

Results from BABAR & Comparison with Other Experiments



invited talk at
IX WHEPP
Bhubaneswar (Orissa)
3-14 /01/ 2006



Results from BABAR & Comparison with Other Experiments

Outline:

- ★ The Physics Program
- ★ The CKM Matrix and the Unitary Triangle
- ★ The Unitary Triangle by Sides
- ★ The Unitary Triangle by Angles
- ★ Search for N.P. & Constraints on the SM
- ★ The Unexpected
- ★ Conclusions & Perspectives

BABAR Physics Program

Study the flavor sector of the S.M. and search for new physics:

- Unitary Triangle
- CP Violation in B decays
- rare processes involving B,D mesons and τ leptons

A Disclaimer:

- BABAR and Belle released more than 300 articles to-date
- Many very interesting measurements ~ constant publishing rate
- Will only highlight the most important (based on my own judgment)

TOPICS:

- ★ The Physics Program
- ★ **The CKM Matrix and the Unitary Triangle**
- ★ The Unitary Triangle by Sides
- ★ The Unitary Triangle by Angles
- ★ Search for N.P. & Constraints on the SM
- ★ The Unexpected
- ★ Conclusions & Perspectives

- Expresses in the Standard Model the coupling between quarks of different flavour
- Only four independent parameters, three Euler's angles and **one phase**

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

- CKM paradigm :

All CP violating phenomena in transitions between hadrons are described in terms of a unique parameter, the CKM phase

$$V_{CKM} \simeq \begin{bmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho+i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\bar{\rho}+i\bar{\eta}) & -A\lambda^2 & 1 \end{bmatrix}$$

$$\lambda = \sin \theta_c = 0.2258 \pm 0.0011$$

$$A, \rho, \eta = o(1)$$

$$\bar{\rho} = \rho \cdot (1 - \lambda^2/2)$$

$$\bar{\eta} = \eta \cdot (1 - \lambda^2/2)$$

- An approximation, precise to $o(\lambda^3)$, underlining the observed (*yet unexplained*) hierarchy of CKM parameters

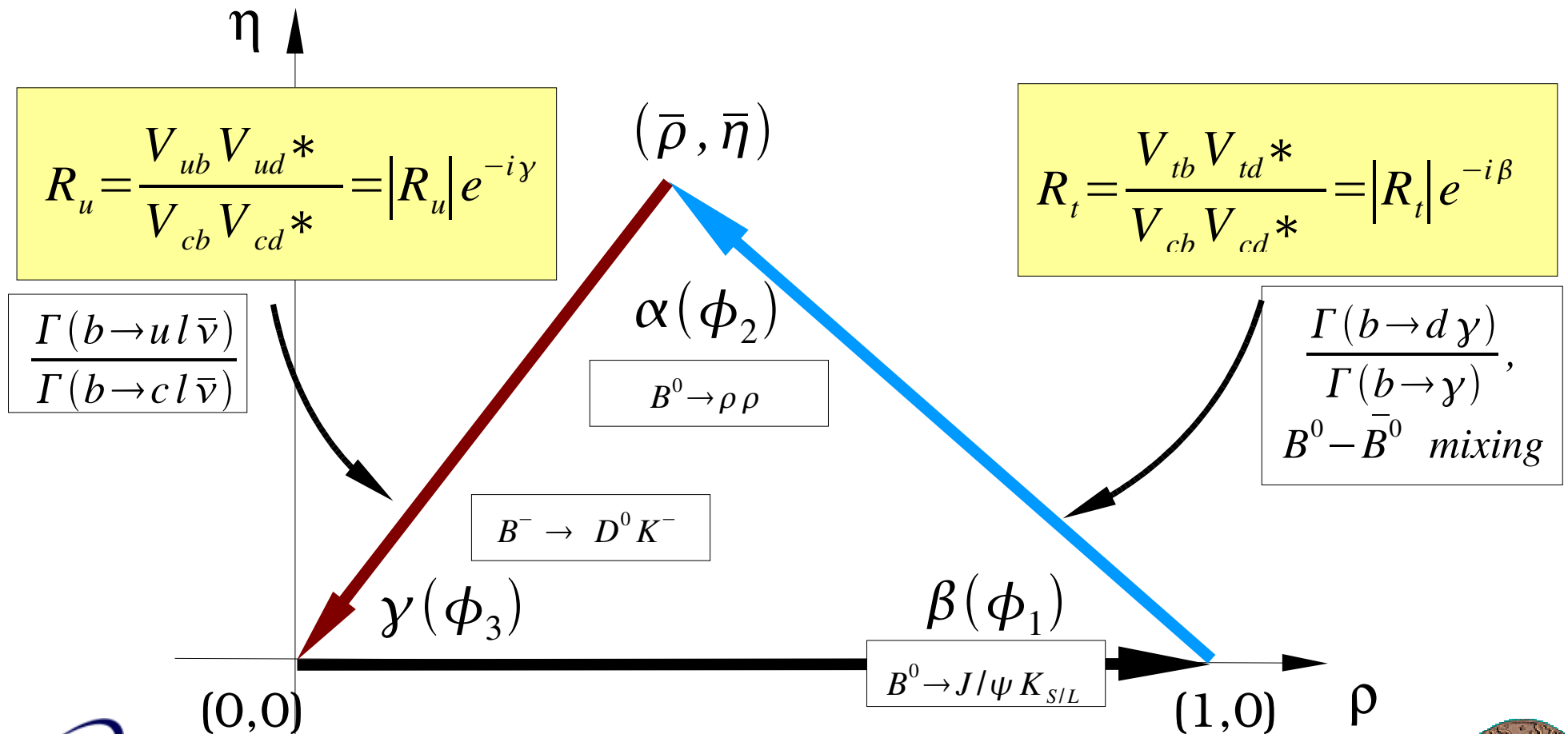
CP Violation : $\eta \neq 0$

CKM and the Unitarity Triangle

- Unitarity Condition:
- Rescaled Triangle:

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

$$R_u + 1 + R_t = 0$$

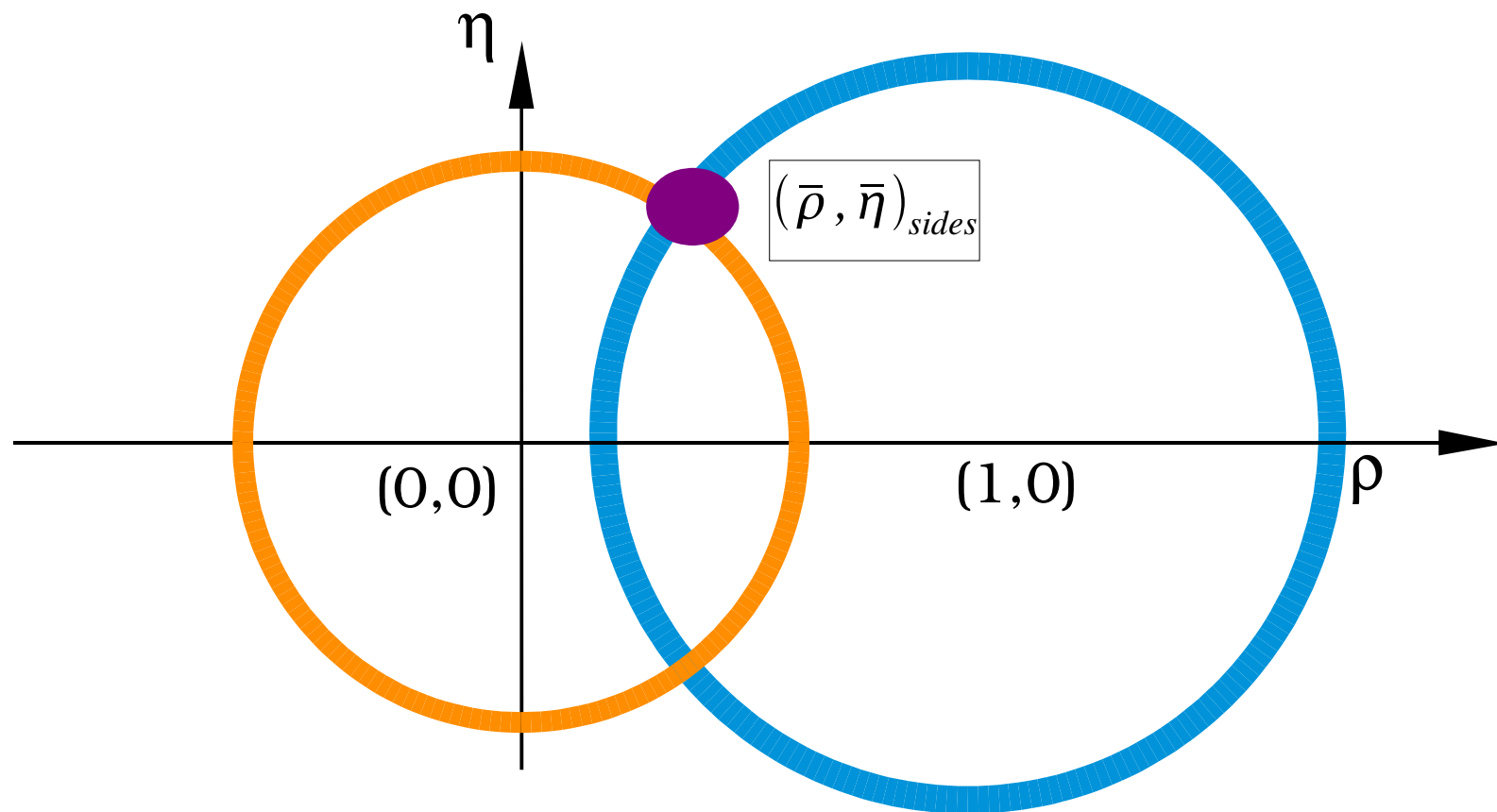


- Determine sides and angles of the UT
- Verify consistency, e.g. getting apex coordinates (ρ, η) of UT

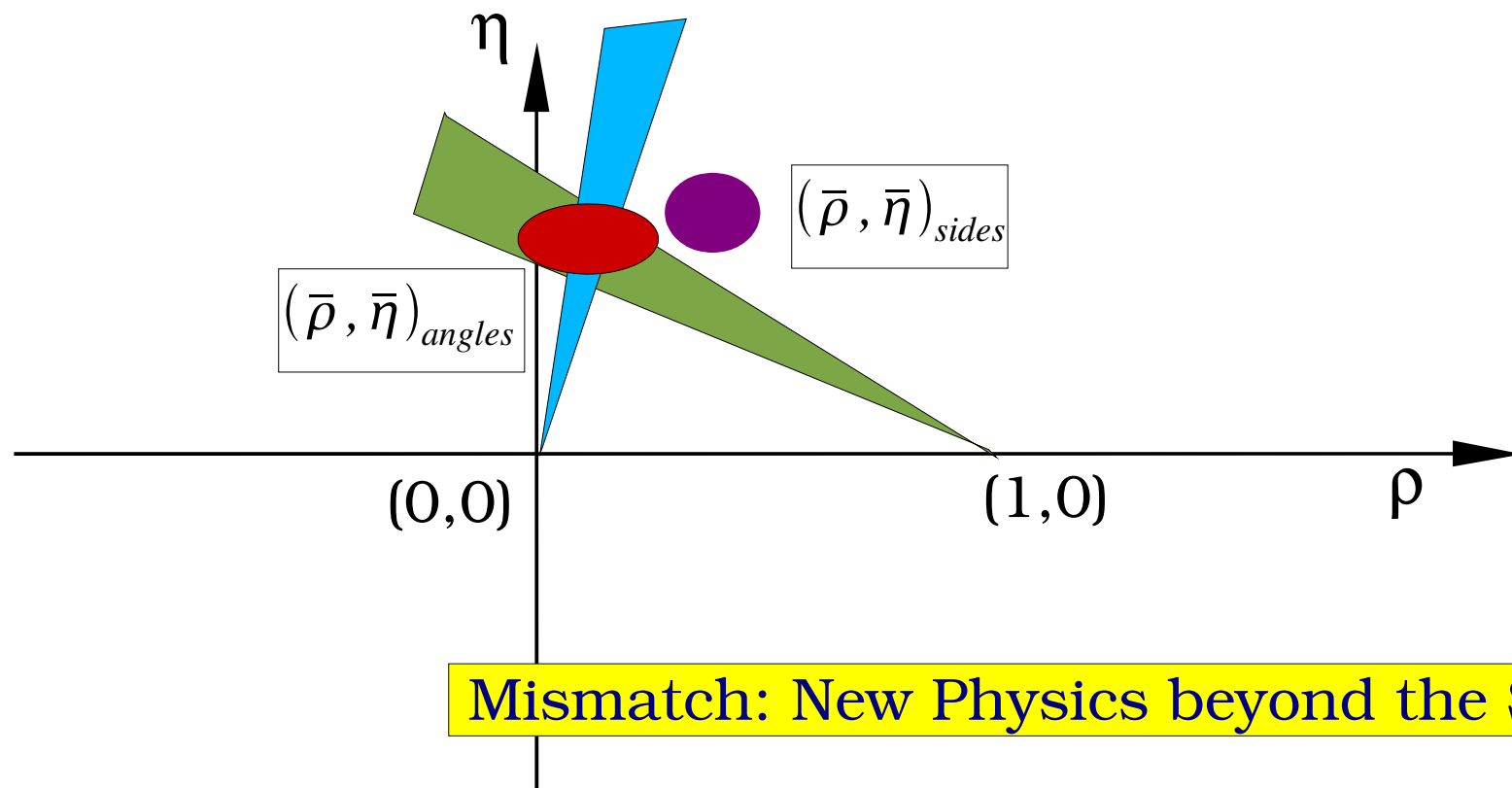
9

Constraining the UT

- Determine sides and angles of the UT
- Verify consistency, e.g. getting apex coordinates (ρ, η) of UT
 - by intersecting sides ($|R_u|$, $|R_t|$)



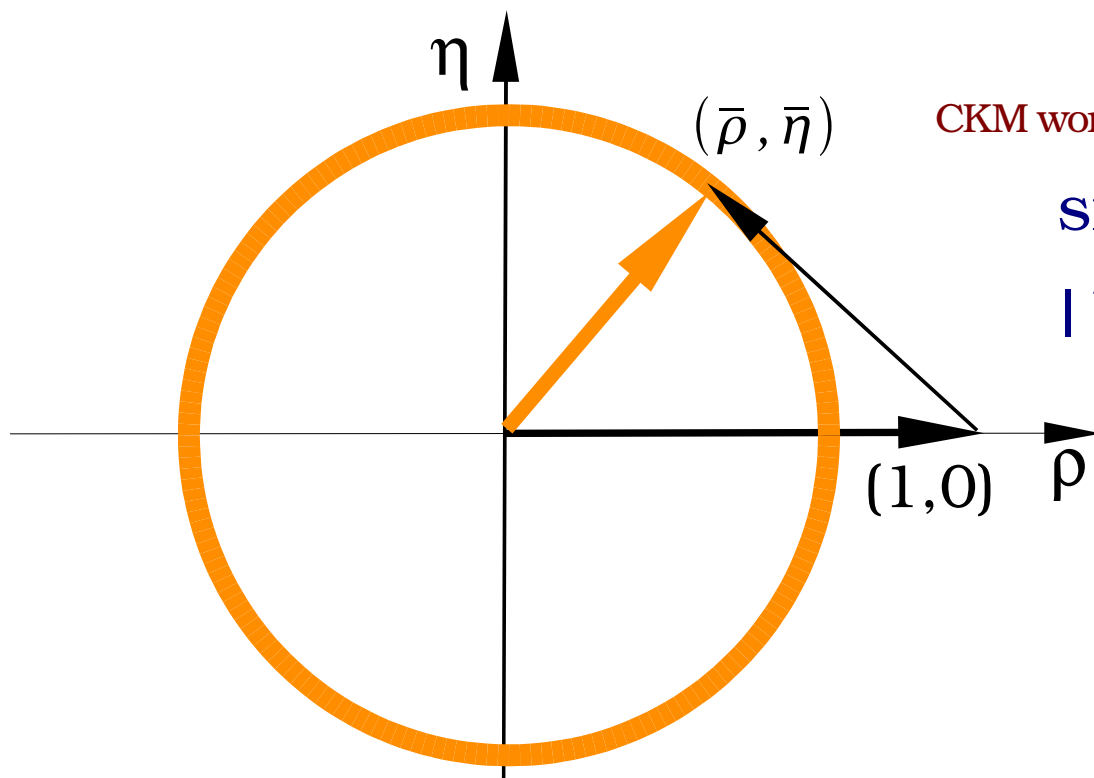
- Determine sides and angles of the UT
- Verify consistency, e.g. getting apex coordinates (ρ, η) of UT
 - by intersecting sides $(|R_u|, |R_t|)$
 - by intersecting angles (α, β, γ)



TOPICS:

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$$|R_u| = \left| \frac{V_{ub} V_{ud}^*}{V_{cb} V_{cd}^*} \right| = \frac{1}{\tan \theta_c} \left| \frac{V_{ub}}{V_{cb}} \right| = \bar{\rho}^2 + \bar{\eta}^2$$



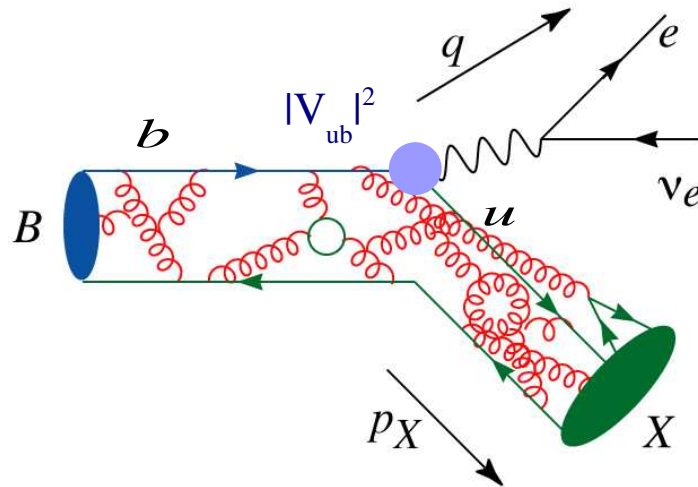
CKM workshop San Diego 2005:

$$\sin \Theta_c = 0.2258 \pm 0.0011$$

$$|V_{cb}| = (41.6 \pm 0.7) \times 10^{-3}$$

Error dominated by $|V_{ub}|$ measurement

1



Determination of $|V_{ub}|$

$$\Gamma(b \rightarrow u l \bar{\nu}) \propto |V_{ub}|^2$$

OPE : $|V_{ub}|$ from $\Gamma(b \rightarrow ul\bar{\nu})$ with 5% error

- Apply hard cuts to reduce $b \rightarrow cl\bar{\nu}$ background $\frac{\Gamma(b \rightarrow cl\bar{\nu})}{\Gamma(b \rightarrow ul\bar{\nu})} \simeq 50$
- Measure *partial Branching Ratio* ΔBr , get $ul\bar{\nu}$ decay width

$$\Gamma(b \rightarrow u l \bar{\nu}) = \frac{\Delta Br}{\tau_B} \cdot f_u$$

- Compute acceptance correction f_u using QCD-inspired models, educated by data

$$f_u = \iiint H(q^2, E_l, M_X) \otimes F(\tilde{k} | m_b, \Lambda, \mu_\pi^2 \dots)$$

parton level

non perturbative
"shape function"



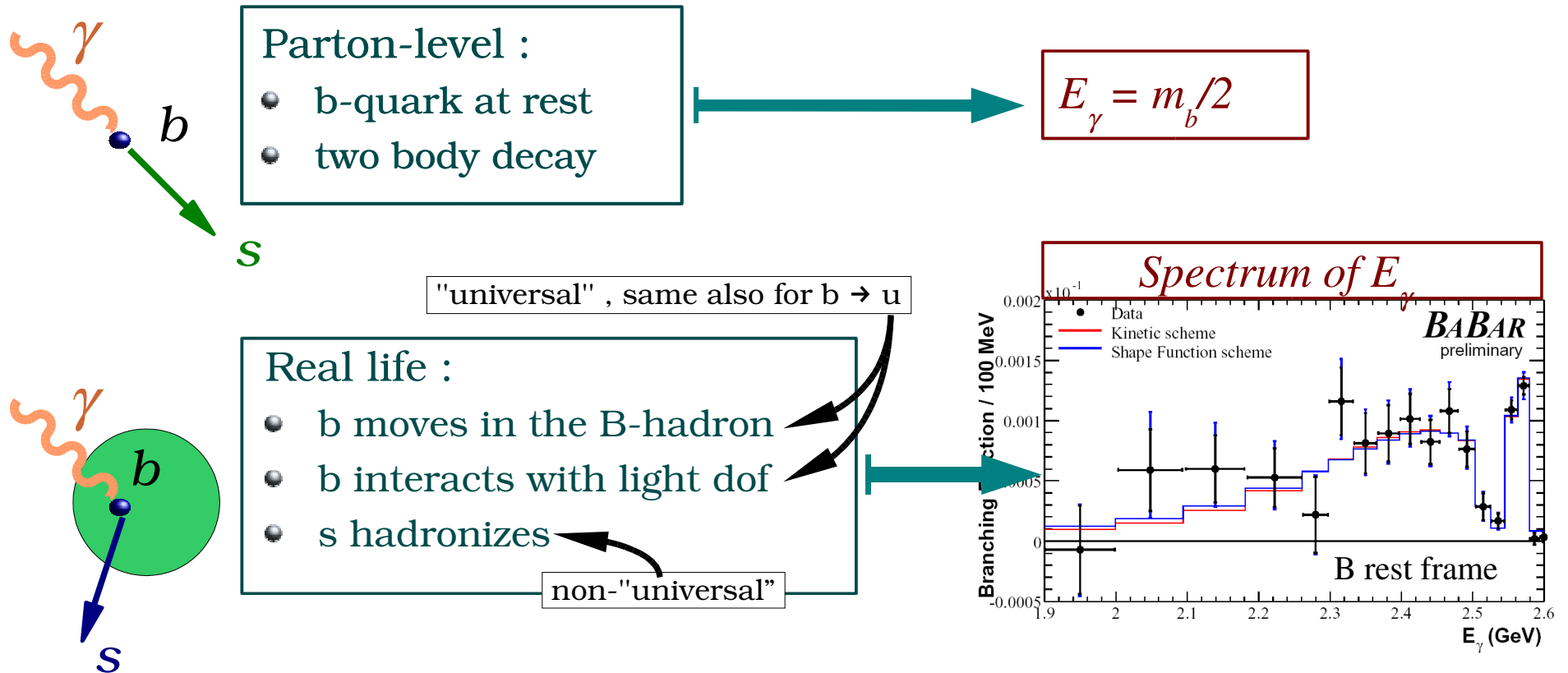
f_u depends on non-perturbative parameters

- m_b : *b-quark mass*
- μ_π^2 : *b-quark kinetic energy in B hadron rest frame*
- Λ : *motion of the light quark*
- ...

determined in the ansatz of an universal (shape) function from:

- $b \rightarrow s\gamma$ decays
- $b \rightarrow cl\nu$ decays

15 Measurement of SF parameters from $b \rightarrow s\gamma$



Compute SF from the (moments of) E_γ spectrum in $b \rightarrow s\gamma$ decays:

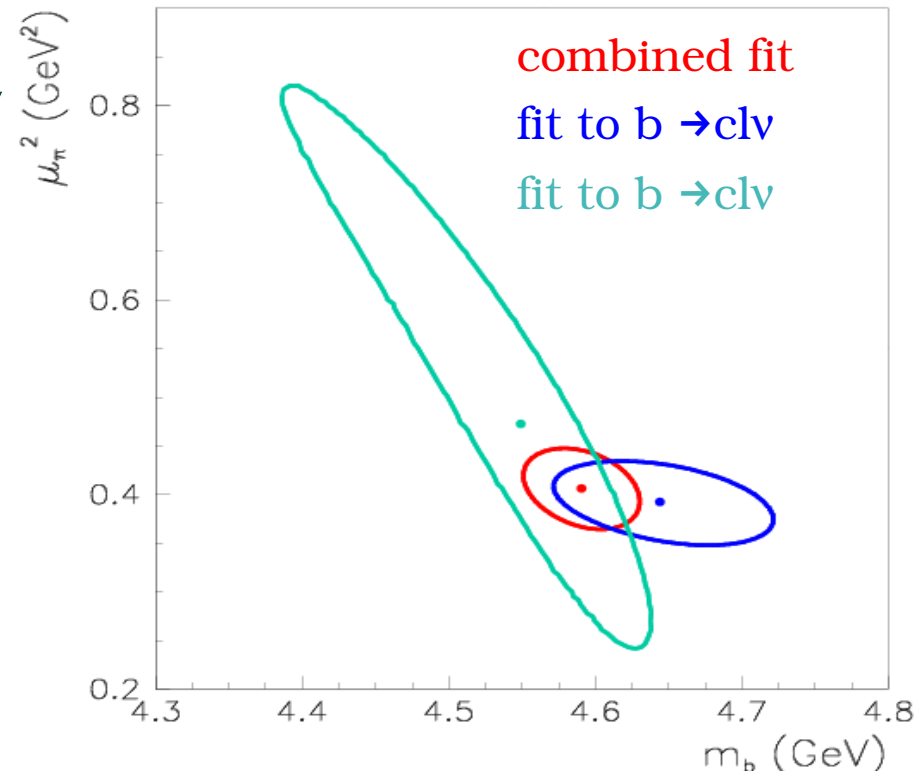
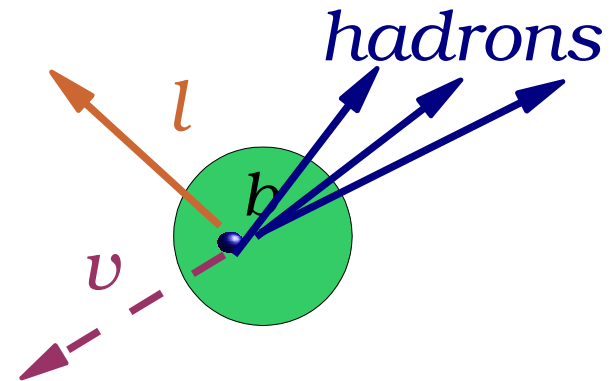
$$E^{(1)} = \langle E_\gamma \rangle \approx \frac{m_b}{2},$$

$$E^{(2)} = \langle E_\gamma^2 - \langle E_\gamma \rangle^2 \rangle \approx \mu_\pi \approx E_{kin}(b),$$

...

