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Sensitivity of ϕ_3 @$3ab^{-1}$

SuperKEKB ϕ_3 meeting, June 12-2003

Outline

- Measuring ϕ_3 using $B^- \to D_{CP}K^-$ mode
- Where are we now with $78fb^{-1}$ (ϕ_3 ?)
- Constraining ϕ_3 with $3ab^{-1}$
- Conclusion

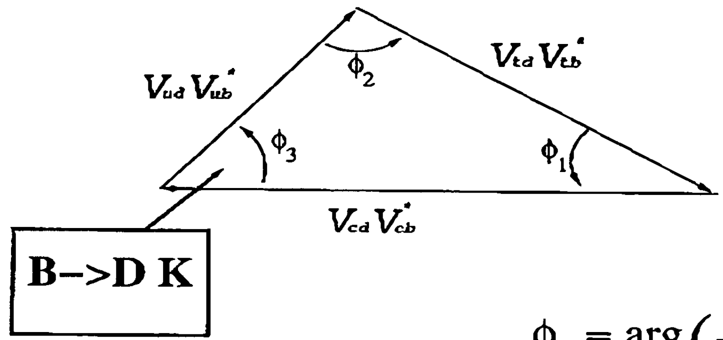
What is ϕ_3?

$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \qquad \phi_3 = \arg(V_{ub}^{*})$$

also known as γ

V -> quark mixing matrix

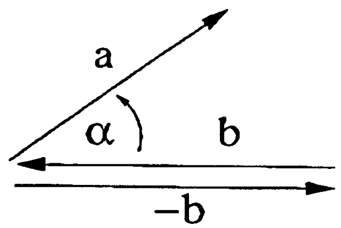
$$V_{ud}V_{ub}^{*} + V_{cd}V_{cb}^{*} + V_{td}V_{tb}^{*} = 0$$



$$\phi_1 = \arg\left(\frac{V_{cd}V_{cb}^{*}}{-V_{td}V_{tb}^{*}}\right)$$

$$\phi_2 = \arg\left(\frac{V_{td}V_{tb}^{*}}{-V_{ud}V_{ub}^{*}}\right)$$

$$\phi_3 = \arg\left(\frac{V_{ud}V_{ub}^{*}}{-V_{cd}V_{cb}^{*}}\right)$$



$$\alpha = \arg\left(\frac{a}{-b}\right)$$

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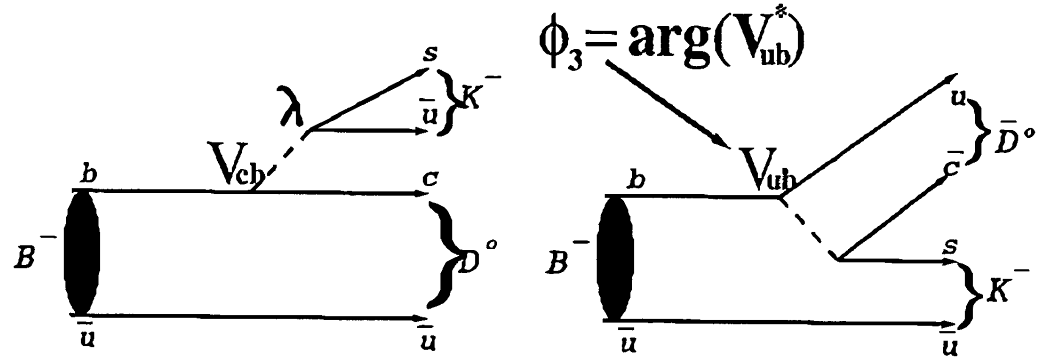
Gronau-London-Wyler(GLW) method

- $B^- \to D_{CP}K^-$ where $D_{1,2} = \frac{1}{\sqrt{2}}(D^0 \pm \bar{D}^0)$

  Neglecting D^0-$\bar{D}^0$ mixing:
- $\sqrt{2}\mathrm{Amp}(B^- \to D_{CP}K^-) = \mathrm{Amp}(B^- \to D^0K^-) + \mathrm{Amp}(B^- \to \bar{D}^0K^-)$
- $\sqrt{2}\mathrm{Amp}(B^+ \to D_{CP}K^+) = \mathrm{Amp}(B^+ \to D^0K^+) + \mathrm{Amp}(B^+ \to \bar{D}^0K^+)$
- Both D^0 and $\bar{D}^0$ decay to common final states
  e.g. $\underbrace{K^+K^-, \pi^+\pi^-}_{CP-even}$ $\underbrace{K_s\pi^0, K_s\phi, K_s\omega, K_s\eta, K_s\eta'}_{CP-odd}$



