SuperB ϕ_3 Sensitivities

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- $D^{(*)+}\pi^-$ Full Reconstruction
  (Tapas Sarangi, Fumiaki Handa)
- $D^{*+}\pi^-$ Partial Reconstruction
  (Tim Gershon)
- $B^\pm \to DK^\pm$, ADS Method
  (Manabu Saigo)
- $B^\pm \to DK^\pm$, $D \to K_S\pi^+\pi^-$ Dalitz
  (Anton Poloektov)

2.Full reconstruction

$B^0 \to D^{*-}\pi^+$

$D^{*-} \to \bar{D}^0\pi^-$

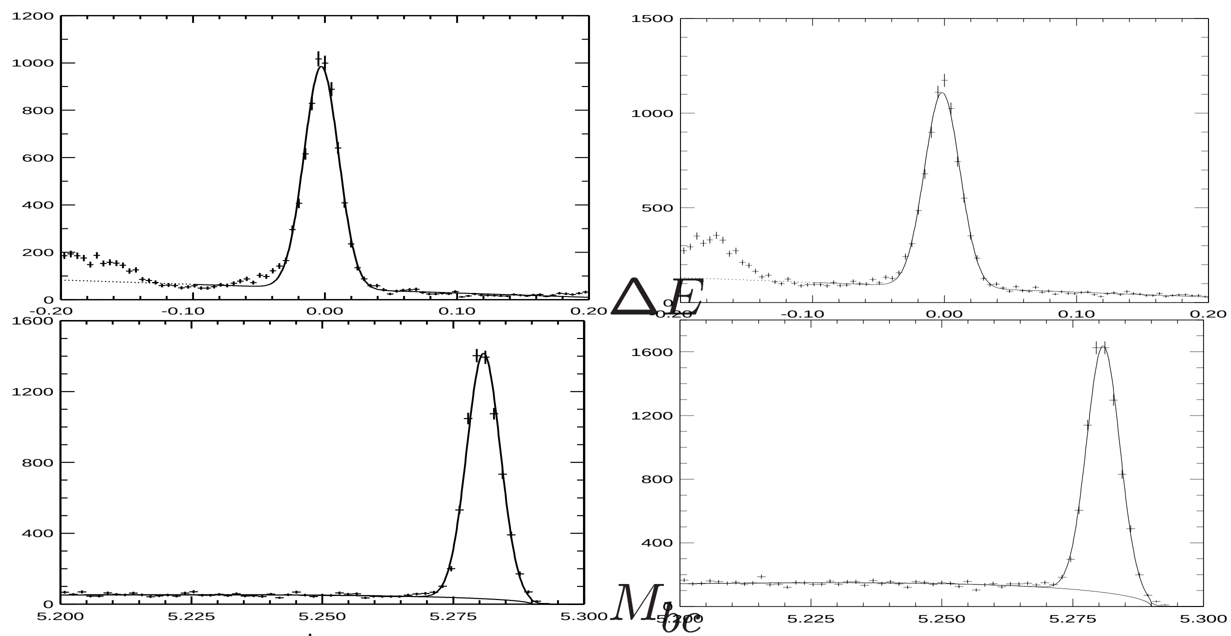
$\bar{D}^0 \to K^+\pi^-$

$K^+\pi^-\pi^0$

$K^+\pi^+\pi^-\pi^-$

$B^0 \to D^-\pi^+$

$D^- \to K^+\pi^-\pi^-$



$D^*\pi$ mode $\qquad$ $D\pi$ mode

Used data $= 125 fb^{-1}$

Signal Yield

$D^*\pi = 6803$

$D\pi = 7487$

Signal Purity

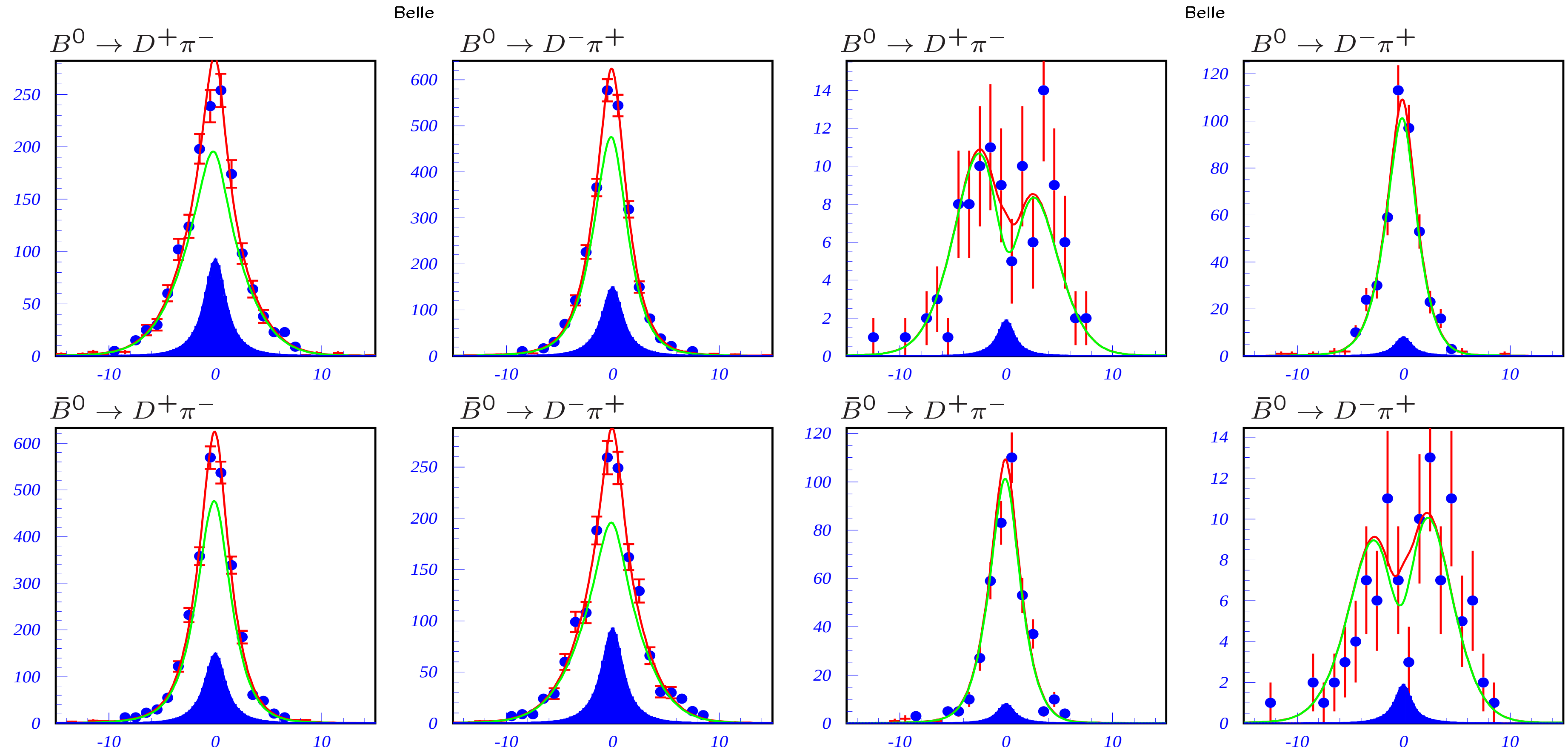
$D^*\pi = 95\%$

$D\pi = 88\%$

Flavor tag

MDLH method is used

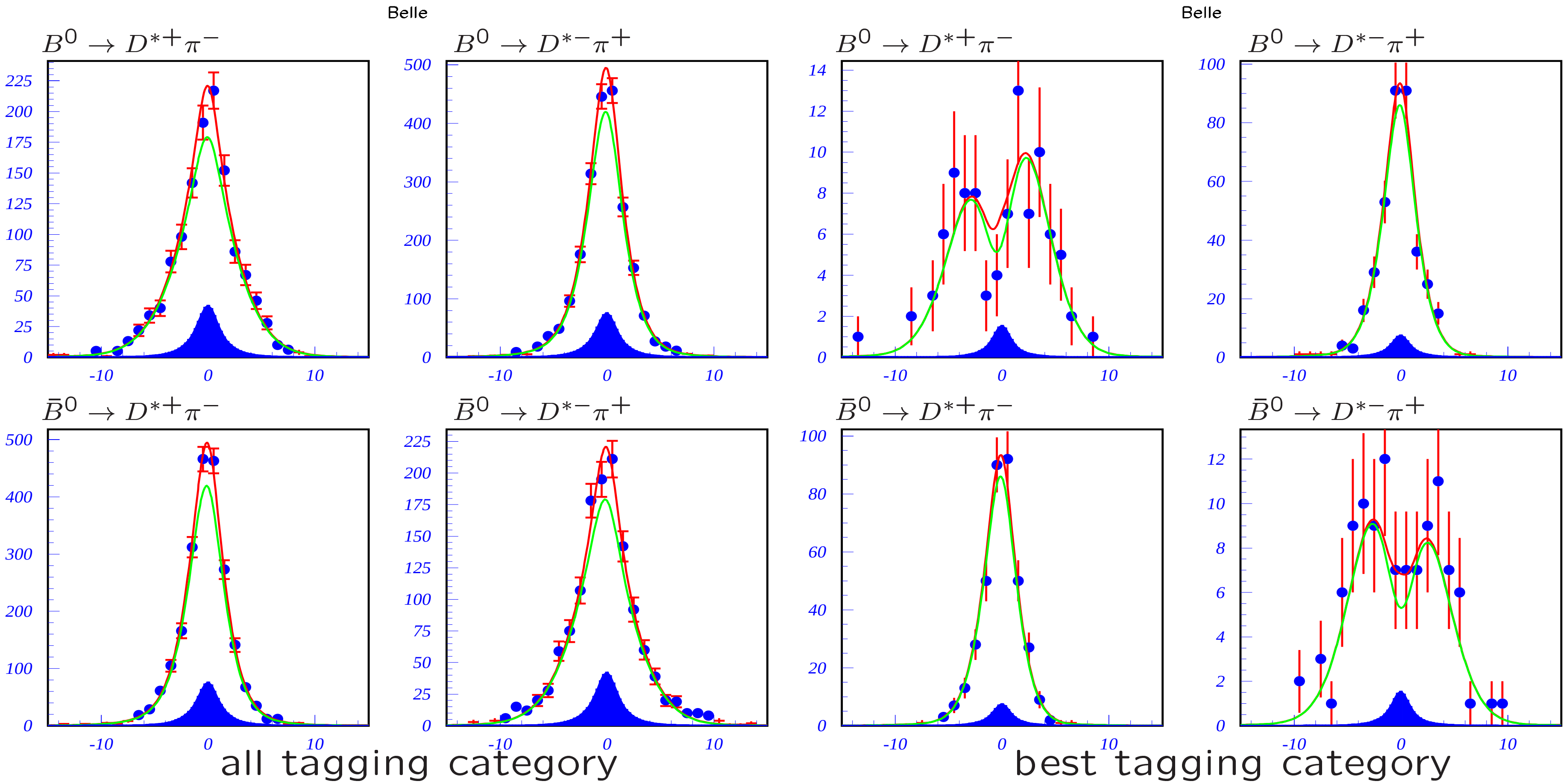
CP fit for $B \to D\pi$



all tagging category

best tagging category

CP fit for $B \to D^*\pi$



