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

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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:

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The CKM matrix

- Expresses in the Standard Model the couping 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

The Wolfenstein Parameterization

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

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

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

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

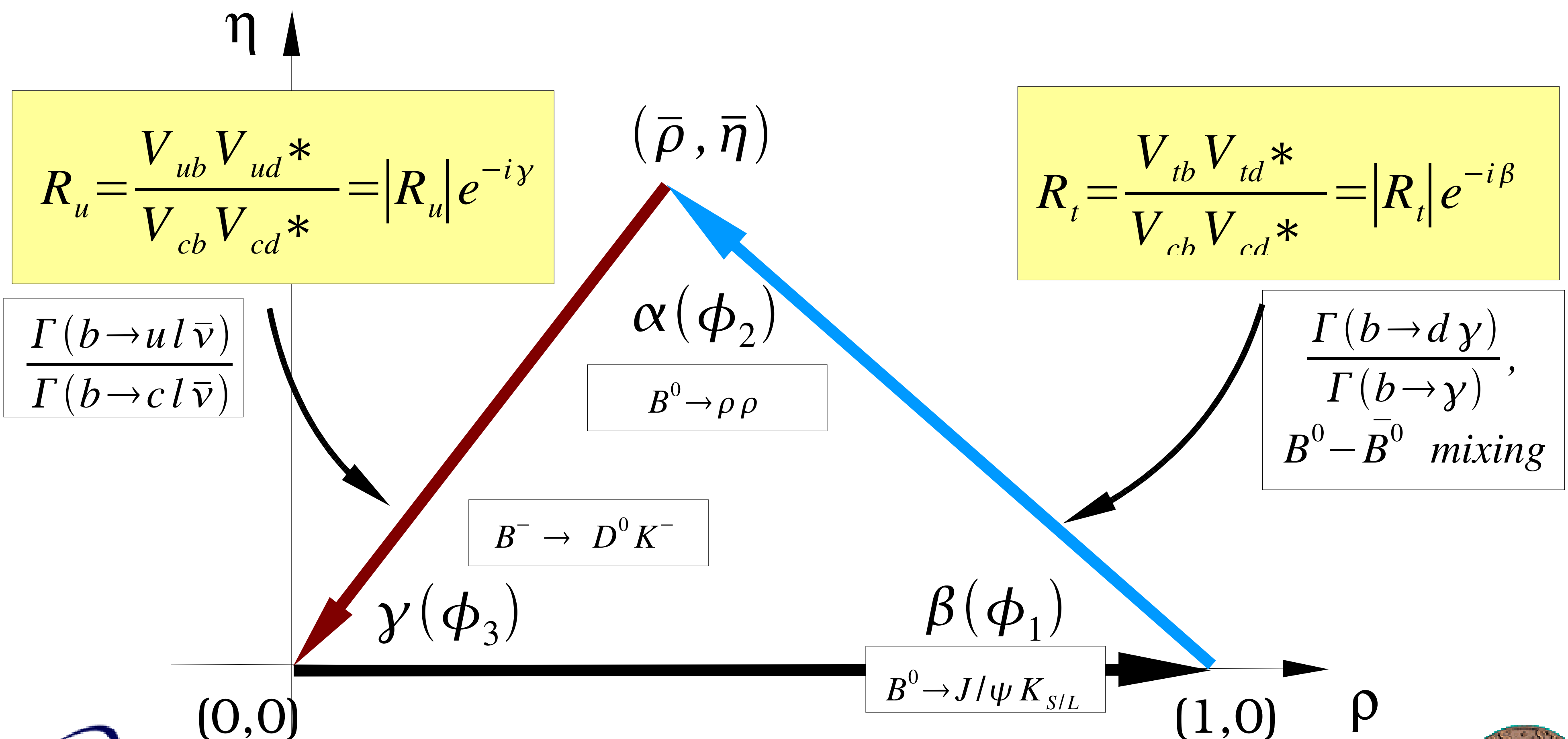
$$\bar{\eta} = \eta \cdot (1-\lambda^2/2)$$

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

CP Violation : $\eta \neq 0$

CKM and the Unitarity Triangle

- Unitarity Condition: $V_{ub}V_{ud}^* + V_{cb}V_{cd}^* + V_{tb}V_{td}^* = 0$
- Rescaled Triangle: $R_u + 1 + R_t = 0$



Constraining the UT

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

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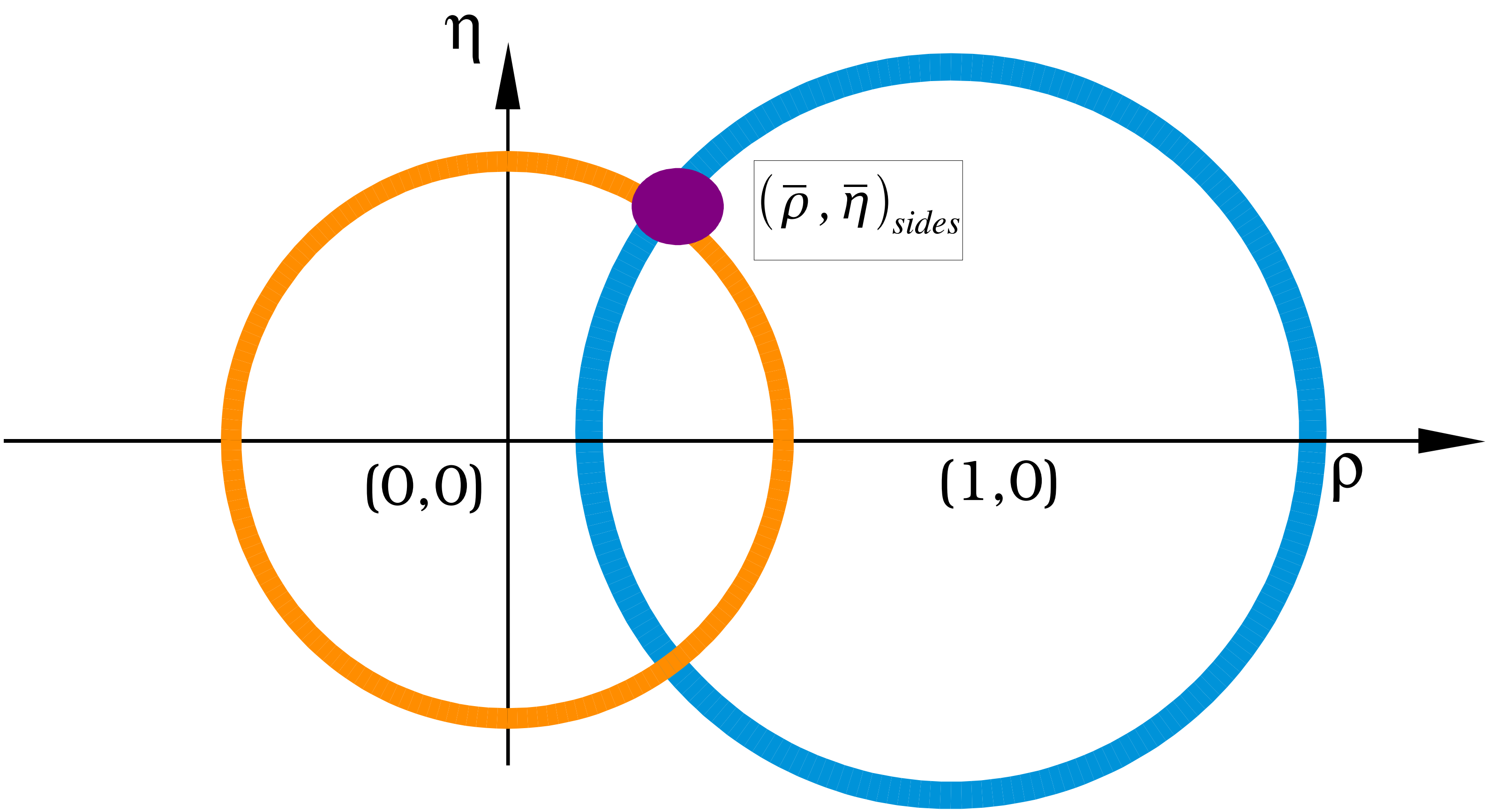
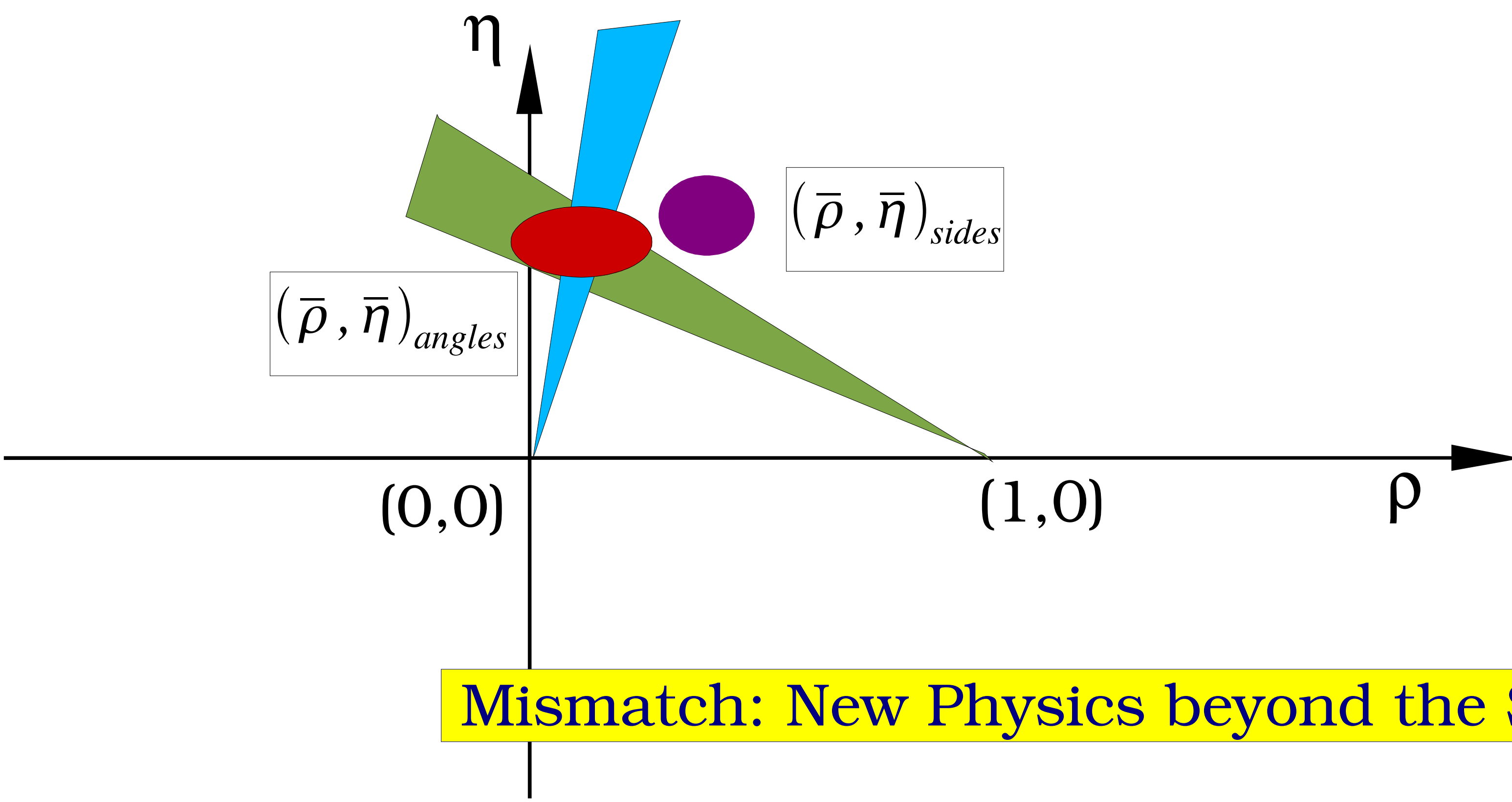


Constraining the UT

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



Mismatch: New Physics beyond the S.M.

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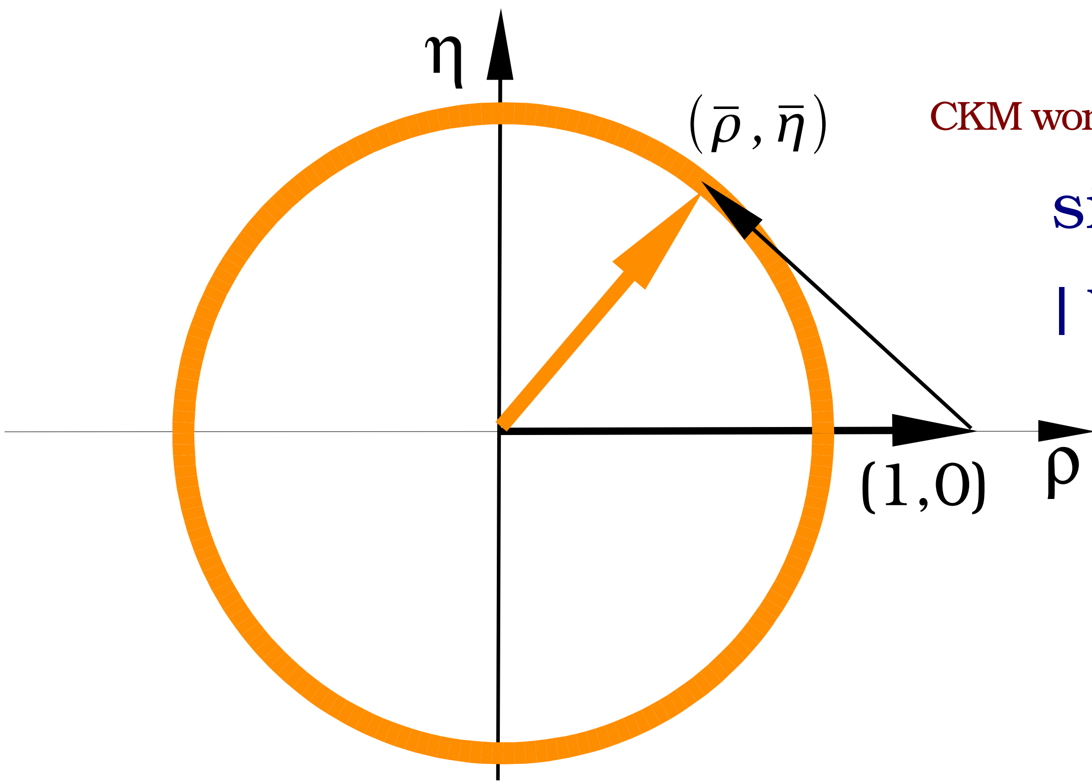
The sides : $|R_u|$

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

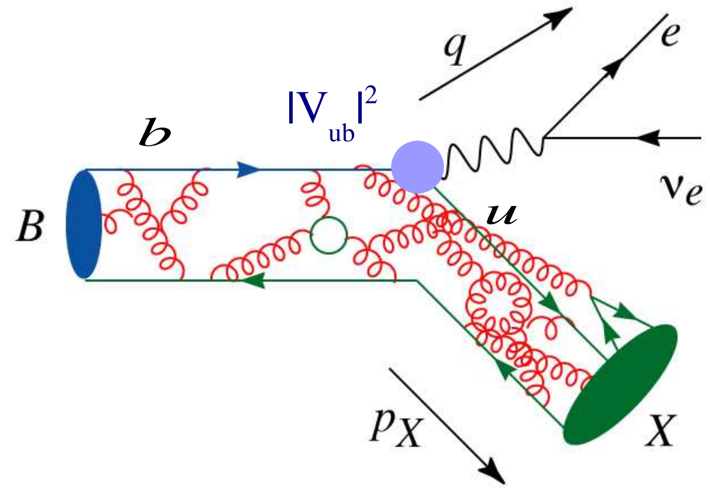


CKM workshop San Diego 2005:

$\sin\Theta_c = 0.2258 \pm 0.0011$

$|V_{cb}| = (41.6 \pm 0.7)x10^{-3}$

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



Determination of $|V_{ub}|$

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

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

- Apply hard cuts to reduce *b → clν* background $\frac{\Gamma(b \to c l \bar{\nu})}{\Gamma(b \to u l \bar{\nu})} \simeq 50$
- Measure *partial Branching Ratio ΔBr*, get *ulν* decay width

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

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

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

parton level

non perturbative "shape function"

The Shape Function

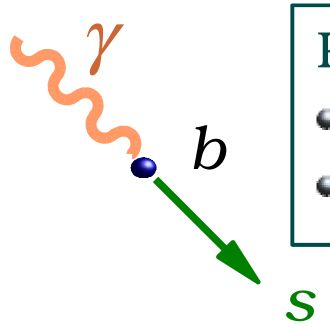
f_u depends on non-perturbative parameters

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

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

- $b \to s\gamma$ *decays*
- $b \to cl\upsilon$ *decays*

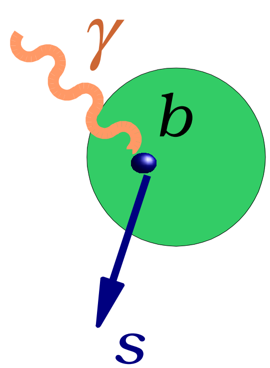
Measurement of SF parameters from $b \to s\gamma$



Parton-level :
- b-quark at rest
- two body decay

→ $E_\gamma = m_b/2$

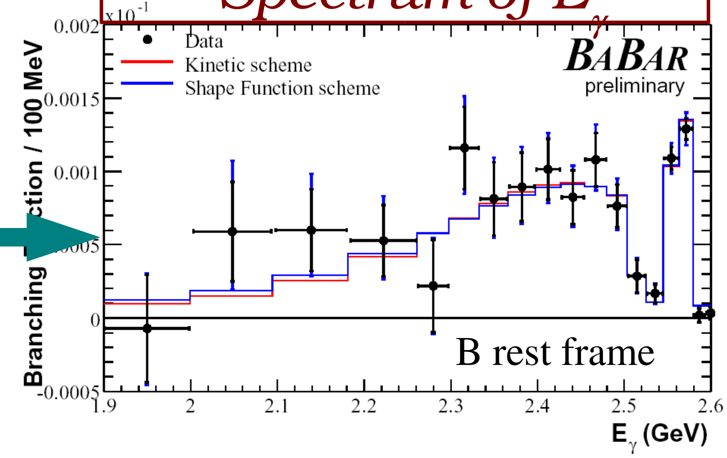
"universal" , same also for $b \to u$



Real life :
- b moves in the B-hadron
- b interacts with light dof
- s hadronizes

non-"universal"

→ Spectrum of E_γ



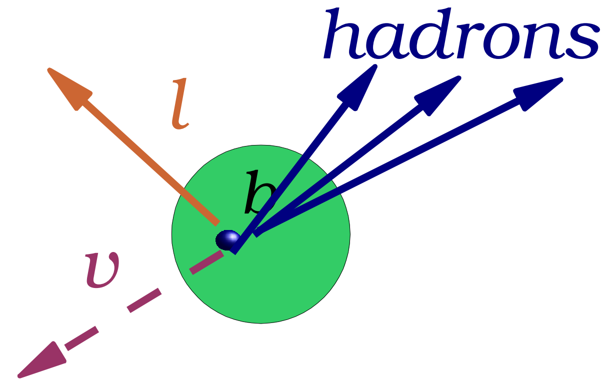
Compute SF from the (moments of) E_γ spectrum in $b \to s\gamma$ decays:

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

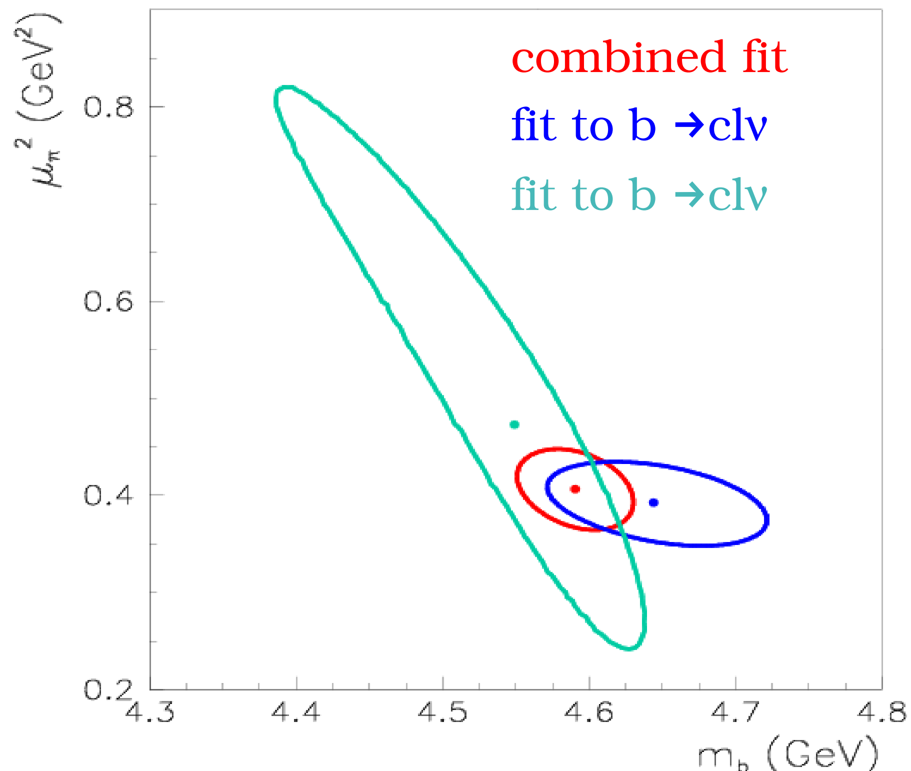
$$E^{(2)} = \langle E_\gamma^2 - \langle E_\gamma^2 \rangle \rangle \approx \mu_\pi \approx E_{kin}(b),$$

...

