Experimental Results on Heavy Quark Hadrons

ALEPH, DELPHI,L3,OPAL,SLD ,CDF,CLEO, BELLE ,BABAR,FOCUS,SELEX

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(LAL-Orsay / CERN)

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B Physics | *Charm Physics*

ALEPH,DELPHI,L3,OPAL	at LEP	Z^0
SLD	at SLD	Z^0
CDF	at TeVatron I	pp 1.8TeV
CLEO	at CERS	Y(4S) symmetric
BELLE	at KEK	Y(4S) asymmetric
BABAR	at PEP	Y(4S) asymmetric
FOCUS	E831 Fermilab	$\gamma < 300$ GeV
SELEX	E781 Fermilab	$p-\pi^- \Sigma^-$ $600GeV$

- ***Introduction. Main motivations of studying Heavy Hadrons***
- ***B Spectroscopy / D Spectroscopy***
- ***Beauty and Charm Lifetimes***
- ***Rare B decays***
- ***Measurement of CKM matrix elements : V_{ub} and V_{cb}. The B semileptonic decays***
- ***Measurement of CKM matrix elements : V_{td} and V_{ts} . The $B^0 - \overline{B}^0$ oscillations***
- ***What we have learnt about the Unitarity Triangle***

Welcome to the world of charm and beauty

H. Bosch (1504)
The garden of Earthly Delights

Flavour Physics in the *Standard Model* (SM) in the quark sector:

~ half of the *Standard Model*

10 free parameters

6 quarks masses

4 CKM parameters

In the Standard Model, charged weak interactions among quarks are codified in a 3 X 3 unitarity matrix : the **CKM Matrix**.

The existence of this matrix conveys the fact that the quarks which participate to weak processes are a linear combination of mass eigenstates

The fermion sector is poorly constrained by SM + Higgs Mechanism

mass hierarchy and CKM parameters

The **CKM** Matrix

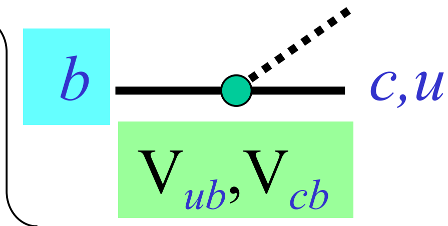
Wolfenstein parametrization

4 parameters : λ ,**A**, ρ, η

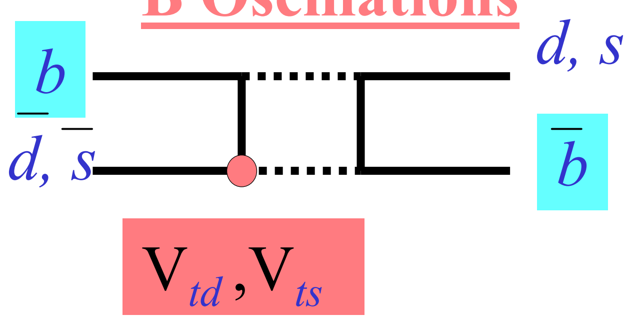
$$
\begin{array}{c|ccc}
 & d & s & b \\
\hline
u & 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\
c & -\lambda & 1-\lambda^2/2 & A\lambda^2 \\
t & A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1
\end{array}
$$

V_{tb}

B decays



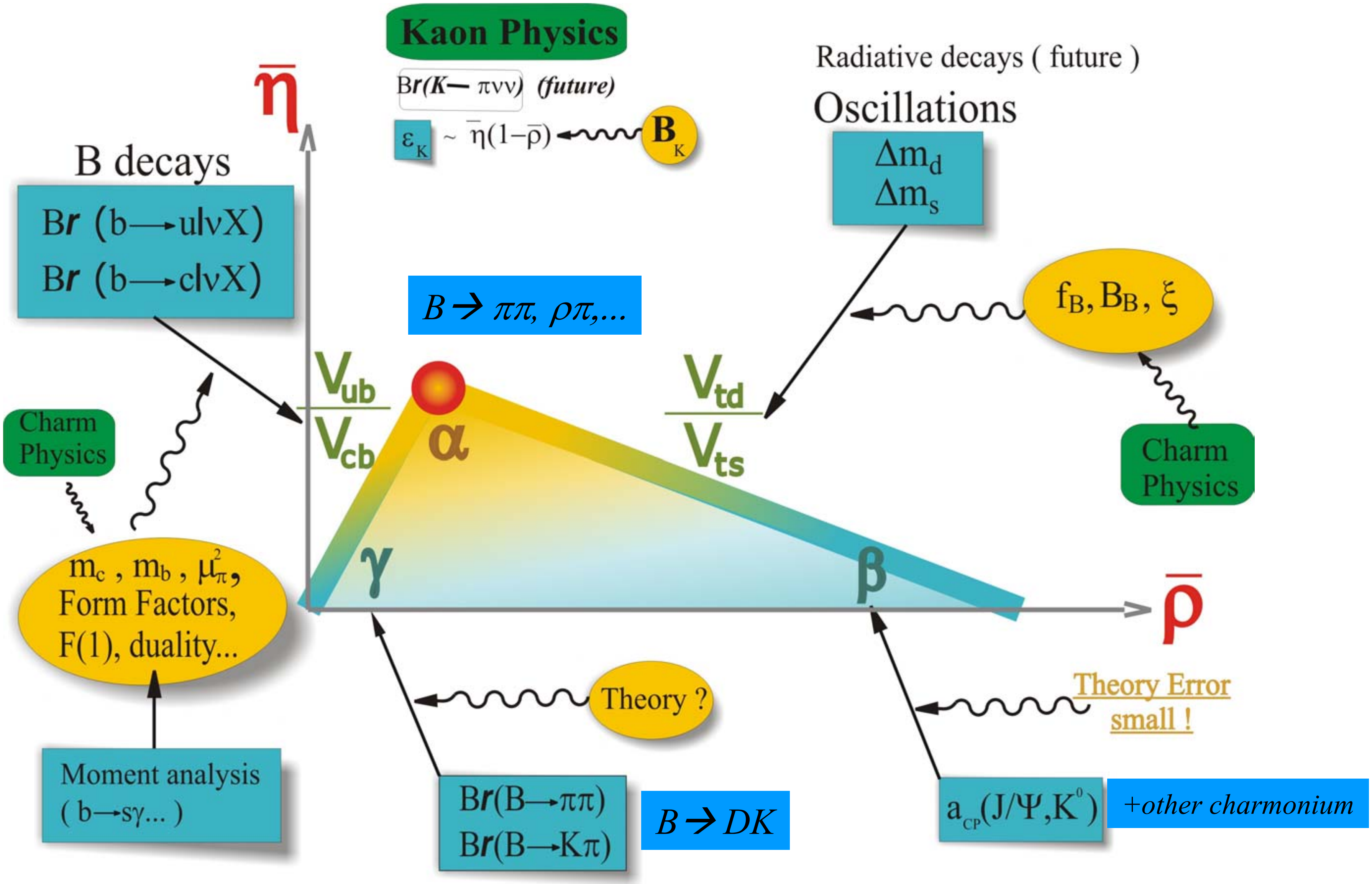
B Oscillations



The *b-Physics* plays a very important role in the determination of those parameters

Visualization of the unitarity of the CKM matrix

Unitarity Triangle in the (ρ−η) plane



MORE GENERALLY

We observe hadrons and not quarks !
theory gives us the link from quarks to hadrons
OPE /HQET/Lattice QCD …. **Need to be tested !**

To access the parameters of the **Standard Model** we need to control the effects induced by strong interactions

Many measurements (with different weights) are essential

→ *Decay properties and production characteristics*

Lifetimes

Branching ratios

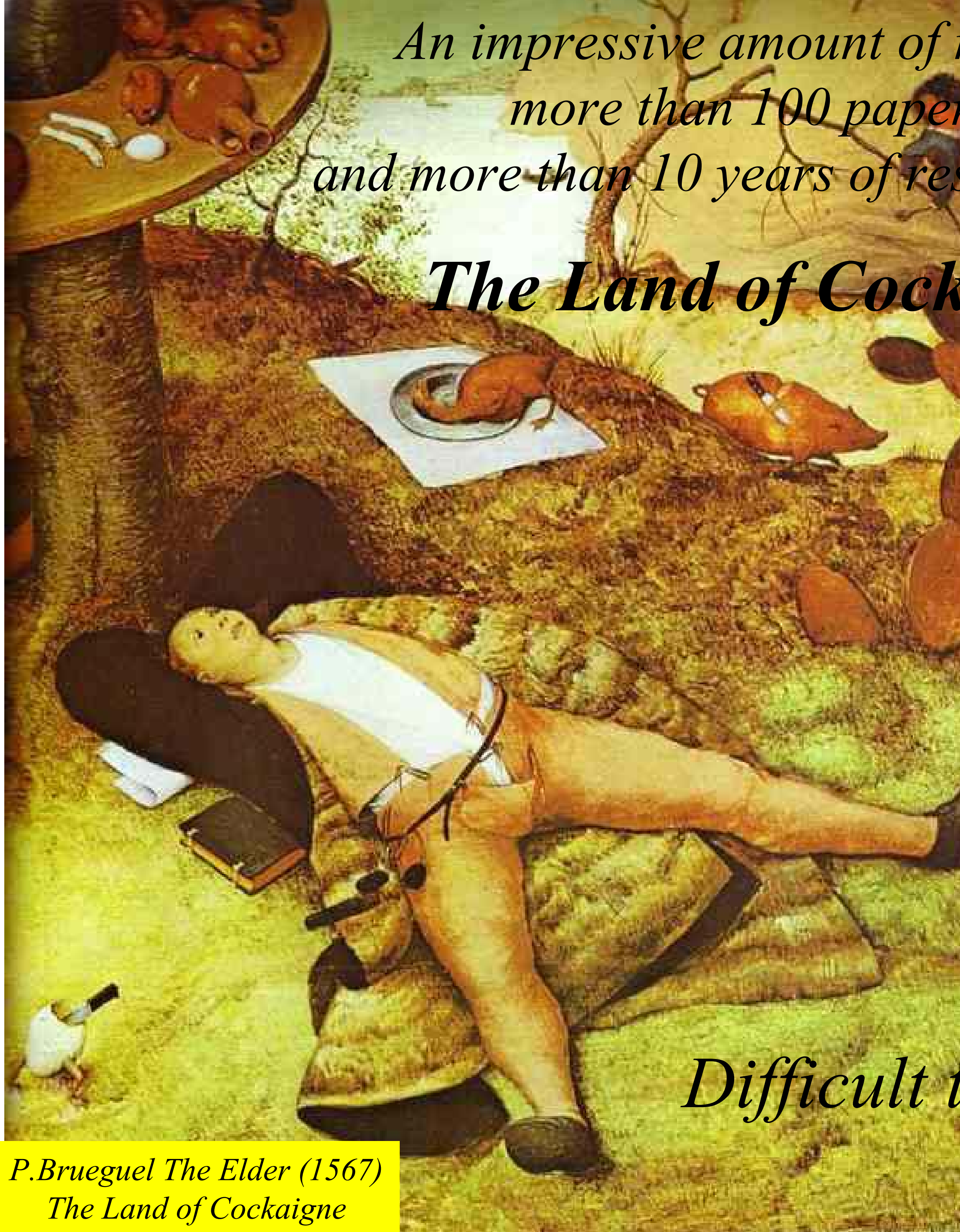
Form factors

Masses (spectroscopy)

beauty an charm physics are equally important

An impressive amount of results :
more than 100 papers !
and more than 10 years of results behind

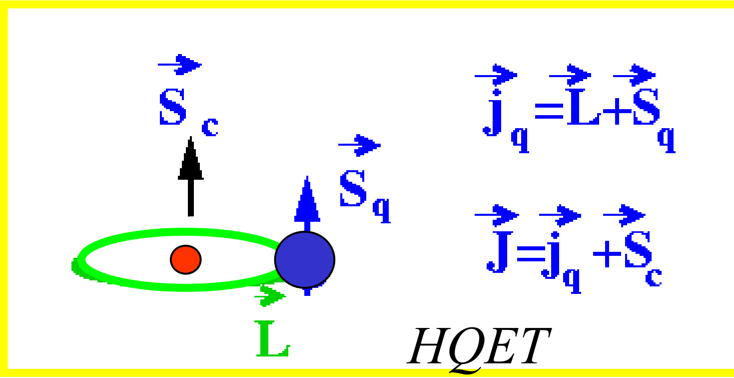
The Land of Cockaigne



Difficult to digest !

P.Brueguel The Elder (1567)
The Land of Cockaigne

B Spectroscopy



l	j_q	J^P	state	dom.decay mode
0	$\frac{1}{2}$	0^-	B	
		1^-	B^*	$B\gamma$
1	$\frac{1}{2}$	0^+	B_0^*	$B\pi$ (s-wave)
		1^+	B_1^*	$B^*\pi$ (s-wave) **broad**
1	$\frac{3}{2}$	1^+	B_1	$B^*\pi$ (d-wave)
		2^+	B_2^*	$B^{(*)}\pi$ (d-wave) **narrow**

$B_s^{**} \rightarrow B^{(*)} K$ (if above thresold)

($\rightarrow B_s^{(*)}\pi$ isospin forbidden)

Spectroscopy of light b-baryons (bqq; q=u,d) with l=0:

$S_{qq} = 0 \rightarrow \Lambda_b$ $\quad$ $S_{qq} = 1$: $J = 1/2 \rightarrow \Sigma_b$

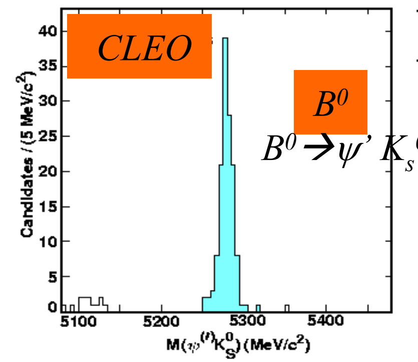
$J = 3/2 \rightarrow \Sigma_b^*$

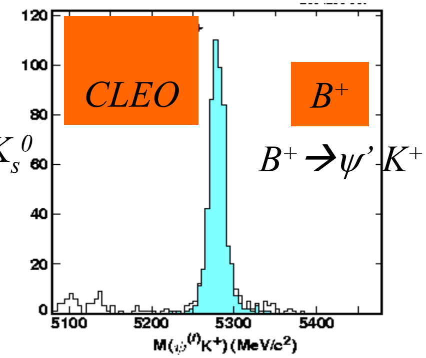
Strongly decaying

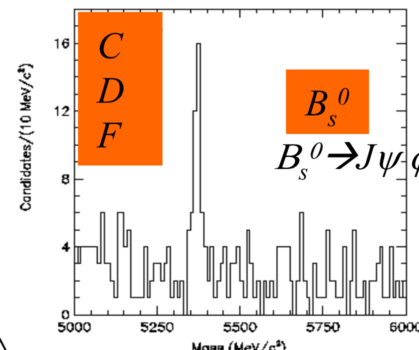
$M(B^0)$ =5279.3 ±0.7 MeV

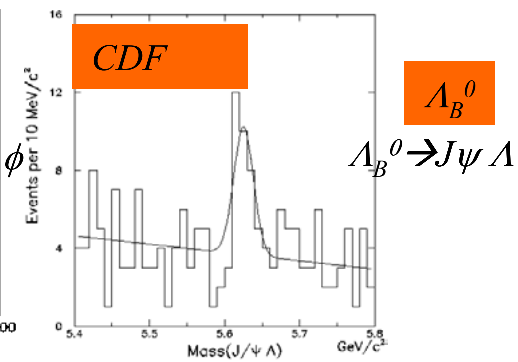
$M(B^+)$ =5279.1 ±0.5 MeV

$M(B^0)$-$M(B^+)$ =0.34 ±0.32 MeV









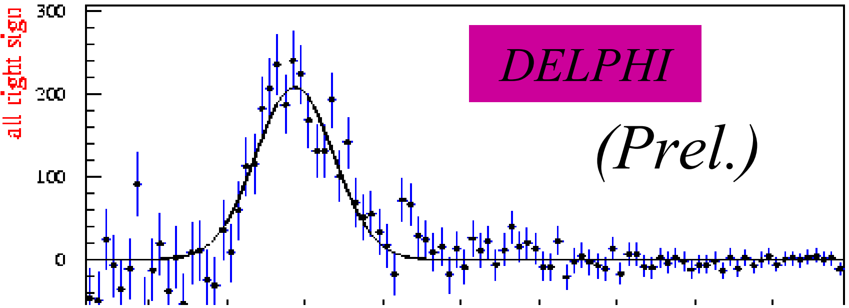
$M(B_s^0)$ = 5369.6±2.4 MeV

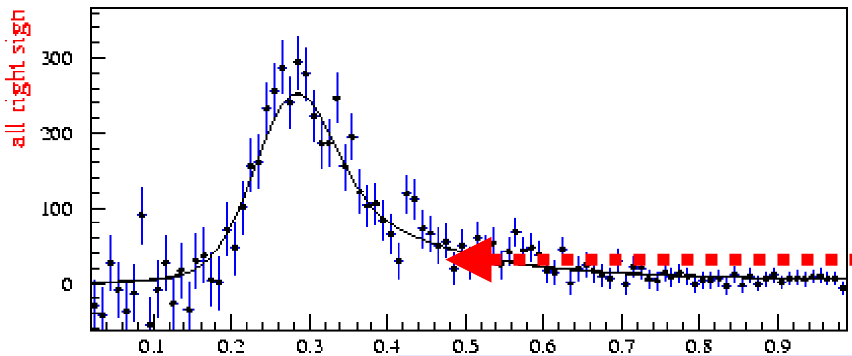
$M(\Lambda_B^0)$ = 5624±9 MeV

New results on L=1 meson and excited baryon

DELPHI

(Prel.)





$Q = M(B^{(*)}\pi)-M(B^{(*)})-m(\pi)$

C. Weiser (LEP/SLD)

Narrow states

$Q = 298 \pm 4 \pm 12$ MeV

$\sigma = 47 \pm 3 \pm 5$ MeV

$\sigma(^{**}_{(u+d)})$ (narrow)/ σ (b) = $(9.8 \pm 0.7 \pm 1.2)$ %

Evidence of broad states at
+ 100MeV and $\Gamma \sim 250$ MeV

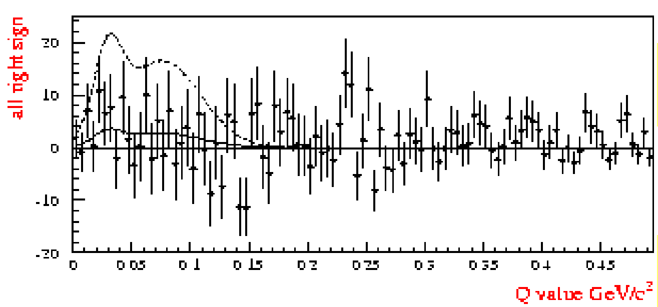
-> Spin-Orbit Inversion ?

DELPHI(prel.)/OPAL had ~2.5σ evidence of B_s^{**}
with $\sigma(B_s^{**}) / \sigma(b) \sim 2\%$

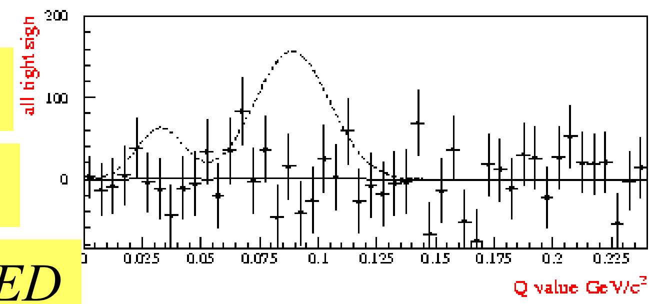
DELPHI(prel.) had a ~3σ evidence of $\Sigma_B^{(*)}$
with $\sigma(\Sigma_B^{(*)}) / \sigma(b) \sim 5\%$

NEW result from DELPHI
$\sigma(B_s^{**}) / \sigma(b) < 1.5\%$ @95%CL

NEW result from DELPHI
$\sigma(\Sigma_B^{(*)}) / \sigma(b) < 1.5\%$ @95%CL



Old signals from
B_s^{**} and $\Sigma_B^{(*)}$
NOT CONFIRMED



Charmed Baryon Spectroscopy

C. Riccardi (FOCUS)
R. Chistov (Belle)
J. Russ (SELEX)

Rich(est) spectroscopy – so far **22** charmed baryons found (some need confirmation)

4 weakly decaying : $(1/2^+)$ $\Lambda_C(cud)$, Ξ_C^0, $\Xi_C^+(cqq)$, $\Omega_C(css)$

$(1/2^+)$ Σ_C^0, Σ_C^+, Σ_C^{++} ; $(3/2^+)$ Σ_C^{0*}, Σ_C^{+*}, Σ_C^{++*}

$(3/2^+)$ Ξ_C^0, Ξ_C^+, $(1/2^+)$ $\Xi_C^{'0}$, $\Xi_C^{'+}$

$(1/2^-)$ Λ_C (2593) ; $(3/2^-)$ Λ_C (2625)

+ two $(3/2^-)$ narrow states (L=1) (~2815) $\Xi\pi\pi$ mass

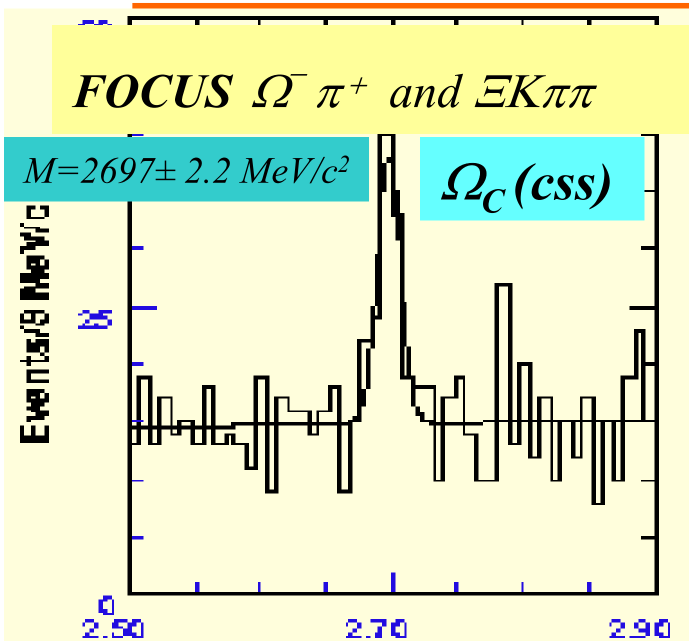
+ two $(1/2^-)$ broad states + ? $(1/2^-)$ narrow Λ_{C0}

<u>Most of the discoveries made by CLEO</u>

***FOCUS** $\Omega^- \pi^+$ and $\Xi K\pi\pi$*

M=2697± 2.2 MeV/c²

$\Omega_C(css)$



BELLE $\Omega^- \pi^+$ M=2693.7± 1.3 ± 1.1 MeV/c²

CLEO 4 modes M=2694.6± 2.6 ± 1.9 MeV/c²

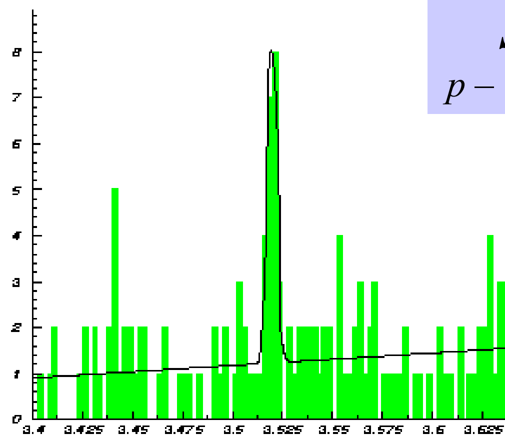
~20 semilept. events seen in BELLE

Ξ_{cc}^+ **(ccd)** → $\Lambda_C K^-\pi^+$

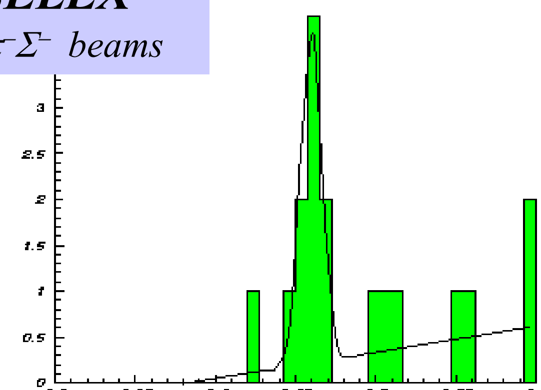
Ξ_{cc}^{++} **(ccu)** → $\Lambda_C K^-\pi^+\pi^+$

SELEX

$p - \pi^- \Sigma^-$ beams



M ~ 3520MeV/c²



M ~ 3460MeV/c²

First Observation of double charm baryons?

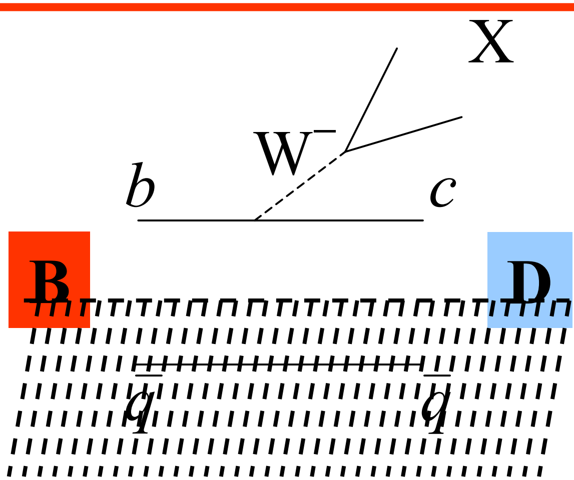
<u>Not confirmed by FOCUS</u>

Interest of measuring the Lifetimes

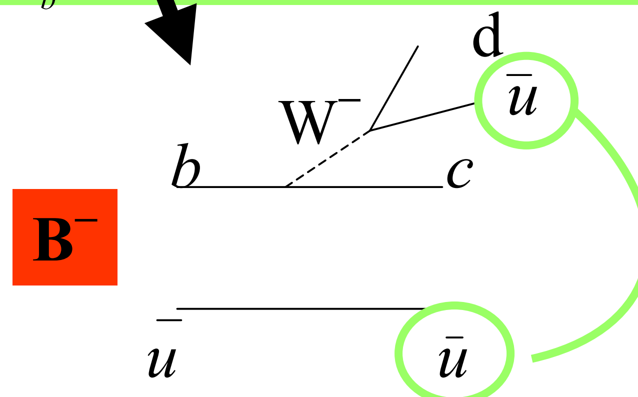
$$\Gamma(H) = \Gamma_{spect} + O(1/m_b^2) + \Gamma(P.I., W.A, W.S) + O(1/m_b^4)$$

$$\frac{\tau(P.I., W.A, W.S)}{\tau(spect)} \approx \frac{f_B^2}{m_b^2}$$

Spectator effects are at order $O(1/m_b^3)$ but phase space enhanced $(16\pi^2)$

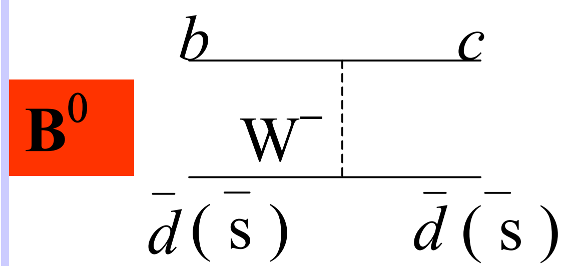


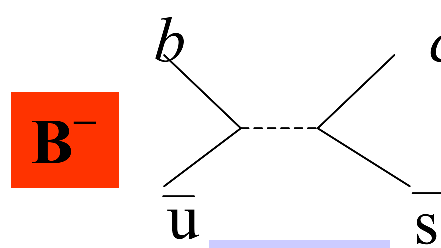
If this were the only diagram all the B/D hadron lifetimes would be the same.



Pauli Interference

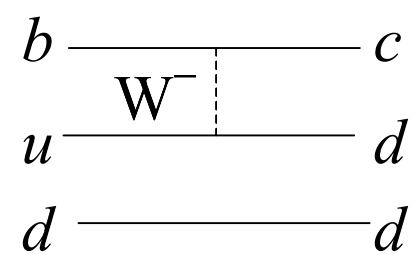
P.I.





W.A.

Weak annihilation



W.S.

Important test of B decay dynamics (OPE)

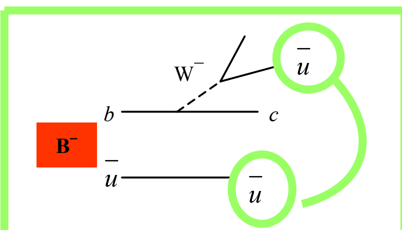
Results on B Lifetimes

New result from Babar (B^0) / DELPHI (B^0,B^+)

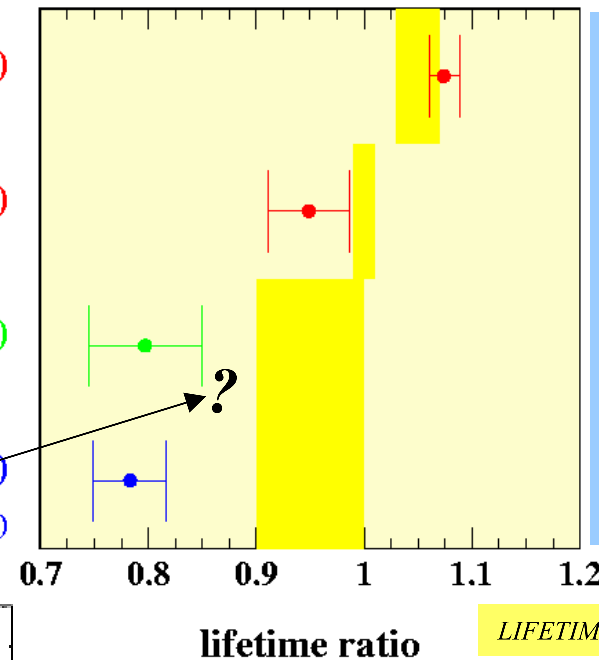
Averages from LEP/SLD/Tevatron

$\tau(B^0_d)$ = 1.540 ± 0.014 ps (0.9%)
$\tau(B^+)$ = 1.656 ± 0.014 ps (0.8%)
} + B-Factories
$\tau(B^0_s)$ = 1.461 ± 0.057 ps (3.9%)
$\tau(\Lambda_B)$ = 1.208 ± 0.051 ps (4.2%)

$\tau(b)$ = 1.573 ± 0.007 ps (0.4%)



$\tau(B^+)/\tau(B^0)$ about 5σ effect in agreement with theory



1.073 ± 0.014

0.949 ± 0.038

0.797 ± 0.052

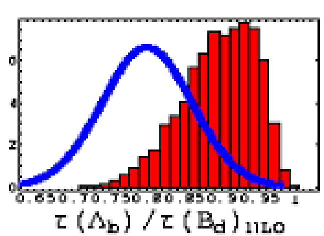
0.784 ± 0.034

LIFETIME Working Group

Λ_B Lifetime shorter Because of W.A.

