Ljubljana 27 March 2001

Ten years of B physics at LEP (mainly)

presented by P. Roudeau (LAL, Orsay)

Why the b-quark is so interesting?

Precision electroweak physics

- Allows to measure accurately $Z \rightarrow$ Down anti-Down
  -because b-quarks can be identified cleanly
- $R_b = \frac{BR(Z \rightarrow b\bar{b})}{BR(Z \rightarrow hadrons)}$ receives contributions from t-quarks and possibly from new physics

Flavour physics

Determination of CKM matrix elements

This matrix originates from the fact that: weak eigenstates differ from mass eigenstates

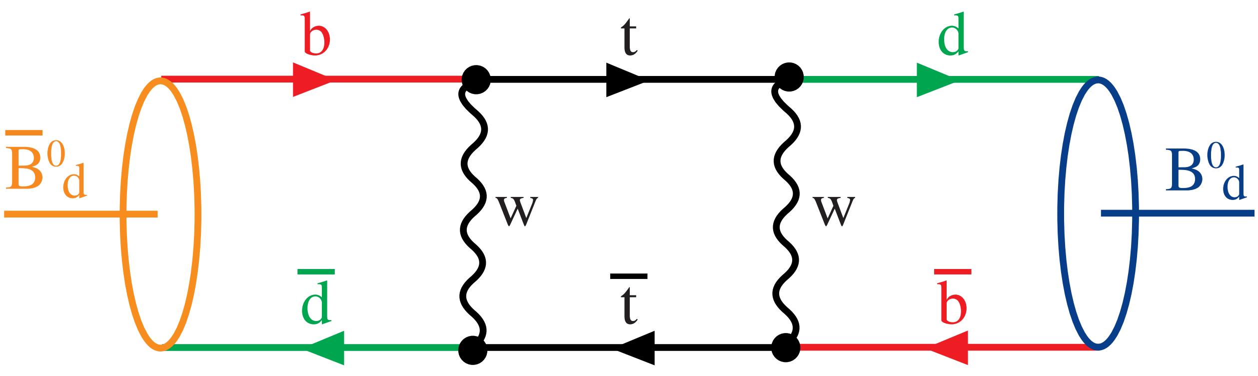
Physical states are a linear combination of weak eigenstates.

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

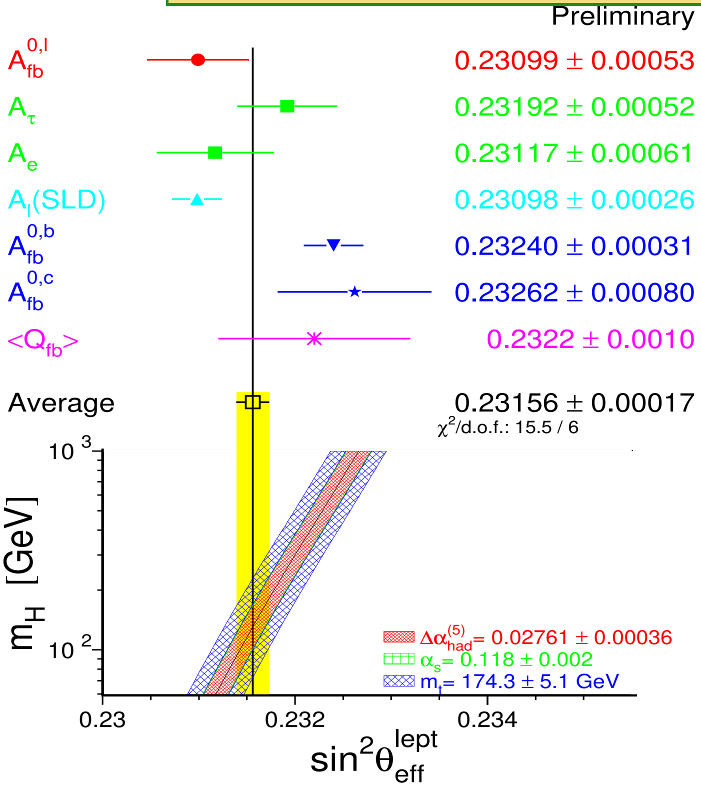
It is a unitary matrix (4 parameters, imaginary part gives CP violation).

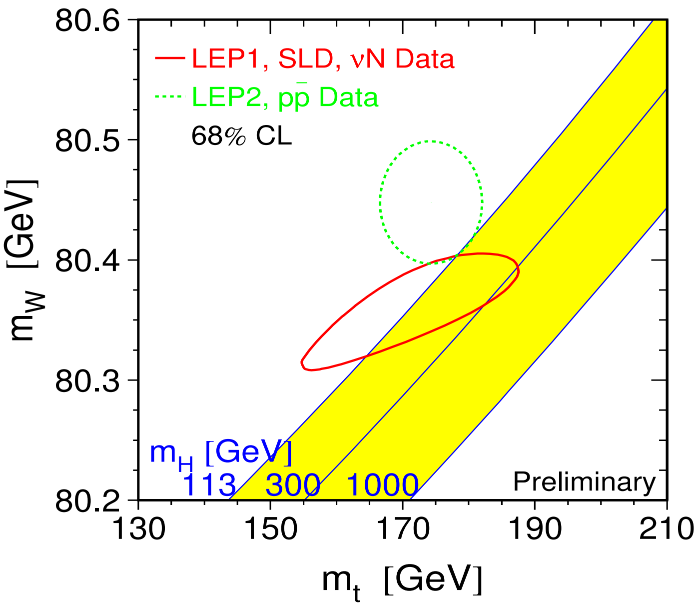
Looking for new physics?

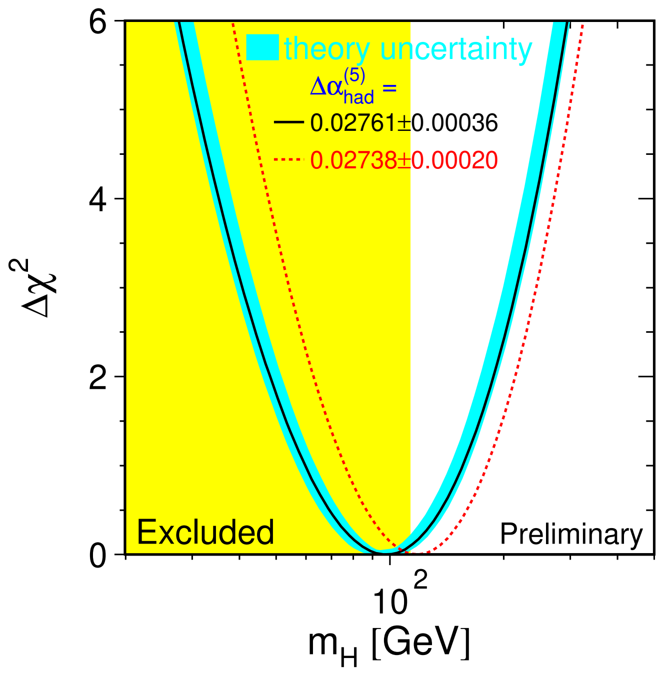
- deviations in SM expectations for electroweak observables
  At present no deviation has been observed, validity of E.W. radiative corrections has been established: m(top), m(Higgs)<200 GeV/c^2
- tests of S.M. scenario for CP violation are passed
  Expect new phases (baryon/anti-baryon asymmetry in Universe)
  Not guarantied that they show-up in b-physics(?)
  Need more accuracy...(future facilities)
- link between quark masses and CKM elements?



Electroweak (too short) summary







- bad χ^2
  - new physics?
  - systematics?
  - statistics?

  uncomfortable ...
- light Higgs
  - $m_h < 200\ GeV/c^2$

LEP b-physics program accomplishment

Main lines defined in 1989

Inclusive or semi-inclusive final states, importance of semileptonic decays. (clean and large BR (20%)

Complex final states

A lot of tools and developments need to be in place.

LEP 4×1 M $b\bar{b}$ evts

SLD ~ 0.1 M

CLEO ~ 3 M $(9$ M$)$

b-factories 1 M / fb^{-1}

$\rightarrow$ A learning phase (1990-1995)

- "new" signals: Λ_b^0, $\mathrm{B_s^0}$, Ξ_b, $\mathrm{B_d^0} - \overline{\mathrm{B_d^0}}(\mathrm{t})$, $\mathrm{B^{**}}$, ...
- "new" ideas:

  - amplitude method to study $\mathrm{B_s^0} - \overline{\mathrm{B_s^0}}$ oscillations (ALEPH),

  - inclusive π^* to select $\overline{\mathrm{B}_d^0} \rightarrow \mathrm{D}^{*+}\ell^-\overline{\nu_\ell}$ (DELPHI)

$\rightarrow$ Final results 1995-2001,...

(end of running at the Z: 1995)

- some data samples have been reprocessed: 97, 98, ..
- algorithms get more complex

  better use of information
- the unexpected: $b \rightarrow s\gamma$, $|\mathrm{V}_{ub}|$, Δm_s,..

$\rightarrow$ What have we learned ?

Measurements

- b-lifetimes: $\sim$ % accuracy
- b-rates: $(2.5 \rightarrow 17)$% accuracy
- semi-leptonic b-hadron decays: $\sim$ % accuracy
- $\mathrm{B_d^0} - \overline{\mathrm{B_d^0}}$ oscillations: 3% accuracy (Δm_d)
- limit on $\mathrm{B_s^0} - \overline{\mathrm{B_s^0}}$ oscillations ($\Delta m_s \sim 20 \times \Delta m_d$)

Outcome

- Lifetimes hierarchy (QCD)
- Determination of CKM parameters

Heavy Flavour Steering Group activities

Members

Representatives from ALEPH, DELPHI, OPAL, L3, CDF and SLD.

Access: http://lephfs.web.cern.ch/LEPHFS/

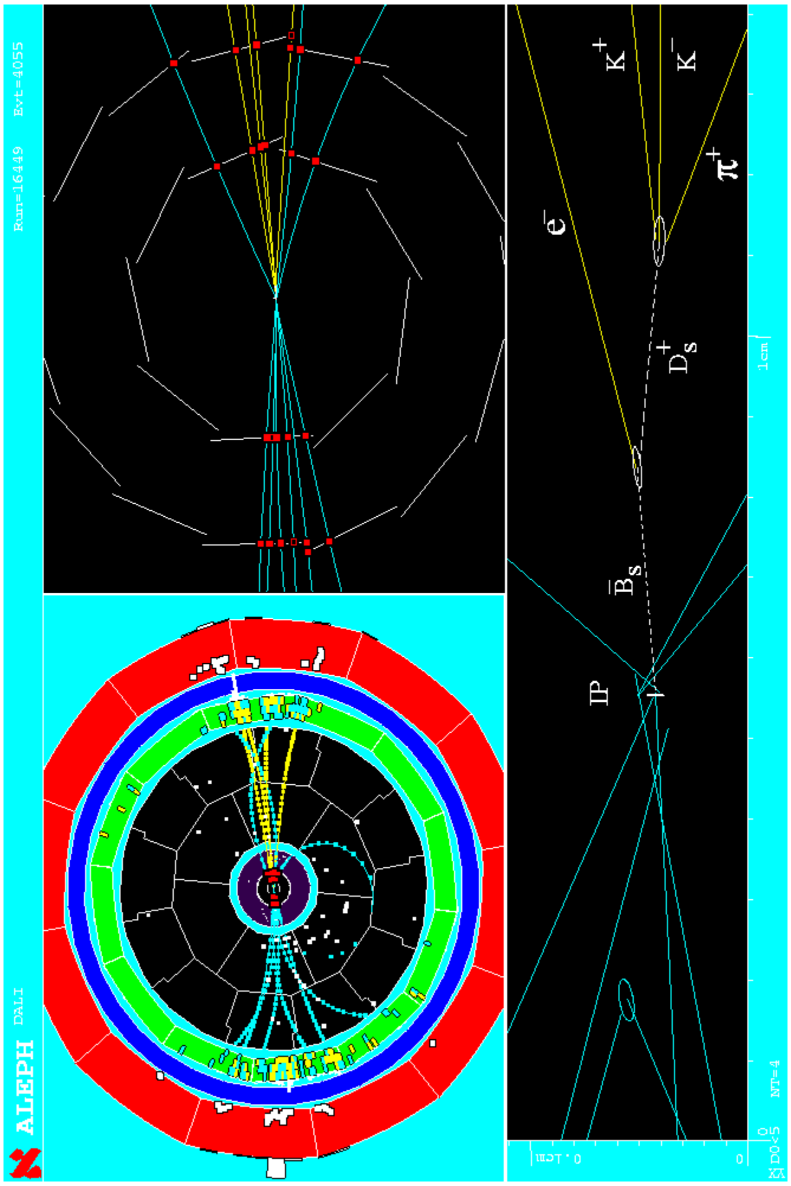
Activities

- Obtain averaged results from measurements of b-hadron production and decays in a coherent way
- coordinate activities of several working groups b-lifetimes, $\mathrm{B}^0-\overline{\mathrm{B}^0}$ oscillations, production rates, $\Delta\Gamma(\mathrm{B}_s^0)$, $|\mathrm{V}_{cb}|$ and $|\mathrm{V}_{ub}|$.
- Define new areas

Outcome

- An EP report on "Summer 99" results, exists: CERN-EP-2000-096, "Summer2000" is in preparation;
- A "final publication" (?) by end 2001 with final results

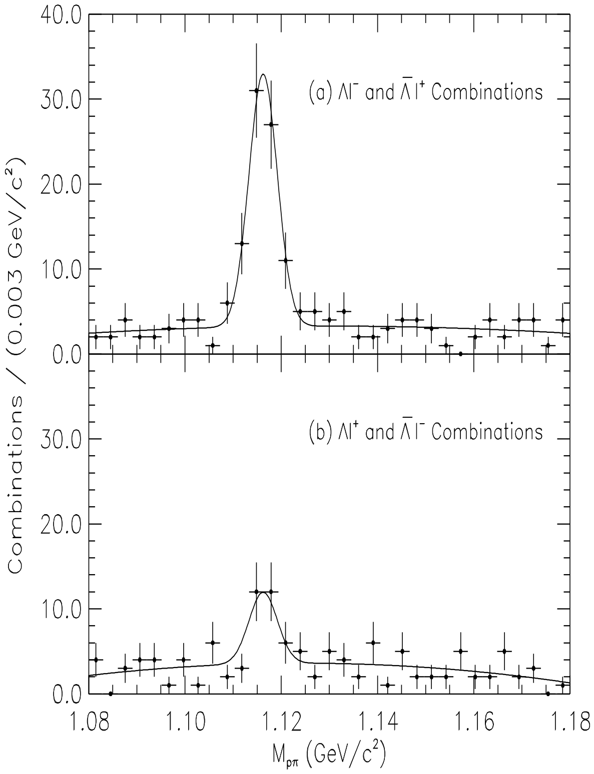
Tagging b-hadrons



- $b \leftrightarrow \mathrm{non} - b$
  - displaced vertex
  - leptons
- $b \leftrightarrow \bar{b}$ (production)
  - jet charge
  - fragmentation products
- $\mathrm{B} \leftrightarrow \overline{\mathrm{B}}$ (decay)
  - lepton
  - D hadron
- $\mathrm{B_i} \leftrightarrow \mathrm{B_j}$
  - semileptonic decays
  - fragmentation products

b-baryon signals 1990: ALEPH

Excess of $\Lambda - \ell^{-}$ combinations as compared to $\Lambda - \ell^{+}$ (and charge conjugate final states).



