$\boxed{\text{CP Violation in } B_s \to D_s K}$

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Introduction

For neutral B mesons, interference between direct and mixing induced decays can give rise to time dependent CP-violating effects.

*New equations include lifetime difference $\Delta\Gamma(B_s)$.

$$\Gamma[B_s(t) \to f]$$
$$\Gamma[\overline{B_s}(t) \to \overline{f}]$$
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$$M = \langle f|B\rangle$$
$$M' = \langle f|\overline{B}\rangle$$
$$\rho = |M'/M|$$
$$x = \Delta m/\Gamma$$
$$y = \Delta\Gamma/2\Gamma$$
$$\delta = \text{strong phase}$$
$$\phi = \text{CKM phase}$$

$$\begin{aligned}\Gamma[B \to f] &= \frac{|M|^2}{2} e^{-t}\{(1+\rho^2)\cosh(yt) + (1-\rho^2)\cos(xt) \\ &\quad +2\rho\cos(\delta+\phi)\sinh(yt) - 2\rho\sin(\delta+\phi)\sin(xt)\}\end{aligned}$$

$$\begin{aligned}\Gamma[\overline{B} \to \overline{f}] &= \frac{|M|^2}{2} e^{-t}\{(1+\rho^2)\cosh(yt) + (1-\rho^2)\cos(xt) \\ &\quad +2\rho\cos(\delta-\phi)\sinh(yt) - 2\rho\sin(\delta-\phi)\sin(xt)\}\end{aligned}$$

$$\begin{aligned}\Gamma[B \to \overline{f}] &= \frac{|M|^2}{2} e^{-t}\{(1+\rho^2)\cosh(yt) - (1-\rho^2)\cos(xt) \\ &\quad +2\rho\cos(\delta-\phi)\sinh(yt) + 2\rho\sin(\delta-\phi)\sin(xt)\}\end{aligned}$$

$$\begin{aligned}\Gamma[\overline{B} \to f] &= \frac{|M|^2}{2} e^{-t}\{(1+\rho^2)\cosh(yt) - (1-\rho^2)\cos(xt) \\ &\quad +2\rho\cos(\delta+\phi)\sinh(yt) + 2\rho\sin(\delta+\phi)\sin(xt)\}\end{aligned}$$

