W_R contribution and CP angles measurements

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"Workshop on Higher Luminosity B Factory"

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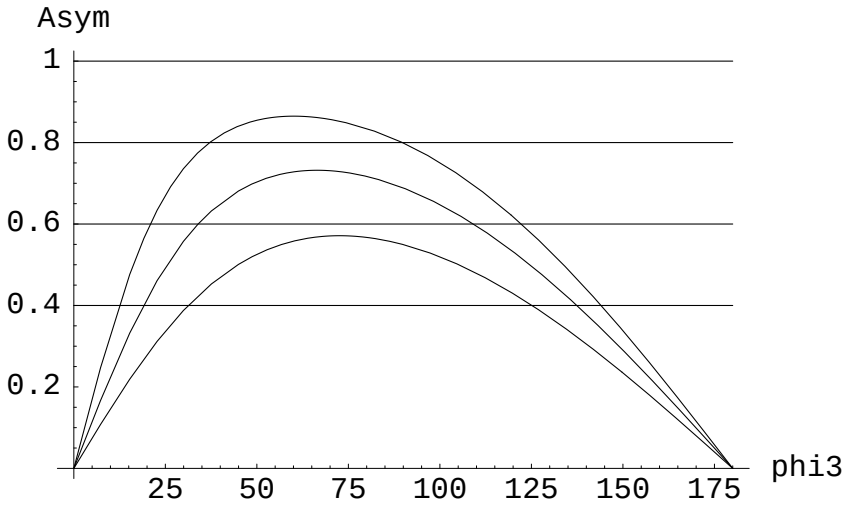
1. Large $\sin 2\phi_1$ at Belle $\Leftarrow$ new physics?

$$\sin 2\phi_1 = 0.99 \pm 0.14 \pm 0.06 \quad \text{(Belle, 2001)}$$
$$0.59 \pm 0.09 \pm 0.03 \quad \text{(Babar, 2001)}$$

in SM

$$\sin 2\phi_1 = \sin\left(2\arg[V_{tb}V_{td}^*]\right) = \sin\left(2\arg[1 - r_{ub}e^{-i\phi_3}]\right)$$

$$(r_{ub} \equiv \sqrt{\rho^2 + \eta^2})$$



SM prediction of $\sin 2\phi_1$

(upper, middle, lower curves correspond to
$|V_{ub}/V_{cb}| = 0.11, 0.09, 0.07$, respectively)

If Belle's high value is favored in the future
$\Rightarrow$ there should be a new physics beyond SM which affects B-$\overline{B}$ mixing and/or $b \to sc\bar{c}$.

2. Left-Right model as a candidate

LR model: $SU_L(2) \times SU(2)_R \times U(1)$ gauge theory,
light handed charged current with $W_R^{\pm}$

$$\mathcal{L}_R = \frac{g_R}{\sqrt{2}}(\bar{u}, \bar{c}, \bar{t})\ \gamma^\mu V^R \begin{pmatrix} d \\ s \\ b \end{pmatrix}_R W_{R\mu}^{+} + \text{(h.c.)}$$

$V_R \neq V_{KM}$ in general

What's interesting

- $M_R \gg M_W$ but $|V^R{}_{(ij)}| \gg |V_{KM(ij)}|$ possible

$\Rightarrow$ W_R process can be comparable with SM
or dominate in some cases.

$$V_{KM} \sim \begin{pmatrix} 1 & \lambda & \leq \lambda^3 \\ \lambda & 1 & \lambda^2 \\ \lambda^3 & \lambda^2 & 1 \end{pmatrix} \text{(1,2-3 elements small)}$$

- V_{KM}: 3 angles and 1 phase
  V^R: 3 angles and **6** phases
  $\Rightarrow$ rich CP violation sources

Constraint from present exp.

$$V^L_{KM} = \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

$\lambda = 0.22$ $(K \to \pi e\nu)$, $A = 0.8 \pm 0.1$ $(b \to cl\nu)$,

$0.3 < \sqrt{\rho^2+\eta^2} < 0.5$ $(b \to ul\nu)$

W_R cannot contribute to the semi-leptonic processes since ν_R is heavy.

K-$\bar{K}$ mixing, ϵ_K

Olness and Ebel, Langacker and Sanker, London and Wyler,

T.K, Tomita and Wakaizumi

Large contribution from $W_L - W_R$ box diagram

$$\mathcal{H}^{eff}_{LR} = \sum_{i,j=u}^{t} \frac{2G_F^2 M_W^2}{\pi^2} \beta_g V^{L*}_{id} V^R_{is} V^{R*}_{jd} V^L_{js} J(x_i, x_j, \beta)\ \overline{d_R} s_L \overline{d_L} s_R + (\text{h.c.}),$$

Enhancement in loop calculation and hadron matirx elements $(M_K^2/(m_s+m_d)^2)$

$\Rightarrow$ $M(W_R) > O(10^2)$ TeV

unless we take a special form of V^R

$$V^R = \begin{pmatrix} 0 & 1 & 0 \\ \cos\theta_R & 0 & -e^{i\omega}\sin\theta_R \\ \sin\theta_R & 0 & e^{i\omega}\cos\theta_R \end{pmatrix}$$

then, relatively light W_R is possible
without affecting ϵ_K.
(c.f $M(W_R) > 0.7$ TeV from EW analysis)

Below we adopt this V^R to study B physics.

