Lifetime and Spectroscopy of Bottom and Charm Hadrons

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Introduction

Physics motivation

Spectroscopy

- Charm hadrons
- Bottom hadrons

Lifetime

- Charm hadron lifetimes
- Bottom hadron lifetimes

I discuss mainly bottom hadrons.

Why spectroscopy and lifetime?

Mass and lifetime are the fundamental properties of a particle.
→ Entries to Particle Data Book.

For bottom and charm hadrons:

Spectroscopy

- Insights into QCD potential.
- All pseudoscalar and vector states have been established.
- Some $L = 1$ states established, others just coming out.
- Heavy quark symmetry.

  N. Isgur and M. Wise, Phys. Rev. Lett. **66**, 1130 (1991).

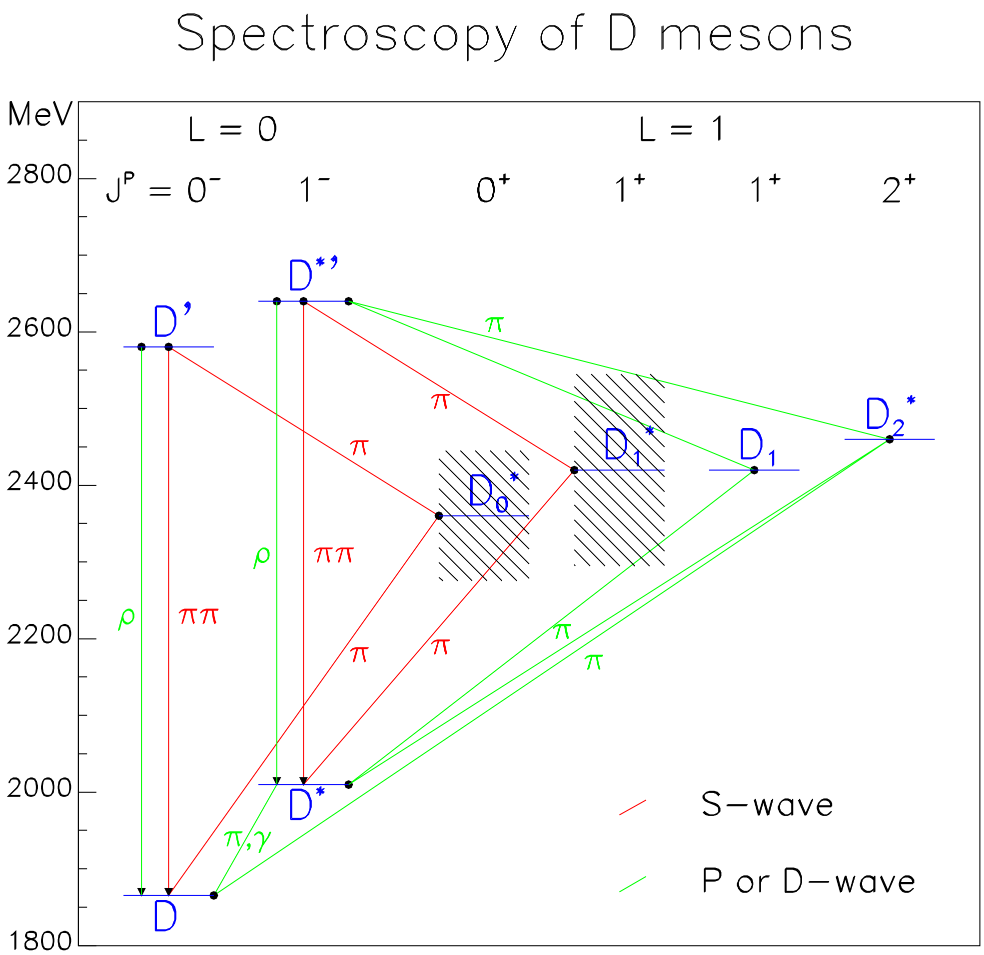
  J. Rosner, Comm. Nucl. Part. Phys. **16**, 109 (1986).

  Heavy-light meson is more like the hydrogen atom rather than the positronium.

Lifetime

- Need $\tau = 1/\Gamma$ to extract $|V_{cb}|$, $|V_{cs}|$.
- At zero-th order, the decay of a heavy hadron is the decay of a heavy quark Q.
  $\rightarrow$ All hadrons with Q should have the same lifetime.
- For charm, this is far from reality:
  $$\tau(D^+) \sim 2.5 \times \tau(D^0).$$
  Perhaps charm is not heavy enough.
  Should be a better approximation for bottom.
- Heavy quark expansion to predict lifetime differences.
  $\Delta\tau \sim \mathcal{O}(10\%)$ for B hadrons.
- Experimental precision still getting better.
  D_s^+ lifetime is different from D^0.
  Beginning to see $\tau(B^+) > \tau(B^0)$?
  $\Delta\Gamma \neq 0$ in B_s^0-$\overline{B}_s^0$ system?

Charm Spectroscopy



- D^{**} mesons: $c\bar{q}$ states with $L = 1$.
- $L = 1$ and $S = 0, 1 \rightarrow$ Four states, $J^P = 1^+, 0^+, 1^+, 2^+$.

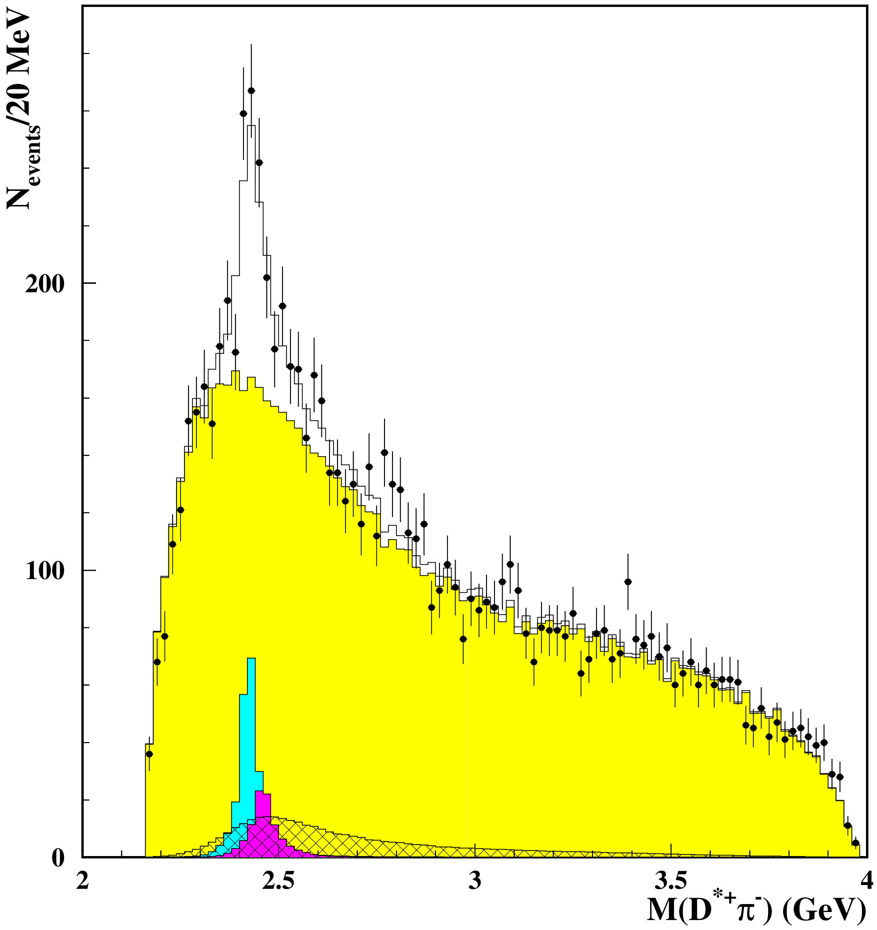
\- $J^P = 0^+$ to $D\pi$, $J^P = 1^+$ to $D^*\pi$, $J^P = 2^+$ to $D\pi$, $D^*\pi$.

- HQET: (in the limit of $m_Q = \infty$)

\- For a $Q\bar{q}$ system, $j = L + S_{\bar{q}}$ is a good quantum number.
$\rightarrow$ doublets with $j = 1/2$ $(J = 0, 1)$ and $j = 3/2$ $(J = 1, 2)$.
\- $j = 3/2$ doublet decays via only D-wave $\Rightarrow$ Narrow.
\- $j = 1/2$ doublet decays via only S-wave $\Rightarrow$ Broad.
\- D_1 and D_2^* (narrow) states have been established.

Wide D^{**} States

CLEO: CLEO CONF 99-6
Use $B^- \to D^{*+}\pi^-\pi^-$, and study $D^{*+}\pi^-$ pairs.
Partial reconstruction: $D^{*+} \to D^0\pi^+$ but D^0 not reconstructed.



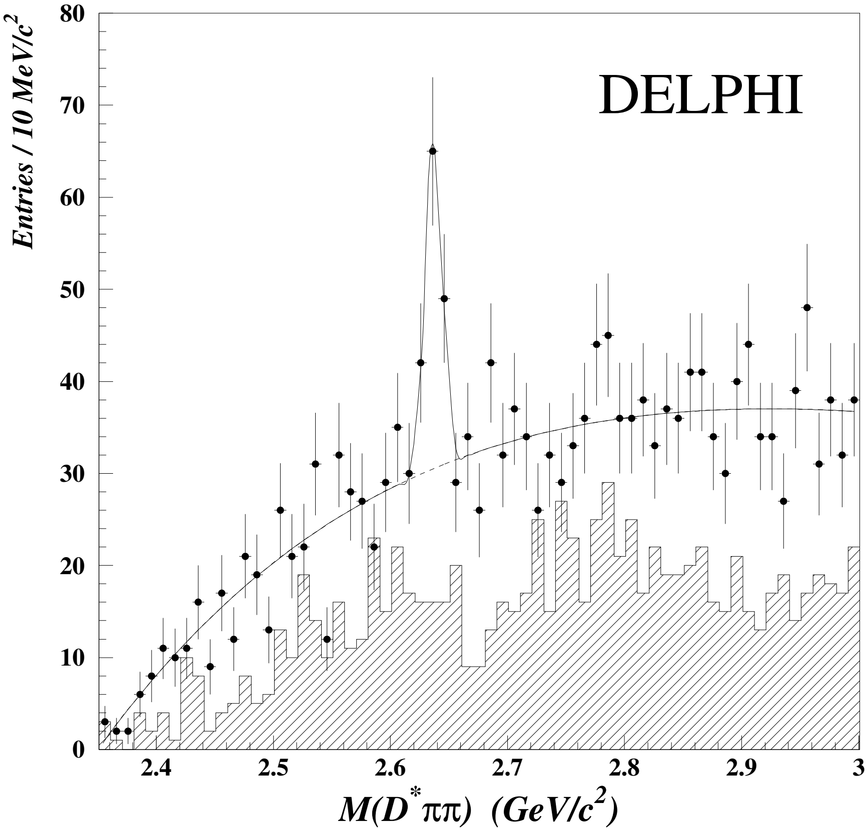
$$m = 2461\,^{+41}_{-34} \pm 10 \pm 32\ \mathrm{MeV}/c^2.$$

$$\Gamma = 290\,^{+101}_{-79} \pm 26 \pm 36\ \mathrm{MeV}/c^2.$$

$$\mathcal{B}(B^- \to D_1^{*0}\pi^-) \cdot \mathcal{B}(D_1^{*0} \to D^{*+}\pi^-\ )$$
$$= (10.6 \pm 1.9 \pm 1.7 \pm 2.3) \times 10^{-4}.$$

Radial Excitation $D^{*\prime}$

DELPHI: Phys. Lett. **B426**, 231 (1998).
$D^{*\prime +} \to D^{*+}\pi^+\pi^-$,
with $D^{*+} \to D^0\pi^-$, $D^0 \to K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$.



Signal: 66 ± 14 events.
$m(D^{*\prime}) = 2637 \pm 2 \pm 6$ MeV, $\Gamma < 15$ MeV at 95% C.L.

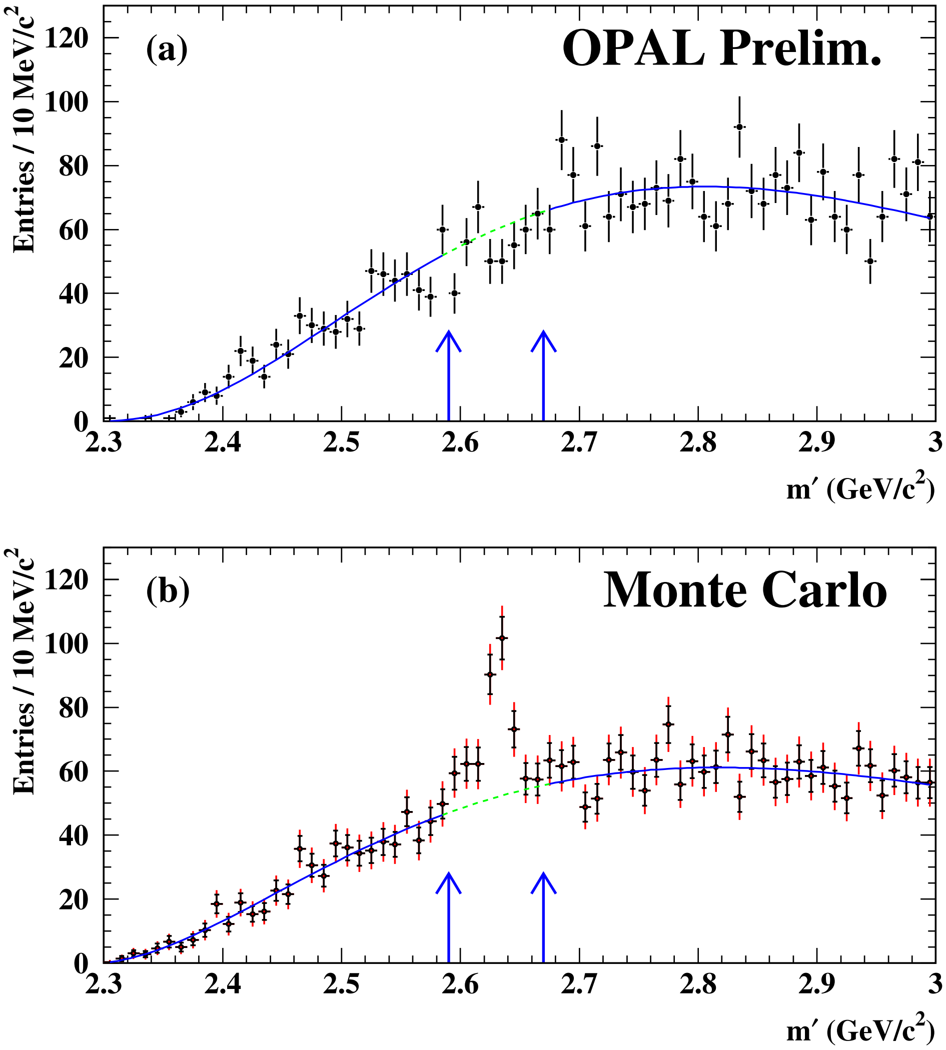
Not seen by OPAL or CLEO.

