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Workshop on the original of P, CP and T Violation

2 - 5 July 2008

CP Violation in B Physics.

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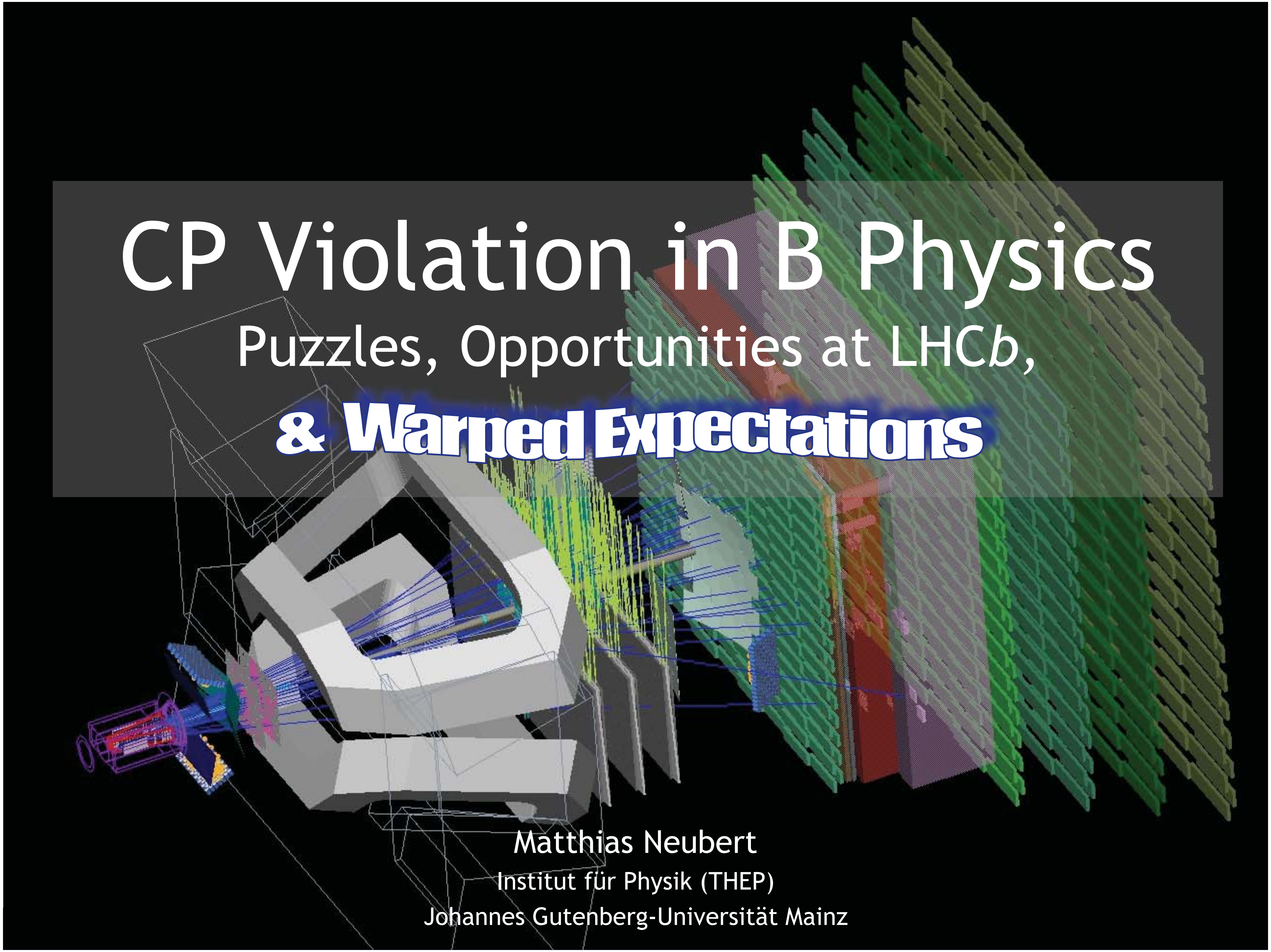

CP Violation in B Physics

Puzzles, Opportunities at LHC*b*,

& Warped Expectations

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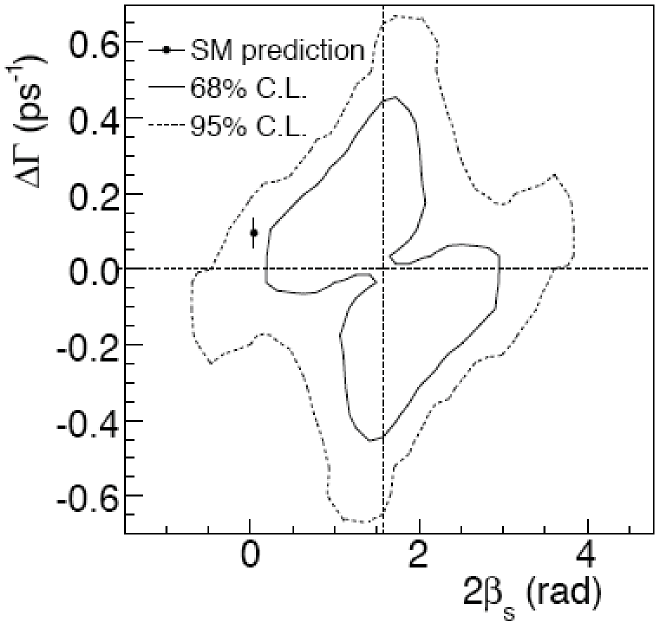
Flavor Puzzles in B Physics and LHC*b* Capabilities

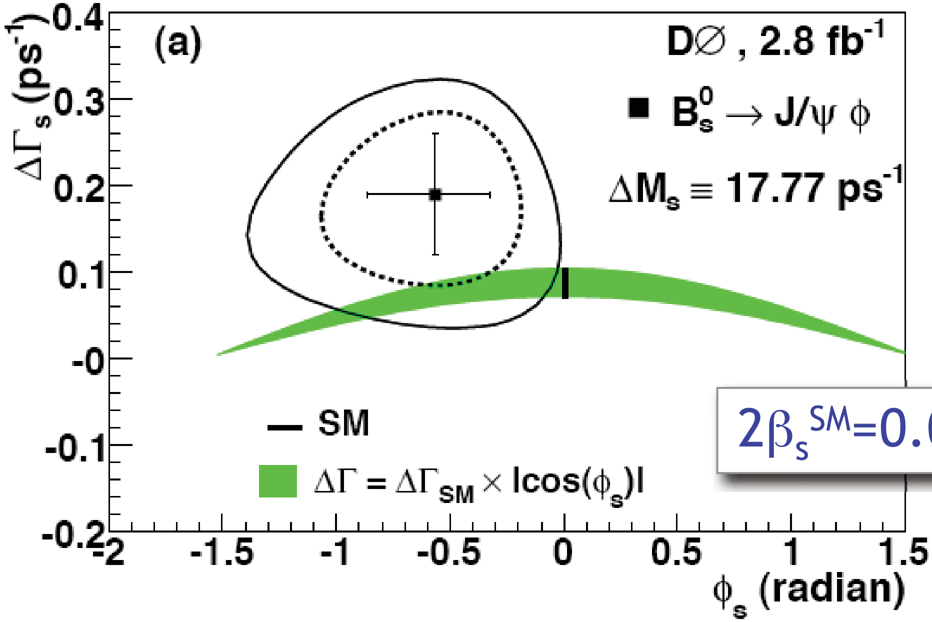
- New Physics CP phase in B_s mixing
- $\sin 2\beta$ from tree vs. penguins
- CP violation in $B \to \pi K$ decays

New physics in B_s mixing ?

- Main information from flavor-tagged analysis of mixing-induced CP violation in $B_s \to J/\psi\, \phi$ decay
- Combined probability regions for $\phi_s = 2\beta_s$ and $\Delta\Gamma_s$



CDF (Dec. 2007)



$2\beta_s^{SM} = 0.04$

D0 (Feb. 2008)

New physics in B_s mixing ?

