Implications of Nonstandard CP Violation in Hadronic B Decays

Are there new physics contributions to sin2β in $B \to \psi K_s$?

David Atwood
Iowa State University

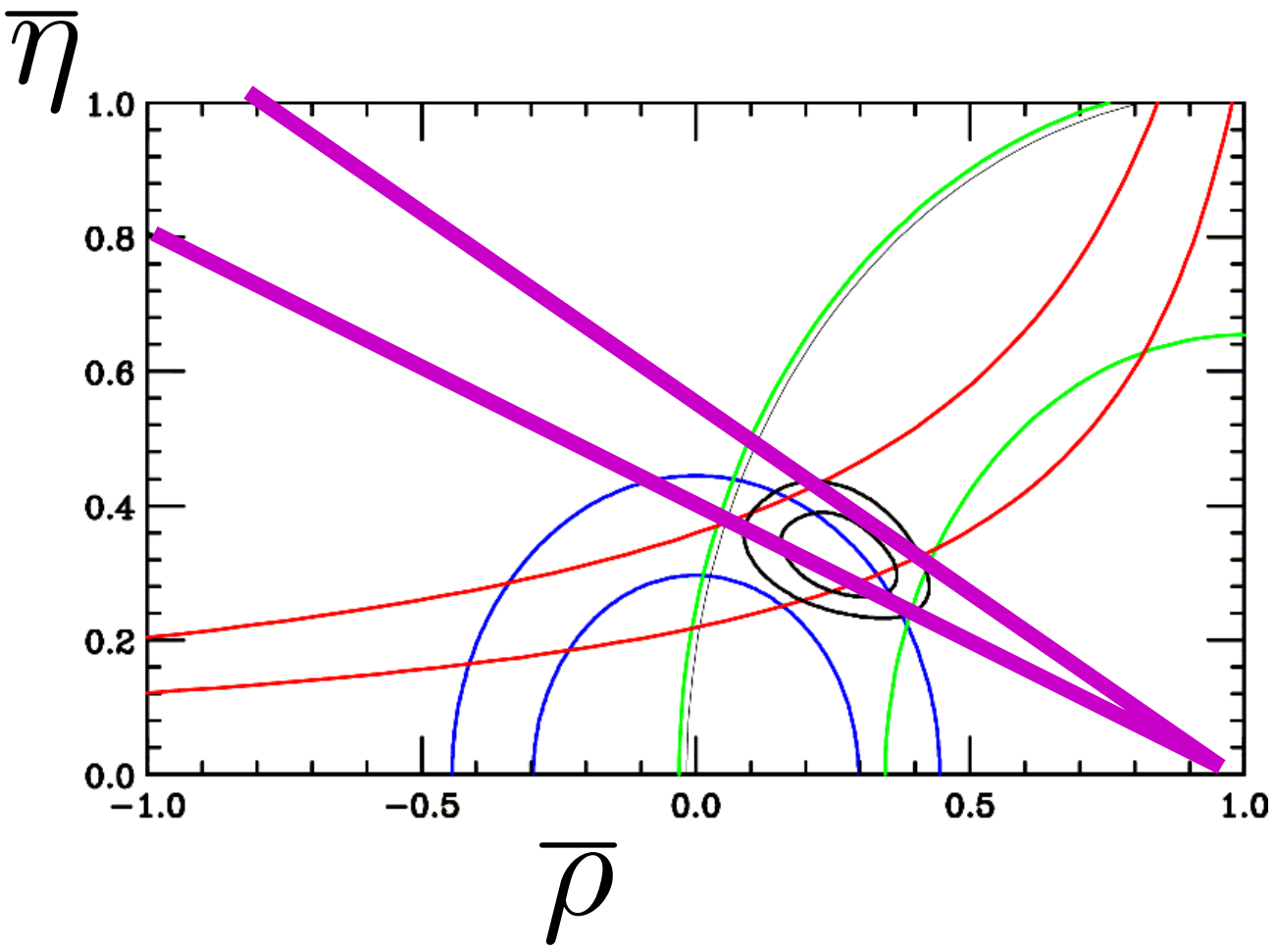
Outline

- sin 2β, triumph of the B factory?
- Model Independent Discussion
- Charmonium+Ks and Z penguins.
- Comparison with SUSY model
- Conclusion - SuperB

DA and G Hiller hep-ph/0307251

sin 2β: The Triumph of the B Factory

- The consistency of sin 2β with the Standard Model expectation is an early triumph of the B factories….



