CKM and Wilson Coefficient Fits with $10ab^{-1}$

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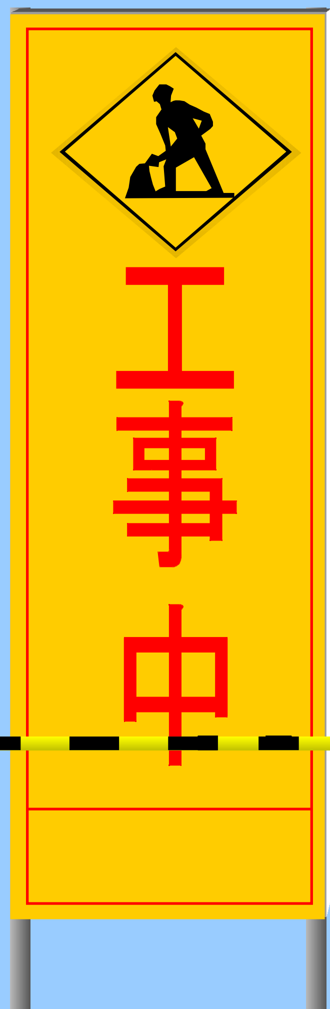
KEK

BNM2008, Atami, Japan
Jan. 26, 2008

Wilson Coefficient Fitter Construction



Danger!
Under Construction

Wilson Coeff. Fitter
Construction Site

until: ~~Jan.26 2008~~
↓
Mar. 2008-

Outline

1. Introduction
2. CKM fit with 10/ab data sample
3. NP sensitivity
4. Status of Wilson coefficient fit
5. Summary

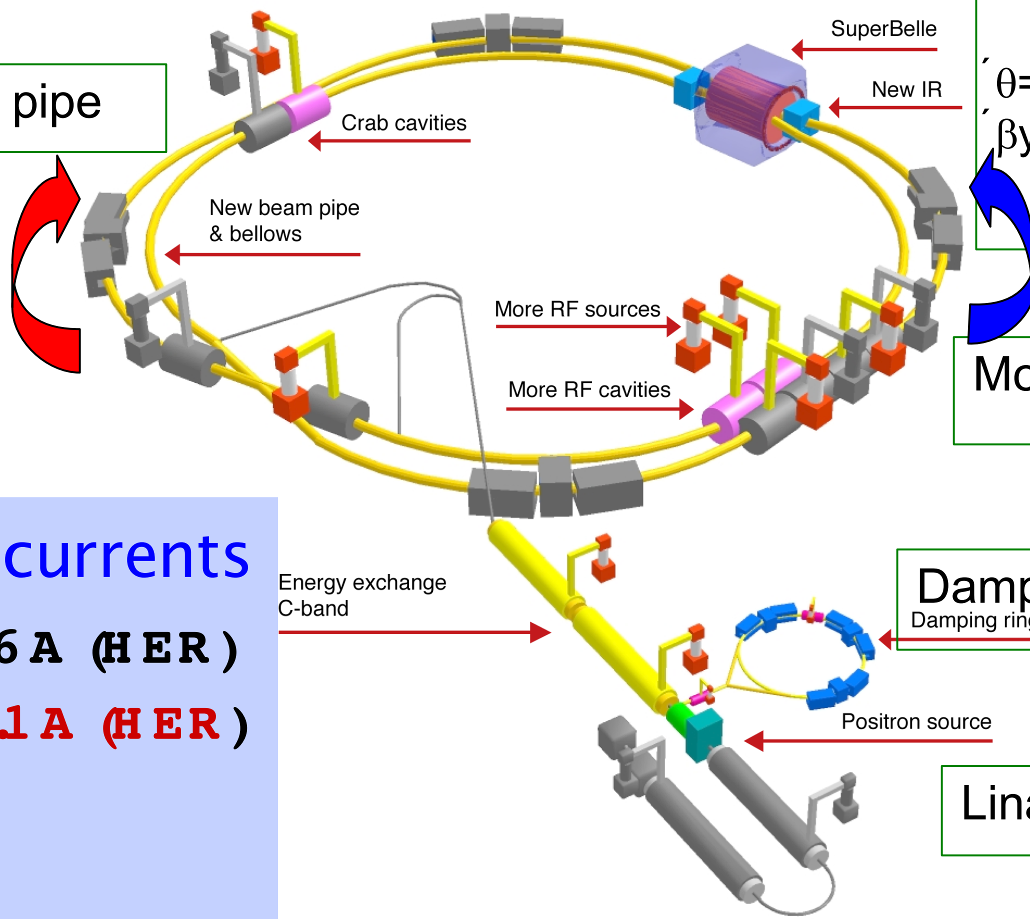
1. Introduction

The upgrade of current KEKB accelerator to SuperKEKB is being planned for the further studies of *B* and other flavor physics.

SuperKEKB

New Beam pipe

8GeV (e+, 4.1A)



Interaction Region
Crab crossing
θ=30mrad.
βy*=3mm
New QCS

3.5GeV (e−, 9.6A)

More RF power

Damping ring

Linac upgrade

Increase beam currents

- 1.75 A (LER) / 1.36 A (HER)
  → 9.6 A (LER) / 4.1 A (HER)

Smaller β_y^*

- 6 mm → 3 mm

Increase ξ_y

- 0.059 → >0.24 (W-S)

$L > 8\times10^{35} cm^{-2}s^{-1}$

Good News: KEK is now serious about this project.

It is officially adopted in the KEK's road map for next decade.

* Shutdown Belle by the end of JFY2008
* Upgrade of KEKB and Belle in JFY2009-2011
* Resumption of operation from JFY2012

Bad News: The budgetary condition is still tight.

* Need to manage the whole upgrade within the cost equivalent to operate current KEKB/Belle for JFY2009-2011....

→ Difficult to cover the full upgrade as planned.
Only the "partial" upgrade is possible.

* Target luminosity is lowered from 8×10^{35} to $2\times10^{35}/cm^2/sec$ leaving a possibility of further upgrade.
* Expected total integrated luminosity by 2015 goes down from 50/ab to ~10/ab

The upgrade is currently called as just "KEKB upgrade".

It is controversial to call it as "SuperKEKB".....

Need to re-evaluate physics potential for the case with 10/ab.....

However,
- We would like to keep the discovery potential as high as possible even with the decreased statistics.

What can we do?

1. CKM fit with improved theoretical inputs.

   As discussed in last BNM and CKM2006, the estimated NP sensitivity by CKM fit largely varies for different estimations of theoretical uncertainties.

   => Better theoretical inputs can be equivalent to have more luminosity!

   $\rightarrow$ today's main topic

2. Global fit to a set of new quantities which are sensitive to NP.
   - Determination of Wilson Coefficients using a set of different radiative/leptonic decays.

   $\rightarrow$ next meeting... Sorry....

2. CKM fit with 10/ab

a) Experimental measurements

	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%
$\sin 2\phi_1$	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

b) Theoretical inputs

- Most of theoretical inputs are given by Lattice QCD calculations

- 3 different cases of theoretical uncertainties are assumed

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]

* "松 matsu" was used by UTfit group to obtain their ultra precise predictions for Italian SuperB.