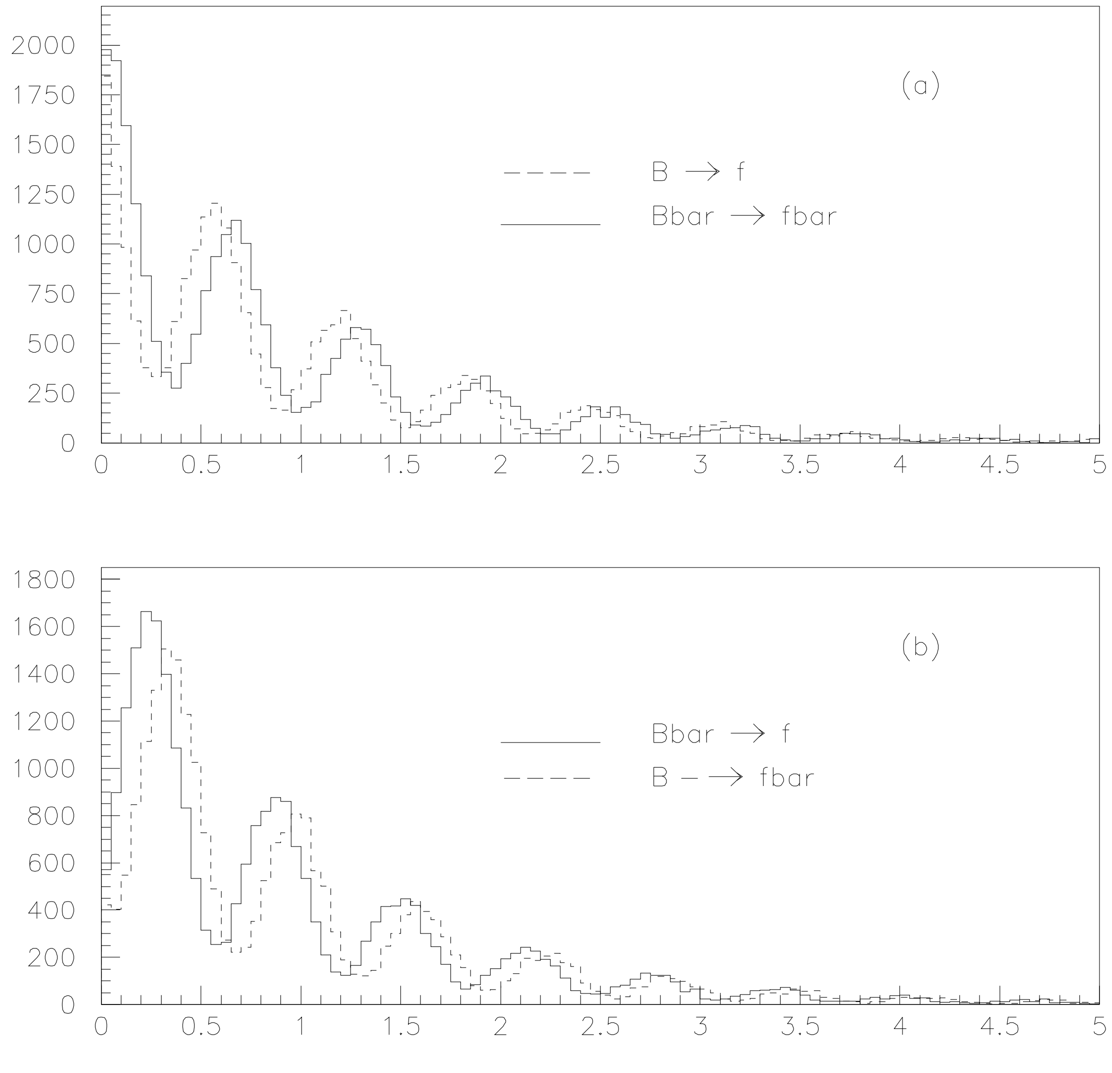

Figure 1: Time Distributions of $B_s^0 \to f, \overline{f}$ processes and CP conjugates

- An example of this is B_s which can decay into both $D_s^+ K^-$ and $D_s^- K^+$.
  Both BRs $\sim 10^{-4}$ and weak angle $\phi = \gamma$.
- If $\Delta\Gamma = 0$ we can extract ρ, $\sin(\gamma+\delta)$ and $\sin(\gamma-\delta)$ from a time-dependent study $\rightarrow$ discrete ambigutites
- If $\Delta\Gamma \neq 0$ the equations depend on $\sin(\gamma+\delta)$, $\sin(\gamma-\delta)$ AND $\cos(\gamma+\delta)$, $\cos(\gamma-\delta)$ so we can resolve the ambiguites.

- Tag initial flavor
- Measure proper time of decay
- CP violation diluted by time resolution, mistagging, background

Reconstruction Efficiency

- Reconstruction effic 2.0% ($\phi\pi$), 1.7%(K^*K)
- Trigger effic $\sim$ 68% (2 tracks @4σ) both modes
- Tagging: preliminary studies $\epsilon = 0.4$, $D = 0.4$, $\epsilon D^2 = 0.64$

Luminosity	2×10^{32}	
Running time	10^7 sec	
Integrated Luminosity	2 fb$-$1	
$\sigma_{b\bar{b}}$	100μb	
Number of $B\overline{B}$ events	2×10^{11}	
Number of $B_s^0 + \overline{B}_s^0$	5×10^{10}	
BR($B_s^0 \to D_s^- K^+$)	$2. \times 10^{-4}$	
BR($B_s^0 \to D_s^+ K^-$)	$1. \times 10^{-4}$	
BR($D_s \to \phi\pi^+$) $\times$ $BR(\phi \to K^+K^-)$	1.8×10^{-2}	
BR($D_s \to \overline{K}^{*0} K$) $\times$ $BR(\overline{K}^{*0} \to K^-\pi^+)$		2.2×10^{-2}
Reconstruction efficiency	.020	.017
Trigger efficiency	0.70	0.70
Number of reconstructed $B_s^0(\overline{B}_s^0) \to D_s K$	3800	3900
Tagging efficiency ϵ	.40	
Number of tagged events	1500	1600

