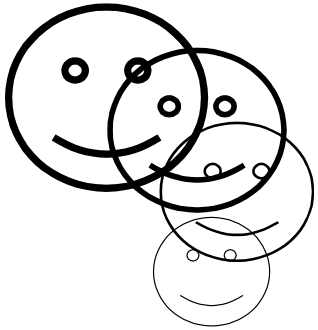
Mixing Limits of the Strange B^0 Meson



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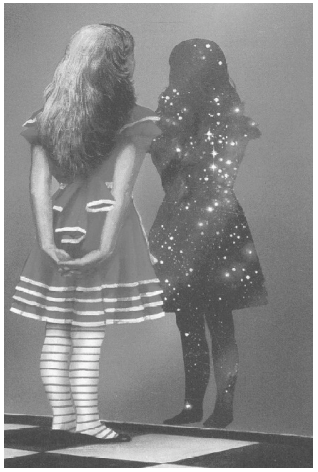
Outline



Standard Model Quarks

★ **Quarks** come in 6 flavors, and 3 "flavor doublets", as do their antiquarks:

Chg:	Quarks		
+2/3	**u**	**c**	**t**
-1/3	**d**	**s**	**b**

CHARGE CONJUGATION

Chg:	Antiquarks		
-2/3	**ubar**	**cbar**	**tbar**
+1/3	**dbar**	**sbar**	**bbar**

★ **Hadrons** are composites of 2 or 3 quarks - *and no more (according to QCD)!*

★ **Mesons** are hadrons which contain quark-antiquark (q,qbar) pairs.

★ The **B^0 meson** contains (b,dbar).

★ The **strange B^0** (B_s) contains (b,sbar).

Why Study the B_s?

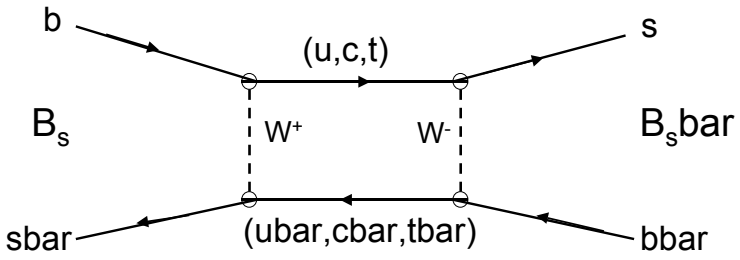
★ B and K mesons decay via $W^{\pm}$, and sometimes in a way that violates CP.

★ Understanding CP-violation may give insight to Matter-Antimatter Asymmetry in the Universe

C = Charge Conjugation
P = Parity
T = Time Reversal

http://www.particleadventure.org/

The B_s Mixing Process

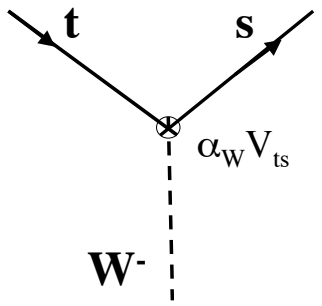


★ B_s transforms into $B_s$bar via an exchange of virtual W's between its consituent quarks

★ *Weak, flavor-changing interaction*

★ Dominated by top quark

B_s Mixing: $W^{\pm}$ coupling



Chg:	Quarks		
+2/3	u	c	t
-1/3	d	s	b

★ The weak interaction ($W^{\pm}$) mediates between flavor doublets.

★ The coupling strength at each node depends on the coupling "constant" α_W and the quarks involved

★ The stronger the coupling, the more likely the process is to occur

The CKM Matrix

★ The V_{qq}'s make up the *Cabibbo-Kobayashi-Maskawa* (CKM) Matrix

★ The CKM Matrix …
- Tells everything about weak interactions
- Is Unitary (V*V = 1)
- Contains a CP-Violation term
- *All terms must be known to test the Standard Model*

★ Frequency of B_s-mixing proportional to V_{ts}

$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

$$\begin{pmatrix} u \\ c \\ t \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

