CKM fits as of winter 2009 and sensitivity to New Physics

V. Tisserand*, LAPP-Annecy (CNRS-IN2P3 et Université de Savoie),
for the CKMfitter group,
Moriond EW (La Thuile), March 7-14 2009

CKM fitter
Moriond 09

http://ckmfitter.in2p3.fr/plots_Moriond09/

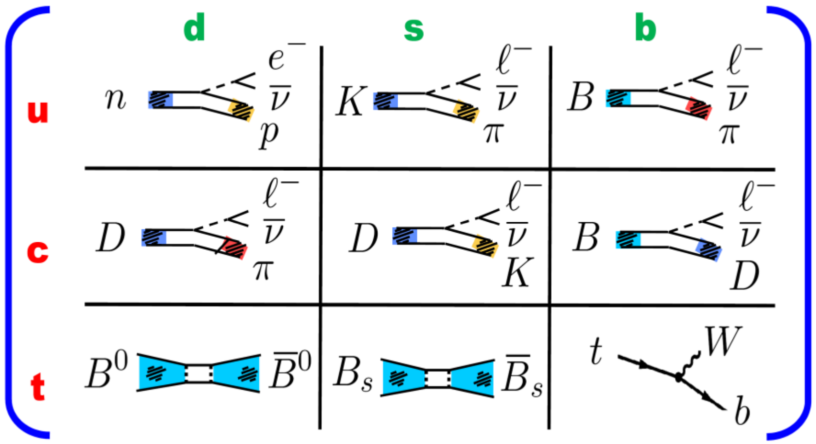
J. Charles, *Theory, CPT Marseille*
O. Deschamps, *LHCb, LPC Clermont-Ferrand*
S. Descotes-Genon, *Theory, LPT Orsay*
R. Itoh, *Belle, KEK Tsukuba*
A. Jantsch, *ATLAS, MPI Munich*
H. Lacker, *ATLAS & BaBar, Humboldt U. Berlin*
A. Menzel, *ATLAS, Humboldt U. Berlin*
S. Monteil, *LHCb, LPC Clermont-Ferrand*
V. Niess, *LHCb, LPC Clermont-Ferrand*
J. Ocariz, *BaBar, LPNHE Paris*
S. T'Jampens, *LHCb, LAPP, Annecy-le-Vieux*
K. Trabelsi, *Belle, KEK Tsukuba*
* *V.T also BaBar.*

IN2P3 cnrs Laboratoire d'Annecy-le-vieux de Physique des Particules — Université de Savoie

The unitary CKM Matrix: mixing the 3 quark generations and CP violation

- **Strong hierarchy** in EW coupling of the 3 families:
diagonal $\approx$1 & between 1 $\leftrightarrow$ 2: $\propto\lambda\approx$0.22,
2 $\leftrightarrow$ 3: $\propto\lambda^2$, and 1 $\leftrightarrow$ 3: $\propto\lambda^3$.

V_{CKM} =

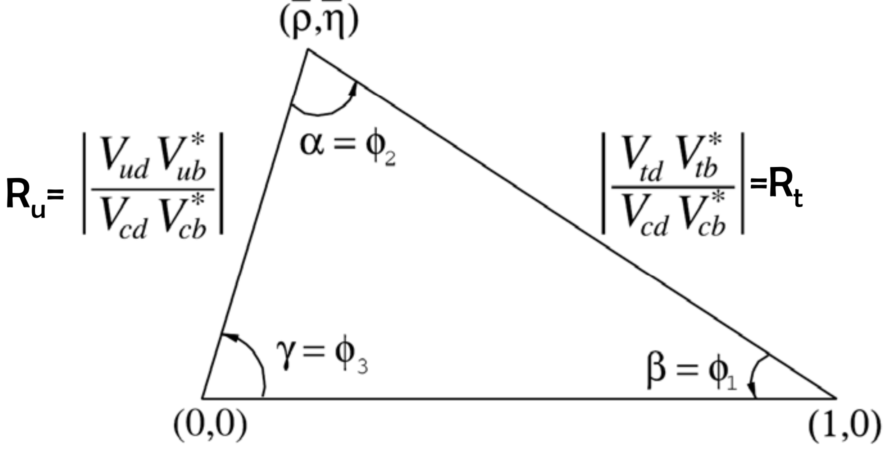


- **KM mechanism**: 3 generations ➔ 1 phase
as only source of CP violation in SM.

- consider the **Wolfenstein parameterization**,
defined to hold to all orders in λ and re-phasing invariant (EPJ C41, 1-131, 2005) :

$$\lambda^2 = \frac{|V_{us}|^2}{|V_{ud}|^2 + |V_{us}|^2} \qquad A^2\lambda^4 = \frac{|V_{cb}|^2}{|V_{ud}|^2 + |V_{us}|^2} \qquad \bar\rho + i\bar\eta = -\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}$$

➔4 parameters: A, λ, $\bar\rho$, and $\bar\eta$ to describe the CKM matrix, to extract from data the Unitary Triangle.



CKM fitter
Moriond 09

Global SM CKM fit: the inputs

Details:
http://ckmfitter.in2p3.fr/plots_Moriond09/

CKM matrix within a frequentist framework ($\cong\chi^2$ minimum) + uses all constraints on which we think we have a good theoretical control + Rfit treat. for theory errors (EPJ C41, 1-131, 2005)

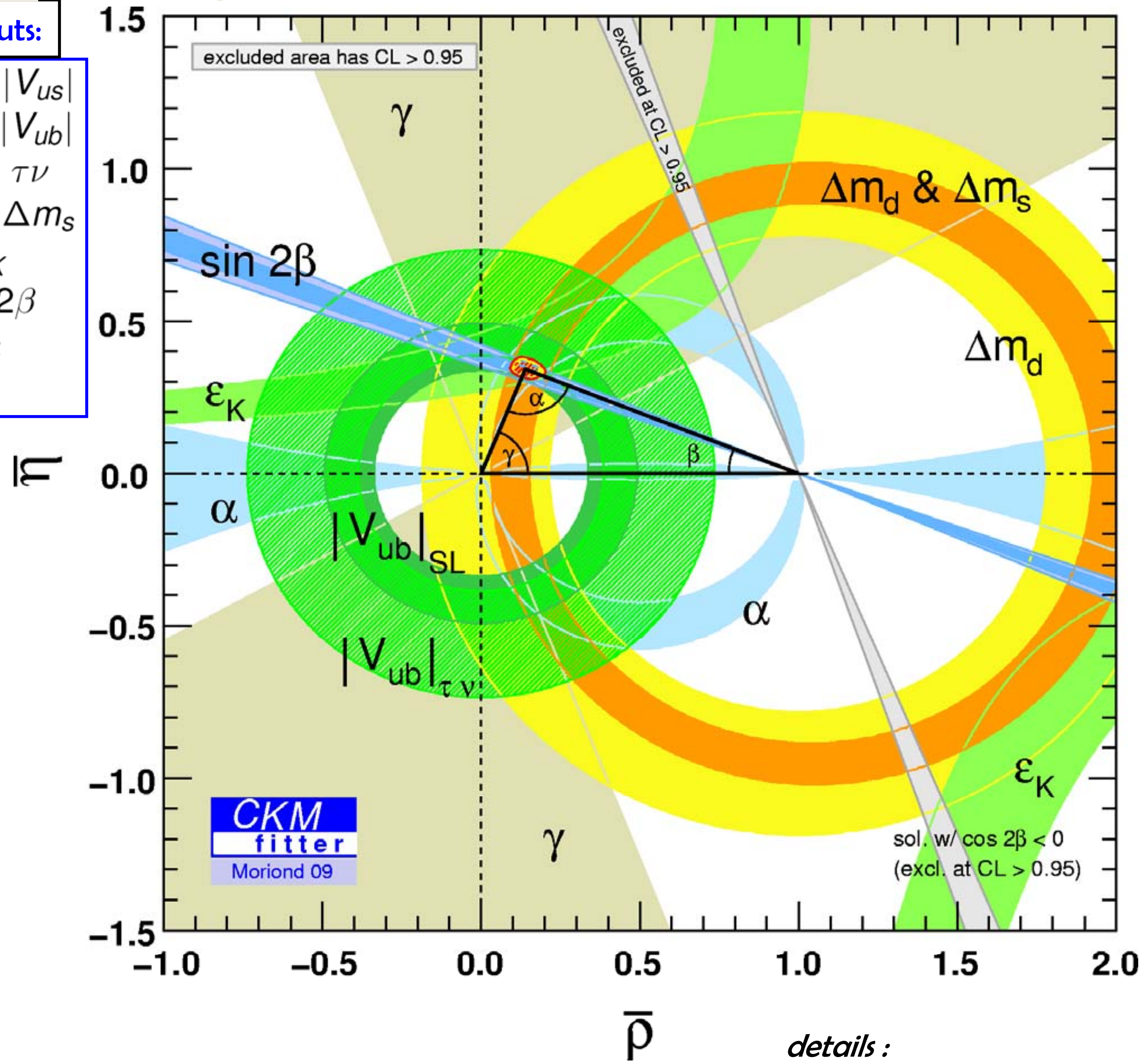
➔ data=weak ⊗ QCD ⇒need for hadronic inputs (often LQCD: Our Own Average (OOA) of latest results)

	Phys.param.	Experim. observable	Theory method/ingredients
CP conserving	$\lvert V_{ud}\rvert$	Superallowed β decays	*Towner & Hardy*, PRC 77, 025501 (2008)
	$\lvert V_{us}\rvert$	K_{l3} (WA Flavianet)	$f_+^{K\pi}(0)=0.964(5)$ (most precise: RBC-UKQCD)
	$\lvert V_{cb}\rvert$	HFAG incl.+excl. $B\to X_c l\nu$	$40.59(38)(58)\times10^{-3}$
	$\lvert V_{ub}\rvert$	HFAG incl.+excl. $B\to X_u l\nu$	OOA (specif. uncer. budget): $3.87(9)(46)\times10^{-3}$
	Δm_d	last HFAG WA B_d-$\bar{B}_d$ mixing	OOA: $\hat{B}_{Bs}/\hat{B}_{Bd}=1.05(2)(5)+f_{Bs}+f_{Bd}$
	Δm_s	CDF B_s-$\bar{B}_s$ mixing	OOA: $\hat{B}_{Bs}=1.23(3)(5)+f_{Bs}+f_{Bd}$
	$B^+\to\tau^+\nu$	last 08 WA: BaBar/Belle	OOA: $f_{Bs}/f_{Bd}=1.196(8)(23)$ & $f_{Bs}=228(3)(17)$
CP violating	$\lvert\varepsilon_K\rvert$	K^0-$\bar{K}^0$ (PDG08: KLOE, NA48,KTeV)	PDG param. (*Buchalla et al. '96*) + OOA: $\hat{B}_K=0.721(5)(40)$
	β/ϕ_1	latest WA HFAG charmonium	-
	α/ϕ_2	last WA $\pi\pi/\rho\pi/\rho\rho$ NEW	isospin SU(2) (GL)
	γ/ϕ_3	latest WA HFAG $B^-\to D^{(*)}K^{(*)-}$	GLW/ADS/GGSZ

Global CKM fit: the Big ($\bar{\rho}$,$\bar{\eta}$) Picture

Inputs:

$|V_{ud}|$, $|V_{us}|$
$|V_{cb}|$, $|V_{ub}|$
$B \to \tau\nu$
Δm_d, Δm_s
ϵ_K
$\sin 2\beta$
α
γ



- overall consistency at 95% CL.
- KM mechanism is at work for CPV and dominant in B's.
- Some tension in $B^+ \to \tau^+\nu$ ➔ the fit χ^2_{min} drops by 2.4 σ when removing this input.
- and NP ? (see later)

$$\begin{cases} \bar{\rho} = 0.139^{+0.025}_{-0.027} \\ \bar{\eta} = 0.341^{+0.016}_{-0.015} \end{cases}$$

details : http://ckmfitter.in2p3.fr/plots_Moriond09/

Global CKM fit: testing the paradigm

Inputs:

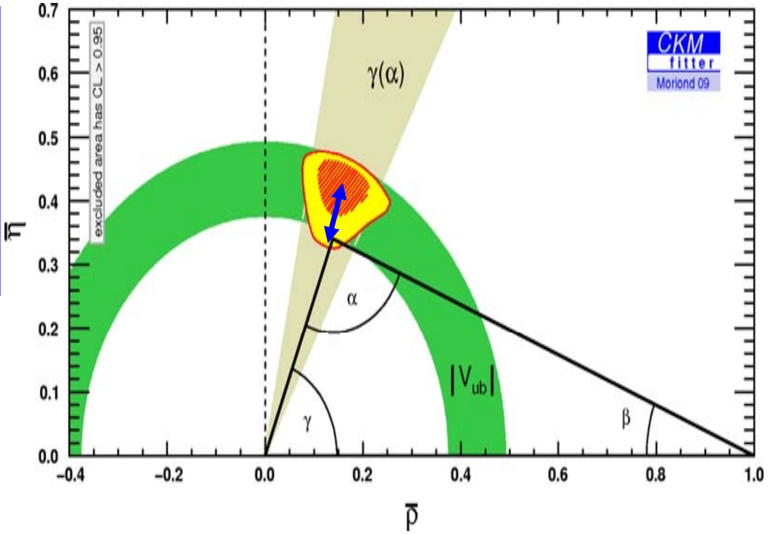
$|V_{ub}|_{SL}$

$B \to \tau\nu$

γ

$\pi-\alpha-\beta$

Observables w/ "Tree" processes



Assuming there is no NP in $\Delta I=3/2$ b→d EW penguin amp.

Use α with β (charmonium) to produce a new γ 'Tree'.

Inputs:

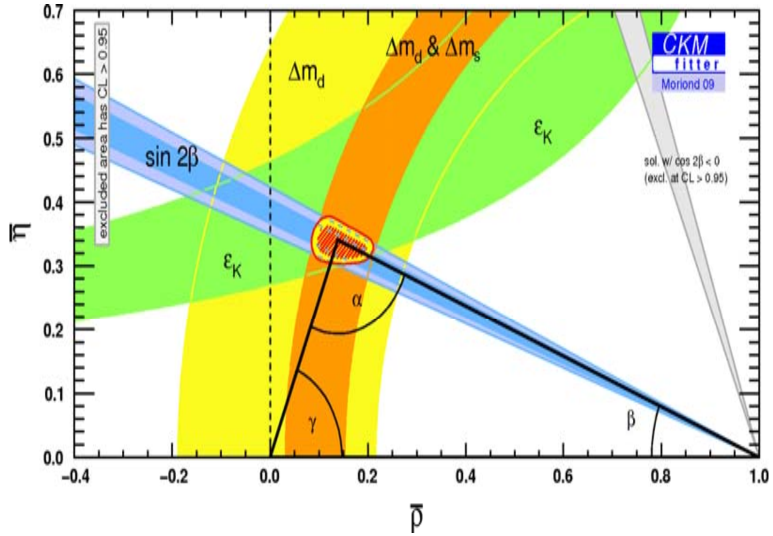
$|\varepsilon_K|$

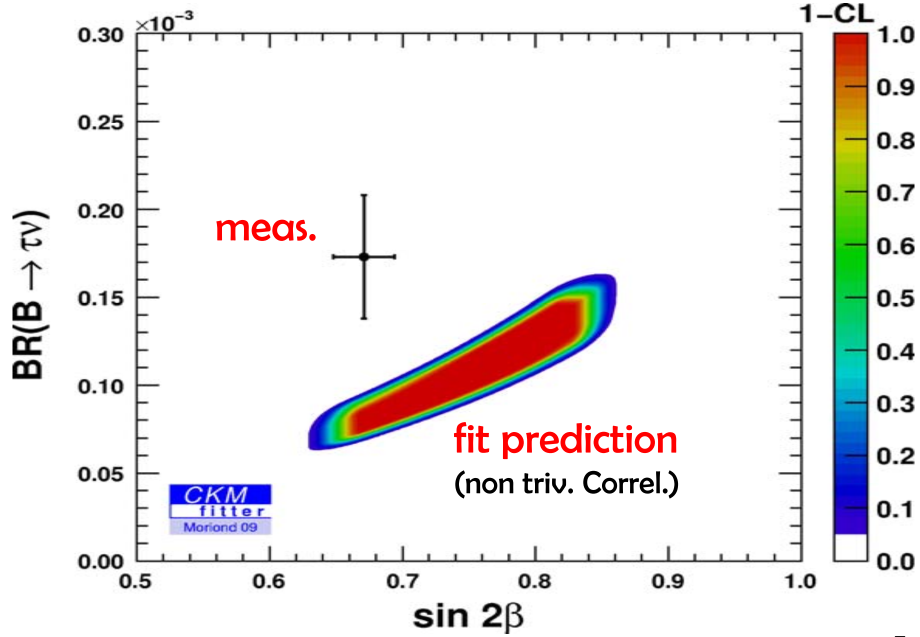
$\sin 2\beta$

Δm_d

Δm_s

Observables involving Loops
(theo. uncertainties, except for β)





Tension in between $\sin(2\beta)$ (I) &

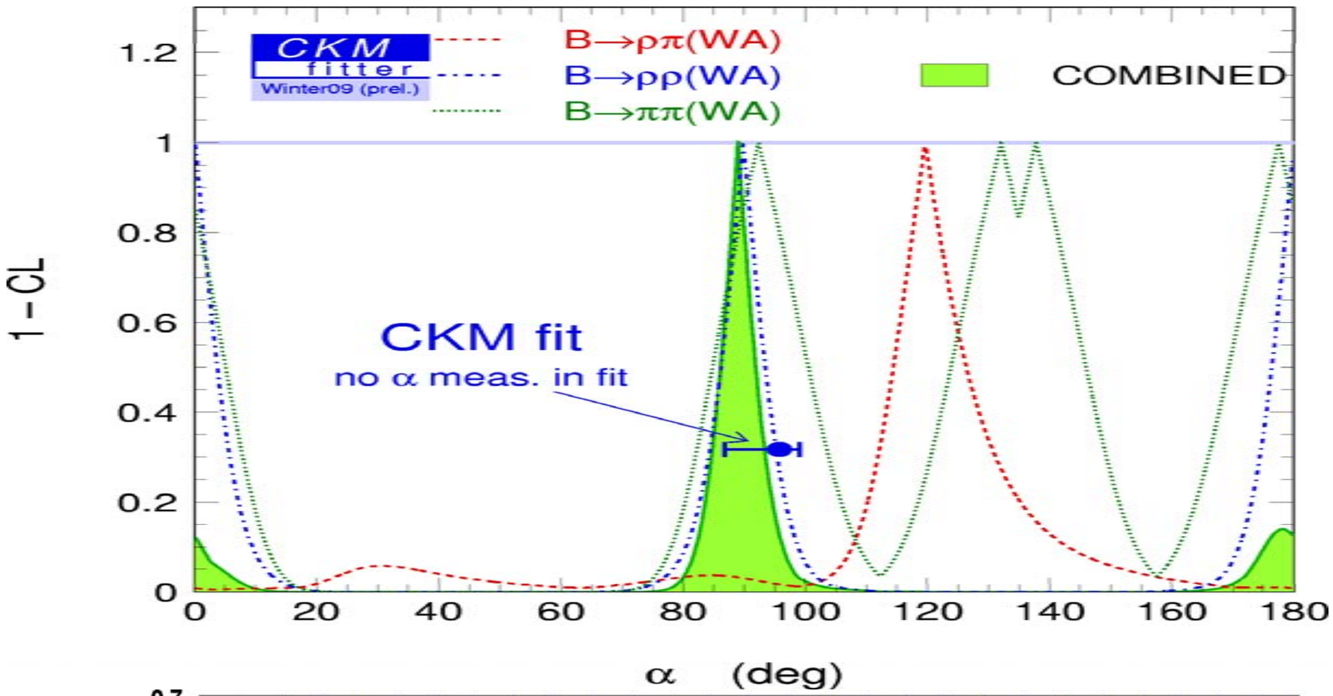
$BR(B^+ \to \tau^+\nu)$ (II) (through |Vub|):

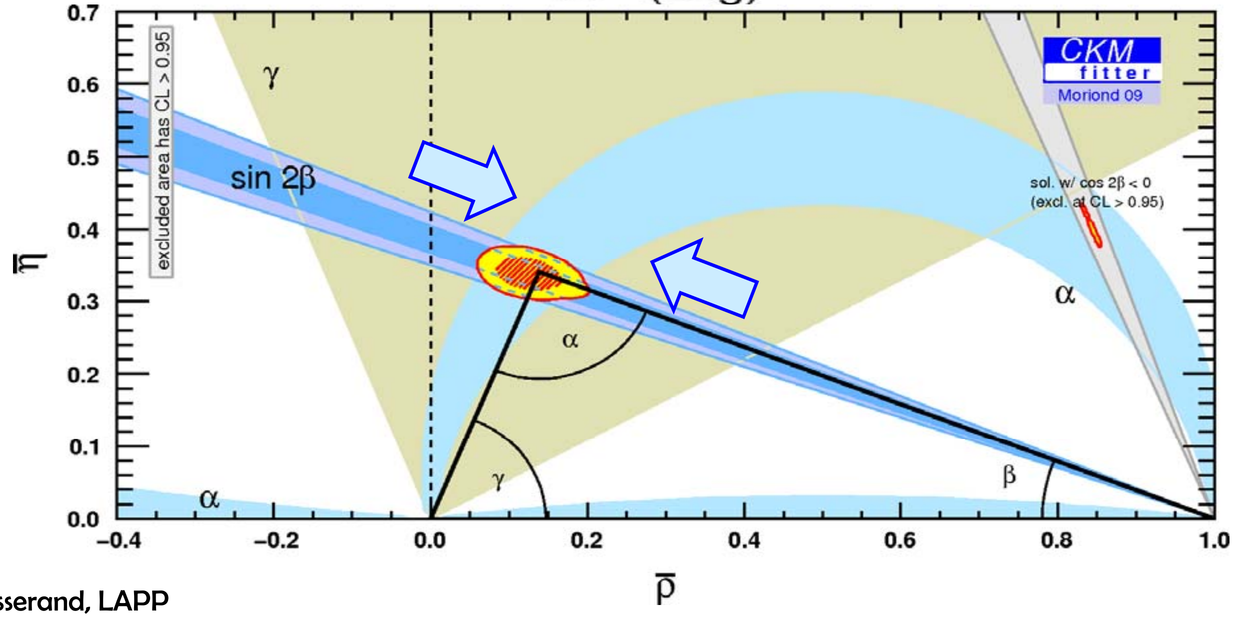
either removing I/II in the CKM global fit

the χ^2_{min} drops by 2.3/2.4 σ. reasons why:

- exp. fluctuations,
- LQCD,
- New Physics ... ?

α from B→ρρ, ρπ, ππ: new WA





NEW $\rho^+\rho^0$ has changed : arXiv:0921.3522

$\alpha = (89.0^{+4.4}_{-4.2})^\circ$

{ [+9.1 °-8.3°] 95% CL}

CKM fit: $(95.6^{+3.3}_{-8.8})^\circ$

Summer'08 was: $(88.2^{+6.1}_{-4.8})^\circ$

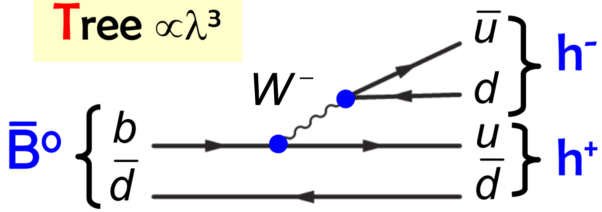
α is now a precise measurement @5% !?

Note that β is @4.2%

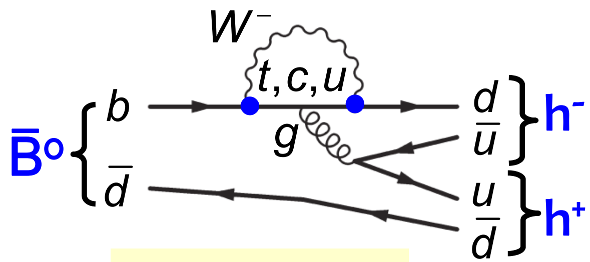
α from $b \to u\bar{u}d$, $B \to \rho\rho, \rho\pi, \pi\pi$

$A(\bar{B}^0 \to h^+h^-) = A_{+-} = V_{ub}V^*_{ud}\, T + V_{tb}V^*_{td}\, P$

Tree $\propto \lambda^3$



+



Penguin $\propto \lambda^3$

$\sin 2\alpha$ from time dep. CP:

$\Gamma(\bar{B}^0(t) \to h^-h^+) \propto [1 + C_{hh}\cos\Delta mt - S_{hh}\sin\Delta mt]$

$\sin 2\alpha_{eff} = S_{hh}/(1-C^2_{hh})^{1/2}$

- Strong effective phases arise from **P** : effective angle α_{eff} measured (**not** α!)

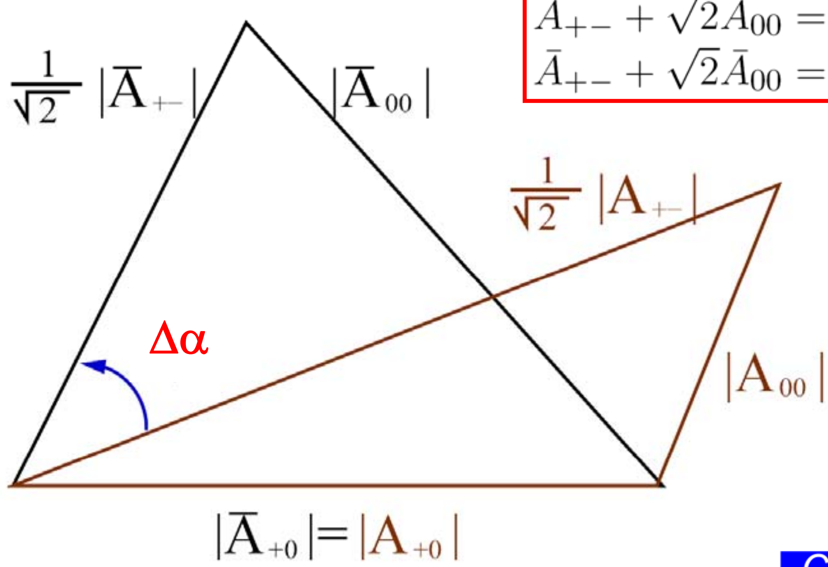
$$\Delta\alpha = 2(\alpha_{eff} - \alpha)$$

- So far the $\rho\rho$ dominates, R=P/T:
  $R(\pi^+\pi^-) > R(\rho^+\pi^-) \sim R(\rho^-\pi^+) > R(\rho^+\rho^-)$

  → smaller $|\Delta\alpha|$ isopin bound
- 8 fold ambiguities (4 $\Delta\alpha$, 2 α_{eff})
- h^+h^0 : pure tree.

