Recent LEP results on b-baryon decays

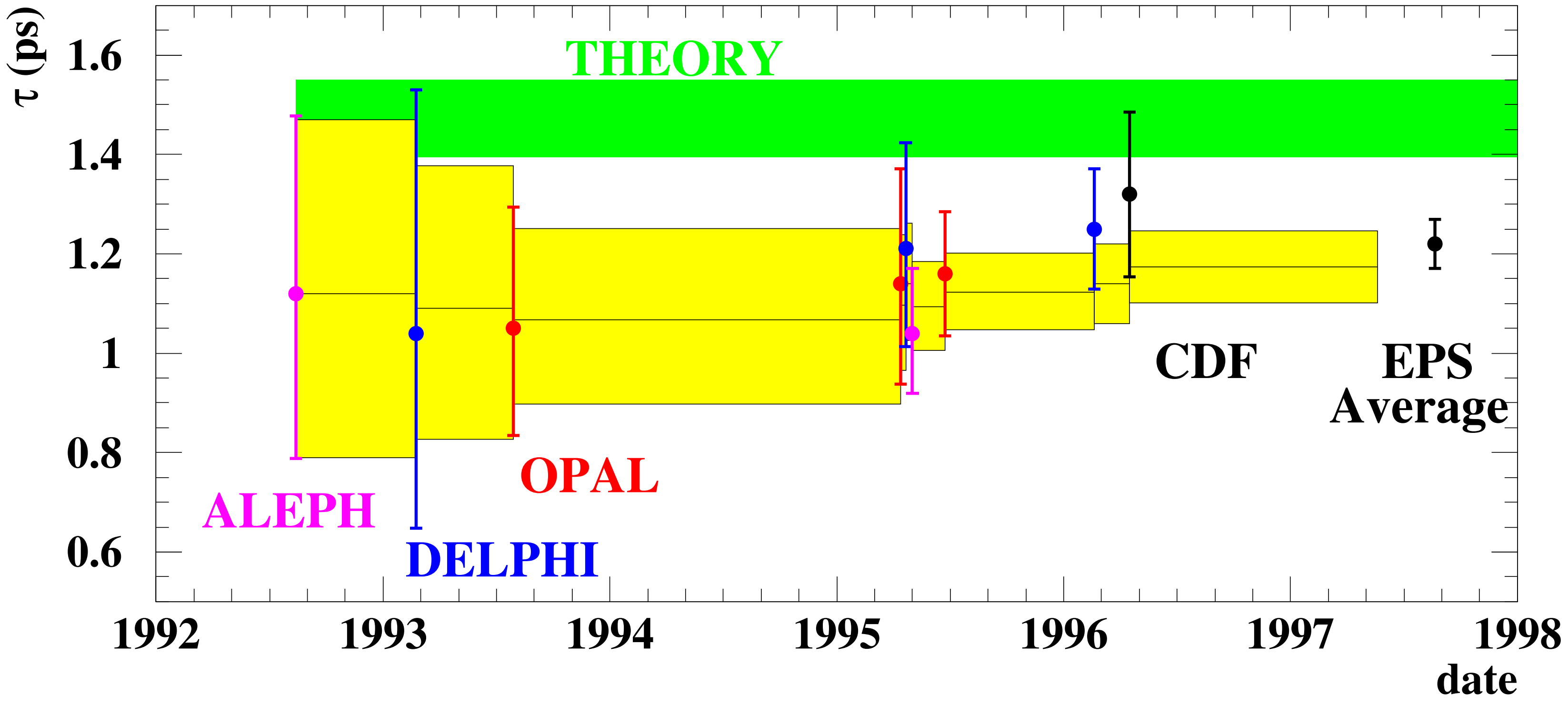
EPS/HEP 97 Jerusalem

Dean Karlen
Carleton University

Representing the OPAL Collaboration

- b-baryon lifetime updates
- b-baryon branching ratio ratios

Evolution of the average b-baryon lifetime



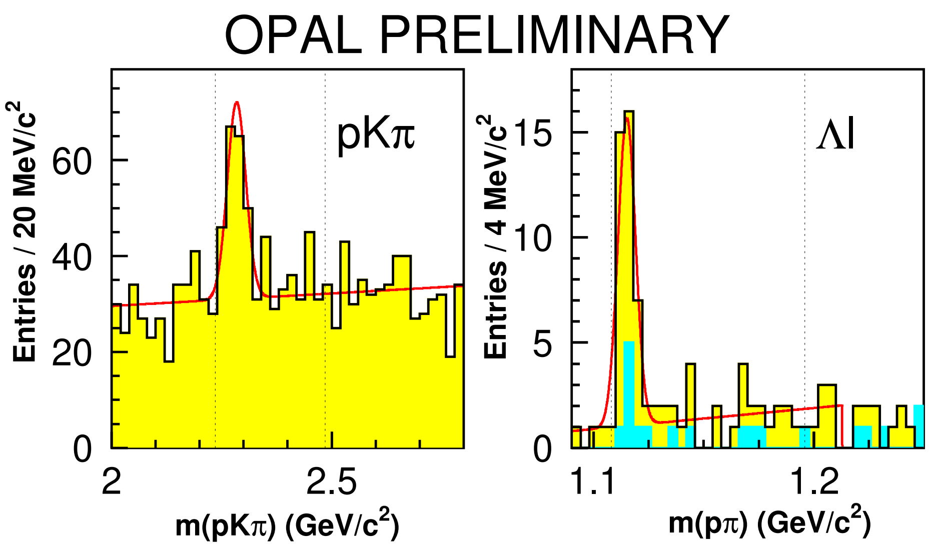
- includes published measurements only

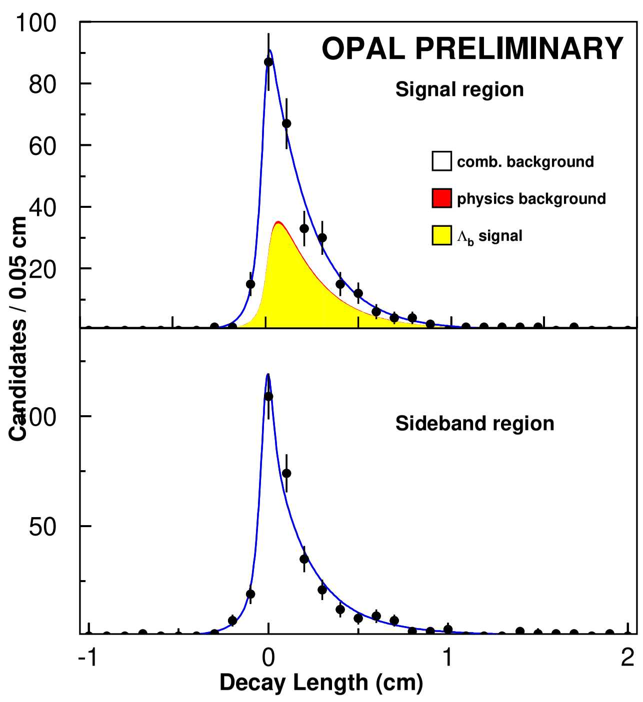
b-baryon lifetime updates

- LEP experiments have preliminary results on their full LEP I data set, for the most common modes:

Experiment	$\Lambda\ell^-$	$\Lambda_c^+\ell^-$	$\Lambda\ell^+\ell^-$
ALEPH	$\surd$	$\surd$	$\surd$
DELPHI	91-94	$\surd$	$\surd$
OPAL	90-94	$\surd$	$\surd$

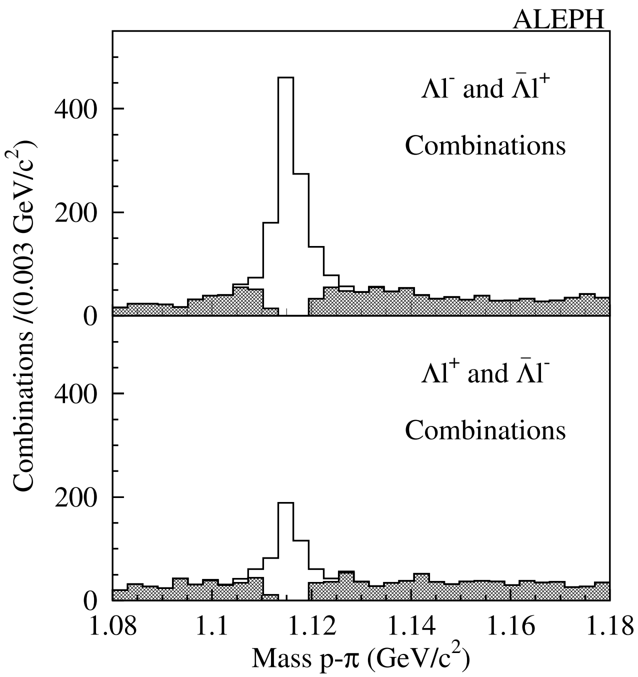
OPAL $\Lambda_c^+ \ell^-$ update (preliminary)



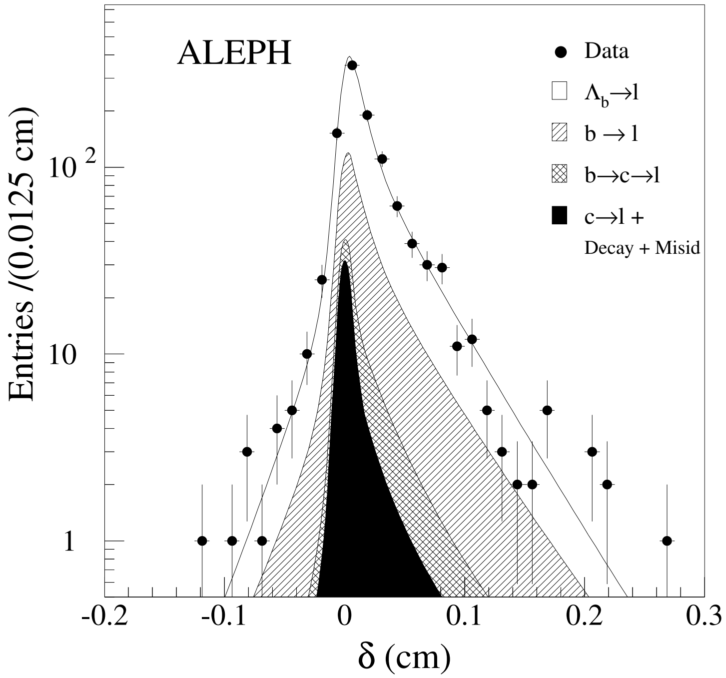


- published (91-94): $1.14\,^{+0.22}_{-0.19} \pm 0.07$ ps
- preliminary (91-95): $1.34\,^{+0.24}_{-0.22} \pm 0.06$ ps

ALEPH $\Lambda\ell$ update (preliminary)

