



北京大学
PEKING UNIVERSITY

BESIII

Charm physics at BESIII

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(On behalf of the BESIII collaboration)



Outline

- Introduction

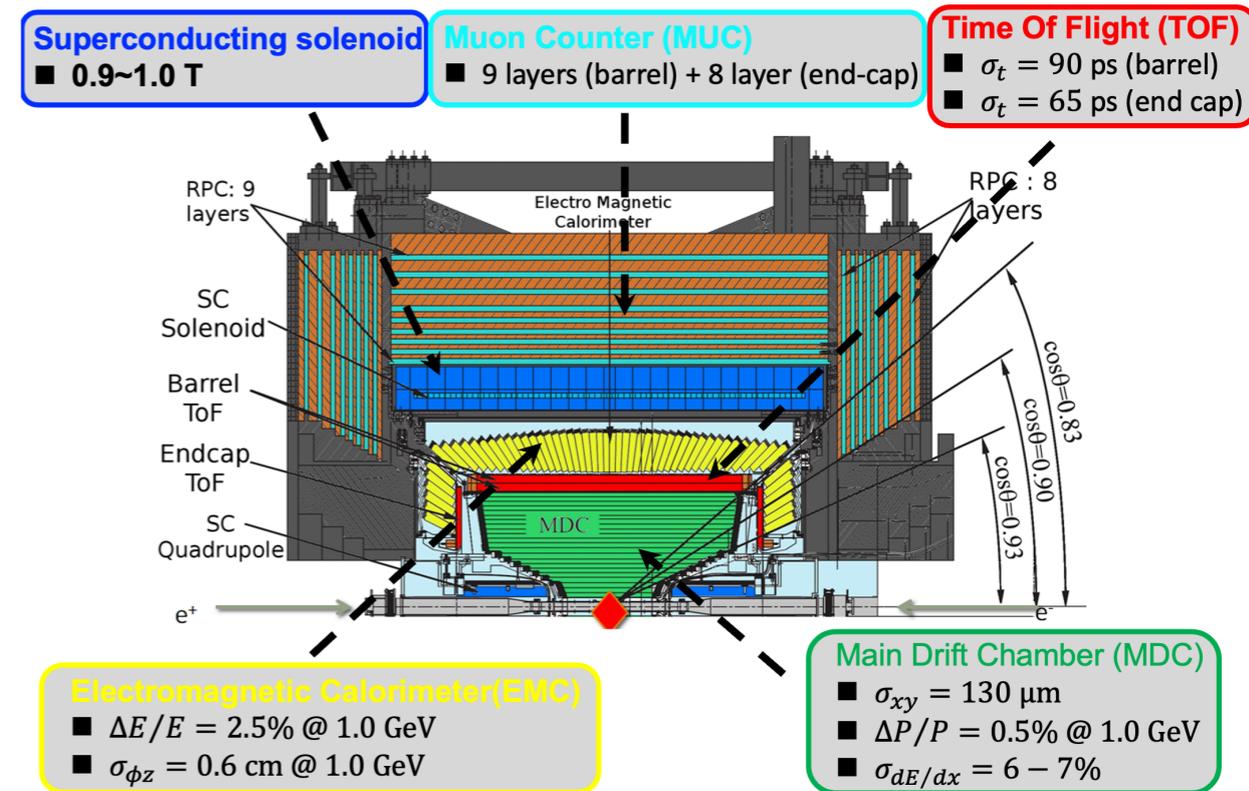
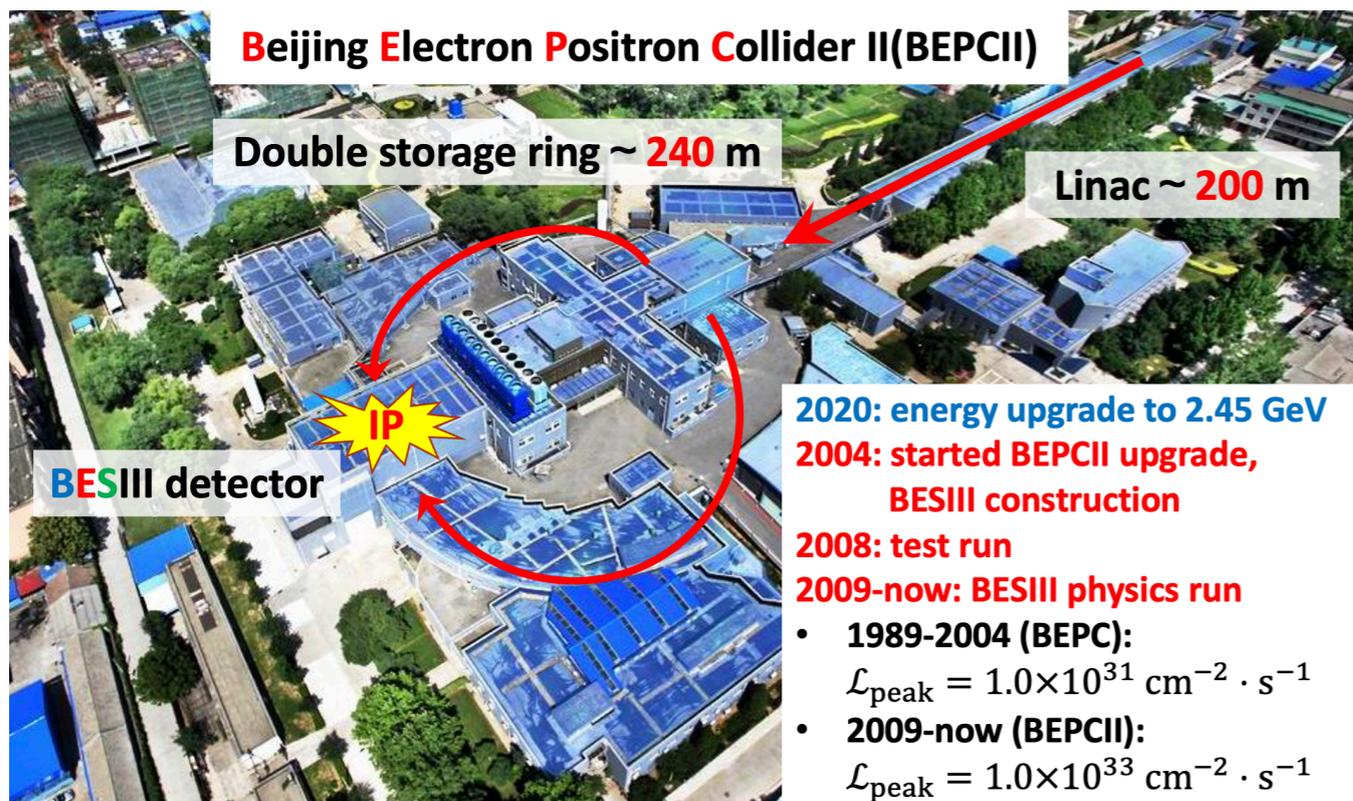
- Highlight results of charm meson physics at BESIII
 - ❖ $D_{(s)}$ (semi-)leptonic decays
 - ❖ $D_{(s)}$ hadronic decays

- Highlight results of charm baryon physics at BESIII
 - ❖ Λ_c semi-leptonic decays
 - ❖ Λ_c hadronic decays

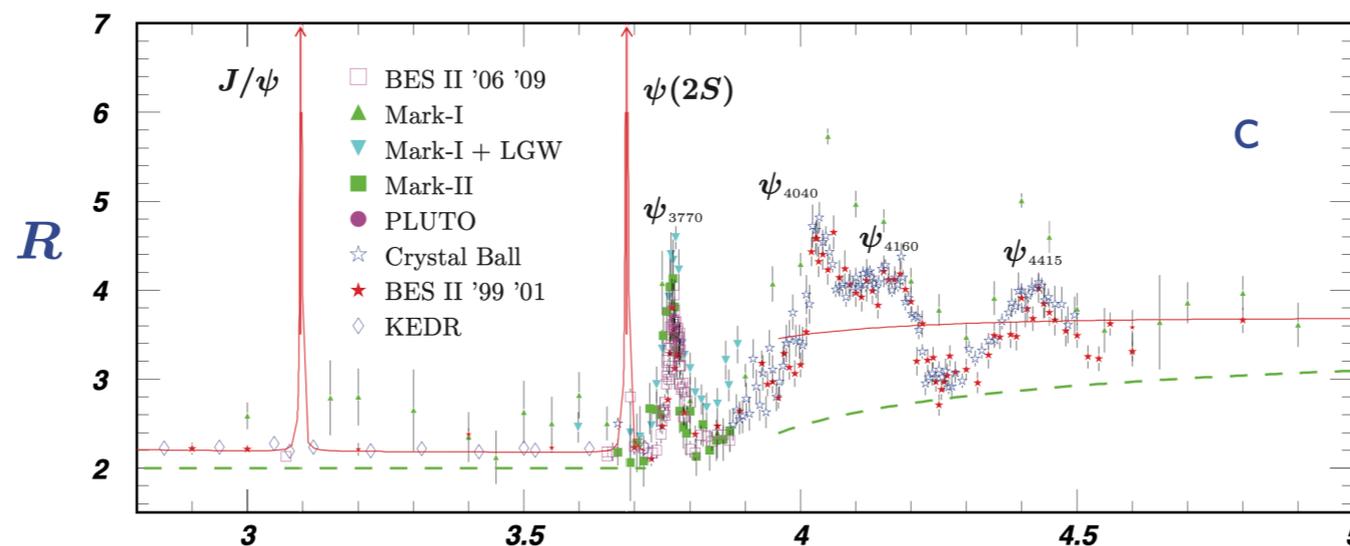
- Summary & Outlook

Introduction

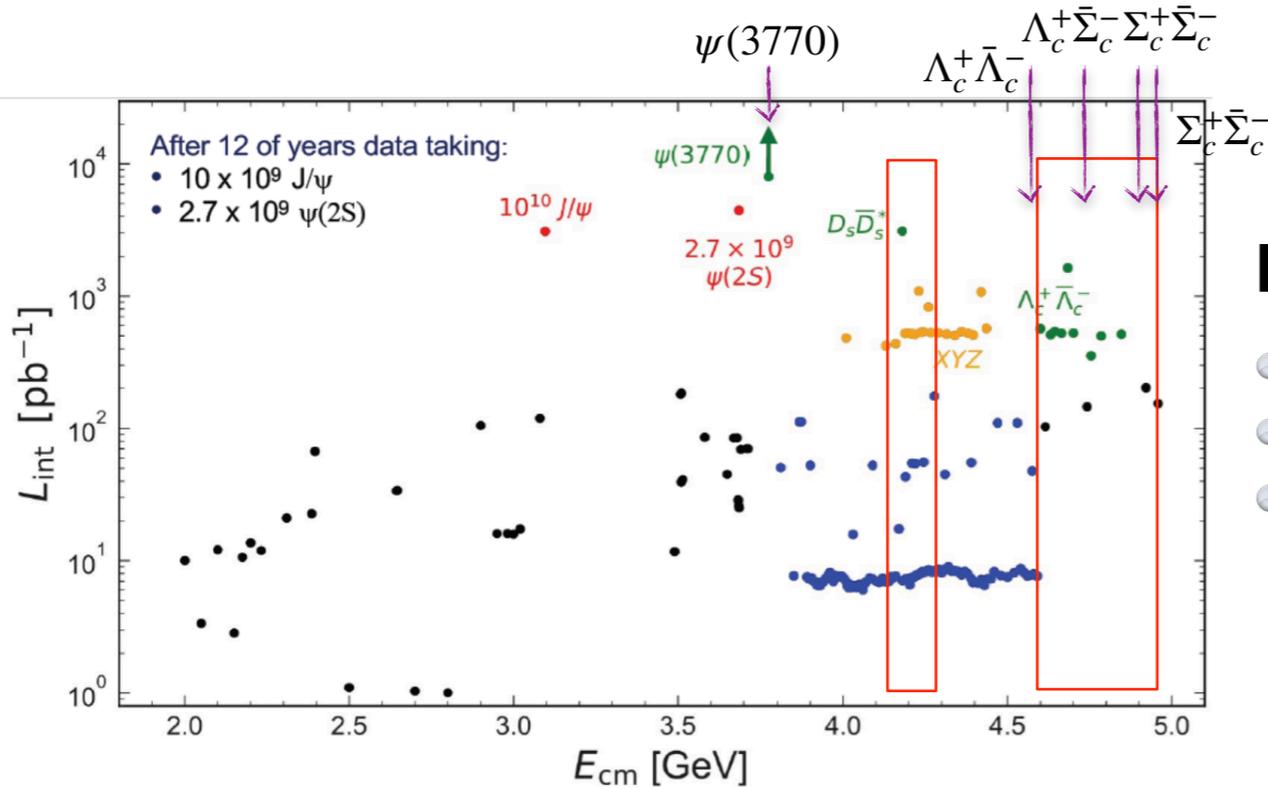
BEPCII & BESIII



$$\sqrt{s} = 2.0 - 4.95 \text{ GeV}$$

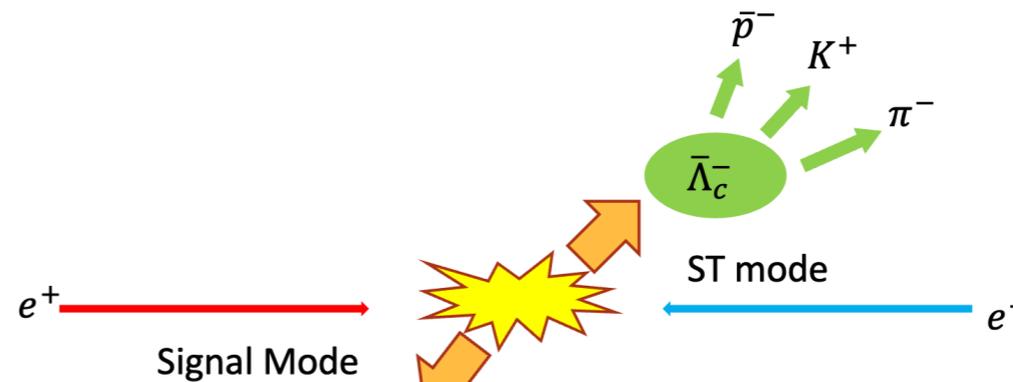


Datasets & Methodology



Dataset

- $e^+e^- \rightarrow \psi(3770) \rightarrow D^{0(+)}\bar{D}^{0(-)}$: 2.93 fb^{-1} @ $E_{\text{cm}} = 3.773 \text{ GeV}$
- $e^+e^- \rightarrow D_s^{*\pm}D_s^\mp$: 7.33 fb^{-1} @ $E_{\text{cm}} = 4.128 - 4.226 \text{ GeV}$
- $e^+e^- \rightarrow \Lambda_c^+\bar{\Lambda}_c^-$: 6.4 fb^{-1} @ $E_{\text{cm}} = 4.60 - 4.95 \text{ GeV}$



Advantage: pair production!

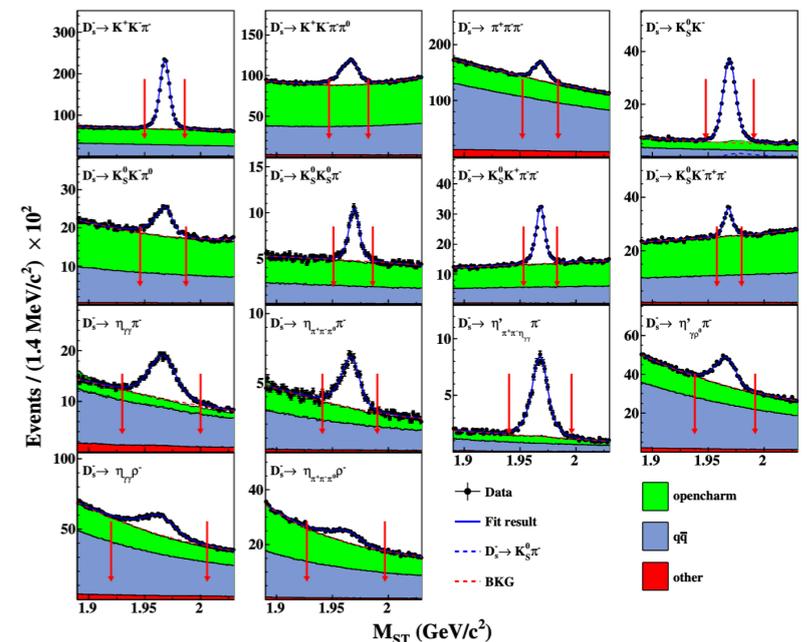
- Single Tag (ST):** reconstruct $D_{(s)}/\Lambda_c$
 - Relative high background
 - High efficiency and yields
- Double Tag (DT):** reconstruct both $D_{(s)}/\Lambda_c$
 - Clean background
 - Systematics from tag side cancelled
 - Kinematic constraint on missing particle

Tag modes:

- $\bar{D}^0 \rightarrow K^+\pi^-, \dots$
- $D^- \rightarrow K^+\pi^-\pi^-, \dots$
- $D_s^- \rightarrow K^+K^-\pi^-, \dots$
- $\bar{\Lambda}_c^- \rightarrow \bar{p}K^+\pi^-, \dots$

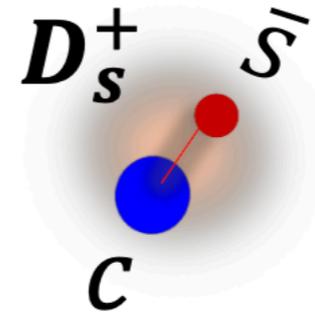
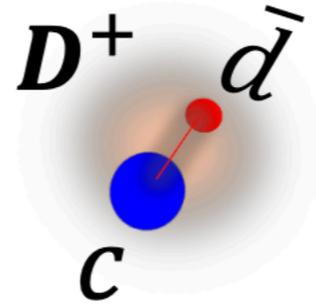
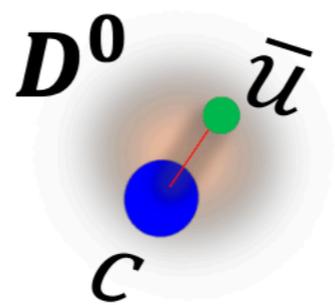
Branching fraction:

- $N_{\text{tag}} = 2N_{D\bar{D}}(\Lambda_c\bar{\Lambda}_c)\mathcal{B}_{\text{tag}}\epsilon_{\text{tag}}$
- $N_{\text{DT}} = 2N_{D\bar{D}}(\Lambda_c\bar{\Lambda}_c)\mathcal{B}_{\text{tag}}\mathcal{B}_{\text{sig}}\epsilon_{\text{DT}}$
- $\mathcal{B}_{\text{sig}} = \frac{N_{\text{DT}}}{N_{\text{tag}}\epsilon_{\text{DT}}/\epsilon_{\text{tag}}}$



