$\frac{\Delta\Gamma_s}{\Gamma_s}$ measurements – Part II

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- limiting theoretical & experimental errors
- expected sensitivity from

  CDF, D0, BTeV, ATLAS, CMS, LHCb
- prospects for error improvement
- SM vs. other model predictions

Phenomenology: SM predictions

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

- $$\Delta\Gamma_S / \Gamma_S = 0.16 \pm \underbrace{0.03}_{f_{B_s}} \pm \underbrace{0.04}_{B_S}$$

operator product /QCD

heavy product expansion

http://www-theory.fnal.gov/people/ligeti/Brun2/sept/nierste.pdf

- $$\Delta\Gamma_S / \Gamma_S = 0.12 \pm 0.06$$

quenched lattice QCD

http://cern.ch/nierste/uli.ps

- $$\Delta\Gamma_S / \Gamma_S = 0.11 \pm 0.07$$

QCD-NLO

http://www-theory.fnal.gov/people/nierste/wg3documents/cern.breport.ps.gz

Existing measurements

- Assuming $\Gamma_S = \dfrac{1}{\tau(B_d)}$ (expected within ±1%)

PDG2001

$$\frac{|\Delta\Gamma_S|}{\Gamma_S} < 0.32 \quad \text{C.L.} = 95\%$$

- Without external constraints

LEP B-Oscillation Group (CDF-RunI not included)

$$\frac{|\Delta\Gamma_S|}{\Gamma_S} < 0.52 \quad \text{C.L.} = 95\%$$

Phenomenology →

$$\frac{|\Delta\Gamma_S|}{\Gamma_S} \sim 10 - 20\%$$

Phenomenology: beyond the SM

- SM : *CP* violation in B_S mixing small

$$\Gamma(B_S^{\text{short}}) - \Gamma(B_S^{\text{long}}) \equiv \Delta\Gamma_S \approx \Delta\Gamma_{CP} \equiv \Gamma(B_S^{\text{CP even}}) - \Gamma(B_S^{\text{CP odd}})$$

$$\Delta\Gamma_S = \Delta\Gamma_{CP} \cos\phi$$

→ ***CPV* phase in mixing**

($\varphi_{SM} \sim 0$)

- New physics: large CP violation; affects only $\Delta\Gamma_S$

$$a_{CP}(B_S \to J/\psi\ \Phi) \propto \sin\phi$$

→ **determine**

***CPV* phase**

Experimental methods

- untagged data samples: sensitivity ~ $\left(\frac{\Delta\Gamma_S}{\Gamma_S}\right)^2$ $B_S \to \text{anything}$
- flavor specific: sensitivity ~ $\left(\frac{\Delta\Gamma_S}{\Gamma_S}\right)^2$ $B_S \to D_S\,\pi$
- *CP* eigenstates : sensitivity ~ $\Delta\Gamma_S \cdot \cos\varphi = \Delta\Gamma_{CP} \cdot \cos^2\varphi$
- *CP* eigenstate + (50%-even, 50%-odd)

$$\Delta\Gamma_S = 2 \times \left[\Gamma(B_S^{\text{CP even}}) - \Gamma(B_S^{\text{CP 50:50}})\right]$$

…Experimental methods

- CP eigenstate + (50%-even, 50%-odd)

$$\Delta\Gamma_S = 2\times\left[\Gamma(B_S^{\text{CP even}}) - \Gamma(B_S^{\text{CP 50:50}})\right]$$

$B_S \to D_S\,\pi$

$"B_S \to J/\psi\,\Phi"$

easy trigger!

