Top Flavor Violation

from the B-Factories to the LHC

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hep-ph/0704.1482

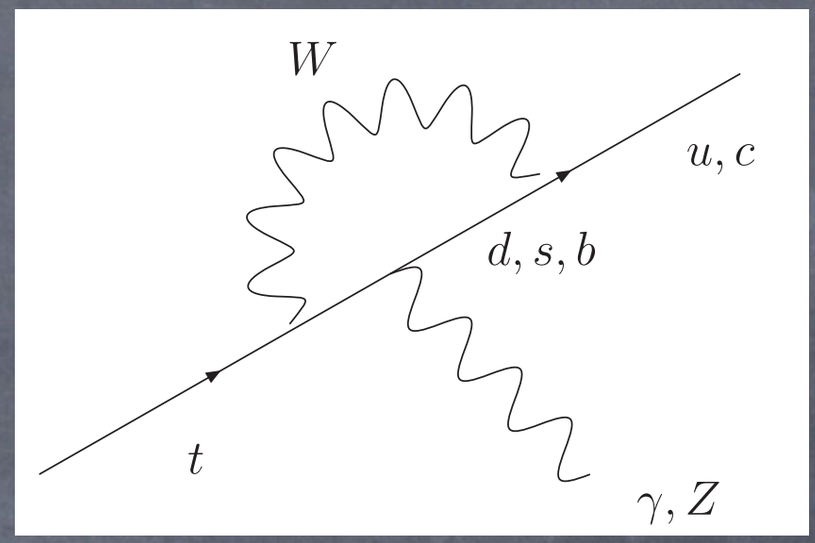
Brookhaven - May 31st 2007

FCNC in top decays

Top rare decays:

- $t \to q\,Z$ $q=u,c$
- $t \to q\,\gamma$

} ⟵ this talk



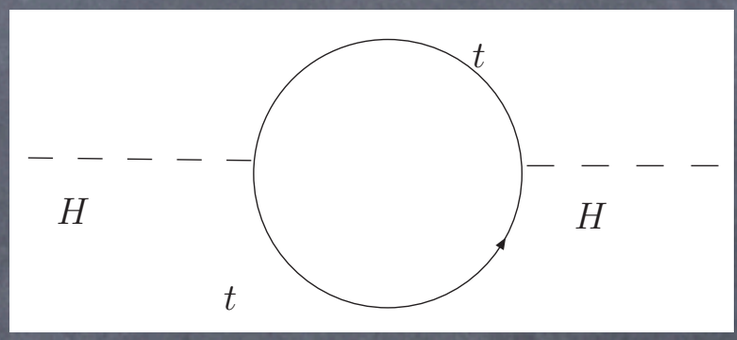
- $t \to q\,g$ ⟵ e.g. ph/0603131
- $t \to q\,h$ ⟵ more model dep' (1HDM,2HDM,...)
- ...

SM: BR ~ 10^{-14} (loop+GIM+Cabibbo)

"SM free" → good place to check for New Physics

New Physics in the top sector?

- NP @ TeV to stabilize the ElectroWeak scale



...NP may interact with the top

Possible new source of flavor violation if

NP ⇔ 3rd gen' ≠ NP ⇔ 1st-2nd gen'

