correlating flavor phys. with precision ILC measurements

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Outline

- Introduction + Motivation.
- Status of precision measu' (quark flavor).
- Top FCNC, LHC & ILC signals.
- Top diagonal couplings.
- Conclusions.

Why LHC ?

Origin of:

electroweak sym' breaking & masses (M_W, m_t).

Stable hierarchy $\Leftrightarrow M_W^2/M_{\rm Pl}^2 \sim 10^{-32}$

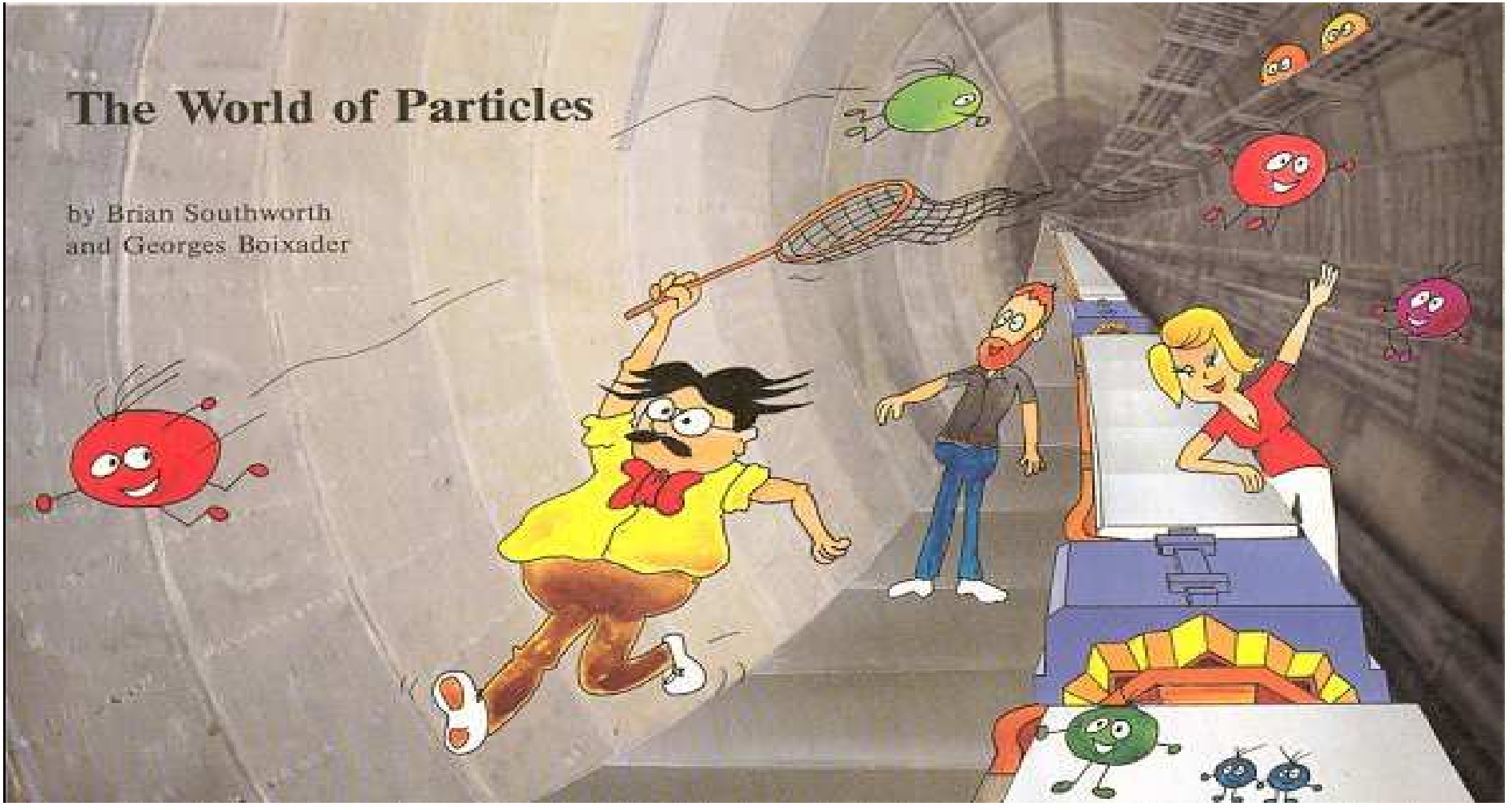
$\Downarrow$

Physics $\sim$ electroweak (EW) scale

Hints: EW breaking & top phys'

- Top quark is special (the only heavy fermion):
  $m_t \sim M_W \Rightarrow H$ & top linked?
- Worst Higgs hierarchy problem $\leftrightarrow$ top.
- EW sym' breaking $\Rightarrow$ top $\leftrightarrow$ new phys.
- TeV NP, $\Lambda_t \Leftrightarrow$ flavor sector.

New Physics (NP)



Is NP generic?

- Expect: $\left(\frac{\bar{d}^i d^j}{\Lambda_t}\right)^2$ from NP ($\Delta F = 2$).
- Define:

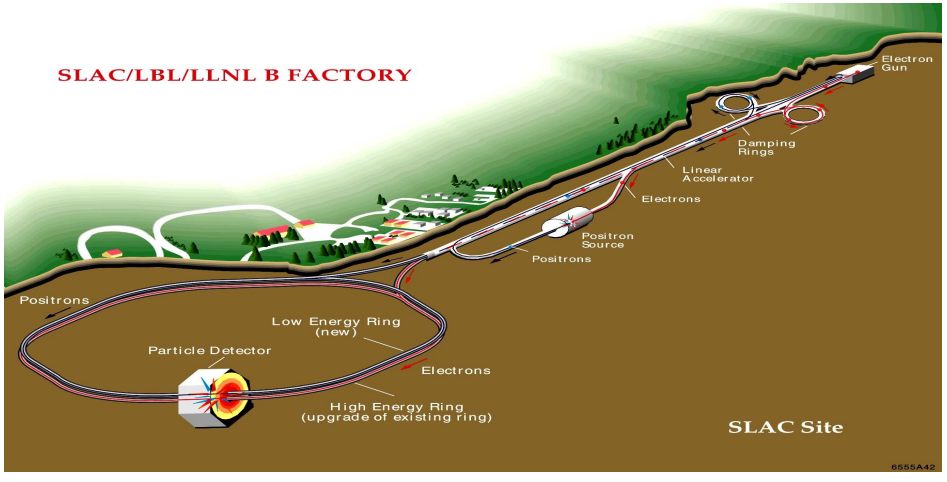
$$M_{12}^{K,d,s} = M_{12}^{K,d,s}\Big|_{\rm SM}(1 + h_{K,d,s}e^{2i\sigma_{K,d,s}}).$$

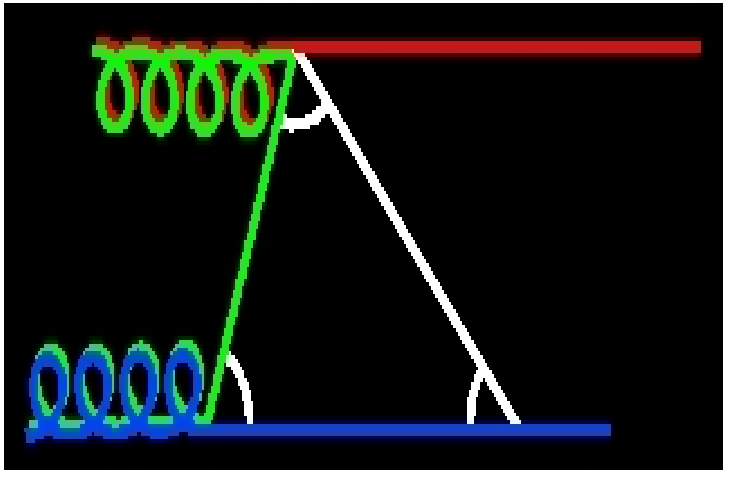
- Gen':

$$h_{K,d,s} \sim \left(\frac{4\pi v}{\Lambda_t \lambda^{5,3,2}}\right)^2 \sim \mathcal{O}(10^5, 10^3, 10^2)$$

