Analysis of $B^0 \to D^{*+} D^{*-}$ decays at Belle

Moriond EW 2012, Young scientists forum 2

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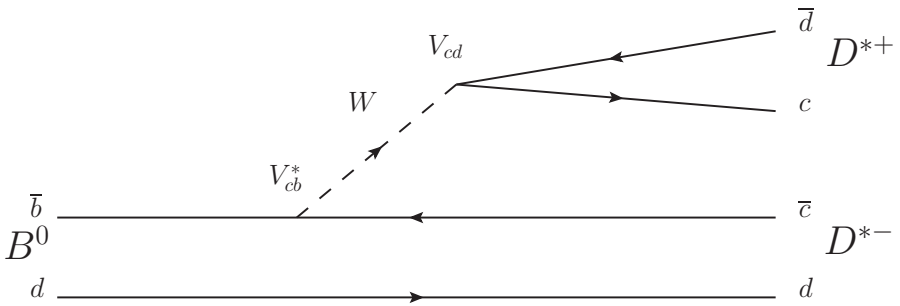
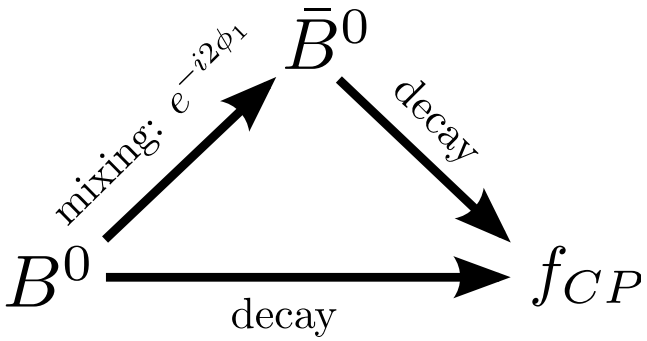
Motivation





Motivation

- *CP*-eigenstates → time-dependent *CP*-violation expected
- Branching fraction $\approx 10^{-3}$
- Similarities to $B^0 \to D^{*\pm} D^{\mp}$ and $B^0 \to D^+ D^-$ [a]

Specifics

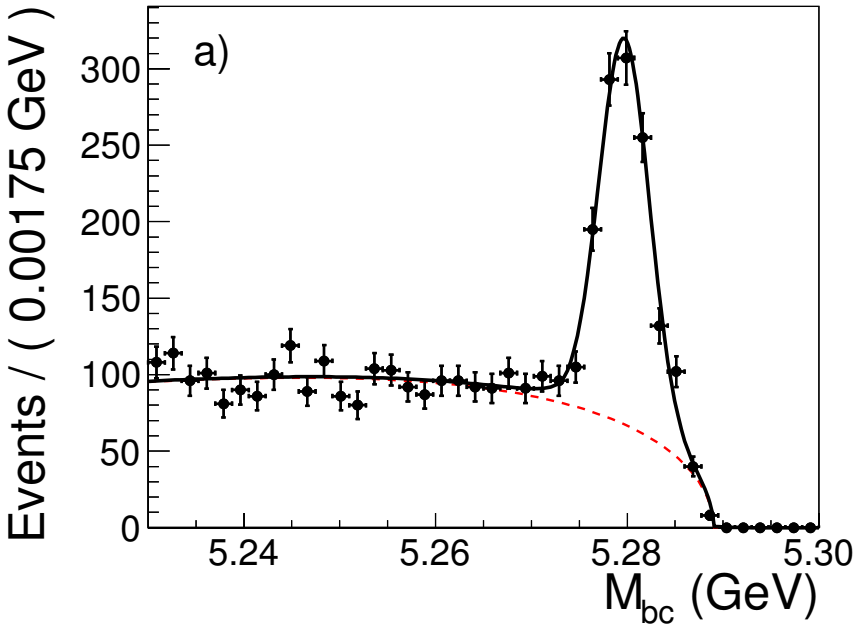
- In the standard model: *CP*-violation is directly related to CKM-angle ϕ_1
- Two D^* mesons
- Final state is a mixture of *CP*-eigenstates

