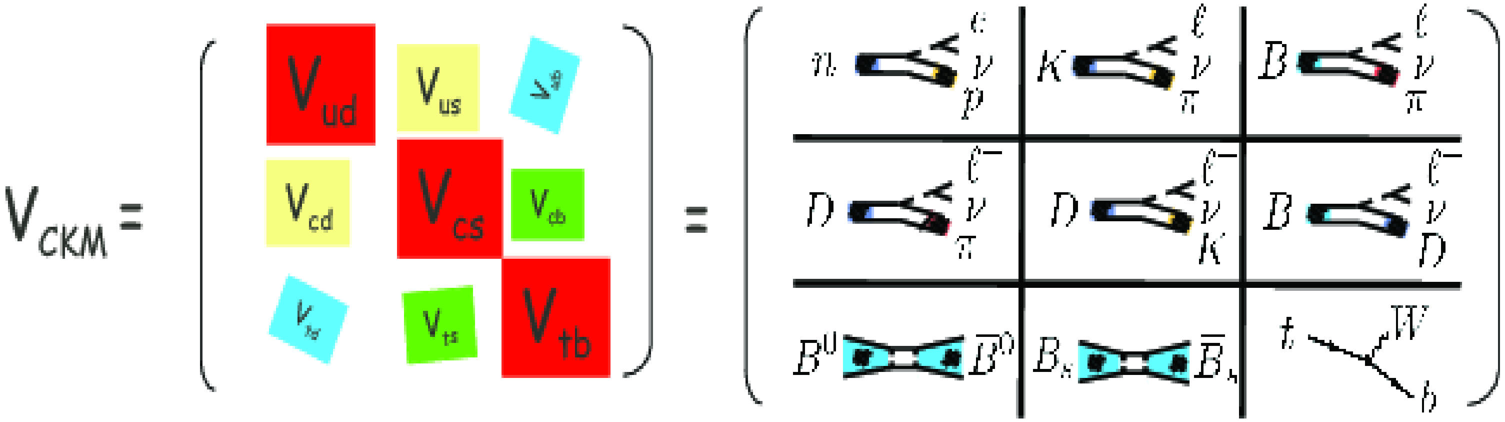
Status of global fit section

Malcella Bona (Queen Mary, U of London)
Gerald Eigen (Bergen), and
Ryosuke Itoh (KEK)

1. Introduction

- CKM matrix has 4 unknown parameters to extract from data

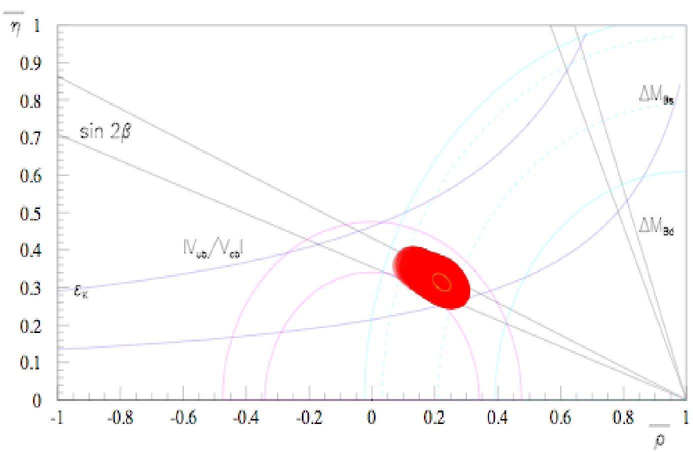


$$\lambda^2 = \frac{|V_{us}|^2}{|V_{ud}|^2 + |V_{us}|^2}, \quad A^2\lambda^4 = \frac{|V_{cb}|^2}{|V_{ud}|^2 + |V_{us}|^2}, \quad \bar{\rho} + i\bar{\eta} = -\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}$$

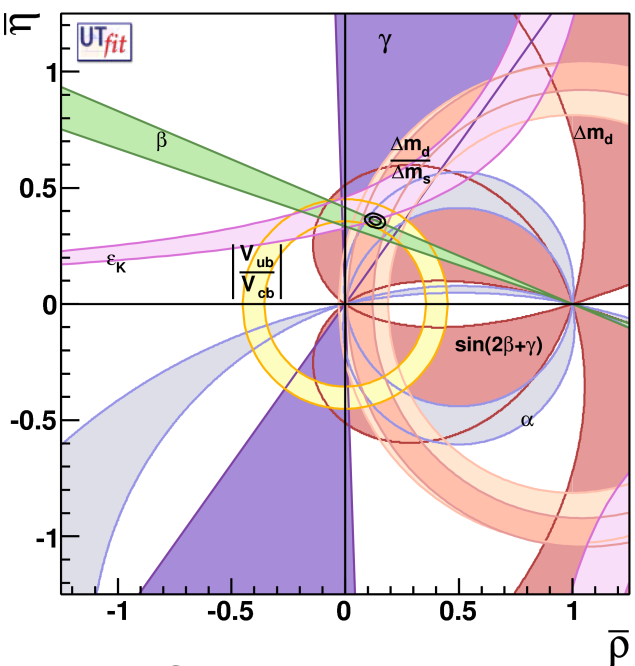
- Global fit : determine the unknowns by a simultaneous fit to various measurements = Belle+BaBar.

- Three approaches are covered in the book.
  1) Scanning Method : frequentist + “scanning” for theo. uncertainty
  2) UTfit : Baysien + Gaussian for theory uncertainty
  3) CKMfitter : frequentist + Rfit for theory uncertainty
  (Detail was already covered in Gerald's talk in last WS.)

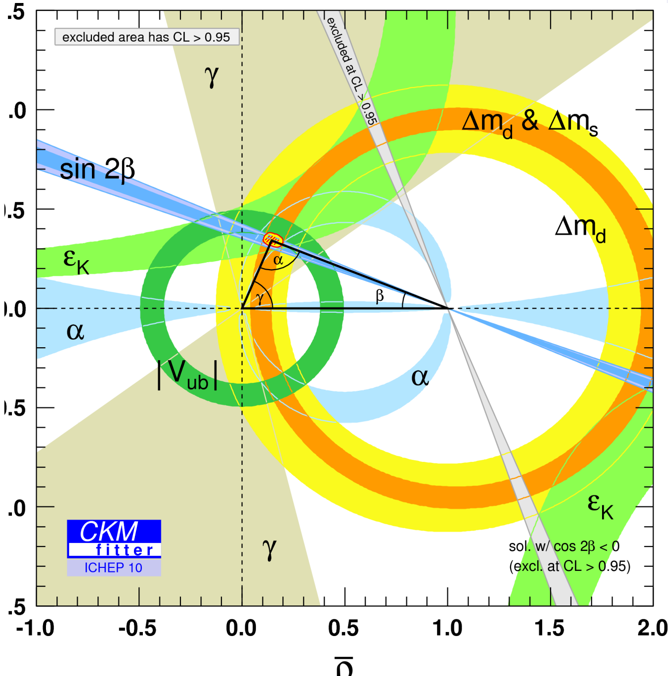
- The differences are not only in the statistical method, but also in the treatment of theoretical uncertainties.