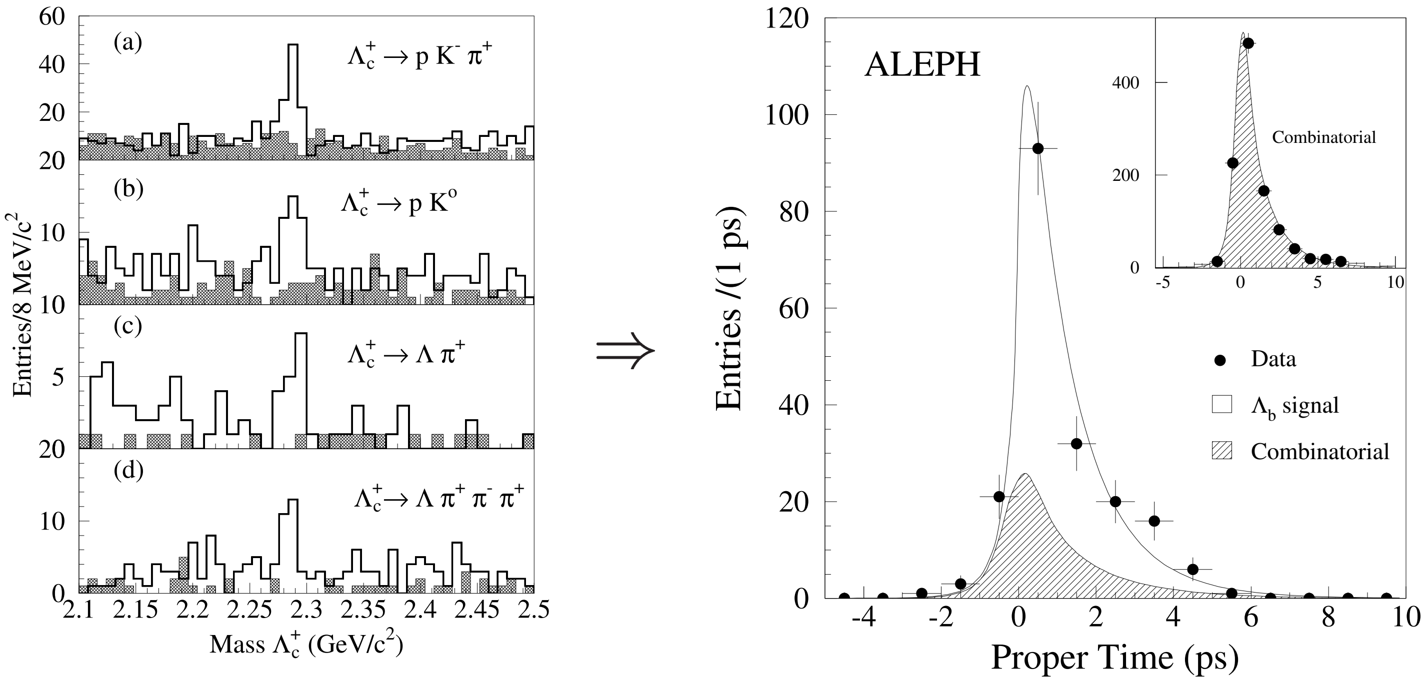


$\Rightarrow$



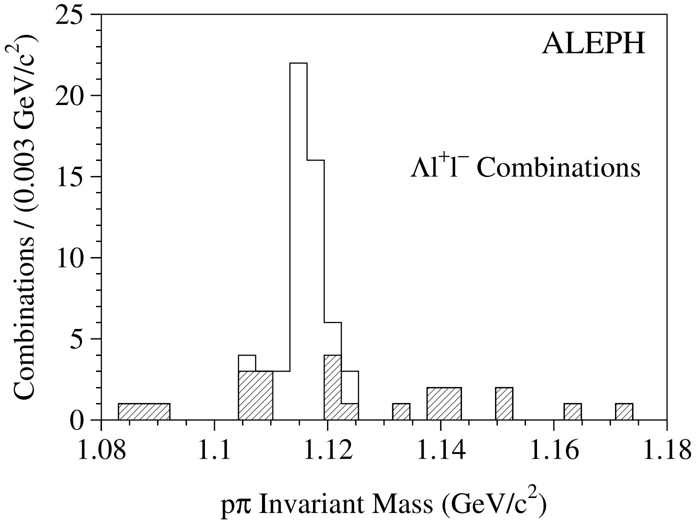
- published (91-93): $1.05\,^{+0.12}_{-0.11} \pm 0.09$ ps
- preliminary (91-95): $1.20 \pm 0.08 \pm 0.06$ ps

ALEPH $\Lambda_c^+ \ell^-$ update (preliminary)

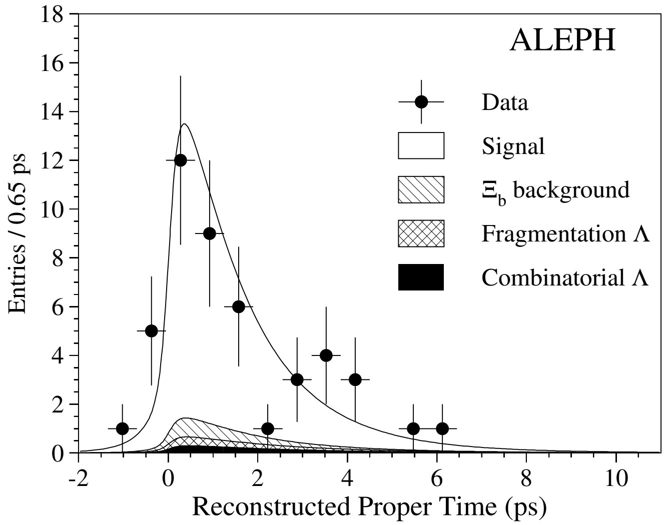


- published (91-93): $1.02\,^{+0.23}_{-0.18} \pm 0.06$ ps
- preliminary (91-95): $1.18\,^{+0.13}_{-0.12} \pm 0.03$ ps

ALEPH $\Lambda\ell^+\ell^-$ (preliminary)