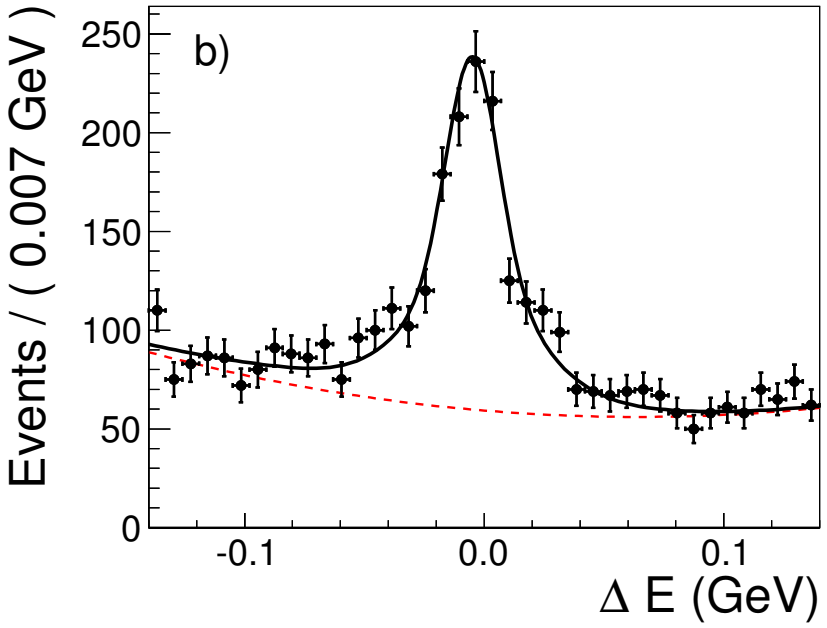
Data sample: Final Belle data sample, containing $(772 \pm 11) \times 10^6$ $B\bar{B}$-pairs.

[a] Previous Belle measurements:
T. Aushev *et al.* (Belle Collaboration), Phys. Rev. Lett. **93**, 201802 (2004).
S. Fratina *et al.* (Belle Collaboration), Phys. Rev. Lett. **98**, 221802 (2007).
K. Vervink *et al.* (Belle Collaboration), Phys. Rev. **D80**, 111104 (2009).

Branching fraction measurement

Fit in $M_{\rm bc} = \sqrt{\left(E_{beam}^{CM}\right)^2 - \left(\vec{p}_B^{CM}\right)^2}$ and $\Delta E = E_B^{CM} - E_{beam}^{CM}$





Number of signal events: 1225 ± 59

Reconstruction efficiency $\times$ $D^{(*)}$ branching fractions: 0.2%

$$\mathcal{B}_{B^0 \to D^{*+} D^{*-}} = (7.82 \pm 0.38 \pm 0.60) \times 10^{-4}$$

Belle preliminary

B decay channels:

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

D decay channels:

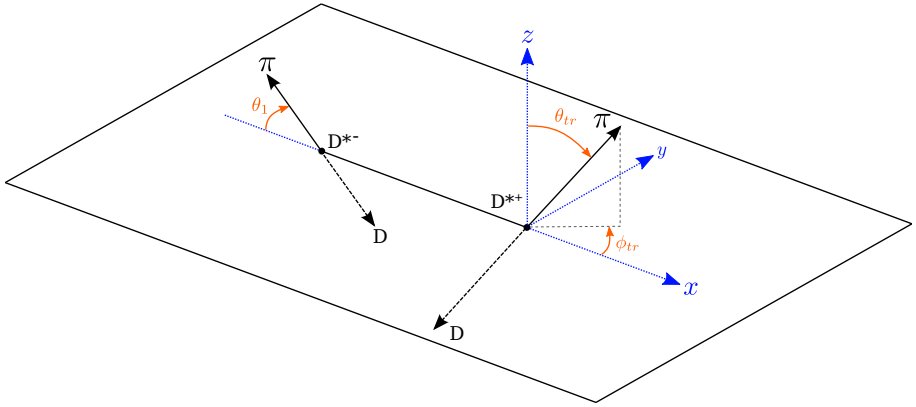
$D^+ \to K^- \pi^+ \pi^+$, $D^+ \to K_S \pi^+$,
$D^+ \to K_S \pi^+ \pi^0$, $D^+ \to K^- K^+ \pi^+$,
$D^0 \to K^- \pi^+$, $D^0 \to K^- \pi^+ \pi^0$,
$D^0 \to K^- \pi^+ \pi^+ \pi^-$, $D^0 \to K_S \pi^+ \pi^-$,
$D^0 \to K^- K^+$

$S \to VV$

$$\mathcal{P}(t) = \frac{1}{4\tau_{B^0}} e^{-|t|/\tau_{B^0}} \left(1 + q\left((1-2P_{\text{odd}})S\sin(\Delta m \cdot t) + A\cos(\Delta m \cdot t)\right)\right)$$

