B^+ and B^0 Meson Lifetimes Status and Prospects

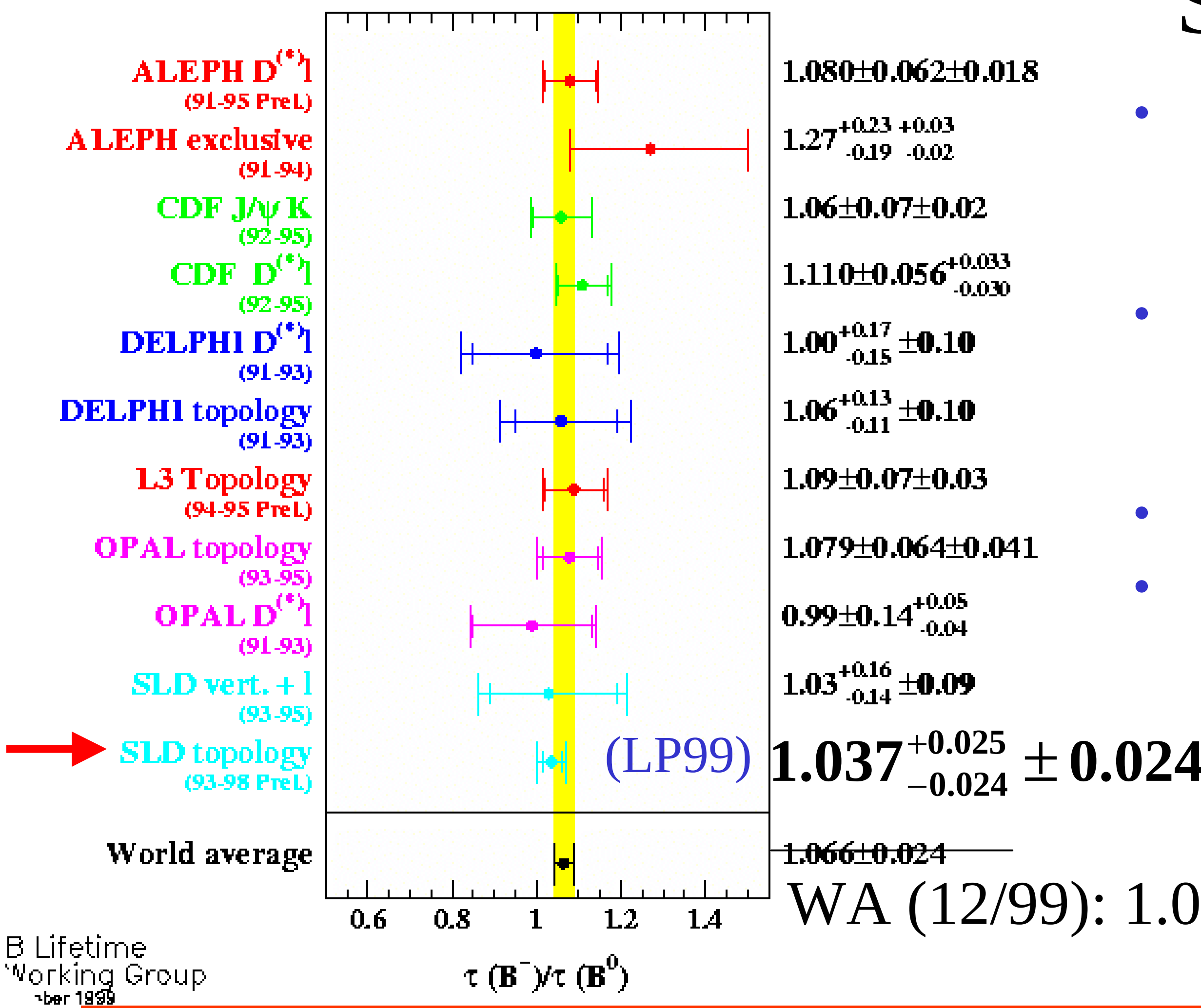
- Quick review of Decay Length method
- Motivation for looking at Impact Parameter method
- Impact Parameter fit results
- Combining the two analyses
- Estimate of errors once VXD-only tracks are used
- Plans for summer conferences

Ken Baird
Univ. of Massachusetts

B^+ / B^0 Analysis Outline

- Reconstruct decay point of B mesons using ZVTOP & calculate decay length from IP
- Divide sample into "B^0" and "B^+" samples
- Use M_{PT}, Q_{vtx}, and $A_{FB}(\cos\theta)$ to improve purity of samples
- Determine lifetime by fitting MC to the Data decay length distributions
- Calculate Systematics

τ_{B+} / τ_{B0} Summary



- SLD Measurement still the most precise for lifetimes & ratio
- τ_{B+} / τ_{B0} ~ 1 σ deviation from naïve spectator model prediction
- World sees 2.8 σ dev.
- need greater precision to discriminate between theoretical predictions

Crosschecks

Very important - results are most precise for now, but will be "checked" in ~ 1 yr by BaBar & few years down the road by CDF/D0

- τ as a function of
  - decay length cuts (min,max)
  - cos θ, ϕ regions
- error magnitude checks (work in progress)
  - errors scale from previous results
  - Data errors agree with MC predictions
  - examining MC pulls, etc.