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$A = \mathrm{Amp}(B^- \to D^0K^-)$ $\quad$ $B = \mathrm{Amp}(B^- \to \bar{D}^0K^-)$

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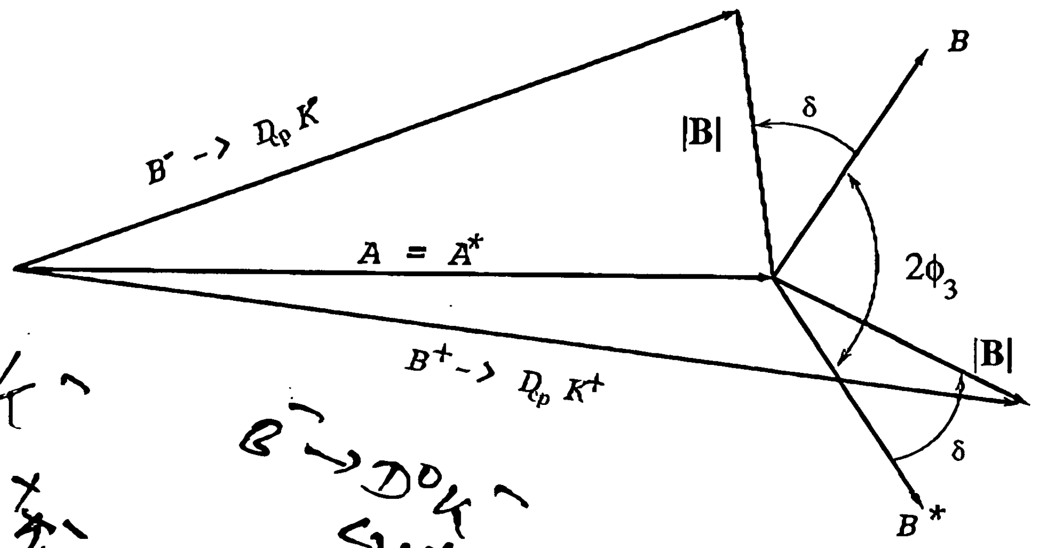
Geometrical Interpretation of GLW method

Convention $A = A^*$

- ✦ $\mathrm{Amp}(B^- \to D_{CP} K^-) = \mathrm{A} + |B| e^{i\phi_3} e^{i\delta}$
- ✦ $\mathrm{Amp}(B^+ \to D_{CP} K^+) = \mathrm{A} + |B| e^{-i\phi_3} e^{i\delta}$



$B^- \to D^0 K^-$ ↳ $K^+\pi^-$

$B^- \to \bar{D}^0 K^-$ ↳ $K^+\pi^-$

Reconstruct the triangles → clean determination of ϕ_3

$\delta \neq 0 \Rightarrow$ Direct CP violation, $\quad r = |\frac{B}{A}| = \frac{Amp(B^- \to \bar{D}^0 K^-)}{Amp(B^- \to D^0 K^-)} \sim 0.1$ $= \text{color} \times \frac{V_{ub}}{\lambda V_{cb}}$

CP asymmetry(a_{cp}) is ~ 10% (can measure ϕ_3 even if $a_{cp} = 0$)

Extension of GLW method

✦ $R_{1,2} \equiv R^{D_{CP}}_{K/\pi} / R^{D_{non-CP}}_{K/\pi} = 1 + r^2 \pm 2r\cos(\delta)\cos(\phi_3)$

where $R^{D_{CP}}_{K/\pi} = \frac{B(B^- \to D_{1,2}K^-)+c.c}{B(B^- \to D_{1,2}\pi^-)+c.c}$

✦ $A_{1,2} \equiv \frac{B(B^- \to D_{1,2}K^-) - B(B^+ \to D_{1,2}K^+)}{B(B^- \to D_{1,2}K^-) + B(B^+ \to D_{1,2}K^+)} = \frac{\pm 2r\sin(\delta)\sin(\phi_3)}{1+r^2 \pm 2r\cos(\delta)\cos(\phi_3)}$

$$A_1 R_1 = -A_2 R_2$$

$\rightarrow$ 3 independent variables

$\Rightarrow$determine r, δ, ϕ_3

Useful inequality: $\boxed{\sin^2\phi_3 \leq R_{1,2}}$ $R_{1,2} < 1$ to constrain ϕ_3

