What if … ?

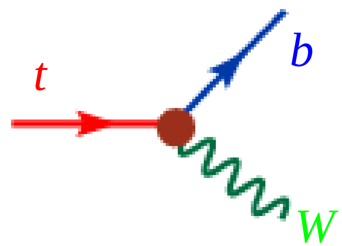
It is however possible that new physics

might not change the $\mathrm{Br}\left(t \to bW\right)$,

(e.g. no additional new light fields with mass less than m_t)

but will strongly modify the width of $\Gamma\left(t \to bW\right)$,

due to the interaction



is strongly modified.

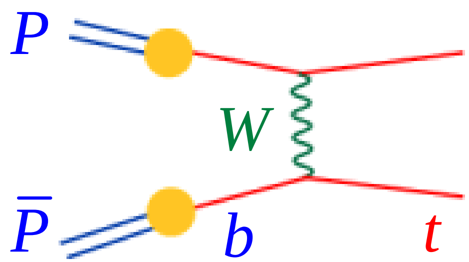
Hence, the lifetime of top quark is different from SM's prediction.

Need to study the interaction of $t - b$ - W .

$P\bar{P} \to t\ X$ and $P\bar{P} \to \bar{t}\ X$

(single top production)

Since



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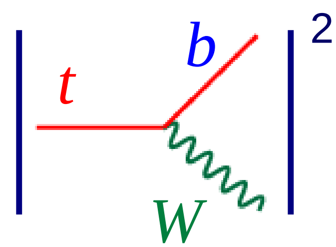


⇒ Measuring σ_t

assume SM → CKM element V_{tb}

in general → $\Gamma\left(t \to bW\right)$

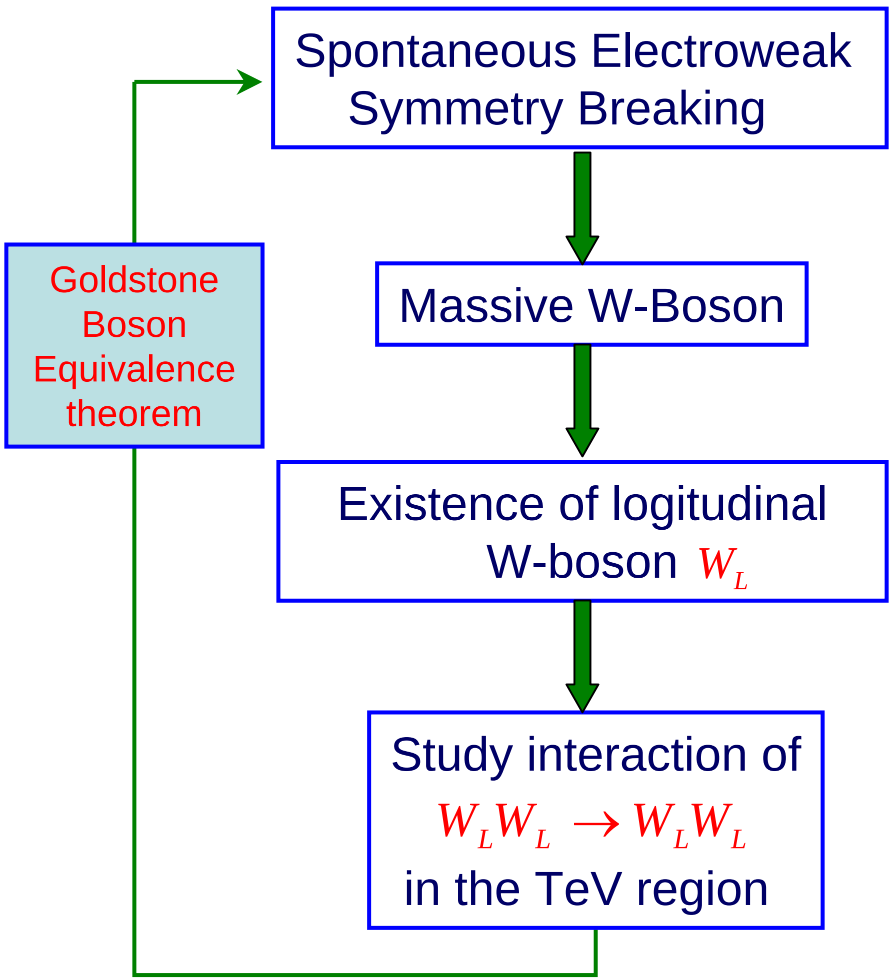
Combine with $\mathrm{Br}\left(t \to bW\right)$