Ξ_b signals 1995: DELPHI

Excess of $\Xi^{\mp} - \ell^{\mp}$ combinations..

b-baryons in 2000

b-baryons have been observed using $(\Lambda, p, \Lambda_c^+, \Xi) - \ell$ correlations and also accompanying $\overline{p}$ and $\overline{\Lambda}$.

- the b-baryon rate in jets amounts to:

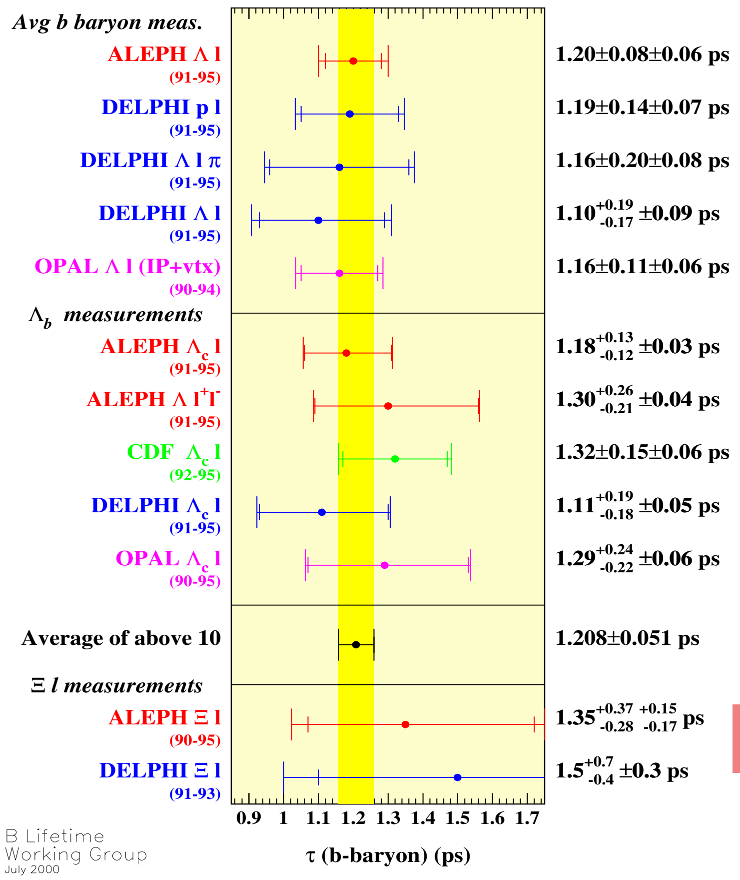
$$f_{\text{b-baryon}} = (10.4 \pm 1.7)\%$$

- the b-quark polarization (-0.94) is diluted:

$$\mathcal{P}(\Lambda_b^0) = -0.45^{+0.19}_{-0.17}$$

- the Λ_b^0 lifetime is “too short” (for theory):

$$\tau(\text{b-baryon}) = 1.208^{+0.051}_{-0.050}\ \text{ps}$$



- accuracy on $f_{\text{b-baryon}}$ better than uncertainty on Λ_c^+
- polarization reflects $\Sigma_b^{(*)}$ production
-

τ(b-baryon) ??: pb. for theory

$\rightarrow$ TeVatron

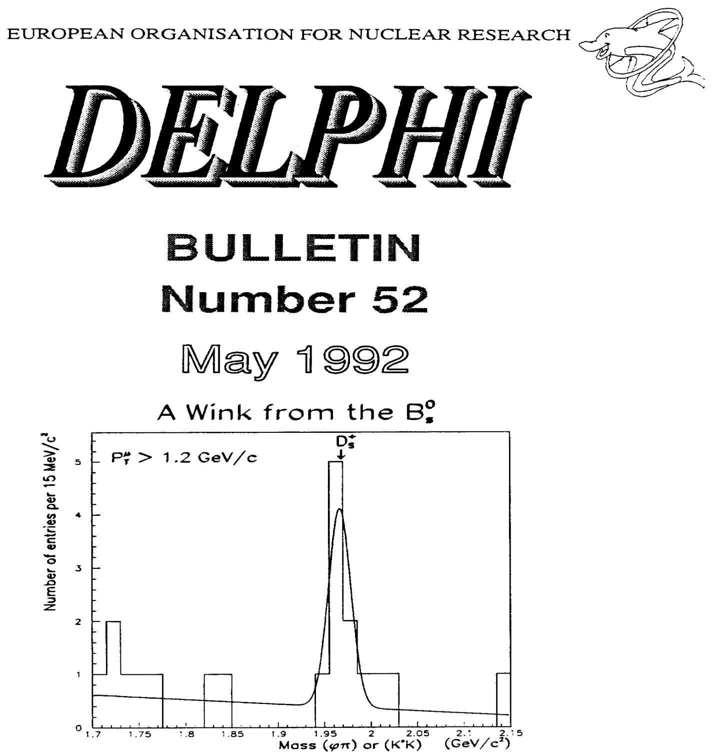
The $\overline{\mathrm{B}_s^0}$ meson (1992)

Before LEP

- UA(1) (1987): Same sign dilepton events from $\mathrm{B}^0 - \overline{\mathrm{B}^0}$ oscillations
- CUSB at $\Upsilon(5S)$ (1990):

  evidence for B_s^* using Doppler effect

First signal at LEP: DELPHI


EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH

DELPHI

BULLETIN

Number 52

May 1992

A Wink from the B_s^0

$\overline{\mathrm{B}_s^0} \to \mathrm{D}_s^+ \ell^- \overline{\nu_\ell}$

7 events ...

The $\overline{\mathrm{B}_s^0}$ meson in 2000

Studied mainly using $D_s^+ - \ell^-$ events.

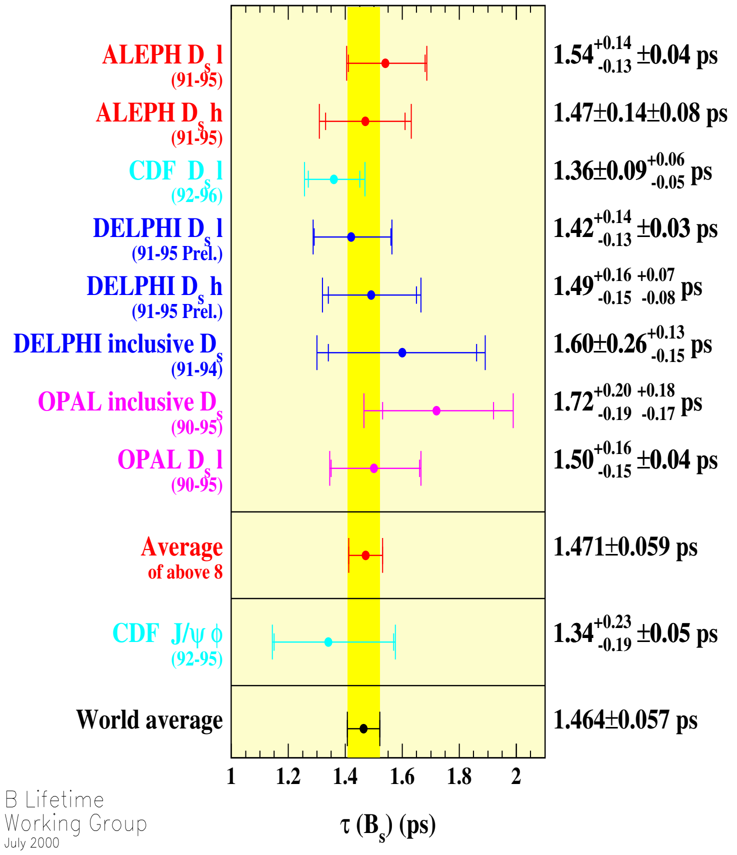
- the $\overline{\mathrm{B}_s^0}$ rate in b-jets amounts to:

$$f_{\mathrm{B_s}} = (9.7 \pm 1.2)\%$$

- the $\overline{\mathrm{B}_s^0}$ lifetime is measured:

$$\tau(\overline{\mathrm{B}_s^0}) = (1.460 \pm 0.056)\ \mathrm{ps}$$

- $\mathrm{B_s^0} - \overline{\mathrm{B_s^0}}$ oscillations: see later.



And also:

$$\Delta\Gamma_{\mathrm{B_s^0}} / \Gamma_{\mathrm{B_s^0}} < 0.31$$

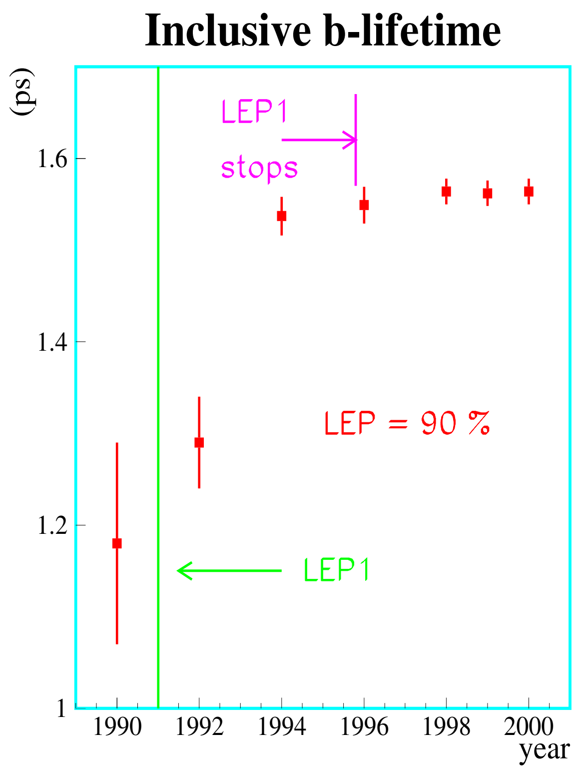
(95% C.L.)

$\sim 5\%$ (Th.)

$\rightarrow$ TeVatron

The inclusive b-lifetime

Its evolution with time !?



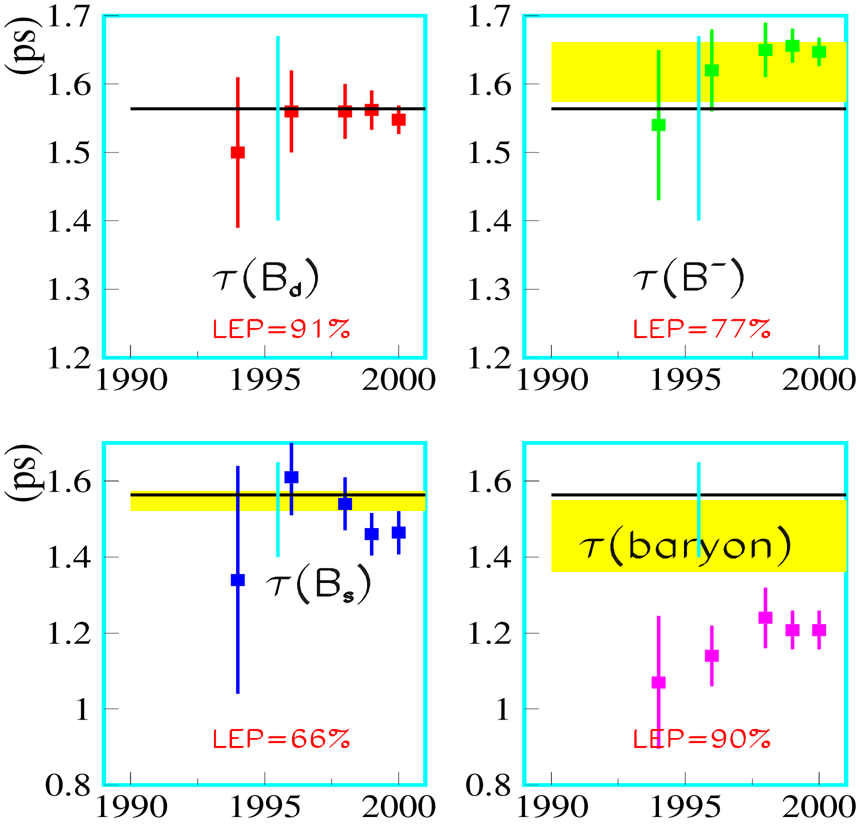
$\sigma(\tau) < 1\%$

Why?

- incorrect low value in 1989
- initial measurements from LEP incorrect

  learning phase: detector alignment, fitting programs, ...

b-hadron lifetimes



What have we learned?

- measured values are MANDATORY inputs to get partial widths: allow comparison with theory
- high accuracy: not the limiting source of uncertainty
- QCD artillery has not reached enough precision in this game: reasonable agreement for mesons, what about b-baryons?

