Report on the Heavy Flavour Working Group (LEP/SLD/CDF)

E.Barberio (CERN/EP)

Thanks to:

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Organization

- **LEP Heavy Flavour Steering Group (P. Roudeau)**
  - **Coordination of H.F. activities at LEP1**
  - **Interactions with theorists**

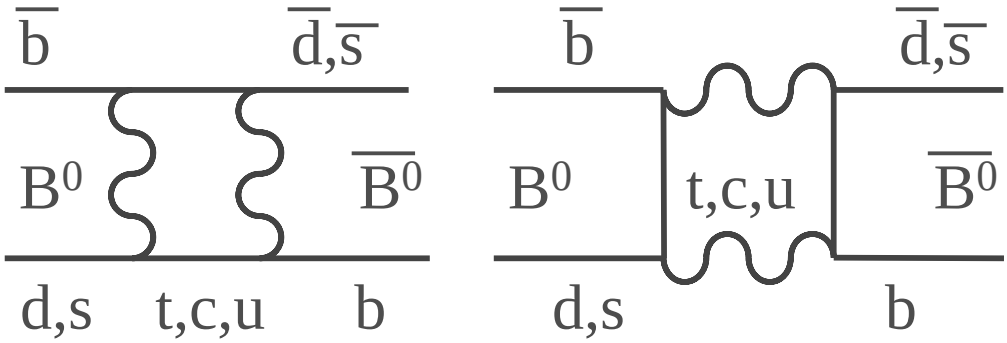
  (http://www.cern.ch/LEPHFS)

- **Working groups (LEP, SLD, CDF):**
  - **Oscillation (O. Schneider)**

    (Δm_d, Δm_s, $\Delta\Gamma_s$, b-hadron fractions)
  - **Lifetime (L. Di Ciaccio)**
  - **V_{cb} (E. Barberio)**
  - **V_{ub} (M. Battaglia)**
- **EP-preprint with summer 99 results (in preparation)**

Oscillations

- **Time dependent mixing**
  (started at LEP)



Δm_d $\Delta m_s \Rightarrow$ V_{td} V_{ts}

V_{td} V_{ts} **extraction limited by theoretical uncertainties**

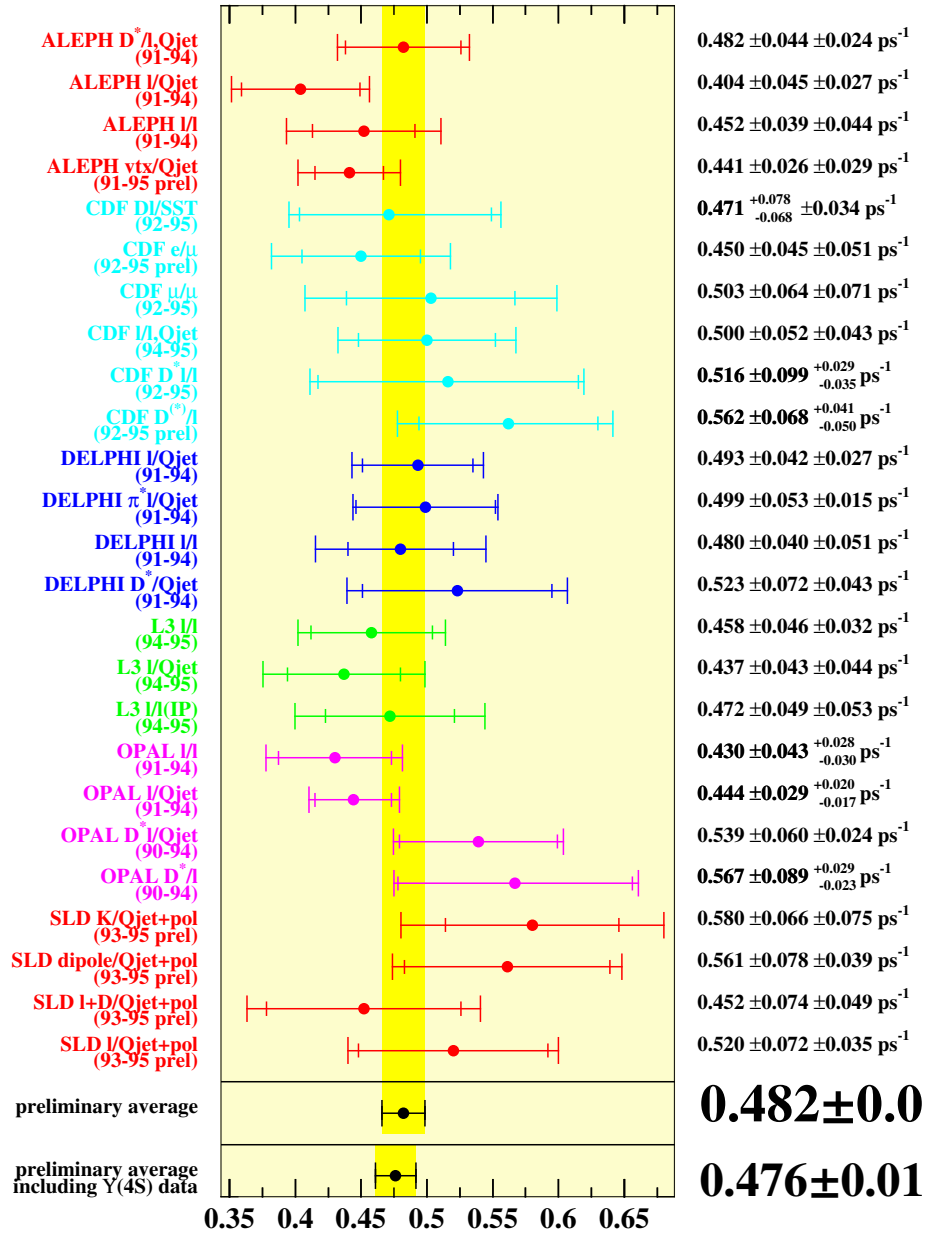
$\Delta m_d/\Delta m_s \Rightarrow V_{td}/V_{ts}$ **less affected by theoretical uncertainties**