Refs:
[1] Talk at Lattice 04 in Orsay (http://events.lal.in2p3.fr/conferences/lqcd/)
[2] Talk at IV SuperB workshop (http://www.infn.it/csn1/conference/superb/)

What is “松竹梅”?

Look at the menu of your favorite Sushi restaurant.

Matsu (Pine) 松 1人前

お客様にも喜ばれる
贅沢なネタをそろえた
人気のシリーズです。

Take (Bamboo) 竹 1人前

おいしさをひとりじめ、
お子様にも好評の
お手頃価格。

Ume (Plum) 梅 1人前

ランチにもご夕食にも、
喜ばれる一品です。

the best!!

nice!

affordable

Estimated TH errors 2015

S. Sharpe, U.S. Lattice QCD executive committee
V. Lubicz, talk given at the IV SuperB workshop

Hadronic matrix element	Current lattice error	6 TFlop Year	60 TFlop Year	1-10 PFlop Year
$f_+^{K\pi}(0)$	0.9% (22% on $1-f_+$)	0.7% (17% on $1-f_+$)	0.4% (10% on $1-f_+$)	**< 0.1% (2.4% on $1-f_+$)**
$\hat{B}_K$	11%	5%	3%	**1%**
f_B	14%	3.5 - 4.5%	2.5 - 4.0%	**1 – 1.5%**
$f_{Bs}B_{Bs}^{1/2}$	13%	4 - 5%	3 - 4%	**1 – 1.5%**
ξ	5% (26% on ξ-1)	3% (18% on ξ-1)	1.5 - 2 % (9-12% on ξ-1)	**0.5 – 0.8 % (3-4% on ξ-1)**
$\mathcal{F}_{B\to D/D^*l\nu}$	4% (40% on $1-\mathcal{F}$)	2% (21% on $1-\mathcal{F}$)	1.2% (13% on $1-\mathcal{F}$)	**0.5% (5% on $1-\mathcal{F}$)**
$f_+^{B\pi}$,...	11%	5.5 - 6.5%	4 - 5%	**2 – 3%**
$T_1^{B\to K^*/\rho}$	13%	----	----	**3 – 4%**

CKM IV Nagoya 13

梅 (ume) | 竹 (take) | 松 (matsu)

Actual values of uncertainties in theory inputs

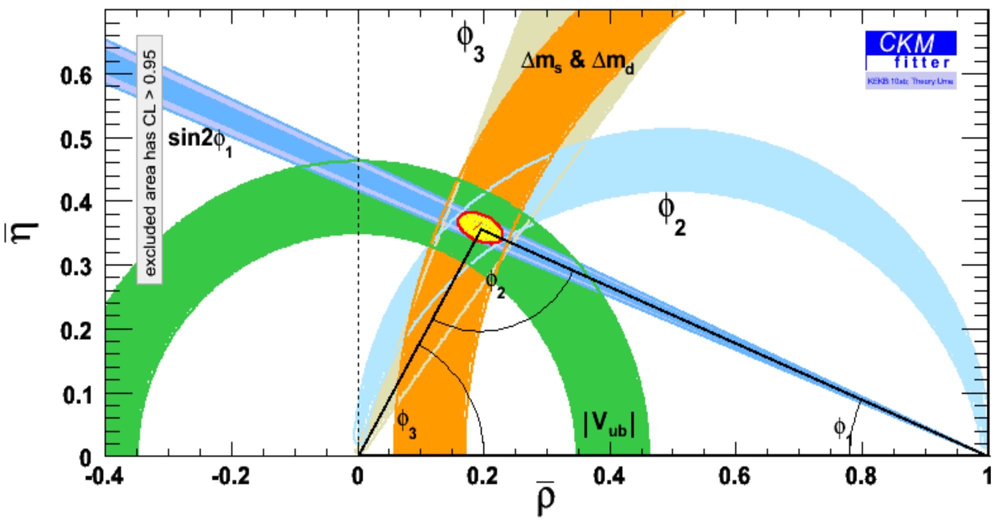
	central value	errors 梅 (ume)	竹 (take)	松 (matsu)
f_{Bs}	0.233	14%	4%	1%
$f_{Bs}\sqrt{B_s}$	0.277	13%	4%	1%
ξ	1.24	5%	2%	1%
V_{ub} theory		7%	4%	2%
$B\to\rho\gamma$ theory		11%	8%	4%

CKM fit framework :

New CKMfitter was used,
which is written in Mathematica.

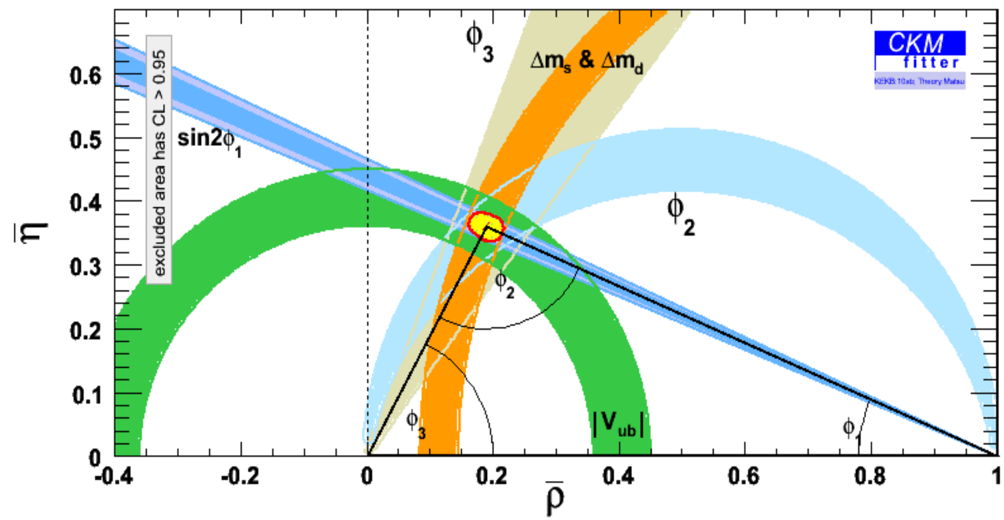
Results of global CKM fit with 10/ab data sample

梅 (ume)



