BESIII

BESIII Reviews

董燎原（代表BESIII合作组）

中国科学院高能物理研究所

第21届全国重味物理与CP破坏研讨会

HFCPV2024 湖南 衡阳 2024.10.25–10.29

BEPCII @ IHEP

Beijing Electron Positron Collider II

$E_{\mathrm{cm}} = 2 - 4.95$ GeV

2004, started construction

2009-2024, BESIII Physics run

Design Luminosity:

$\mathcal{L}_D = 1 \times 10^{33}\mathrm{cm}^{-2}s^{-1}$@$E_{\mathrm{cm}}$= 3.773 GeV

Peak luminosity:

2016 achieved $1.0 \times \mathcal{L}_D$

2023 achieved $1.1 \times \mathcal{L}_D$

Jul. 1, 2024 – Aug. 31, 2028:

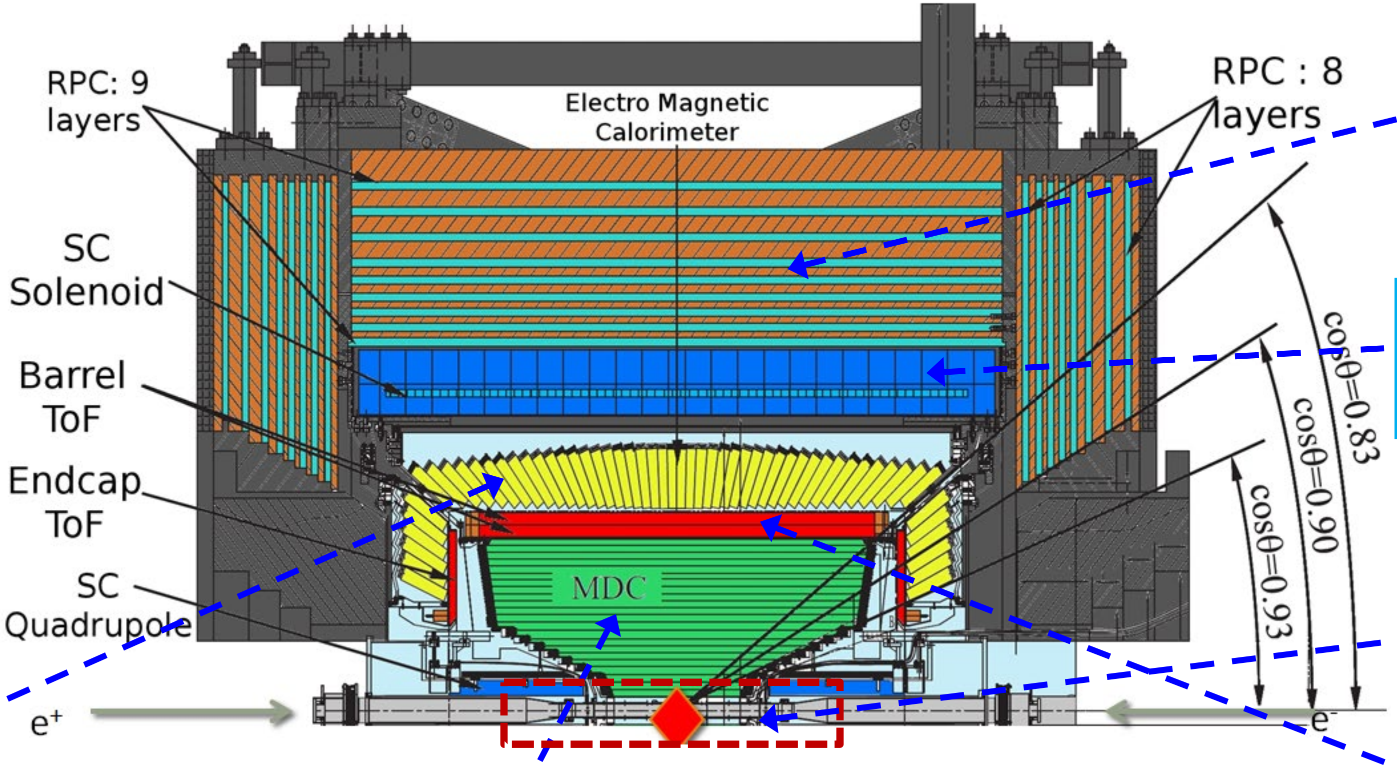
BEPCII upgrade → BEPCII-U

January 2025, restart

- Luminosity × 3 @E_{cm}= 4.7 GeV
- Beam energy up to 2.8 GeV (2028)

BESIII @ BEPCII

- Optimized for flavor physics
- Cover 93% of 4π solid angle



Muon counters (MUC)
$\sigma_{r\phi} = 1.4 - 1.7$ cm

Superconducting solenoid
1 Tesla Magnetic field

inner MDC

Electro Magnetic Calorimeter (EMC)
$\Delta E/E = 2.5\%$ @1.0 GeV
$\sigma_{\phi z} = 0.6$cm @ 1.0 GeV

Main Drift Chamber (MDC)
$\Delta P/P = 0.5\%$ @1.0 GeV
$\sigma_{xy} = 130$ um, $\sigma_{dE/dX} = 6 - 7\%$

Time Of Flight (TOF)
$\sigma_t = 90$ ps @ barrel
$\sigma_t = 60$ ps @ end cap (upgrade in 2016)

July 1 - December 31, 2024: Replace the inner MDC with 3 layers of cylindrical triple-GEM detectors

Datasets (totally ~50 fb^{-1} from 1.84 – 4.95 GeV)

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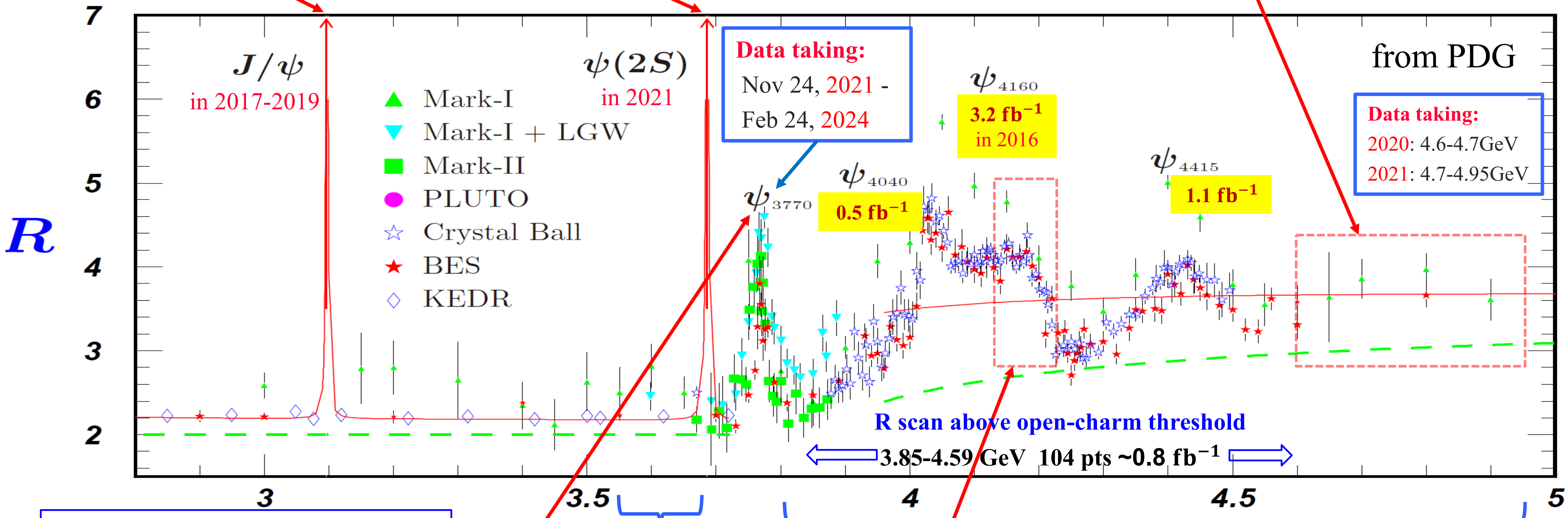
10B: light hadron, hyperon

2.7B: charmonium

6.4 fb^{-1}: ~1.0M $\Lambda_c^+\bar{\Lambda}_c^-$ pairs produced @4.5995-4.9509 GeV



R scan below open-charm threshold
1.84-1.97 GeV 13 pts ~25 pb^{-1}
2.00-3.08 GeV 21 pts ~550 pb^{-1}
2.23-3.67 GeV 14 pts ~110 pb^{-1}

Tau mass scan

3.8-4.96 GeV: ~22.5 fb^{-1}, XYZ, $D_s^+D_s^-$, $\Lambda_c^+\bar{\Lambda}_c^-$ …

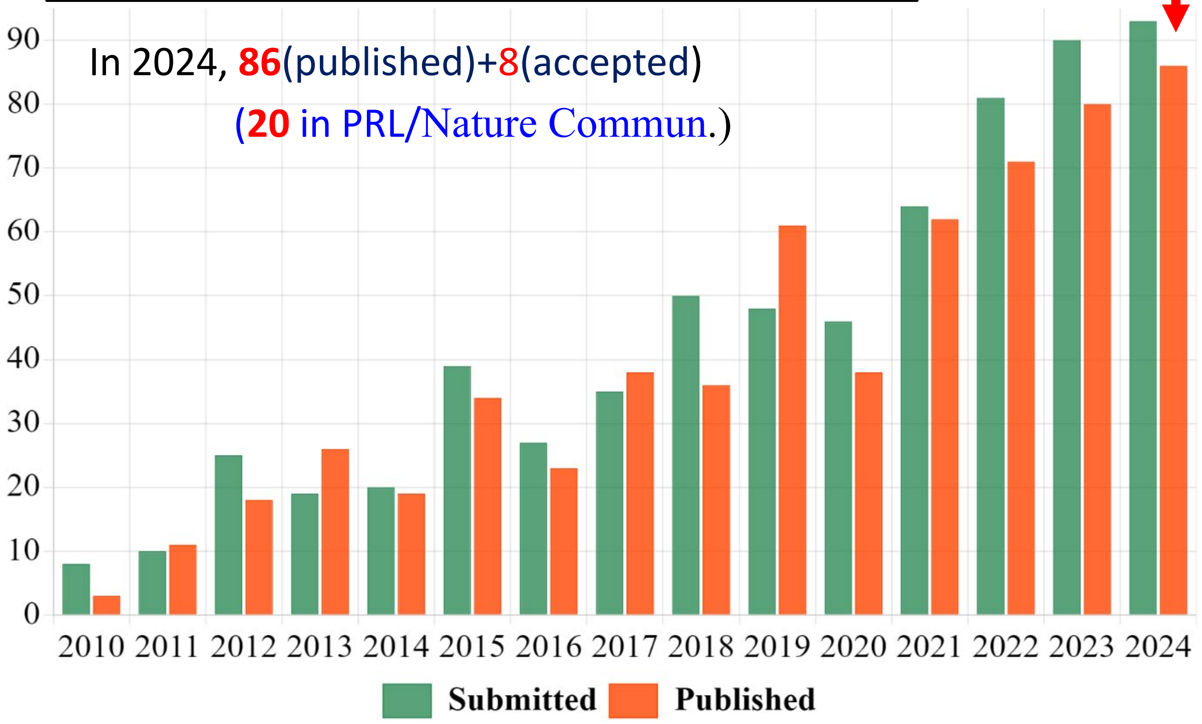
20.3 fb^{-1}: ~73.3M $D^0\bar{D}^0$ pairs produced @3.773 GeV
~57.4M D^+D^- pairs produced @3.773 GeV