$B_d^0 - \overline{B_d^0}$ oscillations

Before LEP

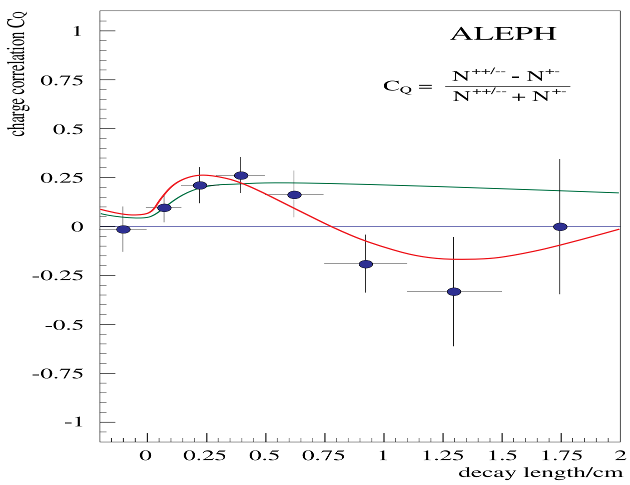
Same-sign dilepton events; $\chi_d = \frac{(\Delta m_d \;\; \tau(B_d^0))^2}{2+(\Delta m_d \;\; \tau(B_d^0))^2}$

- ARGUS, 1987, same-sign dilepton events:

$$\Delta m_d = (0.47 \pm 0.11)\ \mathrm{ps}^{-1}$$

- UA1, 1987, signal from same-sign dileptons due to B_d^0 and B_s^0 oscillations

First $B_d^0(t) - \overline{B_d^0}(t)$: ALEPH (1993)

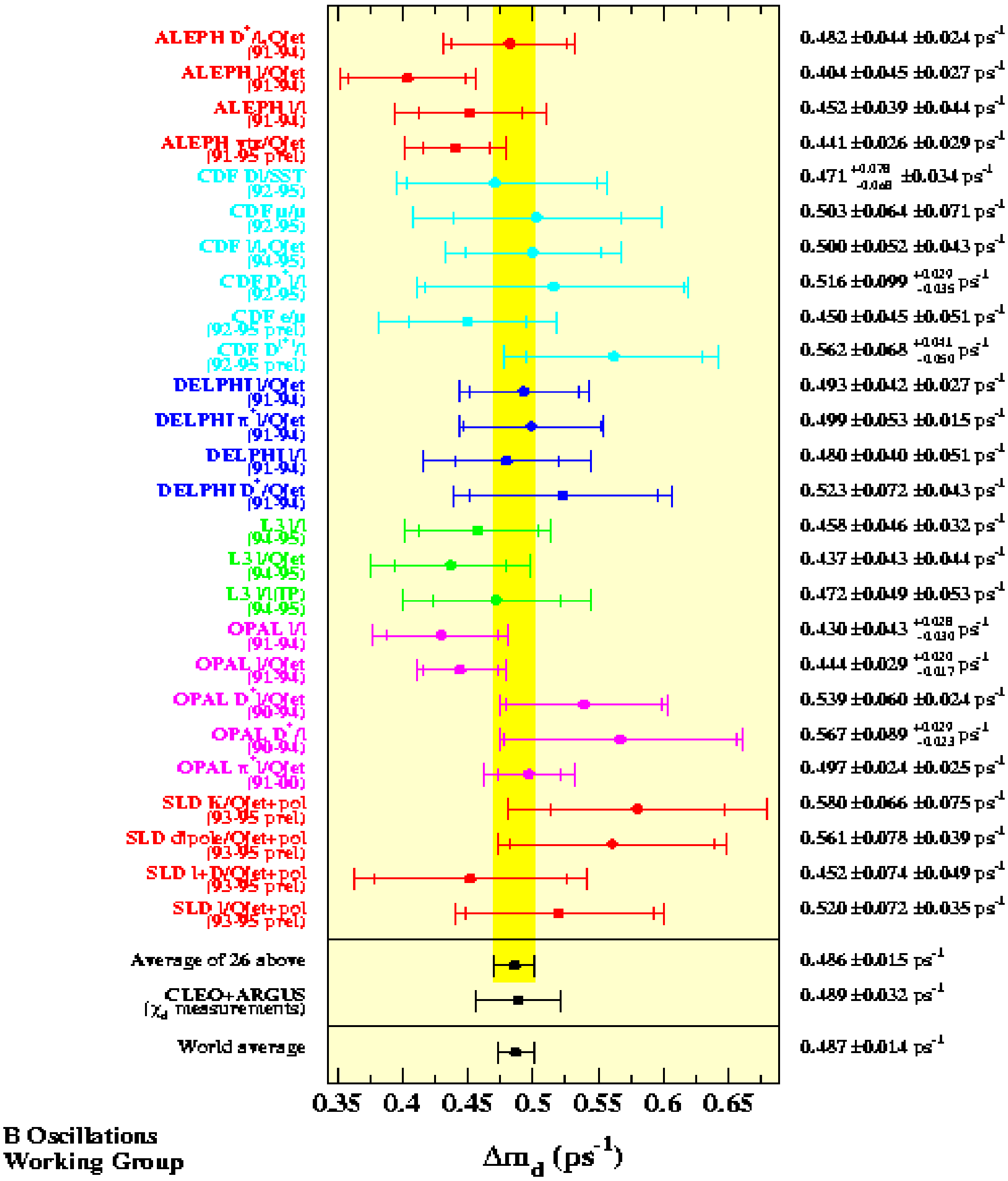


$\mathcal{P}(B_d^0 \to \overline{B_d^0})(t) =$

$\frac{1}{2}[1 - \cos(\Delta m_d \;\; t)] \exp\left(-\frac{t}{\tau(B_d^0)}\right)$

Direct meast. of Δm_d

Δm_d in 2000

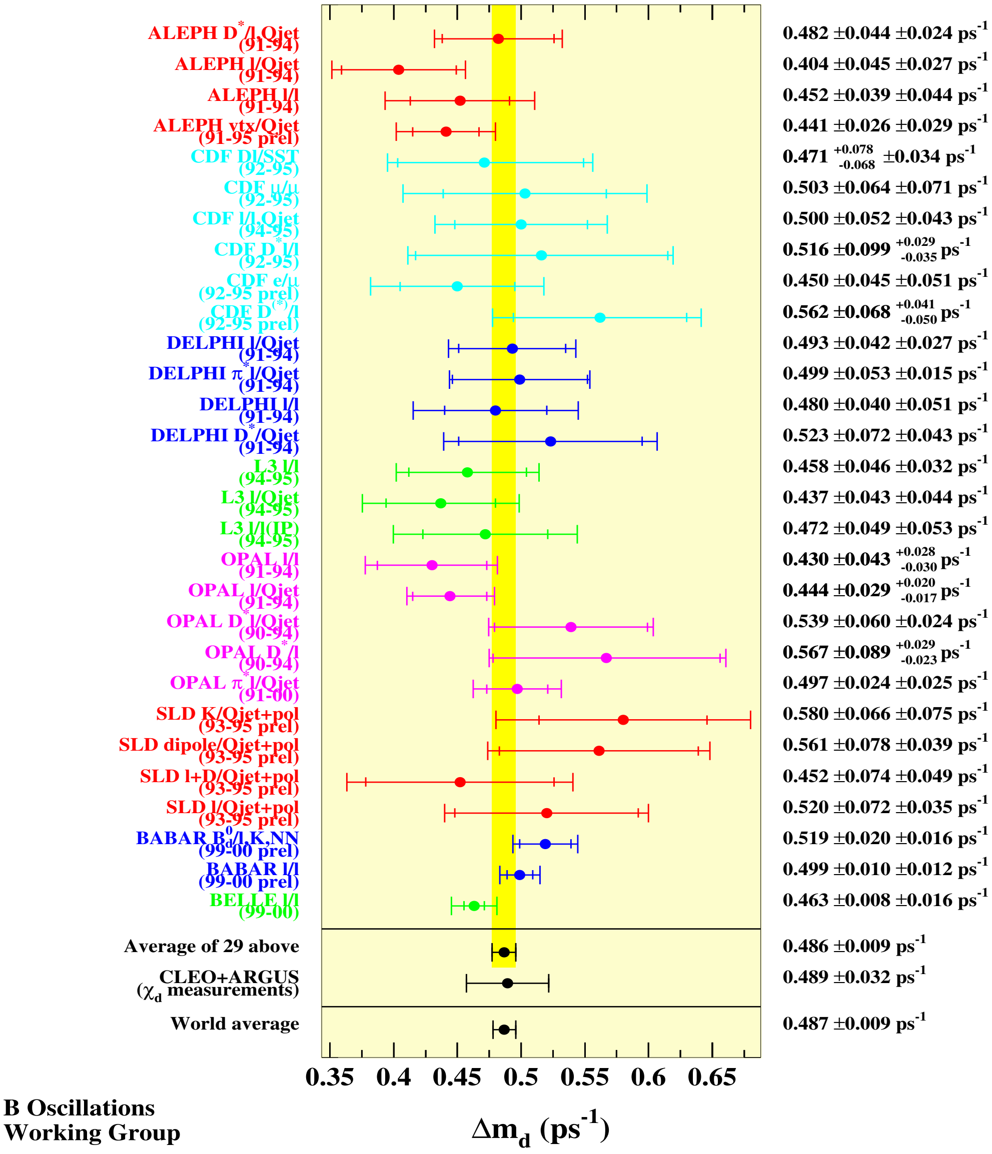


- LEP weight=70 %
- Δm_d and χ_d results agree

$$\Delta m_d = (0.487 \pm 0.014)\ \mathrm{ps}^{-1}$$

$$\sigma(\Delta m_d) < 3\%$$

Δm_d in March 2001



- LEP weight=30 %
- LEP and b-fact. results agree

$$\Delta m_d = (0.487 \pm 0.009)\ \text{ps}^{-1} \qquad \sigma(\Delta m_d) < 2\%$$

Interest?

- constraints on CKM parameters

$$\Delta m_d = \frac{G_F^2}{6\pi^2} m_W^2 A^2 \lambda^6 [(1-\bar{\rho})^2 + \bar{\eta}^2] m_{B_d} f_{B_d}^2 \hat{B}_{B_d} \eta_B S(m_t^2/m_W^2)$$

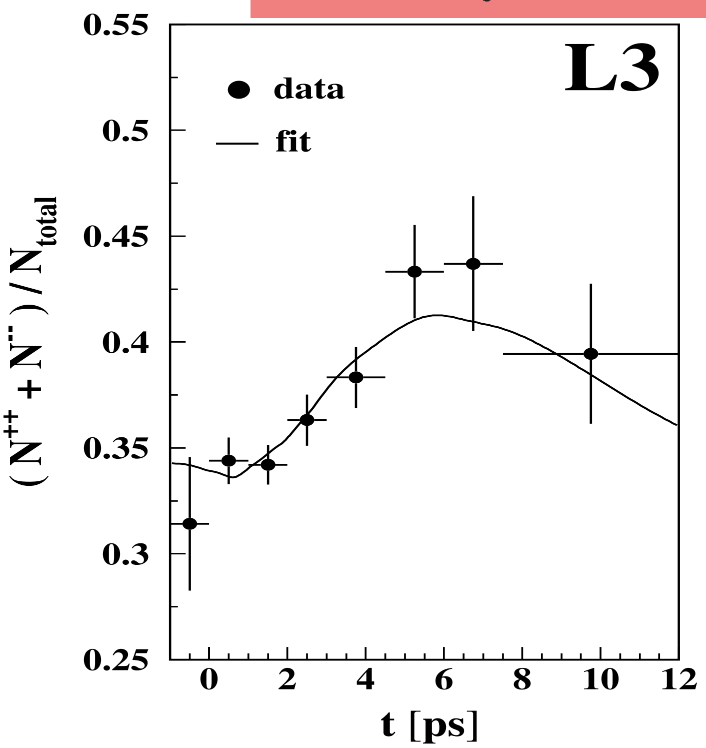
- high accuracy on Δm_d is important.

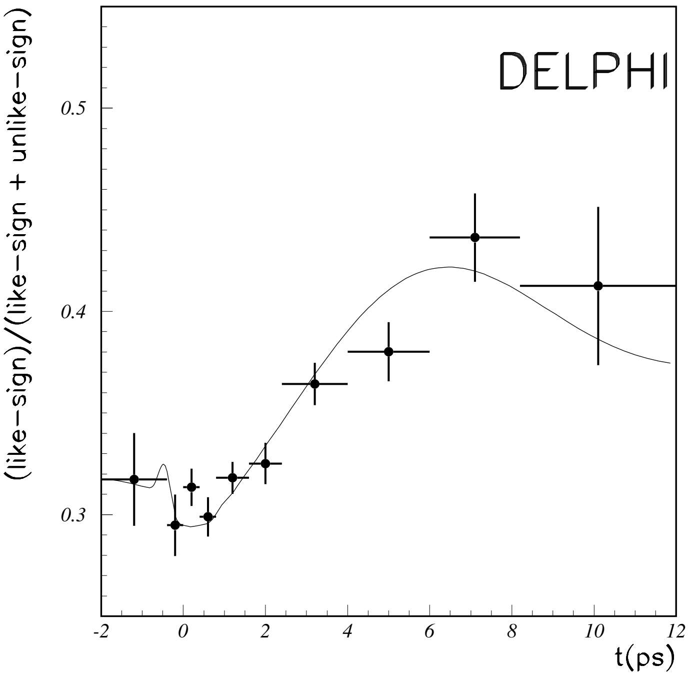
$$\frac{\Delta m_d}{\Delta m_s} = \frac{f_{B_d}^2 \hat{B}_{B_d}}{f_{B_s}^2 \hat{B}_{B_s}} \frac{m_{B_d}}{m_{B_s}} \lambda^2 [(1-\bar{\rho})^2 + \bar{\eta}^2]$$

- improve accuracy on b-rates

$$P(b \to \overline{B_d^0}) = (40.1 \pm 1.0)\%$$

LEP Heavy Flavour Steering group activity





The π^* industry

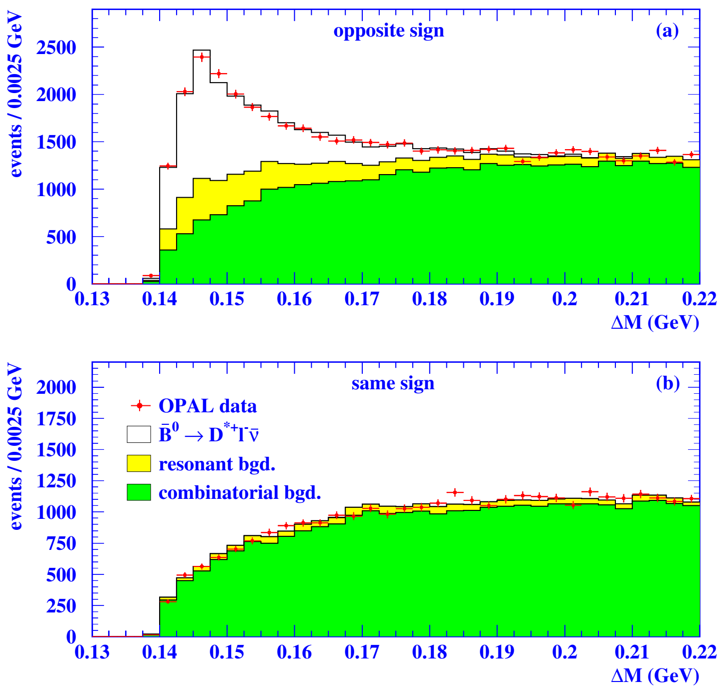
How it works?

