Séminaire à l'IPHC

Strasbourg, le 12 juin 2009

Résultats récents des usines à beauté BABAR et BELLE

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OUTLINE

Introduction

The beauty of the Unitarity Triangle

Measurements of angles

β, α, γ

Measurements of sides

V_{ub}, V_{cb}, V_{td}/V_{ts} from $b \to d\gamma / b \to s\gamma$

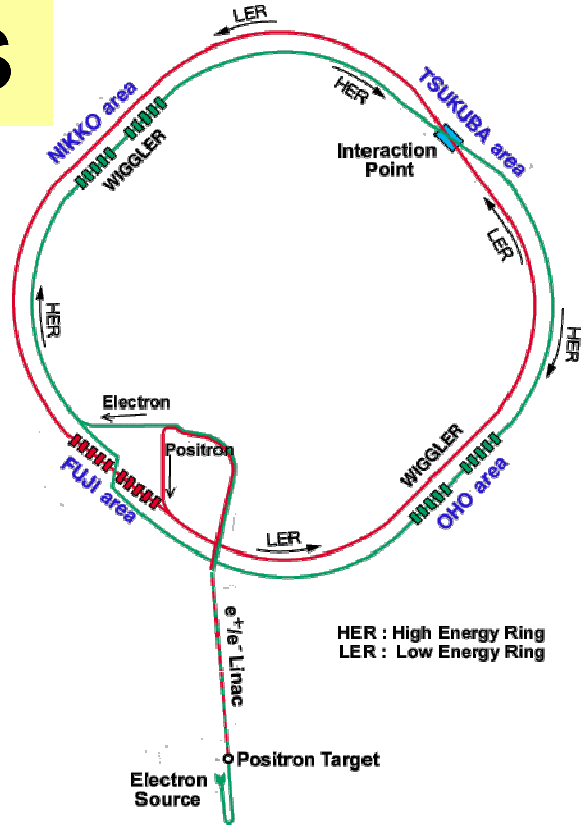
Search for new physics

$B \to \tau \nu$ decay

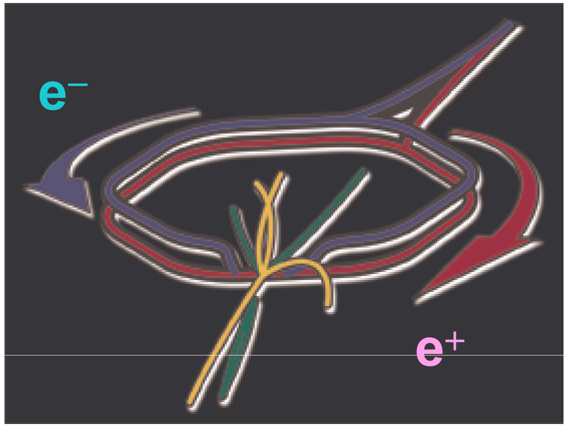
Radiative and electroweak penguins

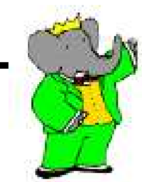
Conclusion & Outlook

The B factories



- $E_{CM}=m\Upsilon(4S)$ =10.58 GeV
- Hauts courants : 1-3 ampères
- Deux anneaux ~ 3km de circonférence



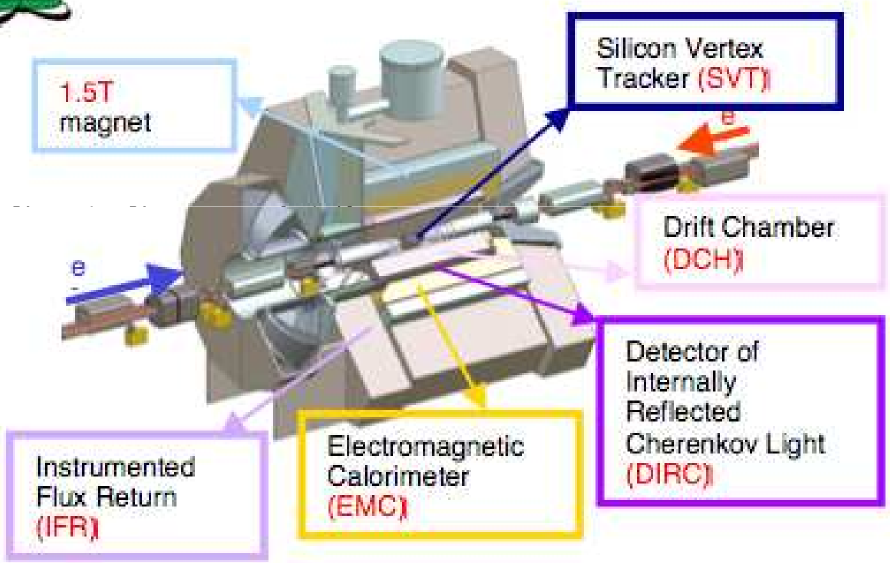


	BABAR	BELLE
Collisionneur asymétrique	e^- (9 GeV) e^+ (3,1 GeV)	e^- (8 GeV) e^+ (3,5 GeV)
Boost $\Upsilon(4S)$: $\beta\gamma$	0.56	0.43
Nb de paires B^+B^- ou $B^0_d \overline{B^0}_d$	465 millions De 1999 à 2007	>750 millions De 1999 à 2009

The B factories

> 600 papers

BaBar experiment,
PEP-II, SLAC

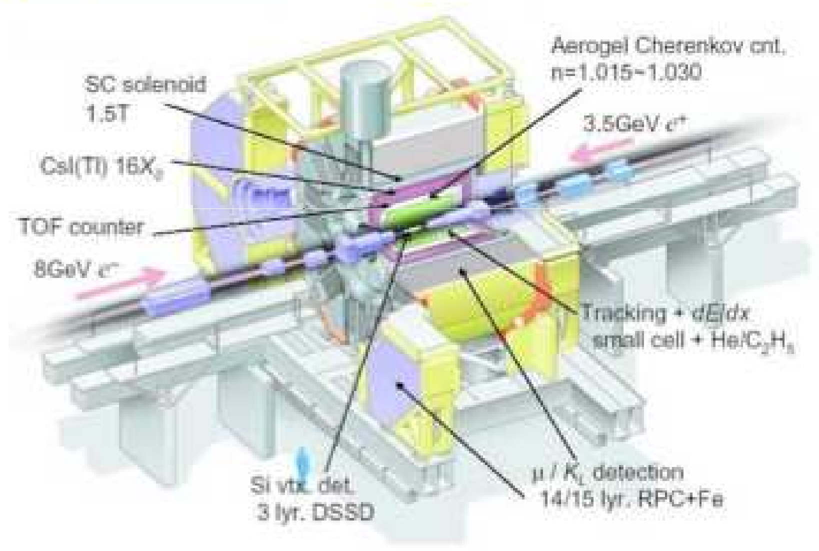


3.1 GeV e^+ & 9 GeV e^- beams

$L = 1.2 \times 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

$\int L\,dt = 530\ \mathrm{fb}^{-1}$ @ $\Upsilon(4S)$+off (~10%)

Belle experiment,
KEKB, KEK, Japan



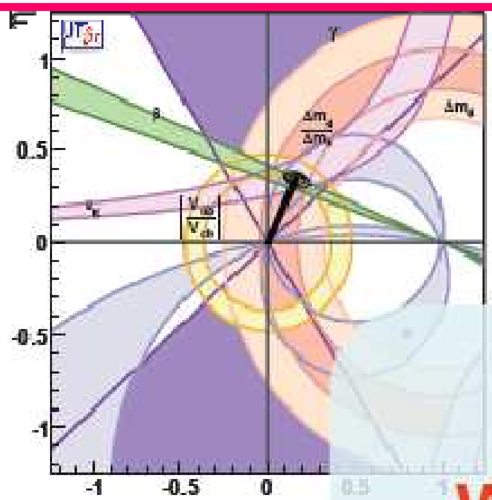
3.5 GeV e^+ & 8 GeV e^- beams

$L = 1.7 \times 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ (world record)

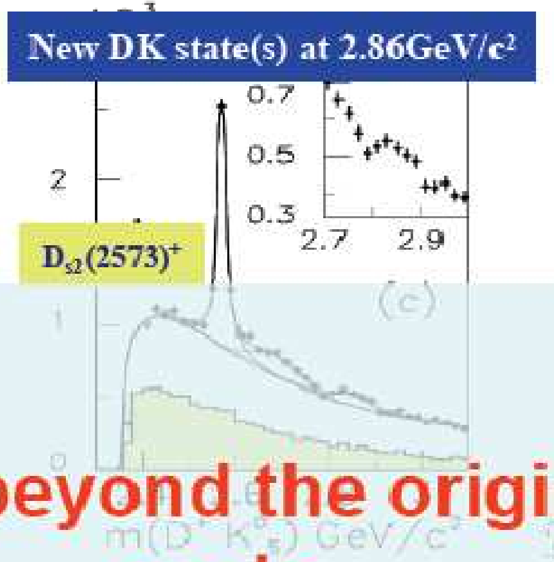
$\int$ Ldt~720 fb^{-1}@Υ(4S)+180 fb^{-1} (Off, Υ(ns))

More than 1 billion of $B\bar{B}$ pairs accumulated at B factories

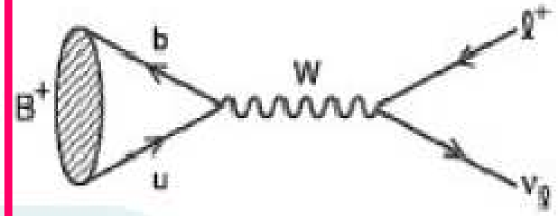
Unitarity Triangle precision measurements



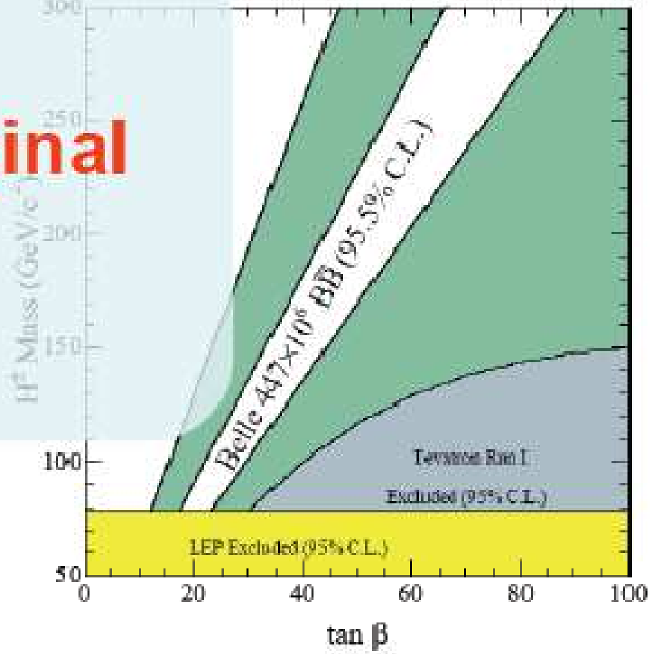
Spectroscopy of new, unexpected states



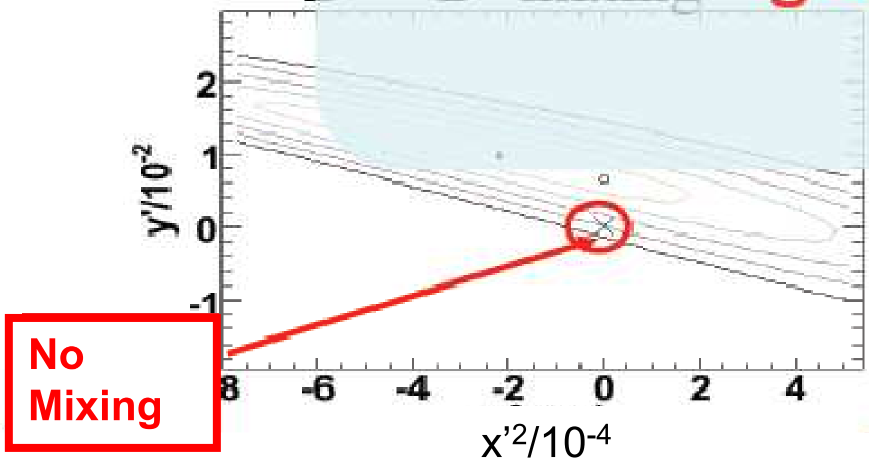
B→τν setting limits on MSSM parameters



Well beyond the original goals



$D^0 - \overline{D}^0$ mixing



Recent Discovery of the bottonium ground state η_b by BABAR
PRL 101, 071801 (2008)

MANY AND VARIOUS RESULTS!

CP violation

- In Standard Model: due to complex CKM unitary matrix

- Wolfenstein parameterization:

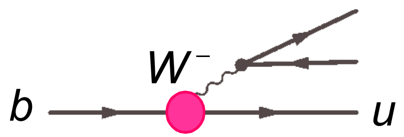
$$V_{CKM} = \begin{pmatrix} V_{ud} V_{us} V_{ub} \\ V_{cd} V_{cs} V_{cb} \\ V_{td} V_{ts} V_{tb} \end{pmatrix} \approx \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

- with $\lambda \cong 0.22$, $A \cong 0.83$
- CP violation if $\eta \neq 0$.

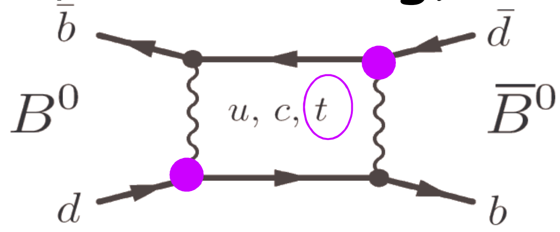
The unitarity triangle

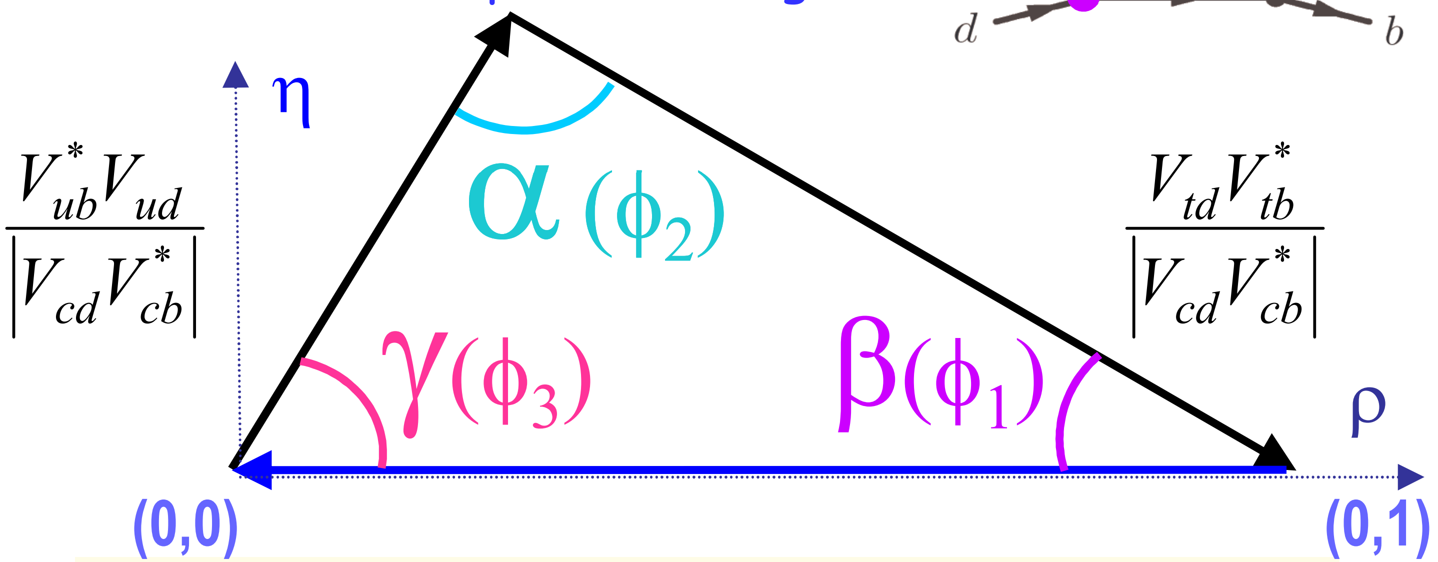
$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$

γ = phase of V_{ub}
(b→u transition)



β = phase of V_{td}
(B^0-$\overline{B}^0$ mixing)



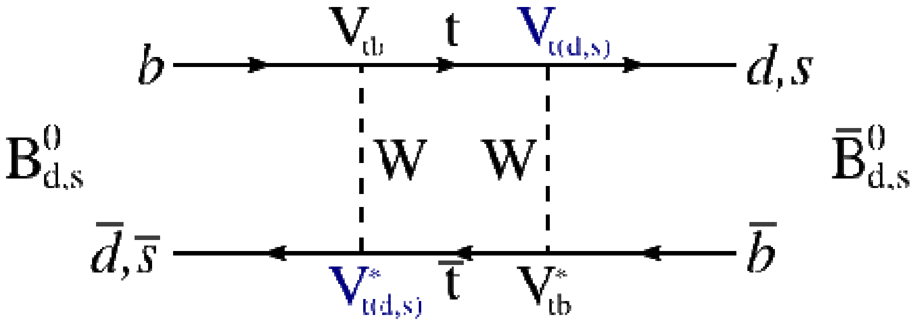


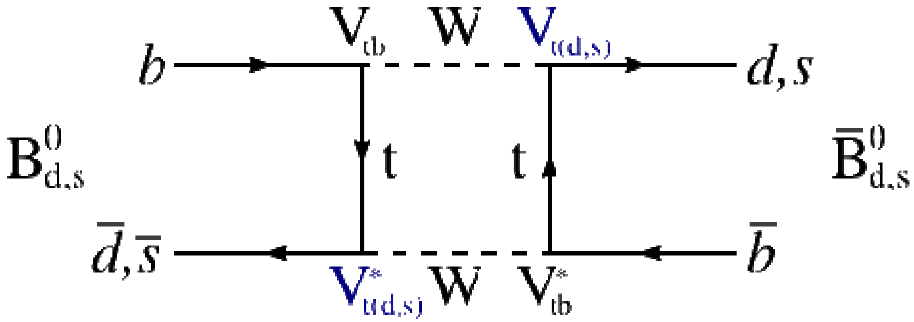
$\alpha = \pi - \beta - \gamma \Rightarrow$ process involving both B^0 mixing and b→u transition

OVERCONSTRAIN (ρ, η) BY MEASURING 3 ANGLES AND TWO SIDES

Oscillations B0-$\overline{\text{B}}$0

Petit rappel





$$Prob_{B^0 \to \overline{B^0}} = \frac{1 - \cos(\Delta m t)}{2} \times e^{-\frac{t}{\tau}}, \quad Prob_{B^0 \to B^0} = \frac{1 + \cos(\Delta m t)}{2} \times e^{-\frac{t}{\tau}}$$

Féquences d'oscillations = $\Delta m_{d,s} / (2\pi)$ ($\neq$ masses des états propres de masse)
$\propto$ amplitudes des diagrammes en boite

Temps de vie τ du B ~ 1,5 ps : $\Delta m_d \sim 0.5\ ps^{-1}$, $\Delta m_s \sim 18\ ps^{-1}$

Contrainte sur le triangle d'unitarité:

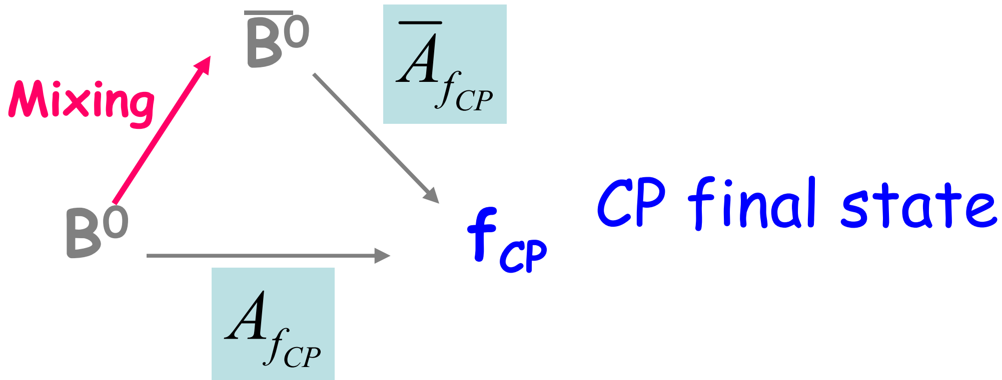
$$\frac{\Delta m_s}{\Delta m_d} = \frac{m_{B_s}}{m_{B_d}} \xi^2 \left| \frac{V_{ts}}{V_{td}} \right|^2$$

QCD sur réseaux

$$\xi = \frac{B_{B_s}\sqrt{f_{B_s}}}{B_{B_d}\sqrt{f_{B_d}}} = 1.210^{+0.047}_{-0.035}$$

Fréquences d'oscillations compatibles avec le modèle standard
Fortes contraintes pour les modèles au-delà

CP violation in the interference between mixing and decay



Time-dependent CP asymmetry

$$A_{f_{CP}}(\Delta t) = \frac{\Gamma(\overline{B}^0 \to f_{CP}) - \Gamma(B^0 \to f_{CP})}{\Gamma(\overline{B}^0 \to f_{CP}) + \Gamma(B^0 \to f_{CP})}$$

$$= S_{f_{CP}} \sin(\Delta m_d \Delta t) - C_{f_{CP}} \cos(\Delta m_d \Delta t)$$

$$\lambda_{f_{CP}} \approx e^{-2i\beta} \times \frac{\overline{A}_{f_{CP}}}{A_{f_{CP}}}$$

