K and B Mixing in Warped Extra Dimensions with Custodial Symmetry

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Outline

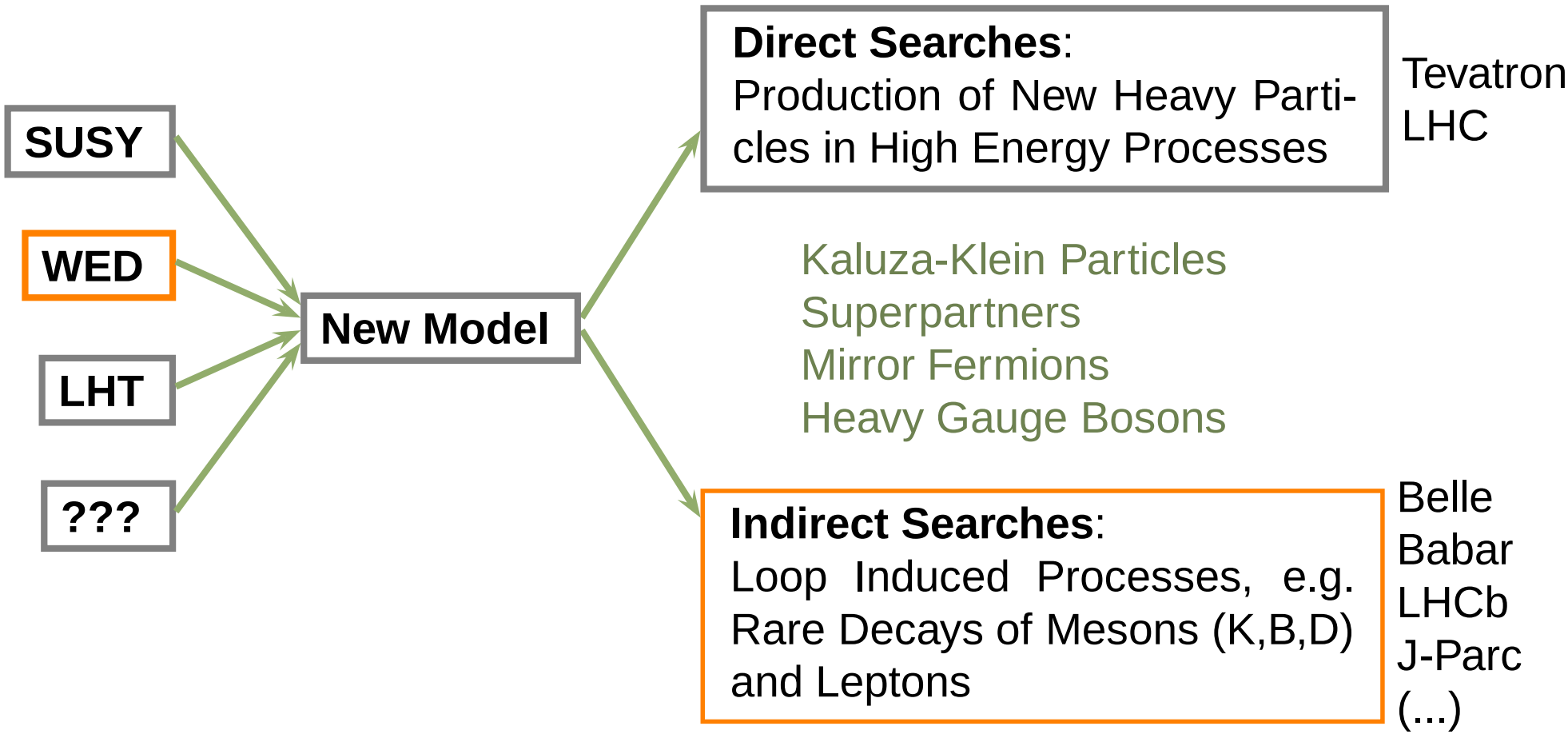
Based on:

M. Albrecht, M. Blanke, A.J. Buras, BD, K. Gemmler, [in preparation]
M. Blanke, A.J. Buras, BD, S. Gori, A. Weiler, [arXiv:0809.1073]
M. Blanke, A.J. Buras, BD, K. Gemmler, S. Gori, [in preparation]

See also:

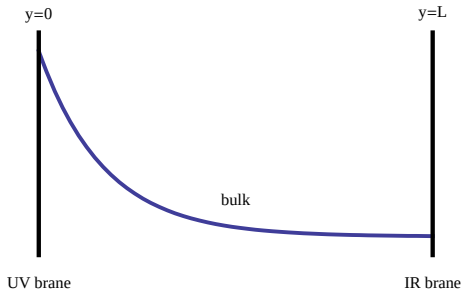
S. Casagrande, F. Goertz, U. Haisch, M. Neubert, T. Pfoh
M. Bauer, S. Casagrande, L. Gruender, U. Haisch, M. Neubert

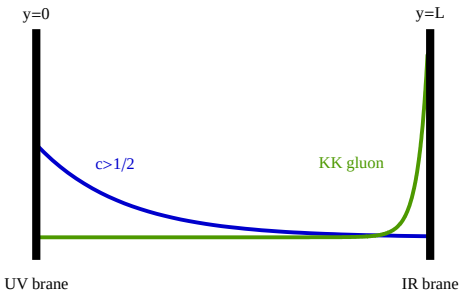
Complementarity of Flavor and Collider Physics



A Very Brief Model Overview

- Slice of AdS_5 bounded by UV and IR brane
  Randall, Sundrum
- $SU(3) \times SU(2)_L \times SU(2)_R \times U(1)_X \times P_{LR}$
  Agashe, Contino, Pomarol
  $\Longrightarrow$ Additional gauge bosons, additional fermions





- all fields (except for the Higgs) can propagate into the bulk
  Chang et al.; Gherghetta, Pomarol; Grossman, Neubert; Arkani-Hamed, Grossman, Schmaltz
  $\Longrightarrow$ Tower of KK modes for gauge bosons and fermions
  $\Longrightarrow$ Non-universal gauge couplings, FCNCs

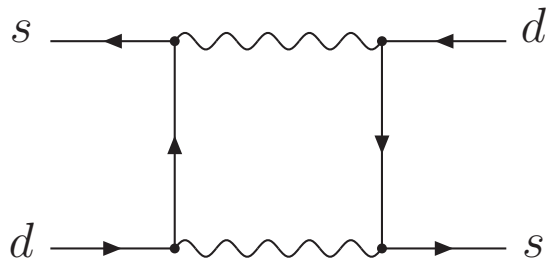
- Additional parameters in the flavor sector beyond CKM
  Agashe, Perez, Soni
  $\Longrightarrow$ Model is beyond MFV
  $\Longrightarrow$ Expect significant effects

RS-GIM mechanism

Impact on K and B Meson Mixing

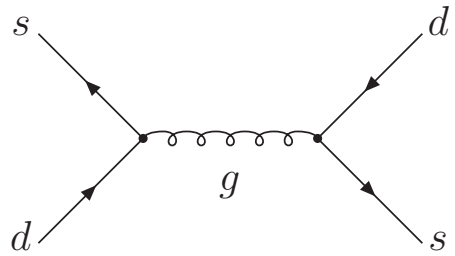
$$\Delta M_K\,,\ \epsilon_K\,,\ \Delta M_{B_{d,s}}\,,\ S_{\psi\phi}\,,\ S_{\psi K_S}\,,\ A_{SL}^s\,,\ A_{SL}^d$$

SM: $\Delta F = 2$ processes proceed through boxes



Q_1^{VLL}

WED: $\Delta F = 2$ processes already at tree level



$Q_1^{VLL}\,,\ Q_1^{VRR}\,,\ Q_1^{LR}\,,\ Q_2^{LR}$

Particles exchanged at tree level:

- KK gluons
- KK photons
- $Z\,, Z_H\,, Z'$

Operators:

$$Q_1^{VLL} = (\bar{s}\gamma_\mu P_L d)(\bar{s}\gamma^\mu P_L d)$$
$$Q_1^{VRR} = (\bar{s}\gamma_\mu P_R d)(\bar{s}\gamma^\mu P_R d)$$
$$Q_1^{LR} = (\bar{s}\gamma_\mu P_L d)(\bar{s}\gamma^\mu P_R d)$$
$$Q_2^{LR} = (\bar{s} P_L d)(\bar{s} P_R d)$$

First Results ...and a Possible Tension

Rough analysis: Csaki, Falkowski, Weiler, 0804.1954

Tension between anarchic Yukawas, ϵ_K, and a low KK-scale

A serious problem one should further investigate!