Select $\overline{\mathrm{B}_d^0} \to \mathrm{D}^{*+}\ell^-\overline{\nu_\ell}$ decays using the lepton, the π^* and a bunch of tracks. ($\mathrm{D}^{*+} \to \mathrm{D}^0\pi^+$, $\pi^+ \equiv \pi^*$)

- developed by DELPHI in LEP environment

Nice results so far!

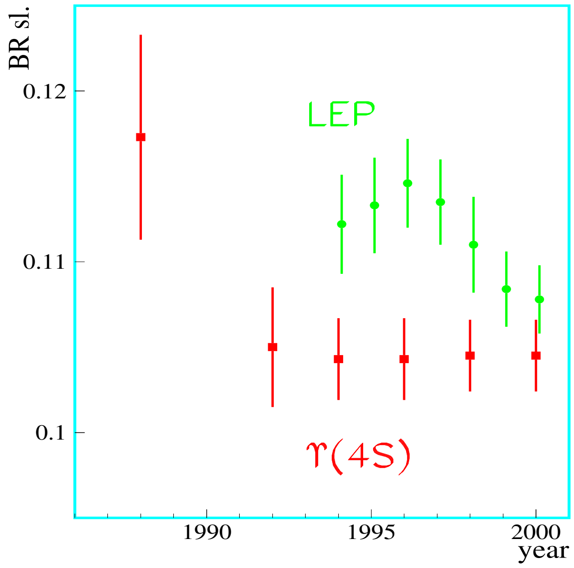
Best individual measurements for $\mathrm{B_d^0}$ lifetimes, $|V_{cb}|$ and Δm_d (DELPHI, OPAL).

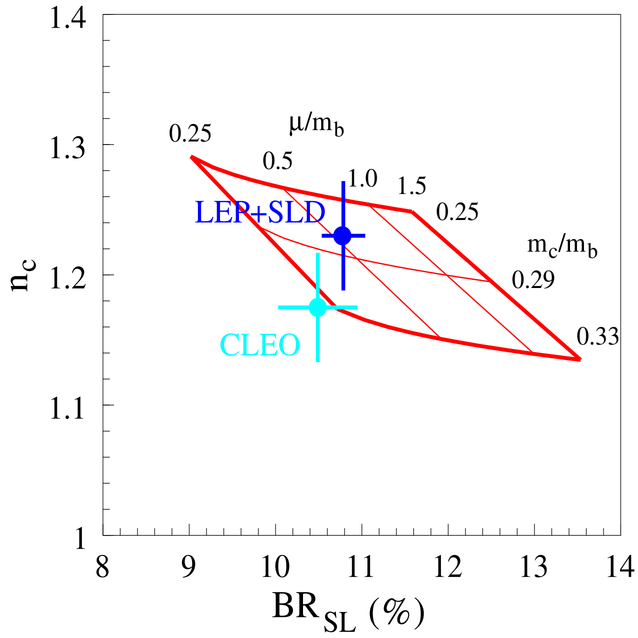


b-hadron semileptonic decays

Inclusive $\mathrm{BR}(b \to \ell X)$

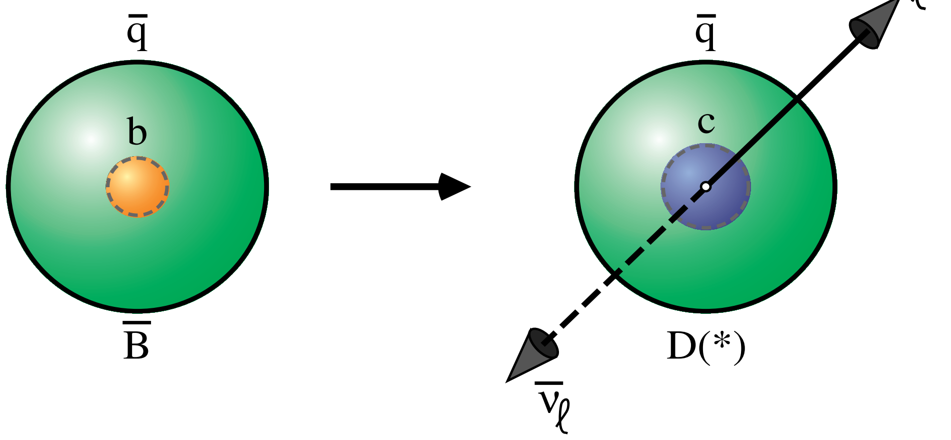
Need to separate $b \to \ell^- X$ from $b \to \overset{(-)}{c} \to \overset{(-)}{\ell^+} X$ and $c\bar{c}$ backgrounds.





- Measured $\mathrm{BR}(b \to \ell X)$ explained by Theory with a standard value for m_c and large QCD corrections.
- Uncertainty on $n_c + n_{\bar{c}}$ in b-hadron dominated by poor control of c-hadron decays.
- In 2000, $\mathrm{D_s}$, Λ_c^+, Ξ_c and Ω_c decays are still Terra Incognita .. Charm factory is needed .

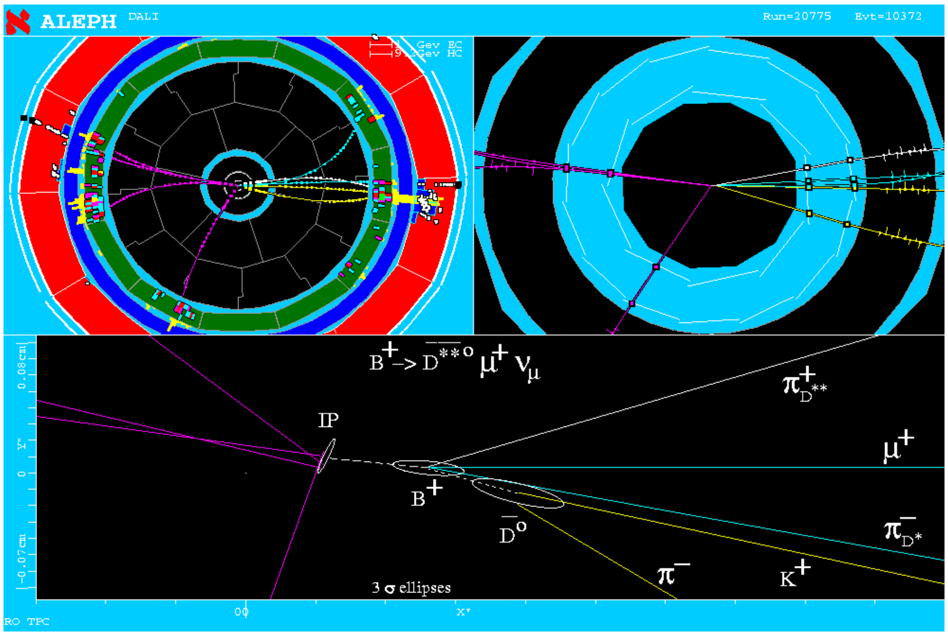
$$\overline{\mathrm{B}^0_d} \to \mathrm{D}^{*+}\ell^-\overline{\nu_\ell}$$



$$\frac{d(\mathrm{BR})}{dw} = \mathcal{K}(w)\mathcal{F}^2(w)\left|\mathrm{V}_{cb}\right|^2;\ \mathcal{F}(1) = 1 \text{ if } m_{c,b} \to \infty$$

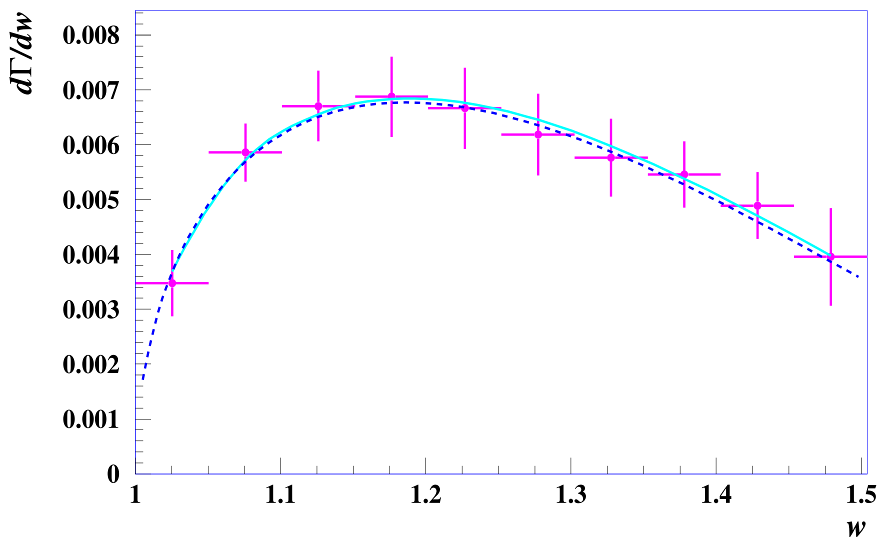
LEP results

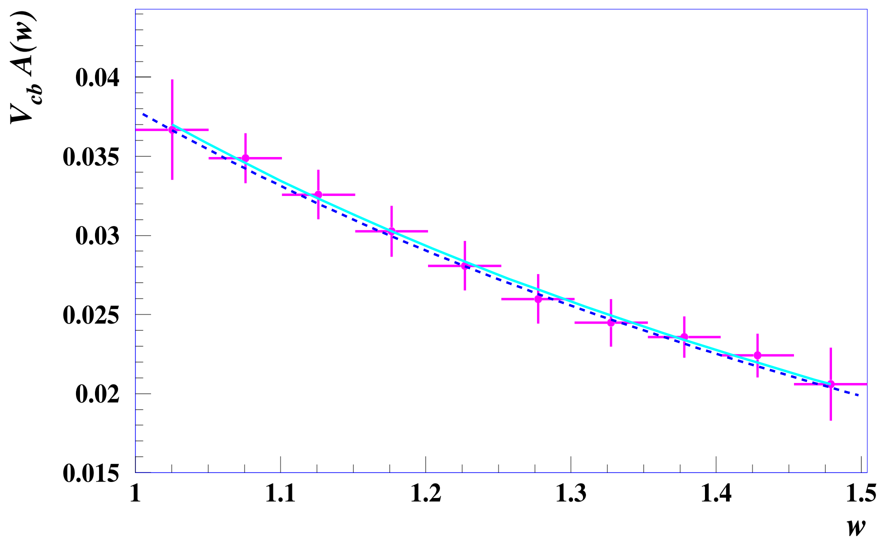
- 4 measurements (each with similar accuracy as CLEO)
- dedicated studies on $\mathrm{B} \to \overline{\mathrm{D}^{**}}\ell^-\overline{\nu_\ell}$, $\overline{\mathrm{D}^{**}} \to \mathrm{D}^{*+}\mathrm{X}$, large corrections to HQET.



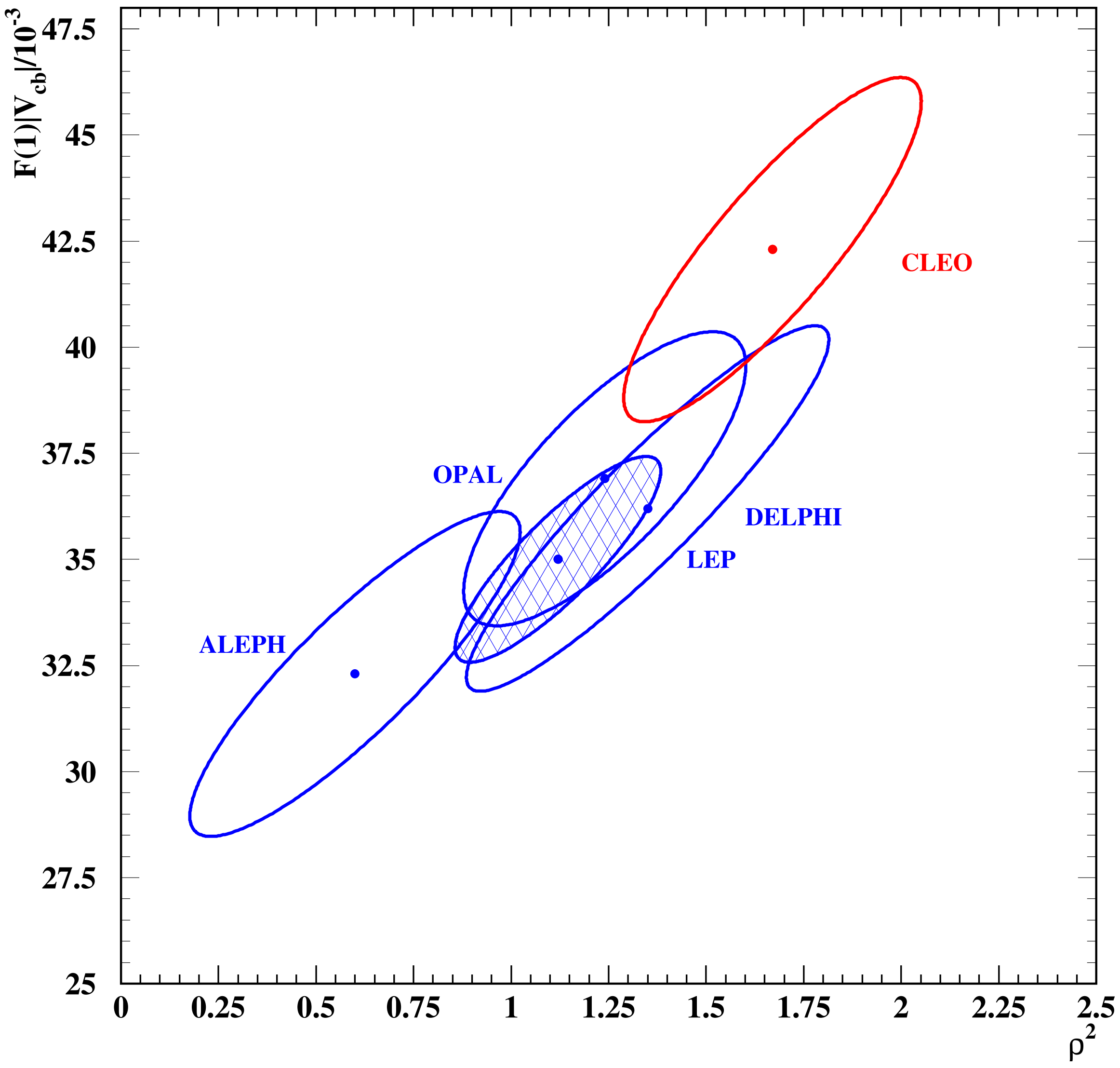
The $F_{D^{*+}}(w)$ form factor.