16 Measurement of SF parameters from $b \rightarrow clv$

- Non-perturbative effects also affect lepton and hadron spectra in $b \rightarrow clv$ decays
- Measurement of E_l and M_{hadron} moments allow another determination of Shape Function
- Results are consistent with $b \rightarrow sy$



Errors on SF parameters:

- **experimental** (measurement of the moments)
- **model** : non – universality (sub-leading S.F.) *not shown in the plot*

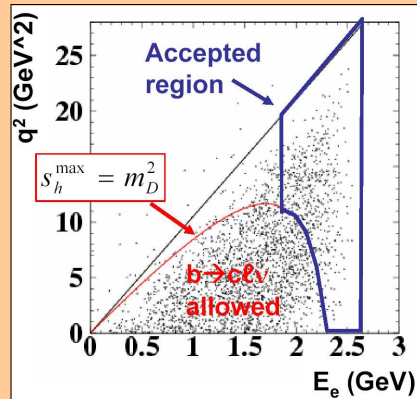
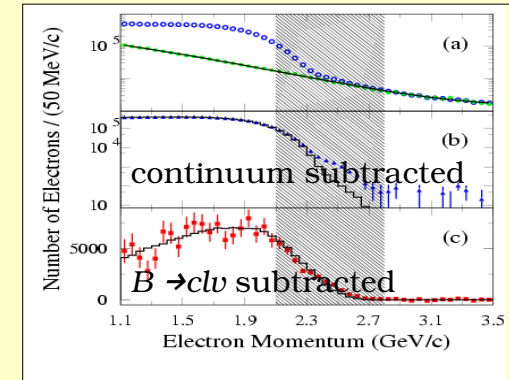
$|V_{ub}|$: inclusive measurements

E_e end point (80 fb⁻¹)

CLEO (1994) : $E_e > 2.3$ GeV, (c threshold)

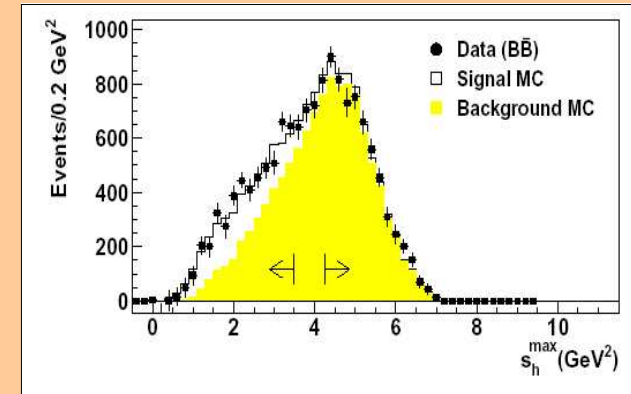
BABAR: $E_e > 2.0$ (↓ model uncertainty)

(Belle $E_e > 1.9$) S/B ~ 1/14, $f_u = 0.250 \pm 0.026$

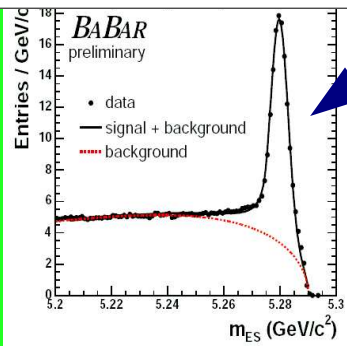


$E_e - q^2$ (80 fb⁻¹)

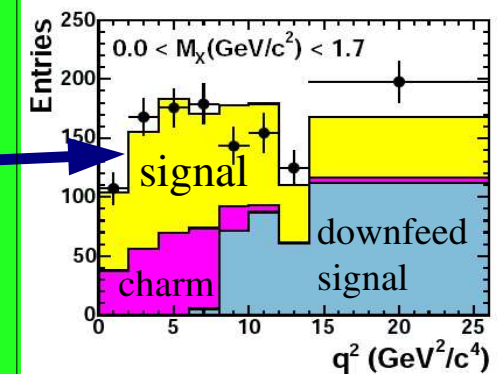
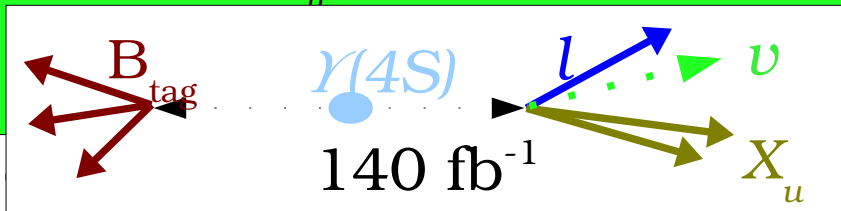
$\vec{p}_\nu$ from missing momentum
correlated cut to reduce c
S/B ~ 1/2, $f_u = 0.163 \pm 0.012$



Recoil Hadrons



Fully reconstruct tag B (↓ efficiency)
Mass (M_X) and q^2 of recoil hadrons (X_u)
Count events in *high- q^2 , low- M_X* bin
S/B > 1/1, $f_u = 0.300 \pm 0.026$

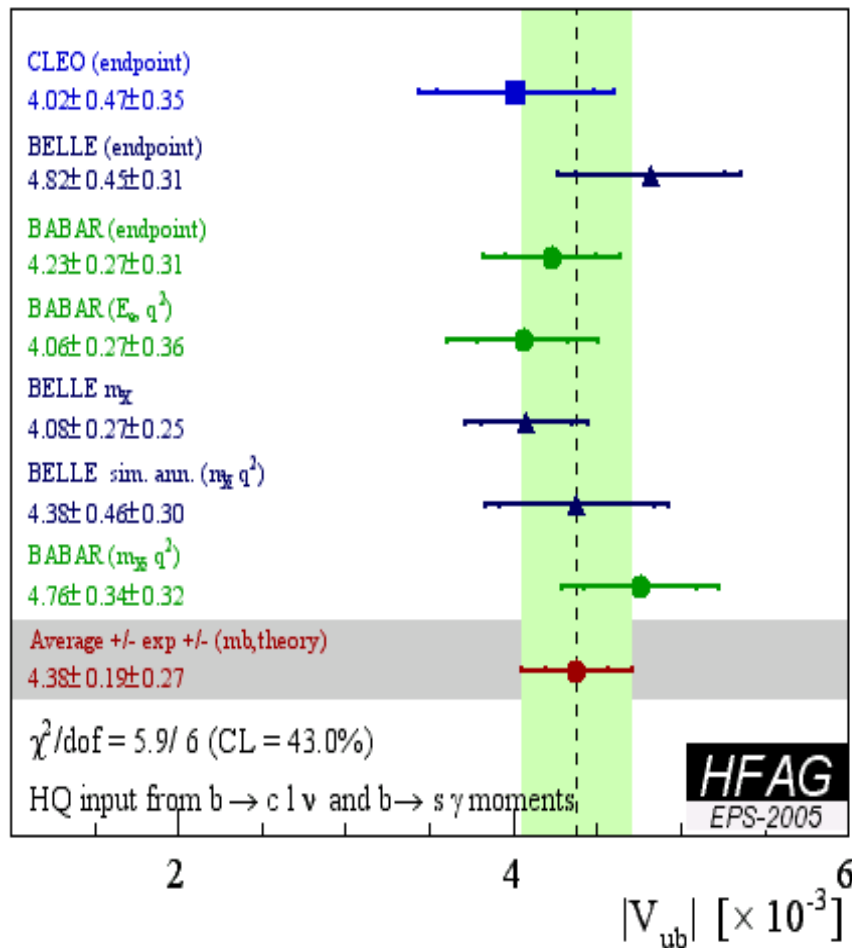


V_{ub} : results & WA

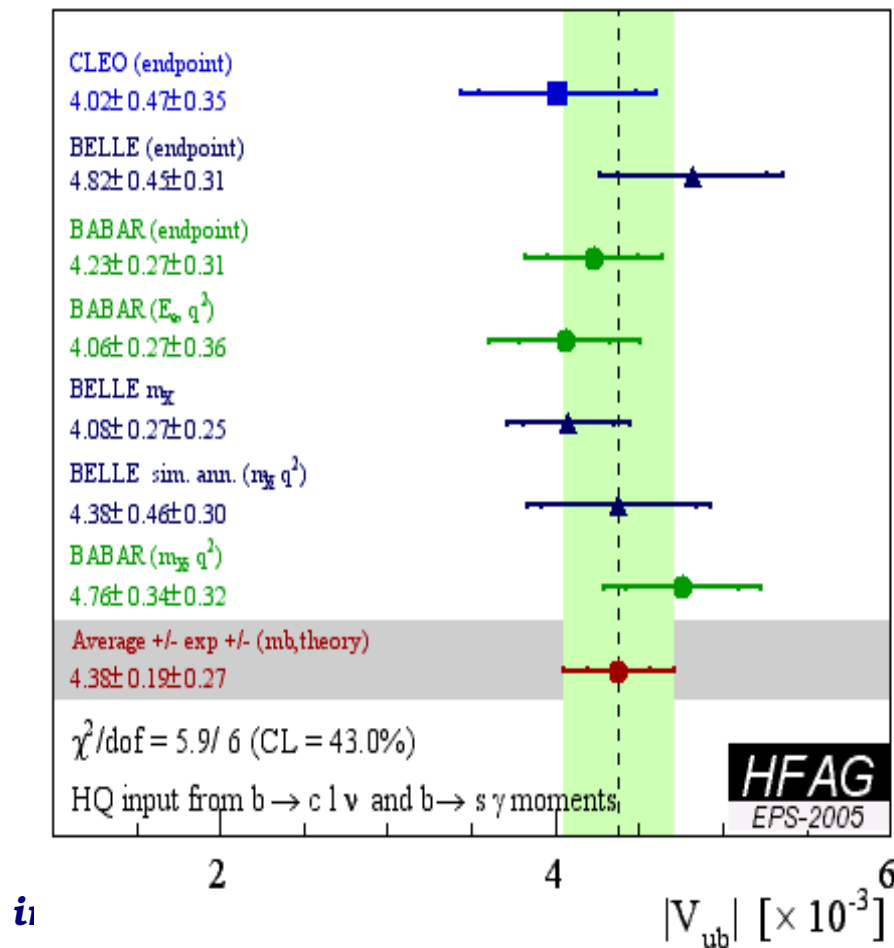
World Average, summer 2005:

$$|V_{ub}| = (4.38 \pm 0.19_{\text{exp}} \pm 0.27_{\text{theo}}) 10^{-3}$$

$$\Delta V_{ub}/V_{ub} = (3.3_{\text{expt}} \oplus 2.9_{\text{model}} \oplus 4.7_{\text{SF}} \oplus 4.0_{\text{theory}})\% = 7.6\%$$



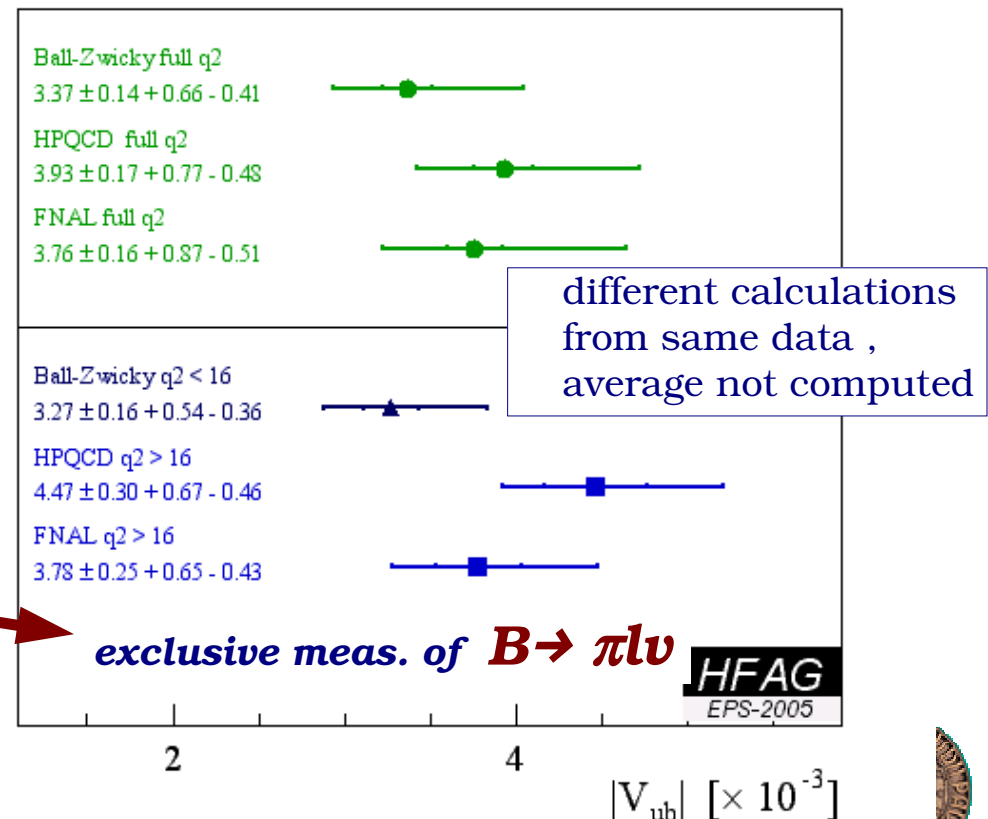
V_{ub} : comparison to exclusive $B \rightarrow \pi l \nu$



World Average, summer 2005:

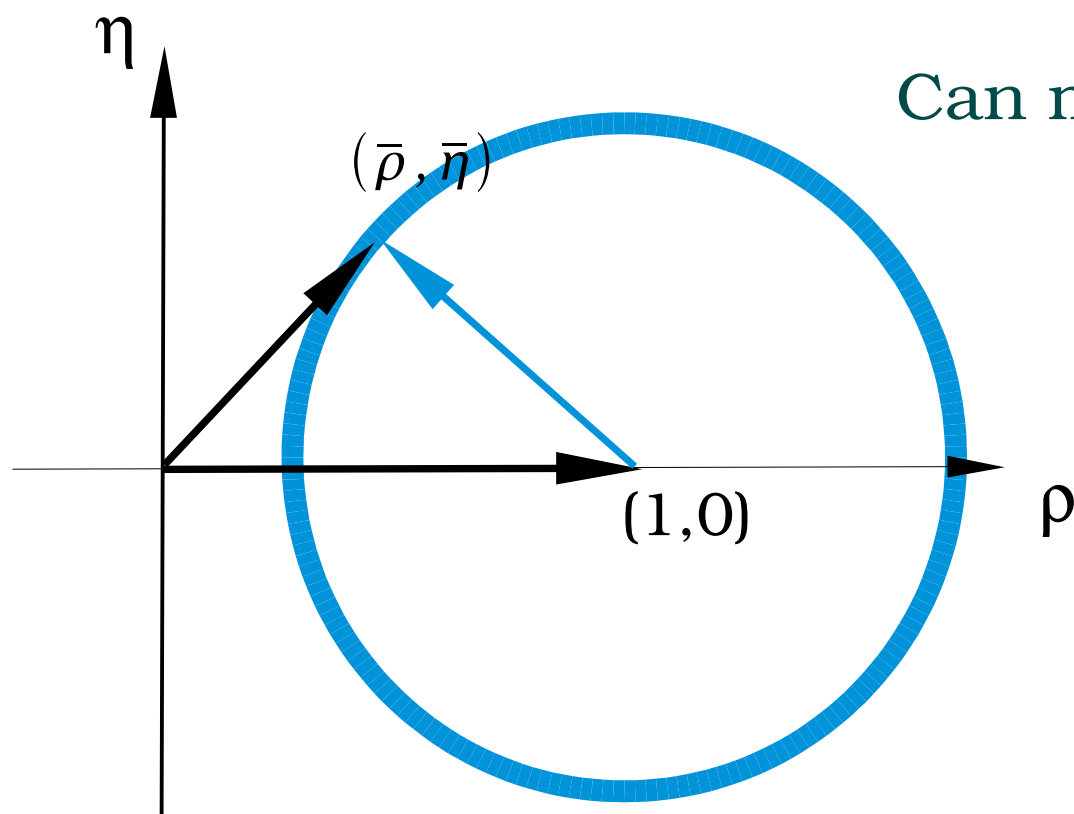
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Consistent with, and more precise than the results from $B \rightarrow \pi l \nu$ exclusive decays

$$|R_t| = \left| \frac{V_{tb} V_{td}^*}{V_{cb} V_{cd}^*} \right| = \frac{1}{\sin \theta_c} \left| \frac{V_{td}}{V_{cb}} \right| = (1 - \bar{\rho})^2 + \bar{\eta}^2$$



Can measure $|V_{td}|$ from :

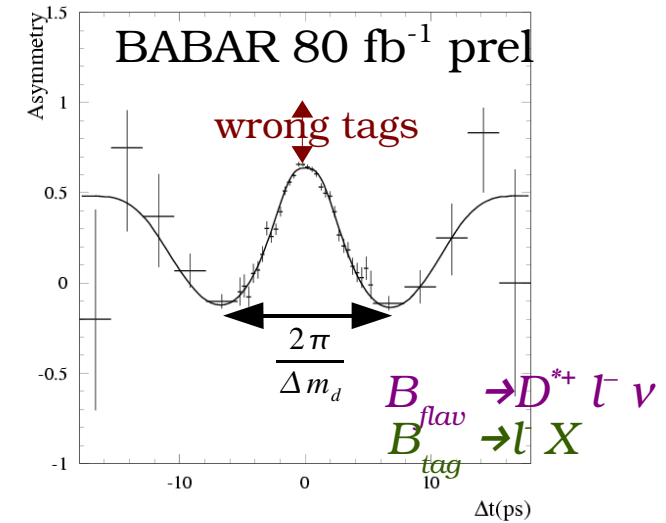
$B^0 \bar{B}^0$ mixing

$$\frac{\Gamma(b \rightarrow d \gamma)}{\Gamma(b \rightarrow s \gamma)}$$

2: $\Delta m_d = \frac{G_F^2}{6\pi^2} m_{B_d} (\hat{B}_{B_d} F_{B_d}^2) \eta_B m_W^2 S_0(x_t) |V_{td}|^2$ $|V_{td}|$ from Δm_d

Time dependent flavor asymmetry :

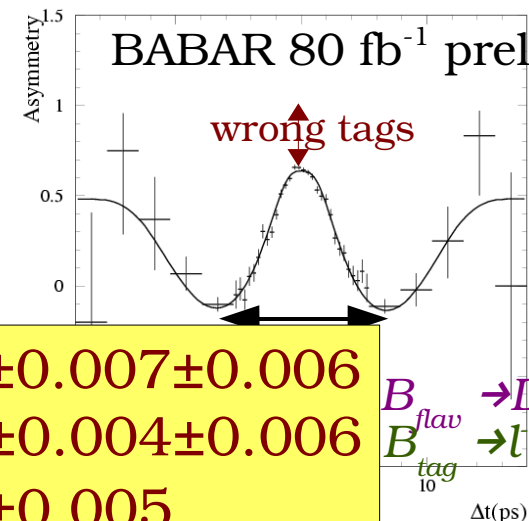
$$\cos(\Delta m \Delta t) = \frac{N(B^0 \bar{B}^0) - N(B^0 B^0)}{N(B^0 \bar{B}^0) + N(B^0 B^0)} (\Delta t)$$



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*BABAR 80 fb⁻¹ : (l vs D*lv)*

$0.510 \pm 0.007 \pm 0.006$

Belle 140 fb⁻¹ : (three analyses)

$0.509 \pm 0.004 \pm 0.006$

W.A. (8 exp., 31 analyses)

0.506 ± 0.005

Best known parameter in B Physics

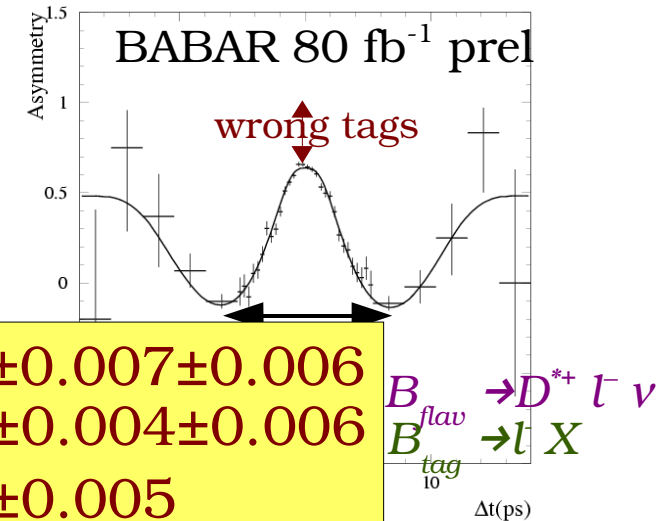
$B \rightarrow D^{*+} l \nu$
 $B_{flav} \rightarrow l X$
 B_{tag}



2: $\Delta m_d = \frac{G_F^2}{6\pi^2} m_{B_d} (\hat{B}_{B_d} F_{B_d}^2) \eta_B m_W^2 S_0(x_t) |V_{td}|^2$ $\frac{|V_{td}|}{\Delta m_d}$ from Δm_d

Time dependent flavor asymmetry :

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BABAR 80 fb ⁻¹ : (l vs D*lv)	0.510±0.007±0.006
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Best known parameter in B Physics	

... however ...

$$F_{B_d} \sqrt{B_{B_d}} = 0.192 \pm 0.026 \pm 0.09$$

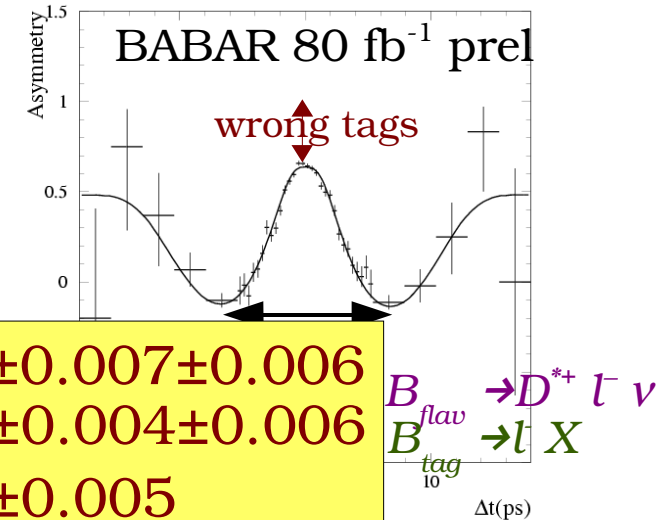
→ Large error band in UT plane



2. $\Delta m_d = \frac{G_F^2}{6\pi^2} m_{B_d} (\hat{B}_{B_d} F_{B_d}^2) \eta_B m_W^2 S_0(x_t) |V_{td}|^2$ $|V_{td}|$ from Δm_d

