B Physics

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PDG 50th Anniversary Festivities, Sep 23, 2006, Lawrence Berkeley National Laboratory

Statistics

B physics fraction of 2006 Book

Meson summary tables : 11.5 / 33 pages

Meson listings : 135 / 418 pages

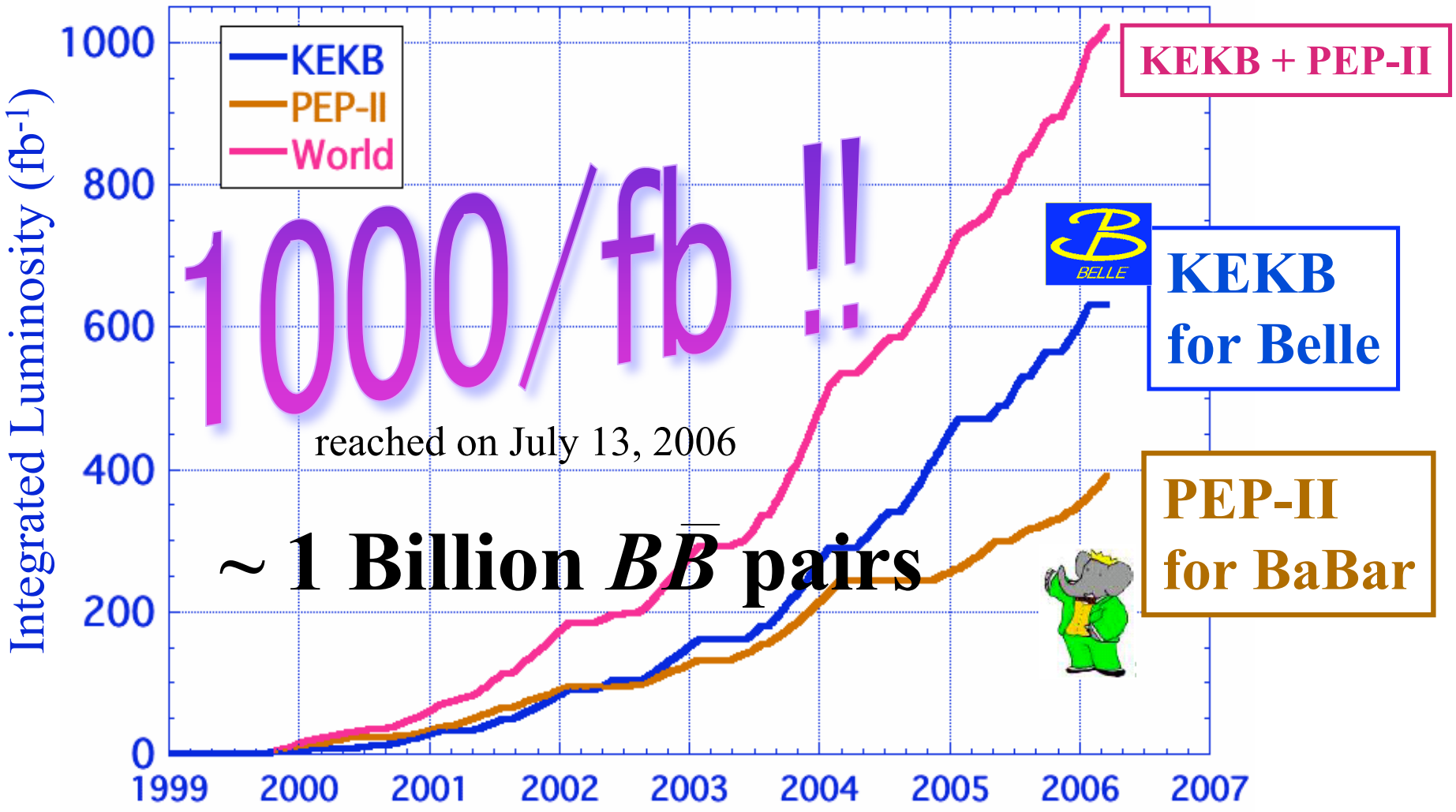
+ 6 reviews

~ 1/3 of current Particle Data are B physics related.

The State of the Art
B Physics

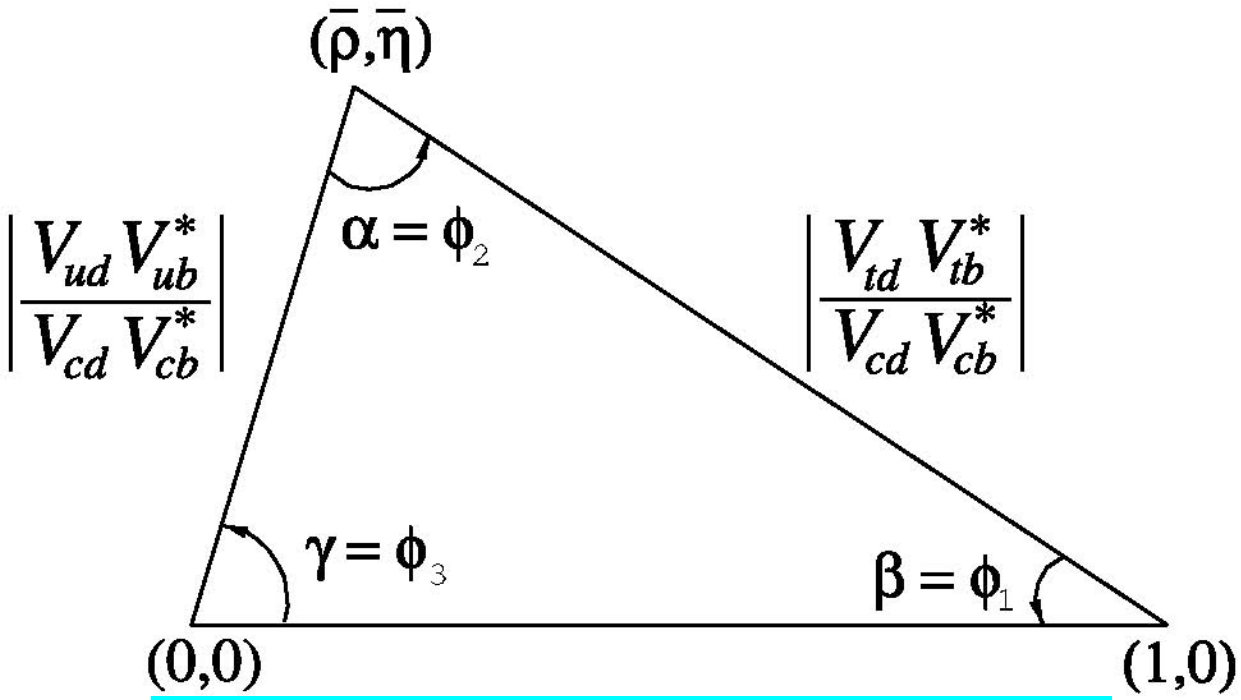
Examples

Integrated Luminosity of B factories



CKM Unitarity Triangle

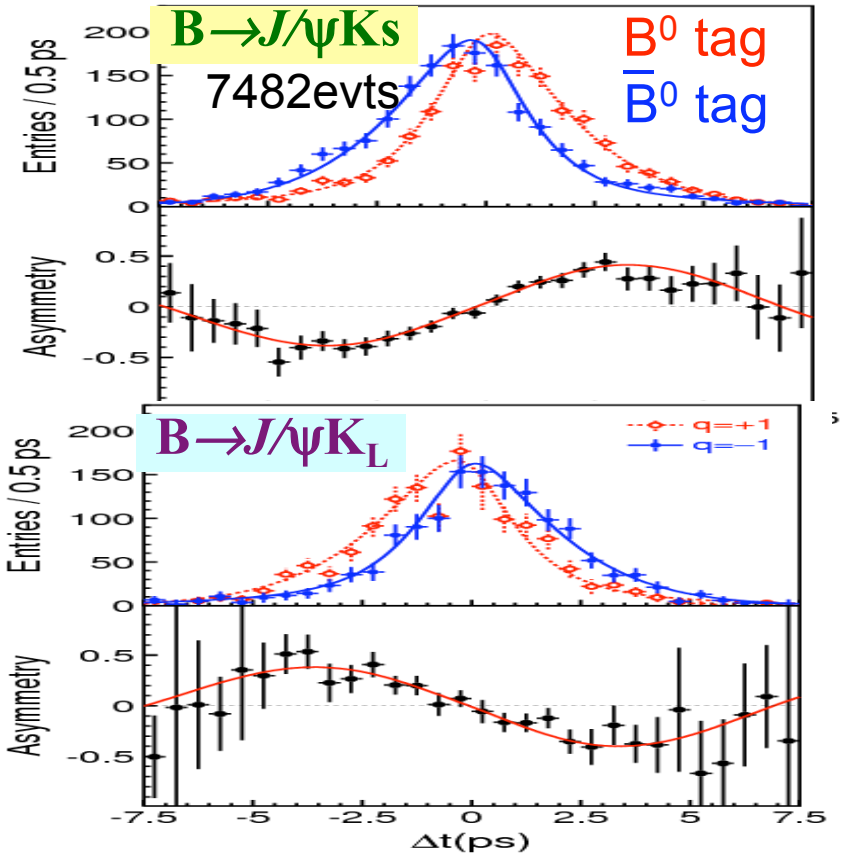
$$\alpha, \beta, \gamma \text{ or } \phi_1, \phi_2, \phi_3 \ ?$$