Measurement of SF parameters from b →clν



- Non-perturbative effects also affect lepton and hadron spectra in b →clν decays
- Measurment of E_l and M_{hadron} moments allow another determination of Shape Function
- Results are consistent with b →sγ



Errors on SF parameters:

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

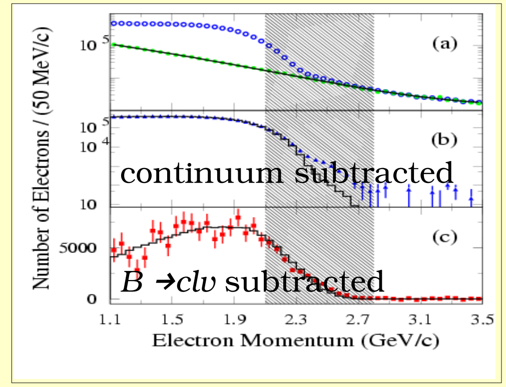
$|V_{ub}|$: inclusive measurements

E_e end point (80 fb^{-1})

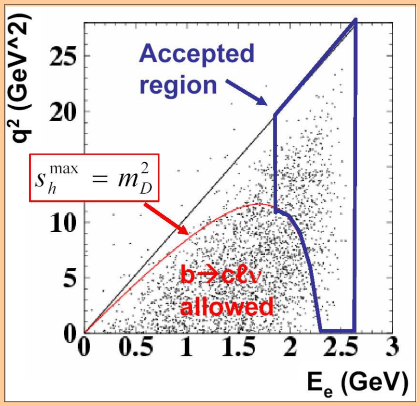
CLEO (1994) : E_e > 2.3 GeV, (c threshold)

BABAR: E_e > 2.0 (↓ model uncertainty)

(*Belle* E_e > 1.9) S/B ~ 1/14 , f_u = 0.250± 0.026



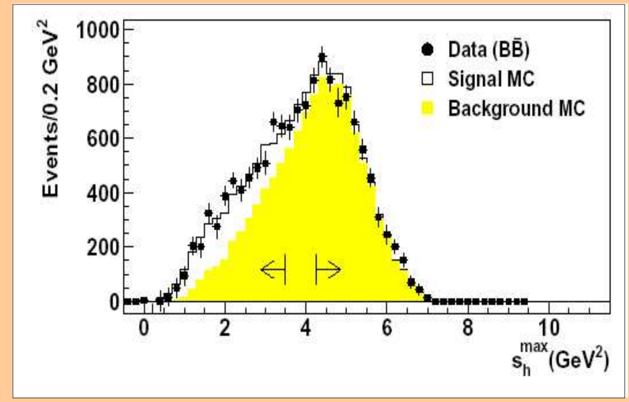
E_e -q^2 (80 fb^{-1})



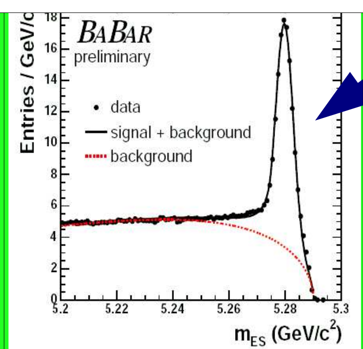
$\vec{p}_\nu$ from missing momentum

correlated cut to reduce *c*

S/B ~ 1/2 , f_u = = 0.163± 0.012



Recoil Hadrons

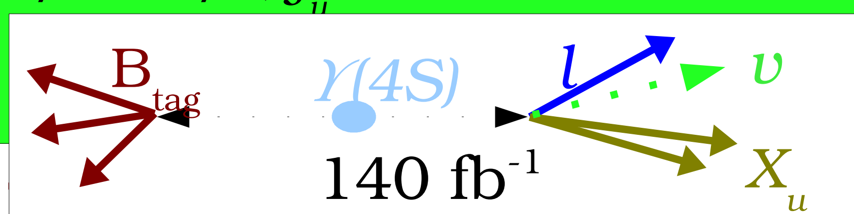


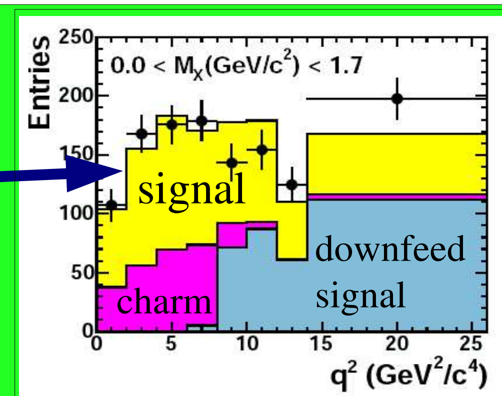
Fully reconstruct tag B (↓efficiency)

Mass (M_x) and q^2 of recoil hadrons (X_u)

Count events in *high-q^2, low- M_x* bin

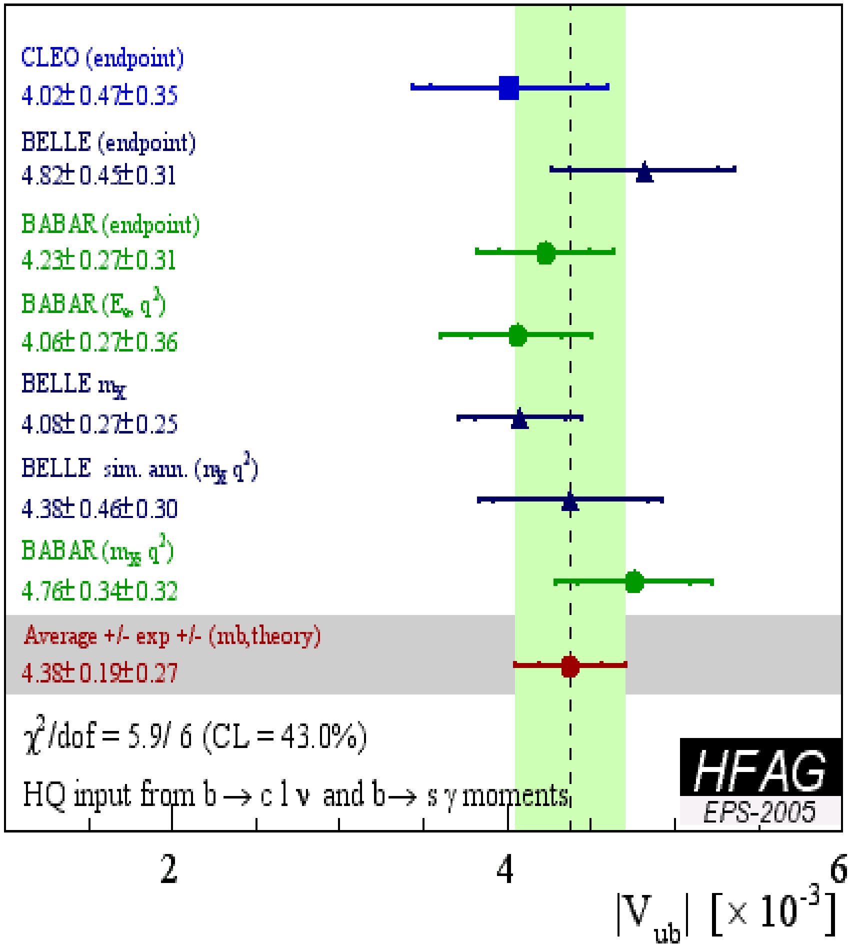
S/B > 1/1, f_u = = 0.300± 0.026





V_{ub}: results & WA

inclusive measurements B→ulν

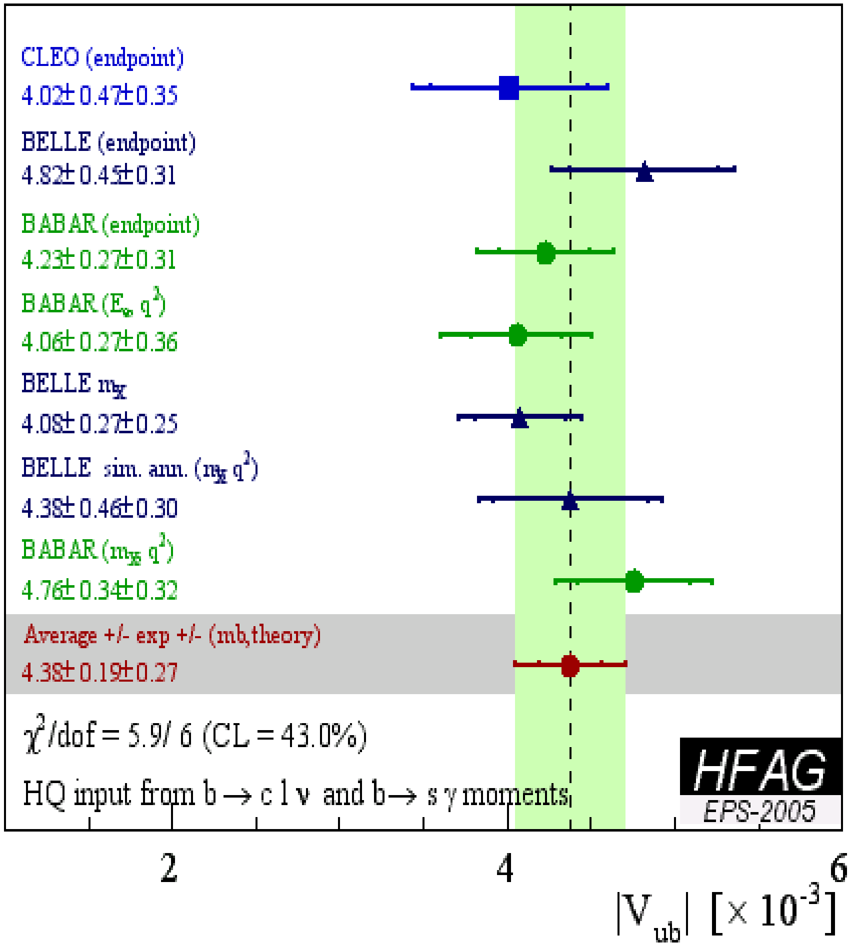


World Average, summer 2005:

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

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

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



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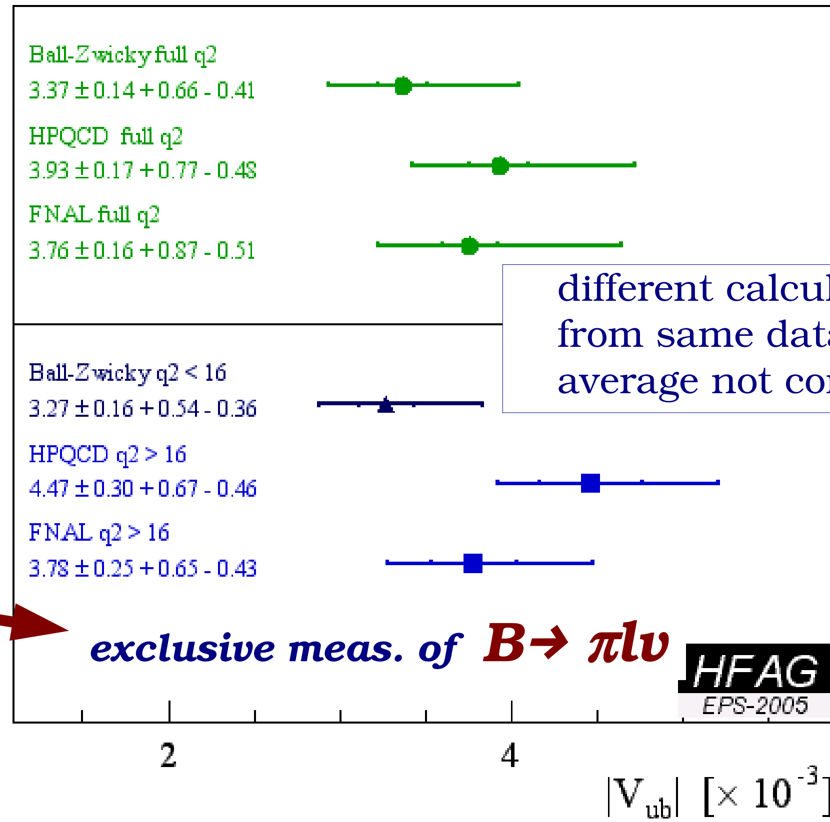
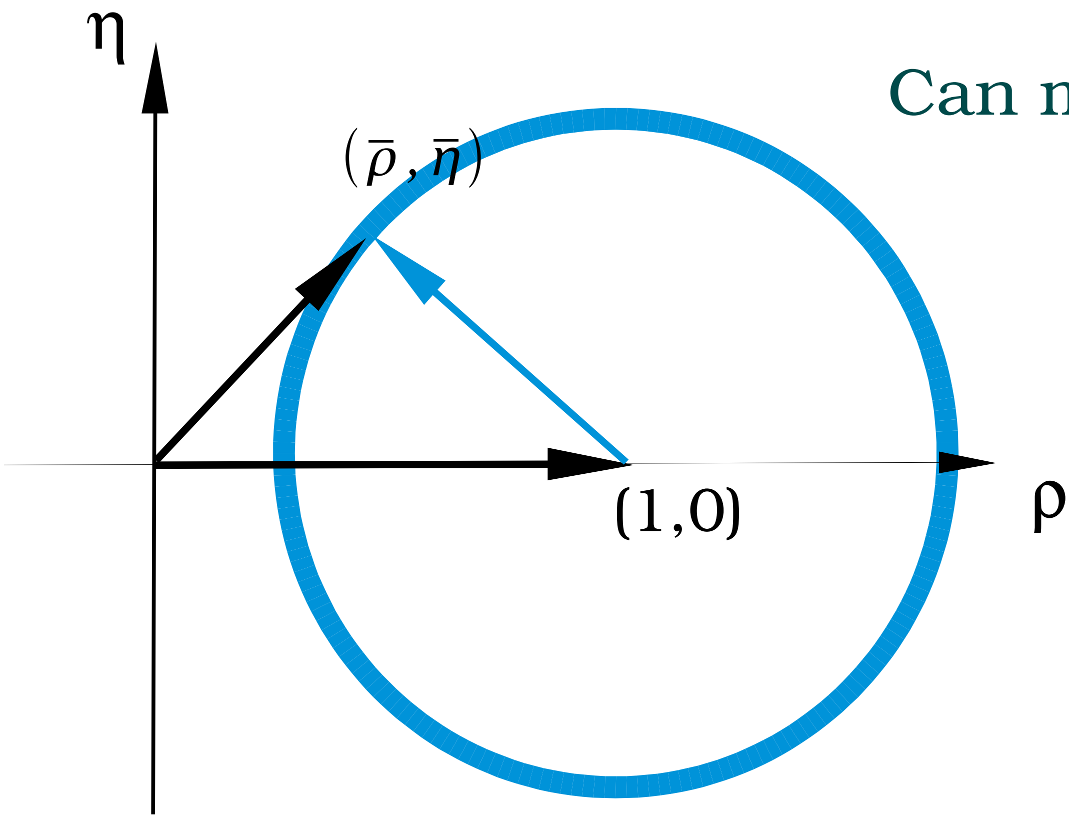


different calculations from same data , average not computed

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

The sides : $|R_t|$

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



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

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

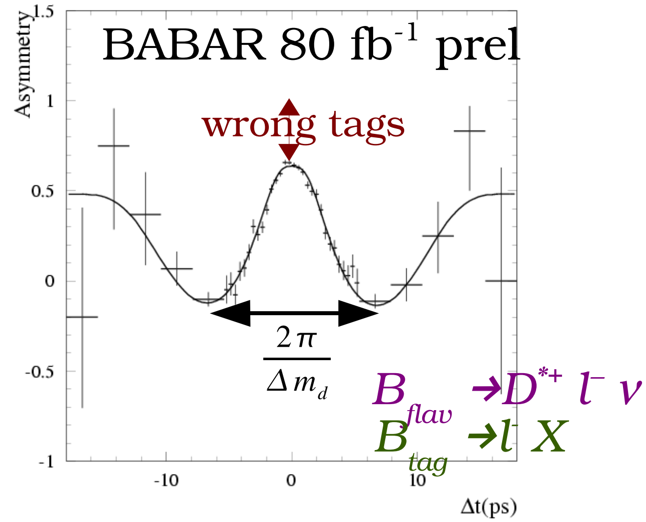
$$\frac{\Gamma(b \to d\gamma)}{\Gamma(b \to s\gamma)}$$

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

$|V_{td}|$ from Δm_d

Time dependent flavor asymmetry :

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



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

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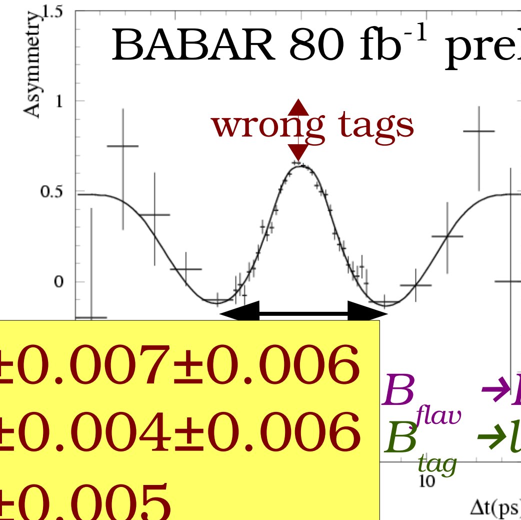

BABAR 80 fb^{-1} : *(l vs D*lν)*	0.510±0.007±0.006
Belle 140 fb^{-1} : *(three analyses)*	0.509±0.004±0.006
W.A. *(8 exp., 31analyses)*	0.506±0.005

Best known parameter in B Physics

2: $|V_{td}|$ from Δm_d

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

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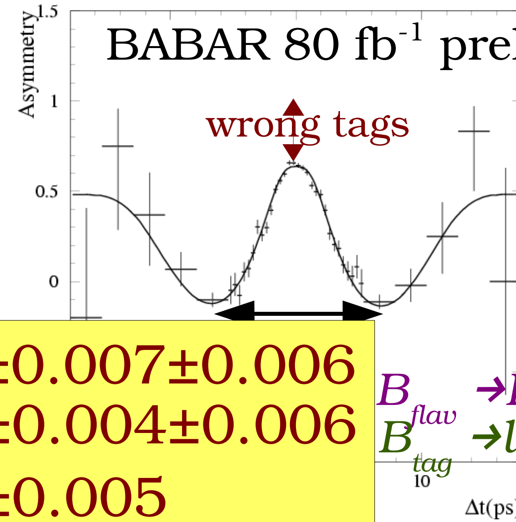

$B_{flav} \rightarrow D^{*+} l^- \nu$

$B_{tag} \rightarrow l^- X$

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Best known parameter in B Physics

... however ...

$F_{Bd} \sqrt{B_{Bd}}$ = 0.192±0.026±0.09

→Large error band in UT plane

$|V_{td}|$ from Δm_d

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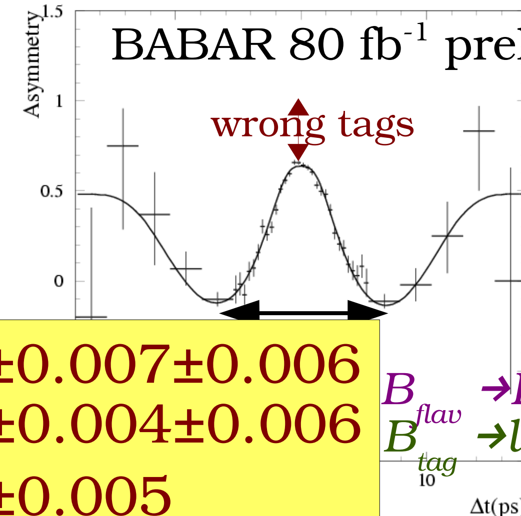

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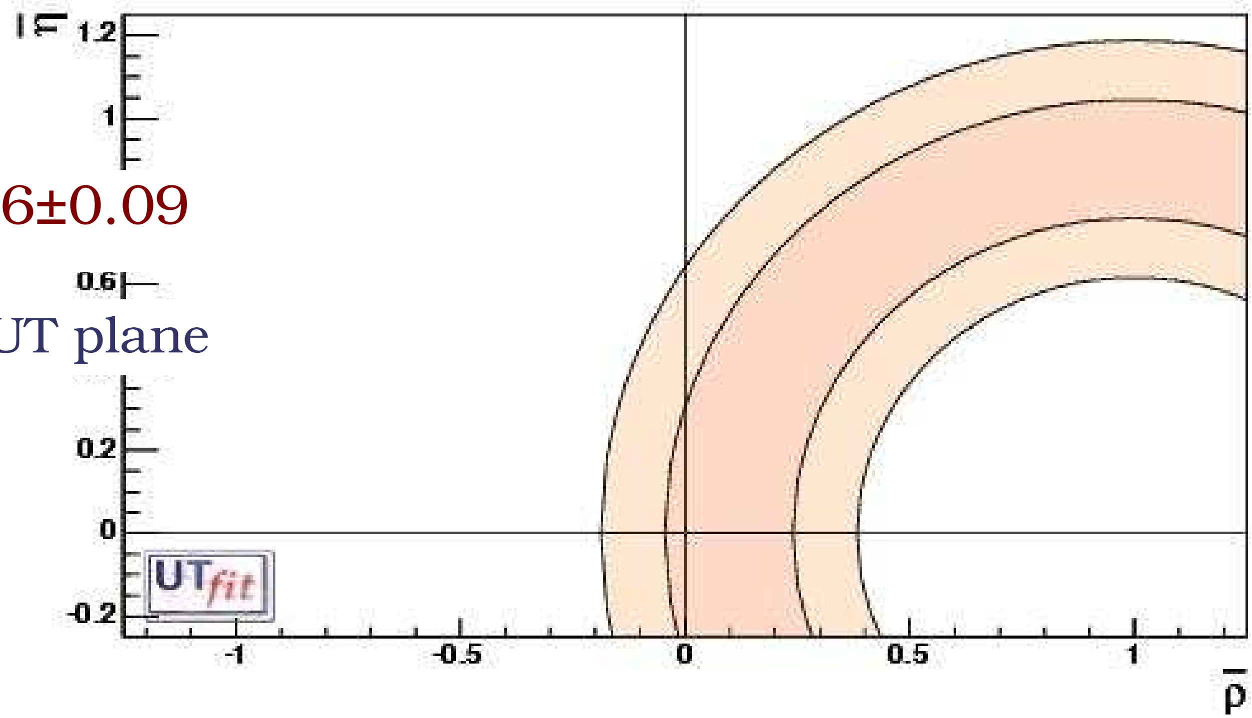
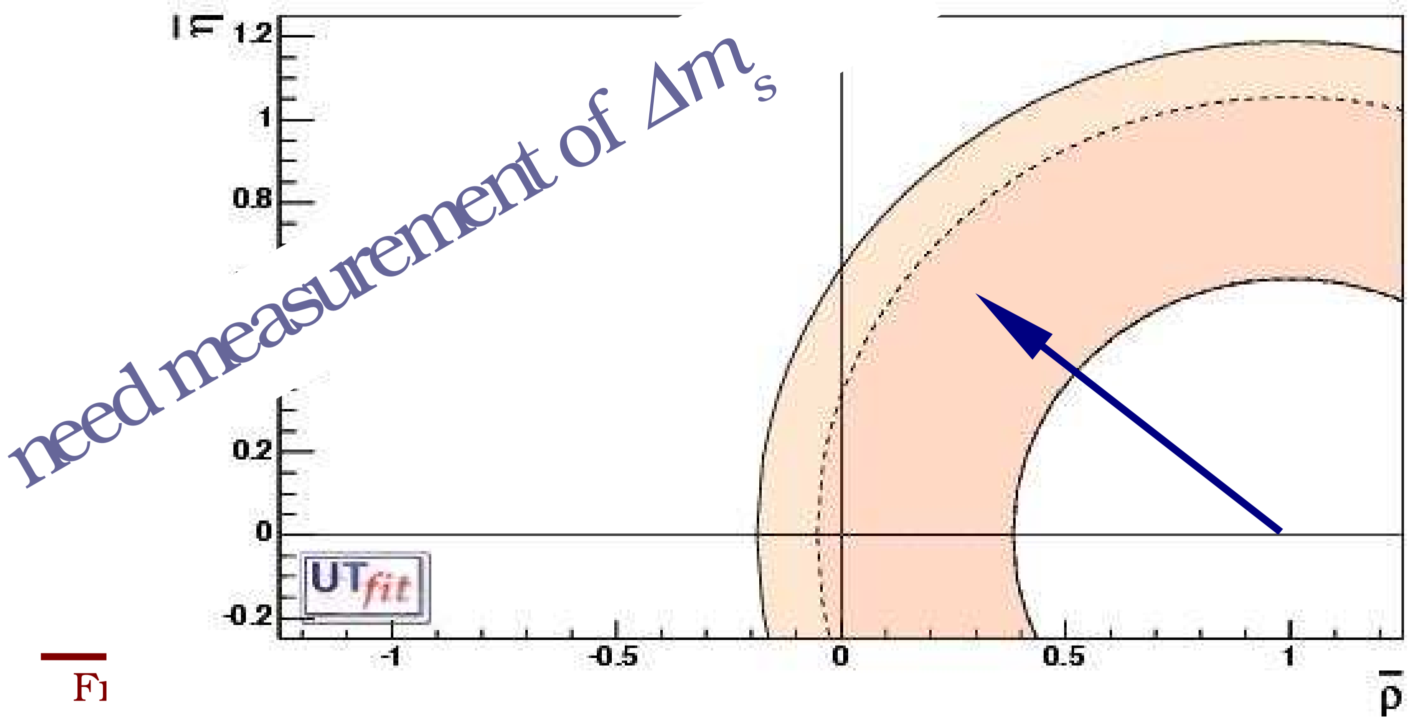


