Testing the CKM mechanism at the B factories: Status & outlook

Heiko Lacker (TU Dresden)

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CKM matrix
&
CP violation

Origin of the CKM matrix:

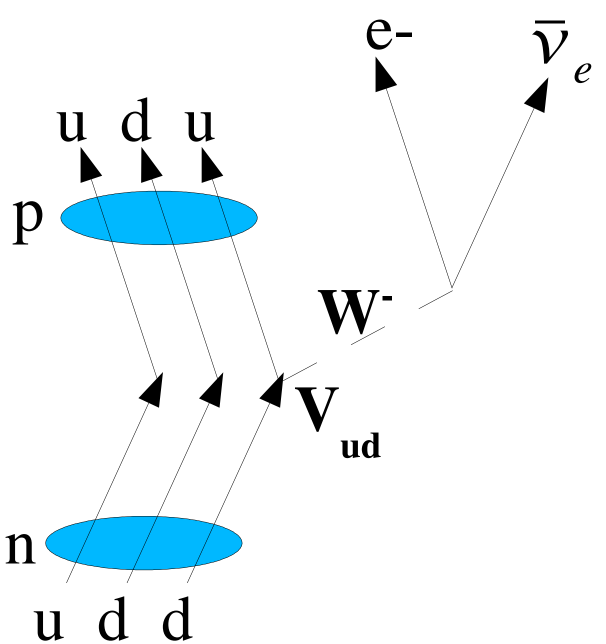
Mass & Weak Interaction Eigenstates

$$L_{quark\ masses} = \bar{u}_L M_u u_R + \bar{d}_L M_d d_R + h.c., \quad u \equiv \begin{pmatrix} u \\ c \\ t \end{pmatrix}, d \equiv \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

M_u, M_d
complex
3x3-Matrices

DIAGONALISATION: $M_{u,diag} = U_L^+ M_u U_R \quad M_{d,diag} = D_L^+ M_d D_R$

Charged weak current:



Eigenstates of weak interaction

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = U_L^+ D_L \cdot \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

Mass Eigenstates

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$ unitary

Why should we care about CKM parameter values?

- **They are fundamental parameters of the theory as the masses!**

$$L_{quark\ masses} = \bar{u}_L M_u u_R + \bar{d}_L M_d d_R + h.c.$$

- **SM: Higgs-Fermion couplings!**

But: Higgs-Fermion couplings are beyond SM physics!

=> Determine CKM parameters as precisely as possible
Physics driving Flavor needs to explain them

$$V_{CKM} \approx \begin{pmatrix} 0.974 & 0.226 & 0.004 \cdot e^{-i59^\circ} \\ -0.226 & 0.973 & 0.042 \\ 0.008 \cdot e^{-i23^\circ} & 0.041 & 0.999 \end{pmatrix}$$

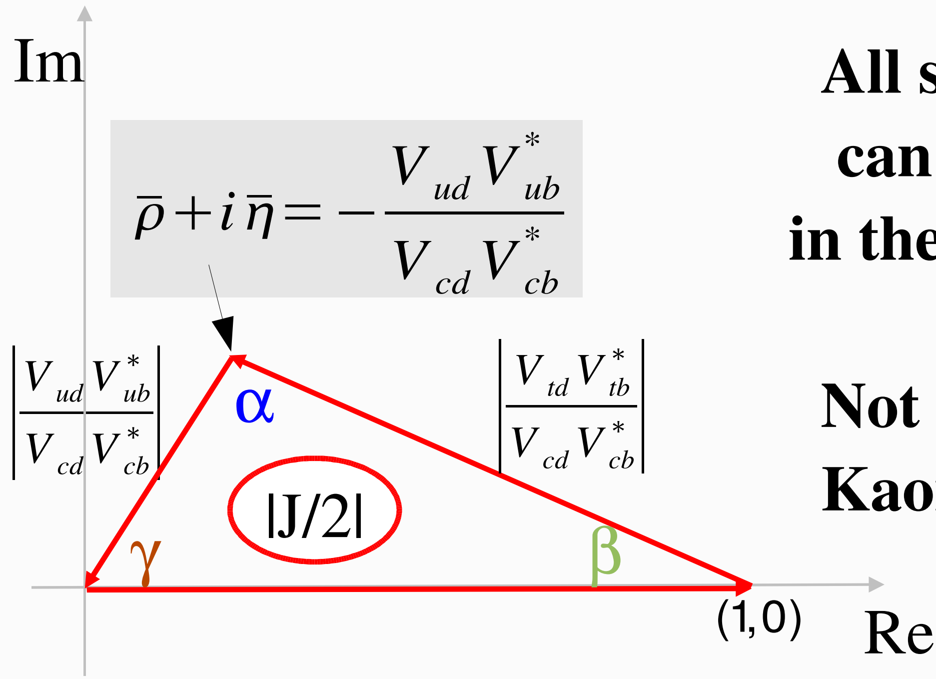
CP violation!

$$V_{PMNS} \approx \begin{pmatrix} 0.8 & 0.6 & <0.07 \\ -0.4 & 0.6 & 0.7 \\ 0.4 & -0.6 & 0.7 \end{pmatrix}$$

CP violation?

CP violation in CKM quantitatively: Unitarity Triangle

$$\frac{1}{V_{cd}V_{cb}^*}\left(V_{ud}V_{ub}^*+V_{cd}V_{cb}^*+V_{td}V_{tb}^*\right)=0$$



J: Jarlskog parameter

All sides & angles can be determined in the B-meson system!

Not the whole story: Kaon, B_s & D system

All data compatible with CKM ?

Yes

Precise determination of CKM parameters

No

New Physics beyond SM (Higgs sector, SUSY, ...)

B factories

Physics Programme
Status & Plans

Physics Programme of BABAR/Belle

CKM parameters

- $\sin 2\beta$
- α
- γ
- $\sin(2\beta+\gamma)$
- V_{ub}
- V_{cb}

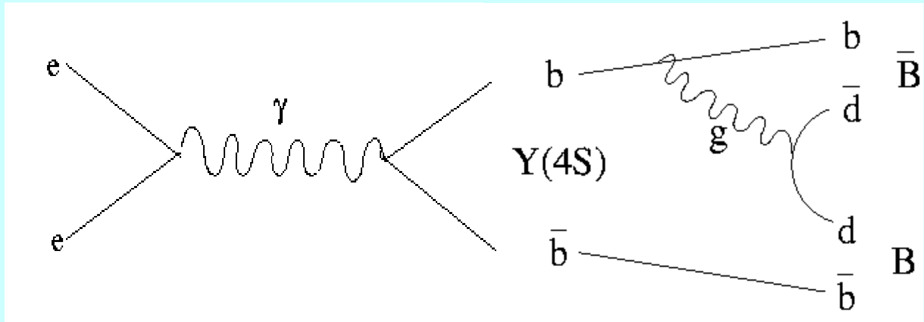
Search for New Physics

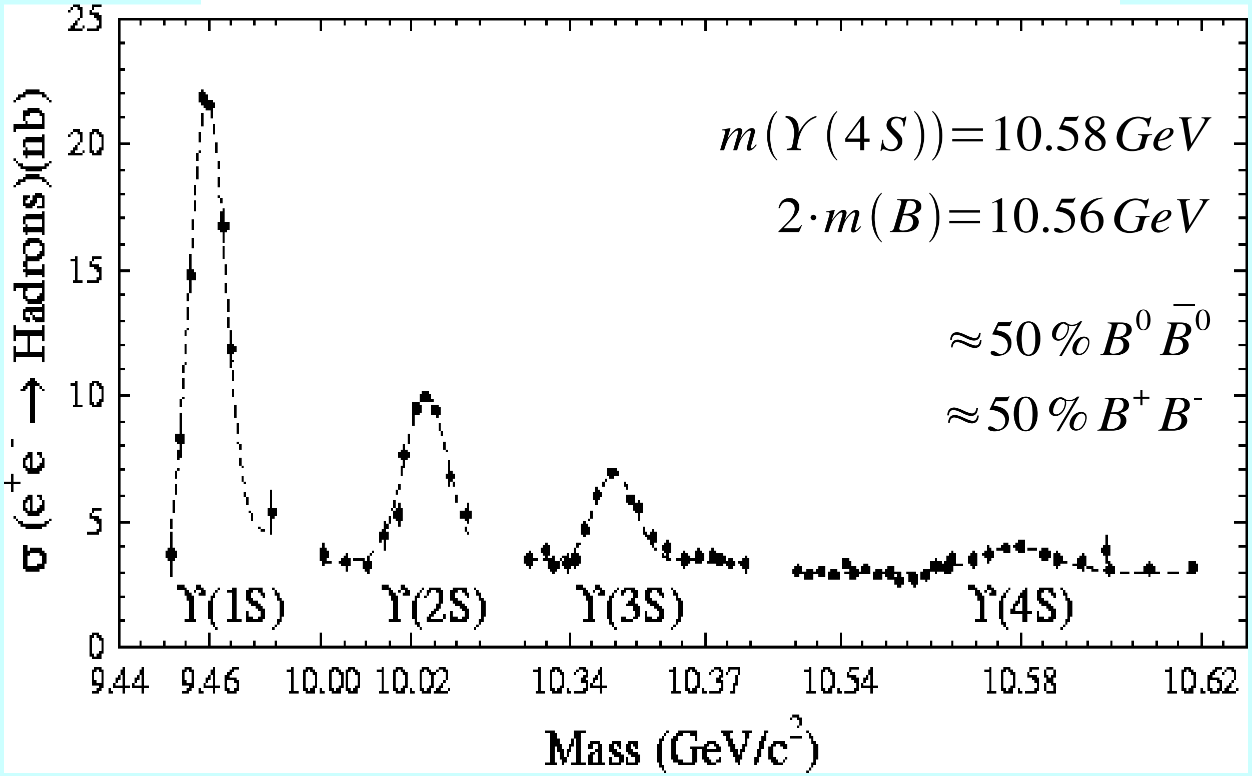
- $\sin 2\beta$ in penguin modes
- Rare B decays
  ($B \to \tau\nu$, $s\gamma$, $\rho\gamma$, $K^{(*)}ll$, $K^{(*)}\nu\bar{\nu}$ ...)

More than just B-factories

- tau, charm, ISR, two photon physics
  => Rare τ ($\tau \to l\gamma$, ...) & charm ($D^0 \to l^+l^-$, ...) decays; R, ...
- Spinoff:
  1. Many new unexpected states discovered (D_{SJ}, X(3872), Y(4260), ...)
  2. Pentaquark search in different environments

A clean B-meson source: ϒ(4S)



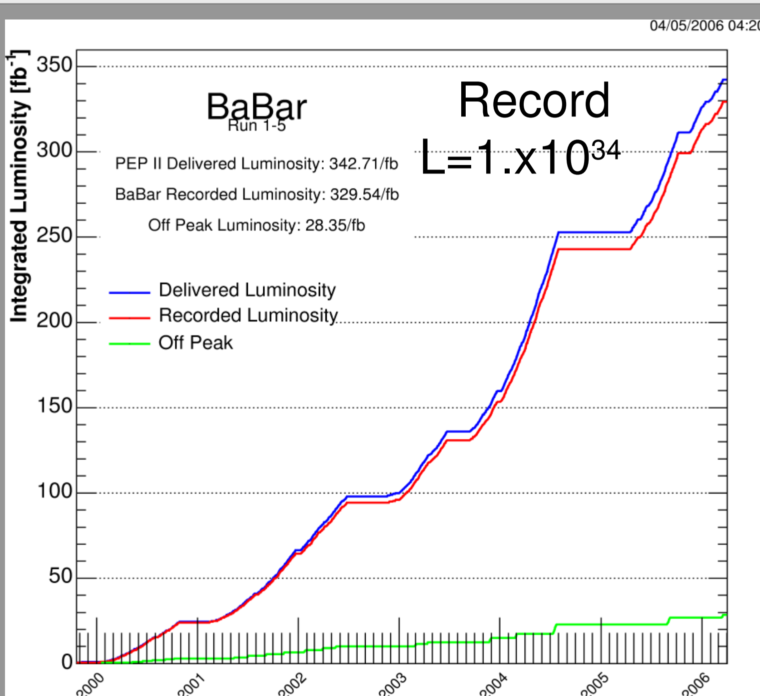


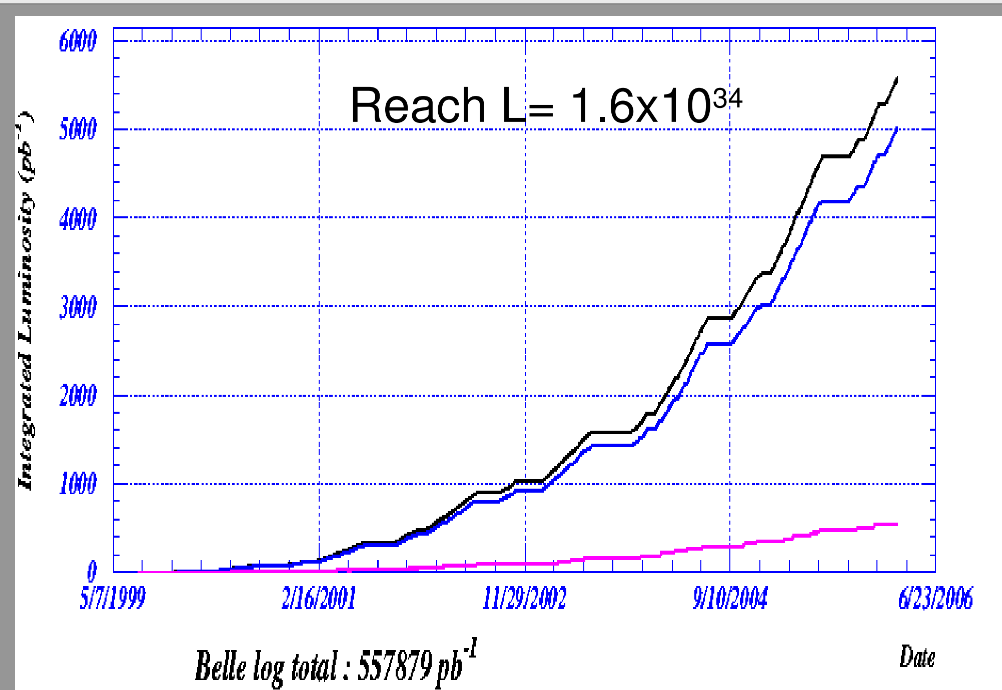
$e^+e^- \rightarrow$	σ(nb)
b $\bar{b}$	1.05
u $\bar{u}$	1.39
d $\bar{d}$	0.35
s $\bar{s}$	0.35
c $\bar{c}$	1.30
$\tau^+\tau^-$	0.94
$\mu^+\mu^-$	1.16
e^+e^-	≈40

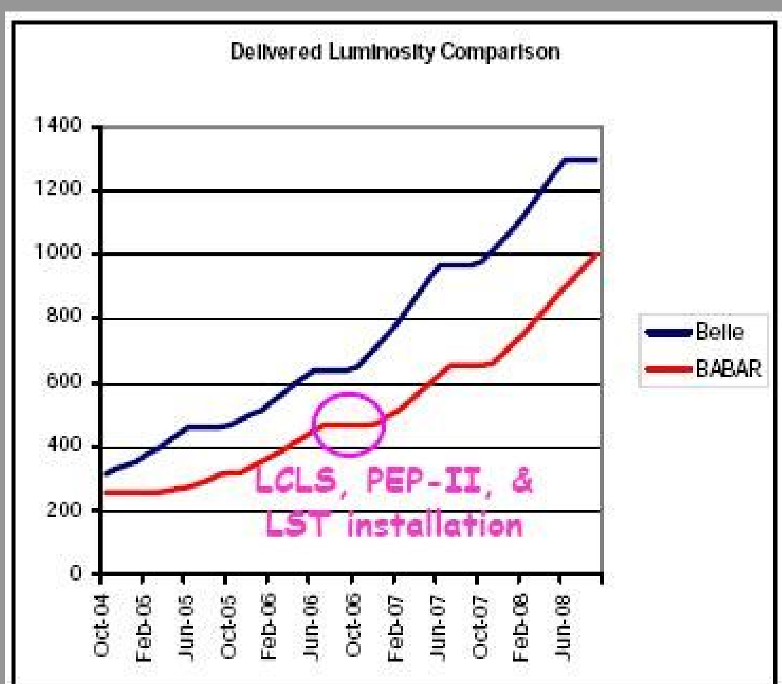
\+ **S/B ~ 1/3.5 (Hadron Machines O(10^{-3}))**

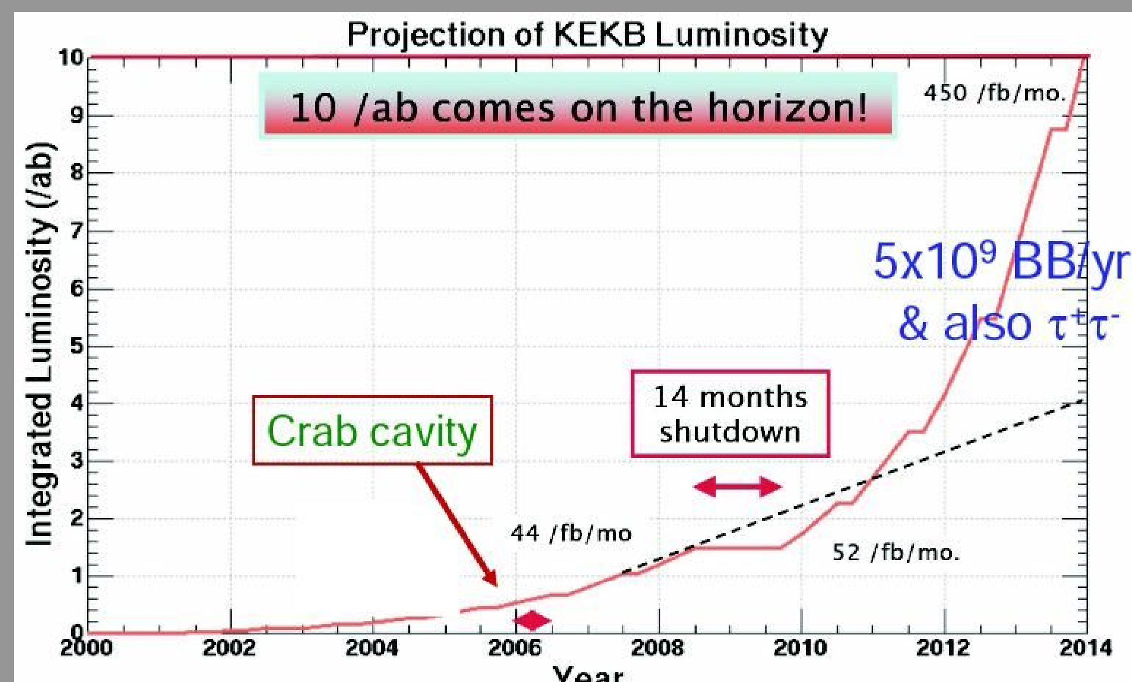
\- **Small cross section => High luminosity needed and provided @ PEP-II/BABAR & KEKb/Belle**

The B-Factories: Performance & Plans







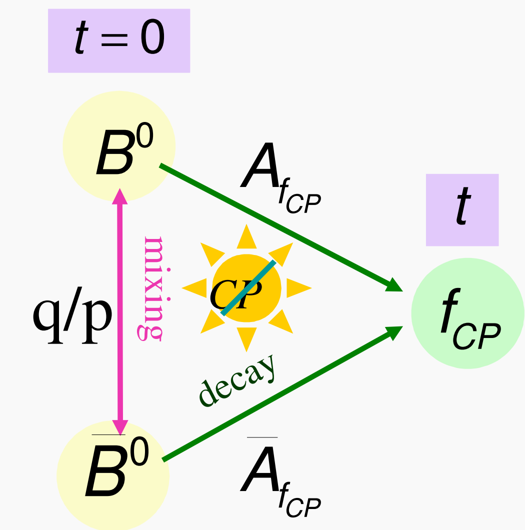


Veni, vidi, vici:
sin2β

Different manifestations of *CP* violation

$$i\frac{d}{dt}\begin{pmatrix}B^0\\ \bar{B}^0\end{pmatrix}=\left(M-\frac{i}{2}\Gamma\right)\begin{pmatrix}B^0\\ \bar{B}^0\end{pmatrix}$$

$$|B_L> \propto p|B^0> + q|\bar{B}^0>$$
$$|B_H> \propto p|B^0> - q|\bar{B}^0>$$
$$\Delta m_d \equiv M_H - M_L$$



$$\lambda_{f_{CP}} = \eta_{f_{CP}} \frac{q}{p}\frac{\bar{A}_{f_{CP}}}{A_{f_{CP}}}$$

***CP*-Eigenvalue**

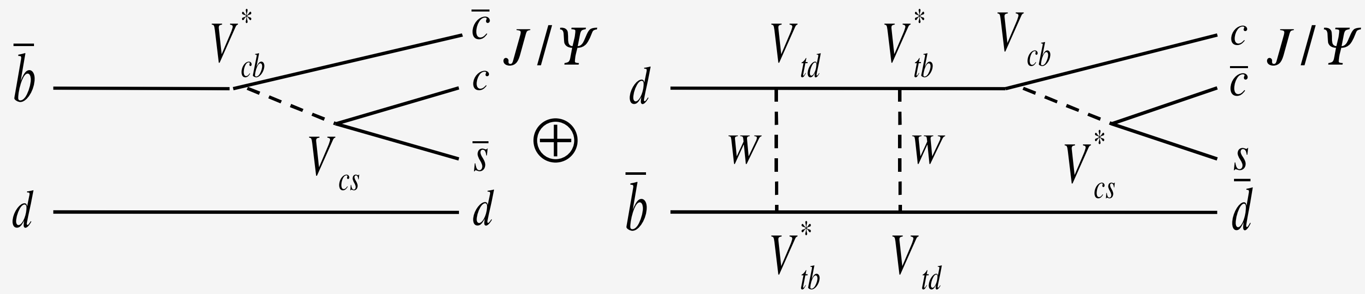
$$A_{CP}(t)=\frac{\Gamma(\bar{B}^0(t)\to f_{CP})-\Gamma(B^0(t)\to f_{CP})}{\Gamma(\bar{B}^0(t)\to f_{CP})+\Gamma(B^0(t)\to f_{CP})}$$

$$=\frac{2\,\mathrm{Im}\,\lambda}{1+|\lambda|^2}\sin(\Delta m_d t)-\frac{1-|\lambda|^2}{1+|\lambda|^2}\cos(\Delta m_d t)$$

Oscillation frequency

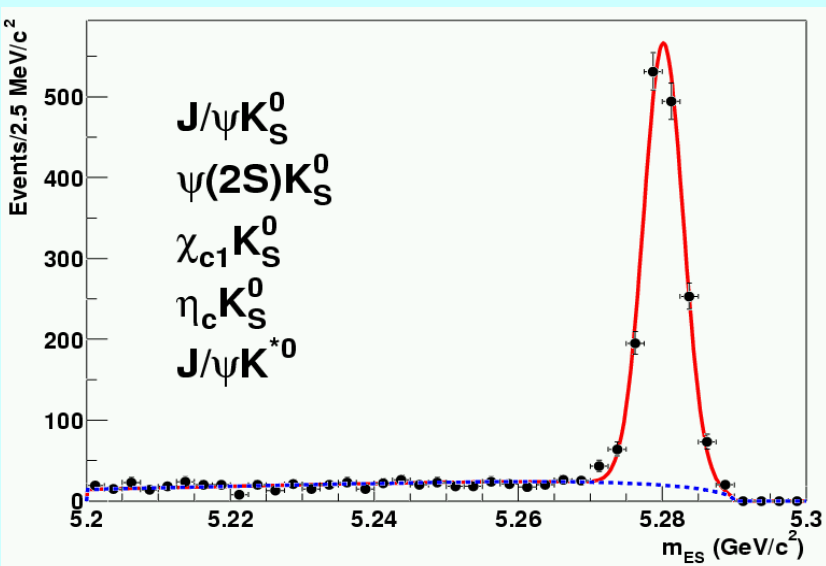
- ***CP* violation in *Mixing*:** $|q/p| \neq 1$
- ***CP* violation in *Decay*:** $|\bar{A}_{f_{CP}}/A_{f_{CP}}| \neq 1$
- ***CP* violation in *Interference between decay with and without Mixing*:** $\mathrm{Im}\,\lambda_{f_{CP}} \neq 0$

