Heavy Flavor Physics — Select

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National Taiwan University

June 5, SPCS2013 @ SJTU, Shanghai, China

外滩 (外灘) - 1928

Heavy Flavor Physics — Select

A. Intro: Heavy Flavor Physics ca. 2013 6

在前 Highlights from LHCb; 在后 Rare B @ CMS

— Where have all the New Phys gone?

B. Enhanced $B_d^0 \to \mu^+\mu^-$: What If? 13

"回馬槍"; Constraints & Formulas; Results; Discussion

C. When Higgs meets Top: $t \to ch^0$ @ LHC 10

BaBar Anomaly & 2HDM-III; B Constraints; $t \to ch$ Search @ LHC

D. Outlook

WSH, M. Kohda, F. Xu, 1302.1471 (PRD)
K.F. Chen, WSH, C. Kao, M. Kohda, 1304.8037

III. Hopes and Wishes for "Paradigm" Shift

— A Perspective

I embarked on studies of 4G that might be behind EWP Enhancement [also C]

WSH, Nagashima, Soddu
PRL'05, PRD'05; PRD'07

By nondecoupling of t' (and b'), the 4G effect in EWP for $\Delta A_{K\pi}$ problem:

→ ~~Large $S_{\psi\phi}$~~;
D mixing with small TCPV;
Very Enhanced $K_L \to \pi^0\nu\nu$
...

Went to Fermilab and CERN to evangelize in 2007; then came 2008 ...

It's Godot, we're saved!

...'observation' of anomalously high CPV in B_s system by UTfit collaboration

FIRST EVIDENCE OF NEW PHYSICS IN $b \to s$ TRANSITIONS

(UTfit Collaboration)

M. Bona,[1] M. Ciuchini,[2] E. Franco,[3] V. Lubicz,[2,4] G. Martinelli,[3,5] F. Parodi,[6] M. Pierini,[1] P. Roudeau,[7] C. Schiavi,[6] L. Silvestrini,[3] V. Sordini,[7] A. Stocchi,[7] and V. Vagnoni[8]

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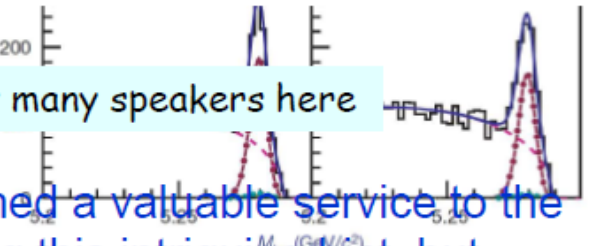
[6]Dipartimento di Fisica, Università di Genova and INFN, I-16146 Genova, Italy
[7]Laboratoire de l'Accélérateur Linéaire, IN2P3-CNRS et Université de Paris-Sud, BP 34, F-91898 Orsay Cedex, France
[8]INFN, Sezione di Bologna, I-40126 Bologna, Italy

We combine all the available experimental information on B_s mixing, including the very recent tagged analyses of $B_s \to J/\Psi\phi$ by the CDF and DØ collaborations. We find that the phase of the B_s mixing amplitude deviates more than 3σ from the Standard Model prediction. While no single measurement has a 3σ significance yet, all the constraints show a remarkable agreement with the combined result. This is a first evidence of physics beyond the Standard Model. This result disfavours New Physics models with Minimal Flavour Violation with the same significance.

UTFIT arXiv:0803.0659 [hep-ph]



history reviewed by many speakers here

Not so fast! UTfit performed a valuable service to the community by highlighting this intriguing hint, but combinations are best left to the experiments themselves

$$\Delta A \equiv A_{K^\pm\pi^0} - A_{K^\pm\pi^\mp} = +0.164 \pm 0.037$$

Experiment Firm.

Godot and the New Physics
Guy Wilkinson, FPCP 09

The LHCb Massacre @ LP2012: All Hints for Godot Gone !

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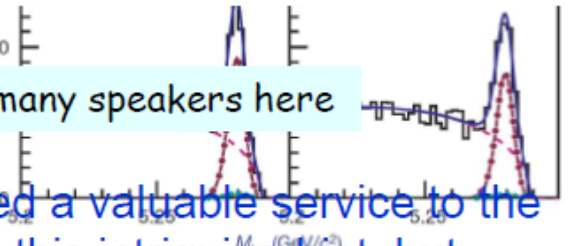

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LHCb: from Now towards 2018/19 Upgrade

Disappointment: No New Physics

CERN/LHCC 2012-007

Type	Observable	Current precision	LHCb 2018	Upgrade ($50\,fb^{-1}$)	Theory uncertainty
B_s^0 mixing	$2\beta_s\ (B_s^0 \to J/\psi\,\phi)$	0.10 [9]	0.025	0.008	~ 0.003
	$2\beta_s\ (B_s^0 \to J/\psi\,f_0(980))$	0.17 [10]	0.045	0.014	~ 0.01
	$A_{fs}(B_s^0)$	6.4×10^{-3} [18]	0.6×10^{-3}	0.2×10^{-3}	0.03×10^{-3}
Gluonic penguin	$2\beta_s^{eff}(B_s^0 \to \phi\phi)$	–	0.17	0.03	0.02
	$2\beta_s^{eff}(B_s^0 \to K^{*0}\bar{K}^{*0})$	–	0.13	0.02	< 0.02
	$2\beta^{eff}(B^0 \to \phi K_S^0)$	0.17 [18]	0.30	0.05	0.02
Right-handed currents	$2\beta_s^{eff}(B_s^0 \to \phi\gamma)$	–	0.09	0.02	< 0.01
	$\tau^{eff}(B_s^0 \to \phi\gamma)/\tau_{B_s^0}$	–	5 %	1 %	0.2 %
Electroweak penguin	$S_3(B^0 \to K^{*0}\mu^+\mu^-; 1 < q^2 < 6\,GeV^2/c^4)$	0.08 [14]	0.025	0.008	0.02
	$s_0\,A_{FB}(B^0 \to K^{*0}\mu^+\mu^-)$	25 % [14]	6 %	2 %	7 %
	$A_I(K\mu^+\mu^-; 1 < q^2 < 6\,GeV^2/c^4)$	0.25 [15]	0.08	0.025	~ 0.02
	$\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)/\mathcal{B}(B^+ \to K^+\mu^+\mu^-)$	25 % [16]	8 %	2.5 %	~ 10 %
Higgs penguin	$\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	1.5×10^{-9} [2]	0.5×10^{-9}	0.15×10^{-9}	0.3×10^{-9}
	$\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	–	~ 100 %	~ 35 %	~ 5 %
Unitarity triangle angles	$\gamma\ (B \to D^{(*)}K^{(*)})$	~ 10–$12°$ [19, 20]	4°	0.9°	negligible
	$\gamma\ (B_s^0 \to D_s K)$	–	11°	2.0°	negligible
	$\beta\ (B^0 \to J/\psi\,K_S^0)$	0.8° [18]	0.6°	0.2°	negligible
Charm	A_Γ	2.3×10^{-3} [18]	0.40×10^{-3}	0.07×10^{-3}	–
CP violation	ΔA_{CP}	2.1×10^{-3} [5]	0.65×10^{-3}	0.12×10^{-3}	–

R. Jacobsson @ LHCP2013

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Where CMS/ATLAS could be Competitive

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R. Jacobsson @ LHCP2013

We'll still wait for Godot. He'll come tomorrow.

Some Comments

- $A_{FB}^{t\bar{t}}$ dubious: Need tree level effect, but NP seems above TeV Scale ... Tough!
- A_{SL} dubious: Need both large $\sin\phi_s$ and large $\Delta\Gamma_s$ — both ruled out by LHCb — Y Xie

  A detailed study of bs(bar) -> csc(bar)s(bar) decay data found no indication of OPE violation [Chua, WSH, Shen, PRD'11]

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- **The LHCb Trio:** $\sin\phi_s$; $B_s \to \mu^+\mu^-$; $A_{FB}(B \to K^{*0}\mu^+\mu^-)$ Now All SM-Like ...

  Mild hint of suppression below SM! [WSH, Kohda, Xu, PRD'12]
- "Flavored" SUSY: Light Stop breaks MFV; Any FPCP Predictions? S. Beckett
- **Higgs as Godot**: 2.x, even 3σ, is nothing. Maybe another "Pozzo" (or "the boy")

But, Higgs or No Higgs (know December), will impact FPCP!!

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Enhanced $B_d^0 \to \mu^+\mu^-$ Decay: What if?

If observed $\gtrsim 4 \times 10^{-10}$ (2011-2012 data!),
then the 126 GeV boson might not be the Higgs.

4G回馬槍?!

