Charm Hadrons and Decays at Belle

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On behalf of the Belle Collaboration

OUTLINE:

(1) Introduction
(2) Measurement of $B \to D D_{s0}(2317)^+$
and search for hypothesized isospin partner $F(2317)_{s0}^{++}$
(3) New Measurement of Double C.-S. $D^0 \to K^+\pi^-\pi^+\pi^-$
(4) New Measurement of leptonic and hadronic D_s^+ Decays and extraction of f_{Ds}
(5) First Observation of C.-S. Ξ_c^0 Decays
(6) Summary

Charm Hadrons at Belle

At B-factories we study not only CPV in B decays but also

τ-lepton and charm mesons (with open or hidden charm) and baryons.

Charmed hadron decays is an excellent laboratory to study the dynamics of light system in the environment of heavy C-quark. ⇒ Many theoretical predictions and approaches could be tested.

Numerous results have been already obtained by Belle on charm spectroscopy and decays
(see Physics Achievements from the Belle Experiment, Prog. Theor. Exp. Phys. **2012 (2012) 04D001**).

In this talk we present the latest results on charm hadrons at Belle.

Measurement of $B \to DD_{s0}^{+}$ and Search for Hypothesized $F_{s0}(2317)^{++}$ (introduction)

$M_{D_{s0}^+} = 2317.8 \pm 0.6$ MeV

$M_{D_0^*} = 2318 \pm 29$ MeV

$D_{s0}(2317)+$ below DK thr. → ther.Speculation – not a simple cs meson

$D_{s0}^+ \to D_s^+ \pi^0$ or the electromagnetic process $D_{s0}^+ \to D_s^{*+} \gamma$

$$R(D_{s0}^+) \equiv \frac{\Gamma(D_{s0}^+ \to D_{s0}^+ \gamma)}{\Gamma(D_{s0}^+ \to D_s^+ \pi^0)} \leq 0.059$$

D. Besson *et al.* (CLEO Collaboration), Phys. Rev. D **68**, 032002 (2003)

$$\frac{\mathcal{B}(B^+ \to \bar{D}^0 D_{s0}^+)}{\mathcal{B}(B^+ \to \bar{D}^0 D_s^+)} = 0.073^{0.026}_{-0.021}$$

$$\frac{\mathcal{B}(B^0 \to D^- D_{s0}^+)}{\mathcal{B}(B^0 \to D^- D_s^+)} = (0.13^{+0.06}_{-0.05}) \times 10^{-4},$$

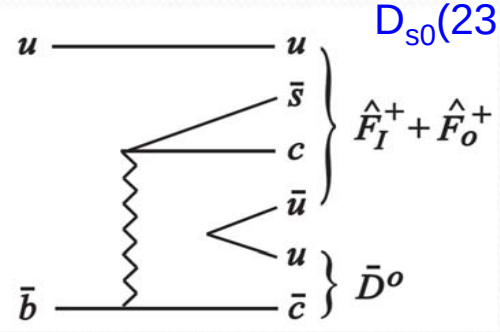
A. Datta and P.J. O'Donnell, Phys. Lett. **B572**, 164 (2003).
B.-H. Chen and H.-n. Li, Phys. Rev. D **69**, 054002 (2004).

Well below expectn's for pure quqrk-antiquark state

Measurement of $B \to D D_{s0}^{+}$ and Search for Hypothesized $F_{s0}(2317)^{++}$

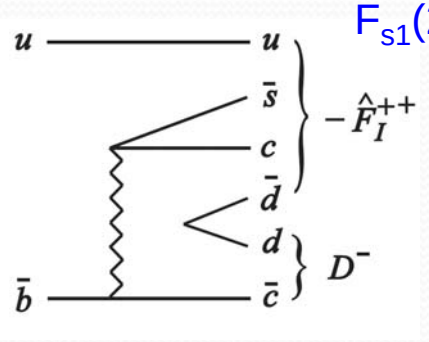
. Terasaki, PTP 116, 435 (2006) interpret D_{sJ} mesons as **tetraquarks**