Issues

- Consider full operator basis and NLO RG running
- Take into account EW contributions
- CFW's results indicate a tension between scales

  $\Longrightarrow$ Partially give up complete anarchy of Yukawas

  $\Longrightarrow$ Identify areas in parameter space with only moderate fine tuning
- Make predictions for other $\Delta F = 2$ observables

Operator Structure in Meson Mixing

In the K system:

- Chiral enhancement $\propto \left(\frac{m_K}{m_s+m_d}\right)^2$ of Q_2^{LR}
- Strong RG running of Q_2^{LR}

$\Longrightarrow$ Q_2^{LR} dominates

In the B system:

- Chiral enhancement $\propto \left(\frac{m_B}{m_b+m_{d,s}}\right)^2$ less pronounced
- RG running less strong since $m_B \gg m_K$

$\Longrightarrow$ all operators important

Electroweak Contributions Do Matter

- At $\mu \simeq 3\text{TeV}$, $\alpha_s(\mu) \approx \frac{1}{4\pi}$

  $\Rightarrow$ EW contributions can (in principle) compete with the KK-gluon contribution
- In the K system:
  Dominant operator Q_2^{LR} receives no EW contributions

$\Longrightarrow$ EW contributions subdominant

- In the B system:

  Here all operators are relevant

  Q_1^{VLL}, Q_1^{VRR} and Q_1^{LR} receive significant EW contributions

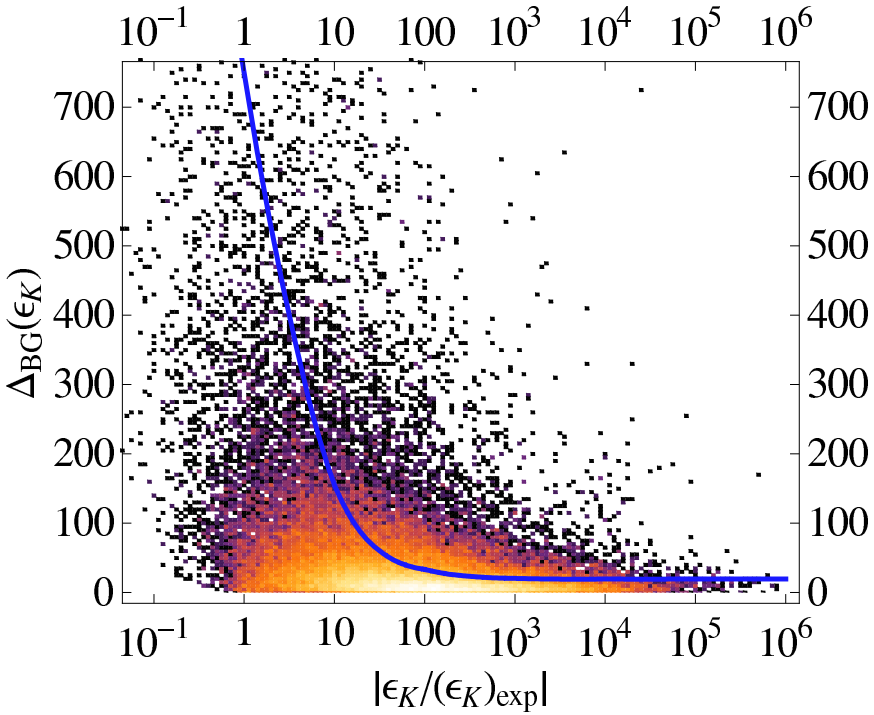
$\Longrightarrow$ EW contributions become important!

Fine Tuning in ϵ_K

$$\left(\frac{1}{t}\right)_{BG} = \max_i \frac{d\ln(Obs.)}{d\ln(x_i)} = \max_i \frac{x_i}{Obs.}\frac{dObs.}{dx_i}$$