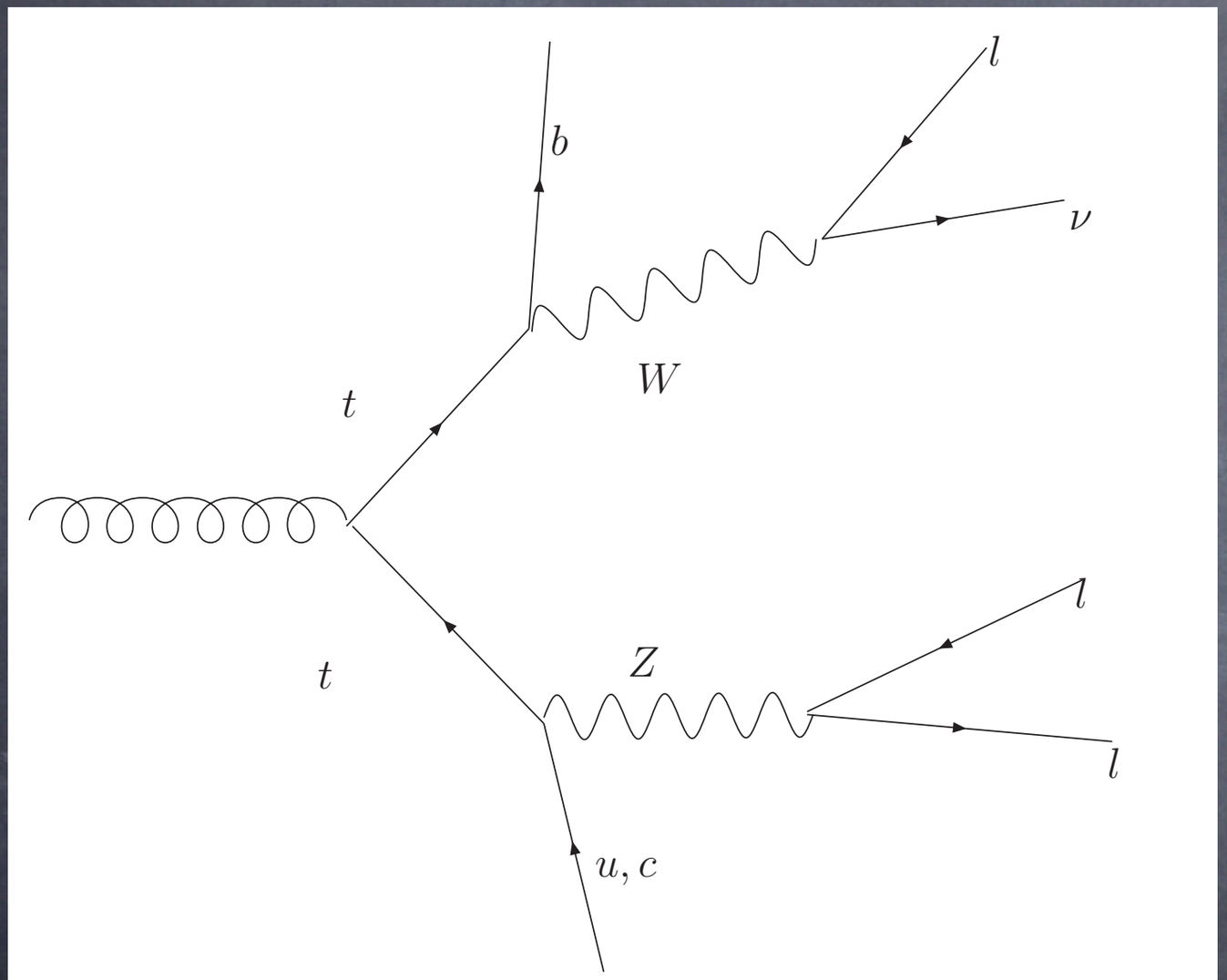
Search for Flavor viol' in the Top sector

Direct bounds on top FCNCs

- LEP2:
  - $e^+ e^- \to t\,c$: $BR(t \to qZ) < 13.7\%$ @ 95%CL
- Hera:
  - $e^- p \to t\, e^-$: $BR(t \to u\gamma) < 0.6\%$ @ 95%CL
- CDF:
  - $BR(t \to qZ) < 3.3\%$ @ 95%CL

Interesting region: 10^{-4} - 10^{-8} → We need a top factory...

The LHC: 1 $t\bar{t}$ pair $s^{-1}\exp^{-1}$



the perfect place...

