What have we learned about flavor from experiment

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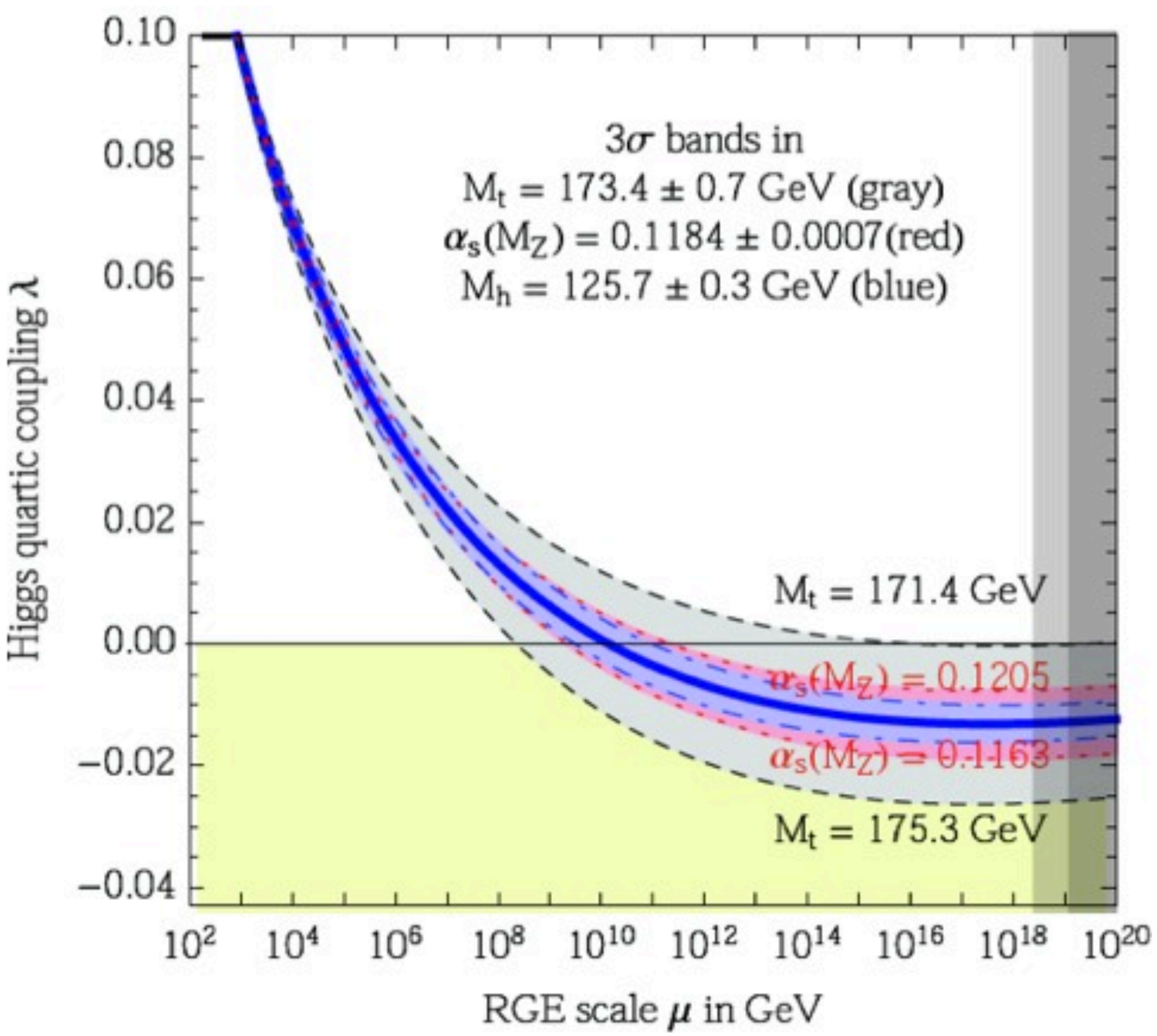
many thanks to Sebastian Jaeger, Jorge Camalich, Gilad Perez and Jure Zupan for sharing unpublished results with me

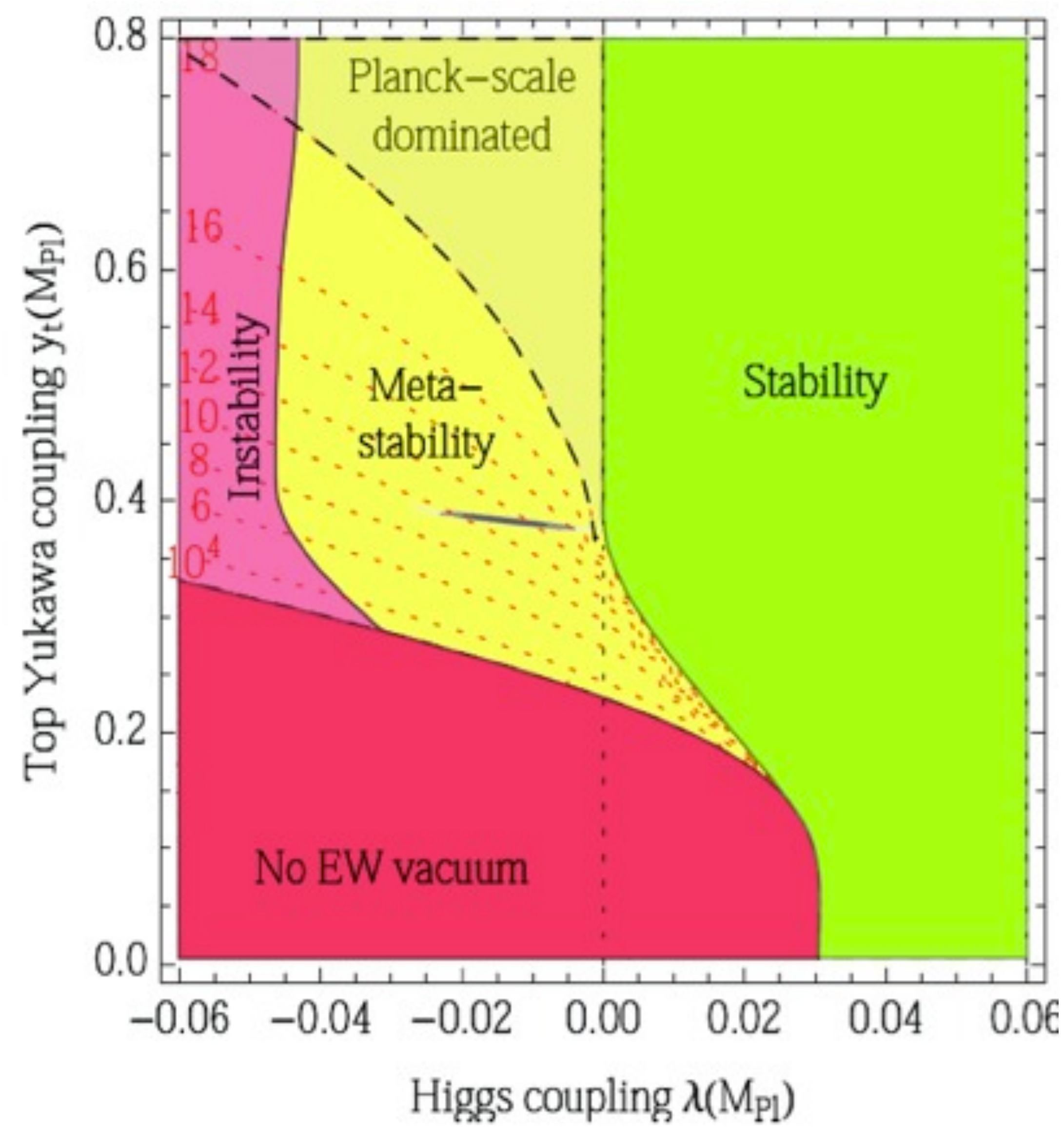
Standard Model Higgs, vacuum metastability

- we are faced with a renormalizable theory, metastable vacuum
  ➡ no clear indication for Mnp < Mpl

- λ never gets too negative: tunneling probability to true vacuum longer than age of universe

- from Buttazzo, Degrassi, Giardino, Giudice, Sala, Salvio, Strumia '13





- The traditional role of flavor physics - provide effective theories $\rightarrow$ scales of new physics

    - weak scale (V-A), charm quark mass ($K-\bar{K}$ mixing), top mass ($B-\bar{B}$ mixing)

- where do we stand today in the search for the next scale of new physics

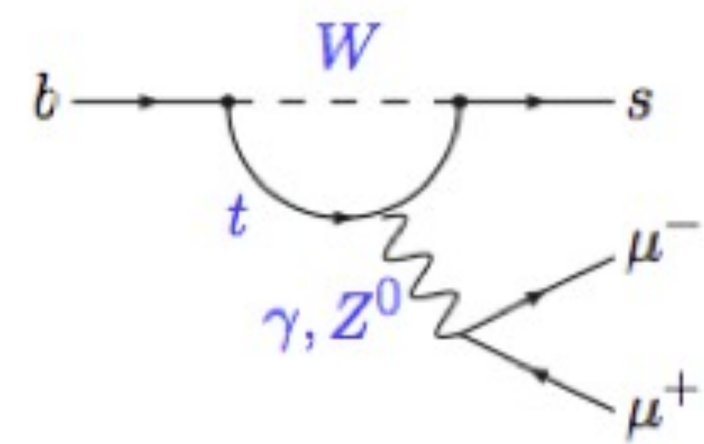
Low p_T

$\bar{B}_d \to \bar{K}^{*0}[\to K^- \pi^+]\,\ell^+\ell^-$

- semileptonic operators: SM dominated by the electoweak penguin operators

$$Q_{7\gamma} = \frac{e}{16\pi^2}\,\hat{m}_b\,\bar{s}\sigma_{\mu\nu}P_R F^{\mu\nu} b \qquad Q_{9V} = \frac{\alpha_{\rm em}}{4\pi}(\bar{s}\gamma_\mu P_L b)(\bar{l}\gamma^\mu l)$$

$$Q_{10A} = \frac{\alpha_{\rm em}}{4\pi}(\bar{s}\gamma_\mu P_L b)(\bar{l}\gamma^\mu \gamma^5 l)$$



  - with NP could have operators with opposite chirality, (pseudo)scalar, tensor currents,...

  eg: Z', susy loops, new Higgs penguins,.....

- The lepton pair and K* can have three helicities

$$\lambda = \pm 1, 0$$

The decay amplitudes given in terms of products of leptonic and hadronic amplitudes

→ hadronic amplitudes have three possible helicities H(λ) correspondence with leptonic currents

$$\bar{\ell}\gamma_\mu \ell \to H_V(\lambda), \quad \ell\gamma_\mu\gamma_5\ell \to \quad H_A(\lambda), ...$$

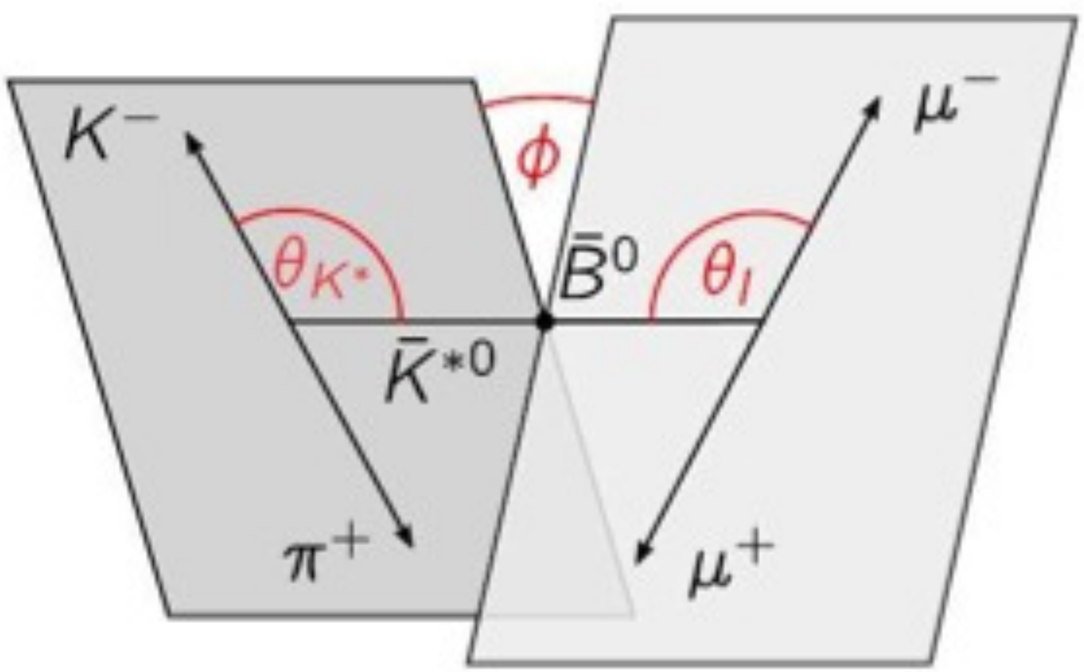
- $H_{V,A,..}(\lambda)$ depend on $q^2_{\ell\ell}$, Wilson coefficients $C_{7V}, C_{9V}, C_{10A}, ...$, form factors, factorizable, and non-factorizable effects (power corrns)

