

Cristian Sierra

Tsung-Dao Lee Institute, Shanghai Jiao Tong University
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Abstract

The general 2HDM allows for off-diagonal flavour violating couplings in the quark sector which are strongly constrained by experiments in traditional 2HDMs. We study how the allowed parameter space of the general 2HDM changes once interactions between 1-3 and 2-3 quark generations are included, generating new interference terms in the one loop diagrams relevant for meson mixing constraints and radiative decays. We show that this interference effect plays a crucial role in simultaneously fitting those constraints and the so-called charged current flavour anomalies. These couplings can be probed and further constrained by current and future measurements by the ATLAS detector via multi-top decay searches with multi-lepton and b-tagged jets.

General 2HDM

The SM is extended by a second Higgs doublet that couples to all fermions [1]:

$$\Phi_i = \begin{pmatrix} \phi_i^+ \\ \frac{1}{\sqrt{2}}(v_i + \xi_i + i\eta_i) \end{pmatrix}, \quad i = 1, 2.$$

$$\begin{pmatrix} G_{W^\pm} \\ H^\pm \end{pmatrix} = R_\beta \begin{pmatrix} \phi_1^\pm \\ \phi_2^\pm \end{pmatrix}, \quad \begin{pmatrix} H \\ h \end{pmatrix} = R_\alpha \begin{pmatrix} \xi_1 \\ \xi_2 \end{pmatrix}$$

$$\begin{pmatrix} G_Z \\ A \end{pmatrix} = R_\beta \begin{pmatrix} \eta_1 \\ \eta_2 \end{pmatrix} \quad R_\theta = \begin{pmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{pmatrix}$$

$$-\mathcal{L}_{Yukawa} = \bar{u}_b (V_{bc} \rho_d^{ca} P_R - V_{ca} \rho_u^{cb*} P_L) d_a H^+ + \bar{\nu}_b \rho_\ell^{ba} P_R l_a H^+ + \text{h.c.} \\ + \sum_{f=u,d,\ell} \sum_{\phi=h,H,A} \bar{f}_b \Gamma_f^{\phi ba} P_R f_a \phi + \text{h.c.},$$

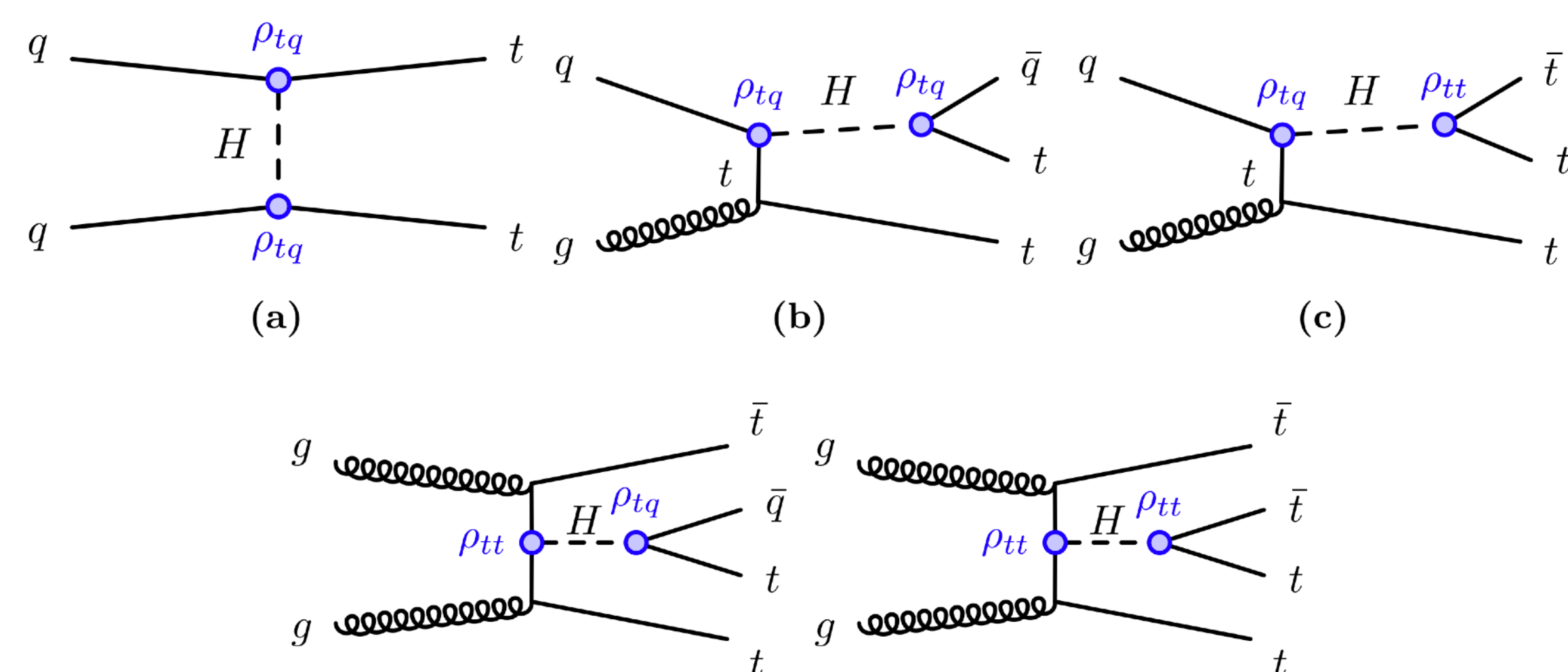
$$\Gamma_f^{Hba} \equiv \frac{\bar{M}_f^{ba}}{v} c_{\beta\alpha} - \frac{1}{\sqrt{2}} \rho_f^{ba} s_{\beta\alpha}$$