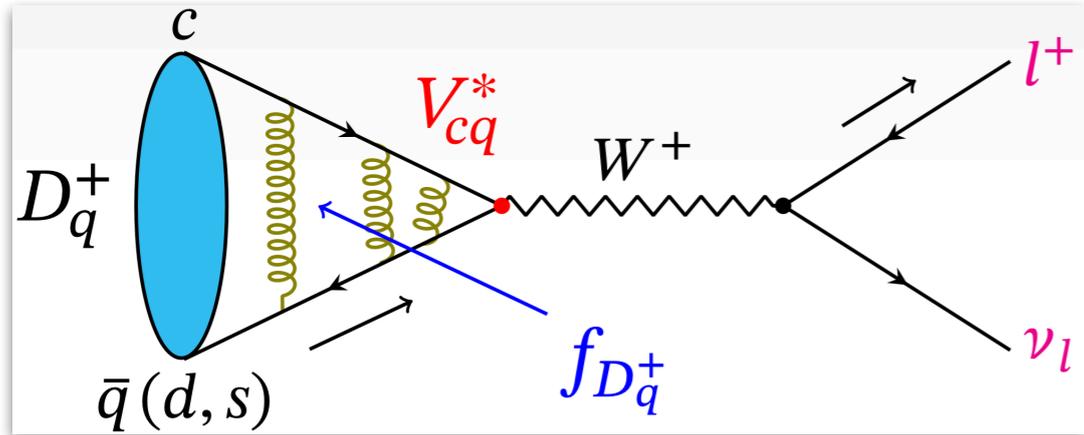


Charm meson decays



$D_{(s)}$ (semi-)leptonic decays

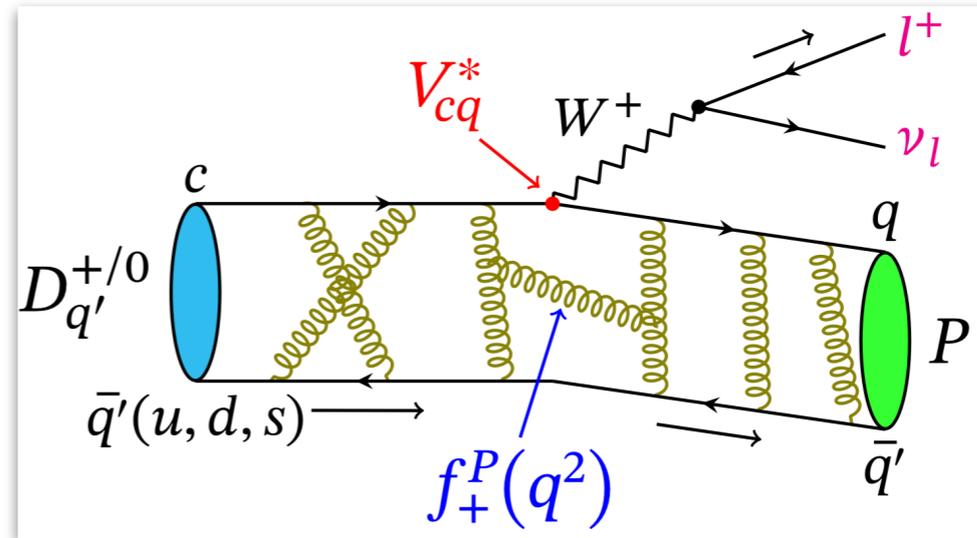
Pure leptonic decay



$$\Gamma(D_s^+ \rightarrow l^+ \nu) = \frac{G_F^2 f_{D(s)}^2}{8\pi} |V_{cd(s)}|^2 m_l^2 m_{D(s)}^+ \left(1 - \frac{m_l^2}{m_{D(s)}^+}\right)^2$$

↓ Decay rate ↓ CKM matrix element

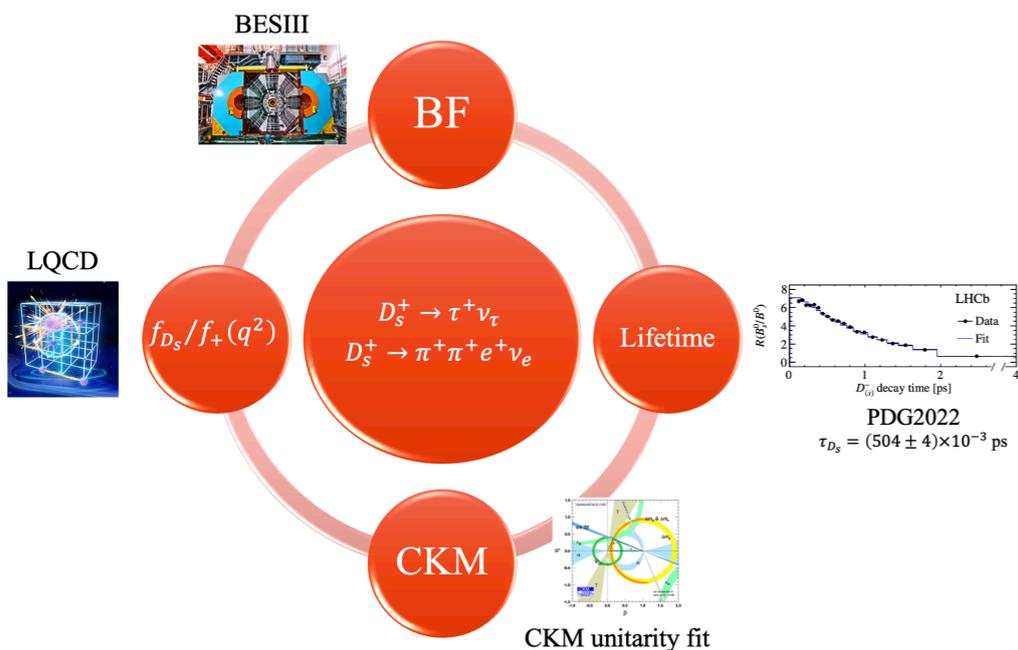
Semi-leptonic decay



$$\frac{d\Gamma}{dq^2} = X \frac{G_F^2 p^3}{24\pi^3} |f_+(q^2)|^2 |V_{cd(s)}|^2$$

↓ Partial decay rate ↓ Form factor (LQCD) ↓ CKM matrix element

$(X = 1 \text{ for } K^-, \pi^-, \bar{K}^0, \eta^{(0)}; X = \frac{1}{2} \text{ for } \pi^0)$



- $|V_{cs}|$ and $|V_{cd}|$ → Test CKM matrix unitarity
- **Decay constants and form factors** → Calibrate LQCD calculations
- Semi-leptonic decays → **Light hadron spectroscopy**
- **Branching fraction (BF) ratios** → Test lepton flavor universality (LFU)

$$\mathcal{R}_{\tau/\mu} = \frac{\mathcal{B}_{D(s)^+ \rightarrow \tau^+ \nu_\tau}}{\mathcal{B}_{D(s)^+ \rightarrow \mu^+ \nu_\mu}} = \frac{m_{\tau^+}^2 \left(1 - \frac{m_{\tau^+}^2}{m_{D_s^+}^2}\right)^2}{m_{\mu^+}^2 \left(1 - \frac{m_{\mu^+}^2}{m_{D_s^+}^2}\right)^2}$$



NEW!

arXiv:2304.12159
Submitted to PRL

$$7.33 \text{ fb}^{-1} e^+e^- \rightarrow D_s^{*\pm} D_s^\mp @ 4.128 - 4.226 \text{ GeV}$$

→ The most promising channel to observe **weak decay of charmed vector meson**^[1]

$$\text{Decay width}^{[2]}: \Gamma(D_s^{*+}) = \frac{G_F^2}{12\pi} |V_{cs}|^2 f_{D_s^{*+}}^2 m_{D_s^{*+}}^3 \left(1 - \frac{m_l^2}{m_{D_s^{*+}}^2}\right)^2 \left(1 + \frac{m_l^2}{2m_{D_s^{*+}}^2}\right)$$

→ **First experimental results on BF and $f_{D_s^{*+}}$**

$$\mathcal{B}(D_s^{*+} \rightarrow e^+ \nu_e) = (2.1_{-0.9}^{+1.2} \text{ stat.} \pm 0.2 \text{ syst.}) \times 10^{-5} (2.9\sigma)$$

$$\mathcal{B} < 4.0 \times 10^{-5} @ 90\% \text{ CL}$$

→ With the input from $\mathcal{B}(D_s^+ \rightarrow \mu^+ \nu_\mu)$ and LQCD $\left(\frac{f_{D_s^{*+}}}{f_{D_s^+}} = 1.12 \pm 0.01\right)$

$$\Gamma_{D_s^{*+}}^{\text{total}} = (121.9_{-52.2}^{+69.6} \pm 11.8) \text{ eV}$$

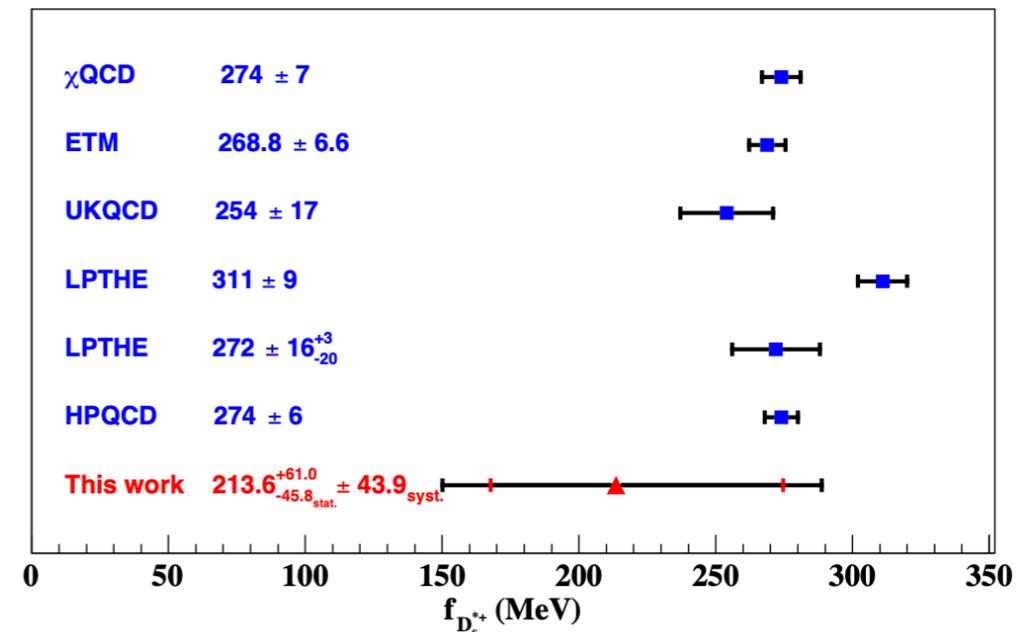
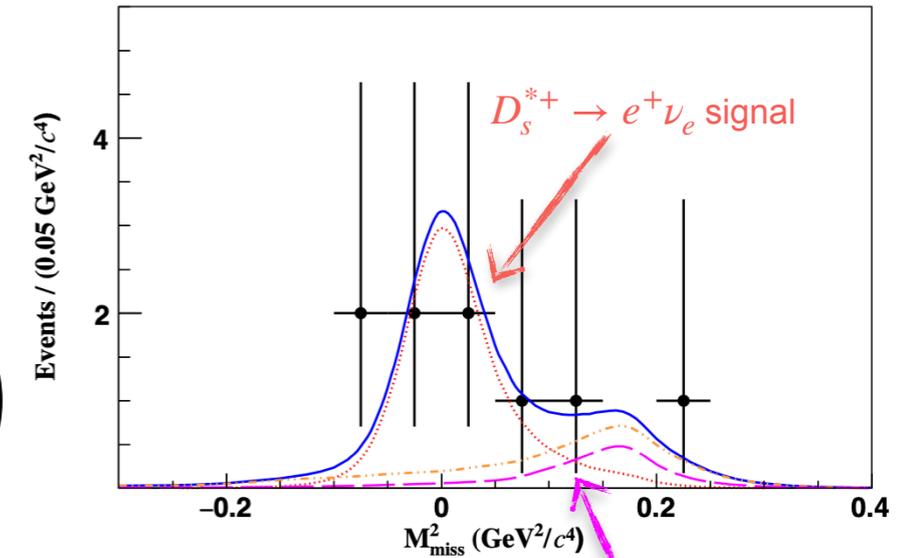
❖ Agree with $(70 \pm 28) \text{ eV}$ predicted by LQCD within $\pm 1\sigma$

❖ Indirectly constrains the upper limit on the total width $\Gamma_{D_s^{*+}}^{\text{total}}$ from MeV to keV level
(PDG2022: $\Gamma_{D_s^{*+}}^{\text{total}} < 1.9 \text{ MeV} @ 90\% \text{ CL}$)

→ With the input from LQCD ($\Gamma_{D_s^{*+}}^{\text{total}}$) and SM global fit
($|V_{cs}| = 0.97349 \pm 0.00016$)

$$f_{D_s^{*+}} = (213.6_{-45.8}^{+61.0} \text{ stat.} \pm 43.9 \text{ syst.}) \text{ MeV}$$

$$f_{D_s^{*+}} < 353.8 \text{ MeV} @ 90\% \text{ CL}$$



[1] EPJC 82, 1037 (2022)
[2] PRL 112, 212002 (2014)

$$D_s^+ \rightarrow \tau^+ \nu_\tau, \tau^+ \rightarrow \mu^+ \nu_\mu \bar{\nu}_\tau$$

NEW!

arXiv:2303.12468
Submitted to JHEP

$$7.33 \text{ fb}^{-1} e^+e^- \rightarrow D_s^{*\pm} D_s^\mp @ 4.128 - 4.226 \text{ GeV}$$

→ $E_{\text{extra}}^{\text{tot}}$: the total energy of the good isolated EMC showers which have not been used in tag selection.

→ DT yield $N_{\text{DT}} = N_{\text{tot}} - N_{\text{BKGI}}^{\text{non-}D_s} - N_{\text{BKGII}}^{K_L^0 \mu^+ \nu_\mu} - N_{\text{BKGIII}}^{\text{others}}$

❖ In signal region $E_{\text{extra}}^{\text{tot}} < 0.4 \text{ GeV}$

❖ $N_{\text{BKG}}^{\text{others}}$: extrapolated from the fits to BKG region $E_{\text{extra}}^{\text{tot}} > 0.6 \text{ GeV}$

$$\mathcal{B}(\tau^+ \rightarrow \tau \nu_\tau) = (5.34 \pm 0.16_{\text{stat.}} \pm 0.10_{\text{syst.}}) \%$$

$$f_{D_s^+} |V_{cs}| = (246.2 \pm 3.7_{\text{stat.}} \pm 2.5_{\text{syst.}}) \text{ MeV}$$

Precision ~1.8%

Taking $|V_{cs}| = 0.97349 \pm 0.00016$ from SM global fit,

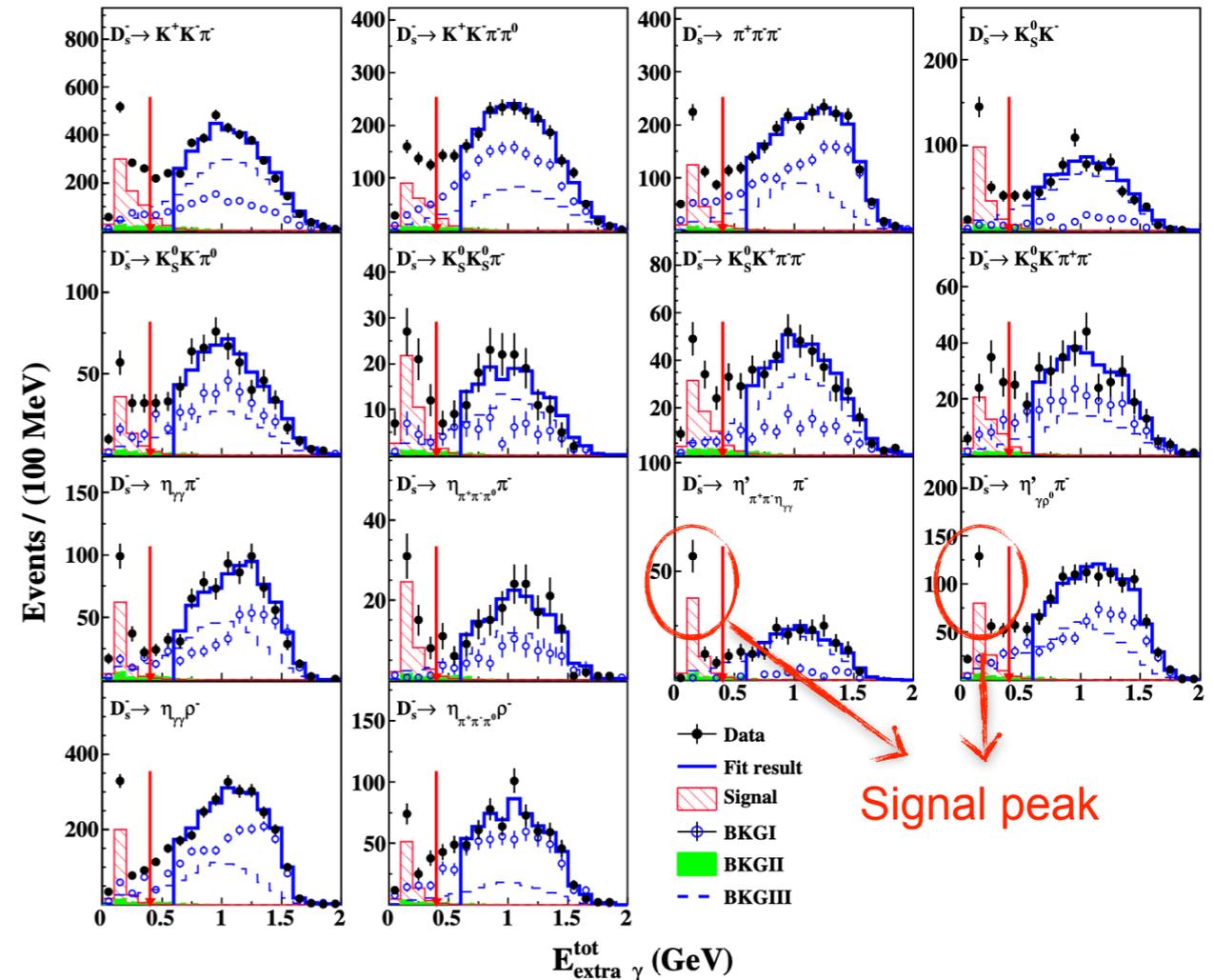
• $f_{D_s^+} = (252.2 \pm 3.8_{\text{stat.}} \pm 2.6_{\text{syst.}}) \text{ MeV}$