Nature distinguishes between Matter and Antimatter



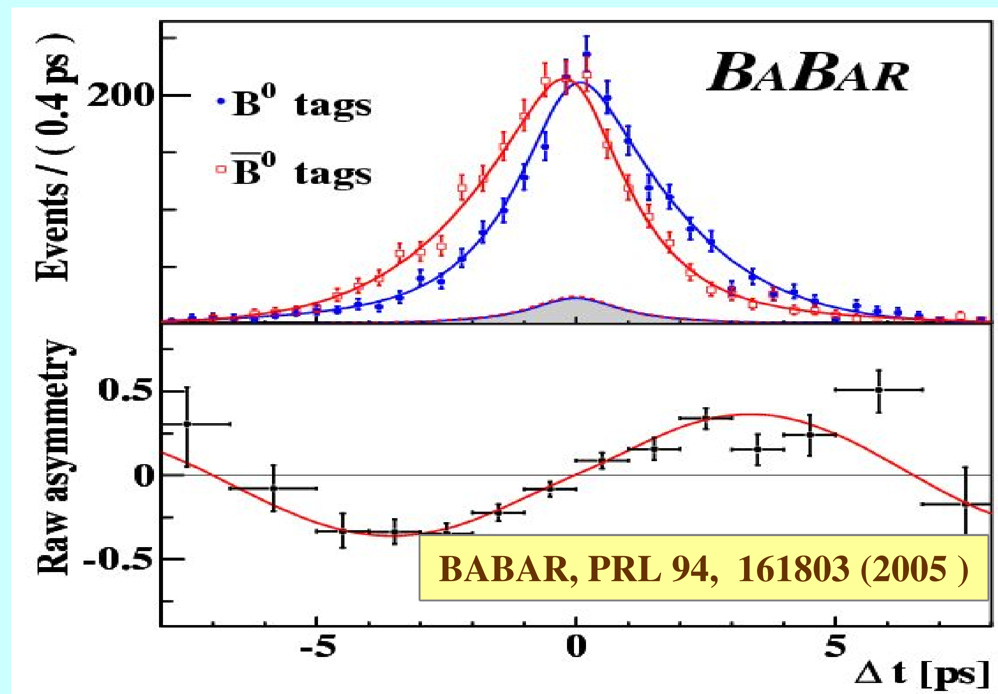
$$\lambda \approx e^{-2 \cdot i\beta}$$

A clean measurement:



Expected CP asymmetry:

$$A_{CP}(t) = \sin(2\beta) \cdot \sin(\Delta m_d \Delta t)$$

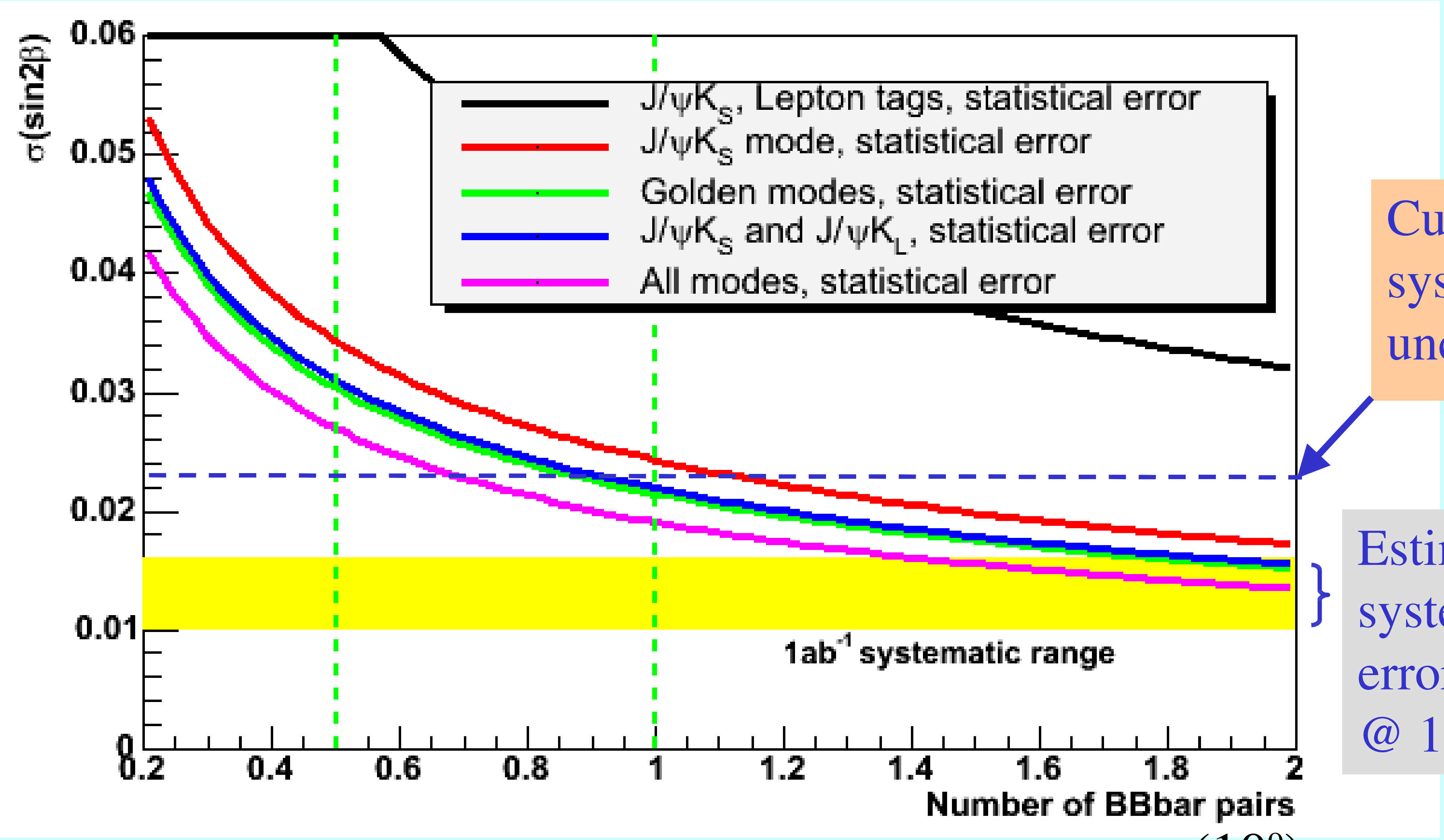


BABAR 0.722±0.040±0.023

Belle 0.652±0.039±0.020

WA: $0.685 \pm 0.032 \pm 0.016$

sin2β uncertainties vs. integrated luminosity

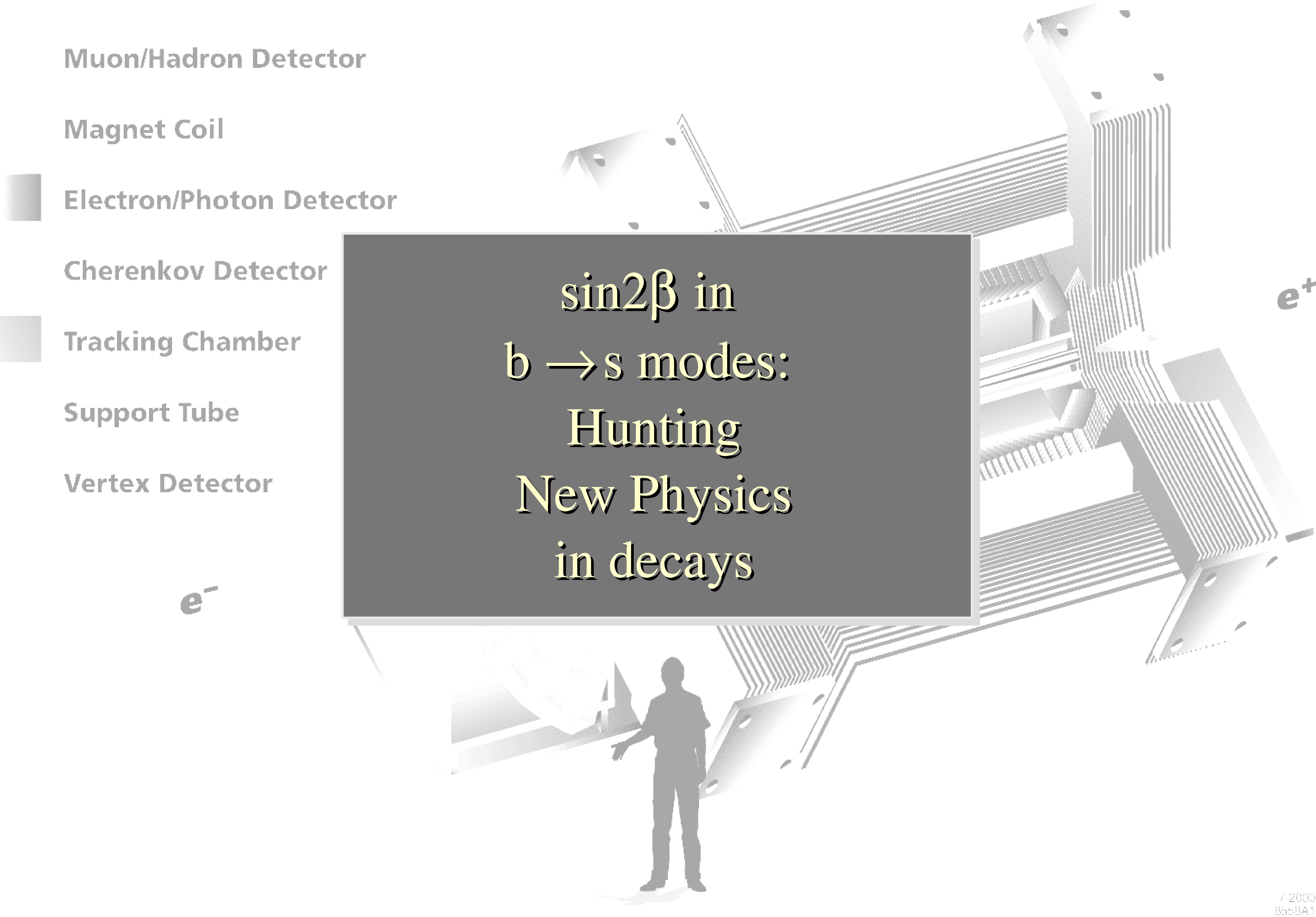


(10^9)

Current systematic uncertainty

Estimated systematic error range @ 1 ab^{-1}

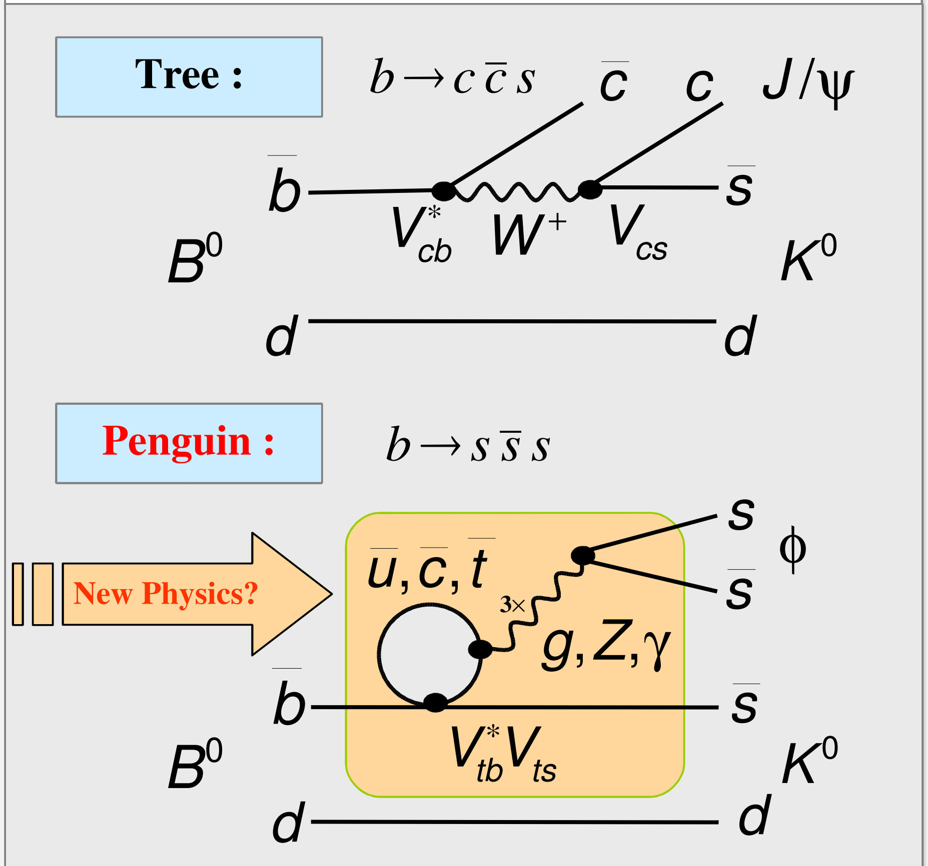
At 1 ab^{-1}, sin2β uncertainty can be improved by nearly a factor of 2.

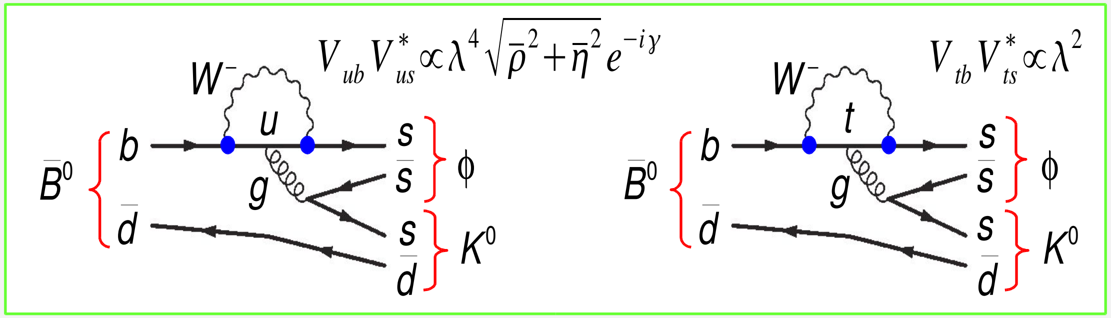


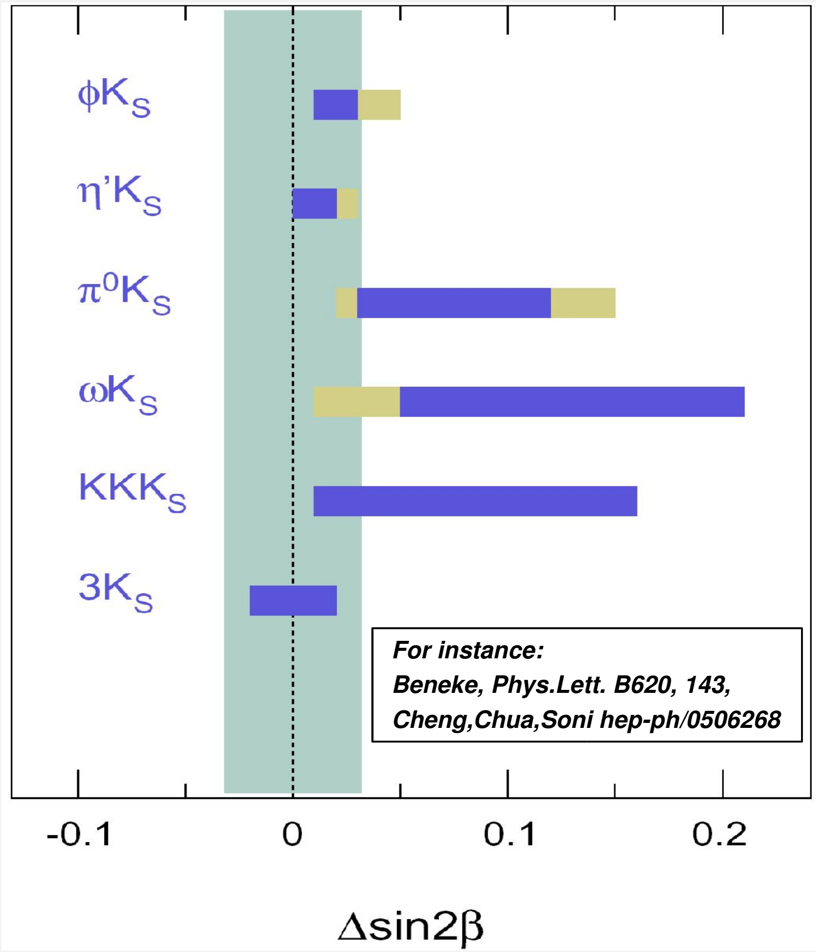
sin2β in $b \rightarrow s$ modes: Hunting New Physics in decays

Confronting Loop Decays with Tree Dominance

Both decays dominated by one single weak phase

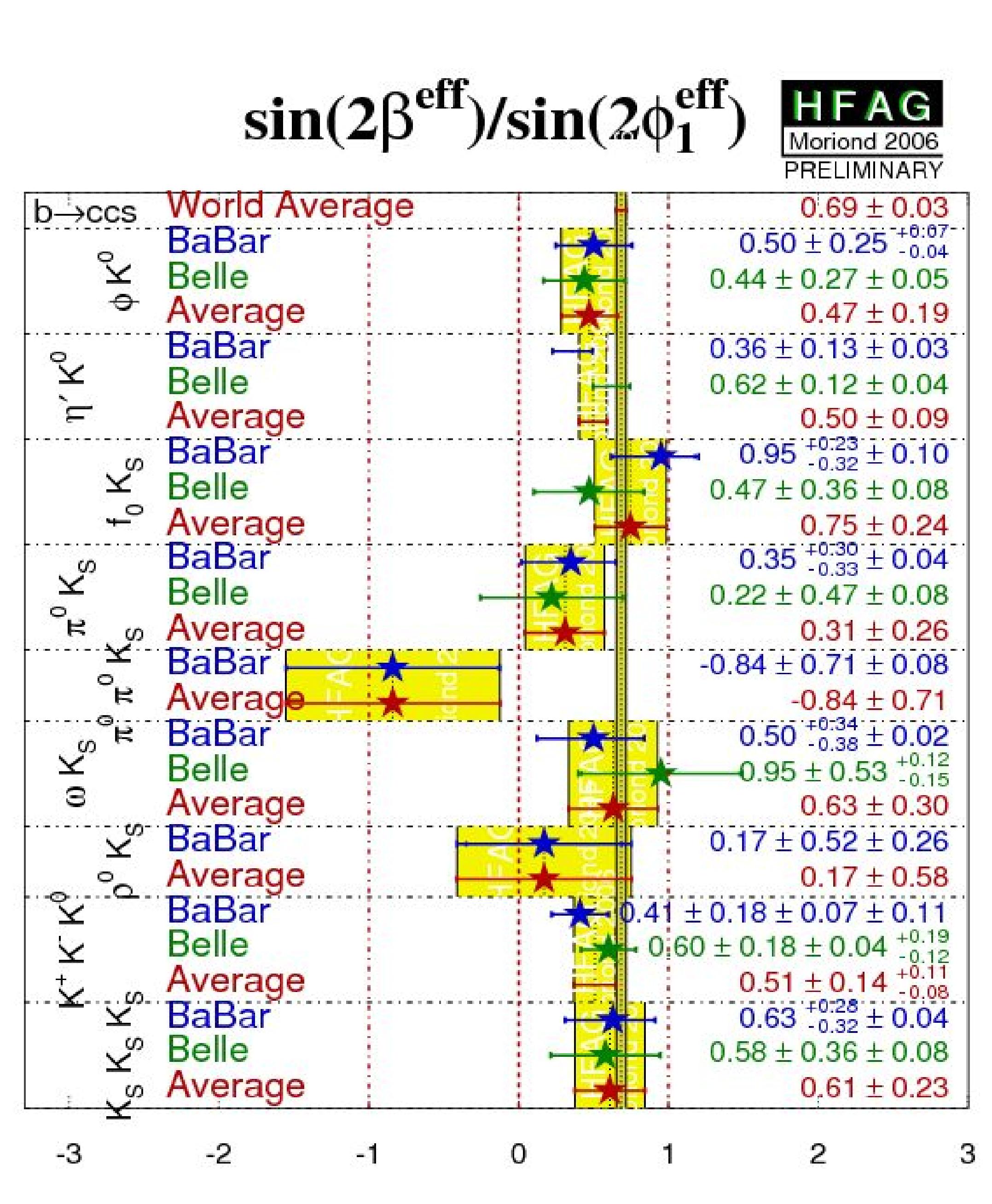




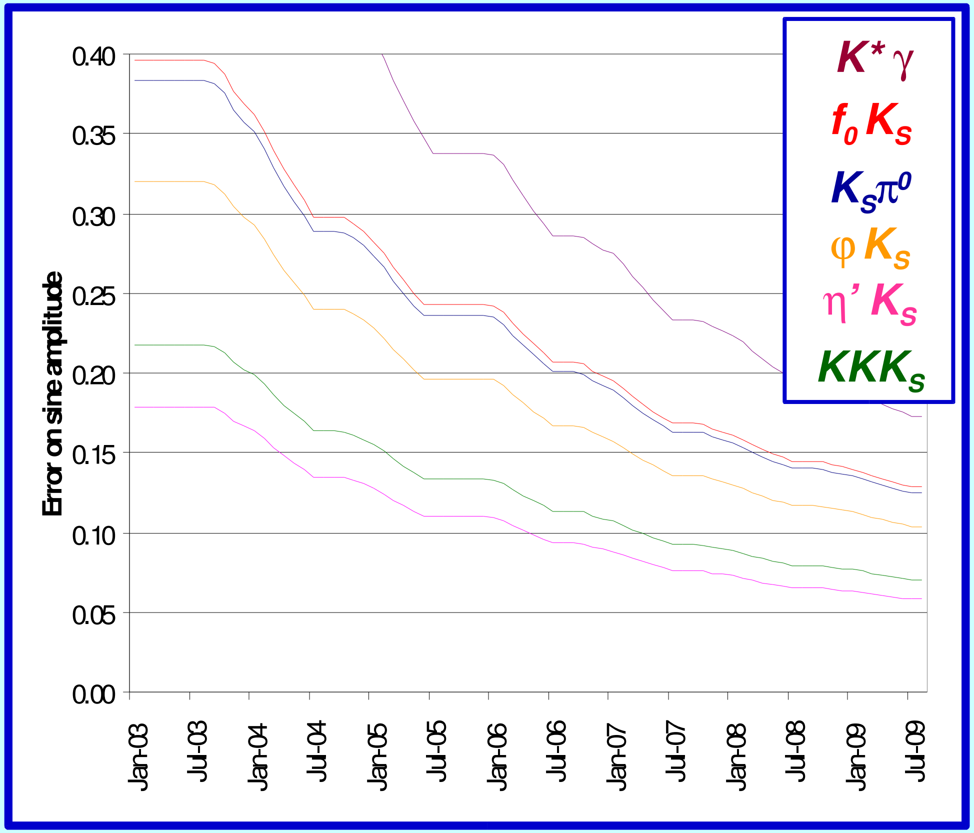


Standard model	New Physics
$S_{J/\psi Ks} = S_{\phi Ks} = \sin 2\beta$	$S_{J/\psi Ks} \neq S_{\phi Ks}$
$C_{J/\psi Ks} \sim C_{\phi Ks} \sim 0$	$C_{J/\psi Ks} \neq C_{\phi Ks}$

Experimental situation and outlook



Extrapolation for *BABAR*:



Averaging all penguin modes misleading:

1. SM uncertainties different

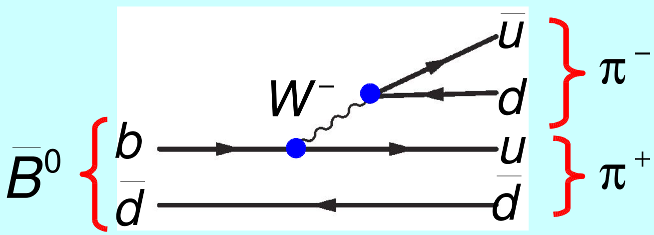
2. NP effects likely to be different

Better than expected: the angle α

"Charmless" $b \to u$ Decays

$\boxed{b \to u \bar{u} d}$

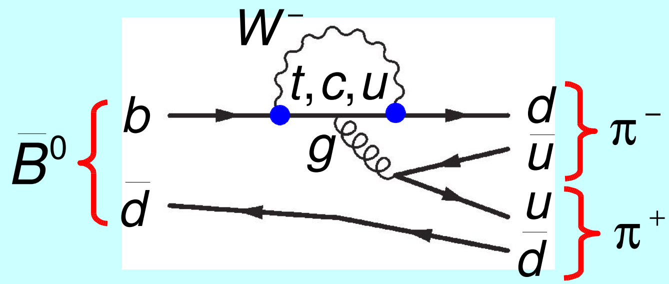
Tree : dominant



$\propto V_{ub} V_{ud}^*$

$\propto \lambda^3$

Penguin : competitive ?