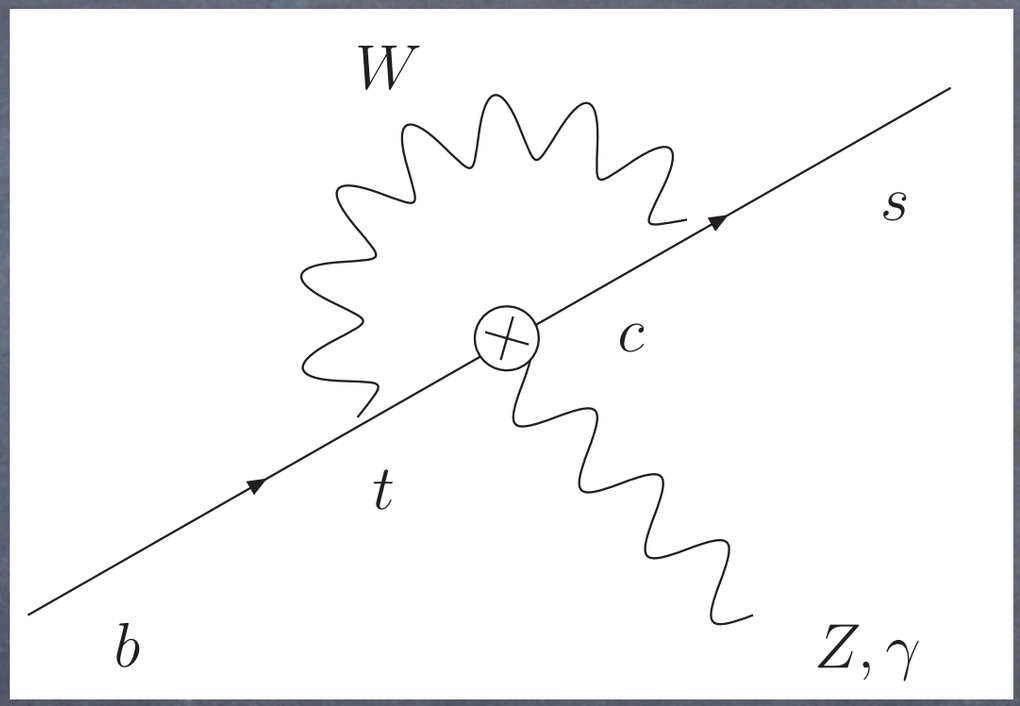
...to probe FCNC top decays

channel	$t \to Zu(c)$	$t \to \gamma u(c)$	$t \to gu(c)$		
			(3 jets)	(4 jets)	(combined)
upper limit on BR ($L = 10$ fb^{-1})	3.4×10^{-4}	6.6×10^{-5}	1.7×10^{-3}	2.5×10^{-3}	1.4×10^{-3}
upper limit on BR ($L = 100$ fb^{-1})	6.5×10^{-5}	1.8×10^{-5}	5.0×10^{-4}	8.0×10^{-4}	4.3×10^{-4}

(Carvalho, Castro, Onofre, Veloso 2005)

Indirect constraints?

- Top FCNCs can affect other observables:



What are the present bounds?
Is the LHC window still open?

A Model-Indep' analysis

- Write SM + all possible dim-6 operators contributing to top FCNCs. (Buchmuller Wyler '86)
- Assume a valid perturbative expansion in v/Λ_{NP}
- Assume $SU(2)_L \times U(1)_Y$ invariance
- be conservative on CP violation
- Look at all the possible indirect bounds...

The main players:

- 2 LL operators:

$$\mathcal{O}^u_{LL} = i\left[\overline{Q}_3\tilde{H}\right]\left[\left(\not{D}\tilde{H}^\dagger\right)Q_i\right] - i\left[\overline{Q}_3\left(\not{D}\tilde{H}\right)\right]\left[\tilde{H}^\dagger Q_i\right] + \text{h.c.}$$

$$\mathcal{O}^h_{LL} = i\left[\overline{Q}_3\gamma^\mu Q_i\right]\left[H^\dagger D_\mu H\right] + \text{h.c.}$$

- 4 LR,RL operators:

$$\mathcal{O}^W_{LR} = g\left[\overline{Q}_3\sigma^{\mu\nu}\tau^a\tilde{H}\right]u_i W^a_{\mu\nu} + \text{h.c.}$$

$$\mathcal{O}^B_{LR} = g'\left[\overline{Q}_3\sigma^{\mu\nu}\tilde{H}\right]u_i B_{\mu\nu} + \text{h.c.}$$