B^0



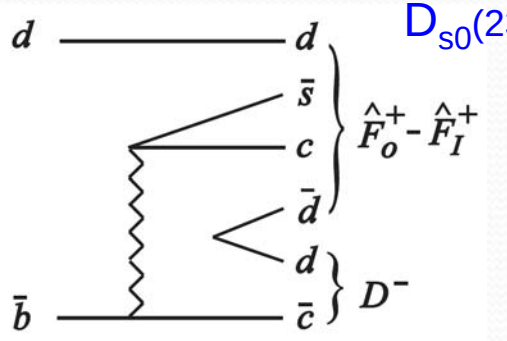
$D_{s0}(2317)+ \to Ds+ \pi 0$

B^+



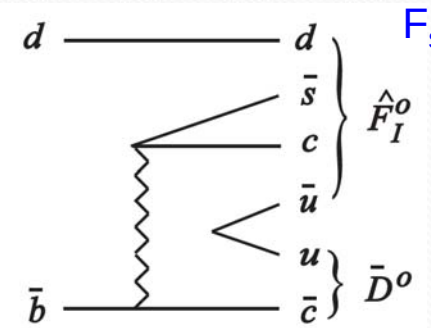
$F_{s1}(2317)+ \to D_s\pi^+$

B^0



$D_{s0}(2317)+ \to Ds+\pi 0$

B^+

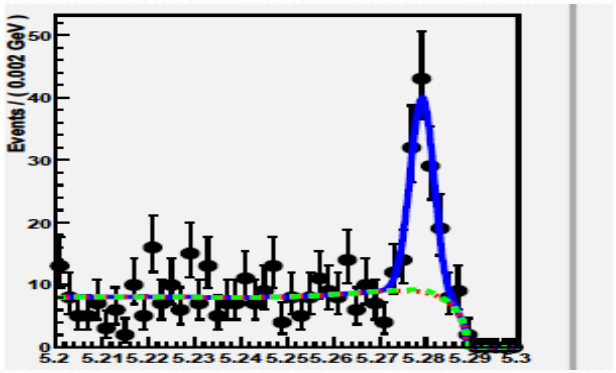


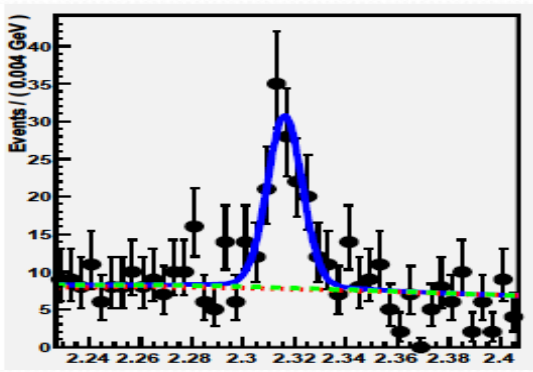
$F_{s1}(2317)0 \to D_s\pi-$

If F^{++}_1 and F^0_1 exist

$$B(B_d^0 \to \bar{D}^0 \hat{F}_I^0) \sim B(B_d^0 \to D^- \tilde{D}_{s0}^+(2317)[D_s^+\pi^0])_{\mathrm{BABAR}} = (1.8 \pm 0.4 \pm 0.3^{+0.6}_{-0.4}) \times 10^{-3}.$$

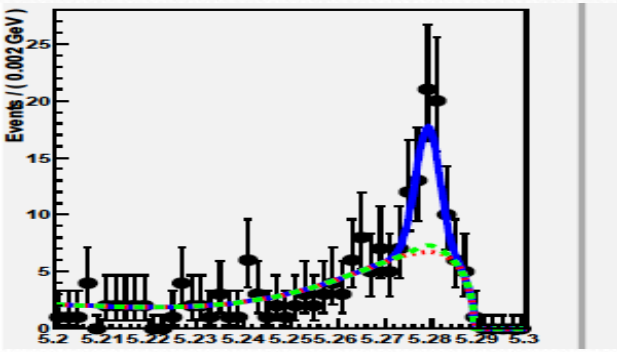
Updated Measurement of $B \to DD_{s0}^{+}$

