Review on
Heavy Flavours Results from CDF/LEP/SLD

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on behalf of the LEP-Heavy Flavour Steering group

LEP-Jamboree , CERN 10^{th} July

The Heavy Flavour Steering group has in charge

- to coordinate the activities on Heavy Flavour Physics between LEP collaborations
- to establish contacts with other experiments working in this field

in view of getting results which include all experimental measurements

Selected topics :

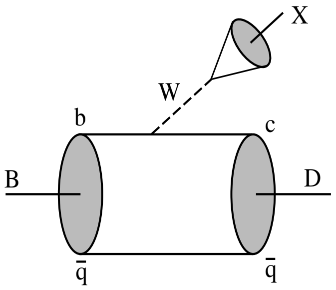
- Measurement of the different B Lifetimes
- Semileptonic B Decays and Charm counting
- Determination of V_{cb}
- Determination of V_{ub}
- Measurement of $B^0 - \bar{B}^0$ Oscillation frequencies
- Determination of the Unitarity Triangle Parameters

b-Lifetime Measurements

All lifetimes of weakly decaying B hadrons have been precisely measured (apart for Ξ_b and Ω_b)

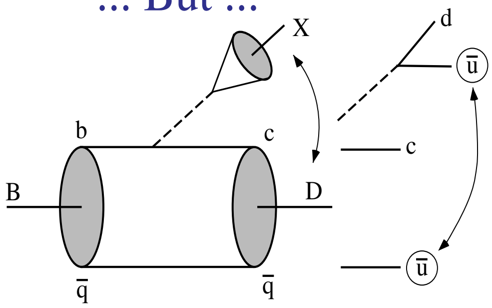
IMPORTANT TEST of B decay DYNAMICS

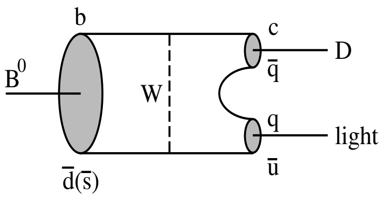
Not only



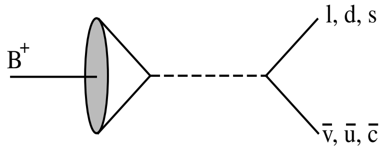
spectator diagram

... But ...



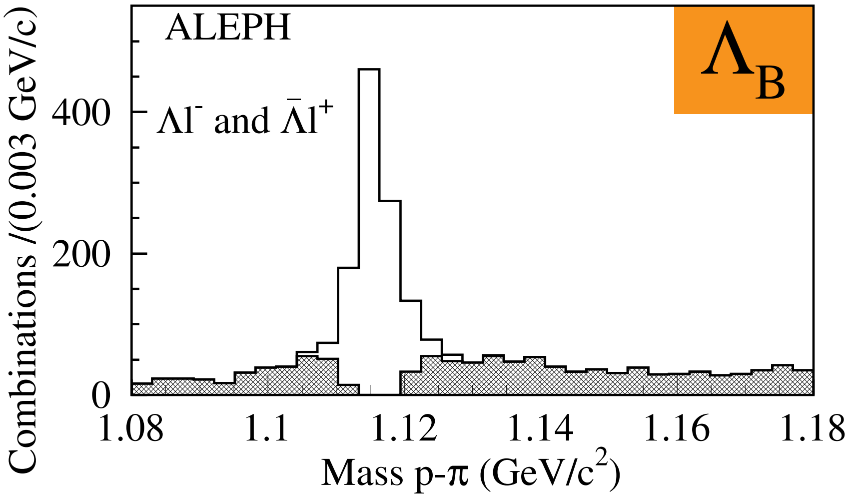


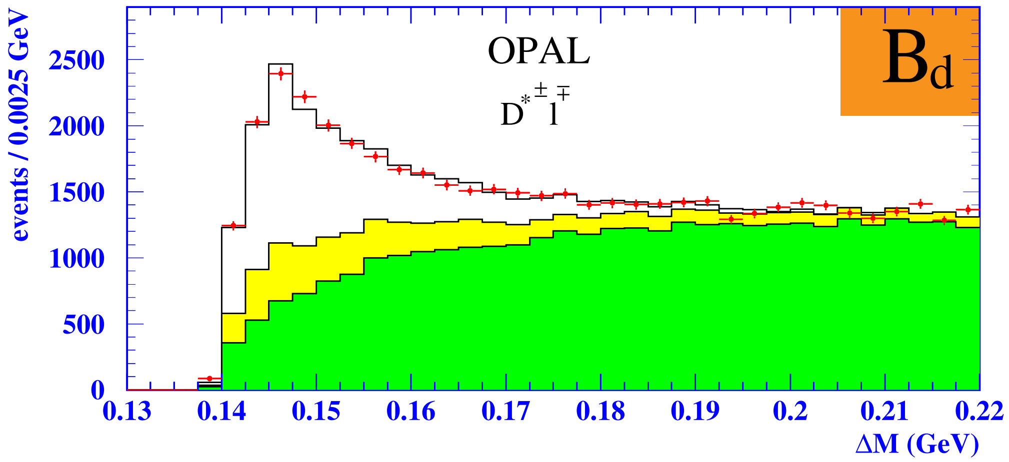
exchange diagram

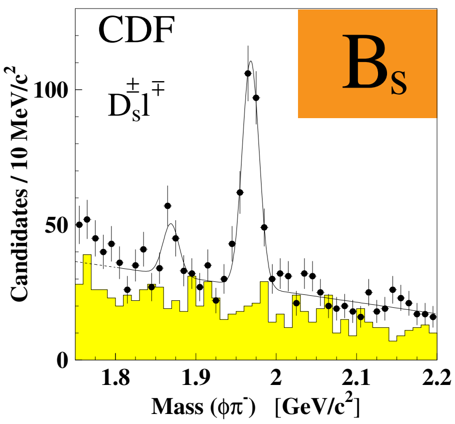


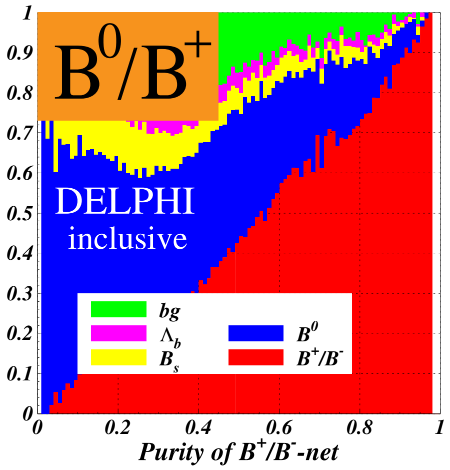
annihilation diagram

Techniques to separate B-hadrons









$$\tau(\bar{B}^0_d) = 1.545 \pm 0.020 ps \ (1.3\%)$$

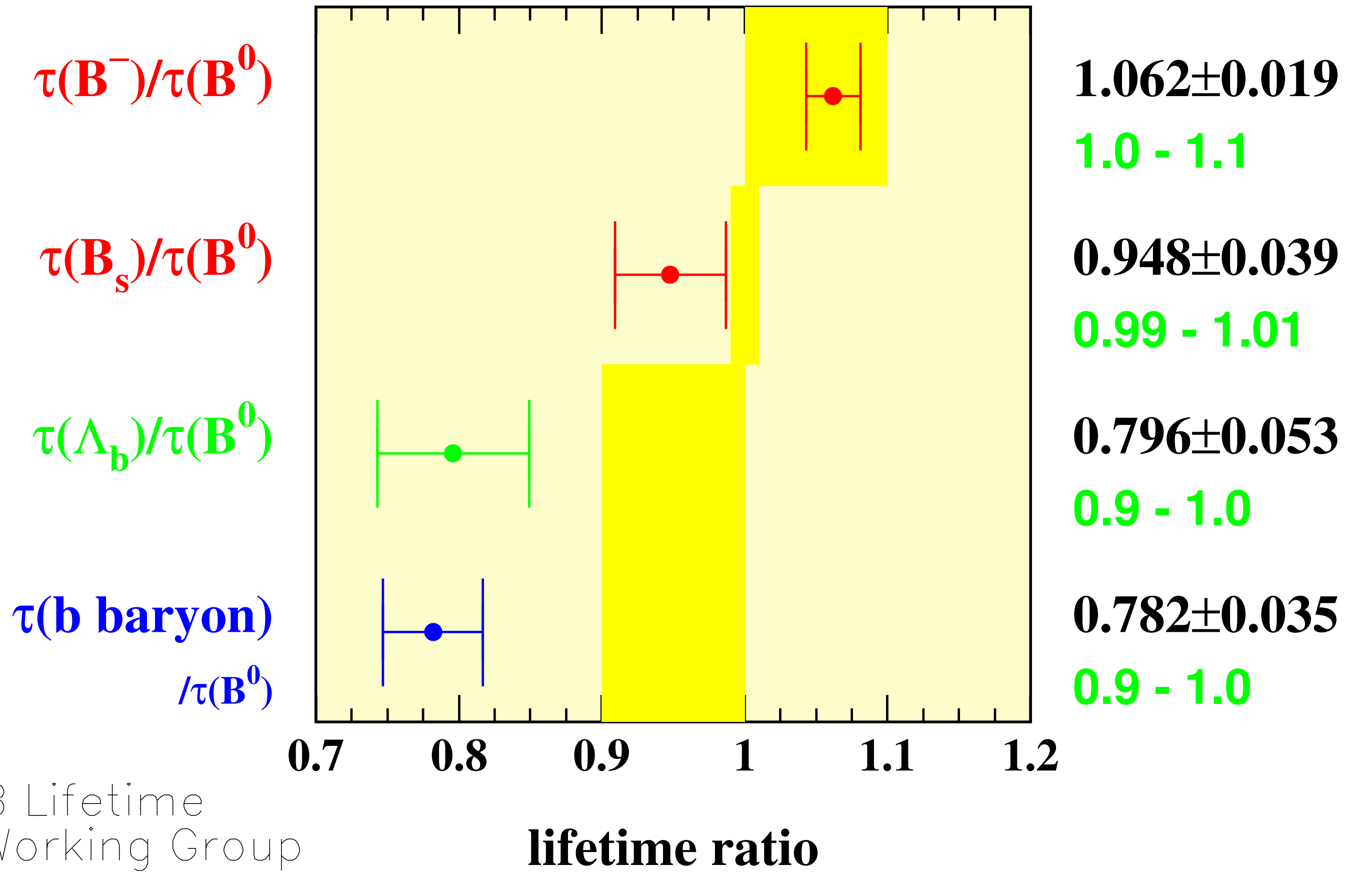
$$\tau(B^+) = 1.642 \pm 0.017 ps \ (1.0\%)$$

$$\tau(\mathrm{B}^0_s) = 1.464 \pm 0.057 ps \ (3.9\%)$$

$$\tau(\Lambda_b) = 1.208 \pm 0.051 ps \ (4.2\%)$$

B-factories will have similar precision this Summer.