Scanning Method
2008 inputs



UTfit
pre-ICHEP2010



CKMfitter
ICHEP2010

Our work goal for physics book

- Obtain CKM fit results by three different method (Scanning Method, UTfit, and CKMfitter), and discuss the constraint on SM (and NP) in the book.

- Use the same input parameters for all three methods as possible as we can for the consistent comparison. "Common Fit"

- The fit results by three methods are supposed to be included in parallel, but a single conclusion is drawn from them in the description.

3 options in “common fit” strategy

1) Use common theoretical and experimental parameters for the fit by all groups: Scanning method, UTfit and CKMfitter.
   - + Best way to discuss physics consistently
   - - Loose feature of each approach, may become just a comparison of statistical methods.

2) Use common experimental input (B-factory measurements and others) while using each group's choice of theoretical parameters/treatment.
   - + Realistic way of “common fit” keeping the identity of each approach
   - - How we describe the difference in book?

3) Just include the latest results of each group in the book (could be ICHEP10 results) without doing refit using common parameters.
   - + The easiest way :-p
   - - Consistent discussion in the book becomes difficult

Where is the landing point?

2. Experimental inputs

a) B-factory measurements:

They are supposed to be provided by editors of each section (for option 1 and 2).

* Angles :

$\sin(2\phi_1)$ ($+\cos(2\phi_1)$ for area constraint)

ϕ_2

ϕ_3

* Sides

$|V_{ub}|$

$|V_{cb}|$

* Bd Mixing

Δm_d

* Leptonic decay

Br(B->$\tau\nu$)

b) Non B-factory measurements:

- We use the numbers in PDG.

- Parameters:
  * ε_K = (2.228 +- 0.011) x 10^{-3}
  * Δm_s = (17.77 +- 0.12) x 10^{12}
  * $|V_{ud}|$ = 0.97425 +- 0.00022
  * $|V_{us}|$ = 0.2246 +- 0.0012

3. Theoretical inputs

a) Lattice parameters

- The treatment of lattice parameters in CKM fit is different among three groups and it seems to be difficult to choose one of them as a common input parameter set.

- One possible approach:
  * Use parameters described in PRD81,034503. The paper was suggested by Kevin Flood and the averaging of various lattice calculations in the paper seems to be reasonable.
  * In the paper, the errors in the average values are given in single normally-distributed (Gaussian) errors,

- Can we use it as common parameter set?
  * CKMfitter: different treatment for stat. and syst. is required and one Gaussian error cannot be accepted.
  * UTfit: uses the quadratic sum of statistical and systematic errors treated Gaussian -> Average similar to PRD81 => OK?
  * Scanning method: ???

The inputs

Example of lattice inputs (in green letters) used by CKMfitter

CKM fitter

CKM matrix within a frequentist framework ($\simeq \chi^2$ minimum)
+ specific scheme for systematic errors (Rfit)

data = weak $\otimes$ QCD $\Longrightarrow$ Need for hadronic inputs (often lattice)

$\lvert V_{ud}\rvert$	superallowed β decays	PRC79, 055502 (2009)
$\lvert V_{us}\rvert$	$K_{\ell 3}$ (Flavianet)	$f_+(0) = 0.963 \pm 0.003 \pm 0.005$
ϵ_K	PDG 08	$\hat{B}_K = 0.723 \pm 0.004 \pm 0.067$
$\lvert V_{ub}\rvert$	inclusive and exclusive	$\lvert V_{ub}\rvert \cdot 10^3 = 3.92 \pm 0.09 \pm 0.45$
$\lvert V_{cb}\rvert$	inclusive and exclusive	$\lvert V_{cb}\rvert \cdot 10^3 = 40.89 \pm 0.38 \pm 0.59$
Δm_d	last WA B_d-$\bar{B}_d$ mixing	$B_{B_s}/B_{B_d} = 1.05 \pm 0.01 \pm 0.03$
Δm_s	last WA B_s-$\bar{B}_s$ mixing	$B_{B_s} = 1.28 \pm 0.02 \pm 0.03$
β	last WA $J/\psi K^{(*)}$	
α	last WA $\pi\pi, \rho\pi, \rho\rho$	isospin
γ	last WA $B \to D^{(*)} K^{(*)}$	GLW/ADS/GGSZ
$B \to \tau\nu$	$(1.73 \pm 0.35) \cdot 10^{-4}$	$f_{B_s}/f_{B_d} = 1.199 \pm 0.008 \pm 0.023$
		$f_{B_s} = 228 \pm 3 \pm 17$ MeV

Lattice parameters in Scanning method

Old Lattice QCD Inputs

- In 2008 we used the following inputs

Parameter	Mean$\pm\sigma_{stat}\pm\delta_{theo}$
f_B [MeV]	216±10±20
B_B	1.29±0.05±0.08
ξ	1.24±0.04±0.06
B_K	0.79±0.04±0.09
$m_c(\overline{m_c})$	1.24±0.1
$m_t(\overline{m_t})$ [GeV]	163.8±2
η_{cc}	1.46±0.22
η_{ct}	0.5765±0.0065
η_{tt}	0.47±0.04
$\eta_B(\overline{MS})$	0.551±0.007

- For red parameters, first error is treated in a statistical way, the second error is scanned over
- For blue parameters, the error is treated in a statistical way

Parameters in Scanning method

Lattice QCD Inputs

- We are switching to the parameters CKMfitter is using
- We also consider to use Monte Carlo integration as an option rather than looping over the non-statistical errors
- For η_{cc}, we will use the Nierste parameterization rather than a fixed value

Parameter
f_{Bs}
f_{Bs}/f_{Bd}
B_{Bs}
B_{Bs}/B_{Bd}
B_K [2 GeV]
B_K
$m_c(\overline{m}_c)$ [GeV]
$m_t(\overline{m}_t)$ [GeV]
η_{cc}
η_{ct}
η_{tt}
$\eta_B(\overline{MS})$
α_s

UTfit lattice inputs:

recently we moved to this set of inputs

f_Bs = 239 ± 10 MeV
f_Bs/f_Bd = 1.23 ± 0.03
B_Bs/B_Bd = 1.06 ± 0.04
B_Bs = 0.87 ± 0.04
B_K = 0.731 ± 0.036

f_Bd = f_Bs/(f_Bs/f_Bd)
*Xi = (f_bs/f_Bd)*sqrt(BBs/BBd)*
*Dmd = [f_Bs / (f_Bs/f_Bd)] * [sqrt(B_Bs) / sqrt(B_Bs/B_Bd)]*
Dms = f_Bs sqrt(B_Bs)
taunu = f_Bs/ (f_Bs/f_Bd)

Why CKMfitter cannot accept the parameters in PRD81?