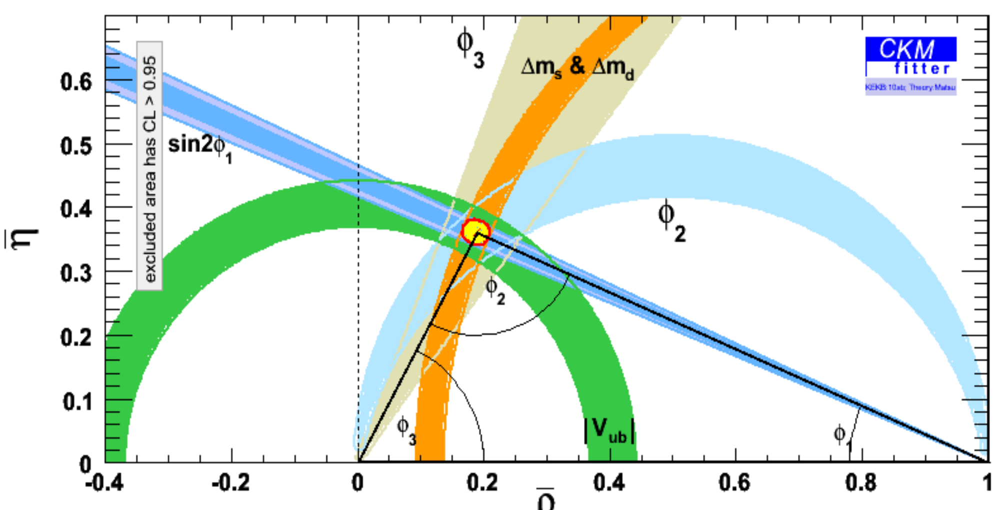
* ϕ_2 (exp) is the main constraint to $\bar{\rho}$

竹 (take)



* Δm_s(=theory) takes over to constrain $\bar{\rho}$

松 (matsu)

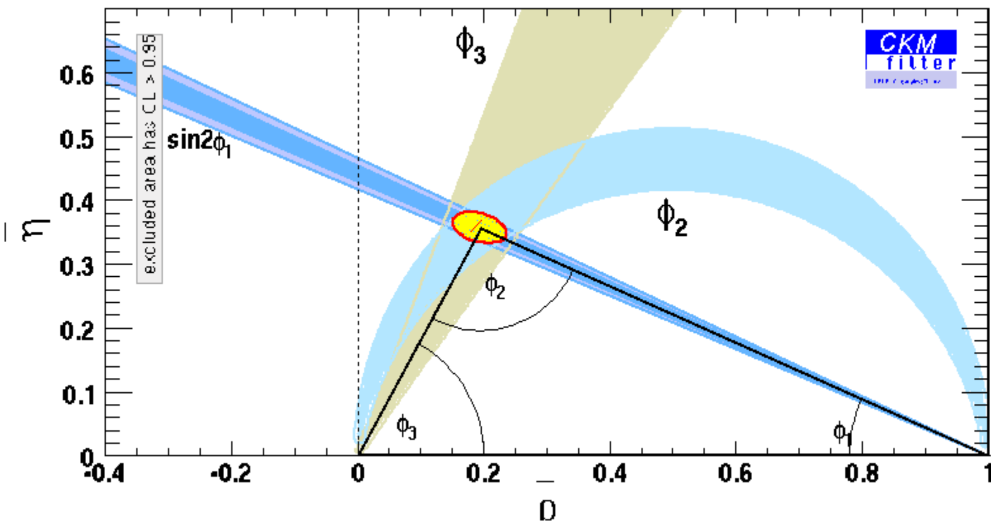


	$\sigma(\bar{\rho})$	$\sigma(\bar{\eta})$
梅 Ume	7.7%	3.1%
竹 Take	6.2%	2.8%
松 Matsu	4.6%	2.5%

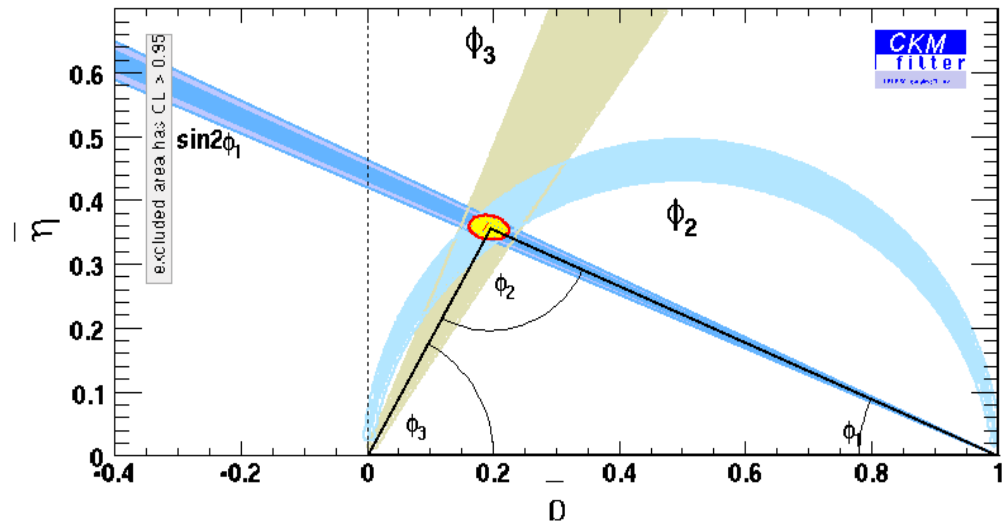
* Significant improvement in $\sigma(\bar{\rho})$!

