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Tauonic-B decays and 2HDMs

Outline:

- Tauonic B decays
  - $B \to \tau\nu$
  - $B \to D\tau\nu$
  - $B \to D^*\tau\nu$
- Two Higgs Doublet Models
  - Type II
  - Type III
- 2HDM III and the MSSM
- Conclusions

Tauonic B decays

- Tree-level decays in the SM via W-boson
- Sensitive to a charged Higgs due to the heavy tau lepton in the final state.

Observable	SM	Experiment	Significance
$\mathrm{Br}[B \to \tau\nu]$	$\left(0.719^{+0.115}_{-0.076}\right)\times 10^{-4}$	$(1.15 \pm 0.23)\times 10^{-4}$	$1.6\,\sigma$
$\mathrm{Br}[B \to D\tau\nu]/\mathrm{Br}[B \to D\ \ \nu]$	0.297 ± 0.017	0.440 ± 0.072	$2.0\,\sigma$
$\mathrm{Br}\left[B \to D^{*}\tau\nu\right]/\mathrm{Br}\left[B \to D^{*}\ \ \nu\right]$	0.252 ± 0.003	0.332 ± 0.030	$2.7\,\sigma$

➡ All three observables are above the SM prediction

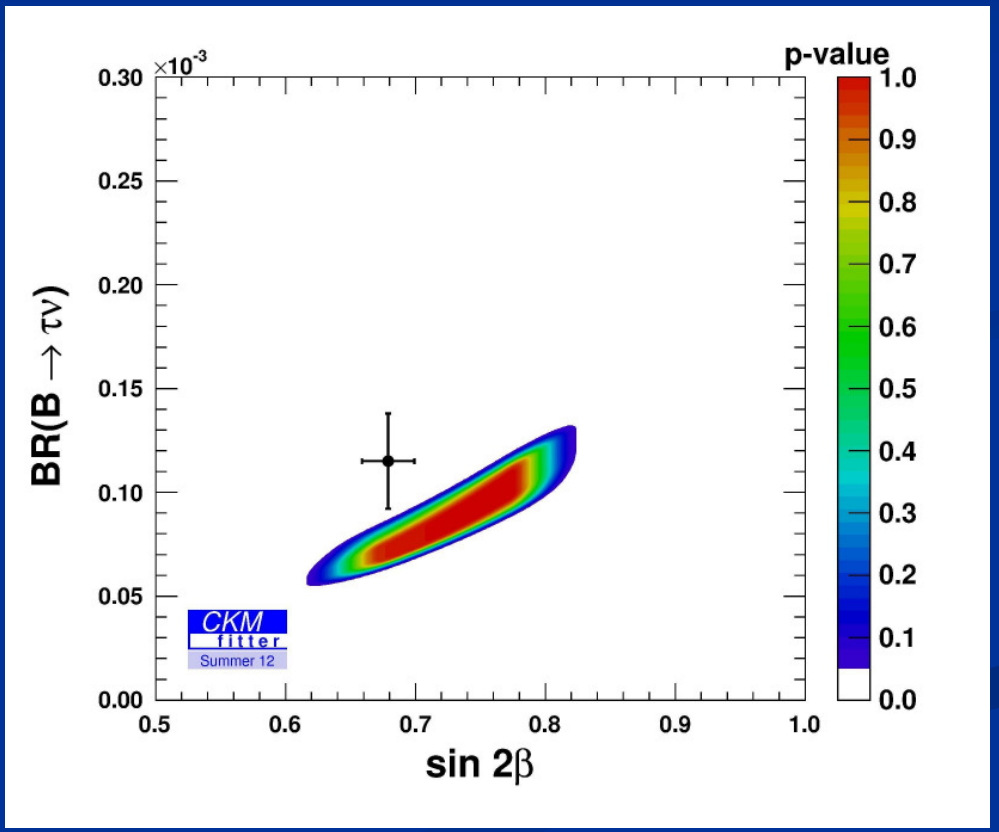
B→τν

$$Br[B \to \tau\nu] = \frac{G_F^2 |V_{ub}|^2}{8\pi} m_\tau^2 f_B^2 m_B \left(1 - \frac{m_\tau^2}{m_B^2}\right) \tau_B \left|1 + \frac{m_B^2}{m_b m_t} \frac{C_R^{ub} - C_L^{ub}}{C_{SM}^{ub}}\right|^2$$