- The uncertainties of lattice average in the paper are supposed to be normally distributed = Gaussian error.

- Sales point of CKMfitter: treatment of systematic errors in Rfit approach. (Gaussian for stat. error, Range for syst. error)
  - -> requires separate estimation of statistical and systematic errors in theoretical parameters.

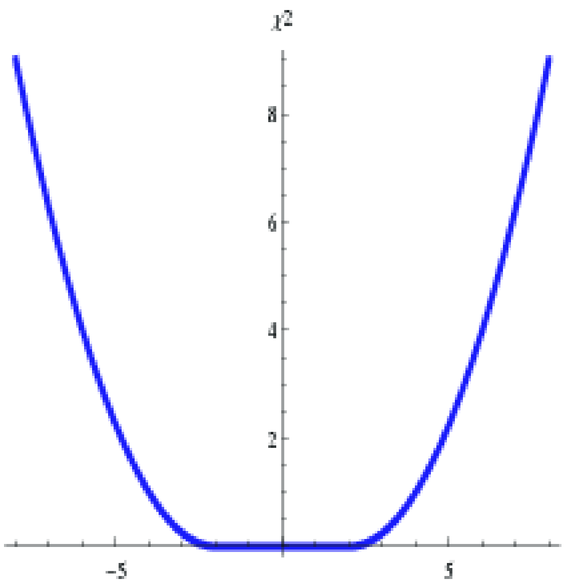
- CKMfitter do their own lattice averaging by using Rfit (Educated Rfit =ERfit) to estimate statistical and systematic errors separately in the average.
  - -> Difficult to do the same for PRD81.........

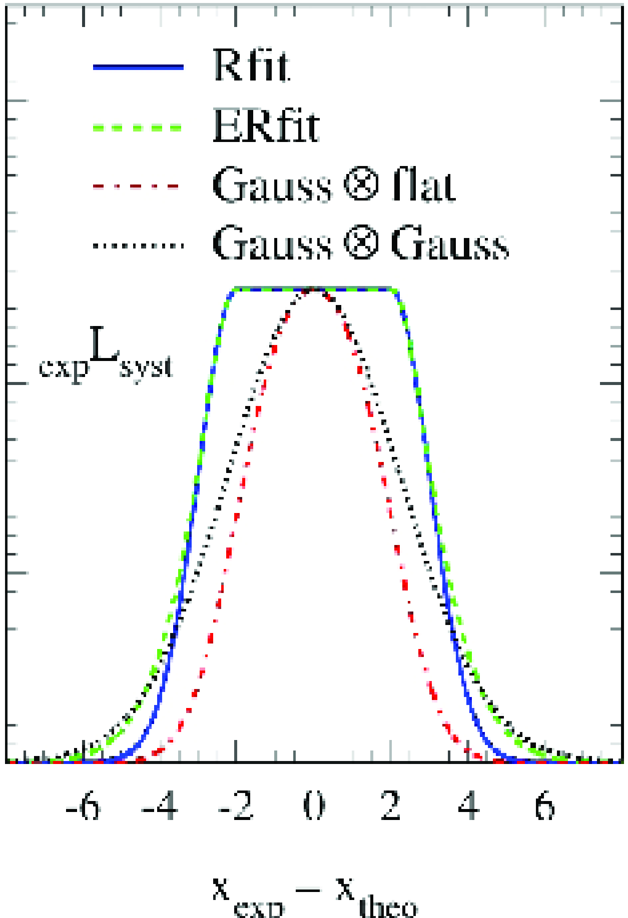
-> Difficult to adopt “Gaussian” errors in PRD81 in CKMfitter.....

Rfit scheme

CKM fitter : Treatment of systematics within the Rfit scheme

- χ^2 with flat bottom (syst) and parabolic walls (stat)
- corresponding likelihood $\mathcal{L} = \exp(-\chi^2/2)$
- all values within range of syst treated on the same footing





Lattice averages

Consistent averages of lattice results for hadronic quantities needed

$\Longrightarrow$ we perform our own averages

- Collecting lattice results
  - only unquenched results with 2 or 2+1 dynamical fermions
  - papers and proceedings (but not preliminary results)
- Splitting error estimates into stat and syst
  - Stat : essentially related to size of gauge conf
  - Syst : fermion action, $a \to 0$, $L \to \infty$, mass extrapolations...
    added linearly when error budget available
- Potential problems
  - proceedings not always followed by peer-reviewed papers
  - some syst estimates controversial within lattice community (staggered action, extrapolations...)

Averaging procedure

"Educated Rfit" used to combine the results, with different treament of statistical and systematic errors

- product of (Gaussian + Rfit) likelihoods for central value
- product of Gaussian (stat) likelihoods for stat uncertainty
- syst uncertainty of the combination
  = the one of the most precise method

Conservative, algorithmic procedure with internal logic for syst

- the present state of art cannot allow us to reach a better theoretical accuracy than the best of all estimates
  (combining 2 methods with similar syst does not reduce the intrinsic uncertainty encoded as a systematic)
- best estimate should not be penalized by less precise methods
  (opposed, e.g., to combined syst = dispersion of central values)

Comparing averaging methods

Modify our compilation to compare with `latticeaverages.org`

- Remove $N_f = 2$ results, add results preliminary/to be published
- Add syst errors in quadrature

Reference	N_f	Mean	Stat	Syst
HPQCD/UKQCD06	2+1	0.830	0.025	0.18
RBC/UKQCD07	2+1	0.720	0.013	0.037
Laiho09	2+1	0.724	0.008	0.029
BSW09 (prelim.)	2+1	0.701	0.019	0.047
Educated Rfit		0.721	0.006	0.029
`latticeaverages.org`		0.720	0.025	

- CKM fitter current average: $\hat{B}_K = 0.724 \pm 0.005 \pm 0.067$
- Combining methods yield a syst smaller than syst of each ?

- Other differences in lattice parameter treatment

* CKMfitter uses B_s caluculations to obtain B_d parameters through B_s/B_d ratio, since their caluculation precision is better.

* UTfit has adopted different approach.

* Scanning method??