The $F_{D^{*+}}(w)$ distribution has been obtained after having unfolded the experimental resolution, in the inclusive DELPHI π^* analysis.





$|V_{cb}|$ Results - Exclusive analyses



The present measurements are only marginally compatible :

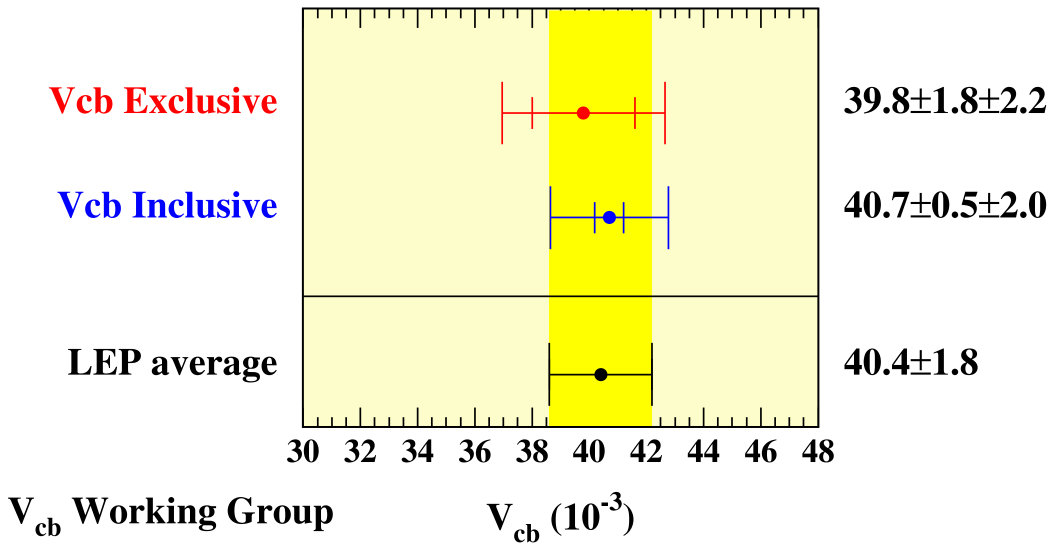
(this may indicate a pb in syst. uncertainties evaluation...)

The fit probability is 6%

LEP $|V_{cb}|$ measurements

- Inclusive
  using $BR(b \to \ell\ X)$ and τ_b measurements +O.P.E.

- Exclusive
  using $BR(\overline{\mathrm{B}^0_d} \to \mathrm{D}^{*+}\ell^-\overline{\nu_\ell})$ +H.Q.E.T.



Considering only LEP measurements (uncertainties from Theory dominate):

$$|V_{cb}| = (40.4 \pm 1.8)10^{-3}$$
$$A = 0.838 \pm 0.037$$

Progress expected on control of Th. errors at b-factories .

- $\overline{\mathrm{D}^{**}}$ detailed spectroscopy (exclusive)
- moments of lepton energy (inclusive)

Vub measurements

At other machines

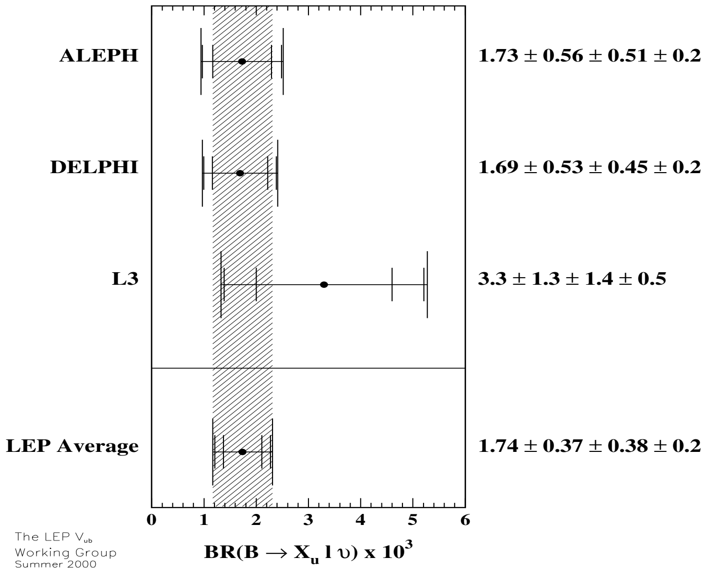
- $b \to u\ell^-\overline{\nu_\ell}$ discovery: CLEO (1990) end-point lepton energy spectrum
- exclusive $B \to (\pi,\ \rho)\ell^-\overline{\nu_\ell}$ decays: CLEO (1996)

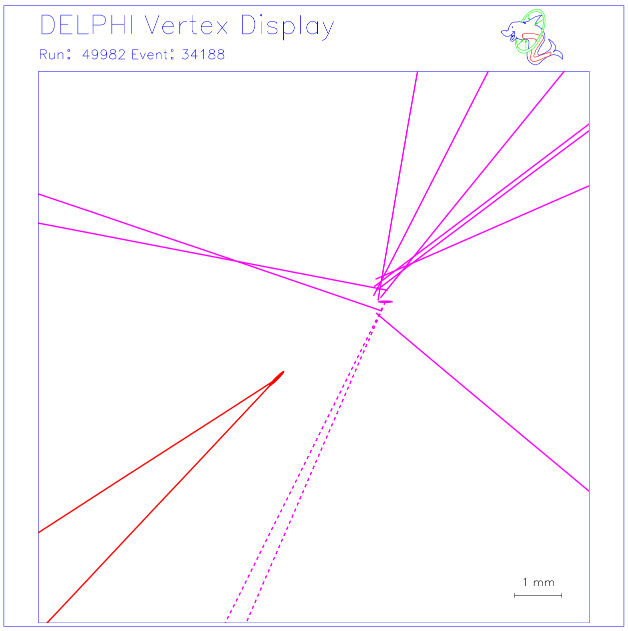
$$|V_{ub}| = (3.25 \pm 0.14^{+0.21}_{-0.29} \pm 0.55) \times 10^{-3}$$

At LEP

Extremely difficult exercise at LEP because of $b \to c$ background.

$$|V_{ub}| = (4.13 \pm 0.45^{+0.43}_{-0.48} \pm 0.32) \times 10^{-3}$$



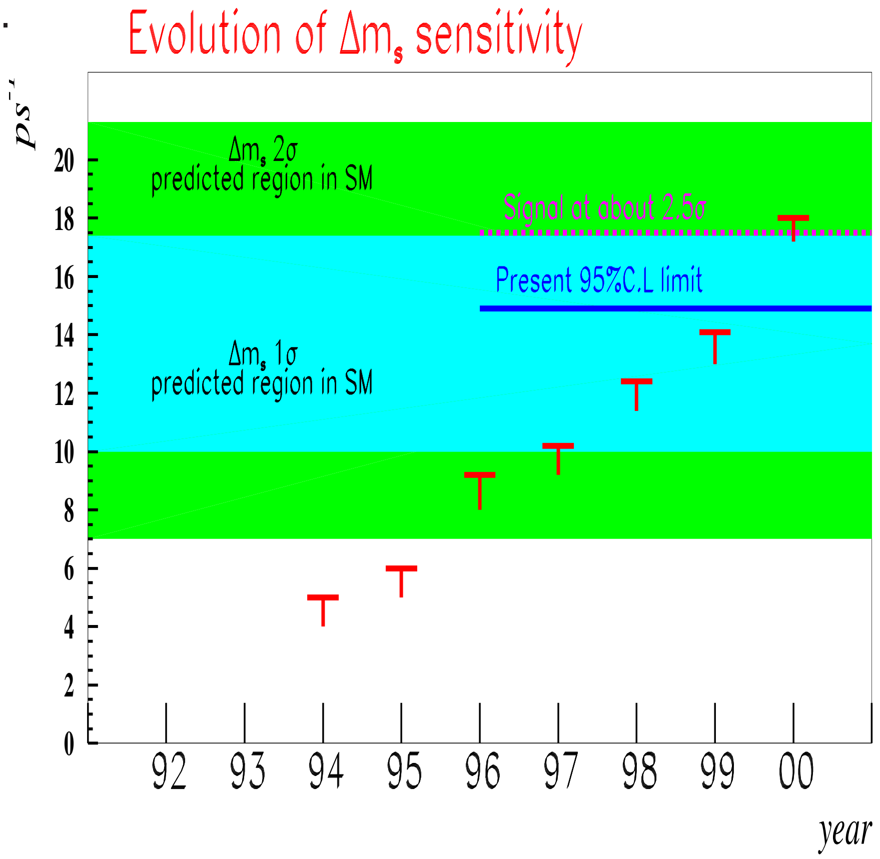


$\mathrm{B_s^0} - \overline{\mathrm{B_s^0}}$ oscillations

The oscillation amplitude

$$\mathcal{P}(\mathrm{B_s^0} \to \overline{\mathrm{B_s^0}}) = \frac{1}{\tau_{\mathrm{B_s^0}}}[1 - \mathcal{A}\cos(\Delta m_s\ t)]\exp\left(-\frac{t}{\tau_{\mathrm{B_s^0}}}\right)$$

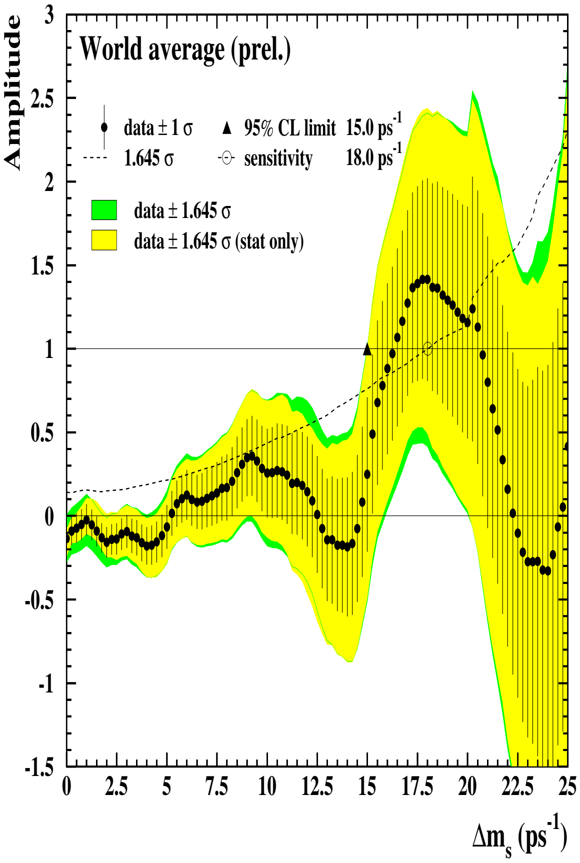
$\mathcal{A}$ is named the oscillation amplitude and its value is fitted on data.

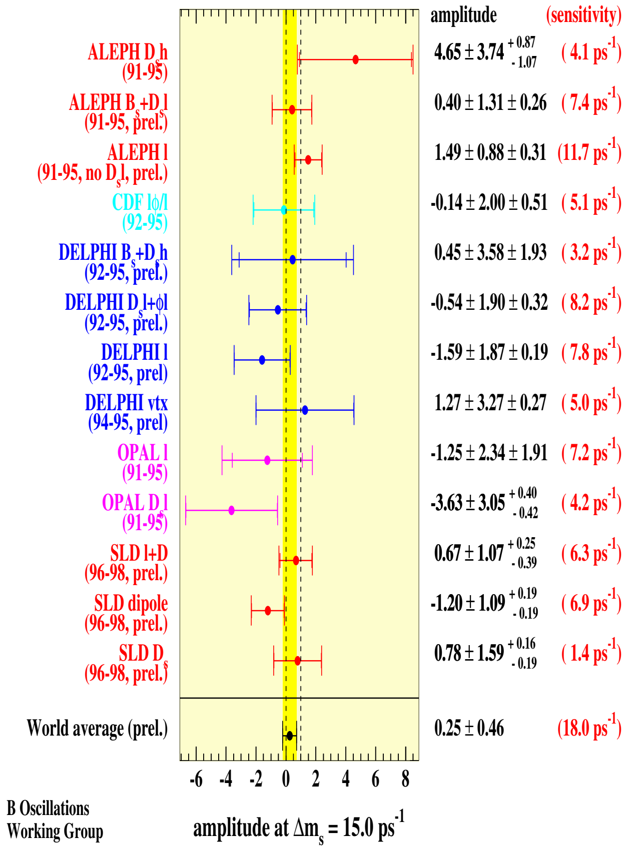


Impressive improvements! Will they stop eventually?

Intrinsic limitation governed by VD accuracy (ultimate resolution on the B decay time)

Results in 2000





$\Delta m_s > 15.0\ \mathrm{ps}^{-1}$ at 95% C.L.