- Combined analysis (UT*fit* collab., March 2008):

$$\Delta m_s \oplus A_{SL}{}^{s} \oplus A_{SL}{}^{\mu\mu} \oplus \tau(B_s) \oplus \{\phi_s, \Delta\Gamma_s\}$$

(CDF) (D0) (CDF, D0) (ALEPH, DELPHI, OPAL, CDF, D0) (CDF, D0)

$\oplus$

some bayesian magic …

New physics in B_s mixing ?

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

(**UT***fit* Collaboration)

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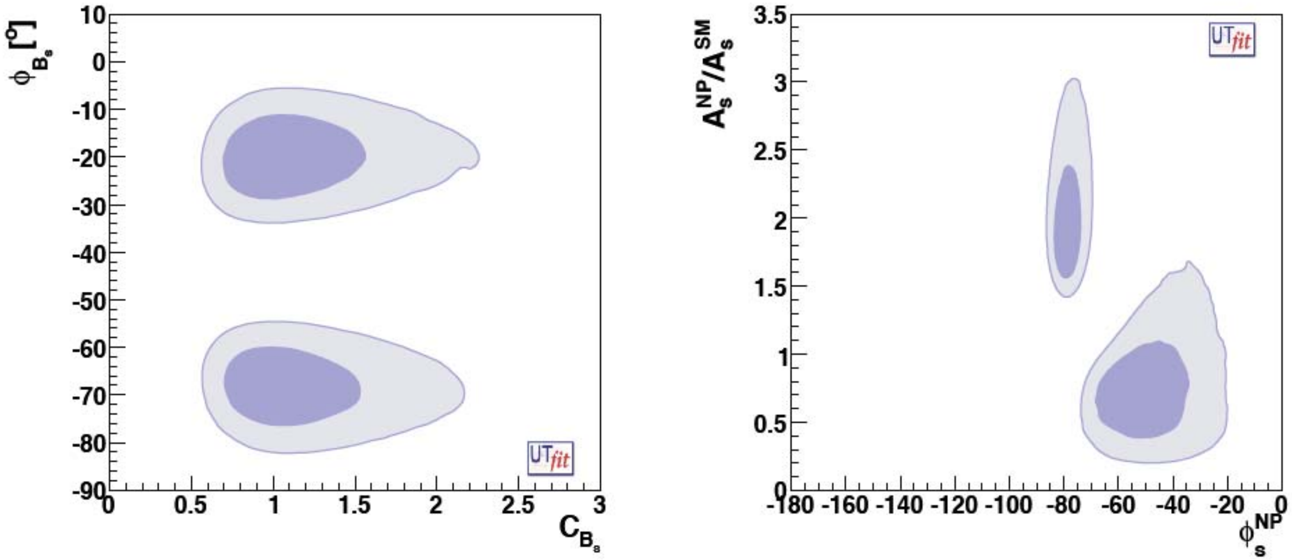
We combine all the available experimental information on B_s mixing, including the very recent tagged analyses of $B_s \to J/\Psi\phi$ by the CDF and DØ collaborations. We find that the phase of the B_s mixing amplitude deviates more than 3σ from the Standard Model prediction. While no single measurement 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.

3.7σ evidence for a non-standard CP phase!

New physics in B_s mixing ?

- Model-independent parameterization:

$$C_{B_s}\, e^{2i\phi_{B_s}} = \frac{A_s^{\rm SM} e^{-2i\beta_s} + A_s^{\rm NP} e^{2i(\phi_s^{\rm NP}-\beta_s)}}{A_s^{\rm SM} e^{-2i\beta_s}}$$



If confirmed with more data, this would be clear evidence for NP!

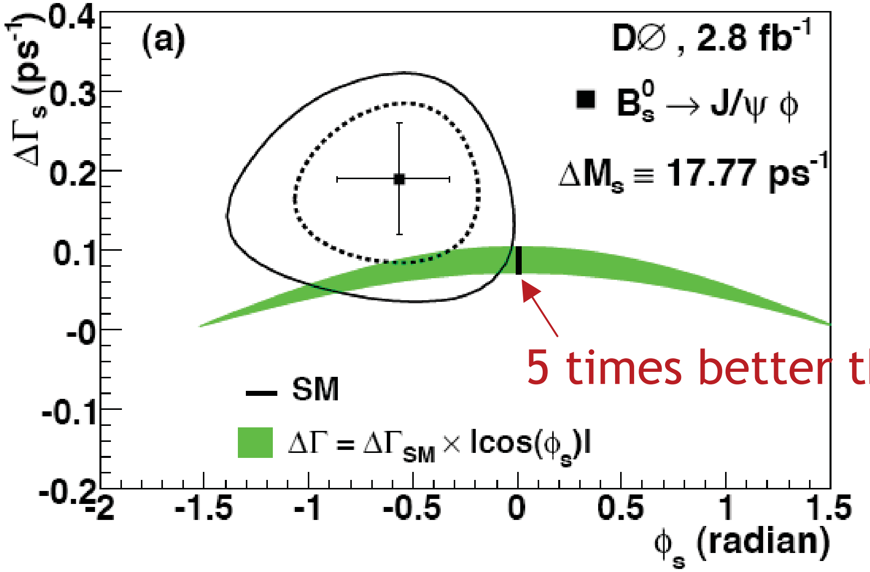
see also: Lenz, Nierste (2006)

New physics in B_s mixing ?

- Capabilities of LHC*b*:

Luminosity	0.5 fb^{-1} (~2009)	2 fb^{-1} (~2010)	10 fb^{-1} (~2013)
$\sigma(2\beta_s)$	0.046	0.021	0.009

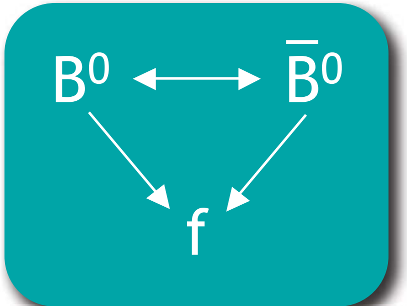
- Precision:



$2\beta_s^{SM}=0.04$

New physics in rare B decays (I) ?

- CP violation in interference of mixing and decays in neutral B decays into CP eigenstates
- Time-dependent CP asymmetry provides direct access to angles of the unitarity triangle:

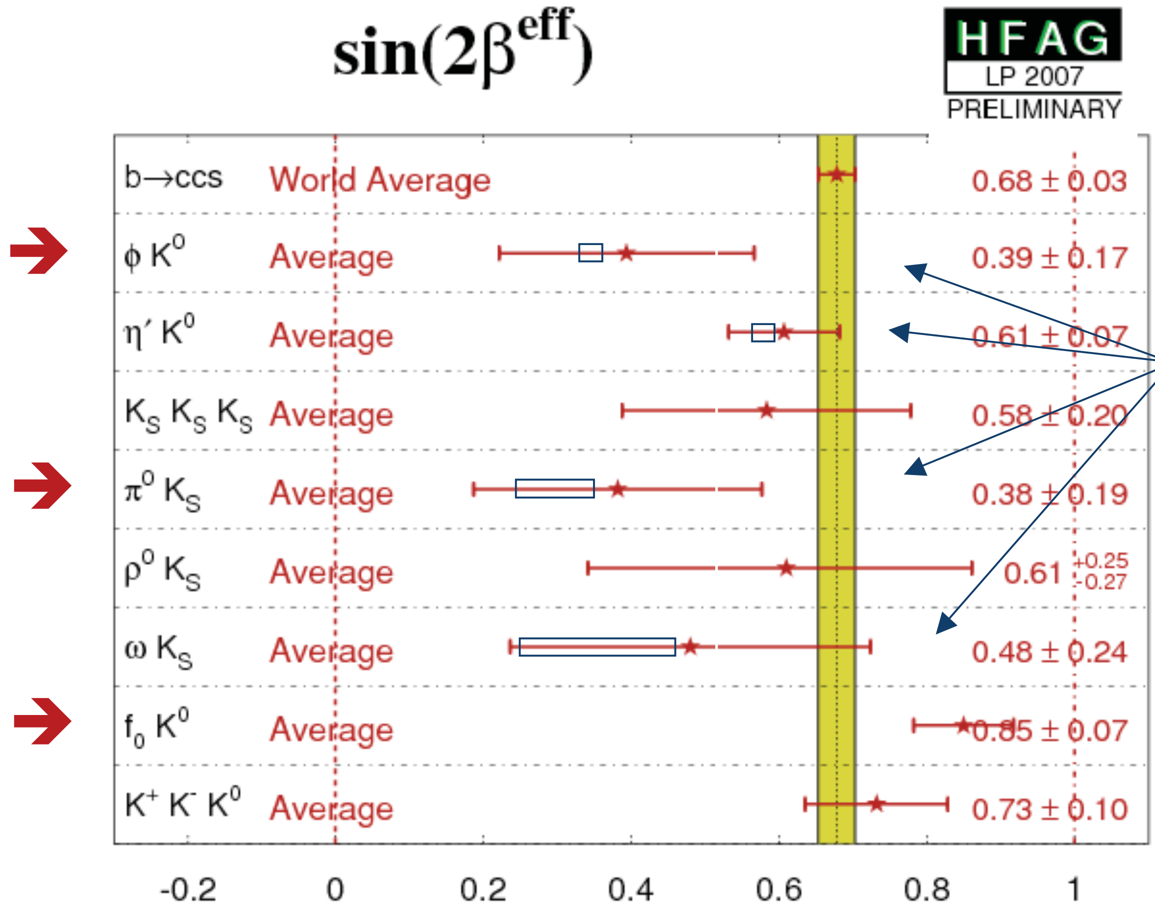


$$A_{\rm CP}(t) = \frac{\Gamma(\bar{B}^0(t) \to f) - \Gamma(B^0(t) \to f)}{\Gamma(\bar{B}^0(t) \to f) + \Gamma(B^0(t) \to f)} = \boxed{\sin 2(\beta - \varphi_A)} \sin(\Delta m t)$$

- Consider modes with $\varphi_A = 0$ and compare results for $\sin 2\beta$ from tree- and loop-dominated processes

Grossman, Worah (1996)

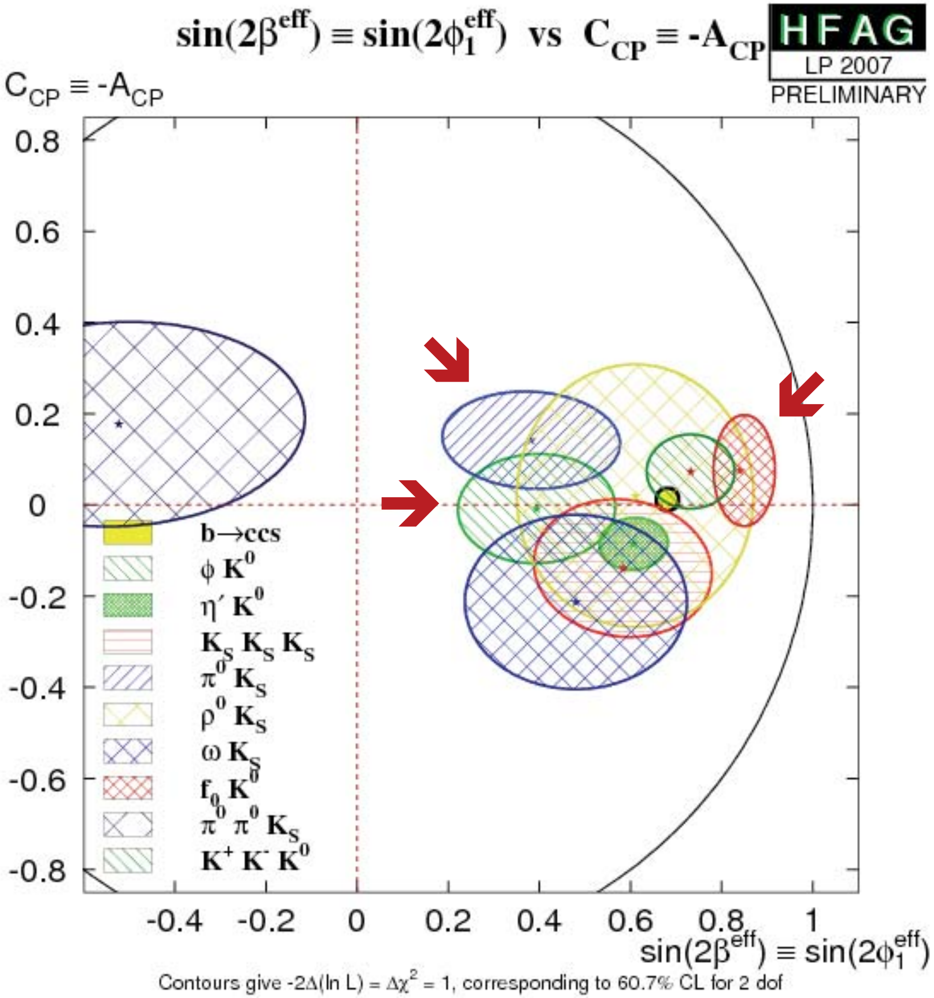
$(\sin 2\beta)_{tree}$ vs. $(\sin 2\beta)_{penguin}$



theor. corrections increase deviations

Beneke, MN (2003)

$(\sin 2\beta)_{\text{tree}}$ vs. $(\sin 2\beta)_{\text{penguin}}$



- Present accuracy:

  $\sigma(\sin 2\beta_{\phi K_S}) = 0.17$

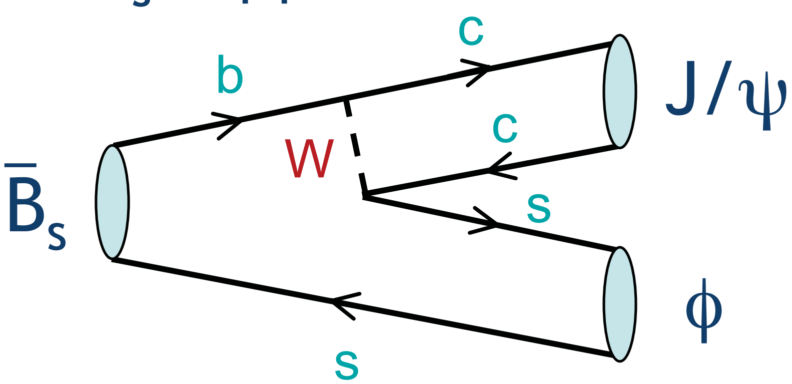
- LHC*b* capability with 10 fb^{-1}:

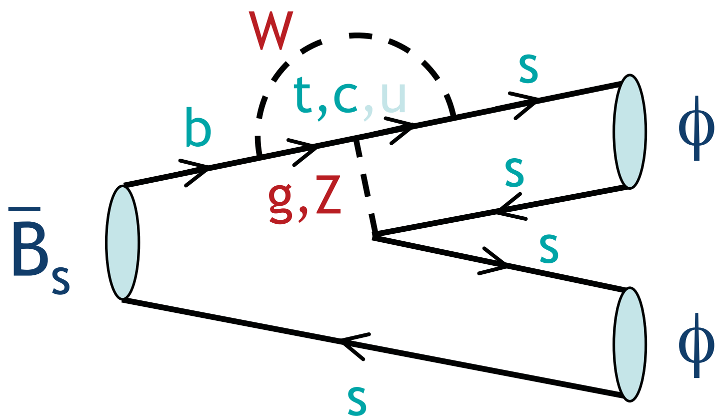
  $\sigma(\sin 2\beta_{\phi K_S}) = 0.10$

$\Rightarrow$ Super-B factory!

$(\sin 2\beta_s)_{tree}$ vs. $(\sin 2\beta_s)_{penguin}$

- But LHC*b* can do analogous test using B_s decays
- Compare $\sin 2\beta_s$ values extracted from $B_s \to J/\psi\, \phi$ vs. $B_s \to \phi\phi$





Luminosity	2 fb^{-1} (~2010)	10 fb^{-1} (~2013)
$\sigma(2\beta_s^{\phi\phi})$	0.11	0.04

$2\beta_s^{\phi\phi,SM}=0$

New physics in rare B decays (II) ?