Mixing

$S \neq 0$: Indirect *CP* violation

$$S_{f_{CP}} = \frac{2\,\Im(\lambda_{f_{CP}})}{1+|\lambda|^2_{f_{CP}}}$$

$C \neq 0$: Direct *CP* violation

$$C_{f_{CP}} = \frac{1-|\lambda|^2_{f_{CP}}}{1+|\lambda|^2_{f_{CP}}}$$

Time-dependent CP asymmetry

$$C_{f_{CP}} = \frac{1-|\lambda|^2_{f_{CP}}}{1+|\lambda|^2_{f_{CP}}} \qquad \lambda_{f_{CP}} \approx e^{-i2\beta} \times \frac{\bar{A}_{f_{CP}}}{A_{f_{CP}}} \qquad S_{f_{CP}} = \frac{2\,\Im(\lambda_{f_{CP}})}{1+|\lambda|^2_{f_{CP}}}$$

If only one diagram involved in $B^0 \to f_{CP}$ decay, no direct CP violation:

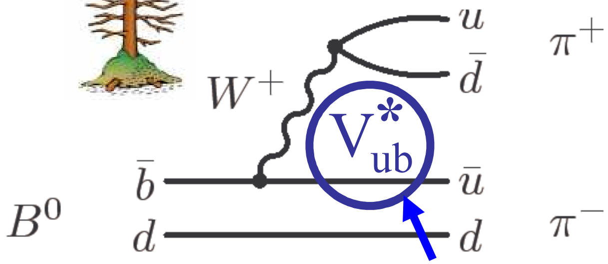
$$|A_{f_{CP}}| = |\bar{A}_{f_{CP}}| \Rightarrow C_{f_{CP}} = 0 \qquad \lambda_{f_{CP}} \approx e^{-i2\beta} \times e^{-i2\phi_{CKM}}, \quad S_{f_{CP}} = -\sin\left(2\times[\beta+\phi_{CKM}]\right)$$

ϕ_{CKM} is the CKM phase in $A_{f_{CP}}$

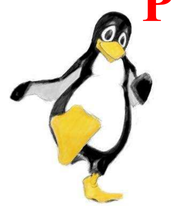
- 0 (ex: $b \to c$): $\sin 2\beta$ measurement
- γ (ex: $b \to u$): $\sin 2\alpha$ measurement

For processes involving tree $b \to u$ tree, penguin diagrams are also involved

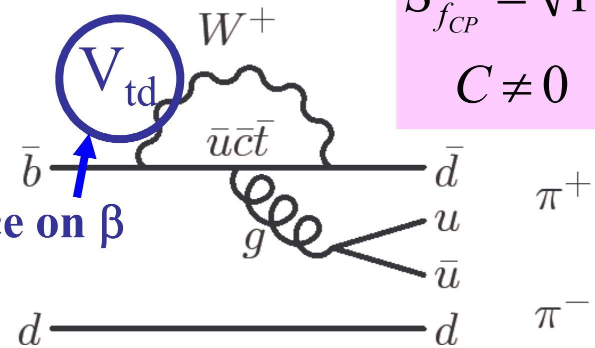
Tree Diagram



Dependence on γ



Penguin Diagram

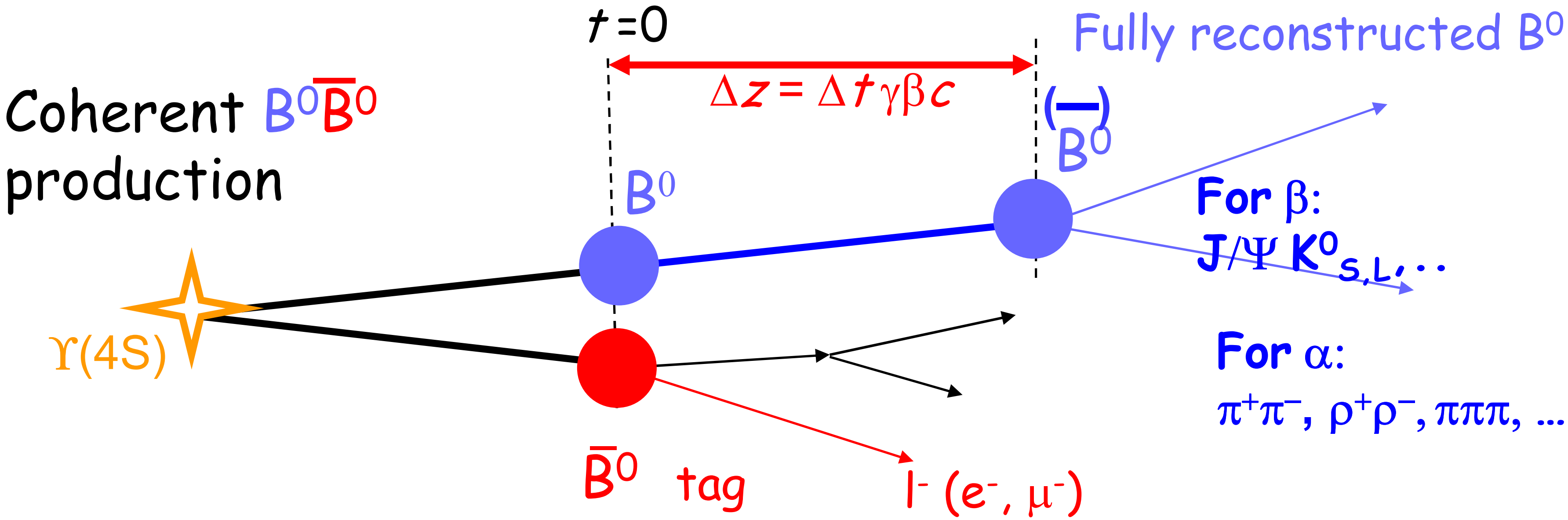


Dependence on β

$$S_{f_{CP}} = \sqrt{1-C^2}\,\sin(2\alpha_{eff})$$

$$C \neq 0$$

CP Asymmetry Measurement



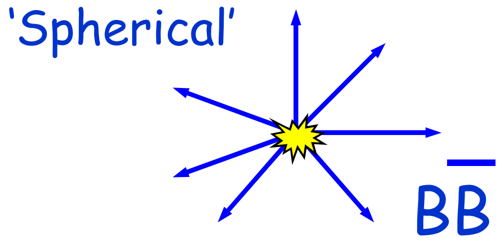
- Exclusive B^0 meson reconstruction.
- Time measurement: $\Delta z \approx 250\ \mu m$, $\sigma \Delta z \approx 170\ \mu m$.

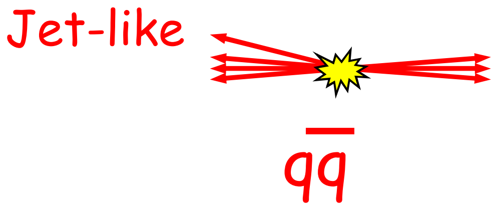
Signal Selection

- Hadron ID $\Rightarrow$ separation π/K

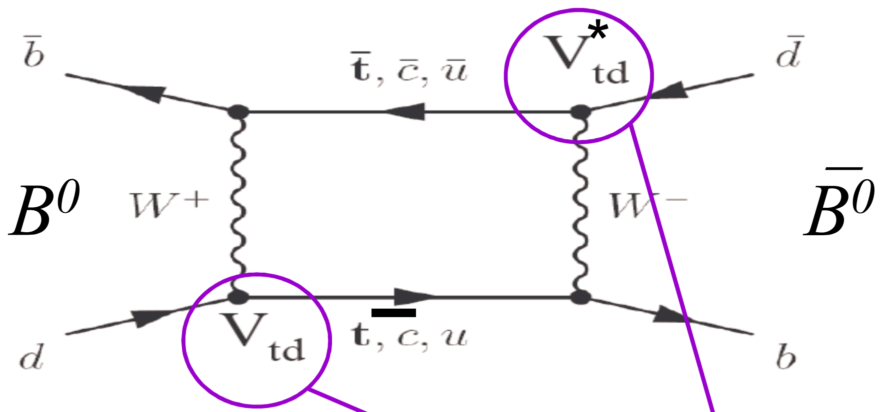
- Kinematical identification with
  - Beam energy substituted mass $m_{ES} = \sqrt{E_{beam}^{*2} - p_B^{*2}}$
  - Energy difference $\Delta E = E_B^* - E_{beam}^*$

- Event-shape variables combined in a neural network or Fisher discriminant to suppress jet-like continuum events

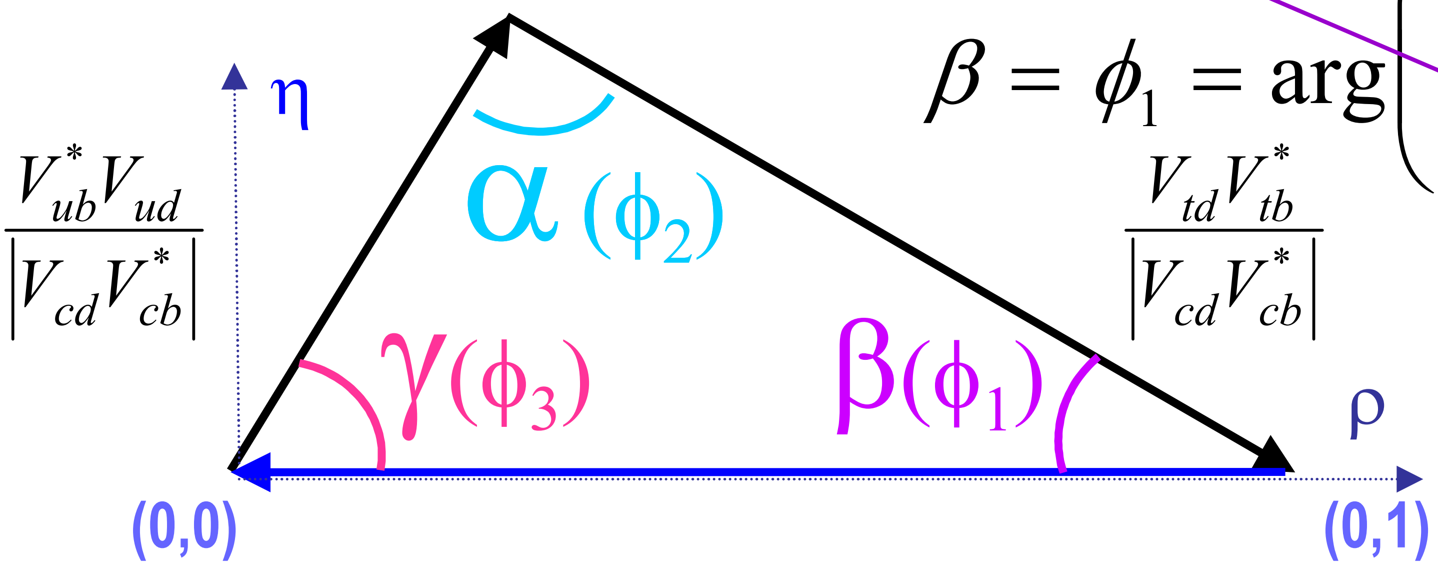




Measurements of β



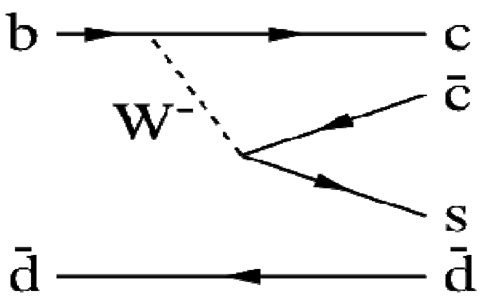
$$\beta = \phi_1 = \arg\left(-\frac{V_{cd}V^*_{cb}}{V_{td}V^*_{tb}}\right)$$

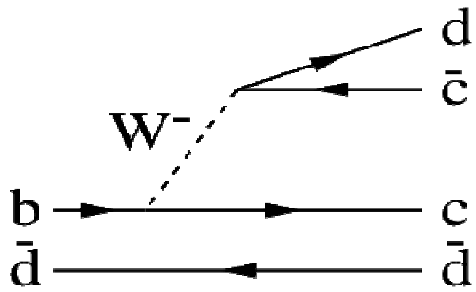


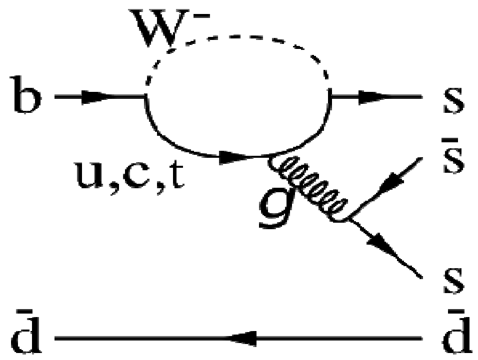
Sin 2β

Golden Mode Reference

New physics tests







$J/\psi K_S^0, \psi(2S)K_S^0, \chi_{c1}K_S^0,$
$\eta_c K_S^0, J/\psi K_L^0,$
$J/\psi K^{*0}(K^{*0} \to K_S^0\pi^0)$

$D^{*+}D^-, D^+D^-$
$J/\psi\pi^0, D^{*+}D^{*-}$

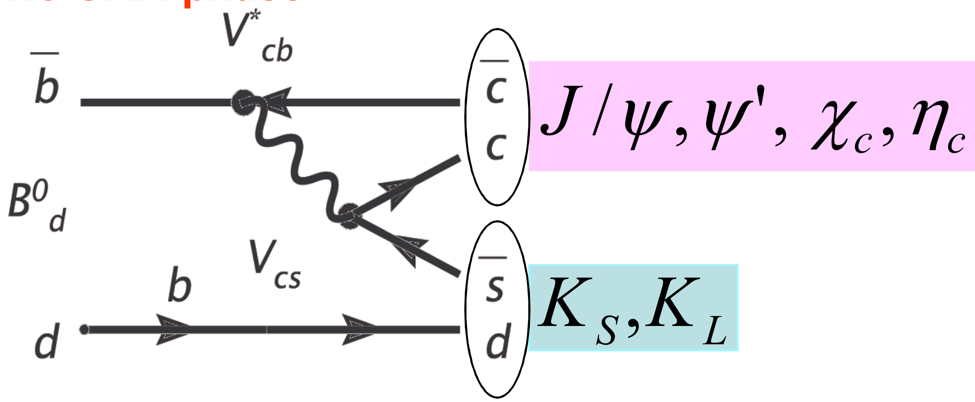
$\phi K^0, K^+K^-K_S^0,$
$K_S^0K_S^0K_S^0, \eta' K^0, K_S^0\pi^0,$
$\omega K_S^0, f_0(980)K_S^0$

Increasing sensitivity to New Physics →

← Increasing diagram amplitude

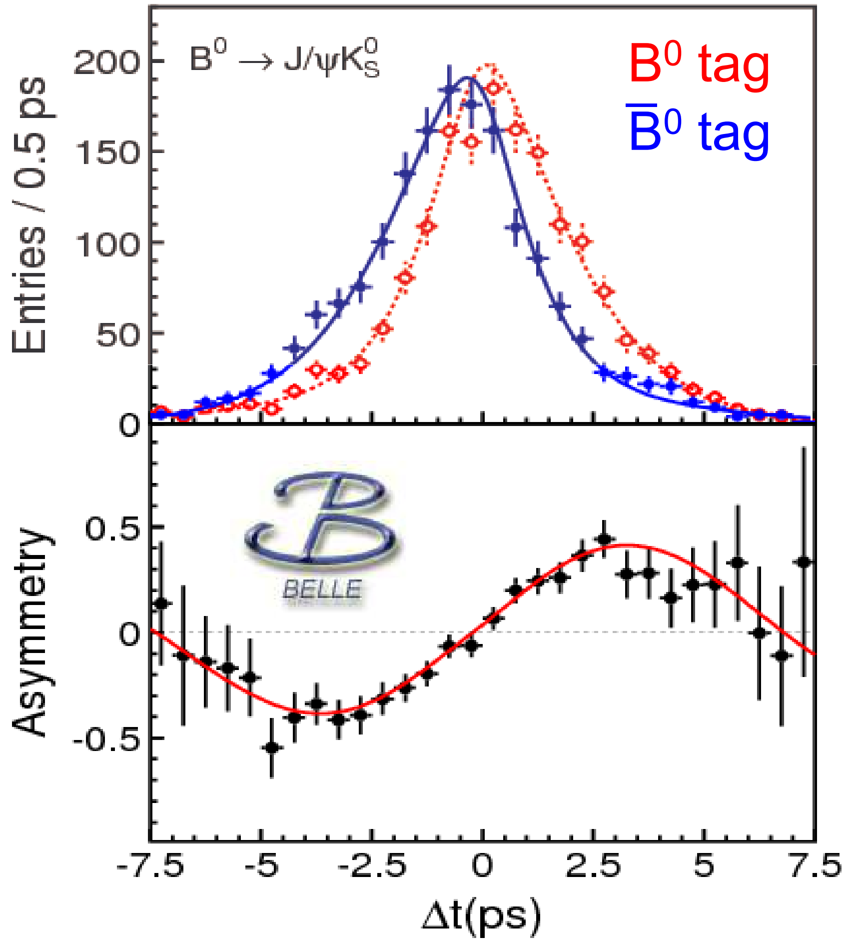
$B^0 \to$ charmonium K^0: $b \to c\bar{c}s$ (golden)

No CKM phase



$$\lambda_{golden} = e^{-i\eta_f 2\beta}$$

CP eigenvalue=-1(K_S),+1(K_L)

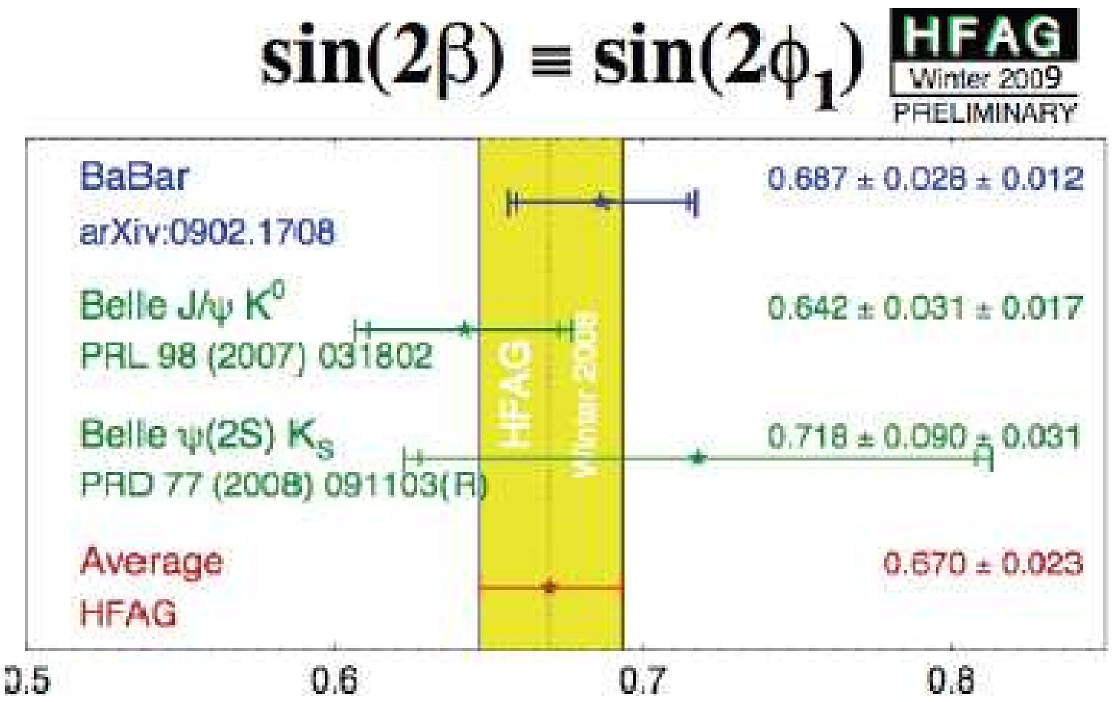


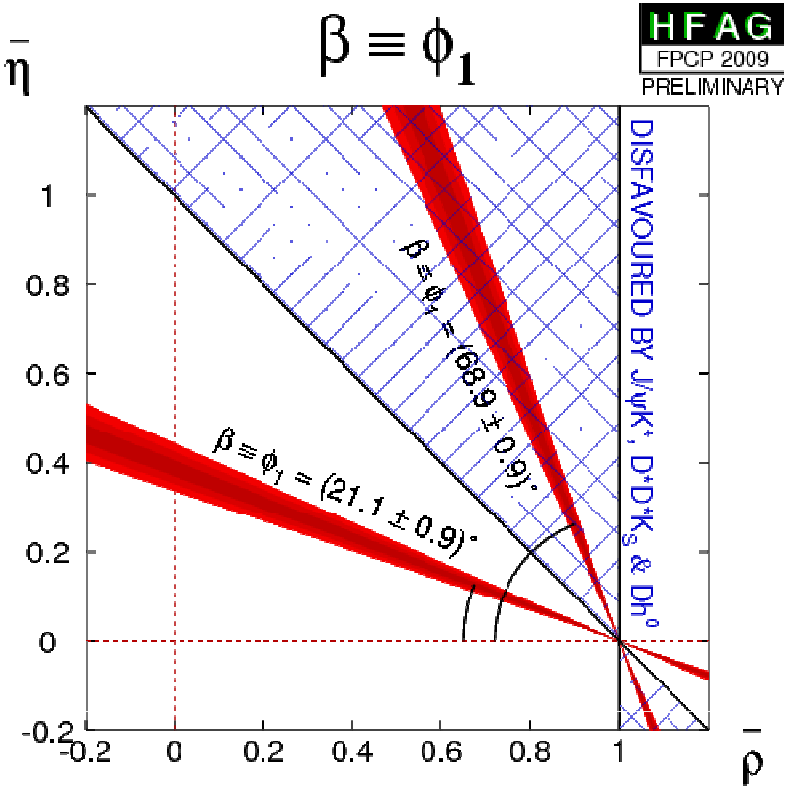
BF $\approx 10^{-3}$ (color suppressed)
Other diagrams negligible

SM expectation: $S = -\eta_f \sin 2\beta$, $C \approx 0$

Accurate measurement of β!