Barbieri, Giudice

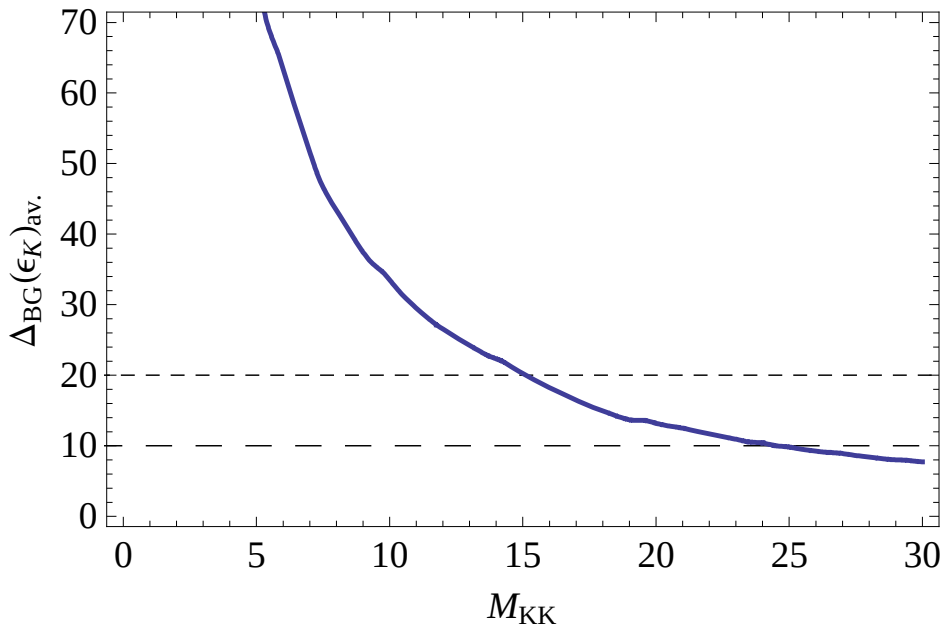
M. Blanke, A. Buras, BD, S. Gori, A. Weiler, [arXiv:0809.1073]



$$M_{KK} \simeq 2.45\text{TeV}$$

- Generically, $\epsilon_K \simeq 10^2 \epsilon_K^{exp}$
- $(1/t)_{BG}$ decreases with increasing ϵ_K
- Parameter sets with moderate $(1/t)_{BG}$ and $\epsilon_K \approx \epsilon_K^{exp}$ exist

A Generic Bound on the KK Scale

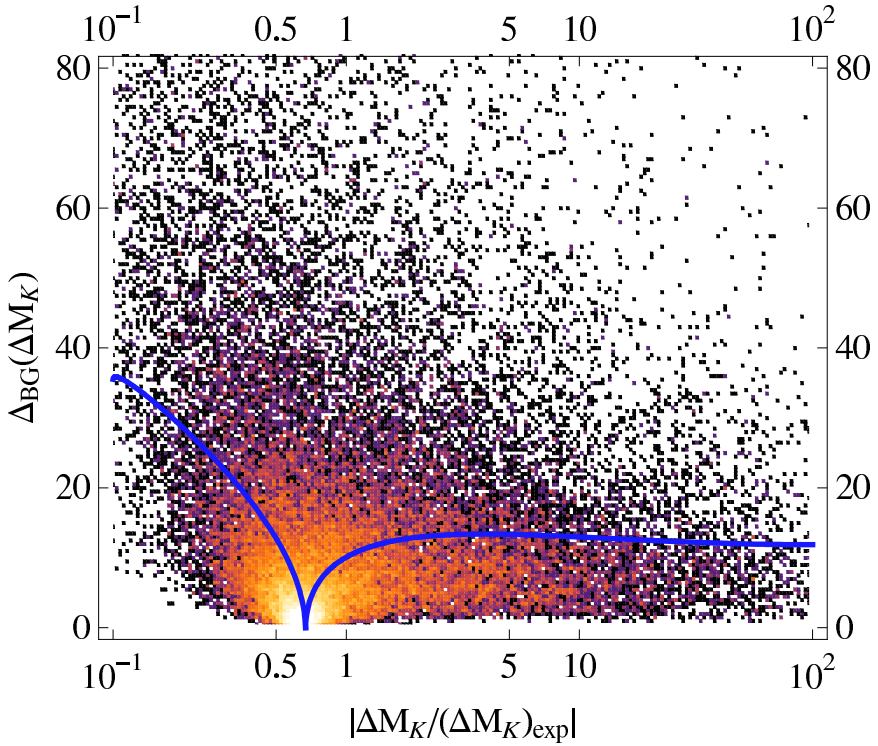


- Depending on the tolerance for fine tuning, one obtains a bound

$$M_{KK} \gtrsim (15 - 25)\text{TeV}$$

- However, a theory consistent with experimental data and moderate fine tuning is possible for M_{KK} in the reach of LHC!
- Brane kinetic terms will have an impact on the generic bound