(There is another kind of V^R which allows light W_R. But it does not contribute B physics so much.)

3. W_R effects on B-$\overline{B}$ mixing, ϕ_1, ϕ_3

$B - \bar{B}$ mixing, ϕ_1

$$M_{12}^B = M_{12}^{SM} + M_{LR} + M_{RR}$$

M_{LR}: W_L-W_R box diagram contribution
M_{RR}: W_R-W_R box diagram contribution
No $b \to sc\bar{c}$ contribution by W_R

ϕ_3

W_R can affect $b \to c\bar{u}s$ decay ($B^\pm \to DK$)

$$\frac{|V_{cb}V_{us}|}{M_W^2} : \frac{|V_{cb}^R V_{us}^R|}{M_{W_R}^2} \sim 1 : \frac{M_W^2}{M_{W_R}^2}\frac{\sin\theta_R}{\lambda^3}$$

Inputs:

$M(W_R) = 1 \sim 5$ TeV, ϕ_3 in $V_{KM}^L = 90°$, $r_{ub} = 0.09/\lambda$, $f_B\sqrt{B_B} = 230$ MeV

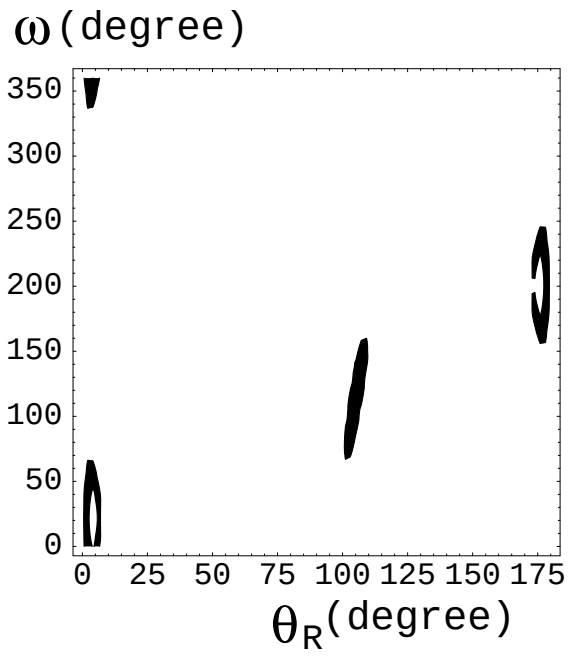
$\Downarrow$

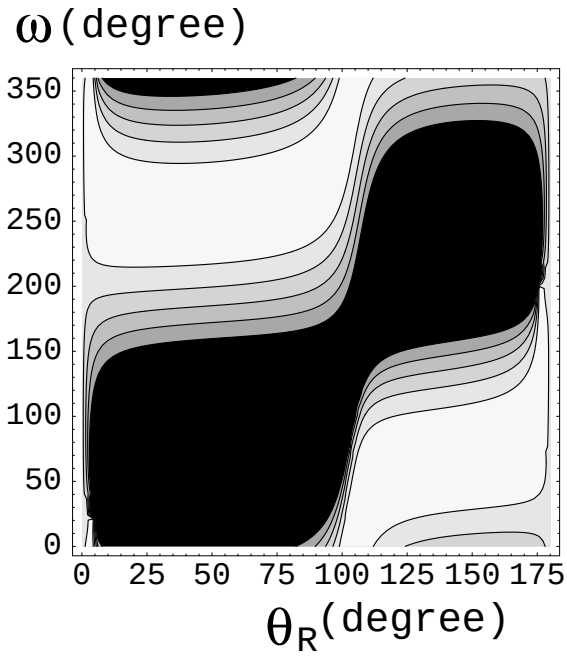
by varying θ_R and ω in V^R

- Draw allowed region by exp. data of ΔM_B considering $\pm 30\%$ error from r_{ub} and $f_B\sqrt{B_B}$
- Calculate $Asy(\Psi K)|_{LR}$
- Calculat $\Delta\phi_3|_{LR}$
  (deviation of ϕ_3 in $B^\pm \to DK$ from SM value)