Constraints - current status ($\Delta F = 2$)

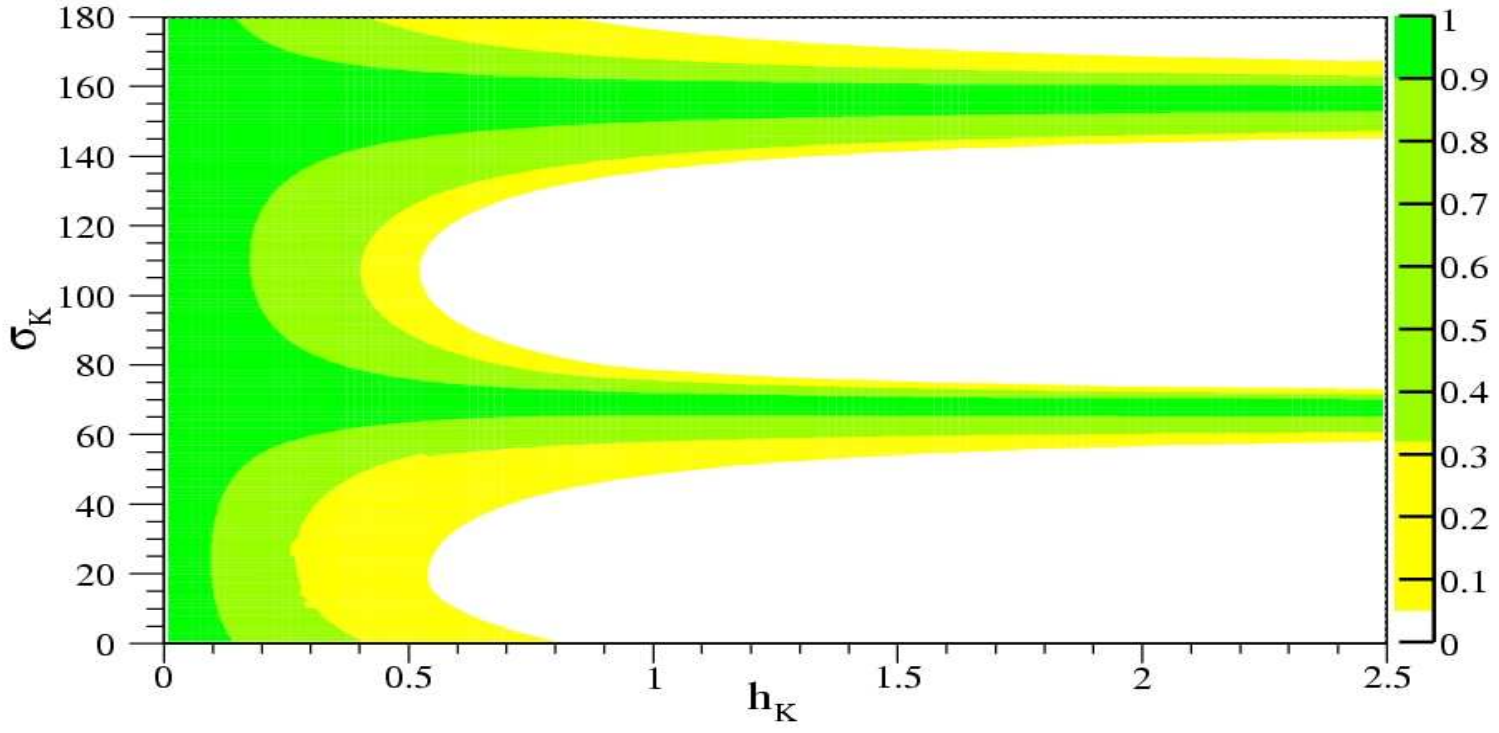
Ligeti, Papucci & GP (06)





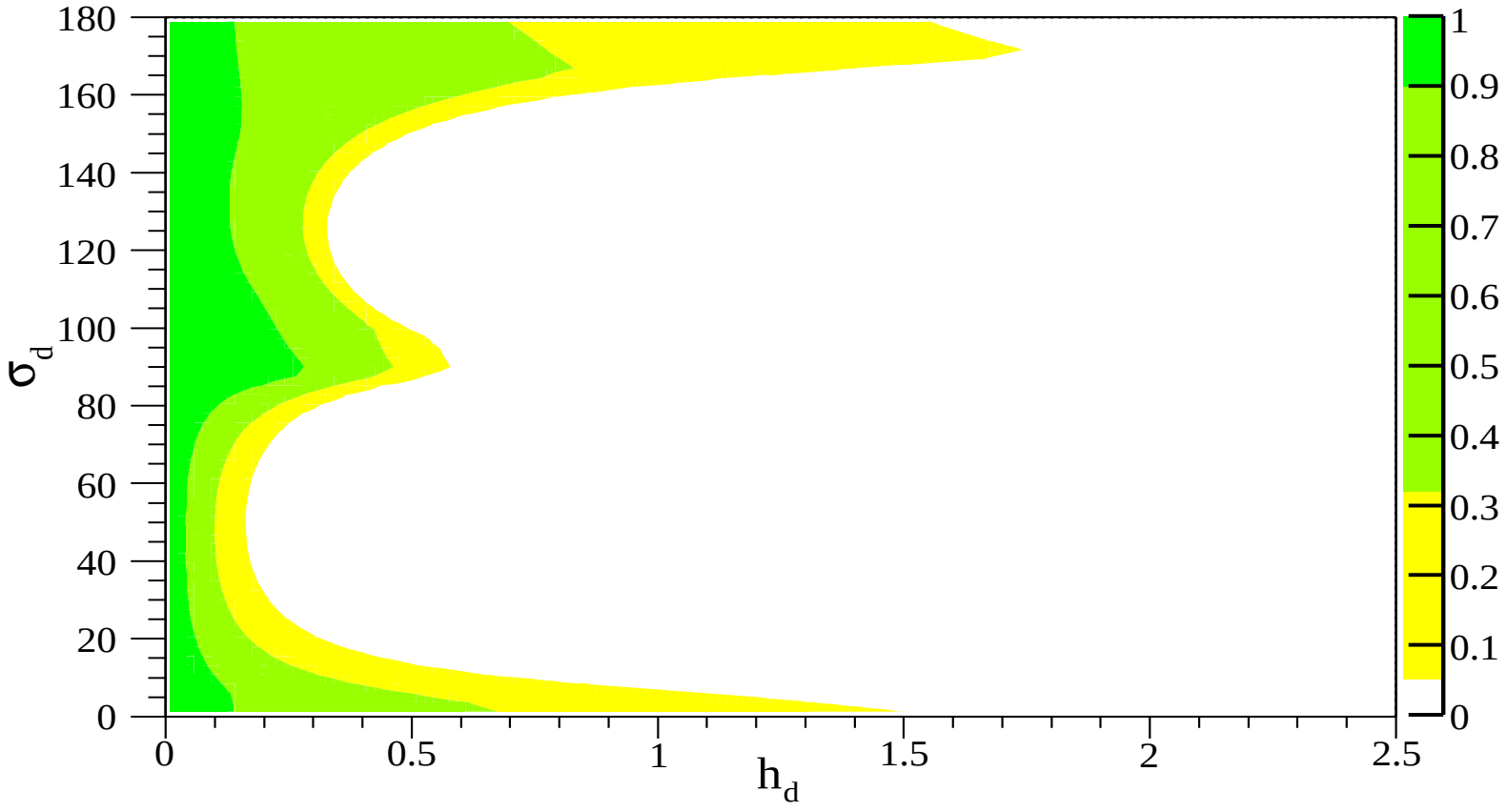
How big is h_K ?

