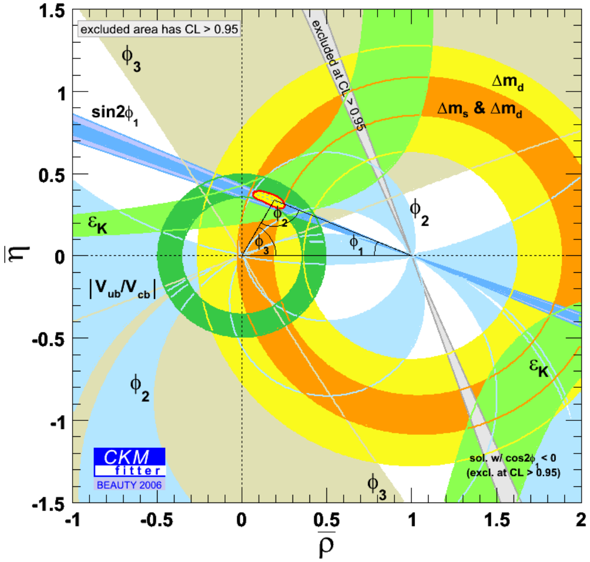
CKM fitter

シーケーエムフィッター

PARTICLE PHYSICS JOINT LAB JAPAN - FRANCE

a statistical tool for phenomenological studies



FJPPL'07 – KEK May 9-12 2007

S. T'JAMPENS [LAPP, CNRS/IN2P3 et Université de Savoie]

Outline

- What is Phenomenology?
- Tool: Statistical Hypothesis Testing
- From Experiments to Theory
- The CKMfitter Package
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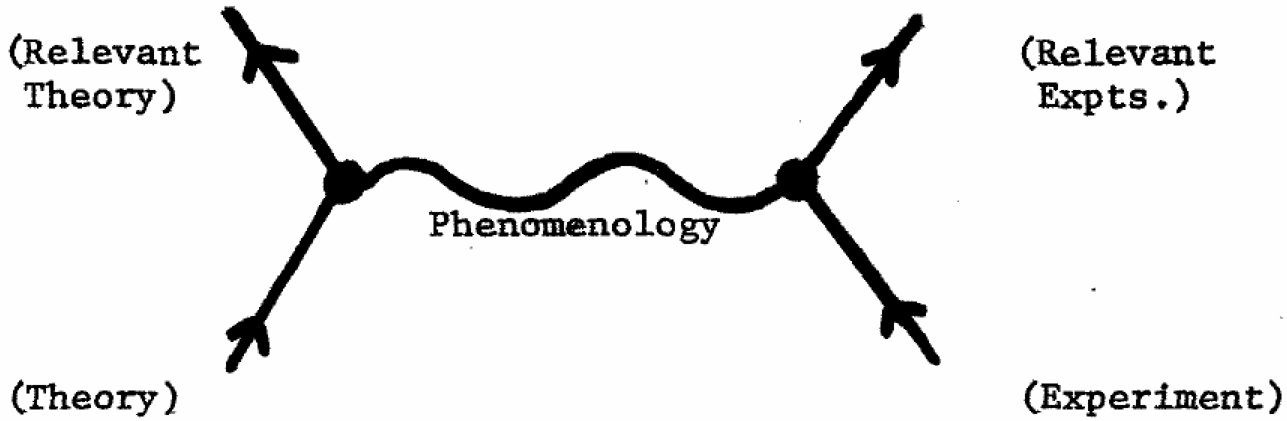
  - The Group and Advertisements
- FJPPL
  - Determination of the angle γ/ϕ_3
  - SuperKEKB
    - Prospective $50ab^{-1}$
    - New Physics
- Conclusion

What is Phenomenology?

Phenomenology in Particle Physics 1971

http:///authors.library.caltech.edu/910/

Phenomenology seeks to close the gap between those once close friends, theory and experiment, and so restore the interaction which is both vital to and characteristic of science. Although a classical concept, phenomenology is best known in its second-quantized form.



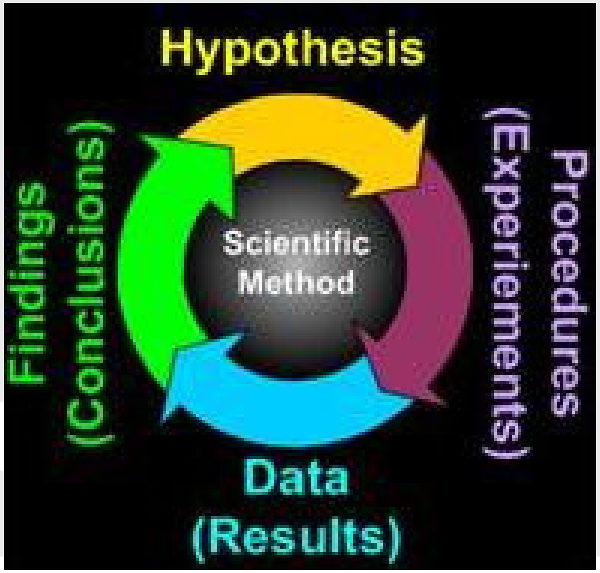
The basic tool of the phenomenologist is, first, the construction of simple models that embody important theoretical ideas, and then, the critical comparison of these models with all relevant experimental data. It follows that a phenomenologist must combine a broad understanding of theory with a complete knowledge of current and future feasible experiments in order to allow him to interact meaningfully with both major branches of a science. The impact of phenomenology is felt in both theory and experiment. Thus it can pinpoint unexpected experimental observations and so delineate areas where new theoretical ideas are needed. Further, it can suggest the most useful experiments to be done to test the latest theories.

Tool to Confront Data to Theory: Hypothesis Testing

- Scientific Method: process of generating, testing, modifying and verifying scientific theories

- Statistics: science and art of collecting, organizing, analyzing and interpreting data, is an ***indispensable instrument in this process***.

PHYSTAT Conferences



Tool: Hypothesis testing in two steps:

- GOF: test the compatibility of the theory with the data
- Metrology: do metrology only if the theory is relevant

From Experiments to Theory

1) Experiments
   ➔Belle
   ➔BABAR
   ➔Tevatron (CDF & D0)
   ➔Future: LHCb, SuperB [c/τ factory], ATLAS, CMS

2) HFAG ➔ averages ➔ PDG
   ➔Provide regular updates to the world averages of heavy flavor quantities.
   ➔Use consistent way in averaging and taking into account syst. Uncertainties

3) CKMfitter ➔ phenomenology (confront data to theory)
   ➔ Provide averages (α from SU(2), γ)
   ➔ Global CKM fit [Metrology of the CKM matrix]: constraints in SM parameters
   ➔ Phenomenological studies in heavy quark physics
   (effective field theories, flavor symmetries (SU(2), SU(3)),
   physics beyond the Standard Model)

➔ Crucial for New Physics discoveries in heavy flavor physics [indirect way]