- SM V-A structure → $H^+ << H^-$, H^0

- A lot of information in the angular dependence of the decays:
  The four-fold differential spectrum

$$\frac{d^{(4)}\Gamma}{dq^2\, d(\cos\theta_l) d(\cos\theta_k) d\phi} = \frac{9}{32\,\pi} \quad \left(I_1^s \sin^2\theta_k + \ldots\right)$$

contains 12 angular coefficients I_i (notn. of Jaeger, Camalich '12)



related to well known A_{FB}

$$\begin{aligned}
I_6^s &\propto \mathrm{Re}\left[H_V^-(H_A^-)^* - H_V^+(H_A^+)^*\right] \\
I_3 &\propto \mathrm{Re}\left[H_V^+(H_V^-)^*\right] + (V \to A) \\
I_5 &\propto \mathrm{Re}\left[(H_V^- - H_V^+)(H_A^0)^*\right] + (V \leftrightarrow A)
\end{aligned}$$

related to P_5'

$I_3 \approx 0$ in SM due to H+ suppression - tests for RH currents

“Clean” observables

- new generation of observables $P_i^{(\prime)}$ with reduced form factor dependence at large recoil, $0.1 < q^2 < 8 \ \mathrm{GeV}^2$, due to cancelations with denominators

  Descotes-Genon, Hurth, Matias, Virto ’13; Matias, Mescia, Ramon, Virto ’12; Becirevic, Schneider ’11; Bobeth, Hiller, van Dyk ’10; Altmanshoffer, Ball, Bharucha, Buras, Straub ’08

- numerators and denominators are CP averaged integrals over bins of q^2, eg.

$$-\frac{A_T^{\mathrm{Re}}}{2} \sim P_2 \sim \frac{\int I_6^s dq^2}{\int \sqrt{F_T F_L} dq^2}, \quad P_5' \sim \frac{\int I_5 dq^2}{\int \sqrt{F_T F_L} dq^2}$$

F_L = longitudinal pol. fraction; $F_T = 1 - F_L$ = transverse pol. fraction

P_2 is the ‘normalized’ A_{FB} (forward-backward asymmetry of μ^-)

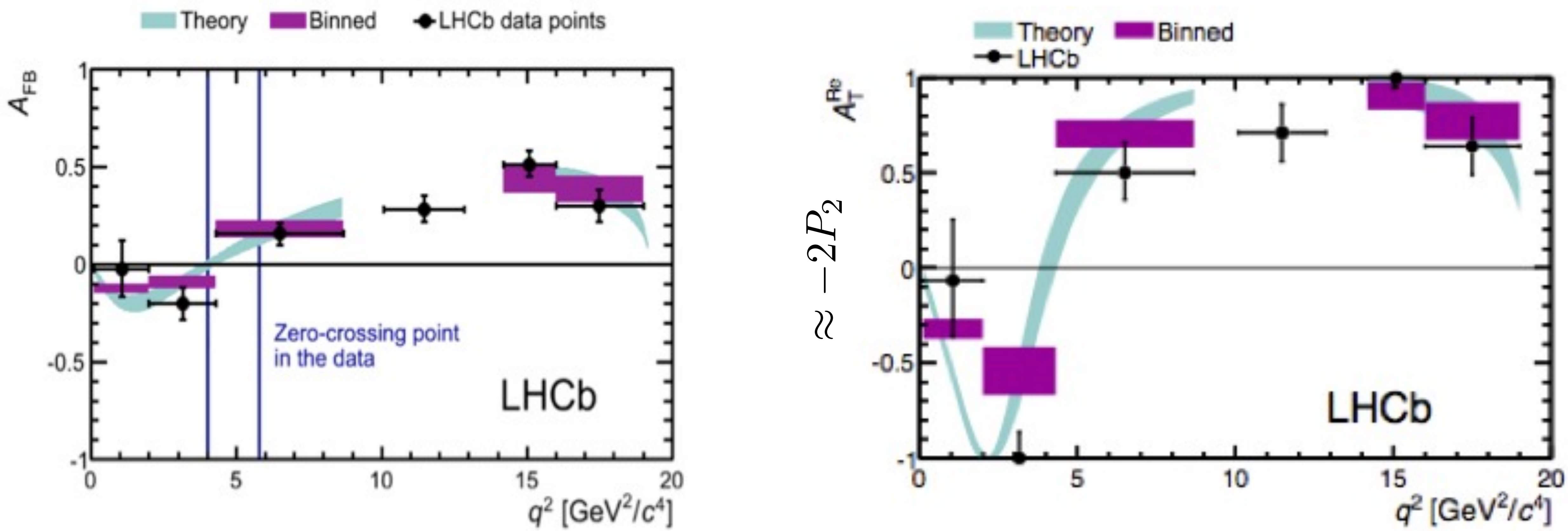
- SM theory predictions show good overall agreement with recent LHCb measurements

- some speculation about 'anomalies' at low q^2 in P_5' , P_2

  Descotes-Genon, Matias, Virto; Altmanshoffer, Straub; Gauld, Goertz, Hasich

  relative to SM theory errors in eg, Descotes-Genon, Hurth, Matias, Virto '13

- from Serra, EPS '13 :



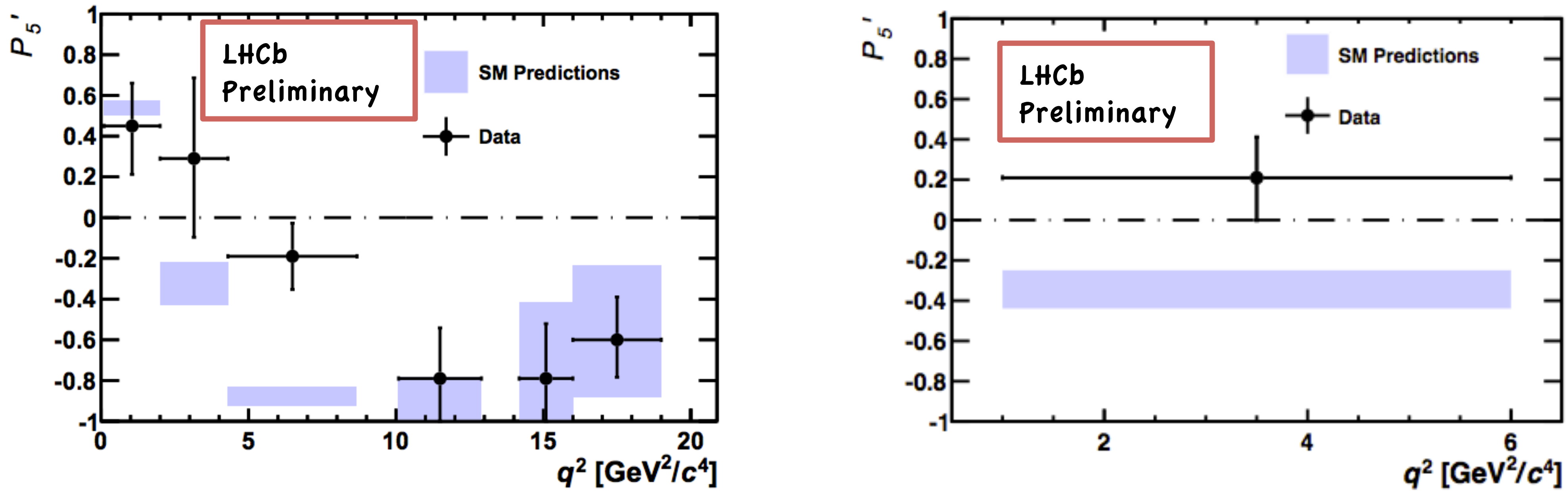
" • P_2 is the evolved version of A_{FB}, but, they play a complementary role.

• It magnifies a tiny tension in the second bin of A_{FB}." - from Matias, EPS '13

Results for new observables

NEW

LHCb collaboration ($1fb^{-1}$), LHCb-PAPER-2013-037



- Discrepancy with respect to SM predictions (arXiv:1303.5794) at low q^2
- 3.7 sigma discrepancy in the region $4.3<q^2<8.68$ GeV^2/c^4
- 0.5% probability (2.8 sigma) to observe such a deviation considering 24 independent measurements)
- 2.5 sigma discrepancy in the region $1.0<q^2<6.0$ GeV^2/c^4

N.B.: Jaeger-Camelich (arXiv:1212.2263) have predictions in the region $1.0<q^2<6.0$ GeV^2/c^4 with much larger theoretical error and small shift in the central value (QCD factorization breaking + ccbar loop)

*slide from N. Serra EPS 2013

- treatment of $O(\Lambda/m_b)$ power correction uncertainties is ad-hoc - insufficient to claim the existence of anomalies

eg, in Descotes-Genon, Hurth, Matias, Virto '13 helicity amplitudes parametrized as

$$H_i^{\lambda} = (H_i^{\lambda})^0 [1 + C_i e^{i\theta_i}]$$

the $C_i,\ \theta_i$ varied independently in the ranges

$$C_i \in [-0.1, 0.1], \quad \theta_i \in [-\pi, \pi]$$

For each observable,

1σ uncertainty = interval containing 66% of scatter about median

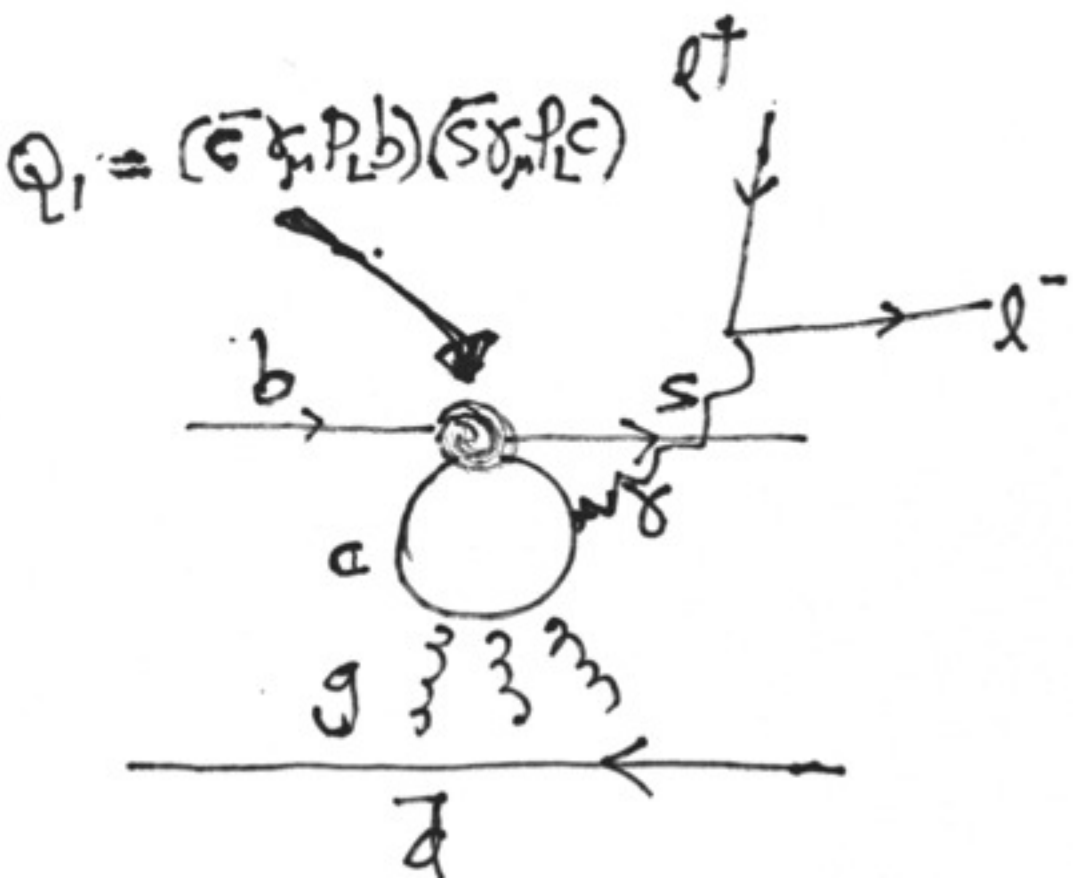
Theory uncertainties Jaeger, Camalich '12

- leading power hadronic params: soft form factors, decay constants, light cone distribution amps,...