- Kaon Oscillation: ϵ_K
- Rate of b→u transitions: $|V_{ub}/V_{cb}|$
- The rate on B_d oscillations: x_d
- Lower bound on B_s oscillation
- Bound on $\sin 2\beta$ from BaBar and Belle

But...

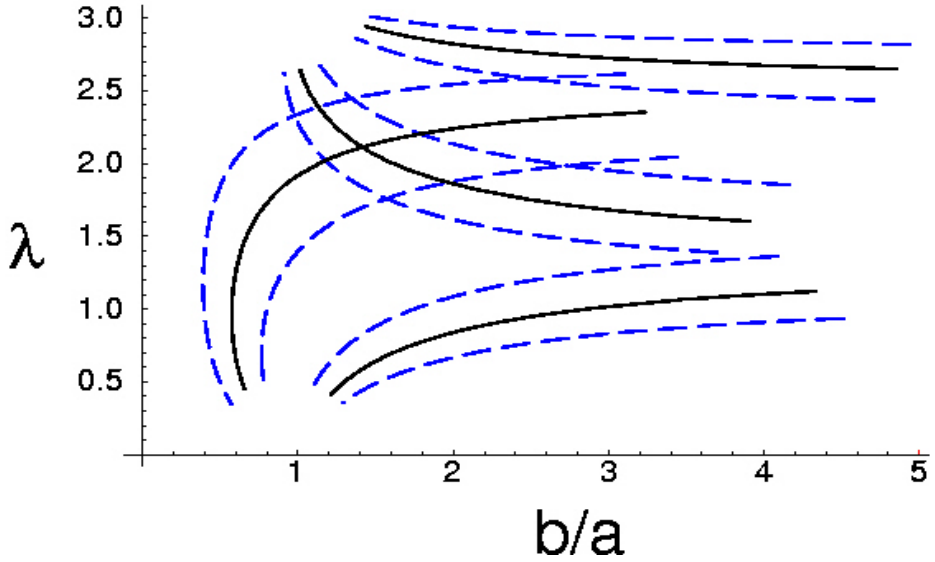
- The purity of the Standard Model interpretation of sin2β can be tested by the corresponding measurement in other modes.
- For instance in the double penguin mode $B \rightarrow \phi K_s$ there is a hint that all is not well.

$$\sin 2\beta_{\phi Ks} = -0.96 \pm 0.50^{+.09}_{-.10} \text{ (BELLE)}$$
$$\sin 2\beta_{\phi Ks} = +0.45 \pm 0.43 \pm 0.10 \text{ (BaBaR)}$$
$$\sin 2\beta_{\phi Ks} = -0.15 \pm 0.33 \text{ (Average)}$$