$\propto V_{tb} V_{td}^*$

$\propto \lambda^3$

Principal modes :

$B^0/\bar{B}^0 \to \pi^+ \pi^-$

$B^0/\bar{B}^0 \to \rho^\pm \pi^\mp$

$B^0/\bar{B}^0 \to \rho^+ \rho^-$

Not a *CP* eigenstate

★ **If penguin is negligible**

$$\lambda_{h^+h^-} = \eta_{h^+h^-} \frac{V_{tb}^* V_{td}}{V_{tb} V_{td}^*} \frac{V_{ub} V_{ud}^*}{V_{ub}^* V_{ud}} = \eta_{h^+h^-} e^{2 \cdot i \alpha}$$

$$C_{h^+h^-} = \frac{1 - |\lambda_{h^+h^-}|^2}{1 + |\lambda_{h^+h^-}|^2} = 0$$

$$A_{\pi^+\pi^-}(t) = \sin(2\alpha)\sin(\Delta m_d t)$$

★ **However: Penguin contribution <u>not</u> negligible!**

$|\lambda| \neq 1 \quad \Rightarrow \quad C_{\pi\pi} \neq 0$

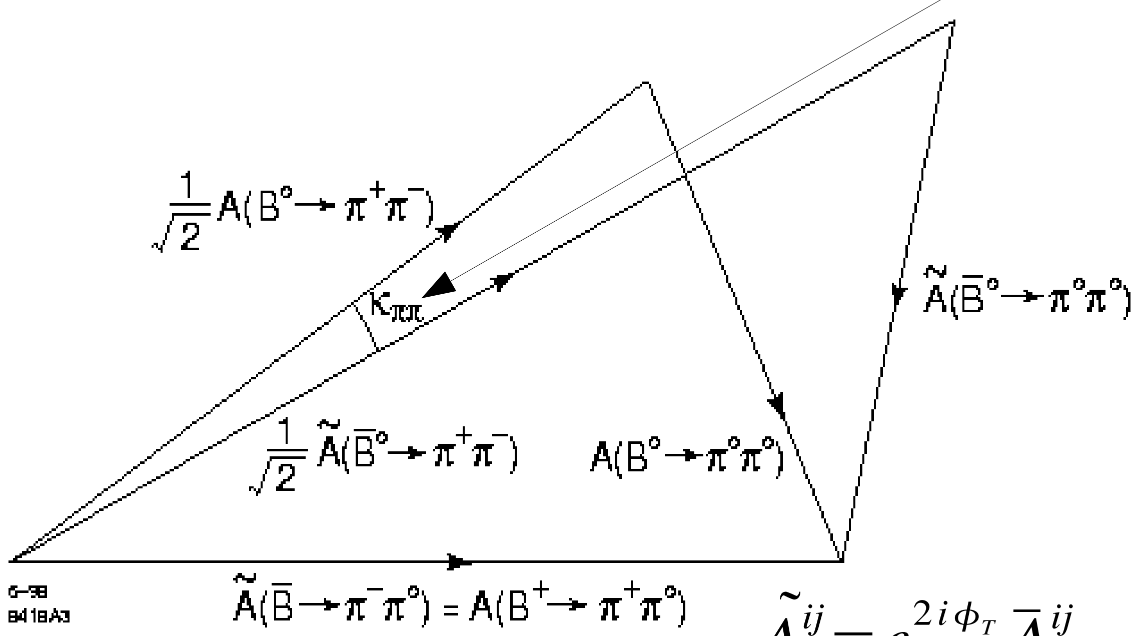
$\mathrm{Im}(\lambda) \neq \sin(2\alpha) \Rightarrow S_{\pi\pi} \sim \sin(2\alpha_{\mathrm{eff}}) \quad \Rightarrow \quad |P_{\pi\pi}/T_{\pi\pi}|, \delta = \arg(P_{\pi\pi}/T_{\pi\pi})$?

Isospin Analysis for $B \to \pi\pi, \rho\rho$

SU(2) analyses : **Gronau-London**, PRL 65, 3381 (1990), **Lipkin *et al.***, PRD 44, 1454 (1991), a.o.

$$A^{+0} = \frac{1}{\sqrt{2}} A^{+-} + A^{00} \quad \xleftrightarrow{\text{CP conjugation}} \quad \bar{A}^{-0} = \frac{1}{\sqrt{2}} \bar{A}^{+-} + \bar{A}^{00}$$

$$2\alpha_{eff} = 2\alpha + \kappa_{\pi\pi}$$



$$\tilde{A}^{ij} = e^{2i\phi_T} \bar{A}^{ij}$$

$$\cos(2\alpha - 2\alpha_{eff}) \geq \frac{1 - 2B^{00}/B^{+0}}{\sqrt{1 - C^2_{\pi\pi}}}$$

Grossman-Quinn 98; Charles 99; Gronau-London-Sinha-Sinha 01

BR($\pi^+\pi^-$) = $(5.0 \pm 0.4)\cdot 10^{-6}$
BR($\pi^\pm\pi^0$) = $(5.5 \pm 0.6)\cdot 10^{-6}$
***BR*($\pi^0\pi^0$) = $(1.45 \pm 0.3)\cdot 10^{-6}$**

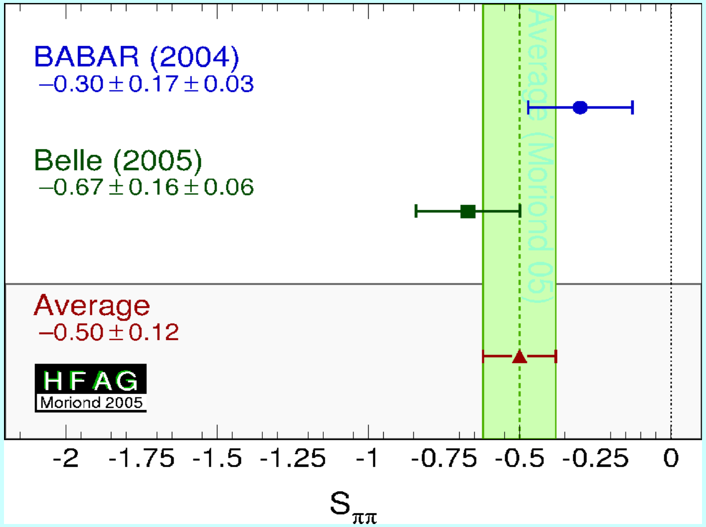
Bound is weak.
Full SU(2) analysis needed

***C*($\pi^0\pi^0$) = 0.28 ± 0.40**

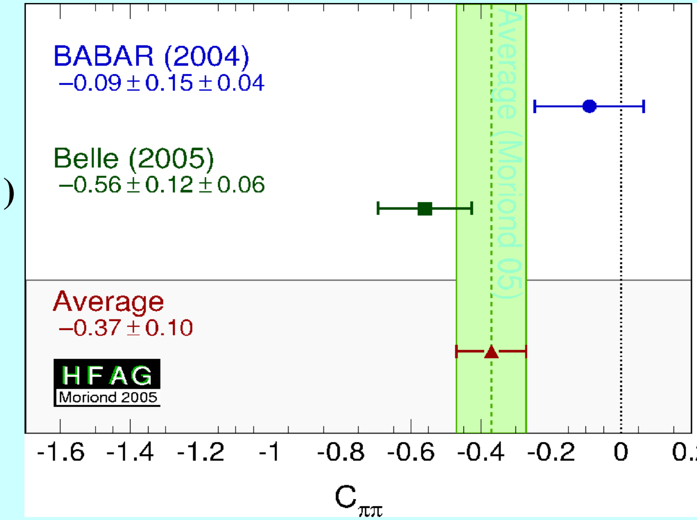
α can be extracted up to

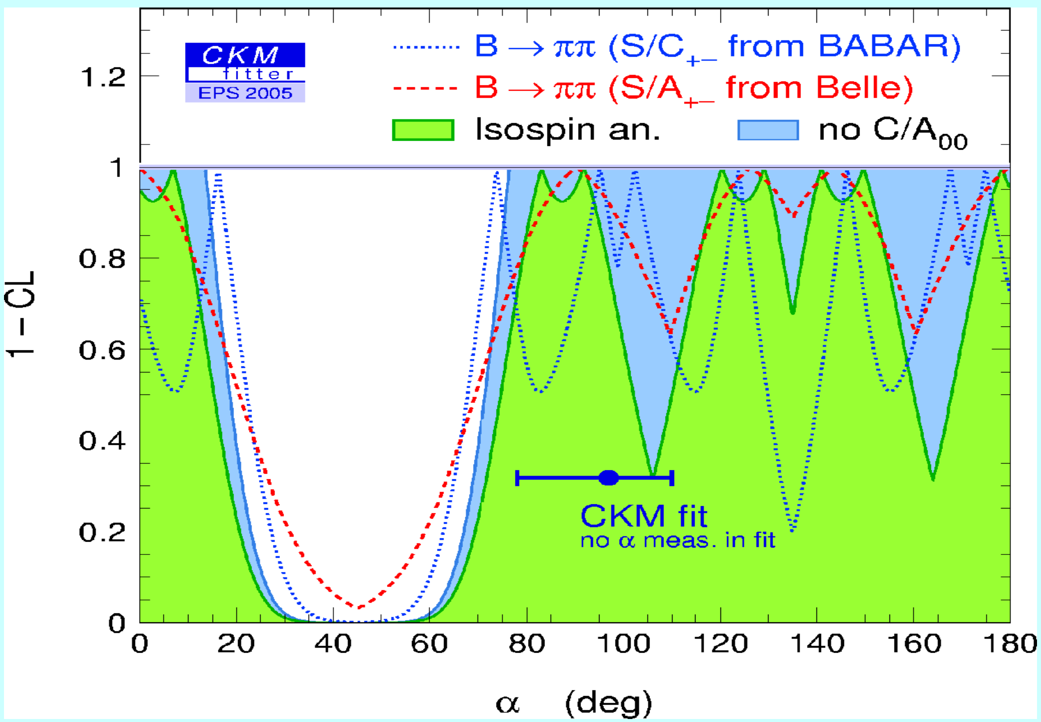
8-fold ambiguity within $[0,\pi]$

Results for $B^0 \rightarrow \pi^+ \pi^-$

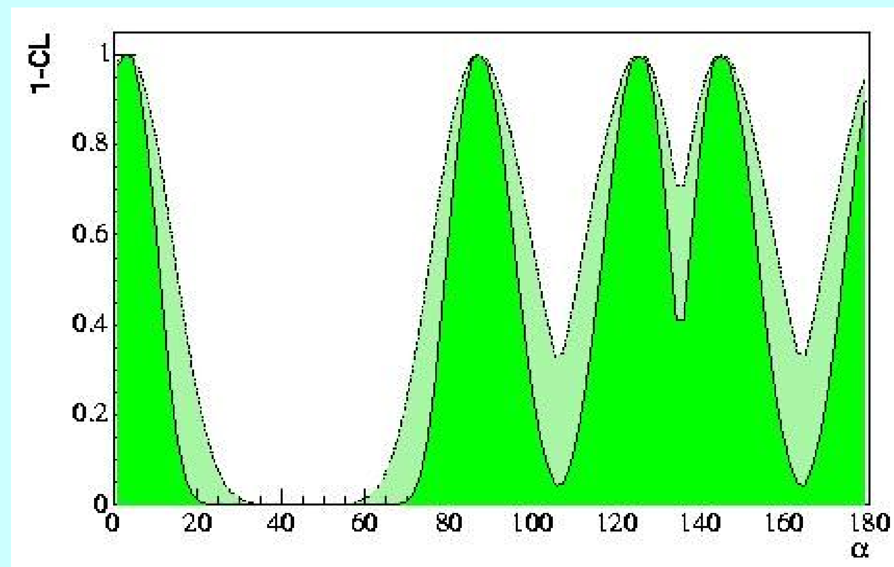


Agreement : $\chi^2 = 7.9$
(CL = 0.019 ⇒ 2.3 σ)





Constraint with same central values: 2 ab^{-1}



=> Precise extraction of α difficult

=> Size & error of *BR*($\pi^0 \pi^0$) & *C*($\pi^0 \pi^0$) important

A "surprise" : $B \to \rho\rho$

★ **BF's for $B \to \rho\rho$ (WA):** $\mathcal{B}^{+-} = (25.2\,^{+3.6}_{-3.7}) \times 10^{-6}$, $\mathcal{B}^{+0} = (26.4\,^{+6.1}_{-6.4}) \times 10^{-6}$, $\mathcal{B}^{00} < 1.1 \times 10^{-6}$ @ 90%CL

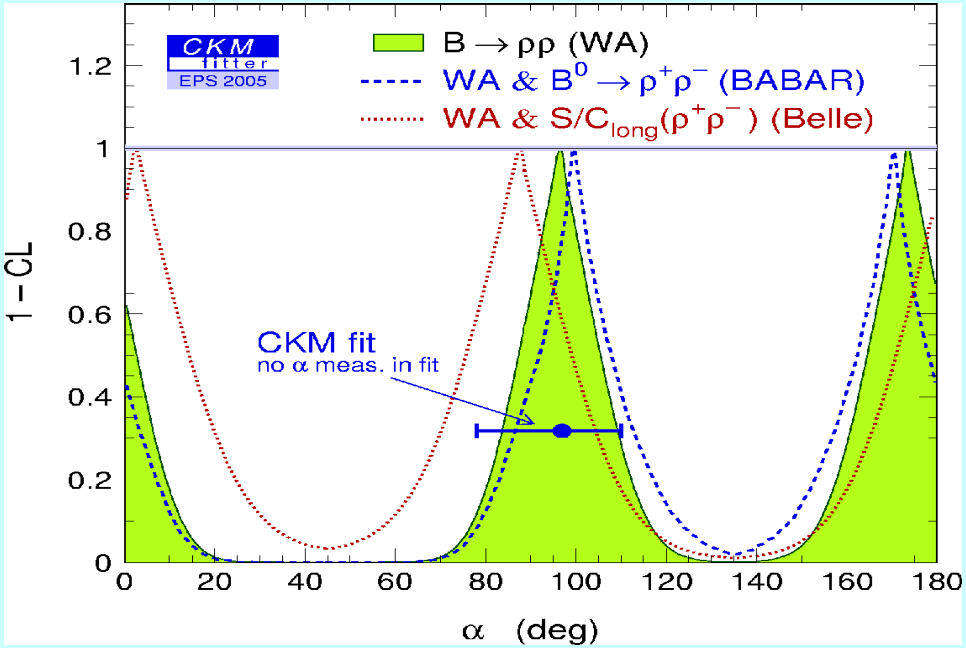
★ $B \to VV$ **can have** $L_{VV} = 0, 1, 2$

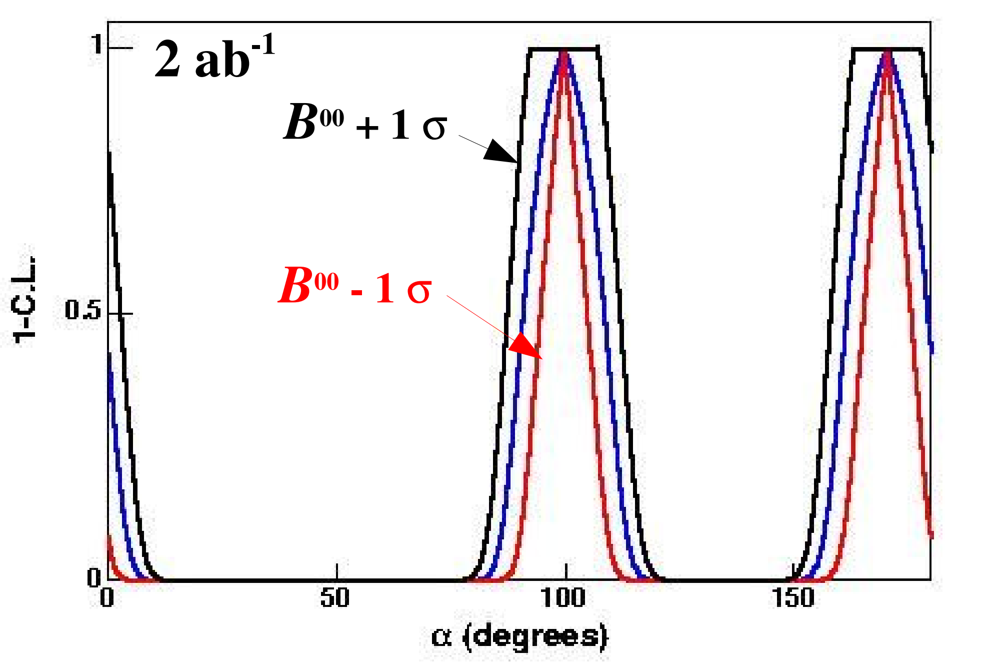
$CP(L_{VV}=0,2) = +1$ & $CP(L_{VV}=1) = -1$

$$f_L(\rho^+\rho^0) = 0.97^{+0.07}_{-0.05},\ f_L(\rho^+\rho^-) = 0.971^{+0.031}_{-0.030}$$

=> almost no *CP* dilution

	BABAR (232 M)		Belle (275 M)
$S_{\rho\rho}$	$-0.33 \pm 0.24^{+0.08}_{-0.14}$	$S_{\rho\rho}$	$0.09 \pm 0.42 \pm 0.08$
$C_{\rho\rho}$	$-0.03 \pm 0.18 \pm 0.09$	$C_{\rho\rho}$	$0.00 \pm 0.30^{+0.10}_{-0.09}$





News at FPCP06 : $B \to \rho\rho$

★ **BF's for $B \to \rho\,\rho$ (WA):** $\mathcal{B}^{+-} = (25.2\,^{+3.6}_{-3.7}) \times 10^{-6}$, $\mathcal{B}^{+0} = (19.1 \pm 3.5) \times 10^{-6}$, $\mathcal{B}^{00} < 1.1 \times 10^{-6}$ @ 90%CL

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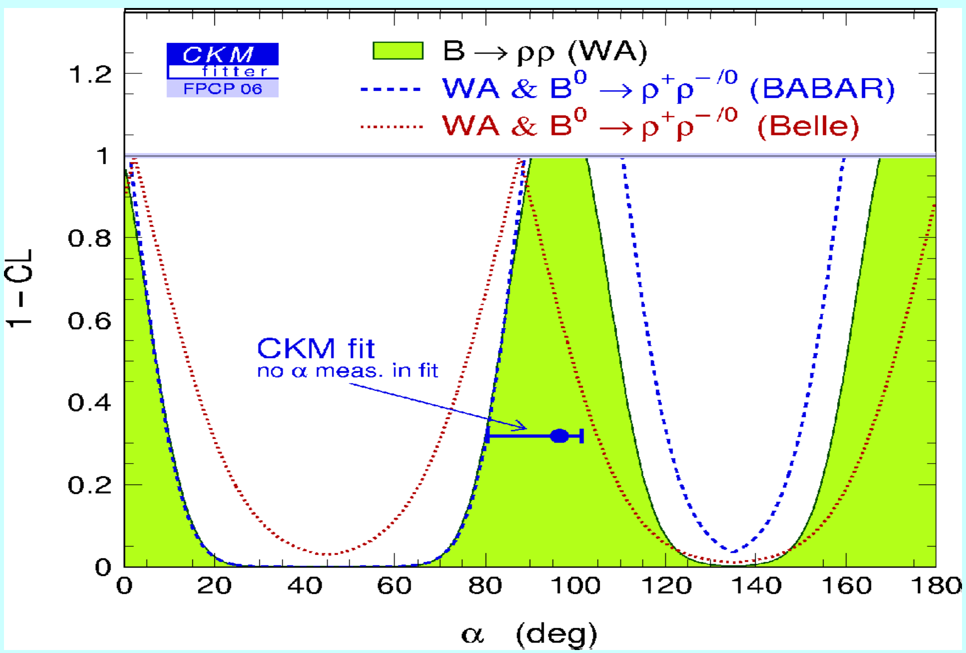
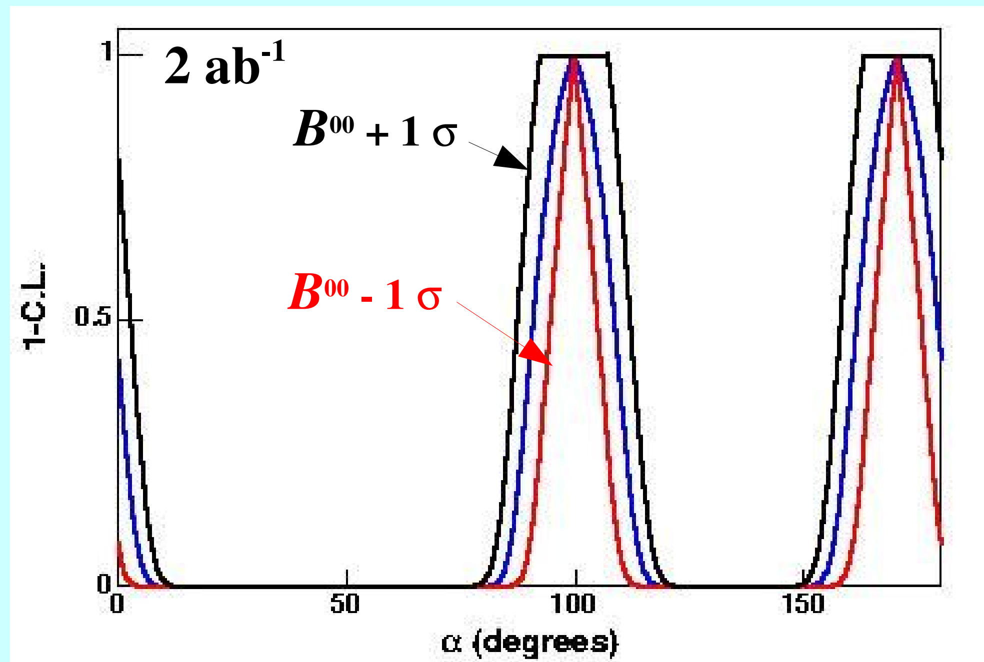
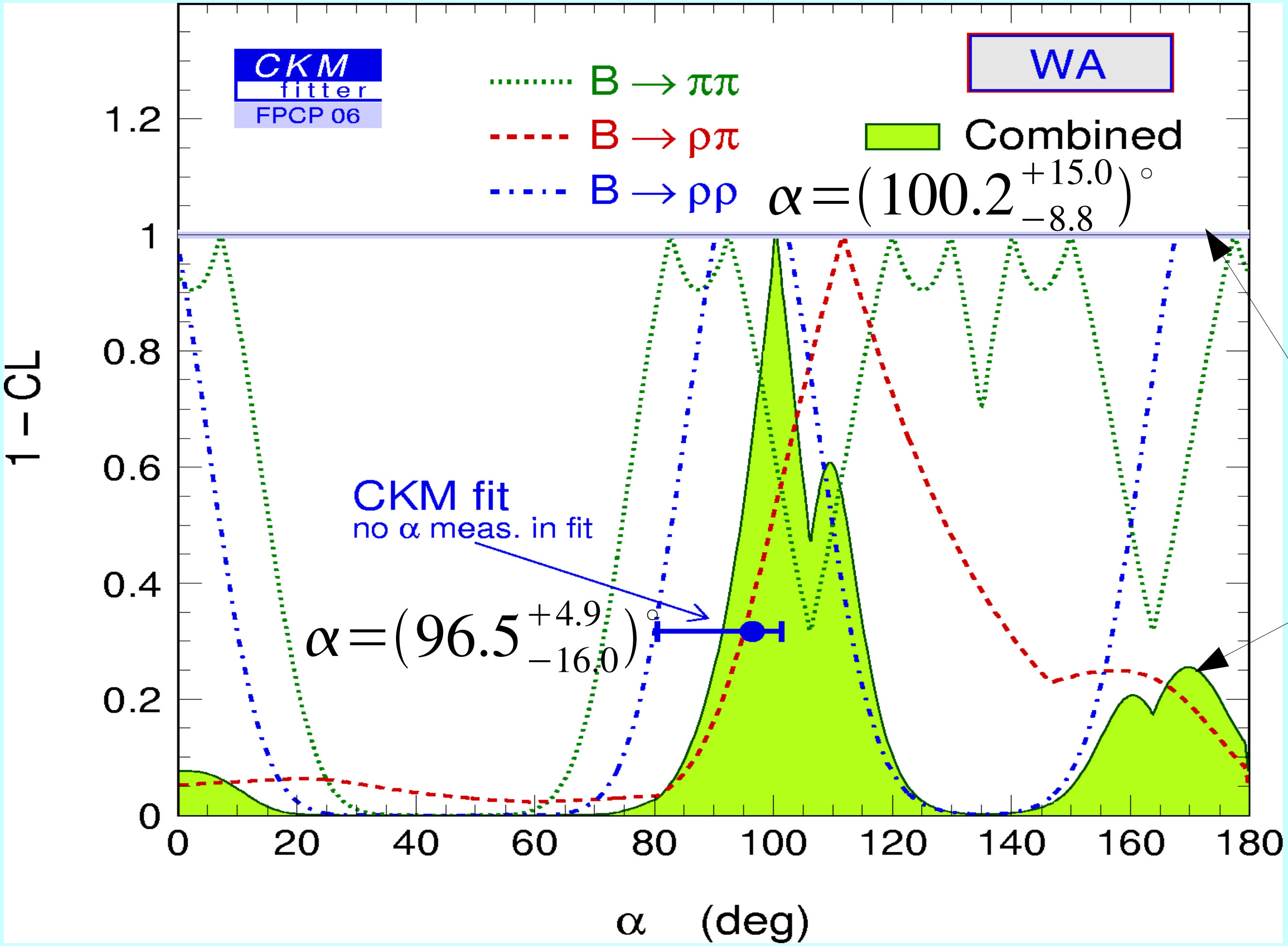