Gronau London SU(2) isospin triangle:

$$A_{+-} + \sqrt{2}A_{00} = \sqrt{2}A_{+0}$$
$$\bar{A}_{+-} + \sqrt{2}\bar{A}_{00} = \sqrt{2}\bar{A}_{+0}$$

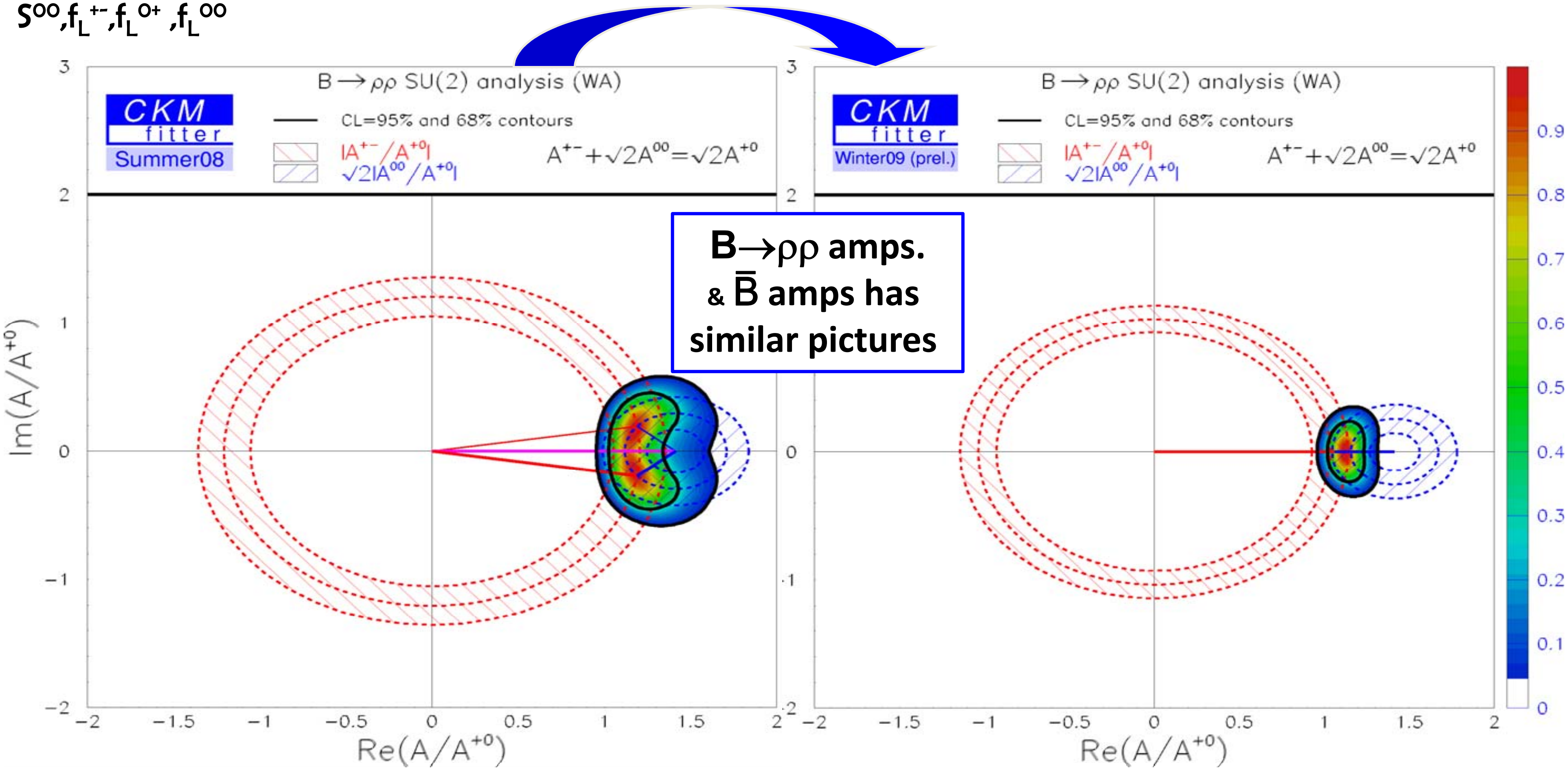


α from $B \to \rho\rho$

Winter' 09 BaBar $\rho^+\rho^0$ update (0921.3522) BR(f_L) ↗ by ~2(1)σ.

Dominates WA {
- BR ($\rho^+\rho^0$)[10^{-6}]= 18.2 (3.0) → 24.0 (1.9)
- $f_L(\rho^+\rho^0)$= 0.912(44) → 0.950(15)

- Inputs : B^{+-}, B^{0+}, B^{00}, C^{+-}, S^{+-}, C^{00}, S^{00}, f_L^{+-}, f_L^{0+}, f_L^{00}



- higher BR: Both B and $\bar{B}$ isospin triangles do not close (consistent within uncert.)
- mirror solutions are degenerated in a single peak.

CKM fitter Moriond 09

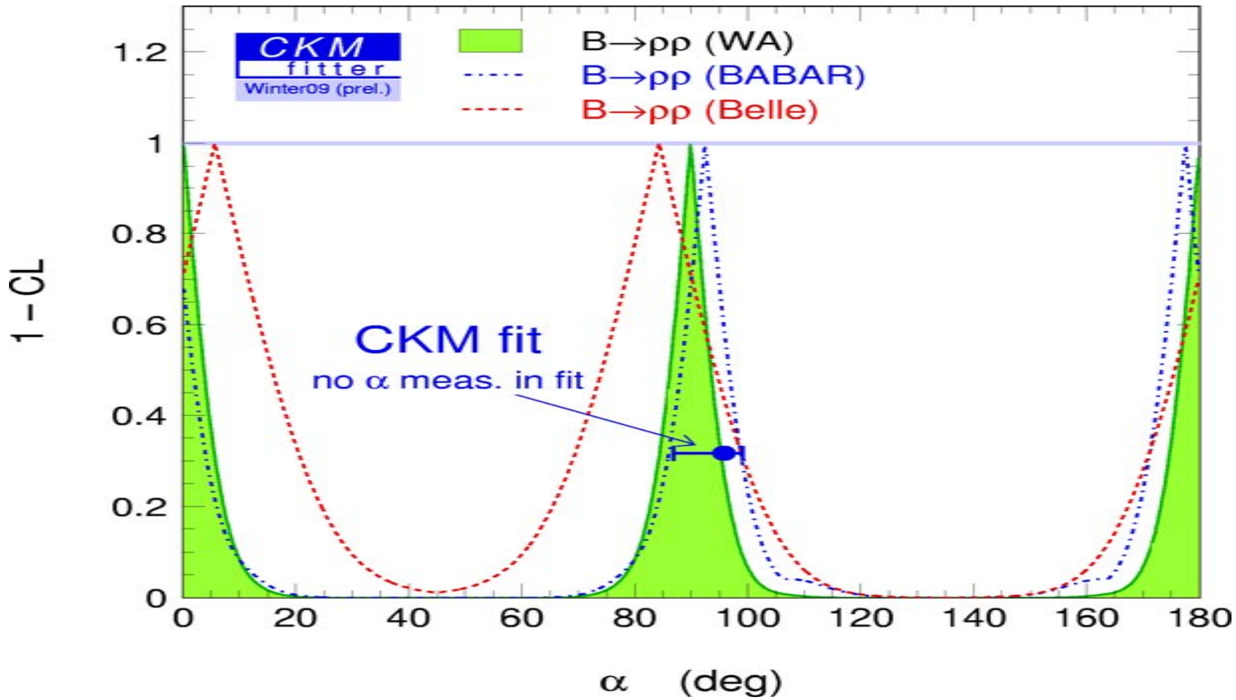
α from $B \to \rho\rho$

α = (89.9 ± 5.4)°
$\Delta\alpha$ = (1.4 ± 3.7)°

Summer'08 was :

$\alpha = (90.9^{+6.7}_{-14.9})°$

$\Delta\alpha = (0.5^{+12.6}_{-5.5})°$



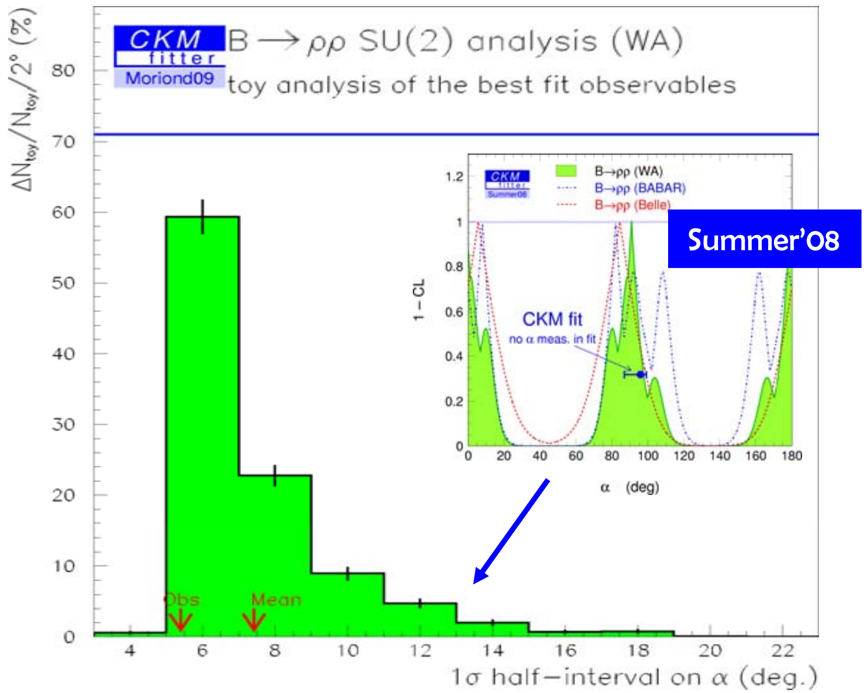
➔ How lucky are we? toy study:

Gaussian smearing of all inputs at best CKM fitted α by 1σ half interval : BR^{+-}, BR^{0+}, BR^{00}, C^{+-}, S^{+-}, C^{00}, S^{00}, f_L^{+-}, f_L^{0+}, f_L^{00}

- average toy error: 7.5° (observed 5.4°)
- long asymmetrical tail (→20° !) when triangle closes ⇒ pseudo mirror solution above the 1σ CL(α) threshold. Only ~34% of SU(2). triangles close:

$$|A_{+-}|/\sqrt{2} + |A_{00}| > |A_{+0}|$$

- same behavior when 2σ half interval (less fluctuating).



Breaking isospin triangle in $B \to \rho\rho$

$\Delta\alpha = (1.4 \pm 3.7)°$

➔ Already sensitive to sources of SU(2) breaking (J. Zupan CKM'06):

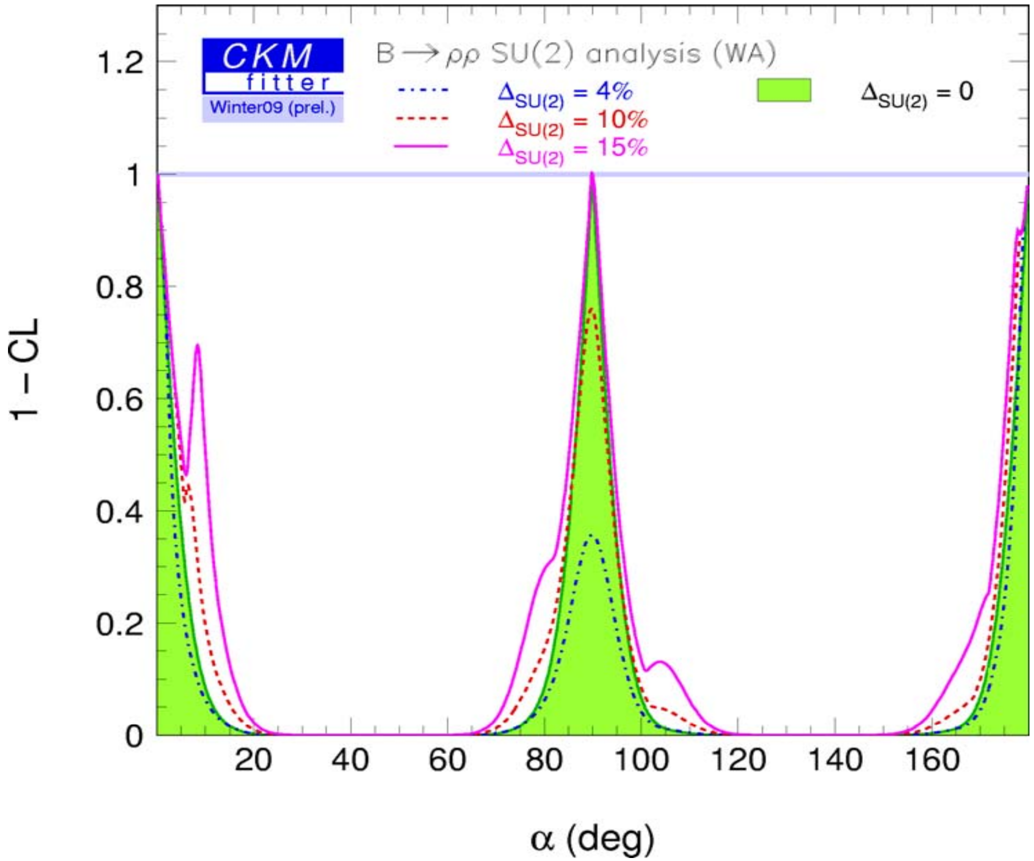
- $m_u \neq m_d$ & $Q_u \neq Q_d$:
  $(m_u - m_d)/\Lambda_{QCD}$ ~1%
- extend the basis of EW penguins: $Q_{7...10}$
  $\Delta_{\alpha EWP}$ ~1.5°
- mass Eigen-States (EG) ≠ isospin EG:
  $(\rho-\omega)$ mixing <2%
- $\Gamma_\rho \neq 0 \Rightarrow$ I=1 contribution possible:
  $O(\Gamma^2_\rho / m^2_\rho)$ ~ 4%
- $\Delta I = 5/2$ operators no more negligible.
- ...

➔ Possible way out: $K^*\rho$ SU(3) constraints

➔ Break the triangle closure:
$A^{+0} \to A^{+0} + \Delta A^{+0}$

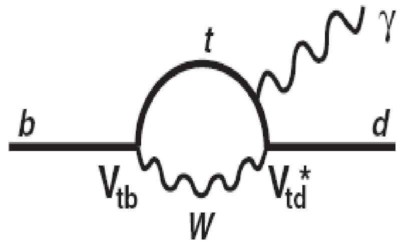
$$\sqrt{2}\,\Delta A^{+0} = V_{ud}V^*_{ub}\,\Delta_T T^{+-} + V_{td}V^*_{tb}\,\Delta_P P^{+-}$$

⇒additional Amp. with Δ_T's & Δ_P's (arbitrary phases)



- tested $|\Delta A^{+0}|$: 4, 10 & 15%
- small correction breaks SU(2) at 90°
but restore SU(2) in the ~0° vicinity
- need ~15% to restore SU(2) at ~90°
- BTW small impact on $\pi\pi/\rho\rho/\rho\pi$ WA combo.

$B\to(\rho,\omega)\gamma$ & $K^*\gamma$ exclusive $b\to D\gamma$ [D=(d,s)]



- access to $|V_{td}/V_{ts}|$ within SM, in ratios of excl. BRs: $R(d/s)\gamma$
- cross check of neutral $B_{d,s}$ mixing (penguins vs box)
- loop : sensitive to NP, in addition to accurate (N)NLO $B\to X_s\gamma$ (inclusive, Misiak et al. '06)
- available many recent('08), more & more accurate excl. meas. $B\to V\gamma$ at B-factories.

- But hadronic effects difficult to estimate:

  -1- early attempts: Ali, Lunghi, Parkhomenko ('02,'04,'06).

  -2- QCD Factorisation for LO in $1/m_b$ up to $O(\alpha_s)$ (Bosch and Buchalla ('02)).

  -3- use a more sophisticated analysis beyond QCDF : adding $1/m_b$-suppressed terms from light-cones sum rules (long dist. γ emission & soft gluon): Ball, Jones, Zwicky ('06).

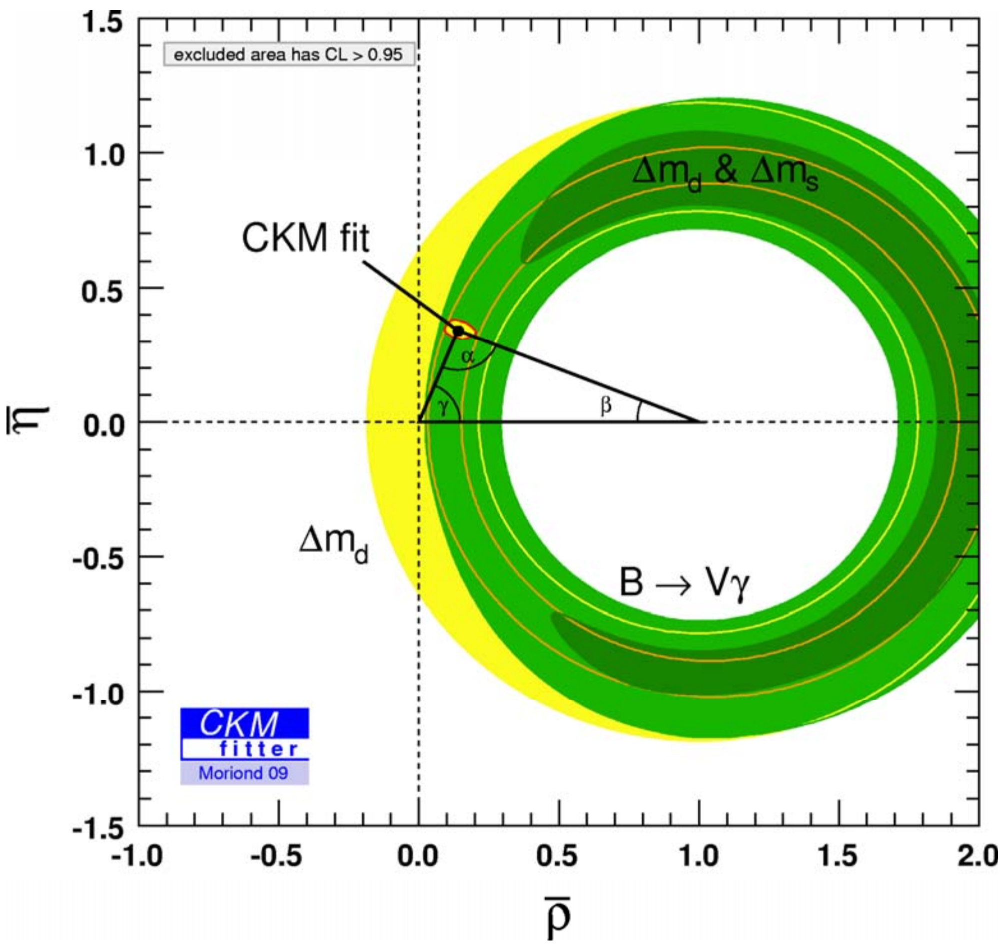
  - ♦each exclusive decay described individually
  - ♦isospin breaking (FF, strong phase)/CP asym. + weak annihilation (tree) can be large in $(\rho,\omega)\gamma$ ...
  - ♦u and c internal loops (long and short distance) + other operators than magnetic operator Q_7 only
  - ♦non trivial CKM matrix elements sensitivity

$$\bar{A} \equiv \frac{G_F}{\sqrt{2}} \left(\lambda_u^D a_7^u(V) + \lambda_c^D a_7^c(V)\right) \langle V\gamma|Q_7|\bar{B}\rangle \qquad \lambda_U^D = V_{UD}^* V_{Ub}$$

D=(d,s)
U=u,c,t

$$a_7^U(V) = a_7^{U,\mathrm{QCDF}}(V) + a_7^{U,\mathrm{ann}}(V) + a_7^{U,\mathrm{soft}}(V) + \ldots$$

$B \to (\rho,\omega)\gamma$ & $K^*\gamma$ impact on $(\bar{\rho},\bar{\eta})$



- HFAG WA '08, all BFs updated ($\times 10^{-6}$):
  - $K^{*-}\gamma$: 45.7±1.9
  - $K^{*0}\gamma$: 44.0±1.5
  - $\rho^+\gamma$: $0.98^{+0.25}_{-0.24}$
  - $\rho^0\gamma$: $0.86^{+0.15}_{-0.14}$
  - $\omega\gamma$: $0.44^{+0.18}_{-0.16}$
- BELLE '08 ($\times 10^{-6}$):
  - $BF(B_s \to \phi\gamma) = 57 \pm 22$
    (strange counter part $B \to K^*\gamma$)
  - $A_{CP}(B^- \to K^{*-}\gamma) = -0.11 \pm 0.32 \pm 0.09$
    (γ polar: NP ? + check strong dynamic)

➔ Penguins constraint at 95% CL, as good as box B mixing Δm_d alone, and at 68% CL almost as good as Δm_d&Δm_s

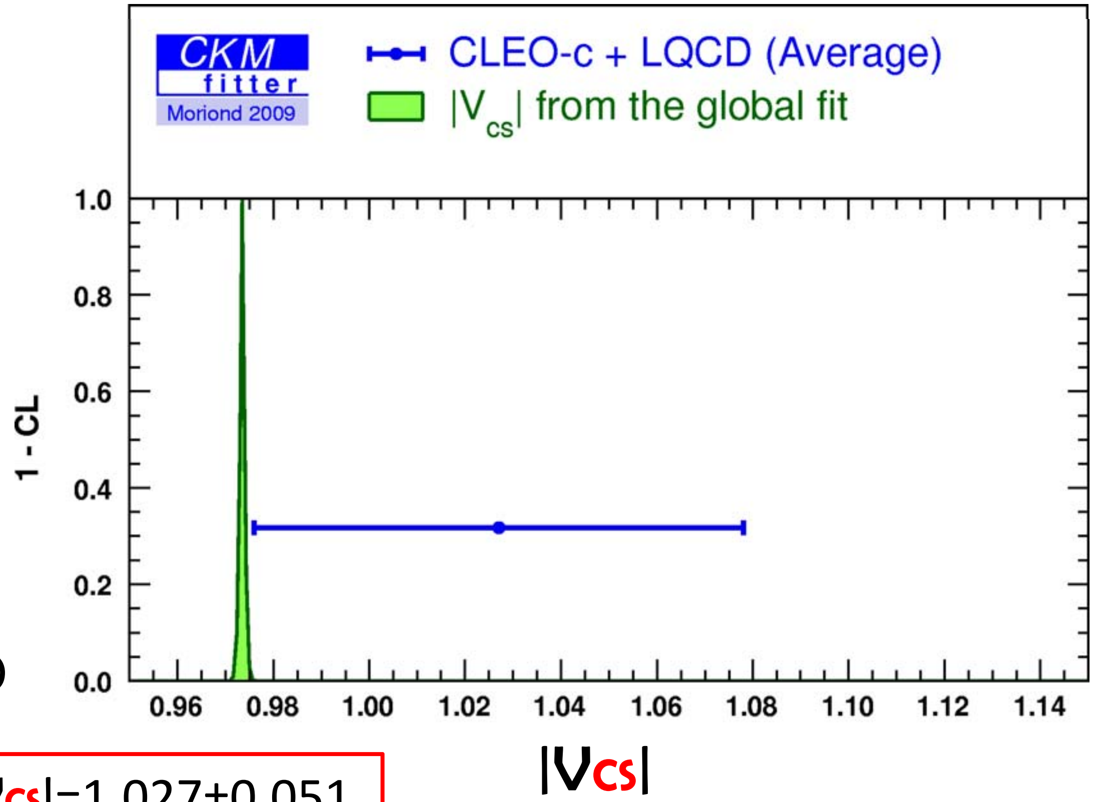
No more trouble with |Vcs|

- Charm sector favorite place to test LQCD [$m_c \sim \Lambda_{QCD}$] for form fact. and decay constants (access |Vcs|)
- CLEO-c '09 $D_s \to (\tau,\mu)\nu$ & $\tau[e\nu\nu,\pi\nu]$ annihilation: arXiv: 0901.1147 & 0901.1216 (fix |Vcs|=|Vud|):

  f_{Ds}=259.5(6.6)(3.1) MeV
- Our LQD average:

  f_{Ds}=246.3(1.2)(5.3) MeV

  (mainly from full unquenched LQCD : HPQCD'07 & FNAL-MILC'07, but not only)



- combined CLEO-c + LQCD: |Vcs|=1.027±0.051
- CKM fit : |Vcs|= 0.97347±0.00019

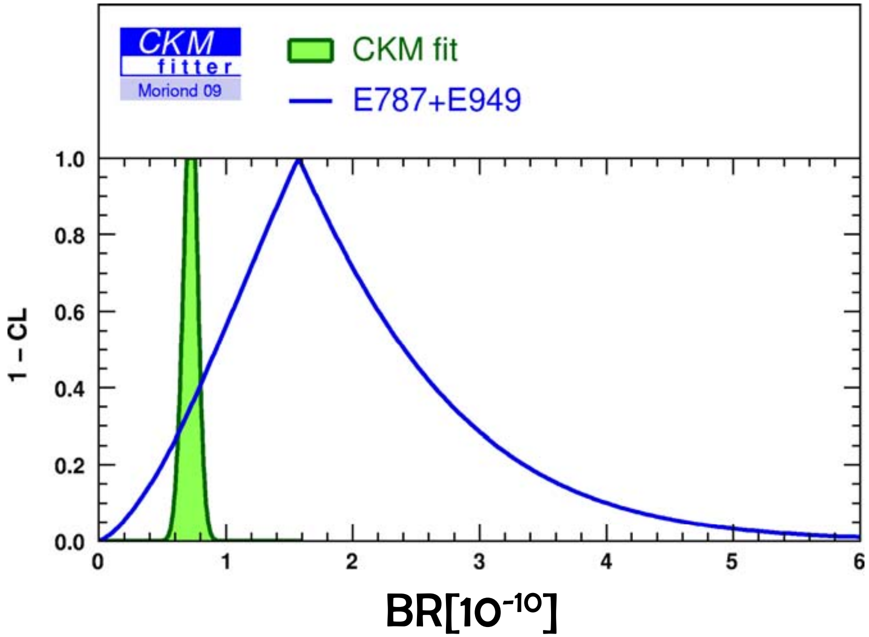
- |Vcs| situation improves : CLEO-C and LQCD have better agreement on f_{Ds}
- f_{Ds} ideal for lattice (cs quarks), better but still worse than f_K & f_K/f_π (light quarks).
- note : f_{Ds} from BaBar, Belle, & CLEO-c in pre-2009 meas. with $D_s \to \mu\nu$ is higher.

a word on rare $K^+ \to \pi^+ \nu \bar{\nu}$

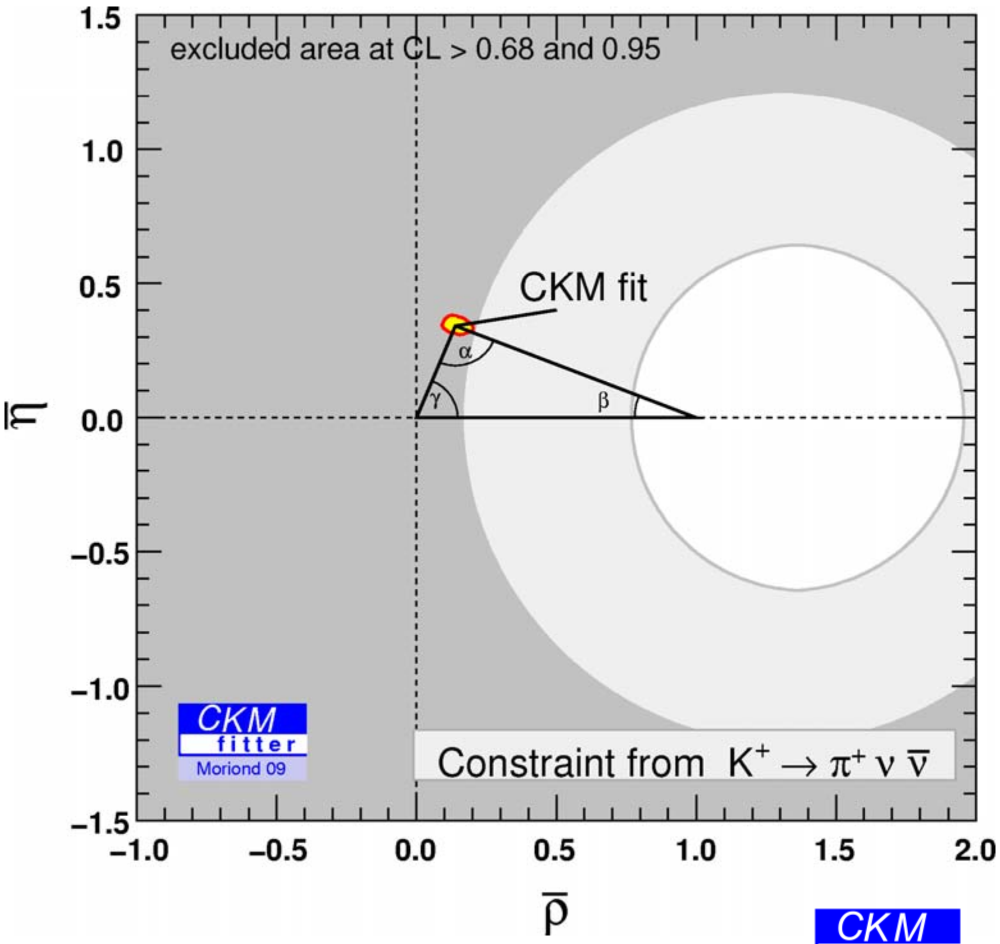
- **Recent E949 update** (arXiv:0903.0030 **with 5 events** (& incl. E787)): BR $[10^{-10}]= 1.73^{+1.15}_{-1.05}$
- **BR parameterization** as Brod & Gorbahn '08 (PRD 78, 034006) :

NLO QED-QCD & EW corr. to the charm quark contrib. ($\alpha_s(m^2_Z)$=0.1176(20) & $\overline{m}_c(\mu_c)$=1.286(13)(40))

CKM fit: BR$[10^{-10}]= 0.730^{+0.081}_{-0.101}$



$$\mathcal{B}(K^+ \to \pi^+ \nu \bar{\nu}) \propto \left[(\sigma \bar{\eta})^2 + (\rho_0 - \bar{\rho})^2 \right]$$



➔ wait for NA62: O(100 events)!