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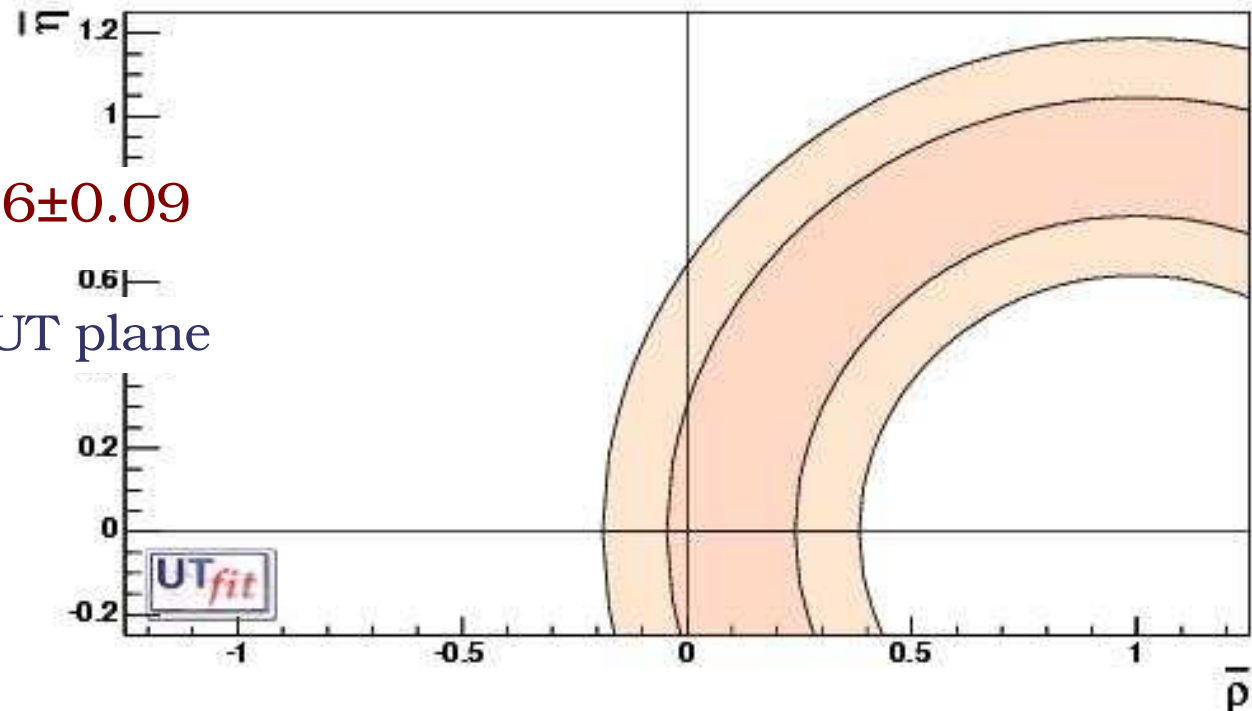


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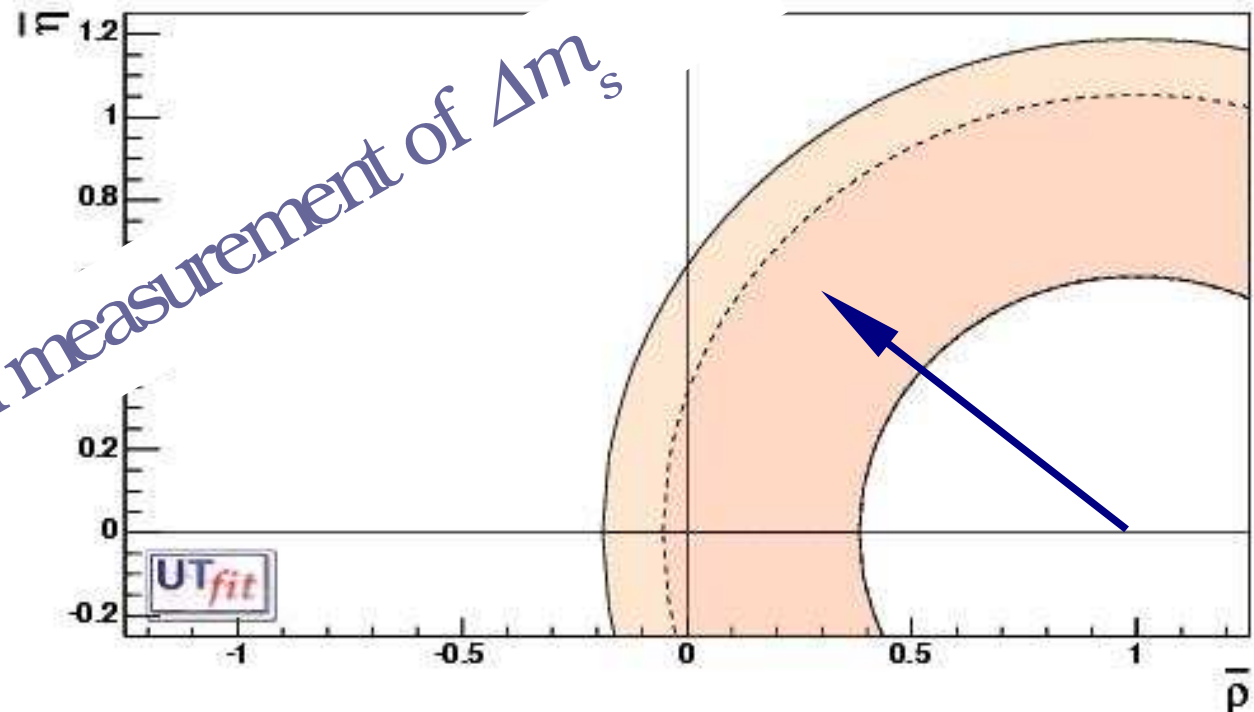


$$\frac{\Delta m_d}{\Delta m_s} = \frac{m_{Bd}}{m_{Bs}} \frac{1}{\xi^2} \frac{|V_{td}|^2}{|V_{ts}|^2} \simeq \frac{m_{Bd}}{m_{Bs}} \frac{1}{\xi^2} \frac{|V_{td}|^2}{|V_{cb}|^2}$$

$$\xi = \frac{f_{Bs} \sqrt{B_{Bs}}}{f_{Bd} \sqrt{B_{Bd}}} = 1.24 \pm 0.06$$

$$\Delta m_s > 14.5 \text{ ps}^{-1} \quad (LEP + SLD + Tevatron)$$

need measurement of Δm_s



$|V_{td}|$ from radiative penguins

$$\frac{|V_{td}|^2}{|V_{ts}|^2} \propto \frac{\Gamma(b \rightarrow d \gamma)}{\Gamma(b \rightarrow s \gamma)}$$

Theoretically clean. Exp. nightmare

$$\frac{\Gamma(B \rightarrow \rho/\omega \gamma)}{\Gamma(B \rightarrow K^* \gamma)}$$

Within exp. reach. Th. concerns: $\left\{ \begin{array}{l} \text{Weak Annihilation} \\ \text{SU(3) Breaking} \end{array} \right.$

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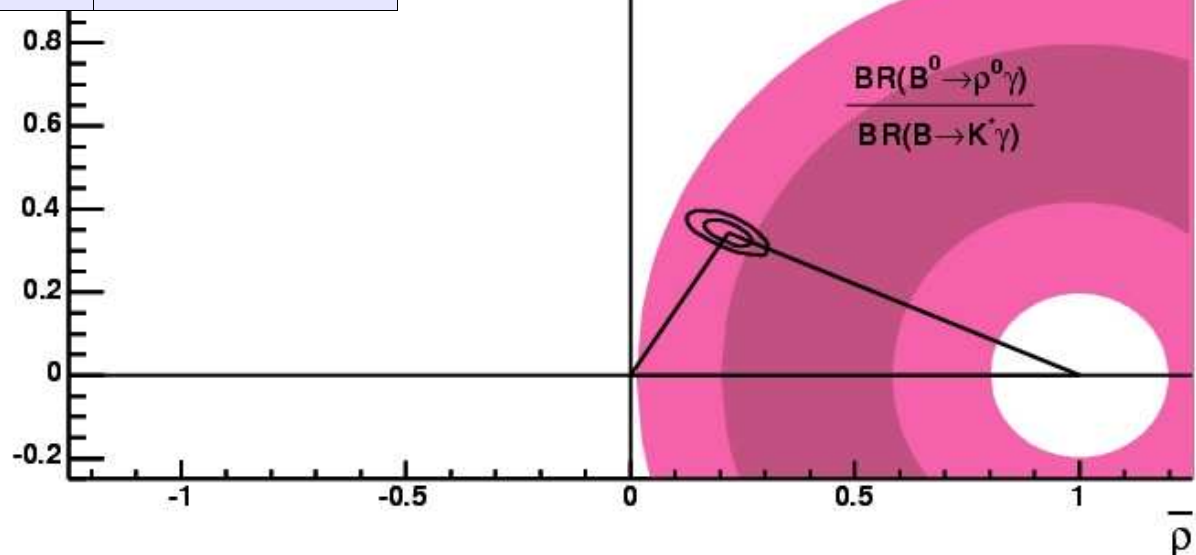
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Within exp. reach. Th. concerns:

{ Weak Annihilation
SU(3) Breaking

	exp	BR (10^{-6})
$K^+ \gamma$	W.A.	40.1 ± 2.0
$K^0 \gamma$	W.A.	40.3 ± 2.6
$\rho/\omega \gamma$	BABAR (200 fb^{-1})	< 1.2
$\rho/\omega \gamma$	Belle (350 fb^{-1})	1.34 ± 0.36



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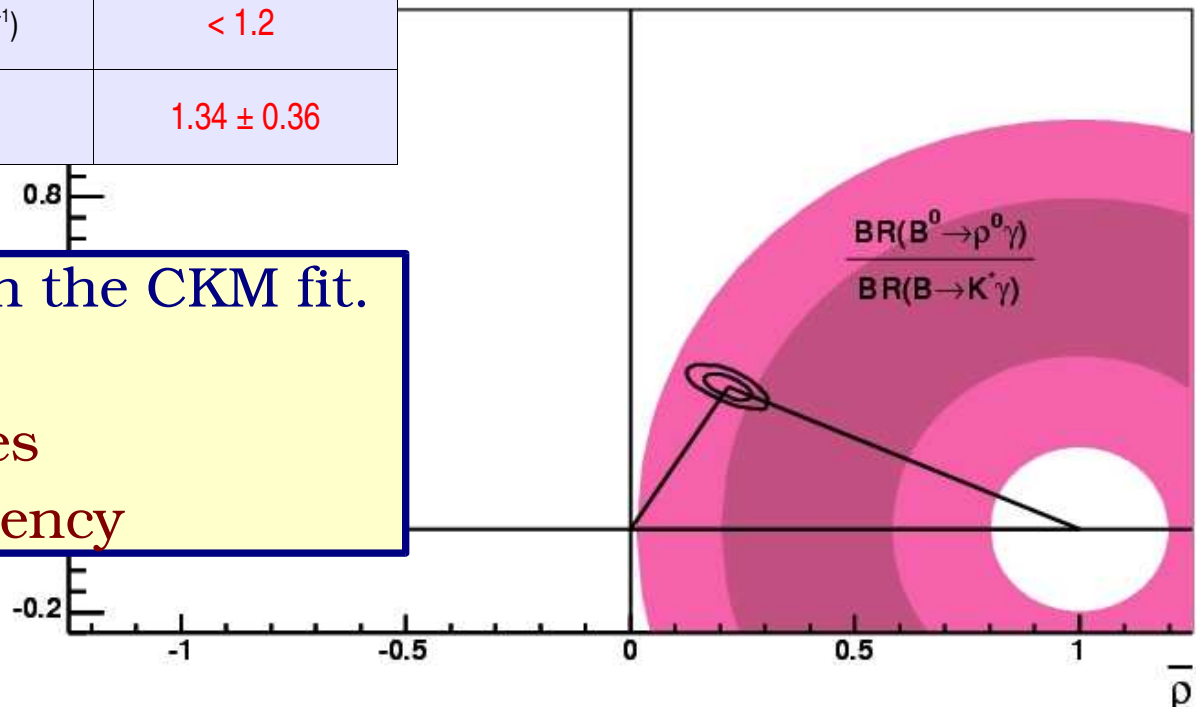
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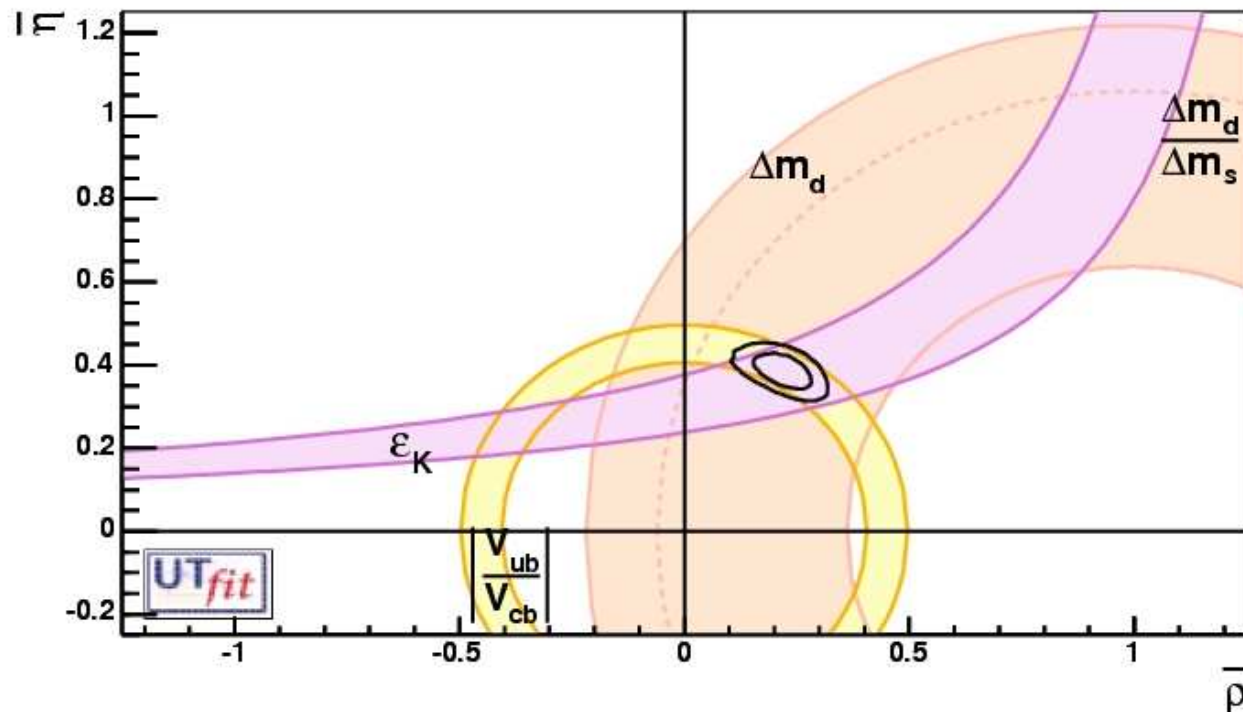
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$\rho/\omega \gamma$	BABAR (200 fb^{-1})	< 1.2
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Not Yet Used in the CKM fit.

Need to assess

- Theory issues
- Exp. consistency





- Prediction from Sides only :

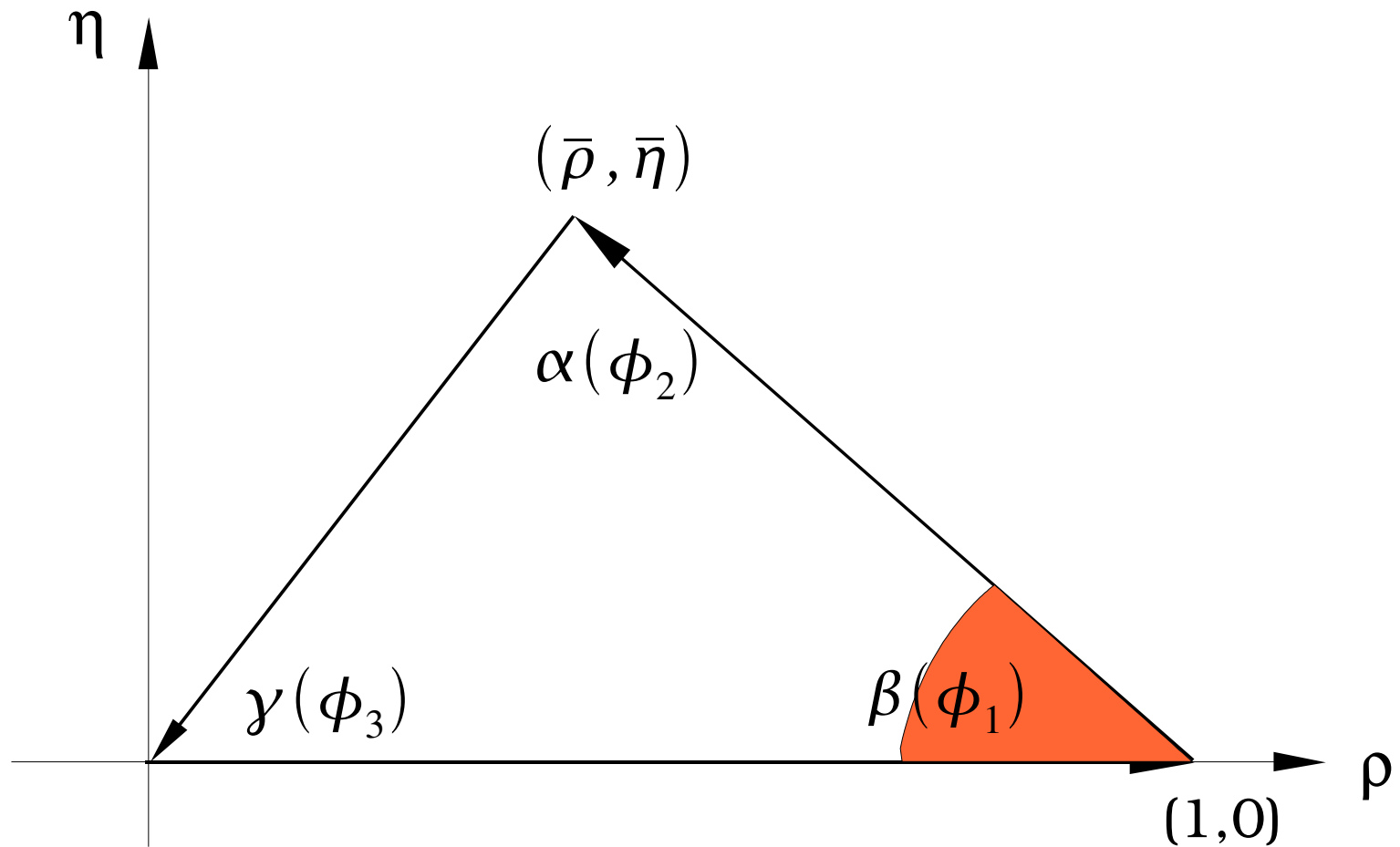
$$\sin(2\beta) = 0.794 \pm 0.032$$

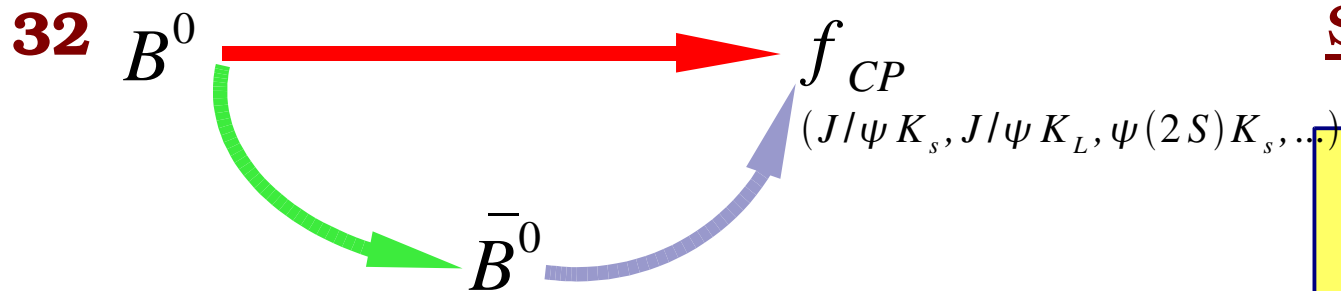
- ... + ϵ_K (CP in K^0 system):

$$\sin(2\beta) = 0.793 \pm 0.032$$

TOPICS:

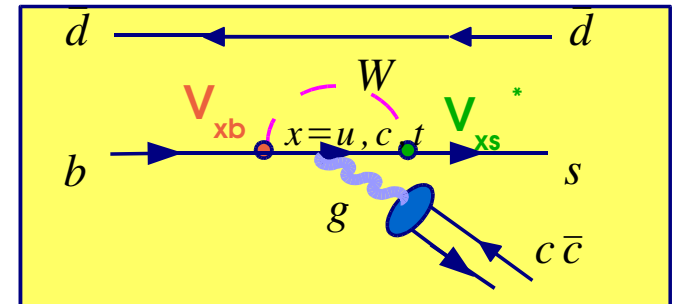
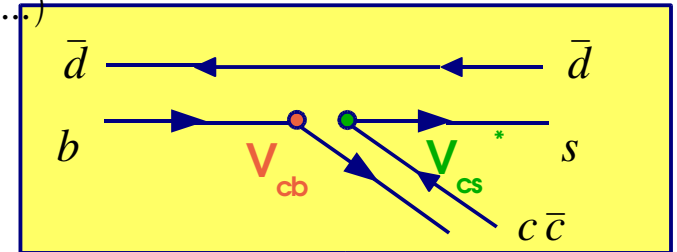
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- Determined from interference of decays with and without mixing in $B^0 \rightarrow J/\psi K_{S/L}$

$\sin 2\beta$ from $b \rightarrow c\bar{c}s$

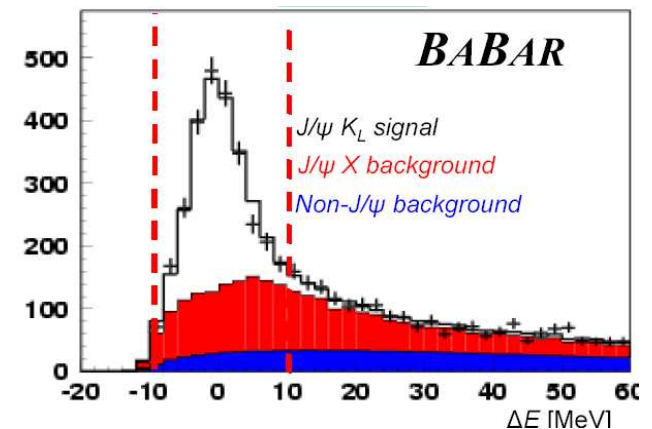
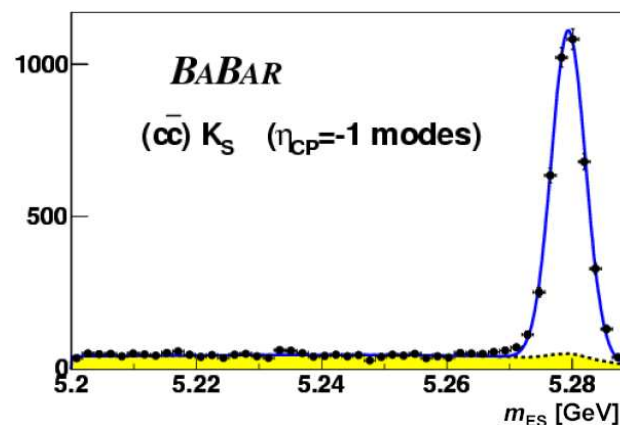


Th. clean:

- Leading interfering penguin has same weak phase as tree
- Other weak phases suppressed by $o(\sin\Theta_c^2) \times o(\alpha_s) \sim 1\%$

Exp. clean:

- Large $B.R.$ $o(\%)$
- Mass-constraints : low background



Golden Mode

Franco Simonetto INFN & Universita' di Padova



Time-dependent CP Asymmetry

$$A_{CP} = \frac{(B^0 \rightarrow f_{CP}) - (\bar{B}^0 \rightarrow f_{CP})}{(B^0 \rightarrow f_{CP}) + (\bar{B}^0 \rightarrow f_{CP})}(\Delta t) = \frac{\Im(\lambda) \sin(\Delta m \Delta t) + (1 - |\lambda|^2) \cos(\Delta m \Delta t)}{1 + |\lambda|^2}$$