SLD has 50% weight

2.5σ effect at $17.8\ \mathrm{ps}^{-1}$

$\rightarrow$ TeVatron

Quark mass matrices

This is also Higgs physics .....

The Lagrangian of weak interactions contains several terms as:

- the weak charged current interaction with quarks

$$\mathcal{L}_w = \frac{g}{\sqrt{2}} W_\mu^\dagger \overline{\mathrm{U}}_\mathrm{L} \gamma^\mu \mathrm{D}_\mathrm{L}$$

- mass terms

$$\mathcal{L}_m = \left(\overline{\mathrm{U}}^\mathrm{i}_\mathrm{L}\ \overline{\mathrm{D}}^\mathrm{i}_\mathrm{L}\right) \Gamma_{ij} \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix} \mathrm{D}^\mathrm{j}_\mathrm{R} + \left(\overline{\mathrm{U}}^\mathrm{i}_\mathrm{L}\ \overline{\mathrm{D}}^\mathrm{i}_\mathrm{L}\right) \Delta_{ij} \begin{pmatrix} \phi^{0\dagger} \\ -\phi^- \end{pmatrix} \mathrm{U}^\mathrm{j}_\mathrm{R}$$

Γ and Δ are complex matrices

After spontaneous symmetry breaking

- $< \phi^+ >= 0$ and $< \phi^0 >\neq 0$
- the mass terms become:

$$\mathcal{L}_m = \overline{\mathrm{D}}_\mathrm{L}\ \mathrm{M}_\mathrm{D}\ \mathrm{D}_\mathrm{R} + \overline{\mathrm{U}}_\mathrm{L}\ \mathrm{M}_\mathrm{U}\ \mathrm{U}_\mathrm{R}$$

  where

$$\mathrm{M}_\mathrm{D} = \Gamma\ < \phi^0 >;\ \mathrm{M}_\mathrm{U} = \Delta\ < \phi^0 >$$

- quark mass eigenstates are obtained by evaluating the diagonal mass matrices

The CKM matrix

This is done through unknown unitary transformations of the fields:

$$\mathrm{U}'_{\mathrm{R}} = \mathrm{A}^{\mathrm{U}}_{\mathrm{R}} \mathrm{U}_{\mathrm{R}}, \;\; \mathrm{U}'_{\mathrm{L}} = \mathrm{A}^{\mathrm{U}}_{\mathrm{L}} \mathrm{U}_{\mathrm{L}}, \;\; \text{and } \mathrm{U} \leftrightarrow \mathrm{D}$$

The "usual" quarks are, for instance:

$$u = \mathrm{U}'_{\mathrm{R}} + \mathrm{U}'_{\mathrm{L}}$$

And the charged current weak interaction becomes:

$$\mathcal{L}_w = \frac{g}{\sqrt{2}} W^{\dagger}_{\mu} \gamma^{\mu} \overline{\mathrm{U}}'_{\mathrm{L}} \mathrm{A}^{\mathrm{U}}_{\mathrm{L}} (\mathrm{A}^{\mathrm{D}}_{\mathrm{L}})^{-1} \mathrm{D}'_{\mathrm{L}} = \frac{g}{\sqrt{2}} W^{\dagger}_{\mu} \gamma^{\mu} \overline{\mathrm{U}}'_{\mathrm{L}} \mathrm{V}_{\mathrm{CKM}} \mathrm{D}'_{\mathrm{L}}$$

Some properties of the CKM matrix

- it is unitary $\rightarrow n_f^2$ parameters
- physics is unchanged if quark phases are modified:

  $$\mathrm{U}'_{\alpha} \rightarrow \exp \mathrm{i}\Psi_{\alpha} \; \mathrm{U}'_{\alpha}, \;\; \mathrm{D}'_{\beta} \rightarrow \exp \mathrm{i}\Psi_{\beta} \; \mathrm{D}'_{\beta}$$

  which correspond to the following transformation:

  $$\mathrm{V}_{\alpha\beta} \rightarrow \exp \mathrm{i}(\Psi_{\alpha} - \Psi_{\beta}) \; \mathrm{V}_{\alpha\beta}$$

  $2n_f - 1$ phases can be eliminated
- it depends on 4 parameters $(n_f = 3)$
- one parameter corresponds to a complex quantity

CKM matrix parametrization

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

There are several ways to introduce the complex phase in the matrix. Physics does not depend on a peculiar choice.

Wolfenstein parametrization

$$\begin{pmatrix} 1-\lambda^2 & \lambda & A\lambda^3(\rho - i\eta) \\ \lambda & 1-\lambda^2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

By definition:

$$V_{us} = \lambda;\ V_{cb} = A\lambda^2,\ V_{ub} = A\lambda^3(\rho - i\eta)$$

λ

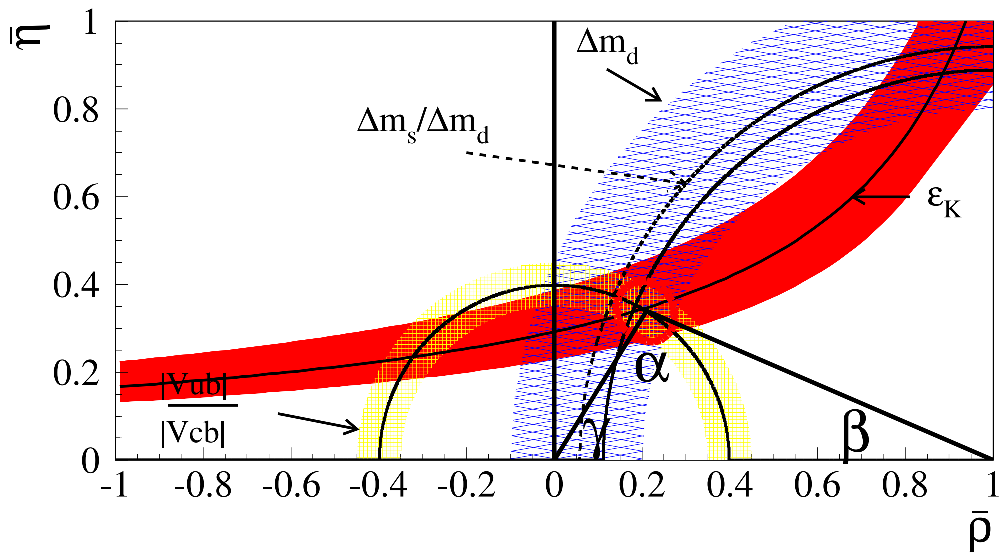
Measured in nuclei and K weak decays. Measurements are $\sim 2\ \sigma$ apart.

$\lambda = 0.2237 \pm 0.0033 \leftrightarrow 0.2196 \pm 0.0023\ (PDG\ 2000)$

The b-CKM unitarity triangle

$$V_{ud}^* V_{ub} + V_{cd}^* V_{cb} + V_{td}^* V_{tb} = 0$$

$$\overline{AC} = \frac{1-\lambda^2/2}{\lambda} \left| \frac{V_{ub}}{V_{cb}} \right| \qquad \overline{AB} = \frac{1}{\lambda} \left| \frac{V_{td}}{V_{cb}} \right|$$



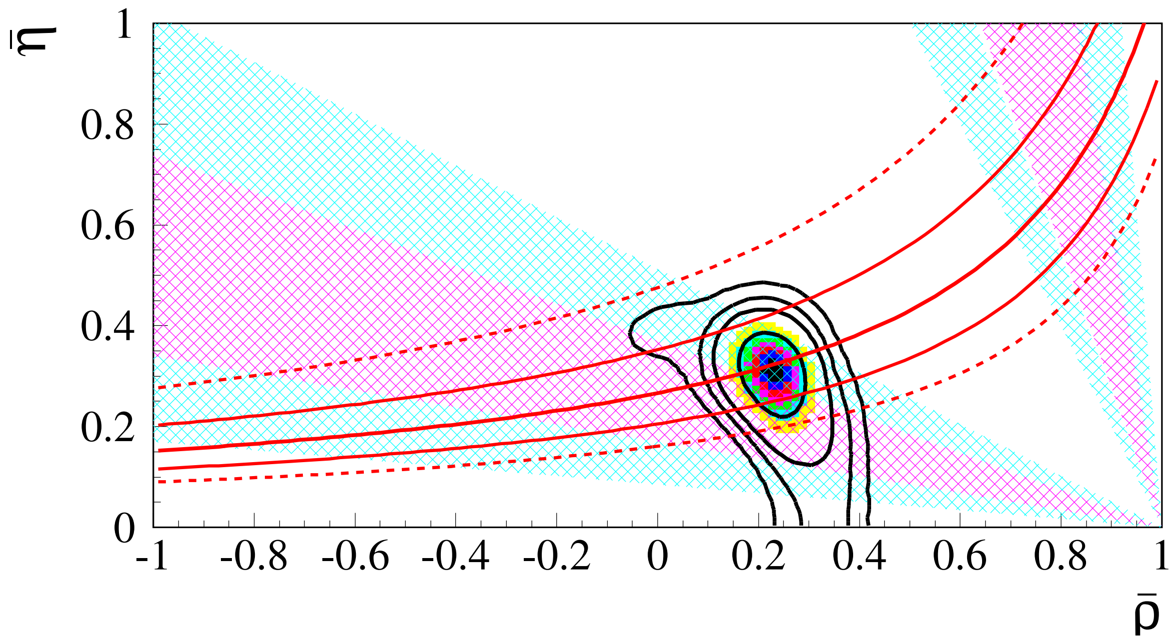
Measurement	$V_{CKM}\times$other	Constraint
$b \to u/b \to c$	$\vert V_{ub}/V_{cb}\vert^2$	$\bar\rho^2 + \bar\eta^2$
Δm_d	$\vert V_{td}\vert^2 f_{B_d}^2 \hat{B}_{B_d} f(m_t)$	$(1-\bar\rho)^2 + \bar\eta^2$
$\frac{\Delta m_d}{\Delta m_s}$	$\left\vert \frac{V_{td}}{V_{ts}} \right\vert^2 \frac{f_{B_d}^2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

$\bar\rho = \rho(1-\lambda^2/2),\ \bar\eta = \eta(1-\lambda^2/2)$

CP (effects) without CP (meas.)

Compatibility between

- the sides of the triangle $|V_{ub}/V_{cb}|$, Δm_d and Δm_s
- CP violation phase from ϵ_K measurement.



"Coherent picture" of CP phenomena described

in terms of a single parameter η:

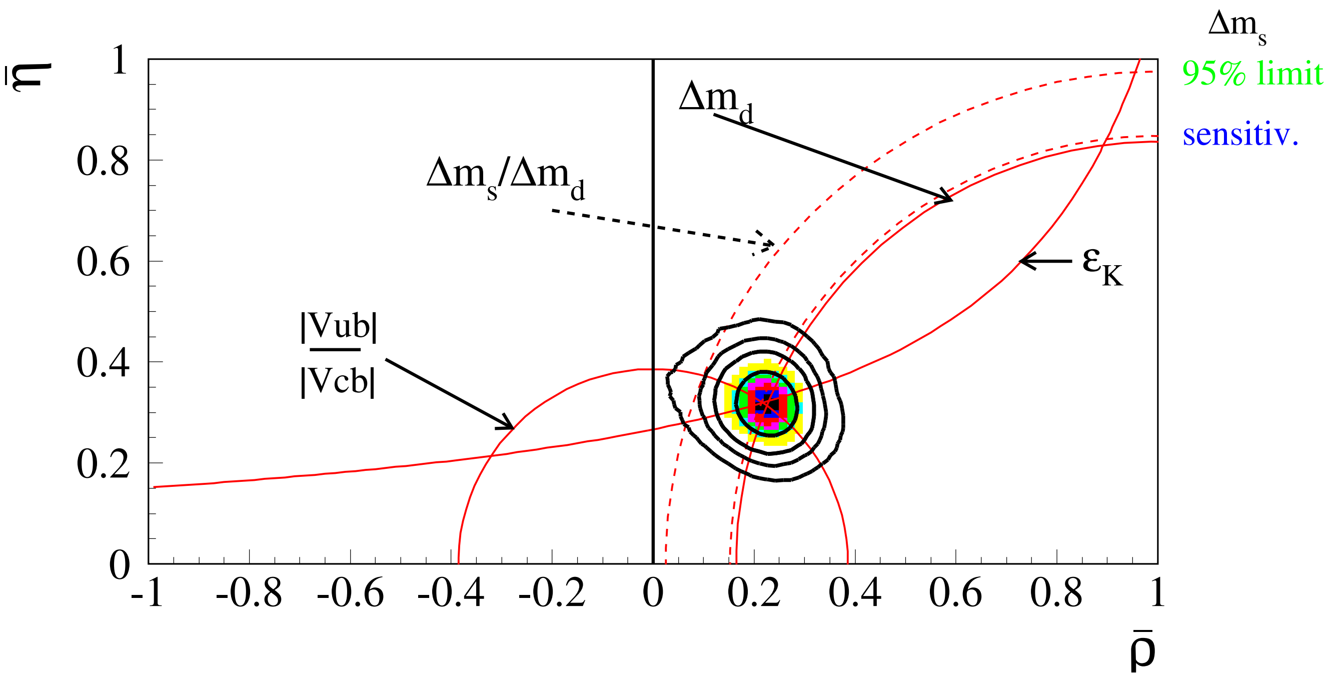
$\bar{\eta} = 0.302^{+0.052}_{-0.061}$ $\qquad sin2\beta = 0.678^{+0.078}_{-0.101}$

DIRECT MEASUREMENT : $sin2\beta$ = 0.49 $\pm$ 0.16.

Yet not precise enough to test the compatibility with sides measurements.

Important progress are expected soon, from B-Factories.

