Updated constraints on New Physics in $B_{d(s)}$-$\bar{B}_{d(s)}$ Mixing

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CKM06 workshop, Nagoya

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WG6

Motivation

* Fleischer, Isidori, Matias, JHEP 0305, 053 (2003):
In a large class of NP models: Contributions to B-$\bar{B}$ Mixing

* <u>Model independent parametrization:</u>

$$r_q^2 e^{2i\theta_q} = \frac{\langle \bar{B}_q^0 | M_{12}^{SM+NP} | B_q^0 \rangle}{\langle \bar{B}_q^0 | M_{12}^{SM} | B_q^0 \rangle}$$

Soares & Wolfenstein, PRD 47, 1021
Deshpande, Dutta & Oh, PRL77, 4499 (1996)
Silva & Wolfenstein, PRD 55, 5331 (1997)
Cohen et al., PRL78, 2300 (1997)
Grossman, Nir & Worah, PLB 407, 307 (1997)

* Study General Flavor Structure of possible NP contributions
(including also K-$\bar{K}$ mixing)

General analyses of NP in mixing (Apologies for missing Refs.)

Branco, Cagarrinho, Krüger (1999): Sensitivity study --> Real CKM matrix ?

Laplace et al., PRD 65, 094040 (2002): Impact of A_{SL}^{d}

Ciuchini et al., econf C0304052 (2003): Sensitivity study

CKMfitter, EPJC 41, 1 (2005): Model independent analysis of B_d-$\bar{B}_d$, real CKM excluded, A_{SL}^{d}

Ligeti, IJMP A20, 5105 (2005), Botella et al., NPB 725, (2005)
Silvestrini, IJMP A21, 1738 (2006), Agashe et al. hep-ph/0509117

UTfit, JHEP0308, 080 (2006): Model independent & MFV analysis of B_d-$\bar{B}_d$ & K-$\bar{K}$

Ciuchini, Silvestrini, PRL97, 021803 (2006): Impact of Δm_s

Ligeti, Papucci, Perez, PRL97, 101801 (2006): Impact of Δm_s & $\Delta\Gamma_s$

Grossman, Nir, Raz, hep-ph/0605028: Impact of Δm_s & $\Delta\Gamma_s$ & A_{SL}

UTfit, PRL97, 151803 (2006): Combined analysis of B_d-$\bar{B}_d$, B_s-$\bar{B}_s$ & K-$\bar{K}$

Basic Assumptions

1. New Physics in B-$\bar{\text{B}}$ Mixing?

$$r_q^2 e^{2i\theta_q} = \frac{\langle \bar{B}_q^0 | M_{12}^{SM+NP} | B_q^0 \rangle}{\langle \bar{B}_q^0 | M_{12}^{SM} | B_q^0 \rangle} = 1 + h_q e^{2i\sigma_q} \qquad \Gamma_{12} = \Gamma_{12}^{SM}$$

2. New Physics in Decays?

Decays with four flavor change
(*SM4FC*, i.e. $b \to q_1 \bar{q}_2 q_3,\ q_1 \neq q_2 \neq q_3$)
are dominated by the Standard Model (SM)

3. 3 x 3 Unitary CKM matrix

Inputs I

Super-allowed β-decays: $V_{ud} = 0.97377 \pm 0.00027$ } $\Rightarrow \lambda$

$K \rightarrow \pi l \nu$: $V_{us} = 0.2257 \pm 0.0021$

} $\Rightarrow A$

$B \rightarrow X_c l \nu$ (incl. & excl.): $V_{cb} = 0.04148 \pm 0.00066$ $\Rightarrow A\lambda^2$

$B \rightarrow X_u l \nu$ (incl. & excl.): $V_{ub} = (4.10 \pm 0.09 \pm 0.39)10^{-3}$ $\Rightarrow A\lambda^3(\rho^2 + \eta^2)$

$B \rightarrow c\bar{c}K^{0(*)}$(t-dependent): $\sin(2\beta + 2\theta_d) = (0.675 \pm 0.026)$

$b \rightarrow c\bar{c}s$ not perfectly *SM4FC*

However: dominated by $V_{cs}V^*_{cb}$ SM tree

Mixing phase θ_K neglected

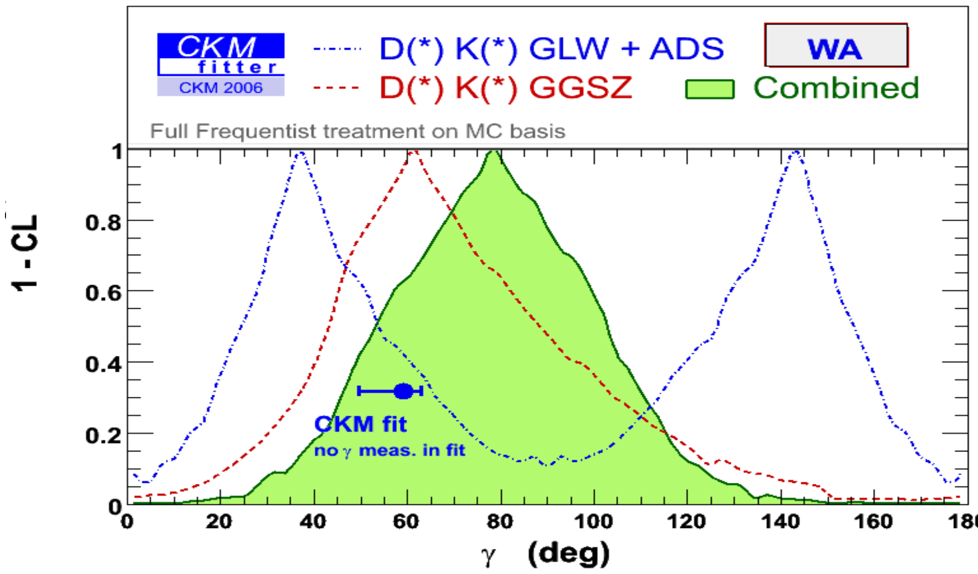
$B \rightarrow J/\Psi K^*$ $\cos(2\beta + 2\theta_d) > 0$

$B \rightarrow D^{(*)0}/\bar{D}^{(*)0}h^0$ HFAG does not provide an average

$B \rightarrow D^{(*)+}D^{(*)-}K_S$ and will not do so for quite some while

Inputs II

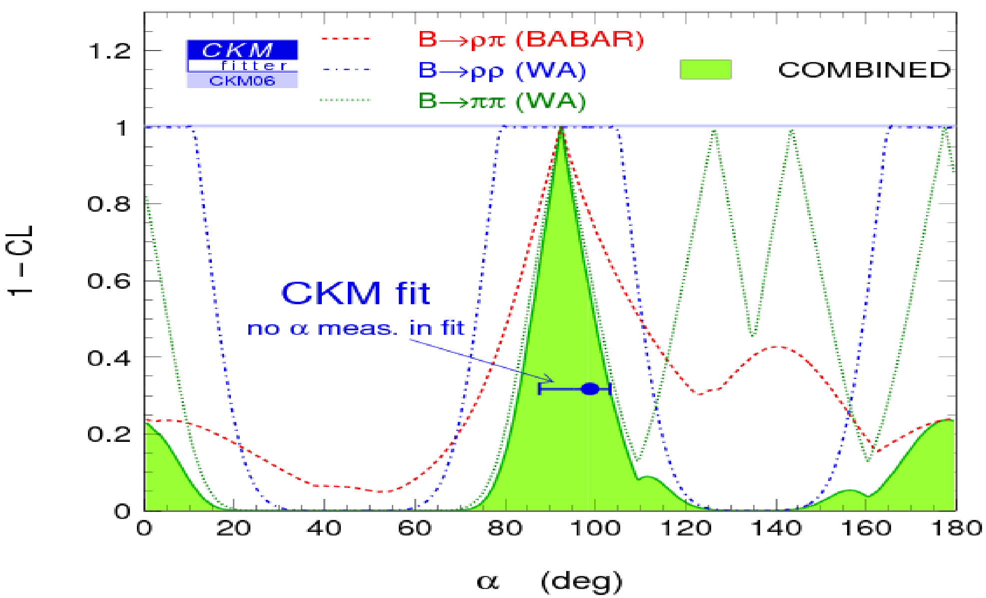
$B \to D^{(*)} K^{(*)}: \ \gamma$



<u>Comments:</u>

No NP contributions due to *SM4FC* hypothesis

$B \to \pi\pi, \rho\rho, 3\pi(\rho\pi): \quad \pi - \beta - \theta_d - \gamma$



<u>Comments:</u>

1) Isospin analysis insensitive to NP in ΔI=1/2 sector <u>for all α ≠ 0</u>!