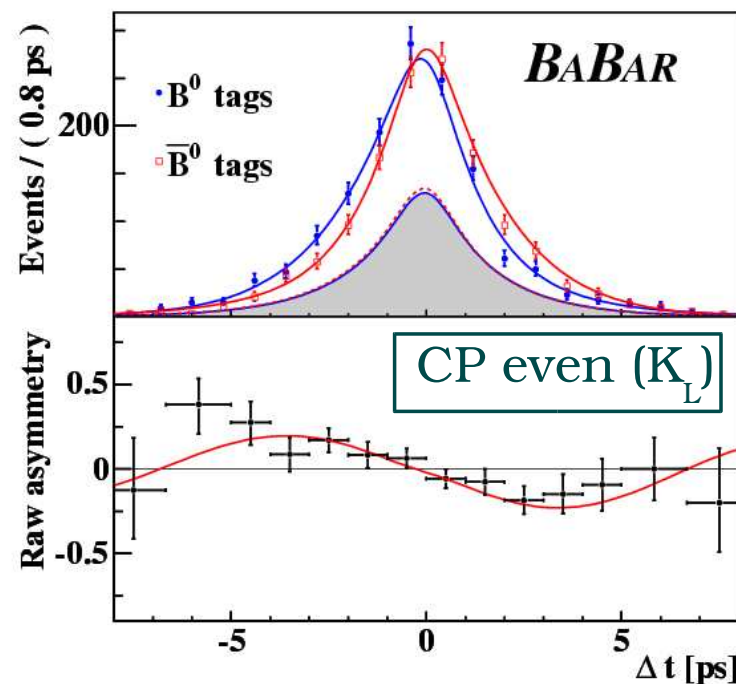
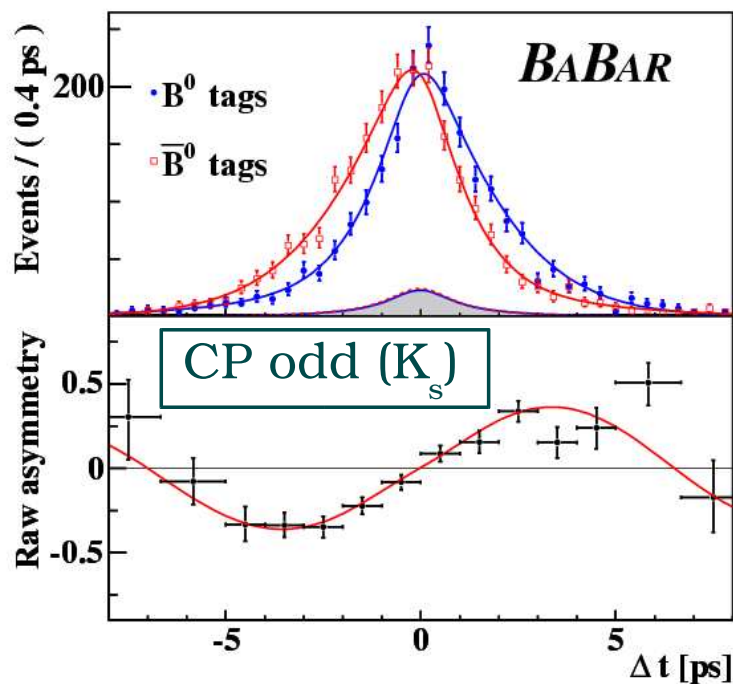
$$\lambda = \frac{V_{tb} V_{td}^*}{V_{td} V_{tb}^*} \frac{V_{cb} V_{cd}^*}{V_{cd} V_{cb}^*} \frac{V_{cd} V_{cs}^*}{V_{cs} V_{cd}^*} = e^{-i2\beta}$$

B mixing

B decay

 K^0 mixing

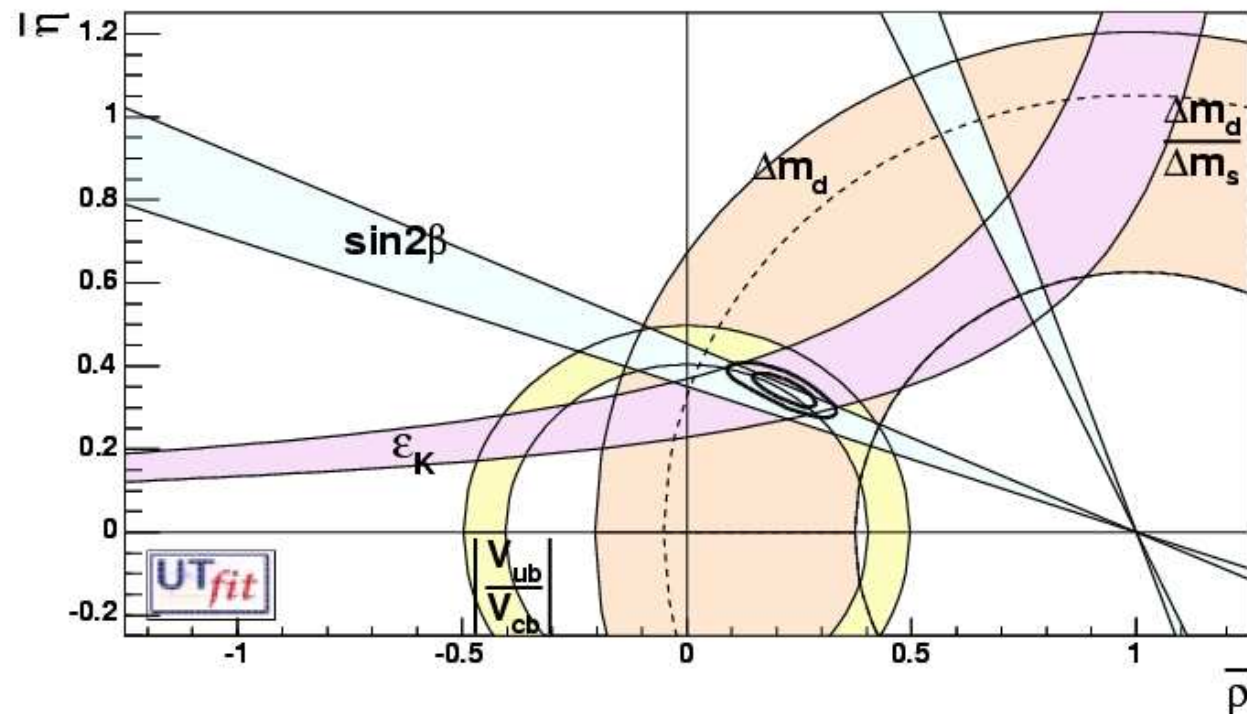
- λ is a pure phase
- $\text{Im}(\lambda) = \sin(2\beta)$

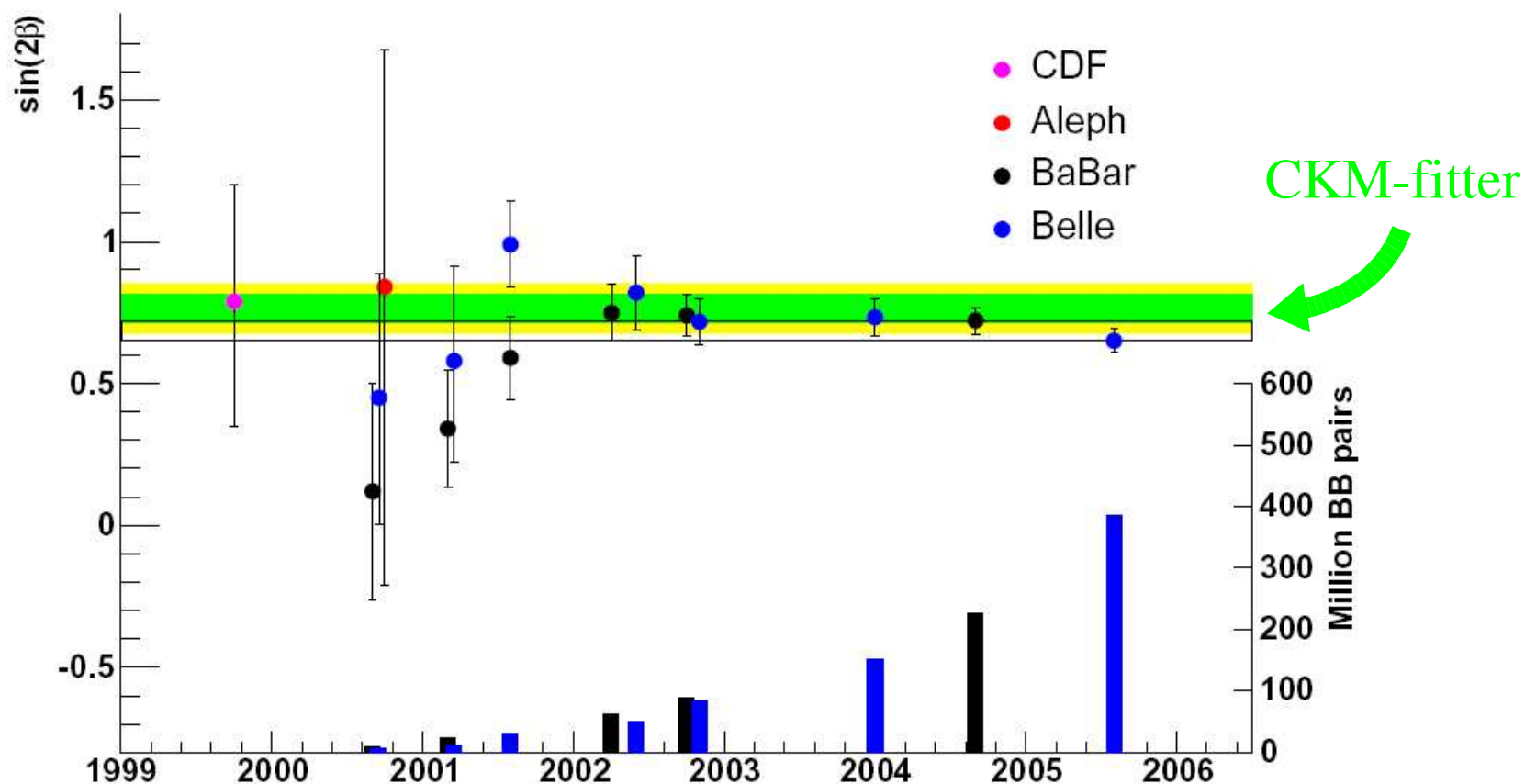


<i>BABAR</i> (205 fb ⁻¹)	$0.722 \pm 0.040 \pm 0.023$
<i>Belle</i> (350 fb ⁻¹)	$0.652 \pm 0.039 \pm 0.020$
Average	$0.685 \pm 0.028 \pm 0.015$
UT-fit prediction sides + ϵ_K	0.793 ± 0.032
CKM-fitter pred. sides + ϵ_K + other angles	$0.742^{+0.072}_{-0.026}$

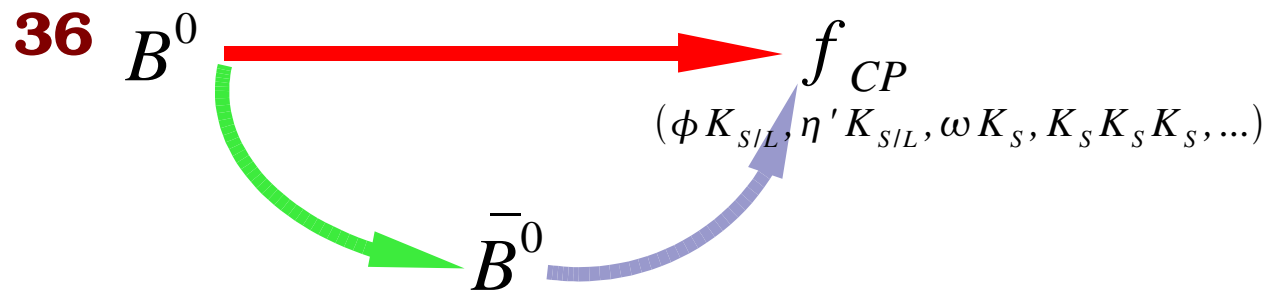
- $\sim 2 \sigma$ wrt UT prediction
- $\sim 1 \sigma$ wrt CKM fitter
- ... interpretation is important !

different interpretation of theoretical errors



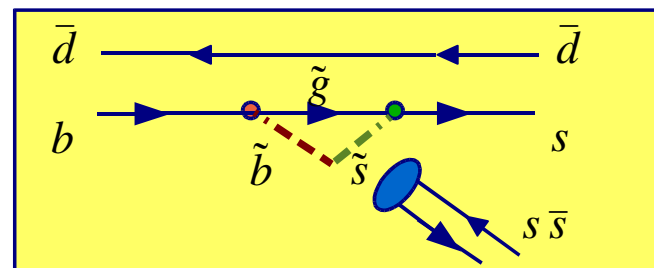
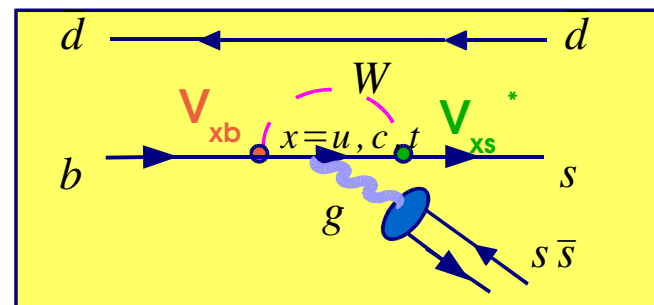


- BABAR ~ double statistics by June 2006
- Stay tuned



- No tree, penguin only
- Leading weak phase : β
- Other weak phases suppressed by $\mathcal{O}(\sin^2 \Theta_c) \sim 5\%$
- New phases from SuSy ?

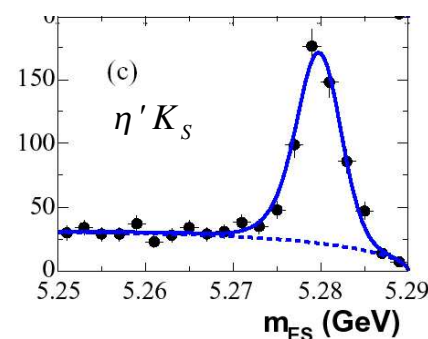
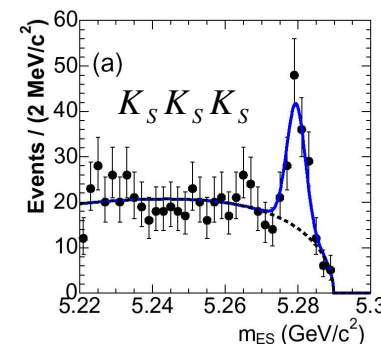
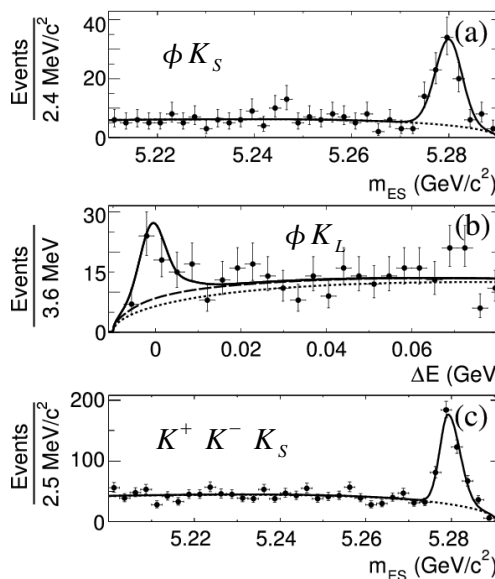
$\sin 2\beta$ from $b \rightarrow sss$



A test for New Physics

Exp Challenges:

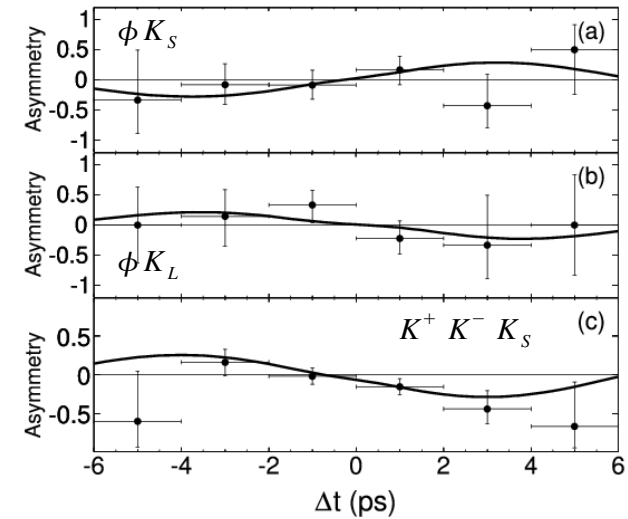
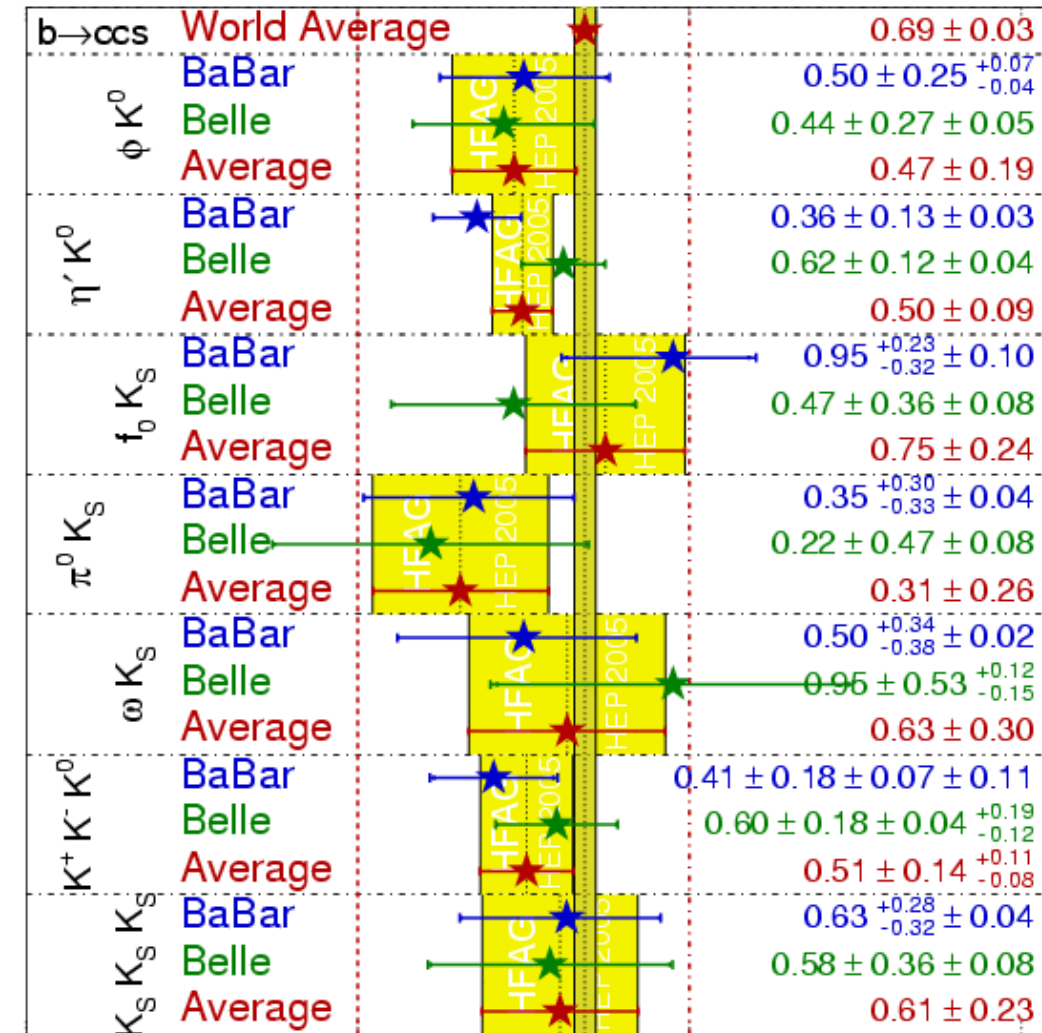
- Smaller BR
- Larger bckg. (continuum)



$\sin 2\beta$ charmless vs charmonium

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

HFAG
HEP 2005
PRELIMINARY



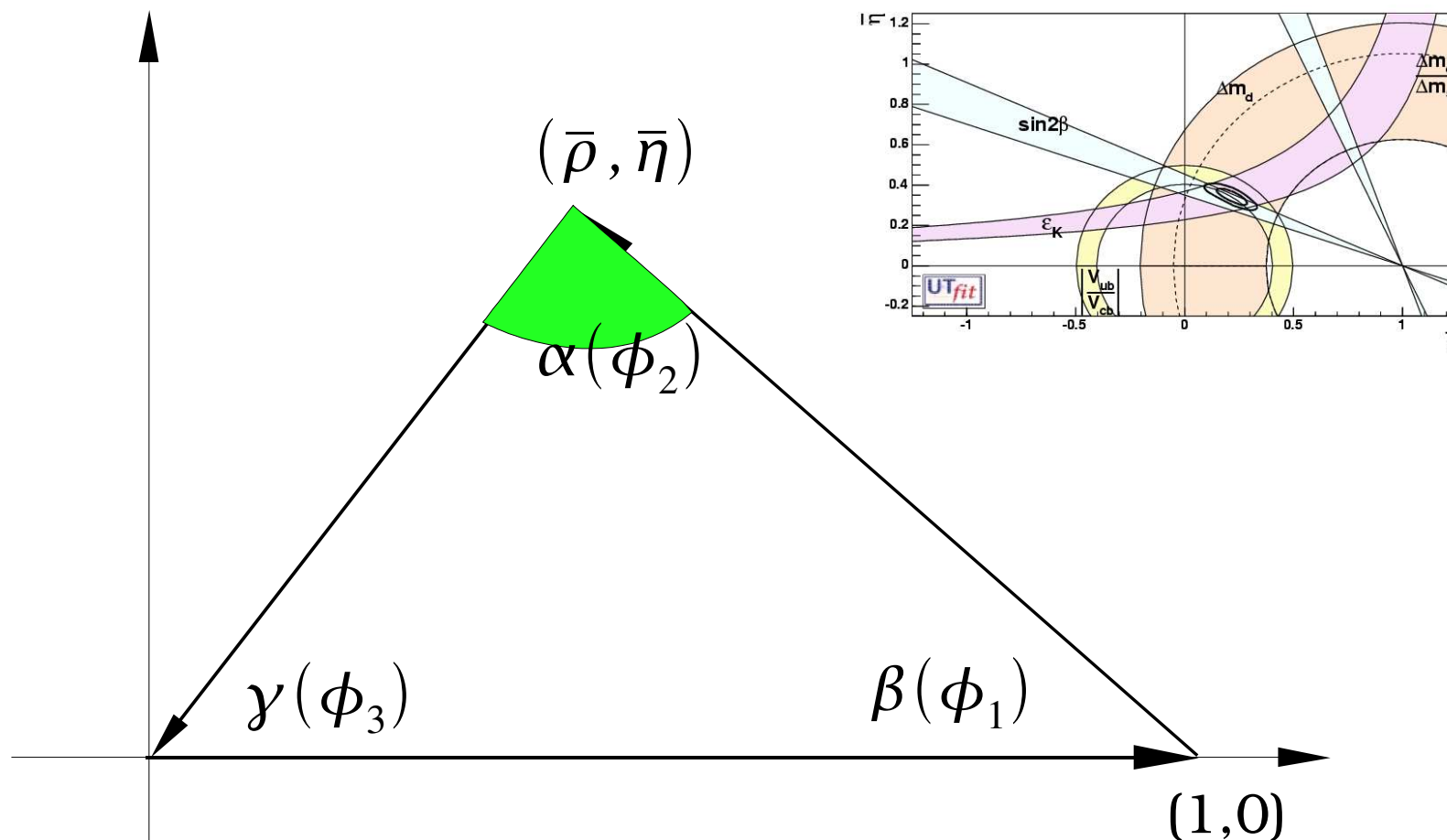
- No significant discrepancy 😊
- No hint of new Physics 😞

consistency improved also due to recent $\sin 2\beta$ measurement



do not average naively
charmless results





- sides + ϵ_K + $\sin 2\beta$:

$$\alpha = (94.9 \pm 7.2)^\circ$$

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- For pure tree transition:

$$\lambda = \frac{V_{td} V_{tb}^*}{V_{tb} V_{td}^*} \frac{V_{ub} V_{ud}^*}{V_{ud} V_{ub}^*} = e^{-i2\alpha}$$

- Penguin introduces new phase

$$\alpha \rightarrow \alpha_{eff} = \alpha + \kappa$$

- Penguin estimated from Isospin relations:

$$\frac{1}{\sqrt{2}} A^{+-} + A^{00} = A^{+0}$$

$$\frac{1}{\sqrt{2}} A^{\bar{+}\bar{-}} + A^{\bar{0}0} = A^{-0}$$

pure tree

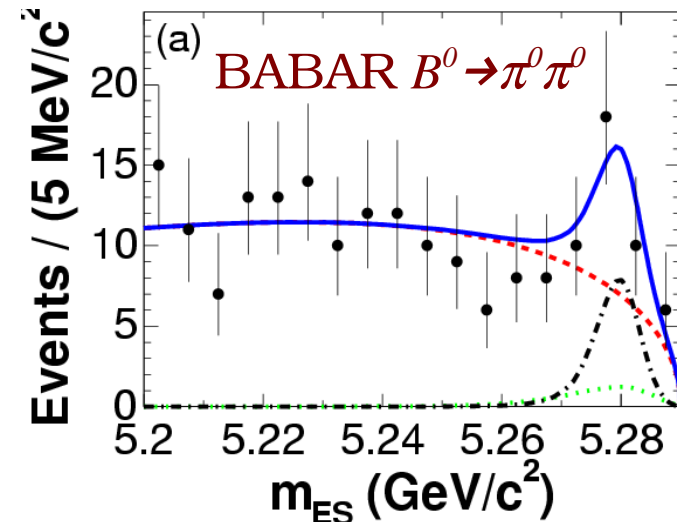
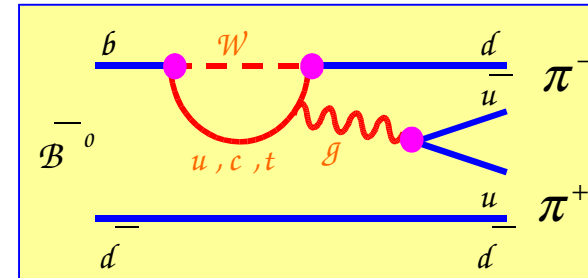
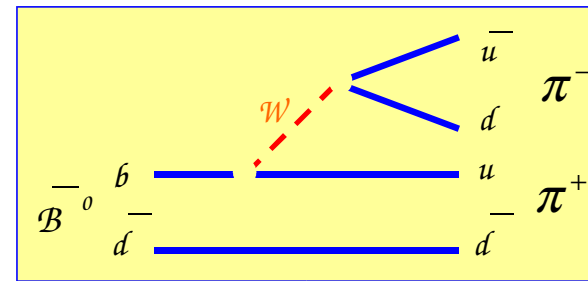
$$A^{ij} = A(B \rightarrow \pi^i \pi^j)$$