- $O(\Lambda/m_b)$ power corrections to heavy quark / large energy limit form factor relations: surveyed their violation in calculations which automatically include power corrections, (LCSR, QCDSR, DSE)

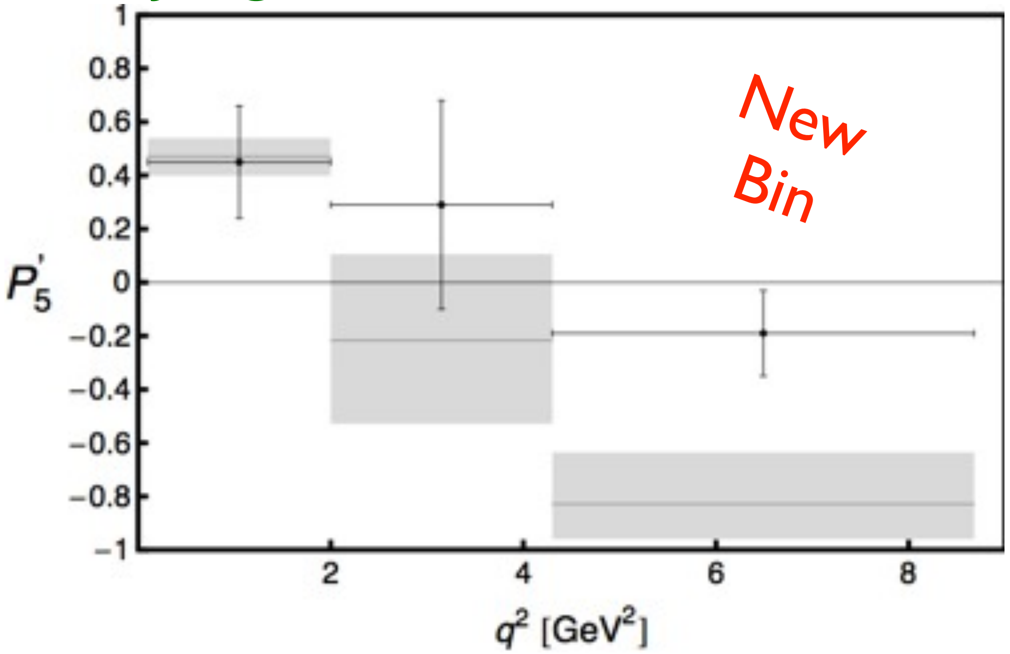
- $O(\Lambda/m_b)$ non-factorizable power corrections, mainly 'charm loops' from current-current operators: estimated in LCSR approach

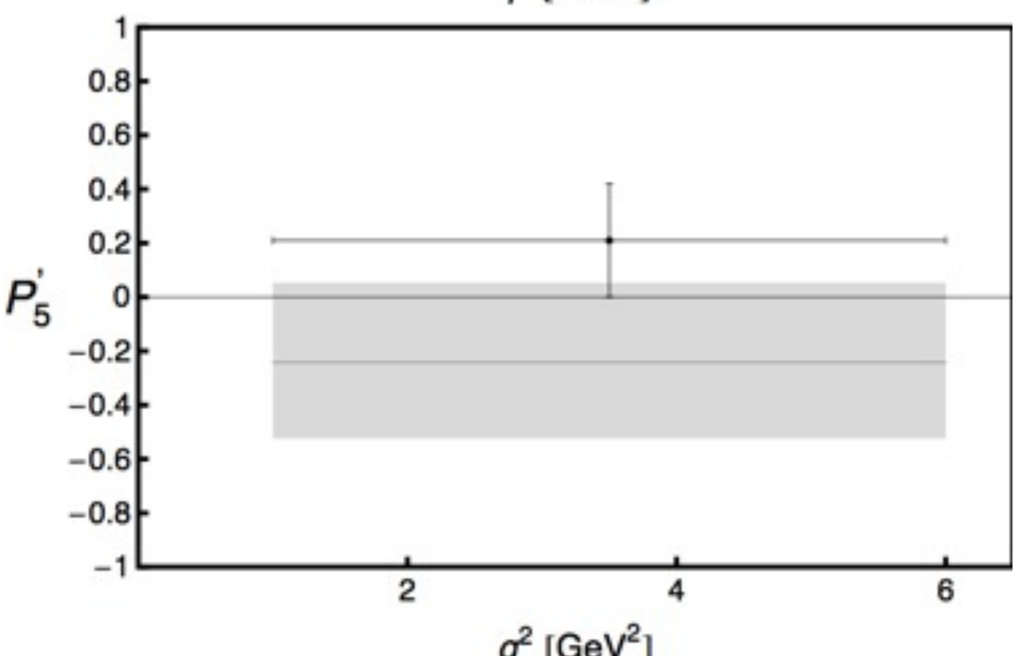
eg.,

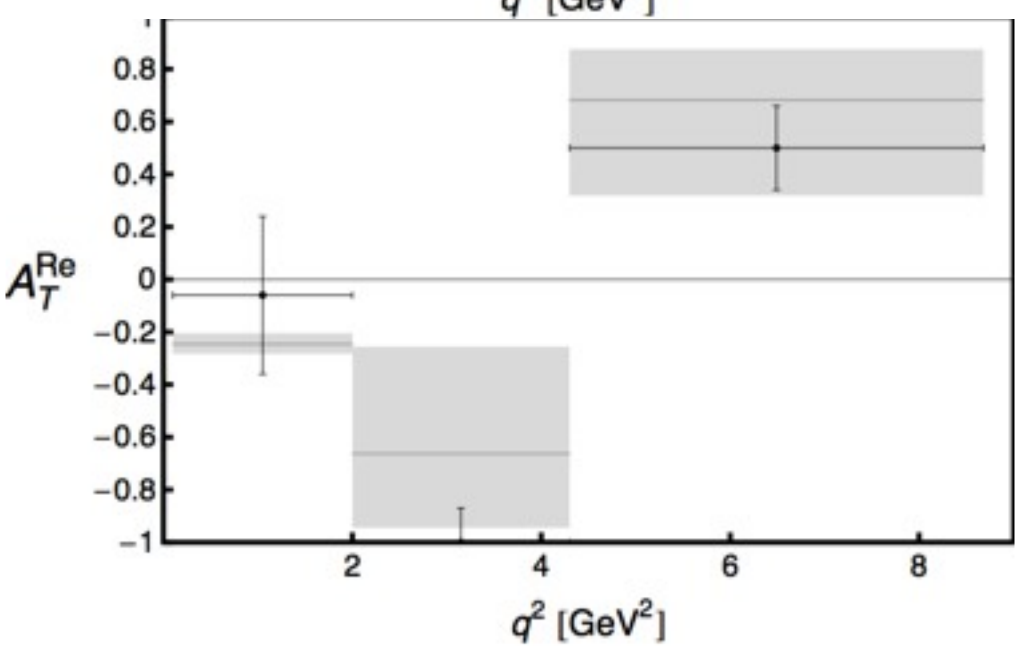


- For each observable, the full scatter ranges obtained in each category are added in quadrature