Ken Baird
Univ. of Massachusetts

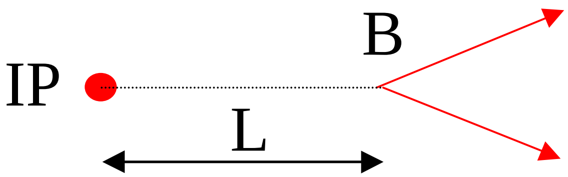
Lifetime Systematics (97-98 Decay Length Analysis)

Physics Systematics (selected subset)		$\Delta\tau_{B+}$ **(ps)**	$\Delta\tau_{B0}$ **(ps)**	$\Delta\ \tau_{B+}/\tau_{B+}$
B frag.	$.714 \pm .008$	.025	.030	.004
	X_E shape	.011	.009	<.003
$B(B \to DD)$	$.18 \pm .05$	.015	.014	.016
b baryon fraction	$.072 \pm .040$	.004	.017	.008
B_s^0 lifetime	$1.49 \pm .06$	<.003	.014	.009
TOTAL (all systs, including trking & detector)		**0.033**	**0.044**	**0.026**

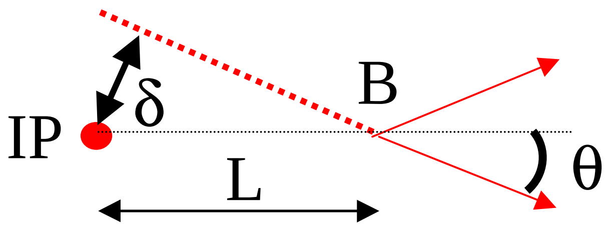
needs more study

- b fragmentation systematics dominant for individual lifetimes

Can we use a variable that is less sensitive to X_E?



$L \sim \tau \bullet E \leftrightarrow$ Large L = Long τ **or** Hard X_E



$\delta \sim L \bullet \theta \sim (\tau \bullet E)\bullet\theta \sim (\tau \bullet \cancel{E})\bullet(1/\cancel{E})$

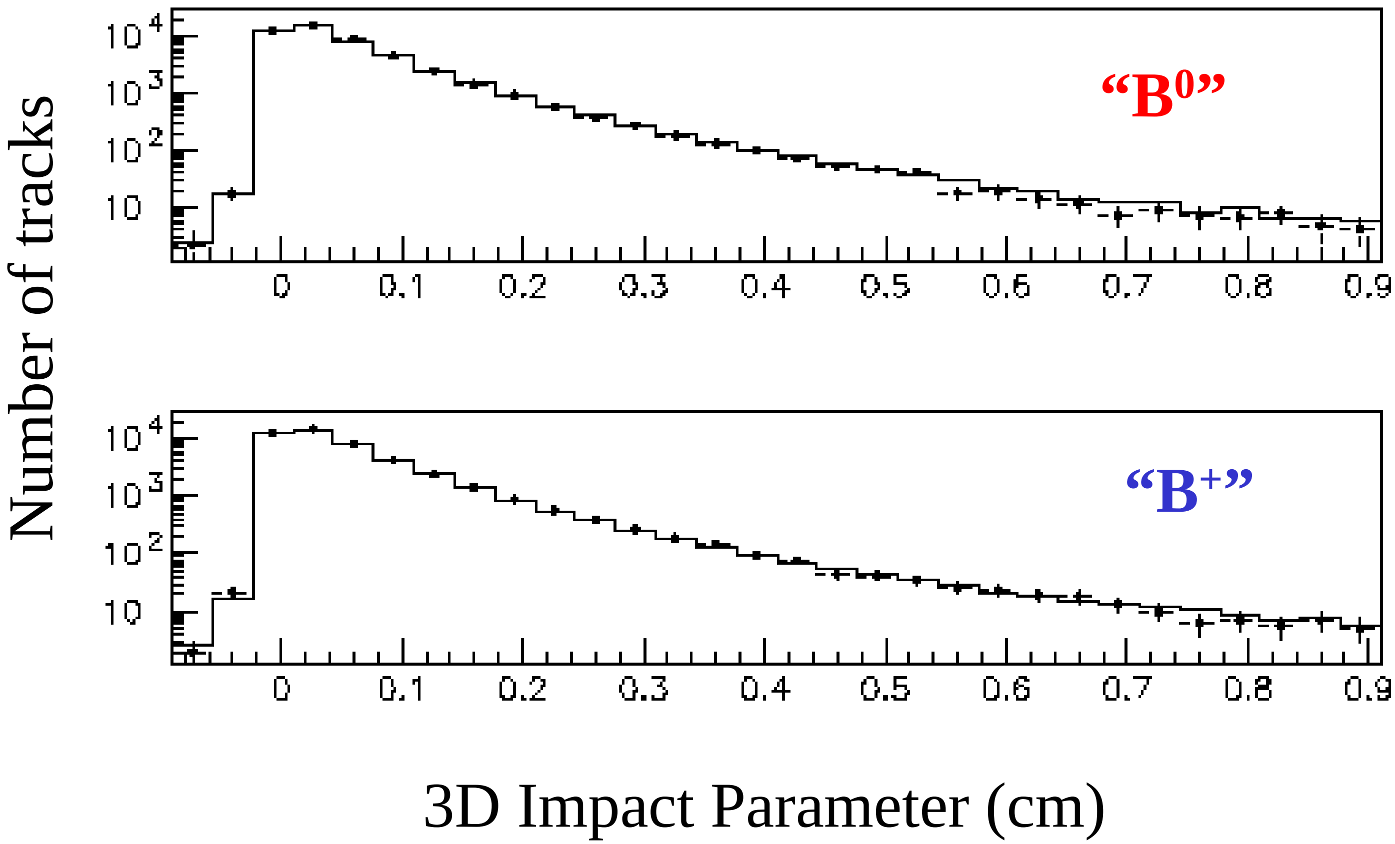
$\rightarrow$ δ independent of X_E

Analysis Outline:

- As before, find ZVTOP vertices
- As before, divide sample into charged & neutral
- As before, enhance $B^{\pm}$ purity using A_{FB}, M_{PT}, etc.
- Use the Average of the 3D Impact Parameters of the Vertex Tracks with respect to the IP

Ken Baird
Univ. of Massachusetts

How does the Impact Parameter distribution look?