Combination of B --> $\pi\pi$, $\pi\pi\pi$, $\rho\rho$



mirror solution ($\rho\rho$)

disfavored

(due to constraint

from $\pi\pi\pi$)

$B\to\pi\pi$: **Needs large statistics; may become competitive with $B\to\rho\rho$ (2 ab^{-1})**

$B\to\rho\rho$: **Currently best constraint; Crucial: size of B^{00}/B^{+0}!**

If BF($B\to\rho^0\rho^0$) not too small: S^{00} measurable (at LHCb?)

$B\to\pi\pi\pi$: **Will become more and more important**

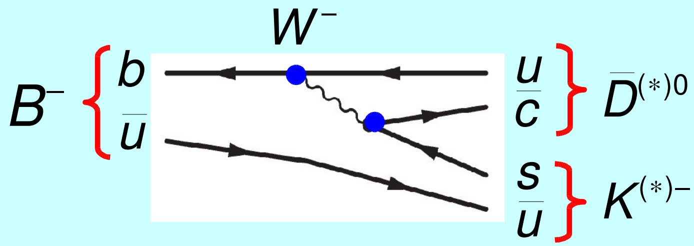
The big surprise :

γ is not out of reach

The Measurement of γ: Methods

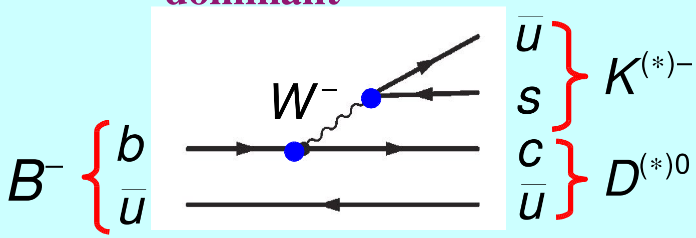
- **Measurement of γ through *CP* violation in decay:** $\boxed{b \to c\bar{u}s,\, u\bar{c}s}$

color-suppressed



$\propto V_{ub} V_{cs}^{*}$

dominant



$\propto V_{cb} V_{us}^{*}$

$$= r_B \cdot e^{i\cdot\gamma} \cdot e^{i\cdot\delta}$$

$\approx 0.1-0.3$	**relative CKM phase : γ**	**relative strong phase : δ**

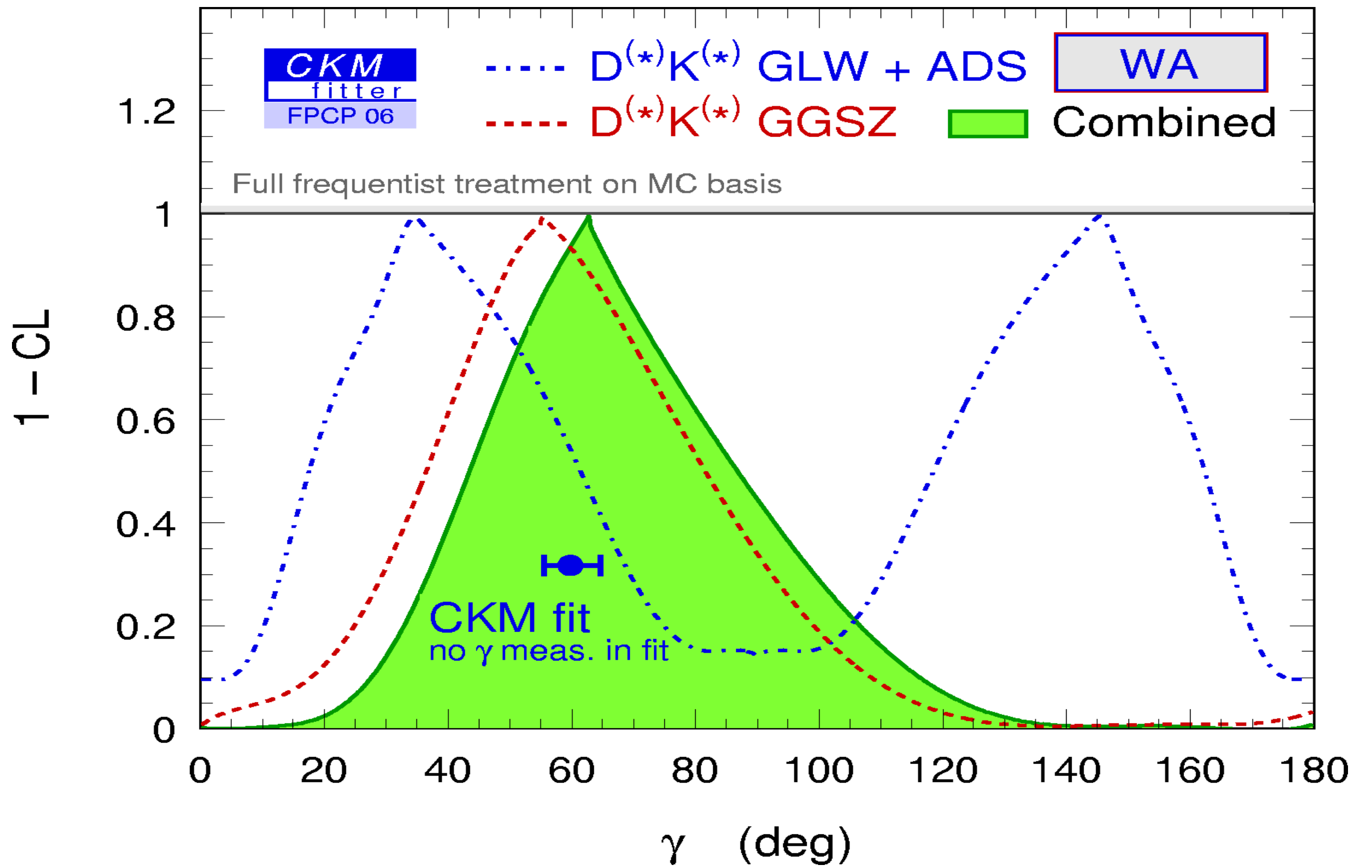
- **Several variants :**
  - ***D*^{0} decays into *CP* eigenstate:** $D^0/\bar{D}^0 \to \pi^+\pi^-, K^+K^-, \ldots$ **« GLW »**
  - $D^0 \to K^+\pi^-$ **(suppressed) and** $\bar{D}^0 \to K^+\pi^-$ **(favored)** **« ADS »**
  - $D^0/\bar{D}^0 \to K_S^0\pi^+\pi^-$ **(interference in Dalitz plot)** **« GGSZ »**

Gronau-London, PL B253, 483 (1991); Gronau-Wyler, PL B265, 172 (1991)

Atwood-Dunietz-Soni, PRL 78, 3257 (1997)

Giri-Grossman-Soffer-Zupan, PRD 68, 054018 (2003)

Constraints on γ (Work in progress)

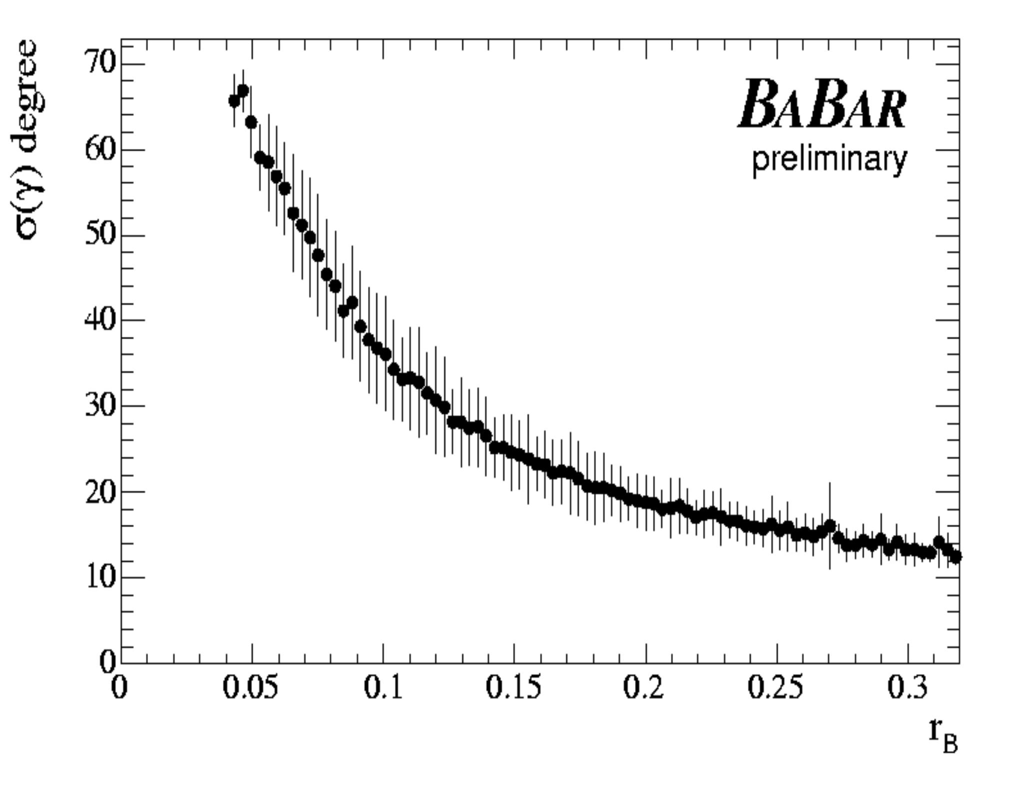


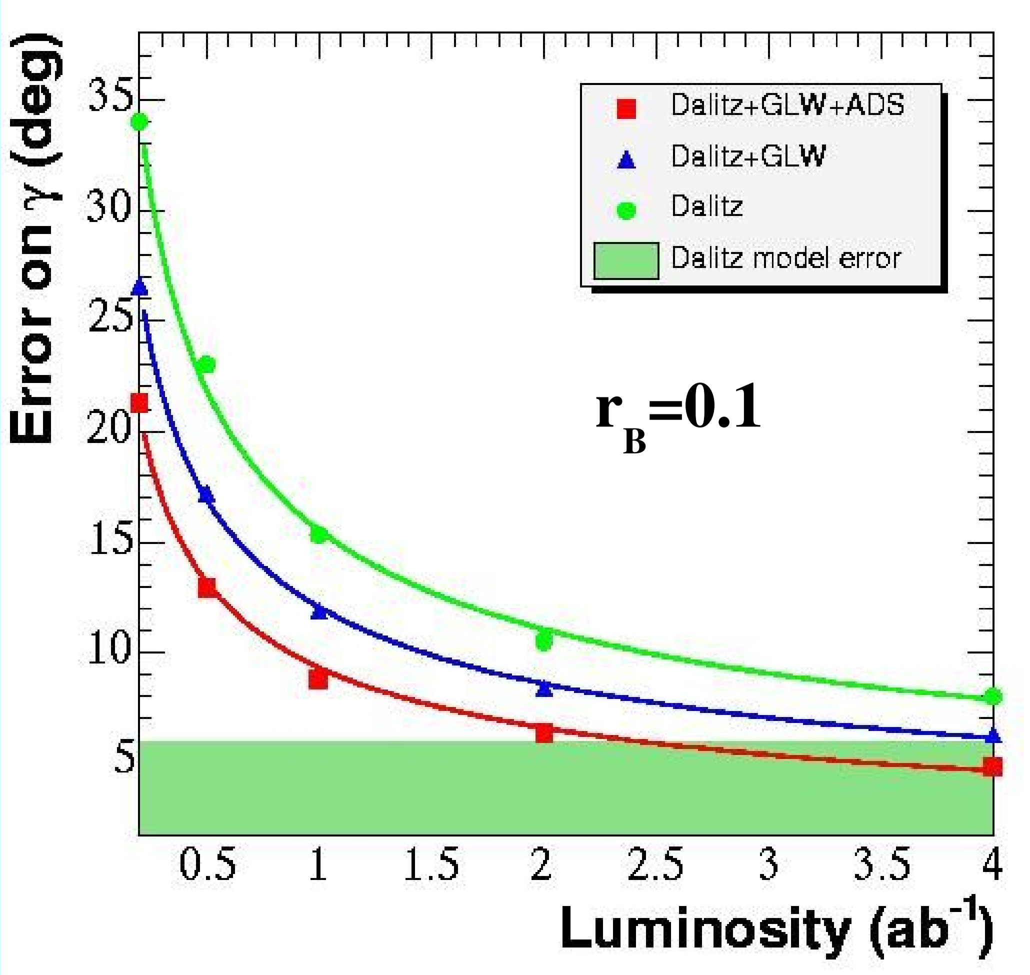
GGSZ:

	BABAR (227 M)		Belle (392)
	$\gamma = 68^\circ \pm 28^\circ_{stat} \pm 13^\circ_{sys} \pm 11^\circ_{model}$		$\gamma = 53^{\circ\,+15}_{\;\;-18} \pm 3^\circ_{sys} \pm 9^\circ_{model}$
$r_b =$	$0.12 \pm 0.08 \pm 0.03 \pm 0.04$	$D\,K$	$0.159^{+0.054}_{-0.050} \pm 0.012 \pm 0.049$
$r_b^* =$	$0.17 \pm 0.10 \pm 0.03 \pm 0.03$	D^*K	$0.175^{+0.108}_{-0.099} \pm 0.013 \pm 0.049$
$r_s <$	0.19 @ 90% CL	$D\,K^*$	$0.120^{+0.216}_{-0.155} \pm 0.041 \pm 0.084$

Projection for γ

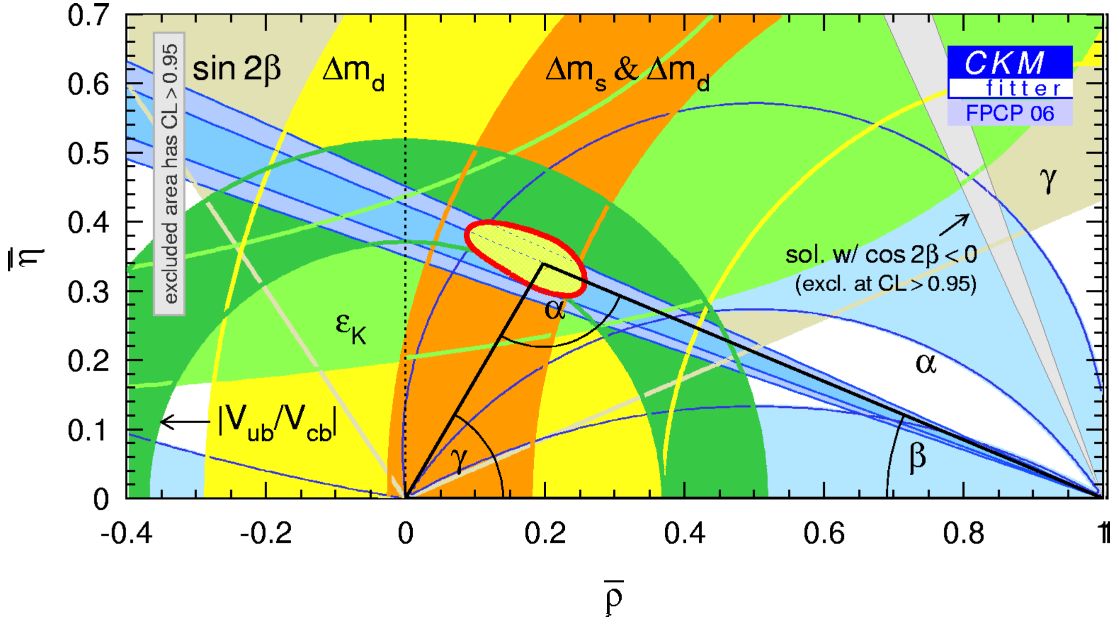
Sensitivity to γ:
Strong dependence on r_B





The unitarity triangle in 2006

CP violation & CKM matrix 2006: a new era



CKM mechanism plays a dominant role

CP violation in SM:

$$J = (3.05 \pm 0.18) \cdot 10^{-5}$$

CP violation too small | **Higgs mass too large**

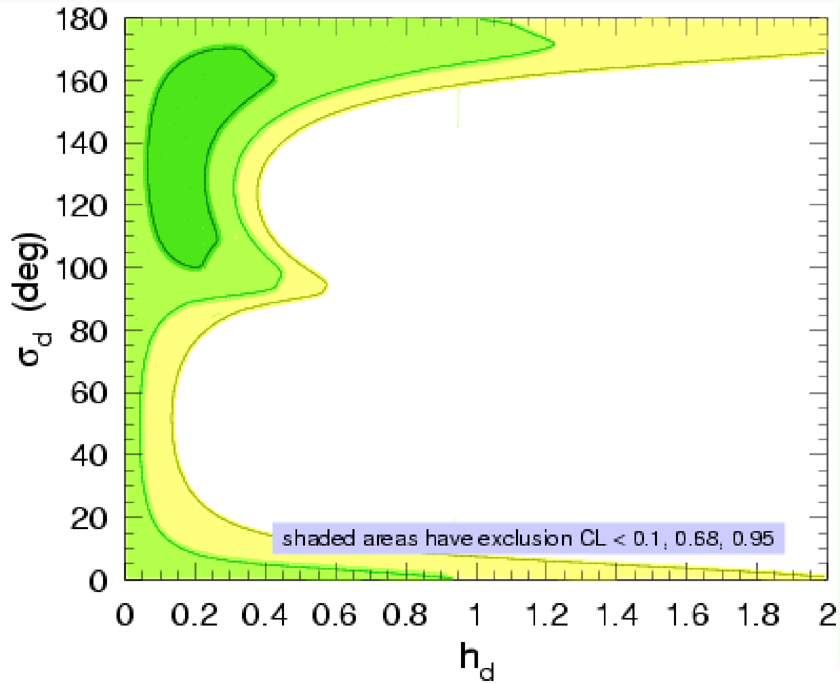
to explain baryon asymmetry in the universe within SM

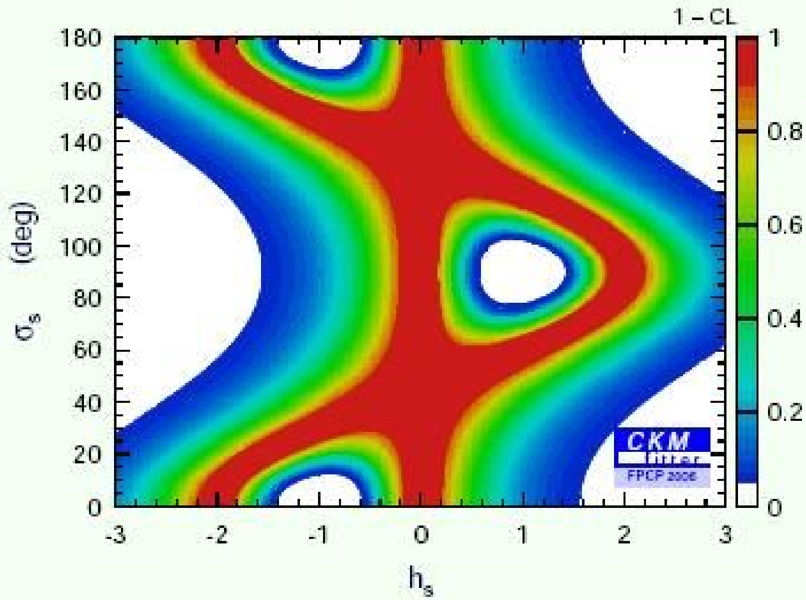
=> Indirect hint for NP ... but where?