⇒ $$\Gamma_{\mathrm{tot}} = \frac{\Gamma\left(t \to bW\right)}{\mathrm{Br}\left(t \to bW\right)}$$ ⇒ Lifetime of Top

$$\tau_{\mathrm{top}} = \frac{1}{\Gamma_{\mathrm{tot}}}$$

What motivated my 1990 single-top paper

(with $m_t = 180$ GeV)



Goldstone Boson Equivalence Theorem

- Denote W_L as longitudinal W-boson and π as pseudo-Goldstone boson, then the scattering amplitudes

$$T[W_L;\Phi_{phys}] = (-i)\ T[\pi\ ;\Phi_{phys}] + \mathrm{O}(\frac{M_W}{E})$$

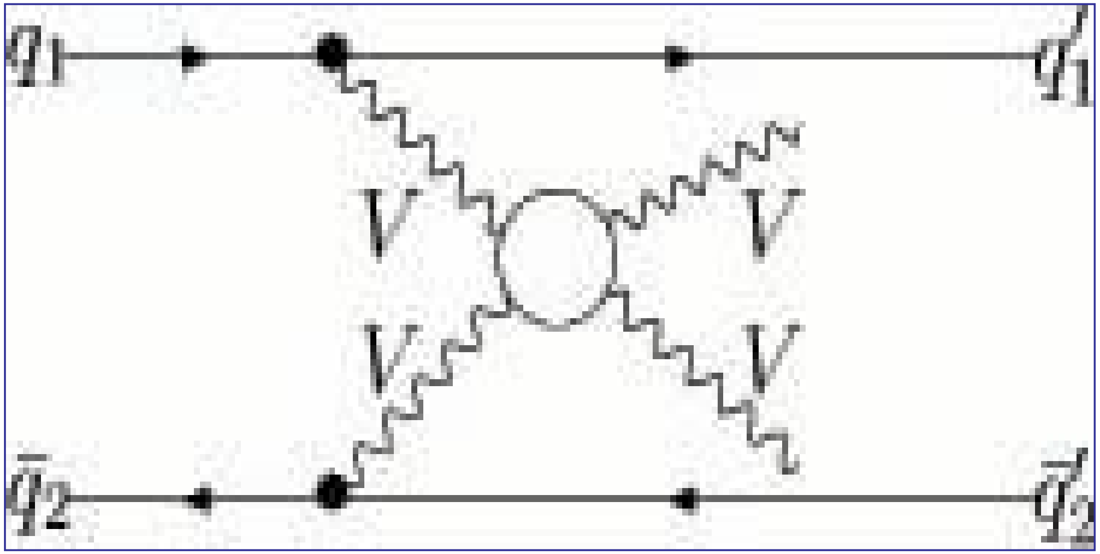
- Similarly,

$$T[W_L^{a_1},\ldots,W_L^{a_n};\Phi_{phys}] = (-i)^n\, T[\pi^{a_1},\ldots,\pi^{a_n};\Phi_{phys}] + \mathrm{O}(\frac{M_W}{E_j})$$

(A classical reference: Hong-Jian He, Yu-Ping Kuang, Xiao-Yuan Li)

Weak Boson Scattering processes

$$pp \to VVjj$$



Scenarios studied:

Linear or Non-Linear Chiral Lagrangian
With or Without a Light Higgs Boson Field

(A recent study: Bin Zhang, Yu-Ping Kuang, Hong-Jian He, CPY)

What motivated my 1990 single-top paper

(with $m_t = 180 \text{ GeV}$)