The CKMfitter Package

- Comprehensive tool for CKM analyses
  - quantify the agreement between theory (SM or beyond) and the experimental results
  - obtain the best estimate of a given set of theoretical parameters within a given theory
- Started development in 2000 with Standard CKM fit – first publication in 2001
- Since then, many additional implementations :
  - $B \to \pi\pi, \rho\pi, \rho\rho$ isospin analyses, and Dalitz interpretation
  - $B \to \pi\pi, K\pi, KK$ isospin + SU(3) analyses
  - full QCD Factorization (BBNS) for $B \to PP, PV$
  - $B \to D^{(*)}K^{(*)}$ (ADS, GLW and Dalitz) interpretation
  - rare B decays: $B \to \tau(\mu)\nu$ and $B \to \rho(K^*)\gamma$
  - CPV and mixing in B_s decays
  - rare kaon decays: $K \to \pi\nu\nu$
  - dilepton *CP* asymmetries
  - new physics analyses

The European Physical Journal C -
Publisher: Springer-Verlag GmbH
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DOI: 10.1140/epjc/s2005-02169-1
Issue: Volume 41, Number 1

Date: May 2005
Pages: 1 - 131

Cited: 309 times

- Main statistical approach:
  - *R*fit (frequentist): the theoretical uncertainties are modeled as allowed ranges and no other *a priori* information is assumed where none is available.

The Code

- Code : ~ 42k lines at present (40k F vs. 2k C++)
- It is publicly available on the CKMfitter website

(Fortran) code is publicly available on the web:
http://ckmfitter.in2p3.fr

- Over the years, the fit problems became more and more complex and the CPU time consumption increases

• Re-foundation meeting in June 2005 to take future technology decision: full rewrite in Mathematica [gain: analytical vs. numerical methods] and ROOT (plots)

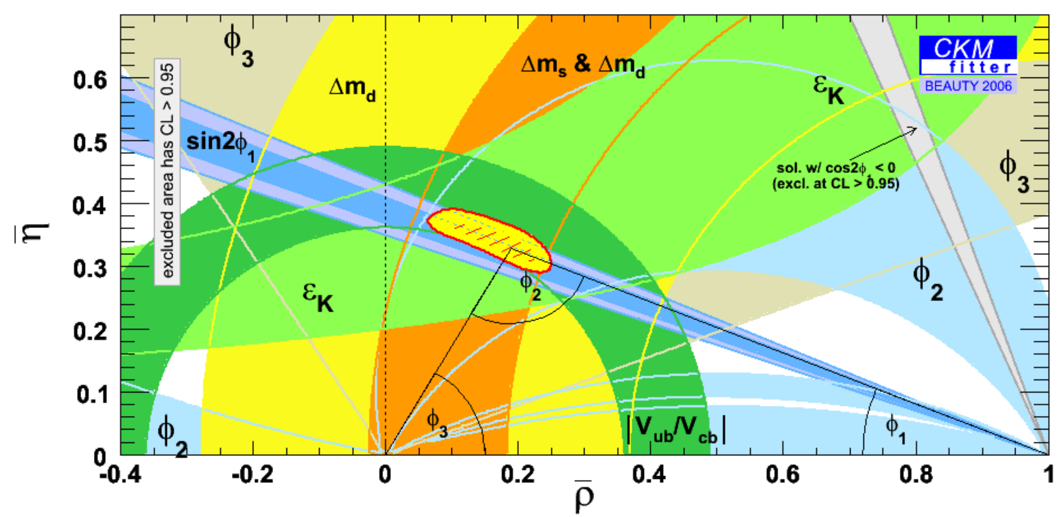
➔ still many implementations yet to be done

The original CKMfitter:

- Combined global fit: 23 h

The Mathematica based version:

- Combined global fit: 10 min



The Group and Advertisements

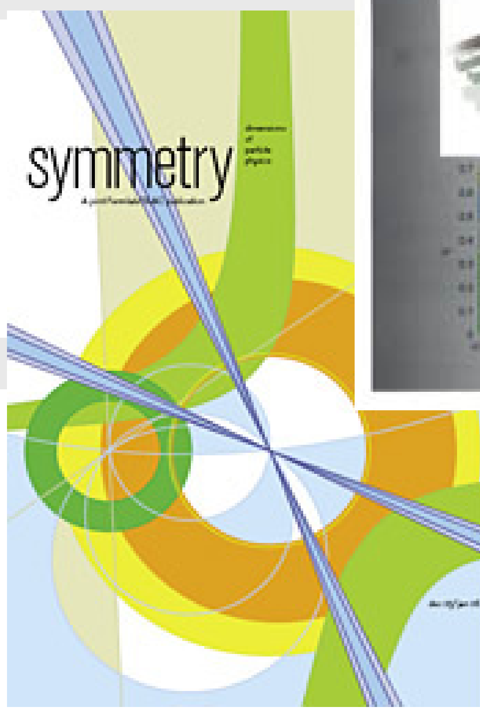
CKMfitter Group: from 4 (2000) to 13 (2007) members, mostly experimentalists:
2 theorists, 3 BABAR, 2 Belle, 4 LHCb, 1 ATLAS and 1 PhD student

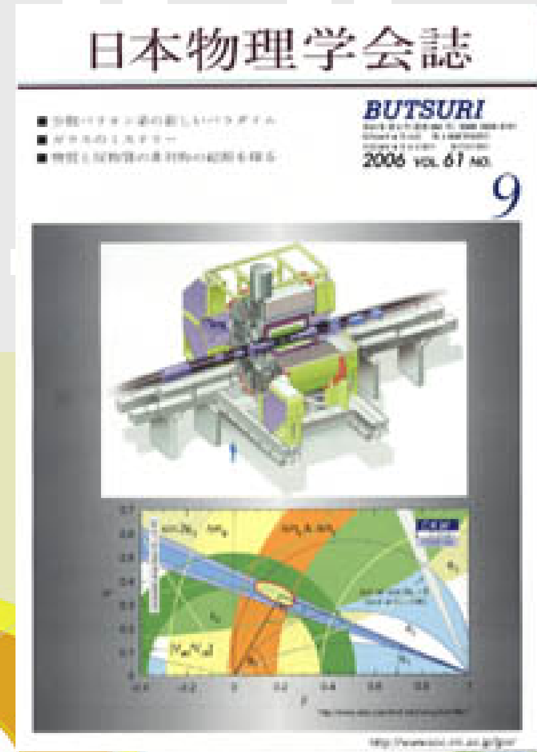
Cover major conferences:
- FPCP 06
- Flavor in the era of LHC
- ICHEP 06
- Beauty 06
- CKM 2006
- BABAR 1ab^{-1} workshop