NP in quark flavor sector ? $\rightarrow$ Era of precision measurements
Measure all flavor transitions as precisely as possible

CP violation & CKM 2006: New Physics in mixing?

$$\langle B_q | \mathcal{H}^{SM+NP}_{\Delta B=2} | \bar{B}_q \rangle \equiv \langle B_q | \mathcal{H}^{SM}_{\Delta B=2} | \bar{B}_q \rangle \times (1 + h_q\, e^{2i\sigma_q})$$

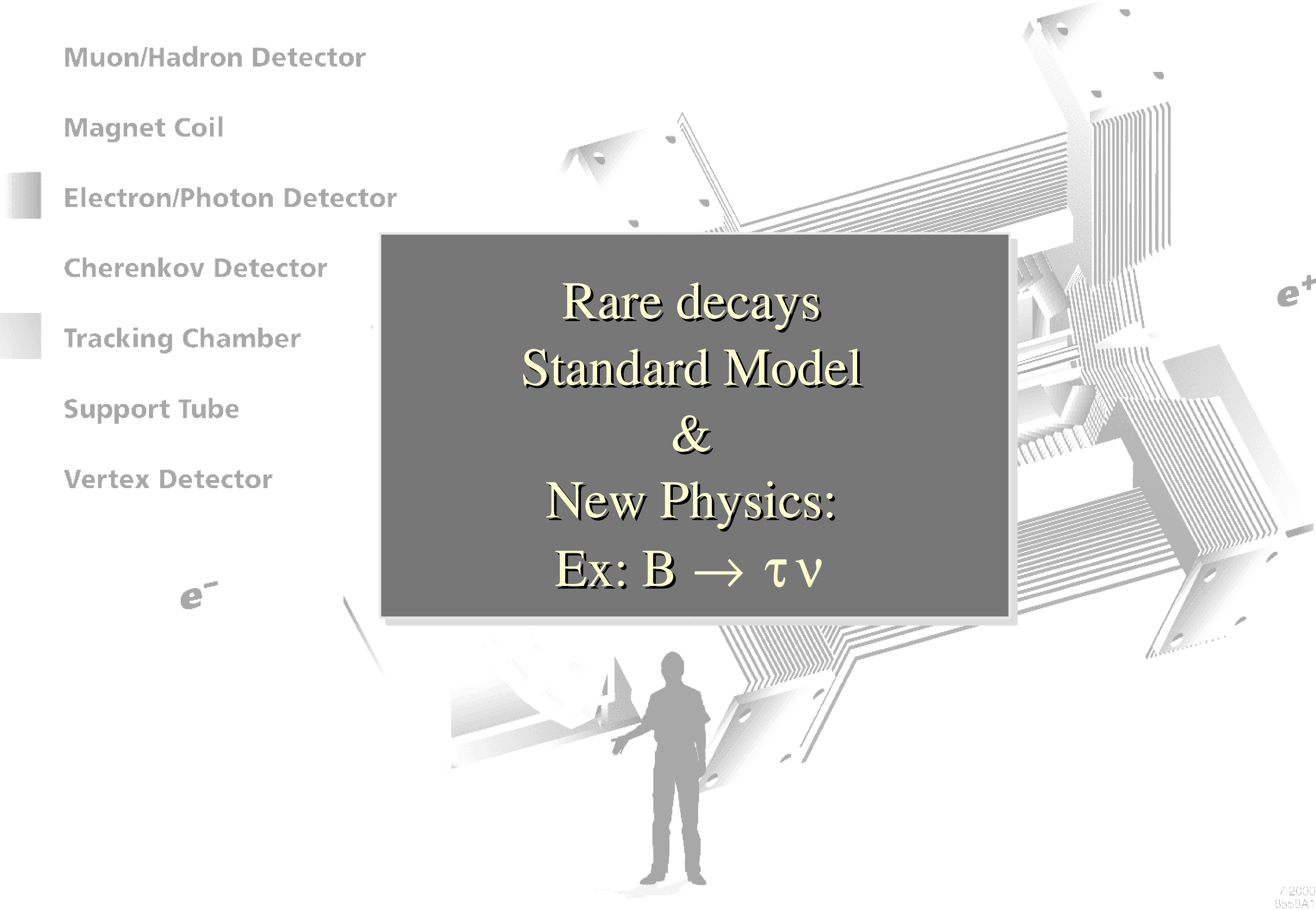




Observable/Parameter

$B \to X_{u,c}\, l\, \nu$	$\lvert V_{ub}\rvert, \lvert V_{cb}\rvert$
$B \to D^{(*)0} K^+$	γ
$B \to \pi\pi, \rho\rho, 3\pi$	$2\beta + 2\theta_d + 2\gamma$
$B \to J/\Psi\, K^0$	$\sin(2\beta + 2\theta_d)$
$B \to J/\Psi\, K^{*0}$	$\cos(2\beta + 2\theta_d)$
$B \to D_{K_s \pi\pi} h^0$	
$\Delta m_{d,s}$	$\Delta m^{SM}_{d,s} r^2_{d,s}$
A_{SL}	$-\Re\left(\frac{\Gamma_{12}}{M_{12}}\right)^{SM} \frac{\sin 2\theta_d}{r^2_d} + \Im\left(\frac{\Gamma_{12}}{M_{12}}\right)^{SM} \frac{\cos 2\theta_d}{r^2_d}$

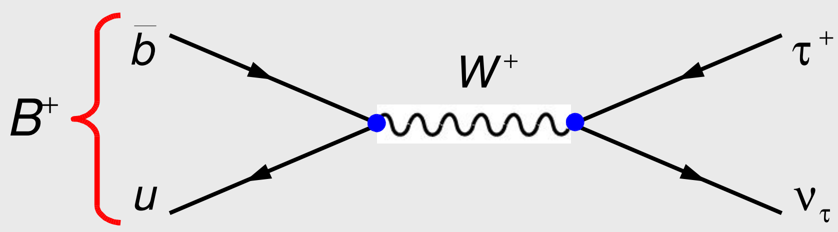
$$r_d^2 \exp(2 i \theta_d) = \frac{\langle B^0 | H^{full}_{eff} | \bar{B}^0 \rangle}{\langle B^0 | H^{SM}_{eff} | \bar{B}^0 \rangle}$$



Rare decays
Standard Model
&
New Physics:
Ex: $B \to \tau \nu$

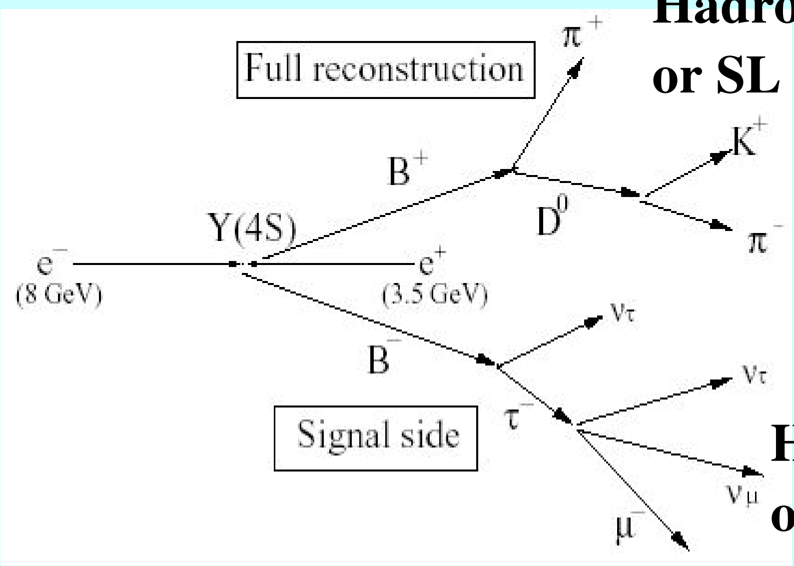
B $\rightarrow \tau\nu$

- Helicity-suppressed annihilation decay sensitive to $(f_B * |V_{ub}|)^2$
- Powerful <u>together</u> with Δm_d : removes f_B (Lattice QCD) dependence
- Sensitive, *e.g.*, to charged Higgs replacing W-propagator



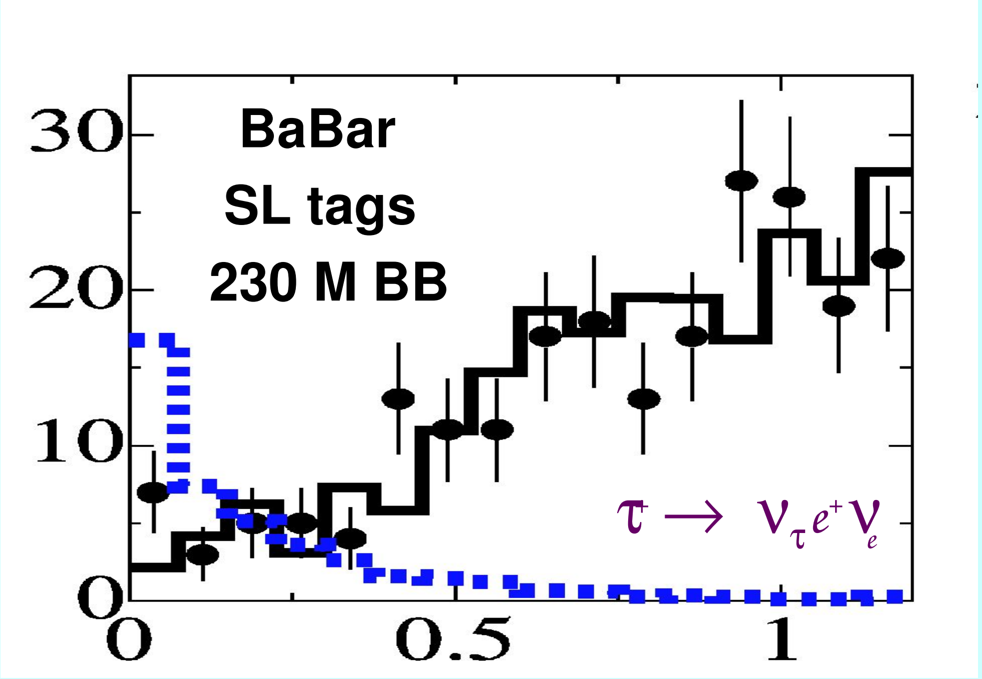
$$\mathcal{B}(B^- \to \ell^- \bar{\nu}) = \frac{G_F^2 m_B m_\ell^2}{8\pi}\left(1 - \frac{m_\ell^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

<u>Experimental techniques:</u>

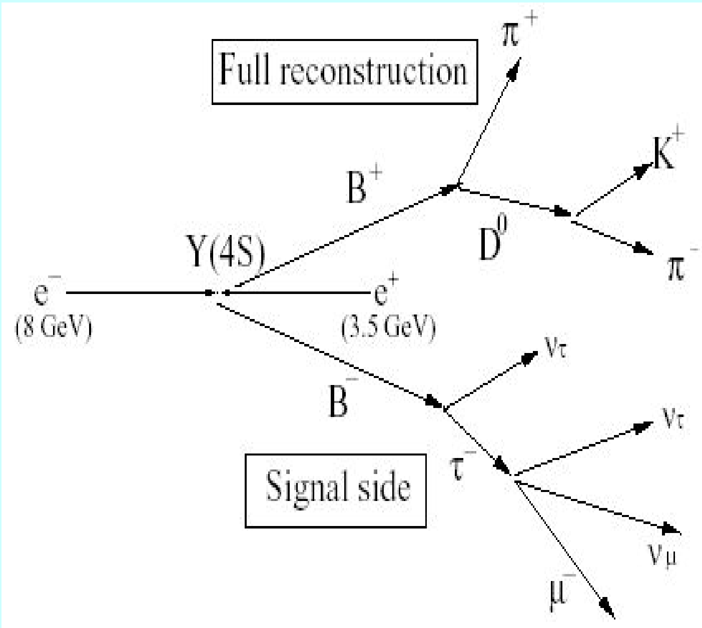


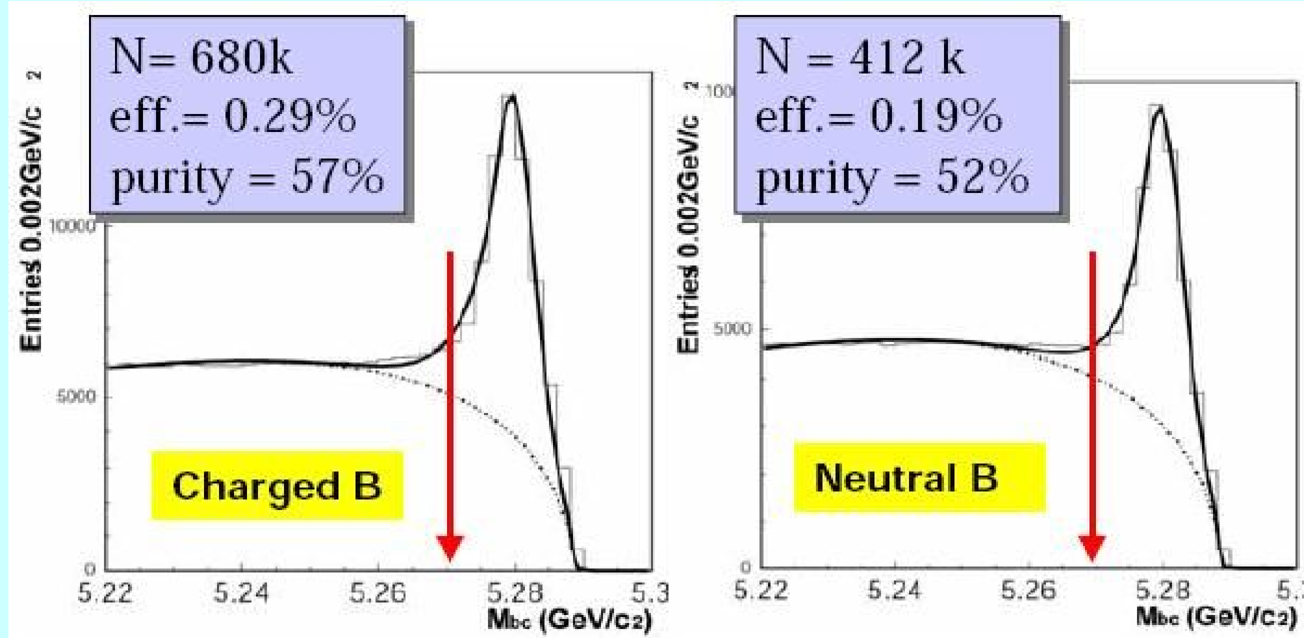
Hadronic or SL tags

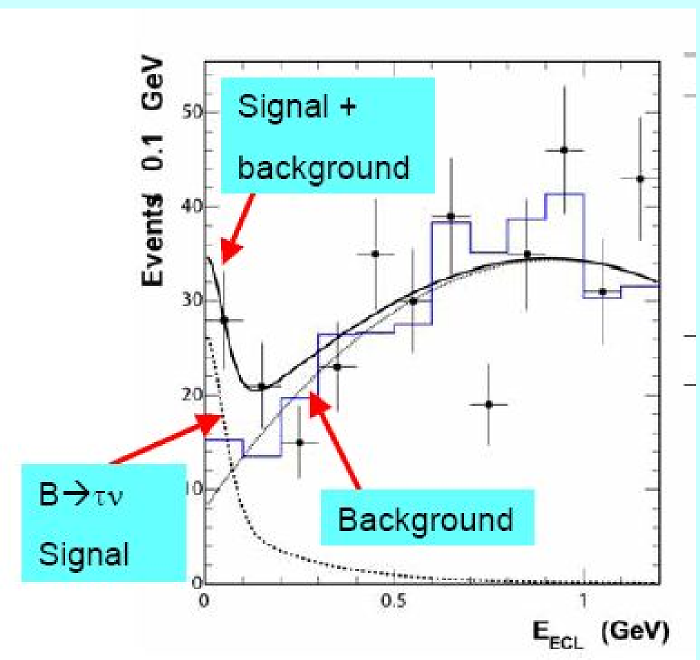
Hadronic or leptonic τ-decays



FPCP06: Belle observes B $\rightarrow \tau\nu$





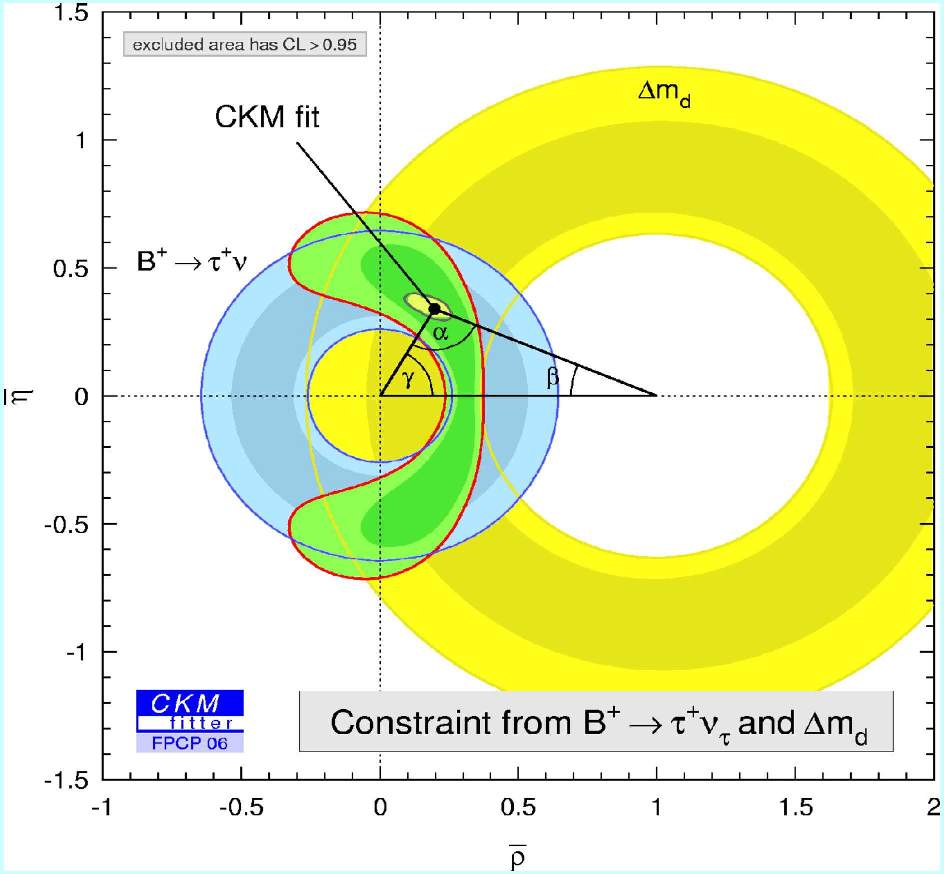


$$\tau^- \rightarrow \mu^-\nu\bar{\nu},\ e^-\nu\bar{\nu},\ \pi^-\nu,\ \pi^-\pi^0\nu,\ \pi^-\pi^+\pi^-\nu$$

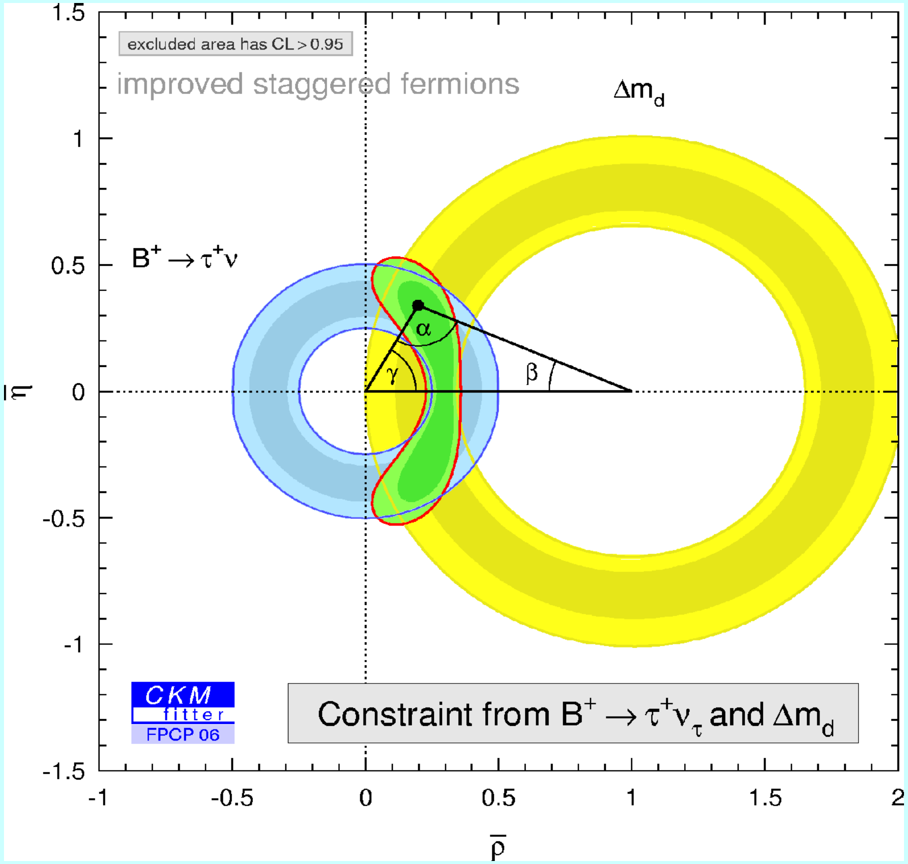
$$\mathcal{B}(B \rightarrow \tau\nu) =$$
$$(1.06^{+0.34}_{-0.28}(\mathrm{stat})^{+0.18}_{-0.16}(\mathrm{syst})) \times 10^{-4}$$

$B \to \tau\nu$: SM implications

Traditional Lattice calculations



Improved Staggered Fermions



$$BF(B^+ \to \tau^+ \nu_\tau) \propto f_{B_d}^2 \; |V_{ub}|^2$$

$$\Delta m_d \propto f_{B_d}^2 B_d |V_{td} V_{tb}^*|^2$$

B → τν: NP implications (2HDM)

$$\mathcal{B}(B \to \tau\nu) = \mathcal{B}(B \to \tau\nu)_{\rm SM} \times r_H,$$
$$r_H = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

Values used by Belle:

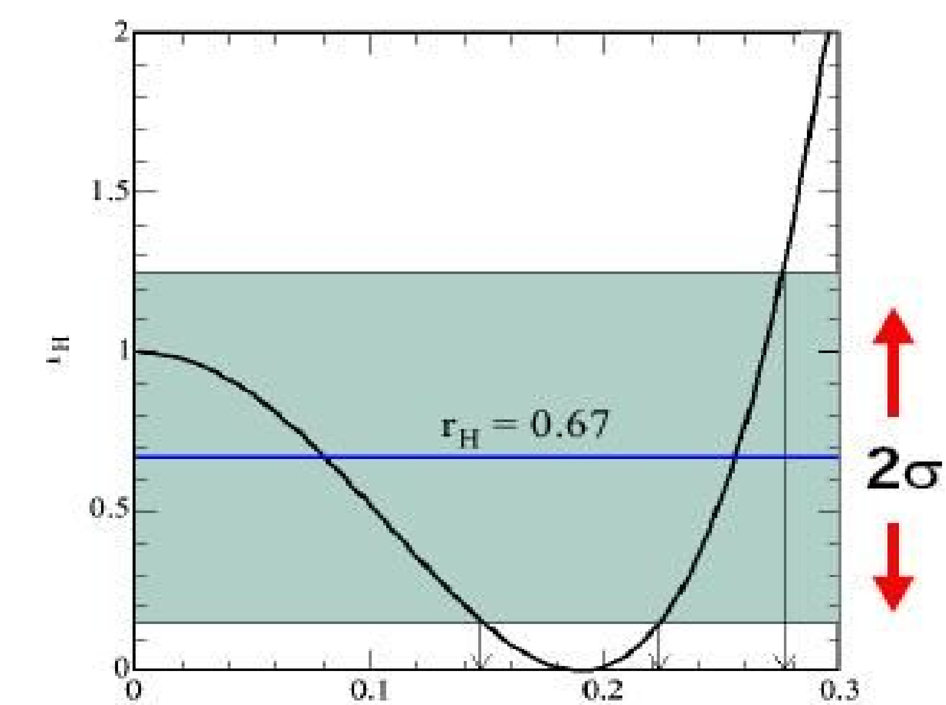
$|V_{ub}| = (4.38 \pm 0.33)\ 10^{-3}$ **("Average" incl. + excl.)**

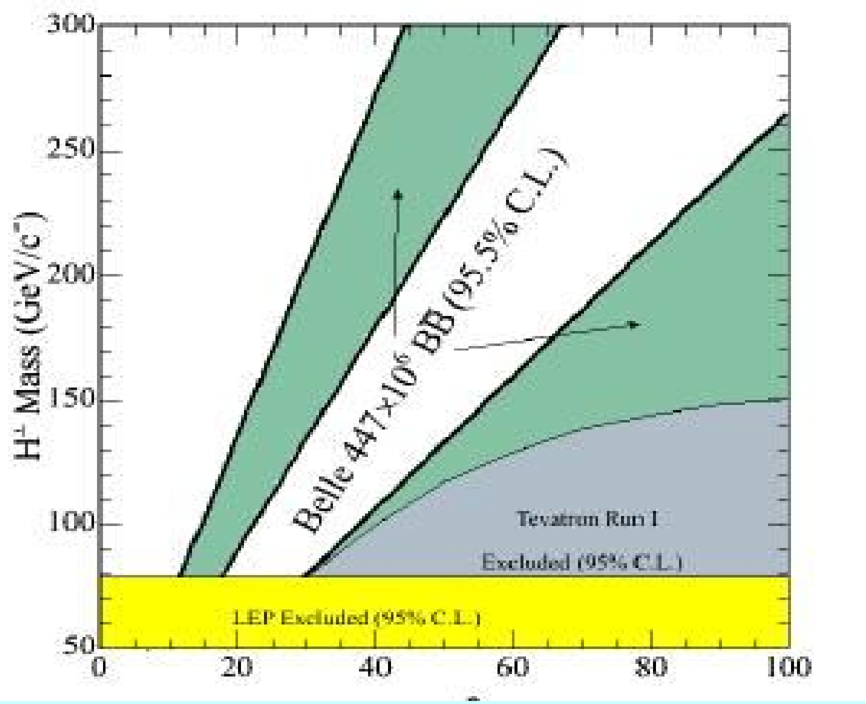
$f_{B_d} = (216 \pm 22)\ MeV$ **(LQCD: Improved Staggered Fermions)**

$$\mathcal{B}(B \to \tau\nu) = (1.06^{+0.34}_{-0.28}(\text{stat})^{+0.18}_{-0.16}(\text{syst})) \times 10^{-4}$$
$$\text{SM}: \mathcal{B}(B \to \tau\nu) = (1.59 \pm 0.40) \times 10^{-4}$$

$|V_{ub}| = (3.82 \pm 0.15)\ 10^{-3}$ **(CKM fit)**

$f_{B_d} = (190 \pm 25 \pm 9)\ MeV$ **(LQCD: non-staggered)**





Conclusions I

* B-factories very successful: Luminosity, detector
  Physics programme until 2008: rich & competitive

* Most of the data to be analyzed still to come!

