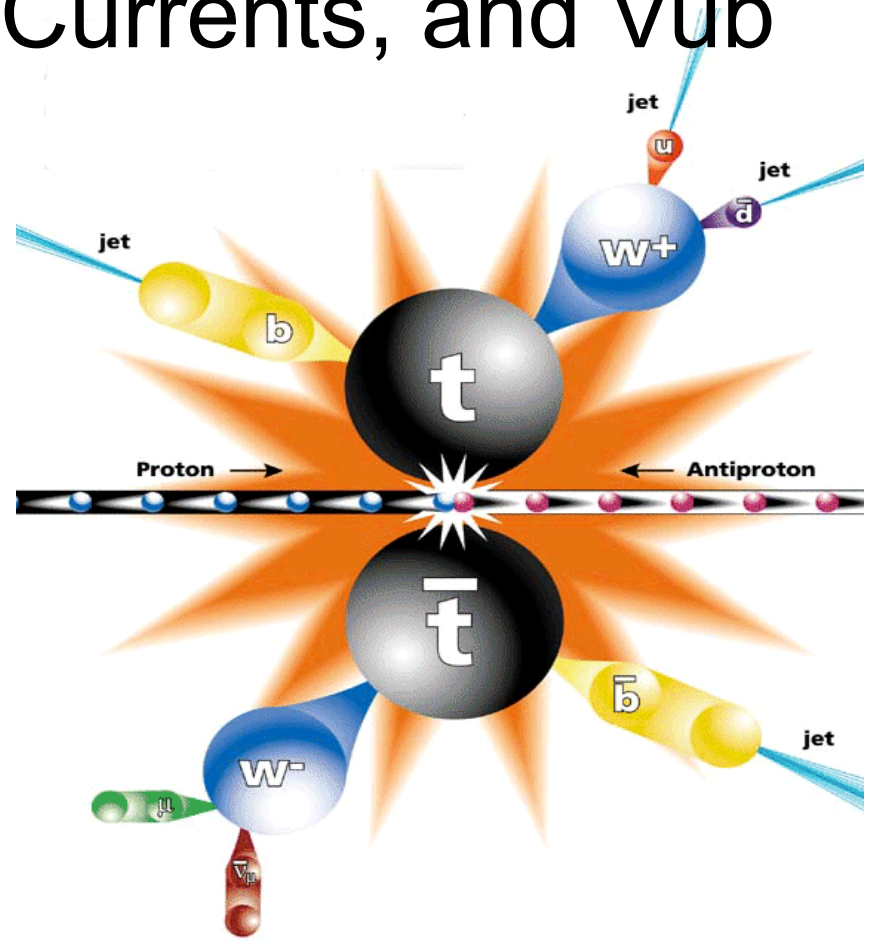
The Top Quark Forward Backward Asymmetry, Right Handed Charge Currents, and Vub



