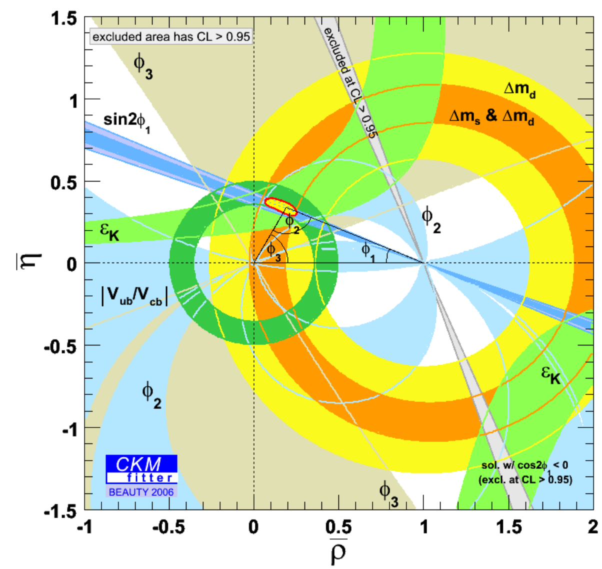
CKM fitter

Particle Physics Joint Lab Japan - France

シーケーエムフィッター



S. T'JAMPENS

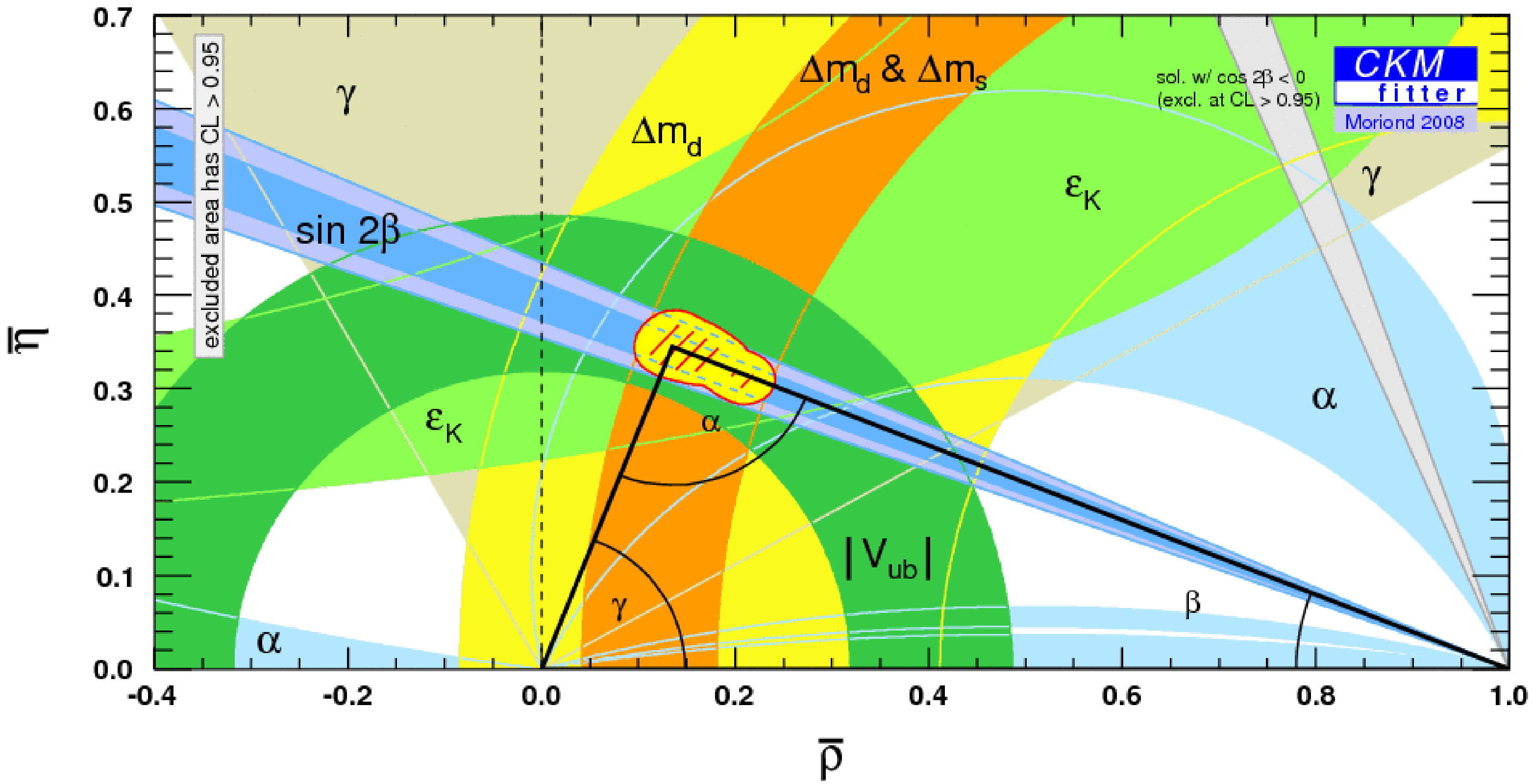
LAPP(CNRS/IN2P3 et Université de Savoie)