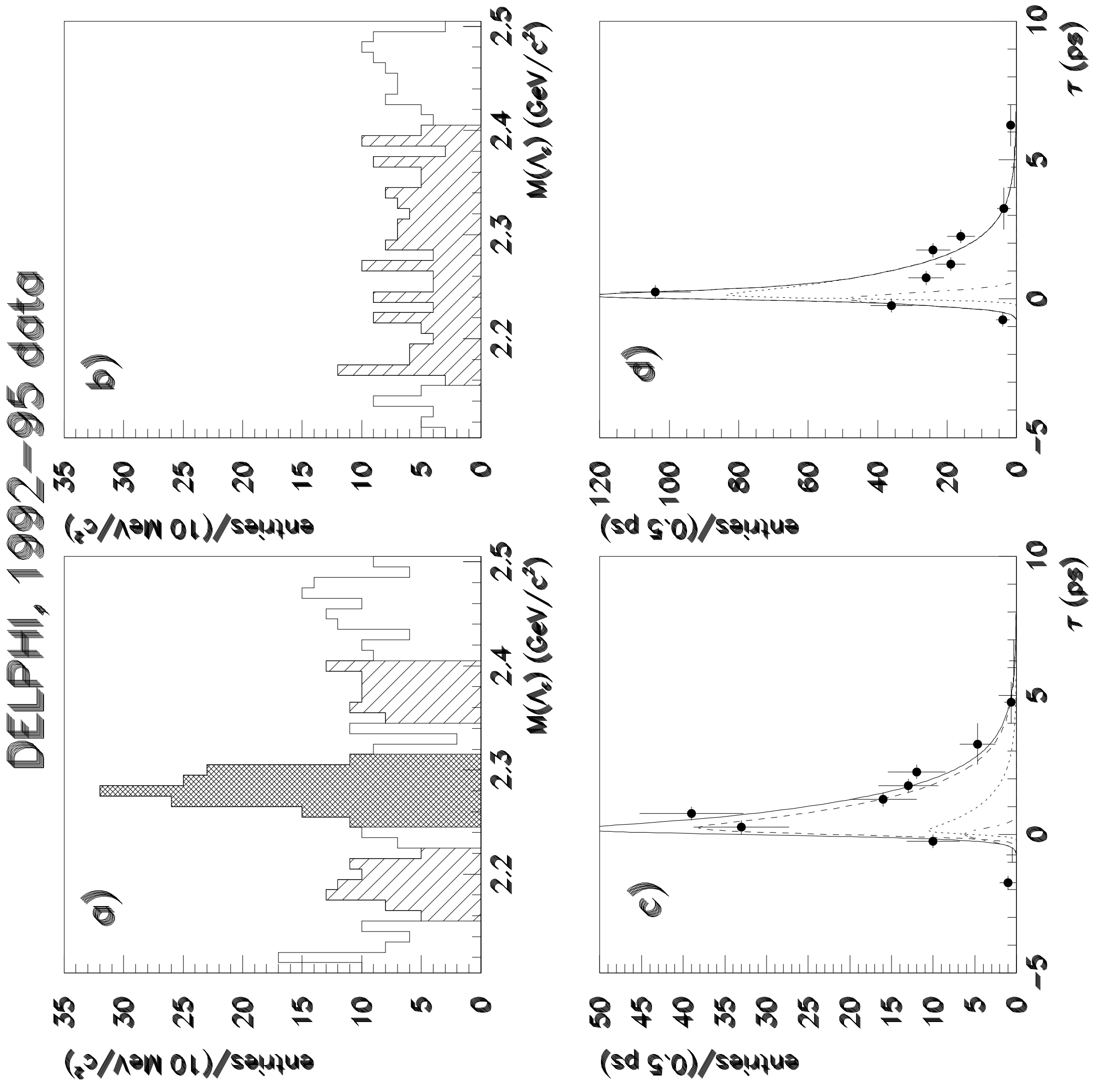


$\Rightarrow$



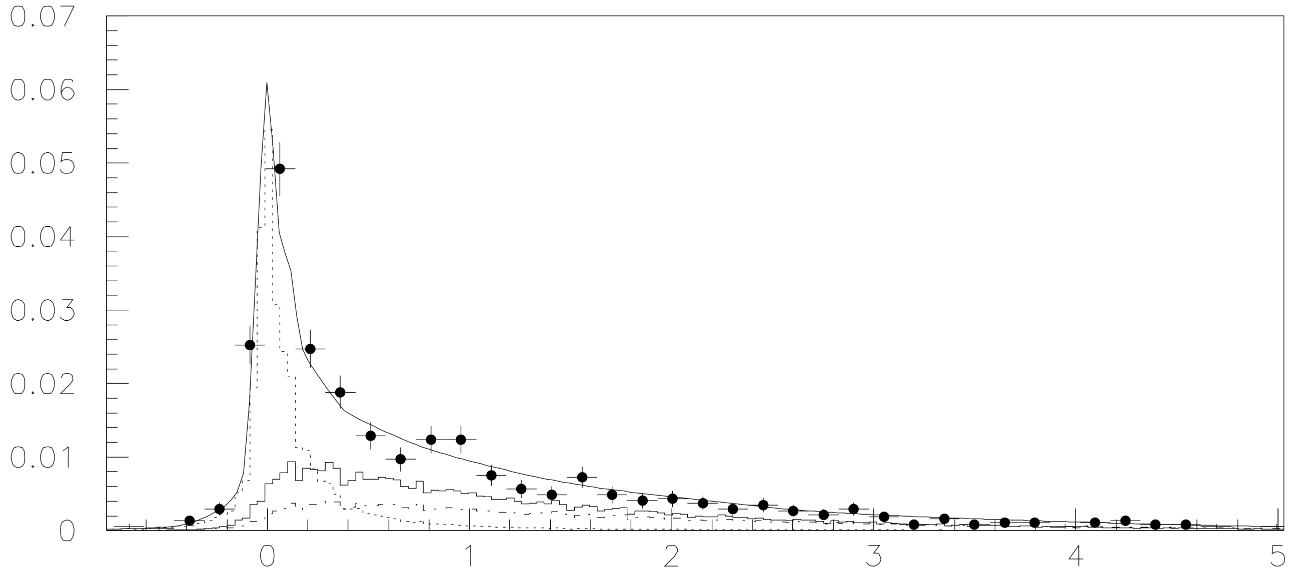
- preliminary (91-95): $1.30\,^{+0.26}_{-0.21} \pm 0.04$ ps

DELPHI $\Lambda_c^+\ell^-$ update (prelim.)



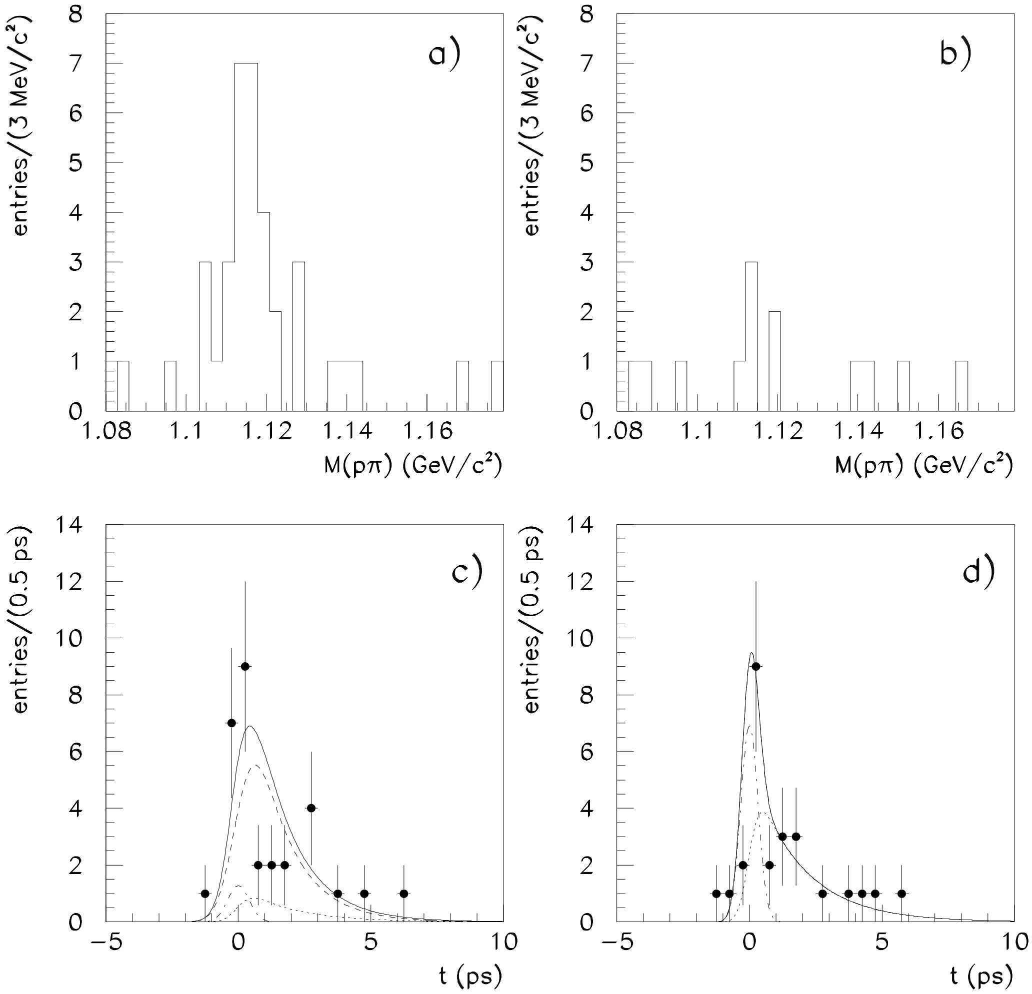
- published (91-94): $1.19^{+0.21}_{-0.18}{}^{+0.07}_{-0.08}$ ps
- preliminary (91-95): $1.11^{+0.15}_{-0.13}{}^{+0.07}_{-0.08}$ ps

DELPHI $p\ell^-$ update (preliminary)



