Flavor Physics Beyond the Standard Model

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Flavor physics beyond the Standard Model???

A few mirages in the past,
some (real???) oasis these days,
the LHC next year...

Outline

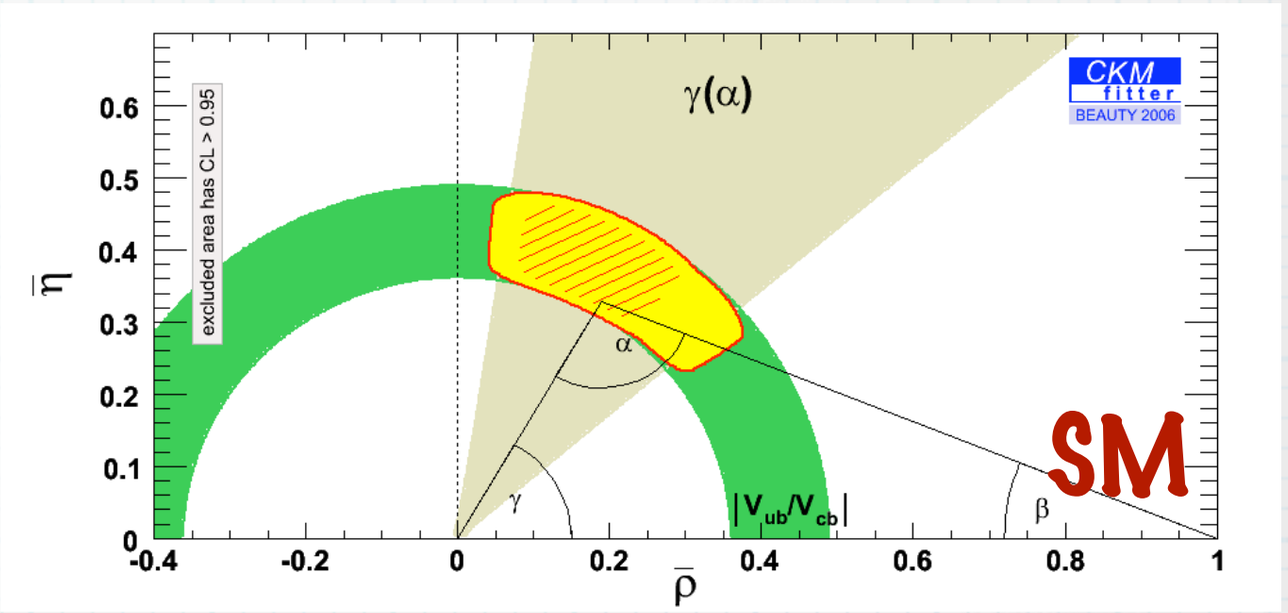
* A few remarks on the "discrepancies" discussed in the past days
* Present status: constraining new physics models
* the LHC is coming! Flavor BSM in the LHC era