- BABAR + Belle :

$$BR(B^0 \rightarrow \pi^0 \pi^0) = (1.45 \pm 0.29) 10^{-6}$$

- Sizable Penguin pollution in $B^0 \rightarrow \pi^+ \pi^-$

$\sin 2\alpha$ from $b \rightarrow u \bar{u} d$



1. BABAR, PRL 94,131801 (2005)

$$BR(B^0 \rightarrow \rho^0 \rho^0) < 1.1 \times 10^{-6}$$

★ Small Penguin pollution in $B^0 \rightarrow \rho^+ \rho^-$

$$★ |\alpha - \alpha_{\text{eff}}| < 11^\circ$$

2. Angular analysis:

★ $\rho^+ \rho^-$ almost pure CP +

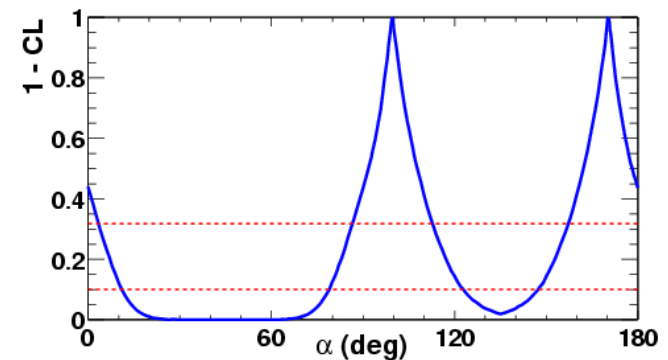
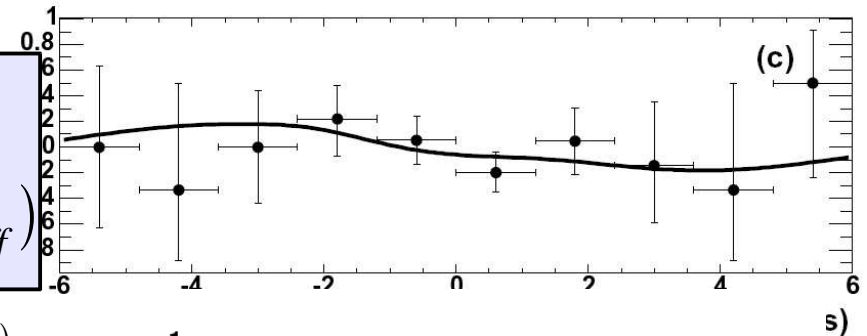
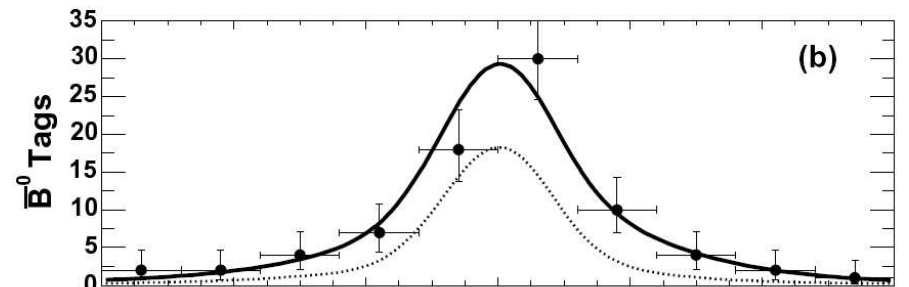
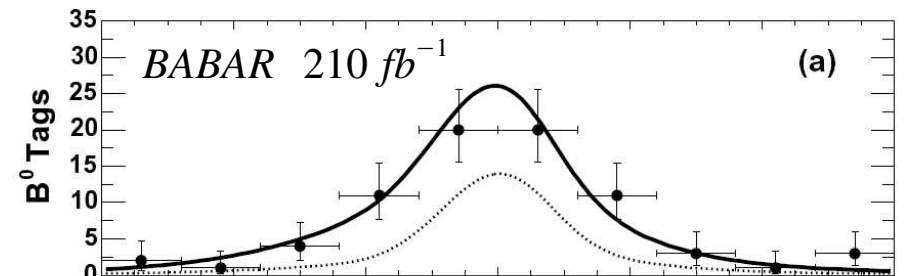
$$\Re(\lambda_{\rho\rho}) = -0.03 \pm 0.18 \pm 0.09$$

$$\Im(\lambda_{\rho\rho}) = -0.33 \pm 0.24^{+0.08}_{-0.14} (= \sin 2\alpha_{\text{eff}})$$

$$\Im(\lambda_{\rho\rho}) = 0.09 \pm 0.42 \pm 0.08 \quad (Belle 350 \text{ fb}^{-1})$$

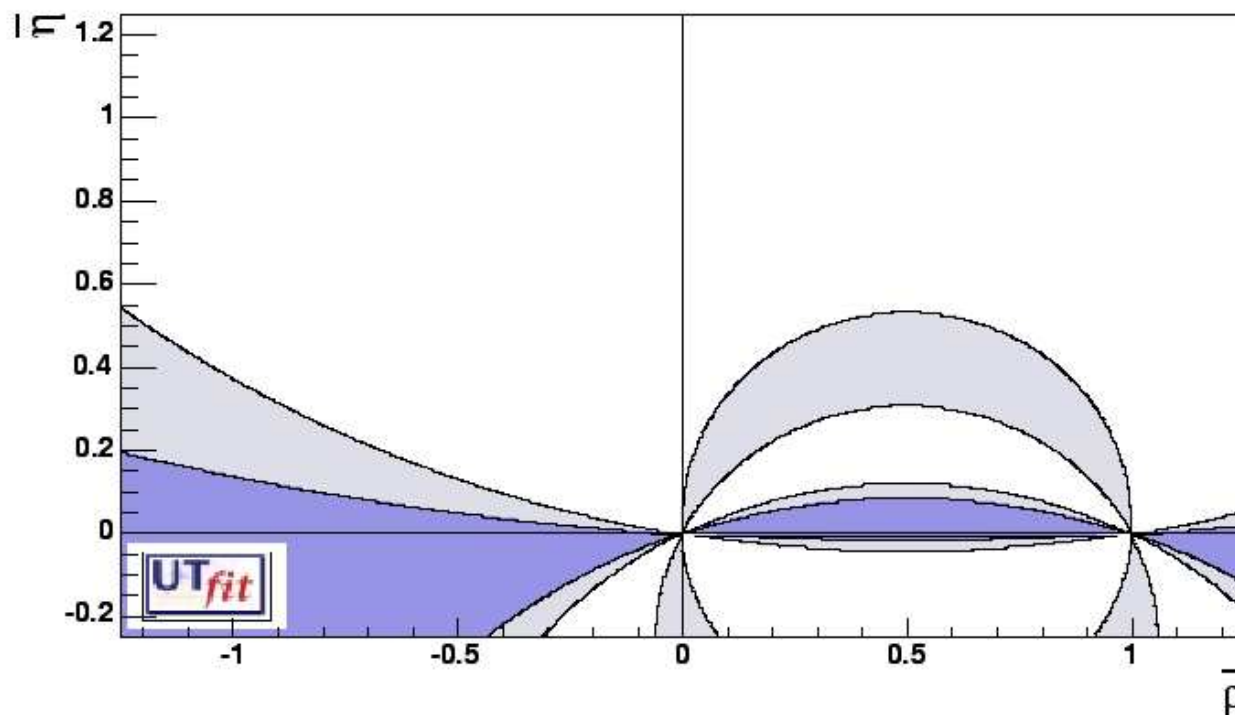
$$\alpha = (100 \pm 13)^\circ$$

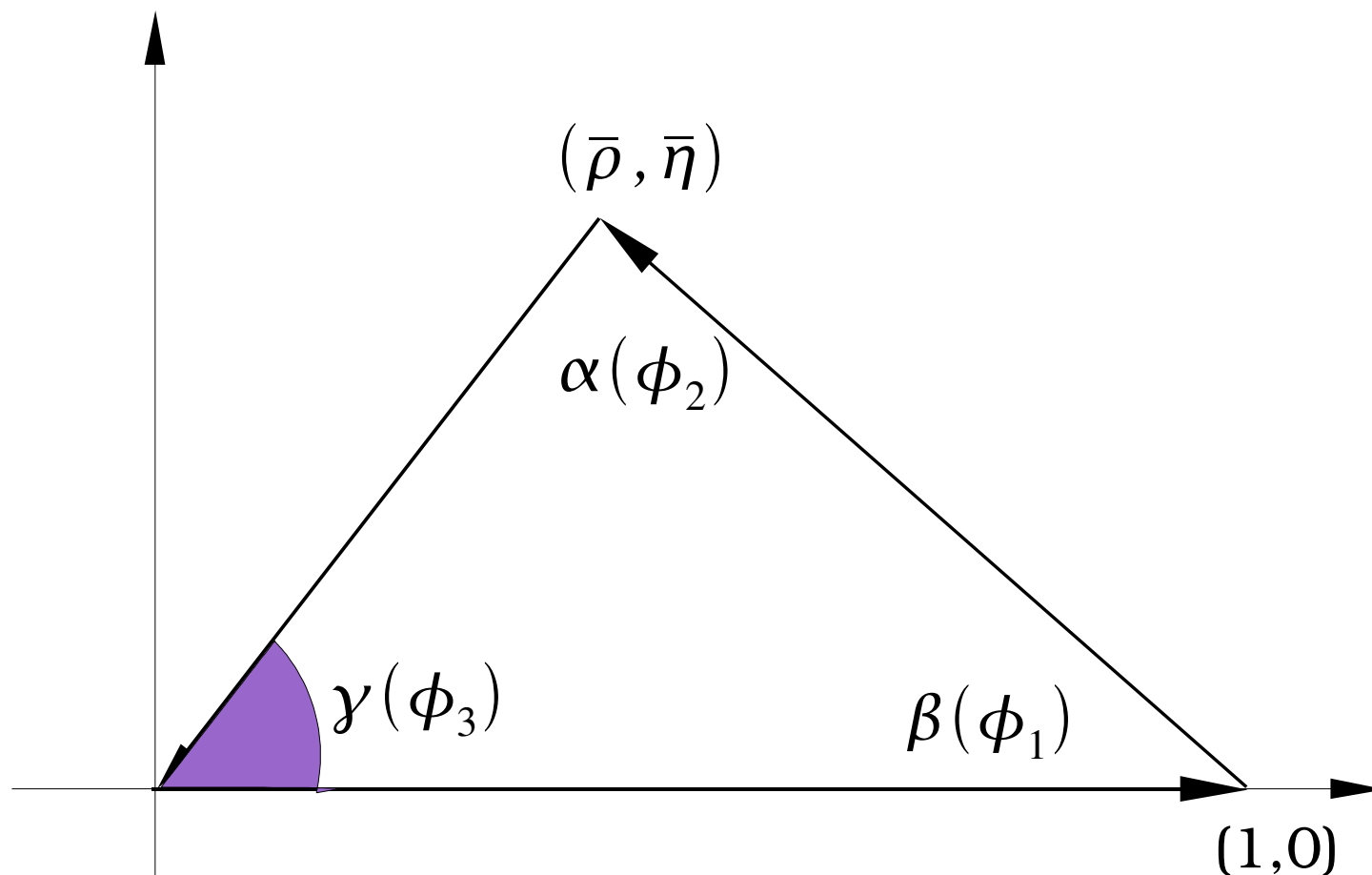
includes $\pm 11^\circ$ error from penguin estimation



- Adding constraints from $B \rightarrow \rho\pi$ Daliz analysis, and neglecting mirror solutions:

α (meas.)	$(99_{-8}^{+13})^\circ$
<i>UT-fit prediction</i>	$(95 \pm 7)^\circ$





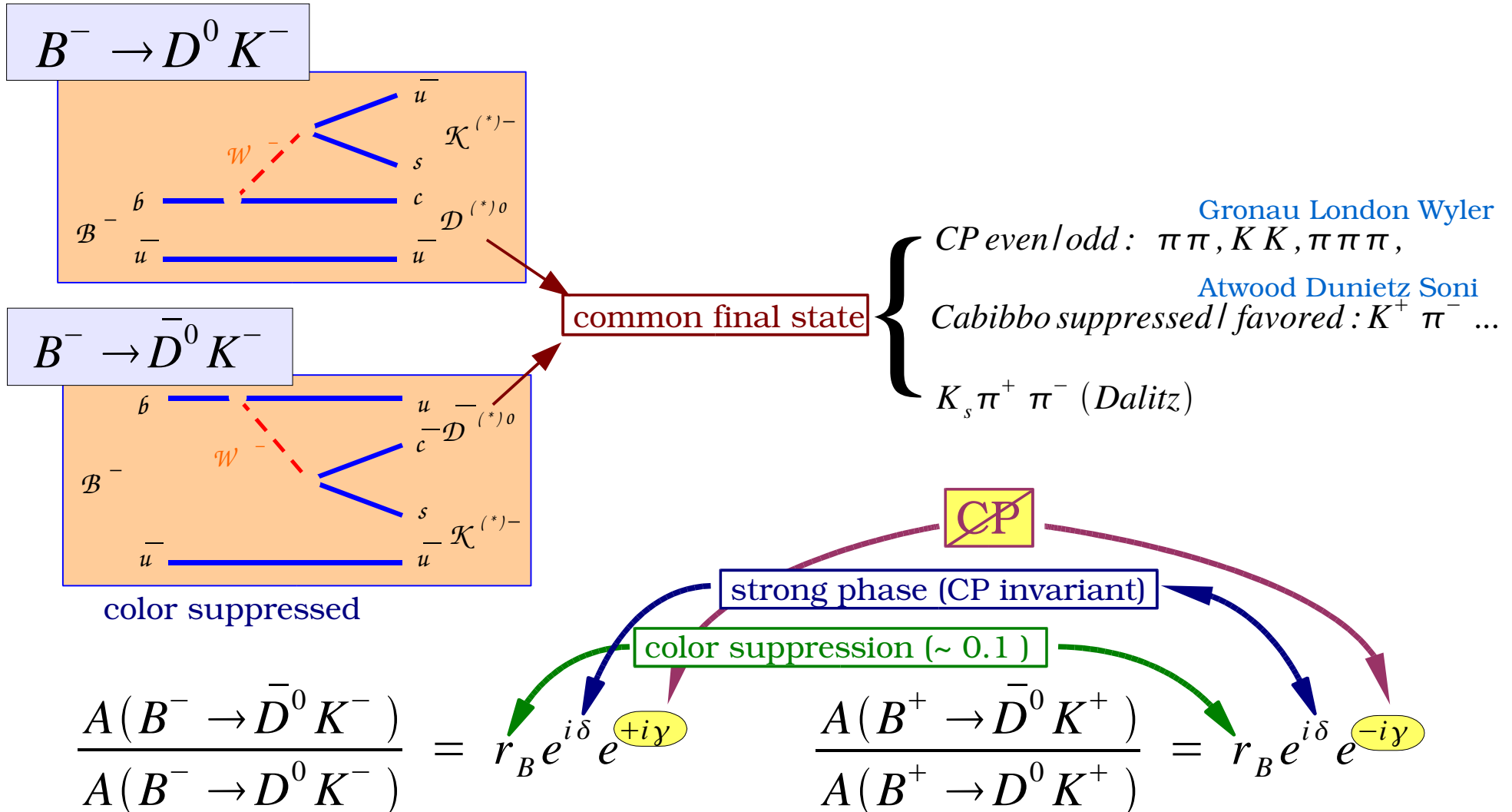
- Prediction from all other constraints:

$$\gamma = (57.6 \pm 5.7)^\circ$$

- BABAR Physics book (Oct 1998):
" Possibly the best tools to extract γ are time-dependent asymmetries in B_s decays "
• .. a job for LHC- b ?



Exploit interference of pure tree transitions:



Three unknowns: r_B , δ , and γ

Franco Simonetto INFN & Universita' di Padova

- Compare rates for CP even and CP odd D^0 final states
- Four observables, three independent constraints: ☹️

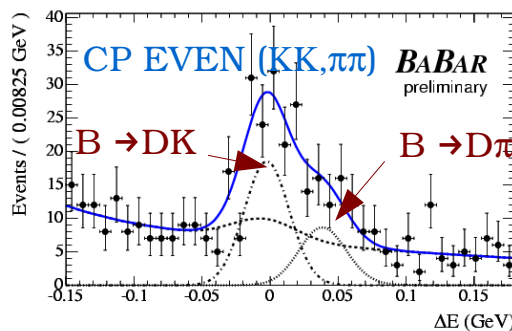
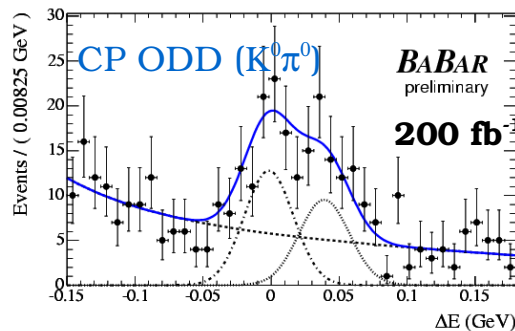
$$A_{CP\pm} = \frac{\Gamma(B^- \rightarrow D_{CP\pm} K^-) - \Gamma(B^+ \rightarrow D_{CP\pm} K^+)}{\Gamma(B^- \rightarrow D_{CP\pm} K^-) + \Gamma(B^+ \rightarrow D_{CP\pm} K^+)} = \frac{\pm 2 r_B \sin \delta \sin \gamma}{R_{CP}}$$

$$R_{CP\pm} = \frac{\Gamma(B^- \rightarrow D_{CP\pm} K^-) + \Gamma(B^+ \rightarrow D_{CP\pm} K^+)}{\Gamma(B^- \rightarrow D^0 K^-)} = 1 + r_B^2 \pm 2 r_B \cos \delta \cos \gamma$$

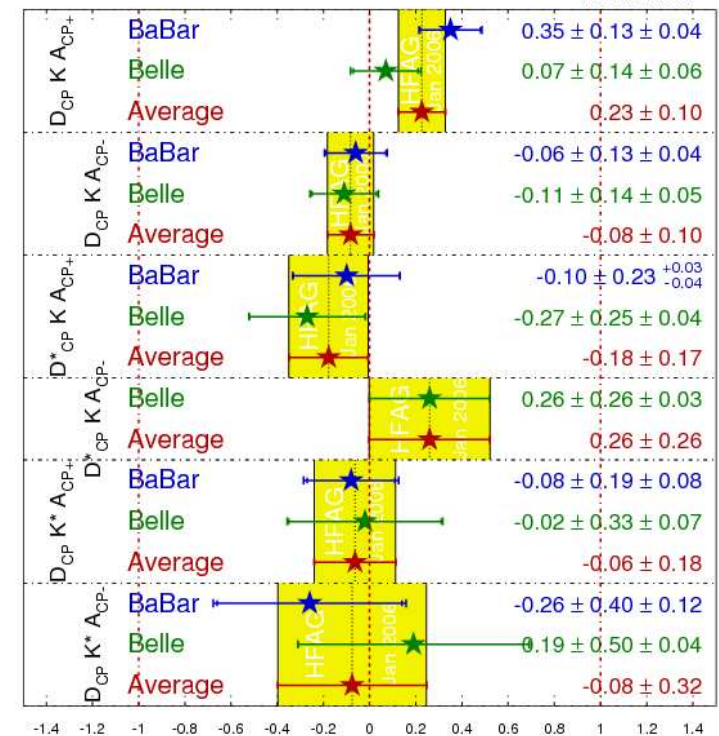
A_{CP} Averages

HFAG
Jan 2006
PRELIMINARY

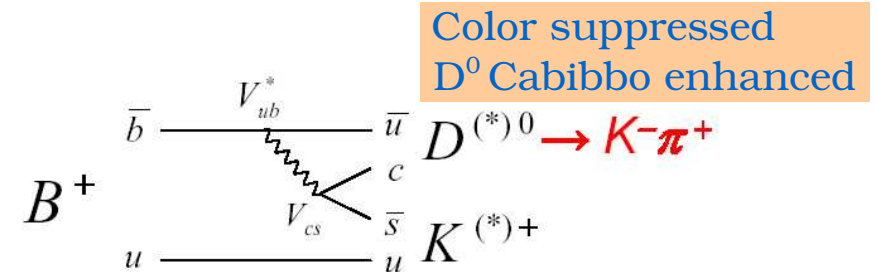
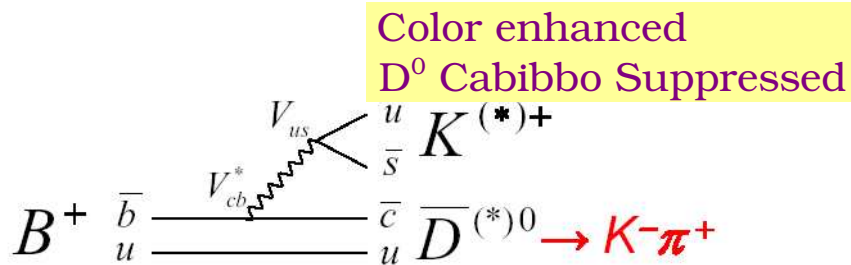
- Rates still too low ☹️
- Small asymmetry ($r_B \sim 0.1$) ☹️



- No significant bound on γ
- Job for super-B ?



