Implications of LHC results for TeV-scale Physics

Working Group 3: Exotics
CERN, Jul 13-17, 2012

Report WG3

New Vector Bosons

Tight relation to Higgs results

Higgs with nonstandard couplings

Elementary or composite extra vector (or scalar) bosons at TeV scale well motivated by perturbative unitarity

Make simplifying assumptions

- Only one extra *vector* boson contributes
- Single production
- Narrow resonance
- Drell-Yan production
- Decay into dilepton and dijet

- For each channel, concentrate in production:

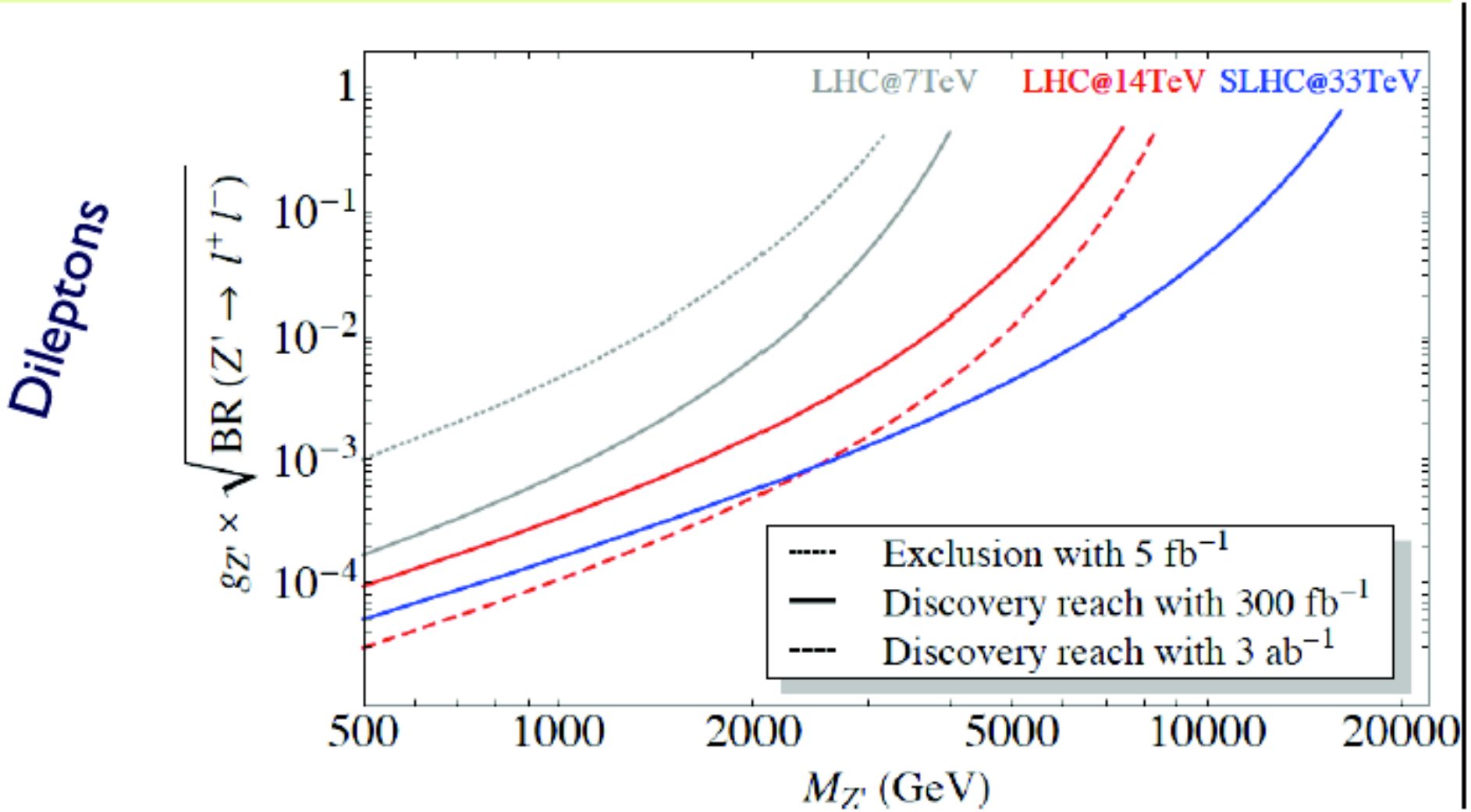
$$
\begin{aligned}
N_s &= \sigma_{V'}(pp \to X)\, A_X\, \epsilon_X\, L \\
&= \sigma(pp \to V')\, \mathrm{BR}(V' \to X)\, A_X\, \epsilon_X\, L \\
&= g^2 \sigma^{g=1}(pp \to V')\, \mathrm{BR}(V' \to X)\, A_X\, \epsilon_X\, L
\end{aligned}
$$