- V_{ub} can be determined from
  - B→πlν
  - inclusive decay
  - Global fit to the CKM matrix

Different determinations do not agree

➡ V_{ub} problem

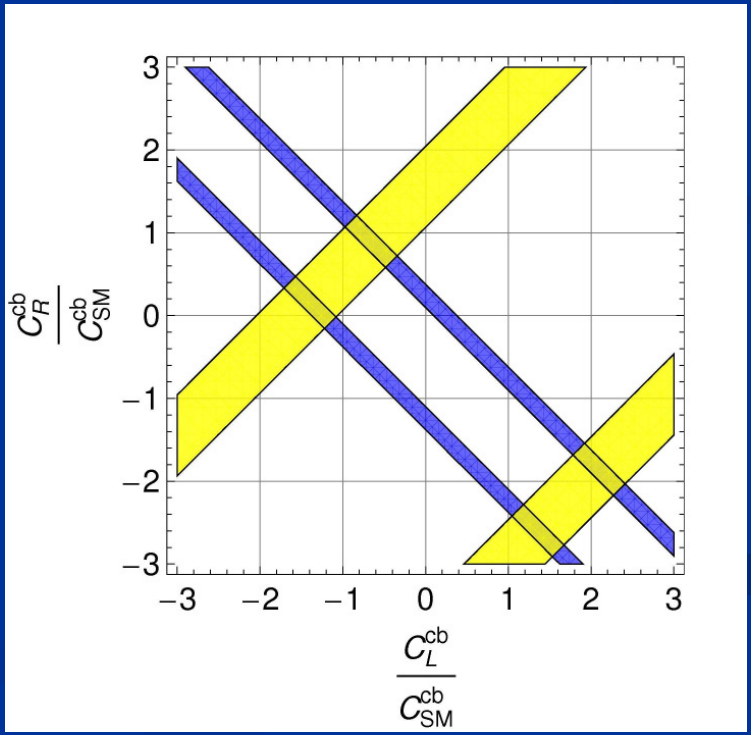


$B \to D^{(*)}\tau\nu$

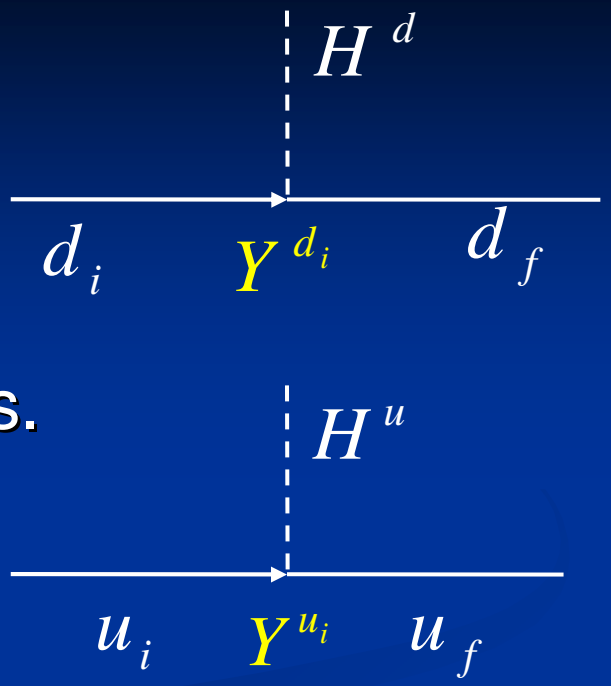
$$R(D) = \frac{\mathrm{Br}[B \to D\tau\nu]}{\mathrm{Br}[B \to D\ \nu]} = R_{SM}(D)\left(1 + 1.5\,\mathrm{Re}\left[\frac{C_R^{cb} + C_L^{cb}}{C_{SM}^{cb}}\right] + 1.0\left|\frac{C_R^{cb} + C_L^{cb}}{C_{SM}^{cb}}\right|^2\right)$$

$$R(D^*) = \frac{\mathrm{Br}[B \to D^*\tau\nu]}{\mathrm{Br}[B \to D^*\ \nu]} = R_{SM}(D^*)\left(1 + 0.12\,\mathrm{Re}\left[\frac{C_R^{cb} - C_L^{cb}}{C_{SM}^{cb}}\right] + 0.05\left|\frac{C_R^{cb} - C_L^{cb}}{C_{SM}^{cb}}\right|^2\right)$$

- Form factors uncertainties drop out to a large extend in the rations R(D) and R(D*).
- R(D*) less sensitive to NP
- C_R cannot explain R(D) and R(D*) simultaneously but C_L can.



