Multi Higgs models, Lisbon, 2009

CP violation in charged Higgs decays and production in MSSM

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SM = the main intellectual achievement of quantum theory of the last 50 years!

What's next?

How can LHC and the next e^+e^- collider answer this question?

$H^{\pm} \Rightarrow$ Physics beyond SM

- 2HDM, 3HDM, ...

- extra dimensions ...

- MSSM, NMSSM, ...

- ...

If $H^{\pm}$ will be found at the Tevatron or LHC

$\Rightarrow$ more work is needed to find which New Physics

$\Rightarrow$ couplings must be measured etc.

Common for almost all extensions of SM:

- enlarge the Higgs sector $\Rightarrow H^{\pm}$ – the hierarchi problem of SM

- additional sources of CP violation – Sakharov's theorem:

  for $B - \bar{B}$ asymm. both C- & CP- viol. needed

We consider: CP violation in $H^{\pm}$ in MSSM

The motivation: CPV in $H^{\pm}$ is a possibility to distinguish among different exts. beyond SM

Plan of the talk

- **CPV in $H^{\pm}$-decays**
- **CPV in $H^{\pm}$-production at LHC**
- **CPV in $H^{\pm}$-prod. and decay at LHC**

MSSM: 5 Higgs bosons $h^0, H^0, A^0, H^{\pm}$

- 2 parms. only: $\tan\beta$, $m_A \Leftrightarrow$ 50 (if FV 124) in MSSM

- TH *and* Exp. bounds on $H^{\pm}$:

  1) TH: $m^2_{H^+} = m^2_W + m^2_{A^0} \geq m^2_{W^+}$

  2) Exp: LEP: $m_{H^+} \geq 78.6$ GeV, Tevatron: $m_{H^+} \geq 200$ GeV

- CP inv. at tree level

- CPV in Higgs sector $\rightarrow$ loop effects

- The particles in the loops: $\tilde{g}$, $\tilde{\chi}^{\pm}$, $\tilde{t}$, $\tilde{b}$ and $\tilde{\chi}^0$

Recall:

gluino $\tilde{g} \leftrightarrow g$,

charginos $\tilde{\chi}^{\pm} \leftrightarrow (\tilde{W}^{\pm}, \tilde{H}^{\pm})$,

neutralinos $\tilde{\chi}^0 \leftrightarrow (\tilde{\gamma}, \tilde{Z}, \tilde{H}_1^0, \tilde{H}_2^0)$

scalar quarks $\tilde{q} \leftrightarrow q$

scalar leptons $\tilde{l} \leftrightarrow l$

- The CP phases:

1) the Higgs mass parameter $\mu = |\mu| e^{i\phi_\mu}$,

- exp: $d_e, d_n \Rightarrow \phi_\mu < 10^{-2}$, $\tilde{m}_{SUSY} \sim$ few 100 GeV

2) the gaugino masses: M_1, M_2, M_3

GUT: $M_1 = (5/3) \tan^2\theta_W \, M_2 \Rightarrow \phi_i = 0$

3) the trilinear coupls. of sfermions and Higgs: $m_f \, A_f$

$A_t = |A_t| e^{i\phi_t}$, $A_b = |A_b| e^{i\phi_b}$, $A_\tau = |A_\tau| e^{i\phi_\tau}$,

CPV in $H^{\pm}$ decays

$H^{\pm}$-decays into ordinary particles:

$$H^{\pm} \to tb$$

$$H^{\pm} \to \tau^{\pm}\nu$$

$$H^{\pm} \to W^{\pm}h^{0}$$

- our observables: the partial decay rate asymmetries:

$$\delta_f^{CP} = \frac{\Gamma(H^+ \to f) - \Gamma(H^- \to \bar{f})}{\Gamma(H^+ \to f) + \Gamma(H^- \to \bar{f})}$$

$$\delta_{tb}, \qquad \delta_{\nu\tau}, \qquad \delta_{Wh^0}$$

δ^{CP} is induced by loop corrections in $H^{\pm} \rightarrow$ ...

in general:

$$\delta^{CP} \simeq \underbrace{\left(ig^{CP}\right)}_{CPV\ coupling} \times \quad i \quad \underbrace{\Im m\,(\,loops)}_{SUSY\ channel\ open}$$

for $\delta^{CP} \neq 0$ we need:

- loop corrs.

- CPV couplings ig^{CP}

- $\Im m$ loop $\Rightarrow$ at least one SUSY channel open for $H^{\pm}$-decay

$$\delta^{CP} = \text{theashold effect}: \; m_{H^+} \geq \tilde{m}_1 + \tilde{m}_2 \geq 200\,GeV$$

$H^\pm \to tb$

$$\mathcal{M}_{H^\pm} = \frac{i\,g}{\sqrt{2}\,m_W}\,\bar{u}(p_t)\left[\mathbf{Y}_t^\pm\,P_L + \mathbf{Y}_b^\pm\,P_R\right]u(-p_{\bar{b}})$$

$$\mathbf{Y}_i^\pm \;=\; y_i + \delta Y_i^{inv} \pm \delta Y_i^{CP}$$

$$\delta Y_i^{CP} = \Re e\,\delta Y_i^{CP} + i\,\Im m\,\delta Y_i^{CP}$$

$$y_t \;=\; m_t \cot\beta, \qquad y_b = m_b \tan\beta$$

- 2 CPV form factors: $\Re e\,\delta Y_t^{CP}$ & $\Re e\,\delta Y_b^{CP}$

- **2 measurable quantities:**

  1) the partial decay rates $\Gamma^{\pm}$ of $H^{\pm} \to tb$:

$$\Gamma^{\pm} = \Gamma^{inv} \pm \Gamma^{CP}, \qquad \delta^{CP} = \frac{\Gamma^{CP}}{\Gamma^{inv}} \simeq \frac{\Gamma^{CP}}{\Gamma_0}$$

$$\begin{aligned} \Gamma^{CP} \;&=\; [y_t \,\Re e\, \delta Y_t^{CP} + y_b \,\Re e\, \delta Y_t^{CP}](p_t p_b) - \\ &\quad -m_t m_b [y_b \,\Re e\, \delta Y_t^{CP} + y_t \,\Re e\, \delta Y_t^{CP}] \end{aligned}$$

  2) the t polarization: $\mathcal{P}^{\pm} = \pm \mathcal{P}^{inv} + \mathcal{P}^{CP}$

$$\mathcal{P}^{CP} = \frac{y_t \,\Re e\, \delta Y_t^{CP} - y_b \,\Re e\, \delta Y_t^{CP}}{(y_t^2 + y_b^2)(p_t p_b) - 2 m_t m_b y_t y_b}$$

$$t \to bW$$

$H^+ \to \nu\tau$

much simpler: $m_\nu = 0 \Rightarrow$ one form factor only δY_τ^{CP}:

$$Y_\tau^\pm = y_\tau + \delta Y_\tau^{inv} \pm \delta Y_\tau^{CP}$$

$$\delta_{\nu\tau}^{CP} = \frac{\Re e\, \delta Y_\tau^{CP}}{y_\tau}$$

$\underline{\underline{H^\pm \to W^\pm h^0}}$

The difference: h^0 = not observed (yet!)

