A review of experiments on B-physics - New results at ICHEP 2002

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RADCOR 2002
Loops & Legs 2002
Kloster Banz
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Overview

Introduction

Spectroscopy
Fragmentation

Lifetimes

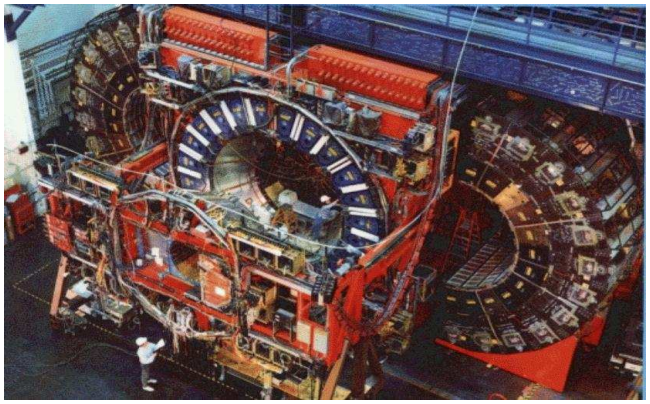
Vcb and Vub
B0 and Bs Oscillations
CP violation
Hadronic and rare decays

Status of the CKM matrix

Conclusion

B-physics at different experiments

CDF ~100 pb^{-1} b-physics (1992-96)



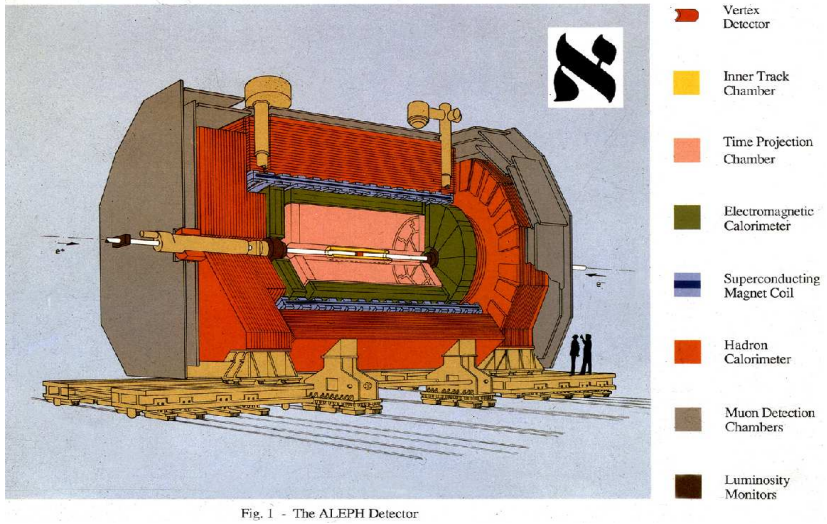
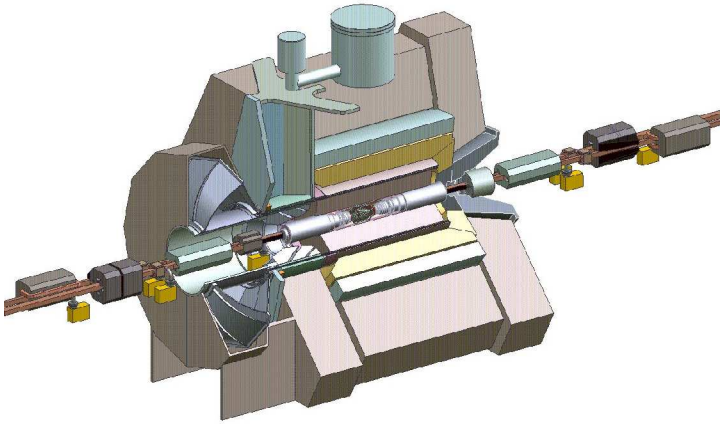
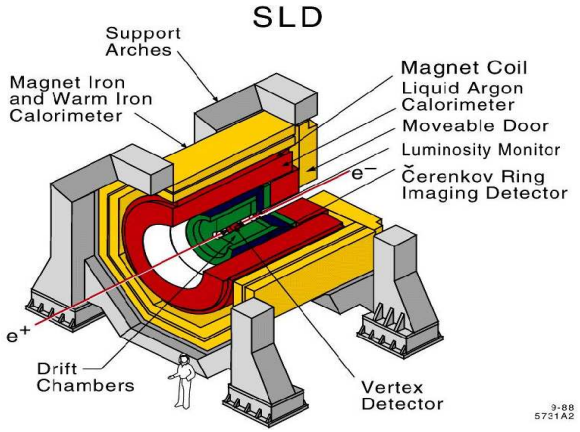


Fig. 1 - The ALEPH Detector

BABAR and BELLE at b-factories running on the Y(4S).
~100 million BB pairs (Winter 2002)



ALEPH, OPAL, L3 and DELPHI running on the Z (1991-1995).
SLD with less statistics, but high decay length performance.



B-physics on the Y(4S)

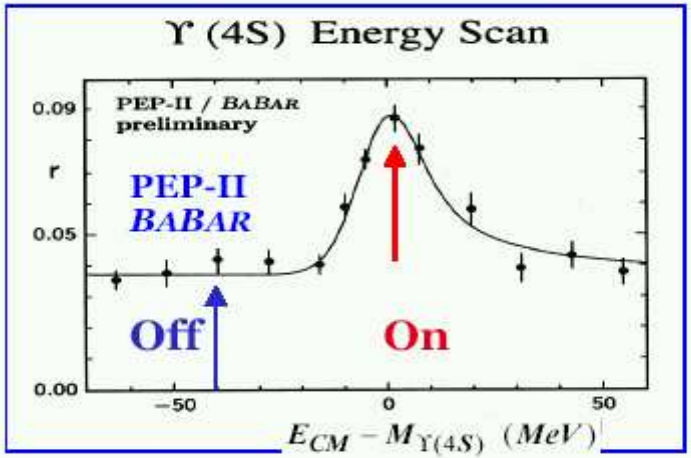
Electron and positrons are collided at a cms energy exactly at the Upsilon(4S) resonance.
The JP=1- Y(4) decays coherently into a B+B- or B0 B0bar.
All other decays are kinematically forbidden.

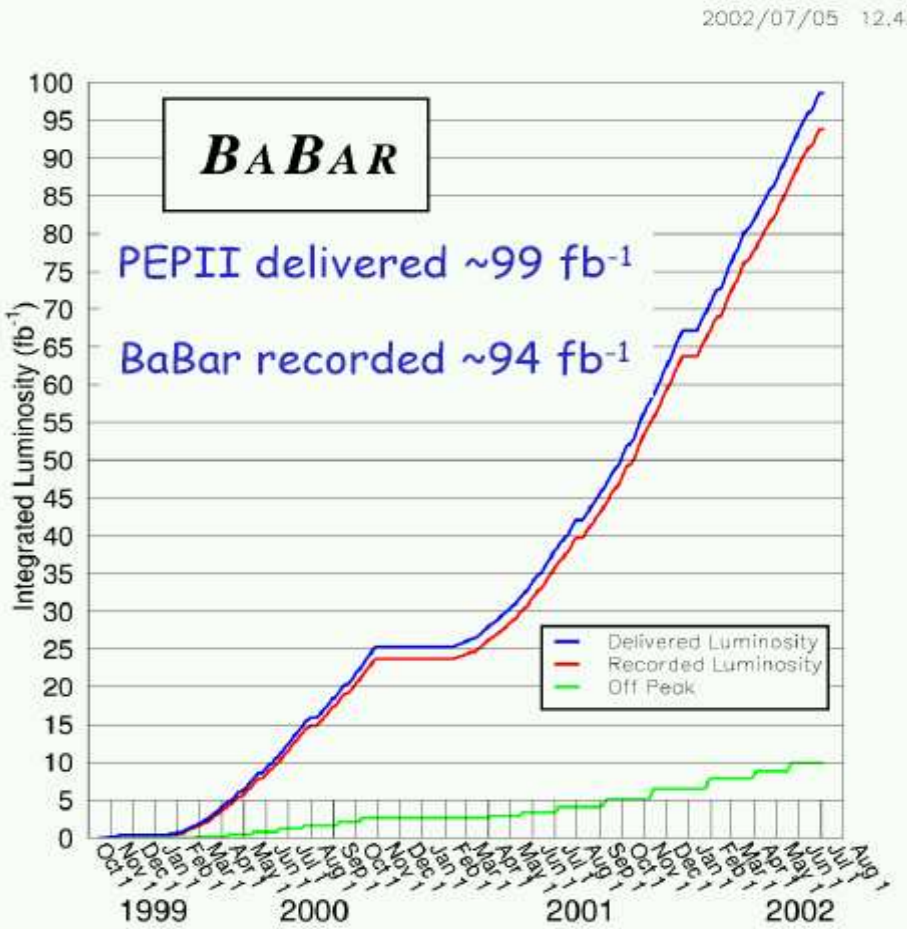
After many years of CLEO physics at symmetric e+e- machine now completely dominated by asymmetric B factories at SLAC and KEK and their detectors BABAR and BELLE.

Fantastic luminosities!
Both experiments collected about 80 fb^{-1} = 80000 pb^{-1} corresponding to about 80 million Bbbar pairs

Data sample

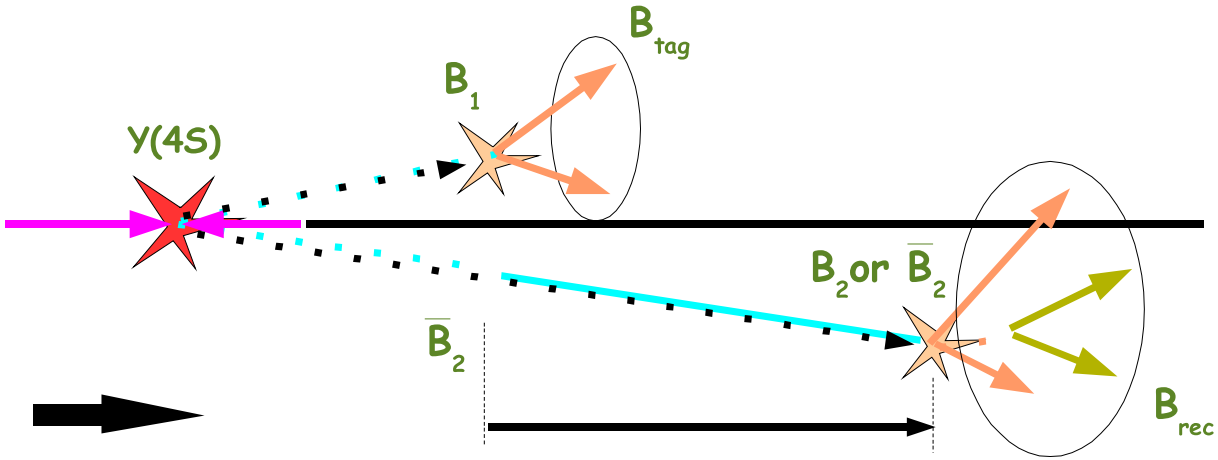
- Used in the analysis
  - 81.2 fb^{-1} on peak
  - 9.6 fb^{-1} off-peak



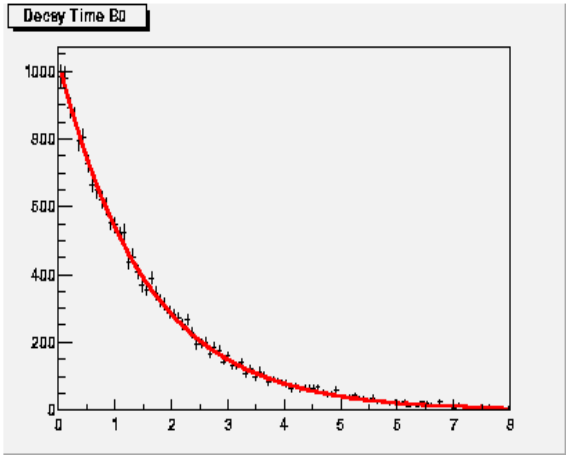


~88M $B\bar{B}$ pairs considered

B-physics on the Y(4S) – asymmetric B-factories



Proper Decay Time (LEP)



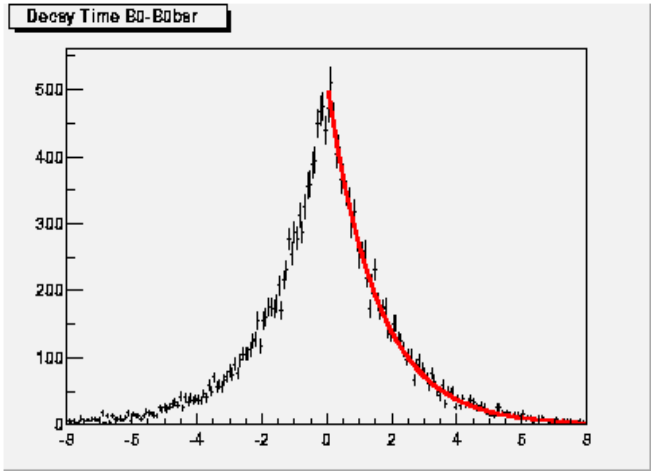
Proper Decay Time

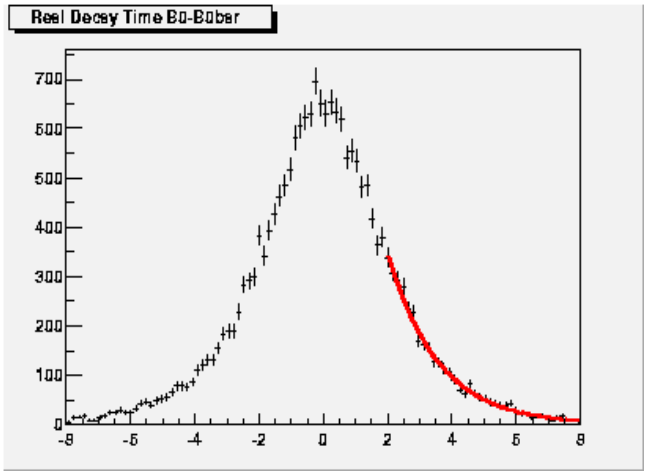
$\Delta t \sim T(B_{rec}) - T(B_{tag})$

leads to extended distribution.

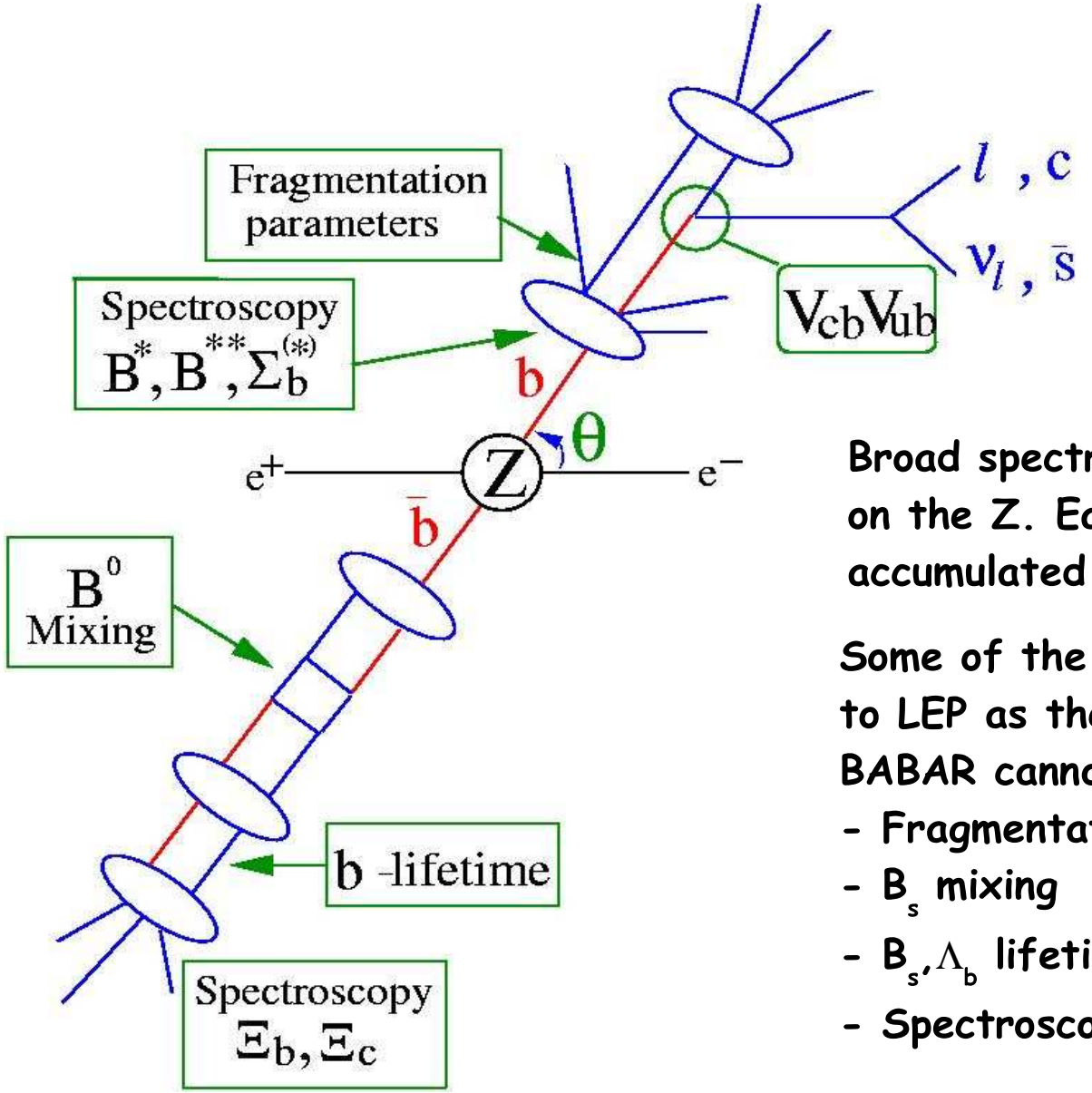
Decay length resolution

$\Delta z \sim 150 - 200\ \mu m$





B-physics on the Z

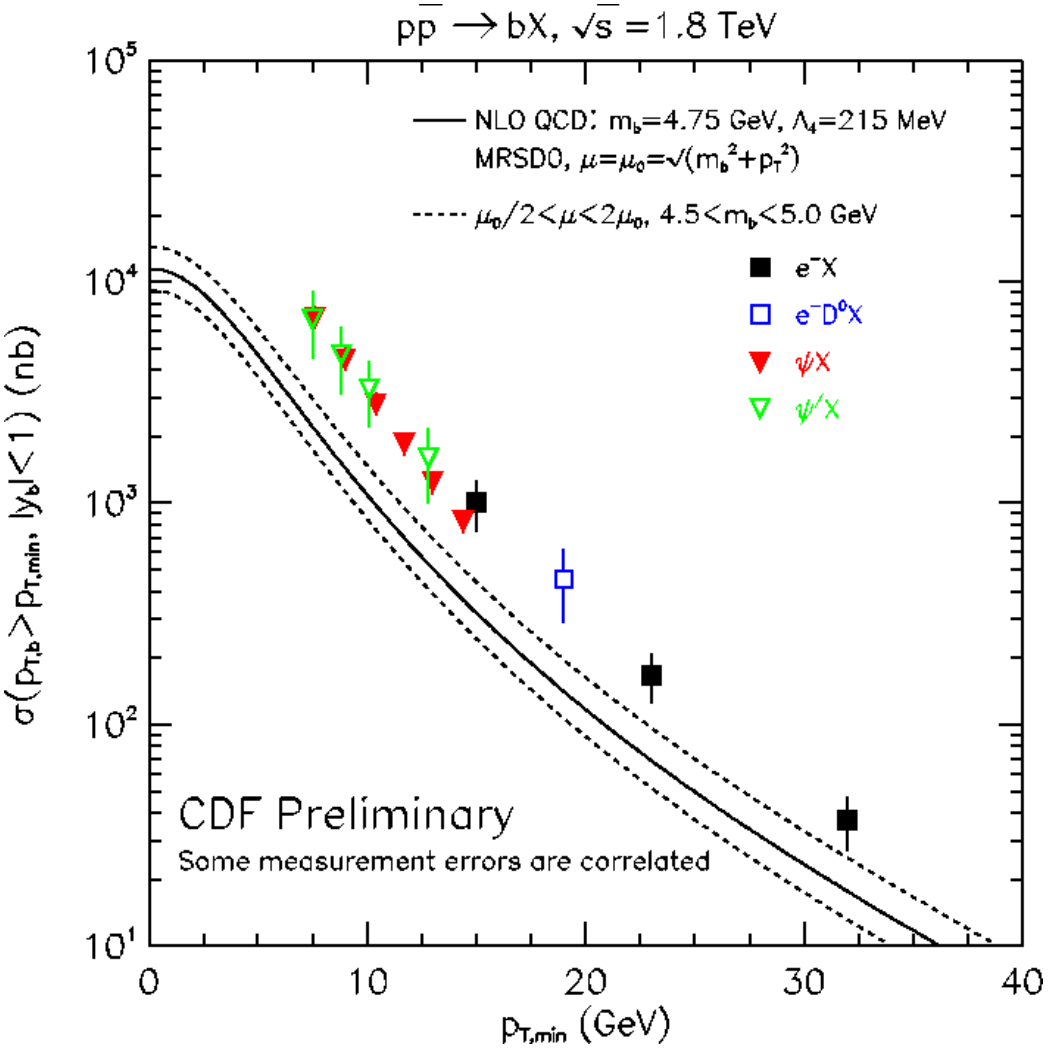


Broad spectrum of b-physics on the Z. Each LEP experiment accumulated $4 \cdot 10^6$ hadronic decays.

Some of the b-physics is still reserved to LEP as the B factories BELLE and BABAR cannot access:

- Fragmentation
- B_s mixing
- B_s, Λ_b lifetime
- Spectroscopy

B-physics in proton antiproton collisions



Strong interactions (QCD):

→parton distribution inside protons
→hard parton scattering
→fragmentation

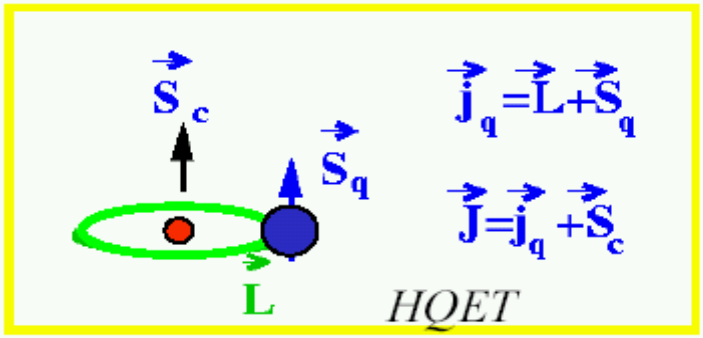
Although 1 TeV beam energy, B mesons are mostly at low p_T
Most events look more like CLEO (+ proton fragments) than LEP events.