Results of global CKM fit with angle measurements only

10/ab



50/ab

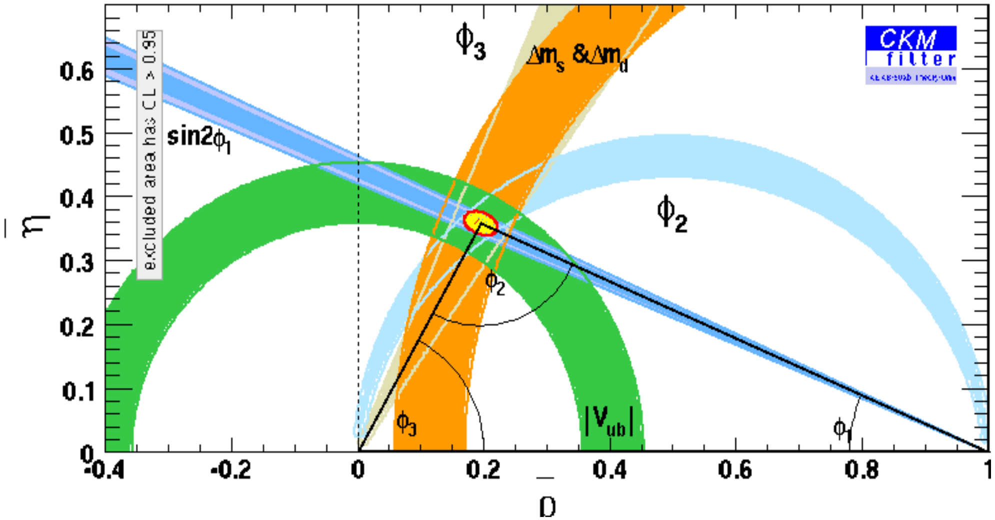


	$\sigma(\bar{\rho})$	$\sigma(\bar{\eta})$
10/ab	8.7%	2.8%
50/ab	6.7%	2.1%

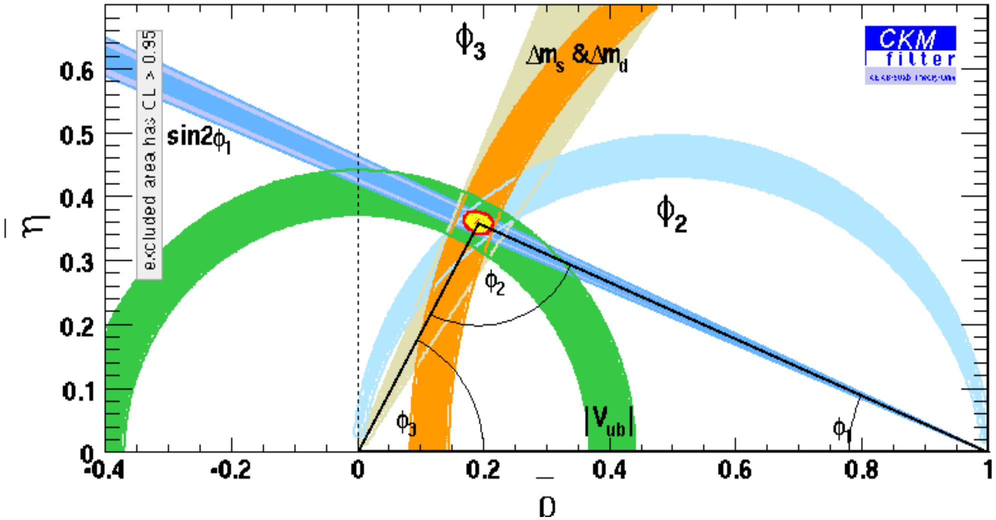
* Constraints by exp. measurements only in principle!

Results of global CKM fit with 50/ab data sample

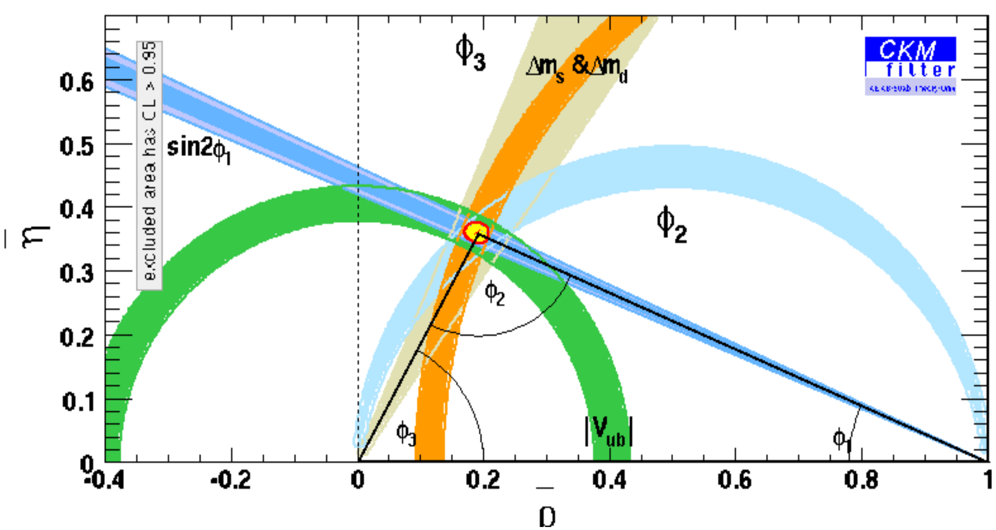
梅 (ume)



竹 (take)



松 (matsu)

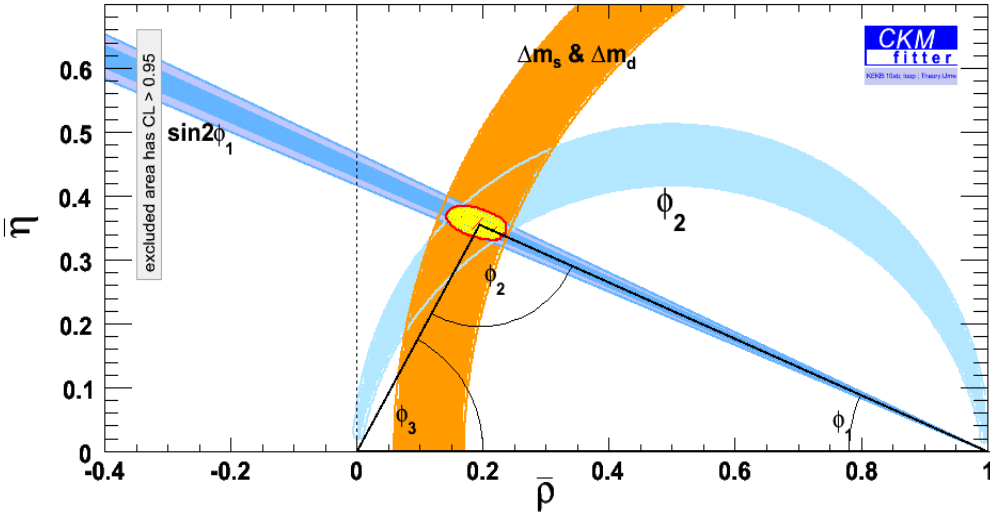


	$\sigma(\bar{\rho})$	$\sigma(\bar{\eta})$
梅 Ume	5.1%	2.1%
竹 Take	4.6%	2.0%
松 Matsu	3.1%	1.8%

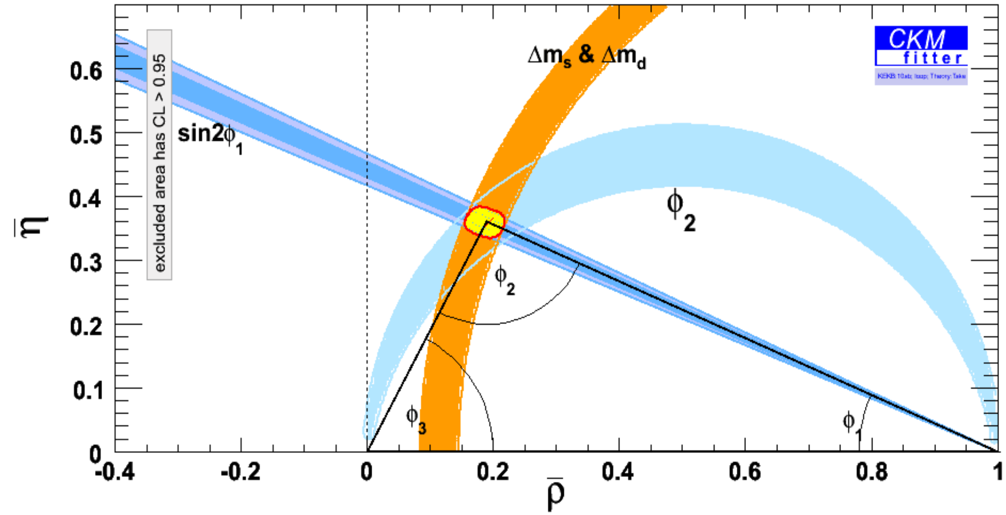
Almost same as " 松 Matsu" case with 10/ab; 4.6% 2.5%