Standard model expectation: $S = \sin 2\phi_1 \quad A \approx 0.01$

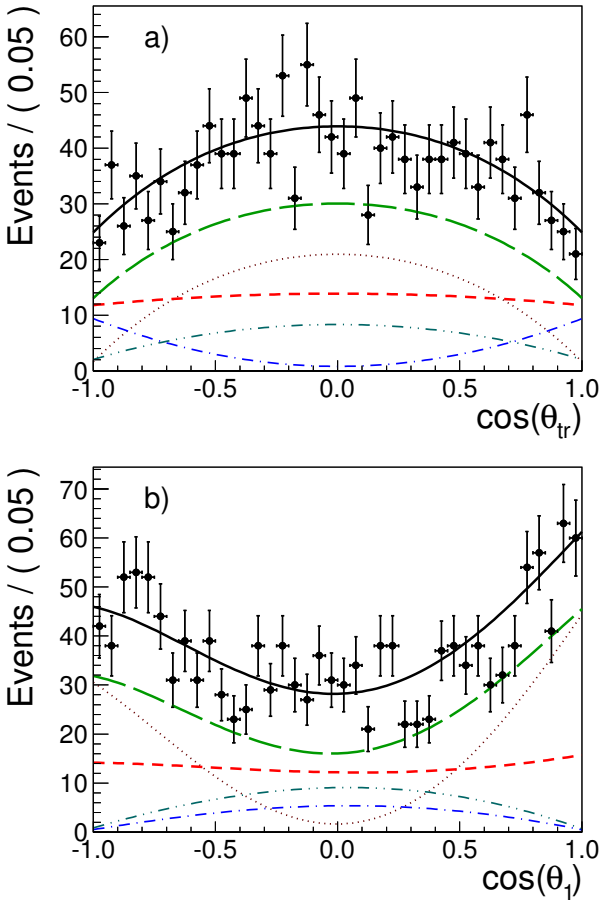
Transversity base



$$P_{\text{odd}} = \frac{f_{\text{odd}} PDF_{\text{odd}}(\cos\theta_{tr}, \cos\theta_1)}{\sum_i f_i PDF_i(\cos\theta_{tr}, \cos\theta_1)}$$