But the experimental result says the effect is more important

Is there a problem for Λ_B ?



RECENT lattice QCD calculations are able to explain lower values

Franco,Lubicz,Mescia,Tarantino

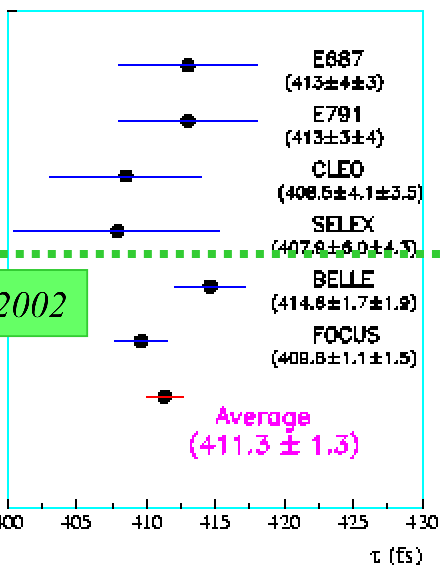
Sandra Malvezzi(FOCUS)
Cristina Riccardi(FOCUS)

Results on D Lifetimes

effects are larger

$$\left.\frac{\tau(\text{P.I.,W.A,W.S})}{\tau(spect)}\right|_{charm} \approx \frac{f_D^2}{f_B^2}\frac{m_b^2}{m_c^2}\left.\frac{\tau(\text{P.I.,W.A,W.S})}{\tau(spect)}\right|_{beauty} \approx 10$$

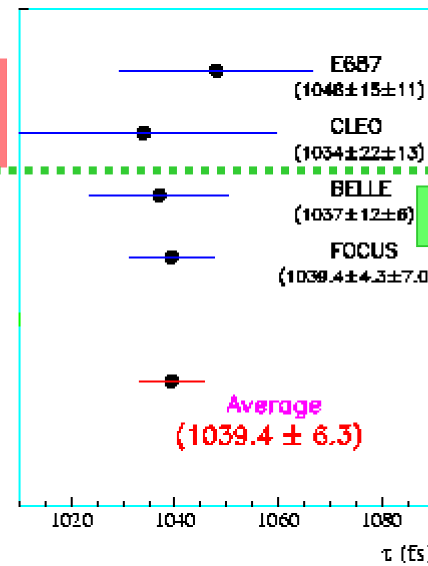
$\tau(D^0)$



NEW since PDG 2002

~3‰ !

$\tau(D^+)$

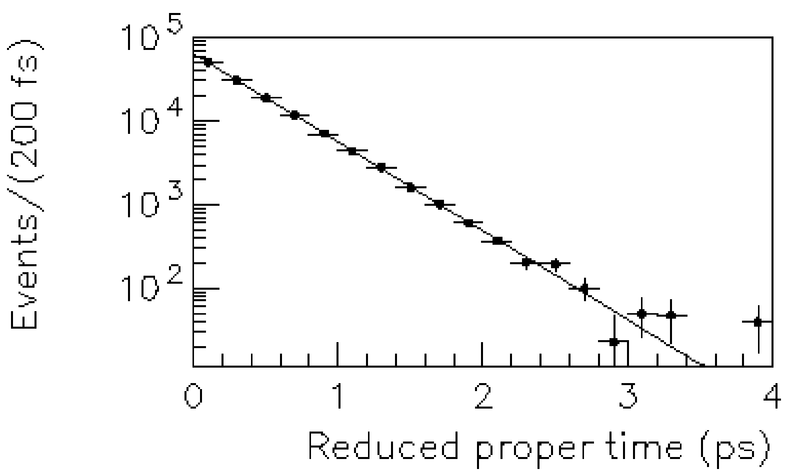


NEW since PDG 2002

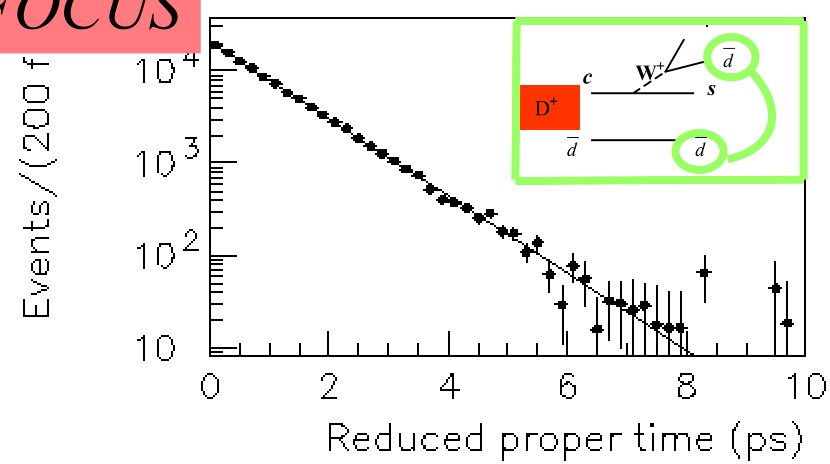
~6‰!

A.S. averages

WATCH B-factories /with 60fb^{-1} ***BaBar*** *$\tau(D^0)$~1.3fs stat.*



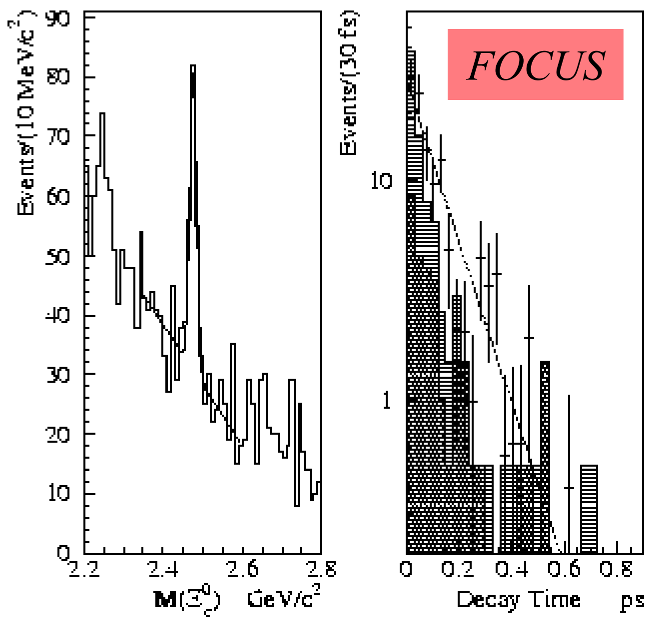
FOCUS



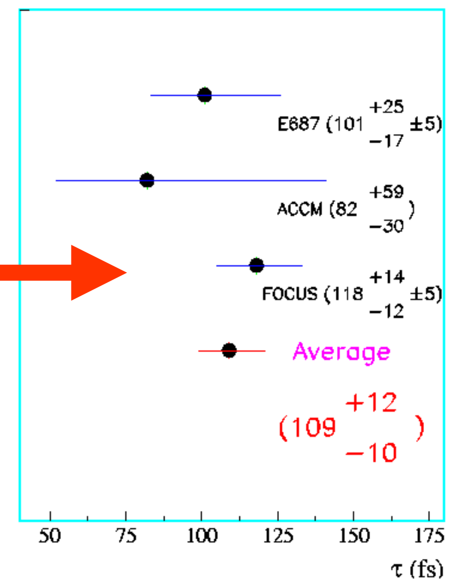
New results on charmed baryons

Ξ^0_c

$\Xi^0_c \rightarrow \Xi^- \pi^+$ and $\Omega^- K^+$



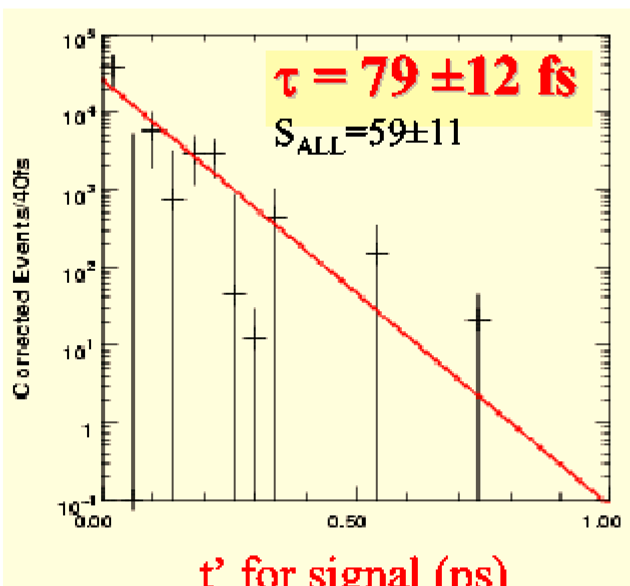
2 very old results



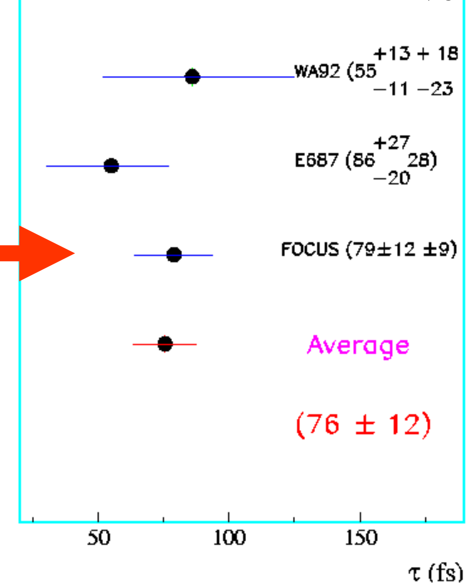
1995

1990

Ω_c



2 very old results



1995

1990

A.S. averages

FOCUS produced new lifetimes results with precision better than previous world average

$\tau(D^0)$	411.3 ± 1.3 fs	*NEW / including new FOCUS/CLEO*
$\tau(D^+)$	1039.4 ± 6.3 fs	*NEW / including new FOCUS/CLEO*
$\tau(D_s)$	490 ± 9 fs	*PDG 2002 / not including FOCUS (506 ± 8 fs (stat only))*
$\tau(\Lambda_c)$	200 ± 6 fs	*PDG 2002 / including recent FOCUS(204.6 ± 3.4 ± 2.5 fs)*
$\tau(\Xi^+_c)$	422 ± 26 fs	*PDG 2002 / including recent CLEO–FOCUS (439 ± 22 ± 9 fs)*
$\tau(\Xi^0_c)$	109(+12)(-10) fs	*NEW / including recent FOCUS*
$\tau(\Omega_c)$	79 ± 12 fs	*NEW / including recent FOCUS*

A.S. averages

$$\tau(D^+)/\tau(D^0) = 2.53 \pm 0.02$$

$$\tau(D_s)/\tau(D^0) = 1.19 \pm 0.02$$

$$\tau(\Lambda_c)/\tau(D^0) = 0.49 \pm 0.01$$

$$\tau(\Xi^+_c)/\tau(\Lambda_c) = 2.11 \pm 0.14$$

NEW

$$\tau(\Omega_c)/\tau(\Xi^0_c) = 0.72 \pm 0.13$$

In Baryon sector the expected hierarchy:

$$\Gamma(\Xi_c^+) < \Gamma(\Lambda_c^+) < \Gamma(\Xi_c^0) \sim \Gamma(\Omega_c^0)$$

P.I(+-) *W.S.+P.I.(-)* *W.S.+P.I.(+)* *(10/3)P.I.(+)*

Very Precise measurements. The agreement with theory is still "qualitative"

Rare B decays

...was the realm of CLEO (9M B) → B-factories are taking over (~90M B)
Domain of BR ~ 10^{-5} ~ 10^{-6}

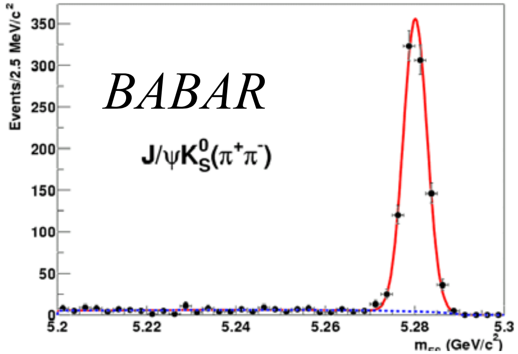
Radiative B decays ($b \to s\gamma$)

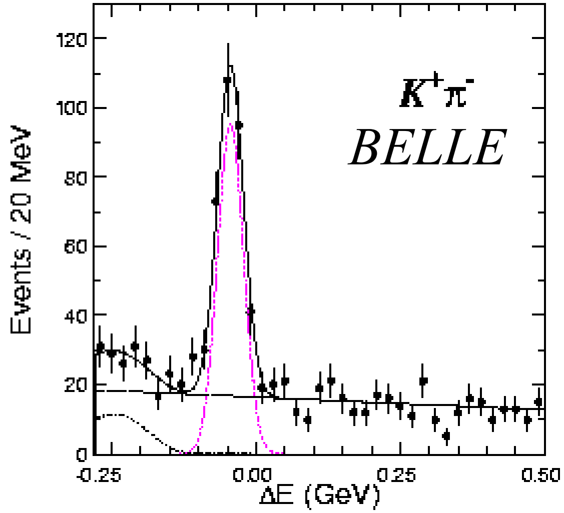
Rare leptonic ($B \to X_s l^+ l^-$)

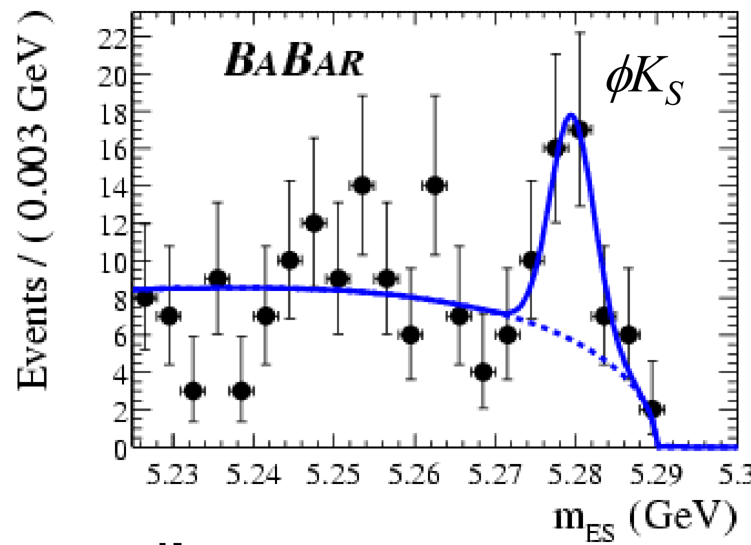
B hadronic decays

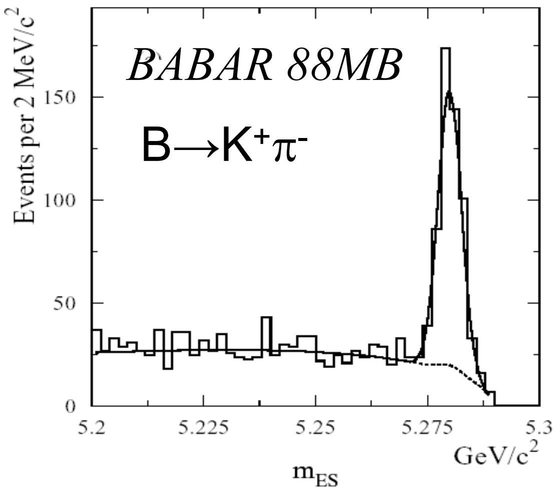
- $B \to$ charmonium
  - Treated by PLENARY: M. Yamauchi (Belle), Y. Karyotakis (Babar)
  - D. Wright(BaBar)/T.Aushev(Belle)/Y.Watanabe(Belle)
- $B \to$ Open Charm (DX,DD,...)
- $B \to$ charmless B decays, $B \to \pi\pi, K\pi, \ldots$
  - Partially treated by PLENARY: M. Yamauchi (Belle), Y. Karyotakis (Babar)
  - J.Olsen(BaBar)\R.Itoh(Belle)

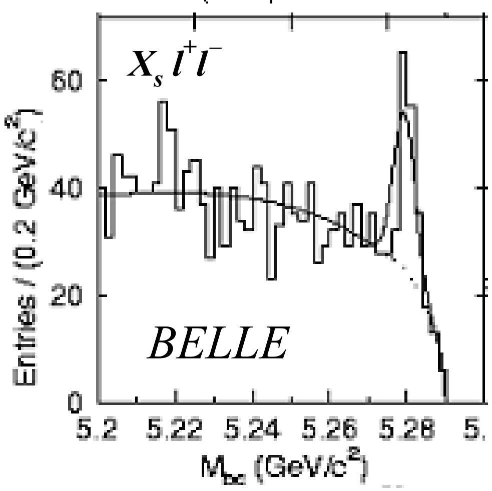
Impressive experimental work from the B-factories →

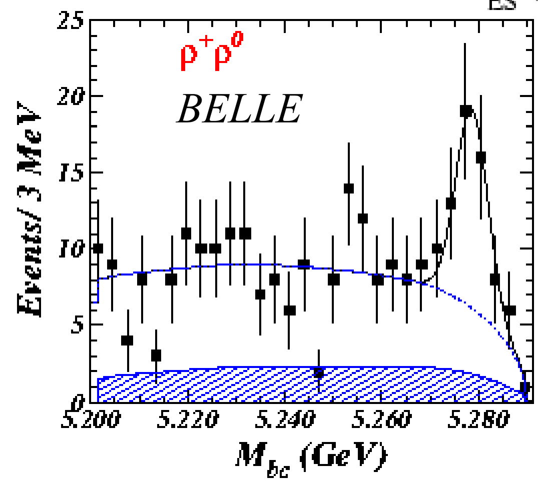

BABAR
J/ψK^0_S(π$^+$π$^-$)
Events/2.5 MeV/c^2
m$_{ES}$ (GeV/c^2)

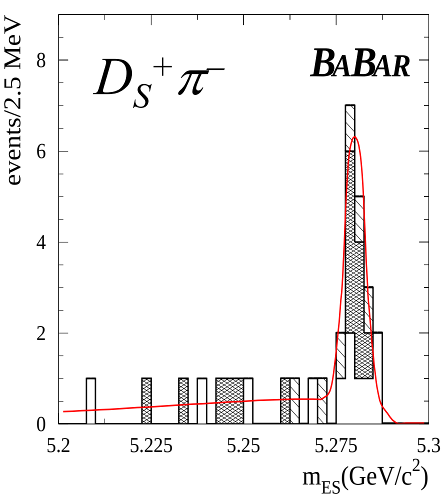

K$^+$π$^-$
BELLE
Events / 20 MeV
ΔE (GeV)

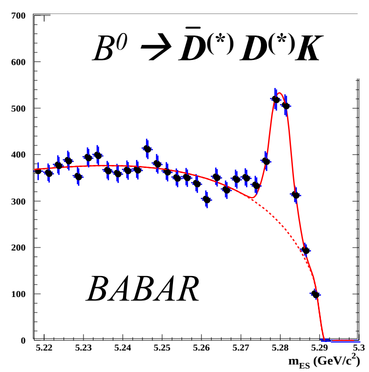

BABAR
φK$_S$
Events / (0.003 GeV)
m$_{ES}$ (GeV)

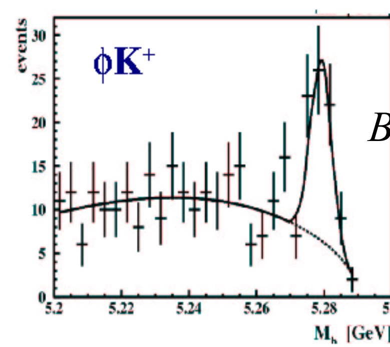

BABAR 88MB
B→K$^+$π$^-$
Events per 2 MeV/c^2
GeV/c^2
m$_{ES}$

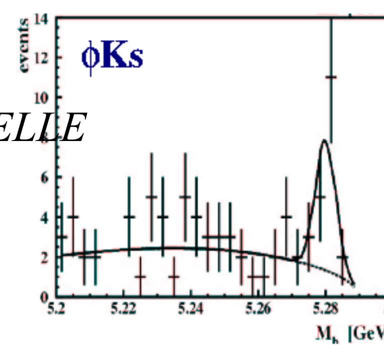

X$_s$ l$^+$l$^-$
BELLE
Entries / (0.2 GeV/c^2)
M$_{bc}$ (GeV/c^2)


ρ$^+$ρ^0
BELLE
Events/ 3 MeV
M$_{bc}$ (GeV)


D$_S$$^+$π$^-$
BABAR
events/2.5 MeV
m$_{ES}$(GeV/c^2)


B^0 → D̄$^{(*)}$ D$^{(*)}$K
BABAR
m$_{ES}$ (GeV/c^2)

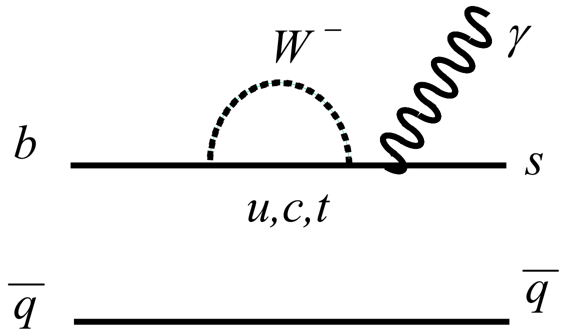

φK$^+$
BELLE
events
M$_b$ [GeV]


φKs
events
M$_b$ [GeV]

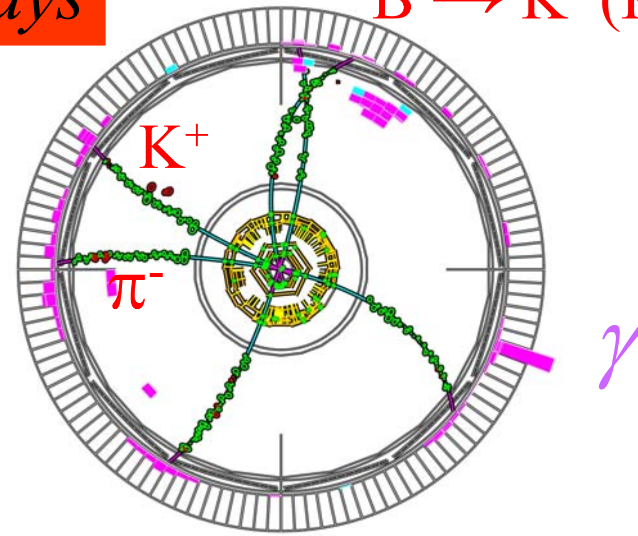
How do I feel in front of them ?   …same as yesterday…

Radiative B decays

predicted by
Hyeronimus Bosch
Final Judgement 1508



$b \rightarrow s\gamma$



Inclusive decays are cleaner
(excl. depends upon not very well known form factors)

Loops sensitive to New Physics (heavy "objects" in the loop)

Photon energy spectrum depends on the quark mass and Fermi movement
$\rightarrow$ *important for addressing theoretical error for V_{cb} (see later)*

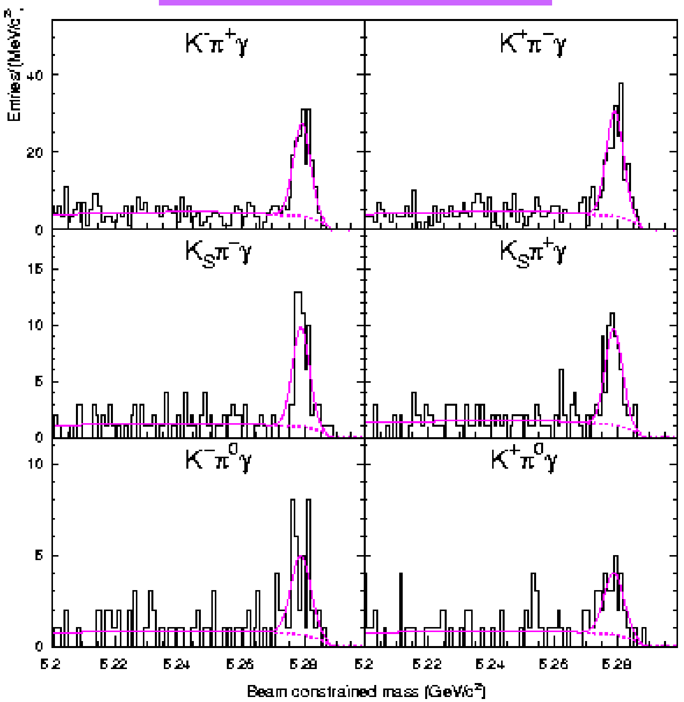
if $b \rightarrow d\gamma$ is also measured : $Br(b \rightarrow d\gamma)/Br(b \rightarrow s\gamma) \propto |V_{td}/V_{ts}|^2$
same constraint as $\Delta m_d / \Delta m_s$

C. Jessop(Babar)/S.Nishida(Belle)

Exclusive radiative decays

$K^*\gamma$ — *Two measurements*

BELLE 65.4 MB



Br — Br($B \to K^* \gamma$) *(70-80)10^{-6} with 50% **theory error***

A_{cp} — <0.5% in SM – Sensitive to non-SM CP-violation

	$B^0 \to K^{*0}\gamma$ (10^{-6})	$B^- \to K^{*-}\gamma$ (10^{-6})	$B^0 \to K_2^{*0}(1430)\gamma$ (10^{-6})
CLEO	45.5±7.0±3.4 A_{cp} = -0.08 ± 0.13 ± 0.03	37.6 ±8.6±2.8	16.6 ±5.6±1.3
BaBar 22.7 MB	42.3±4.0±2.2 A_{cp} = -0.044 ± 0.076 ± 0.012	38.3 ±6.2±2.2	
Belle 65.4 MB	39.1±2.3±2.5 A_{cp} = -0.022 ± 0.048 ± 0.017	42.1 ±3.5±3.1	15(+6)(-5)±1 (only ~30 MB)

$\rho\gamma$ — *Br* (10^{-6} 90% C.L)

$B(B^0 \to \rho^0\gamma)$ < 1.4 Babar
< 2.6 Belle

$B(B^+ \to \rho^+\gamma)$ < 2.3 Babar
< 4.9 Belle

$B(B^0 \to \omega\gamma)$ < 1.2 Babar
< 3.1 Belle

SM 0.49 ±0.21

SM 0.85 ±0.40

$$\frac{B(B \to \rho\gamma)}{B(B \to K^*\gamma)} < 0.036 \quad \propto |V_{td}/V_{ts}|^2$$

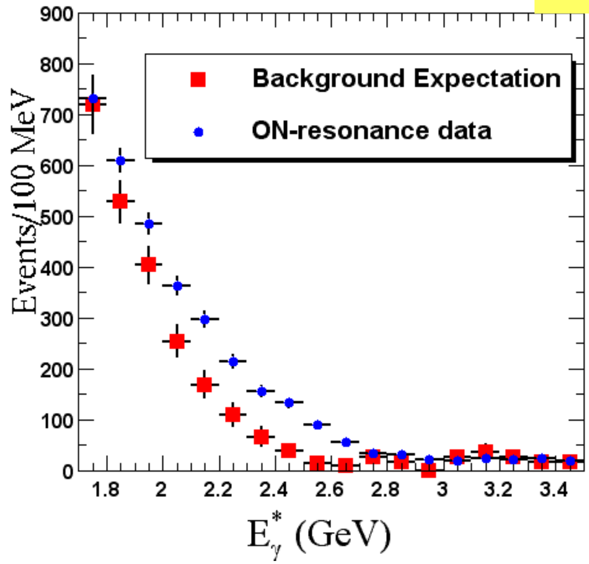
A.S. estimation

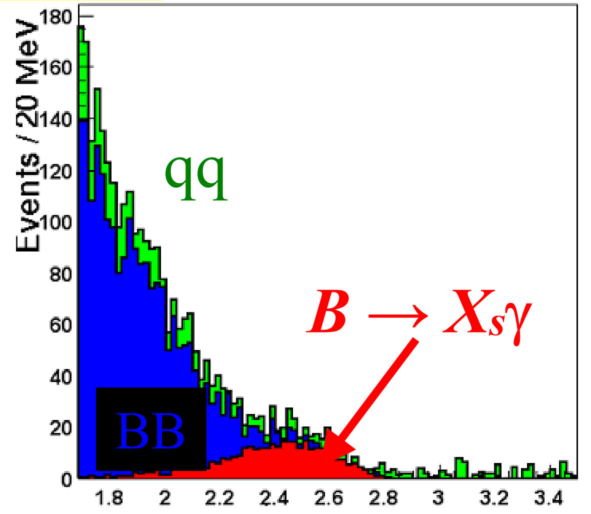
Not yet useful for constraining $(1-\rho)^2+\eta^2$

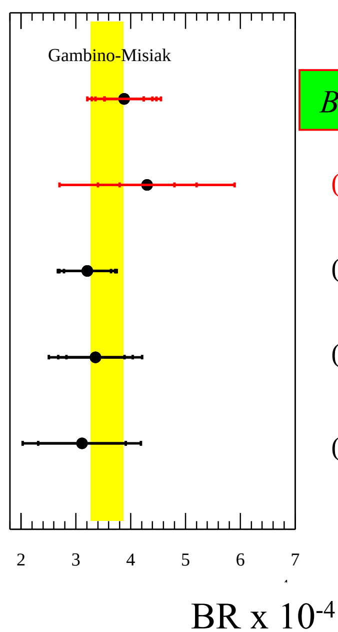
MAINLY because 50% theo. error

Inclusive radiative decays

BABAR 61MB







B ± stat ± syst ± theo

BABAR inclusive — $B(B \rightarrow X_s\gamma) = 3.88 \pm 0.36(\text{stat.}) \pm 0.37(\text{sys.}) + 0.43/-0.28$ (theory)

