On the Importance of $\Delta\Gamma(B^0)$.

a) History of $\Delta\Gamma$

b) $\Delta\Gamma$ resolves CKM ambiguities

c) New $\not{CP}$ effects from $\Delta\Gamma$

d) B_d & $\bar{B}_s \longrightarrow f \quad \Rightarrow$ CKM

a) History of $\Delta\Gamma$

$\frac{\Delta\Gamma(B_s)}{\Gamma} \sim 0.1$

Hagelin
Chau
Buras et al.
Voloshin et al.

} early 80's

thought unobservable $\Rightarrow$ dropped.

$B_s(t) \to D_s \ell \nu,\ D_s \pi \xrightarrow[\text{CDF}]{\text{LEP}}$ single exp. fit $\Rightarrow \tau(B_s)$

early 90's

Dunietz: { Really data sum of 2 exp. $\Longrightarrow \Delta\Gamma$ since $\bar{\Gamma} = \Gamma(B_d)$

$e^{-\Gamma_H t} + e^{-\Gamma_L t} \Leftarrow$ [Dunietz & Rosner, Datta et al., Bigi]

$\Delta\Gamma \neq 0 \Rightarrow$ novel $\not{CP}$ from untagged B_s

Bigi et al.
Neubert & Sachrajda
Beneke, Buchalla & Dunietz

$\frac{|\Delta\Gamma|}{\Gamma}$ {
≤ 0.83 CDF
≤ 0.42 DELPHI
≤ 0.67 L3 (topological)?

$\frac{\Delta\Gamma(B_s)}{\Gamma} \sim 0.1$

Aleksan et al
Bigi et al
Beneke, Buchalla, Dunietz
Beneke, Buchalla, Greub, Lenz, Nierste

late 90's

b) $\Delta\Gamma$ resolves CKM ambiguities

I.D. PRD 52, 3048 (1995)

conventionally

tagged $B_s(t) \to f \longrightarrow \mathrm{Im}\,\lambda \sim \sin(\pm\gamma + \Delta)$

f $(= D_s^{\pm} K^{\mp}$ Aleksan, Kayser, Dunietz, for ex.)

untagged

$$f(t) \equiv \Gamma(B_s(t) \to f) + \Gamma(\bar{B}_s(t) \to f)$$

$\Delta m t$ - osc. cancel, depend only on $\bar{\Gamma}$, $\Delta\Gamma$:

$$f(t) \longrightarrow \mathrm{Re}\,\lambda \sim \cos(\pm\gamma + \Delta)$$

$$\boxed{\mathrm{Re}\,\lambda \;\&\; \mathrm{Im}\,\lambda \implies \text{discrete ambiguity removal}}$$

c) New $\not{CP}$ effects from $\Delta\Gamma$

c.1) f_{CP} = CP eigenstate

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

Theorem:

No $\not{CP}$ $\Longrightarrow$ $f_{CP}(t)$ = single exp. decay

Wolfenstein proved it for kaons 1969

Proof:

CP conserved $\Longrightarrow$ $[H, CP] = 0$

$\Downarrow$

mass e.s. $\left(m_{H_L} - \frac{i}{2} \Gamma_{H_L} \right)$ also def. CP e.s.

$\Downarrow$

single exp. decay for $f_{CP}(t)$.

QED

c) New $\not{CP}$ effects from $\Delta\Gamma$

c.2) $f = J/\psi\,\phi$ good approx. no $\not{CP}$.

(k) ignore tiny $\not{CP}$ ang. corr. $\xrightarrow[\text{Lipkin, Rosner}]{\text{Dighe, Dunietz}}$ $\Delta\Gamma$

(2) $\not{CP}$ CKM : ang. corr $\xrightarrow[\text{Dunietz}]{\text{Fleischer}}$ $\left(e^{-\Gamma_H t} - e^{-\Gamma_L t}\right)$.

$\cdot\, 2\eta\,\theta^2 \implies$ CKM η.

(t) new $\not{CP}$: Grossman; Nierste

$$\Delta\Gamma(J/\psi\,\phi) \neq \Delta\Gamma(D_s\,\pi)$$

Fleischer, Nierste, Dunietz

tagged, time-dep. studies $\Rightarrow$ more incisive

$\Delta\Gamma(D_s\pi)$ – still ok.

$\Delta\Gamma(J/\psi\,\phi)$ – must be modified:

underlying assumption: $\boxed{\text{CP e.s.} = \text{mass e.s}}$

But "new $\cancel{CP}$" $\Rightarrow$ CP=+ part governed by 2 exp

C.3) Non CP e.s

$$B_s \to f = D_s K, \ldots$$
$$\bar{B}_s \to f = D_s K, \ldots$$

I.D., PRD 52, 3048

$$f(t) \neq \bar{f}(t) \Longrightarrow \not{CP}, \text{ CKM } \gamma$$

d) B_d & $\overline{B}_s \to f \Rightarrow$ CKM

B_s important, because same Final-State-Interactions when study

$B_s \to f$, $\overline{B}_d \to f$ (identical particle content

Novel CKM extractions

Dunietz, Snowmass 93

Fleischer 99 refined

$B_d(t) \to \pi^+\pi^-$, $B_s(t) \to K^+K^-$ $\Longrightarrow$ CKM

$B_d(t) \to J/\psi K_s$, $B_s(t) \to J/\psi K_s \Longrightarrow$ CKM γ

$$\frac{|\Delta\Gamma(B_d)|}{\Gamma} \lesssim 1\%$$

Useful for discrete ambiguity removal of β:

$$\text{Asym}\,(B_d(t) \to J/\psi K_s) = -\,\text{Im}\,\lambda \quad \sin \Delta m t$$

untagged $J/\psi K_s(t)$:

$$J/\psi K_s(t) \sim e^{-\Gamma_L t} + e^{-\Gamma_H t} + \text{Re}\,\lambda \left(e^{-\Gamma_L t} - e^{-\Gamma_H t} \right)$$

Need $> 10^5$ $J/\psi K_s$

or, $\text{Re}\,\lambda$ measured via (a) Dighe, Dunietz, Fleischer

(b) Azimov, Kayser, Stodolsky

(c) Charles et al.

then used to determine $\text{Sign}(\Delta\Gamma)$.

Further work

- Develop guidelines to optimally observe "New Physics".

- $\not{CP}$ from ang. corr

$D_1(2420)\ \phi \xrightarrow[\text{Dunietz}]{\text{Fleischer}}$ large $\not{CP}$, CKM γ

$\hookrightarrow D^{*+}\pi^-$