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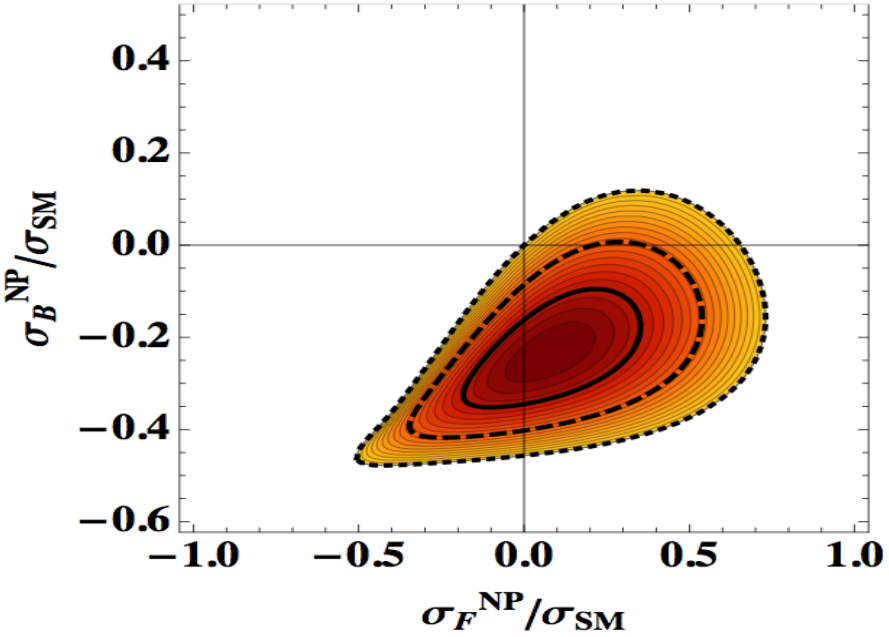
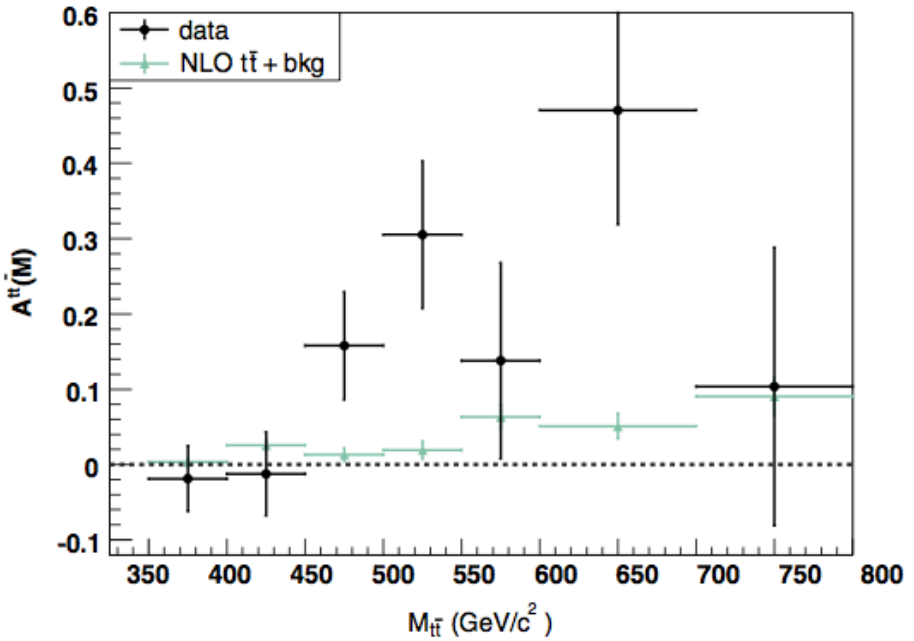
- New Physics in the forward backward asymmetry of the top quark?

- New Physics should interfere with QCD



Grinstein et. al. PRL 107,012002 (2011)



CDF PHYSICAL REVIEW D 83, 112003 (2011)