$\Delta m_d \Rightarrow$ **a lot of measurements**

$\Delta m_s \sim 20\ \Delta m_d \Rightarrow$ **lower limit up to now**

Δm_d

(LEP, SLD, CDF, Y(4S))



0.482±0.016 ps^{-1}

0.476±0.016 ps^{-1}

B Oscillations Working Group

$\Delta m_d = 0.476 \pm 0.016\ ps^{-1}$

Δm_s

- **Amplitude method (H.G. Moser, A. Roussarie)**

$$1 \pm \cos(\Delta m_s t) \rightarrow 1 \pm A\cos(\Delta m_s t)$$

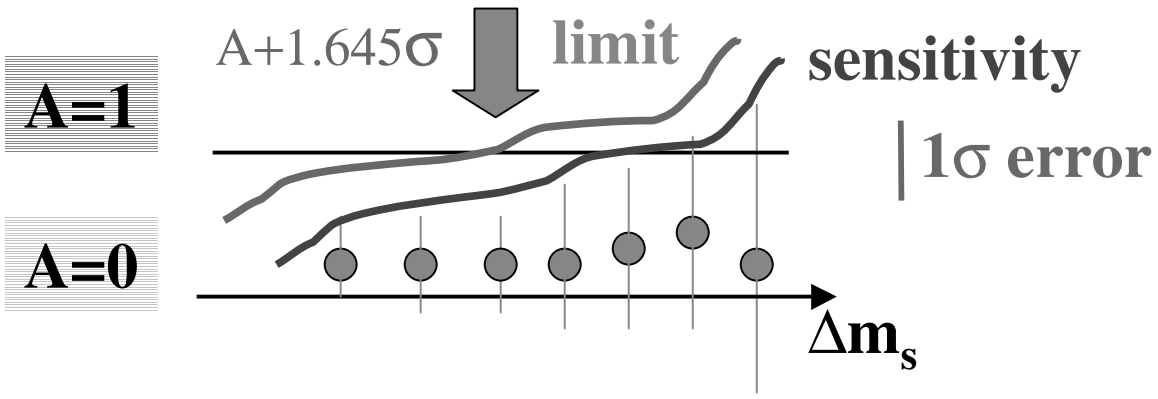
$$\begin{cases} A=0 \Rightarrow \text{no oscillation} \\ A=1 \Rightarrow \text{oscillation} \end{cases}$$

fit for A at different Δm_s values

limit $\Rightarrow$ cannot exclude A<1 at 95% C.L.