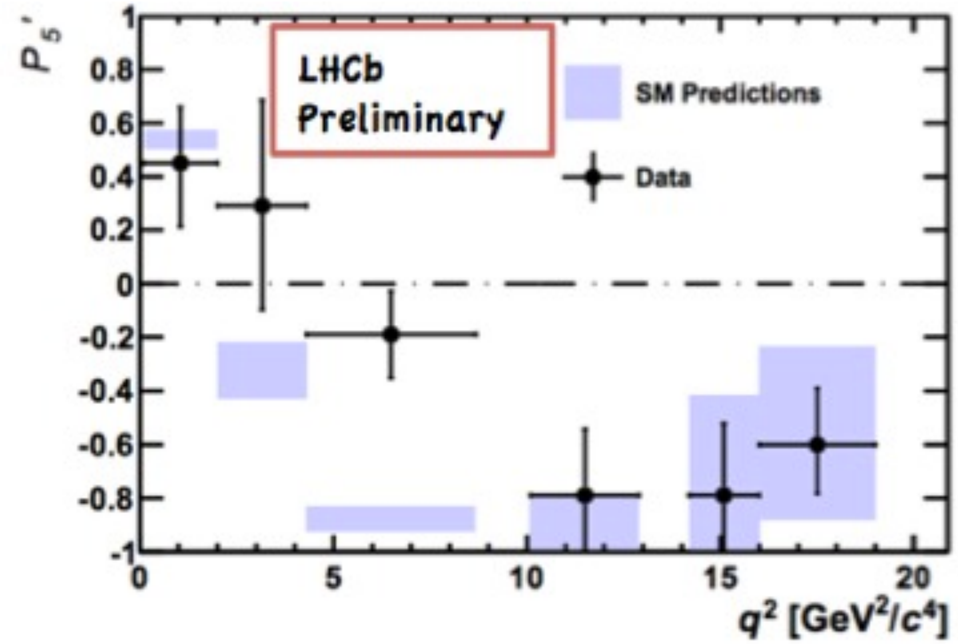
Jaeger, Camalich

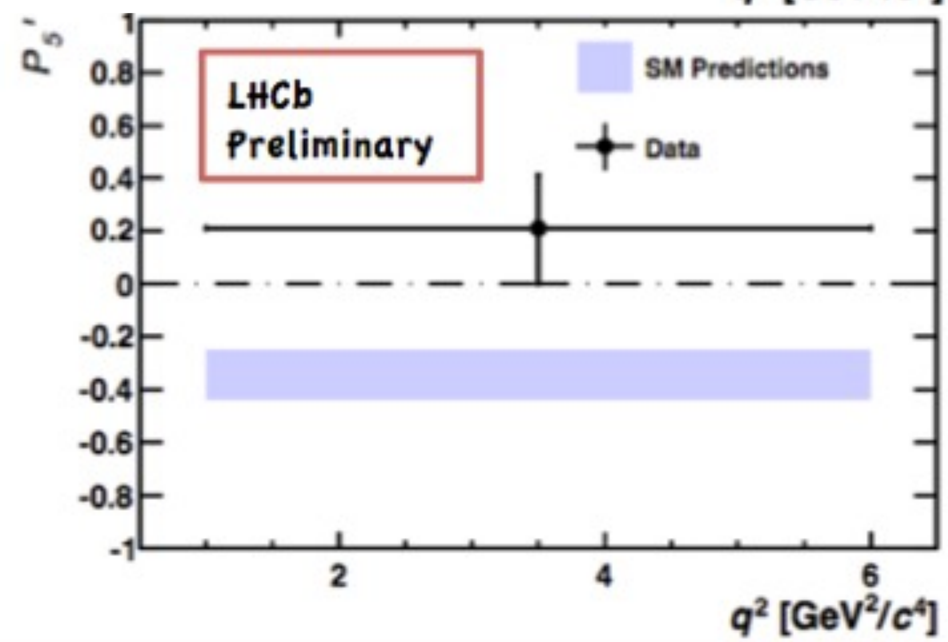


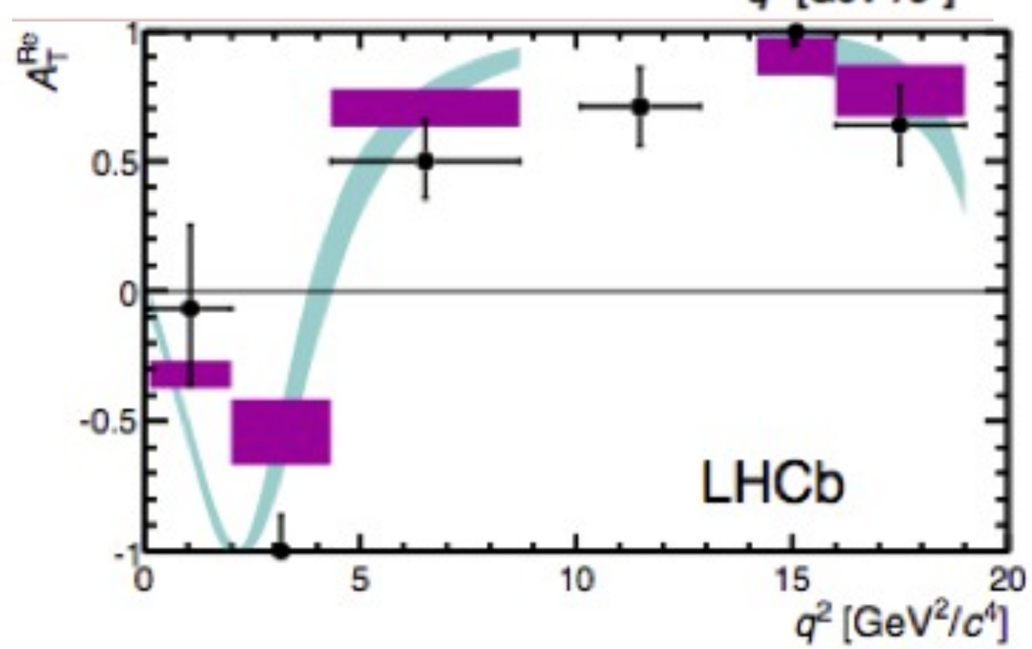


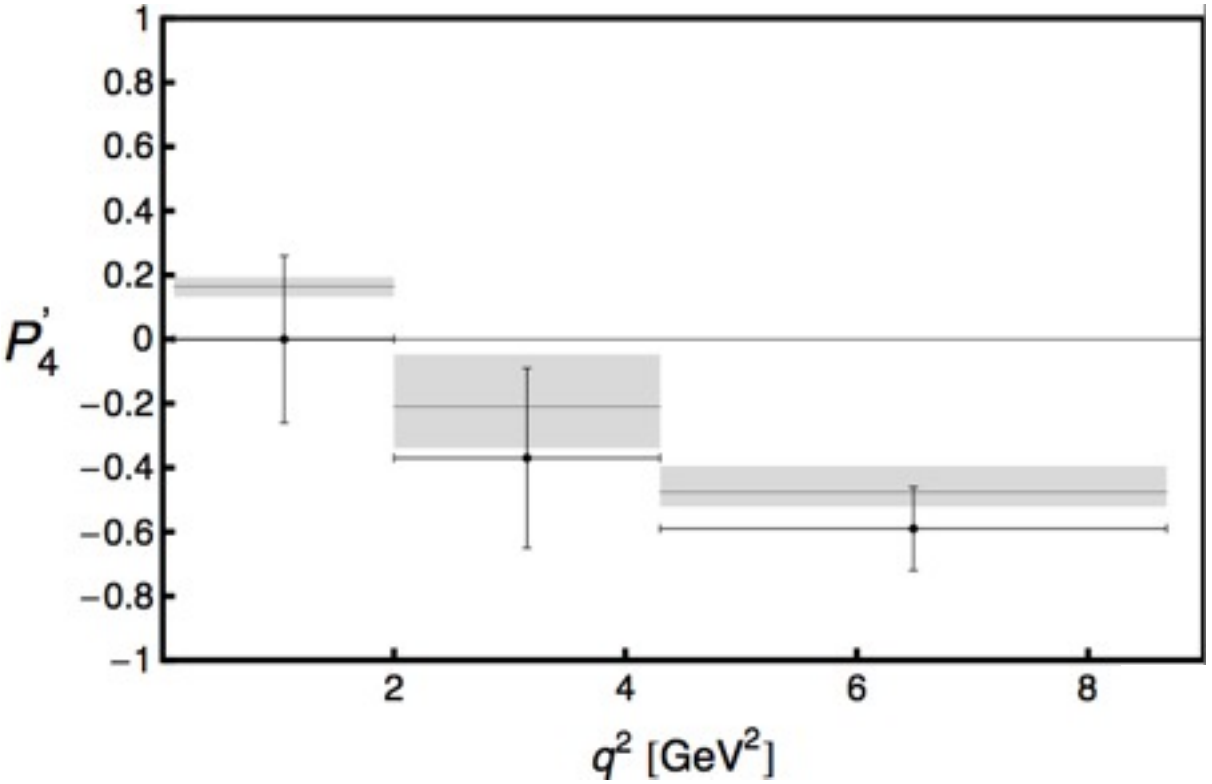


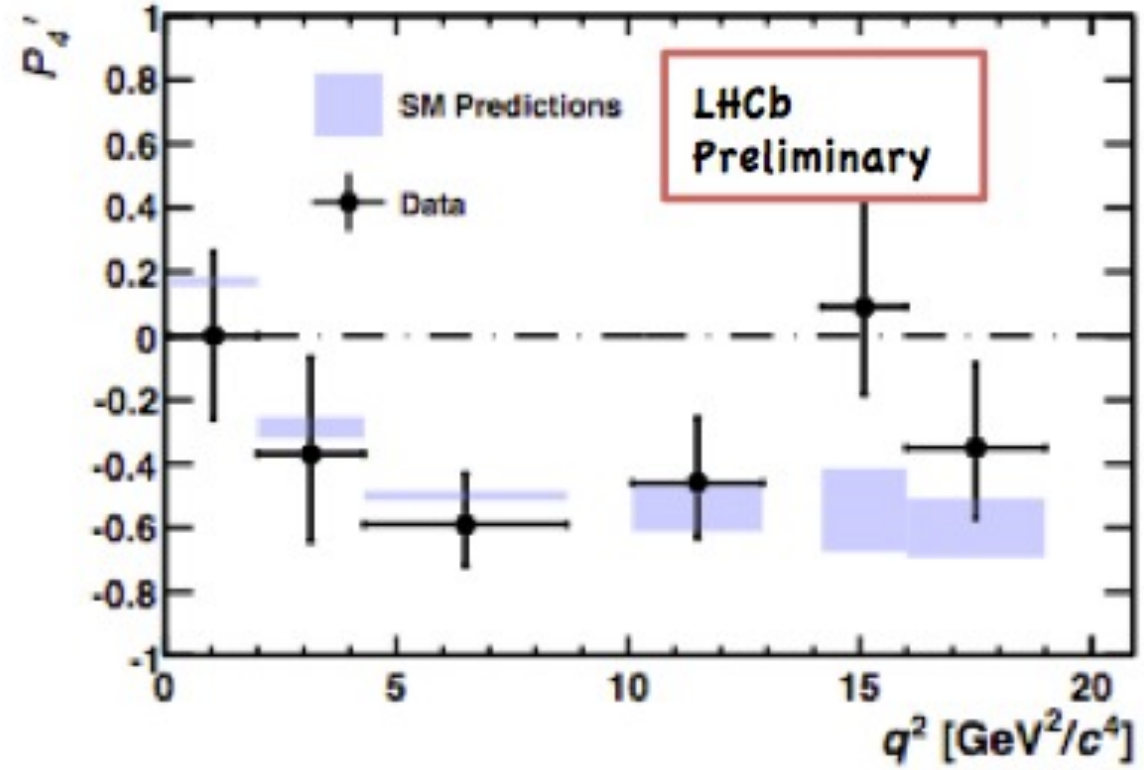
Descotes-Genon et al











- O(TeV) NP, e.g., Z' exchange contributions to $C_{9V}, \; C'_{9V}$, could be lurking in the data Descotes-Genon, Matias, Virto; Altmanshoffer, Straub

- However, the dedicated assessment of power correction uncertainties by Jaeger, Camalich + recent LHCb measurements

→ significant theoretical improvements will probably be required, in order to have a window to NP based solely on CP conserving observables in $B \to K^* \mu^+ \mu^-$ at low q ^{2} (with the exception of the lowest bin)

$B_s \to \mu^+\mu^-, \quad B_d \to \mu^+\mu^-$

- semileptonic effective operators

SM+NP: $Q_{10A} = \frac{\alpha_{\rm em}}{4\pi}(\bar{s}\gamma_\mu P_L b)(\bar{l}\gamma^\mu\gamma^5 l)$ NP: $Q_{S(P)} = \frac{\alpha_{\rm em}}{4\pi}[\bar{s}P_R b][\bar{\ell}(\gamma_5)\ell]$

+ opposite chirality ops

- SM predictions Buras, et al. '13

$$\mathrm{Br}(B_s \to \mu^+\mu^-)_{\rm SM} = (3.56 \pm 0.18) \times 10^{-9}$$

time integrated, as measured

$$\mathrm{Br}(B_d \to \mu^+\mu^-)_{\rm SM} = (1.03 \pm 0.07) \times 10^{-10}$$

largest uncertainties from CKM, 5% from higher order EWK corrections

- LHCb /CMS averages Serrano CERN seminar

LHCb-CONF-2013-012
CMS PAS BPH-13-007

- Several methods used, giving compatible results
- Method based on pseudo experiments, modelling distribution with variable-width Gaussian function (suggested by R. Barlow arXiv:physics/0406120):

preliminary

$$\boxed{BR(B_S^0 \to \mu^+\mu^-) = (2.9 \pm 0.7) \times 10^{-9}}$$

Observation!!

$$\boxed{BR(B^0 \to \mu^+\mu^-) = (3.6^{+1.6}_{-1.4}) \times 10^{-10}}$$

Not statistically significant

$B_s \to \mu^+\mu^-$ vs $B_d \to \mu^+\mu^-$

"Golden" MFV relation: Buras '03; Hurth, Isidori, Kamenik, Mescia '08

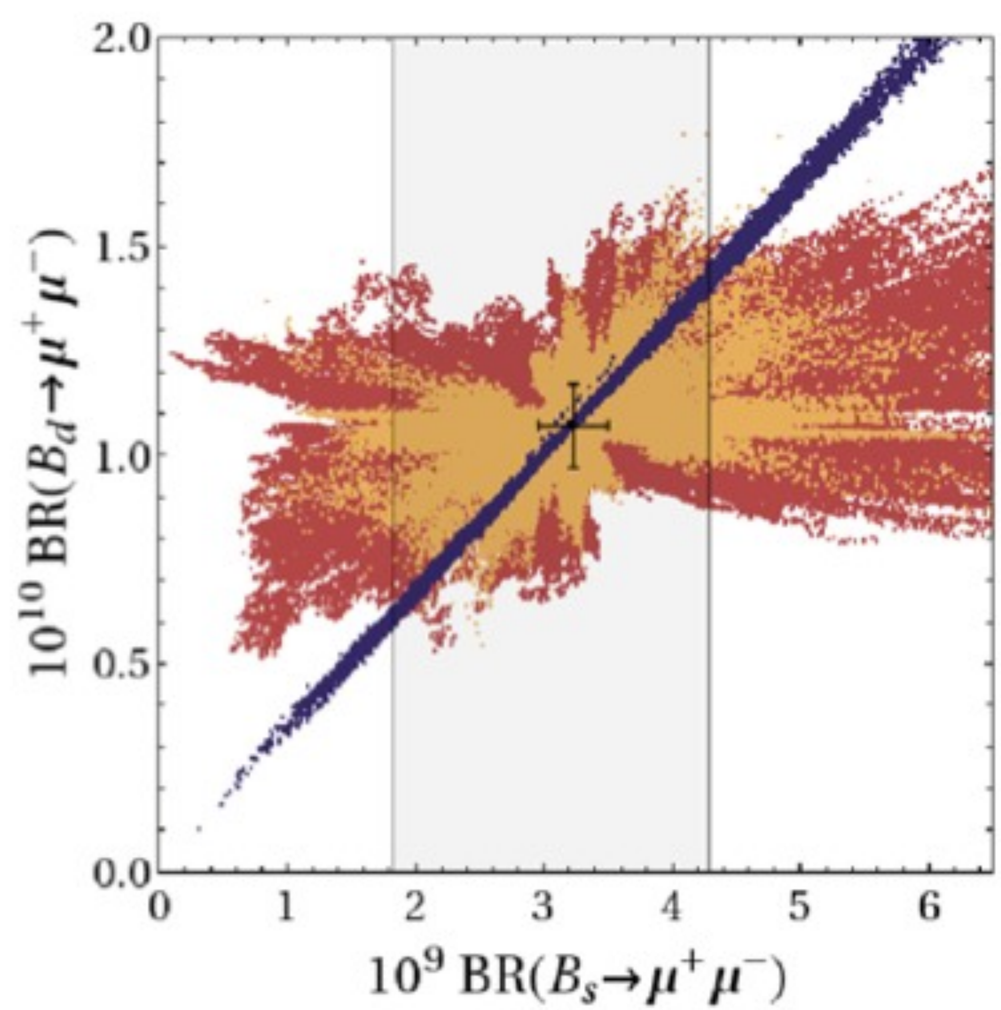
$$\frac{\mathrm{Br}(B_d \to \mu^+\mu^-)}{\mathrm{Br}(B_s \to \mu^+\mu^-)} \simeq \frac{f_{B_d}^2}{f_{B_s}^2}\frac{\tau_{B_d}}{\tau_{B_s}}\frac{|V_{td}|^2}{|V_{ts}|^2} \simeq 0.03$$

holds for SM, MFV, $U(2)^3$ flavor symmetry

- experimental ratio
  (assuming SM time integration for B_s)

$$\frac{\mathrm{Br}(B_d \to \mu^+\mu^-)_{\mathrm{exp}}}{\mathrm{Br}(B_s \to \mu^+\mu^-)_{\mathrm{exp}}} \simeq 0.14 \pm 0.06$$

interesting future flavor symmetry diagnostic !