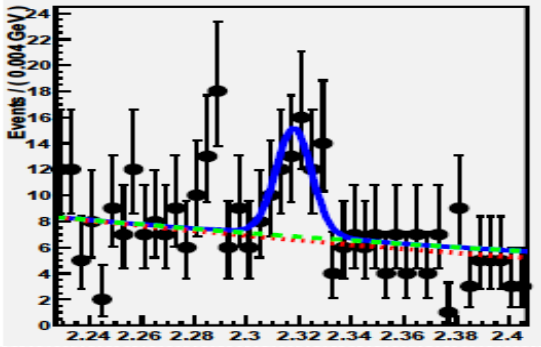




B^0

PDG avg:
$(0.97^{+0.40}_{-0.33}) \times 10^{-3}$





B^+

PDG avg:
$(0.73^{+0.22}_{-0.17}) \times 10^{-3}$

Mbc

M(Ds+π0)

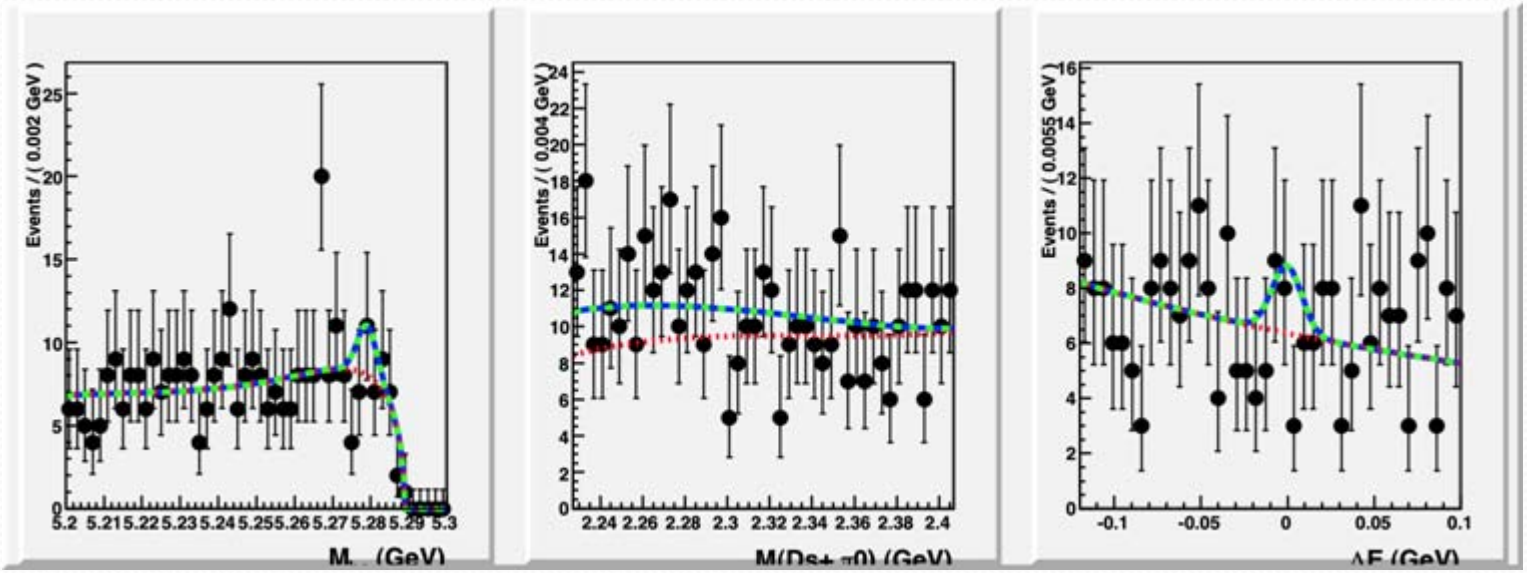
$$Bf(B^0 \to D^- D_{S0}^+(2317)) Bf(D_{S0}^+ \to D_s^+ \pi^0) = (1.00 \pm 0.12 \pm 0.10 \pm 0.05) \times 10^{-3}$$

