

Oscillazioni del B_s e limiti su CKM

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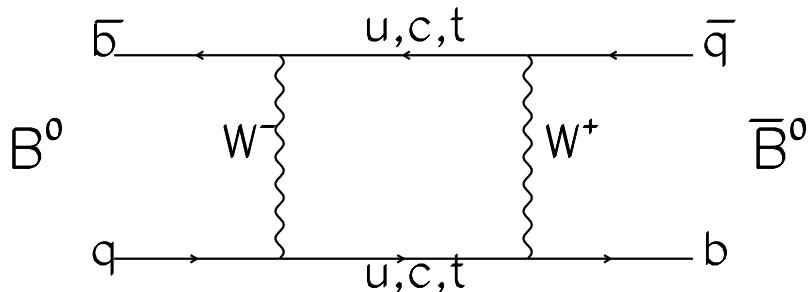
- **Studio delle oscillazioni del B_s**
 - Recenti risultati a LEP e SLD,
 - Risultati combinati e prospettive
- **Matrice CKM e Triangolo di unitarietà*:**
 - Vincoli V_{ub}/V_{cb} , ϵ_K , Δm_d , $\Delta m_s/\Delta m_d$
 - Parametri di Input: $f_B \sqrt{B}$, B_K , V_{cb} , m_t
 - Metodo utilizzato per estrarre le informazioni
- **Risultati**
 - ρ , η
 - Angoli $\sin 2\alpha$, $\sin 2\beta$, γ
 - Risultati senza il vincolo $|\epsilon_K|$
 - Ulteriori commenti sull'importanza di Δm_s
 - Fit di B_K e di $f_B \sqrt{B}$

* Materiale tratto dai lavori :

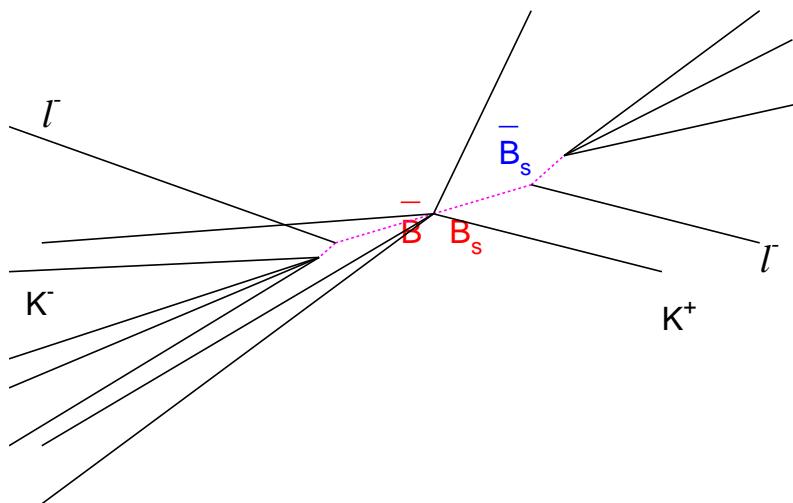
- F. Caravaglios, F. Parodi, P. Roudeau, A. Stocchi *hep-ph/0002171*
- P.Paganini, F.Parodi, P.Roudeau, A.Stocchi *Phys. Scripta* 58, 556 (98)
- F.Parodi, P.Roudeau, A.Stocchi *Nuovo Cimento*, Vol. 112 A (99)

Oscillation analyses

$$\mathcal{P}_{B_q^0 \rightarrow B_q^0, \bar{B}_q^0}(t) = \frac{1}{2} e^{-t/\tau_q} (1 \pm \cos \Delta m_q t) \quad \Delta m_q = m_{B_1^0} - m_{B_2^0}$$



$$\begin{aligned} \Delta m_d &\propto |V_{td}|^2 \\ \Delta m_s &\propto |V_{ts}|^2 \end{aligned} \implies \Delta m_s \approx 1/\sin^2 \theta_{Cabibbo} \quad \Delta m_d \simeq \mathcal{O}(10) \text{ ps}^{-1}$$



An oscillation study requires:

- measurement of the decay proper time
- $B_{s(d)}$ or $B_{s(d)}$ at $t = t^0$ (**decay tag**)
- $B_{s(d)}$ or $B_{s(d)}$ at $t = 0$ (**production tag**)

“Precision” of a Δm_s measurement:

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

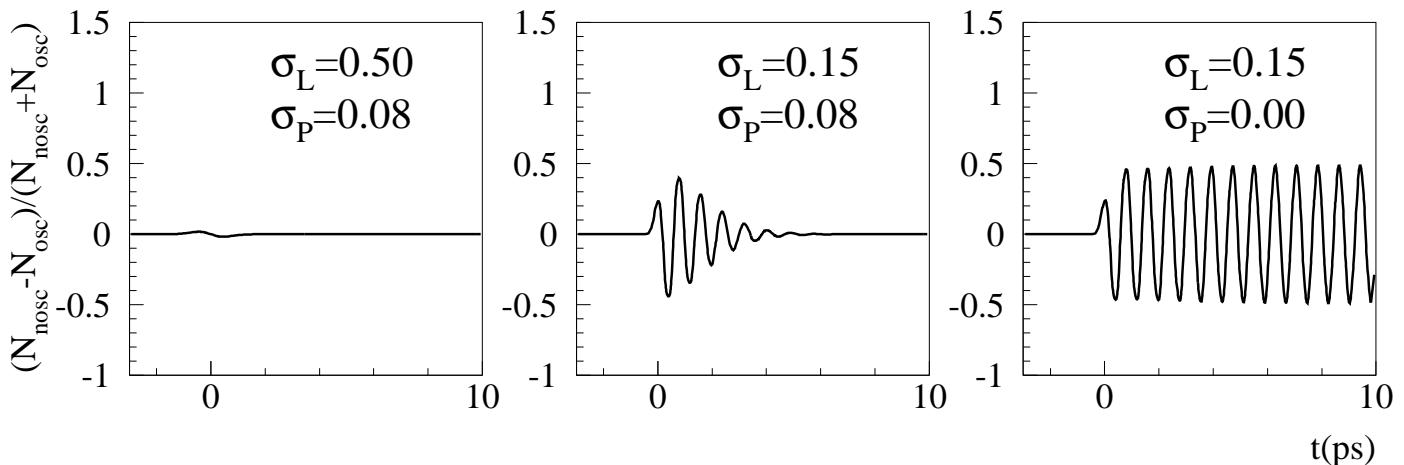
- N total number of events in the sample
- $f_{B_s^0}$ fraction of events due to B_s^0 decays
- ϵ tagging purity:

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

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

- σ_t proper time resolution

$$\sigma_t = \sqrt{\sigma_L^2 + \sigma_P^2 t^2}$$



$$\Delta m_s = 8 \text{ ps}^{-1}$$

Δm_s around the world

Δm_s at LEP

Data sample $\sim 4M$ hadronic Z^0 per expt.

Analyses Exp.

Inclusive lepton/**Comb** **ADO**

Exclusive D_s and/or $D_s^\pm h^\mp$ /**Comb** **AD**

$D_s^\pm \ell^\mp$ /**Comb** **AD**

Exclusive B_s^0 /**Comb** **AD**

Δm_s at SLC (SLD)

Data sample $\sim 350K$ hadronic Z^0 per expt.

Dipole/**Comb**

lepton + tracks/**Comb**

lepton + D/**Comb**

Δm_s at Fermilab (CDF)

Data sample di-lepton triggers

$\phi\ell/\ell$

Inclusive lepton/Comb

Keywords:

high p_t lept

Inclusive VTX

Global tagging

$$N \simeq n \times 10000$$

$$f_{B_s^0} \simeq 10\%$$

$$\epsilon \simeq 70\%$$

$$\sigma_t(t < 1 \text{ ps}) \simeq 0.27 \text{ ps}$$

- ♣ good proper time resolution achieved in inclusive vertexing,
- ♣ use of discriminant variables to increase the “effective” $f_{B_s^0}$
- ♣ good tagging at production.

Exp.	95% limit	Sensitivity
ALEPH	9.5	9.5
DELPHI	4.6	6.5
OPAL	5.2	7.2

$D_s^\pm \ell^\mp / \text{Comb}$

Keywords:

$$N \simeq 300 - 400$$

Good Vertexing

$$f_{B_s^0} \simeq 60\%$$

high p_t lept.

$$\epsilon \simeq 78\%$$

D_s completely rec.

