Study of $D^+_{(s)}$ decay properties at Belle

Division of Particles and Fields, Jul 26-31 2009, Wayne State University

Soohyung Lee, Byeongrok Ko and Eunil Won (Korea University)
on behalf of the Belle Collaboration

Contents

- Doubly Cabibbo Suppressed Decay (DCSD) of $D^+_{(s)}$
  - Motivation
  - Event Selection
  - Additional Background Suppression
  - Observation of $D^+_s \to K^+K^+\pi^-$
  - Systematics
  - Result

- The Relative Branching Fractions of $D^+_{(s)} \to K_S h^+$
  - Motivation
  - Event Selection
  - Selection Optimization
  - Result
  - Systematics and Branching Ratios
  - Comparison with Other Results

- Summary

Doubly Cabibbo Suppressed Decay of $D^+_{(s)}$

The first observation of $D_s^+ \to K^+K^+\pi^-$, DCS decay

Motivation

- Doubly Cabibbo Suppressed (DCS) decays have been observed in D^0 and D^+ only

- According to the Standard Model (SM)
  - Naive expectation: DCS decay rate is $\sim \mathcal{O}(\tan^4\theta_C)$ relative to its Cabibbo-favored (CF) counterpart
  - Expected branching ratios
    - $D^+ \to K^+\pi^+\pi^-$ is $\sim 2\tan^4\theta_C$ relative to its CF counterpart
    - $D_s^+ \to K^+K^+\pi^-$ is $\sim 1/2\tan^4\theta_C$ relative to its CF counterpart
  - SU(3) flavor symmetry (Lipkin, NPB **115** 117 (2003))

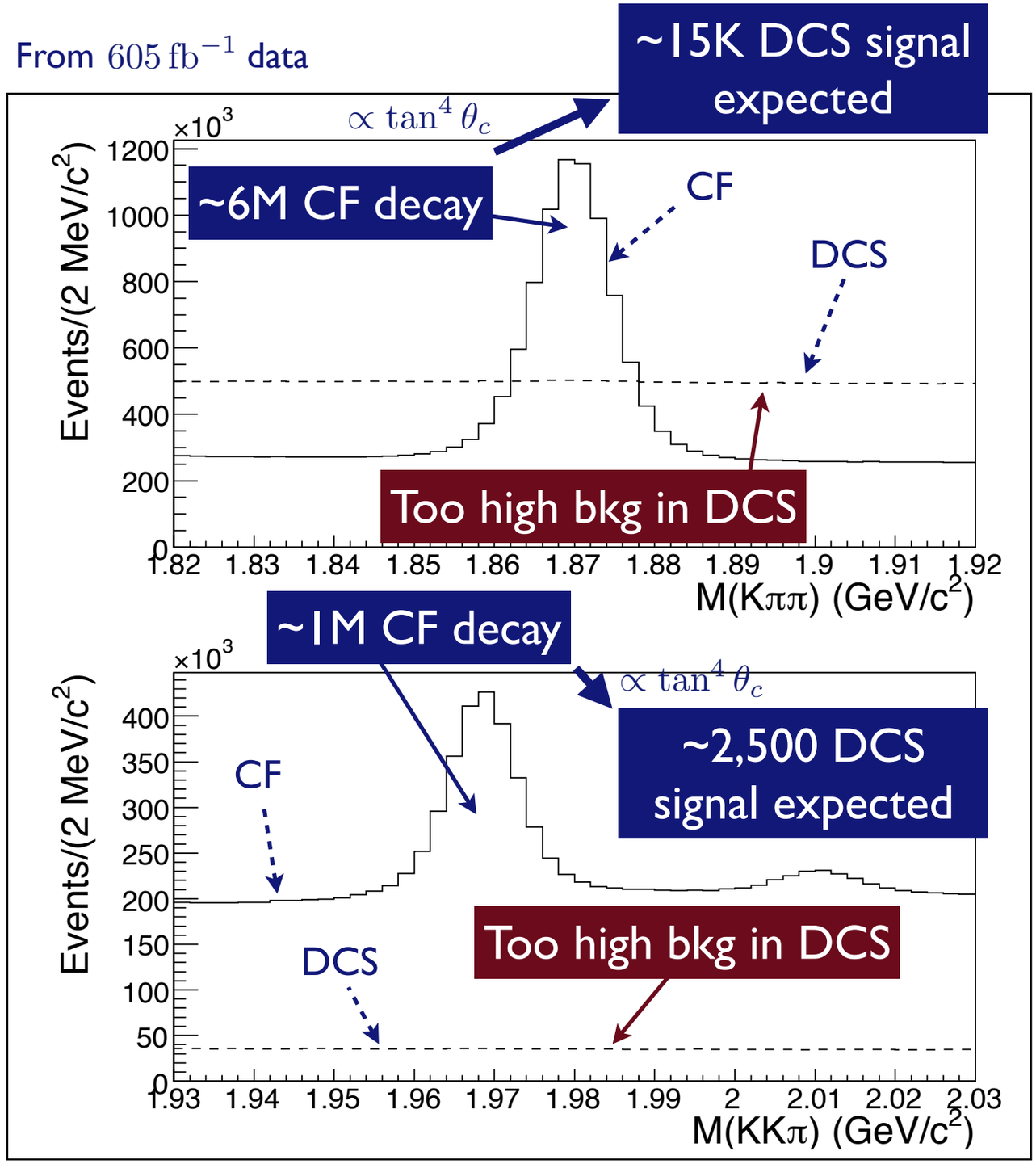
$$\frac{\mathcal{B}(D_s^+ \to K^+K^+\pi^-)}{\mathcal{B}(D_s^+ \to K^+K^-\pi^+)} \frac{\mathcal{B}(D^+ \to K^+\pi^+\pi^-)}{\mathcal{B}(D^+ \to K^-\pi^+\pi^+)} = \tan^8\theta_C$$

- Unique place to test SU(3) flavor symmetry with $\tan^8\theta_C$

Event Selection

- B-Factory usual cuts for initial selection

Charged Track
Impact Parameter: $\lvert dr\rvert < 2cm$ $\lvert dz\rvert < 4cm$ # of SVD hits > 1 CL of decay vertex fit with 3 charged tracks > 0.1%
Particle Identification
$\frac{\mathcal{L}(K)}{\mathcal{L}(K)+\mathcal{L}(\pi)} > 0.6$ for K $\quad$ $\frac{\mathcal{L}(K)}{\mathcal{L}(K)+\mathcal{L}(\pi)} < 0.6$ for π
Scaled Momentum
$x_p = \frac{p^*}{\sqrt{0.25E_{CM}^2 - M^2}} > 0.5$