2HDM of type II



- One Higgs doublet couples only to down-quarks the other Higgs doublet only to up-quarks.
- 2 additional free parameters: $\tan(\beta)=v_u/v_d$ and the heavy Higgs mass M_H
- Neutral Higgs-quark couplings are flavour-conserving.
- Chagred Higgs contribution to $b\to s\gamma$ requires $m_H > 380$ GeV T. Hermann, M. Misiak and M. Steinhauser 1208.2788

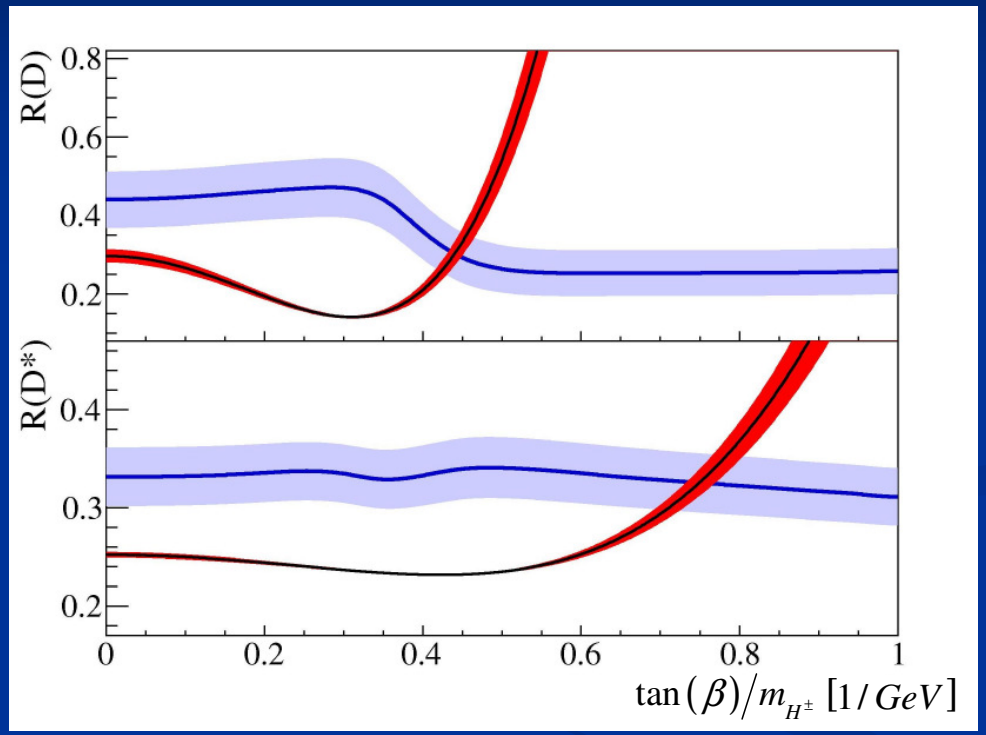
Tauonic B decays in the 2HDM II

$$C_R^{qb} = \frac{-1}{m_{H^\pm}^2} V_{qb} \frac{m_b m_\tau}{v^2} \tan^2(\beta)$$

$$C_L^{qb} \approx 0$$

- Contribution to $B \to \tau\nu$ necessarily destructive.
- $\tan(\beta)/m_{H^\pm}$ needed for R(D*) too large.
- Cannot explain $B \to D^{(*)}\tau\nu$ and $B \to D\tau\nu$ simultaneously.
  BaBar collaboration 1205.5442

➡ Disfavored by current data



arXiv:1205.5442

measurement

theory prediction

2HDM of type III

- Both Higgs doublets couple simultaneously to up and down quarks ➡ Flavour-changing neutral Higgs couplings

- All flavour-changing elements ε^d_{fi} and $\varepsilon^u_{12,21}$ are constrained from FCNCs processes.
- Also $\varepsilon^u_{13,23}$ constrained from charged Higgs diagrams, but $\varepsilon^u_{31,32}$ is unconstrained.
- Contribution to tauonic B decays $\varepsilon^u_{31,32}$ unconstrained from FCNCs

$$C_L^{qb} \approx \frac{\varepsilon^{u*}_{3q}}{m^2_{H^\pm}} \frac{m_\tau}{v} \tan(\beta)$$