Coupling to quarks (assume LH & universal)

Branching ratio, depending on other couplings

Narrow width approx.

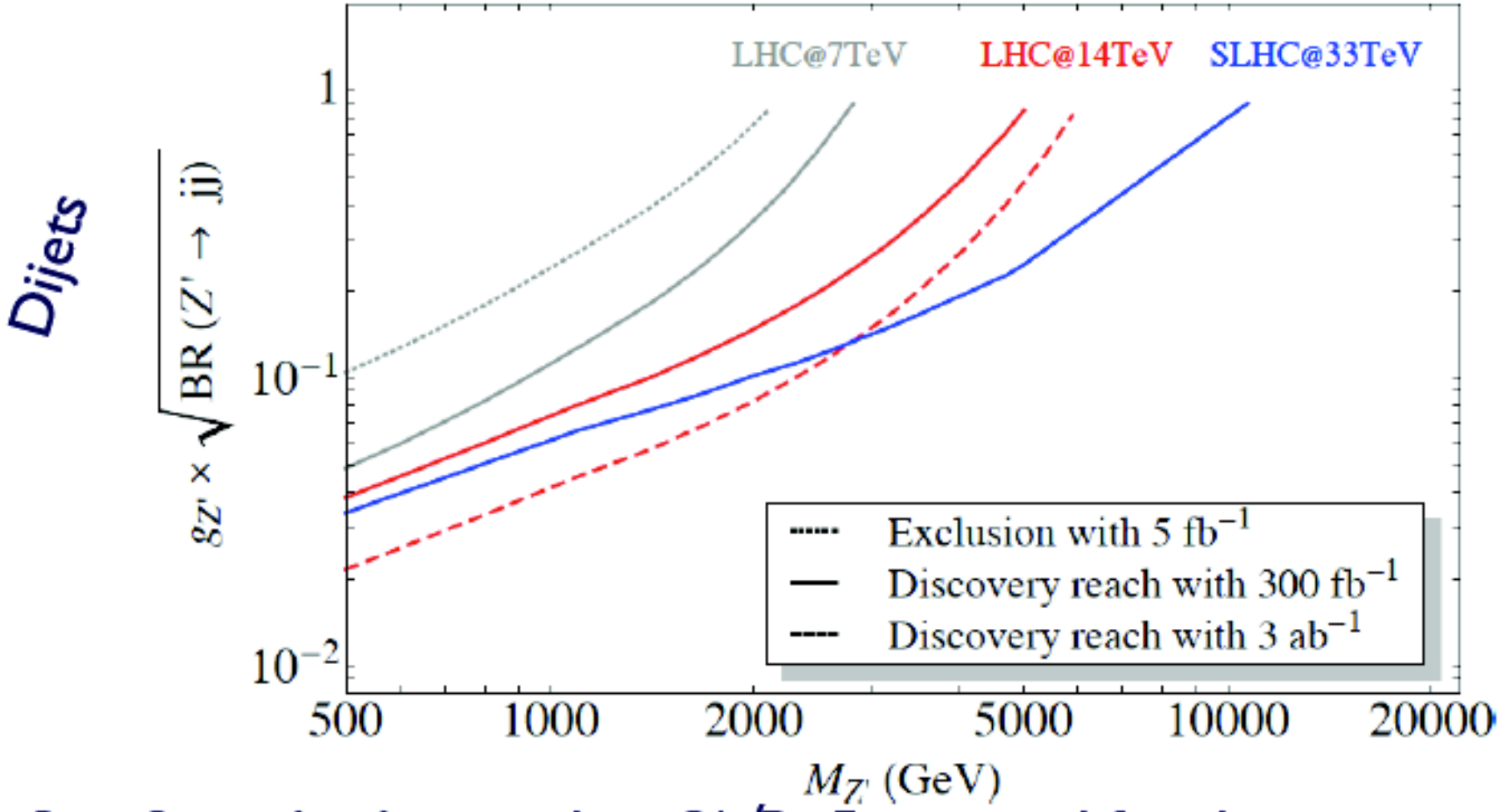
Present in a unified way the discovery reach for foreseen collider energies and luminosities