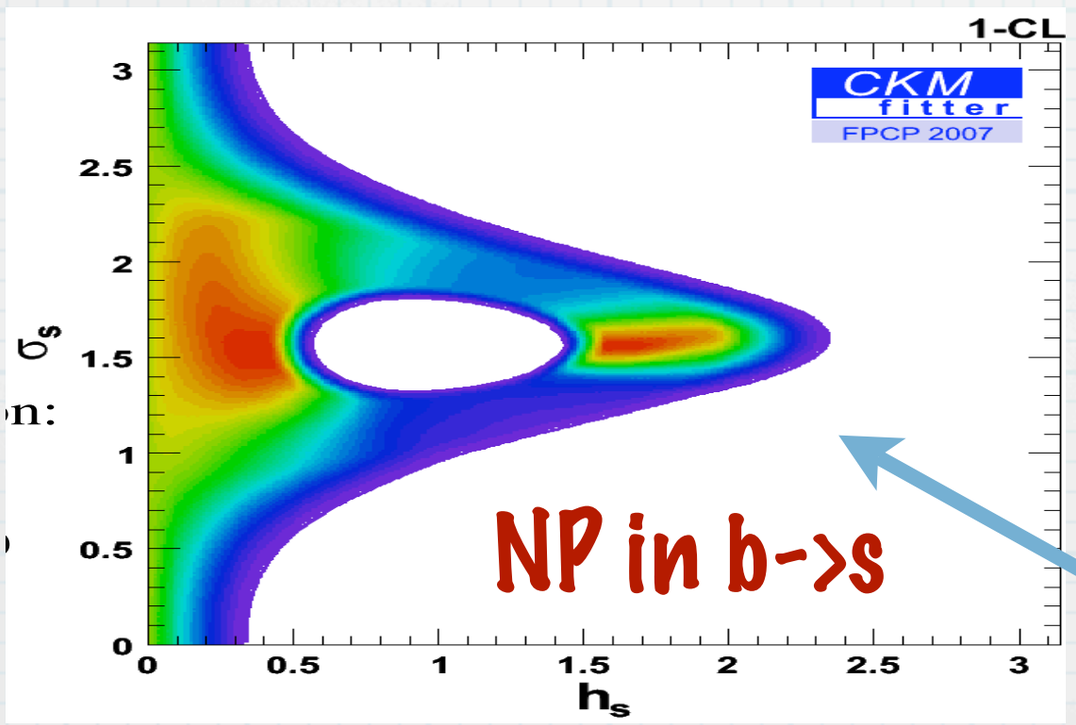
New Physics in flavor

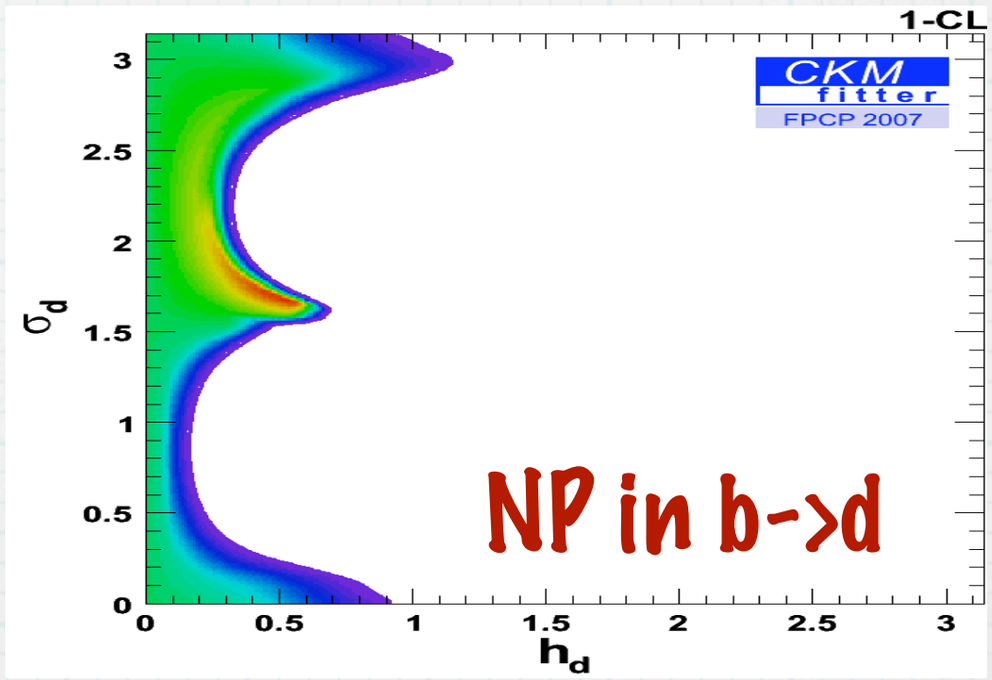
* Since 2004 enough data to constrain SM V_{CKM} + NP:

Model indep' if focus on meson mixing:

$$M^{SM} \longrightarrow M^{SM}(1 + h e^{2i\sigma})$$





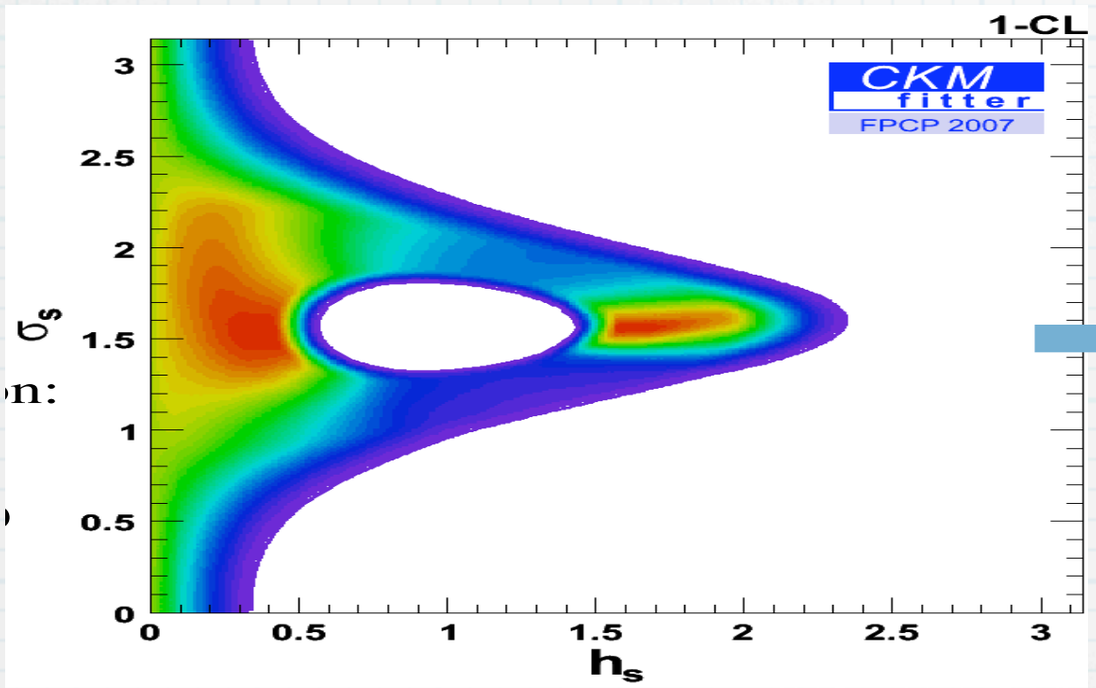


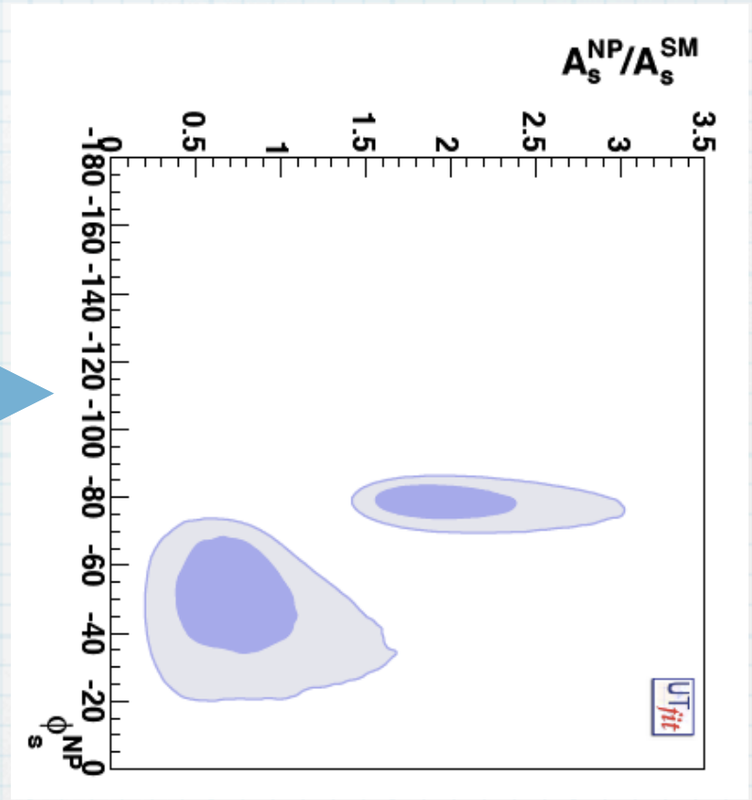
last year...