Ratio $R = N(D^{*\prime} \to D^{*+}\pi^+\pi^-)/N(D_1^0, D_2^{*2} \to D^{*+}\pi^-)$:

$R = 0.49 \pm 0.18 \pm 0.10$		DELPHI	
$R < 0.21$	(95% C.L.)	OPAL	PN 352 (ICHEP98)
$R < 0.16$	(90% C.L.)	CLEO	hep-ex/9901008

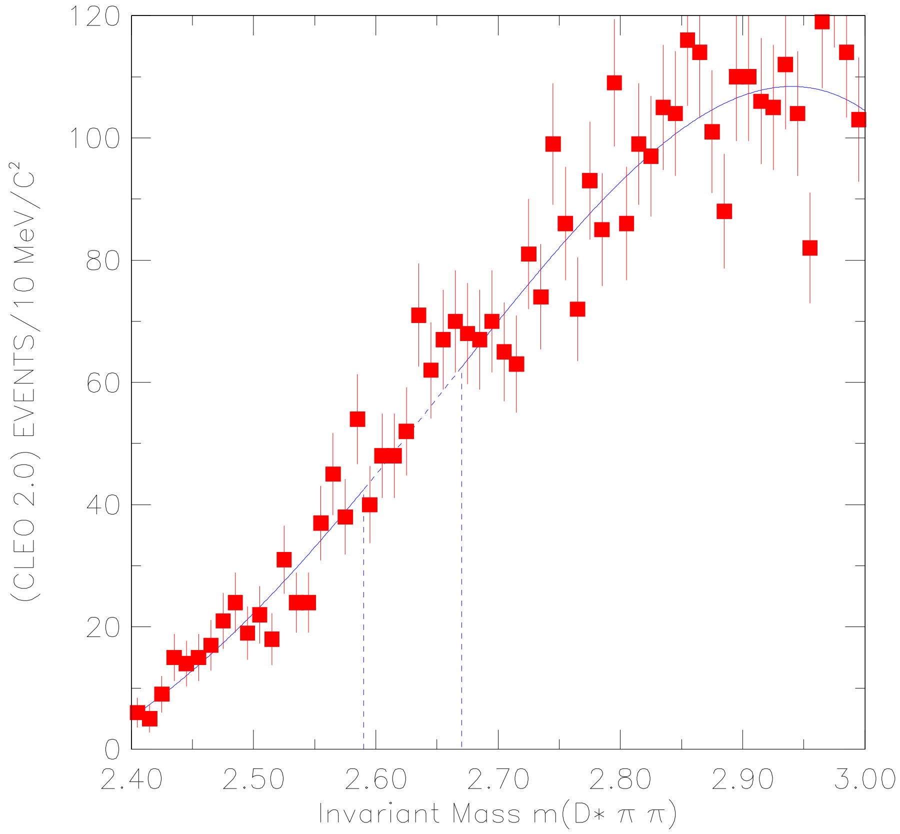
OPAL

PN 352
(ICHEP 98).



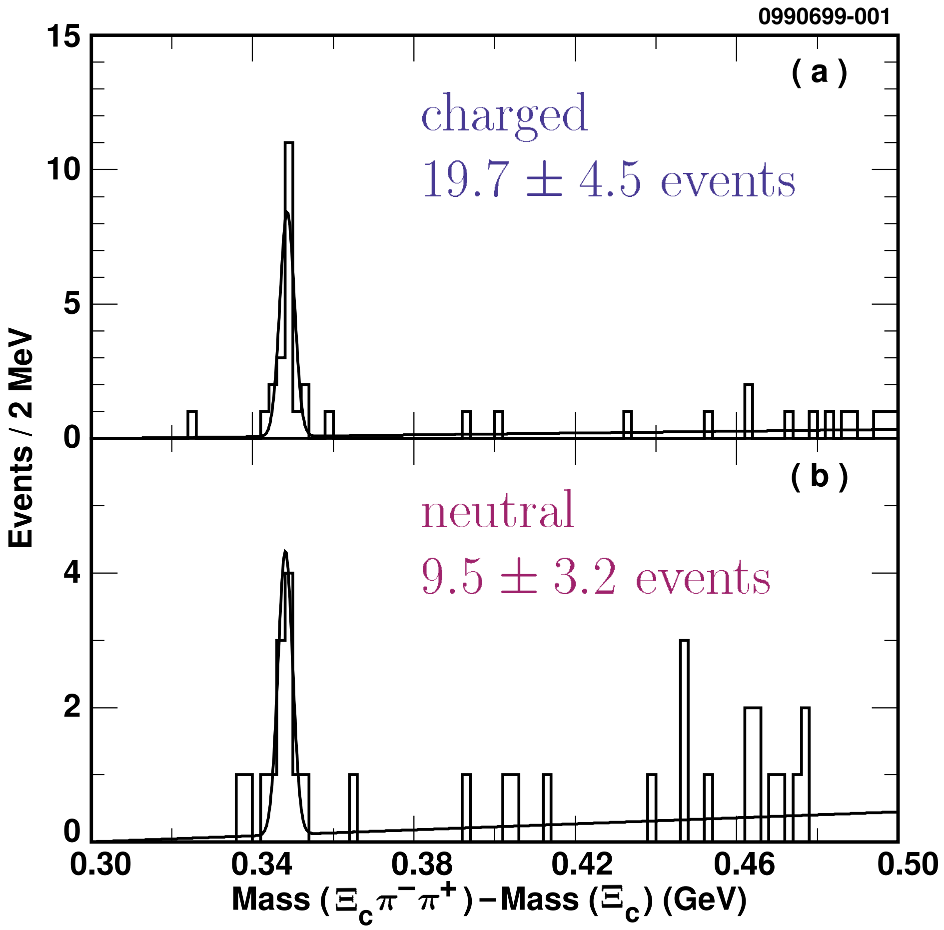
CLEO

hep-ex/9901008.



Charmed Baryons

CLEO: Phys. Rev. Lett. **83**, 3390 (1999).
4.8 fb^{-1} of e^+e^- annihilation near $\Upsilon(4S)$.
Charged $\rightarrow \Xi_c^+\pi^+\pi^-$ via $\Xi_c^{*0}\pi^+$.
Neutral $\rightarrow \Xi_c^0\pi^+\pi^-$ via $\Xi_c^{*+}\pi^-$.
Ξ_c^+ (Ξ_c^0) reconstructed in 3 (6) modes, e.g. $\Xi^0\pi^+\pi^-$ ($\Xi^-\pi^+$).
Examine the mass difference $\Delta m \equiv m(\Xi_c^*\pi) - m(\Xi_c^*)$:



Mass: $\Delta m = 348.6 \pm 0.6$ and 347.2 ± 0.7 MeV.
Width: $\Gamma < 3.5$ and < 6.5 MeV.

Interpreted as the $J^P = \frac{3}{2}^-$ Ξ_{c1} isospin doublet.
($L = 1$ orbital excitation of Ξ_c)

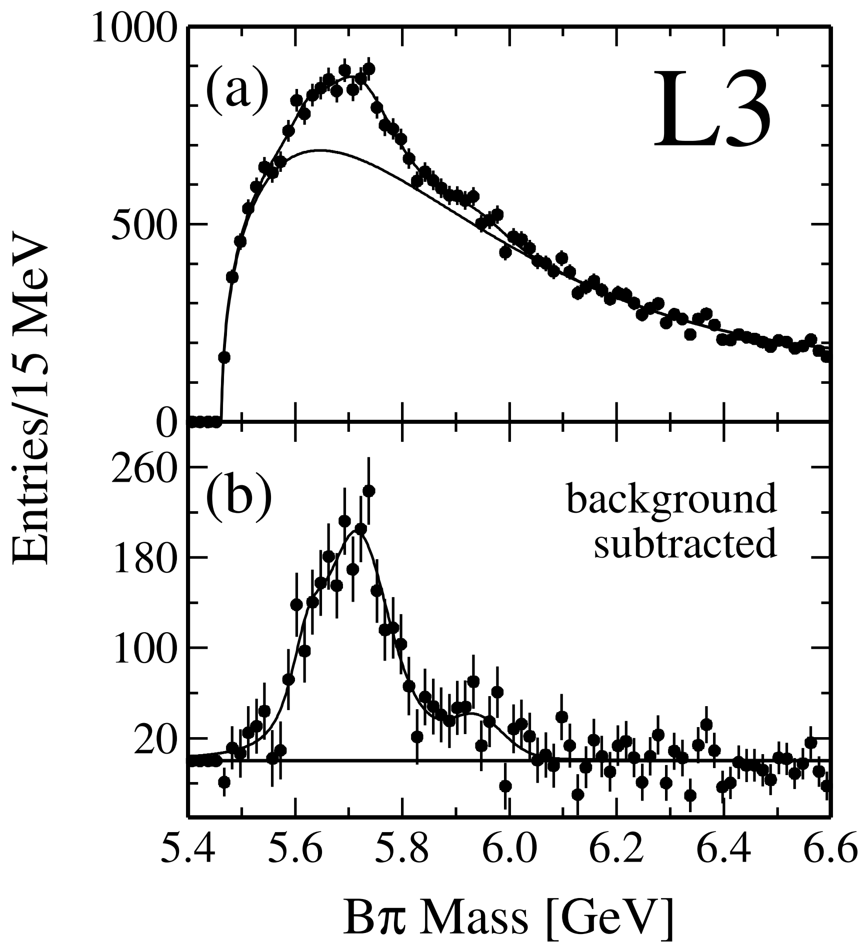
Bottom Spectroscopy

- B and B^* well established.
- B^{**} seen (LEP, CDF).

L3: L3 Note 2423 (EPS 99)

Inclusive B reconstruction (secondary vertex).

Combine with a pion from the primary vertex $\rightarrow m(B\pi)$:



B_1^*: $m = 5670 \pm 10 \pm 13$ MeV, $\Gamma = 70 \pm 21 \pm 25$ MeV.

B_2^*: $m = 5768 \pm 5 \pm 6$ MeV, $\Gamma = 24 \pm 19 \pm 24$ MeV.

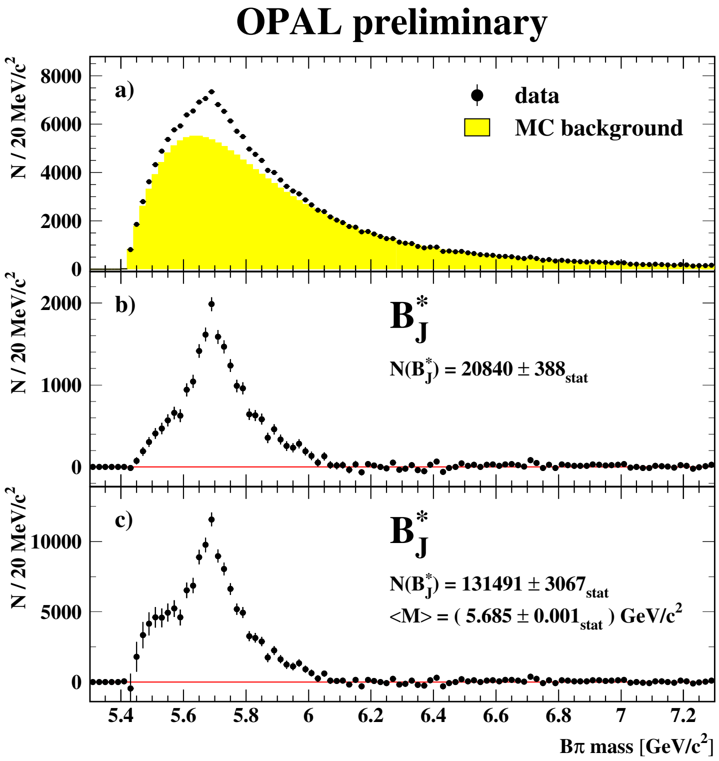
$f(b \rightarrow B^{**} \rightarrow B^{(*)}\pi) = 0.32 \pm 0.03 \pm 0.06$.

Also B': $m = 5937 \pm 21 \pm 4$ MeV, $\sigma = 50 \pm 22 \pm 5$ MeV.

$f(b \rightarrow B' \rightarrow B^{(*)}\pi) = 0.034 \pm 0.011 \pm 0.008$.