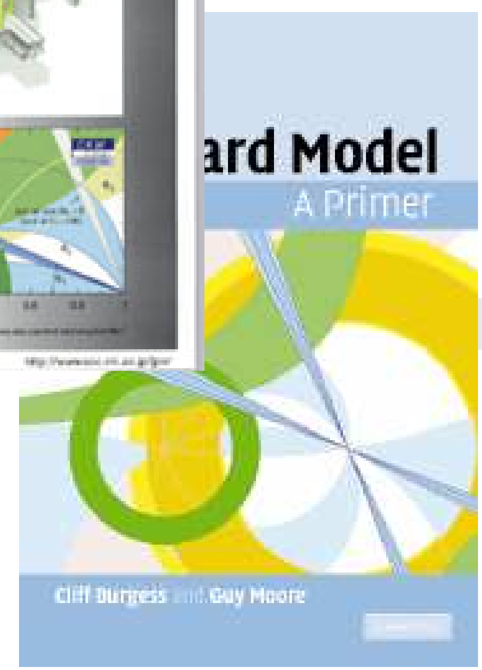
- DPF 06 (Z. Ligeti)
- P5 panel (SLAC)
- BNM06

- Symmetry Magazine (vol. 2 issue 10)
- Butsuri vol. 61 no. 9
- Science Magazine (Vol oct. 13)
- PDG 50th anniversary
- Supersymmetry (Book - P. Binetruy)

Updates available at http://ckmfitter.in2p3.fr







FJPPL

PARTICLE PHYSICS JOINT LAB JAPAN - FRANCE

- The full membership of Belle physicists in the CKMfitter Group
  - ➔ Prof. Ryosuke Itoh and Dr. Karim Trabelsi

- The development of a new global analysis including all available measurements related to the angle γ/ϕ_3 of the Unitarity Triangle
  - ➔development of a sophisticated statistical analysis necessary to obtain the correct significance level from the observables provided by the B-factories

Dr. Trabelsi

- Prospective for SuperKEKB (presented at the CKM06 workshop and the BNM2 workshop) and model-independent search of New Physics

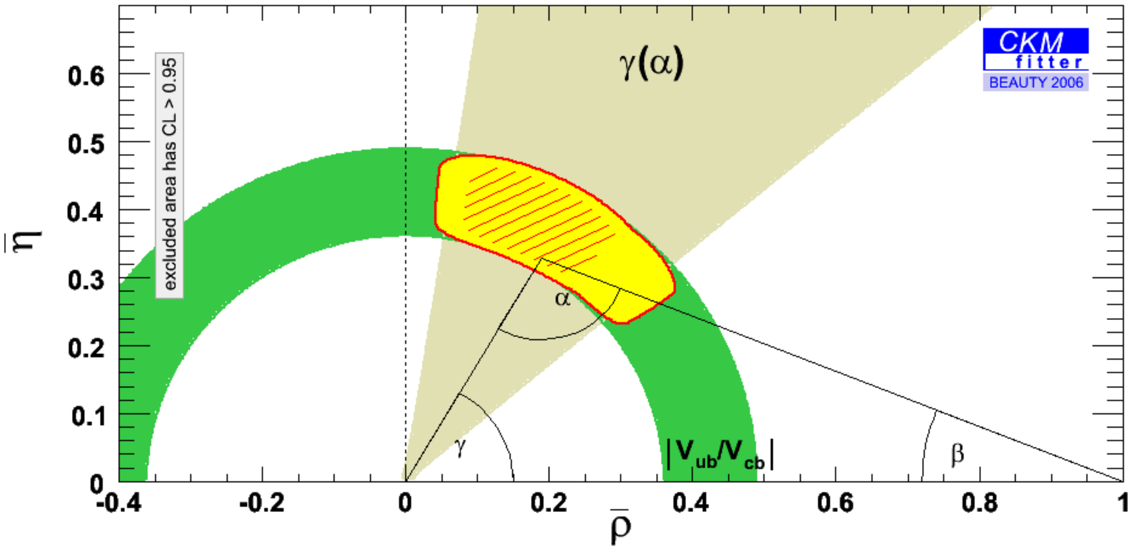
Prof. Itoh-san

3 meetings:

- KEK (December 2006)
- LAPP Annecy (January 2007)
- Annual group meeting – Dresden (March 2007)

[regular phone meetings]

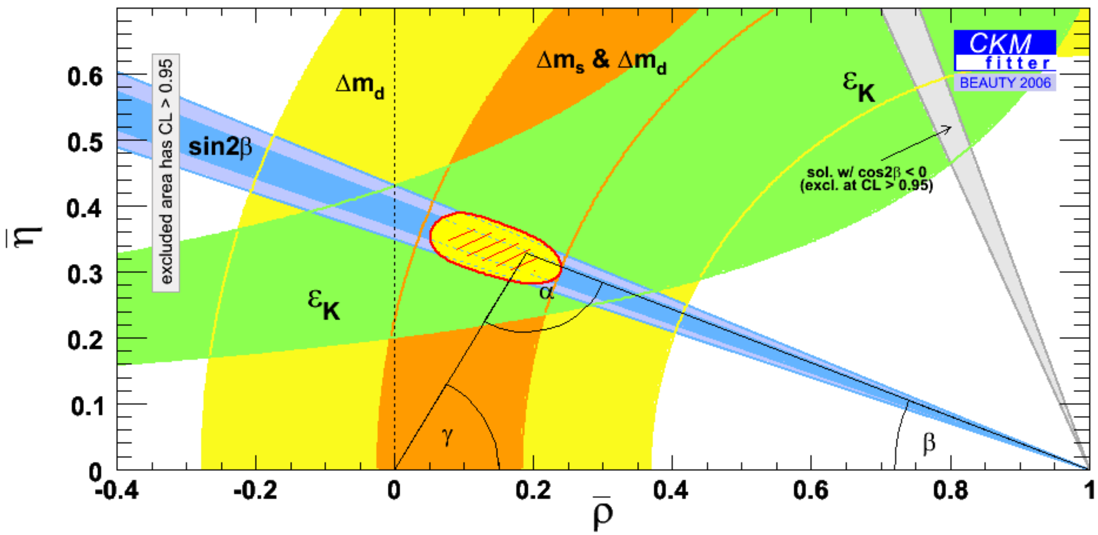
angle γ



Tree (NP-Free)

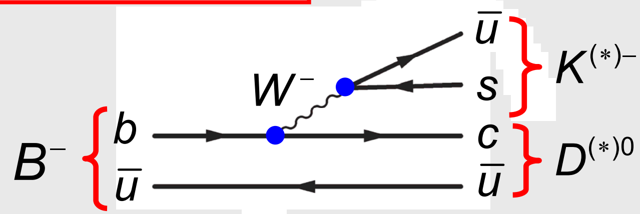
“Reference UT”

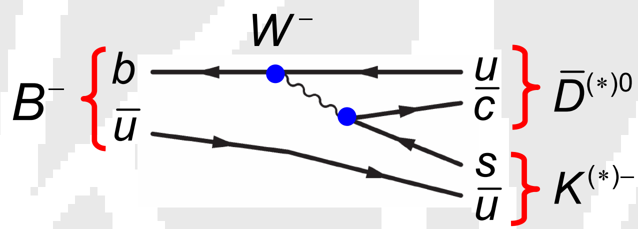
vs Loop



angle γ [UT input that is not theory limited]

