25. IX. 1999

WG 3 Summary

Mixing and Lifetimes

Topics covered

- $B_{d,L} - B_{d,H}$ mass difference Δm_{B_d}
- $B_{s,L} - B_{s,H}$ mass difference Δm_{B_s}
- $B_{d,L} - B_{d,H}$ width difference $\Delta\Gamma_{B_d}$
- $B_{s,L} - B_{s,H}$ width difference $\Delta\Gamma_{B_s}$
- lifetime ratios

beauty: $\frac{\tau(B^+)}{\tau(B_d^0)}, \frac{\tau(B_s)}{\tau(B_d^0)}, \frac{\tau(\Lambda_b)}{\tau(B_d^0)}, \frac{\tau(\Xi_b)}{\tau(\Lambda_b)}$

charm: $\frac{\tau(\Xi_c)}{\tau(\Lambda_c)}$

- inclusive non-leptonic decays
  $b \to u \bar{c} s$
- CPT tests

Presentations

Theory Overview on lifetimes
Misha Voloshin

Theory Overview on mixing
Uli Nierste

New physics in B_d-, B_s-mixing
JoAnne Hewett

Use of $\Delta\Gamma_{B_s}$ for CP studies Isi Dunietz
(jointly with WG 1)

B-mixing studies in CDF Christoph Paus

Lifetime studies in CDF Jeff Tseng

Mixing and Lifetimes in DØ Guilherme Lima

Perspectives of BTeV Rob Kutschke

Lattice studies of bag parameters
Jimmy Juge

Experimental CPT tests Rob Gardner

Determination of $|V_{ub}|$ from $b \to u\bar{c}s$
Alexey Petrov

- Lifetimes and inclusive decay rates of c and b hadrons

- Theoretical input:
  - i) OPE: expansion in $\frac{1}{m_Q}$
  - ii) Local quark-hadron duality
  - iii) HQ symmetries

$$\Gamma(X_Q) = c_1 \frac{G_F^2 m_Q^5}{192\pi^3} \underset{\uparrow}{\langle X_Q | \bar{Q} Q | X_Q \rangle} + c_2 m_Q^3 \langle X_Q | \underset{\uparrow}{\bar{Q}} (\vec{\sigma}\cdot\vec{B}) Q | X_Q \rangle$$

overall scale

baryon-meson splitting

$$+ \langle X_Q | \sum_i c_3^{(i)} \underbrace{m_Q^2 (\bar{q}_i \Gamma_i q_i)}_{\text{spectator-flavor dependent}} (\bar{Q} \Gamma_i' Q) | X_Q \rangle$$

- Works (semi-quantitatively) for charm:

$$\tau(D^\pm) > \tau(D^0) \approx \tau(D_s) > \tau(\Xi_c^+) > \tau(\Lambda_c) > \tau(\Xi_c^0) > \tau(\Omega_c)$$

- For quantitave application: extract matrix elements from lifetimes of charmed $\Longrightarrow$ apply to b and to specific inclusive decay rates of charmed

• Predictions

b :

Mesons:

$$\frac{\tau(B^\pm)}{\tau(B^0)} = 1 + \underset{\uparrow\uparrow}{(4-5)\%} \cdot \left(\frac{f_B}{200\,\text{MeV}}\right)^2$$

"bag" constants

$$\frac{\tau(B_s)}{\tau(B_d)} = 1 \pm \underset{\uparrow}{O(1\%)} \qquad (*)$$

estimate of higher terms + new physics

Baryons:

$$\frac{\tau(\Xi_b^0)}{\tau(\Lambda_b)} = 1 \pm O(1\%)$$ same status as (*)

