Results from the B factories

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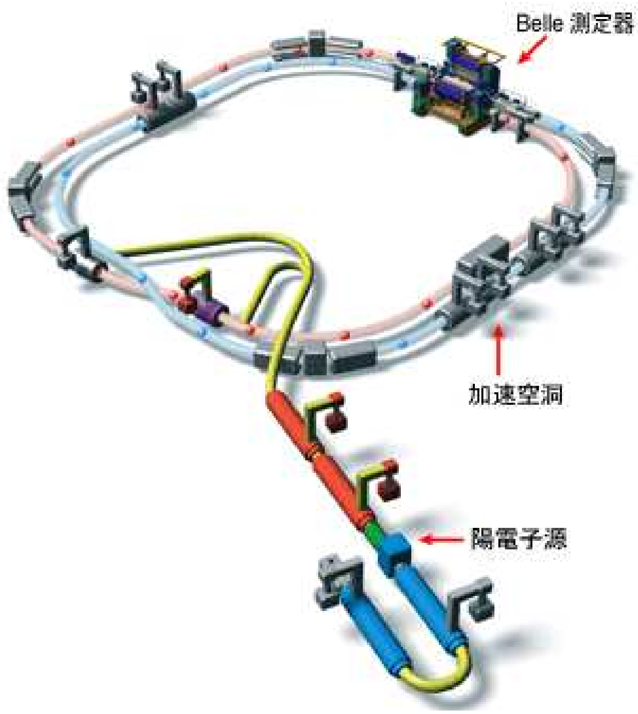
Annual Theory Meeting Durham, December 19th 2005

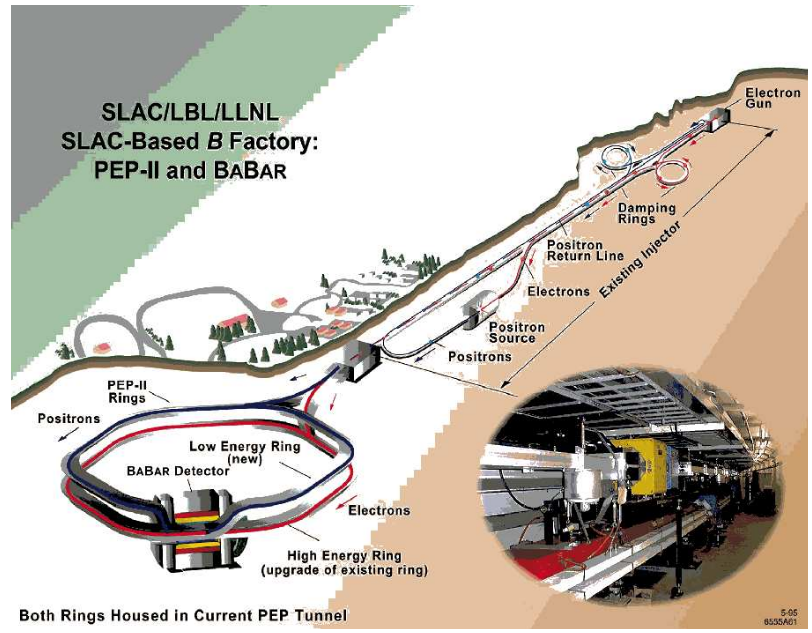
- Rough guide to B-factories for theorists
- How the CKM unitarity triangle was measured
- The search for hints of new physics in B decays
- What happens next?

Apologies for omitting spectroscopy, τ decays, charm physics ...

BaBar/Belle have published >300 papers in last 4 years

KEK-B and PEP-II





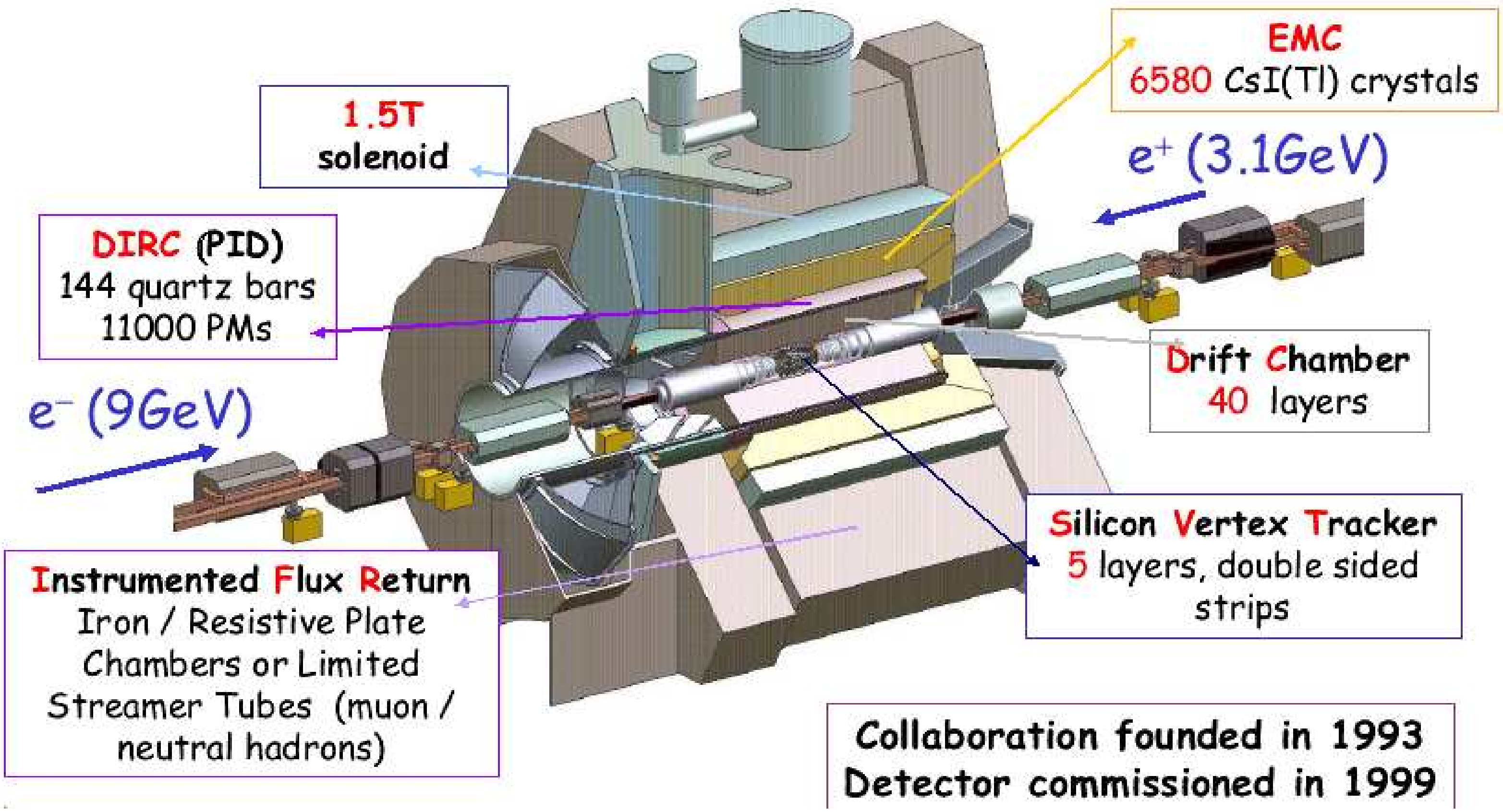
8 GeV e^- on 3.5 GeV e^+

Peak Luminosity 1.6×10^{34}

9 GeV e^- on 3.1 GeV e^+

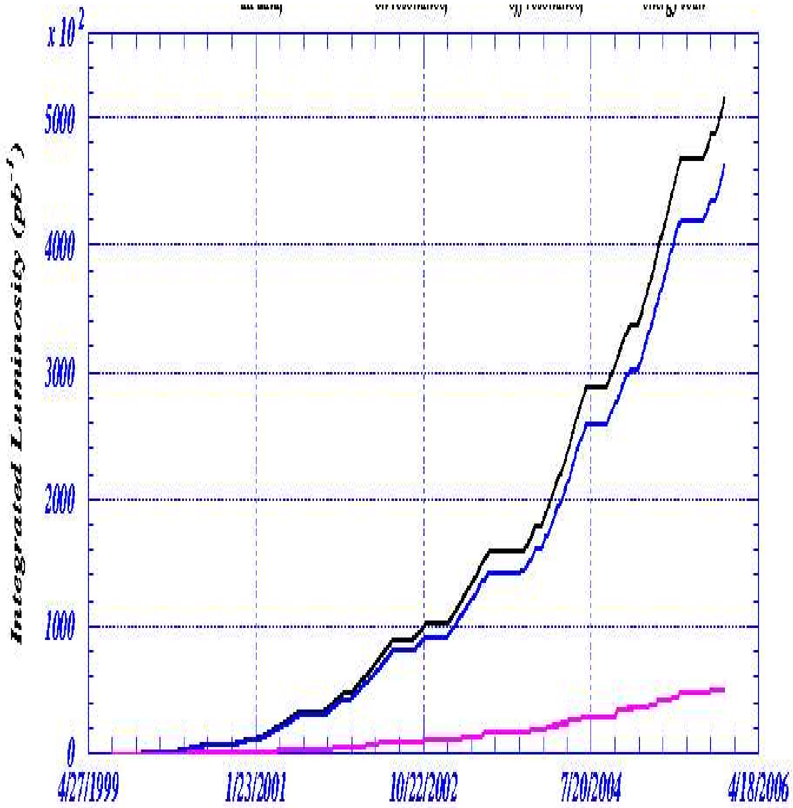
Peak Luminosity 1.0×10^{34}

The BaBar Detector

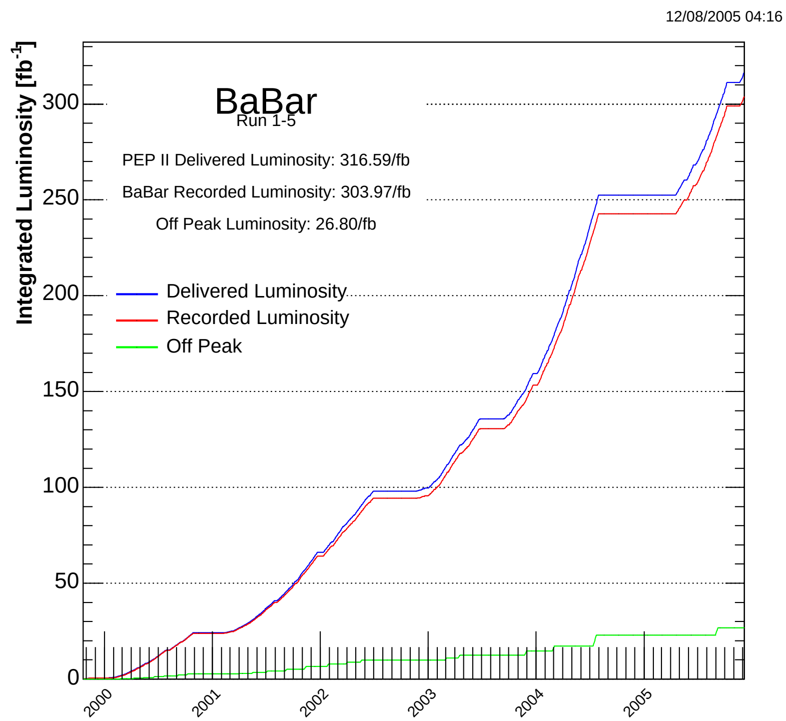


The Belle detector looks very similar!

Integrated Luminosities - December 2005



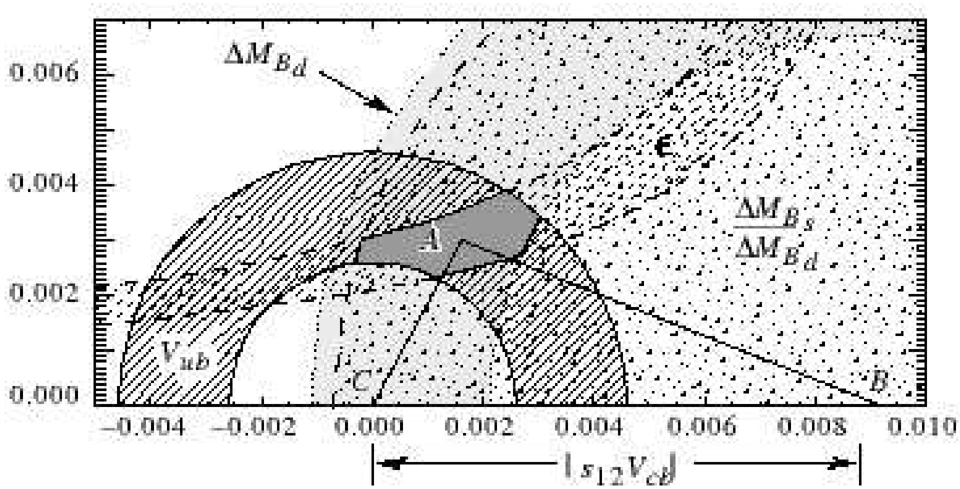
Belle $514 fb^{-1}$



BaBar $317 fb^{-1}$

Both experiments expect to accumulate $1 ab^{-1}$ by 2008

CKM Sector - before and after



PDG 2000

Sides of triangle only:

ϵ from K^0 system

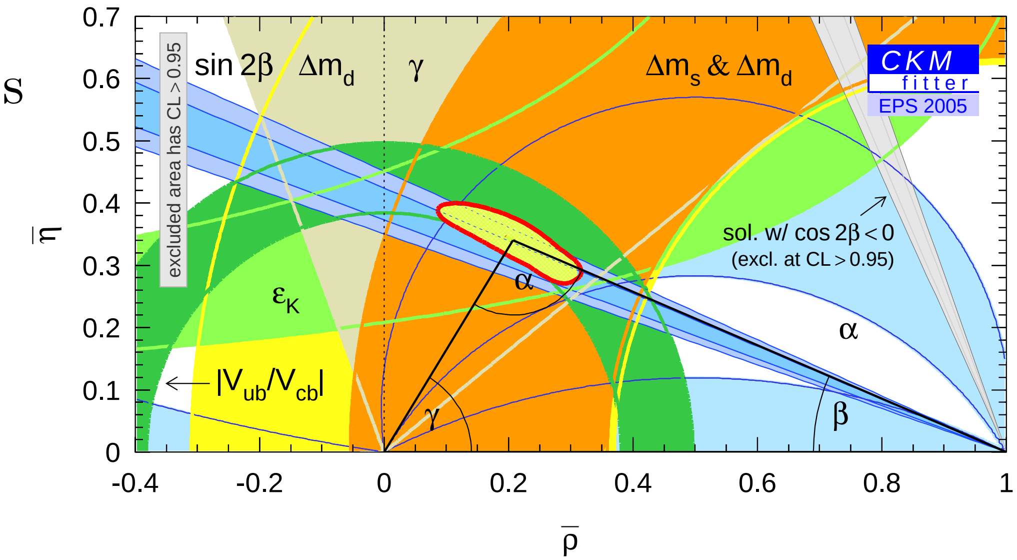
V_{td} from B^0 mixing

V_{ub} from $b \to u\ell\nu$

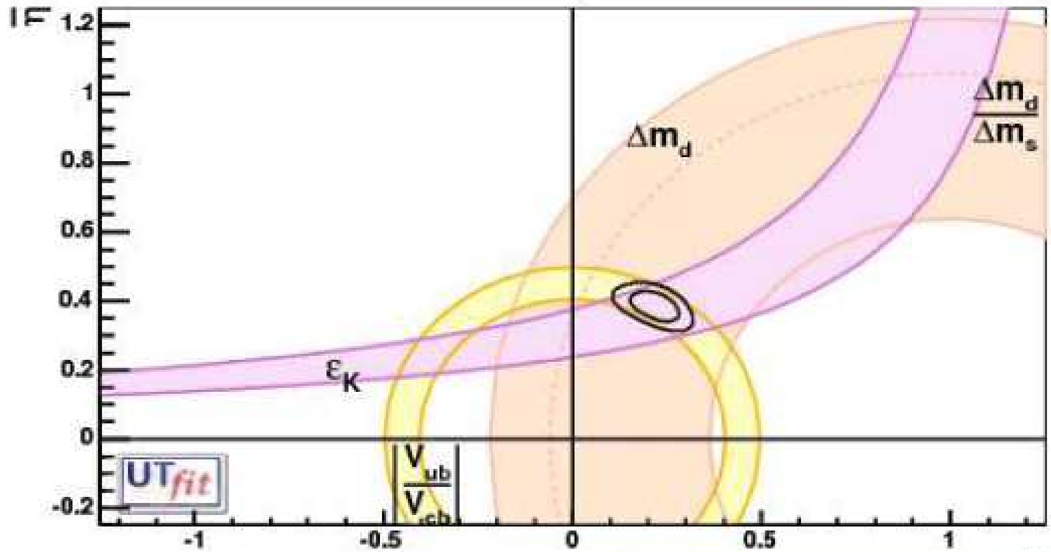
HFAG 2005

Many more measurements from B decays:

Angles of triangle α, β and γ are measured as well

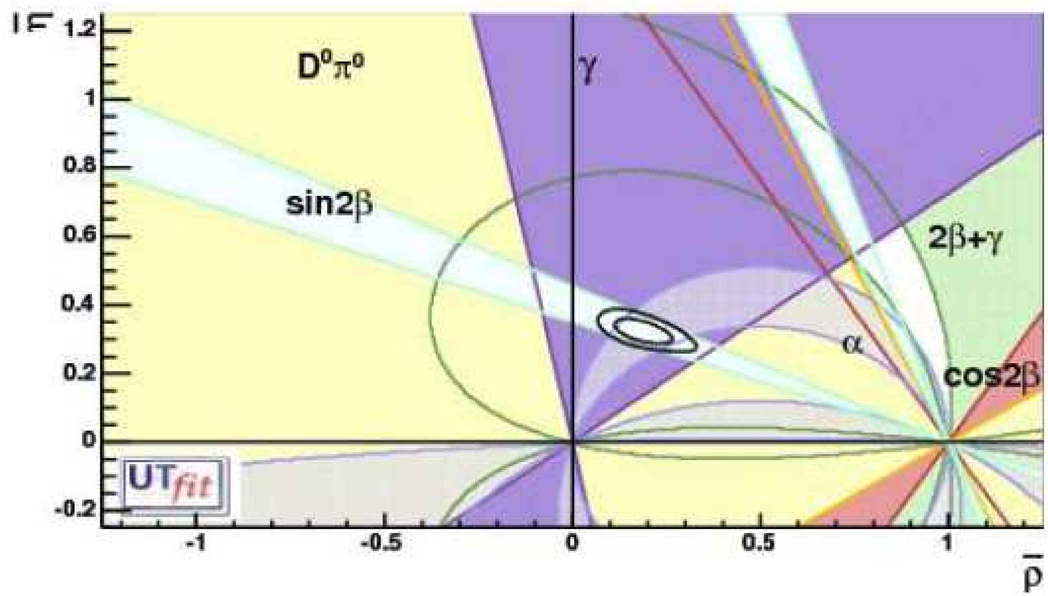


Unitarity Triangle is overconstrained!



