bound suggests that this situation is not favorable and one usually has the SUSY-QCD as the dominant effects, although the SUSY-EW part is generally non-negligible.

• In the limit of large gluino masses (few TeV) the SUSY-QCD effects have a local maximum and decouple very slowly. In this region the SUSY-EW part becomes negligible.

PDF and μ_R-dependence

Checked the uncertainty of the signal due to the choice of PDF sets:

- For the signal and background calculation, we used: $m_t = 175\,\text{GeV}$, $m_b = 4.6\,\text{GeV}$ (pole), $\tan\beta = 50$, and the CTEQ4L set of PDFs
- We have compared the results in our Tables (using the previous set) with the ones obtained with the MRST (central gluon) PDFs. The latter usually give larger σ's than those from CTEQ4L.
- Significant deviations for some of the individual sub-channels (up to $\sim 50\%$), but they are compensated in the sum, leaving a $5-10\%$. The substraction procedure plays a key role in reducing the uncertainty. Reduction is especially effective at the LHC

Checked also the uncertainty of the signal due to the choice of renormalization and factorization scales (assumed both equal to μ_R): $\mu_R \uparrow \Rightarrow \sigma \downarrow$

- Analyzed the dependence inside the interval: $M_{H^\pm}/2 < \mu_R < 2M_{H^\pm}$
- Again, individual sub-channels show a stronger dependence than the total cross-section
- For the total cross-section $\delta\sigma \sim 28\%$ at the Tevatron II and $\delta\sigma \sim 18\%$ at the LHC
- Central value of the μ_R scale for the signal (background) processes chosen equal to $M_{H^\pm}$ ($2m_t$)
- $\delta\sigma$ is very weakly dependent on $M_{H^\pm}$

SUSY K-factor

- Useful to define an "effective K-factor" in the MSSM context:

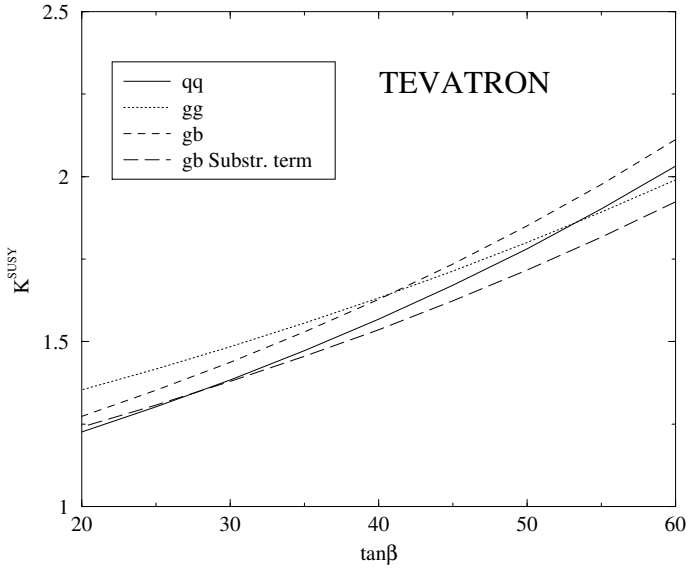
$$\boxed{K^{\text{MSSM}} = K^{\text{QCD}}\, K^{\text{SUSY}}}$$

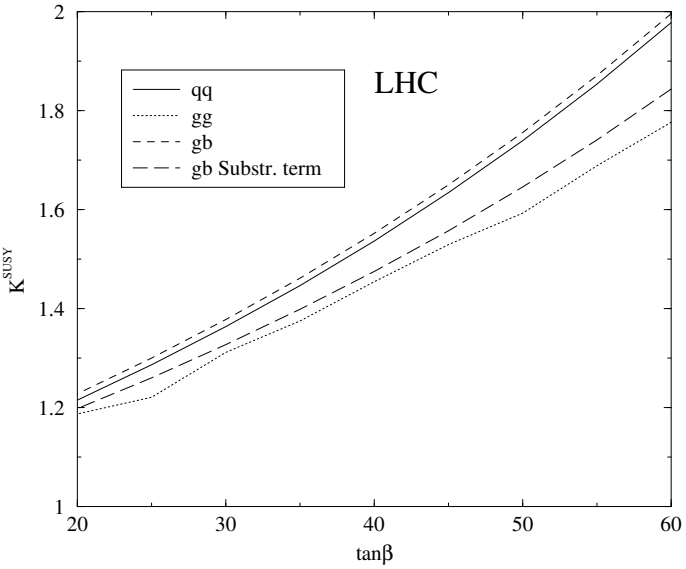
where K^{SUSY} stands for the genuine R-odd effects.