Reasonably good agreement!

Instead, look @ Average of the 3D impact parameters for the tracks in the vertex

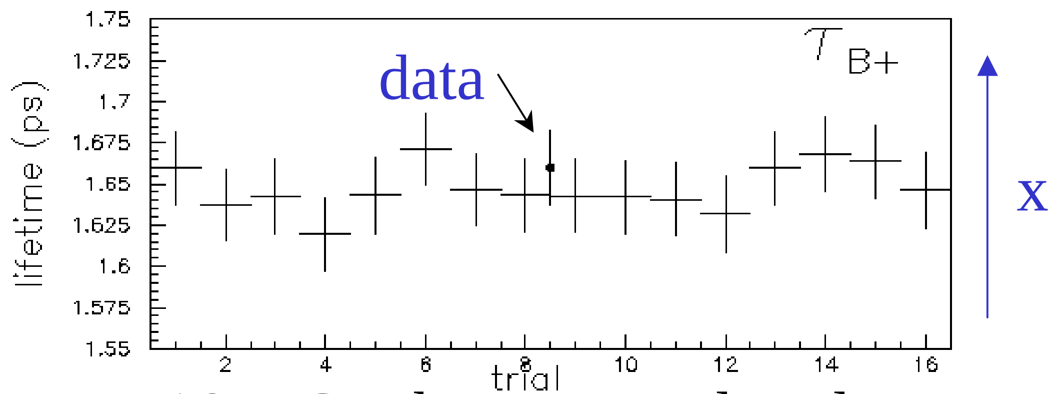
(nice thing: 1 entry/evt; less dependence on B-decay model)

	τ_{B+} (± stat) *psec*	τ_{B0} (± stat) *psec*	τ_{B+}/τ_{B0} (± stat)	Total χ^2 (76 dof)
Decay Length	1.660 ± .024	1.577±.024	1.052±.027	80
Ave. of 3D impact Parameters	1.638 ± .025	1.547 ± .027	1.057±.032	79
Degree of correlation with dkl analysis	65.1%	74.0%	75.1%	

$$\rho = \left\langle \left(\tau_{dkl} - \overline{\tau_{dkl}}\right)\left(\tau_{b3} - \overline{\tau_{b3}}\right) \right\rangle \Big/ \sigma_{dkl}\sigma_{b3}$$

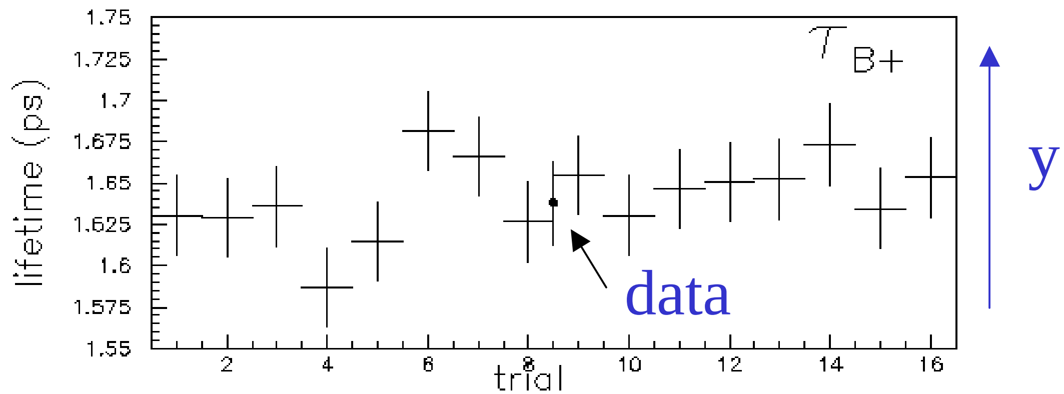
Degree of correlation between two analyses

From Decay Length Method:



16 MC subsets treated as data

From Ave. 3D impact Method:



Correlation Coefficient:

$$\rho = \frac{\langle (\boldsymbol{x}-\bar{\boldsymbol{x}})(\boldsymbol{y}-\bar{\boldsymbol{y}})\rangle}{\sqrt{\langle (\boldsymbol{x}-\bar{\boldsymbol{x}})^2\rangle\langle (\boldsymbol{y}-\bar{\boldsymbol{y}})^2\rangle}}$$

Lifetime Systematics (97-98 Ave. b3 Analysis)

Physics Systematics (selected subset)		$\Delta\tau_{B+}$ **(ps)**	$\Delta\tau_{B0}$ **(ps)**	$\Delta\ \tau_{B+}/\tau_{B+}$	
B frag.	.714 ± .008	~~.025~~ **.004**	~~.030~~ **.008**	~~.004~~	**.003**
	X_E shape	.011 **.004**	.009 **.005**	<.003	**.006**
B(B→DD)	.18 ± .05	.015 **.007**	.014 **.006**	.016	**.007**
b baryon fraction	.072 ± .040	.004 **.010**	.017 **.009**	.008 **.010**	
B_s^0 lifetime	1.49 ± .06	<.003 “	.014 **.015**	.009	**.010**
TOTAL (all systs, including trking & detector)		**0.033**	**0.044**	**0.026**	

But, others now much more important!