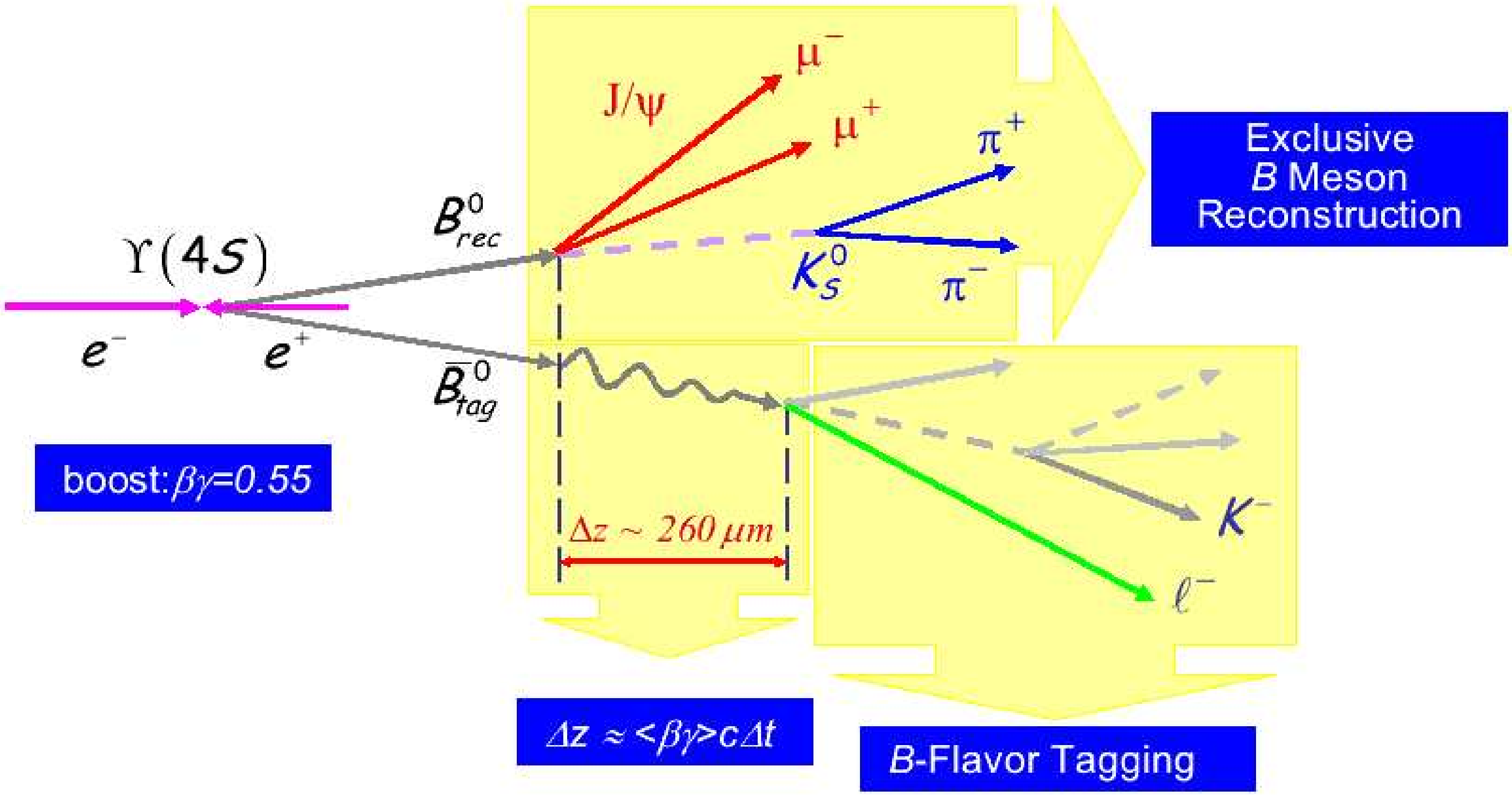
Constraints
on sides
$|\frac{V_{ub}}{V_{cb}}|, \Delta m_d$
$\Leftarrow \Delta m_s, \epsilon_K$

Constraints
on angles
$\alpha, \sin 2\beta, \gamma \Rightarrow$



Why do we need asymmetric B-factories?

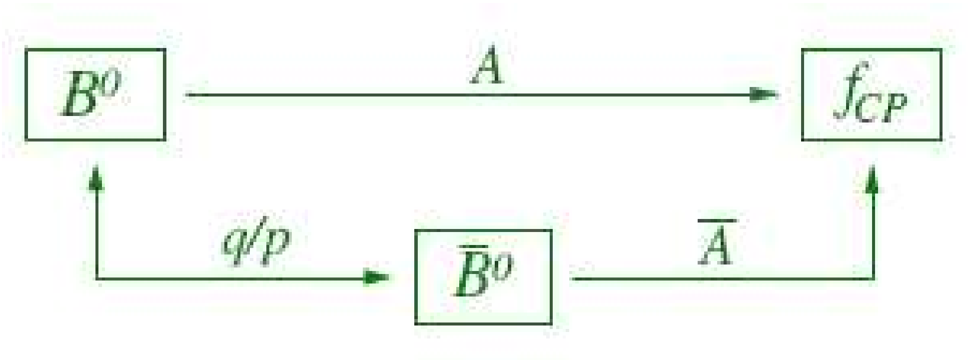
⇒ Coherent production of $B^0\bar{B}^0$ and B^+B^- pairs at the Υ(4S)



⇒ Asymmetric energy boosts B mesons along beam axis

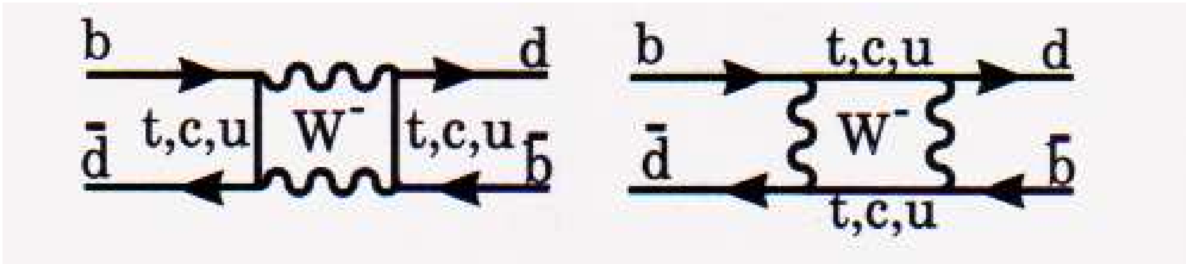
Makes time-dependent CP asymmetry measurements possible!

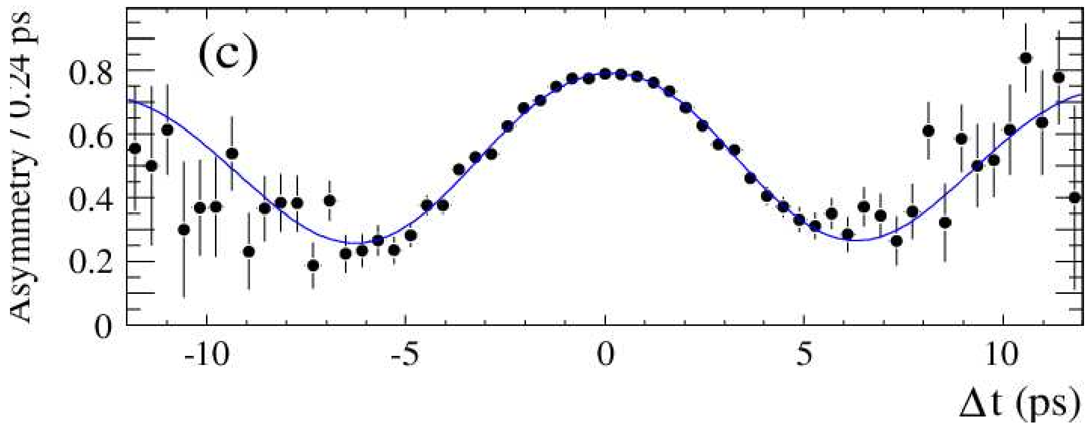
CP violation in B decays



- CP violation from mixing alone is small: $|\frac{q}{p}| \neq 1$
  equivalent to ϵ in K^0 system
- Direct CP violation requires two different weak and strong phases: $|\frac{\bar{A}}{A}| \neq 1$
  equivalent to ϵ' in K^0 system
- Time dependent CP violation can occur via interference between mixing and decay: $Im(\lambda) = Im(\frac{q}{p}\frac{\bar{A}}{A}) \neq 0$
  This is large in the B^0 system!

Mixing of Neutral B mesons





Time-dependent oscillations of an initial B_d beam

Lifetime $\tau_d = 1.528 \pm 0.009$ps

$\Delta m_d = 0.506 \pm 0.005$/ps

$|\psi_{B^0}(t)|^2 = g_+(t)|B^0 > -\frac{q}{p} g_-(t)|\bar{B}^0 >$

$g_\pm = \frac{1}{2}(e^{-\omega_H t} \pm e^{-\omega_L t})$

$|\psi_{\bar{B}^0}(t)|^2 = g_+(t)\bar{B}^0 > -\frac{p}{q} g_-(t)|B^0 >$

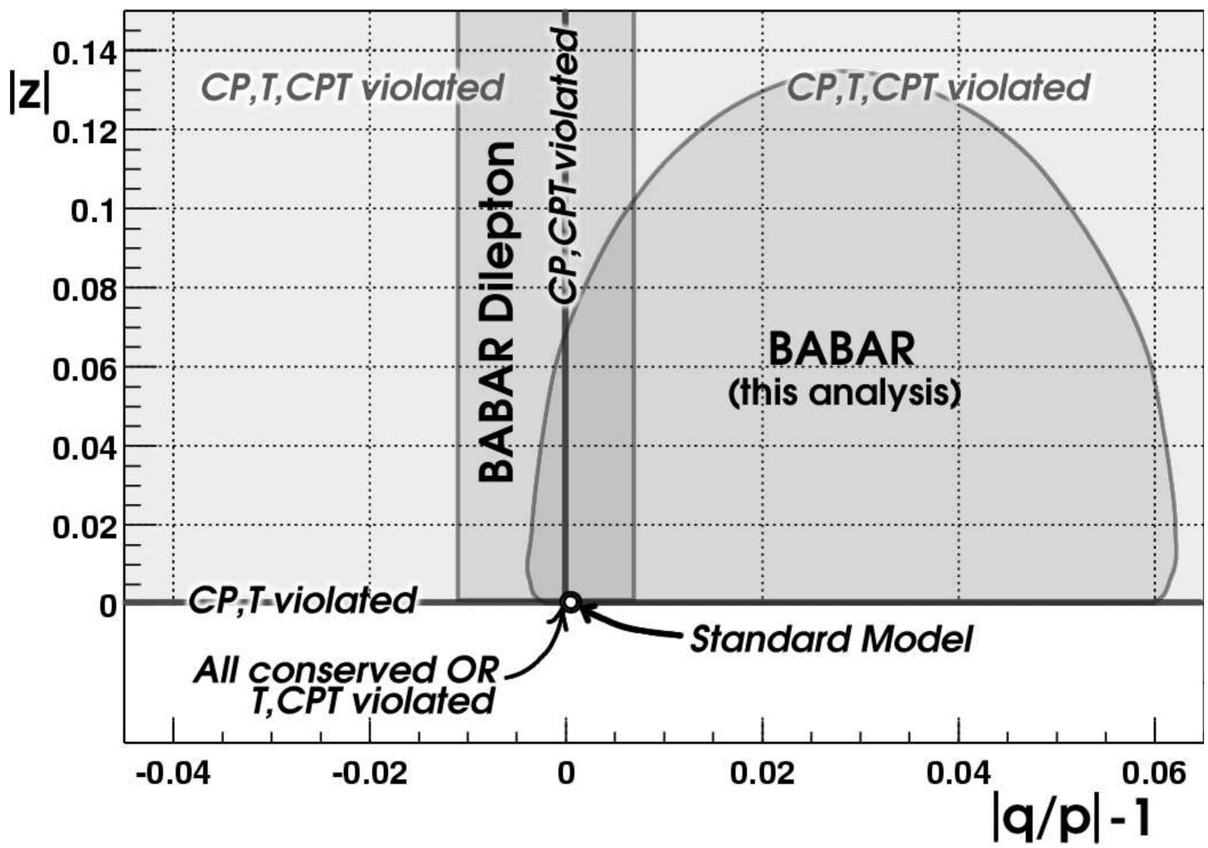
$\omega_{H,L} = M_{H,L} - \frac{i}{2}\Gamma_{H,L}$

CP violation in mixing: $|q/p| = 1.029 \pm 0.013 \pm 0.011$

Decay rate difference: $\mathrm{sgn}(\mathrm{Re}[\lambda])\Delta\Gamma/\Gamma = -0.008 \pm 0.037 \pm 0.018$

CPT and CP violation:

$$(\mathrm{Re}[\lambda]/|\lambda|)\ \mathrm{Re}[z] = 0.014 \pm 0.035 \pm 0.034$$
$$\mathrm{Im}[z] = 0.038 \pm 0.029 \pm 0.025$$

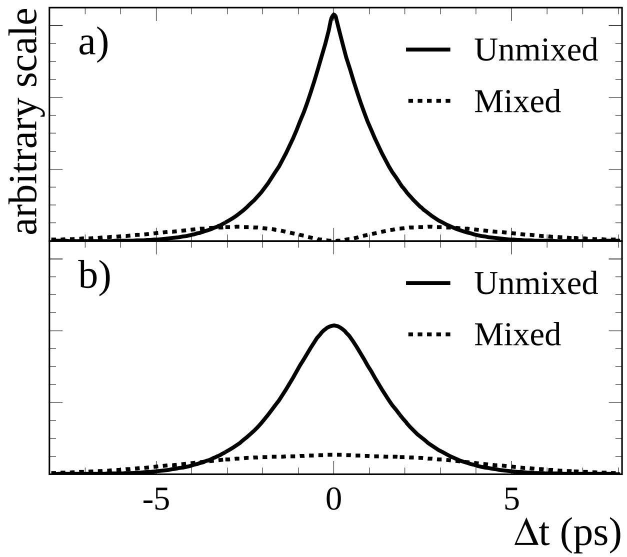


BaBar, PRD 70, 012007 (2004)

Time Dependent CP violation

$$A_{CP}(f) = \frac{\Gamma(\bar{B}^0 \to f) - \Gamma(B^0 \to f)}{\Gamma(\bar{B}^0 \to f) + \Gamma(B^0 \to f)} = S(f)\sin\Delta m t - C(f)\cos\Delta m t$$

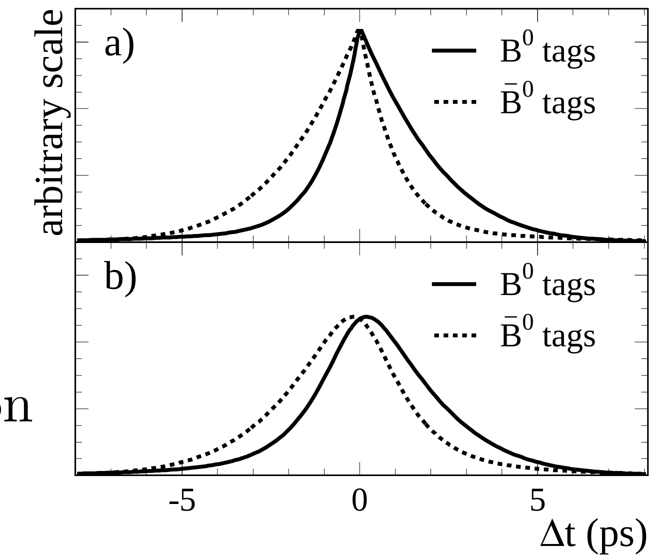
$$S = \frac{2\mathrm{Im}[\lambda]}{1+|\lambda|^2} \qquad C = \frac{1-|\lambda|^2}{1+|\lambda|^2} \qquad \lambda = \frac{q}{p}\frac{\bar{A}}{A}$$