2) Assumption: No NP in ΔI=3/2 (Dominated by $b \to u\bar{u}d$)

Inputs III

Three physical quantities in B mixing: $|M_{12}|, |\Gamma_{12}|, \phi = arg\left(-\frac{M_{12}}{\Gamma_{12}}\right)$

Observables: $\Delta m_q = M_H - M_L \simeq 2|M_{12}| = r_q^2 \Delta m_q^{SM}$

$$\Delta\Gamma_q = \Gamma_L - \Gamma_H \simeq -\Delta m_q \Re\left(\frac{\Gamma_{12}}{M_{12}}\right) = -\Delta m_q^{SM}\left[\Re\left(\frac{\Gamma_{12}}{M_{12}}\right)_{SM}\cos 2\theta_q + \Im\left(\frac{\Gamma_{12}}{M_{12}}\right)_{SM}\sin 2\theta_q\right]$$

$$A_{SL}^q = \Im\left(\frac{\Gamma_{12}}{M_{12}}\right) = -\Re\left(\frac{\Gamma_{12}}{M_{12}}\right)_{SM}\frac{\sin 2\theta_q}{r_q^2} + \Im\left(\frac{\Gamma_{12}}{M_{12}}\right)_{SM}\frac{\cos 2\theta_q}{r_q^2}$$

NLO calculations:

*** Beneke, Buchalla, Lenz & Nierste, PLB576, 173 (2003) (implemented)**

*** Ciuchini et al., JHEP 0308, 031 (2003)**

Inputs IV

$$\Delta m_d = (0.507 \pm 0.004)\, ps^{-1}$$ **(HFAG 06)**

$$A_{SL}^{d} = -0.0005 \pm 0.0055$$ **(BABAR, Belle, CLEO, BABAR |q/p|)**

$$\frac{\Delta\Gamma_d}{\Gamma_d} = 0.009 \pm 0.037$$ **(BABAR, DELPHI; no impact yet)**

$$\Delta m_s = (17.77 \pm 0.12)\, ps^{-1}$$ **(CDF)**

$$\Delta\Gamma_s \cdot \cos(\phi) \approx \Delta\Gamma_s \cos(2\theta_s) = (0.12 \pm 0.08)\, ps^{-1}$$ **(D0, CONF 5144)**

$$A_{SL}^{s} = 0.0245 \pm 0.0196$$ **(D0, CONF 5143)**

$$A_{SL} = -0.0026 \pm 0.0029$$ **(using D0, CONF 5042)**

$$A_{SL} \approx \frac{Z_d f_d A_{SL}^{d} + Z_s f_s A_{SL}^{s}}{Z_d f_d + Z_s f_s} \qquad Z_q = \frac{1}{1-y_q^2} - \frac{1}{1+x_q^2}$$ **Grossman, Nir, Raz hep-ph/0605028**

$$f_d = 0.398 \pm 0.011,\ f_s = 0.104 \pm 0.013,\ \rho(f_d, f_s) = -0.5$$ **(HFAG 06)**