$M(W_R) = 1$ TeV

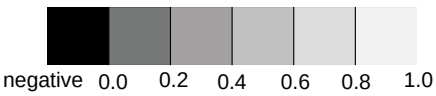
$\phi_3 = 90°$



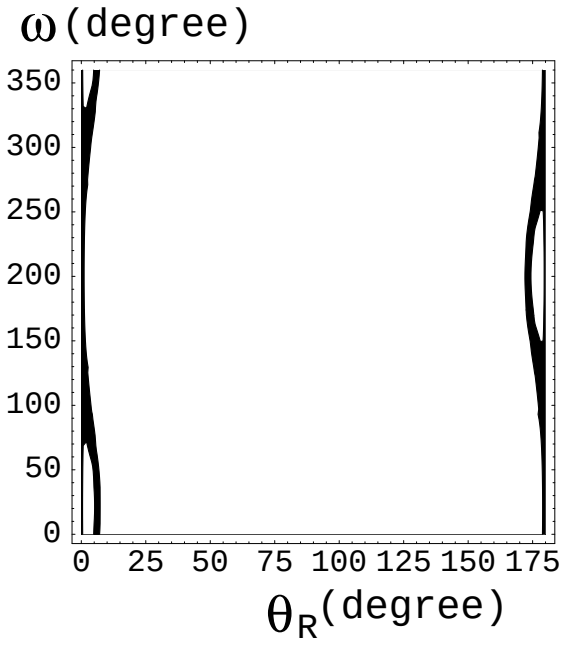


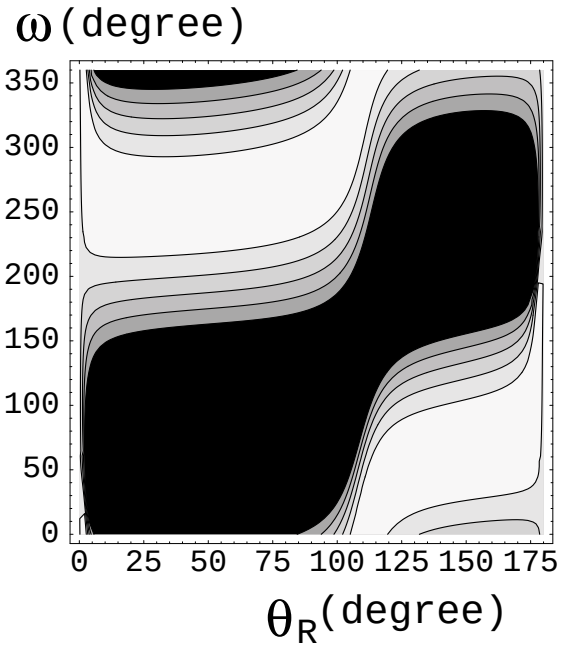
■ allowd region

$Asy(\Psi K)|_{LR}$

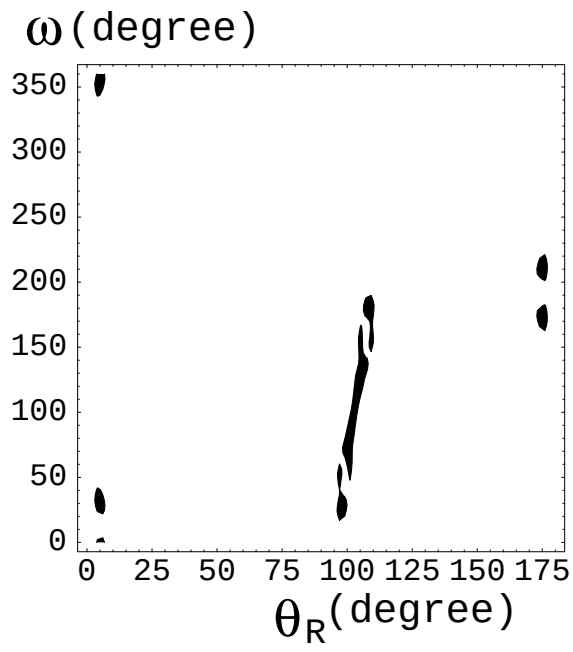


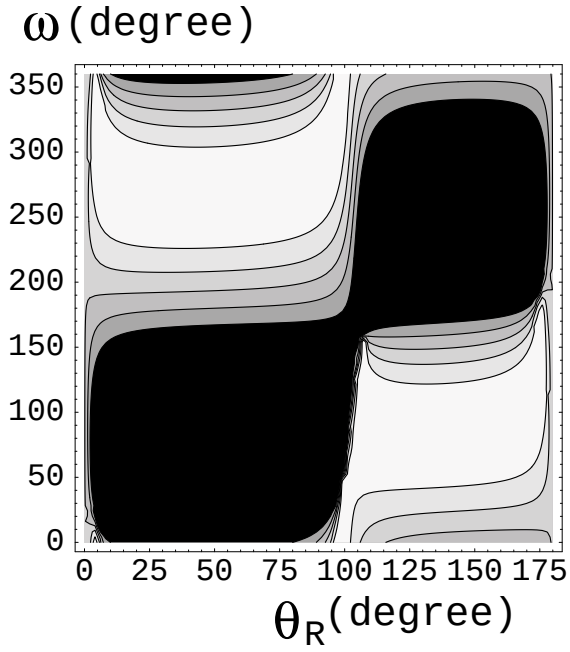
$\phi_3 = 45°$



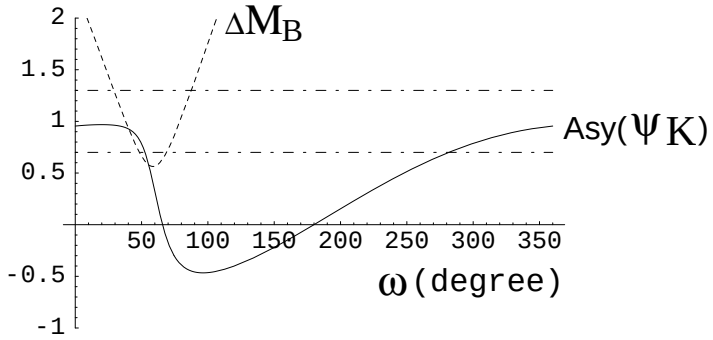


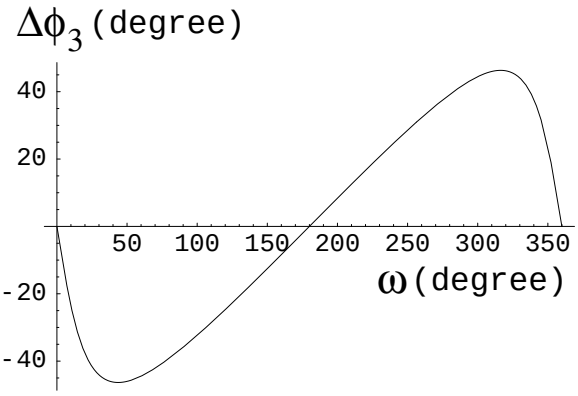
$\phi_3 = 135^\circ$