(a) perfect

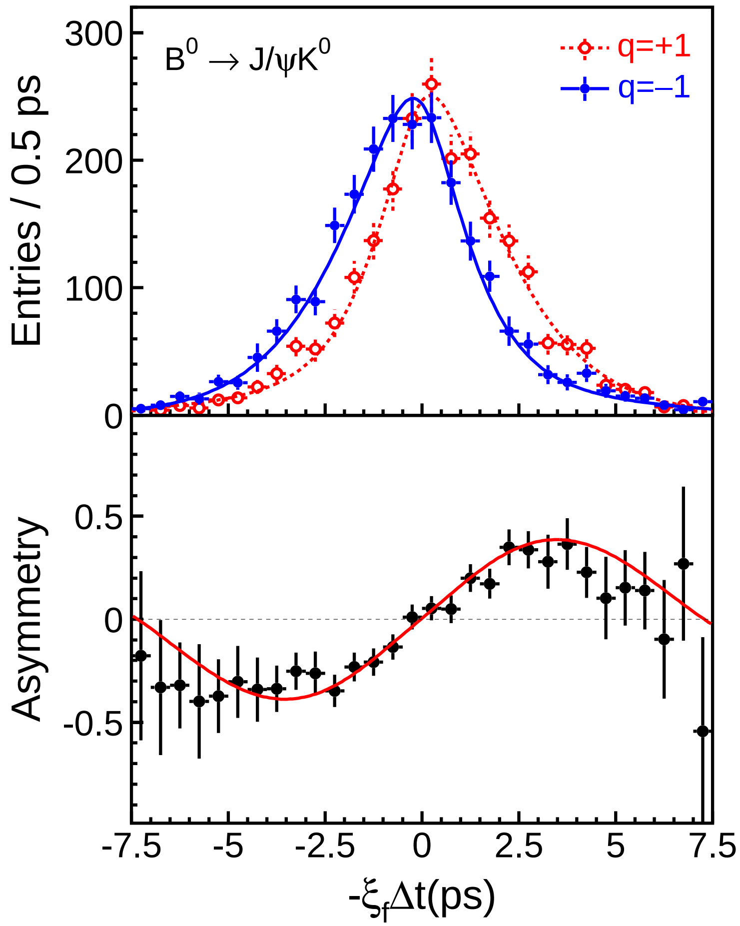
(b) realistic

time resolution



For a single decay amplitude $|\lambda| = 1$, S =Im[λ], C=0

Belle: hep-ex/0507037

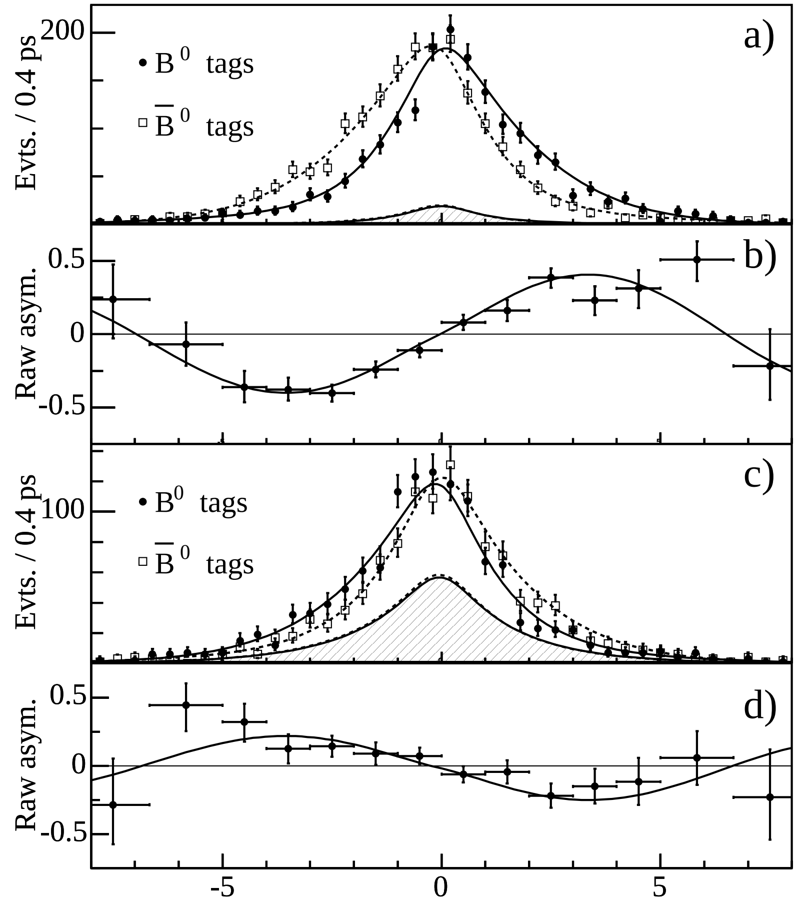


$\sin 2\beta = 0.652 \pm 0.039 \pm 0.020$

$C = 0.010 \pm 0.026 \pm 0.036$

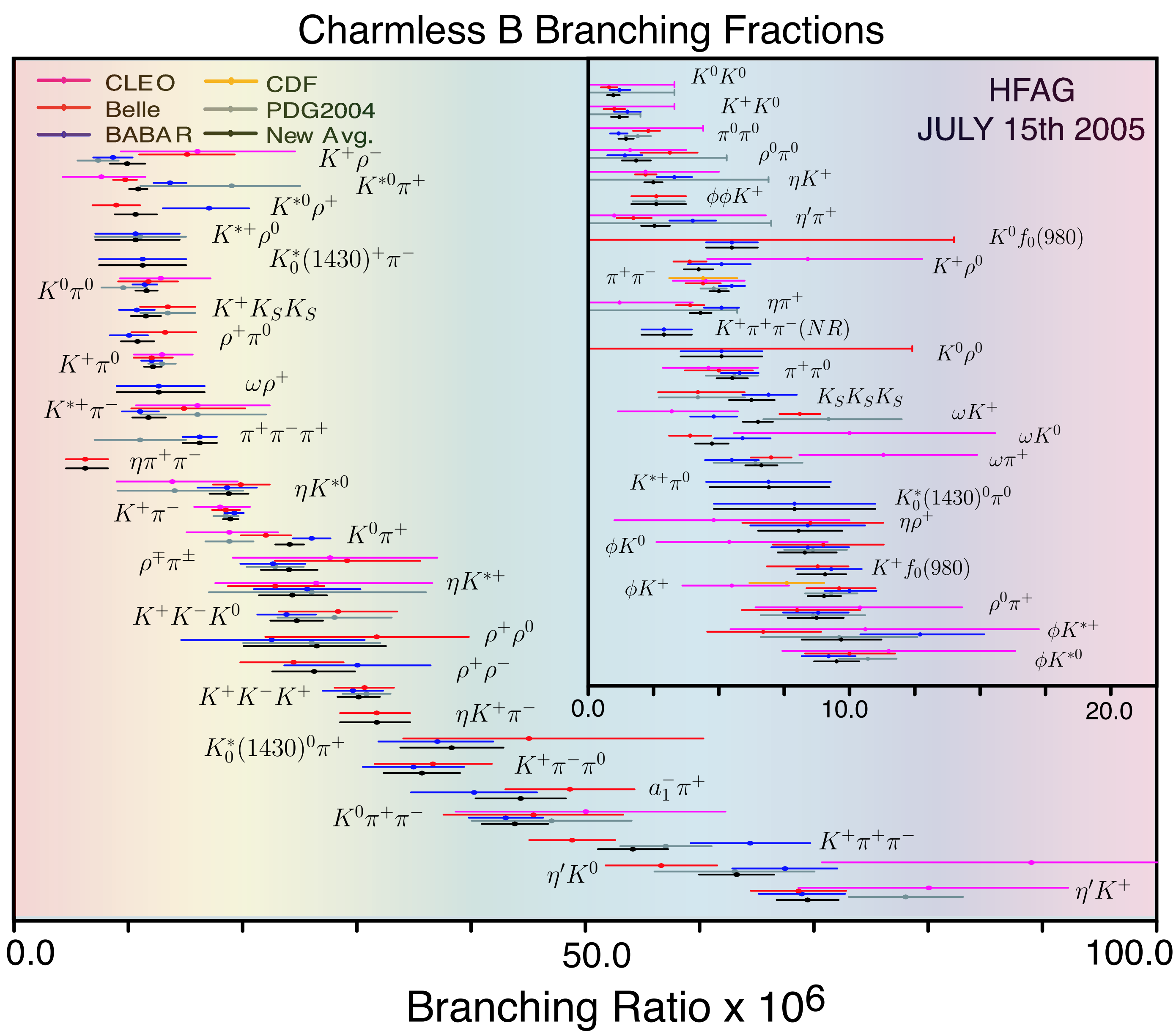
BaBar PRL 94, 161803 (2005)

(Top: $J/\psi K_S$ Bottom: $J/\psi K_L$)



$\sin 2\beta = 0.722 \pm 0.040 \pm 0.023$

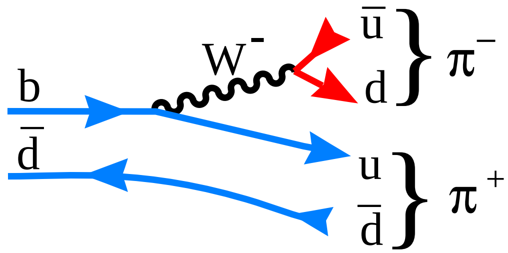
$C = 0.051 \pm 0.033 \pm 0.014$



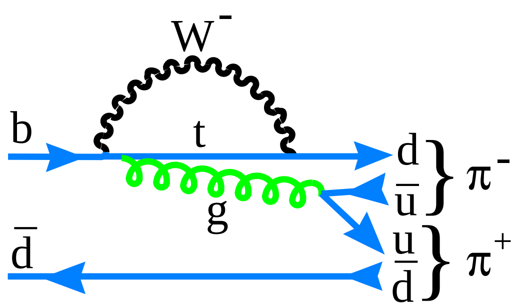
Charmless B Branching Fractions
CLEO
Belle
BABAR
CDF
PDG2004
New Avg.
HFAG
JULY 15th 2005
$K^+\rho^-$
$K^{*0}\pi^+$
$K^{*0}\rho^+$
$K^{*+}\rho^0$
$K_0^*(1430)^+\pi^-$
$K^0\pi^0$
$K^+K_SK_S$
$\rho^+\pi^0$
$K^+\pi^0$
$\omega\rho^+$
$K^{*+}\pi^-$
$\pi^+\pi^-\pi^+$
$\eta\pi^+\pi^-$
ηK^{*0}
$K^+\pi^-$
$K^0\pi^+$
$\rho^\mp\pi^\pm$
ηK^{*+}
$K^+K^-K^0$
$\rho^+\rho^0$
$\rho^+\rho^-$
$K^+K^-K^+$
$\eta K^+\pi^-$
$K_0^*(1430)^0\pi^+$
$K^+\pi^-\pi^0$
$a_1^-\pi^+$
$K^0\pi^+\pi^-$
$K^+\pi^+\pi^-$
$\eta' K^0$
$\eta' K^+$
K^0K^0
K^+K^0
$\pi^0\pi^0$
$\rho^0\pi^0$
ηK^+
$\phi\phi K^+$
$\eta'\pi^+$
$K^0f_0(980)$
$K^+\rho^0$
$\pi^+\pi^-$
$\eta\pi^+$
$K^+\pi^+\pi^-(NR)$
$K^0\rho^0$
$\pi^+\pi^0$
$K_SK_SK_S$
ωK^+
ωK^0
$\omega\pi^+$
$K^{*+}\pi^0$
$K_0^*(1430)^0\pi^0$
$\eta\rho^+$
ϕK^0
$K^+f_0(980)$
ϕK^+
$\rho^0\pi^+$
ϕK^{*+}
ϕK^{*0}
0.0
10.0
20.0
0.0
50.0
100.0
Branching Ratio x 10^6

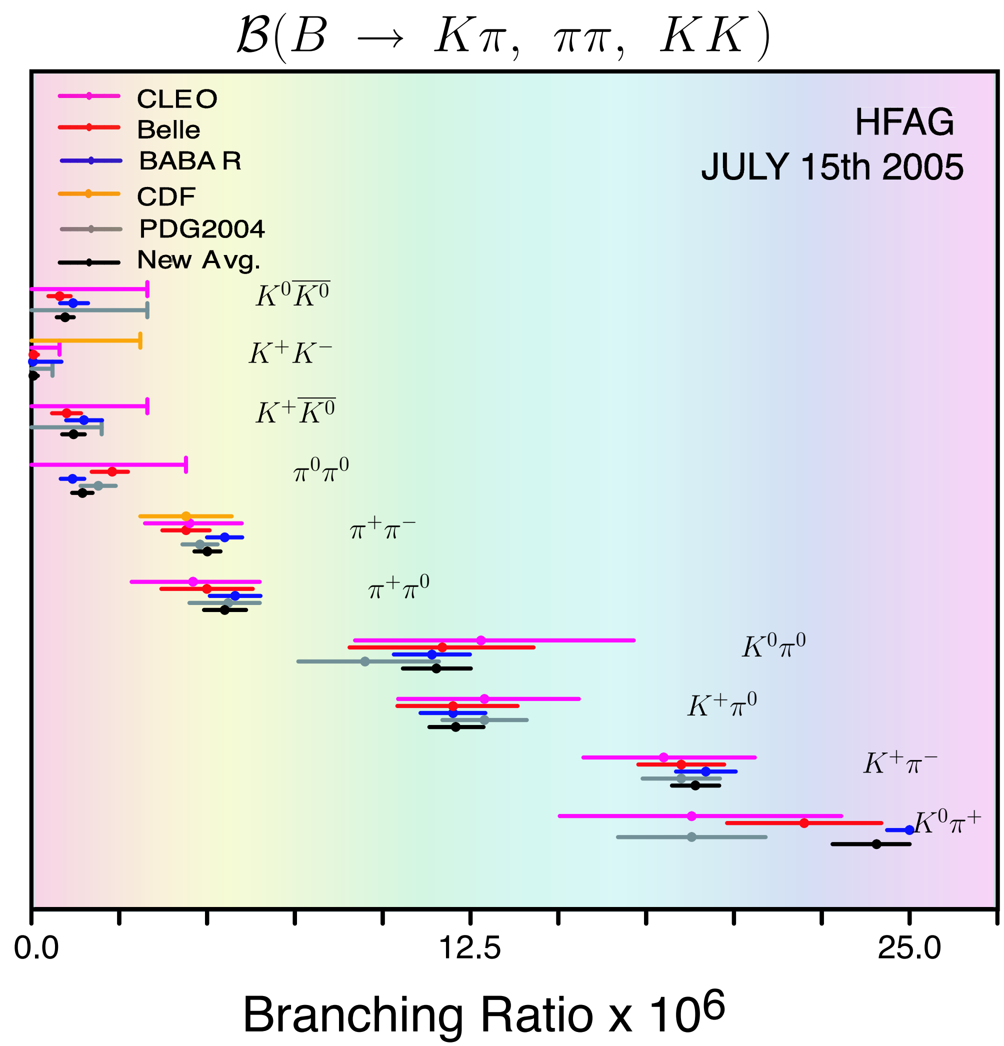
Described by sum

of $b \to u$ tree



and $b \to s(d)$ penguin





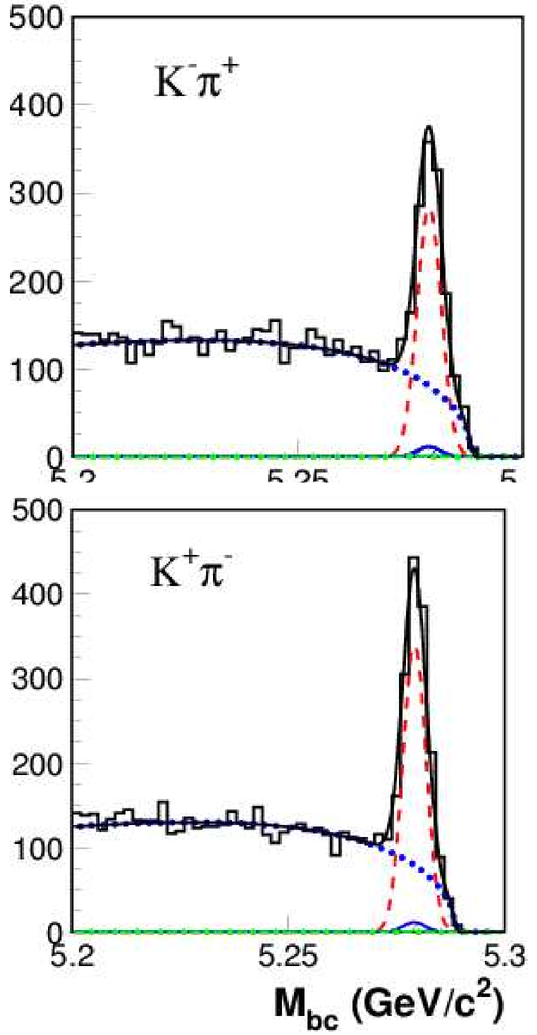
Beneke & Neubert

Nucl.Phys.B675:333-415,2003

Sensitivity to electroweak penguins: Buras et.al. hep-ph/0512059

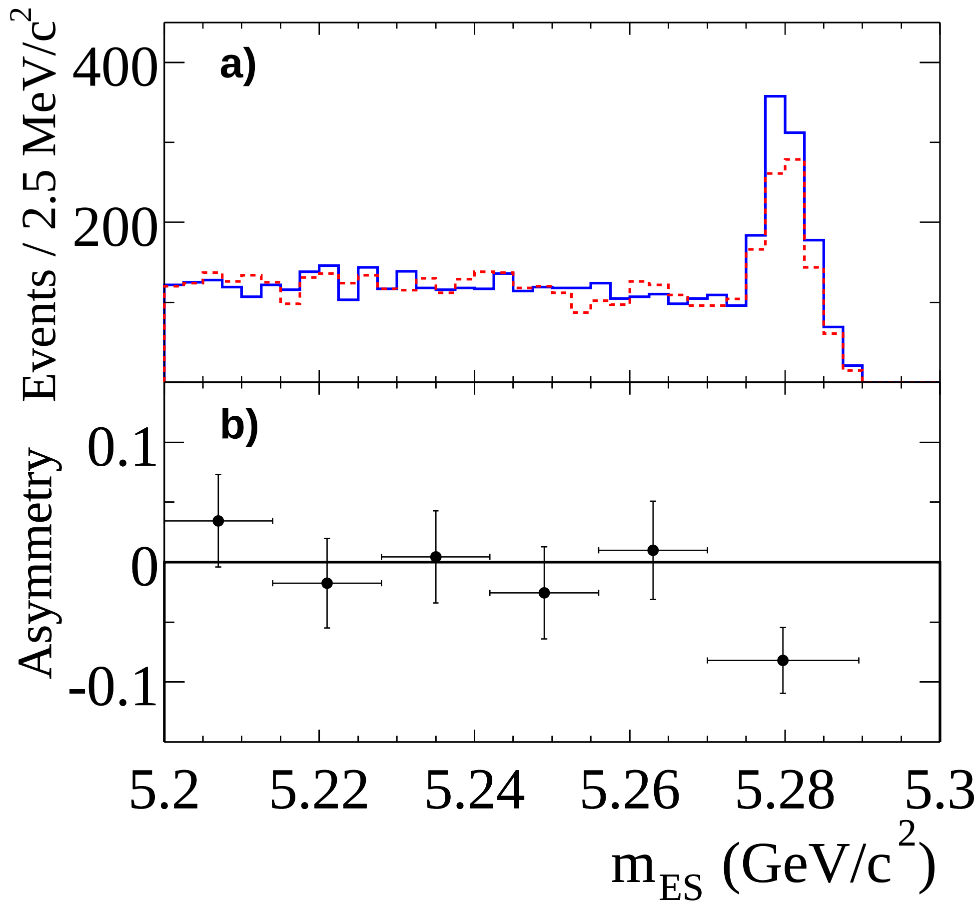
Direct CP violation in $B \to K\pi$

Belle PRL 93, 191802(2004)