- Belle and Babar observe large difference in direct CP asymmetries between $B^{\pm}\to K^{\pm}\pi^{0}$ and $B^{0}\to K^{\pm}\pi^{-+}$ decays (Belle paper in *Nature*, March 2008):
  "this large deviation in direct CP violation between charged and neutral B meson decays could be an indication of new sources of CP violation"
- World-average experimental data:

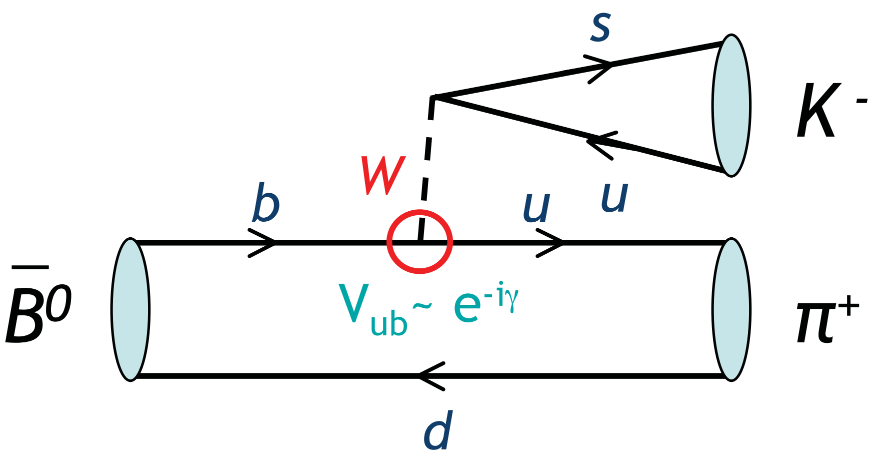
$$A_{CP}(B^{-}\to K^{-}\pi^{0}) = +\,0.050 \pm 0.025$$

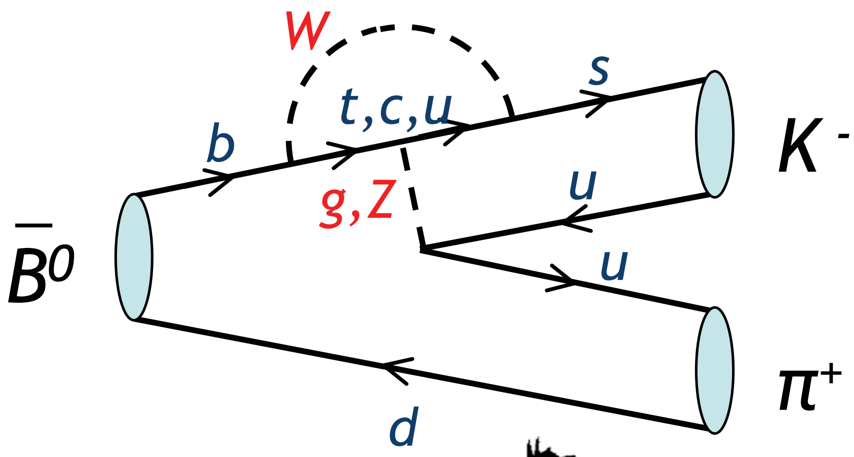
$$A_{CP}(B^{0}\to K^{-}\pi^{+}) = -\,0.097 \pm 0.012$$

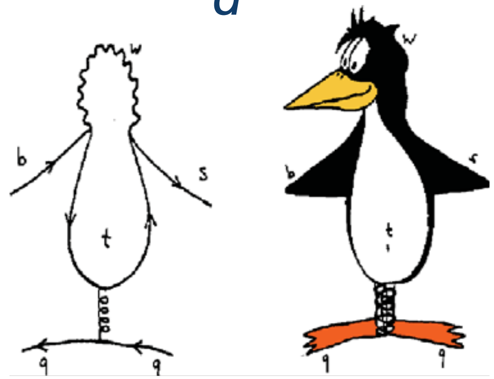
LHC*b* capability: $\sigma(A_{CP}(B^{0}\to K^{-}\pi^{+})) = 0.0014$ with 10 fb^{-1}

New physics in rare B decays (II) ?

- Interference of tree and penguin amplitudes:







A "πK puzzle" ?

- Amplitude interference:

$$\sqrt{2}\, A(B^- \to K^- \pi^0) = P - (T + C)\, e^{-i\gamma} + P_{EW}$$

$$A(B^0 \to K^- \pi^+) = P - T\, e^{-i\gamma}$$

- QCD predictions (model independent):

$$P_{EW} = f_{real}(m_t/m_W)\ (T + C)$$

U-spin symmetry and Fierz relations

Fleischer (1996); MN, Rosner (1998)

$$\arg(C/T) = O[\alpha_s(m_b),\ \Lambda_{QCD}/m_b]$$

QCD factorization, SCET

Beneke, Buchalla, MN, Sachrajda (1999-2001)

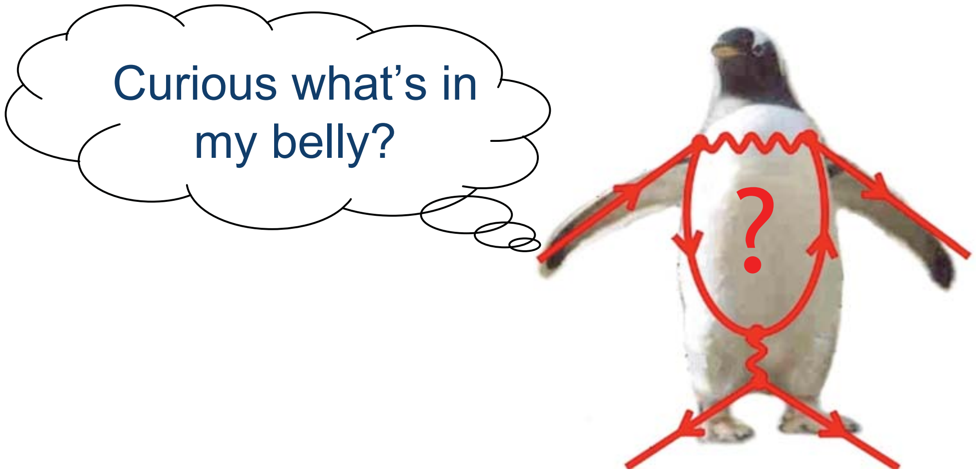
Bauer, Rothstein, Stewart (2005)

CP asymmetries predicted to have same sign !
(and similar magnitude)

→ test of theoretical assumptions requires Super-B factory

If any of these effects are real …

- Hints at O(1) new physics effects in mixing amplitudes and rare decay amplitude
- Requires large, O(1) new CP-violating phases



Check at ATLAS/CMS!

Not a Minimal Flavor Violation scenario !

Warped Expectations

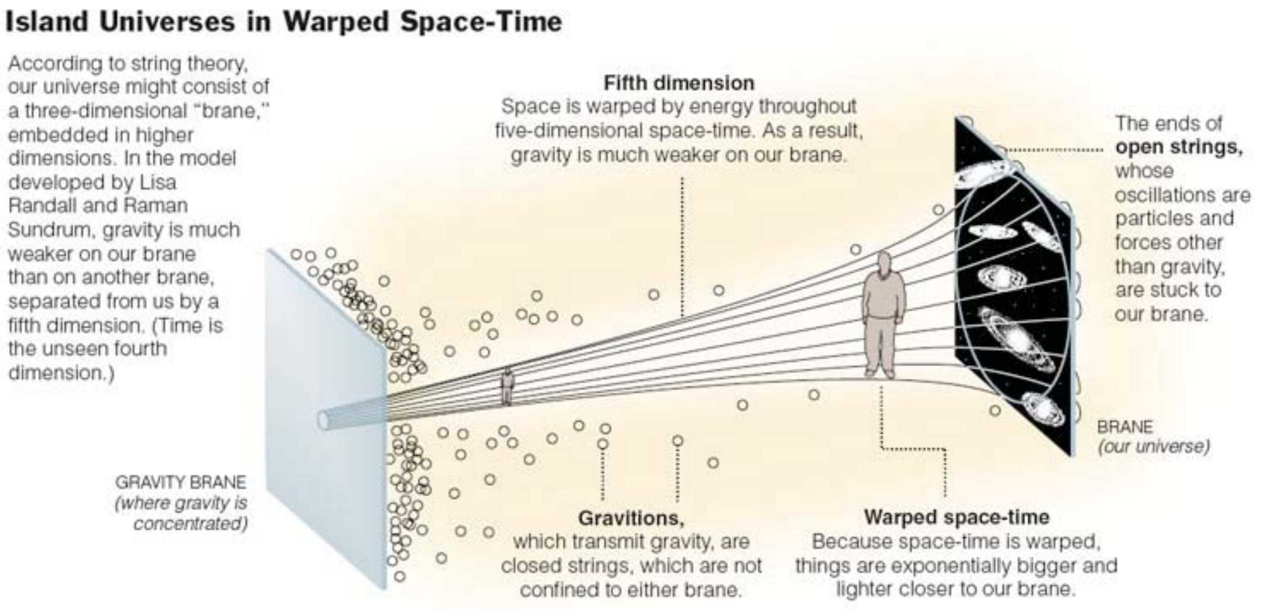
Flavor physics in the Randall-Sundrum Model