for $\theta_R = 100^\circ$

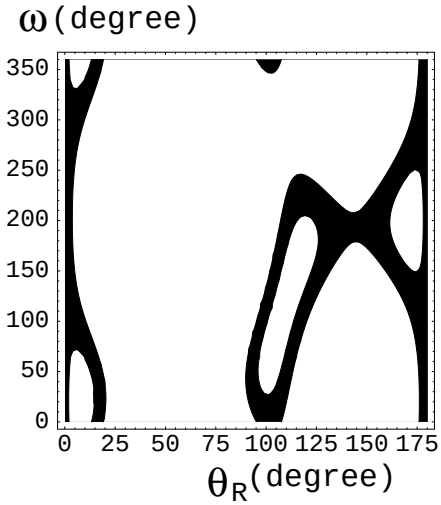


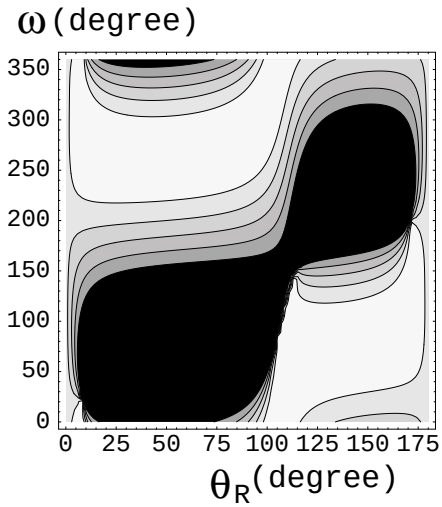


Large $Asy(\Psi K)$ and $|\Delta\phi_3|$ possible for $\omega \sim 30^\circ$

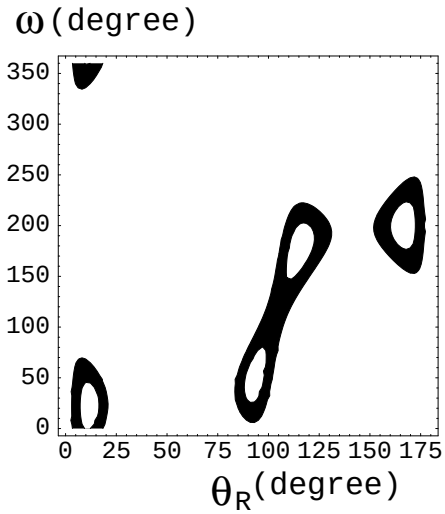
$M(W_R) = 2$ TeV

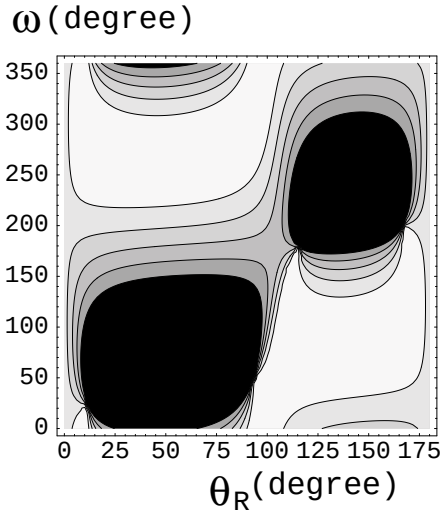
$\phi_3 = 45°$



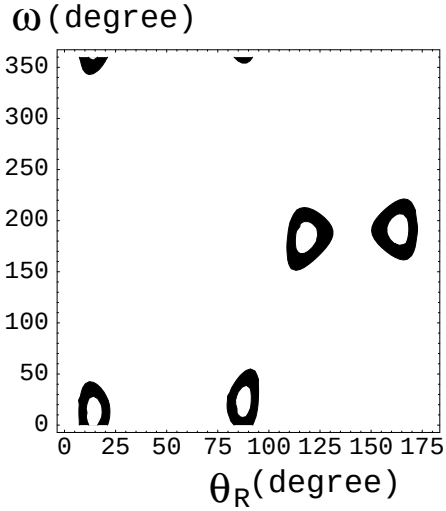


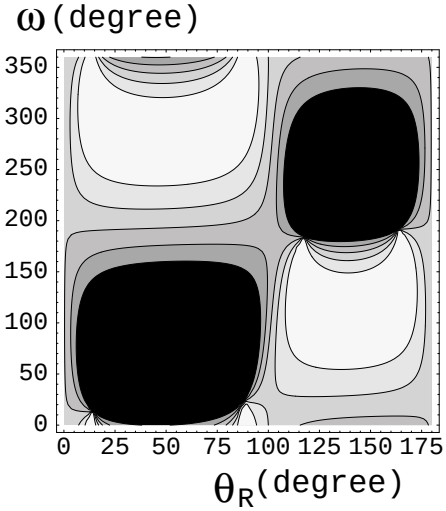
$\phi_3 = 90°$