Large total cross section allows to trigger on specific final states ,
e.g. inclusive $J/\psi \longrightarrow \mu\mu$
or B--> $\pi\pi$ decays (secondary vertices)

No new results from CDF II and D0 at upgraded TEVATRON yet.
Data taking underway

from Achille Stocchi talk at ICHEP 2002

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) broad
		1^+	B_1^*	$B^*\pi$	(s-wave)
1	$\frac{3}{2}$	1^+	B_1	$B^*\pi$	(d-wave) narrow
		2^+	B_2^*	$B^{(*)}\pi$	(d-wave)

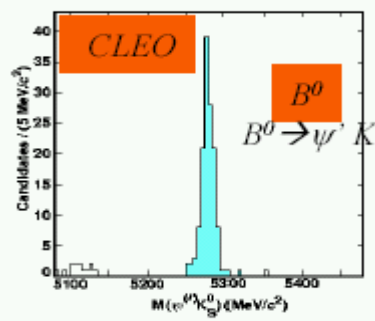
$B_s^{**} \rightarrow B^{(*)} K$ *(if above thresold)*

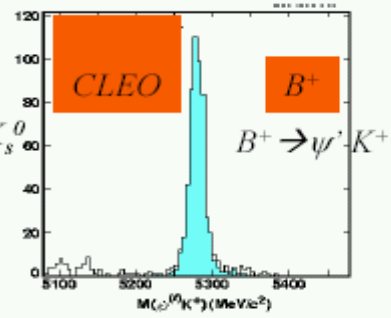
($\rightarrow B_s^{(*)}\pi$ isospin forbidden)

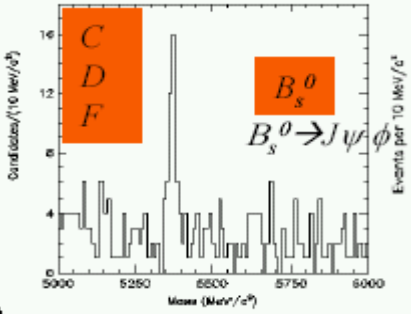
$M(B^0) = 5279.3 \pm 0.7$ MeV

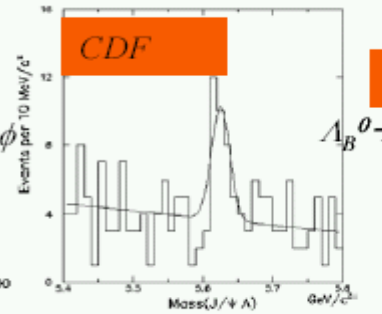
$M(B^+) = 5279.1 \pm 0.5$ MeV

$M(B^0) - M(B^+) = 0.34 \pm 0.32$ MeV









$M(B_s^0) = 5369.6 \pm 2.4$ MeV

$M(\Lambda_B^0) = 5624 \pm 9$ MeV

Strongly decaying

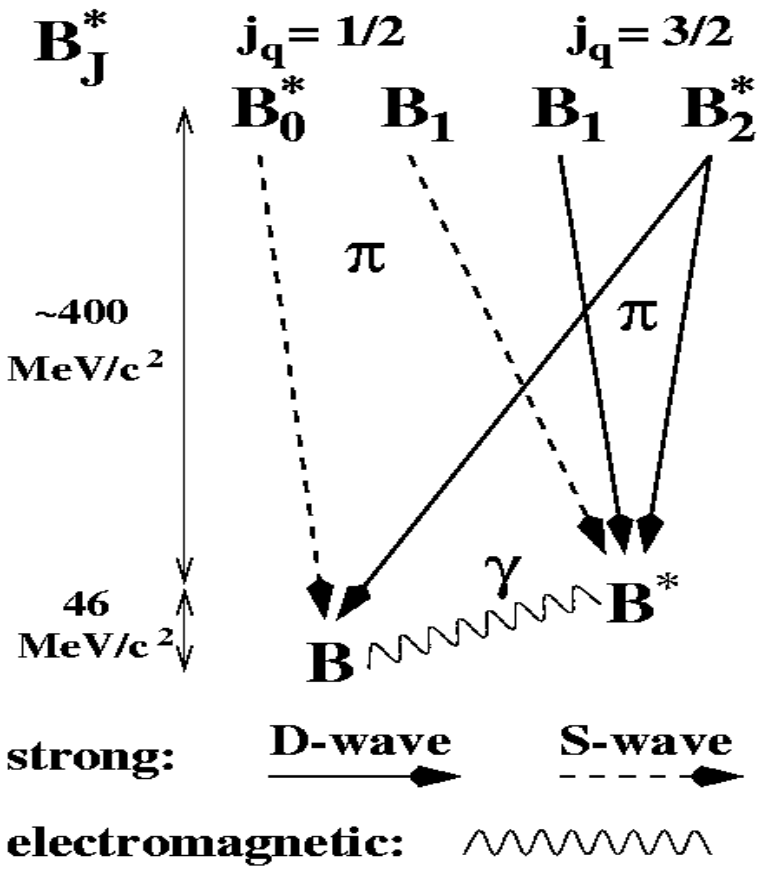
Spectroscopy of light b-baryons (bqq; q=u,d) with l=0:

$S_{qq}=0 \rightarrow \Lambda_b$

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

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

HQET: Heavy quark as static colour source;
light degrees decoupled

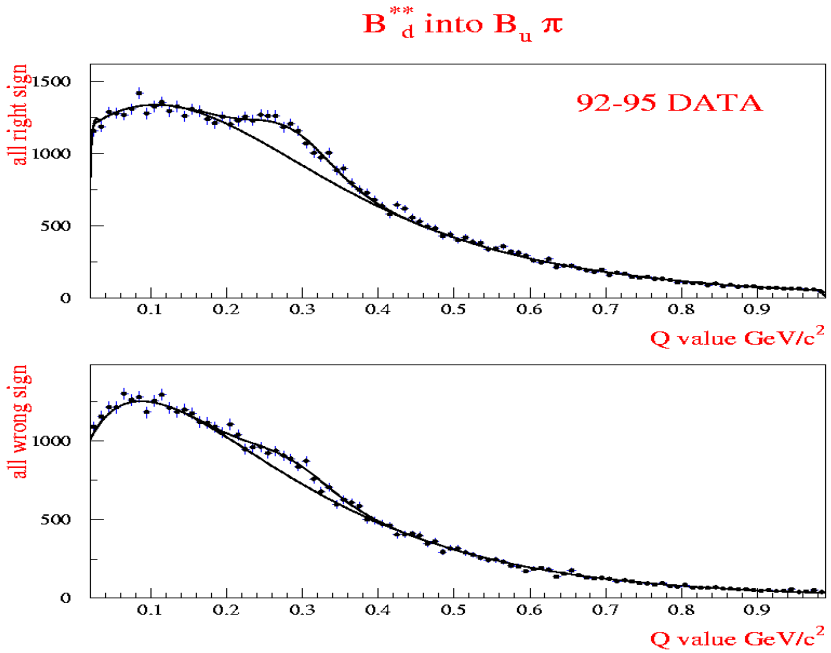


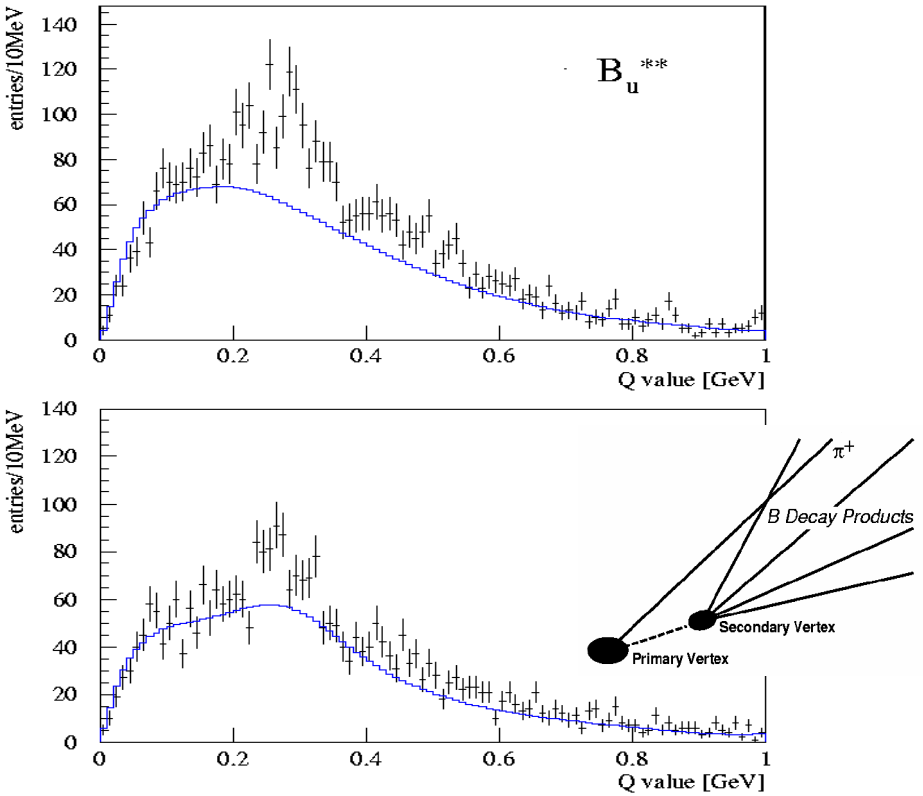
Heavy Quark Symmetry predicts
B** states: $J^P = 0^+, 1^+, 1^+, 2^+$.
Decay properties are fixed
by spin and parity.
($B_0 \rightarrow B$, $B_1 \rightarrow B^*$, $B_2 \rightarrow B, B^*$).
Occupation of the states is unknown.

B_s^{**} decays should be similar,
but decays $B_s^{**} \rightarrow B_s^* \pi$ are
forbidden by Isospin.

New analyses from DELPHI !
Was the signal (1994/95) narrow
and broad states?
Are old prelim. B_s^{**} and Σ_b real ?

B** analyses





"Soft" analysis

Fit to right and wrong sign samples.

Single Gaussian hypotheses:

$Q = 289 \pm 4 \pm 12$ MeV

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

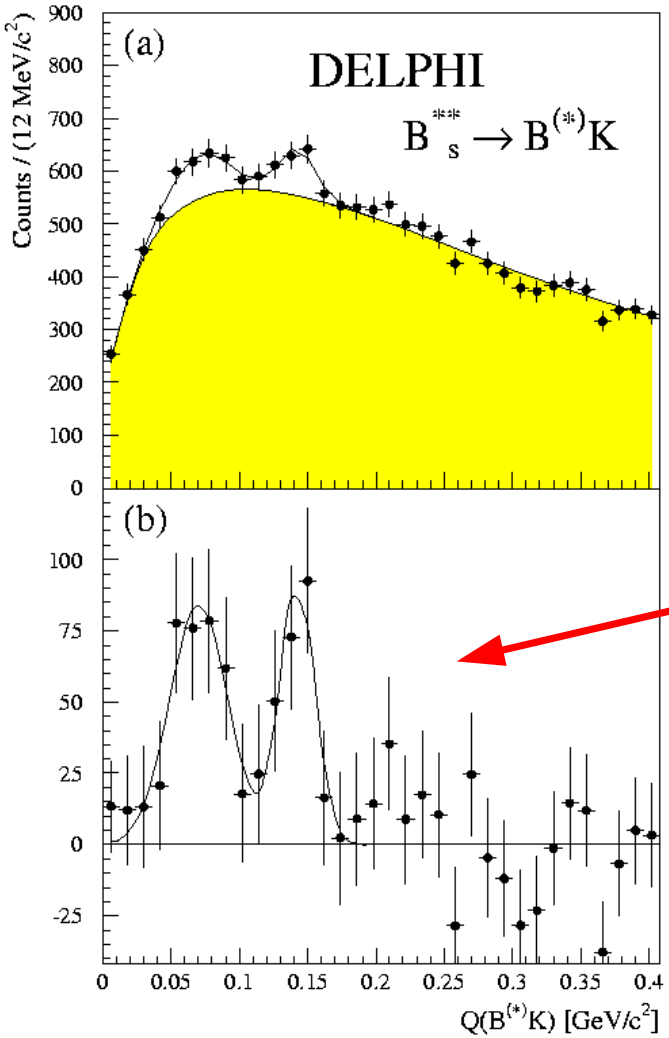
$(\sigma(B_d^{**})+\sigma(B_u^{**}))/\sigma_b = 0.098 \pm 0.007 \pm 0.012$

Working on very high purity.

No final conclusion yet, but probably someting very broad above B** signal

DELPHI 1995:

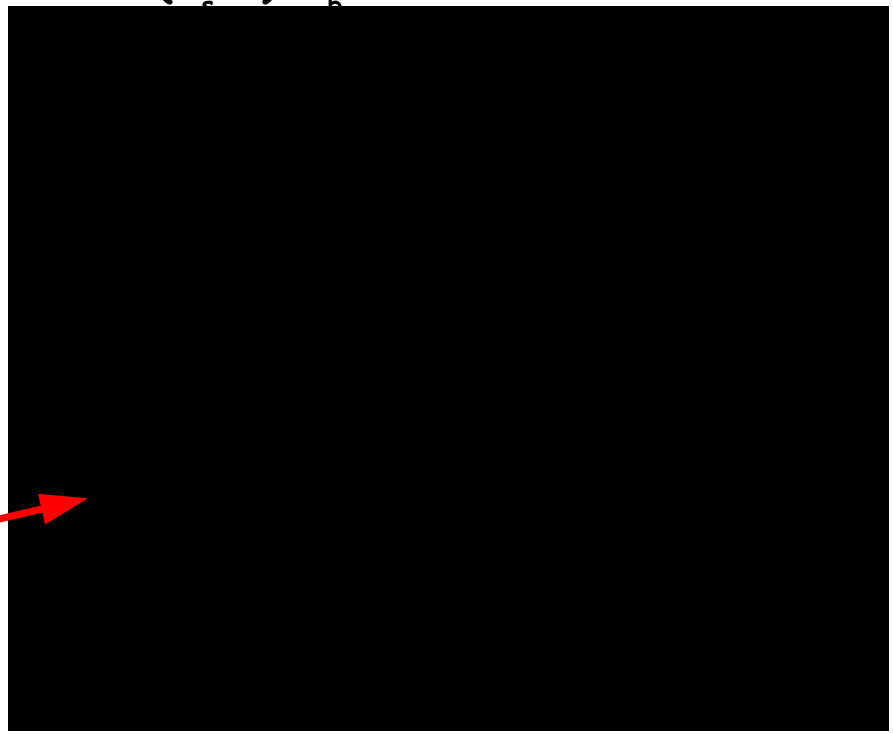
Evidence for 2 narrow resonances



DELPHI 2002:

New analyses could not confirm the signal.

$\sigma(B_s^{**})/\sigma_b$ <0.015 @ 95 % CL



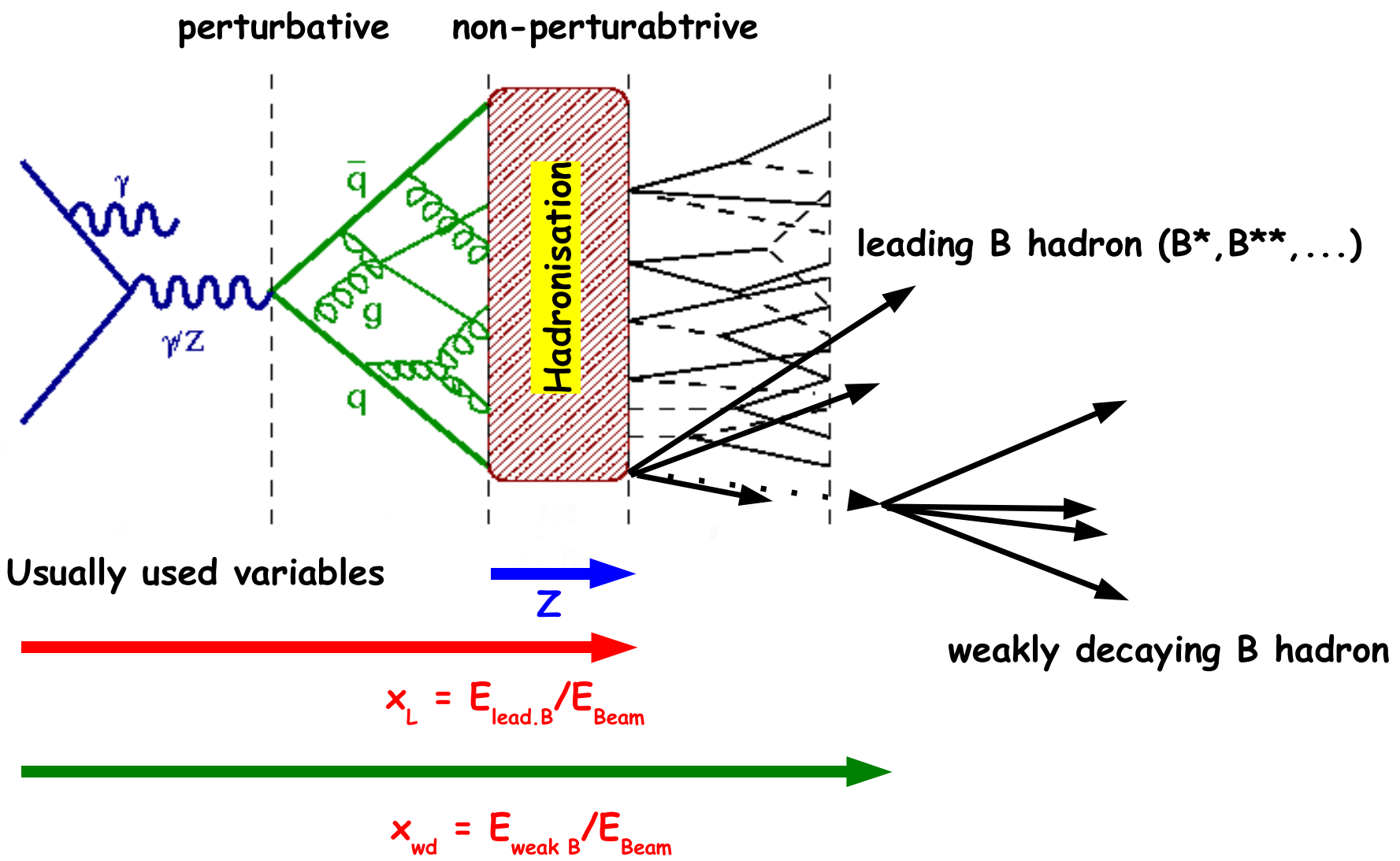
Similar happened to the Σ_b rate (DELPHI 95)

$\sigma(\Sigma_b)/\sigma_b$ <0.015 @ 95 % CL

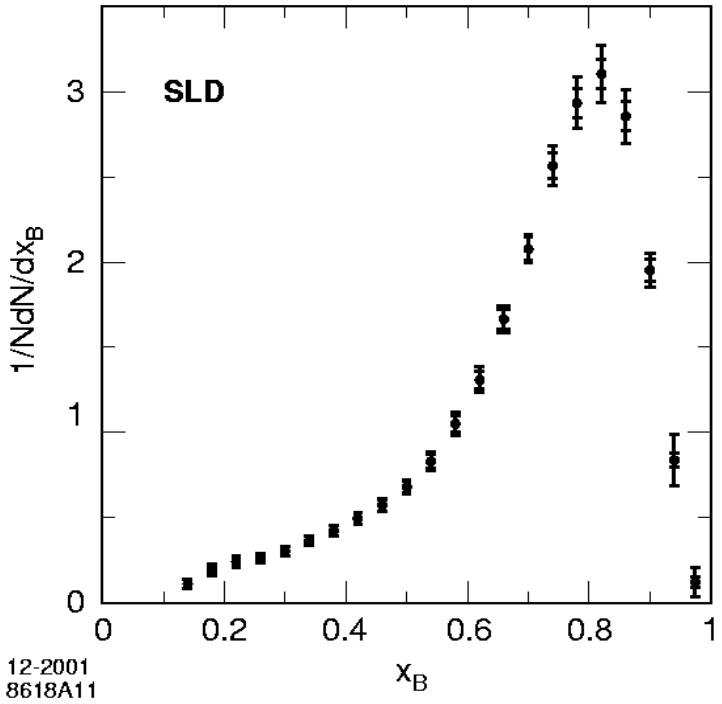
Old signals ruled out. Smaller signals may exist.