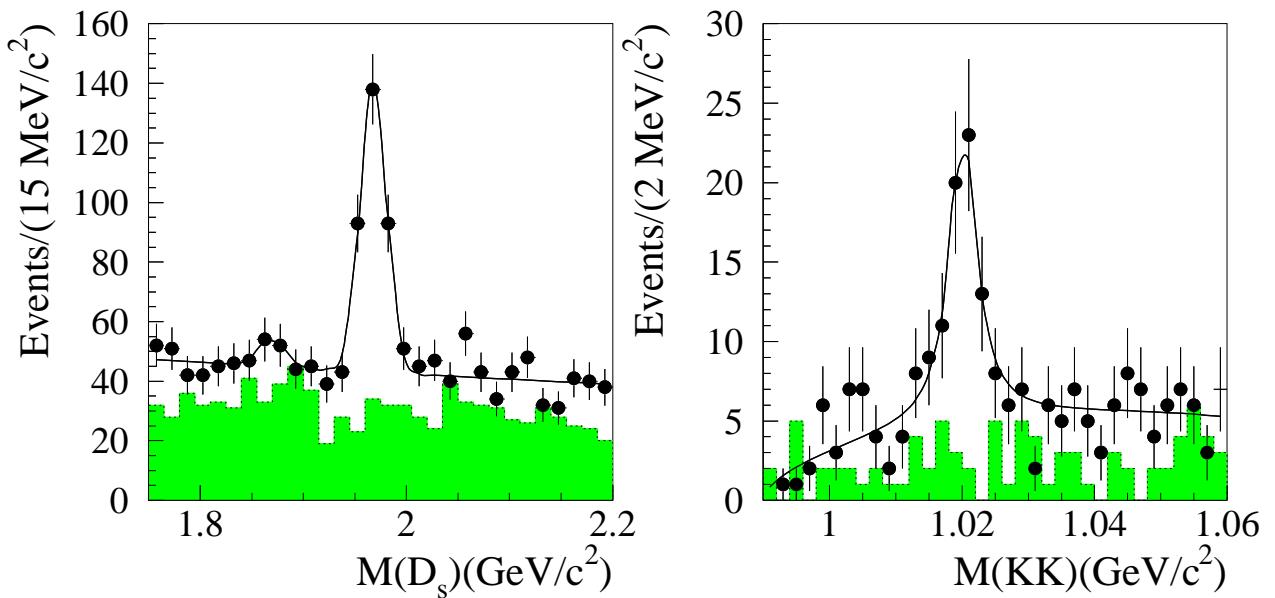
$$\sigma_t(t < 1 \text{ ps}) \simeq 0.18 \text{ ps}$$

Global tagging

♠ Increase statistics by reconstructing several D_s decay modes

$$D_s^+ \rightarrow \phi\pi^+, \phi\pi^+\pi^0, \phi\pi^+\pi^-\pi^+, \overline{K^{0*}}K^+, \overline{K^{0*}}K^{*+}, K_S^0K^+,$$

$$D_s^+ \rightarrow \phi e^+ \nu_e, \phi \mu^+ \nu_\mu$$



♠ very good tagging purity at production (all the charged tracks from B_s are reconstructed).

Exp.	95% limit	Sensitivity
ALEPH	5.2	6.4
DELPHI	7.4	8.2

Exclusive B_s^0 /Comb

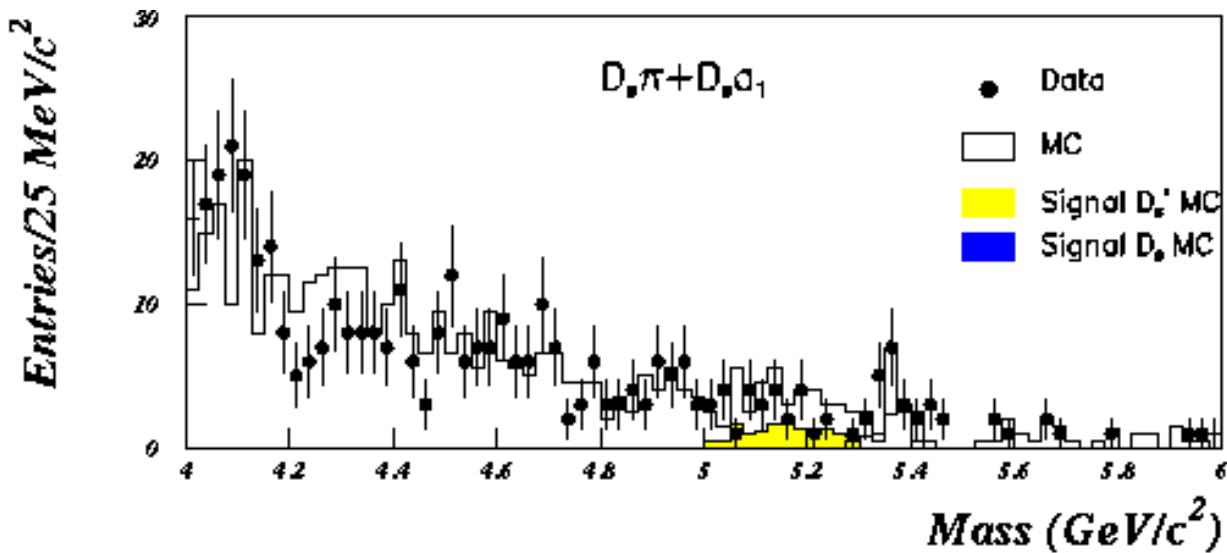
Proposed by DELPHI in Moriond 98.

$$\sigma_A \propto \frac{1}{e^{-(\Delta m_s \sigma_t)^2/2}} \quad \sigma_t = \sqrt{\sigma_L + (\sigma_P/P)^2 t^2}$$

To improve σ_A at high Δm_s needs very good σ_t .

Advantages of exclusive B_s^0 analysis: $\sigma_P/P \simeq 0$.

ALEPH presented an exclusive B_s analysis in Moriond 2000:



Exp.	B_s^0 in the main peak	B_s^0 in the satellite peak
ALEPH	10 ± 3	9 ± 4
DELPHI	8 ± 4	15 ± 8

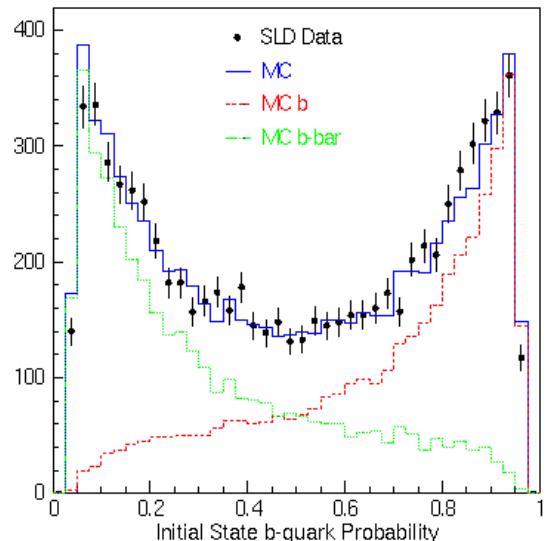
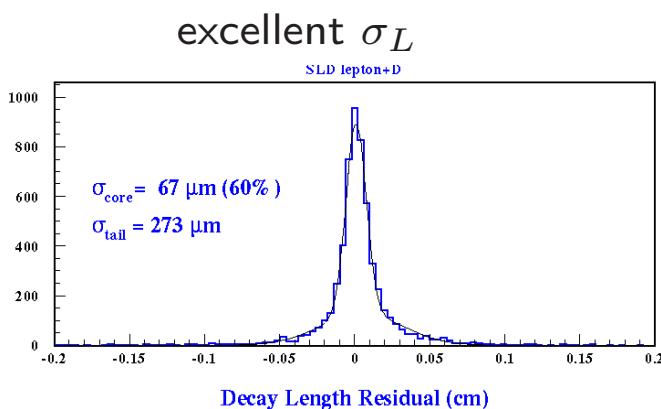
Modest sensitivity and limit (for this analysis alone)... but important contribution for high Δm_s value ($> 10 \text{ ps}^{-1}$).

Δm_s at SLC

lepton + "D" / Comb

Very similar to the inclusive lepton analyses with two great advantages:

high purity: $\epsilon^{eff} = 85\%$



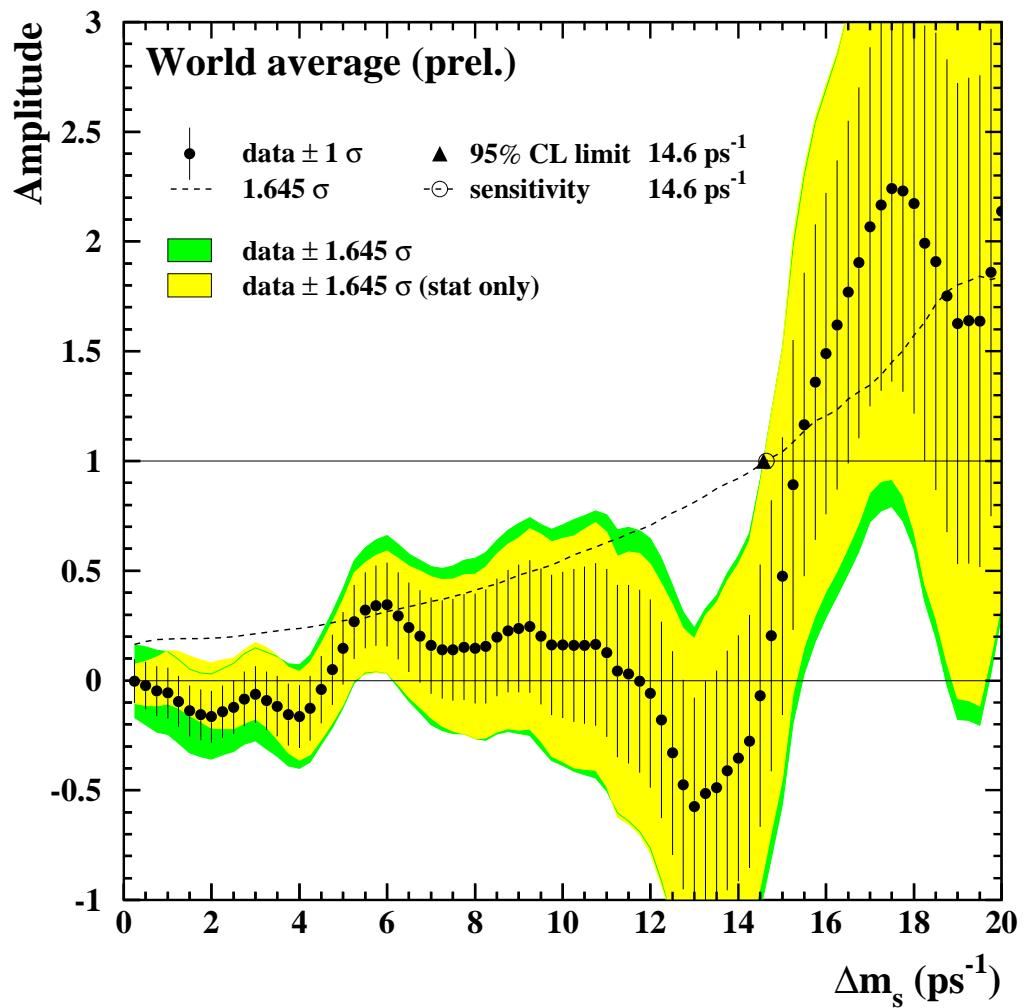
Charge Dipole/Comb

Technique unique to SLD.

- ◊ inclusive reconstruction of the B and D vertices
- ◊ the charge dipole $\delta Q \equiv D_{BD} \times \text{SIGN}(Q_D - Q_B)$ tag the b at decay time. For B_s^0 flying at least 1 mm the purity of this tag is 80%

Analysis	Sensitivity
lepton + tracks	0.1
lepton + "D"	3.5
Dipole	5.4

The combined excluded region is $\Delta m_s < 5.2 \text{ ps}^{-1}$ and $11.3 < \Delta m_s < 14.2 \text{ ps}^{-1}$ with a sensitivity at 8.6 ps^{-1} .



(LEP average: lower limit $10.2 \text{ } ps^{-1}$ with a sensitivity at $13.0 \text{ } ps^{-1}$)

New results expected for Osaka :

- ALEPH: updates of the $D_s^\pm \ell^\mp$ and inclusive lepton analyses (2.5 in stat + better vertexing) (“This upgrade will have a major impact on the world combination”).
- DELPHI: updates of the inclusive lepton analysis and a new totally inclusive analysis
- OPAL: $D_s^\pm \ell^\mp$ analysis
- SLD: “The lepton+D, lepton+tracks, charge dipole and D_s +tracks analyses will be updated with improved sensitivity to B_s mixing and near final data reconstruction for all data collected between 1996 and 1998”

V_{CKM}

There is an experimental hierarchy between the CKM matrix elements that is evident in the Wolfenstein parametrisation:

$$\lambda, A, \rho \text{ e } \eta$$

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

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

- λ is very well known $\lambda = 0.2205 \pm 0.0018$ ($s \rightarrow u$ transitions: $K^+ \rightarrow \pi^0 \ell^+ \nu; K^0 \rightarrow \pi^- \ell^+ \nu$)
- $|V_{cb}| = A\lambda^2$: a lot of activities in the last years.
Two complementary methods have been used:
 - $\tau_B +$ inclusive Br,
 - $\text{Br}(B \rightarrow D^* \ell \nu) + \text{HQET}$.

Preliminary result from the $|V_{cb}|$ WG:

$$|V_{cb}| = (40.4 \pm 1.9)10^{-3}$$

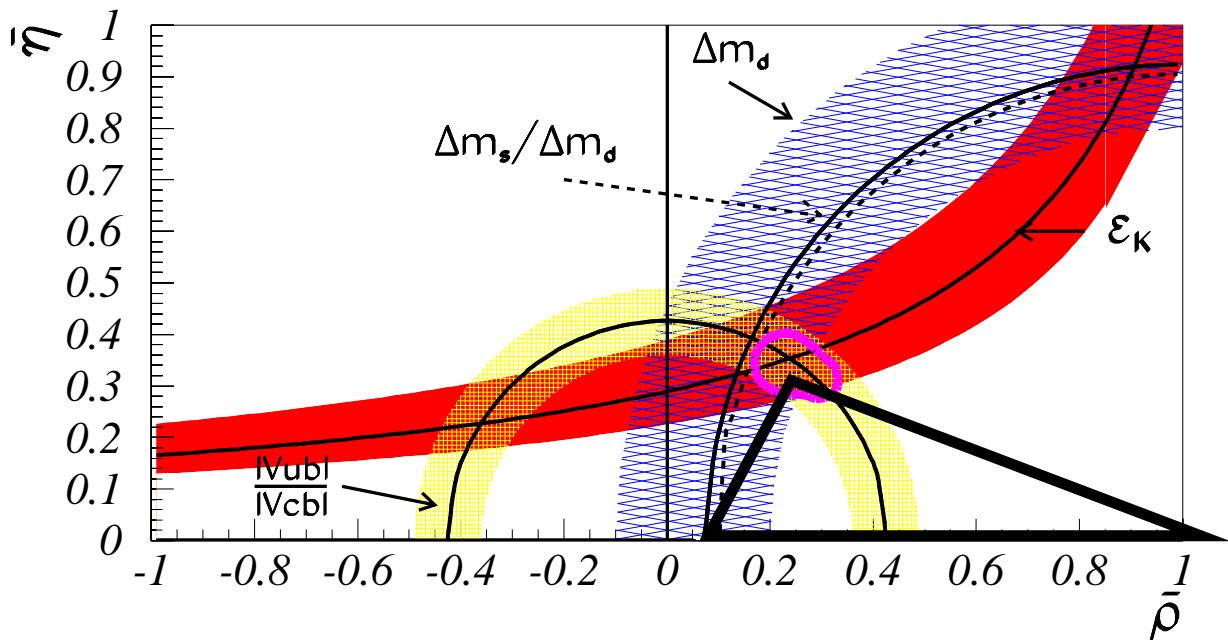
$$A = 0.835 \pm 0.039$$

- ρ and η are the most uncertain parameters

Unitarity Triangle

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

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



Measurement	$V_{CKM} \times \text{other}$	Constraint
$b \rightarrow u/b \rightarrow c$	$ 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	$f(A, \bar{\eta}, \bar{\rho}, B_K)$	$\propto \bar{\eta}(1 - \bar{\rho})$

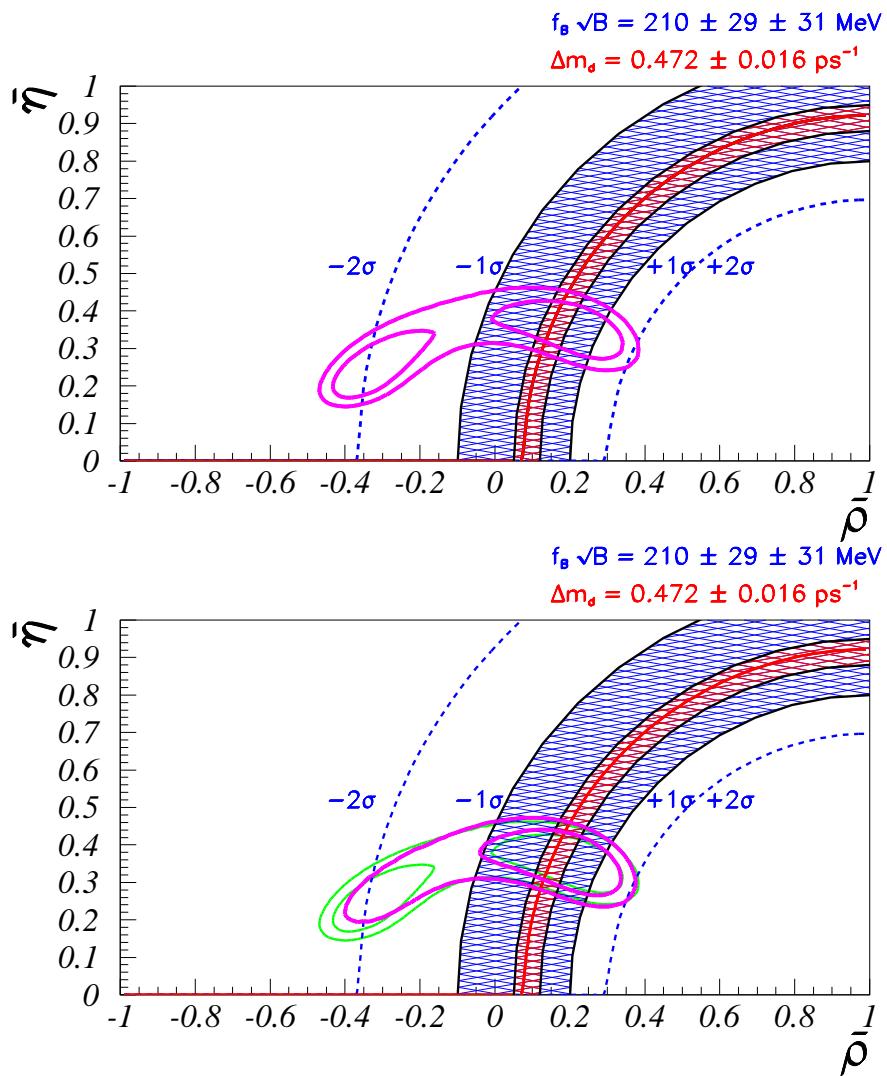
$$\bar{\rho}(\bar{\eta}) = \rho(\eta)(1 - \lambda^2/2)$$