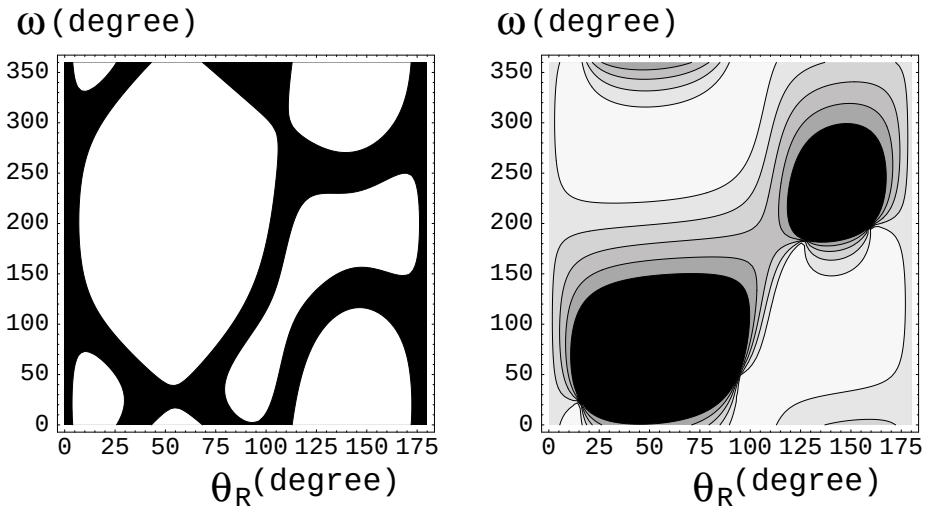
$\phi_3 = 135°$



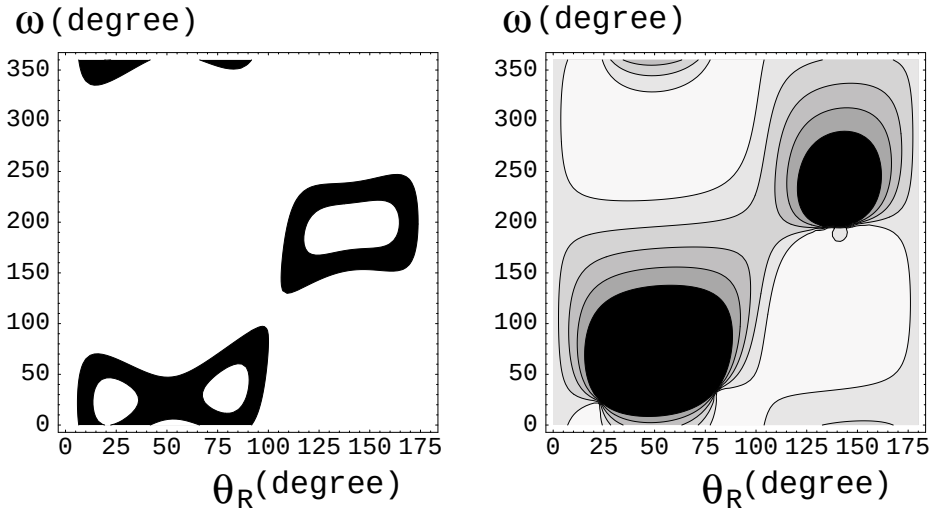


$M(W_R) = 3$ TeV

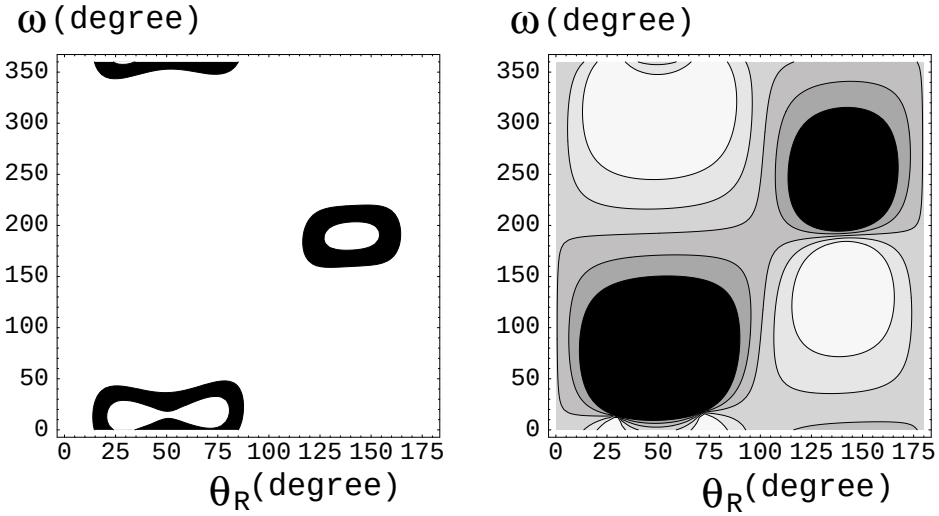
$\phi_3 = 45°$



$\phi_3 = 90°$

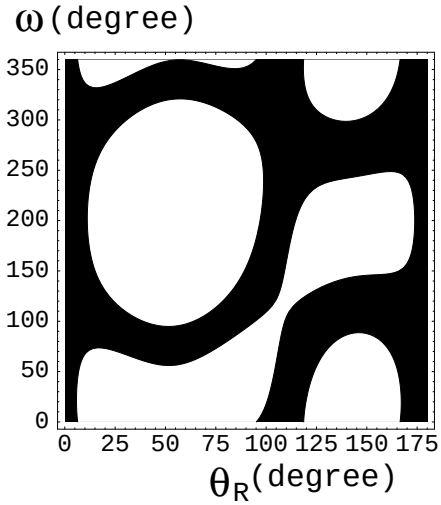


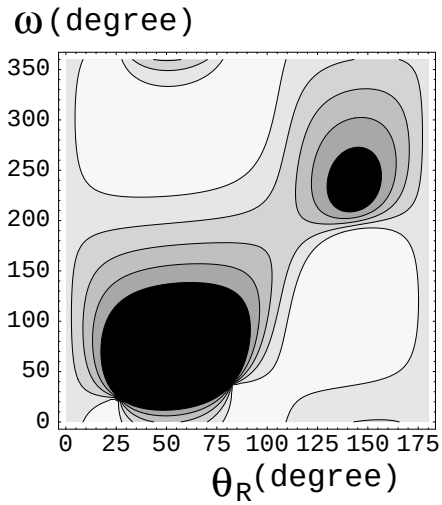
$\phi_3 = 135°$



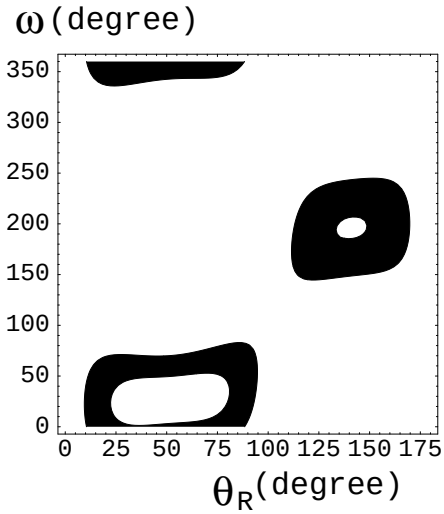
$M(W_R) = 4$ TeV

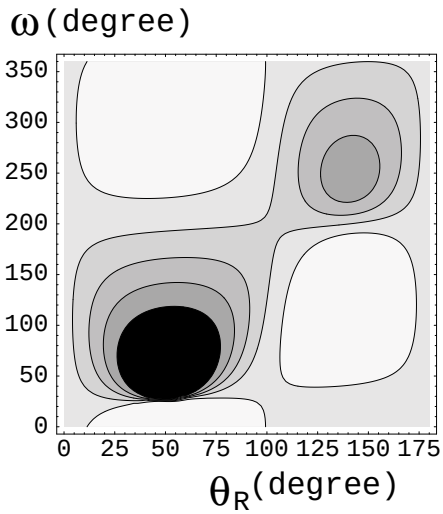