$$R_0 = 0.624 \pm 0.029 \pm 0.007$$
$$R_\perp = 0.138 \pm 0.024 \pm 0.005$$

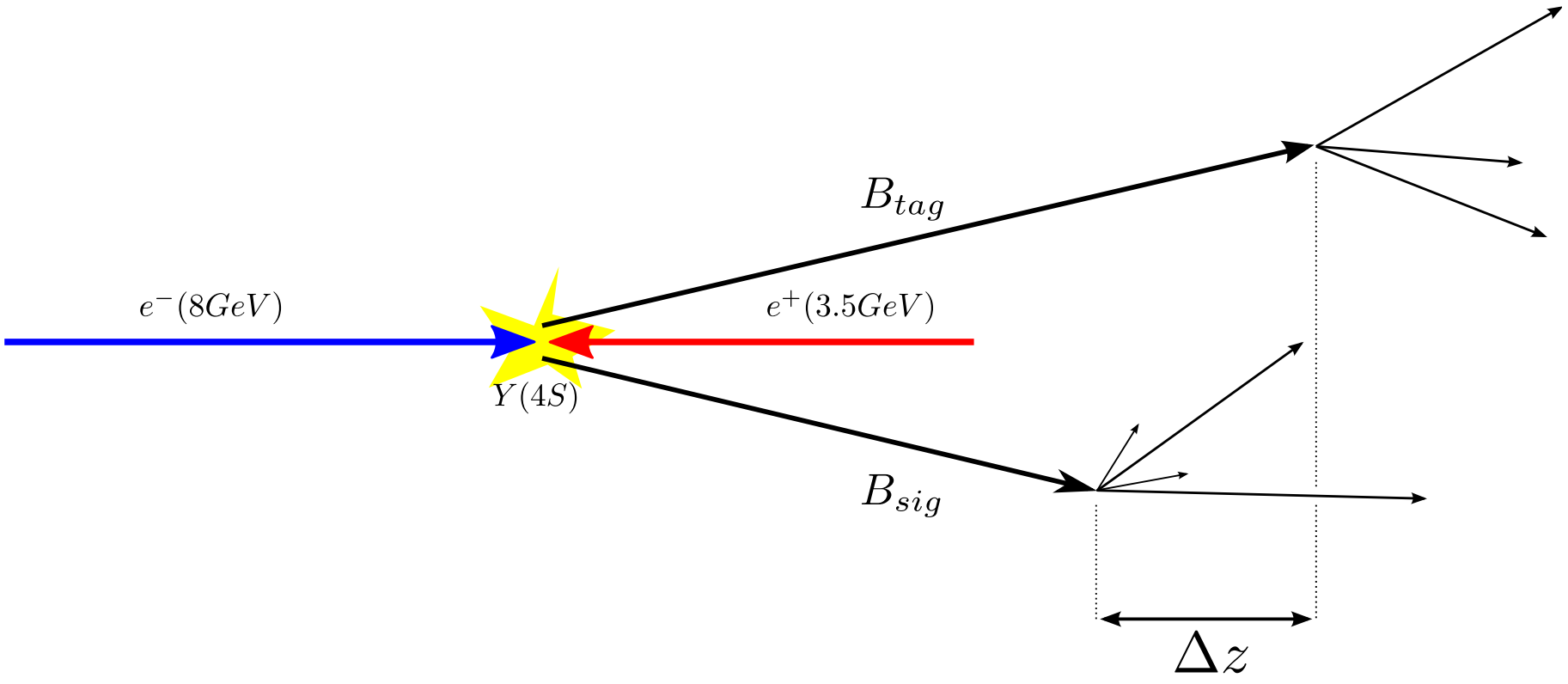
Belle preliminary



green: signal (*CP*-even + *CP*-odd)
red: background
blue: *CP*-odd

Measurement of the *CP*-violation

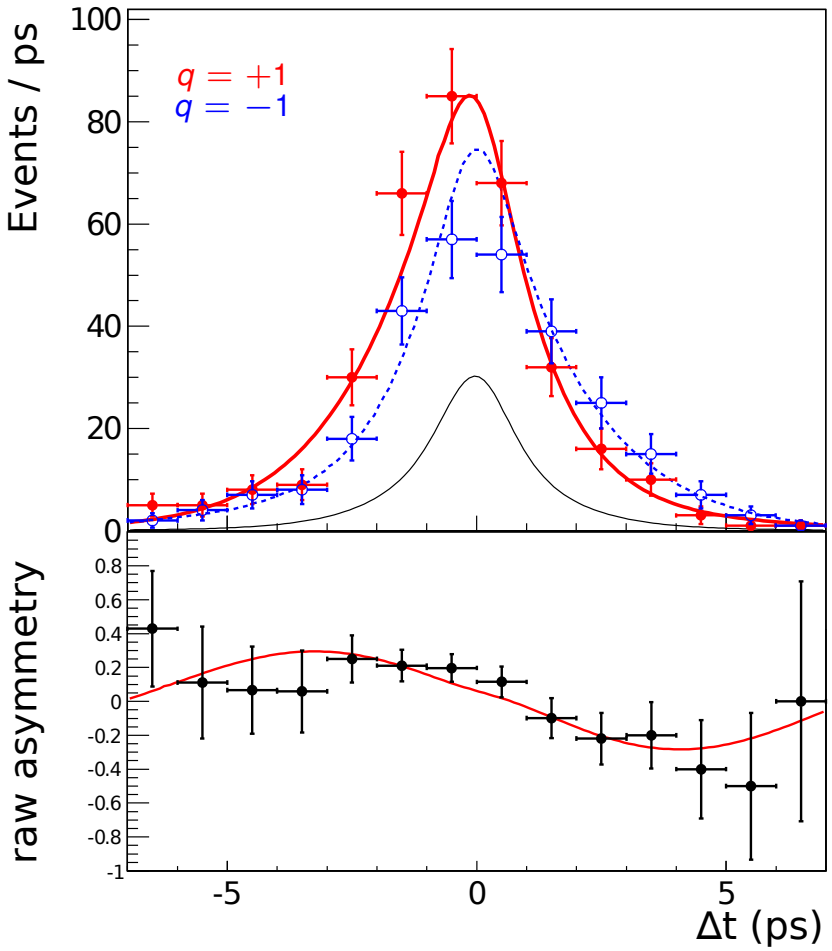
Fit in M_{bc}, ΔE, $\cos\theta_{tr}$, $\cos\theta_1$, and Δt.