Straub '13:
analysis of several models
with partial compositness

* slide adopted from Altmanshofer, Snowmass Argonne Intensity Frontier workshop

CP violation in $D - \bar{D}$ mixing

CP violation (CPV) in charm provides a unique probe of New Physics (NP)

- sensitive to NP in the up sector
- SM charm physics is CP conserving to first approximation (2 generation dominance)
- In the SM, CPV in mixing enters at $O(V_{cb}V_{ub}/V_{cs}V_{us}) \sim 10^{-3}$

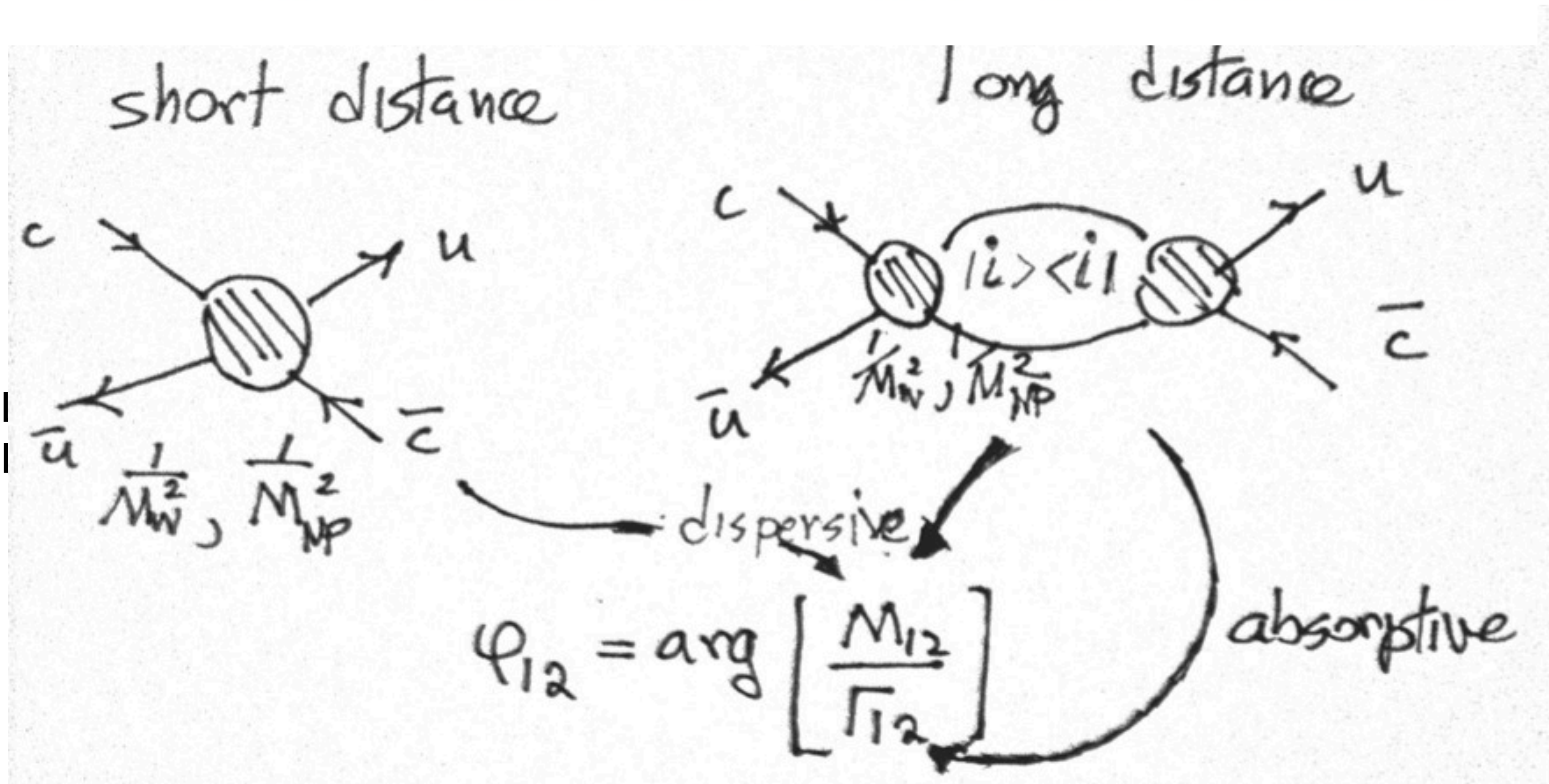
In view of the consensus that $\Delta A_{CP} \leq O(\text{few} \times 10^{-3})$ can be obtained in the SM

- D mixing is probably the only open window for NP in charm CPV, at least in the absence of future precision lattice data on charm direct CPV

The “theoretical" mixing parameters

ep

$$x_{12} \equiv 2|M_{12}|/\Gamma, \quad y_{12} \equiv |\Gamma_{12}|/\Gamma, \quad \phi_{12} \equiv \arg(M_{12}/\Gamma_{12})$$



M_{12} is dispersive mixing: due to long-distance exchange of off-shell intermediate states (dominates in SM), and short-distance effects (NP)

Γ_{12} is absorptive mixing: due to long distance exchange of on-shell intermediate states

- ϕ_{12} is a CP violating phase: responsible for CP violation in pure mixing

  e.g., a non-vanishing semileptonic CP asymmetry, $a_{\rm SL}$

$$\Gamma(D^0(t) \to \ell^- X) \neq \Gamma(\overline{D^0}(t) \to \ell^+ X)$$

- ϕ_{12} is solely responsible for CPV in the interference between decays with and without mixing (time dependent CP asymmetries), in the limit that non-trivial weak phases in decay are neglected

  - excellent approximation given current exp sensitivity to ϕ_{12}

Example: SCS decays to CP eigenstates, $D^0 \to K^+K^-\,,\ \pi^+\pi^-$

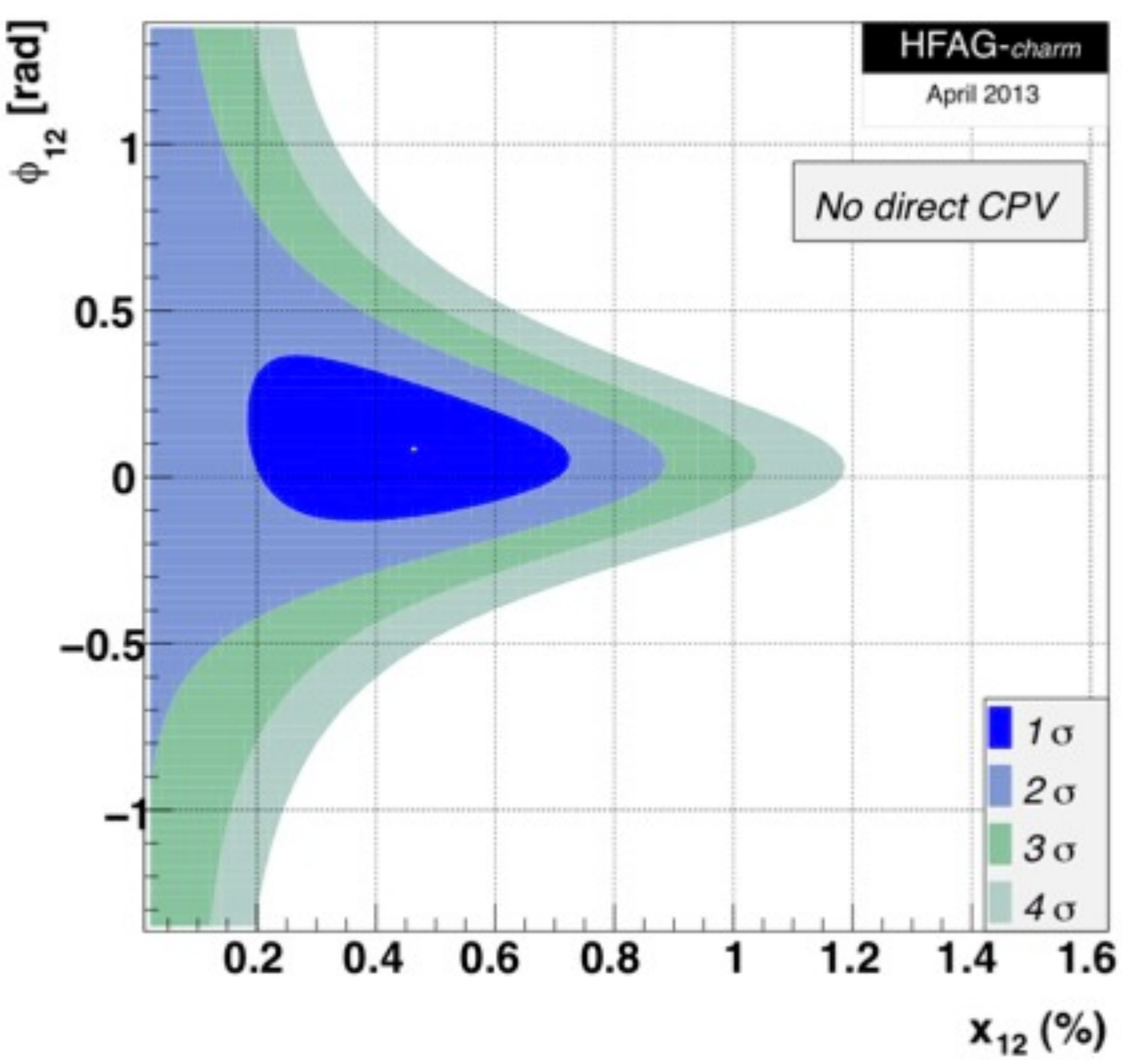
$$\Gamma(D^0(t) \to f) \propto \exp[-\hat{\Gamma}_{D^0\to f}\, t], \qquad \Gamma(\overline{D^0}(t) \to f) \propto \exp[-\hat{\Gamma}_{\overline{D^0}\to f}\, t]$$