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

Angle β / ϕ_1 from $b \to c\bar{c}s$

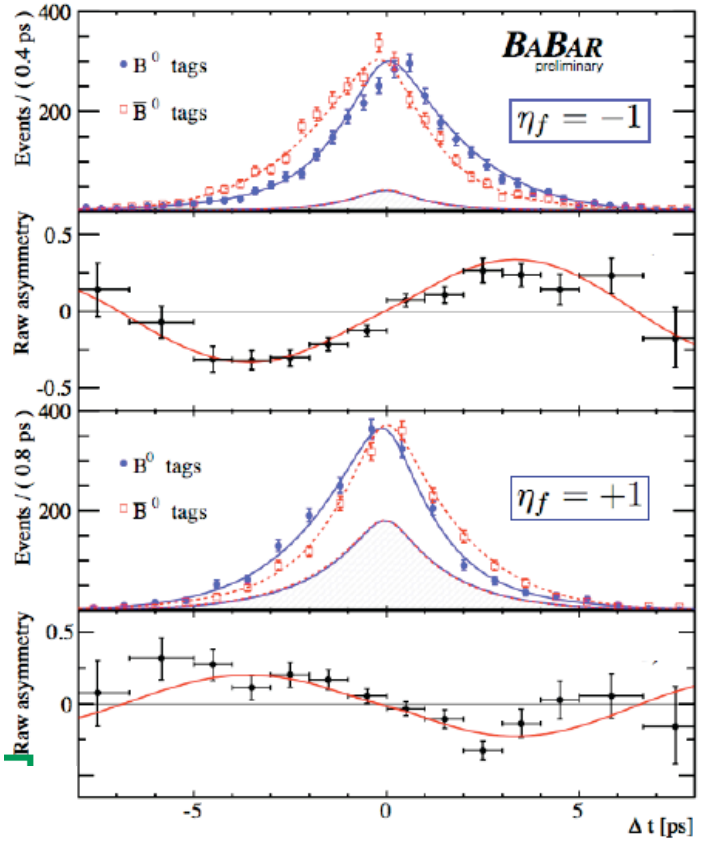
535M $B\bar{B}$



[hep-ex/0608039]

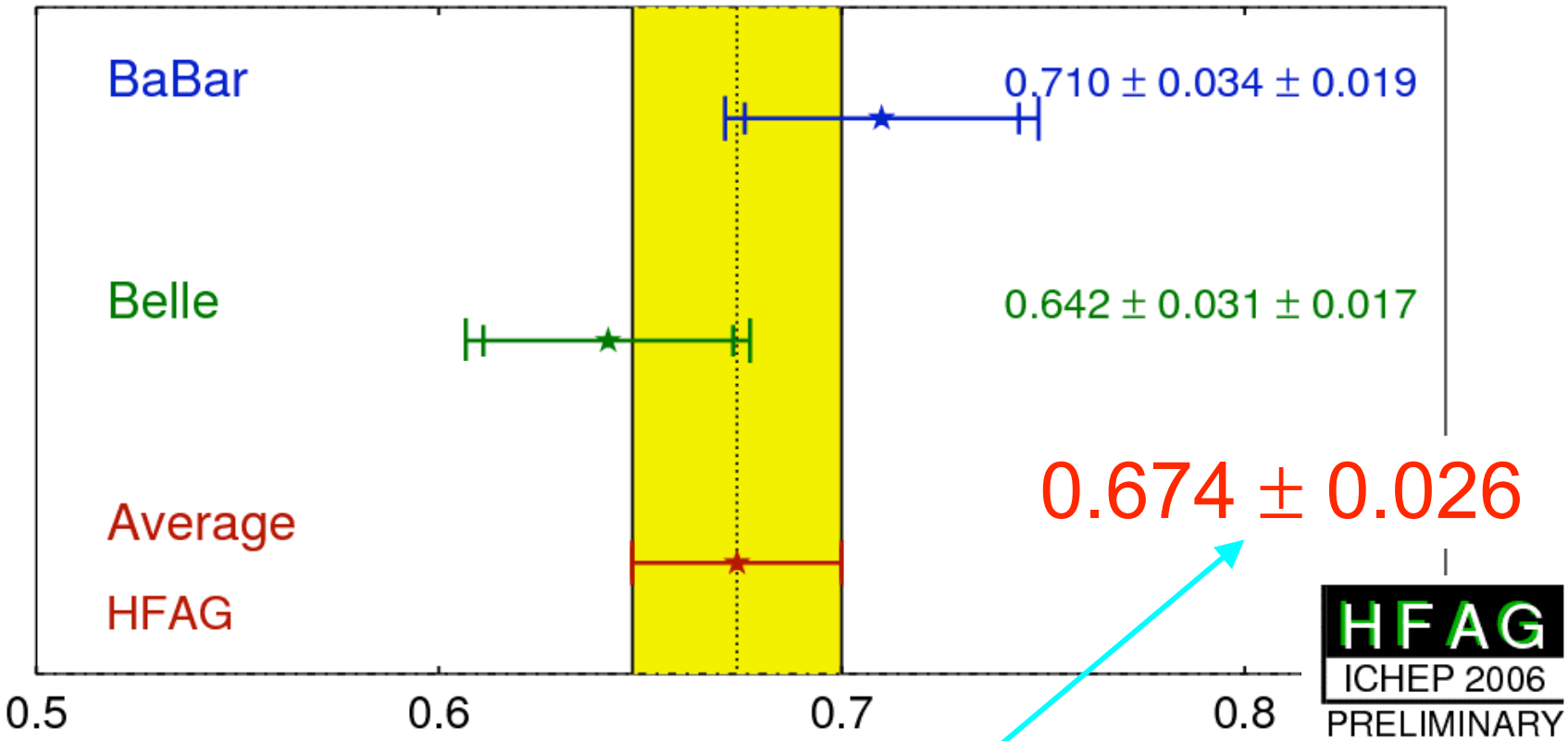
347M $B\bar{B}$

$(c\bar{c})K^{(*)0}$



[hep-ex/0607107]

$\sin 2\phi_1$: 2006 BaBar + Belle

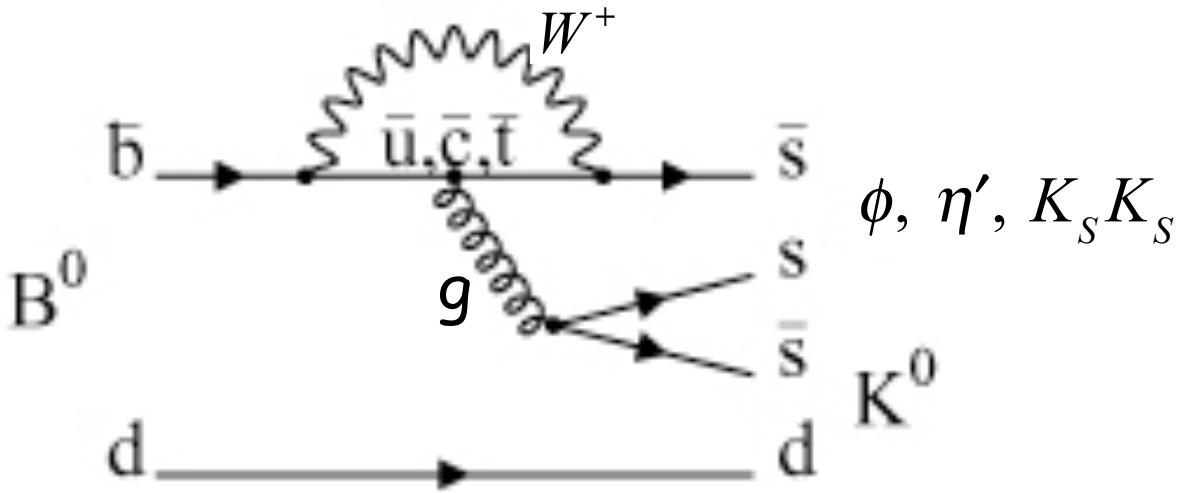


0.674 ± 0.026

~4 % error : Precision measurement !

$$\beta = \phi_1 = (21.2 \pm 1.0)^\circ$$

CP violation in $b \to s$ penguin modes



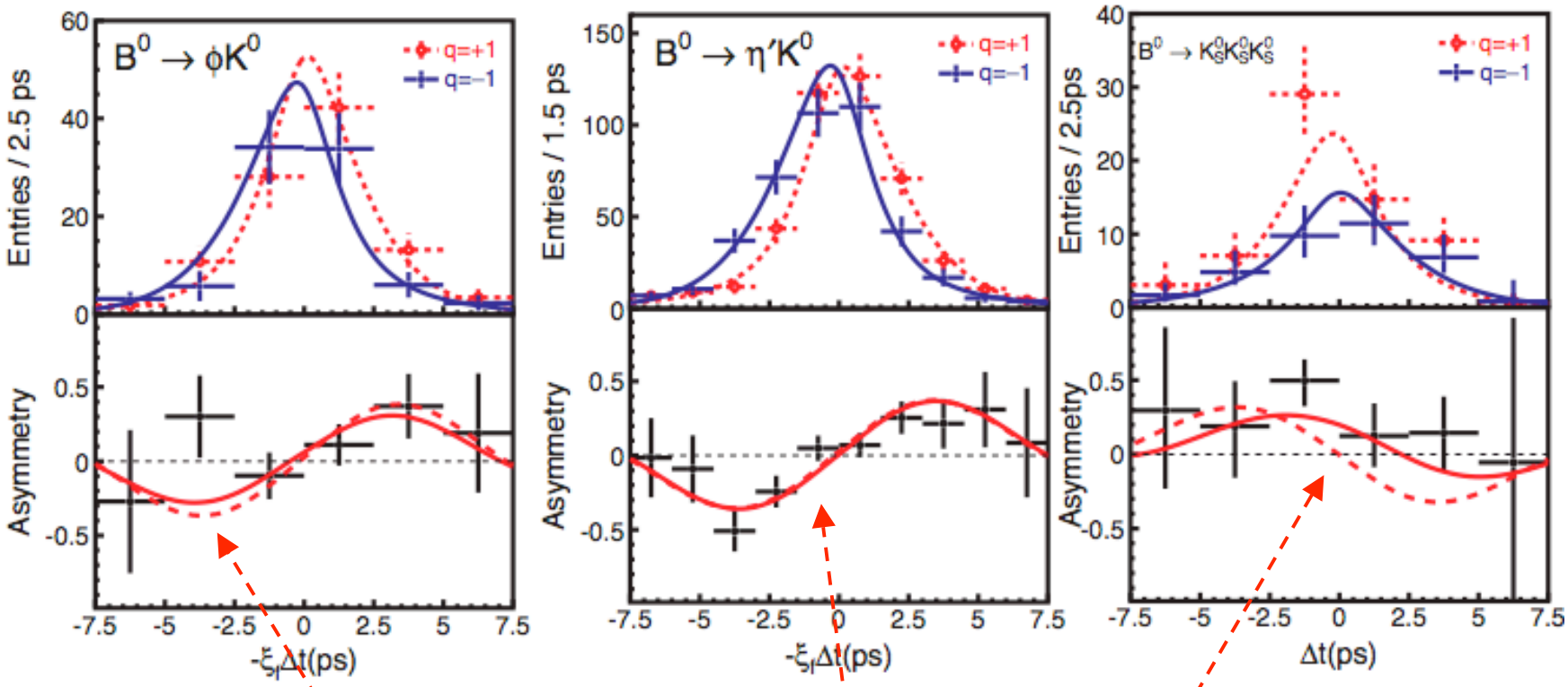
$\sin 2\beta_{\text{effective}}$ from $b \to sss$ loop

$\neq \sin 2\beta$ from $b \to ccs$ tree ?