Fitting result with $125 fb^{-1}$ data

$B \to D\pi$ mode

$$2R_{D\pi}\sin(2\phi_1 + \phi_3 + \delta_{D\pi}) = 0.0xx \pm 0.057$$

$$2R_{D\pi}\sin(2\phi_1 + \phi_3 - \delta_{D\pi}) = 0.0xx \pm 0.055$$

$B \to D^*\pi$ mode

$$2R_{D^*\pi}\sin(2\phi_1 + \phi_3 + \delta_{D^*\pi}) = -0.0xx \pm 0.062$$

$$2R_{D^*\pi}\sin(2\phi_1 + \phi_3 - \delta_{D^*\pi}) = -0.0xx \pm 0.059$$

Values are preliminally

Values expected to be within $\pm 2R$. Statistical errors are still too large.
Expected error for $2R\sin(2\phi_1 + \phi_3 \pm \delta)$ in $\mathbf{3ab^{-1}}$ will be

$$0.06 \times \sqrt{\frac{0.125}{3.0}} \simeq 0.012$$

3.Partial reconstruction

$B^0 \to D^{*-}\pi_f^+$

$D^{*-} \to \bar{D}^0\pi_s^-$

Used data = $140 fb^{-1}$

Reconstruction method

- Identify signal using fast pion(π_f) and slow pion(π_s) from D^*
- Tag using high momentum lepton(l) $\Leftrightarrow$ continuum rejection
- Measure Δz as $z_{\pi_f} - z_l$