(combination not ready today)



The hierarchy was correctly predicted !

$\tau(\mathrm{B}^+)/\tau(\mathrm{B}^0) \rightarrow 3\sigma$ effect in agreement with theory

$\tau(\mathrm{B}^0_s)/\tau(\mathrm{B}^0) \rightarrow 1\sigma$ diff. wrt theory $\rightarrow$ new data needed.....

Λ_b Problem $\rightarrow$ the precision of the results push for a better understanding of the theory

n_c versus $Br(b \to \ell\nu)$

$Br_{sl} : b \to c\ell^- \bar{\nu}$ is on the low side of the theo. expectation
A possible explanation is that the c-quark effective mass is low $\to$ large decay rate for $b \to c\bar{c}s(d)$

$\to n_c (= n_c + n_{\bar{c}})$ is NEGATIVELY CORRELATED TO Br_{sl}

The simultaneous measurement of Br_{sl} and n_c may help to clarify the theoretical picture

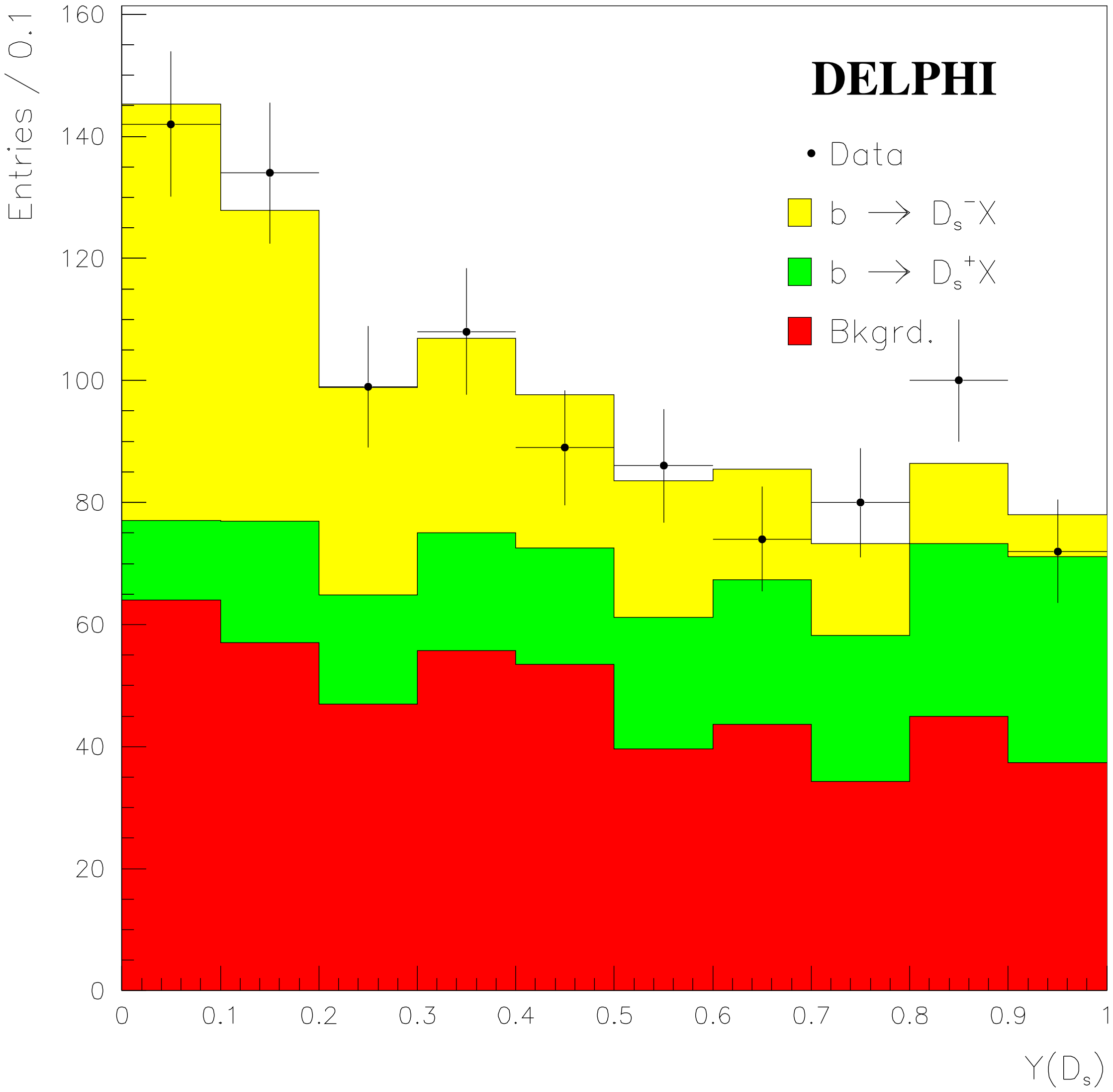
Many different ways of measuring n_c :

- inclusive production of D^0,D^+,D_s^+,Λ_c^+,Ξ_c^{+0}
- inclusive-topological double-open,single and no-charm measurements
- Charmonium production

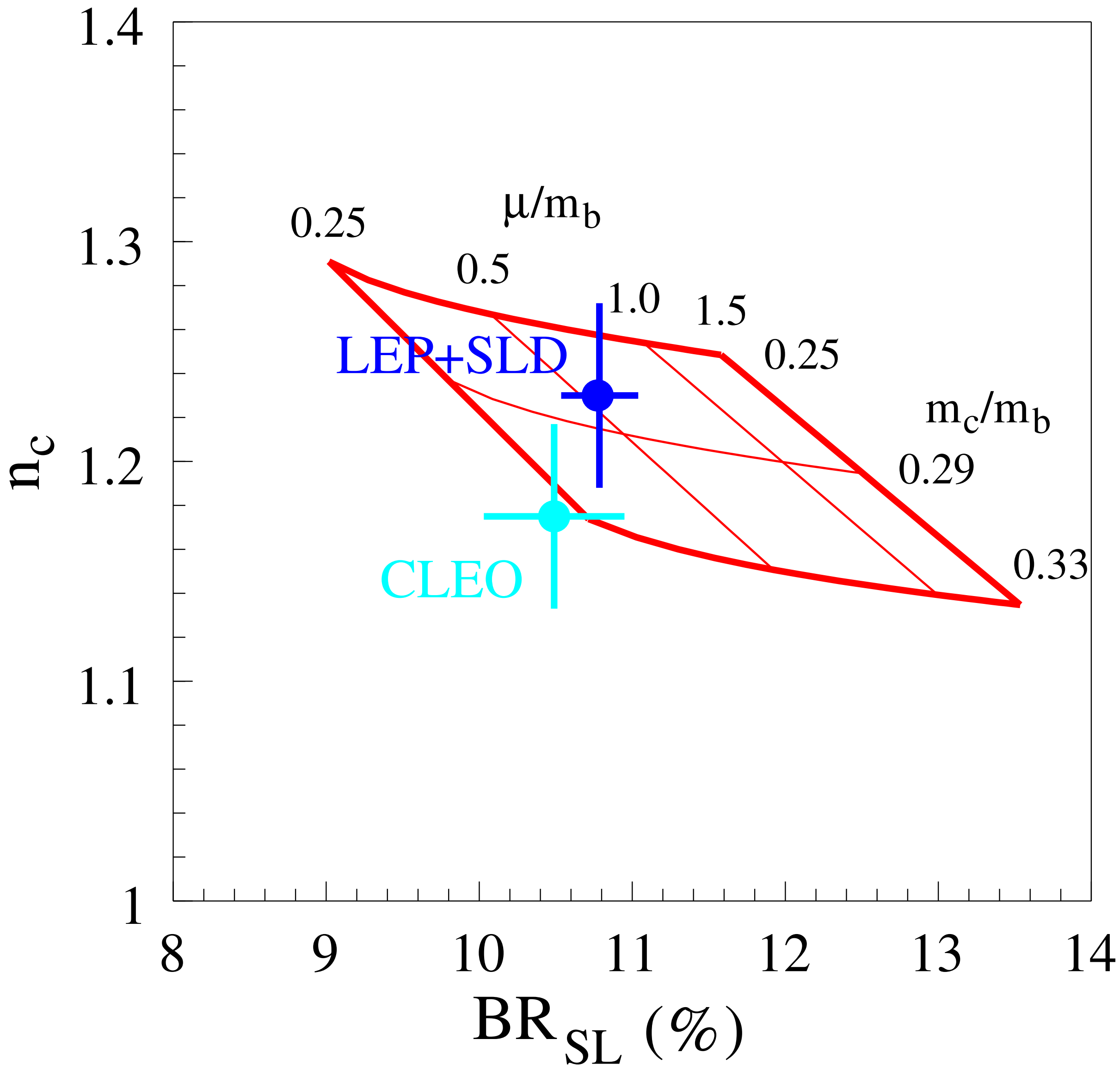
- Exclusive wrong-sign measurements : $b \to D\bar{D}_j X$

Previous measurements from ALEPH (CLEO).