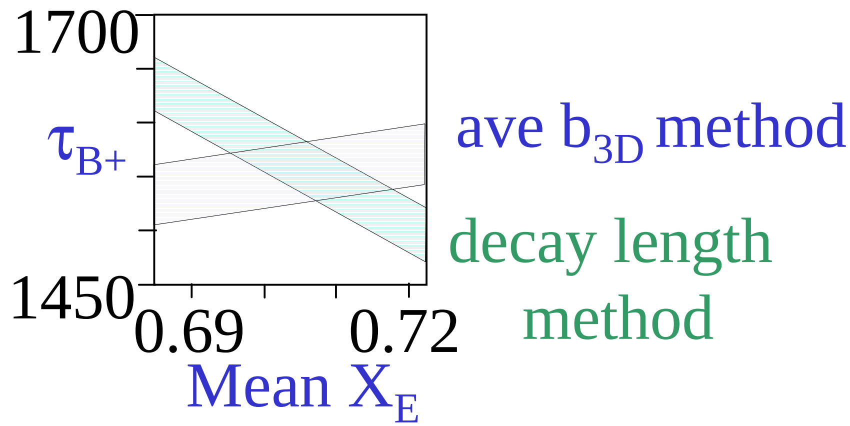
e.g. B decay multi: **0.019** **0.013** **0.019**

(used to be negligible)

Want to combine methods, but since data is the same,we must worry about correlations:

Unfortunately, we're not yet sure how!

Trial #1: treat it like an intersecting track problem



Prob. Dist.:

$$P(x,\ y) = \left(\frac{1}{2\pi\sigma_1\sigma_2} \frac{1}{\sqrt{1-\rho^2}} \right) \times$$

$$\exp\left\{ \left(-\frac{1}{2}\frac{1}{1-\rho^2} \right) \cdot \left(\left[\frac{y-y_1(x)}{\sigma_1} \right]^2 + \left[\frac{y-y_2(x)}{\sigma_2} \right]^2 - \frac{2\rho\left(y-y_1(x)\right)\left(y-y_2(x)\right)}{\sigma_1\sigma_2} \right) \right\}$$

Bottom Line: *Didn't Work!*

Trial 2: Assume can write lifetimes in following form:

$$\tau_{\mathbf{dkl}}(x) = f\tau_1(x) + (1 - f)\tau_2(x)$$

$$\tau_{\mathbf{b3}}(x) = f\tau_1(x) + (1 - f)\tau_3(x)$$

By design, τ_1, τ_2, τ_3 are uncorrelated

$$\sigma_{\tau_{\mathbf{dkl}}}(x) = f\sigma_{\tau_1}(x) \oplus (1 - f)\sigma_{\tau_2}(x)$$

$$\sigma_{\tau_{\mathbf{b3}}}(x) = f\sigma_{\tau_1}(x) \oplus (1 - f)\sigma_{\tau_3}(x)$$

Still working on this, but not converging

How much better might the τ results get...

- …if we use Dan Dong's X_E ($\sim .709 \pm .006$)?
  - For LP99, we used $\sigma_{XE} = \pm .008$
    - $\tau_{B+} = 1.623 \pm .020 \pm \cancel{.034}$ **.025** psec
    - $\tau_{B0} = 1.565 \pm .024 \pm \cancel{.044}$ **.039** psec
    - $R = 1.030 \pm .028 \pm .026$ **stays the same**
- …if we combine the two analyses?
  - $\rho \sim$ **0.7,** so ***maybe*** stat error reduces $\sigma \to \sqrt{\rho}\sigma \to \mathbf{.85}\sigma$
    - $\sigma_{STAT}(B^+) \to .017$
    - $\sigma_{STAT}(B^0) \to .020$

    (but systs prob. won't reduce as much as above)
- …if we use VXD-only tracks?
  - From T. Wright: tag purity goes from ~.79% to ~.82%
    - so A.P. = |2P-1| goes from 0.58 to .64 (10% improvement)
    - $\sigma_{STAT}(B^+) \to .017 \to .015$; $\sigma_{STAT}(B^0) \to .020 \to .018$

How much better might the τ results get...

- …if we use Dan Dong's X_E (~.709 ± .006)?
  - For LP99, we used $\sigma_{XE} = \pm .008$
    - $\tau_{B+} = 1.613 \pm .023 \pm \cancel{.034}$ **.025** psec
    - $\tau_{B0} = 1.565 \pm .024 \pm \cancel{.044}$ **.039** psec
    - R = 1.030 ± .028 ± .026 **stays the same**
- …if we combine the two analyses?
  - ρ ~ **0.7,** so ***maybe*** stat error reduces $\sigma \rightarrow \sqrt{\rho}\sigma \rightarrow \mathbf{.85}\sigma$
    - $\sigma_{STAT}(B^+) \rightarrow .020$
    - $\sigma_{STAT}(B^0) \rightarrow .020$

(but systs prob. won't reduce as much as above)

- …if we use VXD-only tracks?
  - From T. Wright: tag purity goes from ~.79% to ~.82%
    - so A.P. = |2P-1| goes from 0.58 to .64 (10% improvement)
    - $\sigma_{STAT}(B^+ \& B^0) \rightarrow .020 \rightarrow .018$

So……..

$\tau_{B+} = 1.613 \pm .018 \pm .030$ psec

$\tau_{B0} = 1.565 \pm .018 \pm .042$ psec

$R = 1.030 \pm .021 \pm .026$

Really, Really Preliminary!

or…….

$$\sigma_\tau / \tau(B^+) = 2.5\% \rightarrow 2.1\%$$

$$\sigma_\tau / \tau(B^0) = 3.2\% \rightarrow 2.9\%$$

$$\sigma_R / R = 3.7\% \rightarrow 3.2\%$$

Plans & Goals

- For Valencia conference (Hyperons, Charm and Beauty Hadrons; late June), we want to release "almost final" results for 1996-98 data
  - combination of dkl and ave. b3 analyses
  - using VXD-only tracks
  - using best estimate of X_E
  - completed physics note