- admixture of CP-even and CP-odd states

- the $\Delta\Gamma_S$ error depends on the admixture

CDF-RunI: (73 ± 19) % CP-even

Expected sensitivity: CDF-RunII

Mode	Sensitivity	Comments
$B_S \to J/\psi\ \Phi$ $B_S \to D_S\ \pi$	$\sigma(\Delta\Gamma_S/\Gamma_S) \sim 0.035$	100% even
$B_S \to J/\psi\ \Phi$ $B_S \to D_S\ \pi$	$\sigma(\Delta\Gamma_S/\Gamma_S) \sim 0.050$	73% even
$B_S \to J/\psi\ \Phi$ $B_S \to D_S\ \pi$	$\sigma(\Delta\Gamma_S/\Gamma_S) \sim 0.080$	50% even
$B_S \to D_S\ D_S$	$\sigma(\Delta\Gamma_S/\Gamma_S) \sim 0.060$	—

CDF-RunI:

$CP(J/\psi\ \Phi) =$

(73 ± 19) % even

projected #'s

RunI to RunII

(MC: optimistic)

Notes:

- SM gives an upper limit of ~20% for $\Delta\Gamma_S/\Gamma_S$
- To claim a discovery, we need $\geq 5\sigma$

Expected sensitivity: BTeV

Table 8.9: Projections for statistical errors on $\Delta\Gamma_{CP}/\Gamma$ for combining lifetimes from different modes and for using all modes for 2, 10 and 20 fb^{-1}. The values $\Delta\Gamma_{CP}/\Gamma = 0.15$ and $f = 0.229$ are used for the main results and the results for other values of $\Delta\Gamma_{CP}/\Gamma$ and f are also shown for comparison.

Decay Modes Used	Error on $\Delta\Gamma_{CP}/\Gamma$		
	2 fb^{-1}	10 fb^{-1}	20 fb^{-1}
$J/\psi\eta^{(\prime)}$, $D_s^-\pi^+$	0.0273	0.0135	0.0081
$J/\psi\pi$, $D_s^-\pi^+$	0.0349	0.0158	0.0082
$J/\psi\eta^{(\prime)}$, $J/\psi\pi$, $D_s^-\pi^+$	0.0216	0.0095	0.0067
with $\Delta\Gamma_{CP}/\Gamma = 0.03$	0.0198	0.0088	0.0062
with $f = 0.13$	0.0171	0.0077	0.0054
with $f = 0.33$	0.0258	0.0112	0.0078

Report of the B Physics at the Tevatron Workshop

Remember:

$$\Delta\Gamma_S = \Delta\Gamma_{CP}\cos\phi$$

$$a_{CP}(B_S \to J/\psi\,\Phi) \propto \sin\phi$$

Notes:

- SM gives an upper limit of ~20% for $\Delta\Gamma_S/\Gamma_S$
- To claim a discovery, we need $\geq 5\sigma$

Expected sensitivity: LHC

ATLAS, CMS, LHCb:

$$\sigma\left(\frac{\Delta\Gamma_S \cdot \cos\varphi}{\Gamma_S}\right) \sim 0.012 - 0.018$$

Remember:

$$\Delta\Gamma_S \cdot \cos\varphi = \Delta\Gamma_{CP} \cdot \cos^2\varphi$$

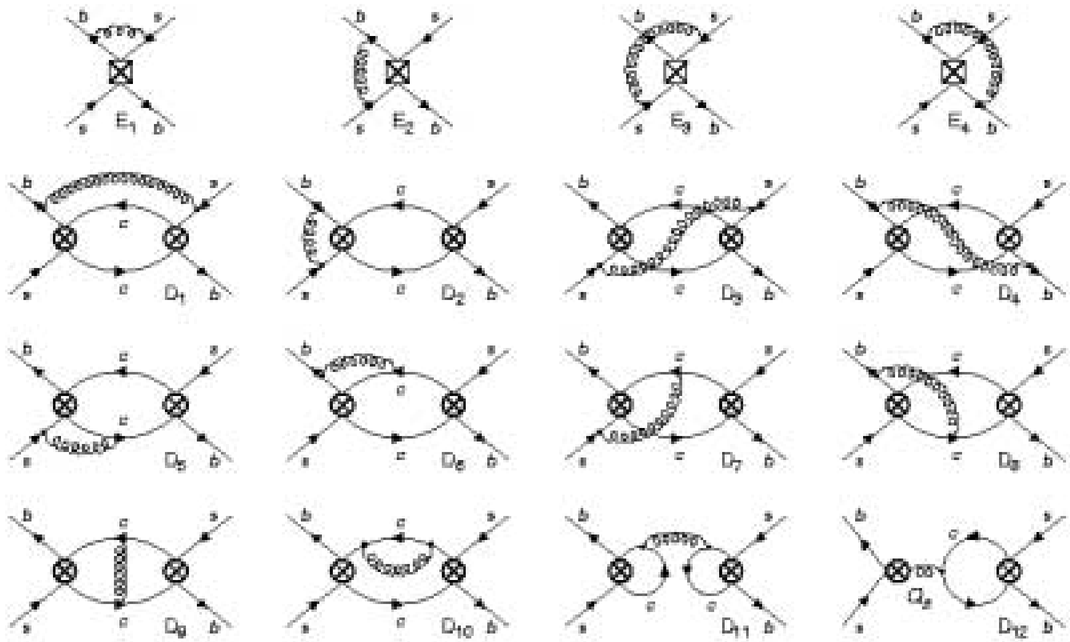
$$a_{CP}(B_S \to J/\psi\ \Phi) \propto \sin\phi$$

Notes:

- SM gives an upper limit of ~20% for $\Delta\Gamma_S/\Gamma_S$
- To claim a discovery, we need $\geq 5\sigma$

Phenomenology: prospects

How did we calculate $(\Delta\Gamma/\Gamma)_{B_s}$?



Alexander Lenz
(Regensburg)

…Phenomenology: prospects

- no NLO: $B = B_S = 1 \quad f_{B_s} = 210 MeV$
- Till 1999: $B(m_b) = 0.9 \quad B_S(m_b) = 0.75 \quad f_{B_s} = 210 MeV$
- Summer conferences 1999:
  $B(m_b) = 0.76 \quad B_S(m_b) = 1.19 \quad f_{B_s} = 245 MeV$
  Yamata et al., Hashimoto

$\Delta\Gamma/\Gamma$	LO	LO + $1/m_b$	NLO
B=1	22 %	16 %	-
old	17%	10 %	6 %
new	35 %	27 %	16 %

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History on $\Delta\Gamma_S$

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.

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

early 90's

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

Isard Dunietz (Fermilab)

…History on $\Delta\Gamma_S$

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

Aleksan et al

Bigi et al — late 90's

Beneke, Buchalla, Dunietz

Beneke, Buchalla, Greub, Lenz, Nierste

Isard Dunietz (Fermilab)

Possible scenarios

CDF x_s Measures in SM range	$\Delta\Gamma_{B_s}$ too small to measure	Depending on Lattice errors…could be new physics
	$\Delta\Gamma_{B_s}$ measured	Test SM prediction
x_s too big to measure	$\Delta\Gamma_{B_s}$ too small to measure	Likely to be new physics
	$\Delta\Gamma_{B_s}$ measured	Depending on measurement and lattice errors..could still be new physics

Matin Martin (Oxford)

Expected sensitivities: References

- http://mit2.fnal.gov/~paus/bw1999/MEETINGS/000217-delta-gamma.ps
- http://www-theory.fnal.gov/people/nierste/second_ws_talks/martin.ps.gz
- http://www-theory.fnal.gov/people/nierste/second_ws_talks/cheung.ps.gz
- http://home.fnal.gov/~cheung/Public/run2/btev_deltag.ps.gz
- http://home.fnal.gov/~cheung/Public/run2/main.ps.gz
- http://mit.fnal.gov/~paus/TMP/Breport/main.ps
- http://cern.ch/nierste/uli.ps
- hep-ph/0003238