Measuring the CP Asymmetry in $B_d \rightarrow \pi\pi$ and $B_s \rightarrow KK$

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Extracting sin 2α from $B_d \rightarrow \pi\pi$ is complicated by backgrounds from $B_d \rightarrow K\pi$ and $B_s \rightarrow K\pi$, KK.

However, these different modes have different CP asymmetry oscillation frequencies and different mass distributions, which allows them to be separated.

Generation and Simulation

❶ Generate with Pythia ($|\eta|<3$ and $P_T^B > 0$)
❷ Accept events with $|\eta|<1$,
$P_T^{track} > 400$ MeV/c, and $P_T^B > 5$ GeV/c
❸ Smear P_T of each track by $0.001\, P_T^2$
❹ Generate decay time as exponential with lifetime of 1.5 ps and smear with $\sigma_t = 0.05$ ps
❺ Generate tag according to time dependent distribution with correct CP asymmetry [$A_{dir}^{\pi\pi} = A_{dir}^{KK} = 0.4$, $A_{mix}^{\pi\pi} = A_{mix}^{KK} = 0.7$, $x_d = 0.7$, and $x_s = 25$]

Assume that resolutions scale with εD^2 of the tag.

Rates

From the CLEO's measured branching ratios for $B_d \to \pi\pi$ and $B_d \to K\pi$ and projections to B_s decays with small SU(3) corrections, we expect

$B_d \to \pi\pi : B_d \to K\pi : B_s \to K\pi : B_s \to KK$
$= 1 : 4 : 0.5 : 2$

$\Rightarrow$ $B_d \to \pi\pi$ is only about 15% of real two body B decays. $B_s \to KK$ is 25%. In limited mass range, fractions are higher.

Include background flat in mass with same non-oscillating liftetime as B's at twice the $B_d \to \pi\pi$ rate in B_d mass range (5.24-5.34 GeV/c^2)

Event Numbers

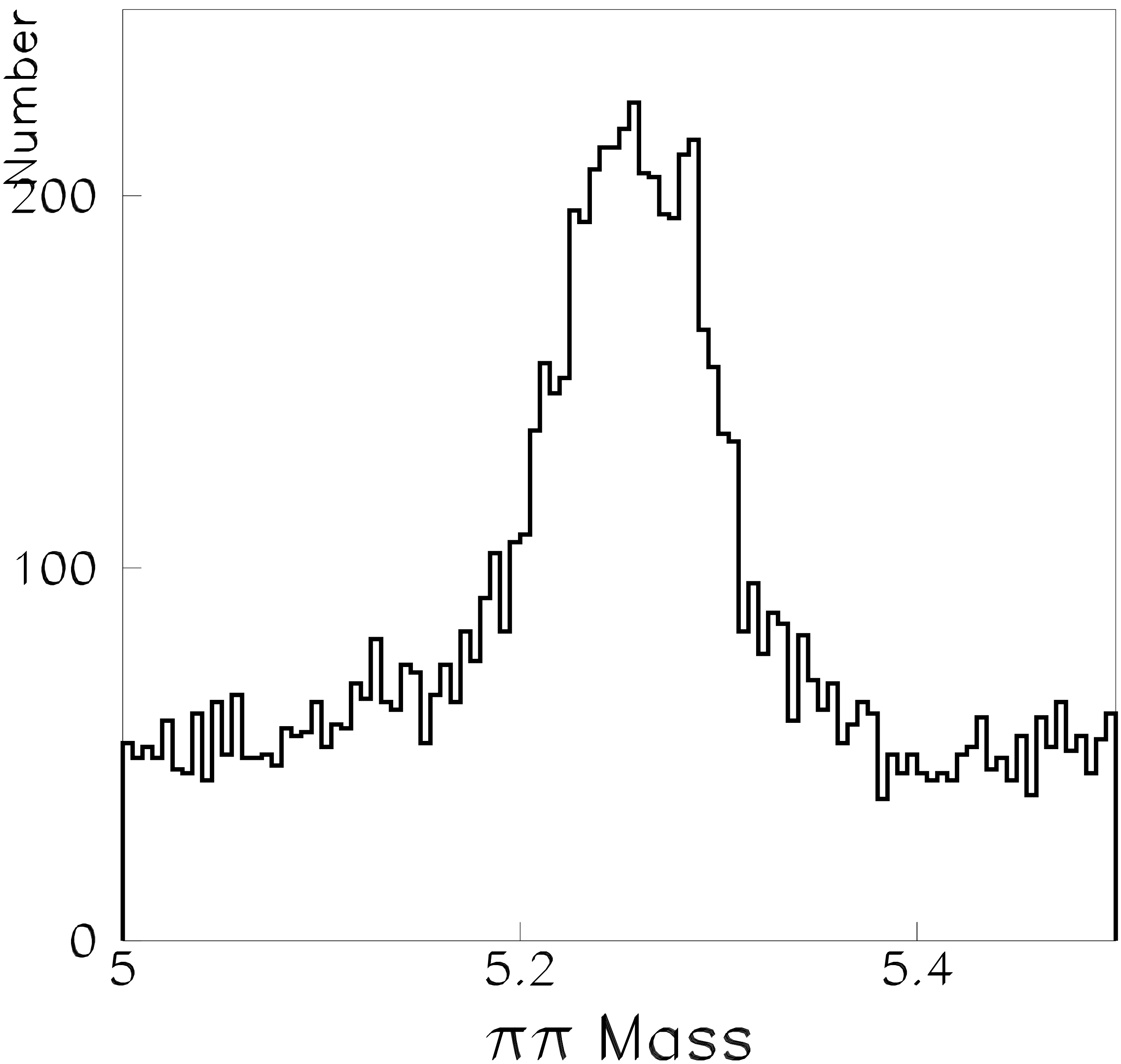
Assume 5,000 $B_d \rightarrow \pi\pi$ and $\varepsilon D^2 = 10\%$ for tagging. Note that B_s tagging may differ from B_d, which is ignored here.