$|V_{td}|$ from $\Delta m_d / \Delta m_s$

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

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

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



Fı

$|V_{td}|$ from radiative penguins

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

Theoretically clean. Exp. nightmare

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

Within exp. reach. Th. concerns:
- Weak Annihilation
- SU(3) Breaking

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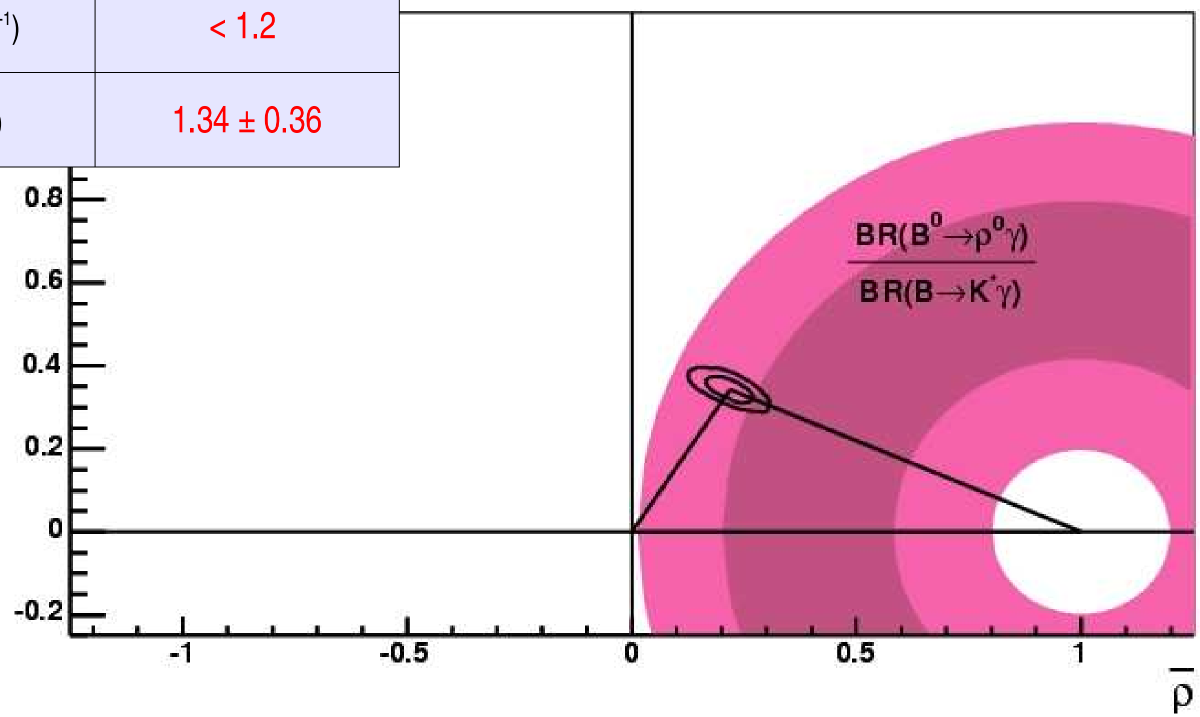
	exp	BR (10^{-6})
$K^{+}\gamma$	W.A.	40.1 ± 2.0
$K^{0}\gamma$	W.A.	40.3 ± 2.6
$\rho/\omega\ \gamma$	BABAR (200 fb^{-1})	< 1.2
$\rho/\omega\ \gamma$	Belle (350 fb^{-1})	1.34 ± 0.36



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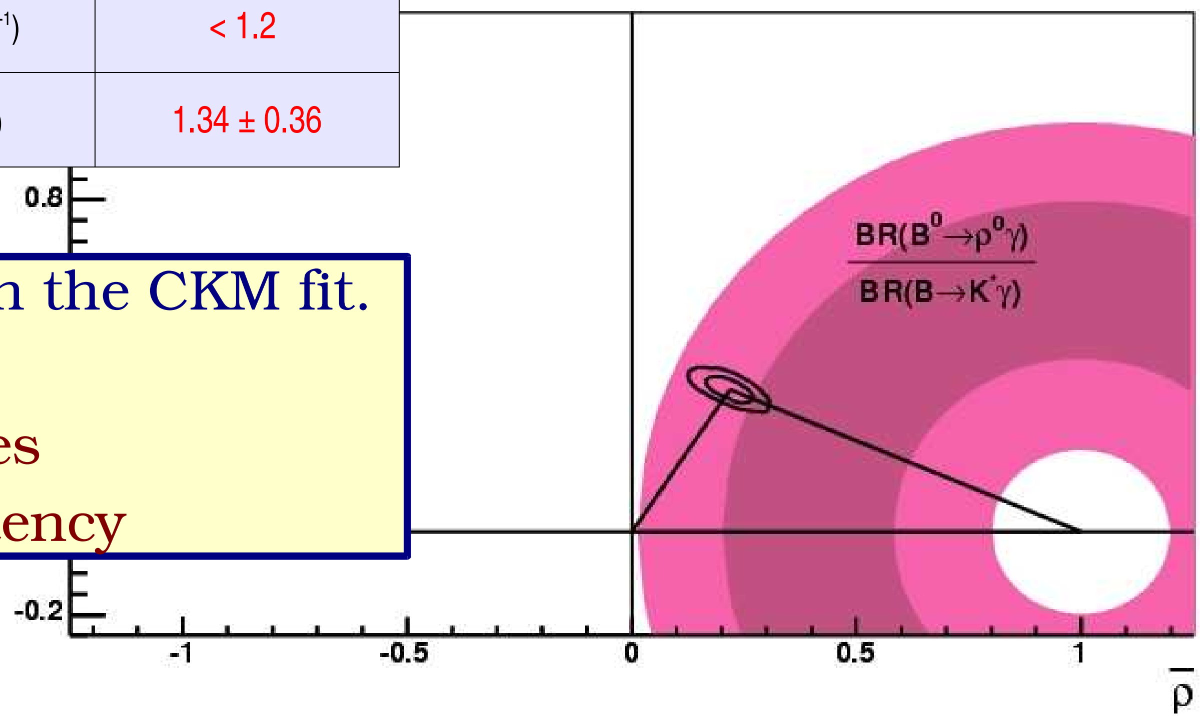
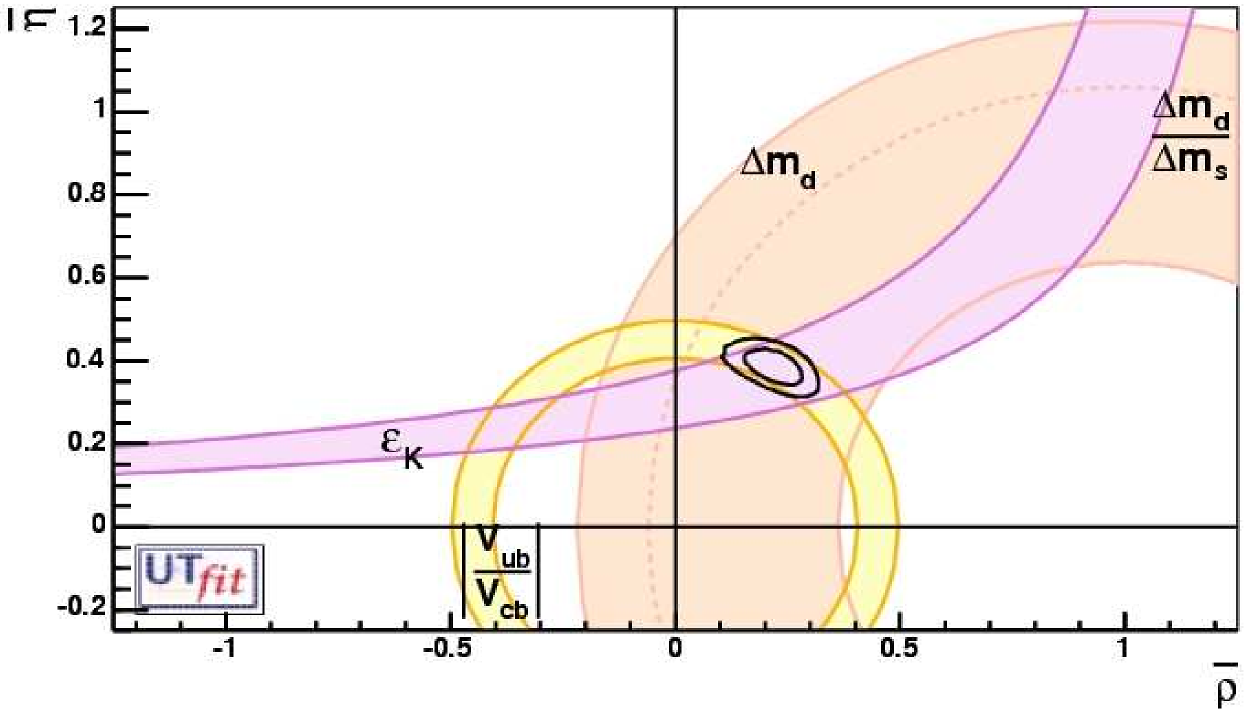


Not Yet Used in the CKM fit.
Need to assess

- Theory issues
- Exp. consistency

UT sides-view



- Prediction from Sides only :

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

- ... + ϵ_K (CP in K^0 system):

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

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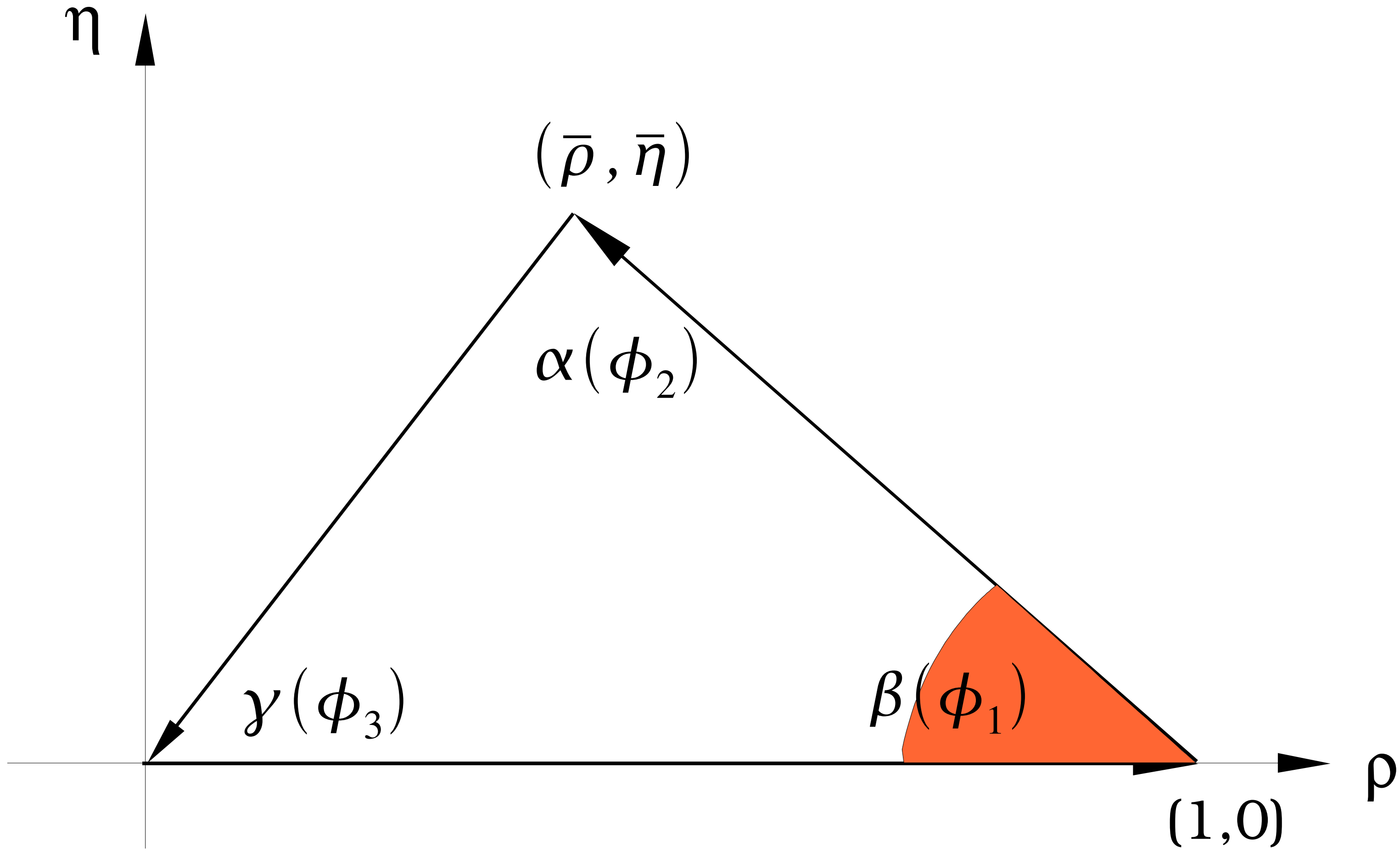
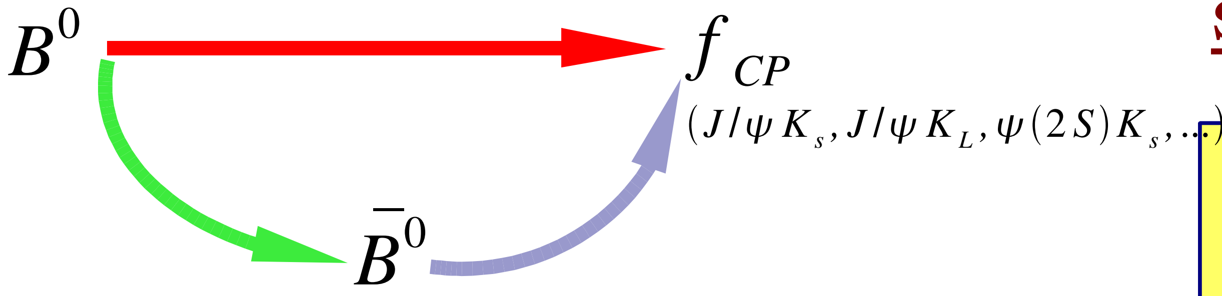
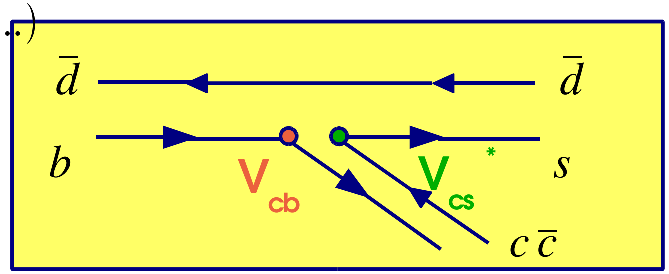
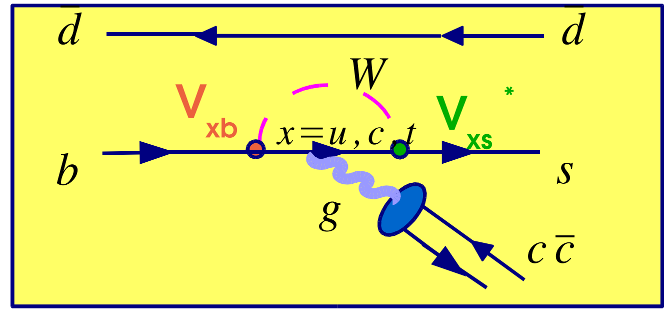
UT angle-view: sin2β



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







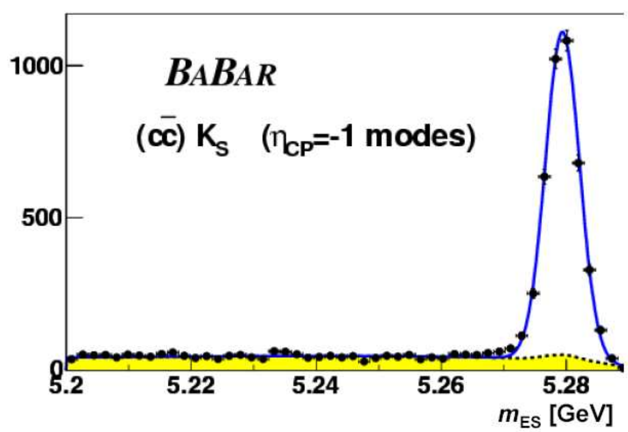
- Determined from interference of decays with and without mixing in $B^0 \to J/\psi\, K_{S/L}$

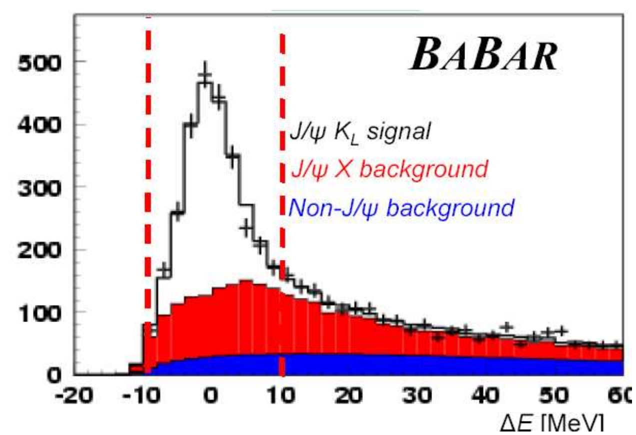
Th. clean:

- Leading interfering penguin has same weak phase as tree
- Other weak phases suppressed by $o(\sin\Theta_c^{\,2})$ x $o(\alpha_S)$ ~ 1%

Exp. clean:

- Large *B.R. o(‰)*
- Mass-constraints : low background





Golden Mode

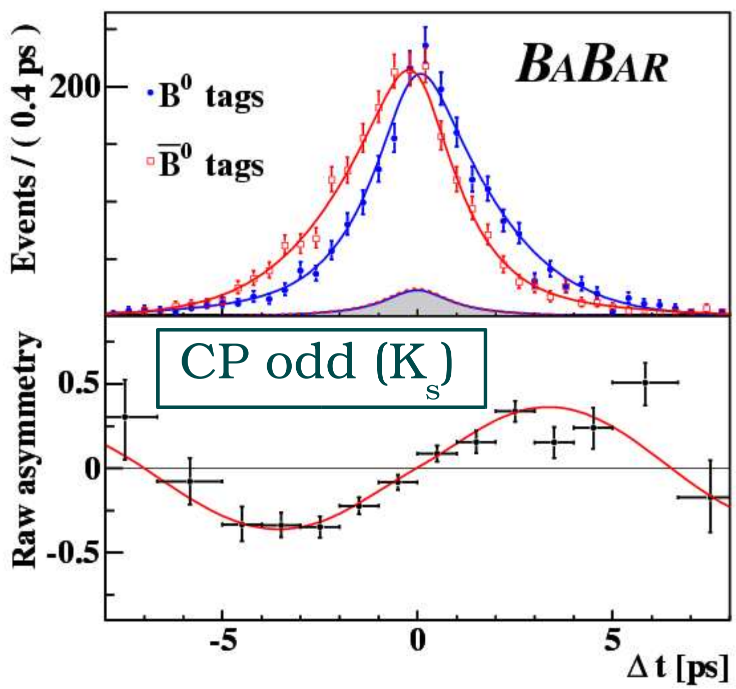
Time-dependent CP Asymmetry

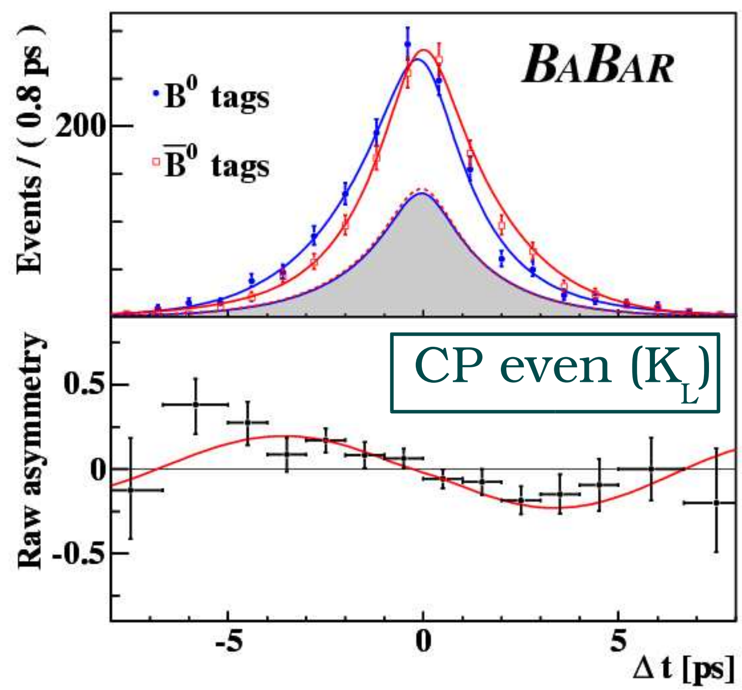
$$A_{CP} = \frac{(B^0 \to f_{CP}) - (\bar{B}^0 \to f_{CP})}{(B^0 \to f_{CP}) + (\bar{B}^0 \to f_{CP})}(\Delta t) = \frac{\Im(\lambda)\sin(\Delta m \Delta t) + (1 - |\lambda^2|)\cos(\Delta m \Delta t)}{1 + |\lambda^2|}$$