TH: $m_{h^0} = m_{h^0}(m_{H^+}, \tan\beta)$, $g_{WH^+h^0} = g_{WH^+h^0}(m_{H^+}, \tan\beta)$

$\Rightarrow m_{h^0}$ not a new parameter: TH + exp: $96 \leq m_{h^0} \leq 130$ GeV

$$\mathcal{M}_{H^\pm} = ig\,\varepsilon^\lambda_\alpha(p_W)\,p_h^\alpha\,Y^\pm, \quad Y^\pm = y + \delta Y^{inv} \pm \delta Y^{CP}, \qquad y = \cos(\alpha - \beta)$$

$$\delta^{CP}_{Wh} = \frac{\Re e\,\delta Y^{CP}}{y}$$

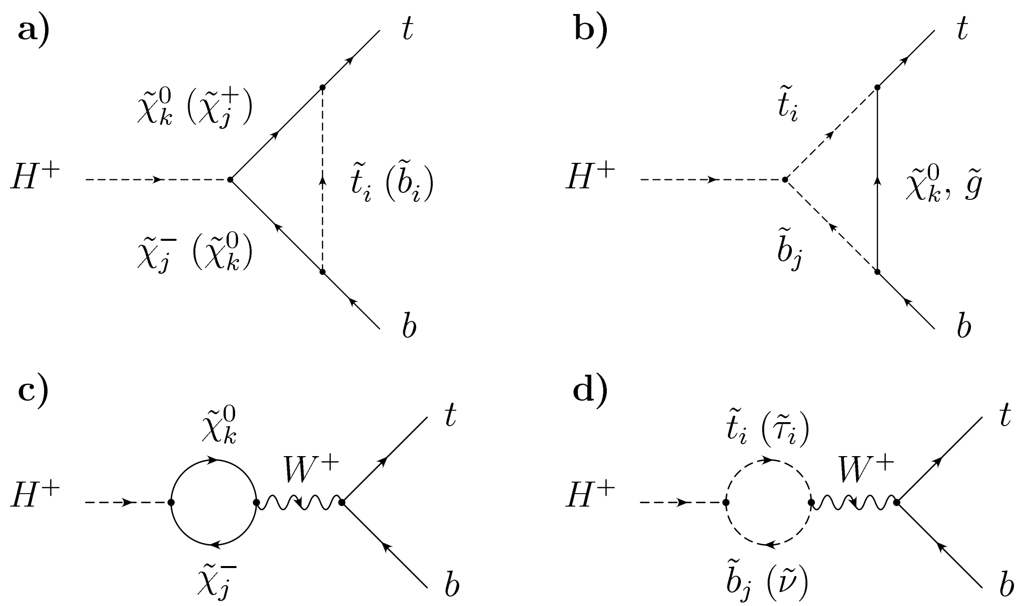
$BR(H^\pm \to W^\pm h^0) \sim$ 10% for low m_{H^+} & low $\tan\beta \simeq 3 - 6$,

very quickly drops with $\tan\beta$

The loops in $H^{\pm} \to tb$

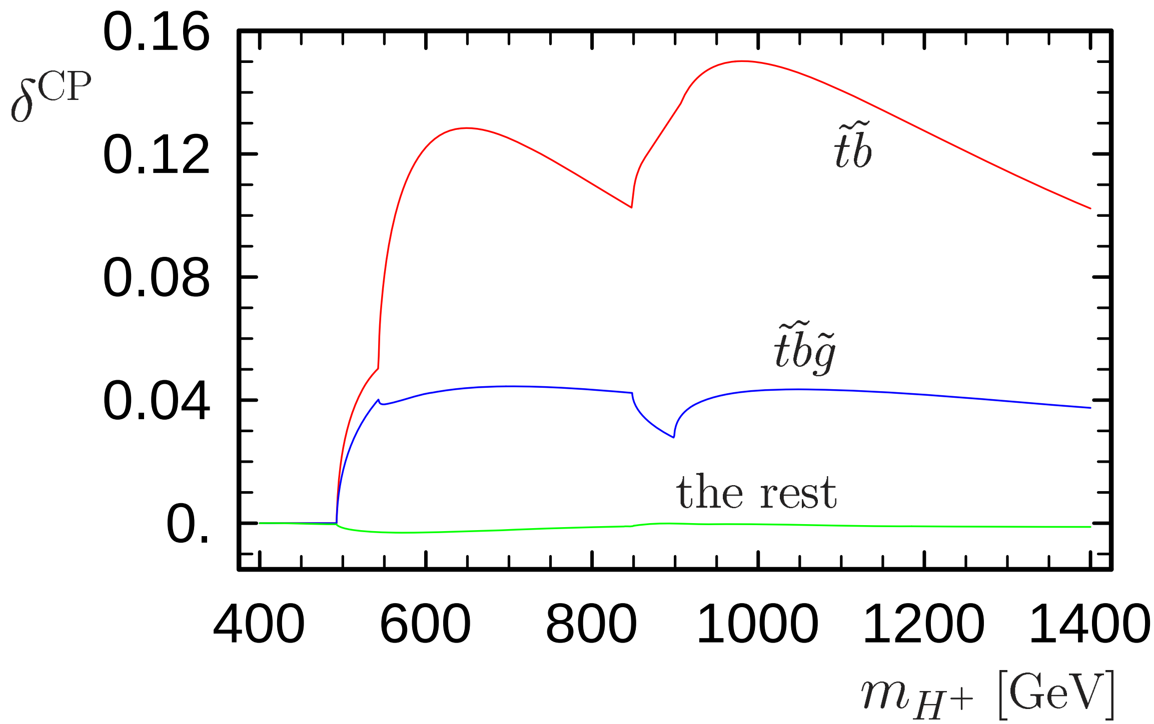
two types of loops: **vertex & self energy corrs.**

1



$(\tilde{t}\tilde{b})$ **enhanced by col. factor 3 and** $h_t \approx m_t$, $(\tilde{t}\tilde{b}\tilde{g})$ **– by** α_s

The contributions in $H^{\pm} \to tb$

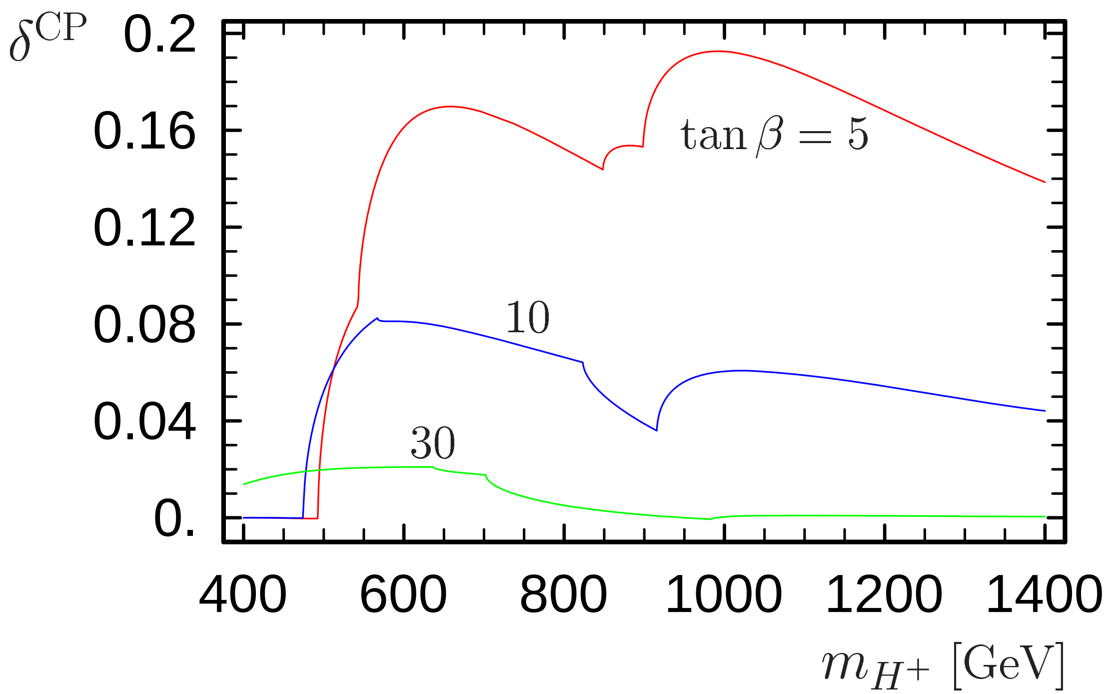


the spikes = the threasholds $H^{\pm} \to \tilde{t}_i\tilde{b}_j$: $m_{H^{\pm}} > m_{\tilde{t}} + m_{\tilde{b}}$