with:
Uli Haisch and Martin Bauer, Sandro Casagrande,
Florian Goertz, Leonard Gründer, Torsten Pfoh

Warped extra dimensions (RS)

[Randall, Sundrum 1999]

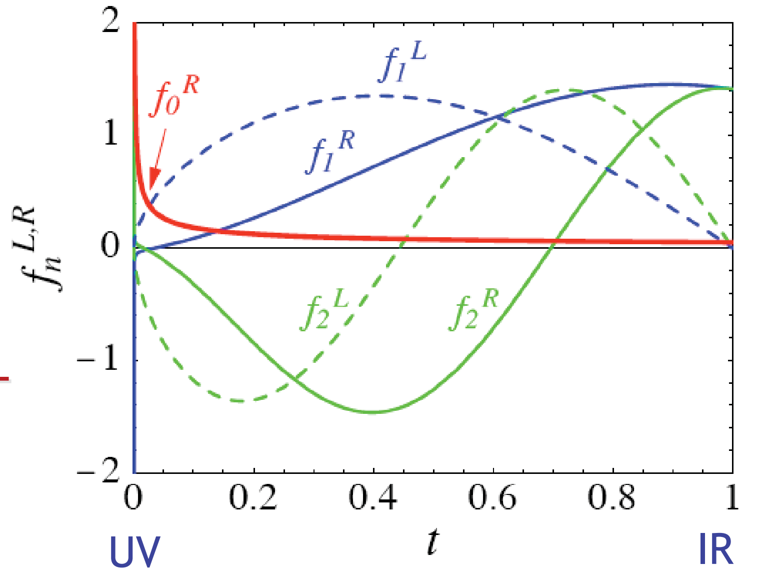
- Appealing solution to hierarchy problem:
  - huge separation between weak and Planck scale generated by exponential warp factor in AdS_5
  - generic in flux compactifications of string theory



Warped extra dimensions (RS)

- Placing matter and gauge fields in the bulk provides new perspective on flavor problem:
  - localization of fermionic zero modes near UV brane leads to exponentially small Yukawas
  - explains huge hierarchies in fermion spectrum: *best theory of flavor to date!*
  - nontrivial overlap with gauge bosons gives rise to rich structure of flavor-violating effects

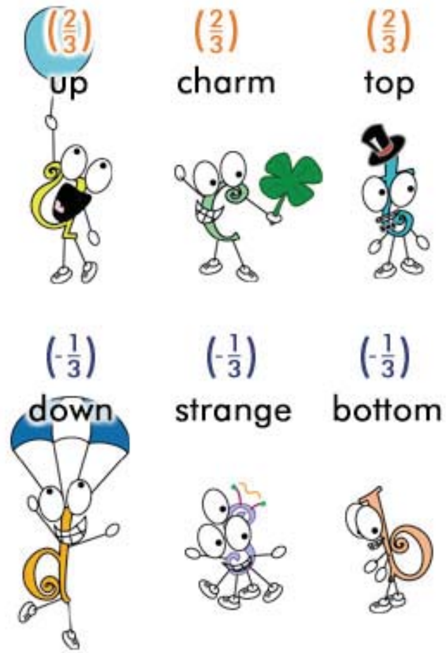
    [Burdman 2003; Agashe, Perez, Soni 2004]



[Grossman, MN 1999; Gherghetta, Pomarol 2000; Huber, Shafi 2000]

Flavor in RS

- Already many studies in literature, in particular:
  - Huber, Shafi 1999; Huber 2003
  - Burdman 2003
  - Agashe, Perez, Soni 2004
  - Agashe, Papucci, Perez, Pirjol 2005
  - Davidson, Isidori, Uhlig 2007
  - Csaki, Falkowski, Weiler 2008



- Here:
  - first complete study of all tree-level processes
  - some important effects neglected so far (not captured by zero-mode approximation)

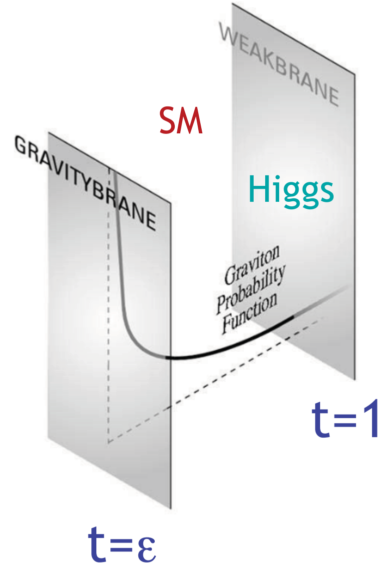
Notations and parameters

- Warp factor:

$$\varepsilon = e^{-kr\pi} \approx 10^{-16} \qquad L = -\ln(\varepsilon) \approx 37$$

- Variable along extra dimension:

$$t = \varepsilon\, e^{-kr|\phi|}$$



- KK scale:

$$M_{KK} = k\varepsilon = O(\text{TeV}) \qquad M_{g1} \approx 2.45\, M_{KK}$$

- Fermion c_i parameters:

$$c_{Qi} = m_{Qi}/k, \quad c_{qi} = -m_{qi}/k$$

Bulk fermions

- KK decomposition (up-quark sector):

$$u_L(x,\phi) = \frac{e^{2\sigma(\phi)}}{\sqrt{r}} \sum_n \boldsymbol{C}_n^{(Q)}(\phi)\, a_n^{(U)}\, u_L^{(n)}(x)\,, \qquad u_R(x,\phi) = \frac{e^{2\sigma(\phi)}}{\sqrt{r}} \sum_n \boldsymbol{S}_n^{(Q)}(\phi)\, a_n^{(U)}\, u_R^{(n)}(x)$$

$$u_L^c(x,\phi) = \frac{e^{2\sigma(\phi)}}{\sqrt{r}} \sum_n \boldsymbol{S}_n^{(u)}(\phi)\, a_n^{(u)}\, u_L^{(n)}(x)\,, \qquad u_R^c(x,\phi) = \frac{e^{2\sigma(\phi)}}{\sqrt{r}} \sum_n \boldsymbol{C}_n^{(u)}(\phi)\, a_n^{(u)}\, u_R^{(n)}(x)$$

expansion coefficients (3-comp. vectors for each n)

exact mass eigenstates

- normalization:

$$a_n^{(U)\dagger}\, a_n^{(U)} + a_n^{(u)\dagger}\, a_n^{(u)} = 1$$

- $C_n(\phi)$ and $S_n(\phi)$ are even/odd solutions to the bulk equations of motion

Grossman, MN (1999)
Gherghetta, Pomarol (2000)

Bulk fermions

- Exact field equations with Yukawa couplings are incompatible with orthonormality relations for fermion profiles
- Generalized relations:

$$\int_{-\pi}^{\pi} d\phi\, e^{\sigma(\phi)}\, C_m^{(A)}(\phi)\, C_n^{(A)}(\phi) = \delta_{mn} + \Delta C_{mn}^{(A)}$$

$$\int_{-\pi}^{\pi} d\phi\, e^{\sigma(\phi)}\, S_m^{(A)}(\phi)\, S_n^{(A)}(\phi) = \delta_{mn} + \Delta S_{mn}^{(A)}$$

  - extra terms are $O(v/M_{KK})$ for KK modes, but $O(1)$ for light SM particles!