This gives the following numbers of events:

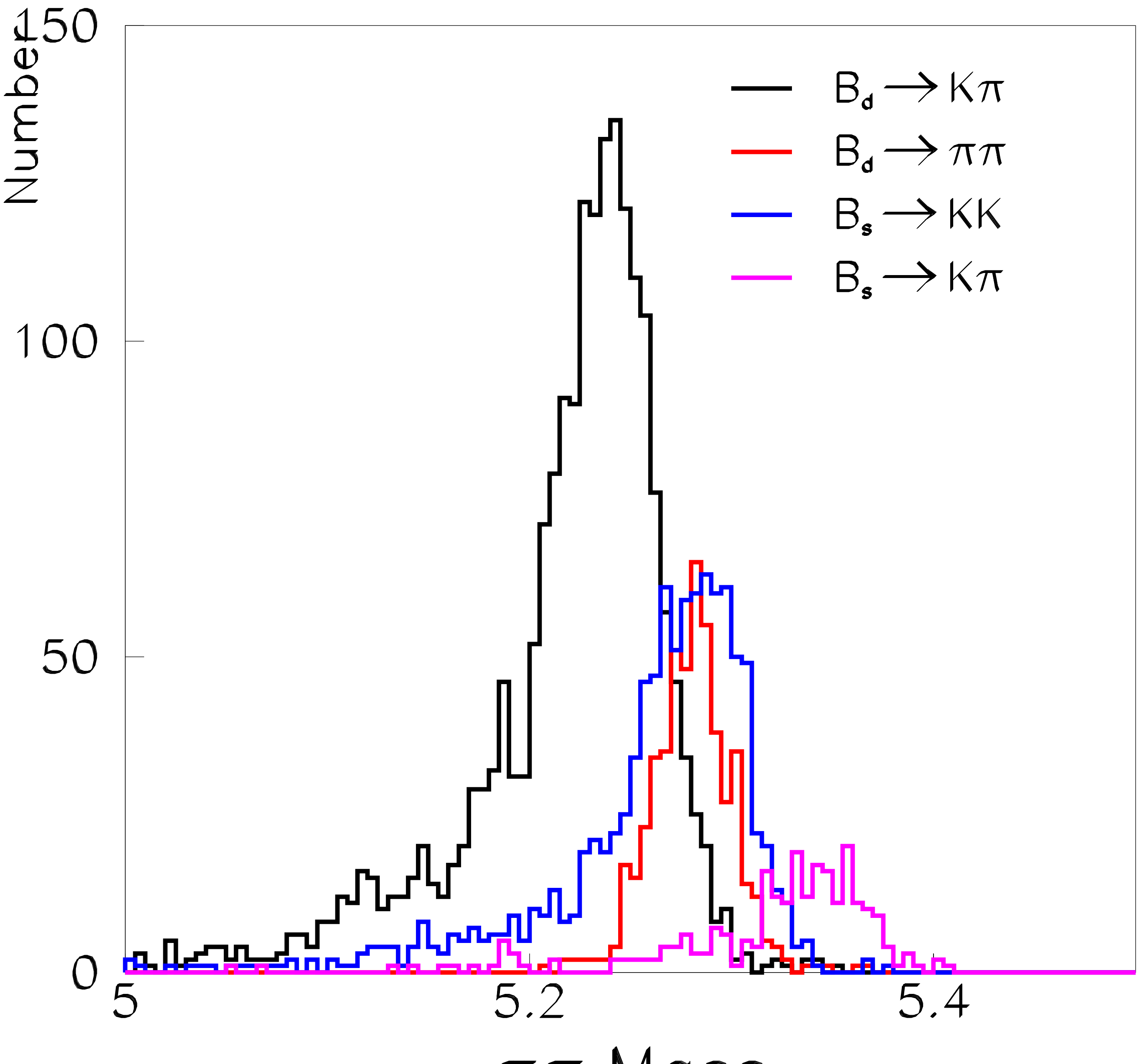
$B_d \rightarrow \pi\pi$	500
$B_d \rightarrow K\pi$	2000
$B_s \rightarrow K\pi$	250
$B_s \rightarrow KK$	1000