$$Bf(B^+ \to \overline{D^0} D_{S0}^+(2317)) Bf(D_{S0}^+ \to D_s^+ \pi^0) = (0.78^{+0.13}_{-0.12} \pm 0.10 \pm 0.05) \times 10^{-3}$$

Preliminary

In agreement with Belle and Babar average +
with substantially improved errors

Search for Hypothesized $F_{s1}(2317)^{++}$



Mbc M(Ds+π+) ΔE

No indications for signal

$Bf(B^+ \to D^- F_{s1}(2317)^{++}) \times Bf(F_{s1}(2317)^{++} \to D_s^+ \pi^+) < 2.8 \times 10^{-5}$ (90% CL)

Preliminary

Factor ~30 below predicted level for Bf

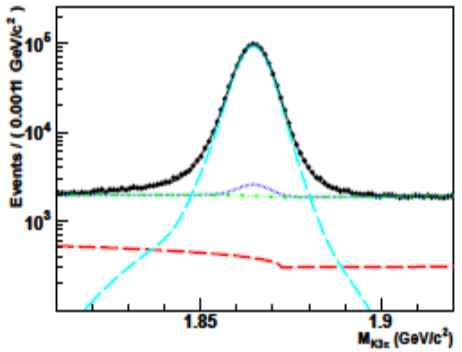
New Measurement of Double C.-S. $D^0 \to K^+\pi^-\pi^+\pi^-$

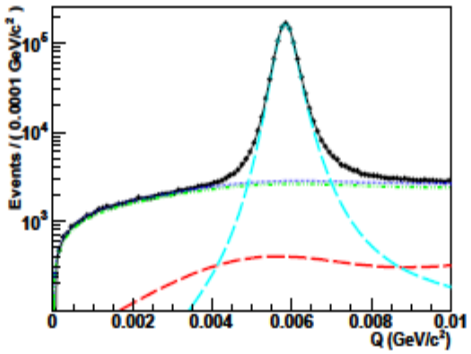
$$R_{\rm WS} \equiv \frac{\Gamma(D^0 \to K^+\pi^-\pi^+\pi^-)}{\Gamma(D^0 \to K^-\pi^+\pi^+\pi^-)} = R_D + \alpha y' \sqrt{R_D} + \frac{1}{2}(x'^2 + y'^2)$$

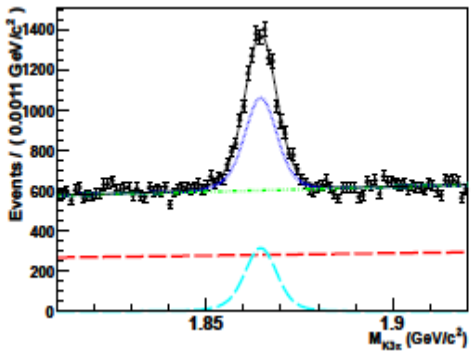
$$x \equiv \Delta m/\overline{\Gamma} \text{ and } y \equiv \Delta\Gamma/2\overline{\Gamma}$$

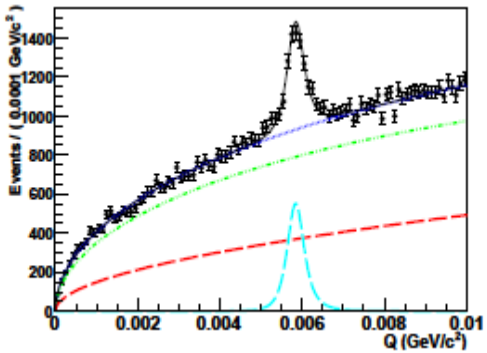
$$x' = x\cos\delta + y\sin\delta \text{ and } y' = y\cos\delta - x\sin\delta$$