* Analyses on recoil of fully reconstructed B decays: V_{ub}, V_{cb}, $B \to \tau \nu$, ...

* Precision on CKM parameters will be significantly improved (1 ab^{-1}):
  $\sigma(\sin 2\beta) \approx 0.02$, $\sigma(\alpha) \approx 8°$, $\sigma(\gamma) \approx 10°$
  V_{ub}: 5%?, V_{cb}: 1-2%

* $\sin 2\beta$ in penguin modes (1 ab^{-1}): $\sigma(\phi K_S) \approx 0.12$, $\sigma(\eta' K_S) \approx 0.07$
  Rare B decays: e.g. $B \to \tau \nu$ (CKM phenomenology <--> NP search)

Conclusions II

* **New Physics in Mixing?**

  If NP present: Minimal Flavor Violation scenario likely

  Hadronic uncertainties are limiting factor: Δm_d, Δm_s, V_{ub}, ε_K

  Partial cancelation by combining Δm_d, V_{ub}, $B \rightarrow \tau\nu$

  Lattice QCD: Improved Staggered Fermions, ...
  Gauged by CLEO-c (BABAR/Belle)

* **SuperB: KEKb and/or SuperB based on ILC technology?**

* **LHC(b): Δm_s**
  B_s--> $\psi\phi$ (As important as sin2β in B_d!)
  γ: B-factories became hard competitors!
  α: B--> $\rho^0\rho^0$ (S & C coefficients)
  Rare decays: $B_{d,s}$ --> $\mu\mu$, B--> $K^*\mu\mu$

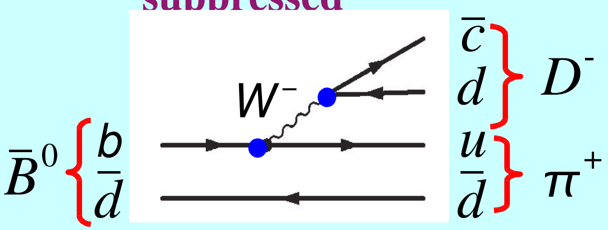
Conclusions III

MERCI BEAUCOUP
POUR
VOTRE ATTENTION!

sin(2β+γ)

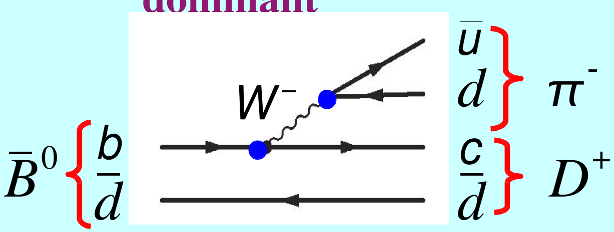
Measurement through time-dependent *CP* asymmetries in $B^0/\bar{B}^0 \to D^{(*)+-}\pi^{-+}$

suppressed



$\propto V_{ub} V_{cd}^*$

dominant

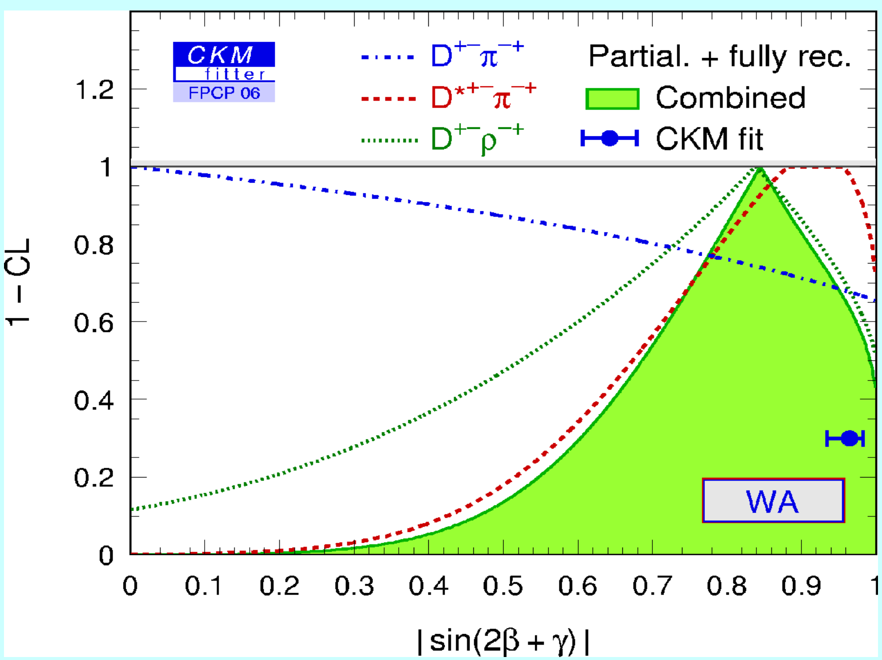


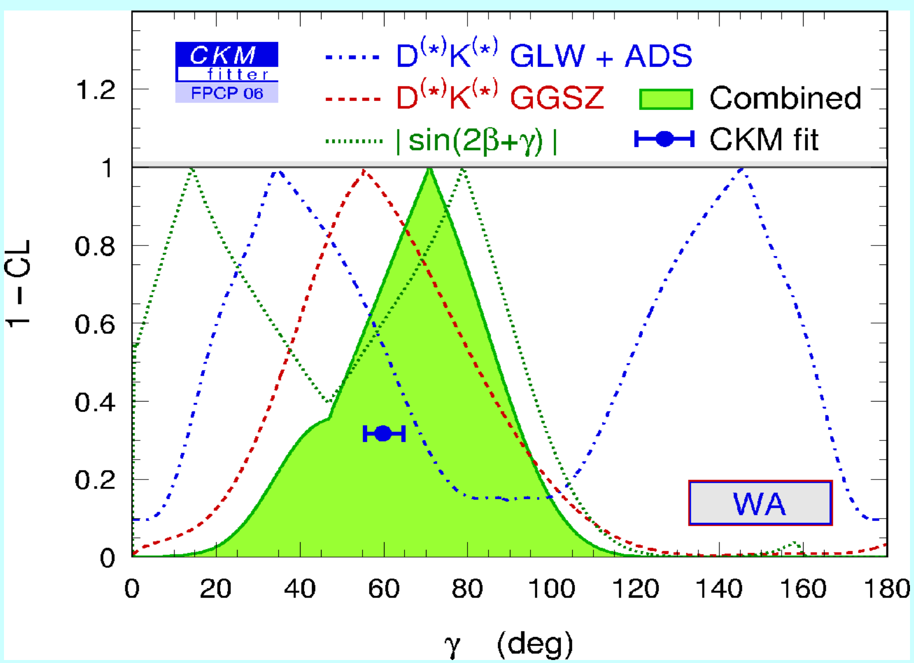
$\propto V_{cb} V_{ud}^*$

estimated currently from $\bar{B}^0 \to D_s^{(*)+}\pi^-$ **using SU(3)**

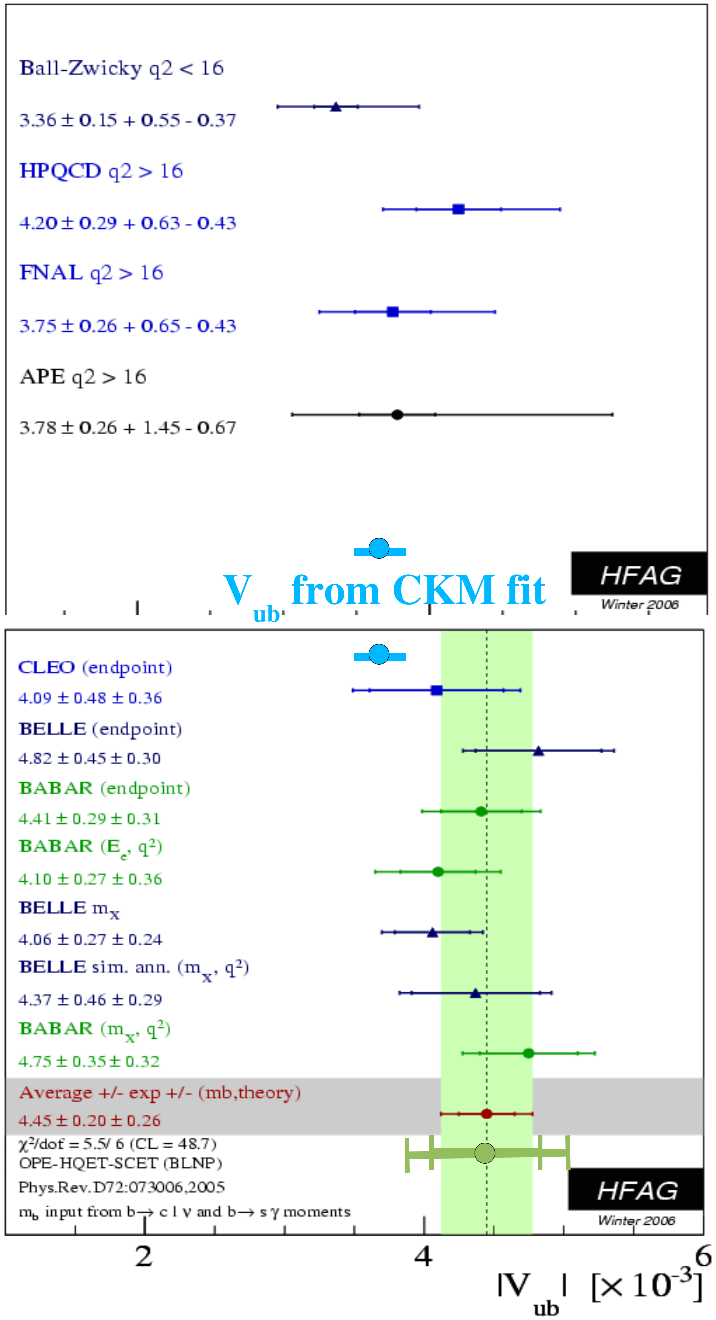
$$= \quad r \quad \cdot \quad e^{i\cdot\gamma} \quad \cdot \quad e^{i\cdot\delta}$$

$\approx 0.01-0.02$	**relative CKM phase : γ**	**relative strong phase : δ**





NP phase in B_d-Mixing? V_{ub} input is crucial !

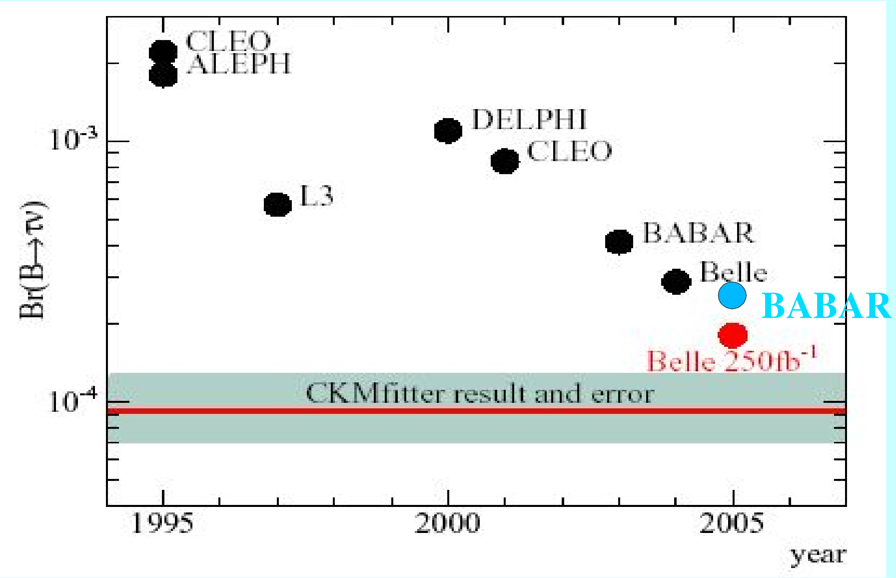


- **Exclusive V_{ub}: (still) large uncertainties (FF calculations: LQCD, LCSR)**

  Consistent with V_{ub} prediction from CKM fit

- **Inclusive V_{ub}: smaller (theor.) uncertainties**
- **Larger than but consistent with excl. V_{ub}**
- **Average not in good agreement with V_{ub} prediction from CKM fit (w/o V_{ub})**
- **Theory error (±0.26): ±0.09 Weak Annih.**
  ±0.17 Subleading SF
  ±0.13 HQE uncert.
- **Adding them linearly: ±0.39**

B → τν



BABAR: $BF(B^+ \to \tau^+ \nu_\tau) < 2.6\ 10^{-4}$ @ 90 % C.L.

Belle: $BF(B^+ \to \tau^+ \nu_\tau) < 1.8\ 10^{-4}$ @ 90 % C.L.

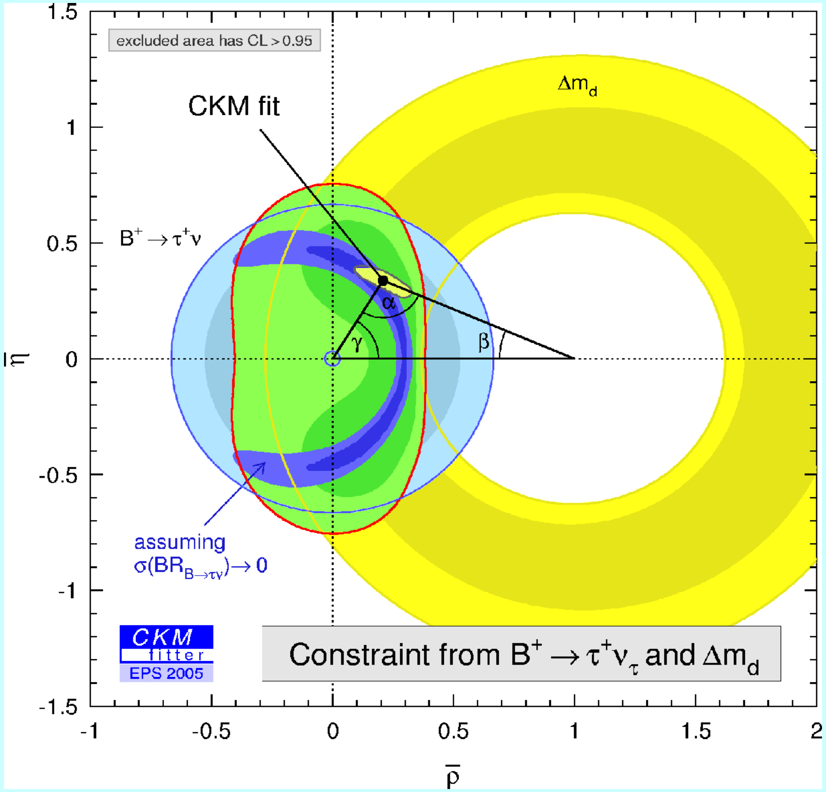
Prediction from global CKM fit (FPCP06):

$$BF(B^+ \to \tau^+ \nu_\tau) = (9.7 \pm 1.3)\ 10^{-5}$$

Take advantage of correlation:

$$BF(B^+ \to \tau^+ \nu_\tau) \propto f_{B_d}^2 \quad |V_{ub}|^2$$

$$\Delta m_d \propto f_{B_d}^2 B_d |V_{td} V_{tb}^*|^2$$



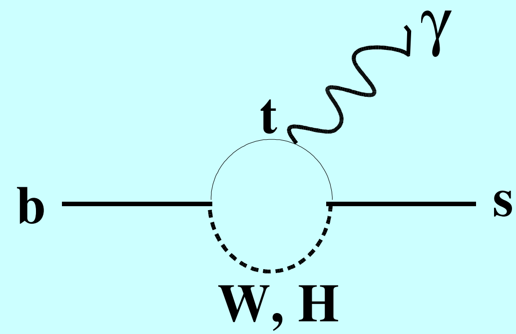
New Physics: B $\to \tau\nu$

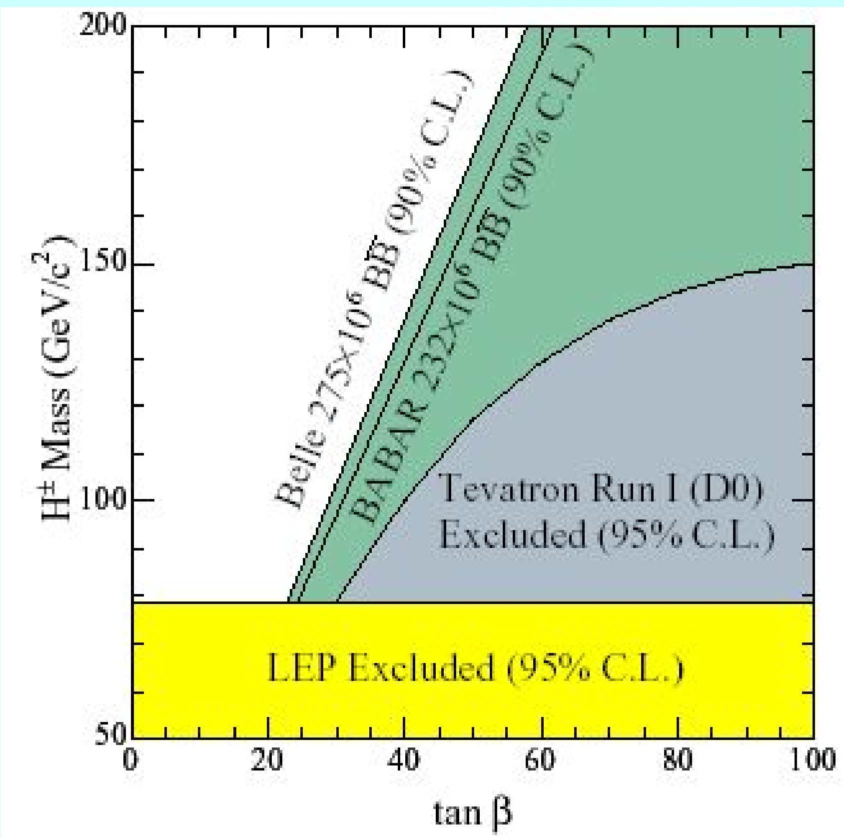
$$\mathcal{B}(B \to \tau\nu) = \mathcal{B}(B \to \tau\nu)_{\rm SM} \times r_H,$$

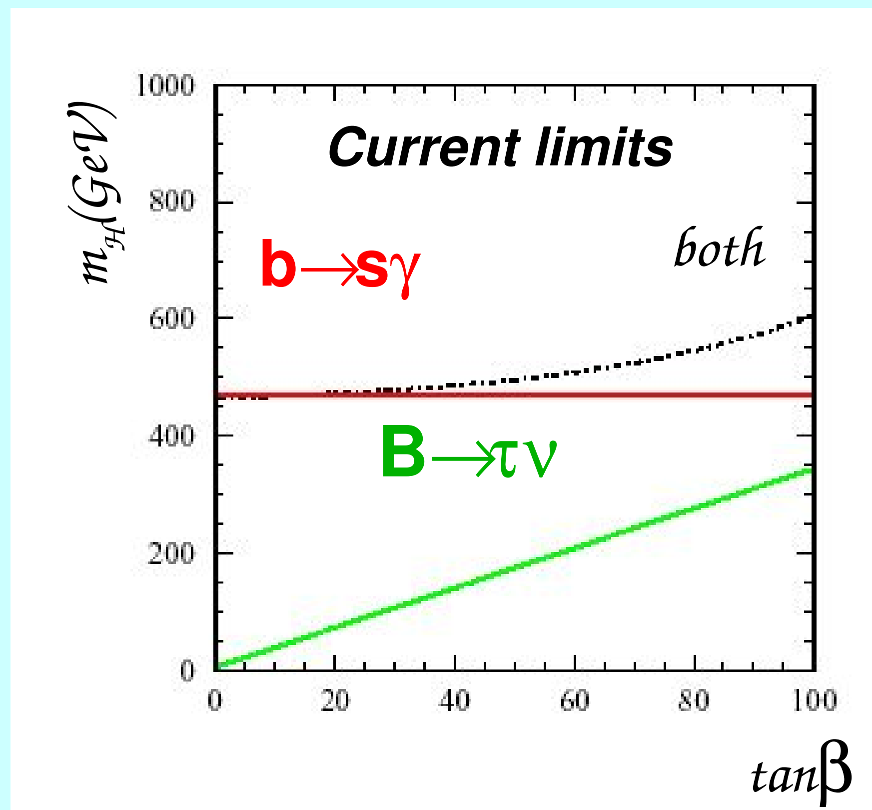
$$r_H = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

Phys. Rev. D **48**, 2342 (1993)