β_s measurement

talks of Donati, Strom

* CDF and D0 ~1.5(8)σ off the SM prediction
* UTfit claims 3σ evidence (arXiv 0803.0659):

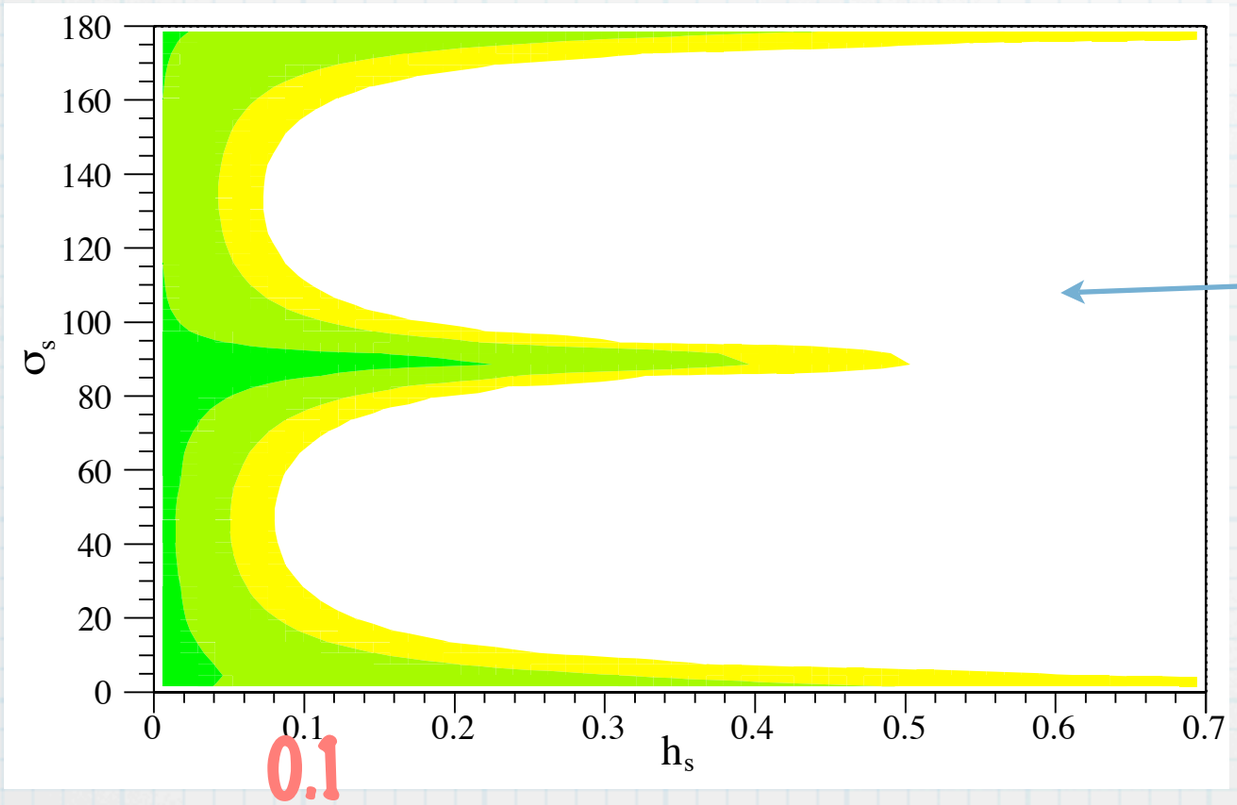




* Is this the first signal of New Physics in a flavor obs'???
* Generic in many models (SUSY, extra dim', 4th gen', ...)

β_s measurement (cont'd)

* BUT still too early to tell... need more data!
* if CDF and DO won't, LHCb should settle it



1 nominal yr in absence of any departure from the SM

If the discrepancy is real, what about $\Delta F=1$ b->s transitions?

