Up sector Minimal Flavor Violation

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Based on:
Y. Bai, J.B., J. Hewett, Y. Li: 1305.5537

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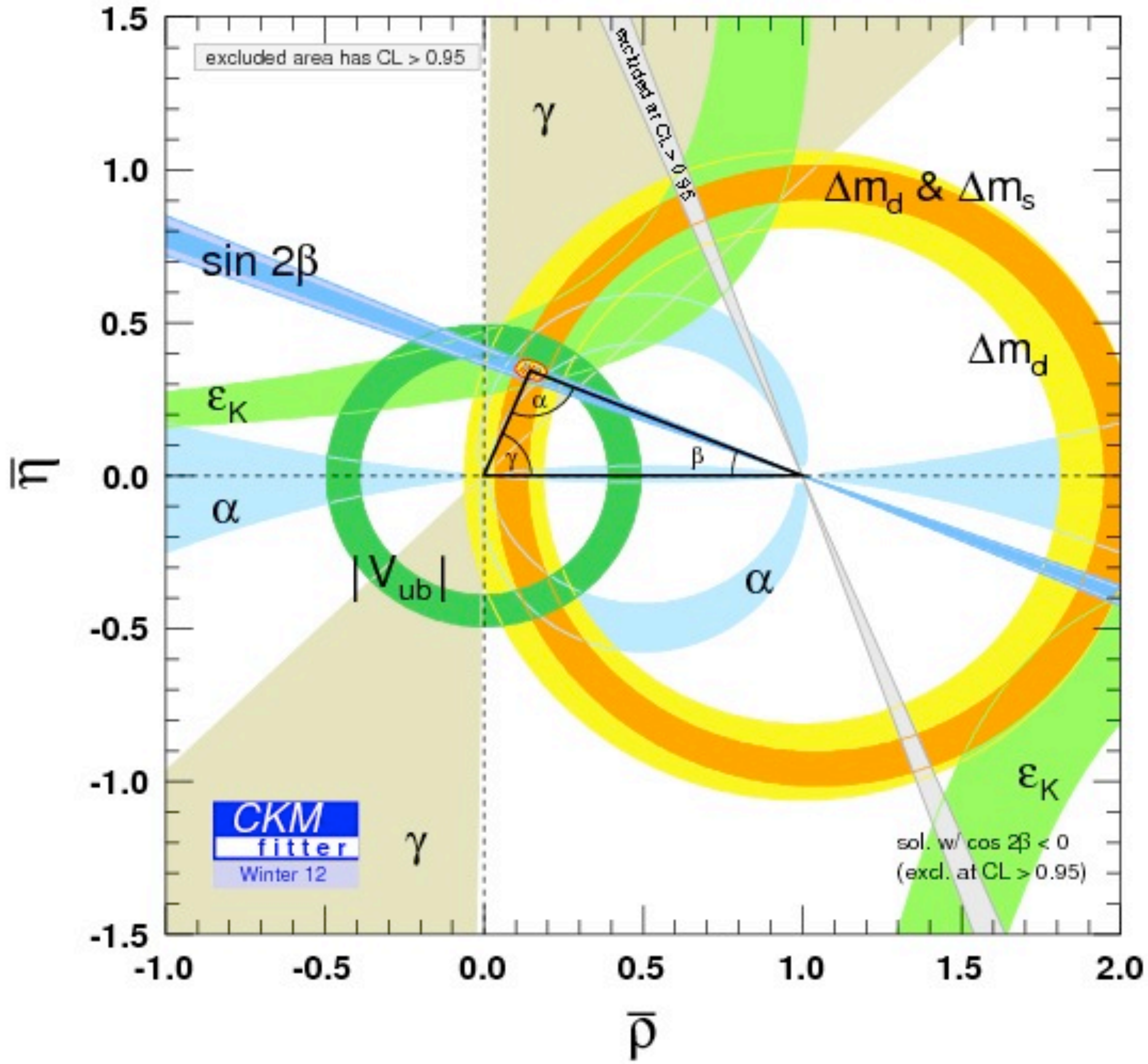
Flavor Status Report



Flavor Status Report

Bounds Λ for $(\overline{f_i}\, f_j)(\overline{f_k}\, f_l)$

- $\Delta F = 2 \rightarrow 10^2$ TeV - 10^5 TeV

Hewett, Weerts, et. al.: 1205.2671
D'Ambrosio, Giudice, Isidori, Strumia: hep-ph/0207036

- $\Delta F = 1$ semi-leptonic $\rightarrow 10^2$ TeV - 10^5 TeV
- $\Delta F = 1$ hadronic? Much harder...
- Top sector? Just getting started...
- Possible NP CP violation in $D \rightarrow KK, \pi\pi$

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Minimal Flavor Violation

- All flavor violation (incl. BSM) proportional to SM Yukawa matrices
- Treat Yukawas as "spurions" under flavor $SU(3)_Q \times SU(3)_U \times SU(3)_D \times SU(3)_L \times SU(3)_E$
- New fields also charged under flavor
- Constraints decrease to $\mathcal{O}$(1 TeV)

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The Hardest Case?

- Focus on up-sector: Top and D physics
- Focus on hadronic operators
- Impose Minimal Flavor Violation
- Are there models? Can we see them?