Negligible background → 5 events required for discovery, less than 3 for 95% C.L. exclusion

Extrapolation beyond NWA at large couplings

Present in a unified way the discovery reach for foreseen collider energies and luminosities

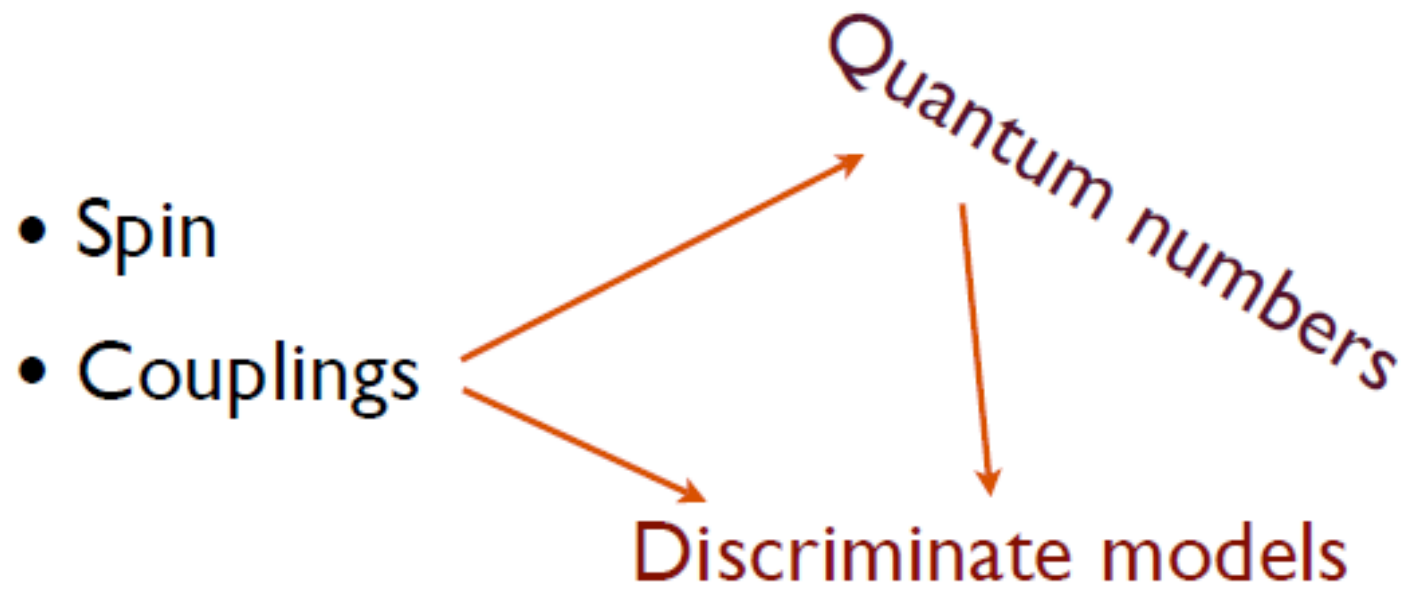


Significant background → S/√B=5 required for discovery,

less than 3 for 95% C.L. exclusion

Extrapolation beyond NWA at large couplings

3. LHC: measuring properties



14 TeV / 100 fb^{-1} GUT strength couplings	⇨ Not possible given existing limits

Need more luminosity or upgrade energy or...