$M_{KK} = k\varepsilon = O(\text{TeV})$

$\varepsilon = e^{-kr\pi} \approx 10^{-16}$

Zero-mode approximation (ZMA)

- Used in all previous work on flavor in RS
- Amounts to keeping leading terms in $x_n = m_n / M_{KK}$ in profiles for light SM fermions:

$\varepsilon = e^{-kr\pi} \approx 10^{-16}$ $L = -\ln(\varepsilon) \approx 37$

with:

$$C_n^{(A)}(\phi) \to \sqrt{\frac{2L\epsilon}{\pi}}\, F(c_A)\, t^{c_A}$$

$t = \varepsilon\, e^{-kr|\phi|}$

$$S_n^{(A)}(\phi) \to 0 \qquad \text{(ZMA)}$$

$$F(c) = \sqrt{\frac{1+2c}{2(1-\epsilon^{1+2c})}}$$

exponentially small if $c < -1/2$

Grossman, MN (1999)

- *Important finding*: $S_n(\phi)$ profiles cannot always be neglected, but give rise to some leading effects

Scaling relations

- Effective Yukawa matrices (in ZMA):

$$\boldsymbol{Y}_q^{\text{eff}} = \boldsymbol{F}(c_Q)\,\boldsymbol{Y}_q\,\boldsymbol{F}(c_q) = \boldsymbol{U}_q\,\boldsymbol{\lambda}_q\,\boldsymbol{W}_q^\dagger$$

diagonal

  - natural to assume that Y_q are anarchical matrices
  - flavor hierarchies explained by fact that $F(c_{Q,q})$ profiles are exponentially small and hierarchical (→ Froggatt-Nielsen mechanism)

Froggatt, Nielsen (1979)
Huber, Shafi (2000)

- Relations for quark masses and CKM parameters:

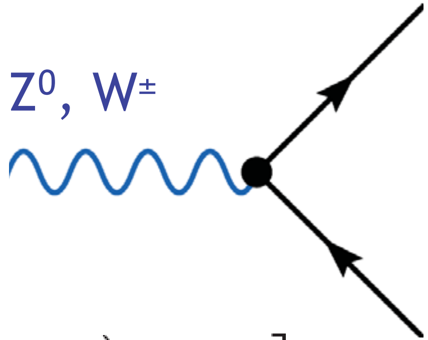
$$m_{q_i} = \mathcal{O}(1) \times \frac{v}{\sqrt{2}}\,F(c_{Q_i})\,F(c_{q_i})$$

$$\lambda = \mathcal{O}(1)\,\frac{F(c_{Q_1})}{F(c_{Q_2})} \qquad A = \mathcal{O}(1)\,\frac{F^3(c_{Q_2})}{F^2(c_{Q_1})\,F(c_{Q_3})} \qquad \bar{\rho},\,\bar{\eta} = \mathcal{O}(1)$$

Gauge interactions with SM fermions

- Couplings of light weak gauge bosons
  - flavor violation from modification of gauge-boson profiles due to EWSB on IR brane

Z^0, $W^\pm$



$L = -\ln(\varepsilon) \approx 37$

$$\chi_{W,Z}(\phi) = \frac{1}{\sqrt{2\pi}}\left[1 + \frac{m_{W,Z}^2}{4M_{\mathrm{KK}}^2}\left(1 - \frac{1}{L} + t^2\,(1 - 2L - 2\ln t)\right) + \dots\right]$$

Csaki, Ehrlich, Terning (2002)

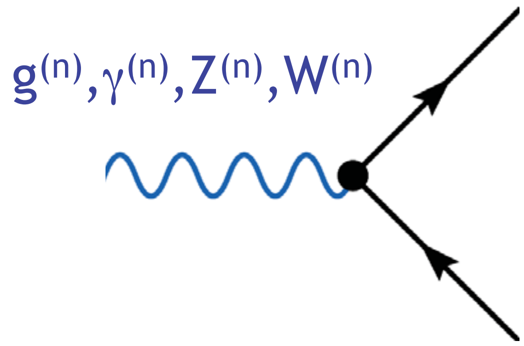
$t = \varepsilon\, e^{-kr|\phi|}$ nontrivial ϕ dependence

  - flavor violation from non-orthonormality of fermion profiles (mixing between $SU(2)_L$ doublets and singlets)

Gauge interactions with SM fermions

- Couplings of KK gauge bosons:
  - flavor violation from nontrivial profiles
  - dominant contributions from KK gluons

  Burdman (2003); Agashe, Perez, Soni (2004)

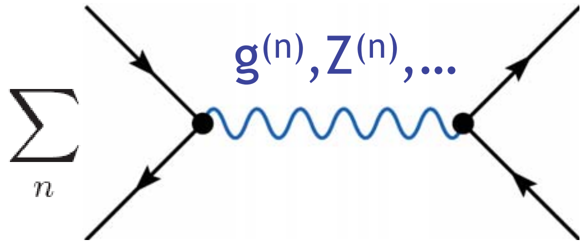


- *Both cases:*
  Fact that flavor-violating effects live near IR brane implies suppression ~ $F(c_i)\, F(c_j)$

RS-GIM mechanism !

Agashe, Perez, Soni (2004); Agashe, Papucci, Perez, Pirjol (2005)

Summing over KK modes



- Sum over KK gluons and photons:

$$\sum_{n=1}^{\infty} \frac{\chi_n(\phi)\,\chi_n(\phi')}{m_n^2} = \frac{1}{4\pi M_{\mathrm{KK}}^2}\left[L\,t_<^2 - t^2\left(\frac{1}{2} - \ln t\right) - t'^2\left(\frac{1}{2} - \ln t'\right) + \frac{1}{2L}\right]$$

- Sum over Z, W and KK excitations:

$$\sum_{n=0}^{\infty} \frac{\chi_n(\phi)\,\chi_n(\phi')}{m_n^2} = \frac{1}{2\pi m_0^2} + \frac{1}{4\pi M_{\mathrm{KK}}^2}\left[L\,t_<^2 - L\,(t^2 + t'^2) + 1 - \frac{1}{2L} + \mathcal{O}\left(\frac{m_0^2}{M_{\mathrm{KK}}^2}\right)\right]$$

$L = -\ln(\varepsilon) \approx 37$

ΔF=2 processes (dominated by KK gluons)

ΔF=1 processes (dominated by Z boson)

Overlap integrals

- Flavor-violating effects described by matrices

$$(\Delta'_Q)_{mn} = \frac{2\pi}{L\epsilon}\int_\epsilon^1 dt\, t^2 \left[a_m^{(Q)\dagger}\, \boldsymbol{C}_m^{(Q)}(\phi)\, \boldsymbol{C}_n^{(Q)}(\phi)\, a_n^{(Q)} + a_m^{(q)\dagger}\, \boldsymbol{S}_m^{(q)}(\phi)\, \boldsymbol{S}_n^{(q)}(\phi)\, a_n^{(q)}\right]$$

$$(\Delta_Q)_{mn} = \frac{2\pi}{L\epsilon}\int_\epsilon^1 dt\, t^2 \left(\frac{1}{2} - \ln t\right) \left[a_m^{(Q)\dagger}\, \boldsymbol{C}_m^{(Q)}(\phi)\, \boldsymbol{C}_n^{(Q)}(\phi)\, a_n^{(Q)} + a_m^{(q)\dagger}\, \boldsymbol{S}_m^{(q)}(\phi)\, \boldsymbol{S}_n^{(q)}(\phi)\, a_n^{(q)}\right]$$

$$(\delta_Q)_{mn} = a_m^{(q)\dagger}\left(\delta_{mn} + \Delta \boldsymbol{S}_{mn}^{(q)}\right) a_n^{(q)}$$ ← omitted by previous authors!

and corresponding matrices Δ'_q, Δ_q, δ_q in right-handed sector

Overlap integrals

- Hermitian matrices in flavor space

CP violation possible with N≥2 generations!