$$h_K \lesssim 0.6$$



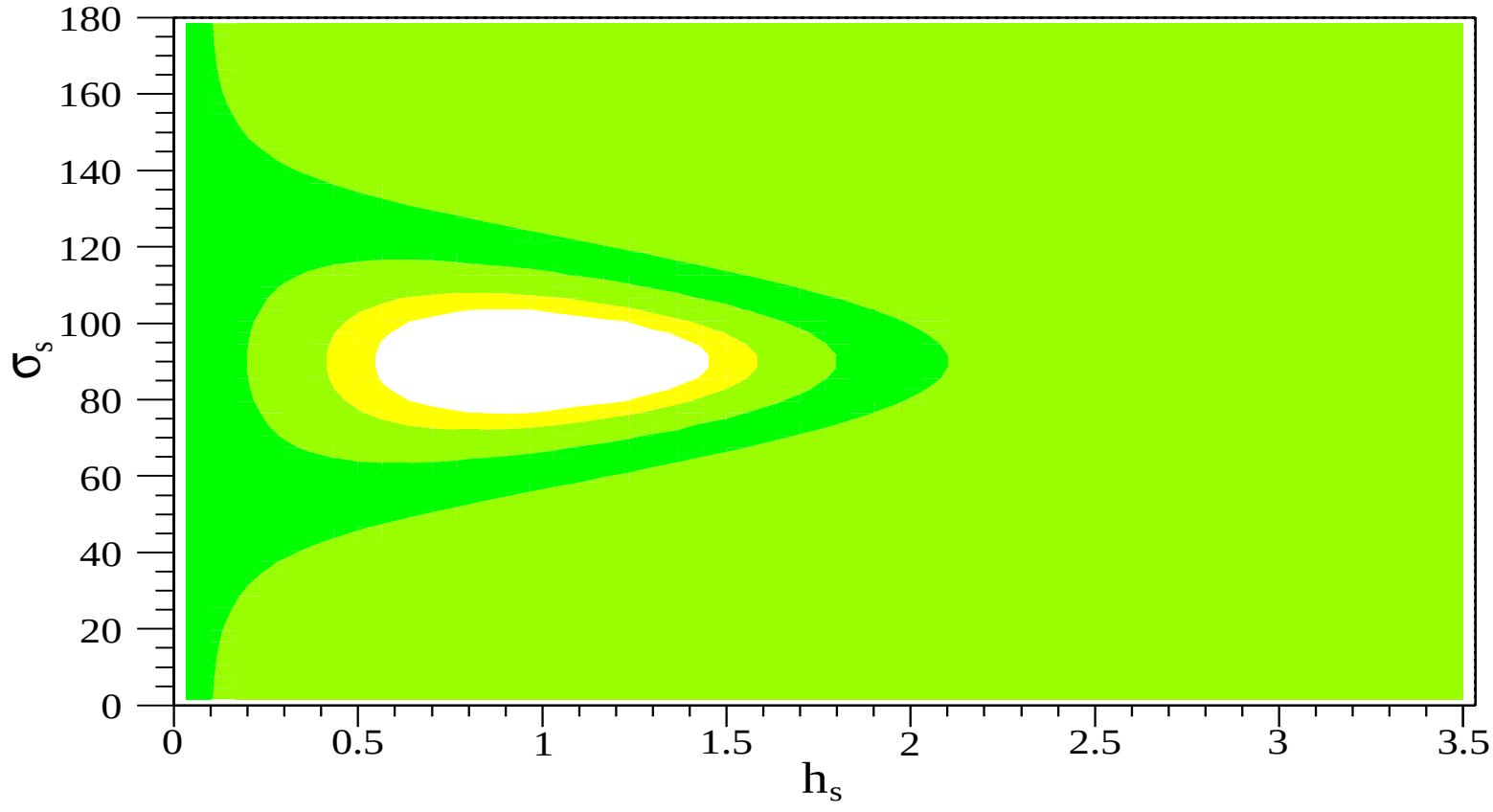
How big is h_d ?

$$h_d \lesssim 0.3$$



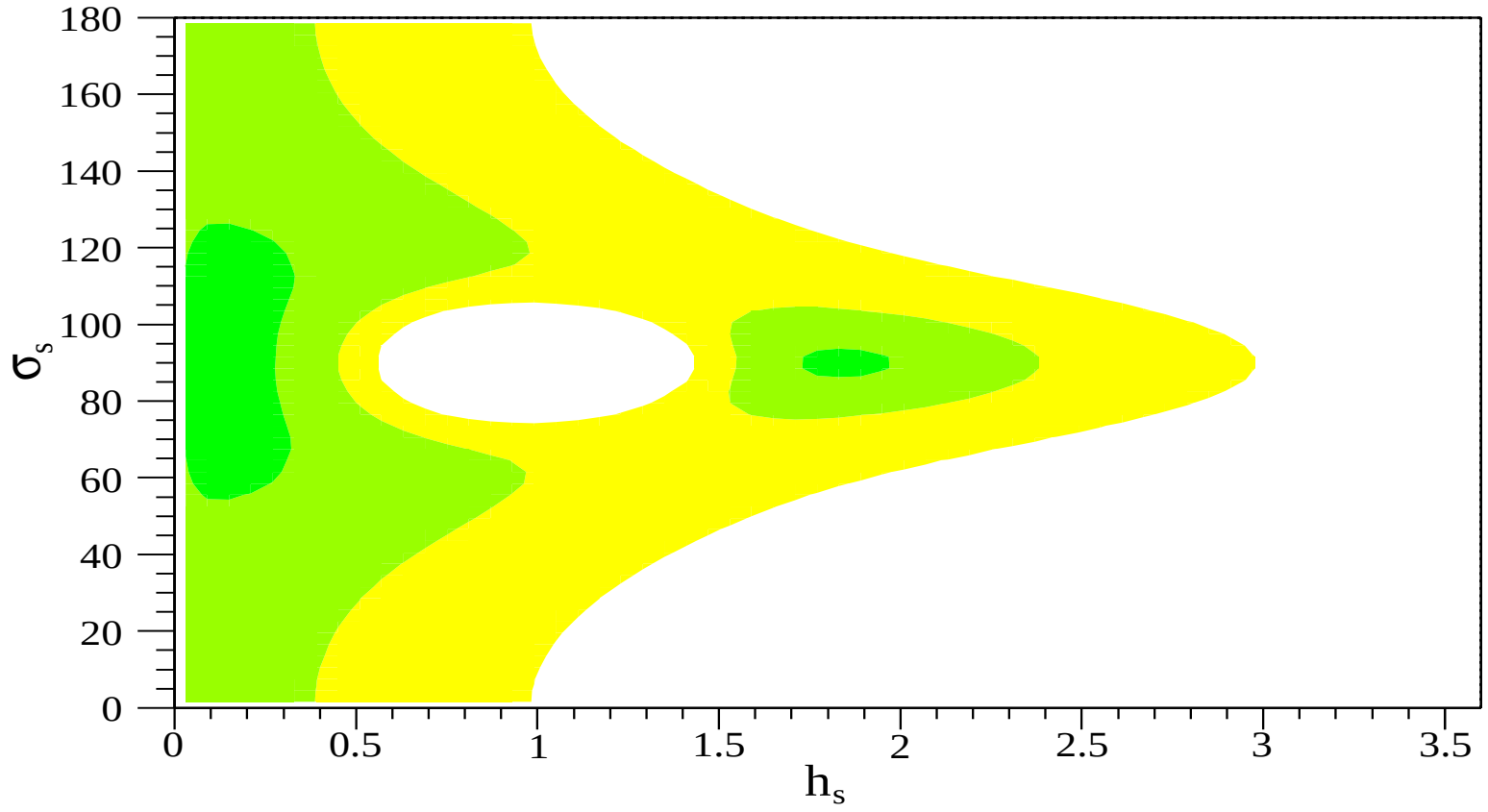
How big is h_s (05)?