New Physics in $B_{q=d,s}$ mixing

Assume that:

- tree-level processes are not affected by NP (SM4FC: $b \to q_i \bar{q}_j q_k$ $(i \neq j \neq k)$) nor non-loop decays, eg: $B^+ \to \tau^+ \nu$ (implies 2HDM model).
- NP only affects the short distance physics in $\Delta B=2$ transitions.
- **Model independent** parameterization: $\Delta_q = |\Delta_q|\, e^{2i\Phi_{NPq}}$ (use Cartesian coords.)

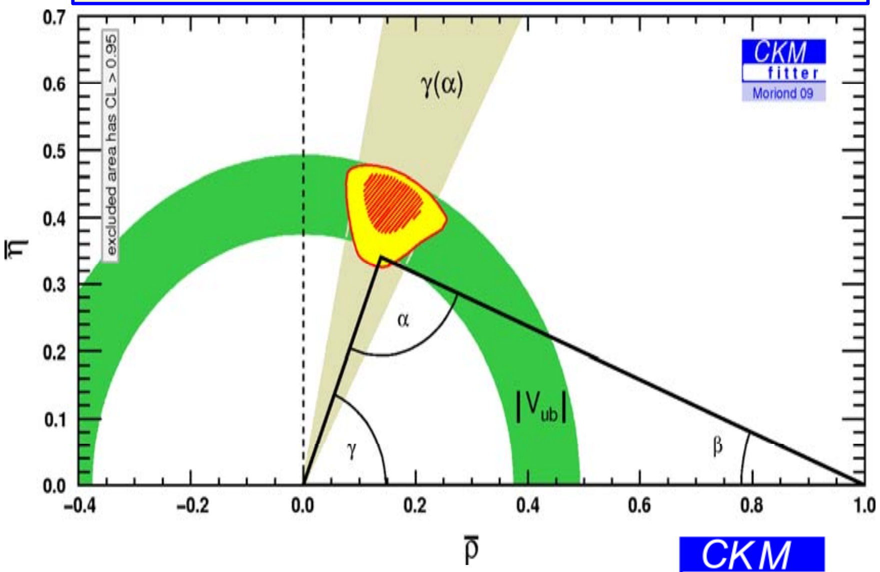
$$\langle B_q | \mathcal{H}^{SM+NP}_{\Delta B=2} | \bar{B}_q \rangle \equiv \langle B_q | \mathcal{H}^{SM}_{\Delta B=2} | \bar{B}_q \rangle \times (\mathrm{Re}(\Delta_q) + i\,\mathrm{Im}(\Delta_q))$$

- $\Delta_q = r^2_q\, e^{2i\theta_q} = 1 + h_q e^{2i\sigma_q}$
- SM $\Rightarrow$ $\Delta_q = 1$
- MFV (Yukawa) $\Rightarrow$ $\Phi^{NP}_q = 0$ and $\Delta_d = \Delta_s$

parameter		prediction in the presence of NP
Oscil.	Δm_q	$\lvert\Delta_q^{NP}\rvert \times \Delta m_q^{SM}$
Phases	2β	$2\beta^{SM} + \Phi_d^{NP}$
	$2\beta_s$	$2\beta_s^{SM} - \Phi_s^{NP}$
	2α	$2(\pi - \beta^{SM} - \gamma) - \Phi_d^{NP}$
	$\Phi_{12,q} = \mathrm{Arg}[-\frac{M_{12,q}}{\Gamma_{12,q}}]$	$\Phi_{12,q}^{SM} + \Phi_q^{NP}$
Asym SL	A^q_{SL}	$\frac{\Gamma_{12,q}}{M^{SM}_{12,q}} \times \frac{\sin(\Phi^{SM}_{12,q} + \Phi^{NP}_q)}{\lvert\Delta^{NP}_q\rvert}$
Lifetime diff.	$\Delta\Gamma_q$	$2\lvert\Gamma_{12,q}\rvert \times \cos(\Phi^{SM}_{12,q} + \Phi^{NP}_q)$

➔ SM parameters are fixed by :

$|V_{ub}|_{SL+\tau\nu}, |V_{cb}|, |V_{ud}|, |V_{us}|, \gamma, \gamma(\alpha) = \pi - \beta - \alpha$

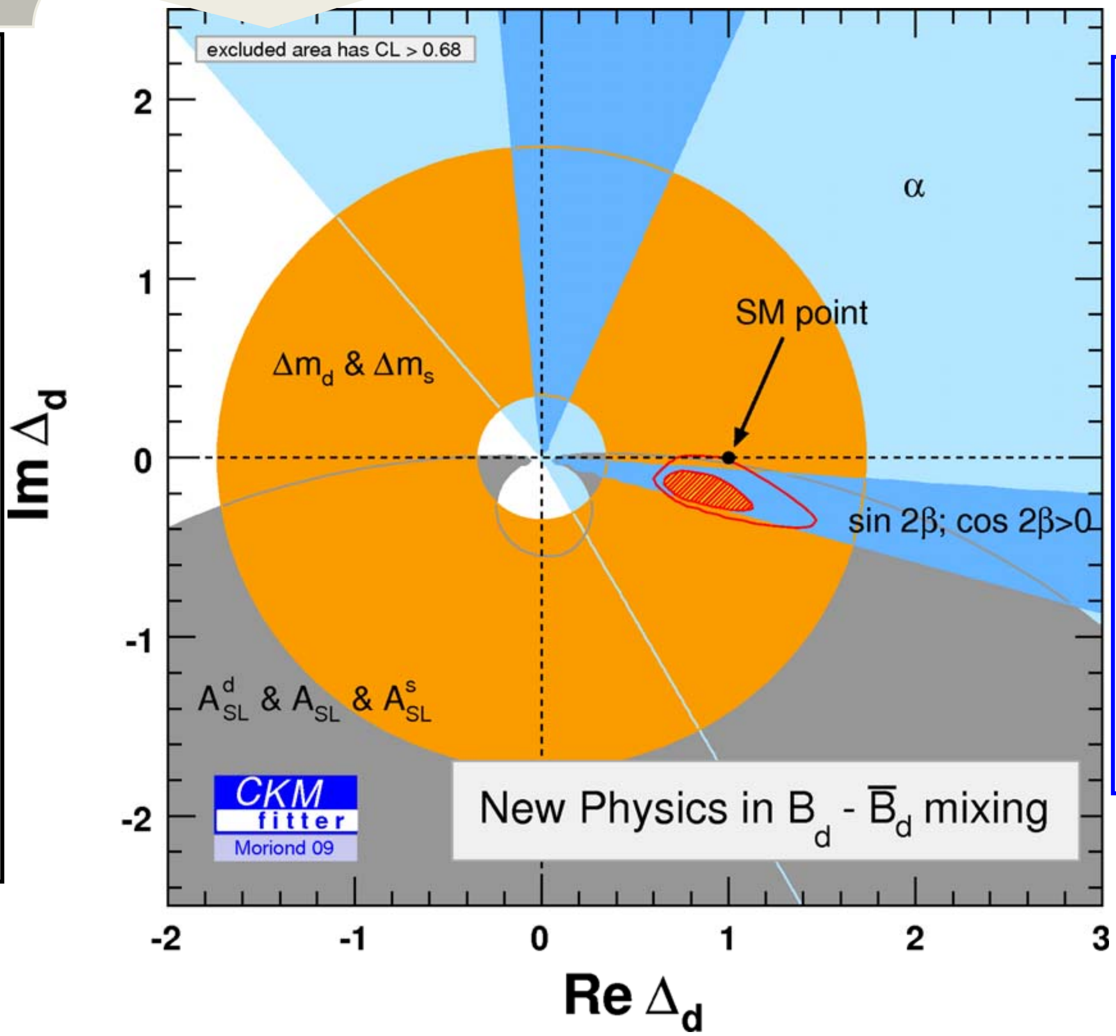


New Physics in B_d mixing

Inputs:

- Δm_s
- Δm_d
- $\sin(2\beta)$
- α
- A_{SL}, $A_{SL}^{B_d}$
- $A_{SL}^{B_s}$
- $\Delta\Gamma_d / \Gamma_d$
- $\Delta\Gamma_s$, ϕ_s

+SM params:
$|V_{ud}|$, $|V_{us}|$, $|V_{ub}|$, $|V_{cb}|$, $\gamma(\alpha)$, $B\to\tau\nu$



Warning : 68% CL

- **Dominant constraints** from β & Δm_d : both agrees with SM. *... but ...*
  ➔ tension from BR($B\to\tau\nu$)
  i.e.: $|V_{ub}| \Rightarrow \sin(2\beta)$
- Cartesian coordinates give simple interpretation of constraints:
  - angles : arcs
  - Δm : ellipses
- $|\Delta_d| <$ or $\sim 1 \Rightarrow$ KM mechanism is dominant.

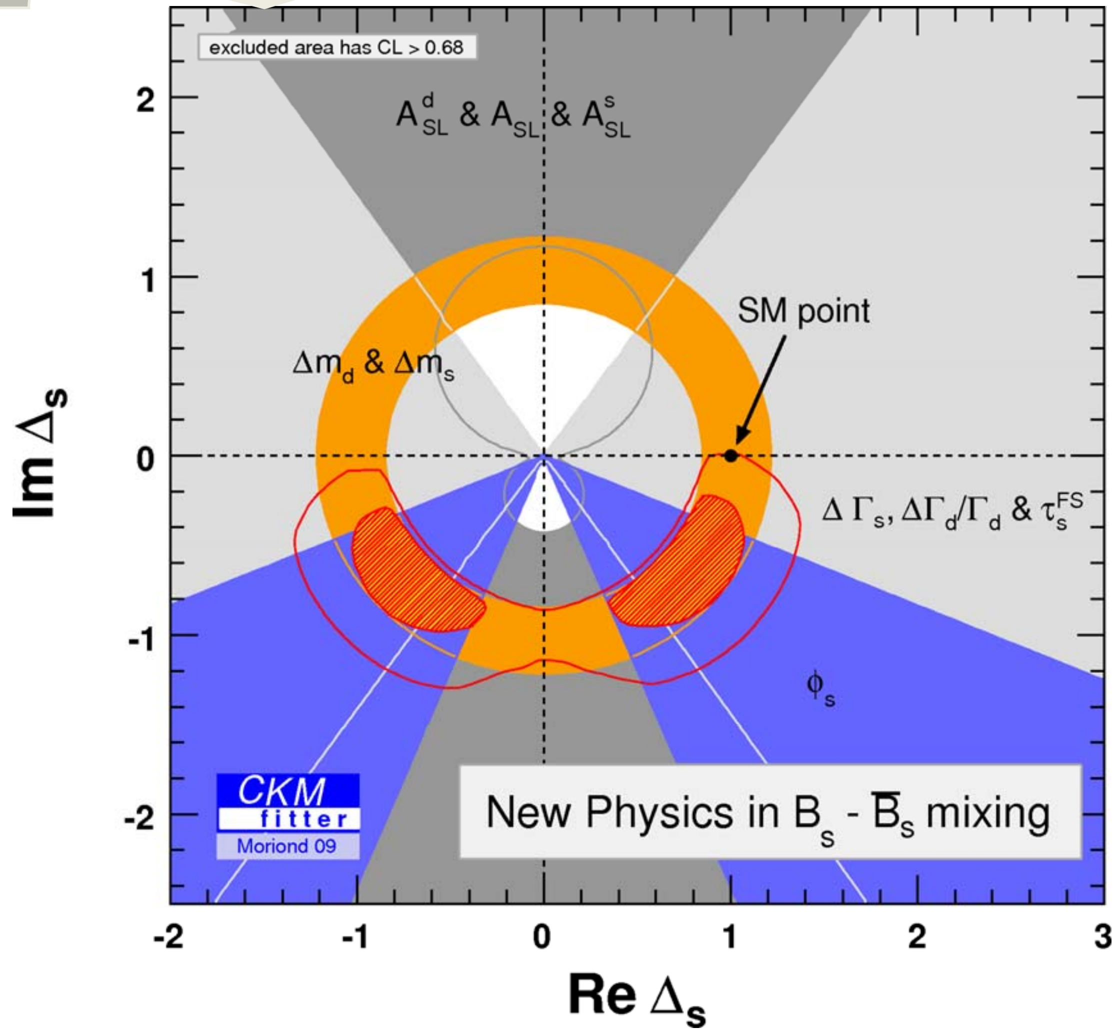
Agreement with SM :

hypothesis	with $B^+\to\tau^+\nu$	with out
$\Delta_d = 1$ (Re=1,Im=0)	2.1 σ	0.6 σ

New Physics in B_s mixing

Inputs:

Δm_s
Δm_d
$\sin(2\beta)$
α
A_{SL}, $A_{SL}^{B_d}$
$A_{SL}^{B_s}$
$\Delta\Gamma_d / \Gamma_d$
$\Delta\Gamma_s$, ϕ_s
+SM params:
|Vud|, |Vus|,
|Vub|, |Vcb|,
$\gamma(\alpha)$, $B \to \tau\nu$



Warning : 68% CL

Dominant constraints:

- Δm_s agrees with SM.
- (ϕ_s=-2β_s,$\Delta\Gamma_s$) through time dependent angular analysis of $B_s \to J/\psi\phi$ by DØ/CDF (HFAG'08 update) is 2.2σ away from SM.

Agreement with SM :

hypothesis	with $B^+ \to \tau^+\nu$	with out
Δ_s= 1 (Re=1,Im=0)	1.9 σ	1.9 σ

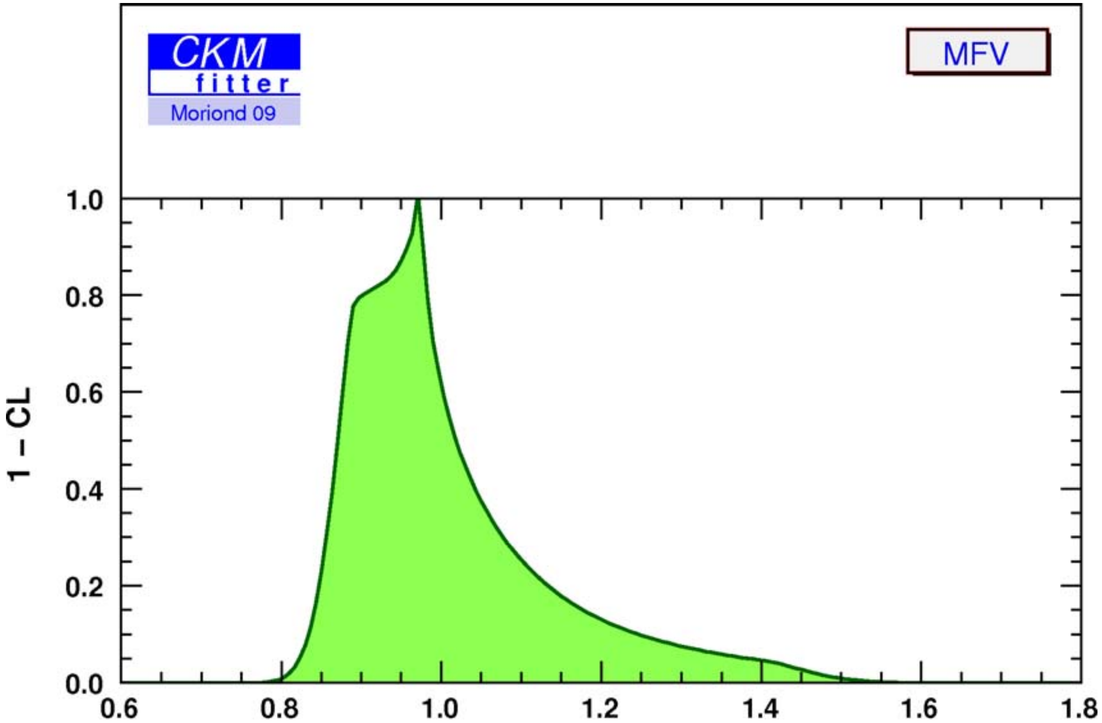
MFV in $B_{q=d,s}$ mixing

additional constraints:

$\Phi^{NP}{}_q=0$ and $\Delta_d = \Delta_s = \Delta$

Inputs:

Δm_s
Δm_d
$\sin(2\beta)$
α
A_{SL}, $A_{SL}^{B_d}$
$A_{SL}^{B_s}$
$\Delta\Gamma_d / \Gamma_d$
$\Delta\Gamma_s$, ϕ_s
+SM params:
|Vud|, |Vus|,
|Vub|, |Vcb|,
$\gamma(\alpha)$, $B\to\tau\nu$



SM point

Δ

In MFV scenario the impact from $\sin(2\beta)$ (tension from $|Vub|_{\tau^+\nu}$) & TeVatron ϕ_s is washed out: no new NP phase !

Conclusions, perspectives

- KM mechanism is at work and dominant for NP in quark b sector

  $\Rightarrow$ still room for NP both in B_d and B_s.

- overall good agreement in the global SM CKM fit:
  - a step forward on α precision, but need to go beyond SU(2).
  - but tension sin(2β) $\Leftrightarrow$ |Vub| with $B^+ \to \tau^+ \nu$:

    - wait for new measurements by B-factories,
      whatever super-B factory ...
    - 2HDM models ?
    - LQCD, ... what else ?
  - but tension in direct TeVatron β_s measurement.

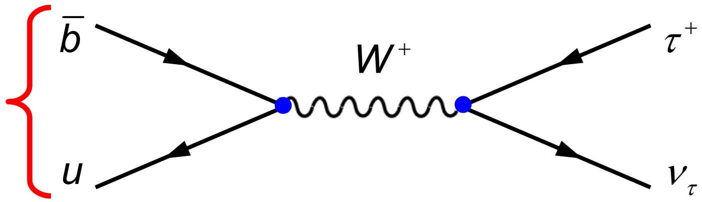
    $\Rightarrow$wait for more data & LHCb to enter the game.

- progresses on constraints from exp. vs LQCD (f_{Ds}), $b \to V\gamma$, and rare K decays.

BACKUP Slides

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

- helicity-suppressed annihilation decay sensitive to $f_B \times |V_{ub}|$
- Sensitive to tree-level charged Higgs replacing the W propagator.



$$BR(B^+ \to \tau^+ \nu) = \frac{G_F^2 m_B \tau_B}{8\pi} m_\tau^2 \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 f_B^2 \, |V_{ub}|^2$$

BR[10^{-4}]=1.80 ± 0.63
- 1.80±1.00 (had)
- 1.80±0.81 (semi-lept)

BR[10^{-4}]=1.70 ± 0.42
- 1.79±0.71 (had)
- 1.65±0.52 (semi-lept)

Measurement are consistent & WA:

BF[10^{-4}]= 1.73 ± 0.35

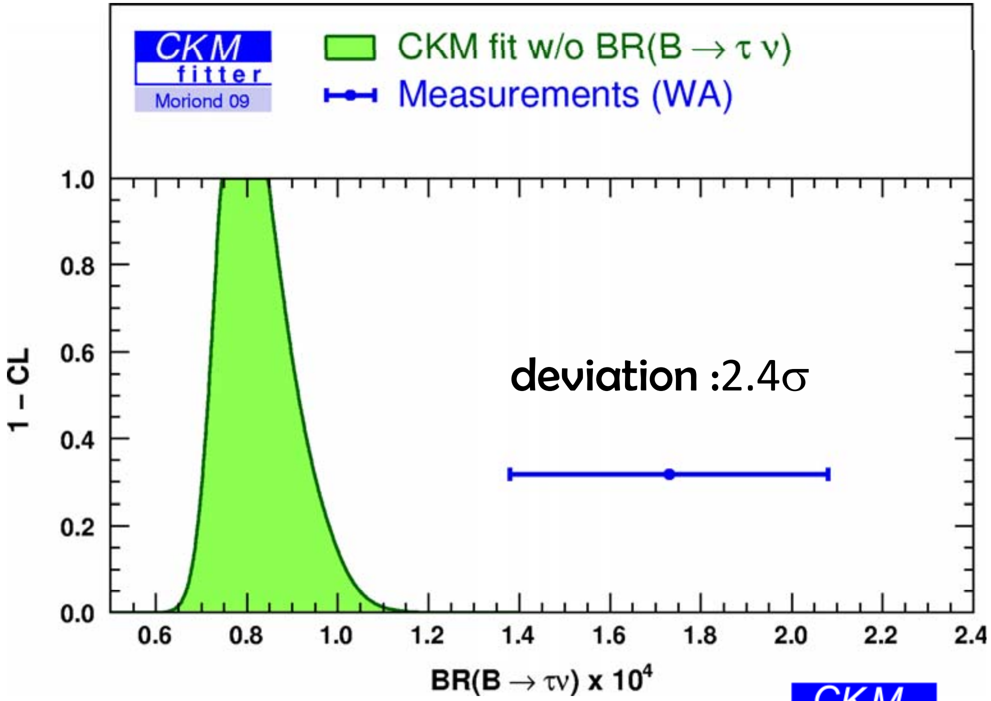
Measurement from global CKMfit:

BF[10^{-4}]= $0.796^{+0.154}_{-0.093}$

Inputs:

$|V_{ub}|$, Δm_d, Δm_s, $|\varepsilon_K|$, $\sin 2\beta$, α, γ

f_{Bd} from our own LQCD average:
f_{Bs}/f_{Bd}= 1.196(8)(23) & f_{Bs}= 228(3)(17)



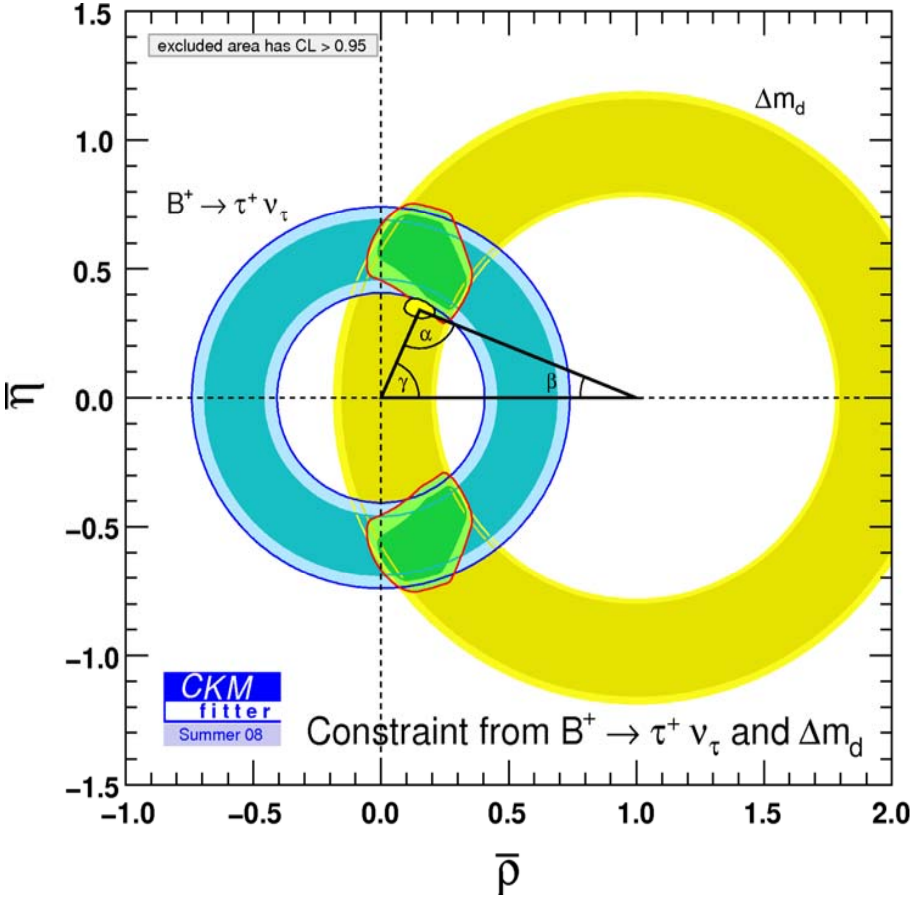
new CLEO-C '09 $D_s^+ \to \tau^+\nu$ (~fine)...