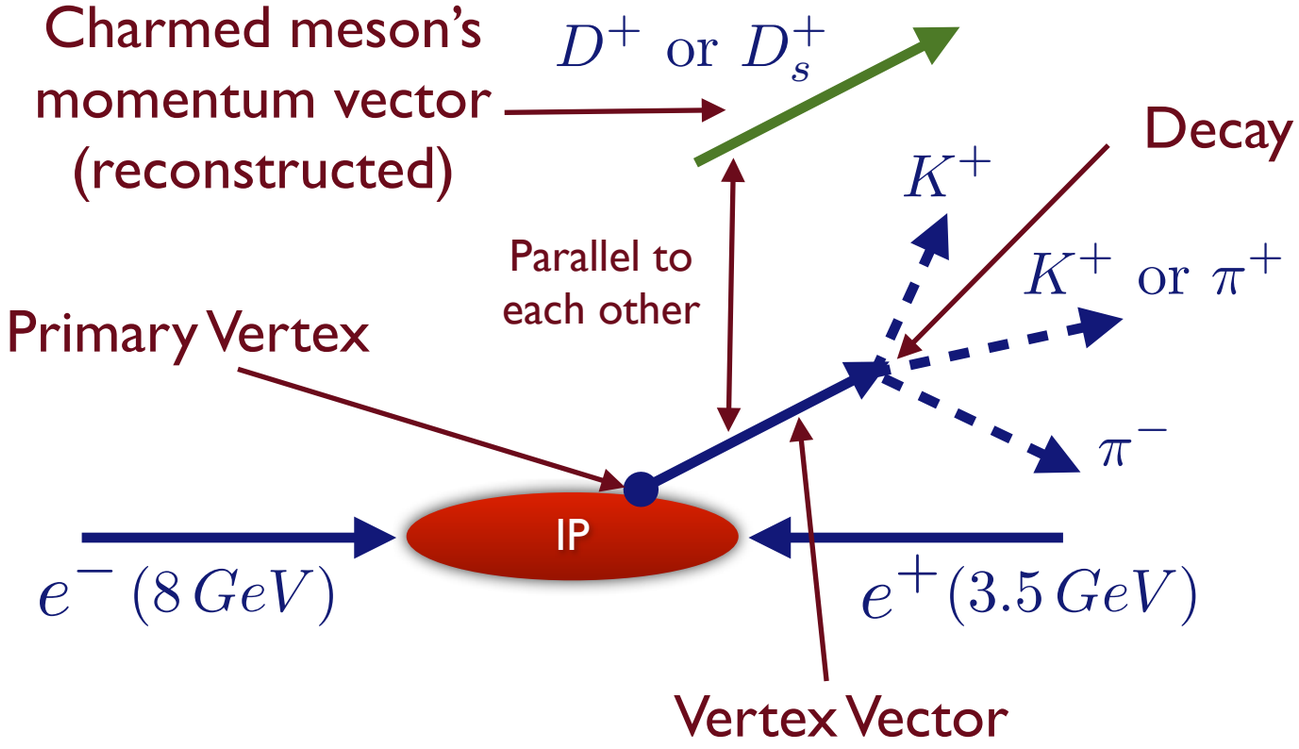


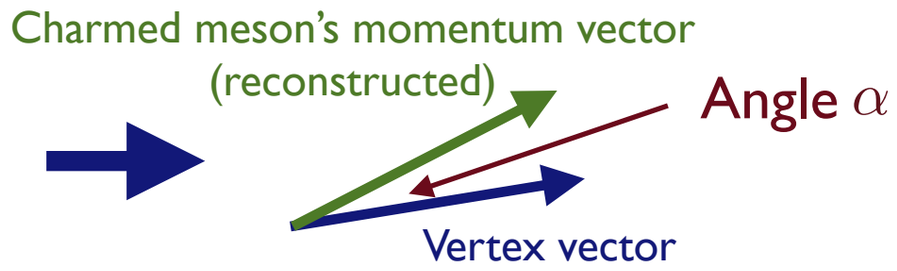
- Too high background level to find DCS signal
  - Solid curve: CF decay channel
  - Dashed curve: DCS decay channel

Additional Background Suppression

- To improve signal sensitivity, further cuts are applied
  - Angle Cut
  - Isolation Cut

- Angle Cut
  - Angle between charmed meson momentum vector and vertex vector
  - In an ideal case, the vectors are parallel to each other

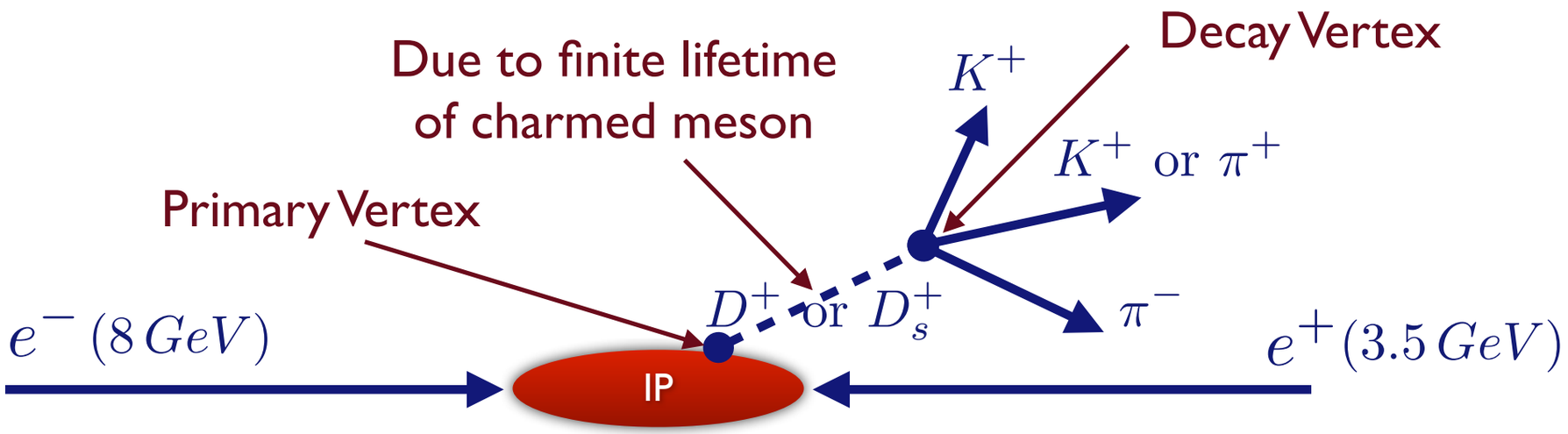




Angle (α) criteria	
D^+	$< 1°$
D_s^+	$< 2°$

Additional Background Suppression (Cont'd)

- Isolation Cut
  - Daughter particles are incompatible with the primary vertex due to finite lifetime of D^+ and D_s^+
  - Hypothesis: χ^2 fit between primary vertex and daughters of charmed meson

