Stripping selection for
B -> Kφφ

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Why this channel?

You can measure CP and T violation in one go =)

$B^{\pm} \to K^{\pm}\phi\phi$ $\qquad$ $B^{\pm} \to \eta_c K^{\pm}$ $\quad$ $\eta_c \to \phi\phi$

$b \to s\bar{s}s$ penguin $\qquad$ $b \to c\bar{c}s$ transition

Both channels look similar in the detector: 5 charged kaons.

Direct measurements of CP violation:

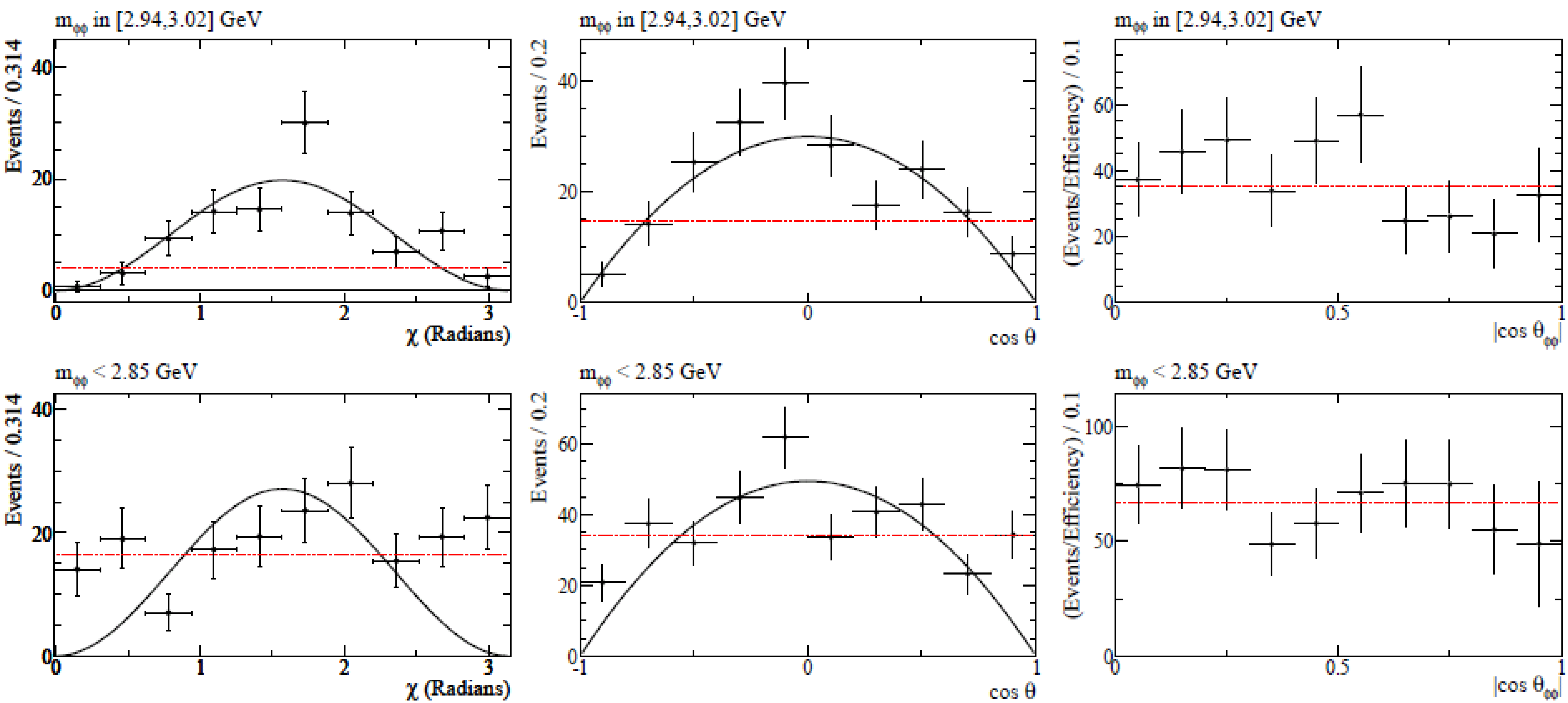
$$A_{cp} = \frac{N(B^-) - N(B^+)}{N(B^-) + N(B^+)} \qquad \arg\left(\frac{V_{tb}V_{ts}{}^*}{V_{cb}V_{cs}{}^*}\right) \approx 0$$

CP violation -BaBar results

BaBar Collaboration found: $BR(B^{\pm} \rightarrow K^{\pm}\phi\phi) = (5.6 \pm 0.5 \pm 0.3 \pm)\, 10^{-6}$

The calculated CP violation (η_c resonance) was:

arXiv:1105.5159v1 $$A_{CP} = -0.10 \pm 0.08 \pm 0.02$$



T violation

The dominating process for this decay is the loop $b \to ss\bar{s}$.

Since ϕ decays mostly into two Kaons, one can connect the T violating phase to the angular distributions of Kaons, which can be calculated.

This time we run below η_c resonance ($m_{\phi\phi}<2.85$ GeV).

Motivation

T-Odd correlations $\vec{p}\cdot(\vec{\epsilon}\times\vec{\epsilon})$ in two body decays were studied by BaBar Collaboration[1] .