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

Powerful <u>together</u> with Δm_d : removes f_B (Lattice QCD) dependence

(left with B_d errors anyway). If error of f_{Bd} small : 2 circles that intersect at ~90°

$$\frac{BR(B^+ \to \tau^+ \upsilon)}{\Delta m_d} = \frac{3\pi}{4} \frac{m_\tau^2 \tau_{B^+}}{m_W^2 S(x_t)} \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 \frac{\sin^2(\beta)}{\sin^2(\gamma)} \frac{1}{|V_{ud}|^2 B_{B_d}}$$



Inputs:

Δm_d

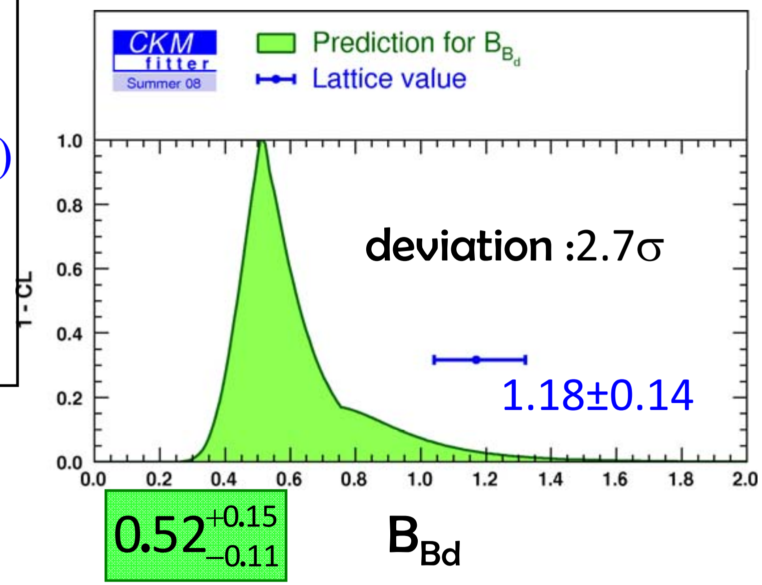
$B \to \tau\nu$

$\gamma(=\pi-\beta-\alpha)$

$\sin 2\beta$

$|V_{ud}|$

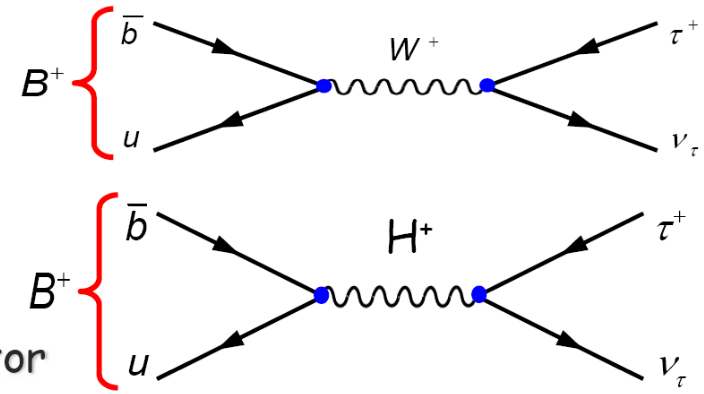
Theory free prediction for B_{Bd}



The tension is not driven by V_{ub} (SL) nor f_{Bd} (nor ε_K)

$B^+ \to \tau^+ \nu$ & charged Higgs

$$BR(B^+ \to \tau^+ \nu) = \frac{G_F^2 m_B \tau_B}{8\pi} m_\tau^2 \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 f_B^2 \, |V_{ub}|^2$$

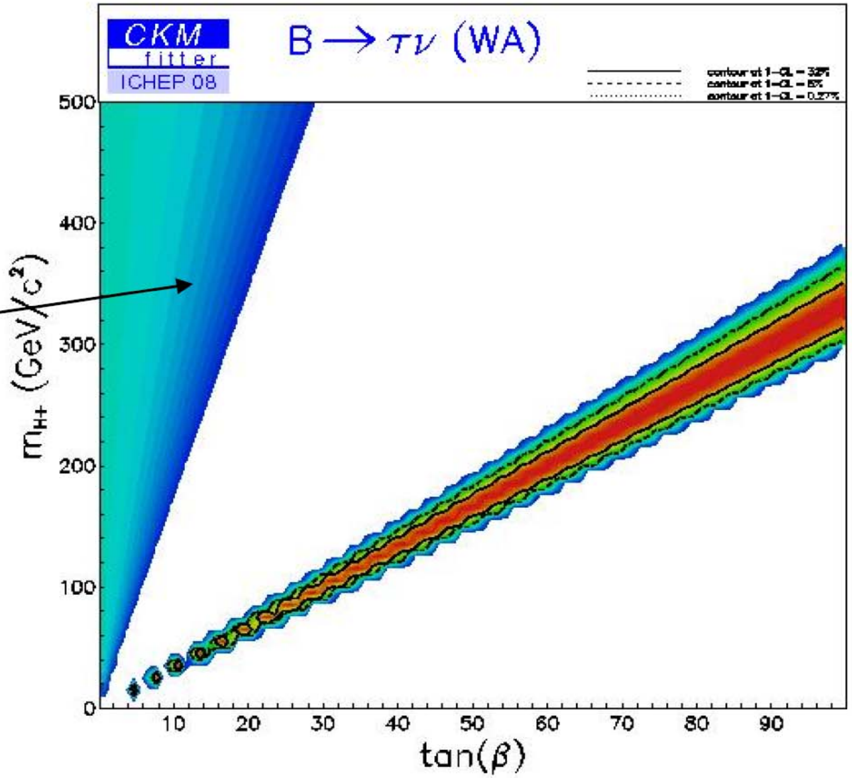


- Helicity-suppressed annihilation decay sensitive to $f_B \times |V_{ub}|$
- Powerful together with Δm_d : removes f_B dependence
- Sensitive to charged Higgs replacing the W propagator

e.g : 2HDM type II

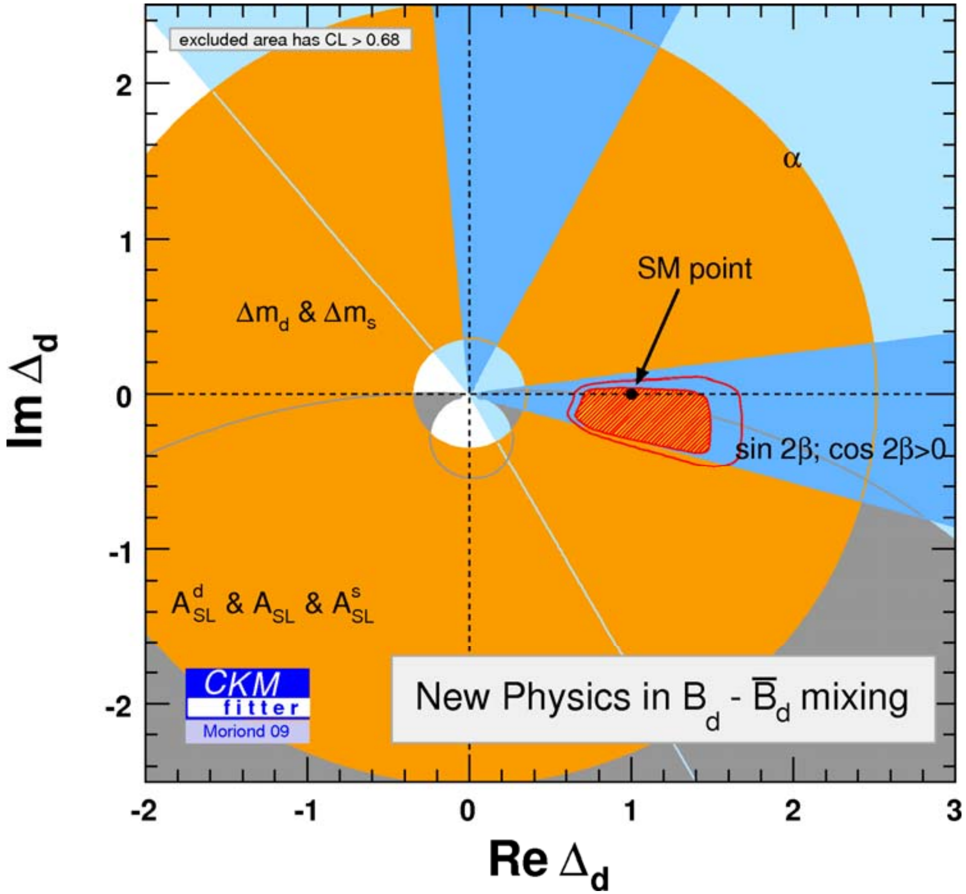
$$BR(B^+ \to \tau^+ \nu_\tau) = BR^{SM} \times \left(1 - \frac{m_B^2}{m_H^2} \tan^2 \beta\right)^2$$

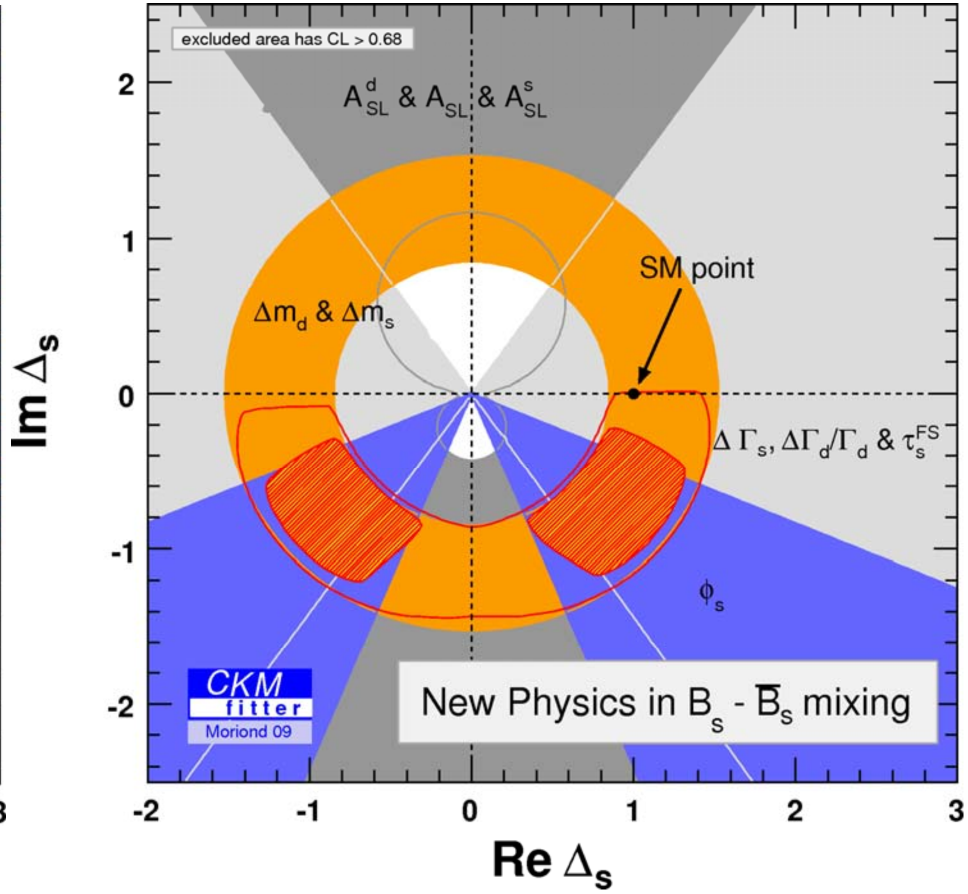
Disfavoured region
$BR/BR^{SM} < 1$



O.Deschamps ICHEP'08

New Physics in B_d & B_s mixing without $B^+ \to \tau^+ \nu$





Removing $B^+ \to \tau^+ \nu$ impacts Δm_d precision $\Rightarrow$ one less constraint for the decay constant f_{Bd} (only LQCD: more SM like) and

relaxes the $\sin(2\beta) \Leftrightarrow |V_{ub}|$ tension but no impact on TeVatron ϕ_s

MFV in $B_{q=d,s}$ mixing without $B^+ \to \tau^+ \nu$

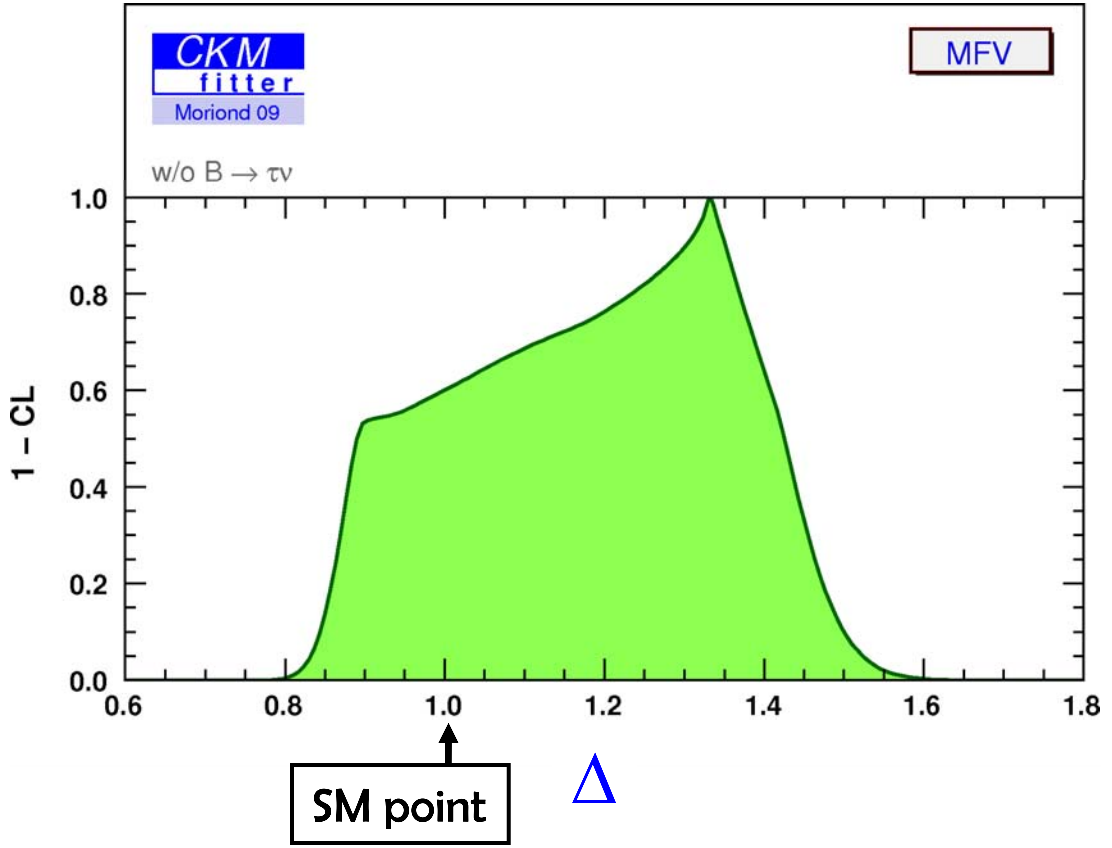
additional constraints:

$\Phi^{NP}_q = 0$ and $\Delta_d = \Delta_s = \Delta$

Inputs:

- Δm_s
- Δm_d
- $\sin(2\beta)$
- α
- A_{SL}, $A_{SL}^{B_d}$
- $A_{SL}^{B_s}$
- $\Delta\Gamma_d / \Gamma_d$
- $\Delta\Gamma_s$, ϕ_s

+SM params:
|Vud|, |Vus|, |Vub|, |Vcb|, $\gamma(\alpha)$, $B \to \tau\nu$



Removing $B^+ \to \tau^+ \nu$ impacts Δm_d precision $\Rightarrow$ one less constraint for the decay constant f_{Bd} (only LQCD: more SM like)

$|\varepsilon_K|$

Only input from indirect CP violation in mixing and in K^0-$\bar{K}^0$ interference w. and w.o. mixing

- dominated by badly controlled long distances contributions but accountable corresponding systematic.
- Note : ε' direct CPV has much larger hadronic uncertainties (gluonic penguins): excluded.

$$|\epsilon_K| = C_\epsilon \hat{B}_K \lambda^2 \bar{\eta}^2 |V_{cb}|^2 \left[|V_{cb}|^2 (1-\bar{\rho}) \eta_{tt} S_0(x_t) + \eta_{ct} S_0(x_c, x_t) - \eta_{cc} S_0(x_c) \right]$$

$$C_\epsilon = \frac{G_F^2 f_K^2 m_K m_W^2}{6\sqrt{2}\pi^2 \Delta m_K}$$

Where S_0 is an Inami-Lim loop function, $x_q = m^2_q/m^2_W$, and η_{ij} are perturbative QCD corrections.

- The constraint from in the $(\bar{\rho},\bar{\eta})$ plane is bounded by approximate hyperbolas.
- The dominant uncertainties are due to the bag parameter, for which we use $\hat{B}_K$=0.721(5)(40) from LQCD, and the parametric uncertainty approximately proportional to $\sigma(|V_{cb}|^4)$~8%, comparable in size.

$|\varepsilon_K|_{PDG08,exp}$= 2.229(12) ×10^{-3} and $|\varepsilon_K|_{CKMfit}$= $(2.06^{+0.47}_{-0.53})$ ×10^{-3}

$$\epsilon_K = e^{i\phi_\epsilon} \sin\phi_\epsilon \left(\frac{\mathrm{Im}(M_{12}^K)}{\Delta M_K} + \xi \right) \qquad \phi_\epsilon = (43.51 \pm 0.05)^\circ \qquad \kappa_\epsilon = \sqrt{2}\sin\phi_\epsilon \bar{\kappa}_\epsilon$$

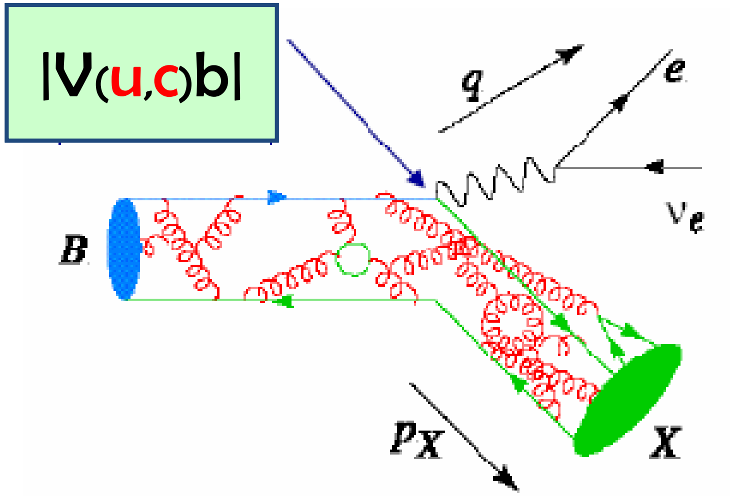
CPV

➔ Recent work by Buras & Guadagnoli (+Soni & Lunghi) suggest an additional effective suppression multiplicative factor κ_ε=0.92(2), 💣 not clear yet how we understand this parameter 💣 in arXiv 0805.3887: *"our very rough estimate at the end of the paper show that $\bar{\kappa}_\varepsilon$<0.96, with 0.94(2) being a plausible figure".*

➔ BTW when plugging sin2β WA + other relevant inputs, they quote (error treatment/budget ??):

$|\varepsilon_K|_{SM}$= 1.78(25) ×10^{-3} ie: deviation ⇒ NP ?!

|V(u,c)b|



- $|V_{cb}|$ ($\rightarrow$ A) is important in the kaon system (ε_K, BR($K\rightarrow\pi\nu\nu$), ...)
- $|V_{ub}|$ ($\rightarrow$ $\bar{\rho}^2+\bar{\eta}^2$) is crucial for the SM prediction of sin(2β)

★ $|V_{cb}|$: already precision measurement: 1.7% !

$|V_{cb}|_{incl.}[10^{-3}]$= 41.67(44)(58)

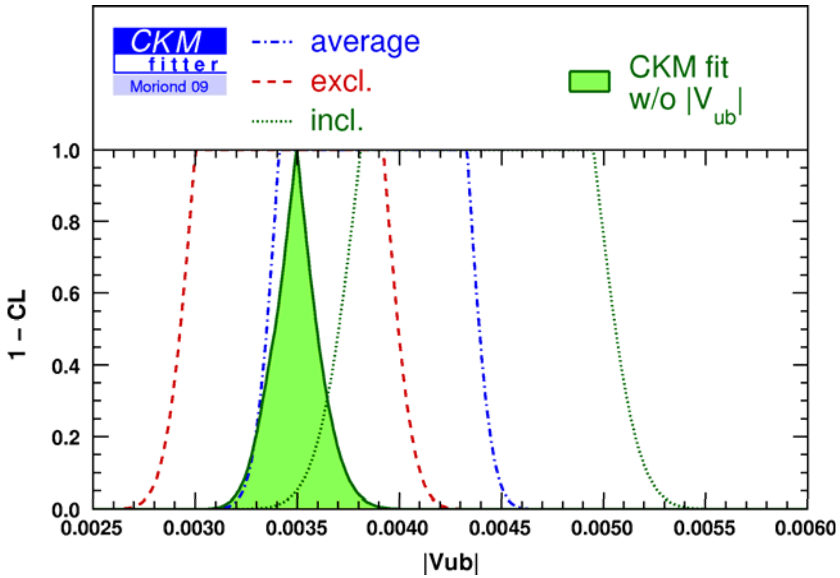
HAFG summer 08

Note: $|V_{cb}|_{excl.}$ $[10^{-3}]$= 38.20(78)(83)
(dominated by Form Factor F(1) =0.921(13)(20))

★ $|V_{ub}|$: room for questions !

Very difficult as phase space cuts applied to suppress b $\rightarrow$clv bkgd (~x 50) complicate the theory for inclus. Meas.: lower scales (non perturb. function), renorm. shape functions, structure of sub-leading terms complicated.
Use the B-beam technique & several kinematic variables:
E_l, m_X, q^2, ...

- SF params. from b$\rightarrow$clν , OPE from BLNP
- BR precision ~8%, |Vub| excl. ~ 14%: FF theory dom.
  (B → $\pi l \upsilon$ important also for $\pi\pi$, $K\pi$ decays ...)
- adapted from HFAG summer 08:
  - $|V_{ub}|_{incl.}[10^{-3}]$= 4.38(16)(57) our syst. estimate
  - $|V_{ub}|_{excl.}$ $[10^{-3}]$=3.46(11)(46)



Δm_d & Δm_s

$\Delta m_s = 17.77(10)(7)\ ps^{-1}$

➔ a 5.4 σ measurement PRL97, 242003 (2006)

HFAG : $\Delta m_d = 0.507(5)\ ps^{-1}$

➔ uncertainty $\sigma(\Delta m_s)$=0.7% already smaller than $\sigma(\Delta m_d)\approx$1% !

$$\Delta m_s = \frac{G_F^2}{6\pi^2} m_{B_s} m_W^2 \eta_B S_0(x_t) f_{B_s}^2 B_s \left|V_{ts} V_{tb}^*\right|^2$$

Very weak dependence on $\bar{\rho}$ and $\bar{\eta}$

$$\xi = \frac{f_{Bs}\sqrt{Bs}}{f_{Bd}\sqrt{Bd}}$$

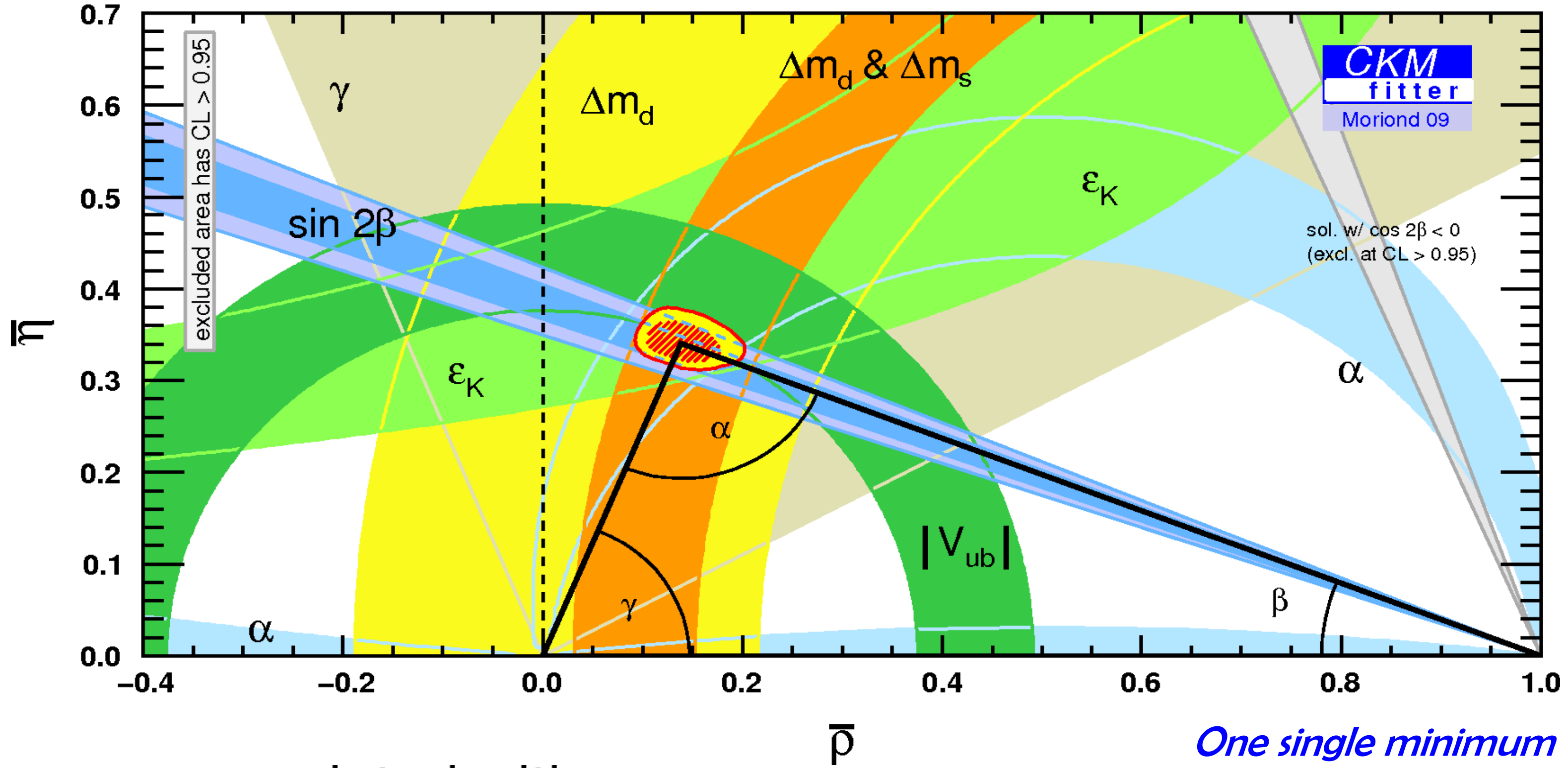
the SU(3) breaking corrections (largest uncertainty)

Measurement of Δm_s reduces the uncertainties on $f^2_{B_d} B_d$ since ξ is better known from LQCD

➔Leads to improvement of the constraint from Δm_d measurement on $|V_{td}V^*_{tb}|^2$

$$\Delta m_d = \frac{G_F^2}{6\pi^2} m_{B_d} m_W^2 \eta_B S_0(x_t) f_{B_d}^2 B_d \left|V_{td} V_{tb}^*\right|^2 \propto A^2 \lambda^6 \left[(1-\bar{\rho})^2 + \bar{\eta}^2\right]$$

Global CKM fit: the B_d mesons $(\bar{\rho},\bar{\eta})$ plane



One single minimum

The one associated with B_d meson

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

$$O(1) + O(1) + O(1)$$

$$\alpha = \arg\left[-\frac{V_{td}V_{tb}^*}{V_{ud}V_{ub}^*}\right], \quad \beta = \arg\left[-\frac{V_{cd}V_{cb}^*}{V_{td}V_{tb}^*}\right],$$

$$\gamma = \arg\left[-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right].$$

Global CKM fit: testing the paradigm

Inputs:

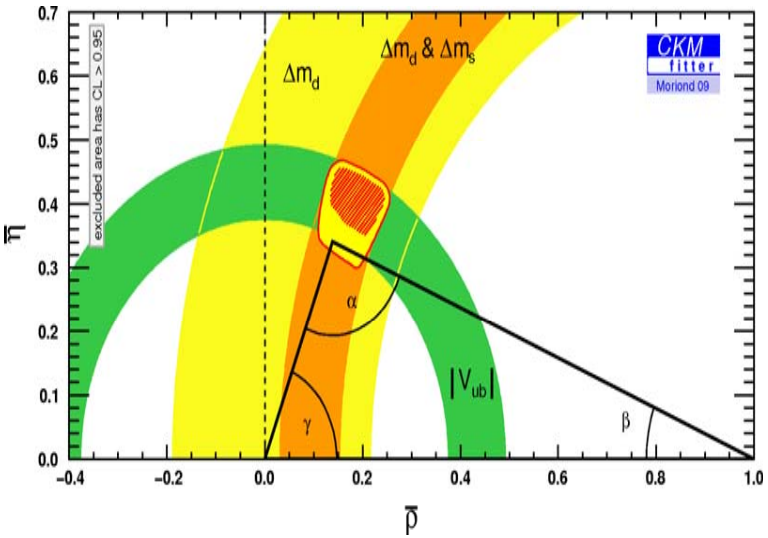
$|V_{ub}|$

$B \to \tau\nu$

Δm_d

Δm_s

CP-conserving observables



Inputs:

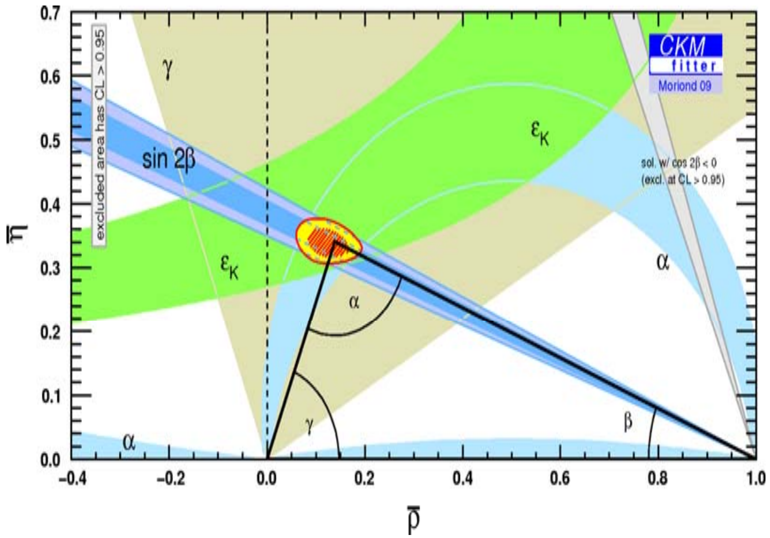
$|\varepsilon_K|$

$\sin 2\beta$

α

γ

CP-violating observables



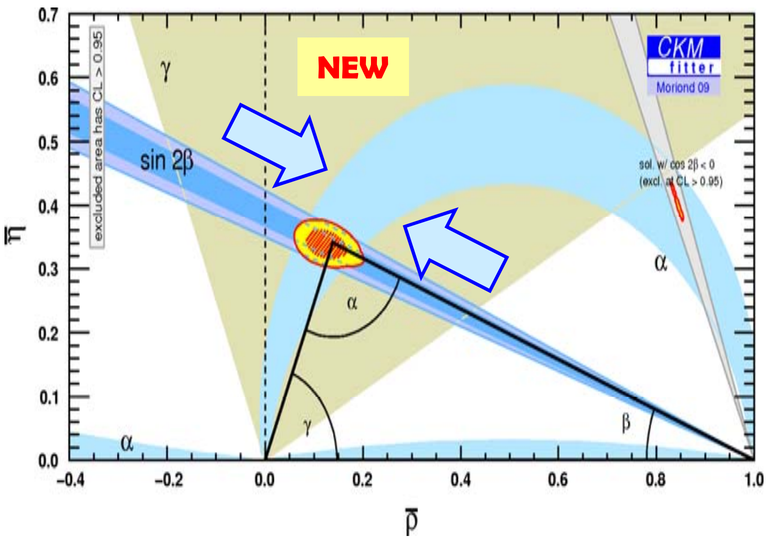
Inputs:

$\sin 2\beta$

α

γ

Angles (small theor. uncertainties)



Inputs:

$|\varepsilon_K|$

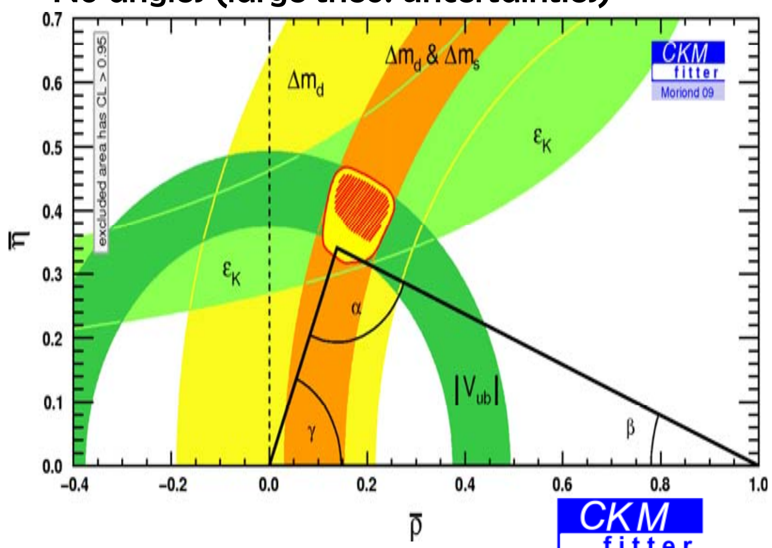
$|V_{ub}|$

$B \to \tau\nu$

Δm_d

Δm_s

No angles (large theo. uncertainties)



Global CKM fit: other numerical results, a selection

Physics param./Observable	Central ± 1 σ
A	0.8116 [+0.0096 -0.0241]
λ	0.22521 [+0.00082 -0.00082]
J [10^{-5}]	2.92 [+0.15 -0.15]
α (deg) (meas. not in the fit)	95.6 [+3.8 -8.8]
β (deg) (meas. not in the fit)	21.66 [+0.95 -0.87]
γ (deg) (meas. not in the fit)	67.8 [+4.2 -3.9]
β_s(deg) (meas. not in the fit)	1.035 [+0.049 -0.046]
Δm_s [ps^{-1}] (meas. not in the fit)	17.6 [+1.7 -1.8]
$\|V_{ub}\|$ [10^{-3}] (meas. not in the fit)	3.50 [+0.15 -0.14]
BR(B->$\tau\nu$) [10^{-4}] (meas. not in the fit)	0.796 [+0.154 -0.093]
BR(B->$\mu^+\mu^-$) [10^{-11}]	10.8 [+0.4 -0.9]
BR(B_s->$\mu^+\mu^-$) [10^{-9}]	3.29 [+0.09 -0.27]

Results and plots at: http://ckmfitter.in2p3.fr/

LQCD own average: the most of hadronic inputs

- Z. Ligeti at USLQCD Dec'07 on lack of LQCD averages: "If experts cannot agree, it's unlikely the rest of the community would believe a claim of new physics".