h_s unconstrained



h_s 2006, Δm_s, $\Delta\Gamma_s$

$$h_s \lesssim 1.5$$



Summary of constraints $h_{K,d,s}$

- $h_K \lesssim 0.6\,.$
- $h_d \lesssim 0.3\,.$
- $h_s \lesssim 1.5\,.$
- Gen': $h_{K,d,s} \sim \mathcal{O}(10^5, 10^3, 10^2)\,.$

Far from gen' !!

What is the underlying structure ?

◇ Minimal flavor violation (MFV) $\longrightarrow$ high Λ_F.

Flavor violation $\leftrightarrow$ SM, NP: $(\bar{d}^i Y_u^2 d^j / \Lambda_t)^2$

(D'Ambrosio, Giudice, Isidori & Strumia (02))

◇ Next to MFV (NMFV) $\longrightarrow$ low $\Lambda_F \sim \Lambda_t$.

Violation $\sim$ SM, only 3rd gen', NP: $(\bar{d}^i D_{3i} D_{3j}^* \bar{d}^j / \Lambda_{\rm t})^2$

($D \sim V_{\rm CKM}$, new sources of flavor & CP violation)

(Agashe, Papucci, GP & Pirjol (05))

N M F V


next...
YOU'RE TOO SCREWED UP— NEXT PATIENT, PLEASE.
PSYCHIATRIST
CALLAHAN

Test the NMFV

Given $\Lambda_t = \mathcal{O}(\mathrm{TeV})$, $\dfrac{M_{12}^{\mathrm{NMFV}}}{M_{12}^{\mathrm{SM}}} \sim 1$.

Against the lore it's still alive ($h_i \sim 1$).

To disfavor NMFV, aim for:

$$h_{d,s,K}, h^1_{d,s,K} \lesssim 10\%. \ (\ h^1_{d,s,K} \Leftrightarrow \Delta F = 1)$$

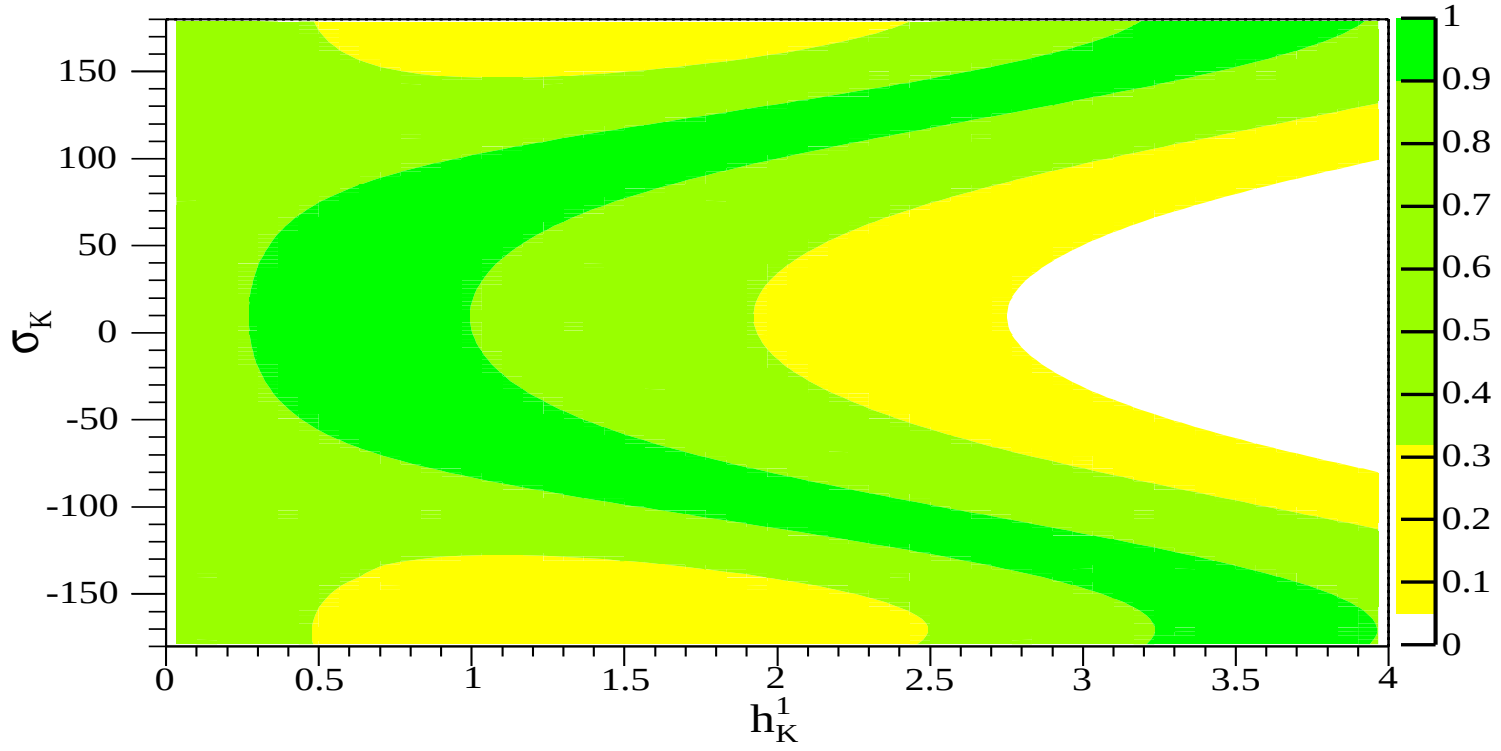
Which observable ?

$\Delta F = 1$ transition yield more info'

- Gen' analysis is more complicated.
- $b \to d \Rightarrow$ subleading (dominated by tree level).
- $d \to s \Rightarrow K \to \pi\nu\bar{\nu}, l\bar{l}\,;$ exp'?
- @ present only few events.