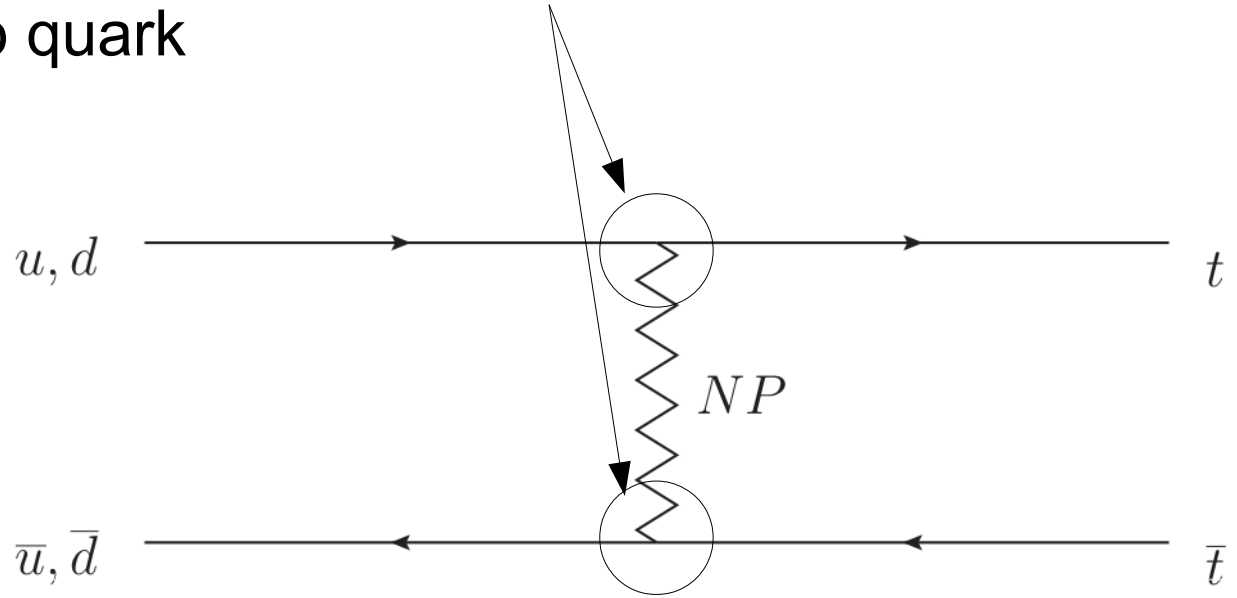
3.4σ discrepancy from NLO SM!!

- What kind of New Physics can reproduce these effects?

- s channel exchange is disfavored due to lack of resonances in $M_{t\bar{t}}$

- t channel exchange naturally interferes with QCD and leads to a Rutherford peak in the forward direction at large $M_{t\bar{t}}$

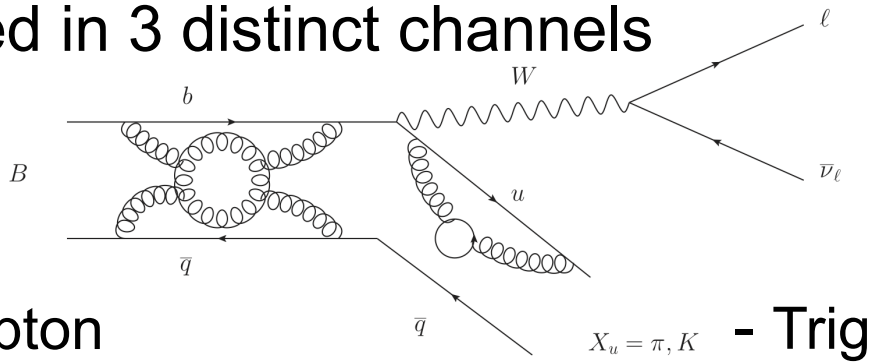
- Implies new flavor changing couplings between 1st generation quarks and the top quark



- What effects can new flavor physics in the top sector have on other flavor observables?

Note: *Shortly after we published these models were shown to be subject to strong constraints from low energy parity violation experiments. See S. Tulin's talk.*

- Vub is measured in 3 distinct channels



1. Inclusive:

- Only final state lepton is detected

2. Exclusive:

- Trigger on a particular final state, e.g., $B \to \pi \ell \nu_\ell$

- There is a persistent **~2σ discrepancy** between inclusive and exclusive determinations

$$|V_{ub}|_{\rm Incl} = (4.25 \pm 0.25) \times 10^{-3} \qquad |V_{ub}|_{\rm Excl} = (3.25 \pm 0.30) \times 10^{-3}$$