B_s Mass and Flavor Eigenstates

$$B_S^0 = \frac{1}{\sqrt{2}} \left| B_{S,1}^0 \right\rangle + \frac{1}{\sqrt{2}} \left| B_{S,2}^0 \right\rangle$$

$$\overline{B}_S^0 = \frac{1}{\sqrt{2}} \left| B_{S,1}^0 \right\rangle - \frac{1}{\sqrt{2}} \left| B_{S,2}^0 \right\rangle$$

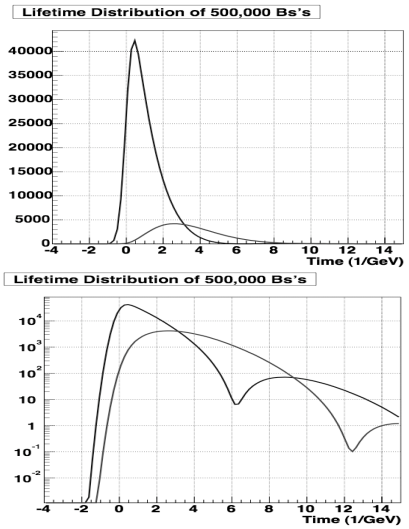
★ The B_s and $B_s$bar each exist in a superposition of 2 mass eigenstates

★ Since the signs are different, there is a difference in the mass between B_s and $B_s$bar (Δm)

★ Mass difference is small enough for "mixing"

B_s Mixing and Lifetime

- ★ B_s and $B_s$bar have very similar lifetimes
- ★ If mixing occurs, some B_s's will become $B_s$bars before they decay
- ★ Mixing exposes itself as an oscillation in the B_s lifetime curve.
- ★ Oscillation frequency *f* proportional to $2\Delta m$ and to V_{ts}
- ★ Total lifetime remains essentially unaffected.



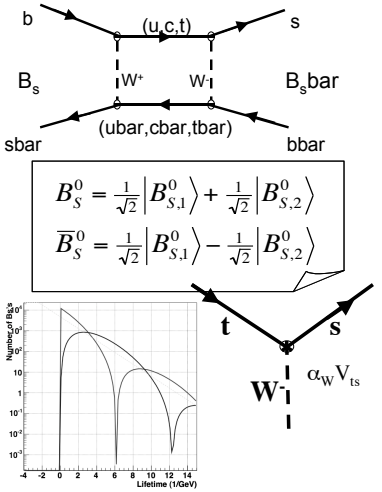
B_s Mixing Limits

- ★ In reality, there are limits to measurement:
  - ✺ Gaussian Smearing due to time/dist resolution limit
  - ✺ "Mistagging" also a problem (confusing a B_s with a $B_s$bar)
  - ✺ Time-Dependent smearing due to neutrinos
  - ✺ Background noise (decay from other processes -- *very* significant in hadron colliders!)
- ★ Capstone Goal: Determine the effect of each of these on measurement of V_{ts} and Δm.
  - ✺ (and maybe, measure them!)

Finding B_s Mixing Limits

- ★ Run "Toy" Monte Carlo Simulations
- ★ Vary the detector parameters, as well as expected measurements
- ★ Fit lifetime distribution to a mixing function
- ★ Determine whether/how detector parameters affect perceived Δm
- ★ Determine whether/how Δm affects perceived detector parameters
- ★ Repeat with background noise in the simulation
- ★ Repeat with full (actual, latest) detector physics in the simulation
- ★ Repeat with data?

Conclusion



- ★ B_s-mixing measurement:
  - ✺ Studies CP-Violation in the quark sector
  - ✺ Gives V_{ts} …
    - ♥ (test Standard Model)
  - ✺ Gives Δm …
    - ♥ (Matter, Anti-matter asymmetry)
  - ✺ Sensitive to new physics
- ★ Goal: Determine mixing limits

References & Acknowledgements

★ References

- Anikeev et. Al, *"B Physics at the Tevatron: Run II and Beyond"*, FERMILAB-Pub-01/197, December 2001
- Perkins, Donald H., *Introduction to High Energy Physics*, 4th ed., Cambridge UP, 2000
- *"CP Violation in B Meson Decay: FAQ"*, http://www.physics.uc.edu/~kayk/cpviol/CP_A0.html, 09/30/04

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