$$\Delta m_d$$

$$\Delta m_d = \frac{g^4 A^2 \lambda^6}{192 m_W^2 \pi^2} |V_{tb}|^2 ((1 - \bar{\rho})^2 + \bar{\eta}^2) f_{B_d}^2 B_{B_d} \eta_B x_t F(x_t)$$

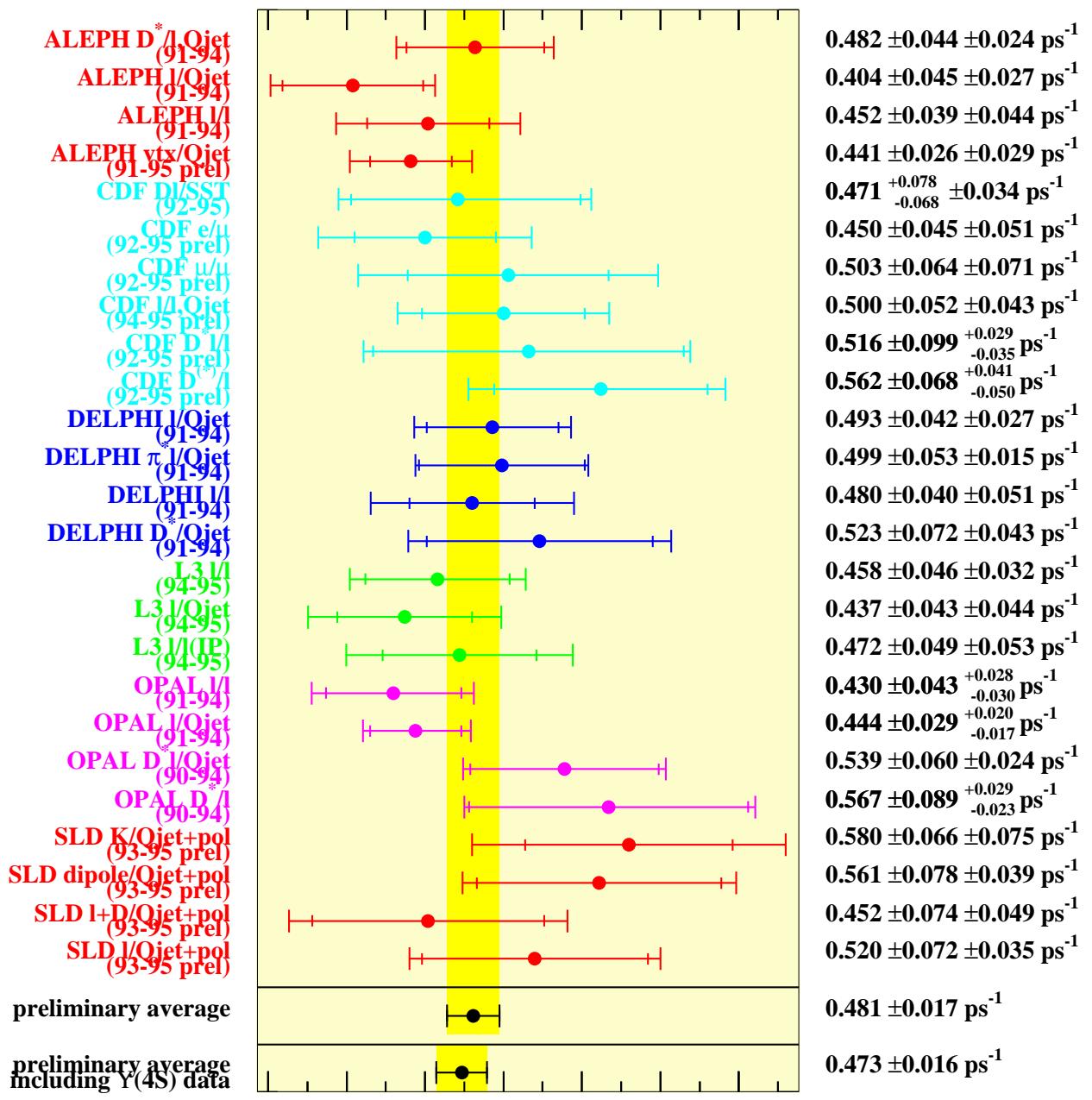
Very nice work from LEP/SLD/CDF.

Selected region without the constraints from Δm_d and Δm_s



Selected region adding the constraint from Δm_d → the limiting factor is f_B !

We CANNOT exploit the precision on Δm_d if we do NOT know better f_B .



B Oscillations
Working Group

$$\Delta m_d (\text{ps}^{-1})$$

f_B from LATTICE QCD

	f_B	stat	syst	quench
JLQCD	173	9	8	11
FNAL/UIUC	164	$^{+14}_{-11}$	8	$^{+16}_{-0}$
GLOK	147	11	11	$^{+8}_{-12}$
MILC	159 ^a	11	$^{+25}_{-9}$	$^{+23}_{-0}$
APE	179		18	$^{+26}_{-9}$

> 15 years effort on lattice QCD calculations.

The most recent results agree very well

f_B from f_{D_s}

$\text{Br}(B^+ \rightarrow \tau\nu_\tau) \propto |V_{ub}|^2 f_B^2 \sim 5 \times 10^{-5}$...it is very difficult to foresee a precise measurement. By the way, using it we measure $|V_{ub}|^2 \times f_B^2$.

$$\text{Br}(D_s^+ \rightarrow \tau\nu_\tau) \propto |V_{cs}|^2 f_{D_s}^2 \sim 5\%$$

$f_{D_s} \rightarrow f_B$ via QCD on lattice

Recent theoretical works have determined f_B/f_{D_s} with good accuracy

f_B/f_{D_s}	references
0.78 ± 0.04	A. X. El-Khadra et al., <i>Phys. Rev.</i> D58 (98)
$0.75 \pm 0.03^{+0.04+0.07}_{-0.02-0.00}$	C. Bernard et al., <i>Phys. Rev. Lett.</i> 81 , 4812 (98)
$0.71 \pm 0.05^{+0.07}_{-0.00}$	D. Becirevic et al.(APE), (hep-lat/9811003)

From the experimental results on f_{D_s} it can be obtained

$$f_B = 181 \pm 24(\text{exp.}) \pm 7(\text{th.stat.})^{+20}_{-5}(\text{th.syst.}) \text{ MeV}$$

which is very well compatible with the result from LATTICE QCD calculations.

Taking $B_{B_d} = 1.35 \pm 0.12$

For the moment the error is symmetrized:

$$f_B \sqrt{B} = 210 \pm 29(\text{stat.}) \pm 31(\text{theo. non stat.}) \text{ MeV}$$