FJPPL'08 – CNRS/IN2P3 Headquarter May 15-16 2008

Outline

- FJPPL '08:
  - SuperBelle: Prospective with 10 ab^{-1}
  - $\Delta F=1$ FCNC transitions: NP in Wilson Coefficients
  - Determination of the angle γ/ϕ_3:
    - statistics: p-value and nuisance parameters

Why believe the KM mechanism?



The great success of the B factories and Tevatron (and the Standard Model): the KM mechanism is the dominant source of CPV at the EW scale.

But the UT is not the whole story!

New Physics in Flavor Physics

decreasing SM contrib. →

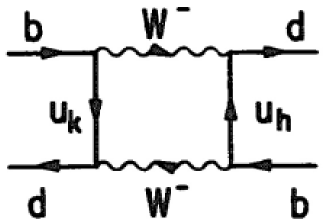
	$b \to s$ $(\sim\lambda^2)$	$b \to d$ $(\sim\lambda^3)$	$s \to d$ $(\sim\lambda^5)$
$\Delta F=2$ box	ΔM_{Bs} $A_{CP}(B_s \to \psi\phi)$	ΔM_{Bd} $A_{CP}(B_d \to \psi K)$	ΔM_K, ε_K
$\Delta F=1$ 4–quark box	$B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to \pi\pi$, $B_d \to \rho\pi$, ...	ε'/ε, $K \to 3\pi$, ...
gluon penguin	$B_d \to X_s \gamma$, $B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to X_d \gamma$, $B_d \to \pi\pi$, ...	ε'/ε, $K_L \to \pi^0 \ell^+\ell^-$, ...
γ penguin	$B_d \to X_s \ell^+\ell^-$, $B_d \to X_s \gamma$ $B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to X_d \ell^+\ell^-$, $B_d \to X_d \gamma$ $B_d \to \pi\pi$, ...	ε'/ε, $K_L \to \pi^0 \ell^+\ell^-$, ...
Z^0 penguin	$B_d \to X_s \ell^+\ell^-$, $B_s \to \mu\mu$ $B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to X_d \ell^+\ell^-$, $B_d \to \mu\mu$ $B_d \to \pi\pi$, ...	ε'/ε, $K_L \to \pi^0 \ell^+\ell^-$, $K \to \pi\nu\nu$, $K \to \mu\mu$, ...
H^0 penguin	$B_s \to \mu\mu$	$B_d \to \mu\mu$	$K_{L,S} \to \mu\mu$

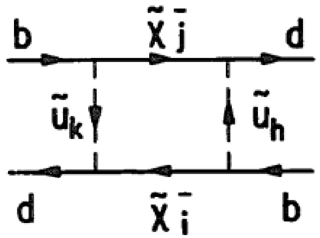
↓ decrea–sing SM contrib.

Theoretical errors $\lesssim 10\%$

There is much more to learn than just the UT consistency check

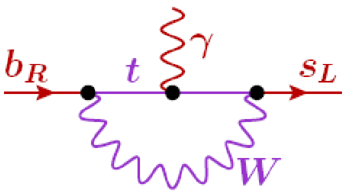
- Mixing

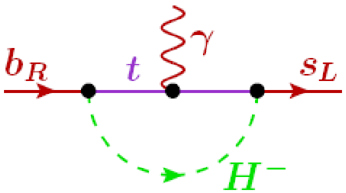




Simple parameterization for each neutral meson: $M_{12} = M_{12}^{\rm SM}\,(1 + h e^{2i\sigma})$

- Penguin decays



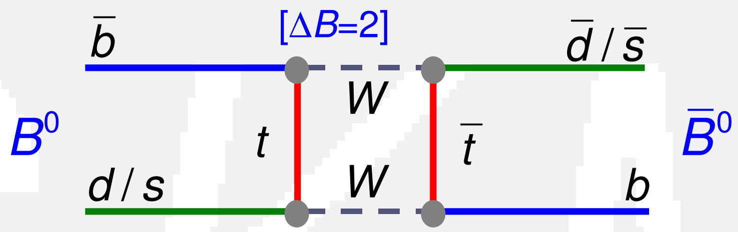


Many operators for $b \to s$ transitions — no simple parameterization of NP

➔ NP in flavor physics: explore FCNC and precision measurements

New Physics in ΔB=2 transitions

Δm_q:



Perturbative QCD

CKM Matrix Elements

$$\Delta m_q = \frac{G_F^2}{6\pi^2} m_{B_q} m_W^2 \, \eta_B \, S(x_t) \, f_{B_q}^2 B_q \left|V_{tq} V_{tb}^*\right|^2 \quad (\text{for } q = d, s)$$

Loop integral
(top loop dominates)

Non-perturbative: Lattice
(eff. 4 fermion operator)

CDF- hep-ex/0609040

HFAG PDG08

Δm_s : 17.77±0.12 ps^{-1}

Δm_d : 0.507±0.005 ps^{-1}

- Dominant theoretical uncertainties : $\sigma_{\text{rel}}\left(f_{B_{d/s}}\sqrt{B_{d/s}}\right)\;;\;16\%$
- Improved error indirect via Δm_s : $\sigma_{\text{rel}}\left(\xi = f_{B_s}\sqrt{B_s} \,/\, f_{B_d}\sqrt{B_d}\right)\;;\;5\%$

  [SU(3) breaking correction]

➔ Lattice QCD

What is required for NP search from the UT?

Itoh-san – BNM '08

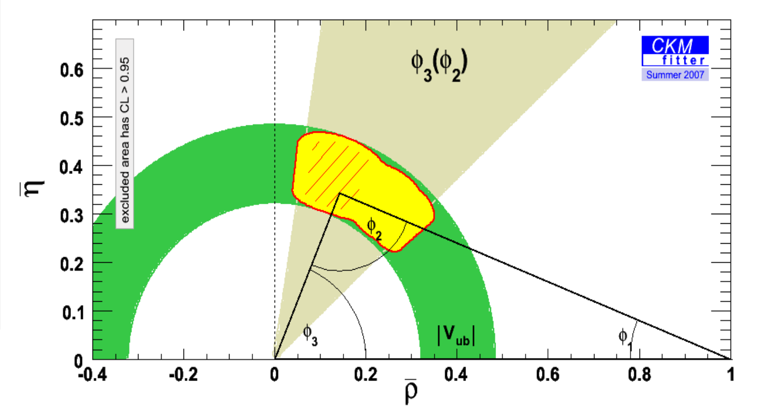
- In the search of NP from the UT consistency check, it is needed:
  - ➔ improve the determination of γ
  - ➔ improve LQCD [bag factors, decay constants, etc.]
- In the coming years, more precise measurements will become available from LHCb and Super B factories [some of which may become systematics-limited]

➔ NP sensitivity from the global fit will become more dependent on theoretical uncertainties.

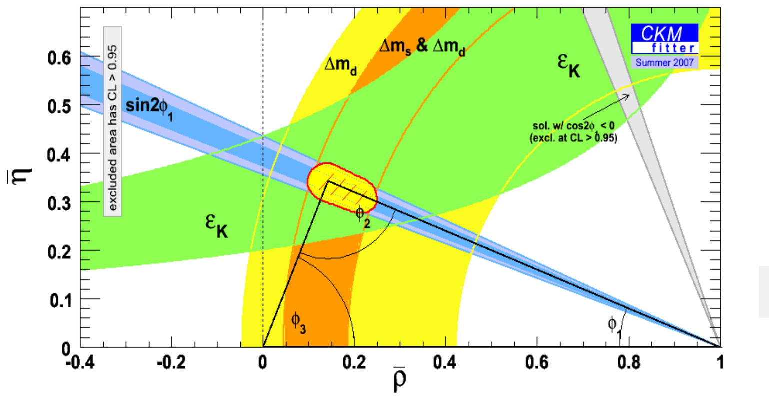
- Case studies for three different predictions of theoretical uncertainties in near future:

  1) current values(>O(10%)), 2) O(5%), 3) O(1%)

- Experimental inputs: expected accuracies at SuperBelle with 10 ab^{-1}.



Tree(NP Free): "Reference UT"



Loop: sensitive to NP

Experimental inputs: from Belle to SuperBelle

Itoh-san – BNM '08

	Center	σ(0.5/ab)	σ(10/ab)	σ(50/ab)
V_{ub}	3.94×10^{-3}	6.3%	3%	2 %
Δm_d	0.507	0.8% (sys.limit)	0.8%	0.8%
$\sin2\phi_1$	0.734	5.5%	2%	1.5%
ϕ_2 (deg.)	94.6	11°	3°	2°
ϕ_3 (deg.)	61.6	19°	4°	3°
$B(B\to\tau\nu)$	1.13×10^{-4}	38%	8%	4%
$\frac{B(B\to\rho/\omega\gamma)}{B(B\to K^*\gamma)}$*	0.032	25%	6%	3%
Δm_s	18.77	0.06%	0.06%	0.06%

* Systematic errors are included in the quoted errors.