Previous Belle result:
281 fb^{-1}
$[0.320 \pm 0.018(\text{stat.})^{+0.018}_{-0.013}(\text{sys.})]\%$









$$R_{\rm WS} = (0.324 \pm 0.008 \pm 0.007)\%$$

$$\mathcal{B}(D^0 \to K^+\pi^-\pi^+\pi^-) = (2.61 \pm 0.06\,^{+0.09}_{-0.08}) \times 10^{-4}$$

791 fb^{-1}

Error ~2 better than existing WA

New Measurement of Leptonic and Hadronic D_s^+ Decays and Extraction of f_{Ds}

$D_s^+ \to l^+ \nu_l$ where $l^+ = e^+, \mu^+$ or τ^+

$$\mathcal{B}(D_s^+ \to \ell^+ \nu_\ell) = \frac{\tau_{D_s} m_{D_s}}{8\pi} f_{D_s}^2 G_F^2 |V_{cs}|^2 m_\ell^2 \left(1 - \frac{m_\ell^2}{m_{D_s}^2}\right)^2$$

$$R_{\tau/\mu}^{D_s} \equiv \mathcal{B}(D_s^+ \to \tau^+ \nu_\tau)/\mathcal{B}(D_s^+ \to \mu^+ \nu_\mu) = m_\tau^2/m_\mu^2 \cdot (1 - m_\tau^2/m_{D_s}^2)/(1 - m_\mu^2/m_{D_s}^2) = 9.76.$$

Current WA:

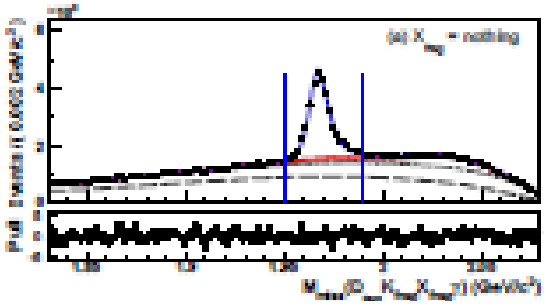
$$f_{D_s}^{\rm exp} = (260 \pm 5.4)\ {\rm MeV} \quad \leftrightarrow \quad f_{D_s}^{\rm LQCD} = (248 \pm 2.5)\ {\rm MeV}$$

Phys.Rev. **D82** (2010) 114504

Any deviation will point to New Physics effects

New measurements with an accuracy that matches the precision of theory will test Lattice QCD (and other models) calculations and probe possible NP effects

New Measurement of Leptonic and Hadronic D_s^+ Decays and Extraction of f_{Ds}

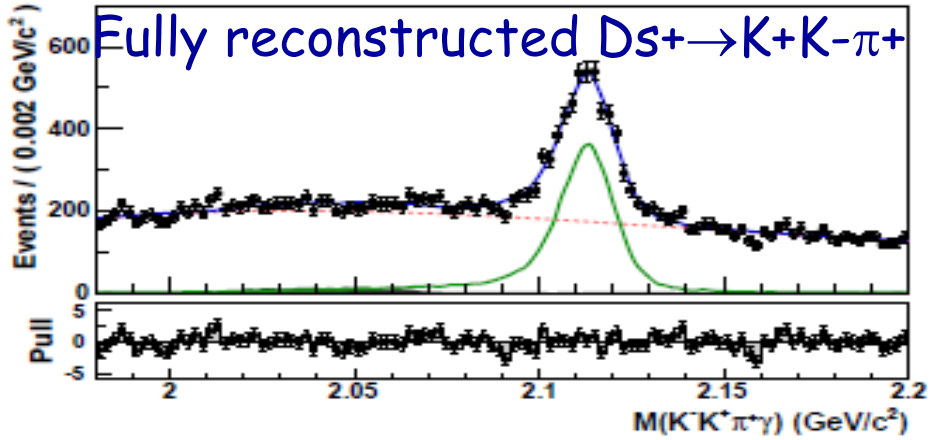


METHOD:

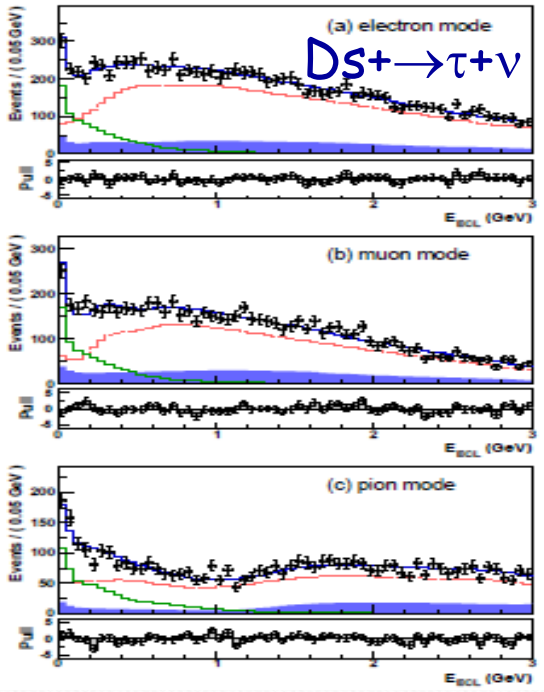
$$e^+e^- \to c\bar{c} \to D_{\rm tag} K_{\rm frag} X_{\rm frag} D_s^{*-},\ D_s^{*-} \to D_s^- \gamma$$

$$M_{\rm miss}(D_{\rm tag} K_{\rm frag} X_{\rm frag} \gamma) = \sqrt{p_{\rm miss}(D_{\rm tag} K_{\rm frag} X_{\rm frag} \gamma)^2},$$

Fully reconstructed $D_s^+ \to K^+K^-\pi^+$

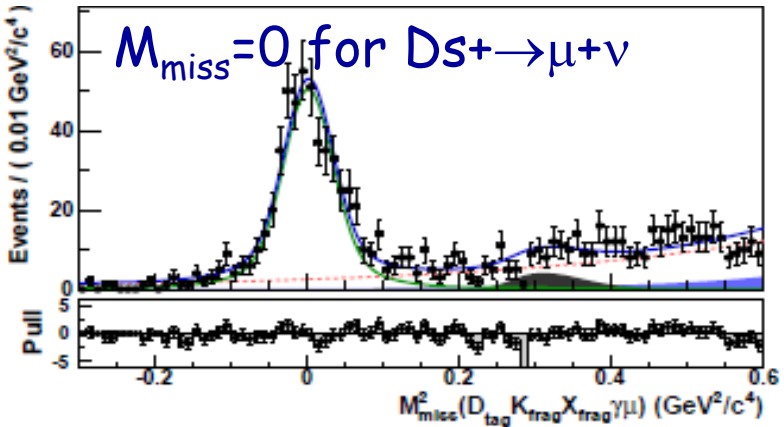


Extra energy in ECL as signal variable in case of

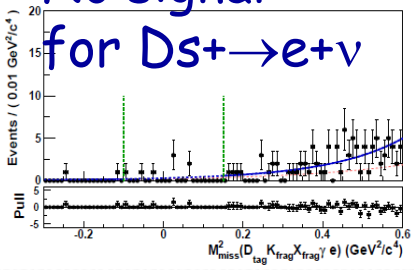


Require large pmiss and non-zero Mmiss

M_{miss}=0 for $D_s^+ \to \mu^+\nu$



No signal for $D_s^+ \to e^+\nu$



New Measurement of Leptonic and Hadronic D_s^+ Decays and Extraction of f_{Ds}

$$\mathcal{B}(D_s^+ \to \mu^+\nu_\mu) = (0.531 \pm 0.028 \pm 0.020)\%,$$
$$\mathcal{B}(D_s^+ \to \tau^+\nu_\tau) = (5.70 \pm 0.21^{+0.31}_{-0.30})\%,$$

$\mathcal{B}(D_s^+ \to e^+\nu_e) < 1.0\ (0.83) \times 10^{-4}$ at 95 (90)% C.L.