Belle 2006

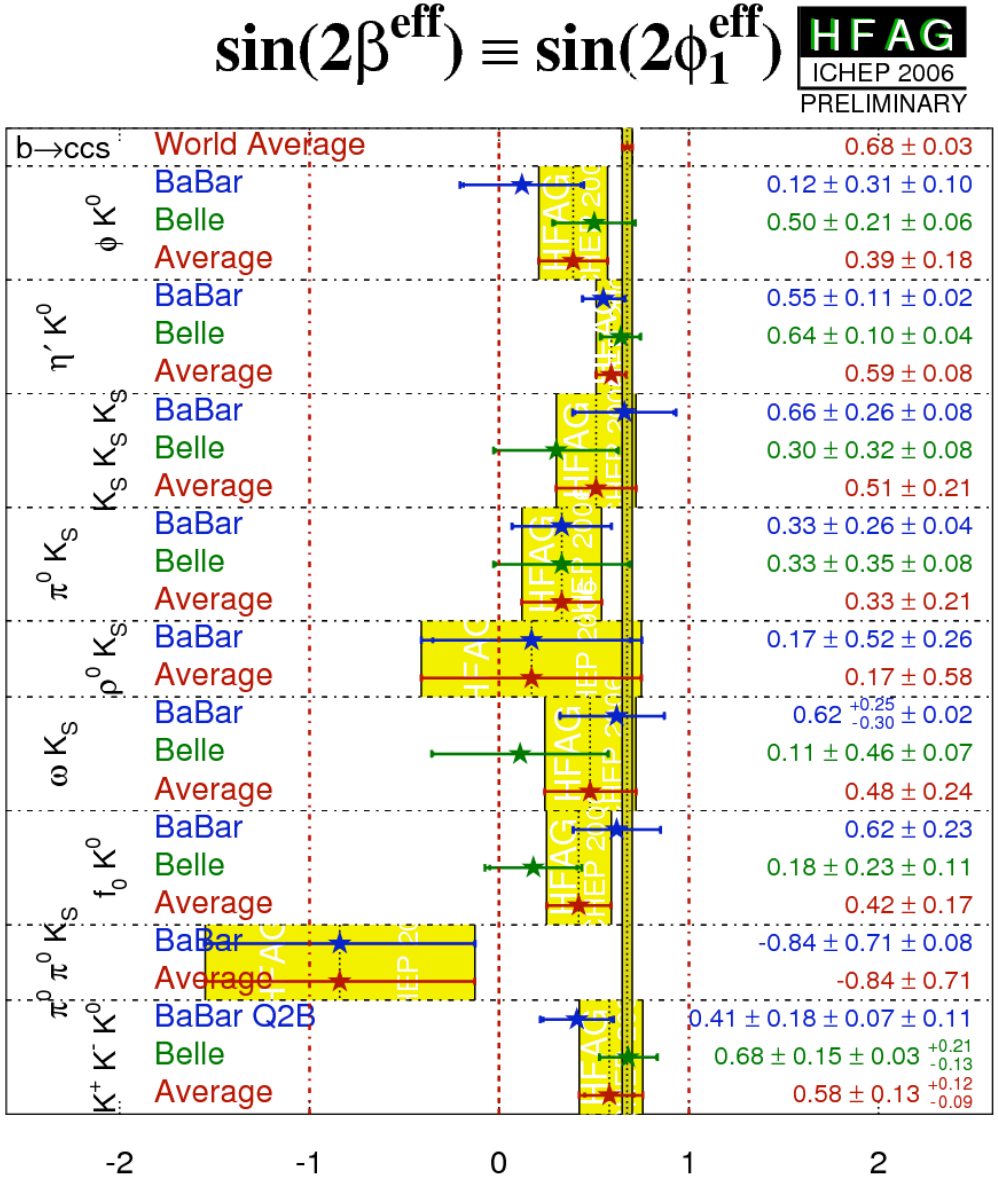
535M $B\bar{B}$

$$b \longrightarrow s\bar{s}s$$



Dashed lines correspond to the SM value.

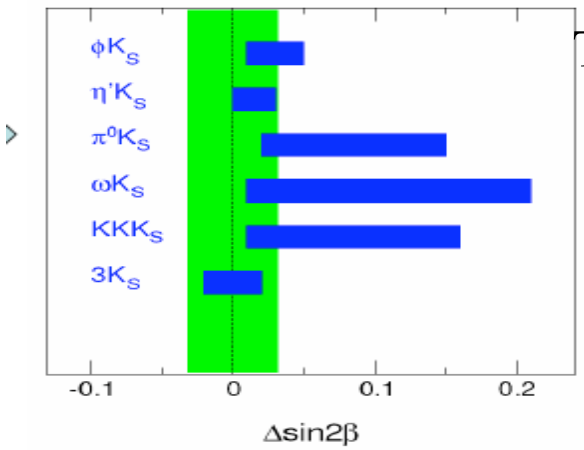
$$\sin(2\beta^{eff}) \equiv \sin(2\phi_1^{eff})$$



Smaller than b→ccs in all of 9 modes

some of recent QCDF estimates

$\sin 2\beta^{f}_{eff} - \sin 2\beta$

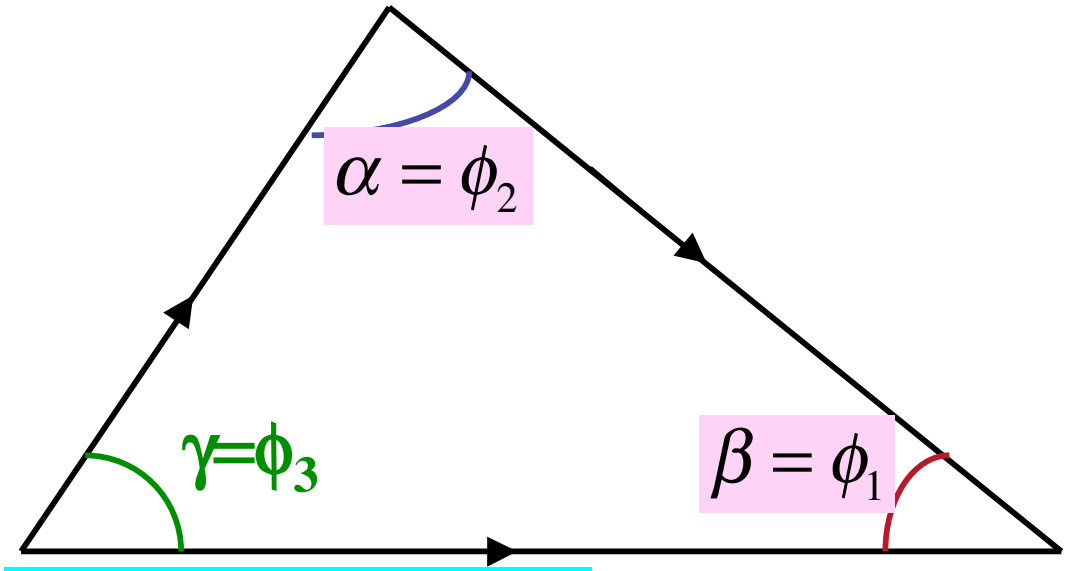


Theory : tend to positively shifts

Deviations of O(1) are ruled out for b→s. But there may be an effect of O(0.2) in b→s

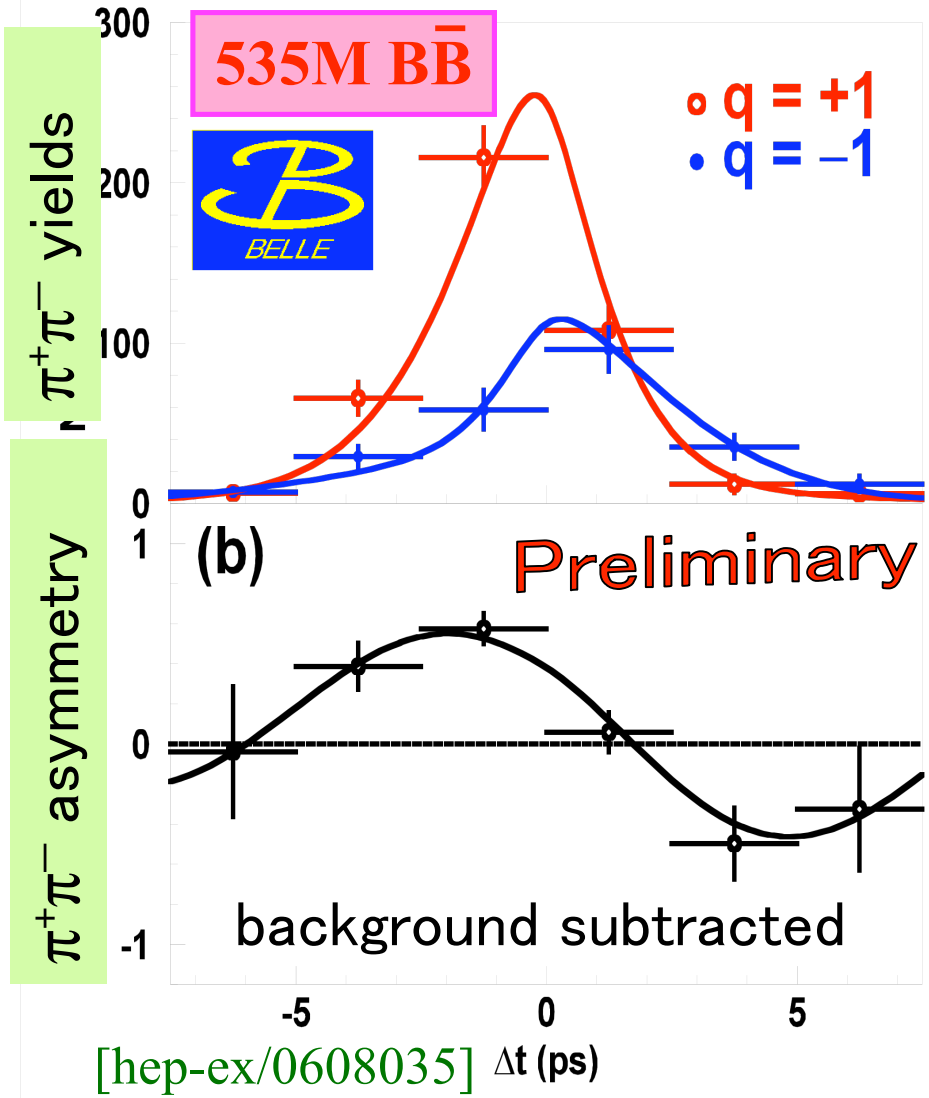
$$\alpha \equiv \pi - \beta - \gamma$$

process involving neutral B meson mixing and b to u transition.