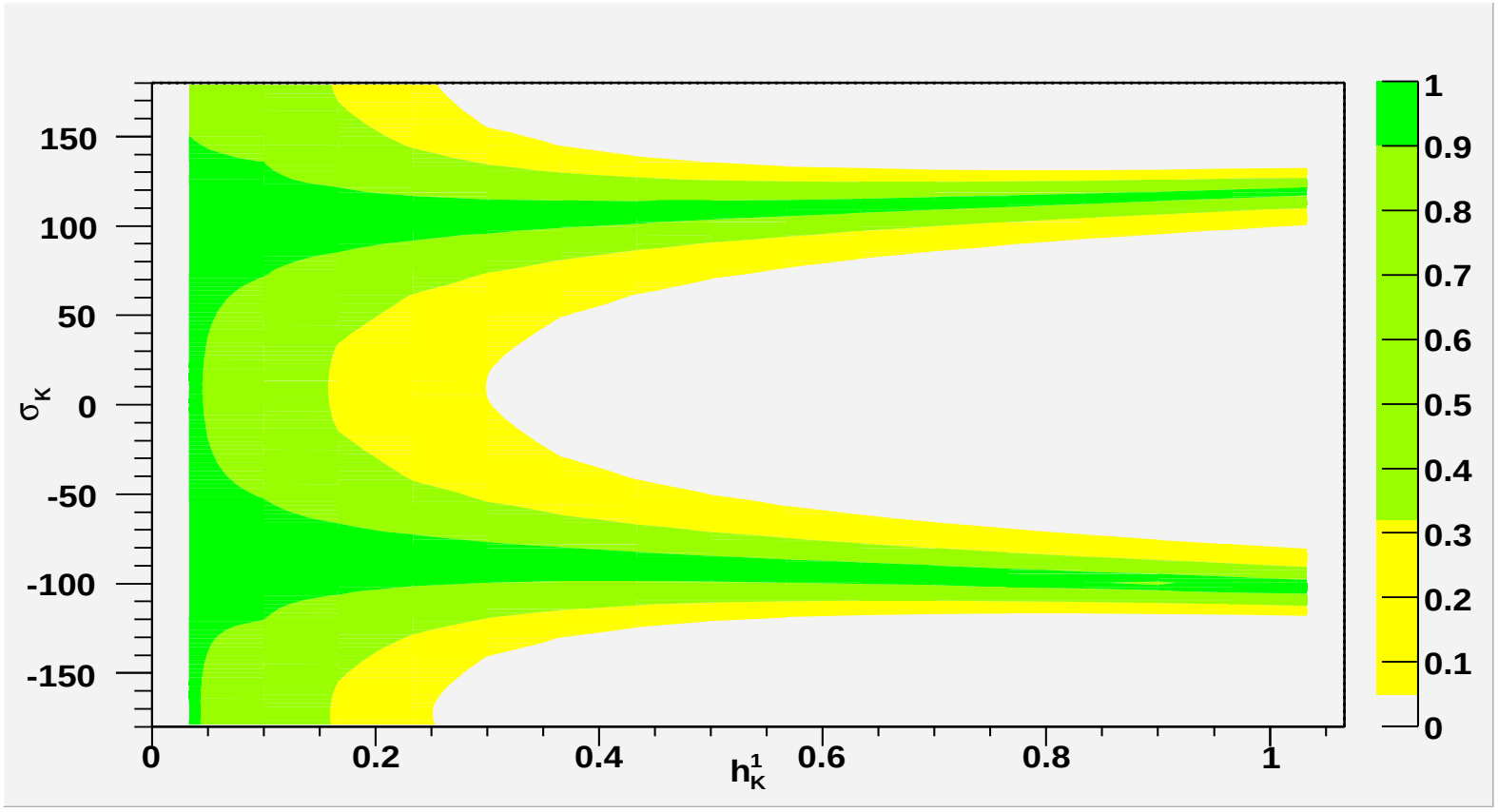
How big is h_K^1 from ($K^+ \to \pi^+ \bar{\nu}\nu$) ?

$$h_K^1 \lesssim \mathcal{O}(10)$$



Future: h_K^1 via $\Delta\left(K^+ \to \pi^+ \bar{\nu}\nu\right) \sim 10\%$

$$h_K^1 \lesssim 0.3$$

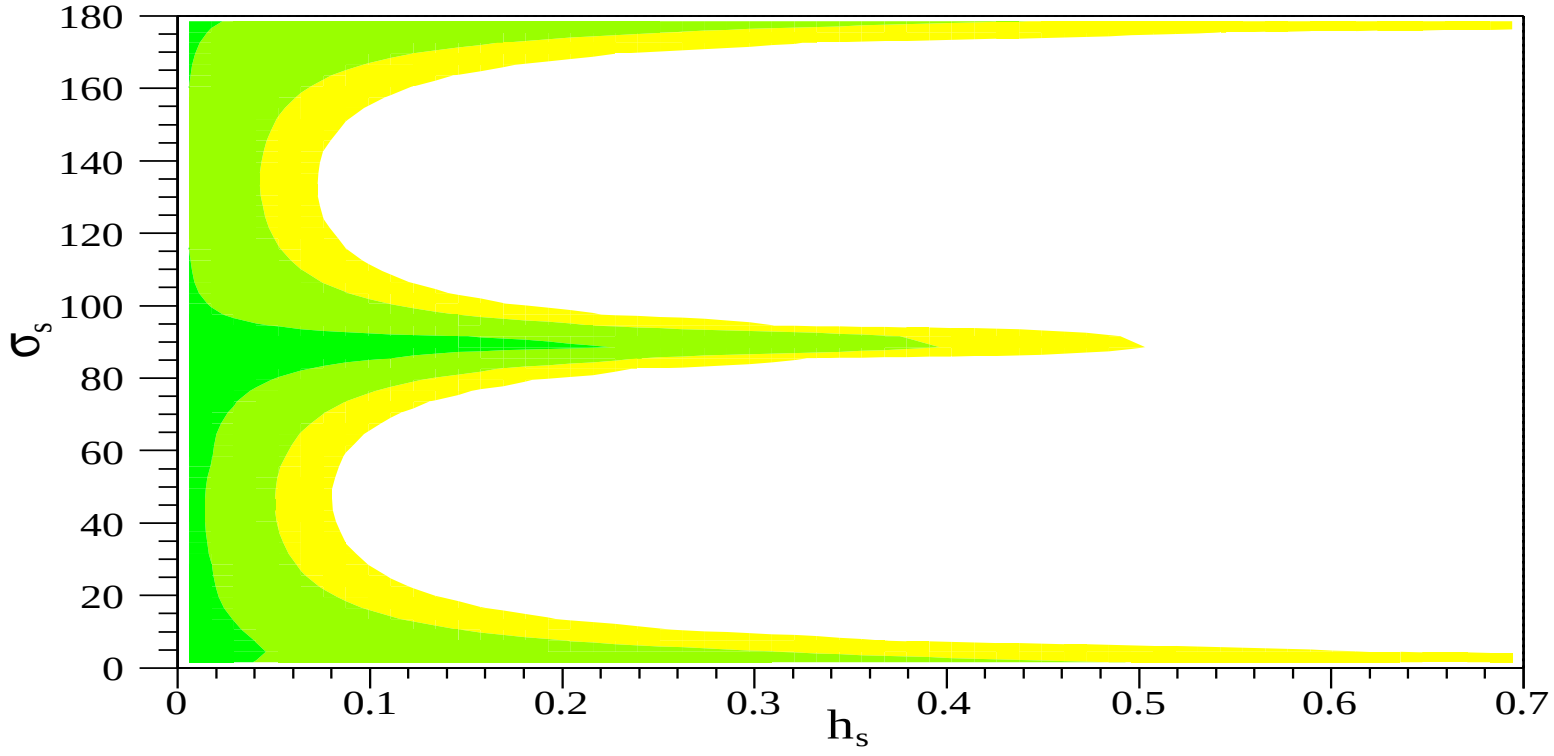


Can we improve (better than 10%)?

Ligeti, Papucci & GP (06)

- LHCb/year dramatically improve $b \to s$.