$D_s^+ \to \ell^+\nu_\ell$	f_{D_s} [MeV]
$\mu^+\nu_\mu$	$249.8 \pm 6.6(\text{stat.}) \pm 4.7(\text{syst.}) \pm 1.7(\tau_{D_s})$
$\tau^+\nu_\tau$	$261.9 \pm 4.9(\text{stat.}) \pm 7.0(\text{syst.}) \pm 1.8(\tau_{D_s})$
Combination	$255.5 \pm 4.2(\text{stat.}) \pm 4.8(\text{syst.}) \pm 1.8(\tau_{D_s})$

Single most precise measurement to date

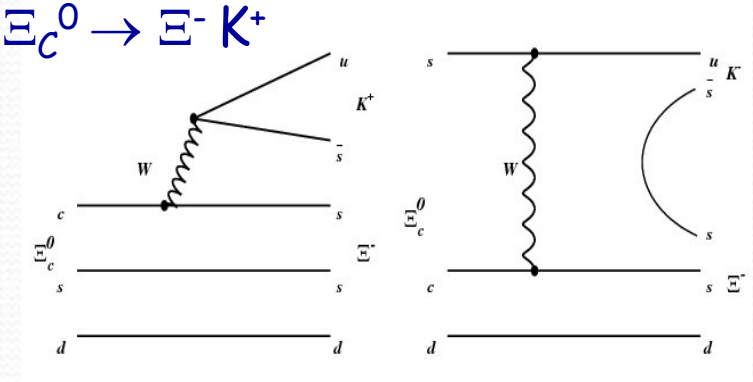
$$\mathcal{B}(D_s^+ \to K^-K^+\pi^+) = (5.06 \pm 0.15 \pm 0.21)\%$$
$$\mathcal{B}(D_s^+ \to \overline{K}^0K^+) = (2.95 \pm 0.11 \pm 0.09)\%$$
$$\mathcal{B}(D_s^+ \to \eta\pi^+) = (1.82 \pm 0.14 \pm 0.07)\%$$

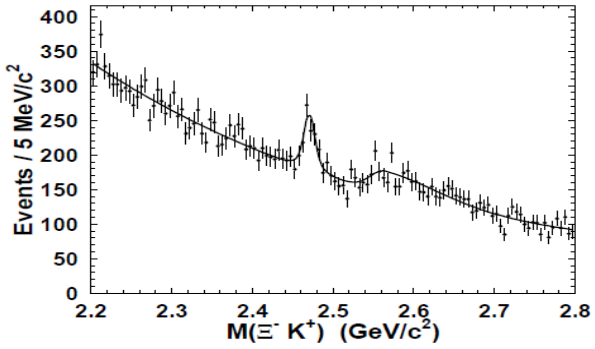
First Observation of C.-S. Ξ_c^0 Decays

A little is known about weak decays of charm baryons (eg t C.-S. modes)
W-internal and –exchange diagrams are not suppressed in charm baryons

$Bf(\Xi_c^0 \to \Omega^- K^+)/Bf(\Xi_c^0 \to \Xi^- \pi^+)$
$=0.294+-0.018+-0.016$ (BaBar, PRL95(2005)142003)