- We have

$$K^{\text{SUSY}} = \frac{\sigma^{\text{MSSM}}}{\sigma^{\text{QCD-corrected}}} = \frac{\sigma^{\text{SUSY-corrected}}}{\sigma^{\text{Tree-level}}}$$

- For instance, for $K^{\text{MSSM}} \gtrsim 2$ (e.g. through $K^{\text{QCD}} = 1.4$ and $K^{\text{SUSY}} = 1.5$) the opportunity to chase a MSSM Higgs boson already at the Tevatron would be open!!





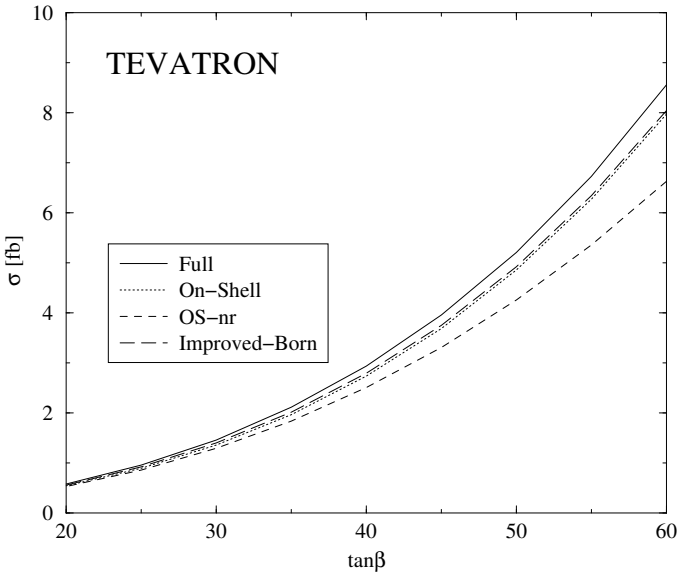
Cross-section in various approximations

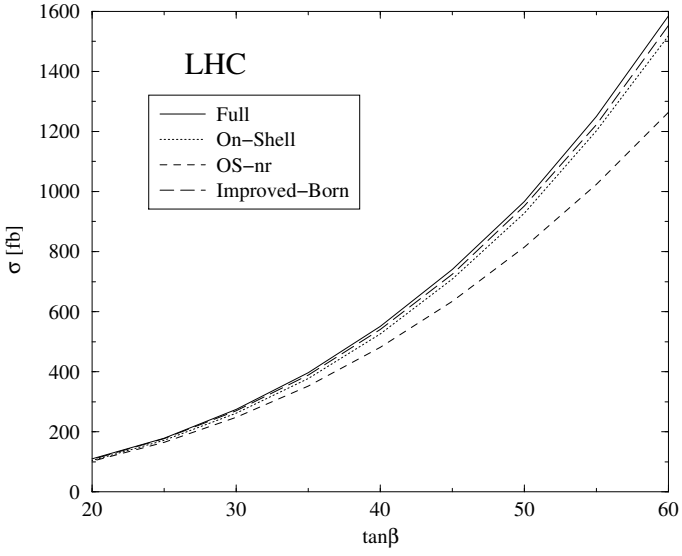
Let us compare the following set of corrections:

- the full set of SUSY corrections, including resummation and the off-shell two- and three-point functions (labeled Full);
- the corrections including resummation, but using on-shell values for the irreducible three-point functions (On-Shell);
- the one-loop (without resummation) corrections, using also on-shell values for the irreducible three-point functions (OS-nr);
- the tree-level result with the pole quark masses replaced by the effective Yukawa couplings (Improved-Born).

