Search for Charged Higgs Boson with Polarized Top

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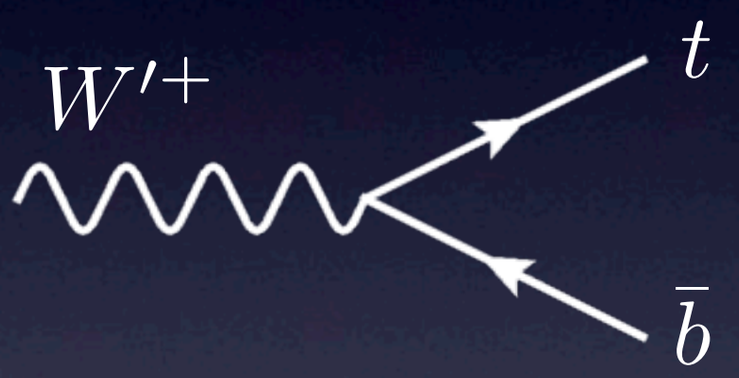
Top-quark is discovered in March 2, 1995

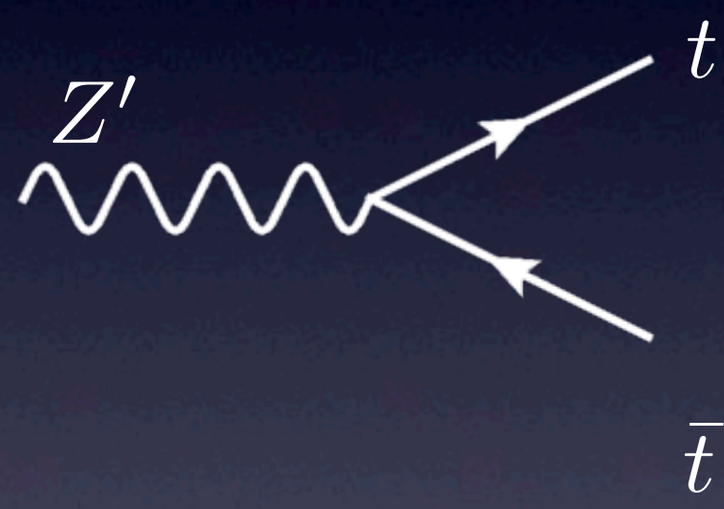
It is my very first time of learning
the quirkish words of “quark” and “top”
from Prof. **Xuan-Qian Li**’s colloquium.

Top-quark: a good probe of NP

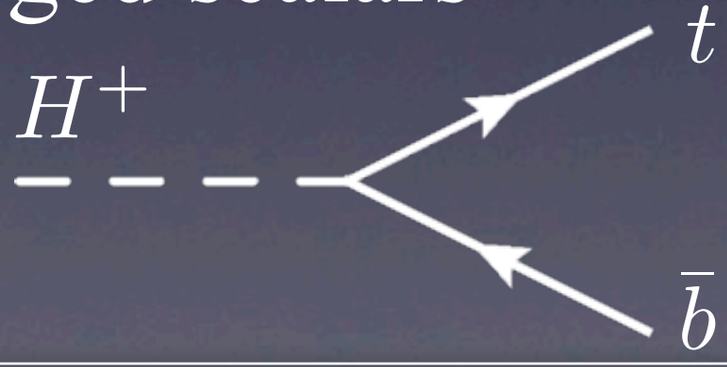
It is a common decay product of many NP resonances.
It is often polarized in many NP models.

Extra gauge bosons





Charged scalars

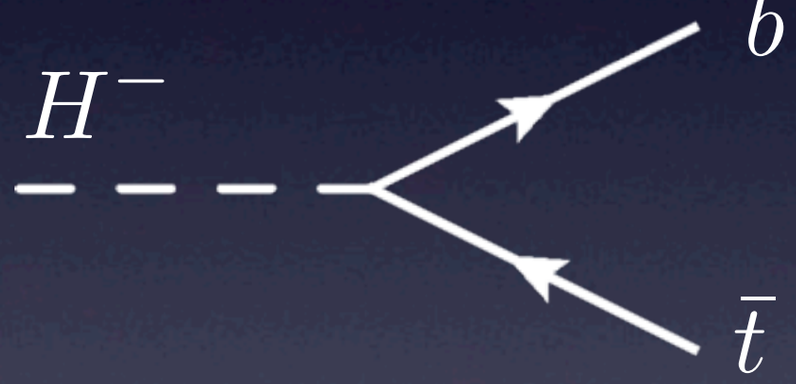


Heavy quark

$H^{\pm}$-t-b coupling in Type-II 2HDM

$$\langle \Phi_1 \rangle_0 = \begin{pmatrix} 0 \\ \frac{v_1}{\sqrt{2}} \end{pmatrix}, \quad \langle \Phi_2 \rangle_0 = \begin{pmatrix} 0 \\ \frac{v_2}{\sqrt{2}} \end{pmatrix}$$