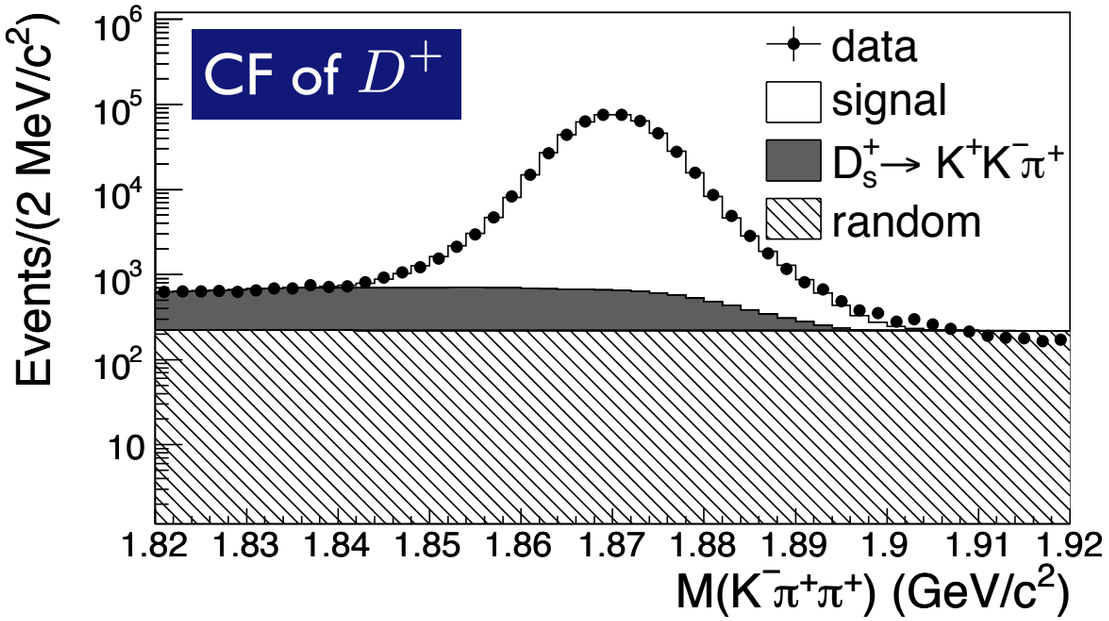


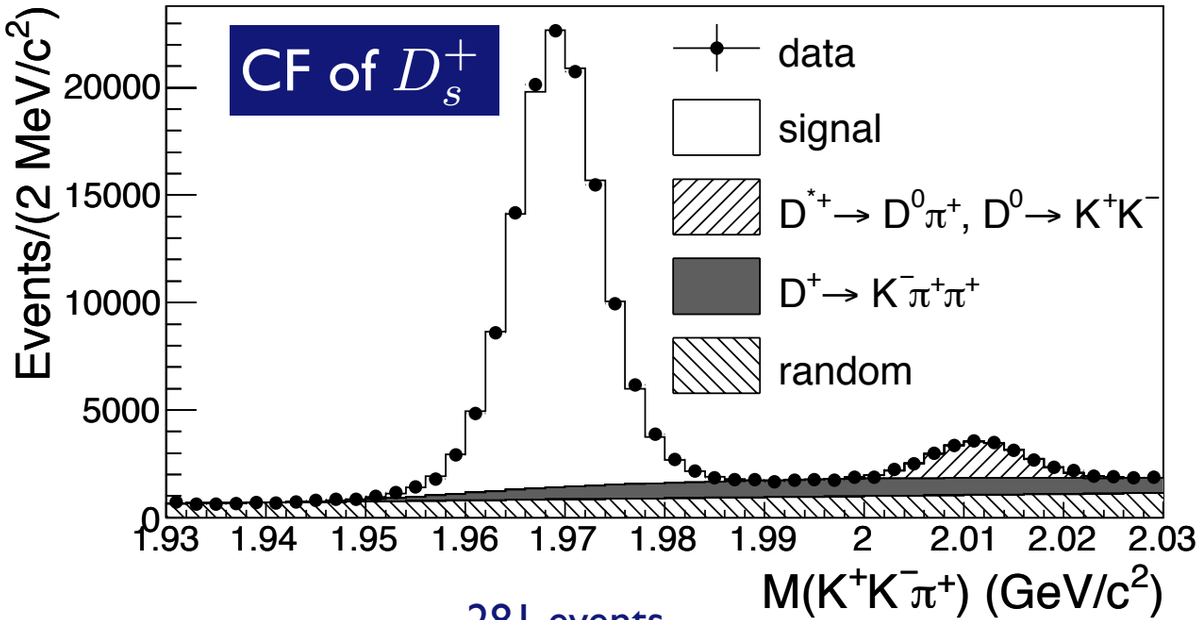
Reduced χ^2 criteria	D^+	> 25
	D_s^+	> 5