Fit to loop-sensitive quantities only(Δm_d, Δm_s, $\sin 2\phi_1$, ϕ_2) with 10/ab

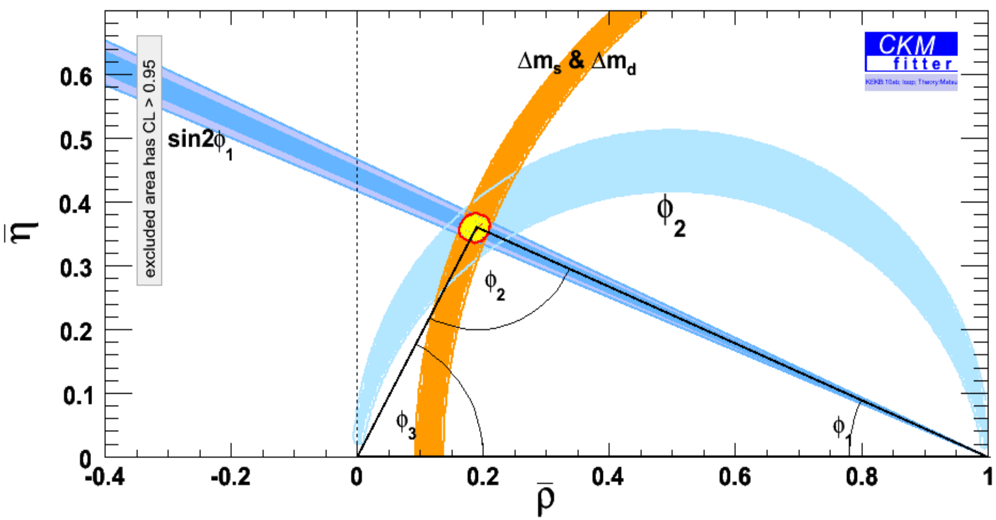
梅 (ume)



竹 (take)



松 (matsu)

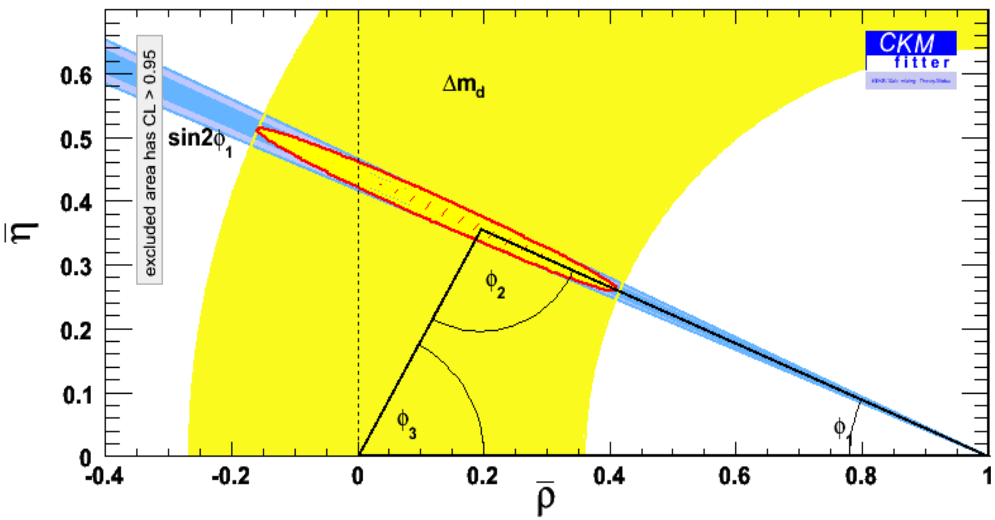


	$\sigma(\bar\rho)$	$\sigma(\bar\eta)$
梅 Ume	10.8%	3.1%
竹 Take	9.2%	3.0%
松 Matsu	6.1%	2.7%

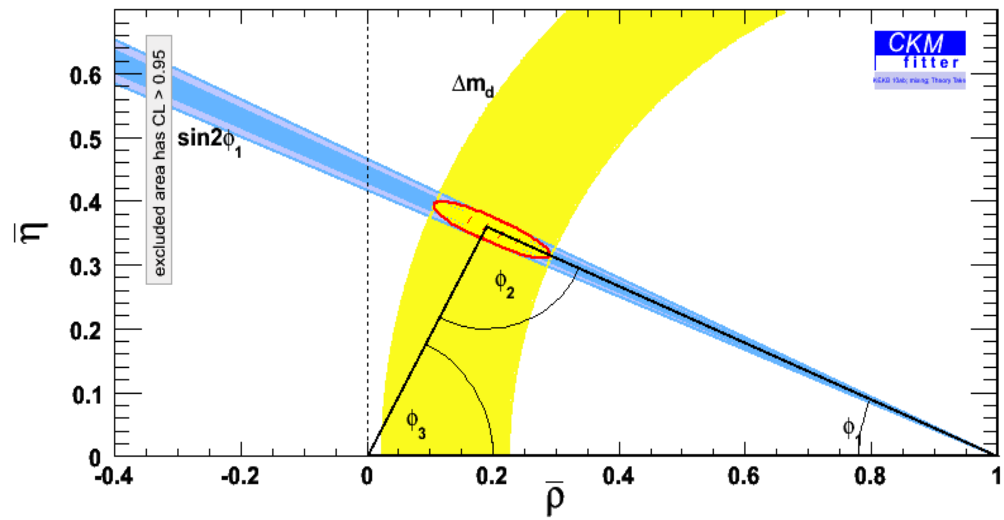
Sensitive to NP in mixing (B_d/B_s)

Fit to loop-sensitive quantities@B-factory only(Δm_d, $\sin 2\phi_1$) w/ 10/ab

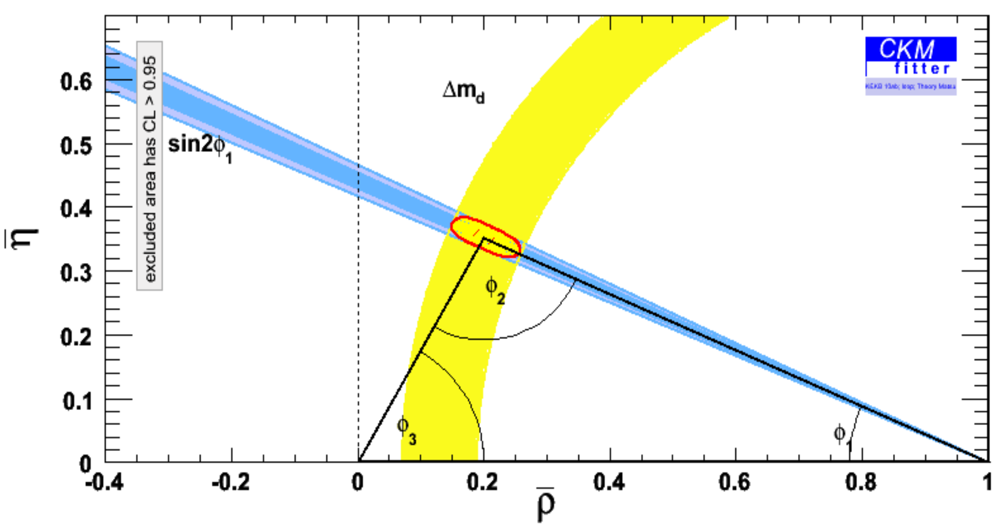
梅 (ume)