Work continues

b -Fragmentation

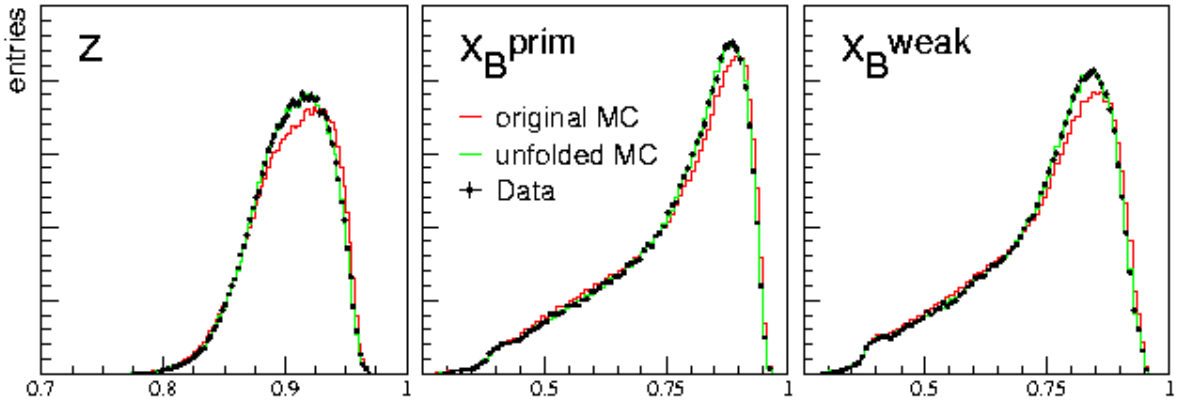


LEP/SLP analyses

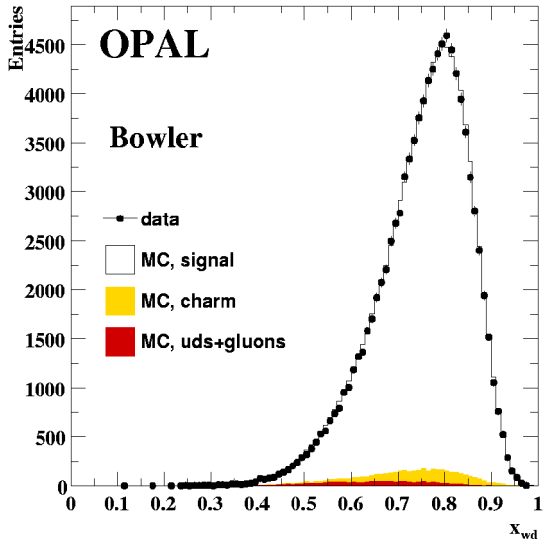


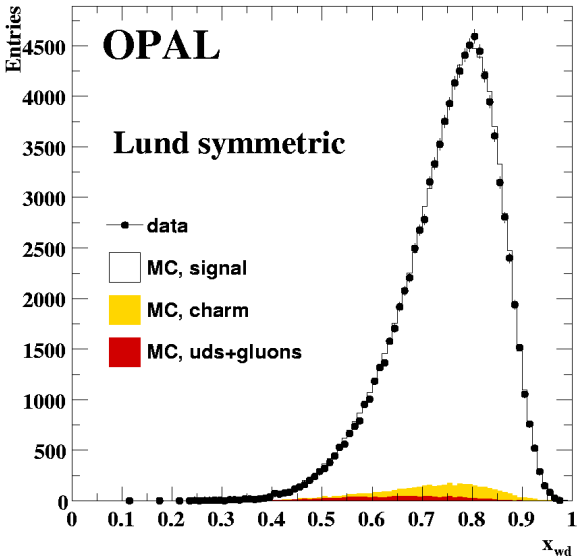
SLD: Inclusive B energy reconstruction using vertex direction information and decay products.
Resolution 10 % ~ 4200 events

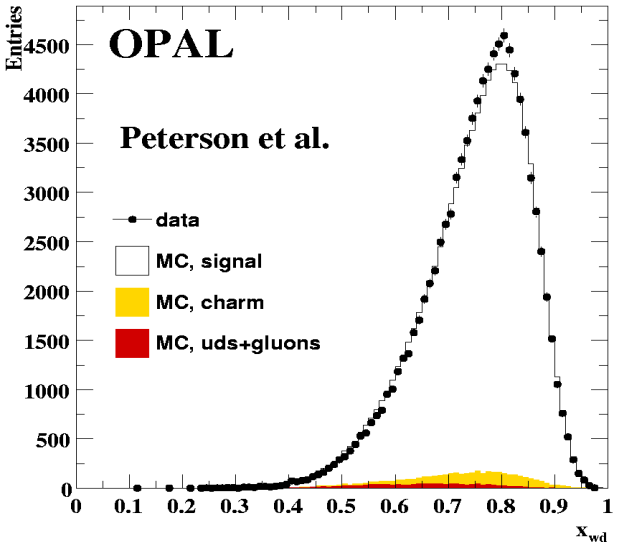
Inclusive B reconstruction using neural network for energy estimates
Resolution 10 % ~ 230000 events
DELPHI: x_{wd}, x_L, Z

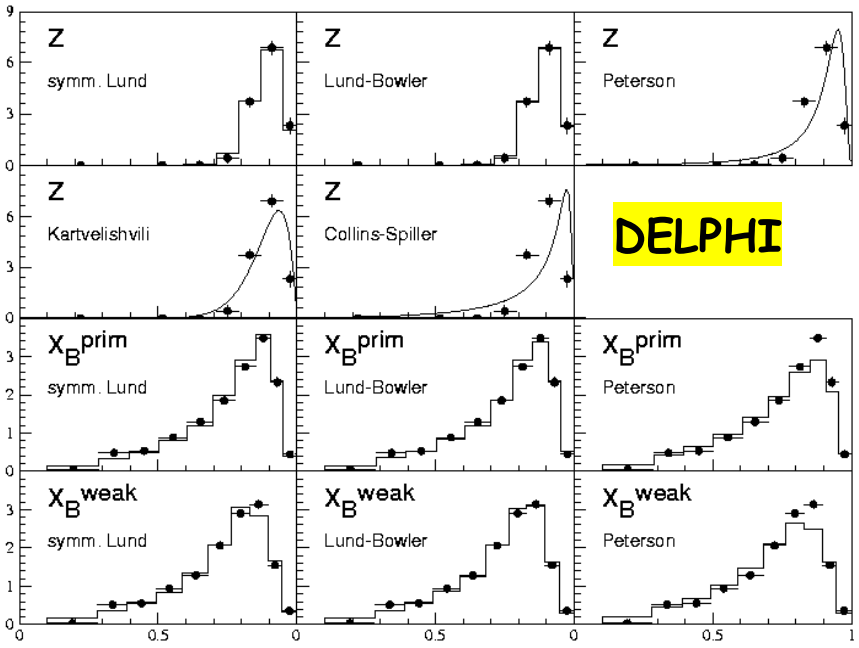


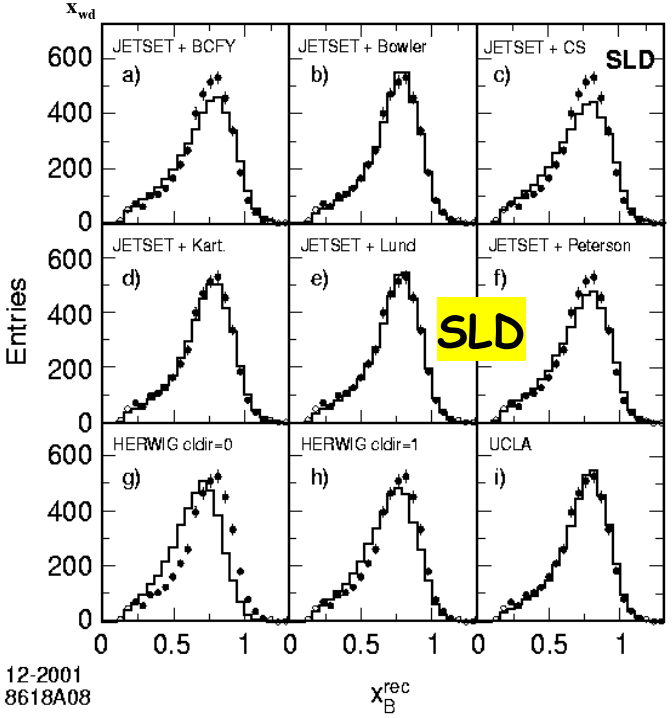
Test of different hadronisation models











Conclusion on b fragmentation

B fragmentation is still very active

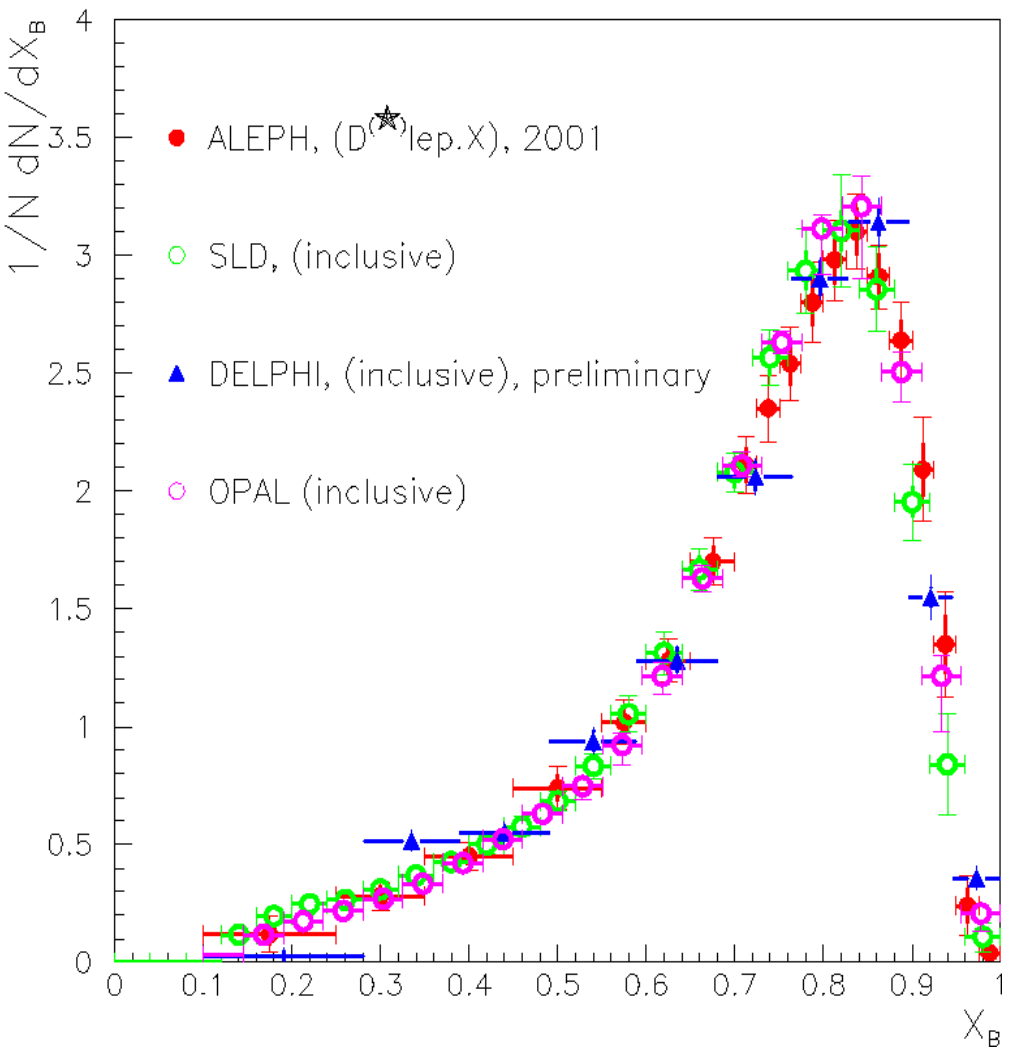
Test of various models

- Jetset/Bowler , Jetset/Lund favoured
- Peterson too broad
- Herwig disfavored

B hadron energy spectrum:

$\langle x_{wd} \rangle = 0.7151 \pm 0.0025$

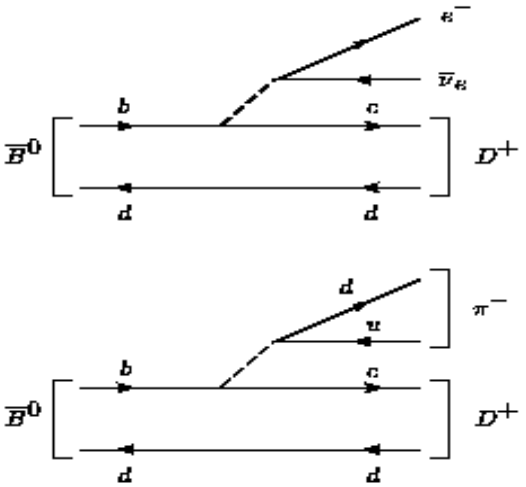
(preliminary LEP/SLD)

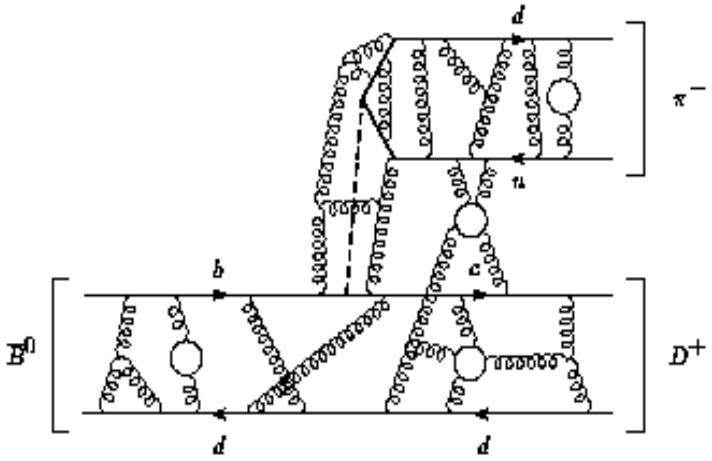


Lifetimes

$$\Gamma_b \approx \frac{G_F^2 m_b^5}{192\pi^3} V_{cb}^2 \left(K_c + K_u \left|\frac{V_{ub}}{V_{cb}}\right|^2\right)$$

In a naive model the decay width is independent from the spectator.
Lifetimes for all B mesons and B baryons should be equal !





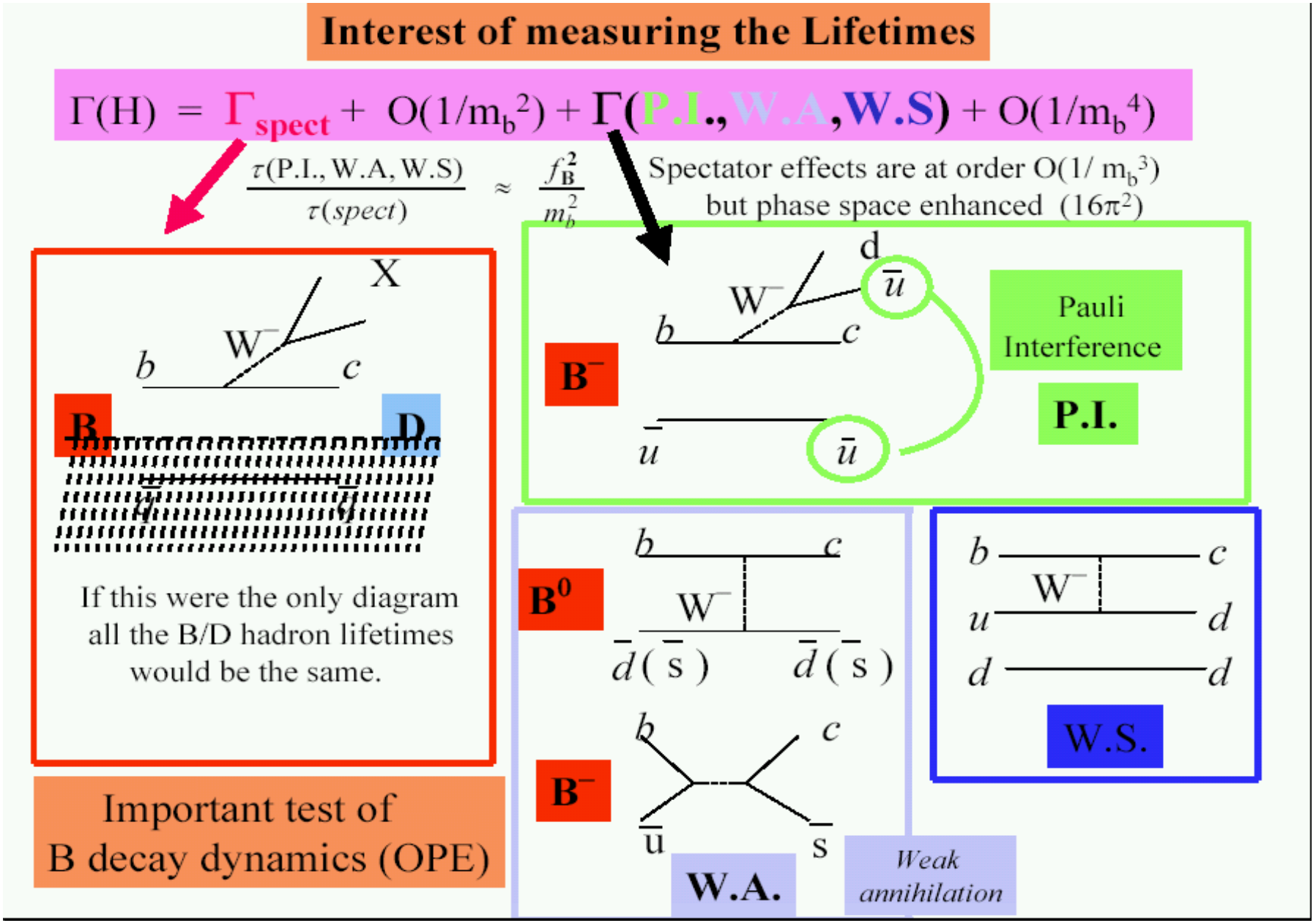
The situation is more complicated !

Higher order effects determine a ranking of the lifetimes.

$$\tau(\Lambda_b) < \tau(B^0) < \tau(B_s) < \tau(B^+)$$

Testing of the theory and higher order effects (P.I.,W.A,W.S.)

from Achille Stocchi talk at ICHEP 2002



BELLE and BABAR exclusive analysis

BABAR

Likelihood fit on 14000 exclusively reconstructed B^0 -> D*lv events: $\tau(B^0)=1.523\pm0.024\pm0.022$ ps

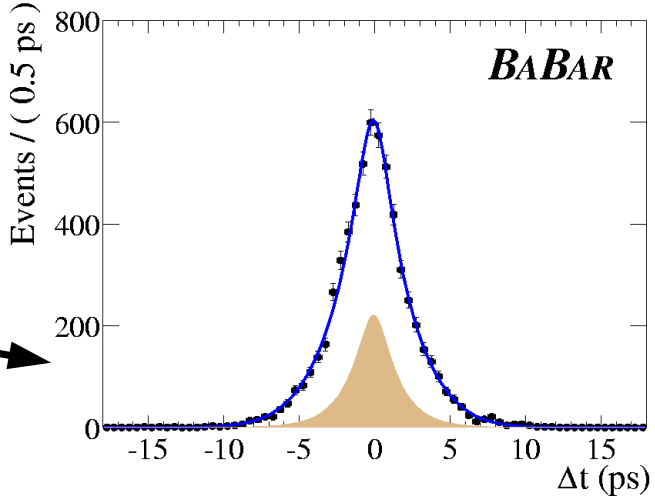
(Mixing analysis also done -> mix/unmix plots)

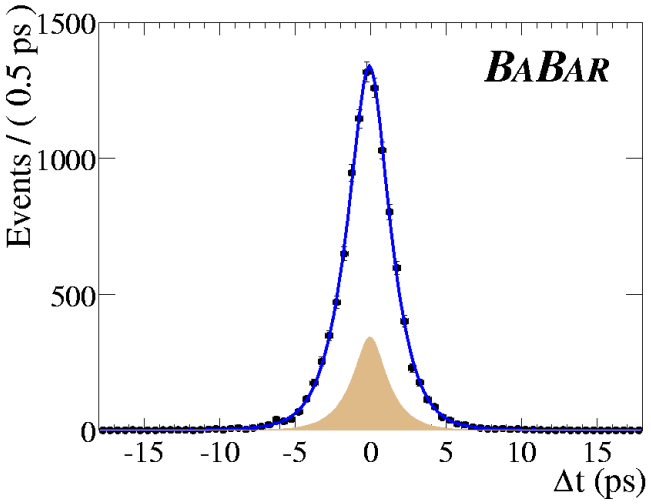
BELLE

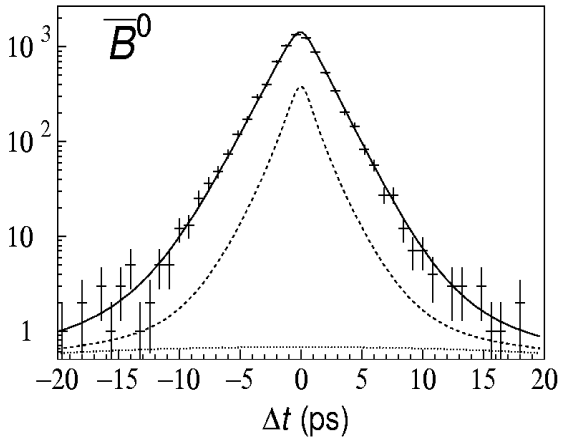
Fully reconstructed hadronic analysis

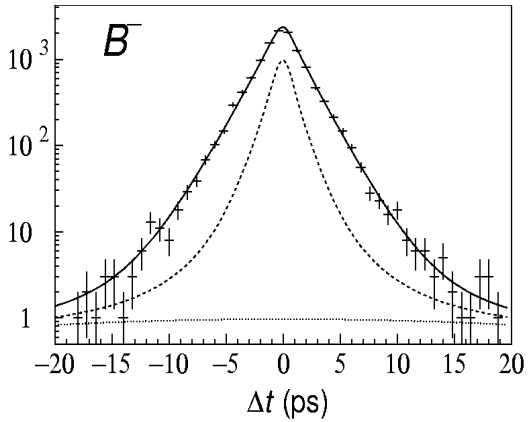
7863 B^0 events : $\tau(B^0)=1.554\pm0.030\pm0.019$ ps

12047 B^+ events: $\tau(B^+)=1.695\pm0.026\pm0.015$ ps







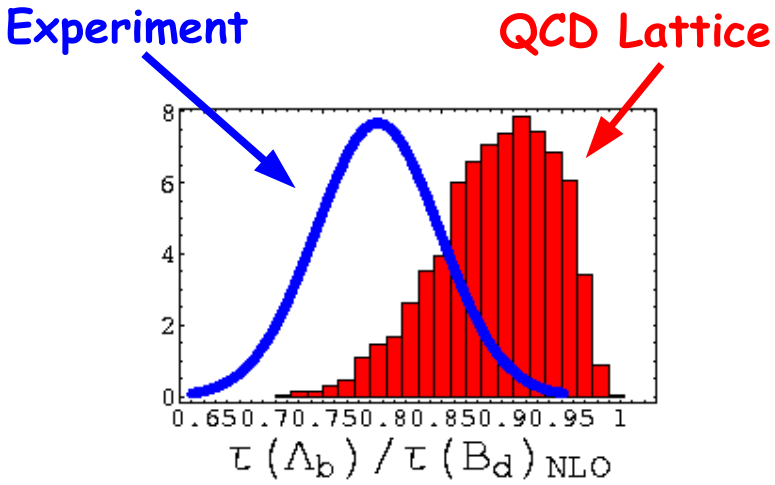


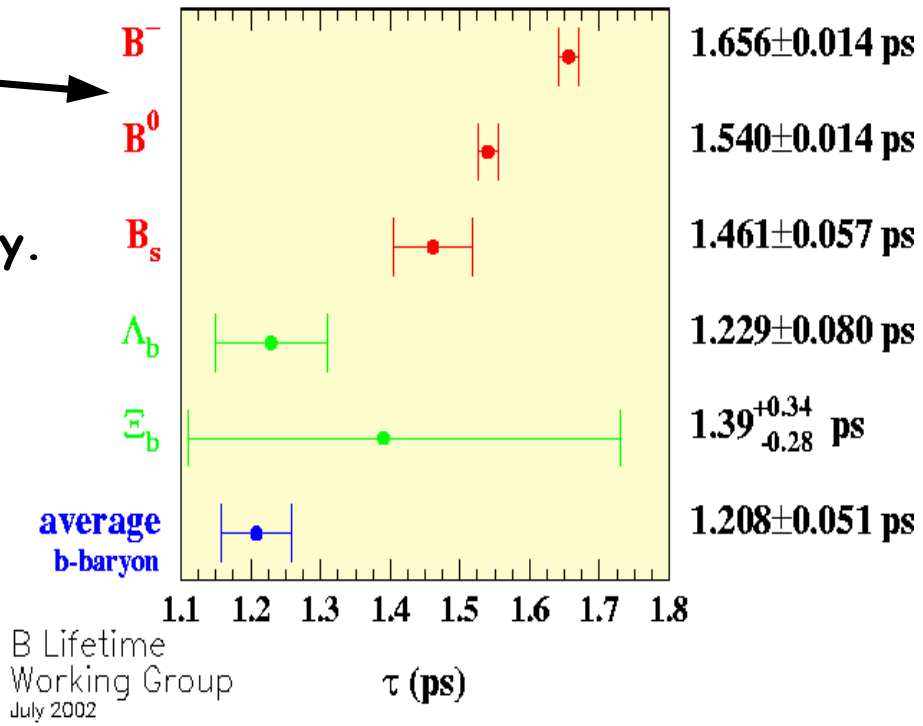
B lifetime averages

B factories improved the precision for B^0 and B^+ a lot.

The $\tau(B^+)/\tau(B^0)$ ratio is 1.073±0.014
A 5 σ effect in agreement with theory.

$\tau(\Lambda_b)$ is due to latest QCD lattice calculation (maybe) not a problem.
(Franco,Lubicz,Mescia,Tarantino)





For the B hadrons answers are awaited from CDF and D0.