4. Linear Collider

- If New Vectors (New Physics) found

- If light enough, scan/autoscan resonance
- Study their properties in clean enviroment

- If New Vectors (New Physics) not found

- Precision study of their indirect effects on electroweak observables

- Suitable for leptophilic (possibly light) vector bosons

New quarks after the Higgs

Exotic quarks after the Higgs

- only 7 possibilities of vector-like quarks coupling to SM Higgs

  2 singlets, 3 doublets, 2 triplets, that's all!

  not a tremendous work to consider all models

Assumption: coupling to SM Higgs ($\phi,\ \tilde{\phi}$) and SM quarks ($q_L,\ t_R,\ b_R$) at renormalizable level

$$T_{\frac{2}{3}} \quad B_{-\frac{1}{3}} \quad \begin{pmatrix} T \\ B \end{pmatrix}_{\frac{1}{6}} \quad \begin{pmatrix} X \\ T \end{pmatrix}_{\frac{7}{6}} \quad \begin{pmatrix} B \\ Y \end{pmatrix}_{-\frac{5}{6}} \quad \begin{pmatrix} X \\ T \\ B \end{pmatrix}_{\frac{2}{3}} \quad \begin{pmatrix} T \\ B \\ Y \end{pmatrix}_{-\frac{1}{3}}$$

$$\bar{q}_L \tilde{\phi} T_R \qquad (\bar{X}_L\ \bar{T}_L)\phi t_R \qquad \cdots$$

Exotic quarks after the Higgs

- only 7 possibilities of vector-like quarks coupling to SM Higgs

  2 singlets, 3 doublets, 2 triplets, that's all!

   not a tremendous work to consider all models

- unique signals not yet fully explored

  $T \to tZ, tH \quad B \to bZ, bH$

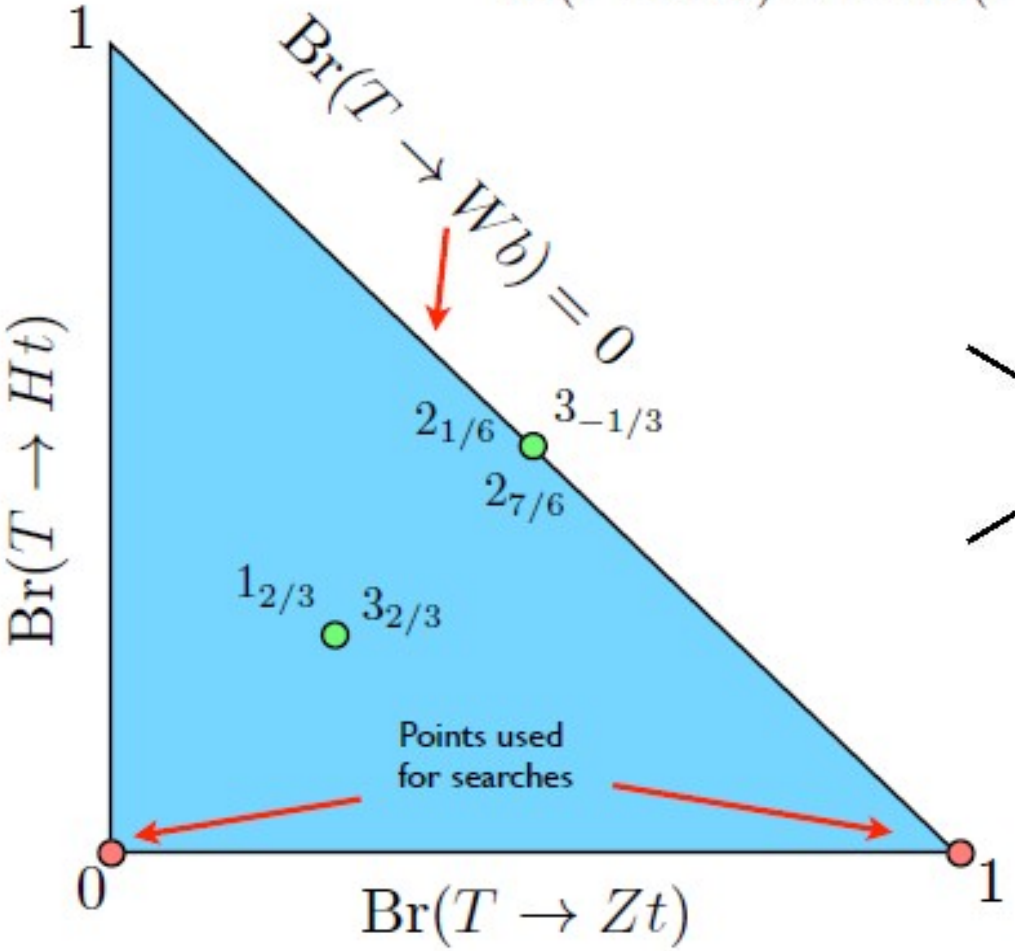
  (I assume dominant coupling to 3rd generation)