7.33 fb^{-1}: ~6.5M $D_s^+D_s^-$ pairs produced @4.128-4.226 GeV

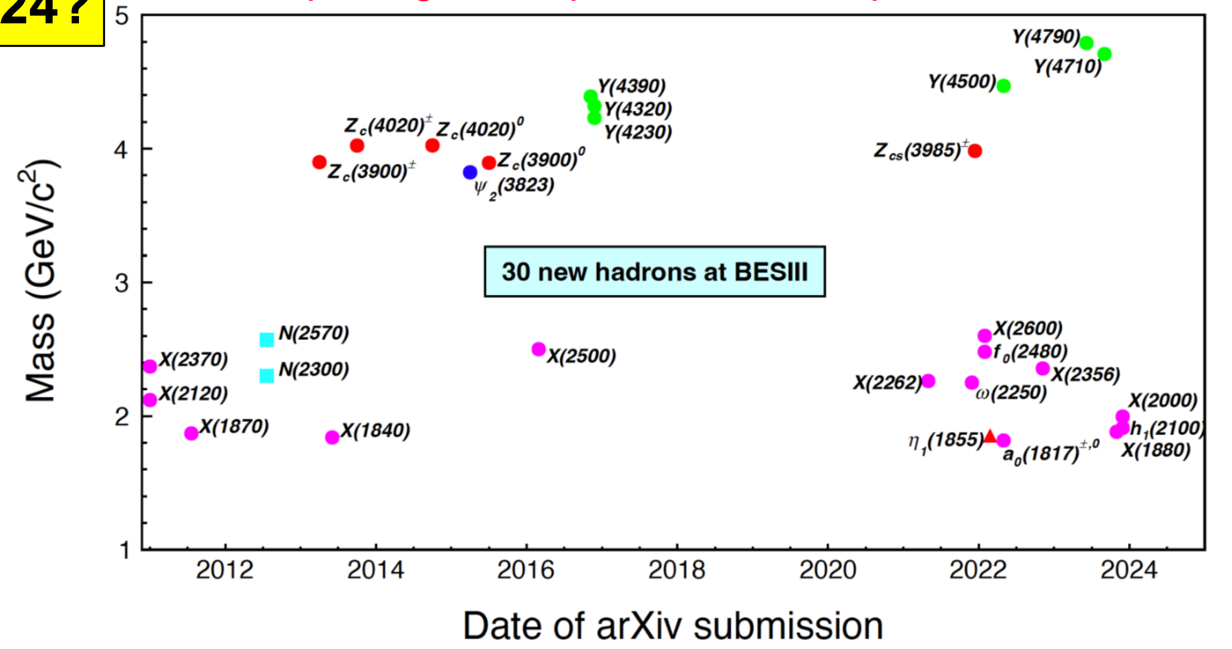
BESIII achievements

Published: 606 (PRL&Nature(physics): **121**)
(by 2024-10-25) + **8**(accepted) + **41**(submitted)

>100 in 2024?



http://english.ihep.cas.cn/bes/re/pu/NewParticles/



In this talk, a selection of latest results published or submitted from November 2023 is presented.

BESIII talks at this meeting

- 10-27, Charm physics, 柯百谦
- 10-28, Charmonium-like states, 朱凯
- 10-28, Rare charm decays, 李志军
- 10-28, Strangeonium , 张亚腾
- 10-28, Light meson spectroscopy, 韩婷婷
- 10-28, $D_s^+ \to \pi^+\pi^+\pi^-\pi^0$, 李晓宇

BESIII Collaboration: >600 members from 82 institutions in 16 countries
(>130 from outside of China)

CKM Matrix

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- CKM matrix elements are fundamental parameters of the Standard Model (SM):

$$V_{\mathrm{CKM}} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + \mathcal{O}(\lambda^4)$$

Charm decays + LQCD (V_{cd}, V_{cs})
Expected precision < **1%** at BESIII

B decays + LQCD (V_{ub}, V_{cb}, V_{td}, V_{ts})

- 3x3 unitary complex matrix
- 4 parameters: 3 mixing angles and 1 phase
- Unitarity: $\sum_i V_{ij}V_{ik}^* = \delta_{jk}$ and $\sum_j V_{ij}V_{kj}^* = \delta_{ik}$

- Any deviation of V_{CKM} from unitarity indicates new physics

→ Measurements of CKM matrix elements [from PDG2024]

$|V_{ud}|^2+|V_{us}|^2+|V_{ub}|^2=0.9984 \pm 0.0009$=1(SM)

$|V_{cd}|^2+|V_{cs}|^2+|V_{cb}|^2 = 1.001 \pm 0.007$ =1(SM)

Precision: 0.7%

$|V_{cd}| = 0.221 \pm 0.004$

$|V_{cs}| = 0.975 \pm 0.006$

$|V_{cb}| = 0.0410 \pm 0.0012$

Precision: (0.6-1.8)%

- ***D/D_s* (Semi-)leptonic decays** provide direct measurements of $|V_{cs}|$ and $|V_{cd}|$

Charm leptonic decays $D^+_{(s)} \to l^+\nu_l$

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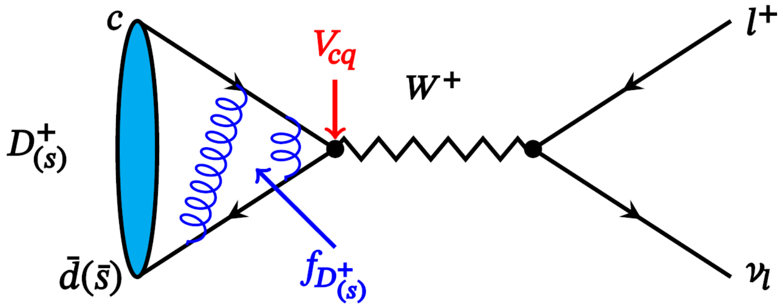
$l = e, \mu, \tau$



Decay constant $f_{D_{(s)}}$ (LQCD)

Decay rate

CKM matrix element

$$\Gamma(D^+_{(s)} \to \ell^+\nu_\ell) = \frac{G_F^2}{8\pi} f^2_{D^+_{(s)}} |V_{cd(s)}|^2 m_\ell^2 m_{D^+_{(s)}} \left(1 - \frac{m_\ell^2}{m^2_{D^+_{(s)}}}\right)^2$$

- **Charm leptonic decays involve weak and strong interactions**

  Weak interaction: annihilation of the quark-antiquark pair via W^+ → $|V_{cd(s)}|$

  Strong interaction: glue exchanges between charm quark and light quark → $f_{D_{(s)}}$

- Exp. decay rate + $|V_{cd(s)}|^{\text{CKMfitter}}$ → $f_{D_{(s)}}$

  Calibrate LQCD @charm

  Extrapolate to Beauty

- Exp. decay rate + $f_{D_{(s)}}$ of LQCD

  → **CKM matrix elements** $|V_{cd(s)}|$

High precision: **0.2%**
FLAG, *Eur. Phys. J. C* 80 (2020) 113

SM expected relative decay widths:

	$e^+\nu_e$	$\mu^+\nu_\mu$	$\tau^+\nu_\tau$
D^+	2.35×10^{-5}	1	2.67
D_s^+	2.35×10^{-5}	1	9.75