竹 (take)



松 (matsu)

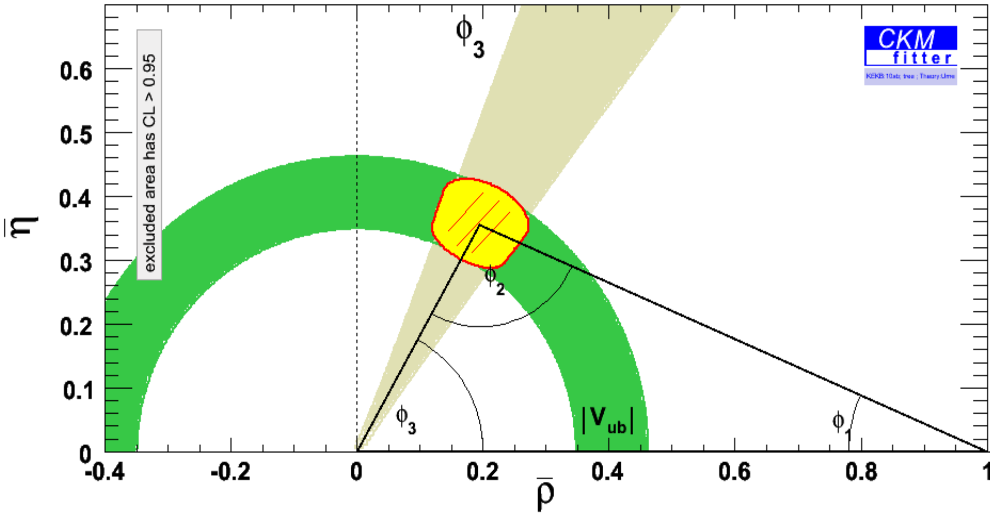


	$\sigma(\bar{\rho})$	$\sigma(\bar{\eta})$
梅 Ume	64%	22%
竹 Take	26%	8%
松 Matsu	17%	6%

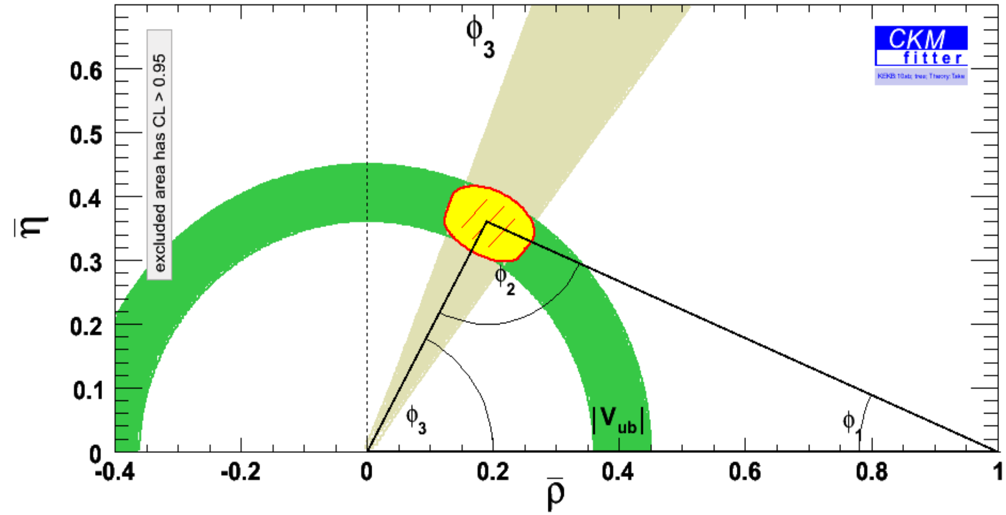
Constraint to NP in B_d mixing by B-factory-only measurements.

Fit to tree level quantities only(V_{ub}, ϕ_3) with 10/ab

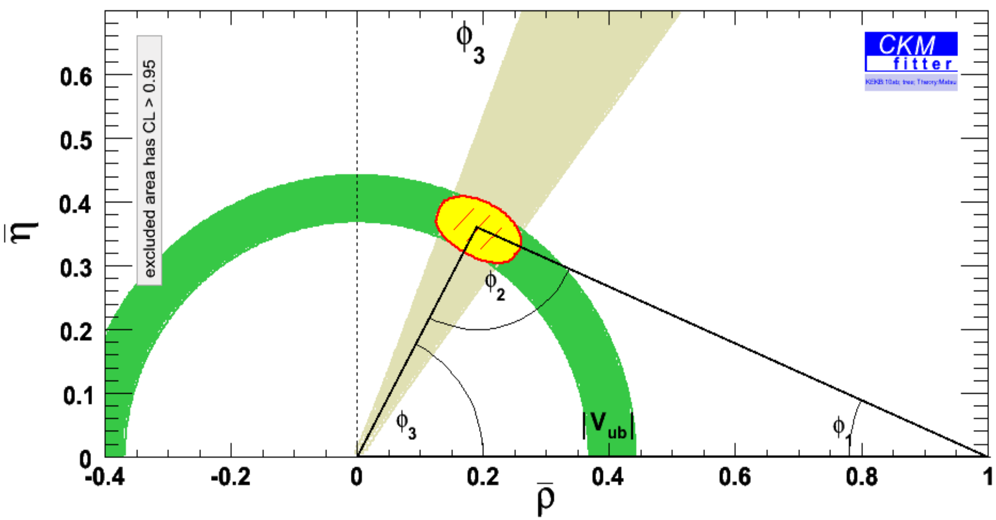
梅 (ume)



竹 (take)



松 (matsu)



	$\sigma(\bar{\rho})$	$\sigma(\bar{\eta})$
梅 Ume	19%	11%
竹 Take	17%	9%
松 Matsu	15%	7%