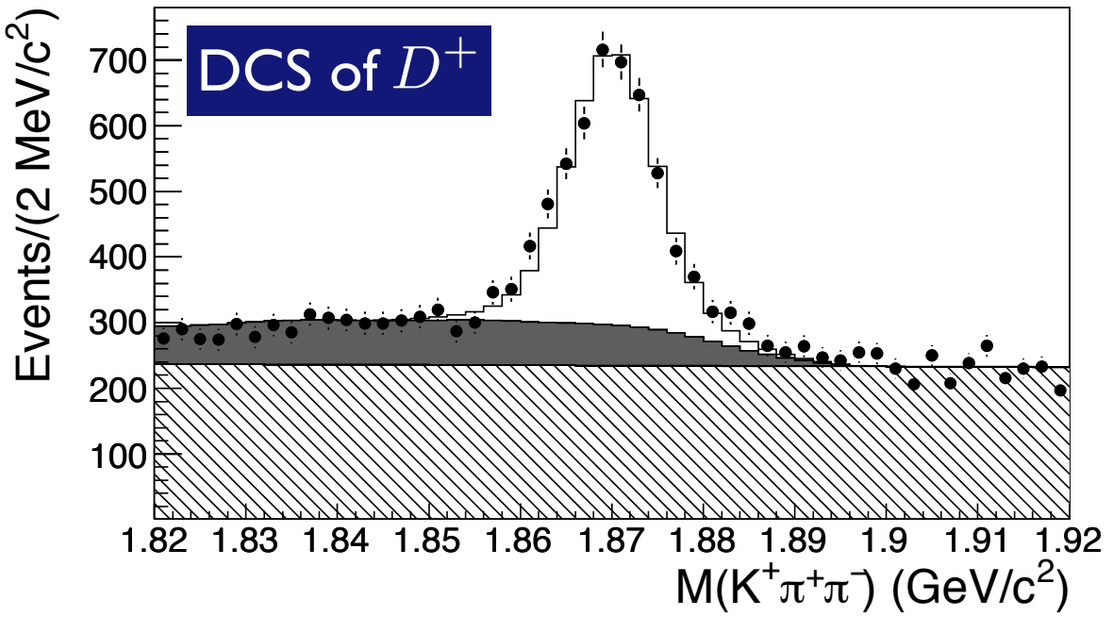
Observation of $D_s^+ \to K^+K^+\pi^-$

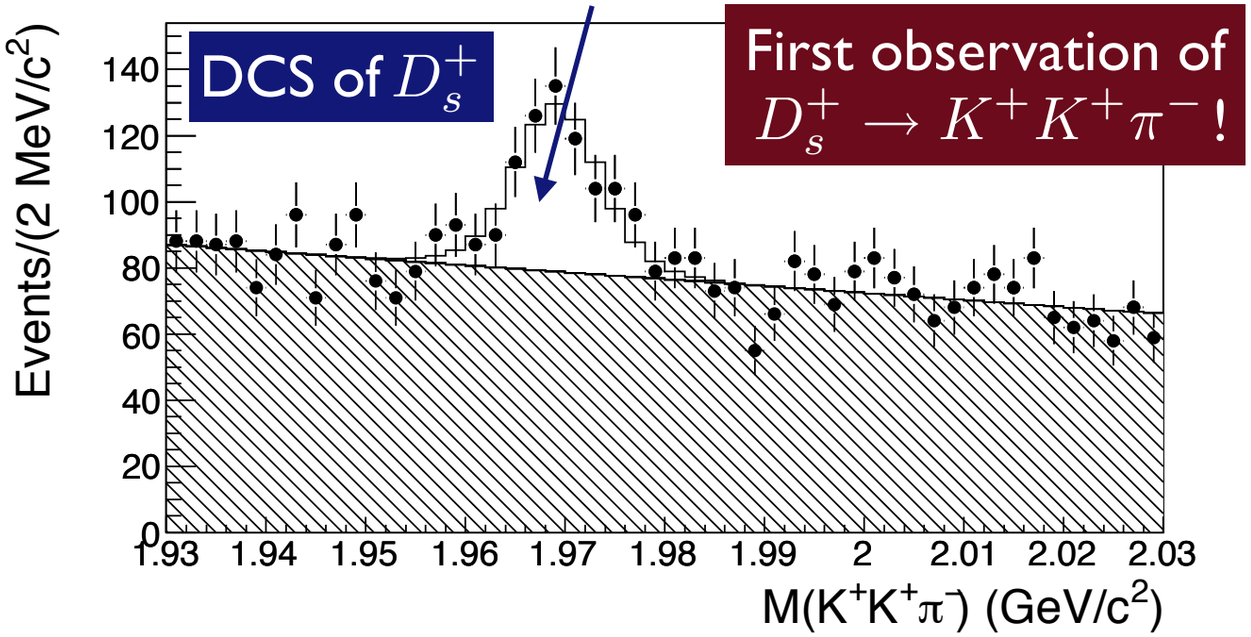
From $605\,\mathrm{fb}^{-1}$ data

PRL **102** 221802 (2009)









- There are contributions from K/π misidentification
- D^{*+} contribution is fit as an independent Gaussian component

Systematics

- Relative systematic uncertainties

Source	$\sigma_{\mathcal{B}_{rel}(D^+)}(\%)$	$\sigma_{\mathcal{B}_{rel}(D_s^+)}(\%)$
Fitting	1.9	4.2
MC statistics	0.8	1.0
Reconstruction efficiency	1.5	3.1
Total	2.5	5.3

Result

- Relative branching fraction

Branching fraction	Belle (%)	World Average (PDG 2008, %)
$\frac{\mathcal{B}(D^+ \to K^+\pi^+\pi^-)}{\mathcal{B}(D^+ \to K^-\pi^+\pi^+)}$	$0.569 \pm 0.018 \pm 0.014$	0.68 ± 0.08
$\frac{\mathcal{B}(D_s^+ \to K^+K^+\pi^-)}{\mathcal{B}(D_s^+ \to K^+K^-\pi^+)}$	$0.229 \pm 0.028 \pm 0.012$	$< 0.78\%$ @ 90% C.L.

- SU(3) flavor symmetry

$$\frac{\mathcal{B}(D_s^+ \to K^+K^+\pi^-)}{\mathcal{B}(D_s^+ \to K^+K^-\pi^+)} \frac{\mathcal{B}(D^+ \to K^+\pi^+\pi^-)}{\mathcal{B}(D^+ \to K^-\pi^+\pi^+)} = (1.57 \pm 0.21) \cdot \tan^8\theta_C$$

From this study
PRL **102** 221802 (2009)

$$\frac{\mathcal{B}(D_s^+ \to K^+K^+\pi^-)}{\mathcal{B}(D_s^+ \to K^+K^-\pi^+)} \frac{\mathcal{B}(D^+ \to K^+\pi^+\pi^-)}{\mathcal{B}(D^+ \to K^-\pi^+\pi^+)} = \tan^8\theta_C$$

Lipkin, NPB **115** 117 (2003)

Study of $D^+_{(s)} \to K_S h^+$

Measurement of the relative branching fractions of
$D^+ \to K_S K^+$ *and* $D^+_s \to K_S \pi^+$

Motivation

- Cabibbo-suppressed (CS) decay
  - No measurement of $D_s^+ \to K_S\pi^+$ from B-Factories
  - Few measurements of $D_s^+ \to K_S\pi^+$ so far (FOCUS and CLEO)
  - Large error in current world average (~10%)
  - High precision measurement is required

- Better understanding of SU(3) flavor symmetry

- Update of measurements of branching ratios of $D_{(s)}^+ \to K_S h^+$
  - Previous measurements