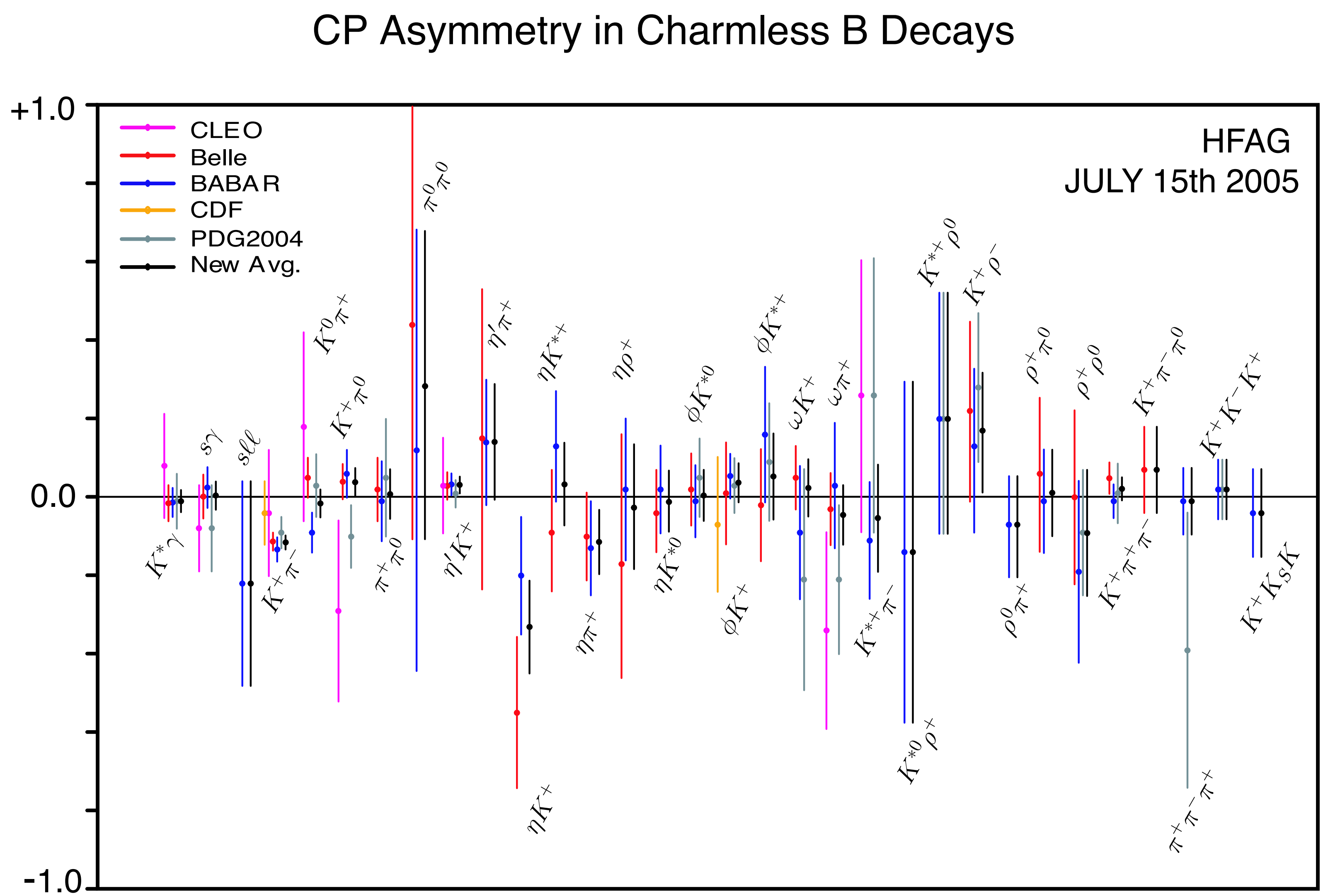


$$A_{CP} = -0.101 \pm 0.025 \pm 0.005$$

BaBar PRL 93, 131801 (2004)



$$A_{CP} = -0.133 \pm 0.030 \pm 0.009$$



Only $A_{CP}(B \to K^\pm\pi^\mp)$ is significant so far ...

$\alpha - \alpha_{eff}$ from isospin analysis of $B \to \pi\pi$

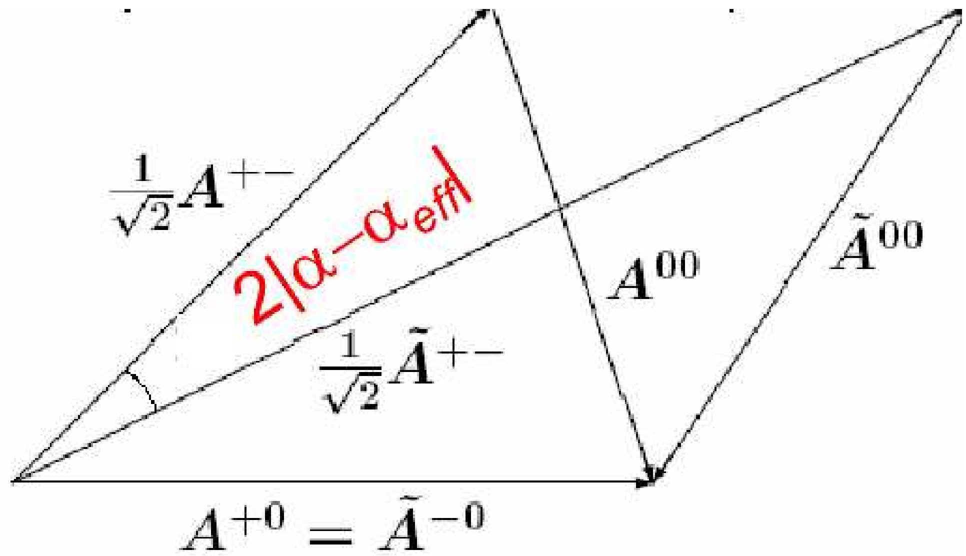
Gronau & London (1990)

$S(\pi\pi) = \sin(2\alpha_{eff})$

$C(\pi\pi) = -A_{CP} \propto \sin\delta$

No penguins:

$C = 0,\ \alpha = \alpha_{eff}$



Measurement	BaBar	Belle
$BF(\pi^+\pi^-) \times 10^{-6}$	$5.5 \pm 0.4 \pm 0.3$	$4.4 \pm 0.6 \pm 0.3$
$BF(\pi^+\pi^0) \times 10^{-6}$	$5.8 \pm 0.6 \pm 0.4$	$5.0 \pm 1.2 \pm 0.5$
$BF(\pi^0\pi^0) \times 10^{-6}$	$1.2 \pm 0.3 \pm 0.1$	$2.3 \pm 0.5 \pm 0.3$
$S(\pi^+\pi^-)$	$-0.30 \pm 0.17 \pm 0.03$	$-0.67 \pm 0.16 \pm 0.06$
$C(\pi^+\pi^-)$	$-0.09 \pm 0.15 \pm 0.04$	$-0.56 \pm 0.12 \pm 0.06$
$C(\pi^+\pi^0)$	$-0.01 \pm 0.10 \pm 0.02$	$+0.02 \pm 0.08 \pm 0.01$
$C(\pi^0\pi^0)$	$+0.12 \pm 0.56 \pm 0.06$	$+0.44 \pm 0.53 \pm 0.17$

α from isospin analysis of $B \to \rho\rho$

There are some advantages to using $\rho\rho$:

- $BF(\rho^0\rho^0) \ll BF(\rho^+\rho^-)$ so penguins are small
- $B^0 \to \rho^+\rho^-$ is $> 95\%$ longitudinally polarized

Measurement	BaBar	Belle
$BF(\rho^+\rho^-) \times 10^{-6}$	$23 \pm 2 \pm 2$	$29 \pm 5 \pm 4$
$BF(\rho^+\rho^0) \times 10^{-6}$	$23 \pm 6 \pm 6$	$32 \pm 7 \pm 6$
$BF(\rho^0\rho^0) \times 10^{-6}$	< 1.1	
$S(\rho^+\rho^-)$	$-0.33 \pm 0.24 \pm 0.11$	$+0.09 \pm 0.42 \pm 0.08$
$C(\rho^+\rho^-)$	$-0.03 \pm 0.18 \pm 0.09$	$0.00 \pm 0.30 \pm 0.10$
$C(\rho^+\rho^0)$	$-0.19 \pm 0.23 \pm 0.03$	$0.00 \pm 0.22 \pm 0.03$

Eventually can measure $S(\rho^0\rho^0)$ as well as $C(\rho^0\rho^0)$

Dalitz analysis of $B \to \pi\rho$

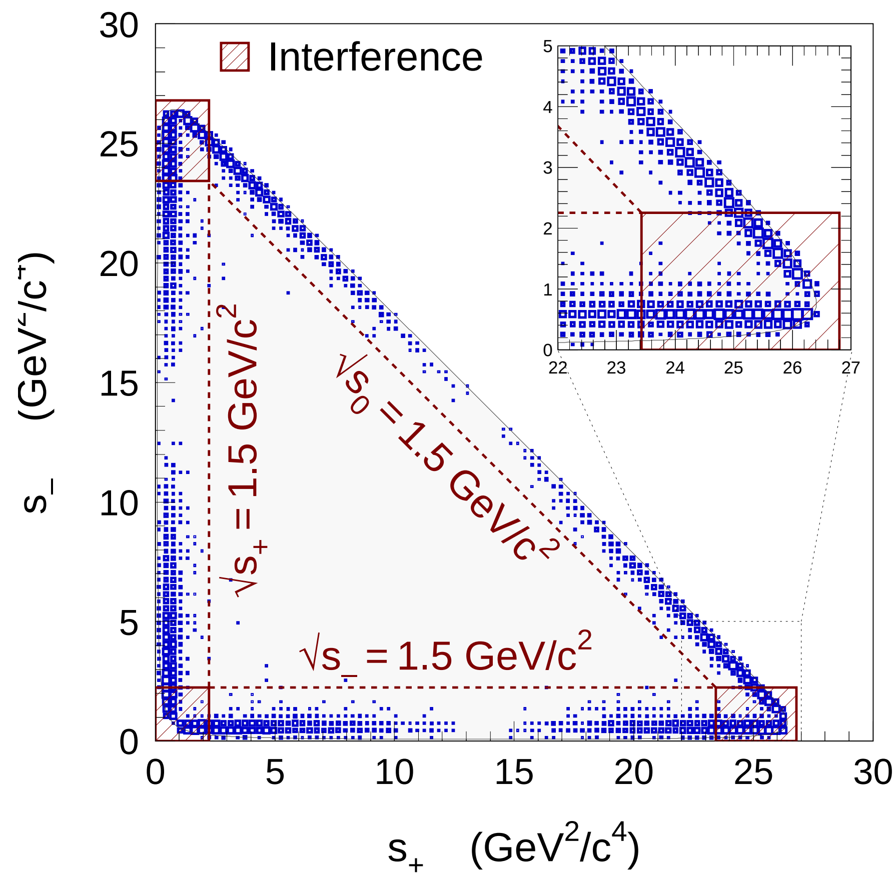
Do a time-dependent analysis of the $\pi^+\pi^-\pi^0$ Dalitz plot

Snyder & Quinn (1993)

$$A_{3\pi} = f_+ A^+ + f_- A^- + f_0 A^0$$

where $+ - 0$ is the ρ charge

Sensitivity is in interference regions



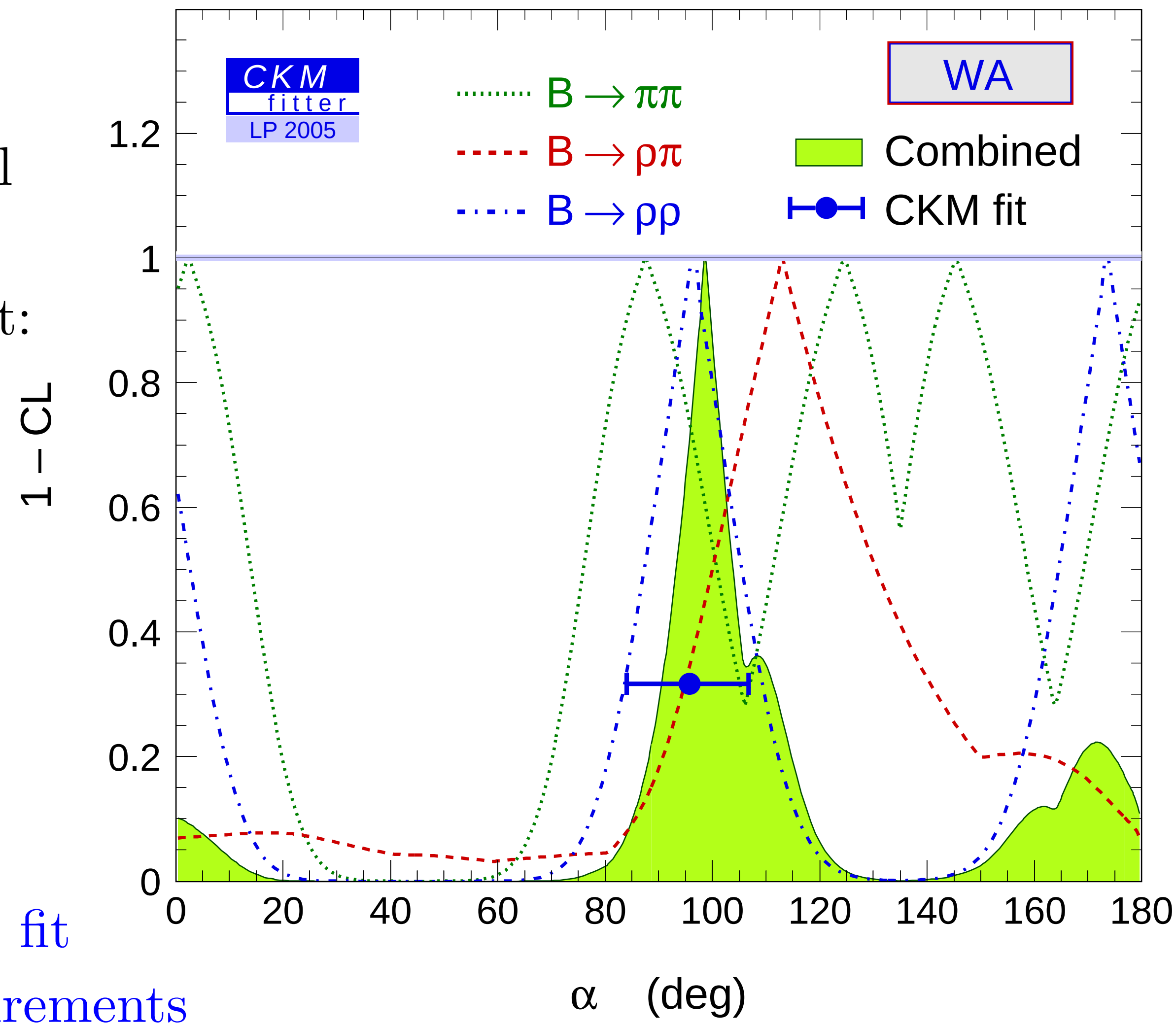
$$|A_{3\pi}(\Delta t)|^2 \propto |A_{3\pi}|^2 + |\bar{A}_{3\pi}|^2$$
$$\pm(|A_{3\pi}|^2 - |\bar{A}_{3\pi}|^2)\cos(\Delta m_d \Delta t) \pm 2Im[\bar{A}_{3\pi} A_{3\pi}]\sin(\Delta m_d \Delta t)$$

Summary of α measurements

Combination of all three modes gives the best constraint:

$\alpha = (99^{+12}_{-9})^{\circ}$

Agrees with CKM fit using other measurements



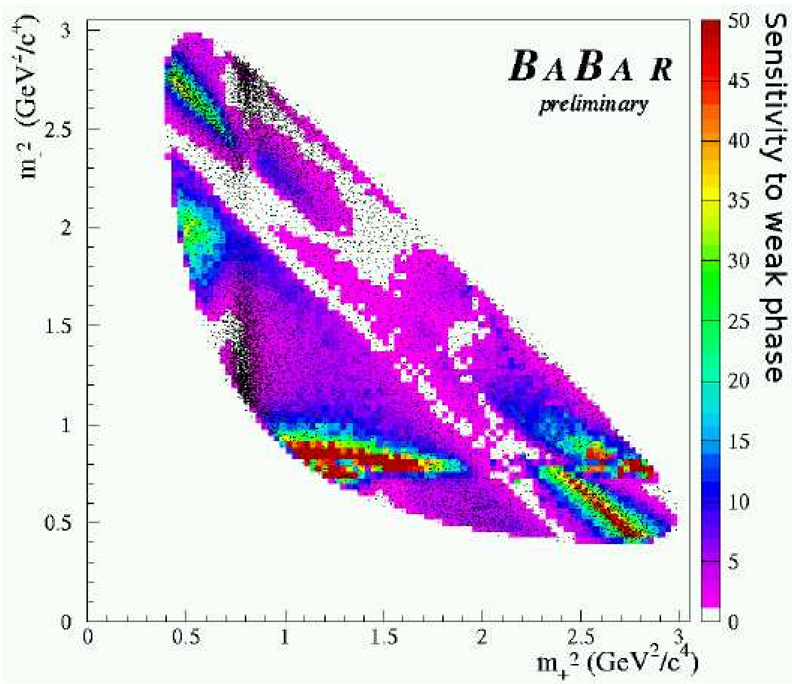
Measuring γ with $B \to D^{(*)} K^{(*)}$

All methods use interference between tree diagrams $b \to u(s\bar{c})$ and $b \to c(s\bar{u})$. The ratio of the diagrams r_B depends on the method.