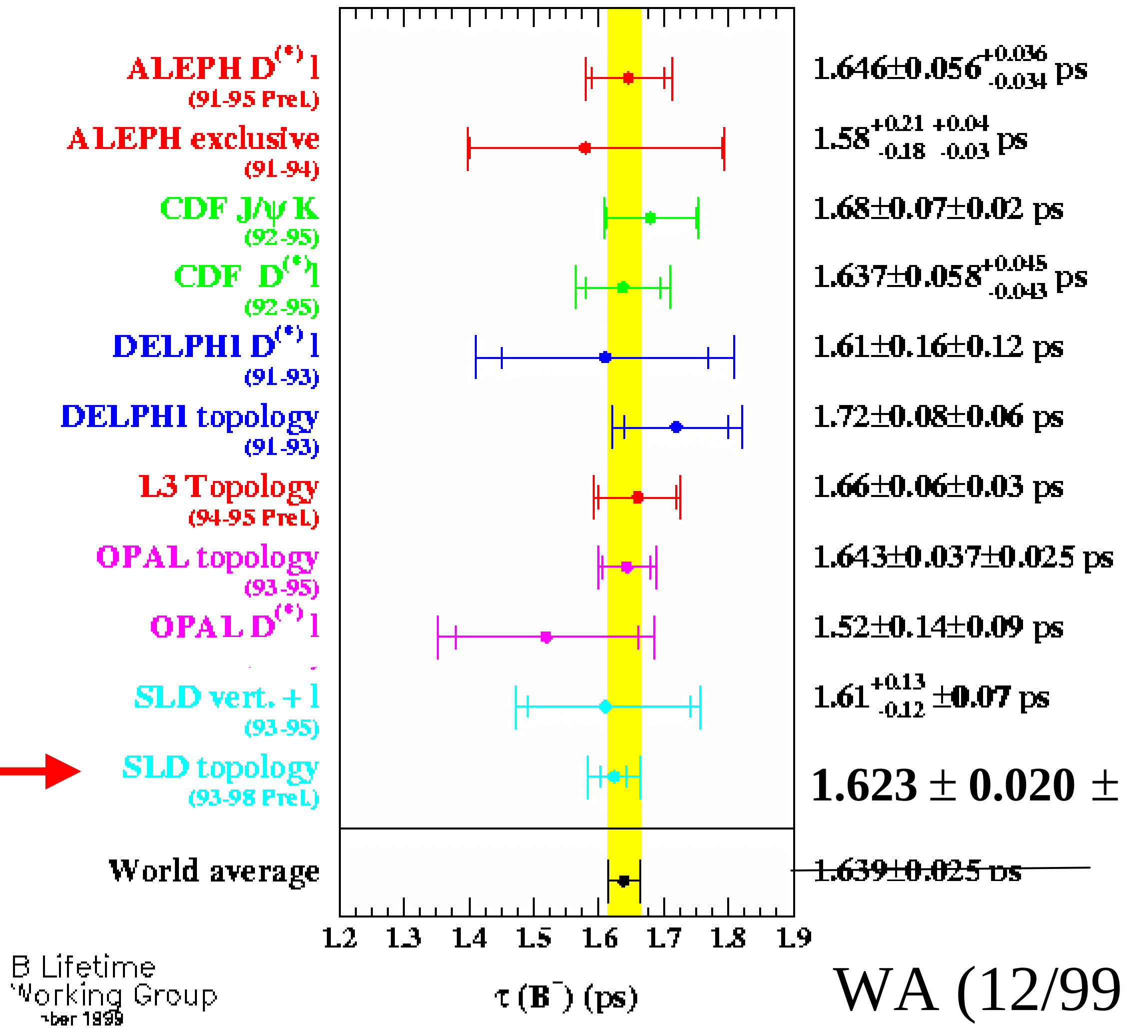
→ Results must freeze by mid-June

- Publication plans: draft 0 will be B-lifetime PRL using 1993-95 data

Ken Baird
Univ. of Massachusetts

Backup stuff for next few pages