$\tan\beta = 5:$ $m_{\tilde{t}_1} = 166,\ m_{\tilde{t}_2} = 522,\ m_{\tilde{b}_1} = 327,\ m_{\tilde{b}_2} = 377$ **[GeV]**

$\tan\beta = 30:$ $m_{\tilde{t}_1} = 172,\ m_{\tilde{t}_2} = 519,\ m_{\tilde{b}_1} = 183,\ m_{\tilde{b}_2} = 464$ **[GeV]**

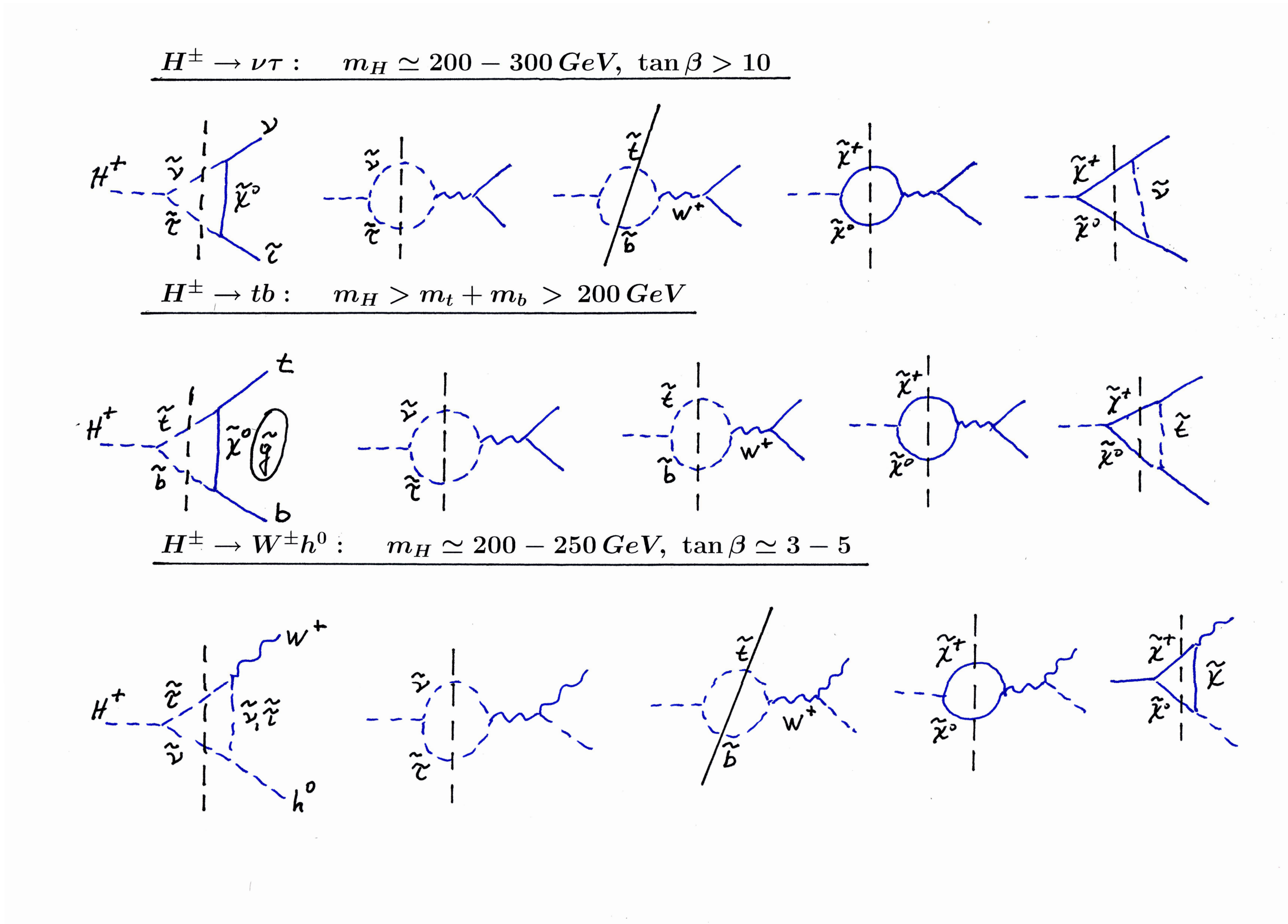
The asymmetry in $H^{\pm} \to tb$



sensitive to ϕ_{A_t} ($\phi_{A_t} = \pi/2$) and no sensitivity to ϕ_{A_b}

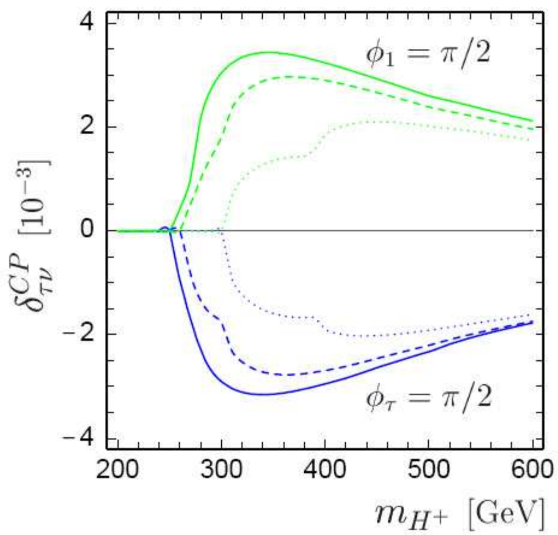
$\delta_{tb} \simeq 15 - 20$ **% if** $m_{H^\pm} > m_{\tilde{t}} + m_{\tilde{b}}$

two types of loop corrs in MSSM: vertex & self energy



The asymmetry $\delta^{CP}_{\nu\tau} \leq 3.5\,10^{-3}$

- BR $(H^+ \to \nu\tau)$ important for low m_{H^+} and high $\tan\beta \Rightarrow$ sensitive to ϕ_{A_τ}