- GLW method: $B^- \to D_{CP} K^-$ with $D_{CP} \to f_{CP}$
  Large rate but small interference because $r_B \ll 1$
- ADS method: $B^- \to D^0 K^-$, $D^0 \to K^+ \pi^-$ (DCS)
  and $B^- \to \bar{D}^0 K^-$, $\bar{D}^0 \to K^+ \pi^-$ (Cabibbo-favoured)
  Interference is large but DCS rate is small
- Dalitz method: $B^- \to D^0 K^-$, $D^0 \to K_s \pi^+ \pi^-$
  Interference term comes from D^0 Dalitz plot analysis
  Errors are very sensitive to value of r_B:
  BaBar $r_B = 0.12 \pm 0.08 \pm 0.05$ Belle $r_B = 0.21 \pm 0.08 \pm 0.05$

$D^0 \to K_S \pi^+ \pi^-$ Dalitz Method

Sensitivity across Dalitz plot

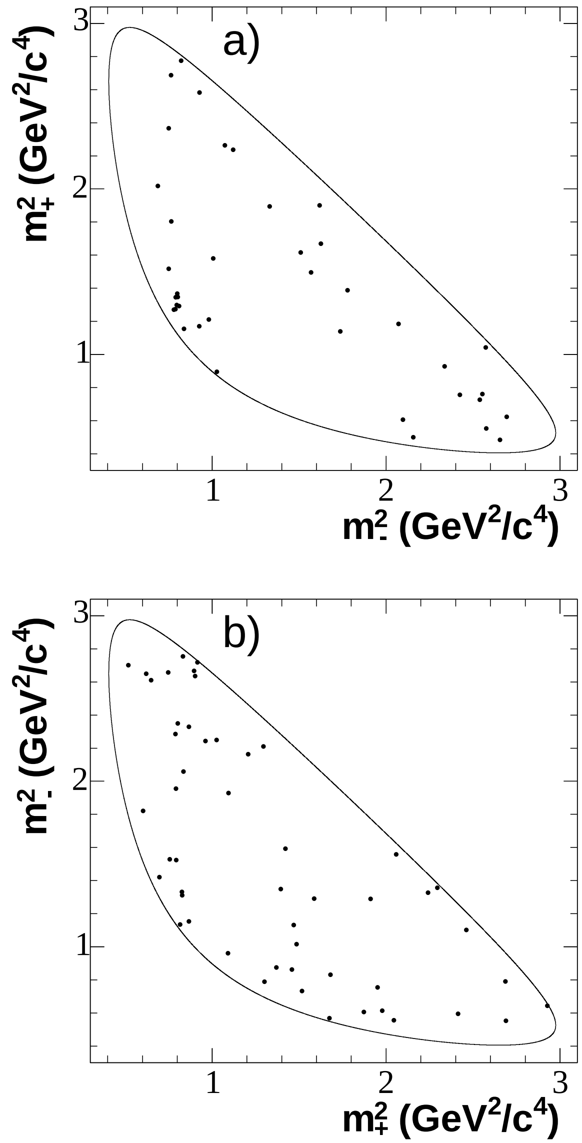


BaBar PRL 95, 121802 (2005)

$\gamma = (67 \pm 28 \pm 13 \pm 11)^\circ$

Belle PRD 70, 072003 (2004)

$\gamma = (64 \pm 19 \pm 13 \pm 11)^\circ$



(a) B^- decays (b) B^+ decays

Measurements of $b \to c\ell\nu$ Decays

- Inclusive $b \to c\ell\nu$ using one reconstructed B decay as a tag, and looking for lepton from other B
  - Measure $BF(B \to \ell) = 10.95 \pm 0.15\%$
  - Moments of lepton energy and hadronic mass spectra
- Exclusive $B \to D^{(*)}\ell\nu$
  - Measure BFs as a function of recoil
  - Determine shape of Isgur-Wise function
  - Measure form factors
  - V_{cb} from zero-recoil point

Heavy Quark parameters from $b \to c\ell\nu$

Remarkable progress in determining quark masses, non-perturbative QCD parameters and V_{cb} using the heavy quark Operator Product Expansion (HQE)

Fit hadronic and leptonic moments in inclusive $b \to c\ell\nu$ decays

$$|V_{cb}| = (41.4 \pm 0.4(exp) \pm 0.4(HQE) \pm 0.6(theo)) \times 10^{-3}$$

$$m_b = 4.61 \pm 0.05(exp) \pm 0.04(HQE) \pm 0.02(\alpha_s) GeV$$

$$m_c = 1.18 \pm 0.07(exp) \pm 0.06(HQE) \pm 0.02(\alpha_s) GeV$$

$$\mu_{\pi^2} = 0.45 \pm 0.04(exp) \pm 0.04(HQE) \pm 0.02(\alpha_s) GeV^2$$

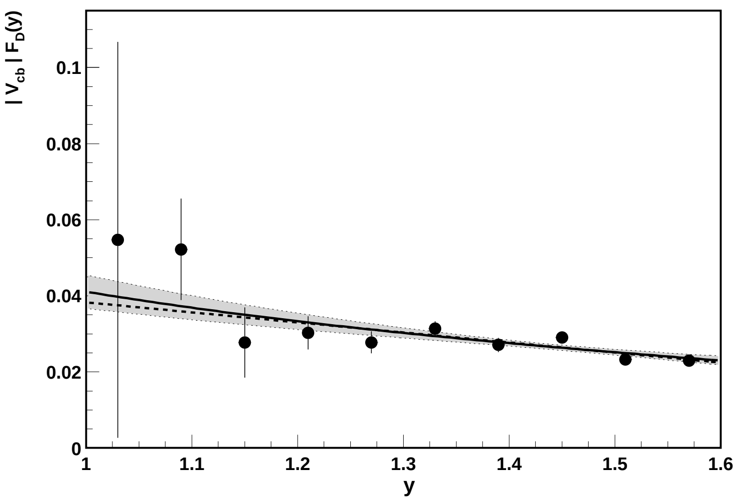
$$\mu_{g^2} = 0.27 \pm 0.06(exp) \pm 0.03(HQE) \pm 0.01(\alpha_s) GeV^2$$

BaBar: PRL 93, 011803 (2004)

Determinations of V_{cb} from $B \to D^{(*)}\ell\nu$

$\bar{B}^0 \to D^+\ell^-\bar{\nu}$

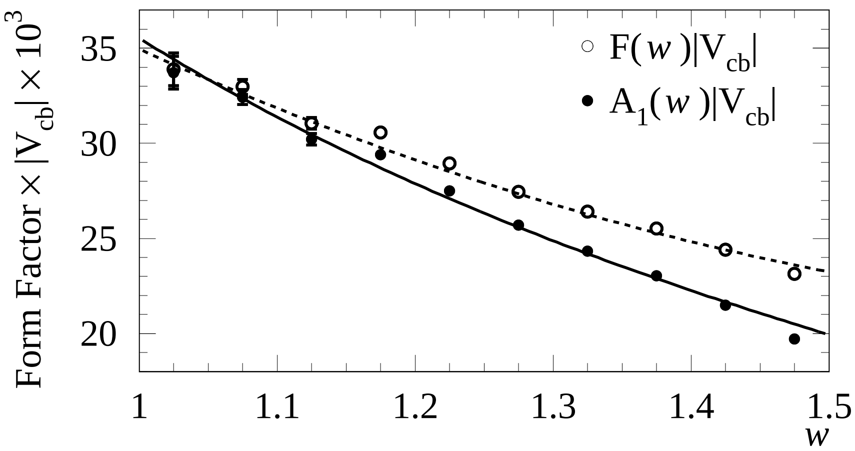
Belle: PLB 526, 258 (2002)



$(41.9 \pm 4.5 \pm 5.3 \pm 3.0) \times 10^{-3}$

$\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}$

BaBar: PRD-RC 71, 051502 (2005)



$(38.7 \pm 0.3 \pm 1.7 \pm 1.4) \times 10^{-3}$

Measurements of $b \to u\ell\nu$ Decays

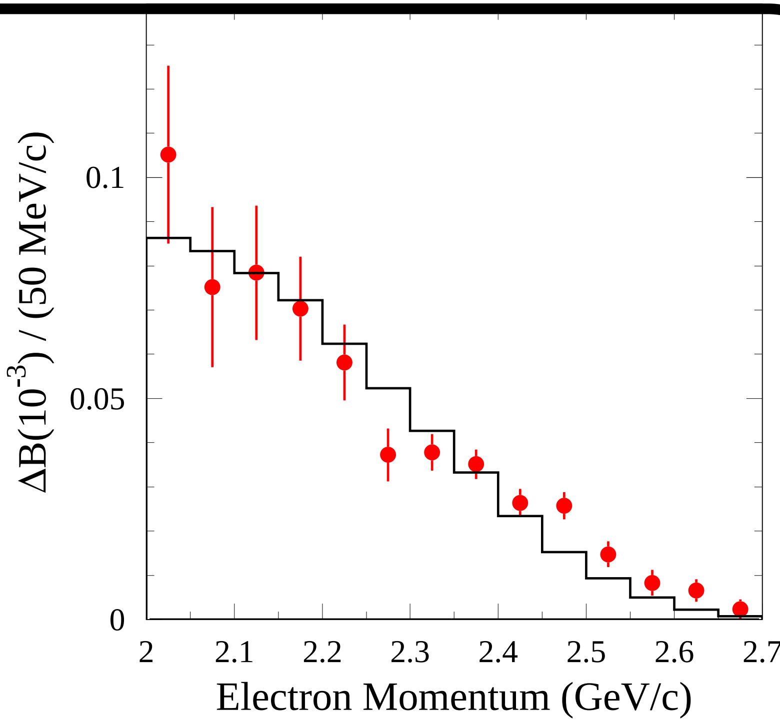
- Inclusive $b \to u\ell\nu$ using one reconstructed B decay as a tag and subtracting the $b \to c\ell\nu$ background:
  - Measure lepton energy endpoint spectrum
  - Measure q^2 from lepton and missing energy (neutrino)
  - Measure hadronic mass M_x
- Exclusive $B \to \pi\ell\nu$ and $B \to \rho\ell\nu$ using one reconstructed B decay as a tag:
  - Measure BFs as a function of q^2
  - Use isospin symmetry to relate $B^+ \to \pi^+$ and $B^0 \to \pi^0$
  - Use isospin symmetry to relate $B \to \rho^+, \rho^0, \omega$

Inclusive V_{ub} results

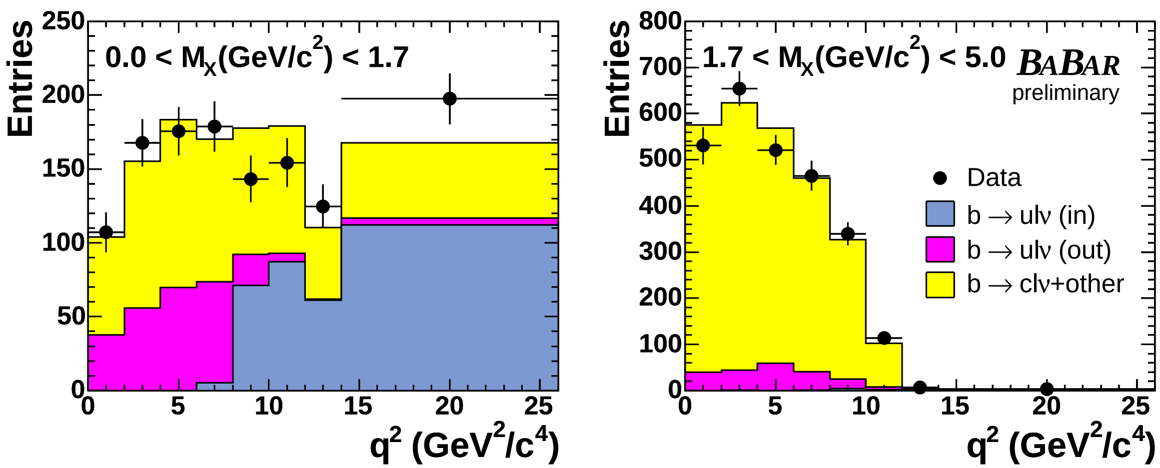
BaBar: hep-ex/0509040

Lepton Endpoint analysis $\Rightarrow$ ($b \rightarrow c\ell\nu$ subtracted)

$$|V_{ub}| = 4.44 \times 10^{-3}$$
$$\pm 0.25(exp.)$$
$$\pm 0.38(shape)$$
$$\pm 0.22(theory)$$



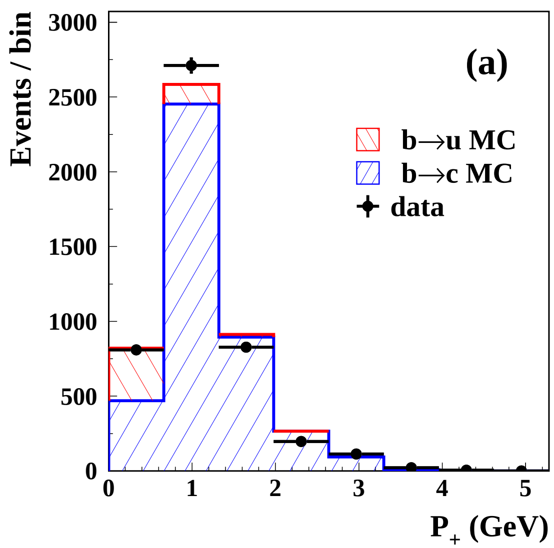
BaBar: hep-ex/0507017

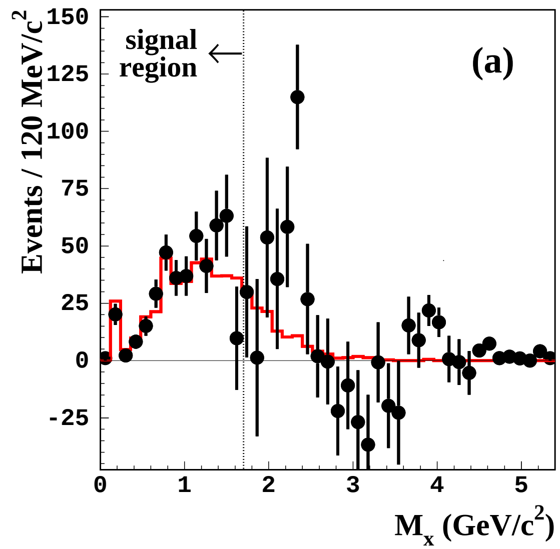


$\Leftarrow M_x/q^2$ analysis

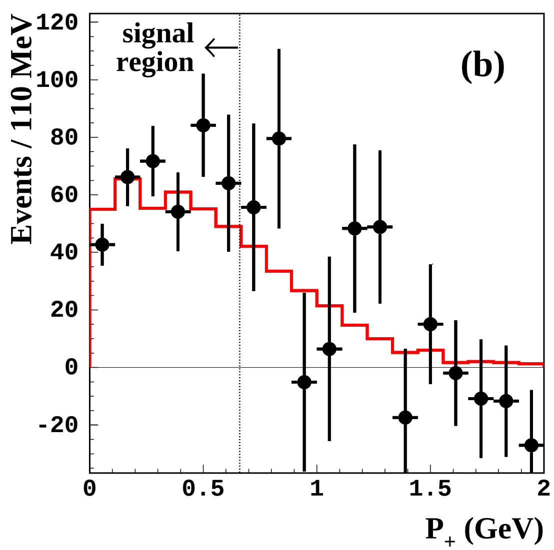
$$|V_{ub}| = 4.65 \times 10^{-3}$$
$$\pm 0.24(stat.)$$
$$\pm 0.24(syst.)$$
$$\pm 0.42(shape)$$
$$\pm 0.23(theory)$$

Inclusive V_{ub} result from Belle: PRL 95, 241801 (2005)

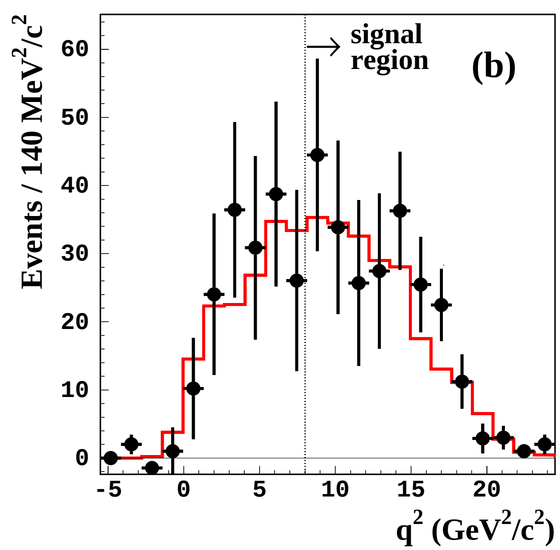




$$P_+ = E_X - |p_X|$$



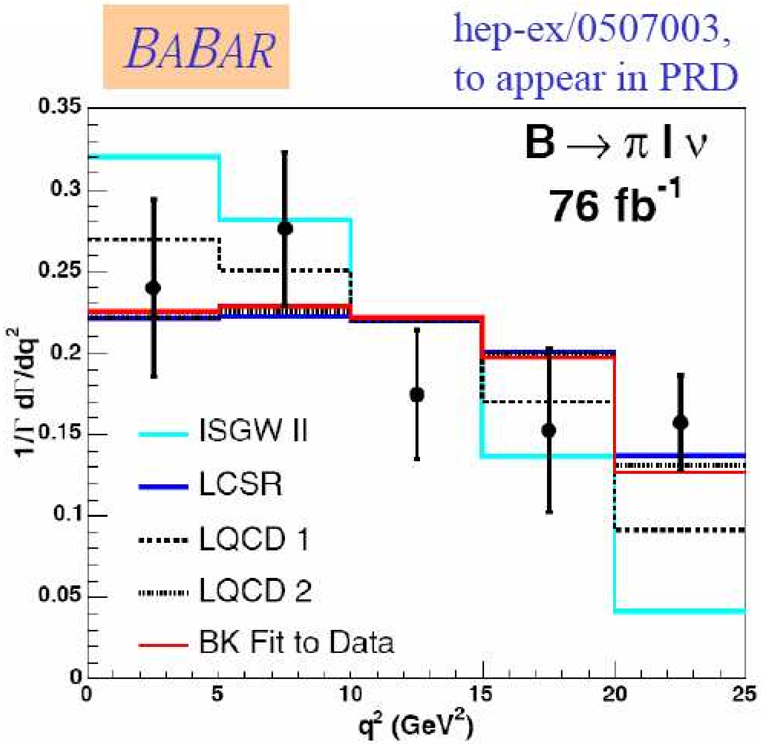
$$|V_{ub}| = 4.56 \times 10^{-3}$$
$$\pm 0.21(stat.)$$
$$\pm 0.32(syst.)$$
$$\pm 0.47(shape)$$
$$\pm 0.16(theory)$$