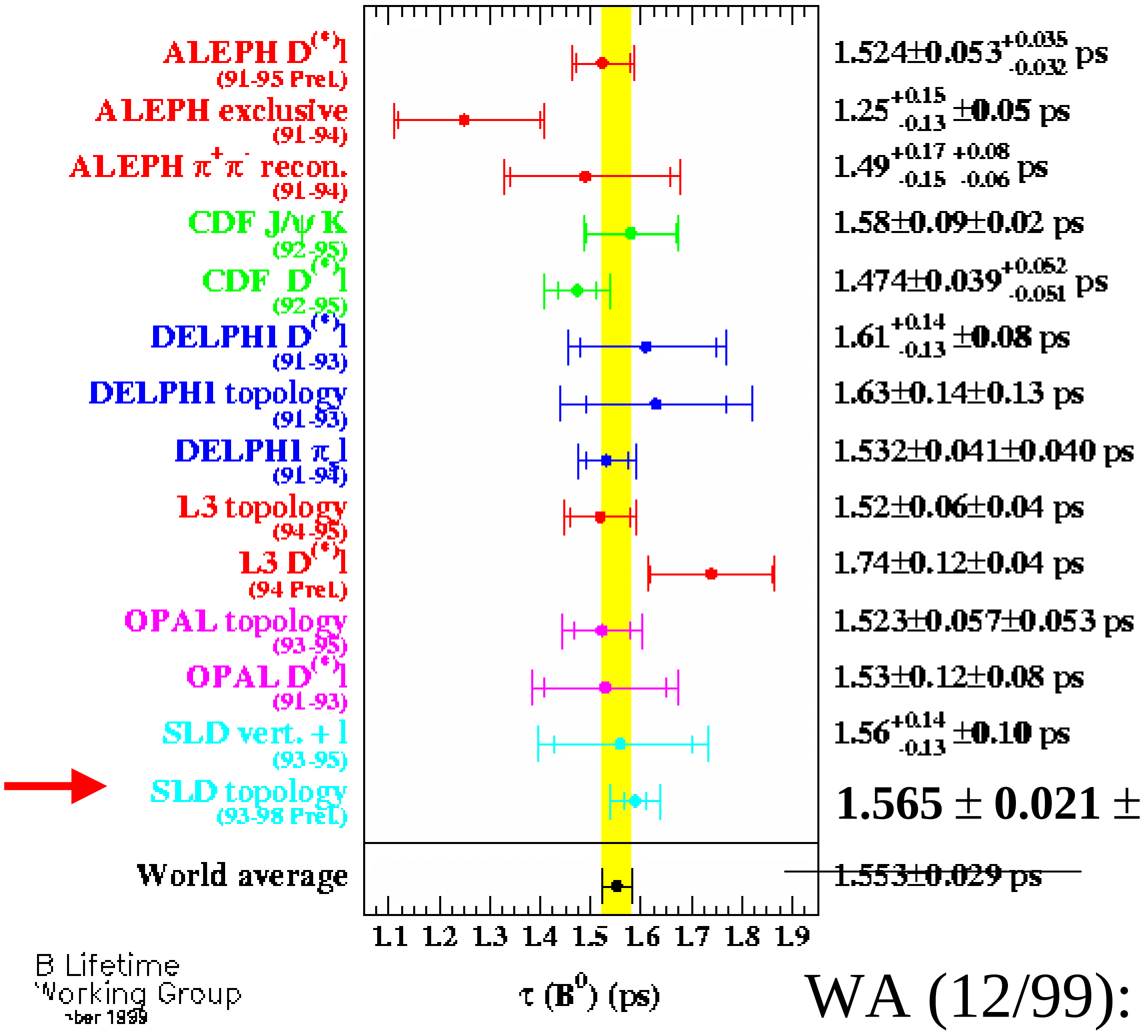
τ_{B+} Summary



1.623 ± 0.020 ± 0.034 ps (LP99)

WA (12/99): 1.656 ± 0.025 ps

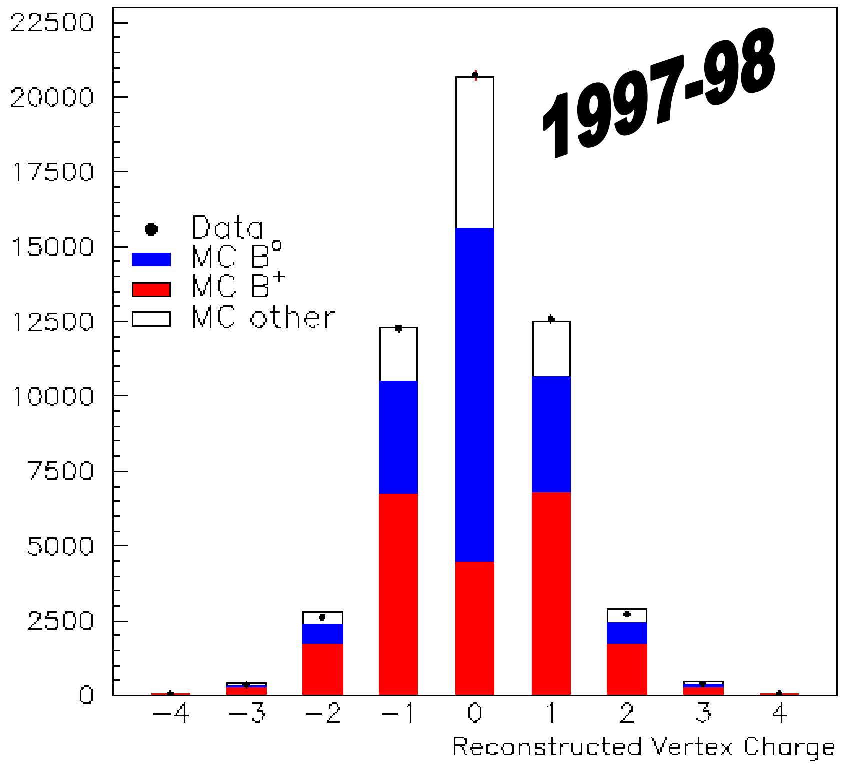
τ_{B0} Summary



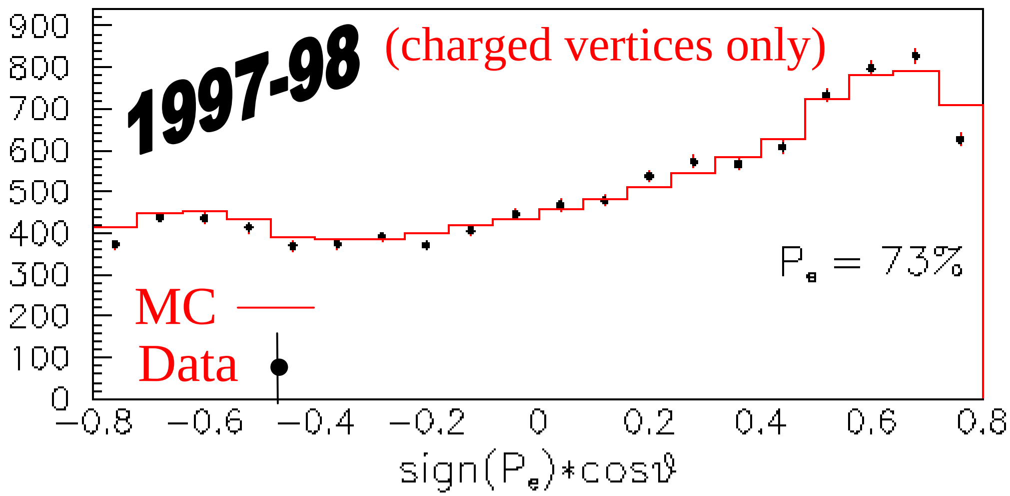
1.565 ± 0.021 ± 0.021 ps (LP99)