Taking $f_{D_s^+} = (249.9 \pm 0.5) \text{ MeV}$ from LQCD,

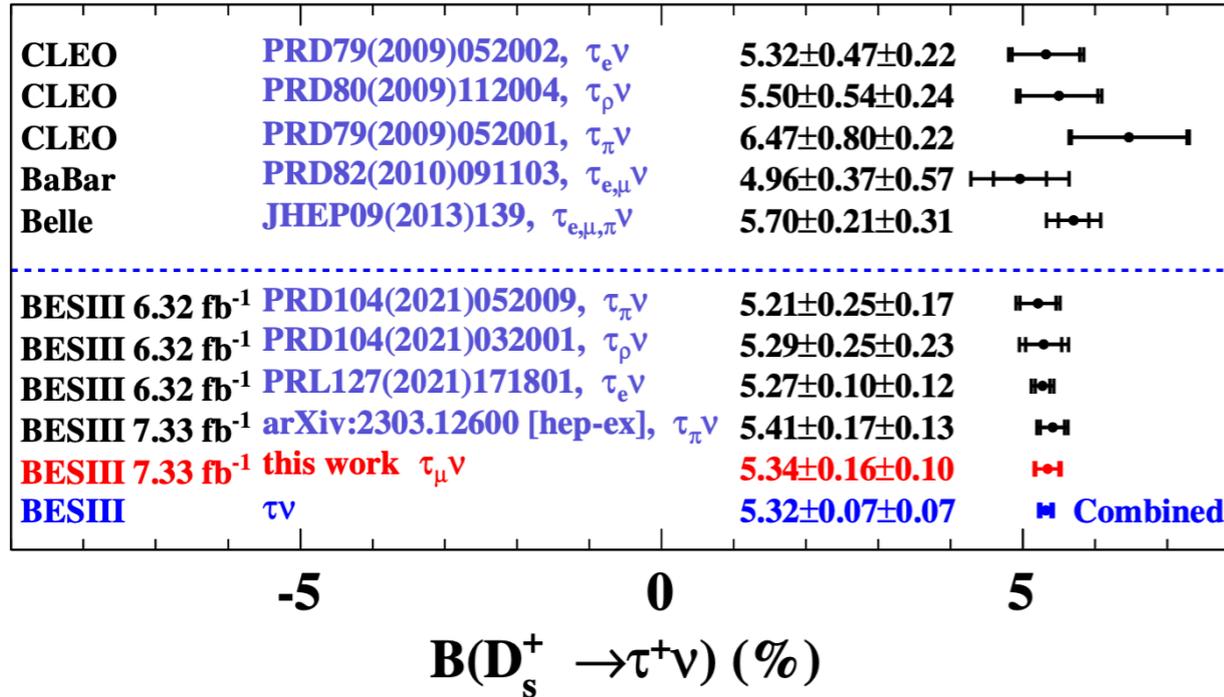
• $|V_{cs}| = 0.984 \pm 0.015_{\text{stat.}} \pm 0.010_{\text{syst.}}$

Taking $\mathcal{B}(D_s^+ \rightarrow \mu^+ \nu_\mu)$ from PDG

• $\mathcal{R}_{\tau/\mu} = 9.83 \pm 0.43$



$\mathcal{B}(D_s^+ \rightarrow \tau^+ \nu_\tau)$ & $f_{D_s^+}$ & $|V_{cs}|$



Precision ~1.9%

$$\mathcal{B}(D_s^+ \rightarrow \tau^+ \nu_\tau) = (5.32 \pm 0.07_{\text{stat.}} \pm 0.07_{\text{stat.}}) \%$$

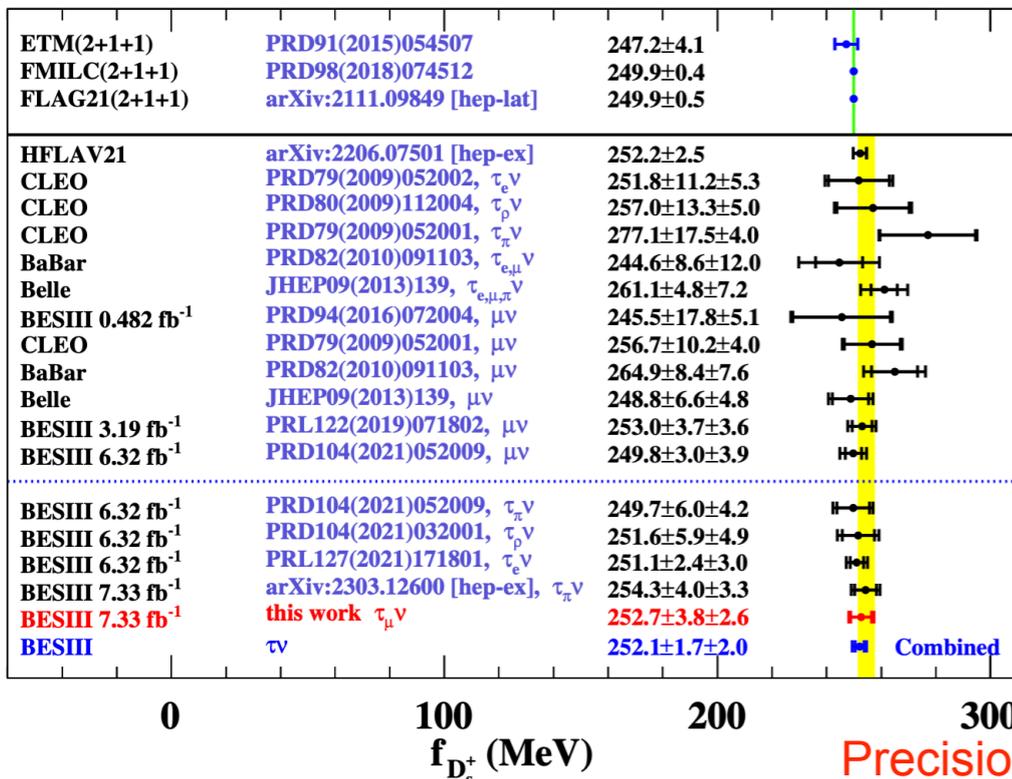
$$\mathcal{R}_{\tau/\mu} = \frac{\mathcal{B}_{D(s)^+ \rightarrow \tau^+ \nu_\tau}}{\mathcal{B}_{D(s)^+ \rightarrow \mu^+ \nu_\mu}}$$

EXP combined: 9.79 ± 0.33

SM prediction: 9.75 ± 0.01

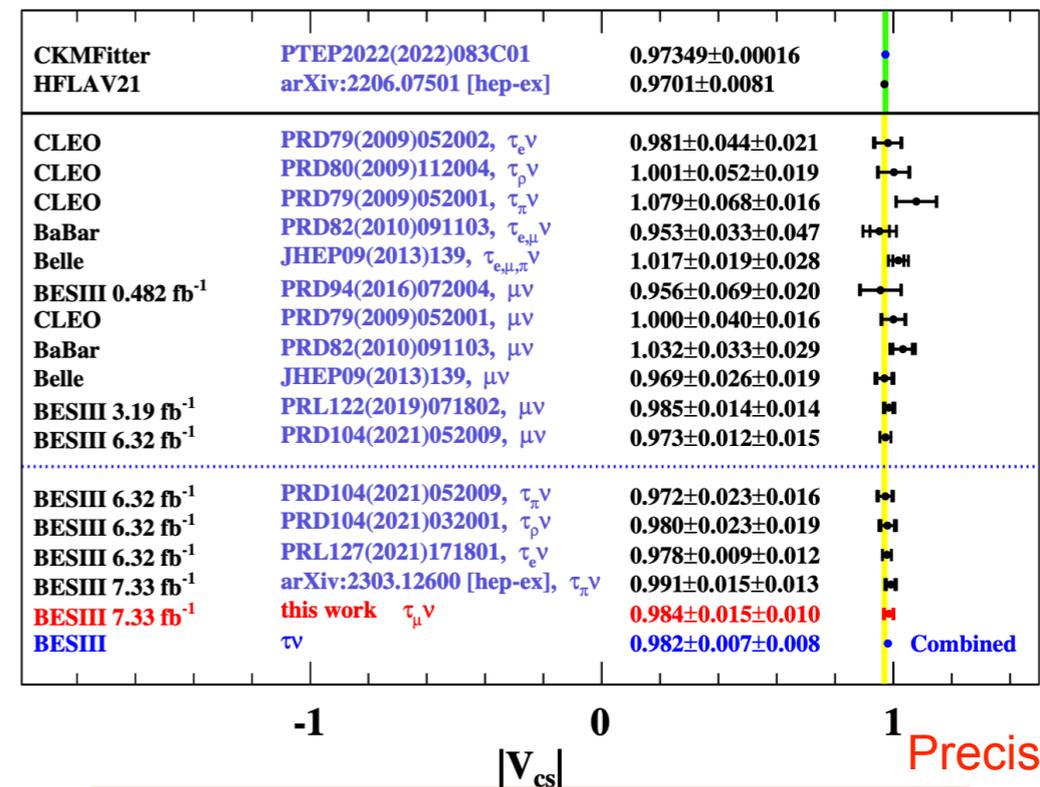
No LFU violation in $\tau - \mu$ flavors with the current precision.

BESIII is leading the measurement precision!



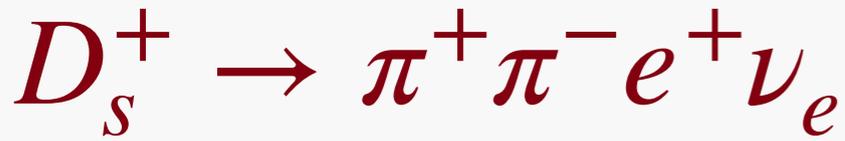
Precision ~1.0%

$$f_{D_s^+} = (252.1 \pm 1.7_{\text{stat.}} \pm 2.0_{\text{stat.}}) \text{ MeV}$$



Precision ~1.1%

$$|V_{cs}| = 0.982 \pm 0.007_{\text{stat.}} \pm 0.008_{\text{stat.}}$$



NEW!

arXiv:2303.12927
Submitted to PRL

$$7.33 \text{ fb}^{-1} e^+ e^- \rightarrow D_s^{*\pm} D_s^\mp @ 4.128 - 4.226 \text{ GeV}$$

→ $f_0(980)$ observed in $\pi^+ \pi^-$ system

❖ $\mathcal{B}(D_s^+ \rightarrow f_0(980) e^+ \nu_e, f_0(980) \rightarrow \pi^+ \pi^-) = (1.72 \pm 0.13_{\text{stat.}} \pm 0.10_{\text{syst.}}) \times 10^{-3}$

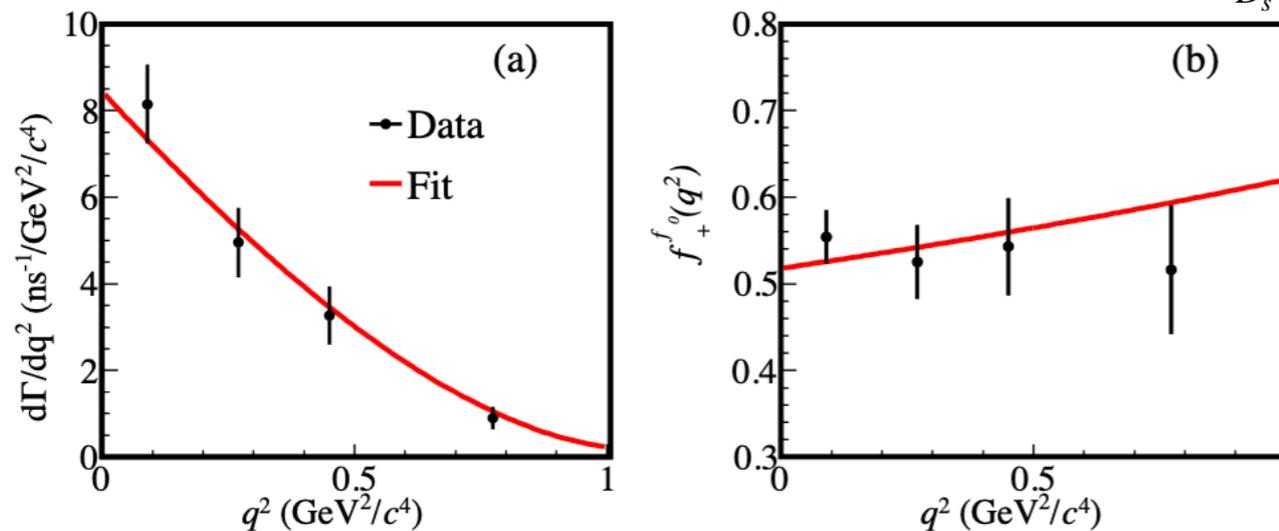
❖ 2.6 times more accurate than previous measurement^[1]

❖ Probe the nature of $f_0(980)$: **$s\bar{s}$ component is important** $|f_0(980)\rangle = \sin\phi |\frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d})\rangle + \cos\phi |s\bar{s}\rangle$

→ Determine $f_+^{f_0}(0) |V_{cs}| = 0.504 \pm 0.017_{\text{stat.}} \pm 0.035_{\text{syst.}}$ for the first time

❖ Taking $|V_{cs}|$ from SM global fit, $f_+^{f_0}(0) = 0.518 \pm 0.018_{\text{stat.}} \pm 0.036_{\text{syst.}}$

Differential decay rate $\frac{d^2\Gamma(D_s^+ \rightarrow f_0(980)e^+\nu_e)}{dsdq^2} = \frac{G_F^2 |V_{cs}|^2}{192\pi^4 m_{D_s^+}^3} \lambda^{3/2}(m_{D_s^+}^2, s, q^2) |f_+^{f_0}(q^2)|^2 P(s)$

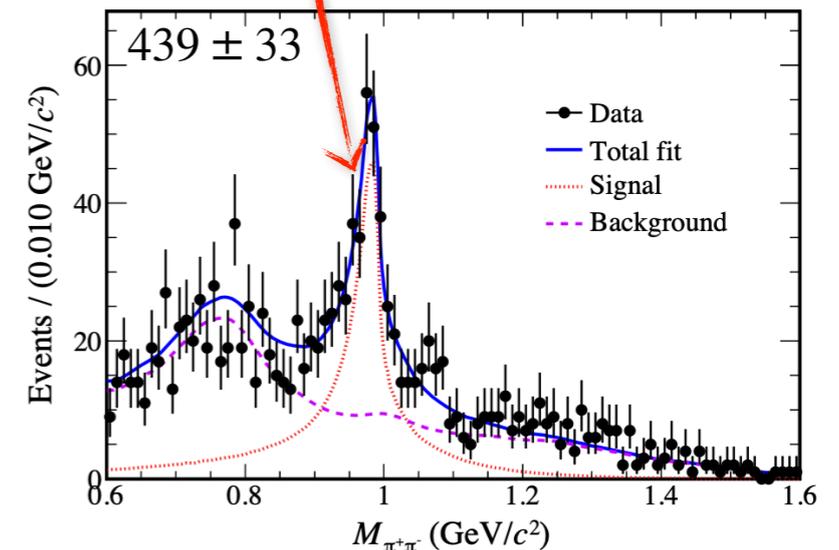


Simple pole parameterization

$$f_+^{f_0}(q^2) = \frac{f_+^{f_0}(0)}{1 - q^2/M_{\text{pole}}^2}$$

Flatté model

$$P(s) = \frac{g_1 \rho_{\pi\pi}}{|m_0^2 - s - i(g_1 \rho_{\pi\pi} + g_2 \rho_{K\bar{K}})|^2}$$



	This work	CLFD [6]	DR [6]	QCDSR [7]	QCDSR [8]	LCSR [9]	LFQM [11]	CCQM [12]
$f_+^{f_0}(0)$	$0.518 \pm 0.018_{\text{stat}} \pm 0.036_{\text{syst}}$	0.45	0.46	0.50 ± 0.13	0.48 ± 0.23	0.30 ± 0.03	0.24 ± 0.05	0.39 ± 0.02
Difference (σ)	—	—	—	0.1	0.2	4.3	4.3	2.8
ϕ in theory	—	$(32 \pm 4.8)^\circ$	$(41.3 \pm 5.5)^\circ$	35°	$(8_{-8}^{+21})^\circ$	—	$(56 \pm 7)^\circ$	31°

Comparison with theoretical calculations

Disagree

[1] PRD 92, 012009 (2015)

$D_{(s)}$ hadronic decays

→ Measurement of absolute BFs

- ❖ Probe non-perturbative QCD
- ❖ Test theoretical calculations of BFs or decay asymmetry parameters
- ❖ Understand $SU(3)$ flavor symmetry and its breaking effect

→ Amplitude analysis of multi-body hadronic charm decays

- ❖ Light hadron spectroscopy
- ❖ More information of $D \rightarrow VP, PS, VV, TS, TP, AP$

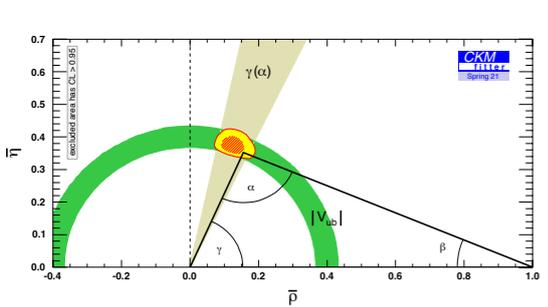
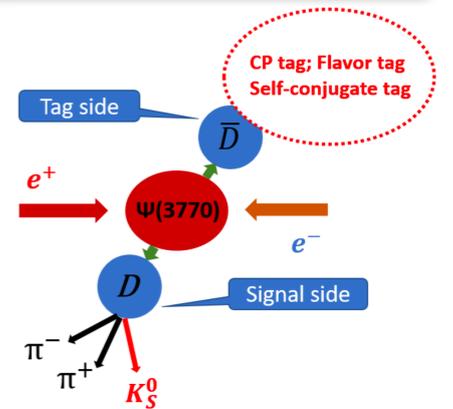
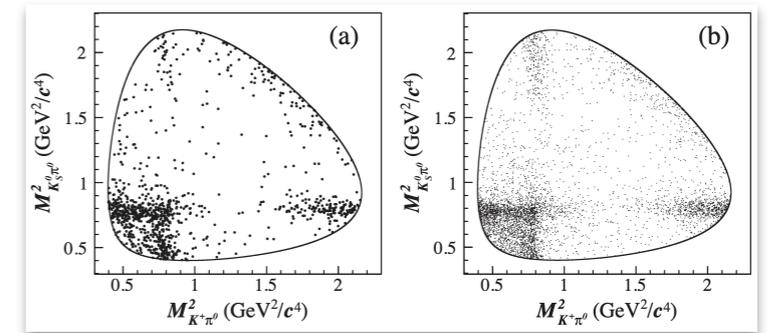
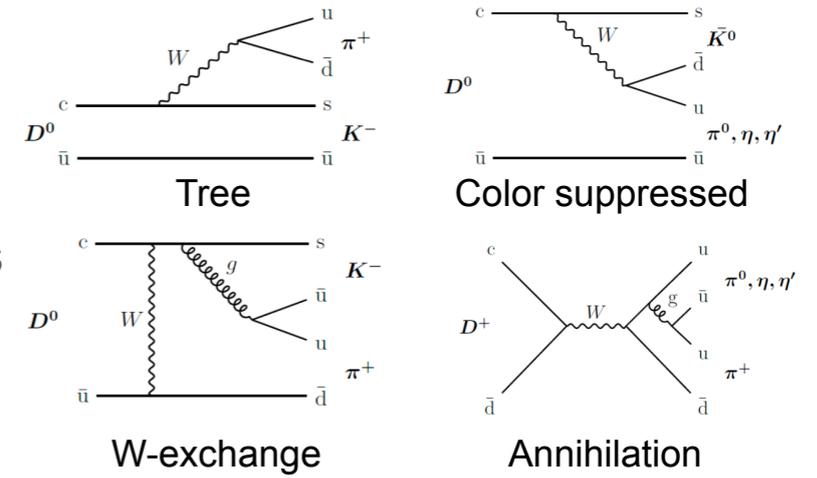
P : pseudo-scalar
 V : vector
 S : scalar
 A : axial-vector
 T : tensor

→ Quantum-correlated (QC) $e^+e^- \rightarrow \psi(3770) \rightarrow D^0\bar{D}^0$

- ❖ Ideal opportunity to extract strong-phase differences between D^0 and \bar{D}^0
- ❖ QC effect $\Rightarrow \Gamma_{QC}(S|T) = \Gamma_0 A_S^2 A_T^2 [(r_D^S)^2 + (r_D^T)^2 - 2R_S R_T r_D^S r_D^T \cos(\delta_D^T - \delta_D^S)]$
- ❖ Important input to the determination of CKM angle γ

QC term
 Strong-phase difference

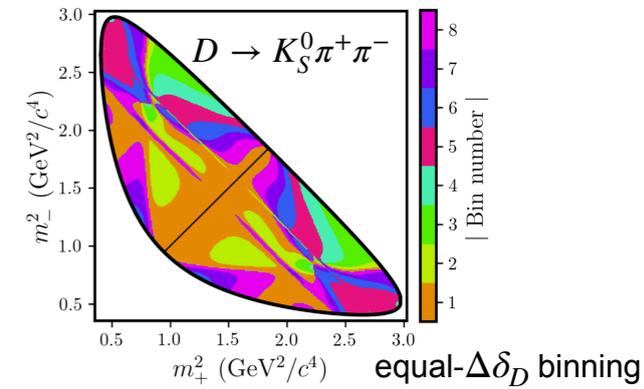
Topological diagrams for $D \rightarrow VP, PP$



ADS ← Flavour
 GLW ← CP-even
 BPGGSZ ← CP-odd
 ← Self-conjugate

$K^\pm \pi^\mp \pi^\mp \pi^\mp, K^\pm \pi^\mp \pi^0, K^\pm \pi^\mp, \dots$
 $K^+ K^-, \pi^+ \pi^-, \pi^0 \pi^0, K_S^0 \pi^0 \pi^0, K_L^0 \pi^0, K_L^0 \omega, \pi^+ \pi^- \pi^0$
 $K_S^0 \pi^0, K_S^0 \eta, K_S^0 \omega, K_S^0 \eta', K_S^0 \phi, K_L^0 \pi^0 \pi^0$
 $K_S^0 \pi^+ \pi^-, K_S^0 K^+ K^-, \dots$

Strong-phase measurement via different tags



$$D_s^+ \rightarrow K_S^0 K^+ \pi^0$$

HIGHLIGHT!