* Δm_s : LHCb expectation

Uncertainties in theory inputs

Itoh-san – BNM '08

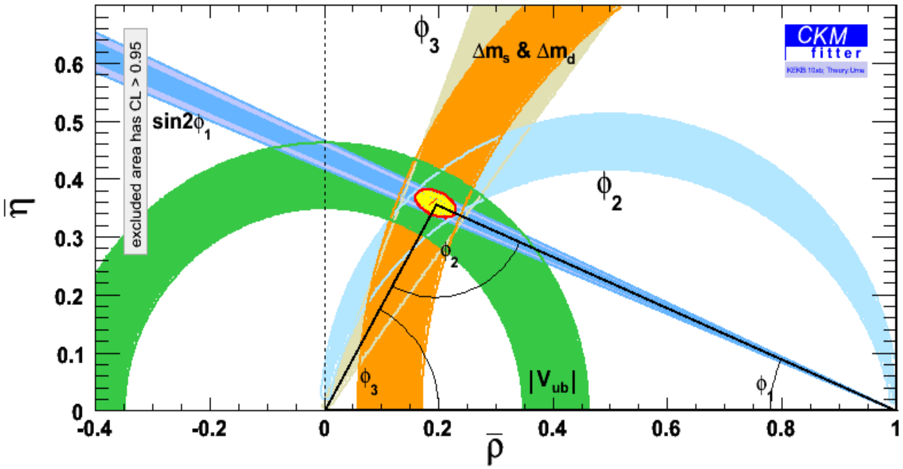
梅 (ume) : uncertainties currently used in CKMfitter
竹 (take) : uncertainties based on the predictions by S.Sharpe[1]
松 (matsu) : uncertainties based on the predictions by V.Lubicz[2]

	central value	errors 梅 (ume)	竹 (take)	松 (matsu)
f_{Bs}	0.233	14%	4%	1%
$f_{Bs}\sqrt{B_s}$	0.277	13%	4%	1%
ξ	1.24	5%	2%	1%
V_{ub} theory		7%	4%	2%
$B\to\rho\gamma$ theory		11%	8%	4%

[1] Lattice '04 ORSAY – 60TFlop year
[2] IV SuperB Workshop '06 – 10 PFlop year

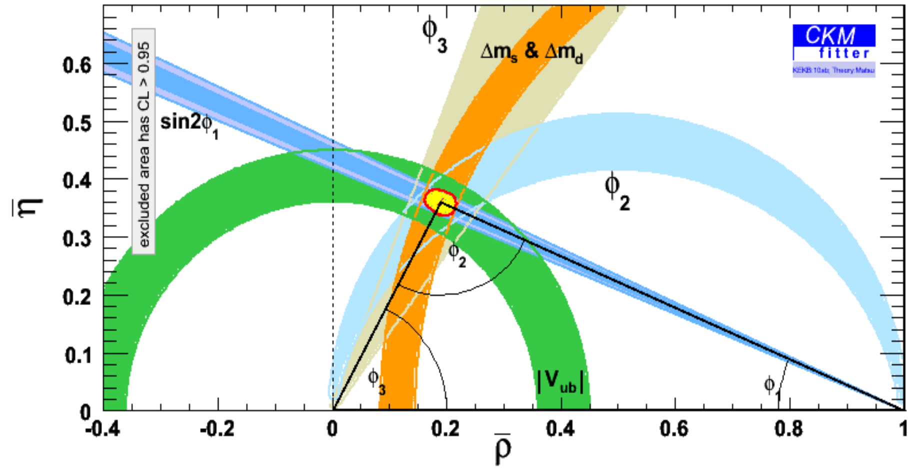
Results of global CKM fit with 10 ab^{-1} data sample

梅 (ume)



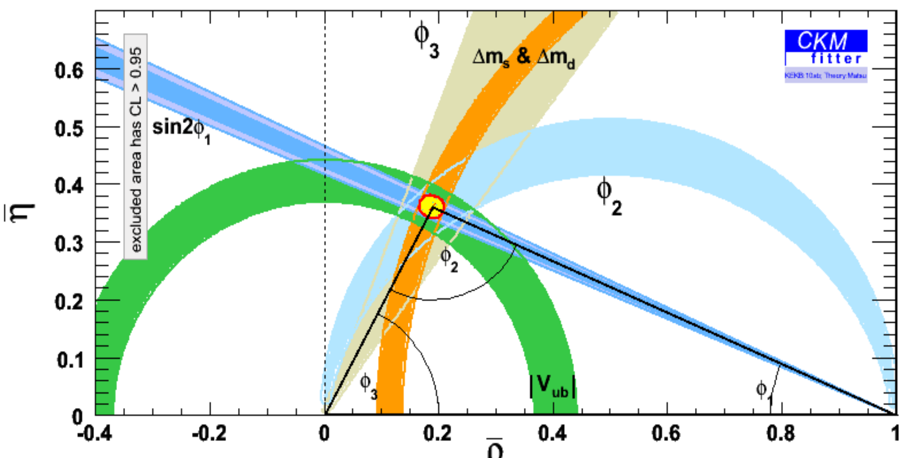
* ϕ_2 is the main constraint to $\bar{\rho}$