Allowing for flavour changing (FV) transitions which are not CKM suppressed:

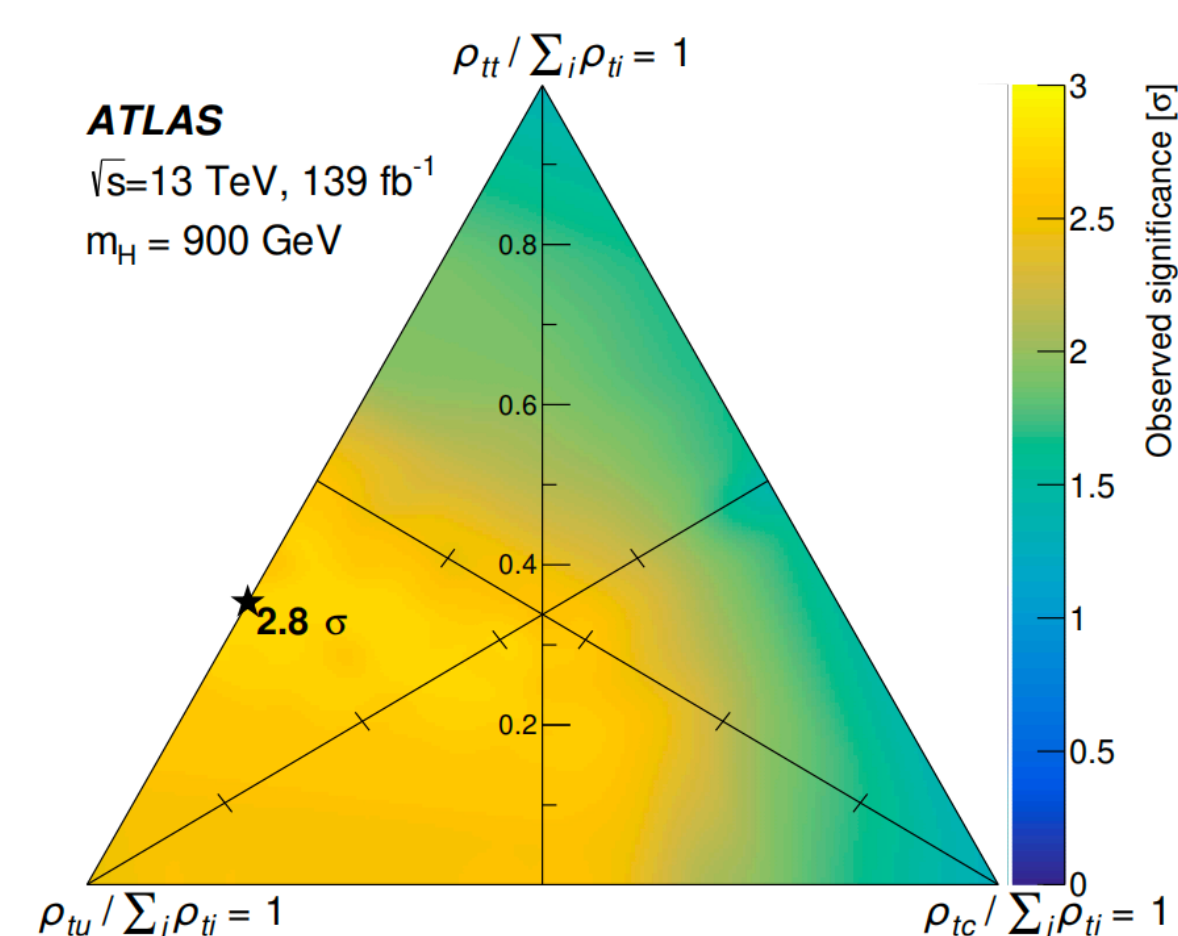
$$\begin{array}{c} \bar{q} \\ \swarrow \\ \text{---} H \text{---} \\ \searrow \\ t \end{array} \propto \rho_u^{tq} \quad q = u, c$$