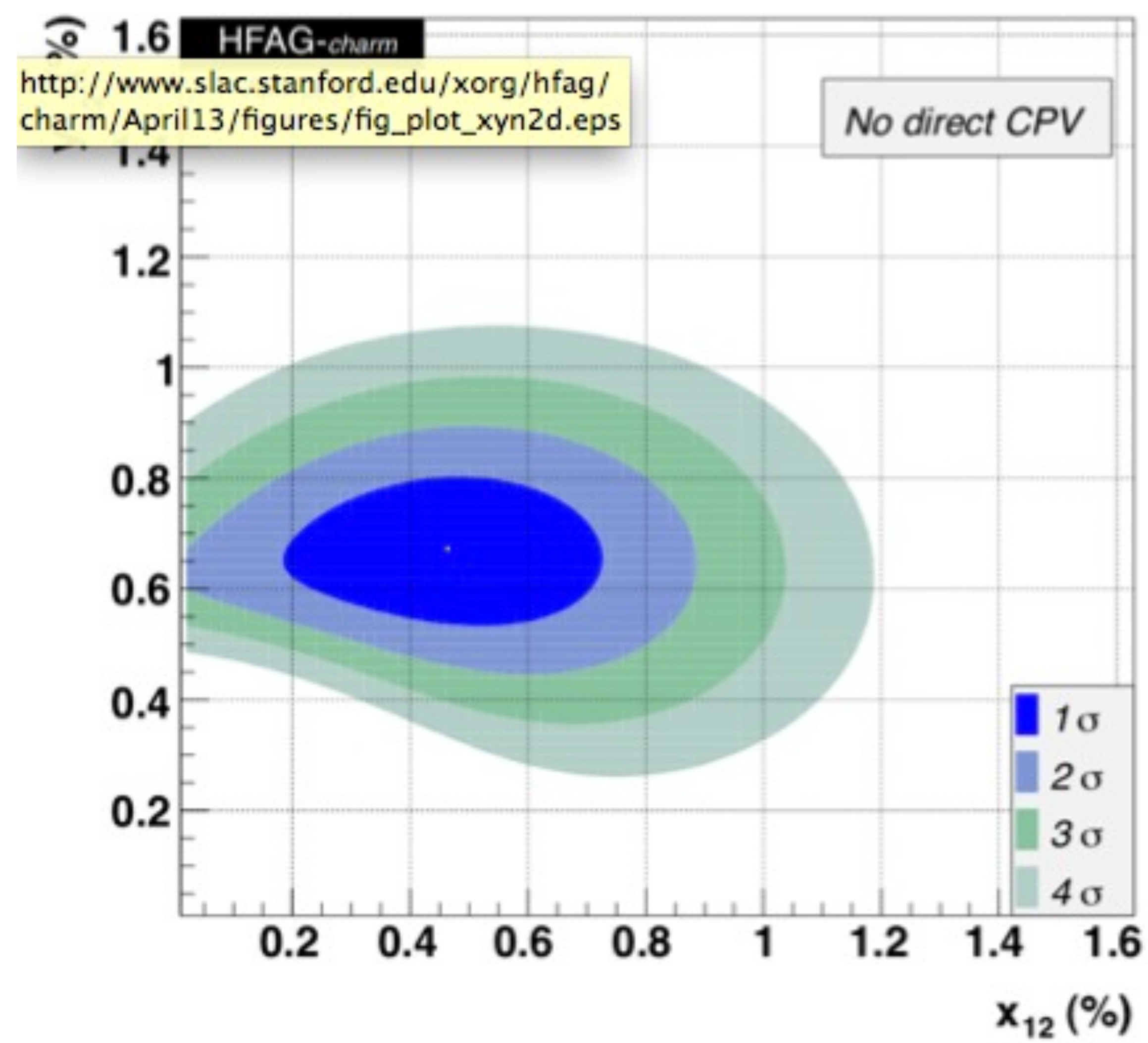
CPV: $\hat{\Gamma}_{D^0\to f} \neq \hat{\Gamma}_{\bar{D}^0\to f}$

Fits of $\phi_{12}, x_{12}, y_{12}$ to data yield

HFAG fit (April 2013): $\phi_{12}\,(^\circ) = 4.8^{+9.2}_{-7.4}$

UTfit (Silvestrini, Beauty 2013) : $\phi_{12}\,(^\circ) = 2 \pm 11$





Weak phases in decay

- In general ϕ_{12} consists of a dispersive part ϕ_{12}^M, and a long-distance absorptive part ϕ_{12}^Γ

  They can be consistently defined relative to the phases of decay amplitudes, eg, $D \to K^\pm \pi^\mp$, with

$$\phi_{12} = \phi_{12}^M - \phi_{12}^\Gamma$$

- In the SM: ϕ_{12}^Γ and the long-distance part of ϕ_{12}^M are due to the weak phase γ in the penguin amplitudes of the singly Cabibbo suppressed intermediate states, and

  - the short distance contribution to ϕ_{12}^M is negligible

- SM U-spin based analysis (Grossman, Ligeti, Perez, Petrov, Silvestrini, AK)

$$\Rightarrow \quad \phi_{12}^{\Gamma} \leq O(0.01)$$

  - expect similar result for ϕ_{12}^{M} , related to ϕ_{12}^{Γ} via dispersion relations

Current exp. sensitivity

$\Rightarrow$ > O(10) window for NP in ϕ_{12}

- LHCb/Belle II or tau/charm factory could measure ϕ_{12}^{Γ} , thus isolating short distance NP in ϕ_{12}^{M}

High p_T

Higgs couplings

- ~~if NP then Higgs couplings could be modified~~
- if EFT description valid

$$\boxed{\Delta\mathcal{L}_Y = -\frac{\lambda'_{ij}}{\Lambda^2}(\bar{f}_L^i f_R^j)H(H^\dagger H) + h.c. + \cdots}$$

Giudice, Lebedev, 0804.1753
Agashe, Contino, 0906.1542
Goudelis, Lebedev, Park, 1111.1715
Arhrib, Cheng, Kong, 1208.4669
McKeen, Pospelov, Ritz, 1208.4597
Blankenburg, Ellis, Isidori, 1202.5704
Harnik, Kopp, Zupan 1209.1397

- therefore, in general

$$\boxed{\mathcal{L}_Y = -m_i \bar{f}_L^i f_R^i - Y_{ij}(\bar{f}_L^i f_R^j)h + h.c. + \cdots}$$

- new neutral currents
  - flavor diagonal @LHC
  - flavor violating @Belle2 and LHC
- both are important diagnostics

*slide on loan from Zupan, Snowmass Seattle

- what is a reasonable aim for precision on Y_{ij}?
  - if off-diagonals are large ⇒ spectrum in general not hierarchical
  - no tuning, if $\boxed{|Y_{\tau\mu} Y_{\mu\tau}| \lesssim \frac{m_\mu m_\tau}{v^2}}$ Cheng, Sher, 1987
- different flavor models give Dery, Efrati, Hochberg, Nir, 1302.3229

Model	$R_{\tau^+\tau^-}$	$X_{\mu^+\mu^-}/(m_\mu^2/m_\tau^2)$	$X_{\mu\tau}$
SM	1	1	0
NFC	$(V_{h\ell}^* v/v_\ell)^2$	1	0
MSSM	$(\sin\alpha/\cos\beta)^2$	1	0
MFV	$1+2av^2/\Lambda^2$	$1-4bm_\tau^2/\Lambda^2$	0
FN	$1+\mathcal{O}(v^2/\Lambda^2)$	$1+\mathcal{O}(v^2/\Lambda^2)$	$\mathcal{O}(\|U_{23}\|^2 v^4/\Lambda^4)$
GL	9	25/9	$\mathcal{O}(X_{\mu^+\mu^-})$

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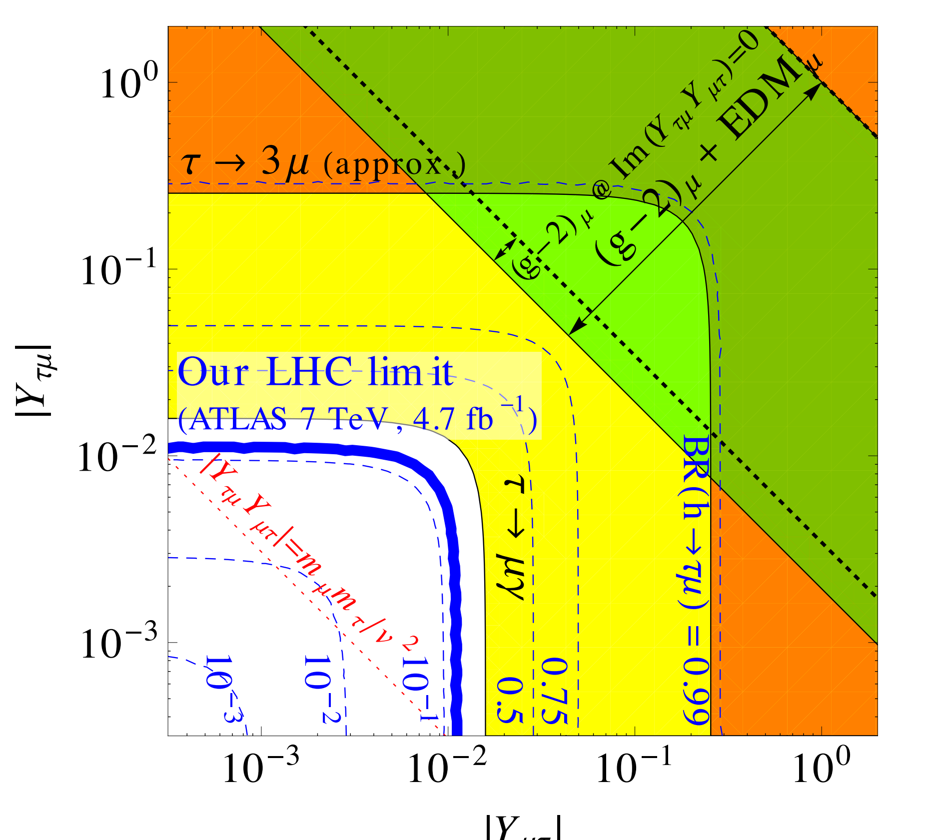
FLAVOR VIOLATING HIGGS COUPLINGS

Harnik, Kopp, Zupan, 1209.1397

- *B*-factories: the best sensitivity for FV higgs couplings to light quarks
- LHC: best constraints on *h-tc*, *h-tu* and $h\rightarrow\tau\mu,\tau e$

see also Davidson, Verdier, 1211.1248; Arhrib, Cheng, Kong, 1210.8241; Dery, Efrati, Hochberg, Nir, 1302.3229; Blankenburg, Ellis, Isidori, 1202.5704; Atwood, Gupta, Soni, 1305.2427, ...



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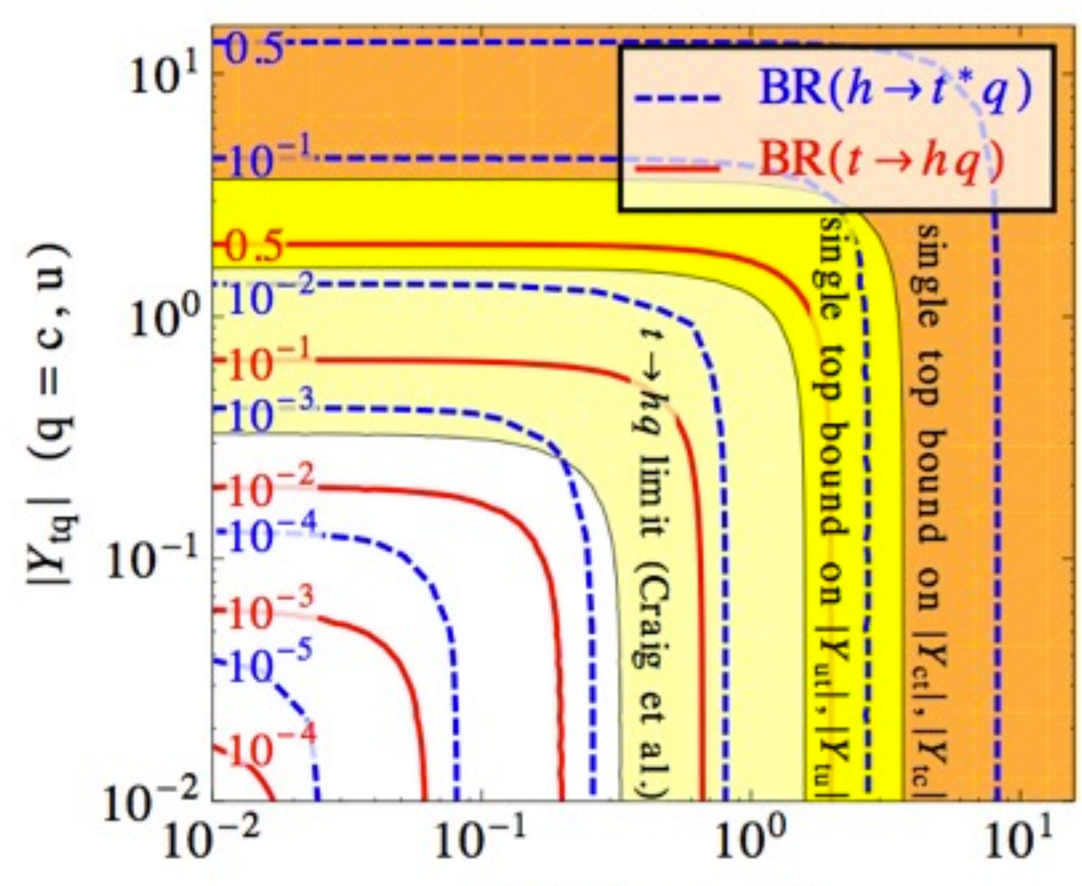

