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Right-handed effects in V_{ub} (and V_{cb})

Outline:

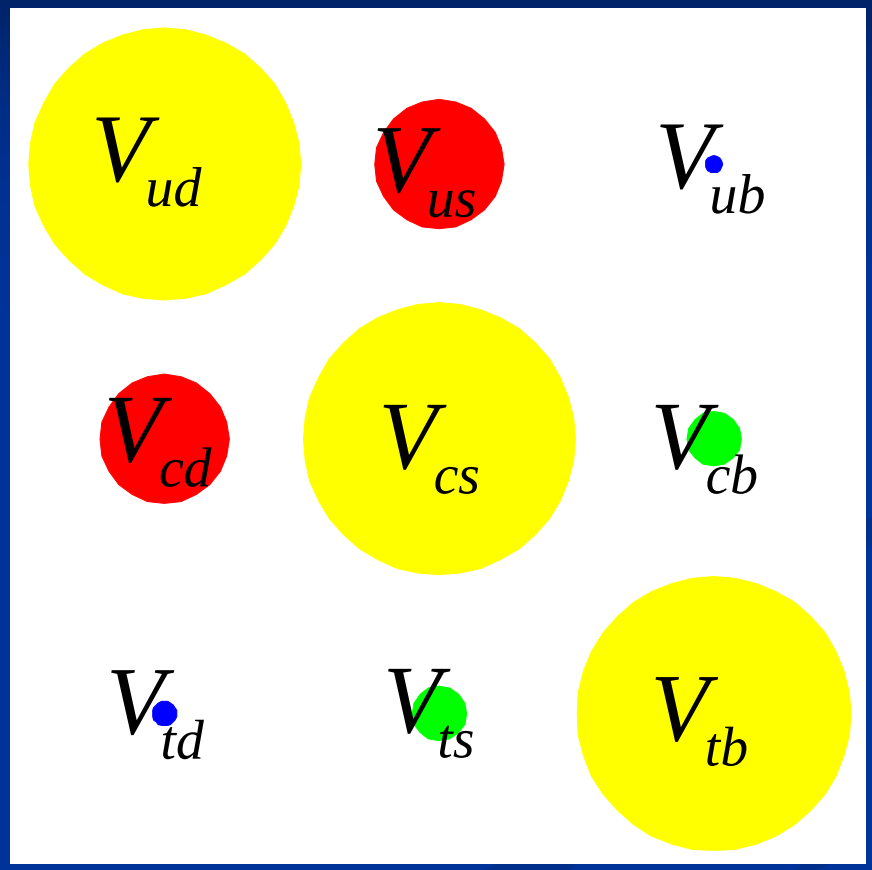
- Right-handed W-coupling in the MSSM
- The determination of V_{ub} and V_{cb} in the presence of a right-handed W-coupling.

Right-handed W-coupling in the MSSM

CKM matrix

- CKM matrix is the only source of flavor and CP violation in the SM.
- No tree-level FCNCs
- Off-diagonal CKM elements are small

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$



➡ Flavor-violation is suppressed in the Standard Model.

SUSY flavor (CP) problem

- The squark mass matrices are not necessarily diagonal (and real) in the same basis as the quark mass matrices.
- Especially the trilinear A-terms can induce dangerously large flavor-mixing (and complex phases) since they don't necessarily respect hierarchy of the SM.
- The MSSM possesses two Higgs-doublets: Flavor-changing charged and (loop-induced) neutral Higgs interactions.

➡ **Why is the observed flavor violation so small?**

- Possible solutions:

  - MFV D'Ambrosio, Giudice, Isidori, Strumia, 2002
  - Flavor-symmetries
  - effective SUSY, split SUSY
  - Radiative flavor violation F. Borzumati et al, 1999. Crivellin et al 2011.