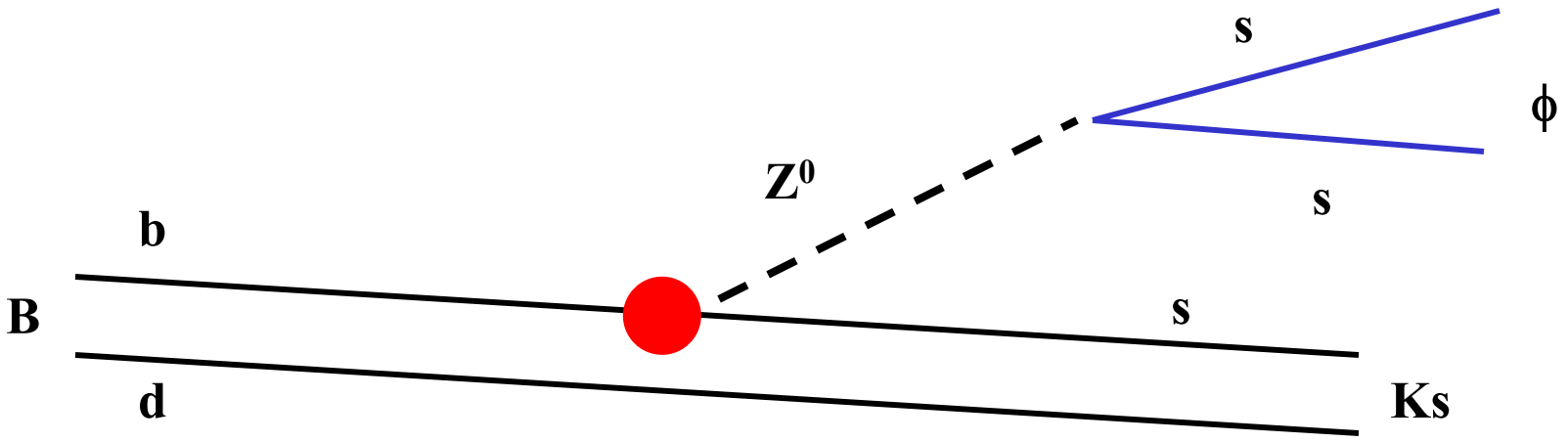
- Although the results are now controversial, this is an excellent way to look for new physics

Model Independent ϕKs

- An observed value of $\sin 2\beta_{\phi Ks}$ puts one constraint on a new physics amplitude.
- If we model the amplitude for $B \rightarrow \phi Ks$ by
  - $a+be^{i\lambda}$ = SM + New Physics
- then this is a constraint on λ versus b/a.



- Of course the deviation in $\sin 2\beta_{\phi Ks}$ does not tell what the new physics is.
- If deviations can be found in related modes, then the pattern of CP violation can give important clues as to the nature of the new physics
- I will illustrate this with models where the NP enters through Z-penguins



Recoil Meson

- The various possible recoil mesons will couple to axial or vector Zqq couplings:
  - Vector Zcc: J/ψ
  - Axial Zcc: η_c χ_{1c}
  - Suppressed: χ_{0c} χ_{2c} h_c
  - Vector Zss: ϕ
  - Axial Z(ss):η, η'
  - Axial Z(uu-dd): π^0

	$c\bar{c}$	$s\bar{s}$	$u\bar{u}-d\bar{d}$
Z_V	+0.19	-0.35	+0.54
Z_A	-0.5	+0.5	-1
Z_A/Z_V	-2.6	-1.4	-1.9

Charmonium

- As yet there is no evidence for deviation in the various charmonium states.

$$\sin 2\beta_{J\Psi K_S(K_S\to\pi^+\pi^-)} = 0.82 \pm 0.08$$

$$\sin 2\beta_{\Psi' K_S(K_S\to\pi^+\pi^-)} = 0.69 \pm 0.24$$

$$\sin 2\beta_{\chi_1 K_S} = 1.01 \pm 0.40$$

$$\sin 2\beta_{\eta_c K_S} = 0.59 \pm 0.32$$

BaBaR

- Separate analysis of charmonia can provide important clues to new physics
- The couplings of the Z imply that the effect in χ_{c1} and η_c should be enhanced
- The fact that the SM amplitude is larger than the pure penguin ϕKs tends to dilute the effect.
- The discrepancy between axial and vector sin 2β should thus be $|\Delta \sin 2\beta| < 0.12$.