Table 1: Expected Number of Events/10^7 sec

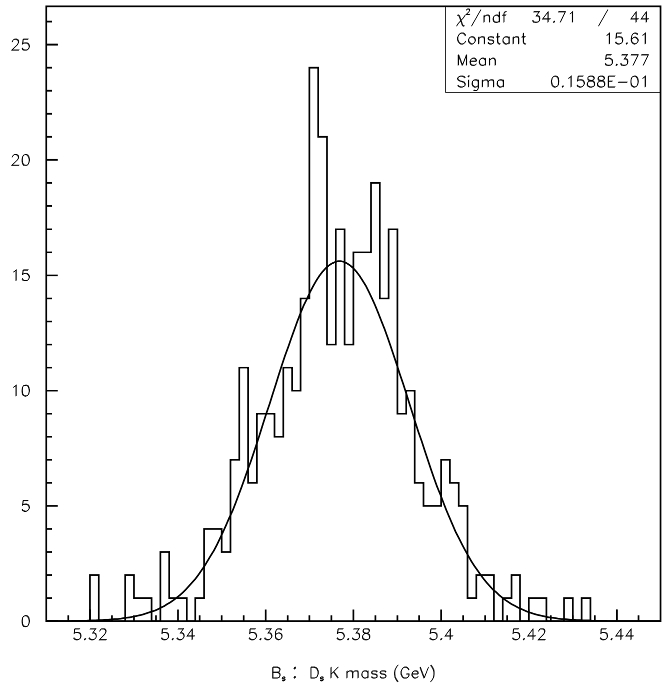

Figure 2: Mass Resolution for B_s

Time Resolution

- CP asymmetry is diluted by $e^{-\sigma_t^2 x_s^2/2}$ (σ_t is in units of τ_{B_s})
- A gaussian fit to the $t_{gen} - t_{res}$ distribution gives $\sigma_t = 45$ fsec for the $D_s \to \phi\pi$ mode
- Given that $\tau_{B_s} = 1.54$ psec, then $\sigma_t/t = .03$

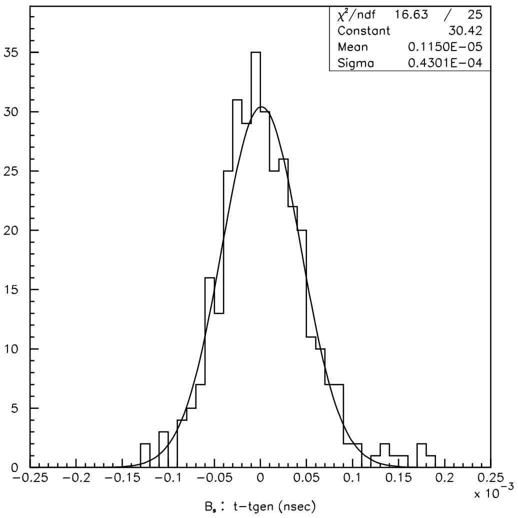

Figure 3: Proper Time Resolution for B_s : $t_{gen} - t_{rec}$ (nsec)

Background

- $B_s \to D_s \pi X$, where the π is misidentified as a K.
  - $B_s \to D_s \pi$
  - $B_s \to D_s^* \pi$
  - $B_s \to D_s \rho$
  - $B_s \to D_s^* \rho$
  - $B_s \to D_s \pi^- \pi^0$

  Estimate S/B> 10.

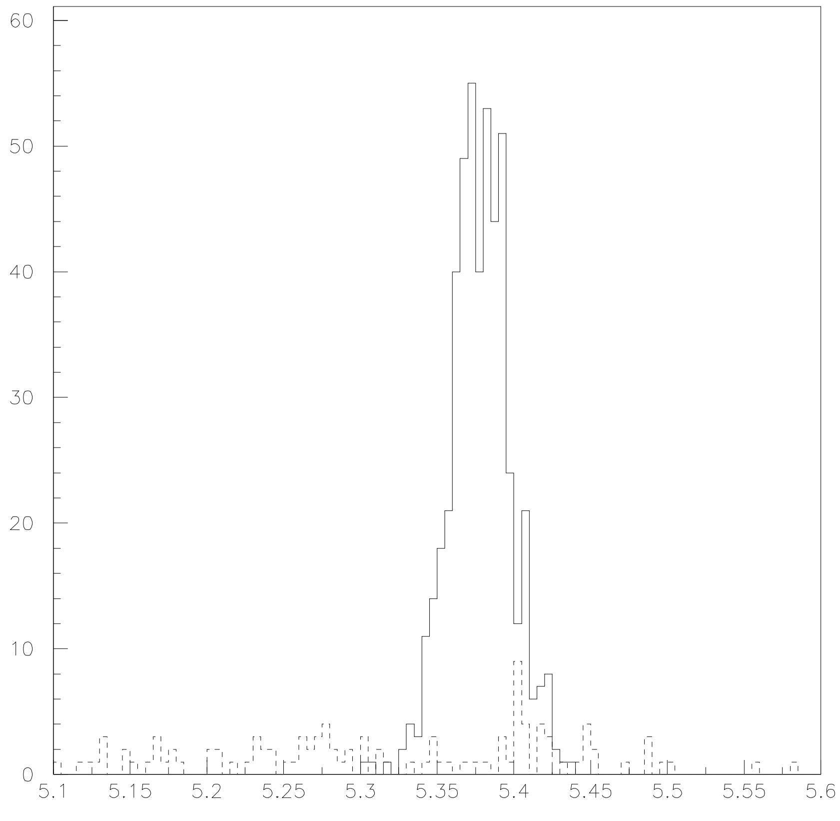

Figure 4:

- Combinatoric Background studied in 2 steps
  - generic $b\bar{b}$ events were generated to study S/B for $D_s \to \phi\pi$ and $D_s \to K^*K$.
  - "B" $\to D_sX, D_s \to \phi\pi$ events and "B" $\to D_sX, D_s \to K^*K$ were generated to study the background from real D_s's combining with other tracks in the event. Estimate S/B$\sim$10.

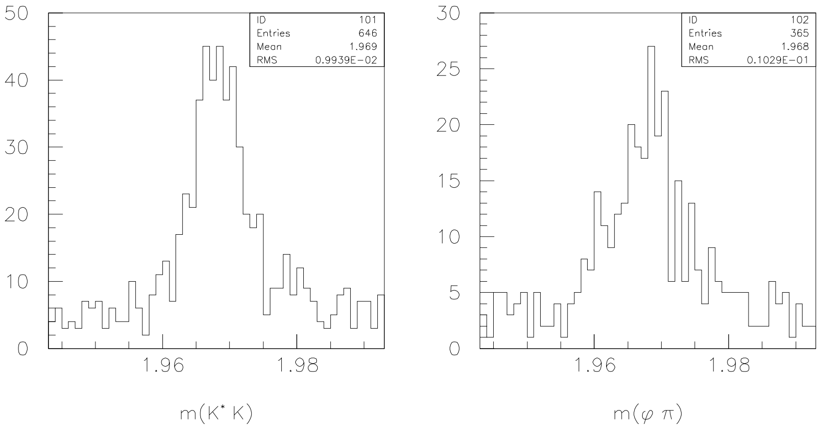

Figure 5: D_s from generic B events (a) K^*K mass (b) $\phi\pi$ mass

Extracting ρ and $\sin\gamma$ using Maximum Likelihood fits

- A mini Monte Carlo was done to determine the expected error on γ.
- Input values of parameters were chosen: $x_s = 30.0$, $\rho = 0.7$, $\gamma = 49\,\mathrm{deg}$, $\delta = 10\,\mathrm{deg}$ and $\Delta\Gamma = 0.16$
- A set of "events" (*ie.* proper times) was generated, split into the 4 decay modes with correct time distributions.
- The proper times were smeared with a gaussian of width $\sigma_t = 0.03\tau$ (Acceptance correction at low t needs to be modelled)
- Some of the events were assigned to come from the "wrong flavor" parent. (30%)
- Background events with a pure exponential time distribution were added to the "signal" events.
- A maximum likelihood fit was done to find the values of ρ, γ, δ, $\Delta\Gamma$
- 1000 trials each of 3000 events