- Many collaborations with different methods of simulations, results, and estimations of errors.

- use only unquenched results with 2 or 2+1 dynamical fermions (sea quarks), also include staggered fermions (even if : still QCD?)

➔ papers & proceedings: RBC, UKQCD, HPQCD, JLQCD, CP-PACS, FNAL Lattice, MILC, ETMC, NPLQCD...

- Our Own Average this time:

1) standard χ^2 fit with only the statistical errors
2) theoretical uncertainty of the combination = the one of the most precise method

➔ conservative approach :

- the present state of art cannot allow us to reach a better theoretical accuracy than the best of all estimates
- this best estimate should not be penalized by less precise methods (opposed to combined syst= dispersion of central values).

Sources of uncertainties

S. Descotes-Genon

Euclidean, finite, discrete box $\langle Q \rangle = \int [dA] \hat{Q}[A] (\det S_f[A])^{N_f} \exp(-S_{YM}[A])$

observable = statistical average over gauge configurations weighted according to gauge and fermion actions

Statistical

- Size of the ensemble of gauge configurations
- Part of errors listed below (when scaling with size of gauge config)

Systematics

- Fermion action : $N_f = 2$, staggered fermions
- Continuum limit/discretisation error $a \to 0$
- Finite volume effects $L \to \infty$
- Quark mass extrapolation (chiral limit and heavy quark limit)

α from b→uūd, B→ππ

Gronau, London (1990)

- completely general isospin decomposition

$$A_{+-} = \langle \pi^+\pi^- | H | B^0 \rangle = -A_{1/2} + \frac{1}{\sqrt{2}} A_{3/2} - \frac{1}{\sqrt{2}} A_{5/2}$$

$$A_{00} = \langle \pi^0\pi^0 | H | B^0 \rangle = \frac{1}{\sqrt{2}} A_{1/2} + A_{3/2} - A_{5/2}$$

$$A_{+0} = \langle \pi^+\pi^0 | H | B^+ \rangle = \frac{3}{2} A_{3/2} + A_{5/2}$$

- neglecting $A_{5/2} \sim \alpha A_{1/2}$ (i.e. $\sim 1\%$ correction)

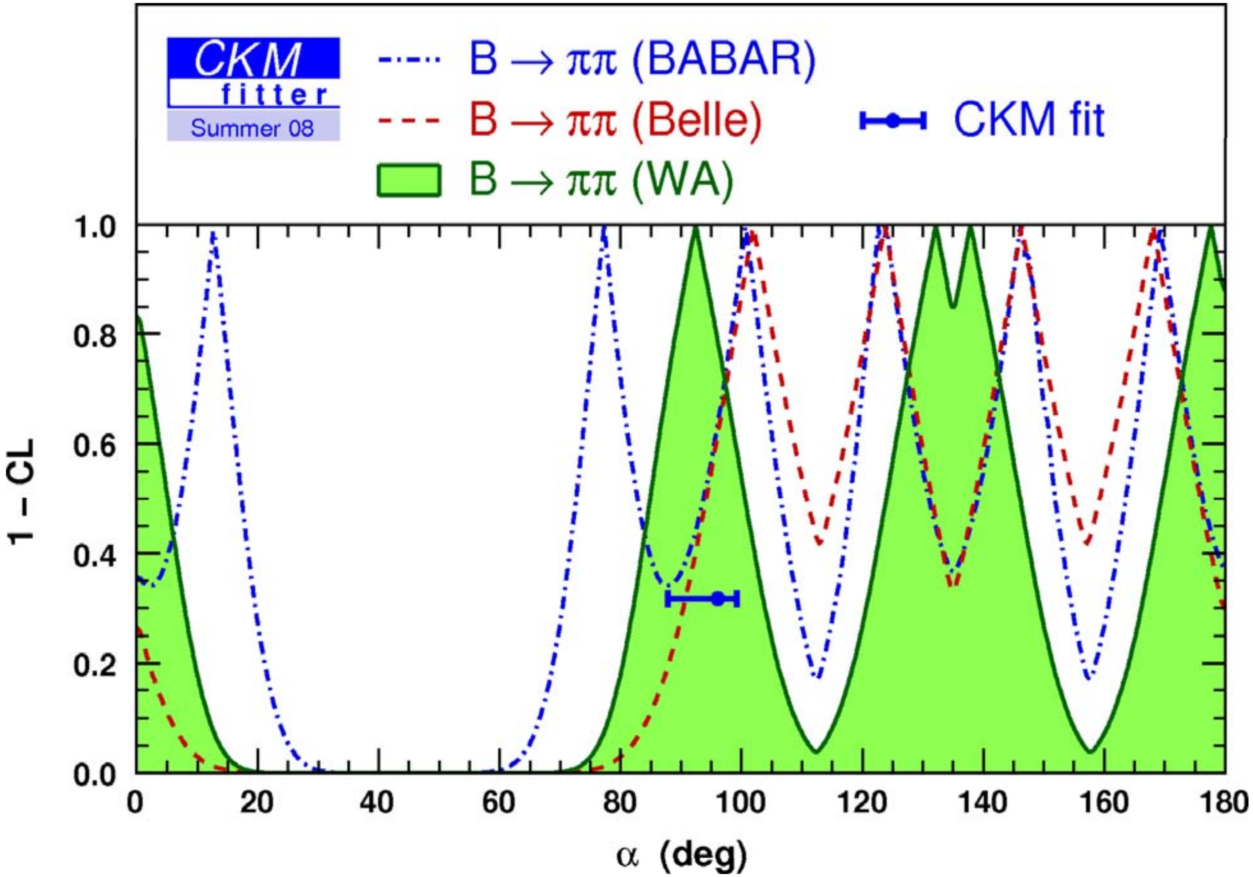
$$A_{+-} + \sqrt{2} A_{00} = \sqrt{2} A_{+0}$$
$$\bar{A}_{+-} + \sqrt{2} \bar{A}_{00} = \sqrt{2} \bar{A}_{+0}$$

- neglecting EWP $\Rightarrow$ A_{+0} only tree contribs.

$$e^{i\gamma} A_{+0} = e^{-i\gamma} \bar{A}_{+0} \quad \Rightarrow \quad |A_{+0}| = |\bar{A}_{+0}|$$

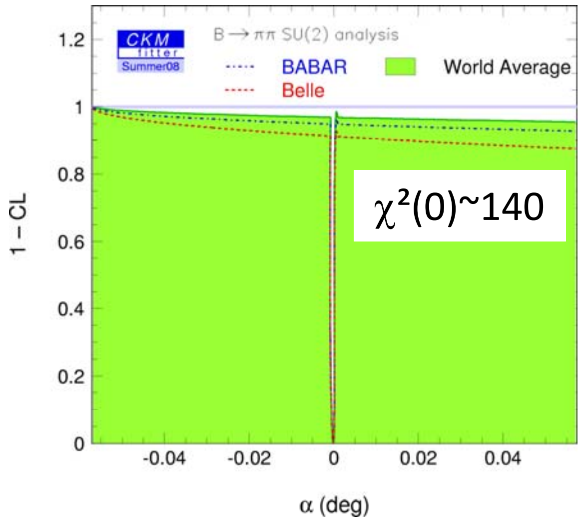
α from b→uūd, B→ππ

Same as for summer'08



$\alpha = (92.4^{+11.2}_{-10.0})°$

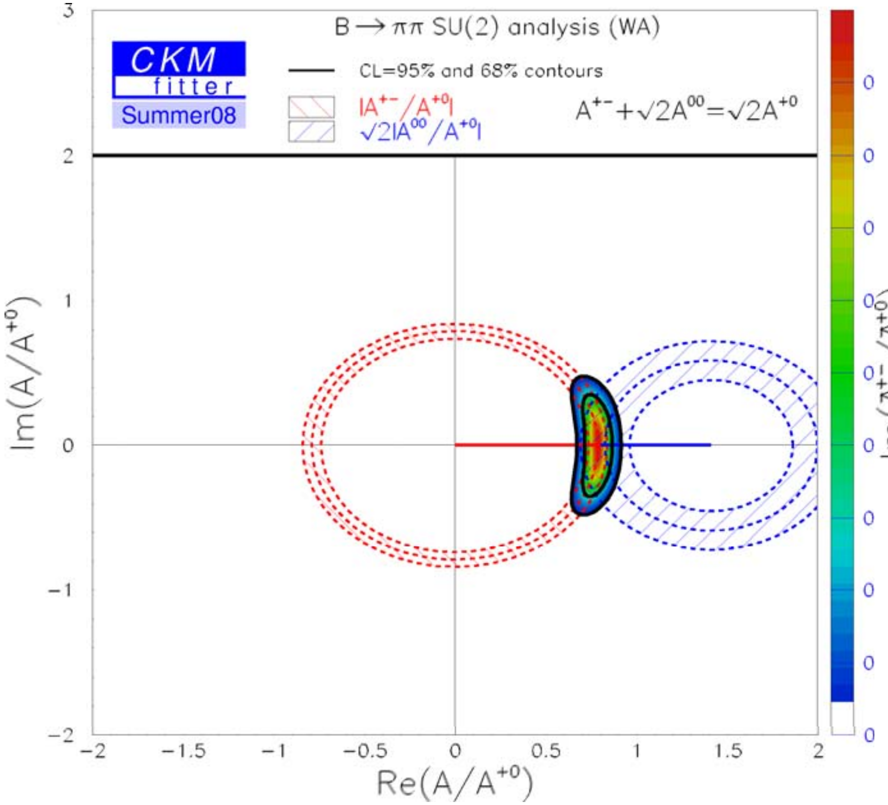
$\Delta\alpha = (20.0 \pm 10.3)°$

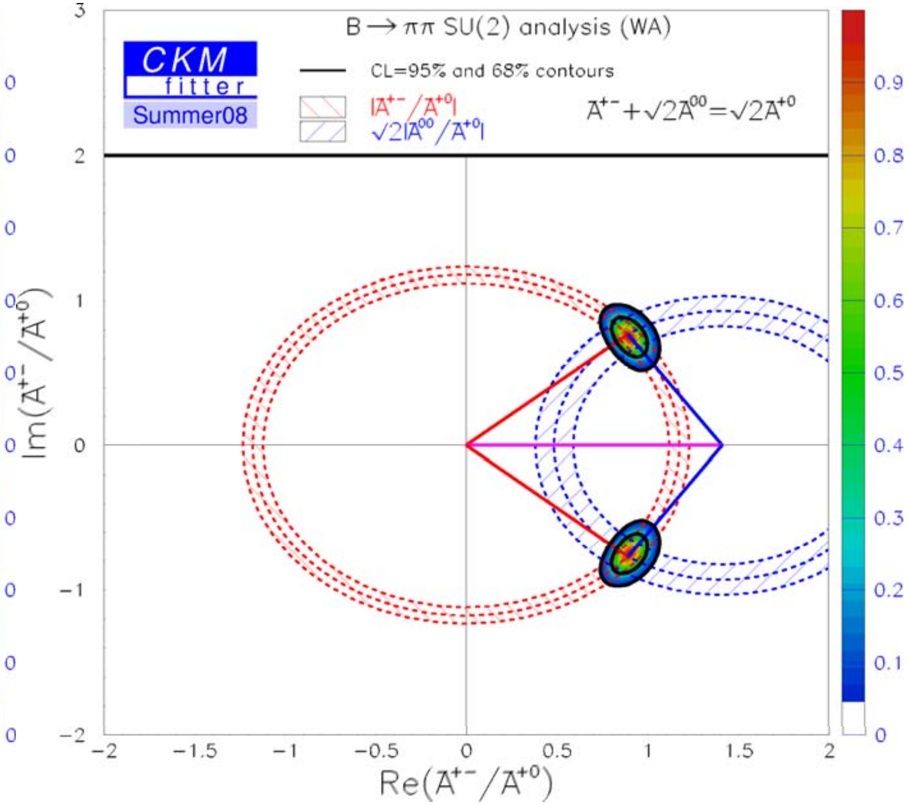


α from $b \to u\bar{u}d$, $B \to \pi\pi$

- Inputs :

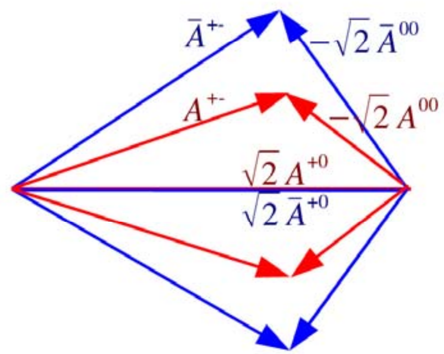
B^{+-}
B^{0+}
B^{00}
C^{+-}
S^{+-}
C^{00}





- One among the 2 triangles does not close

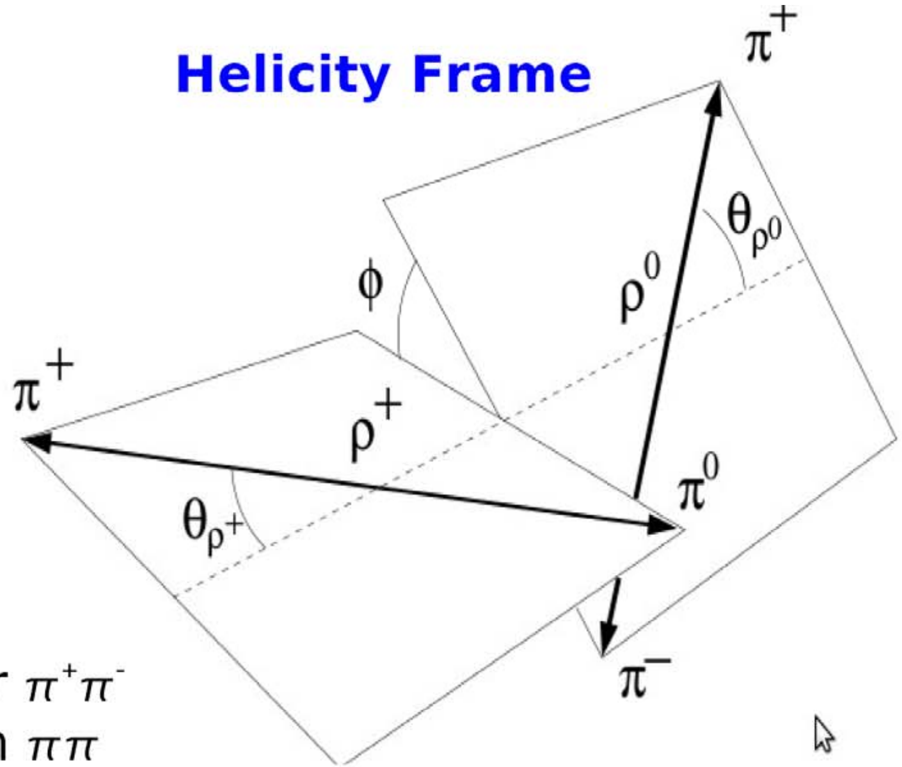
  → 4-fold solution for alpha



α from $b \to u\bar{u}d$, $B \to \rho\rho$

- **Much like $B \to \pi\pi$**
- **Disadvantages:**
  - Wide ρ resonances
  - V-V decay: different polarization states (L=0,1,2)
    - ⇒ Longitudinal: CP-even
    - ⇒ Transverse: Mixed CP states
- **Advantages:**
  - BF($\rho^+\rho^-$) ~ 5 times larger than for $\pi^+\pi^-$
  - Penguin pollution smaller than in $\pi\pi$
  - ρ 99% longitudinally polarized
  - Possible to measure S($\rho^0\rho^0$)
    - ⇒ raise degeneracy in ambiguities

Helicity Frame



f_L~1 ➔ CP+

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

A.Perez Lake Louise '09

α from $b \to u\bar{u}d$, $B \to \rho\rho$

Winter' 09 update : $B \to \rho^+\rho^0$ from BaBar (arXiv:0921.3522 wrt PRL 97, 261801 (06))

Both BR and f_L increase wrt summer '08 by ~2σ and ~1σ, respectively

$$B^{+0} = 16.8(3.2)10^{-6} \Rightarrow 23.7(2.0)10^{-6} \text{ (BaBar)}$$

$$f_L^{+0} = 0.905(47) \Rightarrow 0.950(16) \text{ (BaBar)}$$

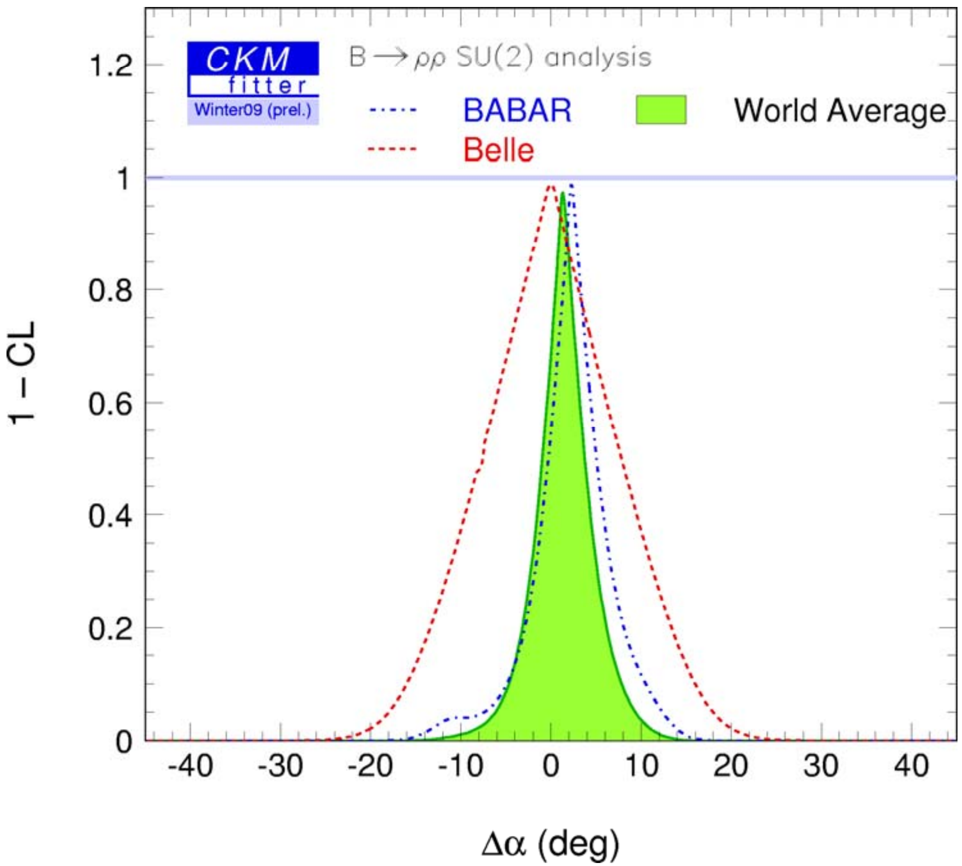
$$B^{+0} = 18.2(3.0)10^{-6} \Rightarrow 24.0(1.9)10^{-6} \text{ (WA)}$$

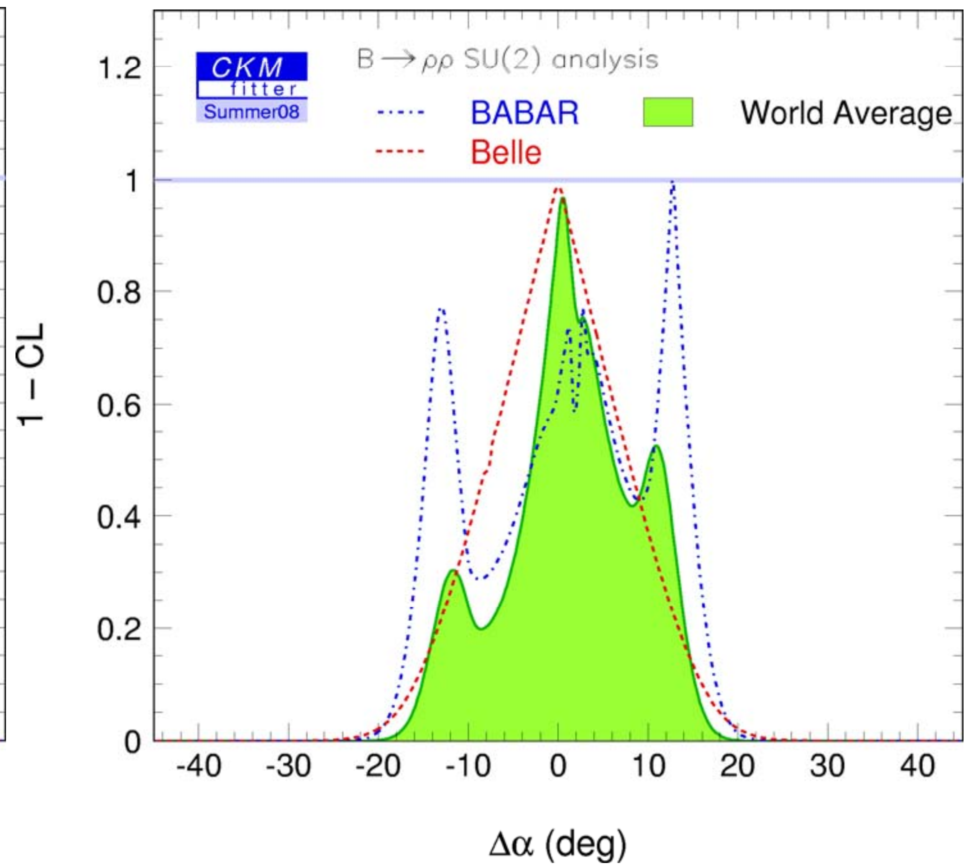
$$f_L^{+0} = 0.912(44) \Rightarrow 0.950(15) \text{ (WA)}$$

α from $B \to \rho\rho$

$\alpha = (89.9 \pm 5.4)^\circ$
$\Delta\alpha = (1.4 \pm 3.7)^\circ$

Summer'08 was :
$\alpha = (90.9^{+6.7}_{-14.9})^\circ$
$\Delta\alpha = (0.5^{+12.6}_{-5.5})^\circ$

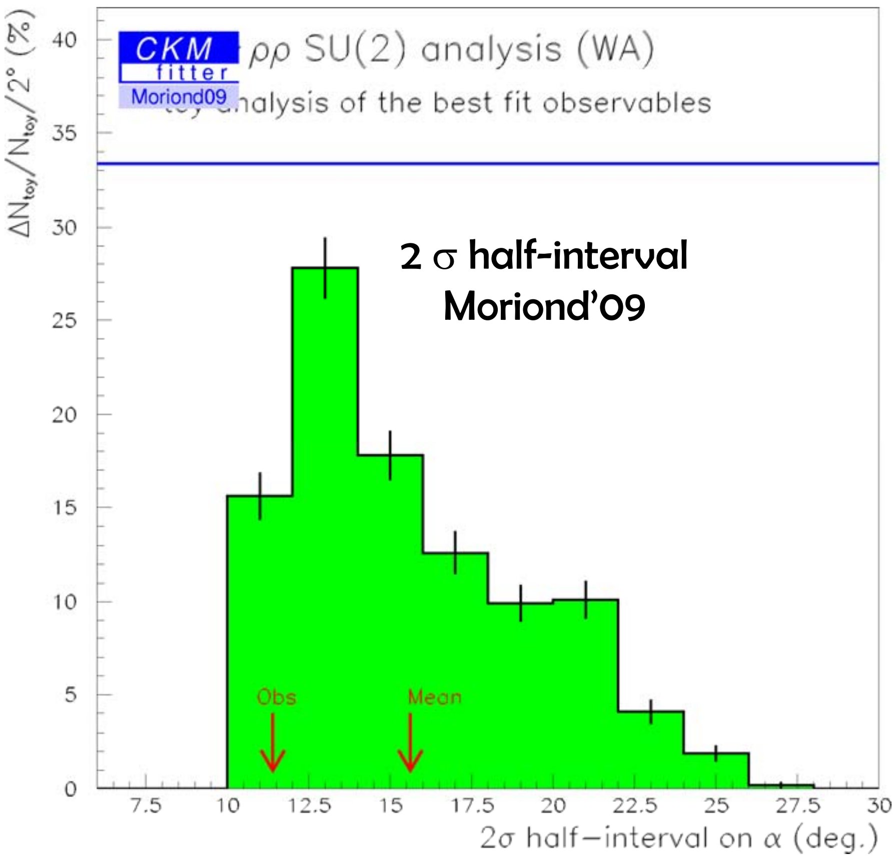




α from $B \to \rho\rho$

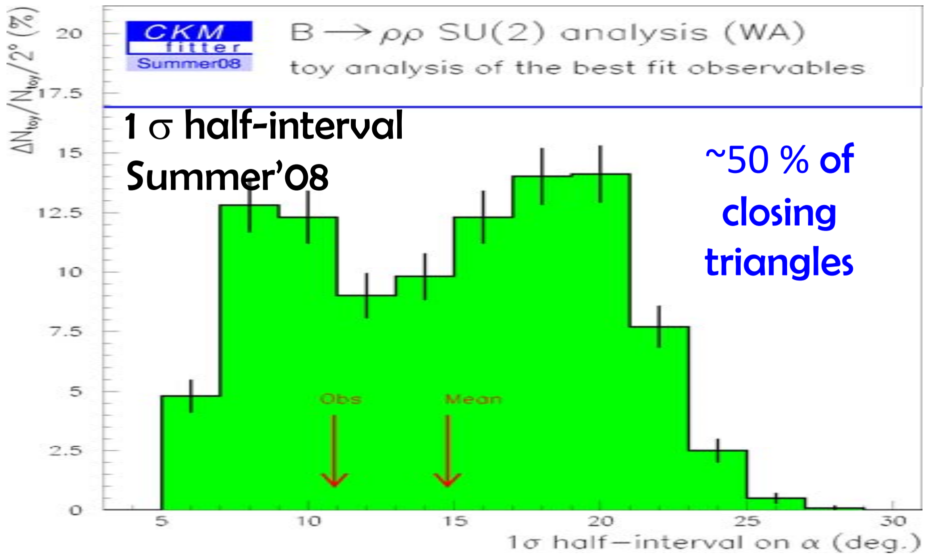
α = (89.9 ± 5.4)°
$\Delta\alpha$ = (1.4 ± 3.7)°