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

B mixing | B decay | K^0 mixing

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



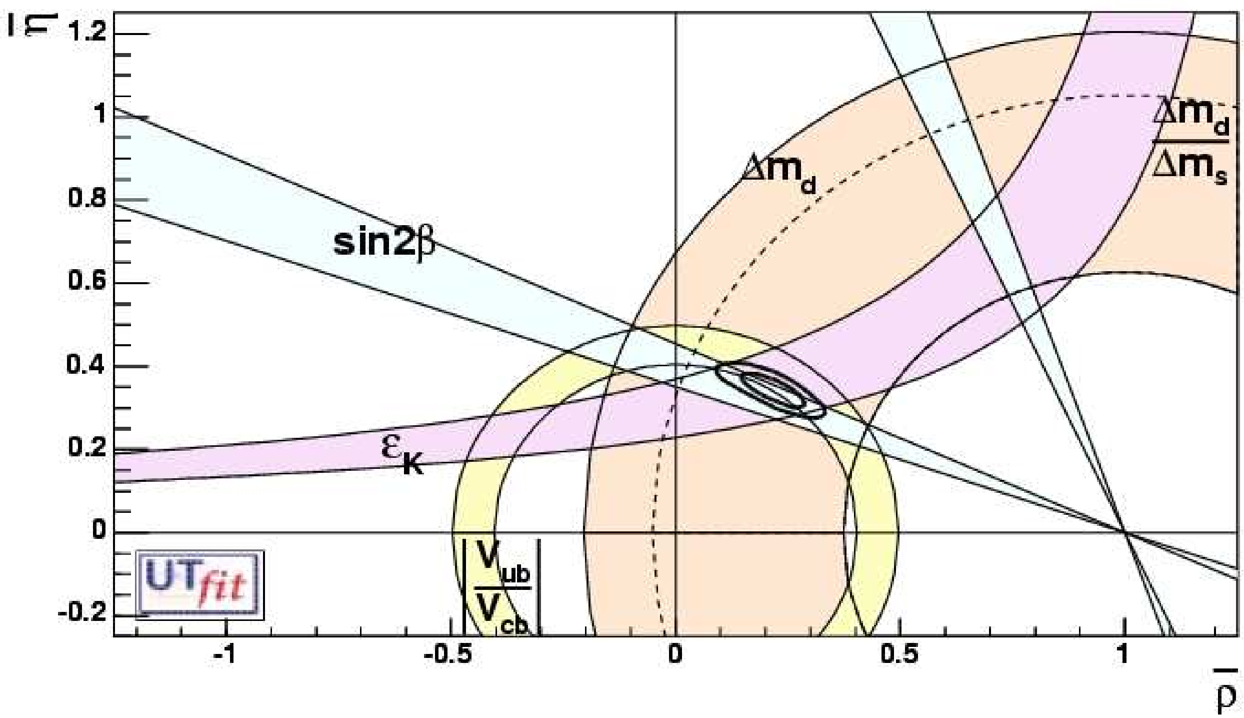


sin2β: results

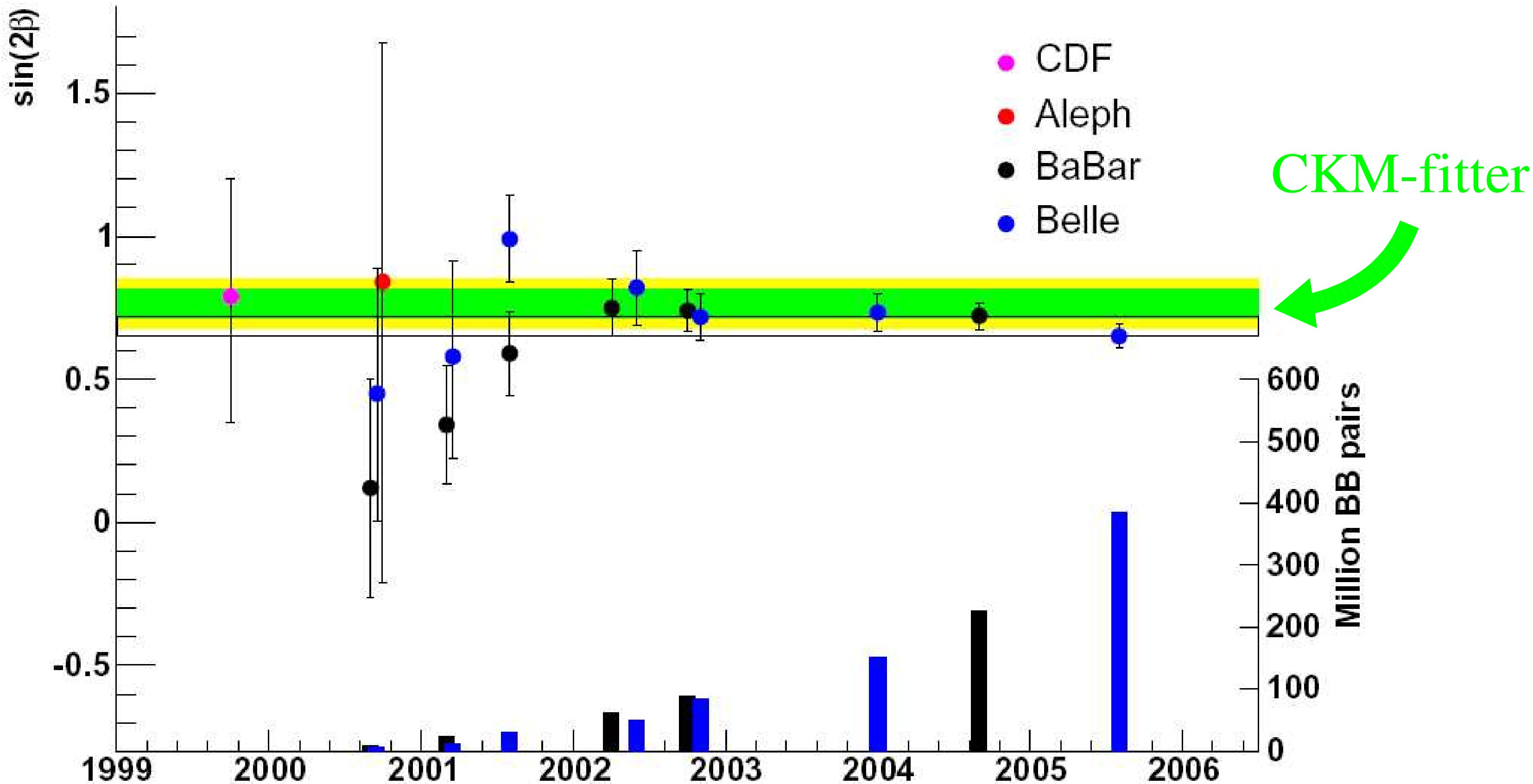
BABAR (205 fb^{-1})	**0.722± 0.040 ± 0.023**
Belle (350 fb^{-1})	**0.652± 0.039 ± 0.020**
Average	**0.685± 0.028 ± 0.015**
UT-fit prediction sides + ϵ_K	**0.793±0.032**
CKM-fitter pred. sides + ϵ_K + other angles	**$0.742^{+0.072}_{-0.026}$**

- ~ 2 σ wrt UT prediction
- ~ 1 σ wrt CKM fitter
- … interpretation is important !

different interpretation of theoretical errors

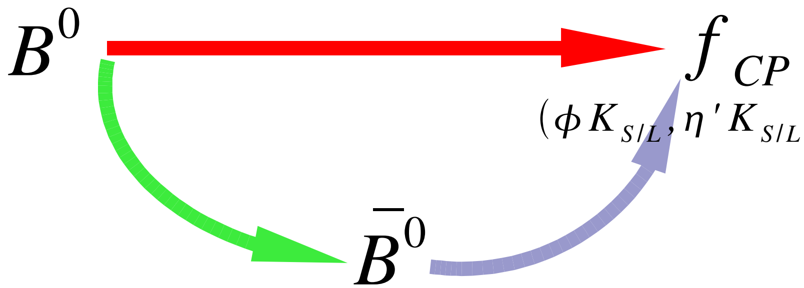


sin2β:time evolution

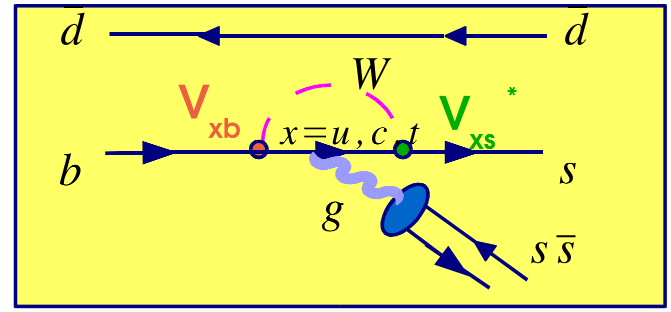


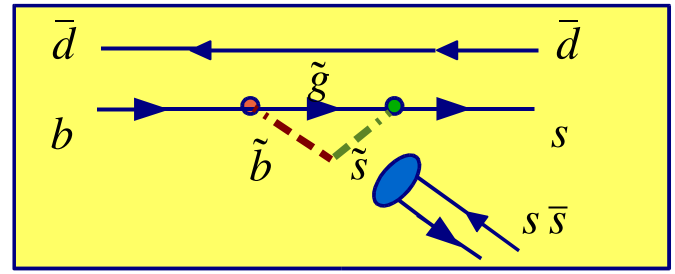
- BABAR ~ double statistics by June 2006
- Stay tuned

sin2β from b→sss



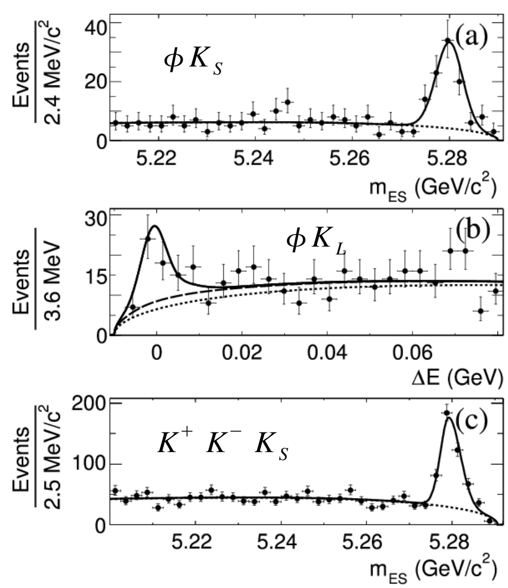
$(\phi K_{S/L}, \eta' K_{S/L}, \omega K_S, K_S K_S K_S, \ldots)$

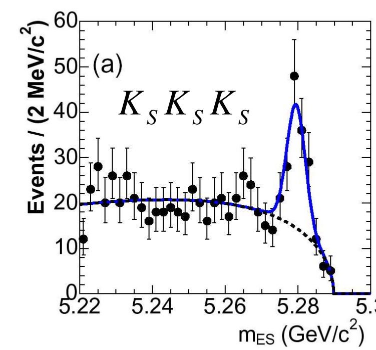


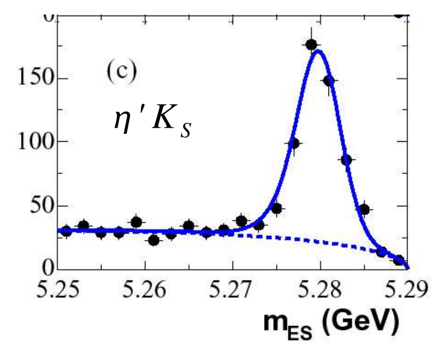


- No tree, penguin only
- Leading weak phase : β
- Other weak phases suppressed by $o(\sin\Theta_c^{\,2})$ ~ 5%
- New phases from SuSy ?

A test for New Physics



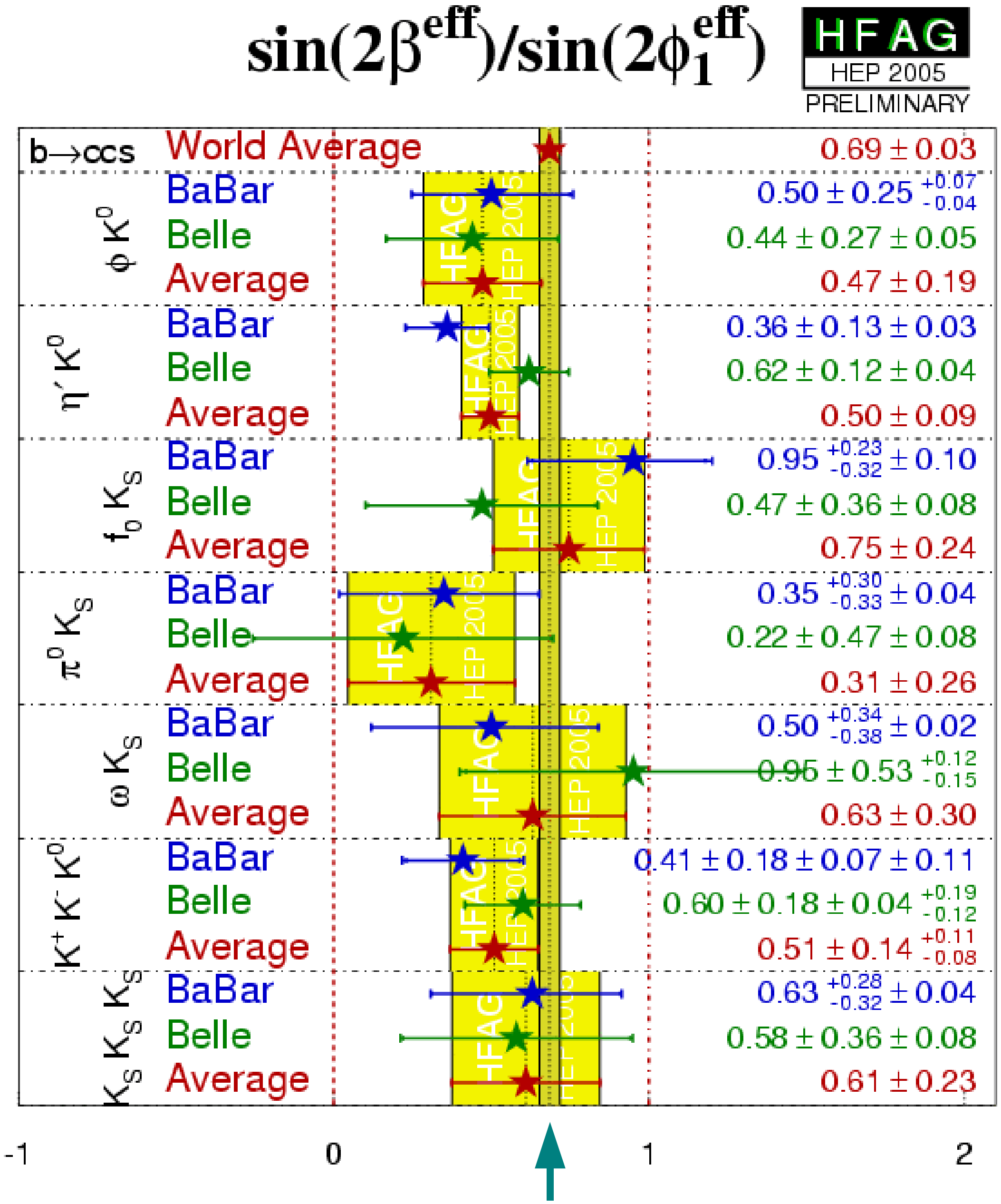


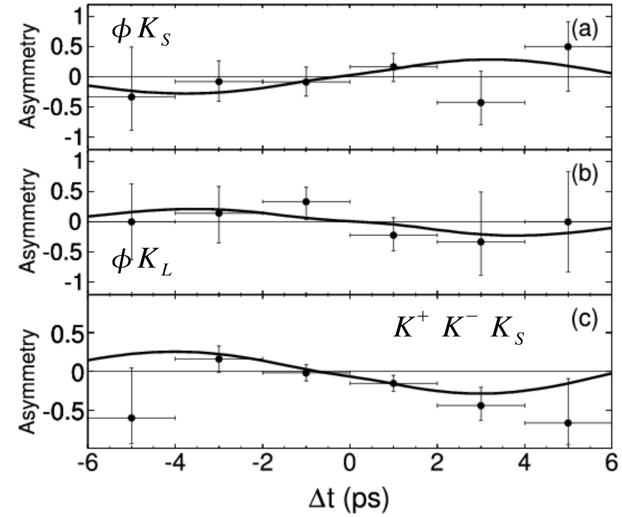


Exp Challenges:

- Smaller BR
- Larger bckg. (continuum)

sin 2β charmless vs charmonium



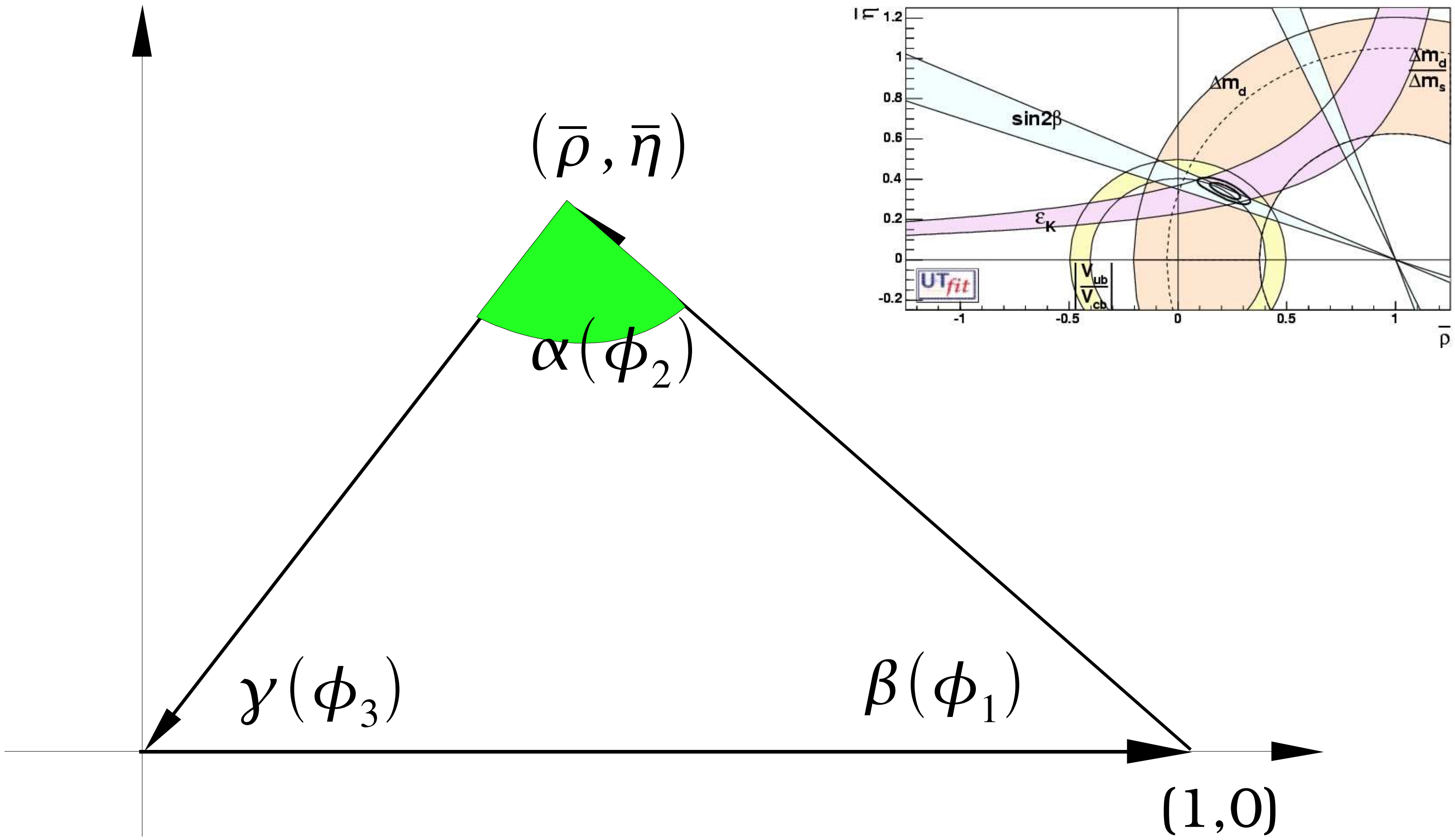


- No significant discrepancy ☺
- No hint of new Physics ☹

consistency improved also due to recent sin2β measurment

do not average naively charmless results

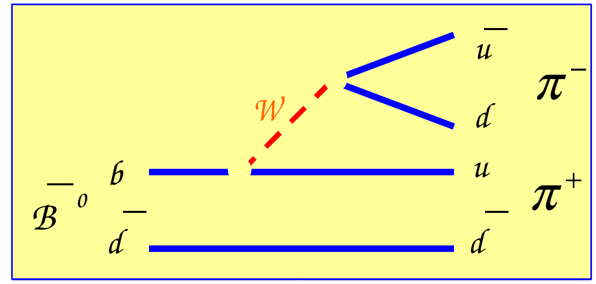
UT angle-view: sin2α

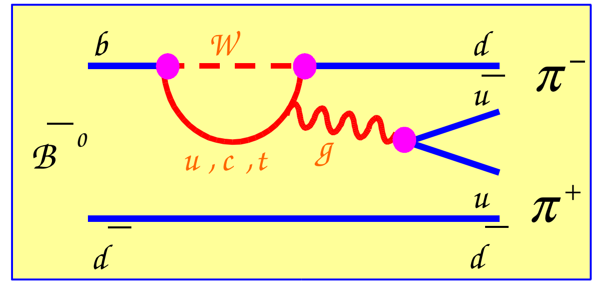


- sides + ϵ_K + sin 2β :