Valiables

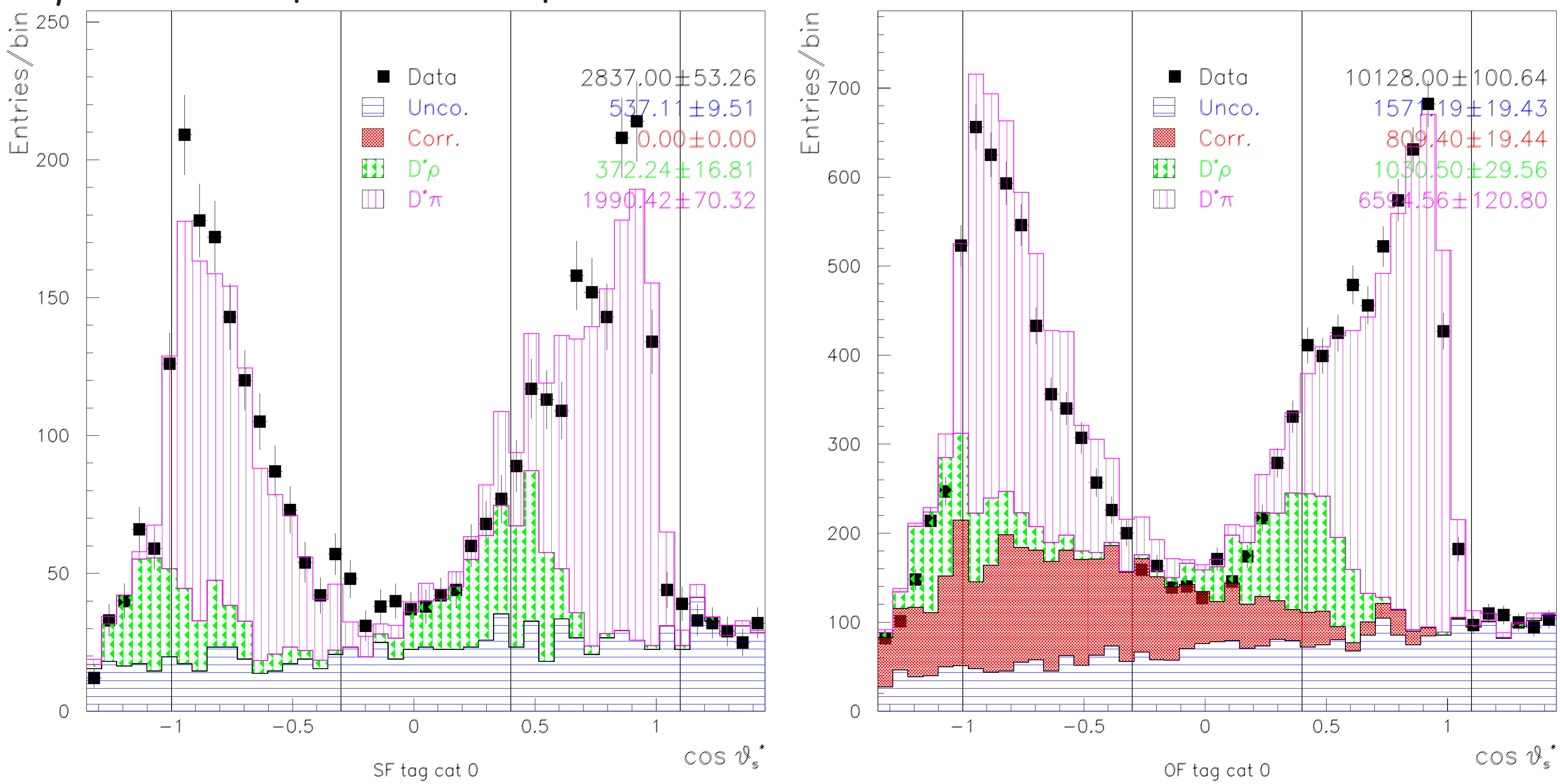
- p_{π_f} : Momentum of π_f
- $\cos(\delta_{fs})$: Angle between π_f and π_s
- $\cos(\theta_s^*)$: Helicity angle of π_s in D^* frame

Backgrounds

Uncorrelated : π_f and π_s come from unrelated source.

