



Charm Decays at Belle

M.-Z. Wang

on behalf of the Belle Collaboration

2012/7/7

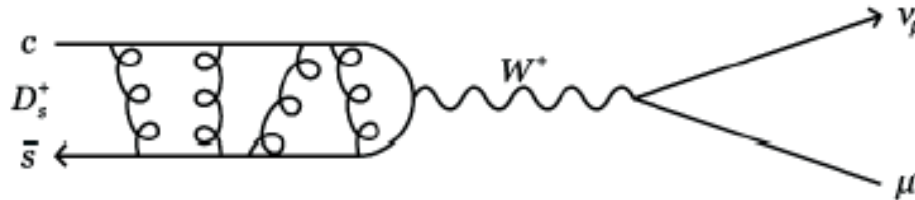
Outline

- $D_s^+ \rightarrow \mu^+ \nu / \tau^+ \nu$ and f_{D_s}
- Cabibbo-suppressed
 Ξ_c^0 Decays
- Summary



Motivation for studying $D_s^+ \rightarrow l^+ \nu$

- Clean mode for SM calculation



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

- Determine f_{D_s} to compare with theoretical prediction
- Sensitive to new physics

Sophisticated analysis

- Using the following process

$$e^+e^- \rightarrow c\bar{c} \rightarrow \bar{D}_{\text{tag}} K X_{\text{frag}} D_s^{*+}$$

- Energetic charmed hadron as the tag

$$\bar{D}_{\text{tag}} = \bar{D}^0, D^-, \Lambda_c^-, D^{*-}, \bar{D}^{*0}$$

Reconstructed by up to 6 dominant sub-decays

e.g.

D^0	\mathcal{B} [%]
$K^-\pi^+$	3.9
$K^-\pi^+\pi^0$	13.9
$K^-\pi^+\pi^+\pi^-$	8.1
$K^-\pi^+\pi^+\pi^-\pi^0$	4.2
$K_S^0\pi^+\pi^-$	2.9
$K_S^0\pi^+\pi^-\pi^0$	5.4
Sum	38.4

- Balance strangeness

$$K = K^\pm, K_S^0$$

- Limited fragmentations

$$X_{\text{frag}} = \text{nothing}, \pi^\pm, \pi^0, \pi^\pm\pi^\pm, \pi^\pm\pi^0, \pi^\pm\pi^\pm\pi^\pm, \pi^\pm\pi^\pm\pi^0$$

- Identifying Signal by $D_s^* \rightarrow D_s\gamma$

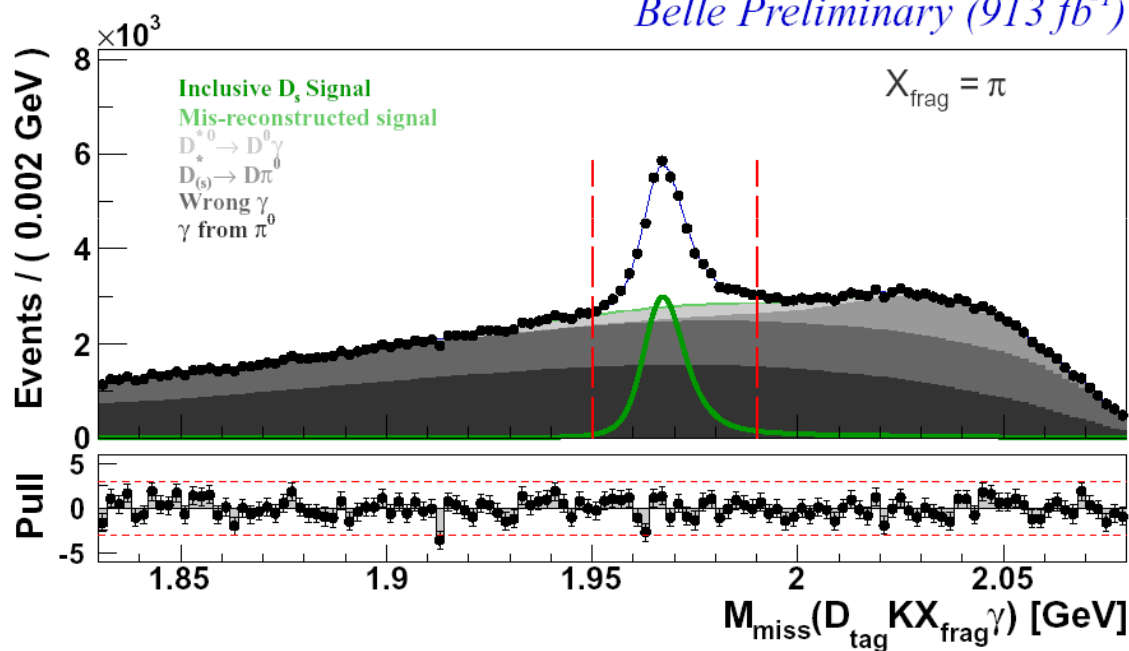
$$M_{\text{miss}}(\bar{D}_{\text{tag}} K X_{\text{frag}} \gamma) = \sqrt{|p_{e^+e^-} - p_{D_{\text{tag}}} - p_K - p_{X_{\text{frag}}} - p_\gamma|^2}$$



Determine total D_s yield

- $E_\gamma > 0.12$ GeV opposite to D_{tag}
- $P_{\text{miss}} > 2.8$ GeV @ CM
- One candidate per event based on γ quality

Belle Preliminary (913 fb⁻¹)