  α = (94.9±7.2)°

sin2α from b→uud





- 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

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

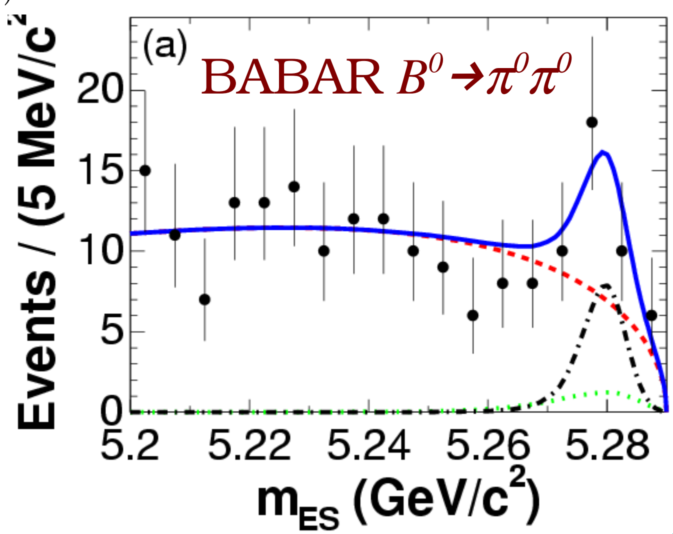
- Penguin estimated from Isospin relations:

pure tree

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

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

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



- *BABAR + Belle* :

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

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

$B^0 \rightarrow \rho^0\rho^0$:a Fortuitous Set of Beneficent Events

1. BABAR, PRL 94,131801 (2005)

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

- Small Penguin pollution in $B^0 \rightarrow \rho^+\rho^-$
- $|\alpha - \alpha_{eff}| < 11^o$

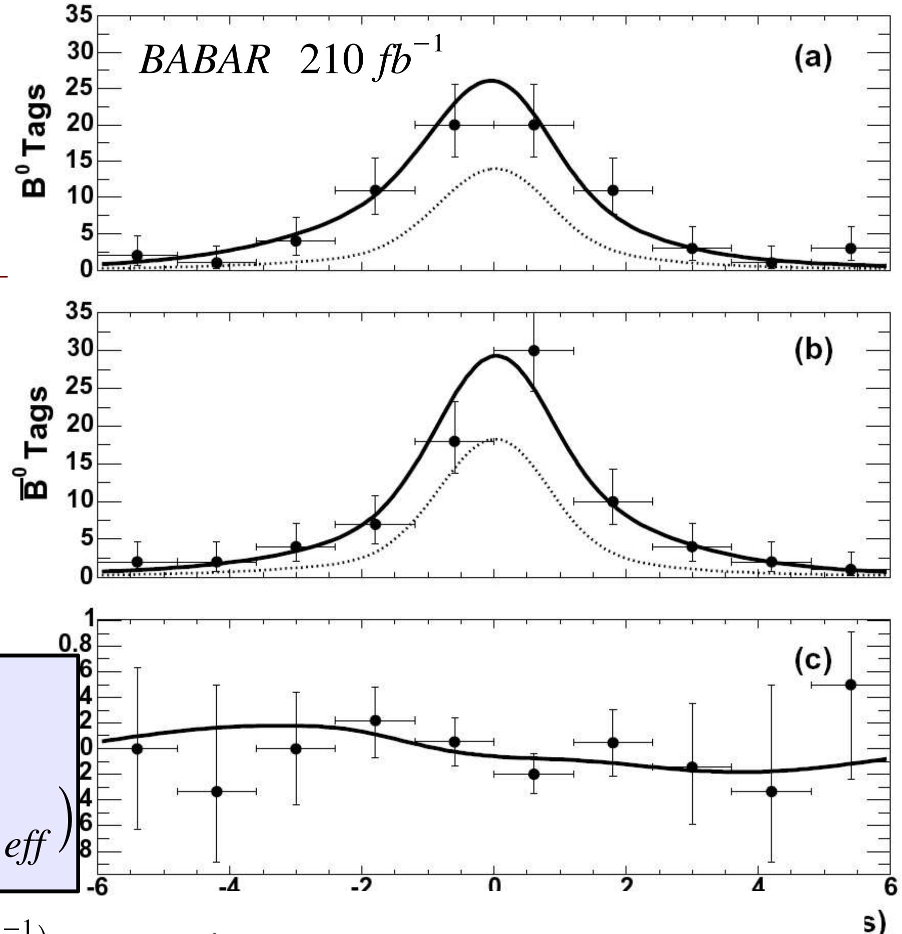
2. Angular analysis:

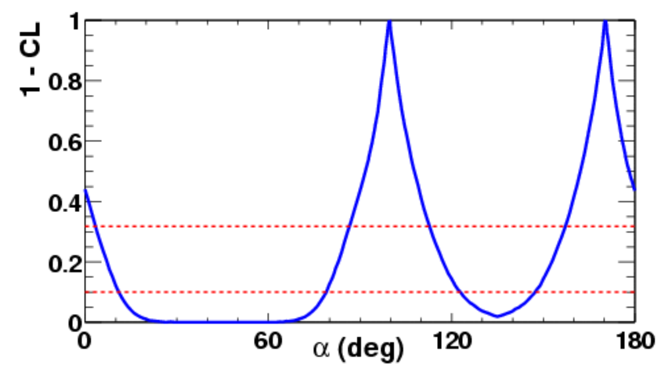
- $\rho^+\rho^-$ almost pure CP +

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

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

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





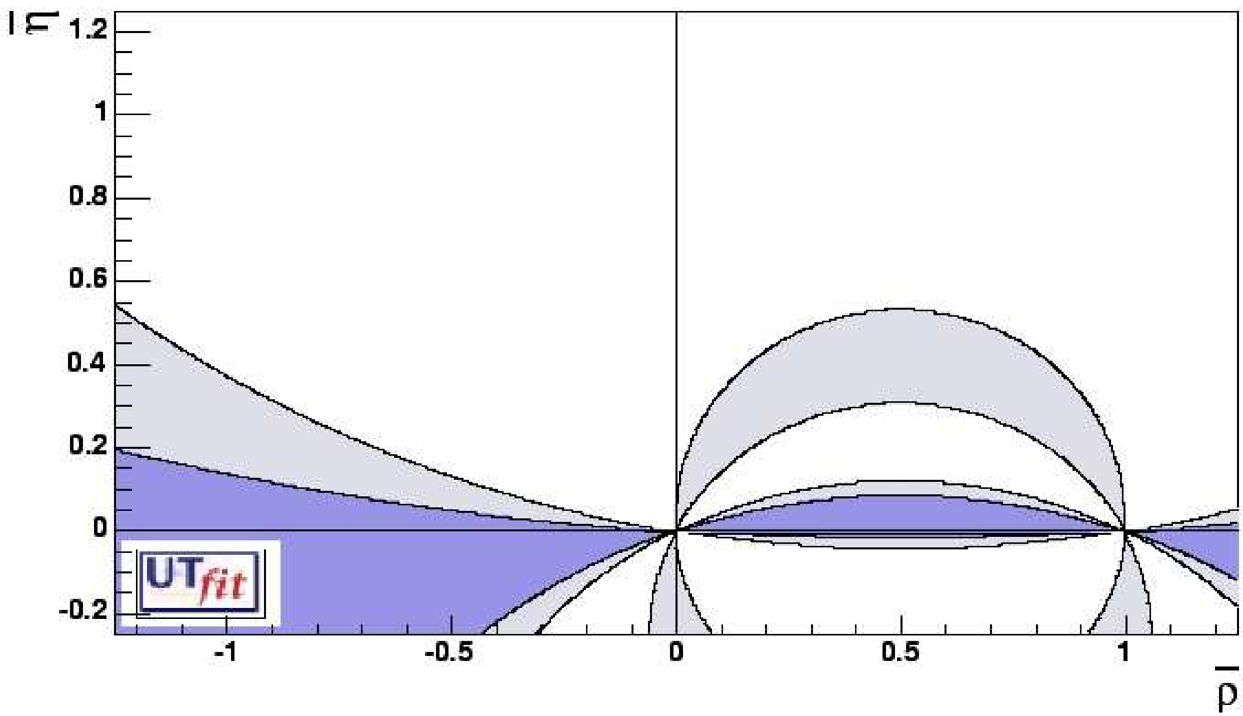
$\alpha = (100 \pm 13)^o$

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

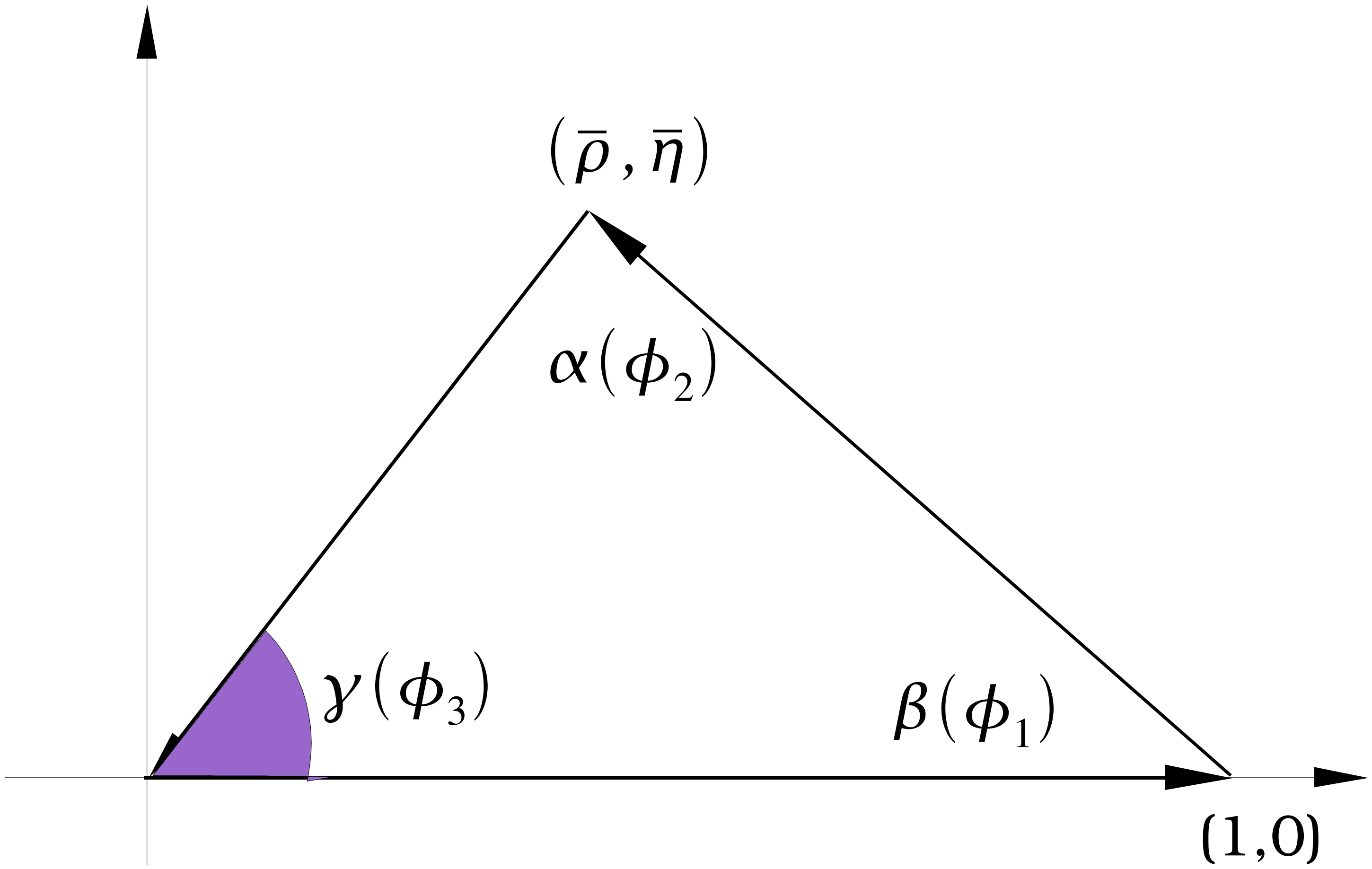
α : results

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

α (meas.)	$(99^{+13}_{-8})^o$
UT-fit prediction	$(95 \pm 7)^o$



UT angle-view: γ



- Prediction from all other constraints:

  γ = (57.6±5.7)°

Premise

- BABAR Physics book (Oct 1998):

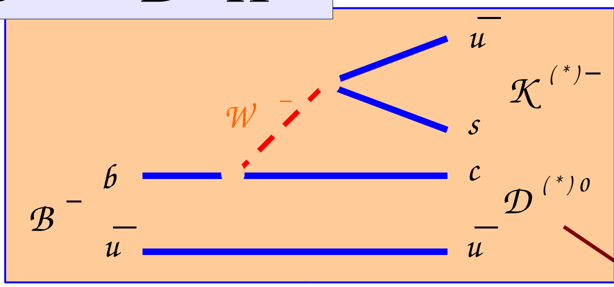
" Possibly the best tools to extract γ are time-dependent asymmetries in $\boldsymbol{B_s}$ decays "

- .. a job for LHC-*b* ?

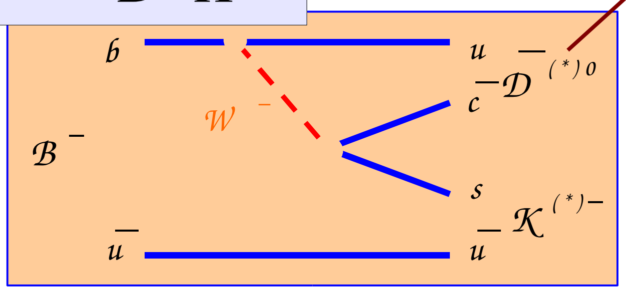
γ : the principle

Exploit interference of pure tree transitions:

$B^- \to D^0 K^-$



$B^- \to \bar{D}^0 K^-$



color suppressed

common final state

Gronau London Wyler

$CP\ even/odd:\ \pi\pi, KK, \pi\pi\pi,$

Atwood Dunietz Soni

$Cabibbo\ suppressed/favored: K^+\pi^- \ldots$

$K_s\pi^+\pi^-\ (Dalitz)$

~~CP~~

strong phase (CP invariant)

color suppression (~ 0.1)

$$\frac{A(B^- \to \bar{D}^0 K^-)}{A(B^- \to D^0 K^-)} = r_B e^{i\delta} e^{+i\gamma} \qquad \frac{A(B^+ \to \bar{D}^0 K^+)}{A(B^+ \to D^0 K^+)} = r_B e^{i\delta} e^{-i\gamma}$$

Three unknowns: r_B, δ, and γ

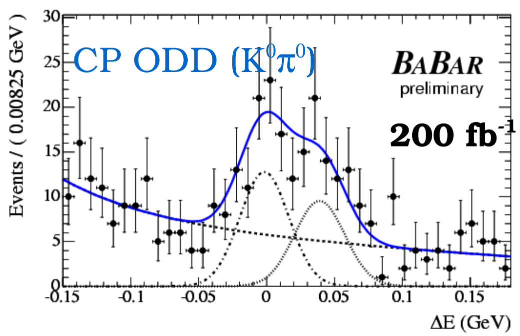
γ: Gronau London Wyler

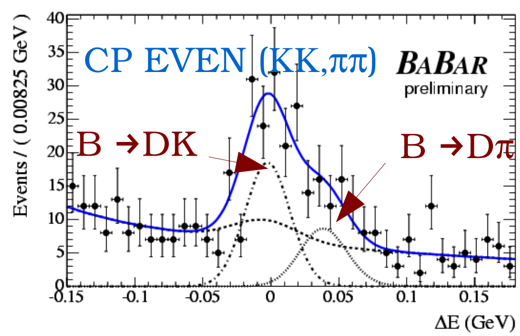
- Compare rates for CP even and CP odd D^0 final states
- Four observables, three independent constraints:☺

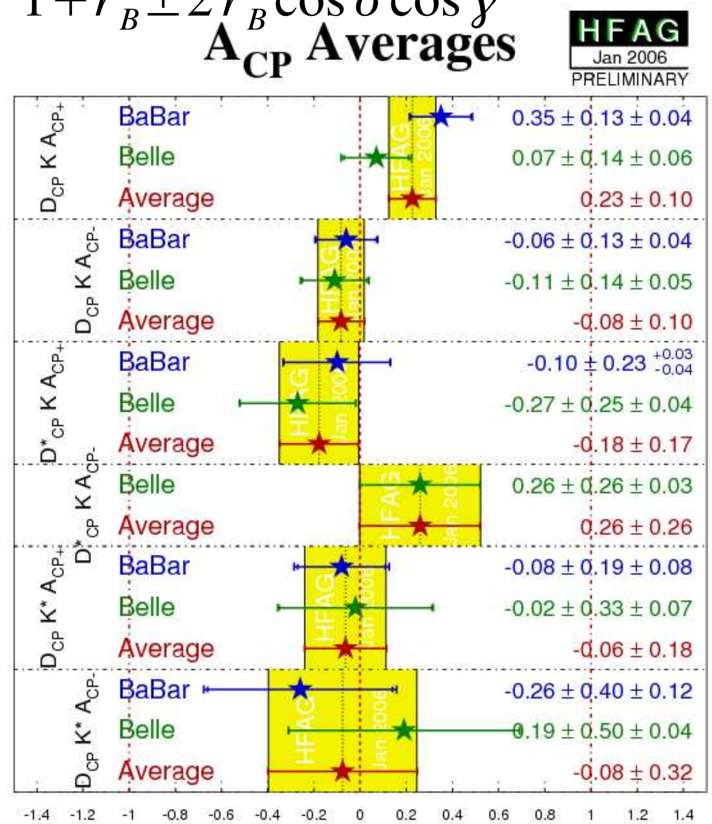
$$A_{CP\pm} = \frac{\Gamma(B^- \to D_{CP\pm} K^-) - \Gamma(B^+ \to D_{CP\pm} K^+)}{\Gamma(B^- \to D_{CP\pm} K^-) + \Gamma(B^+ \to D_{CP\pm} K^+)} = \frac{\pm 2 r_B \sin\delta \sin\gamma}{R_{CP}}$$

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

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





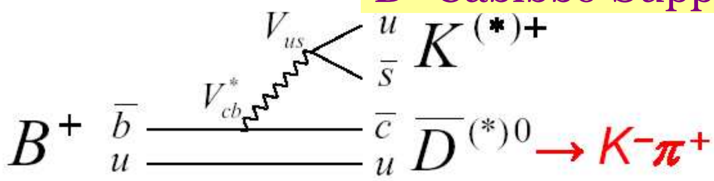


- No significant bound on γ
- Job for super-B ?

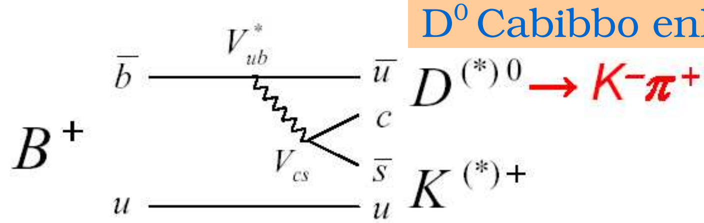
γ: Atwood Dunietz Soni

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

Color enhanced
D^0 Cabibbo Suppressed



Color suppressed
D^0 Cabibbo enhanced



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

D^0 Cabibbo suppression

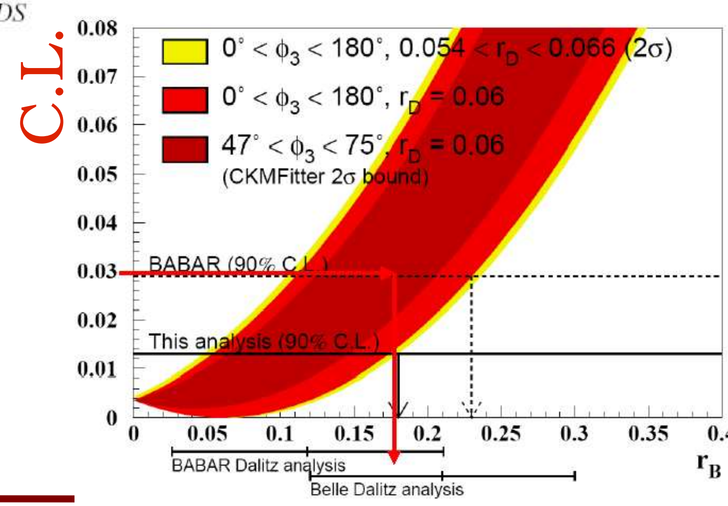
$$R_{ADS} = \frac{\Gamma(B^- \to D_{ADS} K^{(*)-}) + \Gamma(B^+ \to D_{ADS} K^{(*)+})}{\Gamma(B^- \to D^0 K^{(*)-}) + \Gamma(B^+ \to \bar{D}^0 K^{(*)+})} = r_B^2 + r_D^2 + 2 r_B r_D \cos(\delta_B + \delta_D) \cos\gamma$$

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

- Limits on r_B *(90%CL):*

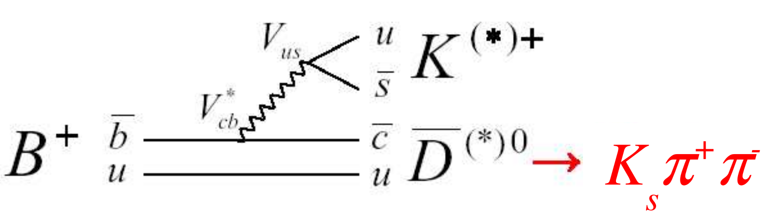
$r_B < 0.23$ *BABAR ~210 fb⁻¹ (PRD 72,032004 (2005))*