+ LR ↔ RL

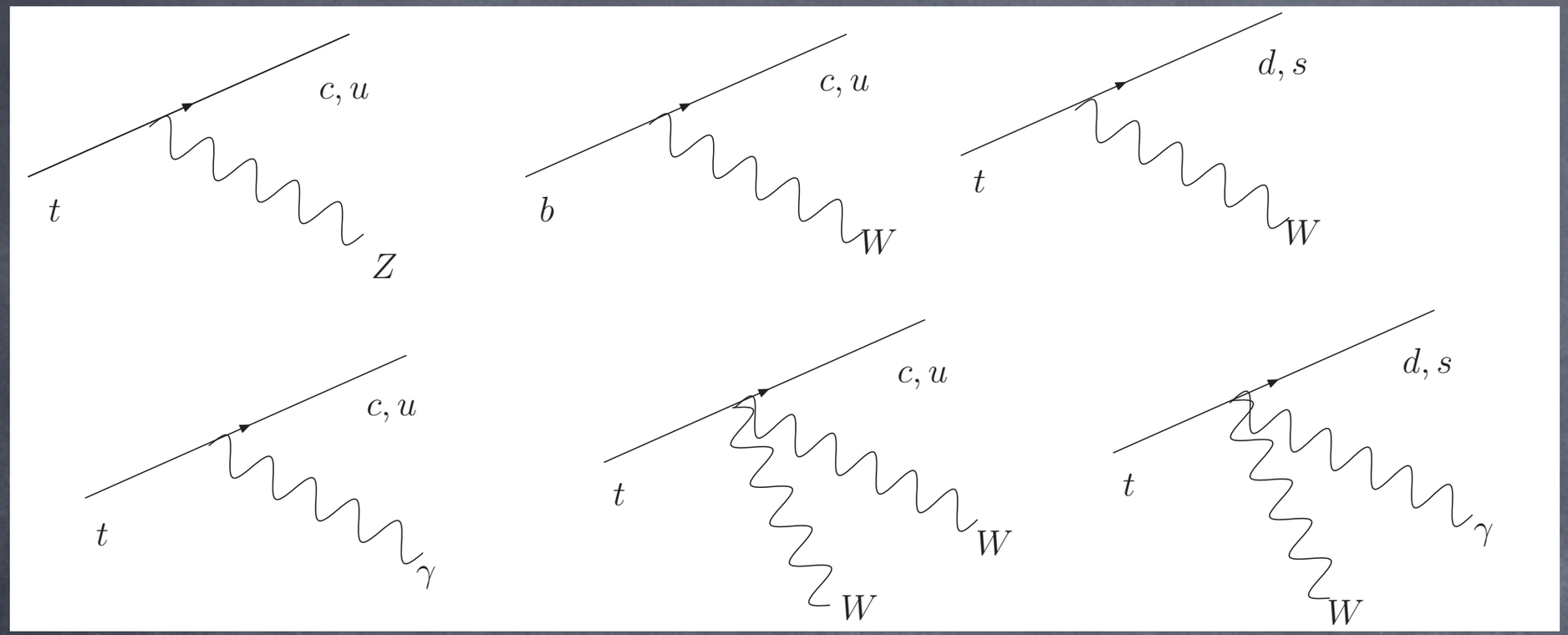
- 1 RR operator:

$$\mathcal{O}^u_{RR} = i\overline{u}_3\gamma^\mu u_i\left[H^\dagger D_\mu H\right] + \text{h.c.}$$

- 4-fermions operators (many)

The plot

- After EWSB:



+...

→ Look at constraints coming from:

- semileptonic B decays
- $b \to s\gamma$ & $b \to s l^+ l^-$
- $b \to \rho\gamma$ & $B \to \mu^+\mu^-$
- $\Delta F=2$ (Unitarity)
- Direct Bounds