$\gamma(\phi_3) = \text{phase of } V_{ub}$

ϕ_2 Belle 2006: $B^0 \to \pi^+\pi^-$ decay (tCPV)



[hep-ex/0608035]

1464±65 signal events

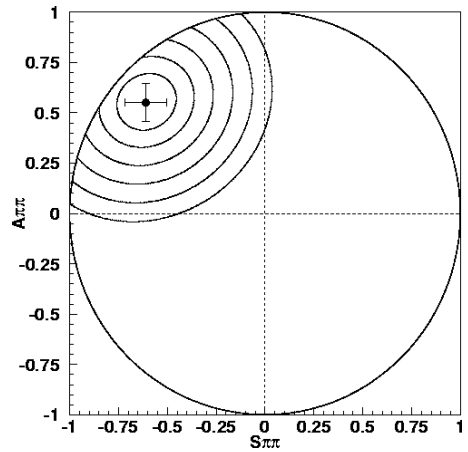
$$A_{\pi\pi} = +0.55 \pm 0.08 \pm 0.05$$
$$S_{\pi\pi} = -0.61 \pm 0.10 \pm 0.04$$

first error: stat., second: syst.

Large Direct CP violation (5.5σ)

Large mixing-induced CPV (5.6σ)

confidence level contour

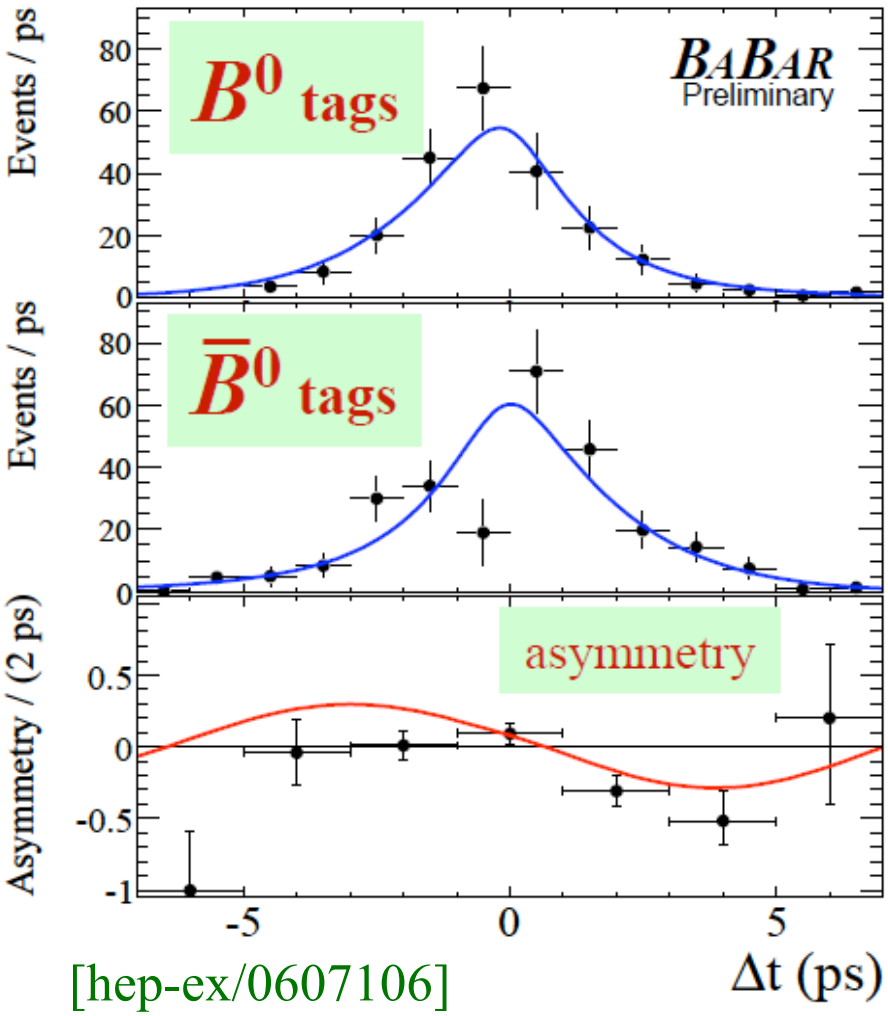


BaBar 2006: t*CPV* in $B^0 \to \pi^+\pi^-$

Preliminary

$N_{\pi^+\pi^-} = 675 \pm 42$

347M $B\bar{B}$



[hep-ex/0607106]

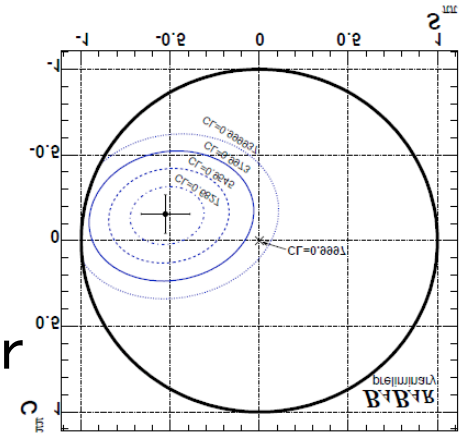
$$A_{\pi\pi} = +0.16 \pm 0.11 \pm 0.03$$

$$S_{\pi\pi} = -0.53 \pm 0.14 \pm 0.02$$

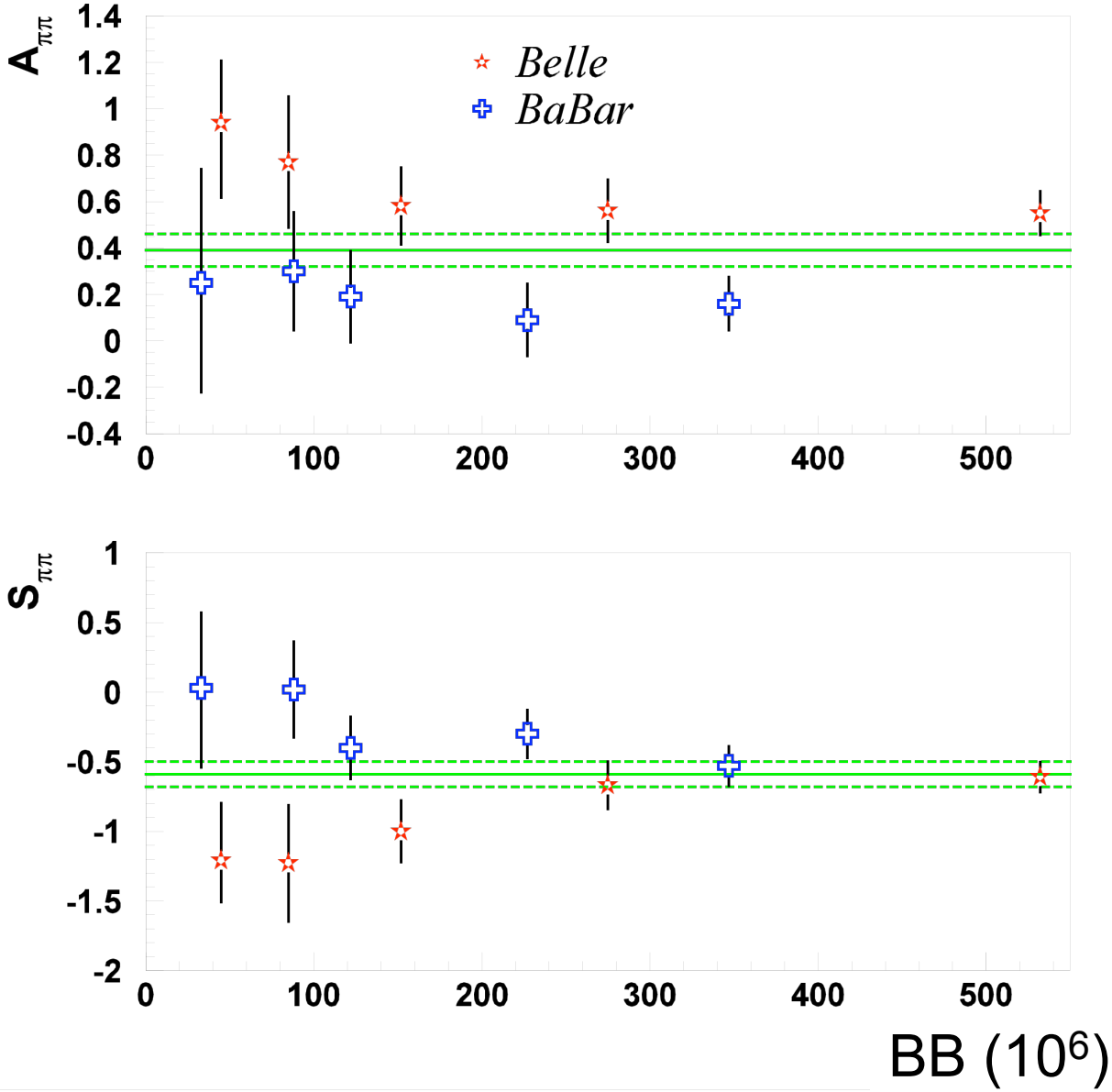
Evidence for CP violation (3.6σ)