$b \rightarrow c\bar{u}s, u\bar{c}s$





No Penguins ☺

Tree: dominant color-allowed

$\propto V_{cb}V_{us}^*$

$\propto \lambda^3$

Tree: color-suppressed

$\propto V_{ub}V_{cs}^*$

$\propto \lambda^3\sqrt{\rho^2+\eta^2}$

relative CKM phase : γ

Several variants:

- GLW : D^0 decays into CP eigenstate
- ADS : D^0 decays to $K^-\pi^+$ (favored) and $K^+\pi^-$ (suppressed)
- GGSZ : D^0 decays to $K_S\pi^+\pi^-$ (interference in Dalitz plot)

Gronau-London, PL B253, 483 (1991); Gronau-Wyler, PL B265, 172 (1991)

Atwood-Dunietz-Soni, PRL 78, 3257 (1997)

Giri *et al*, PRD 68, 054018 (2003)

➧ All methods fit simultaneously: γ, r_B and δ *(different r_B and δ)*

$$r_B = \frac{|A_{suppressed}|}{|A_{favoured}|} \sim \frac{|V_{ub}V_{cs}^*|}{|V_{cb}V_{us}^*|} \times [\text{color supp}] = 0.1\text{-}0.2$$

r_B, r_B^* } how small ?

σ_γ depends significantly on the value of r_B

The "GLW" and "ADS" Analyses

GLW : measure branching fraction of $B^- \to D^0_{(CP)}K^-$

$D^0_{CP\pm}$ reconstructed in $\pm CP$ (for ex., $D^0_{CP+} \to K^-K^+$, $D^0_{CP-} \to K_S\pi^0$) ➡ $b \to c$ and $b \to u$ interfere

4 observables sensitive to γ :

$$r_B \equiv \left| A(b \to u\bar{c}s) / A(b \to c\bar{u}s) \right|$$

~ 0.1 - 0.2 ??

$$R_{CP\pm} \propto \Gamma(B^- \to D^0_{CP\pm}K^-) + \Gamma(B^+ \to D^0_{CP\pm}K^+) \propto 1 + r_B^2 \pm 2r_B \cos\delta_B \cos\gamma$$

$$A_{CP\pm} \propto \Gamma(B^- \to D^0_{CP\pm}K^-) - \Gamma(B^+ \to D^0_{CP\pm}K^+) \propto \pm 2r_B \sin\delta_B \sin\gamma / R_{CP\pm}$$

strong phase in decay of B

Problem of GLW : requires interference of amplitudes with rather different sizes

ADS : disfavor favored amplitude and favor disfavored amplitude

$$B^- \to D^0(\to K^+\pi^-)K^- \quad \longleftrightarrow \quad B^- \to \bar{D}^0(\to K^+\pi^-)K^-$$

2×Cabibbo-suppressed

$$r_D \equiv \left| A(c \to du\bar{s}) / A(c \to su\bar{d}) \right|$$

= 0.060 ± 0.003

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

$$A_{ADS} \equiv (\ldots) = 2r_B r_D \sin\gamma \sin(\delta_B + \delta_D) / R_{ADS}$$

strong phase in decay of D

The “GGSZ” Dalitz Analysis

- Increase B decay interference through D decay Dalitz plot with $D^0 \to K_S\pi^+\pi^-$

Decay amplitudes :

$$A_-\left(m_-^2, m_+^2\right) = \left|A\left(B^- \to D^0 K^-\right)\right| \left[f_{-+} + r_B\, e^{i(\delta-\gamma)} f_{+-}\right]$$

CP

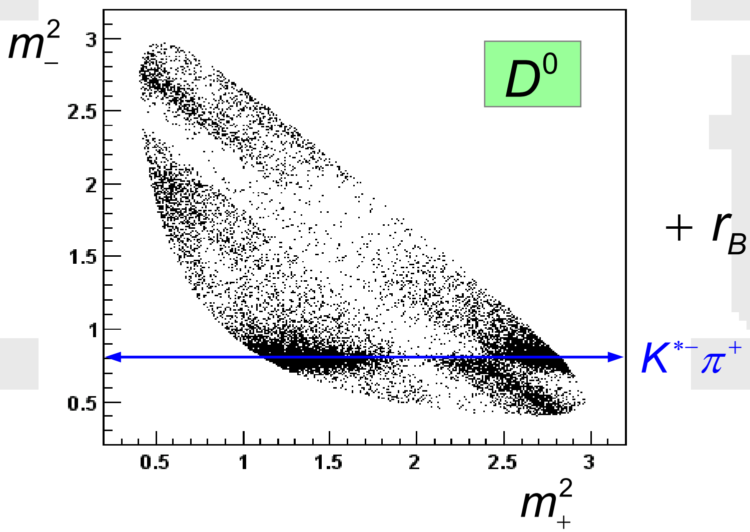
$$A_+\left(m_-^2, m_+^2\right) = \left|A\left(B^+ \to \overline{D}^0 K^+\right)\right| \left[f_{+-} + r_B\, e^{i(\delta+\gamma)} f_{-+}\right]$$

Sum of amplitudes contributing to $D^0 \to K_S\pi^+\pi^-$

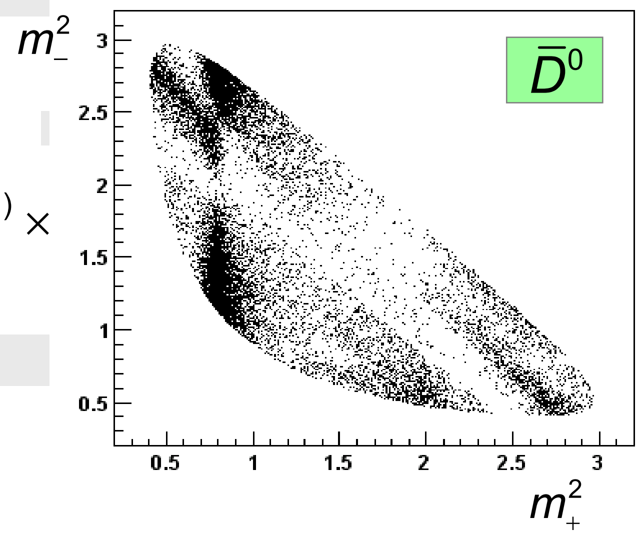
$f_{+-} \equiv f\left(m_+^2, m_-^2\right)$