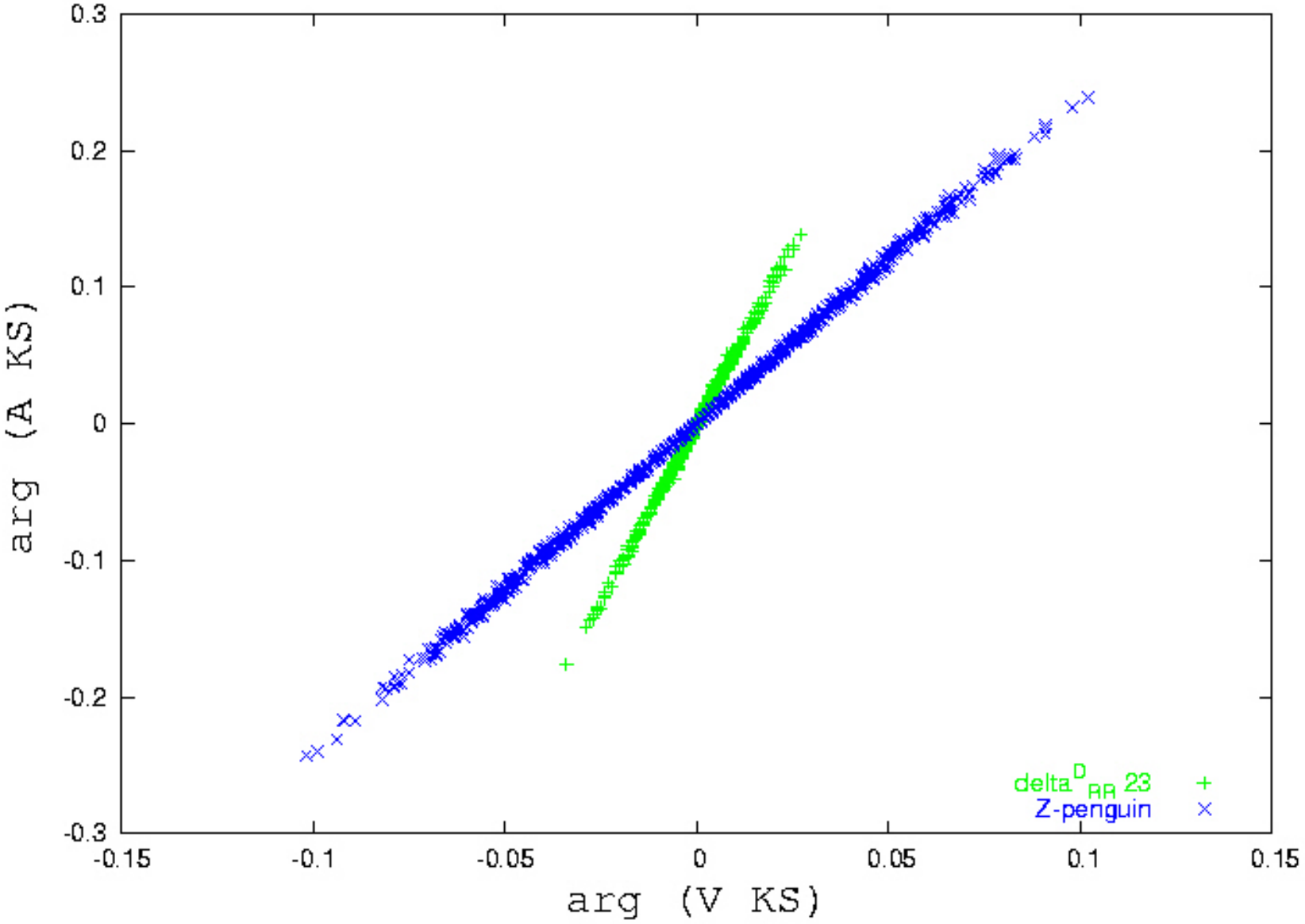


Figure 2: The NP correction for axial coupling mesons $\arg(AK_S)$ as a function of the one for vector coupling mesons $\arg(VK_S)$ induced by non-standard Z-penguins ($\times$, blue) and in the MSSM with down squark mixing $\delta^D_{RR\,23}$ ($+$, green) discussed in Section 4.1.

- The χ_2 h_c and χ_0 states do not get a color enhanced contribution at leading order from Z penguins
- These final states may give a closer read to the true SM value of sin 2β.