Spontaneous Electroweak Symmetry Breaking

Massive W-Boson

Existence of logitudinal W-boson W_L

Study interaction of

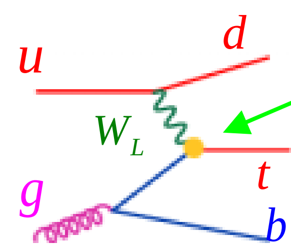
$W_L W_L \to W_L W_L$

in the TeV region

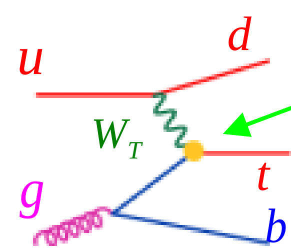
Goldstone Boson Equivalence theorem

W_L can also interact strongly with top quark if

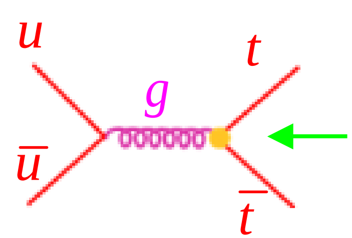
$$m_t \simeq \frac{v}{\sqrt{2}} \approx 175 \text{ GeV}$$



$$g^2{}_{\text{eff}} \simeq \left(\frac{\sqrt{2}m_t}{v}\right)^2 \simeq 1$$



$$g^2{}_{\text{weak}} \simeq \frac{1}{2.5}$$



$$(g_S)^2 \simeq 1$$

An Application of Equivalence Theorem

- Consider the decay of top quark with $m_t \gg M_W$
- The decay amplitude

$$T[t \to bW_L] = (-i)\ T[t \to b\pi] + O(\frac{M_W}{E})$$

- The ratio in the production rates of W_L versus W_T from top decay is

$$\frac{\Gamma(t \to bW_L)}{\Gamma(t \to bW_T)} = \frac{\left(\sqrt{2}\,\frac{m_t}{v}\right)^2}{2\left(\frac{g}{\sqrt{2}}\right)^2} = \frac{m_t^2}{2M_W^2}$$

What motivated my 1990 single-top paper

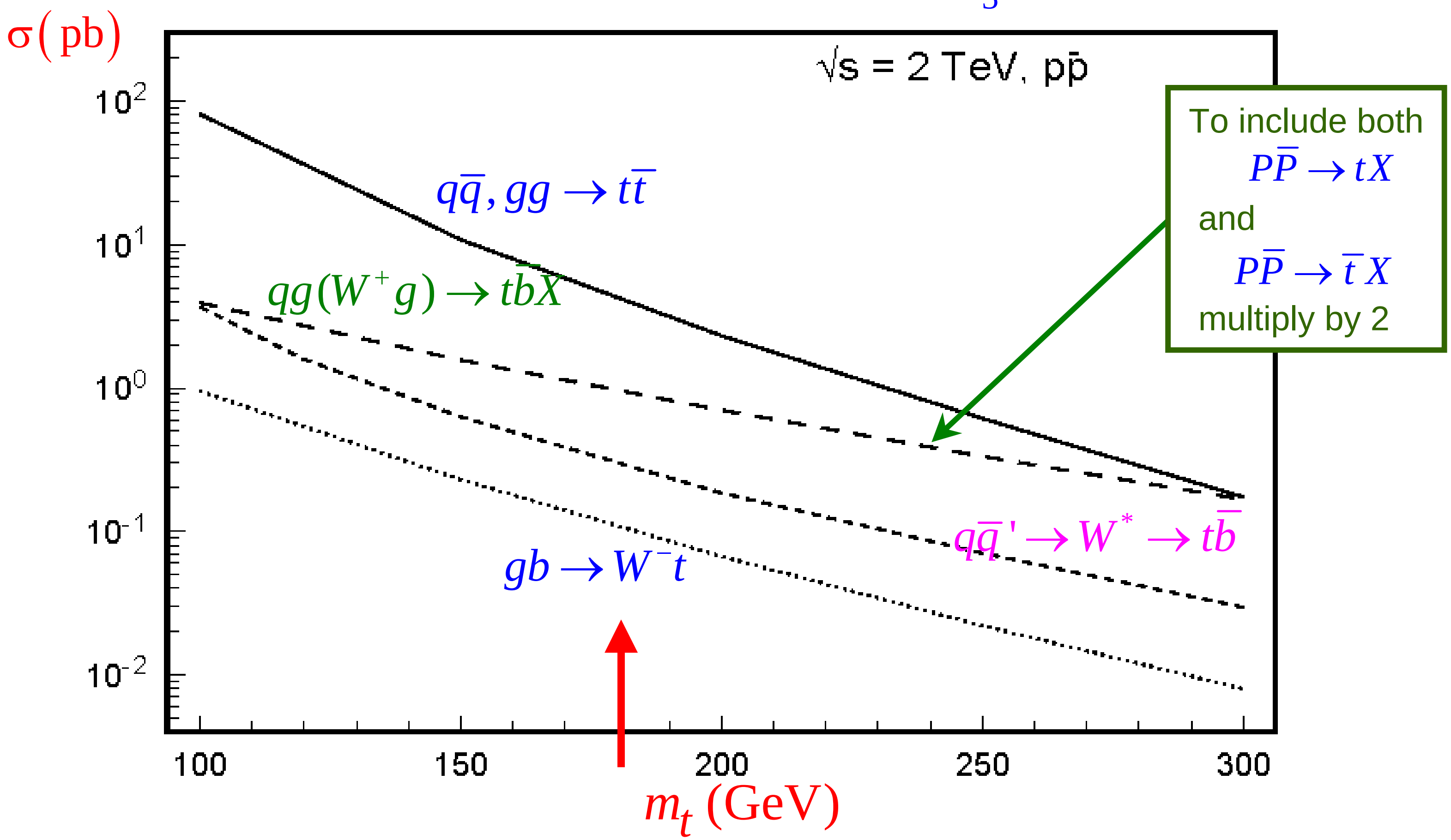
(with $m_t = 180$ GeV)