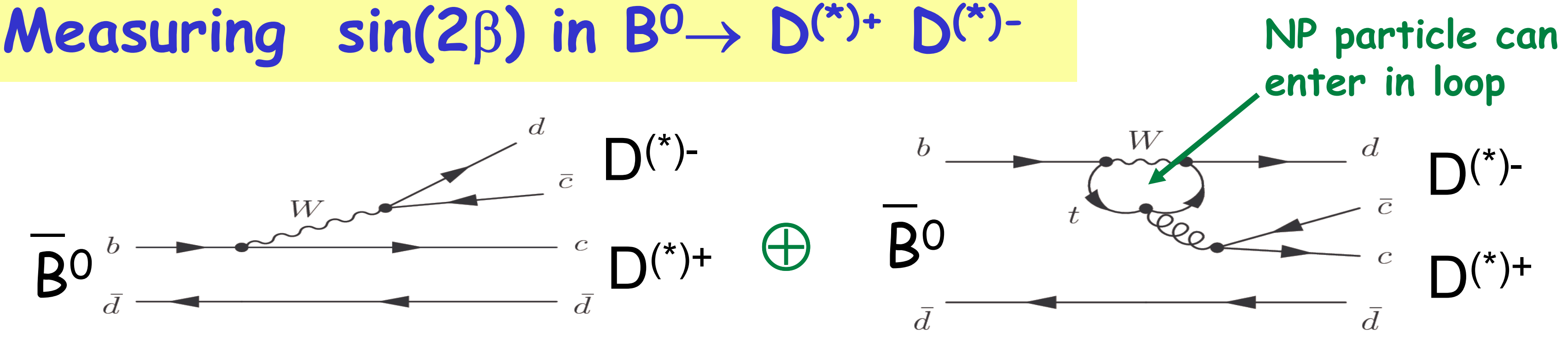
$\sin(2\beta \equiv 2\phi_1) = 0.670 \pm 0.023$
$2\beta \equiv 2\phi1 = (21.1 \pm 0.9)°$



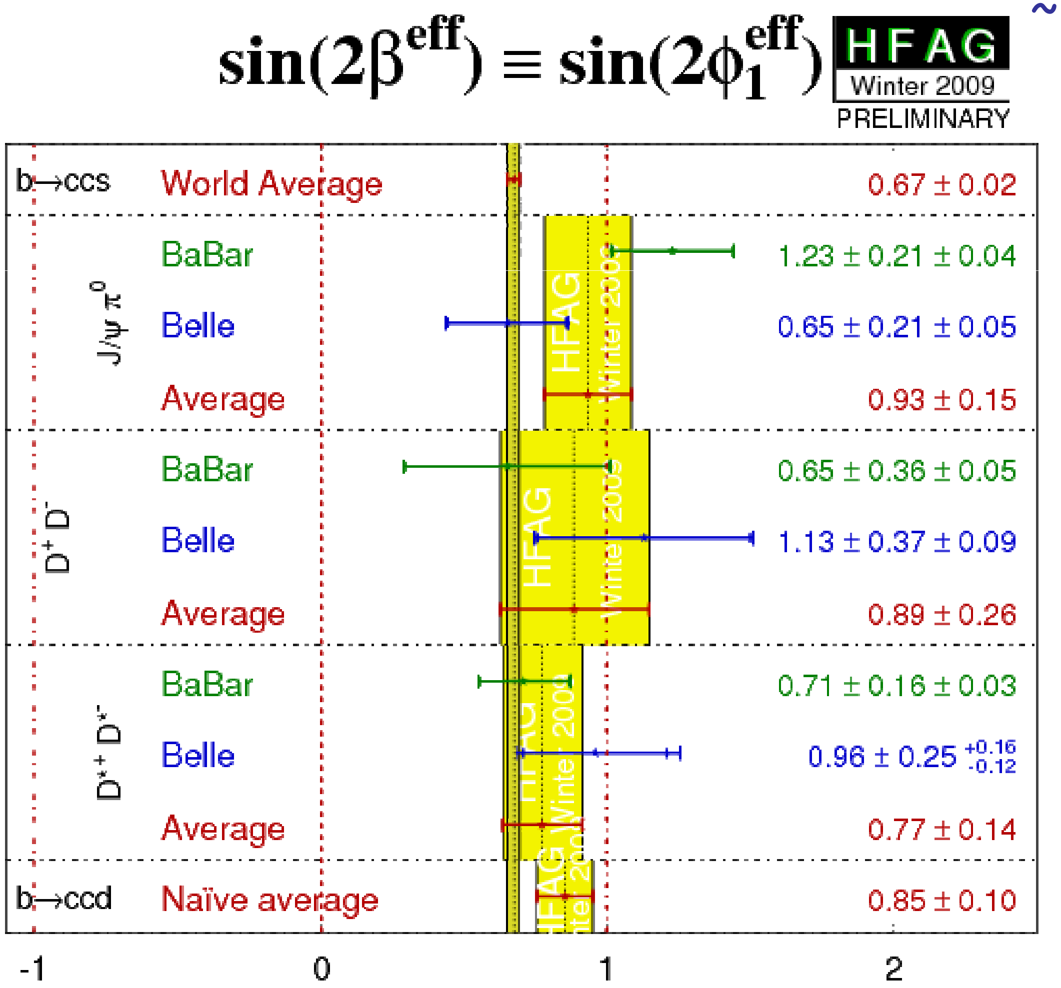


HFAG :
Heavy Flavour averaging group
www.slac.stanford.edu/xorg/hfag/

Measuring sin(2β) in $B^0 \rightarrow D^{(*)+} D^{(*)-}$



~2-10% in SM but sensitive to NP



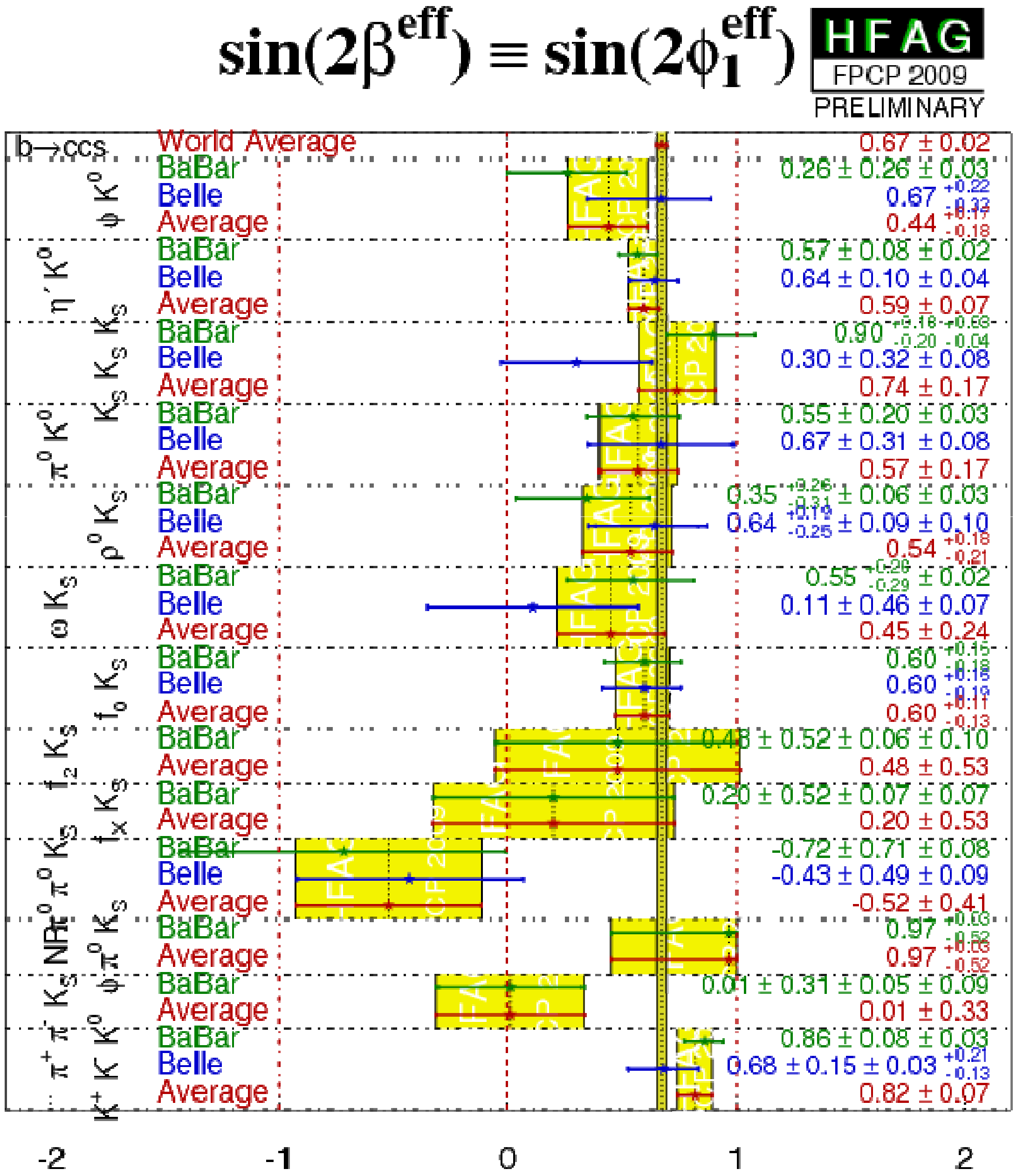
No discrepancy observed Compared to the Golden Mode

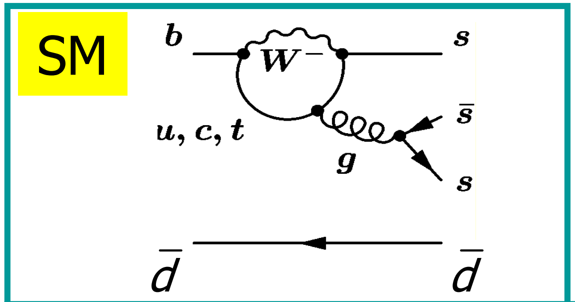
PRD 79, 032002 (2009) 467 M B pairs

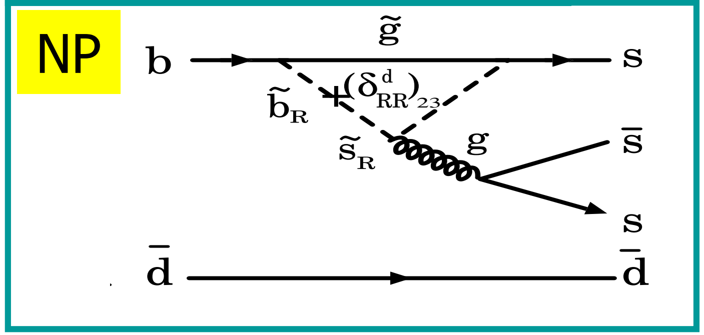
arXiv:0901.4057 657 M B pairs

Sub. To PRL

sin(2β) in b→s $\bar{q}$q penguin modes







No obvious discrepancy compared to golden mode but :

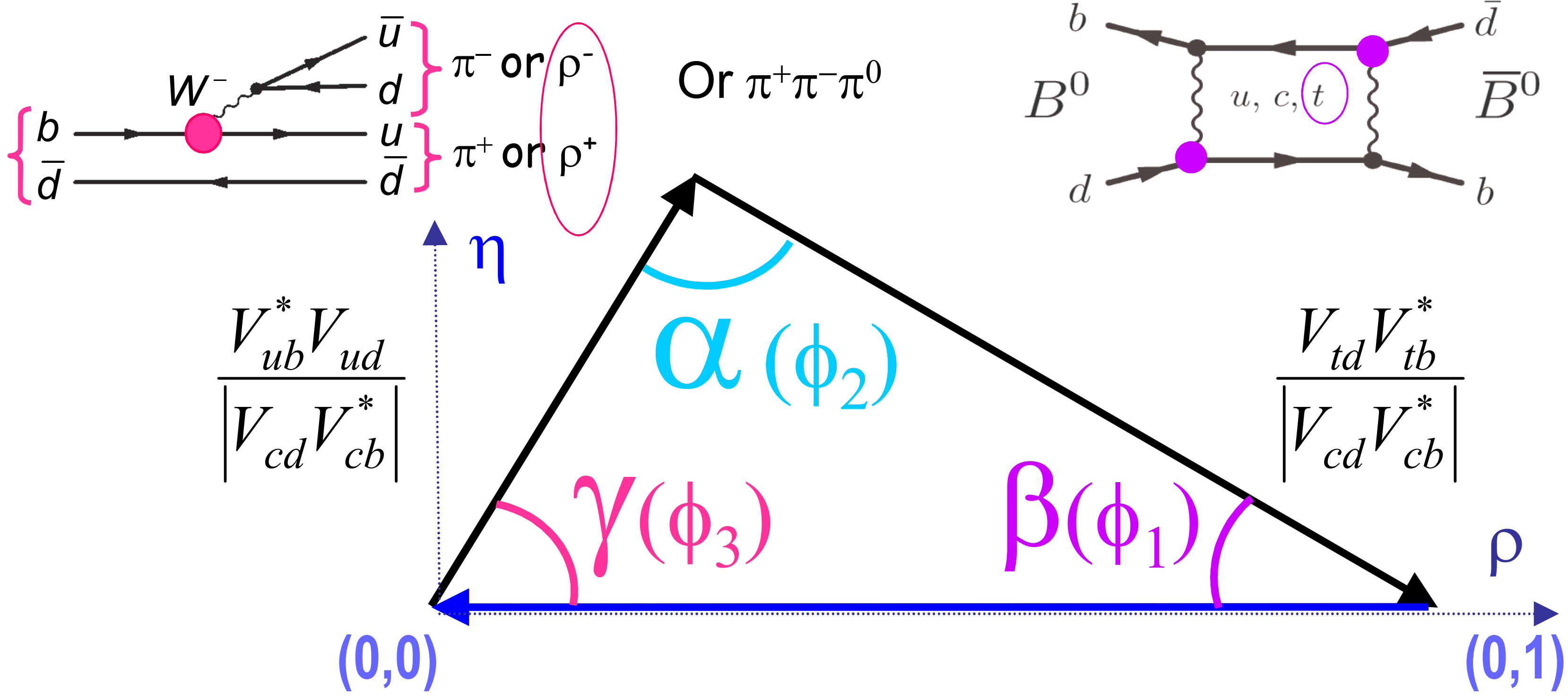
- Different theoretical uncertainties & corrections for hadronic effects on the different modes (averaging delicate)
- Systematic tendancy for the « cleanest » modes to be below golden value

Visible at SuperB or LHCb ?
(Hadronic uncertainties ~0.02)

Measurements of α

γ = phase of V_{ub}
(b→u transition)

β = phase of V_{td}
(B^0-$\bar{B}^0$ mixing)



$\alpha = \pi - \beta - \gamma \Rightarrow$ **process involving both B^0 mixing and b→u transition**

Isospin analysis

Constrains $\alpha - \alpha_{eff}$

Time dependent $\pi^+\pi^-$ or $\rho^+\rho^-$ CP asymmetry allows measuring $\sin 2\alpha_{eff}$.

$$\frac{\mathbf{A}^{+-}}{\sqrt{2}} + \mathbf{A}^{00} = \mathbf{A}^{+0} = \tilde{\mathbf{A}}^{-0} \times e^{2i\gamma} = \frac{\tilde{\mathbf{A}}^{+-}}{\sqrt{2}} + \tilde{\mathbf{A}}^{00}$$

Use SU(2) (u and d quarks) to relate amplitudes of all $\pi\pi$ $(\rho\rho)$ modes.

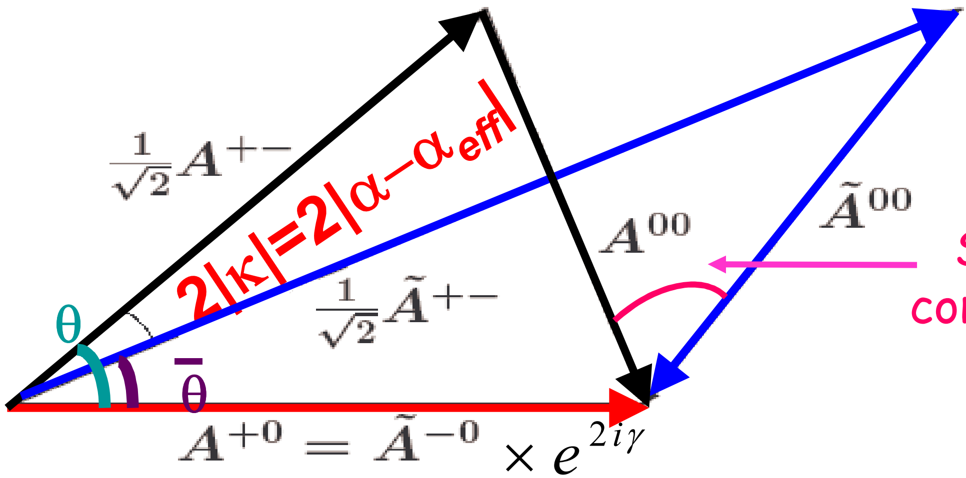
$$B \to h\ h = \pi\pi, \rho\rho$$

$$\mathbf{A}^{+-} = \mathrm{A}(B^0 \to h^+ h^-)$$

$$\mathbf{A}^{+0} = \mathrm{A}(B^+ \to h^+ h^0)$$

$$\mathbf{A}^{00} = \mathrm{A}(B^0 \to h^0 h^0)$$

~ for charge conjugate reaction



(pure tree)

For $B^0 \to \rho^0\rho^0$, S^{00} measurement constrains this angle

4-fold ambiguity $\kappa = \pm(\theta \pm \bar{\theta})$
If only the BRs are measured

Gronau, London : PRL**65**, 3381 (1990)

Neglect EW penguins

$$B^0 \to h^+ h^-$$

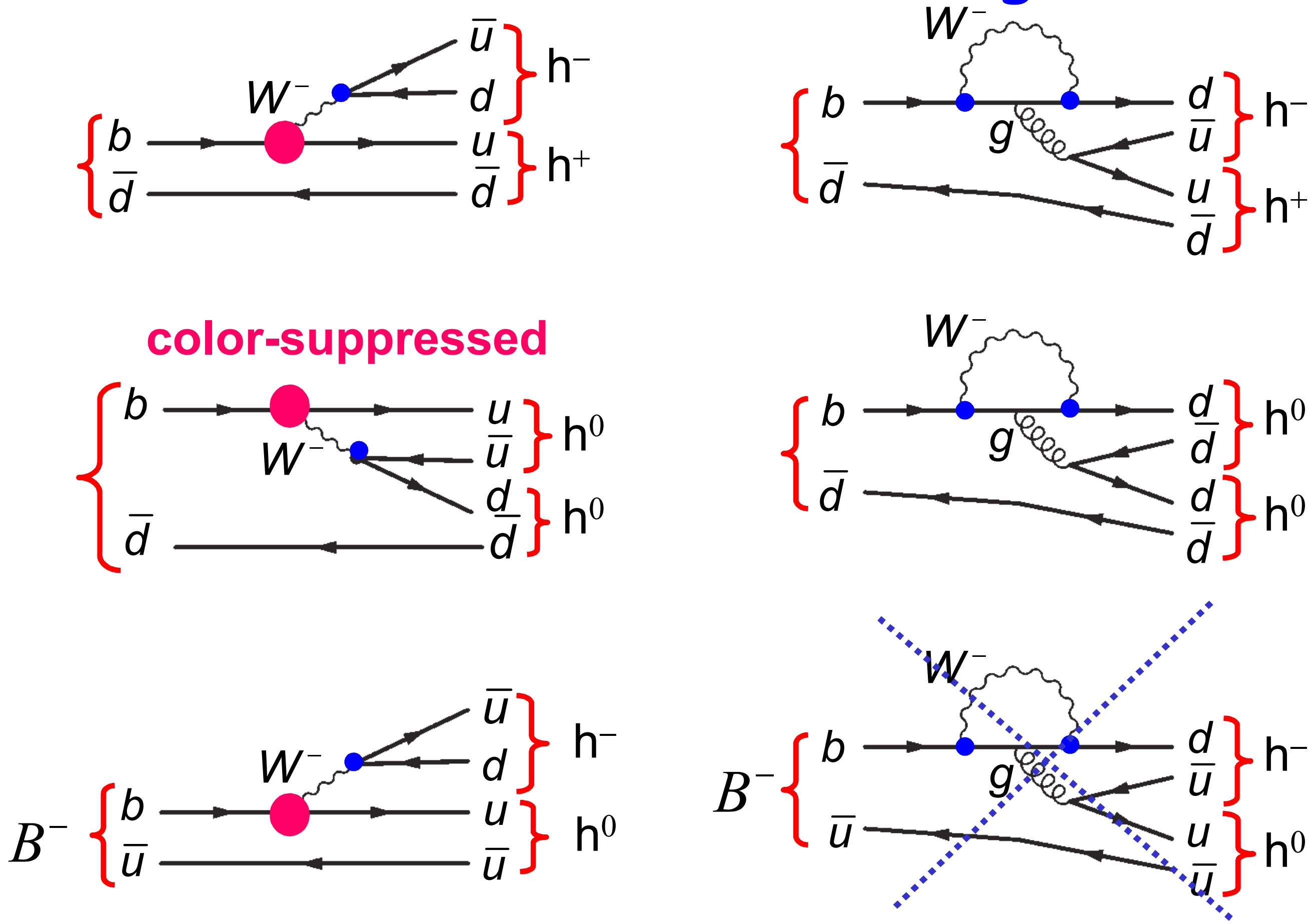
$$\overline{B}^0 \to h^0 h^0$$

small

$$B^- \to h^- h^0$$

$$h = \pi \ \ or \ \ \rho$$

Tree **Penguin**



V_{ub}

Phase γ

Isospin=2 final state for $B^+ \to \pi^+\pi^0$

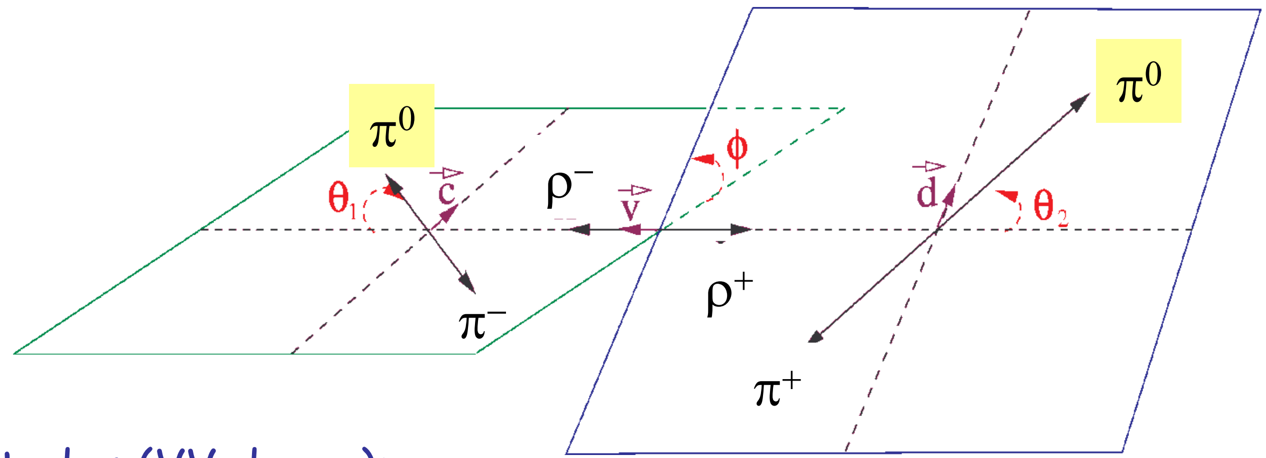
Forbidden for penguins

Almost true for $B^+ \to \rho^+\rho^0$

Falk, Ligeti, Nir, Quinn

hep-ph/0310242

$B^0 \rightarrow \rho^+\rho^-$ analysis



3 amplitudes (VV decay):