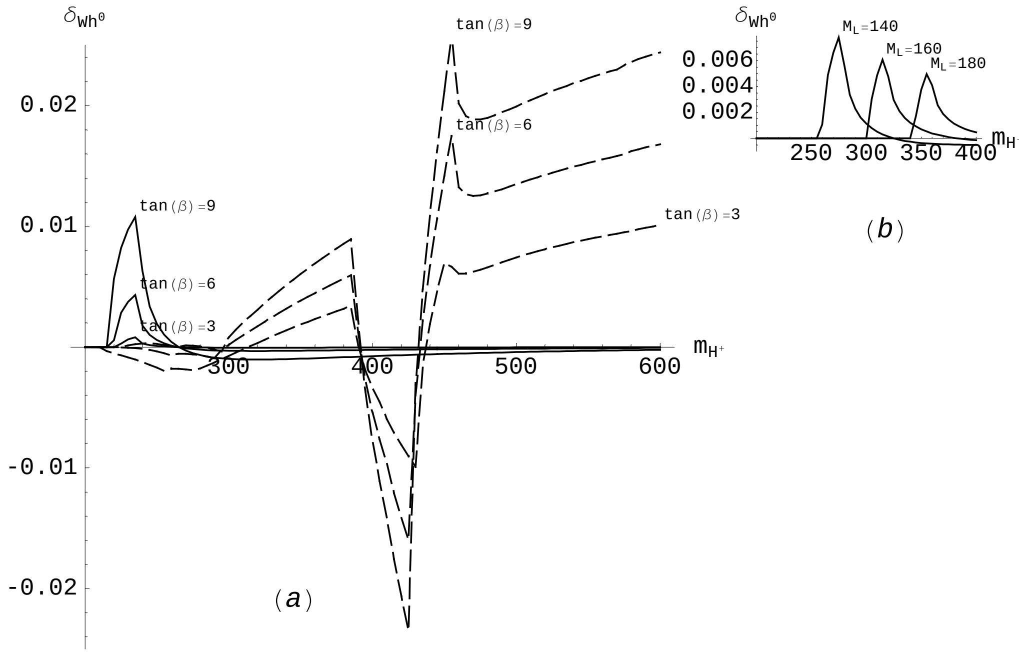


$\tan\beta = 5$(full), 10(dashed),30(dotted)

GUT: $|M_1| = (5/3)\tan^2\theta_W\,|M_2| \;\Rightarrow\; \phi_1 \neq 0$

$\delta^{CP}_{\nu\tau}(\phi_\tau = \pi/2, \phi_1 = 0) \simeq -\delta^{CP}_{\nu\tau}(\phi_1 = \pi/2, \phi_\tau = 0)$, $\delta^{CP}_{\nu\tau}(\phi_\tau = \phi_1 = \pi/2) \simeq 0$

The asymmetry $\delta^{CP}_{Wh^0}$



solid lines: $\phi_\tau = -\pi/2,\ \phi_1 = 0$; **dashed lines:** $\phi_\tau = 0,\ \phi_1 = -\pi/2$.

$m_{h^0} = 125$, $tan\beta = 6$, $m_{\tilde{\nu}} = 102$, $m_{\tilde{\tau}_1} = 118$, $m_{\tilde{\tau}_2} = 133$ **[GeV]**

Summary for CPV in $H^{\pm}$ decays

- δ_{tb}^{CP} is the biggest $\simeq 25\%$
- the main contrb. is from $\tilde{t}$ and $\tilde{b}$ in the loops
- sensitive to the phase of A_t
- $\delta_{\nu\tau}^{CP}$ is small $\simeq 10^{-3}$
- sensitive to the phase of A_τ

CPV in $H^{\pm}$ production at LHC

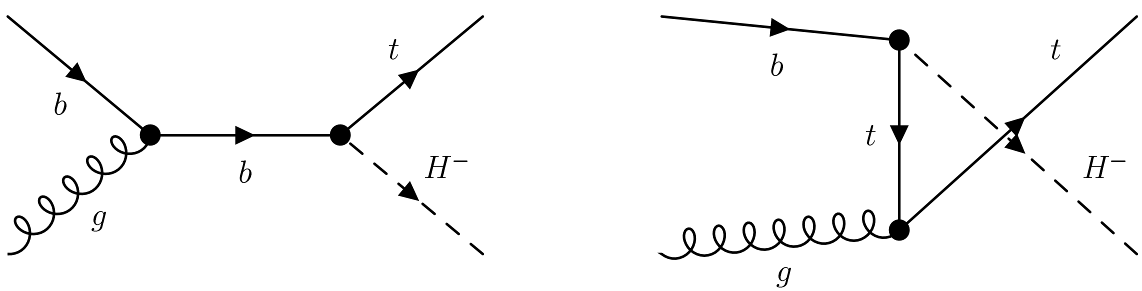
- **the main prod. process at LHC:**

$$p + p \longrightarrow H^{\pm} + t + X$$

- **at parton level:**

$$b + g \longrightarrow t + H^{\pm}$$

- **two diagrams: $\mathcal{M}^s$ and $\mathcal{M}^t$ amplitudes**



our motivation for studying:

the same $H^{\pm}tb$-vertex as in $H^{\pm} \to tb$ decay

$\sim$ the same particles in the loops

$\sim$ large CPV expected

three differences:

I. the particles in the $H^{\pm}tb$-vertex:

- in decay: all particles are on mass shell

- in prod:

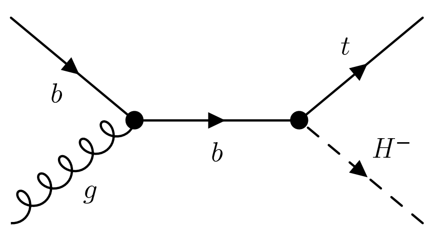
  1) $\mathcal{M}^s \Rightarrow b$-quark in off-shell

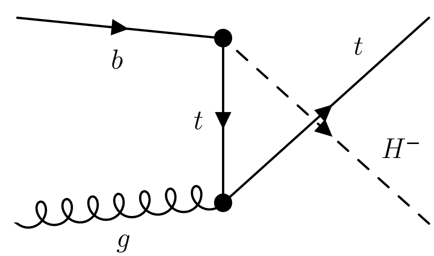
  2) $\mathcal{M}^t \Rightarrow t$-quark in off-shell

  $\Rightarrow$ additional structure in $\mathcal{M}$:

$$\mathcal{M}^s = \frac{g_s}{\hat{s}}\bar{u}(p_t)\{[(y_t + \delta\tilde{Y}_t^s)P_L + (y_b + \delta\tilde{Y}_b^s)P_R](\not{p}_b + \not{p}_g) + $$
$$+\hat{s}[f_{RR}^{s,2}P_L + (f_{LL}^{s,2} - \tilde{f}_{LL})P_R]\}T^\alpha\gamma^\mu u(p_b)\epsilon_\mu^\alpha(p_g)\,,$$

$$\mathcal{M}^t = \frac{g_s}{\hat{t}-m_t^2}\bar{u}(p_t)\epsilon_\mu^\alpha(p_g)\gamma^\mu T^\alpha\{(\not{p}_t - \not{p}_g + m_t)[(y_t + \delta\tilde{Y}_t^t)P_L + (y_b + \delta\tilde{Y}_b^t$$
$$+(\hat{t} - m_t^2)[(f_{LL}^{t,1} + \tilde{f}_{LL})P_L + f_{RR}^{t,1}P_R]\}u(p_b)$$