$$\tan\beta = \frac{v_2}{v_1}$$

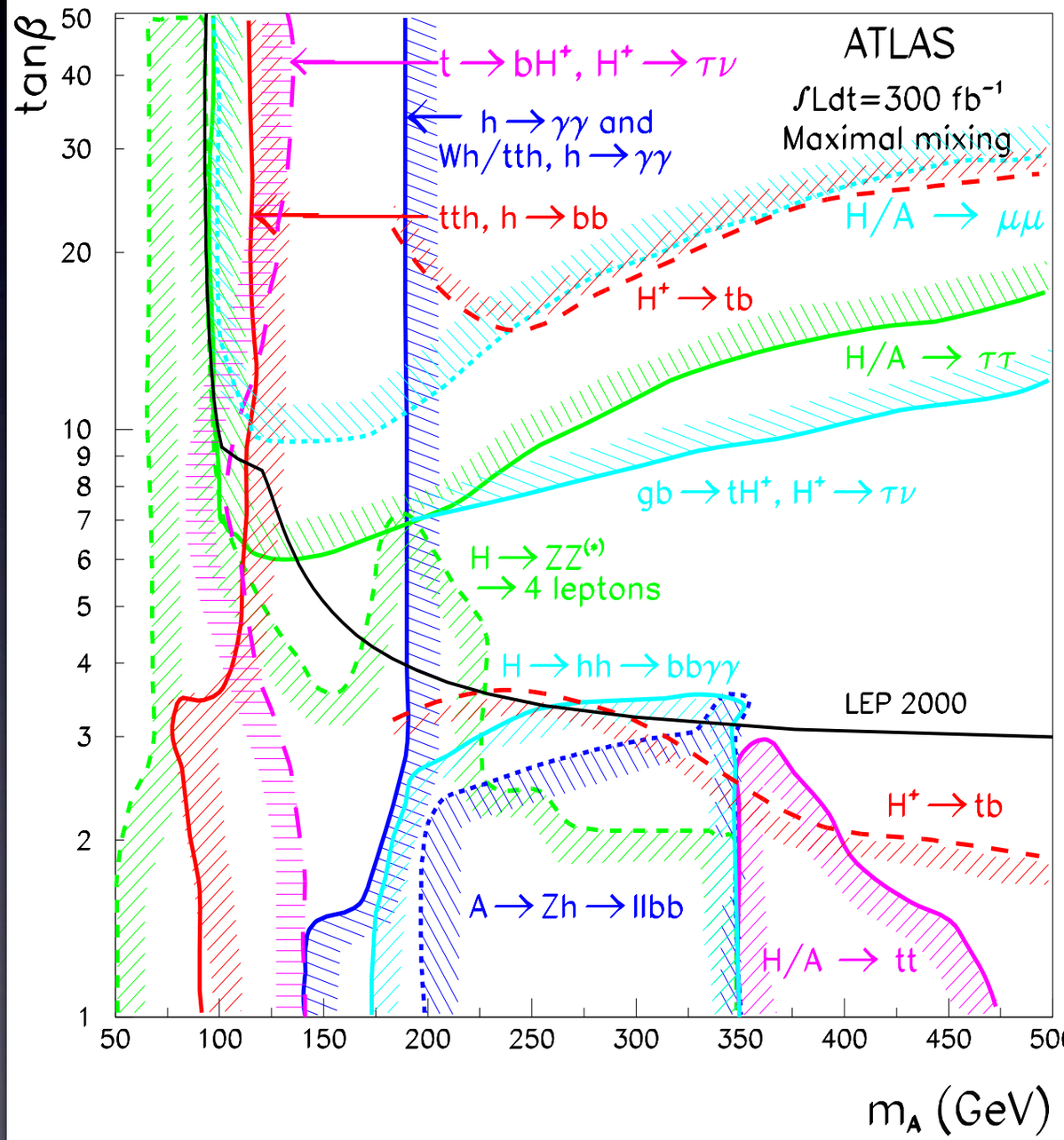


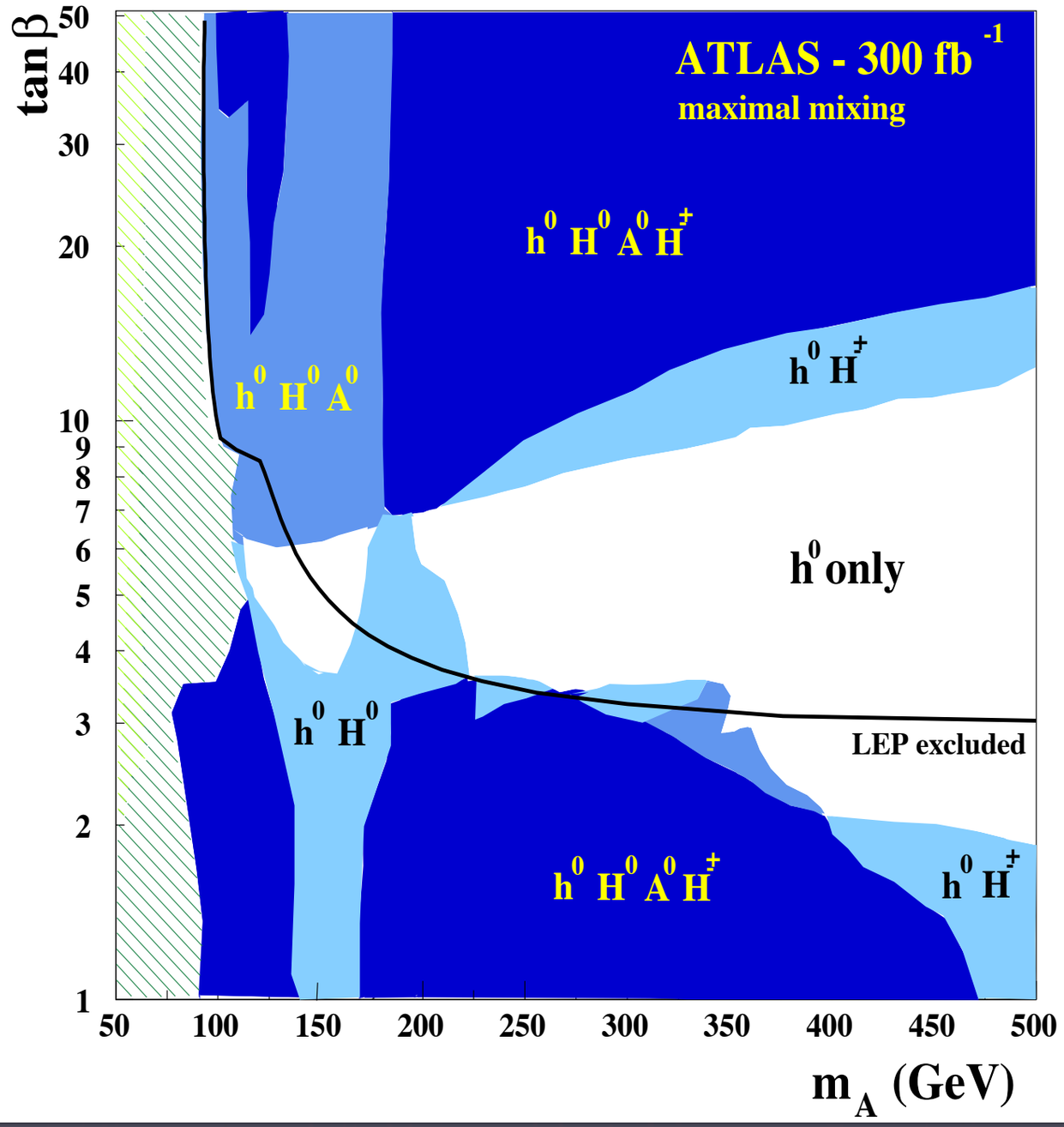
$$g_{H^-\bar{b}t} = \frac{g}{\sqrt{2}m_W}\left[m_b \tan\beta P_L + m_t \cot\beta P_R\right]$$