Constraint to Standard Model

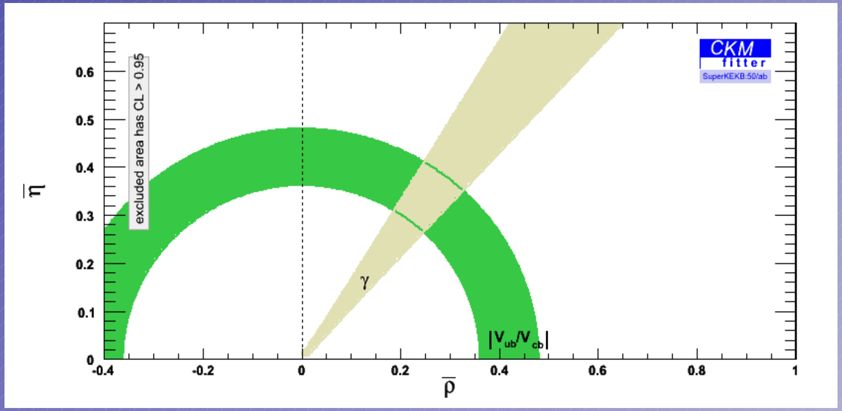
3. NP sensitivity

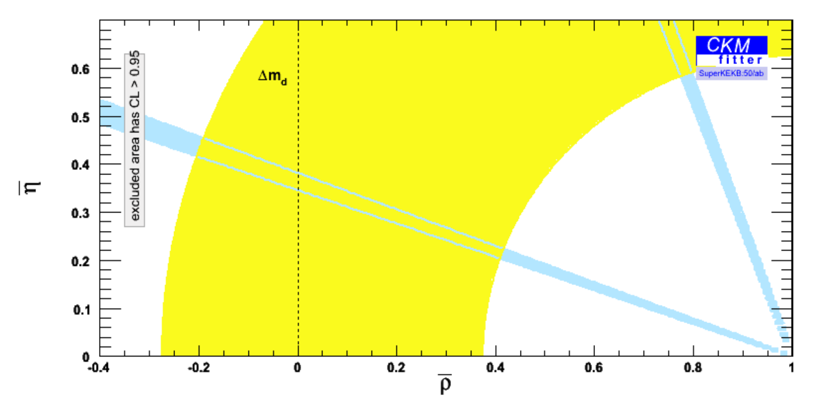
Model-independent study of New Physics(NP) can be done by comparing

- tree level measurements : $|V_{ub}|$ and ϕ_3, and
- measurements sensitive to NP :

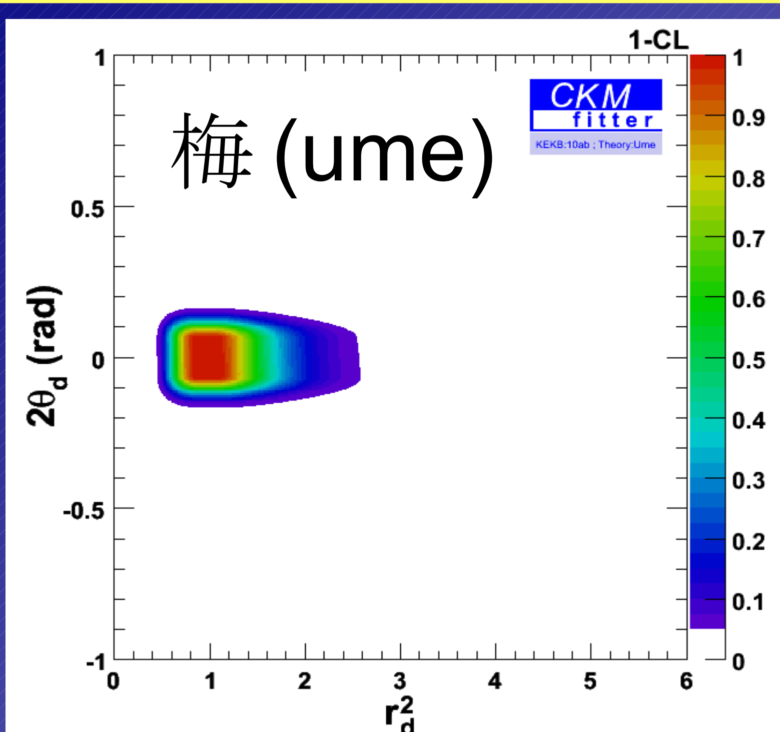
mesasurements	*source of NP*	
ε_K	$\Delta s=2$ box diagram	
Δm_d, ϕ_1	B_d box diagram	B-factory
Δm_s, ϕ_s	B_s box diagram	
$B(K\rightarrow\pi\nu\nu)$	$\Delta s=1$ box diagram	

concentrate on this

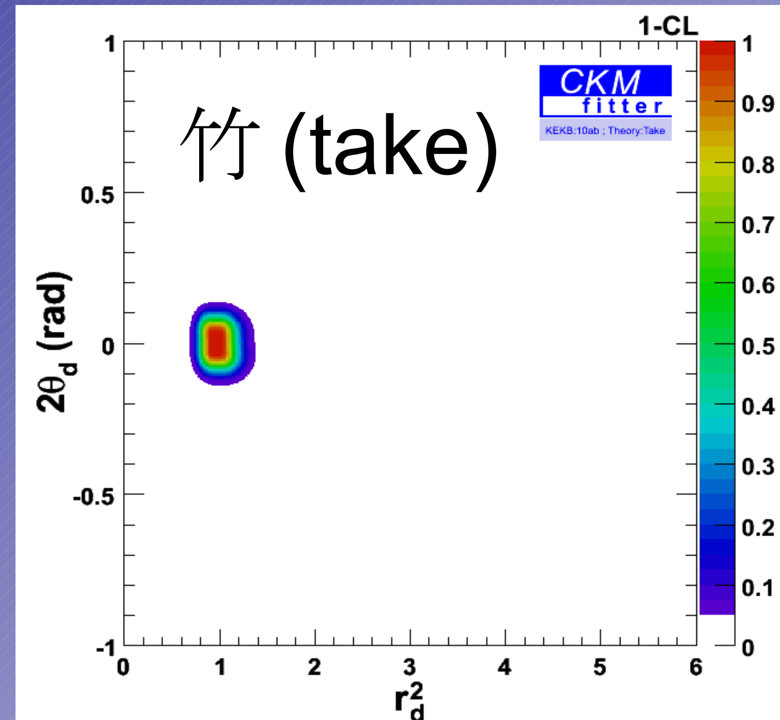


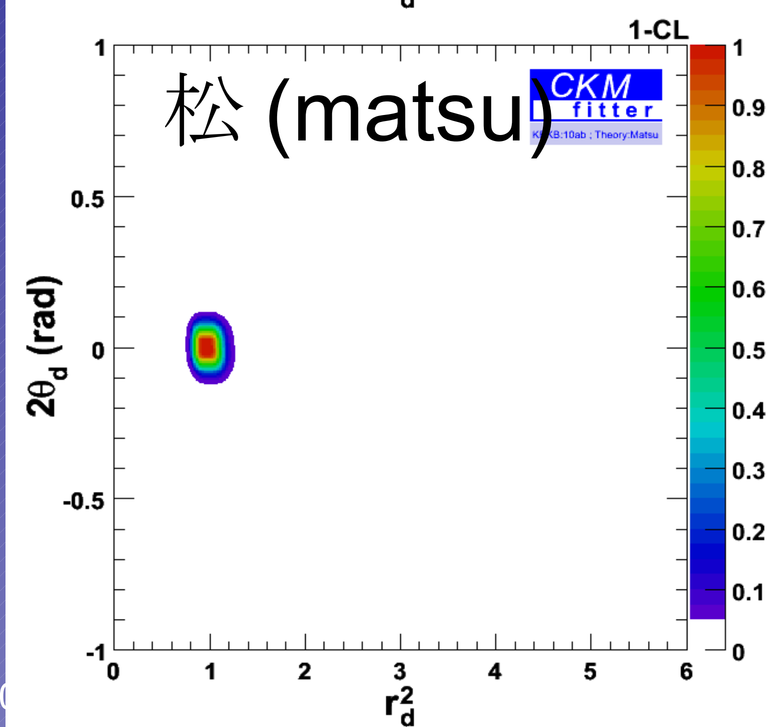


Model independent parameterization of NP effect: $M = r_d^{\,2} M_{SM} \exp(-i2\theta_d)$



10/ab





	$\sigma(r_d^{\,2})$	$\sigma(2\theta_d)$
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.