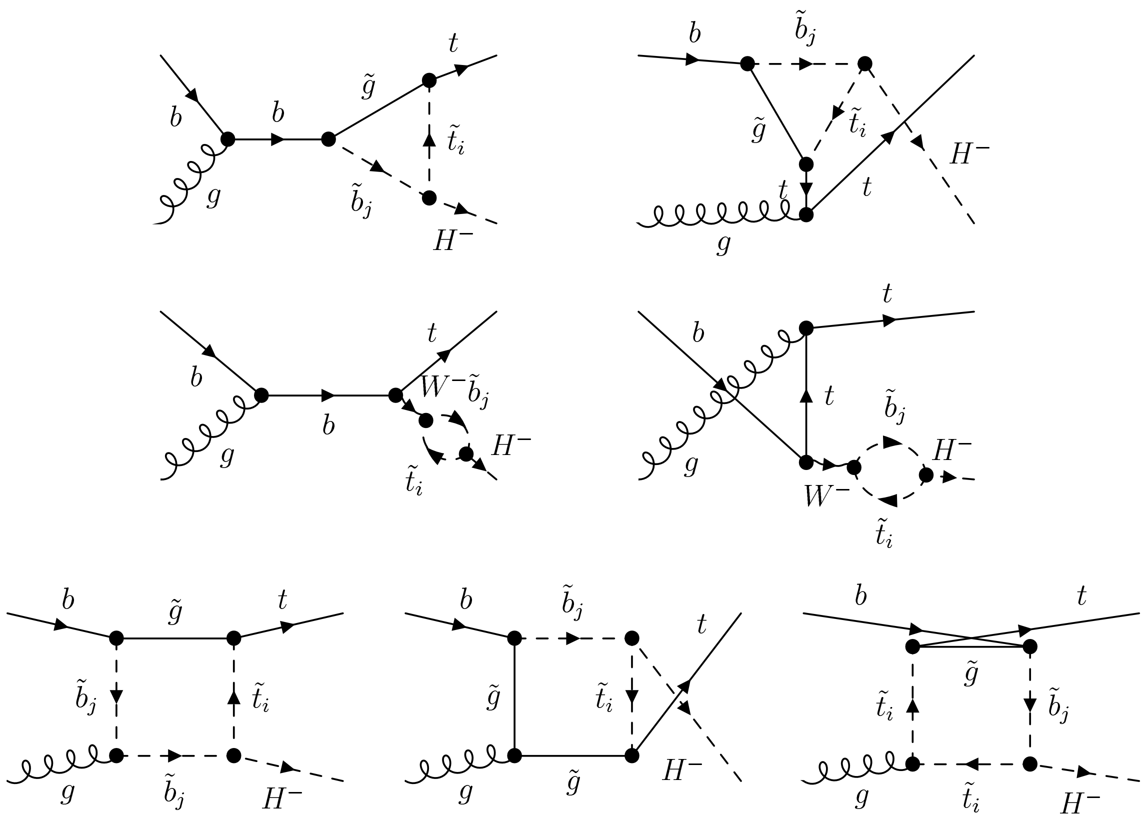
II. **the types of loop diagrams:**

- **in decay: 2 types of loop corrs. – vertex & self-energy**

- **in prod: 3 types of loop corrs. – vertex, self-energy & box diagrams**

box diagrams lead to additional CPV

The loop diagrams in $bg \to tH^{\pm}$



III. technically:

- in decay: no gluons

- in prod: gluons are involved in loop corrs.$\Rightarrow$ careful about gauge inv:

$$\sum_{\lambda=1}^{2} \epsilon_{\mu}^{\alpha *}(k,\lambda)\epsilon_{\nu}^{\beta}(k,\lambda) = \delta^{\alpha\beta}(-g_{\mu\nu} - \frac{\eta^2 k_\mu k_\nu}{(\eta.k)^2} + \frac{\eta_\mu k_\nu + \eta_\nu k_\mu}{\eta.k})$$

axial gauge: η fixes the gauge, $\eta.\epsilon = 0$ and $\eta.k \neq 0$

σ is measurable quantity and thus indep. of η!

The cross section at parton level

$$d\hat{\sigma}^{\pm} = \frac{1}{16\pi\hat{s}^2}\frac{1}{96}|\mathcal{M}^{\pm}|^2 \ dt$$

$$\mathcal{M}^{\pm} = \mathcal{M}^{tree,\pm} + \mathcal{M}^{loop,\pm}, \qquad \mathcal{M}^{loop,\pm} = \underbrace{\mathcal{M}_1^{s,\pm} + \mathcal{M}_1^{t,\pm}}_{tree\ level\ str.} + \underbrace{\mathcal{M}_2^{s,\pm} + \mathcal{M}_2^{t,\pm}}_{add.\ str.}$$

$$|\mathcal{M}^{\pm}|^2 = |\mathcal{M}^{tree,\pm}|^2 + 2\mathrm{Re}\{(\mathcal{M}^{tree,\pm})^*\mathcal{M}^{loop,\pm}\}$$

- the cross section:

$$\hat{\sigma}^{\pm} = \hat{\sigma}^{inv} \pm \hat{\sigma}^{CP}$$

The terms with η should ultimately cancel in the sum!

$$\mathcal{M}_0^{s*,-}\mathcal{M}_1^{s,-} = -32\pi\alpha_s(\delta\tilde{Y}_t^s y_t + \delta\tilde{Y}_b^s y_b)[\mathcal{X}_1(\hat{s},\hat{t}) - 2\mathcal{U}(\hat{s},\hat{t})c_\eta]$$

$$\mathcal{M}_0^{t*,-}\mathcal{M}_1^{s,-} = -32\pi\alpha_s(\delta\tilde{Y}_t^s y_t + \delta\tilde{Y}_b^s y_b)[\mathcal{X}_{12}(\hat{s},\hat{t}) + 2\mathcal{U}(\hat{s},\hat{t})c_\eta + \mathcal{U}(\hat{s},\hat{t})\mathcal{V}(\hat{s},\hat{t})]$$

$$\mathcal{M}_0^{s*,-}\mathcal{M}_1^{t,-} = -32\pi\alpha_s(\delta\tilde{Y}_t^t y_t + \delta\tilde{Y}_b^t y_b)[\mathcal{X}_{12}(\hat{s},\hat{t}) + 2\mathcal{U}(\hat{s},\hat{t})c_\eta + \mathcal{U}(\hat{s},\hat{t})\mathcal{V}(\hat{s},\hat{t})]$$

$$\mathcal{M}_0^{t*,-}\mathcal{M}_1^{t,-} = -32\pi\alpha_s(\delta\tilde{Y}_t^t y_t + \delta\tilde{Y}_b^t y_b)[\mathcal{X}_2(\hat{s},\hat{t}) - 2\mathcal{U}(\hat{s},\hat{t})c_\eta - 2\mathcal{U}(\hat{s},\hat{t})\mathcal{V}(\hat{s},\hat{t})]$$

$$\mathcal{M}_0^{s*,-}\mathcal{M}_2^{s,-} = 32\pi\alpha_s m_t[(f_{LL}^{s,2} - \tilde{f}_{LL})y_t + f_{RR}^{s,2}y_b][1 + 2c_\eta]$$

$$\mathcal{M}_0^{t*,-}\mathcal{M}_2^{s,-} = 32\pi\alpha_s m_t[(f_{LL}^{s,2} - \tilde{f}_{LL})y_t + f_{RR}^{s,2}y_b][\mathcal{Y}(\hat{s},\hat{t}) - 2c_\eta - \mathcal{V}(\hat{s},\hat{t})]$$

$$\mathcal{M}_0^{s*,-}\mathcal{M}_2^{t,-} = 32\pi\alpha_s m_t[(f_{LL}^{t,1} + \tilde{f}_{LL})y_t + f_{RR}^{t,1}y_b][1 + 2c_\eta]$$

$$\mathcal{M}_0^{t*,-}\mathcal{M}_2^{t,-} = 32\pi\alpha_s m_t[(f_{LL}^{t,1} + \tilde{f}_{LL})y_t + f_{RR}^{t,1}y_b][\mathcal{Y}(\hat{s},\hat{t}) - 2c_\eta - \mathcal{V}(\hat{s},\hat{t})]$$

two choices of η: 1) $\eta = p_b,\ c_\eta = 0$; 2) $\eta = p_b + p_g,\ c_\eta = 1$