- Exploit interference of Cabibbo favored and suppressed D^0 final states



- Expect sizable asymmetry ☺
- Only two constraints, low rates: ☹

$$R_{ADS} = \frac{\Gamma(B^- \rightarrow D_{ADS} K^{(*)-}) + \Gamma(B^+ \rightarrow D_{ADS} K^{(*)+})}{\Gamma(B^- \rightarrow D^0 K^{(*)-}) + \Gamma(B^+ \rightarrow \bar{D}^0 K^{(*)+})} = r_B^2 + r_D^2 + 2r_B r_D \cos(\delta_B + \delta_D) \cos \gamma$$

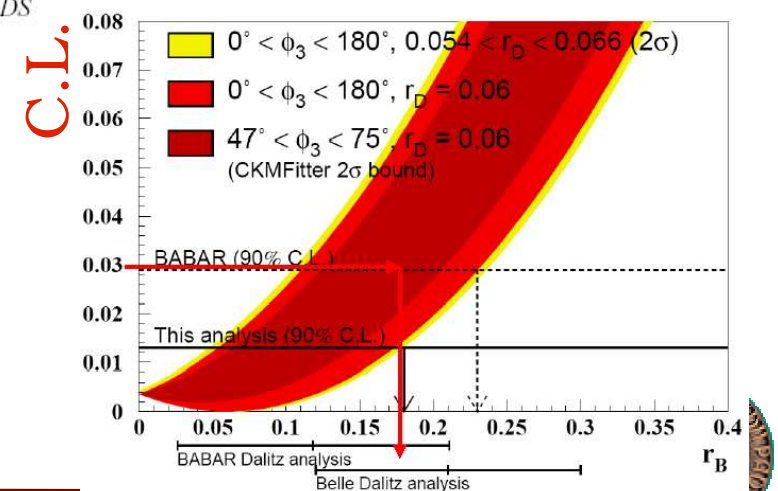
$$A_{ADS} = \frac{\Gamma(B^- \rightarrow D_{ADS} K^{(*)-}) - \Gamma(B^+ \rightarrow D_{ADS} K^{(*)+})}{\Gamma(B^- \rightarrow D_{ADS} K^{(*)-}) + \Gamma(B^+ \rightarrow D_{ADS} K^{(*)+})} = \frac{2r_B r_D \sin(\delta_B + \delta_D) \sin \gamma}{R_{ADS}}$$

- Limits on r_B (90%CL):

$$r_B < 0.23 \text{ BABAR } \sim 210 \text{ fb}^{-1} \text{ (PRD 72,032004 (2005))}$$

$$r_B < 0.18 \text{ Belle } 350 \text{ fb}^{-1}$$

D^0 Cabibbo suppression



- Exploit differences in $(\bar{D}^0 \rightarrow K_s \pi^+ \pi^-)$ Dalitz plots

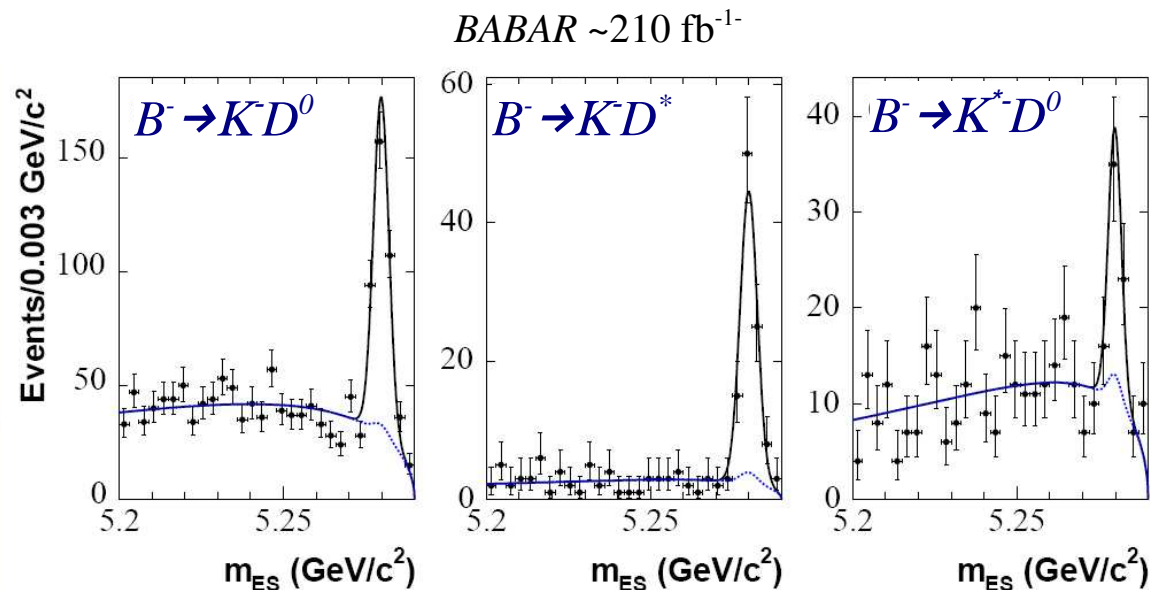
$$B^+ \begin{array}{c} \bar{b} \\ u \end{array} \begin{array}{c} V_{us}^* \\ V_{cb}^* \end{array} \begin{array}{c} u \\ \bar{s} \\ \bar{c} \\ u \end{array} \begin{array}{c} K^{(*)+} \\ \bar{D}^{(*)0} \end{array} \rightarrow K_s \pi^+ \pi^-$$

$$B^+ \begin{array}{c} \bar{b} \\ u \end{array} \begin{array}{c} V_{ub}^* \\ V_{cs} \end{array} \begin{array}{c} \bar{u} \\ c \\ \bar{s} \\ u \end{array} \begin{array}{c} D^{(*)0} \\ K^{(*)+} \end{array} \rightarrow K_s \pi^+ \pi^-$$

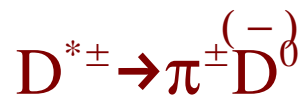
$$A(B^-) \propto f(m_-, m_+) + r_B e^{i(\delta - \gamma)} f(m_+, m_-)$$

$$A(B^+) \propto f(m_+, m_-) + r_B e^{i(\delta + \gamma)} f(m_-, m_+)$$

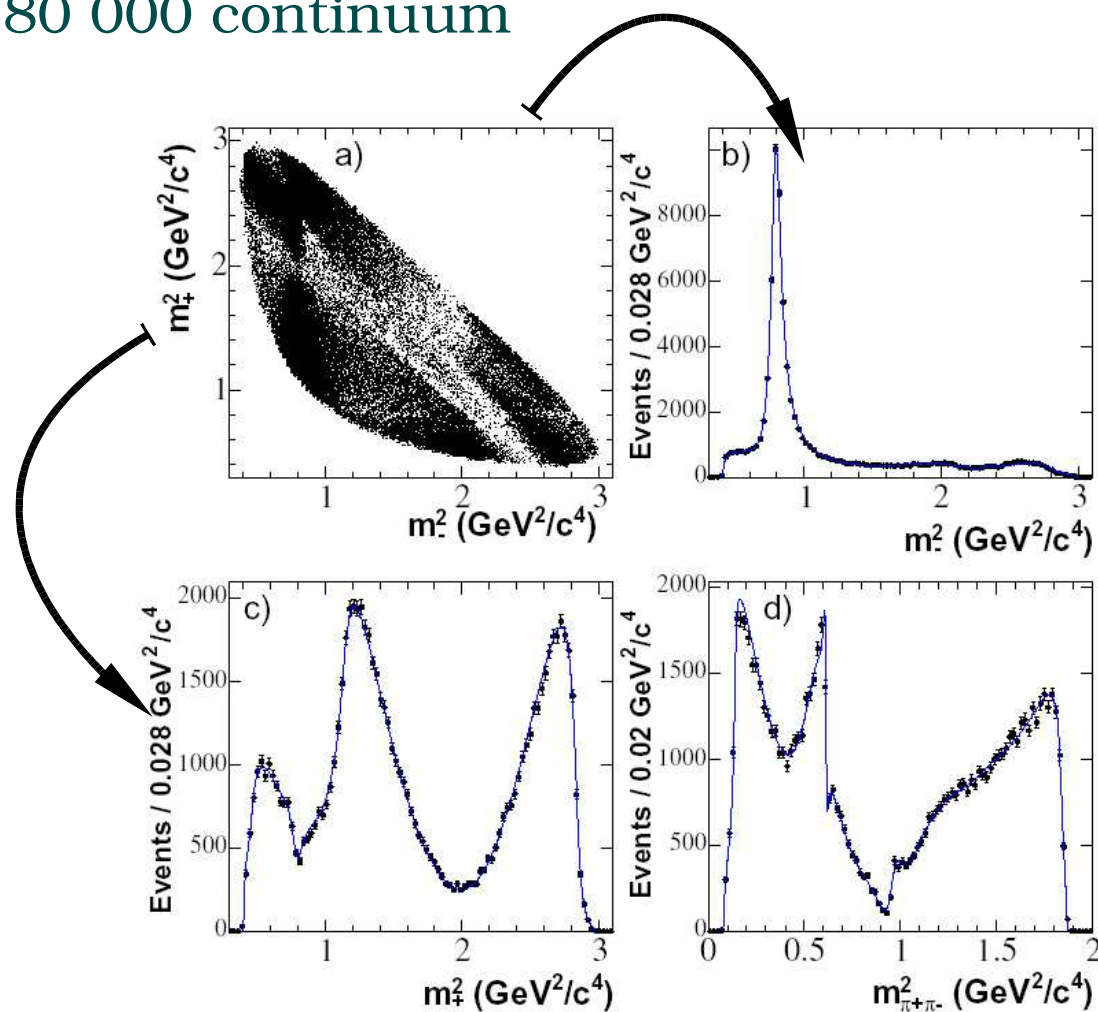
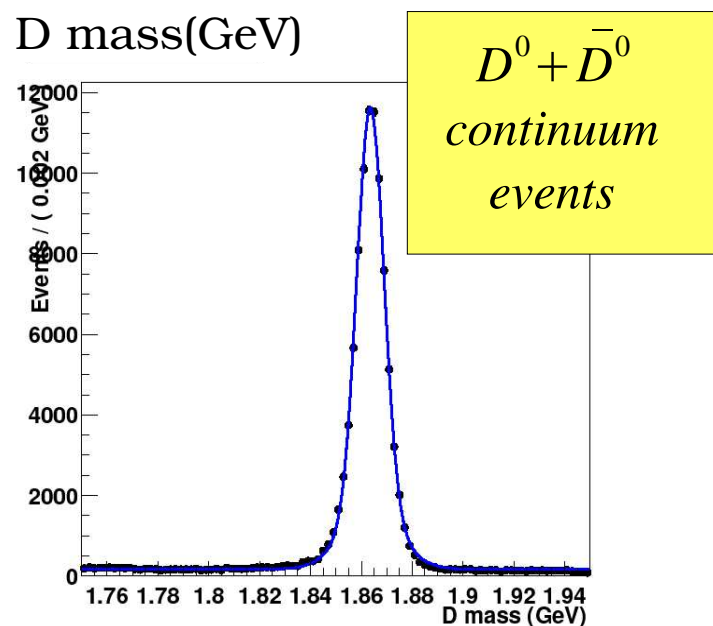
$$m_{+/-} = m(K_s \pi^{+/-})$$



- Fit $\Gamma(B^+)$, $\Gamma(B^-)$ in each point of the Dalitz plot
- Models for $f(m_{\pm}, m_{\mp})$ from $\sim 80\,000$ continuum decays:



tags flavor



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 γ : Dalitz results

- $BABAR$ ($\sim 210 \text{ fb}^{-1}$) :

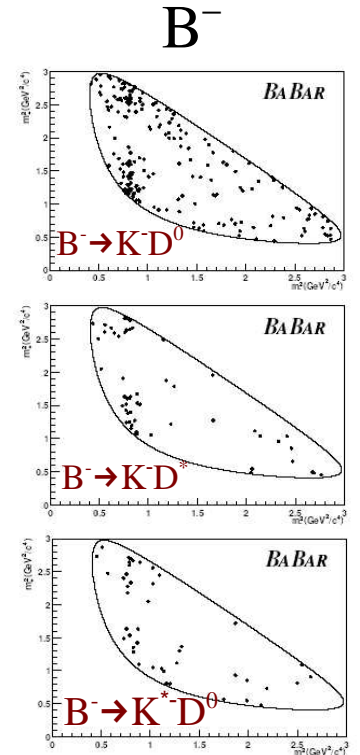
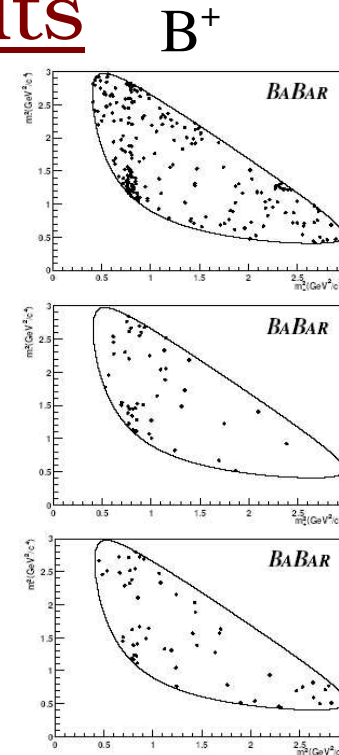
$$\begin{aligned} r_b &= 0.12 \pm 0.08 \pm 0.03 \pm 0.04 & \text{DK} \\ r_b^* &= 0.17 \pm 0.10 \pm 0.03 \pm 0.03 & \text{D}^*\text{K} \\ r_s &< 0.19 & @ 90\% \text{ CL} \quad \text{DK}^* \end{aligned}$$

$$\gamma = (67 \pm 28_{\text{(stat)}} \pm 13_{\text{(syst.)}} \pm 11_{\text{(Dalitz Model)}})^\circ$$

- $Belle$ ($\sim 350 \text{ fb}^{-1}$) :

$$\begin{aligned} r_b &= 0.21 \pm 0.08 \pm 0.03 \pm 0.04 & \text{DK} \\ r_b^* &= 0.12^{+0.16}_{-0.11} \pm 0.02 \pm 0.04 & \text{D}^*\text{K} \\ r_s &= 0.25^{+0.17}_{-0.18} \pm 0.09 \pm 0.04 \pm 0.08 & \text{DK}^* \end{aligned}$$

$$\gamma = (68 \pm 14_{\text{(stat)}} \pm 13_{\text{(syst.)}} \pm 11_{\text{(Dalitz Model)}})^\circ$$



50

 γ : Dalitz results

- $BABAR$ ($\sim 210 \text{ fb}^{-1}$) :

$$\begin{aligned} r_b &= 0.12 \pm 0.08 \pm 0.03 \pm 0.04 & \text{DK} \\ r_b^* &= 0.17 \pm 0.10 \pm 0.03 \pm 0.03 & \text{D}^* \text{K} \\ r_s &< 0.19 & @ 90\% \text{ CL} \quad \text{DK}^* \end{aligned}$$

$$\gamma = (67 \pm 28_{\text{(stat)}} \pm 13_{\text{(syst.)}} \pm 11_{\text{(Dalitz Model)}})^\circ$$

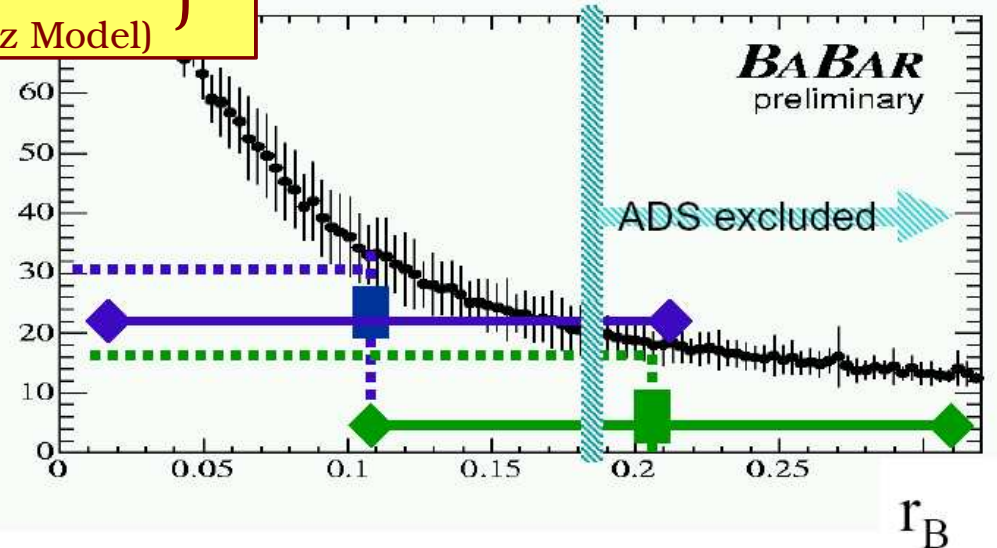
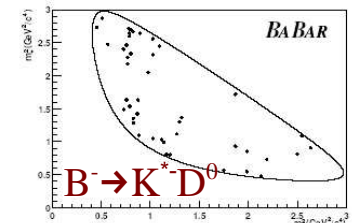
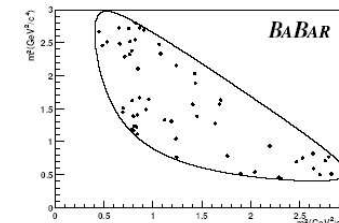
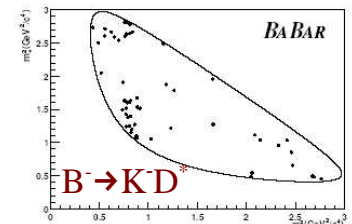
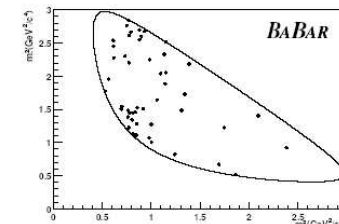
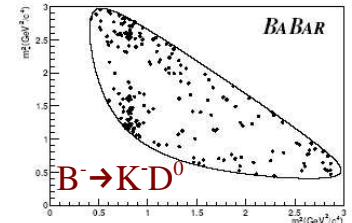
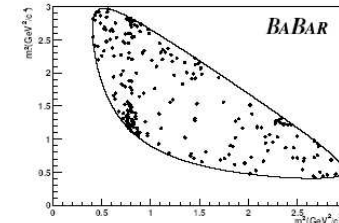
- $Belle$ ($\sim 350 \text{ fb}^{-1}$) :

$$\begin{aligned} r_b &= 0.21 \pm 0.08 \pm 0.03 \pm 0.04 & \text{DK} \\ r_b^* &= 0.12^{+0.16}_{-0.11} \pm 0.02 \pm 0.04 & \text{D}^* \text{K} \\ r_s &= 0.25^{+0.17}_{-0.18} \pm 0.09 \pm 0.04 \pm 0.08 & \text{DK}^* \end{aligned}$$

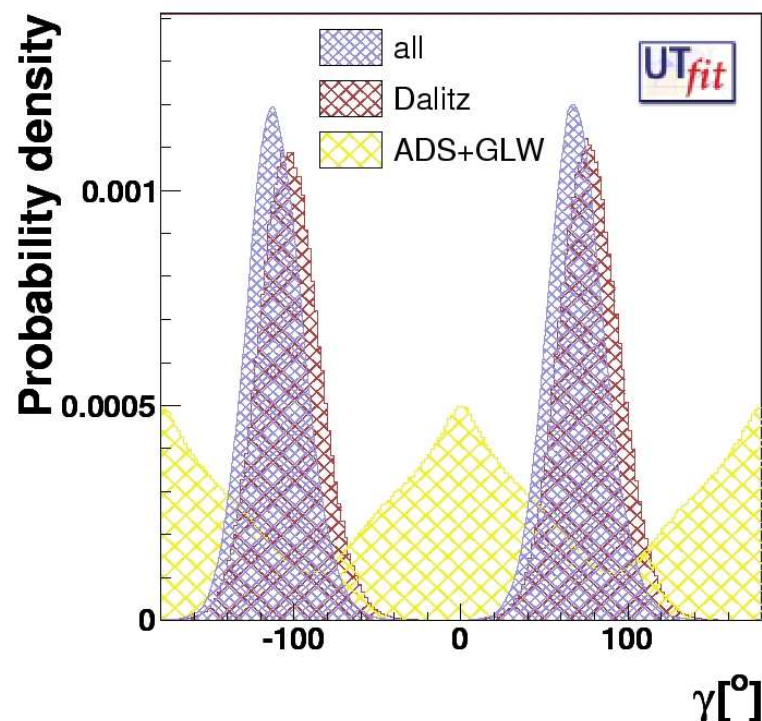
$$\gamma = (68 \pm 14_{\text{(stat)}} \pm 13_{\text{(syst.)}} \pm 11_{\text{(Dalitz Model)}})^\circ$$

- Luck factor: $\sigma(\gamma)$ depends on r_B
- $Belle$ central r_B value excluded by $Belle$ ADS analysis

- More data needed !

 B^+ B^- 

- Dalitz method: first direct measurement of γ !
- Limits on r_B from ADS,DGW help improve allowed bounds
- Of main importance to determine the actual value of r_B



γ (meas.)	$(68 \pm 17)^\circ$
<i>UT-fit prediction</i>	$(58 \pm 6)^\circ$

Summary on CKM Constraints

- B-factories operations allow to constrain the UT from different point of views:

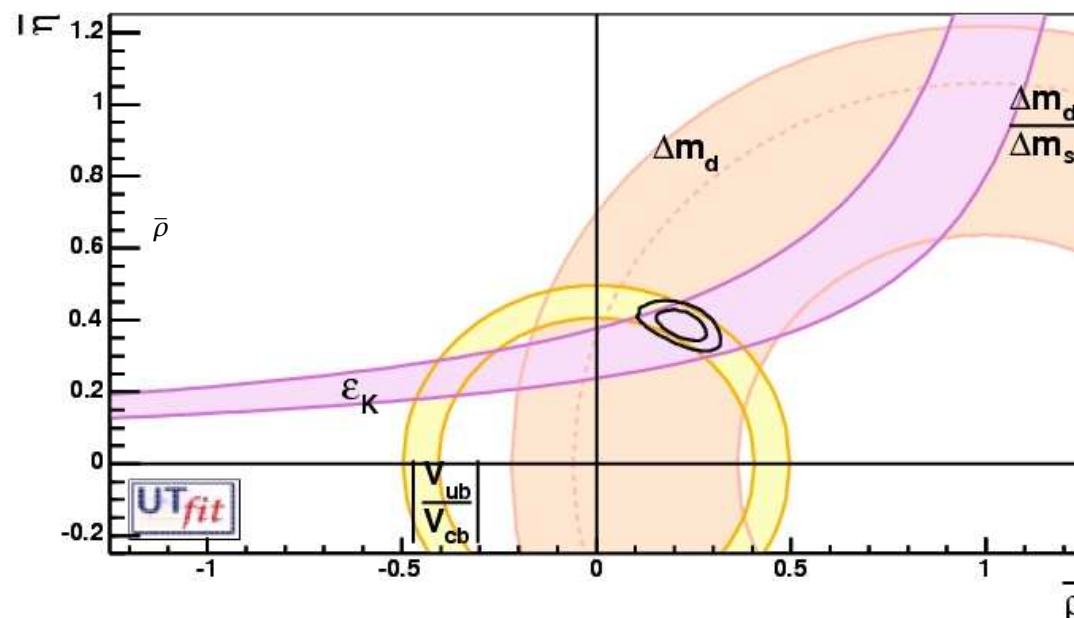


Summary on CKM Constraints

- B-factories operations allow to constrain the UT from different point of views:

The Sides

	$\bar{\rho}$	$\bar{\eta}$
sides	0.218 ± 0.043	0.385 ± 0.028



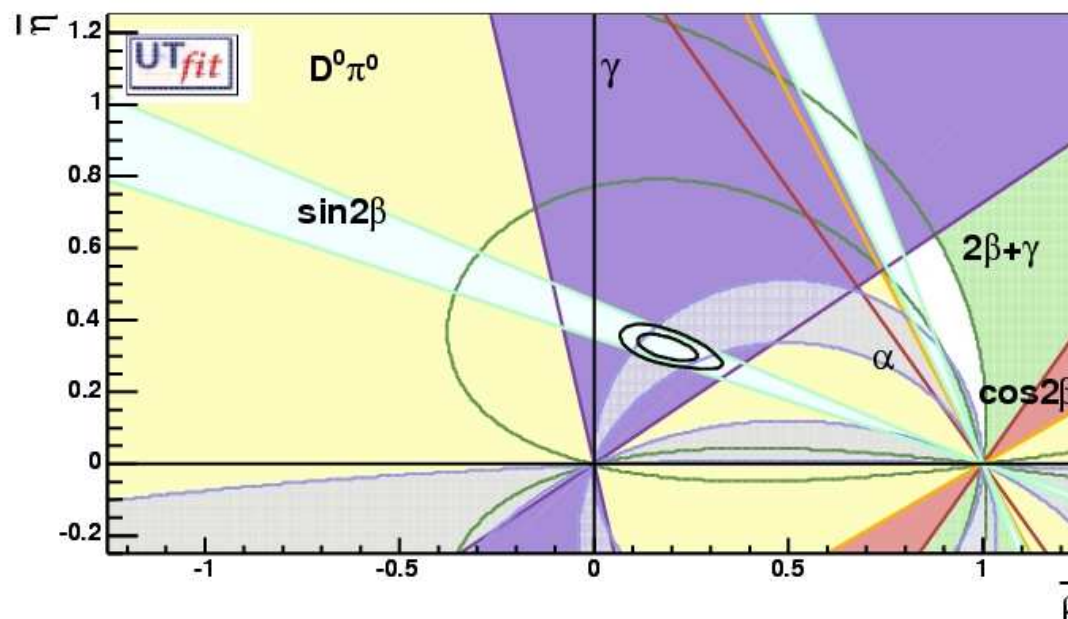
$$\bar{\rho} = 0.218 \pm 0.043 \quad \bar{\eta} = 0.385 \pm 0.028$$

Summary on CKM Constraints

- B-factories operations allow to constrain the UT from different point of views:

The Angles

	$\bar{\rho}$	$\bar{\eta}$
sides	0.218 ± 0.043	0.385 ± 0.028
angles	0.187 ± 0.052	0.322 ± 0.025



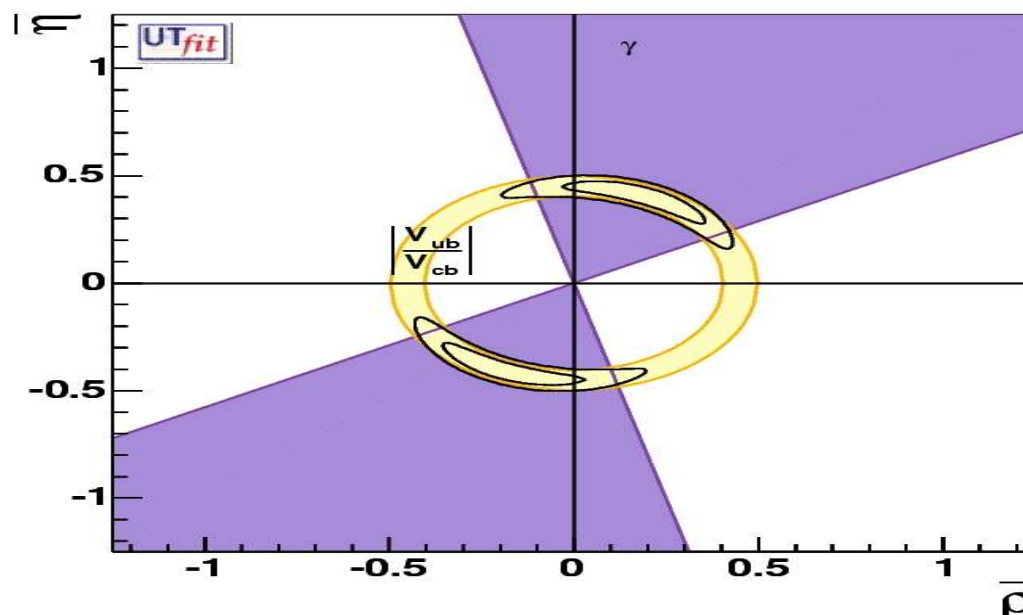
$$\bar{\rho} = 0.187 \pm 0.052 \quad \bar{\eta} = 0.322 \pm 0.025$$

Summary on CKM Constraints

- B-factories operations allow to constrain the UT from different point of views:

Tree Only

	$\bar{\rho}$	$\bar{\eta}$
sides	0.218 ± 0.043	0.385 ± 0.028
angles	0.187 ± 0.052	0.322 ± 0.025
tree	0.18 ± 0.12	0.41 ± 0.05



$$\bar{\rho} = 0.18 \pm 0.12$$

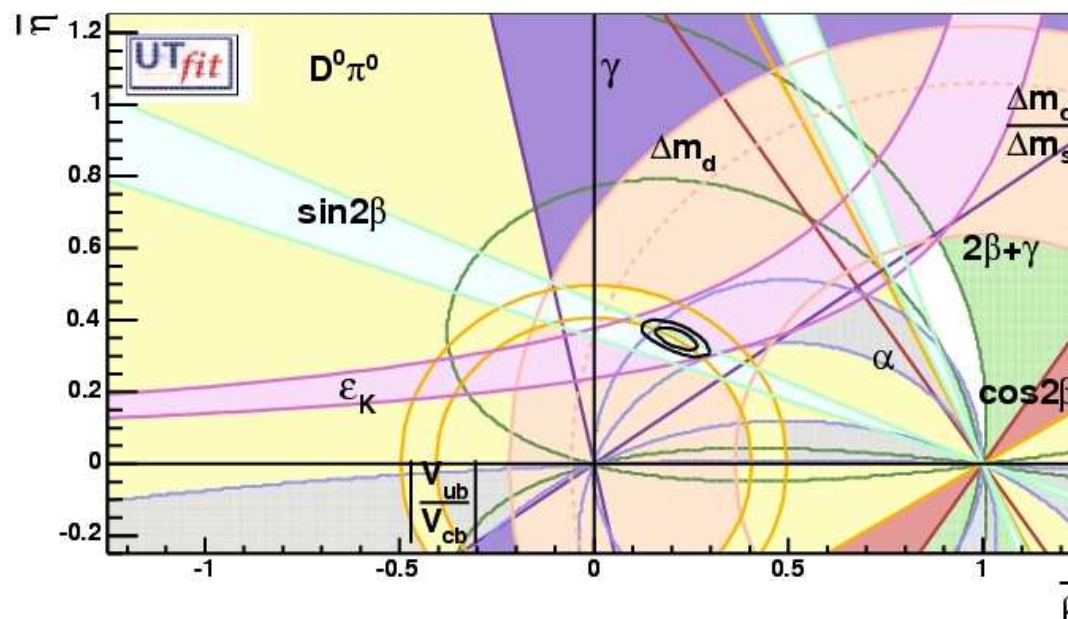
$$\bar{\eta} = 0.41 \pm 0.05$$

Conclusion on CKM Constraints

- The S.M. picture of CP is at date perfectly consistent 😊
- No hint of New Physics from the UT 😞

All the processes

	$\bar{\rho}$	$\bar{\eta}$
sides	0.218 ± 0.043	0.385 ± 0.028
angles	0.187 ± 0.052	0.322 ± 0.025
tree	0.18 ± 0.12	0.41 ± 0.05
all	0.210 ± 0.036	0.347 ± 0.021



$$\bar{\rho} = 0.210 \pm 0.036 \quad \bar{\eta} = 0.347 \pm 0.021$$

TOPICS:

- ★ The Physics Program
- ★ The CKM Matrix and the Unitary Triangle
- ★ The Unitary Triangle by Sides
- ★ The Unitary Triangle by Angles
- ★ Search for N.P. & Constraints on the SM
- ★ The Unexpected
- ★ Conclusions & Perspectives

- The Paradigm:

Search for New Physics contributions to processes
with low expected yield in the Standard Model :



$$B^+ \rightarrow \tau^+ \nu$$

$$B \rightarrow s \gamma$$

$$\tau \rightarrow \mu \gamma, e \gamma, l l l, \dots$$

$$\mathcal{B}(B^+ \rightarrow \tau^+ \nu_\tau) = \frac{G_F^2 m_B}{8\pi} m_\tau^2 \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B = (1.0 \pm 0.5) 10^{-4} UT - fit$$

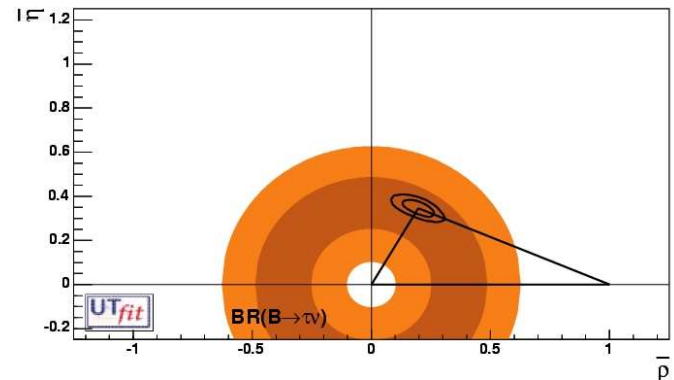
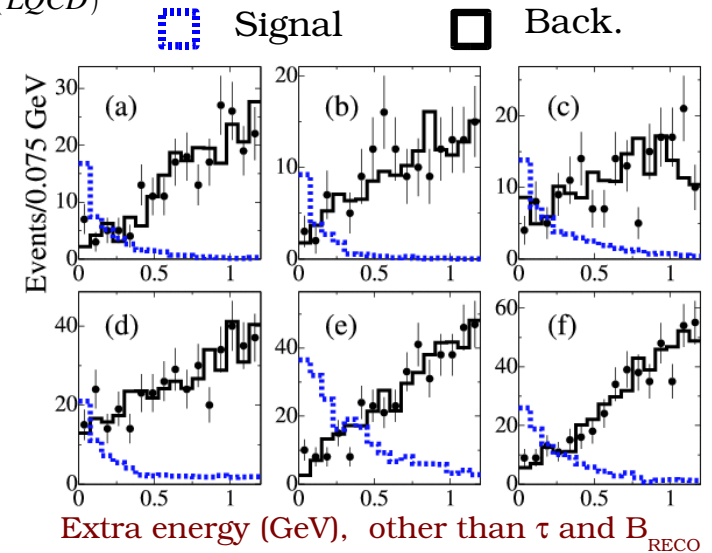
$f_B = 0.192 \pm 0.027 \text{ GeV (LQCD)}$

- Two (and more) neutrinos: no kin. constraints
- Look for 1/3 prongs τ decays on recoil of reconstructed $B^- \rightarrow D^{(*)} h / l \nu$

$$B(B \rightarrow \tau \nu) < 2.6 \cdot 10^{-4} \text{ (90 \% CL) BABAR (230 fb}^{-1}\text{)}$$

$$B(B \rightarrow \tau \nu) < 1.8 \cdot 10^{-4} \text{ (90 \% CL) Belle (350 fb}^{-1}\text{)}$$

- Weak Bound on UT



$$\mathcal{B}(B^+ \rightarrow \tau^+ \nu_\tau) = \frac{G_F^2 m_B}{8\pi} m_\tau^2 \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B = (1.0 \pm 0.5) 10^{-4} UT - fit$$

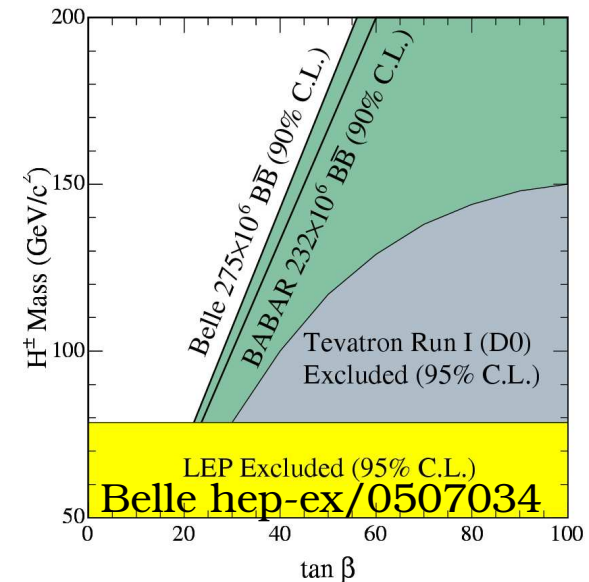
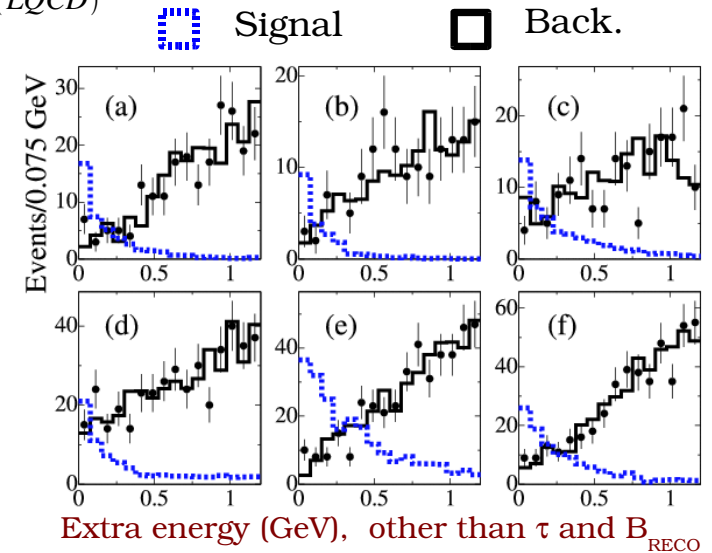
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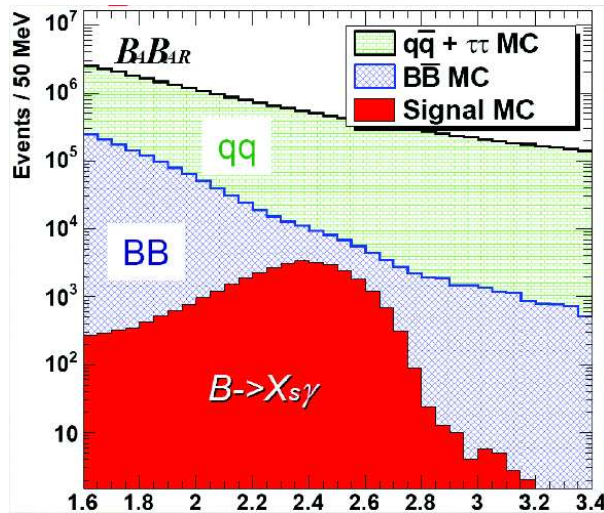
$$B(B \rightarrow \tau \nu) < 2.6 \cdot 10^{-4} \text{ (90 \% CL) BABAR (230 fb}^{-1}\text{)}$$

$$B(B \rightarrow \tau \nu) < 1.8 \cdot 10^{-4} \text{ (90 \% CL) Belle (350 fb}^{-1}\text{)}$$

- Weak Bound on UT
- ... but improves considerably limits on H^+ from direct searches



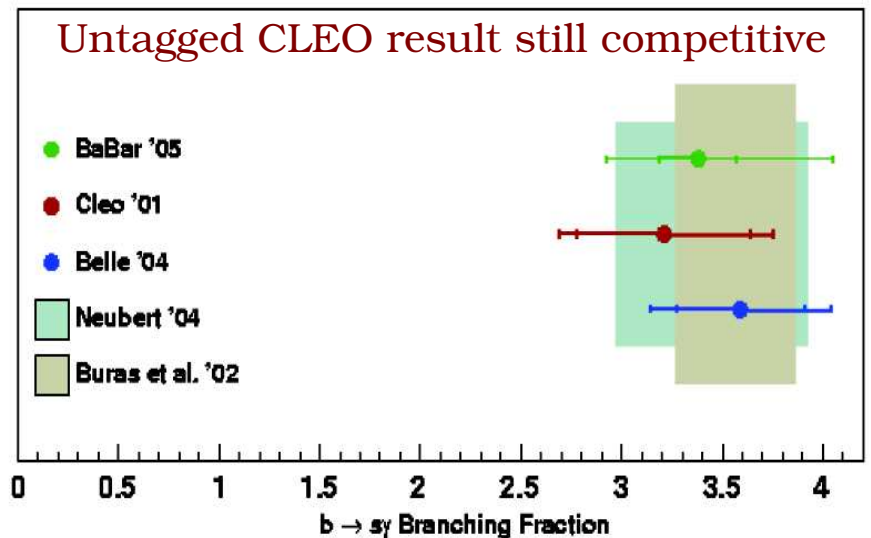
A Penguin Decay: $b \rightarrow \gamma s$



Continuum background reduction:

- ★ sum of 38 exclusive final states
- ★ high- p lepton tag
- ★ B_{RECO} (hadronic and semileptonic)

<i>mode, E_{γ} cut</i>		$BR \times 10^4$
<i>BABAR</i> (80 fb $^{-1}$)	Σ exclusive, 1.9	$3.67 \pm 0.29 \pm 0.34 \pm 0.29$
<i>BABAR</i> (80 fb $^{-1}$)	inclusive, 1.6	$3.38 \pm 0.19^{+0.64}_{-0.41} \pm 0.08$
<i>Belle</i> (150 fb $^{-1}$)	inclusive, 1.8	$3.55 \pm 0.32 \pm 0.30^{+0.11}_{-0.07}$
W.A.		3.39 ± 0.30
S.M.	improved NLO	$3.47 \pm 0.37 \pm 0.31$

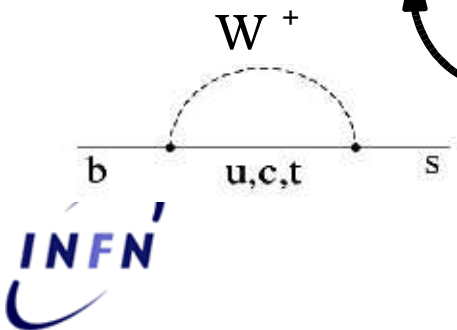


P.Gambino, M.Misiak Nucl.Phys. **B611** , 338 , 2001

M.Neubert, Eur.Phys.J. **C40** , 165 , 2005

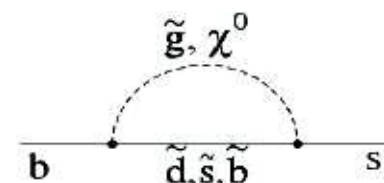
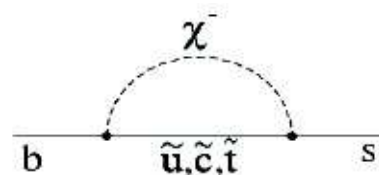
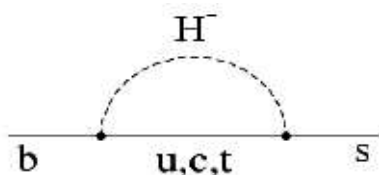
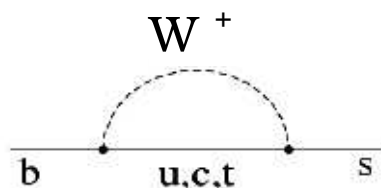
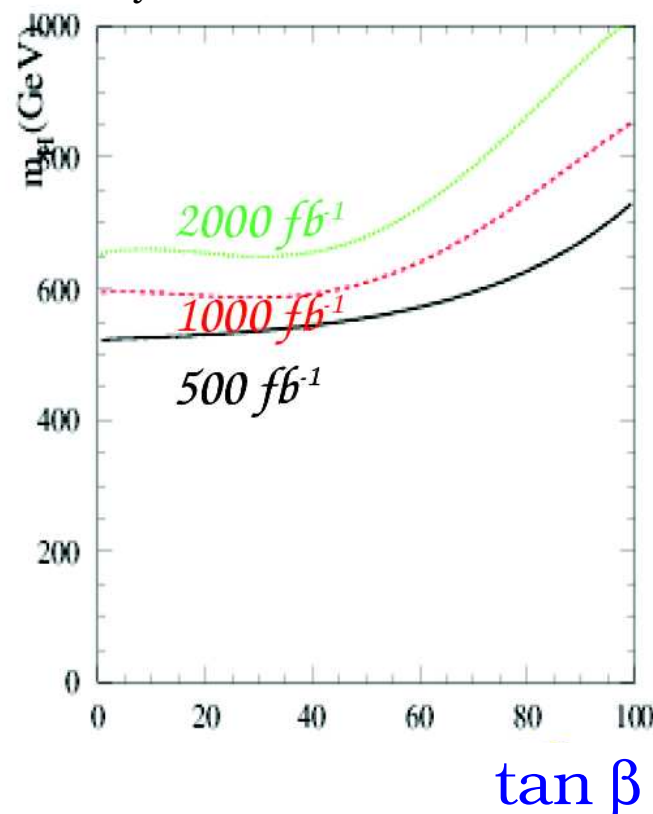
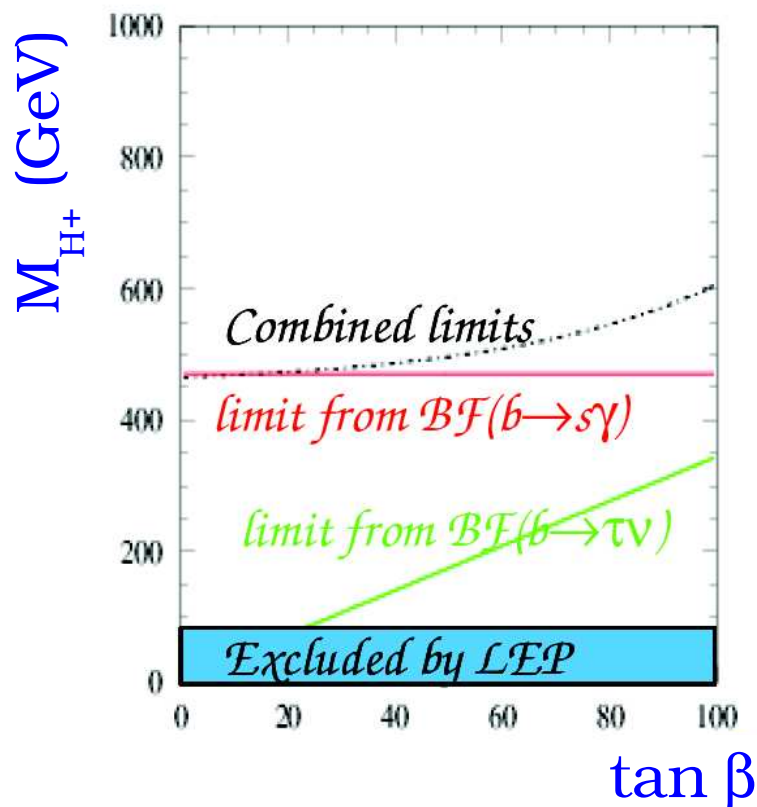
S.M holds well (once again ...)

Franco Simonetto INFN & Universita' di Padova



... so improve limits on $M(H^+)$ further

based on 2DH model described in W.S.Hou Phys.Rev. **D48**, 2342, 1993



Motivation

- Very Rare Processes in the S.M.
- Current results from ν oscillation imply (at most)

$$\text{BR}(\tau \rightarrow \mu \gamma) \sim 10^{-54} !$$

- A smoking gun for New Physics

Role of B-factories

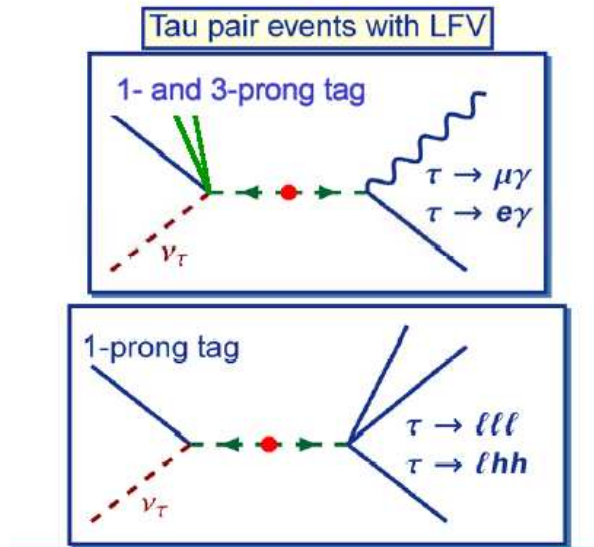
- B-factories are $c\text{-}\tau$ factories !
- $\sigma(\tau^+\tau^-) = 0.89 \text{ nb} \rightarrow 2 \cdot 10^8 \text{ evts} / 100 \text{ fb}^{-1}$
- Improve sensitivity by ~ 10 w.r.t. previous experiments



$\tau \rightarrow \mu\gamma$	PRL 95 (2005) 041802
$\tau \rightarrow e\gamma$	hep-ex/05080, accept.by PRL
$\tau \rightarrow 3\ell$	PRL 92 (2004) 121801
$\tau \rightarrow \ell hh'$	PRL 95 19,191801



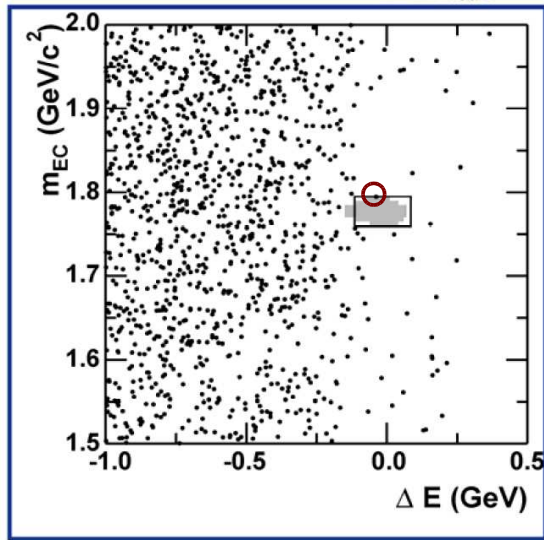
$\tau \rightarrow \mu\gamma$	PRL 92 (2004) 171802
$\tau \rightarrow e\gamma$	PLB 613 (2005) 22-28
$\tau \rightarrow 3\ell$	PLB 598 (2004) 103
$\tau \rightarrow \ell hh'$	Nu.Ph. B144 (2005) 173 (proc)
$\tau \rightarrow \ell K_s^0$	hep-ex/0509014
$\tau \rightarrow \ell^-(\pi^0, \eta, \eta')$	PLB 622 (2005) 218-228
$\tau \rightarrow \bar{\Lambda}\pi^-, \Lambda\pi^-$	to appear in PLB 632,51,2006



- τ produced in pairs, in opposite hemispheres
- "tag-side", from one and three -prong τ decays
- "search-side", no ν : constrain

$$E_{vis} = \frac{\sqrt{s}}{2} \quad M_{vis} = M_\tau$$

BABAR $\tau \rightarrow e\gamma$ search



- search-box $\sim 2 \sigma$ around constraint
- typical efficiency $\sim 5 \%$

- No significant excess observed (yet)
- Report best limit on the market (when >1 available)

Mode	Exp. / Lum.	90% CL ($\times 10^{-7}$)
$e\gamma$	<i>BABAR</i> (230 fb ⁻¹)	1.1
$\mu\gamma$	<i>BABAR</i> (230 fb ⁻¹)	0.7
$3l$	<i>BABAR</i> (90 fb ⁻¹)	1.1-3.3
$3l$	<i>Belle</i> (90 fb ⁻¹)	1.9-3.5
eK_s	<i>Belle</i> (280 fb ⁻¹)	0.6
μK_s	<i>Belle</i> (280 fb ⁻¹)	0.5
$l\pi^0, l\eta, l\eta'$	<i>Belle</i> (150 fb ⁻¹)	1.5 – 10.0
$\bar{\Lambda}\pi^-$	<i>Belle</i> (150 fb ⁻¹)	1.4
$\Lambda\pi^-$	<i>Belle</i> (150 fb ⁻¹)	0.7

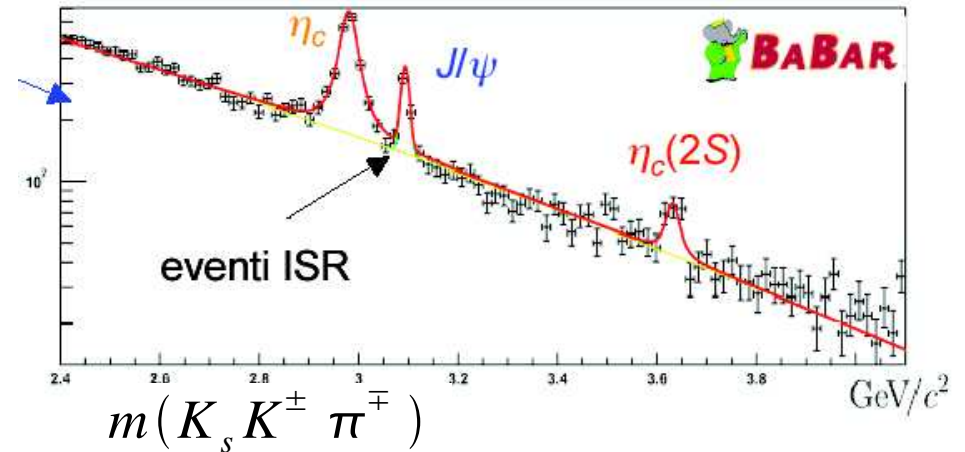
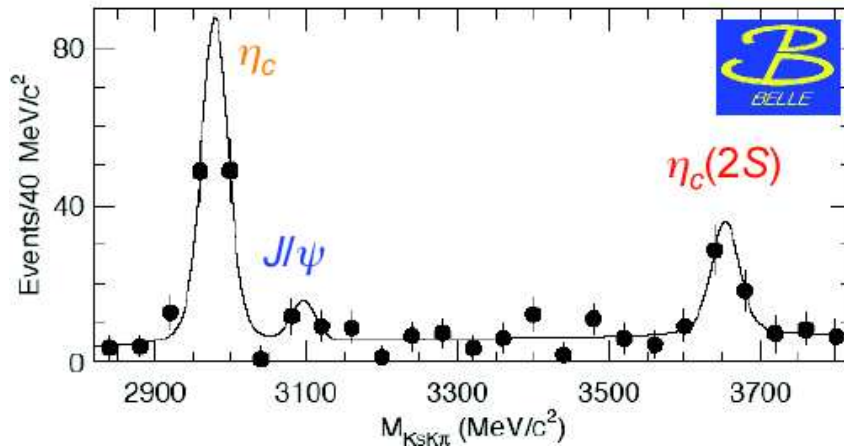
NEW

B-L cons.