$h_s \lesssim 0.1$ from $S_{\psi\phi}$

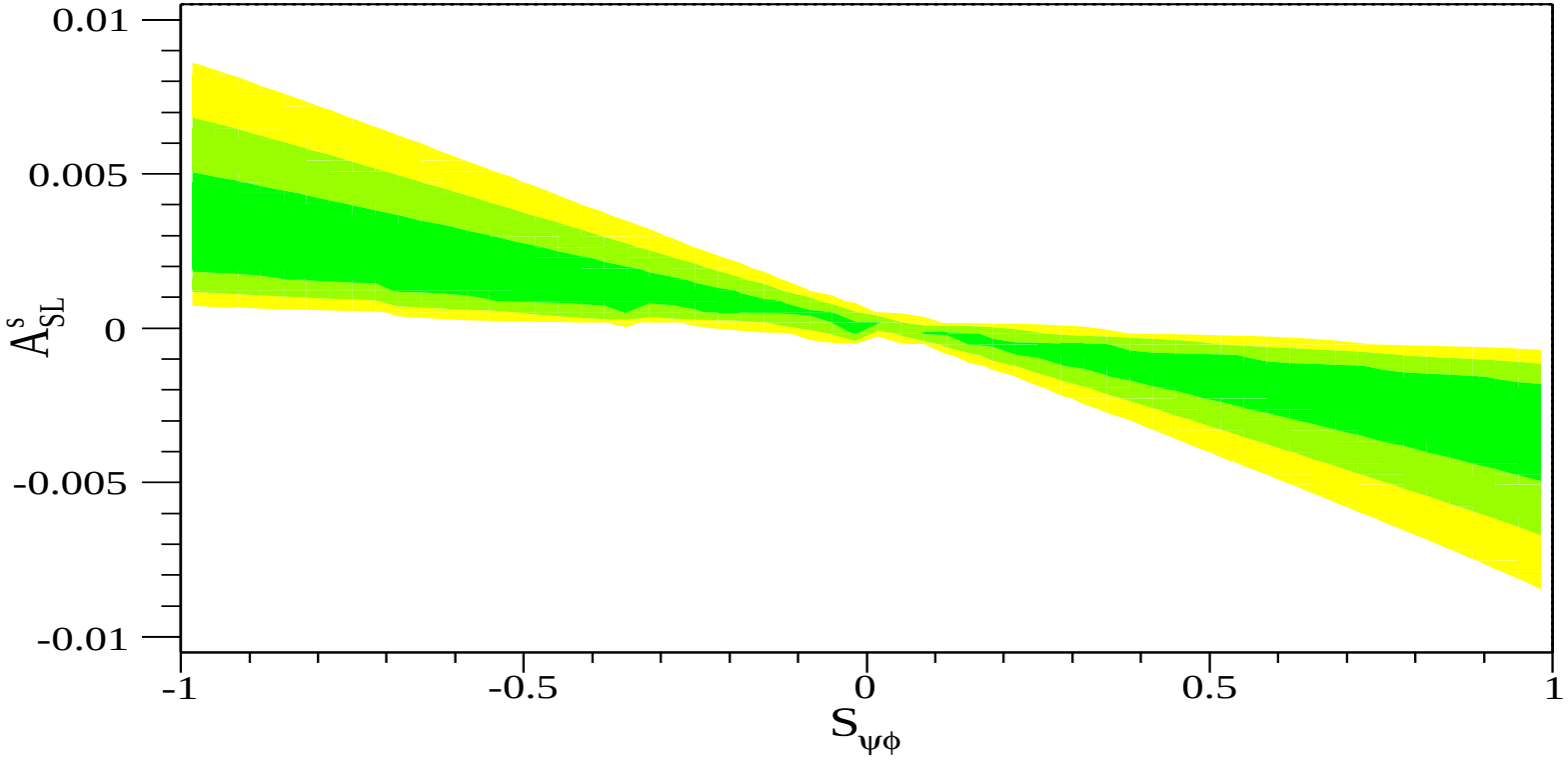


$A^s_{\rm SL} - S_{\psi\phi}$: a powerful test

Ligeti, Papucci & GP (06)

- Correl' for small h_s. ($A^s_{\rm SL} = \frac{\Gamma[\bar{B}_s \to \ell^+ X] - \Gamma[B_s \to \ell^- X]}{\Gamma[\bar{B}_s \to \ell^+ X] + \Gamma[B_s \to \ell^- X]}$)

$A^s_{\rm SL}$ vs. $S_{\psi\phi}$



What if no deviations are found ?

- Must it be MFV ? No! (uNMFV ...)

  Data $\Rightarrow$ down system; $D_L \ll U_L$ ($U_L^\dagger D_L = V_{\rm CKM}$)

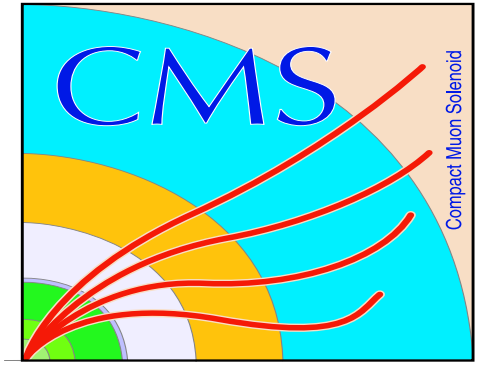
  (Nir & Seiberg (93); Agashe, Contino, Da Rold & Pomarol (06))

- Gen' MFV (which one) or SM ?

$$\Downarrow$$

  - Ups data is needed! (D sys' less clean)
  - LHC$^+$ILC $\Rightarrow$ probe top sector. (linked-Λ_t)

LHC, ILC & Top Phys'



Top flavor violation

- LHC: study int'; ILC: nature of int'.
- Top FCNC: $t \longrightarrow q, Z, \gamma, G$. ($q = u + c$)

  (also $t \longrightarrow qh$ & single top production)
- SM: $BR(t \longrightarrow qZ, \gamma, G) \sim 10^{-12}$.

  (Díaz-Cruz (89); Eilam, Hewett & Soni (90))
- LHC (100fb^{-1}): $BR(t \longrightarrow qZ, \gamma) \gtrsim 10^{-5}$.

  (Carvalho, *et. al* (05))
- ILC (350fb^{-1},.5TeV): $BR(t \longrightarrow qZ^{\mu,\mu\nu}, \gamma) \gtrsim 10^{-4,5,6}$.

  (Aguilar-Saavedra (04))

Top-FCNC: 2 questions

- $BR(t \to qZ\gamma) \sim 10^{-5} \Leftrightarrow$ B phys'+EWPT?

Requires model indep' study.

(Han & Hewett (98); Larios, Martinez & Perez (04); Fox, Ligeti, Papucci, GP & Schwartz)

- Can NP naturally yield enhancement?