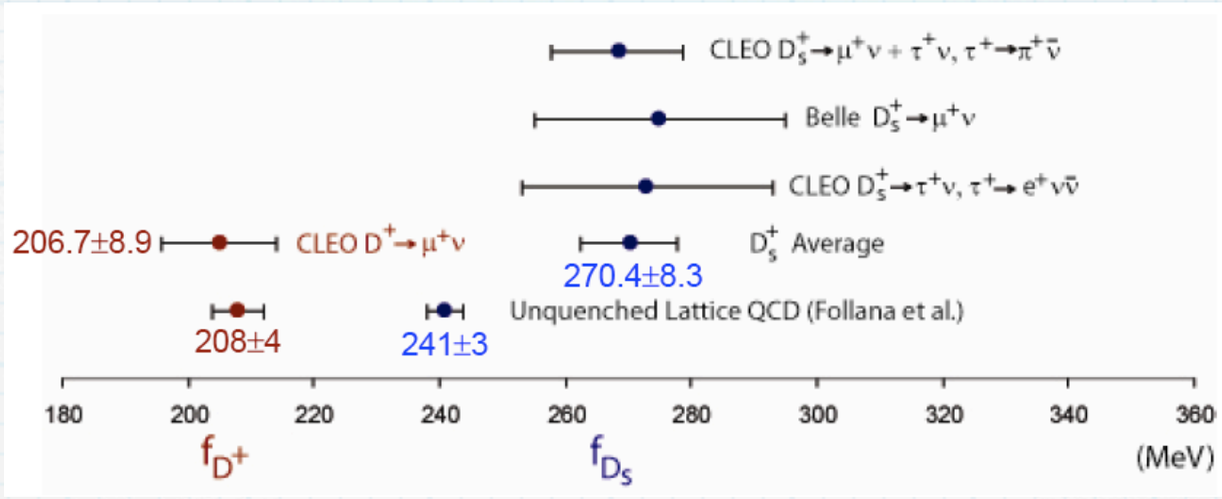
* if only one dominant new CP viol' phase in b->s transitions, it may affect both B_s oscill' and b->s hadronic penguin modes or $b\to s l^+ l^-$ ... correlations should be expected...

* However, present theo' uncert' on hadronic modes makes difficult to assess the presence of NP (e.g. in $B\to K\pi\pi$)

* Unclear if situation will improve before LHC data will come out

* measurement of β_s and discovery of new particles at the LHC: can case be made for NP in b->s penguins?

D_s->lν: FPCP08 hot topic...



* If lattice and exp' are ok, then NP needs to contribute ~12% of a Cabibbo-unsuppressed tree level process in the SM...

* Naive Numerology: a tree level exchange of a new particle around 400 GeV (to avoid direct TeVatron & LEP bounds) gives a contrib' 20-30% of the SM with O(1) couplings

* Couplings cannot be much smaller than 1 !! (Difficult for gauge Yukawa couplings)

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  * ...

→ Not the first place where one would expect to find New Physics...

Constraining BSM physics with flavor

What did we learn?

* New Physics can still affect many flavor and CP viol' observables at the 10-30% level (meson oscill', ...)

* Chirality flipping observables provide the strongest constraints ($b \to s\gamma$, $\mu \to e\gamma$, EDMs, ...)

(e.g. flavor viol' A-terms in SUSY need to be small...)