OPAL: OPAL note PN400 (EPS 99)

Inclusive B reconstruction + pion $\to m(B\pi)$:



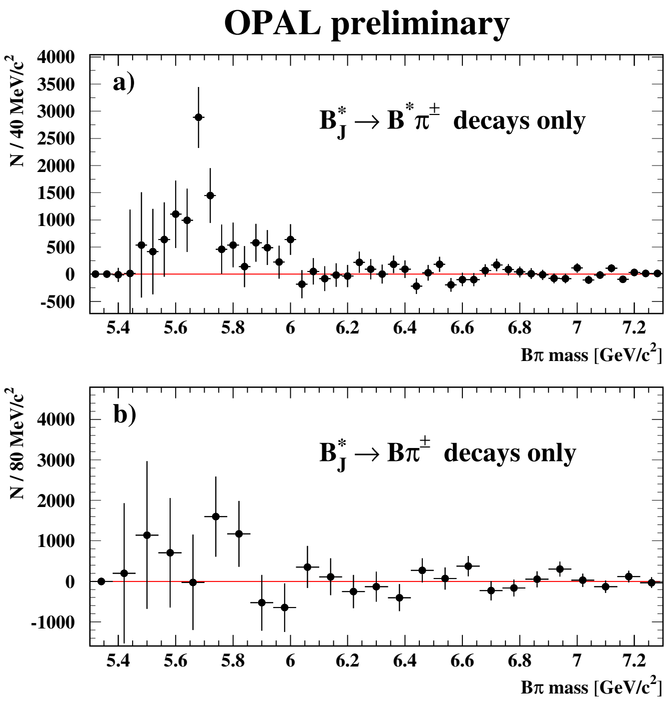
Raw

BG sub.

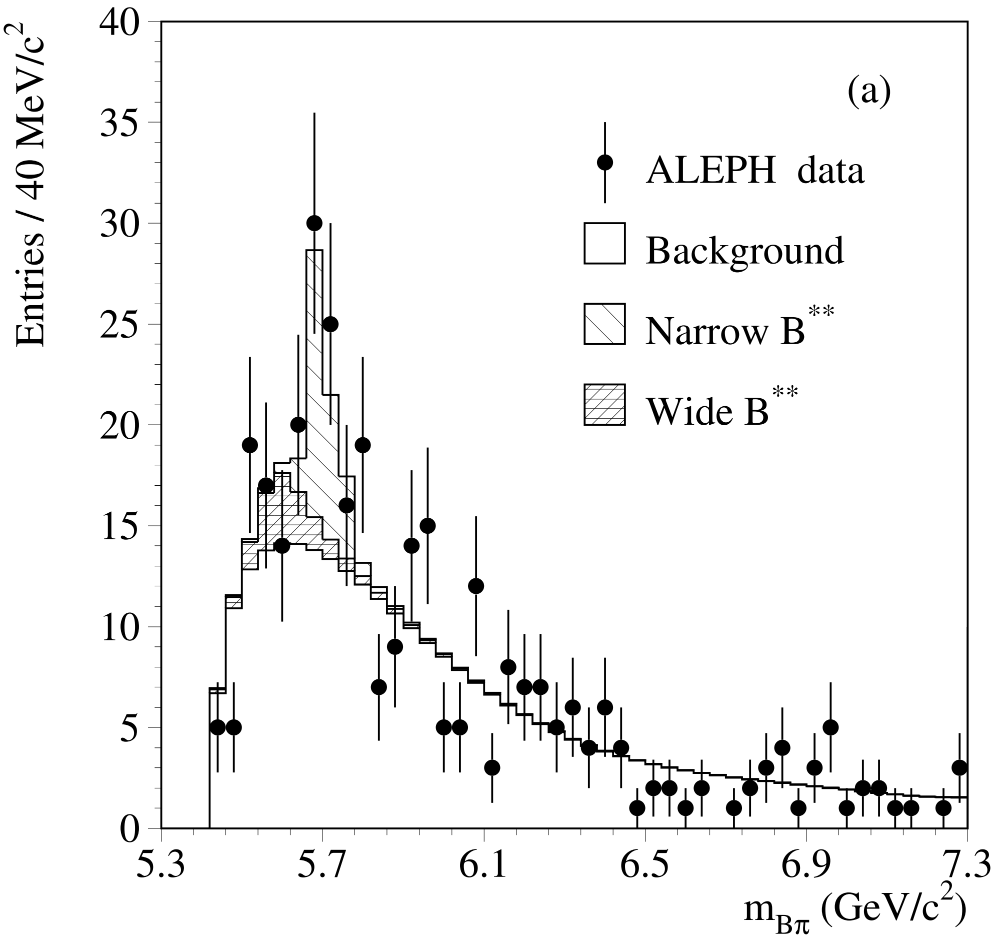
Eff. corr.

Statistical separation of $B^{**} \to B\pi$ and $B^{**} \to B^*\pi$ by looking at γ from B^*. $\Rightarrow$ B^*-enriched and B^*-depleted samples.

$$\mathcal{B}(B^{**} \to B^*\pi) = 0.85\,^{+0.26}_{-0.27} \pm 0.12.$$



ALEPH: Phys. Lett. **B425**, 215 (1998).
Use fully reconstructed decays $B \to D^{(*)} n\pi$, $J/\psi K^{(*)}$, to get better resolution in $m(B)$ and thus in $m(B\pi)$:



$$m(B_2^*) = 5739\,^{+8}_{-11}\,^{+6}_{-4} \text{ MeV.}$$
$$f(b \to B^{**} \to B^{(*)}\pi) = 0.31 \pm 0.09\,^{+6}_{-5}.$$

- B^{**} important for "same-side" flavor tagging :

- Example: $D^{*+} \to D^0\pi^+$.
- $m(B^*) - m(B) \sim 50$ MeV$/c^2$, then $B^* \to B\gamma$.
- B^{**} is the main state that can give a correlated charged particle.
- Also fragmentation particles contribute.

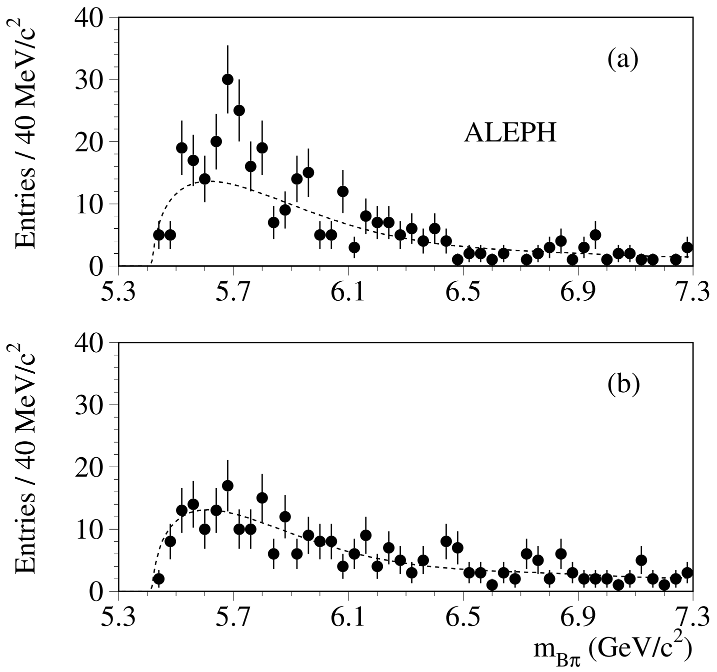
Charge correlation is the same regardless of resonant (B^{**}) or non-resonant (fragmentation).
Need to separate charged and neutral B's.

ALEPH: B^{**} analysis (continued).

Fully reconstructed decays, $B \to D^{(*)}\, n\pi$, $J/\psi K^{(*)}$, and look at "right-sign" and "wrong-sign" pions :
(actually previous plot was already for right-sign)

Right sign

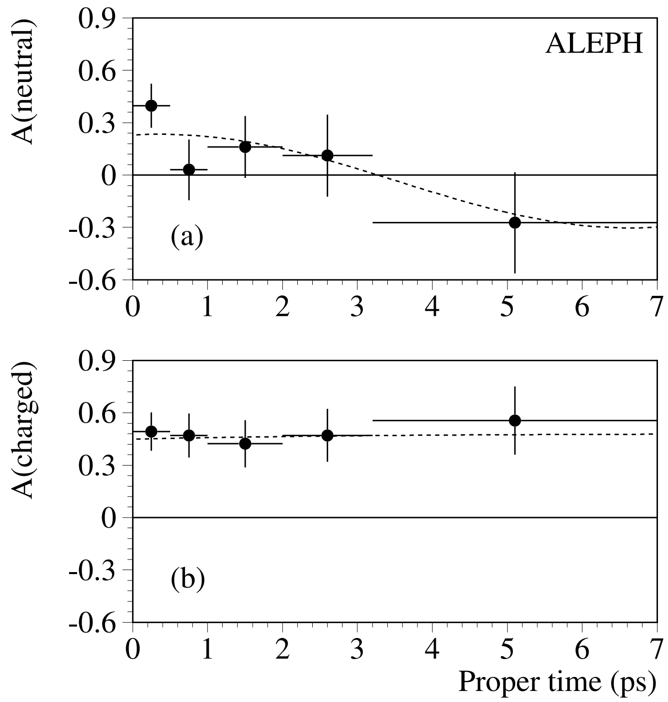
Wrong sign



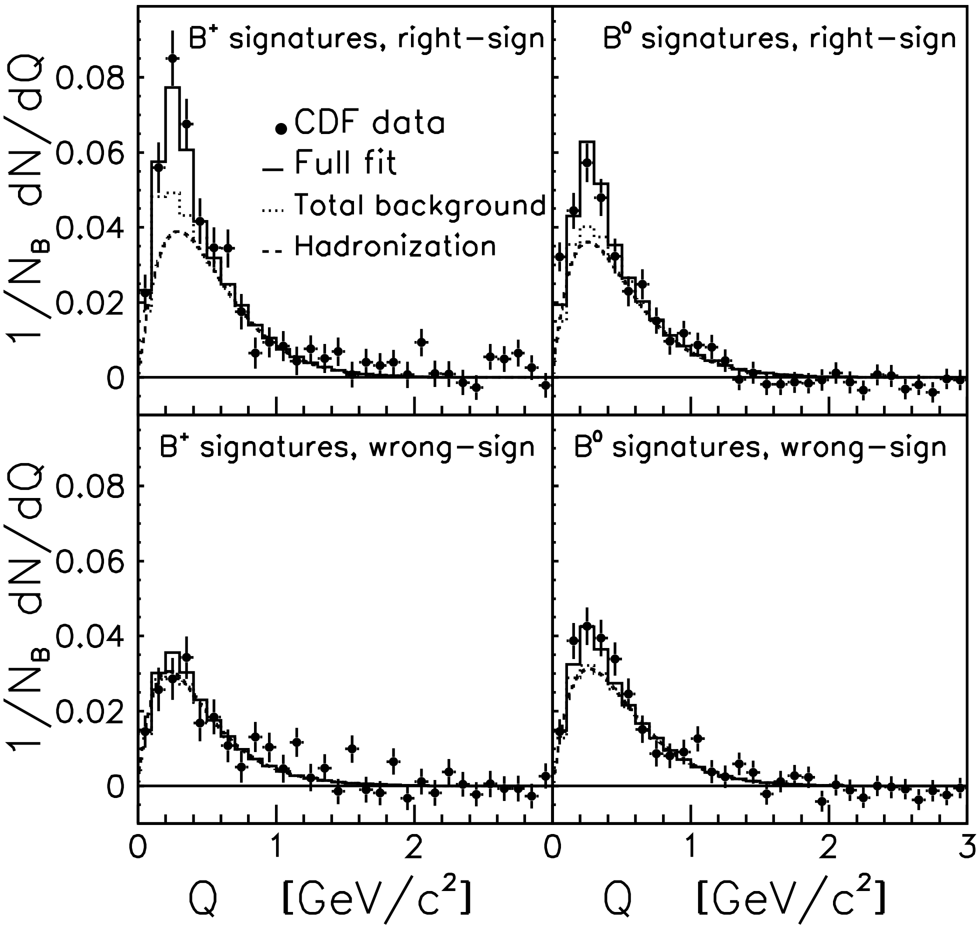
Time development of asymmetry. $\Rightarrow$ mixing for B^0 !

B^0 $\quad D = 0.31 \pm 0.11$

B^+ $\quad D = 0.48 \pm 0.07$



CDF: FERMILAB-Pub-99/330-E, submitted to PRD.
Use $\ell^- D^{(*)+}$ and $\ell^- D^0$ pairs to get $\overline{B}^0$ and B^-.



Note:
Tag purity (dilution) higher for B^+ than for B^0 :
The s-quark in the second fragmentation chain helps B^+, hurts B^0.

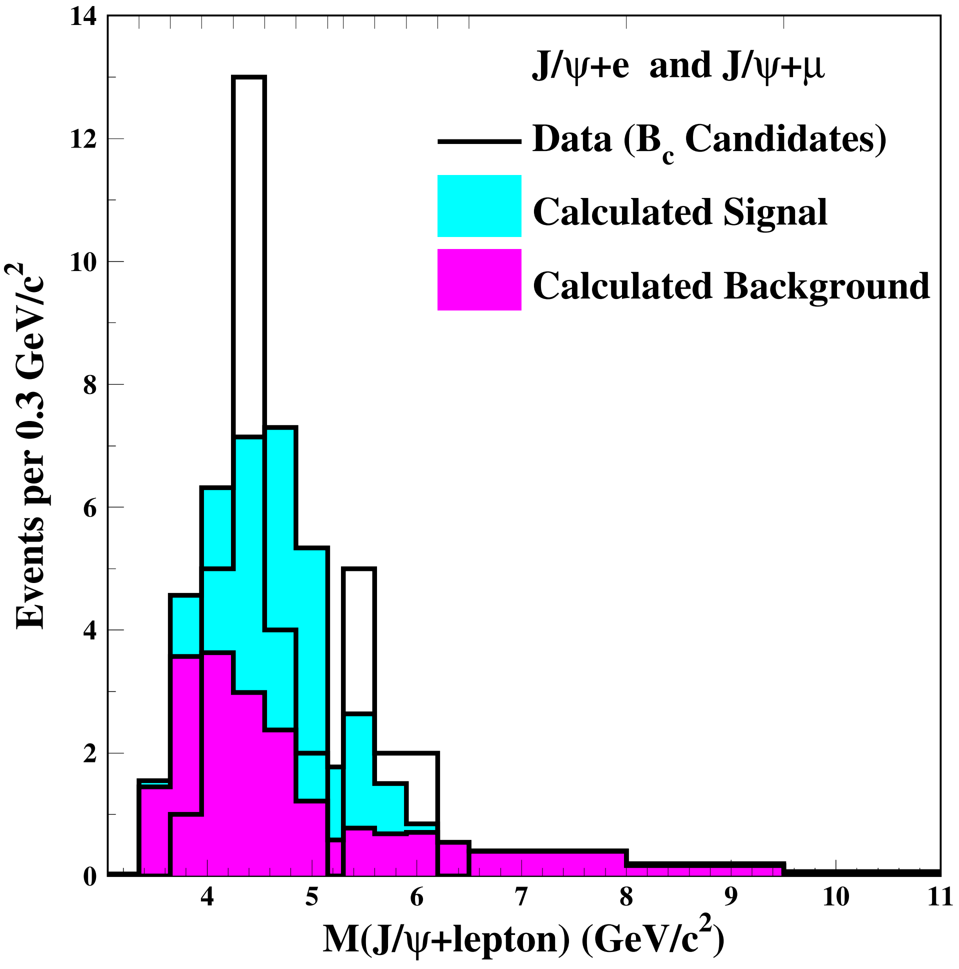
Particle ID should help, esp. for B_s^0.