- Recontruct exclusive D mesons
- Correlate the D charge with the initial b charge



- The values of B_{sl} at CLEO ($\Upsilon(4S)$) and LEP agree.
- Similar precision on n_c and B_{sl}



- std. value of the c mass : $\frac{m_c}{m_b} = 0.30 \pm 0.02$

  (m_q = pole mass defined at one-loop in perturbation theory)

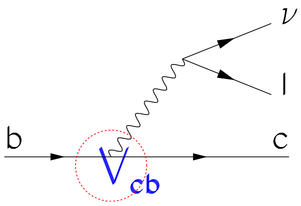
- low scale μ : $\frac{\mu}{m_b} \simeq 0.35$

  (μ = scale at which the QCD corrections have to be evaluated)

The A parameter: $|V_{cb}|$ measurements

A LOT OF ACTIVITIES DURING LAST YEARS

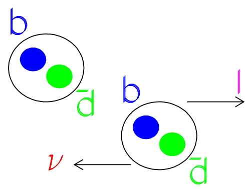
Method 1: τ_B + inclusive Br

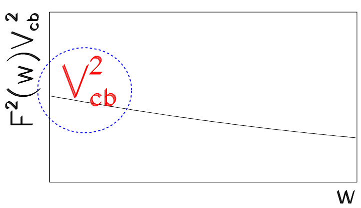


$$A^2\lambda^4 \equiv |V_{cb}|^2 = \frac{\mathrm{Br}(\mathrm{B} \to \mathrm{X_c}\ell\nu)}{\gamma_c \tau_\mathrm{B}}$$

$$\frac{\sigma(\gamma_c)}{\gamma_c} = \pm 0.030(\alpha_s^{\mathrm{MS}}(1GeV)) \pm 0.020(m_b) \pm 0.024(1/m_Q^3) \pm 0.024(\mu_\pi^2)$$

Method 2: $\mathrm{Br}(\mathrm{B} \to \mathrm{D}^*\ell\nu)$ + HQET



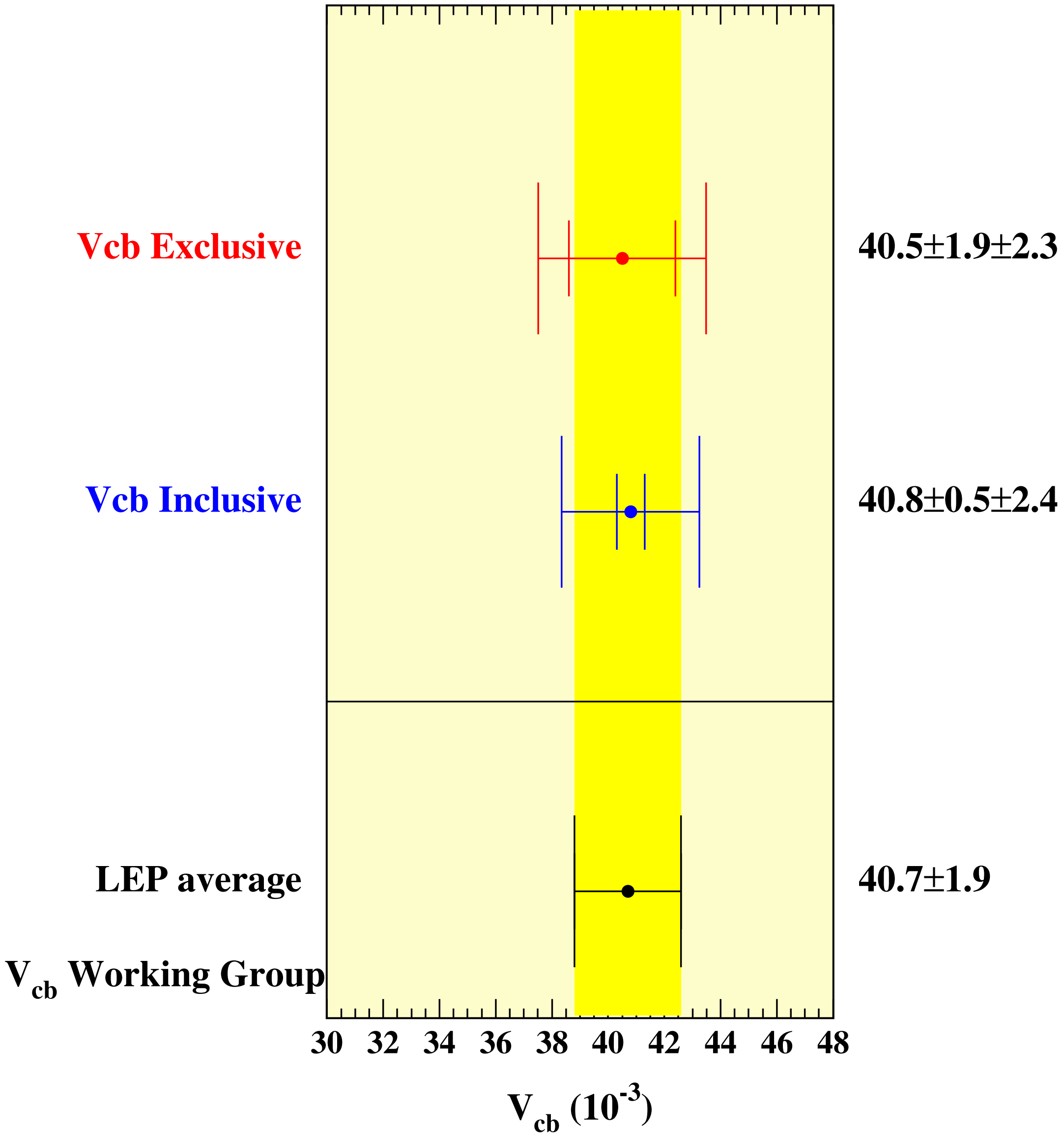


$$\frac{d(Br)}{dw} = \ldots F^2(w)|V_{cb}|^2$$

$$F(w) = F(1)f(\rho, w..); \;\; \rho = \mathrm{slope}, \mathrm{w} = \mathrm{v_B v_D}$$

$$F(1) = 0.88 \pm 0.05$$

$|V_{cb}|$ Results



$$|V_{cb}| = (40.7 \pm 1.9)10^{-3}$$

Comments :

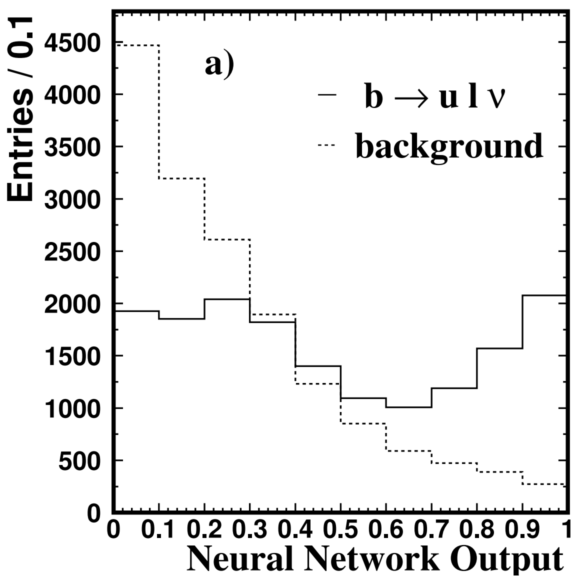
Lot of work done for the inclusive/exclusive V_{cb} measurements $\Rightarrow$ to be pursued by the B-Factories