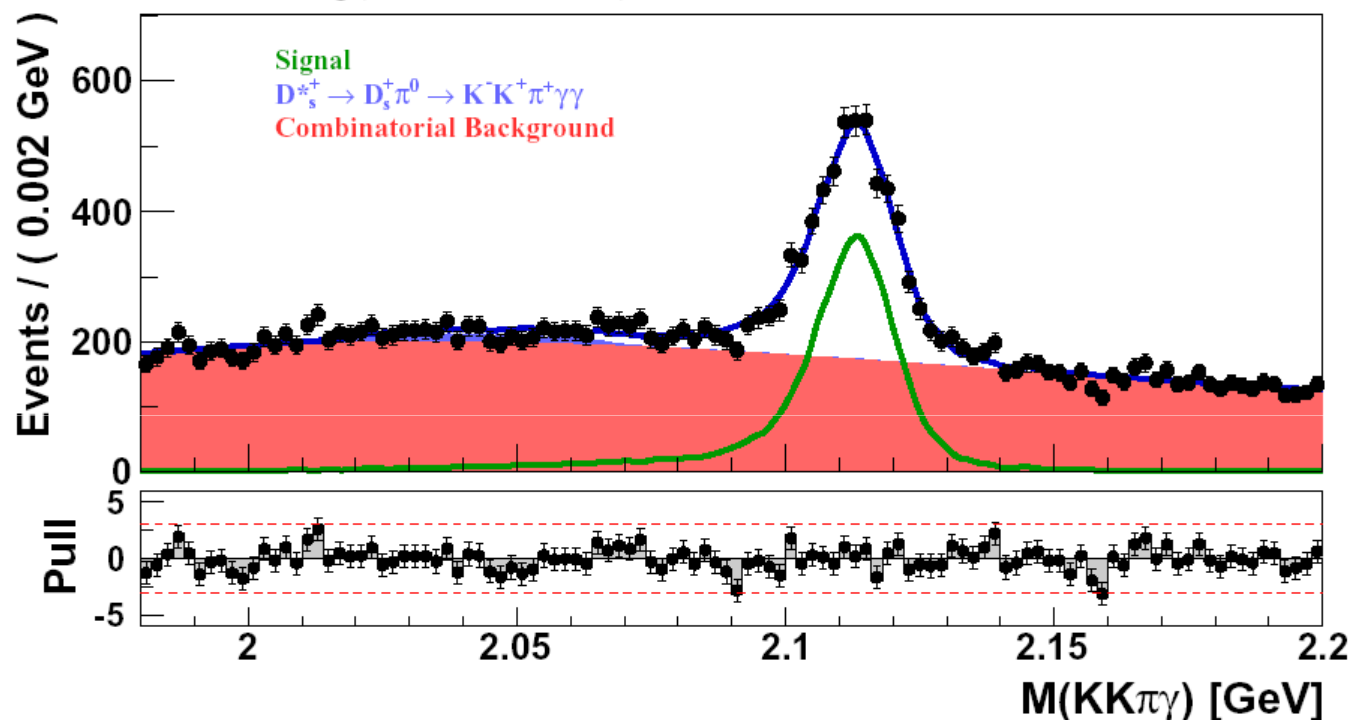


inclusive D_s
with $X_{\text{frag}} = \pi$

- Sum of 7 X_{frag} modes $N_{D_s}^{\text{incl}} = 94400 \pm 1300(\text{stat.}) \pm 1400(\text{syst.})$

Validation with $D_s^+ \rightarrow K^+ K^- \pi^+$

$D_s^{*+} \rightarrow D_s^+ \gamma \rightarrow K^- K^+ \pi^+ \gamma$ *Belle Preliminary (913 fb⁻¹)*



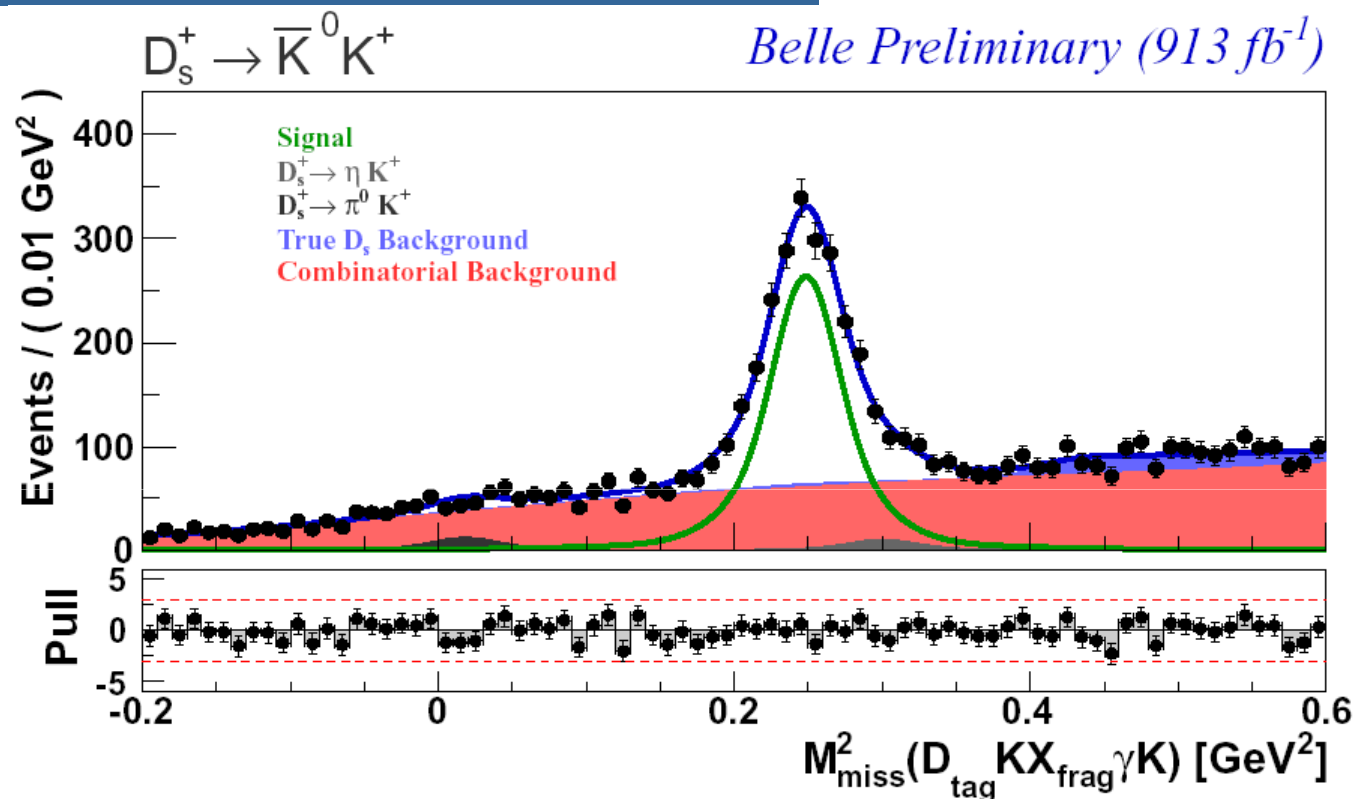
$$\mathcal{B}(D_s^+ \rightarrow K^+ K^- \pi^+) = (5.06 \pm 0.15(\text{stat.}) \pm 0.19(\text{syst.}))\%$$