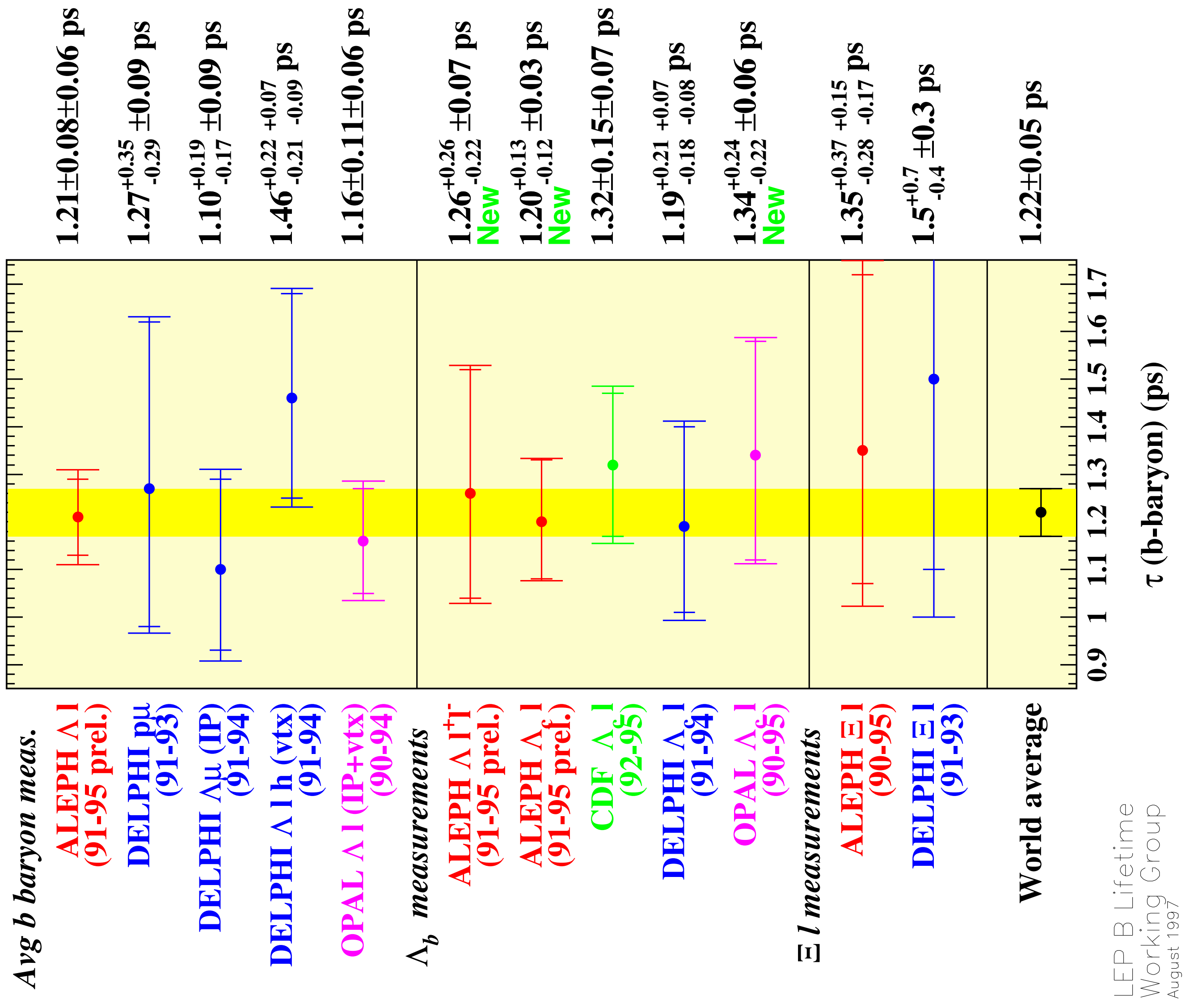
- published (92): $1.27\,^{+0.35}_{-0.29} \pm 0.09$ ps
- preliminary (91-95): $1.30 \pm 0.13\,^{+0.07}_{-0.16}$ ps

DELPHI $\Lambda\ell^+\ell^-$ (preliminary)