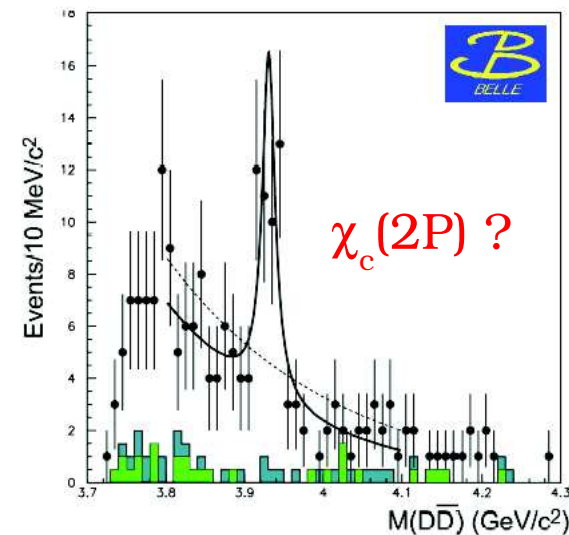
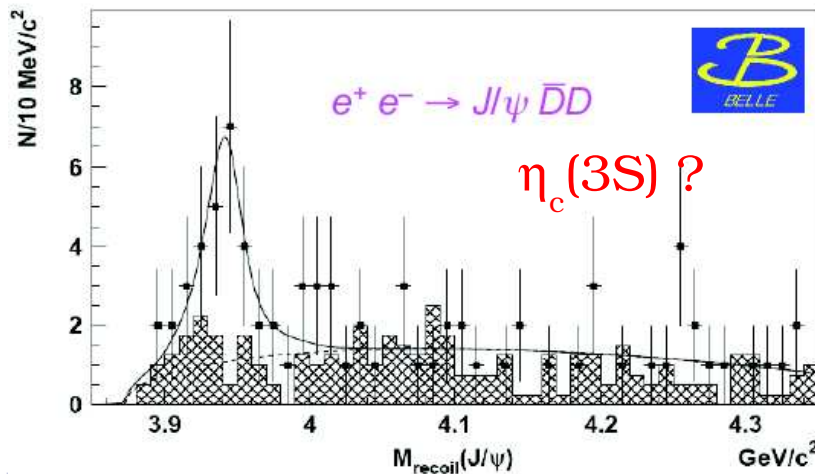
B-L viol.

TOPICS:

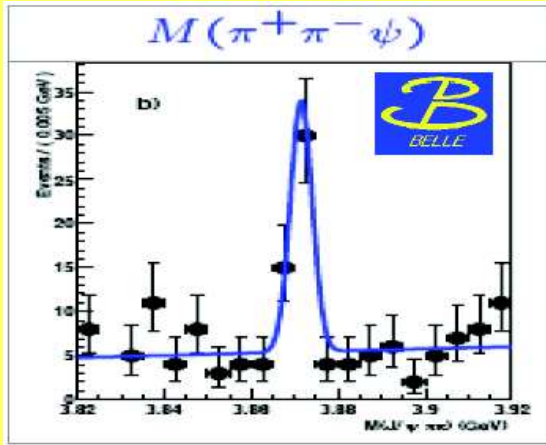
- ★ The Physics Program
- ★ The CKM Matrix and the Unitary Triangle
- ★ The Unitary Triangle by Sides
- ★ The Unitary Triangle by Angles
- ★ Search for N.P. & Constraints on the SM
- ★ **The Unexpected**
- ★ Conclusions & Perspectives



- Several new resonances have been observed
- Some good candidates for charmonium
- ... but also something else ...

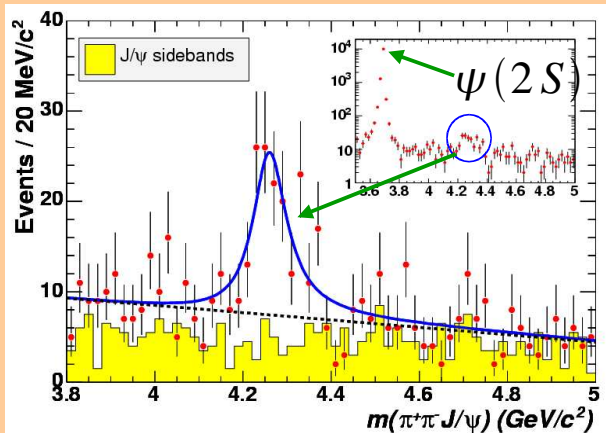
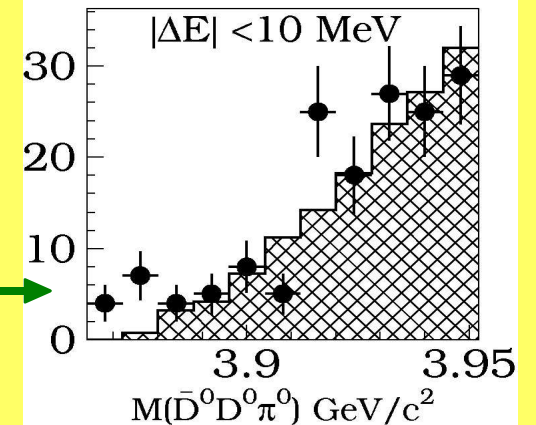


- ... not fitting any spectroscopic expectation !



Belle, $X(3872) \rightarrow J/\psi \pi^+ \pi^-$
 observed first in $B \rightarrow K (J/\psi \pi^+ \pi^-)$
 confirmed by BABAR, CDF, D0
 Belle also observes in $D^0 \bar{D}^0 \pi^0$

$D^0 \bar{D}^{0*}$ molecule?



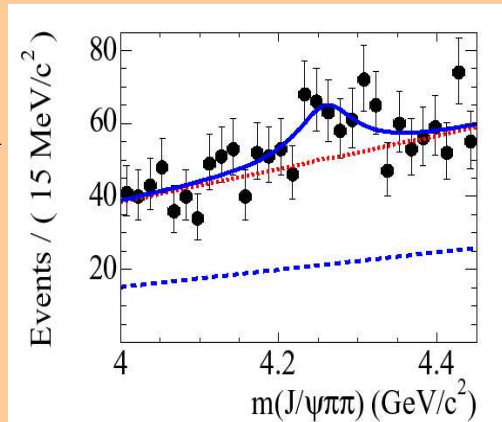
BABAR, $Y(4260) \rightarrow J/\psi \pi^+ \pi^-$
 $e^+ e^- \rightarrow (J/\psi \pi^+ \pi^-) \gamma, \gamma$ not reconstructed
 also as $B^- \rightarrow (J/\psi \pi^- \pi^+) K^-$?

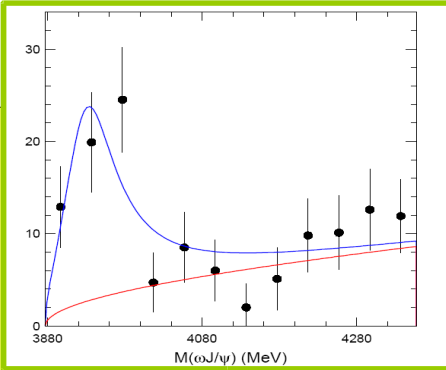
$4S - 3D c \bar{c}$ mixture?

PRD72,031503-2005

hybrid $q \bar{q} g$ meson?

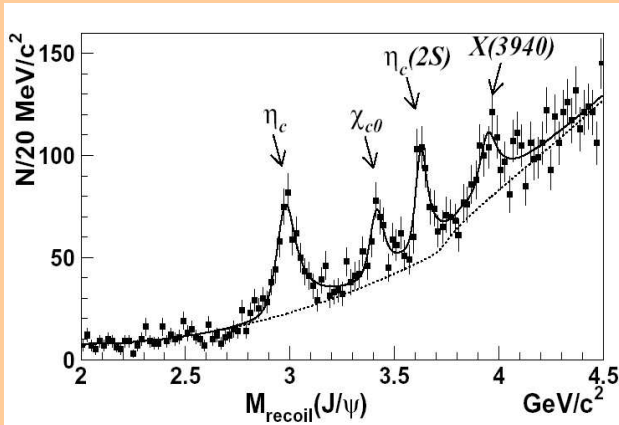
hep-lat/0512044





Belle, $Y(3940) \rightarrow J/\psi \omega$

observed as $B \rightarrow (J/\psi \omega) K$, also observed in continuum ?

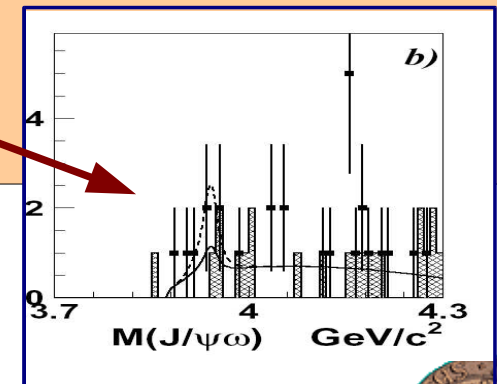
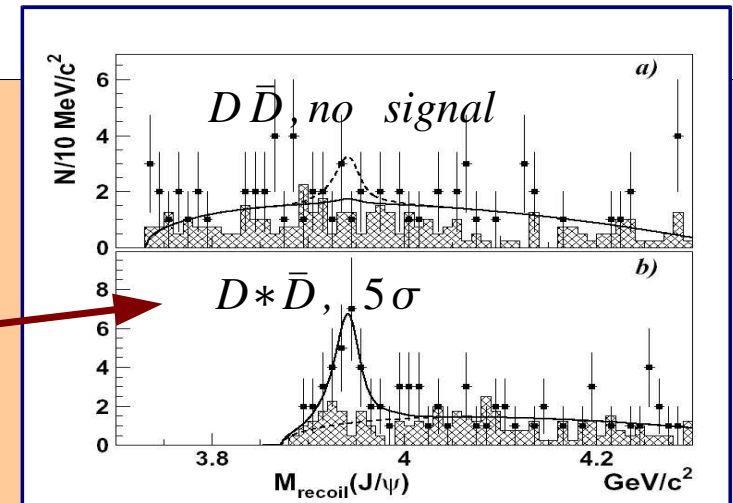


Belle, $ee \rightarrow J/\psi X$,

$X \rightarrow D^* D$ (only one D reconstructed)

but not :

$X \rightarrow J/\psi \omega$



- two different particles with equal mass ?

TOPICS:

- ★ The Physics Program
- ★ The CKM Matrix and the Unitary Triangle
- ★ The Unitary Triangle by Sides
- ★ The Unitary Triangle by Angles
- ★ Search for N.P. & Constraints on the SM
- ★ The Unexpected
- ★ Conclusions & Perspectives

- Beauty Factories successfully pursue their program
- Collider performances and detector results outmatch expectations
- This notwithstanding

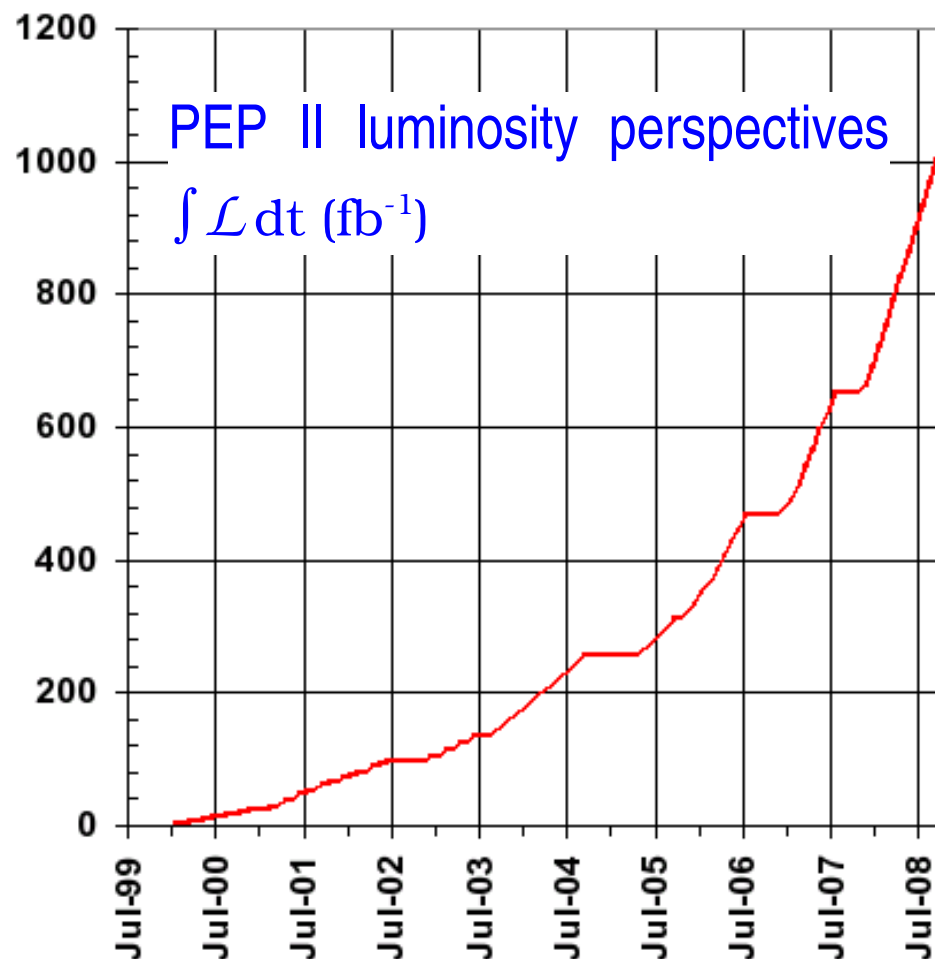
no crack in the S.M. (yet)

- However ...



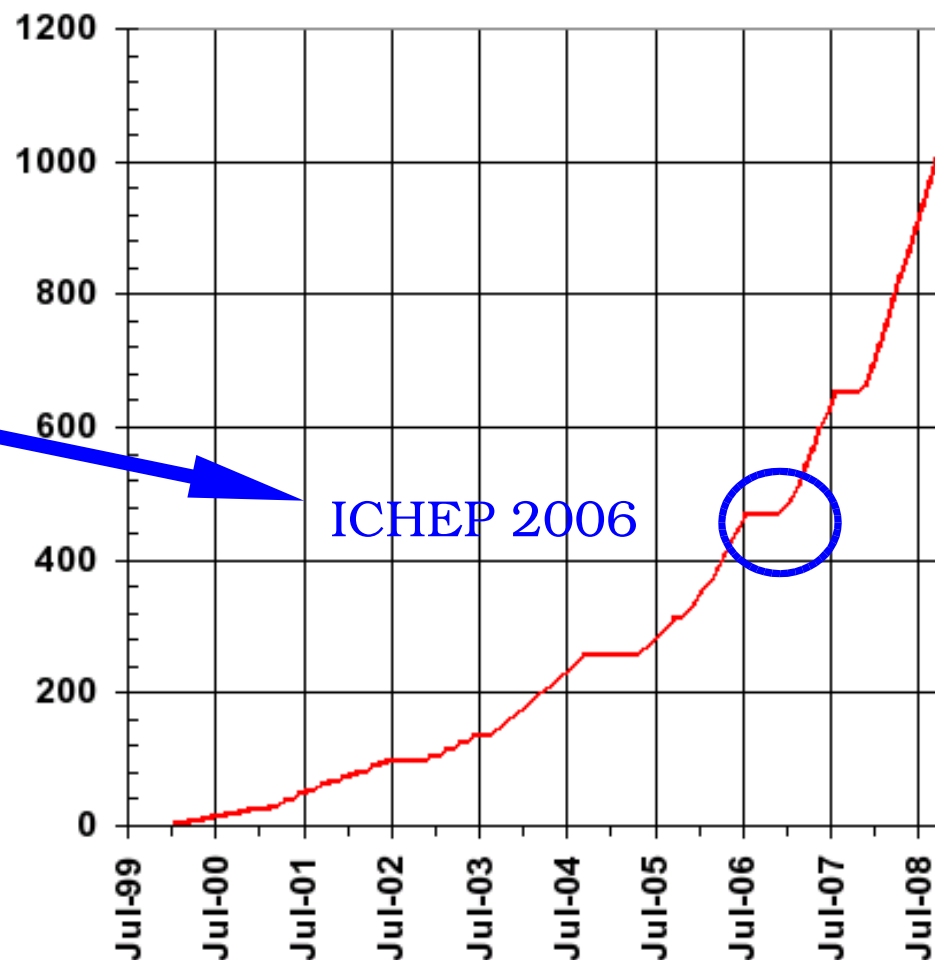
Luminosity: Perspectives

- KEK delivered 500 fb^{-1} before Jan /01/ 2006
- PEP II will cross 500 fb^{-1} by July 2006 (*x 2 results shown here*)
- By July 2008 $\sim 1 \text{ ab}^{-1}$ / experiment (*x4 -if approved*)



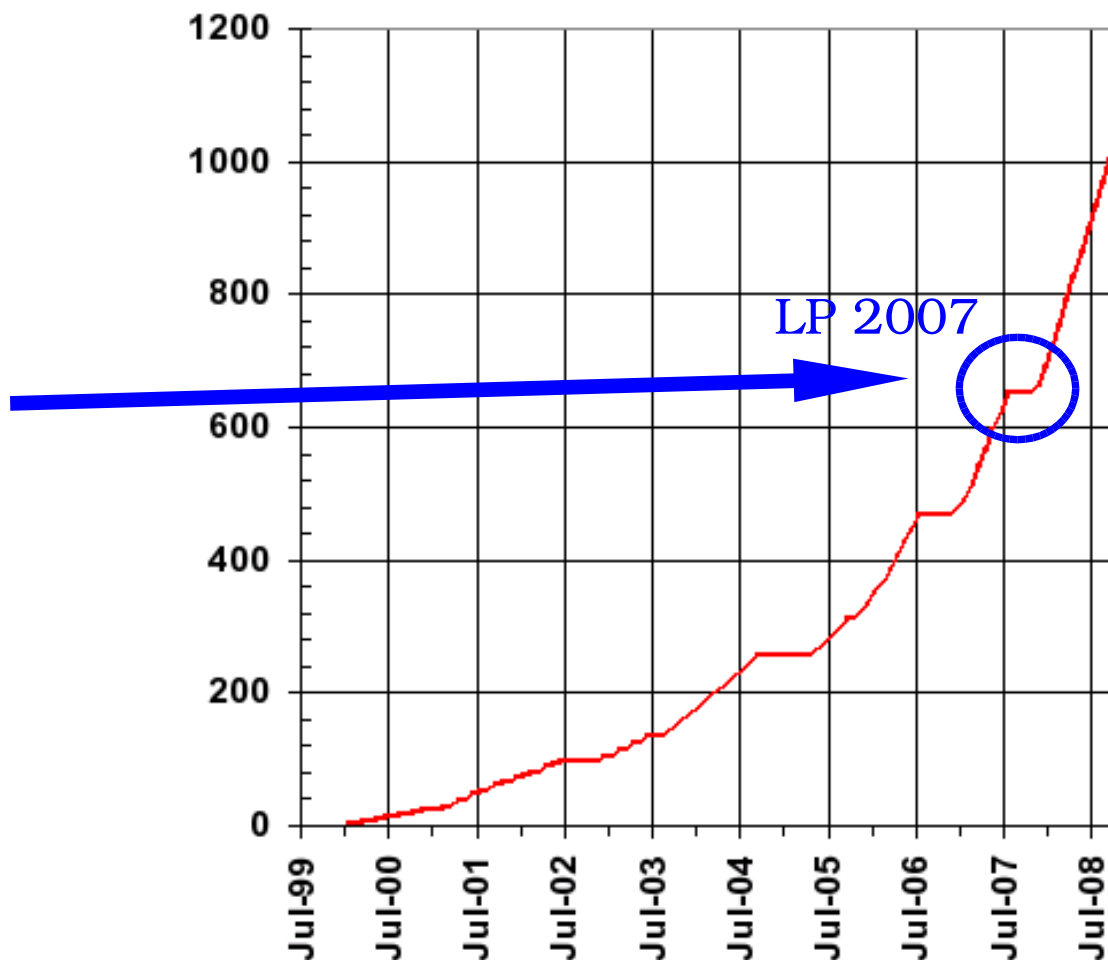
Mc Farlane P5 review:

- $\sigma(V_{ub})$ (inclusive) $\sim 6.5\%$
- $\sigma(\gamma)$ Dalitz $\sim 10\text{-}15^\circ$



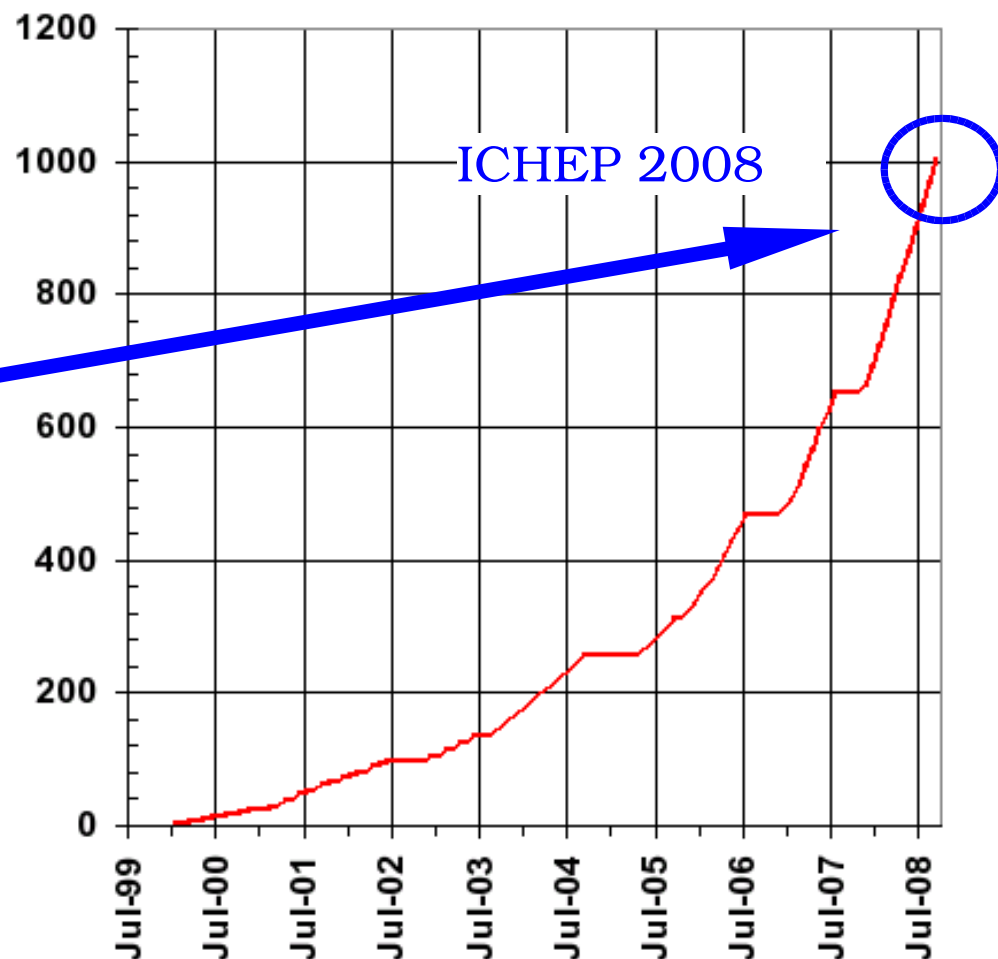
Mc Farlane P5 review:

- discovery of $B \rightarrow \rho^0 \rho^0$
- V_{td} from $B \rightarrow \rho \gamma$



Mc Farlane P5 review:

- discovery of $B \rightarrow \tau \nu$
- asymmetry in $B \rightarrow \eta' K_s$ to 5σ
- $\sigma(V_{ub})$ (in+ex) $< 5\%$
- $\sigma(\gamma) < 10^0$



B-factories Physics Program "just started"
Stay Tuned !

BACKUP



- Unlikely : $\Gamma < 2.3 \text{ MeV}/c^2$ (90 CL)
- Possible narrow candidates
 - 1^3D_2 , 1^1D_2
 - ♠ expect radiative decay ($\chi_c \gamma$) which is not observed
 - 2^3P_1 , 2^1P_1
 - ♠ predicted 100 MeV heavier than X
 - ♠ not expected to decay into $J/\Psi \pi \pi$