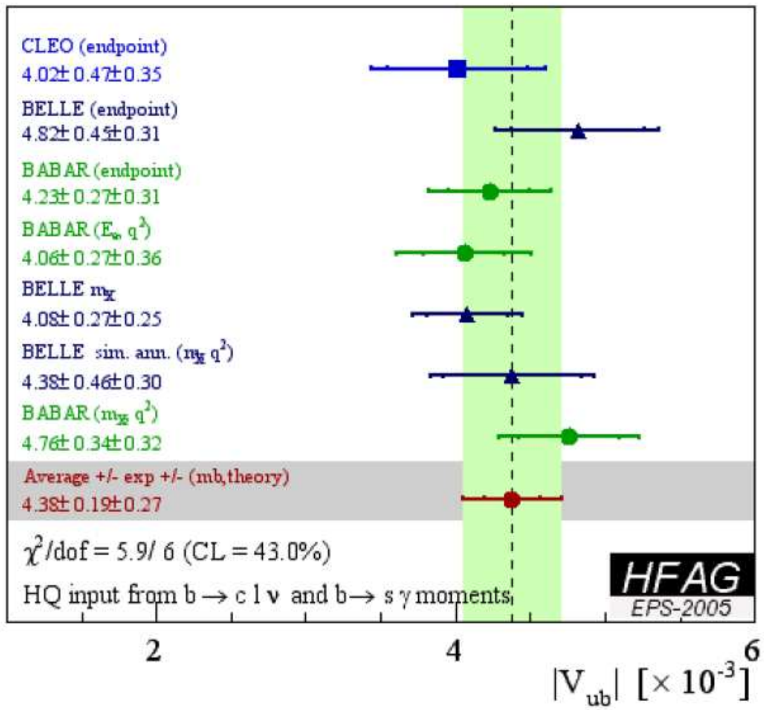


$B \to \pi \ell \nu$ and Summary of V_{ub}

Exclusive $B \to \pi \ell \nu$ with Lattice QCD form factor

Inclusive $b \to u \ell \nu$ with shape parameters from $b \to c \ell \nu$ and $b \to s\gamma$



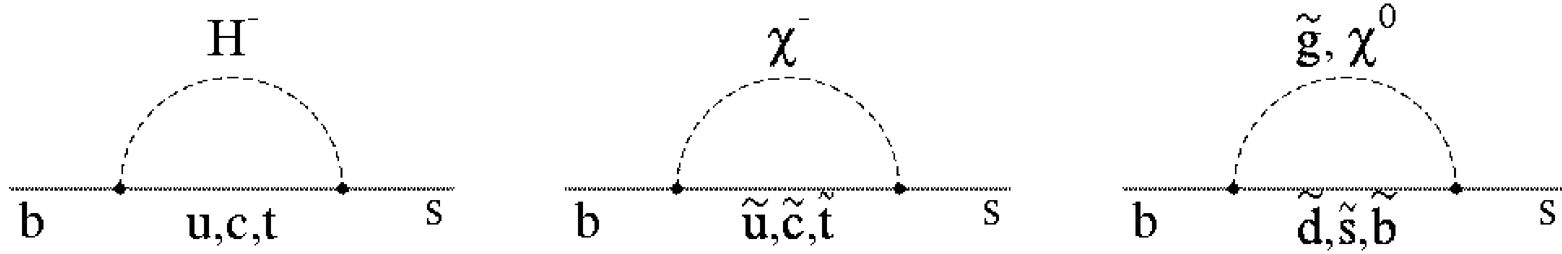


$$|V_{ub}| = (3.7 \pm 0.2^{+0.9}_{-0.5}) \times 10^{-3}$$

$$|V_{ub}| = (4.4 \pm 0.2 \pm 0.3) \times 10^{-3}$$

$b \to s\gamma$ as a probe of New Physics

Can replace the W and t quark in the "penguin" diagram with new particles in the loop:



Additional contributions could change the rate of $b \to s\gamma$

$$BF(b \to s\gamma) = (3.6 \pm 0.3) \times 10^{-4} \;\; \text{SM} \qquad (E_\gamma > 1.6 GeV)$$

$$BF(b \to s\gamma) = (3.5 \pm 0.3) \times 10^{-4} \;\; \text{HFAG} \qquad (E_\gamma > 1.6 GeV)$$

This agreement gives important constraints on New Physics

Experimental error can be reduced to 5% with more data

Theory error can be reduced with NNLO calculations

Measurements of $b \to s\gamma$

BaBar: PRD 72, 052004 (2005)

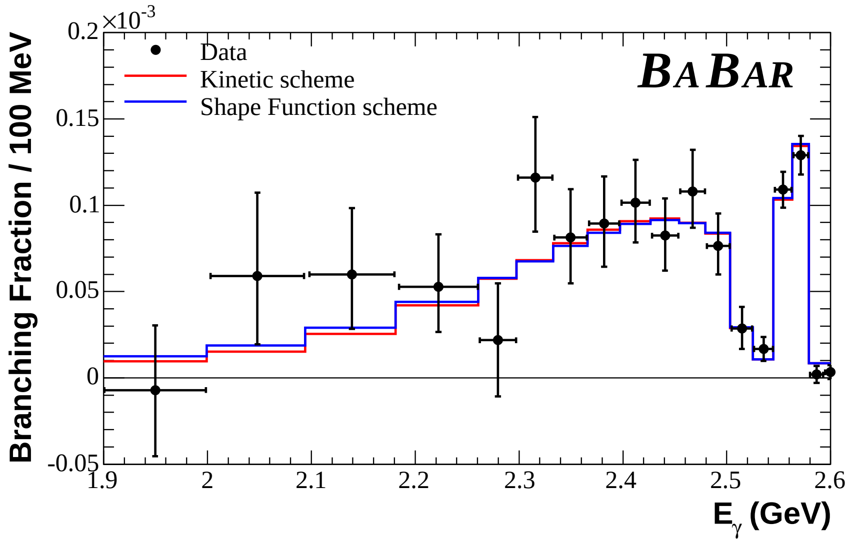
Sum of exclusive modes

Photon spectrum in B rest frame

Belle: PRL 93,061803(2004)

fully inclusive

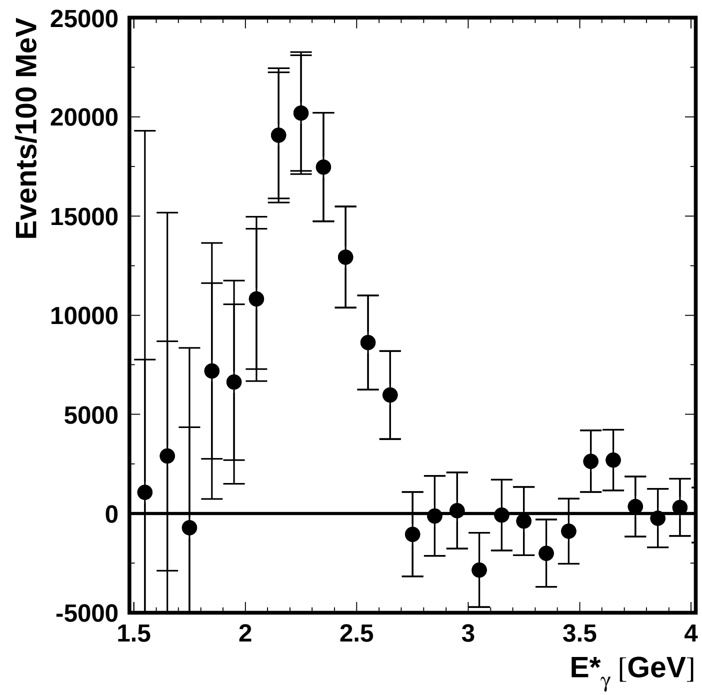
photons in $\Upsilon(4S)$ frame



$$BF = (3.35 \pm 0.19^{+0.56}_{-0.41} \pm 0.06) \times 10^{-4}$$

BF is extrapolated down

to $E_\gamma > 1.6\ GeV$



$$BF = (3.59 \pm 0.32 \pm 0.31 \pm 0.09) \times 10^{-4}$$

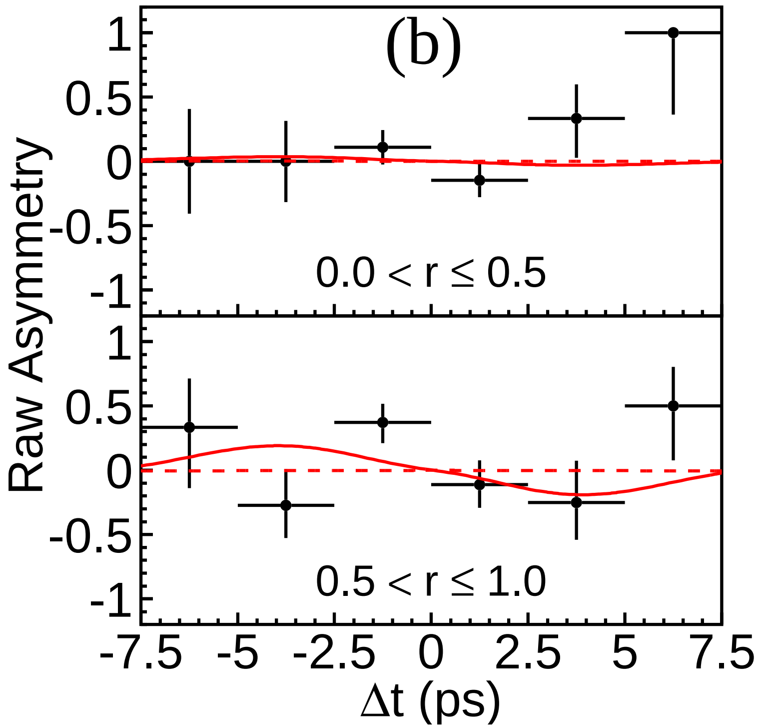
Errors are statistical, systematic, theoretical respectively

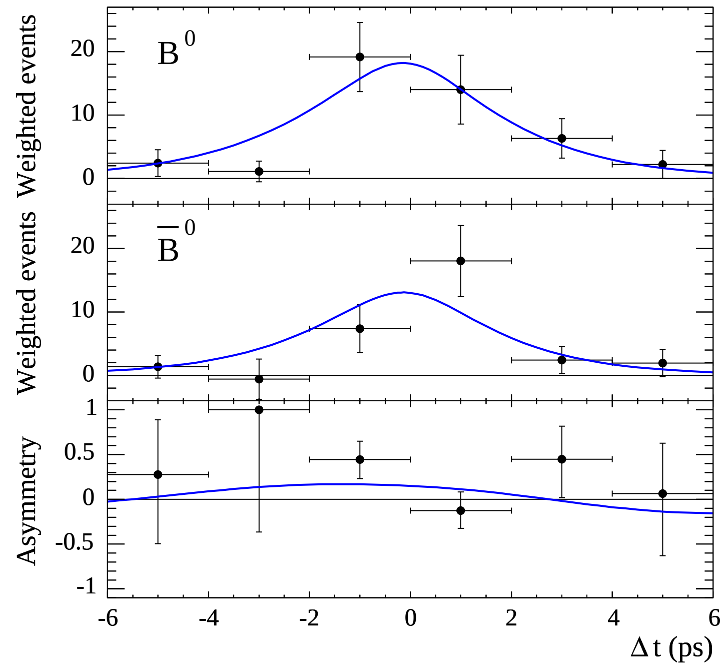
Time-Dependent CP Violation in $B \to K^*\gamma$

Couplings are left-handed (right-handed) for $b \to s\gamma$ ($\bar{b} \to \bar{s}\gamma$)

$S(K_s\pi^0\gamma) \propto \frac{m_s}{m_b} \sin 2\beta = 0.042 \pm 0.021$ $\quad C(K_s\pi^0\gamma) < 0.01$

Matsumori & Sanda hep-ph/0512175





Belle:hep-ex/0507059

$S(K_s\pi^0\gamma) = -0.58 \pm 0.42 \pm 0.11$

$C(K_s\pi^0\gamma) = -0.03 \pm 0.34 \pm 0.11$

BaBar:PRD-RC 72, 051103 (2005)

$S(K^*\gamma) = -0.21 \pm 0.40 \pm 0.05$

$C(K^*\gamma) = -0.40 \pm 0.23 \pm 0.03$

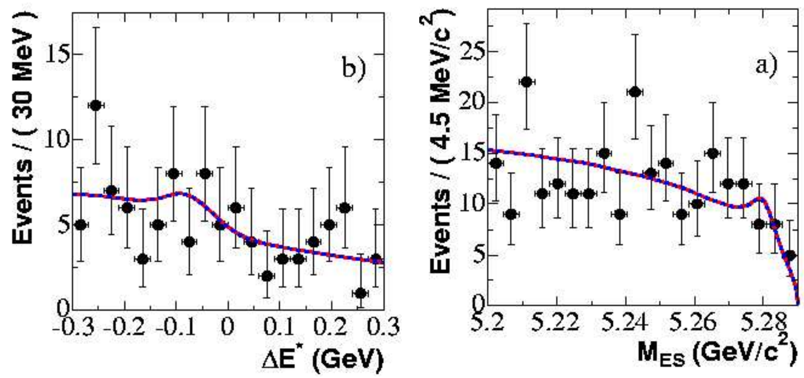
Current status of $B \to \rho\gamma$

BaBar: PRL 94, 011801 (2005)

2σ excesses in $B^{+(0)} \to \rho^{+}(\omega)\gamma$

but nothing in $B^0 \to \rho^0\gamma$

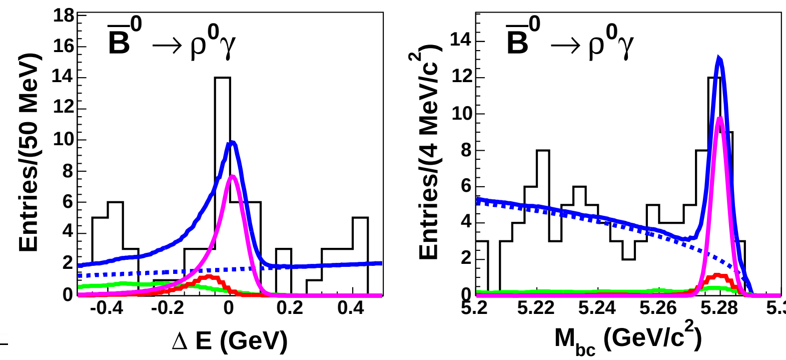
$BF(B^0 \to \rho^0\gamma) < 0.6 \times 10^{-6}$

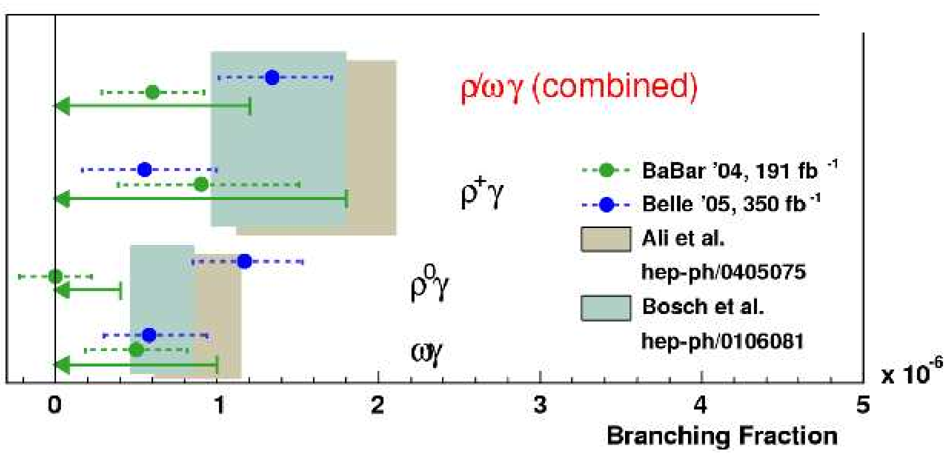


Belle: hep-ex/0506079

5σ excess in $B^0 \to \rho^0\gamma$

$0.8 < BF(B^0 \to \rho^0\gamma) < 1.5 \times 10^{-6}$





Belle and BaBar differ by $\approx 3\sigma$

Is isospin broken?

$\rho^{+} : \rho^{0} : \omega \neq 2 : 1 : 1$

Measuring V_{td}/V_{ts} with $b \to d\gamma$ penguins

$$\frac{BF(B \to \rho\gamma)}{BF(B \to K^*\gamma)} = \left|\frac{V_{td}}{V_{ts}}\right|^2 \frac{(1 - m_\rho^2/m_B^2)^3}{(1 - m_{K^*}^2/m_B^2)^3} \zeta^2 [1 + \Delta R]$$

$\zeta = 0.85 \pm 0.10$ allows for SU(3) breaking in the form factor

$\Delta R = 0.1 \pm 0.1$ allows for weak annihilation ($B^+ \to \rho^+\gamma$ only!)