PRL129,182001 (2022)

$$6.32 \text{ fb}^{-1} e^+e^- \rightarrow D_s^{*\pm} D_s^\mp @ 4.178 - 4.226 \text{ GeV}$$

→ First amplitude analysis of $D_s^+ \rightarrow K_S^0 K^+ \pi^0$

$$\mathcal{B}(D_s^+ \rightarrow K_S^0 K^+ \pi^0) = (1.46 \pm 0.06_{\text{stat.}} \pm 0.05_{\text{syst.}}) \%$$

Precision improved by a factor of 2.8

→ Observation of $a_0(1817)^+$ in $K_S^0 K^+$ mass spectrum ($> 10\sigma$)

$$M = (1.817 \pm 0.008_{\text{stat.}} \pm 0.020_{\text{syst.}}) \text{ GeV}/c^2$$

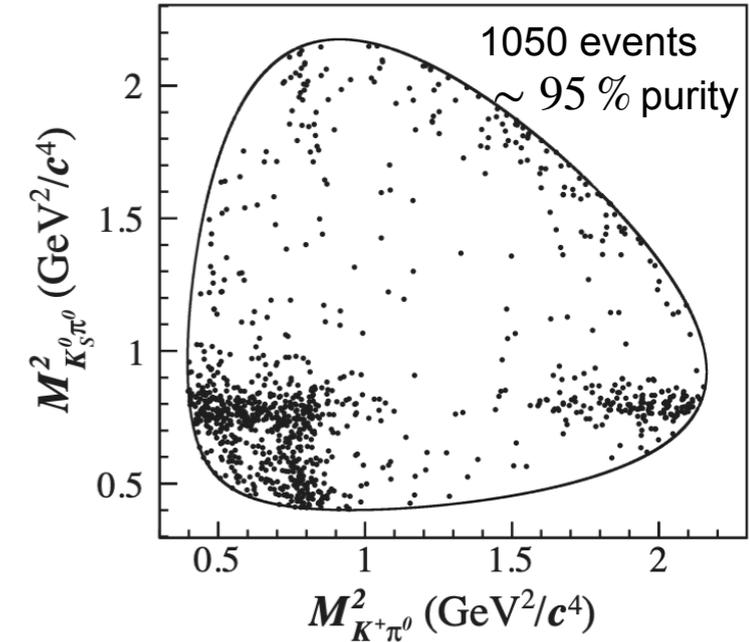
$\sim 100 \text{ MeV}/c^2$

$$\Gamma = (0.097 \pm 0.022_{\text{stat.}} \pm 0.015_{\text{syst.}}) \text{ GeV}/c^2$$

larger than expected

❖ Isovector partner of $f_0(1710)$ ^[1-6] or $X(1812)$ ^[7]?

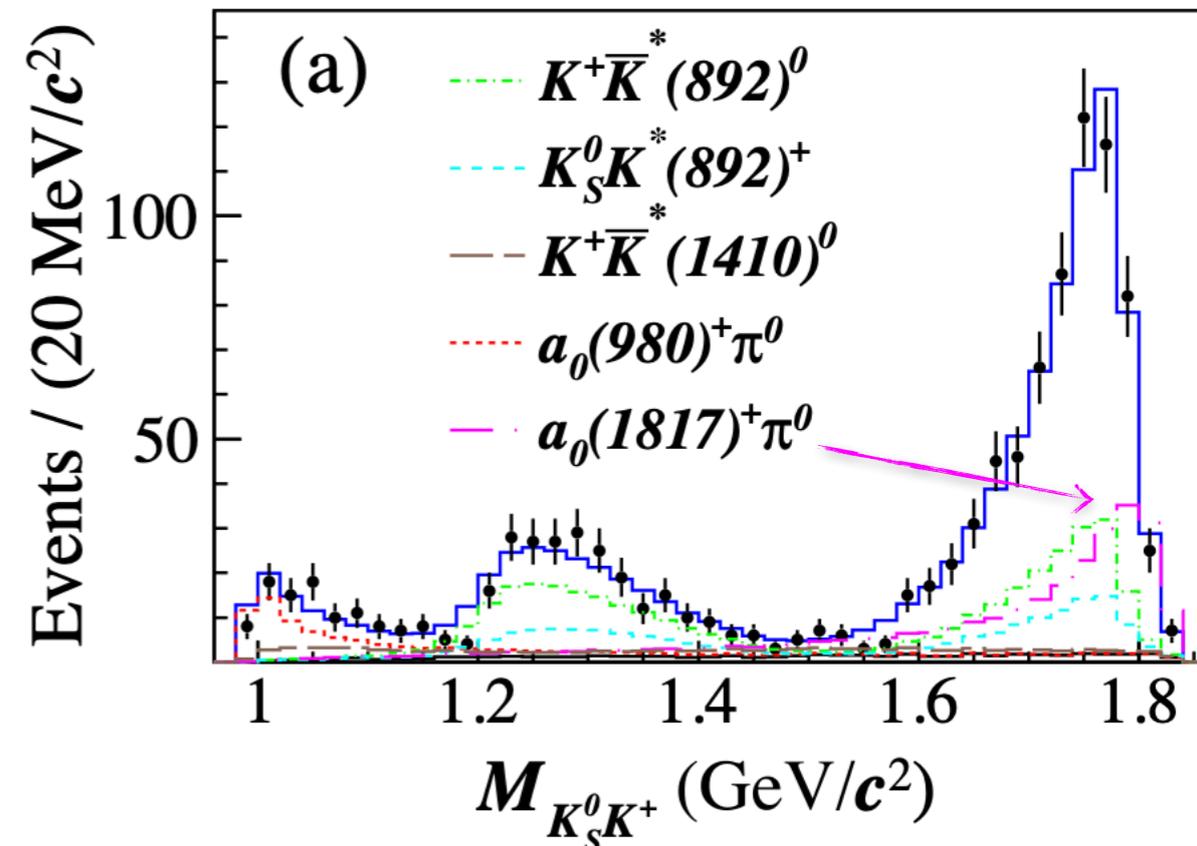
❖ The simultaneous amplitude analysis of $D_s^+ \rightarrow K_S^0 K^+ \pi^0$ and $D_s^+ \rightarrow K_S^0 K_S^0 \pi^+$ can be expected



$$\rightarrow \frac{\mathcal{B}(a_0(980)^+ \rightarrow \bar{K}^0 K^+)}{\mathcal{B}(a_0(980)^+ \rightarrow \pi^+ \eta)} = (13.7 \pm 3.6_{\text{stat.}} \pm 4.2_{\text{syst.}}) \%$$

❖ Key experimental input for coupling constant $g_{a_0 \eta \pi}$ and $g_{a_0 K K}$

$$\rightarrow \frac{\mathcal{B}(D_s^+ \rightarrow K^*(892)^0 K^+)}{\mathcal{B}(D_s^+ \rightarrow \bar{K}^0 K^*(892)^+)} = 2.35_{-0.23}^{+0.42}_{\text{stat.}} \pm 0.10_{\text{syst.}}$$



[1] PRD 79, 074009 (2009)

[2] EPJC 82, 225 (2022)

[3] PLB 820, 136512 (2021)

[4] PLB 816, 136227 (2021)

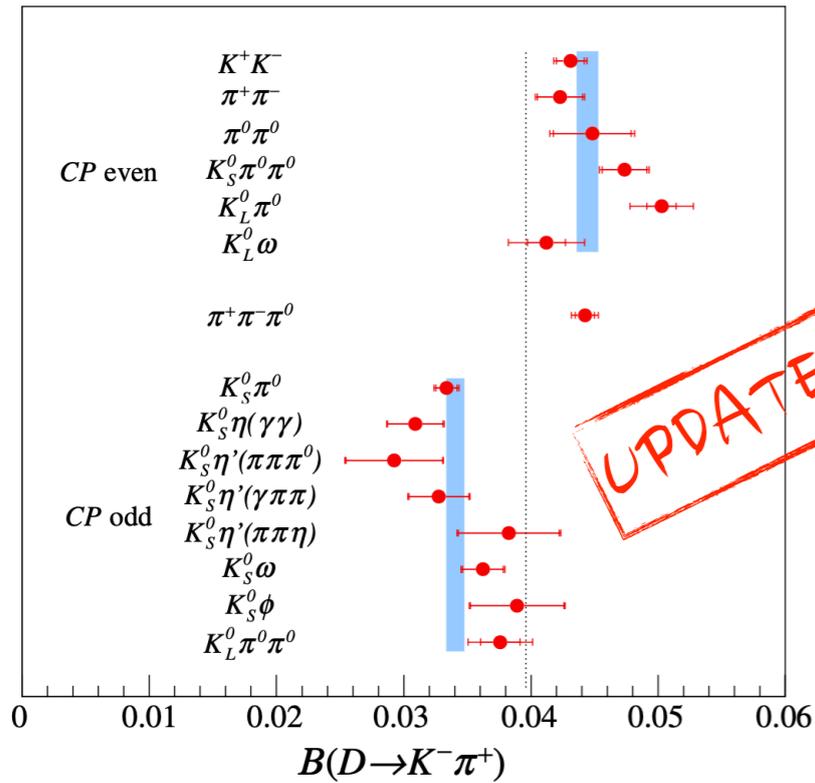
[5] EPJC 82, 509 (2022)

[6] PRD 105, 116010 (2022)

[7] PRD 105, 114014 (2022)

Strong-phase measurement

$2.93 \text{ fb}^{-1} e^+e^- \rightarrow \psi(3770) \rightarrow D^0\bar{D}^0 @ 3.773 \text{ GeV}$ EPJC 82, 1009 (2022)



$\delta_D^{K\pi} = (187.6^{+8.9+5.4}_{-9.7-6.4})^\circ$ **most precise measurement!**

$$r_D^{K\pi} \exp(-i\delta_D^{K\pi}) = \frac{\langle K^+\pi^- | D^0 \rangle}{\langle K^+\pi^- | \bar{D}^0 \rangle}$$

$r_D^{K\pi}$: ratio of amplitudes between DCS and CF decays
 $\delta_D^{K\pi}$: phase difference between DCS and CF decays

$\mathcal{A}_{K\pi} = 0.132 \pm 0.001 \pm 0.007$ **30% more precise!**

$$\mathcal{A}_{K\pi} = \frac{\mathcal{B}(D_- \rightarrow K^- \pi^+) - \mathcal{B}(D_+ \rightarrow K^- \pi^+)}{\mathcal{B}(D_- \rightarrow K^- \pi^+) + \mathcal{B}(D_+ \rightarrow K^- \pi^+)} = \frac{-2r_D^{K\pi} \cos\delta_D^{K\pi} + y}{1 + (r_D^{K\pi})^2}$$

$\mathcal{A}_{K\pi}^{\pi\pi\pi^0} = 0.130 \pm 0.012 \pm 0.008$

$$\mathcal{A}_{K\pi}^{\pi\pi\pi^0} = \frac{\mathcal{B}(D_X \rightarrow K^- \pi^+) - \mathcal{B}(D_+ \rightarrow K^- \pi^+)}{\mathcal{B}(D_X \rightarrow K^- \pi^+) + \mathcal{B}(D_+ \rightarrow K^- \pi^+)} = \frac{(-2r_D^{K\pi} \cos\delta_D^{K\pi} + y)F_+^{\pi\pi\pi^0}}{1 + (r_D^{K\pi})^2 + (1 - F_+^{\pi\pi\pi^0})(2r_D^{K\pi} \cos\delta_D^{K\pi} + y)}$$

• BFs of three $D \rightarrow K_L^0 X$ decays are determined

- $\mathcal{B}(D^0 \rightarrow K_L^0 \pi^0) = (0.97 \pm 0.03 \pm 0.02) \%$
- $\mathcal{B}(D^0 \rightarrow K_L^0 \omega) = (1.09 \pm 0.06 \pm 0.03) \%$
- $\mathcal{B}(D^0 \rightarrow K_L^0 \pi^0 \pi^0) = (1.26 \pm 0.05 \pm 0.03) \%$

Other strong-phase measurements

$D^0 \rightarrow \pi^+ \pi^- \pi^+ \pi^- : F_+ = 0.735 \pm 0.015 \pm 0.005$

PRD 106, 092004 (2022)

Predominantly **CP-even**
Most precise determination

$D^0 \rightarrow K^+ K^- \pi^+ \pi^- : F_+ = 0.730 \pm 0.037 \pm 0.021$

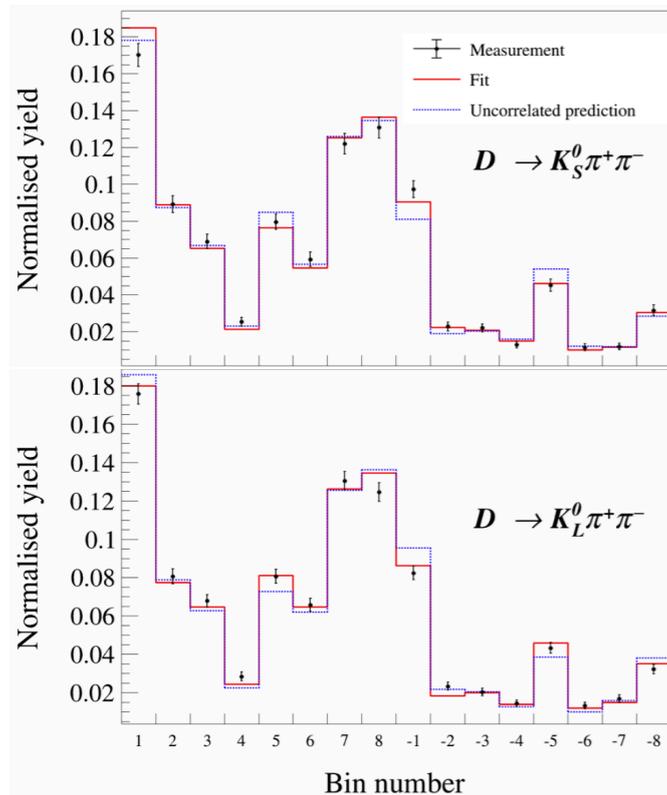
PRD 107, 032009 (2022)

Predominantly **CP-even**
First model-independent measurement of F_+ of this decay

$D^0 \rightarrow K_S^0 \pi^+ \pi^- : F_+ = 0.235 \pm 0.010 \pm 0.002$

arXiv:2305.03975

Predominantly **CP-odd**



Other $D_{(s)}$ results

Recent results since LP2022

→ Hadronic decays

- ❖ Amp Ana $D^+ \rightarrow K_S^0 \pi^+ \pi^0 \pi^0$ [arXiv:2305.15879]
- ❖ Amp Ana $D_s^+ \rightarrow K^+ \pi^+ \pi^- \pi^0$ [JHEP 09, 242 (2022)]
- ❖ Amp Ana $D_s^+ \rightarrow K^+ \pi^+ \pi^-$ [JHEP 08, 196 (2022)]
- ❖ Amp Ana $D_s^+ \rightarrow K^+ K^- \pi^+ \pi^+ \pi^-$ [JHEP 07, 051 (2022)]
- ❖ Amp Ana $D_s^+ \rightarrow \pi^+ \pi^0 \eta'$ [JHEP 04, 058 (2022)]
- ❖ Amp Ana $D^0 \rightarrow K_L^0 \pi^+ \pi^-$ [arXiv:2212.09048]
- ❖ $D^{0(+)} \rightarrow K_S^0 X$ [PRD 107, 112005 (2023)]
- ❖ $D_s^+ \rightarrow \omega \pi^+ \eta$ [PRD 107, 052010 (2023)]
- ❖ $D^{0(+)} \rightarrow \pi^+ \pi^+ \pi^- X$ [PRD 107, 032002 (2023)]
- ❖ $D_s^{*+} \rightarrow D_s^+ \pi^0 (\gamma)$ [PRD 107, 032011 (2023)]
- ❖ $D_s^+ \rightarrow \pi^+ \pi^+ \pi^- X$ [arXiv:2212.13072]
- ❖ SCS decays $D^{0(+)} \rightarrow \text{multiple } \pi$ [PRD 106, 092005 (2022)]
- ❖ DCS decays $D^0 \rightarrow K^+ \pi^- \pi^0$ and $D^0 \rightarrow K^+ \pi^- \pi^0 \pi^0$ [PRD 105, 112001 (2022)]
- ❖ $D^0 \rightarrow K_L^0 X$ ($X = \phi, \eta, \omega, \eta'$) [PRD 105, 092010 (2022)]

→ Semi-leptonic decays

- ❖ $D_s^+ \rightarrow \tau^+ \nu_\tau, \tau^+ \rightarrow \pi^+ \nu_\tau$ [arXiv:2303.12600]
- ❖ $D_s^+ \rightarrow \eta(\eta') e^+ \nu_e$ [arXiv:2306.05194]
- ❖ $D_s^+ \rightarrow \pi^0 e^+ \nu_e$ [PRD 106, 112004 (2022)]
- ❖ $D^{*0} \rightarrow D^0 e^+ e^-$ [PRD 104, 112012 (2021)]
- ❖ $D_s^+ \rightarrow \pi^0 \pi^0 (K_S^0 K_S^0) e^+ \nu_e$ [PRD, 105, L031101 (2022)]

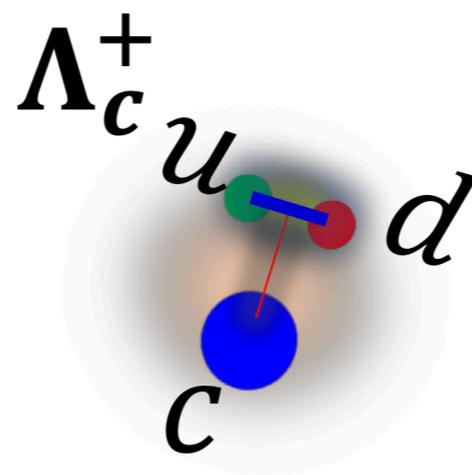
→ Rare decays

- ❖ $D^\pm \rightarrow n(\bar{n}) e^\pm$ [PRD 106, 112009 (2022)]
- ❖ $D^0 \rightarrow \pi^0 \nu \nu$ [PRD 105, L071102 (2022)]
- ❖ $D^0 \rightarrow \bar{p} e^+$ and $p e^-$ [PRD 105, 032006 (2022)]

Many exciting and interesting results!