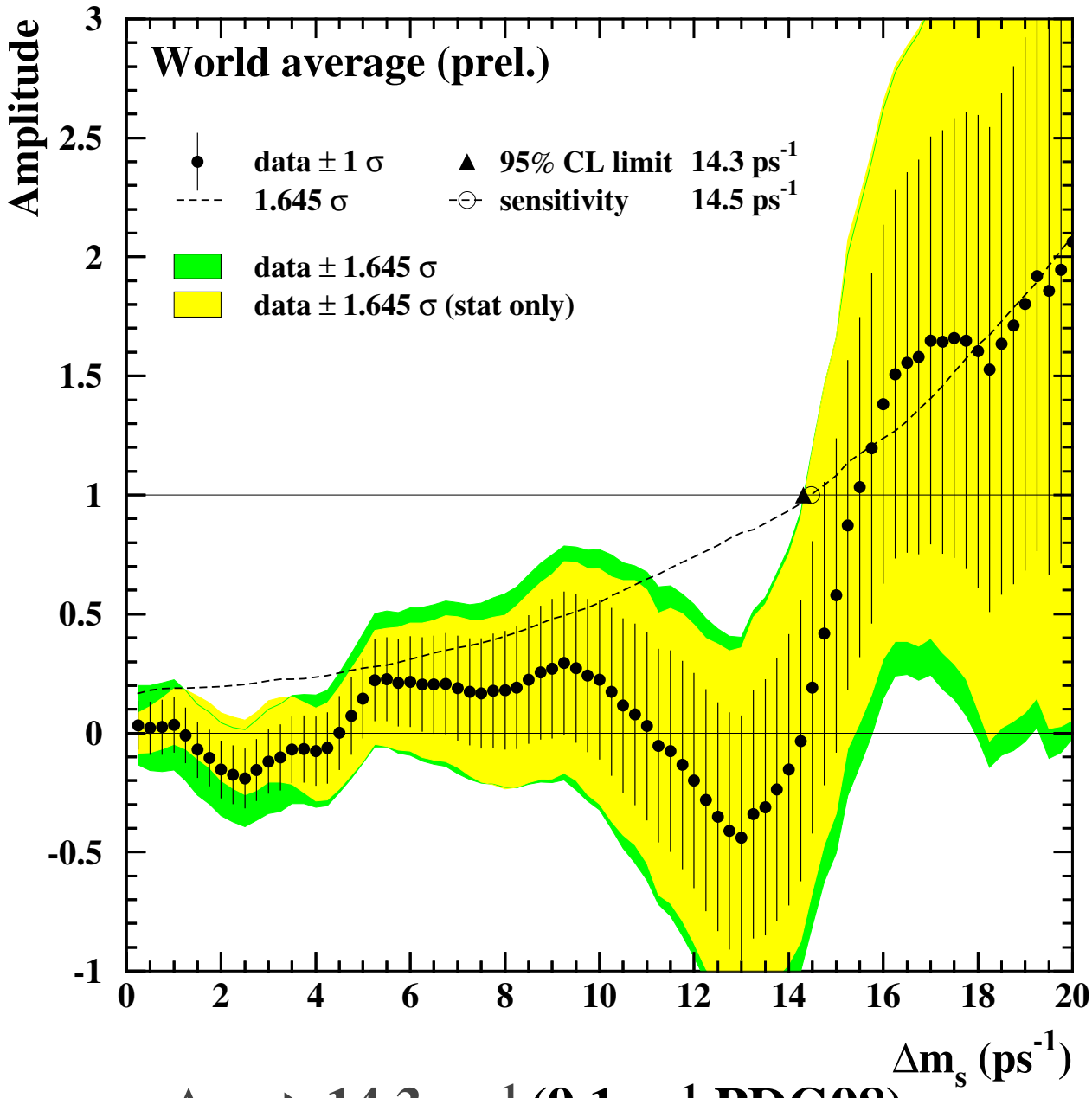
sensitivity $\Rightarrow$ $1.645\sigma = 1$

A is Gaussian $\Rightarrow$ easy to combine



Δm_s

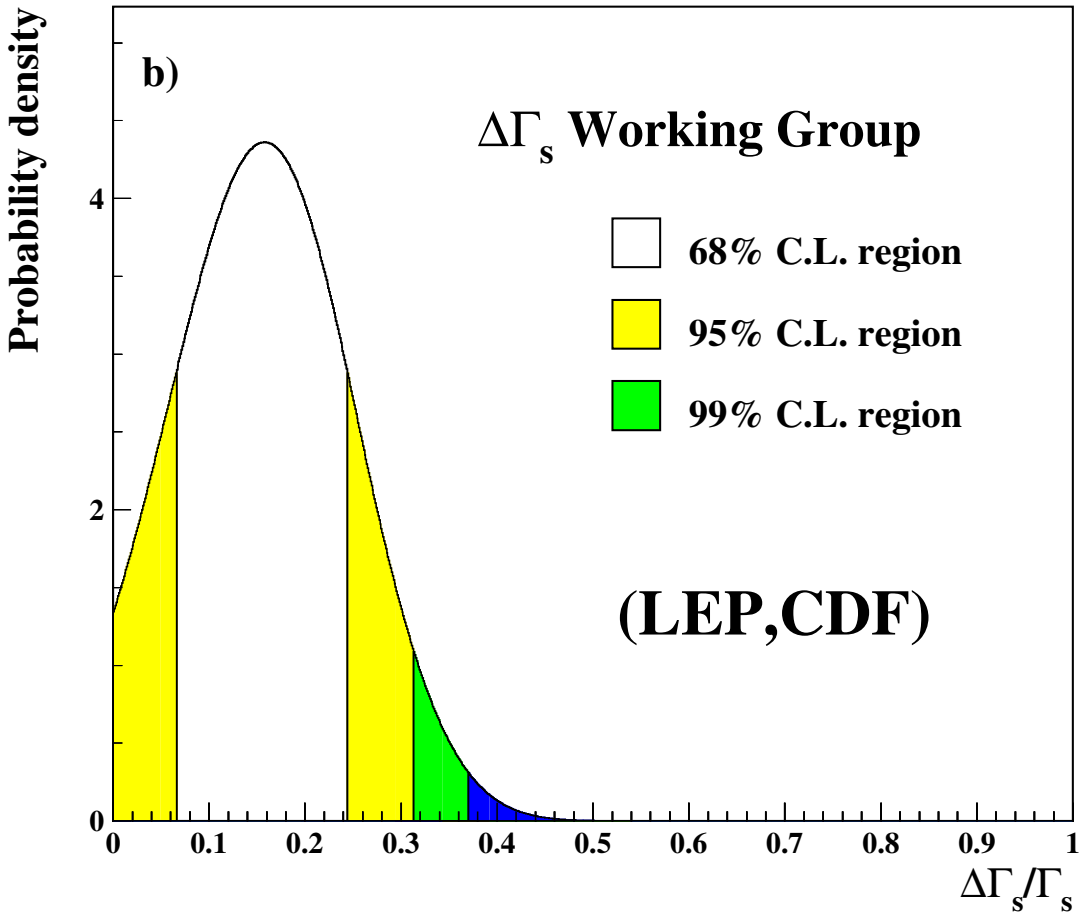
(LEP, SLD, CDF)



$\Delta m_s > 14.3\ ps^{-1}$ **(9.1ps^{-1} PDG98)**

$\Delta\Gamma_s$

B_s mass eigenstates are expected to have different widths ⇒ different lifetimes



$\Delta\Gamma_s/\ \Gamma_s < 0.31$ at 95 % C.L.