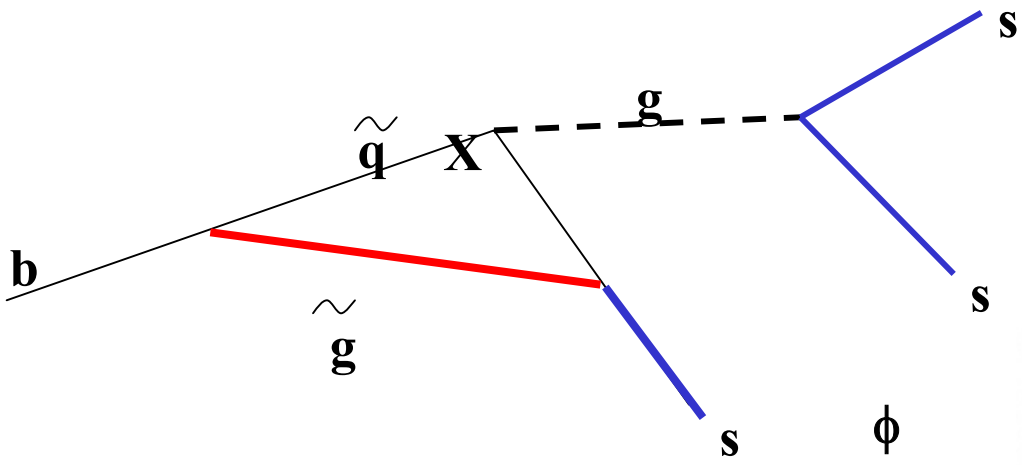
Other data

- Other data which is sensitive to these Z penguins are:
  - The Bs analogs such as $Bs \to \phi\phi$ and $Bs \to \phi\psi$, ϕ+charmonium.
  - $b \to s\, l^+ l^-$ the rate and asymmetries will also be fixed for Z-penguins.
  - Analogs where ϕ is replaced by other ss states such as η.
  - Z penguins may also give rise to isospin breaking in $B \to K\pi$

Comparison with SUSY Scenario

- New physics contributions to these processes can also arise in MSSM with s-squark mixing.
- Scanning over $150GeV < m_{\tilde{q}} < 1000GeV, \qquad 0.2 < m^2_{\tilde{g}}/m^2_{\tilde{q}} < 1.3$

  we obtain the following…



R. Harnik, D. T. Larson, H. Murayama and A. Pierce, arXiv:hep-ph/0212180.

S. Bertolini, F. Borzumati and A. Masiero, Nucl. Phys. B 294, 321 (1987); E. Lunghi and D. Wyler, Phys. Lett. B 521, 320 (2001) [arXiv:hep-ph/0109149]; C. L. Kane, P. Ko, H. b. Wang, C. Kolda, J. H. Park and L. T. Wang, arXiv:hep-ph/0212092; M. Ciuchini, E. Franco, A. Masiero and L. Silvestrini, arXiv:hep-ph/0212397.