Multi-top production@ATLAS

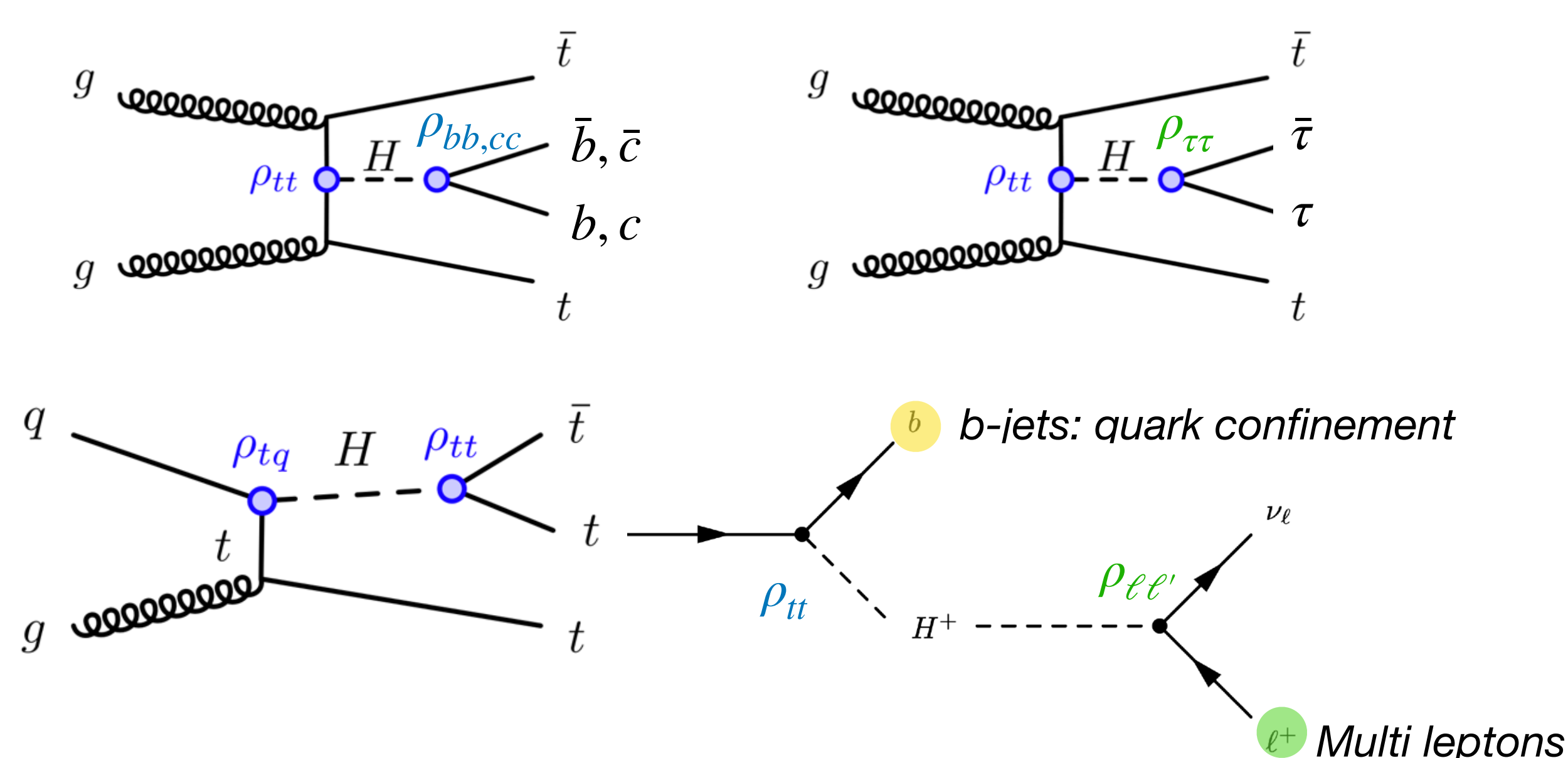
ATLAS [2] searched for heavy Higgses with FV couplings with the top quark