BABAR 22MB summing 12 states — $(4.3 \pm 0.5 \pm 0.8 \pm 1.3)\text{x}10^{-4}$

CLEO — $(3.21 \pm 0.43 \pm 0.27^{+0.18}_{-0.10})\text{x}10^{-4}$

BELLE — $(3.36 \pm 0.53 \pm 0.42 \pm 0.52)\text{x}10^{-4}$

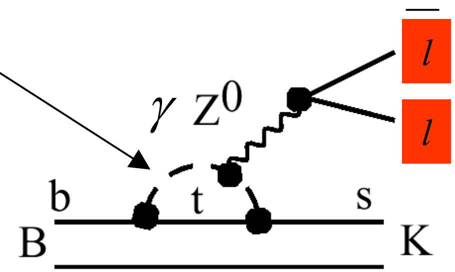
ALEPH — $(3.11 \pm 0.80 \pm 0.72)\text{x}10^{-4}$

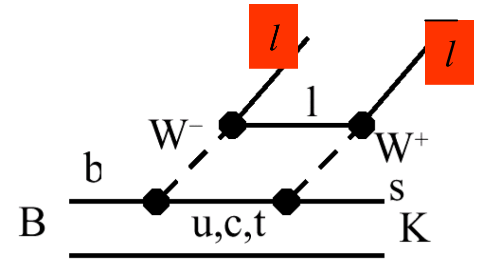
Experimental precision is approaching theoretical errors

J. Richmann (BABAR)
S. Nishida (BELLE)

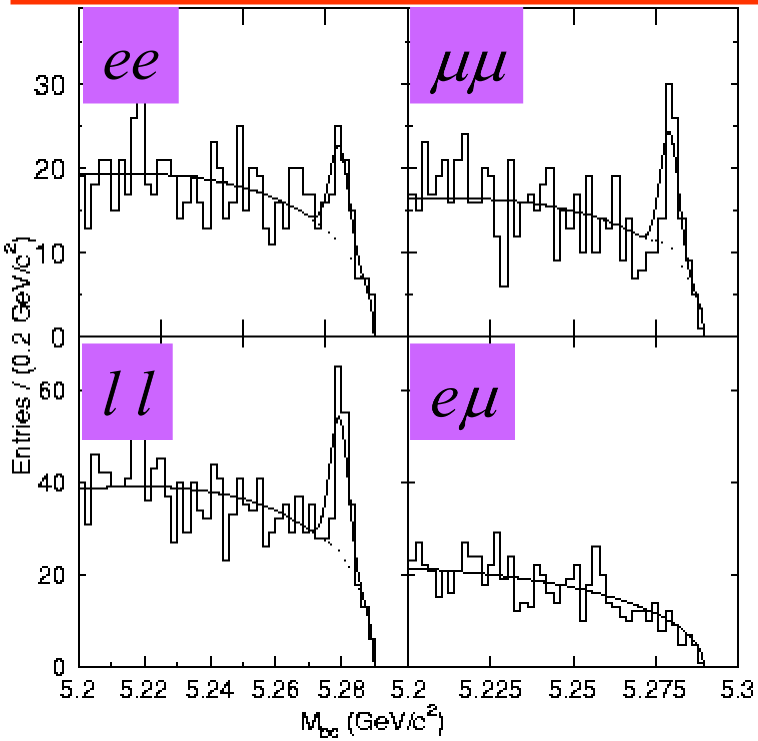
Leptonic B rare decays : $B \rightarrow X_s\, l^+ l^-$

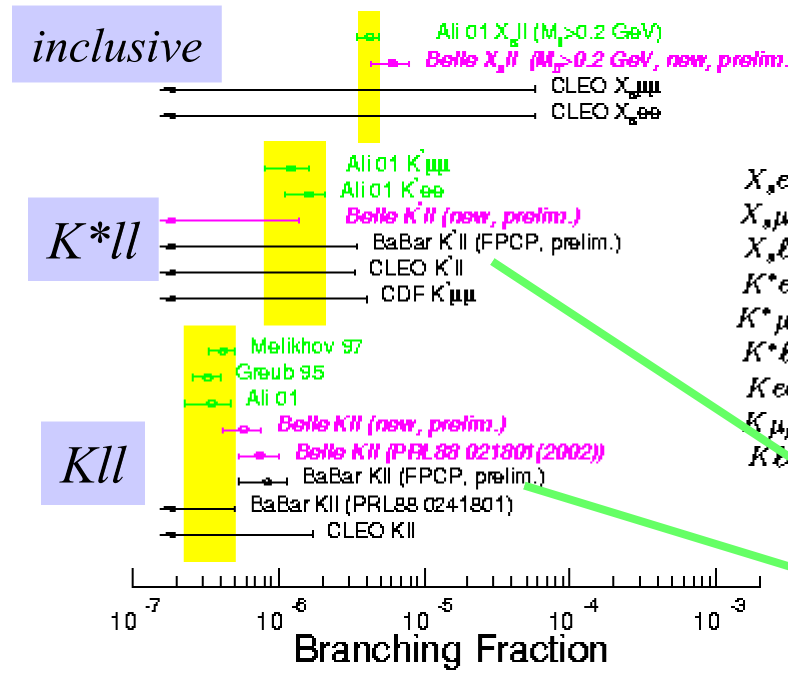
Sensitive to new physics





First Observation of $X_s\, l^+ l^-$ BELLE 65.4 MB

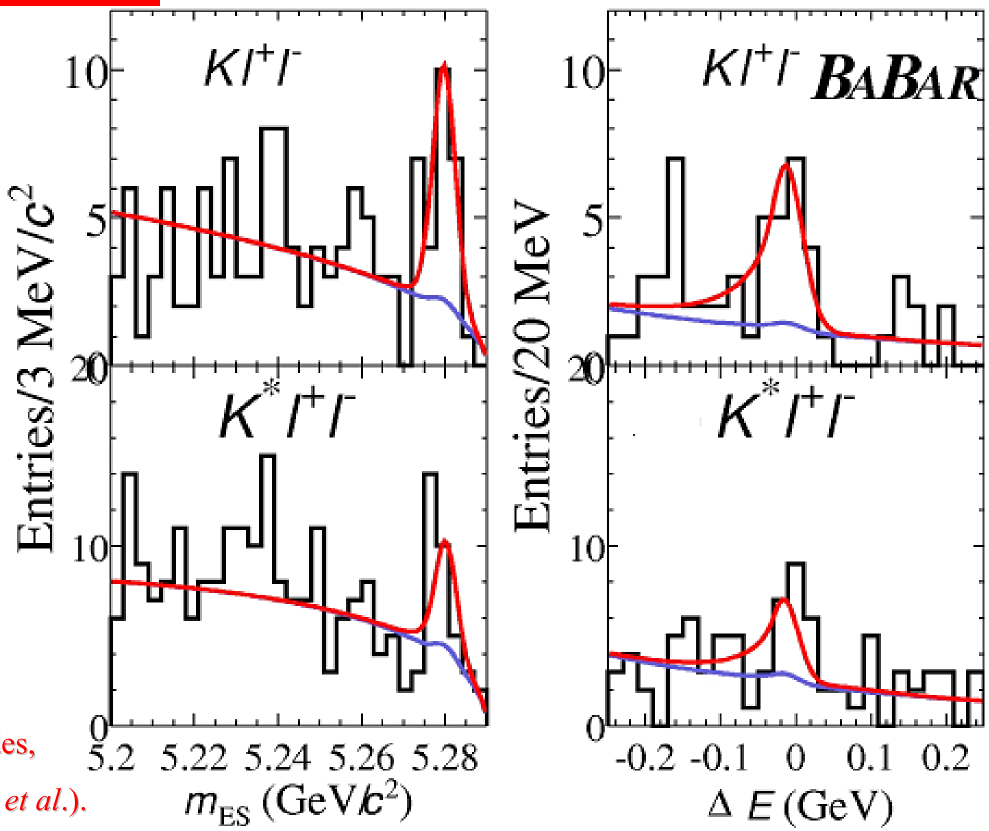




	$\mathcal{B}$ ($\times 10^{-7}$)	signif.
$X_s ee$	$50 \pm 23 ^{+12}_{-11}$	3.4
$X_s \mu\mu$	$79 \pm 21 ^{+20}_{-15}$	4.7
$X_s \ell\ell$	$61 \pm 14 ^{+13}_{-11}$	5.4
$K^* ee$	< 4.7	—
$K^* \mu\mu$	< 1.2	—
$K^* \ell\ell$	< 1.4	—
$K ee$	$3.8 ^{+2.1}_{-1.7} \pm 0.6$	2.7
$K \mu\mu$	$8.0 ^{+2.6}_{-2.3} \pm 0.8$	4.9
$K \ell\ell$	$5.8 ^{+1.7}_{-1.5} \pm 0.6$	5.4

EXCLUSIVE K l l / K* l l

BABAR 84.4 M B



To combine the *K*ll* modes, assume *K*ee/K*μμ*=1.2 (Ali *et al.*).

Theory [2-5] 10^{-7}

$$Br(K\ l^+l^-) = (7.8^{+2.4+1.1}_{-2.0-1.8})\times 10^{-7}$$ *4.4 σ (syst. included)*

$$Br(K^* l^+l^-) = (16.8^{+6.8}_{-5.8} \pm 2.8)\times 10^{-7}$$ *2.8 σ*

$$< 30\times 10^{-7}\ @90\%C.L.$$

T.Moore (Babar)

New limit from Babar ~50MB

$B(B^+\rightarrow K^+\nu\bar{\nu}) < 94\times 10^{-6}$ @90CL

VERY CLEAN MODE

Still far : SM ~ 3.8 10^{-6}

Exclusive hadronic B rare decays

Gold mine of weak and hadronic physics(very rich B decay dynamics)

The rare B decays are described by various tree (T) and penguin diagrams (P)

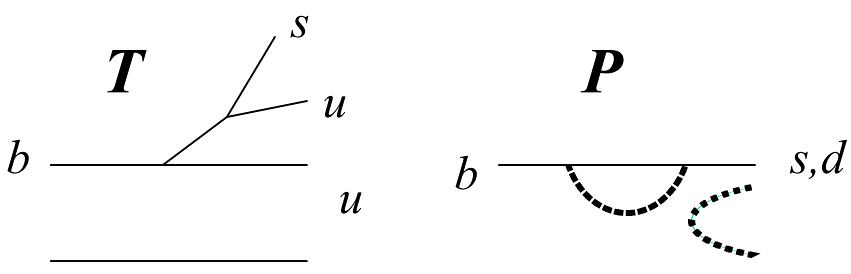
Goal : to use it for the extraction of the UT angles.

for β

Dream channel B→J/ψK^0

For γ and α the life is more difficult

Example : Kπ



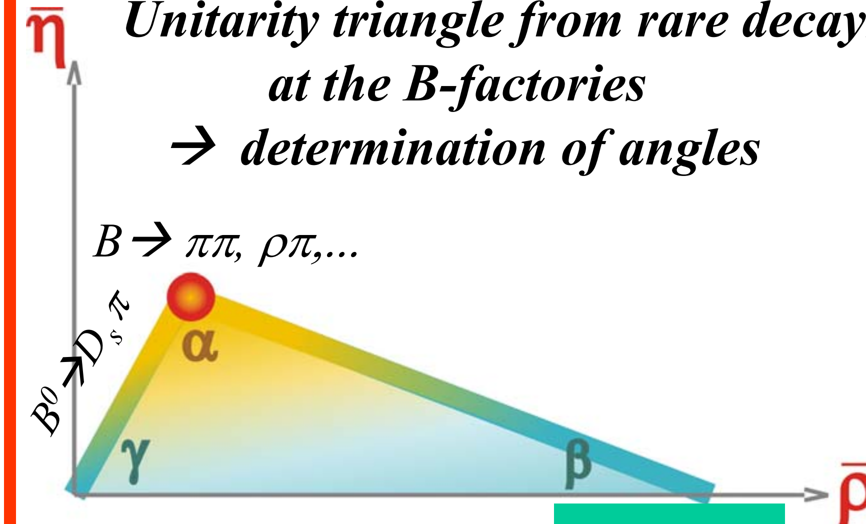
V_{ub} phase → γ

But important contribution from penguins

Many and important progress in the last years with the calculations of amplitudes at m→ ∞ limit

Still controversy on corrections to it

Unitarity triangle from rare decays at the B-factories → determination of angles



B→J/ψK^0

(other B→ charmonium)

B→$D^{(*)}$ $D^{(*)}$

B→ η' Ks

B→DK

B→ ππ,Kπ,...

many different measurements are performed

to constrain hadronic ampl. and strong phases

Branching ratios

measurement of CP asymmetries

$$A_{CP} = \frac{Br(\overline{B} \to \overline{f}) - Br(B \to f)}{Br(B \to f) + Br(\overline{B} \to \overline{f})}$$

Measurement of time dependent CP asymmetries

C≠0 direct CPV

$$f_{\pm}(\Delta t) = \frac{e^{-|\Delta t|/\tau}}{4\tau}\left[1 \pm S_f \sin(\Delta m_d \Delta t) \mp C_f \cos(\Delta m_d \Delta t)\right]$$

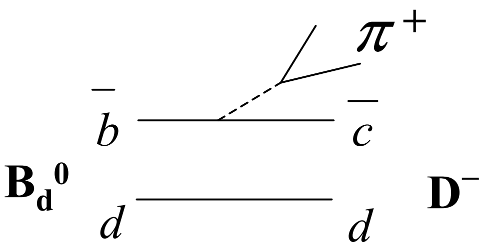
Mixing for neutral B

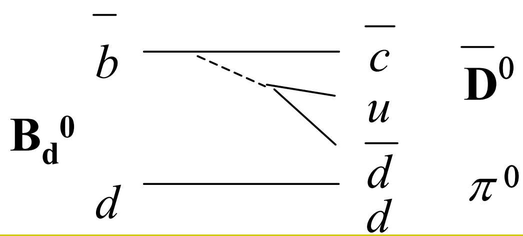
Time dependent analyses for the extraction of the angles α and γ given in the Babar and Belle talks

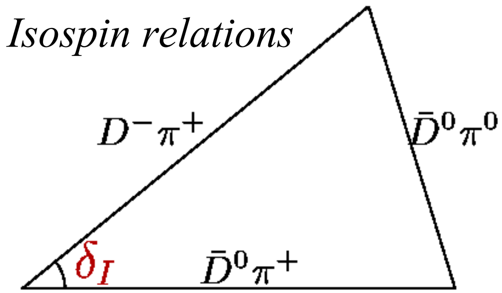
$B \rightarrow$ OPEN CHARM (DX)

E. Varnes (Babar)
P. Krokovny(Belle)

1) ***Test of the B dynamics .*** *Example the Colour-Suppressed Open Charm DX(light)*







Color – allowed (Class I)

$$A \sim (m_B^2 - m_D^2) f_\pi F^{B\to D}(m_\pi^2) a_1(D\pi)$$

Color – suppressed (Class II)

$$A \sim (m_B^2 - m_\pi^2) f_D F^{B\to\pi}(m_D^2) a_2(D\pi)$$

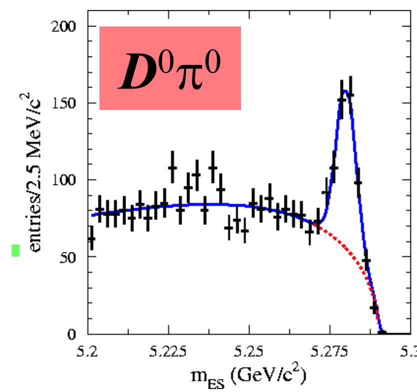
(a_1 and a_2 from data à la Neubert-Stech)

δ_I strong phase angle difference between $A_{1/2}$ and $A_{3/2}$

CLEO and BELLE(NEW ANALYSIS)

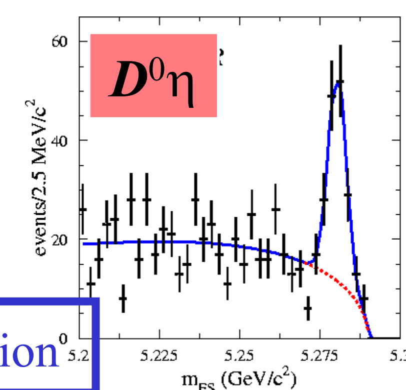
$$\cos\delta_I = 0.866^{+0.042}_{-0.036}$$

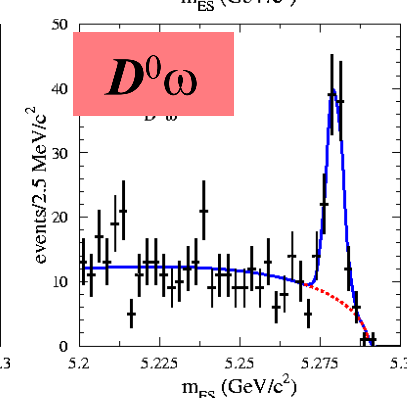
$3.2\sigma \neq 1 \rightarrow$ sizable final-states rescattering effects in $D\pi$ decyas



Many new results from B-factories

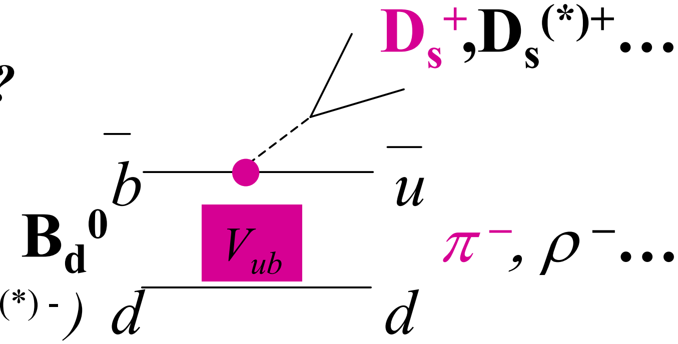
	BELLE(~29MB)	BABAR(~50MB)	CLEO
$D^0\pi^0$	3.1 ± 0.4 ± 0.5	2.9 ± 0.3 ± 0.4	2.7(+0.36)(-0.32) ± 0.55
$D^0\eta^0$	1.4(+0.5)(-0.4) ± 0.3	2.4 ± 0.4 ± 0.3	
$D^0\omega^0$	1.8 ± 0.5 (+0.4)(-0.3)	2.5 ± 0.4 ± 0.3	
$D^0\rho^0$	3.0 ± 1..3 ± 0. 4 (60MB)		





Rates are more than twice the naïve factorization prediction

$B^0 \rightarrow D_s^{(*)+} \pi^-$ ***Extraction of V_{ub} ?***



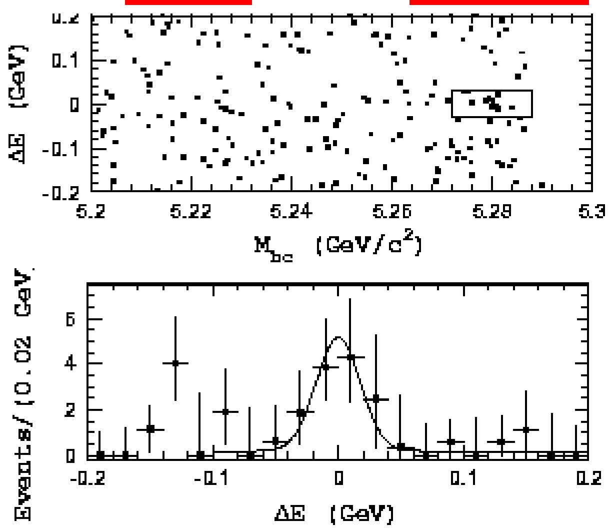
Dominated by b→u transition with no penguin contribution

Possible way of determining V_{ub}

..Many form factors and difficult to normalise (?$D_s^{(*)+} D^{(*)-}$)

Difficult to get better than 20% theo. Error (I'm optimistic!)

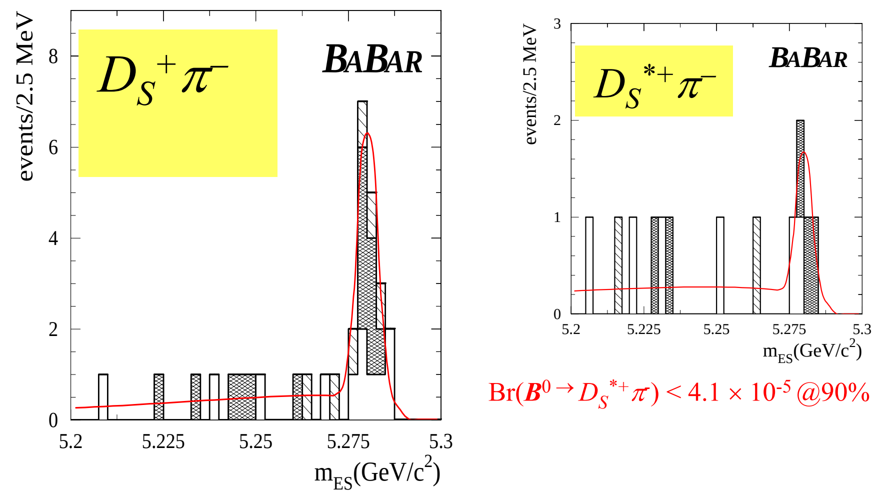
Belle *85M B*



Significance 3.6σ

$$Br(B^0 \rightarrow D_s^+ \pi^-) = (2.4^{+1.0}_{-0.8} \pm 0.7) \times 10^{-5}$$

BaBar *84M fb-1*



$Br(B^0 \rightarrow D_S^{*+} \pi^-) < 4.1 \times 10^{-5}$ @90% C.L.

Significance 3.3σ

$$Br(B^0 \rightarrow D_s^+ \pi^-) = (3.2 \pm 0.9 \pm 1.0) \times 10^{-5}$$

$$= (2.5 \pm 0.7 \pm 0.6 (D_s \rightarrow \phi\pi)) \times 10^{-5}$$

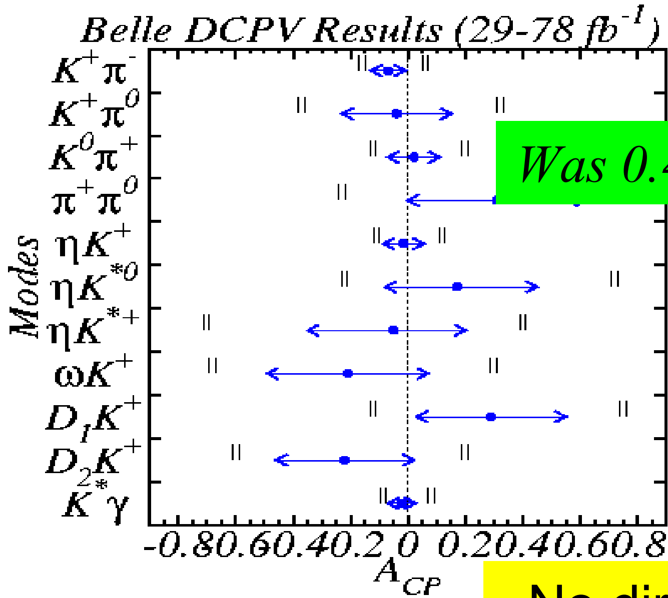
Syst. dominated by the 25% uncertainty on Br($D_s \rightarrow \phi\pi$)

Need of absolute Br.
CLEO-C

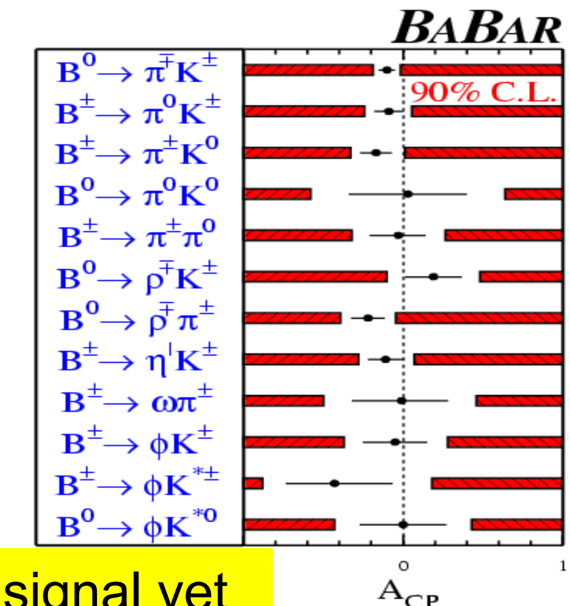
Charmless B Decays

Mode	Branching ratio (×10-6) Belle ~31 MB / ~45MB/~86MB	A_{CP} Belle ~31 MB / ~45MB	Branching ratio (×10-6) BaBAr ~88 MB / ~60MB /~23MB	A_{CP} BaBAr ~88 MB / ~60MB / ~23MB	Branching ratio (×10-6) CLE0
$B^0 \to K^+\pi^-$	22.5 ± 1.9 ± 0.8	-0.06 0.09 +0.01(-0.02)	(17.9±0.9 ±0.6)	-0.102 ±0.050 ±0.016	17.2 (+2.5)(-2.4)±1.2
$B^+ \to K^+\pi^0$	13.0 (+2.5)(-2.4) ± 1.3	-0.02 0.19 0.02	(12.8 ±1.2 ±1.0)	-0.09 ±0.09 ±0.01	11.6(+3.0)(-2.7(+1.4)(-1.3)
$B^+ \to \pi^+\pi^0$	7.4 (+2.3)(-2.2) ± 0.9	0.30 0.030 +0.06(-0.04)	(5.5 ±1.0 ±0.6)	-0.03 ±0.18 ±0.02	5.4)+2.1)(-2.0) ±1.5
$B^0 \to K^0\pi^0$	8.0 (+3.3)(-3.1) ± 1.6		(10.4 ±1.5 ±0.8)	0.03 ±0.36 ±0.09	14.6(+5.9)(-5.1)(+2.4)(-3.3)
$B^0 \to K^+K^-$	<0.9(@90%CL)		<0.6 (90% C.L.)	-	<1.9
$B^+ \to \pi^+\pi^-$	5.4 ± 1.2 ± 0.5		(4.6 ±0.6 ±0.2)	C=-0.30 ± 0.25 ± 0.03 S=0.02 ± 0.34 ± 0.03	4.3(+1.6)(-1.4) ±0.5
$B^+ \to \pi^0\pi^0$	< 6.4 (@90%CL)		<3.6(90%CL)	-	<5.2
$B^+ \to K^+$-anti K^0	< 2.0(@90%CL)		<1.3 (90% C.L.)	-	<5.1
$B^+ \to K^0\pi^+$	19.4(+3.1)(-3.0) ± 1.6	0.46 ± 0.15 ± 0.02	(17.5 ±1.8 ±1.3)	-0.17 ±0.10 ±0.02	18.2(+4.6)(-4.0) ±1.6
$B^0 \to K^0$anti-K^0	< 4.1(@90%CL)		<7.3		<13
$B^+ \to \rho\pi$	8.0(2.3)(-2.0) ± 0.7		10.4(+3.3)(-3.4) ±2.1	-0.22 ±0.08 ±0.07 C = 0.45+0.18(-0.19) ± 0.09 S = 0.16 ± 0.25 ± 0.07	10.4(+3.3)(-3.4) ± 2.1
$B^0 \to \rho^\pm\pi^\pm$	20.8(+6.0)(-6.3)(+2.8)(-3.1)		28.9 ±5.4 ±4.3		27.6(+8.4)(-7.4) ± 4.2
$B^0 \to \rho^0\pi^0$	<5..3(90%CL)		<10.6		<5.5
$B^0 \to a^\pm\pi^\pm$			6.2(+3.0)(-2.5) ±1.1		
$B^+ \to \rho K$				0.19 ±0.14 ±0.11	
$B^+ \to \eta' K^+$	77.9 (+6.2)(-5.9) (+9.3)(-8.7)	-0.015 ± 0.070 ± 0.009	67±5 ±5	-0.11 ± 0.11 ± 0.02	80 (+10)(-9) ± 7
$B^0 \to \eta' K^0$	68.0 (+10.4)(-9.6)(8.8)(-8.2)	0.13 ± 0.32 (+0.09)(-0.06) S=0.28 ± 0.55 (+0.07)(-0.08) 10.7 ± 1.0 (+0.9)(-1.6)	46±6 ±4		89(+18)(-16) ± 9
$B^+ \to \eta' \pi^+$			5.4 (+3.5)(-2.6) ± 0.8		<12
$B^0 \to \eta' K^{*0}/K^{*+}/\rho^0$	<20/90/14 @90%CL		<13 (90% C.L.)		<24/35/12 @95%CL
$B^+ \to \eta K^{*+}$	26.5 (+7.8)(-7.0) ± 3.0		22.1(+11.1)(-9.2)		26.4 (+9.6)(-8.2) ± 3.3
$B^0 \to \eta K^{*0}$	16.5 (+4.6)(-4.2) ± 1.2		19.8(+6.5)(-5.6) ±3.3		13.8(+5.4)(-4.6) ± 1.6
$B \to \eta K$	<7.7		<6.4		<6.9
$B \to \eta\pi$	<8.2		<5.2		<5.7
$B \to \eta\rho^0$ / $\eta\rho+$	<2.7/6.2				<15/10
$B^0 \to \omega\pi^\pm$			6.6+2.1(-1.8) ± 0.7		
$B^\pm \to \omega\pi^\pm$	4.3 (+2.0)(-1.8) ± 0.5		6.6(+2.1)(-1.8) ± 0.5	-0.01 +0.29(-0.31) ±0.0.3	11.3(+3.3)(-2.9) ± 1.5
$B^\pm \to \omega K^\pm$	9.9 (+2.7)(-2.4) ± 1.0	-0.21 ± 0.28 ± 0.03	<4		<7.9
$B^0 \to \omega K^0$			(5.9 +1.7(-1.5) ±0.9		<21
$B^0 \to \omega\pi^0$	-		< 3.3		<5.5
$B^\pm \to \phi K^\pm$	10.7 ± 1.0 (+0.9)(-1.6)		(9.2 ±1.0 ±0.8)	-0.05 ±0.20 ±0.03	5.5(+2.1)(-1.8) ± 0.6
$B^\pm \to \phi K^{*\pm}$	11.2 (+3.3)(-2.6)(+1.3)(-1.7)		(9.7 +4.2(-3.4) ±1.7)	-0.43 +0.36-(0.30) ±0.06	<22.5
$B^0 \to \phi K^{*0}$	8.0 (+2.0)(-1.8)(+0.8)(-1.1)		8.6 +2.8(-2.4) ±1.1)	0.00 ±0.27 ±0.23	11.5(+4.5)(-3.7) (+1.8(-1.7)
$B^0 \to \phi K^0$	10.0(+1.9)(-1.7)(+0.9)(-1.3)		8.7 +(1.7)(-1.5) ± 0.9		<12.3
$B^\pm \to \phi\pi^\pm$	"		<0.56 (90% C.L.)		
$B^+ \to \rho^+\rho$	38.5 ±10.9(+5.9-5.4)(+2.5(-7.5)				

A_{CP}



Was 0.46±0.15

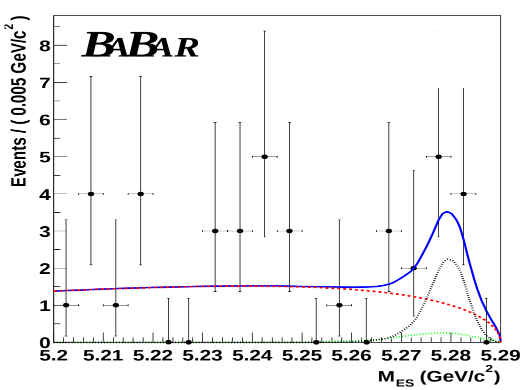


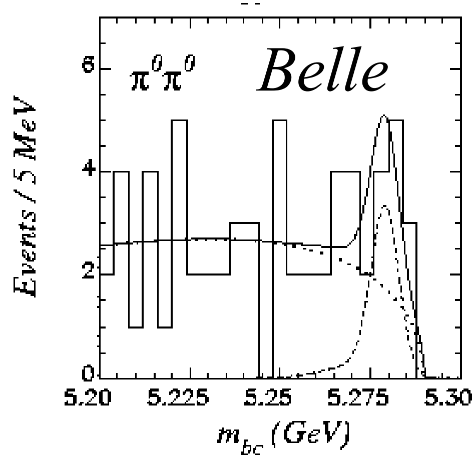
K.Suzuki(Belle)
A.Bevan(Babar)
A. Gordon(Belle)

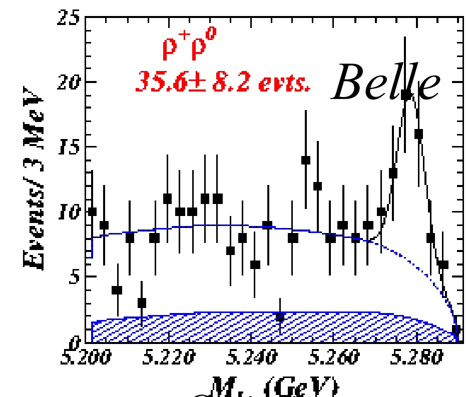
No direct CPV signal yet

BR

Are we about observing the $\pi^0\pi^0$ mode (with Br~ 3 10^{-6}) ?