$\Xi_c^0 \to \Xi^- K^+$

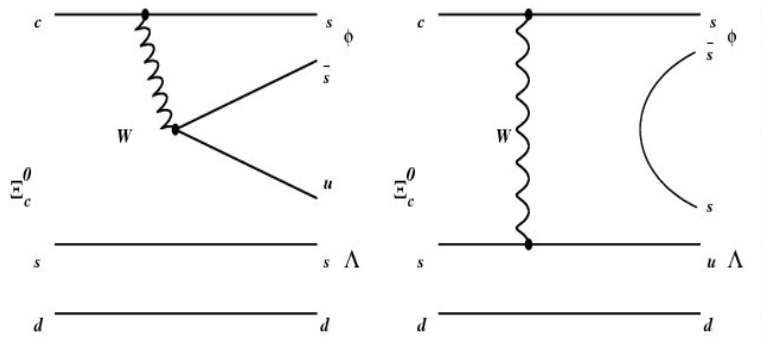


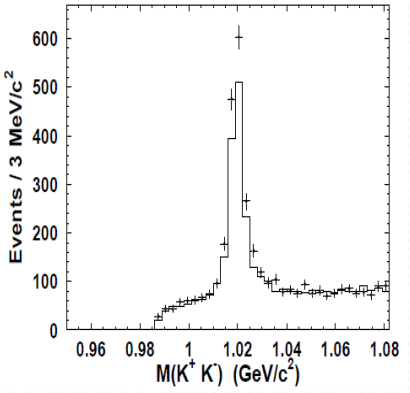


$$\frac{\mathcal{B}(\Xi_c^0 \to \Xi^- K^+)}{\mathcal{B}(\Xi_c^0 \to \Xi^- \pi^+)}$$

$$(2.75 \pm 0.51 \pm 0.25) \times 10^{-2}$$

$\Xi_c^0 \to \Lambda \varphi$

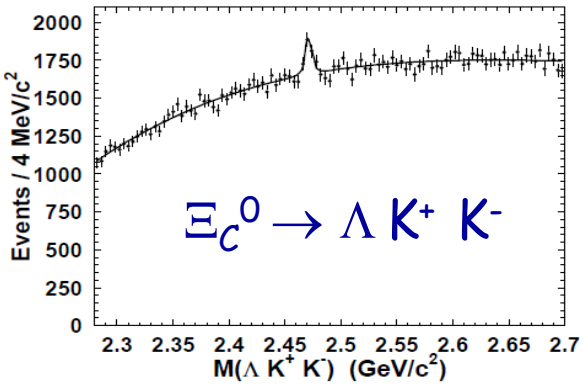




$$\frac{\mathcal{B}(\Xi_c^0 \to \Lambda \phi)}{\mathcal{B}(\Xi_c^0 \to \Xi^- \pi^+)}$$

$$(3.43 \pm 0.58 \pm 0.32) \times 10^{-2}$$

$\Xi_c^0 \to \Lambda K^+ K^-$



$$\frac{\mathcal{B}(\Xi_c^0 \to \Lambda K^+ K^-)}{\mathcal{B}(\Xi_c^0 \to \Xi^- \pi^+)}$$

$$(2.86 \pm 0.61 \pm 0.24) \times 10^{-2}$$

arXiv:1306.5947
Submitted to PRD(RC)

Internal W-emission is not suppressed in CS Ξ_c^0 decays also

Summary

New results on decays of charm hadrons were obtained

- Bf of **B decays to $DD_{s0}(2317)^{++}$** were updated; results are consistent with WA with an improvement in accuracy. Search for hypothesized **$F_{s0}(2317)^{++} \rightarrow D_s^+\pi^+$** was performed. UL on Bf is ~30 less than expectation from tetraquark model.

- New updated measurement of double CS **$D^0 \rightarrow K^+\pi^-\pi^+\pi^-$** The result is in agreement with world average with a factor of 2 improvement in error.

- New measurement of absolute Bf of **$D_s^+ \rightarrow \pi^+K^+K^-$, $\bar{K}^0K^+$, $\pi^+\eta$, $\tau^+\nu$, $\mu^+\nu$, $e^+\nu$;** decay constant **f_{Ds}** were extracted.

- **C.-S. Ξ_c^0** decays were observed for the first time.