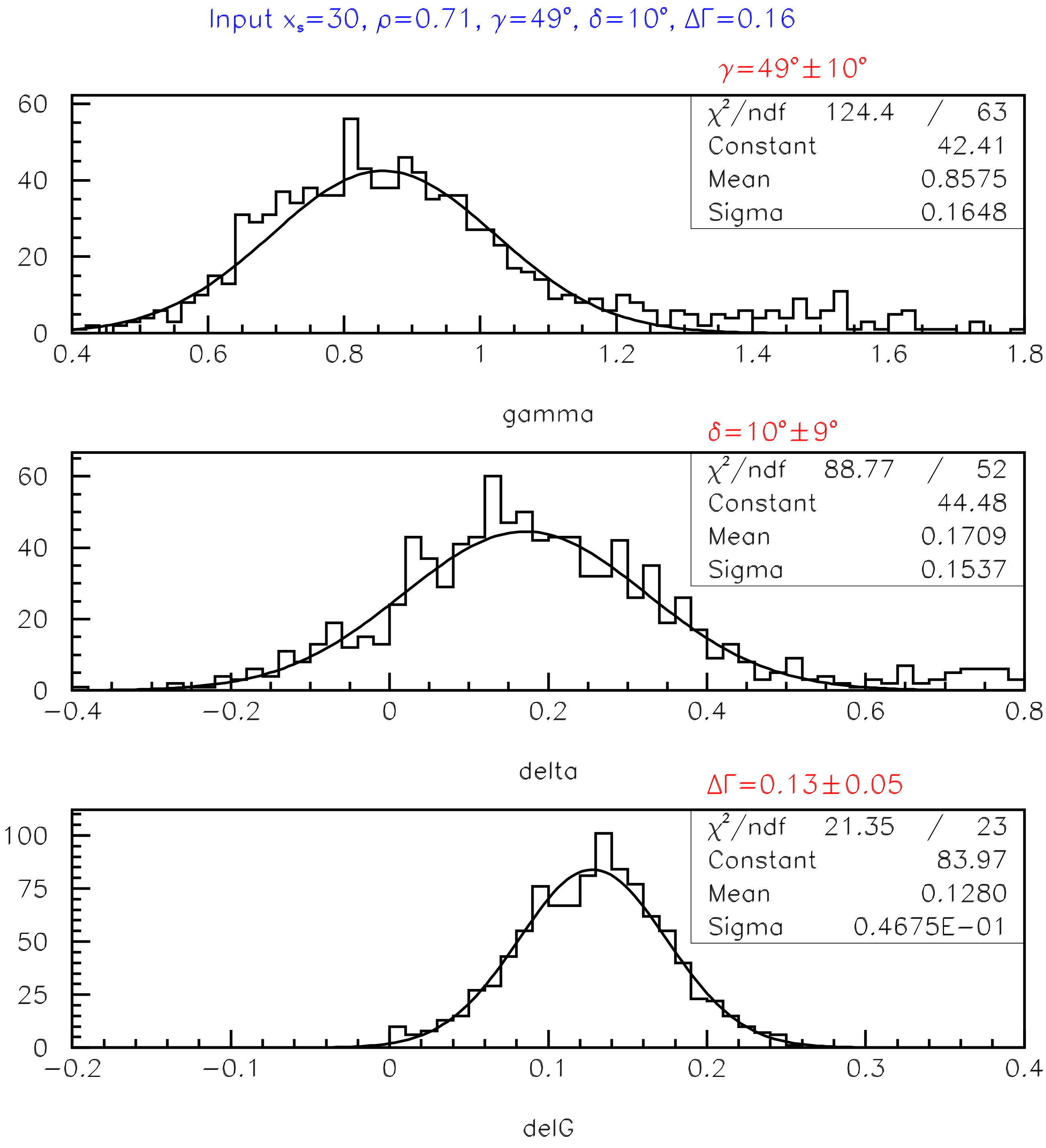

Figure 6: Fitted values of γ, δ, and $\Delta\Gamma$

x_s	ρ	δ	γ	$\Delta\Gamma$	$\sigma(\gamma)$	$\sigma(\Delta\Gamma)$
20	0.71	10^o	49^o	0.16	7^o	0.05
30	0.71	10^o	49^o	0.16	10^o	0.05
40	0.71	10^o	49^o	0.16	12^o	0.04
30	0.50	10^o	49^o	0.16	11^o	0.05
30	0.71	10^o	30^o	0.16	8^o	0.04
30	0.71	10^o	90^o	0.16	13^o	—
30	0.71	0^o	49^o	0.16	10^o	0.04
30	0.71	20^o	49^o	0.16	9^o	0.04
30	0.71	10^o	49^o	0.06	11^o	—
30	0.71	10^o	49^o	0.26	8^o	0.04

Table 2:

** For 2 cases in the table above, an error on $\Delta\Gamma$ is not given. In these runs a the fitted value of $\Delta\Gamma$ was zero some of the time. (10% for the run with $\gamma = 90^o$ and 20% for the run with $\Delta\Gamma = 0.06$) If the fitted value of $\Delta\Gamma$ is zero we have discrete ambiguities in the solution for γ.

Conclusions

- The ability of BTeV to measure the angle γ of the unitarity triangle depends on several factors which are not well-known at the moment, in particular the branching fractions for $B_s \to D_s K$, the B_s mixing parameter x_s and the lifetime difference $\Delta\Gamma(B_s)$.
- We expect to have about 3000 reconstructed and tagged events per year(10^7 sec) at a luminosity of 2×10^{32}.
- Assuming reasonable estimates of branching ratios and x_s we expect to measure γ to about 10^o in one year. If $\Delta\Gamma(B_s) > 0.1$ the measurement of γ will be free from discrete ambiguities.