ϕ_3 sensitivity with Dalitz analysis of $B \to D^0 K$ decay

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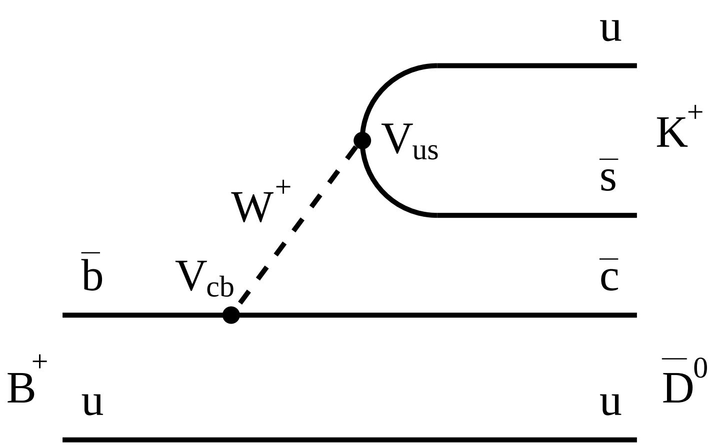
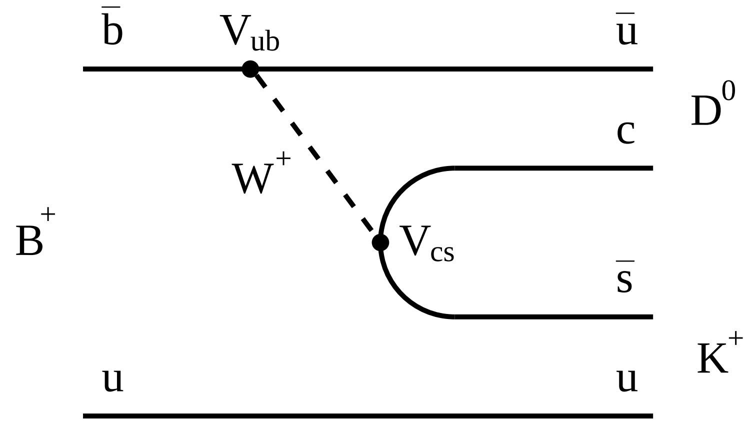
Outline:

- Description of the method
- MC study
  - Statictical accuracy
  - Model systematics

$B^+ \to D^0(\bar{D}^0)K^+$ decay



$M_1 \sim V_{cb}V^*_{us} \sim A\lambda^3$



$M_2 \sim V_{ub}V^*_{cs} \sim A\lambda^3(\rho + i\eta) \sim e^{i\phi_3}$

If D^0 and $\bar{D}^0$ decay into the same final states
$B^+ \to \bar{D}^0 K$ and $B^+ \to D^0 K$ interfere.
Mixed state is produced: $|\tilde{\bar{D}}^0 >= |\bar{D}^0 > + ae^{i\theta}|D^0 >$

$B^+ \to D^0(\bar{D}^0)K^+$ decay

$|\tilde{D}^0 >= |\bar{D}^0 > +ae^{i\theta}|D^0 >$

$a = \frac{|V_{ub}V_{cs}^*|}{|V_{cb}V_{us}^*|} \cdot \frac{|a_2|}{|a_1|} = 0.09/0.22 \cdot 0.35 \simeq \frac{1}{8}$

$\theta = \delta + \phi_3$

Color suppression factor $a_2/a_1 = 0.35$ is extracted from $B^0 \to D^0 K^0$ and $B^- \to D^0 K^-$ branching fractions.

Use 3 body decay of D^0, analyze D^0 Dalitz plot.

References:

http://belle.kek.jp/secured/dcpvrare/meetings/binp/020926/bondar.pdf
A. Giri, Yu. Grossman, A. Soffer, J. Zupan, hep-ph/0303187.

Dalitz plot analysis

Use 3-body final state, identical for D^0 and $\bar{D}^0$: $K_s \pi^+ \pi^-$.

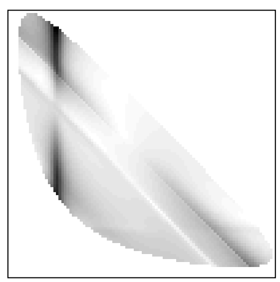
3-body decay is characterized by 2 variables: $m^2_{K_s\pi^+}$ and $m^2_{K_s\pi^-}$.