Three body decays provide more T-odd correlations, one of the simplest is: $\vec{s}\cdot(\vec{p}_i\times\vec{p}_j)$.

An example decay which provides this kind of correlation is:

$$B^{\pm}\rightarrow K^{\pm}\phi\phi$$

By studing helicity angles one can measure T violation.

We don't need to know strong phases.

Details in backup slides.

[1] BABAR Collaboration, J.G. Smith, hep-ex/0406063, contribution to Moriond QCD proceedings;BELLE Collaboration, K. Abe et al., hep-ex/0408141.

Background

Possible background:

$$B^{\pm} \to \phi K^{\pm} K^{-} K^{+}$$
$$B^{\pm} \to K^{\pm} K^{-} K^{+} K^{-} K^{+}$$
$$B^{\pm} \to f_0 K \phi$$
$$B^{\pm} \to f_0 K^{\pm} K^{-} K^{+}$$

These decays can also be studied with this channel.

Stripping selection, cuts

Cut	Value
Kaons:	-------------
Pt	300 MeV
$\chi^2 IP$	>6
$\chi^2 Track$	<5
Φ meson	-------------
Pt	300 MeV
$\chi^2 IP$	>6
$\chi^2 Vertex$	<25
Mass	<1080 MeV
VDZ	>0

Stripping selection, cuts

Cut	Value
B meson:	-------------
Δm	500 MeV
$\cos(pt, track)$	>0.999
$\chi^2 Vertex$	< 5
$\frac{\chi^2 Lifetime}{NDOF}$	>64

Results of stripping testing

rate:	0.02%
time	0.628 ms

Matches the stripping requirements.

Backup

Theoretical concepts 2/2

Branching ratio

Angle between two decaying planes

$$\frac{d\Gamma_{T-odd}(\theta_1,\theta_2,\phi,Q^2)}{dQ^2 d\cos\theta_1 d\cos\theta_2 d\phi} = \frac{9}{4}\frac{G_F^2}{2^{11}\pi^4 m_B} B^2(\phi\to KK)\left(1-\frac{Q^2}{m_B^2}\right)\sqrt{1-\frac{(2m_\phi)^2}{Q^2}}$$
$$\times\left\{-\left[\frac{1}{4}\int_{-1}^{1}\mathrm{Im}(\mathrm{H}_0(\mathrm{H}_-^* - \mathrm{H}_+^*))\mathrm{d}\cos\theta\right]\sin 2\theta_1 \sin 2\theta_2 \sin\phi\right.$$
$$\left.+\left[\frac{1}{2}\int_{-1}^{1}\mathrm{Im}(\mathrm{H}_+\mathrm{H}_-^*)\mathrm{d}\cos\theta\right]\sin^2\theta_1\sin^2\theta_2\sin 2\phi\right\},$$

Longitudinal and transverse polarizations

Helicity angles of kaons in phi1(2) rest frames

$$H_0 = H(0,0) = p_B\cdot(p_1-p_2)\frac{Q^2}{(2m_\phi)^2}$$
$$\times\left[2m_1\left(1-\frac{2m_\phi^2}{Q^2}\right)+m_2\left(1-\frac{(2m_\phi)^2}{Q^2}\right)\right],$$
$$H_\pm = H(\pm,\pm) = -m_1 p_B\cdot(p_1-p_2)\mp 2m_4|\vec{p}_\phi|E_B \mp m_5|\vec{p}_\phi|\sqrt{Q^2},$$

Q=p(phi1)+p(phi2)

arXiv:hep-ph/0412180

T-odd observables

Statistical significance:

Sign function

$$\bar{\varepsilon}_i = \frac{\int \mathcal{O}_i \omega_i(u_{\theta_{K_1}}, u_{\theta_{K_2}}) d\Gamma}{\sqrt{\int d\Gamma \cdot \int \mathcal{O}_i^2 d\Gamma}}$$

u_{θ_i} being $\cos\theta_i$

$$\begin{aligned}
\mathcal{O}_{T_1} &= |\vec{p}_B| \frac{\vec{p}_{K_1} \cdot (\vec{p}_B \times \vec{p}_{K_2})}{|\vec{p}_B \times \vec{p}_{K_1}||\vec{p}_B \times \vec{p}_{K_2}|} = \sin\phi, \\
\mathcal{O}_{T_2} &= |\vec{p}_B| \frac{(\vec{p}_B \cdot \vec{p}_{K_2} \times \vec{p}_{K_1})(\vec{p}_B \times \vec{p}_{K_1}) \cdot (\vec{p}_{K_2} \times \vec{p}_B)}{|\vec{p}_B \times \vec{p}_{K_1}|^2 |\vec{p}_{K_2} \times \vec{p}_B|^2} = \frac{1}{2}\sin 2\phi,
\end{aligned}$$

T violation phase

$$\bar{\varepsilon}_i(B) + \bar{\varepsilon}_i(\bar{B}) \;\propto\; \sin(\theta_W + \theta_s) + \sin(-\theta_W + \theta_s) = 2\cos\theta_W \sin\theta_s,$$

$$\bar{\varepsilon}_i(B) - \bar{\varepsilon}_i(\bar{B}) \;\propto\; \sin(\theta_W + \theta_s) - \sin(-\theta_W + \theta_s) = 2\sin\theta_W \cos\theta_s.$$

Second non vanishing eq. => T violating phase