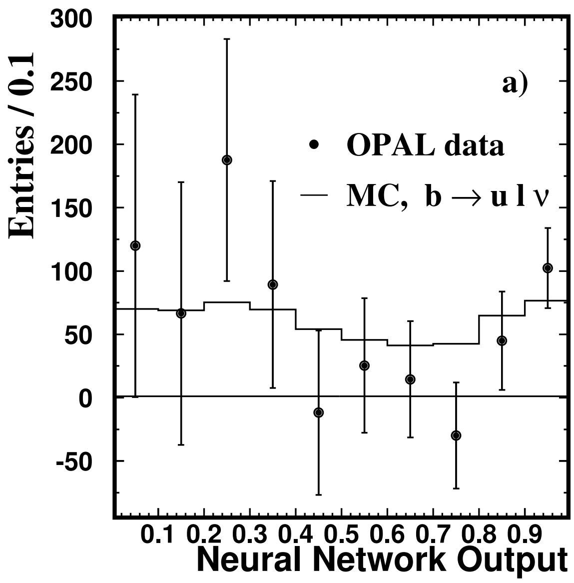
$|V_{ub}|$

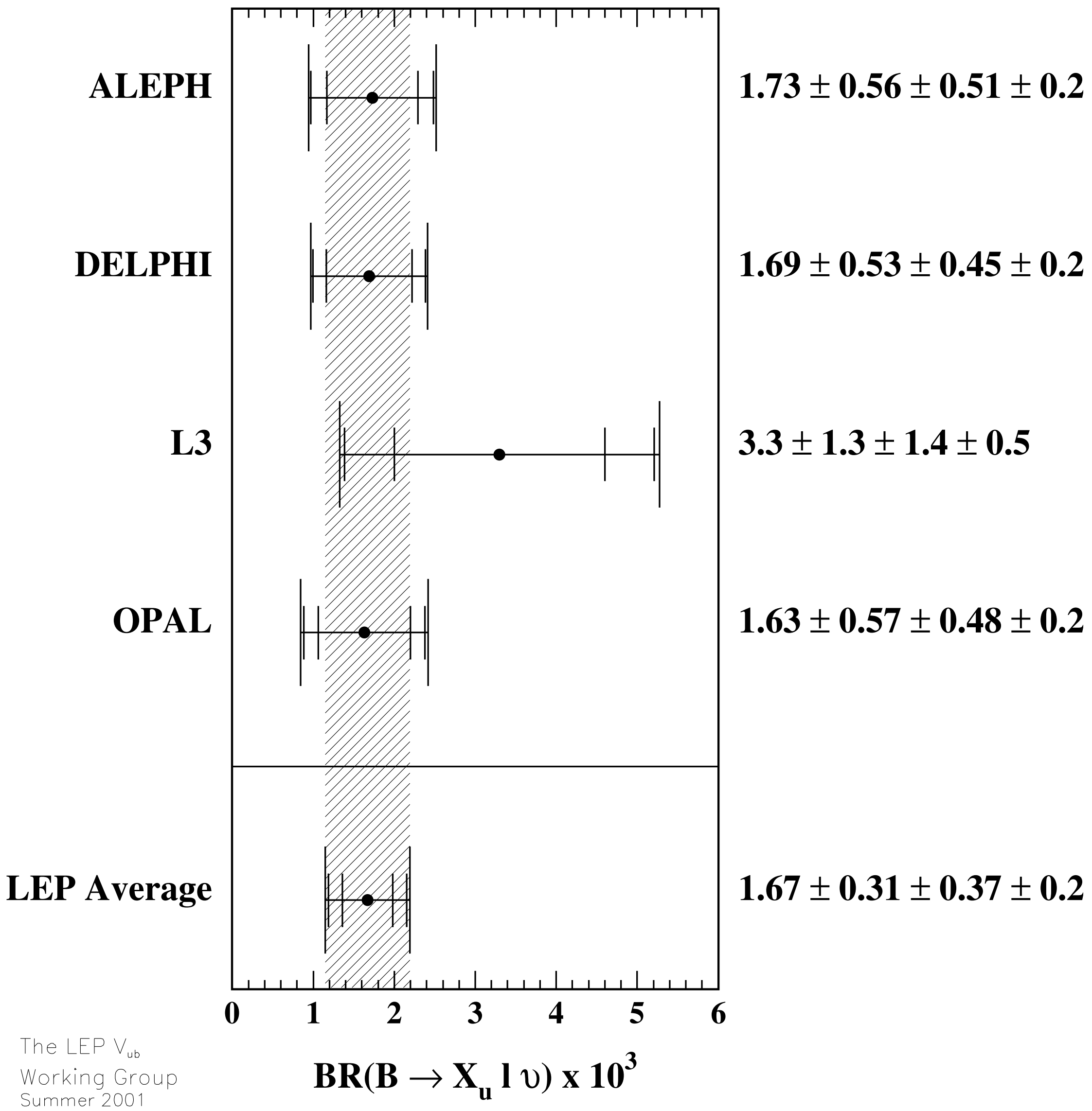
At LEP it is possible to measure V_{ub} using inclusive methods : $|V_{ub}|^2 \propto \mathrm{Br}(\mathrm{b} \to \mathrm{X_u}\ell\nu_\ell)$

By using several kinematical variables which have a distinctive power to discriminate between :

$\mathrm{b} \to \mathrm{c}$ and $\mathrm{b} \to \mathrm{u}$







$$V_{ub} = (40.5 \pm 6.2 \pm 3.1) \times 10^{-4} \quad \text{LEP}$$

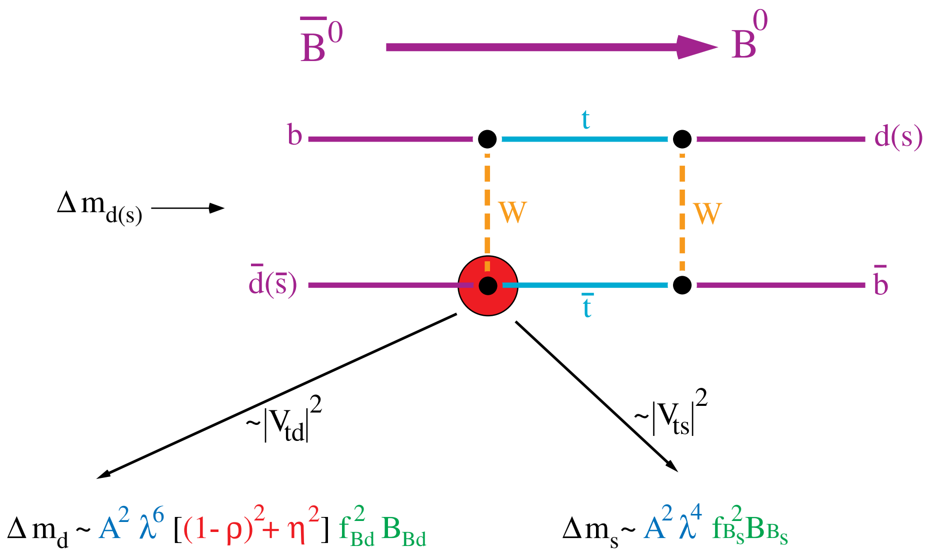
$$V_{ub} = (32.5 \pm 2.9 \pm 5.5) \times 10^{-4} \quad \text{CLEO}(exclusive\ \rho\ell\nu)$$

Comments :

- Pioneering work on inclusive determination of V_{ub} $\Rightarrow$ to be pursued at the B-factories

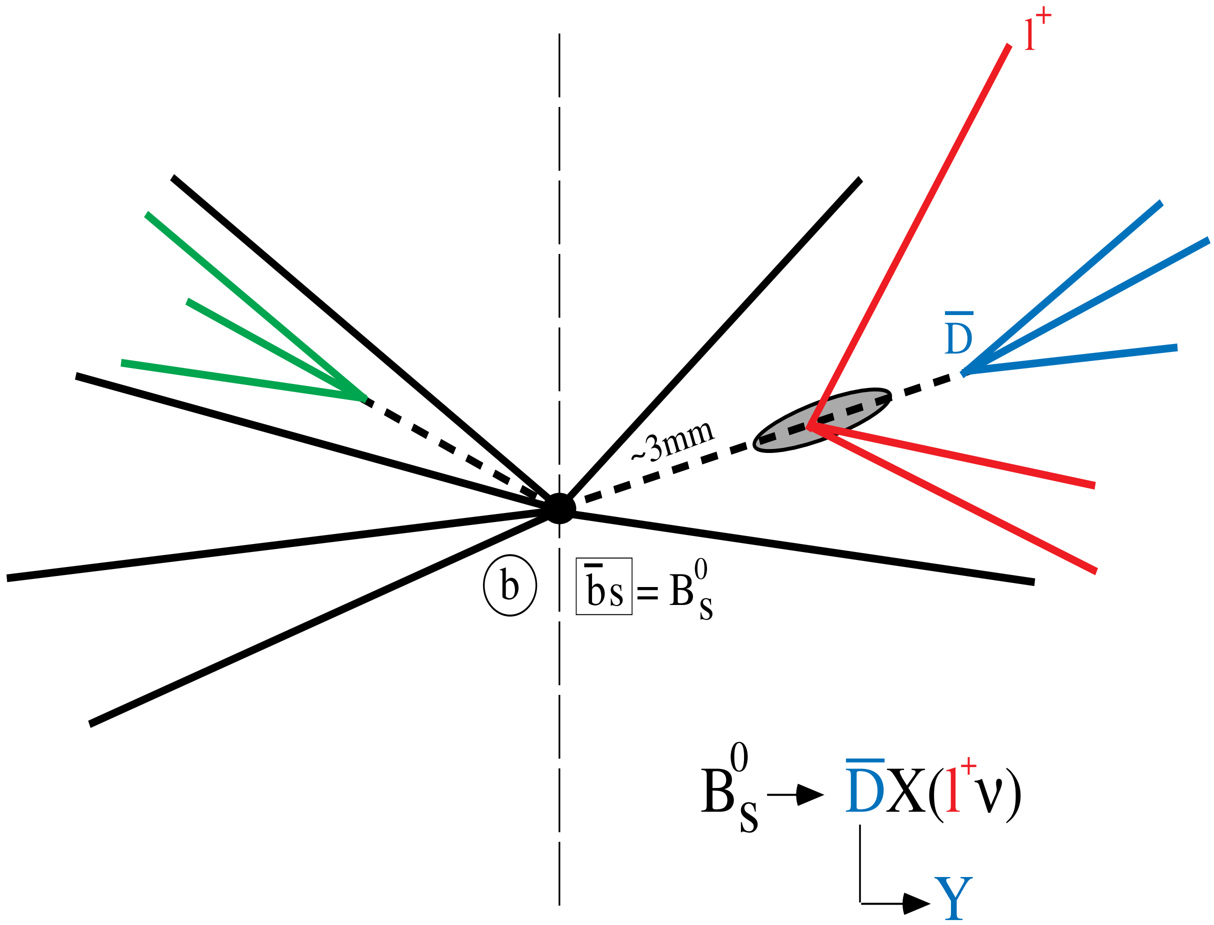
$B^0 - \overline{B^0}$ Oscillations

$$P_{\mathrm{B_q^0 \to B_q^0 (\overline{B}_q^0)}} = \frac{1}{2} e^{-t/\tau_q} (1 \pm cos \Delta \mathrm{m_q t}) \qquad (1)$$



