B physics in the LHC era

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In any event, we need B physics

Outline

- The new physics flavor problem
  - Flavor vs the hierarchy problem
  - Example: SUSY
- What B physics can do?
  - Possible measurements
  - Example: new physics in $B - \bar{B}$ mixing amplitude

The New Physics flavor problem

Reasons not to believe the SM

1. The hierarchy problem
2. The strong CP problem
3. Baryogenesis
4. Dark matter
5. Neutrino masses
6. Gravity

- Very likely, there is new physics
- The hierarchy problem suggests

$$\Lambda \sim 4\pi m_W \sim 1 \text{ TeV}$$

- We can directly probe new physics at such a scale

The new physics flavor problem

The SM flavor structure is special

- Universality of the charged current interaction
- FCNCs are highly suppressed

Any NP model must reproduce these successful SM features

The new physics flavor scale

- K physics: ϵ_K

$$\frac{s\bar{d}s\bar{d}}{\Lambda^2} \quad \Rightarrow \quad \Lambda \gtrsim 10^4 \text{ TeV}$$

- D physics: $D-\overline{D}$ mixing

$$\frac{c\bar{u}c\bar{u}}{\Lambda^2} \quad \Rightarrow \quad \Lambda \gtrsim 10^3 \text{ TeV}$$

- B physics: $B-\overline{B}$ mixing and CPV

$$\frac{b\bar{d}b\bar{d}}{\Lambda^2} \quad \Rightarrow \quad \Lambda \gtrsim 10^3 \text{ TeV}$$

There is no exact symmetry that can forbid such operators

Flavor and the hierarchy problem

There is tension:

- The hierarchy problem $\Rightarrow \; \Lambda \sim 1$ TeV
- Flavor bounds $\Rightarrow \; \Lambda > 10^3$ TeV

Any TeV scale NP has to deal with the flavor bounds

$$\Downarrow$$

Such NP cannot have a generic flavor structure

NP signal in B physics

Any viable NP model has to deal with this tension

- The NP is flavor blind, MFV (GMSB; UED)
  - Small effects, but they are there. Usually $O(1\%)$
- New flavor physics, but there is a mechanism that suppresses it to an acceptable level
  - Large effects are possible. Model dependent

New TeV physics implies $\gtrsim O(1\%)$ effects in B physics

Example: SUSY

The effect on $B-\bar{B}$ mixing is of the order

$$\frac{\Delta m_{SUSY}}{\Delta m_{SM}} \sim 10^4 \left(\frac{100\ \mathrm{GeV}}{m_{\tilde{Q}}}\right)^2 \left(\frac{\Delta m^2_{\tilde{Q}}}{m^2_{\tilde{Q}}}\right)^2 \mathrm{Re}\left[(K_L)_{13}(K_R)_{13}\right]$$

- Heavy squarks
- Degeneracy (GMSB)
- Alignment (Horizontal symmetry)

SUSY breaking

LHC found SUSY, and part of the spectrum. We like to understand SUSY breaking

- Different model predict different spectra
- LHC cannot teach us about SUSY flavor and CPV
- A linear collider can tell us something about flavor
- We will need to count on indirect signals

Example: SUSY effect on B

Different SUSY breaking scenarios give different flavor signals

- GMSB: Very small, $O(1\%)$, effect on $B-\bar{B}$ and $D-\bar{D}$ mixings
- Alignment: Small effect on $B-\bar{B}$ mixing and large $D-\bar{D}$ mixing
- Heavy squarks: $O(10\%)$ effect on B mixing and very small effect on $D-\bar{D}$ mixing

Probing new physics with mesons

Bottom line

- Any new physics model has to deal with flavor
- In some cases we expect large effects in meson physics
- It is very likely that we will see an effect at the 1% level
- Even if the effect is smaller we like to push the bounds to test NP models