Dalitz plot density

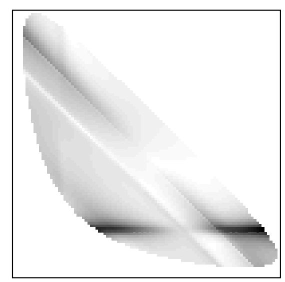
$$d\sigma(m^2_{K_s\pi^+}, m^2_{K_s\pi^-}) \sim |M|^2 dm^2_{K_s\pi^+} dm^2_{K_s\pi^-}$$

$$p(m^2_{K_s\pi^+}, m^2_{K_s\pi^-}) = |f(m^2_{K_s\pi^+}, m^2_{K_s\pi^-}) + ae^{-i\theta} f(m^2_{K_s\pi^-}, m^2_{K_s\pi^+})|^2$$

$$= \Bigg|$$



$$+ \, ae^{-i\theta}$$



$$\Bigg|^2$$

Extracting ϕ_3

From $B^+ \to \tilde{D}^0 K^+$ only total phase θ is extracted.

$$\theta_+ = \delta + \phi_3$$

For $B^- \to \tilde{D}^0 K^-$:

$$M_2 \sim V_{ub}^* V_{cs} \sim A\lambda^3(\rho - i\theta) \sim e^{-i\phi_3}$$

Strong phase δ is not changed.

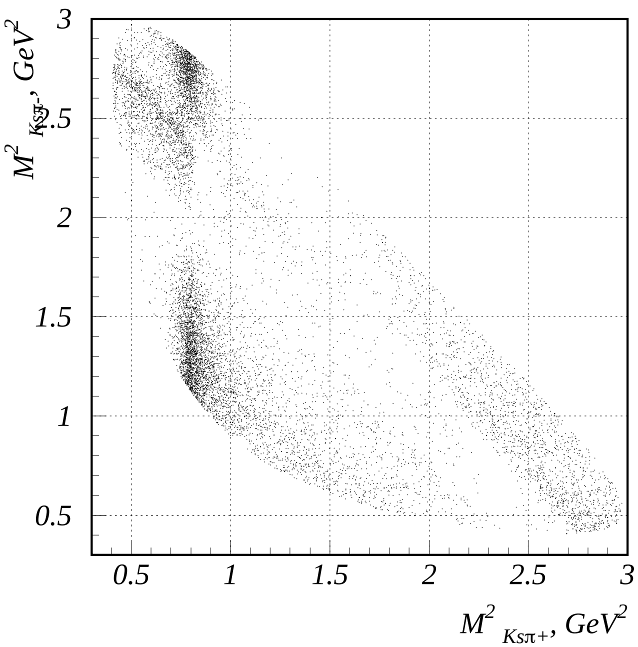
$$\theta_- = \delta - \phi_3$$

Can extract a, ϕ_3 and δ with simultaneous fit of B^+ and B^- data.

D^0 decay model

D^0 amplitude is represented by a sum of 2-body decay amplitudes:

$$f = a_{K^*} e^{i\phi_{K^{*-}}} [F_D F_{K^*} M^J BW(m^2_{K_s\pi^-})] + a_\rho e^{i\phi_\rho} [F_D F_\rho M^J BW(m^2_{\pi^+\pi^-})] + \ldots$$