I. Intro: from Straub to Stone

Mild Motivation: $\sin 2\Phi_{B_d} \equiv \sin 2\beta/\phi_1$ tension

II. Constraints & Formulas

Δm_{B_d} and $B^+ \to \pi^+\mu^+\mu^-$

III. Pheno Results with t′-in-loop

IV. Discussion

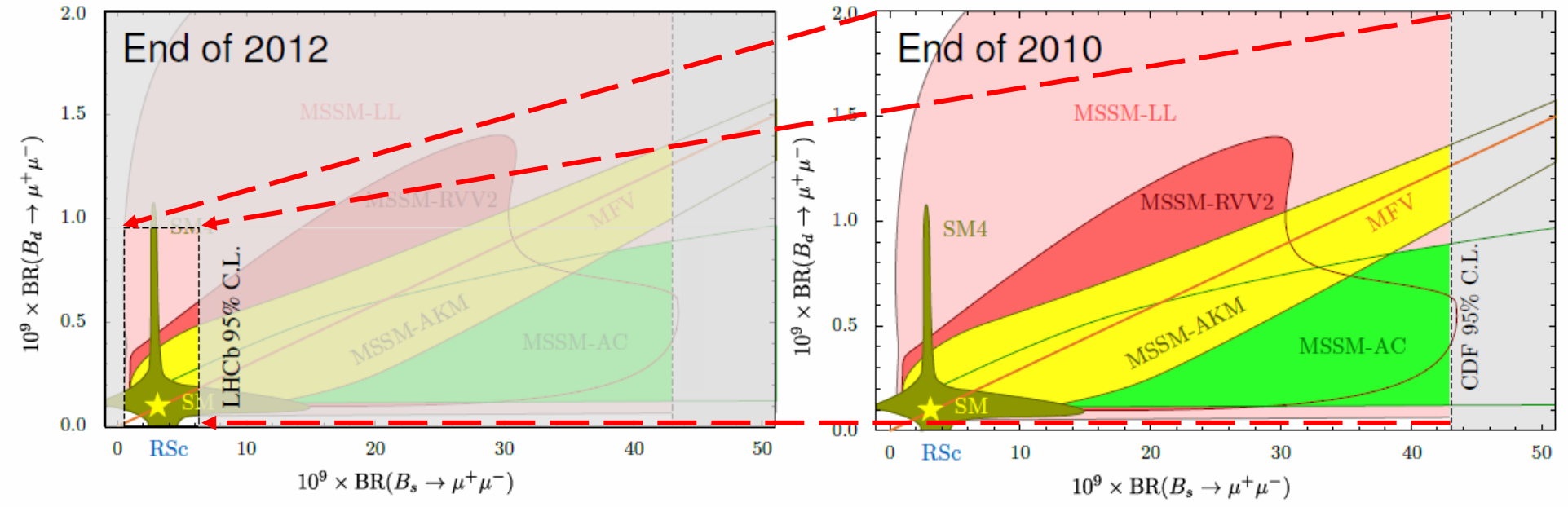
b → d quadrangle; CKM hierarchy implication

V. Conclusion

WSH, Kohda, Xu, 1302.1471, ~~to appear~~ PRD

Evolution of the "Straub plot"

Disappointment: No New Physics



Straub [Nuovo Cim. C 35 1 (2012) 249-256]

(series of Moriond talks)

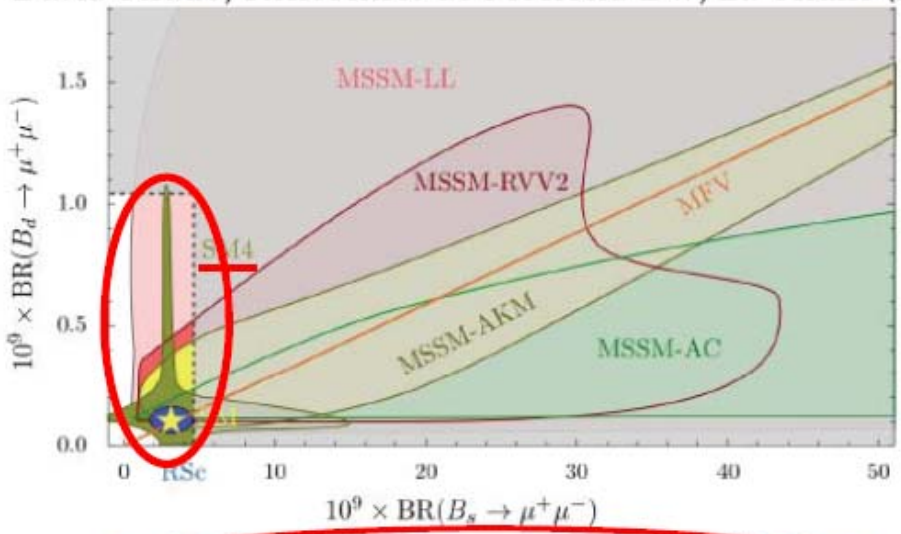
Disappointment: No New Physics

the $\sin\phi_s$ destroyer-of-hope ...

Sheldon Stone @ ICHEP2012

Implications II

David Straub, Rencontres de Moriond EW, La Thuile (2012)



The 125 GeV Higgs observations kills off 4th generation models as the production cross-section would be 9x larger & decays to $\gamma\gamma$ suppressed

R.I.P.

ICHEP, Melbourne, July 9, 2012 39

However, SM Higgs is flavor-blind

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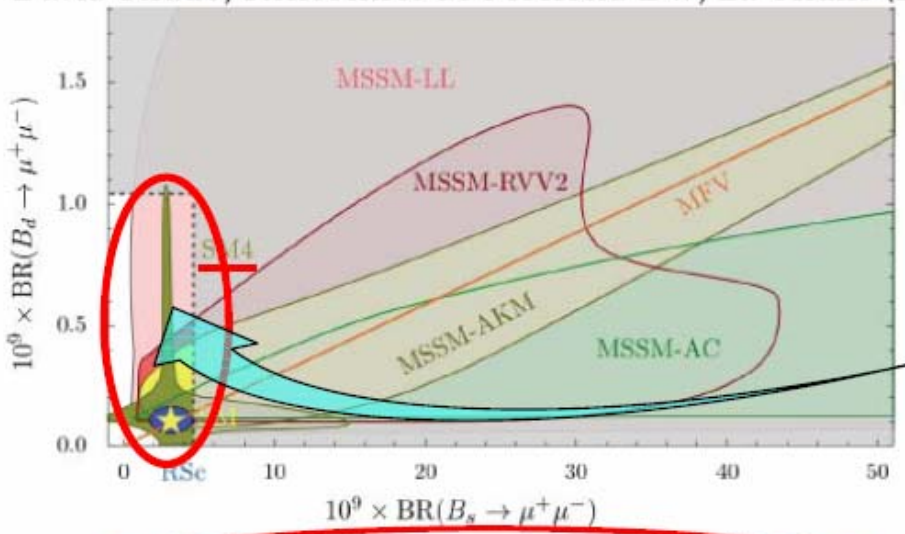

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Flavor people should keep CKM-extension in mind.

Higgs does not enter these loops;

and, 126 GeV boson could be "dilaton" still ...

Keep on Searching w/ Gusto!

However, SM Higgs is flavor-blind

last chance for New Physics in flavor sector at LHC8

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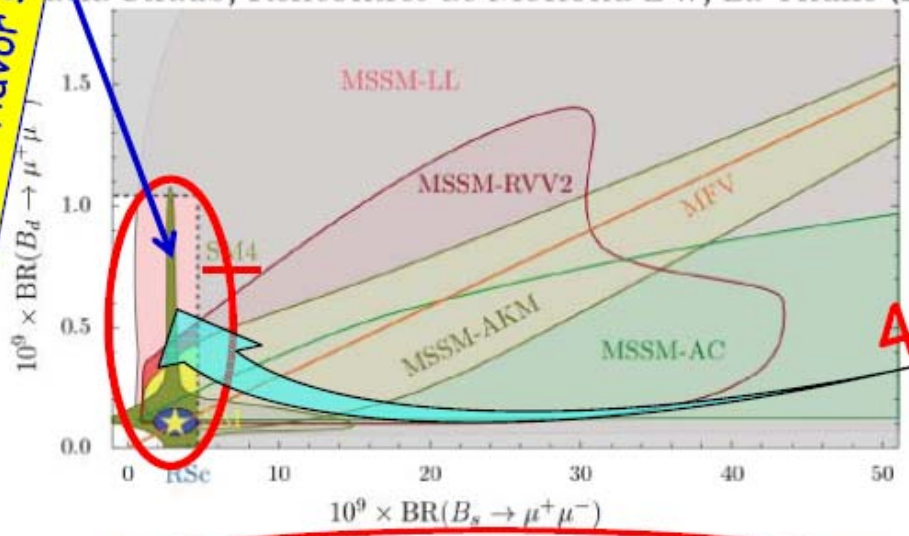

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N.B. For 4G dynamical EWSB that permits dilaton, see Mimura, WSH, Kohyama, 1206.6063

Mild Motivation: $\sin 2\Phi_{B_d} \equiv \sin 2\beta/\phi_1$ tension

Lunghi & Soni, '08; Buras & Guadagnoli, '08

- $\sin 2\beta/\phi_1 = 0.679 \pm 0.020$ — Direct Measurement

- $\sin 2\beta/\phi_1 = \begin{cases} 0.76 & \text{for } |V_{ub}|^{\text{ave}} \\ 0.63 & \text{for } |V_{ub}|^{\text{excl}} \end{cases}$ — Indirect from other meas.