Correlated : π_f and π_s originated from the same B

$D^*\rho$: same quark level process as $D^*\pi$



CP Fit

$$2R_{D^*\pi}\sin(2\phi_1+\phi_3+\delta_{D^*\pi}) = -0.0xx \pm 0.021$$

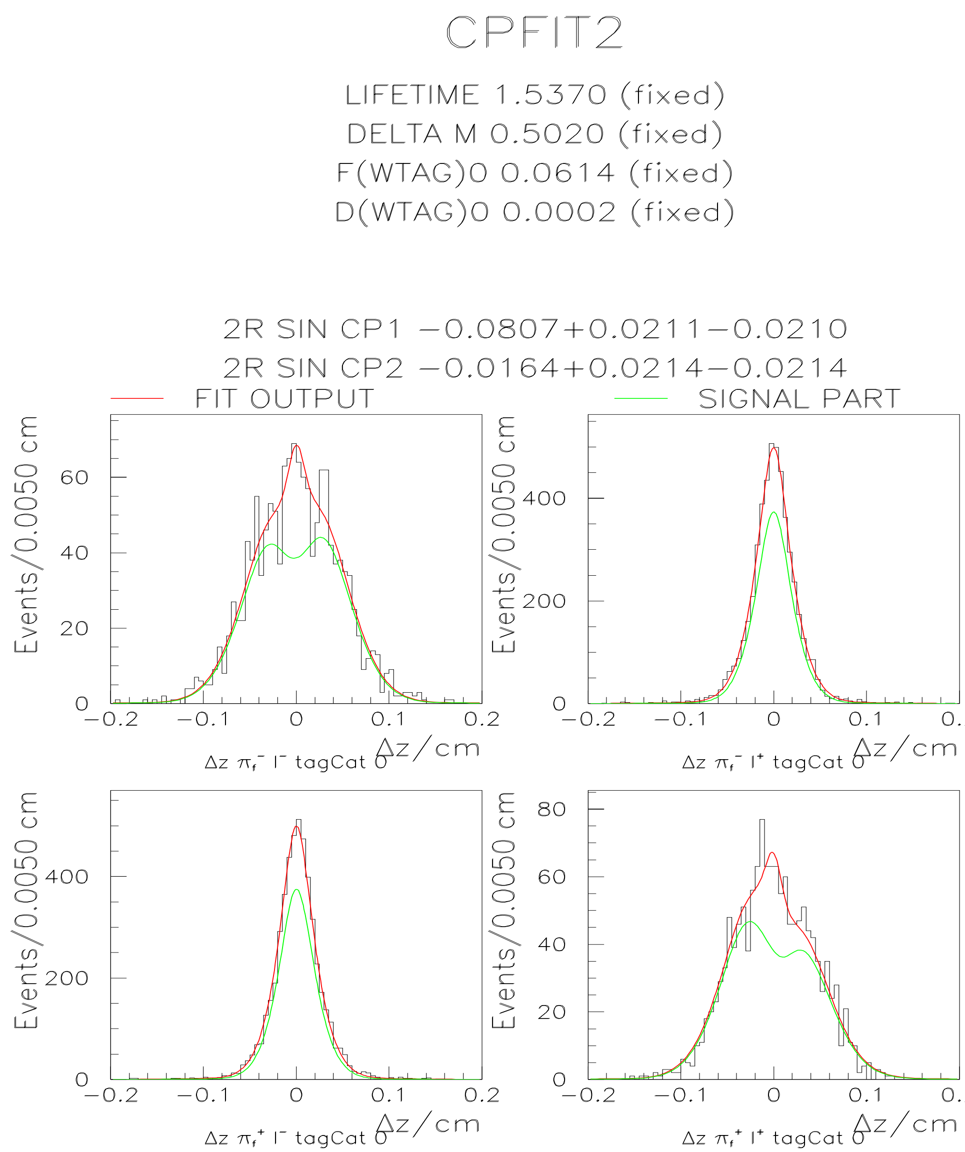
$$2R_{D^*\pi}\sin(2\phi_1+\phi_3-\delta_{D^*\pi}) = -0.0xx \pm 0.021$$

Values are preliminally

There is large systematics due to Δz bias.

Δz bias may change fitting result.

Then fit with floating z offset.



CP Fit with floated offset

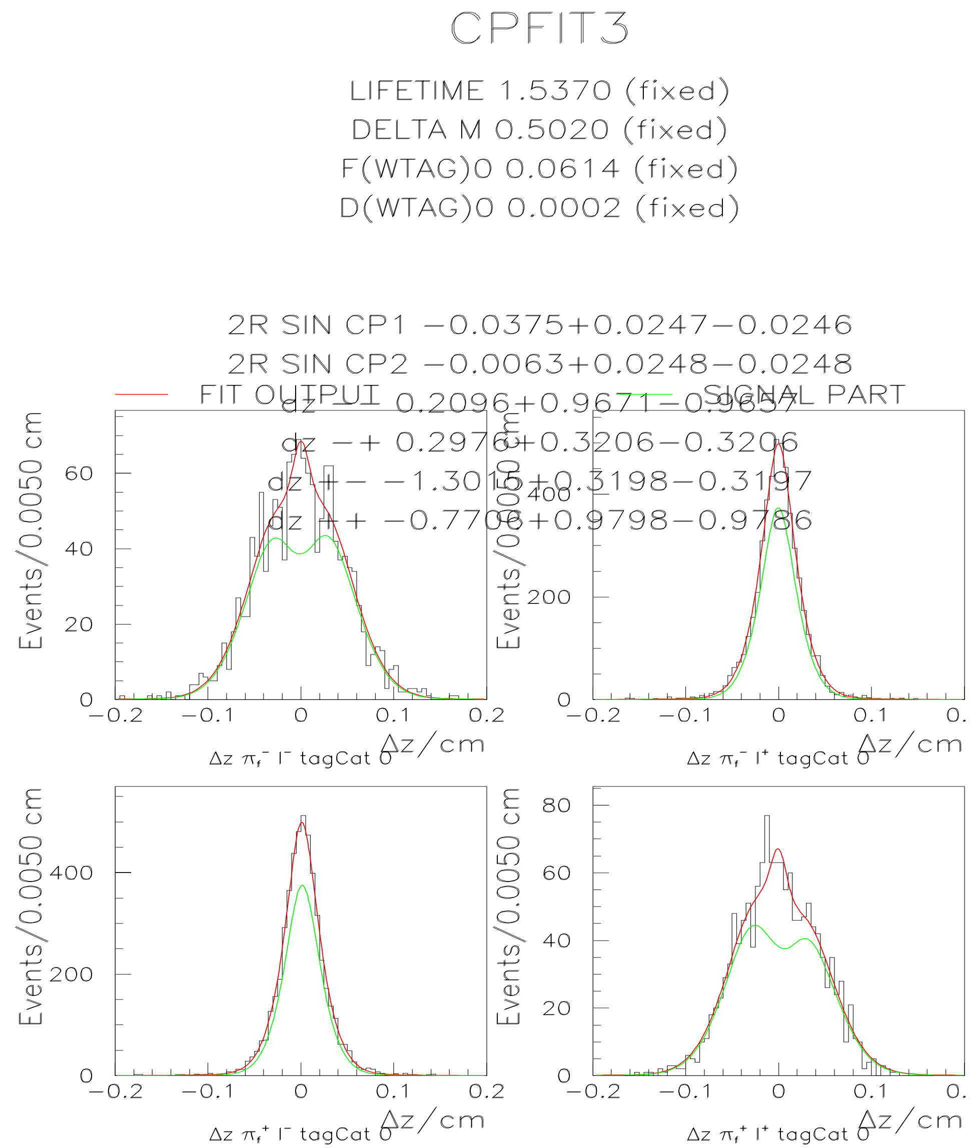
$$2R_{D^*\pi}\sin(2\phi_1+\phi_3+\delta_{D^*\pi}) = 0.0xx \pm 0.025$$