better precision
than PDG average

$$\mathcal{B}^{\text{PDG}}(D_s^+ \rightarrow K^+ K^- \pi^+) = (5.49 \pm 0.27)\%$$



Validation with $D_s^+ \rightarrow K_s K^+$



Missing Mass Method

$$\mathcal{B}(D_s^+ \rightarrow \bar{K}^0 K^+) = (2.84 \pm 0.12(\text{stat.}) \pm 0.08(\text{syst.}))\%$$

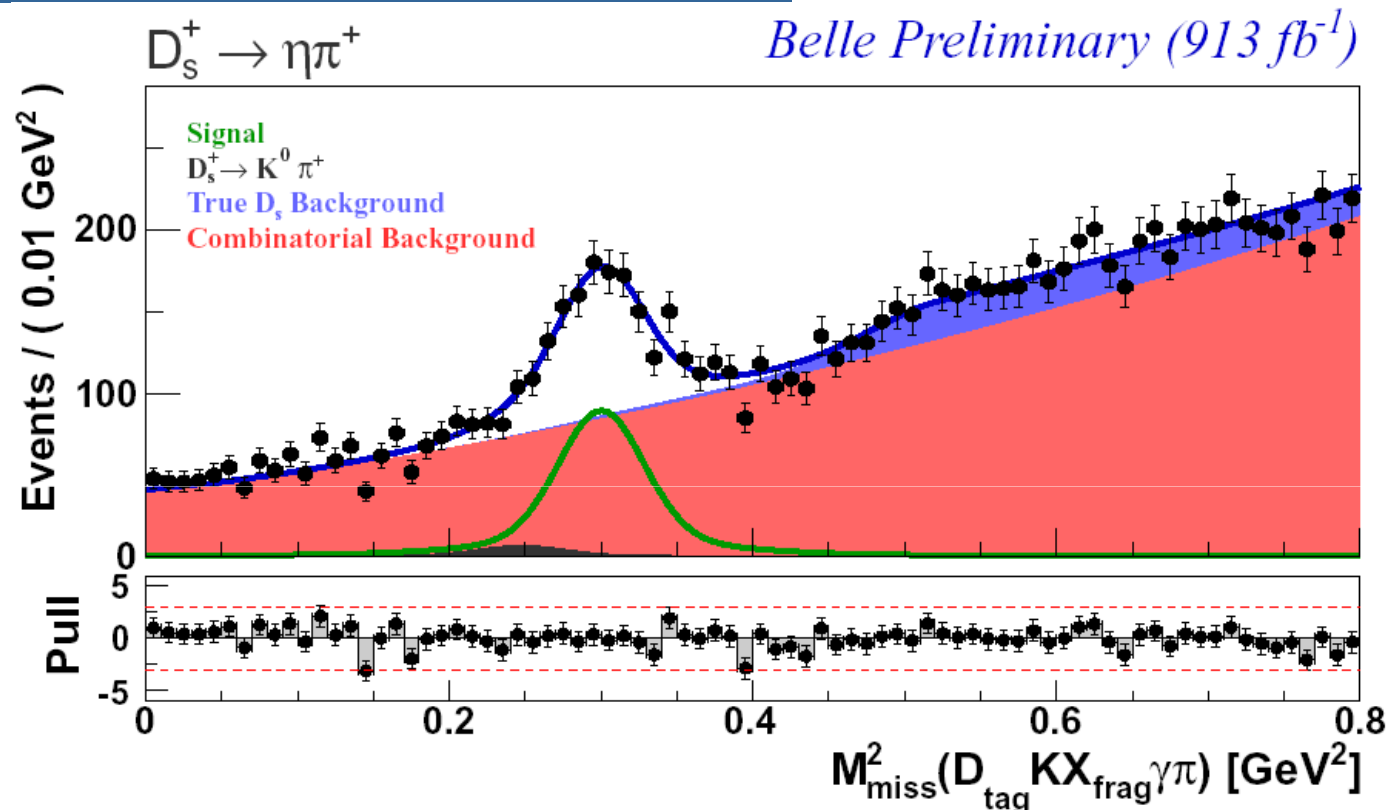
better precision
than PDG average

$$\mathcal{B}^{\text{PDG}}(D_s^+ \rightarrow \bar{K}^0 K^+) = 2 \times \mathcal{B}^{\text{PDG}}(D_s^+ \rightarrow K_S^0 K^+) = (2.96 \pm 0.16)\%$$