→ **Test lepton flavor universality (LFU)**

$|V_{cd}|$ from $D^+ \to \mu^+\nu_\mu$

20.3 fb^{-1}@ 3.773 GeV, arXiv:2410:07626

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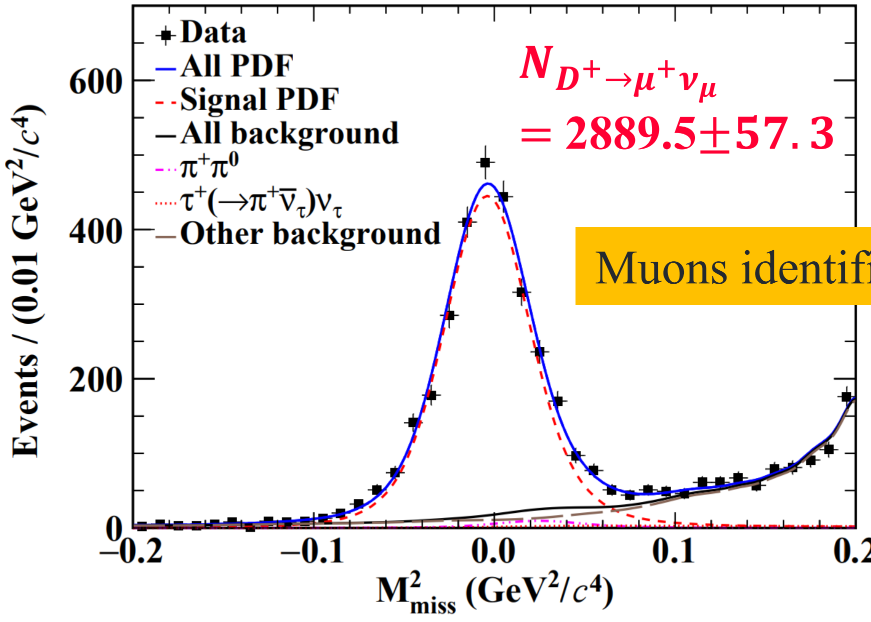
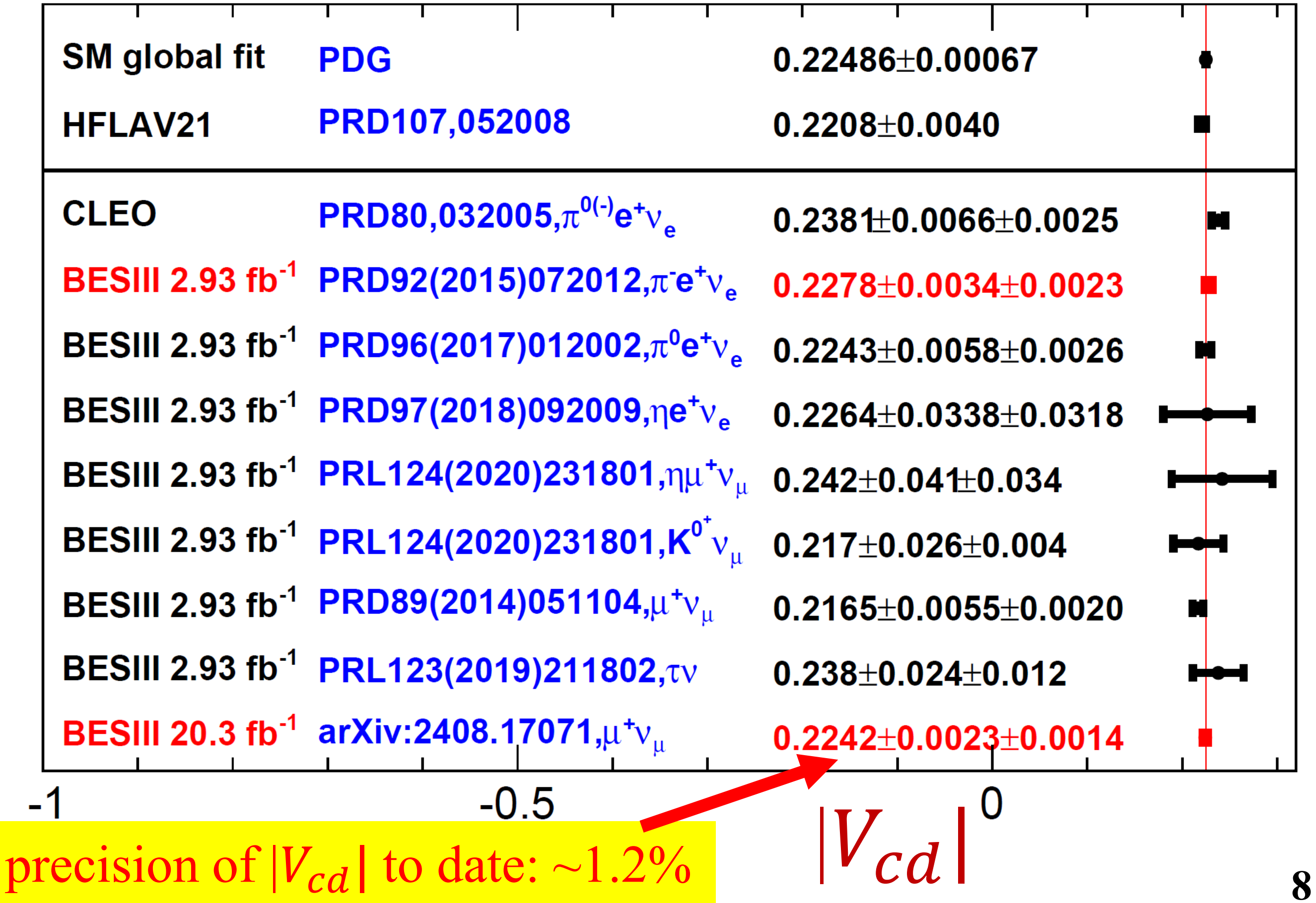


Muons identified from MUC

$$f_{D^+}|V_{cd}| = (47.53 \pm 0.48_{\rm stat} \pm 0.24_{\rm syst} \pm 0.12_{\rm input})\ {\rm MeV}$$

$$f_{D^+} = (211.5 \pm 2.1_{\rm stat} \pm 1.1_{\rm syst} \pm 0.8_{\rm input})\ {\rm MeV}$$

$$|V_{cd}| = 0.2242 \pm 0.0023_{\rm stat} \pm 0.0011_{\rm syst} \pm 0.0009_{\rm input}$$



$$\mathcal{B}_{D^+\to\mu^+\nu_\mu} = (3.98 \pm 0.08_{\rm stat.} \pm 0.04_{\rm syst.}) \times 10^{-4}$$

$$A_{\rm CP} = \frac{\mathcal{B}_{D^+\to\mu^+\nu_\mu} - \mathcal{B}_{D^-\to\mu^-\nu_\mu}}{\mathcal{B}_{D^+\to\mu^+\nu_\mu} + \mathcal{B}_{D^-\to\mu^-\nu_\mu}} = (1.8 \pm 2.0_{\rm stat.} \pm 0.8_{\rm syst.})\%$$

Taking from PDG
BESIII measurement will be released soon

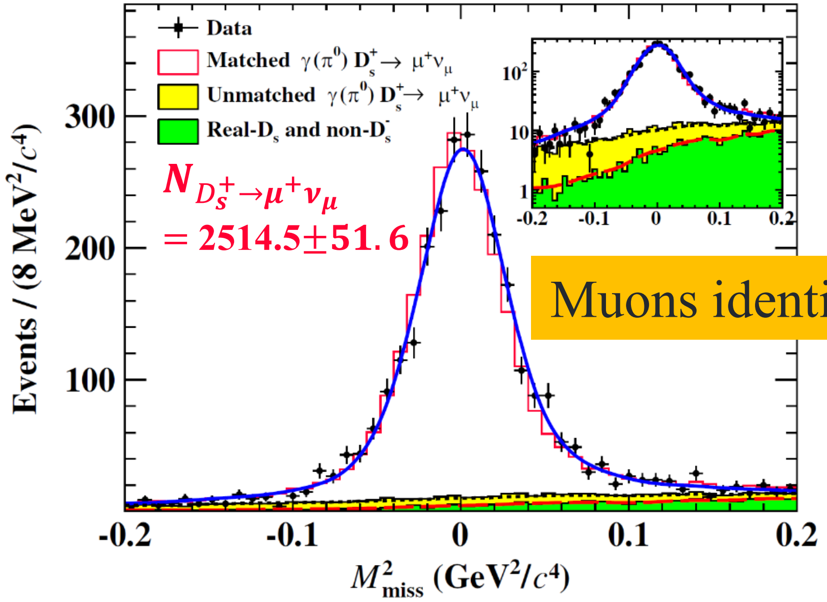
$$\mathcal{R}_{\tau/\mu} = \frac{\mathcal{B}_{D^+\to\tau^+\nu_\tau}}{\mathcal{B}_{D^+\to\mu^+\nu_\mu}} = 3.02 \pm 0.68$$

SM=2.67

Highest precision of $|V_{cd}|$ to date: ~1.2%

$|V_{cs}|$ from $D_s^+ \to \mu^+\nu_\mu$

7.33 fb^{-1}@ 4.128-4.226 GeV, PRD 108, 112001 (2023)



Muons identified from MUC

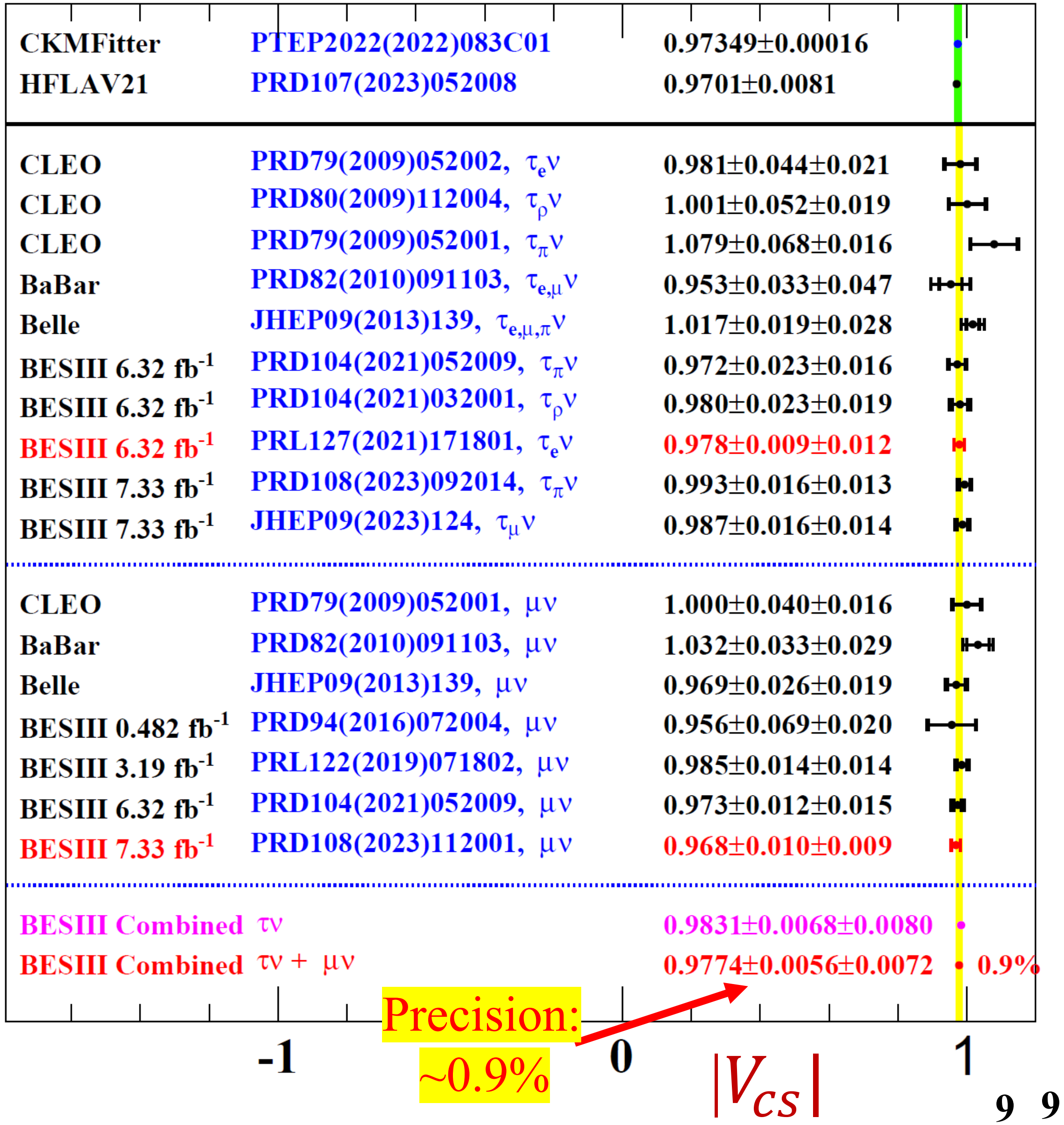
$$\mathcal{B}_{D_s^+\to\mu^+\nu_\mu} = (0.5294 \pm 0.0108_{\rm stat} \pm 0.0085_{\rm syst})\%$$

$$f_{D_s^+}|V_{cs}| = 241.8 \pm 2.5_{\rm stat} \pm 2.2_{\rm syst}\ \text{MeV}$$

$$f_{D_s^+} = 248.4 \pm 2.5_{\rm stat} \pm 2.2_{\rm syst}\ \text{MeV}$$

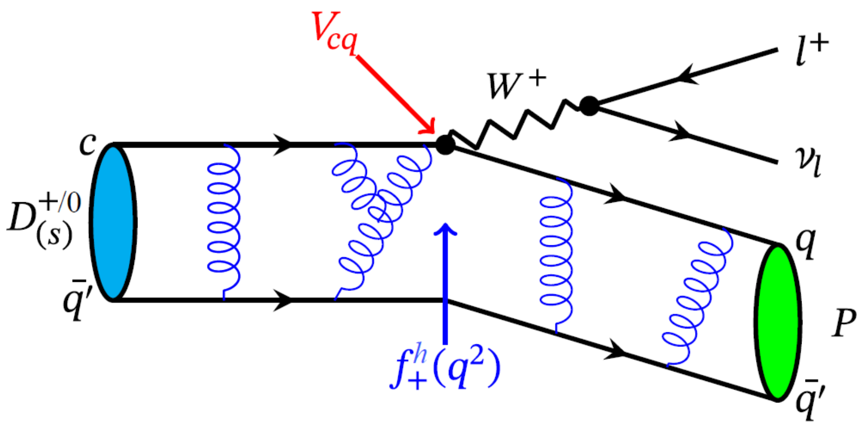
$$|V_{cs}| = 0.968 \pm 0.010_{\rm stat} \pm 0.009_{\rm syst}$$