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Extension to GLW method

Results from $78 fb^{-1}$ data collected with BELLE detector:

$$R_1 = 1.21 \pm 0.25(\text{stat}) \pm 0.14(\text{sys})$$
$$R_2 = 1.41 \pm 0.24(\text{stat}) \pm 0.15(\text{sys})$$

Mode	A_{cp}	90% C.L	#events
$B^\pm \to D_1 K^\pm$	$0.06 \pm 0.19 \pm 0.04$	$-0.26 < A_{cp} < 0.38$	47.3 ± 8.9
$B^\pm \to D_2 K^\pm$	$-0.19 \pm 0.17 \pm 0.05$	$-0.47 < A_{cp} < 0.11$	52.4 ± 9.0

Number of events with $3ab^{-1}$ $\begin{cases} \text{2000 events from } B^\pm \to D_1 K^\pm \text{ mode} \\ \text{2000 events from } B^\pm \to D_2 K^\pm \text{ mode} \end{cases}$

Data	$\delta R_{1,2}$
$80 fb^{-1}$	~ 0.30
$3ab^{-1}$	~ 0.05

What is ϕ_3? @78 fb^{-1}

$R_1 = 1.21 \pm 0.29$ $R_2 = 1.41 \pm 0.31$

$$\boxed{r^2 = \frac{R_1 + R_2}{2} - 1 \quad , \quad R_1 - R_2 = 4\, r \cos\delta \cos\phi_3}$$

$\Rightarrow$ $r^2 = 0.31 \pm 0.21$ -1.

just 1.5σ away from physical boundary

Statistical error is still large to constraint ϕ_3.

Now What happens @ $3ab^{-1}$ data ???

$R_1 = 1.21 \pm 0.05$ $R_2 = 1.41 \pm 0.05$

$r^2 = 0.31 \pm 0.035$

$\Rightarrow r = 0.57$, very unlikely

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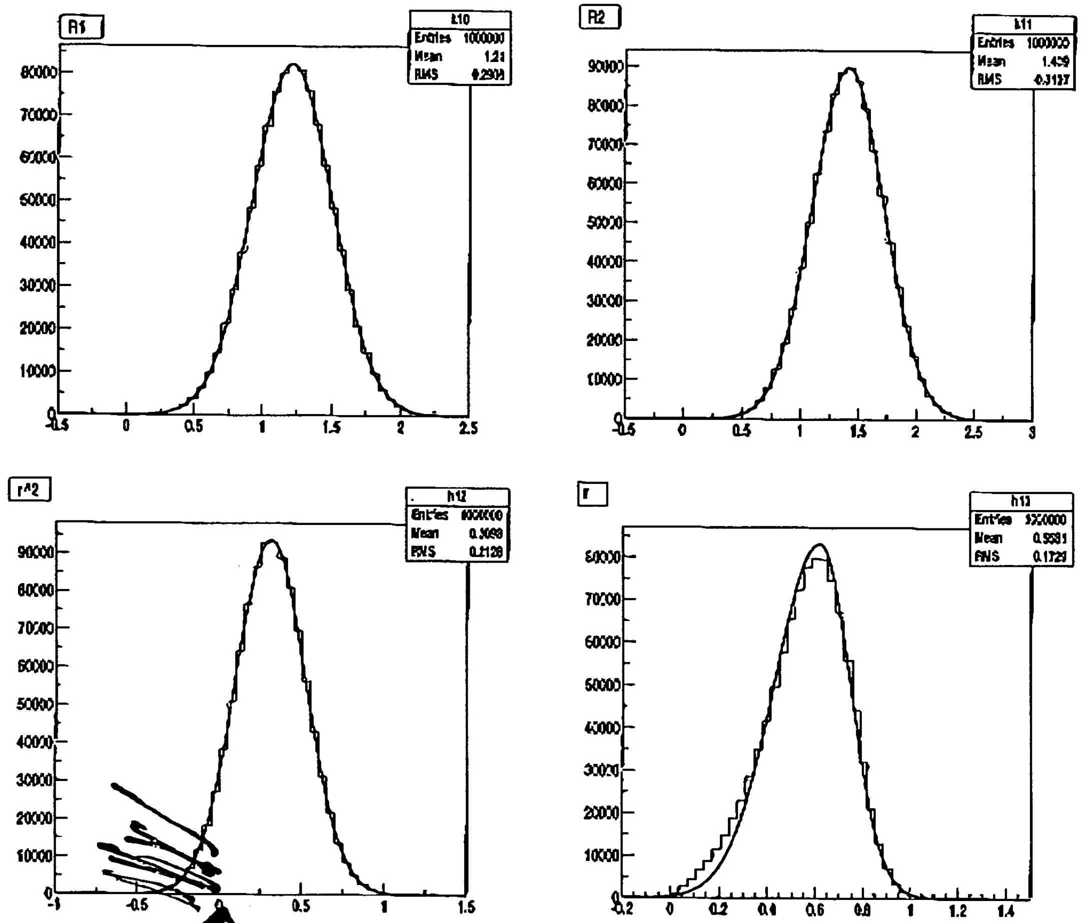
1. *What is ϕ_3? @78fb^{-1}*