And found an excess at 2.8σ with $\rho_{tt} = 0.6, \rho_{tc} = 0.0$ and $\rho_{tu} = 1.1$

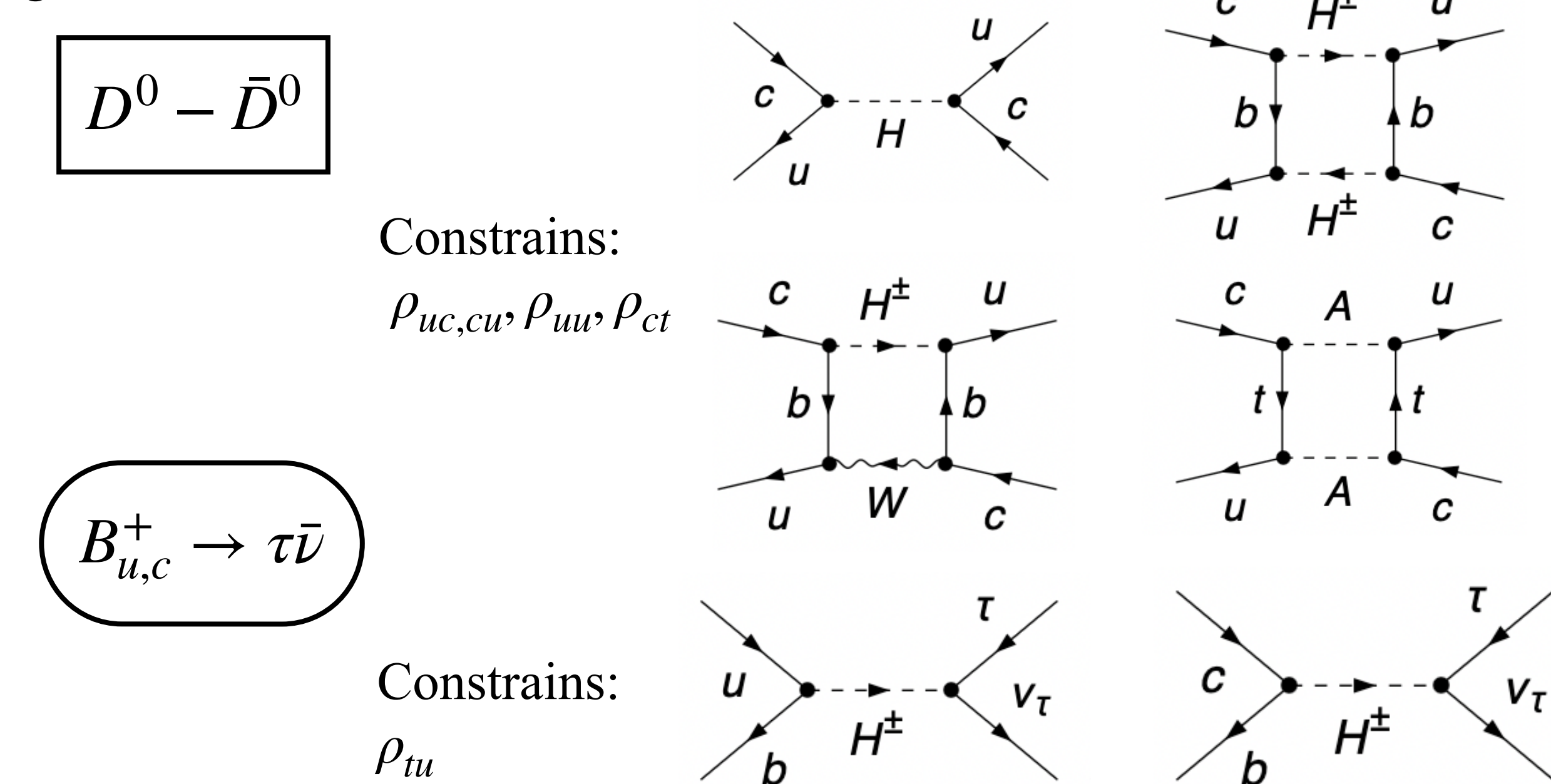


However with $\mu = 0.07 \pm 0.03$. In the new study we turn on new couplings:

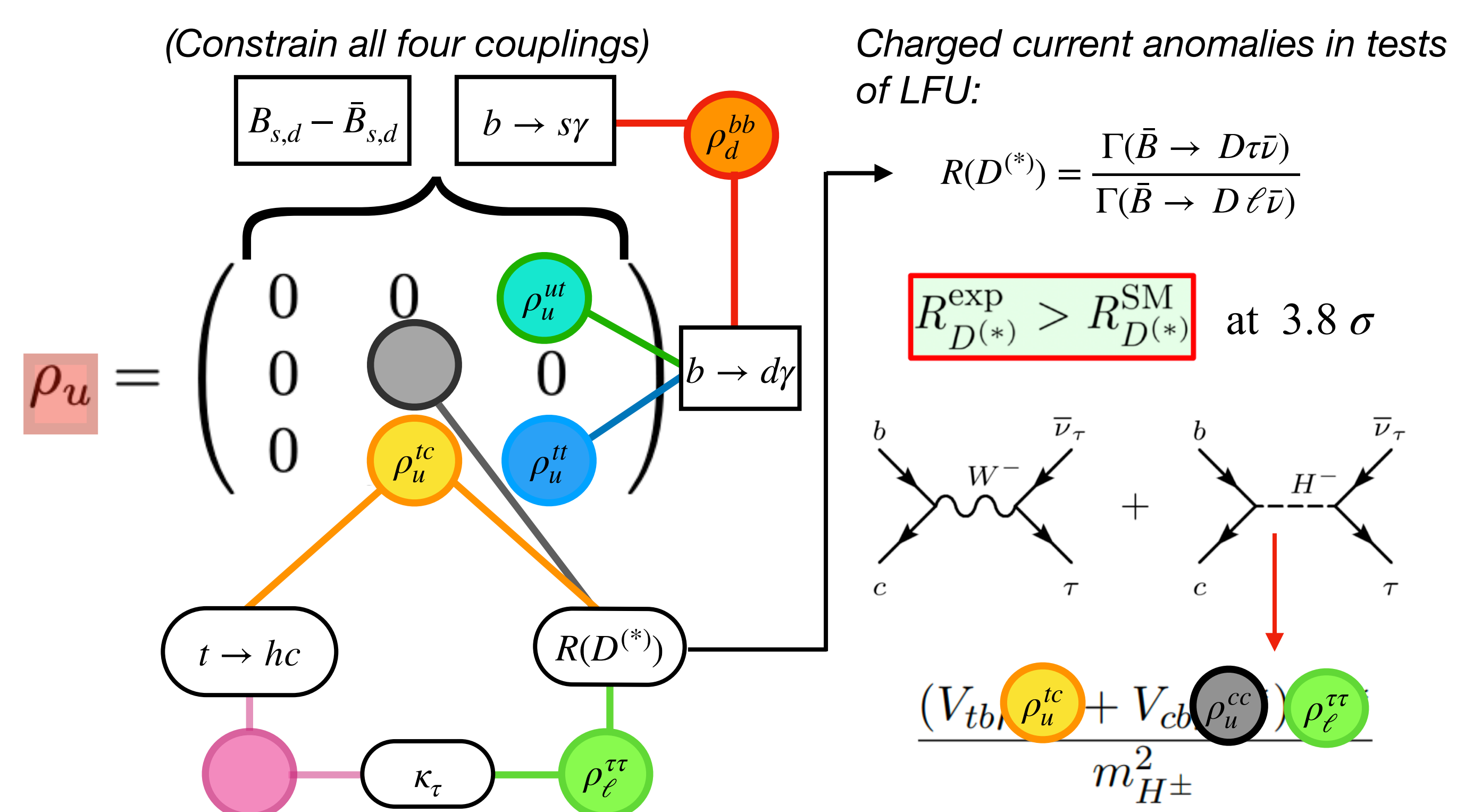


Flavour constraints

All FV couplings are constrained from flavour physics [1,3]. The new diagrams generate interferences:

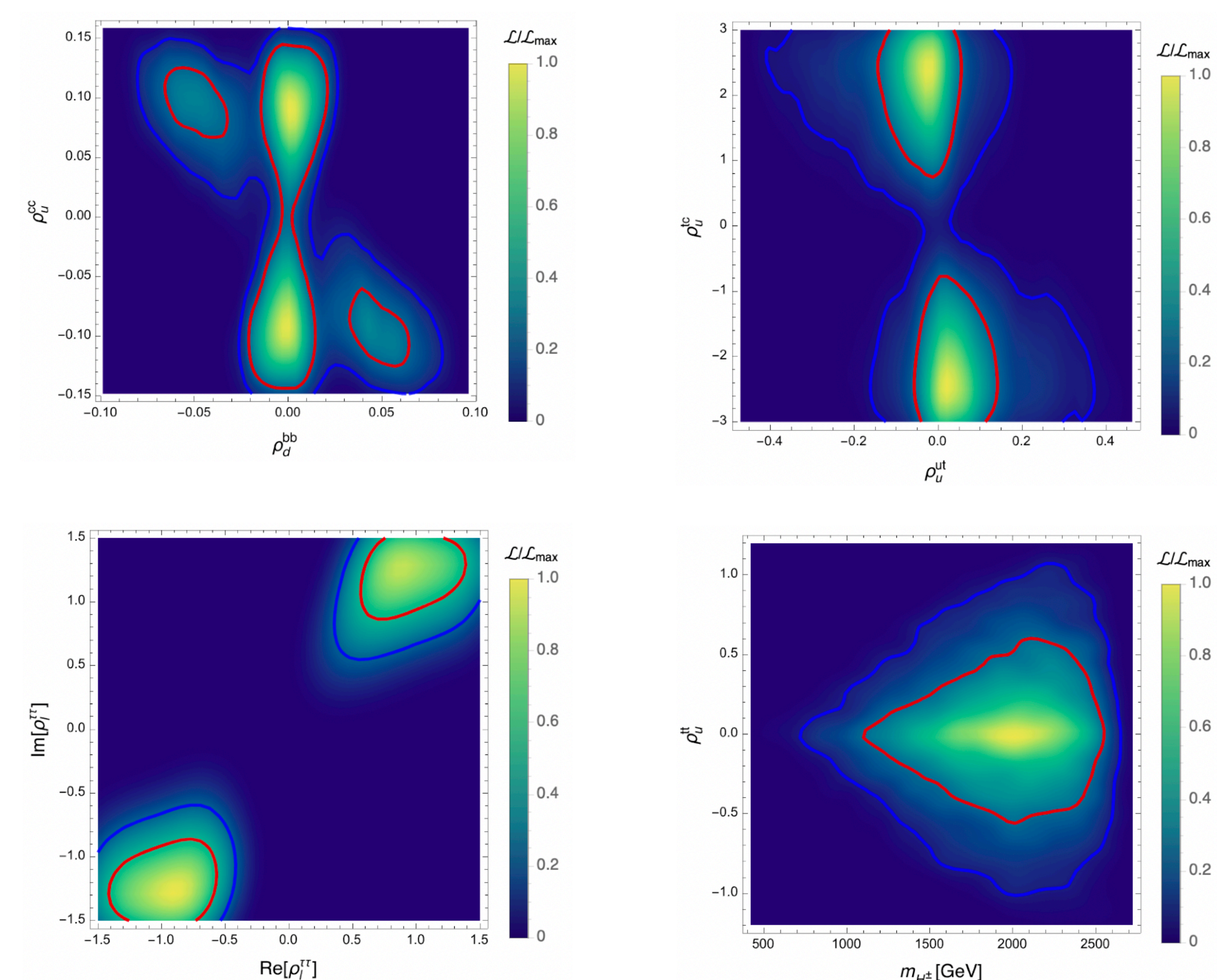


Boxes indicate process at 1-loop while ovals are tree-level decays.