New Physics in B_d-$\bar{B}_d$ Mixing

$|V_{ub}|$

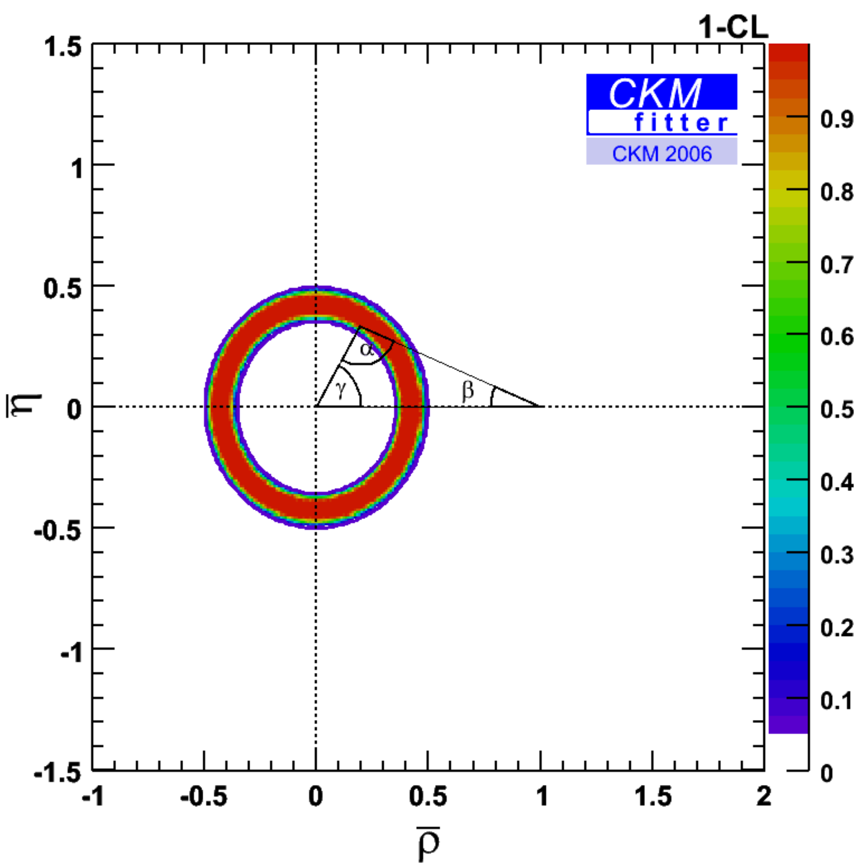
$\Delta m_d^{SM} r_d^2$

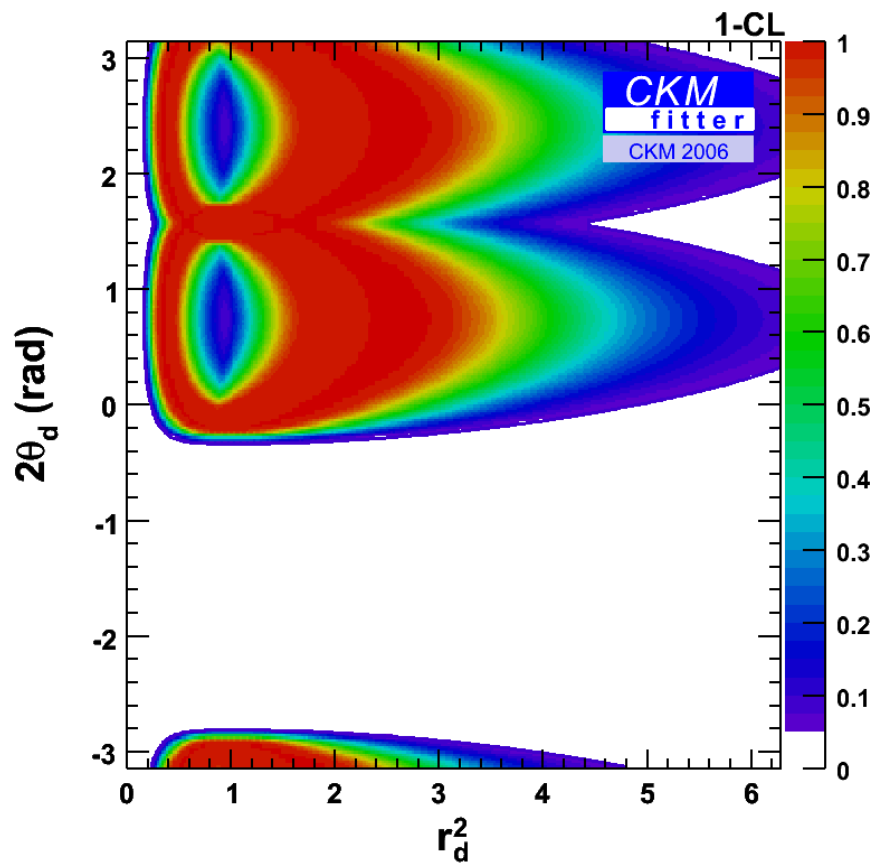
$\sin(2\beta + 2\theta_d)$

Three Observables

Four unknowns:

$r_d^2, 2\theta_d, \bar{\rho}, \bar{\eta}$

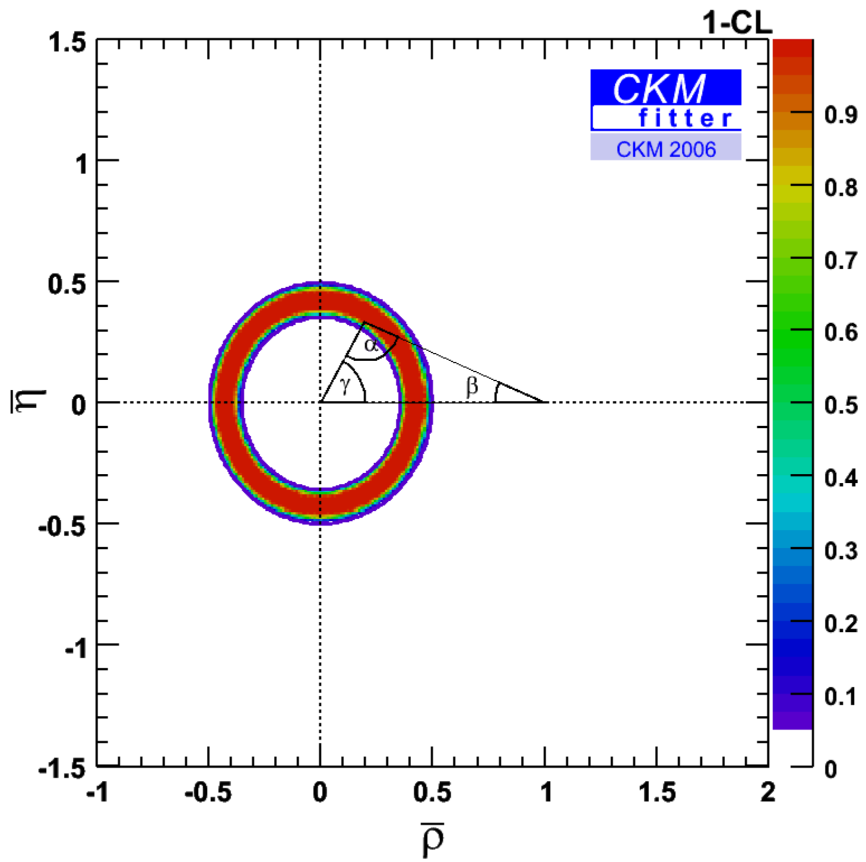


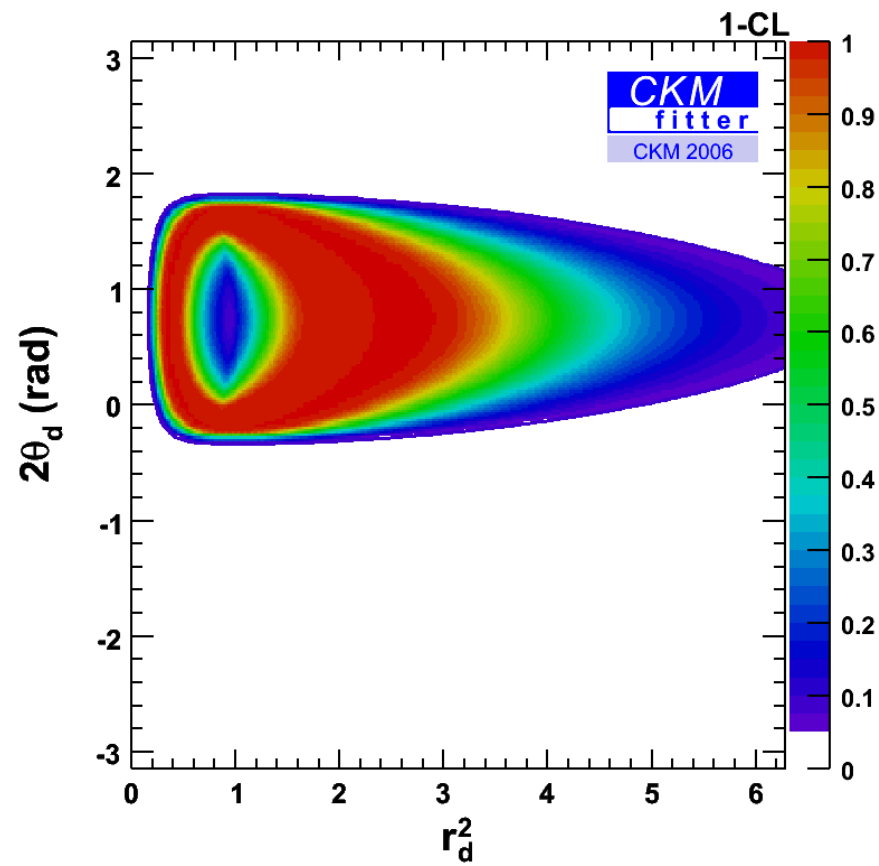


New Physics in B_d-$\bar{B}_d$ Mixing

$|V_{ub}|$
$\Delta m_d^{SM} r_d^2$
$\sin(2\beta+2\theta_d)$
$\cos(2\beta+2\theta_d)$

Sign of $\cos(2\beta+2\theta_d)$ **eliminates half of the** $r_d^2-2\theta_d$ **parameter space**