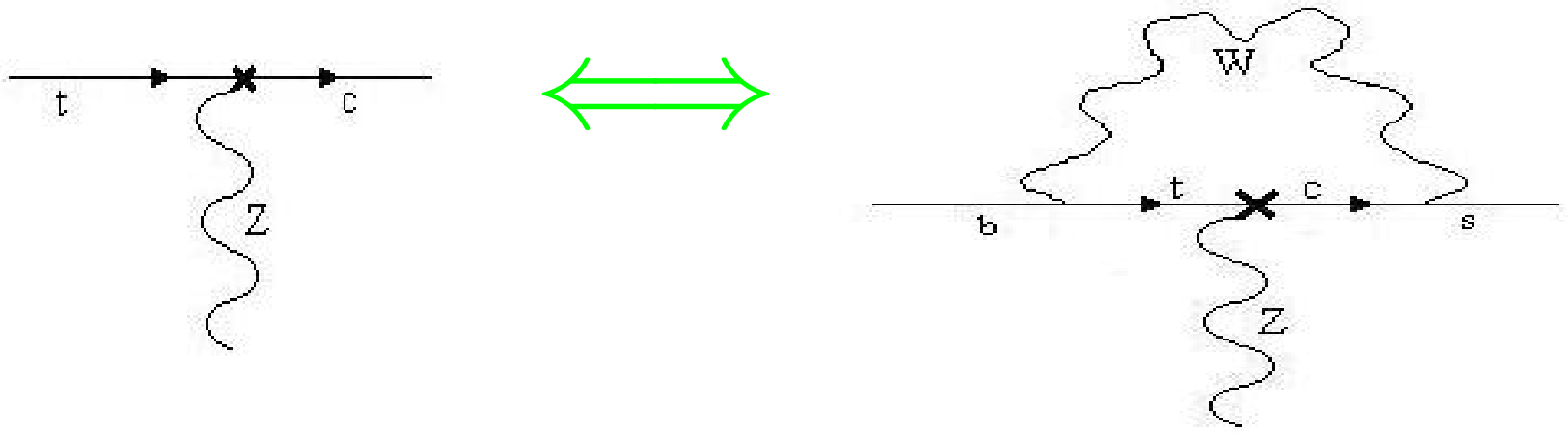
Beyond NMFV- ex.: RS (Del Aguila & Santiago (00), Agashe, GP & Soni (06))

Is the LHC/ILC window closed?

- $t \to c\gamma, Z$: SM + Dim' 6 Op' @ m_t:

$$(LL^u)_{23} \leftrightarrow \bar{Q}_3 H^\dagger \not{D} H Q_2,\ (LR^u)_{23}, (RL^u)_{23}, (RR^u)_{23}.$$

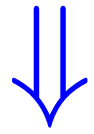
- Confront with $b \to s, c$ data.



Is the window closed?

(Fox, *et. al.*)

	$\Lambda_{C^u_{LL}}$	$\Lambda_{C^h_{LL}}$	$\Lambda_{C^B_{LR}}$	$\Lambda_{C^W_{LR}}$	$\Lambda_{C^B_{RL}}$	$\Lambda_{C^W_{RL}}$	$\Lambda_{C^u_{RR}}$
$t \to cZ(\Lambda <)$	2.2	2.2	1.2	2.2	1.2	2.2	2.2
$t \to c\gamma(\Lambda <)$	-	-	2.6	2.6	2.6	2.6	-
$b \to s\gamma(\Lambda >)$	2.8 (3.3)	-	1.3 (1.6)	1.6 (1.9)	-	-	-
$b \to sll(\Lambda >)$	-	very large	0.6 (1.0)	2.7 (4.4)$[1 < \Lambda_+ < 1.2]$	-	-	-
Window	Closed	Closed	Ajar	Closed	Open	Open	Open

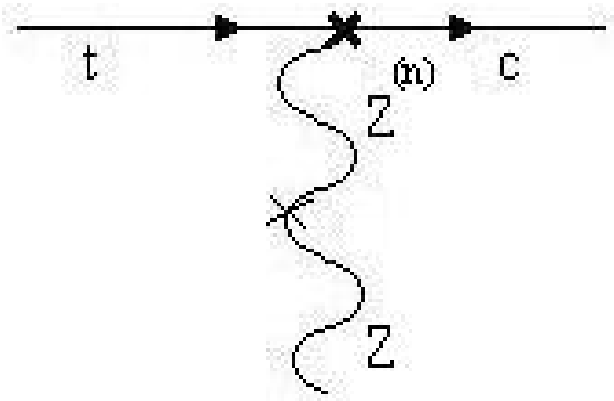


Partially (for $t \to c_L\gamma, Z$.)

Similar conclusion for $t \to uZ, \gamma$. ($\Delta F = 2$)

Huge enhancement in RS1

- After EWSB $Z + t$ mix with the KKs.
- Tree level Z FCNC via KK mixings.
- $BR(t \to c_R Z) \propto |U_R|_{23} \times \delta g_Z \sim 10^{-5}$.



- ILC: FB asym' (without $Zb\bar{b}$ sym, Agashe *et. al.* (06)).

3rd gen' univer'? (flavor diag')

- $t - \Lambda_t$ linked $\Rightarrow$ non-univ. effects.
- Decay before had' $\Rightarrow$ spin info':
  spin-cor', angular analysis', Wtb coupling.
  (Mahlon, Parke; Shadmi (96); Berger & Tait (00); Hubaut *et. al.* (05))
- $m_{tt}^2 \gg m_t^2 \Rightarrow$ helicity, boost $\Rightarrow$ produc'.
  (LHC: GP & Virzi)
- ILC (350fb^{-1},.5TeV): $t_{\rm EDM} \sim \mathcal{O}(10^{-19})$. (RS1 predic')
  (Bernreuther, Ma & Schroder; Atwood & Soni (92); Agashe, GP & Soni (04,06))
- MFV: $H\bar{Q}^3 Y_u u^3 F^{\mu\nu}/{\Lambda_t}^2$, ILC observed?

Conclusions

- MFV vs. NMFV ?
- $\Delta F = 2$ probe NMFV $\Rightarrow$ not there!
- We looked in wrong place? (uFCNC)
- Top FCNC @ Atlas & CMS + ILC.
- 3rd gen' non-univ.?

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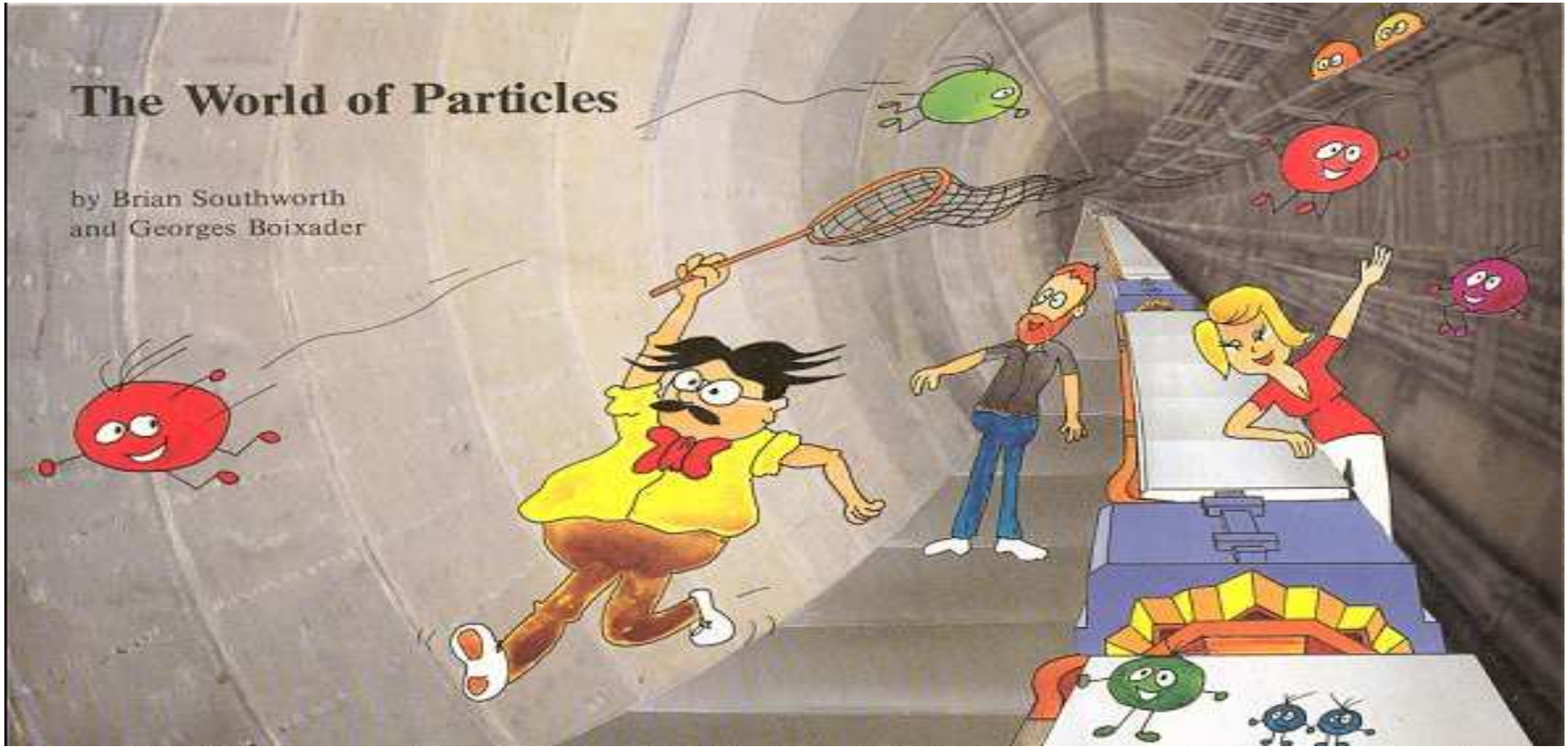