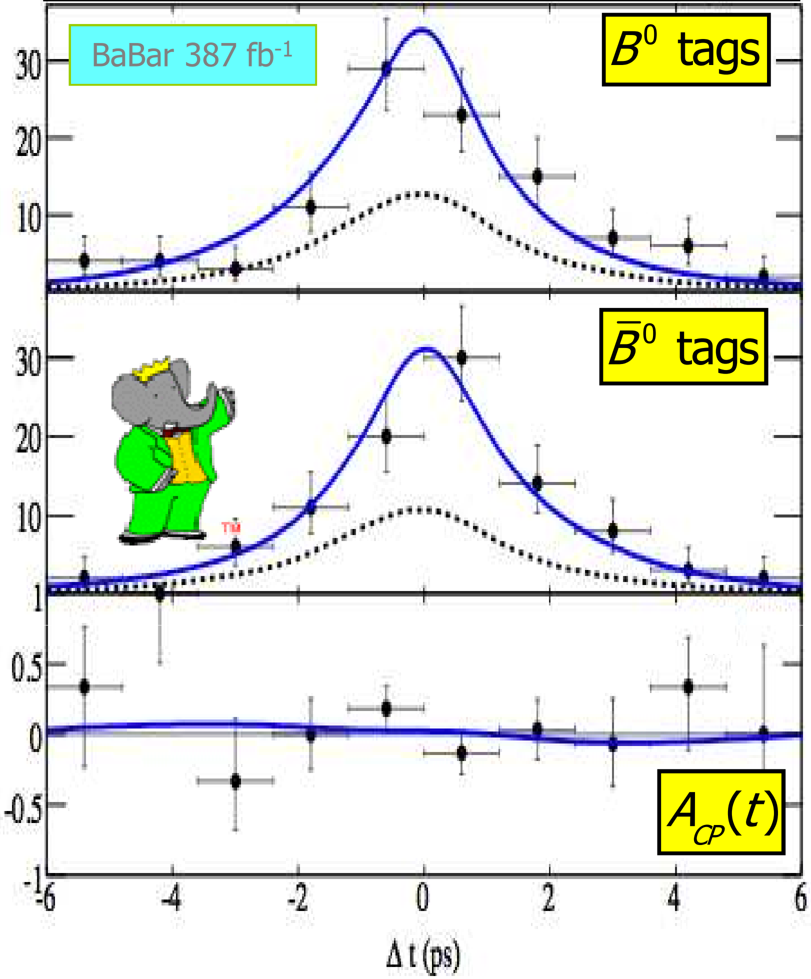
A_0 (CP-even longitudinal), fraction fL
$A_{||}$ (CP-even transverse), $A_\perp$ (CP-odd transverse).

$$\frac{1}{\Gamma}\frac{d^2\Gamma}{d\cos\theta_1 d\cos\theta_2} = \frac{9}{4}\left\{\frac{1}{4}(1-f_L)\sin^2\theta_1\sin^2\theta_2 + f_L\cos^2\theta_1\cos^2\theta_2\right\}$$

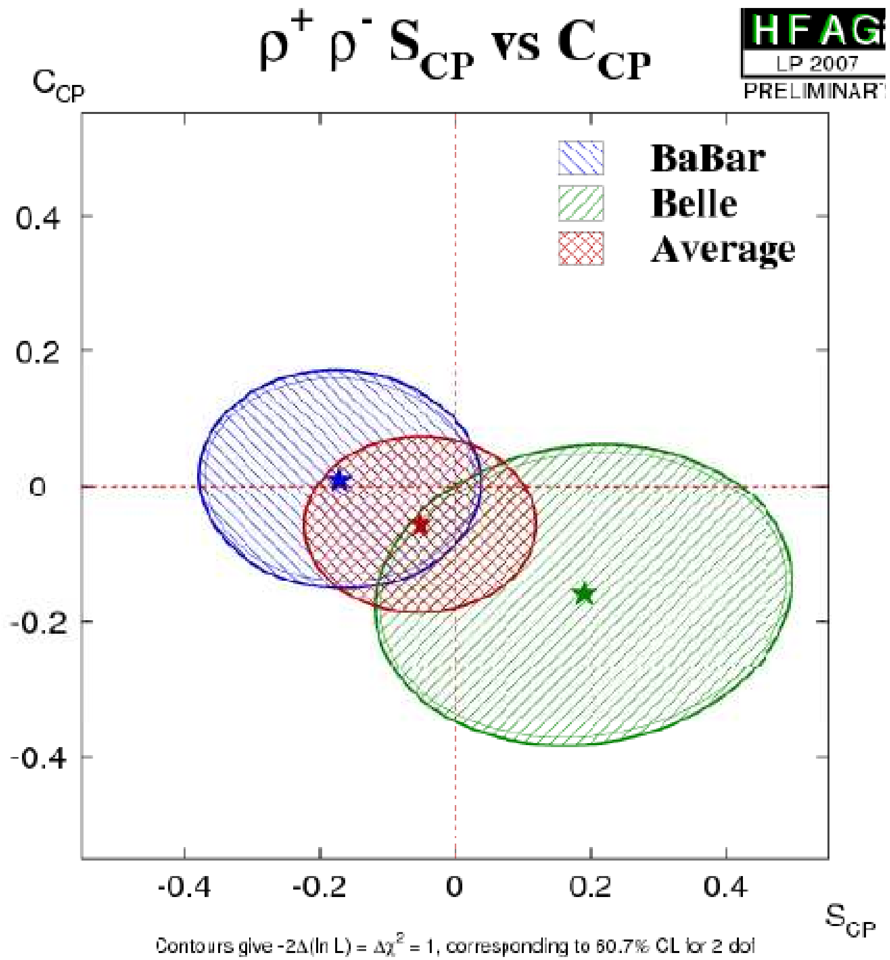
Very efficient mode:

BF~ **5 times larger** than for B→ ππ.
Penguin much smaller than in ππ.
ρ are ~100% longitudinally polarized.
Almost a pure CP-even state

BaBar PRD 76, 052007(2007)



BELLE PRD 76, 011104 (2007)



Time dependent CP asymmetry for $\rho^+\rho^-$

Extraction of CP violating parameters just like for the sin2β measurement.

Measure only sin2α_{eff} due to the penguin contribution.

BaBar PRD 78, 071104 (2008)

$$BF(B^0 \to \rho^0\rho^0) = \left[0.92 \pm 0.32 \pm 0.14\right] \times 10^{-6}$$

$$f_L = 0.75^{+0.11}_{-0.14} \pm 0.04$$

$$S_L^{00} = 0.3 \pm 0.7 \pm 0.2 \quad C_L^{00} = 0.2 \pm 0.8 \pm 0.3$$

BELLE PRD 78, 111102 (2008)

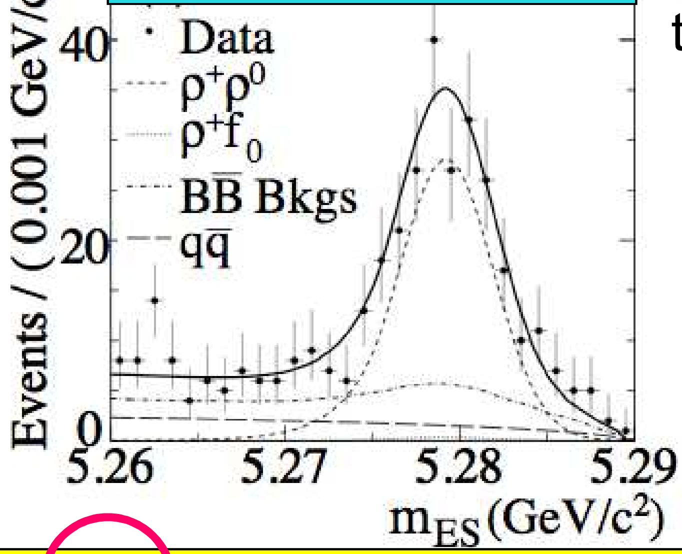
$$BF(B^0 \to \rho^0\rho^0)$$

$$< 1.0 \times 10^{-6} \ @ 90\% \ CL$$

$$= \left[0.4 \pm 0.4^{+0.2}_{-0.3}\right] \times 10^{-6}$$

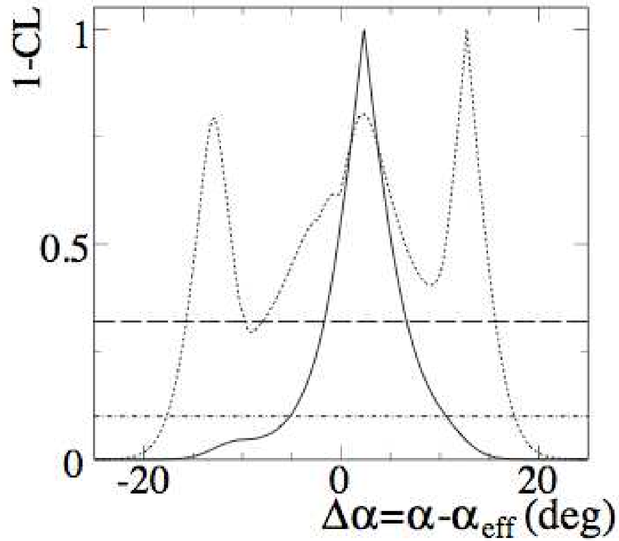
Sub. To PRL

BaBar arXiv:0901.3522



$BF(B^+ \to \rho^+\rho^0) = (23.7 \pm 1.4 \pm 1.4) \times 10^{-6}$

New result central value flattens isospin triangle & increases precision on $\alpha - \alpha_{eff}$



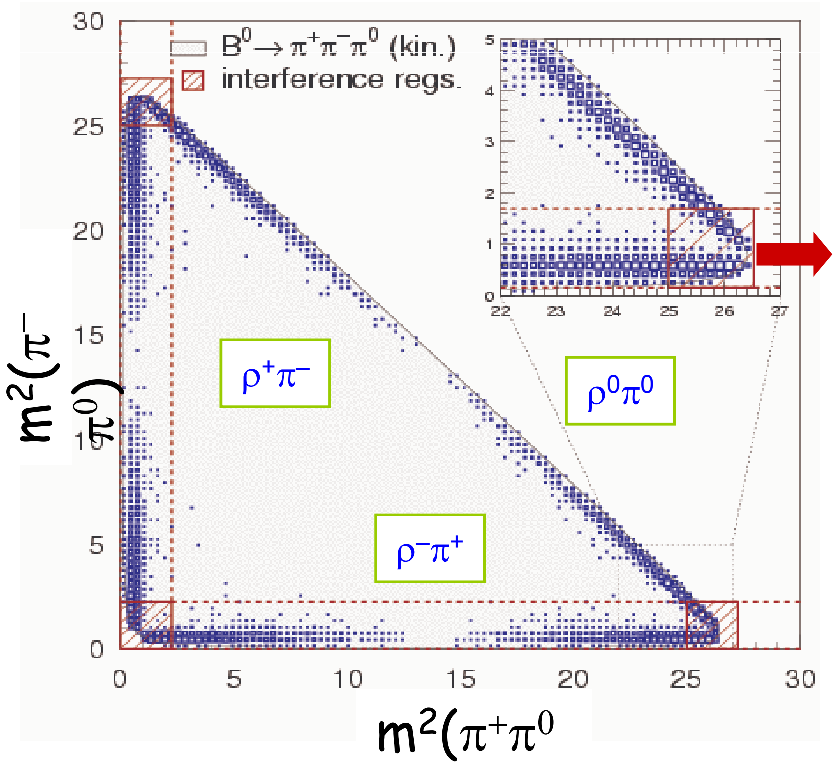
Dalitz analysis of $B^0 \to (\rho\pi)^0 \to \pi^+\pi^-\pi^0$

- Dominant decay $B^0 \to \rho^+\pi^-$: not a CP eigenstate
- Isospin analysis not viable, too many amplitudes

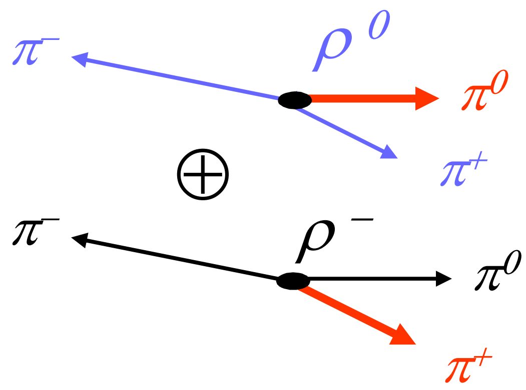
$B^0 \to \rho^+\pi^-$, $B^0 \to \rho^-\pi^+$, $B^0 \to \rho^0\pi^0$, $B^+ \to \rho^+\pi^0$, $B^+ \to \rho^0\pi^+$ and charge conjugates

- Better approach: Time-dependent Dalitz analysis
  - Simultaneous fit of α and T, P amplitudes
  - α constrained with no ambiguity (unlike $\sin(2\alpha)$ measurement)

Snyder-Quinn, PRD **48**, 2139 (1993)



Amplitude $A(B \to 3\pi)$ dominated by ρ^+, ρ^- and ρ^0 resonances

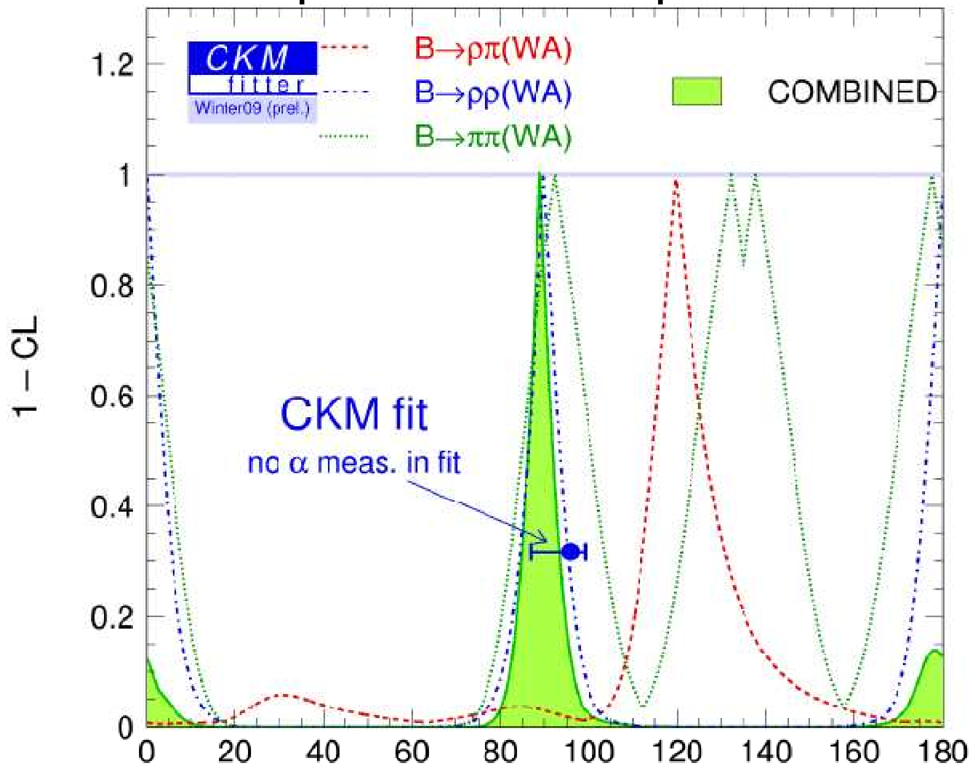


BABAR :
PRD 76 012004 (2007)
BELLE :
PRL 98 221602 (2007)

Summary on α (ϕ_2)

Frequentist approach

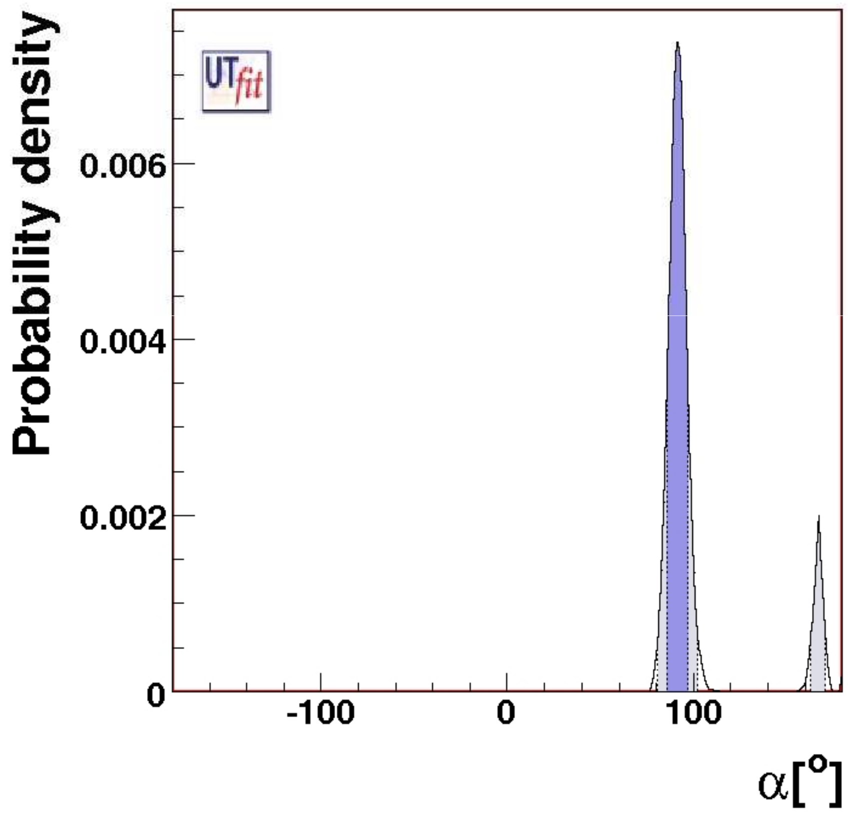
http://ckmfitter.in2p3.fr/



68%C.L. interval: $\alpha = (89.0^{+4.4}_{-4.2})^\circ$

Bayesian approach

http://www.utfit.org



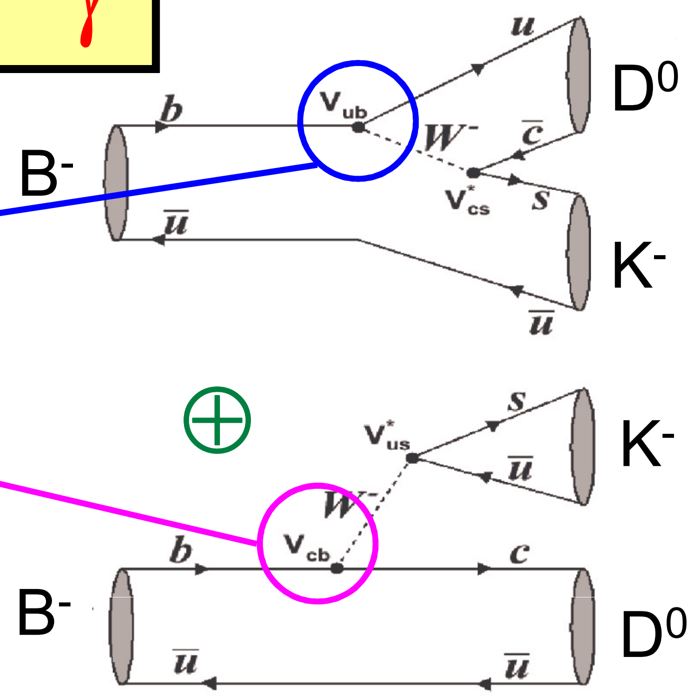
α in [81,102]°U[164,171] ° @95% prob.