Background 5000 from 5.0 to 5.5 GeV/c^2

Mass Distributions



Mass Distributions



CP Decay Asymmetries

$$P_{B_d(\overline{B}_d)\to\pi\pi} = \frac{\Gamma}{2}\left[\begin{array}{l} 1 \mp A_{mix}^{\pi\pi}\sin(\Delta m_d t) \\ \quad \mp A_{dir}^{\pi\pi}\cos(\Delta m_d t) \end{array}\right] e^{-\Gamma t}$$

$$P_{B_d(\overline{B}_d)\to K\pi} = \frac{\Gamma}{2} e^{-\Gamma t}$$

$$P_{B_s(\overline{B}_s)\to KK} = \frac{\Gamma}{2}\left[\begin{array}{l} 1 \mp A_{mix}^{KK}\sin(\Delta m_s t) \\ \quad \mp A_{dir}^{KK}\cos(\Delta m_s t) \end{array}\right] e^{-\Gamma t}$$

$$P_{B_s(\overline{B}_s)\to K\pi} = \frac{\Gamma}{2} e^{-\Gamma t}$$

If there are no penguin amplitudes, $A_{mix}^{\pi\pi} = \sin(2\alpha)$, $A_{mix}^{KK} = \sin(2\gamma)$, and $A_{dir}^{\pi\pi} = A_{dir}^{KK} = 0$.

Log Likelihood Function

$$\ln L = \sum_{\text{events}} \ln\Big\{(1-f_B)\big[f_{\pi\pi} G(M_{\pi\pi}; M_{B_d}, \sigma_{\pi\pi})\tilde{P}^{d}_{\pi\pi}(t) +$$

$$f^{d}_{K\pi} G(M_{\pi\pi}; \overline{M}^{d}_{K\pi}, \sigma^{d}_{K\pi})\tilde{P}^{d}_{K\pi}(t) +$$

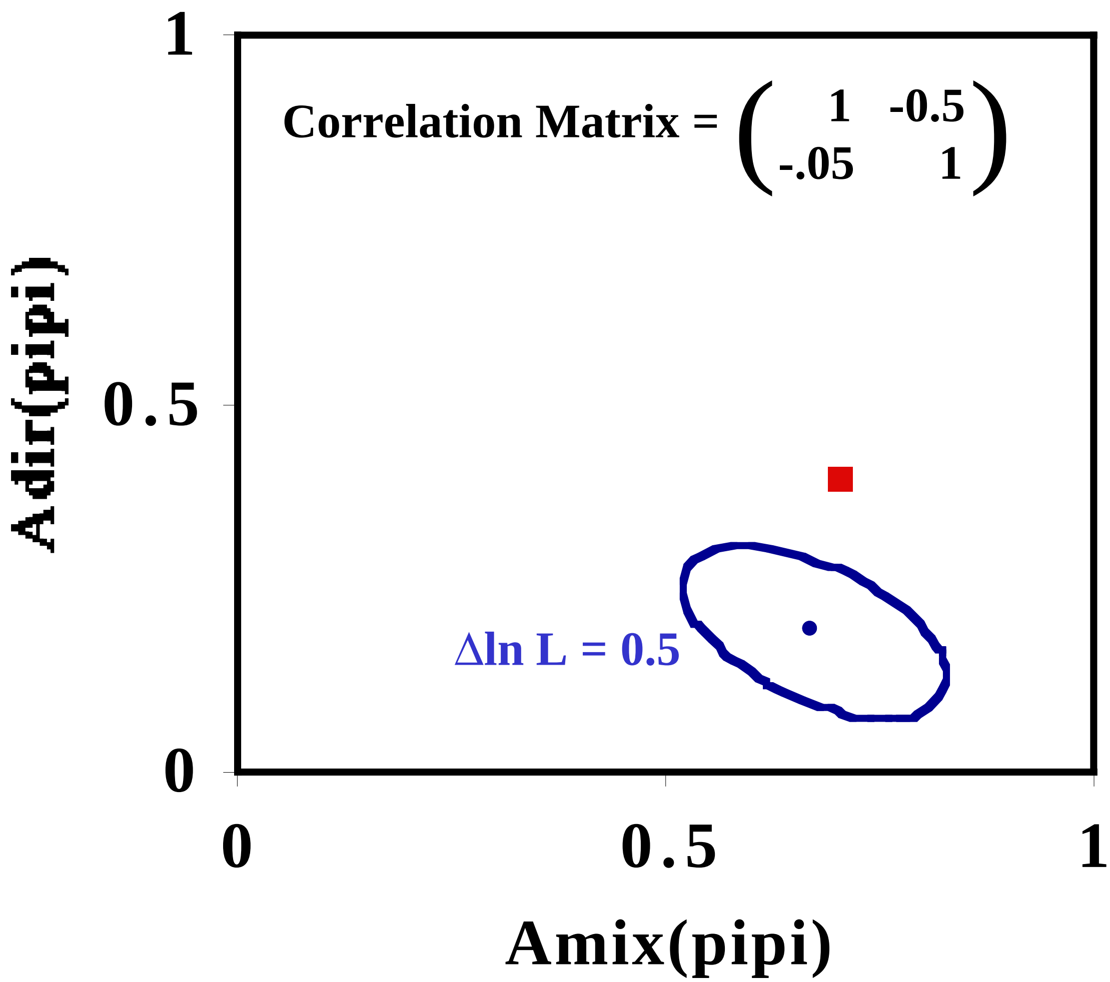
$$f^{s}_{K\pi} G(M_{\pi\pi}; \overline{M}^{s}_{K\pi}, \sigma^{s}_{K\pi})\tilde{P}^{s}_{K\pi}(t) +$$