$r^2 \rightarrow$

$r \rightarrow$

below boundary

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What is ϕ_3? @$3ab^{-1}$

Theoretical prediction is $r = 0.1 \Rightarrow r^2 = 0.01$

Keeping stat error as it is we get

$r^2 = 0.01 \pm 0.035$

$\Downarrow$

you can not measure 'r' with any accuracy.
??

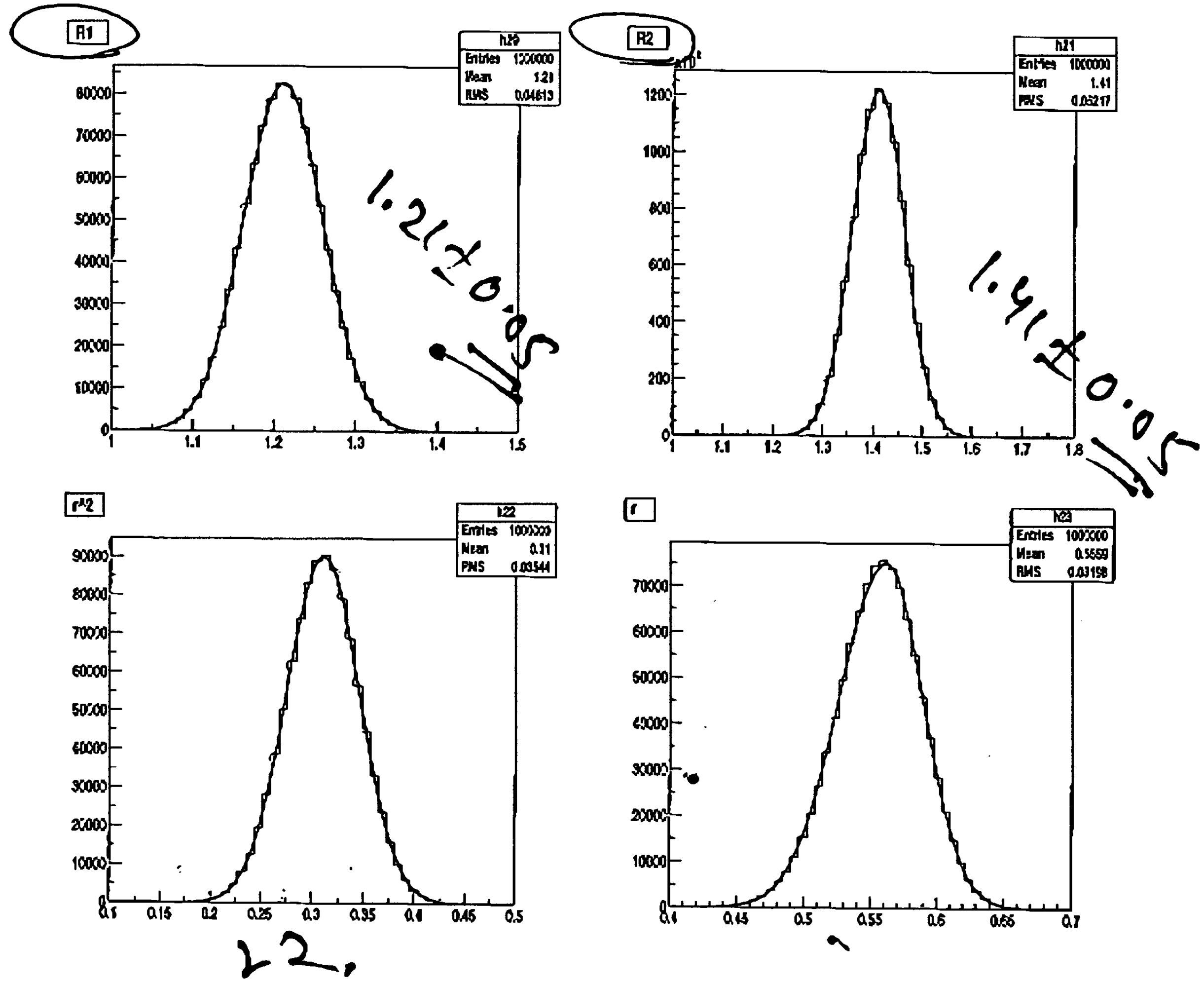
Instead you can measure.