$m_\pm \equiv m(K_S^0\pi^\pm)$

$|A_-|^2 = \Big|$



$+ \, r_B e^{i(\delta-\gamma)} \times$



$\Big|^2$

Simultaneous measurement of r_B , δ and γ

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

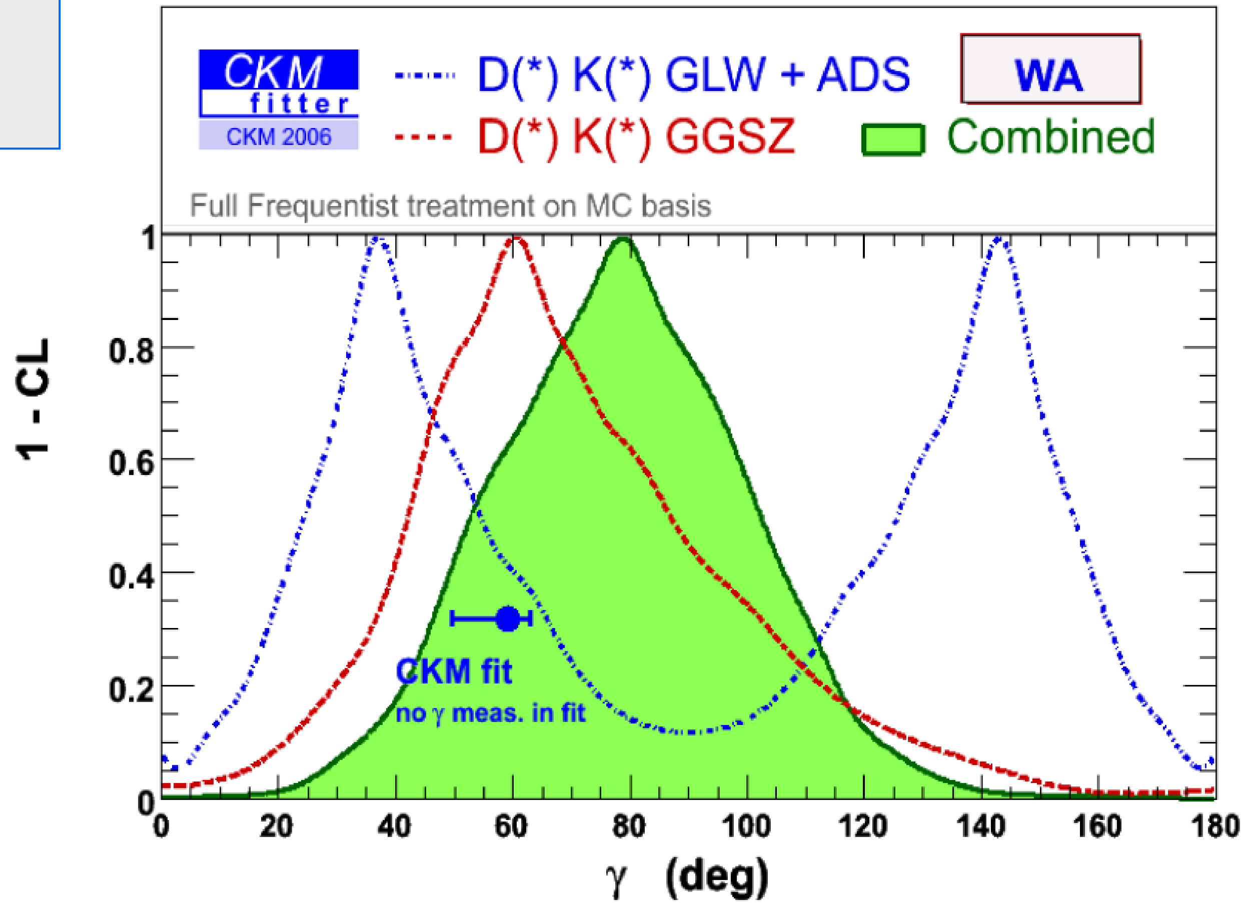
Constraint on γ

$r_B(DK) < 0.13$

$r_B(D^*K) < 0.13$ @90% CL

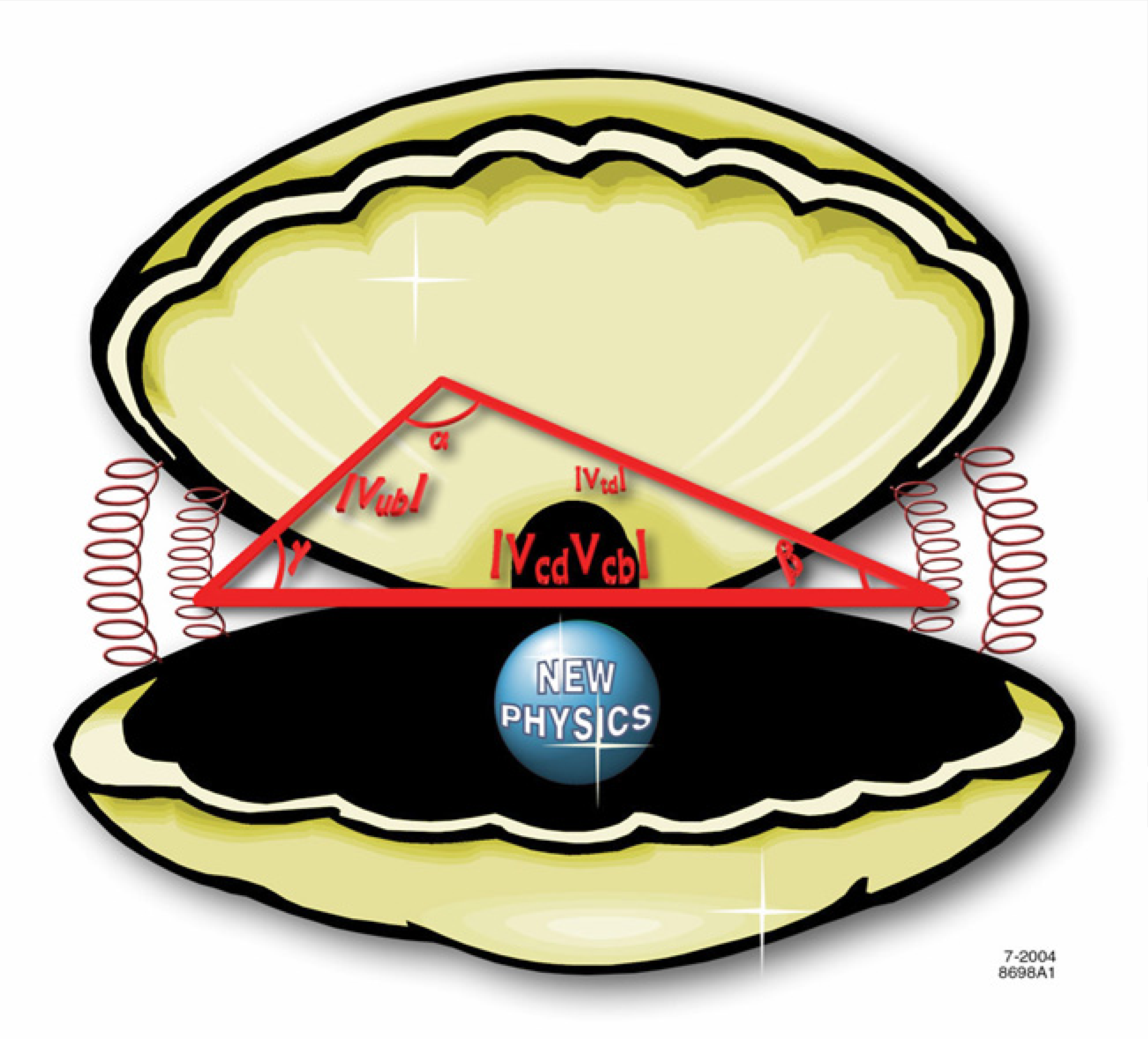
$r_B(DK^*) < 0.27$

$\gamma_{\text{B-Factories}} = [\, 77 \pm 31]^\circ$



Article in preparation

New Physics?