Xue Gong, Zong-Guo Si, et al, Phys. Rev. D87 (2013) 035014

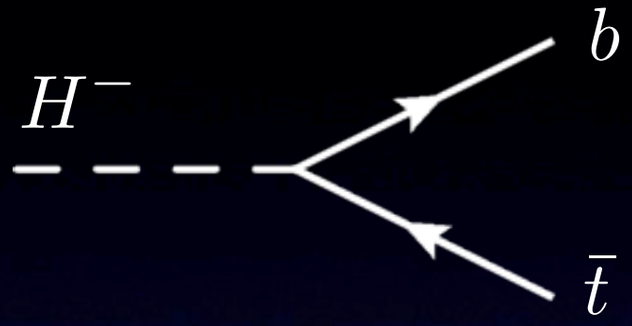
tan β measurements

In the Minimal extension of the Standard Model

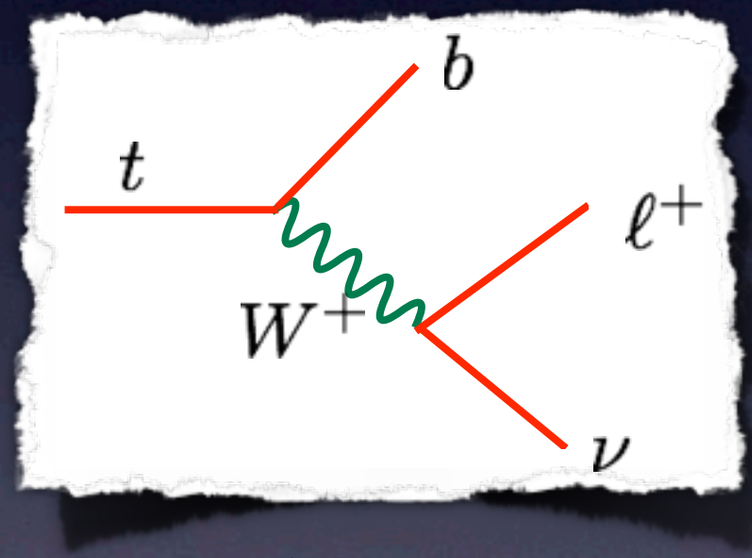


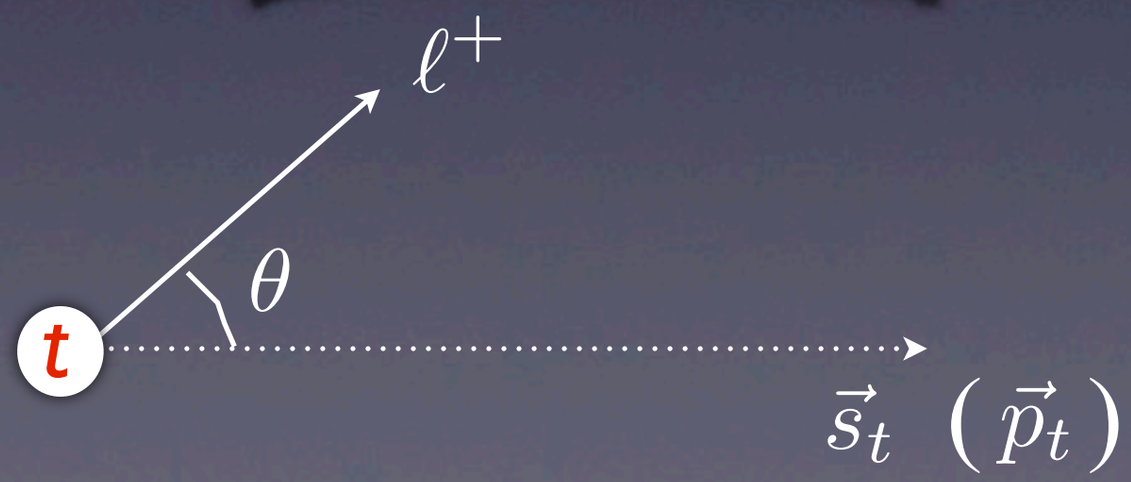


Charged Higgs boson decay



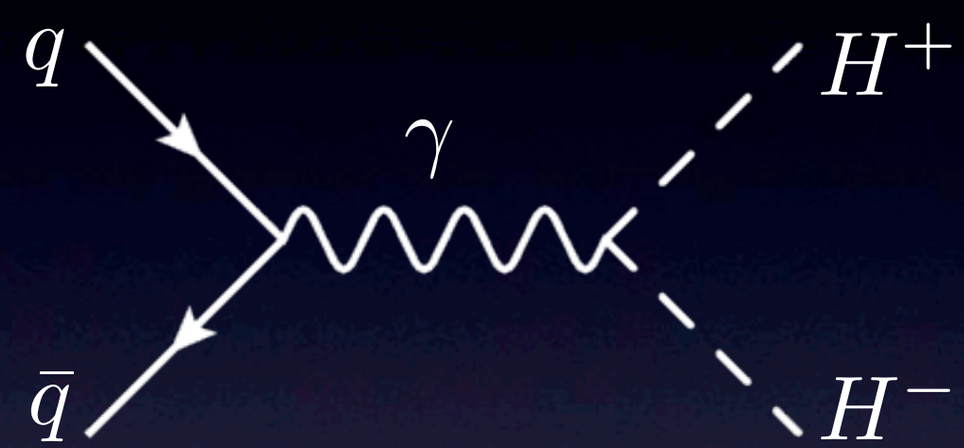
$$D_{\rm decay} \equiv \frac{\Gamma(\bar{t}_L) - \Gamma(\bar{t}_R)}{\Gamma(\bar{t}_L) + \Gamma(\bar{t}_R)} = \frac{(m_t \cot\beta)^2 - (m_b \tan\beta)^2}{(m_t \cot\beta)^2 + (m_b \tan\beta)^2}$$