竹 (take)



* Δm_s becomes the main constraint to $\bar{\rho}$

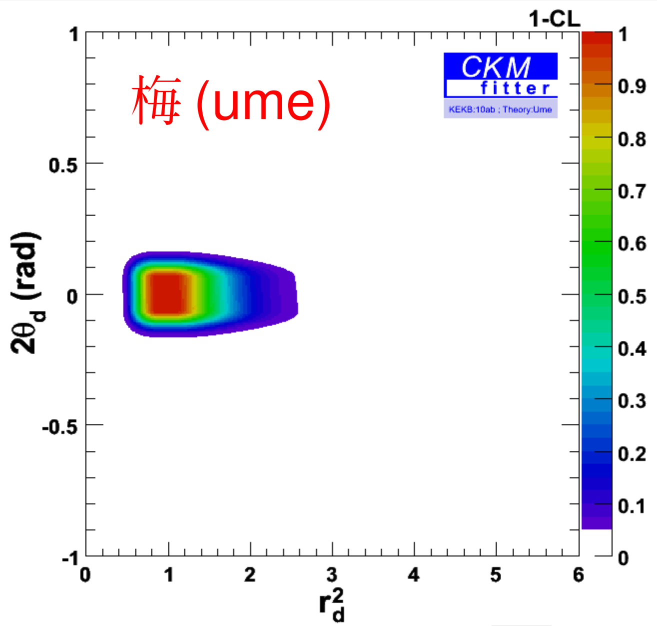
松 (matsu)

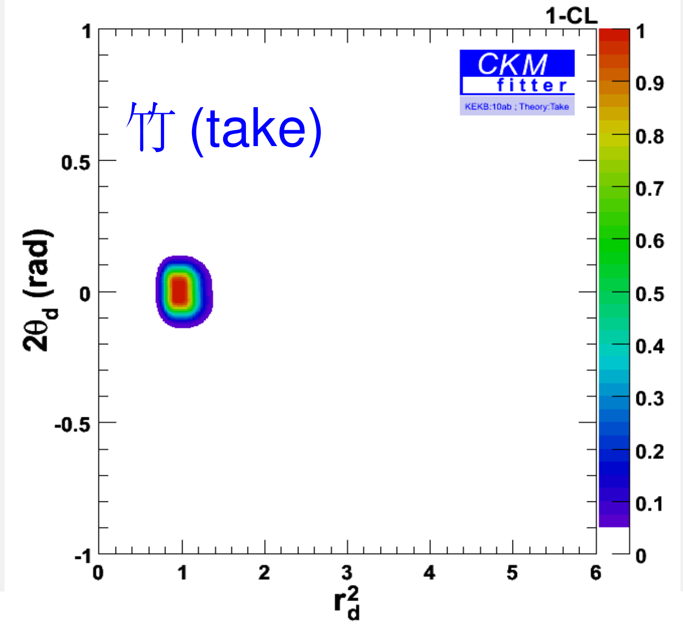


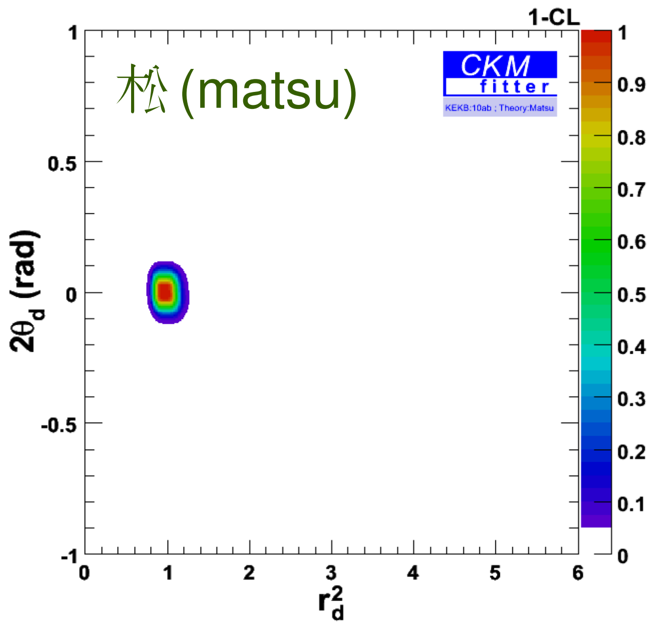
	$\sigma(\bar{\rho})$	$\sigma(\bar{\eta})$
梅 Ume	7.7%	3.1%
竹 Take	6.2%	2.8%
松 Matsu	4.6%	2.5%

New Physics in Mixing [$M = M_{SM} r_d^2 \exp(-i2\theta_d)$]

10 ab^{-1}







	$\sigma(r_d^2)$	$\sigma(2\theta_d)$
梅 Ume	42%	5.9°
竹 Take	17%	4.3°
松 Matsu	13%	3.3°

*Improvement in f_B and B calculations is the key in the model independent NP search.