$$f^{s}_{KK} G(M_{\pi\pi}; \overline{M}_{KK}, \sigma^{s}_{KK})\tilde{P}^{s}_{KK}(t)\big] +$$

$$f_B \tilde{P}_{BG}(t)\Big\}$$

Assume that we know f's, M's, σ's, Γ's, and Δm's well. ln L is then function of the A's.

Likelihood Contours



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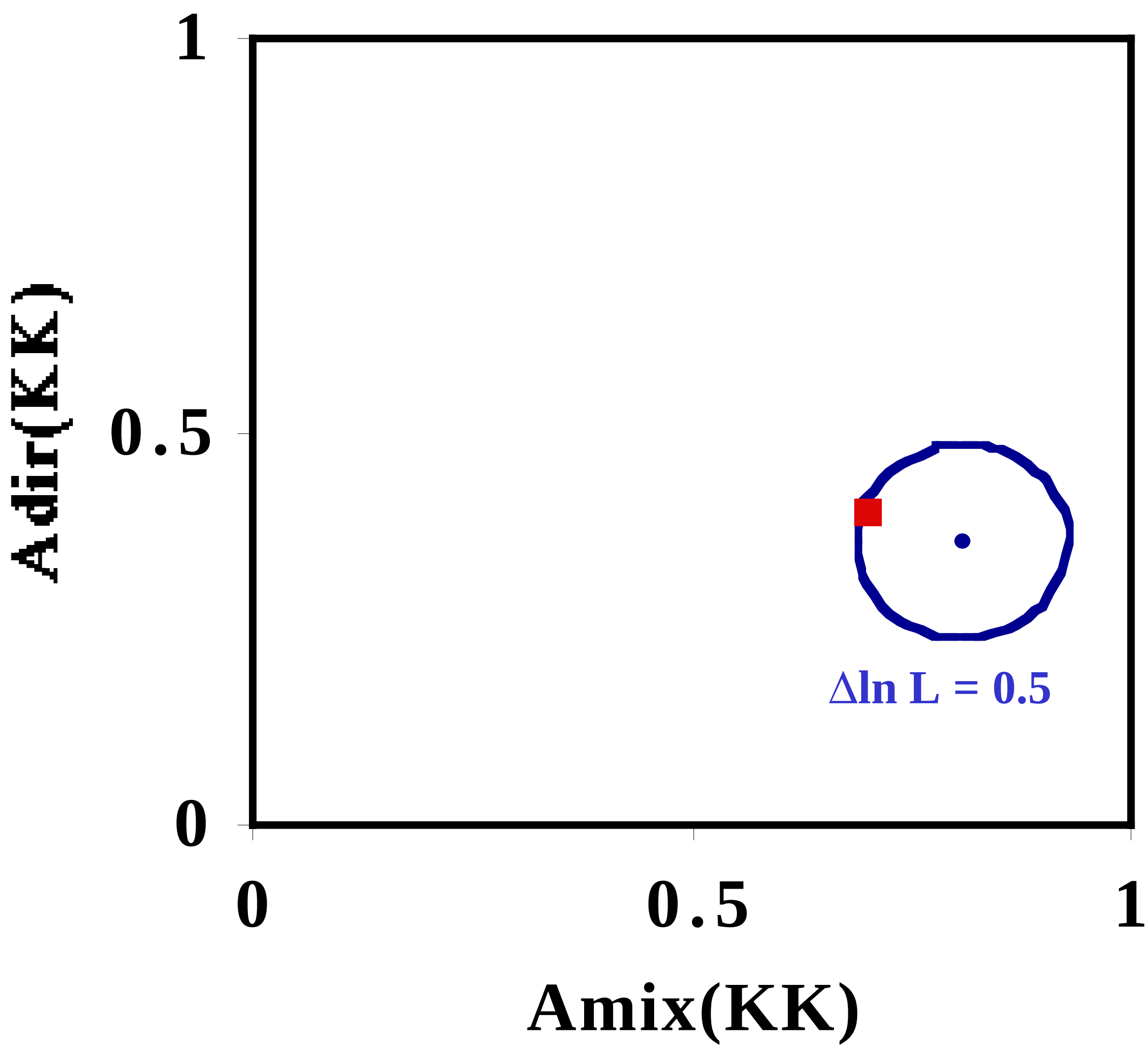
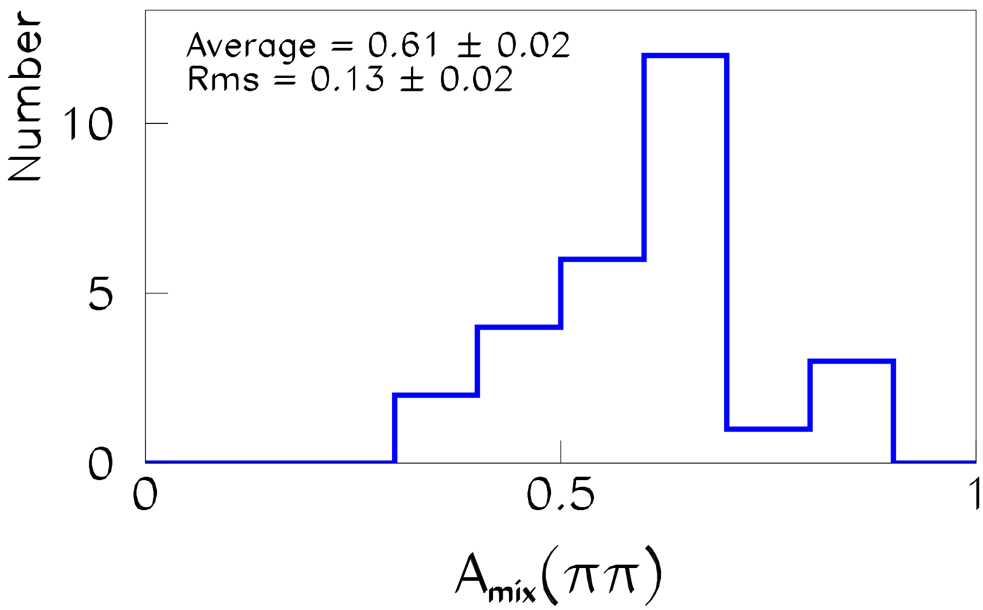
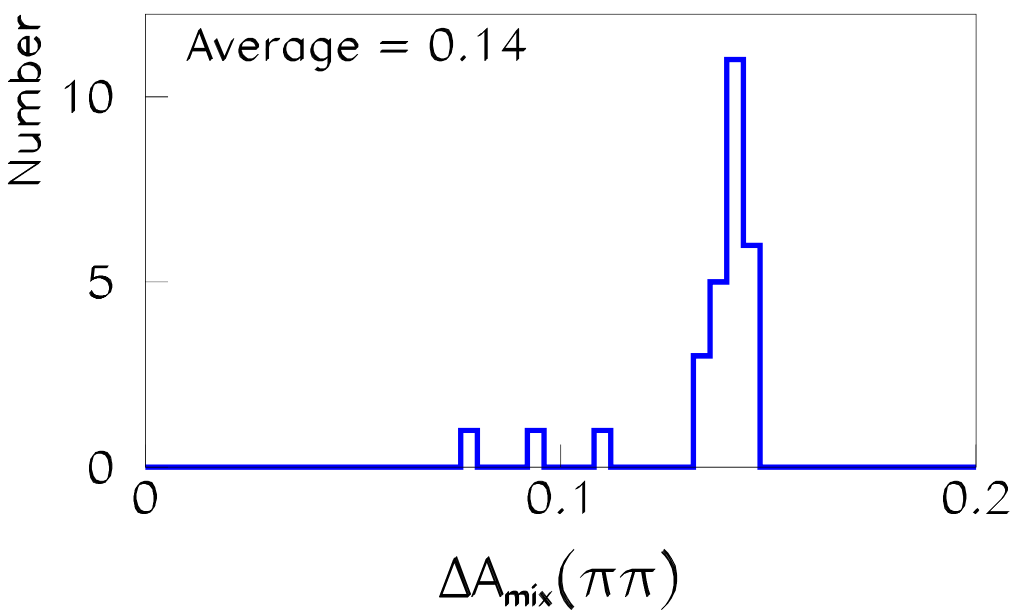
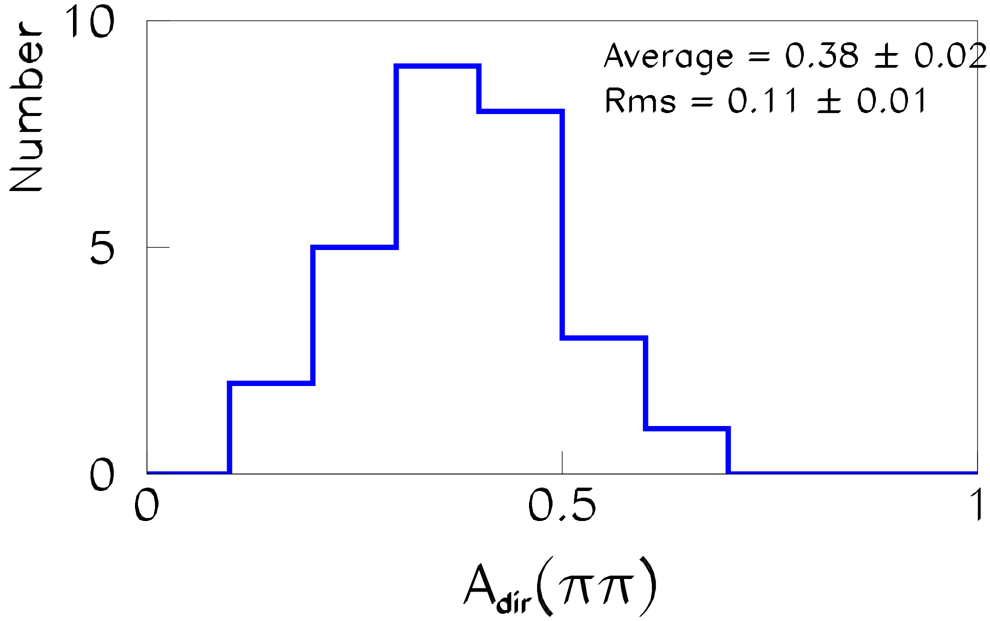