PoS(Beauty 2011) 030

3. Leptonic B decays:

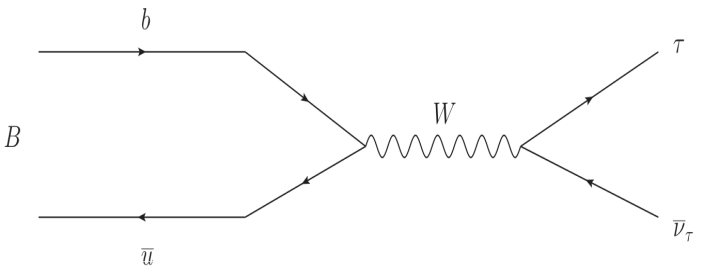
$\mathrm{Br}(B \to \tau\nu)_{exp}$

Phys. Lett. B687 (2010) 61

f_B

Phys. Rev. D81 (2010) 034503

$$|V_{ub}|_\tau = (5.14 \pm 0.57) \times 10^{-3}$$



- RHCC can provide an elegant explanation for this hierarchy

Crivellin, Phys.Rev.D81:031301,2010

- The SM weak CC can be extended to include RH contributions

$$J^{\mu}_{CC} = e_W \overline{u}_i \gamma^{\mu} V^{CKM}_{ij} P_L d_j \Rightarrow e_W \overline{u}_i \gamma^{\mu} \left(V^L_{ij} P_L + V^R_{ij} P_R \right) d_j$$

- RHCC enter distinctively into each decay mode!

$|V_{ub}|_{Incl} \Rightarrow \sqrt{|V^L_{ub}|^2 + |V^R_{ub}|^2} \approx |V^L_{ub}|$ Interference term is suppressed by m_u/m_b

$|V_{ub}|_{Excl} \Rightarrow |V^L_{ub} + V^R_{ub}|$ Only sensitive to the vector current

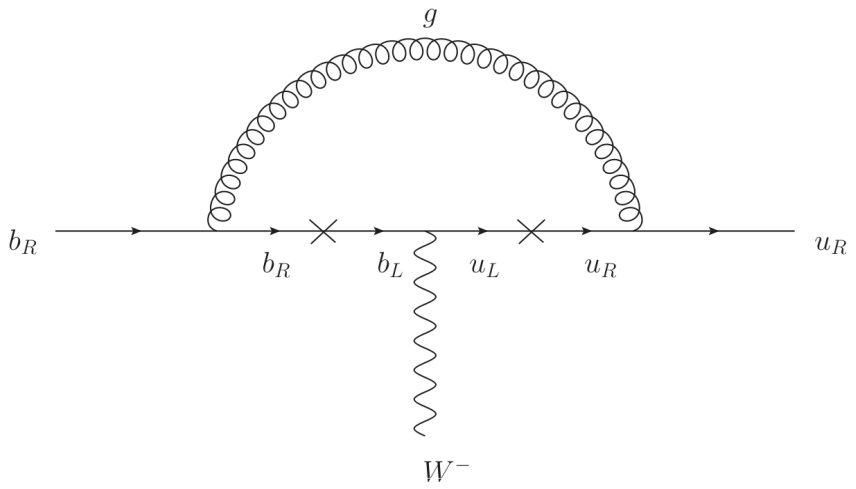
$|V_{ub}|_{\tau} \Rightarrow |V^L_{ub} - V^R_{ub}|$ Only sensitive to the axial current

- Demanding agreement between different determinations of V_{ub} places bounds on the strength of the RHCC

$$\mathrm{Re}(V^R_{ub}) = -(3.1 \pm 1.5) \times 10^{-4}$$

- RHCC arise in the SM at 1-loop. How large are they?

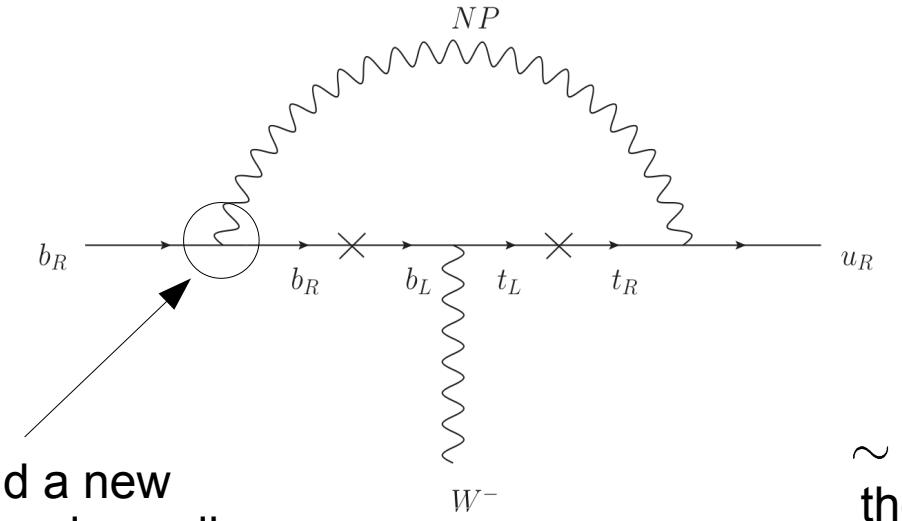
Far too small!!