ΔF=1 FCNC: b→s transitions and OPE

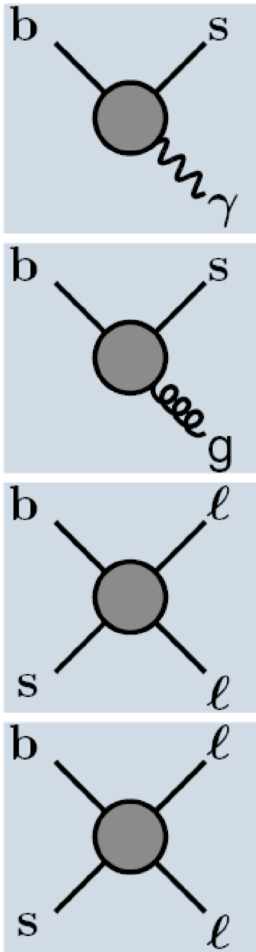
G. Hiller - hep-ph/0308180

$\mathcal{O}_{7\gamma}$

$\mathcal{O}_{8g}$

$\mathcal{O}_{9\ell,10\ell}$

$\mathcal{O}_{S,P}$



Describe *b*→*s* transitions by an effective Hamiltonian

$$\mathcal{H}_{\text{eff}} = -\frac{4G_F}{\sqrt{2}} V_{\mathbf{ts}}^* V_{\mathbf{tb}} \sum_{i=1}^{10} C_i(\mu)\mathcal{O}_i(\mu)$$

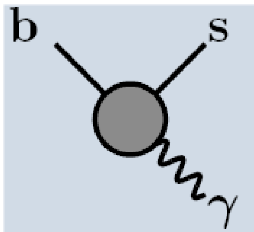
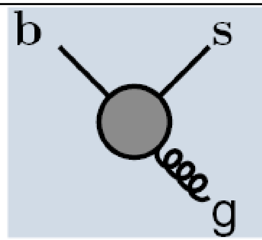
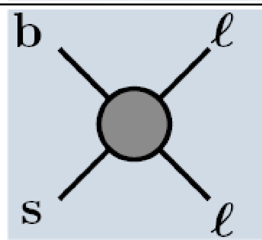
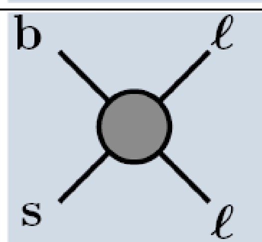
- Long Distance:
  - Operators O_i
- Short Distance:
  - Wilson coef. C_i

New physics shows up as modified C_i,

(or as new operators)

Operators and Observables

G. Hiller - hep-ph/0308180

		magnitude	phase	helicity flip $\mathcal{O}'_i$
$\mathcal{O}_{7\gamma}$		$b \to s\gamma$	$a_{CP}(b \to s\gamma)$	$\Lambda_b \to \Lambda\gamma$ $B \to (K^* \to K\pi)\ell^+\ell^-$ $B \to (K^{**} \to K\pi\pi)\gamma$
$\mathcal{O}_{8g}$		$b \to s\gamma$ $B \to \not{X}_c$	$a_{CP}(b \to s\gamma)$ $B \to K\phi$	$\Lambda_b \to \Lambda\phi$ $B \to K^*\phi$
$\mathcal{O}_{9\ell,10\ell}$		$b \to se^+e^-$	$A_{FB}(b \to s\ell^+\ell^-)$	$B \to (K^* \to K\pi)\ell^+\ell^-$
$\mathcal{O}_{S,P}$		$B_{d,s} \to \mu^+\mu^-$	$B_{d,s} \to \tau^+\tau^-$	$b \to s\tau^+\tau^-$

Wilson Coefficient Fits

- In the framework of CKM fit, the NP effect is searched for in the $B_{d,s}$-$B_{d,s}$ mixing diagram, i.e., comparison of ρ–η constraints by (β/ϕ_1, α/ϕ_2, $\Delta m_{d,s}$) and by (γ/ϕ_3, V_{ub})

- A complementary NP search can be performed by studying the FCNC transitions like $B \to X_s \gamma$ and $B \to X_s l^+ l^-$ which are governed by Wilson Coefficients C_7, C_9 and C_{10}.

- The determination of Wilson Coefficients using various FCNC decays simultaneously in the similar manner as that in CKM fit (global fit) can be a sensitive probe to NP by comparing with the SM expectations.