Experimental situation

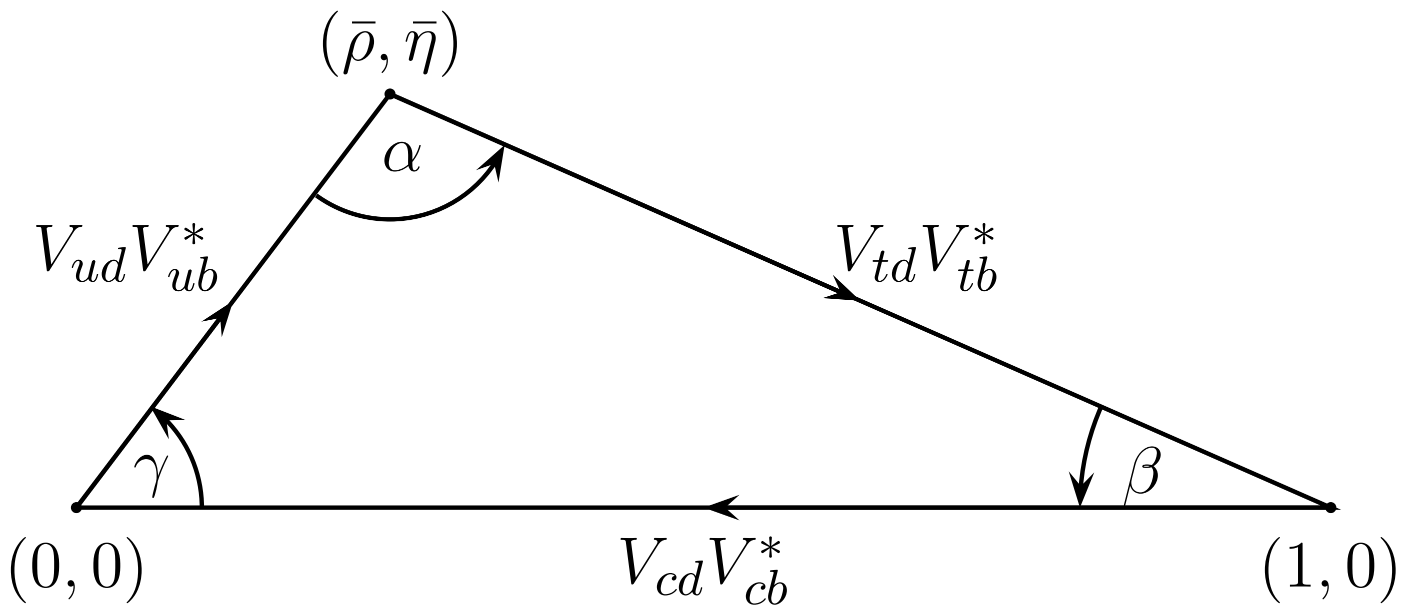
What we will have at 2011?

- BaBar and Belle with at least $1\ \mathrm{ab}^{-1}$
- Cleo-C
- CDF and D0
- LHC-b
- Atlas and CMS
- BTeV
- Super B factory
- Hopefully, $K \to \pi\nu\bar{\nu}$ somewhere

What these experiments can do?