Could get higher purity when cut on mass.

The $B_c^{\pm}$ meson

$B_c^- \equiv b\bar{c}$, contains two different heavy quarks.

CDF: PRL **81**, 2432 (1998); PRD **58**, 112004 (1998).
Use semileptonic decay $B_c^- \to \ell^- \bar{\nu} J/\psi X$, $J/\psi \to \mu^+\mu^-$.
Look at the three lepton mass:



Signal: $N(B_c) = 20.4\,^{+6.2}_{-5.5}$.
$M(B_c) = 6.40 \pm 0.39 \pm 0.13$ GeV$/c^2$.
Should see exclusive decays e.g. $B_c^- \to J/\psi \pi^-$ in Run II.

Charm hadron lifetimes

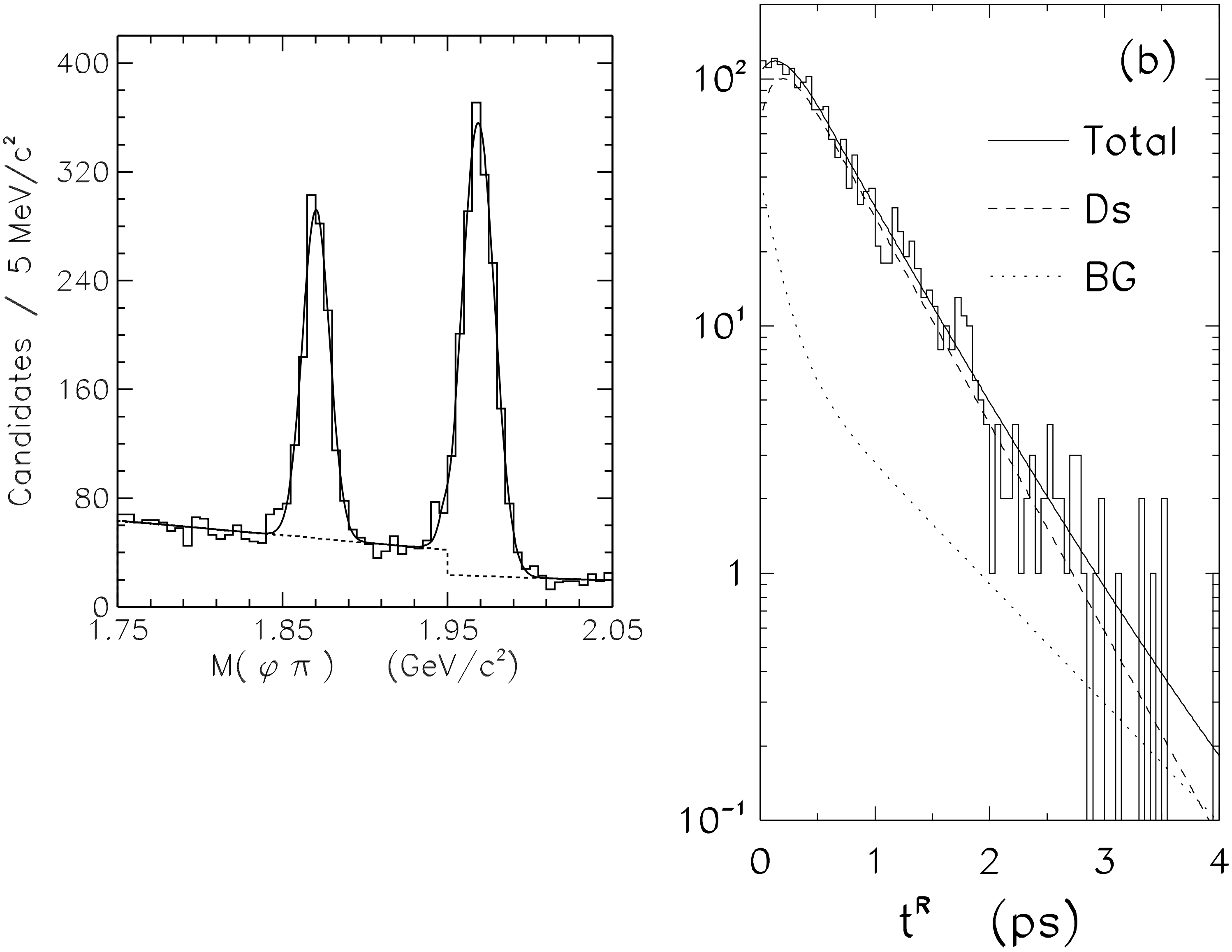
Lifetimes are different among charm hadrons:

- $\tau(D^+)/\tau(D^0) \simeq 2.5$
  $\tau(D_s^+)/\tau(D^0) \sim 1$
  $\tau(\Lambda_c^+)/\tau(D^0) \sim 0.5$
- Final-state Pauli interference, annihilation and W-exchange processes must be very important.

Recent developments:

- New precision in D_s^+ lifetime
  E791, CLEO.
  Now $\tau(D_s^+) \neq \tau(D^0)$ established.
- New experiments: FOCUS, SELEX

E791: Phys. Lett. **B445**, 449 (1999).
500 GeV π^- beam on foil targets. Data in 1991 - 92.
$D_s^+ \to \phi\pi^+$, $\phi \to K^+K^-$.
Fit mass and decay time distributions simultaneously.



$\tau(D_s^+) = 518 \pm 14 \pm 7$ fs
$\tau(D_s^+)/\tau(D^0) = 1.25 \pm 0.04$ using $\tau(D^0) = 415 \pm 4$ fs (PDG 98).

CLEO: Phys. Rev. Lett. **82**, 4586 (1999).

3.7 fb^{-1} of e^+e^- annihilation near $\Upsilon(4S)$.

D states reconstructed with:

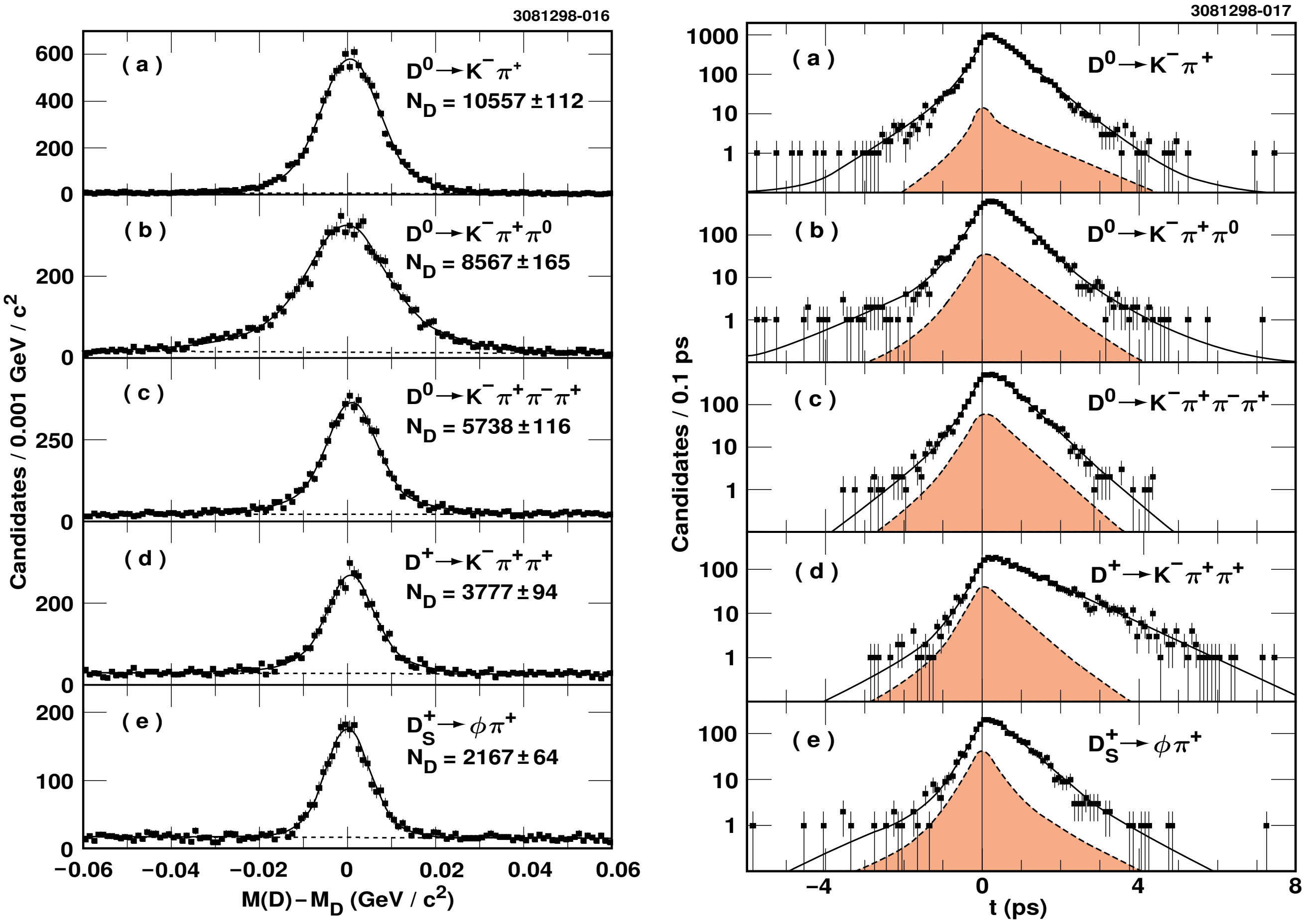
$$D^0 \to K^-\pi^+,\ K^-\pi^+\pi^0,\ K^-\pi^+\pi^+\pi^-.$$

$$D^+ \to K^-\pi^+\pi^+$$

$$D_s^+ \to \phi\pi^+,\ \phi \to K^+K^-.$$

D decay vertex from silicon vertex detector.

Beam spot as the primary vertex.



$$\tau(D^0) = 408.5 \pm 4.1\,^{+\,3.5}_{-\,3.4}\ \mathrm{fs}$$

$$\tau(D^+) = 1033.6 \pm 22.1\,^{+\,9.9}_{-\,12.7}\ \mathrm{fs}$$

$$\tau(D_s^+) = 486.3 \pm 15.0\,^{+\,4.9}_{-\,5.1}\ \mathrm{fs}$$

$$\tau(D_s^+)/\tau(D^0) = 1.19 \pm 0.04$$

Bottom hadron lifetimes

Predictions:

- $\sim 10\%$ difference between B^+ and B^0.
- $\sim 1\%$ between B_s^0 and B^0.
- ~ 0.9 for baryons/B^0.

Techniques:

- Inclusive reconstruction

  Inclusive secondary vertex reconstruction.

  Vertex charge to separate charged and neutral.

  Largest statistics, but samples less pure.

- Partial reconstruction (e.g. semileptonics)

  Lepton with fully reconstructed charm meson.

  Statistics respectable.

  D^{**} introduces B^+/B^0 admixture.

- Full reconstruction

  B mass peak in e.g. $J/\psi K^{(*)}$ or $D^{(*)}n\pi$.

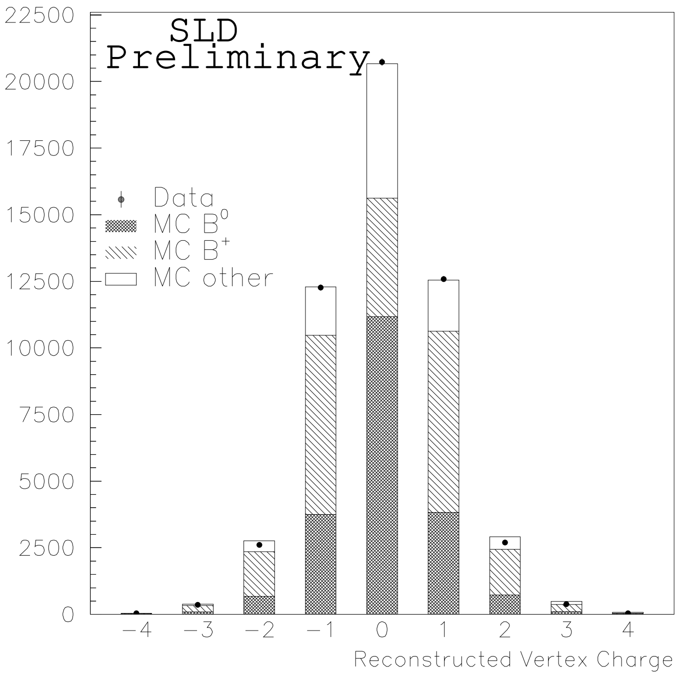
  100% purity.