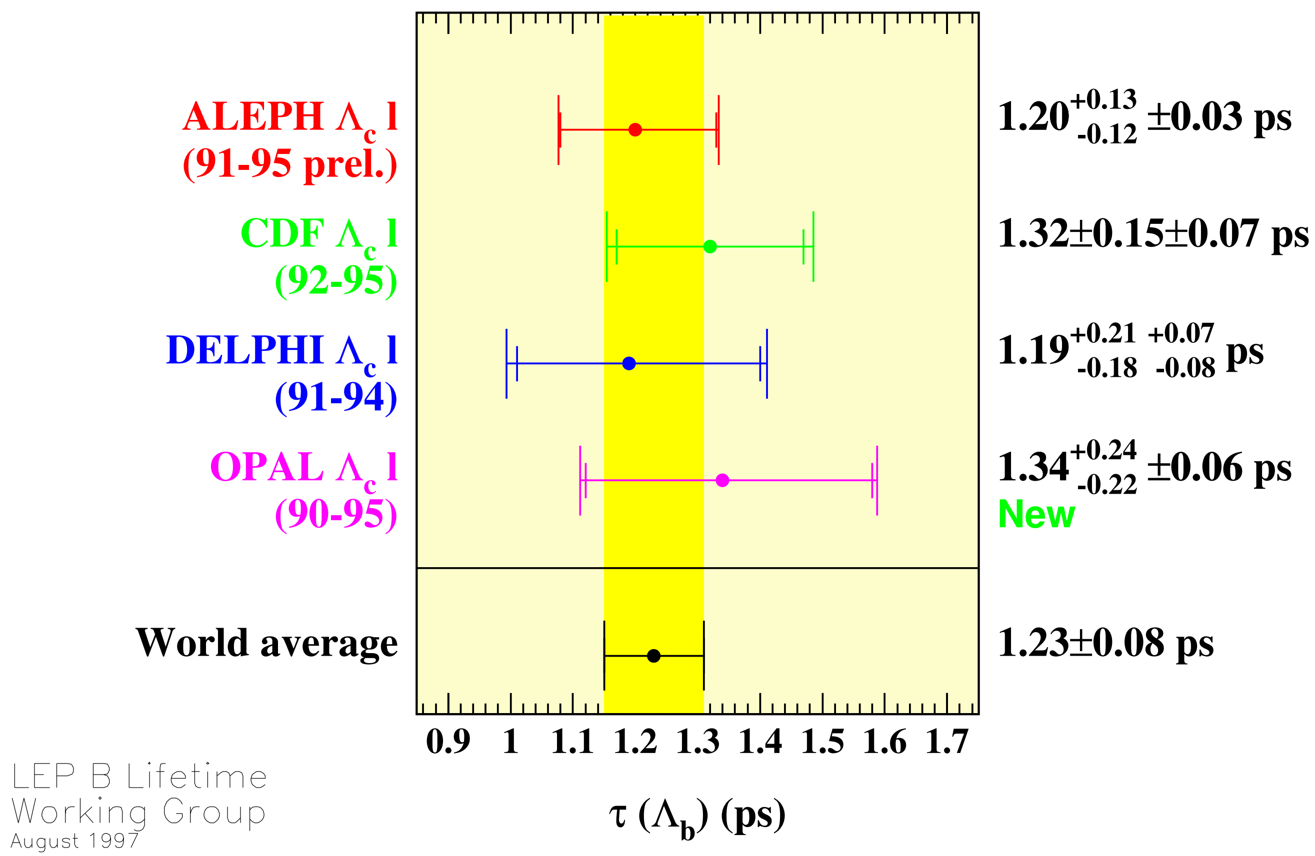


- preliminary (91-95): $1.36\,^{+0.35}_{-0.28}\,^{+0.09}_{-0.10}$ ps

b-baryon lifetime average



Λ_b lifetime average



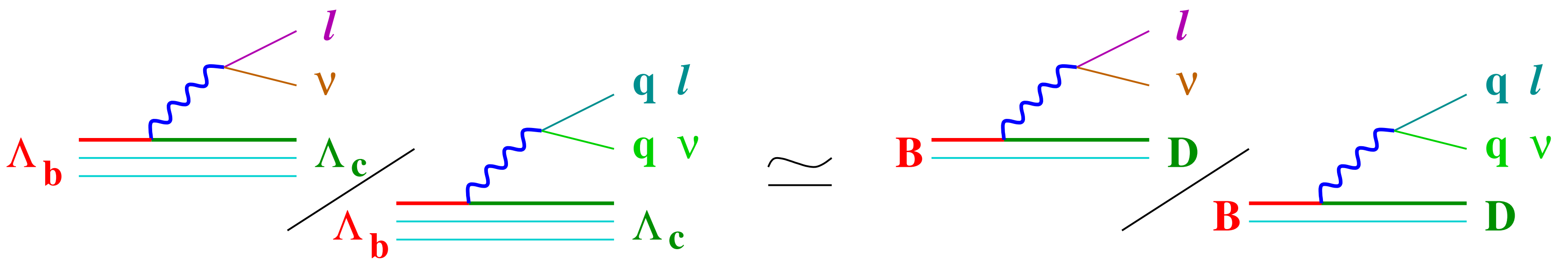
A b-baryon lifetime puzzle?

- $\tau(\text{b-baryon})/\tau(\text{B}^0) = 0.78 \pm 0.04$ is low compared to theoretical expectations of $0.90 - 0.98$.
- more precise or complementary measurements needed for the discrepancy to be definitive
  - for example, $\text{BR}(\text{b-baryon} \to \ell X)$, but no idea how to do it!
  - OPAL and ALEPH have measured ratios of branching ratios:

$$R_{\Lambda\ell} = \frac{\text{BR}(\Lambda_\text{b} \to \Lambda\ell X)}{\text{BR}(\Lambda_\text{b} \to \Lambda X)} \qquad R_{\text{p}\ell} = \frac{\text{BR}(\Lambda_\text{b} \to \text{p}\ell X)}{\text{BR}(\Lambda_\text{b} \to \text{p}X)}$$

b-baryon branching ratio ratios

If light quarks did not participate in the decay of b hadrons...



- *ie.* $R_{\Lambda\ell} \simeq R_{\mathrm{p}\ell} \simeq \mathrm{BR}(\mathrm{B}\to \ell X)$
- the extent to which these differ depends on the strength of the amplitudes involving light quarks
- if short Λ_b lifetime due to larger hadronic partial width, would expect $R_{\Lambda\ell}, R_{\mathrm{p}\ell} < \mathrm{BR}(\mathrm{B}\to \ell X)$

OPAL: $R_{\Lambda\ell}$ (Z. Phys C74 (1997) 423)

$$R_{\Lambda\ell} = \frac{\mathrm{BR}(\Lambda_\mathrm{b} \to \Lambda\ell^- X)}{\mathrm{BR}(\Lambda_\mathrm{b} \to \Lambda X)} = \frac{N(\Lambda_\mathrm{b} \to \Lambda\ell^- X)}{N(\Lambda_\mathrm{b} \to \Lambda X)}$$

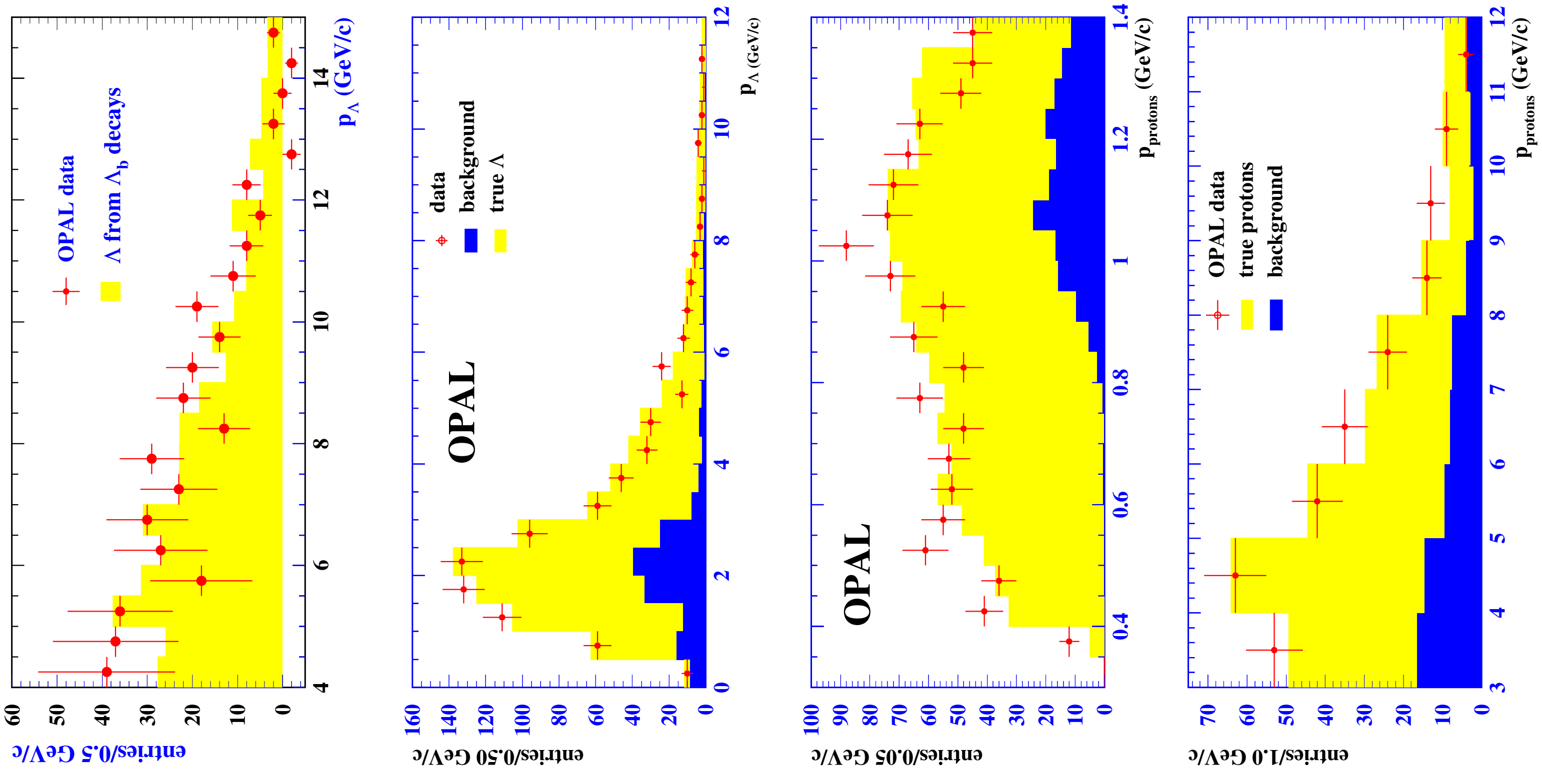
where $N(\ )$ is corrected for efficiencies and background.