Precision : ~1.4%



Precision: ~0.9%

Charm semi-leptonic decays $D^+_{(s)} \to \pi(K) l^+ \nu_l$



Partial decay rate

Form factor (LQCD)

CKM matrix element

$$\frac{d\Gamma}{dq^2} = X \frac{G_F^2}{24\pi^3} |f^h_+(0)|^2 |V_{cq}|^2 |\vec{p}_h|^3$$

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

- **The weak and strong interactions can be separated:**

  Weak interaction: CKM matrix elements $|V_{cd(s)}|$

  Form factors $f^h_+(0)$ describe strong interaction can be calculated in LQCD

- Exp. partial decay rate → q^2 dependence of $f^{\pi(K)}_+(q^2)$,

  → **extract** $f^{\pi(K)}_+(0)$ with $|V_{cd(s)}|^{\text{CKMfitter}}$ as input → **calibrate QCD**

- Exp. partial decay rate + LQCD calculation of $f^{\pi(K)}_+(0)$

  → **CKM matrix elements** $|V_{cd(s)}|$

Low precision: **>2%**
FLAG, *Eur. Phys. J. C* 80 (2020) 113

$|V_{cs}|$ from $D^0 \to K^- l^+ \nu_l$ and $D^+ \to \bar{K}^0 l^+ \nu_l$

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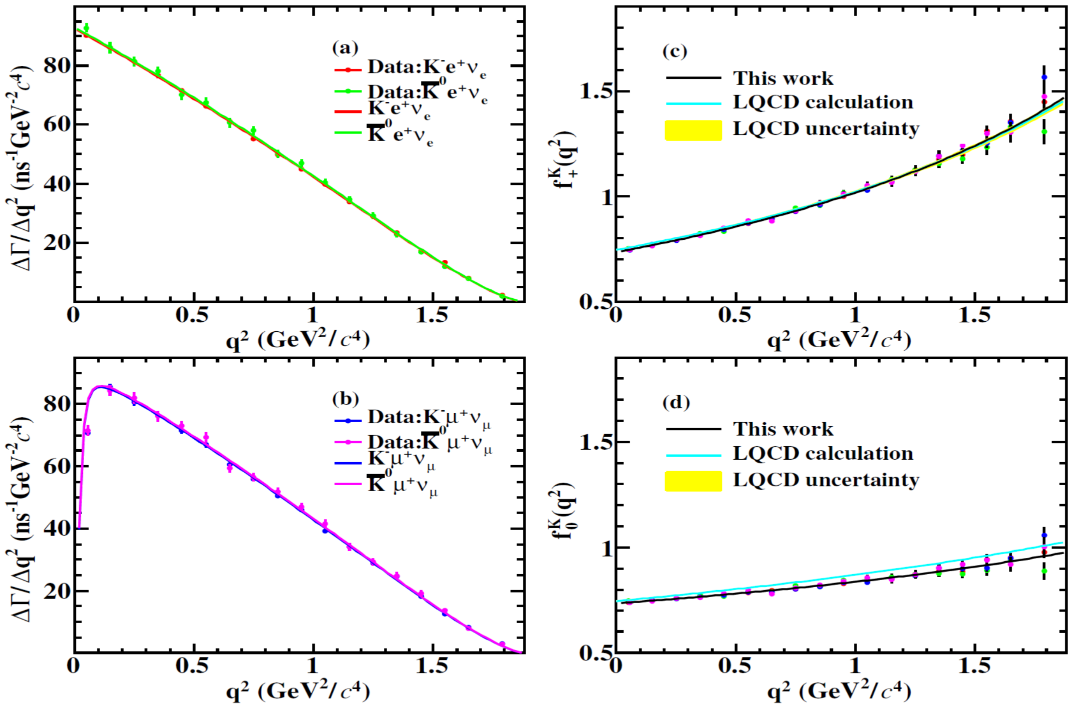
Branching fractions:

Decay	$N_{\rm DT}$	$\mathcal{B}_{\rm sig}$ (%)
$D^0 \to K^- e^+ \nu_e$	190605 ± 471	$3.509 \pm 0.009 \pm 0.013$
$D^0 \to K^- \mu^+ \nu_\mu$	147596 ± 488	$3.408 \pm 0.011 \pm 0.013$
$D^+ \to \bar{K}^0 e^+ \nu_e$	57846 ± 256	$8.856 \pm 0.039 \pm 0.078$
$D^+ \to \bar{K}^0 \mu^+ \nu_\mu$	47229 ± 248	$8.661 \pm 0.046 \pm 0.080$



Simultaneous fit to the partial decay rates

Extract $|V_{cs}|$

7.93 fb^{-1}@ 3.773 GeV, arXiv:2408.09087

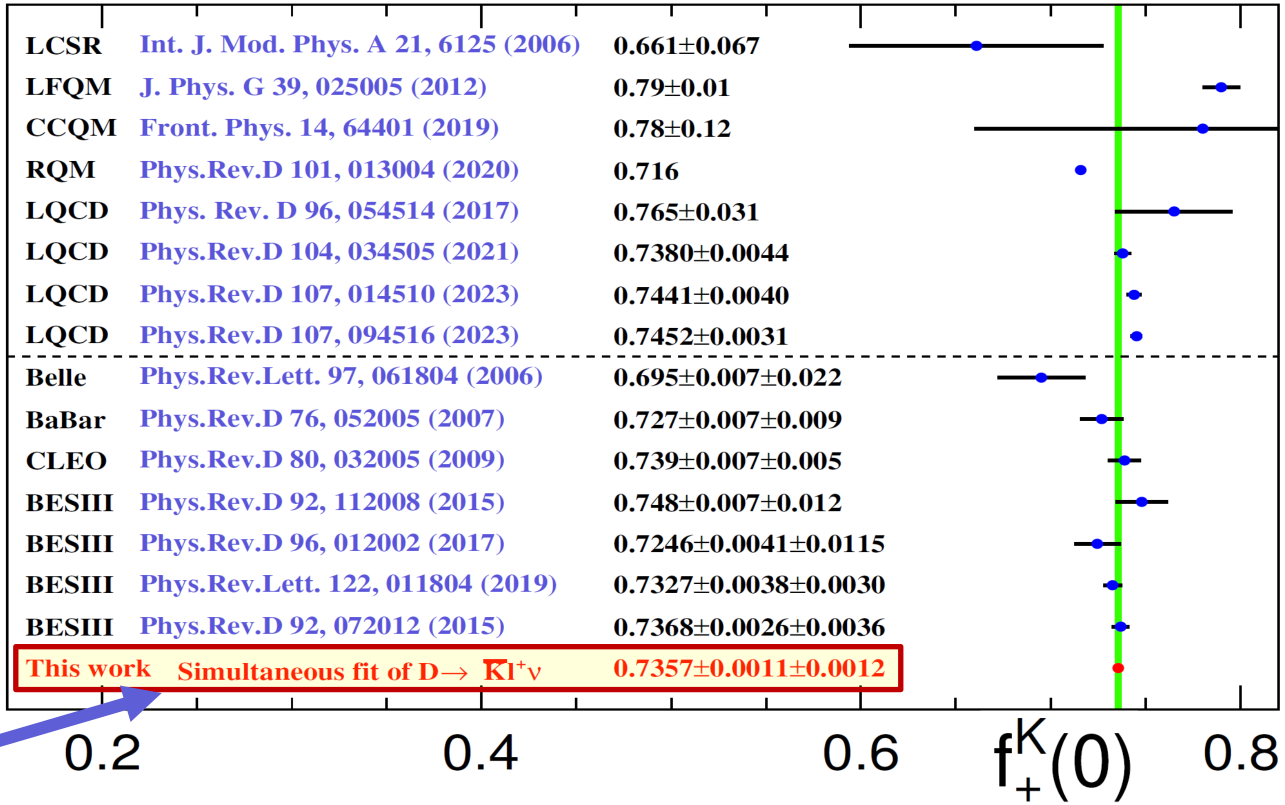
$$|V_{cs}| = 0.9611 \pm 0.0015_{\rm stat.} \pm 0.0016_{\rm syst.} \pm 0.0040_{\rm LQCD}$$

Precision: 0.5%

Test lepton flavor universality (SM=0.975):

$$\frac{\mathcal{B}_{D^+ \to \bar{K}^0 \mu^+ \nu_\mu}}{\mathcal{B}_{D^+ \to \bar{K}^0 e^+ \nu_e}} = 0.978 \pm 0.007_{\rm stat.} \pm 0.012_{\rm syst.}$$

$$\frac{\mathcal{B}_{D^0 \to K^- \mu^+ \nu_\mu}}{\mathcal{B}_{D^0 \to K^- e^+ \nu_e}} = 0.971 \pm 0.004_{\rm stat.} \pm 0.005_{\rm syst}$$