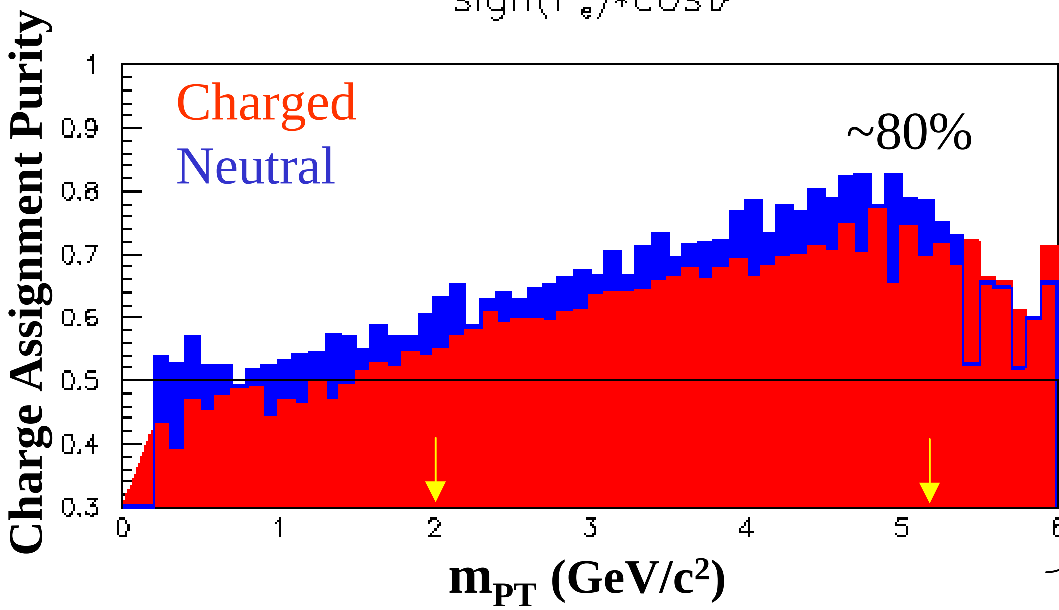
WA (12/99): 1.562 ± 0.029 ps

For LP99, we used 1997-98 R16 Data and MC.
However, the tracking corrections were based upon R15.
Now, using R16 trking corrections.



- ~ 30 K charged ($|Q_{vtx}|$=1,2,3)
- ~ 20 K neutral ($|Q_{vtx}|$=0)
- For analysis, require
  - $|Q_{vtx}| \leq 3$
  - L > 1 mm
  - R < 2.2 cm
  - M_{Pt} >2 GeV/c^2
  - M_{Pt} < 5.2 GeV/c^2



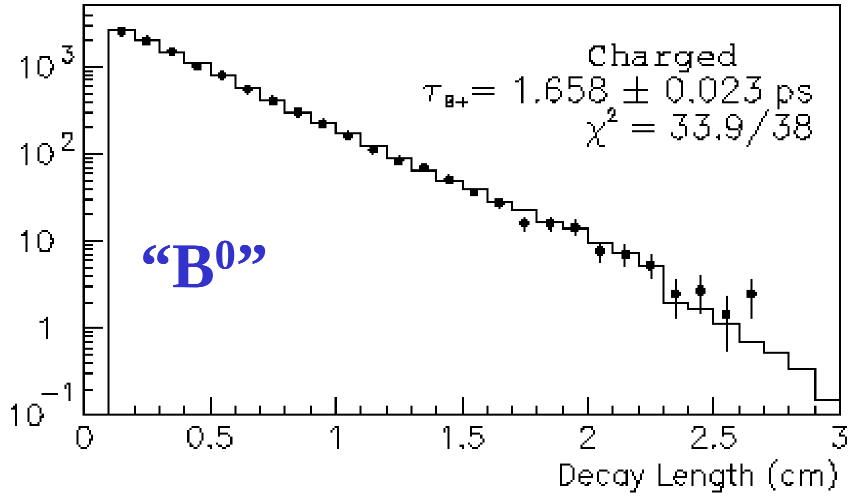


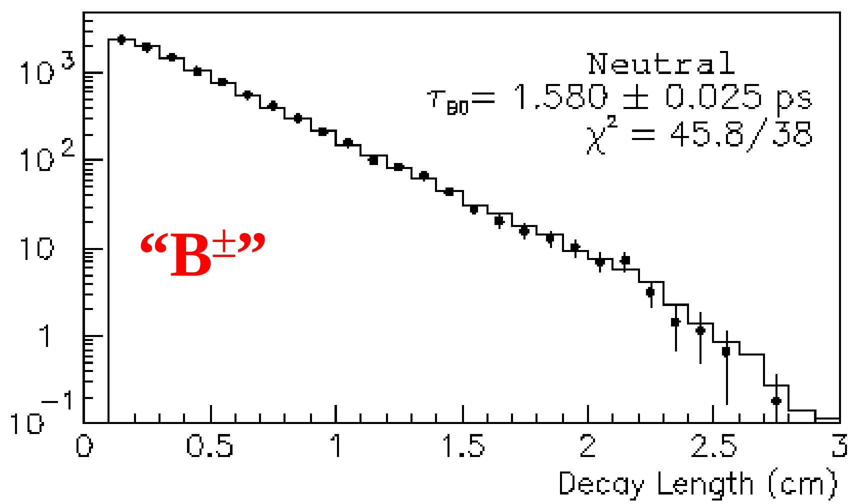
We combine info from I.S. Tagging (Pol + Q_{jet}) and $Q_{purity}(M_{pt})$ to assign vertices to either a "B^0" or "B_+" distribution. Each entry is weighted by the P_{B0} or P_{B+},

"B^0" sample purity =

"B^+" sample purity =

Binned Decay Length Fits (1997-98)





LP99 plots
(Before Mean Shifts)

Latest:

- $\tau_{B+} = 1.660 \pm 0.024$ ps
- $\tau_{B0} = 1.577 \pm 0.024$ ps
- $\dfrac{\tau_{\mathbf{B+}}}{\tau_{\mathbf{B0}}} = \mathbf{1.052}^{+0.028}_{-0.026}$

(Before Mean Shifts)

What do we actually report to conferences?