($\Gamma_s = 1/\tau_{Bd}$)

B Fractions

$f(b \longrightarrow B_{d/u})$, $f(b \longrightarrow B_s)$, $f(b \longrightarrow$ b-baryon)

(b decays weakly)

direct measurements+mixing+$\Sigma f=1$

$f(b \longrightarrow B_s)=(10.0 \pm 1.2)\%$

(10.5 ±1.8)% (PDG98)

$f(b \longrightarrow B_d)= f(b \longrightarrow B_u)= (40.1 \pm 1.0)\%$

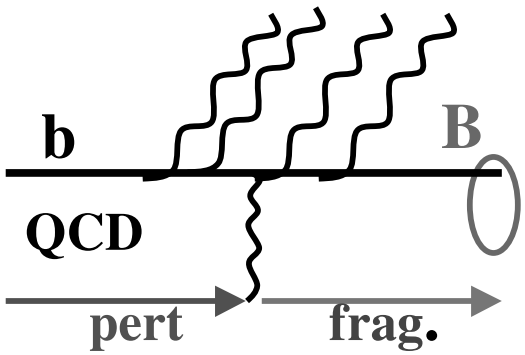
(39.7±2.0)% (PDG98)

$f(b \longrightarrow$ b-baryon) $=(9.9 \pm 1.7)\%$

(10.1±3.5)% (PDG98)

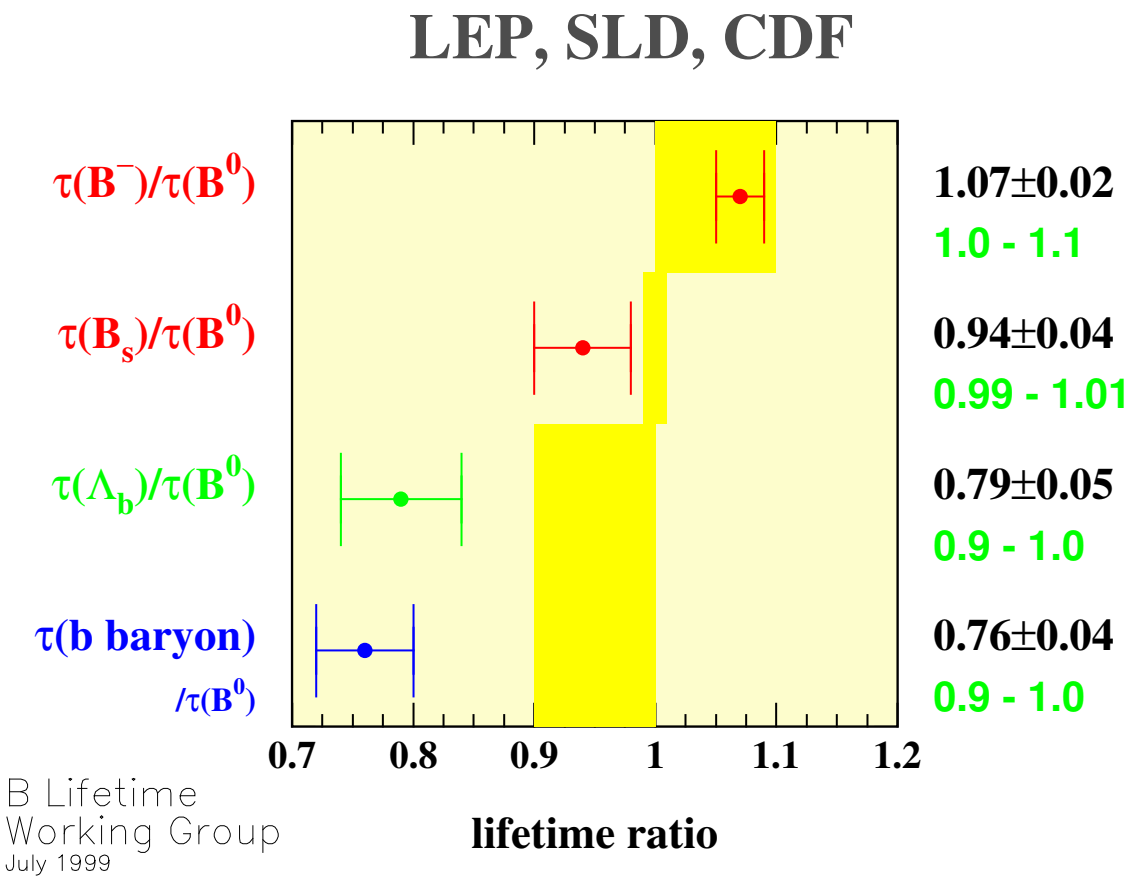
- new activity

b fragmentation:



QCD-HF working group

Lifetimes



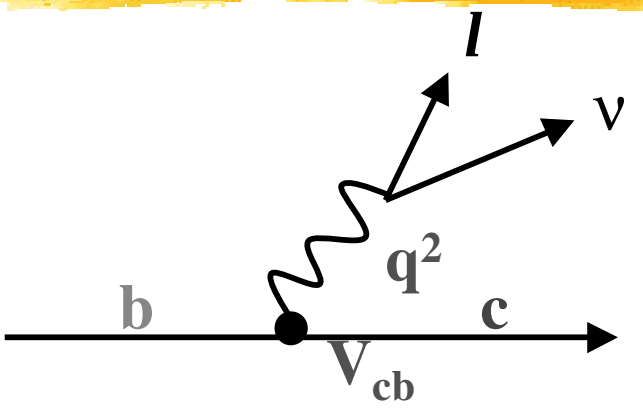
$$\tau(B^-) > \tau(B^0) = \tau(B_s) > \tau(\text{b-bary})$$

why $\tau_{\Lambda b}$ is so short?

$\tau_{Bs} < \tau_{B^0}$? ⇒need more τ_{Bs} measurements

V_{cb}

Two methods



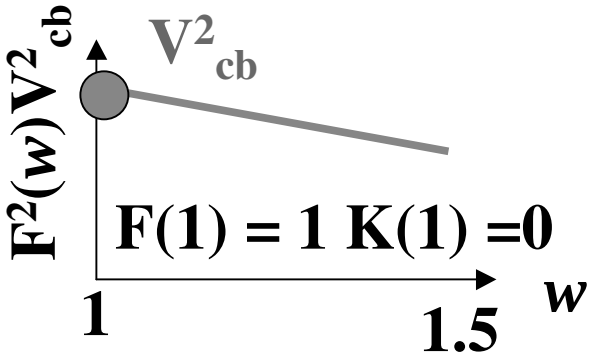
- **Inclusive** $\tau_b + \mathrm{Br}(b \to l)$

$$|V_{cb}|^2 = \frac{\mathrm{Br}(B \to X_c l \upsilon)}{\gamma_c \tau_B}$$

- **Exclusive** $\mathrm{Br}(B \to D^* l \upsilon) + \mathrm{HQET}$

$$\frac{1}{\tau_b}\frac{d\mathrm{Br}(B^0 \to D^* l \upsilon)}{dw} = K(w) F^2(w) |V_{cb}|^2$$

$$w = \frac{m_B^2 + m_{D^*}^2 - q^2}{2 m_B m_{D^*}}$$

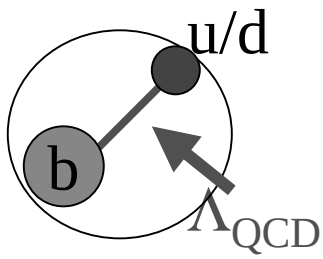


Contacts with theorists

Heavy Quark Effective Theory (HQET)

Simplified description of processes involving heavy quark transitions

$(m_b >> \Lambda_{QCD})$



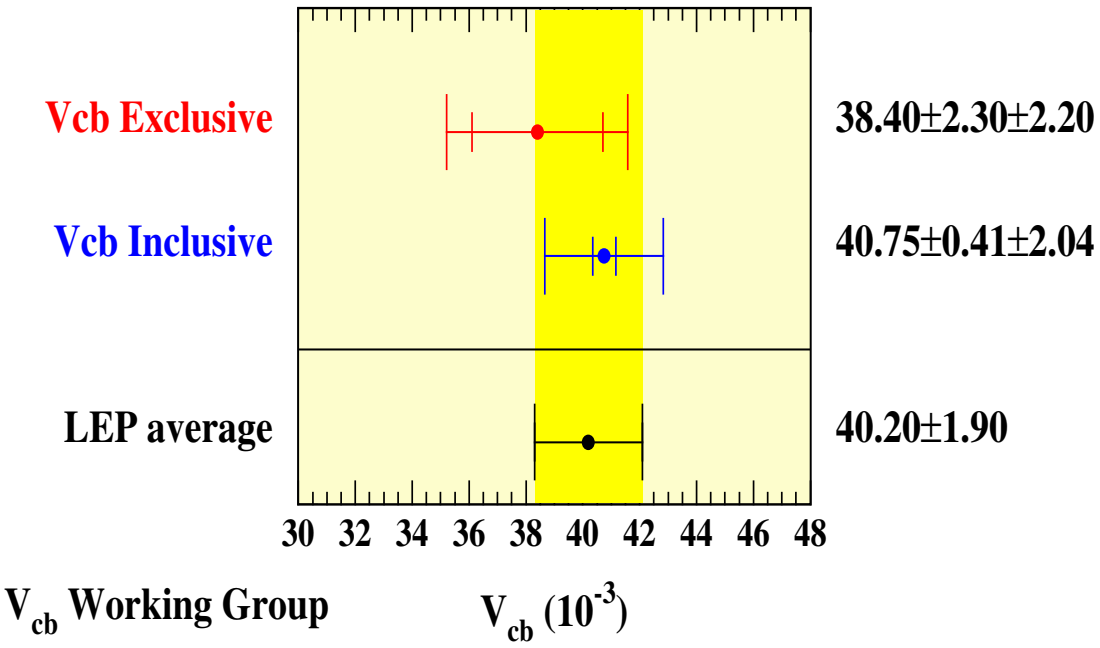
- **measurements limited by theoretical errors**
  - **Reduction of theoretical errors**
    - **Experimental inputs**
    - **What can be done by theorists**