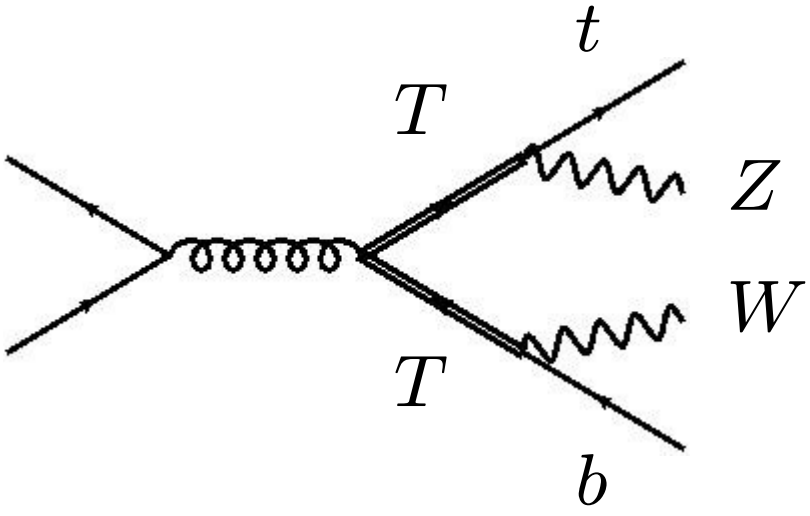
   limits looser than for 4th generation quarks

