FCNCs and CP Violation in the Minimal 331 Model

Felix Schwab, IFAE,
Universitat Autònoma de Barcelona

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Christoph Promberger, Sebastian Schatt, Felix Schwab

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331 Models I: Why bother?

331 models have several nice features:

- Connection between anomaly cancellation and number of families: For anomalies to be canceled, the number of families has to be a multiple of 3. Using asymptotic freedom, only the possibility of 3 generations remains.
- Flavor physics is interesting because EWP test are only affected at loop level, while FCNCs arise at tree level.
- In flavor physics, we are dealing with an effective Z' model (sort of) $\Rightarrow$ What can we learn more generally?
- Mixing parameters are most stringent constraints $\Rightarrow$ Recent measurement of ΔM_s suggests a complete analysis.

331 Models II: Basic Features

We now discuss only the *minimal* 331 model (Frampton; Pisano, Pleitez, 1992, further developed since then)

- Based on a gauge group $SU(3)_C \times SU(3)_L \times U(1) \Rightarrow$ Broken down to $U(1)_{SM}$ in two steps, uses 3 Higgs doublets.
- Important ingredient: Third generation is treated as $\bar{3}$; Leads to FCNCs at tree level.
- Particle content: Fermion doublets are extended to triplets. Third member is a heavy quark/charged conjugate lepton.
- Gauge Bosons: In addition to the SM, there is a neutral Z' and charged $V^{\pm}$ and $Y^{\pm\pm}$. Masses of order of 331 breaking scale
- The model develops a Landau Pole when $\sin^2\theta_W = 0.25$. $\Rightarrow$ Upper bound on M_Z' of several TeV.

FCNCs in 331 models

Look at gauge fermion vertices: Charged gauge bosons always couple to heavy quark $\Rightarrow$ Not observable at tree level for low energy processes

Z' quark vertices can be flavor changing due to different treatment of third generation.

$$\mathcal{L}_{FCNC} = \frac{g c_W}{\sqrt{3}\sqrt{1-4s_W^2}} [\bar{d}\gamma_\mu \gamma_L \tilde{V}_L^\dagger \begin{pmatrix} 0 & & \\ & 0 & \\ & & 1 \end{pmatrix} \tilde{V}_L d] Z'^\mu \, .$$

$\tilde{V}$ is mixing matrix in down quark sector. Introduces 6 new parameters, which can be further reduced to 4: 2 angles and 2 phases.

Feature of the model: Z' lepton coupling are suppressed, so we expect only moderate modifications. $\Rightarrow$ Look for correlations.

B and K mixing in the 331 model

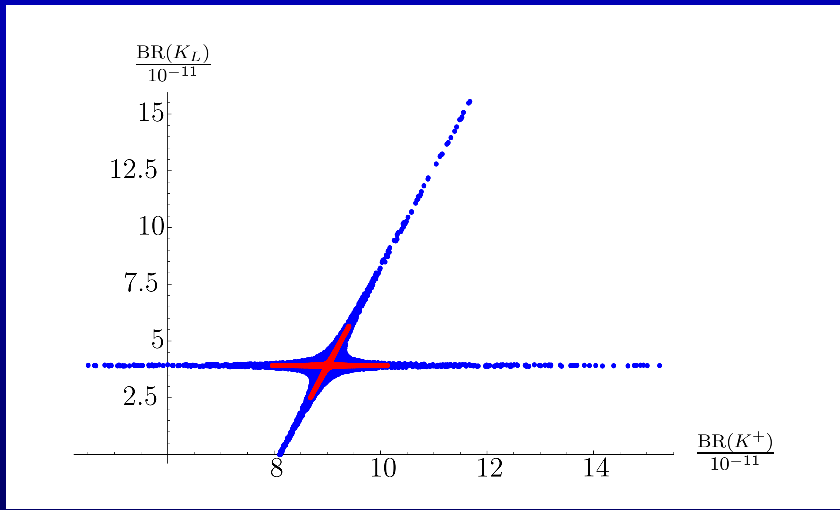
Relevant observables: ε_K, ΔM_K, $\Delta M_{d/s}$, $\sin 2\beta_{d/s}$. We neglect ε'/ε because of large SM uncertainties.

$$H^{eff}_{\Delta S=2} = \frac{G_F}{\sqrt{2}} \frac{1}{3} \frac{c_W^4}{1-4s_W^2} \left(\frac{M_Z}{M_{Z'}}\right)^2 (\tilde{V}_{31}\tilde{V}^*_{32})^2 (\bar{s}d)_{V-A}(\bar{s}d)_{V-A}\,,$$

- In K sector, ε_K constrains imaginary part, ΔM_K constrains real part.
- In B sector angles constrain component orthogonal to SM, mass differences roughly constrain absolute values.
- Note: β_s is still essentially unconstrained, and can therefore be arbitrarily large.