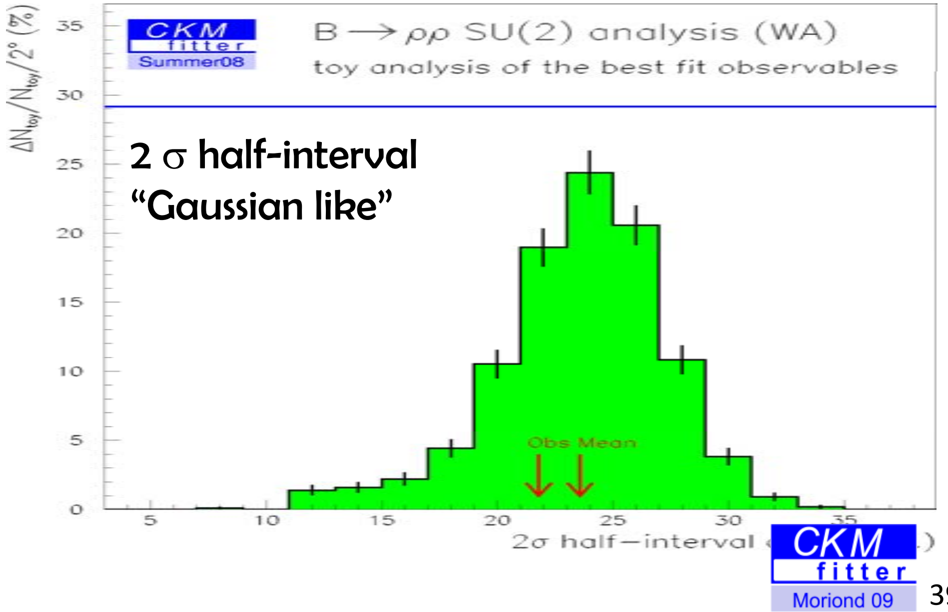
Summer'08 was :
$\alpha = (90.9^{+6.7}_{-14.9})^\circ$
$\Delta\alpha = (0.5^{+12.6}_{-5.5})^\circ$



→ How lucky are we ? toy study:

Gaussian smear of all inputs around best CKM fitted values: BR^{+-}, BR^{0+}, BR^{00}, C^{+-}, S^{+-}, C^{00}, S^{00}, f_L^{+-}, f_L^{0+}, f_L^{00}





Isospin breaking

SOURCES

- the standard methods for obtaining α from $B \to \pi\pi, \rho\rho, \rho\pi$ use isospin
  Gronau, London (1990)
  Snyder, Quinn (1993)
- theory error on α due to isospin breaking
  - d and u charges different
  - $m_u \neq m_d$
- extends the basis of operators to EWP $Q_{7,...,10}$
- mass eigenstates do not coincide with isospin eigenstates: $\pi - \eta - \eta'$ and $\rho - \omega$ mixing
- reduced matrix elements only appr. related by Clebsch Gordan coeff.
- may induce $\Delta I = 5/2$ operators not present in H_W

SIZES

- not all isospin breaking effects can be calculated/constrained at present
- the ones that can be are of expected size

$$\sim (m_u - m_d)/\Lambda_{QCD} \sim \alpha_0 \sim 1\%$$

- EWP effect known model indep. (negl. $Q_{7,8}$)
  Neubert, Rosner; Gronau, Pirjol, Yan;Buras, Fleischer (1999)

$$\Delta\alpha_{\text{EWP}} = (1.5 \pm 0.3 \pm 0.3)^\circ$$

  the same for $\pi\pi, \rho\rho, \rho\pi$
- for $\pi^0 - \eta - \eta'$ mixing M. Gronau, J.Z. (2005), S. Gardner (2005)

$$|\Delta\alpha_{\pi\pi}^{\pi-\eta-\eta'}| < 1.6^\circ$$

Isospin breaking B→ρρ

J. Zupan CKM WS'06

- since $\Gamma_\rho \neq 0 \Rightarrow I = 1$ contributions possible
  Falk, Ligeti, Nir, Quinn (2003)
  - $O(\Gamma_\rho^2/m_\rho^2)$ effect
  - possible to constrain experimentally
- isospin breaking M. Gronau, JZ (2005)
  - EWP same as for $B \to \pi\pi$
  - $\rho - \omega$ mixing, integrated effect $< 2\%$
  - other: $g_I \equiv g(\rho_I \to \pi^+\pi^-) \neq g_c \equiv g(\rho^+ \to \pi^+\pi_3)$
    [PDG: $g_c/g_I - 1 = (0.5 \pm 1.0)\%$]

Breaking isospin triangle in $B \to \rho\rho$ WA all channels

➔ Already sensitive to sources of SU(2) breaking (J. Zupan CKM'06):

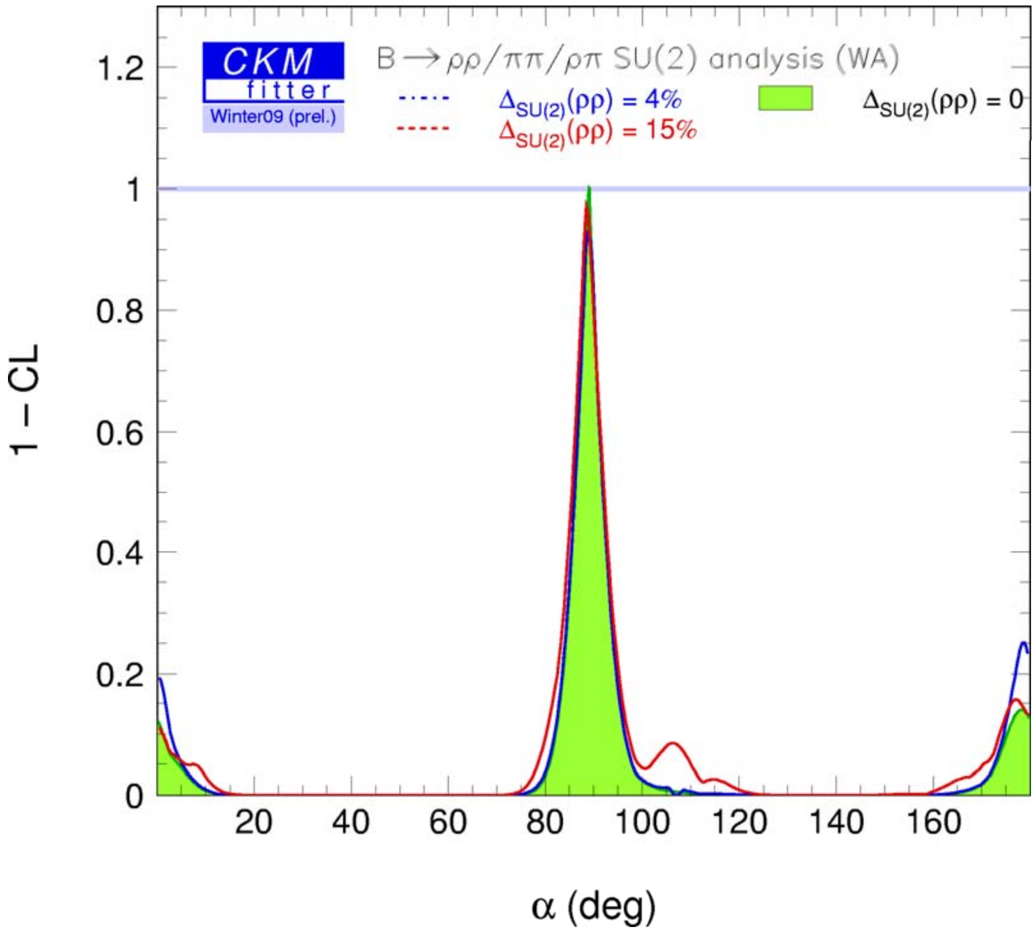
- $m_u \neq m_d$ & $Q_u \neq Q_d$:
  $(m_u - m_d)/\Lambda_{QCD} \sim 1\%$
- extend the basis of EW penguins: $Q_{7\ldots10}$
  $\Delta_{\alpha EWP} \sim 1.5^o$
- mass Eigen-States (EG) ≠ isospin EG:
  $(\rho-\omega)$ mixing <2%
- $\Gamma_\rho \neq 0 \Rightarrow$ I=1 contribution possible:
  $O(\Gamma^2_\rho/m^2_\rho) \sim 4\%$
- $\Delta I=5/2$ operators no more negligible.
- ...

➔ Possible way out: $K^*\rho$ SU(3) constraints

➔ Break the triangle closure:
$A^{+0} \to A^{+0} + \Delta A^{+0}$

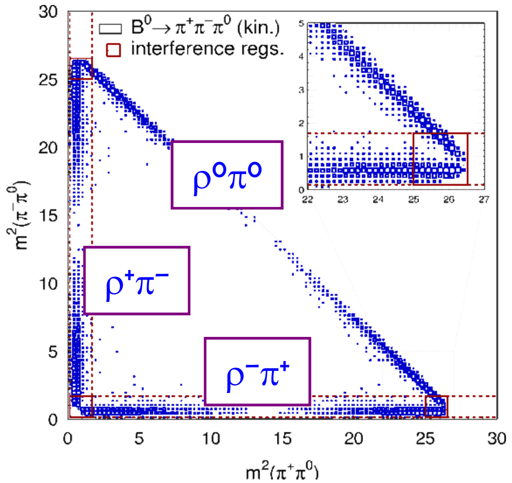
$$\sqrt{2}\,\Delta A^{+0} = V_{ud}V_{ub}^*\,\Delta_T T^{+-} + V_{td}V_{tb}^*\,\Delta_P P^{+-}$$

addit. Δ_T's & Δ_P's (arbitrary phases)



- tested $|\Delta A^{+0}|$: 4, 10 & 15%
- small impact on ππ/ρρ/ρπ WA combo.
  ⇒ only visible @95 % CL

α from $b \to u\bar{u}d$, $B \to \rho\pi$

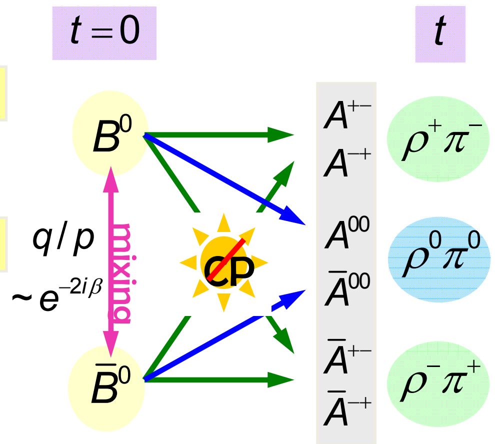


Dominant mode $\rho^+\pi^-$ is not a CP eigenstate

Aleksan et al, NP B361, 141 (1991)

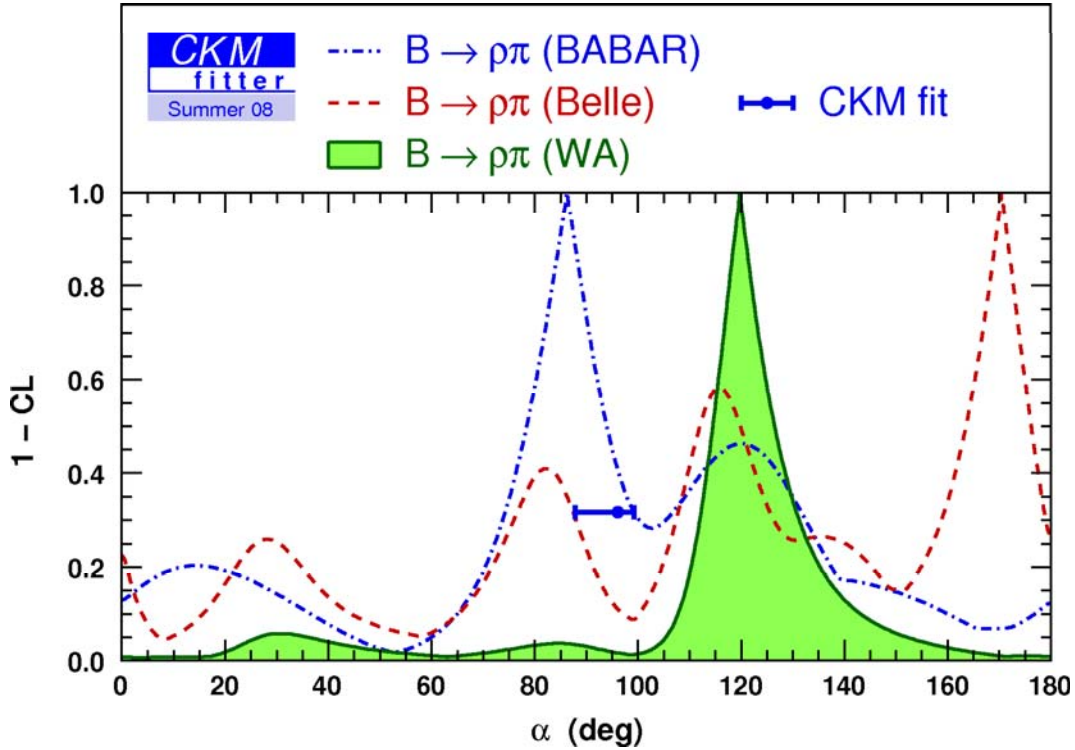
Amplitude interference in Dalitz plot

Snyder-Quinn, PRD 48, 2139 (1993)

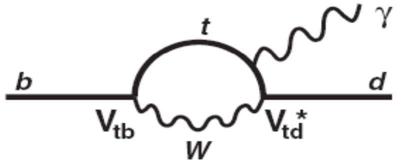


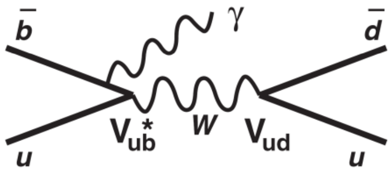
- simultaneous fit of α and strong phases
- Measure 26 (27) bilinear Form Factor coefficients
- correlated χ^2 fit to determine physics quantities

Same as for Moriond'07



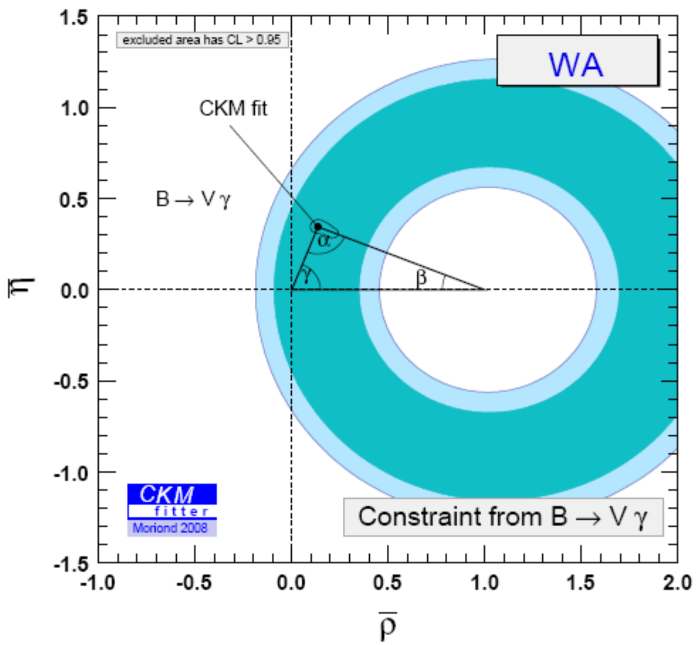
B→(ρ,ω)γ & B→K*γ exclusive b→ Dγ where D=(d,s)





$b \to d, s\gamma$: loop processes, give access to $|V_{t(d,s)}|$, complement $\Delta m_{d,s}$

Early days : focus on magnetic op. $Q_7 = (e/8\pi^2) m_b \bar{D}\sigma^{\mu\nu}(1+\gamma_5)F_{\mu\nu}\, b$ and assume short-distance dominance



$$R_{\rho/\omega} = \frac{\overline{\mathcal{B}}(\rho^\pm\gamma) + \frac{\tau_{B^\pm}}{\tau_{B^0}}[\overline{\mathcal{B}}(\rho^0\gamma)+\overline{\mathcal{B}}(\omega\gamma)]}{\overline{\mathcal{B}}(K^{*\pm}\gamma) + \frac{\tau_{B^\pm}}{\tau_{B^0}}[\overline{\mathcal{B}}(K^{*0}\gamma)]}$$

$$= \left|\frac{V_{td}}{V_{ts}}\right|^2 \left(\frac{1-m_\rho^2/m_B^2}{1-m_{K^*}^2/m_B^2}\right)^3 \frac{1}{\xi^2}\,[1+\Delta R]$$

- ξ ratio of form factors
- ΔR estimated as $\Delta R = 0.1 \pm 0.1$

Ali, Lunghi, Parkhomenko 02,04,06

Many open questions : dependence of ΔR on CKM matrix ? isopin breaking ? weak annihilation (tree for $(\rho,\omega)\gamma$) ?

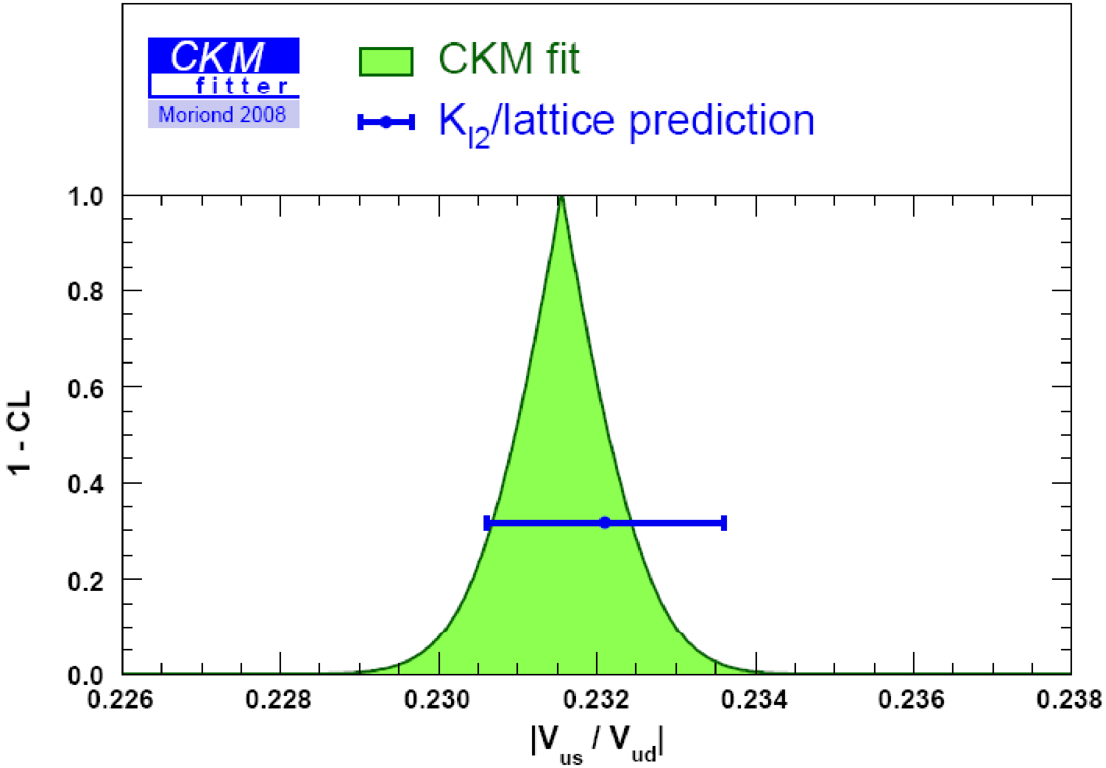
S. Descotes-Genon MEW'08

Improvements on $|V_{ud}|$ & $|V_{us}|$

Recently, big steps in lattice simulations : 3 dynamical quarks (unquenched) with light masses and (very) small errors

$\Longrightarrow$Essential role in reducing the theoretical QCD uncertainties

- $|V_{ud}|$: improved analysis of nuclear β decays [in fit]
- $|V_{us}|$: $K \to \pi \ell \nu$ + (dom wall) $f_+(0) = 0.964(5)$ [in fit] (UKQCD+RBC)
- $|V_{us}/V_{ud}|$: $K \to \ell\nu/\pi \to \ell\nu$ + (staggered) $f_K/f_\pi =$ 1.189(7) [not in fit] (HPQCD+UKQCD)



Remarkable : f_K/f_π very difficult to control on the lattice [light quarks]

S. Descotes-Genon MEW'08

|Vcd| & |Vcs| status

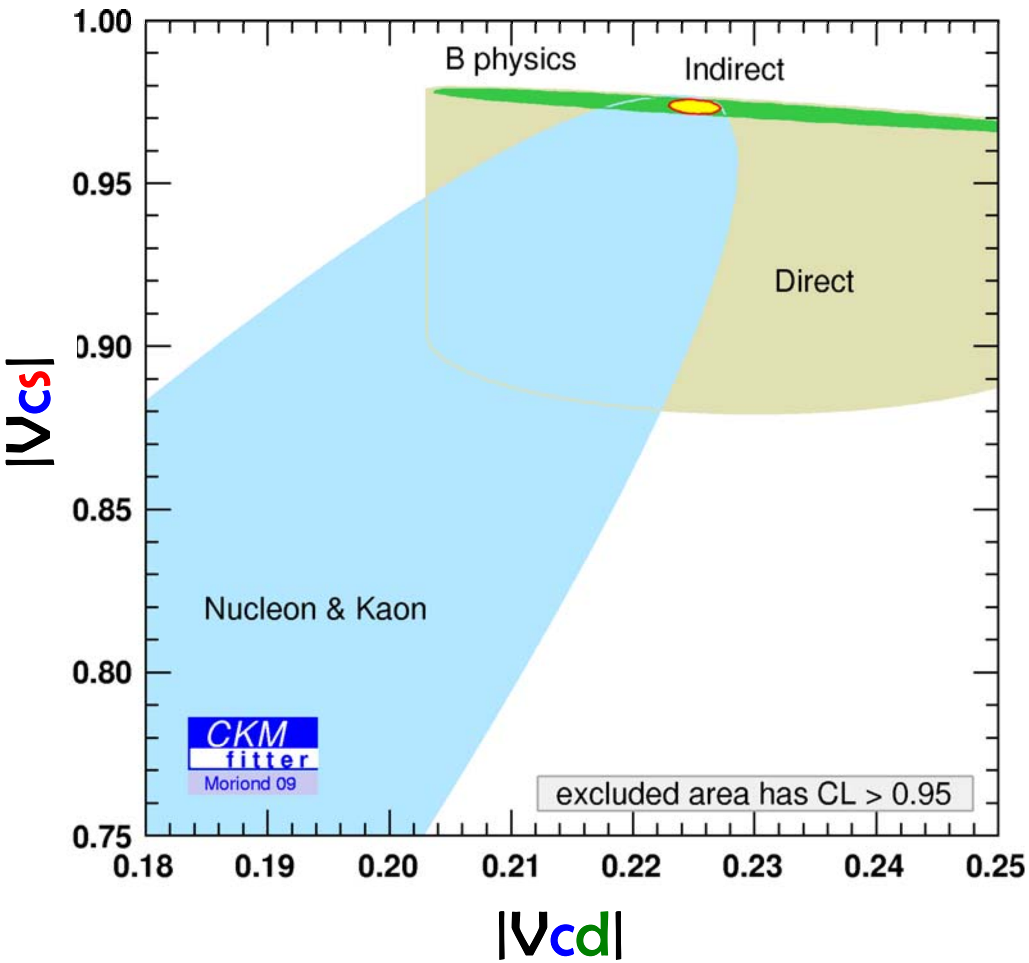
- Charm sector favorite place to test LQCD [$m_c \sim \Lambda_{QCD}$] for form fact. and decay constants (access |Vc(d,s)|)

- K and nucleon: Vud~Vcs (Vcd~Vus) only at first non trivial order in λ.

+ B physics ⇒ indirect strong constraint

(from global CKM fit).

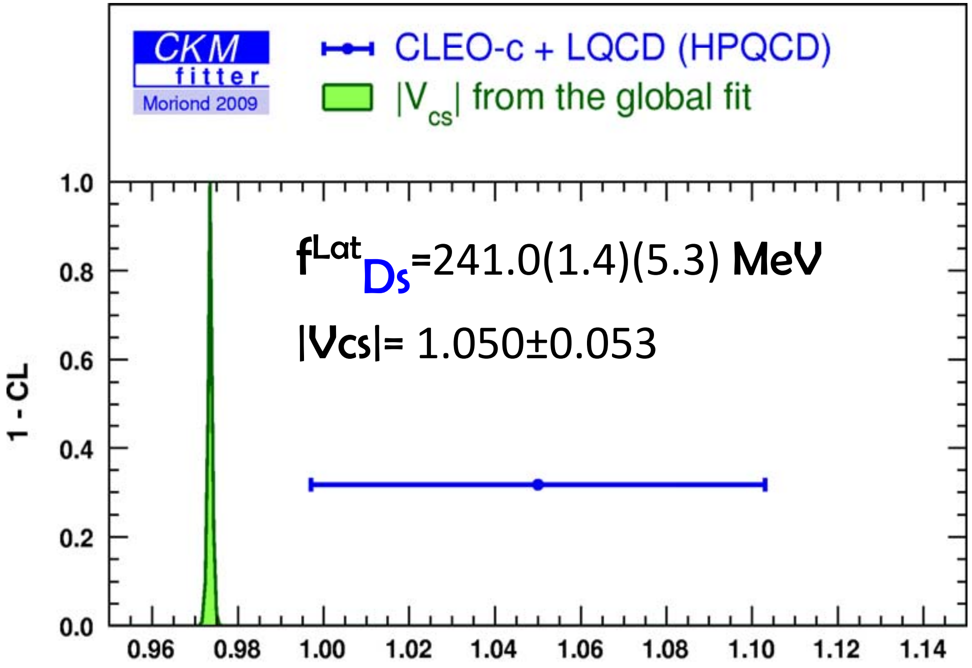
- Unitarity : $|Vcd|^2 + |Vcs|^2 \leq 1$



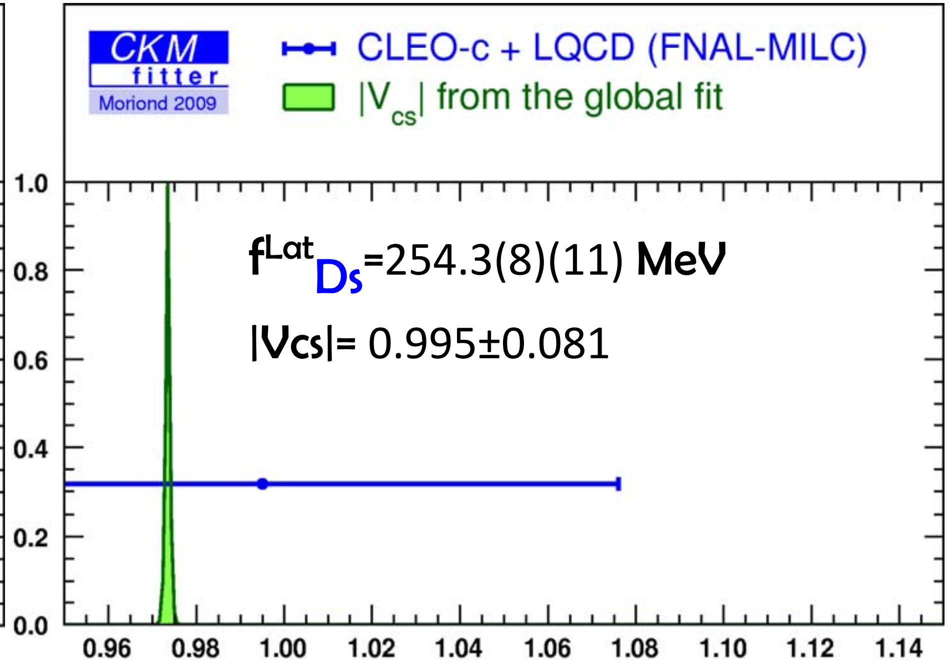
- Direct (new) : I. Shipsey Aspen'09

  - |Vcd| from DIS νN scattering (still most precise meas. !)
  - $|Vcs| = 1.018(10)_{stat}(8)_{syst}(106)_{theo}$ (above 1!) from LQCD + CLEO-c D→Klν SL absolute BRs ((un-)tagged 280/pb (×3 under study + future BES-III game field!)).