arg

$$\lambda_t^{\rm SM} = -\lambda_u - \lambda_c \simeq -|V_{ud}||V_{ub}|e^{-i\phi_3} + |V_{cd}||V_{cb}|$$

taking $|V_{ud}| = 0.974$, $|V_{cd}| = 0.23$ and $|V_{cb}| = 0.041$

$\phi_3 = (68^{+11}_{-10})^\circ$

parameterize t′-effect to alieviate tension

$$\lambda_t = \lambda_t^{\rm SM} - \lambda_{t'}$$

$$\lambda_u + \lambda_c + \lambda_t + \lambda_{t'} = 0$$

$V^*_{t'd}V_{t'b}$

$$\lambda_{t'} = r_{db}\, e^{i\phi_{db}}$$

Constrain

Constraints & Formulas

Δm_{B_d} and $\boxed{B^+ \to \pi^+ \mu^+ \mu^-}$

LHCb 2012: rarest B decay measured

N.B. $b \to d\gamma$ hard to separate from $b \to s\gamma$,
hard for LHCb, and insensitive to 4G.
$B \to \pi\pi$ much hadronic effect.

$$\Delta m_{B_d} \simeq \frac{G_F^2 M_W^2}{6\pi^2} m_{B_d} \hat{B}_{B_d} f_{B_d}^2 \eta_B |\Delta_{12}^d|,$$

$$\sin 2\Phi_{B_d} \simeq \sin(\arg \Delta_{12}^d),$$

sin2β/ϕ_1

$$\Delta_{12}^d \equiv (\lambda_t^{\rm SM})^2 S_0(x_t) + 2\lambda_t^{\rm SM}\lambda_{t'}\Delta S_0^{(1)} + \lambda_{t'}^2 \Delta S_0^{(2)}$$

Remaining hadronic uncertainty

t′-effect

$$\Delta S_0^{(1)} \equiv \tilde{S}_0(x_t, x_{t'}) - S_0(x_t),$$

$$\Delta S_0^{(2)} \equiv S_0(x_{t'}) - 2\tilde{S}_0(x_t, x_{t'}) + S_0(x_t),$$

$$x_i = m_i^2/M_W^2$$

$$\hat{\mathcal{B}}(B_d \to \mu^+\mu^-) \equiv \frac{\mathcal{B}(B_d \to \mu^+\mu^-)}{\Delta m_{B_d}} \Delta m_{B_d}^{\rm exp}$$

$$= C \frac{\tau_{B_d} \Delta m_{B_d}^{\rm exp}}{\hat{B}_{B_d}} \frac{\eta_Y^2}{\eta_B} \frac{\left|\lambda_t^{\rm SM} Y_0(x_t) + \lambda_{t'} \Delta Y_0\right|^2}{|\Delta_{12}^d|}$$

Ratio w/ Box Buras '03

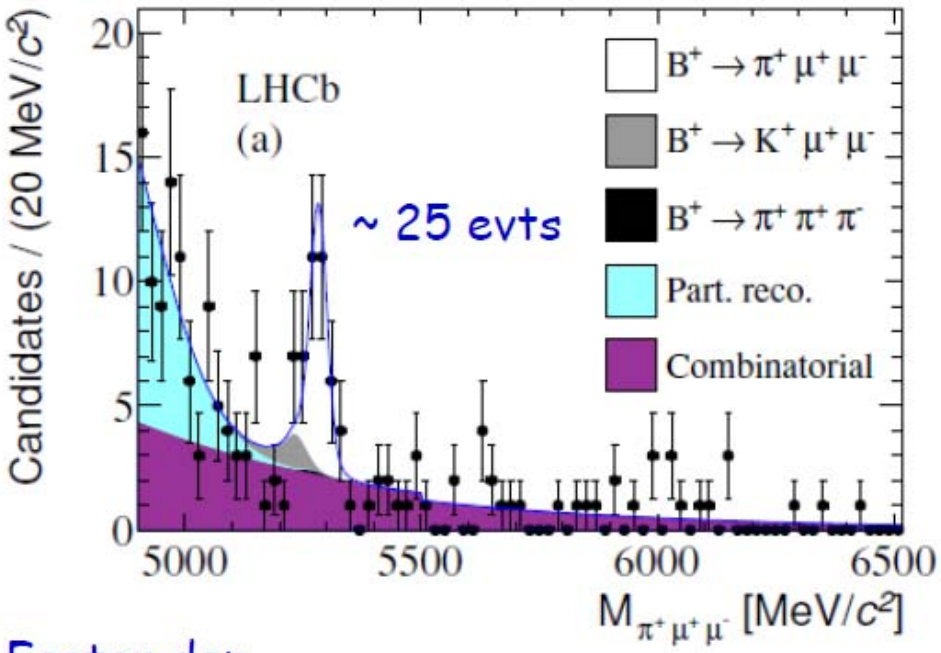
$$\Delta Y_0 = Y_0(x_{t'}) - Y_0(x_t)$$

$$C = 6\pi \left(\frac{\alpha}{4\pi \sin^2\theta_W}\right)^2 \frac{m_\mu^2}{M_W^2}$$

$$(2.3 \pm 0.6\,(\text{stat.}) \pm 0.1\,(\text{syst.})) \times 10^{-8}$$

first observation of $B^+ \to \pi^+\mu^+\mu^-$ $b \to d\ell^+\ell^-$ transition

LHCb, JHEP 2012



$1.0\,\text{fb}^{-1}$

To reduce Form Factor dep.

$$R_{\pi\mu\mu} \equiv \frac{\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)|_{\text{4G}}}{\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)|_{\text{SM}}}$$

integrated from $q^2 = (1,\ 6)\ \text{GeV}^2$

better numerical control

- W.C. @ NLO
- LO amplitude in QCDF

Beneke, Feldmann, Seidel, '01, '03

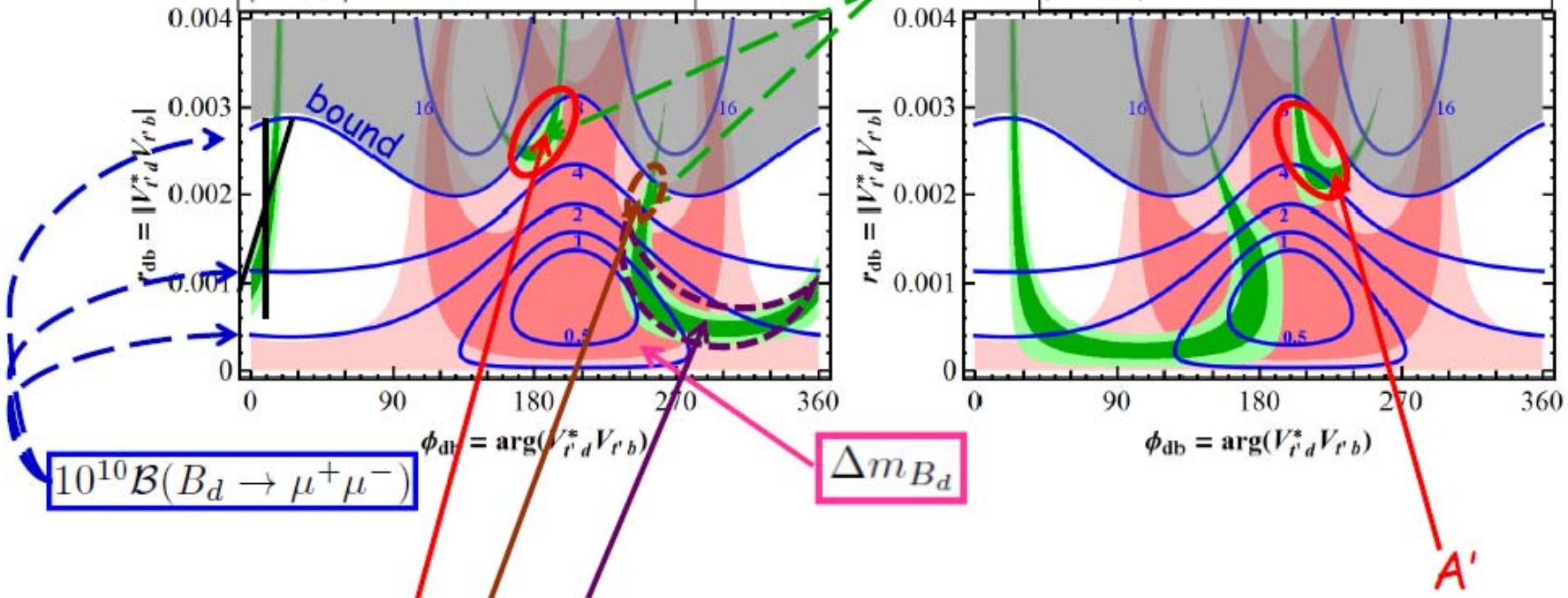
Will plot contours to 2x - 3x

otherwise LHCb could tell?

Results

$m_{t'} = 700$ GeV [LHC bound

~ incl. $|V_{ub}| = 4.15 \times 10^{-3}$ $\sin 2\Phi_{B_d}$ $|V_{ub}| \sim 3.23 \times 10^{-3}$ excl.