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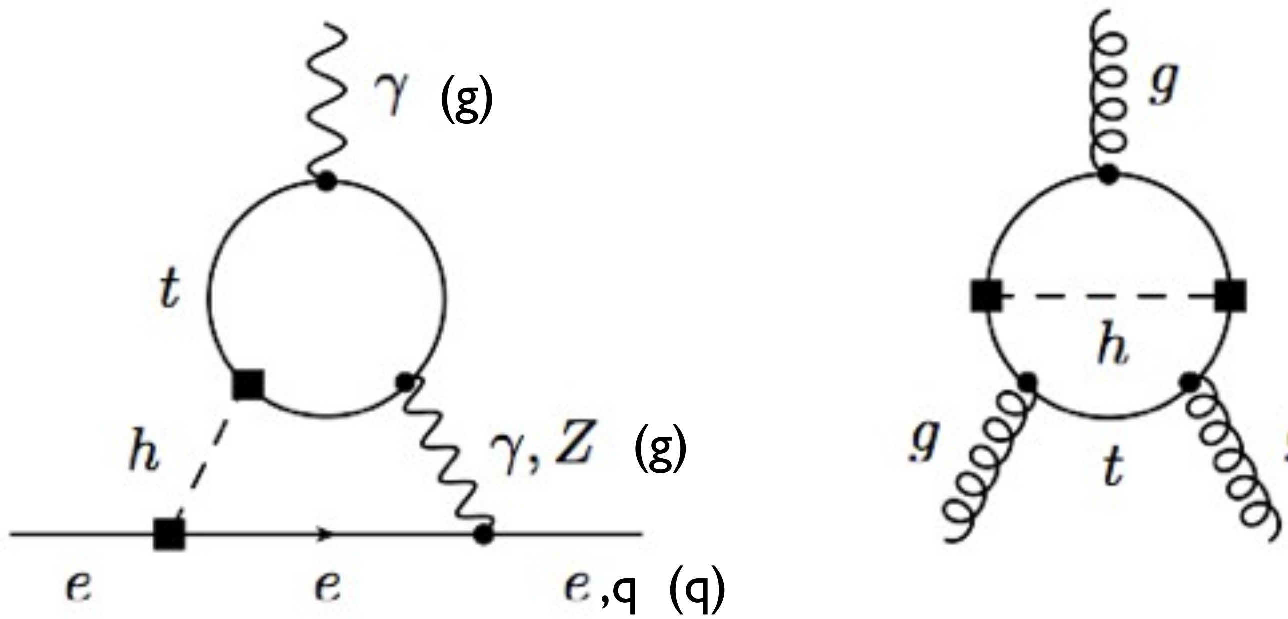
*from the Zupan collection

Bounds on CP violating Higgs-top coupling from EDMs

Brod, Haisch, Zupan in prep

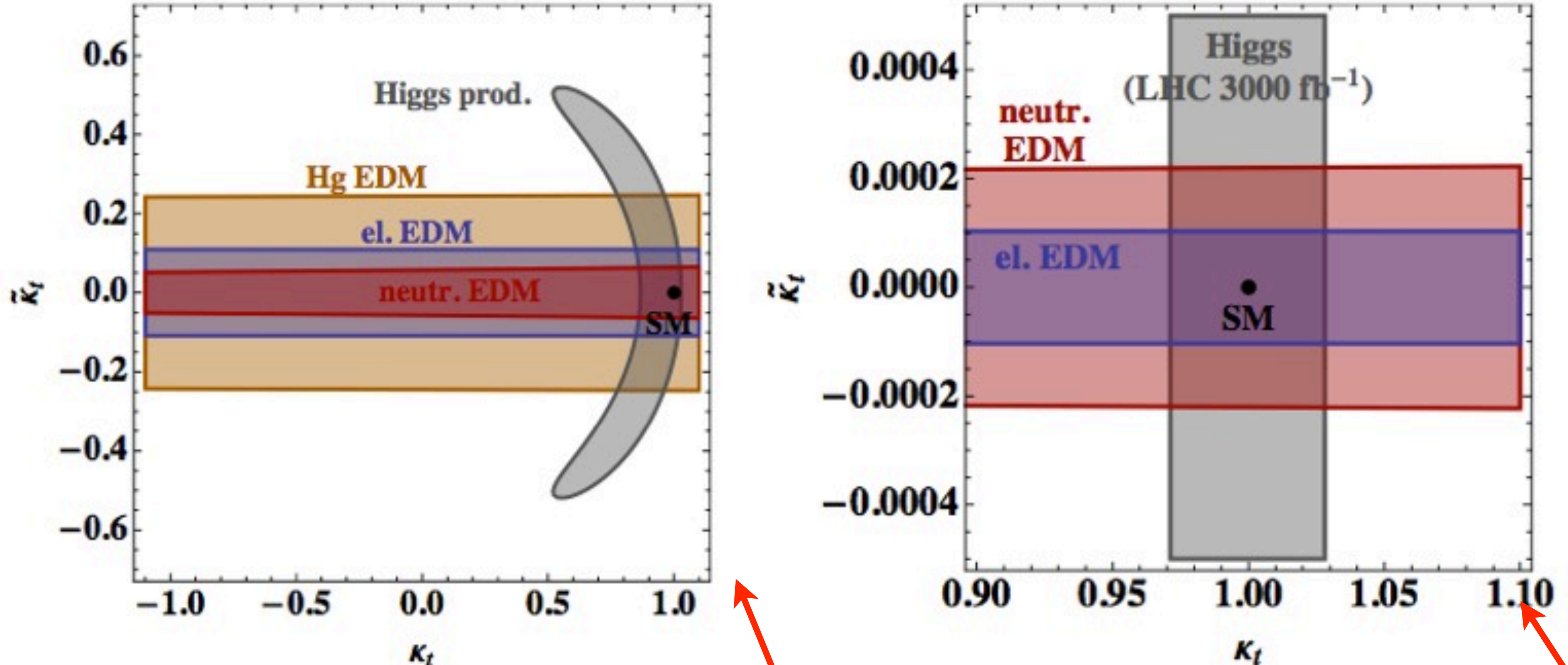


Left: Bar-Zee contributions to electron and quark EDMs, quark chromo-EDMs.
Right: contribution to Weinberg's operator

General Yukawa coupling for fermion f (in the SM $\kappa_f = 1, \tilde{\kappa}_f = 0$)

$$\mathcal{L} \supset -\frac{y_f}{\sqrt{2}}\left(\kappa_f \bar{f} f + i\tilde{\kappa}_f \bar{f}\gamma_5 f\right) h$$

A top quark CP violating coupling $\tilde{\kappa}_t$ would induce contributions to the charged lepton and neutron EDMs via the above diagrams



Brod, Haisch, Zupan

left: current constraints on κ_t, $\tilde{\kappa}_t$ from the electron, mercury, and neutron EDM bounds, and Higgs physics

right: projected future constraints, for 1000 x improvement in electron EDM bound, 300 x improvement in neutron EDM bound, and expected Higgs production sensitivity with 3000 fb^{-1} at LHC

- will be interesting to compare with sensitivity of direct measurements of $\tilde{\kappa}_t$, eg via CPV triple products

(above plots assume SM Higgs couplings to electron, light quarks; weaker EDM bounds follow from Weinberg's operator alone)

Charm tagging at the LHC   ATLAS EPS 2013

- In new ATLAS search for stop decay to charm + neutralino ($\tilde{t} \to c + \chi^0$), charm jet tagging has been employed for the first time at LHC

ATLAS-CONF-2013-068

- charm jets identified by combining "information from the impact parameters of displaced tracks and topological properties of secondary and tertiary decay vertices" using multivariate techniques

  - 'medium' operating point: c-tagging efficiency = 20%, rejection factor of 5 for b jets, 140 for light jets.
    #'s obtained for simulated $t\bar{t}$ events for jets with $30 < p_T < 200$, and calibrated with data

Significance of charm tagging for flavor physics:

- increased sensitivity to flavor violating (s)top + (s)charm production, or flavor violating t -c couplings in top decay

- perhaps provide tests for horizontal flavor symmetries at high p_T ,

  e.g. discriminate between SU(2) vs. U(1) horizontal symmetries ?

- charm squark vs up squark masses?

- $\overset{(\sim)}{t} + \overset{(\sim)}{c}$ production vs. $\overset{(\sim)}{t} + \overset{(\sim)}{u}$ production?

- analogous sensitivities in models with partially composite quarks: charm partners, charm partners vs. up partners?

Flavor, naturalness, and the LHC

- naturalness of the weak scale

→ new fields with large couplings to the Higgs, introduced to stabilize the Higgs mass, should have $\lesssim$O(TeV) masses, eg. stops, LH sbottom

- pre LHC:

FCNC + naturalness → horizontal flavor symmetries

The motivation was model-dependent: certain dynamics can automatically yield flavor blind NP to very good approx, eg. supersymmetry breaking via gauge or anomaly mediation

- today:

LHC bounds on NP + naturalness → horizontal flavor symmetries two strategies for flavor symmetries were introduced in context of supersymmetry: non-Abelian and Abelian

- non-Abelian (2+1) structure: first two families are doublets of an SU(2) horizontal symmetry, the third family is a singlet

Dine, Leigh, AK '93; Pomarol, Tomassini '95

SU(2) $\Rightarrow$ squarks / sleptons of first two families approximately degenerate. if their masses also >> stop masses, FCNC, eg $\epsilon_K, \mu \to e\gamma$ are OK, and maintain naturalness, evade LHC squark bounds

$\Rightarrow$ effective susy, or natural susy spectrum;

Cohen, Kaplan, Nelson '96

- could yield observable $\mu \to e\gamma$, neutron EDMs in future experiments. CPV in D mixing is small

- can be extended to explain fermion mass hierarchies

- most recently, see Dudas, Gersdorff, Pokorski, Ziegler '13

- Abelian U(1)'s: with appropriate charge assignments can explain quark mass hierarchy and obtain alignment of the down squark and down quark mass eigenstates in flavor space

Nir, Seiberg '93;
Leurer, Nir, Seiberg '93

→ ϵ_K is sufficiently small

- residual misalignment between up squark and up quark mass eigenstates in flavor space, (u, c) vs (ũ,c̃)

→ $\phi_{12} = O(10\%)$ CP violation in $D - \bar{D}$ mixing is possible

$\mu \to e\gamma$, neutron EDMs could be observed in future experiments

- 3rd strategy: flavor symmetries which yield controlled violations of R parity (rather than ad-hoc assumption that it holds)
  - sufficient suppression of proton decay, and

Smith, '08; Csaki, Grossman, Heidenreich, '11; Bhattacherjee et al, '13

→ eliminates standard SUSY missing E_T (MET) signature: substantialy weakens squark, gluino mass bounds

Berger, Perelstein, Saelim, Tanedo, '13

→ eliminates dangerous FCNC

- can follow from imposing MFV SM flavor symmetry $U(3)^3$

Smith, '08; Csaki, Grossman, Heidenreich, '11; Bhattacherjee et al, '13

- could follow from U(1) Abelian models - which also yield quark/squark alignment