$$\underline{R_1} - \underline{R_2} = 4\boxed{r \cos(\delta) \cos\phi_3}$$

$$-A_2R_2 = \underline{A_1R_1} = 2\boxed{r \sin(\delta) \sin(\phi_3)}$$

Can not separate 'r'

What is ϕ_3? @$3ab^{-1}$



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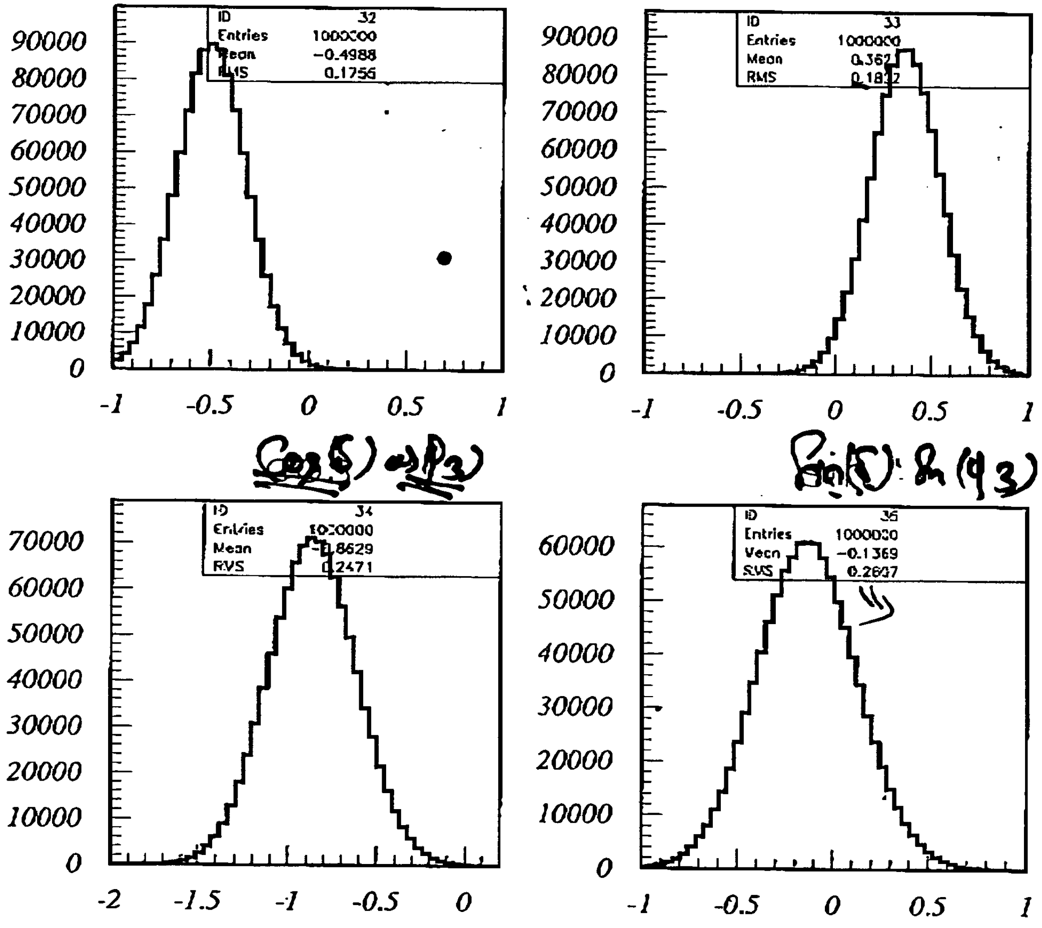
Putting $r = 0.1$ $R_1 = 1.21 \pm 0.05$ $R_2 = 1.41 \pm 0.05$

$A_1 = 0.06 \pm 0.03$



cos (δ-φ3)

sin (δ+φ3)   (sin δ + φ3)