Squark mass matrix

$$M^2_{\tilde{q}} = \begin{pmatrix} M^{\tilde{q}\,2}_{LL} & \Delta^{\tilde{q}\,LR} \\ \Delta^{\tilde{q}\,LR\,\dagger} & M^{\tilde{q}\,2}_{RR} \end{pmatrix}$$

hermitian: $\Rightarrow$ $W^{\tilde{q}\,\dagger} M^2_{\tilde{q}} W^{\tilde{q}} = M^{2(D)}_{\tilde{q}}$

$M^{\tilde{q}\,2}_{LL,RR}$ involves only bilinear terms (in the decoupling limit)

The chirality-changing elements are proportional to a vev

$$\Delta^{d\,LR}_{ij} = -v_d \left(\mu \tan(\beta) Y^{d(0)}_i \delta_{ij} + A^d_{ij} \right)$$

$$\Delta^{u\,LR}_{ij} = -v_u \left(\mu \cot(\beta) Y^{u(0)}_i \delta_{ij} + A^u_{ij} \right)$$

$$\tan(\beta) = \frac{v_u}{v_d}$$

Mass insertion approximation

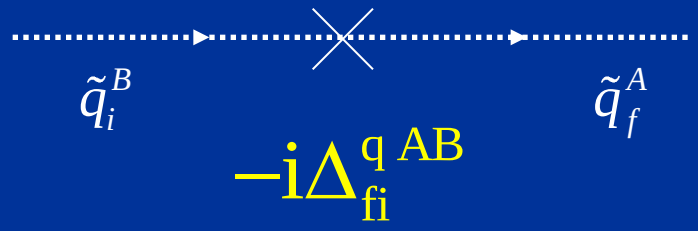
(L.J. Hall, V.A. Kostelecky and S. Raby, Nucl. Phys. B 267 (1986) 415.)

- Useful to visualize flavor-changes in the squark sector

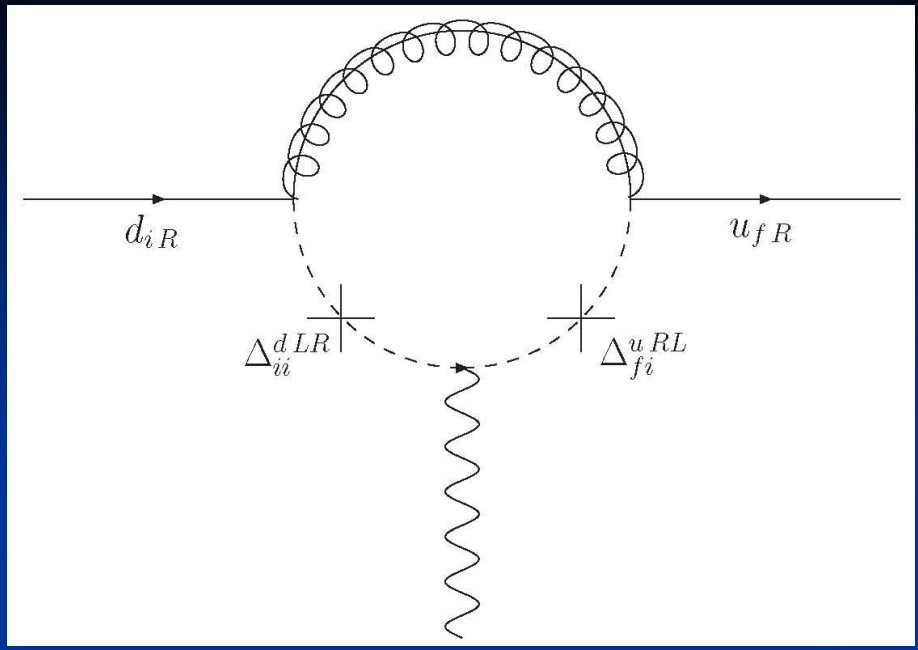
  $\Delta_{ij}^{q\,AB}$ off-diagonal element of the squark mass matrix