Flavour physics in the Standard Model

In the Standard Model, charged weak interactions among quarks are described by a 3x3 matrix: the CKM matrix

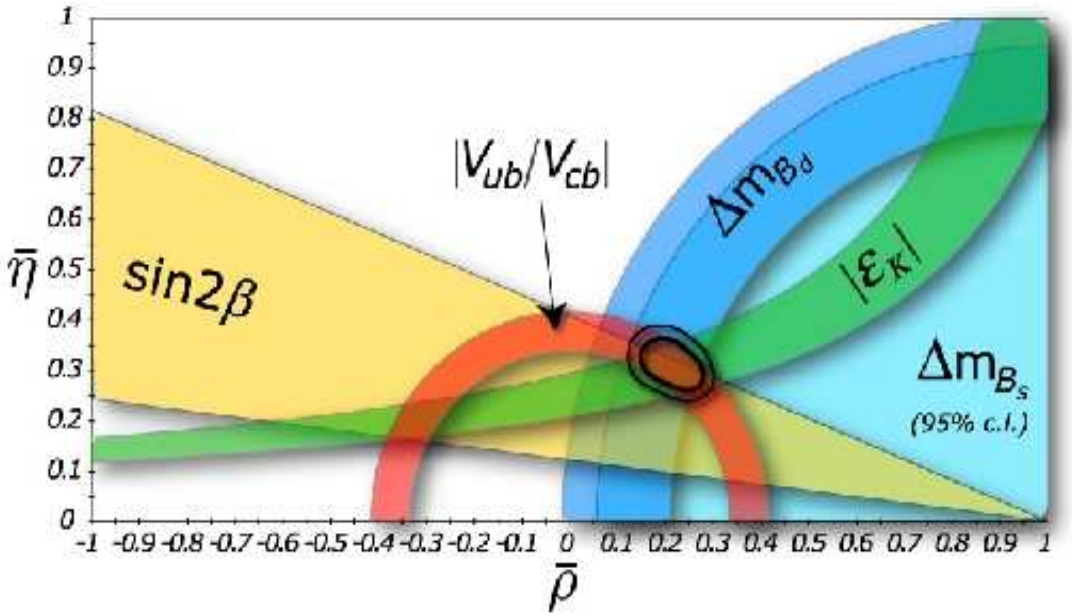
$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \cdot \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

Wolfenstein parametrization:4 parameters (1 CP violating phase + 3 angles)

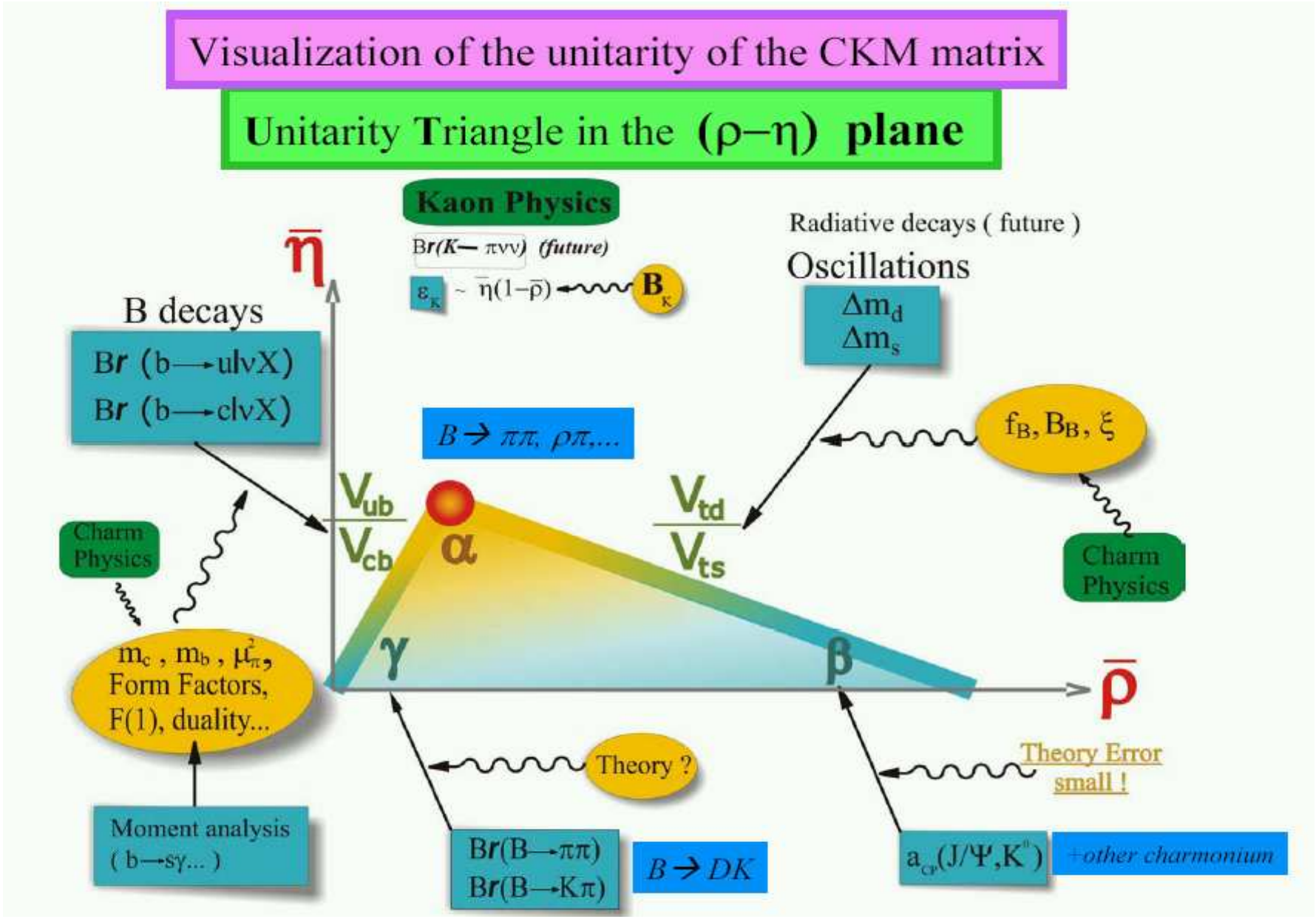
$$\hat{V}_{CKM} = \begin{pmatrix} 1-\frac{1}{2}\lambda^2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{1}{2}\lambda^2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

B-physics plays a major role in the determination of those parameters:

- B oscillations (Δm_s Δm_d)
- sin 2β (B^0 -> J/ψ K_s.)
- V_{cb} (Semileptonic B decays)
- V_{ub} (charmless s.l. B decays)



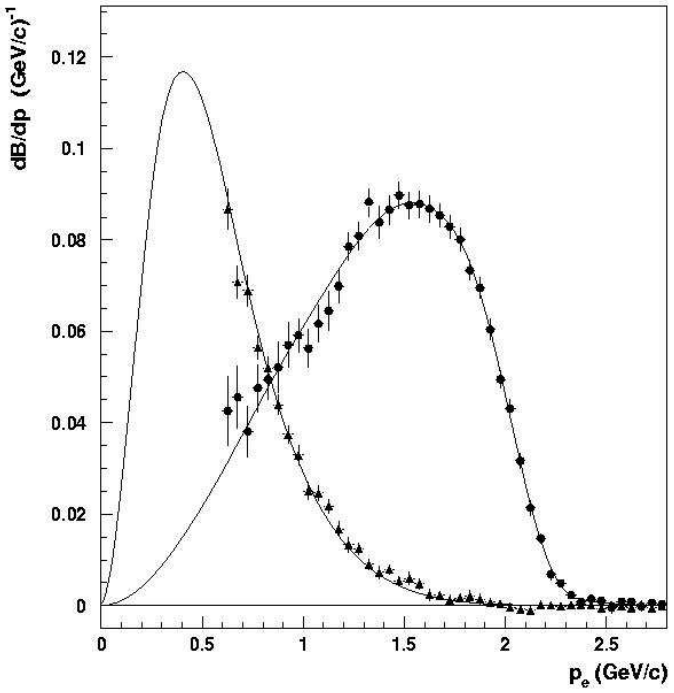
from Achille Stocchi talk at ICHEP 2002



Analyses for V_{cb}

Inclusive determination using semi-leptonic decays.

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

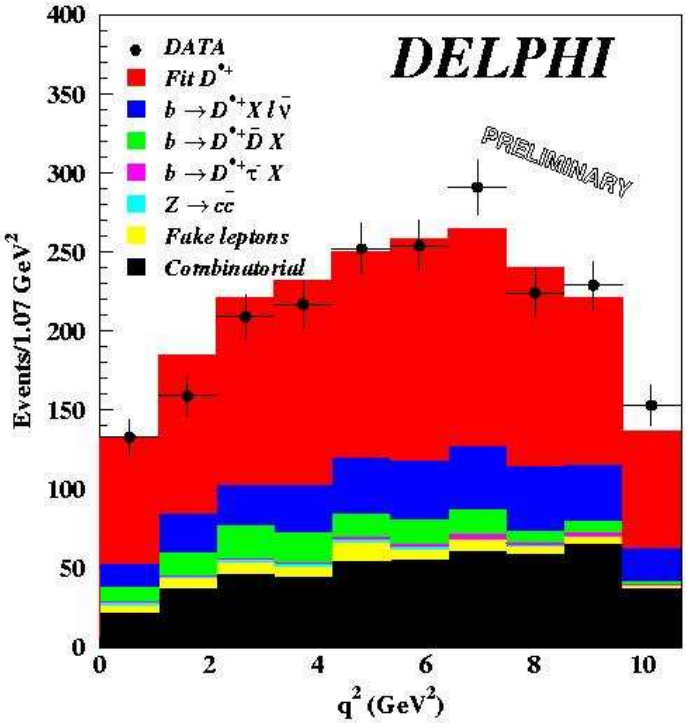


BELLE:

V_{cb} = (40.8 ± 1.0 ± 2.5) x 10^{-3}

Exlusive determination using semi-leptonic decays.

$$\frac{d\,\Gamma(B^0 \to D^{*+}\, l^-\, \nu)}{d\,\omega} = K(\omega)\, F^2(\omega) |V_{cb}|^2$$



DELPHI:

$F(1) \cdot V_{cb}$ = (38.0 ± 1.8 ± 2.0) x 10^{-3}

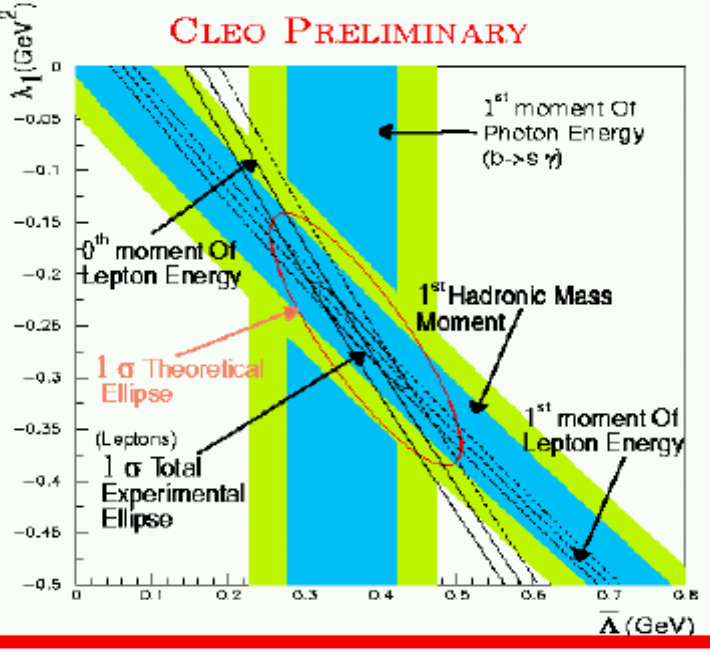
from Achille Stocchi talk at ICHEP 2002

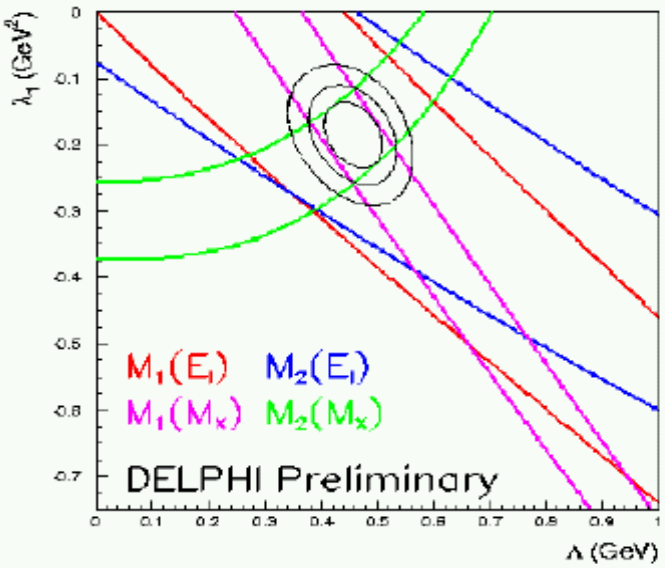
Measurement of the moments of the distributions of the

HADRONIC mass (CLEO/DELPHI)

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

Photon energy b → s γ (CLEO)





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

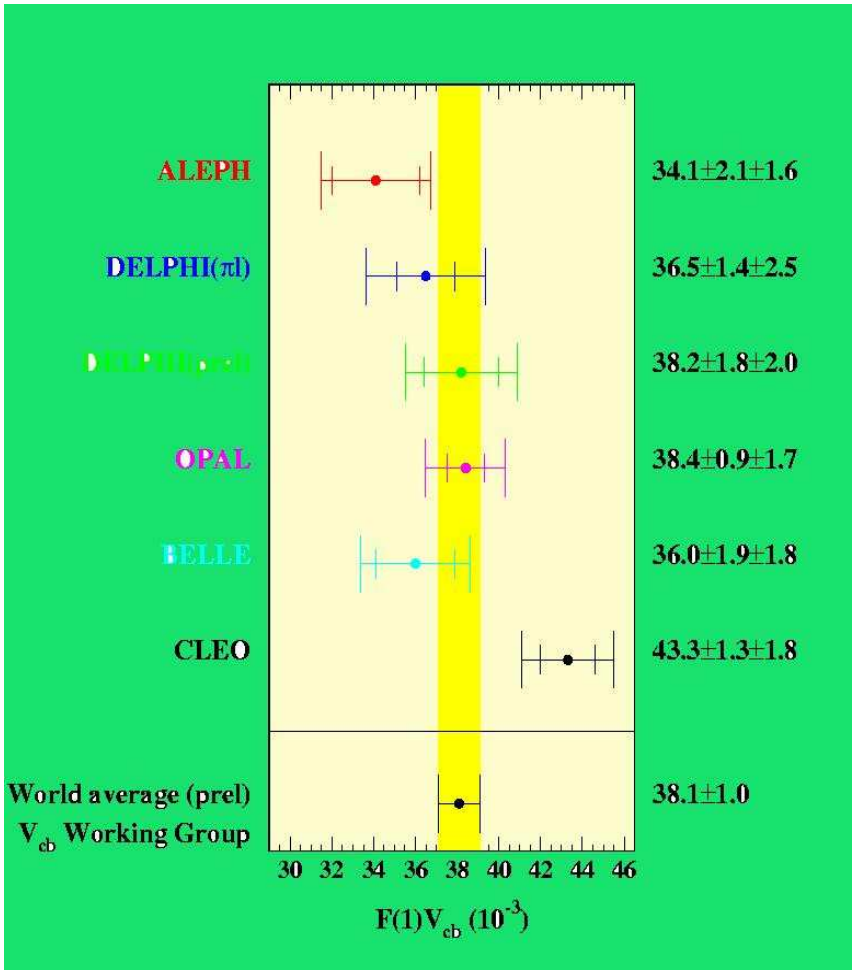
$\bar{\Lambda}$=(0.44±.04±.05±.07) GeV
λ_1=(-0.23±.04±.05±.08) GeV^2

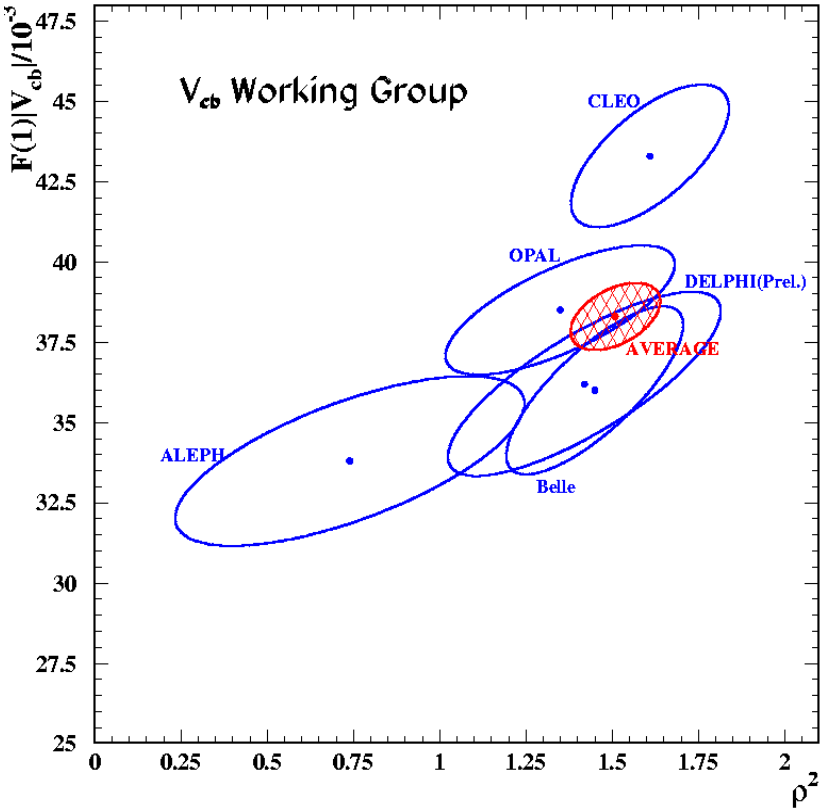
V_{cb}(inclusive)= (40.7 ± 0.6 ± 0.8(theo.)) 10^{-3}

V_{cb} Working Group

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

World averages for V_{cb}



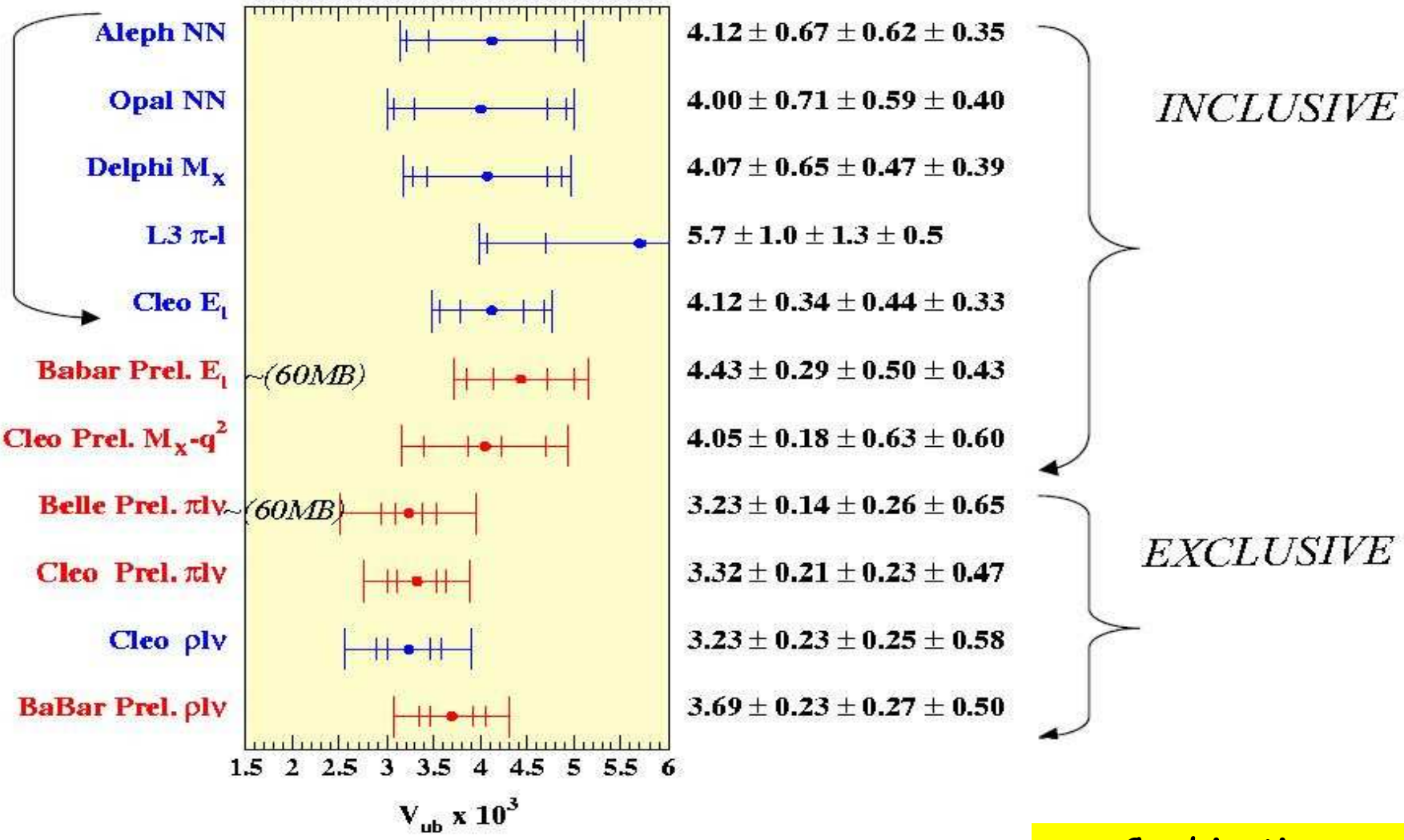


V_{cb} (exlusive) = (41.9 ± 1.1 ± 1.9) x 10^{-3} , F(1) = 0.91 ± 0.04

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

V_{cb} = (40.9 ± 0.8) x 10^{-3}

World averages for V_{ub}



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

from CKM workshop Spring 2002

Combination inclusive + exclusive allowed ?

from Achille Stocchi talk at ICHEP 2002

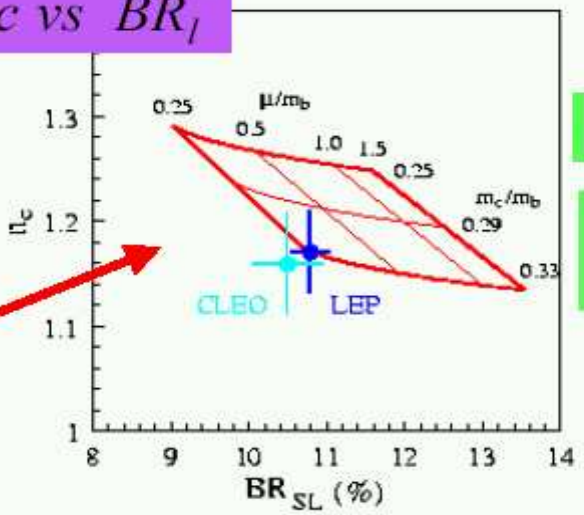
Charm multiplicity : nc vs BR_l

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

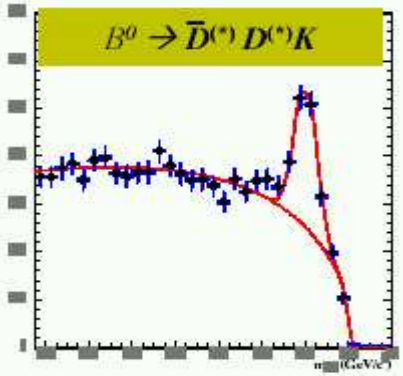


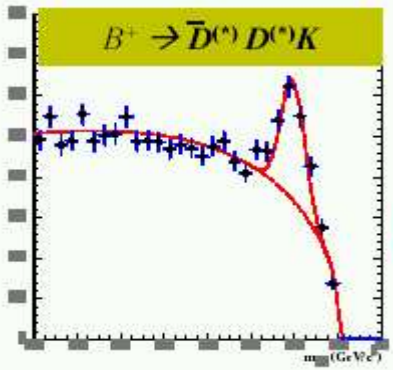
$m_c/m_b \sim 0.3$

$\mu \sim 0.35$ low scale ?