Decays of T

$\mathrm{SU}(2)_L \times \mathrm{U}(1)_Y$ invariance: 2 possibilities

$$\mathrm{Br}(T \to Wb) = 1 - \mathrm{Br}(T \to Zt) - \mathrm{Br}(T \to Ht)$$

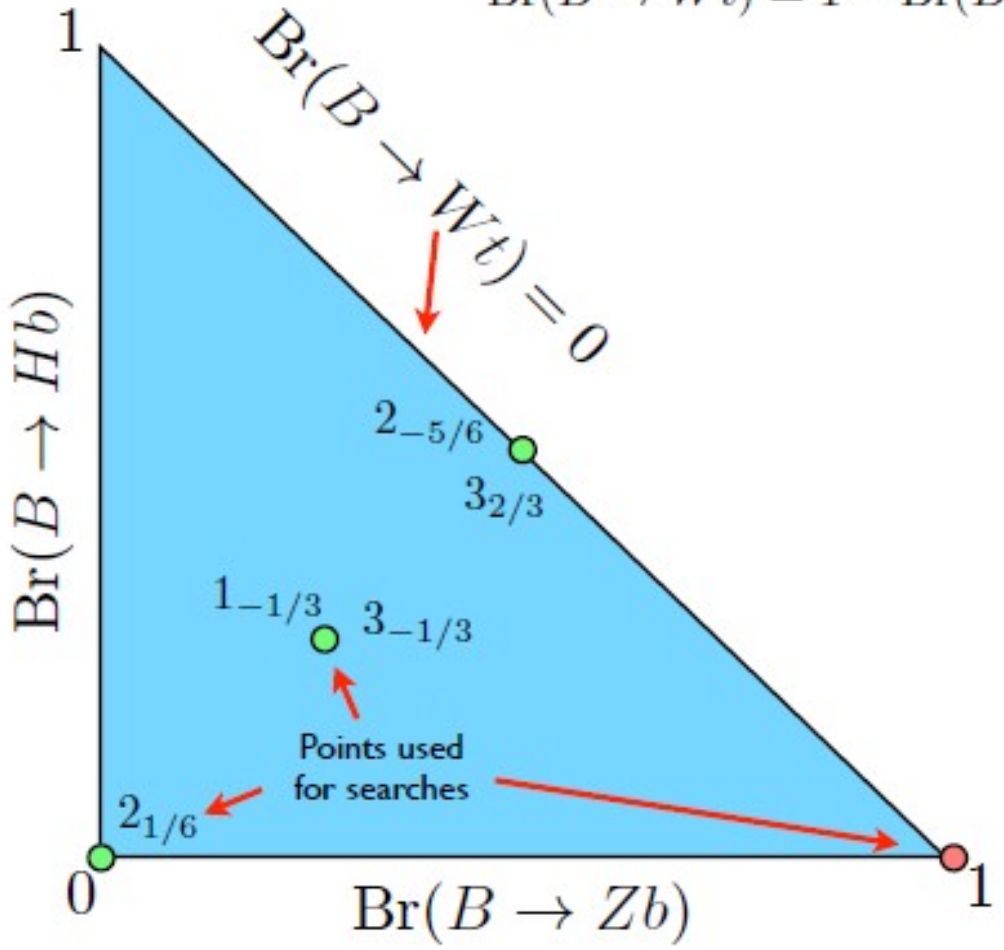




Decays of B

$\mathrm{SU}(2)_L \times \mathrm{U}(1)_Y$ invariance: **3** possibilities