Curiosity…

First B→VV charmless b→u

Need to put some order out of it

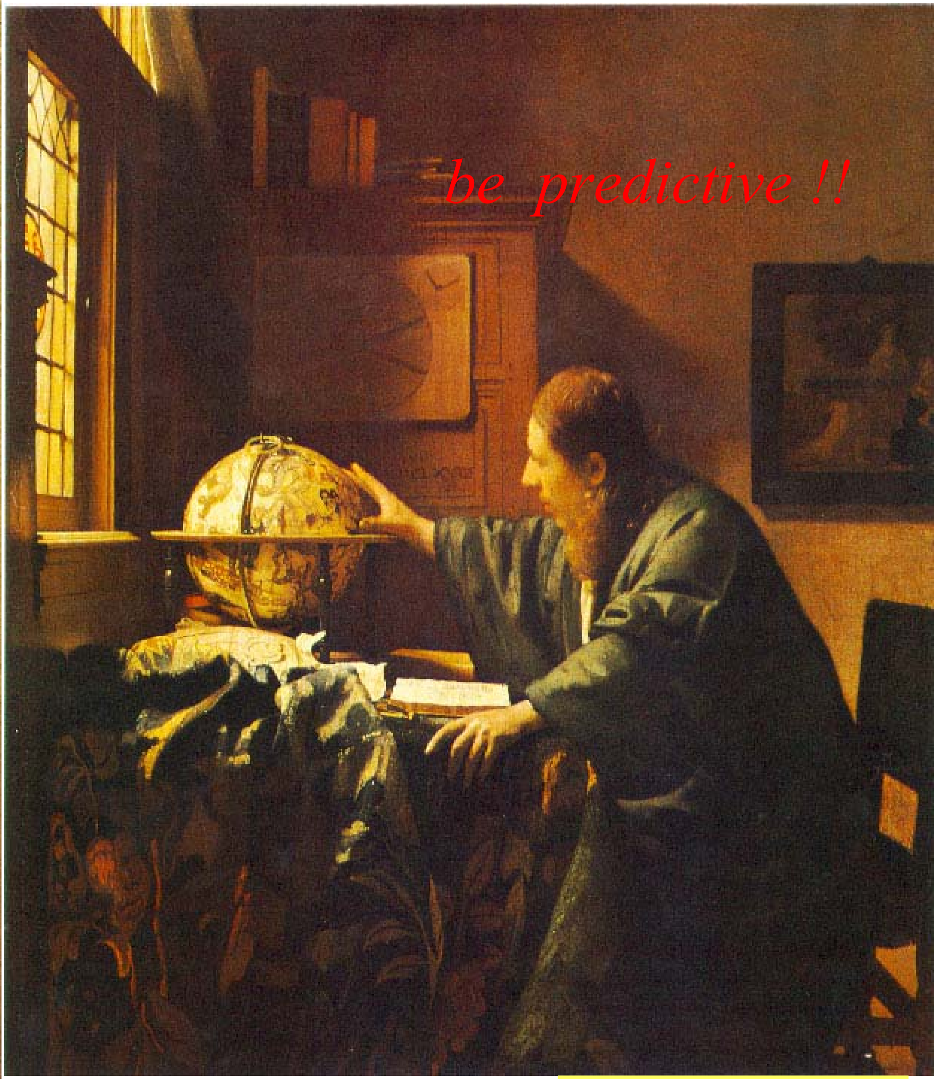
Also multibody are coming

P. Chang(Belle)

Experimentalists at work…

J. Vermeer (1669-70)
The Lacemaker

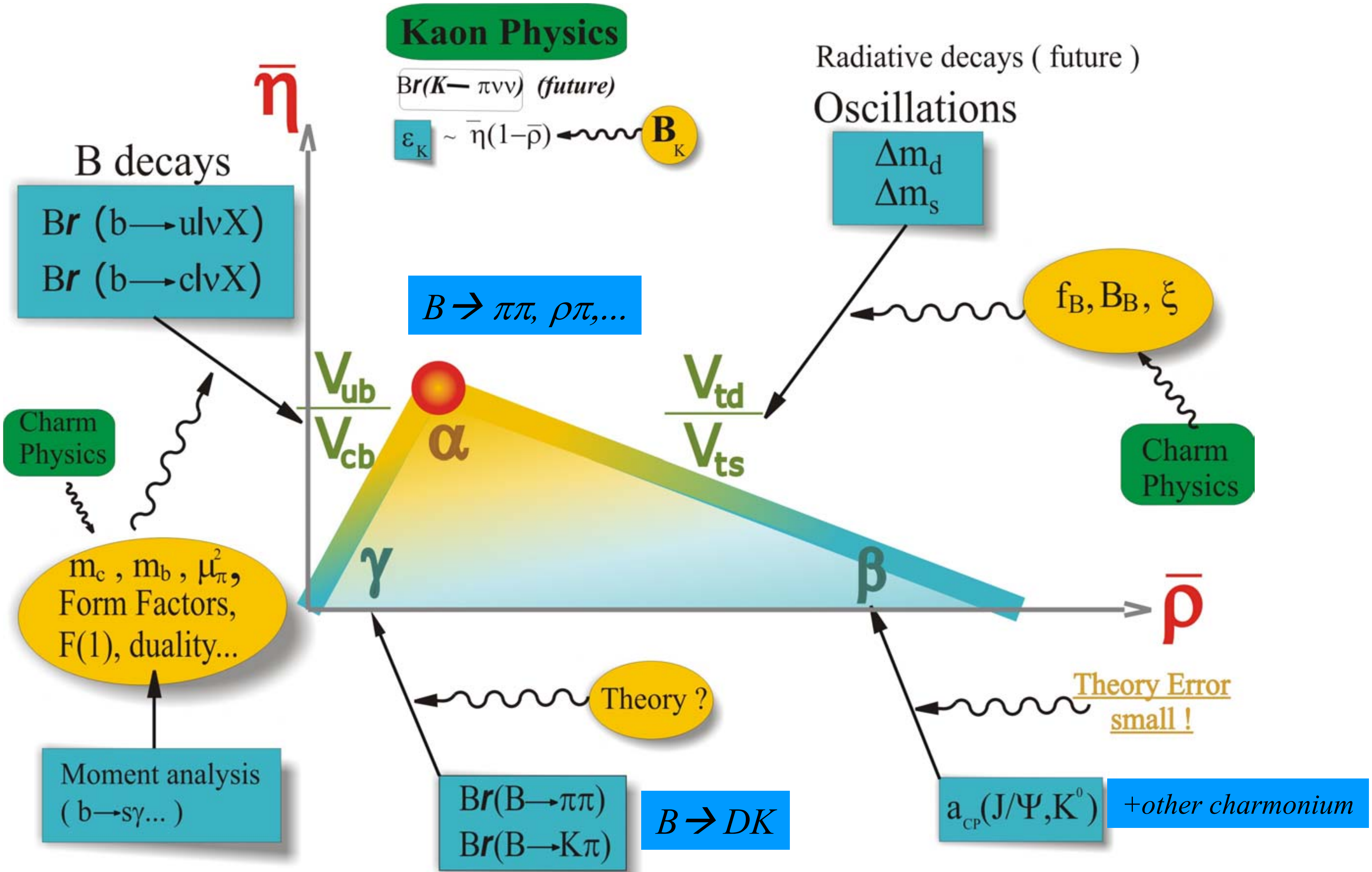
Theorists at work…



J. Vermeer (1668)
The Astronomer

Visualization of the unitarity of the CKM matrix

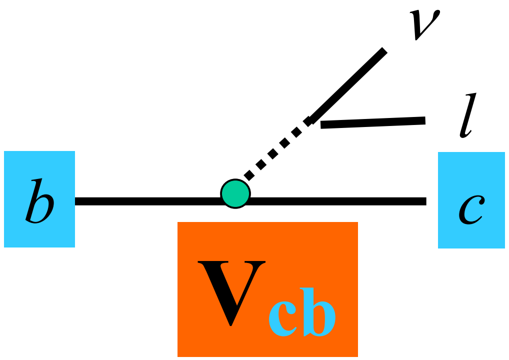
Unitarity Triangle in the (ρ−η) plane



N. Uraltsev
M. Battaglia(LEP)
V.Luth (BaBar)
D. Cronin-Hennessy (CLEO)
M. Calvi (LEP)
A.Tricomi (LEP)

Determination of V_{cb}

Inclusive Method



$$\Gamma_{sl}(b \to c l^- \nu) \overset{theo.}{=} |V_{cb}|^2 \, F \overset{exp.}{=} \frac{Br_{sl}}{\tau_b}$$

$f(\mu^2_\pi , m_b , \alpha_s , \rho_D (\text{or } 1/m_b^3))$

m_b (also named $\overline{\Lambda}$) μ^2_π (λ_1 Fermi movement)

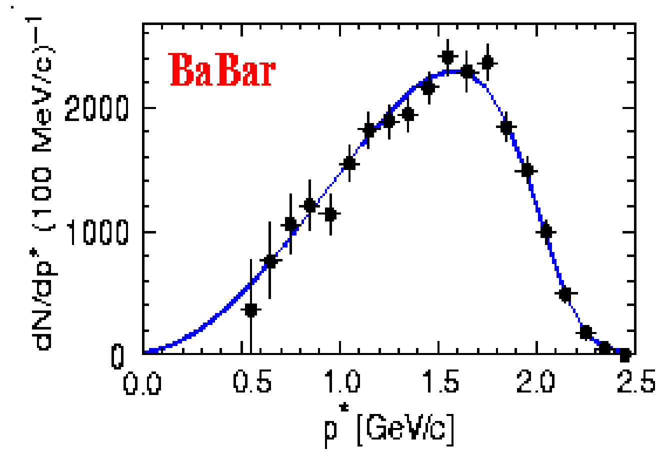
Based on ***OPE***

$\Gamma_{sl} = (0.431 \pm 0.008 \pm 0.007)\ 10^{-10}$ *MeV Y(4S)*

$\Gamma_{sl} = (0.439 \pm 0.010 \pm 0.007)\ 10^{-10}$ *MeV LEP*

$\Gamma_{sl} = (0.434 \times (1 \pm 0.018))\ 10^{-10}$ *MeV*

at 2% precision



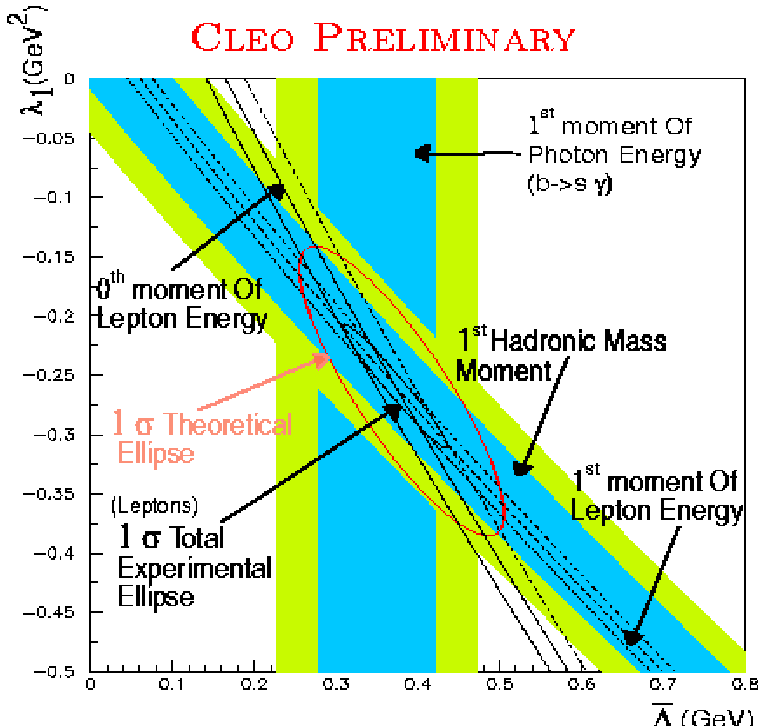
→Determination of V_{cb} limited by theoretical uncertainties …..

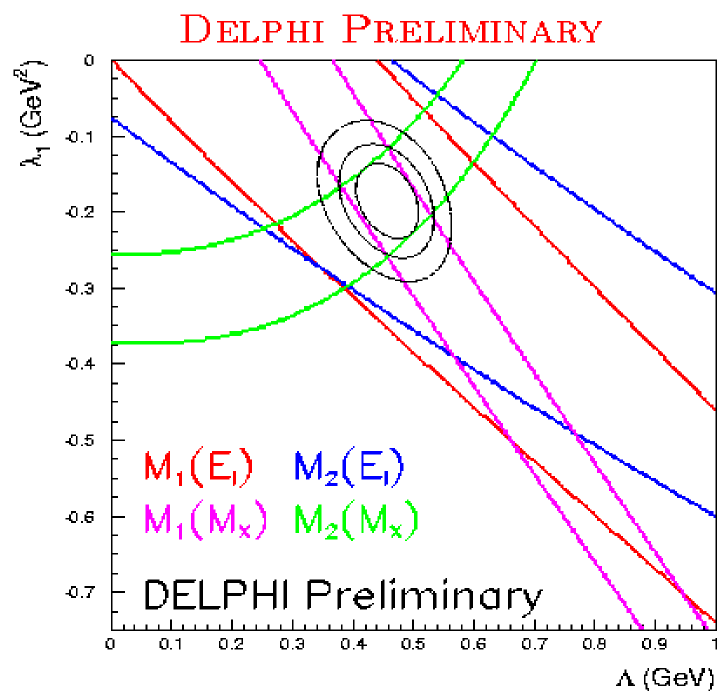
Measurement of the moments of the distributions of the

HADRONIC mass (CLEO/DELPHI)

LEPTON Momentum (CLEO/ DELPHI/BABAR (55MB)))

Photon energy $b \rightarrow s\ \gamma$ (CLEO)





$\bar{\Lambda}$=(0.39±.03±.06±.12) GeV	$\bar{\Lambda}$=(0.44±.04±.05±.07) GeV
λ_1=(-0.25±.02±.05±.14) GeV^2	λ_1=(-0.23±.04±.05±.08) GeV^2

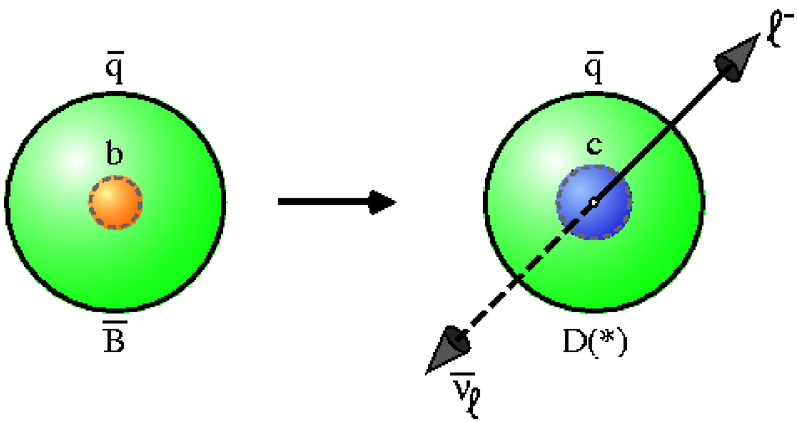
V_{cb}(inclusive)= (40.7 ± 0.6 ± 0.8(theo.)) 10^{-3}

V_{cb} Working Group

Caveat : control of power corrections $1/m_b^3$

Exclusive method

Based on ***HQET***



$$\frac{d\Gamma}{dw} = \frac{G_F^2}{48\pi^2} \; |V_{cb}|^2 \; |F(w)|^2 \; G(w)$$

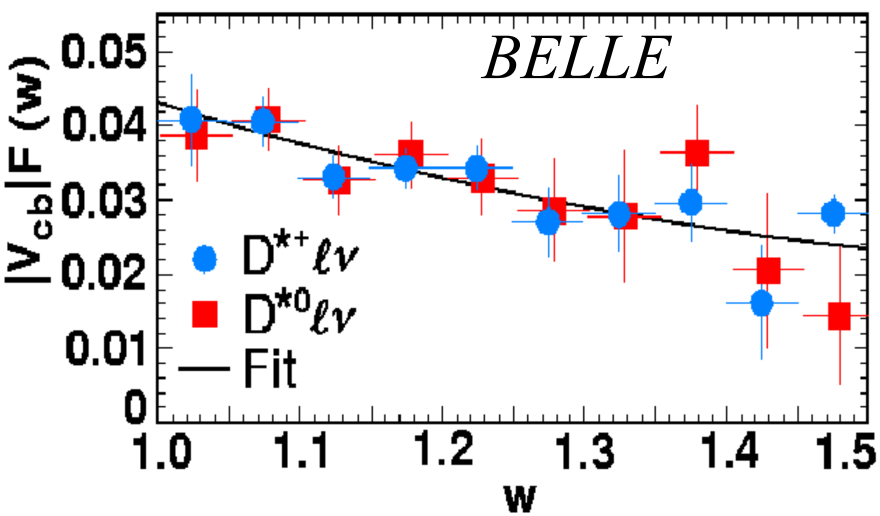
$$w = v_B . v_{D^{(*)}}$$

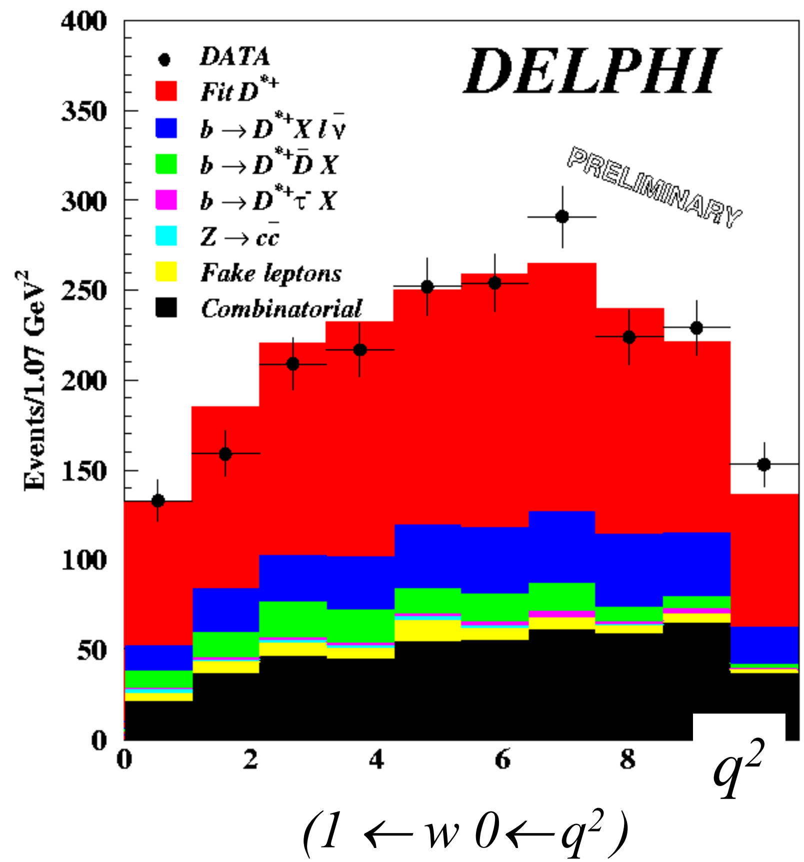
$$w = \frac{m_{D*}^2 + m_B^2 - q^2}{2 m_{D*} m_B}$$

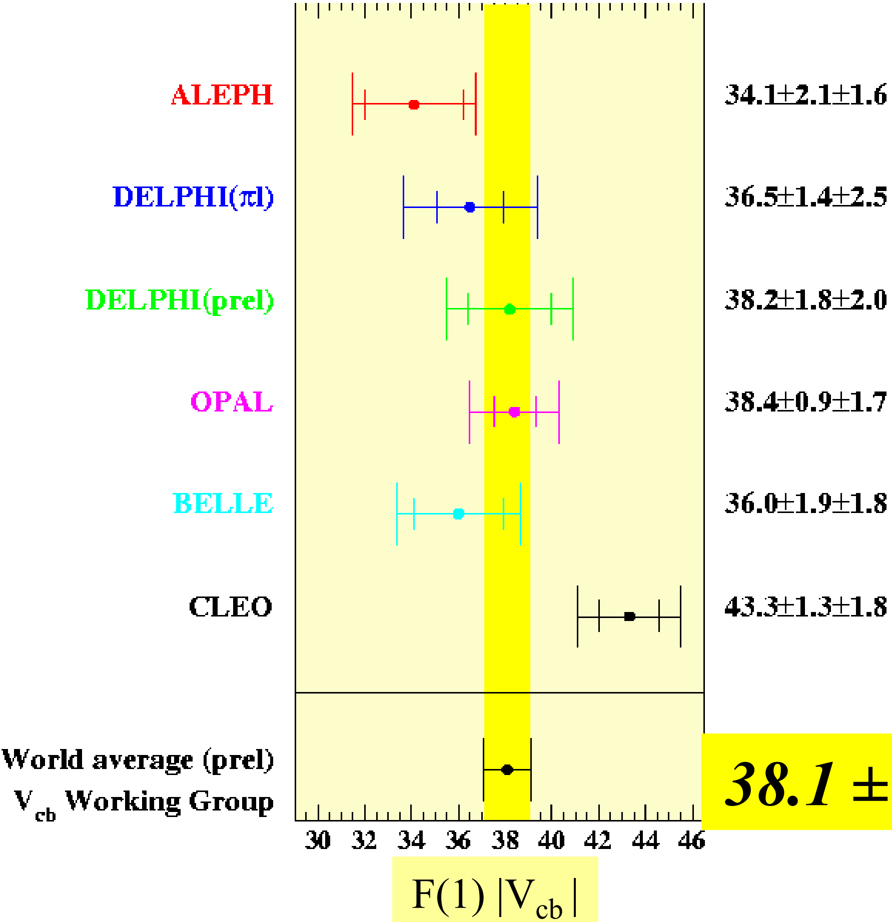
F(w) is the form factor describing the B→ D^* transition

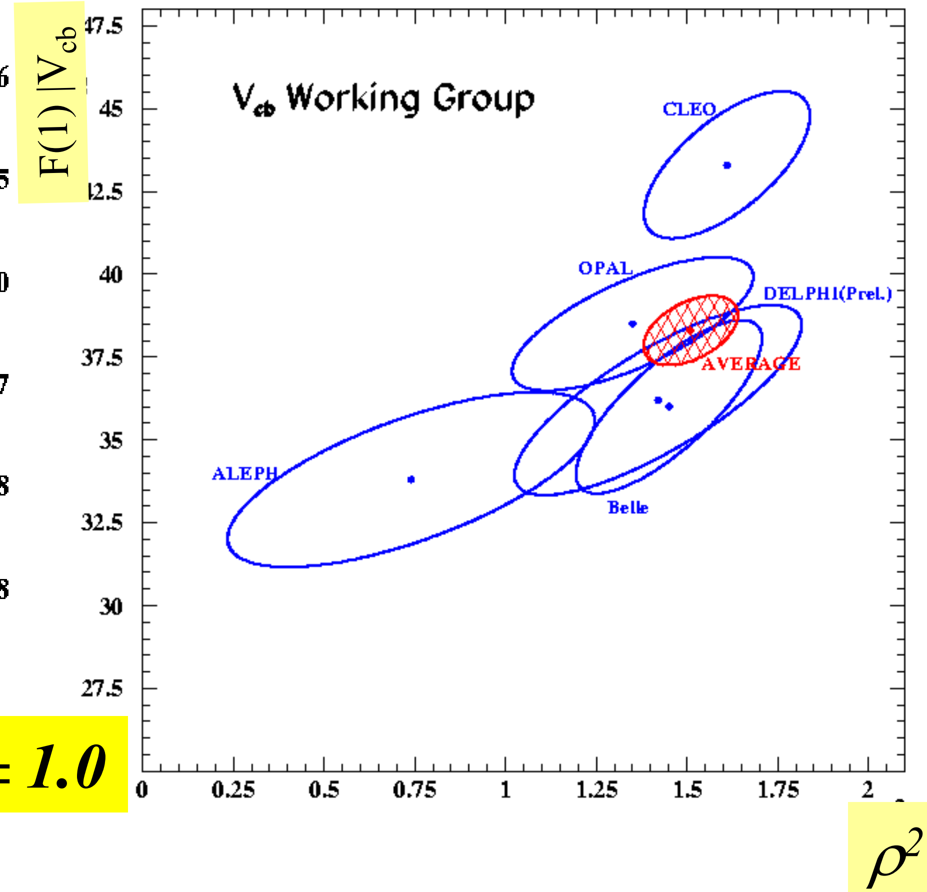
At zero recoil (w=1), as $M_Q \rightarrow \infty$ $F(1) \rightarrow 1$

Strategy : Measure dΓ/dw extrapolate to w=1 to extract F(1) $|V_{cb}|$









F(1) = 0.91 **± 0.04**

Laurent Lellouch (plenary)

James Simone

V_{cb}(exclusive)= (41.9 ± 1.1 ± 1.9) 10^{-3}

V_{cb}(inclusive)= (40.7 ± 0.6 ± 0.8) 10^{-3}

V_{cb} = (40.9 ± 0.8) 10^{-3}

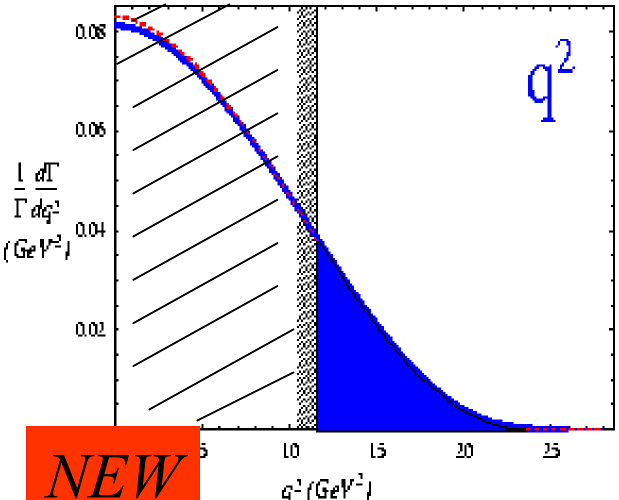
A.S. average

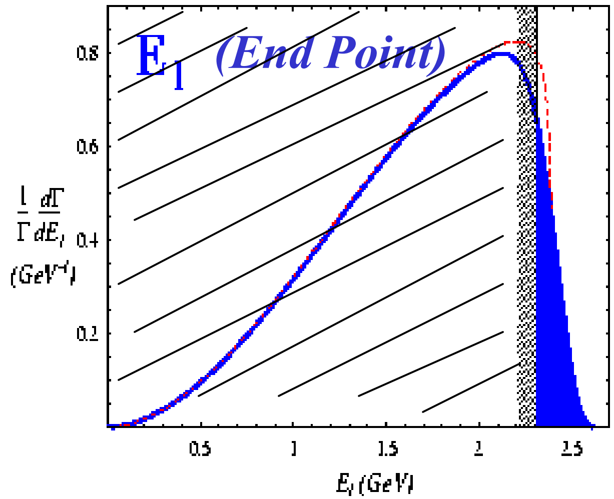
T.Mannel
N. Uraltev
M.Battaglia(LEP)
V.Luth (BaBar)
D. Cronin-Hennessy (CLEO)