Direct CPV not yet observed

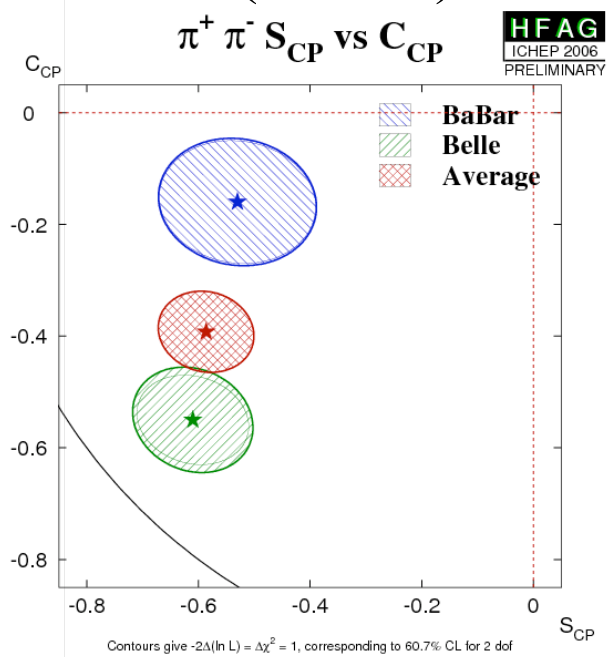
confidence level contour



History of $B^0 \to \pi^+\pi^-$ decay



$(C = -\mathcal{A})$



2.3σ diff. btw. Belle and BaBar

BaBar2006: t*CP*V in B → $\rho^+\rho^-$

$\mathcal{B}(B^0 \to \rho^+\rho^-) = (23.5 \pm 2.2 \pm 4.1) \times 10^{-6}$

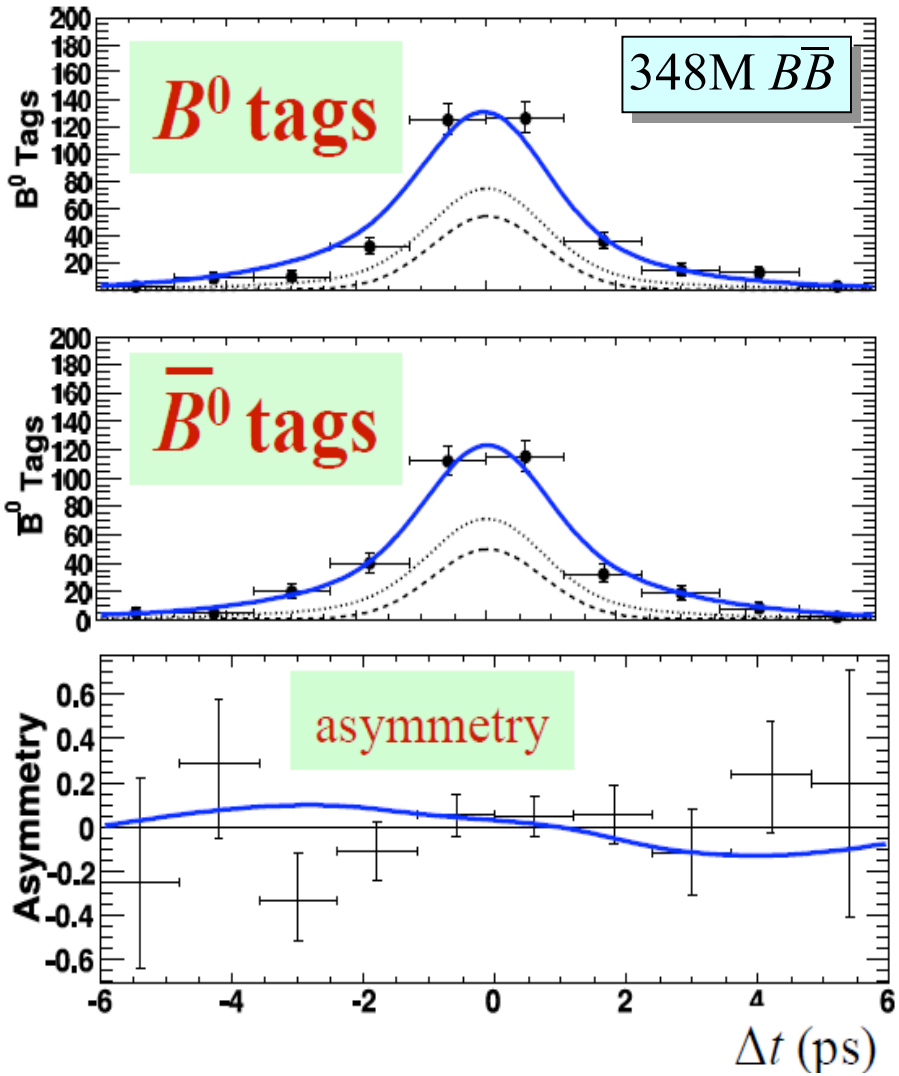
$f_L(B^0 \to \rho^+\rho^-) = 0.977 \pm 0.024^{+0.015}_{-0.013}$

$S_{\text{long}} = -0.19 \pm 0.21^{+0.05}_{-0.07}$

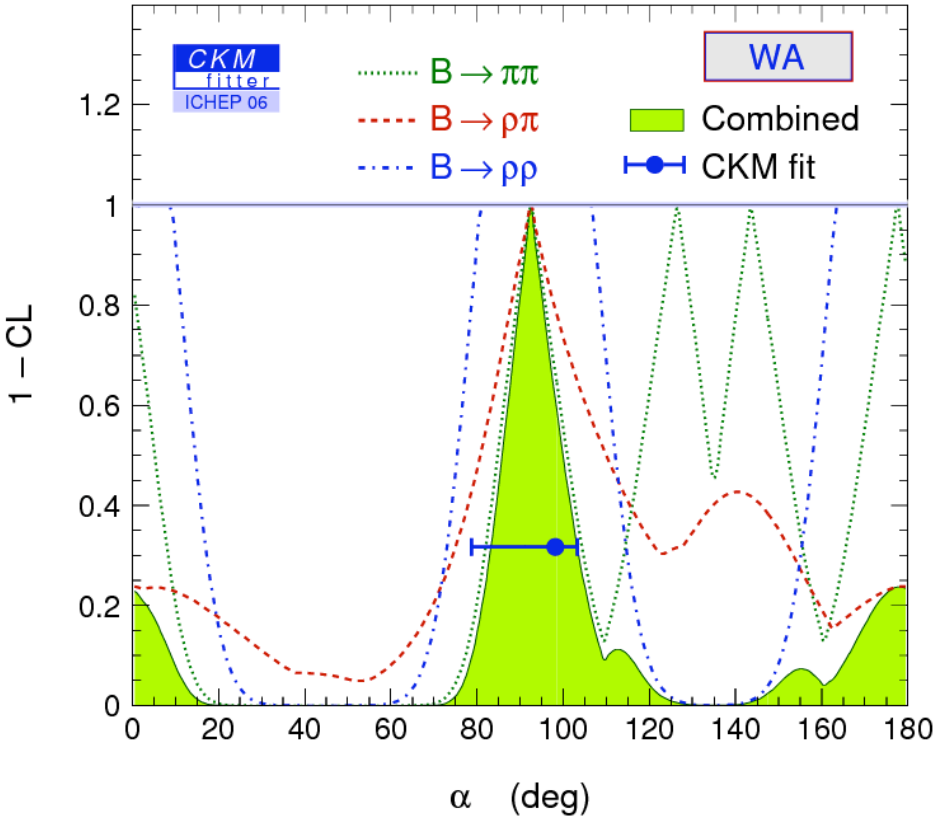
$C_{\text{long}} = -0.07 \pm 0.15 \pm 0.06$

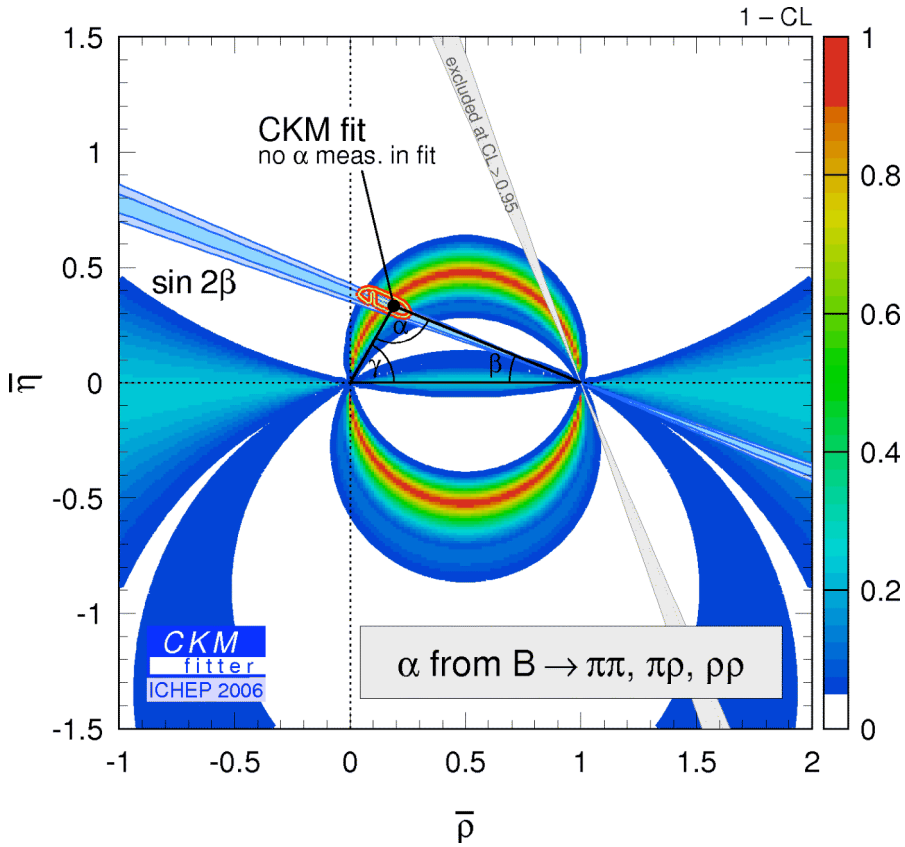
[hep-ex/0607098]

long=longitudinal component (CP+)



ICHEP2006: BaBar($\pi\pi/\rho\pi/\rho\rho$) + Belle($\pi\pi/\rho\rho$)