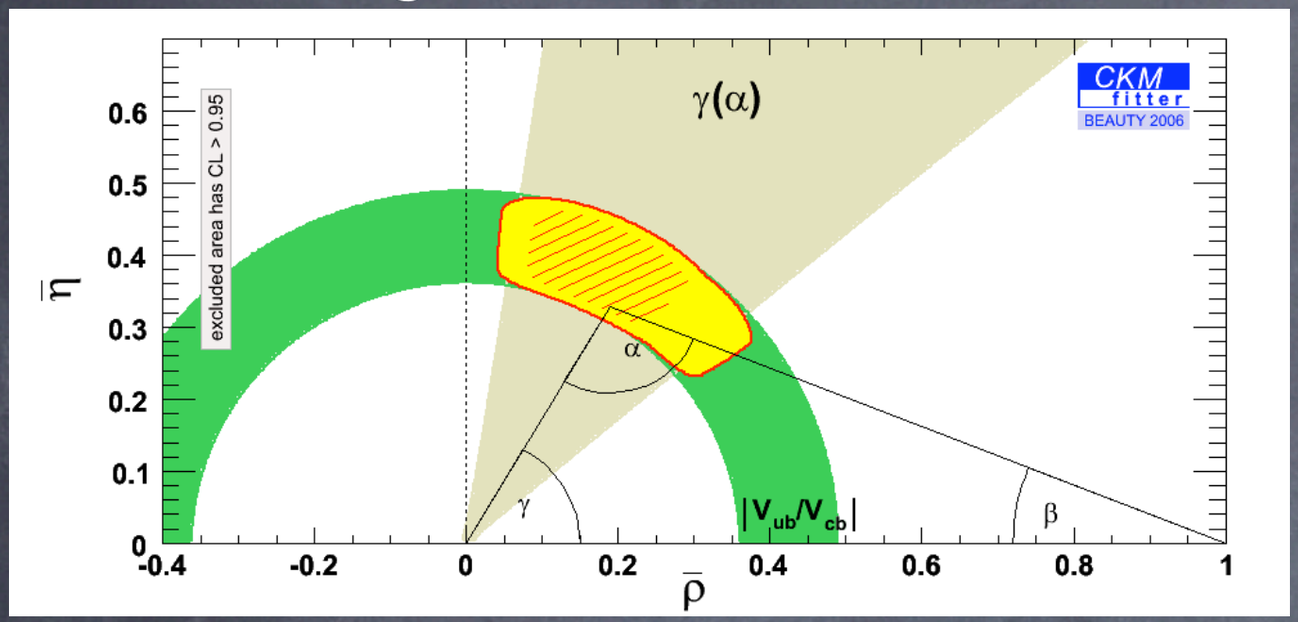
Semileptonic B-decays

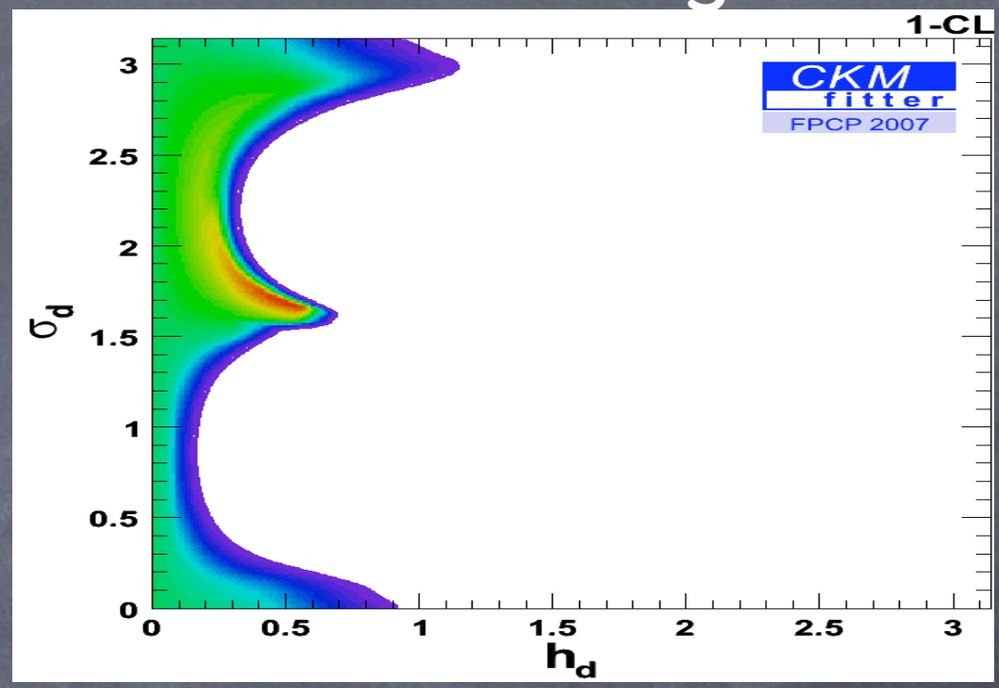
- Tree level bWc & bWu couplings
  - LL operator: same structure of the SM
    - shift of V_{cb} and V_{ub}
      - constrained only by unitarity / $\Delta F=2$
- $b_L c_R$ & $b_L u_R$ coupl' modify energy spectrum of the lepton
  - can be indep' constrained using inclusive $B \to X_c l \nu$, $B \to X_u l \nu$ & exclusive $B \to D^* l \nu$, $B \to D^* l \nu$, $B \to \pi l \nu$