$$\Delta m_s$$

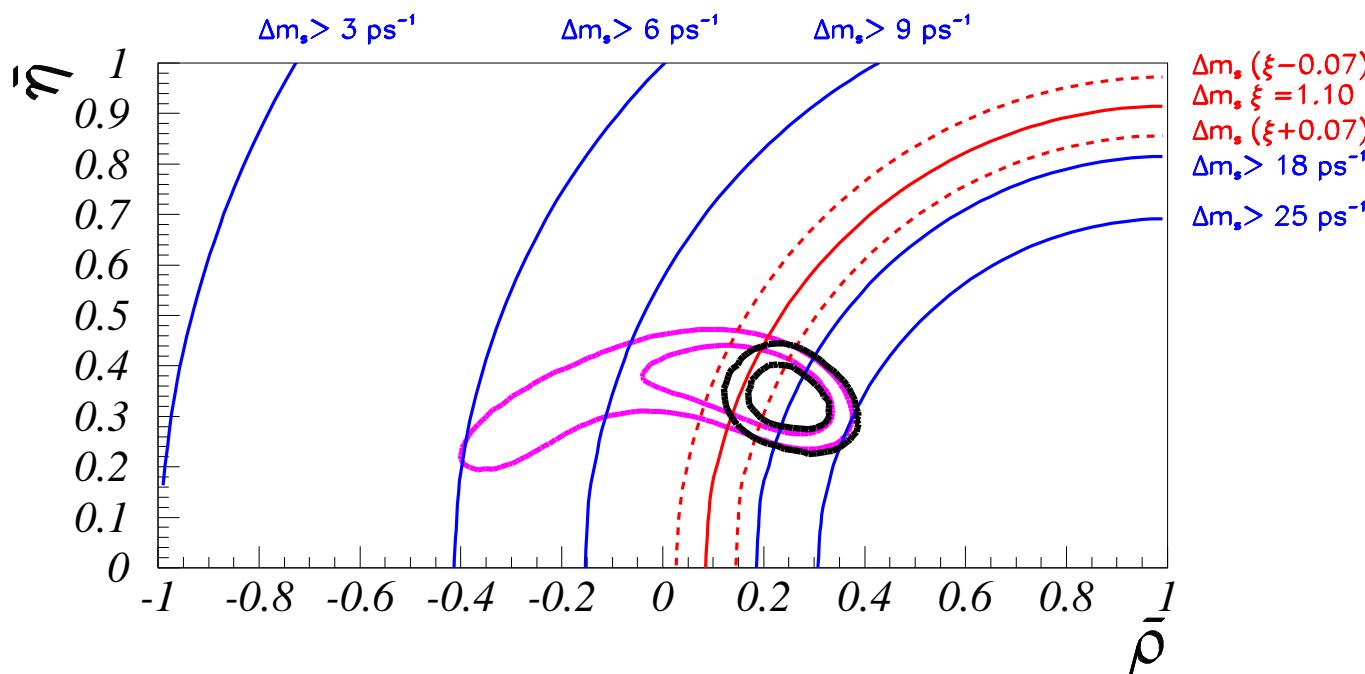
$$\left(\frac{1 - \lambda^2/2}{\lambda}\right)^2 \xi^2 \frac{\Delta m_d}{\Delta m_s} = (1 - \bar{\rho})^2 + \bar{\eta}^2 ; \quad \xi = \frac{f_{B_s} \sqrt{B_{B_s}}}{f_{B_d} \sqrt{B_{B_d}}}$$

Quite a lot of activity.. still a limit for the moment:

$$\Delta m_s > 14.3 \text{ ps}^{-1} \quad \text{at 95% C.L.}$$

IT IS VERY IMPORTANT to control the parameter ξ :

ξ	References
$1.10 \pm 0.02^{+0.05}_{-0.03} {}^{+0.03}_{-0.02}$	MILC Phys. Rev. Lett. 81(1998) 4812
$1.13^{+0.05}_{-0.04}$	A.X. El-Khadra et al., Phys Rev. D58 (1998)
$1.14 \pm 0.03^{+0.00}_{-0.01}$	D. Becirevic et al.(APE) hep-lat/9811003



Summary: List of parameters

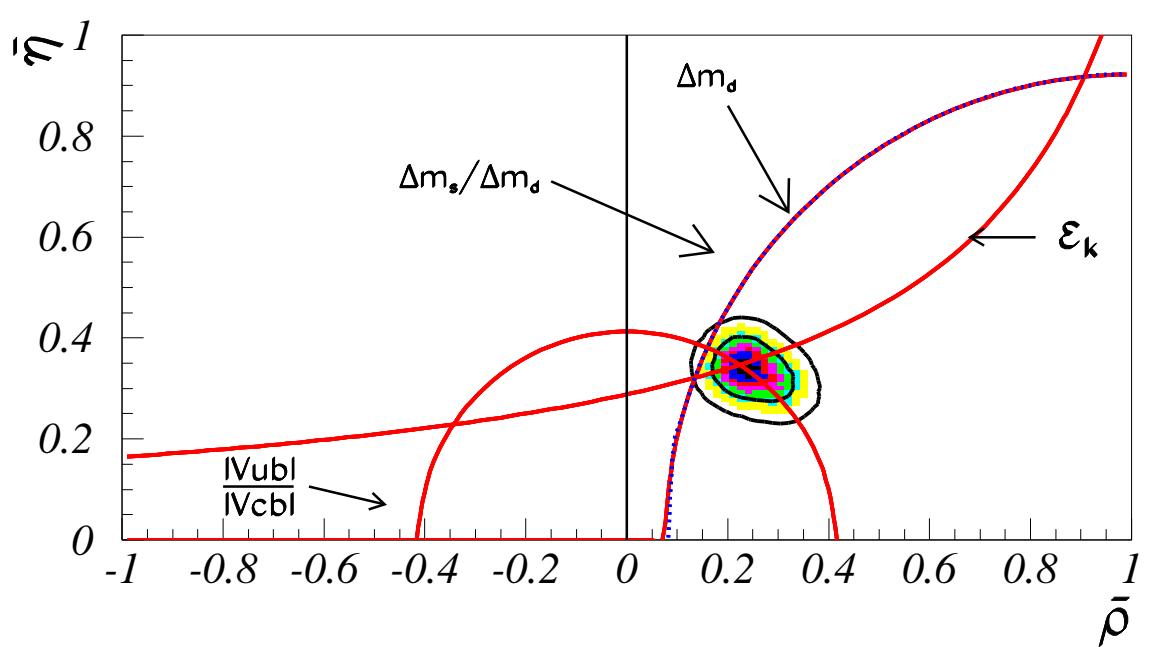
Param.	Value \pm Gauss. Err. \pm Flat Err.
ϵ_K	$(2.280 \pm 0.019)10^{-3}$
$\frac{ V_{ub} }{ V_{cb} } CLEO(excl.)$	$0.080 \pm 0.006 \pm 0.016$
$\frac{ V_{ub} }{ V_{cb} } LEP$	$0.104 \pm 0.012 \pm 0.015$
Δm_d	$(0.472 \pm 0.016) ps^{-1}$
Δm_s	$> 14.3 ps^{-1}$
$ V_{cb} $	$(40.4 \pm 1.9) \times 10^{-3}$
$\overline{m}_t(m_t)$	$(167 \pm 5) GeV/c^2$
B_K	$0.86 \pm 0.06 \pm 0.08$
$f_{B_d} \sqrt{B_{B_d}}$	$(210 \pm 29 \pm 31) MeV$
$\xi = \frac{f_{B_s} \sqrt{B_{B_s}}}{f_{B_d} \sqrt{B_{B_d}}}$	$1.11 \pm 0.02^{+0.06}_{-0.04}$

Method: Bayes + MonteCarlo integration

$$\mathcal{P}(x_1, \dots, x_N | c_1, \dots, c_M) \propto \prod_{j=1,M} \mathcal{P}_j(c_j | x_1, \dots, x_N) \times \prod_{i=1,N} \mathcal{P}_i(x_i).$$

the first terms in the right-hand side of this expression correspond to the product of the probability distributions for the observed values of the constraints c_j , corresponding to a fixed set of values for the parameters x_i , $i = 1, N$. The other term is the product of the probability distributions for the different values of the parameters.