$|V_{cs}|$ from $D_s^+ \to \eta^{(\prime)} l^+ \nu_l$

7.33 fb^{-1}@ 4.128-4.226 GeV

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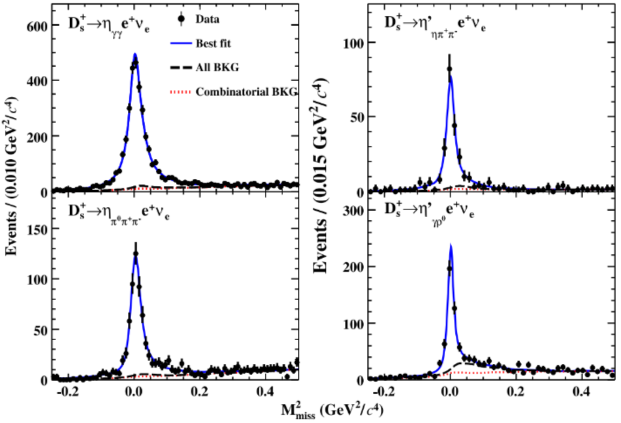
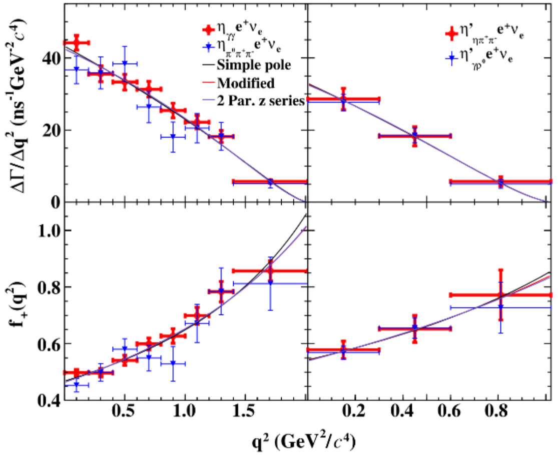
PRL132,091802(2024)

$D_s^+ \to \eta^{(\prime)} e^+ \nu_e$

PRD108,092003(2023)





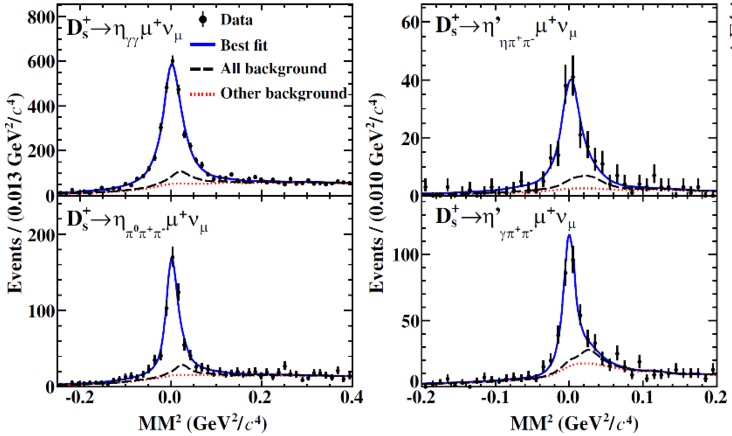
→ Improve the BFs:

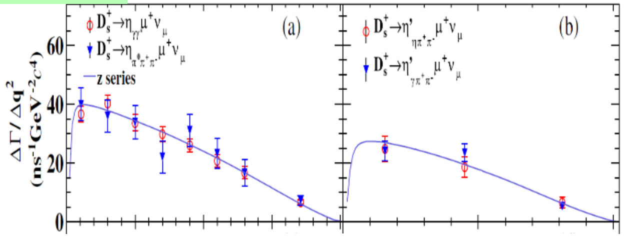
$$\mathcal{B}(D_s^+ \to \eta e^+ \nu_e) = (2.255 \pm 0.039_{stat} + 0.051_{syst})\%$$
$$\mathcal{B}(D_s^+ \to \eta' e^+ \nu_e) = (0.810 \pm 0.038_{stat} \pm 0.024_{syst})\%$$

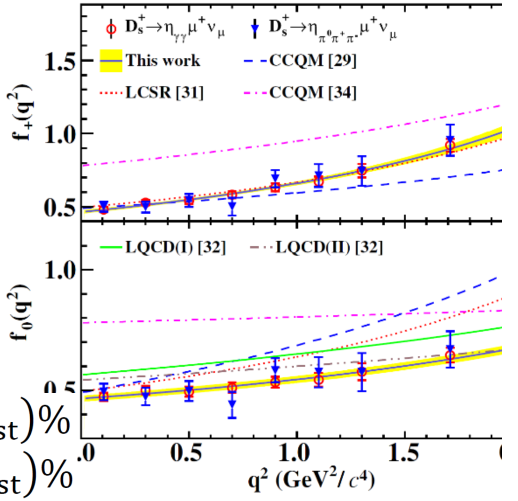
→ Form factor and $|V_{cs}|$:

$$f_{+,0}^{\eta}(0) = 0.4642 \pm 0.0073_{stat} \pm 0.0066_{syst}$$
$$f_{+,0}^{\eta'}(0) = 0.540 \pm 0.025_{stat} \pm 0.008_{syst}$$
$$|V_{cs}|_{\eta} = 0.913 \pm 0.014_{stat} \pm 0.013_{syst}{}^{+0.055}_{-0.053}{}_{theo}$$
$$|V_{cs}|_{\eta'} = 0.941 \pm 0.044_{stat} \pm 0.016_{syst}{}^{+0.078}_{-0.076}{}_{theo}$$

$D_s^+ \to \eta^{(\prime)} \mu^+ \nu_\mu$







→ Improve the BFs:

$$\mathcal{B}(D_s^+ \to \eta \mu^+ \nu_\mu) = (2.235 \pm 0.051_{stat} + 0.052_{syst})\%$$
$$\mathcal{B}(D_s^+ \to \eta' \mu^+ \nu_\mu) = (0.801 \pm 0.055_{stat} \pm 0.028_{syst})\%$$

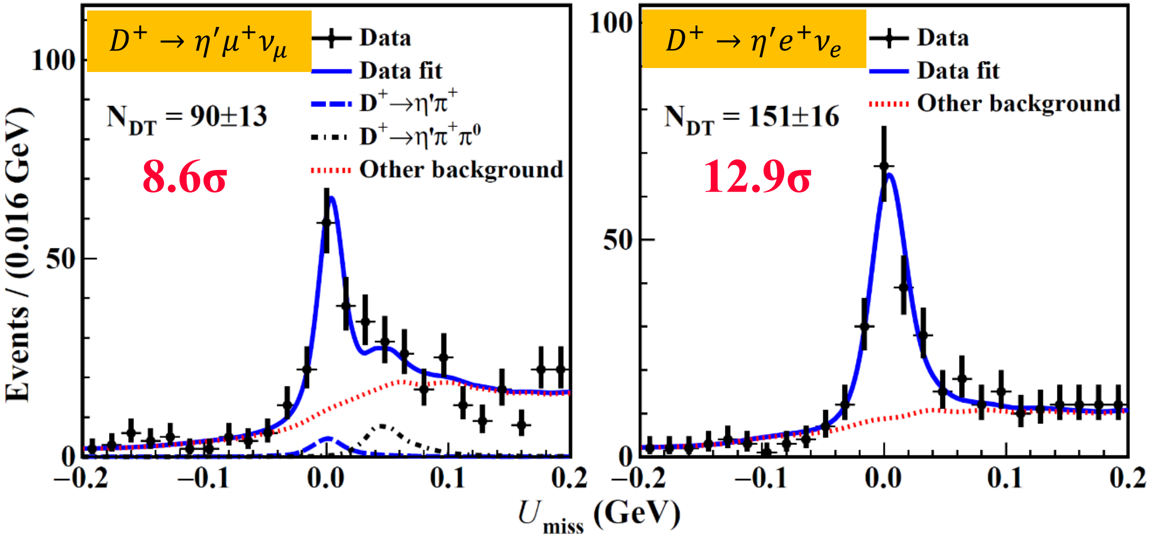
→ Form factor and $|V_{cs}|$:

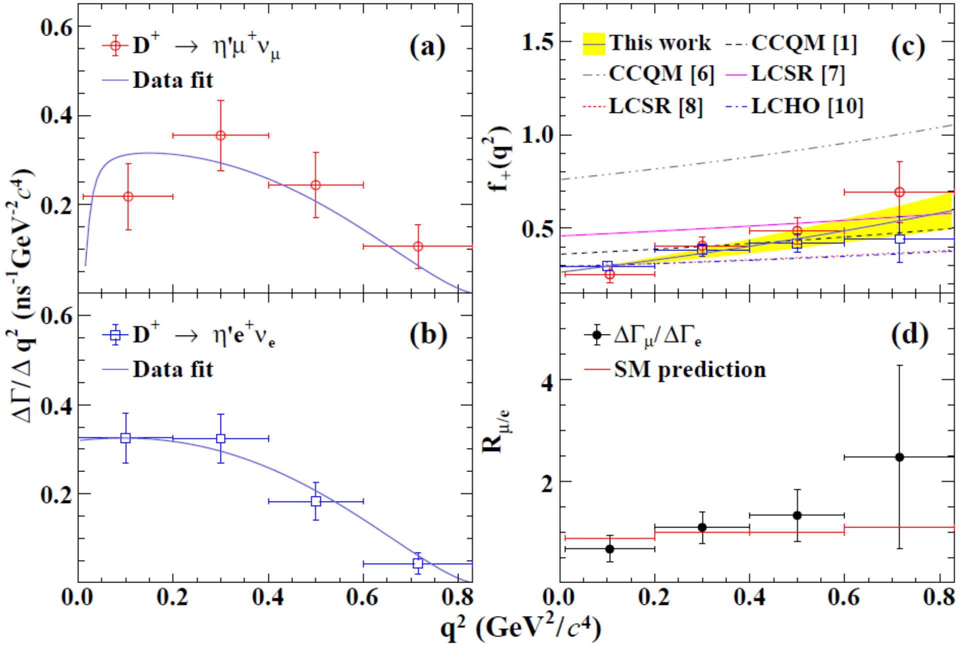
$$f_{+,0}^{\eta}(0) = 0.465 \pm 0.010_{stat} \pm 0.007_{syst}$$
$$f_{+,0}^{\eta'}(0) = 0.518 \pm 0.038_{stat} \pm 0.012_{syst}$$
$$|V_{cs}|_{\eta} = 0.913 \pm 0.020_{stat} \pm 0.014_{syst}{}^{+0.055}_{-0.053}{}_{theo}$$
$$|V_{cs}|_{\eta'} = 0.904 \pm 0.067_{stat} \pm 0.021_{syst}{}^{+0.076}_{-0.073}{}_{theo}$$