$$\sim \frac{m_b m_u}{(4\pi)^2 M_W^2} \alpha_s V_{ub}^L \sim 10^{-13}$$

However...

with a small addition of a new flavor diagonal $b\bar{b}$ coupling
==> the NP in the $A_{FBA}^{t\bar{t}}$ generates large enhancements of the RHCC!!



Need to add a new flavor diagonal coupling

$$\sim \frac{m_b m_t}{(4\pi)^2 M_W^2} V_{tb}^L g_{ut} g_{bb} \sim g_{ut} g_{bb}\ 10^{-4}$$

$\sim 10^9$ enhancement over the SM and just the right ballpark size to explain the V_{ub} hierarchy with O(1) couplings!!

Example Model

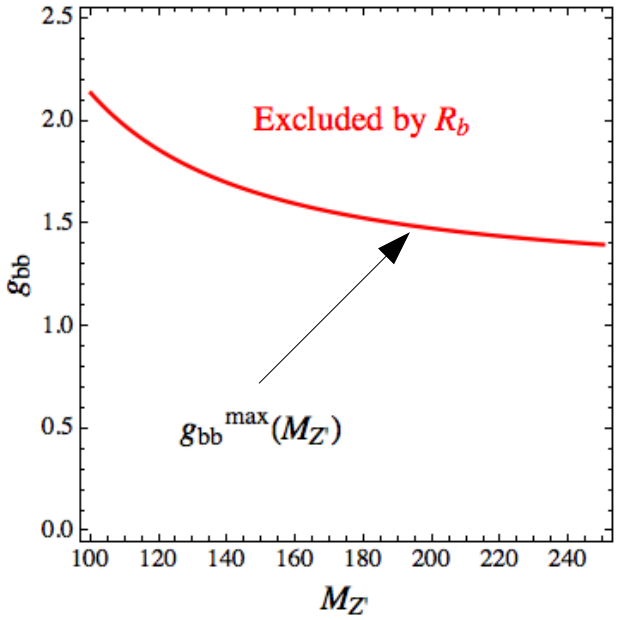
Jung et. al. PHYSICAL REVIEW D 81, 015004 (2010)

$$\mathcal{L} \supset g_{ut}\bar{t}\gamma^{\mu}P_R u Z'^{\mu} + \text{h.c.} + g_{bb}\bar{b}\gamma^{\mu}P_R b Z'^{\mu}$$

RH coupling avoids large FCNC in $\bar{B}_d^0 - B_d^0$ mixing and generates $A_{FBA}^{t\bar{t}}$

RH coupling avoids large deviations of

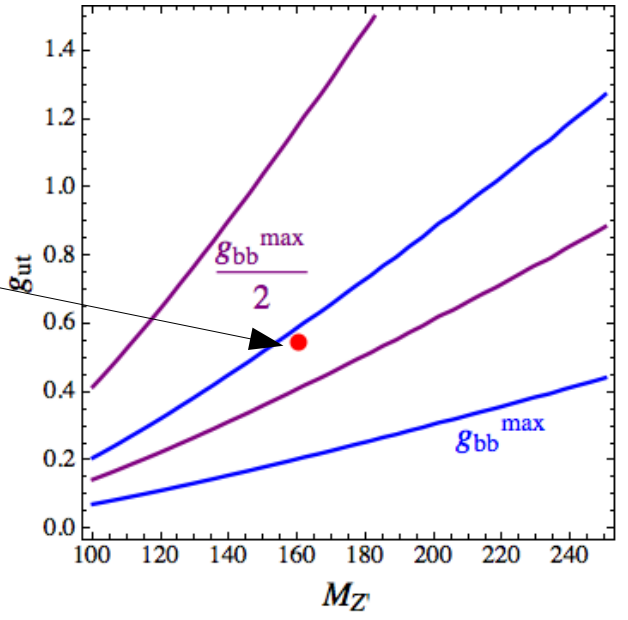
$$R_b = \frac{\Gamma(Z \to b\bar{b})}{\Gamma(Z \to \text{hadrons})}$$