Our production asymmetry

$$p + p \rightarrow t + H^{\pm} + X.$$

- the asymmetry:

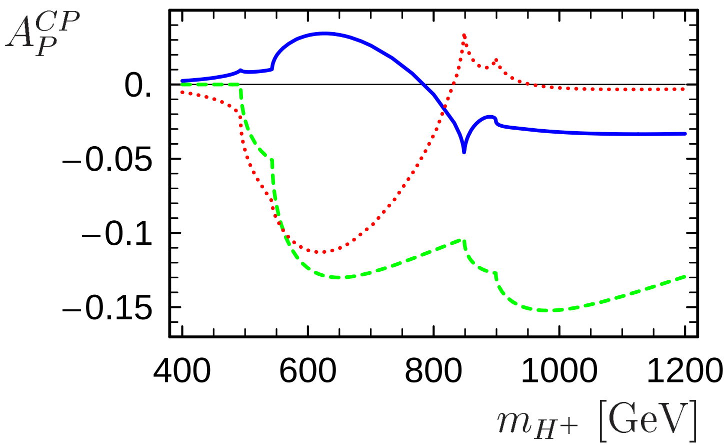
$$A_P^{CP} = \frac{\sigma(pp \rightarrow \bar{t}H^{+}) - \sigma(pp \rightarrow tH^{-})}{\sigma(pp \rightarrow \bar{t}H^{+}) + \sigma(pp \rightarrow tH^{-})}$$

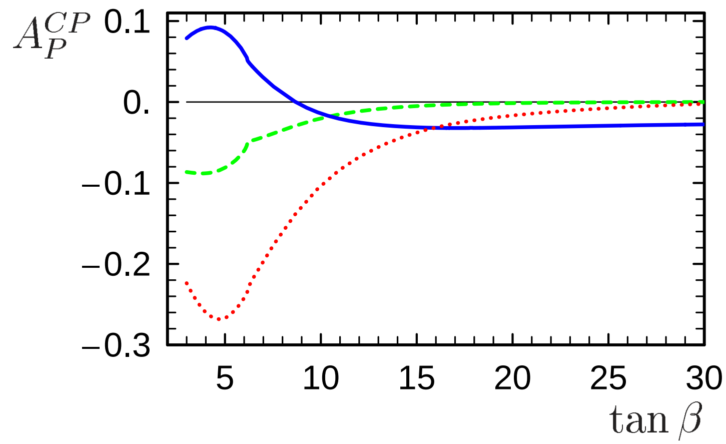
$$A_P^{CP} = \frac{\int f_b(x_b) f_g(x_g)(\hat{\sigma}^{+} - \hat{\sigma}^{-})\theta(x_b x_g S - S_0)\, dx_b\, dx_g}{\int f_b(x_b) f_g(x_g)(\hat{\sigma}^{+} + \hat{\sigma}^{-})\theta(x_b x_g S - S_0)\, dx_b\, dx_g}$$

$$\sqrt{S} = 14\, TeV,\ S_0 = (m_t + m_{H^+})^2$$

$$\hat{s} = (p_b + p_g)^2 \simeq x_b x_g S \leq S_0$$

The prod. asymmetry A_P^{CP}





$m_{\tilde{g}}$=727 GeV: **red = box, blue = vertex, green = self-energy**

$\tan\beta = 5$: $m_{\tilde{t}_1} = 166$, $m_{\tilde{t}_2} = 519$, $m_{\tilde{b}_1} = 183$, $m_{\tilde{b}_2} = 464$ [GeV]

$\tan\beta = 30$: $m_{\tilde{t}_1} = 172$, $m_{\tilde{t}_2} = 522$, $m_{\tilde{b}_1} = 327$, $m_{\tilde{b}_2} = 377$ [GeV]

Summary for CPV in production

- we have examined the vertex, self-energy and box diagrams to A_P^{CP} – $\tilde{t}$, $\tilde{b}$ and $\tilde{g}$ the main contrs

- A_P^{CP} is large $\simeq 25\%$

- the main contr. is from self energy and box diagrams

- drops with $\tan\beta$

CPV in production and decay at LHC

- the process:

$$p + p \to t + H^{\pm} + X, \qquad H^{\pm} \to f, \quad f = tb,\ \nu\tau^{\pm},\ W^{\pm}h^{0}$$

- the subprocess:

$$b + g \to t + H^{\pm}, \qquad H^{\pm} \to f$$

- the asymmetry:

$$A_f^{CP} = \frac{\sigma(pp \to \bar{t}H^{+} \to \bar{t}f) - \sigma(pp \to tH^{-} \to t\bar{f})}{\sigma(pp \to \bar{t}H^{+} \to \bar{t}f) + \sigma(pp \to tH^{-} \to t\bar{f})}$$

- we assume CPV in both prod. and decay:

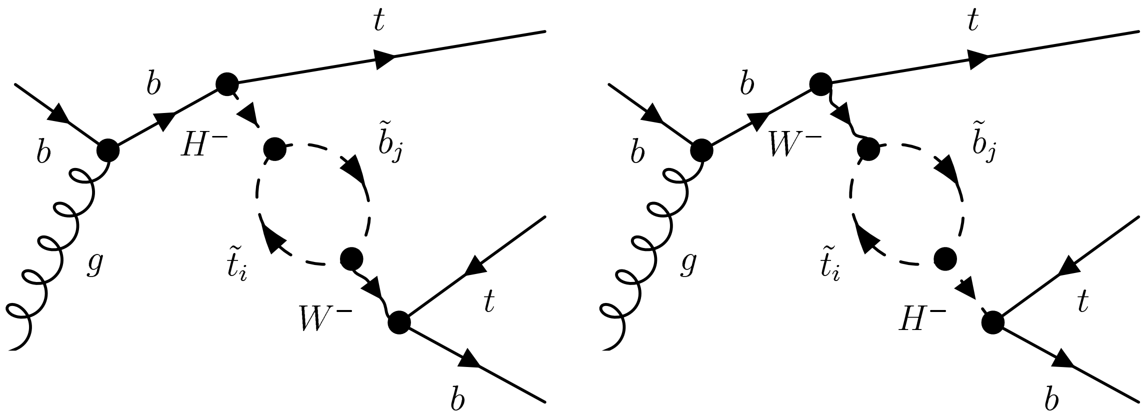
$$A_f^{CP} = A_P^{CP} + A_{D,f}^{CP}$$

$A_f^{CP} \simeq$ **algebraic sum of prod. + decay asymms.**

$\Rightarrow A_f^{CP}$ **expected to be large**

A_{tb}^{CP}: $pp \to tH^{\pm}, H^{\pm} \to tb$

The self-energy $\tilde{t}\tilde{b}$ from prod. & decay are complex conjugate:



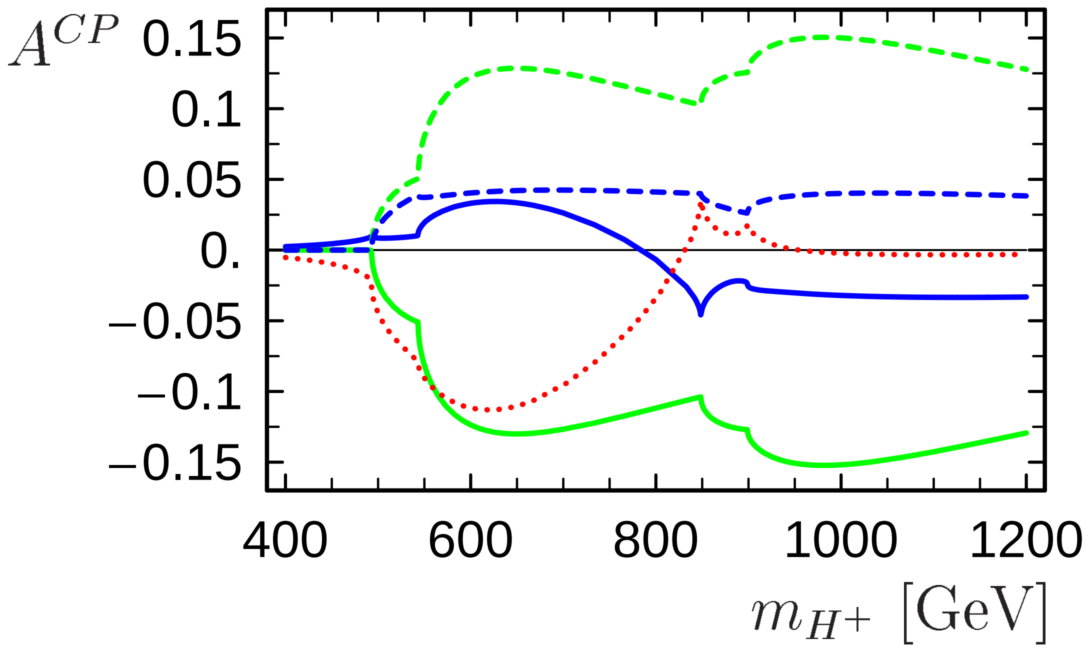
$\Im m$ self-energy in s & t-channels for all SE = completely cancel!

$\Im m$ vertex diagrams $\simeq g^{CP}[PV(\hat{s}, m_t^2, m_{H^+}^2) - PV(m_b^2, m_t^2, m_{H^+}^2)]$

$\simeq g^{CP}[PV(m_b^2, \hat{t}, m_{H^+}^2) - PV(m_b^2, m_t^2, m_{H^+}^2)]$

box diagrams − only in production

The contributions to total A_{tb}^{CP}

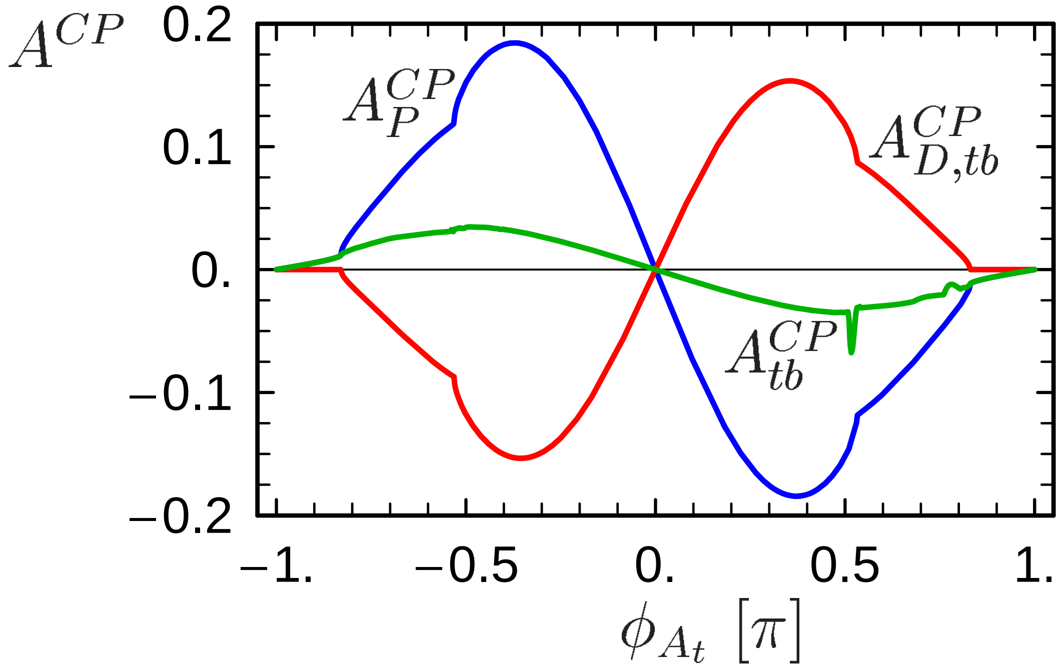


d line = box, blue lines = vertex, green lines = self-energy diagrams

dashed lines = prod, full lines = decay, $m_{\tilde{g}}$=727 GeV

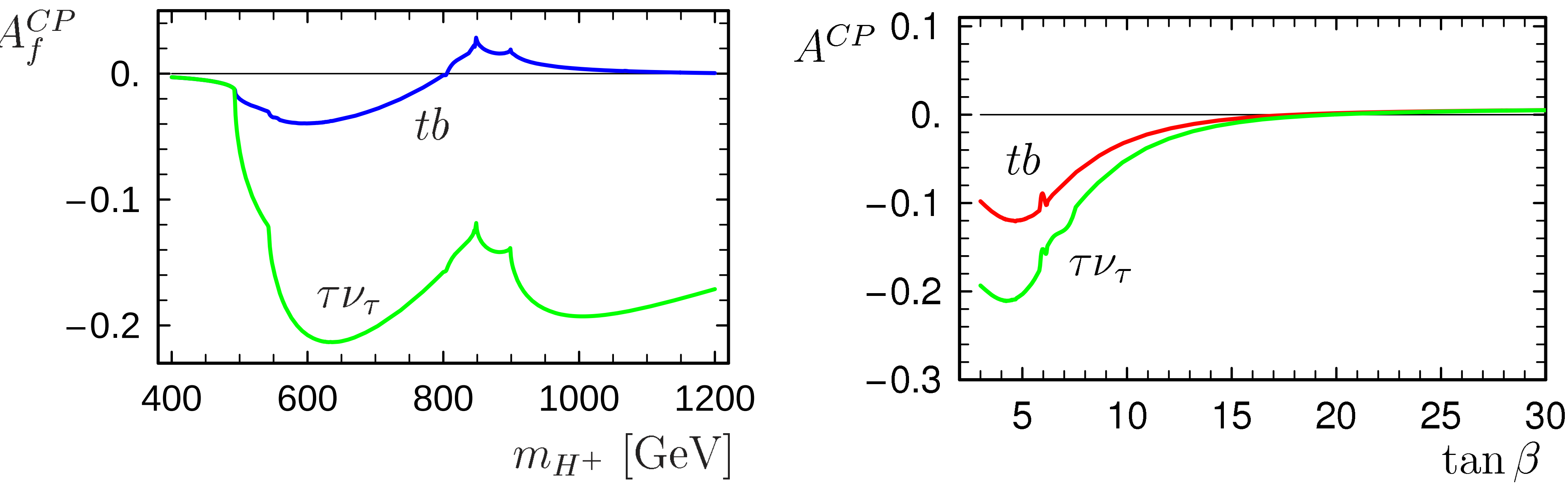
- complete cancel. of SE + partial cancel. of vertex & box!