Regions A, B & C: A & B give $B_d \to \mu^+\mu^-$ > 4x SM
C gives broad cresent in phase

A point each from A & A' is taken for later illustration

$m_{t'} = 700$ GeV [LHC bound

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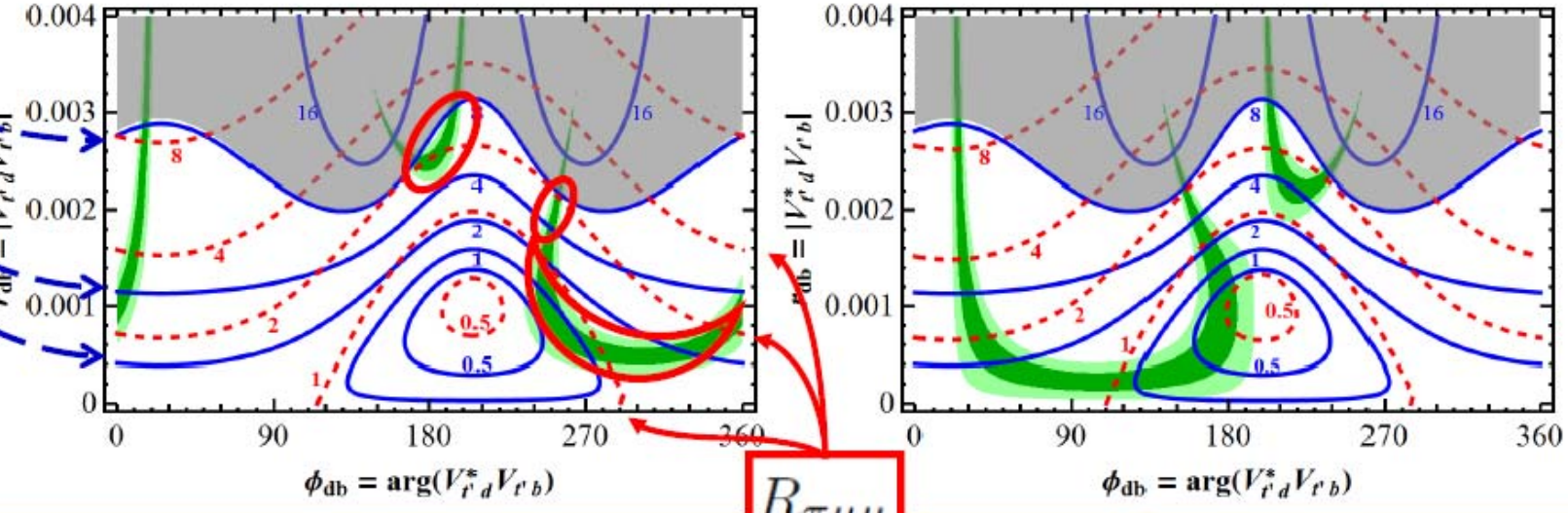
The 3 Regions survive $R_{\pi\mu\mu} \lesssim 2$ - 3 Constraint!

$$R_{\pi\mu\mu} \equiv \frac{\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)|_{\rm 4G}}{\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)|_{\rm SM}}$$

$10^{10}\mathcal{B}(B_d \to \mu^+\mu^-)$



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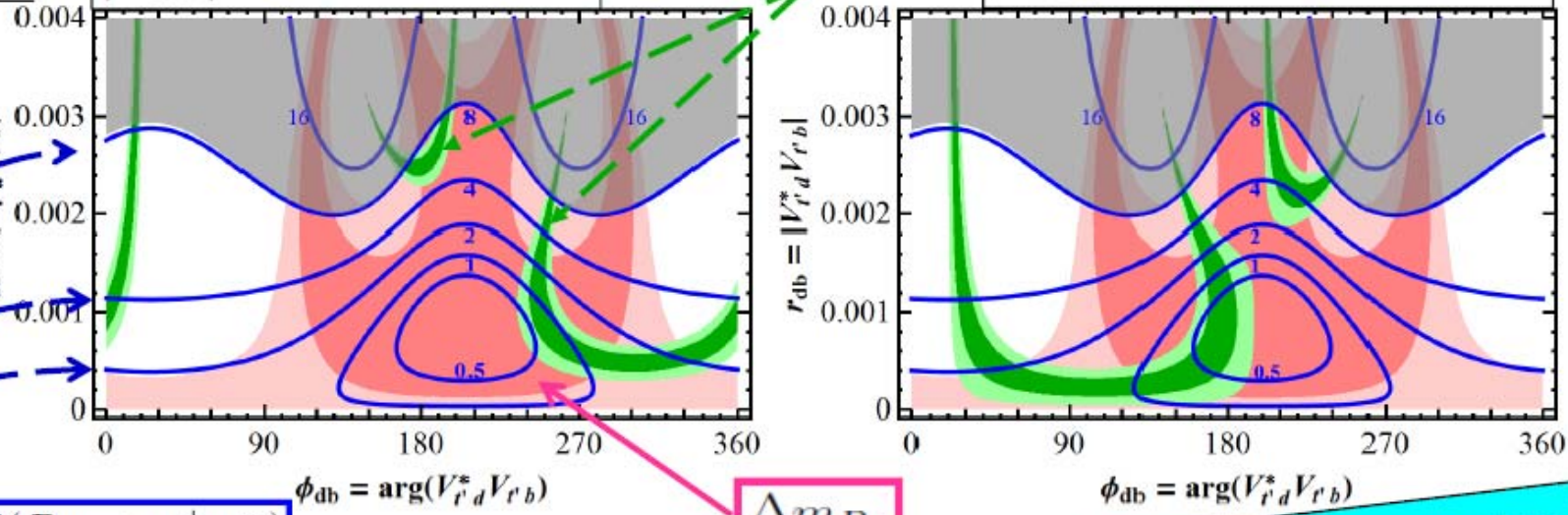
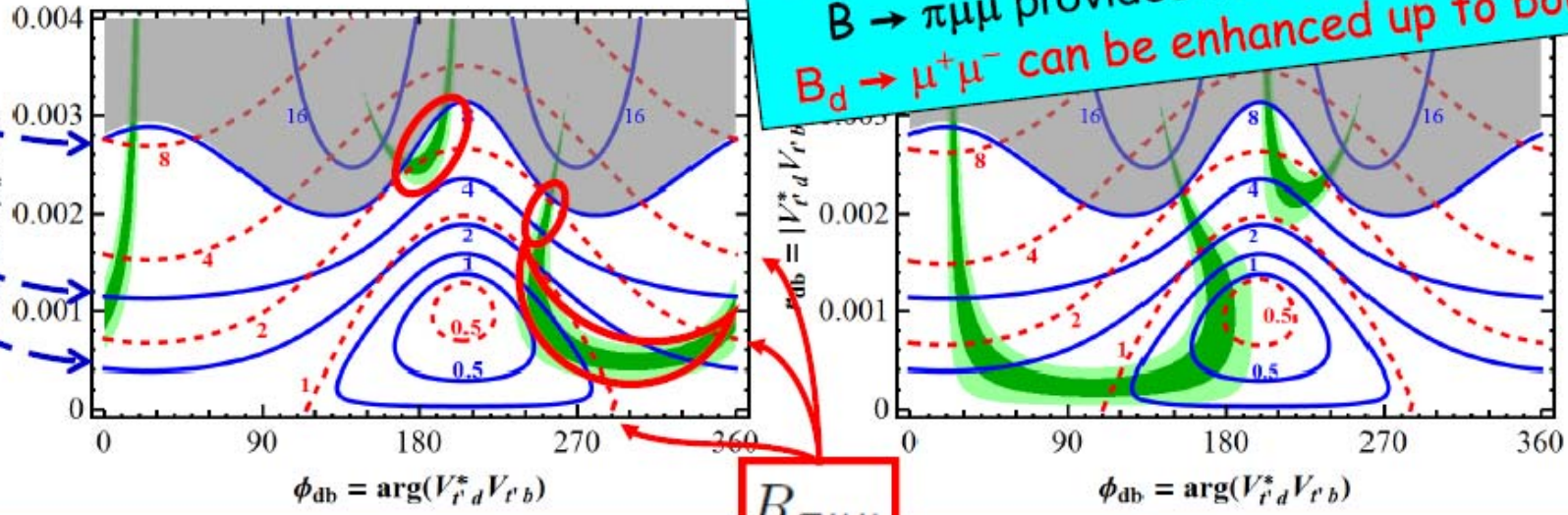