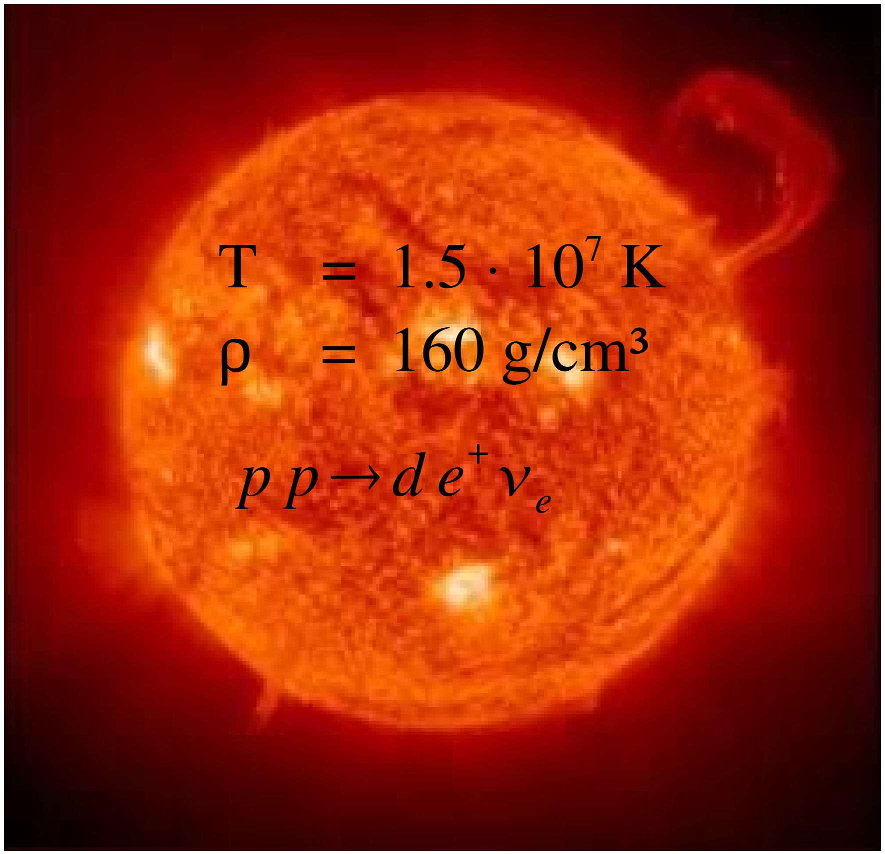
2HDM
Gambino, Misiak Nucl. Phys. B611 338
Hou Phys.Rev.D48:2342-2344,1993







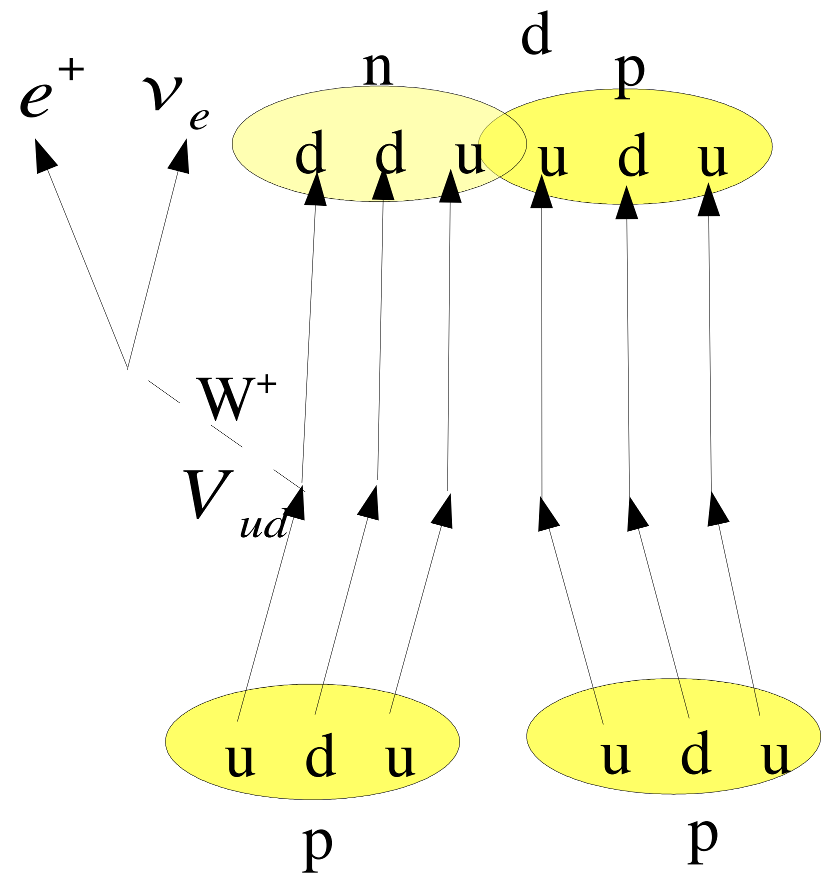
- fusion rate in the sun



$T \;=\; 1.5 \cdot 10^7$ K

$\rho \;=\; 160$ g/cm^3

$p\,p \rightarrow d\,e^+\,\nu_e$



$$\sigma \propto |V_{ud}|^2$$

- Lifetime of radioactive nuclei
  (^{14}C-method; energy budget in the interior of planets; ...)

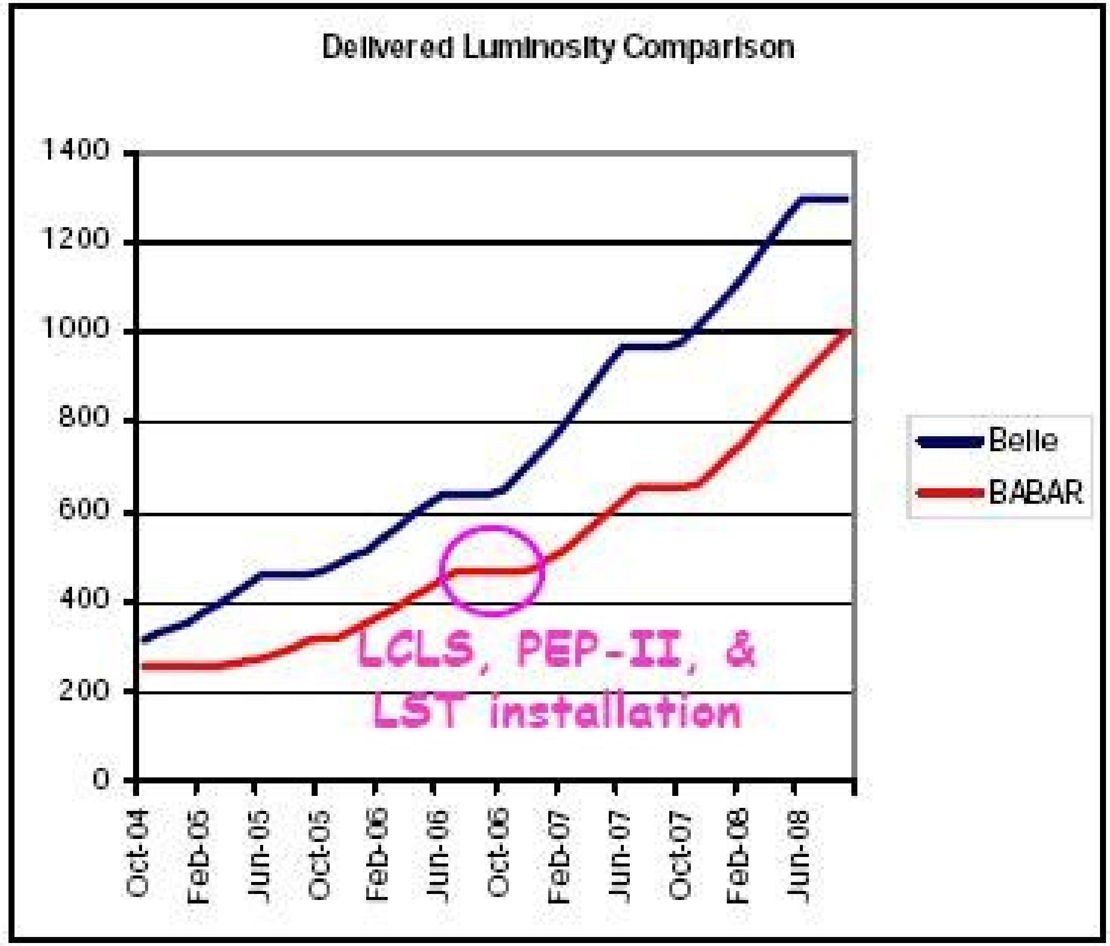
PEP II Plans

Goals:

* 1.2×10^{34} spring 2006
  (3300 mA LER,
  1700 mA HER)
* Improve peak lumi
  to 2×10^{34} by 2008

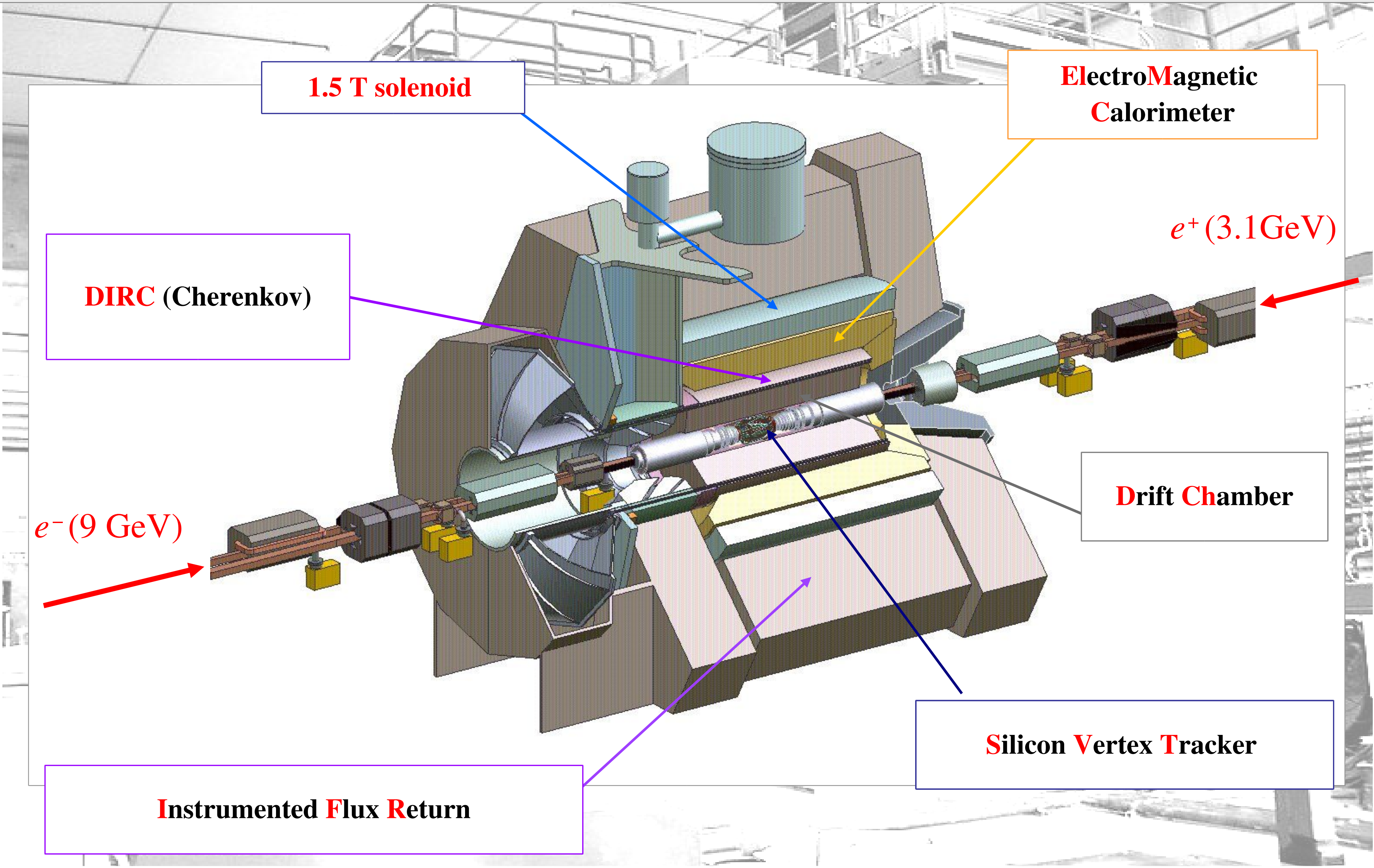
2006: Double data to 450 fb^{-1}

2008: Double again to 1000 fb^{-1}



BABAR Detector

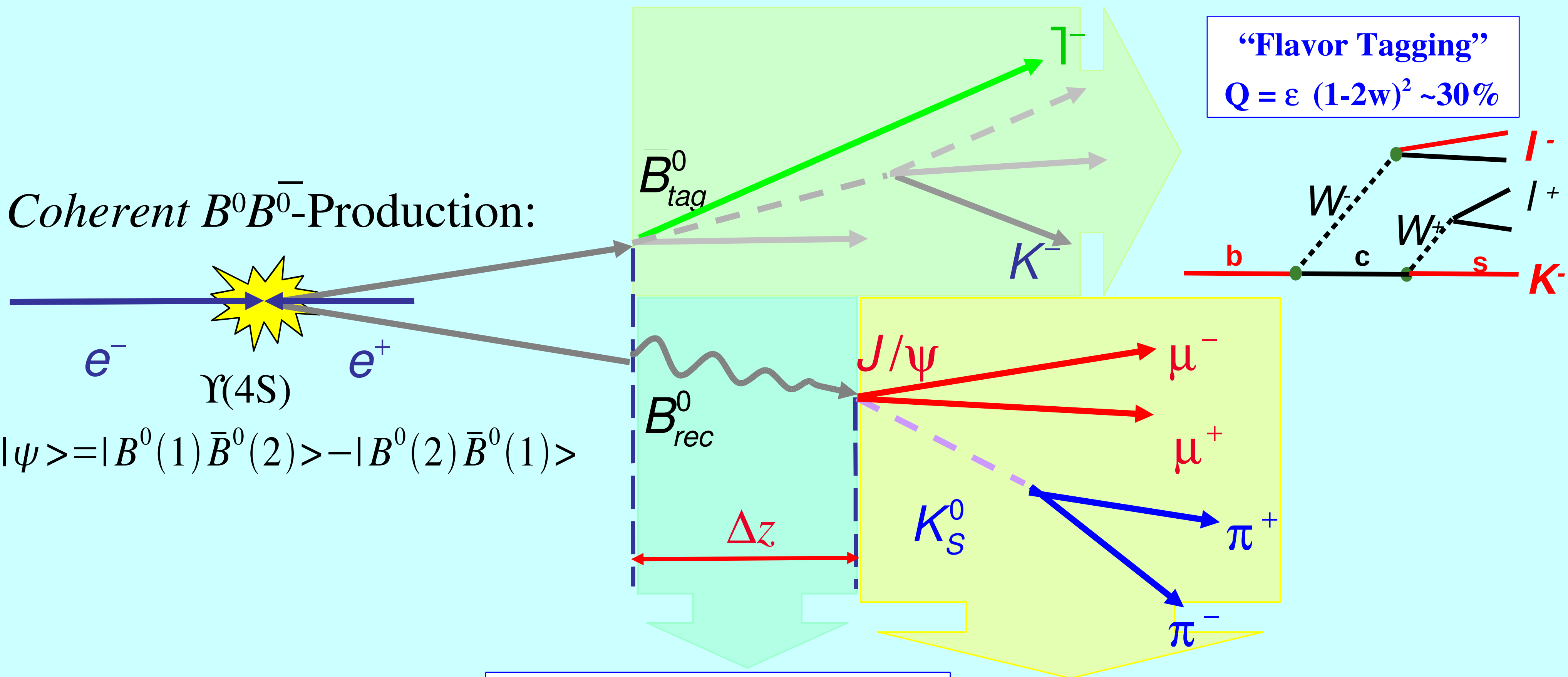
BABAR, NIM A479, 1 (2002)



Time-dependent CP violation: Experimental Technique

Coherent $B^0\bar{B^0}$-Production:

$$|\psi> = |B^0(1)\bar{B}^0(2)> - |B^0(2)\bar{B}^0(1)>$$



$$\Delta t \approx \Delta z / \langle \beta\gamma \rangle c$$

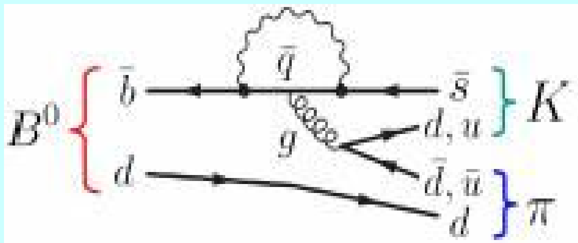
$\langle \Delta z \rangle \approx 250\ \mu m$

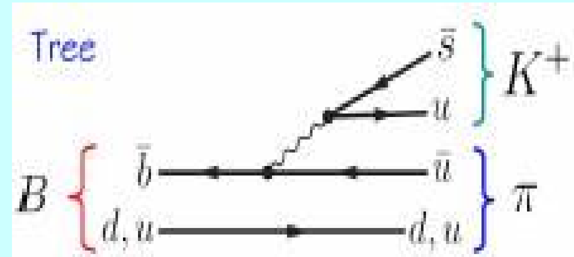
($\beta\gamma$ = 0.56(BABAR), 0.42 (Belle))

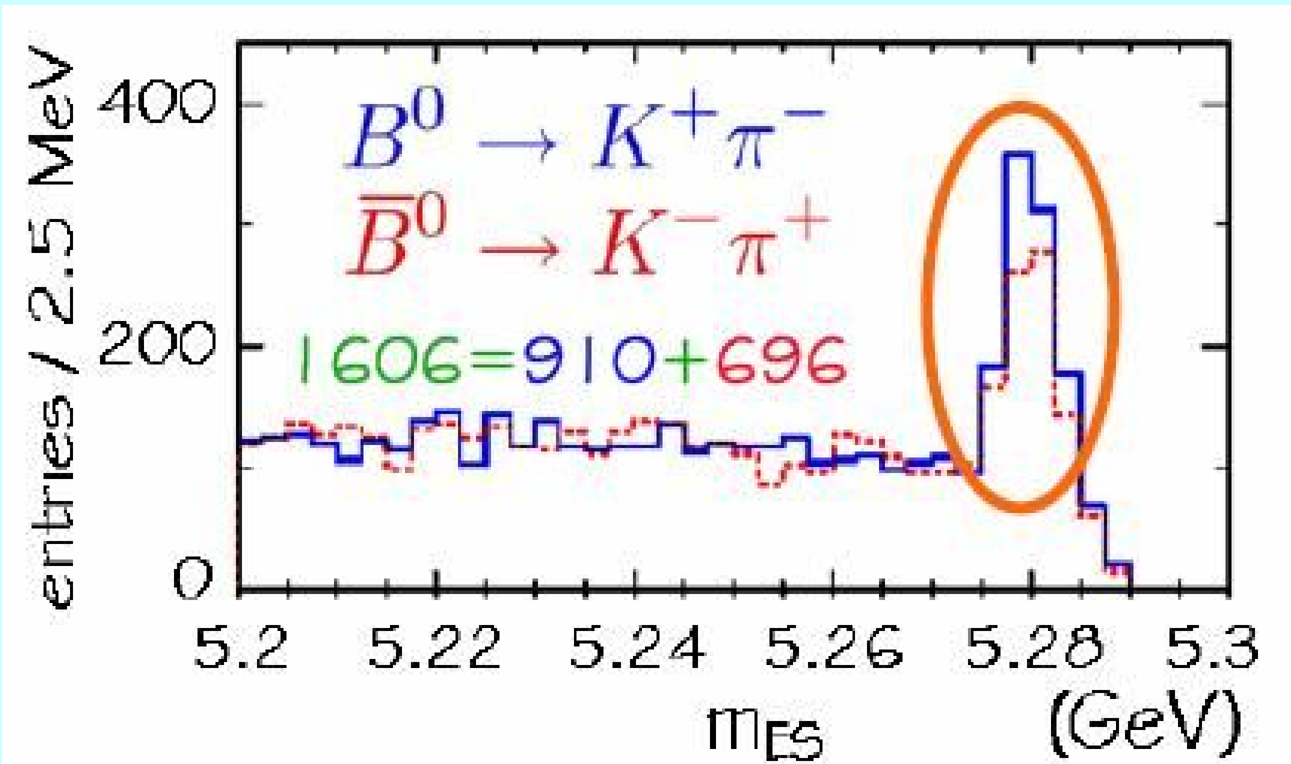
$\langle \Delta z \rangle \approx 30\ \mu m$ without Boost

$B^0_{rec} = B^0_{flav}$ **(Flavor eigenstate)**	➡	**Oscillation, life time, ...**
$B^0_{rec} = B^0_{CP}$ **(*CP* eigenstate)**	➡	***CP* asymmetries**

CP violation in decay in the B system







$$\mathcal{A}_{K\pi} = -0.133 \pm 0.030 \pm 0.009$$

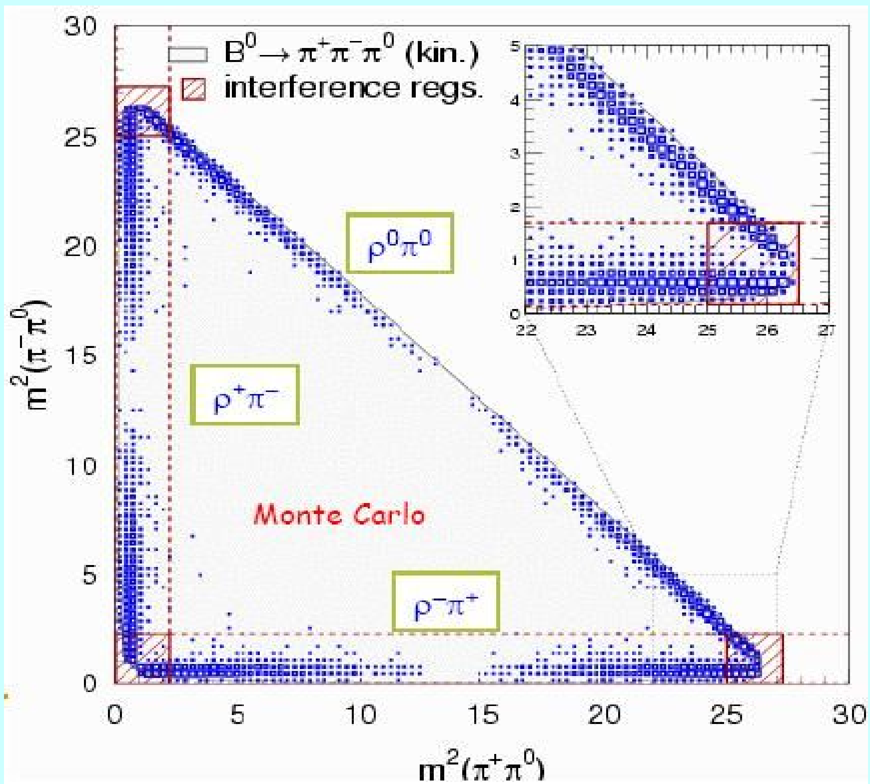
(a 4.2 sigma effect)

$$m_{ES} = \sqrt{E^{*2}_{beam} - \vec{p}^{\,2}_B}$$

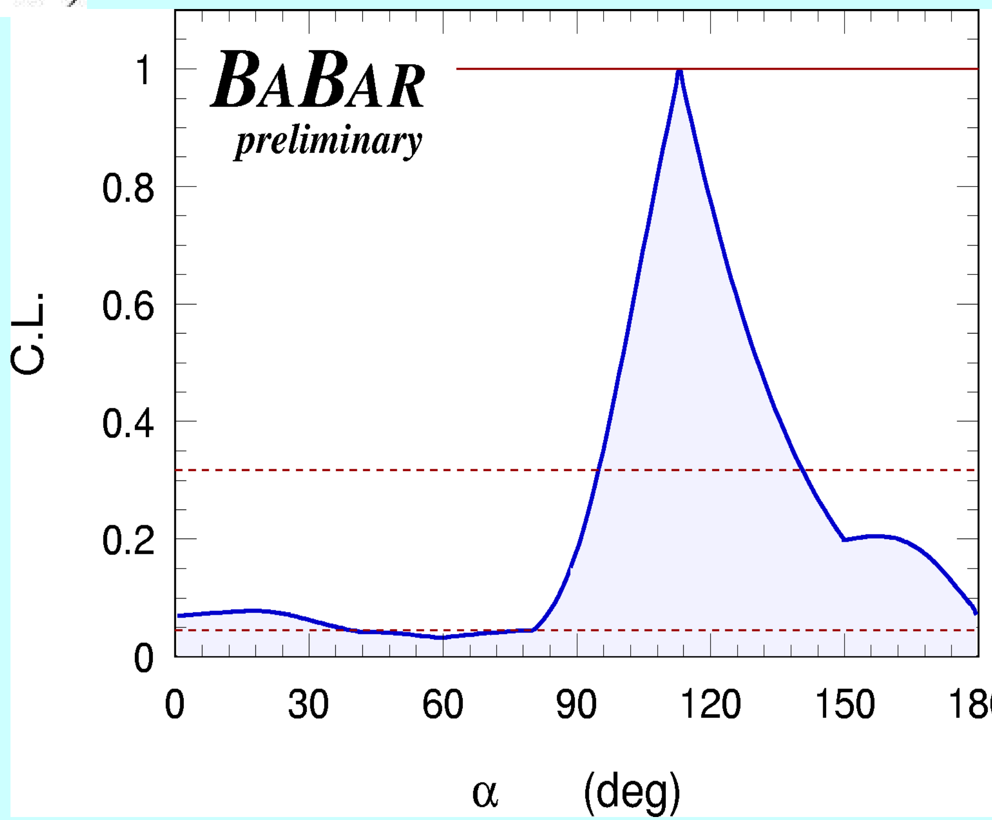
The third way to α:
Time-dependent Dalitz plot analysis $B^0 \to \pi^0 \pi^+ \pi^-$