The choice of the treatment of theoretical parameters in the fit is an “identity” of each method.

UTfit lattice input

BK, f_Bs, f_Bs/f_Bd, B_Bs, B_Bs/B_Bd

1) The ratio f_Bs/f_Bd and the value of f_Bs, being related to the "slope" and the "intercept" of the decay constant as a function of the light quark mass, can be assumed to be uncorrelated among each other, to a (presumably) good extent. Similarly, we can assume that the ratio B_Bs/B_Bd is uncorrelated with B_Bs.

2) We can also assume that the lattice results for the decay constants (f_Bs, f_Bs/f_Bd) on one side and for the bag parameters (B_Bs, B_Bs/B_Bd) on the other side are uncorrelated among each other.

3) this choice uses at most the input from the Bs sector which do not suffer, in the lattice approach, of the systematic uncertainty related to the chiral extrapolation.

b) Other theory treatment

- ε_K related
  - * Correction factors in Inami-Lim function
    - η_{cc}
    - η_{tt}
    - η_{ct}
  - * $\kappa_{\varepsilon K}$ (additional parameter from I=0 contribution)

- Determination of these parameters are done by each approach in a different way... (Also the "identity" of each approach)

- There may be differences in the theoretical formulation of measurements among three approaches.
  - * Treatment of higher order in Δm, ε_K , etc...
  - * Clarification of the difference might be necessary(?)

This slide will be replaced with the one describing our discussion conclusion

My opinion on theory treatment in each approach

- Treatment of theory (both formulation and choice of parameter values) is the identity of each approach. (Not only the statistical method!)

- We are not expected to show only the difference in the statistical approach in the physics book, I believe. It is meaningful to show the integrated difference among three groups.

- We should avoid another "frequentist vs. baysien" type argument in the common theory treatment....

-> As a conclusion, I strongly suggest Option 2.

- Common experimental inputs to all approaches are important to discuss the difference clearly in the book.

- Basic theory parameters (as in PDG) should be common.

- The difference in theoretical formulation/parameter in three methods has to be examined and discussed in detail in the book.

- The decision of the option heavily depends on what we expect by having three methods in the book.

- If the purpose is the exact cross check of CKM fit by three methods expecting exactly the same output, we should use the exactly same theory/parameters in three methods.
    -> But what is Physics to have three methods?

- IMHO, the reason to have three approaches in the book is not the cross check. It is to record there are three different approaches using different choice of theories in the book, and also to show the results are consistent even using different methods.

- How do you think? We should follow the majority, anyway.....

4. Benchmark models and NP

- SM is of course the baseline model.

- Do we need to discuss any specific NP models?
  * Emi Kou is supposed to cover them: MFV, 2HDM......
  * Maybe we can provide constraint plots on her request.
  * Remaining model could be “model independent” fit.

- Model independent fit is really useful when discussing B-factory results (= B_d only results)?
  <- Recent constraint comes mainly from B_s (CDF/D0).

- B_s based results are supposed to be out of our coverage.....

- The same model independent parameterization of NP effect:

$$M = r_d^2 M_{SM} \exp(-i2\theta_d)$$

- A_{SL}?

Model Independent Fit

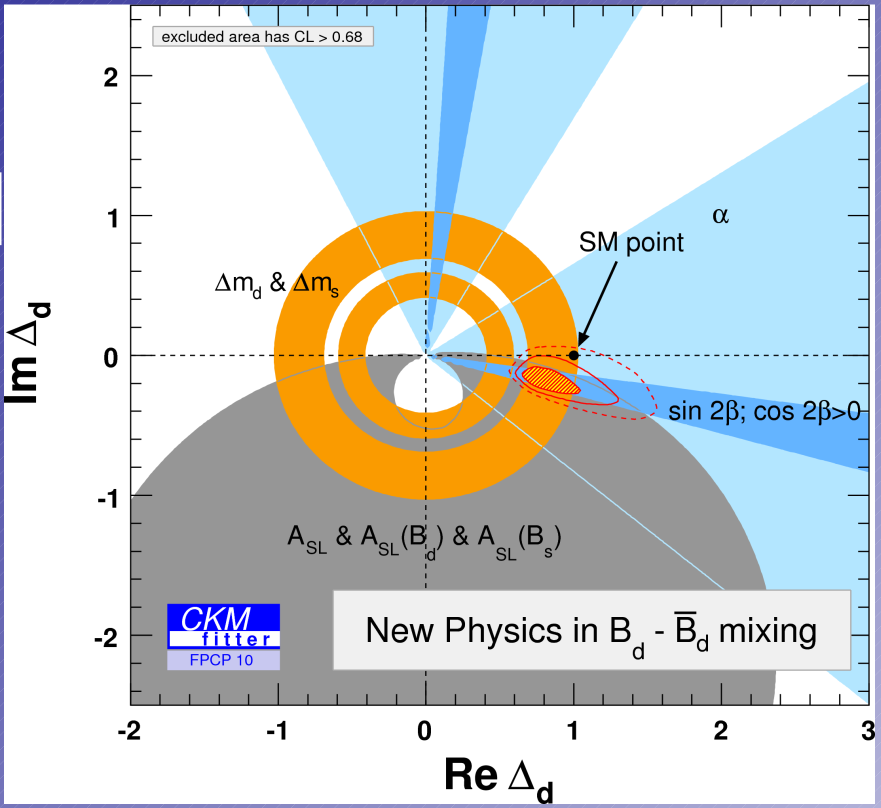
CKMfitter 2010

Constraining Δ_d:

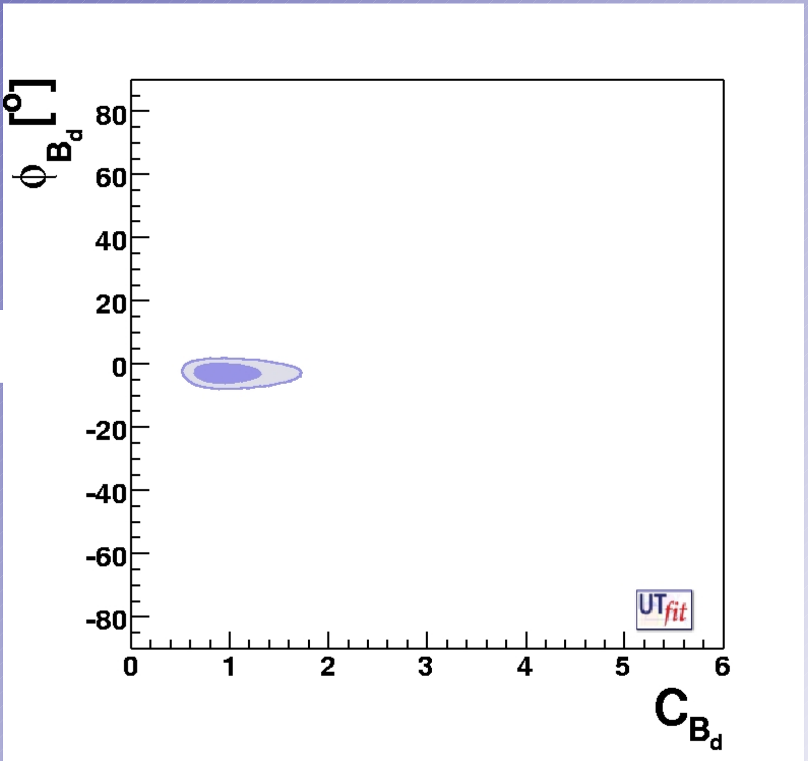
- Δm_d
- Δm_d & Δm_s
- $\sin 2\beta$
- α
- A^d_{SL} & A^s_{SL} & A_{SL}
- +Reference UT