- $q = u, d$
- i, j flavor indices 1,2,3
- A, B chiralitys L,R

$$\delta_{fi}^{q\,AB} = \frac{\Delta_{fi}^{q\,AB} v}{\tilde{m}_{\tilde{q}}^2}$$



Genuine vertex-correction



$$-i\Lambda^{W\tilde{g}}_{u_f d_i} = \frac{g_2}{\sqrt{2}}\frac{i\alpha_s}{3\pi}\gamma^\mu \sum_{s,t=1}^{6}\sum_{j,k=1}^{3}\Big(W^{\tilde{u}}_{fs} W^{\tilde{u}*}_{ks} V^{CKM}_{kj} W^{\tilde{d}}_{jt} W^{\tilde{d}*}_{it} P_L + W^{\tilde{u}}_{f+3,s} W^{\tilde{u}*}_{ks} V^{CKM}_{kj} W^{\tilde{d}}_{jt} W^{\tilde{d}}_{i+3,t}{}^{*} P_R \Big) C_2\left(m_{\tilde{u}_s}, m_{\tilde{d}_t}, m_{\tilde{g}}\right)$$

- Corrections to the left-handed coupling suppressed because the hermitian part of the WFR cancels with the genuine vertex correction.
- Right-handed coupling not suppressed!

Where are SUSY effects possible?

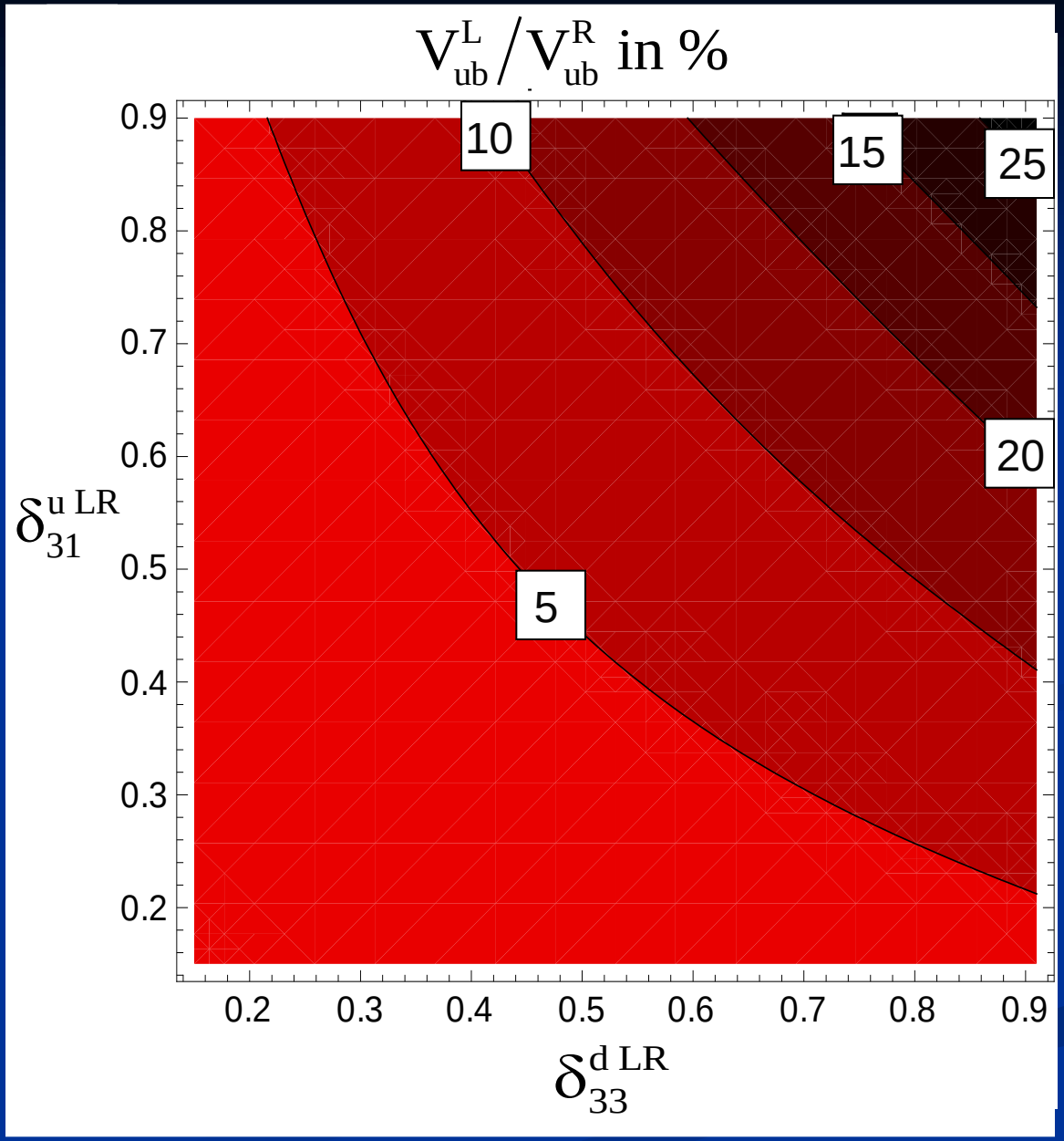
- $\delta^{d\,LR/RL}_{fi}$ strongly constrained from FCNC processes.
- $\delta^{u\,LR}_{13,23}$ less constrained from FCNCs $\left(B \to K^* \ell^+ \ell^-\right)$