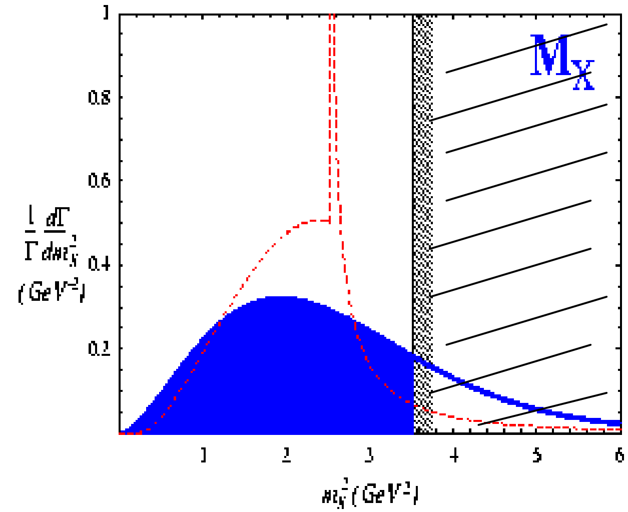
Determination of V_{ub}

Inclusive methods

$B \rightarrow X_u l^+ \nu$







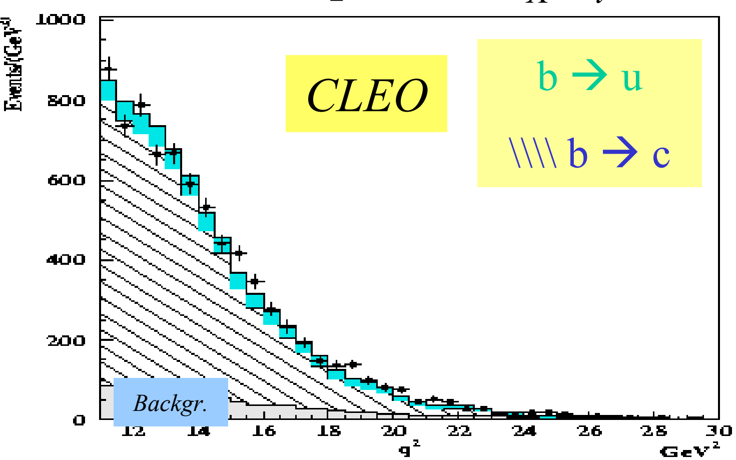
NEW

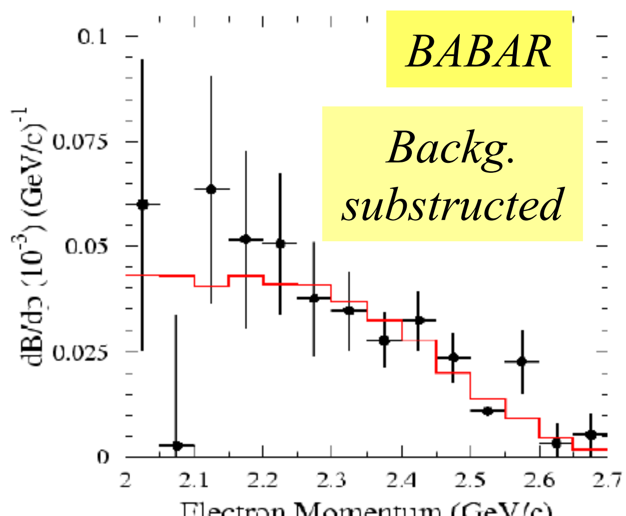
$$M_{\ell\nu}^2 = q^2 > (M_B - M_D)^2$$

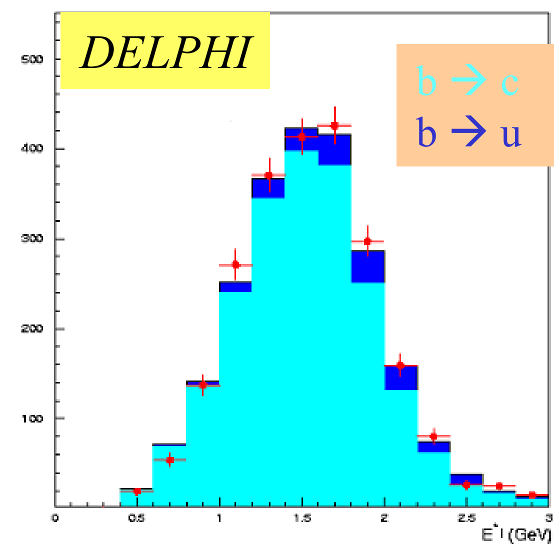
$$E_\ell > \frac{M_B^2 - M_D^2}{2M_B}$$

$$M_{uq} < M_{cq}$$

3–D Fit : q2 and M_X E_l







Y. Kwon(Belle)
L.Wilden(Babar)

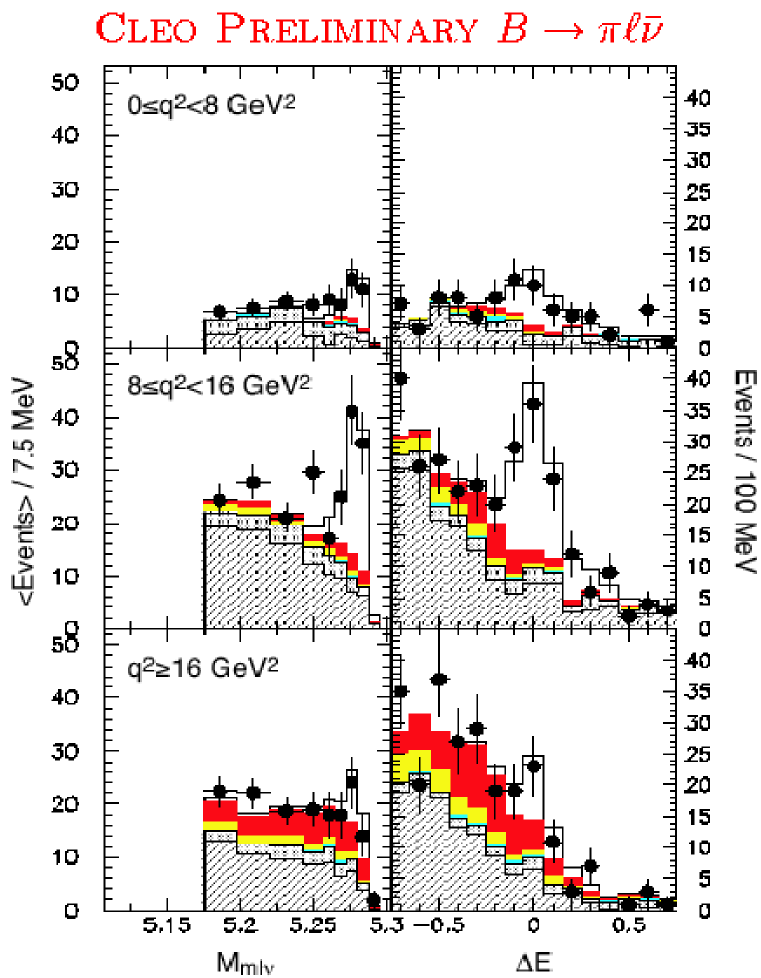
Exclusive methods

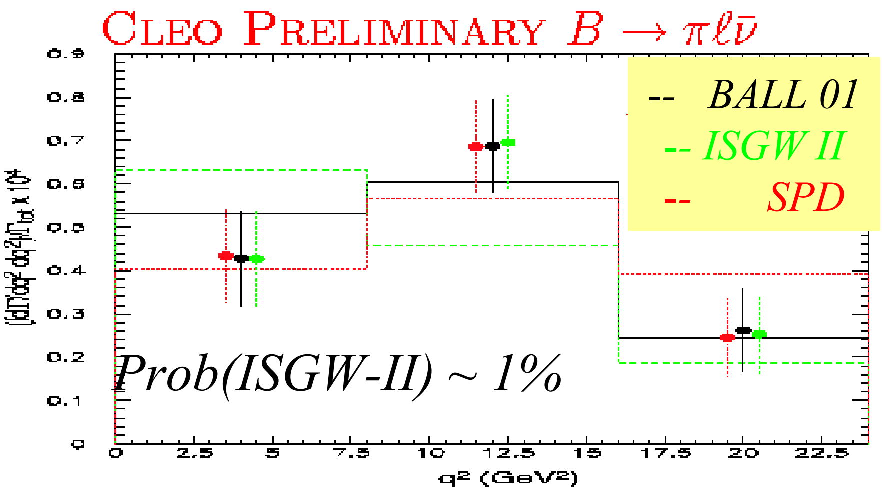
$B \to (\pi,\rho,\omega) l\ \nu$

Results from BELLE/CLEO/BABAR

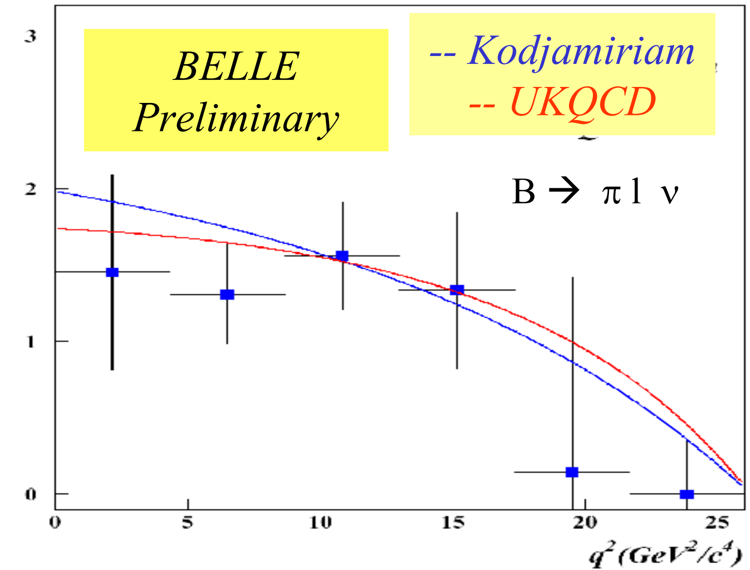
MAIN problem : large error from models

Analyses vs q^2 to distinguish between model



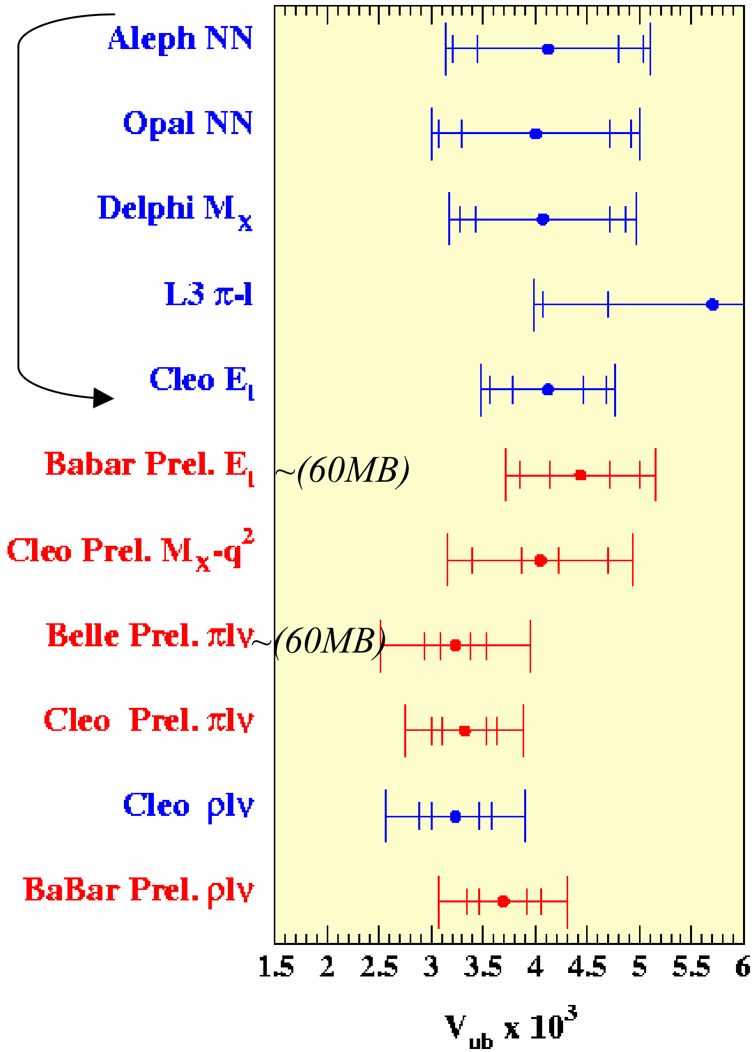


$d\Gamma/dq^2(/10^2\,ns^{-1}/4.3GeV^2/c^4)$ (corrected dist.)



M.Battaglia

V_{ub} Summary



Aleph NN	$4.12 \pm 0.67 \pm 0.62 \pm 0.35$	*INCLUSIVE*
Opal NN	$4.00 \pm 0.71 \pm 0.59 \pm 0.40$	
Delphi M_x	$4.07 \pm 0.65 \pm 0.47 \pm 0.39$	
L3 π-l	$5.7 \pm 1.0 \pm 1.3 \pm 0.5$	
Cleo E_l	$4.12 \pm 0.34 \pm 0.44 \pm 0.33$	
Babar Prel. E_l	$4.43 \pm 0.29 \pm 0.50 \pm 0.43$	
Cleo Prel. M_x-q^2	$4.05 \pm 0.18 \pm 0.63 \pm 0.60$	
Belle Prel. πlν	$3.23 \pm 0.14 \pm 0.26 \pm 0.65$	*EXCLUSIVE*
Cleo Prel. πlν	$3.32 \pm 0.21 \pm 0.23 \pm 0.47$	
Cleo ρlν	$3.23 \pm 0.23 \pm 0.25 \pm 0.58$	
BaBar Prel. ρlν	$3.69 \pm 0.23 \pm 0.27 \pm 0.50$	

At the CKM Workshop (LEP+End-Point CLEO)

V_{ub}(inclusive) = $(4.09 \pm 0.46 \pm 0.36)\ 10^{-3}$

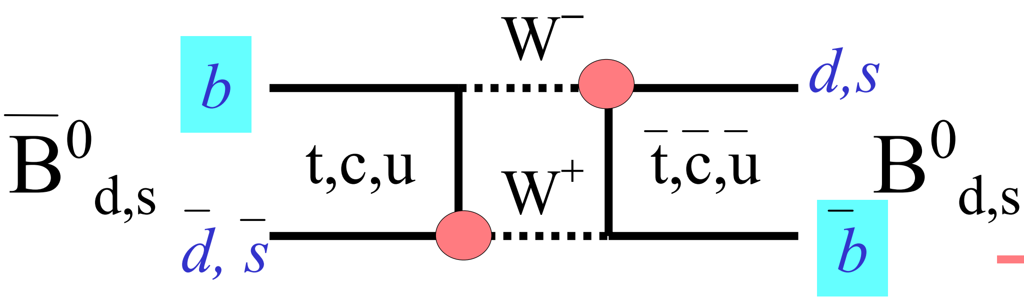
+ CLEO Exclusive results

V_{ub} =

For expert !!
Vub Working Group

B^0/ D^0 oscillations

In SM :ΔF=2 process GIM mechanism (Rate ~ $m_1^2 - m_2^2$)



Dominated by ***t*** *exchange*

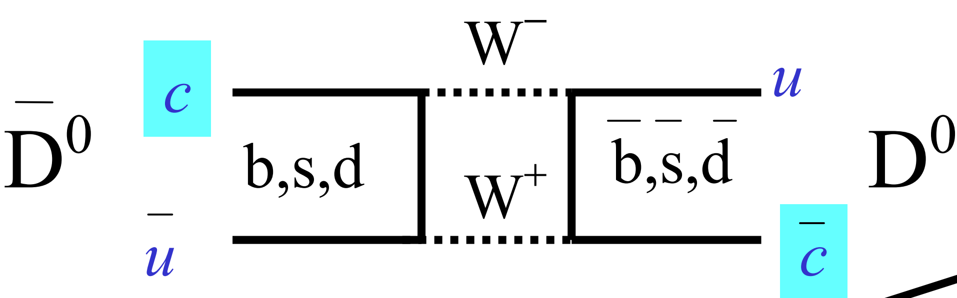
Rate LARGE

V_{td} V_{ts}

Allow to access fundamental parameters of the Standard Model

$y = \Delta\Gamma/2\Gamma \ll x = \Delta m/\Gamma$

(due to the large phase phase in B decays)



~~*b contribution ~* $V_{ub}\, m^2_b$~~

Rate ~ 0 at $SU(3)_F$ *limit*

Sensitive to long-distance QCD

....and New Physics ?

$x \gg y$

$y \sim x \leq 10^{-3}$

Oscillations in B system

The probability that the meson B^0 produced (by strong interaction) at $t = 0$ transforms (weak interaction) into $\overline{B^0}$ (or stays as a B^0) at time t is given by :

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

Δm_q can be seen as **an oscillation frequency : 1 ps^{-1} = 6.58 10^{-4} eV**

$$\Delta m_d \propto f_{B_d}^2 B_{B_d} |V_{cb}|^2 \lambda^2 |V_{td}|^2 \propto f_{B_d}^2 B_{B_d} |V_{cb}|^2 \lambda^2 ((1-\bar{\rho})^2 + \bar{\eta}^2)$$

$$\Delta m_s \propto f_{B_s}^2 B_{B_s} |V_{td}|^2 \propto f_{B_s}^2 B_{B_s} |V_{cb}|^2$$

$\Delta m_s \approx 20 \Delta m_d$

Δm_s oscillations fast

Excellent time resolution required

$$\frac{\Delta m_d}{\Delta m_s} \propto \frac{f_{B_d}^2 B_{B_d}}{f_{B_s}^2 B_{B_s}} \lambda^2 ((1-\bar{\rho})^2 + \bar{\eta}^2)$$

ξ^2

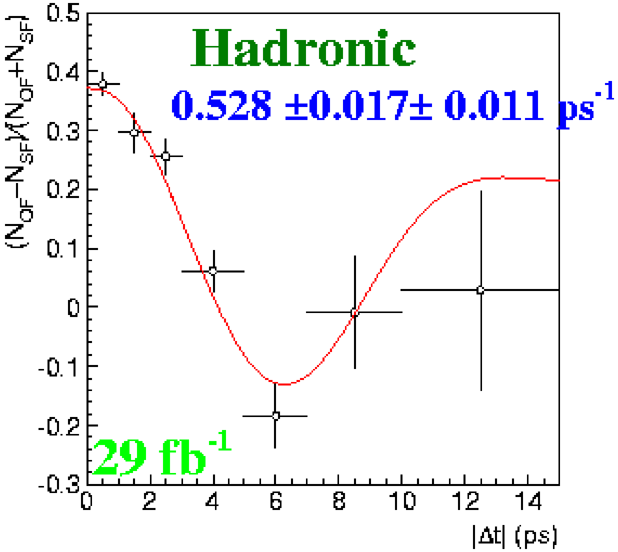
ξ better know than $f_B B_B$

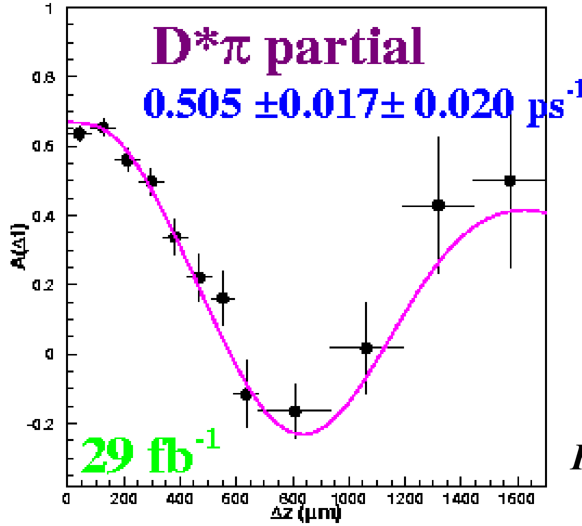
$\Delta m_d / \Delta m_s$ performant contraint for $\bar{\rho}$ and $\bar{\eta}$

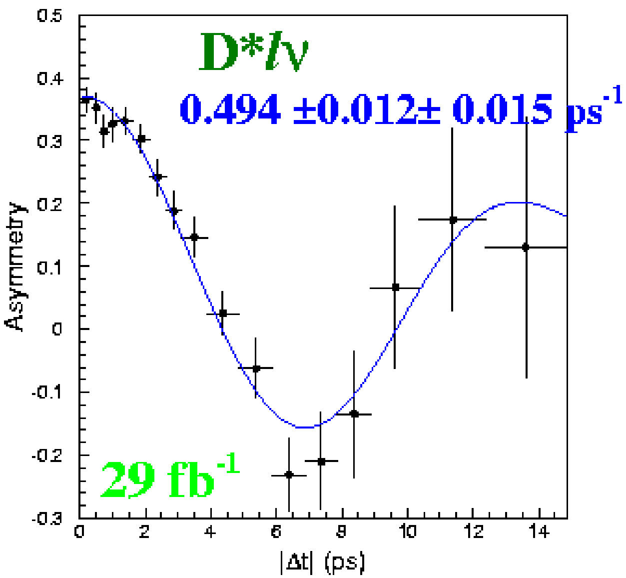
Δm_d

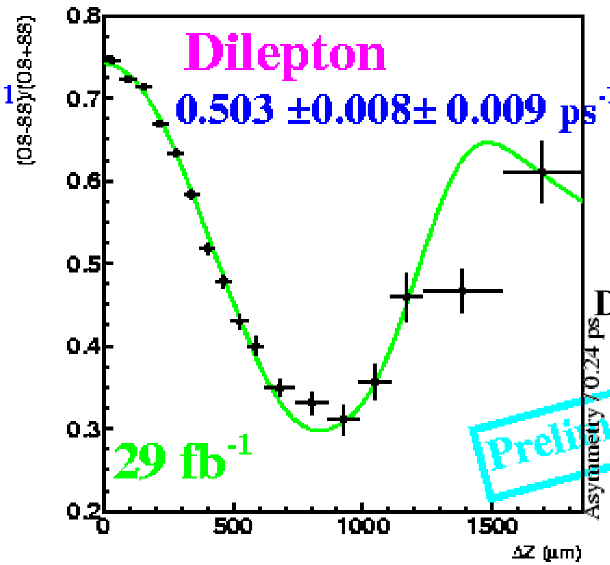
C. Voena(BaBar)
F. Ronga (Belle)

*Many new measurements : **4** from **Belle*** *and* ***3** from **Babar***

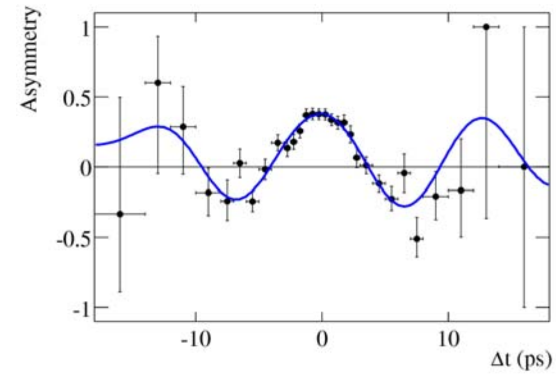




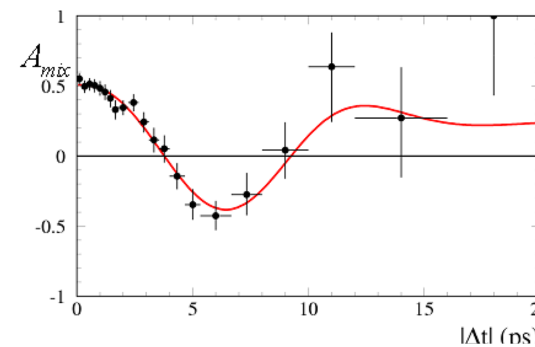




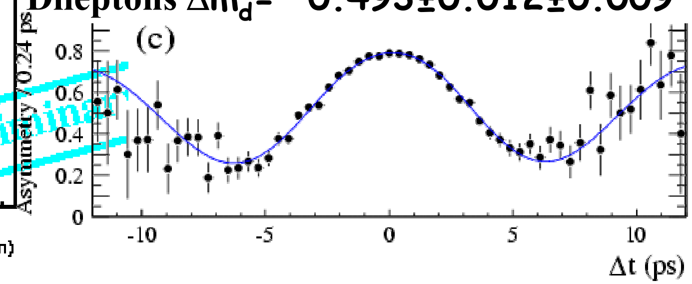
*D*lν* Δm_d=0.492±0.018±0.013ps^{-1}



Hadronic Δm_d= 0.516±0.016±0.010 ps



Dileptons Δm_d= 0.493±0.012±0.009 ps

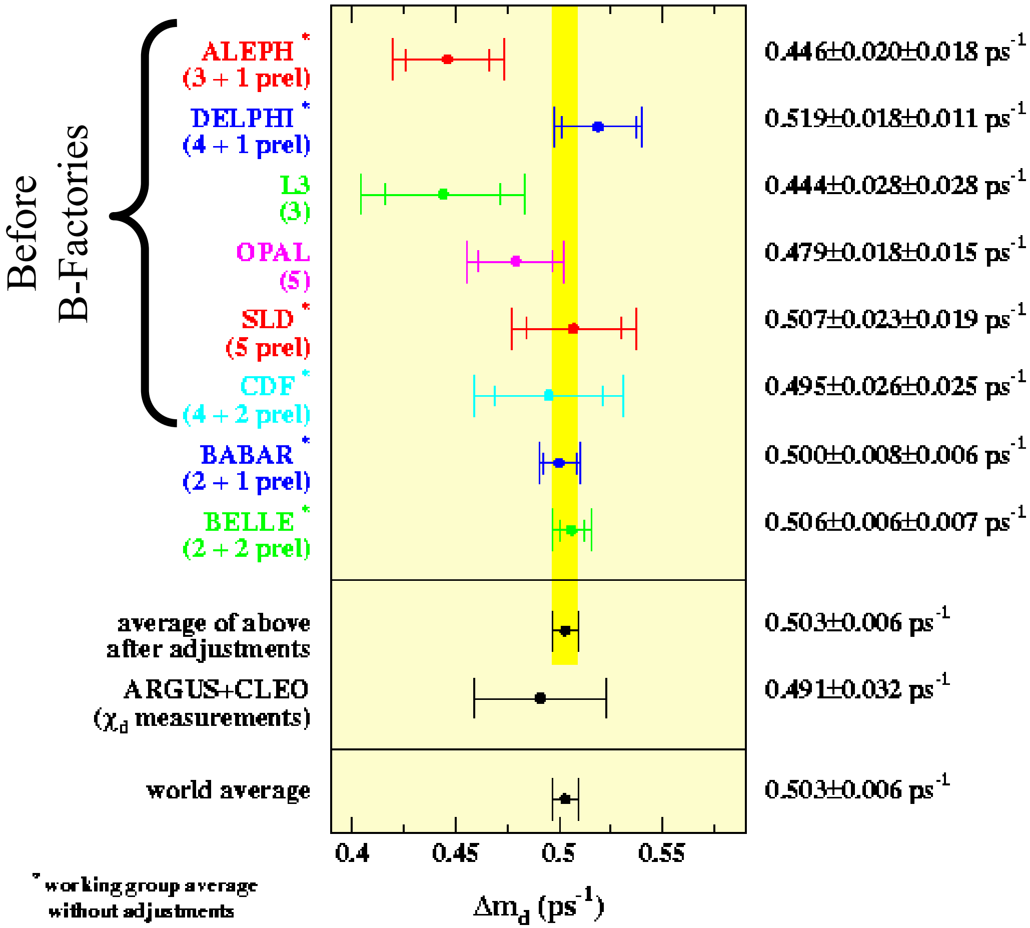


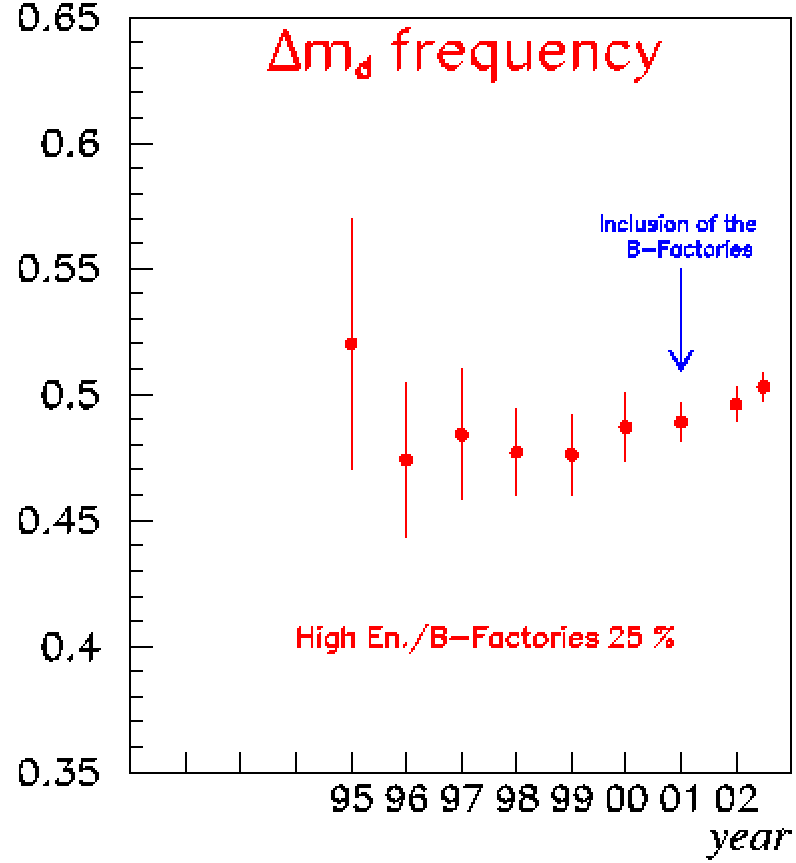
LEP/SLD/CDF measured precisely the $\Delta \mathbf{m_d}$ frequency

$\Delta \mathbf{m_d} = 0.498 \pm 0.013\ ps^{-1}$ LEP/SLD/CDF **(2.6 %)**

B-factories confirmed the value improving the precision by a factor 2

$\Delta \mathbf{m_d} = 0.503 \pm 0.006\ ps^{-1}$ LEP/SLD/CDF/B-factories **(1.2%)**





Δm_s

S. Willocq(SLD/LEP)

Combine many different analyses which give limits

Combination using the **amplitude method**

$$P_{B_s^0 \to B_s^0(\overline{B}_s^0)} = \frac{1}{2} e^{-t/\tau_s} (1 \pm A \cos \Delta m_s t)$$