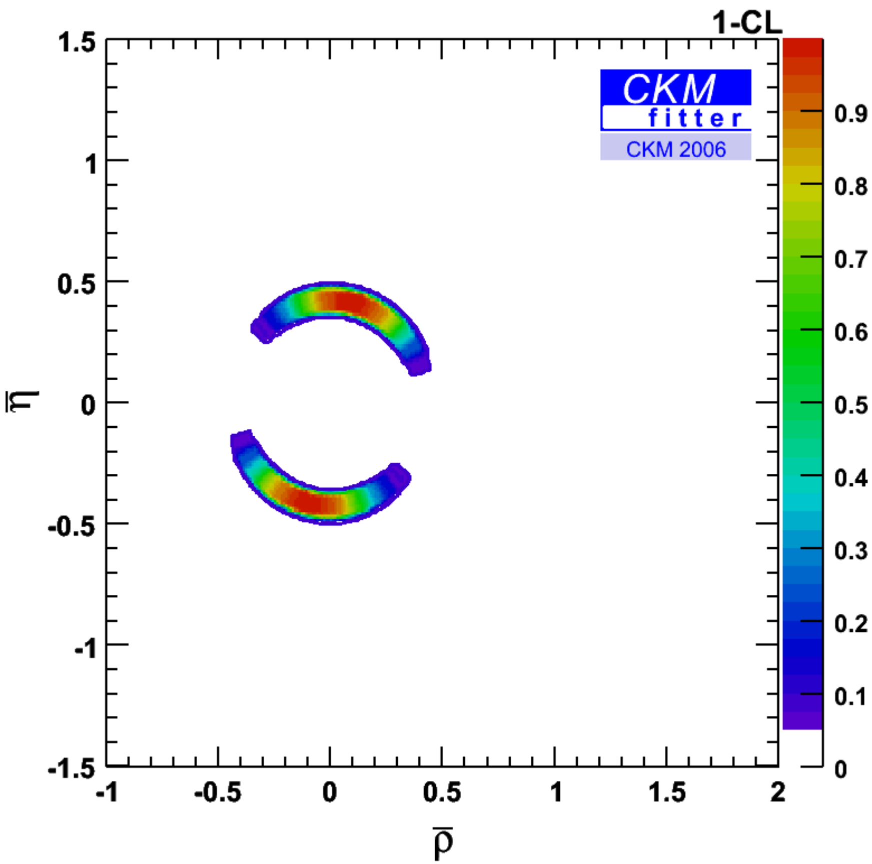


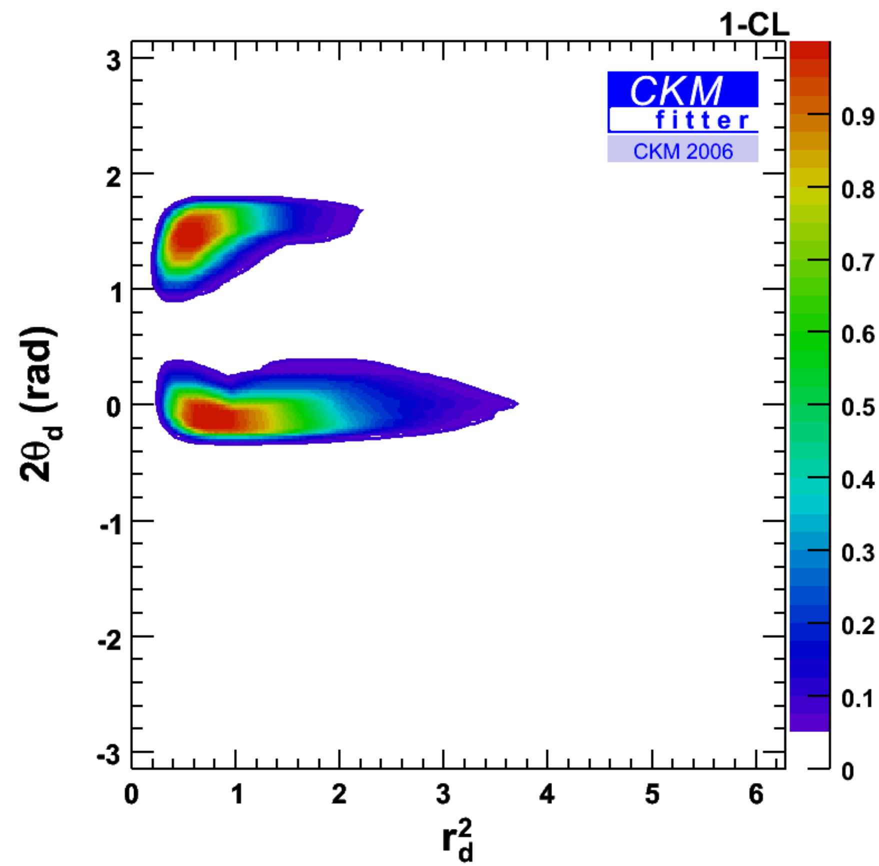


New Physics in B_d-$\bar{B}_d$ Mixing

$|V_{ub}|$
$\Delta m_d^{SM} r_d^2$
$\sin(2\beta+2\theta_d)$
$\cos(2\beta+2\theta_d)$
γ