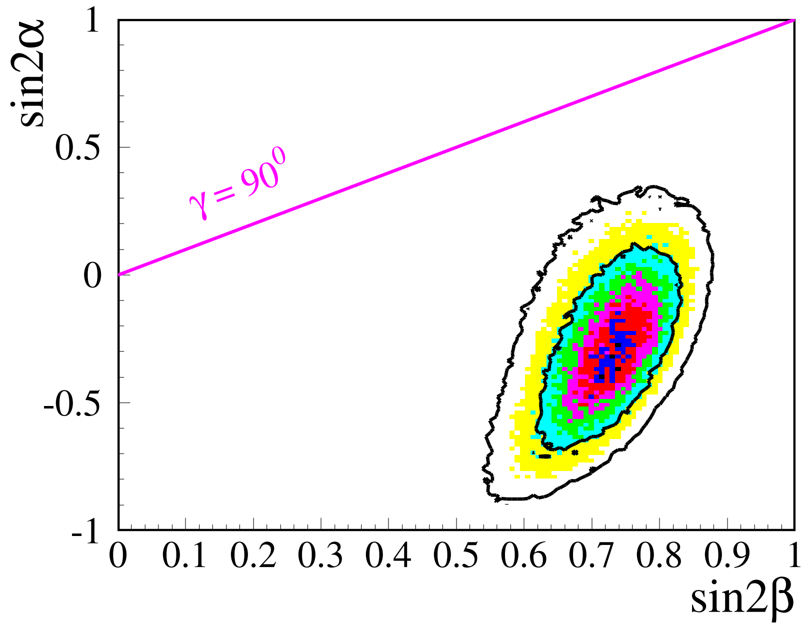
Results on $\bar{\rho}$ and $\bar{\eta}$

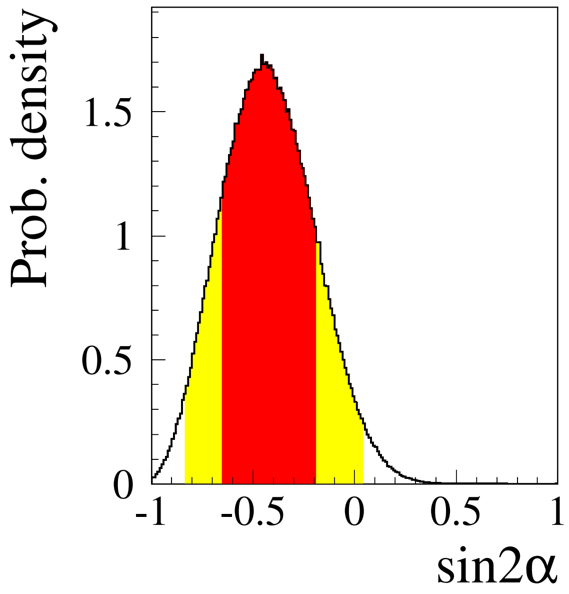


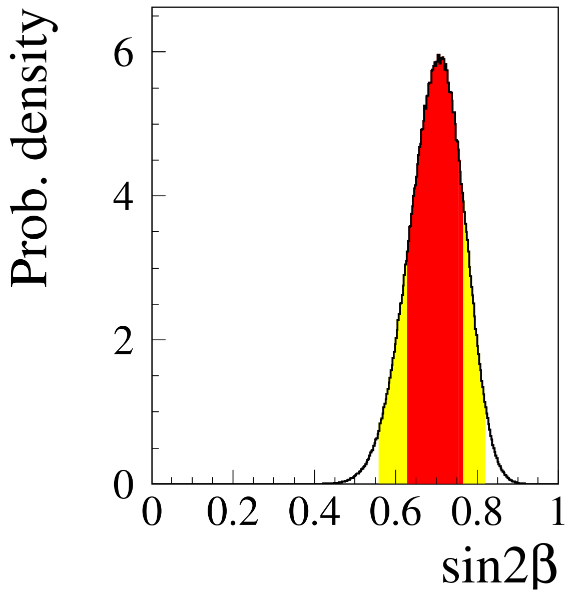
$$\bar{\rho} = 0.224 \pm 0.038$$

$$\bar{\eta} = 0.317 \pm 0.040$$

$sin2\beta$ and $sin2\alpha$



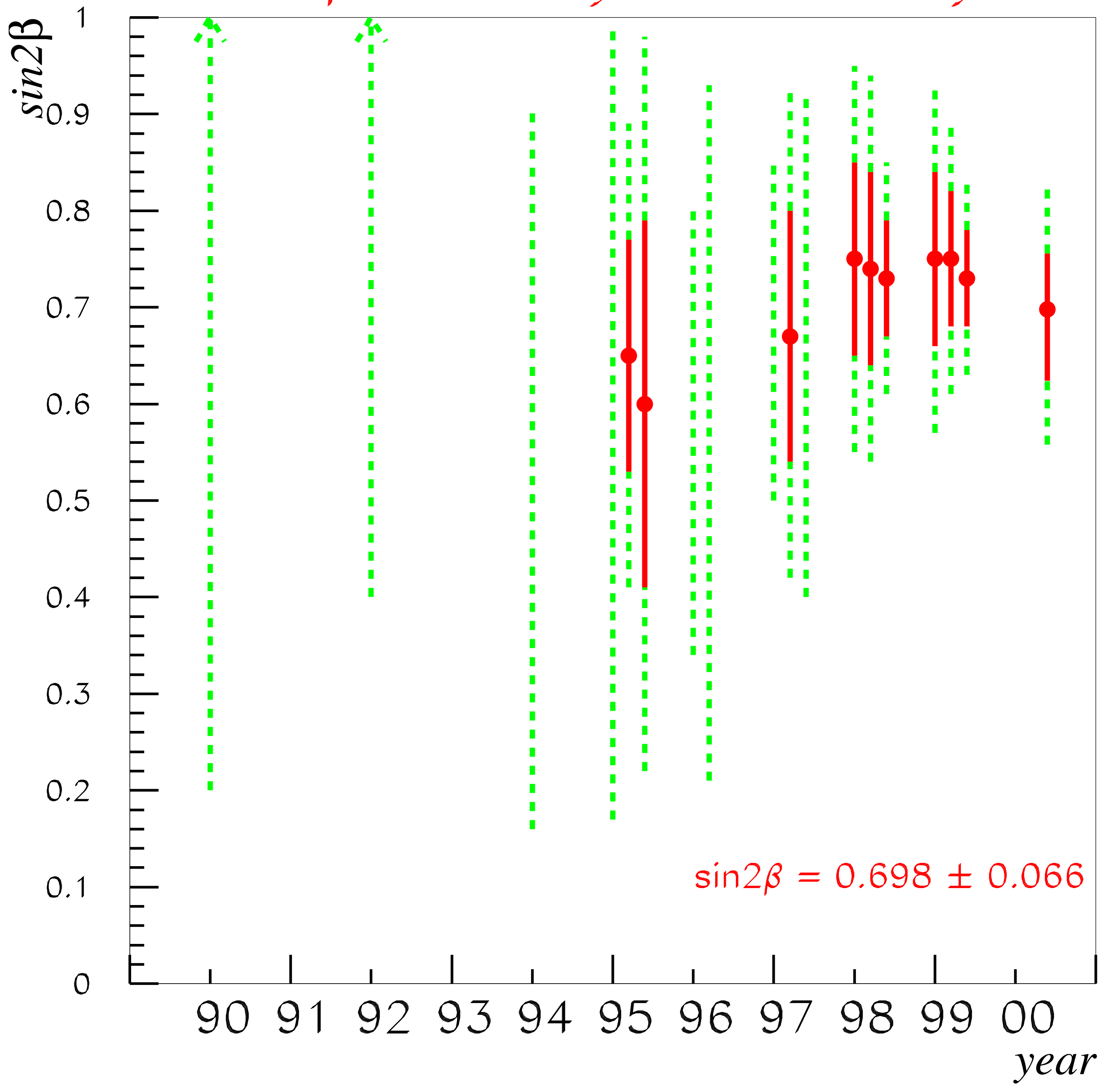




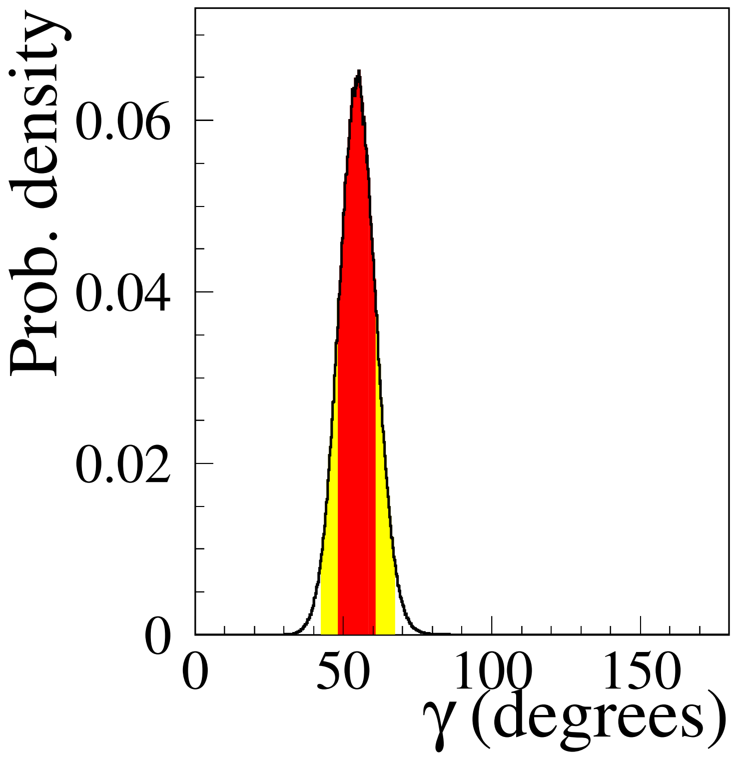
$$sin2\beta = 0.698 \pm 0.066$$

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

$\sin 2\beta$ – 10 years Story



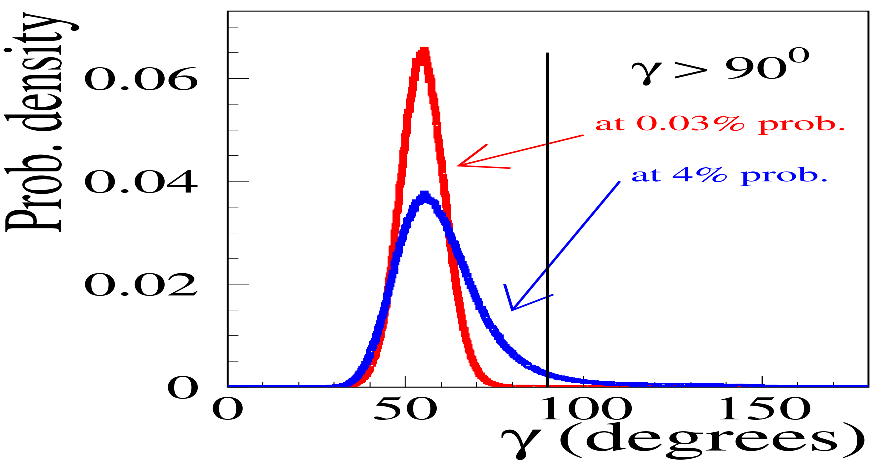
The angle γ



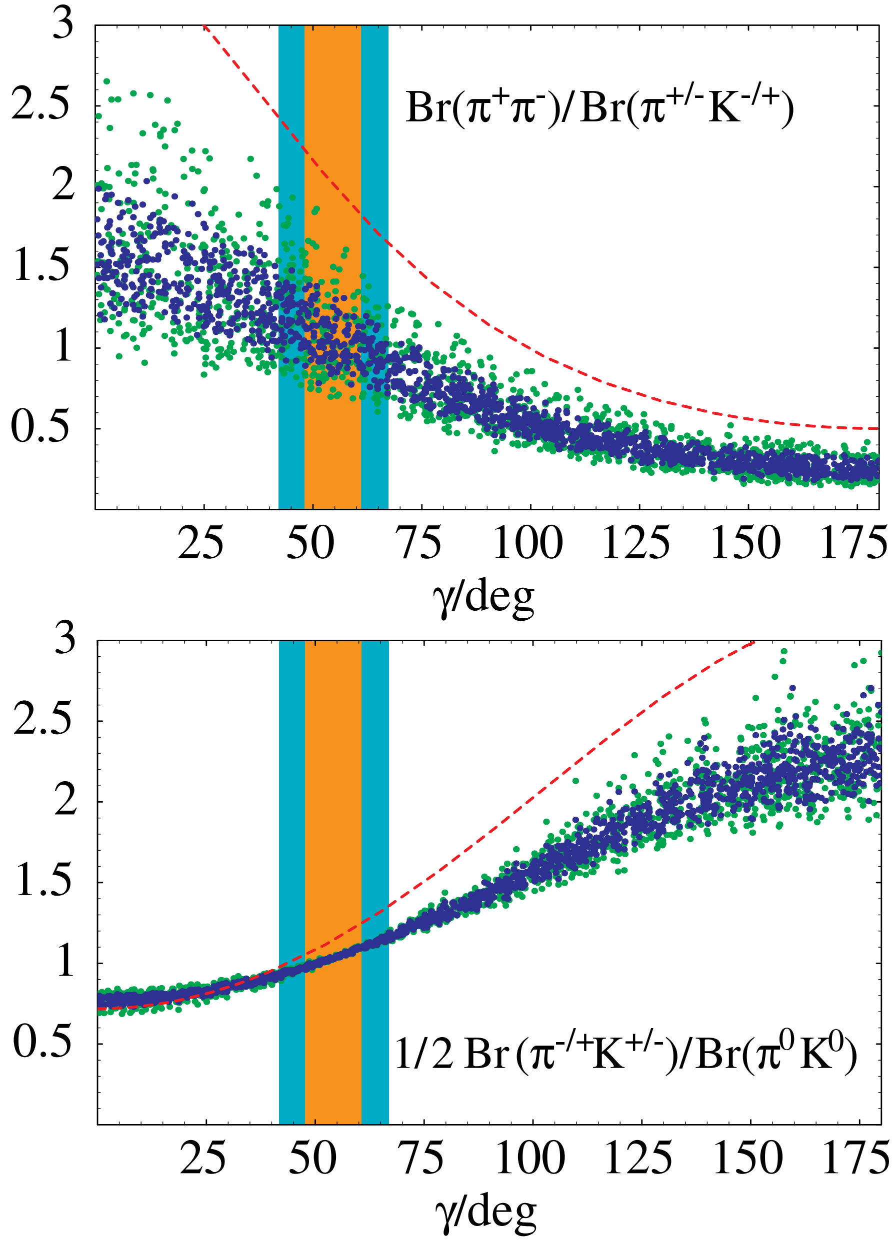
$\gamma = (54.8 \pm 6.2)^o$

$\gamma > 90^o$ at 0.03% C.L.