$$\mathrm{Br}(B \to Wt) = 1 - \mathrm{Br}(B \to Zb) - \mathrm{Br}(B \to Hb)$$



Current limits on exotic quarks

T

- ~ 420 GeV $1_{2/3}$, $3_{2/3}$
- ??? $2_{1/6}$, $2_{7/6}$, $3_{-1/3}$

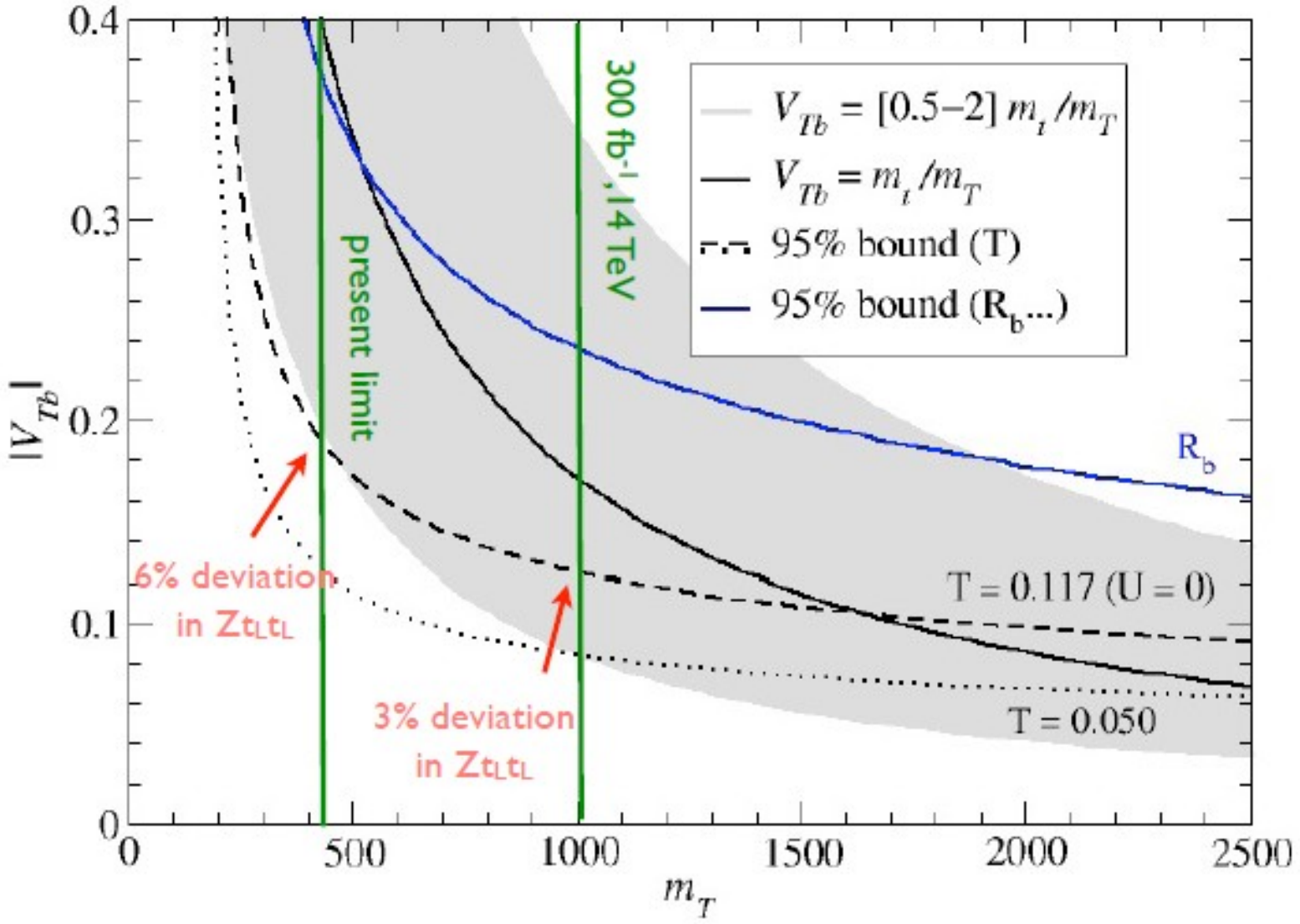
corrections to top couplings observable at ILC