Measurement of A at each $\Delta \mathbf{m_s}$

Combination using A and σ_A

At given $\Delta \mathbf{m_s}$

A = 0 no oscillation

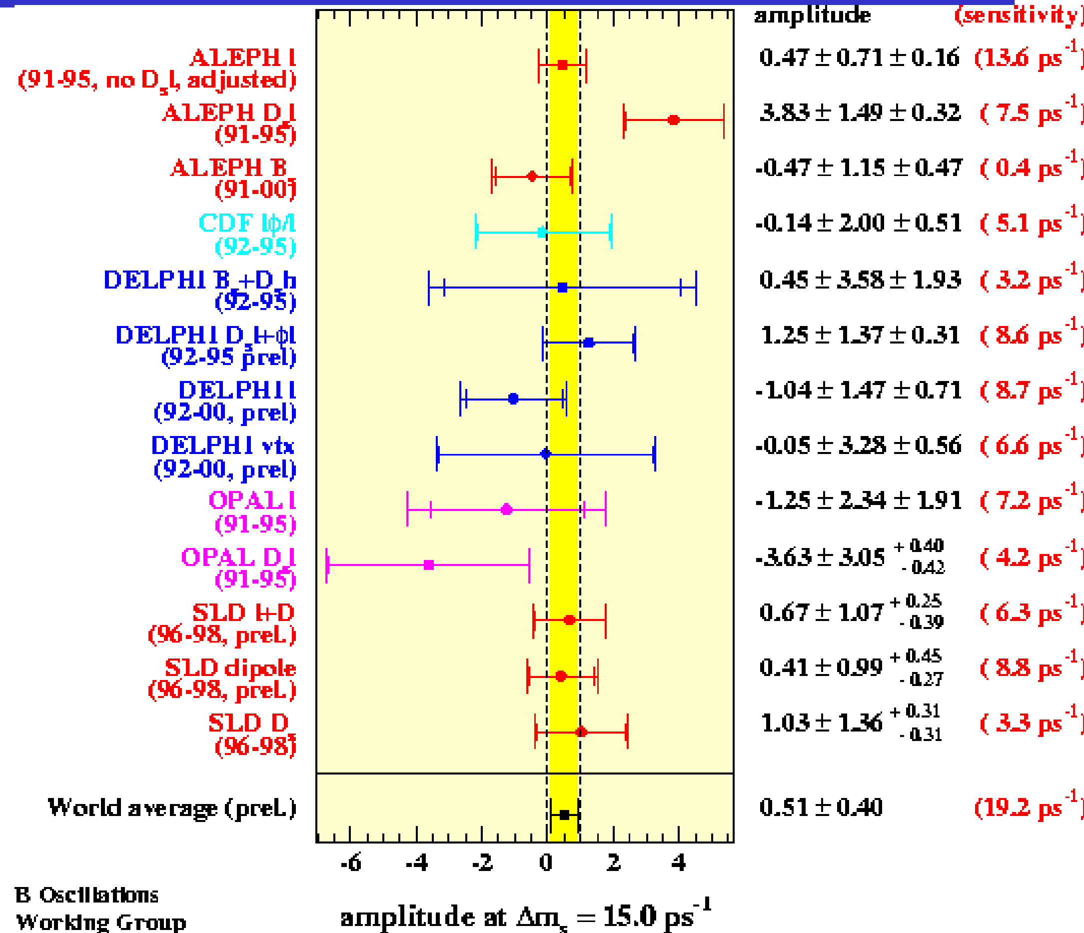
A = 1 oscillation

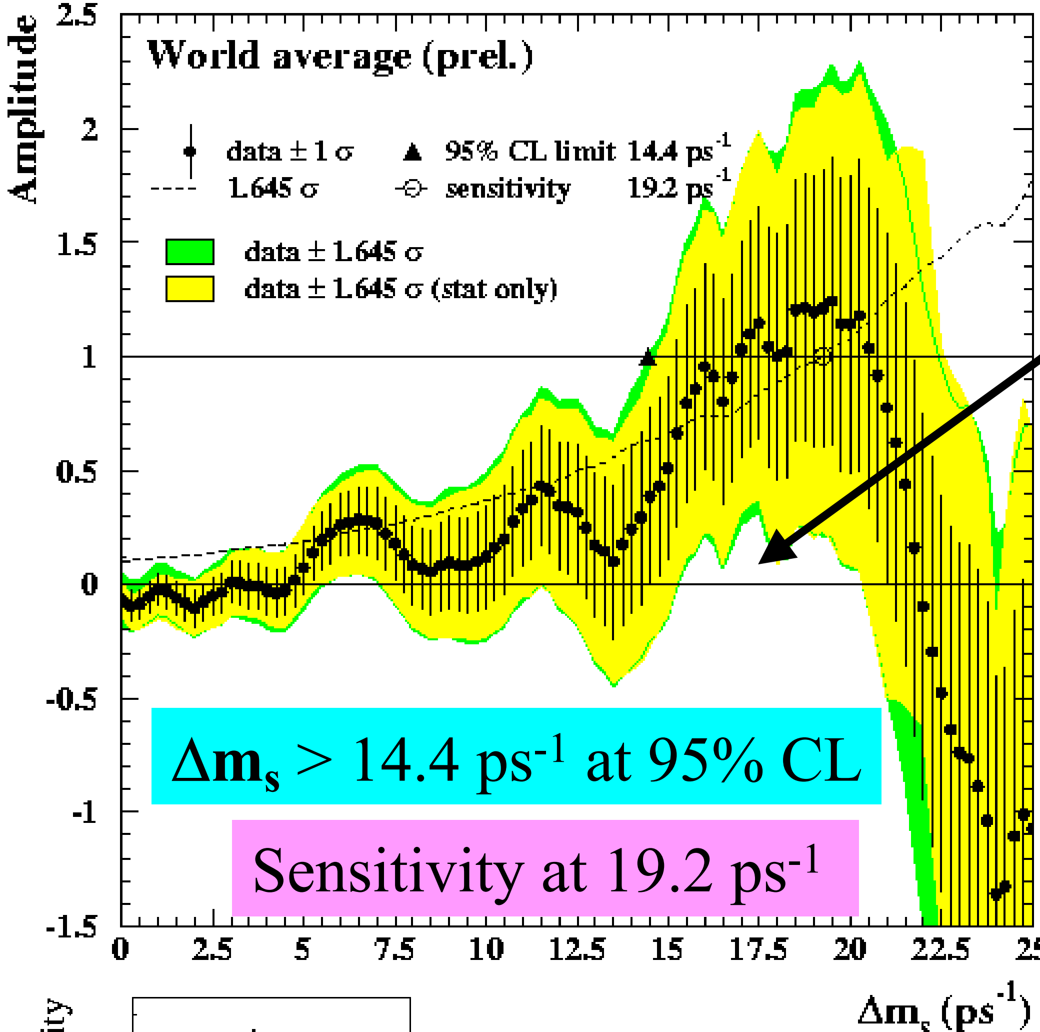
$\Delta \mathbf{m_s}$ excluded at 95% CL

$$A + 1.645\sigma_A < 1$$

Sensitivity same relation with A = 0

$$1.645\sigma_A < 1$$

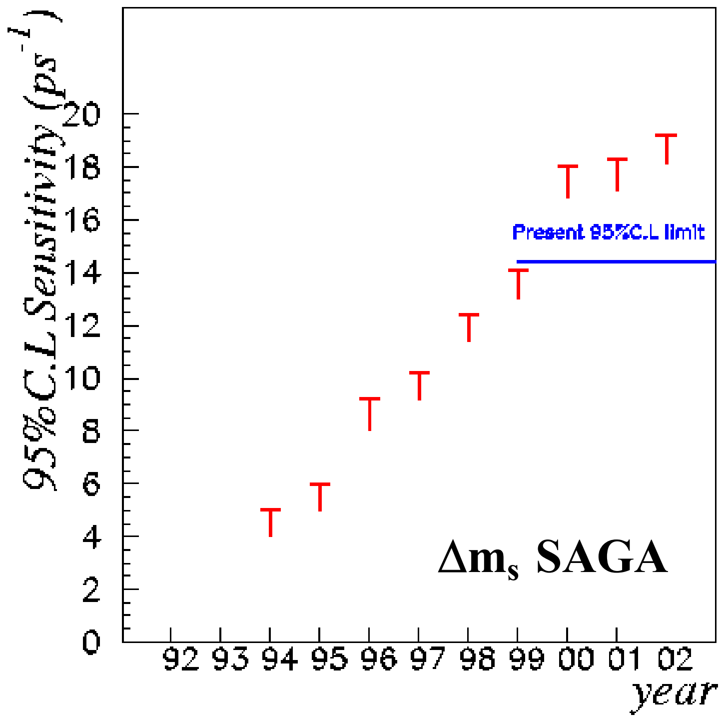


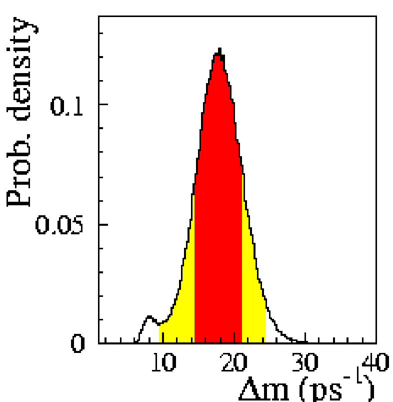


"Hint of signal"
at $\Delta \mathbf{m_s} \sim 17.5$ ps^{-1}
with significance at 2.3 σ

$\Delta \mathbf{m_s} > 14.4$ ps^{-1} at 95% CL

Sensitivity at 19.2 ps^{-1}





Expectation in
The Standard Model

$\Delta \mathbf{m_s}$ 17.5 ± 3.3 ps^{-1}
<24.4 @ 95% CL

Including $\Delta \mathbf{m_s}$ →

$\Delta \mathbf{m_s}$ 17.6 +(2.0)(-1.3) ps^{-1}
<20.9 @ 95% CL

The CKM people at work……

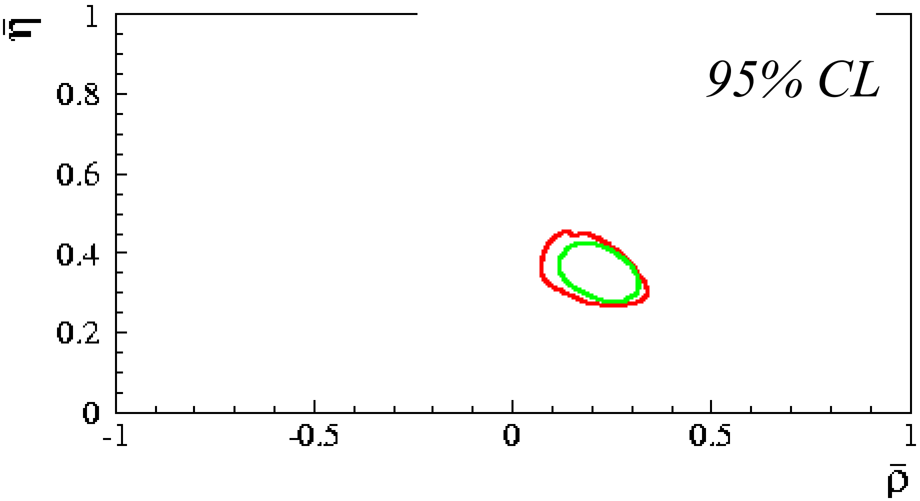
H.Bosch Players of GO

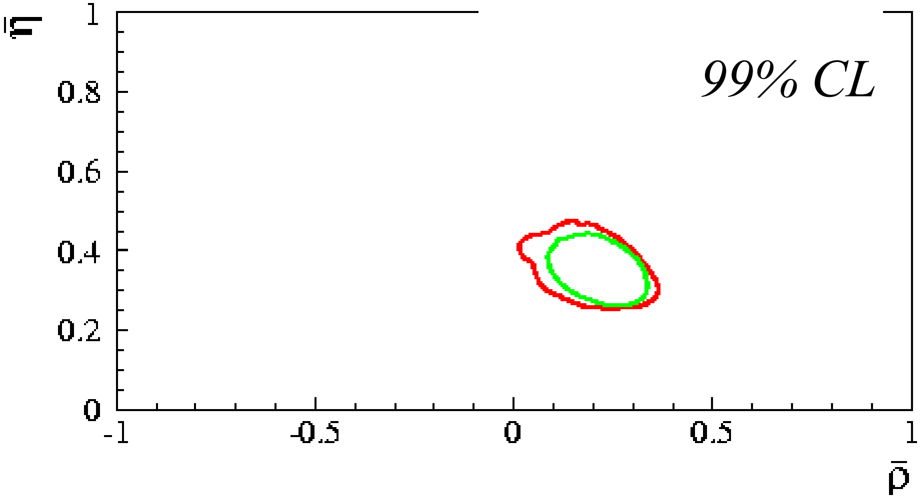
碁

F. Parodi

Fit Comparison

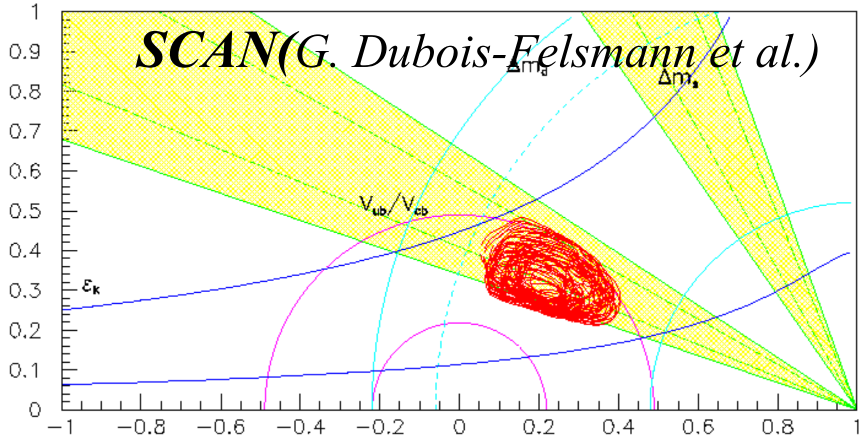
Frequentist(*A. Hocker et al.)*/ **Bayesian(***M.Ciuchini et al).*





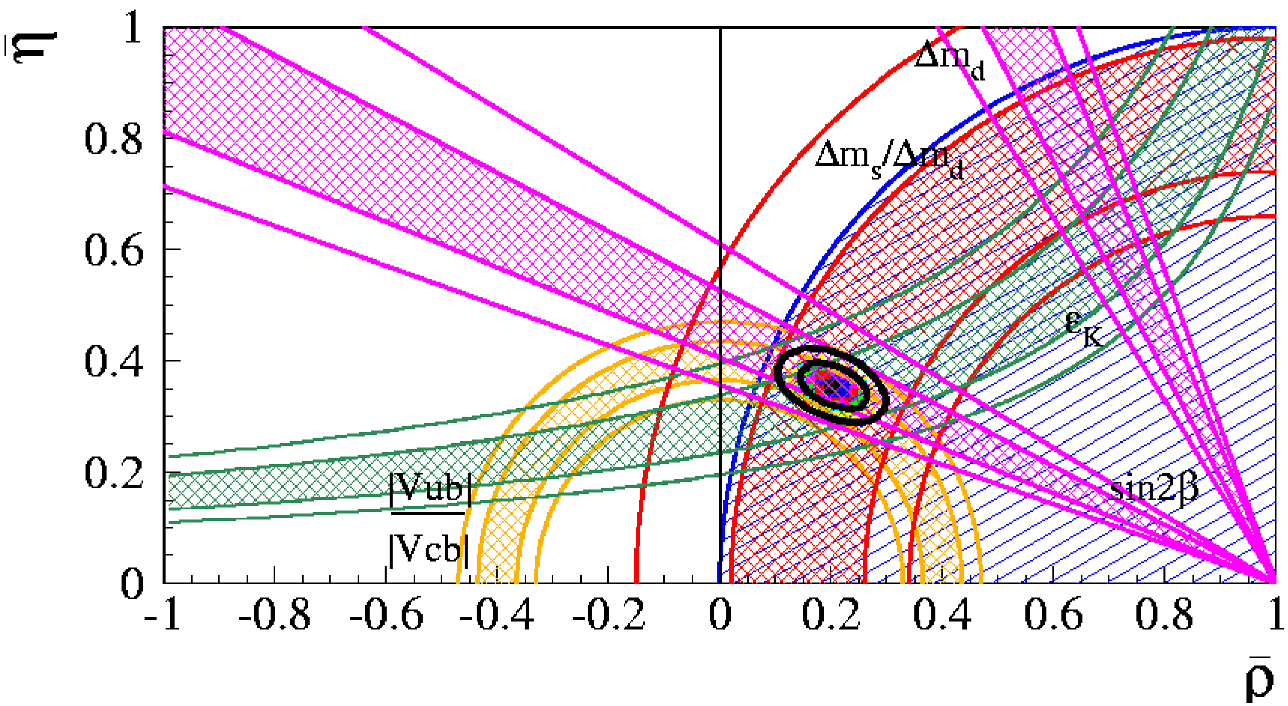
Ratio RFit/Bayesian Method			
Parameter	5% CL	1% CL	0.1% CL
$\bar{\rho}$	1.42	1.34	1.12
$\bar{\eta}$	1.18	1.12	1.05
$\sin 2\beta$	1.16	1.16	1.17
γ°	1.51	1.31	1.09

Quantitative differences in the selected (ρ,η) regions between Bayesian and Frequentist are small



Both qualitatively comparable with scan

Constraints : V_{ub} , V_{cb} , ε_K , Δm_d , Δm_d , $\sin 2\beta$



$V_{cb} = (40.4 \pm 0.8)10^{-3}$

$\bar{\rho} = 0.203 \pm 0.040$

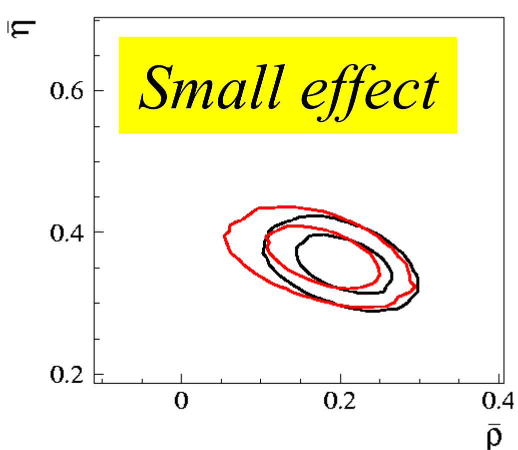
$\eta = 0.335 \pm 0.027$

$\sin 2\beta = 0.734^{+0.045}_{-0.034}$

$\gamma = (59.5^{+6.5}_{-5.5})^\circ$

$\sin 2\alpha = -0.20^{+0.23}_{-0.20}$

$\Delta m_s = 17.6^{+2.0}_{-1.3}\ ps^{-1}$



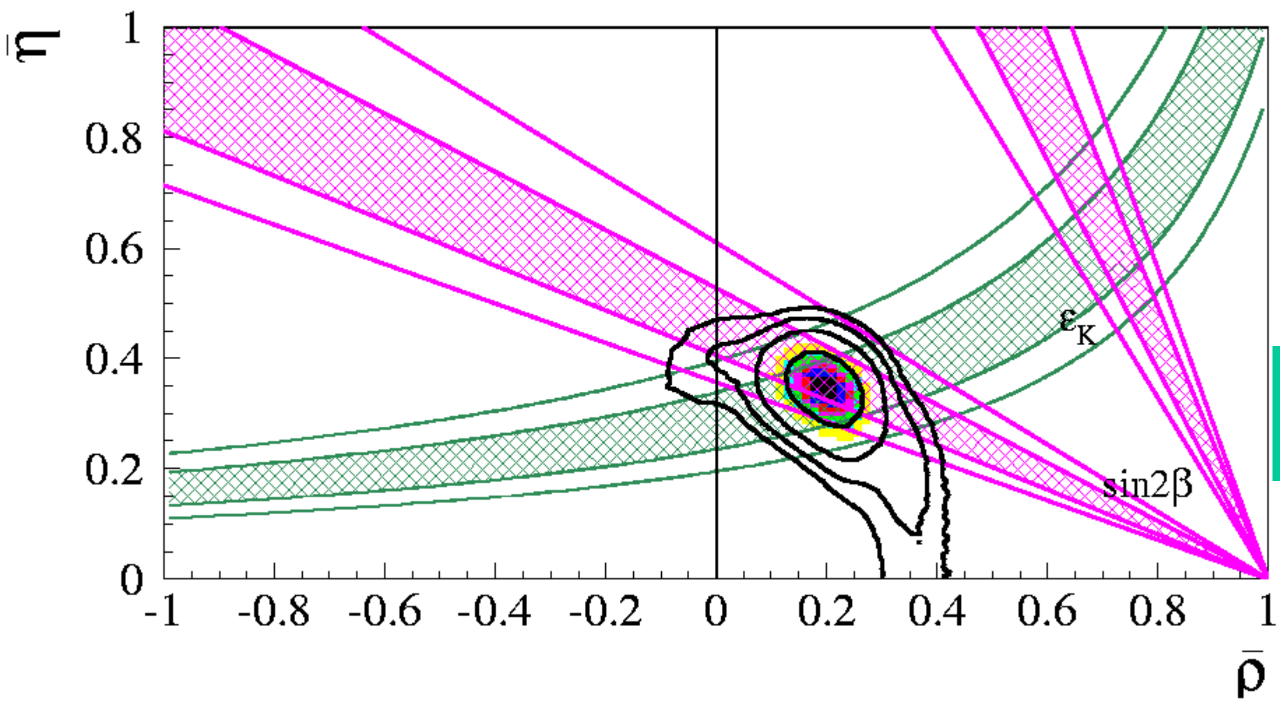
Effect of the "chiral logs" in f_B and ξ

L.Lellouch(PLENARY)
D. Becirevic

$\bar{\eta} = 0.365 \pm 0.028$ *No change*

$\bar{\rho} = 0.177^{+0.047}_{-0.044}$ *-0.5σ shift +15% error*

($+0.7\sigma$ for γ)



CP Violation

Very important in reducing the allowed region

$\sin 2\beta = 0.762 \pm 0.064$ direct from $B \rightarrow J/\psi\, K^0_s$

$\sin 2\beta = 0.734^{+0.055}_{-0.045}$ *"indirect"*

Coherent picture of CP Violation in SM

There is more to come……

…but I think is time to conclude

P.Brueguel The Elder (1567)

The Peasent Wedding

15 Years of B Physics behind,

old actors are still quite active (LEP/SLD/CLEO)

B-factories have already produced a lot and interesting results

Many measurements are already very precise

Lifetimes

B^0-B^+ 1% B_s -Λ_B ~ 4%

D^0 3‰ ,D^+ 3‰ ,D_s 2% ,Λ_C 3% ,Ξ^+_C 6% , Ξ^0_C 10% , Ω_C 15%

B decays

Many new results from B-factories

Radiative/Leptonic/Open Charm/Charmonium/Charmless…..

V_{cb} *enters in a mature age. It is a precise measurement ~ (2-3)%*

V_{ub} many different methods are on the market (~ 10%)

if we were really able to exploit all of them ...!

Often the limitation are from theory. It is very important to define extra measurements to address those uncertainties (ex: moments analysis)

Need close contact with theorists, new ideas, some fanstasy !

Δm_d *at 1% fantastic experimental effort*

Oscillations

The **Δm_s** *saga*. **Δm_s** > 14.4 ps^{-1} at 95% CL

(B_s oscillates 30 times faster than B_d)

Tevatron we tell us if we were close to the signal

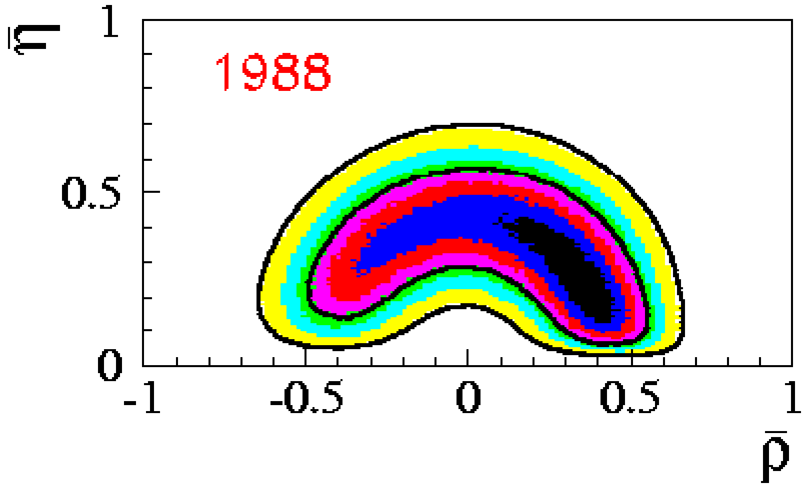
D^0 . A window for new physics. New results are about to come.

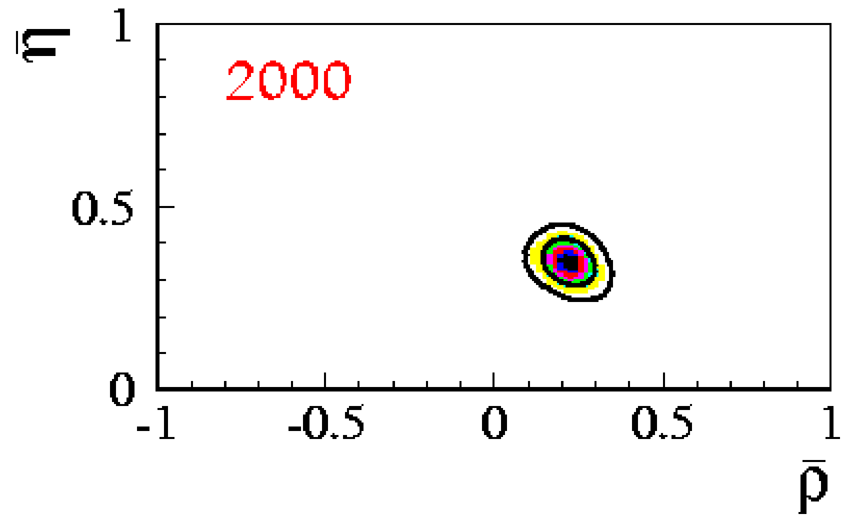
Important improvements on Lattice QCD / OPE / HQET

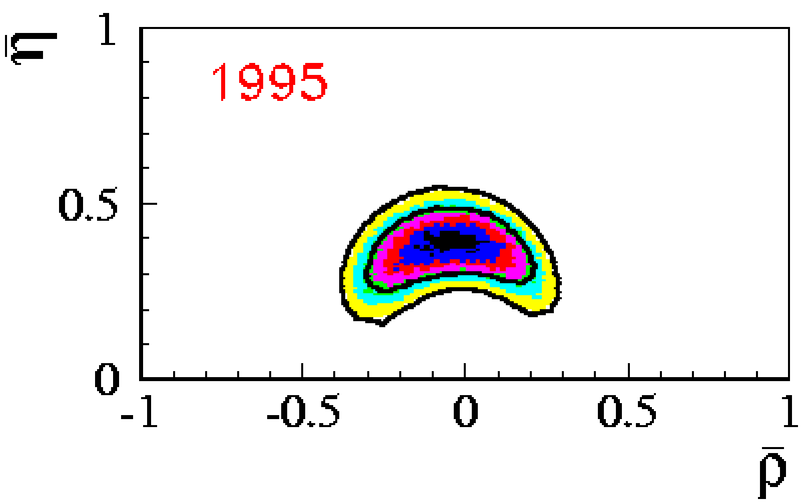
Charm physics play a role in understanding the QCD in a non-perturbative regime. (crucial the impact of CLEO-C)

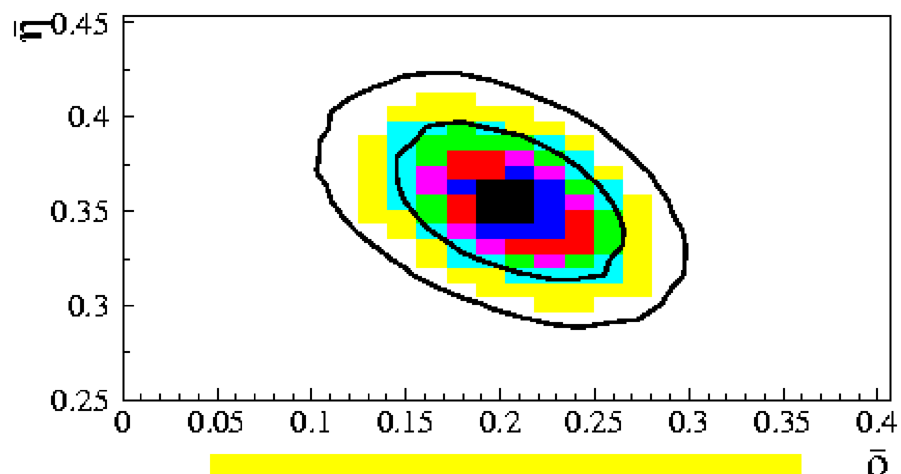
So far the Standard Model is Standardissimo

Sad !