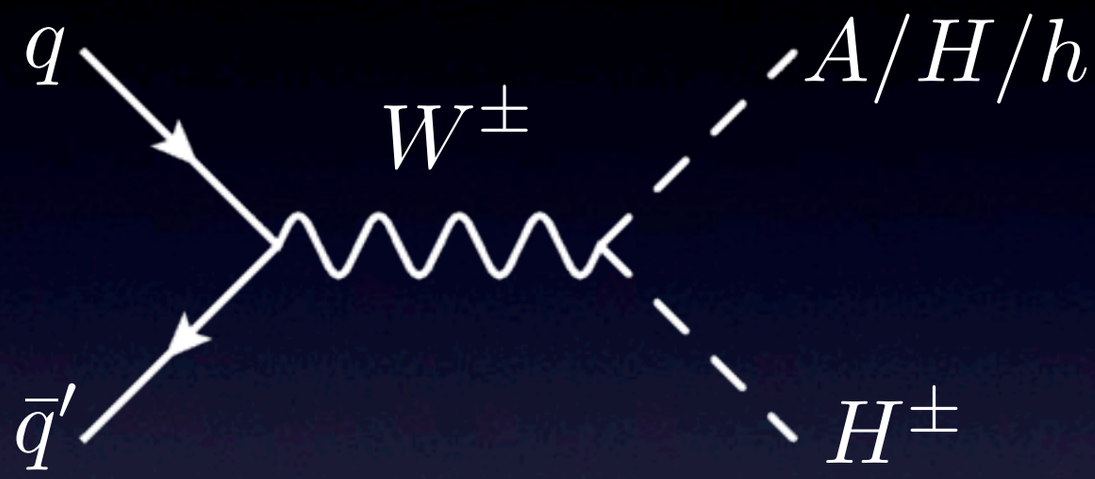


Charged Higgs boson production

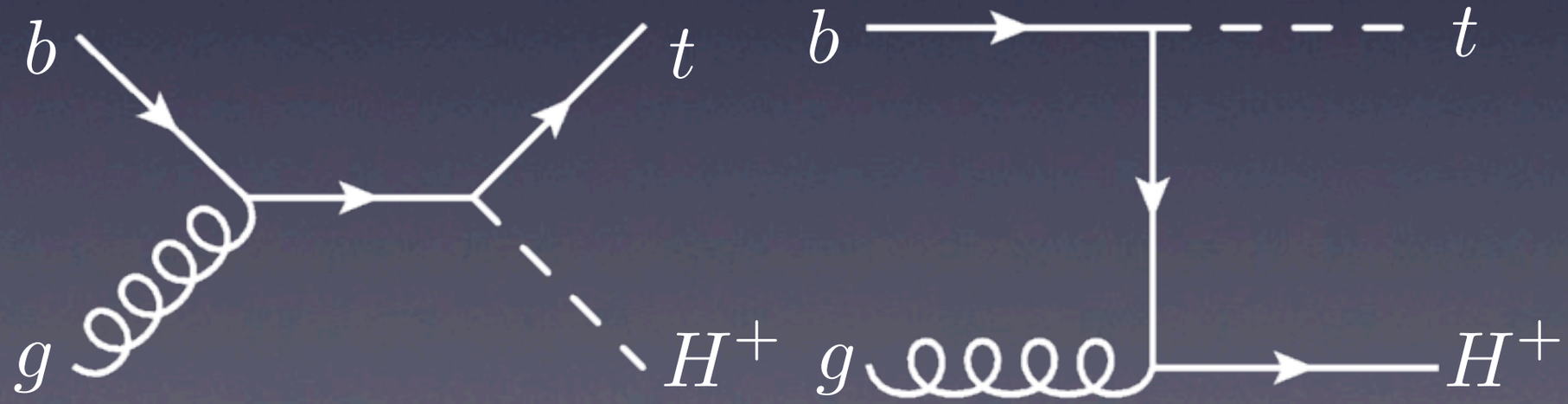
- $H^{\pm}H^{\mp}$ production



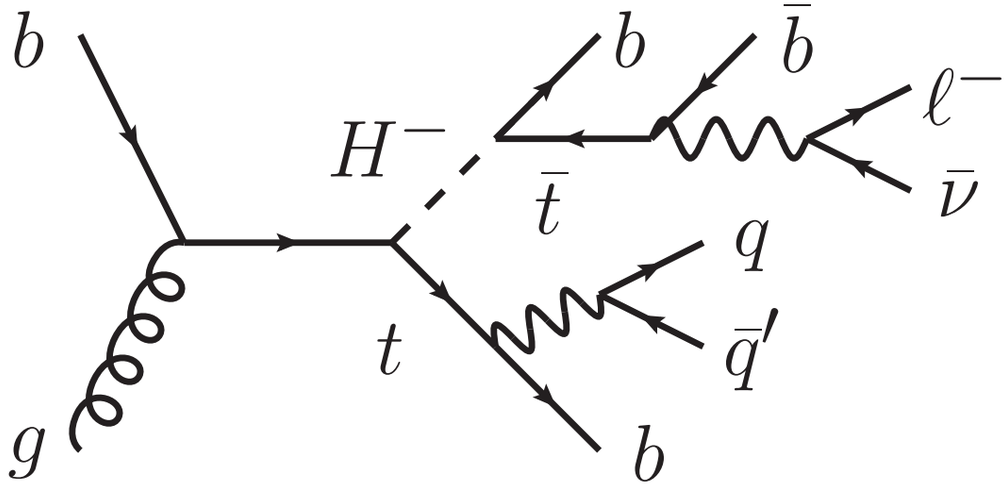
- $H^{\pm}A/H/h$ production



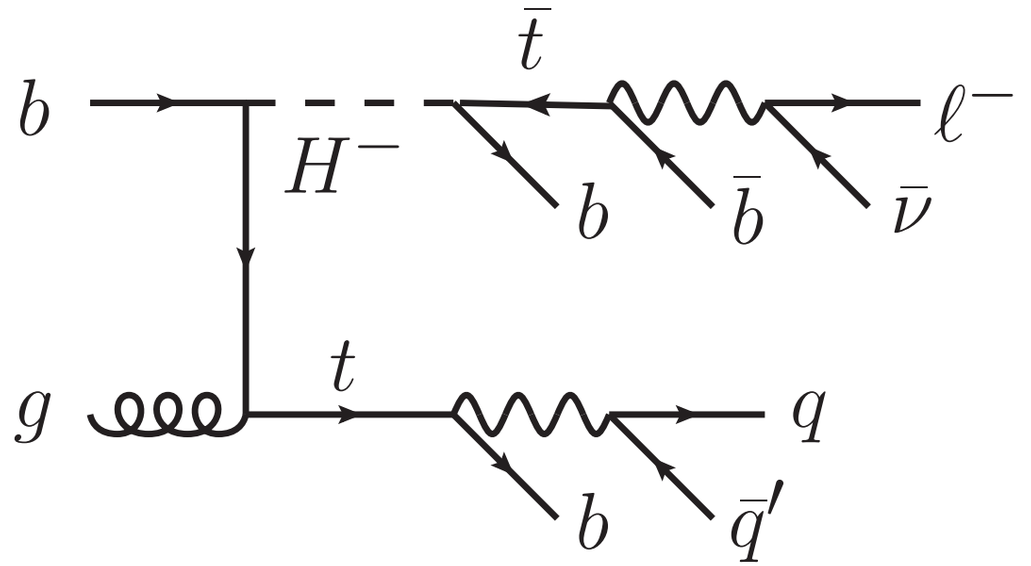