* In some cases (Bs oscill', top FCNCs, ...) large contrib' still allowed

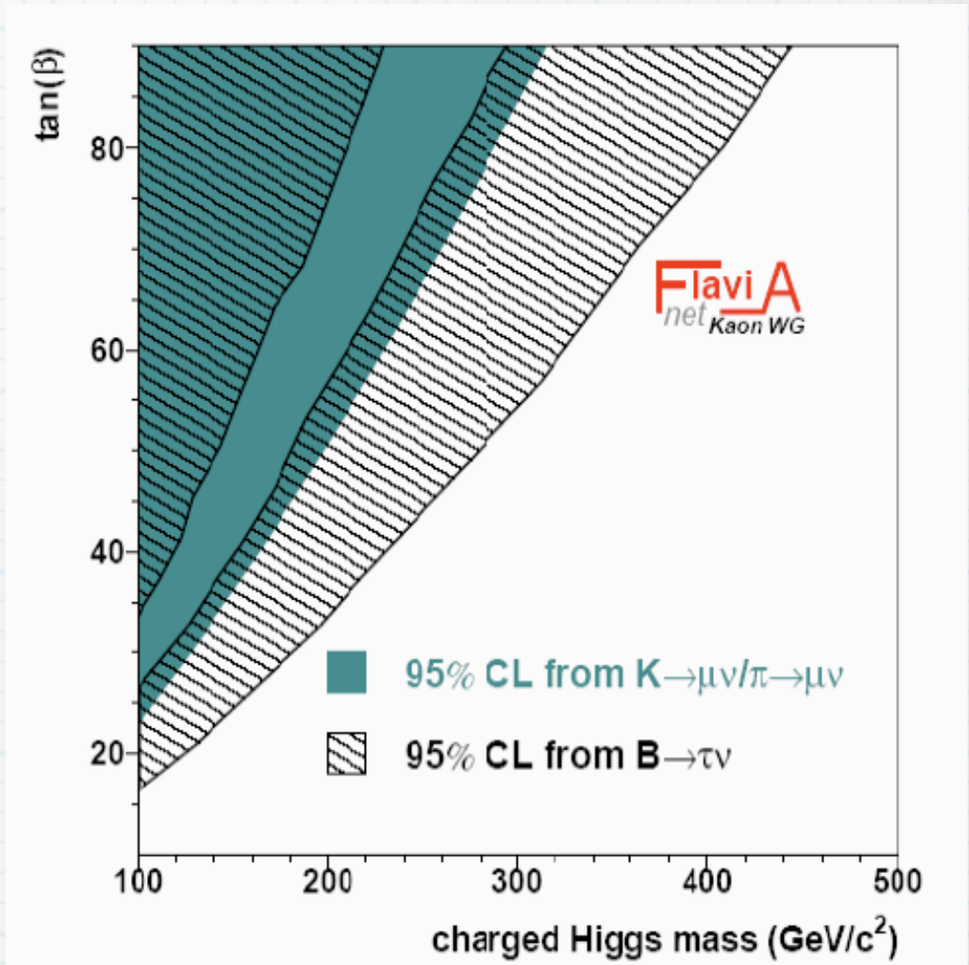
↓

Constraints on specific New Physics Models

Flavor expt's & BSM

* Many observables are most effective in constraining the (extended) Higgs sector:

see talks of Mescia, Haisch



extra Higgses will probably not be the first particles to be discovered at the LHC

← complementarity!

"Constraining BSM" saga...

* This year highlights:
* Randall Sundrum (RS1) models have problems with kaon oscill' unless:
  * some sort of MFV is implemented or
  * an U(2) symmetry between d-s quarks is at work in the bulk or
  * the compactification scale is >25 TeV or
  * ....

UTFit coll., 0707.0636
Fitzpatrick et al., 0710.1869
Cacciapaglia et al., 0709.1714
Csaki et al., 0804.1954

"Constraining BSM" saga...

* This year highlights:
* Top-Bottom-Tau unification in SUSY GUTs is disfavored by b->sγ

Altmannshofer et al., 0801.4363

* In SUSY, because both D and K mixing are measured, the 1st and 2nd gen' squarks cannot be naturally split by more than ~15% unless they are out of LHC reach

Nir, 0708.1872

Minimal Flavor Viol' news

* MFV can be richer (and not appear as MFV in low energy expt's) in certain theories

* MFV: all the flavor info is encoded in the Yukawa at Λ_{MFV}

* at low energy all the masses and couplings are functions of Y_u, Y_d in flavor space (e.g. in SUSY $m_{ij}=f_{ij}(Y_u,Y_d)$)

* Usual case: Taylor expansion of these functions in $Y_{u,d}$ up to first order

Λ_{flavor}

Λ_{MFV}

EWSB

MFV news cont'd

* In some cases one **cannot** capture the main effects by **Taylor expanding** to **linear order** (e. g. strongly coupled NP sector)

* the full $f_{ij}(Y_u, Y_d)$ may give flavor viol' **"beyond" MFV** (but addt'l sources of flavor and CP viol' are still functions of the Yukawas)