HQ symmetry

$$\Gamma(\Lambda_b) - \Gamma(\Xi_b^-) \overset{\downarrow}{=} 0.015\left[\bar{\Gamma}(\Xi_c^0) - \Gamma(\Lambda_c)\right] + 0.016\left[\bar{\Gamma}(\Lambda_c) - \Gamma(\Xi_c^+)\right]$$

$$= 0.11 \pm 0.03\ \text{ps}^{-1} \implies \frac{\tau(\Xi_b^-)}{\tau(\Lambda_b)} \approx 1.15$$

$$\Gamma(\Lambda_b) - \Gamma(B^0) \lesssim 0.07\ \text{ps}^{-1} \implies \frac{\tau(\Lambda_b)}{\tau(B^0)} > 0.9$$

$$\Gamma_{sl}(B^\pm, B^0, B_s) \underset{2-3\%}{\lesssim} \Gamma_{sl}(\Lambda_b, \Xi_b)$$

c - baryons :

$$\Gamma_{sl}(\Xi_c) - \Gamma_{sl}(\Lambda_c) = 0.13\left[\Gamma(\Xi_c^0) - \Gamma(\Lambda_c)\right] - 0.065\left[\Gamma(\Lambda_c) - \Gamma(\Xi_c^+)\right]$$

$$= 0.59 \pm 0.32\ \text{ps}^{-1} \implies \frac{\Gamma_{sl}(\Xi_c)}{\Gamma_{sl}(\Lambda_c)} \doteq (2-3)$$ is possible

Mixing

$\Delta m_{B_d} = x_d/\tau_{B_d}$ techniques well understood from CDF-Run-1

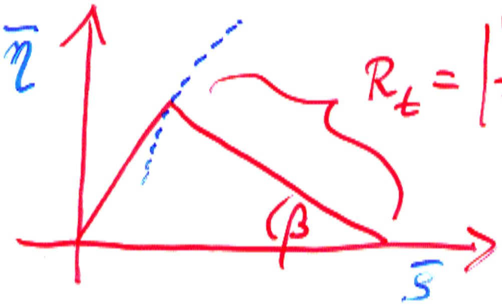
$\Delta m_{B_s} = x_s/\tau_{B_s}$ $> 14.3\ ps^{-1}$ current limit

$[\Leftrightarrow x_s > 21]$

Standard Model: Can determine $\left|\frac{V_{td}}{V_{ts}}\right|$ with (at present) 4% theoretical uncertainty from $\Delta m_{B_d}/\Delta m_{B_s}$. Uncertainty stems from

$$\frac{f_{B_d}^2 B_{B_d}}{f_{B_s}^2 B_{B_s}} = \left[1.16 \pm 0.04\right]^2$$

(Lattice)



$R_t = \left|\frac{V_{td}}{V_{ts}}\right| \frac{1}{\lambda}$ Dramatic impact

← unitarity triangle

New physics: Much drops out, but not all....

→ JoAnne's talk

Experimentally:

Tag B_s at time $t=0$

Tag oscillated $B_s(t)$ at $t>0$

Experimental Studies performed so far

CDF/DØ

Tagging modes [= flavor-specific decays]

$B_s \to D_s^- \pi^+, D_s^- \pi^+ \pi^- \pi^+, J/\psi K^*,$

with $D_s^- \to \phi \pi^-$
$\hookrightarrow K^+ K^-$

$D_s^- \to K^{*0}(892) K^-$
$\hookrightarrow K^+ \pi^-$

For comparison also

$B_s \to D_s^{*-} \pi^+$

Reach: $x_s \to 60$ with $2\ fb^{-1}$

BTeV

Tagging modes

$B_s \to D_s^- \pi^+$

$\Delta\Gamma_{B_s}$: Calculable with an Operator Product Expansion (Heavy quark expansion)

same method as in $\frac{\tau(B_d)}{\tau(B_s)}$, $\frac{\tau(B^+)}{\tau(B_d)}$ ...

Accuracy currently limited by lattice data for $f_{B_s}^2 \cdot B_s$

$$\frac{\Delta\Gamma_{B_s}}{\Gamma_{B_s}} \simeq 0.16 \pm 0.07$$

(may change dramatically)

allows for many interesting studies with untagged samples

→ Isi's talk

In $\frac{\Delta\Gamma_{B_s}}{\Delta m_{B_s}}$ the factor $f_{B_s}^2$ cancels

⇒ reduces hadronic uncertainty.