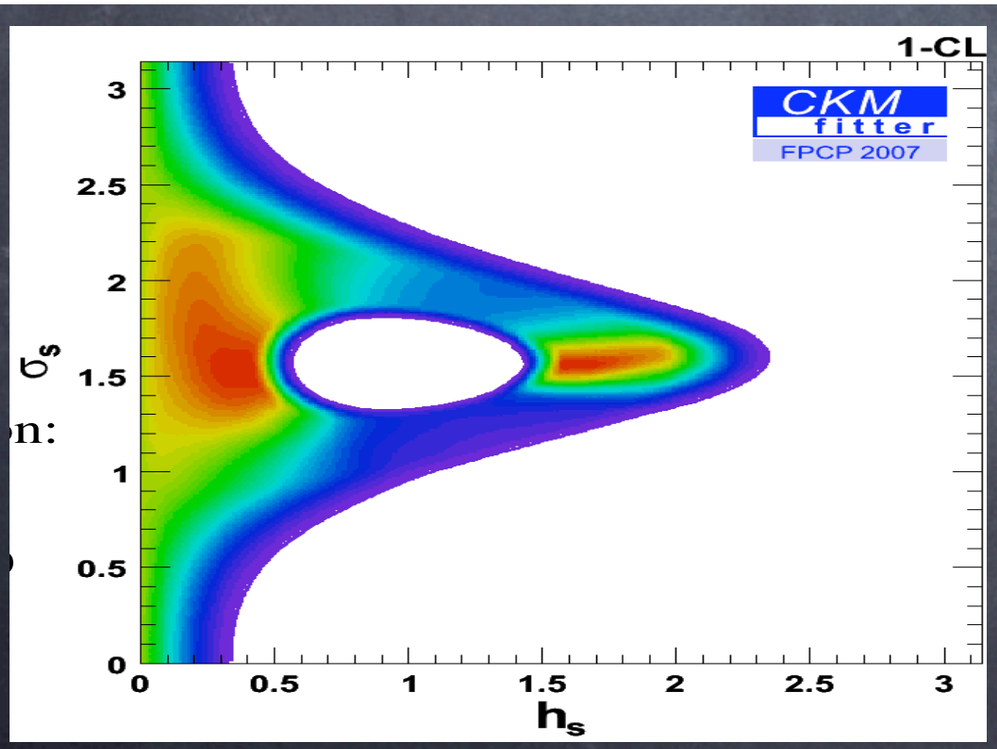
→ $\Lambda > 0.8$ TeV

Unitarity & New Physics in ΔF=2

- Enough data to constrain SM V_{CKM} + NP in mixing:







SM NP in b->d

NP in b->s

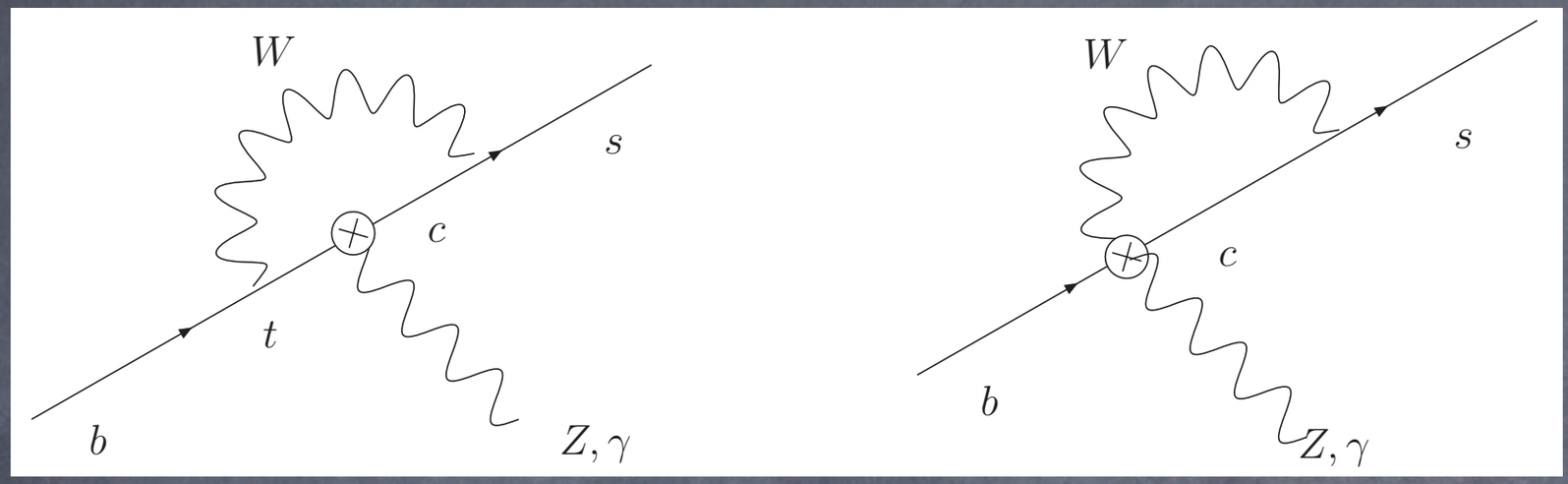
Assumptions: V_{CKM} unitary, NP affects meson mixing

$\Delta F=2$ constraints on top FCNCs

- Constraints on op' involving $t_L q_L$ (tree level + 1-loop):
  - $\Lambda > 3.8$ TeV for O_{LL}^{u}
  - $\Lambda > 8.5$ TeV for O_{LL}^{h}
- Constraints on op' involving $t_R q_L$ and W's (1-loop)
  - $\Lambda > 2.6$ TeV

$b \to s l^+ l^-$ & $b \to s \gamma$

- NP contributions to C_3, $C_{7\gamma}$, C_{9V}, C_{10A} @ M_W:



+ many others

- Contributions from:
  - $t_L c_L$ operators (tree level + 1-loop)
    - $\Lambda > 5.6$ TeV & $\Lambda > 3.9$ TeV
  - $t_R c_L$ operators at 1-loop
    - $\Lambda > 2.6$ TeV for $W_{\mu\nu}$ op′ & $\Lambda > 2.0$ TeV for $B_{\mu\nu}$ op′
  - no relevant constraint on $t_R c_R$ & $t_L c_R$ (m_c/m_W suppr′)

Results

Λ [TeV]	O_{LL}^u	O_{LL}^h	O_{RL}^W	O_{RL}^B	O_{LR}^W	O_{LR}^B	O_{RR}^u
LHC reach in $t\to cZ$ ($\Lambda<$..)	2.3	2.3	2.3	1.2	2.2	1.2	2.3
LHC reach in $t\to c\gamma$ ($\Lambda<$..)	-	-	2.6	2.6	2.6	2.6	-
present constraints ($\Lambda>$..)	3.8	8.5	2.6	2.0	0.8	0.4	0.3
LHC window	closed	closed	ajar	ajar	open	fully open	fully open

and similar for $t\to u$...

Conclusions

- New Physics involved in EWSB may induce new source of flavor violation in top decays
- LHC can probe FCNCs top decays up to BR~10^{-4}-10^{-5}
- Present data from B-factories constrain these decays
  - decays involving c_L,u_L already tightly constrained (beyond LHC reach)
  - $t_{L,R} \to q_R$ very little constrained ⇒ possible surprises @ LHC
- B-factories & the LHC together can probe the nature of NP inducing Top FCNCs