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

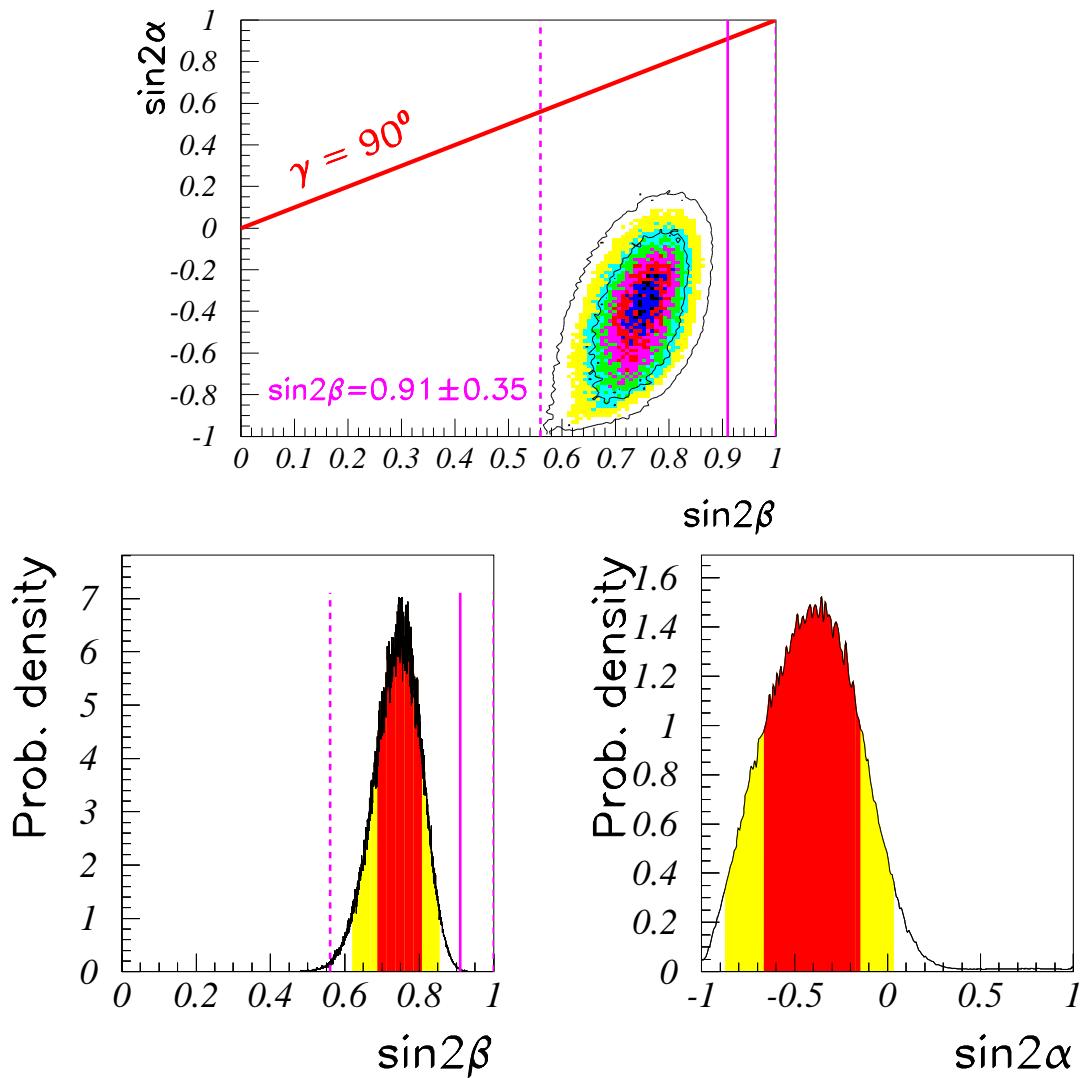


$$\bar{\rho} = 0.240^{+0.057}_{-0.047}$$

$$\bar{\eta} = 0.335 \pm 0.042$$

$\sin 2\beta$ and $\sin 2\alpha$

INDIRECT MEASUREMENTS



$$\sin 2\beta = 0.750^{+0.057}_{-0.064}$$

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

The indirect measurements are needed TO TEST if direct measurements of the same quantities give ANY HINT FOR NEW PHYSICS

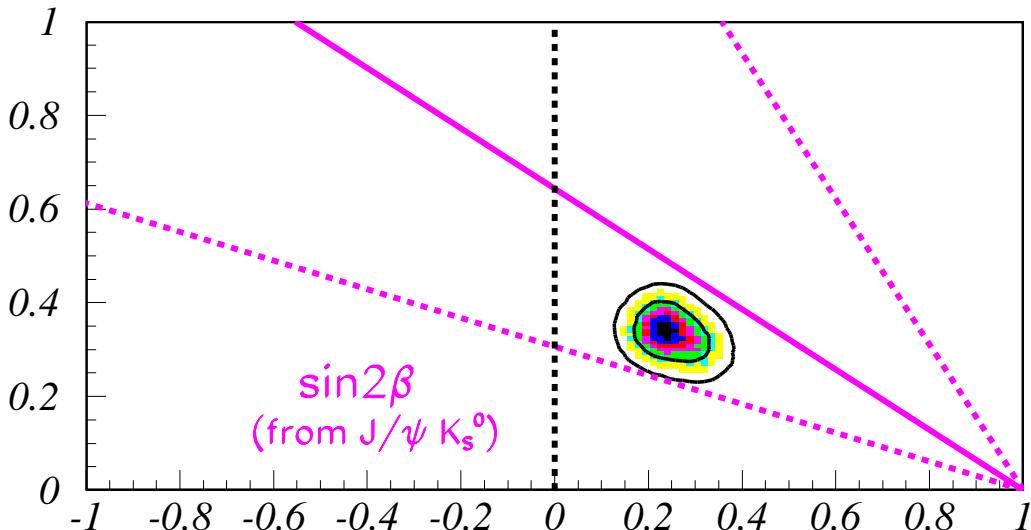
DIRECT MEASUREMENTS of $\sin 2\beta$

First determinations of $\sin 2\beta$ are available !!

Most precise so far from CDF Coll. (also measurements from ALEPH and OPAL)

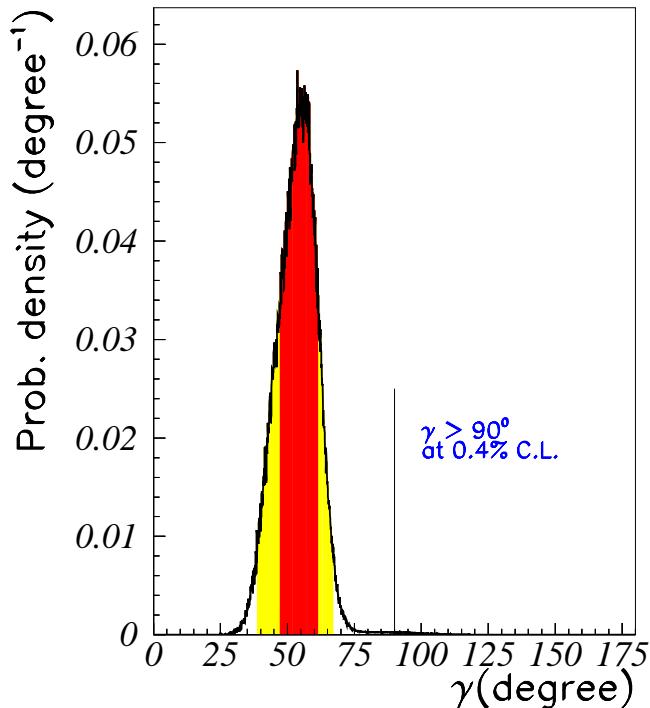
$$\sin 2\beta = 0.91 \pm 0.35.$$

Yet not too precise to really test the compatibility with sides measurements ^a



^a - Works have been already started, see for instance G.Barenboim,G.Eyal and Y.Nir hep-ph/9905397
- For general approach to new physics effects, see A.Ali D.London hep-ph/9903535

The angle γ



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

Hadronic B decays can also give constraints on the angle γ (like $\sin^2 \gamma < R_1 = \frac{Br(B^0(\bar{B}^0) \rightarrow \pi^\pm K^\mp)}{Br(B^\pm \rightarrow \pi^\pm K^0)}$ if $R_1 < 1$)

New fit with several B decay modes give : $\gamma = (113^{+25}_{-23})^\circ$ ^a

Interesting ! Still controversies on the hadronic uncertainties to attach to this determination

-
- ^a - Y.-H.Cheng, H.-Y.Cheng, B.Tseng, K.-C.Yang hep-ph/9903453
 - W.-S.Hou, J.G.Smith, F.Wurthwein hep-ex/9910014
 - A.Ali, G.Kramer, C.Dian Lu hep-ph/9804363
 - CLEO Coll. hep-ex/9908039.

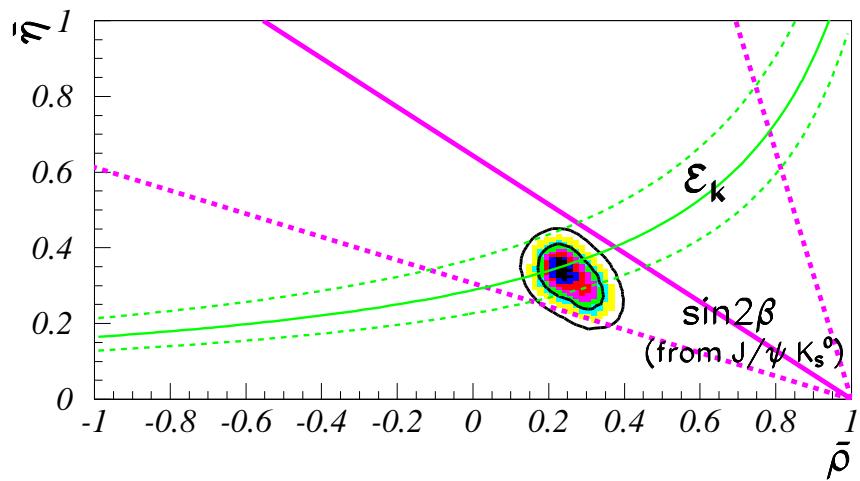
CP (effects) without CP (meas.)