- $H^{-}t$ production



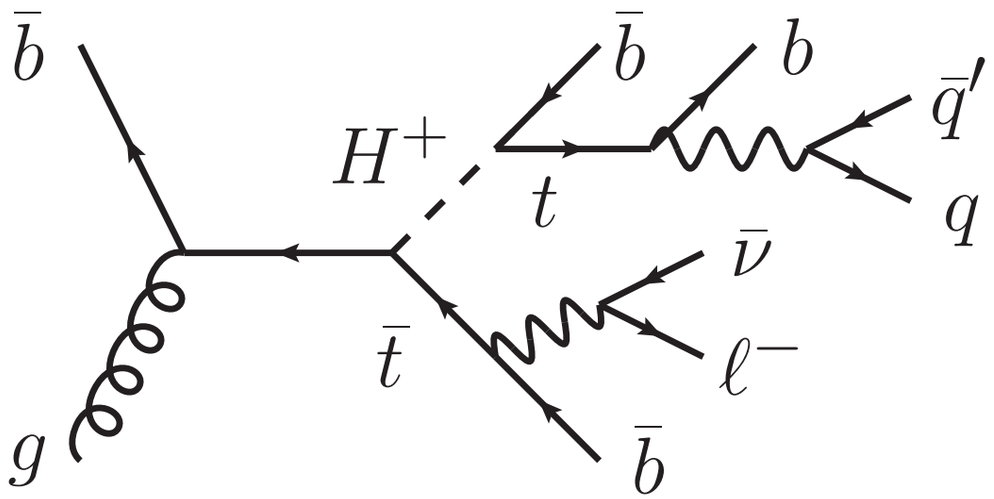
Charged Higgs production and decay



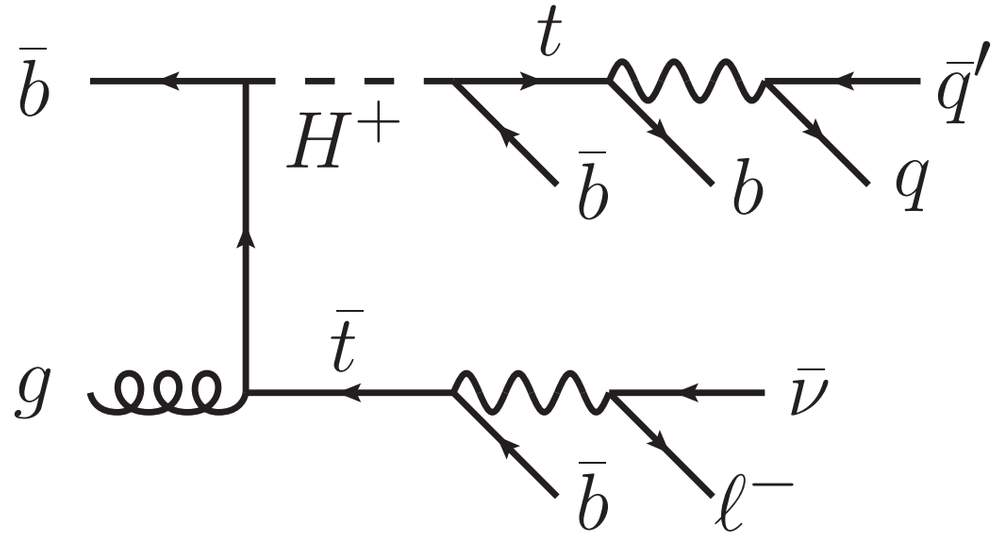
(a)



(b)

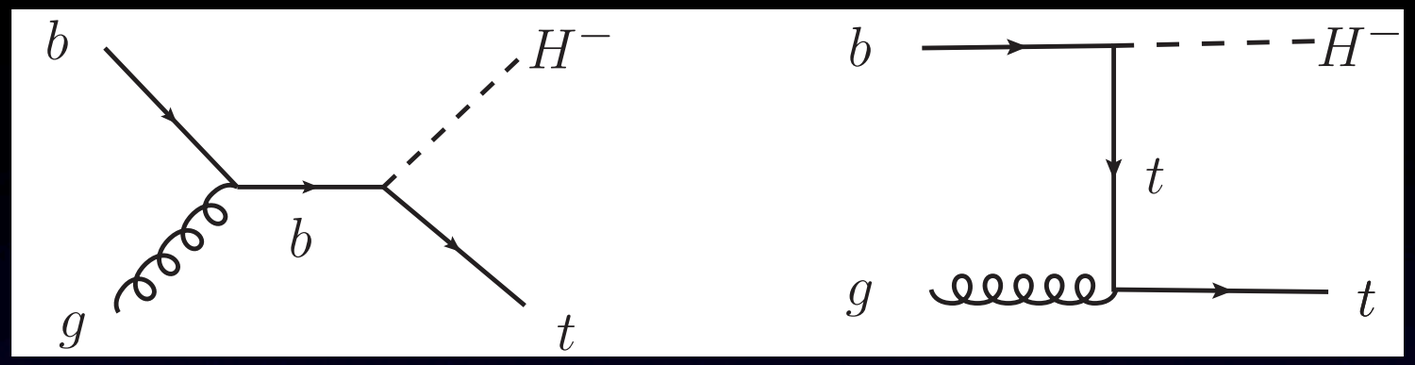


(c)



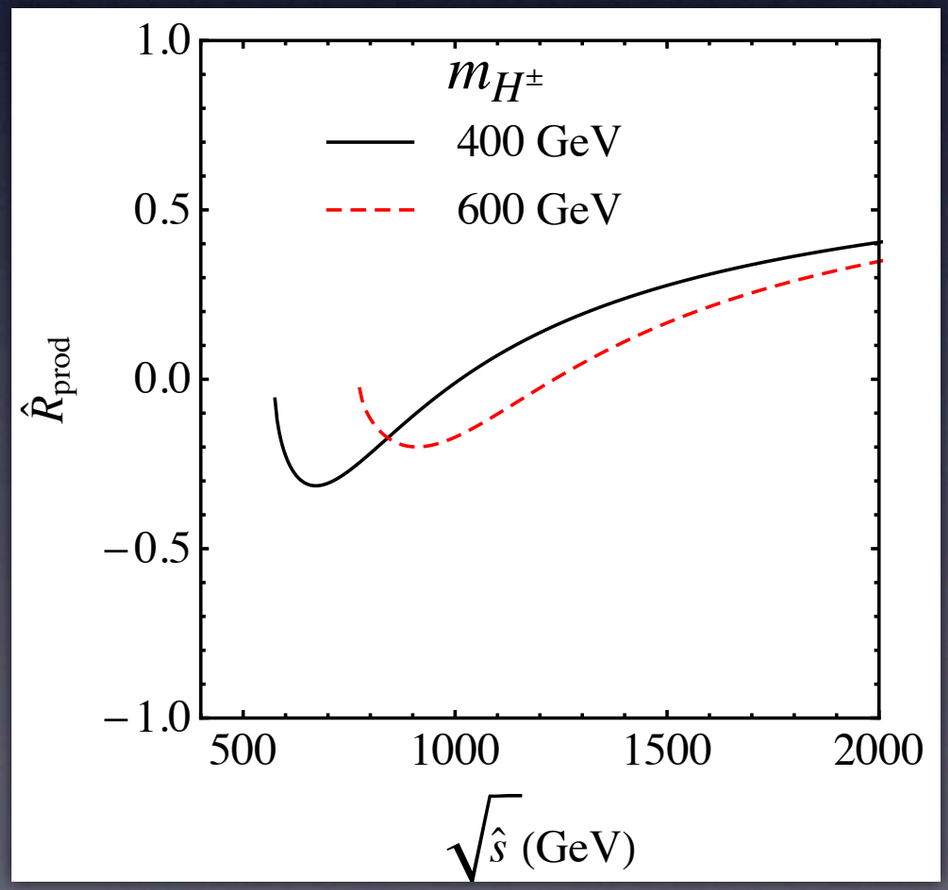
(d)