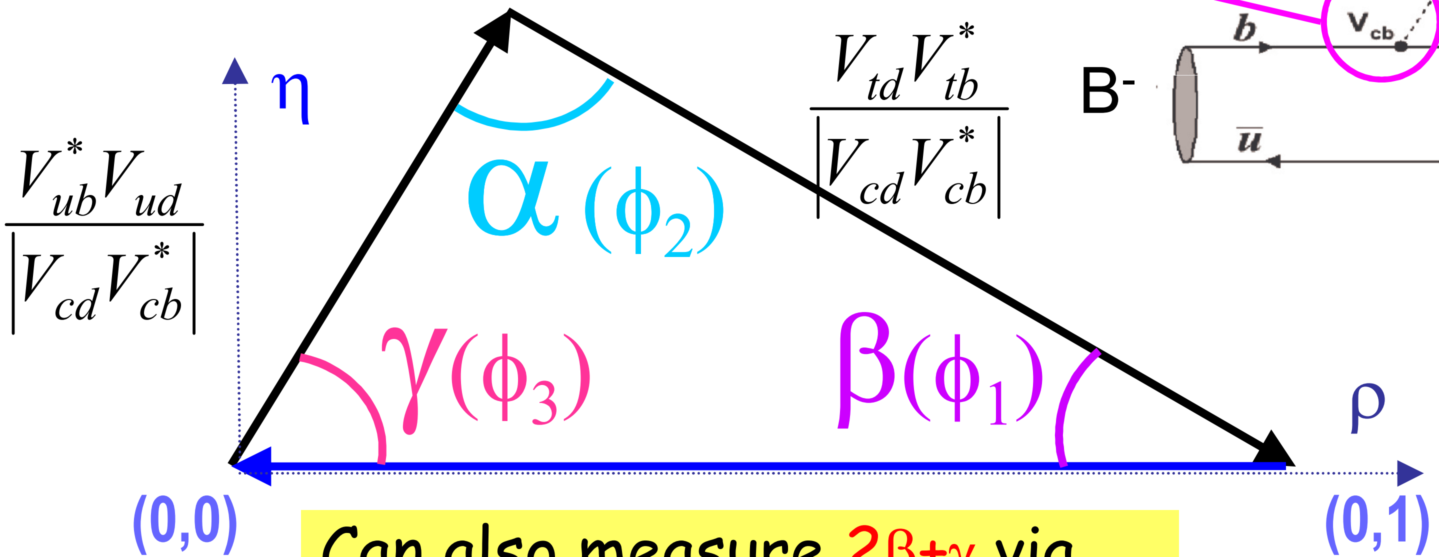
α = 91.4 ± 4.6 °

Measurements of γ

Colour **suppressed** b→u

$$\gamma = \phi_3 = \arg\left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right)$$



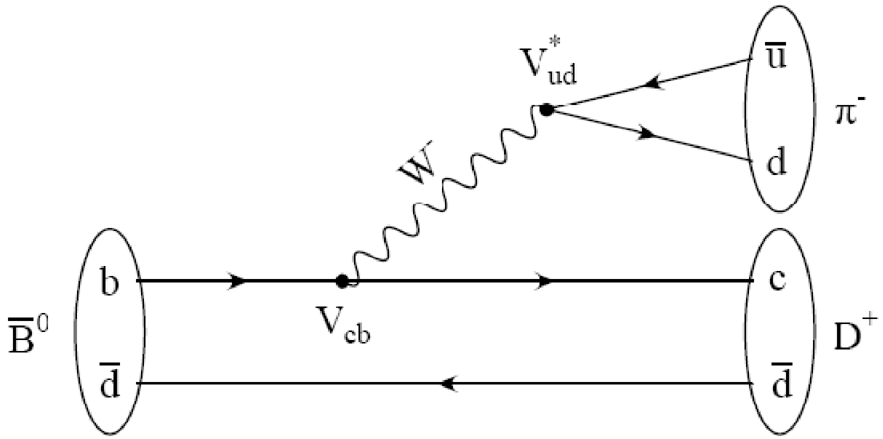


Can also measure $2\beta+\gamma$ via TDCPV in $B^0 \to D^+\pi^{-,+}$ ($\rho^{-,+}$)

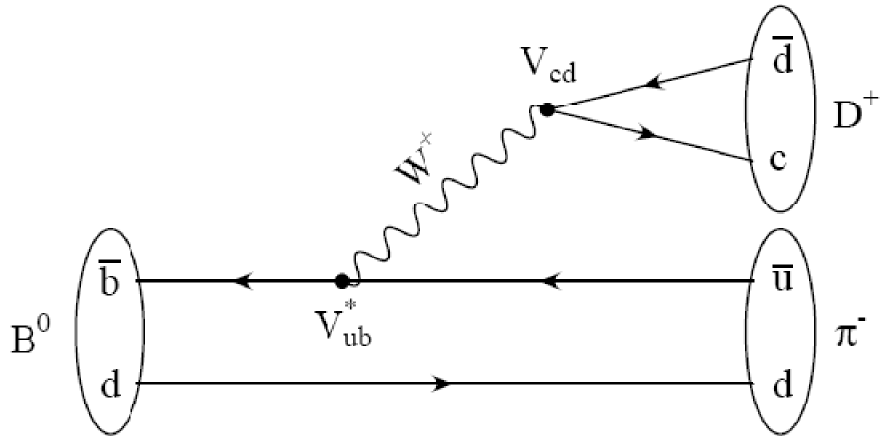
Can also measure $2\beta+\gamma$ via TDCPV in $B^0 \to D^+\pi^{-,+}$ ($\rho^{-,+}$)

BABAR
PRD71, 112003 (2005)
PRD73, 111101 (2006)

BELLE
arXiv:0809.3203 [hep-ex]
PRD73, 092003 (2006)



CKM-favored amplitude

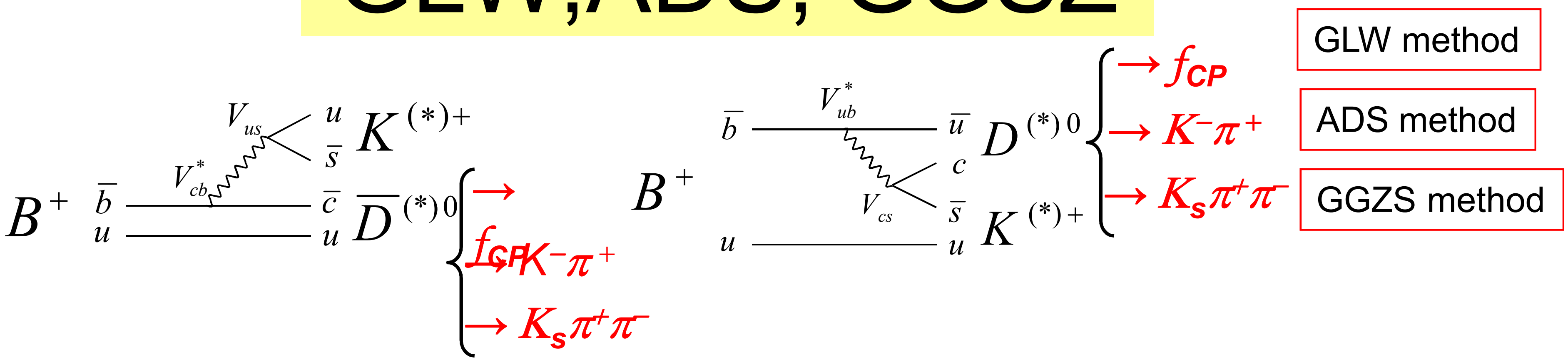


doubly-CKM suppressed amplitude

Interférence entre les amplitudes {CKM-favored + B^0 oscillation} et doubly-CKM suppressed

Etude en fonction de Δt (désintégration des deux mésons beaux)

GLW,ADS, GGSZ



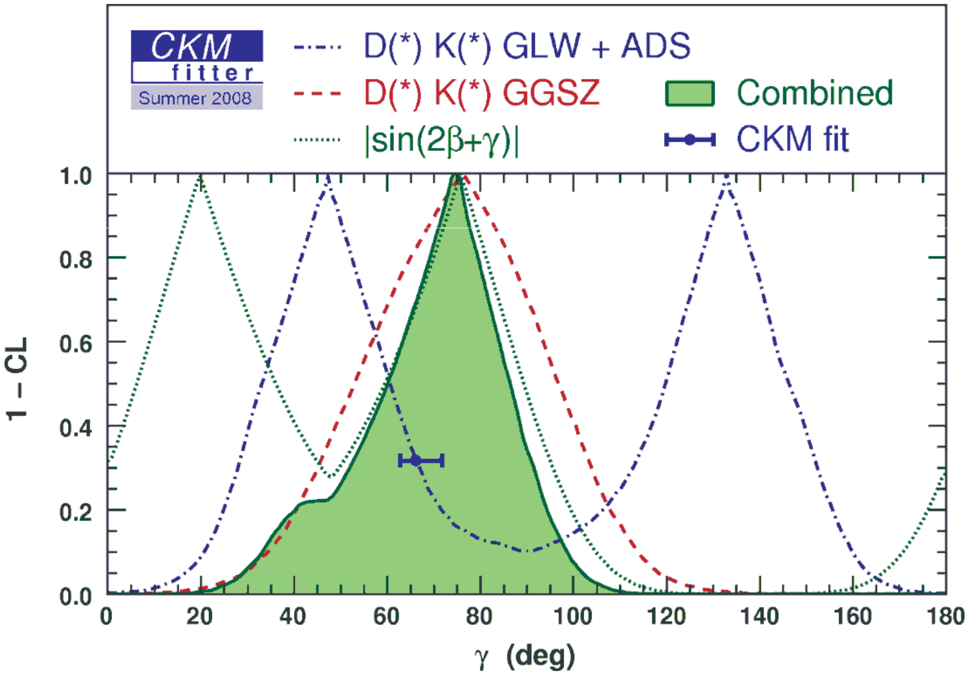
GLW: Gronau, London (1991) ; Gronau, Wyler (1990).
Small interference, but hadronic unknowns from $D^{(*)0}$ decay cancel out

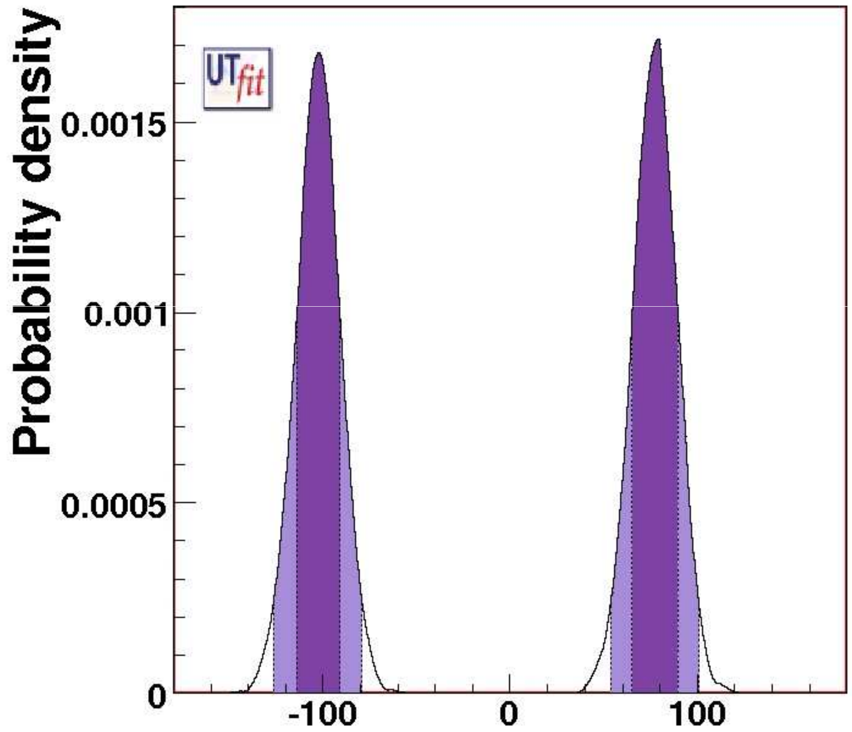
ADS: Atwood, Danietz, Soni (1997)
Larger interference between more comparable amplitudes:
b→u + regular D →Kπ decay
b→c + doubly cabibbo suppressed D →Kπ
But D decay hadronic uncertainties

GGSZ: Giri, Grossman, Sofer, Zupan (2003) Currently the most sensitive
Exploits interference pattern in $D\to K_S\,\pi^+\pi^-$ Dalitz plot, combines many modes, small systematic error from Dalitz model

Summary on γ (ϕ2)

Many new results from BABAR and BELLE in summer 2008.
Latest results from BABAR $B^+ \rightarrow DK^*$ ADS and GLW analyses not included yet.



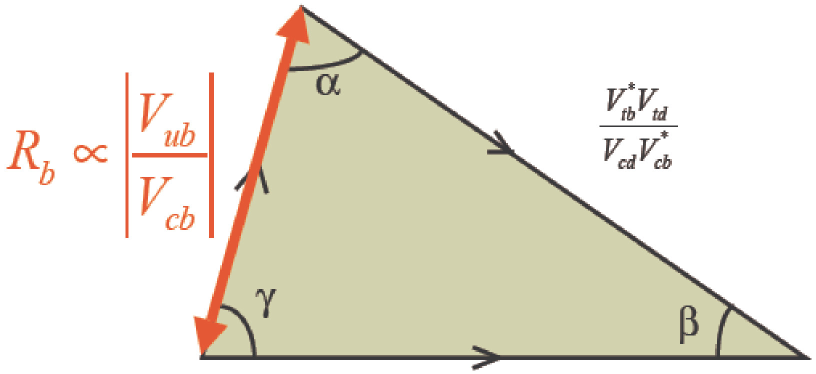


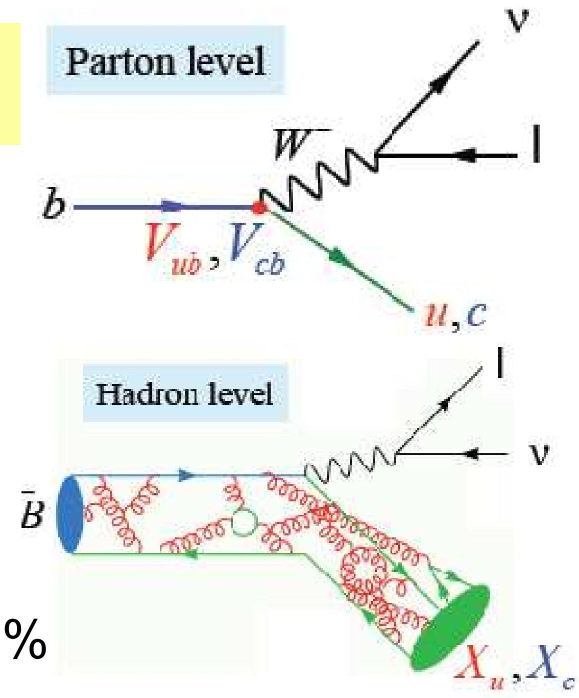
$$\gamma = 76^{+16}_{-23}\,^{\circ} \quad \left(\gamma = 76^{+27}_{-29}\,^{\circ}\right)$$

Without $\sin(2\beta+\gamma)$

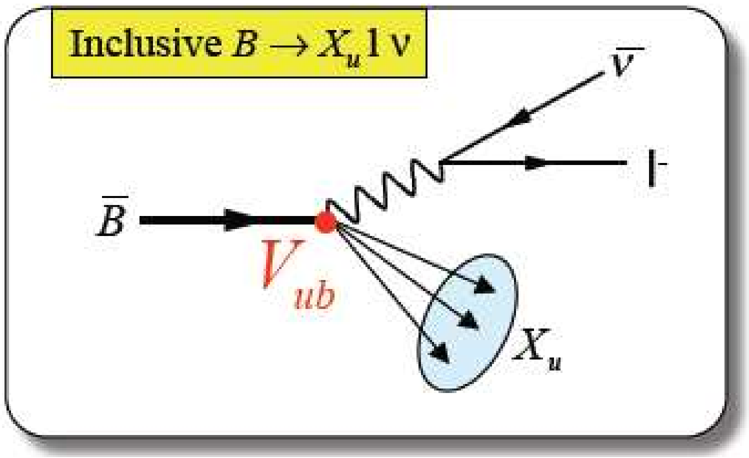
$$\gamma = 78 \pm 12\,^{\circ}$$

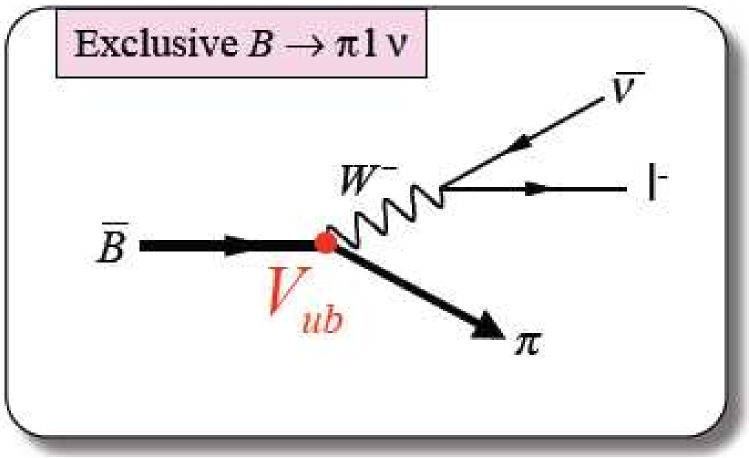
Left side of the unitarity triangle





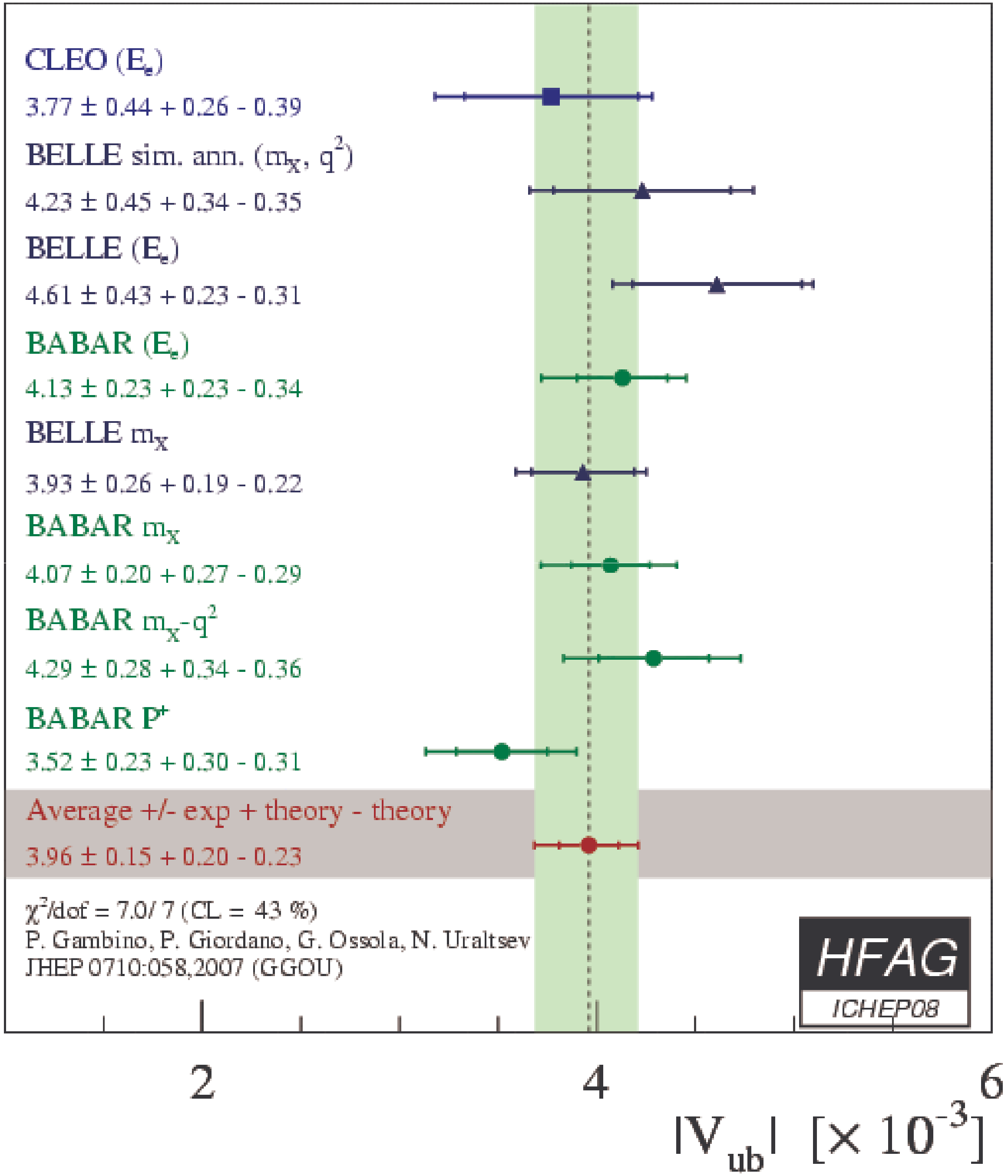
Prob(b→c)/ Prob(b→u) ~50 ; Vcb measured at ±2%





Partial rate is measured
Theoretical uncertainties ~6%
from HQET parameters

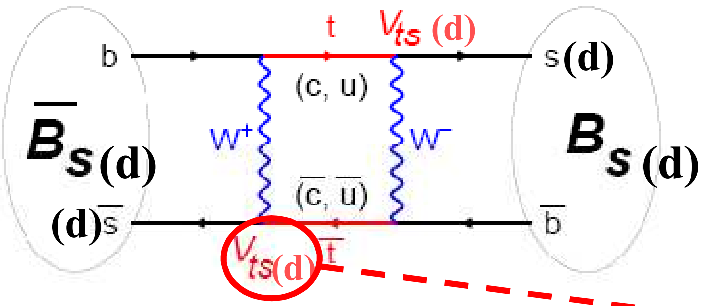
Theoretical uncertainties ~10%
From from factor calculation
from lattice QCD



+ new preliminary result from BELLE given at CKM 2008 (P. Urquijo's talk)

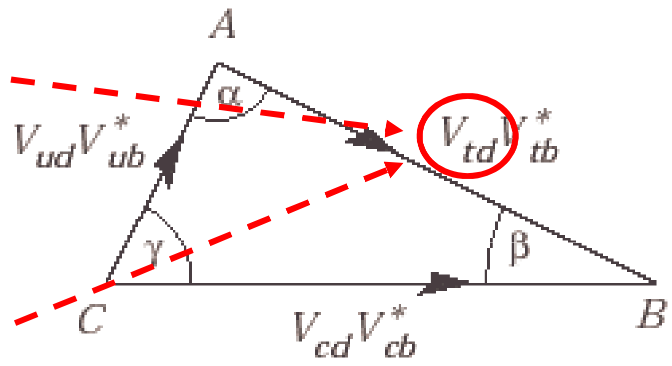
Average
Vub inclusive ± 6.5%

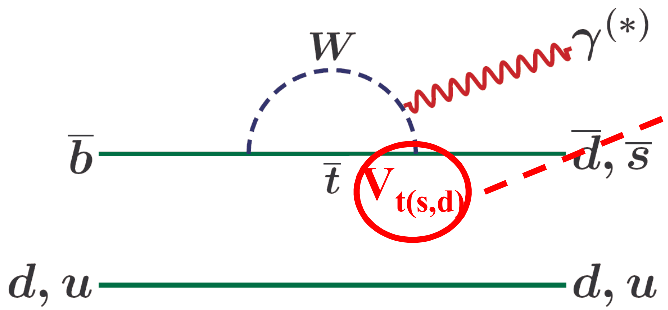
Measuring $|V_{td}/V_{ts}|$



B Mixing

Two independent diagrams provide sensitivity to CKM parameter V_{td}





Radiative Penguins

Note: In both cases:
-hadronic uncertainties minimized by comparing to corresponding V_{ts} process (B_s mixing, $b \to s\gamma$).
-New physics could enter in loops, but differently.