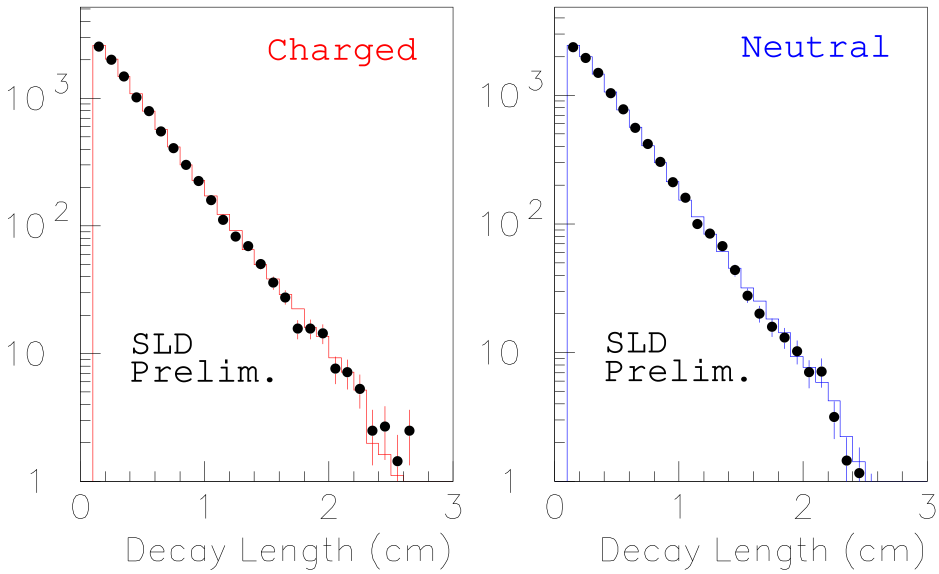
  Momentum known precisely for each event.

  Don't have to assume anything. Free from systematics.

  Low stat due to branching fractions.

SLD: SLAC-PUB-8206 (EPS99, LP99)
350 k hadronic Z^0 decays (97 - 98).
Inclusive B reconstruction (secondary vertex).
Vertex charge:

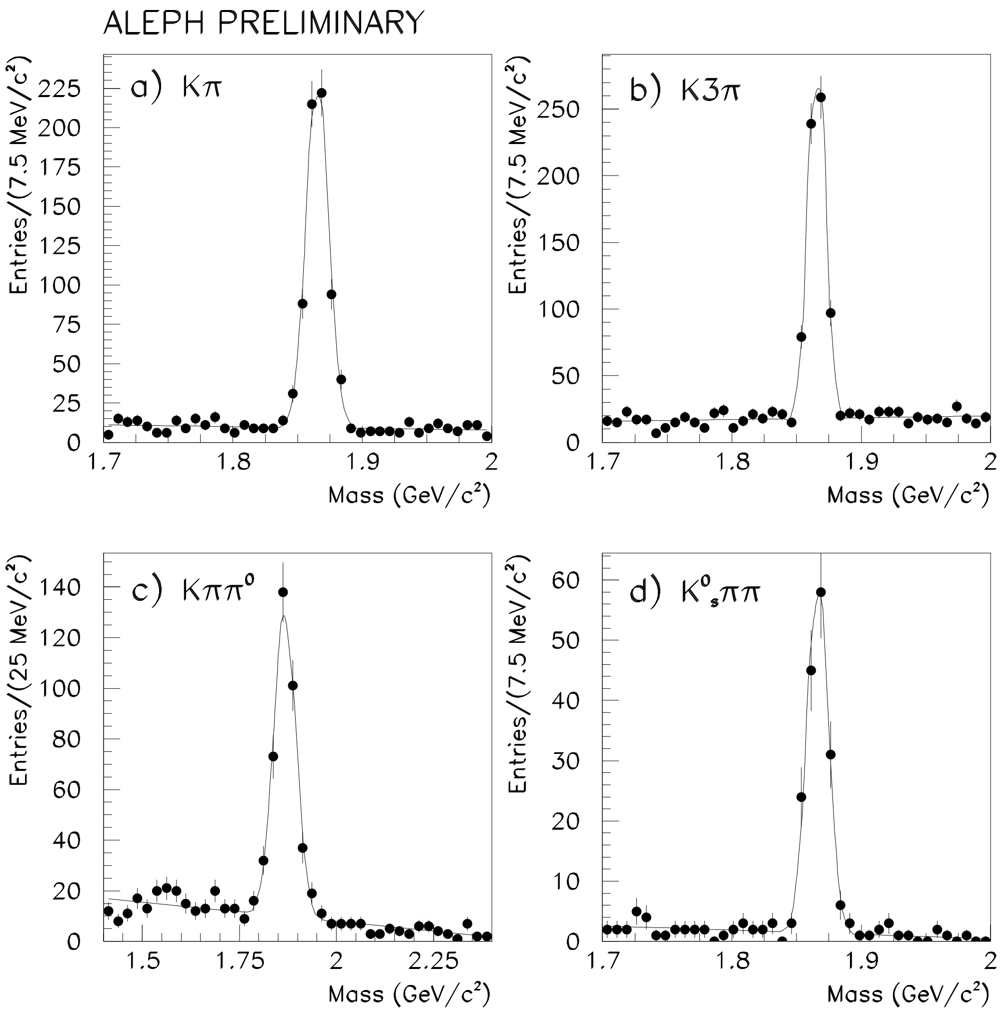




$$\tau(B^+) = 1.623 \pm 0.020 \pm 0.034 \text{ ps}$$
$$\tau(B^0) = 1.589 \pm 0.021 \pm 0.043 \text{ ps}$$
$$\tau(B^+)/\tau(B^0) = 1.037 \,^{+0.025}_{-0.024} \pm 0.024$$

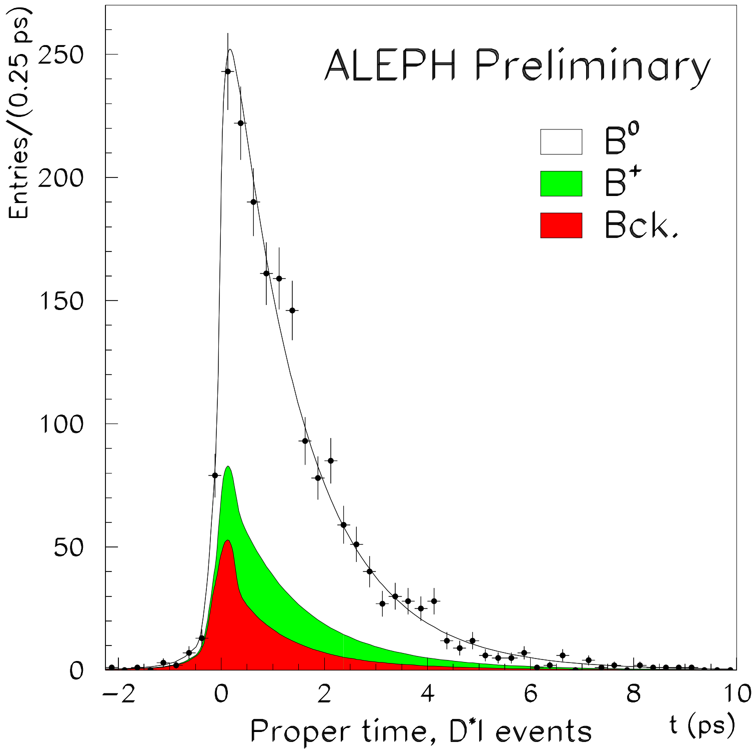
ALEPH: ALEPH 99-005 (winter 99)
Re-analysis of 4 M hadronic Z^0 decays (91 - 95).
Use $\ell^- D^{*+}$ (mostly $\overline{B}^0$) and $\ell^- D^0$ (mostly B^-) events.

Charm reconstruction:
$D^{*+} \to D^0 \pi^+$,
with $D^0 \to K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$, $K^-\pi^+\pi^0$, $K^0_S\pi^+\pi^-$.

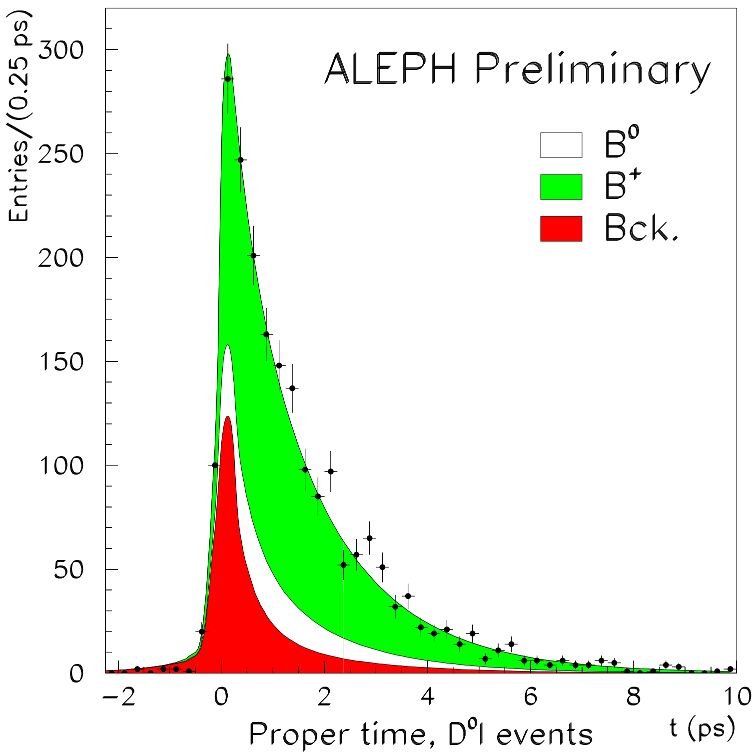


D^0 not from D^{*+},
with $D^0 \to K^-\pi^+$, $K^-\pi^+\pi^0$, $K^0_S\pi^+\pi^-$.
Similar signals observed.