Charm baryon decays

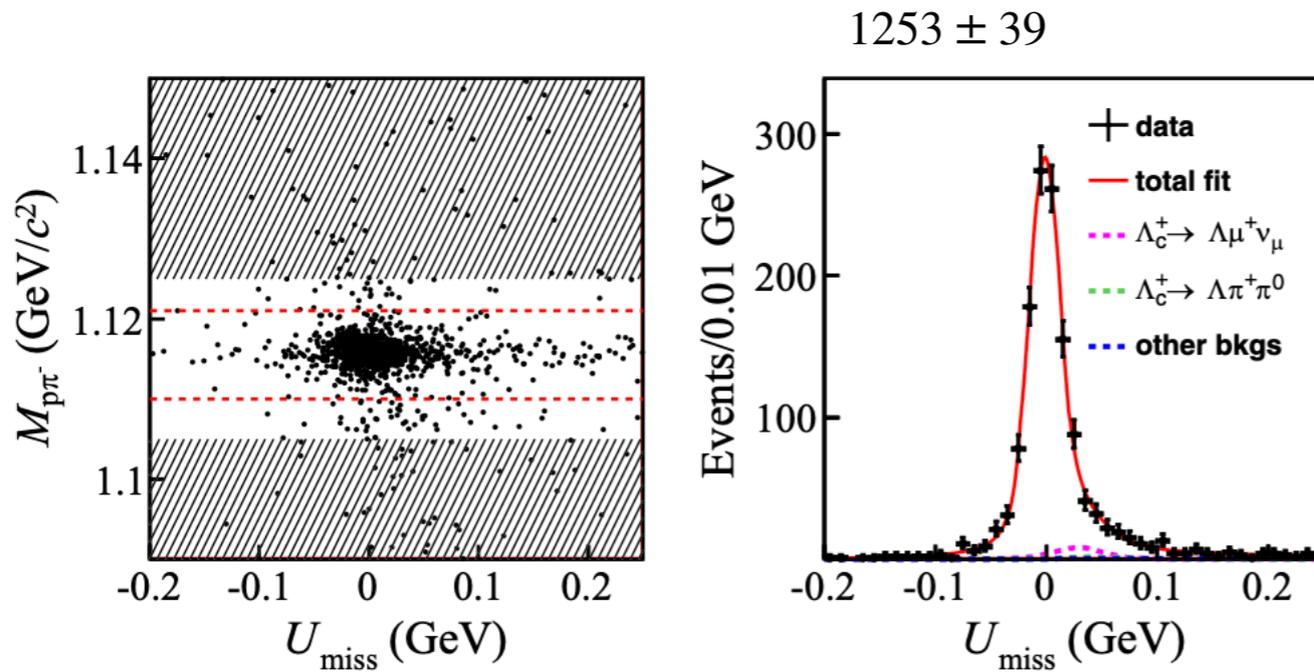




$4.5 \text{ fb}^{-1} e^+e^- \rightarrow \Lambda_c^+ \bar{\Lambda}_c^- @ 4.600 - 4.699 \text{ GeV}$

UPDATE!
HIGHLIGHT!

PRL129,231803 (2022)



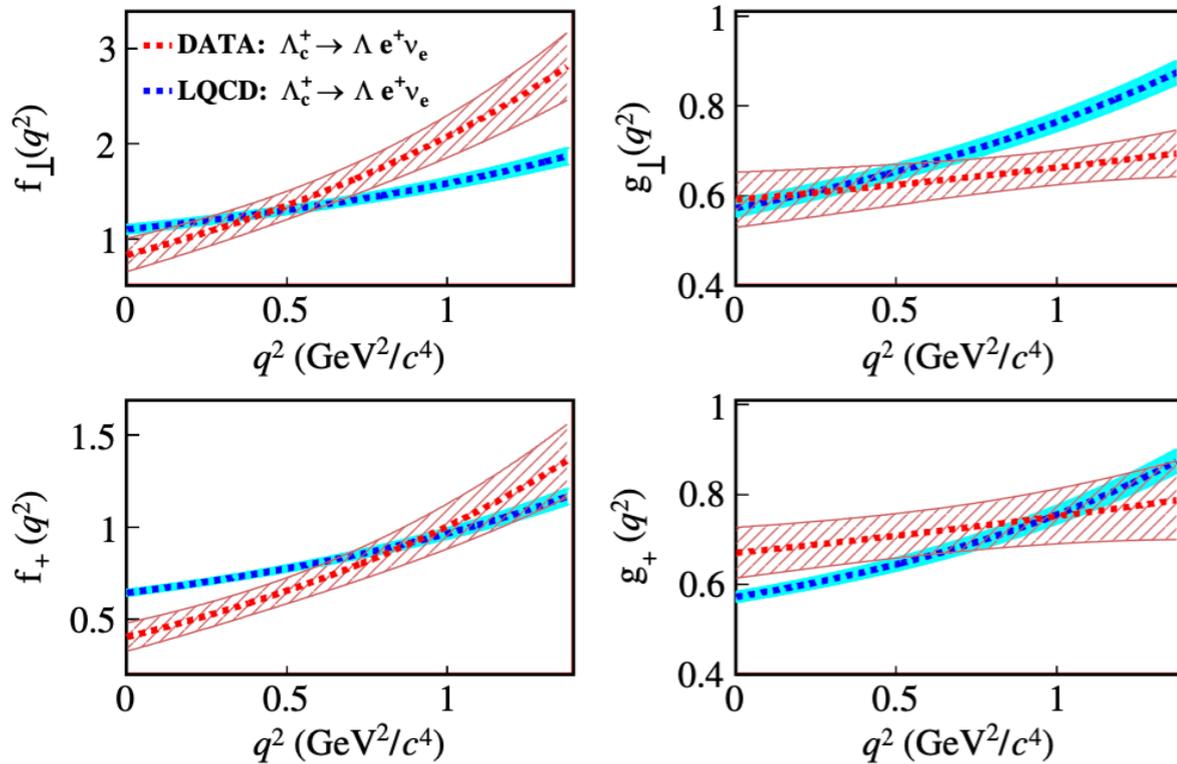
Comparisons between measurement and theoretical predictions.

	$\mathcal{B}(\Lambda_c^+ \rightarrow \Lambda e^+ \nu_e) (\%)$	
Constituent quark model (HONR) [9]	4.25	} $> 2\sigma$ deviation
Light-front approach [10]	1.63	
Covariant quark model [11]	2.78	
Relativistic quark model [12]	3.25	
Non-relativistic quark model [13]	3.84	
Light-cone sum rule [14]	3.0 ± 0.3	
Lattice QCD [15]	3.80 ± 0.22	
$SU(3)$ [16]	3.6 ± 0.4	
Light-front constituent quark model [17]	3.36 ± 0.87	
MIT bag model [17]	3.48	
Light-front quark model [18]	4.04 ± 0.75	
This Letter	$3.56 \pm 0.11 \pm 0.07$	

$$\mathcal{B}(\Lambda_c^+ \rightarrow \Lambda e^+ \nu_e) = (3.56 \pm 0.11_{\text{stat.}} \pm 0.07_{\text{syst.}}) \%$$

Most precise measurement to date!

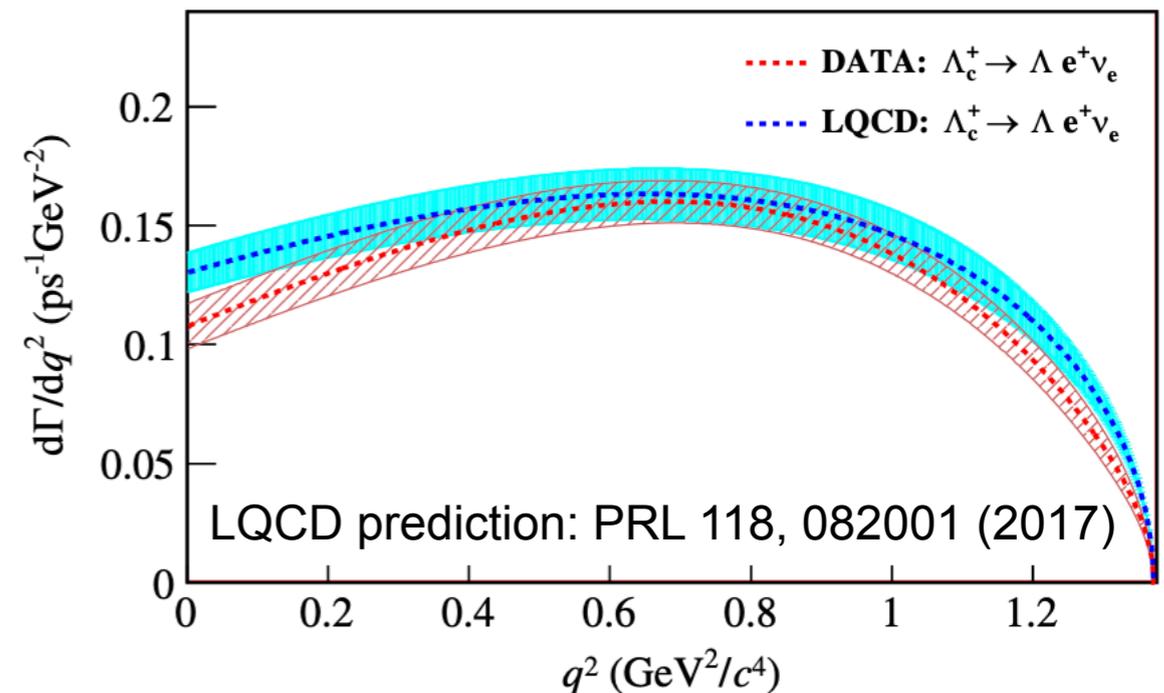
$$|V_{cs}| = 0.936 \pm 0.017_{\mathcal{B}} \pm 0.024_{\text{LQCD}} \pm 0.007_{\tau_{\Lambda_c}}$$



Steeper slope

Gentler slope

First direct comparisons of the differential decay rate and form factors with LQCD calculations





NEW!

PRD 106, 112010 (2023)

$$4.5 \text{ fb}^{-1} e^+e^- \rightarrow \Lambda_c^+ \bar{\Lambda}_c^- @ 4.600 - 4.699 \text{ GeV}$$

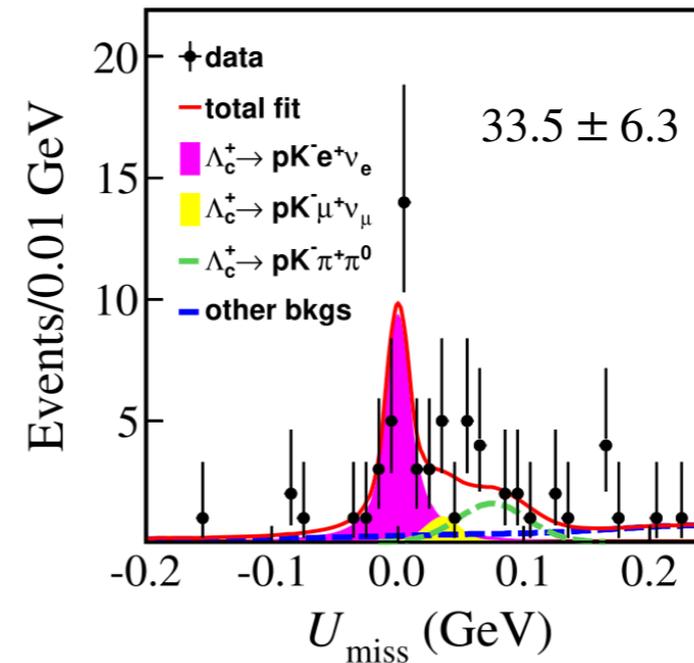
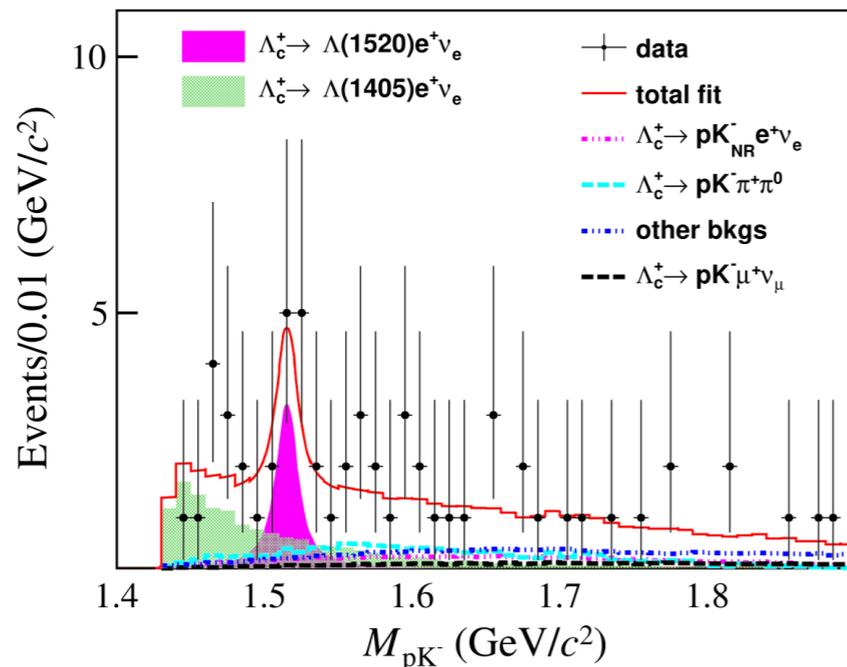
→ The new observed Λ_c^+ SL decay mode:

- ❖ $\mathcal{B}(\Lambda_c^+ \rightarrow pK^- e^+ \nu_e) = (0.88 \pm 0.15_{\text{stat.}} \pm 0.07_{\text{syst.}}) \times 10^{-3} \quad (8.2\sigma)$
- ❖ Clear confirmation that Λ_c^+ SL decays are not saturated by $\Lambda l^+ \nu_l$

	$\mathcal{B}(\Lambda_c^+ \rightarrow \Lambda(1520)e^+\nu_e)$	$\mathcal{B}(\Lambda_c^+ \rightarrow \Lambda(1405)e^+\nu_e)$
Constituent quark model [8]	1.01	3.04
Molecular state [9]	...	0.02
Nonrelativistic quark model [10]	0.60	2.43
Lattice QCD [12,13]	0.512 ± 0.082	...
Measurement	$1.02 \pm 0.52 \pm 0.11$	$\frac{0.42 \pm 0.19 \pm 0.04}{\mathcal{B}(\Lambda(1405) \rightarrow pK^-)}$

→ Study of pK^- mass spectrum to understand the nature of excited Λ^* states

- ❖ $\mathcal{B}(\Lambda_c^+ \rightarrow \Lambda(1520)[\rightarrow pK^-]e^+\nu_e) = (0.23 \pm 0.12_{\text{stat.}} \pm 0.02_{\text{syst.}}) \times 10^{-3} \quad (3.3\sigma)$
- ❖ $\mathcal{B}(\Lambda_c^+ \rightarrow \Lambda(1405)[\rightarrow pK^-]e^+\nu_e) = (0.42 \pm 0.19_{\text{stat.}} \pm 0.04_{\text{syst.}}) \times 10^{-3} \quad (3.2\sigma)$



$$\Lambda_c^+ \rightarrow \Lambda \pi^+ \pi^0$$

NEW!