Traditional Exclusive Approach: $B \to \rho(\omega)\,\gamma$

Measure exclusive rate $Br(B \to \rho(\omega)\,\gamma)$; normalize with $Br(B \to K^*\,\gamma)$

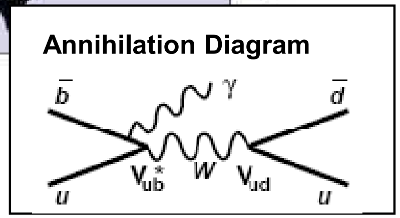
isopin factor: 1(.5) for $\rho^{\pm}(\rho^0)$(and ω)

form factor ratio

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

well measured

annihilation amplitude corrections



Values of ς^2 and ΔR are state (ρ^+,ρ^0,ω) dependent and are available from

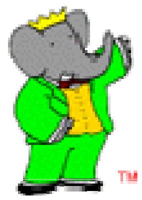
- **Ali, Parkhomenko, arXiv:hep-ph/0610149**
- **Ball, Zwicky, J. High. Energy Phys. 0604, 046 (2006); Ball, Jones, Zwicky, Phys. Rev. D 75 054004 (2007)**

at approximately 8% overall accuracy.

New semi-inclusive approach: $B \to X_{s,d}\,\gamma$

iType	X_s	X_d
1	$K^+\pi^-\gamma$	$\pi^+\pi^-\gamma$
2	$K^+\pi^0\gamma$	$\pi^+\pi^0\gamma$
3	$K^+\pi^-\pi^+\gamma$	$\pi^+\pi^-\pi^+\gamma$
4	$K^+\pi^-\pi^0\gamma$	$\pi^+\pi^-\pi^0\gamma$
6	$K^+\pi^-\pi^+\pi^-\gamma$	$\pi^+\pi^-\pi^+\pi^-\gamma$
7	$K^+\pi^-\pi^+\pi^0\gamma$	$\pi^+\pi^-\pi^+\pi^0\gamma$
9	$K^+\eta^0\gamma$	$\pi^+\eta^0\gamma$

Reconstruct 7 final states



$|V_{td}/V_{ts}|^2$ related to $\Gamma(b\to d\gamma)/\Gamma(b\to s\gamma)$ with ~1% theoretical uncertainty [**Ali, Asatrian, Greub, Phys. Lett. B 429, 87 (1998)**]

New BaBar preliminary result:
arXiv:0807.4975 submitted to PRL

ICHEP '08 B Mixing Results [Farrington(CDF), Moulik(D0), averaged by F. De Lodovico (BaBar)]: $|V_{td}|/|V_{ts}| = 0.207 \pm 0.001_{exp} \pm 0.006_{theo}$

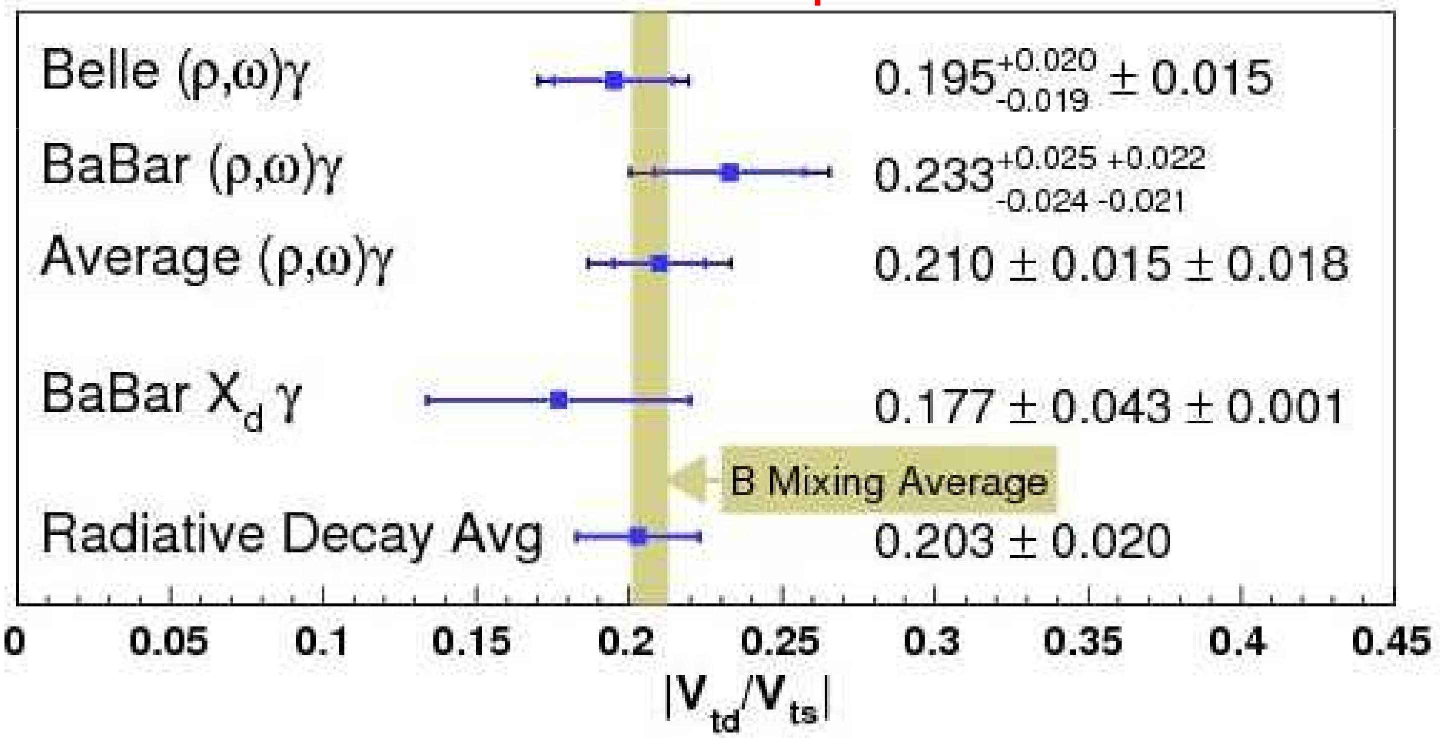
Accurate measurements of Δmd at B factories, of Δms at Tevatron

Summer 2008 updates

PRD**101**, 111801 (2008)

PRD**78**, 112001 (2008)

Semi-inclusive
arXiv:0807.4975
sub. to PRL



Unitarity Triangle Summary

2008 Nobel Prize awarded to M. Kobayashi and T. Maskawa
Major contribution from BaBar and BELLE

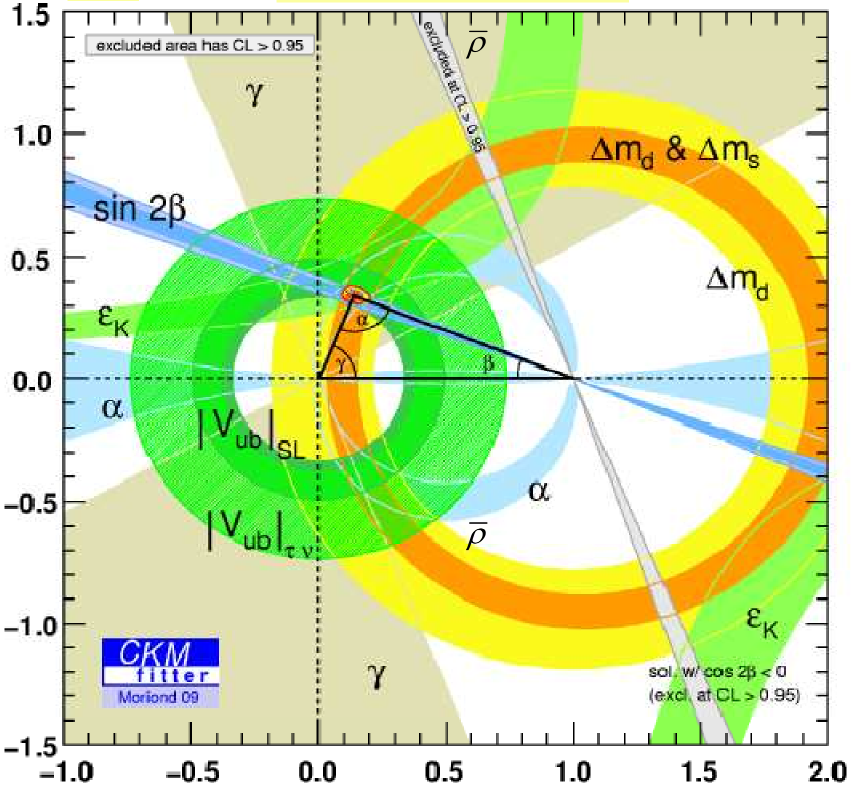
$$\bar{\rho} = 0.139^{+0.025}_{-0.027}$$

$$\bar{\eta} = 0.341^{+0.016}_{-0.015}$$

$$\bar{\rho} = 0.156 \pm 0.020$$

$$\bar{\eta} = 0.342 \pm 0.013$$

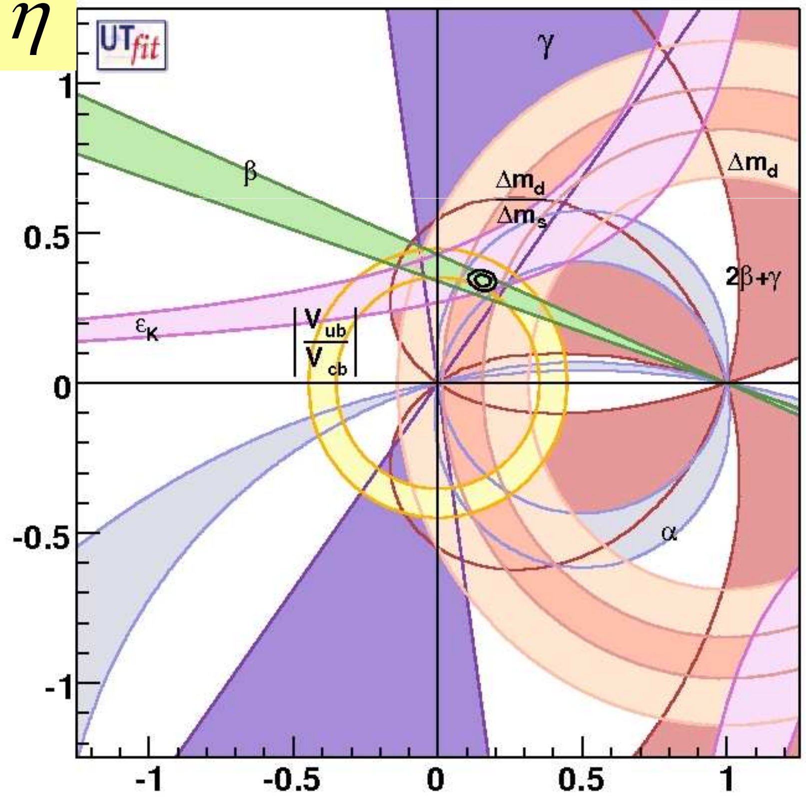
$\bar{\eta}$



$\bar{\rho}$

http://ckmfitter.in2p3.fr

$\bar{\eta}$



$\bar{\rho}$

http://www.utfit.org/

Search for new physics

Many rare decays studied!

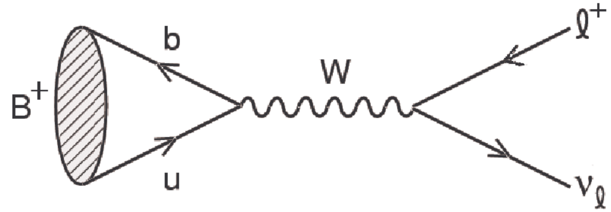
Focus here on the superB golden matrix to constrain models beyond SM.

X = Golden Channel o = Observable effect	H^+ high $\tan\beta$	Minimal FV	Non-Minimal FV (1-3)	Non-Minimal FV (2-3)	NP Z-penguins	Right-Handed currents
$\mathrm{BR}(B \to X_s\gamma)$		X		o		o
$A_{CP}(B \to X_s\gamma)$				X		o
$\mathrm{BR}(B \to \tau\nu)$	X-CKM					
$\mathrm{BR}(B \to X_s l^+ l^-)$				o	o	o
$\mathrm{BR}(B \to K\nu\overline{\nu})$				o	X	
$S(K_S\pi^0\gamma)$						X
β (ΔS)			X-CKM			X

(A. Bevan's talk on superB at Moriond EW)

	Mode	Sensitivity Current	10 ab^{-1}	75 ab^{-1}
	$\mathcal{B}(B \to X_s\gamma)$	7%	5%	3%
	$A_{CP}(B \to X_s\gamma)$	0.037	0.01	0.004–0.005
	$\mathcal{B}(B^+ \to \tau^+\nu)$	30%	10%	3–4%
Upper limit on BF	$\mathcal{B}(B^+ \to \mu^+\nu)$	X	20%	5–6%
	$\mathcal{B}(B \to X_s l^+ l^-)$	23%	15%	4–6%
	$A_{\mathrm{FB}}(B \to X_s l^+ l^-)_{s0}$	X	30%	4–6%
Upper limit on BF	$\mathcal{B}(B \to K\nu\overline{\nu})$	X	X	16–20%
	$S(K_S^0\pi^0\gamma)$	0.24	0.08	0.02–0.03

$B^+ \to \tau^+ \nu$



- In SM, decay rate related to decay constant and V_{ub}

$$\mathcal{B}(B \to \ell\nu) = \frac{G_F^2 m_B}{8\pi} m_\ell^2 (1 - \frac{m_\ell^2}{m_B^2})^2 f_B^2 |V_{ub}|^2 \tau_B$$

- Charged Higgs may contribute to BF.

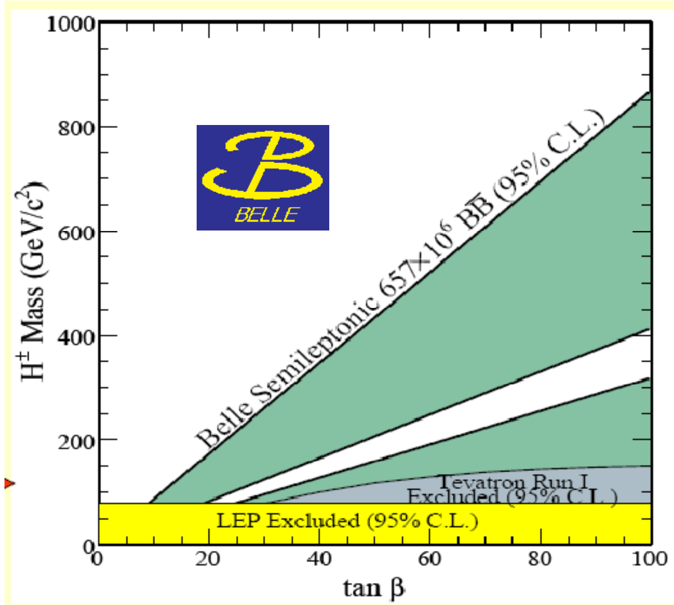
$$\mathcal{B}(B \to \tau\nu) = \mathcal{B}(B \to \tau\nu)_{\mathsf{SM}} \times r_H$$

Provided f_B is known

destructive

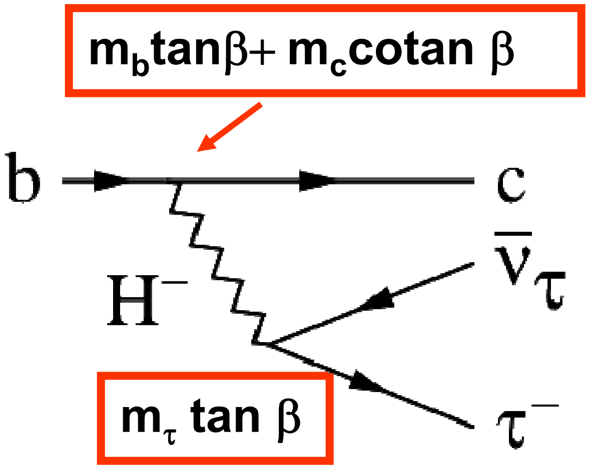
$$r_H = (1 - \frac{m_B^2}{m_H^2} \tan^2\beta)^2$$

	Tag	N B pairs	BF($B\to\tau\nu$) (10^{-4})	σ	Reference
(BaBar)	hadronic	383 M	$1.8 ^{+0.9}_{-0.8} \pm 0.4 \pm 0.2$	2.2	PRD-RC 77, 011107 (2008)
NEW (BaBar)	semileptonic	459 M	$1.8 \pm 0.8 \pm 0.1$	2.4	**BABAR-CONF 08/005** **SLAC-PUB 13300**
(Belle)	hadronic	447 M	$1.79 ^{+0.56}_{-0.49} {}^{+0.46}_{-0.51}$	3.5	PRL 97, 251802 (2006)
NEW (Belle)	$D^* l \nu$	657 M	$1.65 ^{+0.38}_{-0.37} {}^{+0.35}_{-0.37}$	3.8	**arXiv: 0809.3834**

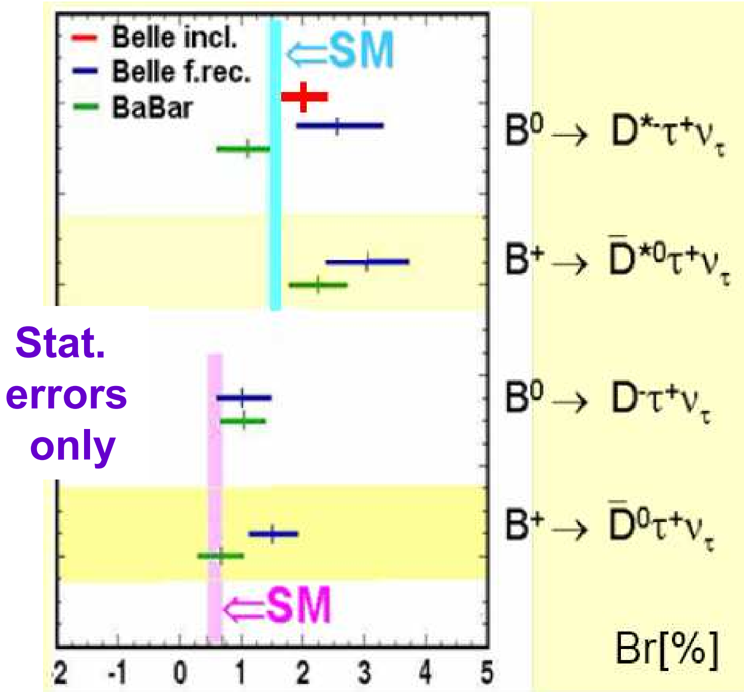


Constraint complementary to hadron colliders

New BELLE B → $D^{(*)}\ \tau^+\ \nu$ result @ MORIOND EW (talk « Hot topics BELLE ») :



$W^\pm$ instead of $H^\pm$ in standard model



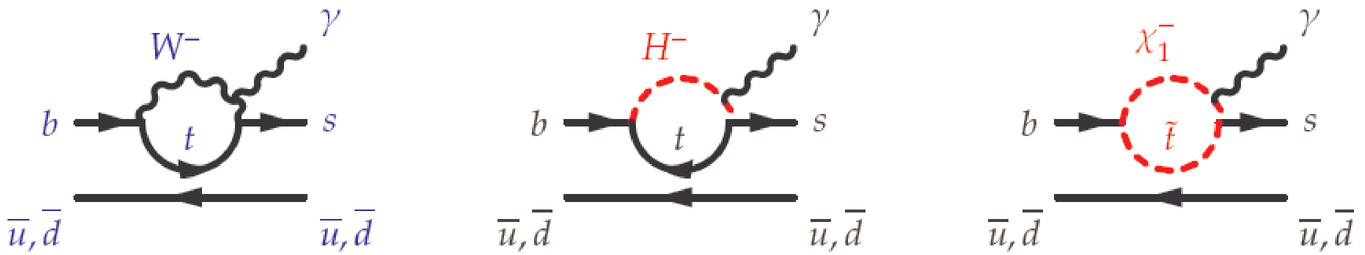
Belle incl. Tag rec.
PRL 99, 191807 (2007)

BELLE full rec.
New analysis

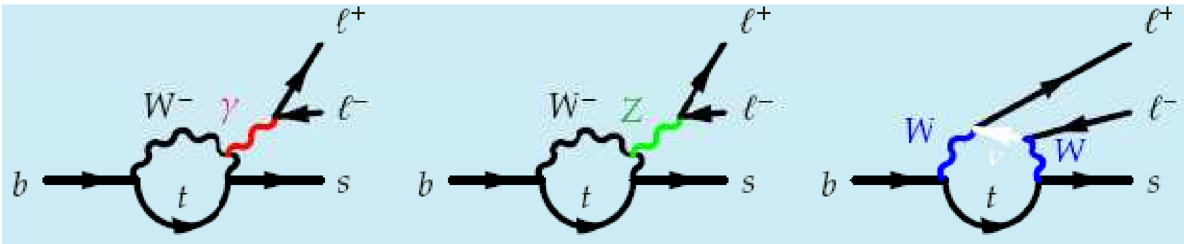
BABAR analysis:
PRL 100 021801 (2008)
arXiv:0902.2660, sub. to PRD

Radiative and electroweak penguins

See Mikihiko Nakao, « Review of radiative penguin measurements » at Moriond EW



Radiative penguin



Electroweak penguin

Rich program, many new measurements in summer 2008.
Constrain physics beyond SM
Decays $b \to s\,\gamma$, $b \to d\,\gamma$, and $b \to s\, l^+ l^-$ now almost fully explored by BELLE and BABAR.