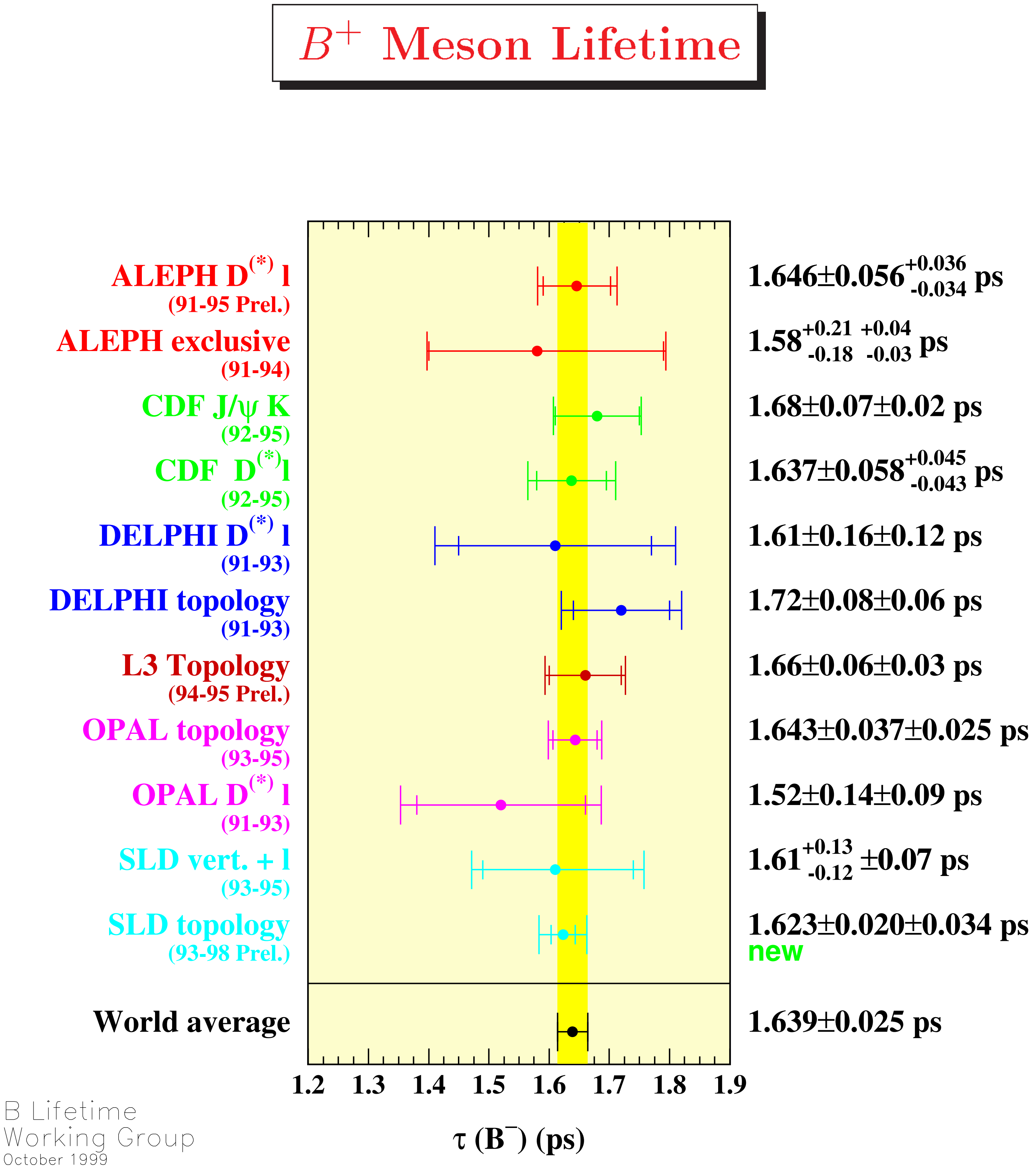
$\ell^- D^{*+}$



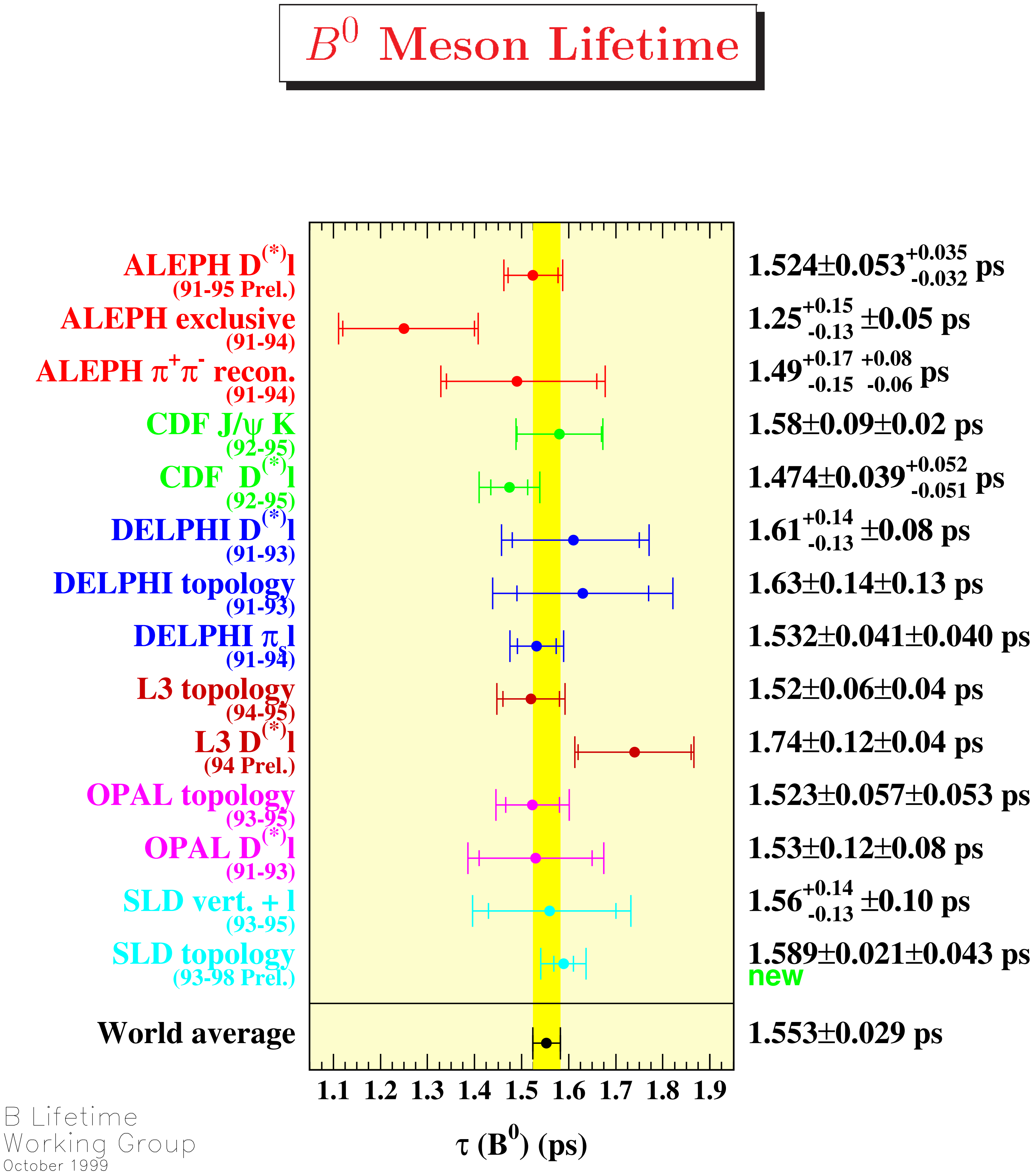
$\ell^- D^0$



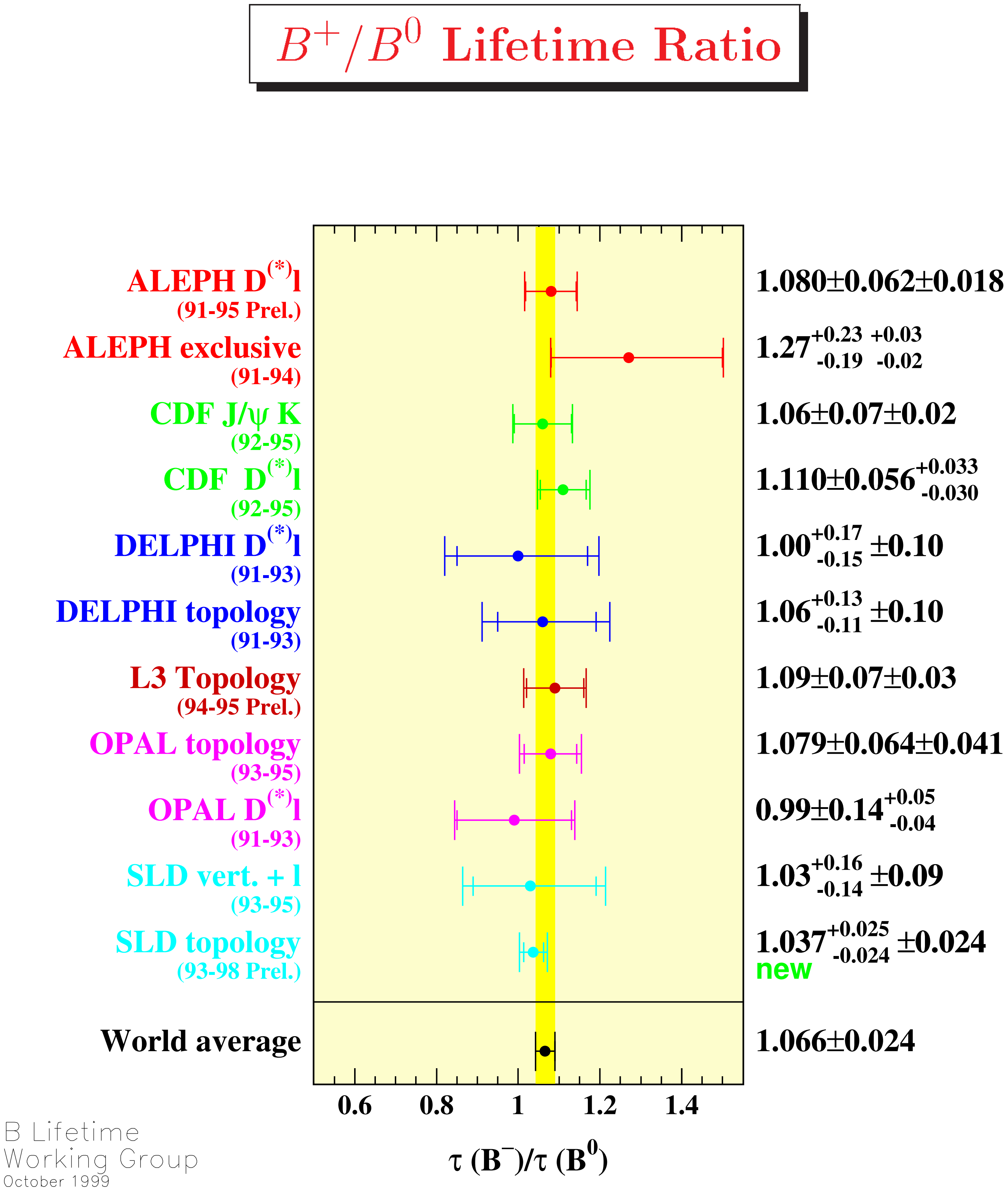
$$\tau(B^+) = 1.646 \pm 0.056 \,^{+0.036}_{-0.034} \text{ ps}$$
$$\tau(B^0) = 1.524 \pm 0.053 \,^{+0.035}_{-0.032} \text{ ps}$$
$$\tau(B^+)/\tau(B^0) = 1.080 \pm 0.062 \pm 0.018$$



B+ Meson Lifetime
ALEPH D(*) l
(91-95 Prel.)
1.646±0.056 +0.036 -0.034 ps
ALEPH exclusive
(91-94)
1.58 +0.21 -0.18 +0.04 -0.03 ps
CDF J/ψ K
(92-95)
1.68±0.07±0.02 ps
CDF D(*)l
(92-95)
1.637±0.058 +0.045 -0.043 ps
DELPHI D(*) l
(91-93)
1.61±0.16±0.12 ps
DELPHI topology
(91-93)
1.72±0.08±0.06 ps
L3 Topology
(94-95 Prel.)
1.66±0.06±0.03 ps
OPAL topology
(93-95)
1.643±0.037±0.025 ps
OPAL D(*) l
(91-93)
1.52±0.14±0.09 ps
SLD vert. + l
(93-95)
1.61 +0.13 -0.12 ±0.07 ps
SLD topology
(93-98 Prel.)
1.623±0.020±0.034 ps
new
World average
1.639±0.025 ps
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
τ (B⁻) (ps)
B Lifetime
Working Group
October 1999



B^0 Meson Lifetime
ALEPH D(*)l (91-95 Prel.)
1.524±0.053 +0.035 -0.032 ps
ALEPH exclusive (91-94)
1.25 +0.15 -0.13 ±0.05 ps
ALEPH π+π- recon. (91-94)
1.49 +0.17 -0.15 +0.08 -0.06 ps
CDF J/ψ K (92-95)
1.58±0.09±0.02 ps
CDF D(*)l (92-95)
1.474±0.039 +0.052 -0.051 ps
DELPHI D(*)l (91-93)
1.61 +0.14 -0.13 ±0.08 ps
DELPHI topology (91-93)
1.63±0.14±0.13 ps
DELPHI π l (91-94)
1.532±0.041±0.040 ps
L3 topology (94-95)
1.52±0.06±0.04 ps
L3 D(*)l (94 Prel.)
1.74±0.12±0.04 ps
OPAL topology (93-95)
1.523±0.057±0.053 ps
OPAL D(*)l (91-93)
1.53±0.12±0.08 ps
SLD vert. + l (93-95)
1.56 +0.14 -0.13 ±0.10 ps
SLD topology (93-98 Prel.)
1.589±0.021±0.043 ps
new
World average
1.553±0.029 ps
1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9
τ (B0) (ps)
B Lifetime Working Group
October 1999



B^+/B^0 Lifetime Ratio
ALEPH $D^{(*)}l$
(91-95 Prel.)
$1.080 \pm 0.062 \pm 0.018$
ALEPH exclusive
(91-94)
$1.27^{+0.23}_{-0.19}\,^{+0.03}_{-0.02}$
CDF J/ψ K
(92-95)
$1.06 \pm 0.07 \pm 0.02$
CDF $D^{(*)}l$
(92-95)
$1.110 \pm 0.056^{+0.033}_{-0.030}$
DELPHI $D^{(*)}l$
(91-93)
$1.00^{+0.17}_{-0.15} \pm 0.10$
DELPHI topology
(91-93)
$1.06^{+0.13}_{-0.11} \pm 0.10$
L3 Topology
(94-95 Prel.)
$1.09 \pm 0.07 \pm 0.03$
OPAL topology
(93-95)
$1.079 \pm 0.064 \pm 0.041$
OPAL $D^{(*)}l$
(91-93)
$0.99 \pm 0.14^{+0.05}_{-0.04}$
SLD vert. + l
(93-95)
$1.03^{+0.16}_{-0.14} \pm 0.09$
SLD topology
(93-98 Prel.)
$1.037^{+0.025}_{-0.024} \pm 0.024$
new
World average
1.066 ± 0.024
0.6
0.8
1
1.2
1.4
$\tau(B^-)/\tau(B^0)$
B Lifetime
Working Group
October 1999

B_s^0 Meson Lifetimes

- Use $D_s^+\ell^- X$ or $D_s^+h^- X$ as the B_s^0 signature.
- $\tau(B_s^0)/\tau(B_d^0) = 1 \pm \mathcal{O}(1\%)$ expected.
  $\rightarrow$ Not much we can do for now.

- Neutral mesons mix.
  Flavor eigenstates $\leftrightarrow$ mass eigenstates.
  Example: K^0 and $\overline{K}^0 \leftrightarrow K_S^0$ and K_L^0.
  $B_{s,L}^0 =$ short $\sim CP$-even, $B_{s,H}^0 =$ long $\sim CP$-odd.
- $\Delta\Gamma \equiv \Gamma_L - \Gamma_H$ can be non-zero.
  Expect $\Delta\Gamma/\Gamma \sim 0$ for B_d^0,
  can be $(10-20)\%$ for B_s^0.
- Sizable $\Delta\Gamma_s$ interesting because:
  - We should see it.
  - May allow CP studies with untagged decays.
  - $\Delta m_s/\Delta\Gamma_s \sim -180$, indep. of CKM elements.
  - $\Delta\Gamma$ smaller than SM if new physics.
- $\Delta\Gamma$ shows up as
  $\tau(\overline{B}_s^0 \rightarrow \ell^-\bar{\nu}D_s^+X) \neq \tau(\overline{B}_s^0 \rightarrow CP\,\text{eigenstate})$.
  - Fit $\overline{B}_s^0 \rightarrow \ell^-\bar{\nu}D_s^+X$ with $e^{-\Gamma_L t} + e^{-\Gamma_H t}$.
  - $B_s^0 \rightarrow J/\psi\phi$, $D^{(*)+}D^{(*)-}$:

  Generally mixture of CP-even and CP-odd.
  $\rightarrow$ Transversity analysis.
  $\rightarrow$ Could be dominated by one CP state.