  $\delta^{u\,LR,LL,RR}_{12,21}$ constrained from D mixing
- $\delta^{u\,RL}_{13,23}$ unconstrained from FCNCs
- Large $\delta^{d\,LR}_{33}$ possible if A^b or tan(β) is large.
- V_{ud}, V_{us}, V_{cd}, V_{cs} are to large for observable effects

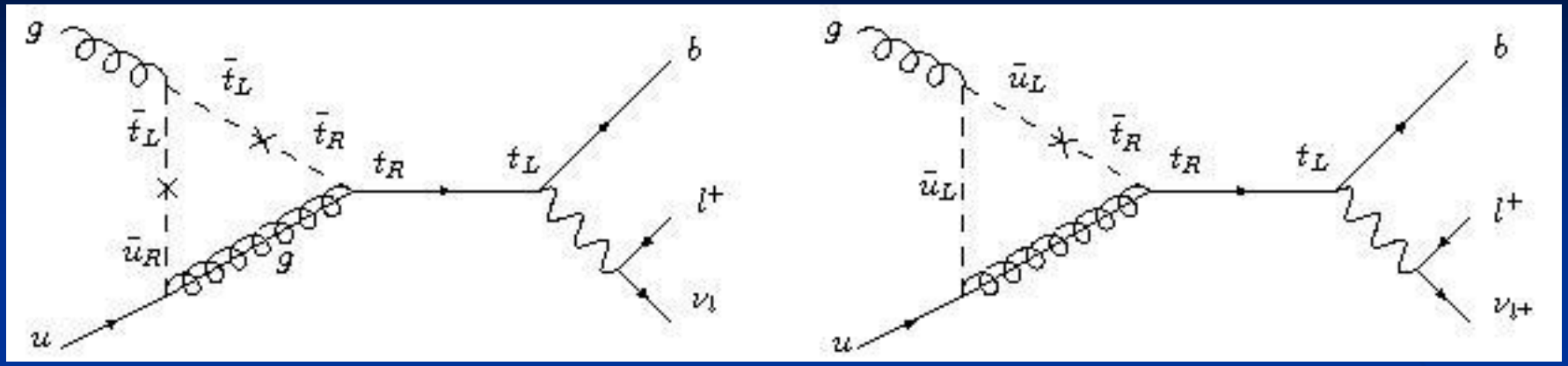
➡ Only V_{ub}, V_{cb} can be affected by SUSY effects.

Largest SUSY effect in V_{ub} possible.