The following hierarchy of quantum effects is observed:

$$\sigma(\text{Full}) \gtrsim \sigma(\text{Improved} - \text{Born}) > \sigma(\text{On} - \text{shell}) > \sigma(\text{OS} - \text{nr})$$





CONSEQUENCES FOR $H^{\pm}$-SEARCH

$H^+ \to t\bar{b}$ versus $H^+ \to \tau^+\nu_\tau$ signature

- As $BR(H^+ \to t\bar{b}) \gg BR(H^+ \to \tau^+\nu_\tau)$, the quantum corrections to the branching ratio $BR(H^{\pm} \to t\bar{b})$ will be small in general. Decreasing $M_{H^{\pm}}$, the τ-mode increases fast.

- For charged Higgs masses in the heavy range ($M_{H^{\pm}} > 300\,\text{GeV}$), and $\mu > 0$, $A_t < 0$ (sets C,D), the branching ratio of the τ-mode can remain at the level of 15% (even for $M_{H^+} \gtrsim 500\,\text{GeV}$) $\Rightarrow$ thanks to SUSY effects, there are situations for $M_{H^+} \gtrsim m_t - m_b$ where the τ-mode could be successfully used to explore the light charged Higgs mass region.

- Nevertheless, the τ-mode can be highly suppressed by the SUSY effects themselves – if they turn out to greatly enhance $\Gamma(H^+ \to t\bar{b})$. Indeed, for $\mu < 0, A_t > 0$ (sets A,B) the τ-decay of the charged Higgs can be dwarfed to a 5% or less $\Rightarrow$ the SUSY suppression of the τ-mode turns out to occur in the regions of the MSSM parameter space where the H^+-production process is maximized.

Effect of $H^+ \to \tilde{b}_i\tilde{t}_j$

- At the opposite end of the spectrum, where $M_{H^{\pm}} \gtrsim 1\,TeV$, $BR(H^+ \to t\bar{b})$ significantly decreases if $M_{H^{\pm}} > m_{\tilde{b}_1} + m_{\tilde{t}_1}$, due to the opening of the squark decay channels $H^+ \to \tilde{b}_i\tilde{t}_j$

- Quickly becomes dominant at high $\tan\beta$

- Due to non-decoupling behavior, this mode does not disturb conclusions on the charged Higgs boson discovery/exclusion limits: our numerical results can be extended to $M_{H^{\pm}} > 1\,TeV$ since we can always find a heavier particle spectrum satisfying $M_{H^{\pm}} < m_{\tilde{b}_1} + m_{\tilde{t}_1}$ and producing the same radiative corrections.

CONCLUSIONS

- At high $\tan\beta$ the MSSM quantum effects are dominated by exceptionally important effects that can be absorbed into an effective $tbH^{\pm}$ vertex, and therefore in practice they can be treated as an "improved Born approximation"
- From a detailed signal versus background study we have shown that the prospects for the signal discovery are viable for the **Tevatron** if

  $$M_{H^{\pm}} \lesssim 250\, GeV$$

  and promising for the **LHC** if

  $$M_{H^{\pm}} \lesssim 1.5\, TeV$$

- In deriving these limits we have demonstrated that the quantum machinery from the MSSM can play a crucial role to increase the signal. In large portions of the parameter space the genuine SUSY corrections could show up as a *smoking gun* over the tree-level cross-section (after subtracting the conventional QCD effects) with a contribution of the order or larger than the QCD effects themselves.
- A close comparison with the corresponding neutral Higgs boson production processes should be, if available, very useful to confirm or dismiss the MSSM nature of the charged and neutral Higgs bosons.

$\Downarrow$

Tevatron and LHC could make it!