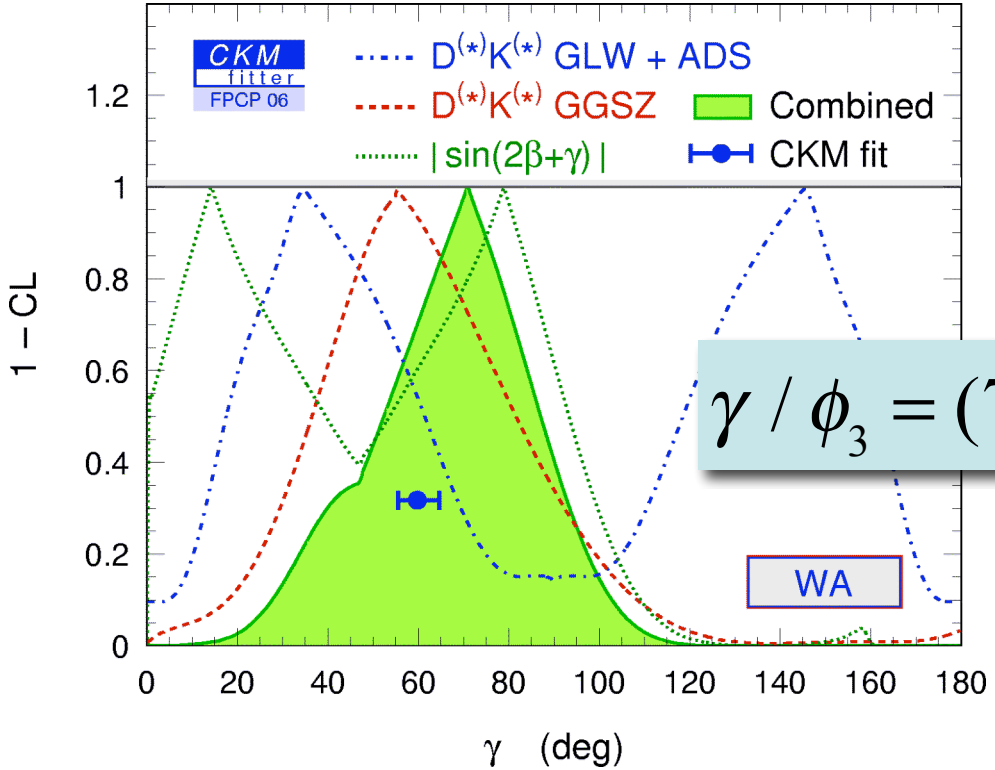


$$\alpha / \phi_2 = (93^{+11}_{-9})^\circ$$

consistent with a global fit w/o α/ϕ_2

$\alpha_{\text{Global Fit}} = [\,98\ ^{+5}_{-19}\,]^\circ$

γ/ϕ_3 = phase of V_{ub}



Dalitz analysis

$$\gamma / \phi_3 = (78 \pm 30)^\circ \quad @\text{ICHEP06}$$

$$\alpha \equiv 180^\circ - \beta(21.2 \pm 1.0)^\circ - \gamma(78 \pm 30)^\circ$$

$$= (80.8 \pm 30)^\circ$$

$$\alpha = (93^{+11}_{-9})^\circ$$

UT sides: V_{cb} , V_{ub} , V_{td}

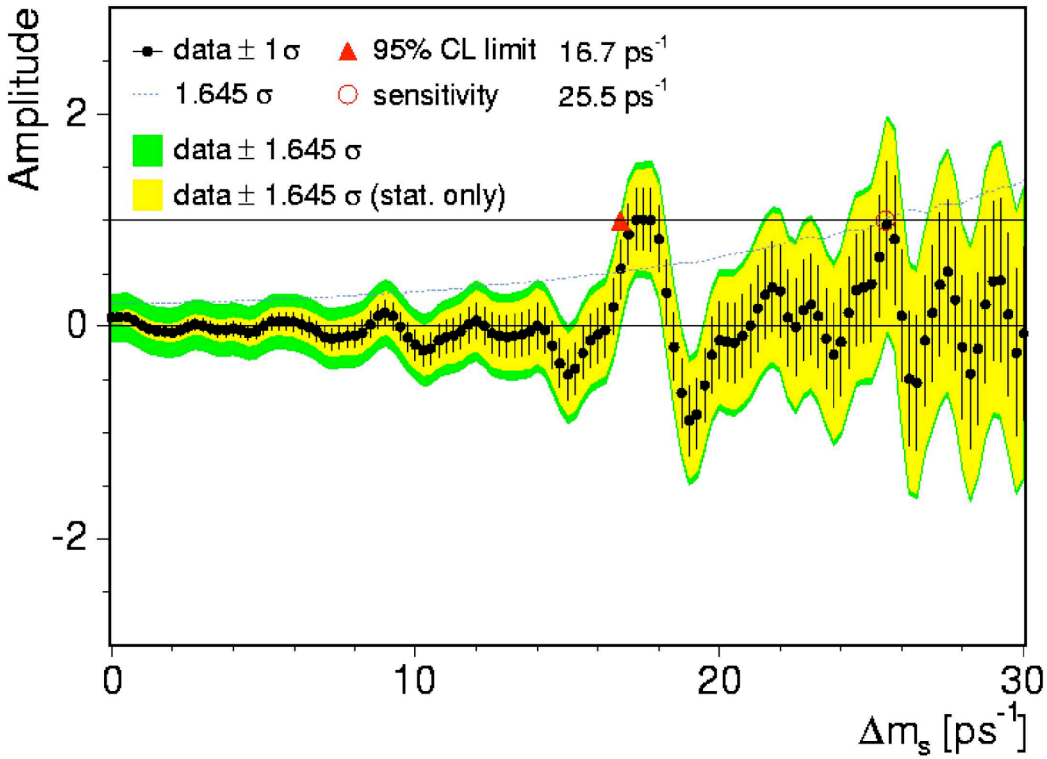
$$\left|V_{cb}\right| = \left(42.0 \pm 0.23_{\text{exp}} \pm 0.69_{\text{the}}\right) \times 10^{-3}$$

1.7% precision

$$\left|V_{ub}\right| = \left(4.49 \pm 0.19_{\text{exp}} \pm 0.27_{\text{the}}\right) \times 10^{-3}$$

7.4% precision

B_s Mixing: CDF 1fb^{-1} Result



$$\Delta m_s = 17.31^{+0.33}_{-0.18}(\text{stat}) \pm 0.07(\text{syst})\ \text{ps}^{-1}$$

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

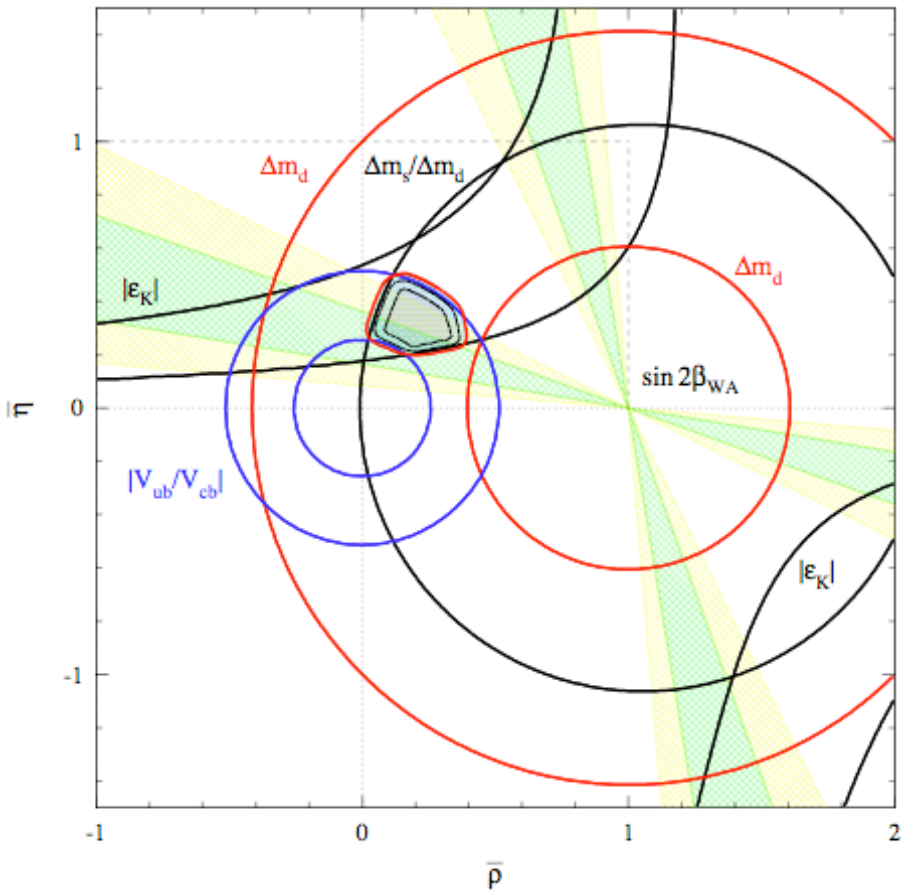
$$= 0.208\ ^{+0.001}_{-0.002}\ (\text{stat})\ ^{+0.008}_{-0.007}(\text{theor})$$

4%precision

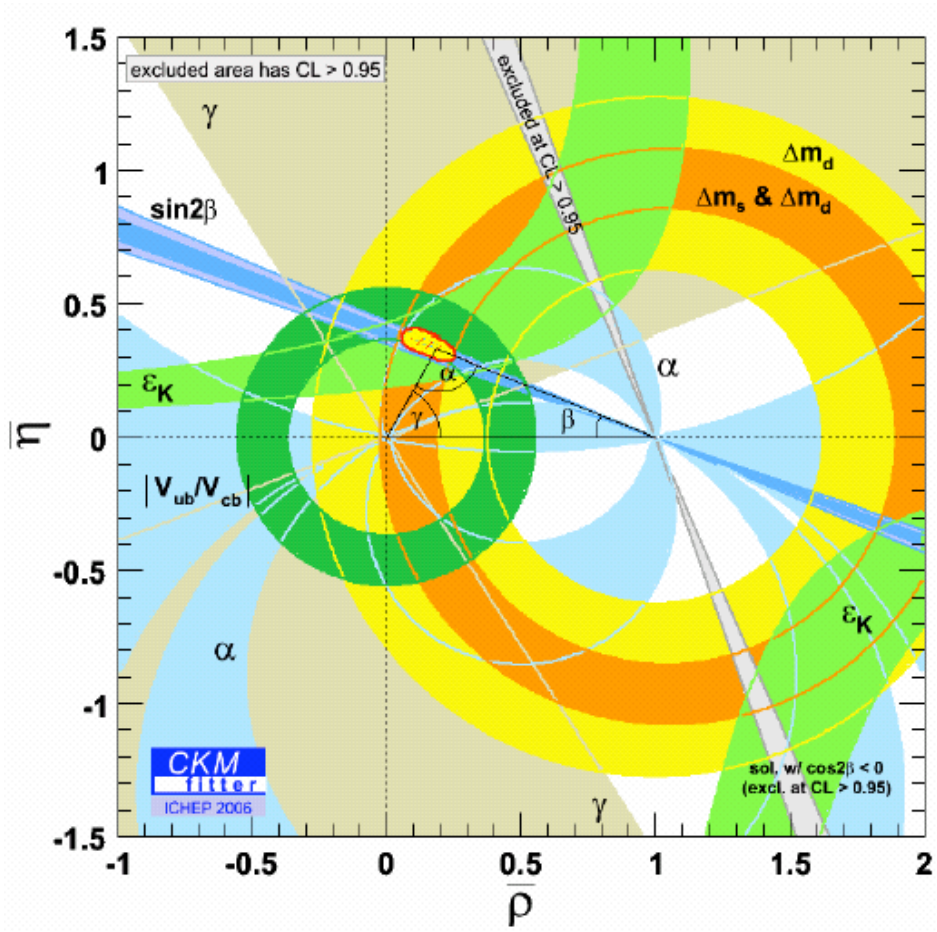
$$\Delta m_d = 0.507 \pm 0.004\ \text{ps}^{-1}$$