Effect in V_{cb} ≈10% compared to V_{ub}

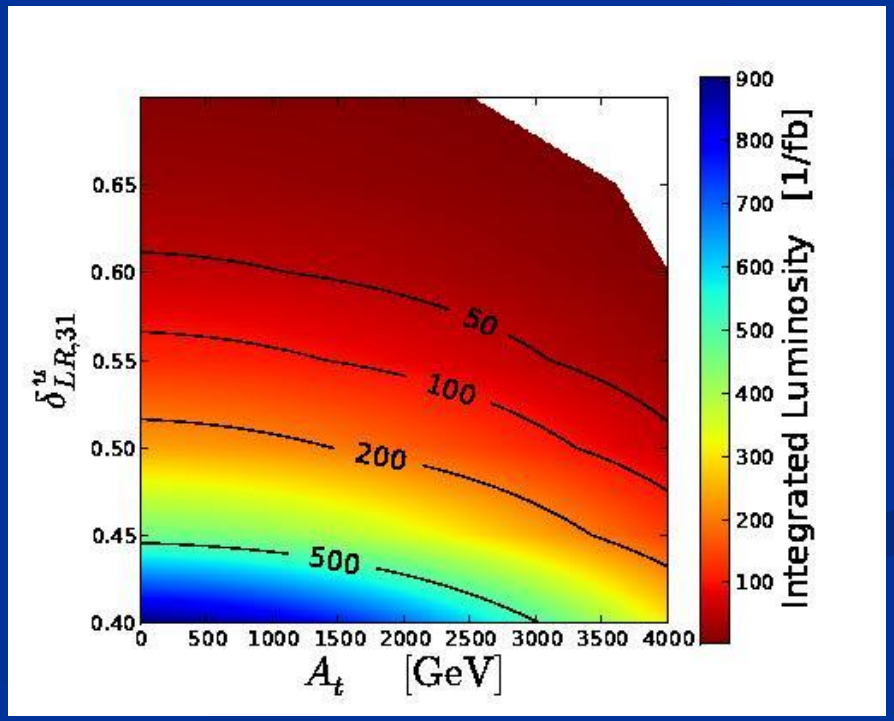


Enhancement of Single-Top Production



Feynman diagrams contributing to single-top production

Integrated luminosity necessary to discover single tops



Plehn, Rauch, Spannowski: 0906.1803

Right-handed W-coupling and the determination of V_{ub} and V_{cb}

Motivation for a right-handed W coupling

- 2.2 σ discrepancy between the inclusive and exclusive determination of V_{cb}
- 2.5 - 2.8 σ deviation from the SM expectation in $B \to \tau\nu$ UTfit, CKMfitter
- Tree-level processes. Commonly believed to be free of NP. (Charged Higgs contribution to $B \to \tau\nu$ is destructive.)

➡ Notoriously difficult to explain the deviations from the SM

Effective field theory

$$L = L_{SM} + \frac{1}{\Lambda}\sum_i C_i Q_i^{(5)} + \frac{1}{\Lambda^2}\sum_i C_i Q_i^{(6)} + O\left(\frac{1}{\Lambda^3}\right)$$

Buchmüller, Wyler Nucl. Phys. B268 (1986)

- $O^{(5)}$ gives rise to neutrino masses
- Focus on the dimension 6 operator

$$Q_{RR} = \bar{u}_f \gamma^\mu P_R d_i \left(\tilde{\phi}^\dagger i D_\mu \phi\right)$$

which generates the anomalous W couplings

$$-i\frac{g_W}{\sqrt{2}}\gamma^\mu\left(P_L V_{fi}^L + P_R V_{fi}^R\right)$$

Possible size of V^R

- V^R_{tb} strongly constrained from b→sγ

  Misiak et. al. 0802.1413

- V^R_{ts} $\left(V^R_{td}\right)$ also constrained from b→sγ (b→dγ)

  A.C. Lorenzo Mercolli arXiv:1106.5499

- No large effect for the first two generations possible because the CKM elements are big and the chirality violation is small.

- Sizable effects possible in V^R_{ub} and V^R_{cb} possible

Right-handed W coupling in exclusive and inclusive B decays

V = measured CKM element

- Exclusive leptonic B decays: $\sim|\gamma^\mu\gamma^5|^2$

  ⟹ $V^L=V+V^R$

- Exclusive semi-leptonic B decays to pseudo-scalar mesons $\sim|\gamma^\mu|^2$

  ⟹ $V^L=V-V^R$

- Exclusive semi-leptonic B decays to vector mesons $\sim|\gamma^\mu\gamma^5|^2$ at $\omega=1$