Δm_{B_d}

$10^{10}\mathcal{B}(B_d \to \mu^+\mu^-)$

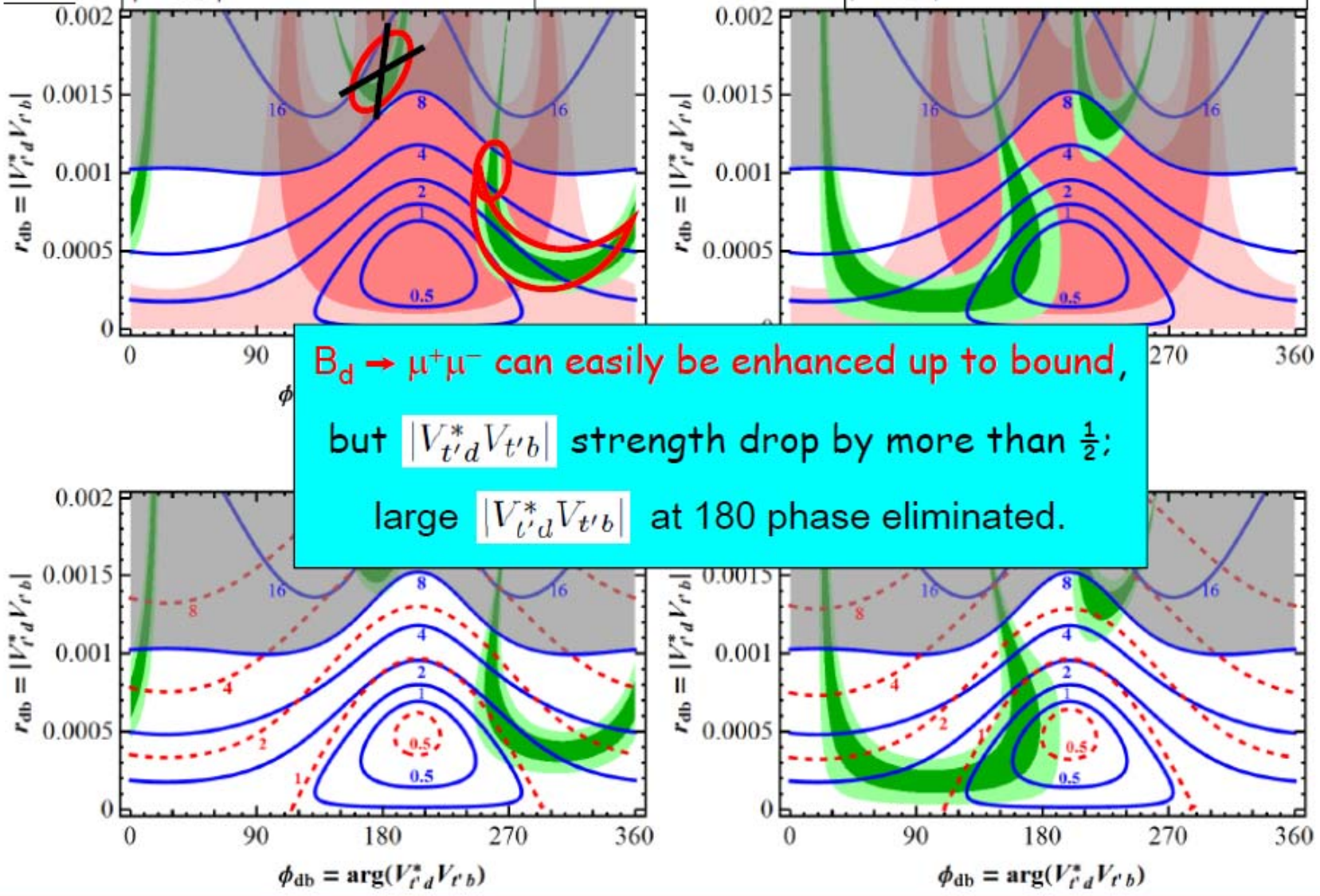


B → πμμ provides useful sanity check;
$B_d \to \mu^+\mu^-$ can be enhanced up to bound

$R_{\pi\mu\mu}$

$m_{t'} = 1000$ GeV [far beyond unitarity bound

~ incl. $|V_{ub}| = 4.15 \times 10^{-3}$ $|V_{ub}| \sim 3.23 \times 10^{-3}$ excl.



$B_d \to \mu^+\mu^-$ can easily be enhanced up to bound,

but $|V^*_{t'd}V_{t'b}|$ strength drop by more than $\frac{1}{2}$;

large $|V^*_{t'd}V_{t'b}|$ at 180 phase eliminated.

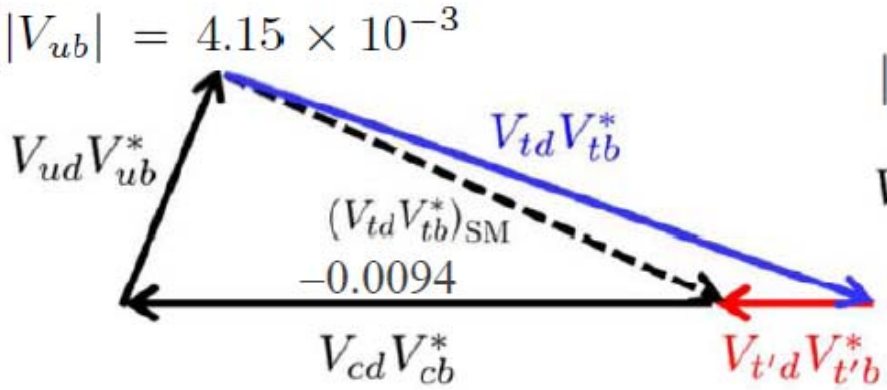
Discussion on CKM4

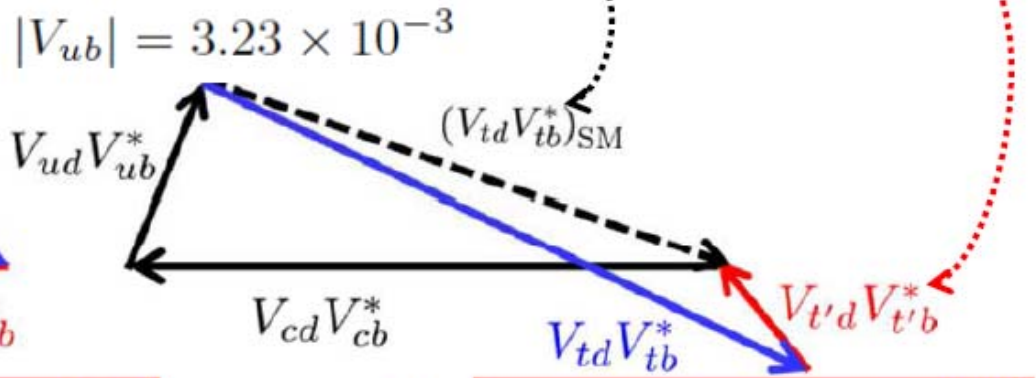
CPV4BAU?

- b → d quadrangle in our lap !

$$\lambda_u + \lambda_c + \lambda_t + \lambda_{t'} = 0$$

$$-\lambda_t^{\rm SM}$$





from: Region A $V_{t'd}^* V_{t'b} = 0.0025\, e^{i180^\circ}$

A' $V_{t'd}^* V_{t'b} = 0.0023\, e^{i230^\circ}$

- The above CKM4 values are quite large. [$V_{t'b} < 0.1$ necessary] WSH & Ma, PRD'11

  If we learn from $\sin\phi_s$ experience [CKM hierarchy seem upheld], then $B_d \to \mu^+\mu^-$ > 4x SM is possible, but not particularly likely.

  Heavier t' could still do it with more "naturally" small CKM4.

When Higgs meets Top: $t \to ch^0$ @ LHC

Pro-found if Found

FCNH: verboten in SM & 2HDM I/II

Glashow-Weinberg 1977

$$\rho_{ct} \cos(\beta - \alpha)\, \bar{c} t h^0 + \text{h.c.}$$

- BaBar Anomaly, 2HDM-III & ***tch*** Coupling
- B Physics Constraints
- $t \to ch$ Search at LHC

Fajfer, Kamenik, Nisandzic, Zupan, PRL 2012
Crivellin, Greub, Kokulu, PRD 2012; 1303.5877

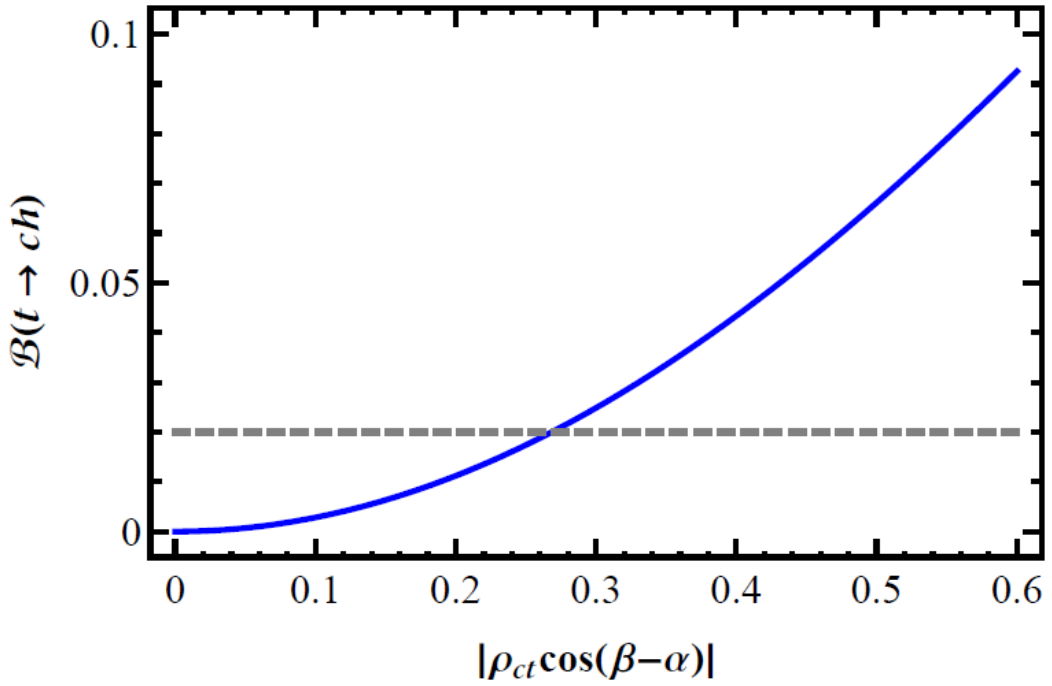
CGK

CHKK
KCHS

Chen, WSH, Kao, Kohda, 1304.8037
also Kao, Cheng, WSH, Sayre, PLB 2012

$\mathcal{B}(t \to ch^0)$ vs $\rho_{ct}\cos(\beta-\alpha)$

First discussion: WSH, PLB 1991



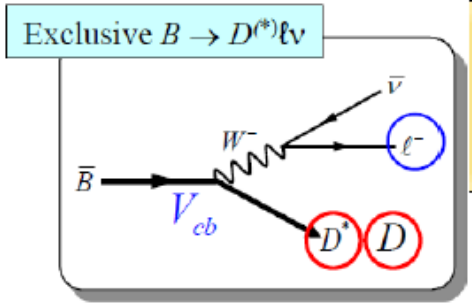
← 2%

How large can ρ_{ct} cos (β–α) be?

exotic admixture of 126 GeV boson

BaBar "Anomaly", 2HDM-III & *tch* Coupling

New BaBar Result Reported!