$Re\Delta_d = +0.732^{+0.216}_{-0.056}$

$Im\Delta_d = -0.156^{+0.039}_{-0.087}$



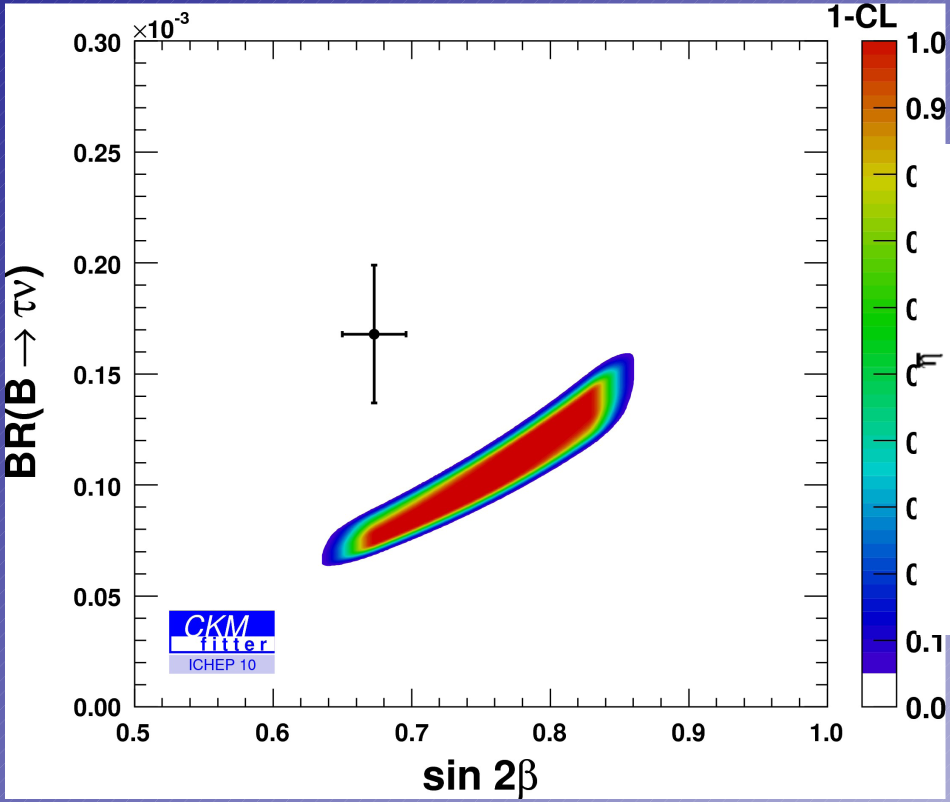
UTfit 2008

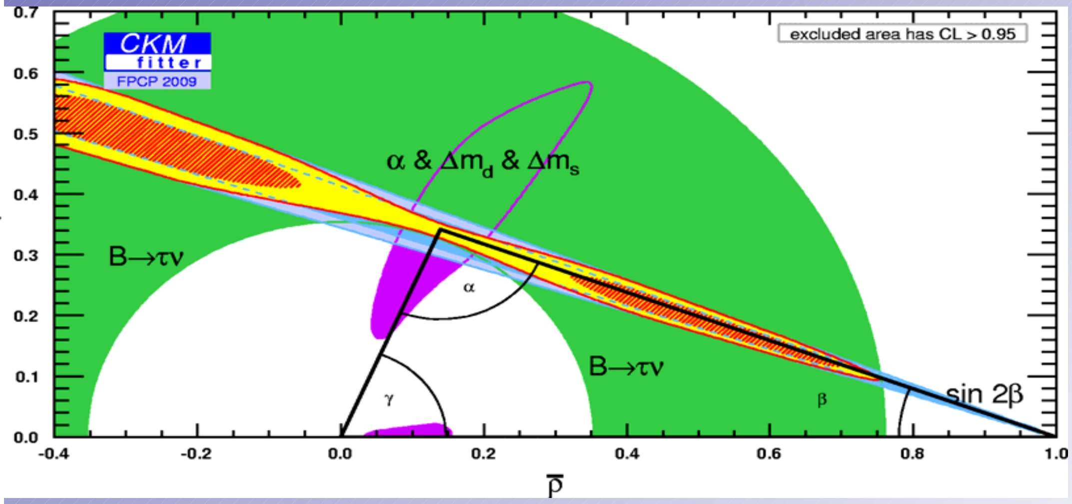


5. B-> τν

- Do we include B->τν in global CKM fit?