Validation with $D_s^+ \rightarrow \eta \pi^+$

One more check for
missing mass method

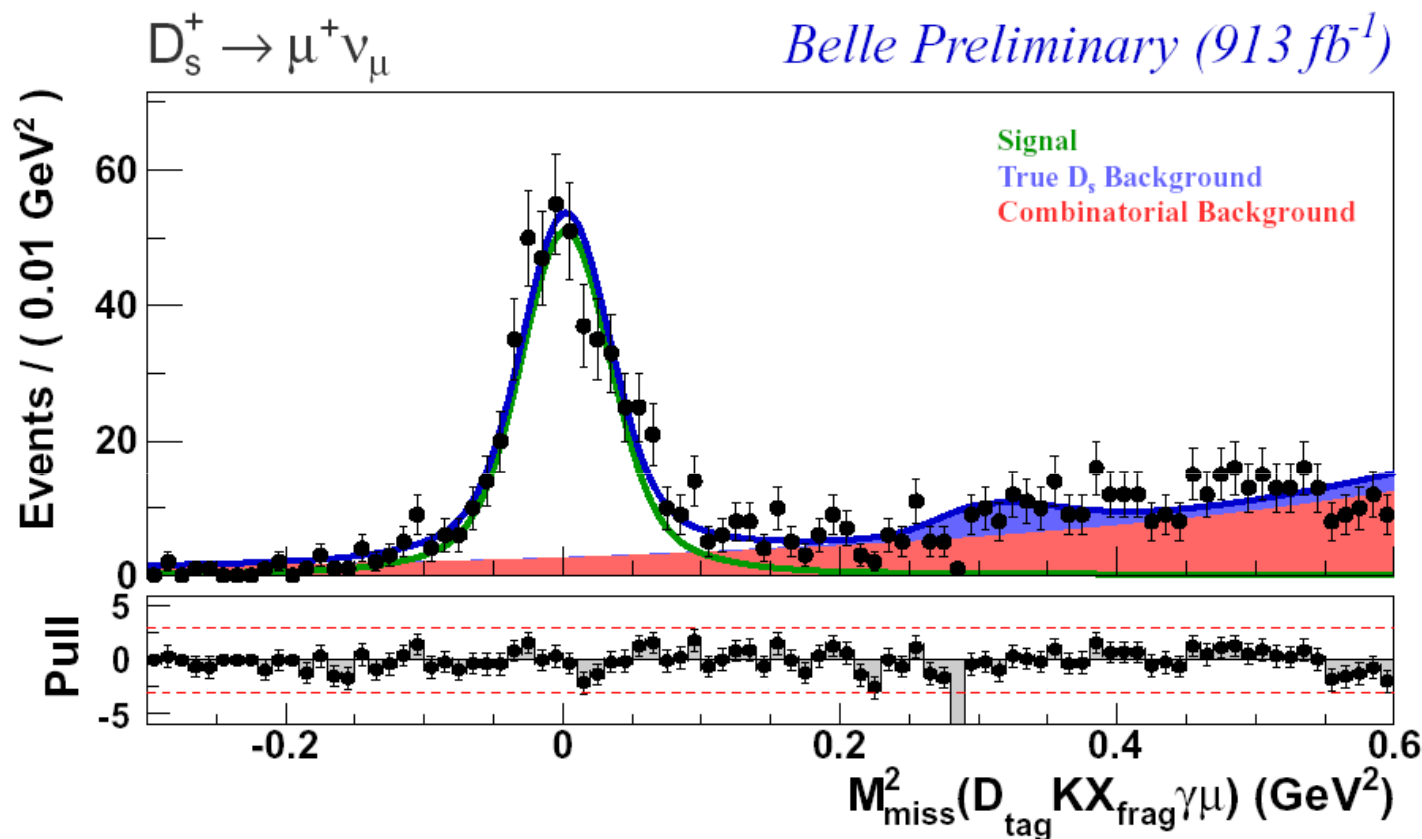


$$\mathcal{B}(D_s^+ \rightarrow \eta \pi^+) = (1.79 \pm 0.14(\text{stat.}) \pm 0.05(\text{syst.}))\%$$