The Punchline

- New model possible with extremely light (< 100 GeV) new states
- Gives novel signatures in top production and decay
- Could explain D-meson CP violation

Operators & Models

The ΔF = 1 Operators

- Catalog all possible operators that give only ΔF = 1
- Focus on two (out of four) operators that can have new CPV phases

$$\mathcal{O}_{V2} = 2V_{il}(\lambda_D^\dagger V^\dagger \lambda_U)_{kj}(\bar{u}^i_{L\alpha} u^j_{R\alpha})(\bar{d}^k_{R\beta} d^l_{L\beta})$$

$$\mathcal{O}_{S2} = \frac{1}{2}(\lambda_U^\dagger V)_{il}(\lambda_D^\dagger V^\dagger)_{kj}(\bar{u}^i_{R\alpha} u^j_{L\alpha})(\bar{d}^k_{R\beta} d^l_{L\beta})$$

- Λ ~ 10 GeV for D-meson CPV

The Model

- New gauge-neutral particle w/ flavor charge
- Can be as light as 10 GeV
- Couples only to quarks w/ FV suppressed by Yukawas + CKM
- Several flavor charges allowed

A Prototype Example

$$\mathcal{L} \supset \kappa_{U_L}\, \overline{u}^i_R (\lambda^\dagger_U V)^{il} \phi_{lk} (\lambda^\dagger_D V^\dagger)^{kj} u^j_L$$
$$+\ \kappa_{U_R}\, \overline{u}^i_L V^{il} \phi_{lk} (\lambda^\dagger_D V^\dagger \lambda_U)^{kj}\, u^j_R$$
$$+\ \kappa_D\, \overline{d}^k_R (\phi^\dagger)_{kl} d^l_L \ +\ \text{h.c.}$$

- Down-sector: FV
- Up-sector: suppressed by Yukawas λ_U, λ_D, CKM matrix V
- Define $\overline{\kappa_i} = \kappa_i\, \lambda_t\, \lambda_b$