- **Theoretical issue to be solved in the interpretations of the experimental results**

- **2 Workshops last year**
  Next Workshop: March 17th (steering web page)

Vcb

(LEP)



- inclusive ⇒ theoretically limited
- exclusive ⇒ B⟶D** l ν background

new decay models ⇒ larger systematics BUT

new Br measurements and limits ⇒ constraints on decay models

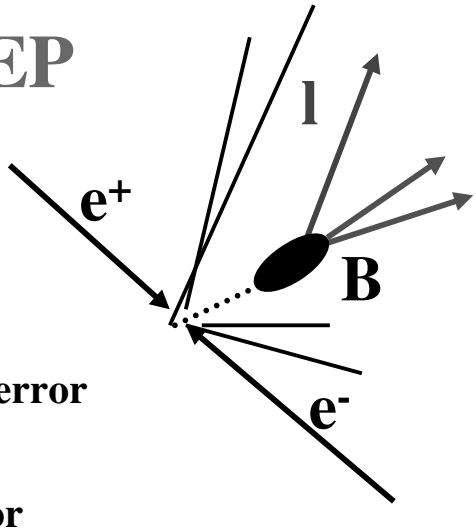
6% (OPAL 95) ⇒ 2% (OPAL 2000)*

future ⇒ average with CLEO for the exclusive

*(same analysis)