$$\mathcal{B}^{\text{PDG}}(D_s^+ \rightarrow \eta \pi^+) = (1.83 \pm 0.15)\%$$

$$D_s^+ \rightarrow \mu^+ \nu$$

Zero Missing Mass



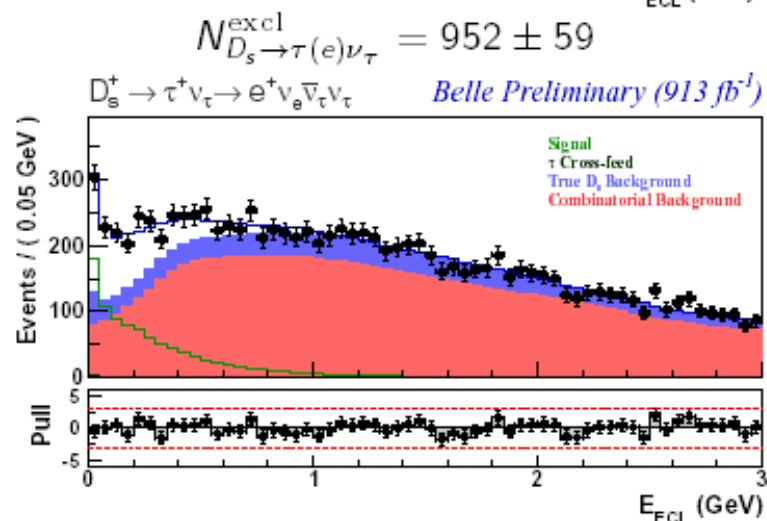
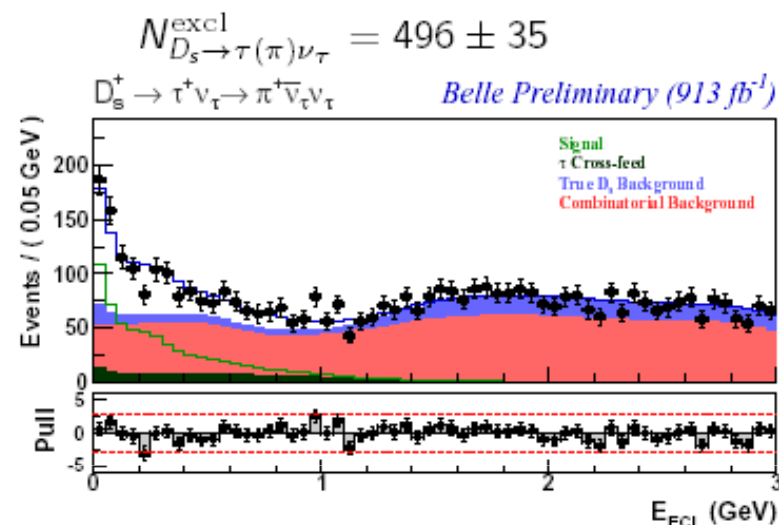
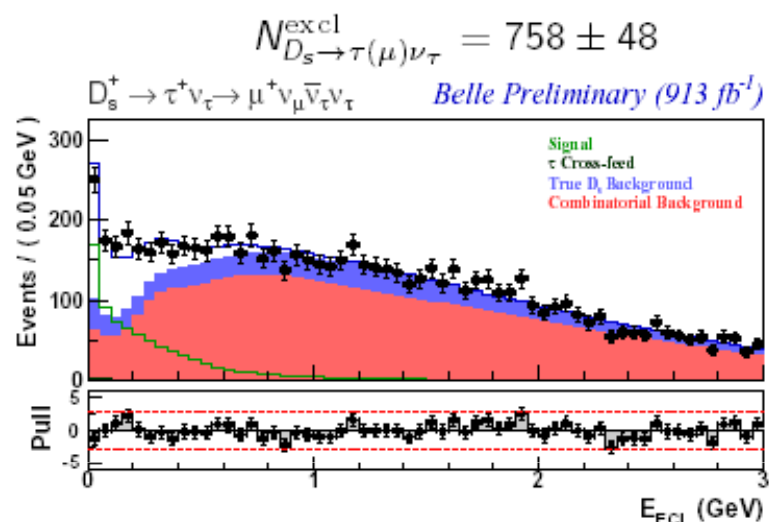
$$\mathcal{B}(D_s^+ \rightarrow \mu^+ \nu_\mu) = (0.528 \pm 0.028(\text{stat.}) \pm 0.019(\text{syst.}))\%$$

PDG value : (0.590±0.033)%



$$D_s^+ \rightarrow \tau^+ \nu$$

No Calorimeter activity



τ decay mode	$\mathcal{B}(D_s^+ \rightarrow \tau^+ \nu_\tau) [\times 10^{-2}]$
$e\nu\nu$	$5.37 \pm 0.33^{+0.35}_{-0.30}$
$\mu\nu\nu$	$5.88 \pm 0.37^{+0.34}_{-0.58}$
$\pi\nu$	$5.96 \pm 0.42^{+0.45}_{-0.39}$
Combination	$5.70 \pm 0.21^{+0.31}_{-0.30}$