  ⟹ $V^L=V+V^R$

- Inclusive B→u decay $\sim|1+\gamma^\mu\gamma^5|^2+|1-\gamma^\mu\gamma^5|^2$

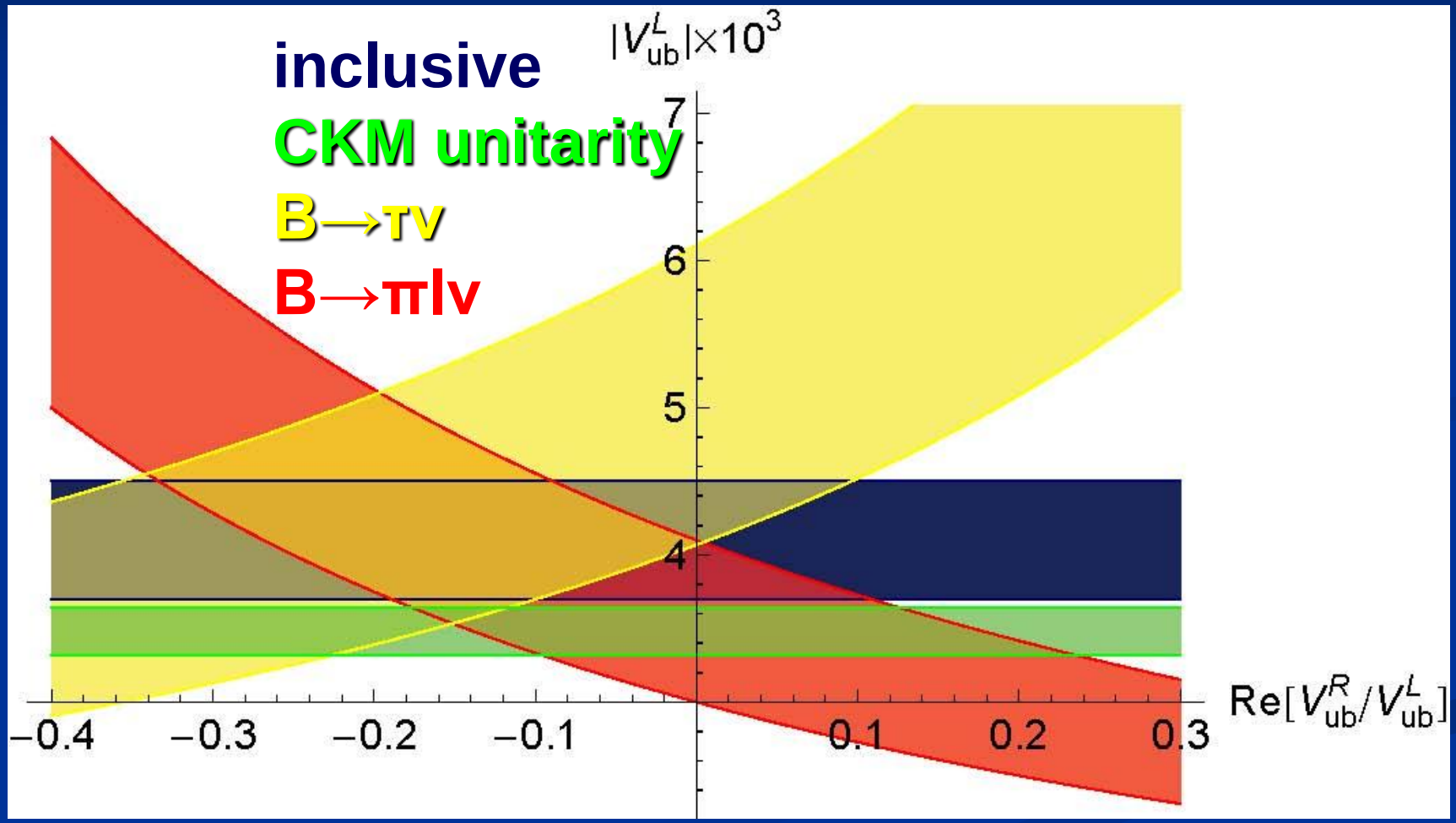
  ⟹ $V^L\approx V$

- Inclusive B→c decay receive correction proportional to m_c/m_b

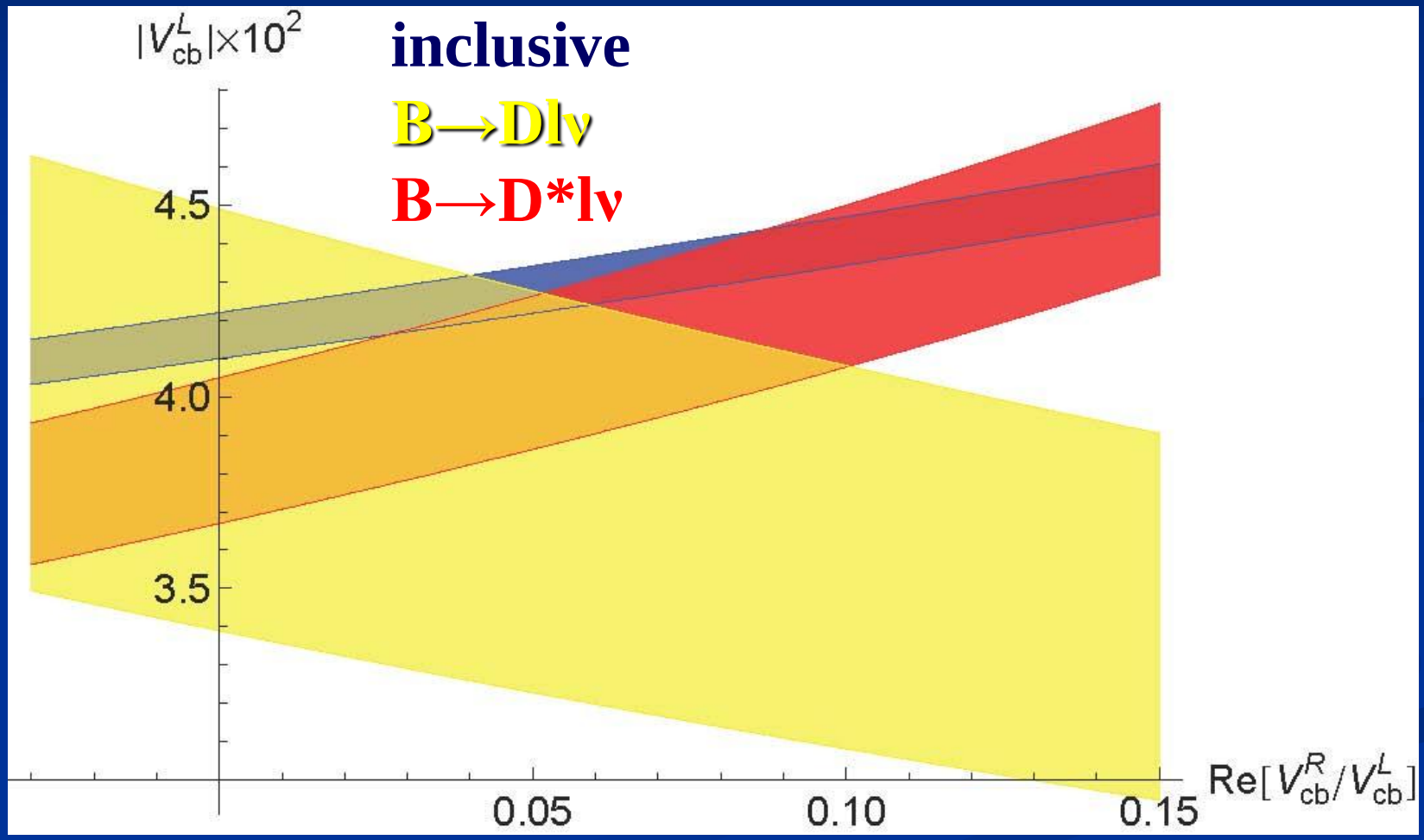
  Dassinger, Feger, Mannel: Complete Michel Parameter Analysis of inclusive semileptonic b→c transition

  ⟹ $V^L=V+0.56V^R$

Effects of a right-handed W-coupling on V_{ub}



Effects of a right-handed W-coupling on V_{cb}



Conclusions

- The MSSM can generate such a sizeable right-handed W-coupling
- A right-handed W-coupling changes the determination of the CKM elements.
- A right-handed W-coupling can enhance $B \to \tau\nu$ and solve the V_{ub} problem