0.8% precision
dominated by Belle/BaBar

May, 2001 (before Belle/BaBar)



Aug, 2006 (Belle/BaBar/CDF/D0)

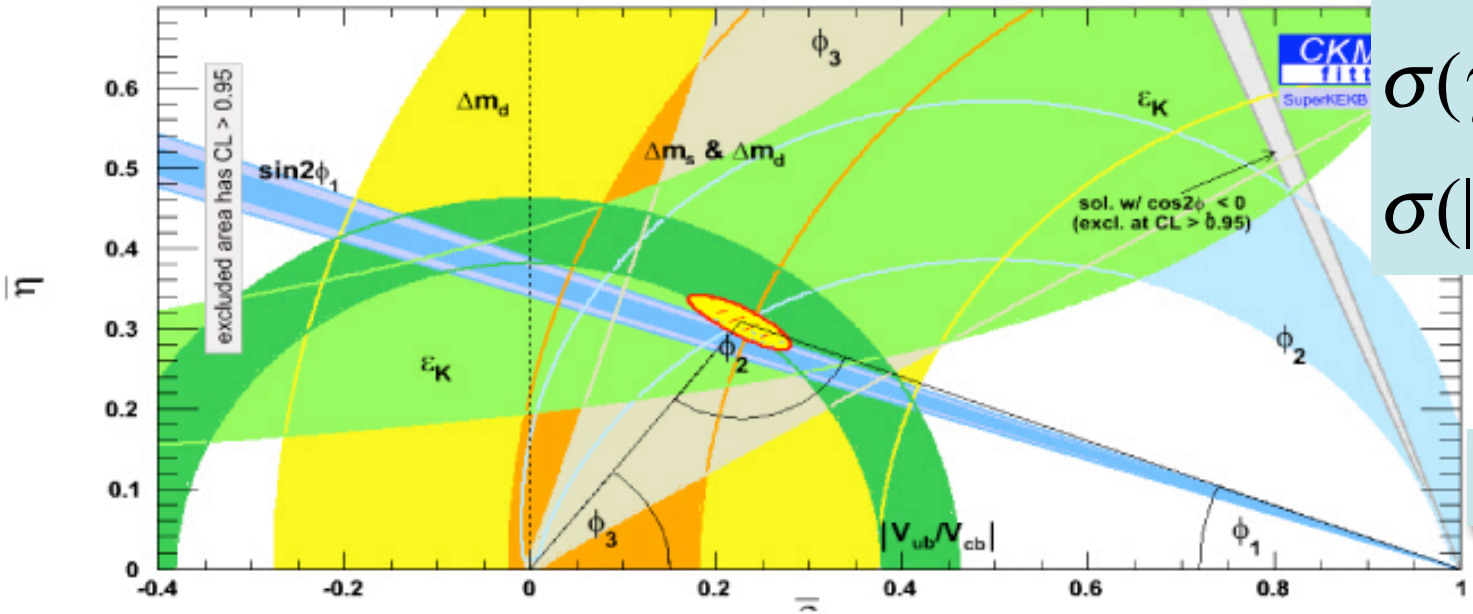


progress

$$\sigma(\alpha / \phi_2) \sim 5^\circ$$

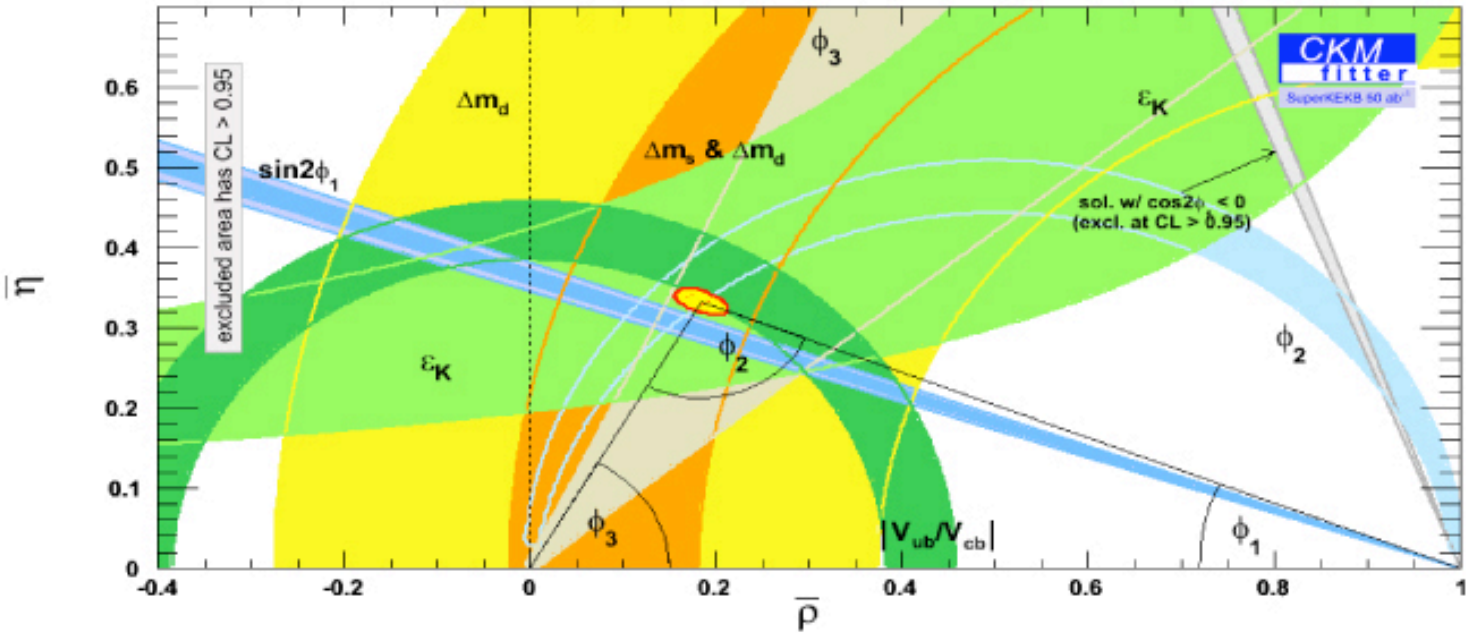
$$\sigma(\gamma / \phi_3) \sim 10^\circ$$

$$\sigma(|V_{ub}|) \sim 5\% \ ?$$



5/ab

Future



50/ab

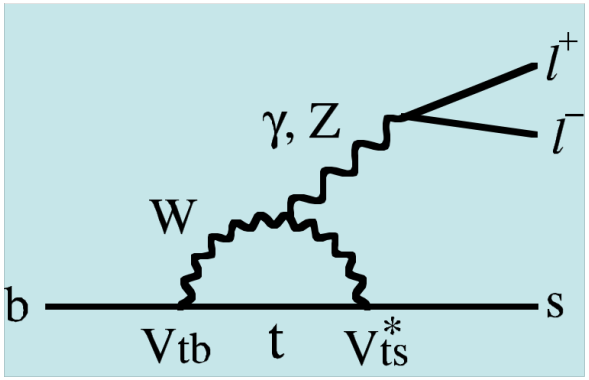
Far Future ?