NP in Wilson Coefficients (cont'd)

- Belle measurement of A_{FB} in $B \to K^* ll$ already gives good constraints to Wilson coefficients.
- The extension of this approach is considered to include other measurements together in the fit.
- Inputs
  - * $Br(B \to K^* \gamma)$
  - * $Br(B \to K^* l^+ l^-)$
  - * $A_{FB}(B \to K^* l^+ l^-)$ as a function of q^2 (5 points)
- Free parameters: Wilson Coefficients C_7, C_9 and C_{10}.
  - * $|V_{tb} V_{ts}^*|$ is given through the standard CKMfitter interface.
- Theoretical model:

  based on the paper by A. Ali, *et al.*

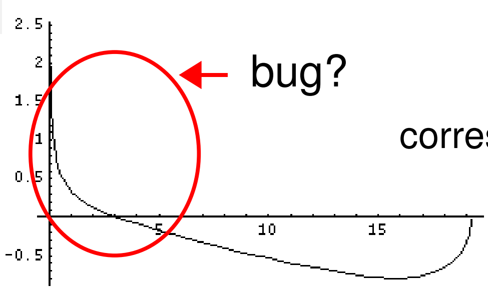
  PRD **61**, 0704024 (2000)

- Coded as an add-on theory model for CKMfitter.

Status: some work still needed

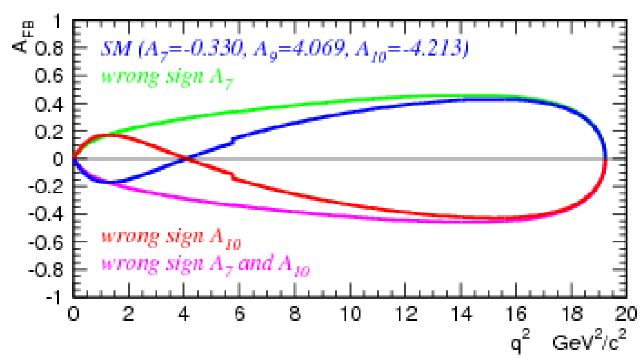
- Coding of theory model in Mathematica completed.
- Test of the coding is in progress:
  - * Still have problems to reproduce $A_{FB}(q^2)$ written in the paper by Ali, et al.
    - $\rightarrow$ Careful check of both coding and theoretical expression
- More up-to-date NNLO theoretical calculations will be implemented after this trial is successful.
- Aiming at the completion by next annual CKMfitter meeting and hopefully the presentation at autumn JPS meeting.

```
Plot[AFBnormqsq[qsq],{qsq,0.0,20.0}];
Plot::plnr : AFBnormqsq[qsq] is not a machine-size real number at qsq = 19.990385710617627`. More...
Plot::plnr : AFBnormqsq[qsq] is not a machine-size real number at qsq = 19.6055412395194`. More...
Plot::plnr : AFBnormqsq[qsq] is not a machine-size real number at qsq = 19.392358042486258`. More...
General::stop : Further output of Plot::plnr will be suppressed during this calculation. More...
```



corresponding to red line in right fig.

Current trial implementation in CKMfitter



Ali's paper (drawn by Ishikawa)

Complex extraction of γ

GLW

$$R_{CP+-} = 1 \pm 2 r_B \cos(\delta_B)\cos(\phi_3) + r_B^2$$

$$A_{CP+-} = \pm 2 r_B \sin(\delta_B)\sin(\phi_3)/R_{CP+-}$$

ADS

$$R_{ADS} = r_B^{\,2} + r_D^{\,2} + 2 r_B r_D \cos(\delta_B + \delta_D)\cos\phi_3$$

GGSZ

$$(x_{+-}, y_{+-}) = (r_B \cos(\delta_B \pm \phi_3), r_B \sin(\delta_B \pm \phi_3))$$

32 observables

$R_{CP\pm}$, $A_{CP\pm}$ for DK, D^*K, DK^*

R_{ADS} for DK, D^*K, DK^*, for $K\pi$, $K\pi\pi^0$

$(x_\pm, y_\pm)$ for DK, D^*K, DK^*

↓

r_B, r_B^*, $r_B^{K^*}$, δ_B, δ_B^*, $\delta_B^{K^*}$, $r_{D_{K\pi}}$, $\delta_{D_{K\pi}}$, $r_{D_{K\pi\pi^0}}$, $\delta_{D_{K\pi\pi^0}}$, ϕ_3

11 parameters

➔ composite hypothesis (nuisance parameters): heavy statistical procedure

Metrology

Assuming that the agreement between the data and the theory is OK (p-value(χ^2_{min}))

Perform metrology (estimation of theory parameters):

1) Wilks (profile) likelihood-ratio test statistic [$W(a) \equiv \Delta\chi^2(a) = \chi^2(a,\hat{\mu}(a)) - \chi^2_{min}$]

- a=parameters of interest (γ), μ=nuisance parameters (r,δ)
- profile: take MLE of μ for each value of a [MINOS for CI in Minuit]

2) if the sampling pdf of W is a χ^2 law, p-value (CL) with Prob()

[the W test is pivotal [distribution under H_0 independent of nuisance parameters]]

3) if not: it's where the situation starts becoming complicated ↳ toy Monte Carlo

But the sampling pdf depends, in general, on the nuisance parameters.