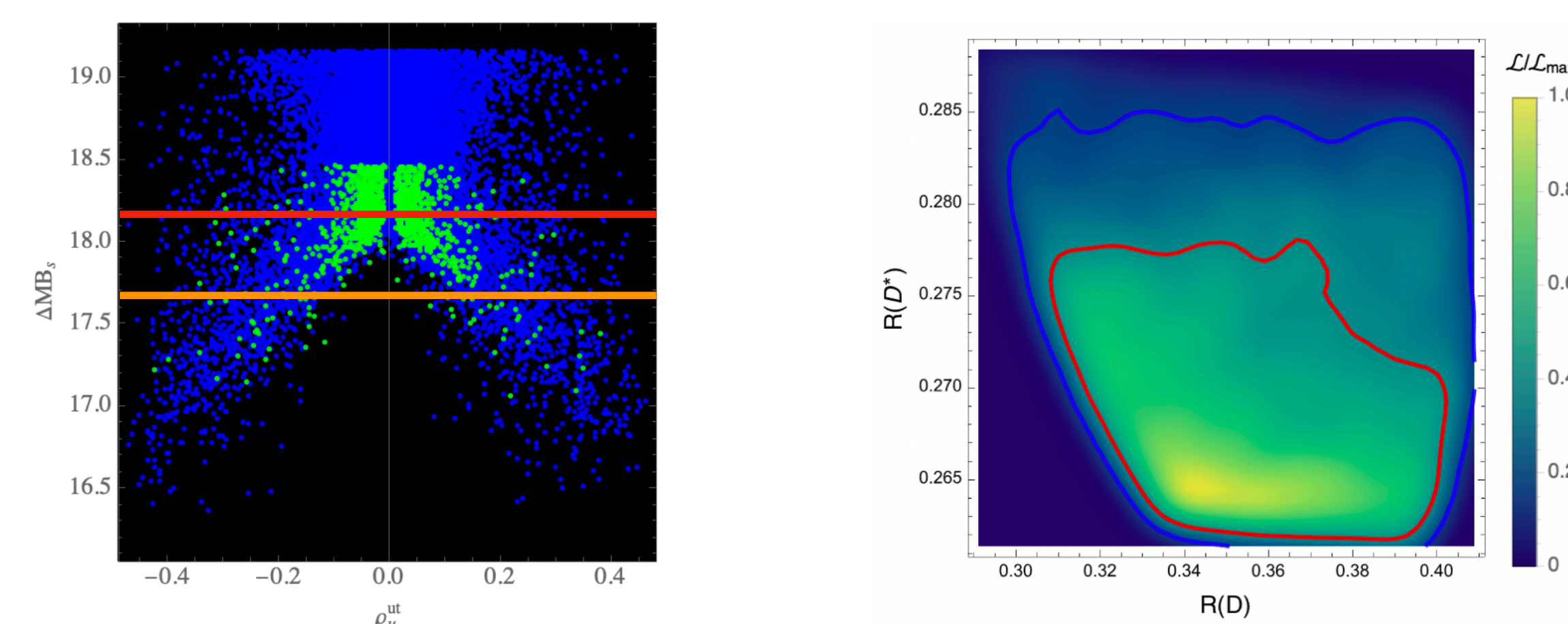


Results

The parameter space is constrained, obtaining allowed ranges for the couplings



On the left non-zero ρ_{tu} fits $\Delta M_{B_u}^{\text{exp}}$ (orange) better w.r.t the SM prediction (red). On the right we see the model can fit the charged anomalies at 1σ .



References

1. Peter Athron; Andreas Crivellin; Tomas Gonzalo; Syuhei Iguro; CS, JHEP, 2024, 11(2024)133: 1-32.
2. ATLAS Collaboration, JHEP 12 (2023) 081, arXiv: 2307.14759 [hep-ex].
3. Peter Athron; Csaba Balazs; Tomas Gonzalo; Douglas Jacob; Farvah Mahmoudi; CS, JHEP, 2022, 2022(37): 1-50.
4. A. Juste Rozas, CS, T. Vasquez, Y. Wu, Interference effects from flavour physics in the general 2HDM and LHC multi-top probes. WIP.