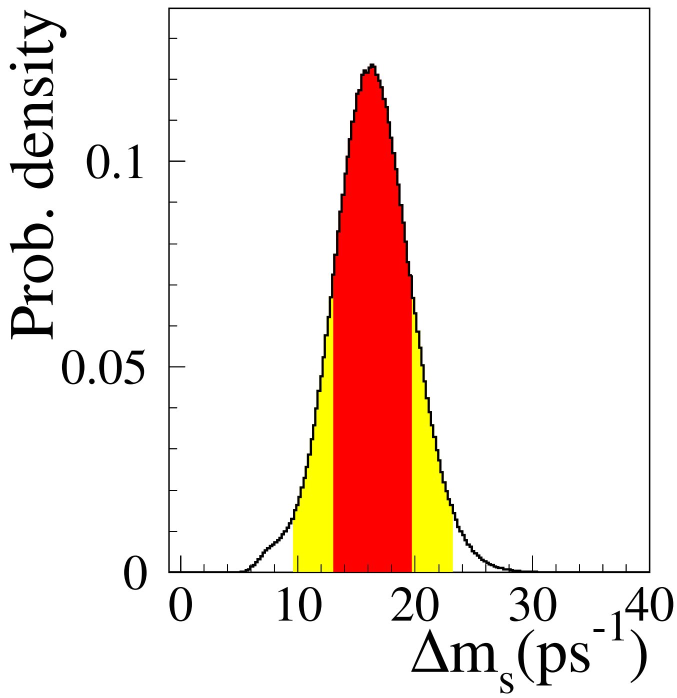
This important result is mainly due to the Δm_s constraint :



γ from 2 body-hadronic decays



Δm_s probability density

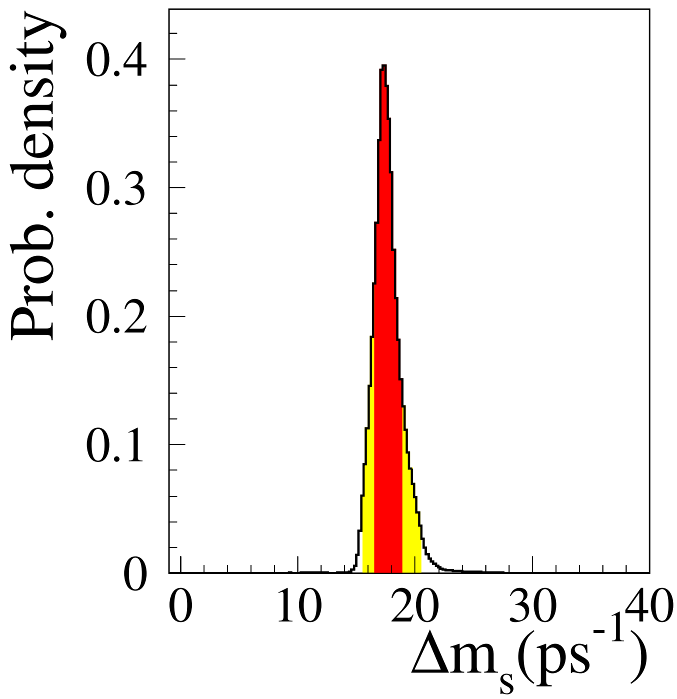


Without Δm_s

Δm_s = 16.3 $\pm 3.4\ ps^{-1}$.

$[9.7-23.2]\ ps^{-1}$ at 95%C.L.

15.8 (2.3)(3.3) Lattice

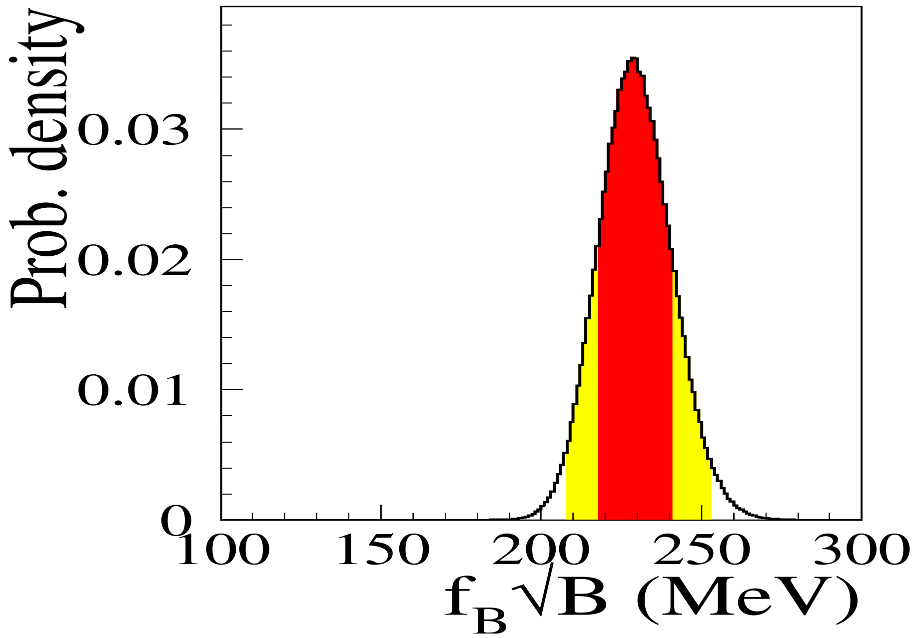


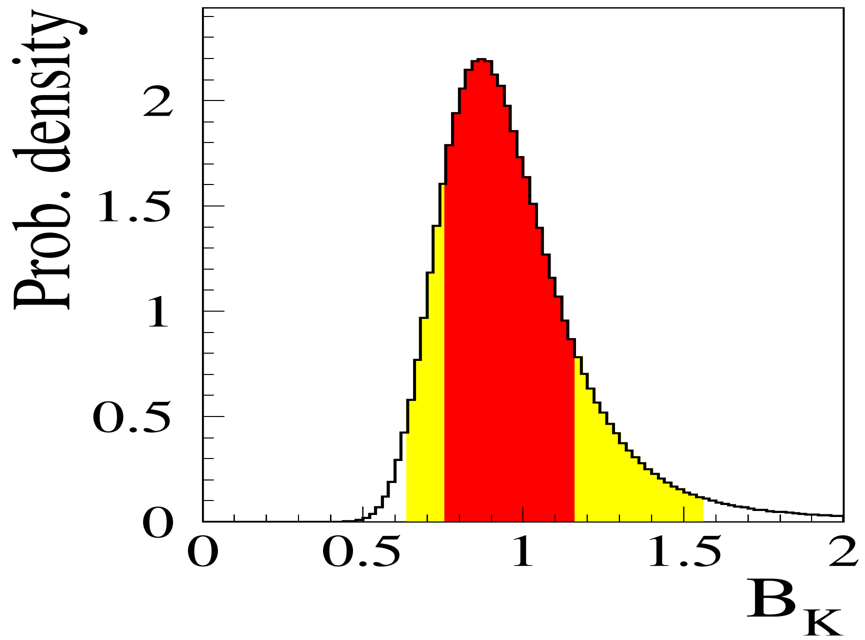
With Δm_s

Δm_s = 17.3 $^{+1.5}_{-0.7}\ ps^{-1}$.

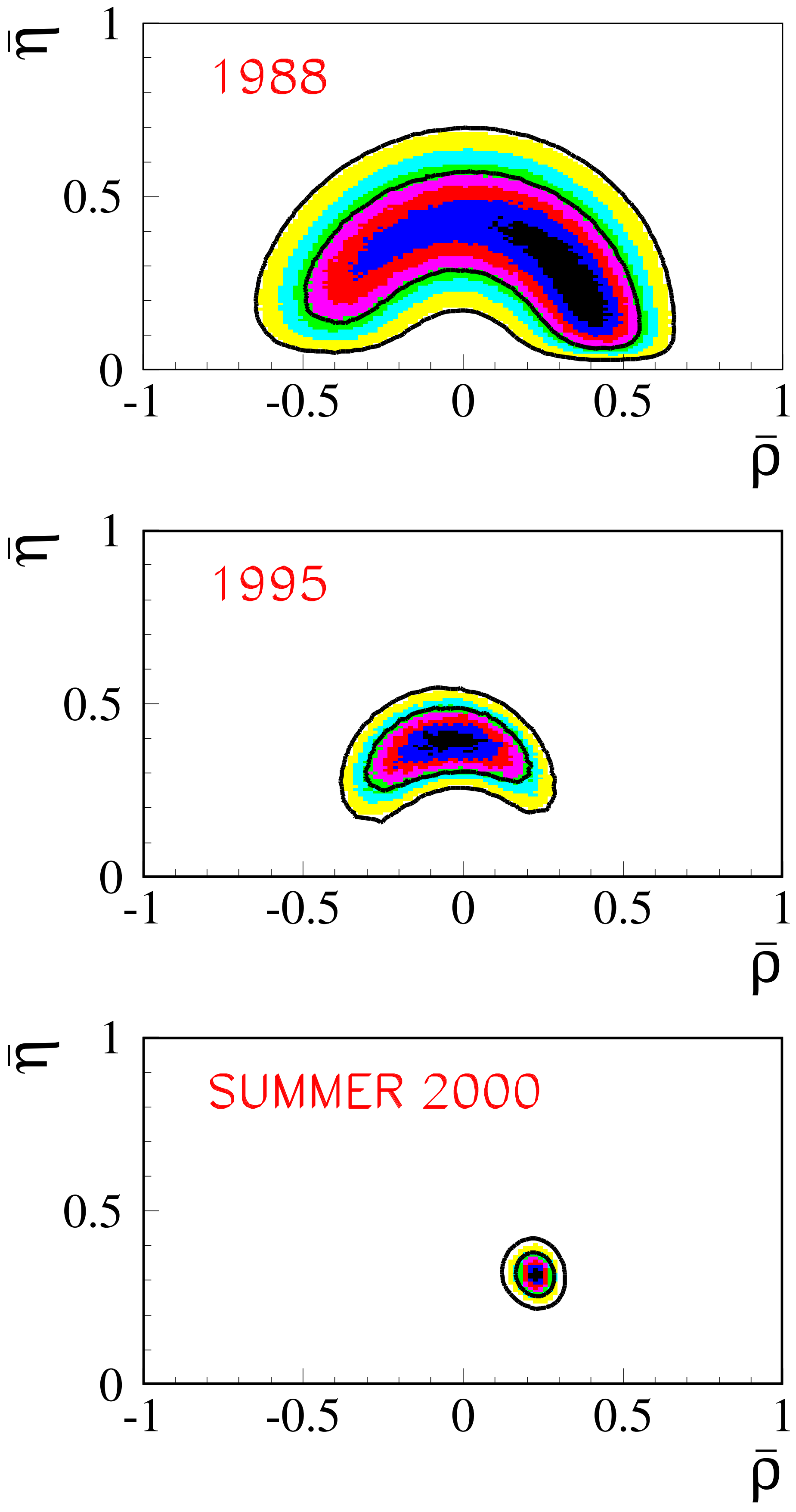
[15.6-20.5] ps^{-1} at 95%C.L.

$B_K,\ f_B\sqrt{B}$





Parameter	Input value	Fitted value
B_K	$0.86 \pm 0.06 \pm 0.13$	$B_K = 0.90^{+0.30}_{-0.14}$
$f_B\sqrt{B}$	$220 \pm 20 \pm 25\ MeV$	$231 \pm 15\ MeV$



1988
1995
SUMMER 2000
$\bar{\eta}$
$\bar{\rho}$

Conclusions

Large improvements since LEP1 stops

- b-lifetimes, $\mathrm{B_d^0}-\overline{\mathrm{B_d^0}}$ oscillations, $|\mathrm{V}_{cb}|$, $|\mathrm{V}_{ub}|$: almost completed

  1-few % accuracy on several measurements

  systematics match high statistical accuracy

  for $\mathrm{B_d^0}$ and B^- $\rightarrow$ b-factories.

  for $\mathrm{B_s^0}$ and Λ_b^0 (and $\mathrm{B_c^+}$) $\rightarrow$ TeVatron.

- $\mathrm{B_s^0}-\overline{\mathrm{B_s^0}}$ oscillations: still in progress +SLD

  exploring $\Delta m_s \sim 17\ \mathrm{ps}^{-1}$ was unexpected

  Δm_s measured at Tevatron soon?

- b-fragmentation ...: to be finalized

  important data for high energy colliders

Non-trivial test of SM CP violation done

LEP (mainly) + m_t + Lattice QCD

$|V_{cb}|$, $|V_{ub}|$, Δm_d, Δm_s $\rightarrow$ sides of Unitarity triangle

B decays agree with CP violation in K physics

and with CP violation in B physics

	S.M. fit	actual	in future
$f_B\sqrt{B}$ $(^*)$	(231 ± 15) MeV	$(220 \pm 20 \pm 25)$ MeV	c-fact., lattice QCD ± 15 MeV - 2005
B_K $(^+)$	$0.90^{+0.30}_{-0.14}$	$0.86 \pm 0.06 \pm 0.13$	lattice QCD ± 0.08 - 2003
$\sin(2\beta)$	0.70 ± 0.07	0.49 ± 0.16	b-fact., LHC ± 0.05 - 2006 ± 0.01 - 2008
$\sin(2\alpha)$	-0.4 ± 0.2	?	b-fact., LHCb, BTeV $\pm ?$
γ	$(55 \pm 6)^\circ$	?	LHCb, BTeV $\pm ?$
Δm_s	$(17.3^{+1.5}_{-0.7}) ps^{-1}$	?	Tevatron 3σ - 2001(?) 5σ - 2004
$BR(K^+ \rightarrow \pi^+ \nu \overline{\nu})$	$(6.6 \pm 1.1)\ 10^{-11}$	$< 15\ 10^{-11}$	BNL
$BR(K^0 \rightarrow \pi^0 \nu \overline{\nu})$	$(2.5 \pm 0.5)\ 10^{-11}$	?	BNL

$(^*)$: the Δm_d constraint is not included in the fit

$(^+)$: the $|\epsilon_K|$ constraint is not included in the fit