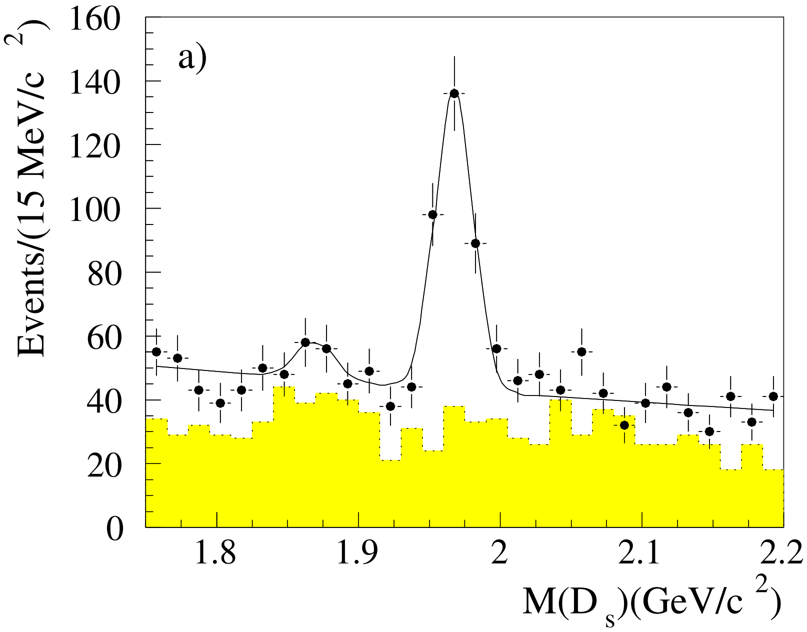
DELPHI: DELPHI 99-109 CONF 296 (EPS99)

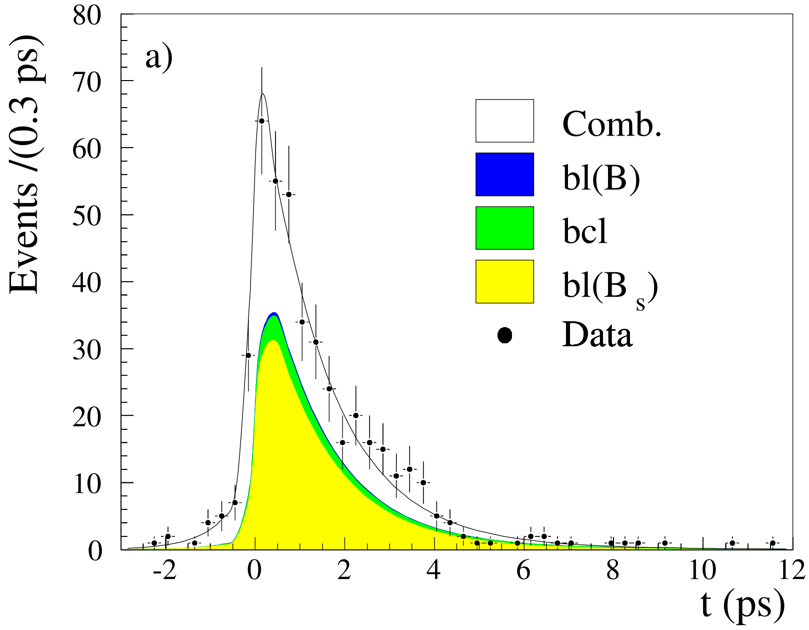
3.5 M hadronic Z^0 decays (92 - 95).

Use $\ell^- D_s^+ X$, $h^- D_s^+ X$, and inclusive B reconstruction.

Example: $D_s^+ \ell^-$ analysis

$D_s^+ \to \phi\pi^+, \overline{K}^{*0} K^{(*)+}, K_S^0 K^+, \phi\pi^+\pi^+\pi^-, \phi\pi^+\pi^0.$





$\tau(B_s^0) = 1.42\,^{+0.14}_{-0.13} \pm 0.03$ ps, $\quad \Delta\Gamma/\Gamma < 0.46$ at 95% C.L.

Also $D_s^+ h^- X$ mode gives:

$\tau(B_s^0) = 1.49\,^{+0.16}_{-0.15}\,^{+0.07}_{-0.08}$ ps, $\quad \Delta\Gamma/\Gamma < 0.58$ at 95% C.L.

Other $\Delta\Gamma$ searches :

- L3: Phys. Lett. **B438**, 417 (1998).
  Inclusive B reconstruction
  $\Delta\Gamma/\Gamma < 0.67$ at 95% C.L.

- CDF: Phys. Rev. D **59**, 032004 (1999).
  $D_s^+ \ell^- X$
  $\tau(B_s^0) = 1.36 \pm 0.09\,^{+0.06}_{-0.05}$ ps, $\quad \Delta\Gamma/\Gamma < 0.83$ at 95% C.L.

Lifetime of possible CP eigenstates :

- ALEPH: ALEPH 98-064 (ICHEP98)
  $B_s^0/\overline{B}_s^0 \to D^{(*)+}D^{(*)-} \to \phi\phi X.$
  $\tau(B_s^0) = 1.42 \pm 0.23 \pm 0.16$ ps.

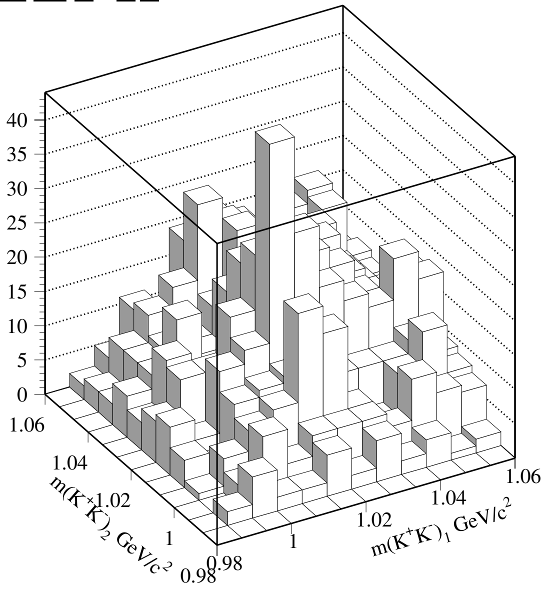
- CDF: Phys. Rev. Lett. **77**, 1945 (1996).
  $B_s^0/\overline{B}_s^0 \to J/\psi\,\phi$
  $\tau(B_s^0) = 1.34\,^{+0.23}_{-0.19} \pm 0.05$ ps.

cf. $\tau(B_s^0) = 1.467 \pm 0.058$ ps
(world ave. of flavor eigenstates).

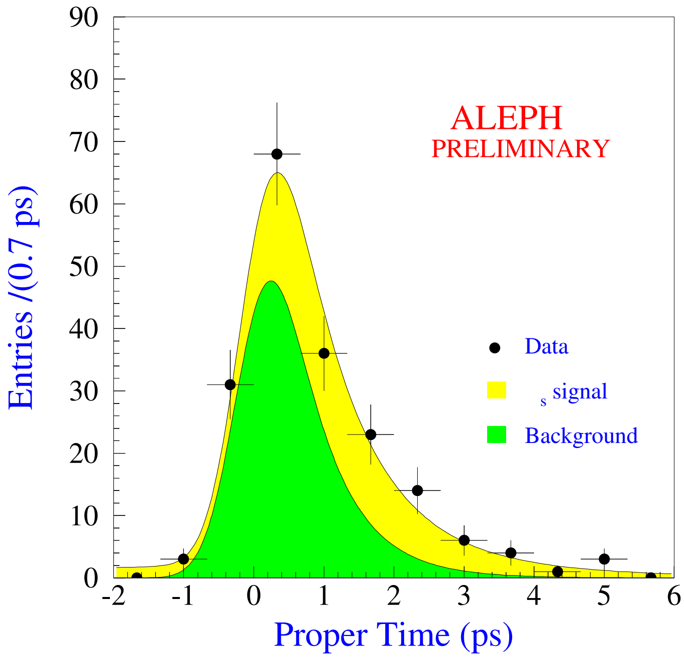
Transversity analysis :

$J/\psi\,\phi$	$\Gamma_\perp/\Gamma = 0.229 \pm 0.188 \pm 0.038$	CDF	prelim
$J/\psi K^{*0}$	$\Gamma_\perp/\Gamma = 0.126\,^{+0.121}_{-0.098} \pm 0.028.$	CDF	prelim.
$J/\psi K^{*0}$	$\Gamma_\perp/\Gamma = 0.16 \pm 0.08 \pm 0.04$	CLEO	
		PRL **79**, 4533 (1997).	

ALEPH

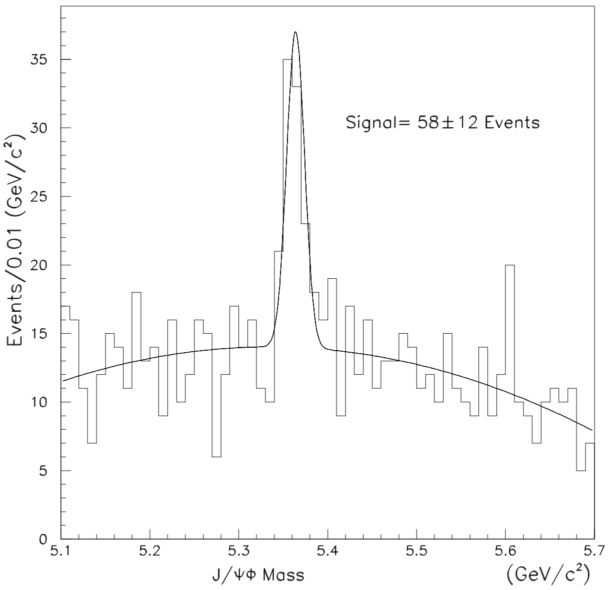


m(K⁺K⁻)₂ GeV/c²
m(K⁺K⁻)₁ GeV/c²

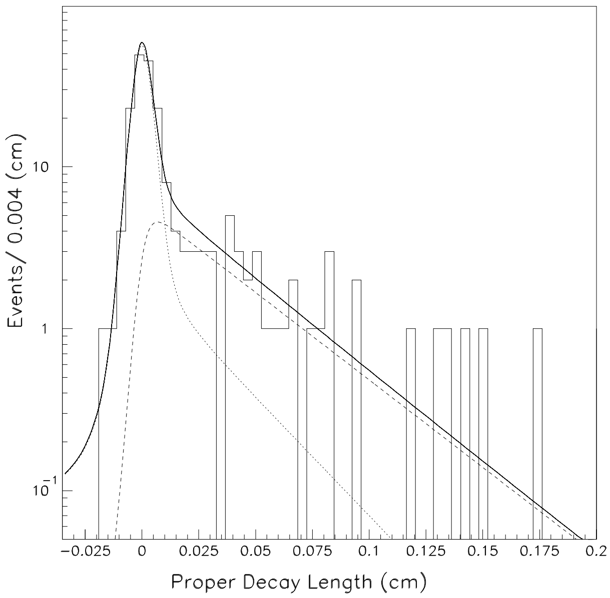


ALEPH
PRELIMINARY
Data
s signal
Background
Entries /(0.7 ps)
Proper Time (ps)

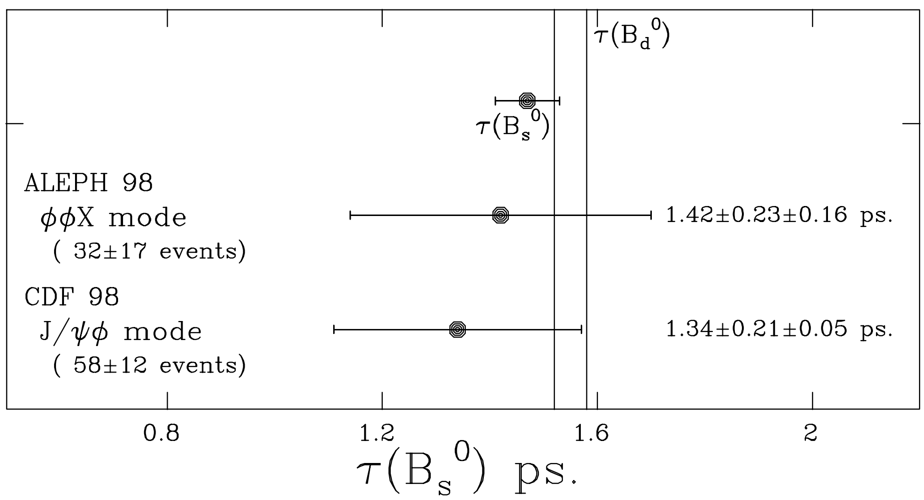
CDF



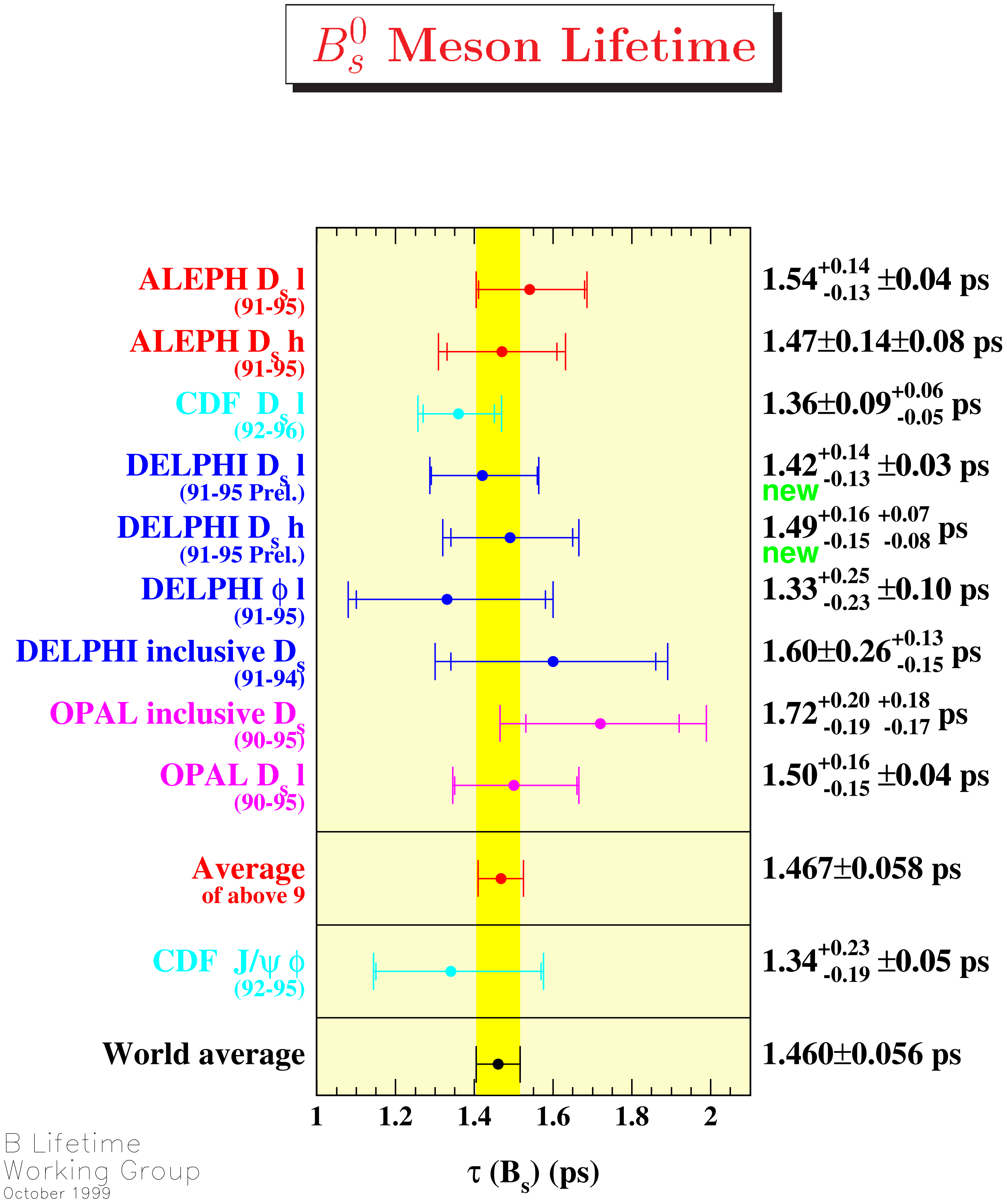
Signal= 58±12 Events
Events/0.01 (GeV/c²)
J/ψΦ Mass
(GeV/c²)