$\phi_3 = 45°$



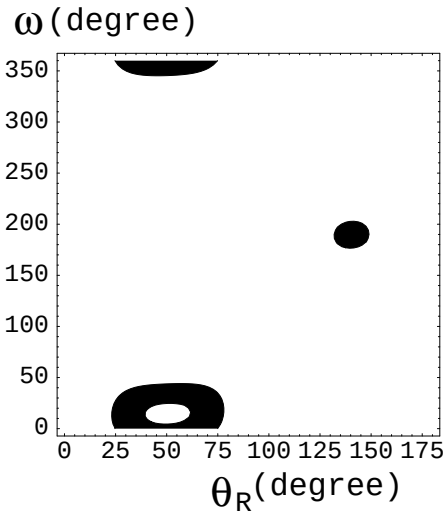


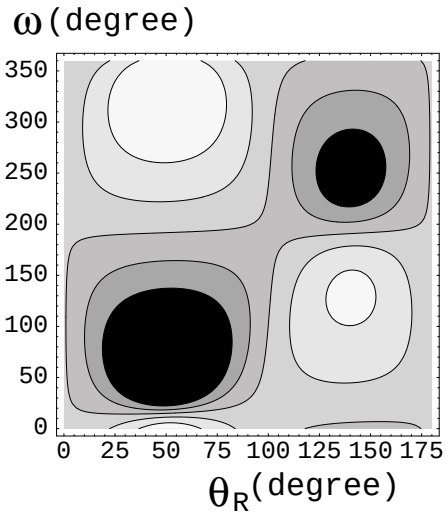
$\phi_3 = 90°$





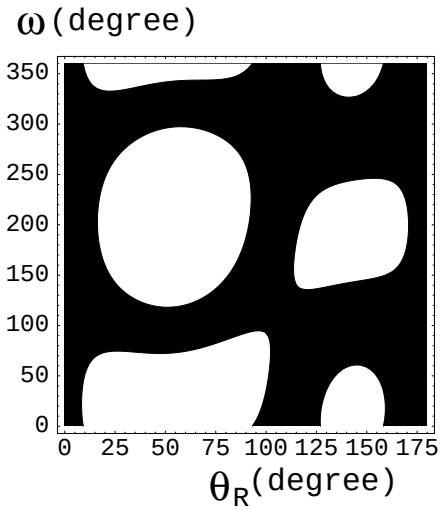
$\phi_3 = 135°$

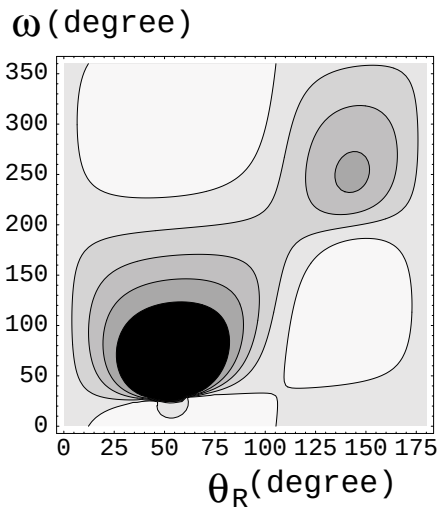




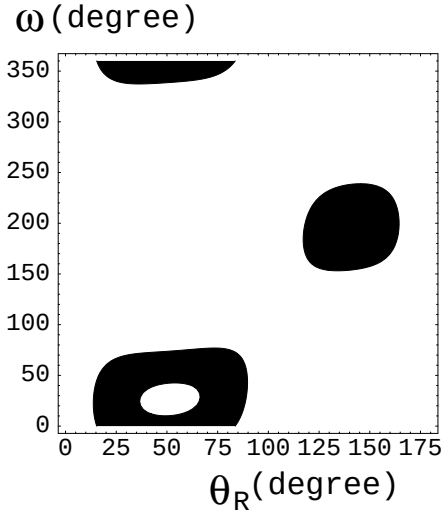
$M(W_R) = 5$ TeV

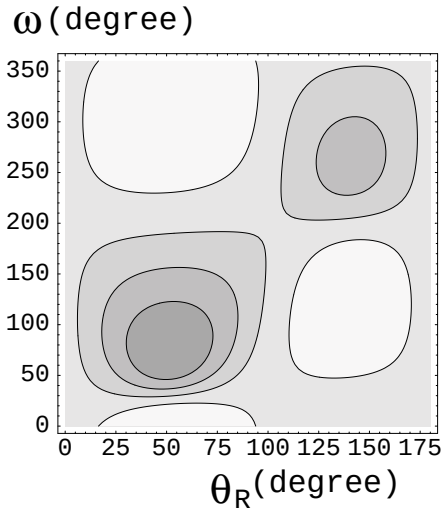
$\phi_3 = 45°$



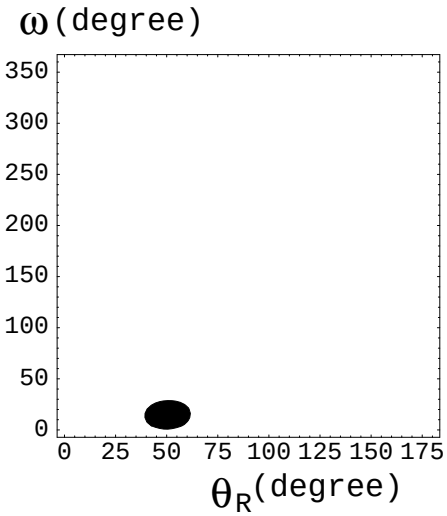


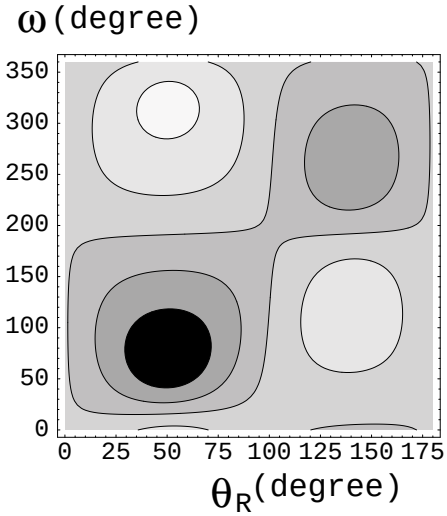