- $\Delta m_s \simeq 20 \times \Delta m_d$ $\qquad$ ($20 \propto 1/\lambda^2$)
- $\frac{\xi^2}{\lambda^2} \frac{\Delta m_d}{\Delta m_s} = (1-\bar{\rho})^2 + \bar{\eta}^2$ $\qquad$ $\xi = \frac{f_{B_s}\sqrt{B_{B_s}}}{f_{B_d}\sqrt{B_{B_d}}}$

Experimental Techniques



A time dependent $B^0_q (q = d, s)$ oscillation study requires:

- precise measurement of the decay proper time
- B^0_q or $\overline{B^0_q}$ at $t = t^0$ (DECAY TAG)
- B^0_q or $\overline{B^0_q}$ at $t = 0$ (PRODUCTION TAG)

KEY Ingredients :

$$\sigma_{\Delta m_s} = \frac{1}{\sqrt{N} f_{\mathrm{B_s^0}} (2\epsilon - 1) e^{-(\Delta m_s \sigma_t)^2/2}}$$

- N total number of events in the sample
- $f_{\mathrm{B_s^0}}$ fraction of events due to $\mathrm{B_s^0}$ decays
- ϵ tagging purity:

$$\epsilon = \frac{N_{right}}{N_{right} + N_{wrong}}$$

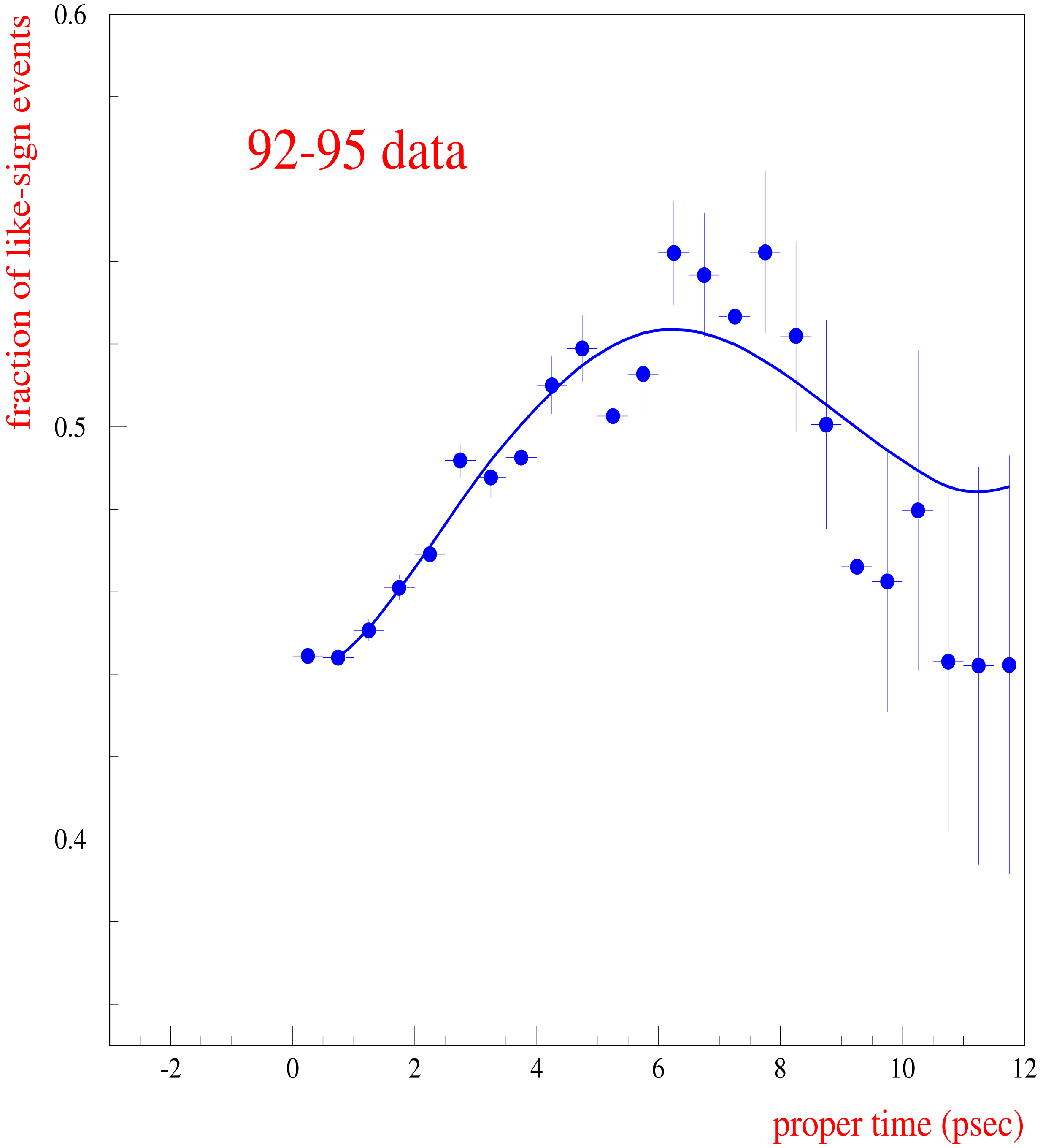
  where $N_{right}(N_{wrong})$ is the number of correctly (incorrectly) tagged events.

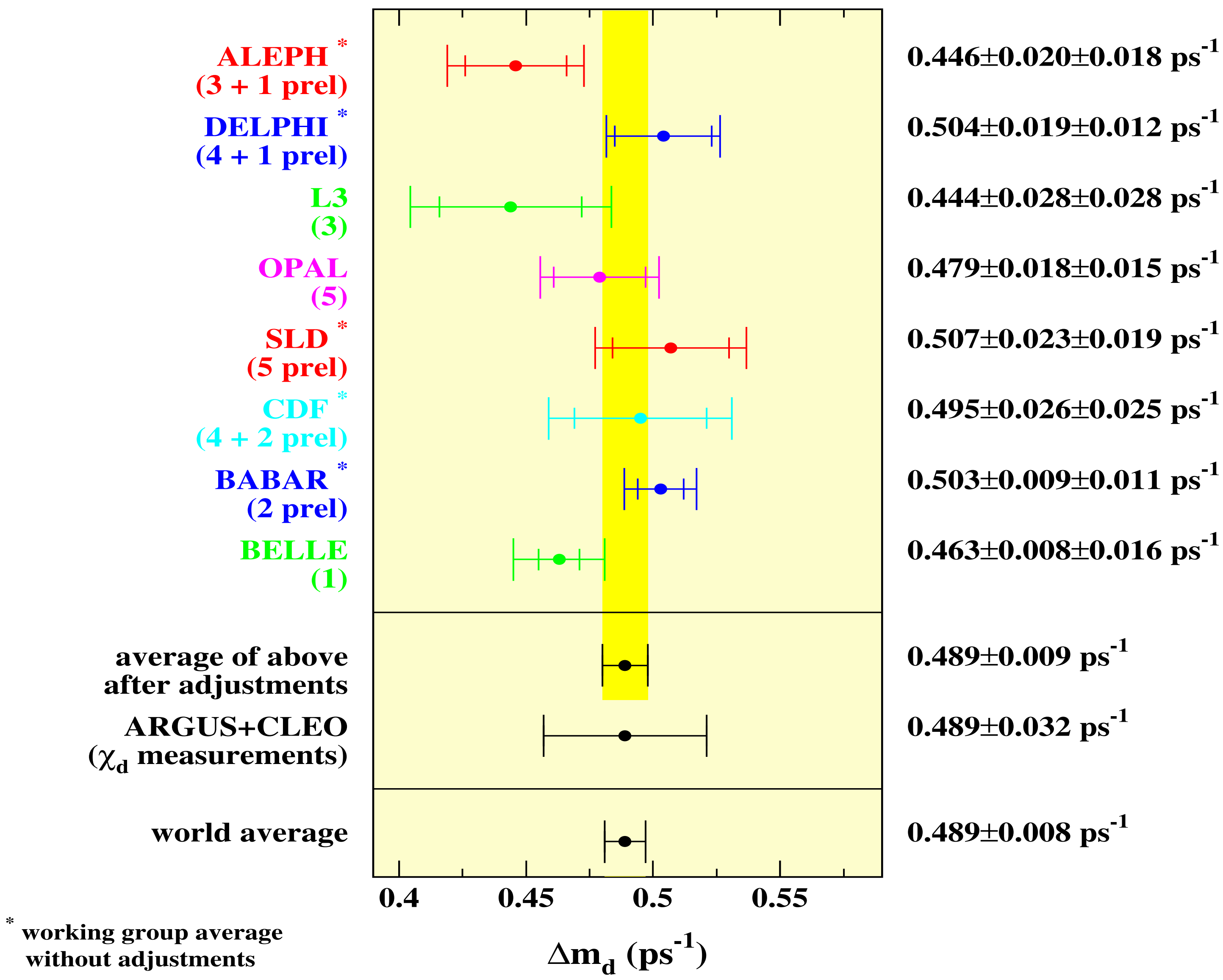
- σ_t proper time resolution

$$\sigma_t = \sqrt{\sigma_L^2 + \sigma_P^2 t^2}$$ $\rightarrow \sigma_L$ dominates at small t

$B_d^0 - \overline{\mathrm{B}_d^0}$ Oscillations : Δm_d

A TextBook Plot !