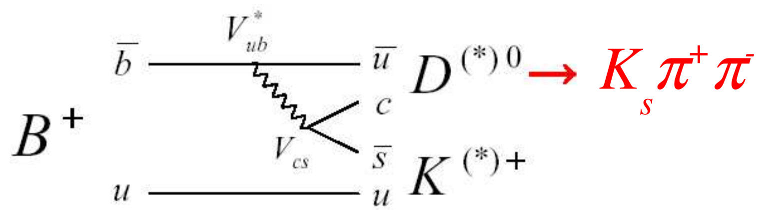
$r_B < 0.18$ *Belle 350 fb⁻¹*



γ: Dalitz Analysis

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

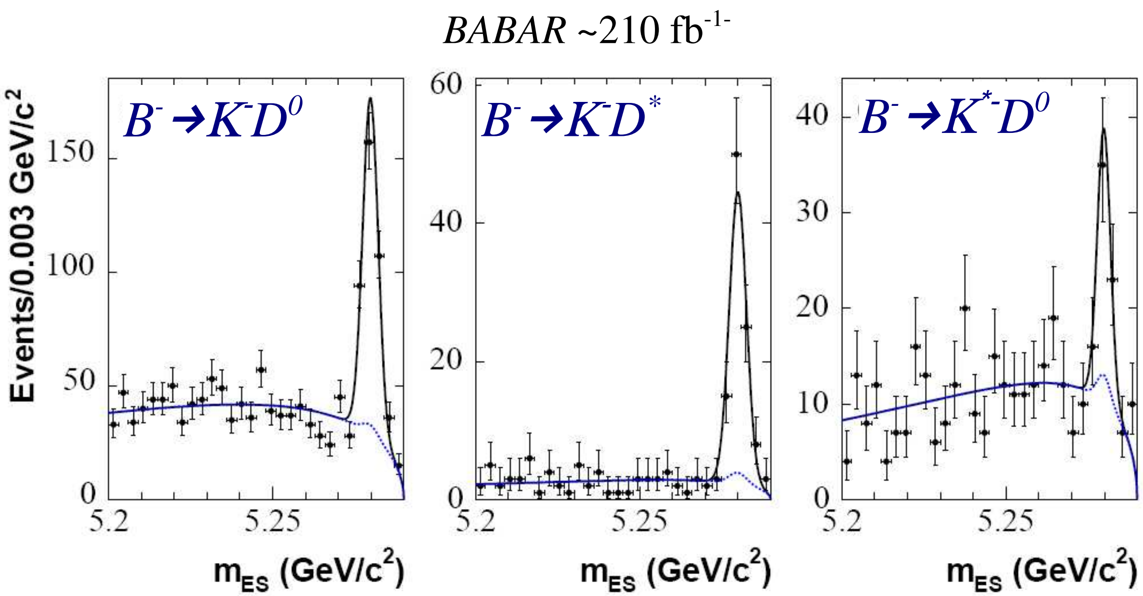




$$A(B^-) \propto f(m_-, m_+) + r_B e^{i(\delta-\gamma)} f(m_+, m_-)$$

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

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

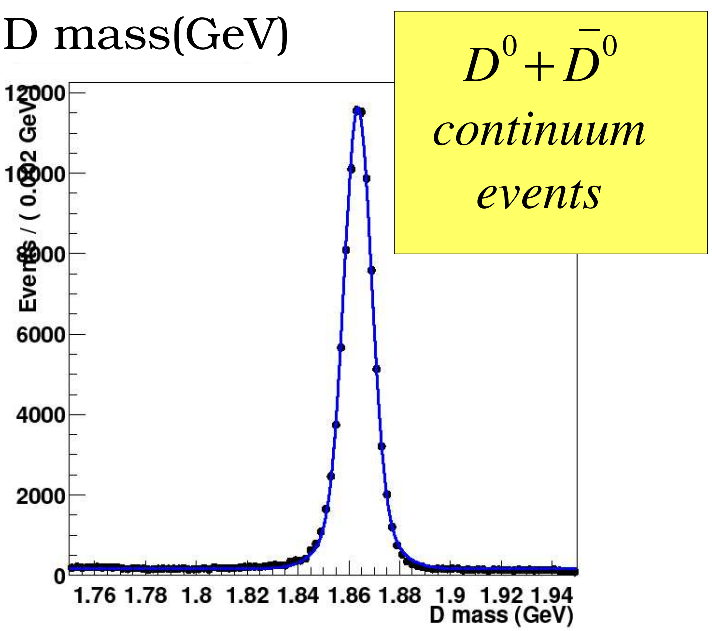


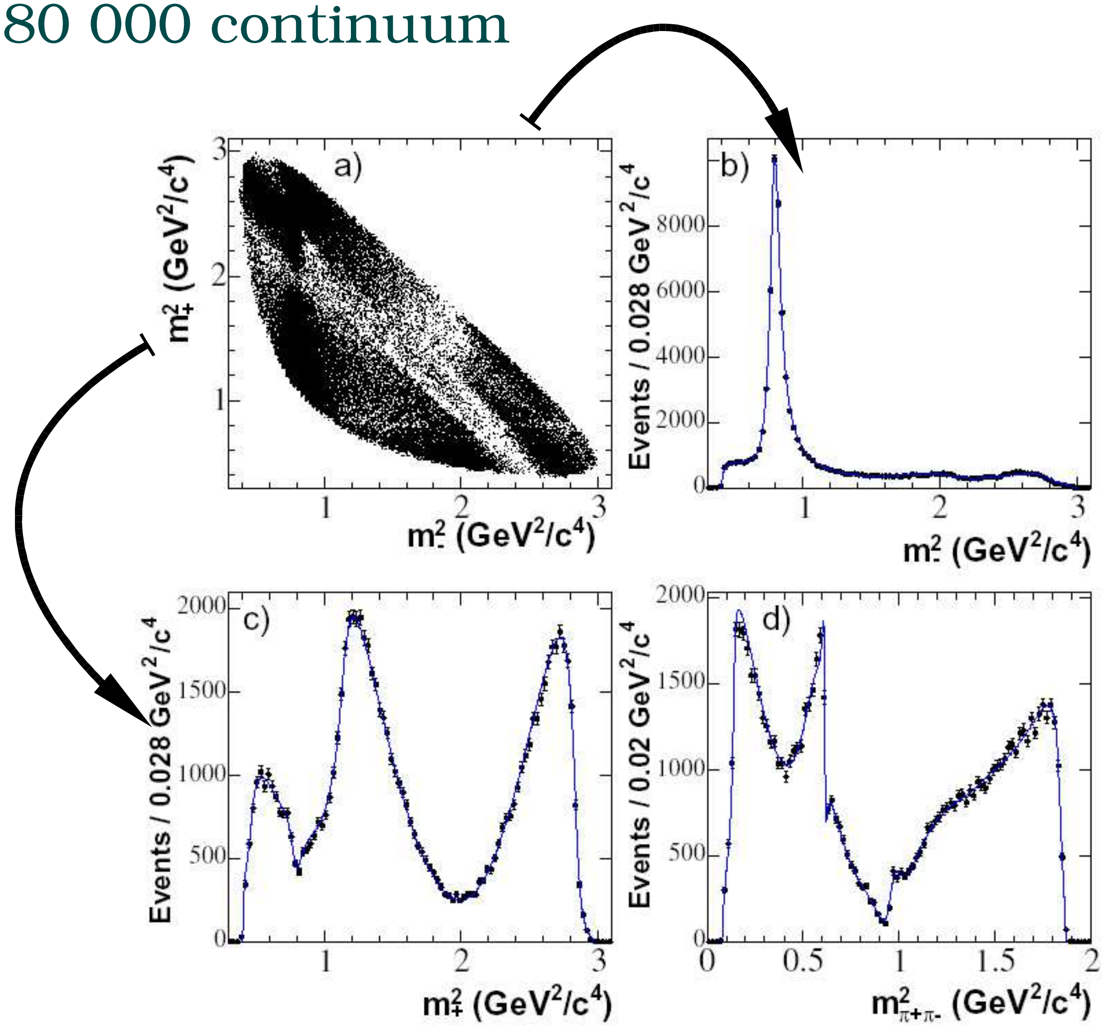
Pionereed by *Belle*

γ: Dalitz Analysis

- Fit $\Gamma(B^+)$, $\Gamma(B^-)$ in each point of the Dalitz plot
- Models for $f(m_{\pm}, m_{\mp})$ from ~ 80 000 continuum decays: $D^{*\pm} \to \pi^{\pm} \overset{(-)}{D}{}^0$

tags flavor





γ: Dalitz results

- *BABAR* (~210 fb^{-1}) :

r_b = 0.12±0.08±0.03±0.04 DK

r_b^* = 0.17±0.10±0.03±0.03 D*K

r_s < 0.19 @ 90% CL DK*

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

- *Belle* (~350 fb^{-1}) :

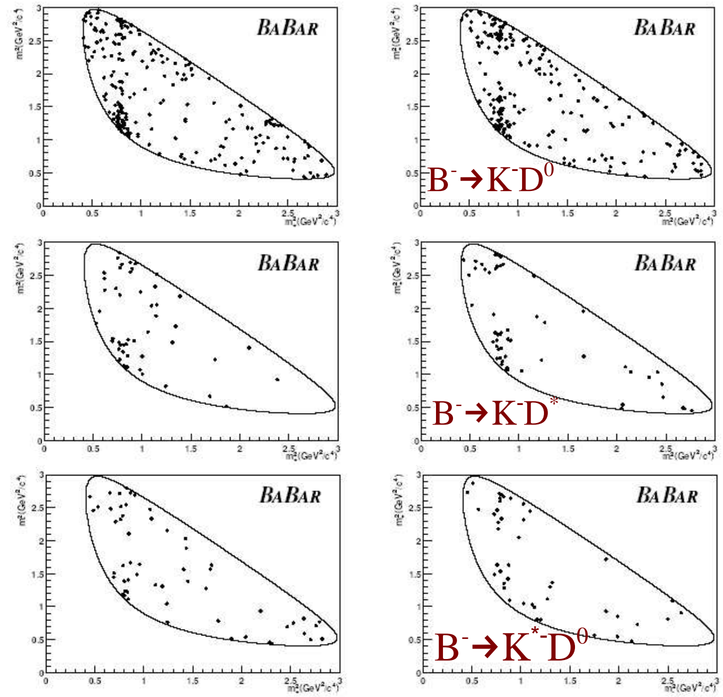
r_b = 0.21±0.08±0.03±0.04 DK

$r_b^* = 0.12^{+0.16}_{-0.11} \pm 0.02 \pm 0.04$ D*K

$r_s = 0.25^{+0.17}_{-0.18} \pm 0.09 \pm 0.04 \pm 0.08$ DK*

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

B^+ B^-



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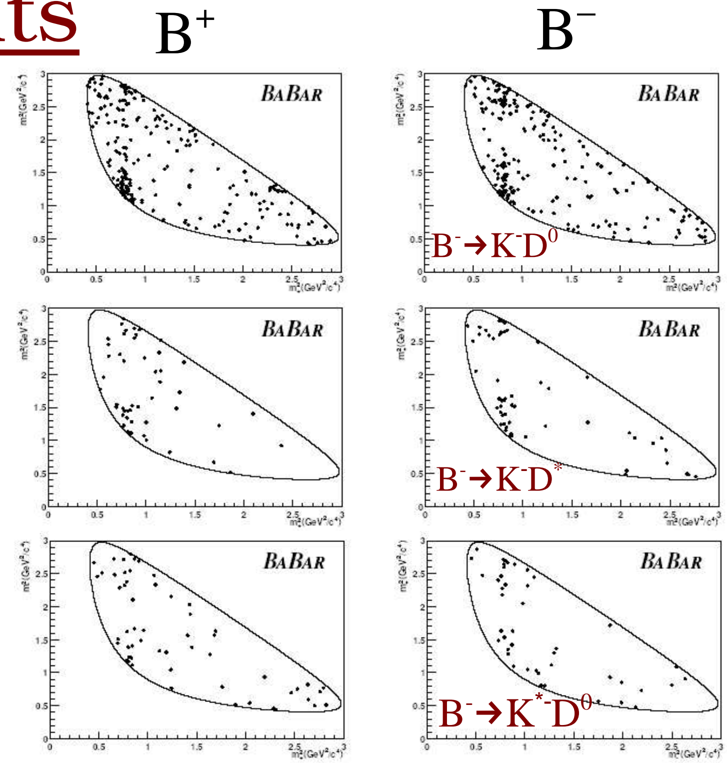
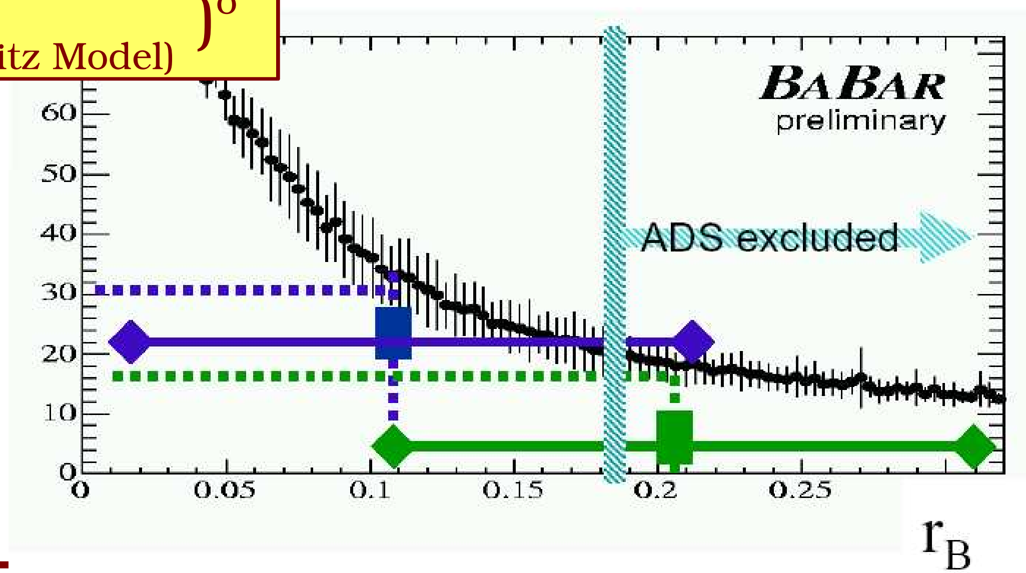


- *Belle* (~350 fb^{-1}) :

  r_b = 0.21±0.08±0.03±0.04 DK
  r_b^* = $0.12^{+0.16}_{-0.11}$±0.02±0.04 D*K
  r_s = $0.25^{+0.17}_{-0.18}$±0.09±0.04±0.08 DK*

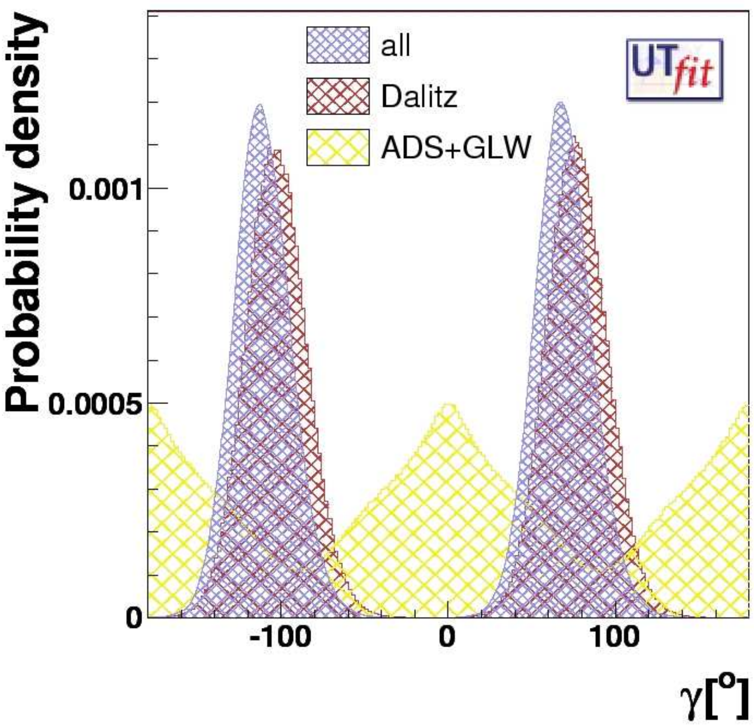
$$\gamma = (68 \pm 14_{(stat)} \pm 13_{(syst.)} \pm 11_{(Dalitz\ Model)})^{o}$$

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



Overall γ results

- 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.)	$(68 \pm 17)^o$
UT-fit prediction	$(58 \pm 6)^o$

Summary on CKM Constraints

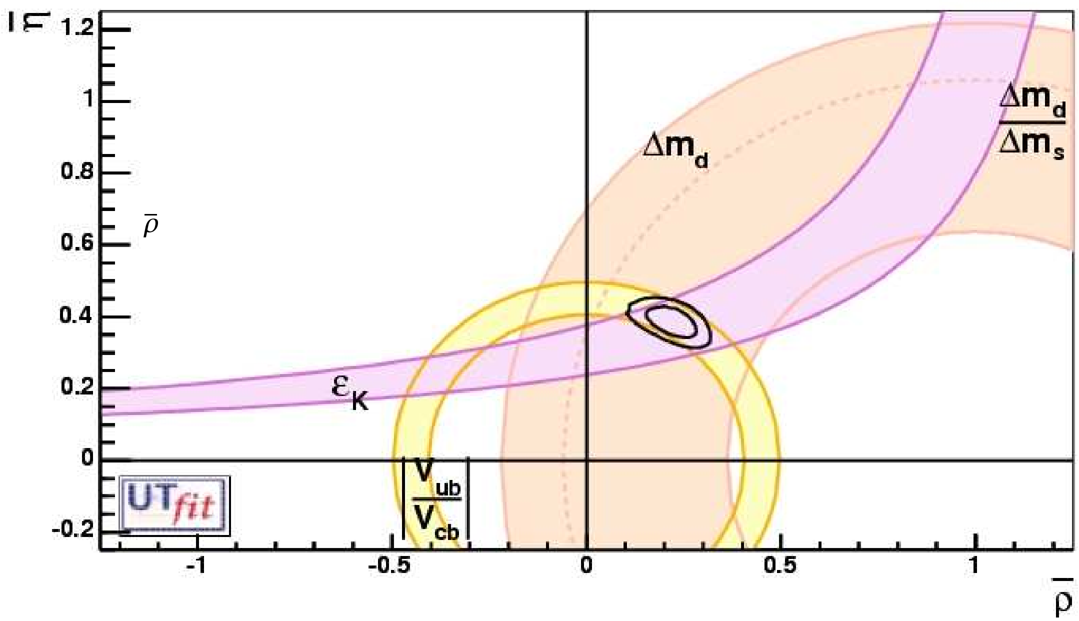
- B-factories operations allow to constrain the UT from different point of views:

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



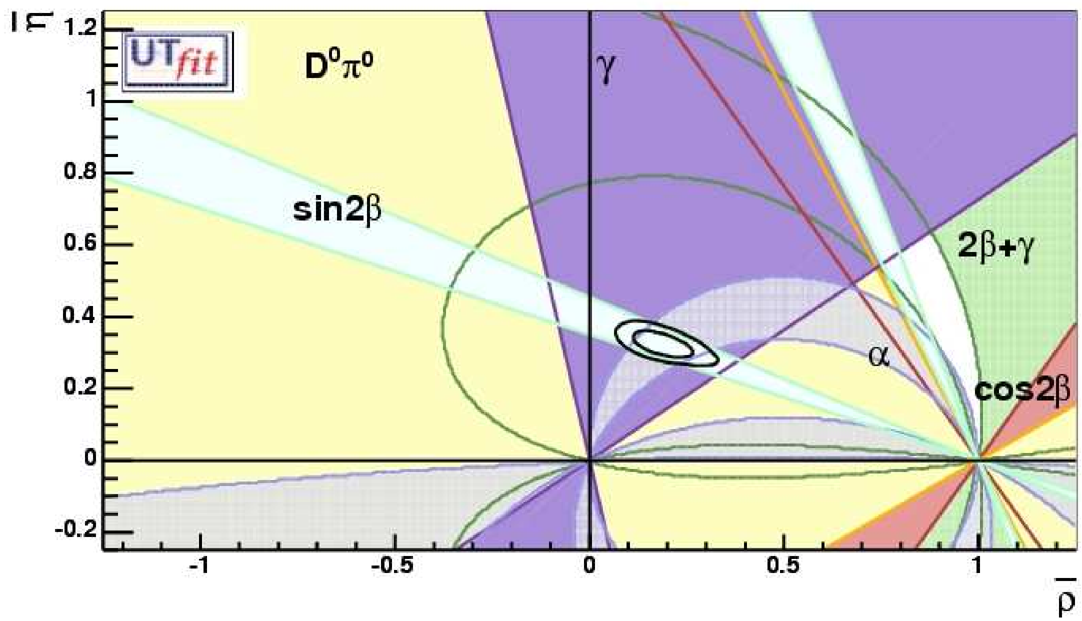
$$\bar{\rho} = 0.218 \pm 0.043 \qquad \bar{\eta} = 0.385 \pm 0.028$$

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



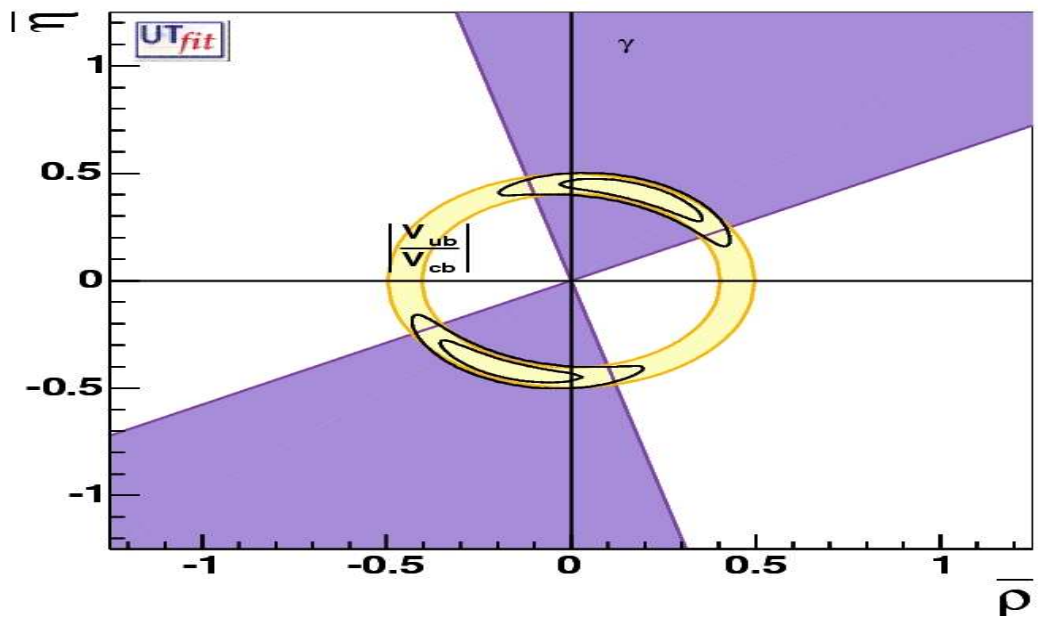
$$\bar{\rho} = 0.187 \pm 0.052 \qquad \bar{\eta} = 0.322 \pm 0.025$$