BaBAR

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





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

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

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 ?)

Oscillations in the B system

The probability that an initially produced B0 meson at t=0 decays as B0 or B0-bar at proper decay time t is given by:

$$P(t)_{B^0_{s,d} \to B^0_{s,d},\, \bar{B}^0_{s,d}} = \Gamma \frac{e^{-\Gamma t}}{2} (1 \pm \cos(\Delta m_{s,d}\, t))$$

$$\Delta m_d \propto f^2_{B_d} B_{B_d} |V_{cb}|^2 \lambda^2 |V_{td}|^2$$

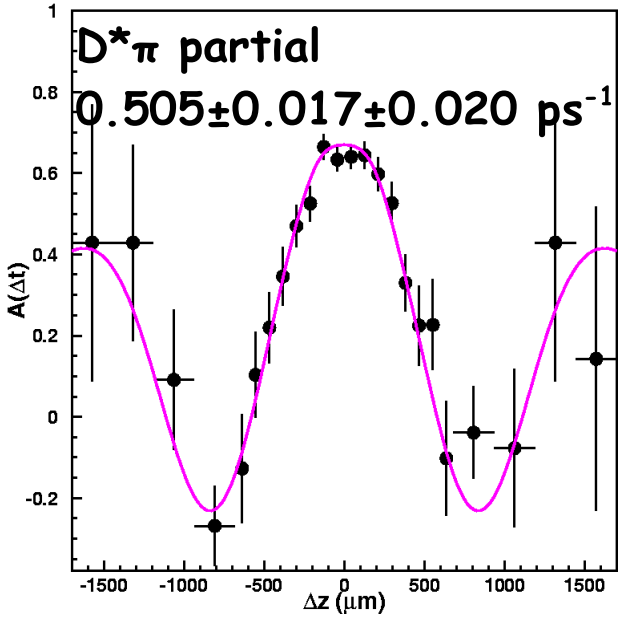
$$\Delta m_s \propto f^2_{B_s} B_{B_s} |V_{ts}|^2$$

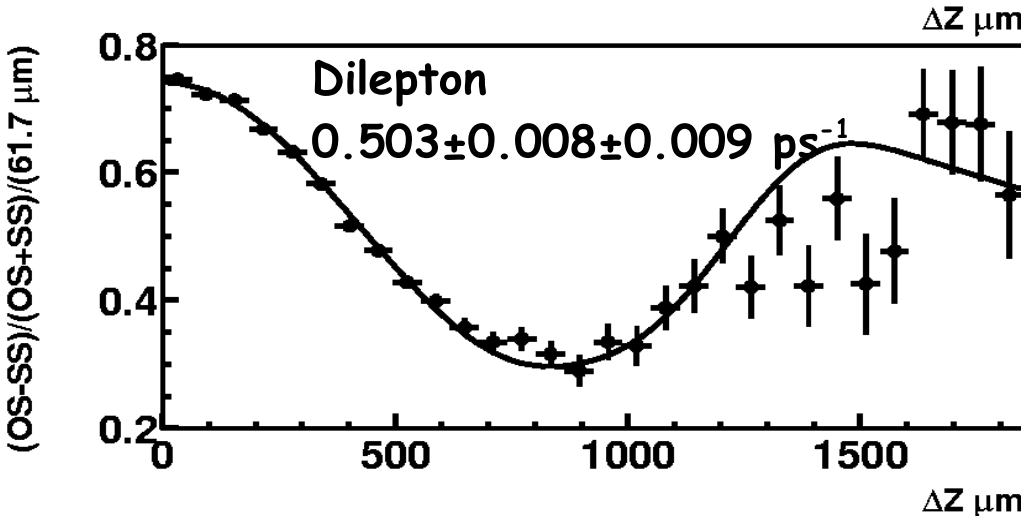
The oscillation frequency Δm_s for B_s mesons is approximately ~30 times faster than Δm_d for B_d mesons -> Excellent time resolution required !

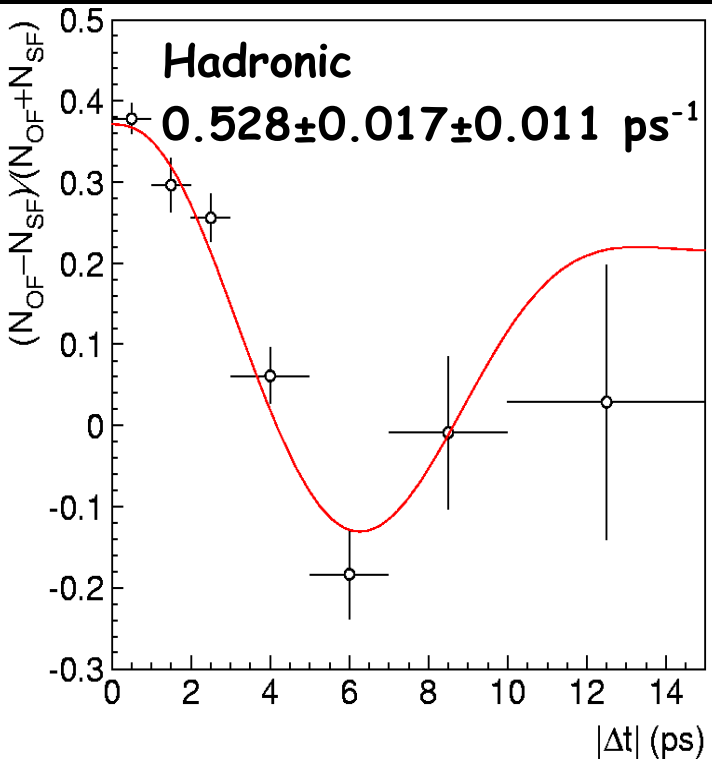
The ratio of the oscillation frequencies is theoretically under good control.
--> Precise CKM element determination

$$\left|\frac{V_{td}}{V_{ts}}\right| = \xi \sqrt{\frac{m_{B_s}}{m_{B_d}}} \sqrt{\frac{\Delta m_d}{\Delta m_s}} \qquad \xi = 1.16 \pm 0.05$$

Δm_d - BELLE

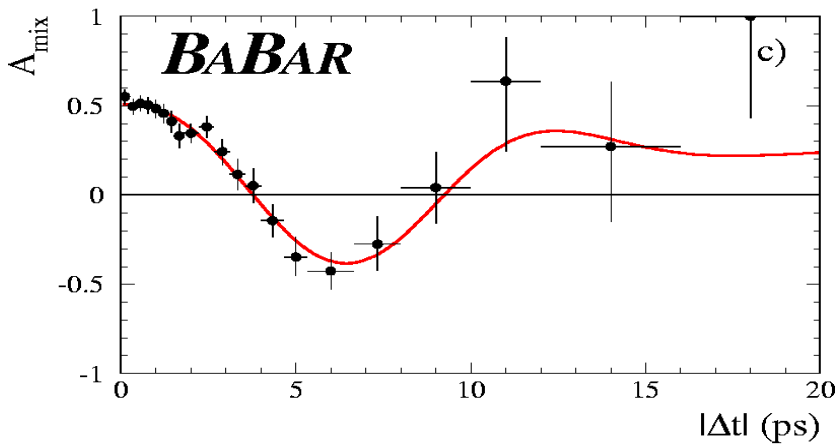




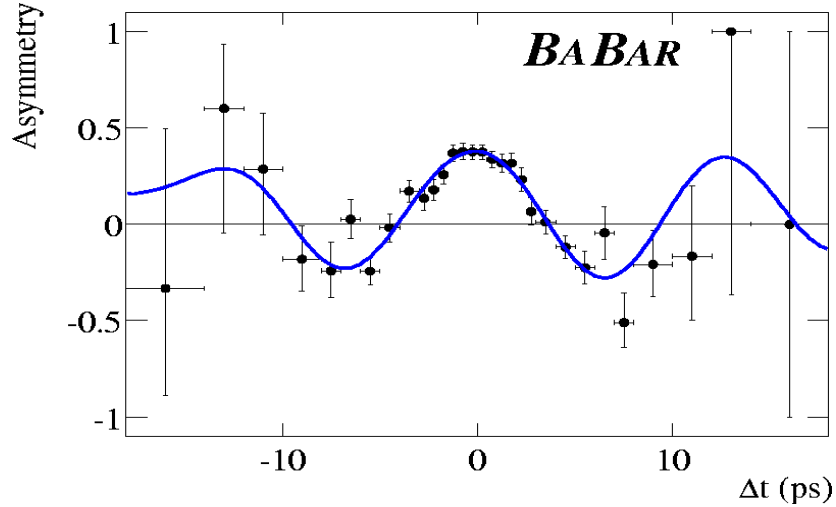


Δm_d – BABAR

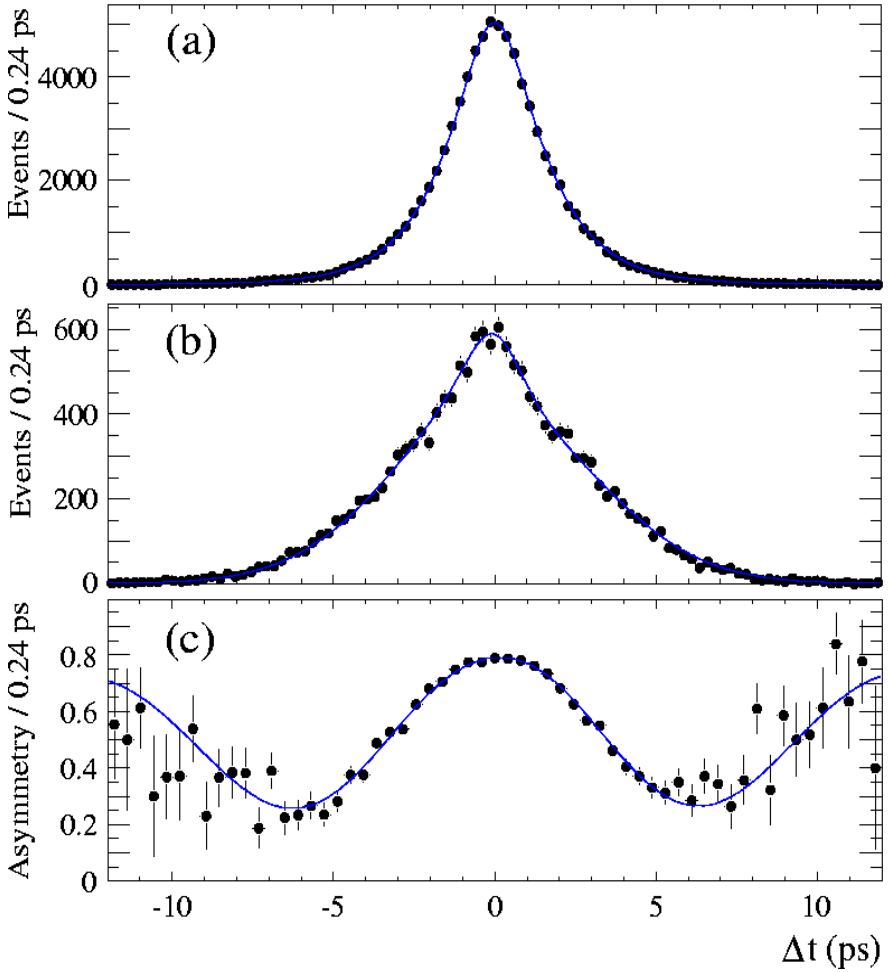
Hadronic analysis:
$0.516 \pm 0.016 \pm 0.010$ ps^{-1}



D*lν : $0.492 \pm 0.018 \pm 0.013$ ps^{-1}



Dilepton analysis:
$0.493 \pm 0.012 \pm 0.009$ ps^{-1}



Δm_d - Average

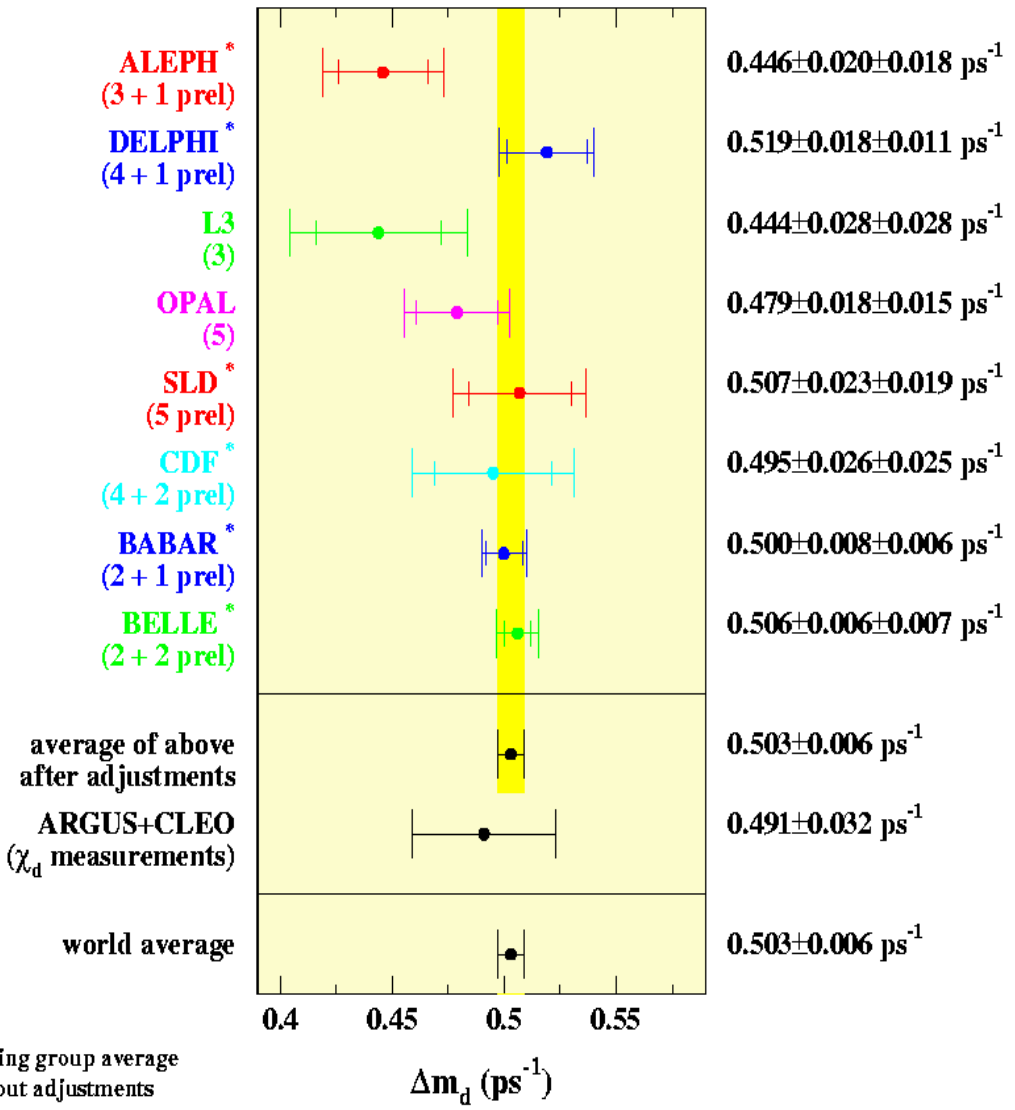
LEP/SLD/CDF measured Δm_d on a 2.6 % level:

$\Delta m_d = 0.498 \pm 0.013\ ps^{-1}$

The B factories improved the precision by a factor of 2 !

Average of LEP/SLD/CDF/BELLE /BABAR (1.2 %)

$\Delta m_d = 0.503 \pm 0.006\ ps^{-1}$



Δm_s

Combination using the amplitude method

Easy combination of different analysis

$$P(B_s^0 \to B_s^0, \bar{B}_s^0) = \frac{\Gamma e^{-\Gamma t}}{2}(1 \pm A \cdot \cos(\omega t))$$

At a given Δm_s value:

A = 1 oscillation

A = 0 no oscillation

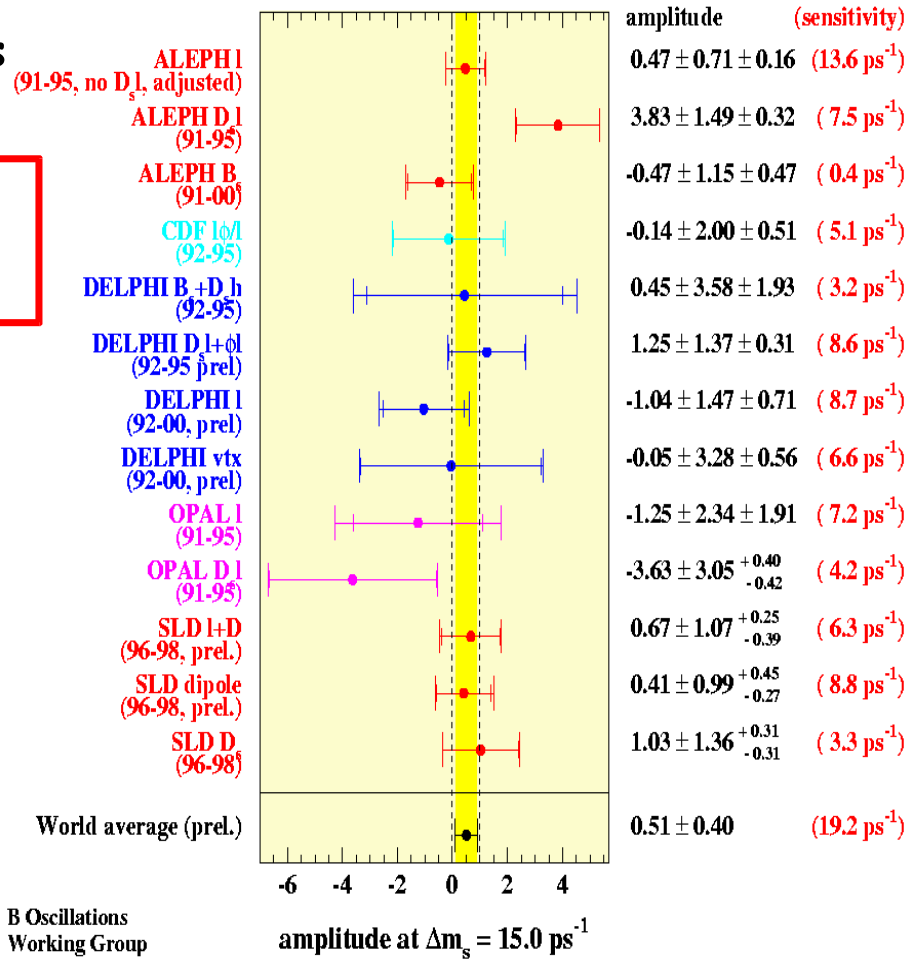
Set 95 % Confidence Level limit for:

Δm_s value for which $A + 1.65\ \sigma_A = 1$

Determine Sensitivity:

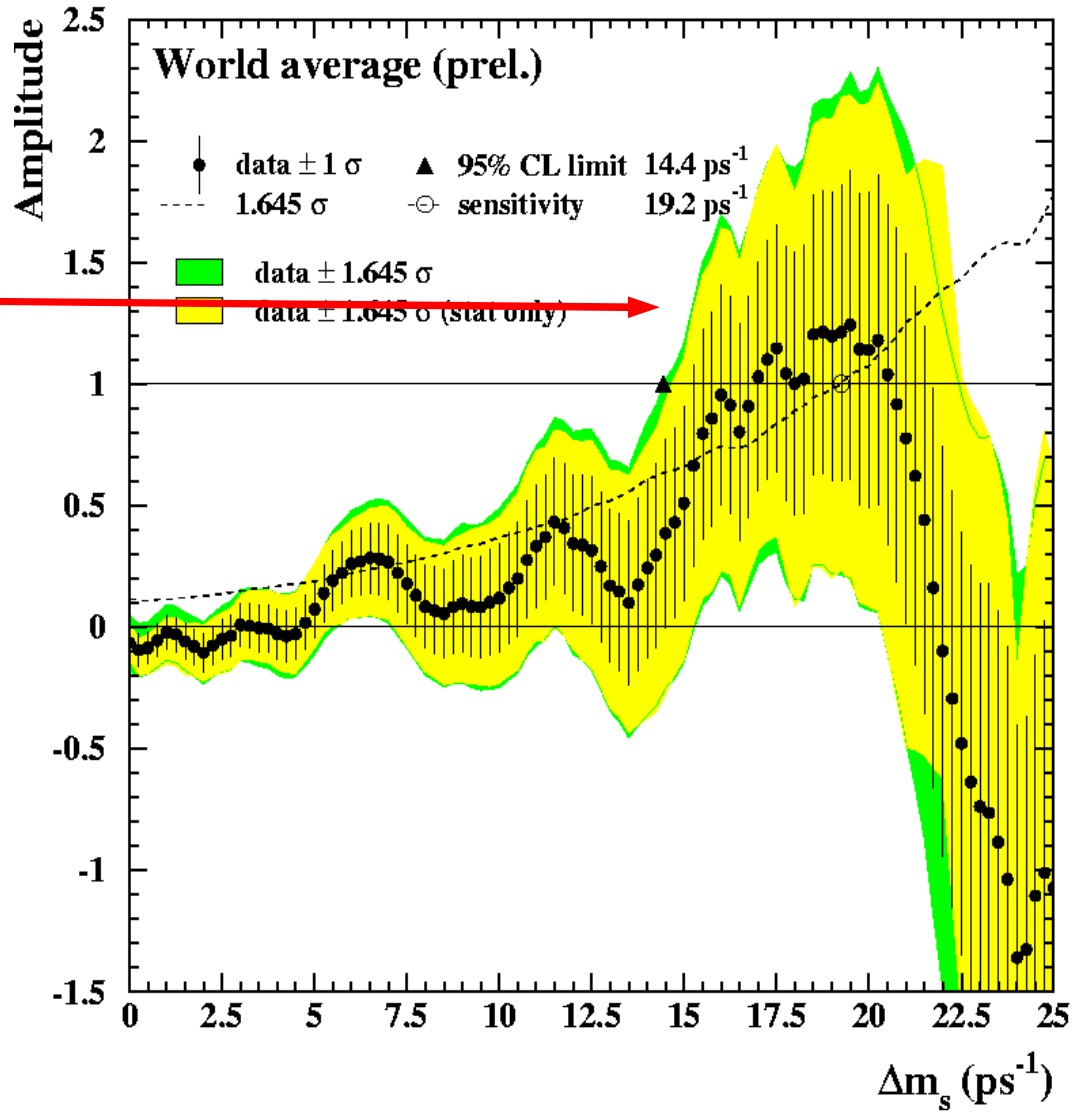
Δm_s value for which $1.65\ \sigma_A = 1$

Combination of LEP/SLD/CDF I



Δm_s

"Signal hint" at 17.5 ps^{-1}
with 2.3 σ significance.
(SM expectation ~17.5±3.3ps^{-1})



This is probably the final word from LEP/SLD !