- 2HDM III with MFV cannot explain $B \to \tau\nu$, $B \to D^{(*)}\tau\nu$ and $B \to D\tau\nu$

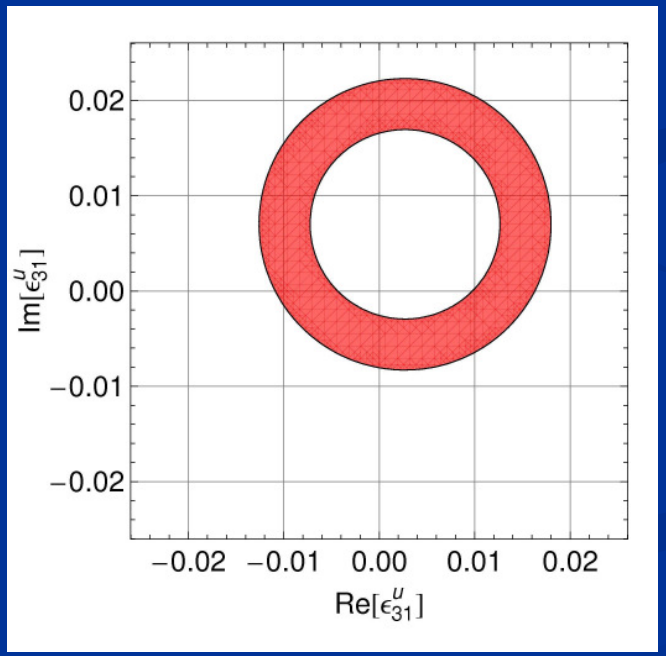
2HDM of type III with flavour-violation in the up-sector

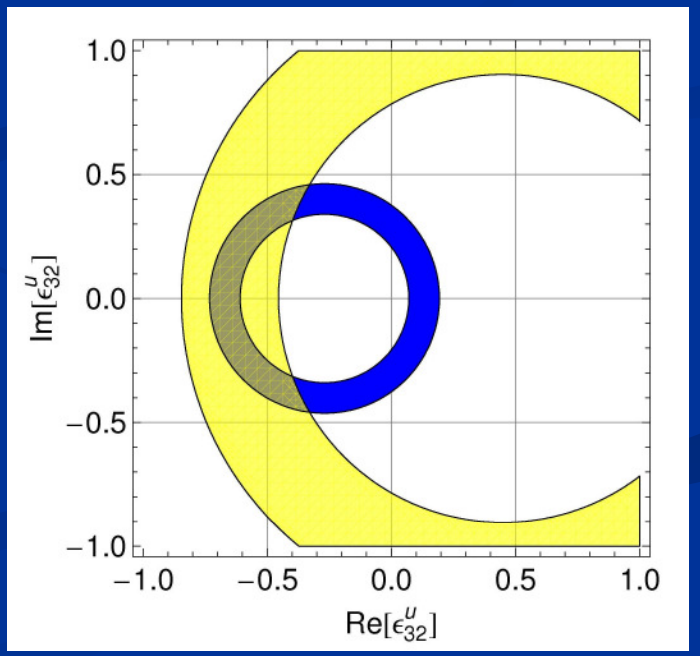
A.C., C. Greub, A. Kokulu 1208.2788

- Constructive contribution to B→τν using ε^u_{31} is possible.
- B→D$^{(*)}$τν and B→Dτν can be explained simultaneously using ε^u_{32}. ➡ Check model via $H^0, A^0 \to \bar{t}c$