$$2R_{D^*\pi}\sin(2\phi_1+\phi_3-\delta_{D^*\pi}) = 0.0xx \pm 0.025$$

$$\Delta z_{--} = 2.1 \pm 9.7\mu m$$
$$\Delta z_{-+} = 3.0 \pm 3.2\mu m$$
$$\Delta z_{+-} = -13.0 \pm 3.2\mu m$$
$$\Delta z_{++} = -7.7 \pm 9.8\mu m$$

Values are preliminally

Floating offset inclease the error $\simeq 20\%$. But floaing offset seems to reduce systematics.(under study)



extrapolate to 3 ab^{-1}

Majour sources of error are Δz bias and backgrounds.
Both of them seem to implove with higher statistics.

Expected error for $2R\sin(2\phi_1 + \phi_3 \pm \delta)$ in $\mathbf{3ab^{-1}}$ will be

$$0.025 \times \sqrt{\frac{0.140}{3.0}} \simeq 0.0045$$

R : theoritical input(separate issue)

DK, ADS Method

$Br(B^- \rightarrow D^0(f_i)K^{*-}) = d\,(\phi_3, \delta_i, b_B)$

$Br(B^+ \rightarrow D^0(f_i)K^{*+}) = d\,(\phi_3, \delta_i, b_B)$

Using 2 equation, we can eliminate δ_i.

We can draw 1 line as function of (ϕ_3, b_B)

Multiple modes : Crossing point - determination of ϕ_3

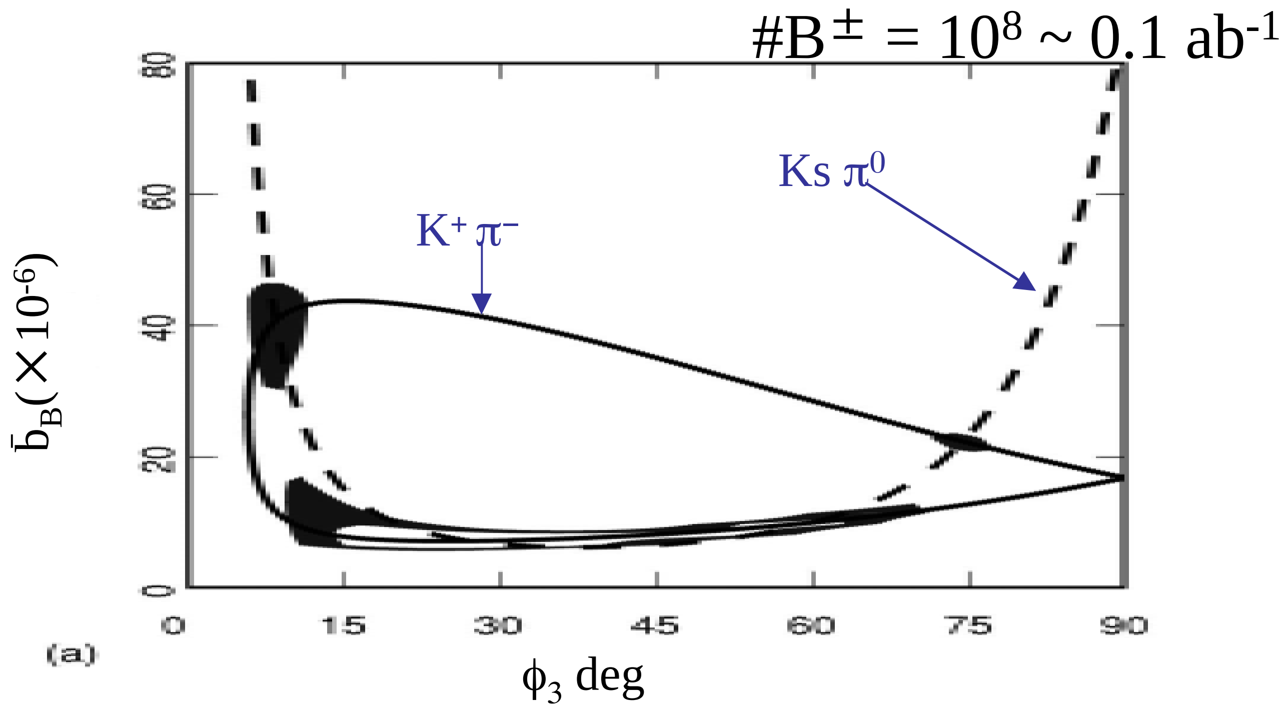
B → $D^0(f_i)K^*$ decay channels

mode (f_i)	#events@$10^8 B^{\pm}$	δ_i (assumption)
$K^+\pi^-$	83	10°
$K_s\pi^0$	791	20°
$K^+\rho^-$	224	30°
$K^+a_1^-$	791	40°
$K_s\rho^0$	362	200°
$K^{*+}\pi^-$	65	50°