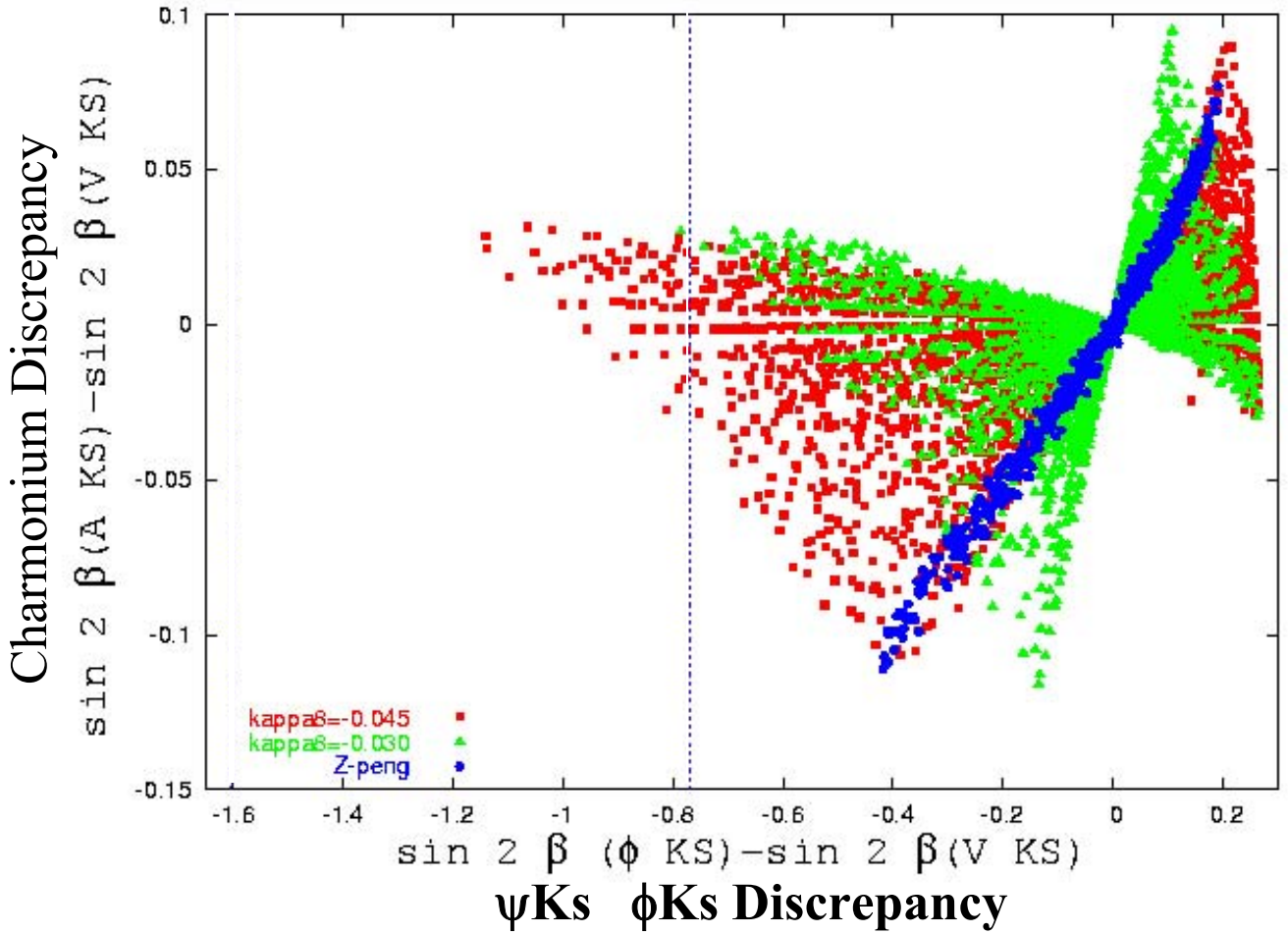


Figure 5: Difference in mixing $[\sin 2\beta_{AK_S} - \sin 2\beta_{VK_S}]$ as a function of $[\sin 2\beta_{\phi K_S} - \sin 2\beta_{VK_S}]$ in the non-SM Z-scenario (blue) and in the MSSM with additional flavor violation induced by $\delta^D_{RR\,23}$. The latter is shown for $\kappa_8 = -0.045$ (red) and $\kappa_8 = -0.030$ (green).

- If the super low BELLE-like numbers hold up then Z-penguin does not work but SUSY could explain the results.
- Again, in the Z-penguin picture a specific relation between the chamonium discrepancy and ϕKs versus J/ψ Ks is implied.

Conclusions-SuperB

- The status of CP violation in $B \to \phi K_s$ needs to be resolved.
- High resolution measurements of sin 2β for charmonium $+K_s$ final states provides a rich source of data for distinguishing different flavors of new physics.
- Other related decays such as isospin violation in $K\pi$ and $b \to s\, l^+ l^-$ will also be important in distinguishing NP scenarios.
  - High luminosity will determine exact $K\pi$ isospin amplidues
  - $Ks\eta$
  - High luminosity required to extract all distributions and asymmetries in $b \to s\, l^+ l^-$.