* general formalism in Feldmann Mannel 0801.1802

* e.g.: **5D MFV** in RandallSundrum = **4D NMFV**

Fitzpatrick et al. 0710.1869

* more **examples needed** to understand the general features

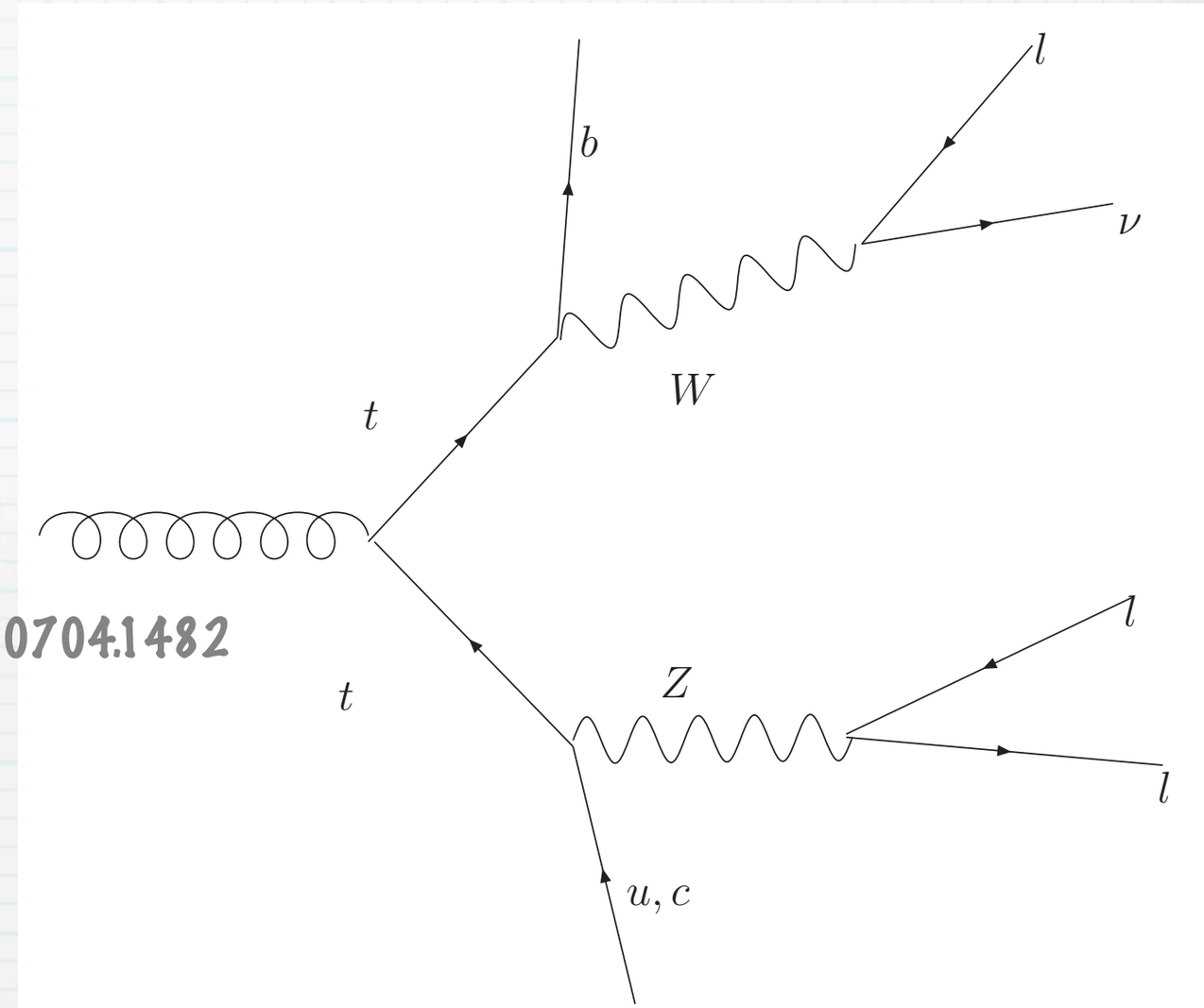
Flavor physics @ the LHC

Flavor physics @ the LHC

Flavor viol' in the top sector
not very well explored

Top FCNCs possible in
extensions of the SM
and still allowed by
Bfactories in RH sector

Fox, Ligeti, P, Perez, Schwartz 0704.1482



LHC: 1 ttbar pair / sec
will greatly improve on
the present bounds:

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)

Flavor physics @ the LHC

* LHC (hopefully) will find new particles
* after the champagne: measure their properties: mass, some of their decay modes, spin (?), production xsect' (?), ...
* if these new particles interact directly with quark and leptons, what about their flavor properties?