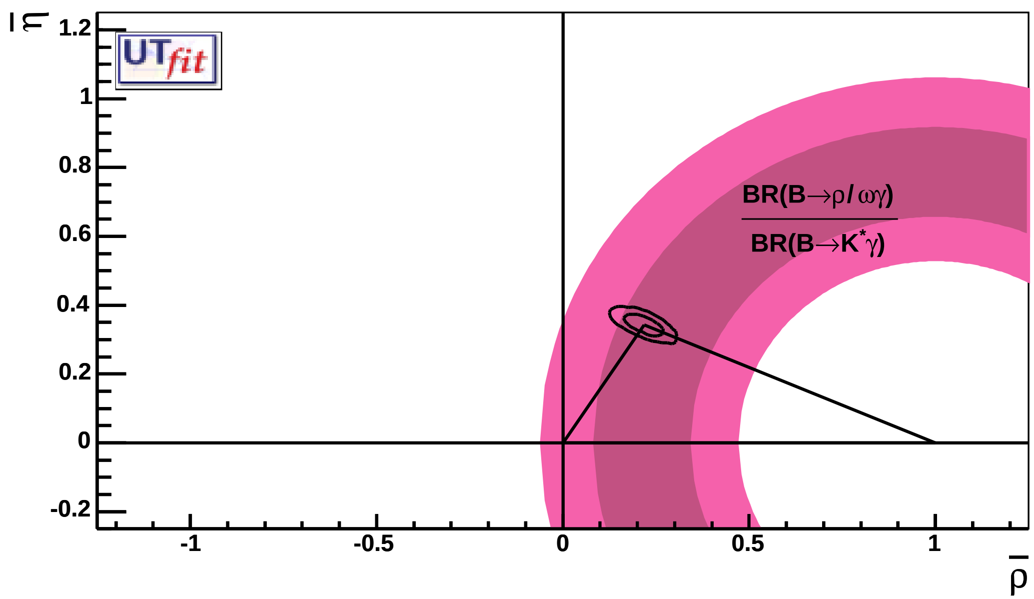
BaBar (95% CL)

$|V_{td}/V_{ts}| < 0.21$

Belle (95% CL)

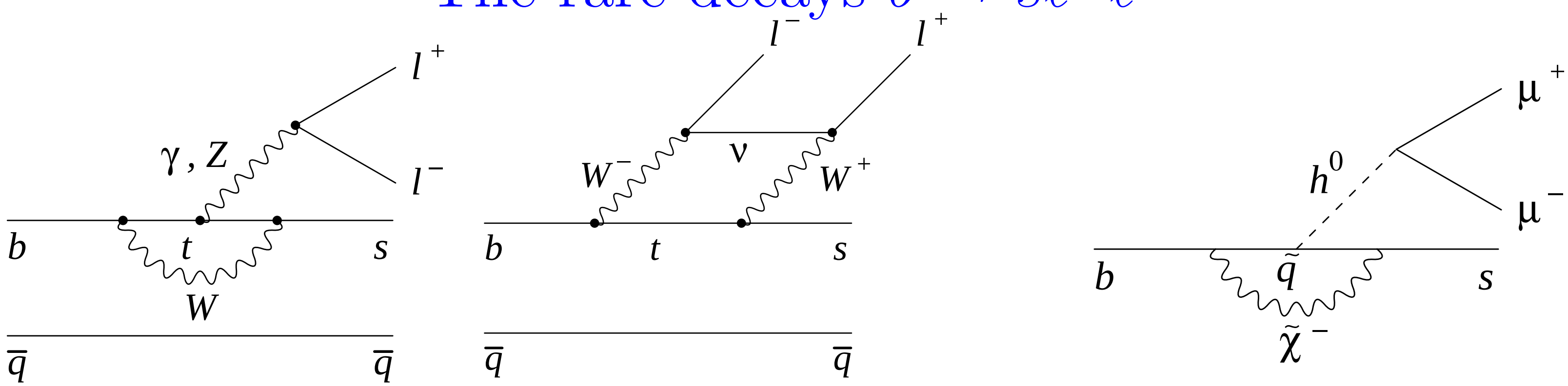
$|V_{td}/V_{ts}| > 0.14$

Currently better than B_s mixing!



Is an inclusive measurement of $b \to d\gamma$ also possible?

The rare decays $b \to s\ell^+\ell^-$



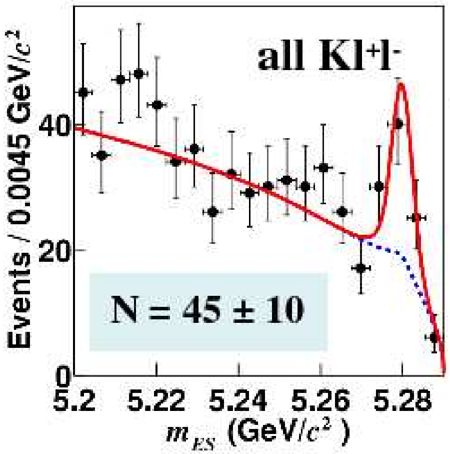
Wilson coefficients C_7, C_9 and C_{10} (sensitive to New Physics) from:

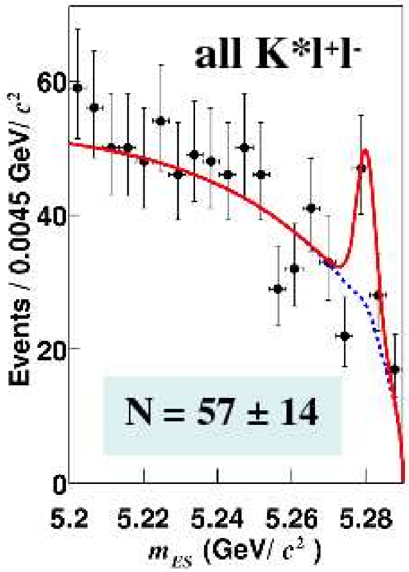
- Inclusive and exclusive (K, K^*) Branching Fractions as a function of q^2 of the leptons
- Forward-Backward lepton asymmetry as a function of q^2 (note that this is zero for $K\ell^+\ell^-$)
- The ratio of $se^+e^-/s\mu^+\mu^-$
- Direct CP asymmetries
- Eventually $b \to d\ell^+\ell^-$ (using $B \to \pi\ell^+\ell^-$)

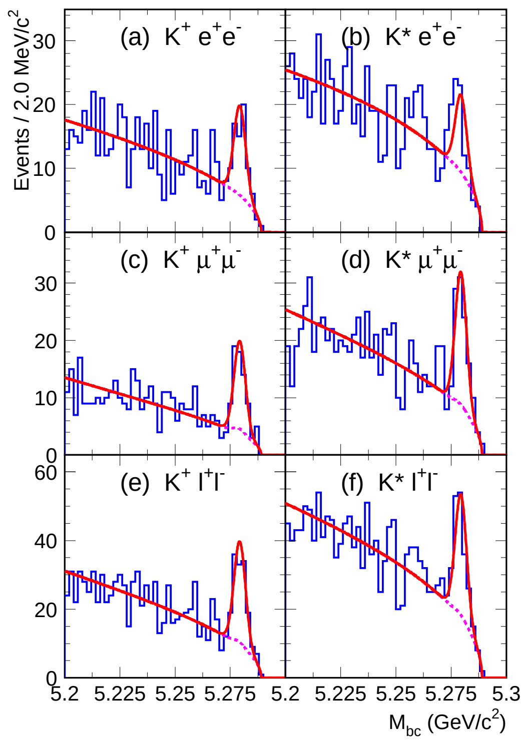
Exclusive $B \to K^{(*)}\ell^+\ell^-$

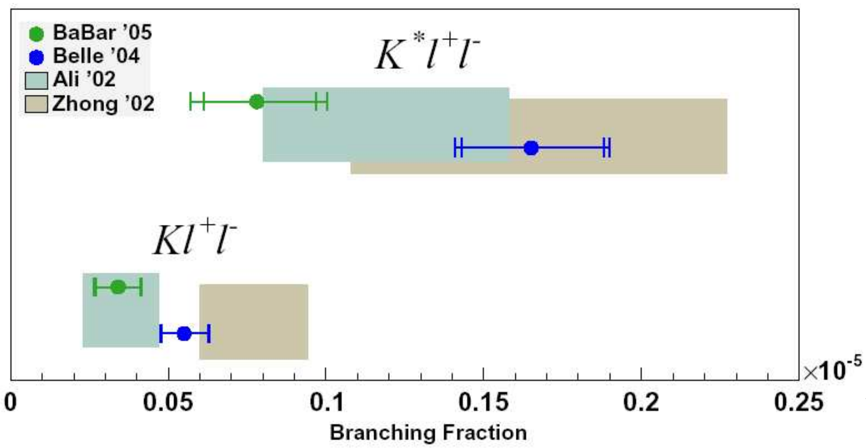
BaBar: hep-ex/0507005

Belle: PRL 91, 261601 (2003)







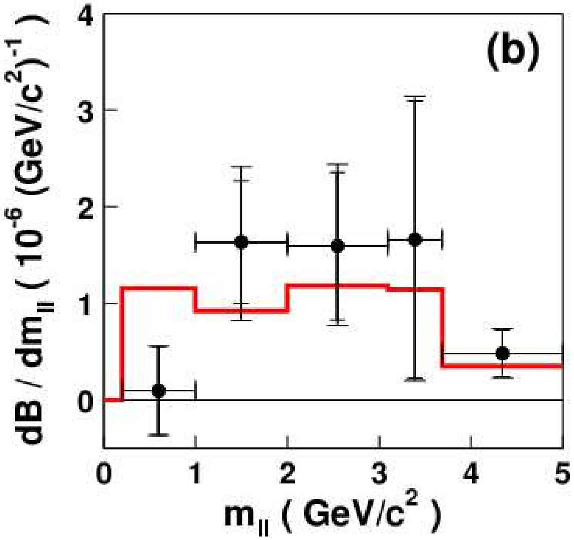


Direct CP asymmetries:

$$A_{CP}(K\ell\ell) = 0.08 \pm 0.22 \pm 0.11$$

$$A_{CP}(K^*\ell\ell) = -0.03 \pm 0.23 \pm 0.12$$

Measurements of inclusive $b \to s\ell^+\ell^-$

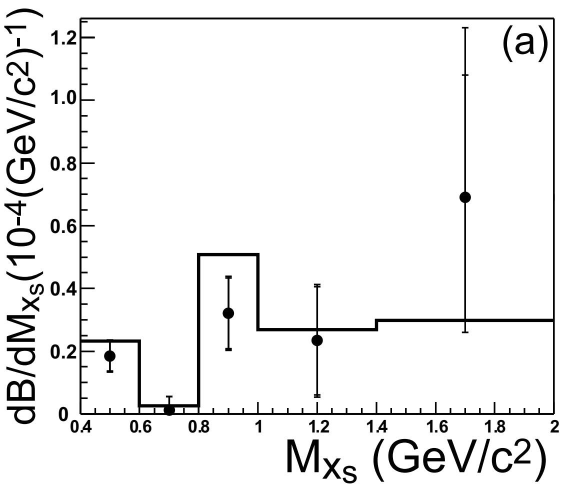


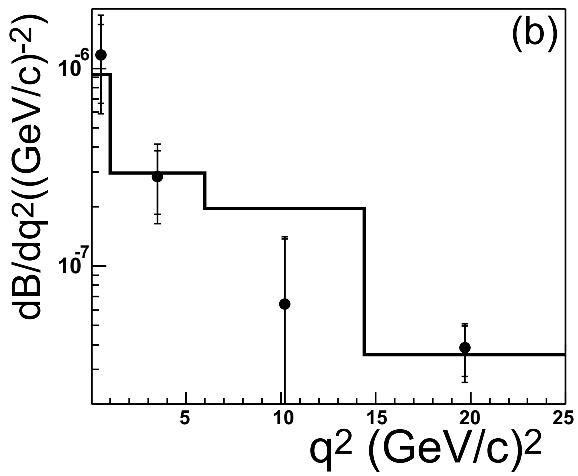
BaBar: PRL 93, 081802 (2004)

$$BF(b \to s\ell^+\ell^-) = (5.6 \pm 1.5 \pm 1.3) \times 10^{-6}$$

Belle: hep-ex/0408119

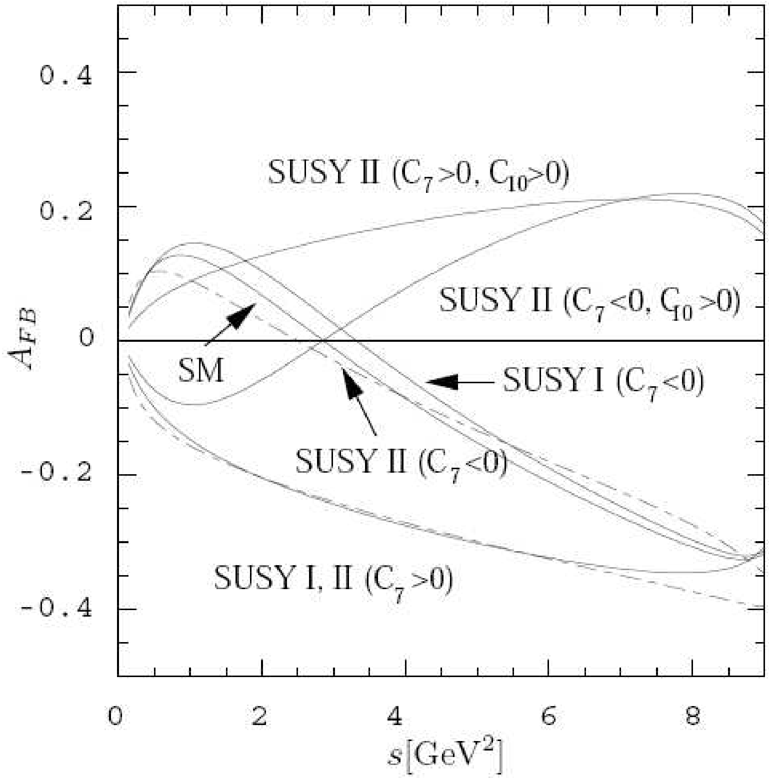
$$BF(b \to s\ell^+\ell^-) = (4.1 \pm 0.8 \pm 0.8) \times 10^{-6}$$

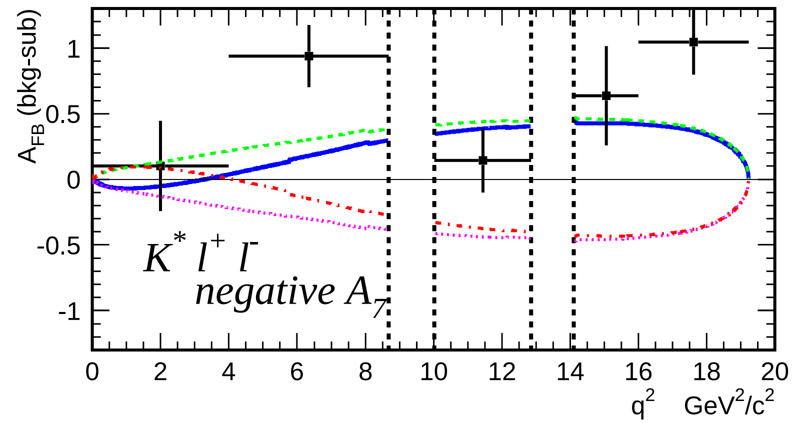




BF is in agreement with Standard Model

Forward-Backward Asymmetry in $B \to K^* \ell^+ \ell^-$



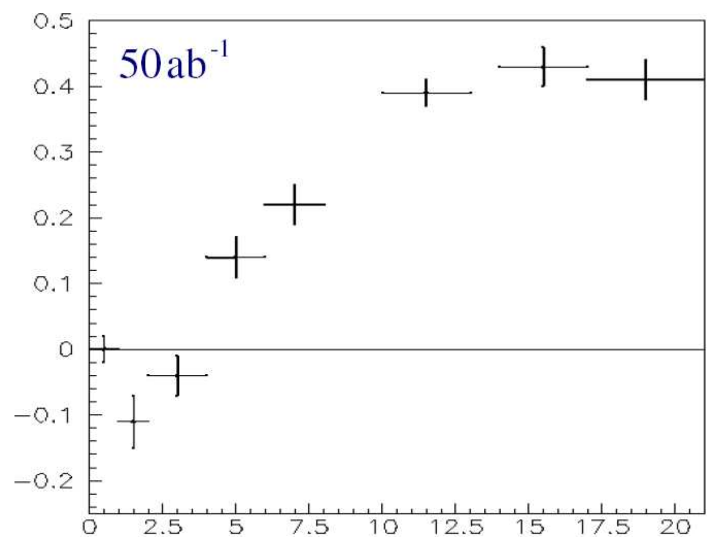


Belle: hep-ex/0508009

fit favours SM

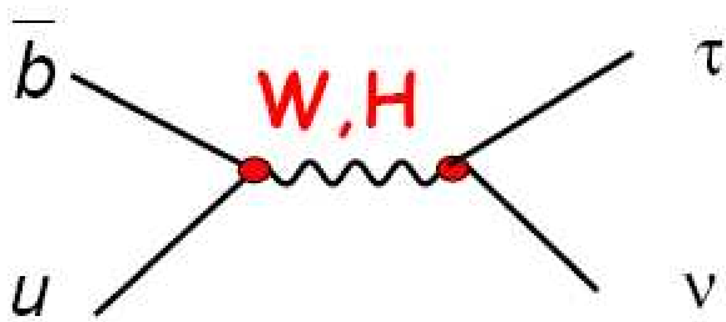
$C_7, C_{10} < 0$ and $C_9 > 0$

SuperB factory with $50/ab \Rightarrow$
or a few years of LHCb data



Purely leptonic B decays

$B \to \ell\nu$ proceeds via a weak annihilation diagram:



Standard Model prediction:

$$BF(B^+ \to \tau^+\nu_\tau) = 1.2 \times 10^{-4} \left(\frac{f_B}{200MeV}\right)^2 \left(\frac{V_{ub}}{0.004}\right)^2$$

can be modified by an H^+ at large $\tan\beta$

The decays $B^+ \to \mu^+\nu_\mu$ and $B^+ \to e^+\nu_e$ are helicity suppressed

$$\tau\nu : \mu\nu : e\nu = 1 : 4 \times 10^{-3} : 1 \times 10^{-7}$$

BaBar search for $B \to \tau\nu$: hep-ex/0507069

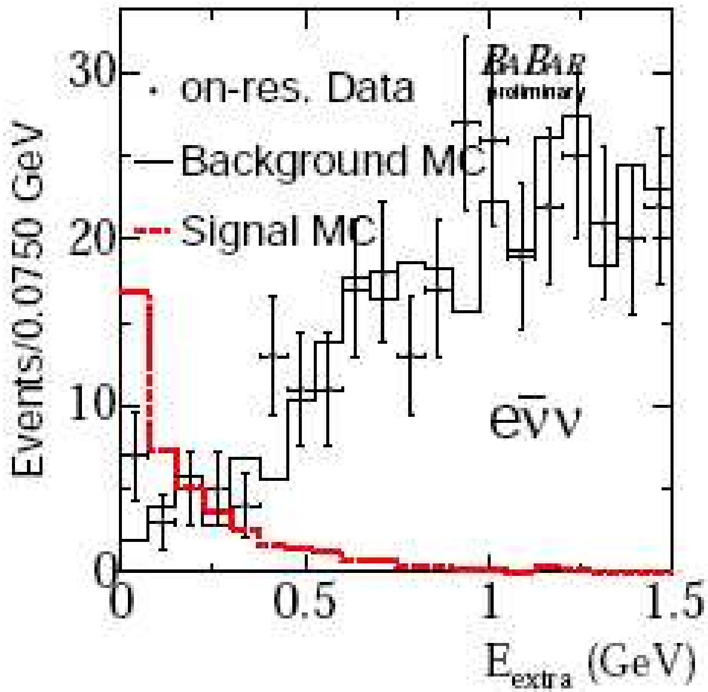
A tag B^- is reconstructed as:
$\Rightarrow$ semileptonic $B^- \to D^{*0}\ell^-\nu$
$\Rightarrow$ hadronic final states