Real CKM matrix disfavoured





New Physics in B_d-$\bar{B}_d$ Mixing

$|V_{ub}|$

$\Delta m_d^{SM} r_d^2$

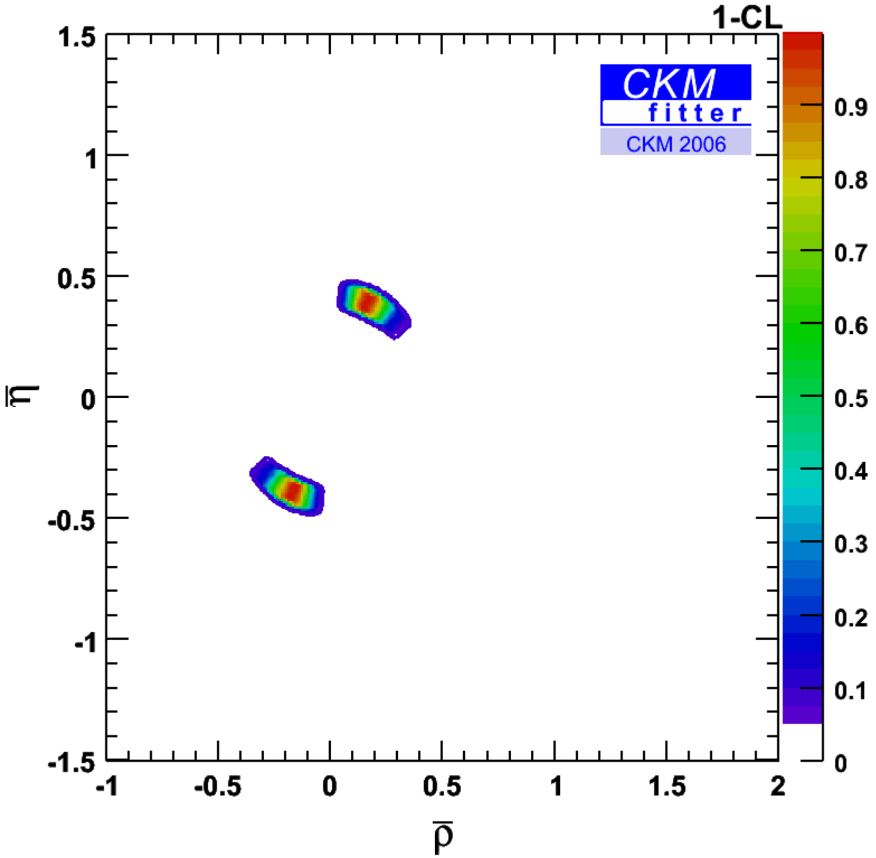
$\sin(2\beta + 2\theta_d)$

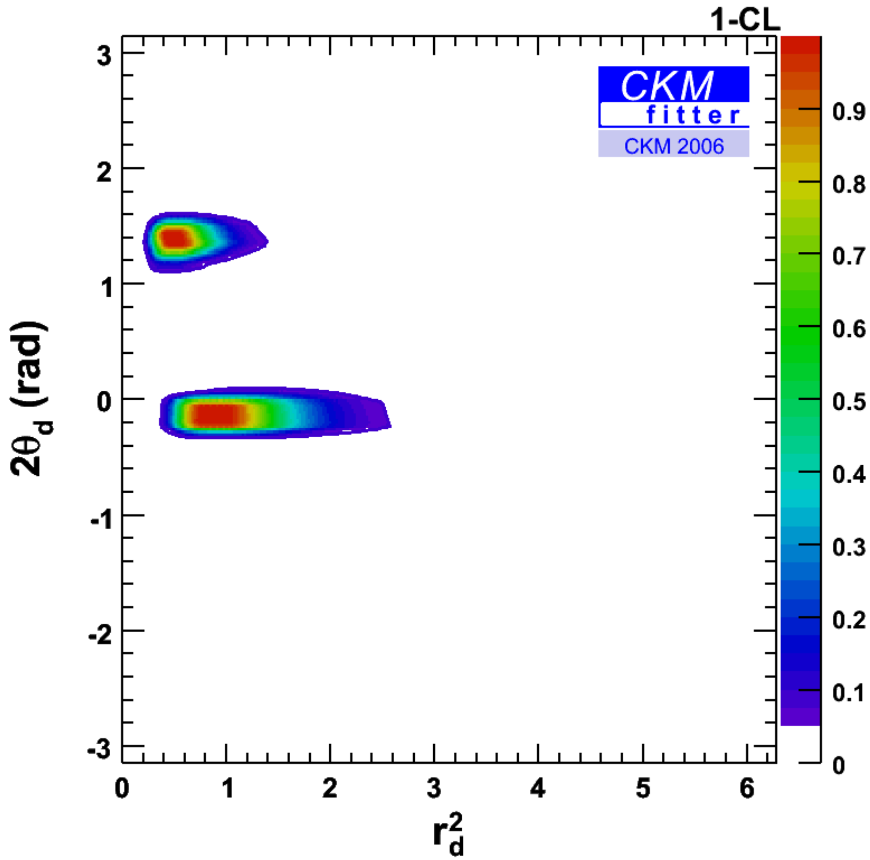
$\cos(2\beta + 2\theta_d)$

γ

$\alpha = \pi - \beta - \theta_d - \gamma$

Real CKM matrix excluded at high CL





New Physics in B_d-$\bar{B}_d$ Mixing

$|V_{ub}|$

$\Delta m_d^{SM} r_d^2$

$\sin(2\beta + 2\theta_d)$

$\cos(2\beta + 2\theta_d)$

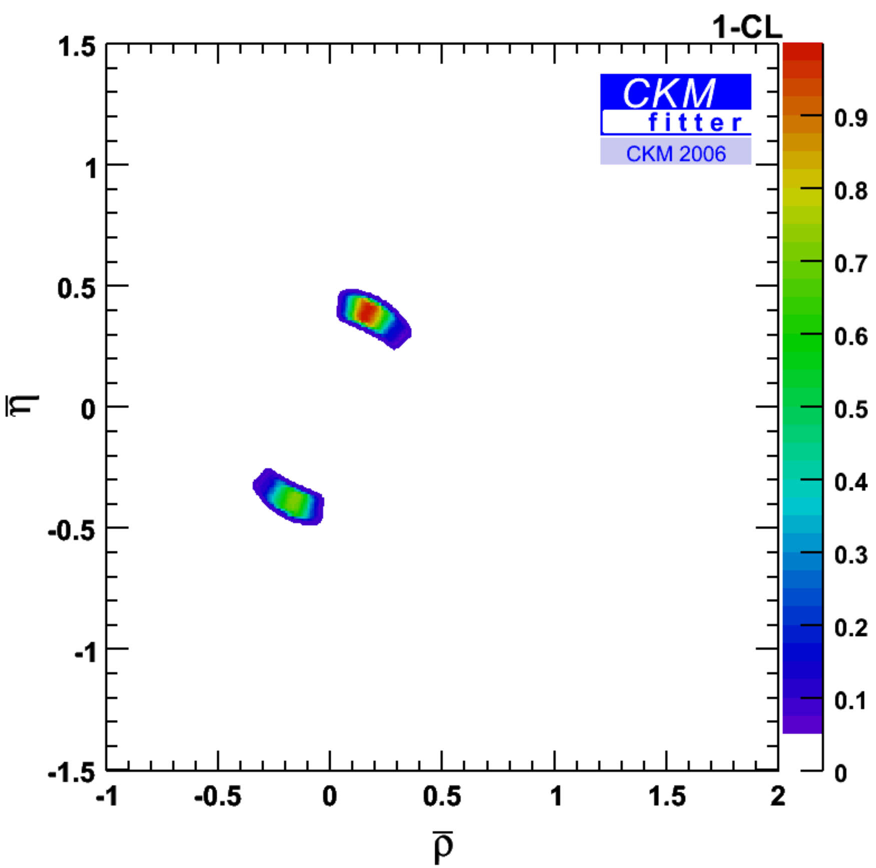
γ

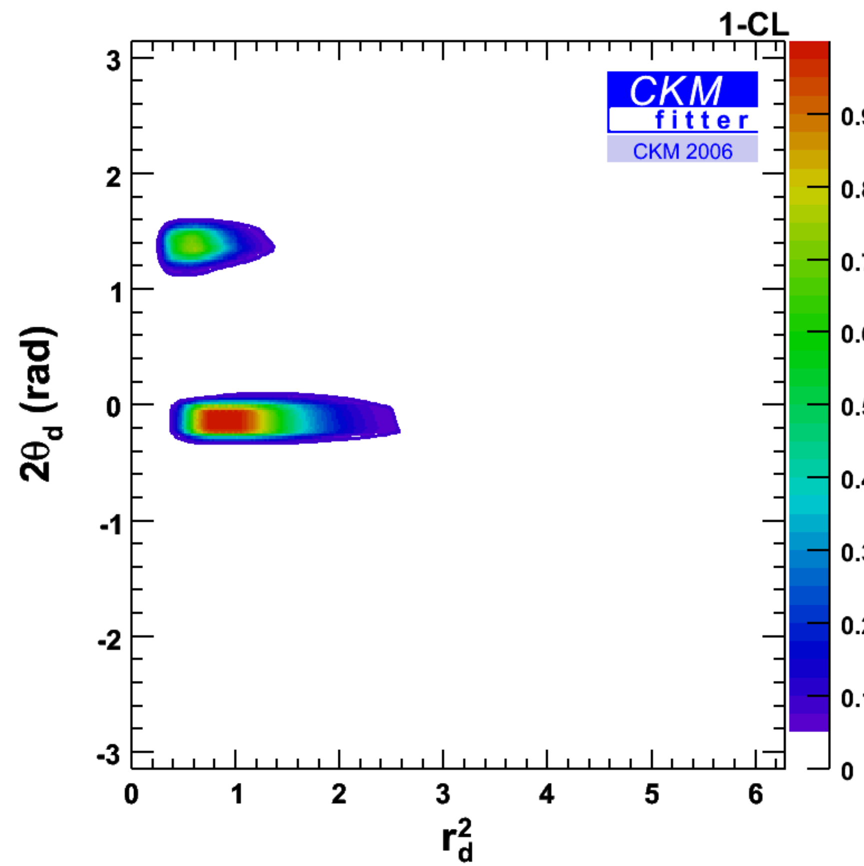
$\alpha = \pi - \beta - \theta_d - \gamma$

A_{SL}^d

A_{SL}^d helps to distinguish between standard and non-standard solution (CKMfitter, EPJ C41 (2005))