Events/ 0.004 (cm)
Proper Decay Length (cm)

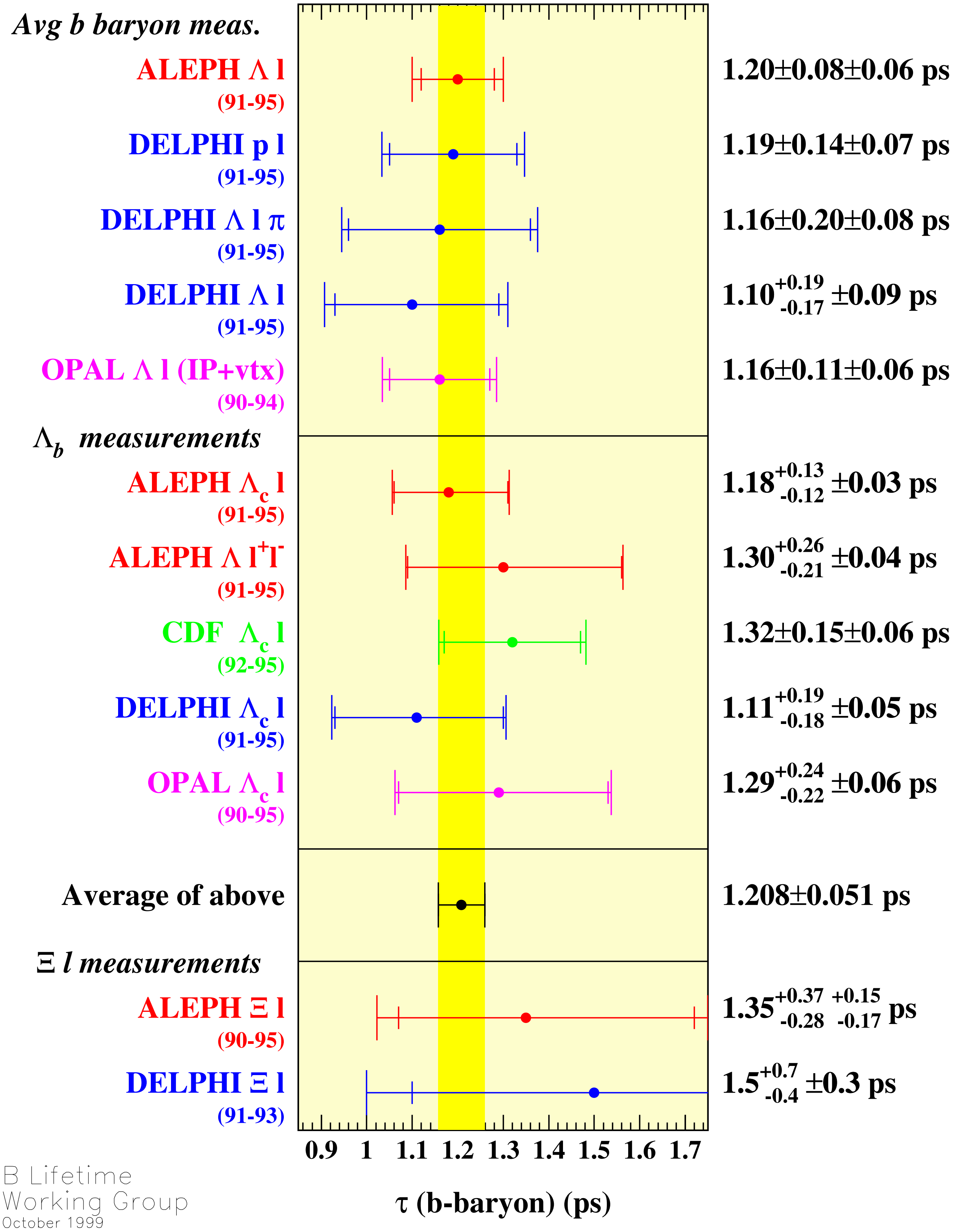


τ(B_d⁰)
τ(B_s⁰)
ALEPH 98
φφX mode
(32±17 events)
1.42±0.23±0.16 ps.
CDF 98
J/ψφ mode
(58±12 events)
1.34±0.21±0.05 ps.
τ(B_s⁰) ps.

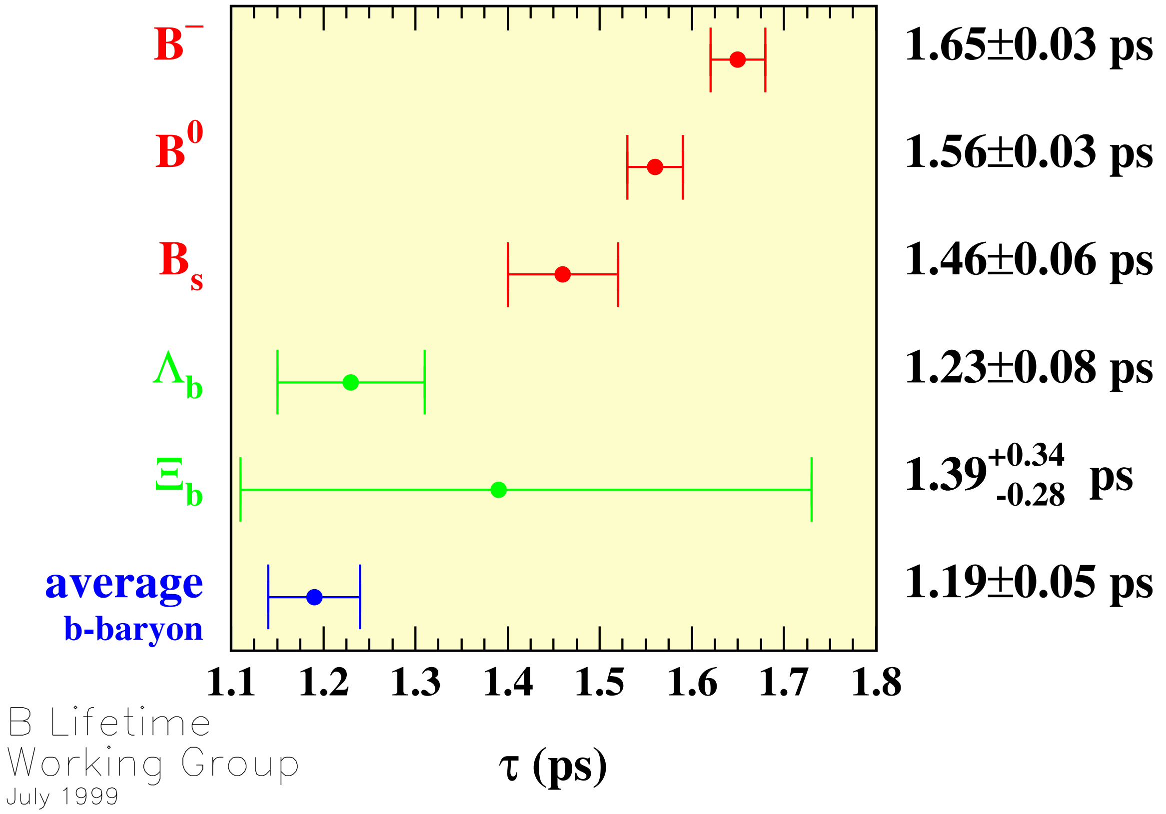


B_s^0 Meson Lifetime
ALEPH D_s l (91-95)
$1.54^{+0.14}_{-0.13} \pm 0.04$ ps
ALEPH D_s h (91-95)
$1.47 \pm 0.14 \pm 0.08$ ps
CDF D_s l (92-96)
$1.36 \pm 0.09^{+0.06}_{-0.05}$ ps
DELPHI D_s l (91-95 Prel.)
$1.42^{+0.14}_{-0.13} \pm 0.03$ ps
new
DELPHI D_s h (91-95 Prel.)
$1.49^{+0.16}_{-0.15}{}^{+0.07}_{-0.08}$ ps
new
DELPHI ϕ l (91-95)
$1.33^{+0.25}_{-0.23} \pm 0.10$ ps
DELPHI inclusive D_s (91-94)
$1.60 \pm 0.26^{+0.13}_{-0.15}$ ps
OPAL inclusive D_s (90-95)
$1.72^{+0.20}_{-0.19}{}^{+0.18}_{-0.17}$ ps
OPAL D_s l (90-95)
$1.50^{+0.16}_{-0.15} \pm 0.04$ ps
Average of above 9
1.467 ± 0.058 ps
CDF $J/\psi\ \phi$ (92-95)
$1.34^{+0.23}_{-0.19} \pm 0.05$ ps
World average
1.460 ± 0.056 ps
1
1.2
1.4
1.6
1.8
2
τ (B_s) (ps)
B Lifetime Working Group
October 1999

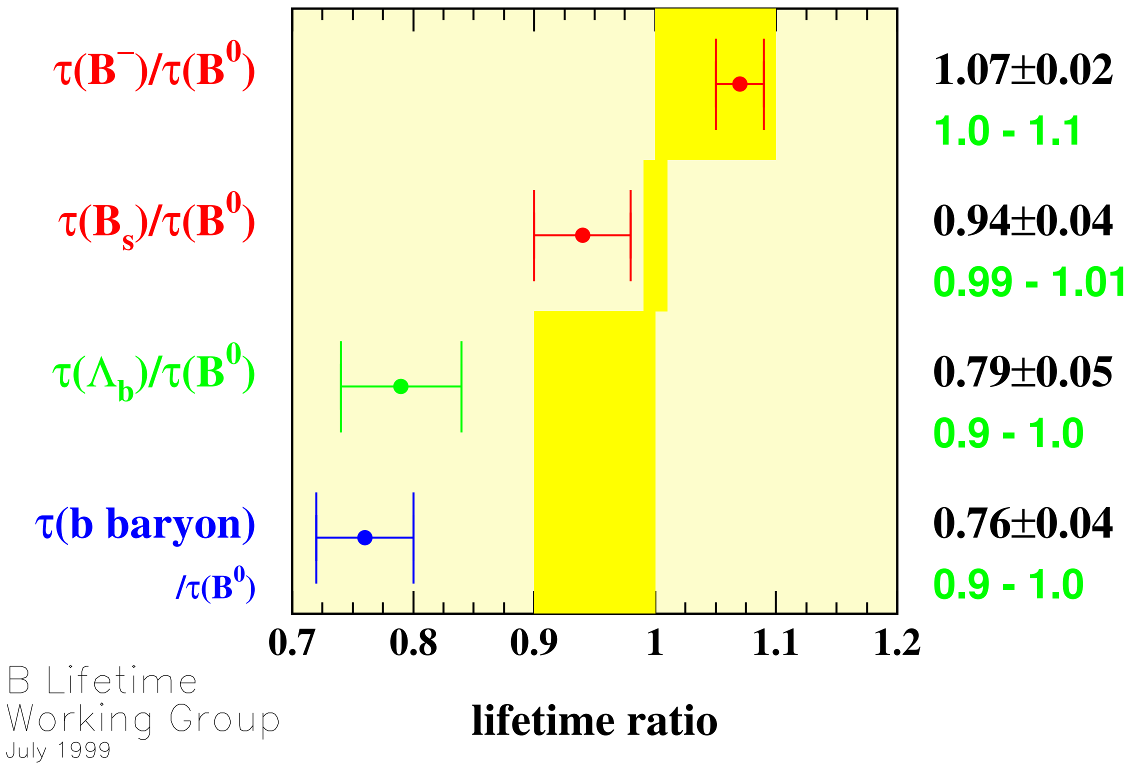
B Baryon Lifetime



Summary



Also: $\tau(B_c^+) = 0.46\ ^{+0.18}_{-0.16} \pm 0.04$ ps.



Conclusions

Spectroscopy

- All ground states established. Even $B_c^{\pm}$ seen.
- Some $L = 1$ states established. Not just narrow ones.
- B^{**} important for flavor tagging (CP, mixing).

Lifetime

- Charm hadron lifetimes
  D_s^+ lifetime *is* longer than D^0.
- Bottom hadron lifetimes
  Maybe B^+ lifetime is longer than B^0.
  $\Delta\Gamma$ in B_s^0-$\overline{B}_s^0$ system interesting. Need more precise measurements, though.

Thanks to the experiments other than CDF, their web pages, and people:
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