JHEP 12, 033 (2022)

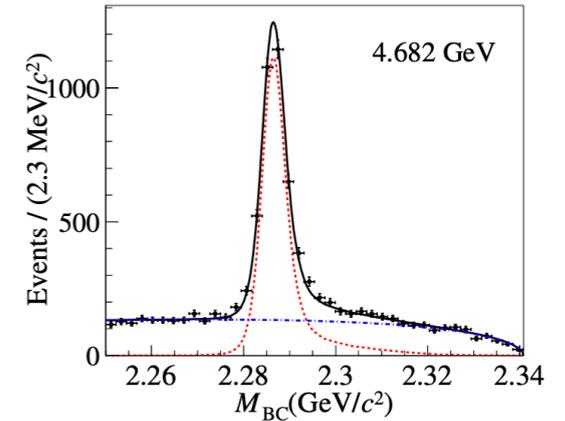
$$4.4 \text{ fb}^{-1} e^+e^- \rightarrow \Lambda_c^+ \bar{\Lambda}_c^- @ 4.600 - 4.699 \text{ GeV}$$

→ First partial wave analysis of $\Lambda_c^+ \rightarrow \Lambda \pi^+ \pi^0$

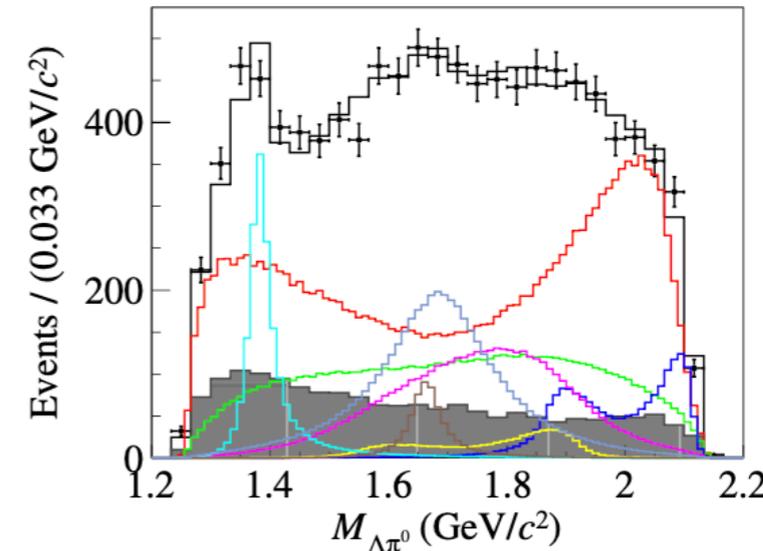
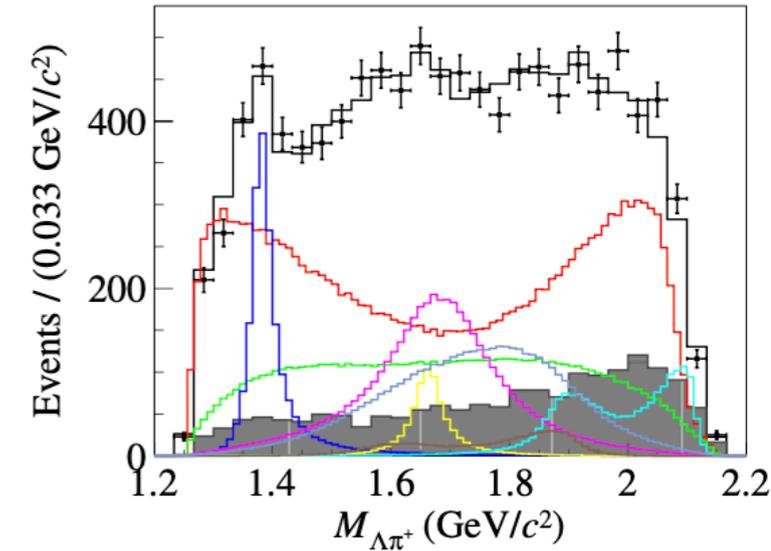
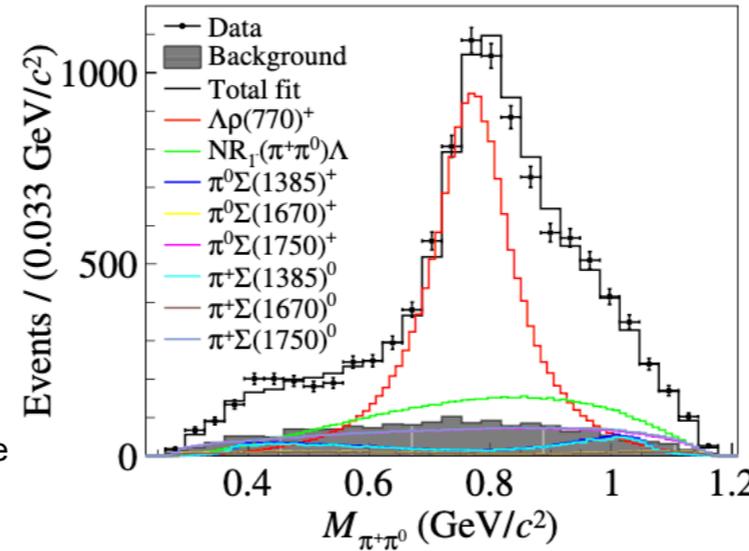
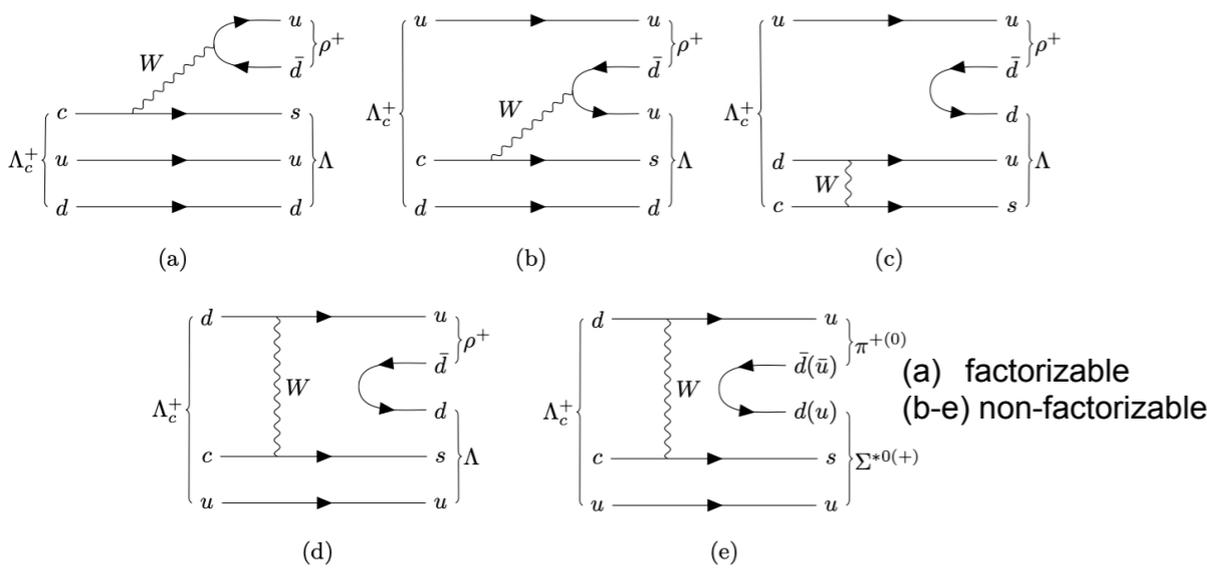
❖ Crucial test on $\Lambda_c^+ \rightarrow \Lambda \rho(770)^+, \Sigma(1385)\pi$ which suffer non-factorizable contributions

→ Helicity amplitude fit implemented by TF-PWA[1]

→ BF and decay asymmetry parameters are determined



Single Tag method
~10k signal events with purity > 80%



	Theoretical calculation		This work	PDG
$10^2 \times \mathcal{B}(\Lambda_c^+ \rightarrow \Lambda \rho(770)^+)$	4.81 ± 0.58 [13]	4.0 [14, 15]	4.06 ± 0.52	< 6
$10^3 \times \mathcal{B}(\Lambda_c^+ \rightarrow \Sigma(1385)^+ \pi^0)$	2.8 ± 0.4 [16]	2.2 ± 0.4 [17]	5.86 ± 0.80	—
$10^3 \times \mathcal{B}(\Lambda_c^+ \rightarrow \Sigma(1385)^0 \pi^+)$	2.8 ± 0.4 [16]	2.2 ± 0.4 [17]	6.47 ± 0.96	—
$\alpha_{\Lambda \rho(770)^+}$	-0.27 ± 0.04 [13]	-0.32 [14, 15]	-0.763 ± 0.070	—
$\alpha_{\Sigma(1385)^+ \pi^0}$	$-0.91^{+0.45}_{-0.10}$ [17]		-0.917 ± 0.089	—
$\alpha_{\Sigma(1385)^0 \pi^+}$	$-0.91^{+0.45}_{-0.10}$ [17]		-0.79 ± 0.11	—

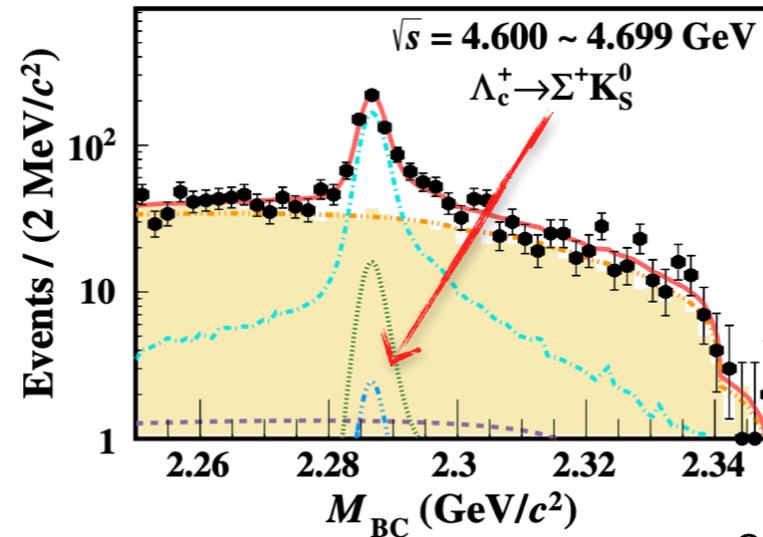
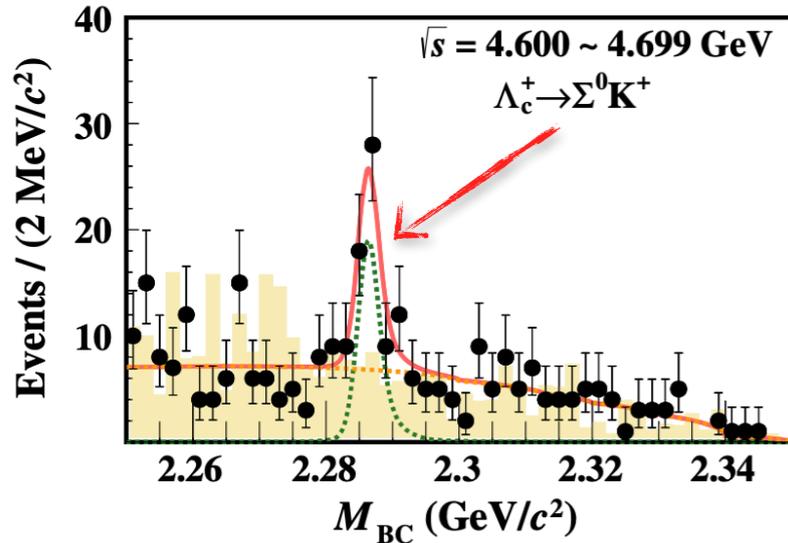
TF-PWA [1] <https://github.com/jiangyi15/tf-pwa>

$\Lambda_c^+ \rightarrow \Sigma^0 K^+$ and $\Sigma^+ K^0$

NEW!

PRD 106, 052003 (2022)

$4.5 \text{ fb}^{-1} e^+e^- \rightarrow \Lambda_c^+ \bar{\Lambda}_c^- @ 4.600 - 4.699 \text{ GeV}$



Comparison of theoretical predictions and experimental results

ST, Reference channel $\Sigma^0 K^+ \Leftrightarrow \Sigma^0 \pi^+$, $\Sigma^+ K^0 \Leftrightarrow \Sigma^+ \pi^+ \pi^-$

$\bullet \mathcal{B}(\Lambda_c^+ \rightarrow \Sigma^0 K^+) = (4.7 \pm 0.9_{\text{stat.}} \pm 0.1_{\text{syst.}} \pm 0.3_{\text{ref.}}) \times 10^{-4}$

\Rightarrow Comparable precision to PDG 2020

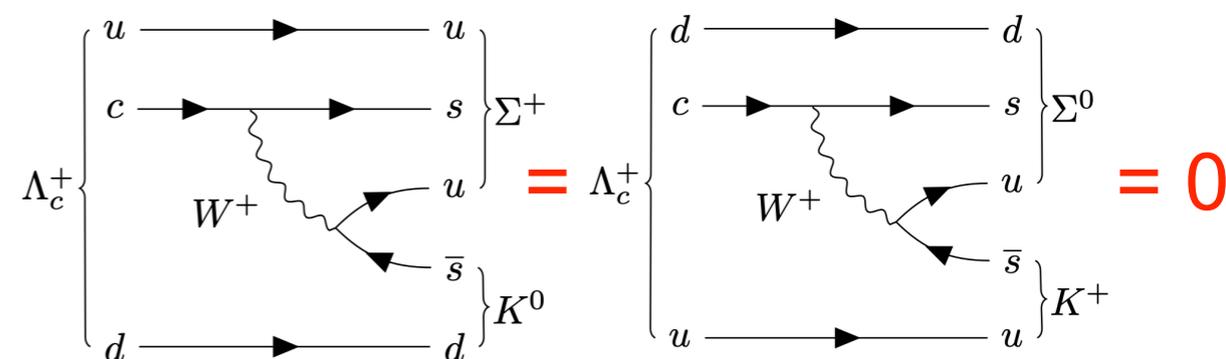
$\bullet \mathcal{B}(\Lambda_c^+ \rightarrow \Sigma^+ K_S^0) = (4.8 \pm 1.4_{\text{stat.}} \pm 0.2_{\text{syst.}} \pm 0.3_{\text{ref.}}) \times 10^{-4}$

\Rightarrow First measurement

$\bullet \mathcal{B}(\Lambda_c^+ \rightarrow \Sigma^0 K^+) / \mathcal{B}(\Lambda_c^+ \rightarrow \Sigma^+ K_S^0) = 0.98 \pm 0.35_{\text{stat.}} \pm 0.04_{\text{syst.}} \pm 0.08_{\text{ref.}}$

	$\mathcal{B}(\Lambda_c^+ \rightarrow \Sigma^0 K^+)$	$\mathcal{B}(\Lambda_c^+ \rightarrow \Sigma^+ K_S^0)$
QCD corrections [2]	2(8)	2(4)
MIT bag model [3]	7.2 ± 1.8	7.2 ± 1.8
Diagrammatic analysis [4]	5.5 ± 1.6	9.6 ± 2.4
$SU(3)_F$ flavor symmetry [5]	5.4 ± 0.7	5.4 ± 0.7
IRA method [6]	5.0 ± 0.6	6.3 ± 2.5
PDG 2020 [28]	5.2 ± 0.8	...

Körner-Pati-Woo theorem is confirmed!



Other Λ_c^+ results

→ Semi-leptonic decays

- ❖ $\Lambda_c^+ \rightarrow \Lambda \mu^+ \nu_\mu$
- ❖ $\Lambda_c^+ \rightarrow \Lambda \pi^+ \pi^- e^+ \nu_e$ and $p K_S^0 \pi^- e^+ \nu_e$
- ❖ $\Lambda_c^+ \rightarrow X e^+ \nu_e$

→ Hadronic decays

- ❖ $\Lambda_c^+ \rightarrow n \pi^+$
- ❖ $\Lambda_c^+ \rightarrow \Sigma^+ h^+ h^- (\pi^0)$
- ❖ $\Lambda_c^+ \rightarrow \bar{n} X$
- ❖ $\Lambda_c^+ \rightarrow n \pi^+ \pi^0, n \pi^+ \pi^- \pi^+$ and $n K^- \pi^+ \pi^+$
- ❖ $\Lambda_c^+ \rightarrow \Lambda K^+$
- ❖ $\Lambda_c^+ \rightarrow p \eta'$

→ Rare decays

- ❖ $\Lambda_c^+ \rightarrow \Sigma^+ \gamma$
- ❖ $\Lambda_c^+ \rightarrow p \gamma'$

Recent results since LP2022

[arXiv:2306.02624]

[PLB 843, 137993 (2023)]

[PRD 107, 052005 (2023)]

[PRL 128, 142001 (2022)]

[arXiv:2304.09405]

[arXiv:2210.09561]

[CPC 47, 023001 (2023)]

[PRD 106, L111101 (2022)]

[PRD 106, 072002 (2022)]

[PRD 107, 052002 (2023)]

[PRD 106, 072008 (2022)]

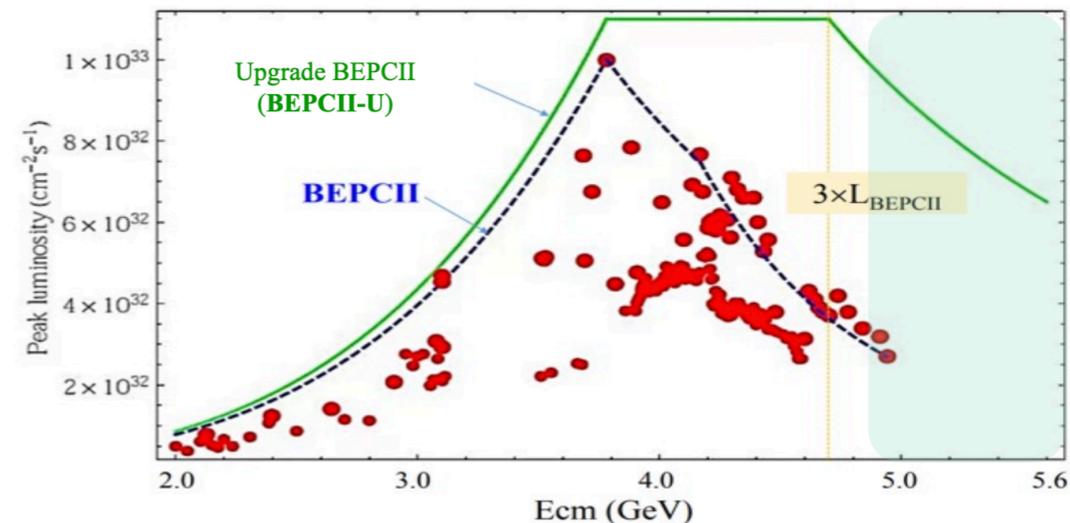
Many exciting and interesting results!

Summary & Outlook

Summary & Outlook

- Charm is charming
- BESIII makes great achievements
- Bright future of charm physics at BESIII

- ❖ Lots of results are close to be public
- ❖ $20 \text{ fb}^{-1} \psi(3770)$ data at BESIII by next year
- ❖ Opportunities to study other charmed baryons ($\Sigma_c, \Xi_c, \Omega_c$) in the BEPCII-U



- Planned to be completed in summer of 2024
- Improve luminosity by 3 times higher than current BEPCII at 4.7 GeV
- Extend the maximum energy to 5.6 GeV

Energy	Physics motivations	Current data	Expected final data	T_C / T_U
1.8 - 2.0 GeV	R values Nucleon cross-sections	N/A	0.1 fb^{-1} (fine scan)	60/50 days
2.0 - 3.1 GeV	R values Cross-sections	Fine scan (20 energy points)	Complete scan (additional points)	250/180 days
J/ψ peak	Light hadron & Glueball J/ψ decays	3.2 fb^{-1} (10 billion)	3.2 fb^{-1} (10 billion)	N/A
$\psi(3686)$ peak	Light hadron & Glueball Charmonium decays	0.67 fb^{-1} (0.45 billion)	4.5 fb^{-1} (3.0 billion)	150/90 days
$\psi(3770)$ peak	D^0/D^\pm decays	2.9 fb^{-1}	20.0 fb^{-1}	610/360 days
3.8 - 4.6 GeV	R values XYZ /Open charm	Fine scan (105 energy points)	No requirement	N/A
4.180 GeV	D_s decay XYZ /Open charm	3.2 fb^{-1}	6 fb^{-1}	140/50 days
4.0 - 4.6 GeV	XYZ /Open charm Higher charmonia cross-sections	16.0 fb^{-1} at different \sqrt{s}	30 fb^{-1} at different \sqrt{s}	770/310 days
4.6 - 4.9 GeV	Charmed baryon/ XYZ cross-sections	0.56 fb^{-1} at 4.6 GeV	15 fb^{-1} at different \sqrt{s}	1490/600 days
4.74 GeV	$\Sigma_c^+ \bar{\Lambda}_c^-$ cross-section	N/A	1.0 fb^{-1}	100/40 days
4.91 GeV	$\Sigma_c \bar{\Sigma}_c$ cross-section	N/A	1.0 fb^{-1}	120/50 days
4.95 GeV	Ξ_c decays	N/A	1.0 fb^{-1}	130/50 days

Energy thresholds
 $e^+e^- \rightarrow \Lambda_c^+ \bar{\Sigma}_c^-$ 4.74 GeV
 $e^+e^- \rightarrow \Lambda_c^+ \bar{\Sigma}_c^- \pi$ 4.88 GeV
 $e^+e^- \rightarrow \Sigma_c \bar{\Sigma}_c$ 4.91 GeV
 $e^+e^- \rightarrow \Xi_c \bar{\Xi}_c$ 4.94 GeV
 $e^+e^- \rightarrow \Omega_c^0 \bar{\Omega}_c^0$ 5.40 GeV

CPC 44, 040001 (2020)

2022: $3 \rightarrow 8 \text{ fb}^{-1}$

2023: $8 \rightarrow 16 \text{ fb}^{-1}$

2024: $16 \rightarrow 20 \text{ fb}^{-1} @ \psi(3770)$

Thanks for your attention!