Courtesy A. Roodman

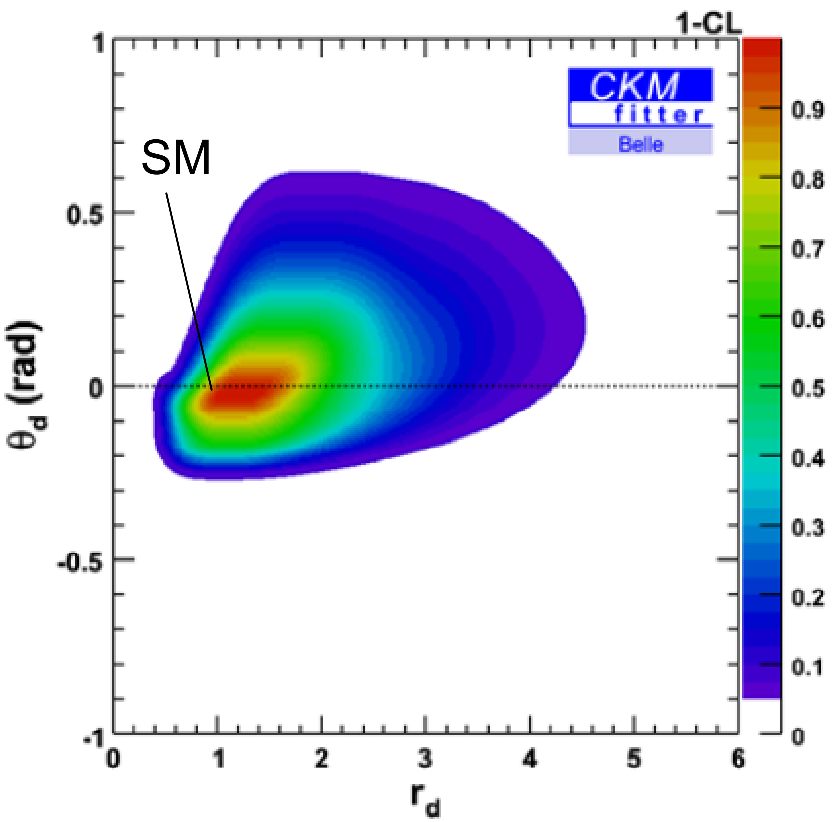
New Physics in B_d-B_d Mixing?

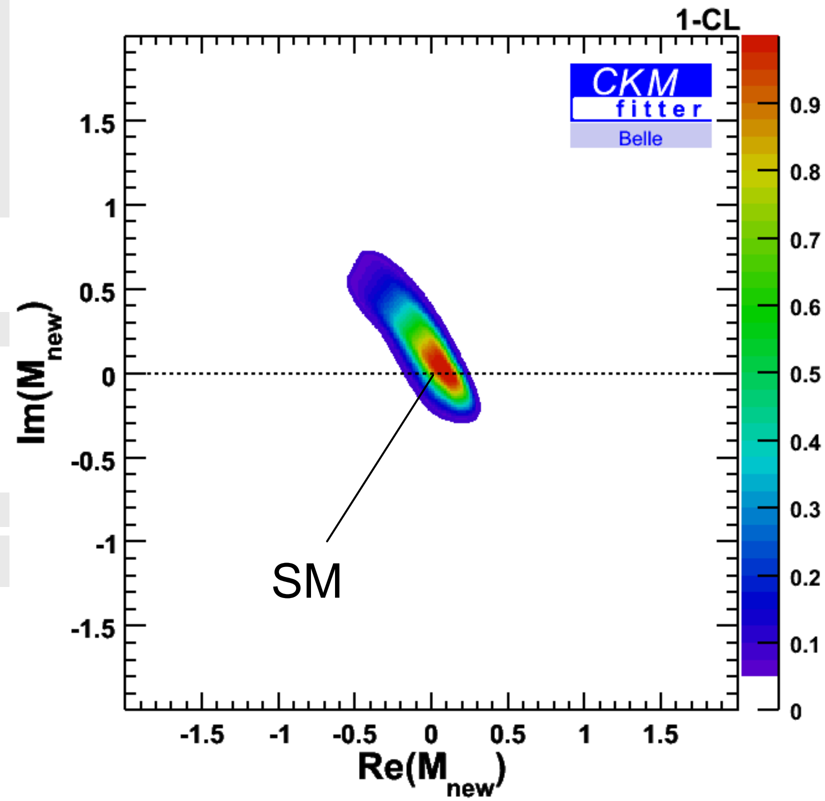
Hypothesis testing: from SM to SM+NP (model-independent approach)