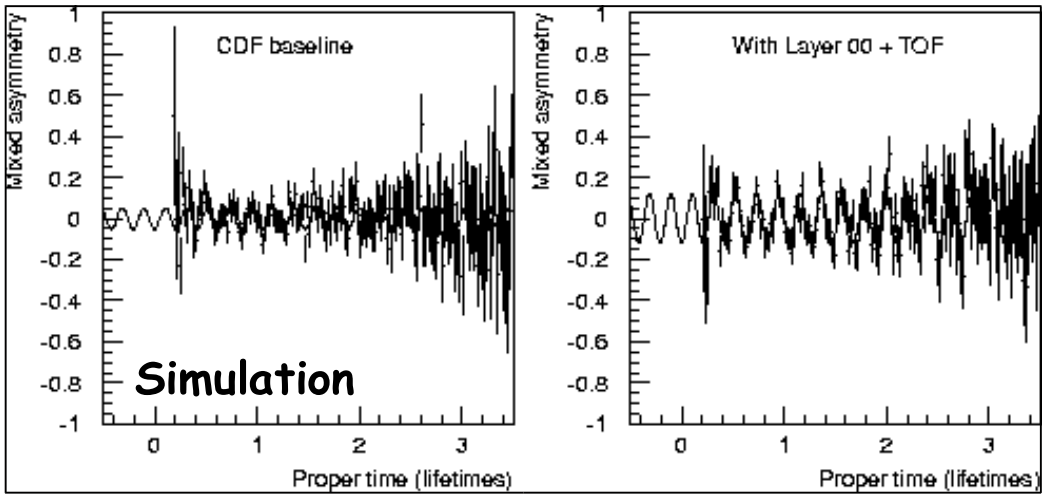
Δm_s

Bs mixing (up to xs=63)

and Bs CP violation

will be prime goals for

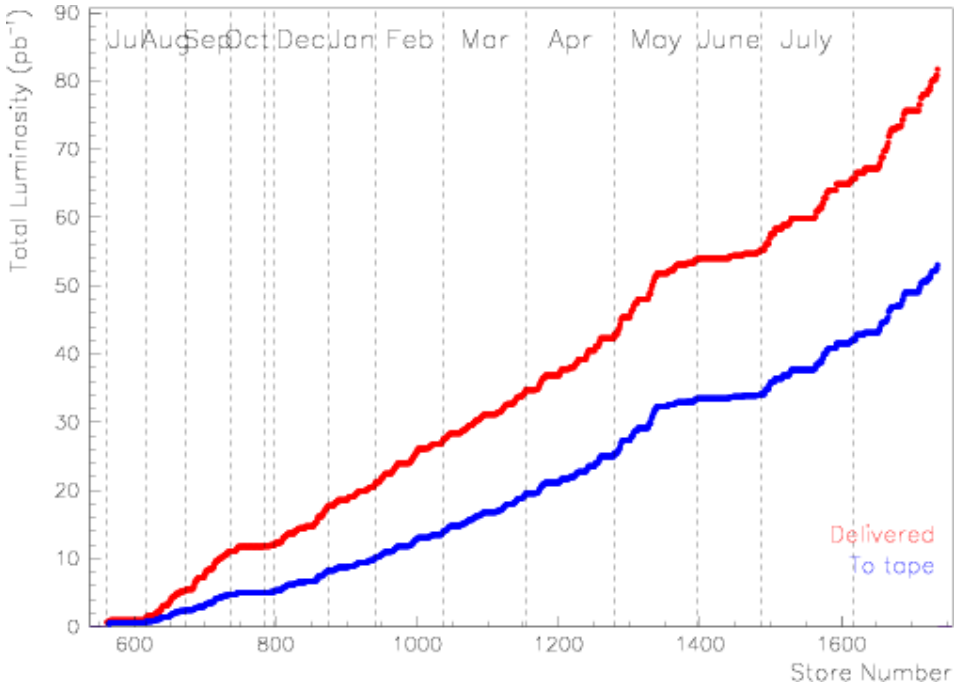
CDF II and D0 at Fermilab



Waiting for upgraded

Tevatron luminosity

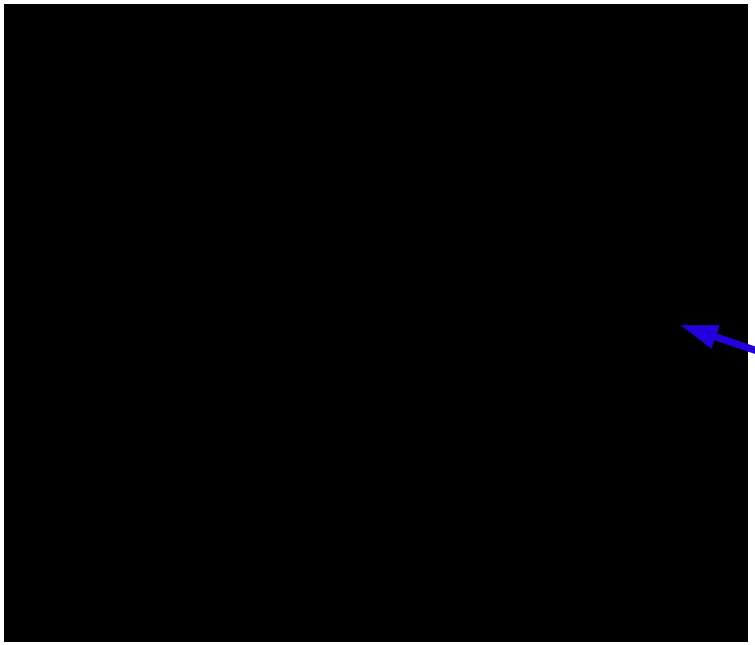
to shoot off...

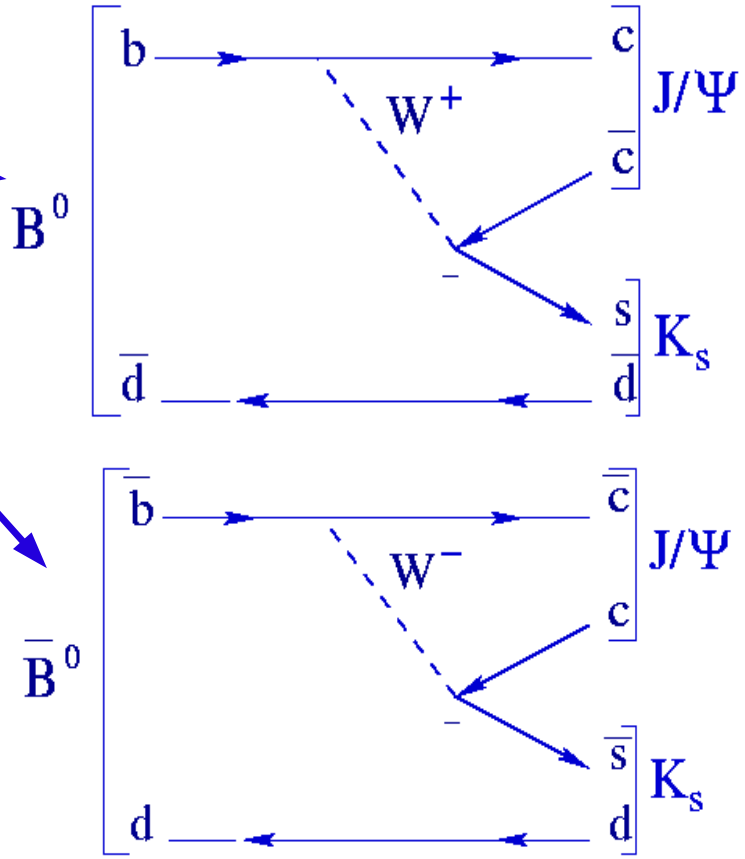


CP violation analysis - "Theory"

The same CP eigenstate produced from $B^0(\bar{B}^0) \rightarrow J/\psi\, K_s$.

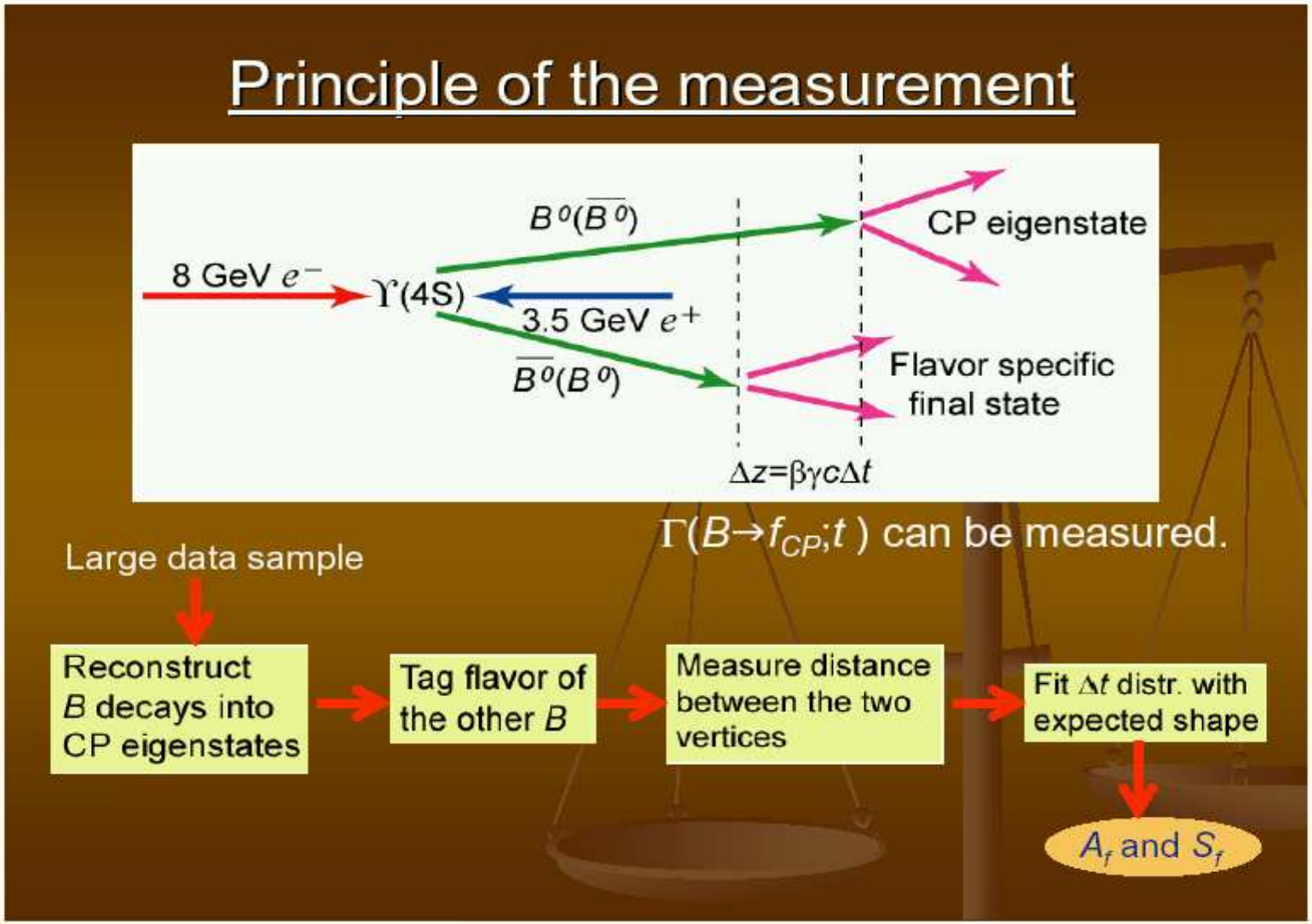
Interference of mixing and decay leads to a time dependent CP-asymmetry, determined by mixing phase --> allows to measure sin 2β in unitarity triangle





Expectation of A_{CP} measurement with and without resolution.

from Masa Yamauchi talk at ICHEP 2002



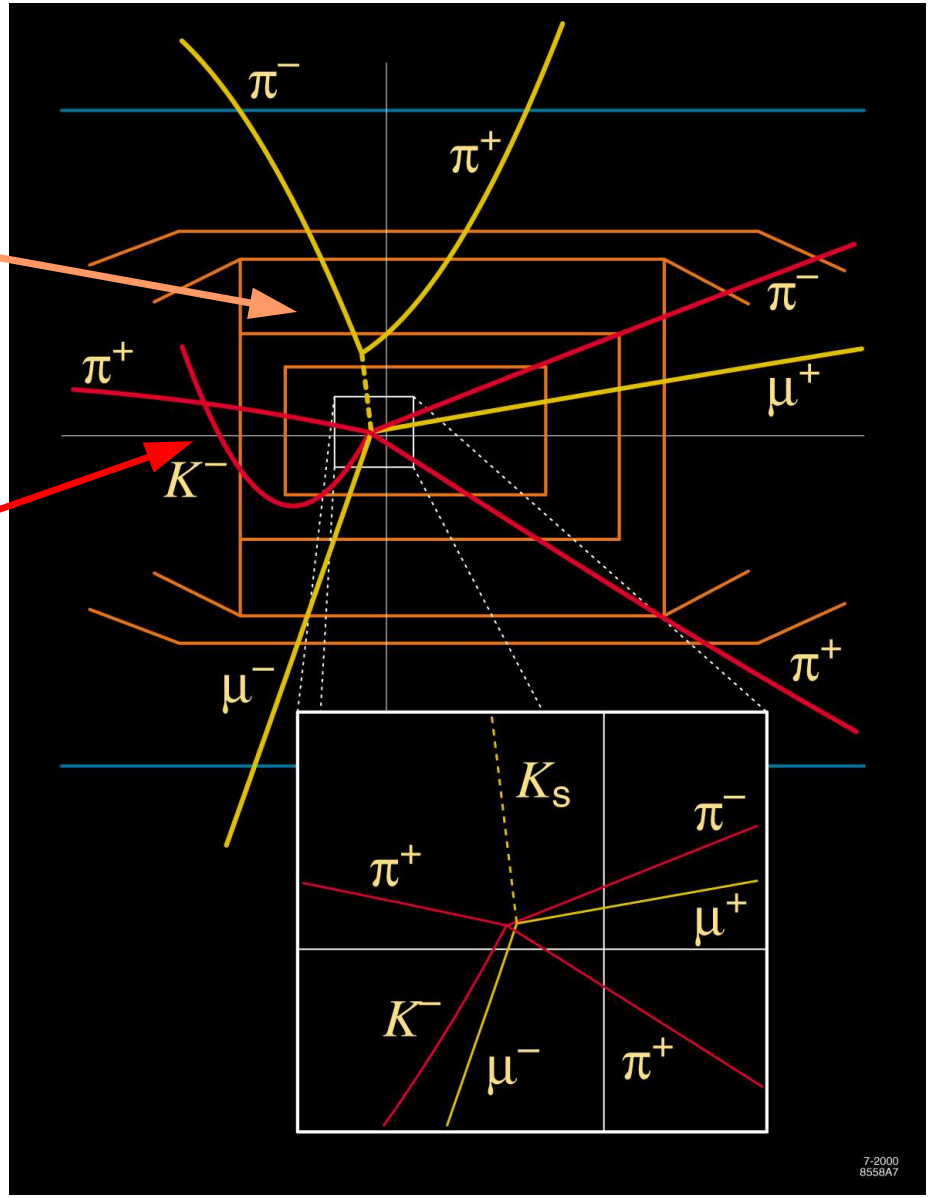
CP event -BABAR

Beautyful B^0 -> J/ψ K_s

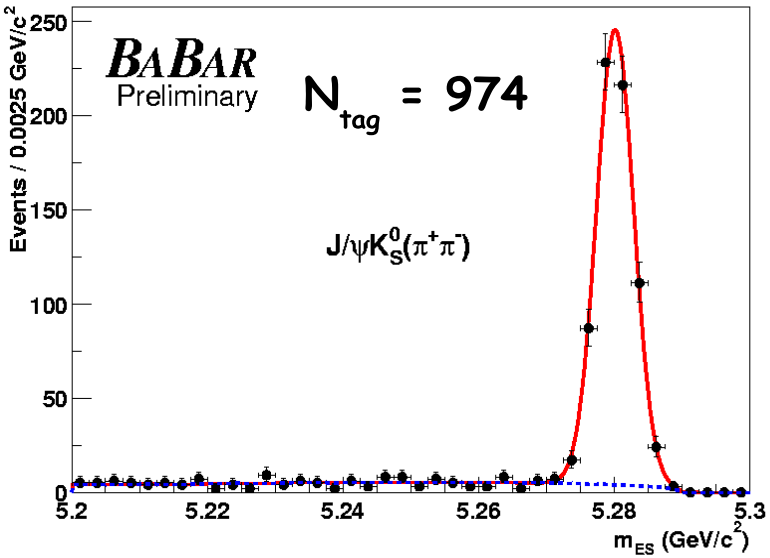
Reconstructed from $J/\psi \rightarrow \mu^+\mu^-$ and $K_s \rightarrow \pi^+\pi^-$

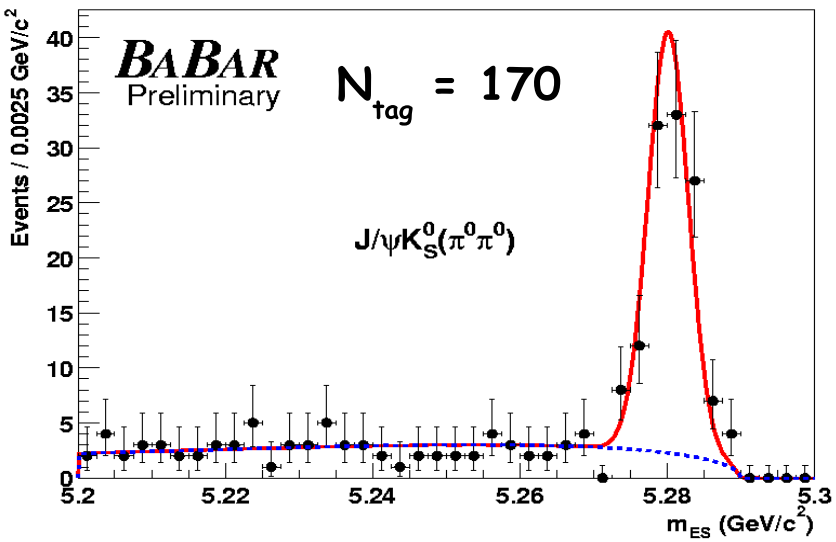
Production flavour is determined from opposite side tag.

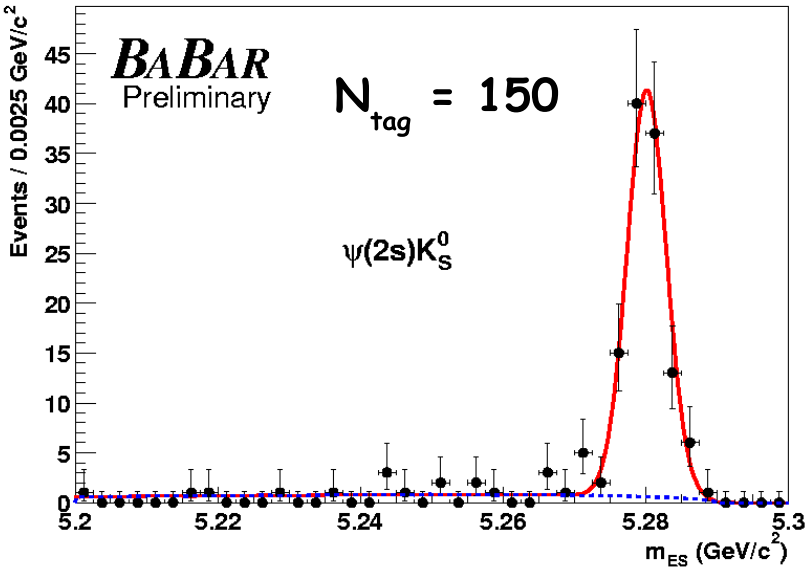
$\overline{B}^0$ -> $D^0\pi^+\pi^-$ -> $K^-\pi^+\pi^+\pi^-$

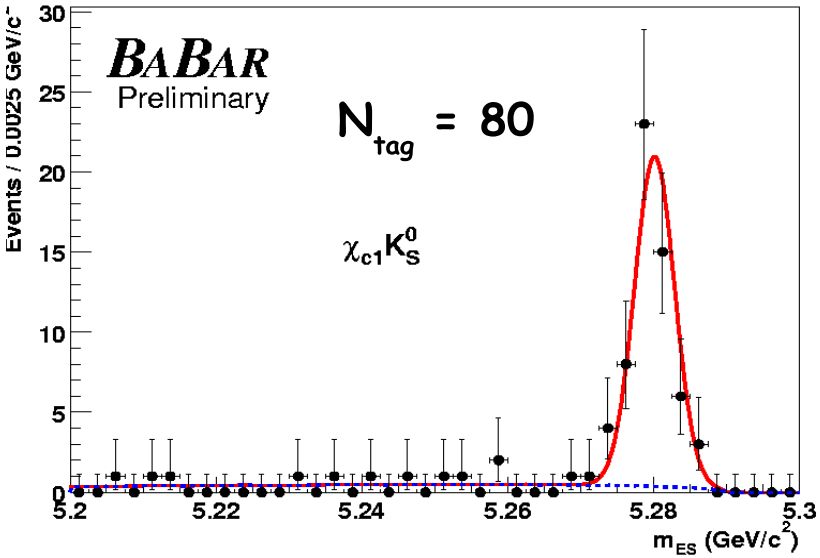


CP sample – BABAR: Golden (η =-1) events









Flavour tagging – BABAR

Flavour tagging is done in steps:

1. Lepton from semileptonic decay available ? (Charge determines flavour)
2. Identified Kaon from cascade b -> c -> s (Kaon charge)
3. Soft pions from D* decays (Soft pion charge)
4. Neural network for the rest of the events.