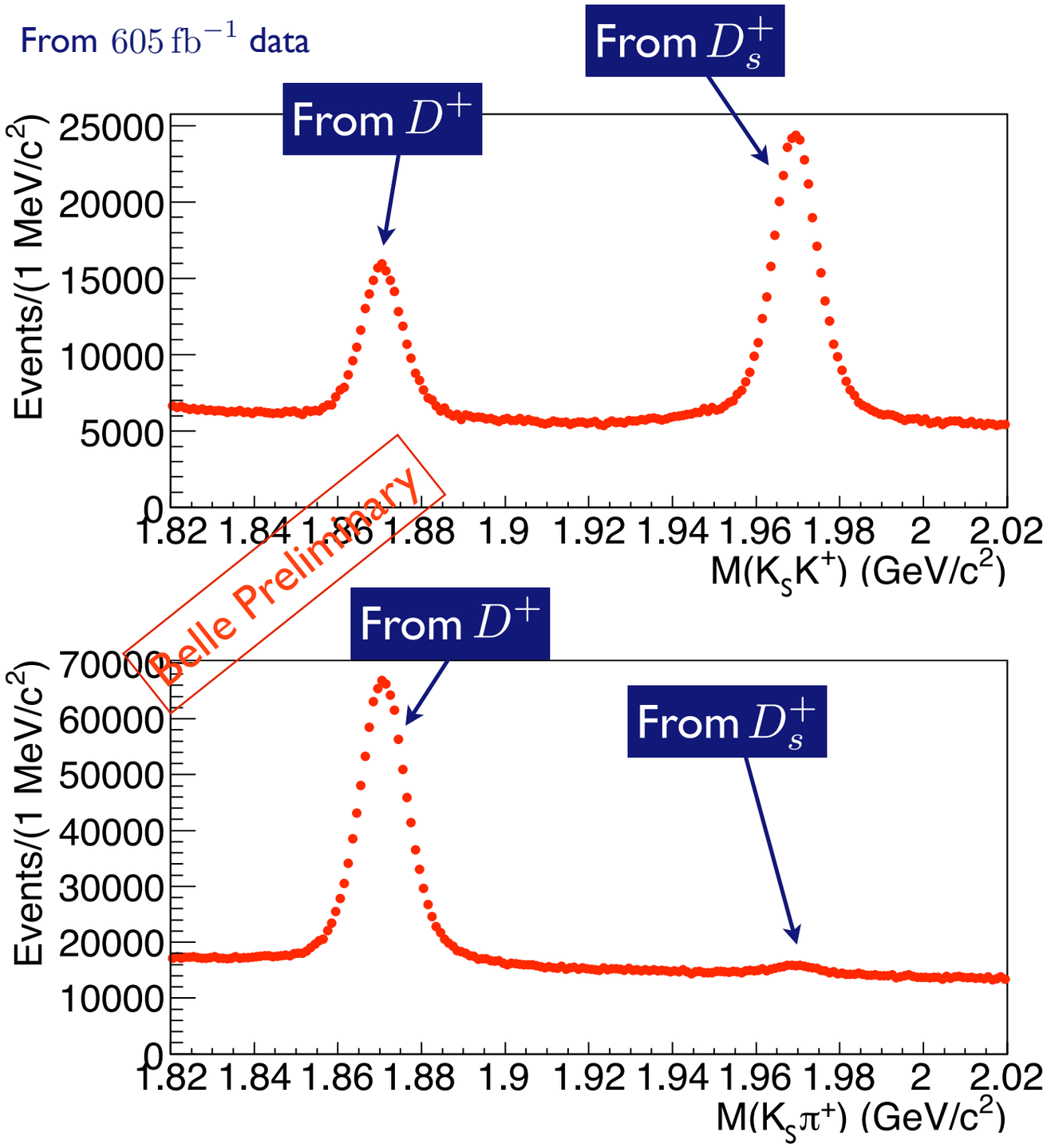
Mode	PDG 2008	CLEO 2009(*)
$\frac{\mathcal{B}(D^+ \to K_S K^+)}{\mathcal{B}(D^+ \to K_S\pi^+)}$	0.206 ± 0.014	0.199 ± 0.007
$\frac{\mathcal{B}(D_s^+ \to K_S\pi^+)}{\mathcal{B}(D_s^+ \to K_S K^+)}$	0.084 ± 0.009	0.085 ± 0.007

(*) Our calculation from CLEO arXiv:0906.3198v1 (including systematics)

Event Selection

- B-Factory usual cuts for initial selection

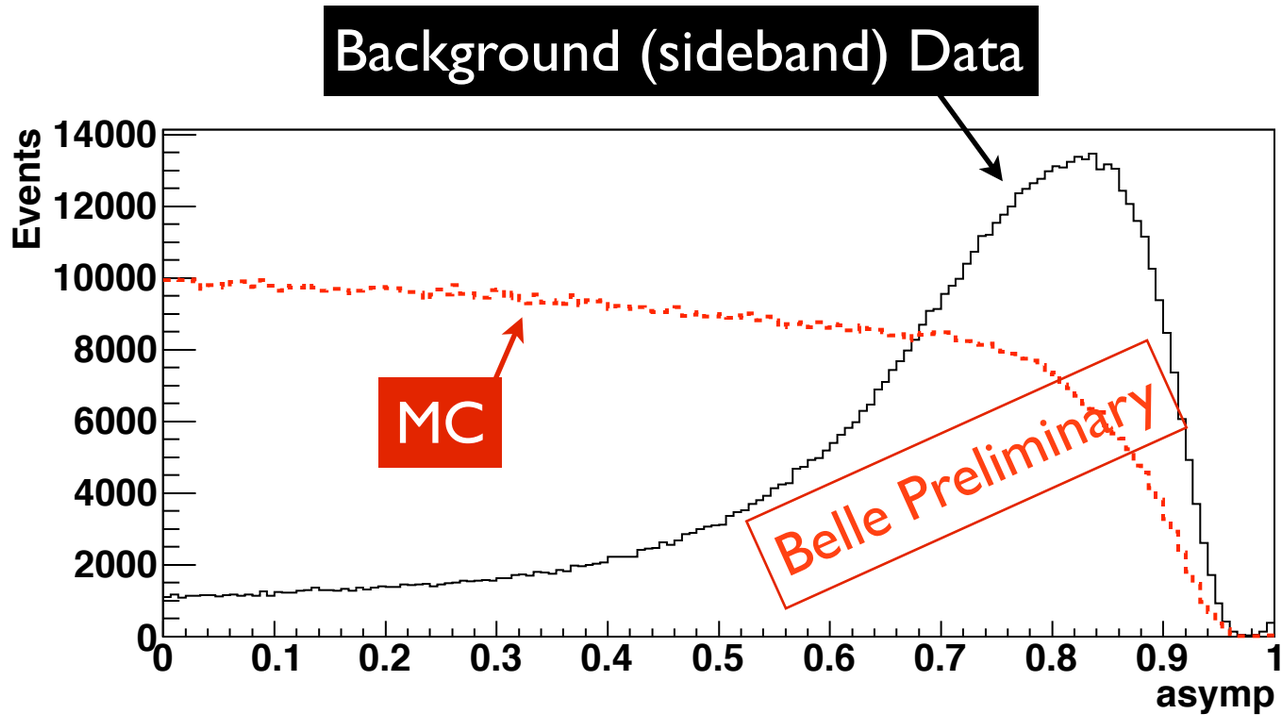
Charged Track
Impact Parameter: $\lvert dr\rvert < 2cm \quad \lvert dz\rvert < 4cm$ # of SVD hits > 1 CL of decay vertex fit ($K_s h^+$) > 0.1%
Particle Identification
$\frac{\mathcal{L}(K)}{\mathcal{L}(K)+\mathcal{L}(\pi)} > 0.6 \quad \text{for } K$ $\frac{\mathcal{L}(K)}{\mathcal{L}(K)+\mathcal{L}(\pi)} < 0.6 \quad \text{for } \pi$
K_S Mass Window
$0.4886\ GeV < m(K_S) < 0.5066\ GeV$
Vertex Fit between h^+ and daughters of K_S
Reduced χ^2 of vertex fit > 10
Center-of-mass Momentum
$p^* > 2.6\,GeV$