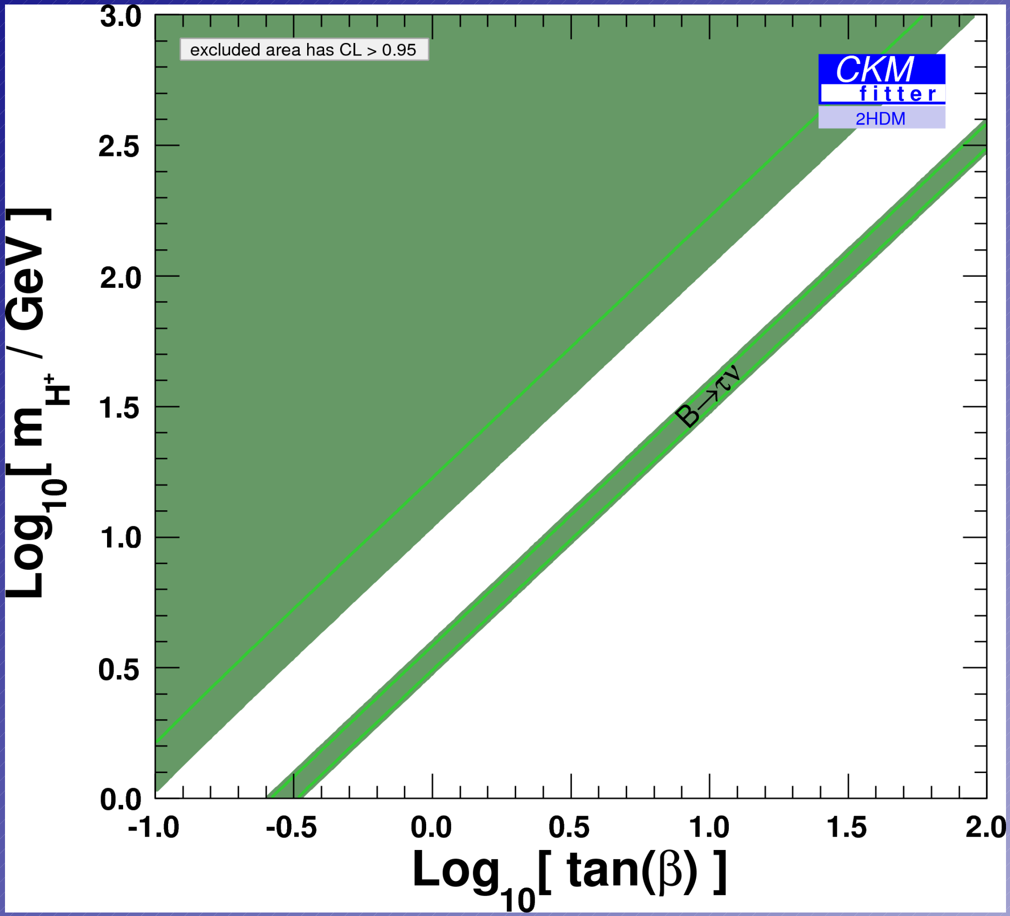
- The B->τν <-> sin2ϕ_1 tension is better to be discussed separately, but in which section??

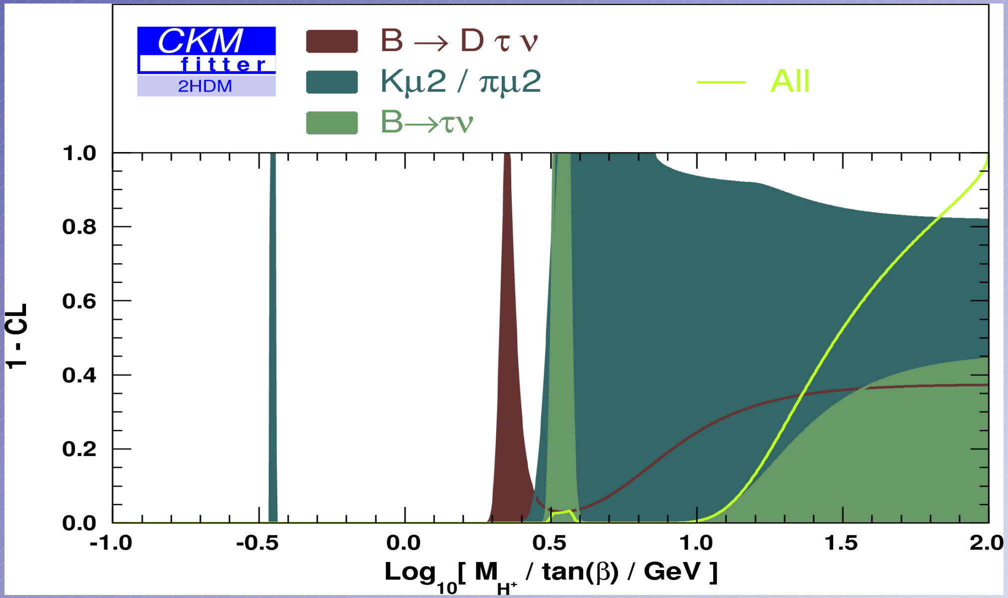




2HDM

$$\frac{\mathcal{B}[M \to l\nu]}{\mathcal{B}[M \to l\nu]_{\rm SM}} = (1 + r_H)^2 \qquad r_H = \left(\frac{m_{q_u} - m_{q_d} \tan^2\beta}{m_{q_u} + m_{q_d}}\right)\left(\frac{m_M}{m_{H^+}}\right)^2$$





6. Section layout

Gerald's proposal @ KEK meeting:

- Section: Introduction and goals 2p
- Section: Methodology
  - Subsection: CKMfitter 2p
  - Subsection: UTfit 2p
  - Subsection: Scanning method 2p
- Section: Experimental Inputs
  - Subsection: B-factories results: β, α (which decays to consider), γ, $2\beta+\gamma$, V_{ub}, V_{cb}, Δm_d, A^d_{SL}, $B(B\rightarrow\tau\nu)$,radiative penguins (how to use them) 4p
  - Subsection: Non-B-factories results (briefly on their threatment): ε_K, Δm_s, A^s_{SL}, TD $B_s \rightarrow J/\psi\phi$, $\Delta\Gamma_s$ (with order calculation). 2-3p
    - Rather than having subsubsections we indicate in the table which are inputs for the SM fit and inputs for the BSM fits
- Section Theoretical Inputs
  - Subsection Derivation of hadronic observables 2p
  - Subsection Lattice QCD inputs 4p
- Benchmark models 5p
- Section Results from the global fits
- Section Global fits beyond the Standard Model 4p
  - Subsection New-physics parameterizations 4p
  - Subsection Operator analysis 2p
- Section Conclusions 1-2p
- total: 36-38 pages

- Layout could change depending on which option we take for fit.

- If option 2 is taken, treatment of theoretical parameters is better to be described together with the methodology.

- What can be the prospects for “results” and “conclusion”? How do we discuss three different results and aufheben them into a single conclusion?