$Br(b \longrightarrow X_u l \nu)$

Unique to LEP



statistical + detector error

b → c error

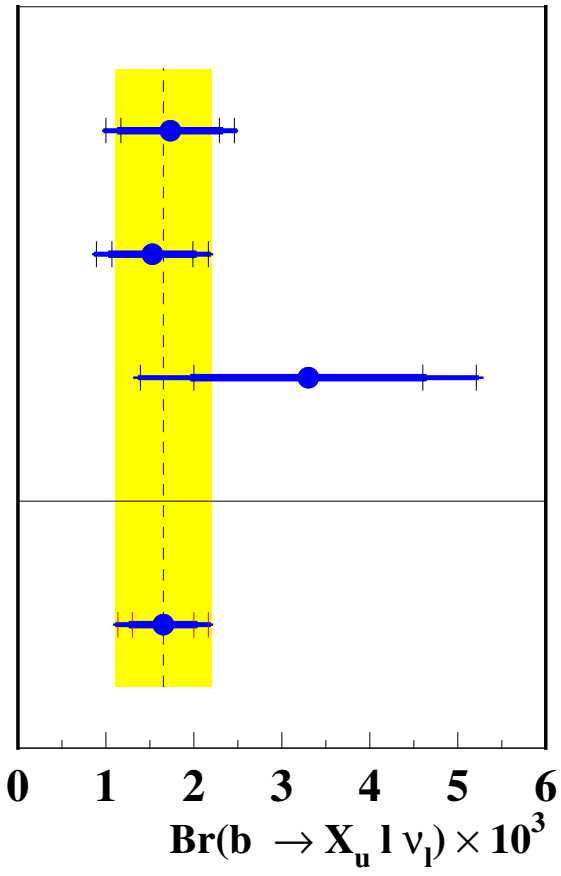
b → u modelling error

ALEPH
1.73±0.56±0.51±0.21

DELPHI
1.56±0.46±0.44±0.22

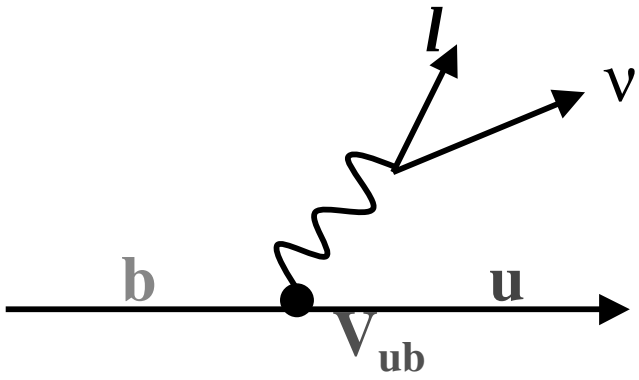
L3
3.3±1.3±1.4±0.5

LEP average
1.67±0.35±0.38±0.20



V_{ub}

LEP ⇒inclusive



τ_b and $\mathrm{Br}(b \to u l \upsilon)$

$$|V_{ub}|^2 = \frac{\mathrm{Br}(B \to X_u l \upsilon)}{\gamma_c \tau_B}$$

$$|V_{ub}| = (4.04^{+1.17}_{-1.71}) \times 10^{-3}$$

CLEO ⇒ B⟶ρlν

V_{ub} inclusive ⇒theoretical error more under control

Future ⇒ do a global average with CLEO

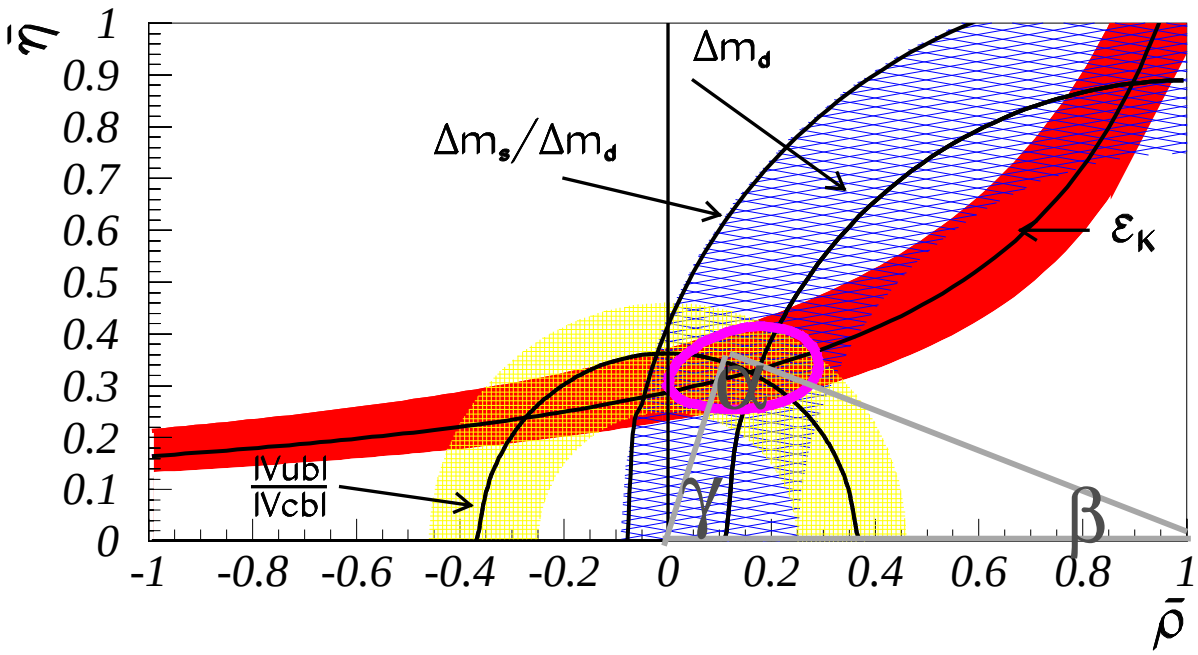
Global fit of CKM matrix

- **Wolfenstein parameterization:**

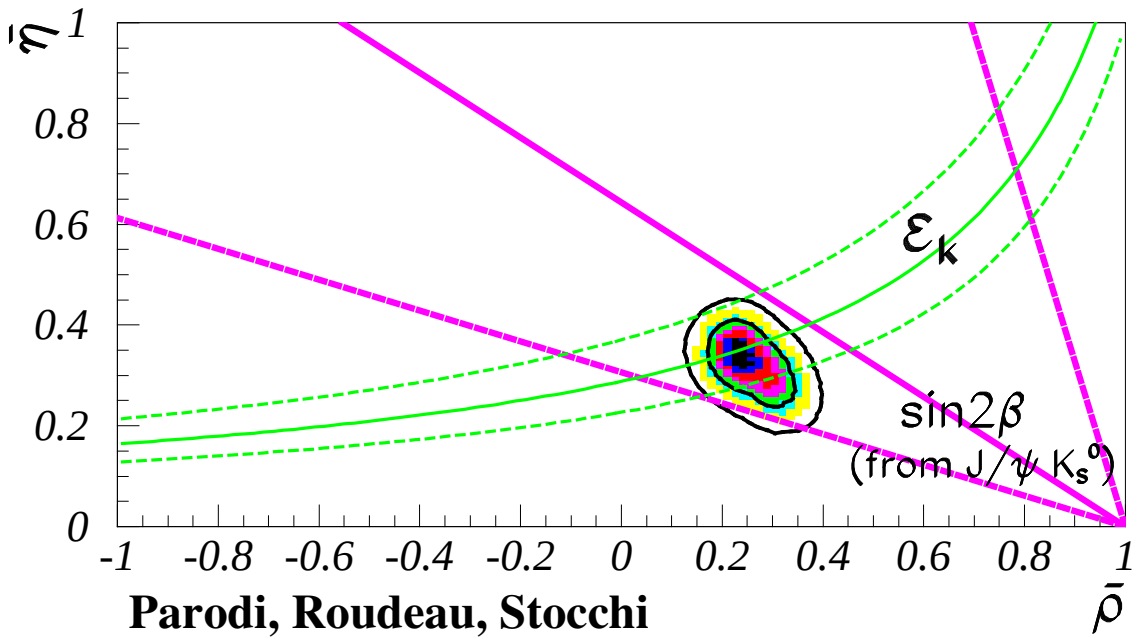
$$\mathrm{CKM}=\begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho-i\eta) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}+O(\lambda^4)$$