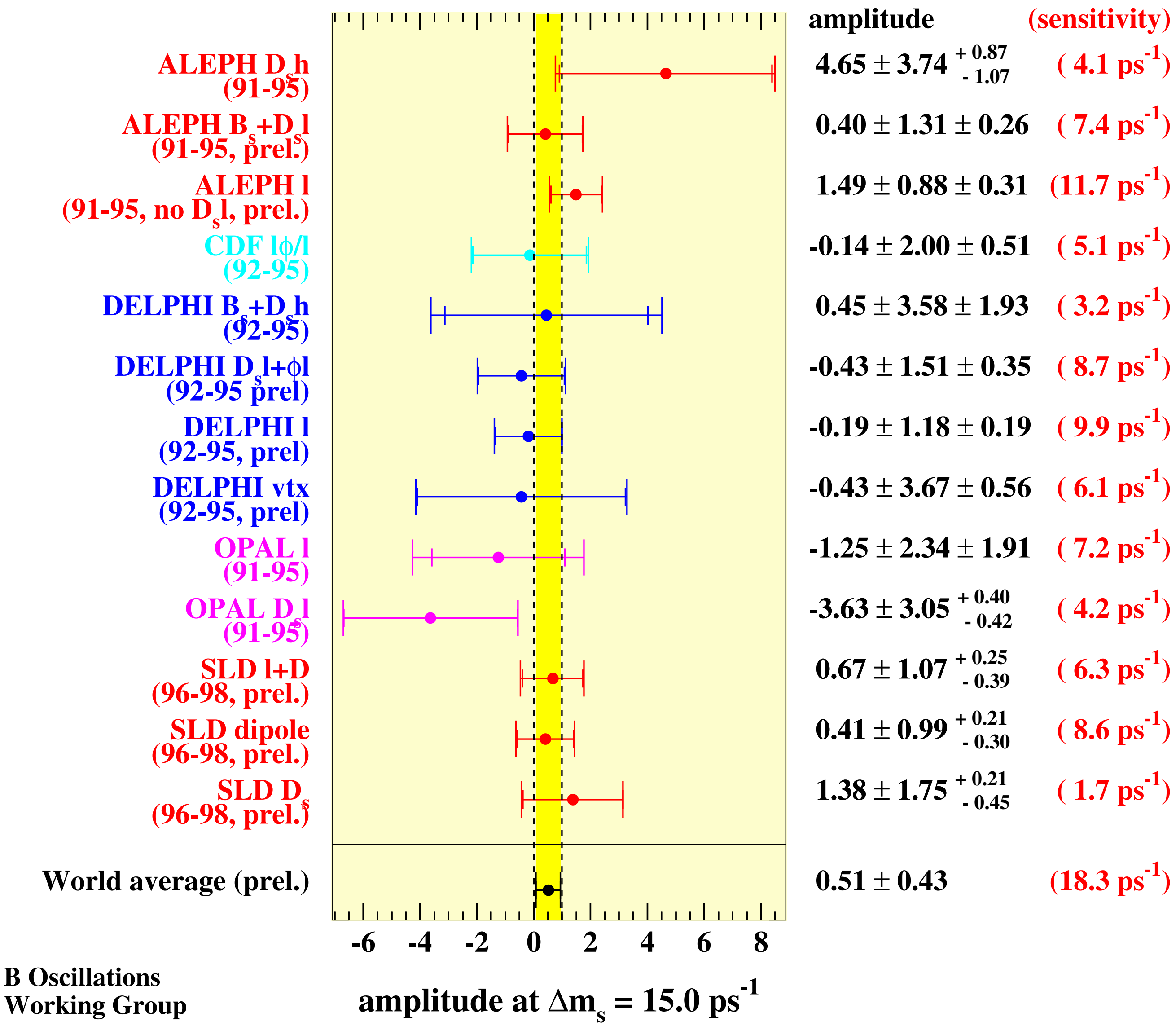
$$\Delta m_d = 0.489 \pm 0.008 \text{ ps}^{-1}$$

known with 1.6% precision !

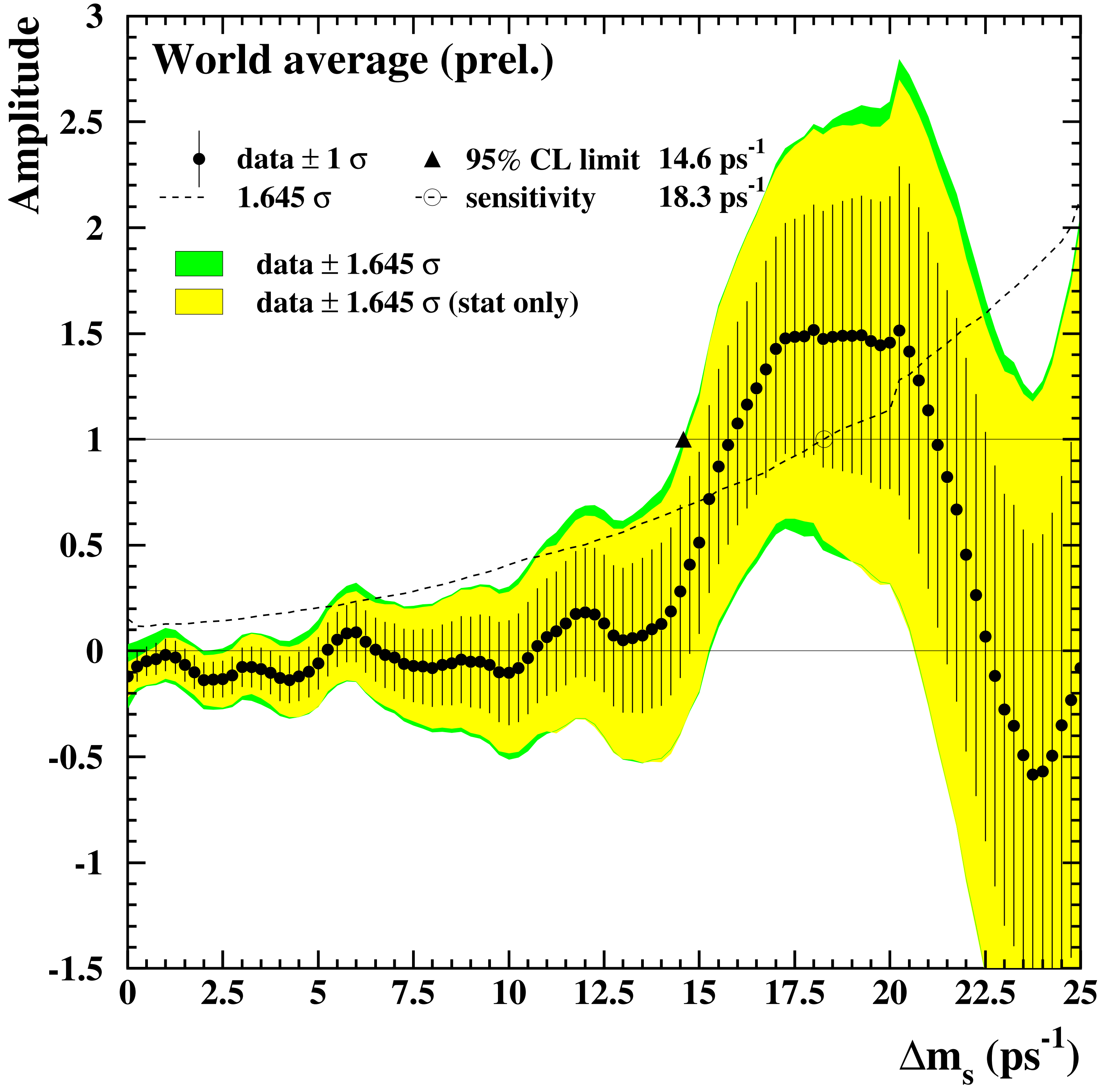
$$\Delta m_d(\text{LEP/SLD/CDF}) = 0.492 \pm 0.013 \text{ ps}^{-1}$$