Top Properties

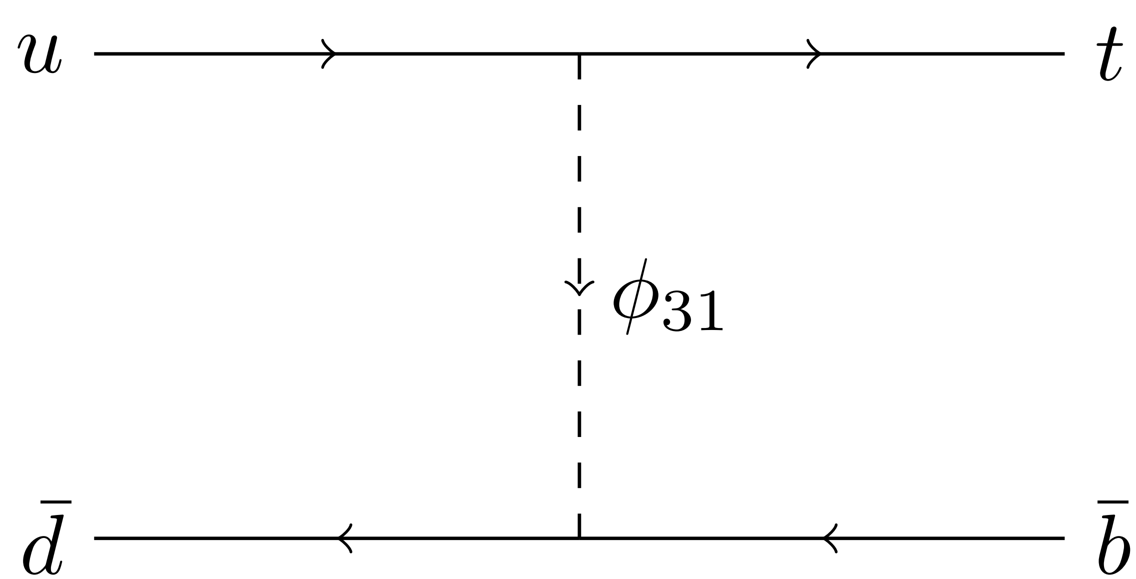
The Dominant Effects

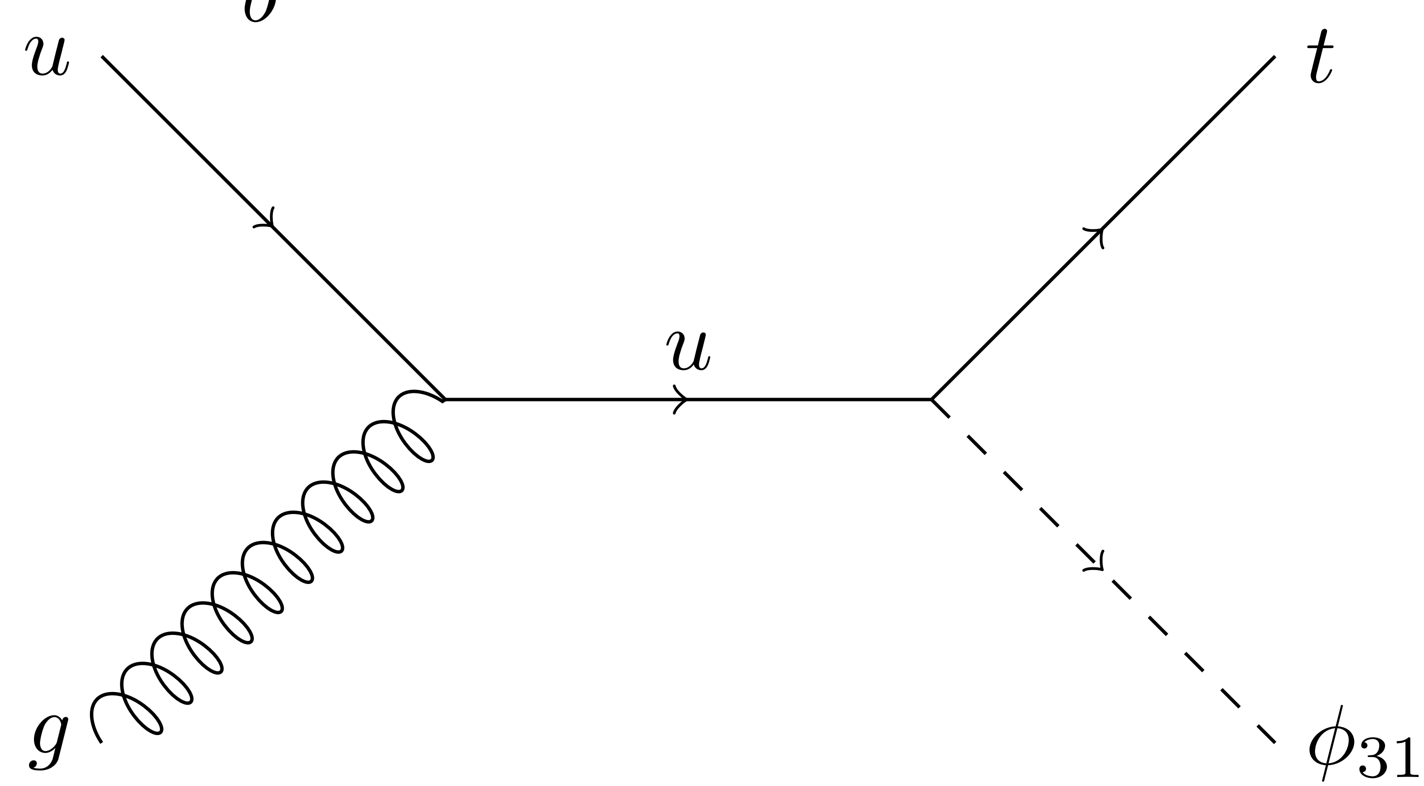
- Single top production ($u\bar{d} \to t\bar{b}$, $ug \to t\varphi$)!
- Top pair production ($q\bar{q} \to t\bar{t}$)!
- Top decays ($t \to q\varphi$)!

Some details...

- Only $\overline{\kappa}_{UR}$ contributes significantly
- $\overline{\kappa}_{UL}$ always gets u/c Yukawa suppression or CKM angle suppression
- Dominant constraint: single top
- Non-standard top decay → smoking gun