Idea in the paper: R. Barbieri, L. Hall, A. Stocchi e N. Weiner: Phys. Lett. B425 (1998) 119-125

Compatibility between

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

Fit without ϵ_K : ^a



“Coherent picture” of CP phenomena described
in term single phase η :

$$\bar{\eta} = 0.325 \pm 0.054$$

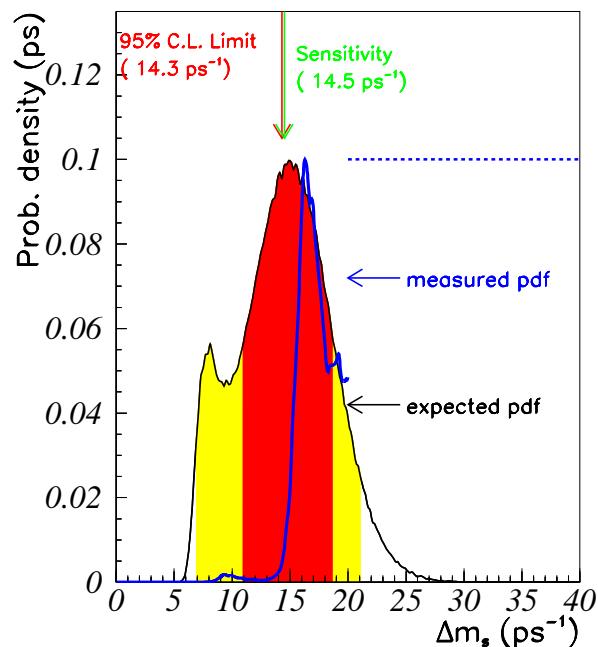
$$\sin 2\beta = 0.747^{+0.067}_{-0.084}$$

^aTest of $\bar{\eta} = 0$ in P. Checchia, E. Piotto and F. Simonetto *hep-ph/9907300*

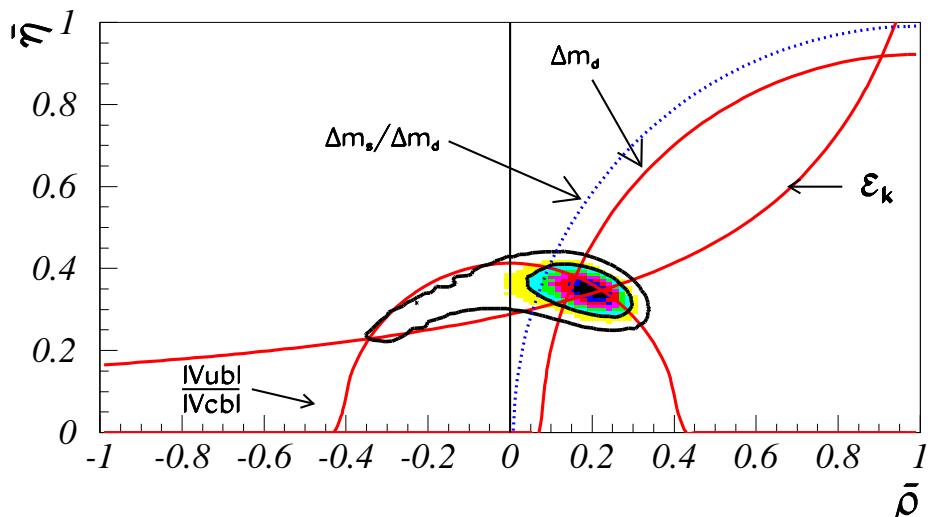
Δm_s probability density

Removing a constraint or an input value we can determine its probability density function.

First example Δm_s :

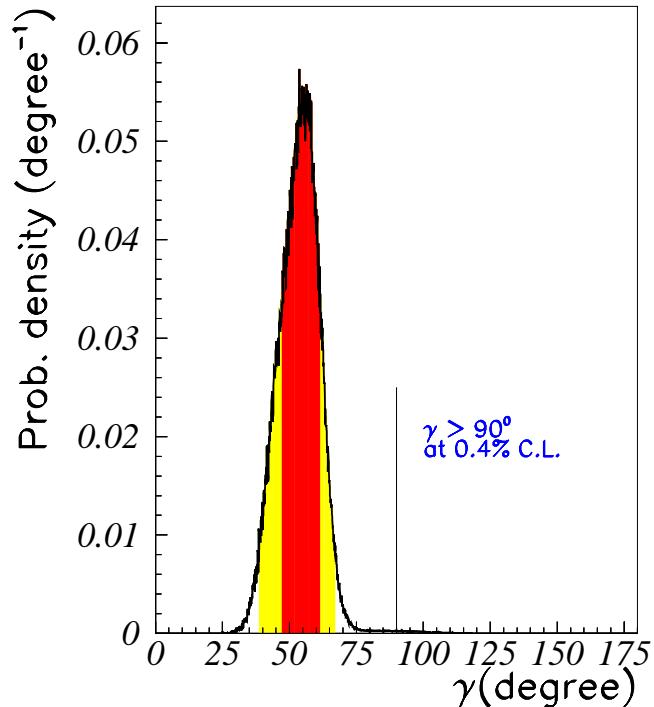


Selected $\bar{\rho}$ - $\bar{\eta}$ region without the constraint on Δm_s

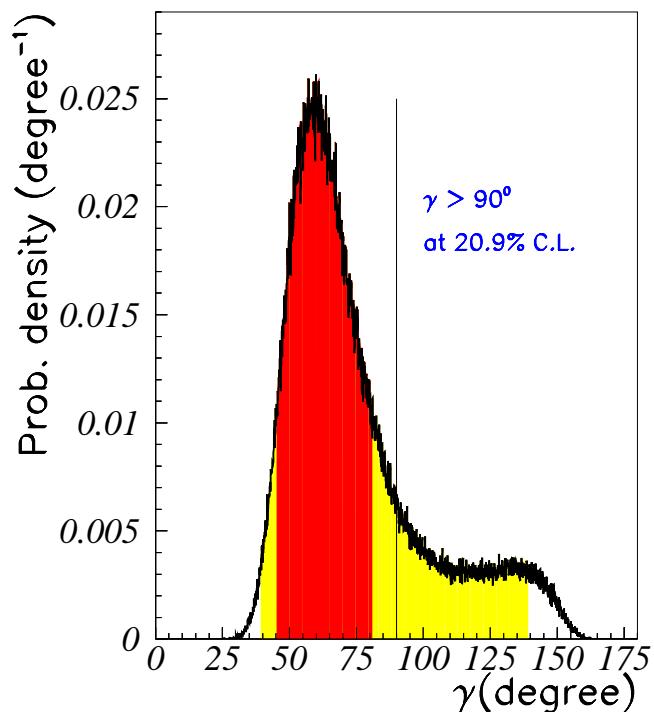


An other example of the importance of the constraint on Δm_s .

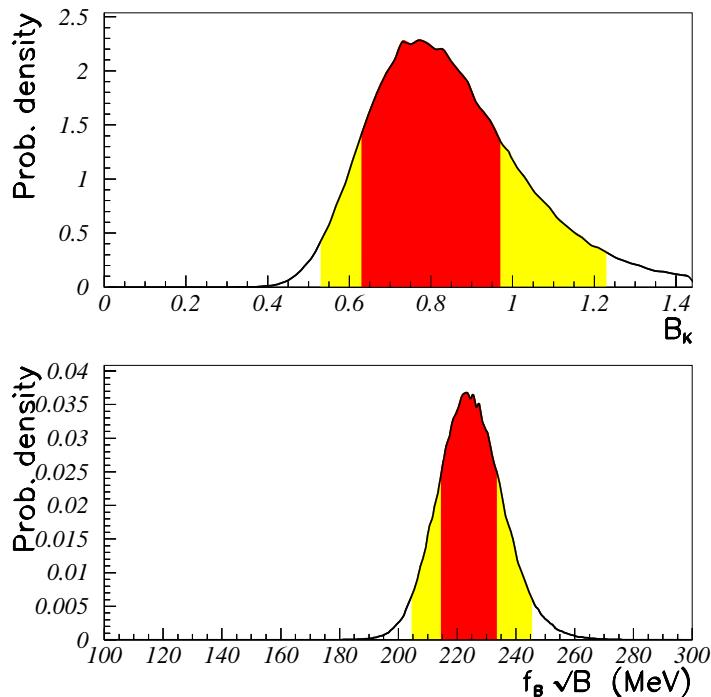
The p.d.f of the angle γ with the Δm_s constraint



..... and without the constraint on Δm_s



$$B_K, f_B \sqrt{B}$$



Parameter	Input value	Fitted value
B_K	0.86 ± 0.10	$B_K = 0.80^{+0.15}_{-0.17}$
$f_B \sqrt{B}$	$210 \pm 42 \text{ MeV}$	$232 \pm 13 \text{ MeV}$

As a consequence, it is important to observe, contrarily to common belief, that:

A large uncertainty attached to $f_B \sqrt{B}$ has no real impact on the present analysis. Evaluation of this parameters with 5-10% relative error are needed to bring additional information.

On the contrary, the parameter B_K is determined with a 20% relative error, the present estimate of this parameter from lattice QCD calculations has thus an impact on the present analysis.