$\phi_3 = 90°$





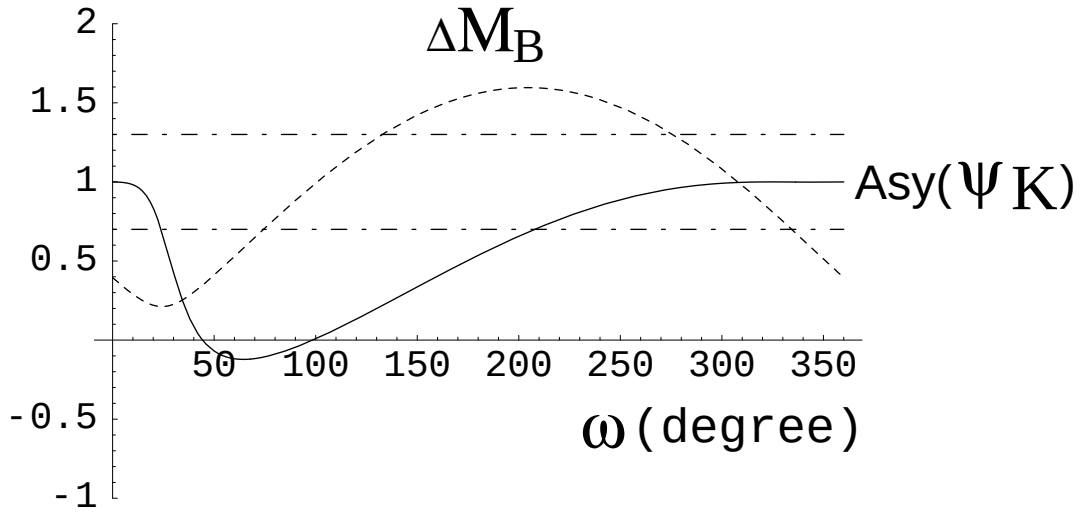
$\phi_3 = 135°$



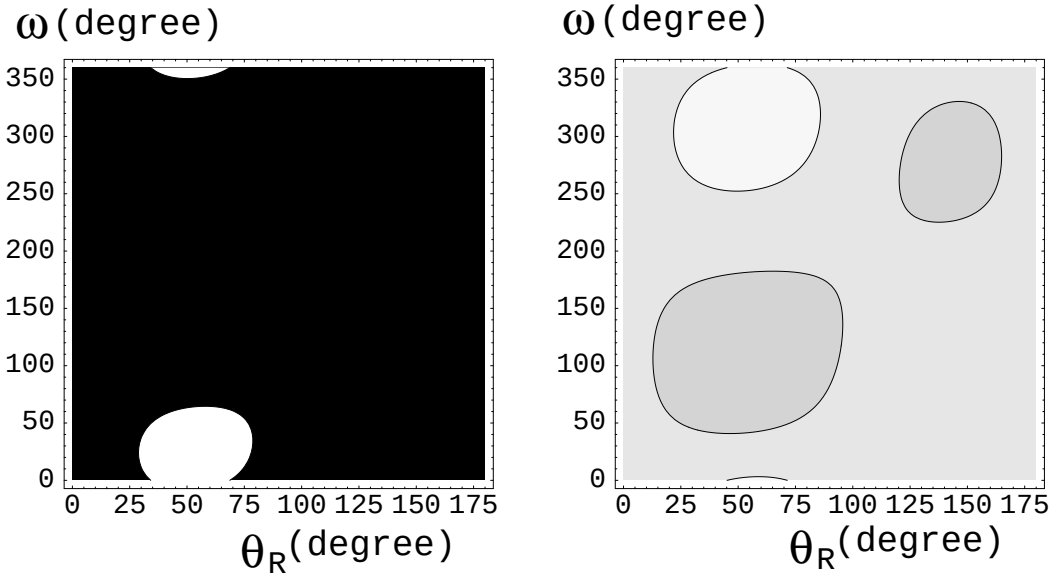


Even with heavy W_R mass of about $5 \sim 10$ TeV, large $Asy(\Psi K_S)$ is possible!

for $\phi_3 = 45°$, $\theta_R = 100°$



$M(W_R) = 10$ TeV, $\phi_3 = 45°$



4. Conclusion

- Large $\sin 2\phi_1$ can be obtained even with relatively heavy W_R ($1 \sim 10$ TeV).

- Similar effects can be expected for ϕ_2 as W_R affects B-$\overline{B}$ mixing.

- No effects on $b \to s$ penguin.

- ϕ_3 from direct CPV in $B^{\pm} \to DK$ can be largely deviated from SM value depending on V^R parameters for $M(W_R) \simeq 1$ TeV.

  $\Updownarrow$

  Deviation of ϕ_3 from $B \to \pi K$ ($V^R_{ub} V^R_{us} = 0$)

Fine measurements of CP angles in various modes are important for new physics check.