SM solution on $\bar{\rho} - \bar{\eta}$ almost as constraining as in Standard Model Fit





New Physics in B_d-$\bar{B}_d$ Mixing

$|V_{ub}|$

$\Delta m_d^{SM} r_d^2$

$\sin(2\beta + 2\theta_d)$

$\cos(2\beta + 2\theta_d)$

γ

$\alpha = \pi - \beta - \theta_d - \gamma$

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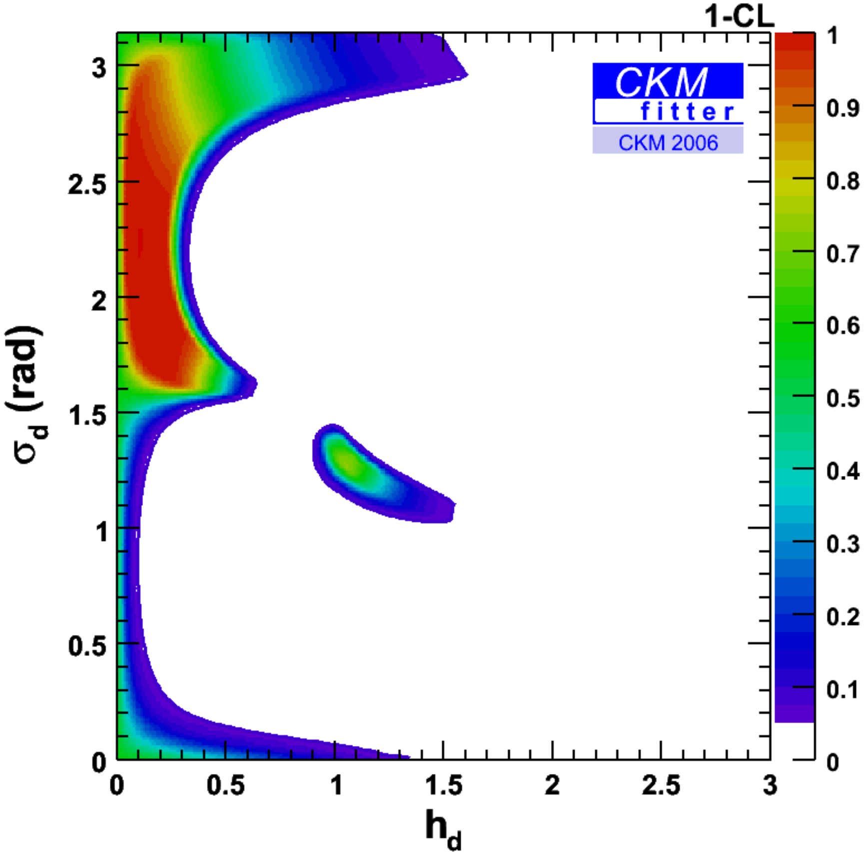
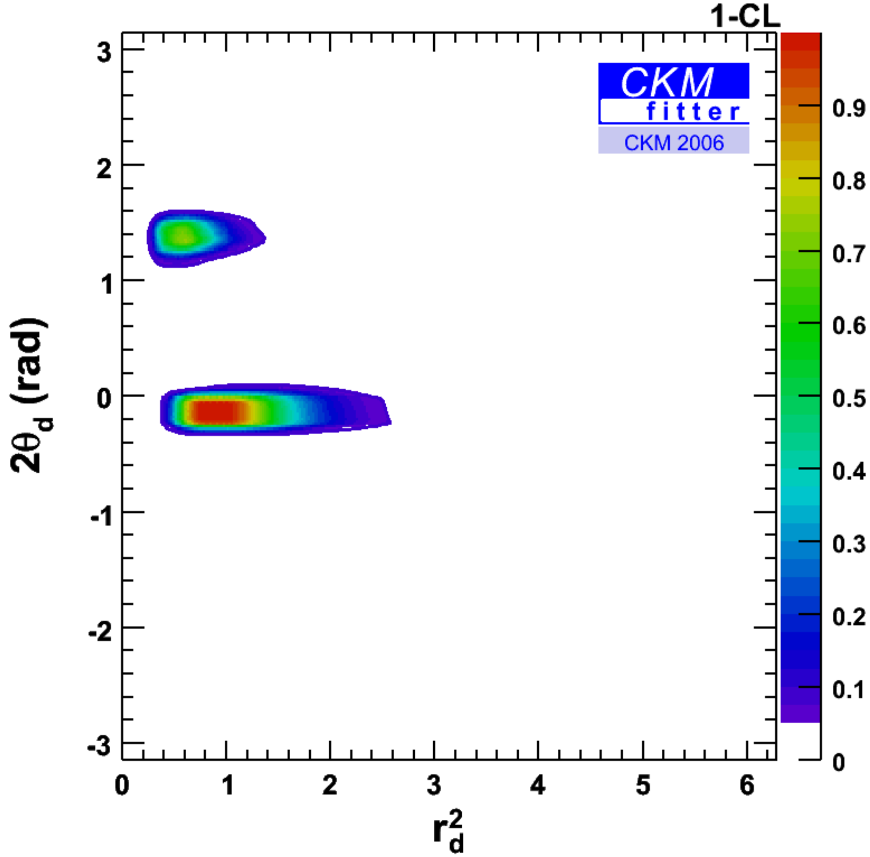