- counting $\Lambda_\mathrm{b} \to \Lambda\ell^- X$ done as in lifetime measurements
- counting $\Lambda_\mathrm{b} \to \Lambda X$ more difficult:
  - apply a high efficiency b-tag (ANN)
  - select hard Λ's ($p > 4.5$ GeV)
  - to distinguish signal from background, the second baryon in the jet (the *companion*) is searched for ($\bar{\mathcal{B}} = \bar{\mathrm{p}}$ or $\bar{\Lambda}$)

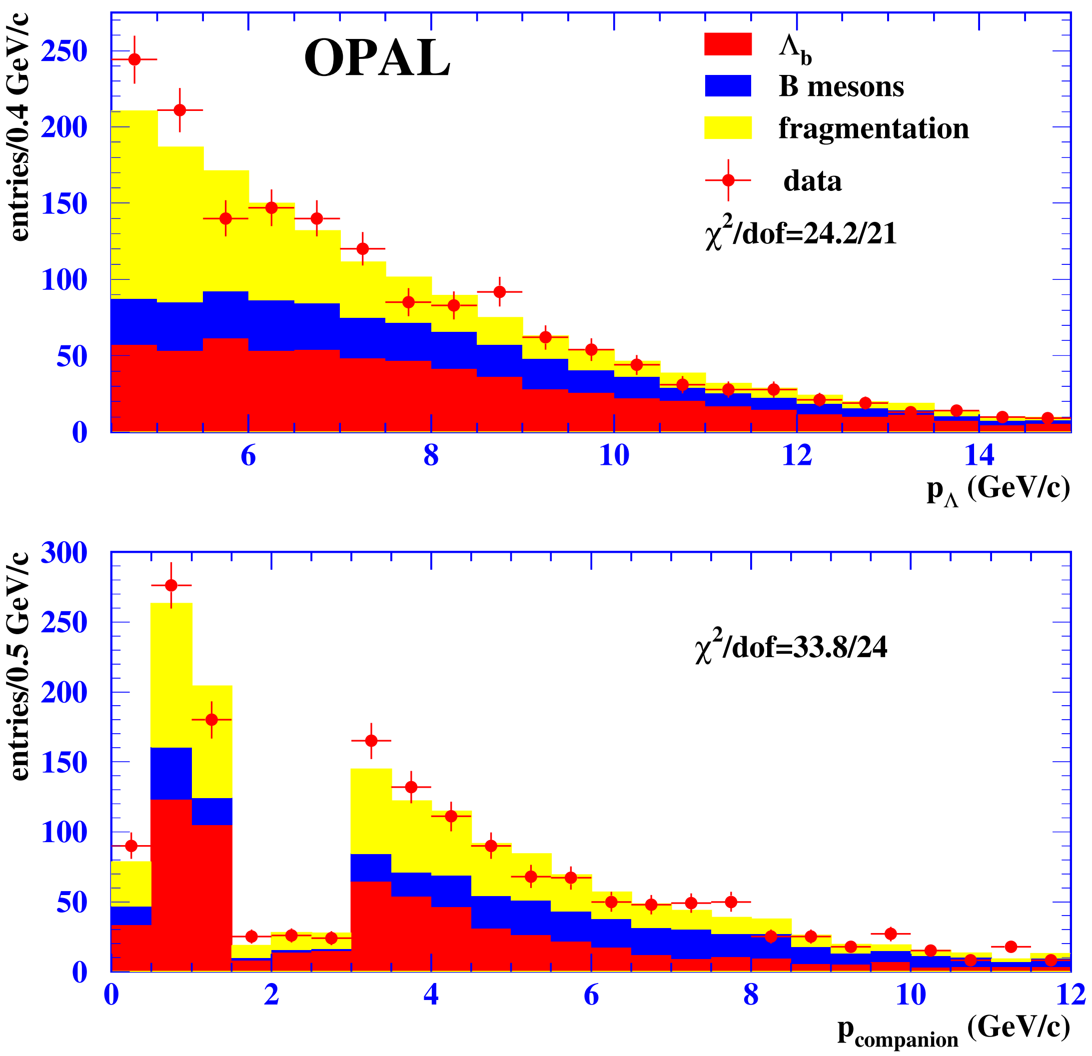
	Λ	$\bar{\mathcal{B}}$
$\Lambda_{\mathrm{b}} \to \Lambda X$	hard	soft
B$\to \Lambda X$	hard	hard
fragmentation Λ	soft	soft

- a binned 2D fit is performed to extract $N(\Lambda_{\mathrm{b}} \to \Lambda X)$
- Data is used to adjust MC reference spectra:
  - Λ from Λ_{b}: use $\Lambda_{\mathrm{b}} \to \Lambda \ell^- X$ sample
  - Λ or $\bar{\mathcal{B}}$ from B: use spectrum measured by CLEO
  - fragmentation: use $\Lambda_{\mathrm{b}} \to \Lambda \ell^- \bar{\mathcal{B}} X$ and b-tagged events with $\bar{\mathcal{B}} \ell^-$