Goto et al., PRD 53 (1996) 6662

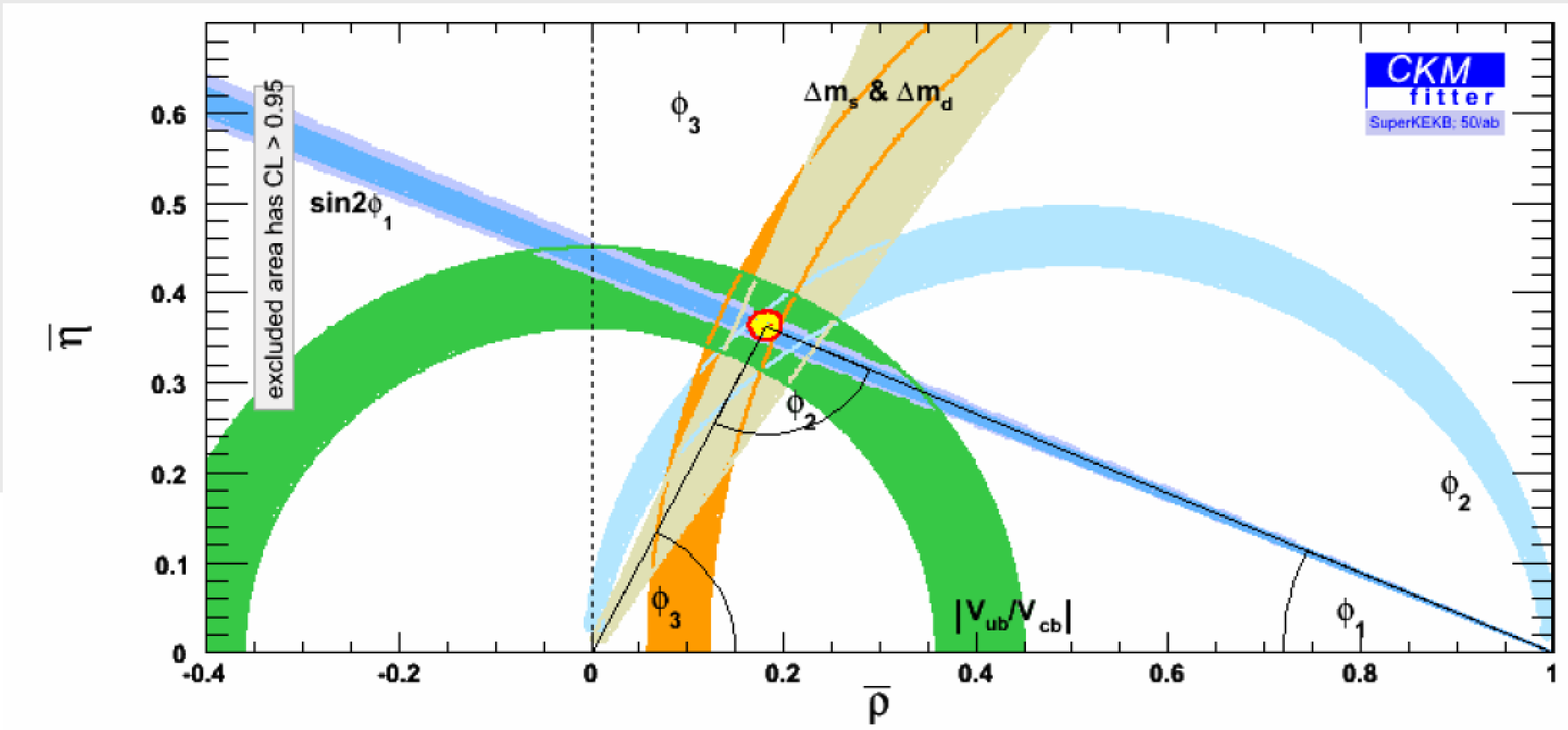
$$M = r_d^2 M_{SM} \exp(-i2\theta_d)$$

$$M = M_{SM} + M_{new}$$





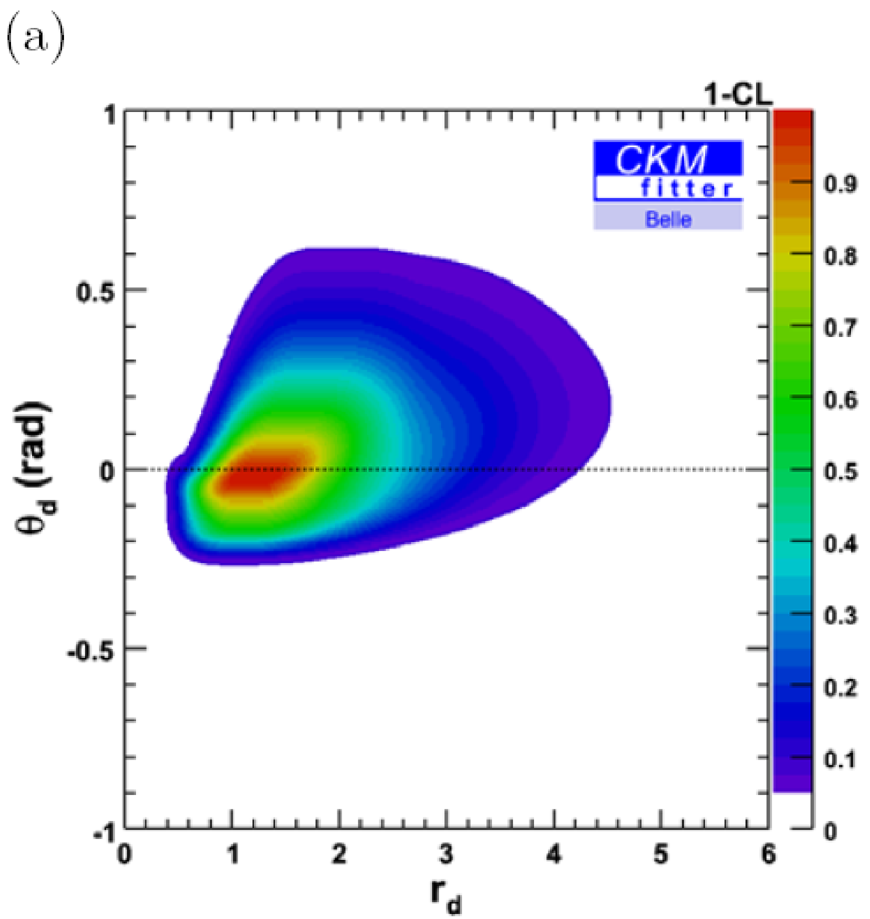
SuperKEKB prospective (50 ab^{-1})