Top polarization in tH$^-$ production

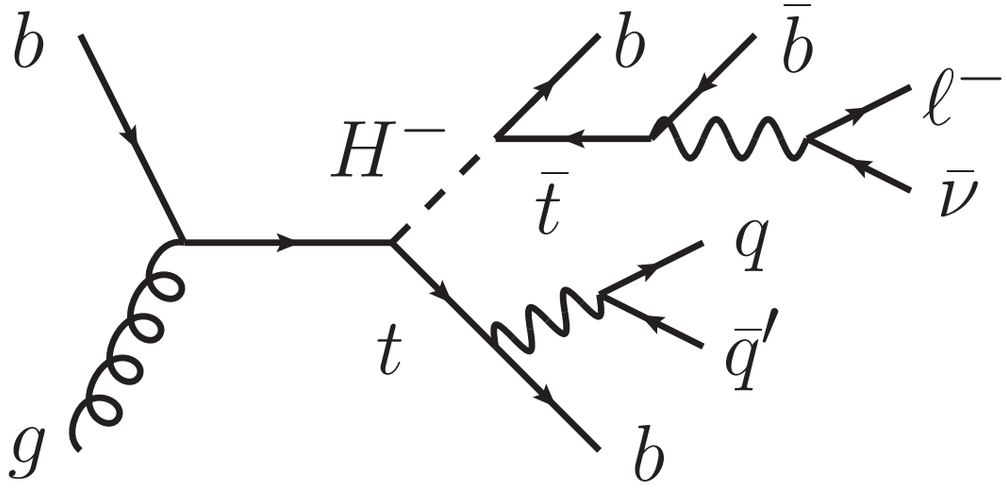


$$D_{\rm prod}(\hat{s}) \;=\; \frac{(m_t\cot\beta)^2-(m_b\tan\beta)^2}{(m_t\cot\beta)^2+(m_b\tan\beta)^2}\times\hat{R}_{\rm prod}$$

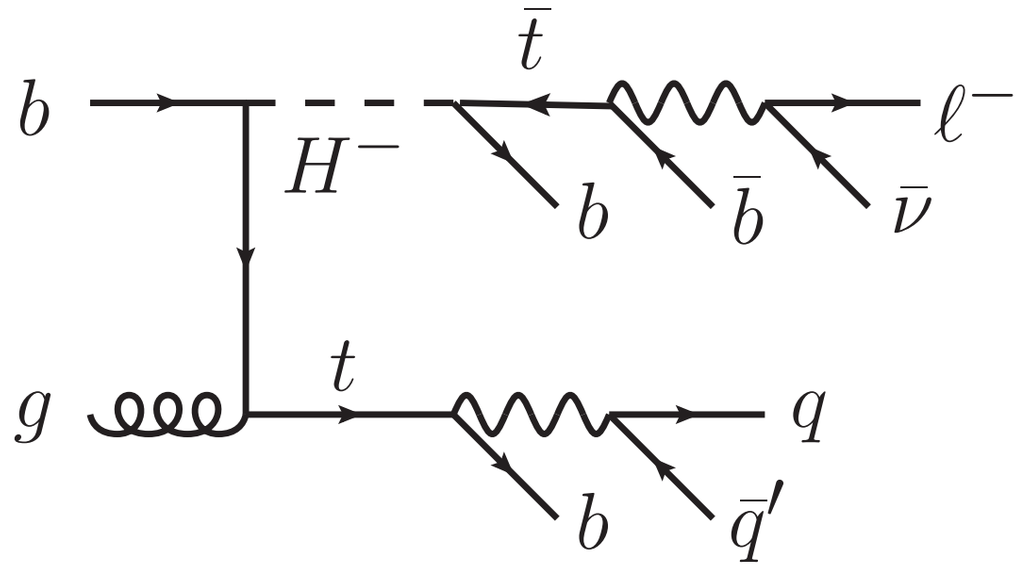
$D_{\rm decay}$



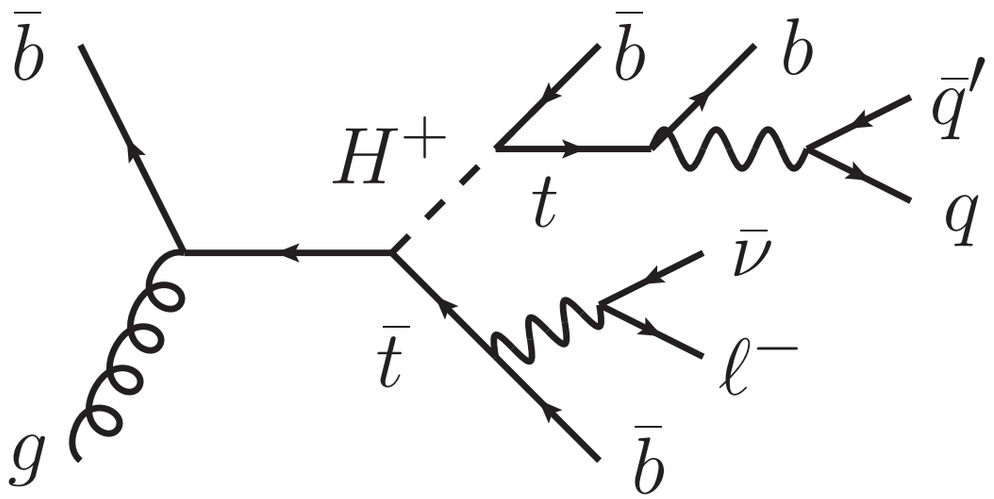
Charged Higgs production and decay



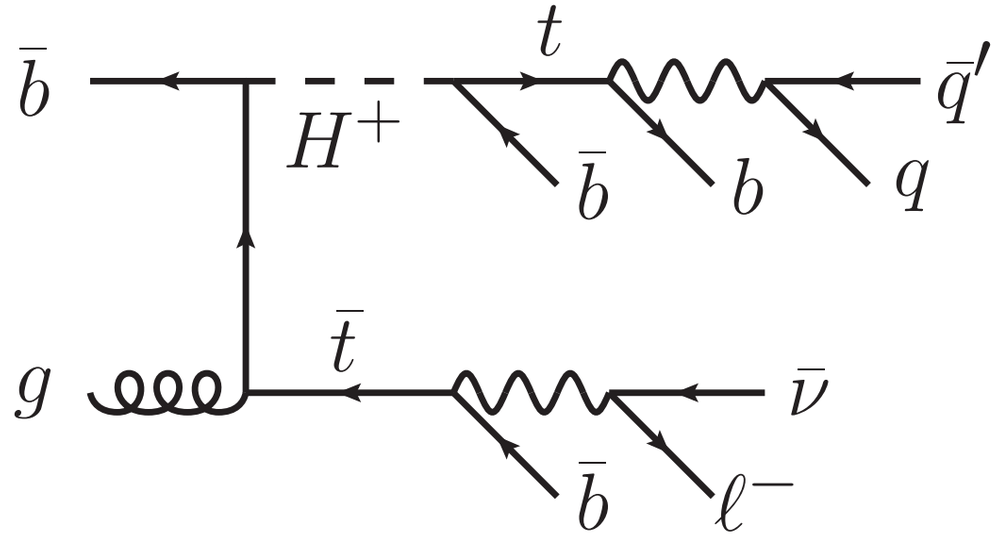
(a)