τ^+ decays to:
e^+, μ^+, π^+, ρ^+, a_1^+
(81% of τ decays)

Plot of extra energy in event

Semileptonic tags

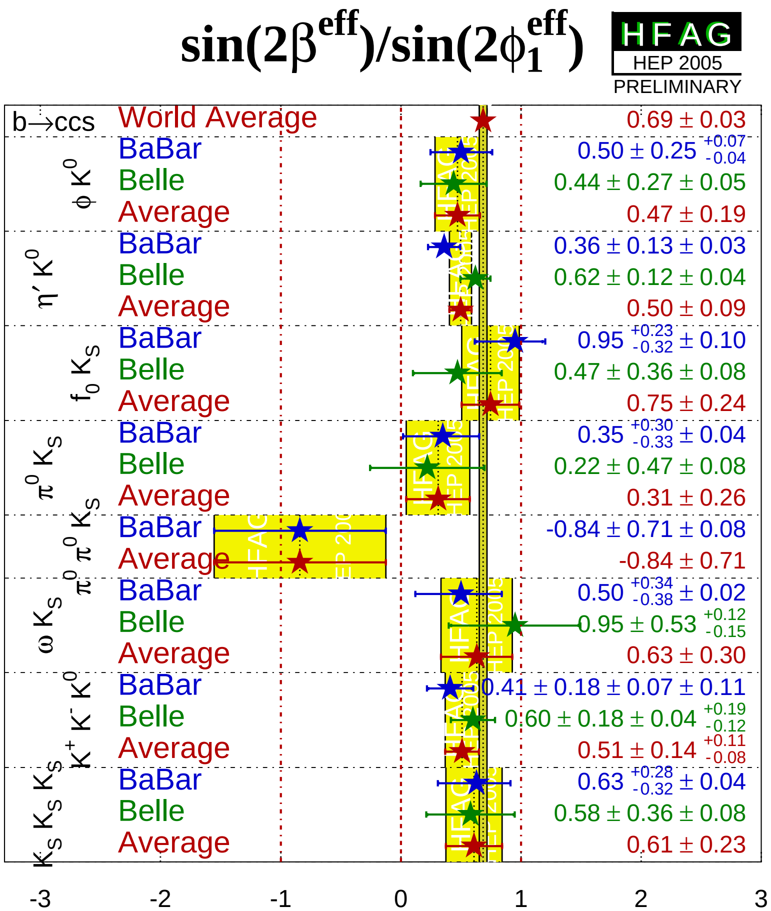
$\tau \to e$ decays

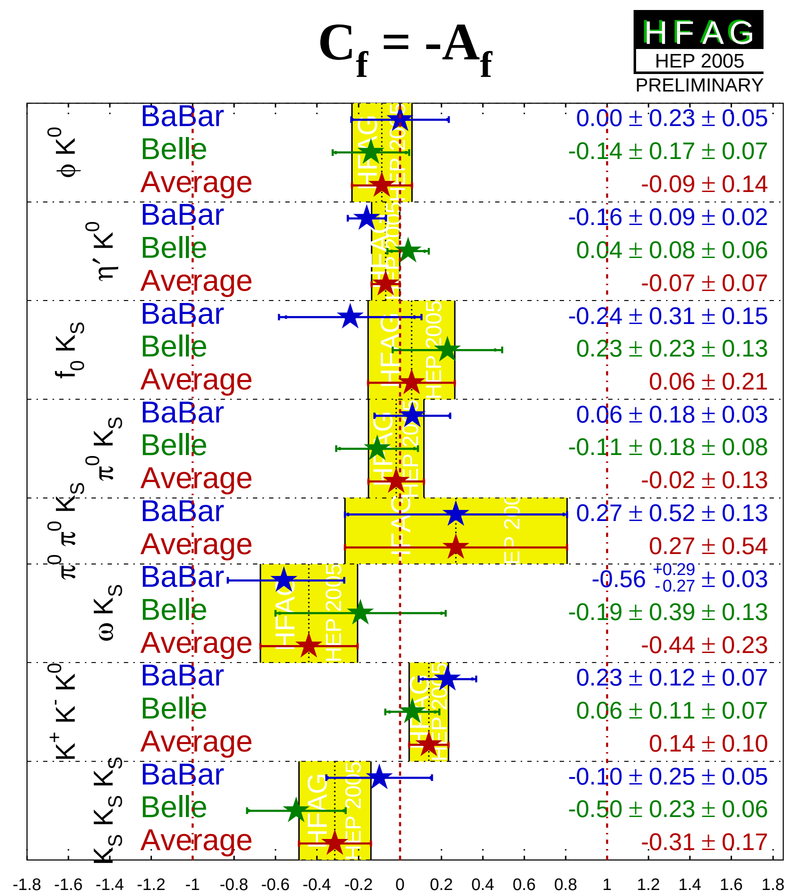


Combined result from all tags and decays is close to expected BF:

$BF(B^+ \to \tau^+\nu_\tau) = 1.3^{+1.0}_{-0.9} \times 10^{-4}$ $(< 2.6 \times 10^{-4}$ at 90% C.L.)

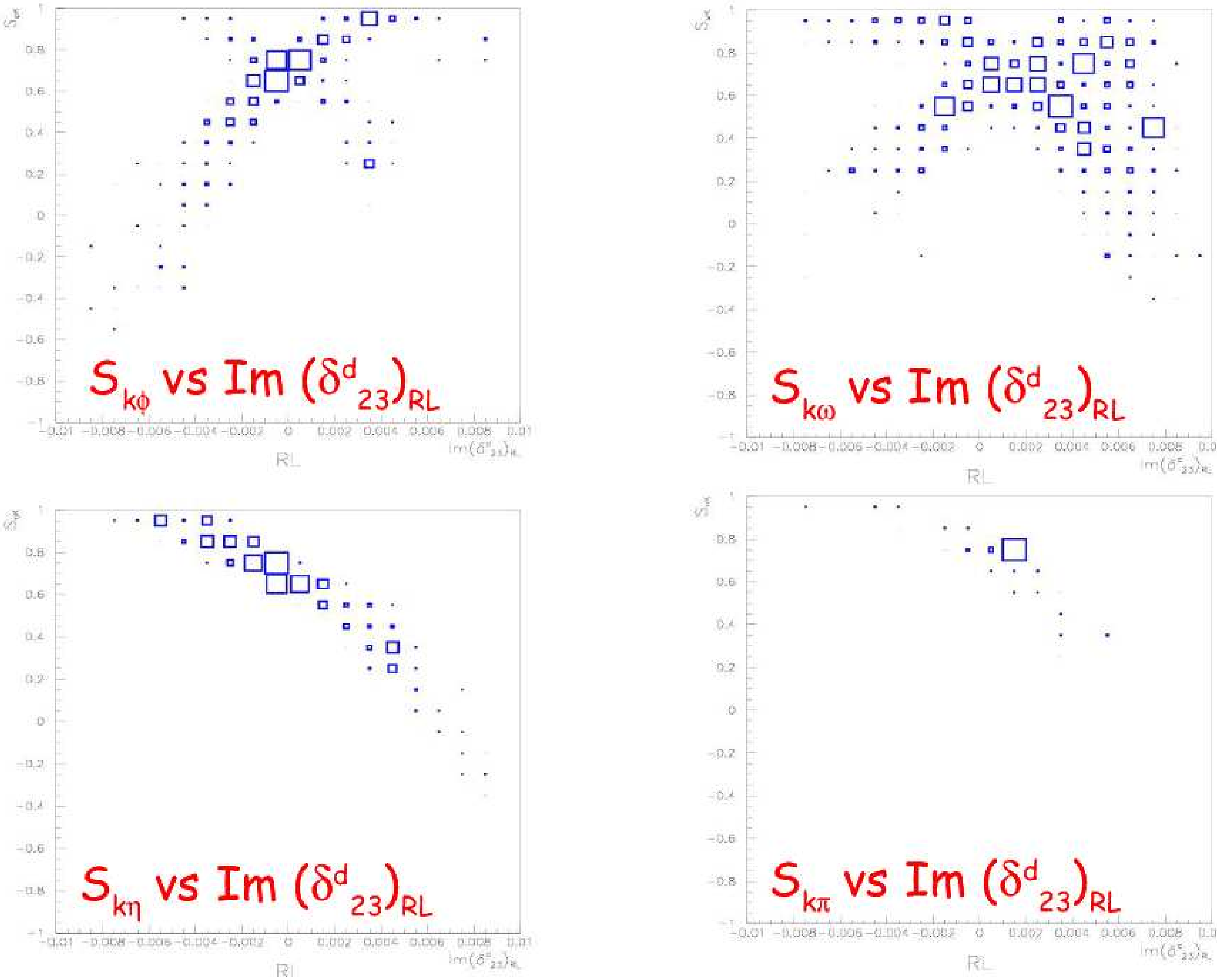
A hint of New Physics in Gluonic Penguins?





$\sin 2\beta(b \to s) \neq \sin 2\beta(b \to c\bar{c}s)$ … but no direct CP violation

"Naive" average $\sin 2\beta^{eff} = 0.50 \pm 0.06$ $C_f = -0.04 \pm 0.04$



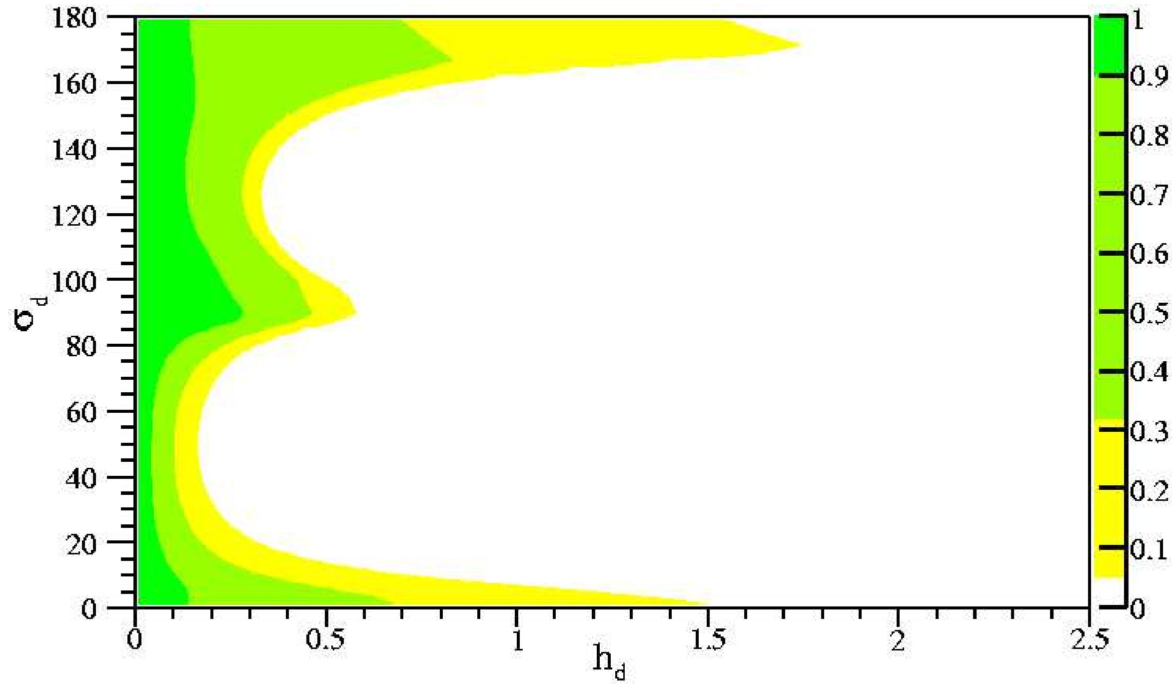
Effect of SUSY $b \to s$ couplings - Silvestrini hep-ph/0510077

Already includes constraints from $b \to s\gamma$ *and* $b \to s\ell^+\ell^-$

Next to Minimal Flavour Violation

General class of new physics models - Agashe et al. hep-ph/0509117

- Flavour structure quasi-aligns with SM Yukawa couplings
- New couplings are dominantly to third generation quarks



Constraints on magnitude h_d and phase ϕ_d of new $b \to d$ coupling

b Physics programme at LHCb

For many B^+ and B^0 decays:

one year of data matches all the data from the B factories...

... but there are also plenty of B_s, B_c and Λ_b!

A personal list of interesting measurements:

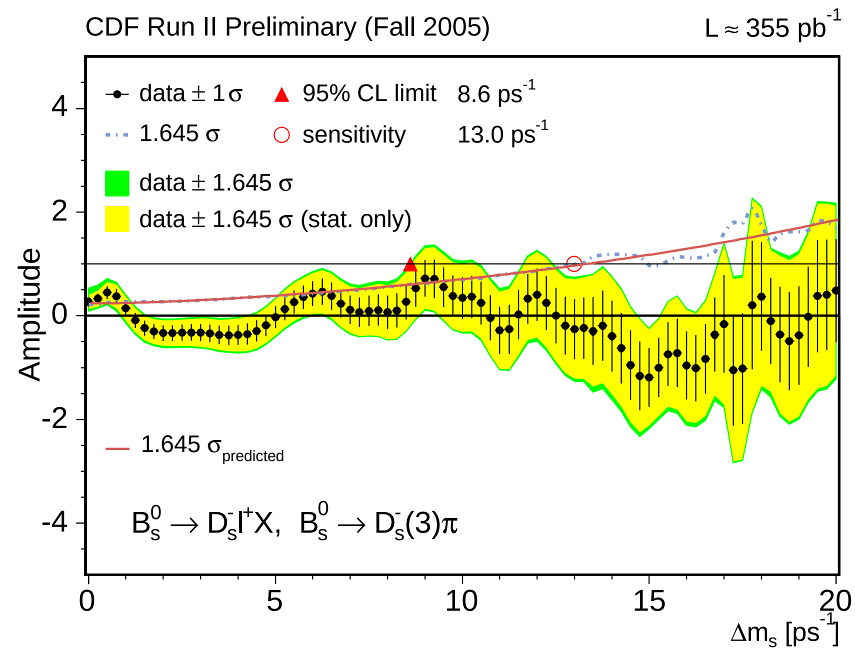
- Accurate measurements of Δm_s and $\Delta\Gamma_s$
- Constraints on ϕ_s from time-dependent CP violation in $B_s \to J/\psi\phi$
- Measurements of γ using $B_s \to D_s K$ and $B_s \to K^+K^-$
- Search for new physics in $b \to s$ penguins using rare decays of B_d and B_s to ϕ and η'
- Measurements of asymmetries in $B \to K^*\ell^+\ell^-$

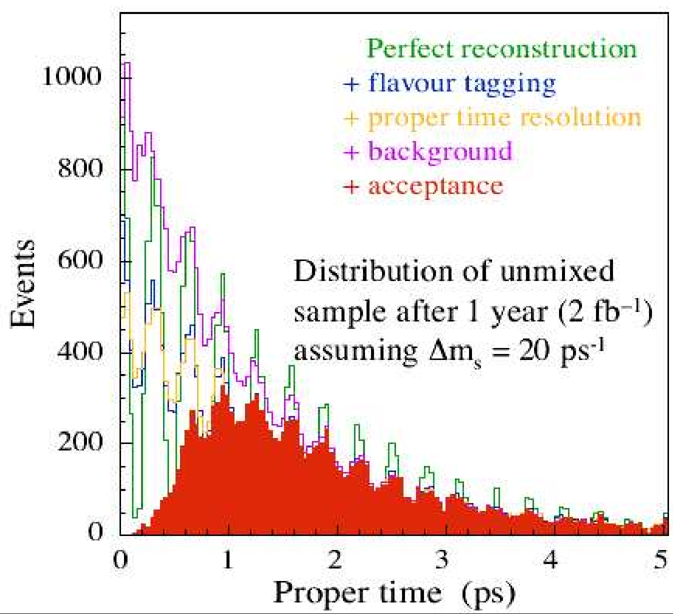
B_s mixing

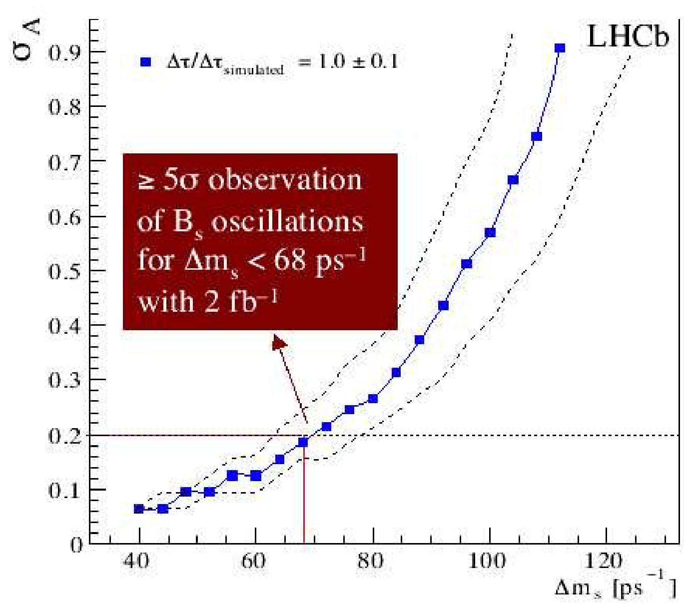
CKM fit predicts:

$$\Delta m_s = 18.3^{+6.5}_{-1.5}$$

Should eventually be measured at Tevatron $\Rightarrow$ and at LHCb $\Downarrow$







...or new Physics at LHCb?

Super B Factories?

e^+e^- colliders at the $\Upsilon(4S)$ after BaBar/BELLE/LHCb

- SuperBELLE at KEK:
  - Luminosity: $2 - 5 \times 10^{35}$ $\quad \int = 20 ab^{-1}$
  - Timescale: 2011-2020 Cost: 450M$
  - *Proposal is under review in Japan*
- SuperBaBar:
  - Luminosity: $5 - 7 \times 10^{35}$ $\quad \int = 50 ab^{-1}$
  - Timescale: 2013-2020 Cost: $\approx$ 500M$
  - *Not supported by SLAC/US at present*
- Linear Collider Super B:
  - Luminosity: $1 - 2 \times 10^{36}$ $\quad \int \approx 100 ab^{-1}$
  - *Feasibility is being studied at Frascati*