Selection Optimization

- Maximized the expected signal significance ($\mathcal{N}_S/\sigma_{\mathcal{N}_S}$) using the single variable

$$\text{asymp} \equiv \frac{|p_{K_s} - p_{h+}|}{|p_{K_s} + p_{h+}|}$$

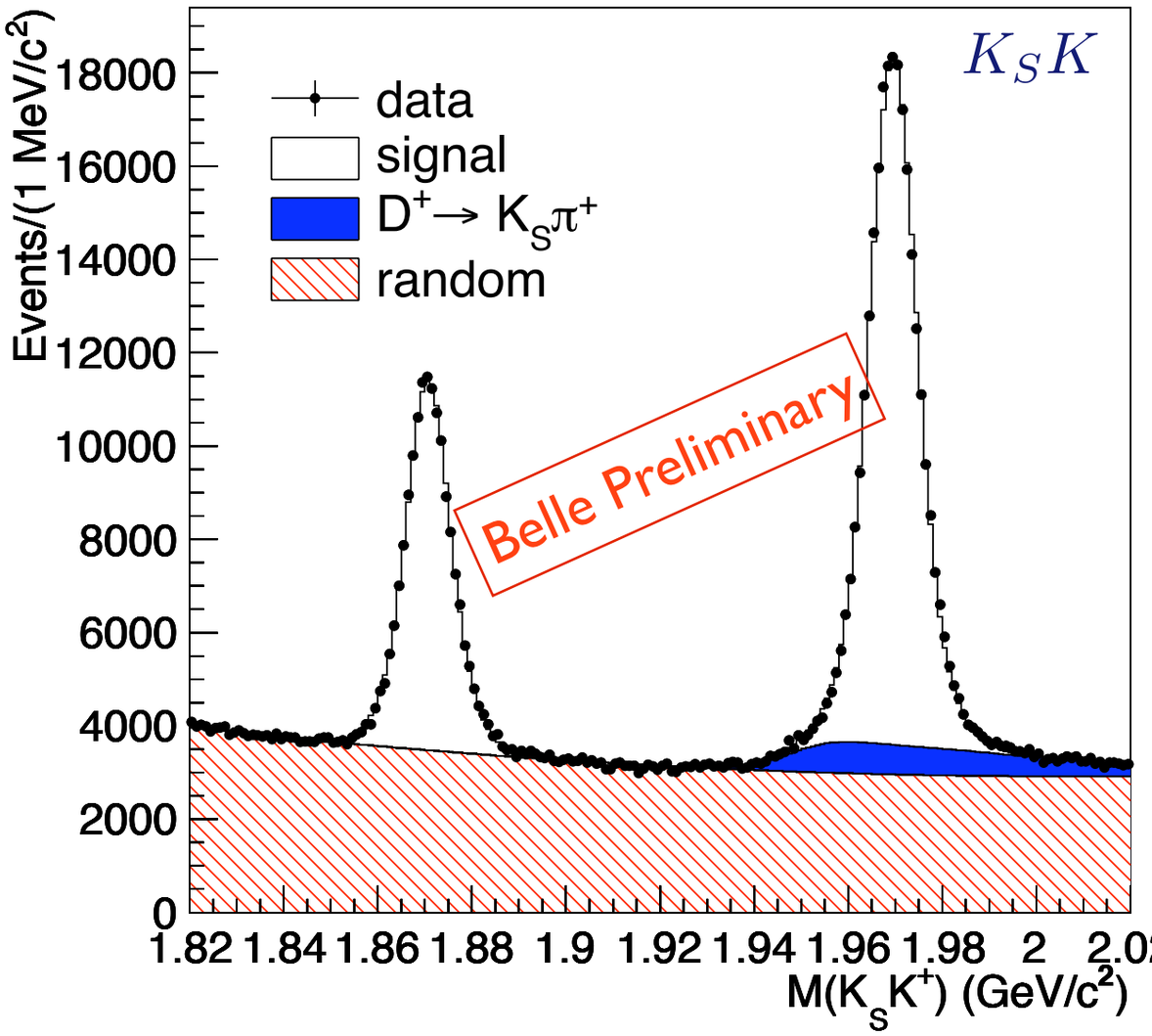


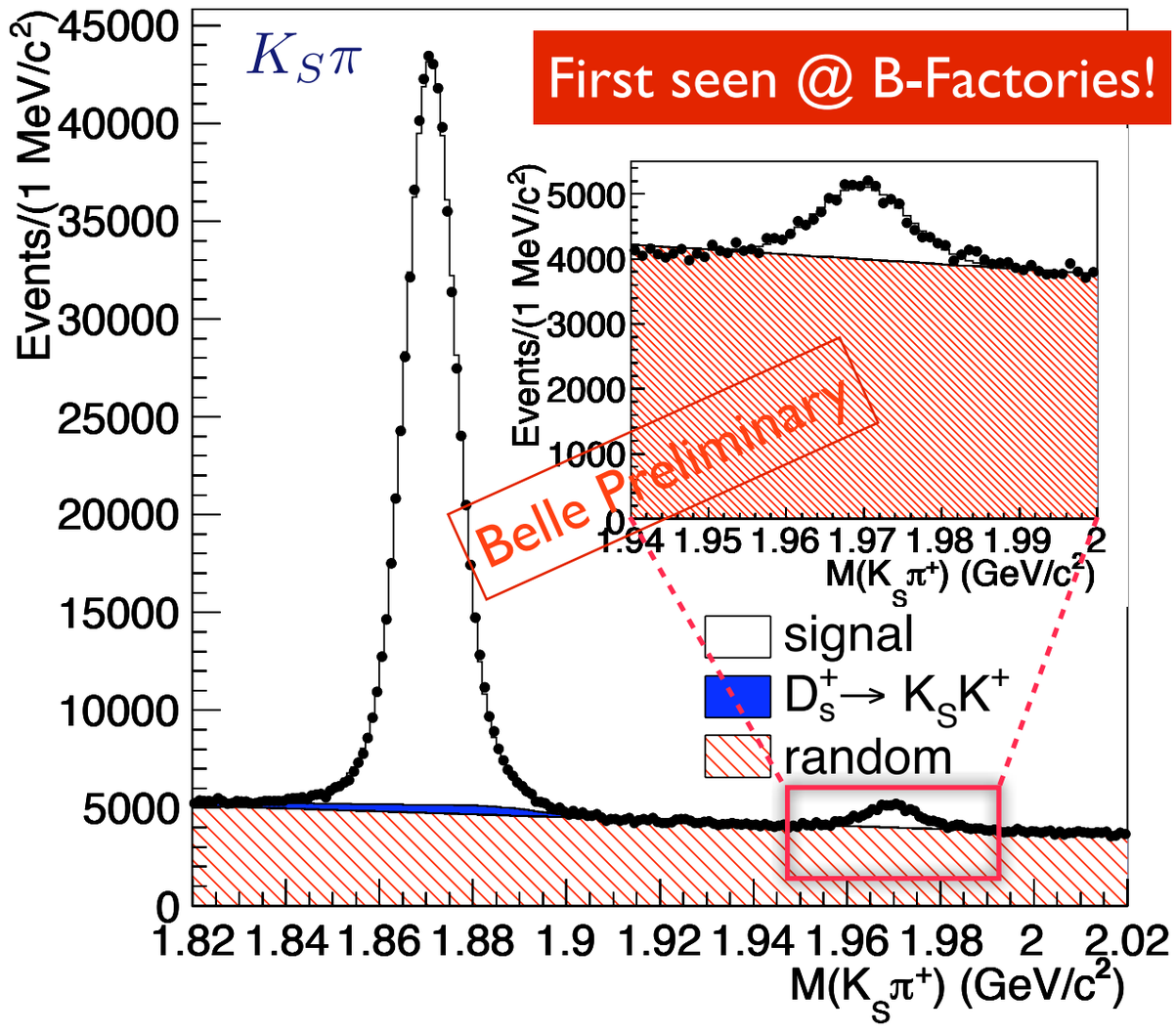
- From FOM study,
  - asymp < 0.6

- Reflection Backgrounds
  - Due to K/π misidentification, there are peaking backgrounds
    - $D_s^+ \to K_S K^+$ under $D^+ \to K_S \pi$ signal region
    - $D^+ \to K_S \pi^+$ under $D_s^+ \to K_S K$ signal region
  - Extract these reflection backgrounds by using MC

Result

From $605\,\mathrm{fb}^{-1}$ data