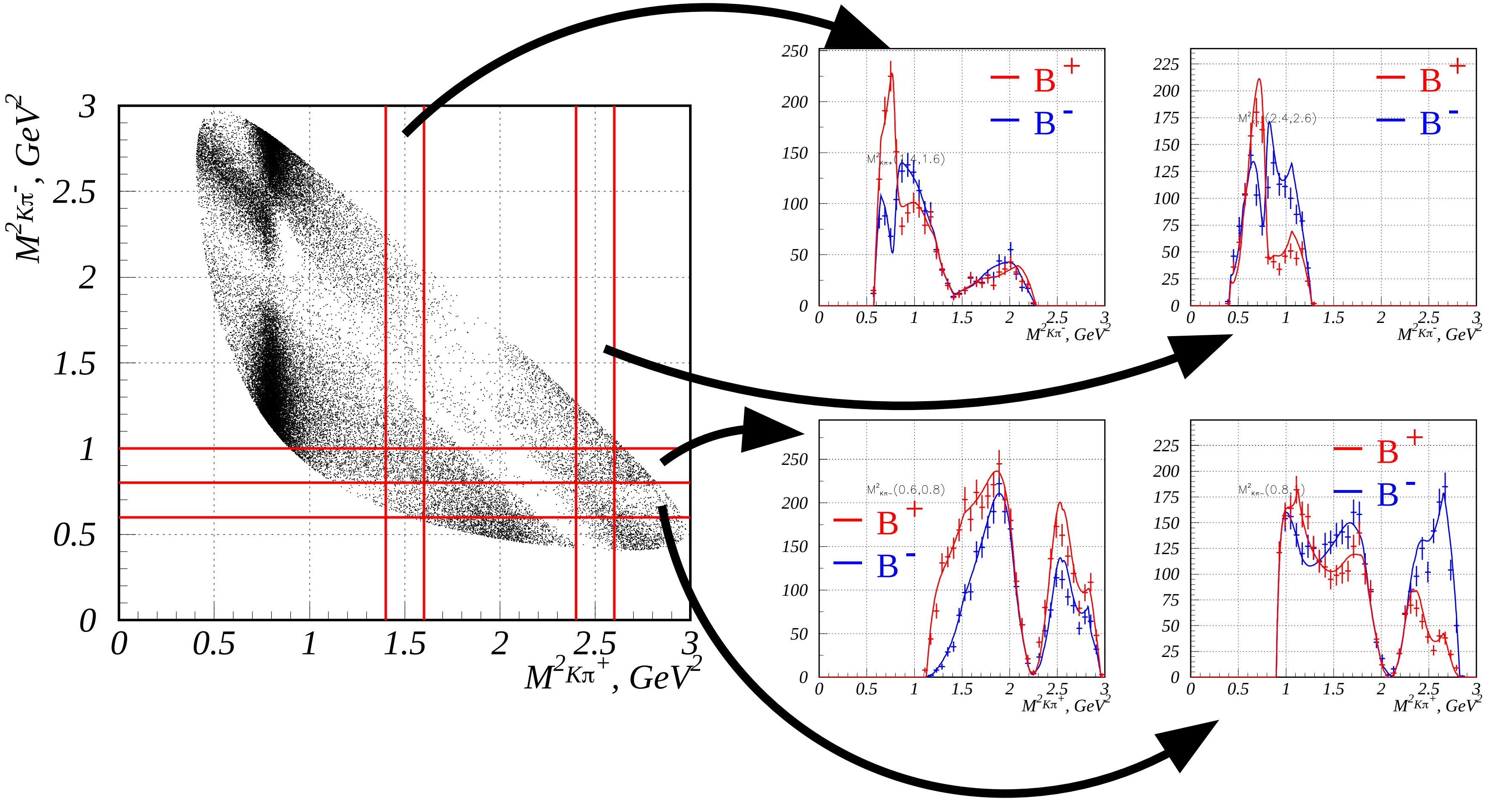


Dalitz plot of $D^0 \to K_s\pi^+\pi^-$ decay, MC simulation

CLEO $D^0 \to K_s\pi^+\pi^-$ model
[PRL **89**, 251802 (2002)]

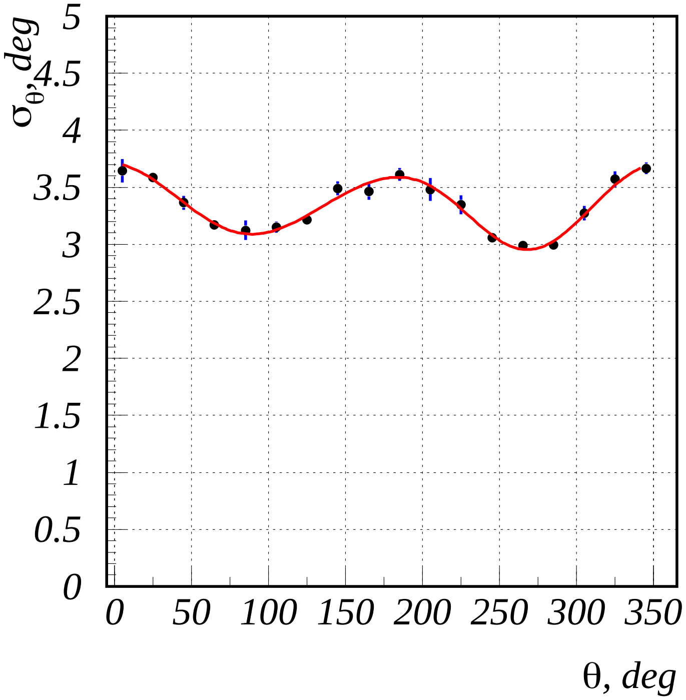
Resonance	Ampl.	Phase,^{0}	Br, %
$K^*(892)^-\pi^+$	1.56	150	65.7
$K_s\rho^0$	1.0	0	26.4
$K^*(892)^+\pi^-$	0.11	321	0.34
$K_s\omega$	0.037	114	0.72
$K_s f_0(980)$	0.34	188	4.3
$K_s f_0(1370)$	1.8	85	9.9
$K_0^*(1430)^-\pi^+$	2.0	3	7.3
non-resonant	1.1	160	0.9

Effect of $D^0 - \bar{D}^0$ interference



Most sensitive regions on the Dalitz plot ($\delta = 0^o$, $\phi_3 = 70^o$)

Statistical accuracy



Statistical error of phase θ for 10^4 decays.