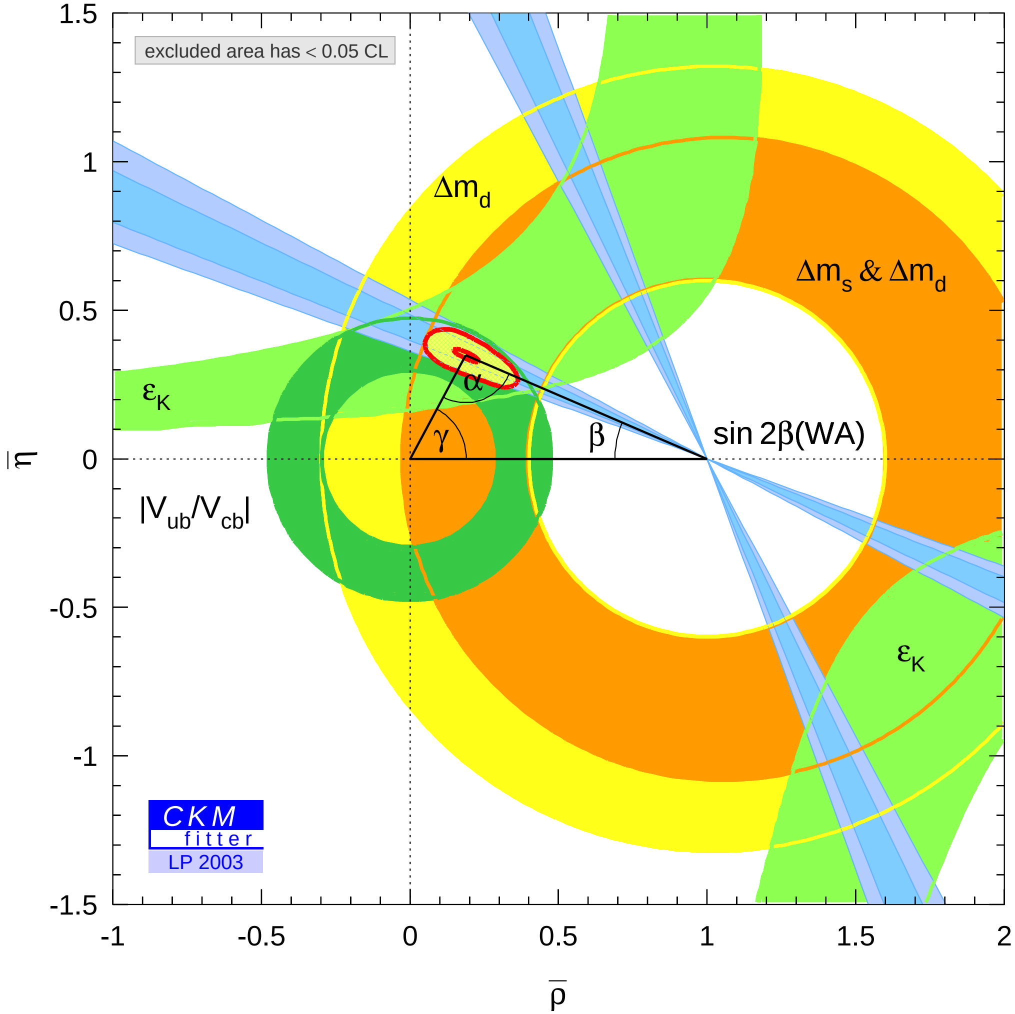
Measurement	Ex. error	Th. error
$B \to \psi K_S$ (β)	$< 1\%$	$< 1\%$
$B \to \phi K_S$, $B \to \eta' K_S$, ... (β)	$\sim 1\%$	$< 5\%$
$B \to DK$ (γ)	$\sim 1\%$	$< 10^{-3}$
$B \to \pi\pi$, $B \to \rho\pi$, $B \to \rho\rho$ (α)	$< 5\%$	$< 5\%$
B_s mixing (V_{td})	$< 1\%$	$< 5\%$
$B_s \to \psi\phi$ (β_s)	$\sim 1\%$	$< 1\%$
V_{cb}	$< 1\%$	$\sim 1\%$
V_{ub}	$\sim 5\%$	$\sim 5\%$
$B \to X\ell^+\ell^-$	$\sim 1\%$	$\sim 5\%$
$B \to K^*\nu\bar{\nu}$	$\sim 10\%$	$\sim 5\%$

Example: New physics in $B - \bar{B}$ mixing



- We will know the UT at the 1% level (β, γ and V_{cb})
- More processes are needed to test for NP
  - V_{ub}
  - B_s mixing. Can test also CP "conserving" NP
  - $K \to \pi\nu\bar\nu$

Global fit



Hocker et al. (CKMfitter)

- **Present:** V_{cb}, V_{ub}/V_{cb}, ε_K, Δm_d , Δm_s, $a_{\rm CP}(B \to \psi K_S)$
- **Future:** γ, α, $K \to \pi\nu\bar{\nu}$
- **Tiny Errors**

Conclusions

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- It is likely that there is new physics at a TeV
- Such new physics can show up in K, D and B physics
- Flavor physics is complementary to LHC/LC