Lüth

$$R(D) = \frac{\Gamma(\bar{B} \to D\tau\nu)}{\Gamma(\bar{B} \to D\ell\nu)} \qquad R(D^*) = \frac{\Gamma(\bar{B} \to D^*\tau\nu)}{\Gamma(\bar{B} \to D^*\ell\nu)}$$

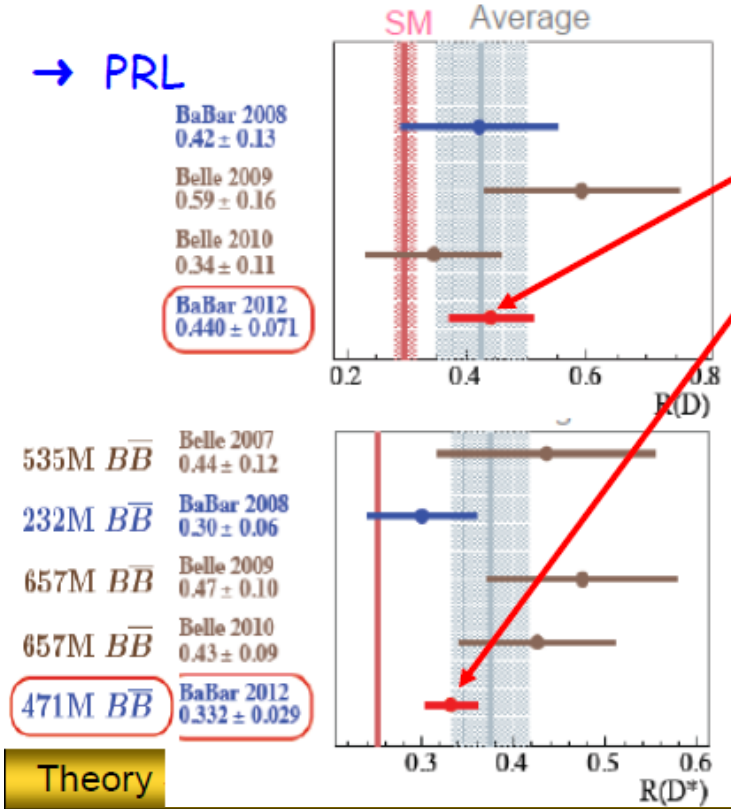
"theoretical element"
~ corrected mistake of theorist

Several experimental and theoretical uncertainties cancel in the ratio!

$$\frac{d\Gamma_\tau}{dq^2} = \frac{G_F^2 |V_{cb}|^2 |\mathbf{p}| q^2}{96\pi^3 m_B^2} \left(1 - \frac{m_\tau^2}{q^2}\right)^2 \left[\left(|H_{++}|^2 + |H_{--}|^2 + |H_{00}|^2\right) \left(1 + \frac{m_\tau^2}{2q^2}\right) + \frac{3}{2}\frac{m_\tau^2}{q^2} |H_t|^2 \right]$$

For $D\tau\nu$, only H_{00} and H_t contribute!

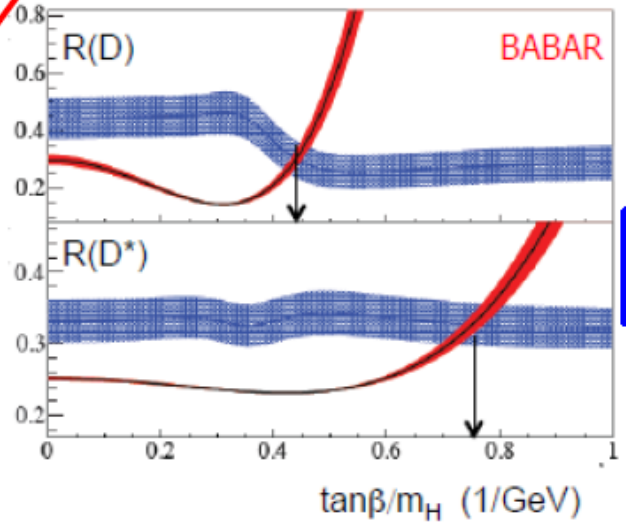
→ PRL



3.4 σ combined!

$$H_t^{2HDM} = H_t^{SM} \times \left(1 - \frac{\tan^2\beta}{m_{H^\pm}^2} \frac{q^2}{1 \mp m_c/m_b}\right)$$

- for $D\tau\nu$
+ for $D^*\tau\nu$



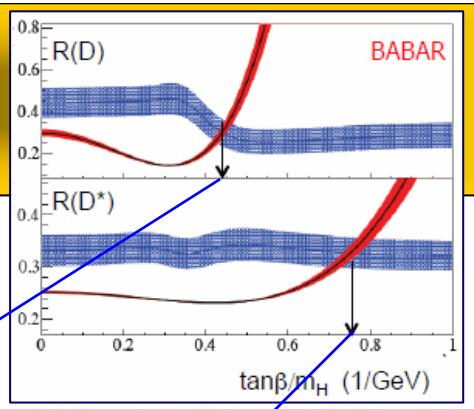
Mismatch of preferred $\tan^2\beta/m_H$

excludes Type II 2HDM
w/ probability > 99.8%

Astounding!
what if they met ...

Belle, please check.
Theorists, too.

BaBar "Anomaly"



BaBar, PRL 2012

The BaBar experiment measured the ratios $\mathcal{R}(D^{(*)}) = \Gamma(\bar{B} \to D^{(*)}\tau\nu)/\Gamma(\bar{B} \to D^{(*)}\ell\nu)$, finding them both larger than SM expectations, with a combined significance of 3.4σ.

- In the type II 2HDM, this implied that $\tan\beta/m_{H^+} = 0.44 \pm 0.02$ GeV^{-1} and 0.75 ± 0.04 GeV^{-1} from $\mathcal{R}(D)$ and $\mathcal{R}(D^*)$, respectively.
- The two numbers are incompatible with each other, hence "excludes the 2HDM-II charged Higgs boson with a 99.8% confidence level for any value of $\tan\beta/m_{H^+}$".
- Either $\tan\beta/m_{H^+}$ value, however, would over-enhance $B \to \tau\nu$, which is found in agreement with SM expectation, spelling further trouble.

Very Large!

2HDM-III (General) Yukawa Interactions

Mahmoudi and Stal, PRD 2010

$s_{\beta-\alpha}$ $(c_{\beta-\alpha})$ stands for $\sin(\beta-\alpha)$ $(\cos(\beta-\alpha))$

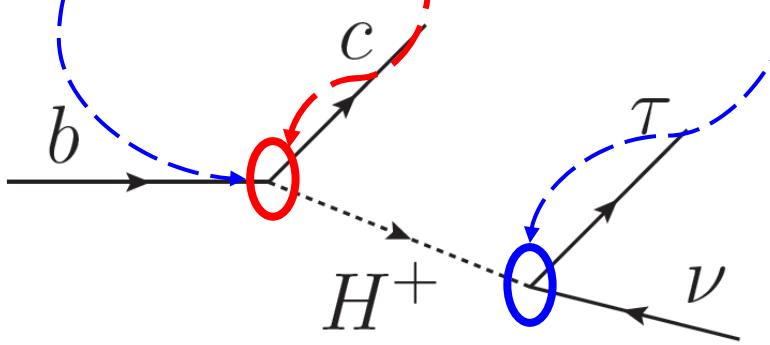
$$-\frac{1}{\sqrt{2}}\sum_{f=}^{u,\,d,\,\ell}\bar{f}\left[\left(\kappa^f s_{\beta-\alpha}+\rho^f c_{\beta-\alpha}\right)h^0\right.$$

$$\left.+\left(\kappa^f c_{\beta-\alpha}-\rho^f s_{\beta-\alpha}\right)H^0-i\,\mathrm{sgn}(Q_f)\rho^f\gamma_5 A^0\right]f$$

$$-\left[\bar{u}\left(V\rho^d R-\rho^u V L\right)dH^+ + \bar{\nu}\rho^\ell R\ell H^+ + \mathrm{h.c.}\right],$$

"Standard"

Exotic



CGK "considered" Decoupling Limit:
$\sin(\beta-\alpha)\to 1$, h^0 becomes SMH

To consider t → ch:

- Need Nondecoupled:
  h^0 mixes in $\cos(\beta-\alpha)$ frac. of H^0
- Not only ρ_{bb}, but $\rho_{\tau\tau}$ turn out small (next page)
  → deviate from CGK [and separate from BaBar
- ρ_{ct} ~ 1, implying
  ρ_{tt} and ρ_{cc} need be considered!