PDG value : $(5.43 \pm 0.31)\%$

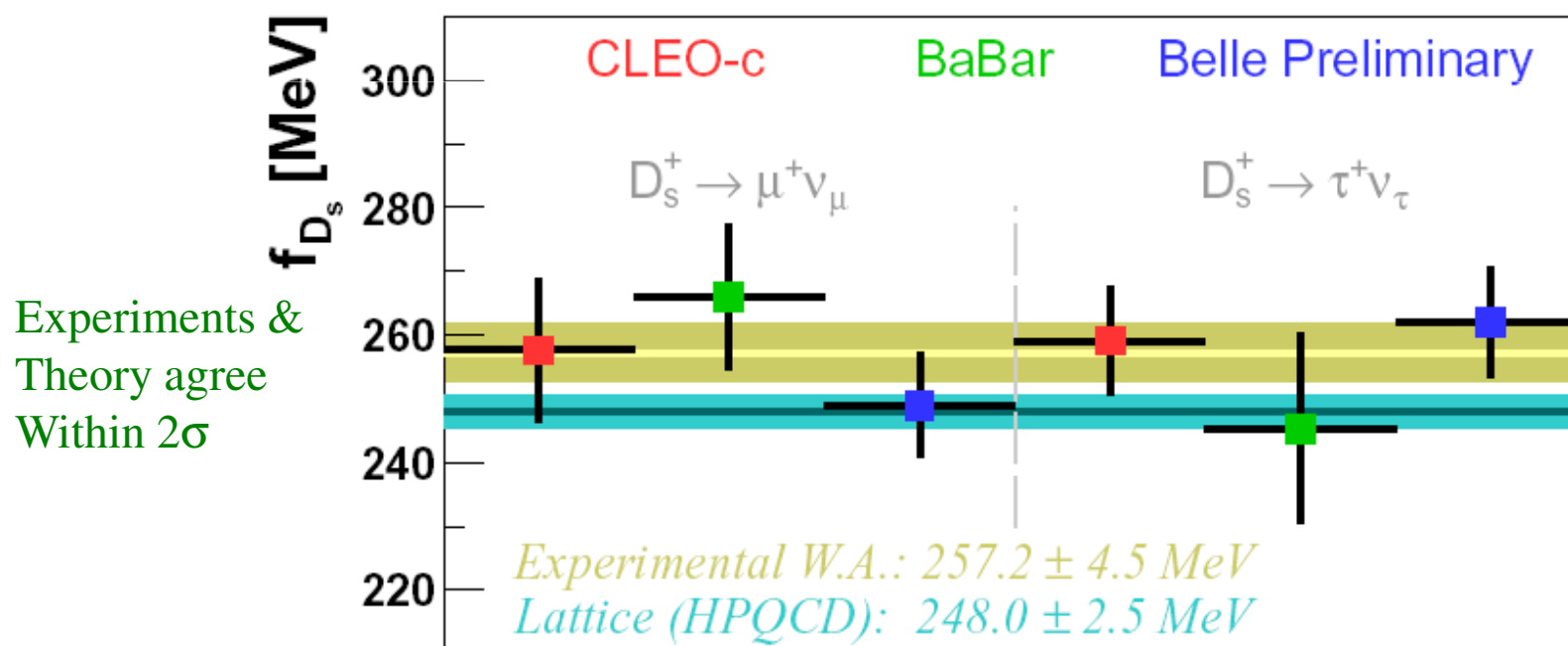


Compare with f_{D_s} theoretical prediction

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

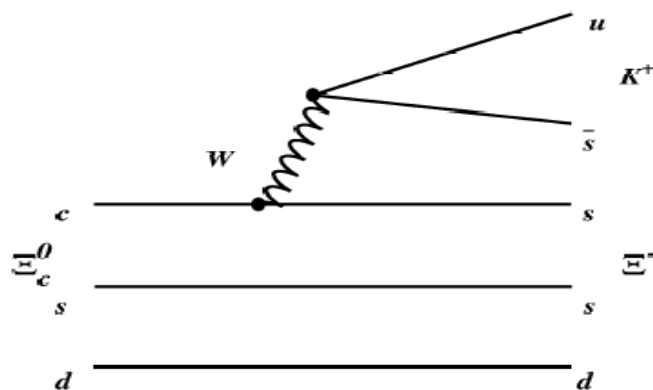
Belle Preliminary (913 fb⁻¹)

$D_s \rightarrow \ell \nu$	f_{D_s} [MeV]
$\mu \nu$	$249.0 \pm 6.6(\text{stat.}) \pm 4.6(\text{syst.}) \pm 1.7(\tau_{D_s})$
$\tau \nu$	$261.9 \pm 4.9(\text{stat.}) \pm 7.0(\text{syst.}) \pm 1.8(\tau_{D_s})$
Combination	$255.0 \pm 4.2(\text{stat.}) \pm 4.7(\text{syst.}) \pm 1.8(\tau_{D_s})$

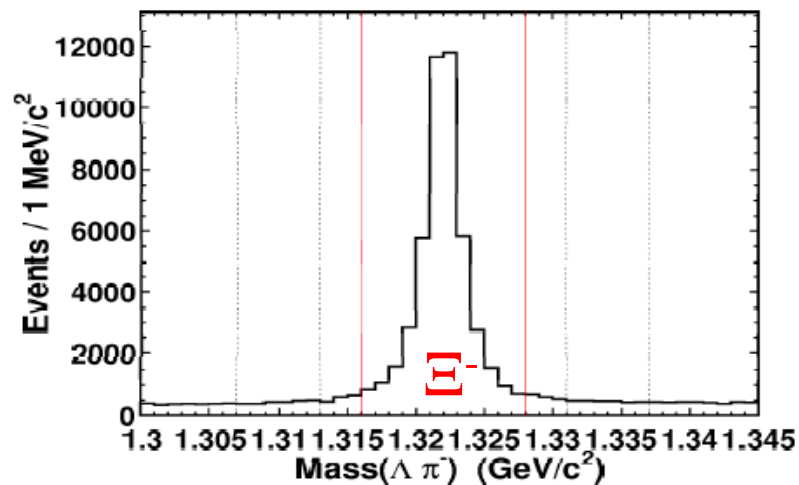
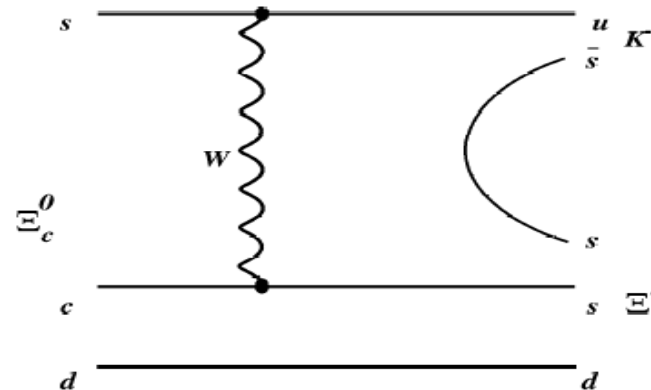