The discussed asymmetries for $H^{\pm} \to tb$



: $A_P^{CP} \sim 20\%$, decay: $A_{D,tb}^{CP} \sim 16\%$ and total: $A_{tb}^{CP} \leq 4\%$ asymmetries

The total asymmetries A^{CP}_{tb} and $A^{CP}_{\nu\tau}$

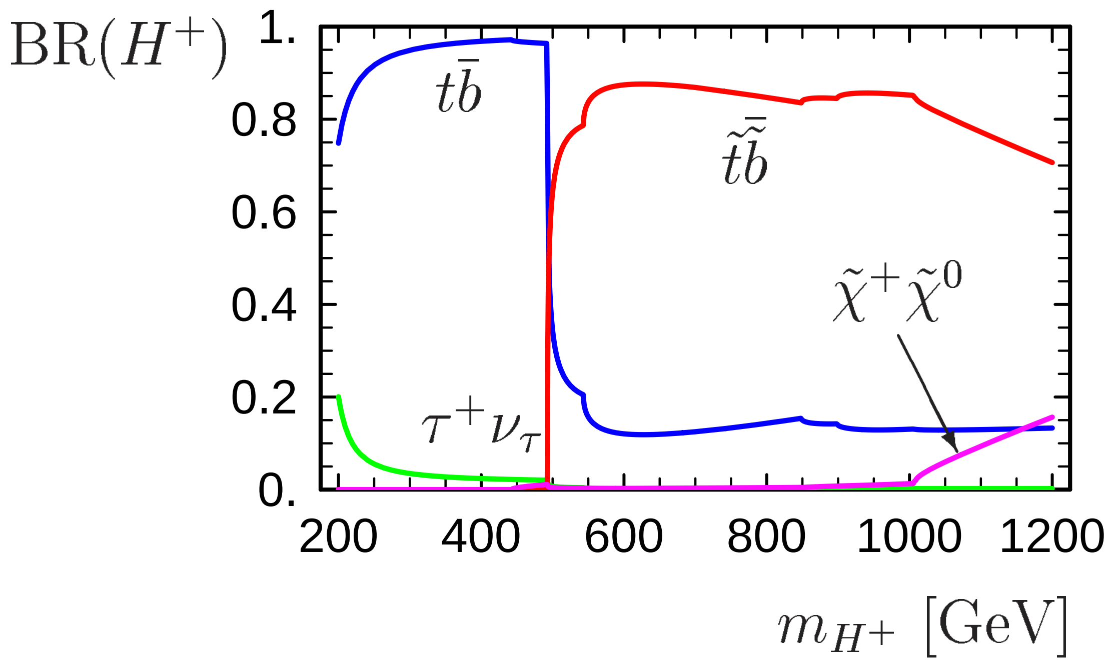


due to cancelations A^{CP}_{tb} is small: $A^{CP}_{tb} < 4\%$

no cancelations in $A^{CP}_{\nu\tau} \simeq 20\%$

But what are the BR?

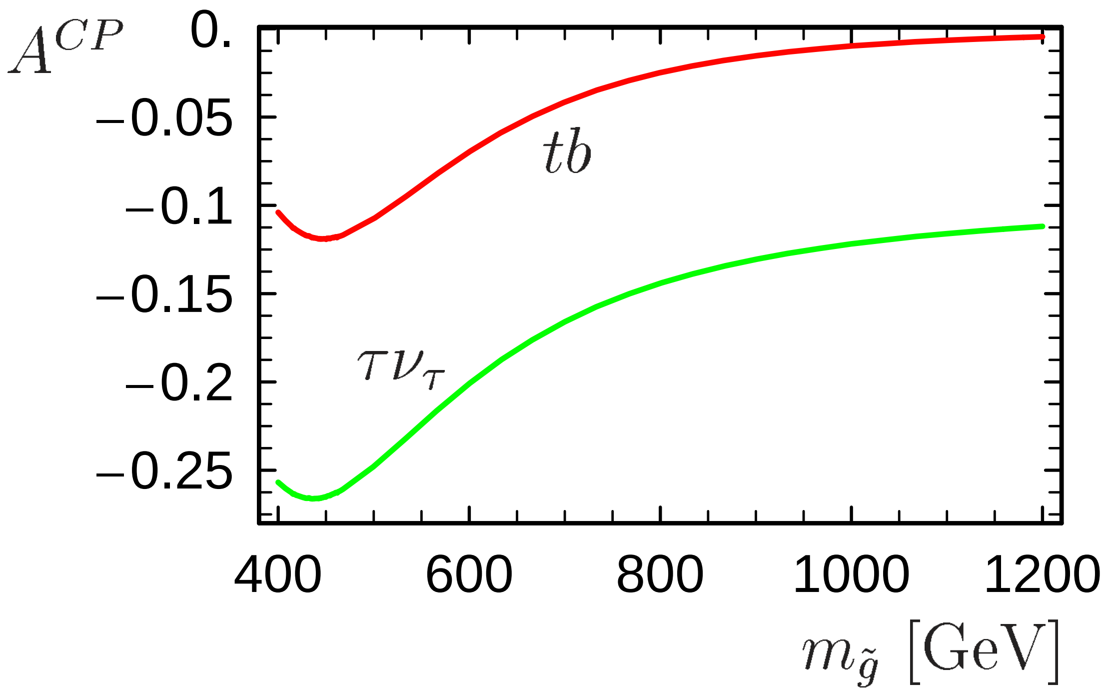
The tree level BR of $H^{\pm}$



The $BR(tb)$ remains 15-20% even when $H^{\pm} \rightarrow \tilde{t}\tilde{b}$ is kinem. allowed

$BR(Wh0)$ & $BR(\nu\tau)$ are very small for bigger m_{H^2}

The total asymmetries as a function of $m_{\tilde{g}}$:



$m_{H^+} = 550$ **GeV**

Conclusions

- The decay rate CPV asym. for $H^{\pm} \to tb$ is big: $\delta_{tb}^{CP} \simeq 0.25$
- The prod CPV asymmetry in $pp \to tH^{\pm}$ is big: $A_P^{CP} \simeq 0.25$
- big cancelations in the total (prod. + decay) asymmetry:

$$A_{tb}^{CP} = A_P^{CP} + \delta_{tb}^{CP} < 0.5$$

$BR(H^{\pm} \to tb) \simeq 0.2$

- the number of $H^{\pm}$ needed to measure A_f is

$$N_{H^{\pm}} \geq \frac{1}{A_f^2 \, BR(H^{\pm} \to f)}$$

$$N_{H^{\pm}} \longrightarrow \varepsilon N_{H^{\pm}}, \quad \varepsilon_{H^{\pm} \to tb} \simeq 0.2 \; for \, LHC$$

hard for LHC: large background

- The decay rate CPV asym. for $H^{\pm} \to \nu\tau$ is small: $\delta_{\nu\tau}^{CP} \simeq 10^{-3}$

- no cancelations in the total (prod. + decay) asymmetry

$$A_{\nu\tau}^{CP} = A_P^{CP} + \delta_{\nu\tau}^{CP} \simeq 0.20$$

but $BR(H^{\pm} \to \nu\tau)$ very small

- **analogous for** $H^{\pm} \to W^{\pm} h^0$**:** $BR(H^{\pm} \to W h^0) \simeq$ **very small**

- δ_f^{CP} **are very promising for** e^+e^-**-colliders:**

  $\diamondsuit$ $m_H^{\pm}$ **= the only param. in** $e^+e^- \to H^+H^-$

  $\diamondsuit$ $H^{\pm}$ **= copiously produced – very good for studying CPV**

  NLC: $\sqrt{s} = 800\,GeV \to \sigma \simeq 29 fb$, $m_{H^{\pm}} = 200\,GeV$;

  $\sigma \simeq 12\, fb, m_{H^{\pm}} = 300\,GeV$

  CLIC: $\sqrt{s} = 3\,TeV \to \sigma \simeq 3\,fb$, $m_{H^{\pm}} = 400\,GeV$

  $N_{H^+H^-}$ **depends on luminosity** L