Results consistent with SM, but may-be hints for new physics in:

- Inclusive $B \to X_s\, \gamma$
- Time-dependent CP asymmetry in $B \to K^0{}_S \pi^0 \gamma$, $B \to K^0{}_S \rho^0 \gamma$, …
- Isospin asymmetry in $b \to \rho\, \gamma$
- Forward-Backward asymmetry in $B \to K^*\, l^+ l^-$

Need for more data: Super B factory? $B \to K^*\, l^+ l^-$ can also be studied at LHCb

Many more topics and hints for new physics.

- The inconsistency in the unitarity triangle (« tensions »)
- Anomalies in charmless B decays such as the K-π puzzle and $B \to VV$ polarization
- Anomalies in radiative/EW B decays such as the isospin and forward-backward asymmetries in $B \to K^*ll$
- The excessive D^0-$\bar{D}^0$ mixing
- The g-2 puzzle

Upcoming dedicated workshop « Hints for new physics in flavour decays » at KEK, Tsukuba, Japan – March 20-21 2009.

http://belle.kek.jp/hints09/

Conclusion

- Unitarity triangle overconstrained with good consistency: large contribution from BaBar and BELLE:
  - Kobayashi and Maskawa 's theory tested: CKM mixing is the source for CP violation in the quarks sector.
  - Angles of the unitarity triangle from CP violating processes: accuracy ~ 1° for β, ~5° for α, ~20° for γ, errors still limited by statistics.
  - Sides of the unitarity triangle : both limited by theoretical errors.
  - New physics tests made within the triangle (β measurements, measurement of the right side with radiative penguin modes and mixing).

- New physics search using rare decays:
  - No evidence of new physics so far but shows feasability for future experiments LHCb, super flavour factory …
  - Some ranges of parameters for models beyond standard model can already be excluded.

Related talks at Moriond EW 2009

- BABAR and BELLE results related to the Unitarity Triangle :
  - **Angles**: Karim Trabelsi, « review of ϕ1, ϕ2, ϕ3 mesaurements ».
  - **Sides:**
    - V_{cb} & V_{ub}: Fabrizio Bianchi, « review of Vub and Vcb ».

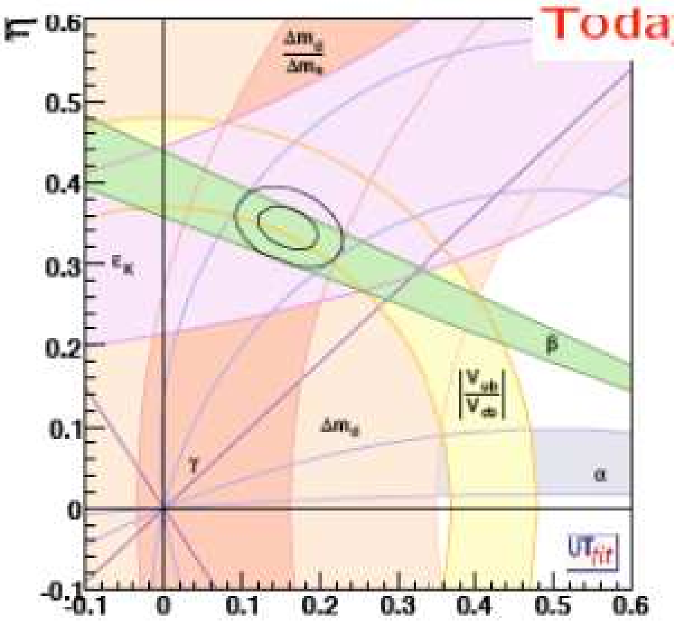
    (new Vub result from Belle: P. Urquijo's talk at CKM workshop 2008)
    - V_{td} / V_{ts} : Mikihiko Nakao, « Review of radiative penguin measurements » and Bruce Schumm's talk at CKM workshop 2008.

- BABAR and BELLE results related to New physics search :
  - Mikihiko Nakao, « Review of radiative penguin measurements ».
  - Elisabetta Baracchini « Review of rare decays (BABAR) ».
  - Joao Costa, « Hot topics BABAR ».
  - Andrzej Bozek, « Hot topics BELLE ».

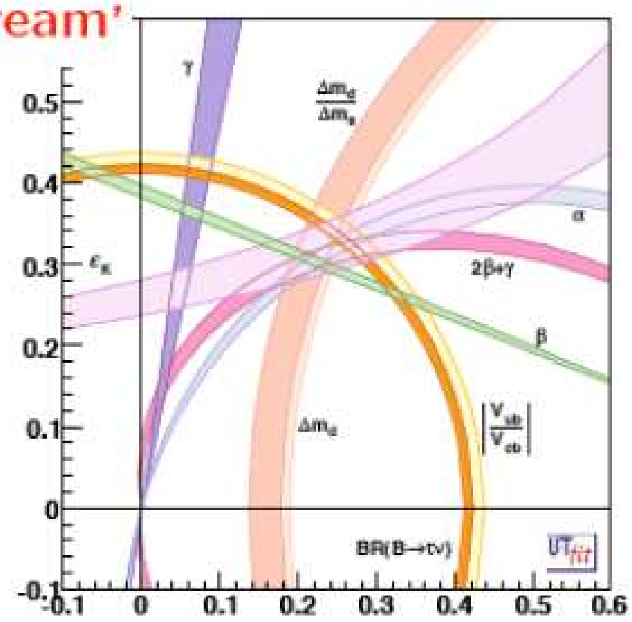
- CKMFitter and UTfit results on the Unitarity Triangle :
  - Vincent Tisserand, «EW fits CKMFitter ».
  - Viola Sordini, «EW fits UtFit ».

Outlook (1/2)

Superflavour factory: CKM theory gets tested at 1%



Transition also assumes theoretical progress to reduce hadronic uncertainties Lattice QCD, etc.



LHCb: won't do much better than BABAR and BELLE for α, as π^0 reconstruction from $B\rightarrow \rho^+\rho^-$ is difficult. But the $\rho^0\rho^0$ analysis can gain more. And γ will be measured precisely.
It will be difficult to improve the Vub measurement (semileptonic decays) and the study of radiative penguins is difficult too. But large boost for time dependent measurements, tops, …

A Super Flavour Factory can improve significantly all the CKM measurements, in particular the least well measured angles α and γ, and Vub.

Outlook (2/2)

NEW PHYSICS SEARCH:

• Some modes used for new physics search would be much better studied at a super flavour factory than at LHC if they include a neutrino or neutral particle in the final state.

• Reducing hadronic uncertainties is also crucial for some modes used for new physics searches in order to have accurate SM reference predictions.

BACK-UP SLIDES

« Wish list for the theorists » (1/2)

B physics, related to measurement of CKM elements:

$|V_{ub}|$: More precise form factors for exclusive modes, especially $B \to \pi l \nu$.

$|V_{us}|$: smaller theory uncertainties in the extraction of $|V_{us}|$ from hadronic τ decays ?

B physics, radiative and Electroweak penguin decays:

$b \to s \gamma$: is there more room for improvement on the calculation of $B(B \to X_s \gamma)$ (with a finite amount of work)?

"Semi-inclusive" decays ($b \to d \gamma$, $b \to s \gamma$, $b \to sll$): we try to estimate fully inclusive processes (e.g. $b \to d \gamma$) from an extrapolation from the sum of many exclusive states, but we only catch about 50% of the inclusive rate this way. Can the uncertainty on this extrapolation be quantified? Should we just stick with either fully inclusive measurements or well-measured exclusive modes and not bother with the "semi-inclusive" approach?

$b \to sll$: are there any explanations (SM or NP) at all for the isospin asymmetry at low q^2 in $K^{(*)}ll$? Maybe someone has some new ideas?

« Wish list for the theorists » (2/2)

B physics: the polarization puzzle

B→VV and VT charmless decays: polarization and BF predictions for charmless B→VT decays. BABAR just measured f_L for B→ $\omega K_2^*(1430)$ to be close to 0.5 (like for VV b→s penguin modes), but we have also measured fL for B→ϕ K_2^* to be close to 1 (incompatible with 0.5). Can you explain this new « polarization puzzle » ?

Charm Mixing:

Is it possible to make reliable predictions for x and y in the Standard Model with uncertainties significantly smaller than 1%?

Thinking about D^0-$\overline{D}^0$ mixing and CP violation (CPV) in charm decays, we have observed oscillations with relatively large mixing parameters. This might be a SM process, but it might be a signature for new physics. If the latter, where else should we be looking for the new physics? If we are seeing new physics here, where else will the same physics produce observables? Will models which produce mixing parameters at the percent level necessarily produce CPV in charm decays? Are there related signatures in B-meson decay? Would such physics affect the interpretation of the electroweak limits on the Higgs mass which emerge from analyses like that of the LEP Electroweak Working Group? Are there signatures which might be accessible at the Tevatron using existing datasets?

How specific models of new physics might generate observable CPV, and which searches for CPV are most likely to be fruitful (mixing-related analyses, Dalitz plot analyses, triple-product studies in 4-body decays, etc.) is certainly interesting. But we also want the theorists to think about the bigger picture -how what we study in charm decay relates to other types of measurements.

CP violation in the interference between mixing and decay

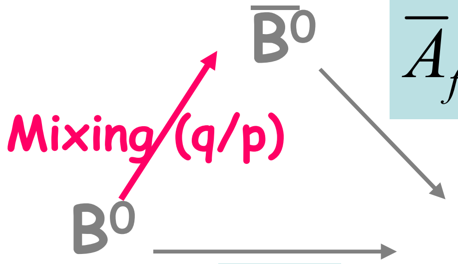
B⁰ mixing

$$|B_L\rangle = p|B^0\rangle + q|\overline{B}^0\rangle$$

$$|B_H\rangle = p|B^0\rangle - q|\overline{B}^0\rangle$$

$$\left|\frac{q}{p}\right| \cong 1$$

phase 2β



$\overline{A}_{f_{CP}}$

$A_{f_{CP}}$

f_{CP}

CP final state like $\pi^+\pi^-$ or $\rho^+\rho^-$

Time-dependent CP asymmetry

$$A_{f_{CP}}(\Delta t) = \frac{\Gamma(\overline{B}^0 \to f_{CP}) - \Gamma(B^0 \to f_{CP})}{\Gamma(\overline{B}^0 \to f_{CP}) + \Gamma(B^0 \to f_{CP})}$$

$$= S_{f_{CP}} \sin(\Delta m_d \Delta t) - C_{f_{CP}} \cos(\Delta m_d \Delta t)$$

$$\lambda_{f_{CP}} = \frac{q}{p} \times \frac{\overline{A}_{f_{CP}}}{A_{f_{CP}}}$$

***S* ≠ 0 : Indirect *CP* violation**

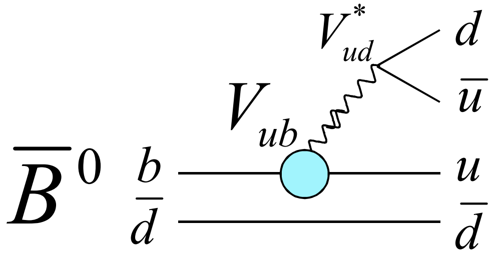
$$S_{f_{CP}} = \frac{2\,\Im(\lambda_{f_{CP}})}{1 + |\lambda|^2_{f_{CP}}}$$

***C* ≠ 0 : Direct *CP* violation**

$$C_{f_{CP}} = \frac{1 - |\lambda|^2_{f_{CP}}}{1 + |\lambda|^2_{f_{CP}}}$$

Case of $B^0 \to \pi^+\pi^-$ or $B^0 \to \rho^+\rho^-$

Tree decay

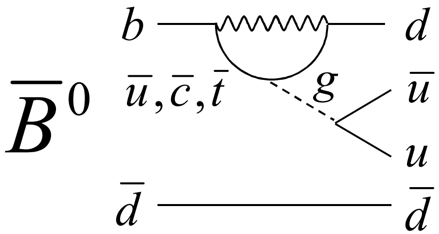


$\pi^-(\rho^-)$

$\pi^+(\rho^+)$

$\oplus$

Penguin decay pollution



$\pi^-(\rho^-)$

$\pi^+(\rho^+)$

phase γ

$$Amplitude\ T \propto V_{ud}^* V_{ub}\ (\propto A\lambda^3 \times e^{i\gamma})$$

$$Amplitude\ P \propto V_{td}^* V_{tb} (\propto A\lambda^3)$$

δ = strong phase difference between penguin and tree

Tree only

$$\lambda_{\pi^+\pi^-(\rho^+\rho^-)} = \frac{q}{p} \times \frac{\overline{T}}{T} = e^{-i2\beta} e^{-i2\gamma} = e^{i2\alpha}$$

$$S = \sin(2\alpha)$$

$$C = 0$$

Tree + Penguin

$$\lambda_{\pi^+\pi^-(\rho^+\rho^-)} = e^{i2\alpha} \times \frac{|T| + |P| e^{+i\gamma} e^{i\delta}}{|T| + |P| e^{-i\gamma} e^{i\delta}}$$

$$S = \sqrt{1 - C^2} \sin(2\alpha_{eff})$$

$$C \propto \sin\delta$$

α effective only

'α-scan' methods

- Fit on the dataset → measured values $\boldsymbol{M}_{fit}$ = {BR, C, S…} + correlation matrix C_{fit}
- *M* is function of the physical quantities {α, Ts, Ps…}

- How to constraint α?
  - ✓ Discretize [0°;180°] and for each scanned value α_k, minimize

$$\chi^2(\alpha_k) = {}^t\left[M(\alpha_k, Ts, Ps) - M_{fit}\right] C_{fit}^{-1} \left[M(\alpha_k, Ts, Ps) - M_{fit}\right] + \text{any constraint}$$

- ✓ Noting $\chi^2_{min} = \min_k\left[\chi^2(\alpha_k)\right]$, set $\Delta\chi^2(\alpha_k) = \chi^2(\alpha_k) - \chi^2_{min}$

  - ✓ Either directly compute a confidence level $CL(\alpha_k) = 1 - \text{Prob}\left[\Delta\chi^2(\alpha_k), N_{dof}\right]$

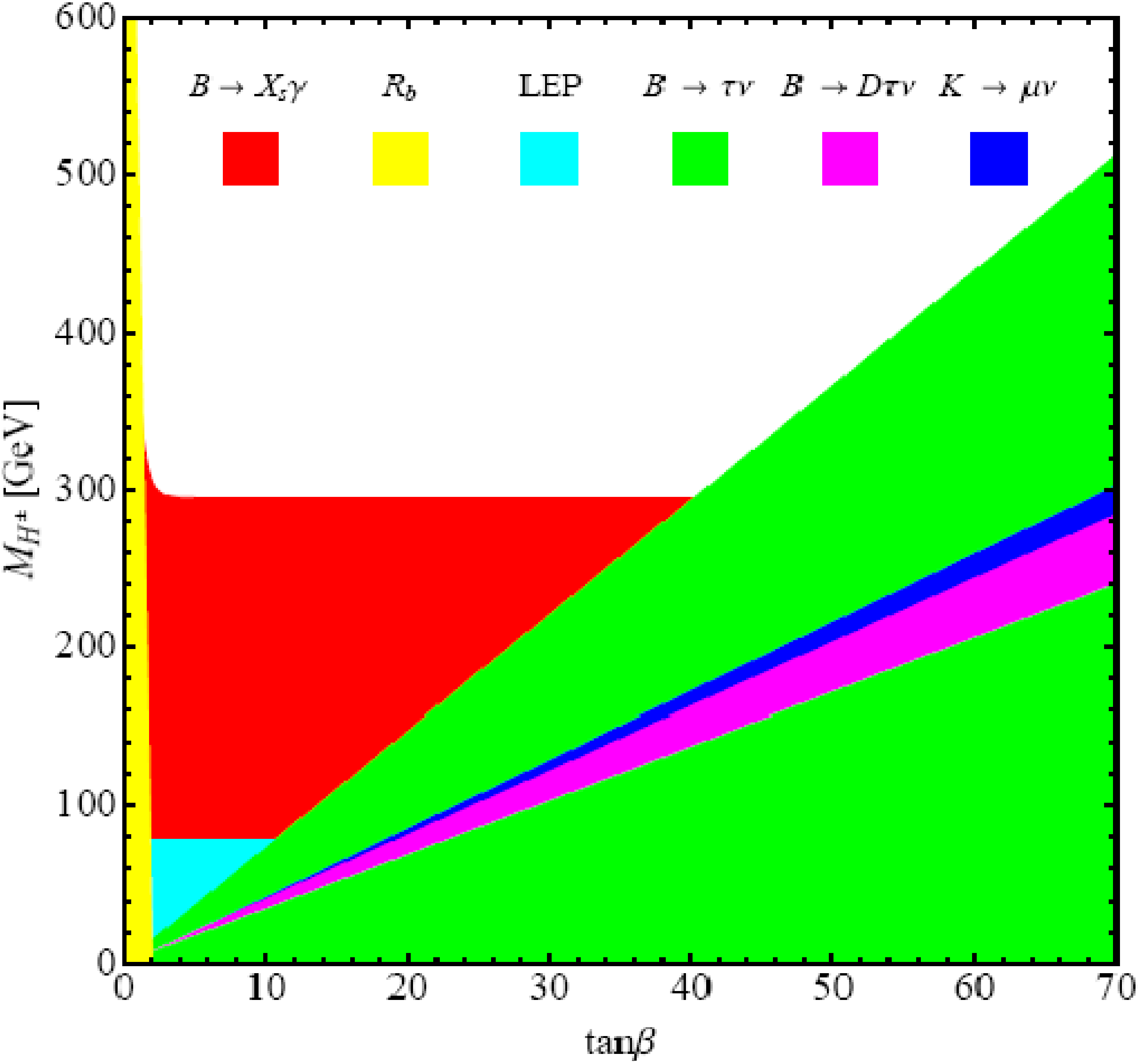
    ⇒ B → ππ, B → ρπ

  - ✓ Or generate MC experiments `à la Feldman-Cousins` (B → ρρ):

$$CL(\alpha_k) = \frac{\text{Number of experiments for which } \Delta\chi^2_{MC}(\alpha_k) < \Delta\chi^2_{data}(\alpha_k)}{\text{Number of experiments}}$$

  - ✓ Finally, plot $1 - CL(\alpha_k)$ vs α_k.