$f_+^{\eta'}(0)|V_{cd}|$ from $D^+ \to \eta' l^+ \nu_l$

20.3 fb^{-1}@ 3.773 GeV, arXiv:2410.08603

- Observe $D^+ \to \eta' l^+ \nu_l$





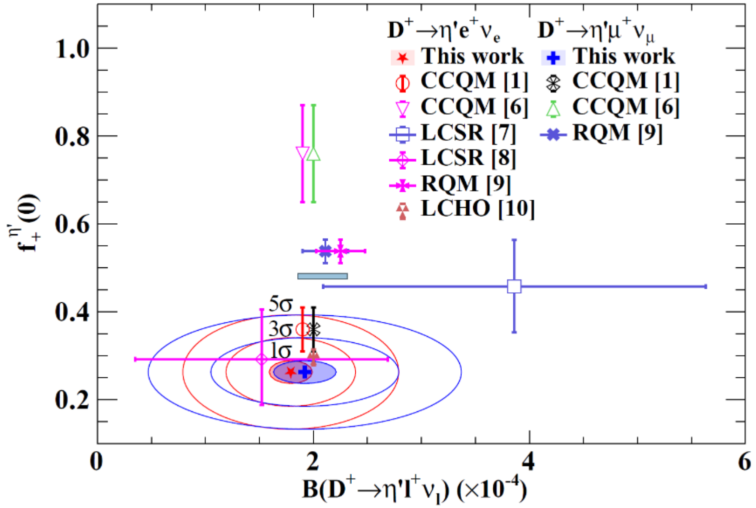
Decay	$\eta'\mu^+\nu_\mu$		$\eta' e^+\nu_e$	
η' decay	$\eta\pi^+\pi^-$	$\gamma\pi^+\pi^-$	$\eta\pi^+\pi^-$	$\gamma\pi^+\pi^-$
$\mathcal{B}$ $(\times 10^{-4})$	$1.92 \pm 0.28 \pm 0.08$		$1.79 \pm 0.19 \pm 0.07$	

$$f_+^{\eta'}(0)|V_{cd}| = (5.92 \pm 0.56_{\rm stat} \pm 0.13_{\rm syst}) \times 10^{-2}$$

→ Form factor: $f_+^{\eta'}(0) = 0.263 \pm 0.025_{\rm stat} \pm 0.006_{\rm syst}$

→ LFU: $\mathcal{R}_{\mu/e}^{\eta'} = \frac{\mathcal{B}_{D^+ \to \eta'\mu^+\nu_\mu}}{\mathcal{B}_{D^+ \to \eta' e^+\nu_e}} = 1.07 \pm 0.19 \pm 0.03$

SM=0.94-0.95



$f_+^{f_0}(0)$ in $D_s^+ \to \pi^+\pi^- e^+\nu_e$

7.33 fb^{-1}@ 4.128-4.226 GeV

PRL132,141901(2024)

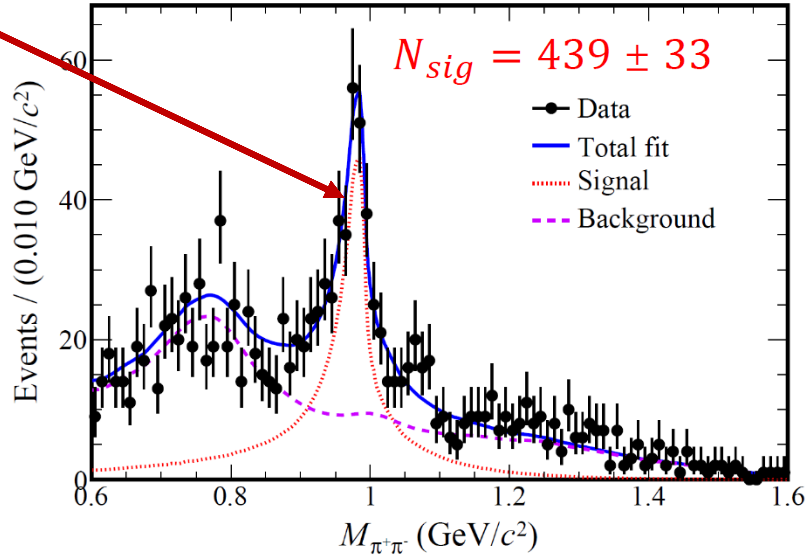
$$\frac{d^2\Gamma(D_s^+ \to f_0(980)e^+\nu_e)}{dsdq^2} = \frac{G_F^2|V_{cs}|^2}{192\pi^4 m_{D_s^+}^3}\lambda^{3/2}(m_{D_s^+}^2, s, q^2) \times |f_+^{f_0}(q^2)|^2 P(s)$$

Flatté model

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

Simple pole parameterization

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



Observe $f_0(980)$

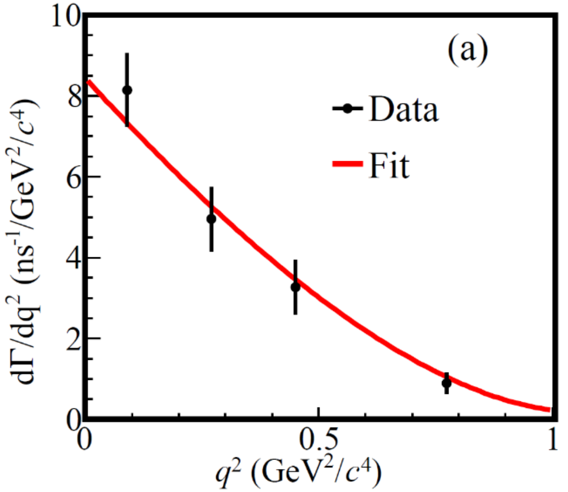
$$\mathcal{B}(D_s^+ \to f_0(980)e^+\nu_e, f_0(980) \to \pi+\pi-) = (1.72 \pm 0.13 \pm 0.19) \times 10^{-3}$$

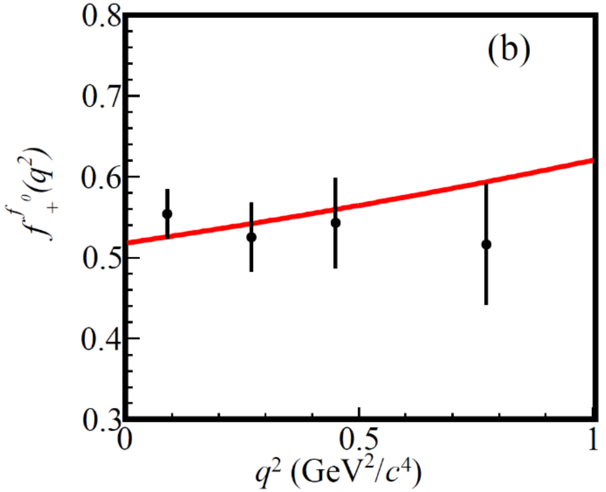
$$\mathcal{B}(D_s^+ \to f_0(500)e^+\nu_e, f_0(500) \to \pi+\pi-) < 3.3 \times 10^{-4} \text{ @ } 90\% \ C.L.$$

Determine form factor

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

$$f_+^{f_0}(0) = 0.518 \pm 0.018_{\text{stat.}} \pm 0.036_{\text{syst.}}$$





Charmed mesons hadronic decays

Measurements of the BFs

→ Are important component of heavy-flavor physics program.

→ Prob and calibrate non-perturbative QCD

→ Understand SU(3) flavor symmetry and its breaking effect

→ Test theoretical calculations of BFs and improve theoretical predictions of *CP* violation

Amplitude analysis of multi-body decays

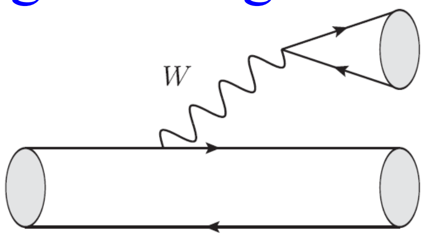
→ Information of $D \to VP, PP, SP, SV, VV, AP, AV, TP$ ...

→ Light hadron spectroscopy

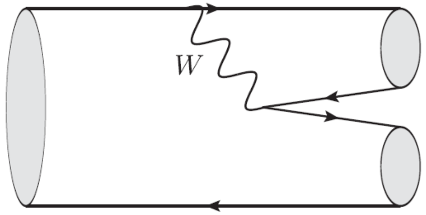
P: pseudo-scalar
V: vector
S: scalar
A: axial-vector
T: tensor

Topological Diagrammatic for D/D_s^+ decays:

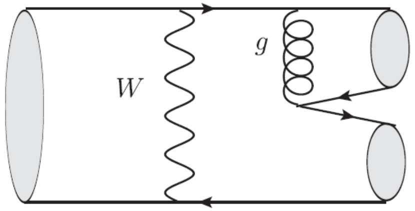
H.-Y. Cheng, *et al.* PRD 85, 034036



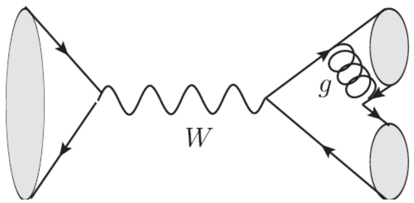
Color-allowed tree *T*



Color-suppressed tree *C*



W-exchange *E*



W-annihilation *A*

Calculation is not reliable, need exp. input

Amplitude analysis of $D_s^+ \to \pi^+\pi^+\pi^-\pi^0$

$7.33\,\mathrm{fb}^{-1}$ @ $4.178 - 4.226\,\mathrm{GeV}$, arXiv:2406.17452

1552 candidates with >75% purity

Observe of $D_s^+ \to f_0(980)\rho(770)^+$

$$\mathcal{B}(D_s^+ \to \pi^+\pi^+\pi^-\pi^0|_{\text{non}-\eta}) = (2.04 \pm 0.08_{\text{stat.}} \pm 0.05_{\text{syst.}})\%$$

$$\mathcal{B}(D_s^+ \to \eta\pi^+) = (1.56 \pm 0.09_{\text{stat.}} \pm 0.04_{\text{syst.}})\%$$