Backup

Dataset

CPC 39, 093001 (2015)
 CPC 40, 063001 (2016)
 CPC 45, 103001 (2021)
 CPC 46, 113002 (2022)
 CPC 46, 113003 (2022)

$\Lambda_c^+ \bar{\Lambda}_c^-$ datasets

Center-of-Mass energy (GeV)	Luminosity (pb ⁻¹)
4.5995	586.89
4.6119	103.65
4.6280	521.53
4.6409	551.65
4.6612	529.43
4.6819	1667.39
4.6988	535.54
4.7397	163.87
4.7500	366.55
4.7805	511.47
4.8431	525.16
4.9180	207.82
4.9509	159.28

$D_s^{*\pm} D_s^\mp$ datasets

Sample	Year	Luminosity (pb ⁻¹)	Center-of-Mass energy (GeV)
4128	2019	401.5	4128.48
4157	2019	408.7	4157.44
4178	2016	3189.0	4178.0 on average
4189	2017	$526.7 \pm 0.1 \pm 2.2$	$4188.99 \pm 0.06 \pm 0.41$
	2012	$43.33 \pm 0.03 \pm 0.29$	$4188.59 \pm 0.15 \pm 0.68$
4199	2017	$526.0 \pm 0.1 \pm 2.1$	$4199.03 \pm 0.05 \pm 0.41$
4209	2017	$517.1 \pm 0.1 \pm 1.8$	$4209.25 \pm 0.06 \pm 0.42$
	2012	$54.95 \pm 0.03 \pm 0.36$	$4207.73 \pm 0.14 \pm 0.61$
4219	2017	$514.6 \pm 0.1 \pm 1.8$	$4218.84 \pm 0.05 \pm 0.40$
	2012	$54.60 \pm 0.03 \pm 0.36$	$4217.13 \pm 0.14 \pm 0.67$
4226	2013	$1047.34 \pm 0.14 \pm 10.16$	$4225.54 \pm 0.05 \pm 0.65$
	2012	$44.54 \pm 0.03 \pm 0.29$	$4226.26 \pm 0.04 \pm 0.65$

$$D_s^+ \rightarrow \tau^+ \nu_\tau, \tau^+ \rightarrow \pi^+ \nu_\tau$$

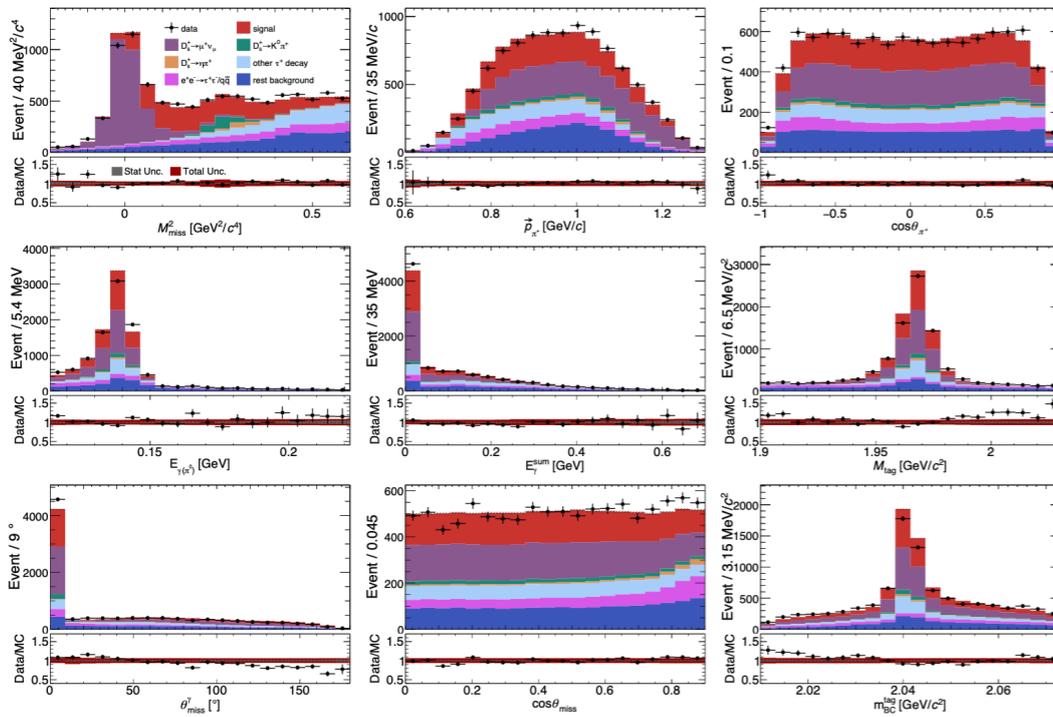
UPDATE!

arXiv:2303.12600
Submitted to PRD

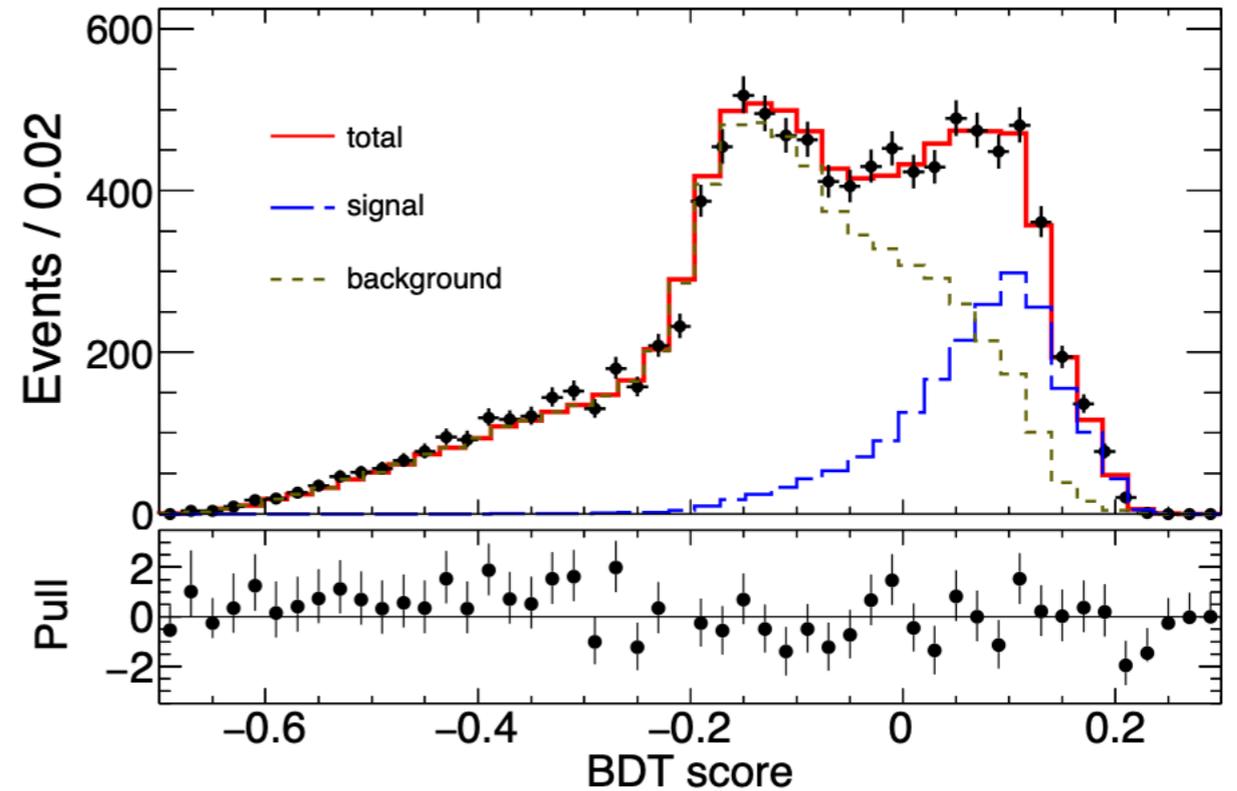
$$7.33 \text{ fb}^{-1} e^+e^- \rightarrow D_s^{*\pm} D_s^\mp @ 4.128 - 4.226 \text{ GeV}$$

→ Boosted decision tree (BDT) to discriminate signal and BKG

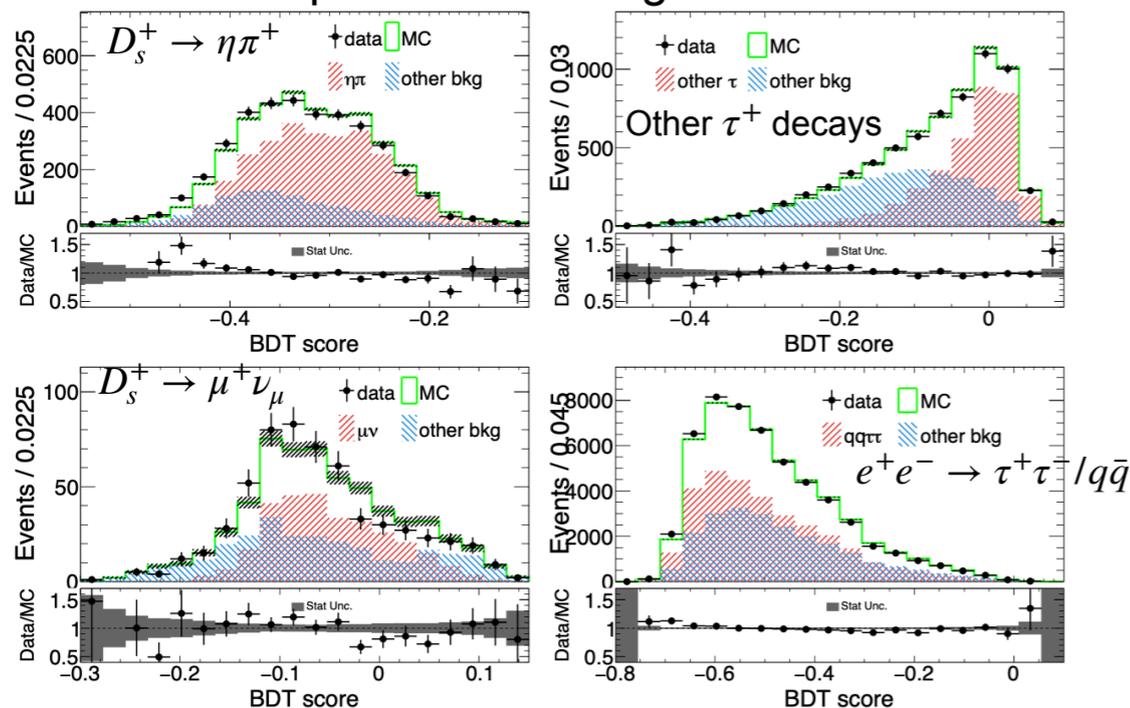
BDT input



BDT output in signal region for signal measurement



BDT output in control regions for validation



$$\mathcal{B}(\tau^+ \rightarrow \tau \nu_\tau) = (5.41 \pm 0.17_{\text{stat.}} \pm 0.13_{\text{syst.}}) \%$$

$$f_{D_s^+} |V_{cs}| = (247.6 \pm 3.9_{\text{stat.}} \pm 3.4_{\text{syst.}}) \text{ MeV}$$

Precision ~2.1%

Taking $|V_{cs}|$ from SM global fit,

$$f_{D_s^+} = (254.3 \pm 4.0_{\text{stat.}} \pm 3.3_{\text{syst.}} \pm 1.0_{\text{input}}) \text{ MeV}$$

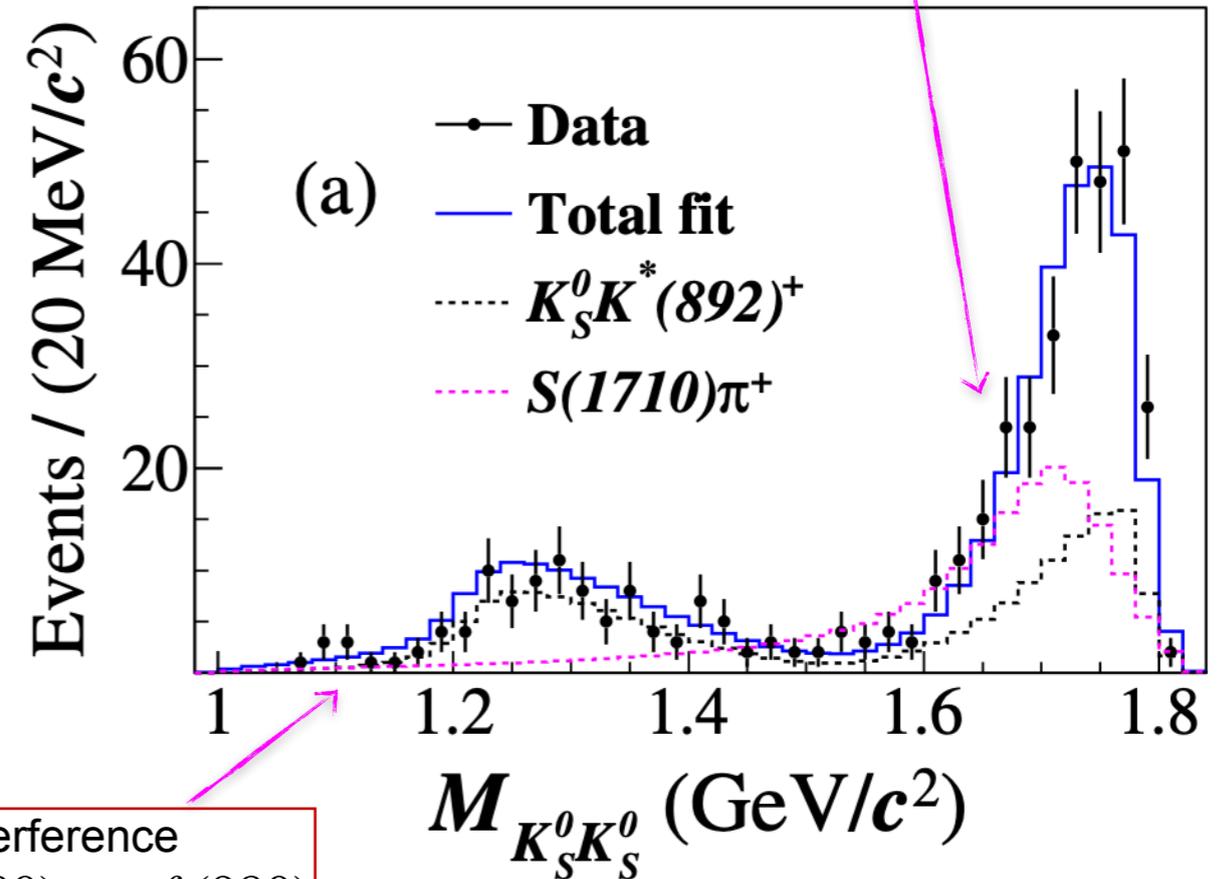
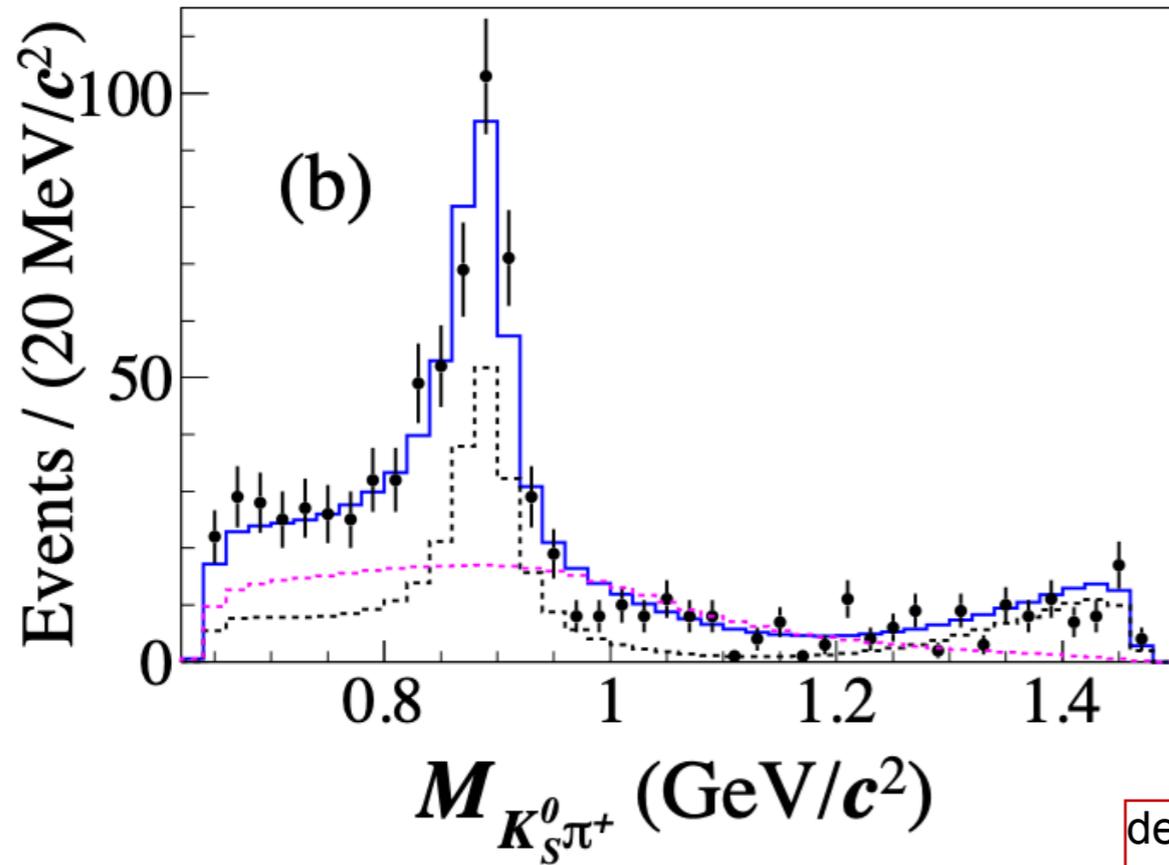
Taking $f_{D_s^+}$ from LQCD,

$$|V_{cs}| = 0.991 \pm 0.015_{\text{stat.}} \pm 0.013_{\text{syst.}} \pm 0.004_{\text{input}}$$