Search for Cabbibo –suppressed $\Xi_c^0 \rightarrow \Xi^- K^+$

external W emission



W exchange

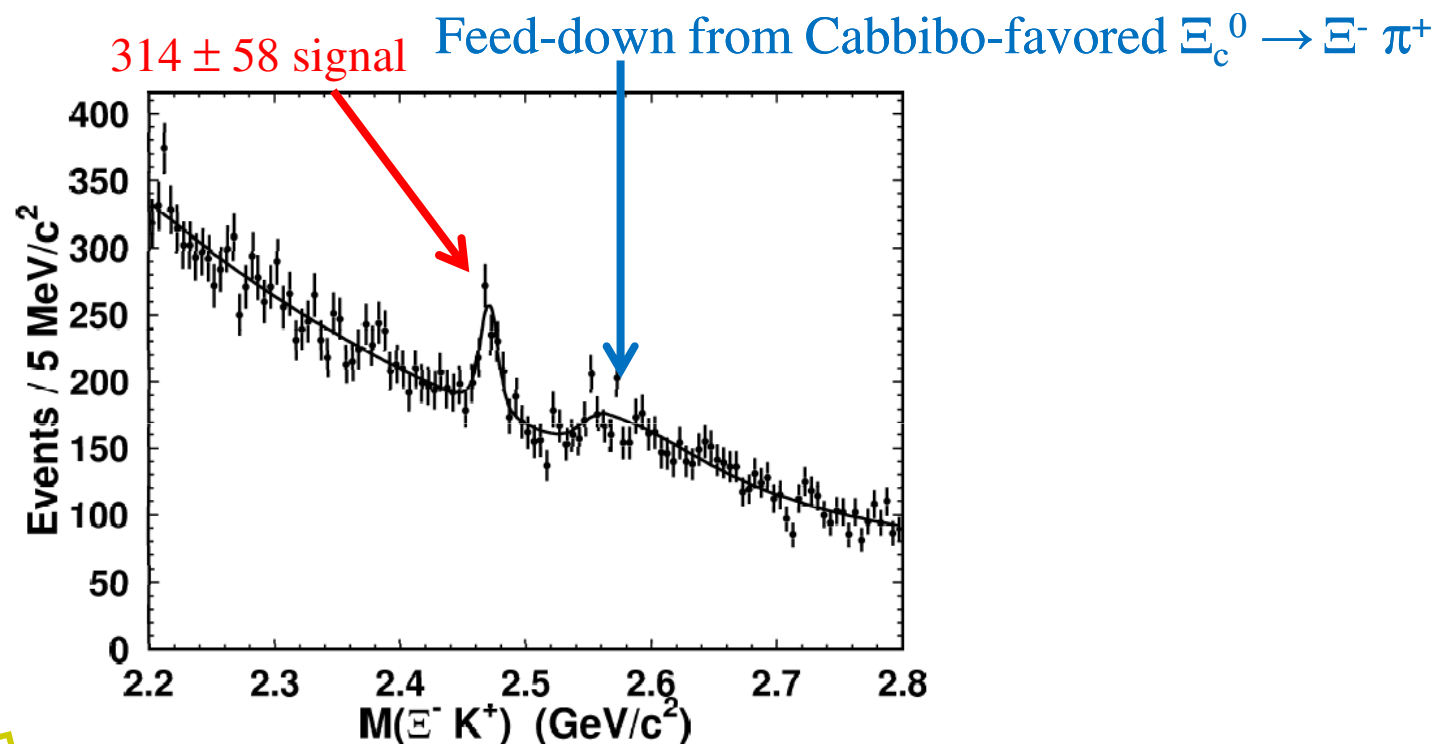


- $\Xi^- \rightarrow \Lambda \pi^-$
- Long-lived Λ
- Ξ^- momentum pointing to IP
- Ξ^- sideband for background study



Observation of $\Xi_c^0 \rightarrow \Xi^- K^+$

Significance 8.3σ



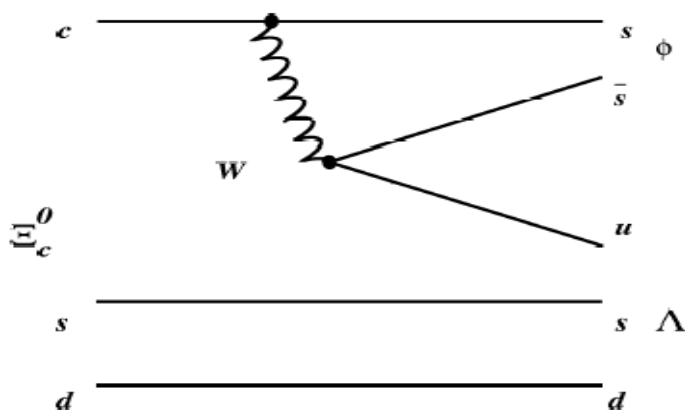
preliminary

mass peak $2470.6 \pm 1.5 \text{ MeV}$ within 1 MeV PDG (Ξ_c^0)