Λ and $\bar{\mathcal{B}}$ spectra



OPAL $R_{\Lambda\ell}$ result



Fraction from Λ_b: $0.396 \pm 0.046 \pm 0.031$

$$R_{\Lambda\ell} = \frac{\mathrm{BR}(\Lambda_b \to \Lambda\ell^- X)}{\mathrm{BR}(\Lambda_b \to \Lambda X)} = 7.0 \pm 1.2 \pm 0.7$$

ALEPH: $R_{p\ell}$ (preliminary)

$$R_{\mathrm{p}\ell} = \frac{\mathrm{BR}(\Lambda_\mathrm{b} \to \mathrm{p}\ell^- X)}{\mathrm{BR}(\Lambda_\mathrm{b} \to \mathrm{p}X)} = \frac{N(\Lambda_\mathrm{b} \to \mathrm{p}\ell^- X)}{N(\Lambda_\mathrm{b} \to \mathrm{p}X)}$$

Determine $N(\Lambda_\mathrm{b} \to \mathrm{p}X)$ indirectly from $N(\mathrm{b} \to \mathrm{p}X)$:

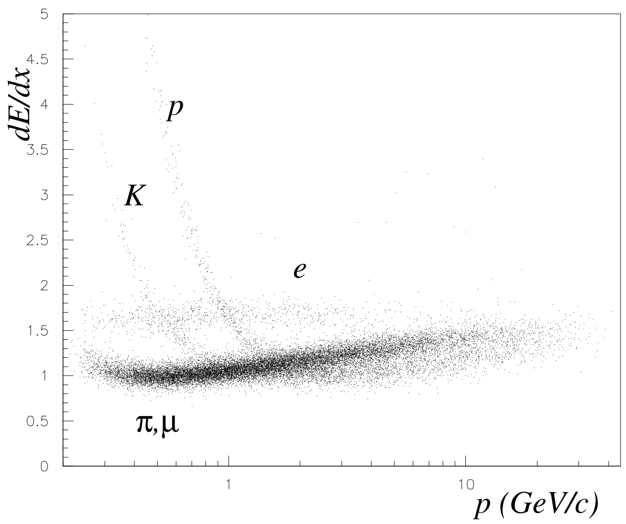
$$N(\Lambda_\mathrm{b} \to \mathrm{p}X) = N(\mathrm{b} \to \mathrm{p}X) - (1 - f_{\Lambda_b})\, N(\mathrm{b})\, \mathrm{BR}(\mathrm{B} \to \mathrm{p}X)$$

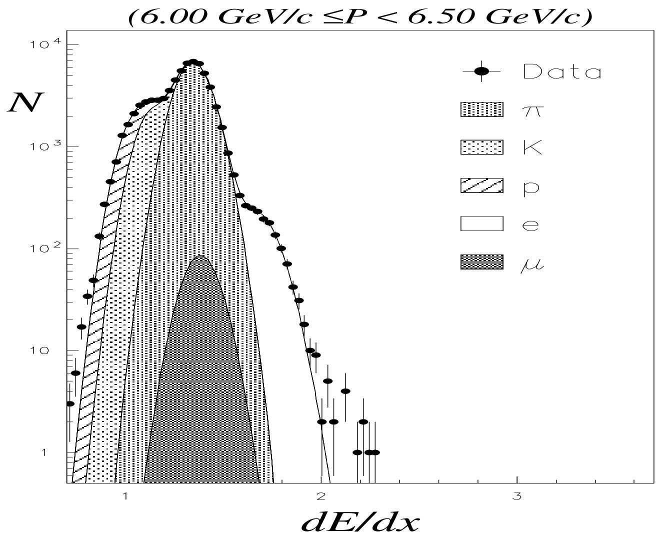
and f_{Λ_b} is determined from:

$$N(\mathrm{b} \to \mathrm{p}X) = \left[f_{\Lambda_b}\, \mathrm{BR}(\Lambda_\mathrm{b} \to \mathrm{p}X) + (1 - f_{\Lambda_b})\, \mathrm{BR}(\mathrm{B} \to \mathrm{p}X) \right] N(\mathrm{b})$$

- $\mathrm{BR}(\mathrm{B} \to \mathrm{p}X) = 8.0 \pm 0.4$ % (CLEO/ARGUS) + $\mathrm{B_s}$ estimate
- $\mathrm{BR}(\Lambda_\mathrm{b} \to \mathrm{p}X) = 50 \pm 5$ % (estimate)

- tag b hemispheres using impact parameters into 5 purity intervals
- using double tagging to estimate the 12 of 15 tagging efficiencies
- fit dE/dx to determine number of protons in opposite hemisphere (in 50 momentum bins $\times$ 5 purity intervals)





To distinguish fragmentation protons from those from b-hadron decay, further classify:

- impact parameter (< 0 and > 0)
- angle to thrust axis ($|\cos\alpha| < 0.975$ and > 0.975)

To estimate $N(\Lambda_\mathrm{b} \to \mathrm{p}\ell^- X)$, divide sample into 8 categories and fit:

- 4 bins of p_t of lepton
- 2 bins of impact parameter of proton (< 0 and > 0)
- for the fit, use MC distributions for signal and background

$$
\begin{aligned}
f_{\Lambda_b} &= 12.1 \pm 0.9 \pm 2.6 \pm 1.8\ \% \\
R_{\mathrm{p}\ell} &= 7.8 \pm 1.2 \pm 1.4\ \%
\end{aligned}
$$

Branching ratio ratio summary

OPAL: $R_{\Lambda\ell} = 7.0 \pm 1.2 \pm 0.7\ \%$

ALEPH: $R_{\mathrm{p}\ell} = 7.8 \pm 1.2 \pm 1.4\ \%$

Both results are less than the b semileptonic branching ratio,

$$\begin{aligned} \mathrm{BR}^{4S}(\mathrm{b} \to \ell X) &= 10.18 \pm 0.40\ \% \\ \mathrm{BR}^{Z}(\mathrm{b} \to \ell X) &= 10.95 \pm 0.31\ \% \end{aligned}$$

and so this confirms that light quarks play a significant role in the decay of b-baryons, as suggested by the short b-baryon lifetime measurements.

Are HQET calculations of $R_{\Lambda\ell}$ or $R_{\mathrm{p}\ell}$ possible?

Summary

Short b-baryon lifetimes lifetimes suggest non-spectator amplitudes are larger than expected

- $\tau(\mathrm{b-baryon})/\tau(\mathrm{B}^0) = 0.78 \pm 0.04$

LEP experiments will soon publish their final results. Look to the Tevatron for further improvements.

Small branching ratio ratios give further evidence for this effect

- $R_{\Lambda\ell}/\mathrm{BR}(\mathrm{b} \to \ell X) = 0.66 \pm 0.13$
- $R_{\mathrm{p}\ell}/\mathrm{BR}(\mathrm{b} \to \ell X) = 0.73 \pm 0.17$

Other measurements of this kind from LEP may be possible.