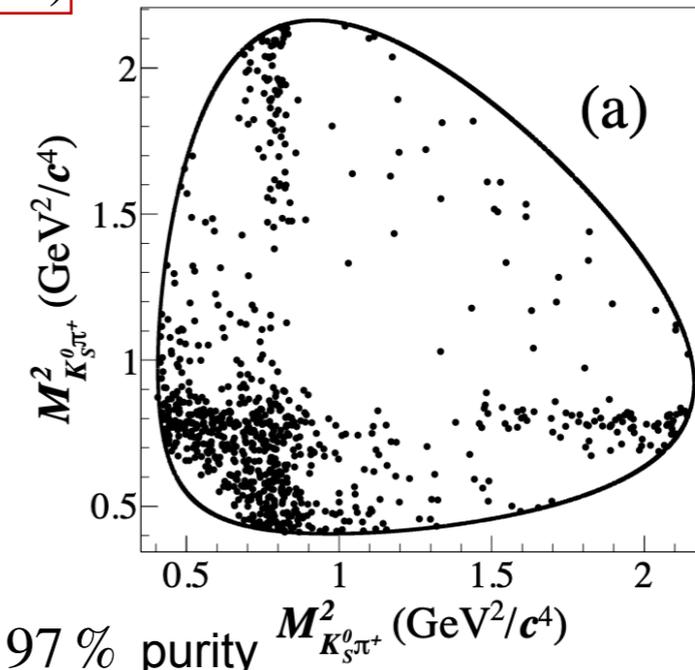
PRD105,L051103 (2022)

constructive interference
between $a_0(1710)$ and $f_0(1710)$



destructive interference
between $a_0(980)$ and $f_0(980)$

Amplitude	Phase	FF (%)
$D_s^+ \rightarrow K_S^0 K^*(892)^+$	0.0(fixed)	$43.5 \pm 3.9 \pm 0.5$
$D_s^+ \rightarrow S(1710)\pi^+$	$2.3 \pm 0.1 \pm 0.1$	$46.3 \pm 4.0 \pm 1.2$



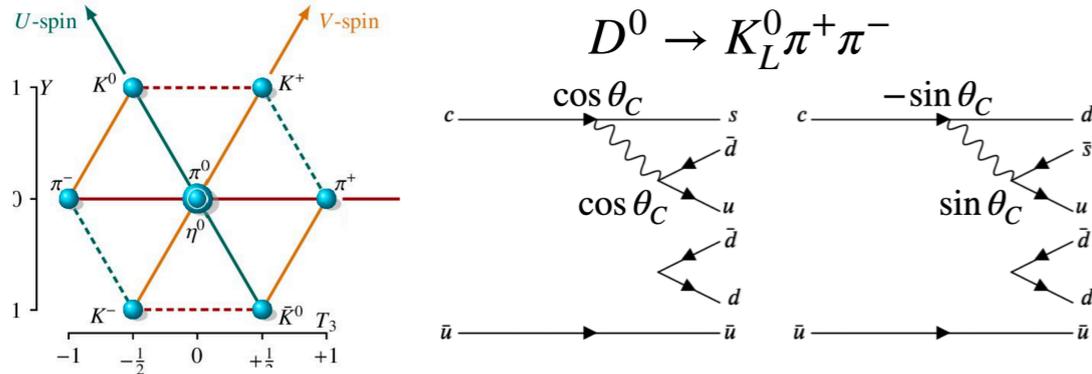
412 events, $\sim 97\%$ purity

U-spin breaking parameter

NEW!

arXiv:2212.09048
Submitted to JHEP

$2.93 \text{ fb}^{-1} e^+e^- \rightarrow \psi(3770) \rightarrow D^0 \bar{D}^0 @ 3.773 \text{ GeV}$



First amplitude analysis involving a K_L^0 !

First measurement of complex U-spin breaking parameters ($\hat{\rho}$)

U-spin symmetry: $SU(2)$ doublet under the exchange of d and s quarks

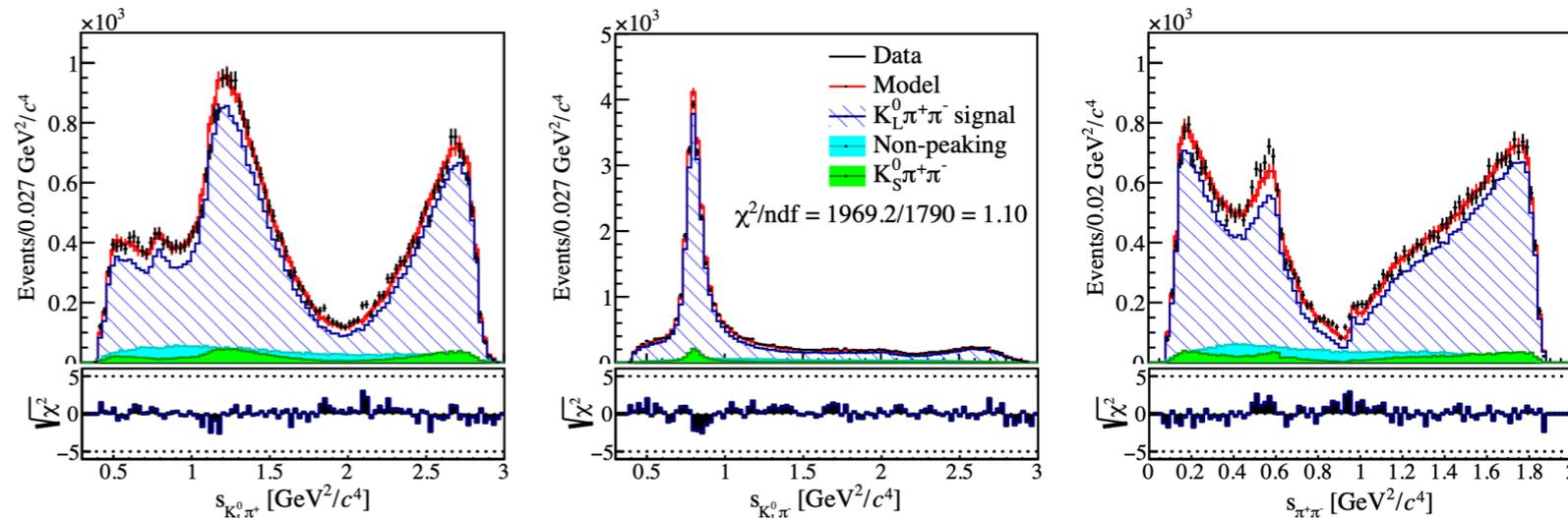
Broken under the chiral symmetry

$$\mathcal{A}(D^0 \to K^0(\pi^+\pi^-)) / \mathcal{A}(D^0 \to \bar{K}^0(\pi^+\pi^-)) = -\tan^2\theta_C \hat{\rho}$$

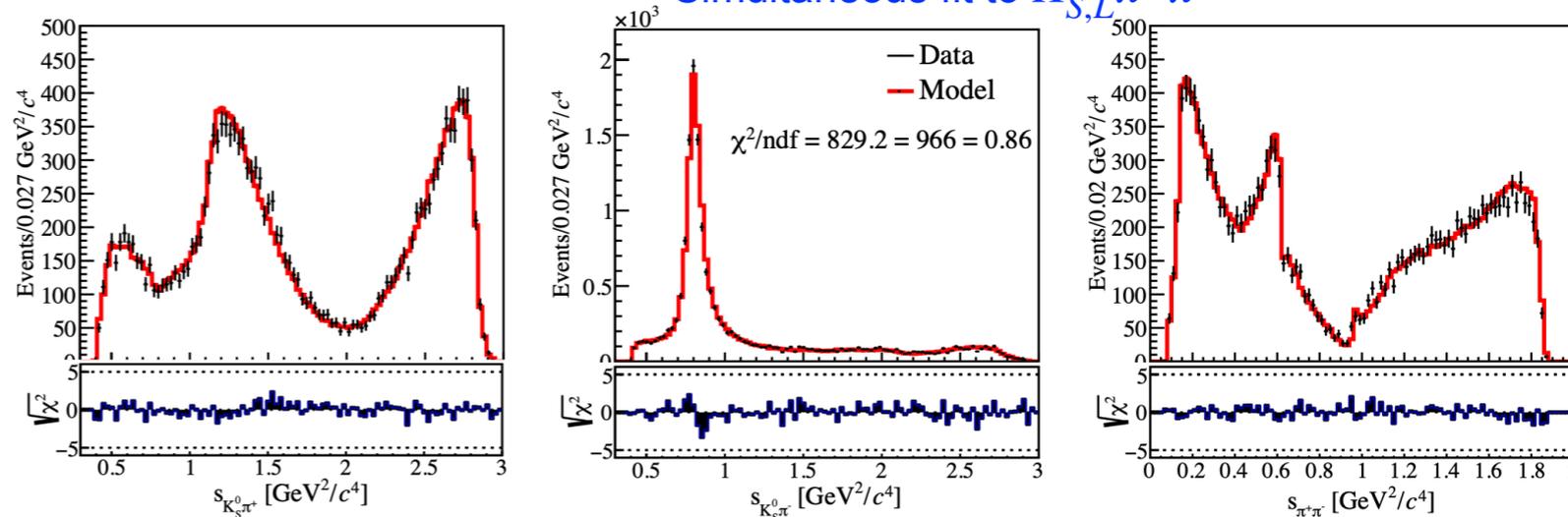
Systematics in model-independent strong-phase measurement of $D^0 \to K_{S,L}^0 \pi^+ \pi^-$

Assumed to be unity

Resonance	$K_L^0 \pi^+ \pi^- FF_R$ [%]	$K_S^0 \pi^+ \pi^- FF_R$ [%]
$\rho(770)$	$18.16^{+0.53}_{-0.45} \pm 2.50$	$18.90 \pm 0.42 \pm 2.12$
$\omega(782)$	$0.06^{+0.03}_{-0.02} \pm 0.04$	$0.54 \pm 0.09 \pm 0.14$
$f_2(1270)$	$0.40 \pm 0.08 \pm 0.37$	$0.61^{+0.13}_{-0.11} \pm 0.29$
$\rho(1450)$	$0.42 \pm 0.08 \pm 0.53$	$0.21 \pm 0.10 \pm 0.40$
$K^*(892)^-$	$56.98^{+0.58}_{-0.56} \pm 3.10$	$62.18^{+0.55}_{-0.59} \pm 2.58$
$K_2^*(1430)^-$	$1.64^{+0.10}_{-0.09} \pm 0.48$	$1.79 \pm 0.09 \pm 0.47$
$K^*(1680)^-$	$0.25^{+0.06}_{-0.05} \pm 0.68$	$0.27 \pm 0.06 \pm 0.63$
$K^*(1410)^-$	$0.19 \pm 0.06 \pm 0.46$	$0.21 \pm 0.06 \pm 0.19$
$K^*(892)^+$	$0.45 \pm 0.05 \pm 0.14$	$0.49 \pm 0.05 \pm 0.35$
$K_2^*(1430)^+$	$0.05 \pm 0.02 \pm 0.04$	$0.05 \pm 0.02 \pm 0.03$
$K^*(1410)^+$	$0.04 \pm 0.02 \pm 0.03$	$0.05 \pm 0.02 \pm 0.02$
$K_0^*(1430)^-$	$6.84^{+0.24}_{-0.25} \pm 1.84$	$7.47 \pm 0.26 \pm 1.55$
$\pi\pi$ S-wave	$10.12^{+0.32}_{-0.33} \pm 0.96$	$10.24 \pm 0.23 \pm 1.62$
Total	$95.59^{+2.16}_{-2.07} \pm 11.17$	$103.02^{+2.11}_{-2.10} \pm 10.39$



Simultaneous fit to $K_{S,L}^0 \pi^+ \pi^-$



16490 events for $K_S^0 \pi^+ \pi^-$, 39085 for $K_L^0 \pi^+ \pi^-$

Vary in a wide range from 0.4 to 12.1

Resonance	$ \hat{\rho} $	$\arg(\hat{\rho})$ [$^\circ$]	$ 1 - 2\tan^2\theta_C \hat{\rho} ^2$
$\rho(770)$	$1.93 \pm 0.27 \pm 0.42$	$-90.6 \pm 5.8 \pm 7.6$	$1.05 \pm 0.04 \pm 0.06$
$\omega(782)$	$6.13 \pm 0.75 \pm 0.53$	$2.2 \pm 7.0 \pm 4.8$	$0.12 \pm 0.05 \pm 0.04$
$f_2(1270)$	$3.75 \pm 0.90 \pm 0.81$	$-56.5 \pm 16.8 \pm 12.9$	$0.72 \pm 0.20 \pm 0.15$
$\rho(1450)$	$12.12 \pm 2.92 \pm 1.88$	$78.4 \pm 14.4 \pm 15.6$	$2.19 \pm 0.95 \pm 0.83$
$\pi\pi$ S-wave	$0.37 \pm 0.21 \pm 0.37$	$-164.4 \pm 15.7 \pm 13.4$	$1.08 \pm 0.04 \pm 0.08$

Helicity amplitude formalism

- Helicity amplitude formalism
- Full procedure is based on the open-source framework TF-PWA
- Helicity amplitude for $0 \rightarrow 1 + 2$

$$\diamond A_{\lambda_0, \lambda_1, \lambda_2}^{0 \rightarrow 1+2} = H_{\lambda_1, \lambda_2}^{0 \rightarrow 1+2} D_{\lambda_0, \lambda_1 - \lambda_2}^{J_0^*}(\phi, \theta, 0) \rightarrow \text{Wigner D-function}$$

- Helicity coupling $H_{\lambda_1, \lambda_2}^{0 \rightarrow 1+2}$ can be expanded by LS coupling formula

$$\diamond H_{\lambda_1, \lambda_2}^{0 \rightarrow 1+2} = \sum_{ls} g_{ls} \sqrt{\frac{2l+1}{2J_0+1}} \langle l0, s\delta | J_0, \delta \rangle \langle J_1 J_2, \lambda_1 - \lambda_2 | s, \delta \rangle \left(\frac{q}{q_0}\right)^l B_l'(q, q_0, d)$$

Partial wave amplitude
Spin of particle 0,1,2
Helicity of particle 1,2
Blatt-Weiskopf barrier factor

$$q = \frac{\sqrt{[m^2 - (m_1 + m_2)^2][m^2 - (m_1 - m_2)^2]}}{2m} \quad (q = q_0, \text{ when } m = m_0)$$

Radius of the centrifugal barrier $d = 3.69 (\text{GeV}/c^2)^{-1}$

- Sequential decay amplitude

$$\diamond A_{\lambda_{\Lambda_c^+}, \lambda_p}^{\rho^+} = \sum_{\lambda_\rho, \lambda_\Lambda} A_{\lambda_{\Lambda_c^+}, \lambda_\rho, \lambda_\Lambda}^{\Lambda_c^+ \rightarrow \rho^+ \Lambda} R_{\rho^+}(M_{\pi^+ \pi^0}) A_{\lambda_\rho, 0, 0}^{\rho^+ \rightarrow \pi^+ \pi^0} A_{\lambda_\Lambda, \lambda_p, 0}^{\Lambda \rightarrow p \pi^-}$$

$$\diamond A_{\lambda_{\Lambda_c^+}, \lambda_p}^{\Sigma^{*+}} = \sum_{\lambda_{\Sigma^{*+}}, \lambda_\Lambda} A_{\lambda_{\Lambda_c^+}, \lambda_{\Sigma^{*+}}, 0}^{\Lambda_c^+ \rightarrow \Sigma^{*+} \pi^0} R_{\Sigma^{*+}}(M_{\Lambda \pi^+}) A_{\lambda_{\Sigma^{*+}}, \lambda_\Lambda, 0}^{\Sigma^{*+} \rightarrow \Lambda \pi^+} A_{\lambda_\Lambda, \lambda_p, 0}^{\Lambda \rightarrow p \pi^-}$$

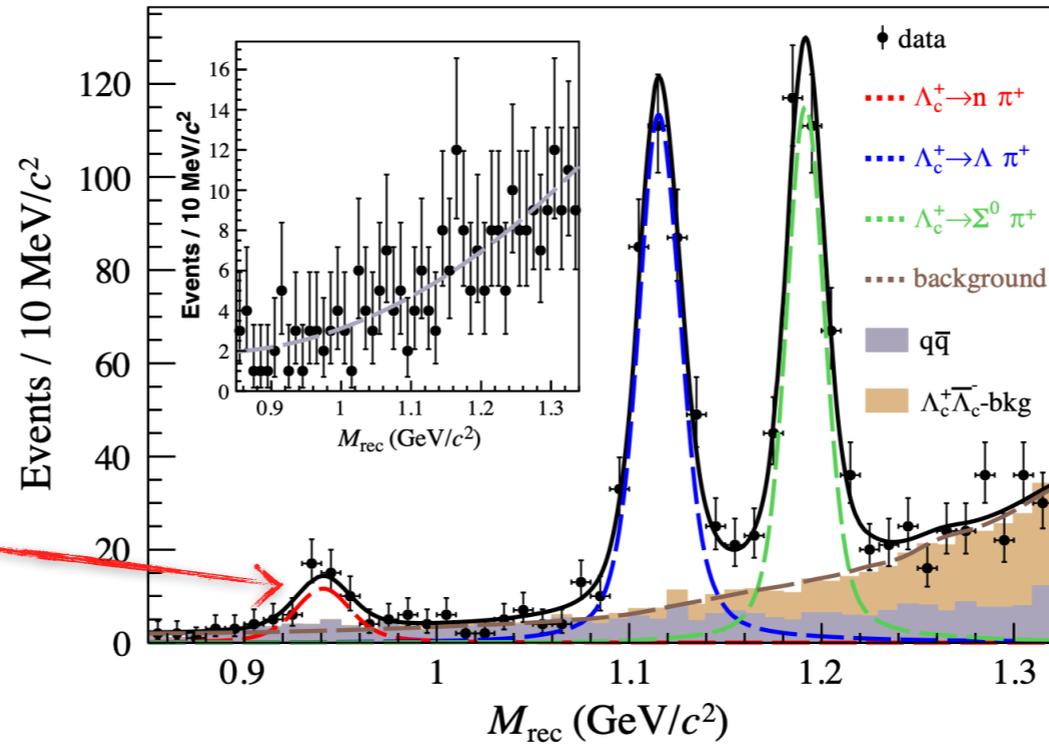
Dynamical function



$$3.9 \text{ fb}^{-1} e^+e^- \rightarrow \Lambda_c^+ \bar{\Lambda}_c^- @ 4.612 - 4.699 \text{ GeV}$$

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Observation of $\Lambda_c^+ \rightarrow n\pi^+$



DT, Missing-neutron method

$$\bullet \mathcal{B}(\Lambda_c^+ \rightarrow n\pi^+) = (6.6 \pm 1.2_{\text{stat.}} \pm 0.4_{\text{syst.}}) \times 10^{-4} \quad (7.3\sigma)$$

$$\bullet \mathcal{B}(\Lambda_c^+ \rightarrow \Lambda\pi^+) = (1.31 \pm 0.08_{\text{stat.}} \pm 0.05_{\text{syst.}}) \times 10^{-2}$$

$$\bullet \mathcal{B}(\Lambda_c^+ \rightarrow \Sigma^0\pi^+) = (1.22 \pm 0.08_{\text{stat.}} \pm 0.07_{\text{syst.}}) \times 10^{-2}$$

Consistent with BESIII previous

Taking $\mathcal{B}(\Lambda_c^+ \rightarrow p\pi^0) < 8.0 \times 10^{-5}$ @ 90 % CL from Belle, $\frac{\Lambda_c^+ \rightarrow n\pi^+}{\Lambda_c^+ \rightarrow p\pi^0} > 7.2$ @ 90 % CL

• Disagree with most phenomenological models predictions

• Improved measurements of $\Lambda_c^+ \rightarrow n\pi^+$ and $p\pi^0$ is needed.