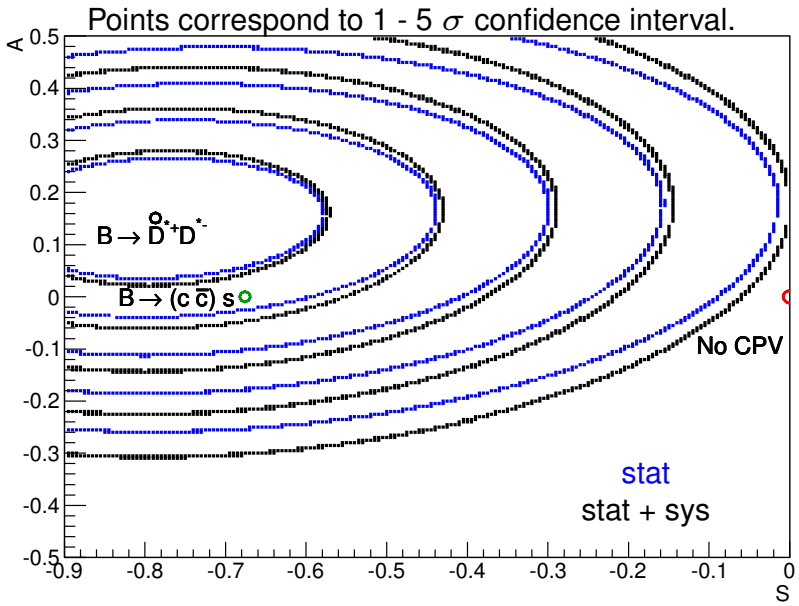


Δz parametrization

$$PDF_{sig}(\Delta t) = \frac{1}{4\tau_{B^0}} e^{-|\Delta t|/\tau_{B^0}} \left(1 - q\Delta w + q(1-2w)\left((1-2P_{odd})S\sin(\Delta m\Delta t) + A\cos(\Delta m\Delta t)\right)\right) \otimes R_{sig}$$

Results





First observation of *CP*-violation in double charm decays.

$$S = -0.79 \pm 0.13 \pm 0.05 \qquad A = 0.15 \pm 0.08 \pm 0.06$$

Belle preliminary

Backup: double charm decays

decay channel	experiment	data sample (M $B\bar{B}$)	S	A	
$B^0 \to D^{*+}D^{*-}$	BaBar	467	$-0.71 \pm 0.16 \pm 0.03$	$-0.05 \pm 0.09 \pm 0.02$	[1]
	Belle	657	$-0.96 \pm 0.25^{+0.12}_{-0.16}$	$0.15 \pm 0.13 \pm 0.04$	[2]
		772	$-0.79 \pm 0.13 \pm 0.05$	$0.15 \pm 0.08 \pm 0.06$	Belle preliminary
$B^0 \to D^{+}D^{-}$	BaBar	467	$-0.65 \pm 0.36 \pm 0.05$	$0.07 \pm 0.23 \pm 0.03$	[3]
	Belle	535	$-1.13 \pm 0.37 \pm 0.09$	$0.91 \pm 0.23 \pm 0.06$	[4]
		772	$-1.06 \pm 0.21 \pm 0.07$	$0.43 \pm 0.17 \pm 0.04$	Belle preliminary
$b \to (c\bar{c})s$	HFAG	-	0.676 ± 0.020		[5]

[1] PRD 79, 032002 (2009)
[2] PRD 80, 111104 (2009)
[3] PRD 79, 032002 (2009)
[4] PRL 98, 221802 (2007)
[5] HFAG average Winter 2011

Backup: systematics

Branching fraction

Source	Systematic error (%)
Charged track reconstruction	± 1.7
K_S reconstruction	± 0.8
π^0 reconstruction	± 3.0
Slow pion reconstruction	± 3.2
K/π selection efficiency	± 5.0
$N_{B\bar{B}}$	± 1.4
Fit model	± 0.2
D and D^* branching fractions	± 3.1
Event reconstruction	± 0.8
Total	± 7.8

CPV parameters

	S	A	R_0	$R_\perp$
Fit model	± 0.002	< 0.001	± 0.005	± 0.002
Physics parameters	± 0.004	± 0.001	± 0.001	< 0.001
Flavor tagging	± 0.003	± 0.002	< 0.001	< 0.001
Tag side interference	± 0.007	± 0.032	± 0.002	± 0.001
Δt signal resolution	± 0.021	± 0.006	± 0.001	± 0.001
Reconstruction efficiencies	< 0.001	< 0.001	± 0.002	± 0.001
Vertexing	± 0.017	± 0.021	± 0.004	± 0.004
Total	± 0.029	± 0.038	± 0.007	± 0.005