4. Status of Wilson Coefficient Fit

Motivation

- The application of global fit to the quantities specialized in searching for NP is considered to be a good method to improve the sensitivity with a limited statistics.

- Radiative/pure leptonic B decays are sensitive to NP with less theoretical uncertainties (in principle....).
  A collection of various quantities related to such decays could be the most sensitive to NP if used as an input to the global fit .

- Common parameterization among these radiative decays:
  Wilson Coefficients : C_7, C_9, and C_{10}

- This approach was first pioneered by G.Eigen.

My trial approach:

- Belle's measurement of A_{FB} in $B \to K^*ll$ gives a good constraint in Wilson coefficients.

- The extention of this approach is considered to include other measurements together in the fit.

- Inputs
  * $Br(B \to K^*\gamma)$
  * $Br(B \to K^*ll)$
  * $A_{FB}(B \to K^*ll)$ as a function of q^2 (5 points)

- Theoretical model:
  based on the paper by A.Ali, et al. (Phys. Rev. D 61, 074024 (2000))

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

ファイル 編集 セル 書式 入力 カーネル 検索 ウィンドウ ヘルプ

```
Shut[s_] := s/mB
```

Form factors

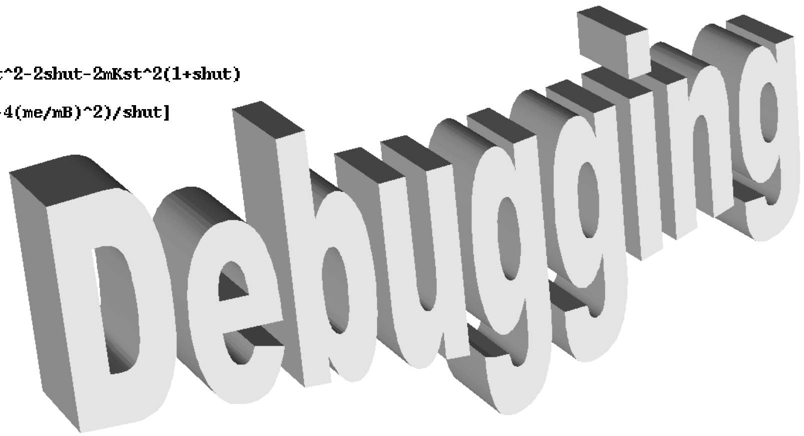
```
CfA1 = {0.337, 0.602, 0.258, 0.0}
CfA2 = {0.282, 1.172, 0.567, 0.0}
CfA0 = {0.471, 1.505, 0.710, 0.0}
CfV = {0.457, 1.482, 1.015, 0.0}
CfT1 = {0.379, 1.519, 1.030, 0.0}
CfT2 = {0.379, 0.517, 0.426, 0.0}
CfT3 = {0.260, 1.129, 1.128, 0.0}
A1[shut_] := CfA1[[1]] Exp[CfA1[[2]] shut + CfA1[[3]] shut^2]
A2[shut_] := CfA2[[1]] Exp[CfA2[[2]] shut + CfA2[[3]] shut^2]
A0[shut_] := CfA0[[1]] Exp[CfA0[[2]] shut + CfA0[[3]] shut^2]
V[shut_] := CfV[[1]] Exp[CfV[[2]] shut + CfV[[3]] shut^2]
T1[shut_] := CfT1[[1]] Exp[CfT1[[2]] shut + CfT1[[3]] shut^2]
T2[shut_] := CfT2[[1]] Exp[CfT2[[2]] shut + CfT2[[3]] shut^2]
T3[shut_] := CfT3[[1]] Exp[CfT3[[2]] shut + CfT3[[3]] shut^2]

aKst=21.295; bKst=0.502; cKst=0.500; dKst=3.530; eKst=1.434; fKst=0.413; gKst=0.148; mb=4.613;
```

* Coded in Mathematica
* Debugging in progress

Local variables

```
Lambda[shut_] := 1+(mKst/mB)^4+shut^2-2shut-2mKst^2(1+shut)
Uhut[shut_] := Sqrt[Lambda[shut](1-4(me/mB)^2)/shut]
(* mb = 0.1  Just for debug *)
absVtsStarVtb = 0.0385
mKst = 0.89166;
mB = 5.2790;
me = 0.510999892 10^-3;
mμ = 105.658369 10^-3;
fermiGF = 1.16637 10^(-5);
αEM = 1/129;
mb = 4.6;
C7 = -0.313;
C9 = 4.344;
C10 = -4.699;
tauB = 1.61 10^(-12);
hbarc = 197.326969;
Bdrate = 1/(hbarc/tauB);
```



AFB

```
AFB[shut_]:=ComplexExpand[fermiGF^2 αEM^2 mB^5/(2^8 Pi^5) absVtsStarVtb^2 shut Uhut[shut]^2 C10 (Re[C9] V[shut]A1[shut] +
(mb/mB)/shut C7 ( V[shut]T2[shut](1-mKst/mB)+A1[shut]T1[shut](1+mKst/mB) )),{C7,C9,C10},TargetFunctions→{Re,Im}]
```

Outputs

```
GamKstγ = ComplexExpand[fermiGF^2 αEM absVtsStarVtb^2/(32 Pi^4) mb^2 mB^2 (1-mKst^2/mB^2)^3 Abs[C7]^2 Abs[T1[0]]^2]
BrKstγ = GamKstγ/Bdrate
BrKstll = ComplexExpand[aKst Abs[C7]^2 + bKst Abs[C9]^2 + cKst Abs[C10]^2 + dKst C7 C9 + eKst* C7 + fKst C9 + gKst]
```

No results today.
Sorry!!!!

5. Summary

* Even with a limited statistics (~10/ab) data set given by the upgraded KEKB experiment, the potential of NP search can be maximized by improving the theory errors.

10/ab	$\sigma(\bar{\rho})$	$\sigma(\bar{\eta})$	$\sigma(r_d^2)$	$\sigma(2\theta_d)$
梅 Ume	7.7%	3.1%	42%	5.9^{o}
竹 Take	6.2%	2.8%	17%	4.3^{o}
松 Matsu	4.6%	2.5%	13%	3.3^{o}
竹 Take with 50/ab	4.6%	2.0%		

* Theorists are asked to reduce the errors in theoretical inputs as low as possible for the success of the KEKB upgrade!

* One idea:
How about building a "LQCD factory" as a part of the upgraded B-factory? :-P