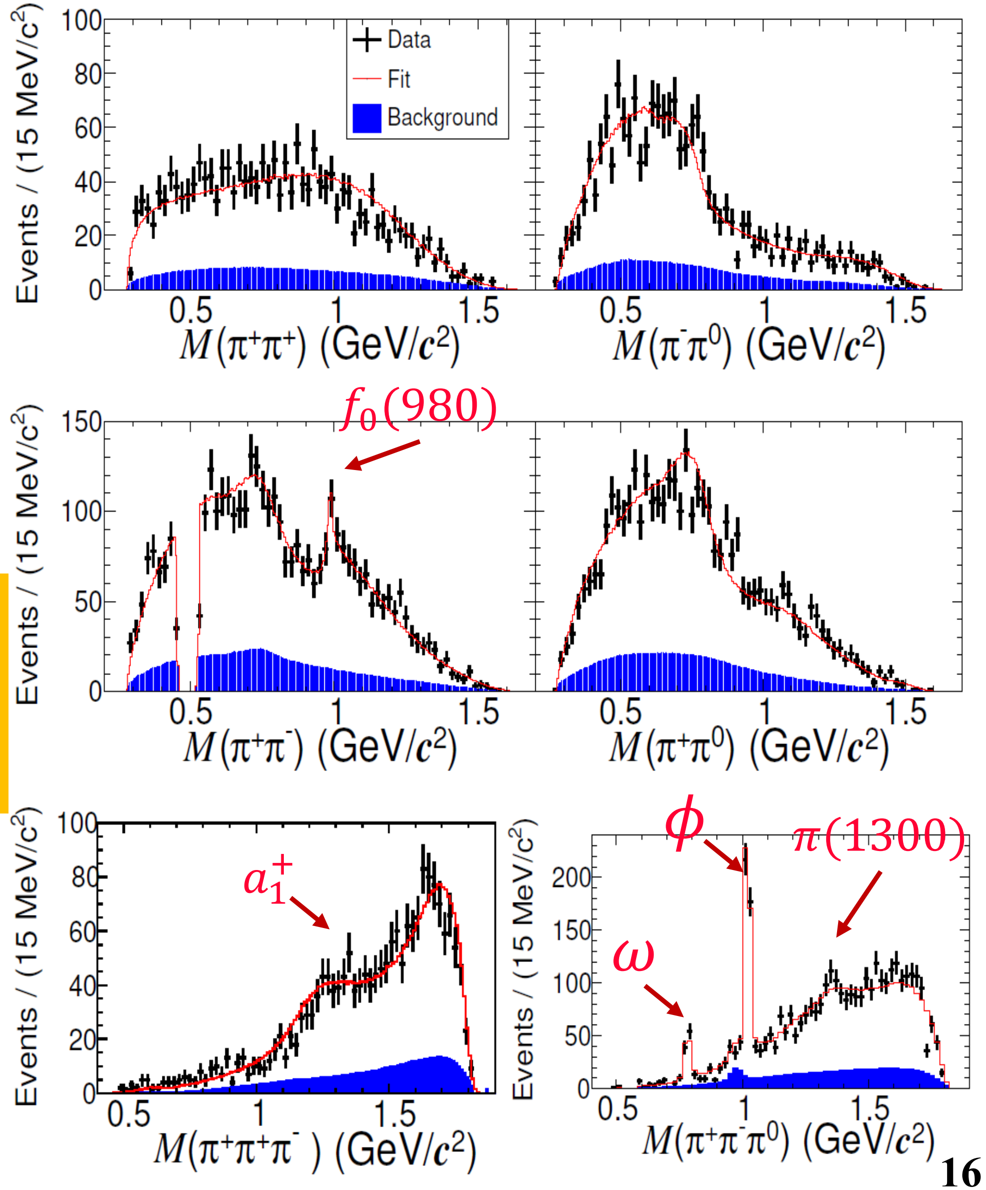
$$\frac{\mathcal{B}(\phi(1020) \to \pi^+\pi^-\pi^0)}{\mathcal{B}(\phi(1020) \to K^+K^-)} = 0.230 \pm 0.014_{\text{stat.}} \pm 0.010_{\text{syst.}}$$

Taking from $D_s^+ \to K^+K^-\pi^+$
BESIII, PRD 104, 012016 (2021)

Deviates from PDG value (0.313±0.010) by >4σ

Component	Phase (rad)	BF (10^{-3})
$f_0(1370)\rho^+$	0.0(fixed)	$5.08 \pm 0.80 \pm 0.43$
$f_0(980)\rho^+$	$3.99 \pm 0.13 \pm 0.07$	$2.57 \pm 0.44 \pm 0.20$
$f_2(1270)\rho^+$	$1.11 \pm 0.10 \pm 0.10$	$1.94 \pm 0.36 \pm 0.12$
$(\rho^+\rho^0)_S$	$1.10 \pm 0.18 \pm 0.10$	$0.71 \pm 0.25 \pm 0.12$
$(\rho(1450)^+\rho^0)_S$	$0.43 \pm 0.18 \pm 0.17$	$0.94 \pm 0.27 \pm 0.16$
$(\rho^+\rho(1450)^0)_P$	$4.58 \pm 0.16 \pm 0.09$	$1.75 \pm 0.27 \pm 0.08$
$\phi((\rho\pi) \to \pi^+\pi^-\pi^0)\pi^+$	$2.90 \pm 0.15 \pm 0.18$	$5.08 \pm 0.32 \pm 0.10$
$\omega((\rho\pi) \to \pi^+\pi^-\pi^0)\pi^+$	$3.22 \pm 0.21 \pm 0.09$	$1.41 \pm 0.17 \pm 0.06$
$a_1^+(\rho^0\pi^+)_S\pi^0$	$3.78 \pm 0.16 \pm 0.12$	$2.55 \pm 0.34 \pm 0.20$
$a_1^0((\rho\pi)_S \to \pi^+\pi^-\pi^0)\pi^+$	$4.82 \pm 0.15 \pm 0.12$	$1.29 \pm 0.39 \pm 0.24$
$\pi(1300)^0((\rho\pi)_P \to \pi^+\pi^-\pi^0)\pi^+$	$2.22 \pm 0.14 \pm 0.08$	$2.39 \pm 0.48 \pm 0.45$

W-annihilation decay
BF = $(1.92 \pm 0.30) \times 10^{-3}$
(PDG)



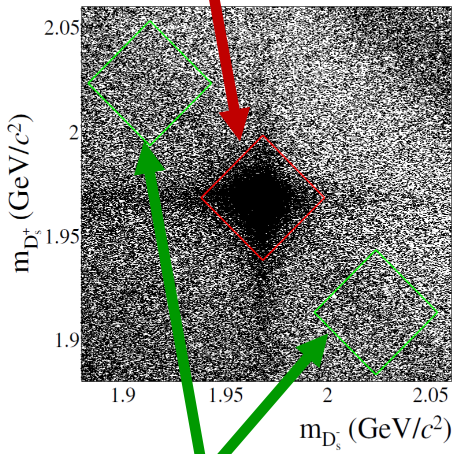
BF of D_s^+ hadronic decays

7.33 fb^{-1} @4.178 – 4.226 GeV, JHEP05(2024)335

BESIII

Global fit to ST and DT yields and obtain:

42965 events in signal region



14728 events in combined sideband

Mode	$\mathcal{B}$ (%)	$\mathcal{A}_{CP}$ (%)
$D_s^+ \to K_S^0 K^+$	$1.502 \pm 0.012 \pm 0.009$	$0.29 \pm 0.50 \pm 0.21$
$D_s^+ \to K^+ K^- \pi^+$	$5.49 \pm 0.04 \pm 0.07$	$0.48 \pm 0.26 \pm 0.24$
$D_s^+ \to K_S^0 K^+ \pi^0$	$1.47 \pm 0.02 \pm 0.02$	$-0.85 \pm 1.97 \pm 0.46$
$D_s^+ \to K_S^0 K_S^0 \pi^+$	$0.73 \pm 0.01 \pm 0.01$	$1.14 \pm 1.58 \pm 0.44$
$D_s^+ \to K^+ K^- \pi^+ \pi^0$	$5.50 \pm 0.05 \pm 0.11$	$-0.66 \pm 0.91 \pm 0.33$
$D_s^+ \to K_S^0 K^+ \pi^+ \pi^-$	$0.93 \pm 0.02 \pm 0.01$	$2.00 \pm 2.37 \pm 0.70$
$D_s^+ \to K_S^0 K^- \pi^+ \pi^+$	$1.56 \pm 0.02 \pm 0.02$	$-0.24 \pm 1.05 \pm 1.07$
$D_s^+ \to \pi^+ \pi^+ \pi^-$	$1.09 \pm 0.01 \pm 0.01$	$-0.88 \pm 1.17 \pm 0.38$
$D_s^+ \to \pi^+ \eta$	$1.69 \pm 0.02 \pm 0.02$	$-0.44 \pm 0.89 \pm 0.19$
$D_s^+ \to \pi^+ \pi^0 \eta$	$9.10 \pm 0.09 \pm 0.15$	$1.05 \pm 1.45 \pm 0.62$
$D_s^+ \to \pi^+ \pi^+ \pi^- \eta$	$3.08 \pm 0.06 \pm 0.05$	$2.42 \pm 2.85 \pm 0.78$
$D_s^+ \to \pi^+ \eta'$	$3.95 \pm 0.04 \pm 0.07$	$-0.59 \pm 0.76 \pm 0.20$
$D_s^+ \to \pi^+ \pi^0 \eta'$	$6.17 \pm 0.12 \pm 0.14$	$-1.60 \pm 2.57 \pm 0.64$
$D_s^+ \to K_S^0 \pi^+ \pi^0$	$0.51 \pm 0.02 \pm 0.01$	$-2.17 \pm 4.65 \pm 1.10$
$D_s^+ \to K^+ \pi^+ \pi^-$	$0.620 \pm 0.009 \pm 0.006$	$1.81 \pm 2.01 \pm 0.45$

Agree with PDG with much improved precision

Multi-body decays based on amplitude models

15 Amplitude analyses published/submitted

- $D_s^+ \to K^+ K^- \pi^+$ Phys. Rev. D **104** (2021) 012016
- $D_s^+ \to K_S^0 K^+ \pi^0$ Phys. Rev. Lett. **129** (2022) 182001
- $D_s^+ \to \pi^+ \pi^+ \pi^-$ Phys. Rev. D **106** (2022) 112006
- $D_s^+ \to \pi^+ \pi^+ \pi^- \eta$ Phys. Rev. D **104** (2021) L071101
- $D_s^+ \to \pi^+ \pi^0 \eta'$ **JHEP 04** (2022) 058
- $D_s^+ \to \pi^+ \pi^0 \pi^0$ **JHEP 01** (2022) 052
- $D_s^+ \to K^+ \pi^+ \pi^-$ **JHEP 08** (2022) 196
- $D_s^+ \to K^+ \pi^+ \pi^- \pi^0$ **JHEP 09** (2022) 242
- $D_s^+ \to K_S^0 K_S^0 \pi^+$ Phys. Rev. D **105** (2022) L051103
- $D_s^+ \to K_S^0 K^- \pi^+ \pi^+$ Phys. Rev. D **103** (2021) 092006
- $D_s^+ \to K^+ K^- \pi^+ \pi^0$ Phys. Rev. D **104** (2021) 032011
- $D_s^+ \to K^+ K^- \pi^+ \pi^+ \pi^-$ **JHEP 07** (2022) 051
- $D_s^+ \to K_S^0 \pi^+ \pi^0$ **JHEP 06** (2021) 181
- $D_s^+ \to \pi^+ \pi^0 \eta$ Phys. Rev. Lett. **123** (2019) 112001
- $D_s^+ \to \pi^+ \pi^+ \pi^- \pi^0$ arXiv:2406.17452
- $D_s^+ \to \pi^+ \pi^+ \pi^- \pi^0 \pi^0$ will be released soon