Snyder & Quinn, PRD 48, 2139 (1993)

$$A(B^0 \to \pi^+\pi^-\pi^0) = f_+ A(\rho^+\pi^-) + f_- A(\rho^-\pi^+) + f_0 A(\rho^0\pi^0)$$
$$\overline{A}(\overline{B}^0 \to \pi^+\pi^-\pi^0) = f_+ \overline{A}(\rho^+\pi^-) + f_- \overline{A}(\rho^-\pi^+) + f_0 \overline{A}(\rho^0\pi^0)$$



Assume ρ dominance and use phase information across Dalitz plane to extract α



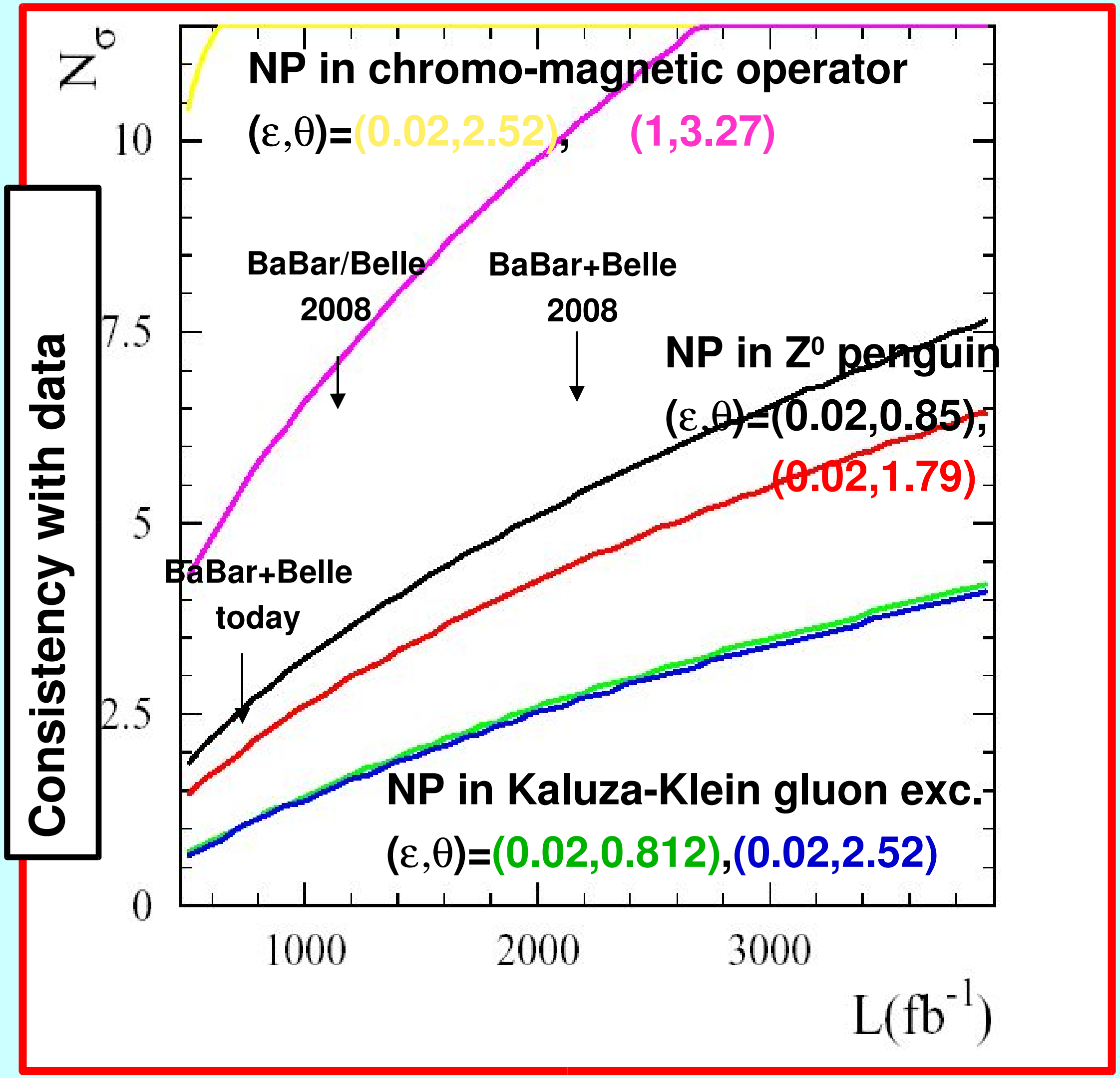
Extraction of α without ambiguity!

Discriminating between models

Buchalla, Hiller, Nir, Raz (hep-ph/0503151): differences among the values of S in several modes would discriminate between models.

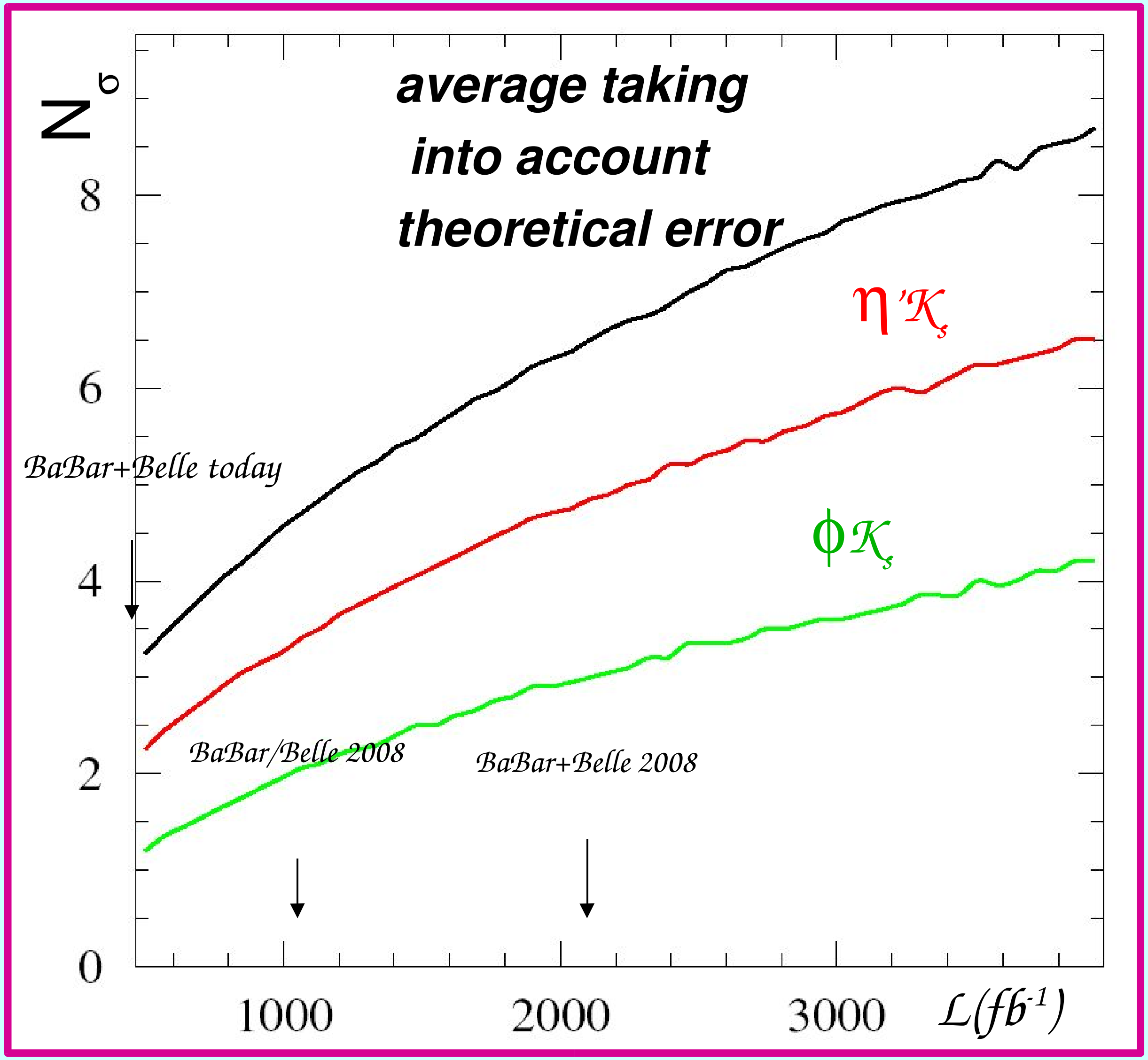
Wilson coefficients:

$$C_{NP}=C_{SM}(1+\varepsilon e^{i\theta})$$



Deviation from Standard Model

Assume that current values stay the same and compare with theoretical expectation



The "GGSZ" Dalitz Analysis

- **GGSZ : $B^- \to D^0(\to K_S \pi^+\pi^-)\, K^-$: Interference between amplitudes in Dalitz plot**

$$A_-(m_-^2, m_+^2) = \left|A(B^- \to D^0 K^-)\right| \left(f_{-+} + r_B e^{i(\delta-\gamma)} f_{+-}\right)$$

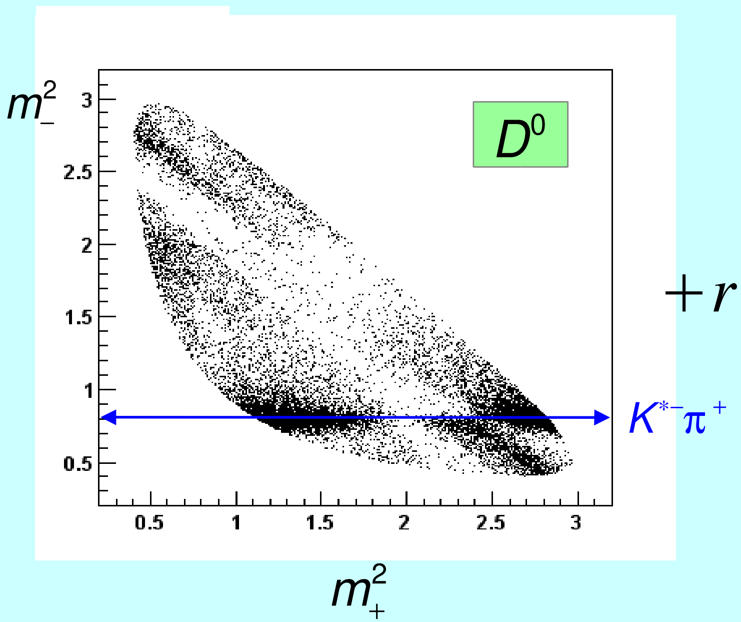
CP

$$A_+(m_+^2, m_-^2) = \left|A(B^+ \to \bar{D}^0 K^+)\right| \left(f_{+-} + r_B e^{i(\delta+\gamma)} f_{-+}\right)$$

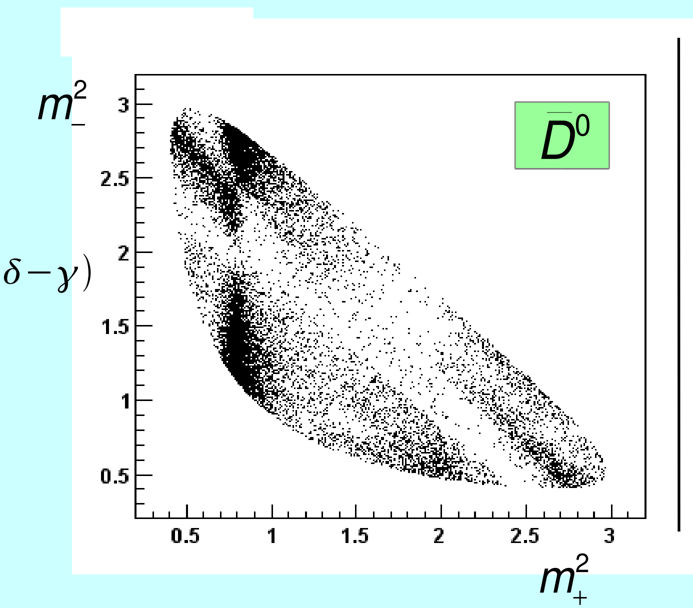
Sum of amplitudes contributing to $D^0 \to K_S \pi^+ \pi^-$

$$f_{+-} = f(m_+^2, m_-^2)$$
$$m_\pm = m(K_S^0 \pi^\pm)$$

$$|A_-|^2 = \left|A(B^- \to D^0 K^-)\right|^2 \Bigg|$$



$$+ r_B e^{i(\delta-\gamma)}$$

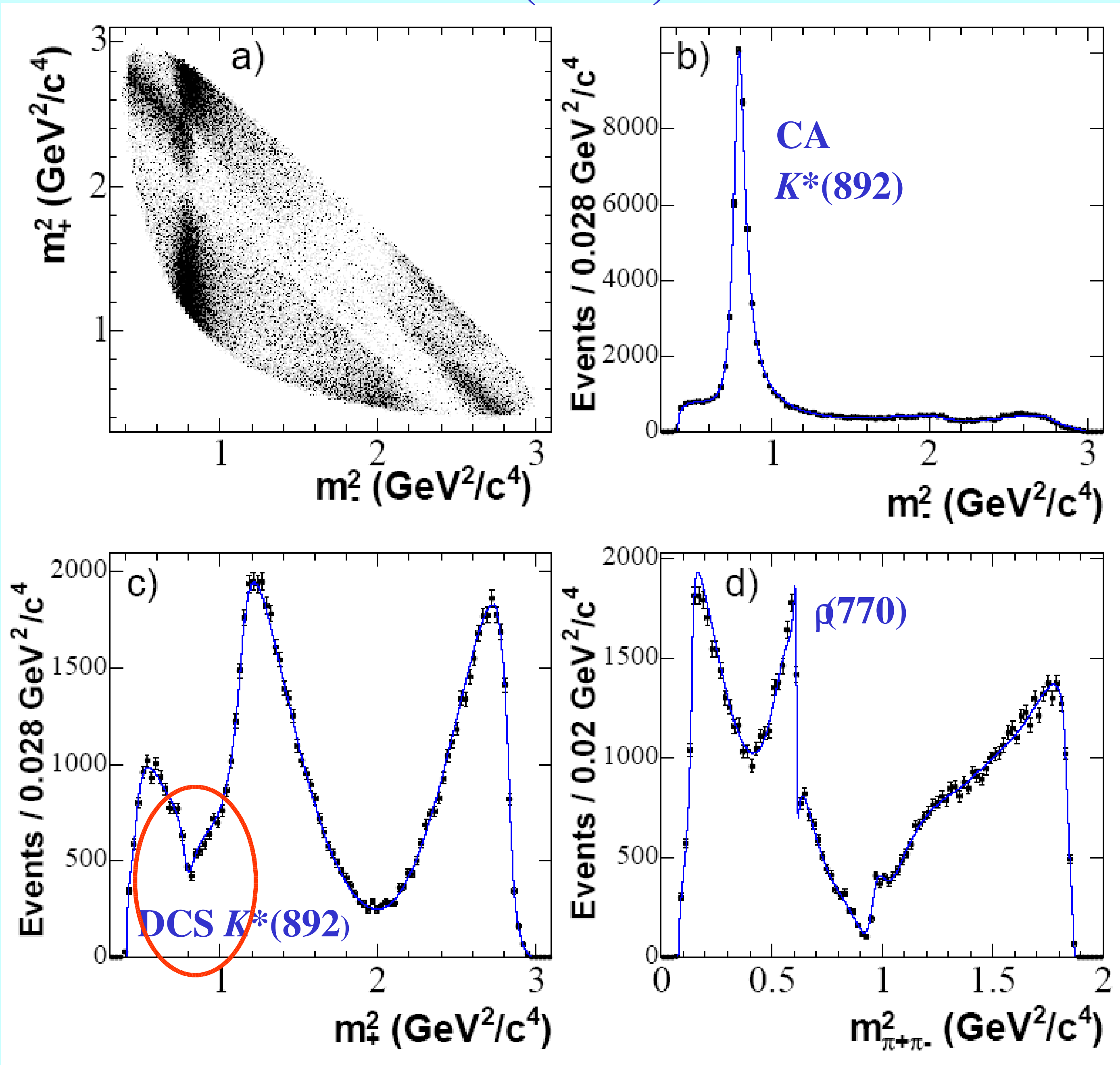


$$\Bigg|^2$$

Simultaneous measurement of r_B, δ and γ

The "GGSZ" Dalitz Analysis: Dalitz plane model

BABAR PRL 95(2005) 121802



Continuum data
$D^{*+} \to D^0\pi^+$ (91.5 fb^{-1})

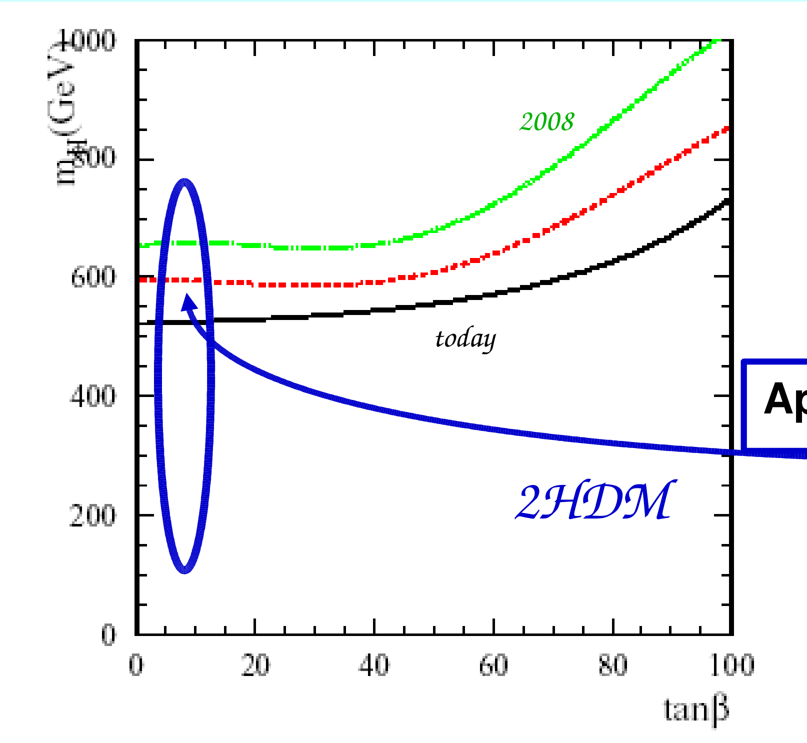
N_{evts} = 82 K
Purity: 97%

Issue: contribution of broad, s-wave resonances
Orig. method: 2 BWs
New: K-matrix

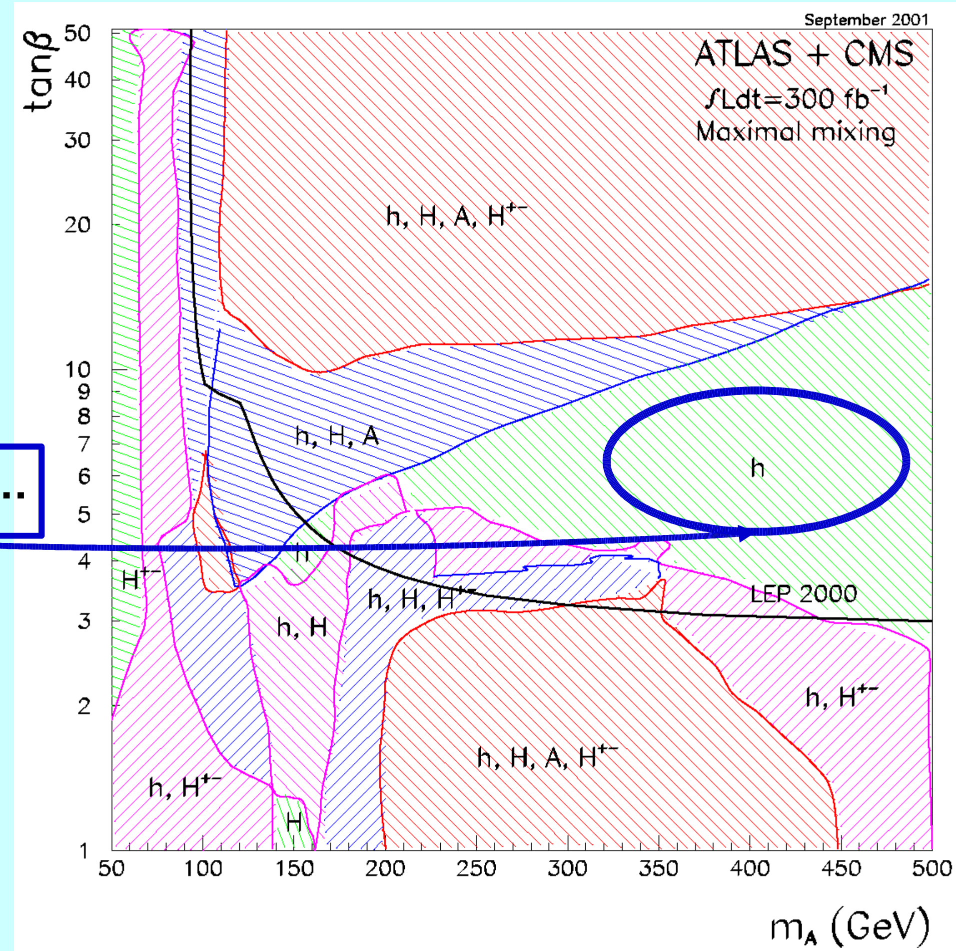
Anisovich & Saratev
Eur. Phys. J A16, 229 (2003)

χ^2/dof≈3824/3022=1.27

Projections and LHC: B $\rightarrow \tau\nu$ & b $\rightarrow s\gamma$



Approx…



Uncertain regions could be clarified by B-Factories

- **<u>depends on all other SUSY parameters</u> …**