$$\Delta m_d(\text{B-Factories}) = 0.485 \pm 0.010 \text{ ps}^{-1}$$

$B_s^0 - \overline{B_s^0}$ Oscillations : Δm_s



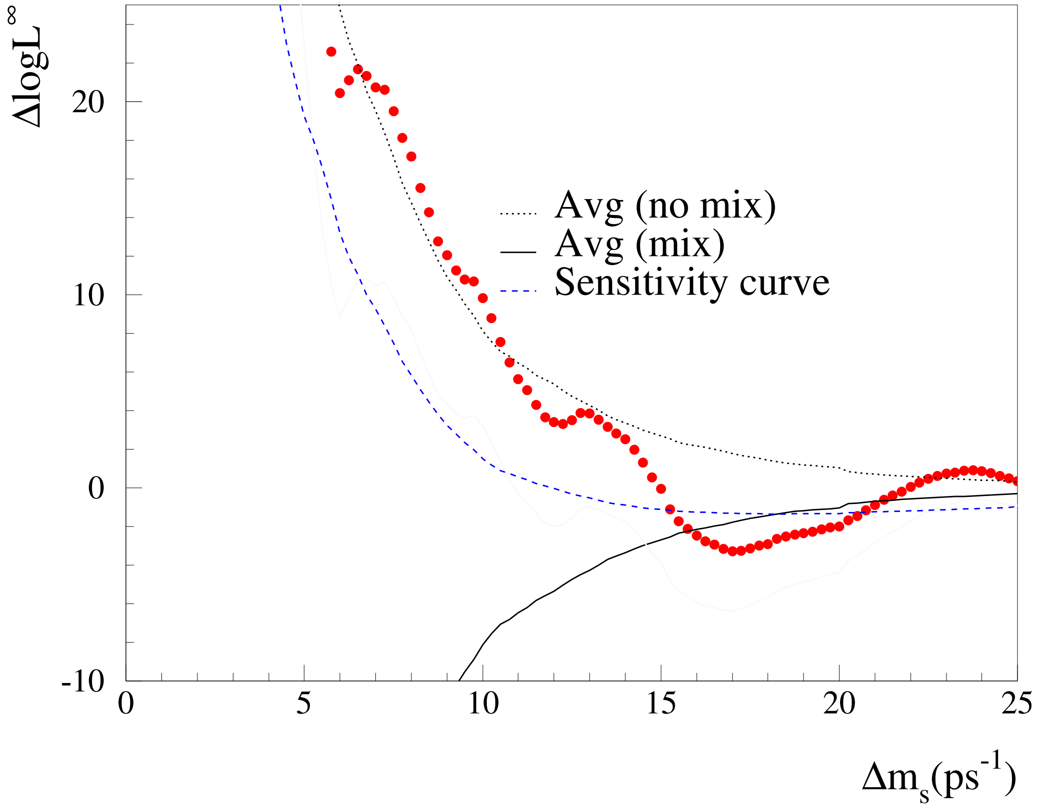
The amplitude A is introduced : $(1 \pm cos\Delta m_s t) \rightarrow (1 \pm A\cos\Delta m_s t)$

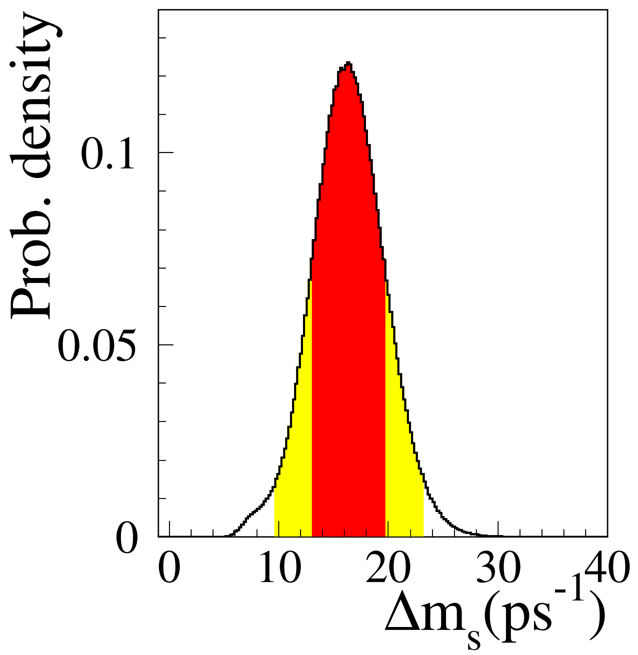


sensitivity : 18.3 ps^{-1}

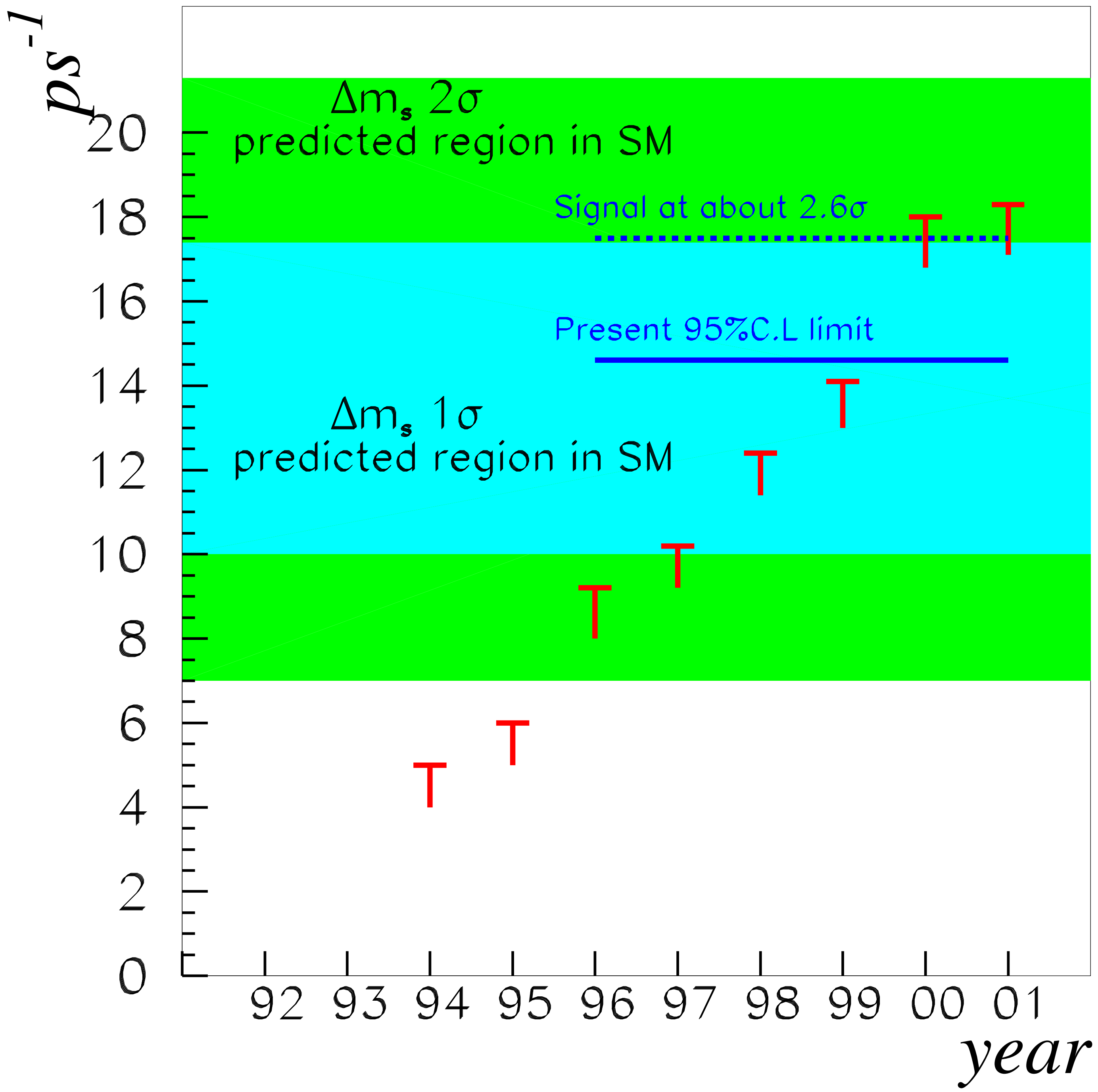
limit : 14.6 ps^{-1} at 95 % C.L.

minimum at 17.0 ps^{-1} with 2.6σ significance





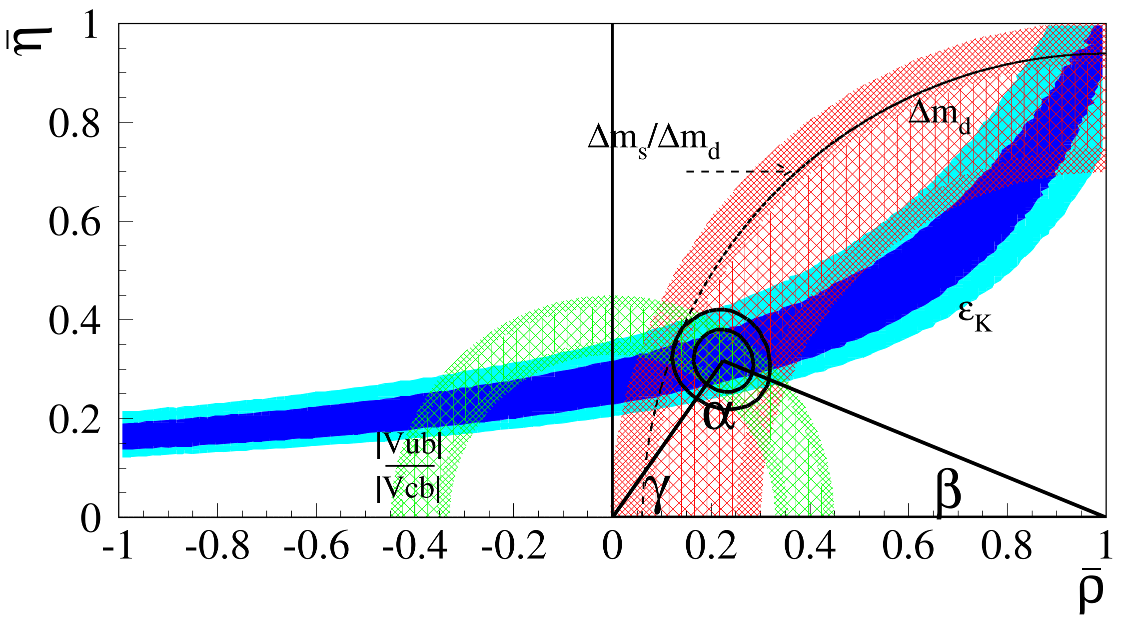
$\Delta m_s = 16.3 \pm 3.4$ ps^{-1} ; $<$ 23.2 ps^{-1} at 95 % C.L.