New Physics in B_d-$\bar{B}_d$ and B_s-$\bar{B}_s$ Mixing

$|V_{ub}|$

$\Delta m_d^{SM} r_d^2$

$\sin(2\beta+2\theta_d)$

$\cos(2\beta+2\theta_d)$

γ

$\alpha=\pi-\beta-\theta_d-\gamma$

A_{SL}^d

$\Delta m_s^{SM} r_s^2$

A_{SL}^s

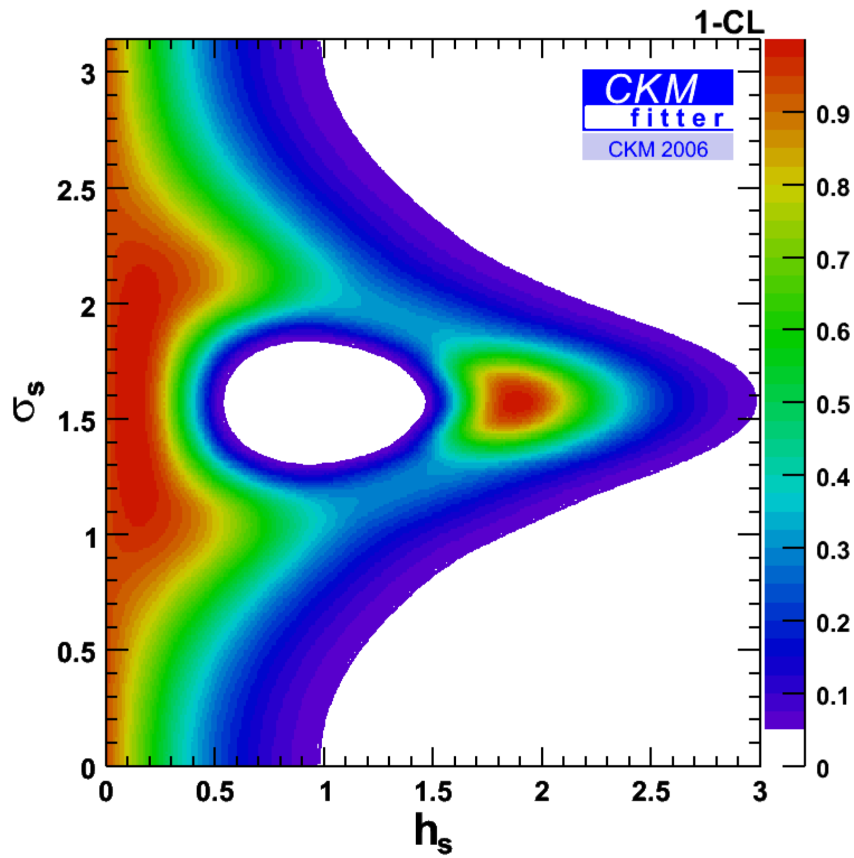
A_{SL}

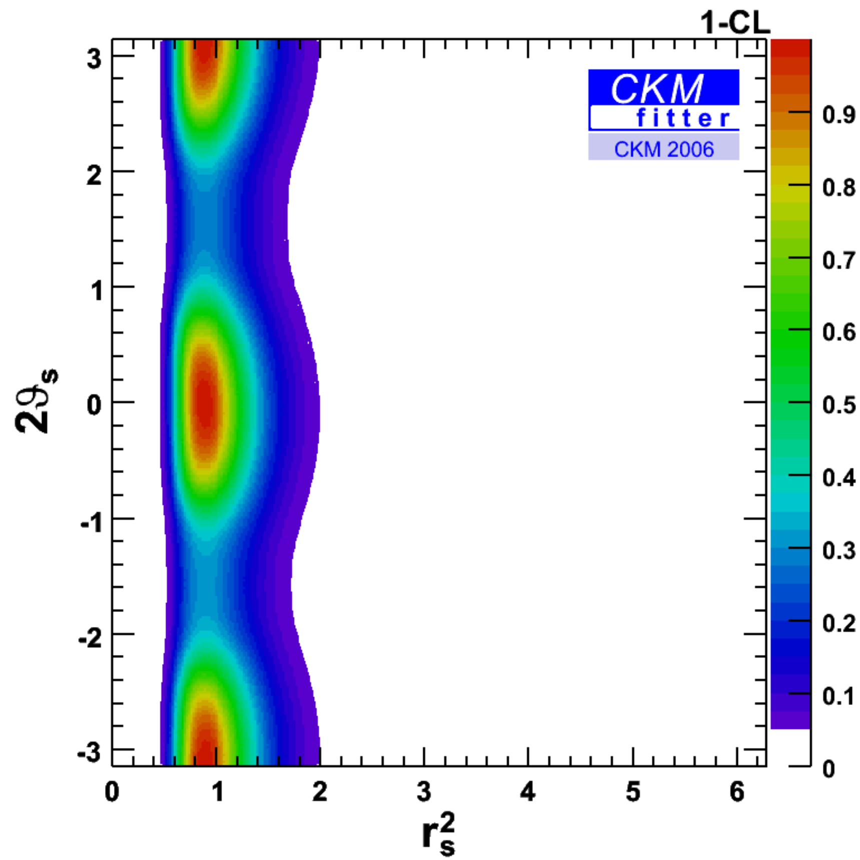
$\Delta\Gamma_s^{SM}\cos^2(2\theta_s)$

Δm_s strongly constrains r_s^2

$\Delta\Gamma_s$ bit larger than SM

=> $2\theta_s$ = $|\pi/2|$ disfavored

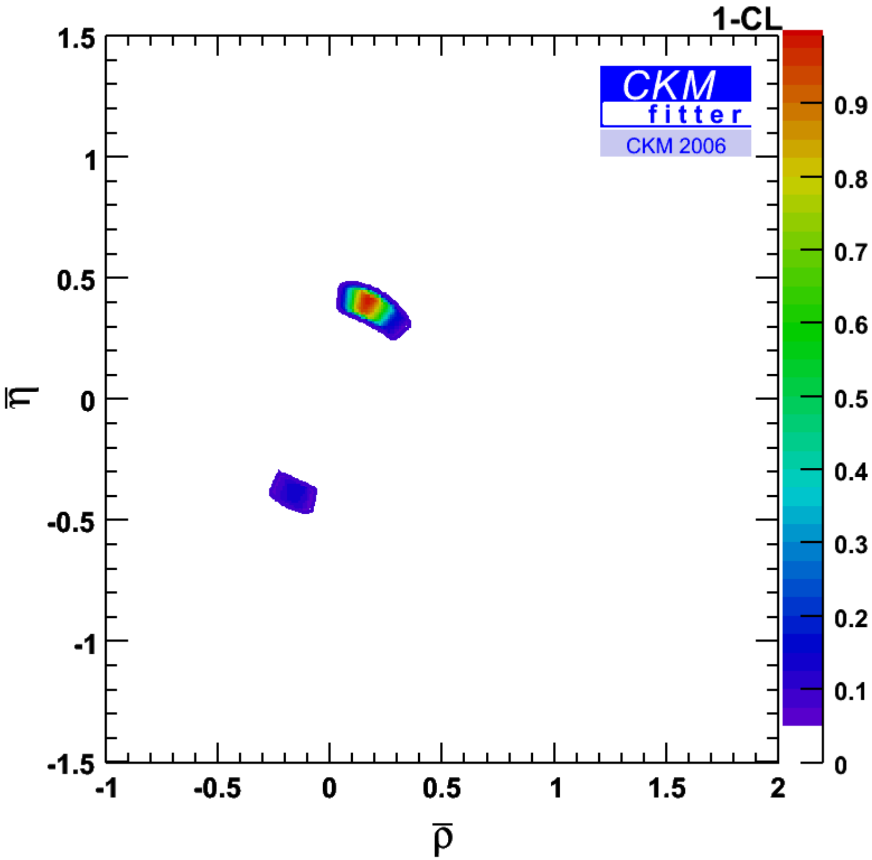


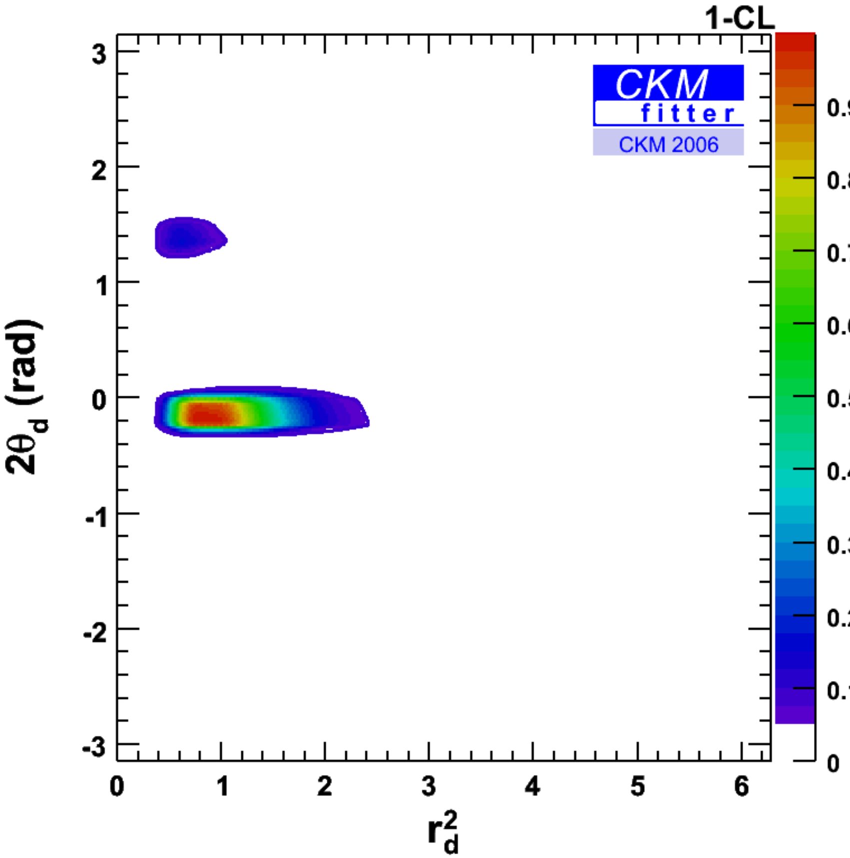


New Physics in B_d-$\bar{B}_d$ and B_s-$\bar{B}_s$ Mixing

$\lvert V_{ub} \rvert$	$\Delta m_s^{SM} r_s^2$
$\Delta m_d^{SM} r_d^2$	A_{SL}^s
$\sin(2\beta+2\theta_d)$	A_{SL}
$\cos(2\beta+2\theta_d)$	$\Delta\Gamma_s^{SM}\cos^2(2\theta_s)$
γ	
$\alpha=\pi-\beta-\theta_d-\gamma$	
A_{SL}^d	