- $\tau_{B+} = 1.658 \pm 0.023 \pm 0.033$ ps
- $\tau_{B0} = 1.580 \pm 0.025 \pm 0.044$ ps

1997-98 results
(LP99, before shifts)

We shifted central values of lifetimes to account for differences between MC centroid values for different systs. & what we want to use as a central value (assume linear extrapolation OK):

$\overline{X}_E$ (MC) =.698 $\rightarrow$ .714 : $\tau_{B+} \rightarrow$ 1.607 ps

Won't need to do these two in future

$\overline{\tau_{Bs}}$(MC) = 1.55 ps $\rightarrow$ 1.49 ps : $\tau_{B+} \rightarrow$ 1.607 ps

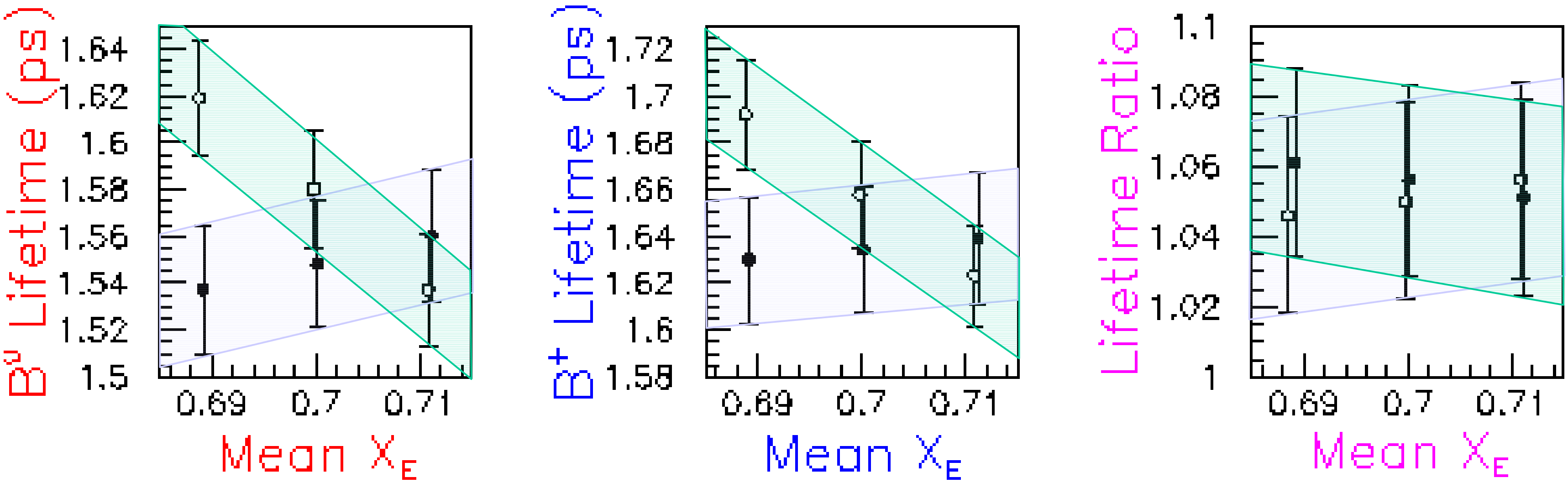
$\overline{f_{\text{b-baryon}}}$(MC) =7.2% $\rightarrow$ 10.2% : $\tau_{B+} \rightarrow$ 1.613 ps

- $\tau_{B+} = 1.613 \pm 0.023 \pm 0.033$ ps
- $\tau_{B0} = 1.565 \pm 0.025 \pm 0.044$ ps

1997-98 results
(LP99, after shifts)

Recall from last collab. mtg :

Lifetime dependence on X_E



Decay Length Analysis

Ave 3D Impact Parameter Analysis

Physics systematics for both analyses

Decay Length

b fragmentation	0.02456	0.02934	0.00363
bowler shape	0.01044	0.00863	0.00098
BR(B-->DX)	0.00505	0.00846	0.00712
BR(B-->DDX)	0.01445	0.01365	0.01602
B decay multi.	0.00072	0.00267	0.00126
B_s fraction	0.00298	0.00116	0.00266
b_baryon frax.	0.00410	0.01656	0.00826
b_s lifetime	0.00003	0.01356	0.00891
B baryon life	0.00036	0.00528	0.00324
D decay multi.	0.00327	0.00536	0.00559
D decay K0 yield	0.00153	0.00832	0.00452

Average 3D imp. param.

b fragmentation	0.00359	0.00821	0.00297
bowler shape	0.00409	0.00541	0.00598
BR(B-->DX)	0.00963	0.03648	0.02464
BR(B-->DDX)	0.00665	0.00596	0.00727
B decay multi.	0.01850	0.01281	0.01935
B_s fraction	0.00217	0.00305	0.00327
b_baryon frax.	0.00278	0.01862	0.01005
b_s lifetime	0.00030	0.01535	0.00998
B baryon life	0.00057	0.01123	0.00686
D decay multi.	0.00555	0.01396	0.00535
D decay K0 yield	0.01127	0.00659	0.01119