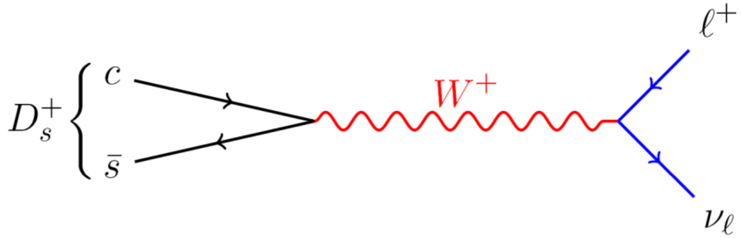
No more trouble with |Vcs|



|Vcs|



|Vcs|



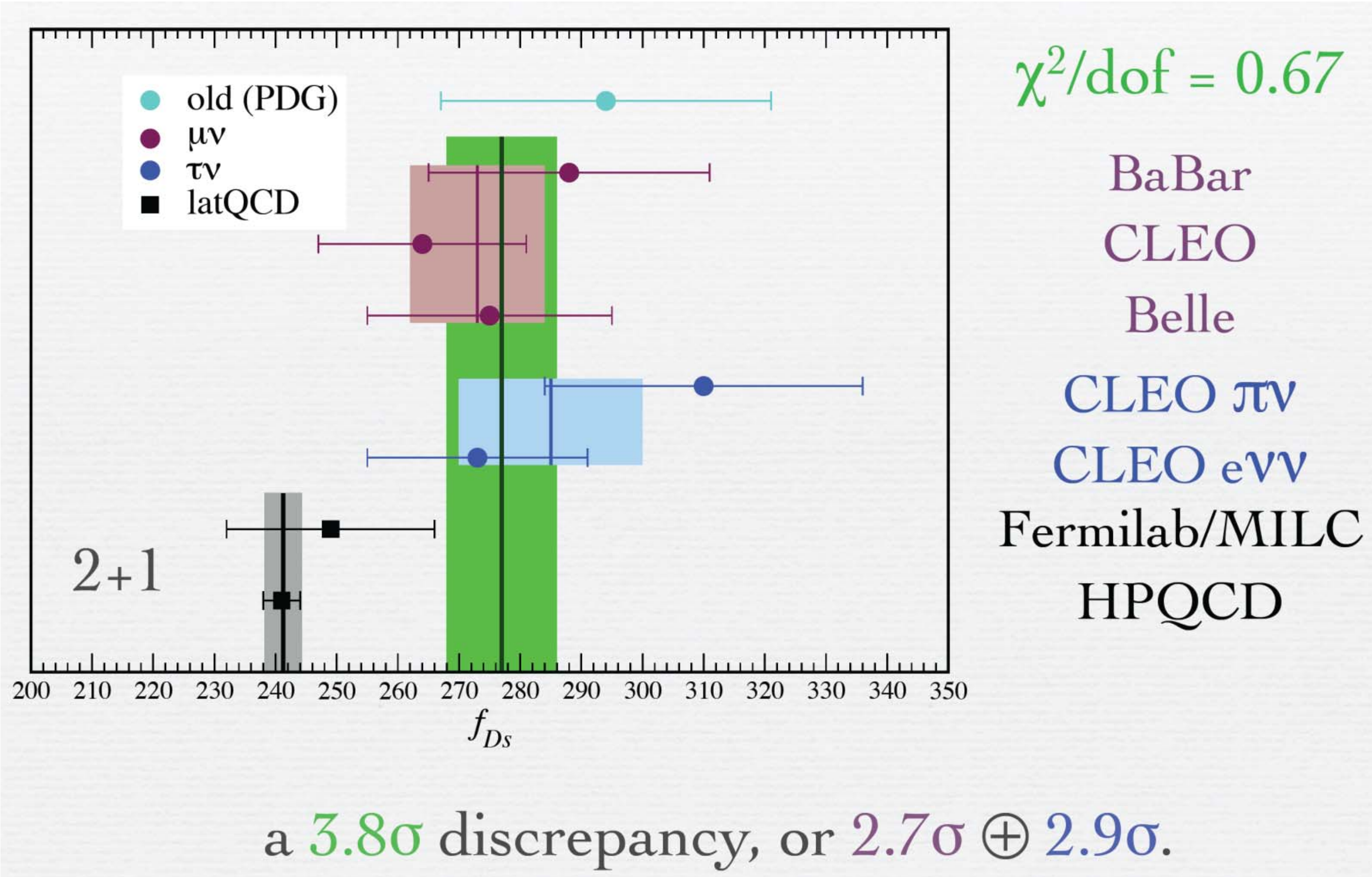
We measure $\mathcal{B}(D_s^+ \to \ell\nu_\ell)$ and **extract** $f_{D_s^+}$

$$\mathcal{B}(D_s^+ \to \ell^+\nu_\ell) = \frac{\tau_{D_s}}{8\pi} f_{D_s^+}^2 \; |V_{cs}|^2 \; G_F^2 \; M_{D_s^+} \left(1 - \frac{m_\ell^2}{M_{D_s^+}^2}\right)^2 m_\ell^2$$

J.Hunt
Lake Louise'09

f_{Ds} Puzzle : end 2007 !

Charm sector favorite place to test LQCD [$m_c \sim \Lambda_{QCD}$]
for form fact. & decay constants (|Vcs| through f_{Ds})

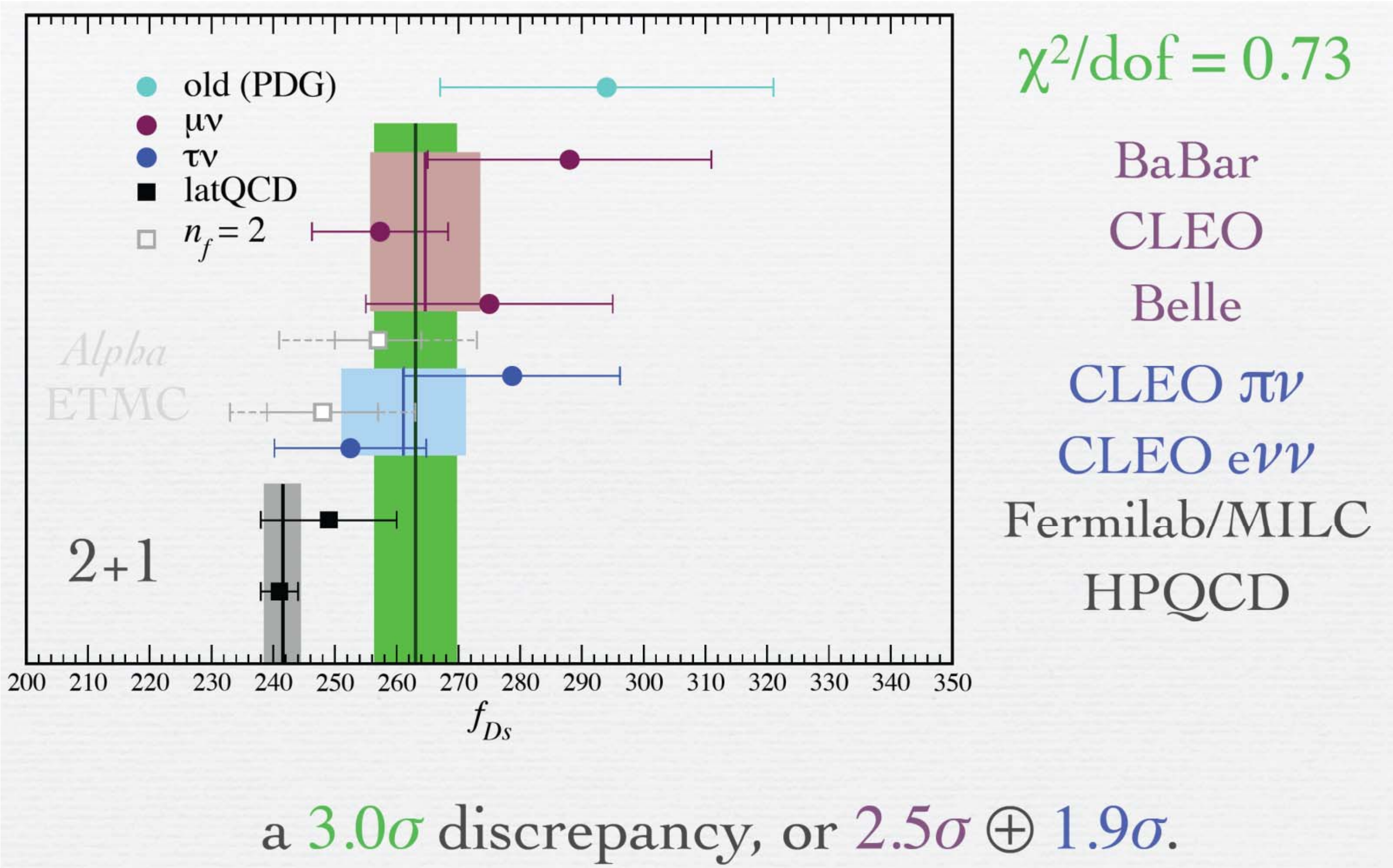


A. Kronfeld Aspen'09

f_{D_s} Puzzle : Jan 2009 ?

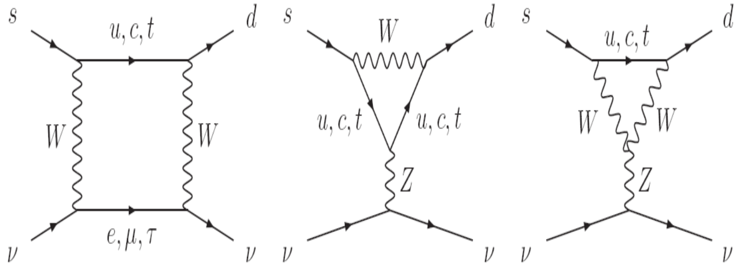
Charm sector favorite place to test LQCD [$m_c \sim \Lambda_{QCD}$]
for form fact. & decay constants (|Vcs| through f_{D_s})

CLEO-C Ds to $(\tau,\mu)\nu$: arXiv:hep/ex 0901.1147 and 0901.1216: f_{D_s}=(259.5±6.6±3.1) MeV



A. Kronfeld Aspen'09

a word on rare $K^+ \to \pi^+ \nu\bar{\nu}$



BR parameterization as Brod & Gorbahn '08 (PRD 78, 034006), NLO QED-QCD & EW corr. to the charm quark contrib. ($\alpha_s(m^2_Z)$=0.1176(20) & $m_c(\mu_c)$=1.286(13)(40)):

$$x_c = \sqrt{2}\frac{\sin^2\theta_W}{\pi\alpha}G_F m_c^2(\mu_c)$$

$$B\left(K^+ \to \pi^+\nu\bar{\nu}(\gamma)\right) = \kappa_+(1+\Delta_{\rm EM})\left[\left(\frac{{\rm Im}\lambda_t}{\lambda^5}X(x_t)\right)^2 + \left(\frac{{\rm Re}\lambda_c}{\lambda}\left(P_c(X)+\delta P_{c,u}\right)+\frac{{\rm Re}\lambda_t}{\lambda^5}X(x_t)\right)^2\right]$$

$$P_c(X) = \frac{1}{\lambda^4}\left(\frac{2}{3}X^e(x_c)+\frac{1}{3}X^\tau(x_c)\right)$$: short distance cham quark

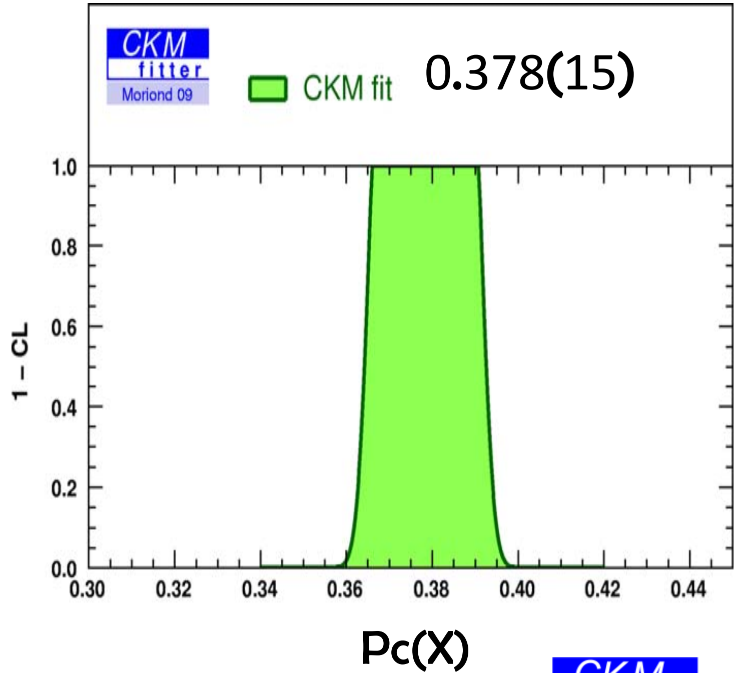
$\delta P_{c,u} = 0.04 \pm 0.02$: long distance corr. LQCD

κ_+: higher order EW corr.

Δ_{EM}: long dist. QED corr

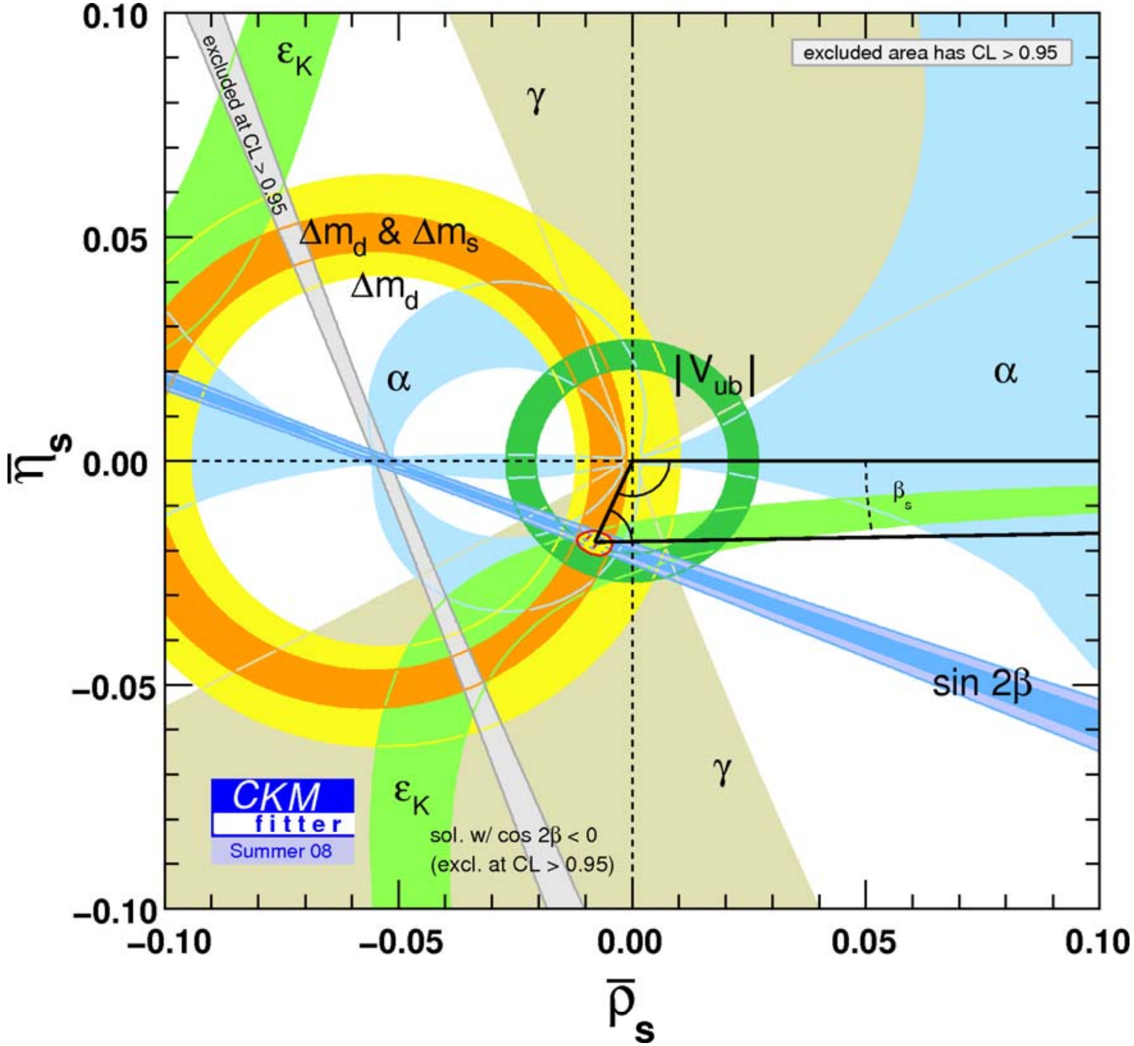
λ_i: $V^*_{is}V_{id}$

$X(x_i)$: Inami Lim loop function



$$\mathcal{B}(K^+ \to \pi^+\nu\bar{\nu}) \propto \left[(\sigma\bar{\eta})^2 + (\rho_0 - \bar{\rho})^2\right]$$

Global CKM fit: the B_s mesons $(\bar{\rho}_s, \bar{\eta}_s)$ plane



CDF+D∅ HFAG'08: $\beta_s = (22.3^{+10.3}_{-8.0})^\circ$

(Squashed)
B_s unitarity triangle

$$\frac{V_{us}V_{ub}^*}{V_{cs}V_{cb}^*} + 1 + \frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*} = 0$$
$$O(\lambda^2) + O(1) + O(1)$$

CP-violation for B_s meson

$$\bar{\rho}_s + i\bar{\eta}_s = -\frac{V_{us}V_{ub}^*}{V_{cs}V_{cb}^*}$$

$$\beta_s = -\arg\left[-\frac{V_{cs}V_{cb}^*}{V_{ts}V_{tb}^*}\right]$$

$\beta_s = (1.035^{+0.049}_{-0.046})^\circ$
(from global CKM fit MEW '09)

New Physics in B_s mixing

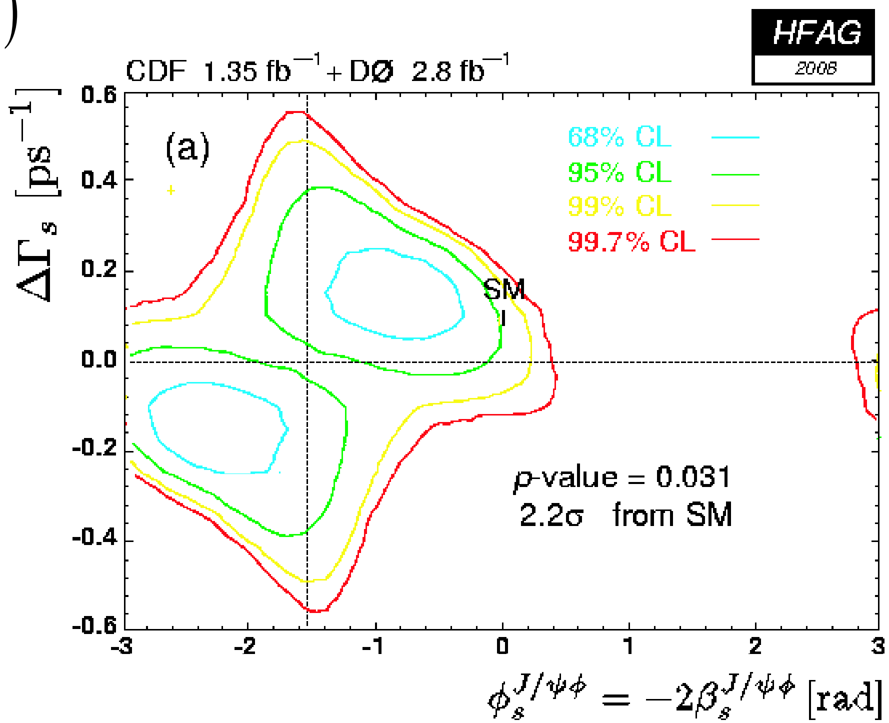
- **Direct constraint on NP phase in B_s mixing**

- The CDF/D0 measurement of $(-2\beta_s, \Delta\Gamma_s)$ from the time-dependent angular analysis of the $B_s \to J/\psi\phi$ provides a direct constraint on Φ^{NP}_s

- Using the HFAG combination of CDF and D0 likelihood :

$$(-2\beta_s, \Delta\Gamma_s) / (\pi + 2\beta_s, -\Delta\Gamma_s) = \left((-44^{+17}_{-21})°, 0.154^{+0.054}_{-0.070}\,\mathrm{ps}^{-1}\right)$$

CDF '08 update with 2.8/fb not yet combined

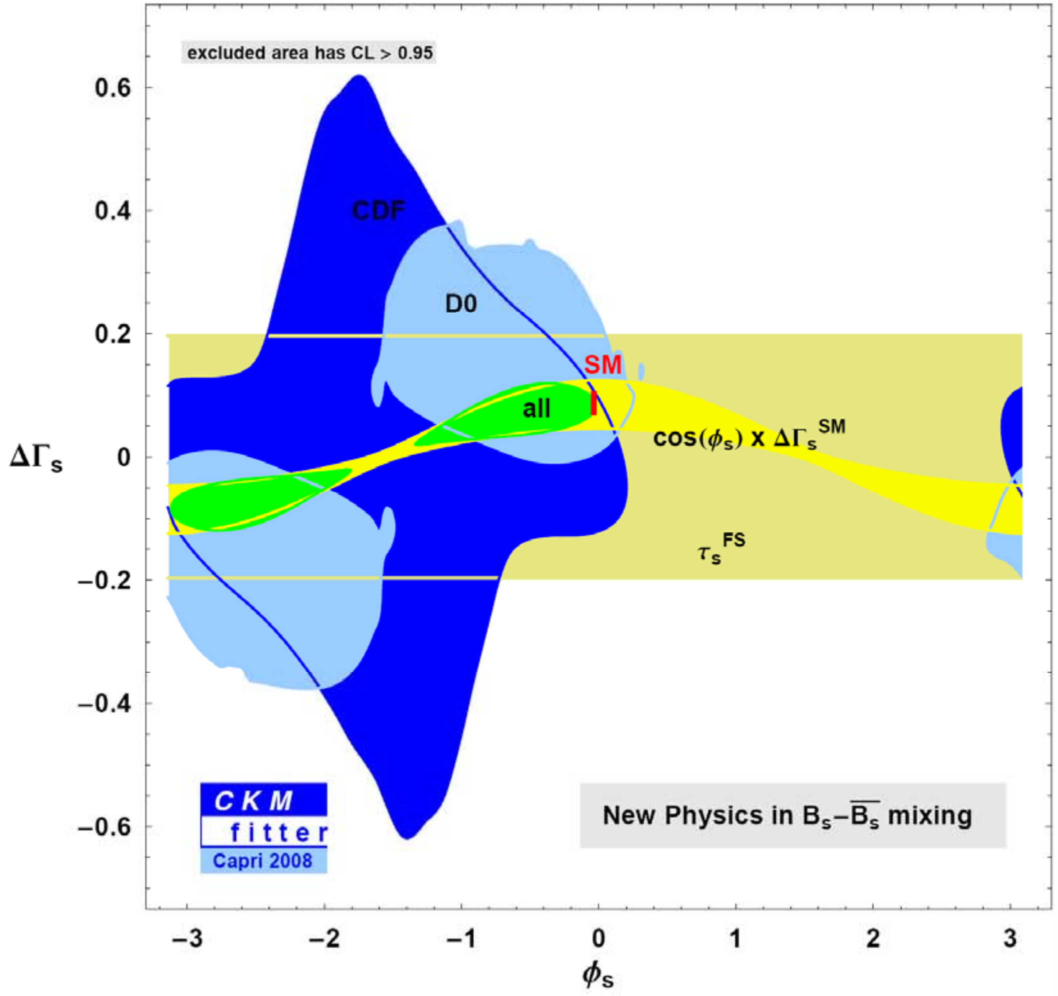


- **Other constraints**
  - Δm_s : consistent with SM expectation
  - $A_{SL}(B_s)$: large error wrt SM prediction
  - τ^{FS} : weak constraint on $\Delta\Gamma_s$
  - NP relation $\Delta\Gamma_s \approx \Delta\Gamma_s^{SM} \cos(\Phi_s^{NP})$
    - $\Delta\Gamma_s^{SM} = (0.090\ ^{+0.019}_{-0.022})\,\mathrm{ps}$ [Lenz,Nierste]
    - tends to push the NP phase Φ^{NP}_s towards SM.