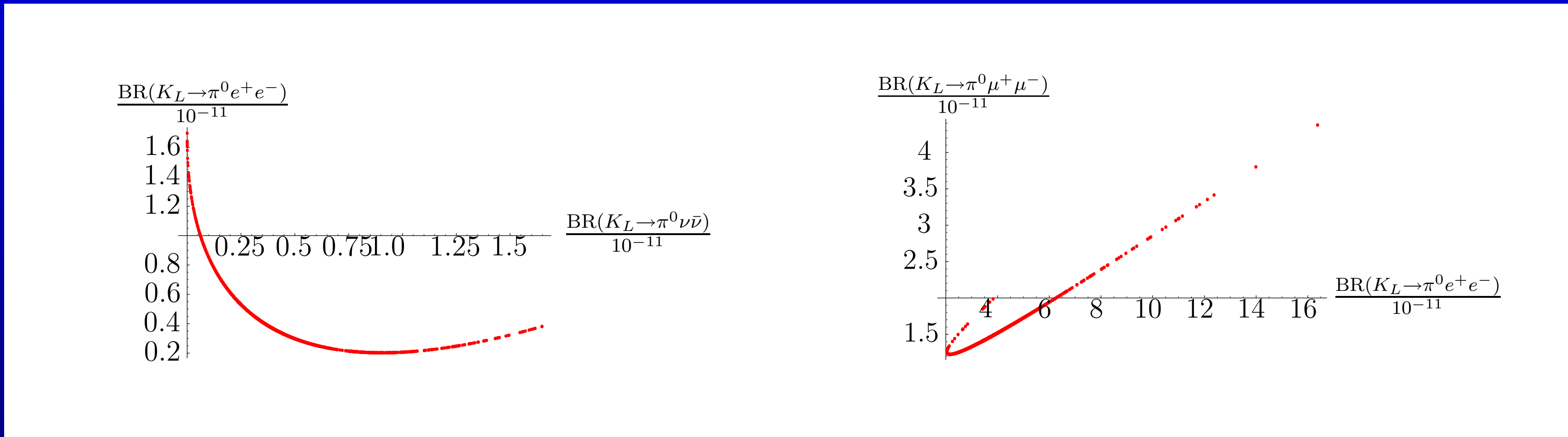
Rare decays

We study implications for the following decays: $K^+ \to \pi^+ \nu\bar{\nu}$, $K_L \to \pi^0 \nu\bar{\nu}$, $B_{d/s} \to \mu^+\mu^-$, $K_L \to \pi^0 l^+ l^-$.



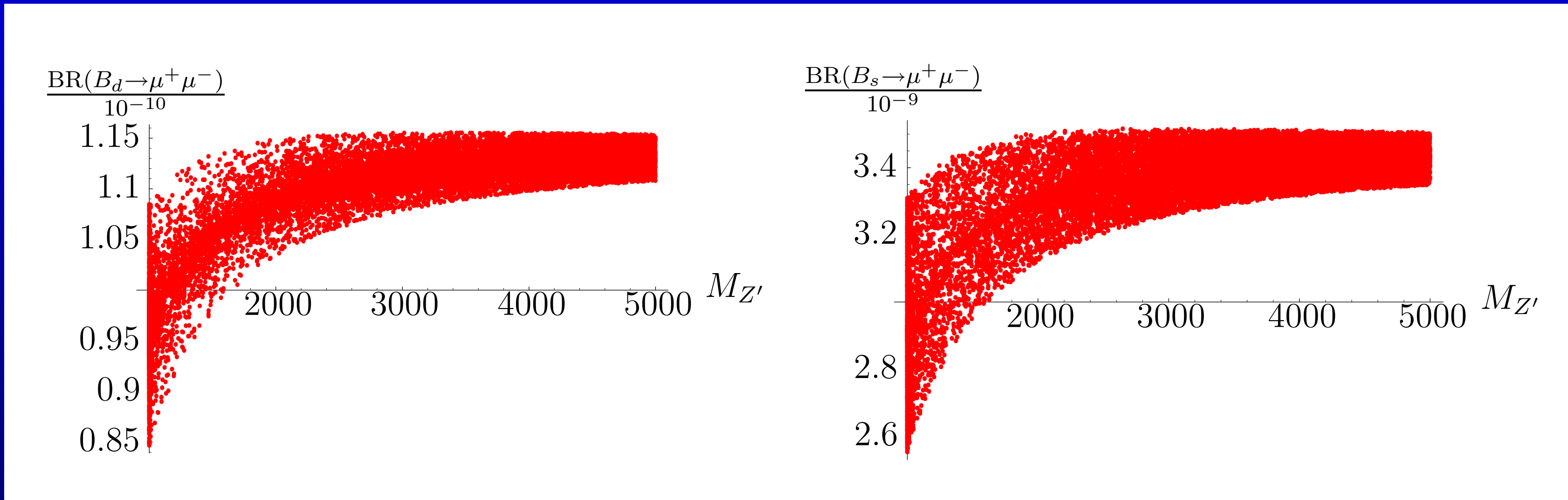
- $K^+ \to \pi^+ \nu\bar{\nu}$ and $K_L \to \pi^0 \nu\bar{\nu}$ show very distinctive pattern. $\Rightarrow$ Significant enhancements possible
- measurement of both decays uniquely fixes phase and absolute value of new contribution.