- Scaling relations:

$$(\Delta_Q^{(\prime)})_{ij} \sim F(c_{Q_i})\,F(c_{Q_j})\,, \qquad (\Delta_q^{(\prime)})_{ij} \sim F(c_{q_i})\,F(c_{q_j})$$

$$(\delta_Q)_{ij} \sim \frac{v^2}{M_{\rm KK}^2}\,F(c_{Q_i})\,F(c_{Q_j})\,, \qquad (\delta_q)_{ij} \sim \frac{v^2}{M_{\rm KK}^2}\,F(c_{q_i})\,F(c_{q_j})$$

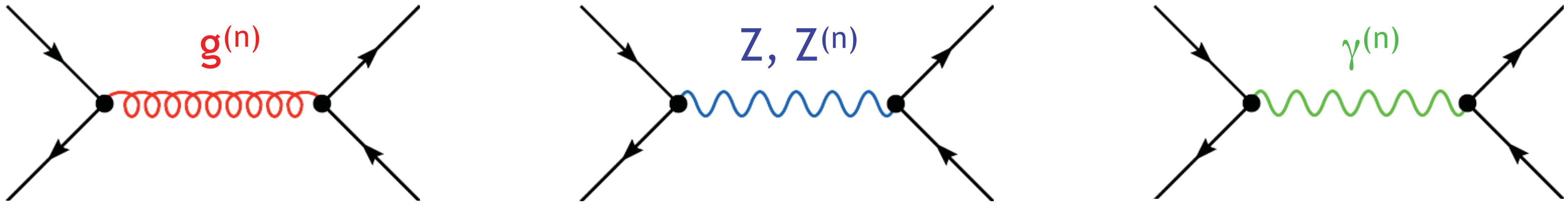
but effects enhanced by M_{KK}^2/m_Z^2 !

$\longrightarrow$ parametrically of same order!

Applications

Tree-level FCNCs

- Generic diagrams:



dominant for $\Delta F=2$ processes	dominant for $\Delta F=1$ processes	always small

  - likely to give largest flavor-violating effects
  - consider $b \to s+qq$ for example
  - analogous results hold for $b \to d$ and $s \to d$ FCNCs, and for decays of the type $b \to s+l^+l^-$, $b \to s+\nu\nu$
  - no tree-level contribution to $b \to s\gamma$ dipole operator!

b→s+qq

- Effective weak Hamiltonian:

$$\mathcal{H}_{\text{eff}} = \frac{G_F}{\sqrt{2}} \sum_{p=u,c} V_{pb} V_{ps}^* \left(C_1\, Q_1^p + C_2\, Q_2^p + \sum_{i=3,\dots,10} C_i\, Q_i + C_{7\gamma}\, Q_{7\gamma} + C_{8g}\, Q_{8g} \right)$$

$$+ \sum_{i-3,\dots,10} \left(C_i^{\text{RS}}\, Q_i + \tilde{C}_i^{\text{RS}}\, \tilde{Q}_i \right) .$$

  - list RS contributions to Wilson coefficients of QCD and electroweak penguin operators $Q_{3,\dots,10}$
  - analogous expressions for coefficients of opposite-chirality operators

b→s+qq

- Wilson coefficients:

$$C_3^{\rm RS} = \boxed{\frac{\pi\alpha_s}{M_{\rm KK}^2}\,\frac{(\Delta_D)_{23}}{2N_c}} - \boxed{\frac{\pi\alpha}{6\sin^2\theta_W\cos^2\theta_W\,M_{\rm KK}^2}\left[L\left(\frac{1}{2}-\frac{\sin^2\theta_W}{3}\right)(\Delta'_D)_{23}+\frac{M_{\rm KK}^2}{m_Z^2}\,(\delta_D)_{23}\right]}$$

$$C_4^{\rm RS} = C_6^{\rm RS} = -\boxed{\frac{\pi\alpha_s}{2M_{\rm KK}^2}\,(\Delta_D)_{23}}$$

sources: g, γ, Z

$$C_5^{\rm RS} = \boxed{\frac{\pi\alpha_s}{M_{\rm KK}^2}\,\frac{(\Delta_D)_{23}}{2N_c}}$$

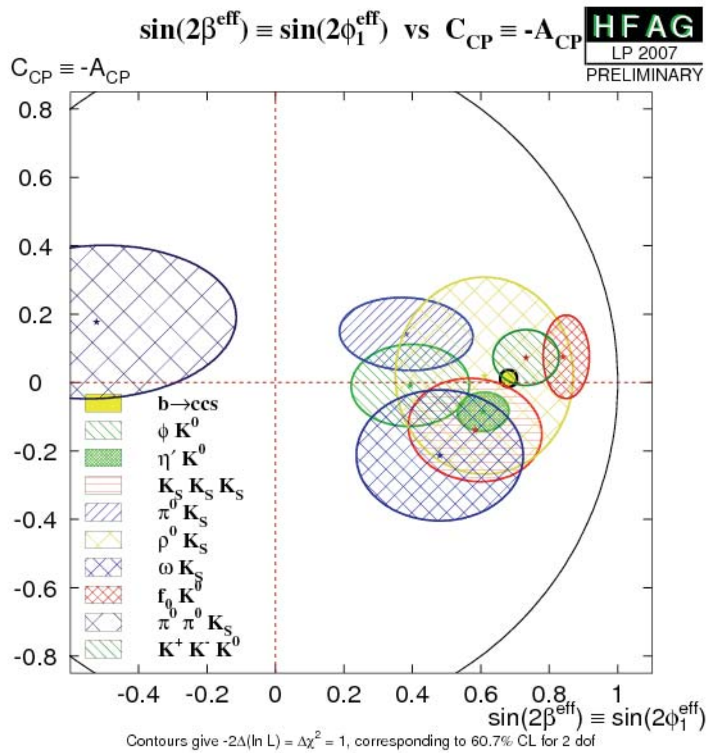
$$C_7^{\rm RS} = \boxed{\frac{2\pi\alpha}{9M_{\rm KK}^2}\,(\Delta_D)_{23}} - \boxed{\frac{2\pi\alpha}{3\cos^2\theta_W\,M_{\rm KK}^2}\left[L\left(\frac{1}{2}-\frac{\sin^2\theta_W}{3}\right)(\Delta'_D)_{23}+\frac{M_{\rm KK}^2}{m_Z^2}\,(\delta_D)_{23}\right]}$$

$$C_8^{\rm RS} = C_{10}^{\rm RS} = 0\,,$$

$$C_9^{\rm RS} = \boxed{\frac{2\pi\alpha}{9M_{\rm KK}^2}\,(\Delta_D)_{23}} + \boxed{\frac{2\pi\alpha}{3\sin^2\theta_W\,M_{\rm KK}^2}\left[L\left(\frac{1}{2}-\frac{\sin^2\theta_W}{3}\right)(\Delta'_D)_{23}+\frac{M_{\rm KK}^2}{m_Z^2}\,(\delta_D)_{23}\right]}$$

$b \to s + q\bar{q}$ phenomenology

- Electroweak penguin effects in rare hadronic decays such as $B \to \pi K$ or $B \to \phi K$ are naturally $O(\geq 1)$ compared with SM and can introduce new, large CP-violating phases
- Potentially relevant for "$B \to \pi K$ puzzle" and $\sin 2\beta$ extractions from penguin modes
- Similarly, potentially large effects in $B \to X_s l^+ l^-$ and $B \to K^* \mu^+ \mu^-$ decay



Neutral meson mixing

- Effective weak Hamiltonian:

$$H_{\text{eff}}^{\Delta S=2} = \sum_{i=1}^{5} C_i\, Q_i^{sd} + \sum_{i=1}^{3} \tilde{C}_i\, \tilde{Q}_i^{sd}$$