Measurement Inputs

Observable	Scanning M
$\lvert V_{us}\rvert$	
$\lvert V_{ub}\rvert$ $[10^{-3}]$	inc, exc, or average
$\lvert V_{cb}\rvert$ $[10^{-3}]$	inc, exc, or average
$B(B\to\tau\nu)$ $[10^{-4}]$	
Δm_{Bd} $[ps^{-1}]$	
Δm_{Bs} $[ps^{-1}]$	
$\lvert\varepsilon_K\rvert$ $[10^{-3}]$	
$\sin 2\beta$	charmonium, DD, rare
$\alpha[\pi\pi, \rho\pi, \rho\rho]$	B, S, C for $\pi\pi$, $\rho\pi$, $\rho\rho$, $a_1\pi$
γ [GGSZ, GLW, ADS]	GGSZ, GLW, ADS
$\cos 2\beta$	$J/\psi K^*$
$2\beta+\gamma$	$D(^*)\ \pi$, $D\rho$

* use average values

experimental inputs:

V_{ub}/V_{cb}: currently auto-produced:
from the relative sections
CKM fitter will have problems with the exclusive?
Δm_d, Δm_s: currently from PDG/HFAG and Tevatron
from the relative sections and Tevatron
α, γ: currently auto-produced:
from the relative sections
sin2β: take into account the theory uncertainties
will that be done in the sin2β section?
I think we should consider this issue
cos2β, cos2β+γ: auto-produced
B to $\tau\nu$: HFAG
relative section.
dedicated subsection in our chapter?

$|V_{ub}|/|V_{cb}| \sim R_b$

- inclusive:
  - $b \rightarrow c l \nu \Rightarrow |V_{cb}|=(41.54 \pm 0.44 \pm 0.58) 10^{-3}$
  - $b \rightarrow u l \nu \Rightarrow |V_{ub}|=(42.0 \pm 1.5 \pm 5.0)\ 10^{-4}$

    (HFAG + flat error for model spread)
- exclusive:
  - $B \rightarrow D^{(*)} l \nu \Rightarrow |V_{cb}|=(39.0 \pm 0.9) 10^{-3}$
  - $b \rightarrow \pi(\rho) l \nu \Rightarrow |V_{ub}|=(35.0 \pm 4.0)\ 10^{-4}$

    using LQCD form factors

angles:

Sin2β from B → J/ψK^0

+ theory error from CPS:

sin2β = 0.655 ± 0.024 **HFAG**

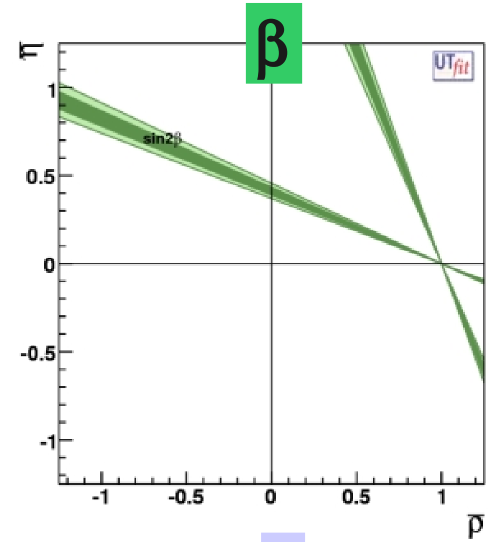
α combined: isospin ππ/ρρ and ρπ

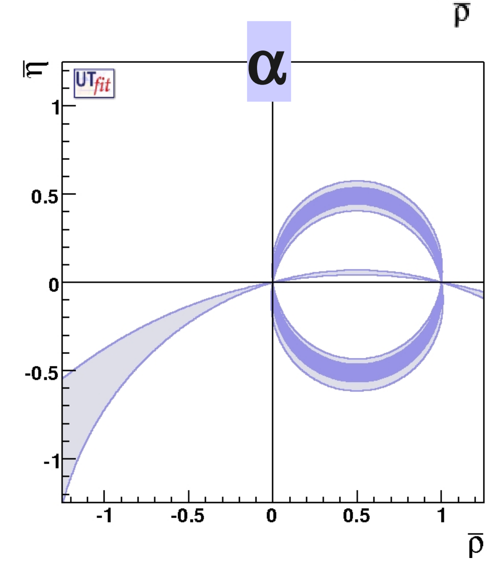
α = (91 ± 6)º

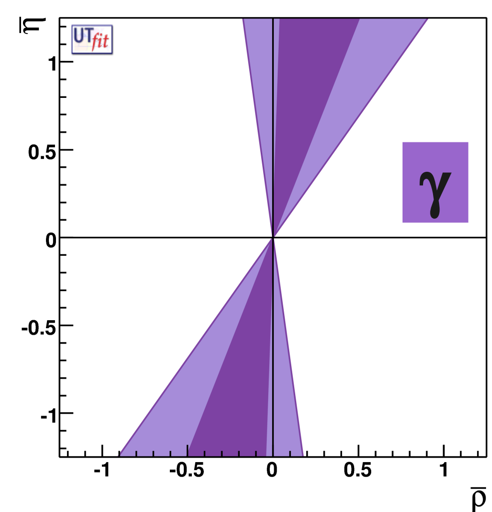
γ combined: GLW/ADS/Dalitz

both charged and neutrals

γ = (74 ± 11)º U (-106 ± 11)º







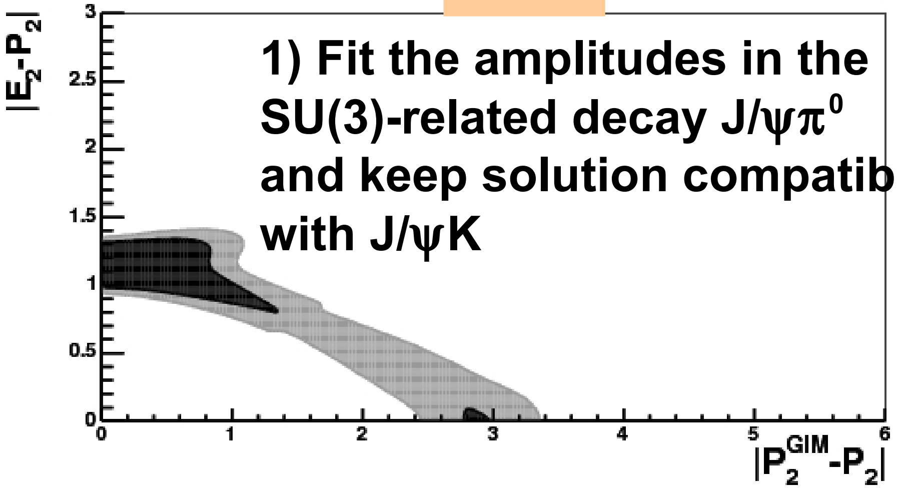
Theory error on sin2β:

A.Buras, L.Silvestrini
Nucl.Phys.B569:3-52(2000)