B

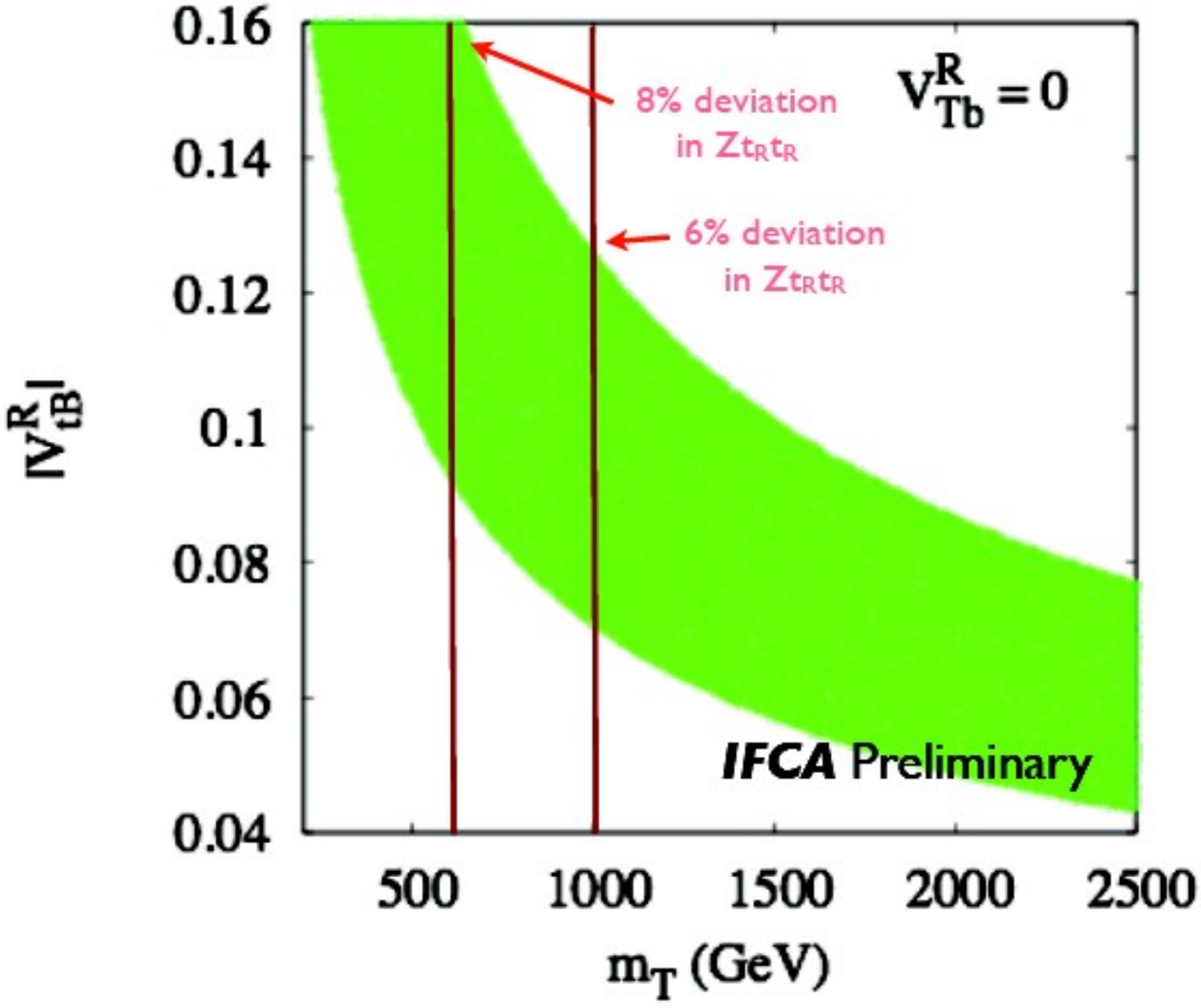
- 611 GeV $2_{1/6}$
- 358 GeV $1_{-1/3}$, $3_{-1/3}$
- ??? $2_{-5/6}$, $3_{2/3}$

Effects on LH top mixing

$T \quad 1_{2/3}$



Effects on RH top mixing $T \quad 2_{1/6}$



Optimistic scenario

New quarks are discovered in 2012 (which is possible)

- deviations expected in top / bottom couplings
- excellent case for ILC (and gigaZ for B-type quarks)

Less optimistic scenario

New quarks are *not* discovered in 2012 (which is also possible)

- still have to wait for 14 TeV run to probe 1 TeV mass range
- if still not discovered, sLHC trivially extends reach, but:
- deviations still at the reach of ILC sensitivity

Conclusions

- New discoveries possible (and motivated) at LHC8
- If no new fermions or vectors are discovered:
  - Possible discovery at LHC14 but no precise measurements
  - HE/HL or ILC necessary for precision measurements

- Other options will be included in the document (new leptons, V-> tt, non-renormalizable couplings, ...)