- Coefficients in RS (examples):

$$C_1^{\text{RS}} = \frac{4\pi L}{M_{\text{KK}}^2}\,(\widetilde{\Delta}_D)_{12} \otimes (\widetilde{\Delta}_D)_{12} \left[\frac{\alpha_s}{2}\left(1 - \frac{1}{N_c}\right) + Q_d^2\,\alpha + \frac{(T_3^d - \sin^2\theta_W\, Q_d)^2\,\alpha}{\sin^2\theta_W \cos^2\theta_W}\right]$$

$$C_4^{\text{RS}} = \frac{4\pi L}{M_{\text{KK}}^2}\,(\widetilde{\Delta}_D)_{12} \otimes (\widetilde{\Delta}_d)_{12}\,[-2\alpha_s]$$

gluon contribution agrees with:
[Csaki, Falkowski, Weiler 2008]

  - for CP violation in K mixing (ε_K), KK gluon contribution to C_4 is by far dominant

Neutral meson mixing

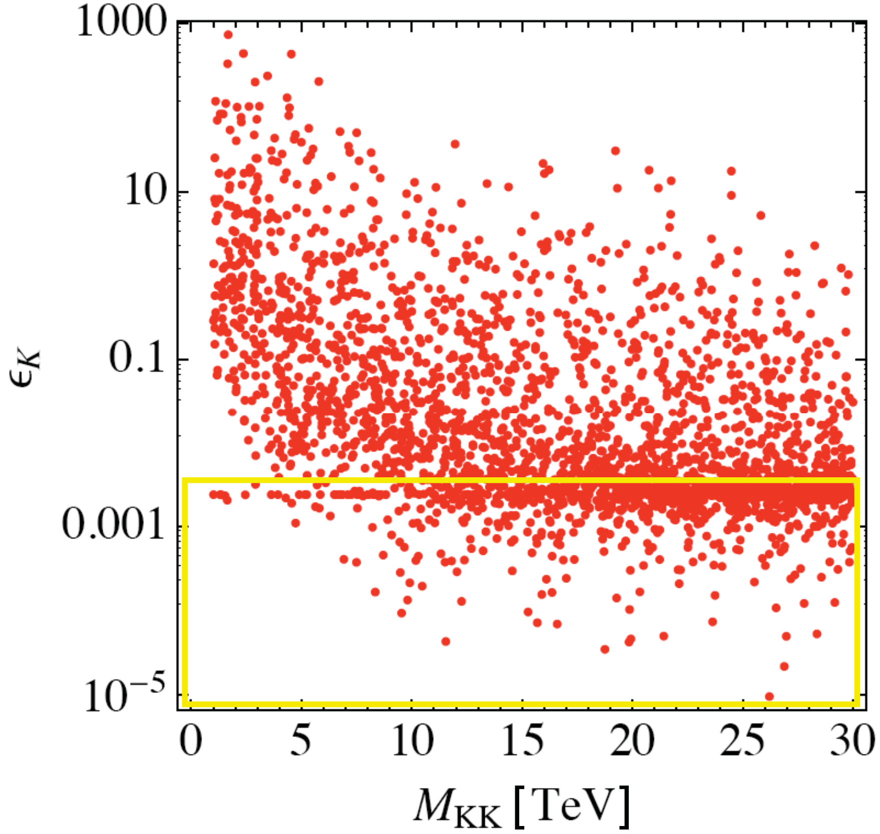
- Presence of tree-level FCNCs mediated by vector bosons potentially disastrous [Bona et al. (UT*fit*) 2007]
- Recent analysis finds typical bound M_{KK}>10 TeV (KK gluon mass >21 TeV) [Csaki, Falkowski, Weiler 2008]
- Reason is enhancement of $\langle Q_4 \rangle$ matrix element from RG evolution and chiral factor $\sim(m_K/m_s)^2$
- In RS model: [Burdman 2003; Agashe, Perez, Soni 2004]

$$[\Delta\epsilon_K]_{\rm RS} \simeq \boxed{-3.8\cdot 10^{-3}}\,\frac{\mathrm{Im}\left[(\Delta_D)_{12}(\Delta_d)_{12}\right]}{10^{-12}\,M_{\rm KK}^2\,[\mathrm{TeV}^2]} + 5.2\cdot 10^{-6}\,\frac{\mathrm{Im}\left[(\Delta_D)_{12}^2+(\Delta_d)_{12}^2\right]}{10^{-12}\,M_{\rm KK}^2\,[\mathrm{TeV}^2]}$$

  - only second term included in early papers

Neutral meson mixing

- "Generic" results for ε_K:



Neutral meson mixing

- Possible ways out:
  - accidental smallness of relevant Yukawa couplings, requires ~1-5% fine-tuning (not so bad …)
  - make L significantly smaller (little RS models); e.g., UV scale at 1000 TeV lowers bound to M_{KK}>4 TeV [Davoudiasl, Perez, Soni 2008]
  - impose bulk flavor symmetry to get hierarchical Yukawas (Y_d~1)

    [Cacciapaglia et al. 2007; Fitzpatrick, Perez, Randall 2007]

Neutral meson mixing

- *More alternatives:*
  i) increase Yukawa couplings to O(10) while keeping effective Yukawas unchanged (quark masses and CKM matrix unaffected), thus lowering KK scale to O(1 TeV):

$$\boldsymbol{Y}_q \to \frac{1}{\eta^2}\boldsymbol{Y}_q \qquad F(c_i) \to \eta\,F(c_i)$$

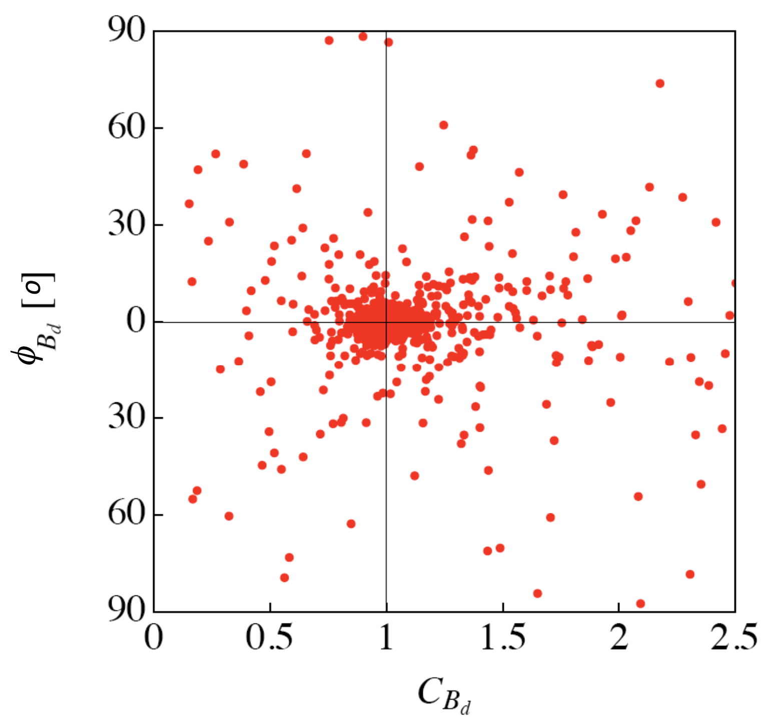
$$[\Delta\epsilon_K]_{\rm RS} \to \eta^4\,[\Delta\epsilon_K]_{\rm RS}$$

  ii) impose equality of c_i parameters in right-handed down sector ("principle of minimal flavor protection"): $c_{d1}=c_{d2}=c_{d3}$ [Santiago 2008]

Neutral meson mixing

- Either solution leaves large, irremovable effects in $\Delta F=1$ processes and $B_{d,s}$ mixing
- Preliminary scan:

similar effects in B_s mixing



Summary (I)

- Existing puzzles in flavor physics point to new physics that is *not* of MFV type!
- LHC*b* experiment offers significant reach to explore this physics
- Capability to definitively settle question of new CP phases in B_s mixing, and shed light on possible new physics effects in rare B_s and B_d decays

Summary (II)

- Randall-Sundrum models offer viable solution to the gauge and fermion hierarchy problems (attractive alternative to supersymmetry)
- Rich structure of flavor-violating interactions in gauge couplings to fermions (generically not MFV)
  - $\Delta F=1$ FCNC processes dominated by Z exchange
  - $\Delta F=2$ FCNC processes dominated by KK gluon exchange
- Effects naturally of O(1) in modes where deviations from SM are allowed/indicated by the data, while small in other modes (e.g., $B \to X_s\gamma$)
- More results to come soon … !