Fine Tuning in Other Observables, e.g. ΔM_K

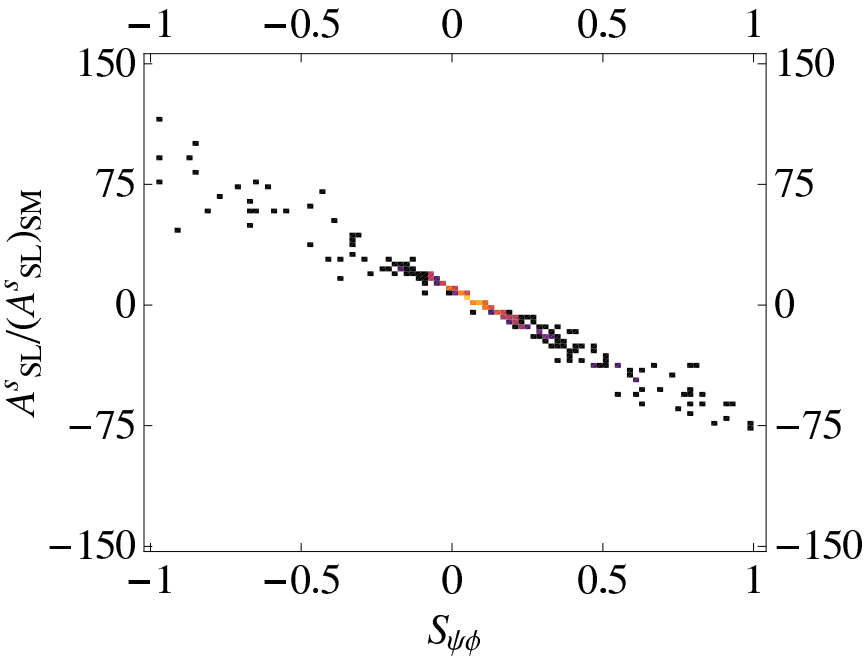


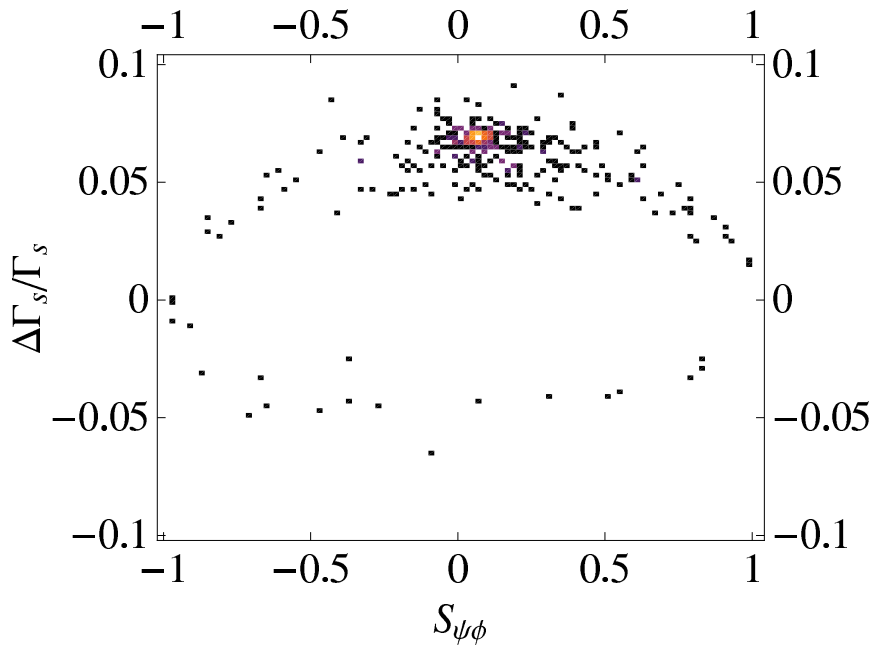
$M_{KK} \simeq 2.45\text{TeV}$

- Generically, $\Delta M_K \sim \Delta M_K^{exp}$
- $(1/t)_{BG}$ small for all possible values of ΔM_K
- Similar picture for all other $\Delta F = 2$ observables (except for ϵ_K)

RS-GIM very effective!

Predictions for Observables not yet Measured





- Constrain parameter space by experimental $\Delta F = 2$ data and small finetuning
- $S_{\psi\phi}$ can be enhanced well beyond the SM prediction $\simeq 0.04$
- Strong correlations between observables exist
  CDF, D0 hint at $S_{\psi\phi} \simeq 0.4 \implies$ significant effects in A^s_{SL}, $\Delta\Gamma_s/\Gamma_s$

Conclusions

- Model addresses the gauge hierarchy problem as well as the flavor problem
- ϵ_K is hard to control due to chiral enhancement and RG effects
- But: It is possible! Areas in parameter space with moderate fine tuning exist for M_{KK} in the reach of LHC
- EW gauge bosons contribute significantly to $\Delta B = 2$ processes
- Large effects in the B system are possible
- WED models are phenomenologically extremely rich - stay tuned!