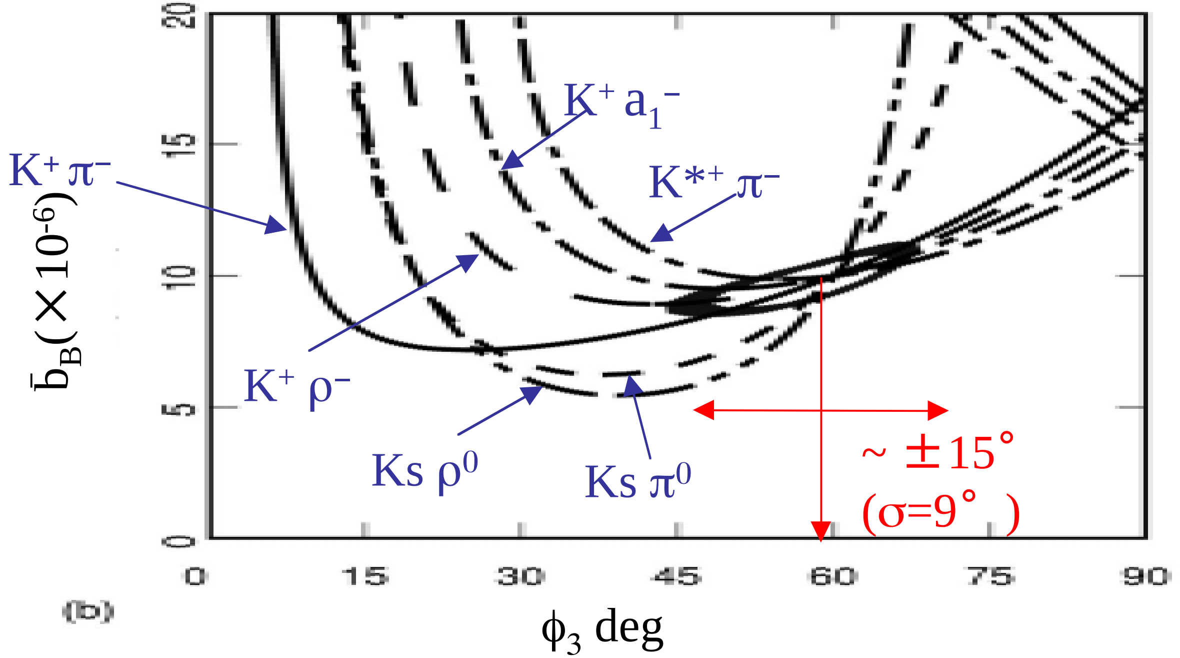
Assumptions

- $\#B^{\pm} = 10^8 \sim 0.1\ ab^{-1}$
- $eff(K^*) = 100\%$, $eff(D^0 \rightarrow f_i) = 100\%$
- no background
- $\phi_3 = 60°$

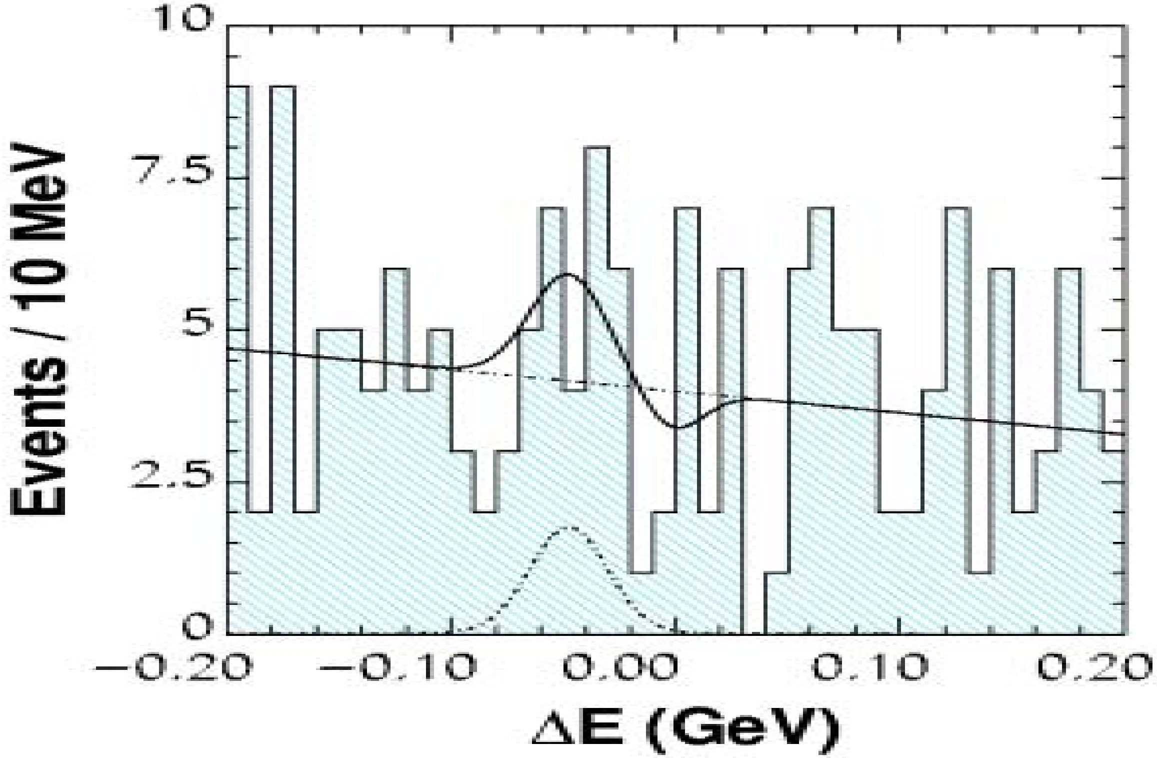
2 modes



6 modes



ΔE distribution of $B^{\pm} \rightarrow D(K\pi)K^{\pm}$ (suppressed)



78 fb^{-1}

- efficiency 27%, S : N ~ 1 : 7. Using expected signal and measured bkg

D^0 efficiency corrections

Estimation of efficiency relative to $D^0 \to K^+\pi^-$

- Reference mode $B^- \to D(K^+\pi^-)K^-$ (27%)
- $\varepsilon_{trk} = 2/3$, $\varepsilon_{\pi 0} = 1/2$
- $K^{*+} \to K^0\pi^+, K^+\pi^0$

mode (f_i)	#trk	$\#\pi^0$	Br'	$\epsilon_i = (\frac{2}{3})^{\#trk}(\frac{1}{2})^{\#\pi^0} Br'/(\frac{2}{3})^2$	N_i	$N_i \times \epsilon_i$
$K^+\pi^-$	2	0	1	1	83	83
$K_s\pi^0$	2	1	0.68	$0.68 \cdot \frac{1}{2}$	791	269
$K^+\rho^-$	2	1	1	$\frac{1}{2}$	224	112
$K^+a_1^-$	4	0	$\frac{1}{2}$	$\frac{2}{9}$	146	32
$K_s\rho^0$	4	0	0.68	$0.68 \cdot \frac{4}{9}$	362	109
$K^{*+}(K^+\pi^0)\pi^-$	2	1	1	$\frac{1}{2}$	$65 \cdot \frac{1}{2}$	11
$K^{*+}(\bar{K}^0\pi^+)\pi^-$	4	0	$0.68 \cdot \frac{1}{2}$	$0.68 \cdot \frac{2}{9}$	$65 \cdot \frac{2}{3}$	7
sum					1671	615