Probing flavor directly at high-pT?

Flavor @ high-Pt

* Hot topic: is flavor directly accessible at high-pT?
* In the quark sector non trivial:
* access to top, bottom, charm flavor only (Efficiencies?) can look for 3rd gen' vs. 2nd+1st gen'
* Mass resolution? Which mass splittings can be probed?

Flavor @ high-Pt

* Hot topic: is flavor directly accessible at high-pT?
* In the lepton sector easier to tag flavor
* If NP only interacts with leptons and SU(2)xU(1) gauge bosons -> prod xsect are small... cascades from colored particles?

Simple question: can we test MFV?

* Hardest to answer: MFV can be disproved or made plausible, but very difficult to confirm
  * mass splittings controlled by Yukawas -> very small,
  * most BR's controlled by CKM -> Cabibbo suppr'
* Model dip' answer!
  * some info gained from measuring the spectrum, xsects and BR's

    Grossman et al., 0706.1845
  * if some decay are kinematically forbidden one may probe some flavor viol' decays (e.g. $\tilde{t} \to c\chi_0$)

    Hiller & Nir, 0802.0916

Learning about the flavor symm' of NP in high-pT

* Many studies in progress (mostly based on SUSY):

* build viable SUSY scenarios with non negligible flavor violation
* focus on LHC phenomenology

Sflavor viol' @ LHC

* Build SUSY flavor models (i.e. flavor sym' determine both Yukawas and sparticle masses at high scale)

* "Dilute" SUSY flavor viol' with:

  * flavor blind SUSY breaking (gauge med') at a lower scale

Feng et al. 0712.0674,
Nomura P & Stolarski, 0712.2074,
0802.2582

  * Heavy Dirac gaugino masses (going beyond the MSSM)

Kribs et al. 0712.2039

* Sizable flavor non-universalities @ LHC possible!!

Sflavor viol' cont'd

* In the squark case look for decays into 3rd gen' vs. 1st+2nd generation quarks
* will probe 31 and 32 contrib' (the one relevant for b->s)
* 12 contrib' to BR's impossible to tell apart (except for charm), mass diff' already constrained to be small: Kaon physics may play an important role
* Best way to go in MSSM: slepton flavor viol'
* sleptons spectrum and BR's may contain useful info' on flavor symmetries

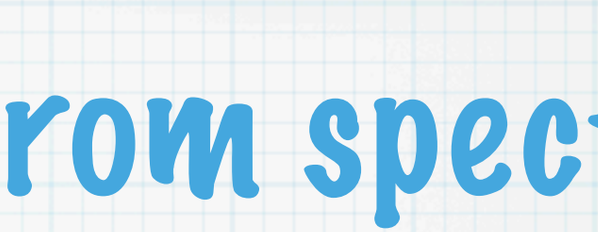
E.g.: Flavor properties from spectrum

* Measuring **mass differences** already gives a lot of **info'** on **flavor structure**:

* e.g. for RH slepton:

MFV
(splitting prop' to Yukawas)

U(1) sym'
(all splittings can be O(1))



wave funct. profiles, non-abelian sym', ...
(one splitting can be O(1) >> the other)

stau lightest

any flavor can be the lightest!

moreover: very **distinct signatures** if **smuon, selectron** are the lightest!!

Flavor effects on NP searches

* The presence of flavor violation can alter the LHC searches by altering decay modes and production xsect, ...
* Need to be taken into account:
  * can complicate SUSY analyses (usually done in MFV limit) with more complex decay chains

    Hurth et al., ph/0311075
  * can modify the discovery potential of some particles

    Dittmaier et al., 0708.0940

Conclusions

* Flavor and CP viol' poses important constraints on physics beyond the SM
* sizable room in the exp' and theo' uncertainties still exists for NP to hide
* LHC (hopefully) will find new particles and study some of their properties (becoming a "flavor" exp' in the long run)
* Interplay between indirect and direct searches may provide addt'l info (both on NP and on theo uncert')
* Probing direrctly flavor properties of new particles in high-pT events may provide useful info on the flavor puzzle