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



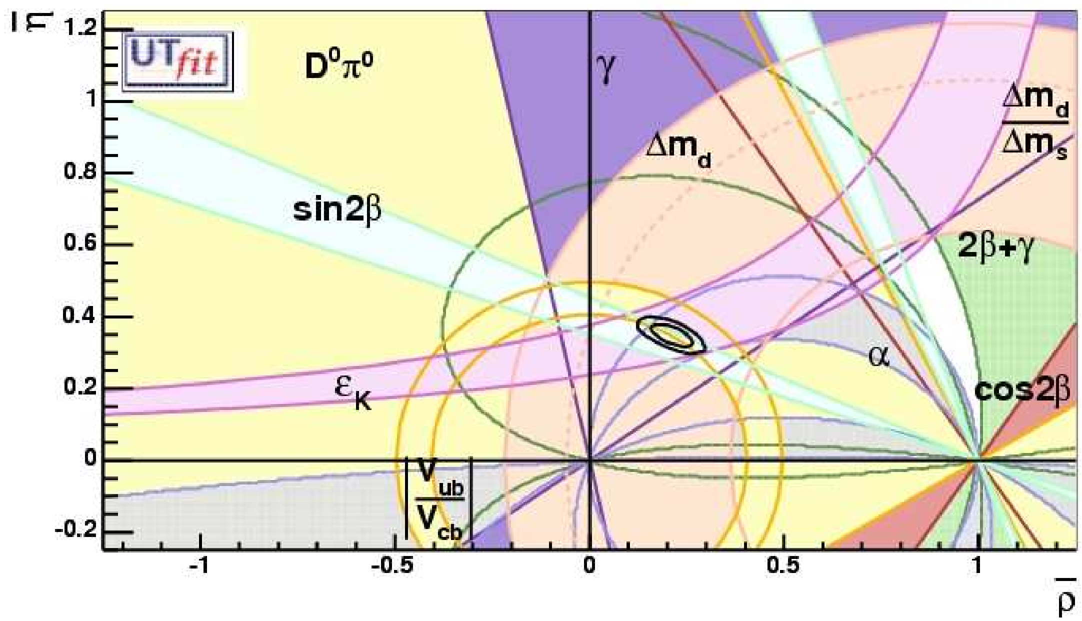
$$\bar{\rho} = 0.18 \pm 0.12 \qquad \bar{\eta} = 0.41 \pm 0.05$$

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



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

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

Rare Decays

- The Paradigm:

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

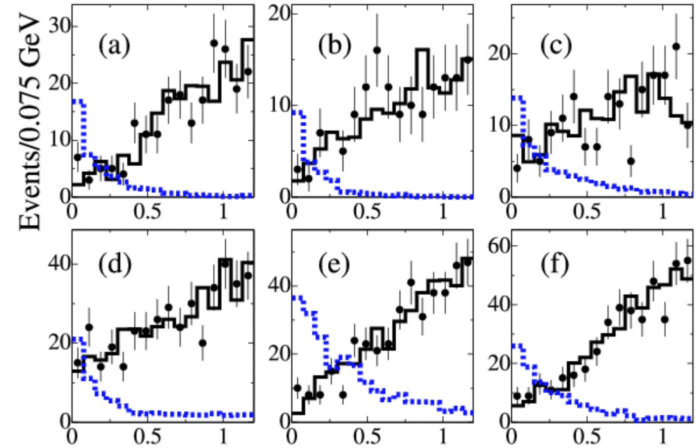
$$B^+ \to \tau^+ \nu$$
$$B \to s\gamma$$
$$\tau \to \mu\gamma, e\gamma, lll, \ldots$$

A Tree Process: $B^+ \to \tau^+ \upsilon$

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

$f_B = 0.192 \pm 0.027\ \ GeV\,(LQCD)$

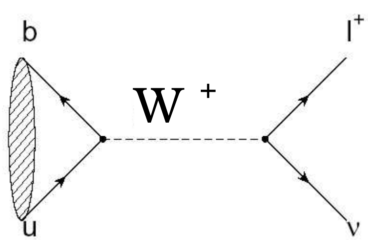
- Two (and more) neutrinos: no kin. constraints
- Look for 1/3 prongs τ decays on recoil of reconstructed $B^- \to D^{(*)} h / l\upsilon$

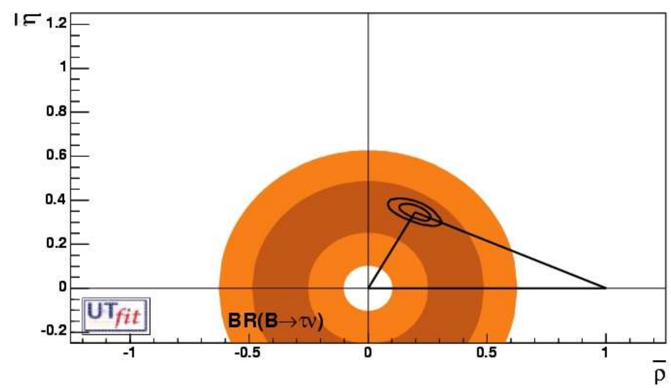


Extra energy (GeV), other than τ and B_{RECO}

$B(B \to \tau \upsilon) < 2.6\ 10^{-4}$	(90 % CL) *BABAR* (230 fb^{-1})
$B(B \to \tau \upsilon) < 1.8\ 10^{-4}$	(90 % CL) *Belle* (350 fb^{-1})

- Weak Bound on UT

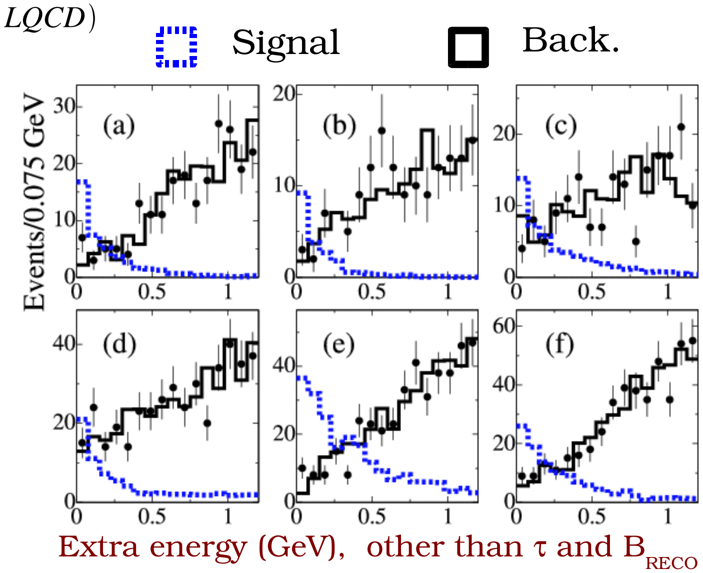




A Tree Process: $B^+ \to \tau^+ \upsilon$

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

$f_B = 0.192 \pm 0.027 \;\; GeV\,(LQCD)$

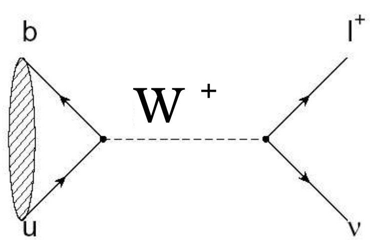


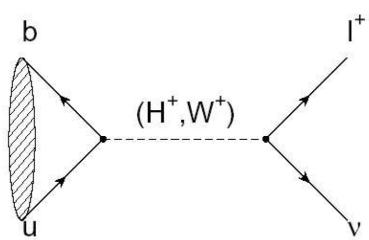
- Two (and more) neutrinos: no kin. constraints
- Look for 1/3 prongs τ decays on recoil of reconstructed $B^- \to D^{(*)} h / l\upsilon$

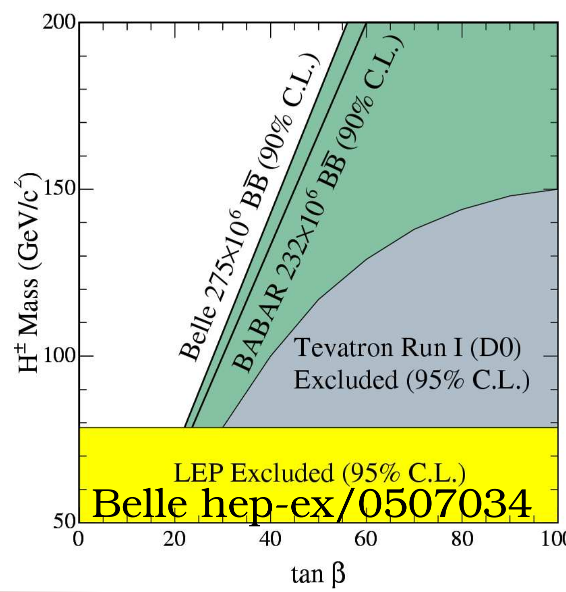
$B(B \to \tau \upsilon) < 2.6 \; 10^{-4}$ (90 % CL) *BABAR* (230 fb^{-1})

$B(B \to \tau \upsilon) < 1.8 \; 10^{-4}$ (90 % CL) *Belle* (350 fb^{-1})

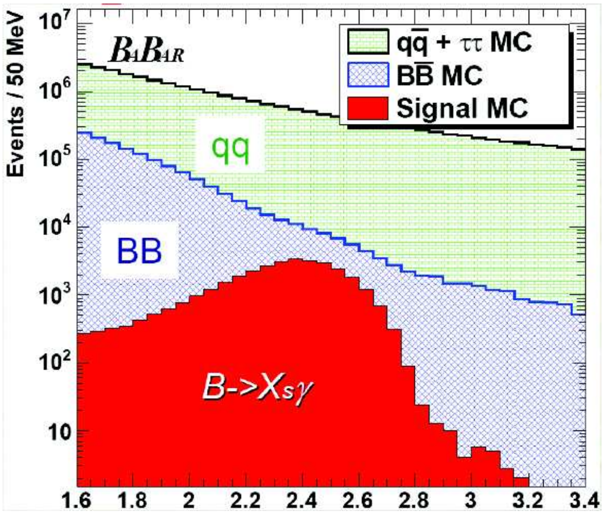
- Weak Bound on UT
- ... but improves considerably limits on H^+ from direct searches







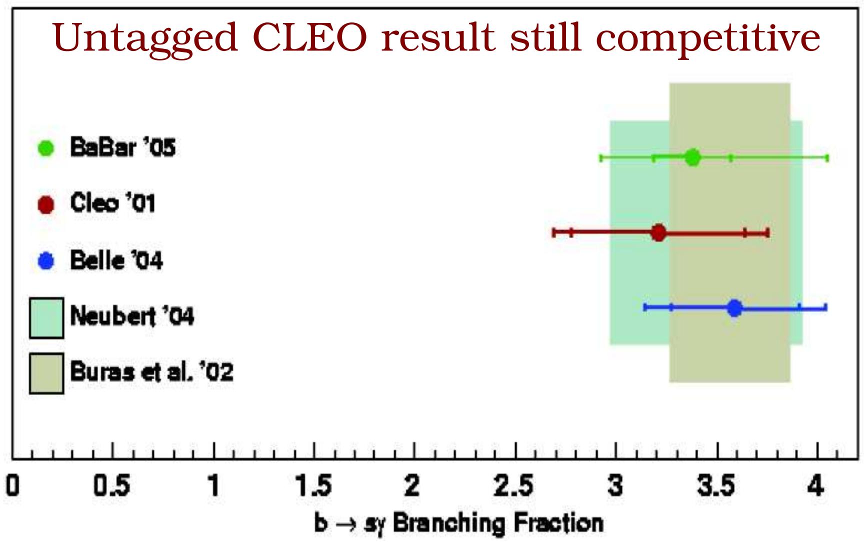
A Penguin Decay: b→ γs

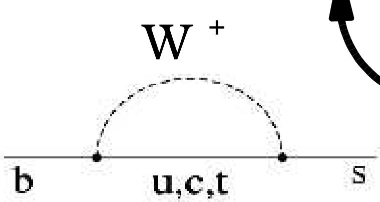


Continuum background reduction:

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

	mode, Eγ cut	*BR x 10⁴*
BABAR (80 fb⁻¹)	Σ exclusive, 1.9	**3.67±0.29±0.34±0.29**
BABAR (80 fb⁻¹)	inclusive, 1.6	**$3.38\pm0.19^{+0.64}_{-0.41}\pm0.08$**
Belle (150 fb⁻¹)	inclusive, 1.8	**$3.55\pm0.32\pm0.30^{+0.11}_{-0.07}$**
W.A.		**3.39±0.30**
S.M.	improved NLO	**3.47±0.37±0.31**





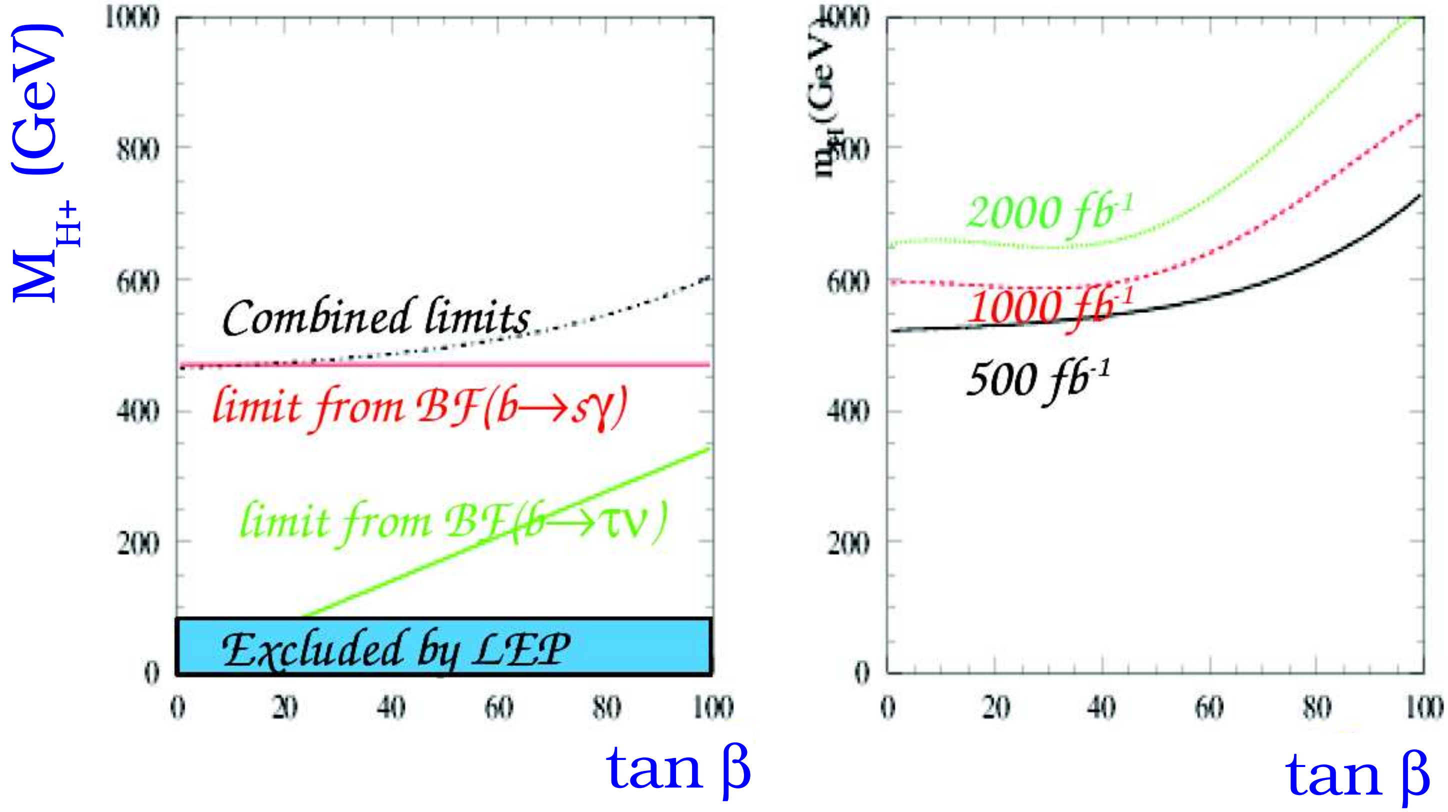
P.Gambino, M.Misiak Nucl.Phys. **B611** , 338 , 2001
M.Neubert, Eur.Phys.J. **C40** , 165 , 2005

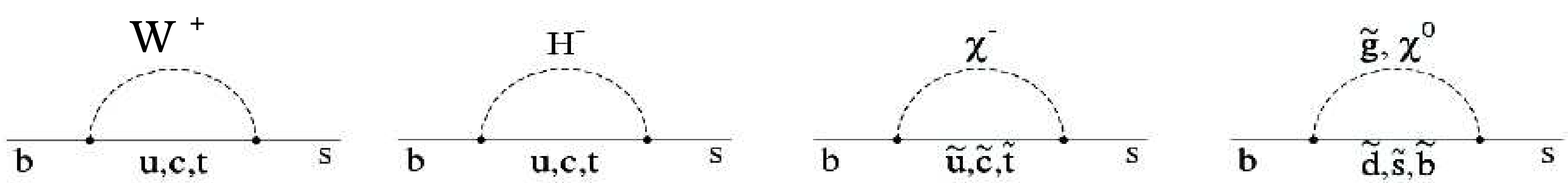
S.M holds well (once again …)

A Penguin Decay: b→ γs

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

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





Lepton Flavour Violation

Motivation

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

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

- A smoking gun for New Physics

Role of B-factories

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

Lepton Flavour Violation

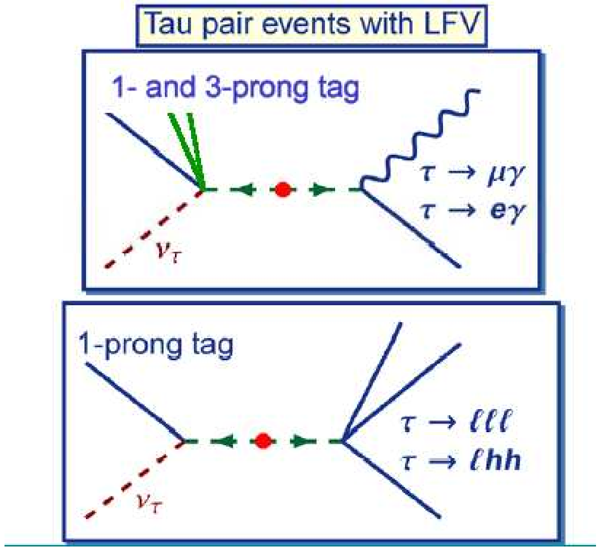
BABAR

$\tau \rightarrow \mu\gamma$	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

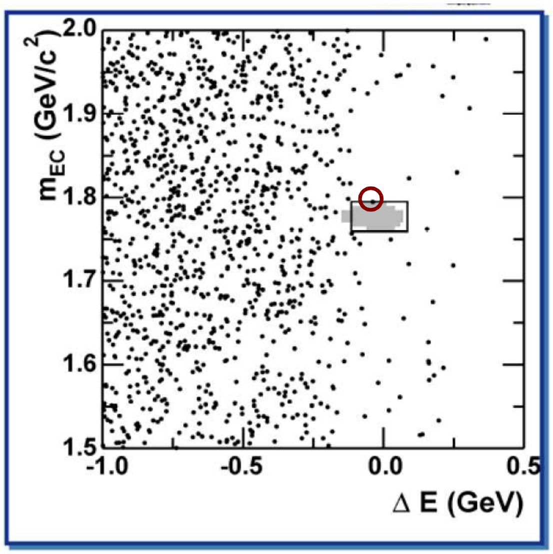
BELLE

$\tau \rightarrow \mu\gamma$	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)
$\tau \rightarrow \ell K^0_s$	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

Means of the Searches



BABAR τ →eγ search



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

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

- search-box ~ 2 σ around constraint
- tipical efficiency ~ 5 %

LFV: Results

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

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

NEW

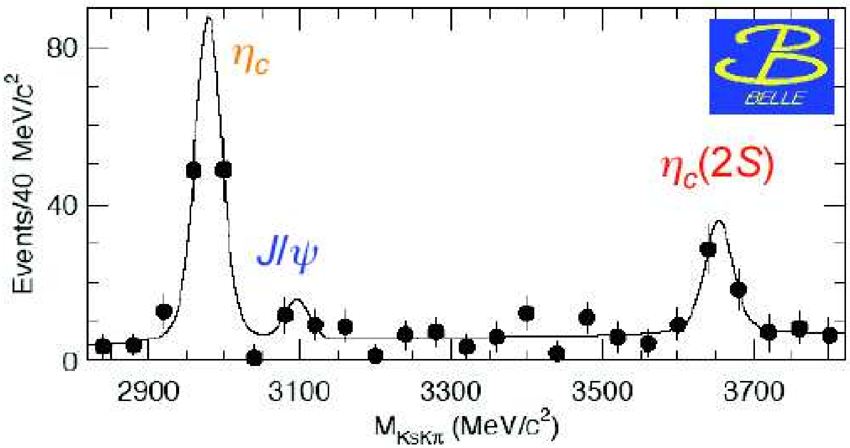
B-L cons.

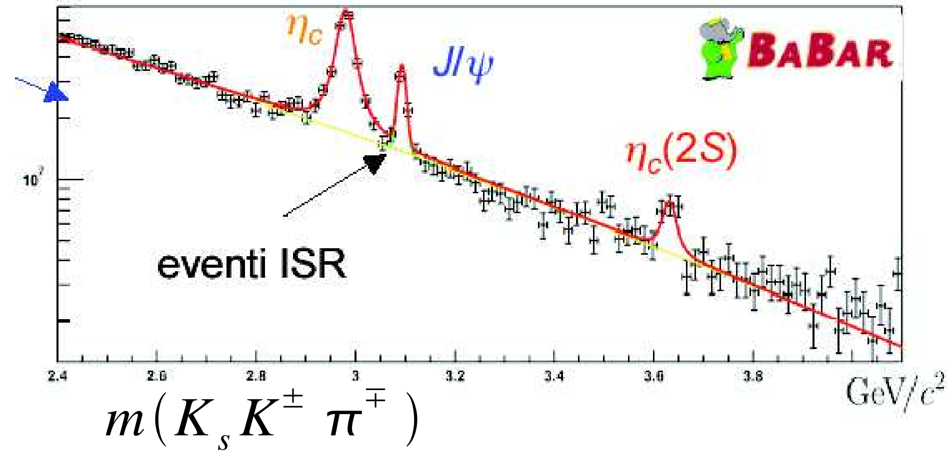
B-L viol.