Efficiency relative to $K\pi$ mode

$$\varepsilon_D = \frac{\text{sum}(N_i \times \varepsilon_i)}{\text{sum}(N_i)} = \frac{165}{1671} = 0.37$$

Sensitivity with $B \to D(f_i)K^*$

- efficiency of $B \to D^0(K^+\pi^-)K^*$
  - K^* efficiency correction

$$\varepsilon_{K^*} / \varepsilon_K \sim 1/4$$

- The needed luminosity

$$1/\varepsilon_{det} \times 1/\varepsilon_D \times (S+N)/S \times 0.1ab^{-1} = 31\ ab^{-1}$$

(1/0.068) (1/0.37) (8)

We need 31 ab^{-1} for measurement of ϕ_3 at $\pm 9°$

(300 times more than theoretical estimations)

Sensitivity with $B \rightarrow D(f_i)K$

- $$\frac{Br(B \rightarrow D(K^+\pi^-)K^*)}{Br(B \rightarrow D(K^+\pi^-)K)} = 3.2$$
- $\varepsilon_{det}(B \rightarrow D^0(K^+\pi^-)K) = 0.27$

- The needed luminosity

$$1/\varepsilon_{det} \times 1/\varepsilon_D \times (S+N)/S \times 3.2 \times 0.1ab^{-1} = 26\ ab^{-1}$$

(1/0.27) (1/0.37) (8)

- for $B \rightarrow D(f_i)K$

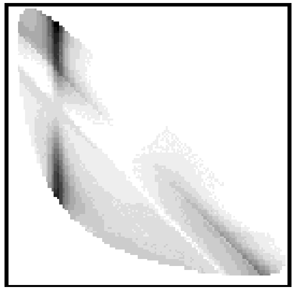
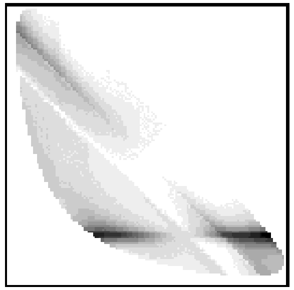
We need 26 ab^{-1} for measurement of ϕ_3 at $\pm 9°$
(260 times more than theoretical estimations)

$B^\pm \to DK^\pm, D \to K_S\pi^+\pi^-$ Dalitz Analysis

$$B^+ \to \begin{cases} D^0K^+ \ (Amp = a^{-i\theta}) \\ \bar{D}^0K^+ \quad (Amp = 1) \end{cases} \to (K_S\pi^+\pi^-)K^+$$

$K_S\pi^+\pi^-$ Dalitz Distribution :

$$|M|^2 = |A(m_{K_S\pi^+}, m_{K_S\pi^-}) + ae^{-i\theta}A(m_{K_S\pi^-}, m_{K_S\pi^+})|^2$$

$= \Bigg|$  $+ ae^{-i\theta}$  $\Bigg|^2$

$$a = 0.1 \sim 0.2\,,$$

$$(B^+) : \theta = \delta_{\text{strong}} + \phi_3$$

$$(B^-) : \theta = \delta_{\text{strong}} - \phi_3$$

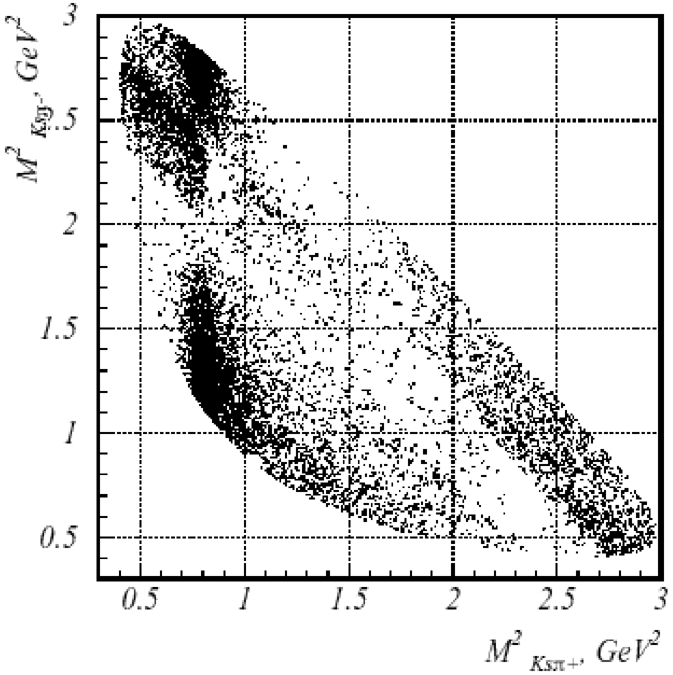
$D^0 \to K_S\pi^+\pi^-$ Dalitz Amplitude