A_{SL} from D0 helps to further suppress the non-standard solution in $\bar{\rho}-\bar{\eta}$ and hence also in $r_d^2-2\theta_d$





New Physics in B_d-$\bar{B}_d$ and B_s-$\bar{B}_s$ Mixing

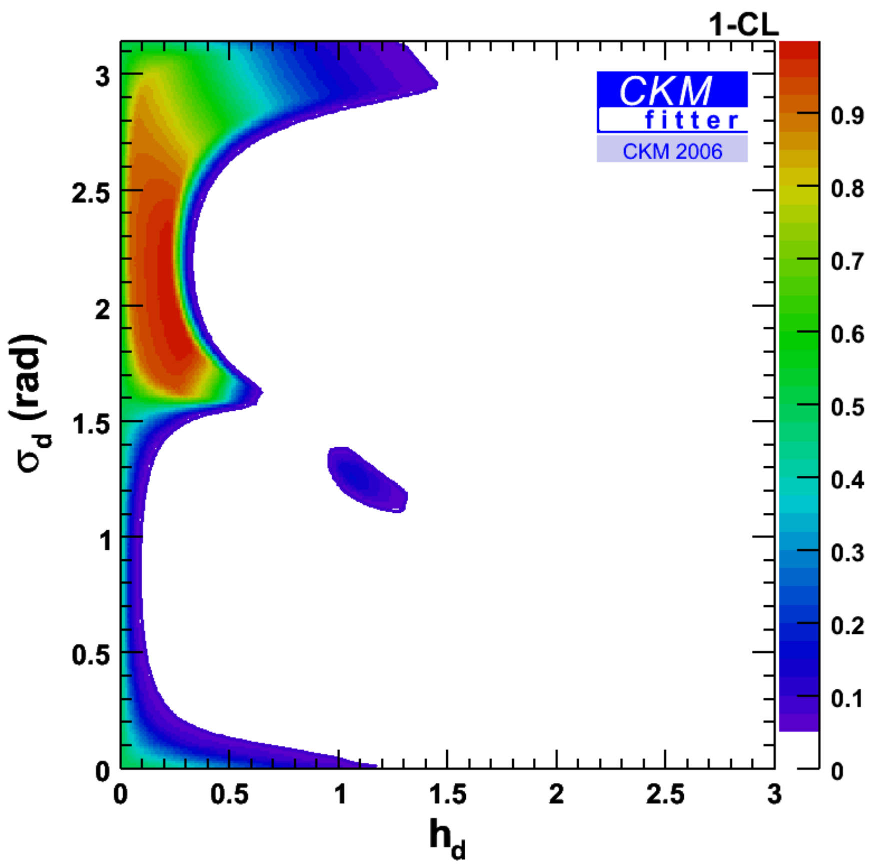
$\lvert V_{ub} \rvert$	$\Delta m_s^{SM} r_s^2$
$\Delta m_d^{SM} r_d^2$	A_{SL}^s
$\sin(2\beta + 2\theta_d)$	A_{SL}
$\cos(2\beta + 2\theta_d)$	$\Delta\Gamma_s^{SM} \cos^2(2\theta_s)$
γ	
$\alpha = \pi - \beta - \theta_d - \gamma$	
A_{SL}^d	

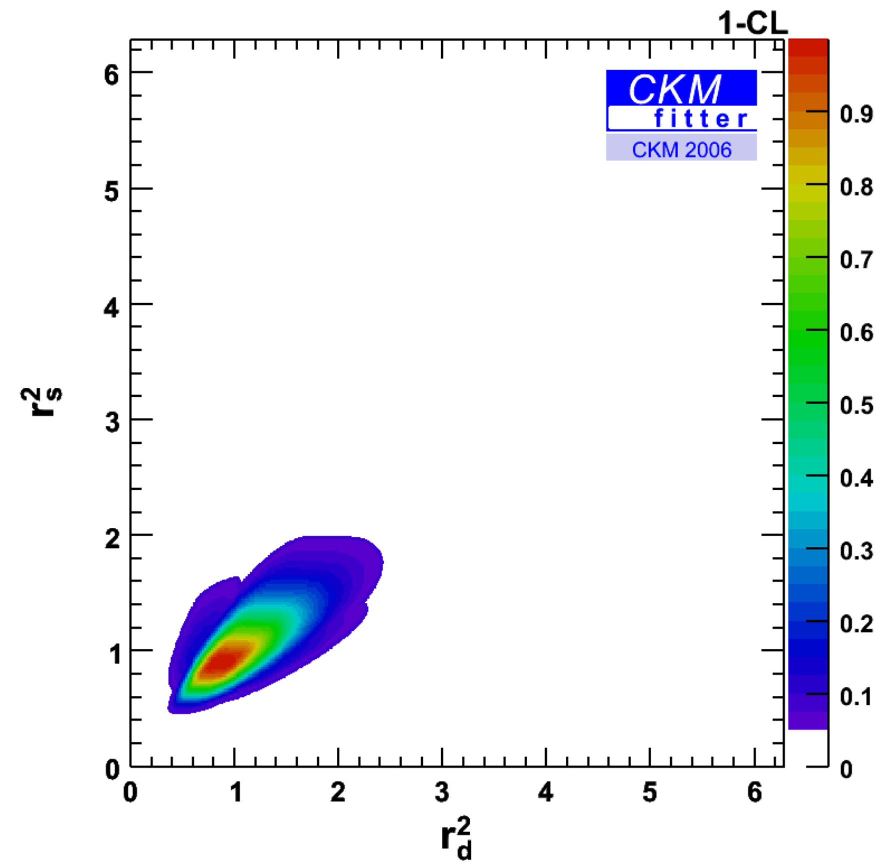
UTfit, PRL97, 151803 (2006)

Correlation between r_d^2 and r_s^2

Qualitatively similar

Difference in treatment of theoretical error in ξ





Summary & Outlook

* NLO calculation for $\Delta\Gamma_s$ and A_{SL}^q implemented in CKMfitter (Andreas Jantsch)

* Combined general analysis for B_d-$\bar{B}_d$ and B_s-$\bar{B}_s$ mixing performed

* B-meson factories and Tevatron provide stringent constraints on NP in B_d-$\bar{B}_d$ and B_s-$\bar{B}_s$ mixing

* Awaiting updated HFAG averages for $\Delta\Gamma_s$

* Not included for this talk: $\sin(2\beta + 2\theta_d + \gamma)$ ("Underdog")
  To be done using constraint from toy MC (--> talk by Max Baak)

Many thanks to:
U. Nierste, G. Buchalla, Z.Ligeti and M. Papucci for clarifying discussions