Regions bound by purple and blue contours can expalin the V_{ub} hierarchy

Best fit point for reproducing $A_{FBA}^{t\bar{t}}$ and avoiding large $\text{Br}(t \to Z'u)$

Easily explains V_{ub} hierarchy within same parameter space favored by $A_{FBA}^{t\bar{t}}$



Flavor diagonal coupling helps avoid same sign top constraints at the Tevatron

This model is disfavored by same sign top at the LHC and low energy PV experiments

- The top quark FBA remains an interesting and unexplained phenomena

- We have explored the possibility that the same NP generating the top quark FBA can simultaneously explain the persistent observed hierarchy of determinations of V_{ub} and, in the case of the models we investigated, found this to be true

- Although some t channel models have been shown to be strongly constrained by low energy PV observables, the connection between the FBA and the V_{ub} hierarchy could remain a viable possibility....

Thank you!

Model 2 JHEP 1110, 124 (2011)

Second scalar doublet is a color singlet, with same electroweak representation as the Higgs

$$\mathcal{L} \supset X_{ij}\overline{Q}_{i_L}\Phi u_{j_R} + \tilde{X}_{ij}\overline{Q}_{i_L}\tilde{\Phi}d_{j_R} + \text{h.c.}$$

$$\Phi = \begin{pmatrix} \phi^{0,R} + i\phi^{0,I} \\ \phi^- \end{pmatrix}$$

$$X_{ij} = \lambda \begin{pmatrix} V_{ub} & 0 & 0 \\ V_{cb} & 0 & 0 \\ V_{tb} & 0 & 0 \end{pmatrix}$$

Generates $A_{FBA}^{t\bar{t}}$

$$\tilde{X}_{ij} = g_{bb\phi} \begin{pmatrix} 0 & 0 & V_{ub} \\ 0 & 0 & V_{cb} \\ 0 & 0 & V_{tb} \end{pmatrix}$$

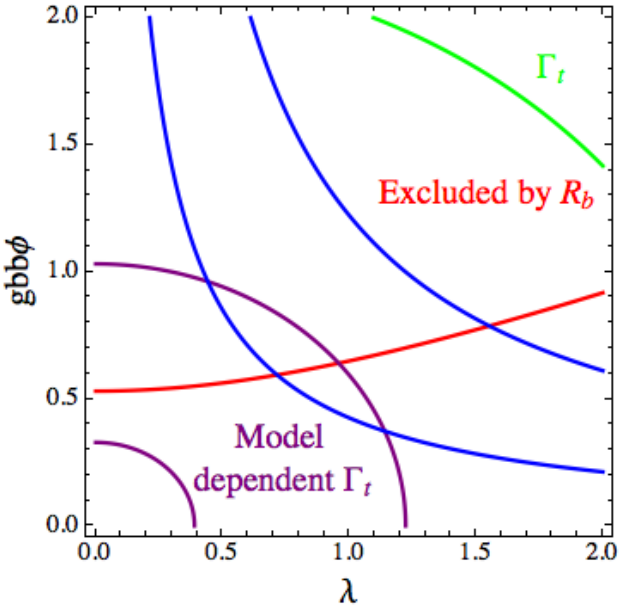
Generates $b\bar{b}$ coupling and avoids FCNC in the down quark sector

- LEP bounds require m_0, $m_\pm > 100$ GeV and $m_0 \leq 130$ GeV, $\lambda > 1$ for agreement with $A_{FBA}^{t\bar{t}}$