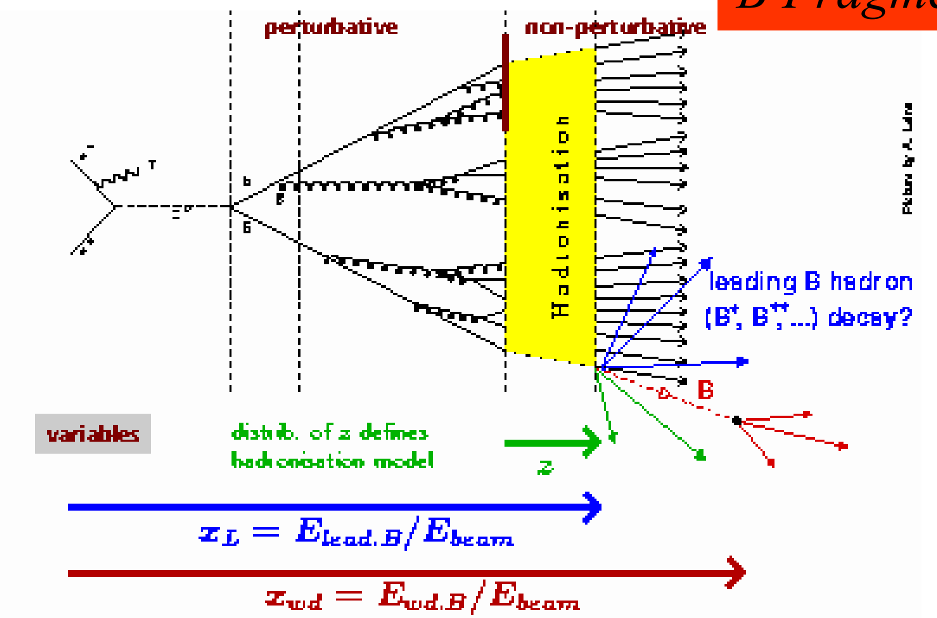


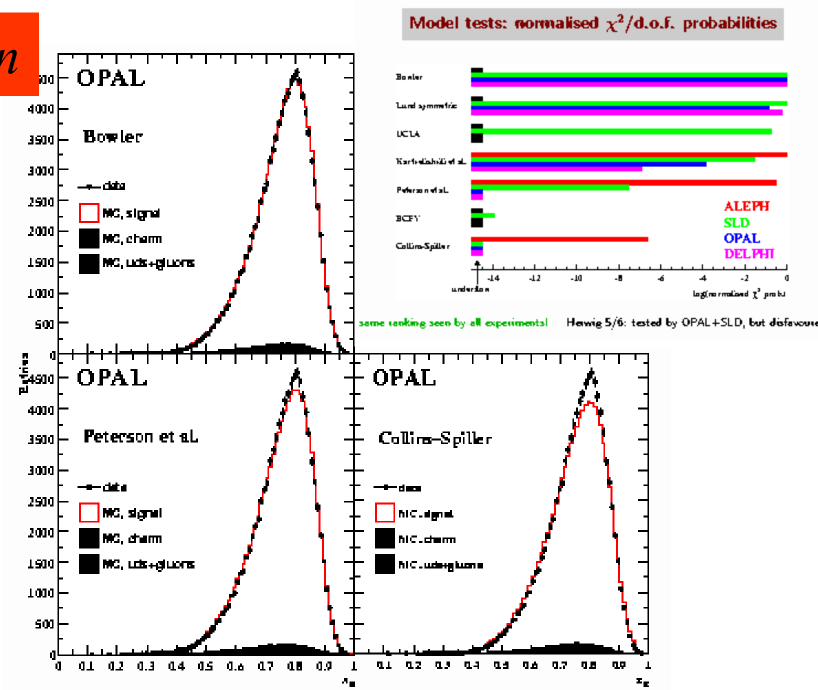
It is a question of scale …
now we have to look
to effects below 10% !

Some More Material

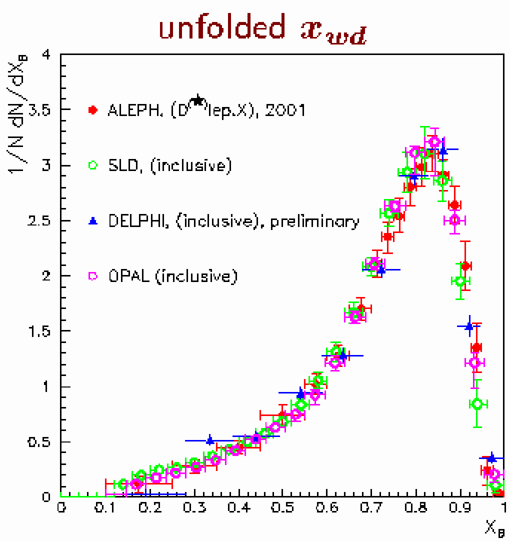
K. Harder (LEP/SLD)

B Fragmentation





New method



description of the shape in terms of x_{wd} moments:

$$D_i = \int_0^1 dx\, x^{i-1} D(x)$$

values from *very* preliminary LEP/SLD combination (P. Roudeau, E. Ben Haim):

$$\begin{aligned} D_1 &= 1 \text{ (definition)} \\ \langle x_{wd} \rangle = D_2 &= 0.7151 \pm 0.0025 \\ D_3 &= 0.5426 \pm 0.0012 \\ D_4 &= 0.4268 \pm 0.0010 \\ D_5 &= 0.3440 \pm 0.0017 \end{aligned}$$

motivation: for future tests of hadronisation models without redoing analysis
higher moments needed for application in hadron collider physics

Observation of the $\eta_C(2S)$ in exclusive B decays

Y.Watanabe(Belle)

$$\eta_C = J^{PC} = 0^{-+}$$

$\eta_C(1S) = \eta_C$: singlet S charmonium state

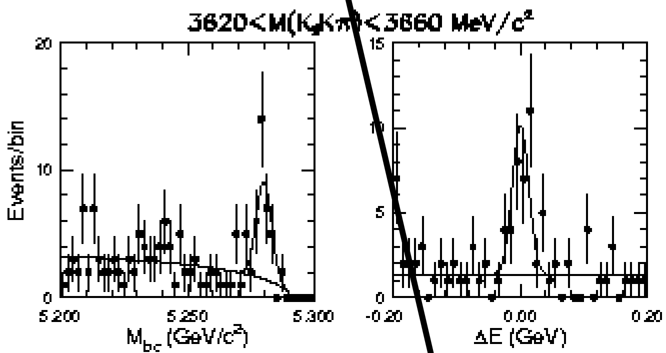
$\eta_C(2S)$: n=2 singlet S charmonium state

Heavy Quark Potential Model

$$\Delta M(J/\psi(2S)-\eta_C(2S)) < \Delta M(J/\psi-\eta_C)$$

$$3625\,MeV < \eta_C(2S) < 3645\,MeV$$

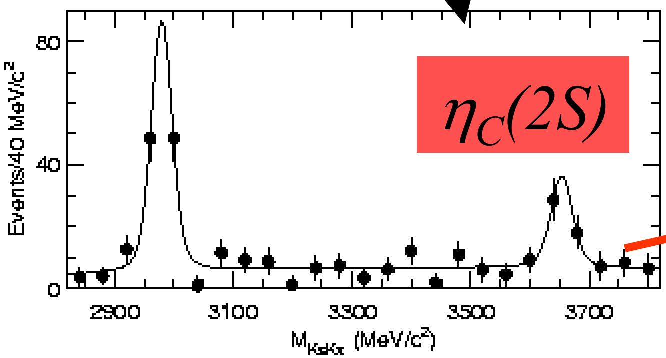
$B \rightarrow K(K_S K^- \pi^+)$ BELLE



Why in exclusive B decays ?

Radial excitations (n=2) are expected to be copiously produced in B exclusive decays

(6σ significance)



$$M\,(\eta_C(2S)) = 3654 \pm 6 \pm 8\ MeV$$

$$\Gamma\,(\eta_C(2S)) < 50\ MeV$$

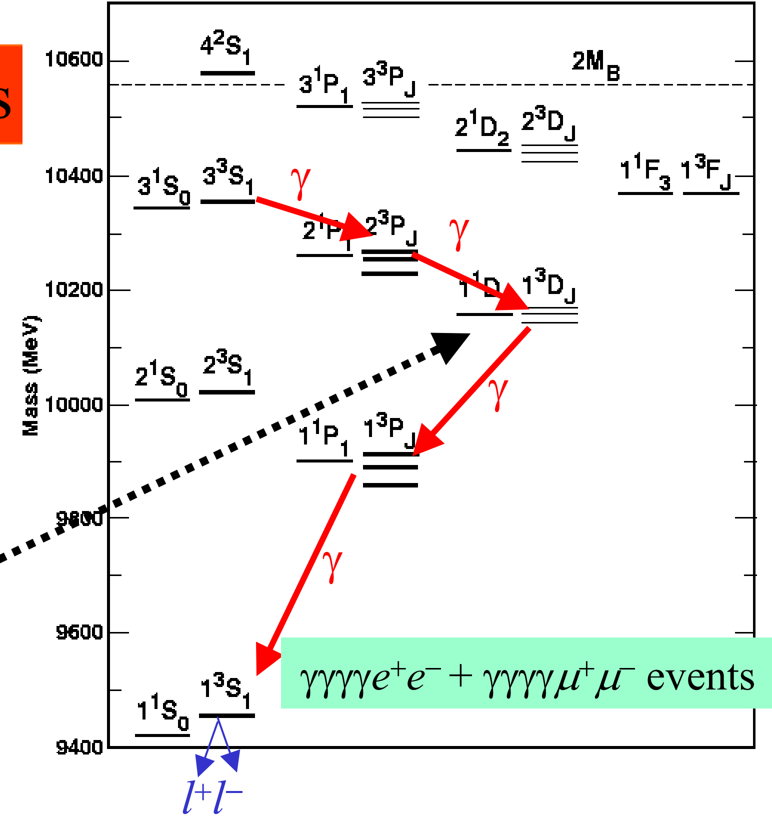
The evidence from Crystall Ball(1982) $M = 3594 \pm 5 MeV$

Υ Spectroscopy Discovery of Υ(1D) states

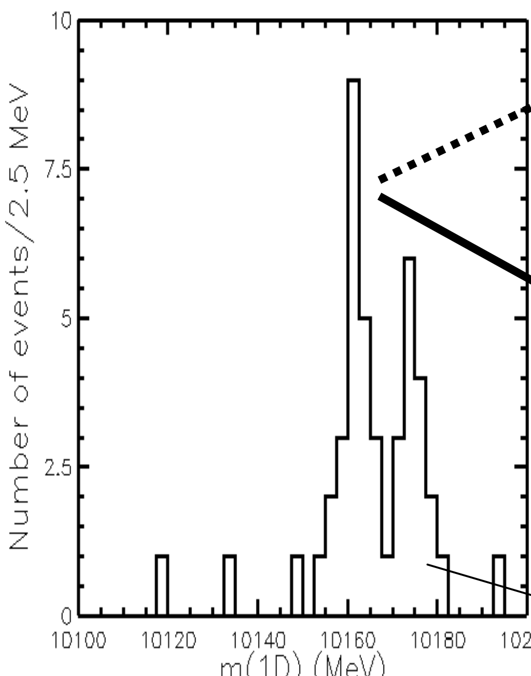
Last stable quarkonium state discovered :

$\chi_b(2P_J)$, $\chi_b(1P_J)$ in 1982/1983

No stable L=2 meson observed ever



CLEO-III 4.7 10^6 Υ(3S)



9.6σ significance from the compatibilty with the wonderful decay cascade through the Υ(1D)

$BR(\gamma\gamma\gamma\gamma\ l^+ l^-) = 3.3 \pm 0.6 \pm 0.5\ 10^{-5}$

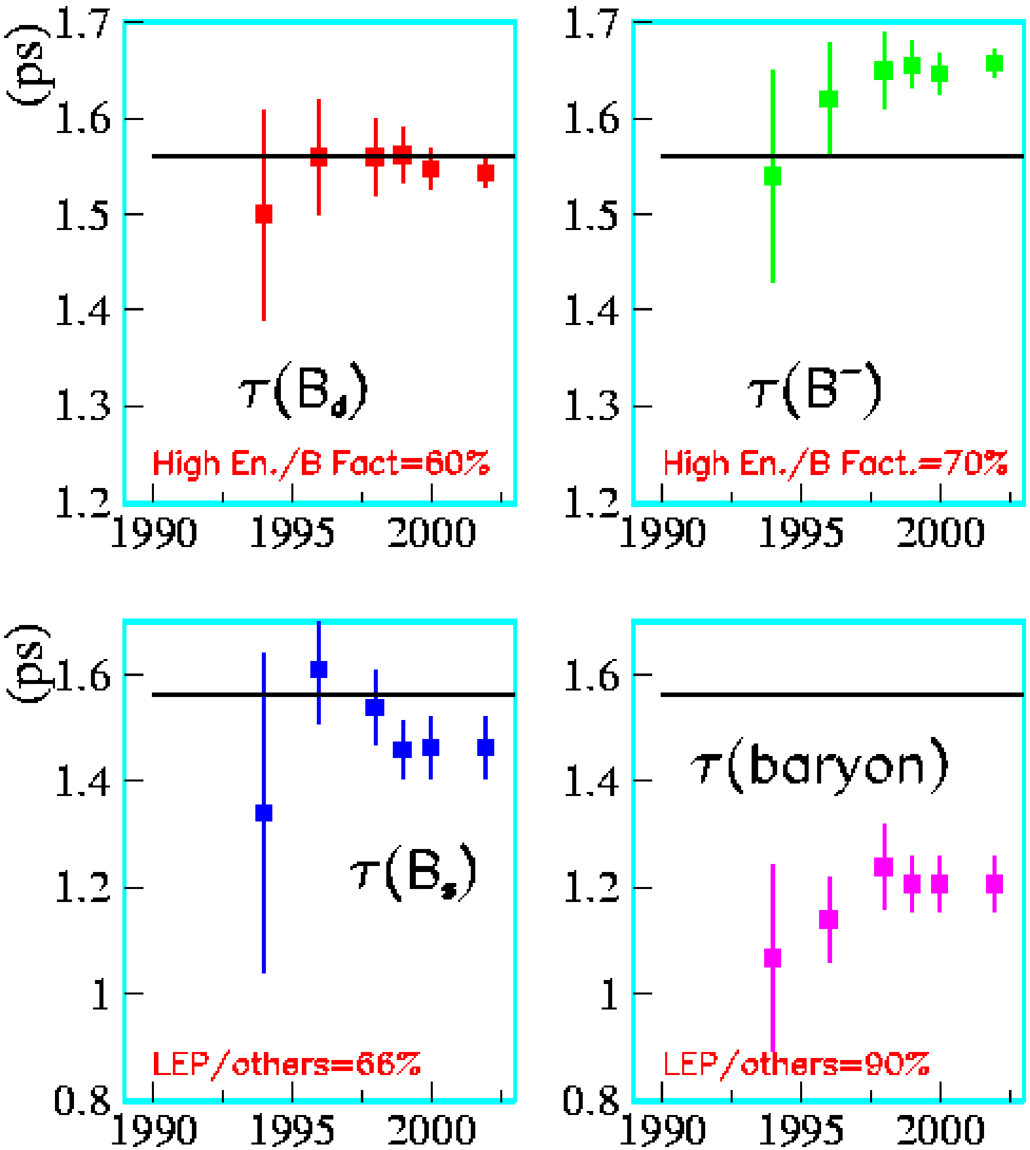
Predicted by Godfrey&Rosner $3.5\ 10^{-5}$

$M(\ \Upsilon(1^3D_2)\ ) = 10161.2 \pm 0.7 \pm 1.0$ MeV

More likely hypothesis,but 1^1D_2 *not completely ruled out*

? *MORE data* are being accumulated

B Hadron Lifetimes History



Expected Improvements

$\tau(B^+)/\ \tau(B^0)$

Already very precise !

improvements from B-factories

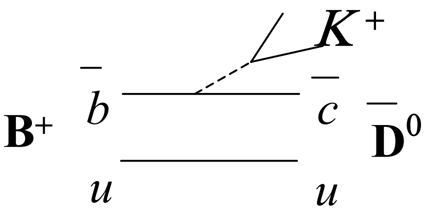
But more important

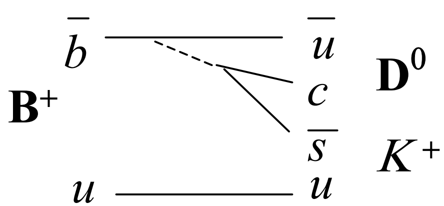
$\tau(B^0_s)$ and $\tau(\Lambda_B)$ …. and Ξ_B B_c, Ω_c

from Tevatron

$B \rightarrow$ OPEN CHARM (DK) and (D_{CP} K)

POSSIBLE WAY OF DETERMINING THE ANGLE γ



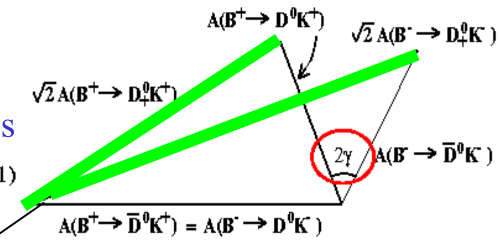


$$\sqrt{2}A(B^{\pm} \rightarrow D^0_+ K^{\pm}) = A(B^{\pm} \rightarrow D^0 K^{\pm}) + A(B^{\pm} \rightarrow \overline{D}^0 K^{\pm})$$

$$D^0_{\pm} \equiv 1/\sqrt{2}\,(D^0 \pm \overline{D}^0)$$

$D_{\pm}$ are CP eigenstates

Gronau & Wiler; Dunietz (1991)



As previously , need to deal with strong interactions :

Possibility to determine γ through amplitude relations

$B \rightarrow D^0 K^{*-} = (5.4 \pm 0.6 \pm 0.8)10^{-4}$ BELLE

verify

$B \rightarrow D^0 \pi^- / B \rightarrow D^0 K^- = (8.31 \pm 0.35 \pm 0.13)\%$ BABAR (81MB)

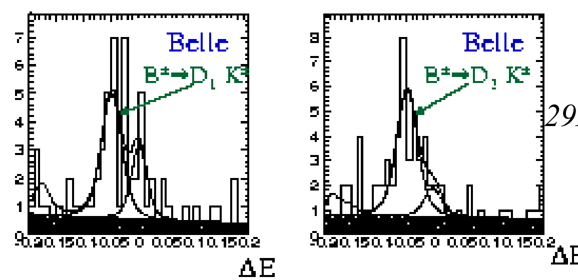
Interesting Alternative

Direct CP Asymmetry in $B \rightarrow D_{CP}K$

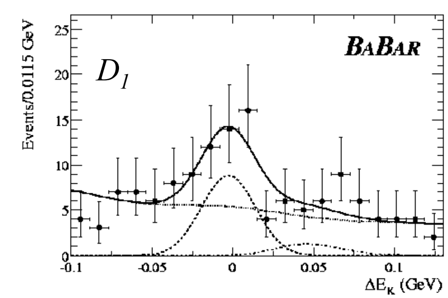
(D_1) $CP = +1$ $D^0 \rightarrow K^+K^-, \pi^+\pi^-$; (D_2) $CP = -1$ $D^0 \rightarrow K_s\pi^0, K_s\eta, K_s\eta', K_s\phi, K_s, \omega$

$$r = \frac{|A(B^- \rightarrow \overline{D}^0 K^-)|}{|A(B^- \rightarrow D^0 K^-)|} \approx 0.1$$

$$A_{CP} = \frac{BR(B^- \rightarrow D^0_{CP}K^-) - BR(B^+ \rightarrow D^0_{CP}K^+)}{BR(B^- \rightarrow D^0_{CP}K^-) + BR(B^+ \rightarrow D^0_{CP}K^+)} \approx \pm r \sin\Delta\delta_S \sin\gamma$$



29MB



81MB

$A_{CP}(B^{\pm} \rightarrow D_1 K^{\pm}) = 0.29 \pm 0.26 \pm 0.05$ (Belle)

$= 0.17 \pm 0.23 + 0.09(-0.08)$ (Babar)

$A_{CP}(B^{\pm} \rightarrow D_2 K^{\pm}) = -0.22 \pm 0.24 \pm 0.04$ (Belle)

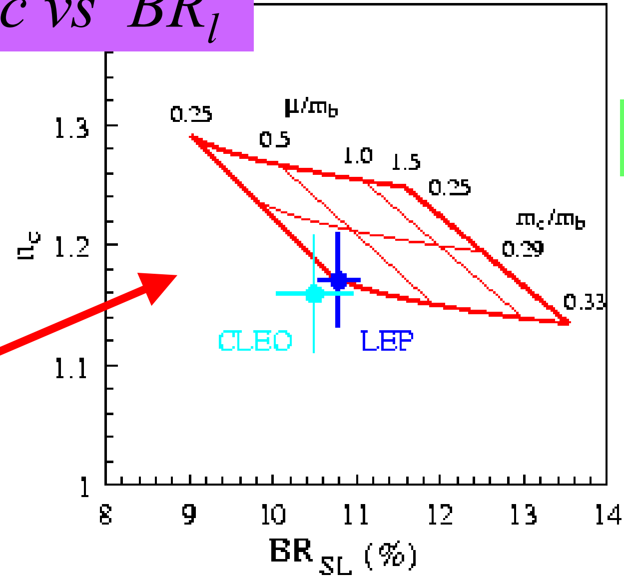
Charm multiplicity : nc vs BR_l

BR_l is on the low side of the theo. expectation

Possible explanation : effective c mass low → large b→ccs(d)

$n_c = n_c + n_c$ is NEGATIVELY CORRELATED to BR_l

10 Years of exper. and theo. efforts

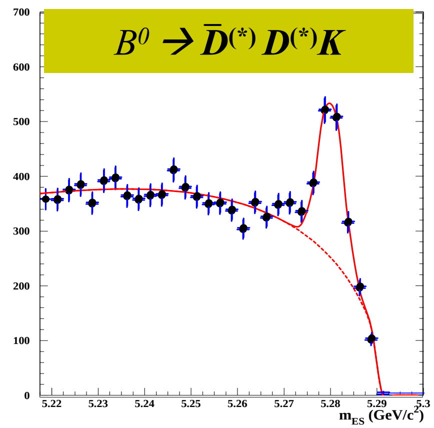


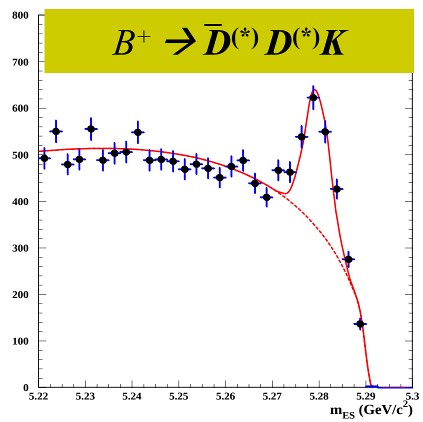
$m_c/m_b \sim 0.3$

$\mu \sim 0.35$
low scale ?

BaBAR

B Decays to ***$D^{(*)}$ $D^{(*)}K$ in 22 decay modes (82MBB)***





$B^0 \rightarrow D^{(*)} \bar{D}^{(*)}K = 4.3 \pm 0.3 \pm 0.6$ %

$B^+ \rightarrow D^{(*)} \bar{D}^{(*)}K = 3.5 \pm 0.3 \pm 0.5$ %

NEXT to DO

Precision dominated by the poor knowledge of

Charm Branching ratio CLEO-C mandatory

B decays in charmed baryons from B-Factories

measure exclusively the number of charm in decays
(other contributions than ccs and charmonium ?)

$B \rightarrow$ Baryons

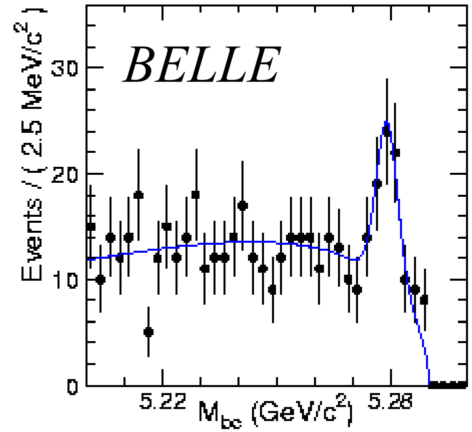
R. Chistov(Belle)

Stringent limit on $B \rightarrow$ baryon antibaryon $Br(B \rightarrow p\bar{p},\ \Lambda\bar{\Lambda},\ p\bar{\Lambda} < (1.2, 1.0, 2.2)\ 10^{-6}$

Dominanace of multi-body final states

$B^0 \rightarrow D^{*-} p\bar{p}\pi^+, D^{*-} p\bar{n}$ (CLEO)

$Br(B^\pm \rightarrow p\bar{p}K^\pm) = 4.3 + 1.1(-0.9) \pm 0.5)\ 10^{-6}$



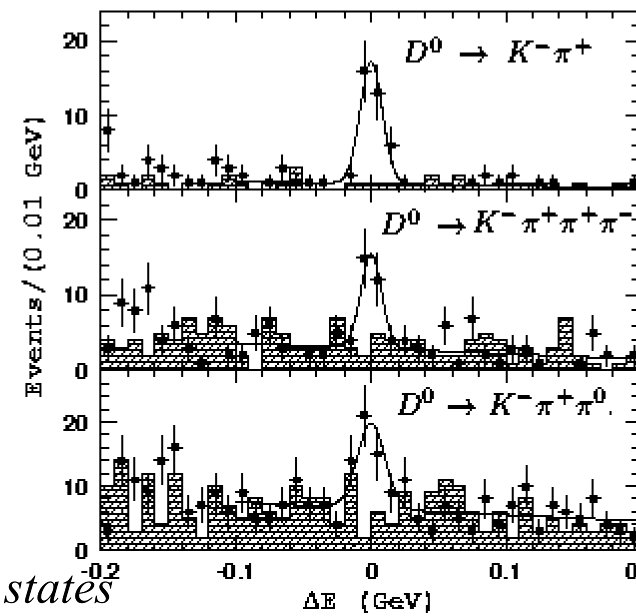
Also three-body signals with Λc

Observation $B^0 \rightarrow \bar{D}^{(*)} p\bar{p}$

(color suppressed)

Sizeable as suggested by

$B^0 \rightarrow D^0\pi^0, D^0\eta, D^0\omega$



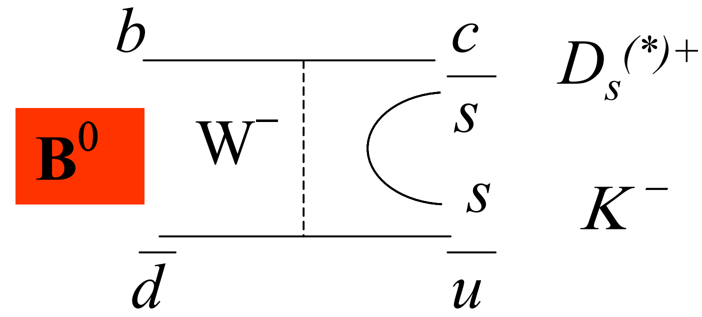
$Br(B^0 \rightarrow D^0 pp) = (1.18 \pm 0.15 \pm 0.16)10^{-4}$

$Br(B^0 \rightarrow D^{*0} pp) = (1.20 + 0.33(-0.29) \pm 0.21)10^{-4}$

(no signal with D^+)

Also first signa on Charmless decays with hyperion in final states

$\overline{B}^0 \to D_s^{(*)+} K^-$



Can proceed only via exchange diagram or final state interaction

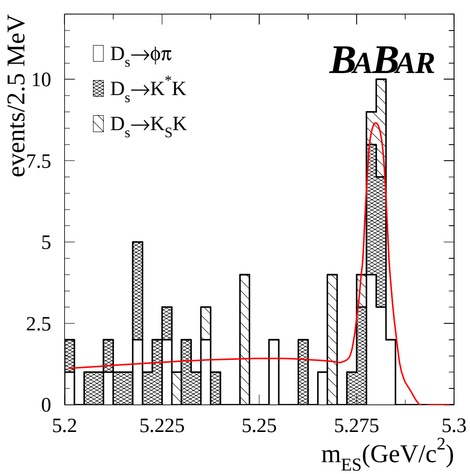
$$\overline{B}^0 \to D_s^{(*)+} K^- \;/\; \overline{B}^0 \to D_s^{(*)+} \pi^-$$

Only exch. *(exch + spect.)*

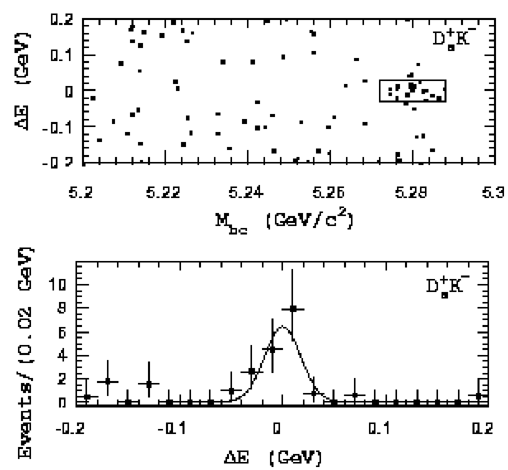
→ *Information on the importance of the exchange mechanism ?*

Important Time-dependent asymmetry in $B \to D^{(*)}\pi$: Amplitude ∝ sin(2β+γ)

Cleaness of the method if some SU(3) relation holds only if *W*-exchange is small



~85MBB



Significance 3.5σ *Significance* 6.4σ

$$Br(B^0 \to D_s^+ K^-) = (3.2 \pm 1.0 \pm 1.0) \times 10^{-5}$$

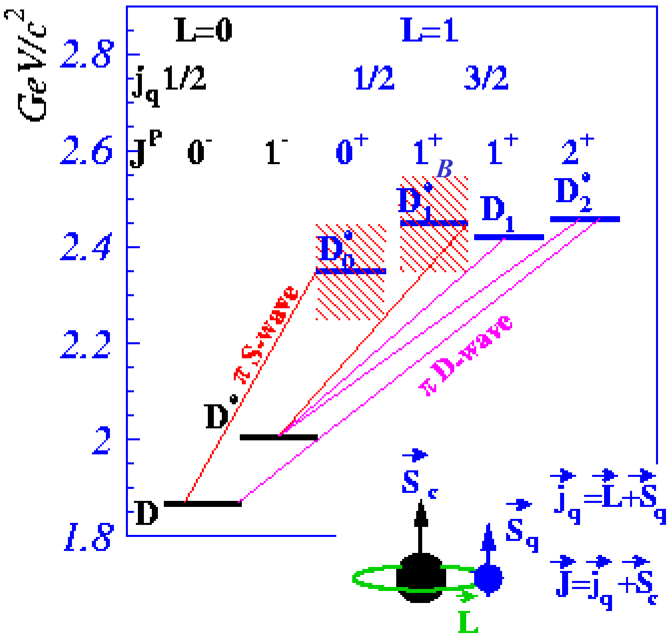
$$Br(B^0 \to D_s^+ K^-) = (4.6^{+1.2}_{-1.1} \pm 1.3) \times 10^{-5}$$

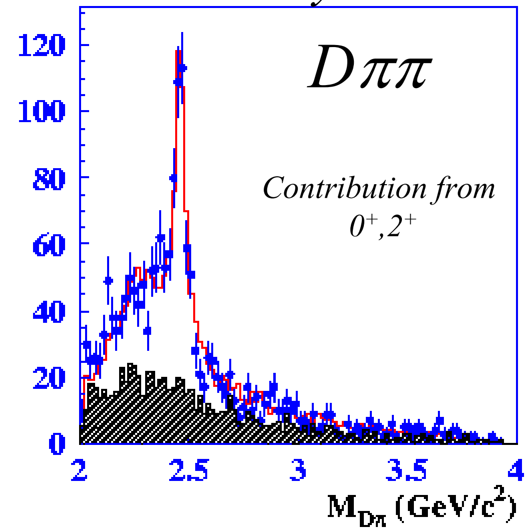
$$= (3.8 \pm 0.9 \pm 1.0(D_s \to \phi\pi)) \times 10^{-5}$$