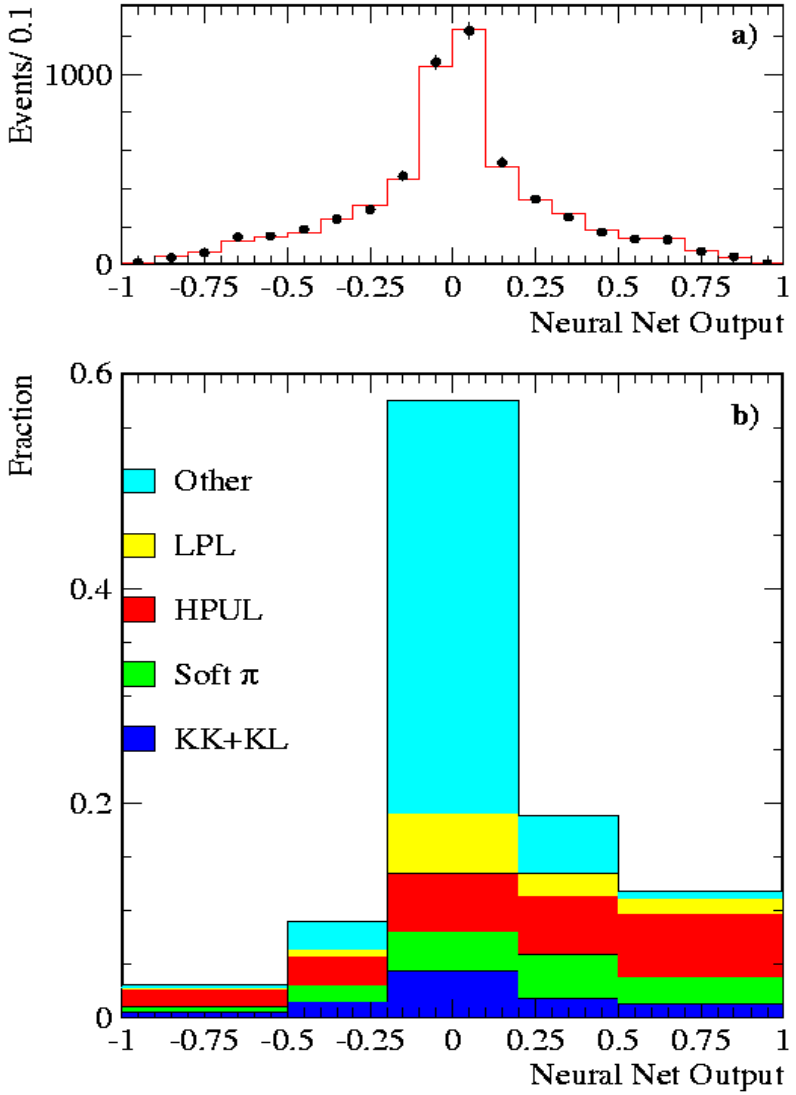
Results (ω=Mistag, ε=Effiency)

Lepton tag: ω=8.6 % ε=11.1 %

Kaon tag : ω=18.1 % ε=34.71 %

D* tag : ω=22.0 % ε=7.7 %

NT1 tag : ω=37.3 % ε=14.0 %

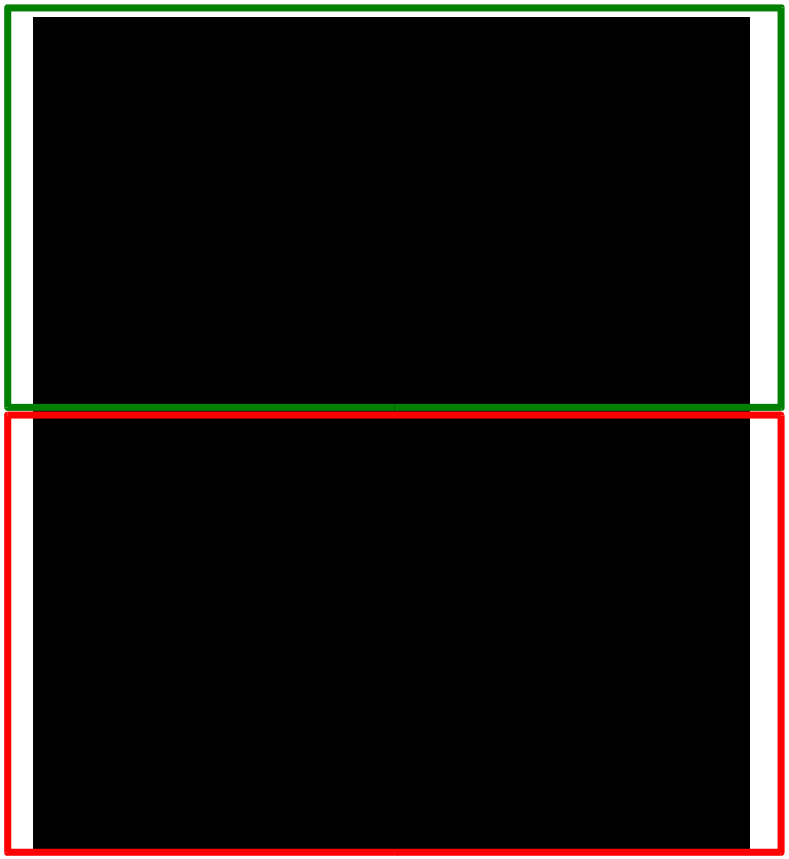


Results for sin 2β at BELLE and BABAR

BABAR result (81.2 fb^{-1}):

sin 2β = 0.755 ± 0.074 (η = -1)

sin 2β = 0.723 ± 0.158 (η = +1)

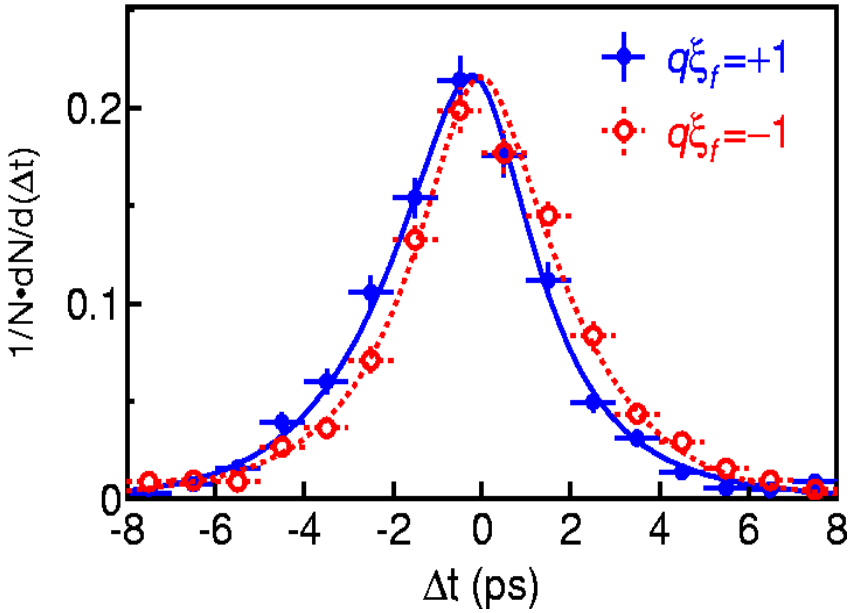


sin 2β = 0.741 ± 0.067 ± 0.033

BELLE result (78 fb^{-1}):

sin 2β = 0.716 ± 0.083 (η = -1)

sin 2β = 0.78 ± 0.17 (η = +1)



sin 2β = 0.719 ± 0.074 ± 0.035

Search for direct CP violation

Direct CP violation is not yet established in the B system.

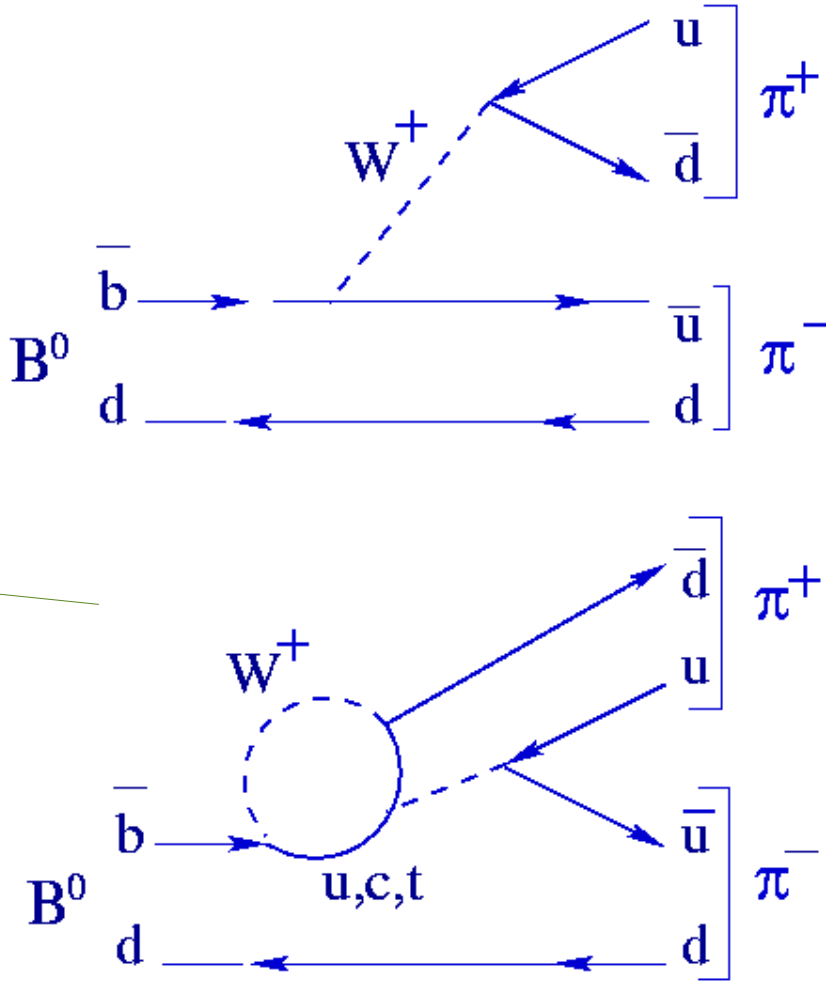
$$A_{CP} \propto -C_{CP} \cos \Delta m_d \Delta t + S_{CP} \sin \Delta m_d \Delta t$$

If direct CP violation is realised a second term ~cos($\Delta m_d \Delta t$) show up ($C_{CP} \neq 0$).

Penguin contribution is necessary.

A good candidate for this process is
$B^0 \rightarrow \pi^+\pi^-$

Experimental challenge is high due to
$B^0 \rightarrow K^+\pi^-$ and three body background !



B -> $\pi^+\pi^-$ reconstruction - BELLE

Reconstruction:

$\Delta E = E^*_{rec} - E^*_b$

$M_{BC} = \sqrt{(E^{*2}_b - p^{*2}_{rec})}$

ΔE after signal cut on M_{bc} :

$5.271 < M_{bc} < 5.287$ GeV/c2

$|\Delta E| < 0.067$ GeV

$N(\pi^+\pi^-) = 73.5 \pm 13.8$

$N(K^+\pi^-) = 28.4 \pm 12.5$

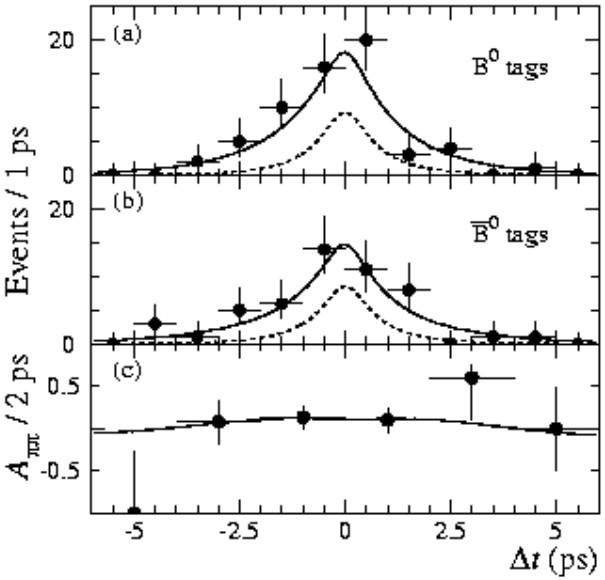
Results for $S_{\pi\pi}$ and $C_{\pi\pi}$

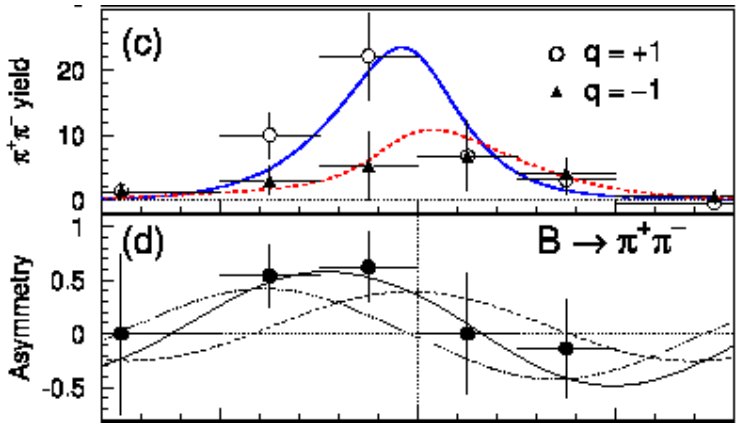
Different results on direct CPV from the B -> $\pi^+\pi^-$ analysis of both experiments !

BABAR Result (81.2 fb^{-1}):

$$S_{\pi\pi} = 0.02 \pm 0.34 \pm 0.05$$

$$C_{\pi\pi} = -0.30 \pm 0.25 \pm 0.04$$



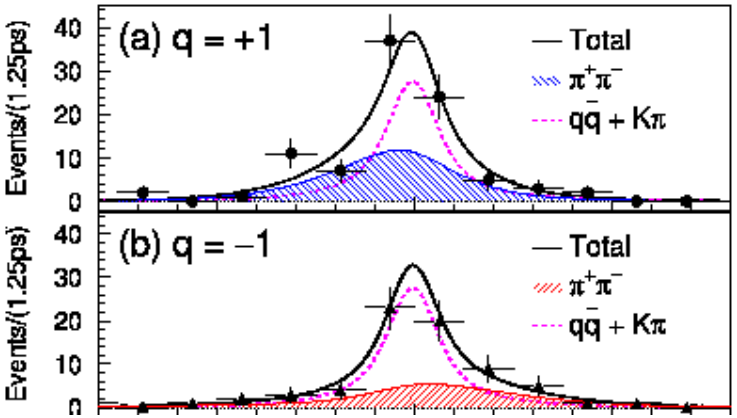


BELLE Result (41.8 fb^{-1})

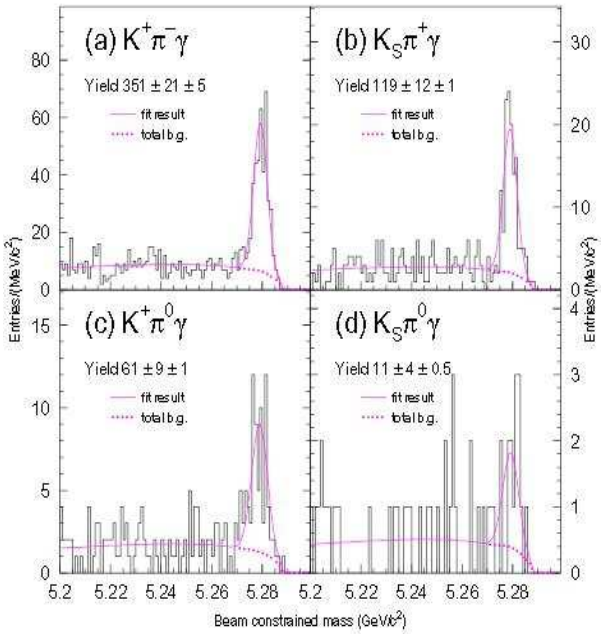
$C_{CP} \neq 0$:Direct CPV:

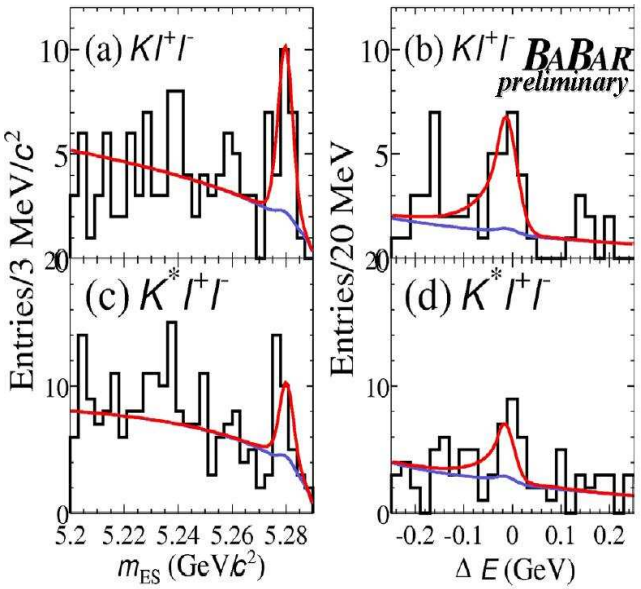
$$S_{\pi\pi} = -1.21\ ^{+0.38}_{-0.27}\ ^{+0.16}_{-0.13}$$

$$C_{CP} = A_{\pi\pi} = +0.94\ ^{+0.25}_{-0.31}\ ^{+0.09}_{-0.09}$$



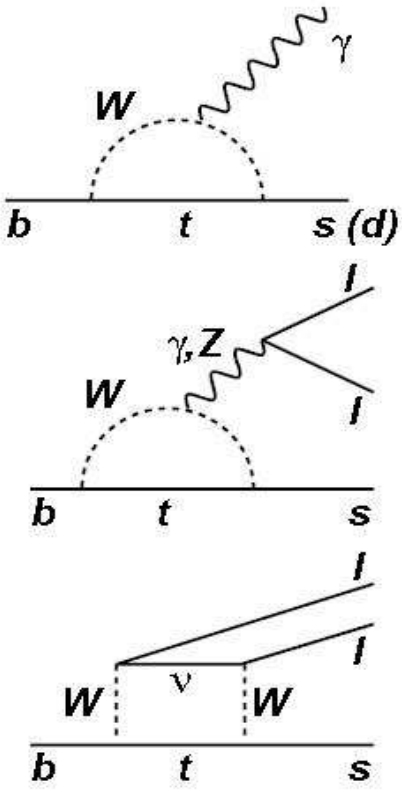
Radiative penguins





Exclusive radiative decays of BELLE and BABAR open up a new window for b->sγ precision measurements

B factories start to explore the 10^{-7} regime.



Inclusive observation of

B-> $X_s l^+l^-$ BR(BELLE) = $(61 \pm 14 \pm 13)\cdot 10^{-7}$

Exclusive channels B->$K^{(*)}l^+l^-$ from BABAR

BR(Kl^+l^-) □ $(8 \pm 2.5)\cdot 10^{-7}$

BR($K^*l^+l^-$) □ $(17 \pm 7.5)\cdot 10^{-7}$

from Achille Stocchi talk at ICHEP 2002

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

Exclusive radiative decays

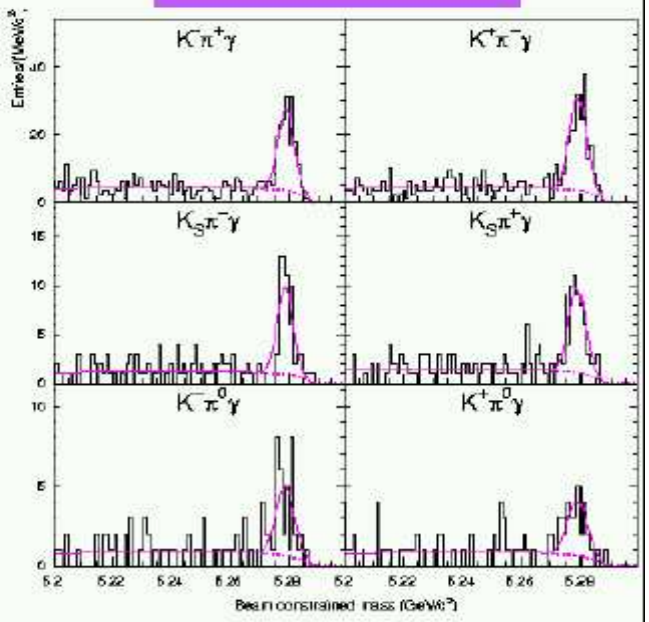
$K^*\gamma$ — Two measurements

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)

BELLE 65.4 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

$$\frac{B(B \to \rho\gamma)}{B(B \to K^*\gamma)} < 0.036$$

$\propto |V_{td}/V_{ts}|^2$

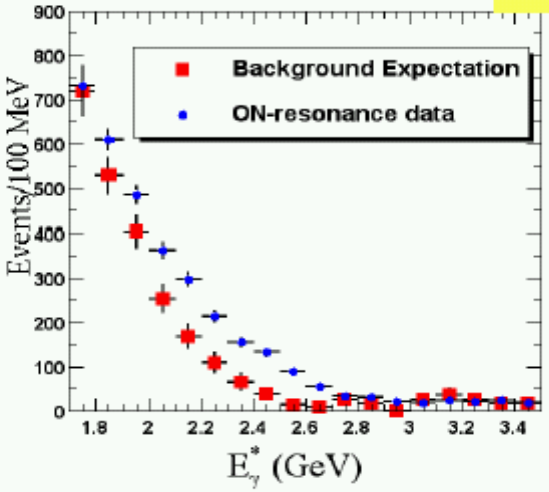
A.S. estimation

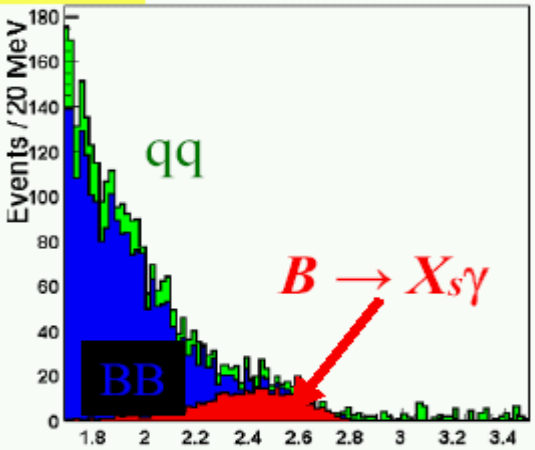
Not yet useful for constraining $(1-\rho)^2 + \eta^2$