TOPICS:

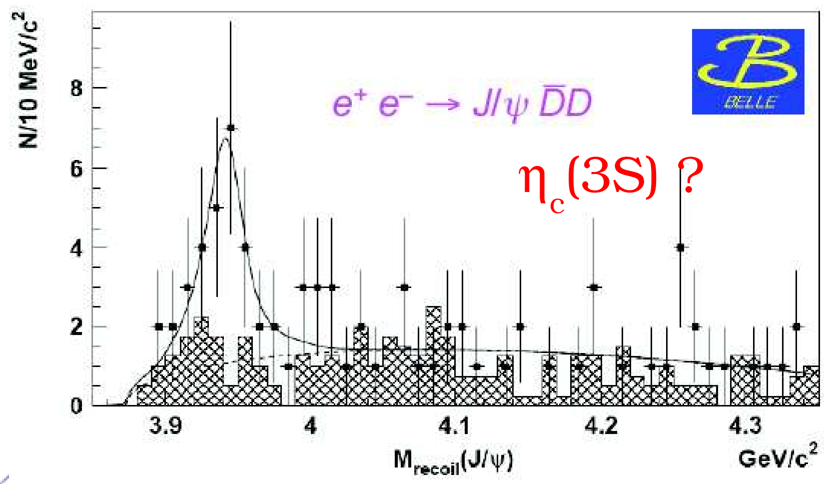
- The Physics Program
- The CKM Matrix and the Unitary Triangle
- The Unitary Triangle by Sides
- The Unitary Triangle by Angles
- Search for N.P. & Constraints on the SM
- The Unexpected
- Conclusions & Perspectives

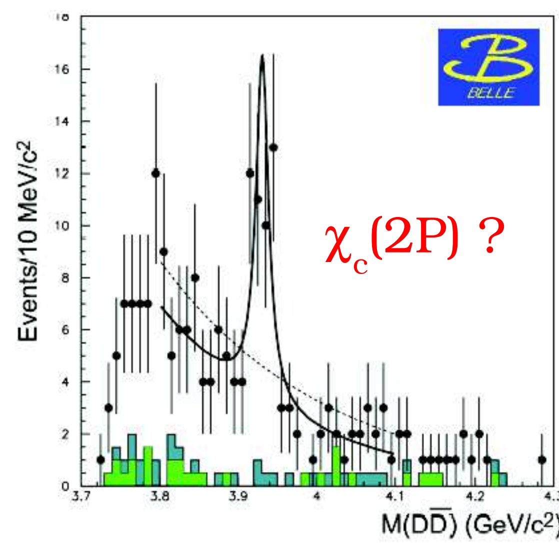
New Particles





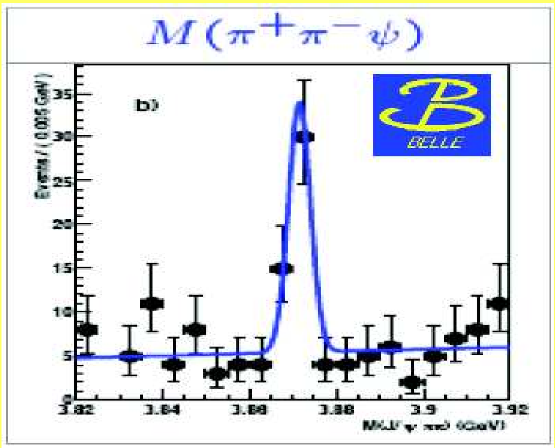
- Several new resonances have been observed
- Some good candidates for charmonium
- … but also something else …





The Unexpected(1)

- … not fitting any spectroscopic expectation !

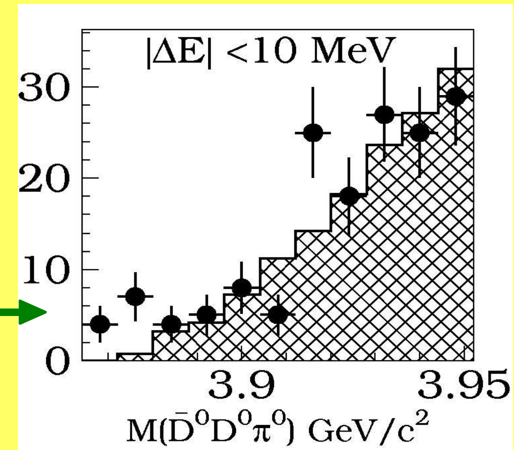


Belle, X(3872) $\rightarrow J/\psi\,\pi^+\pi^-$

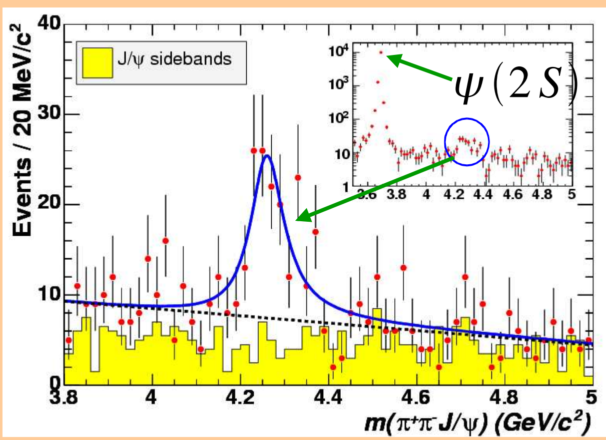
observed first in $B \rightarrow K\,(J/\psi\,\pi^+\pi^-)$

confirmed by *BABAR* , *CDF, D0*

Belle also observes in $D^0\bar{D}^0\pi^0$ →



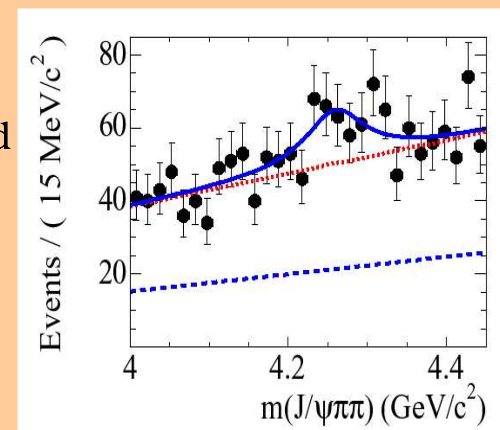
$D^0\bar{D}^{0*}$ *molecule ?*



BABAR, Y(4260) $\rightarrow J/\psi\,\pi^+\pi^-$

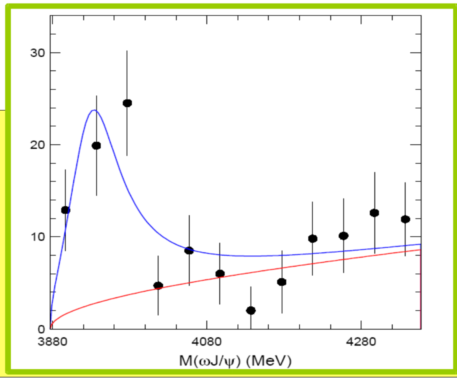
$e^+e^- \rightarrow (J/\psi\,\pi^+\pi^-)\gamma$, γ not reconstructed

also as $B^- \rightarrow (J/\psi\,\pi^-\,\pi^+)K^-$?



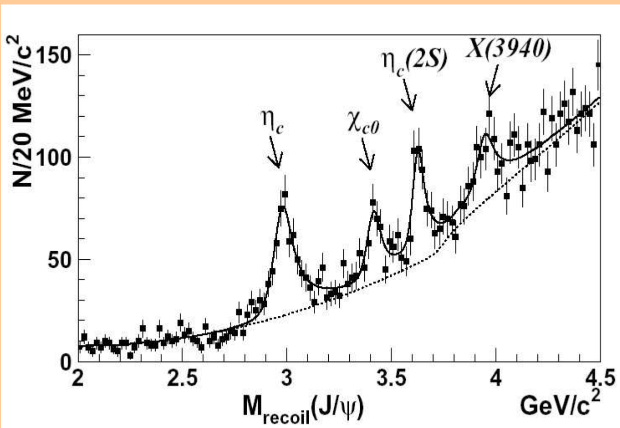
hybrid $q\bar{q}g$ *meson ?*
hep-lat/0512044

The Unexpected(2)



Belle, *Y(3940)* → $J/\psi\,\omega$

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

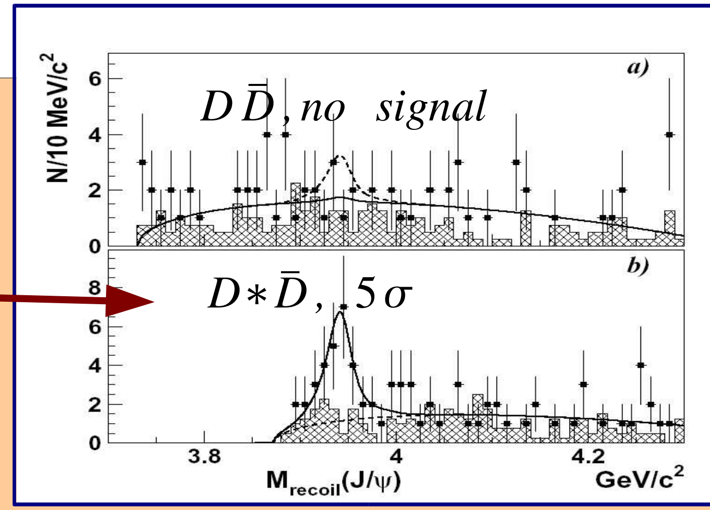


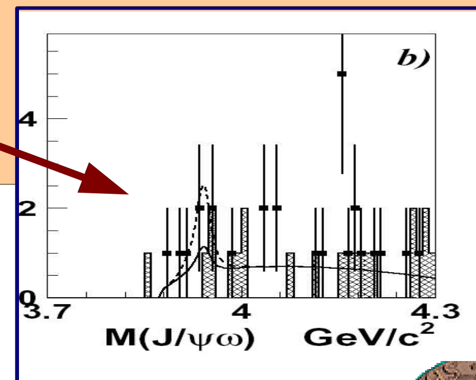
Belle, *ee*→$J/\psi X$,

X →*D* D* *(only one D reconstructed)*

but not :

X →$J/\psi\,\omega$





- 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

Conclusions

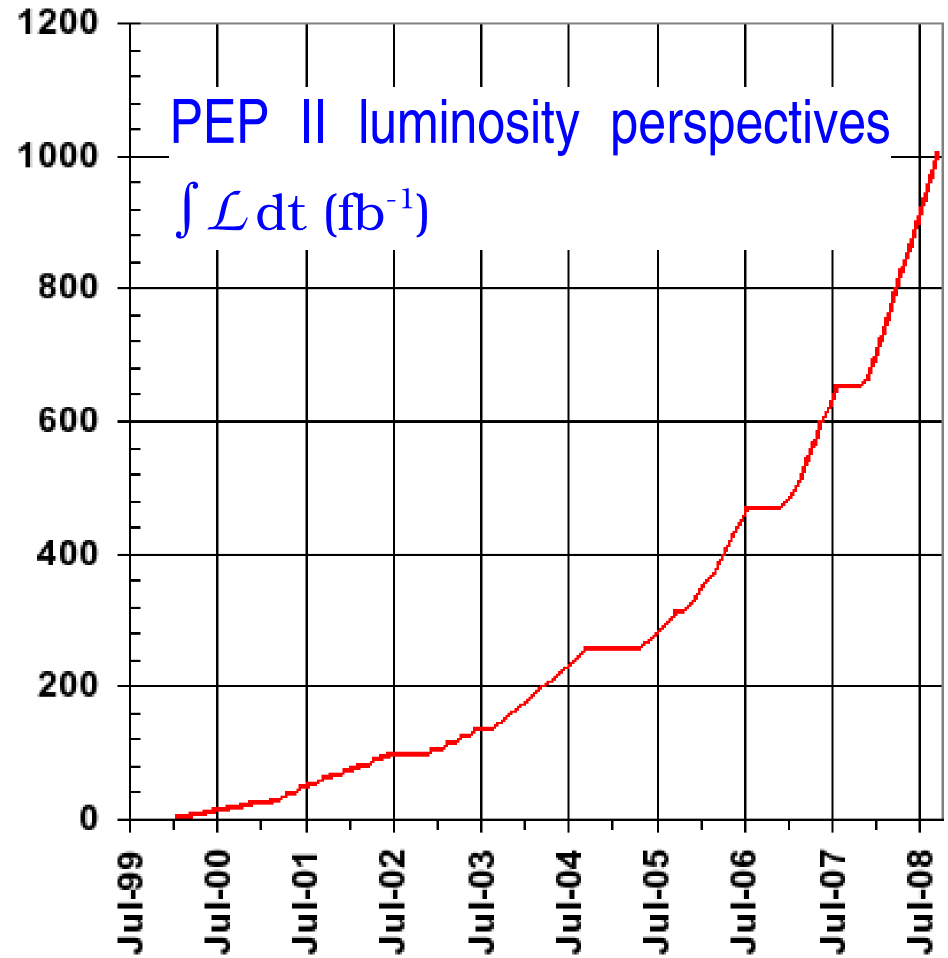
- Beauty Factories successfully pursue their program
- Collider performances and detector results outmatch expectations
- This notwithstanding

no crack in the S.M. (yet)

- However …

Luminosity: Perspectives

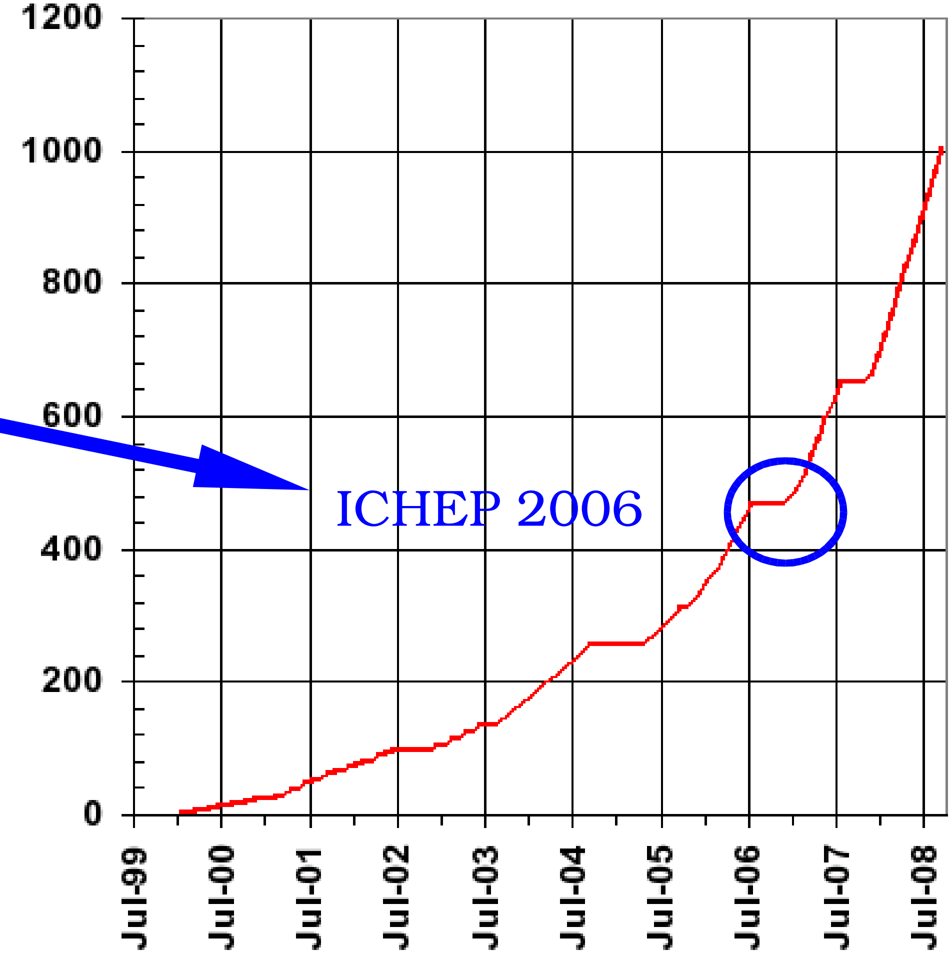
- KEK delivered 500 fb^{-1} before Jan /01/ 2006
- PEP II will cross 500 fb^{-1} by July 2006 (*x* 2 results shown here)
- By July 2008 ~ 1 ab^{-1} / experiment (*x4 -if approved)*



Luminosity: Perspectives

Mc Farlane P5 review:

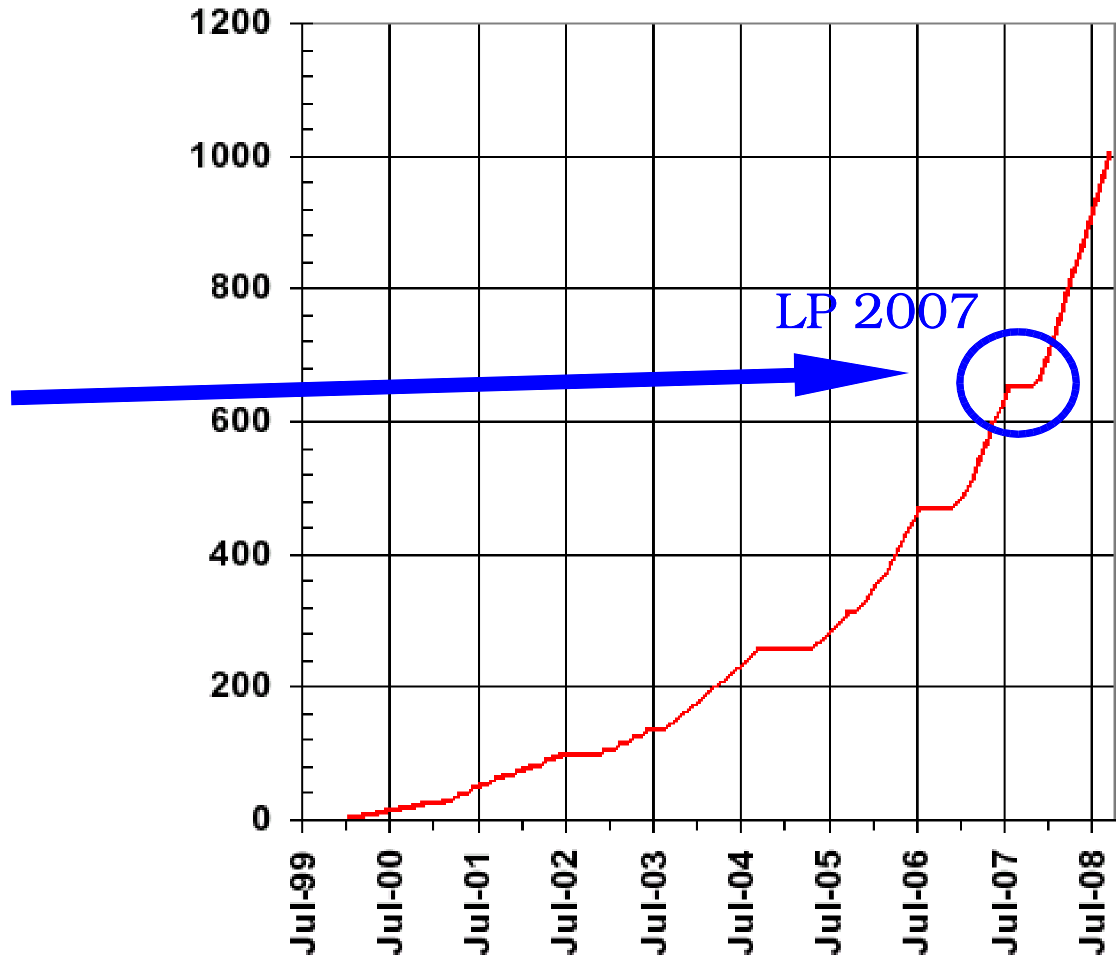
- $\sigma(V_{ub})$ (inclusive) ~ 6.5 %
- $\sigma(\gamma)$ Dalitz ~ 10-15^0



Luminosity: Perspectives

Mc Farlane P5 review:

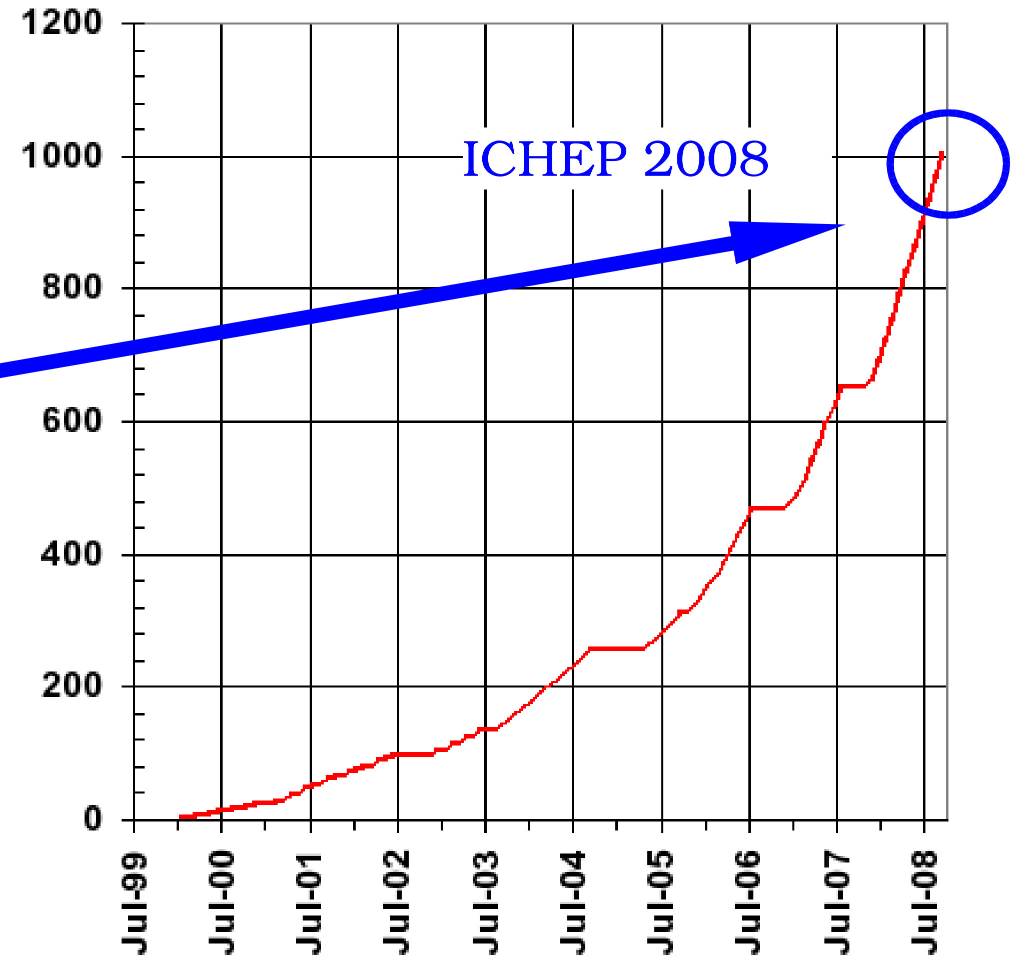
- discovery of $B \to \rho^0 \rho^0$
- V_{td} from $B \to \rho\gamma$



Luminosity: Perspectives

Mc Farlane P5 review:

- discovery of B →τν
- asimmetry in B → η' Ks to 5 σ
- $\sigma(V_{ub})$ (in+ex) < 5 %
- $\sigma(\gamma) < 10^0$



B-factories Physics Program "just started"

Stay Tuned !