Numeric II: Correlation between K decays



- Contours in the observable plane allow rather unambiguous tests of the model - as with any model.
- In particular $K_L \to \pi^0 e^+ e^-$ is interestingly sensitive due to separate vector and axial vector contributions.

Numeric III: B decays



Large effects in $B \to \mu^+\mu^-$ are excluded - in particular a large enhancement.

Probably similar in $B \to X_s l^+ l^-$, so existing measurement should be no problem.

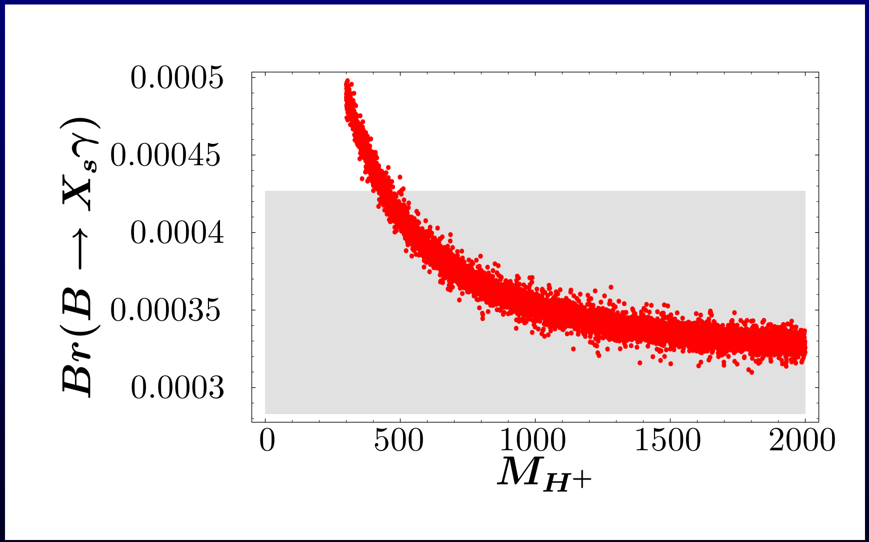
Preliminary Results on $B \to X_s\gamma$

(PSS + S.Uhlig, in prep.)

$B \to X_s\gamma$ is interesting because:

- No contributions at tree level; Therefore, also the charged gauge bosons contribute;
- Additional contributions from the Higgs sector; Equivalent to a 2HDM;

$\Rightarrow$ Complimentary information can be obtained;
Our (preliminary) main result: Gauge contributions are so strongly constrained that one is left with the 2HDM term.



Conclusions and Outlook

- Flavor Physics is very well suited to place constraints on 331 models.
- In the K system, CP violation is stronger constrained than CP conserving contributions.
- Still sizeable effects in $K \to \pi\nu\bar{\nu}$. Characteristic feature in observable plane.
- Effects in $B_{d/s} \to \mu^+\mu^-$ rather small. Preliminary result on $B \to X_s\gamma$: Main satement is that the minimal 331 model looks very similar to the 2HDM model.
- Most interesting quantity at the moment is the B_s mixing phase.

A lot of these findings are very general for Z' models!!!