Clean analysis : all theoretical uncertainties are in the DG^{SM} prediction but…

… it cannot tell much more on Φ^{NP}_s than the direct TeVatron measurement

Back to the $(\phi_s, \Delta\Gamma_s)$ plane



here $\tau_s^{FS} = \frac{1+(\tau_s\Delta\Gamma_s)^2}{1-(\tau_s\Delta\Gamma_s)^2}$ can be viewed as an independent measurement of $\Delta\Gamma_s$

using all $(\phi_s, \Delta\Gamma_s)$ inputs, $\phi_s = -2\beta_s$ is excluded at 2.4σ, while the 2D hypothesis $\phi_s = -2\beta_s$, $\Delta\Gamma_s = \Delta\Gamma_s^{SM}$ is excluded at only 1.9σ

(wrt to 1.4σ from FC treatment by CDF)

the combined region is tangent to the SM one, simply because the phase is vanishingly small there and thus $\cos 2\phi_s \sim 1 + \mathcal{O}(\phi_s^2)$

very transparent analysis: all theoretical uncertainties are contained in the SM prediction

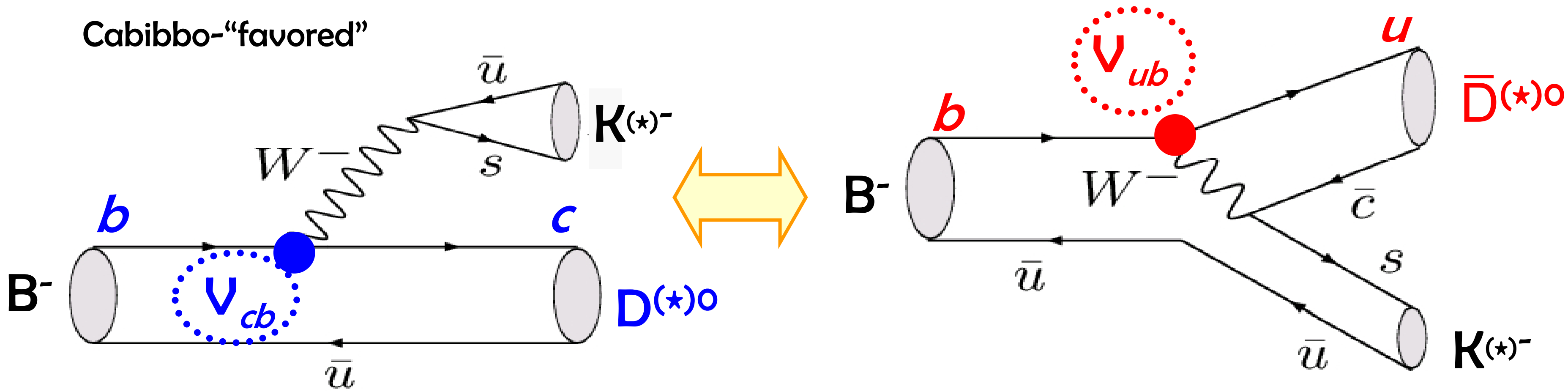
$\Delta\Gamma_s^{SM} = 0.090^{+0.017}_{-0.022}$ ps (red line)

J.Charles Capri '08

γ from interference in charged $B^- \to \tilde{D}^{(*)0} K^{(*)-}$ decays

Cabibbo-"favored"

(Cabibbo & color)-suppressed



$\mathcal{A}_{cb}(D^{(*)0}K^{(*)-}) \propto \lambda^3$

$\mathcal{A}_{ub}(\bar{D}^{(*)0}K^{(*)-}) \propto \lambda^3 \sqrt{\bar{\eta}^2 + \bar{\rho}^2}\; e^{i(\delta_B - \gamma)}$

relative strong & weak phases

➔ Measurement of γ using direct CP violation (interference [$b \to c \Leftrightarrow b \to u$]):

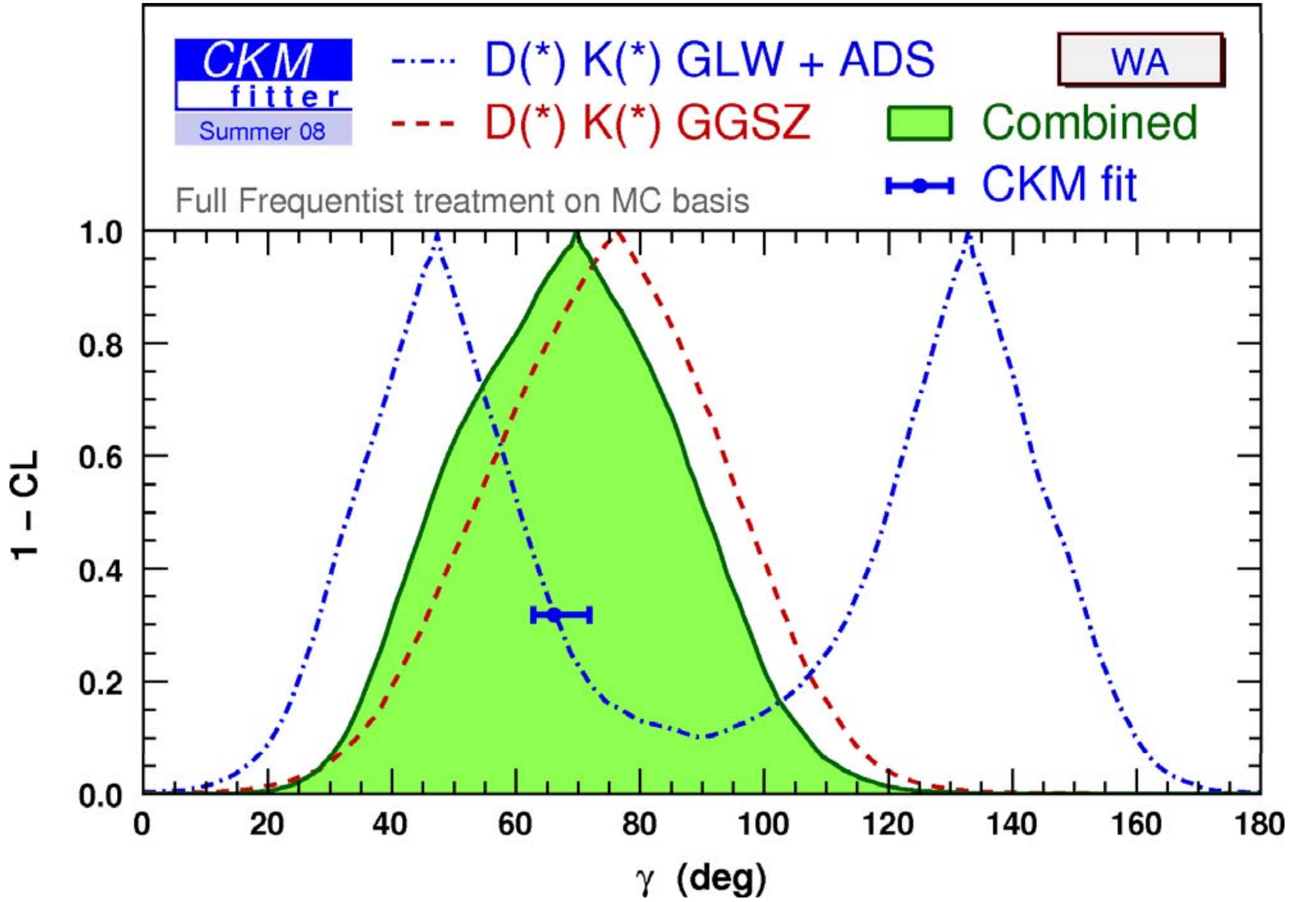
- 3 various $B^- \to \tilde{D}^{(*)0} K^{(*)-}$ charged decays (no time dependence): DK, D*K, and DK*.
- Size of CPV is limited by the size of $|\mathcal{A}_{ub}/\mathcal{A}_{cb}|$ amplitudes ratio: 3 $r^{(*)}_{(s)B}$ nuisance parameters (~5-30% ?).

➔ 3 methods that need a lot of B mesons:

Same $\tilde{D}^0 \equiv [D^0/\bar{D}^0]$ final state

- GLW: $\tilde{D} \equiv$CP-eigenstate: many modes, but small asymmetry.
- ADS: $\tilde{D} \equiv$DCS: large asymmetry, but very few events.
- GGSZ: $\tilde{D} \equiv$Dalitz: better than a mixture of ADS+GLW $\Rightarrow$ large asymmetry in some regions, but strong phases varying other the Dalitz plane.

γ from interference in charged $B^- \to \tilde{D}^{(*)0} K^{(*)-}$ decays

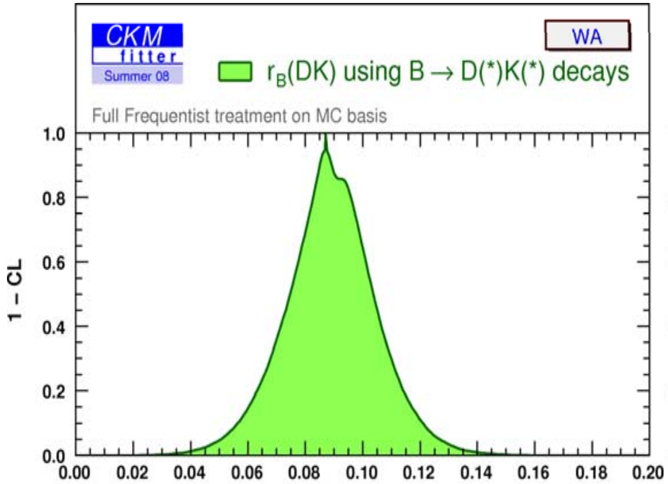


$\gamma = (70.9^{+27}_{-29})^\circ$ { [+44 °-41°] 95% CL}

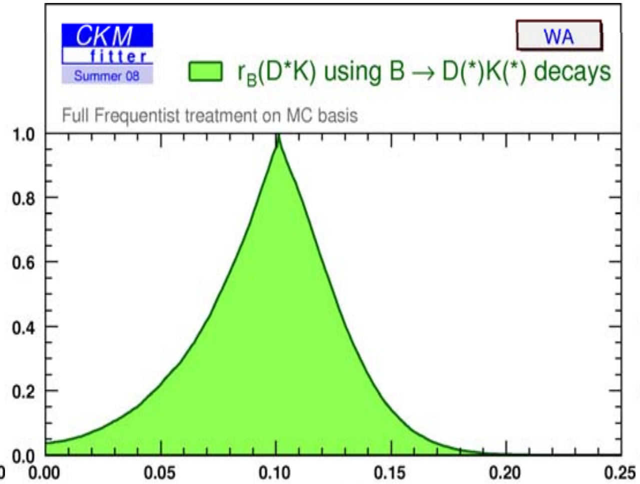
CKM fit MEW'09: $(67.8^{+4.2}_{-3.9})^\circ$

➔ Only recent meas. is ADS/GLW BaBar DK* at CKM'08

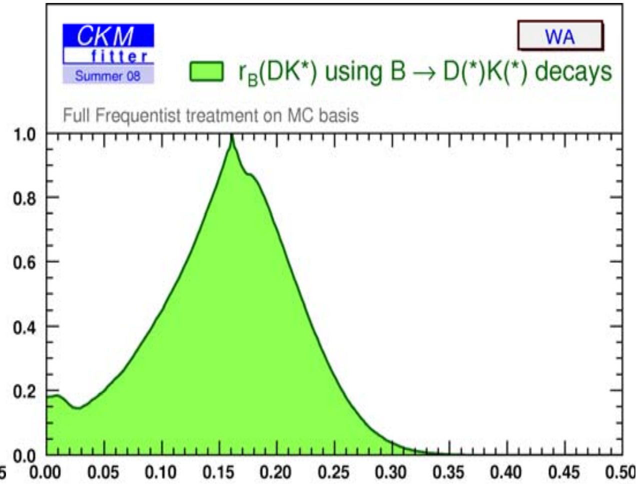
r_B and strong phase δ_B from GLW+ADS+GGSZ WA global fit



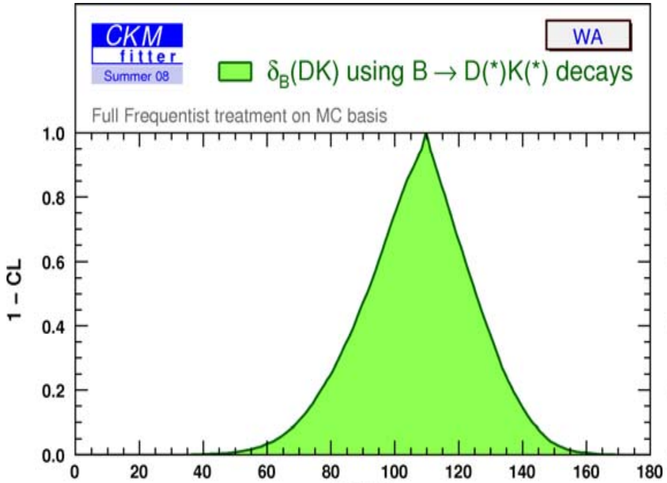
$$r_B(DK)=(0.087^{+0.022}_{-0.028})$$



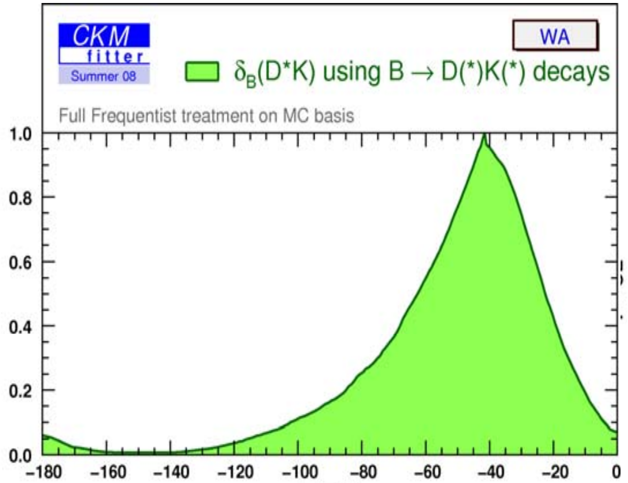
$$r_B(D^*K)=(0.101^{+0.034}_{-0.040})$$



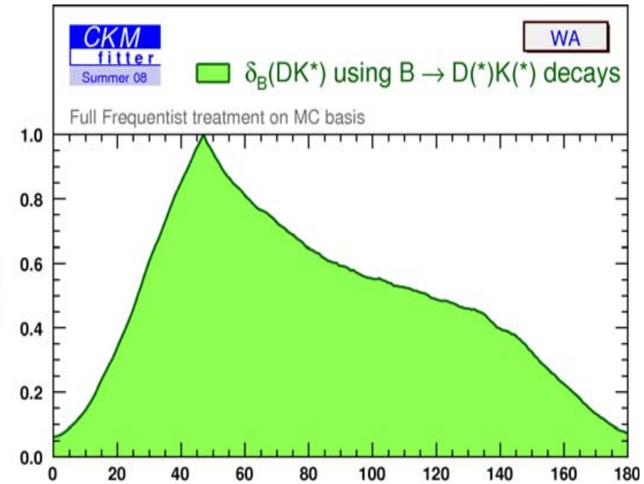
$$r_B(DK^*)=(0.161^{+0.079}_{-0.084})$$



$$\delta_B(DK)=(110^{+22}_{-27})^\circ$$



$$\delta_B(D^*K)=(-42^{+26}_{-32})^\circ$$



$$\delta_B(DK^*)=(47^{+103}_{-28})^\circ$$

γ from direct CPV in charged $B^- \to \tilde{D}^0 K^{*-}$ decays

GLW ≡ D⁰ CP final state

$$A^s_{CP+} = 0.09 \pm 0.13 \pm 0.05$$
$$A^s_{CP-} = -0.23 \pm 0.21 \pm 0.07$$
$$R^s_{CP+} = 2.17 \pm 0.35 \pm 0.09$$
$$R^s_{CP-} = 1.03 \pm 0.27 \pm 0.13$$

⊕

ADS ≡ D⁰ Doub. Cabbibo Suppressed

$$A^s_{ADS} = -0.34 \pm 0.45 \pm 0.16$$
$$R^s_{ADS} = 0.066 \pm 0.029 \pm 0.010$$

±stat.±syst.

⊕

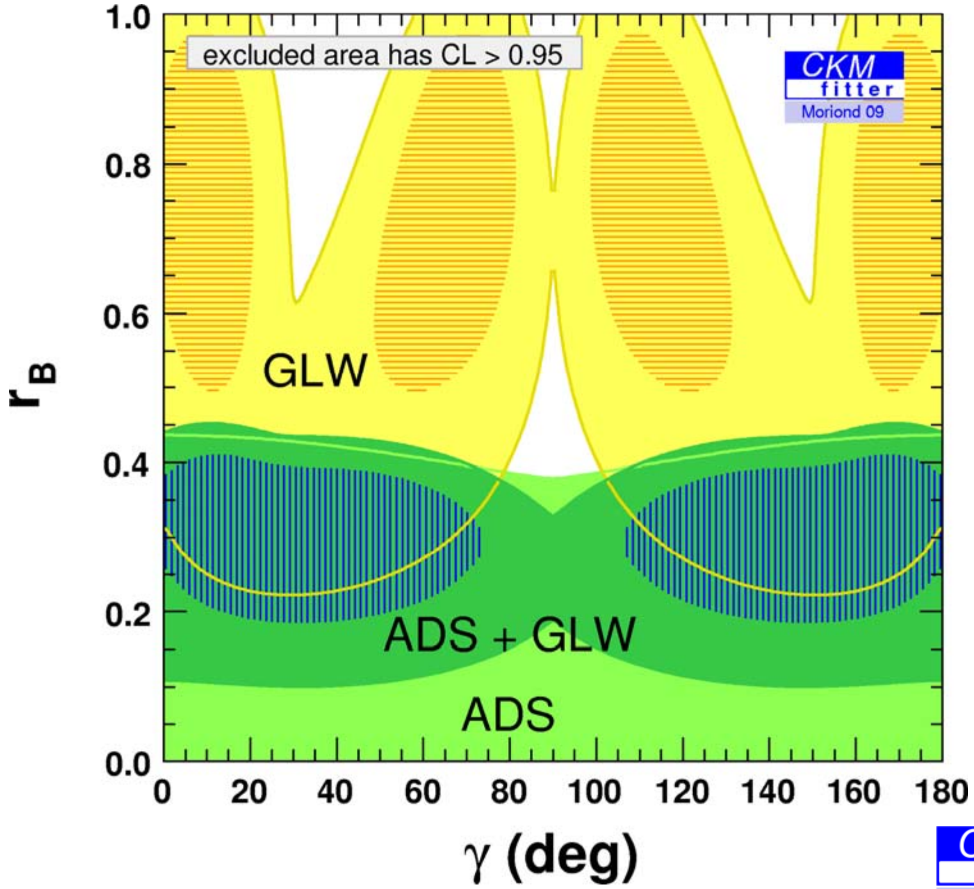
r_D= (5.78±0.08)% CS HFAG WA

$r_B \in [14,43]\%$
$\gamma \notin [87,94]°$

@ 95 % CL

Combination may not lead to naïve expectation. The r_B nuisance parameter ([b→u]/[b→c] transition size), even when large(~30%) , interferes in the CKM angle γ extract:

- This is not a naïve GLW+ADS average (multi-dim.)
- The accuracy may degrade in combo.



CKM fitter Moriond 09

γ from direct CPV in charged $B^- \to \tilde{D}^0 K^{*-}$ decays

marginal sensitivity to $r_B^2 \ll 1$

good sensitivity to $r_B^2 > r_D^2$

GLW

$$R_{CP\pm} = 1 + r_B^2 \pm 2\, r_B \cos(\delta_B)\cos(\gamma)$$

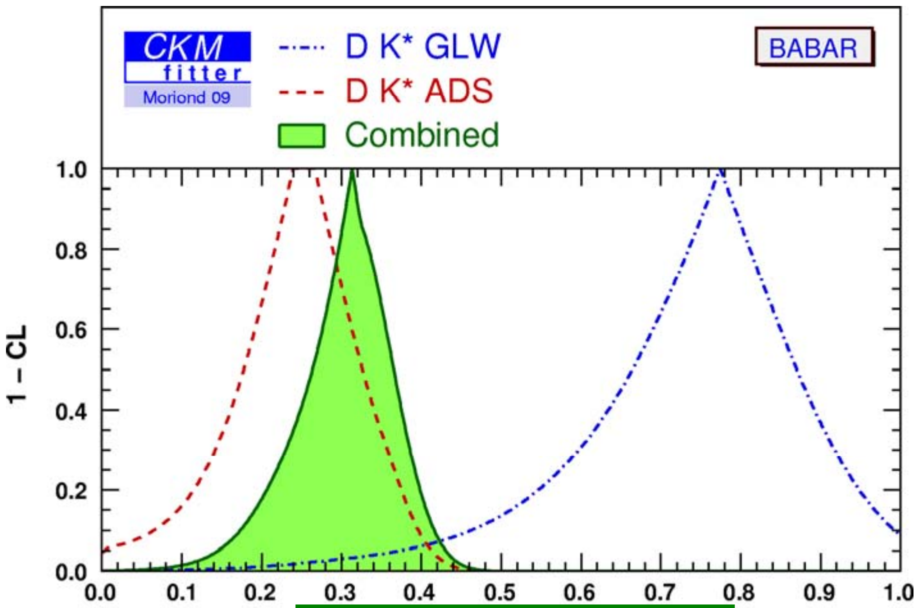
$$A_{CP\pm} = \frac{\pm 2\, r_B \sin(\delta_B)\sin(\gamma)}{R_{CP\pm}}$$

ADS

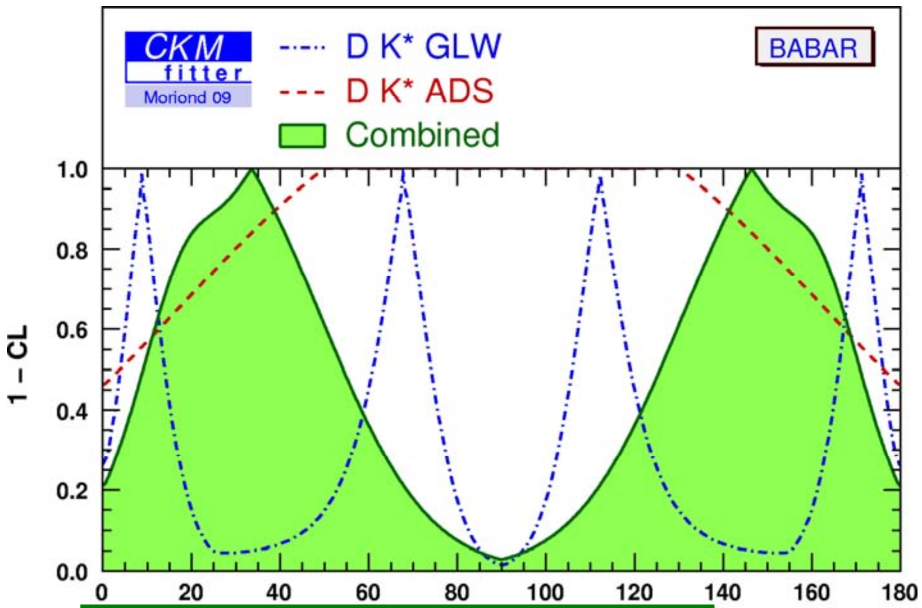
$$R_{ADS} = r_B^2 + r_D^2 + 2 r_B r_D \cos(\delta_B + \delta_D)\cos(\gamma)$$

$$A_{ADS} = \frac{2\, r_B\, r_D \sin(\delta_B + \delta_D)\sin(\gamma)}{R_{ADS}}$$

8 fold-ambiguities on γ



$r_B = (31.1^{+7.1}_{-8.0})\%$

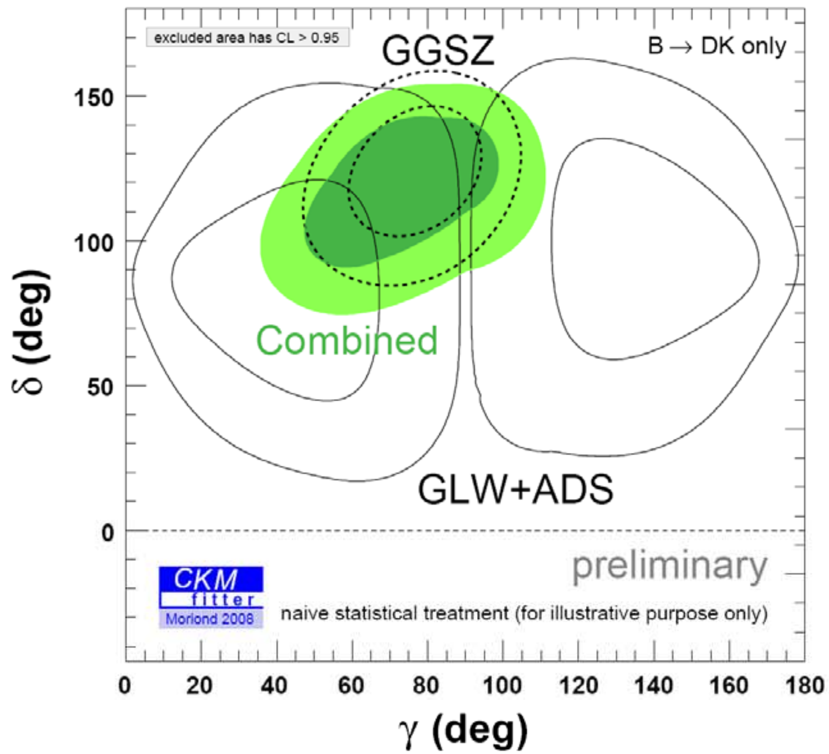


$\gamma = (34^{+28}_{-30})°$ or $(146^{+30}_{-29})°$

Combining methods on γ not always leads to what one naïvely expects (nuisance params)

Not only γ in 3 methods, also hadronic quantities (strong phases...)

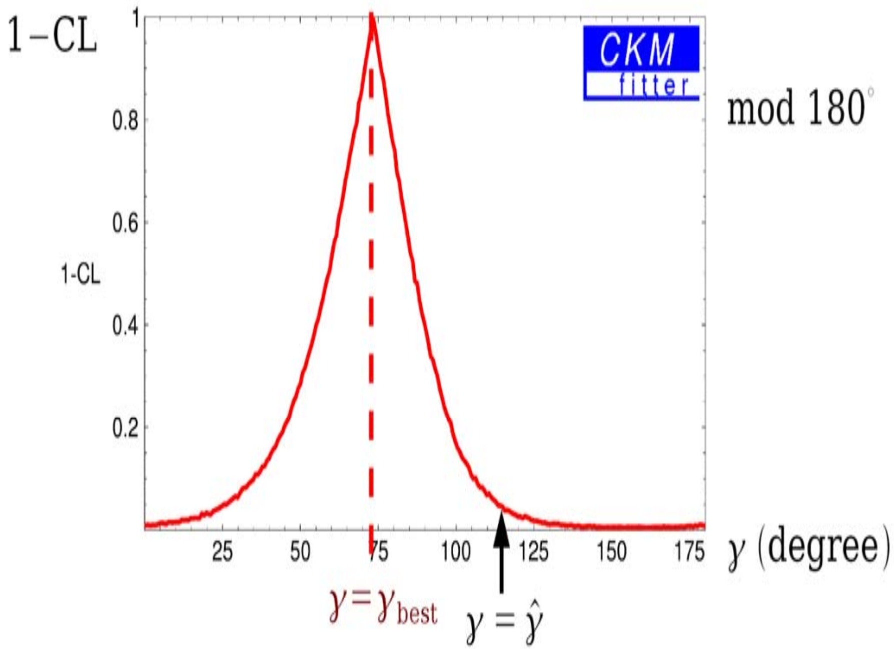
- GLW (DK, D^*K, DK^*)
  $R_{CP\pm} = 1 \pm 2r_B \cos\delta_B \cos\gamma + r_B^2 \quad A_{CP\pm} = \pm 2r_B \sin\delta_B \sin\gamma / R_{CP\pm}$
- ADS (DK, D^*K, DK^* for $K\pi, K\pi\pi^0 \ldots$)
  $R_{ADS} = r_B^2 + r_D^2 + 2r_B r_D \cos(\delta_B + \delta_D)\cos\gamma$
- GGSZ (DK, D^*K, DK^*)
  $x_\pm = r_B \cos(\delta_B \pm \gamma)$
  $y_\pm = r_B \sin(\delta_B \pm \gamma)$
- Combining results may not yield the naive average and may not improve the accuracy
  ...at least sometimes (DK^*)



Combining methods on γ: statistical treatment matters!

Determination of γ (central value and intervals)

from different measurements, independently of other parameters



γ parameter of interest, μ $(= r_B, \delta_B)$ nuisance parameters

$$\Delta\chi^2(\hat{\gamma}) = \chi^2(\hat{\gamma}, \hat{\mu}) - \chi^2(\gamma_{best}, \mu_{best})$$

best parameters for the given $\hat{\gamma}$ and actual z measurements

N_γ minimisations

get the CL:

- if the sampling PDF of $\Delta\chi^2$ is a χ^2 law

$\Rightarrow$ cumulative distribution function (prob)

(true asymptotically)

if not: the sampling PDF depends, in general, on the nuisance parameters

what to do with the nuisance parameters ?

$\rightarrow$ plug-in principle ($\hat{\mu}$ method): nuisance parameters are fixed to $\hat{\mu}$ values

$\rightarrow$ supremum method: least favored values of the nuisance parameters

(sure to never undercover)

So far CKMfitter conservative baseline method

K.Trabelsi CKM'08