Conclusions

A lot of work has been done in B physics in the last decade

$$|V_{cb}| = (40.4 \pm 1.9)10^{-3}$$

$$\bar{\rho} = 0.240^{+0.057}_{-0.047}$$

$$\bar{\eta} = 0.335 \pm 0.042$$

$$\sin 2\beta = 0.750^{+0.057}_{-0.064}$$

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

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

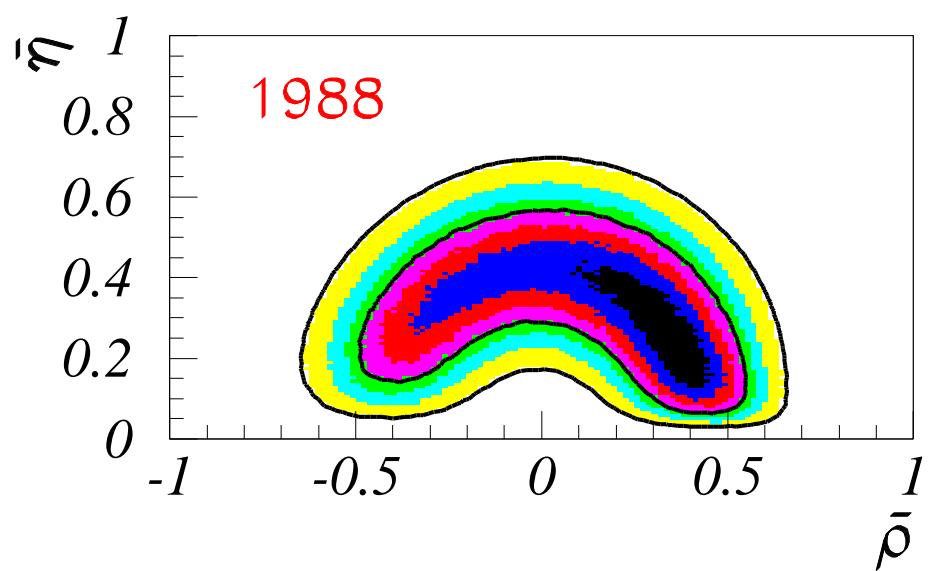
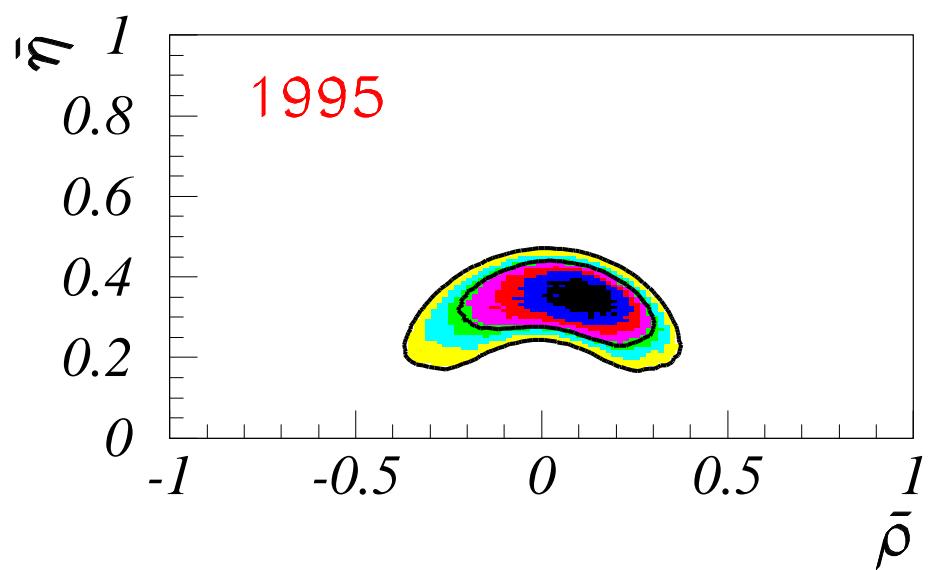
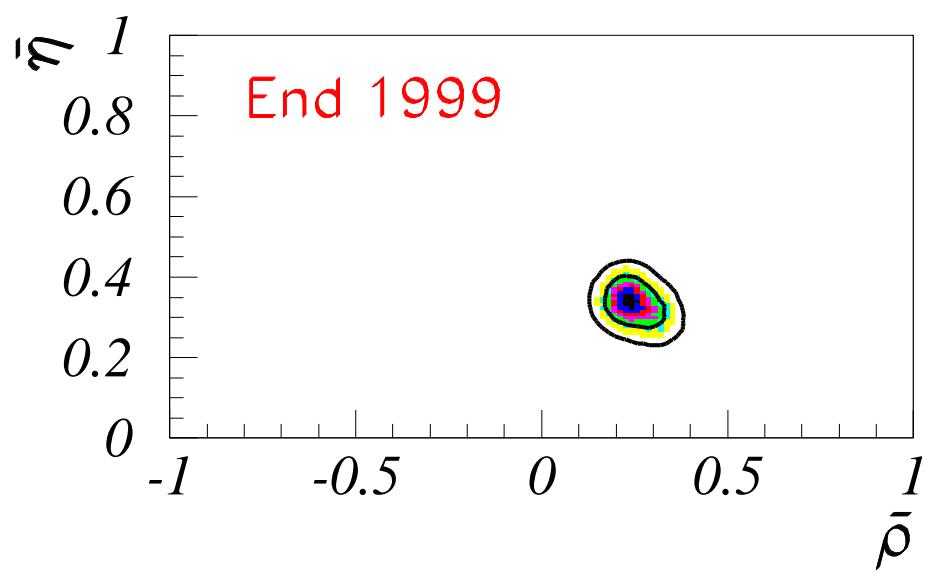
Important conclusions :

- The selected region in the $(\bar{\rho}, \bar{\eta})$ plane is very well compatible with the measurement of the CP violation in the Kaon physics.
- $\sin 2\beta$ is measured with an accuracy better than 10% within the SM framework
- The angle γ is smaller than 90° at 99.6% C.L.

These results will be still improved at least until Summer2000

THANKS TO ALL THIS WORK and the achieved accuracy:
future measurements of the CP violation on the B sector would
further test the consistency of the Standard Model by
determining directly the angles of the Unitarity Triangle.

→ NEW PHYSICS PHENOMENA



The method used to include Δm_s was, until last summer:

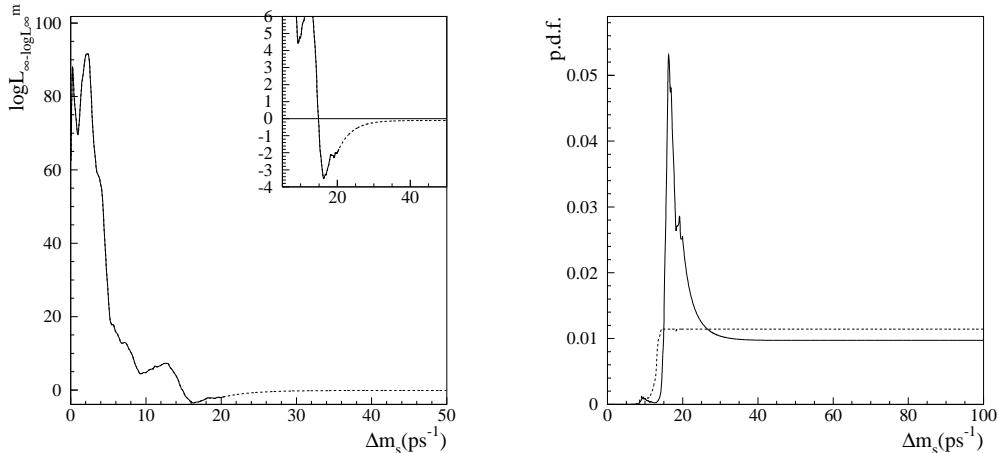
$$\chi^2 = \left(\frac{\mathcal{A} - 1}{\sigma_{\mathcal{A}}} \right)^2$$

A more appropriate approach has been suggested^a based on the log-likelihood function referenced to its value at $\Delta m_s = \infty$.

$$\Delta \mathcal{L}^\infty(\Delta m_s) = (1/2 - \mathcal{A}(\Delta m_s)) / \sigma_{\mathcal{A}}(\Delta m_s)$$

The probability density function for Δm_s is then given by:

$$\mathcal{P}(\Delta m_s) \propto e^{-\Delta \mathcal{L}^\infty(\Delta m_s)}$$



Comments :

- The constant level, at large values of Δm_s corresponds to the fact that the measured minimum of the log-likelihood distribution, around 16 ps^{-1} , is not significant enough to forbid large values of Δm_s with a high confidence level.
- In this approach, an observed signal at $\Delta m_s = \Delta m_s^0$, corresponds to a Gaussian probability density centred on this value.

^aP. Checchia, E. Piotto and F. Simonetto [hep-ph/9907300](https://arxiv.org/abs/hep-ph/9907300)

Analysis of S. Plaszczynski, M.H. Schune [hep-ph/9911280](#)

Param.	Value \pm Gauss. Err. \pm Flat Err.
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$\frac{ V_{ub} }{ V_{cb} }$	$0.085 \pm 0.0033 \pm 0.015$
Δm_d	$(0.472 \pm 0.016) \text{ } ps^{-1}$
Δm_s	$> 14.3 \text{ } ps^{-1}$
$ V_{cb} $	$(40.0 \pm 2.0) \times 10^{-3}$
$\overline{m_t}(m_t)$	$(167 \pm 5) \text{ } GeV/c^2$
B_K	$0.86 \pm 0.00 \pm 0.15$
$f_{B_d} \sqrt{B_{B_d}}$	$(200 \pm 0.0 \pm 40) \text{ } MeV$
$\xi = \frac{f_{B_s} \sqrt{B_{B_s}}}{f_{B_d} \sqrt{B_{B_d}}}$	$1.14 \pm 0.00 \pm 0.08$