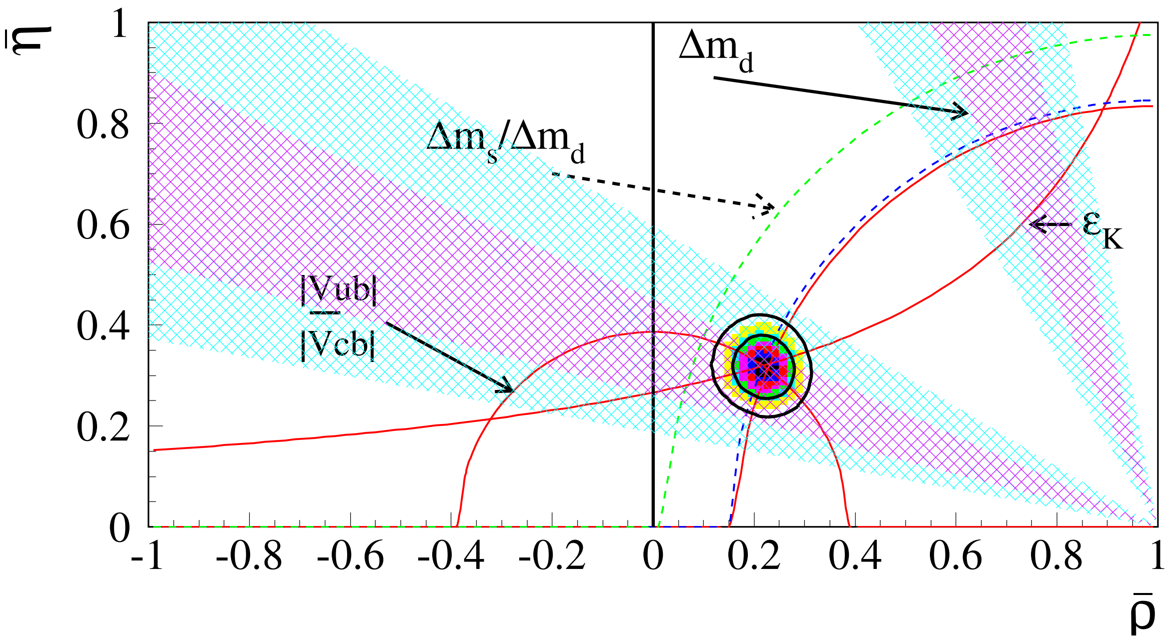
ps^{-1}
Δm_s 2σ
predicted region in SM
Signal at about 2.6σ
Present 95%C.L limit
Δm_s 1σ
predicted region in SM
0
2
4
6
8
10
12
14
16
18
20
92
93
94
95
96
97
98
99
00
01
year

Unitarity Triangle

Measurement	$V_{CKM} \times$other	Constraint
$b \to u / b \to c$	$\|V_{ub}/V_{cb}\|^2$	$\bar\rho^2 + \bar\eta^2$
Δm_d	$\|V_{td}\|^2 f_{B_d}^2 B_{B_d} f(m_t)$	$(1-\bar\rho)^2 + \bar\eta^2$
$\frac{\Delta m_d}{\Delta m_s}$	$\left\|\frac{V_{td}}{V_{ts}}\right\|^2 \frac{f_{B_d}^2 B_{B_d}}{f_{B_s}^2 B_{B_s}}$	$(1-\bar\rho)^2 + \bar\eta^2$
ϵ_K	$f(A, \bar\eta, \bar\rho, B_K)$	$\propto \bar\eta(1-\bar\rho)$



Results on $\bar{\rho}$ and $\bar{\eta}$



$$\bar{\rho} = 0.218 \pm 0.038$$
$$\bar{\eta} = 0.316 \pm 0.040$$

$$sin2\beta = 0.696 \pm 0.067$$
$$sin2\alpha = -0.42 \pm 0.23$$

$$\gamma = (55.5 \pm 6.2)^o$$

Direct measurement (LEP/CDF + Belle + New Babar (0.59 ± 0.14)) :

$$sin2\beta = 0.62 \pm 0.13$$

In agreement with the value obtained with the measurement from "sides"

Conclusions

B Physics has been intensively studied during the last 10 years at CDF/LEP/SLD and spectacular improvements have been obtained in the last years

LEP/SLD/CDF have been privileged places to study B-Physics and we have been leading this field during last few years

All b-lifetimes known with high precision.

$\tau(\mathrm{B}^+)/\tau(\mathrm{B}^0)$ Hierarchy has been observed

$$\tau(B^0) = 1.545 \pm 0.020 ps \text{ (1.3\%)}$$
$$\tau(B^+) = 1.642 \pm 0.017 ps \text{ (1.0\%)}$$
$$\tau(\mathrm{B}^0_\mathrm{s}) = 1.464 \pm 0.057 ps \text{ (3.9\%)}$$
$$\tau(\Lambda_b) = 1.208 \pm 0.051 ps \text{ (4.2\%)}$$

B Decays picture is today better understood : Br_{sl} vs n_c.

V_{cb} is measured at 4.5%

(two methods inclusive/exclusive have been introduced)

V_{ub} is measured at $\simeq (15 - 20)\%$

(NEW inclusive method "applied", competitive with the exclusive one)

The time dependence of the oscillations has been precisely measured :

$$\Delta m_d = 0.492 \pm 0.013 \text{ ps}^{-1} \rightarrow 2.6\%$$

Δm_s Sensitivity at 18.3 ps^{-1} ; Limit at 14.6 ps^{-1}

hint of a signal at 17.0 ps^{-1} with 2.6σ significance

The Unitarity triangle parameters are today already known with a good precision within the Standard Model:

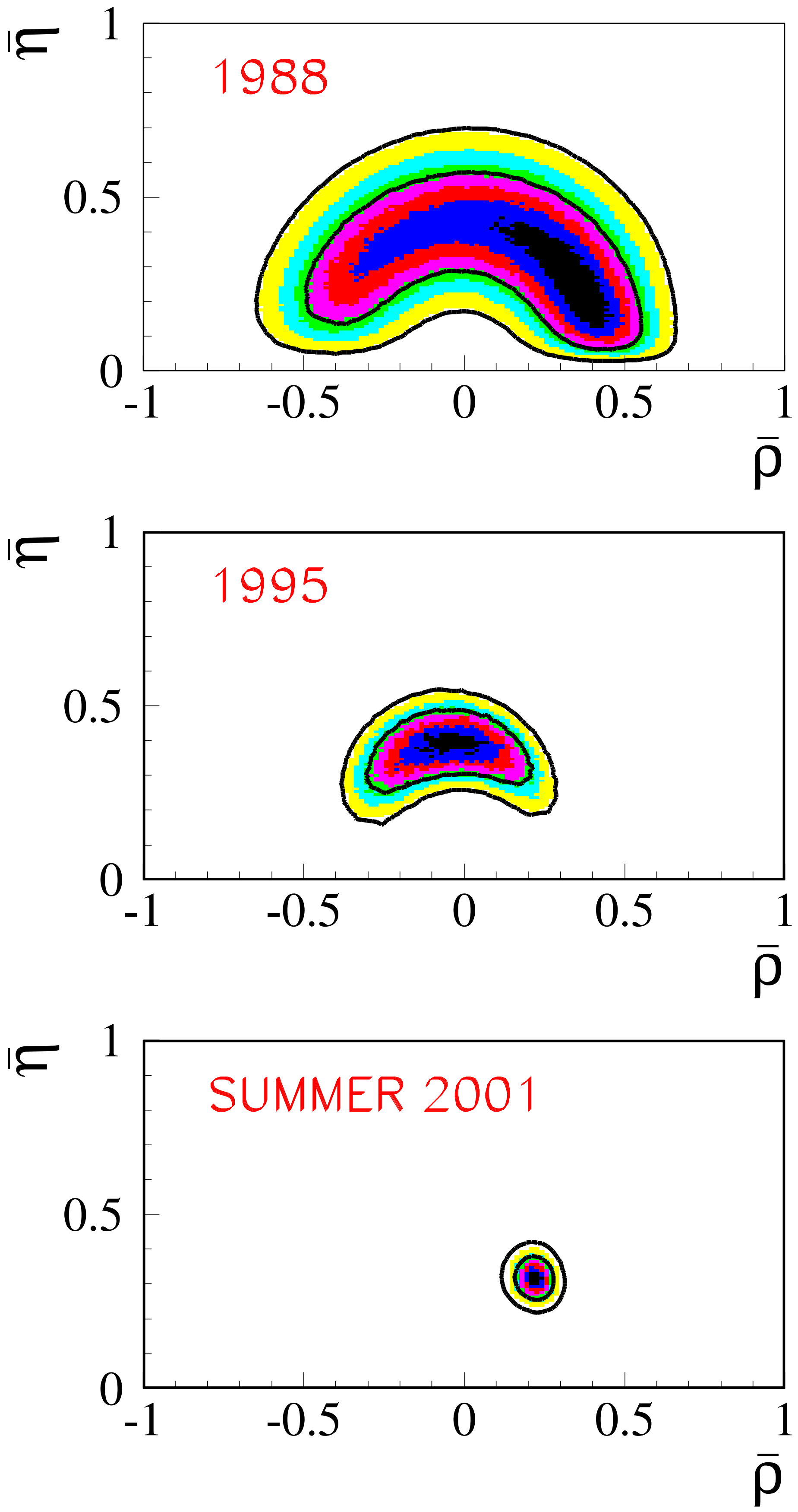
$$\bar{\rho} = 0.218 \pm 0.038$$

$$\bar{\eta} = 0.316 \pm 0.040$$

$$sin2\beta = 0.696 \pm 0.067$$

$$sin2\alpha = -0.42 \pm 0.23$$

$$\gamma = (55.5 \pm 6.2)^o$$



1988
1995
SUMMER 2001
$\bar{\eta}$
$\bar{\rho}$
1
0.5
0
-1
-0.5