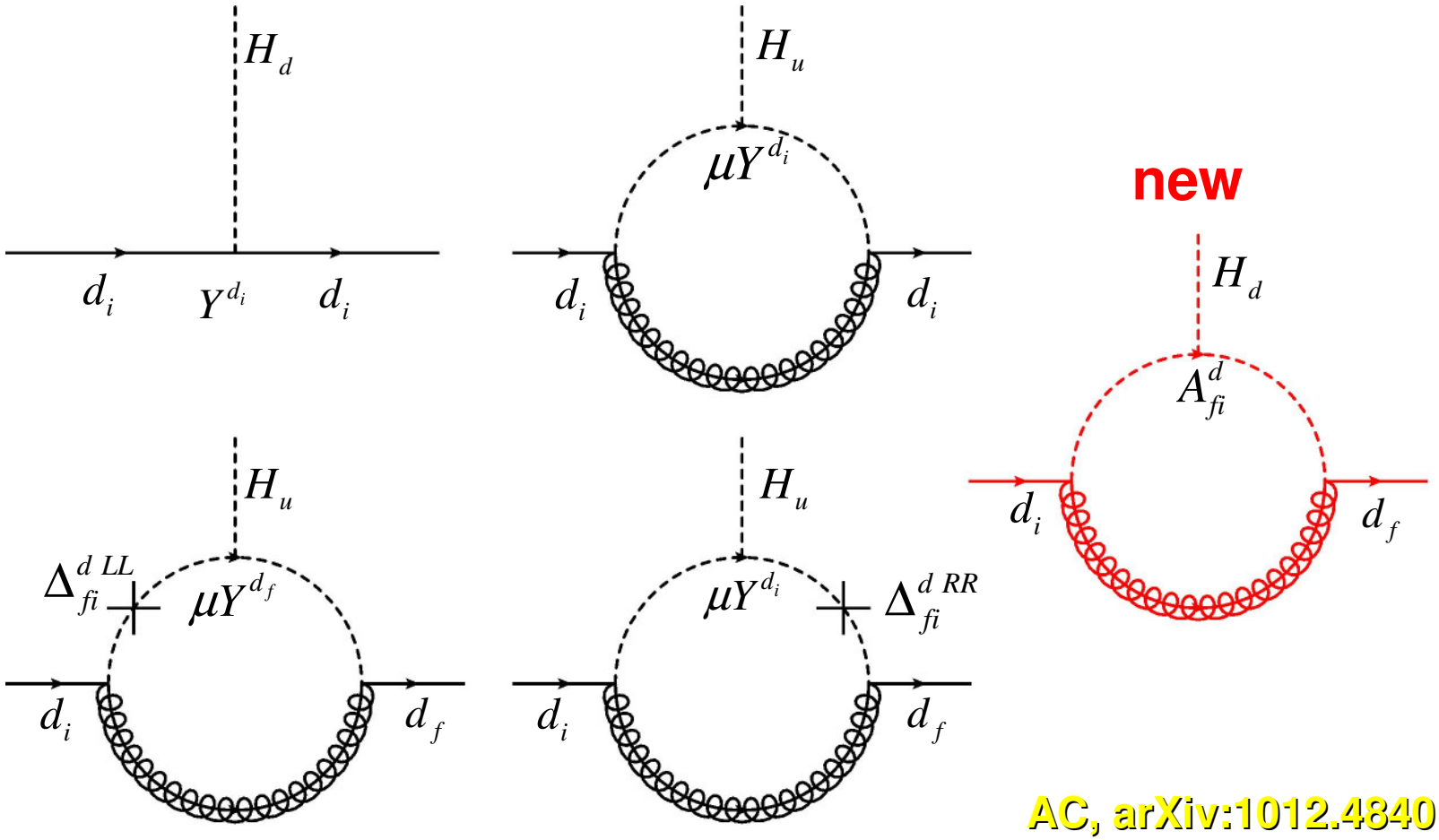
Allowed regions from:

- $B \to D\tau\nu$
- $B \to D^*\tau\nu$
- $B \to \tau\nu$





Effective Higgs-quark-quark vertices in the MSSM



AC, arXiv:1012.4840

MSSM and the decoupling limit

- Effective Higgs vertices generate important threshold corrections to the relation between Yukawa couplings and quark masses.

  ➡ Resummation of all (tan(β)) enhanced contribution necessary.

  L. Hall, R. Rattazzi, U. Sarid hep-ph/9306309,
  A.C., L. Hofer, J. Rosiek, arXiv:1103.4272

- MSSM corrections are too small to generate $\varepsilon^{u}_{32,31}$ needed for $B \to \tau\nu$ and $B \to D^{(*)}\tau\nu$.

- NLO calculation in preparation including analytic results and tan(β) resummation in the generic MSSM.

  Δ_b at order α_s^2 A.C., Christoph Greub arXiv:1012.xxxx

Conclusions

- First hints for violation of lepton universality tauonic B-decays.
- 2HDM II disfavored by current data.
- 2HDM of type III with flavour-violation in the up-sector can explain the $B \to \tau\nu$, $B \to D^{*}\tau\nu$ and $B \to D\tau\nu$.
- 2HDM III is the decoupling limit of the MSSM ➡ NLO matching is important.

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