Assume $A(m_{K_s\pi^-}, m_{K_s\pi^+})$ is a sum of 2-body decays

$$D^0 \longrightarrow f_i\,, \qquad f_i = b_i(\text{broad}) + n_i(\text{narrow})$$

$$A(m_{K_s\pi^-}, m_{K_s\pi^+}) = \sum_i a_i e^{i\phi_i} BW(m_{b_i})$$

MC

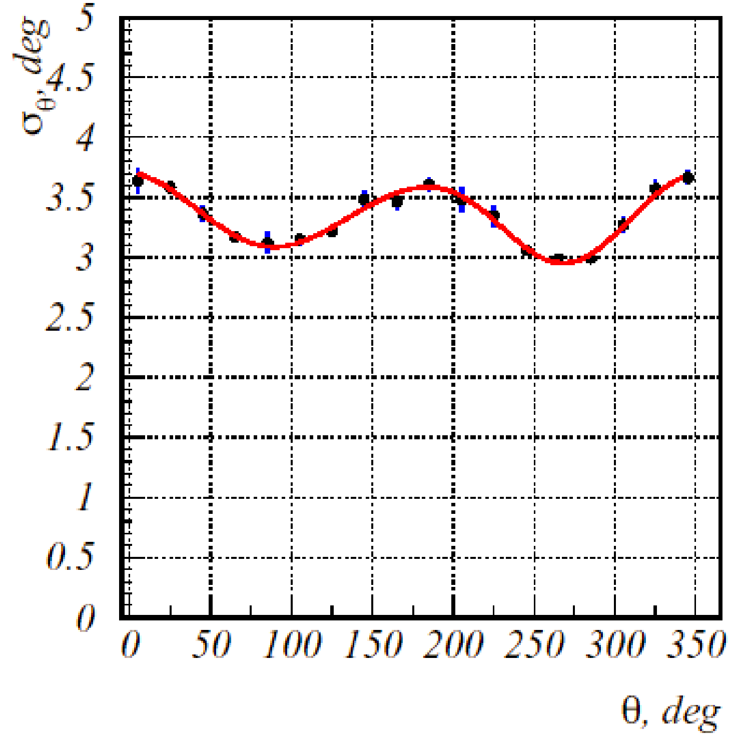


(CLEO 2002)

D^0 mode	Br (%)	phase (deg)
$K^{*-}\pi^+$	65.7	150
$K_S\rho^0$	26.4	0
$K^{*+}\pi^-$	0.34	321
$K_S\omega$	0.72	114
$K_S f_0(980)$	4.3	188
$K_S f_0(1370)$	9.9	85
$K_0^{*-}(1430)\pi^+$	7.3	3
non-res	3	7.3

MC Sensitivity

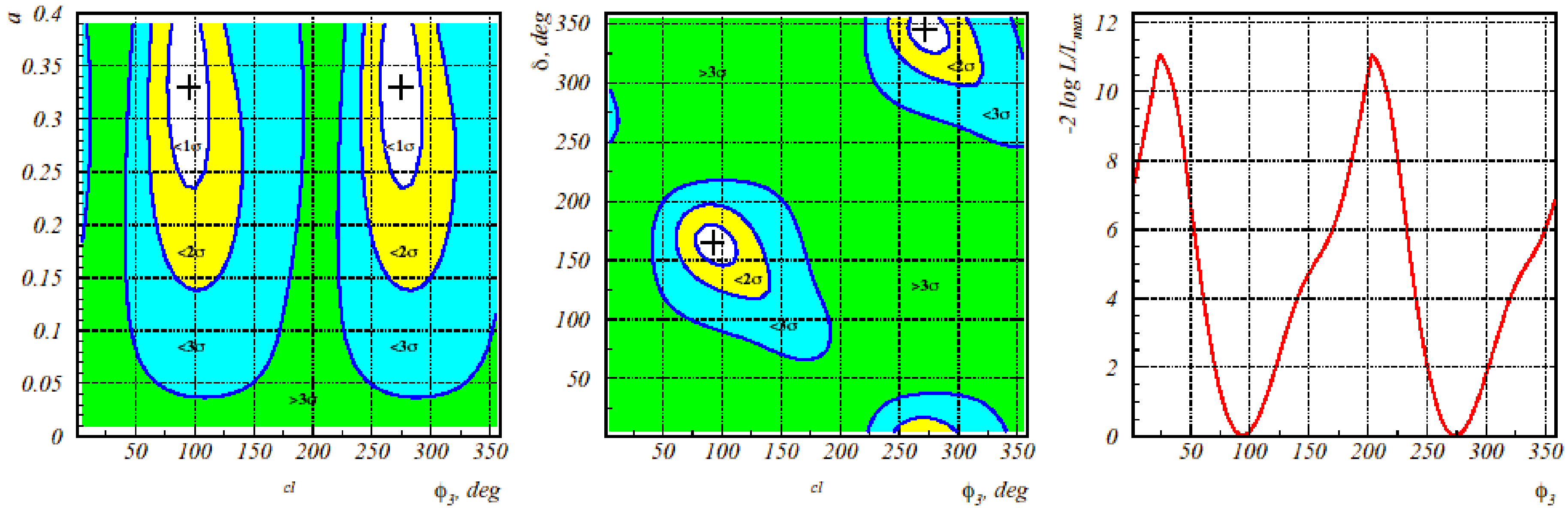
$3.0^\circ < \sigma_{\phi_3} < 3.7^\circ$ for 10^4 detected $B^\pm$.



$\sigma_{\phi_3} \sim \sigma_\theta$.

Does not strongly depend on θ or ϕ_3.

Belle Data (140 fb^{-1})



- D^0 decay model systematics in $\phi_3 \sim 10^\circ$ (Expect to improve with statistics)
- $\phi_3 = 95^{+25}_{-20} \pm 13 \pm 10^\circ$
- $\delta = 162^{+20}_{-25} \pm 12 \pm 24^\circ$
- $a = 0.33 \pm 0.10 \pm 0.03 \pm 0.03$

Summary

mode	quantity	σ (3 ab^{-1})	σ (30 ab^{-1})
$D\pi$ full	$2R\sin(2\phi_1+\phi_3)$	0.012	0.004
$D^*\pi$ full	$2R^*\sin(2\phi_1+\phi_3)$	0.012	0.004
$D^*\pi$ partial	$2R^*\sin(2\phi_1+\phi_3)$	0.0045	0.0015
$DK^{(*)}$, ADS	ϕ_3	18°	6°
$DK, K_S\pi\pi$ Dalitz	ϕ_3	6°	2°

- $R^{(*)}$ need to be input externally.
  (systematic error?)
- IF $R^{(*)}$ is known, $\sigma_{2R\sin} = 0.012$ is $\sigma_{\phi_3} \sim 25^\circ$.
- Dalitz analysis may hit model syst. at 30 ab^{-1}.

Other modes :

- $B^\pm \to DK^\pm$, $D \to K^*K$ (Nick Kent)
- $B^0 \to D^0 K_S/K^{*0}$