What to do with the nuisance parameters?

- plug-in principle (first order parametric bootstrap): take MLE for the nuisance parameters
- adjusted p-value (second order parametric bootstrap)
- supremum method: least favorable values for the nuisance parameters

L. Demortier's talk@PHYSTAT2007 [http://phystat-lhc.web.cern.ch/phystat-lhc/]

A.C. Davison and D.V. Hinkley, Bootstrap Methods and their Application (1997)

Conclusion

Several on-going activities:

- prospective studies for SuperBelle
- New Physics search in Wilson coefficients.
- Longer term: $\Delta F=1$ rare decays. [very complex NNLO formulas ... to be implemented and checked]
- Try to improve statistical treatment [beware of naïve average and/or naïve confidence interval from likelihood (check coverage probability if you want to have correct uncertainties)]

BACKUP SLIDES

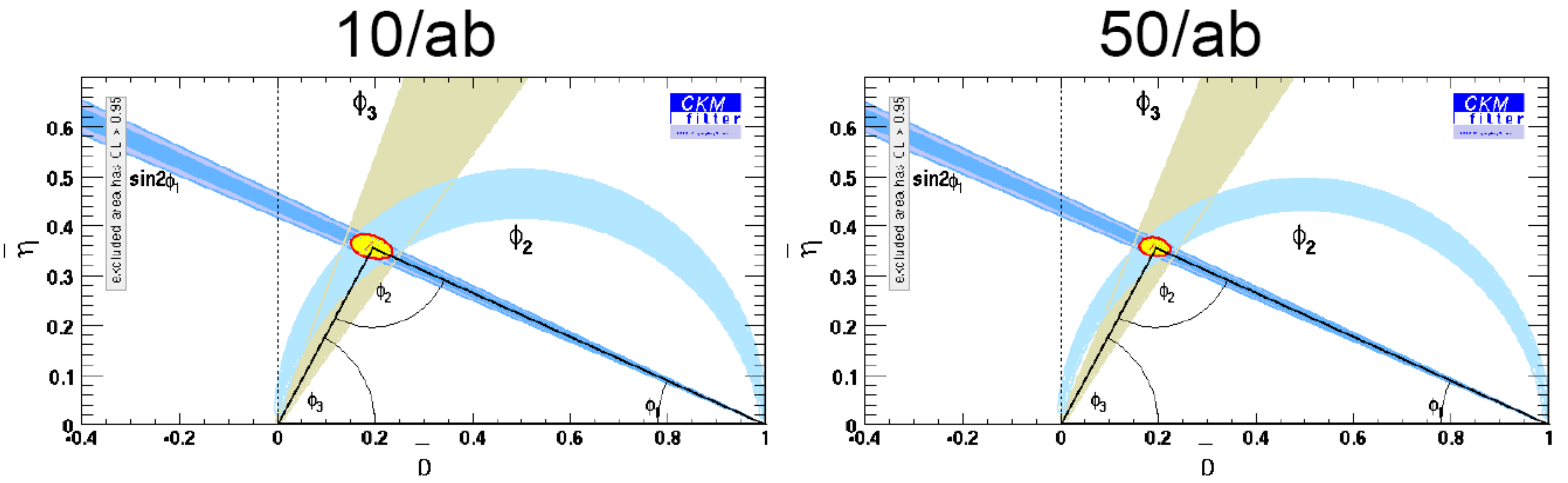
Bayesian?

F. James – Moriond QCD 07

Conclusions: Bayesian or frequentist?

1. The main problem in Bayesian methodology is the prior. Use Bayesian methods when you know the prior and have a good reason to use it. The only case I know where that is true is maximum entropy image processing.
2. Use Bayesian decision theory to make it clear what are the subjective criteria for your decision. [Example: where to look for new physics.]
3. For everything else, in particular objective data analysis, I don't see any reason to use Bayesian methods. We now know how to handle all the situations (nuisance parameters, systematic errors) that used to cause problems in the frequentist methodology.
4. Very few people would believe a result that can only be obtained by a Bayesian analysis with an arbitrary prior.

Results of global CKM fit with angle measurements only



	$\sigma(\bar{\rho})$	$\sigma(\bar{\eta})$
10/ab 50/ab	8.7% 6.7%	2.8% 2.1%

* Constraints by exp. measurements only in principle!