(b)



(c)



(d)

Collider simulation

Signal

$$g\bar{b} \to \bar{t}H^+ \to (W^-\bar{b})(t\bar{b}) \to (\ell^-\bar{\nu}_\ell\bar{b})(jjb\bar{b})$$

$$gb \to tH^- \to (W^+b)(\bar{t}b) \to (jjb)(\ell^-\bar{\nu}_\ell\bar{b}b)$$

Background

$$t\bar{t}b \ : \ pp \to t\bar{t}j_b \to bW^+\bar{b}W^-j_b \to j_bj_bj_bjj\ell^-\bar{\nu}$$

$$t\bar{t}j \ : \ pp \to t\bar{t}j \to bW^+\bar{b}W^-j \to j_bj_bjjj\ell^-\bar{\nu}.$$

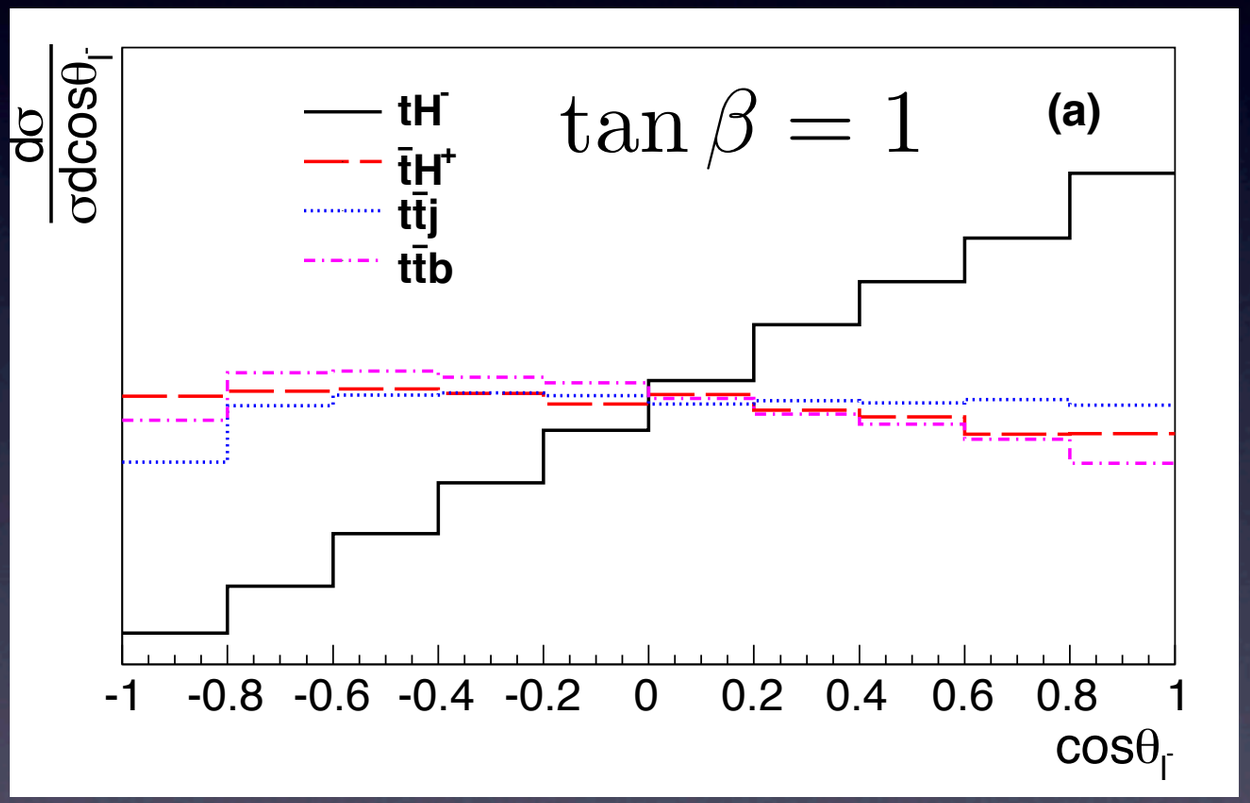
Event topology: 3 b-jets + 2 non-b-jets
1 charged lepton
missing energy