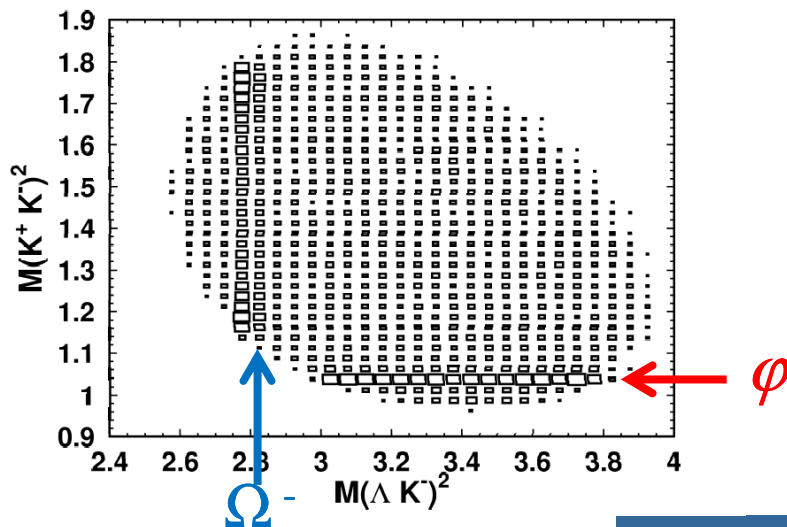
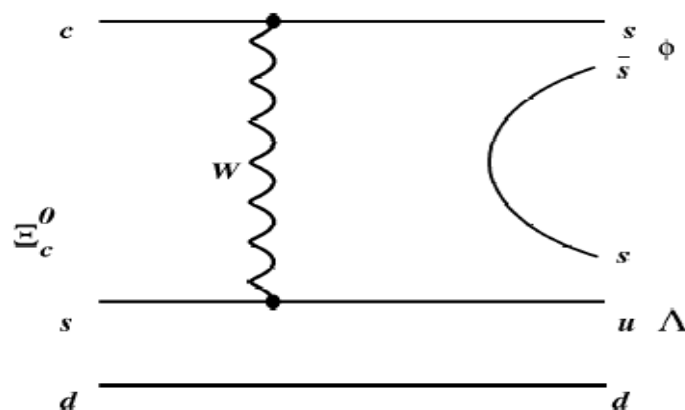
$$\frac{\mathcal{B}(\Xi_c^0 \rightarrow \Xi^- K^+)}{\mathcal{B}(\Xi_c^0 \rightarrow \Xi^- \pi^+)} = (2.75 \pm 0.51 \pm 0.25) \times 10^{-2}$$

Search for Cabbibo -suppressed $\Xi_c^0 \rightarrow \Lambda \phi$

internal W emission



W exchange



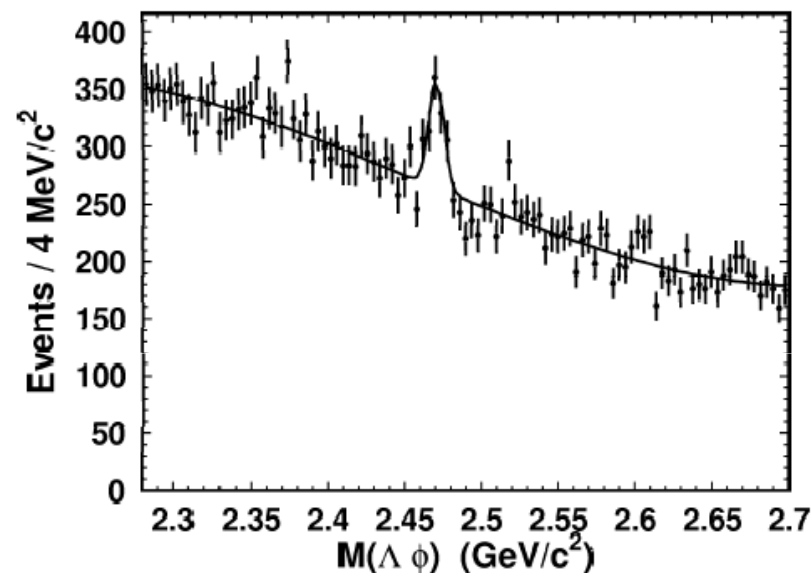
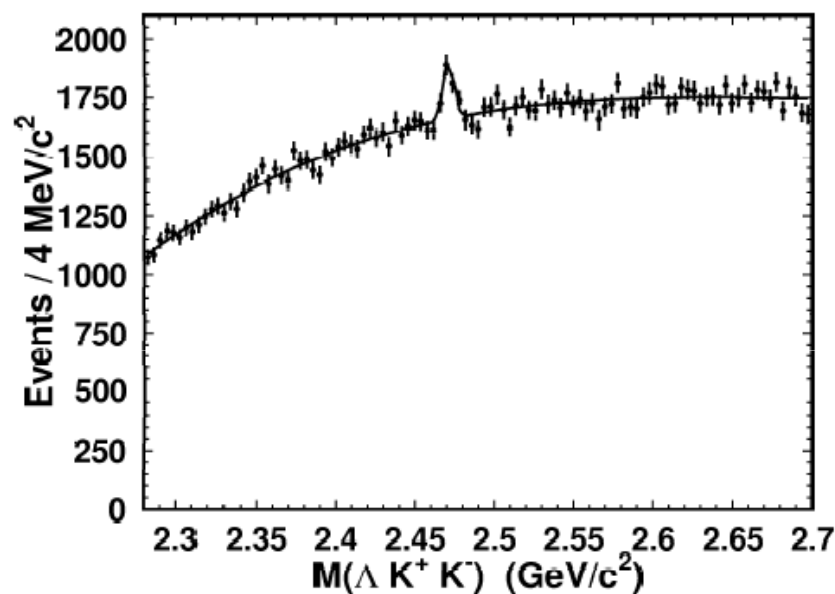
- Check Dalitz plot in Ξ_c^0 mass window
- Reject $\Xi_c^0 \rightarrow \Omega^- K^+$, $\Omega^- \rightarrow \Lambda K^-$



Observation of $\Xi_c^0 \rightarrow \Lambda K^+ K^- / \Lambda \phi$

Significance 7.4σ

With Ω -rejection



after ϕ selection \rightarrow
(background subtraction)

preliminary

$$\frac{\mathcal{B}(\Xi_c^0 \rightarrow \Lambda \phi)}{\mathcal{B}(\Xi_c^0 \rightarrow \Xi^- \pi^+)} = (3.43 \pm 0.58 \pm 0.32) \times 10^{-2}$$



Summary

- Most precise measurement by a single experiment for $D_s^+ \rightarrow l^+ \nu$ up-to-date
- f_{D_s} agrees with theoretical predictions
- Super B factories can do a good job on $f_{D_s}(f_D)$
- First observation of Cabibbo-suppressed Ξ_c^0 decays
- Looking for understanding the decay dynamics of charmed baryon