Backups


ORIGINAL GLAZED


MAPLE ICED


GLAZED CINNAMON


GLAZED CRULLER


GLAZED BLUEBERRY CAKE


GLAZED SOUR CREAM


GLAZED DEVIL'S FOOD CAKE


CHOCOLATE ICED GLAZED


CHOCOLATE ICED CRULLER


CHOCOLATE ICED GLAZED WITH SPRINKLES


CHOCOLATE ICED CREME FILLED


CHOCOLATE ICED CUSTARD FILLED


CINNAMON APPLE FILLED


GLAZED CREME FILLED

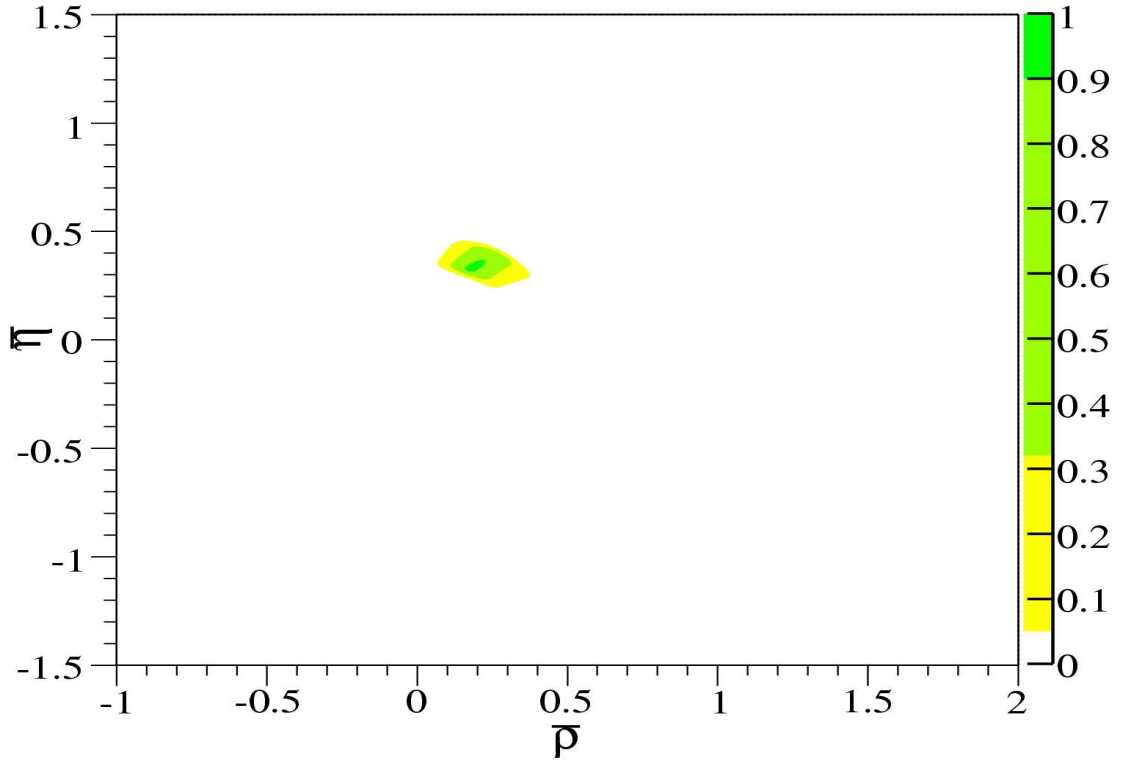

POWDERED STRAWBERRY FILLED


GLAZED RASPBERRY FILLED


GLAZED LEMON FILLED

The $\rho - \eta$ Plane + NP (06)

$\Delta m_{d,s}, V_{ub}, S_{\psi K,\pi\pi,\rho\rho}, A_{DK}$ ...
($h_{d,s}, \sigma_{d,s}$-scanned)



Features of the NMFV

Flavor violation $\leftrightarrow$ 3rd gen'. (top int')

Info' on flavors' origin via near future exp'!

(Isidori, Papucci & GP; Agashe, GP & Soni, *in progress*)

Link EW sym' stabilization with flavors!

Is it allowed by present data?

The lore: no ...

NMFV, Definition

- $3^{\rm rd}$ gen' is special, $U(2)^3$ approx' sym'.
- Like $Y_u Y_u^\dagger \leftrightarrow Y_d Y_d^\dagger$, NP$\leftrightarrow 3^{\rm rd}$ gen' int' $\Rightarrow$ quasi-align, $D_L, U_L \sim \mathcal{O}(V_{\rm CKM})$.
- Ex., $U(2)_Q \times U(3)_d$ sym': int' basis, below $\Lambda_{\rm NMFV}$ $\Rightarrow$ $\frac{(\bar{Q}_3 Q_3)^2}{\Lambda^2_{\rm NMFV}}$.

Flavor violation in NMFV

In mass basis, down quarks $\Delta F = 2$:

$$(\bar{Q}_3 Q_3)^2 \Rightarrow (D_L^*)^2_{3i}(D_L)^2_{3j}\ (\bar{Q}_i Q_j)^2 \approx (V^*_{\rm CKM})^2_{3i}(V_{\rm CKM})^2_{3j}\ (\bar{Q}_i Q_j)^2$$

$$\text{FCNC } (\Delta m_d) \Rightarrow (D_L)^2_{31}\ \frac{(\bar{Q}_3 Q_1)^2}{\Lambda^2_{\rm NMFV}} \sim \lambda_C^6\ \frac{(\bar{Q}_3 Q_1)^2}{\Lambda^2_{\rm NMFV}}$$

$$\Downarrow$$

$$\frac{M_{12}^{\rm NMFV}}{M_{12}^{\rm SM}} \sim \frac{16\pi^2 M_W^2/g_2^4}{\Lambda^2_{\rm NMFV}}$$

$$\Downarrow$$

$$\text{Given } \Lambda_{\rm NMFV} \sim \Lambda_{\rm EW} \sim 3\,{\rm TeV} \Rightarrow \frac{M_{12}^{\rm NMFV}}{M_{12}^{\rm SM}} = \mathcal{O}(1)\,!$$

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