For $m_t = 180$ GeV,

$$\sigma\left(Wg \to t\bar{b}, \bar{t}b\right) \sim \frac{1}{3}\sigma\left(t\bar{t}\right)$$

$$\sigma\left(W^* \to t\bar{b}, \bar{t}b\right) \sim \frac{1}{3}\sigma\left(Wg \to t\bar{b}, \bar{t}b\right)$$

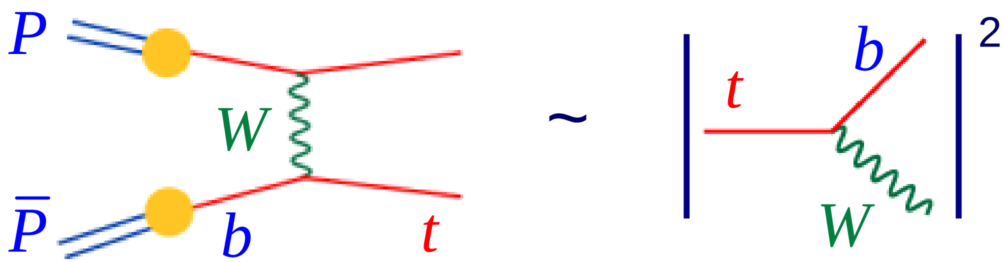
$$\sigma\left(Wt\right) \sim \frac{1}{3}\sigma\left(W^* \to t\bar{b}\right)$$



$P\bar{P} \to t\,X$ and $P\bar{P} \to \bar{t}\,X$

(single top production)

Since



The asymmetry in the production rate

$$A_t^{\mathrm{CPX}} = \frac{\sigma\left(p\bar{p} \to t\right) - \sigma\left(p\bar{p} \to \bar{t}\right)}{\sigma\left(p\bar{p} \to t\right) + \sigma\left(p\bar{p} \to \bar{t}\right)}$$

can be used to measure CP-violation.