MAINLY because 50% theo. error

Inclusive radiative decays

BABAR 61MB





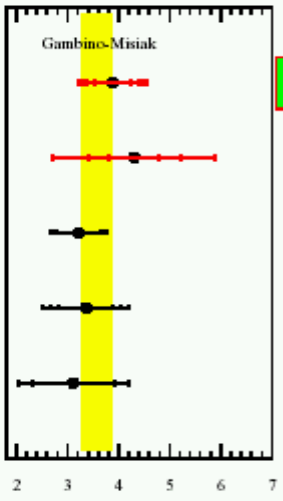
BABAR inclusive

BABAR 22MB summing 12 states

CLEO

BELLE

ALEPH



B ± stat ± syst ± theo

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

$(4.3 \pm 0.5 \pm 0.8 \pm 1.3) \times 10^{-4}$

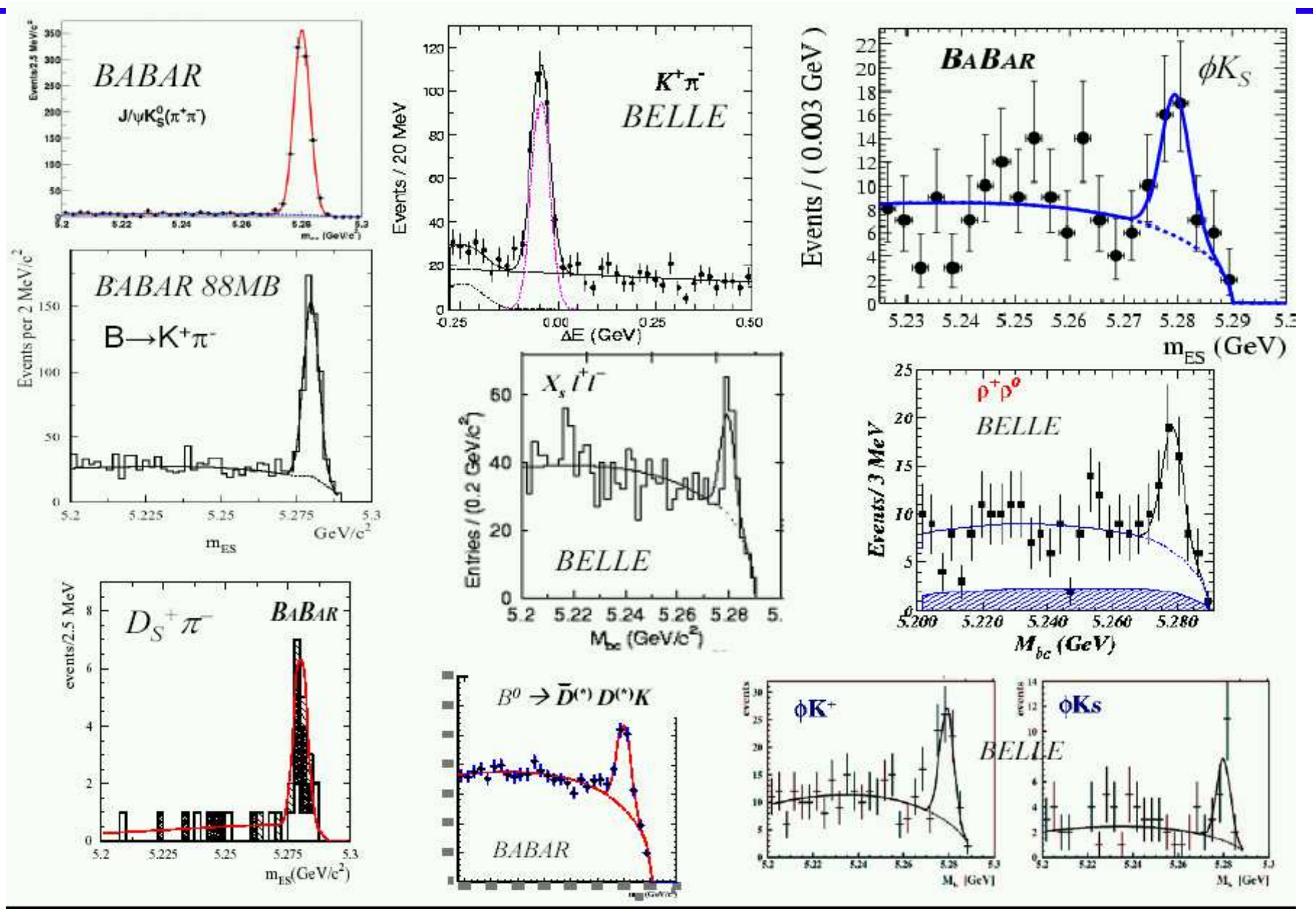
$(3.21 \pm 0.43 \pm 0.27^{+0.18}_{-0.10}) \times 10^{-4}$

$(3.36 \pm 0.53 \pm 0.42 \pm 0.52) \times 10^{-4}$

$(3.11 \pm 0.80 \pm 0.72) \times 10^{-4}$

Experimental precision is approaching theoretical errors

from Achille Stocchi talk at ICHEP 2002



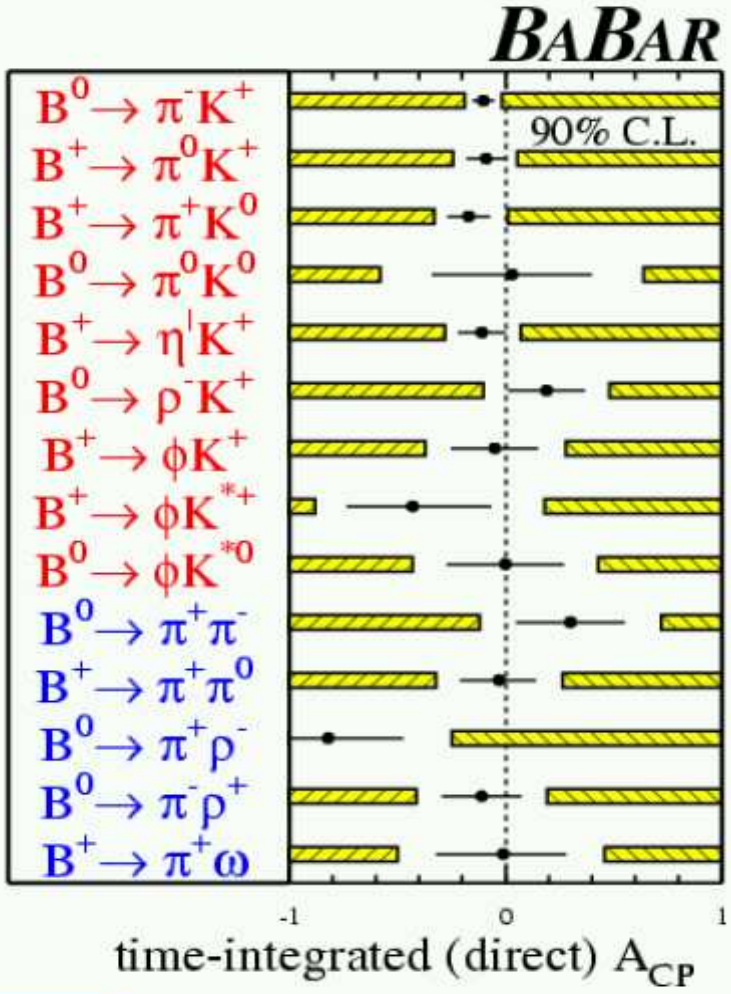
Charmless decays and CP violation "summary"

Mode	Branching ratio (x10^{-6}) Belle ~31 MB / ~45MB/~86MB	A_{CP} Belle ~31 MB / ~45MB	Branching ratio (x10^{-6}) BaBAr ~88 MB / ~60MB /~23MB	A_{CP} BaBAr ~88 MB / ~60MB /~23MB	Branching ratio (x10^{-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)		<3.3		<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)		23.9 ±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
$B^0 \to a^\pm\pi^\pm$			6.3(+2.0)(-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)	46±6 ±4 +0.7 ± 1.0 (+0.9)(-1.6)		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) ±0.03	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)				

Charmless B Decays

Direct CP measurements summary

No evidence for direct CP violation yet



from Achille Stocchi talk at ICHEP 2002

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

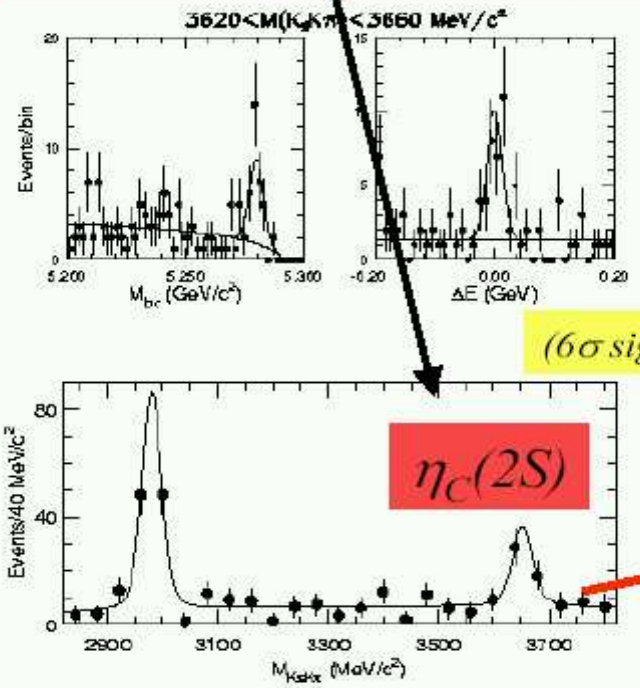
$\eta_C(2S)$: n=2 singlet S charmonium state

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



(6σ significance)

Why in exclusive B decays ?

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

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

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

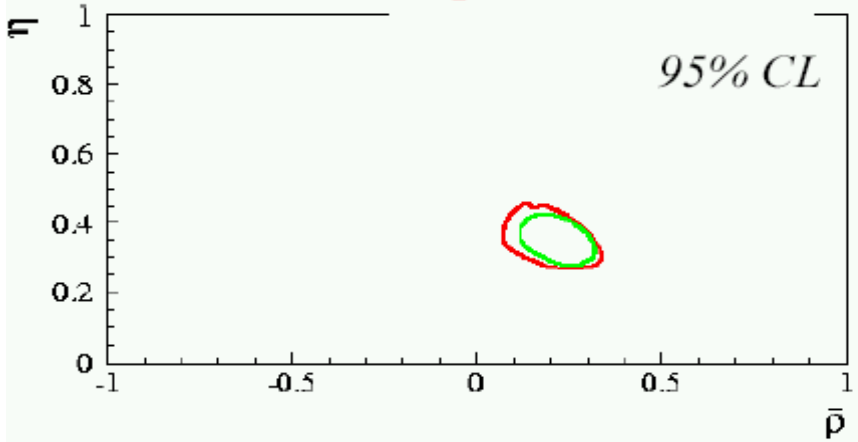
The evidence from Crystall Ball(1982) M = 3594 ± 5MeV

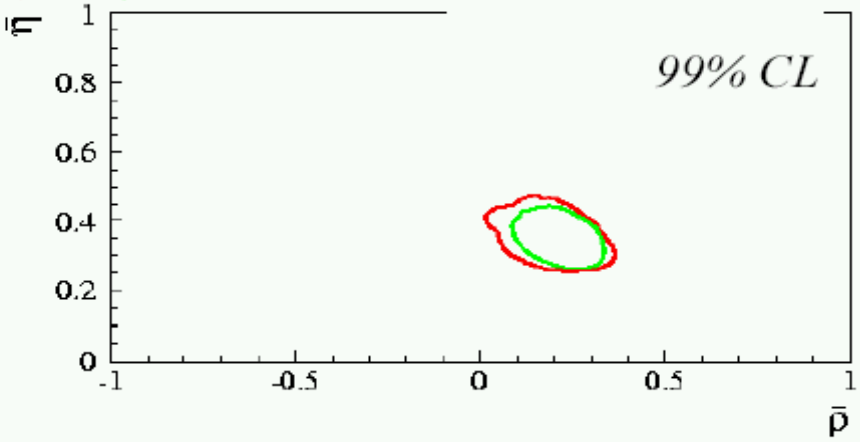
from Achille Stocchi talk at ICHEP 2002

F. Parodi

Fit Comparison

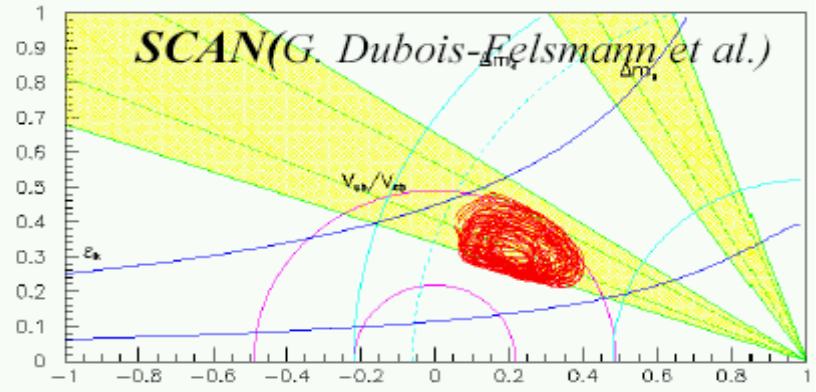
Frequentist(A. Hocker et al.)/ **Bayesian**(M.Ciuchini et al).





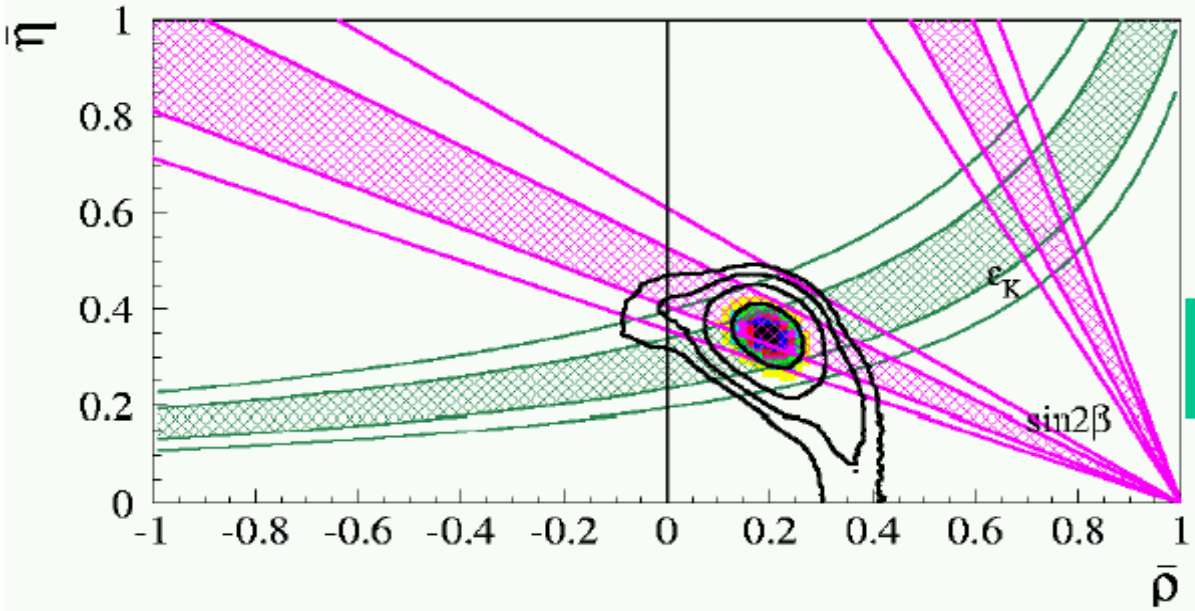
Ratio RFit/Bayesian Method			
Parameter	5% CL	1% CL	0.1% CL
$\bar{\rho}$	1.42	1.34	1.12
$\bar{\eta}$	1.18	1.12	1.05
$\sin 2\beta$	1.16	1.16	1.17
γ°	1.51	1.31	1.09

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



Both qualitatively comparable with scan

from Achille Stocchi talk at ICHEP 2002



CP Violation

Very important in reducing the allowed region

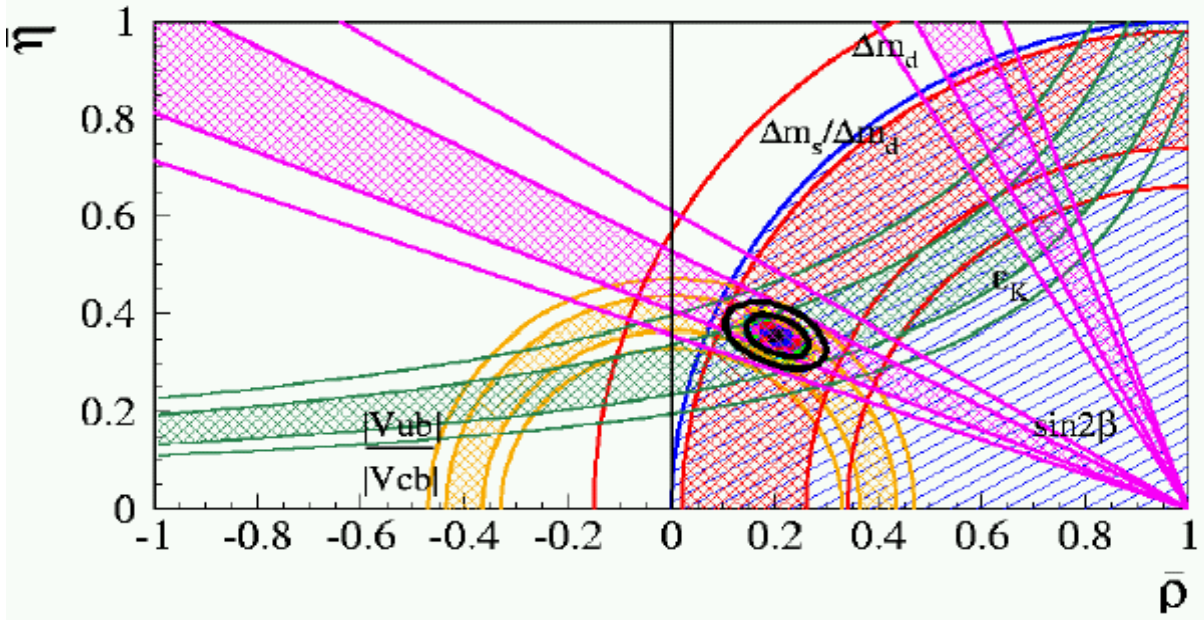
$\sin 2\beta = 0.762 \pm 0.064$ direct from B → J/ψ K^0_s

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

Coherent picture of CP Violation in SM

from Achille Stocchi talk at ICHEP 2002

Constraints : V_{ub} , V_{cb} , ε_K , Δm_d , Δm_d , $sin2\beta$



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

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

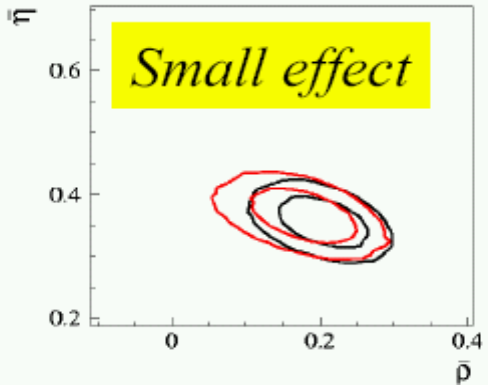
$\eta = 0.335 \pm 0.027$

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

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

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

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



Small effect

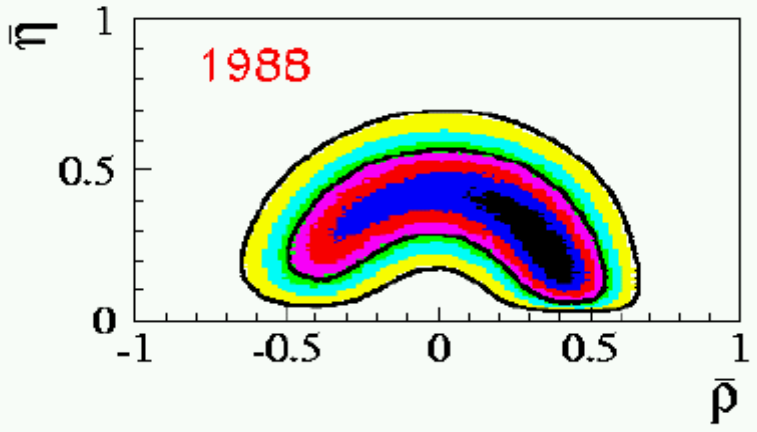
Effect of the "chiral logs" in f_B and ξ — *L.Lellouch(PLENARY) D. Becirevic*

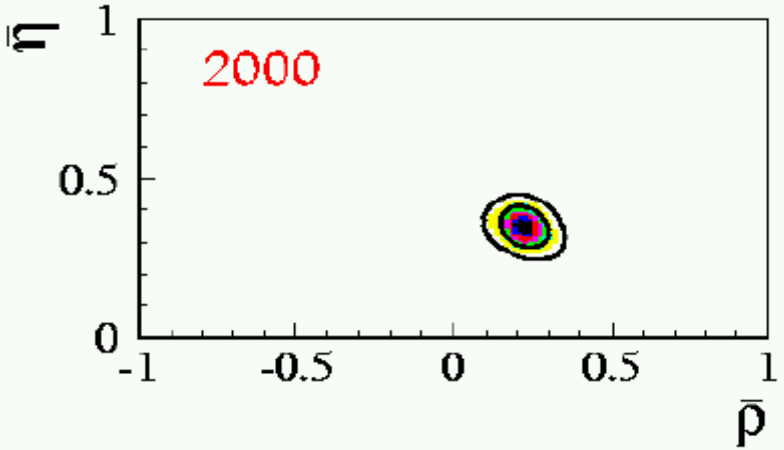
$\bar{\eta} = 0.365 \pm 0.028$ *No change*

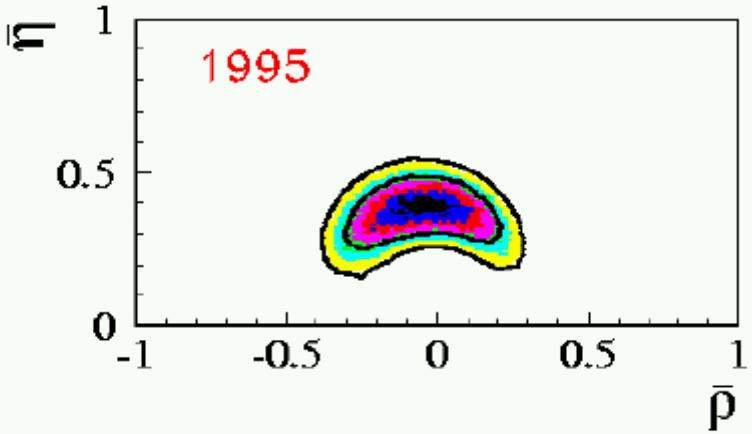
$\bar{\rho} = 0.177^{+0.047}_{-0.044}$ *-0.5σ shift $+15\%$ error*

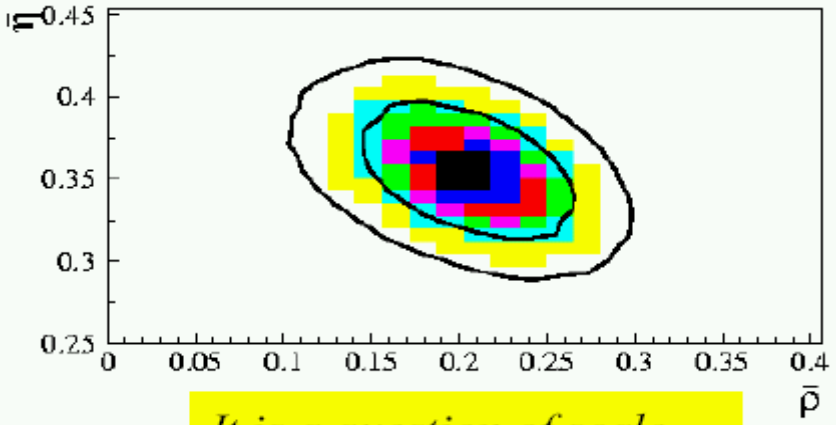
$(+0.7\sigma$ for $\gamma)$

from Achille Stocchi talk at ICHEP 2002









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

Conclusion

- LEP and SLD are finalizing their unexpectedly rich B physics programs.
- Still activity in b fragmentation and B spectroscopy areas at LEP/SLD.
- B_s oscillations still remain unresolved -> CDF and D0 have to do the job.
- Due to the superb performance of the B factories, the field is already fully dominated by them. (CDFII and D0 are at the start !)
- CP violation is fully established in the B system. The measurement has made the step from discovery to high precision.

  $\sin(2\beta) = 0.731 \pm 0.055$ (ICHEP 02)
- Direct CP violation is not yet established ($B \to \pi^+\pi^-$ discrepancies between experiments !?). A "industrial" number of branching ratio and CP analyses are underway.
- The B factories are close to rare decay branching ratio measurements of ~ 10^{-7}
- Heavy flavour physics (especially B physics) is one of the most interesting high energy physics fields in the "waiting for LHC" years !
- Will there be surprises? Or just Standard Model in good shape again?

Acknowlegements

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Y. Karyotakis (BABAR)
and
Masa Yamauchi (BELLE)
whose transparencies were of great help.