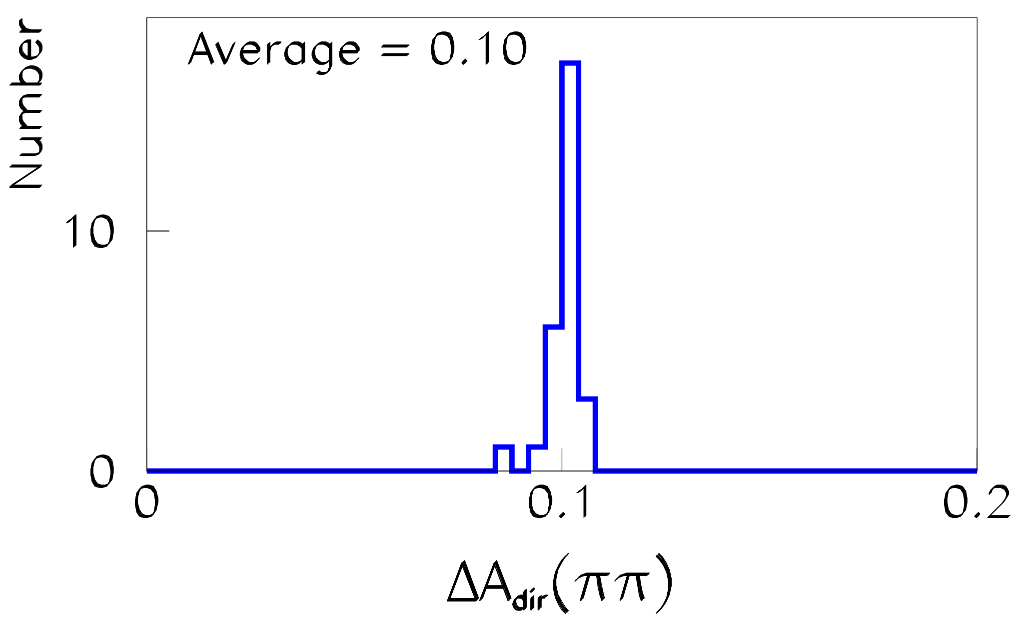
$A_{mix}(\pi\pi)$ Resolutions



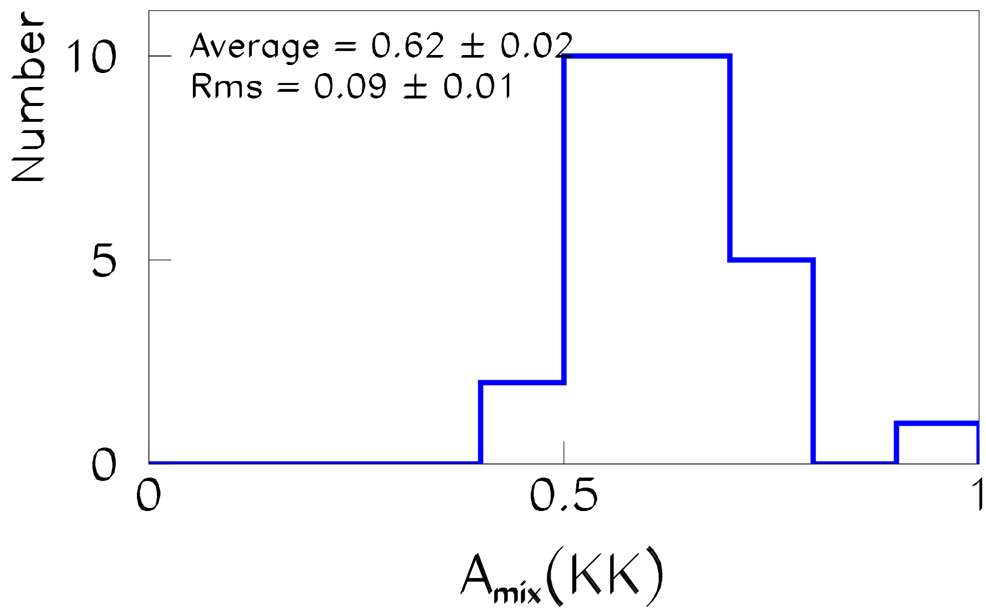


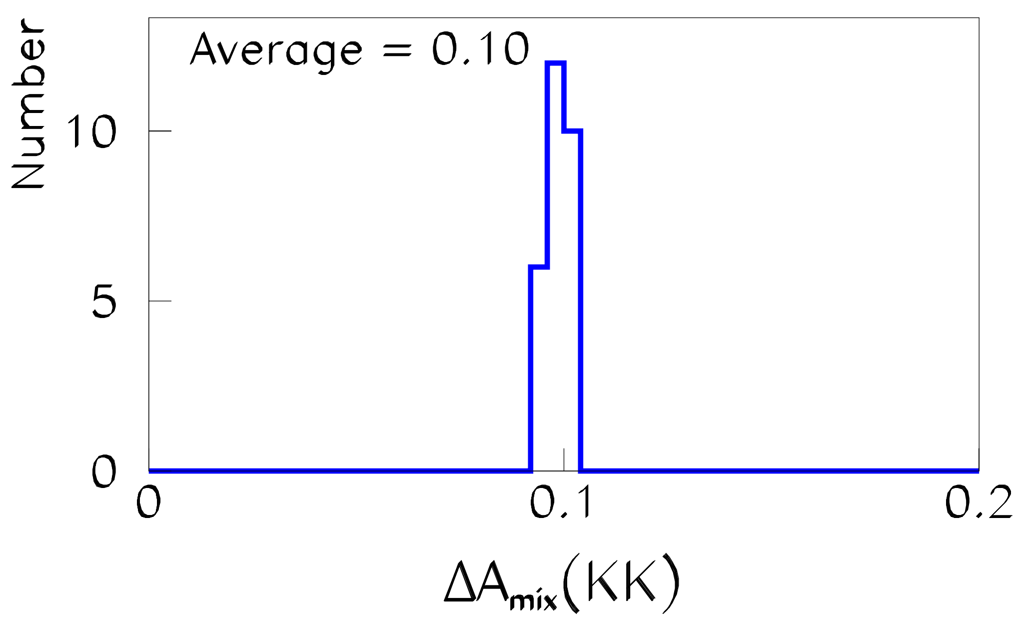
$A_{dir}(\pi\pi)$ Resolutions



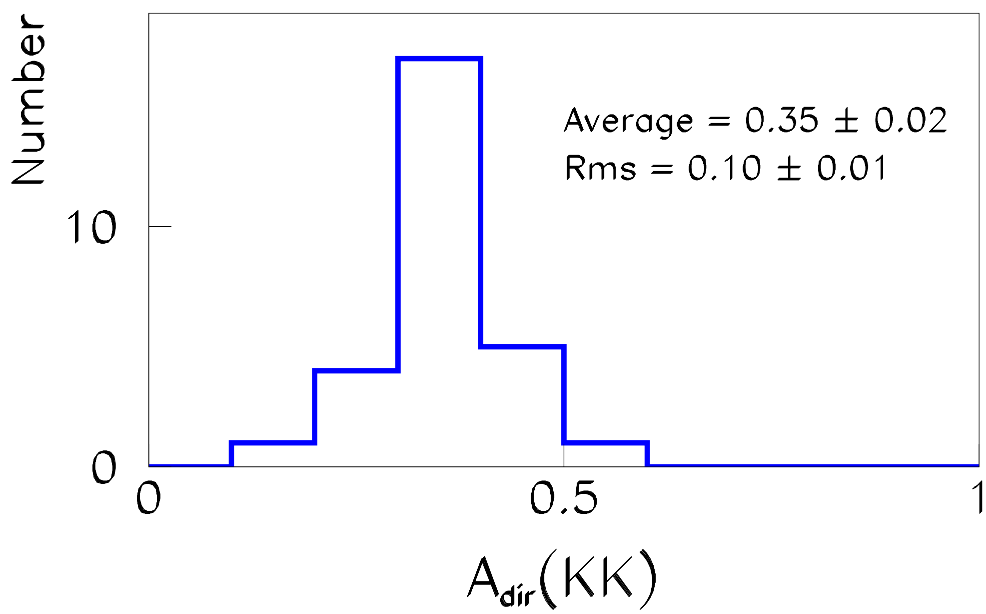


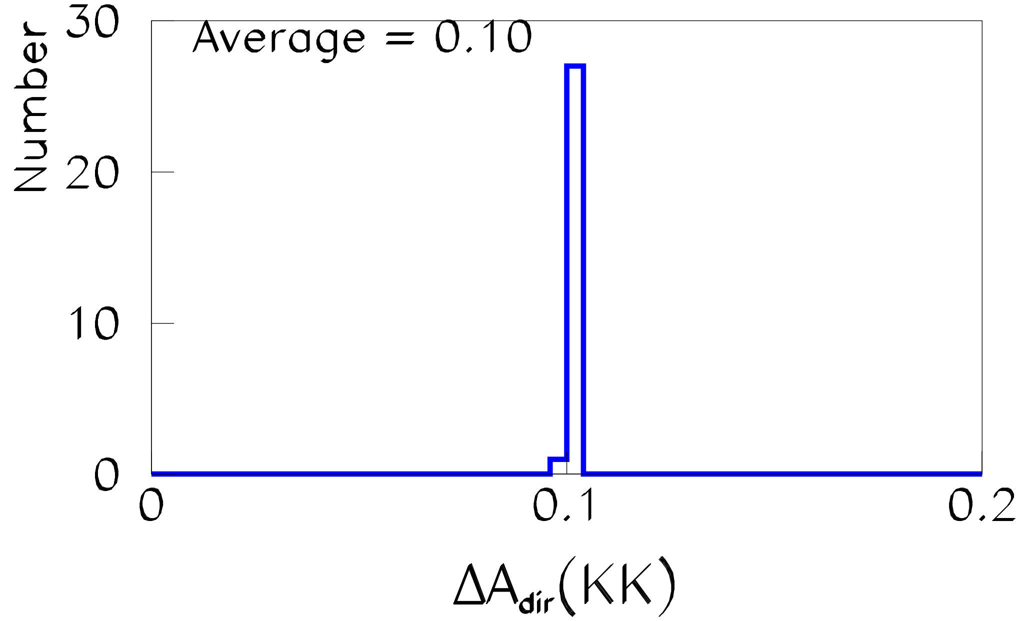
A_{mix}(KK) Resolutions





$A_{dir}(KK)$ Resolutions





Extracting α and γ from $B_d \to \pi\pi$ and $B_s \to KK$

R. Fleischer has suggested a method of extracting α and γ from $B_d \to \pi\pi$ and $B_s \to KK$ decays that resolves penguin contributions. Frank Wuerthwein will discuss this.

Conclusions

❶ **CDF will measure the direct and mixing CP asymmetries in $B_d \rightarrow \pi\pi$ and $B_s \rightarrow KK$ to about 0.1 to 0.15 in 2 fb^{-1}.**

❷ **It may be possible to resolve the contributions of penguin diagrams to get measurements of α and γ.**