Montheaux '13

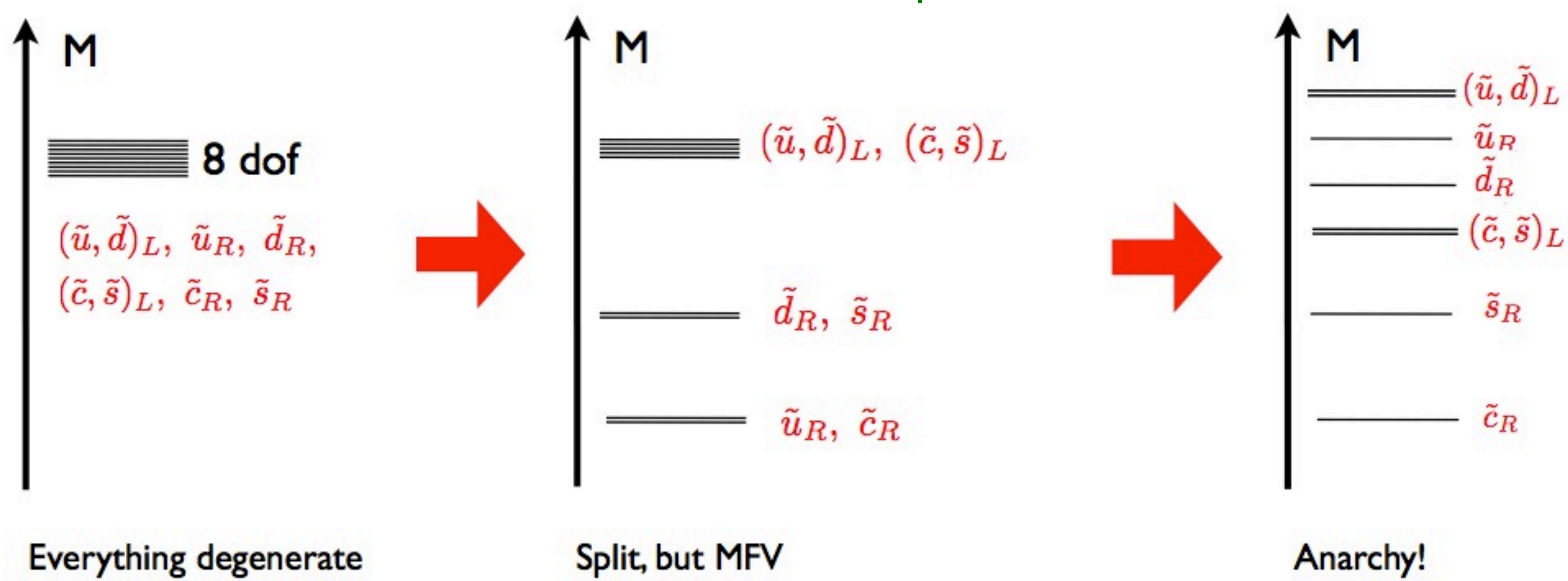
- alignment and naturalness at the LHC

  - squark masses of same order but highly non- degenerate, eg,

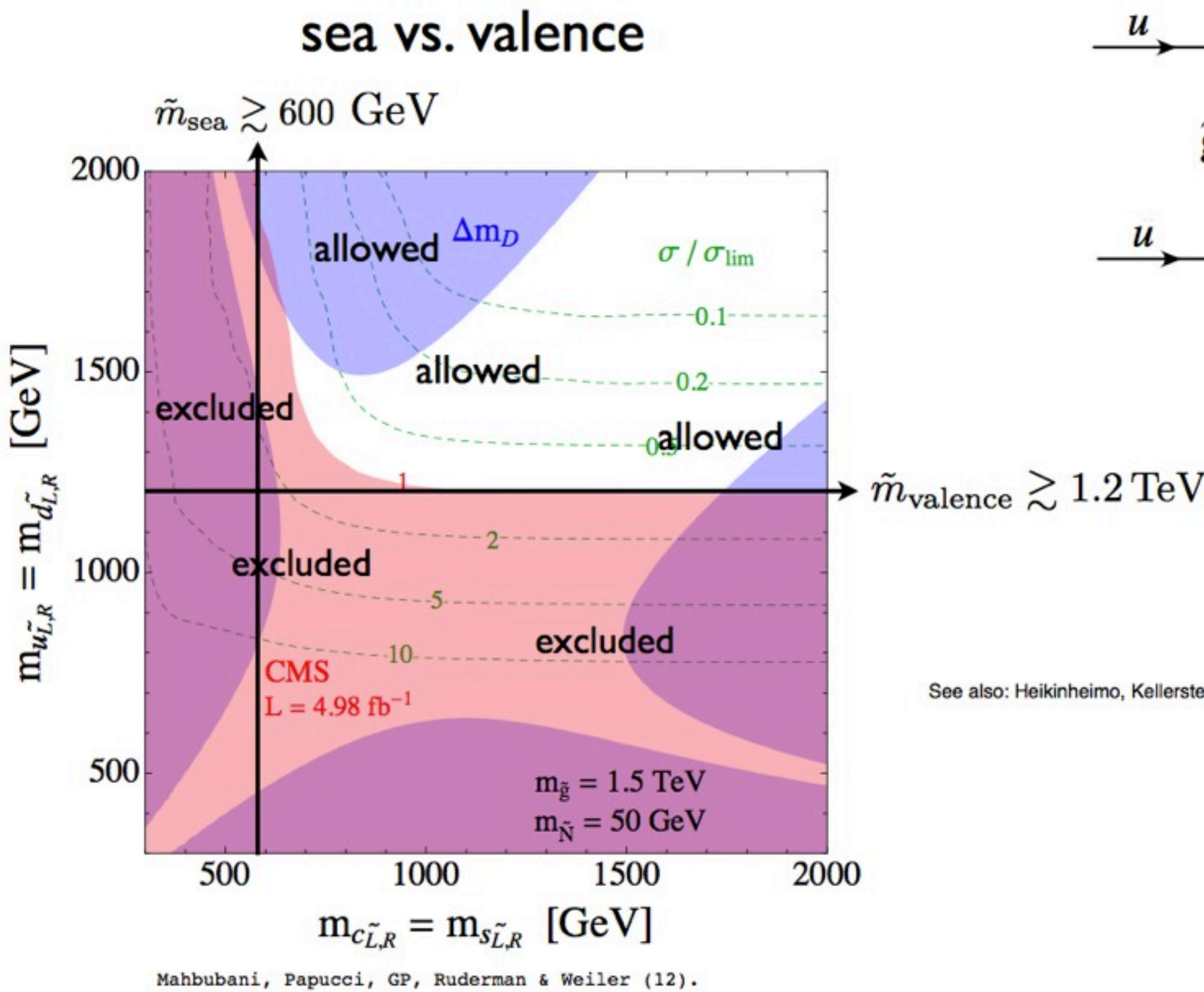
$$m_{\tilde{u}} \neq m_{\tilde{c}}, \quad m_{\tilde{u}}, m_{\tilde{c}} > m_{\tilde{t}}$$

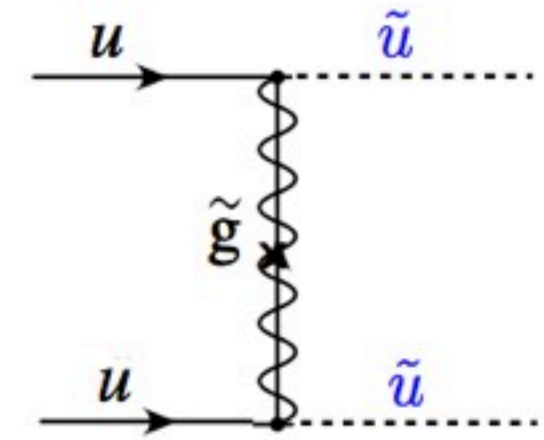
stop can be light $\Rightarrow$ naturalness

Mahbubani, Papucci, Perez, Ruderman, Weiler '12



Mahbubani, Papucci, Perez, Ruderman, Weiler ’12





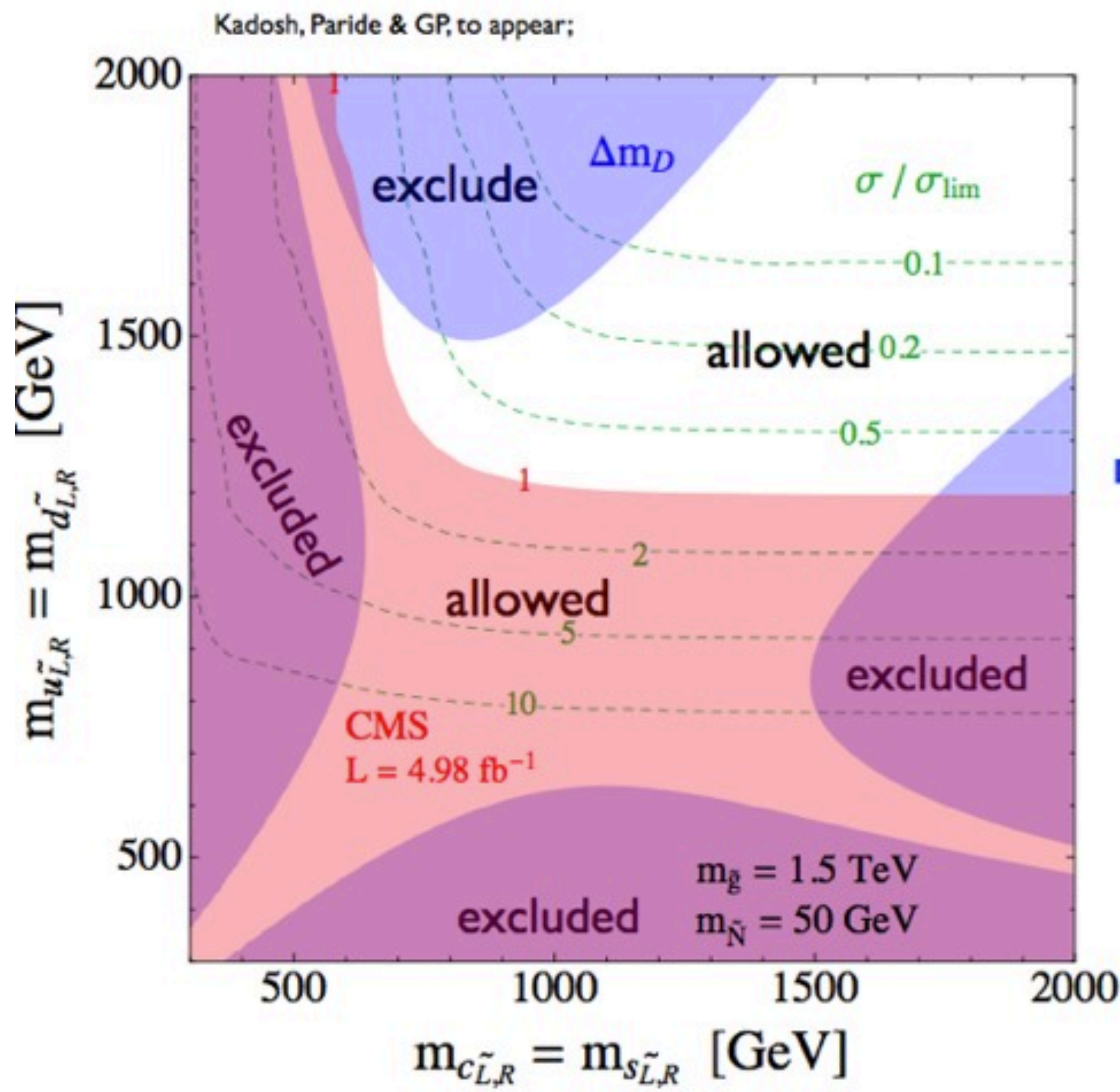
See also: Heikinheimo, Kellerstein & Sanz (11); Kribs & Martin (12),

*from G Perez “Flavorful naturalness and the top charm frontier” La Sapienza 2013

Sea LH squarks vs. valence RH squarks

Kadosh, Paride,Perez to appear

Adding flavor constraints (Δm_D) for LH squarks:



$$\delta_Q^{12} \equiv \frac{m_{\tilde Q_2} - m_{\tilde Q_1}}{m_{\tilde Q_2} + m_{\tilde Q_1}}$$

alignment: new upper bound on CP violation (CPV) in *D-phys*.:

$$\text{CPV in } D-\bar D:\ \delta_{\epsilon_K}/2\lambda_C\,\delta_Q^{12} \lesssim 10\% \times (0.3/\delta_Q^{12})$$

$$(\delta_{\epsilon_K} \sim 1\%)$$

LHCb soon start testing alignment paradigm!

Kadosh, Paride & GP, to appear.

O(10%) CPV

*adapted from G Perez "Flavorful naturalness and the top charm frontier" La Sapienza 2013

Summary

- phenomenal progress in flavor measurements

  - theoretical progress probably required on SM predictions for $B \to K^* \mu^+ \mu^-$ CP conserving observables at low q^2 (with exception of lowest bin)

  - observation of $B_s \to \mu^+ \mu^-$! entering an exciting time in which can test for SU(2) based symmetry structure via comaprison to $B_d \to \mu^+ \mu^-$

  - O(10) window for new physics in D mixing CP violation to be probed in the coming years

  - tests for new physics in flavor violating Higgs decays are becoming interesting

- naturalness + FCNC+ LHC bounds suggest the existence of flavor symmetries
    - possibility to evade LHC bounds on 1st two generation squarks via light "sea" squarks (charm, strange squarks) in Abelian alignment models- they can be relatively light
    - new charm jet tagging capability could help to test this scenario further
    - similar in spirit search strategies for composite Higgs with partially composite quarks

      - Fraille, Flacke, Delauney, Lee, Perez in prep
    - alignment models could lead to O(10%) CPV in D mixing
- In abelian and non-abelian models $\mu \to e\gamma$ and neutron EDM could be at observable levels in future experiments