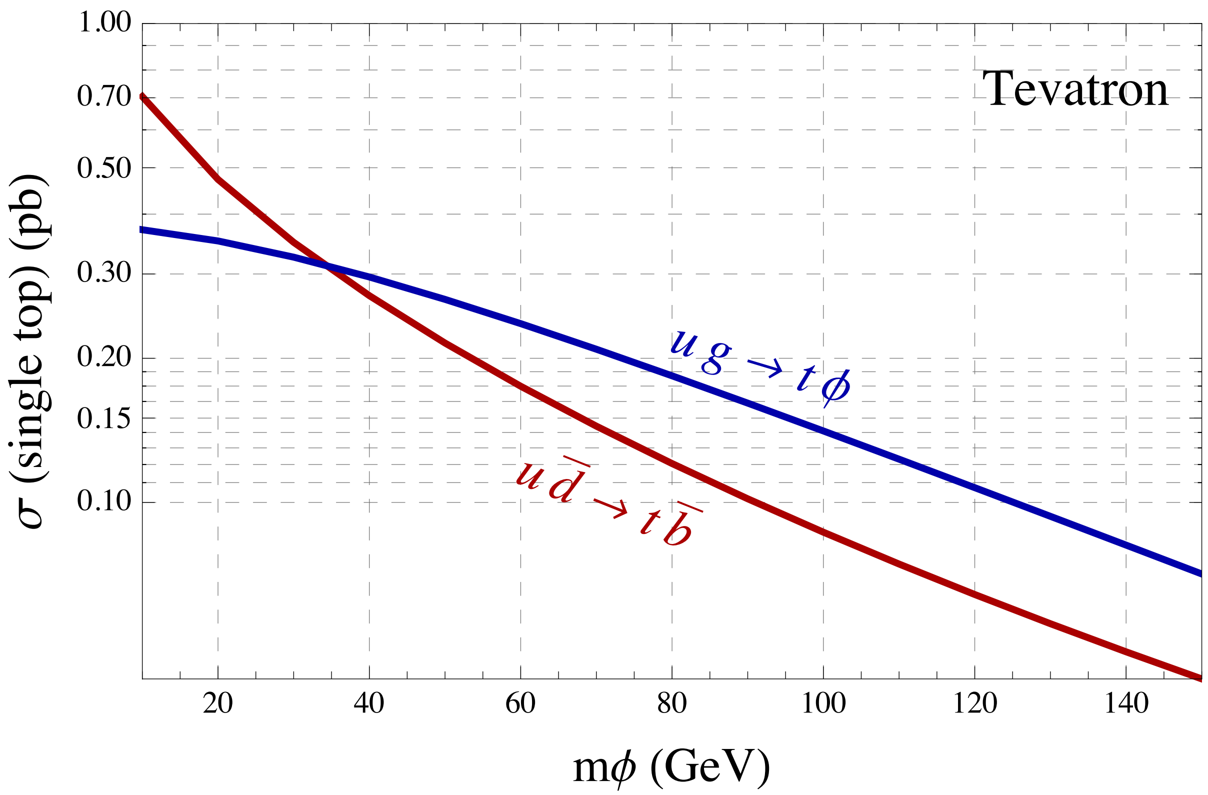
Single Top Diagrams

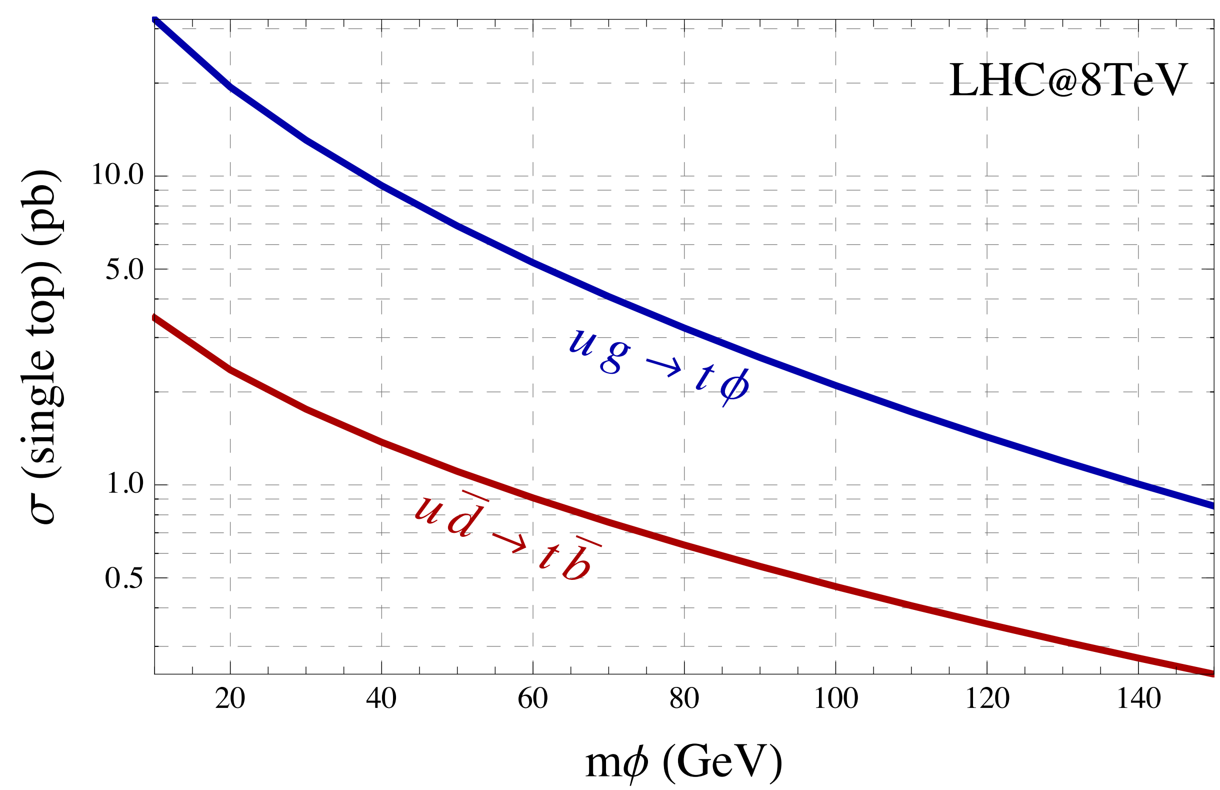




Single Top Production

$|\overline{\kappa}_{UR}| = |\kappa_D| = 0.2$



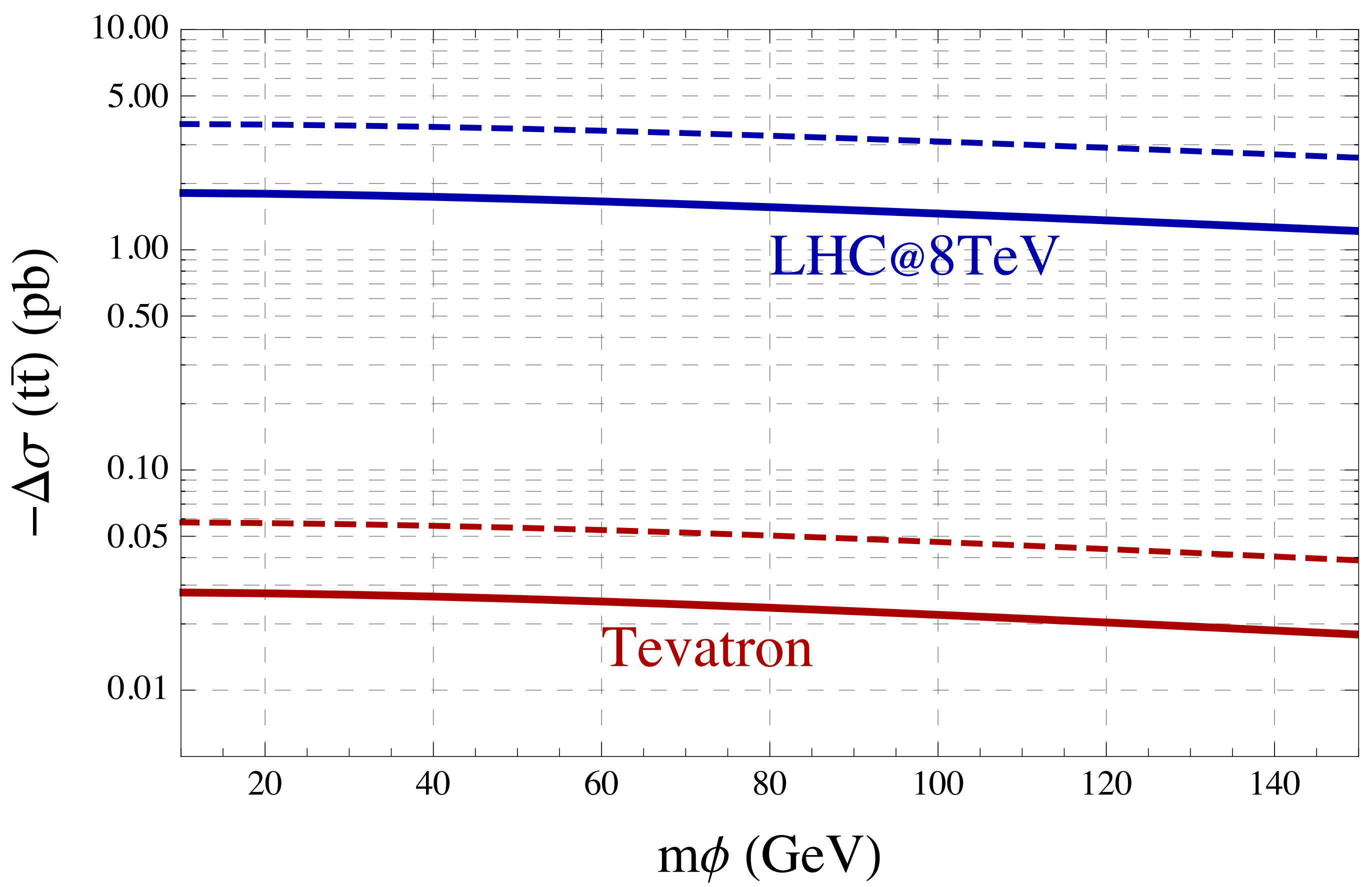


- Latest: $\Delta\sigma_{TeV} \lesssim 1$ pb, $\Delta\sigma_{LHC} \lesssim 10$ pb

CDF/PUB/TOP/PUBLIC/10793, , CMS-PAS-TOP-12-011

Top Pair Production

$|\overline{\kappa}_{UR}| = 0.2$ (solid), $|\overline{\kappa}_{UR}| = 0.3$ (dashed)