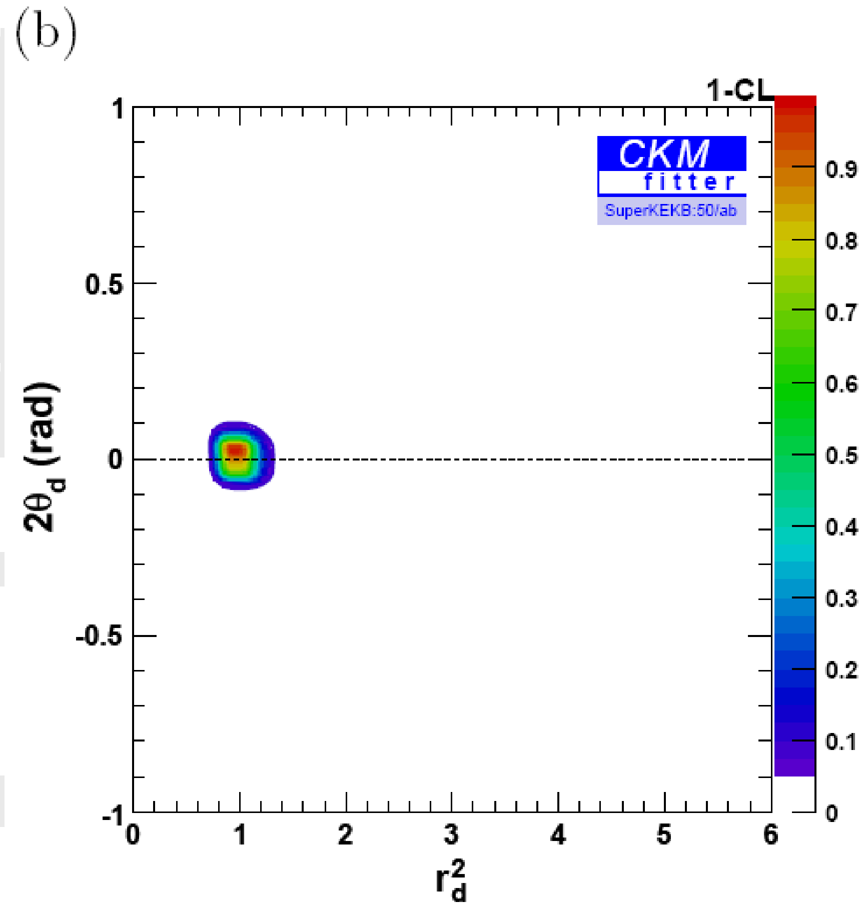


	$\sigma(\bar{\rho})$	$\sigma(\bar{\eta})$
Belle (~0.5ab^{-1})	20.0%	7.7%
SuperKEKB (50ab^{-1})	3.4%	1.7%

Updated LOI in preparation

SuperKEKB prospective: New Physics?

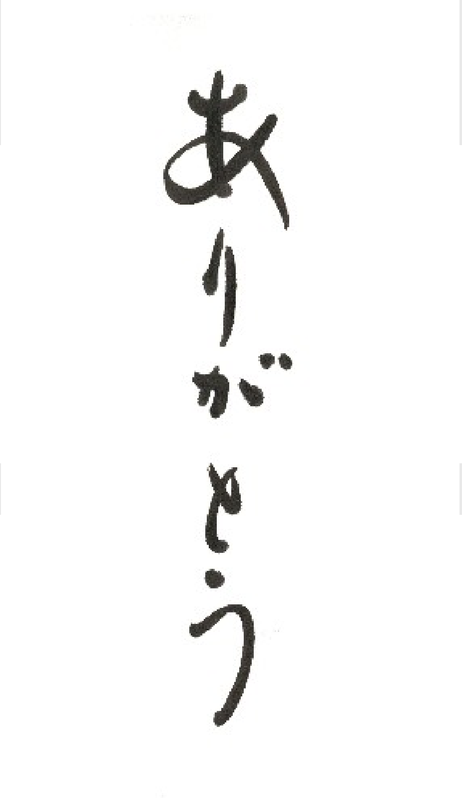




Parameter	Belle ($\sim 0.5\text{ab}^{-1}$)	SuperKEKB (50ab^{-1})
r_d^2	± 0.7	± 0.15
$2\theta_d$	$\pm 11^o$	$\pm 3^o$

Conclusion

- In 2007, go on started activities in 2006
- Radiative and leptonic rare decays and New Physics search in Wilson coefficients
- Several papers in preparation



BACKUP SLIDES

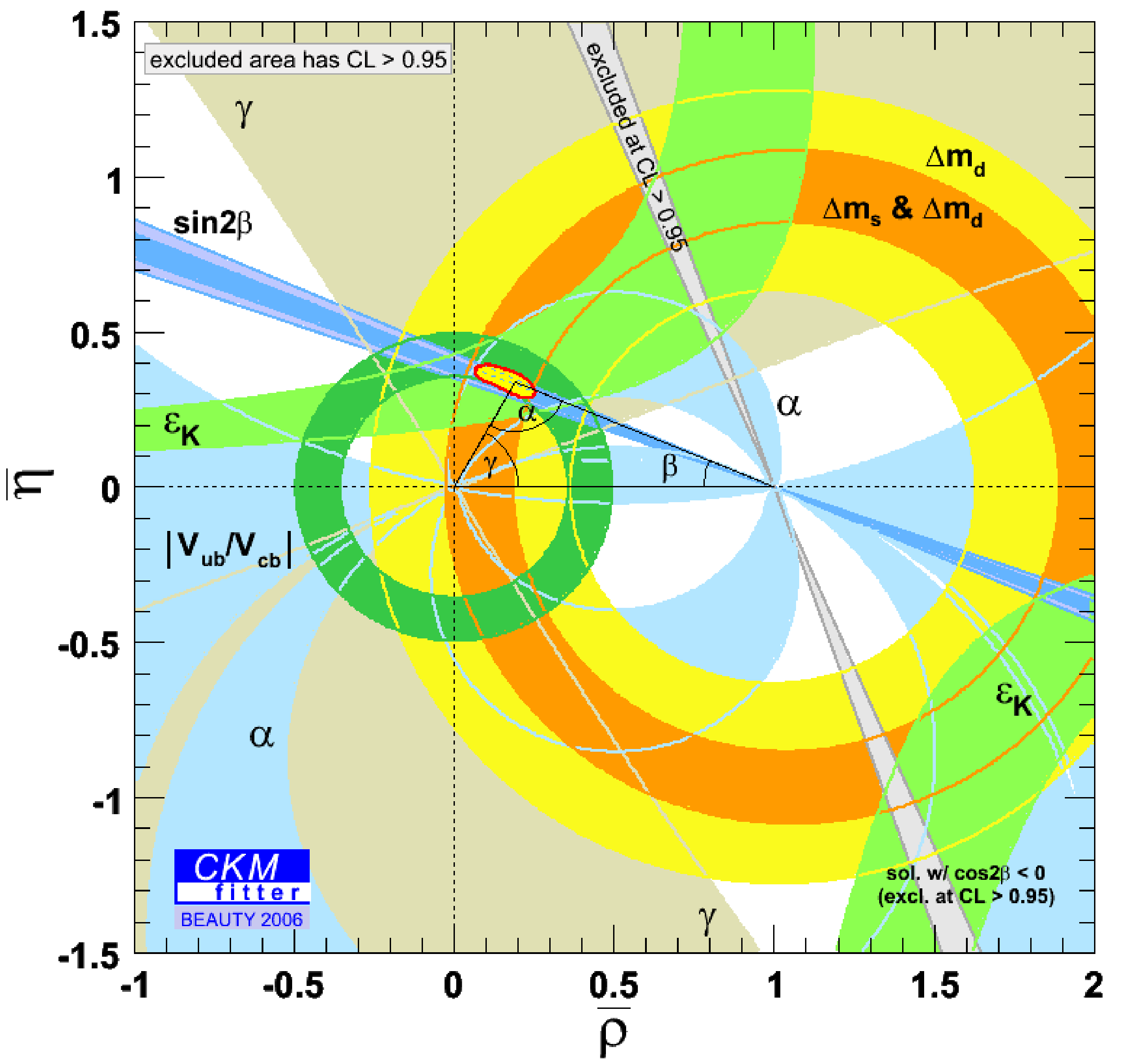
Bayesian?

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.

Putting it all together



Inputs:

$\left|\frac{V_{ub}}{V_{cb}}\right|$

Δm_d

Δm_s

$B \to \tau\nu$

$|\varepsilon_K|$

$\sin 2\beta$

α

γ