Generate $\tilde{D}^0$ Dalitz plot for $0^0 < \theta < 360^0$.

Fit Dalitz plot with free a and θ, extract σ_θ.

$$\phi_3 = \frac{\theta^+ - \theta^-}{2}$$

If $\sigma_\theta = Const$

$$\sigma_{\phi_3} = \sqrt{2} \cdot \frac{\sigma_\theta}{\sqrt{2}} = \sigma_\theta$$

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

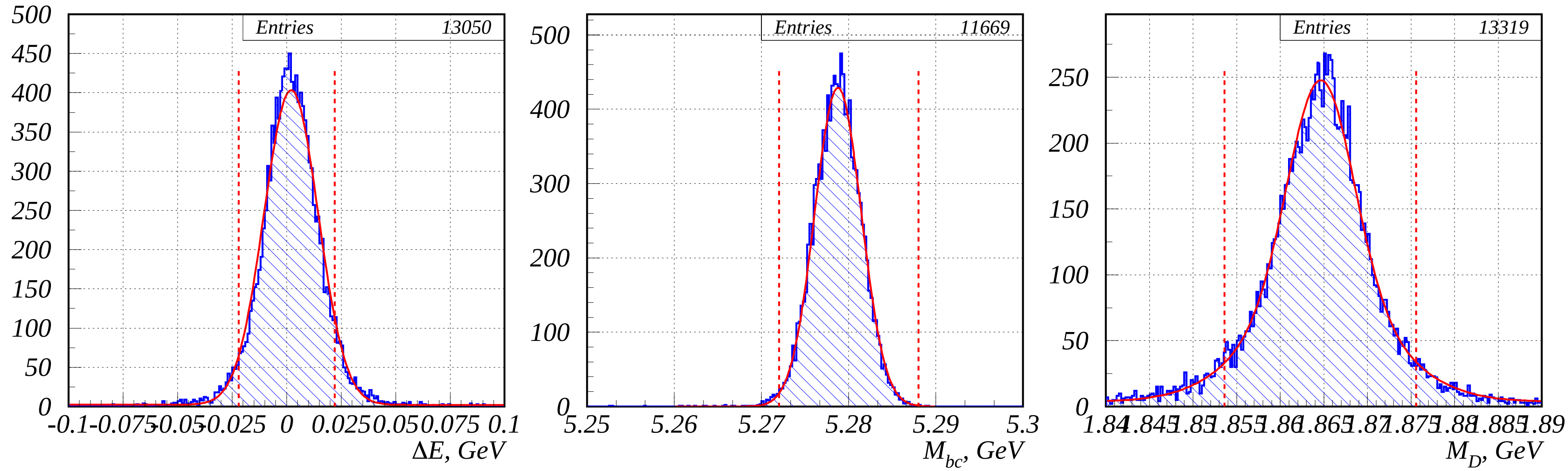
Model systematics

Generate $\tilde{D}^0$ Dalitz plot for $0^0 < \theta < 360^0$.

Fit Dalitz plot with different model (free a and θ), $\Delta\theta = \theta_{fit} - \theta$.

Fit model	$(\Delta\phi_3)_{max}, deg$
$K^*(892)$, ρ, nonres	29.3
$K^*(892)$, ρ, DCS $K^*(892)$, $f^0(980)$, nonres	9.9
Meson formfactors $F_r = F_D = 1$	3.1
Width dependence $\Gamma(q^2) = Const$	4.7

$B^+ \to \bar{D}^0 K^+$, $\bar{D}^0 \to K_s \pi^+ \pi^-$ — BELLE MC



11% detection efficiency

3 ab^{-1} $\Rightarrow$ 3000 detected events

ϕ_3 accuracy: $\sim 7^o$.

$|\Delta E| < 0.022$ GeV

$5.272 < M_{bc} < 5.288$ GeV

Fisher discriminant $F > -0.35$

$|M_D - 1.865 \text{ GeV}| < 11$ MeV

π/K PID probability $Pr(\pi/K) > 0.7$

K_s vertex distance from I.P. > 5 mm

Conclusion

- ϕ_3 can be measured in $B \to D^0 K$, $D^0 \to K_s \pi^+ \pi^-$ decay. The advantages are:
  - Do not need absulute values of branchings.
  - Sensitive to ϕ_3 itself, no discrete ambiguities.
  - Model uncertainty is $< 10^0$, can be improved using BELLE data
  - Model-independent approach exists (need $c\tau$-factory)
- Sensitivity with 3 ab^{-1} is $\sim 7 - 10^o$ (with 10% detection efficiency).