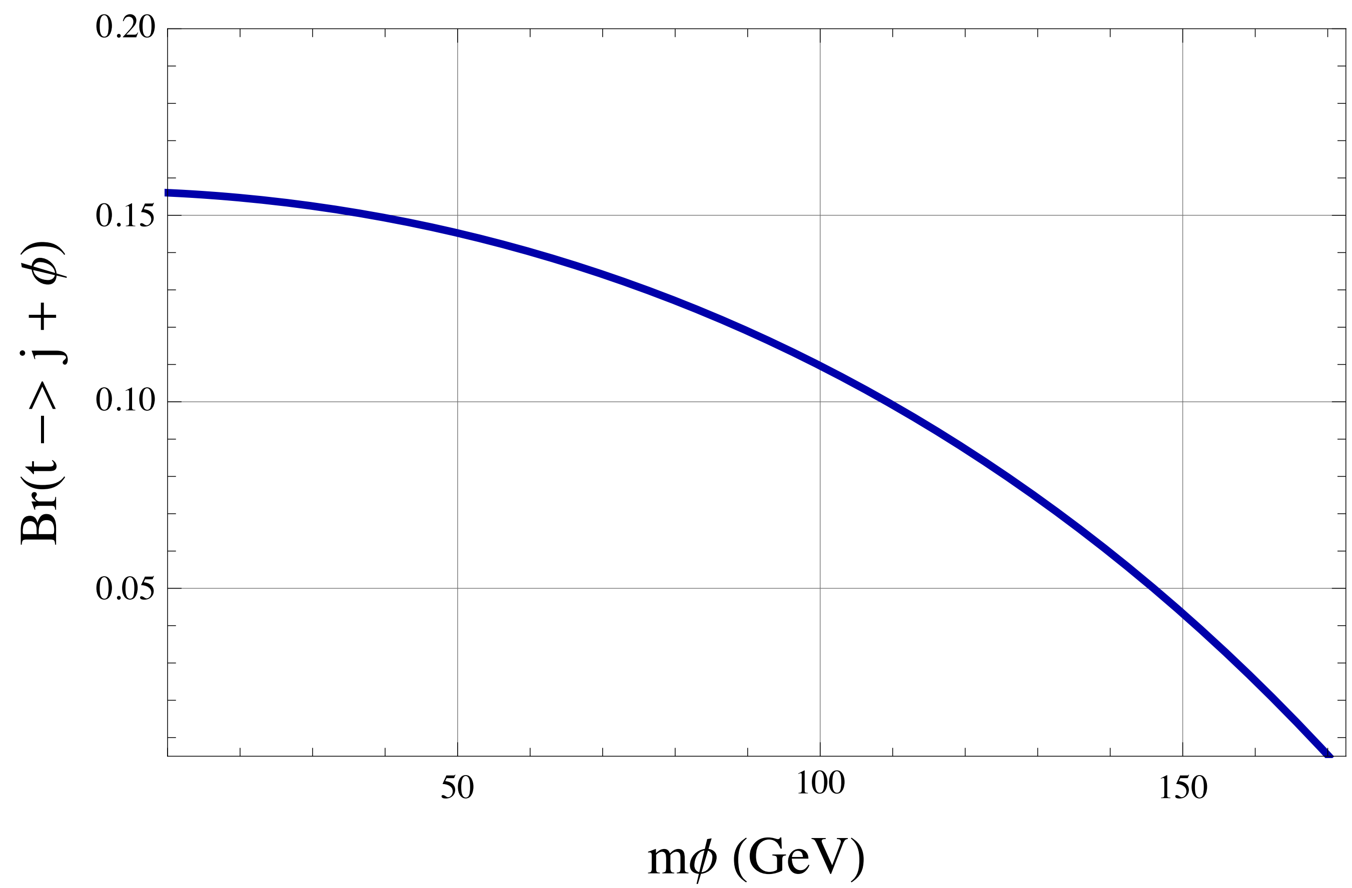


- Latest: $\Delta\sigma_{TeV} \lesssim 0.4$ pb, $\Delta\sigma \lesssim 30$ pb

CDF/PUB/TOP/PUBLIC/10926, ,ATLAS-CONF-2012-149

Rare Top Decays

$|\overline{\kappa}_{UR}| = 0.2$



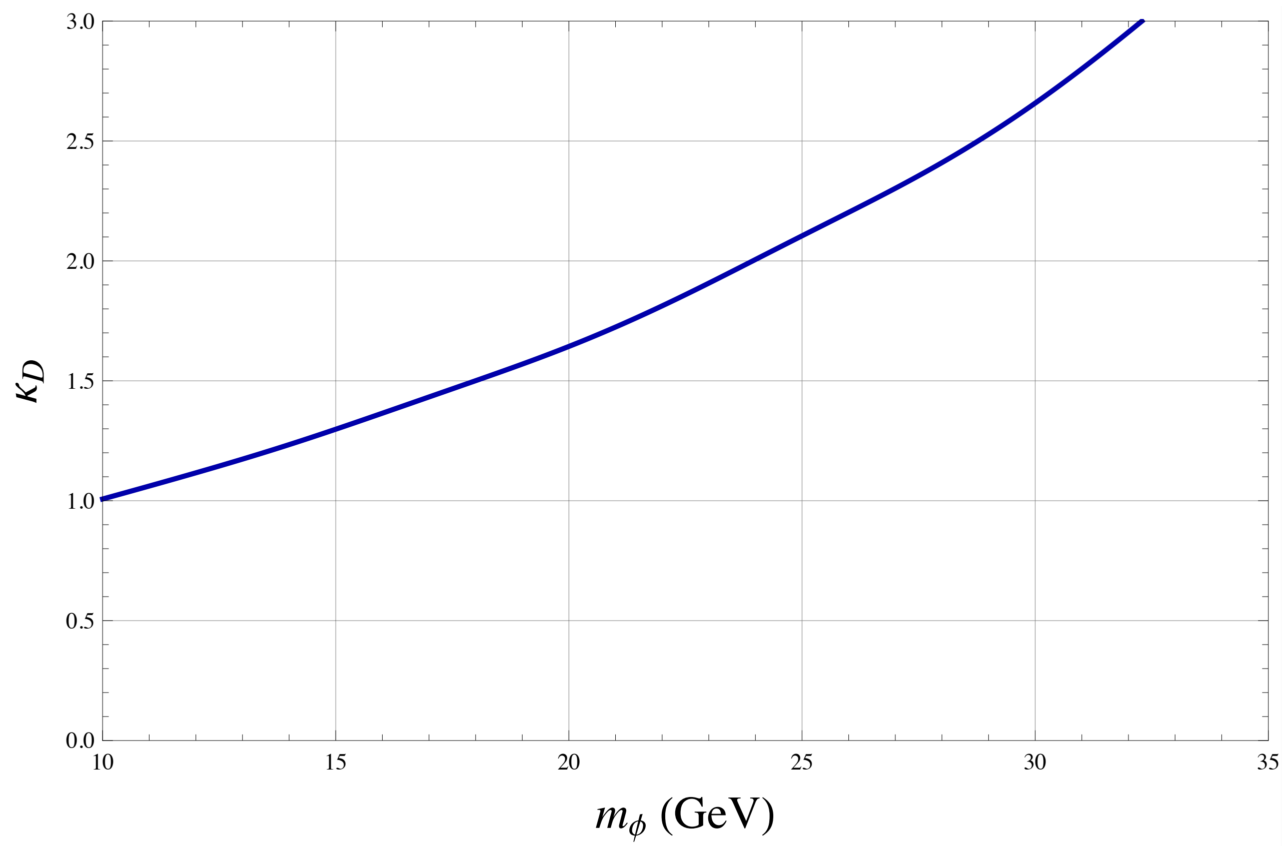
- Latest: $\Delta\Gamma \lesssim 2$ GeV

D0: 1009:5686

Comments

- Room for $\mathcal{O}(1)$ corrections to top
- Top cross-sections: naturally high priority
- Other properties need attention too!

Interlude: Rare Z Decay



- New Z decay: $Z \to q\,\bar{q}\,\varphi$