- **unitarity ($A^{\dagger}A = 1$) ⇒**

unitarity triangle in ρ–η plane



Unitarity Triangle



- **from summer 99 results (with ε_K)**

$$\sin(2\beta) = 0.750^{+0.058}_{-0.064}$$

$$\sin(2\alpha) = -0.38^{+0.24}_{-0.28}$$

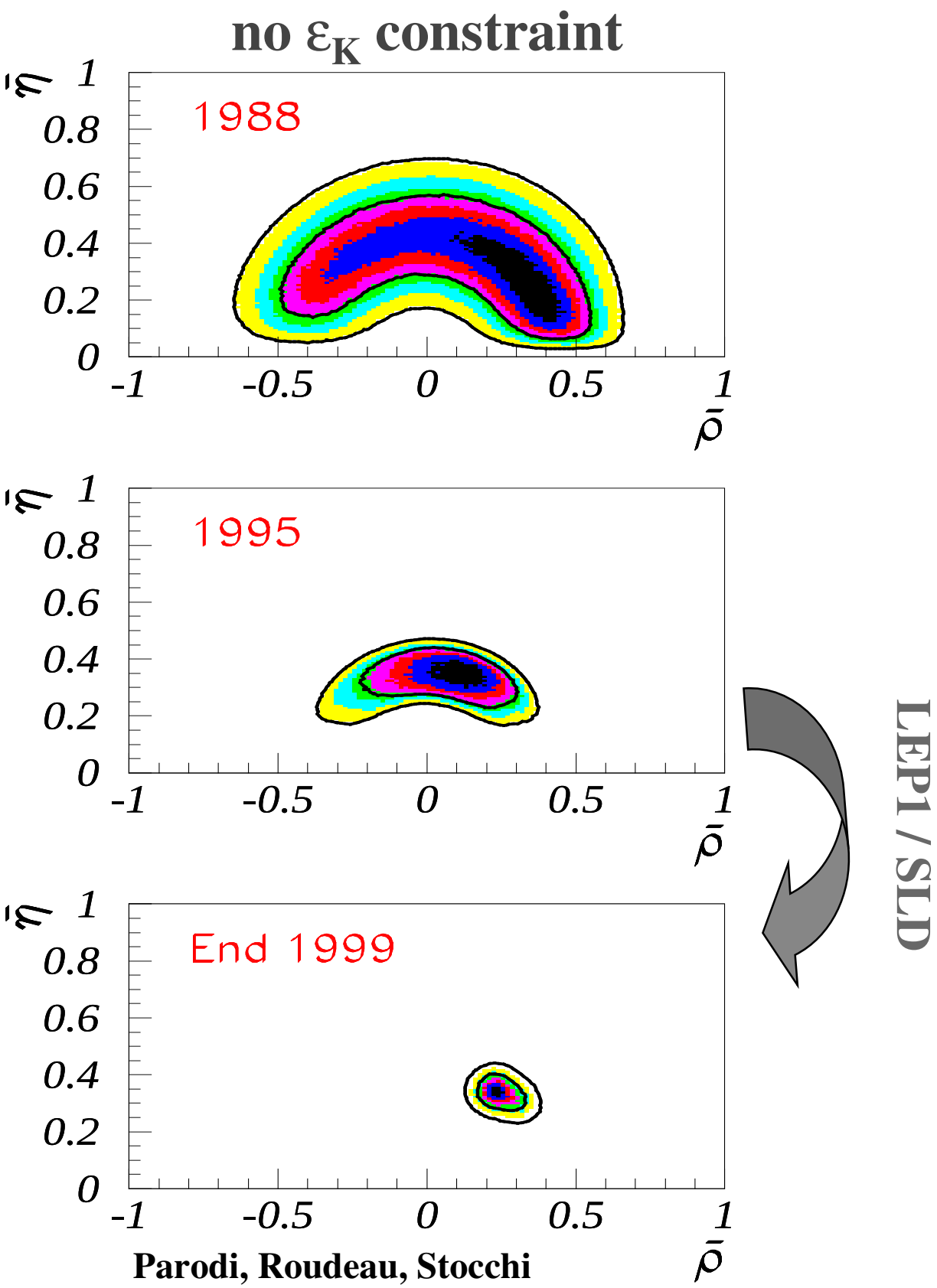
$$\gamma = (55.5^{+6.0}_{-8.5})^0$$

- **from summer 99 results (without ε_K)**

$$\sin(2\beta) = 0.747^{+0.067}_{-0.084}$$

- **current knowledge (ALEPH,CDF,OPAL)**

$$\sin(2\beta) = 0.91 \pm 0.35$$


no ε_K constraint
1988
1995
End 1999
$\bar{\eta}$
$\bar{\rho}$
1
0.8
0.6
0.4
0.2
0
-1
-0.5
0
0.5
1
LEP1 / SLD
Parodi, Roudeau, Stocchi

Conclusions

Future work

- **Averages**
  - **fractions, $\Delta\Gamma_s$, Δm_s**
  - **lifetimes**
  - **V_{ub}**
  - **V_{cb}**
  - **Branching fractions**
- **Reduction of systematic errors**
  - **new decay models**
  - **constraint from branching ratios measurements/averages**
  - **workshops with theorists ⇒reduction of theoretical errors**
  - **$B \longrightarrow D^* l\nu$ and $b \longrightarrow u l\nu$ unfolded spectra**
- **New activities**
  - **b fragmentation**
  - **global fit to the CKM matrix**