Rare B decays

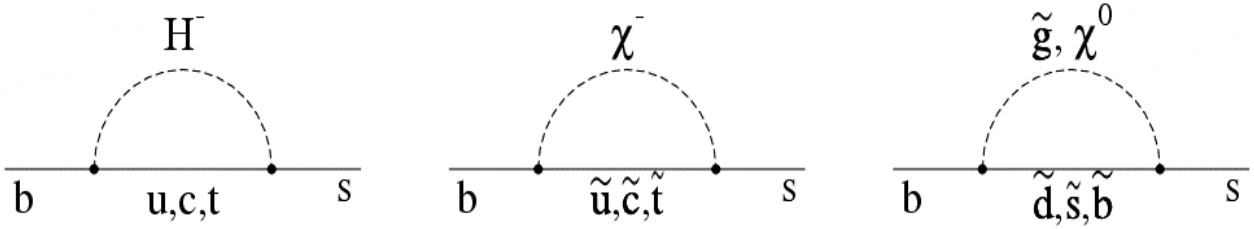
Probe new physics

Constrain models

Flavor Changing Neutral Current B Decays



Suppressed in SM: sensitive to new particles in loops



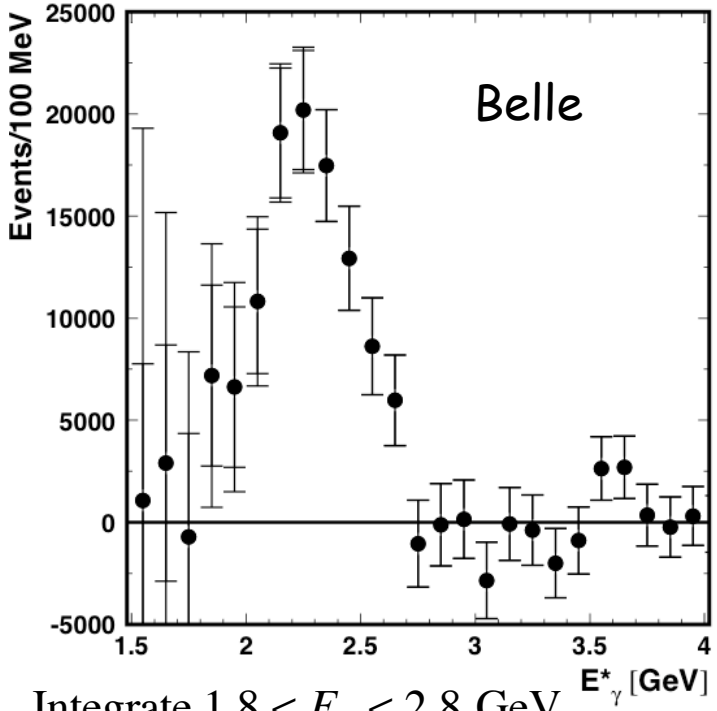
Example : b to s γ

Belle

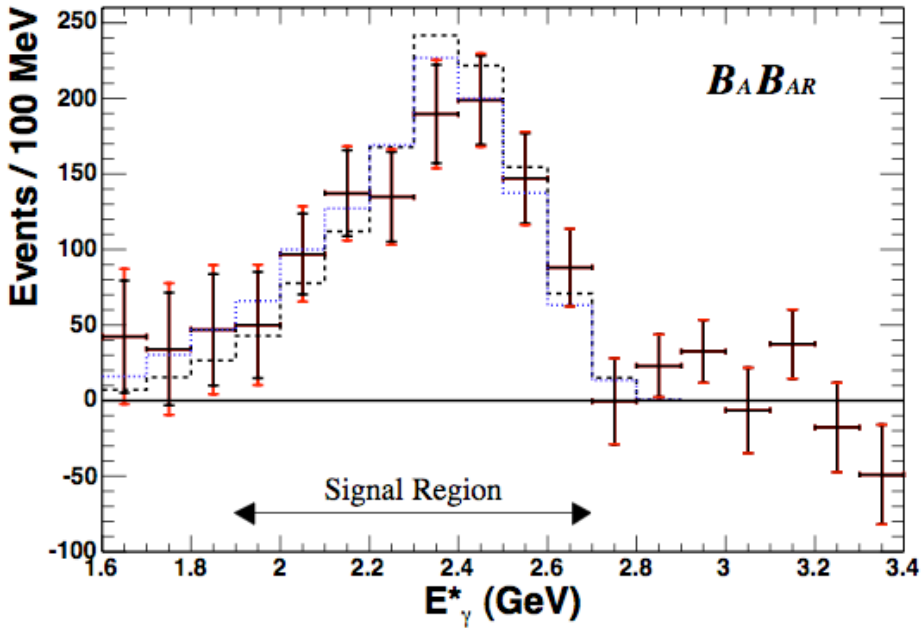
140fb^{-1} on resonance (152M BBar)
15 fb^{-1} off resonance
efficiency corrected

BaBar

81.5fb^{-1} on resonance (88.5M BBar)
9.6 fb^{-1} off resonance
efficiency uncorrected



Integrate $1.8 < E_\gamma < 2.8$ GeV

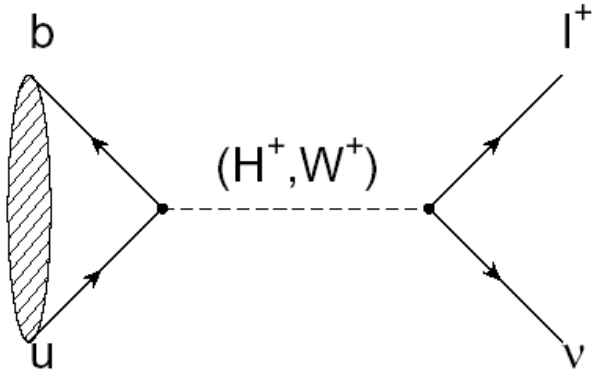


Integrate $1.9 < E_\gamma < 2.7$ GeV

$$Br(B \to X_s\gamma) = (3.55 \pm 0.24^{+0.09}_{-0.10} \pm 0.03) \times 10^{-4} \text{ (HFAG average)}$$
$$= (3.61^{+0.37}_{-0.49}) \times 10^{-4} \text{ (NLO calculation)}$$

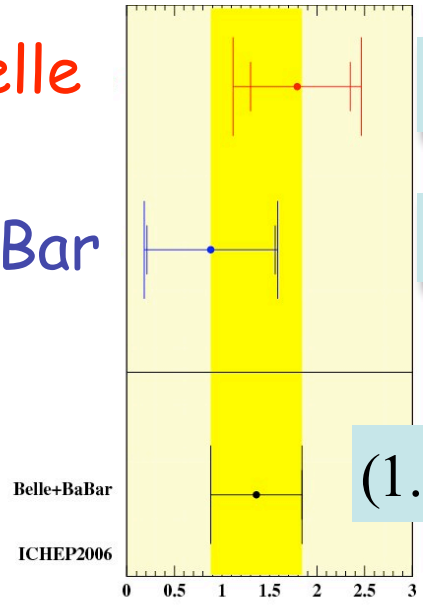
Not much room for new physics here.

$B^{\pm} \to \tau^{\pm}\nu$



Belle

BaBar



$BF(B^+ \to \tau^+\nu_\tau)$

$$Br(B^{\pm} \to \tau^{\pm}\nu) = (1.79^{+0.56+0.39}_{-0.49-0.46}) \times 10^{-4}$$

3.5σ evidence

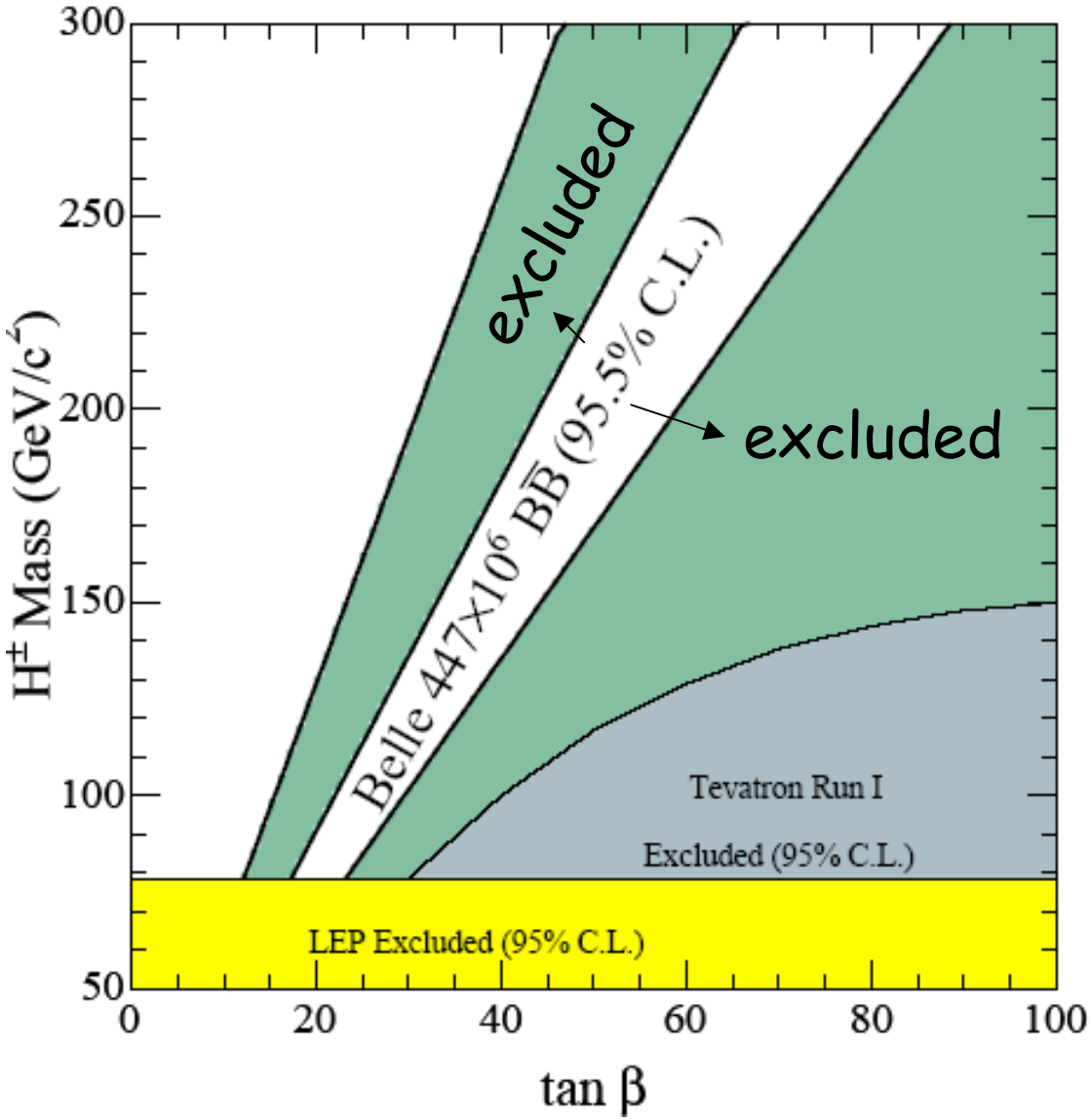
$$Br(B^{\pm} \to \tau^{\pm}\nu) = (0.88^{+0.68}_{-0.67} \pm 0.11) \times 10^{-4}$$

$$(1.36 \pm 0.48) \times 10^{-4}$$

SM prediction

$$(1.59 \pm 0.40) \times 10^{-4}$$

Constraints on the charged Higgs mass



Assume f_B and $|V_{ub}|$ are known, take the ratio to the SM BF.

$$r_H = (1 - \frac{m_B^2}{m_H^2} \tan^2 \beta)^2$$

$r_H = 1.13 \pm 0.51$

(from Belle measurement)

Impact of B physics

- Flavor structure of quark sector is now (almost) completely known :

  masses, mixing angles and a phase

  (which is NOT the case for neutrino sector.)

- Foundation for the Standard Model

  and upcoming discoveries (at LHC).

- CP asymmetries and rare decays

  probe new physics/ constrain models.

and, therefore

Particle Data Book will continue to

grow.

Perhaps the next edition better be printed on lighter papers...