- Strongest constraint from search for $Z \to 4\,b$ @ LEP

Charm Physics

2011 D Meson CPV

- Theory: Charm CPV in SM is small
- Experiment: LHCb (+others) measures

$$\Delta A_{CP} = A_{CP}(D \to KK) - A_{CP}(D \to \pi\pi)$$
$$= (-0.645 \pm 0.180)\ \%$$ HFAG

- 3.6σ "clear" evidence of new physics...

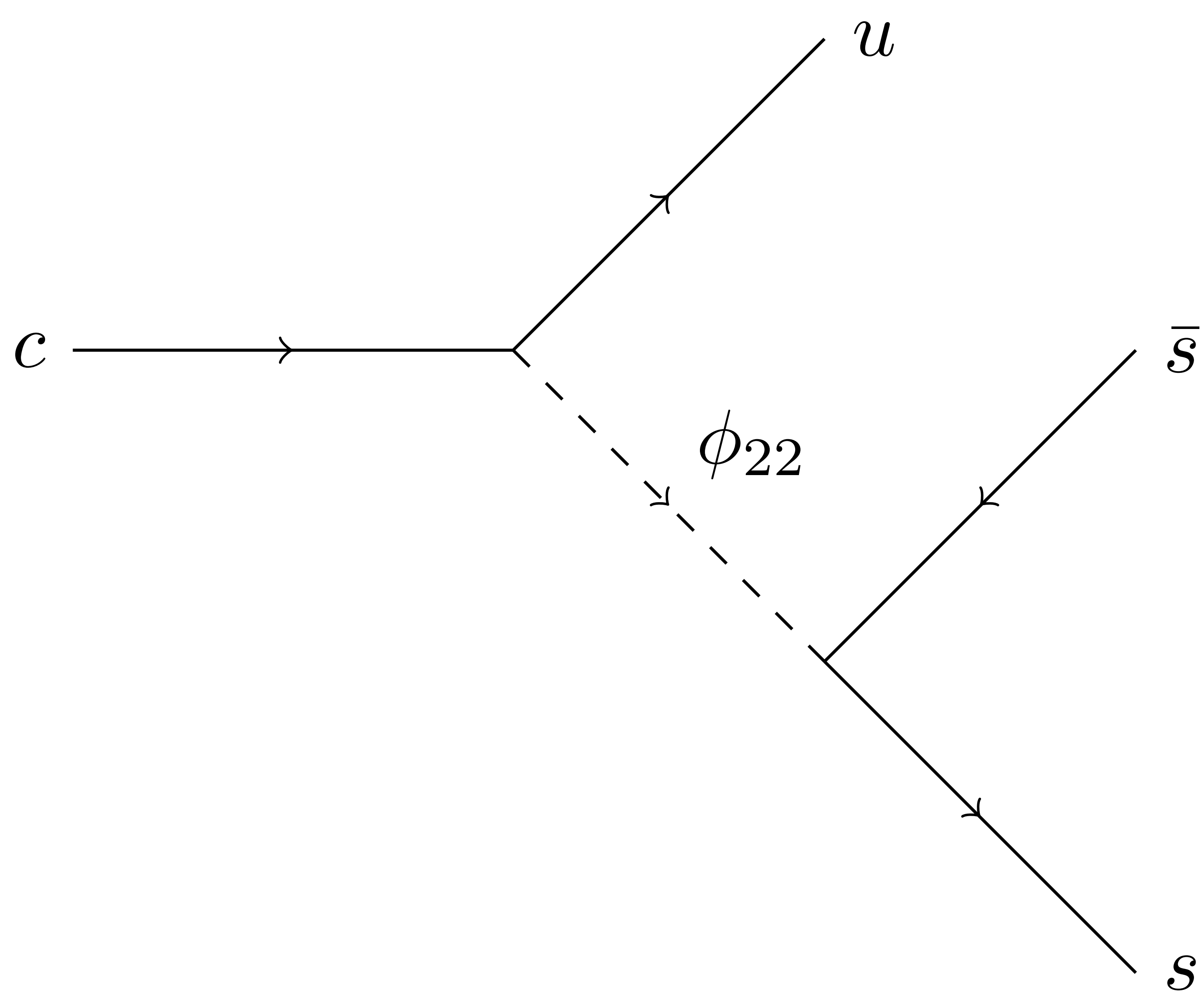
2013 D Meson CPV

- Theory: Some charm CPV may get OOM enhancement in SM
- Experiment: LHCb updates analysis

$$\Delta A_{CP} = (-0.329 \pm 0.121)\ \%$$ HFAG

- Down to 2.7σ and smaller in magnitude
- For this talk: assume it's real and it's BSM