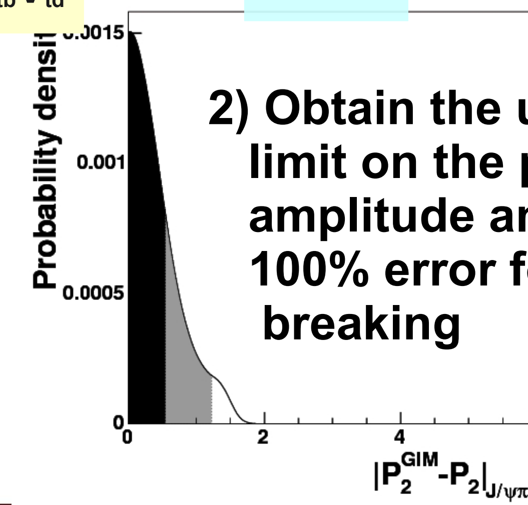
Channel	Cl.	E_1	E_2	EA_2	A_2	P_1	P_2	P_3	P_1^{GIM}	P_2^{GIM}	P_3^{GIM}	P_4	P_4^{GIM}
			$\frac{1}{N}$	$\frac{1}{N^2}$	$\frac{1}{N}$	$\frac{1}{N}$	$\frac{1}{N^2}$			$\frac{1}{N^2}$			$\frac{1}{N^3}$
$B_d \to J/\psi K^0$	C	–	λ^2	–	–	–	λ^2			λ^4	–	–	–
$B_d \to \pi^0 J/\psi$	D	–	λ^3	λ^3	–	–	λ^3	–	–	λ^3	–	$[\lambda^3]$	$[\lambda^3]$

$V^*_{cb}V_{cs}$ $V^*_{tb}V_{ts}$ $V^*_{ub}V_{us}$

$V^*_{cb}V_{cd}$ $V^*_{tb}V_{td}$ $V^*_{ub}V_{ud}$

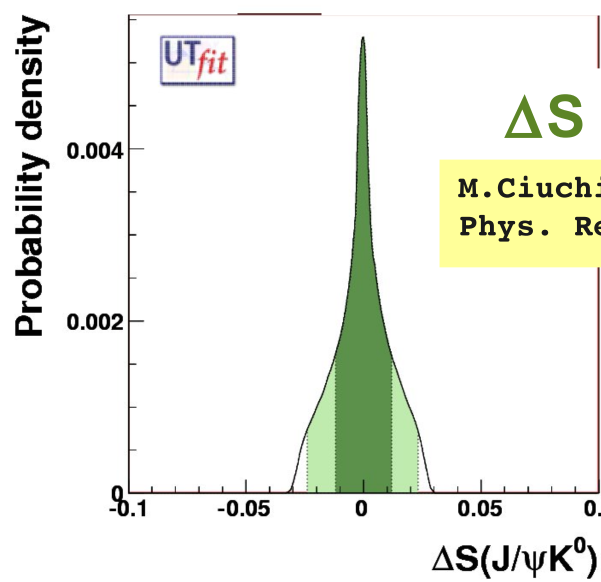


1) Fit the amplitudes in the SU(3)-related decay J/ψπ⁰ and keep solution compatible with J/ψK



2) Obtain the upper limit on the penguin amplitude and add 100% error for SU(3) breaking

3) Fit the amplitudes in J/ψK⁰ imposing the upper bound on the CKM suppressed amplitude and extract the error on sin2β



$\Delta S = 0.000 \pm 0.012$

M.Ciuchini, M.Pierini, L.Silvestrini
Phys. Rev. Lett. 95, 221804 (2005)

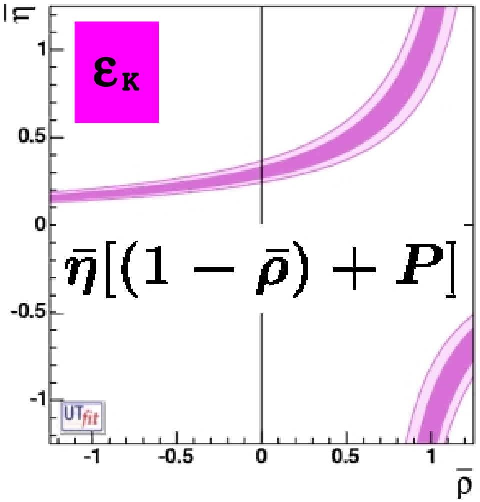
BK comes from Lubicz's talk at Lattice 2009:
V.~Lubicz, arXiv:1004.3473 [hep-lat]

B-physics parameters:
J.~Laiho, E.~Lunghi and R.~S.~Van de Water,
Phys.\ Rev.\ D {\bf 81} (2010) 034503
arXiv:0910.2928 [hep-ph]

exclusive Vub and BSM B-physics parameters
V.~Lubicz and C.~Tarantino,
Nuovo Cim.\ {\bf 123B} (2008) 674
arXiv:0807.4605 [hep-lat]

mainly two reasons for amending the Laiho et al paper:
they exclude all Nf=2 results
they do not analyse the details on the systematics of the various analyses they include

the case: form factor f+(0) of Kl3 where ETMC calculation with Nf=2 has a systematic error well more under control then the Nf=2+1 calculation from RBC-UKQCD. The authors Laiho et al agreed in Lattice 2010 and CKM2010 that both should be considered but no new average has been presented.



Buras, Guadagnoli, Isidori

ε_K corrected for measured phase, Im A_0 and LD contributions

- F_K = 156.0 ± 1.3 MeV
- B_K = 0.731 ± 0.036 Lubicz @ Lattice09

this decreases the SM prediction for ε_K by ~6%

Back up slides

the method and the inputs:

$$f(\bar\rho,\bar\eta,X|c_1,...,c_m) \sim \prod_{j=1,m} f_j(\mathcal{C}|\bar\rho,\bar\eta,X) * \prod_{i=1,N} f_i(x_i) f_0(\bar\rho,\bar\eta)$$

Bayes Theorem

$$X \equiv x_1,...,x_n = m_t, B_K, F_B, ...$$

$$\mathcal{C} \equiv c_1,...,c_m = \epsilon, \Delta m_d/\Delta m_s, A_{CP}(J/\psi K_S), ...$$

$(b \to u)/(b \to c)$	$\bar\rho^2 + \bar\eta^2$	$\bar\Lambda, \lambda_1, F(1), ...$
ϵ_K	$\bar\eta[(1-\bar\rho)+P]$	B_K
Δm_d	$(1-\bar\rho)^2+\bar\eta^2$	$f_B^2 B_B$
$\Delta m_d/\Delta m_s$	$(1-\bar\rho)^2+\bar\eta^2$	ξ
$A_{CP}(J/\psi K_S)$	$\sin 2\beta$	

Standard Model
OPE/HQET
Lattice QC
to g
mt from quark
to hadron

M. Bona *et al*. (UTfit Collaboration) JHEP 0507:028,2005 hep-ph/0501199
M. Bona *et al*. (UTfit Collaboration) JHEP 0603:080,2006 hep-ph/0509219