Decay Modes	Yields
$D^+ \to K_S K^+$	100855 ± 561
$D_s^+ \to K_S K^+$	204093 ± 768
$D^+ \to K_S \pi^+$	566105 ± 1159
$D_s^+ \to K_S \pi^+$	16817 ± 448

Preliminary Fit Yields

Systematics and BRs

- Systematics
  - Systematic uncertainties from PID are dominant as expected

Sources	$\frac{\mathcal{B}(D^+ \to K_S K^+)}{\mathcal{B}(D^+ \to K_S \pi^+)}$ (%)	$\frac{\mathcal{B}(D_s^+ \to K_S \pi^+)}{\mathcal{B}(D_s^+ \to K_S K^+)}$ (%)
PID	0.90	0.90
fit method	0.15	0.39
single gaussian for $D_s^+ \to K_S \pi^+$	negligible	2.61
Total	0.91	2.79

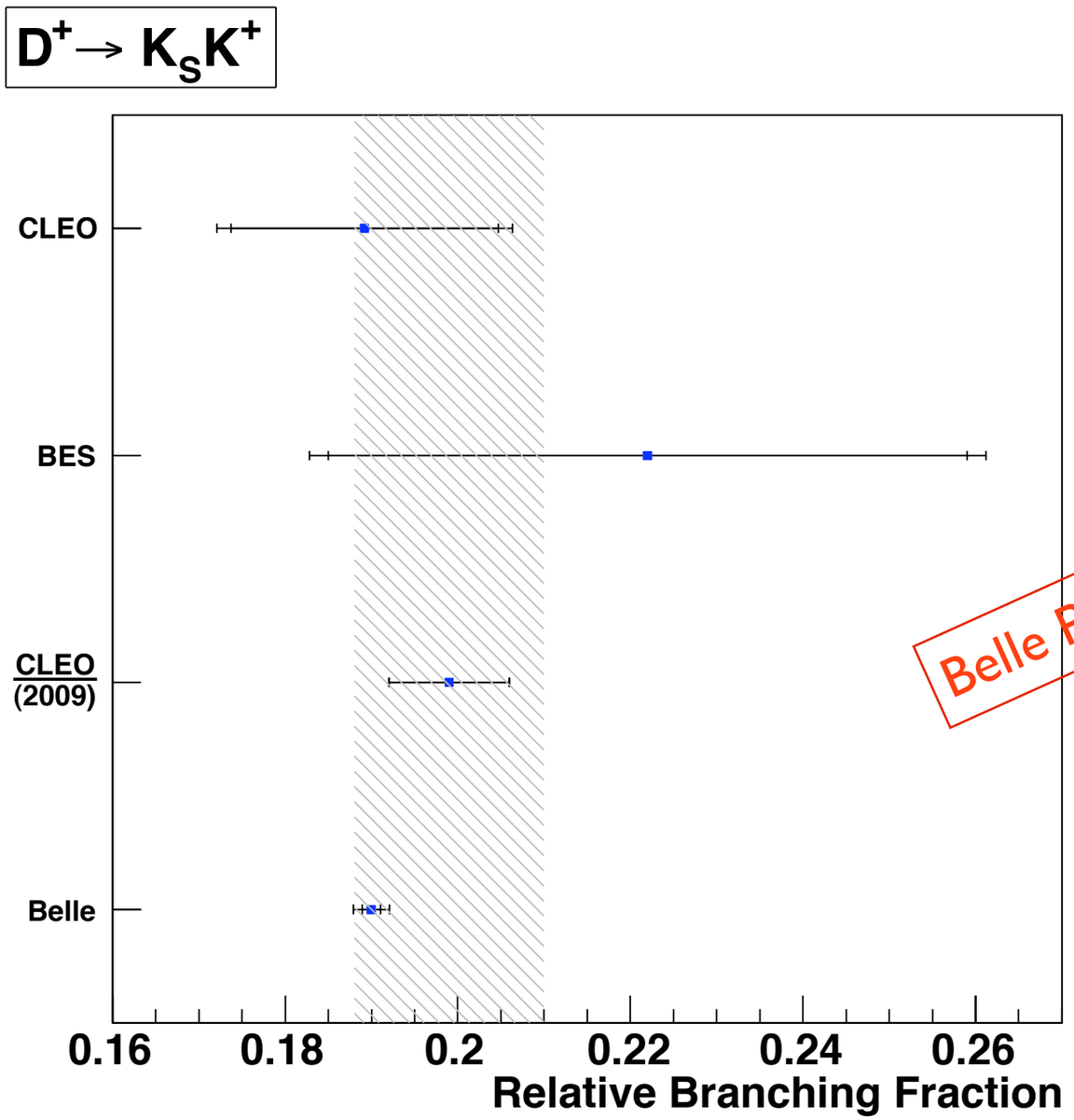
- Branching Ratios (preliminary)