In Our Model

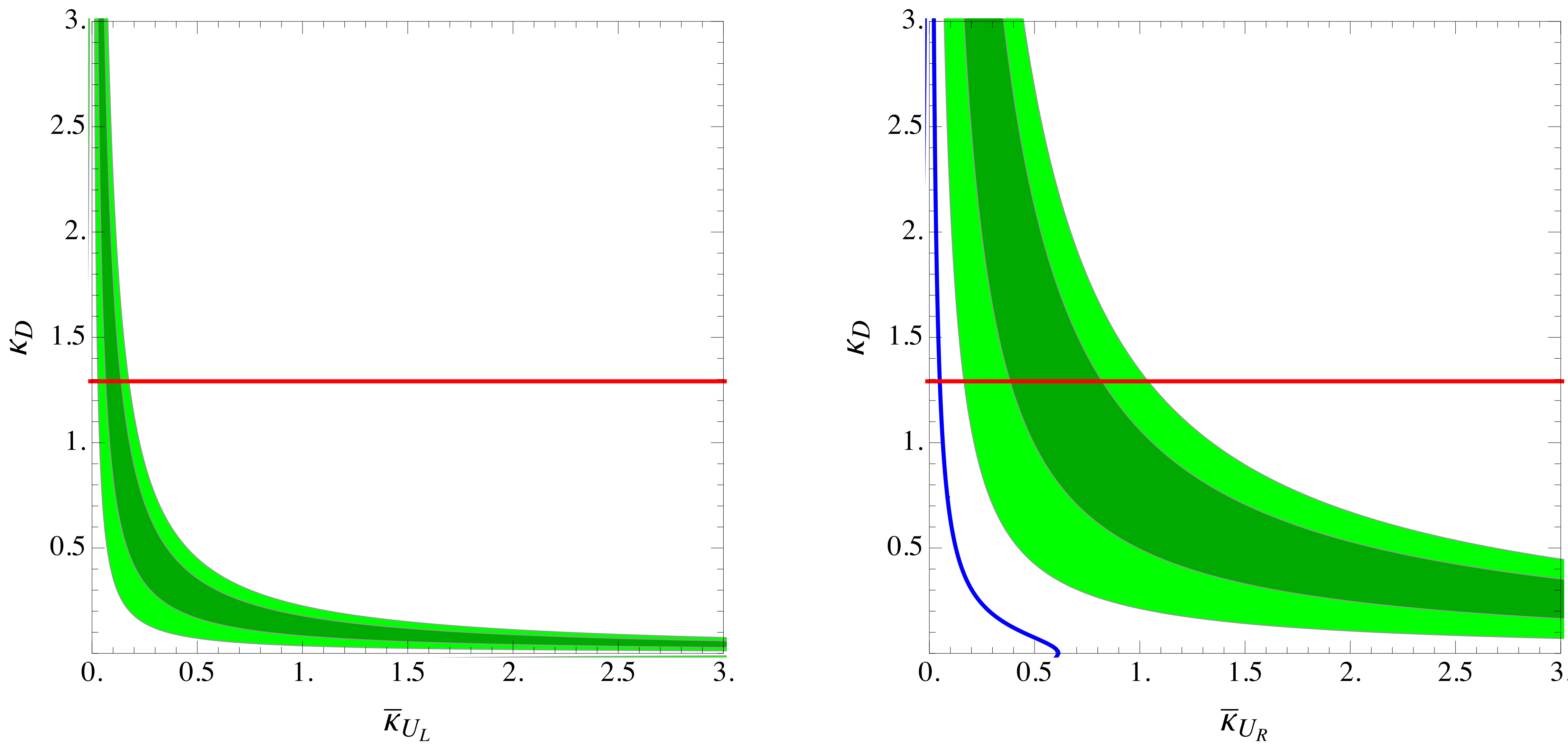


Calculating ΔA_{CP}

$$A_{CP} \sim \frac{2\sqrt{2}}{3G_F}\lambda_c\lambda_s\left(\frac{1}{4}\sin\delta\,\mathrm{Im}C\right) \quad C_{L,R} = \frac{\kappa_{U_{L,R}}\kappa_D^*}{2m_\phi^2}$$

- Phase of $\kappa_{U_{L,R}}\kappa_D{}^*$ is physical
- A_{CP} Proportional to strange Yukawa
- Naive factorization to get HME ratio
- For $m_\varphi \lesssim 40$ GeV, sufficient contribution to ΔA_{CP} to explain measurement

Results



m_φ = 10 GeV

Conclusions

UV Completion

- Model requires Higgs insertion to be SU(2) invariant → new physics at ~ few 100 GeV
- SU(2) doublet scalar or SU(3) triplet fermion with appropriate flavor charge
- Needs further study

Recap

- Up sector is under-explored territory
- Rich new phenomena possible
- Many opportunities for LHC (top factory!), heavy flavor factories, GigaZ