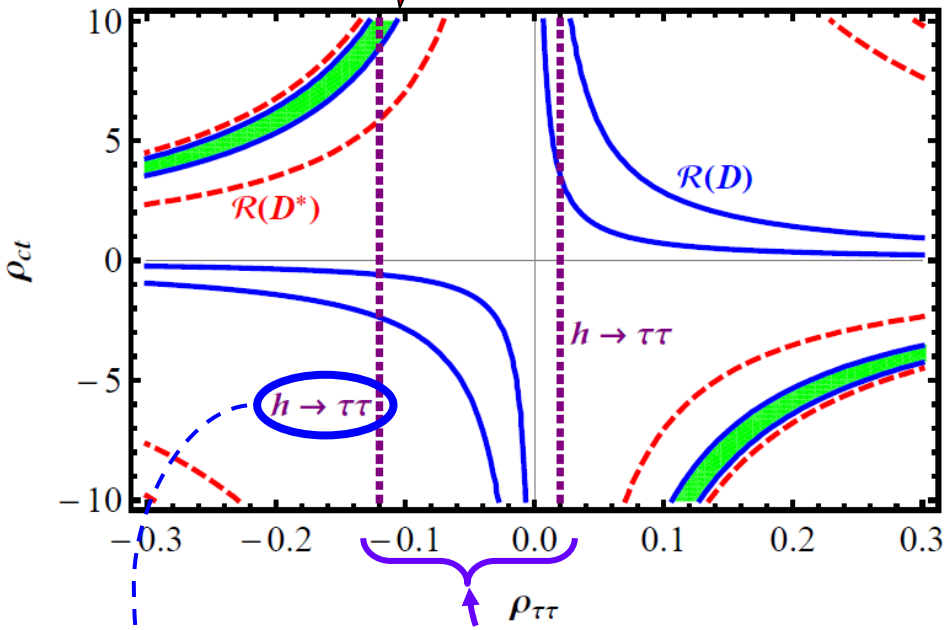
B Physics Constraints

Higgs → ττ : $\rho_{\tau\tau}$ small

b → sγ : ρ_{bb} tiny

Nonperturb. ρ_{ct} needed

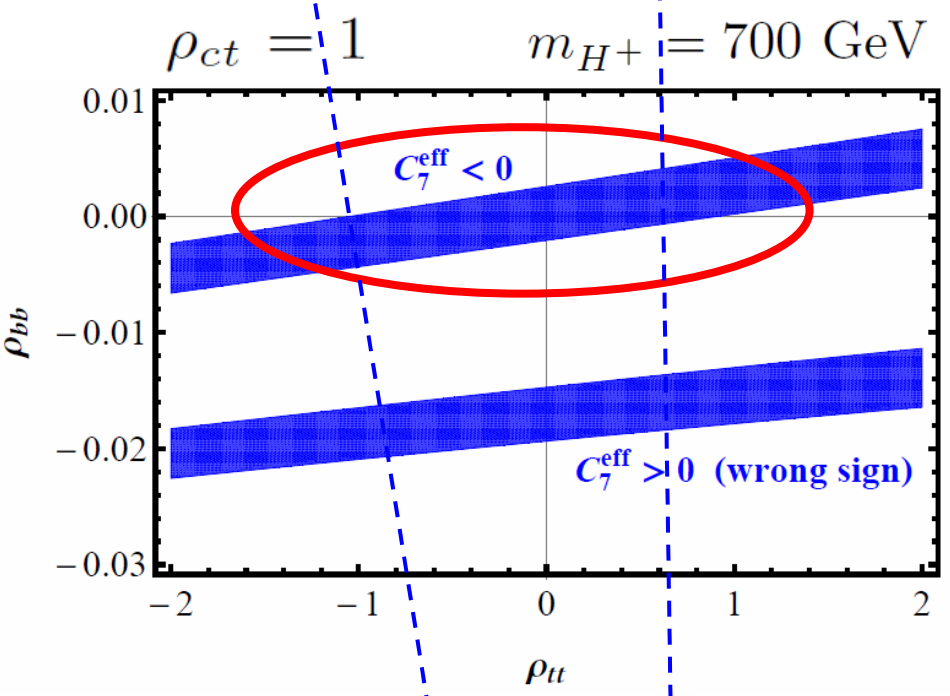
Detach from BaBar anomaly



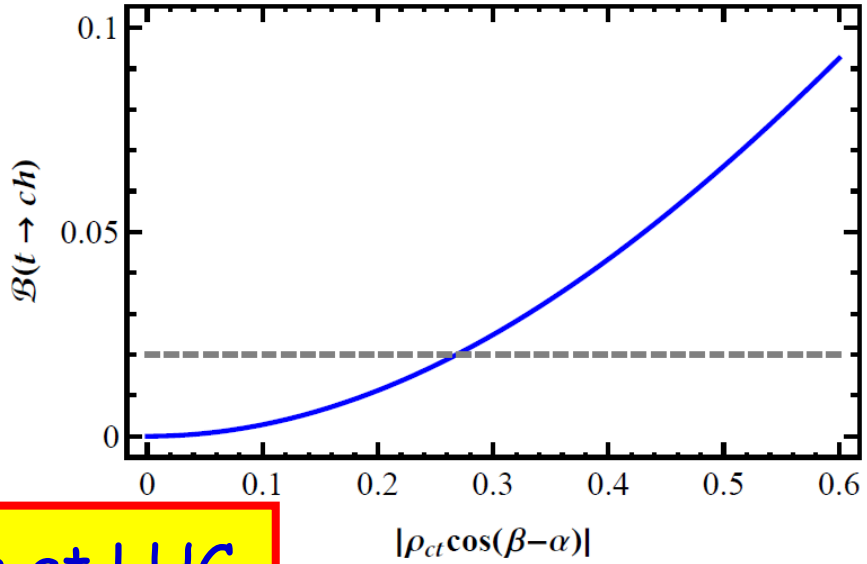
$c_{\beta-\alpha} = 0.2$

$$|s_{\beta-\alpha} + (\rho_{\tau\tau} v/\sqrt{2} m_\tau) c_{\beta-\alpha}| \lesssim \sqrt{2}$$

Because of chiral m_t/m_b and KM enhancement, ρ_{bb} tiny!



$$\delta C_{7,8} \simeq \frac{1}{3}\left(\rho_{tt} + \frac{V_{cs}^*}{V_{ts}^*}\rho_{ct}\right)\left(\rho_{tt}^* + \frac{V_{cb}}{V_{tb}}\rho_{ct}^*\right)\frac{F_{7,8}^{(1)}(y)}{2m_t^2/v^2} - \left(\rho_{tt} + \frac{V_{cs}^*}{V_{ts}^*}\rho_{ct}\right)\rho_{bb}\frac{F_{7,8}^{(2)}(y)}{2m_t m_b/v^2},$$



$t \to ch$ Search at LHC

How large can $\mathcal{B}(t \to ch)$ be?

If $\rho_{ct} \sim 1$, what constraint we have on $\cos(\beta-\alpha)$?

N.B. From $\sigma_{tt(bar)}$ measurement with dileptons, one infers $\mathcal{B}(t \to ch)$ cannot be larger than 5-6%.

Example: Clean Sample of ZZ* → 4ℓ

$$\sigma_{gg\to h^0} \cdot \frac{\Gamma_{h^0\to ZZ^*}}{\Gamma^{\rm SM}_{h^0}} \cdot \frac{\Gamma^{\rm SM}_{h^0}}{\Gamma_{h^0}} \simeq [\sigma\cdot\mathcal{B}]^{\rm SM}_{ZZ^*}$$

~ 22 pb

Consistency of 15-20 evts ~ SM w/ little BG, for both CMS/ATLAS

With 126 GeV dominantly SMH, i.e. $\sin(\beta-\alpha) \simeq 1$ (near Decoupling), ZZ* (and WW*) Rate hard to change.

The width of 126 GeV Higgs can be enhanced by ρ_{cc} as not measured.

Gluon Fusion can be enhanced by ρ_{tt}, even though damped by $\cos(\beta-\alpha)$.

Cf.: $\sigma_{tt(bar)}$ ~ 220 pb, if t → ch 2%, then tt(bar) → chbW is at 9 pb!

Could we have seen it already!?