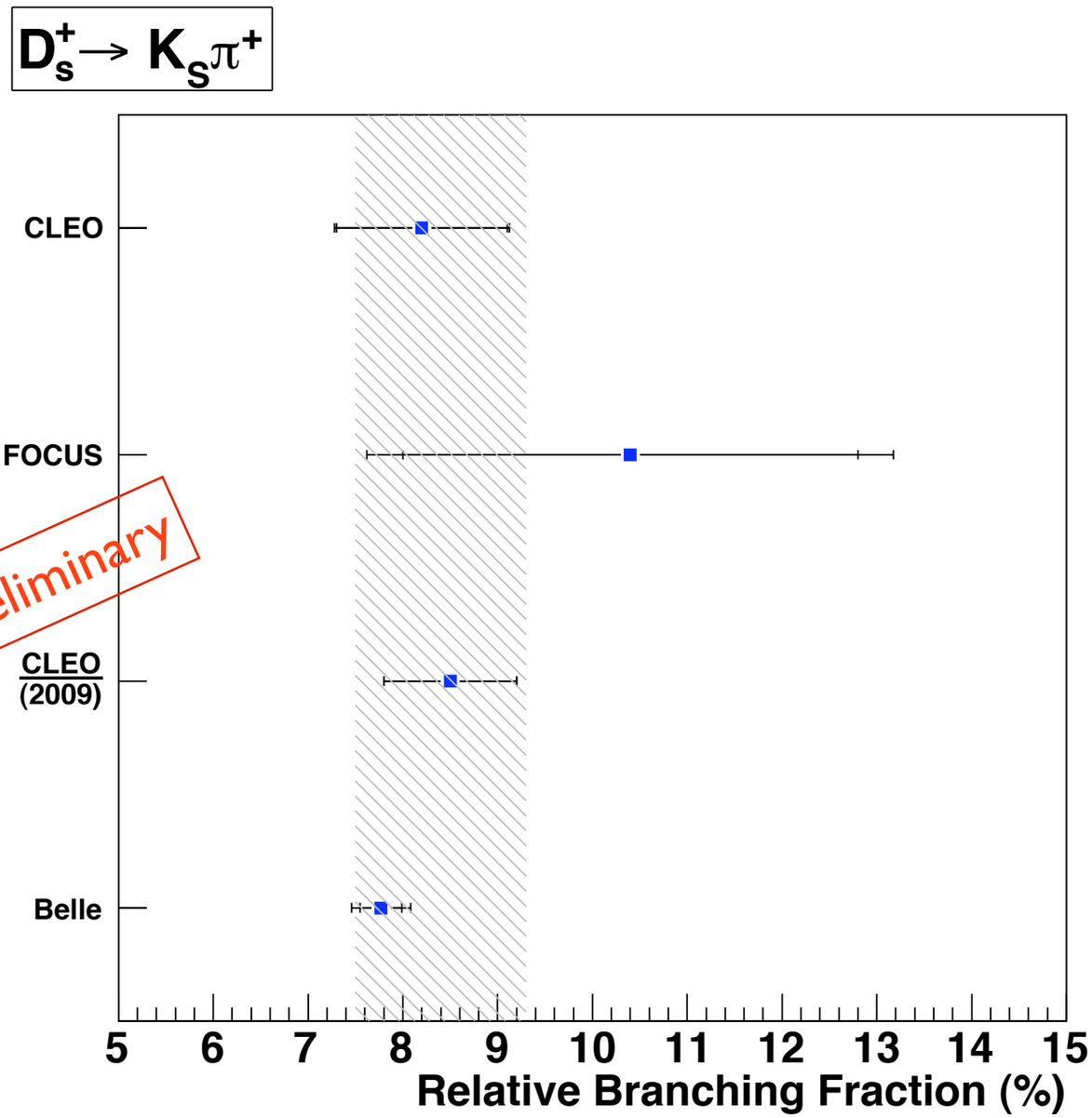
$$\frac{\mathcal{B}(D^+ \to K_S K^+)}{\mathcal{B}(D^+ \to K_S \pi^+)} = 0.190 \pm 0.001 \pm 0.002$$

$$\frac{\mathcal{B}(D_s^+ \to K_S \pi^+)}{\mathcal{B}(D_s^+ \to K_S K^+)} = 0.077 \pm 0.002 \pm 0.002$$

Most precise!

Comparison with Other Results





$$\frac{\mathcal{B}(D^+ \to K_S K^+)}{\mathcal{B}(D^+ \to K_S \pi^+)} = 0.190 \pm 0.001 \pm 0.002$$

$$\frac{\mathcal{B}(D_s^+ \to K_S \pi^+)}{\mathcal{B}(D_s^+ \to K_S K^+)} = 0.077 \pm 0.002 \pm 0.002$$

Highest Precision Measurement for these BRs Ever!

Summary

Doubly Cabibbo Suppressed Decay of $D^+_{(s)}$

Observed for the first time (PRL **102** 221802 (2009))

Branching fraction	Belle (%)	World average (PDG 2008, %)
$\frac{\mathcal{B}(D^+ \to K^+\pi^+\pi^-)}{\mathcal{B}(D^+ \to K^-\pi^+\pi^+)}$	$0.569 \pm 0.018 \pm 0.014$	0.68 ± 0.08
$\frac{\mathcal{B}(D_s^+ \to K^+K^+\pi^-)}{\mathcal{B}(D_s^+ \to K^+K^-\pi^+)}$	$0.229 \pm 0.028 \pm 0.012$ First Observation!	$< 0.78\%$ @ 90% C.L.

$$\frac{\mathcal{B}(D_s^+ \to K^+K^+\pi^-)}{\mathcal{B}(D_s^+ \to K^+K^-\pi^+)} \frac{\mathcal{B}(D^+ \to K^+\pi^+\pi^-)}{\mathcal{B}(D^+ \to K^-\pi^+\pi^+)} = (1.57 \pm 0.21) \cdot \tan^8 \theta_C$$

Study of $D^+_{(s)} \to K_S h^+$

Most precise BRs are obtained (preliminary)

Preliminary ratios of CS/CF

$$\frac{\mathcal{B}(D^+ \to K_s K^+)}{\mathcal{B}(D^+ \to K_s \pi^+)} = 0.190 \pm 0.001 \pm 0.002$$

$$\frac{\mathcal{B}(D_s^+ \to K_s \pi^+)}{\mathcal{B}(D_s^+ \to K_s K^+)} = 0.077 \pm 0.002 \pm 0.002$$

Most precise measurement fot these BRs!


KOREA
UNIVERSITY
1905