New physics does not cancel.

We study the following ways to measure

$$\Delta\Gamma_{B_s} = \Gamma_L - \Gamma_H$$

1. $B_s \to f_{FS}$

$\uparrow$ flavor specific final state, e.g. semileptonic, ... any tagging mode,

$$\Gamma(t) = a\cdot e^{-\Gamma_L t} + b\, e^{-\Gamma_H t}$$

2-exponential fit

2. $B_s \to f_{CP}$ $\nwarrow$ CP-eigenstate $f_{CP} = J/\psi\phi\big|_{\text{S-wave}}$; $D_s^+ D_s^-$

$$\Gamma(t) = a\cdot e^{-\Gamma_L t}$$

In the standard model $B_{s,L}$, B_{sH} are CP-eigenstates and $B_{s,H} \not\to f_{CP=1}$

Compare measured lifetime with average B_s-lifetime $\Rightarrow$ $\dfrac{\Delta\Gamma_{B_s}}{2}$

3. Compare CP-even with CP-odd mode?

New physics searches

$$\Delta\Gamma_{B_s} = \Delta\Gamma_{SM} \cdot \cos\phi$$

new phase (CP-violating)
in $B_s - \overline{B}_s^0$ mass matrix

Then

$$\Gamma(B_s \to f_{CP=1}, t) \propto \cos^2\frac{\phi}{2}\, e^{-\Gamma_L t} + \sin^2\frac{\phi}{2}\, e^{-\Gamma_H t}$$

1. Decay rate difference

$$\Delta\Gamma_{B_s \to f_{CP}} = \Delta\Gamma \cdot \cos\phi = \Delta\Gamma_{SM} \cos^2\phi$$

measured with CP-method

measured with flavor specific mode

or

2. Fit $\Gamma(B_s \to f_{CP}, t)$ to two exponentials

→ Yuval's talk

Pattern:

untagged studies with $\Delta\Gamma_{B_s}$

↓

$\cos\phi$

$\sin\phi$

↑

tagged studies with $a_{CP}(B_s \to J/\psi\,\phi)$

To gain statistics, one can sum over many final states with same CP-parity.

$\Rightarrow$ Trigger on as many CP-eigenstates as possible!

$$\Delta\Gamma_{B_d}$$

$$\frac{\Delta\Gamma_{B_d}}{\Gamma_{B_d}} = O(1\%)$$

Measurement gives information on V_{ub}.

Hadronic uncertainty in

$$\frac{a_{SL}(B_d)}{\Delta\Gamma_{B_d}}$$

cancels (if quark-hadron-duality holds).

Same true for $\frac{\Delta\Gamma_{B_d}}{\Delta\Gamma_{B_s}}$ up to $SU(3)_F$ corrections.

Possible measurements:

1. Measure average B_d-lifetime at permille level
   [current world average accurate at 1% level]

   Measure lifetime in CP-eigenmode,
   e.g. $B_d \to J/\psi K_S$

   Free lunch from $\sin 2\beta$-measurement.
   untagged sample sufficient!

   → Find more CP-channels ...?.

2. Fit $\Delta\Gamma_{B_d}$ from time evolution together with Δm_{B_d}.

3. New ideas....

Outlook

until next workshop and beyond...
37 people (26 exp., 11 theo.) signed up for:

- Δm_{B_d}; "standard lifetimes" $\tau(B^+)$, $\tau(B_d^0)$, $\tau(B_s^0)$, $\tau(\Lambda_b)$
  → bread & butter from Run-I
- $\Delta\Gamma_{B_s}$, $\Delta\Gamma_{B_d}$: explore the reach of the different methods
  → find as many CP-specific final states as possible
  → trigger
- "non-standard" lifetimes
  → explore b-baryons such as Ξ_b ....
- Δm_{B_s}-studies: in progress and good shape
- a_{SL}: experimental study
  → WG 2 ???