Probability of having the data described by the 'model' @ $\alpha = \alpha_k$


$B \to X_s\gamma$
R_b
LEP
$B \to \tau\nu$
$B \to D\tau\nu$
$K \to \mu\nu$
$M_{H^\pm}$ [GeV]
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
$\tan\beta$

CONCLUSIONS

$\Upsilon(3S) \to \gamma A^0, A^0 \to \mu^+\mu^-$

No significant $\Upsilon(3S) \to \gamma A^0$, $A^0 \to \mu\mu$ signal observed

Conference note at arXiv:0902.2176 [hep-ex]

Upper limits (90% CL) range from (0.25-5.2) x 10^{-6}

No significant signal at HyperCP mass (di-muon threshold)

BF($\Upsilon(3S) \to \gamma A^0$ ($m_{\mu\mu}$=214 MeV/c²)) < 0.8 x 10^{-6} (90% CL)

No evidence of $\eta_b \to \mu^+\mu^-$ decays

BR($\eta_b \to \mu^+\mu^-$) < 0.8% (90% CL)

$\Upsilon(3S) \to e^{\pm}\tau^{\mp}, \mu^{\pm}\tau^{\mp}$

No charged LFV observed

BR($\Upsilon(3S) \to e^{\pm}\tau^{\mp}$) < 5×10^{-6} (90% CL)

BR($\Upsilon(3S) \to e^{\pm}\tau^{\mp}$) < 4.1×10^{-6} (90% CL)

arXiv:0812.1021[hep-ex]

$\tau \to 3l(l = e, \mu)$

Results are not background limited, great opportunities for SuperB factories

No charged LFV observed in the 6 analysed channels

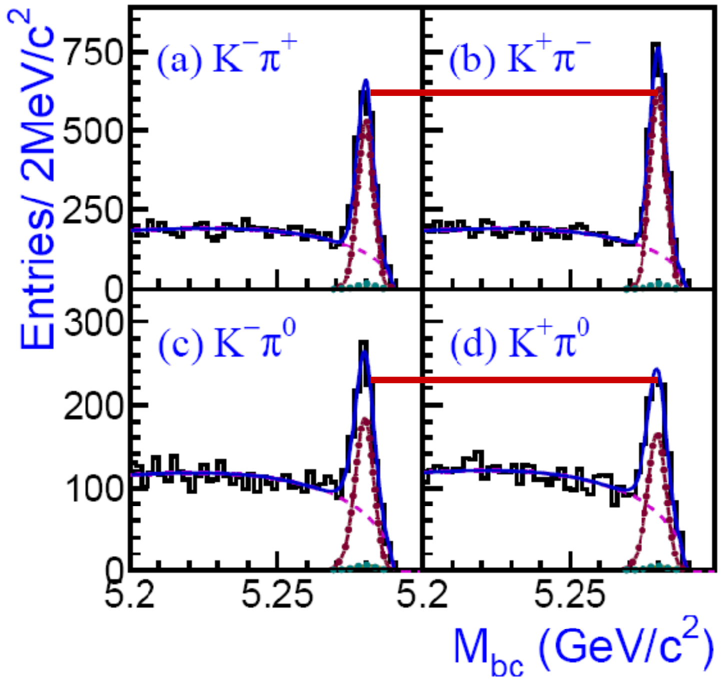
BR($\tau \to 3l$)< $(1.8 - 3.3)\times10^{-6}$ (90%CL) depending on the channel (preliminary results)

Significant improvement from previous BaBar analysis

Direct CP Violation in B→Kπ Decays

$$\mathcal{A}_{CP}(B \to f) = \frac{|\overline{A}|^2 - |A|^2}{|\overline{A}|^2 + |A|^2} \propto \sum_{i,j} A_i A_j \sin(\delta_i - \delta_j)\sin(\phi_i - \phi_j)$$

Belle Results: Nature 452, 332 (2008)



New Update

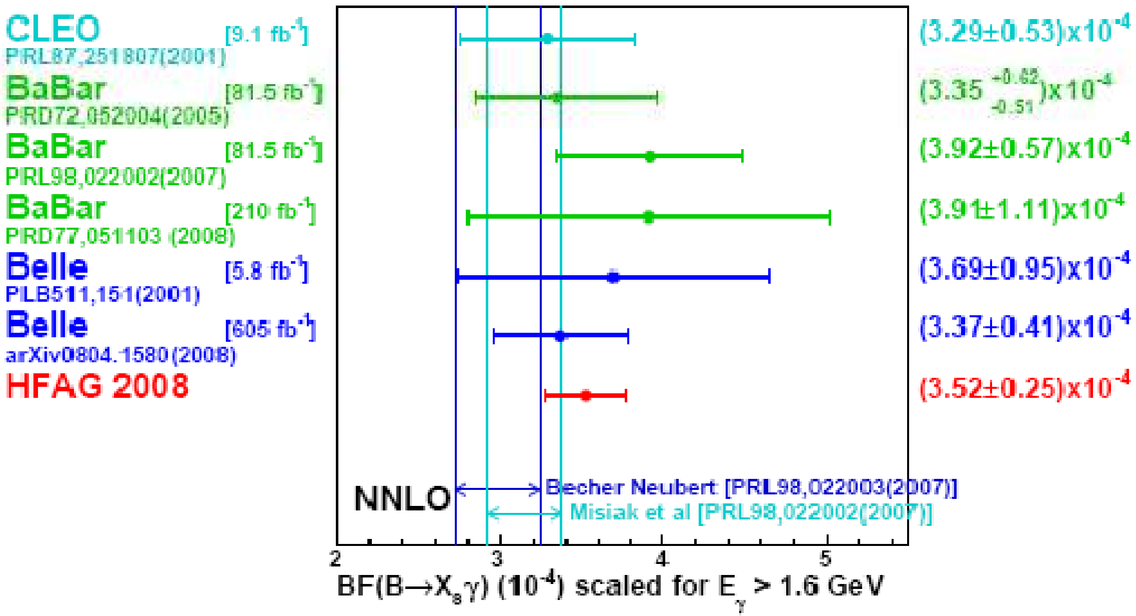
$A_{cp}(K^+\pi^-)$ =

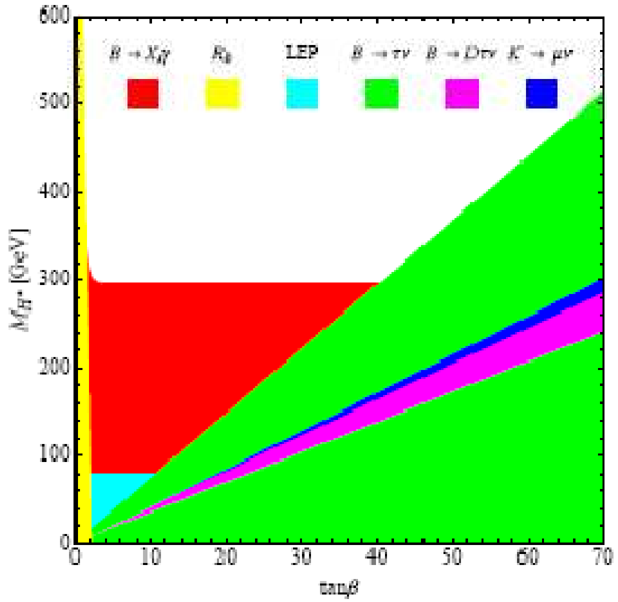
$-0.107 \pm 0.016\ ^{+0.006}_{-0.004}$	**BaBar**
$-0.094 \pm 0.018 \pm 0.008$	**Belle**
$-0.086 \pm 0.023 \pm 0.009$	**CDF**
$-0.04 \pm 0.16 \pm 0.02$	**CLEO**
$\Rightarrow -0.098\ ^{+0.012}_{-0.011}$ @ 8.1σ	**AVG**

$A_{cp}(K^+\pi^0)$ =

$+0.030 \pm 0.039 \pm 0.010$	**BaBar**
$+0.07 \pm 0.03 \pm 0.01$	**Belle**
$-0.29 \pm 0.23 \pm 0.02$	**CLEO**
$\Rightarrow +0.050 \pm 0.025$ **@2.0**σ	**AVG**

$\Delta A_{K\pi} = A_{cp}(K^+\pi^-) - A_{cp}(K^+\pi^0)$
$= -0.147 \pm 0.028$ @ 5.3σ





HFAG average: $\mathcal{B}(B \to X_s\gamma)_{E_\gamma > 1.6\ \mathrm{GeV}} = (3.52 \pm 0.25) \times 10^{-4}$

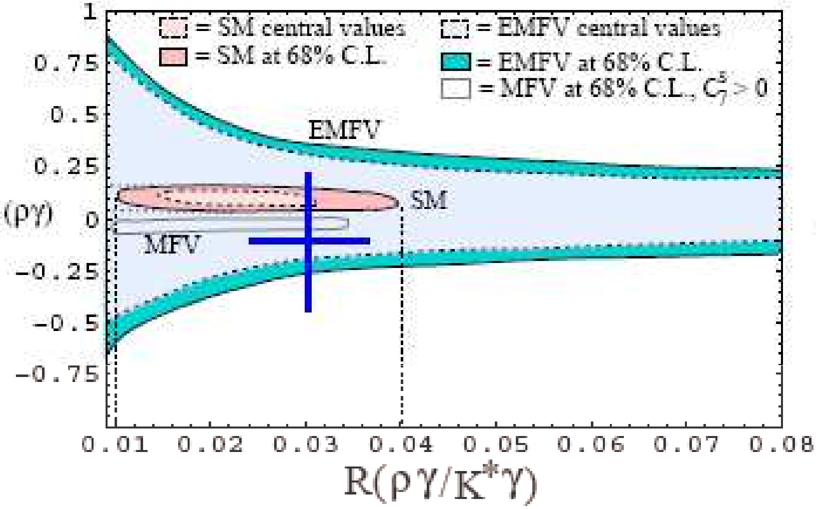
(scaling down to 1.6 GeV may be controvertial — motivation to lower E_γ)

- Agreement with latest NNLO calculation
- Strong constraints on generic 2HDM charged Higgs
  (MSSM charged Higgs case is more complicated due to possible destructive interference)
- Also strong constraints on various new physics scenarios
  (but bigger room than before as data $\mathcal{B}$ is now higher than SM)

CPV and isospin asymmetry in $B \to \rho\gamma$

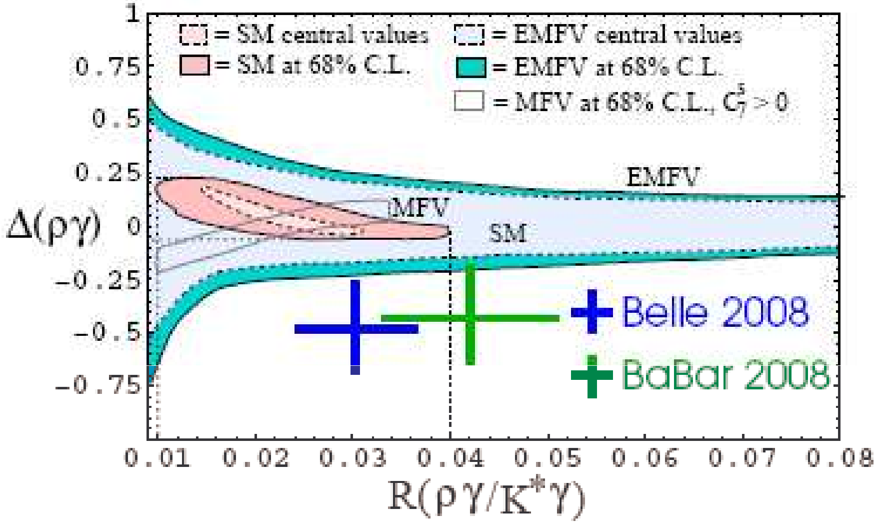
Direct CP asymmetry

$$A_{CP} = \frac{\mathcal{B}(B^- \to \rho^-\gamma) - \mathcal{B}(B^+ \to \rho^+\gamma)}{\mathcal{B}(B^- \to \rho^-\gamma) + \mathcal{B}(B^+ \to \rho^+\gamma)}$$



Isospin asymmetry

$$\Delta(\rho\gamma) = \frac{\Gamma(B^+ \to \rho^+\gamma)}{2\Gamma(B^0 \to \rho^0\gamma)} - 1$$



	Belle	BaBar
$R(\rho\gamma/K^*\gamma)$	$0.0302\,^{+0.0060}_{-0.0055}\,^{+0.0026}_{-0.0028}$	0.042 ± 0.009
$A_{CP}(\rho^+\gamma)$	$-0.11 \pm 0.32 \pm 0.09$	—
$\Delta(\rho\gamma)$	$-0.48\,^{+0.21}_{-0.19}\,^{+0.08}_{-0.09}$	$-0.43\,^{+0.25}_{-0.22} \pm 0.10$

Large Δ_ρ could be sign of new physics (Ali-Lunghi EPJC26, 195(2002)), or O(10%) Δ_ρ may be explained by non-perturbative charming penguin (C. Kim *et al.*, PRD78,054024(2008))

Wilson coeffients and $B \to K^*\ell^+\ell^-$

- Wilson coefficients to identify type of new physics

C_7 for magnetic penguin operator $[\frac{e}{8\pi^2}m_b\bar{s}_i\sigma^{\mu\nu}(1+\gamma_5)b_iF_{\mu\nu}]$

(size is determined from $b \to s\gamma$, but sign is from $b \to s\ell^+\ell^-$)

C_9 for vector electroweak operator $[(\bar{b}s)_{V-A}(\bar{\ell}\ell)_V]$

C_{10} for axial-vector electroweak operator $[(\bar{b}s)_{V-A}(\bar{\ell}\ell)_A]$

- Foward-backward asymmetry ($A_{\rm FB}$) and Wilson coefficients

$$A_{\rm FB}(q^2) = -C_{10}^{\rm eff}\xi(q^2)\left[Re(C_9^{\rm eff})F_1 + \frac{1}{q^2}C_7^{\rm eff}F_2\right]$$

(similar to γ-Z interference at high energy)

- Angular distributions to extract FB asymmetries

K^* logitudinal polarization F_L from kaon angle θ_K

$$\tfrac{3}{2}F_L\cos^2\theta_K + \tfrac{3}{4}(1-F_L)(1-\cos^2\theta_K)$$

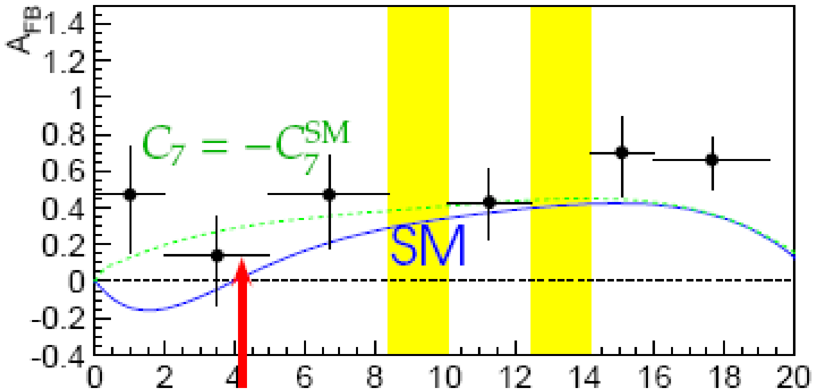
Forward-backward asymmetry $A_{\rm FB}$ from lepton angle θ_ℓ

$$\tfrac{3}{4}F_L(1-\cos^2\theta_\ell) + \tfrac{3}{8}(1-F_L)(1+\cos^2\theta_\ell) + A_{\rm FB}\cos\theta_\ell$$

F_L and $A_{\rm FB}$

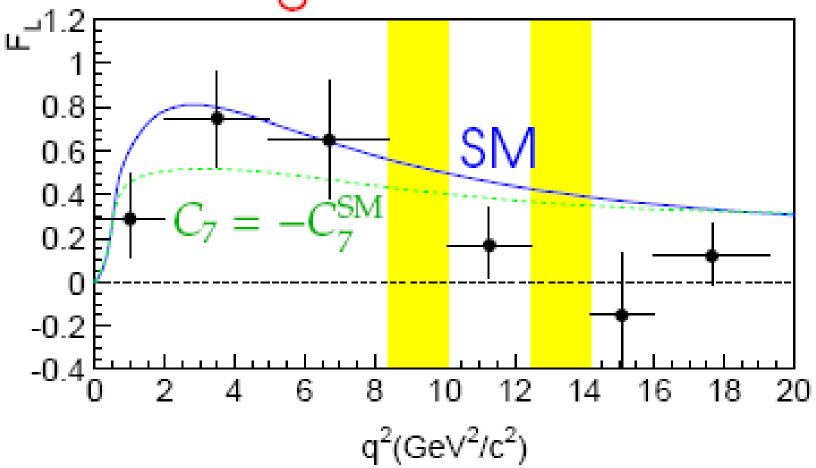
Belle

$A_{\rm FB}$ (Belle arXiv:0810.0335, 657M $B\overline{B}$)



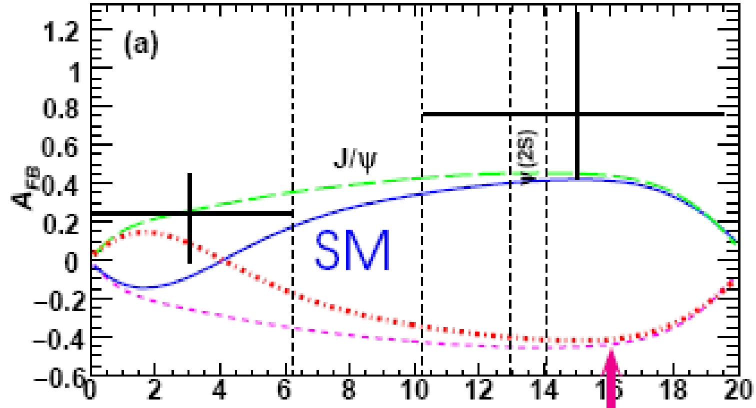
No crossing (Opposite sign C_7)?
Not enough statistics

F_L

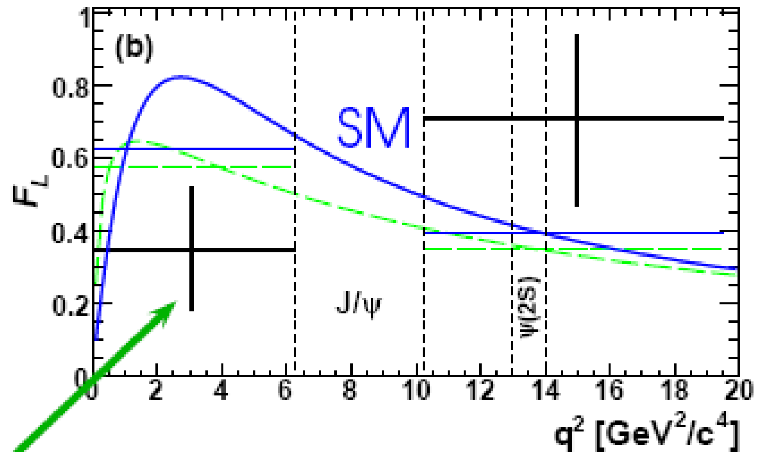


BaBar

(BaBar arXiv:0804.4412, 384M $B\overline{B}$)



Opposite sign C_9C_{10} is disfavored



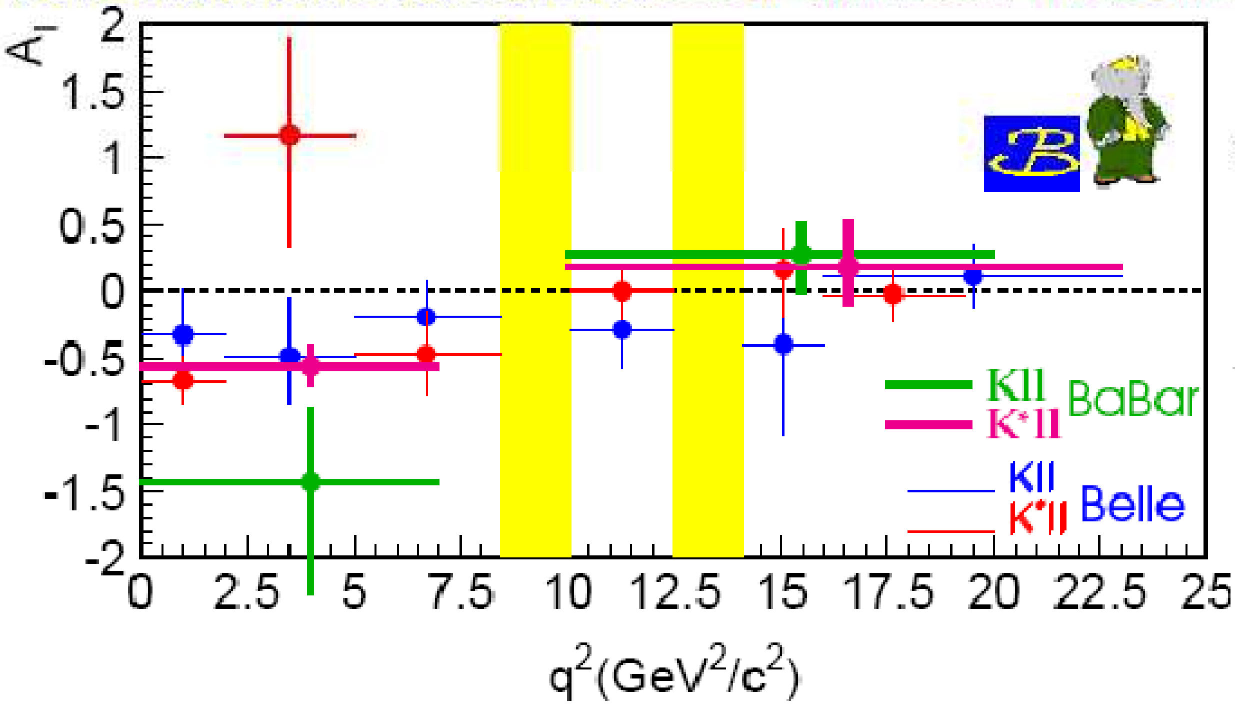
Anomaly? not in Belle

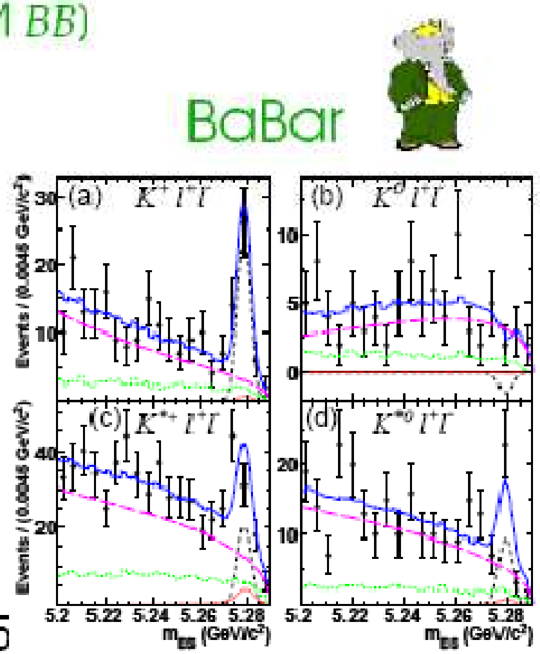
Review of Radiative Penguin Measurements — M. Nakao — p.16

Isospin asymmetry in $B \to K^*\ell^+\ell^-$

$$A_I^{K^{(*)}} = \frac{\Gamma(B^0 \to K^{(*)0}\ell^+\ell^-) - \Gamma(B^\pm \to K^{(*)+}\ell^+\ell^-)}{\Gamma(B^0 \to K^{(*)0}\ell^+\ell^-) + \Gamma(B^\pm \to K^{(*)+}\ell^+\ell^-)}$$

(Belle arXiv:0810.0335,657M $B\bar{B}$, BaBar arXiv:0807.4119,384M $B\bar{B}$)





Clear deficit of neutral $B^0 \to K^{(*)0}\ell^+\ell^-$ at low q^2 at BaBar?

Belle's data is consistent with null isospin asymmetry