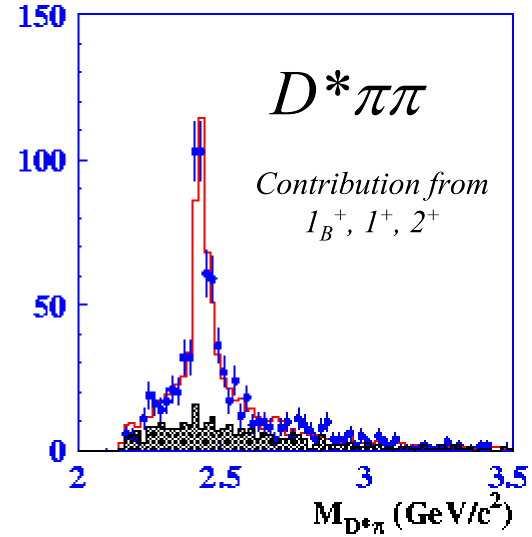
*NEW Results on D** from exclusive B decays*

$B \rightarrow D^{**}\pi$

BELLE







$M(0^+)=2290 \pm 22 \pm 30$ MeV	$\Gamma(0^+) = 300 \pm 30 \pm 30$ MeV
$M(1_B^{\;+})= 2400 \pm 30 \pm 20$ MeV	$\Gamma(1_B^{\;+}) = 380 \pm 100 \pm 100$ MeV
$M(1^+)= 2424 \pm 2$ MeV	$\Gamma(1^+) =26.7 \pm 3.1 \pm 2.2$ MeV
$M(2^+)= 2461 \pm 2 \pm 3$ MeV	$\Gamma(2^+) = 46.4 \pm 4.4 \pm 3.1$ MeV

$D\rho$ vs $D\omega$ D(*) KK(*)

Br(B → ll)

T.Moore(BaBar)

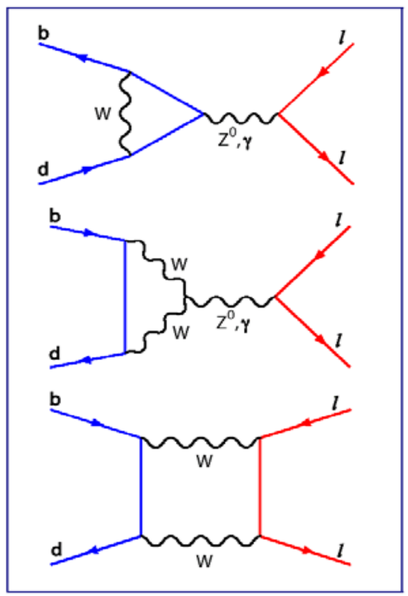
SM : Br($B^0 \to e^+e^-$ ($\approx 10^{-15}$ Br($B^0 \to \mu^+\mu^-$) $\approx 10^{-10}$

Br($B^0 \to e\mu$) forbidden

Sensitive to New Physics (ex :$H^\pm$)

So far (BELLE)

e^+e^- ($\mu^+\mu^-$) [eμ] 6.3 (2.8) [9.4] 10^{-7} (90% CL)



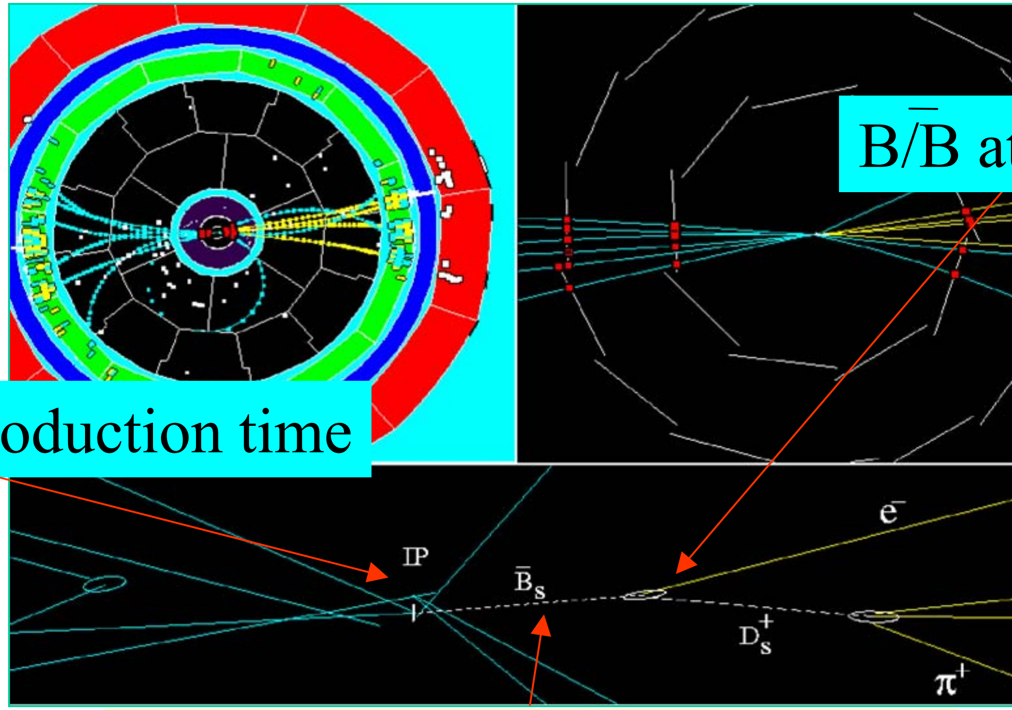
$\boldsymbol{B}(\mathbf{B} \to e^+e^-) < 3.3 \times 10^{-7}$

$\boldsymbol{B}(\mathbf{B} \to \mu^+\mu^-) < 2.0 \times 10^{-7}$

$\boldsymbol{B}(\mathbf{B} \to e^+\mu^-) < 2.1 \times 10^{-7}$

Babar 55MB

Δm_s *Analyses*



$B/\bar{B}$ at the decay time

Purity of tagging at decay time :

ε_d

$b/\bar{b}$ at the production time

Purity of tagging at production time:

ε_p

Measurement of the decay time

$$\sigma(\Delta m) \approx \frac{1}{\sqrt{N} P_s} \frac{1}{(2\varepsilon_d - 1)} \frac{1}{(2\varepsilon_p - 1)} \frac{1}{e^{-(\sigma_t \Delta m_s)^2}}$$

N = *number of events ;* P_s = B_s *purity*

σ_t *is the time resolution. As soon as* Δm_s *becomes larger, the precision on the time measurement becomes crucial*

Use D^0 from D^* to tag the flavour of D^0

$$D^{*+} \rightarrow D^0 \pi^+$$

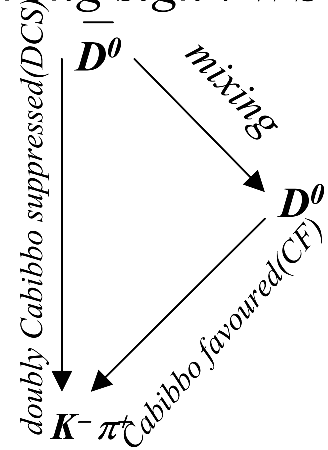
Oscillations in D^0 system

S. Malvezzi(FOCUS)
D.Williams(BaBar)

$$x = \frac{\Delta m}{\Gamma}, \quad y = \frac{\Delta\Gamma}{2\Gamma}$$

$$x' = x\cos\delta + y\sin\delta$$
$$y' = -x\sin\delta + y\cos\delta$$

Wrong sign : WS



1)
$$R_{WS}(t) = \left|\frac{<K^-\pi^+/\overline{D}^0(t)>}{<K^-\pi^+/D^0(t)>}\right|^2 = R_{DCS} + \sqrt{R_{DCS}}\, y'\left(\frac{t}{\tau(D^0)}\right) + \frac{x'^2+y'^2}{2}\left(\frac{t}{\tau(D^0)}\right)^2$$

DCS decays

Interference

Oscillations

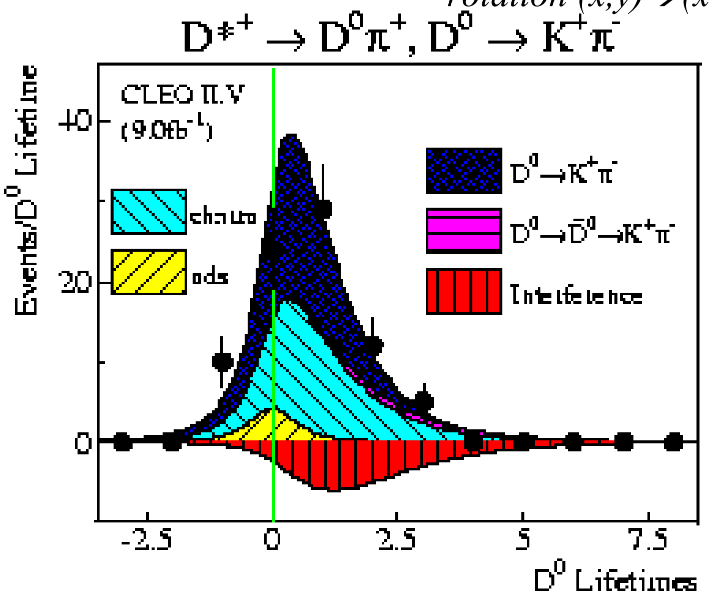
$(1 \pm \cos\Delta m\, t) \sim x^2/2$
idem for $\Delta\Gamma \sim y^2/2$

δ strong phase CF/DCS ampl.
rotation $(x,y) \rightarrow (x',y')$

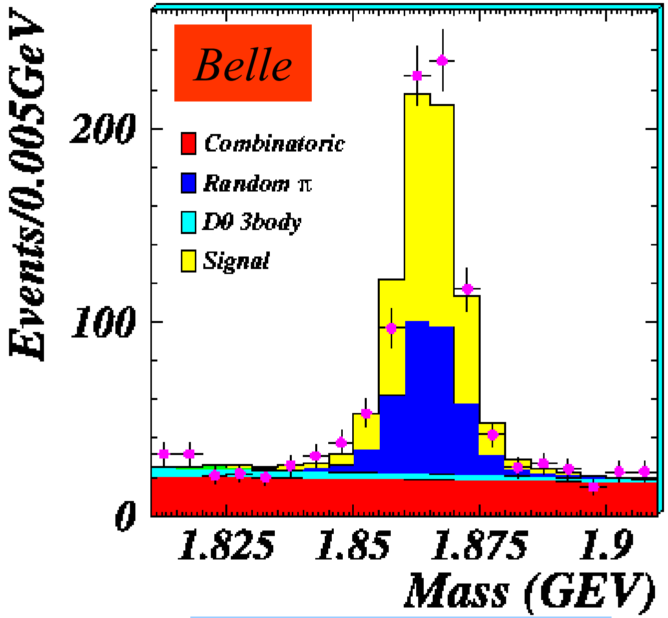
Just a note : with 90fb^{-1} B-factories
has 222000D* tagged D0 decays ~ X 2 wrt FOCUS

$$R_{WS} \approx R_{DCS} + \sqrt{R_{DCS}}\, y'$$

$x', y' < R_{DCS} \sim \lambda^2 \sim 0.05$

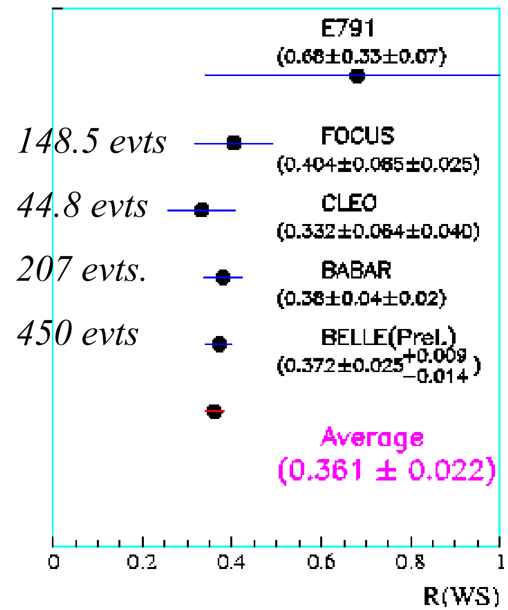


Measurement of the WS total rate
Constraint in (R_{DCS}, y') plane
or (y', x'^2)



Not yet the time Fit.

New results are coming from B-factories with huge statistics



A.S. average

2) New method using Dalitz ex : $D^0 \rightarrow K^0_S \pi^- \pi^+$

RS and WS occupy the same Dalitz plot
Measurement of strong phase δ
Constraint on x, y^2
(also sensitive to sign of x)

CLEO 5σ WS $D^0 \rightarrow K^*\pi$

First measurment of δ CF/DCS

$\delta(K^*p) = (-3 \pm 14)°$

$R(WS) = (0.6 \pm 0.3 \pm 0.3)\%$

Time Fit expected soon

(and also Dalitz from $K_s K^+ K^-$ and $\pi^+\pi^-\pi^0$)

3) Semileptonic decay $D^0 \rightarrow K^{*+} l^- \overline{\nu}$

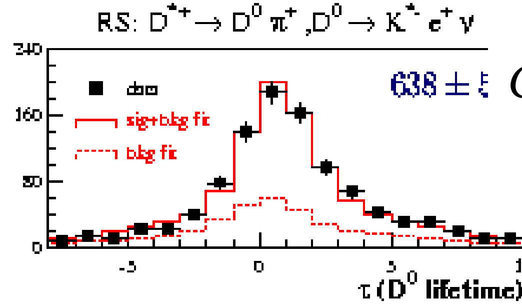
$$R_{MIX}(t) = \left| \frac{<K^{*+} l^- \overline{\nu} / \overline{D}^0(t)>}{<K^{*-} l^+ \nu / D^0(t)>} \right|^2 = \frac{x^2+y^2}{2}\left(\frac{t}{\tau(D^0)}\right)^2$$

No interference with DCS/Mixed

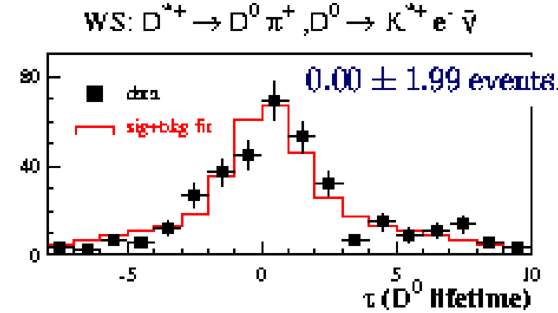
Constraint on x^2, y^2

$R_{MIX} = (0.00 \pm 0.31 \pm 0.32)\%$ *or* $< 0.87\%$ *@ 95 C.L.*

FOCUS at the last minute $R_{MIX} < 0.12\%$ *@ 95 C.L. (STAT ONLY)*



CLEO



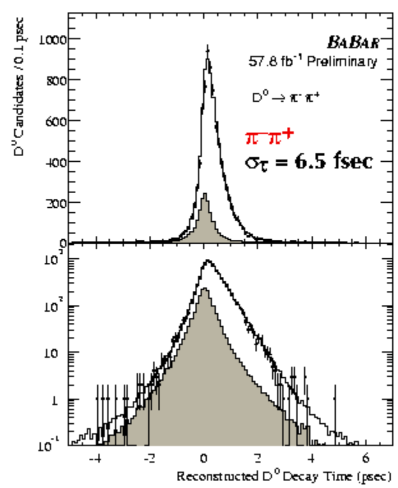
Soon analysis with $K e \nu$

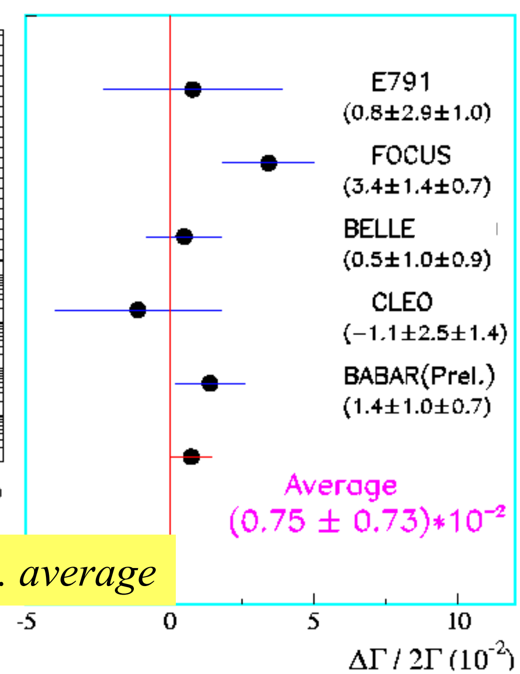
4) CP eingenstate lifetimes

$$\frac{\Delta\Gamma}{2\Gamma} = \frac{\tau(K^-\pi^+)}{\tau(K^-K^+) or \tau(\pi^+\pi^-)} - 1$$

K^-K^+ (or $\pi^-\pi^+$)	pure CP D_1^0
$K^-\pi^+$	50% $D_1^0 + D_2^0$

Constraint on y





A.S. average

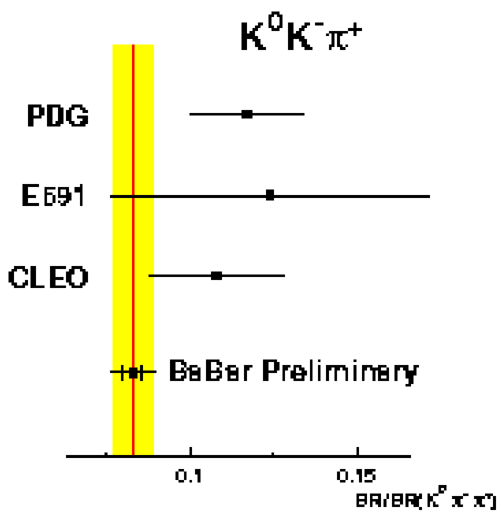
Three-Body D^0 Decays

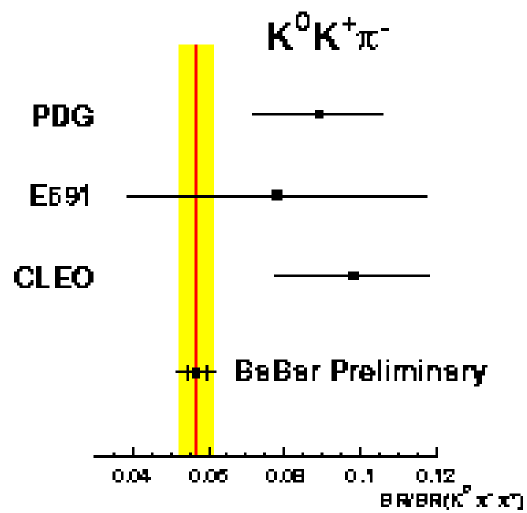
Branching Ratios

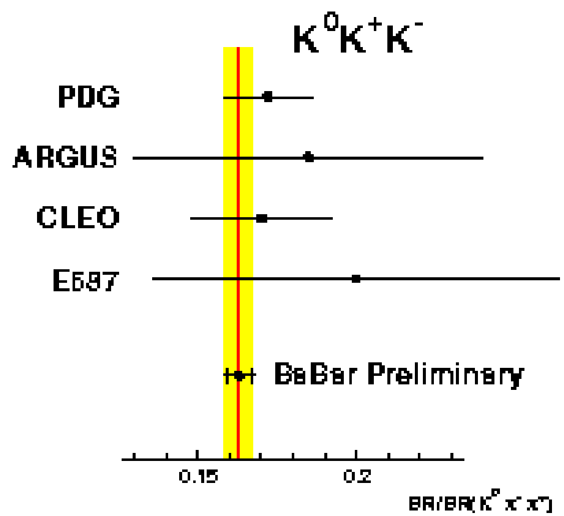
$$\frac{\Gamma(D^0 \to K^0 K^- \pi^+)}{\Gamma(D^0 \to K^0 \pi^+ \pi^-)} = 8.32 \pm 0.29\,(\text{stat}) \pm 0.56\,(\text{syst}) \times 10^{-2}$$

$$\frac{\Gamma(D^0 \to K^0 K^+ \pi^-)}{\Gamma(D^0 \to K^0 \pi^+ \pi^-)} = 5.68 \pm 0.25\,(\text{stat}) \pm 0.41\,(\text{syst}) \times 10^{-2}$$

$$\frac{\Gamma(D^0 \to K^0 K^+ K^-)}{\Gamma(D^0 \to K^0 \pi^+ \pi^-)} = 16.30 \pm 0.37\,(\text{stat}) \pm 0.27\,(\text{syst}) \times 10^{-2}$$







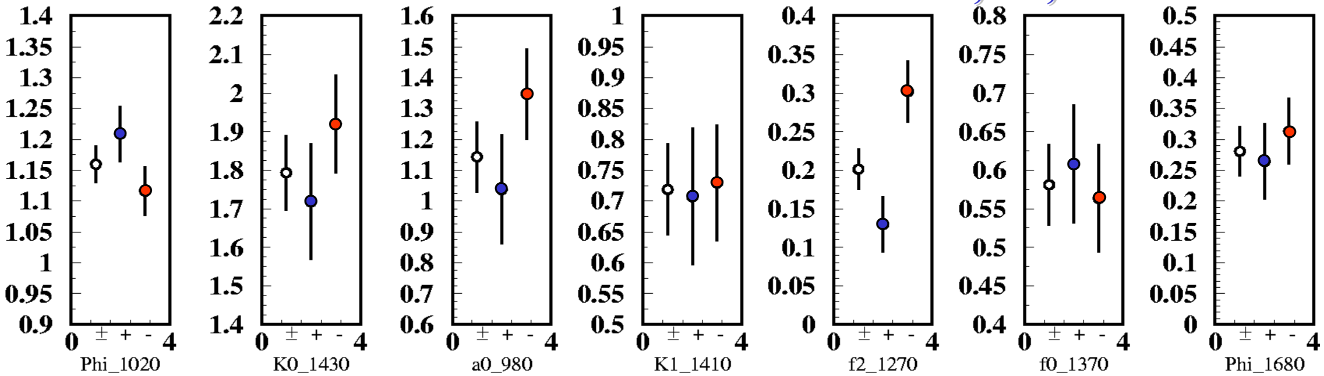
S. Malvezzi(FOCUS)

Measure of direct CP violation:
asymmetrys in decay rates of **$D^{\pm} \to K^{\pm} K \pi^{\pm}$**

D^+/D^- split sample analysis

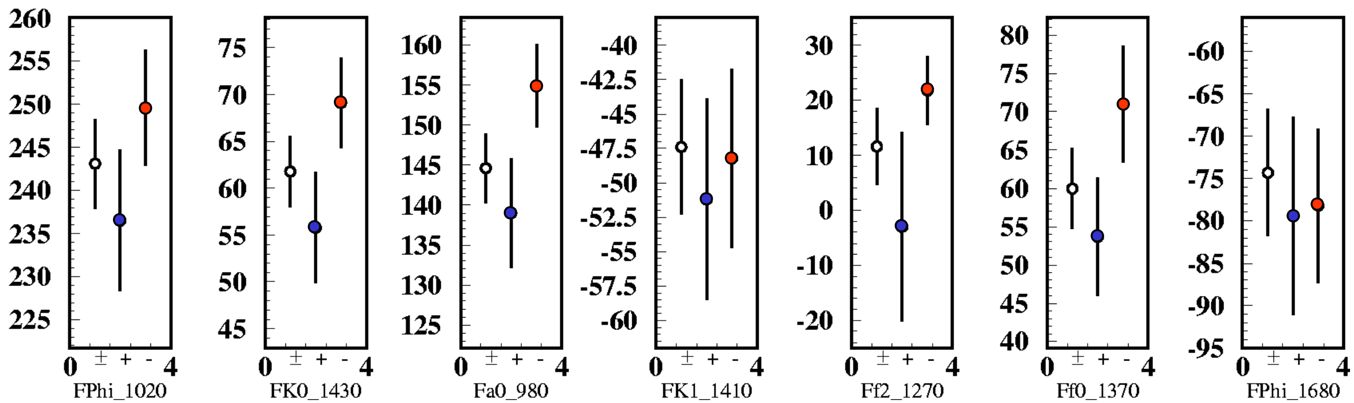
Preliminary!

Coefficients: $D^{\pm}$, D^+, D^-



Phases: $D^{\pm}$, D^+, D^-

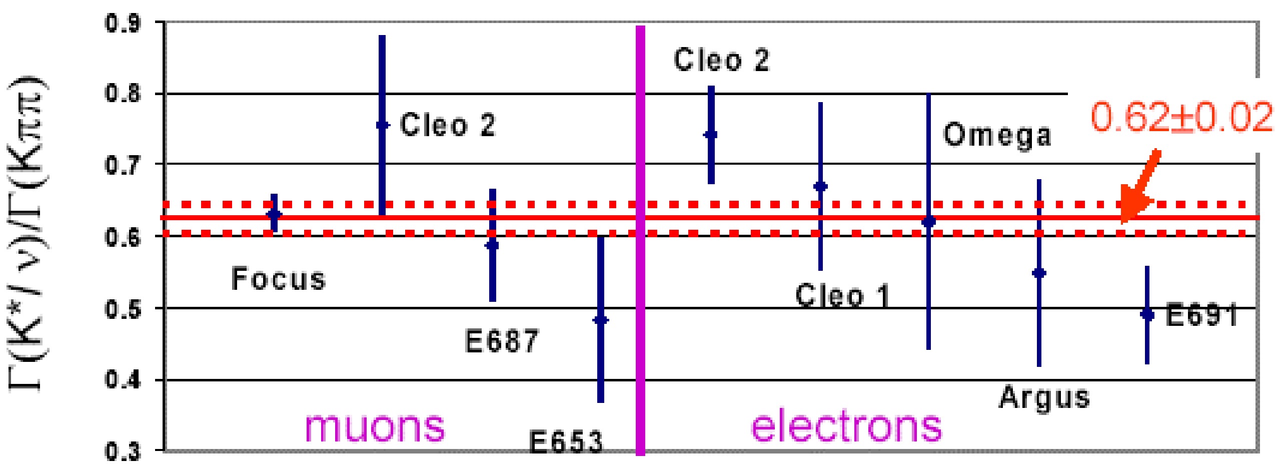
No evidence of CPV



K-matrix approach to improve the quality of the analysis

New FOCUS semileptonic BRs & Form Factors

$$\frac{\Gamma(D^+ \to \overline{K^{*0}}\mu^+\nu)}{\Gamma(D^+ \to K^-\pi^+\pi^+)} = 0.602 \pm 0.01(stat) \pm 0.021(sys)$$



Our number is 1.59 standard deviation below CLEO and 2.1 standard deviation above E691

All values consistent with their average value with a CL of 19%

$\Gamma(D^+ \to \overline{K^{*0}} \mu^+ \nu)$ Form Factors

The vector and axial form factors are generally parametrized by a pole dominance form

$$A_i(q^2) = \frac{A_i(0)}{1 - q^2/M^2_A} \quad V(q^2) = \frac{V(0)}{1 - q^2/M^2_V}$$

$M_A = 2.5 \ GeV/c^2$
$M_V = 2.1 \ GeV/c^2$

Nominal spectroscopic pole masses

Decay intensity (including s-wave amplitude) parametrized by

$$r_v \equiv V(0)/A_1(0) \qquad r_2 \equiv A_2(0)/A_1(0) \qquad r_3 \equiv A_3(0)/A_1(0)$$

Group	r_v	r_2
FOCUS	$1.504 \pm 0.057 \pm 0.039$	$0.875 \pm 0.049 \pm 0.064$
BEATRICE	$1.45 \pm 0.23 \pm 0.07$	$1.00 \pm 0.15 \pm 0.03$
$E791(e)$	$1.90 \pm 0.11 \pm 0.09$	$0.71 \pm 0.08 \pm 0.09$
$E791(\mu)$	$1.84 \pm 0.11 \pm 0.09$	$0.75 \pm 0.08 \pm 0.09$
$E687$	$1.74 \pm 0.27 \pm 0.28$	$0.78 \pm 0.18 \pm 0.11$
$E653$	$2.00 \pm 0.33 \pm 0.16$	$0.82 \pm 0.22 \pm 0.11$
$E691$	$2.0 \pm 0.6 \pm 0.3$	$0.0 \pm 0.5 \pm 0.2$

$A = 0.330 \pm 0.022 \pm 0.015 \ GeV^{-1}$
$\delta = 0.68 \pm 0.07 \pm 0.05$ rad

Form Factor Ratios

Inputs for the CKM fit

Standard set:

Parameter	Value	Gaussian σ	Uniform half-width
λ	0.2210	0.0020	-
$\|V_{cb}\|$(excl.)	42.1×10^{-3}	2.1×10^{-3}	-
$\|V_{cb}\|$(incl.)	40.4×10^{-3}	0.7×10^{-3}	0.8×10^{-3}
$\|V_{cb}\|$(ave.)	40.6×10^{-3}	0.8×10^{-3} *	
$\|V_{ub}\|$(excl.)	32.5×10^{-4}	2.9×10^{-4}	5.5×10^{-4}
$\|V_{ub}\|$(incl.)	40.9×10^{-4}	4.6×10^{-4}	3.6×10^{-4}
$\|V_{ub}\|$(ave.)	36.3×10^{-4}	3.2×10^{-4} *	
$\|V_{ub}\|/\|V_{cb}\|$(ave.)	0.089	0.008*	
ΔM_d	0.503 ps^{-1}	0.006 ps^{-1}	–
ΔM_s	$>$ 14.4 ps^{-1} at 95% C.L.	sensitivity 19.2 ps^{-1}	
m_t	167 GeV	5 GeV	–
sin 2β	0.762	0.064	-
$\hat{B}_K$	0.86	0.06	0.14
$f_{B_d}\sqrt{\hat{B}_{B_d}}$	230 MeV	30 MeV	15 MeV
ξ	1.18	0.03	0.04

New lattice QCD parameters with "chiral logarithms"

$f_{B_d}\sqrt{\hat{B}_{B_d}}$	235 MeV	33 MeV	$^{+0}_{-24}$ MeV
$\xi =$	1.18	0.04	$^{+12}_{-0}$