$\mathrm{C}: \; P \leftrightarrow \bar{P}$

$\mathrm{P}: \; \vec{x} \leftrightarrow -\vec{x}$

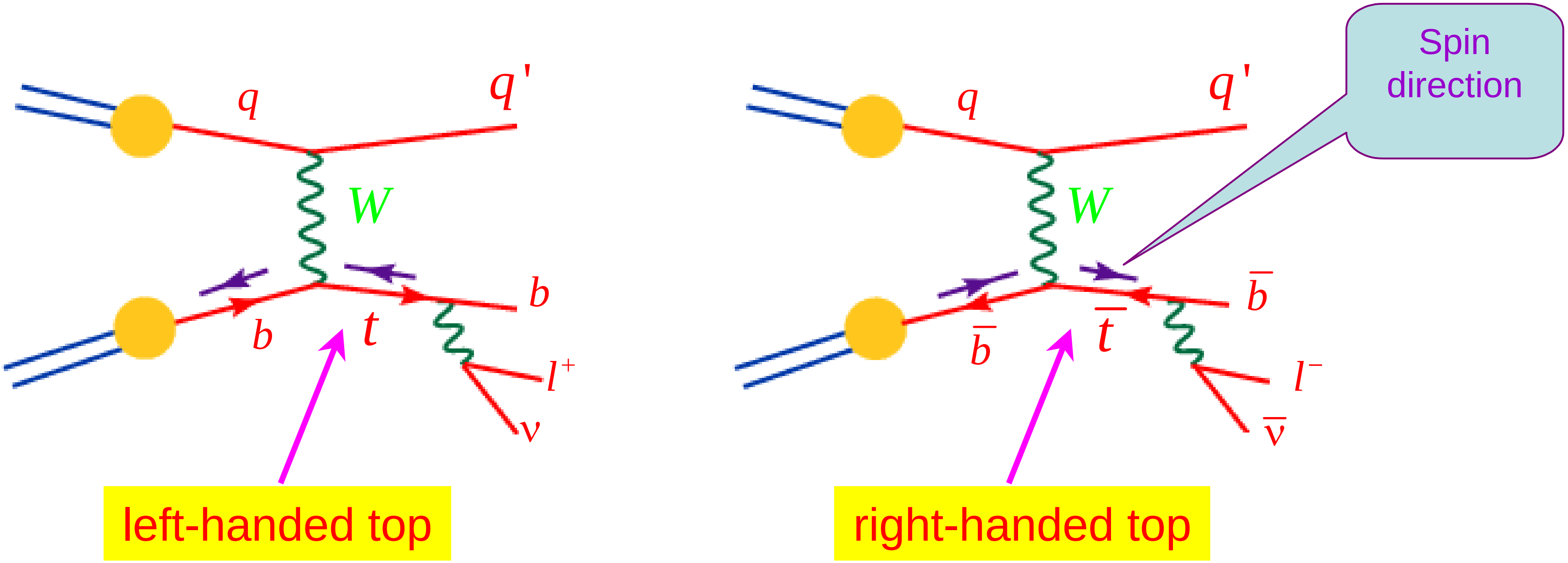
This observable is unique for $p\bar{p}$ collider.
(Tevatron)

For 2 fb^{-1}, $\delta A_t^{\mathrm{CPX}} \sim 20\%$

A SM t ($\bar{t}$) is purely

left-handed (right-handed) polarized

in the single-top process.



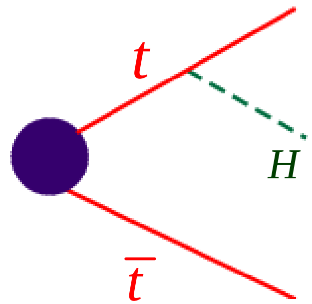
Measuring both

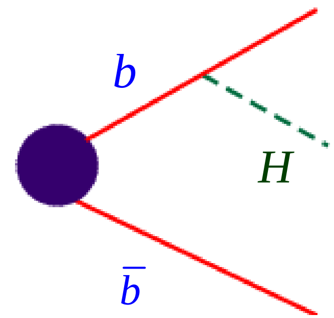
$$\left\langle \vec{\sigma}_t \bullet \vec{p}_b \times \vec{p}_{l^+} \right\rangle \text{ and } \left\langle \vec{\sigma}_{\bar{t}} \bullet \vec{p}_{\bar{b}} \times \vec{p}_{l^-} \right\rangle$$

➡ Probe CP-violation at the LHC

Discriminating Models of Electroweak Symmetry Breaking

Testing the interaction of Top, Bottom and Higgs Boson





SM: $y_t^{SM} = \frac{m_t}{\sqrt{2}v} = 1$ $\quad y_b^{SM} = \frac{m_b}{\sqrt{2}v} = \frac{1}{40}$

MSSM: $(\tan\beta = 40)$ $\quad y_t = y_t^{SM} \cdot \cot\beta = \frac{1}{40}$ $\quad y_b = y_b^{SM} \cdot \tan\beta = 1$

TopColor: $H \equiv < t\,\bar{t} >$ $\quad y_t = 1$ $\quad y_b = 1$

If Higgs boson exists,

Discovering the Higgs boson and studying its interaction is essential to probe the electroweak symmetry breaking and the flavor symmetry breaking .

Otherwise,

Need to study interaction among longitudinal W and Z bosons in the TeV region and interaction of longitudinal W (Z) boson to heavy fermions (top and bottom).