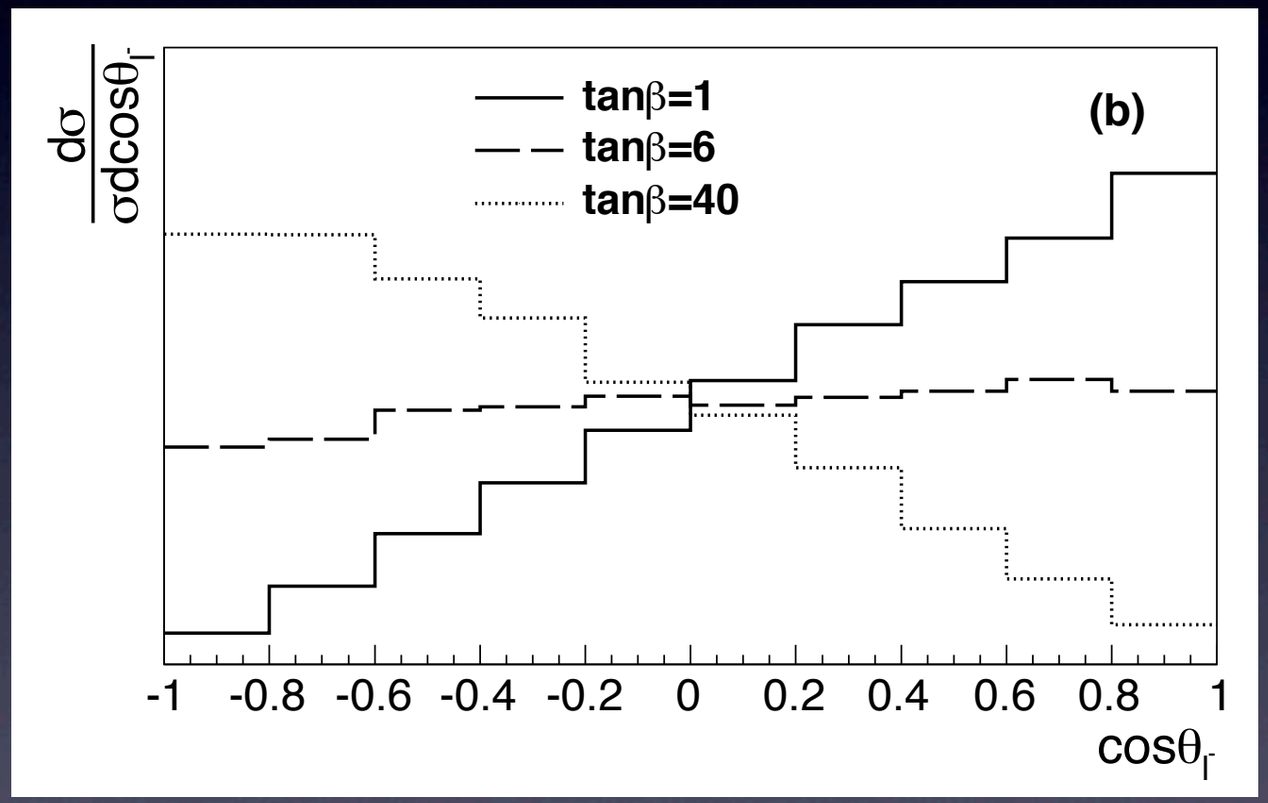
Discovery potential

TABLE I: Number of events of the signal and backgrounds at the 14 TeV LHC with an integrated luminosity of 100 fb^{-1} for $m_{H^\pm} = 400$ GeV and three values of $\tan\beta$.

$\tan\beta$	1		6		40		SM backgrounds	
	tH^-	$\bar{t}H^+$	tH^-	$\bar{t}H^+$	tH^-	$\bar{t}H^+$	$t\bar{t}j$	$t\bar{t}b$
Inclusive rate	23310	23300	1255	1227	24660	23520	1.075×10^7	234000
Hard p_T cuts	11843	13466	687	719	14421	13890	2.12×10^6	25052
$\Delta M_{\bar{t}j_{\rm extra}}$	4980	368	672	20	5680	383	39238	386
$p_T(j_{\rm extra})$	3910	305	532	16	4375	310	14942	171
b tagging	2346	183	312	10	2625	186	299	102
Number of events	2529		322		2811		401	
S/B	6.3		0.8		7.0		–	
$S/\sqrt{B}$	126.3		16.1		140.3		–	
$\sqrt{S+B}$	54.1		26.9		56.7		–	

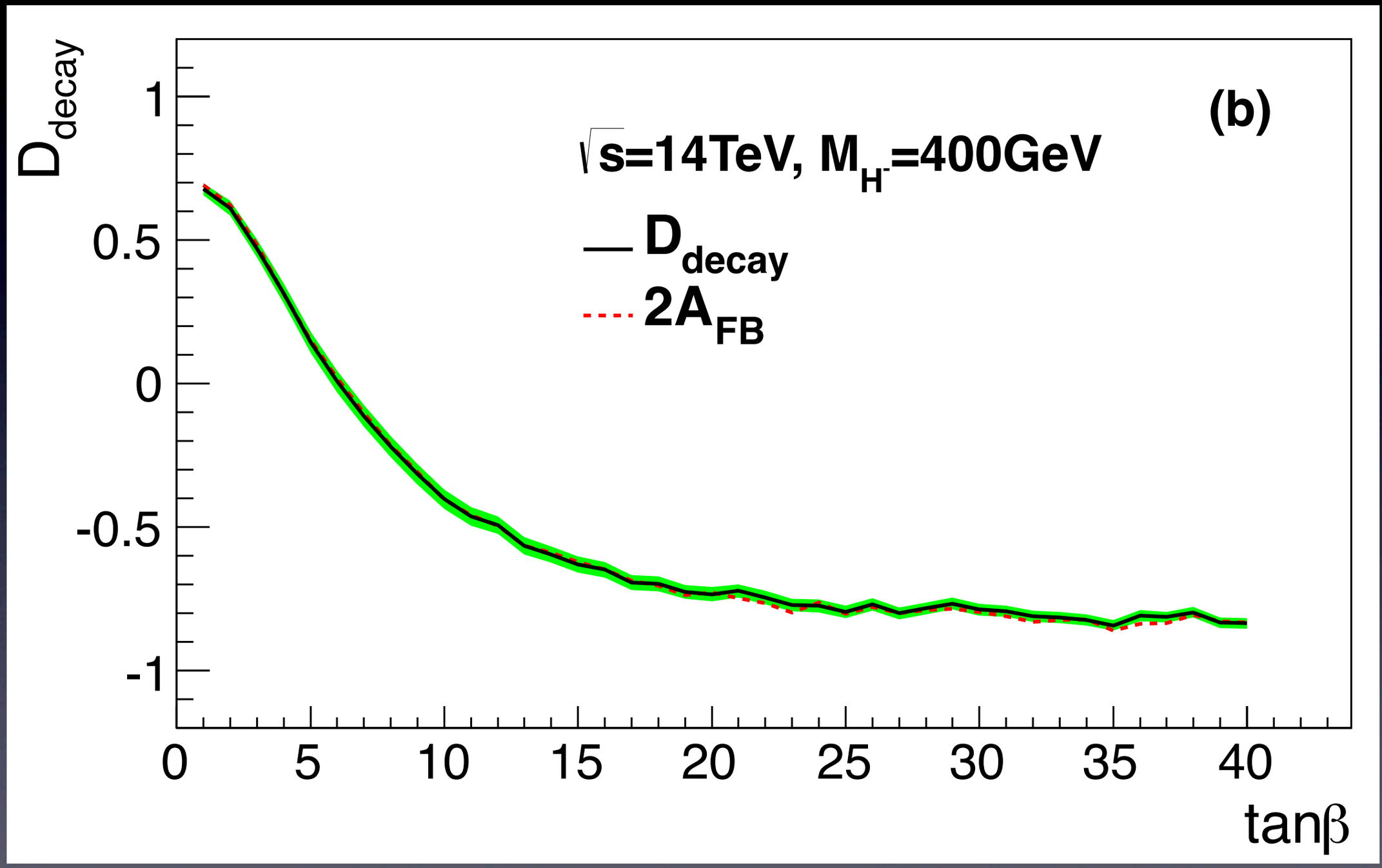
$\tan\beta$ versus top-quark polarization





$$m_{H^\pm} = 400 \text{ GeV}$$

$\tan\beta$ versus top-quark polarization



谢谢！