- RHCC is maximized for large mass splitting between neutral scalars and light charged scalars

- Region bounded by blue contours explains V_{ub} hierarchy

- Model is disfavored by APV

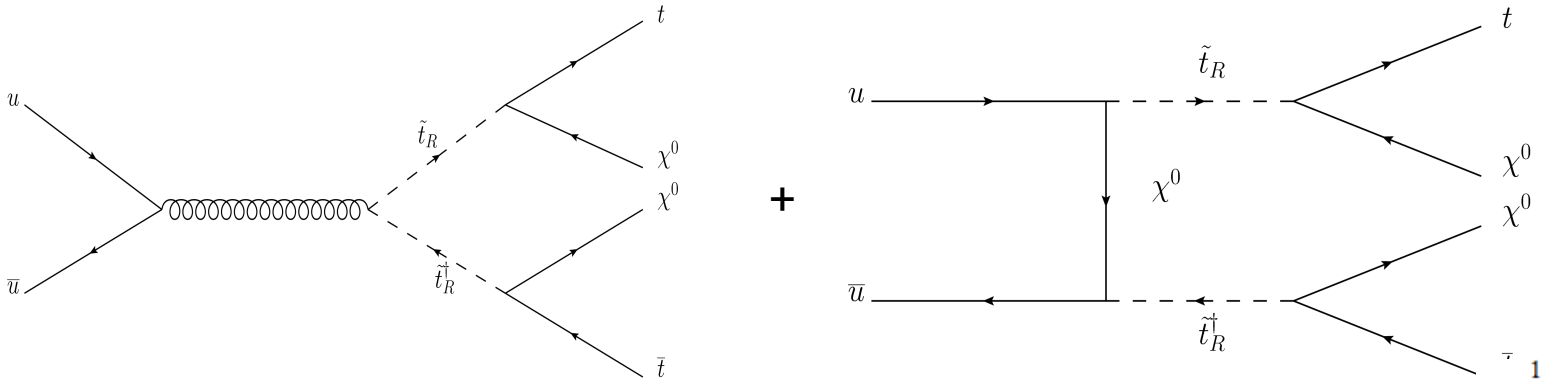


Model 3 Phys. Lett. B 700, 145 (2011)

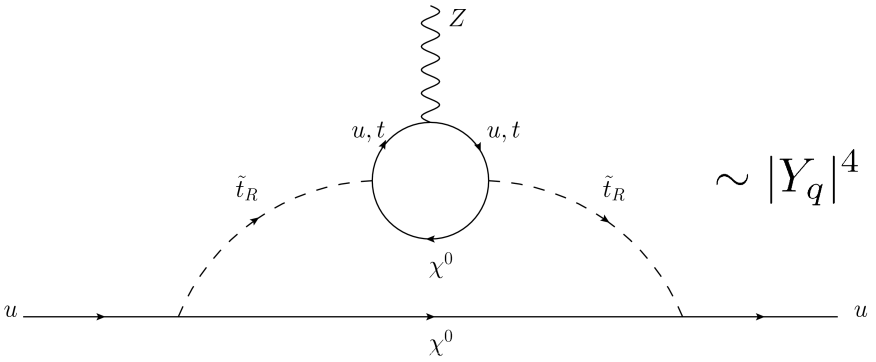
Extend the MSSM by adding a SU(2)XU(1) singlet Majorana fermion

$$\mathcal{L} \supset \overline{\chi^0} i\gamma_\mu \partial^\mu \chi^0 - m_\chi \overline{\chi^{0c}} \chi^0 + \sum_{q=u,c,t} \tilde{Y}_q \bar{q}_R \tilde{t}_R \chi^0 + Y_b \bar{b}_R \tilde{b}_R \chi^0 + \text{h.c.}$$

Not the same kind of t channel model - FBA is generated in the $\tilde{t}_R \tilde{t}_R^\dagger$ production process



APV appears only at 2 loop



$\sim |Y_q|^4 \; 10^{-5}$

RHCC is dependent on squark mass insertions