Summary of Constained 2HDM-III

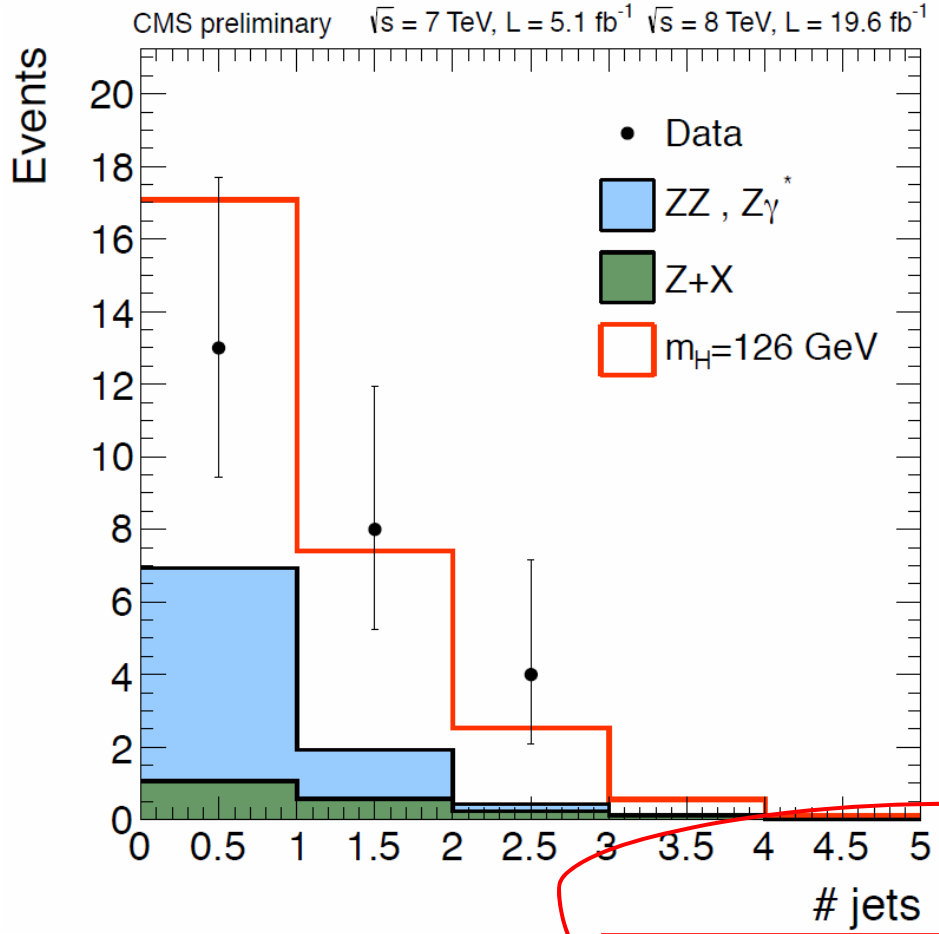
TABLE I. Light Higgs h^0 properties in 2HDM-III with $\rho_{ct} \sim 1$. Widths are in MeV units, with $\Gamma^{\rm SM}_{h^0} \simeq 4.55$ MeV.

	$\mathcal{B}^{\rm SM}$	$\Gamma^{\rm SM}$	Γ	Comment
WW^*	21.5%	0.98	hard to change	$\sin(\beta-\alpha) \simeq 1$
ZZ^*	2.7%	0.12	hard to change	$\sin(\beta-\alpha) \simeq 1$
$\gamma\gamma$	0.24%	0.011	hard to change	W-loop dom.
bb	59.4%	2.70	hard to change	$b \to s\gamma$
$\tau\tau$	5.7%	0.26	within fac. 2	direct
cc	2.6%	0.12	up to $\sim \Gamma_{b\bar{b}}$	not measured ($\rho_{cc} \lesssim 0.2$)
gg	7.7%	0.35	up to fac. 2	$\rho_{tt} \sim 1$

- For enhanced $\sigma_{gg\to h^0}$, then dilution of $\mathcal{B}_{ZZ^*}$ would be necessary, implying enhanced $h^0 \to c\bar{c}$;
- If $\sigma_{gg\to h^0}$ is suppressed, or $\mathcal{B}_{ZZ*}$ is diluted, then more ZZ^* events may come from $t\bar{t}$ feeddown!

No Evidence of Excess Jets in ZZ* …

Any tt(bar) → chbW?



Simple CLs estimate gives (95% C.L.)

$\mathcal{B}(t \to ch) < 1.5\%$

Best done directly by the Experiments.

Craig et al., PRD 2012: < 2.7% (can improve)

also the $h^0 \to WW^*, b\bar{b}, \tau^+\tau^-$ and $\gamma\gamma$ modes

KCHS'12: Can probe down to 1%

D. Outlook

"No Higgs"

- 2013 Pivotal: If $B_d \to \mu^+\mu^-$ > 4x SM, We Will Discover It!
  Certainly in expt'l range, and w/ some $\sin 2\Phi_{Bd}$ motivation.
  Chance is finite, but not large, because of CKM hierarchy.

- If discovery with 2011-2012 data, then
  - Uplifting 4G (hopes again for CPV4BAU), but only in loop ...
  - Cast doubt on "the Higgs" — turning "it" into New Physics?
  - Theorist might scramble, but will need much fine-tuning ...

Two Higgs

A discovery of the $t \to ch^0$ process with present data would suggest the existence of an extended Higgs sector beyond the usual 2HDM-II implied by minimal SUSY. It is rather impressive that the intense efforts of Higgs search in the past two years could already push the limit on $t \to ch^0$ down to the percent level. Actual experimental studies, incorporating also the $h^0 \to WW^*$, $b\bar{b}$, $\tau^+\tau^-$ and $\gamma\gamma$ modes,

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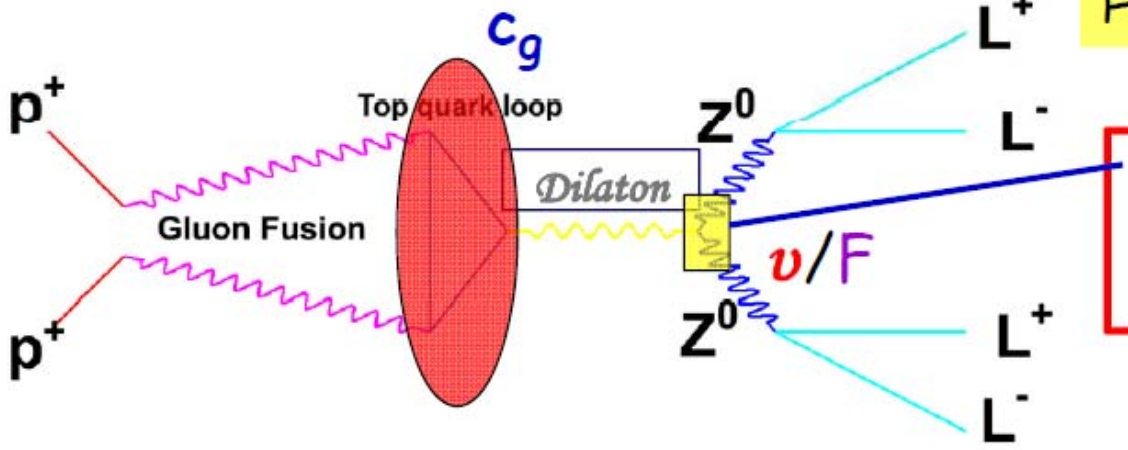
But, Higgs or No Higgs (know ~~December~~), will impact FPCP!!

How does *Dilaton* rescue the situation ?



$H \to ZZ^* \to ee\mu\mu$

no convincing evidence
for VBF (Vector Boson Fusion)
or VH (Higgsstrahlung off V) so far

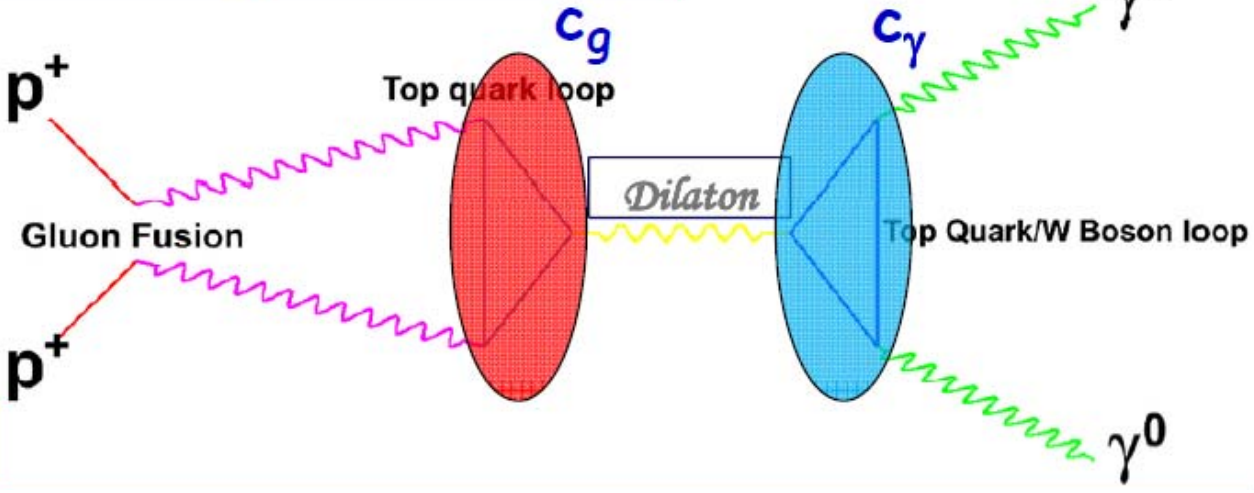
→ *Dilaton* not ruled out!

Leading Processes

Elander, Piai, 8/12

Treat 3 parameters

v/F, c_g, c_γ



$H \to \gamma\gamma$