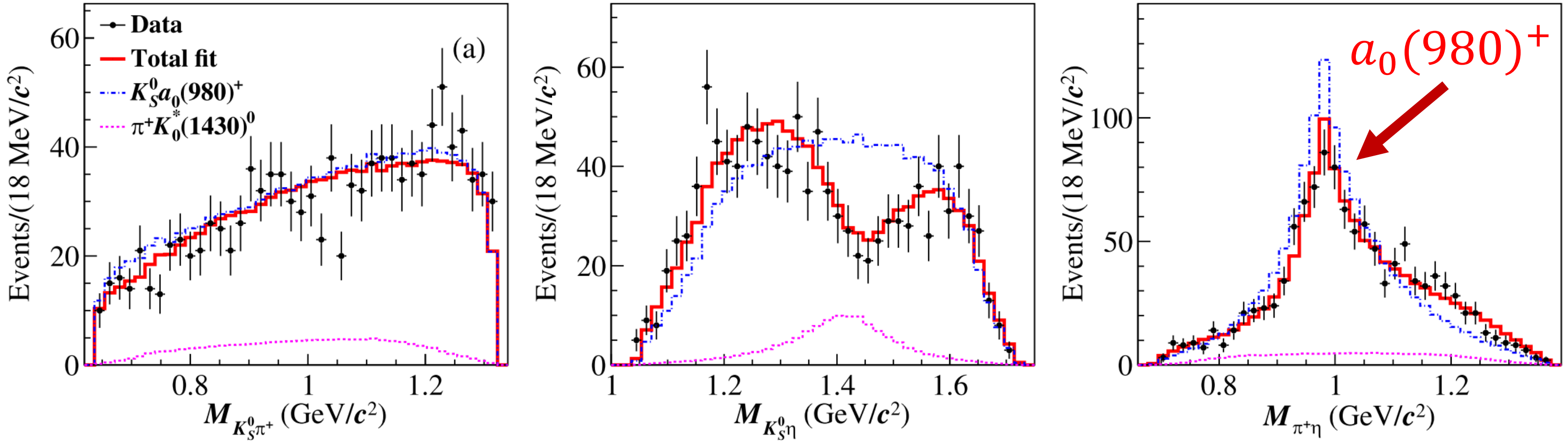
Amplitude analysis of $D^+ \to K_S^0\pi^+\eta$

PRL 132, 131903 (2024)

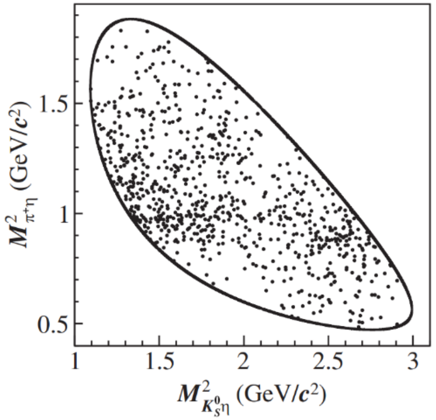
BESIII

2.93fb^{-1} @3.773GeV

Observe W-annihilation-free decay $D^+ \to K_S^0 a_0(980)^+$



1113 candidates with 98% purity

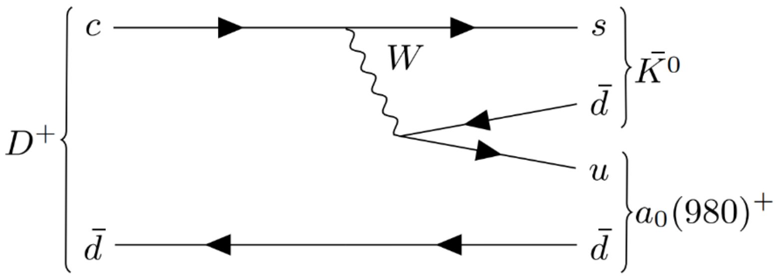


$$\mathcal{B}(D^+ \to K_S^0 a_0(980)^+, a_0(980)^+ \to \pi^+\eta) = (1.33 \pm 0.05_{\text{stat}} \pm 0.04_{\text{syst}})\%$$

$$\mathcal{B}(D^+ \to \bar{K}_0^*(1430)^0\pi^+,\ \bar{K}_0^*(1430)^0 \to K_S^0\eta) = (0.14 \pm 0.02_{\text{stat}} \pm 0.02_{\text{syst}})\%$$

$$\mathcal{B}(D^+ \to K_S^0\pi^+\eta) = (1.27 \pm 0.04_{\text{stat}} \pm 0.03_{\text{syst}})\%$$

Provide sensitive constraints in the extraction of contributions from internal W-emission diagrams →



Amplitude analysis of $D^0 \to \pi^+\pi^-\eta,\ D^+ \to \pi^+\pi^0\eta$

BESIII

$7.9\ \text{fb}^{-1}@E_{\text{cm}} = 3.773\text{GeV}$, arXiv:2404.09219

Observe $D \to a_0(980)\pi$

$\mathcal{B}(D^0 \to \pi^+\pi^-\eta) = (1.24 \pm 0.04 \pm 0.03)\%$

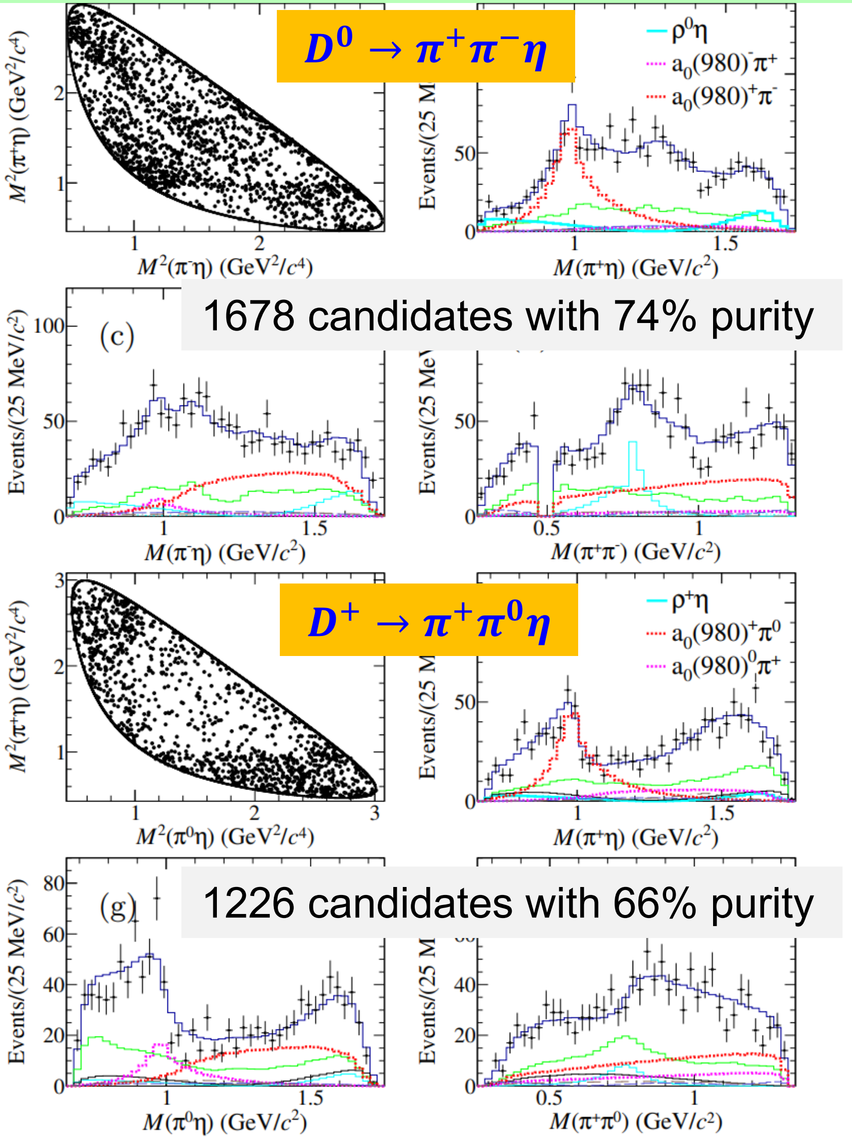
$\mathcal{B}(D^+ \to \pi^+\pi^0\eta) = (2.18 \pm 0.12 \pm 0.03)\%$

Amplitude	Phase (in unit rad)	BF ($\times 10^{-3}$)
$D^0 \to \rho^0\eta$	0 (fixed)	$0.19 \pm 0.02 \pm 0.01$
$D^0 \to a_0(980)^-\pi^+$	$0.06 \pm 0.16 \pm 0.12$	$0.07 \pm 0.02 \pm 0.01$
$D^0 \to a_0(980)^+\pi^-$	$-1.06 \pm 0.12 \pm 0.10$	$0.55 \pm 0.05 \pm 0.07$
$D^0 \to a_2(1320)^+\pi^-$	$-1.16 \pm 0.25 \pm 0.23$	$0.03 \pm 0.01 \pm 0.01$
$D^0 \to a_2(1700)^+\pi^-$	$0.08 \pm 0.17 \pm 0.23$	$0.07 \pm 0.02 \pm 0.03$
$D^0 \to (\pi^+\pi^-)_{S-\text{wave}}\eta$	$-0.92 \pm 0.29 \pm 0.14$	$0.05 \pm 0.02 \pm 0.03$
$D^+ \to \rho^+\eta$	$-4.03 \pm 0.19 \pm 0.13$	$0.20 \pm 0.07 \pm 0.05$
$D^+ \to (\pi^+\pi^0)_V\eta$	$-0.64 \pm 0.22 \pm 0.19$	$0.34 \pm 0.11 \pm 0.11$
$D^+ \to a_0(980)^+\pi^0$	0 (fixed)	$0.95 \pm 0.12 \pm 0.05$
$D^+ \to a_0(980)^0\pi^+$	$2.44 \pm 0.20 \pm 0.10$	$0.37 \pm 0.10 \pm 0.04$
$D^+ \to a_2(1700)^+\pi^0$	$0.92 \pm 0.20 \pm 0.14$	$0.09 \pm 0.05 \pm 0.02$
$D^+ \to a_0(1450)^+\pi^0$	$0.63 \pm 0.41 \pm 0.30$	$0.15 \pm 0.06 \pm 0.02$

$\mathcal{B}(D^0 \to a_0(980)^+\pi^-)/\mathcal{B}(D^0 \to a_0(980)^-\pi^+)$ $\quad 7.5^{+2.5}_{-0.8\,\text{stat.}} \pm 1.7_{\text{syst.}}$

$\mathcal{B}(D^+ \to a_0(980)^+\pi^0)/\mathcal{B}(D^+ \to a_0(980)^0\pi^+)$ $\quad 2.6 \pm 0.6_{\text{stat.}} \pm 0.3_{\text{syst.}}$

→ **Disagrees with theoretical predictions by orders of magnitude**



Observe $D_s^+ \to a_0(980)\pi$

$3.19\ \text{fb}^{-1}@E_{\text{cm}} = 4.176\text{GeV}$
PRL123, 112001(2019)

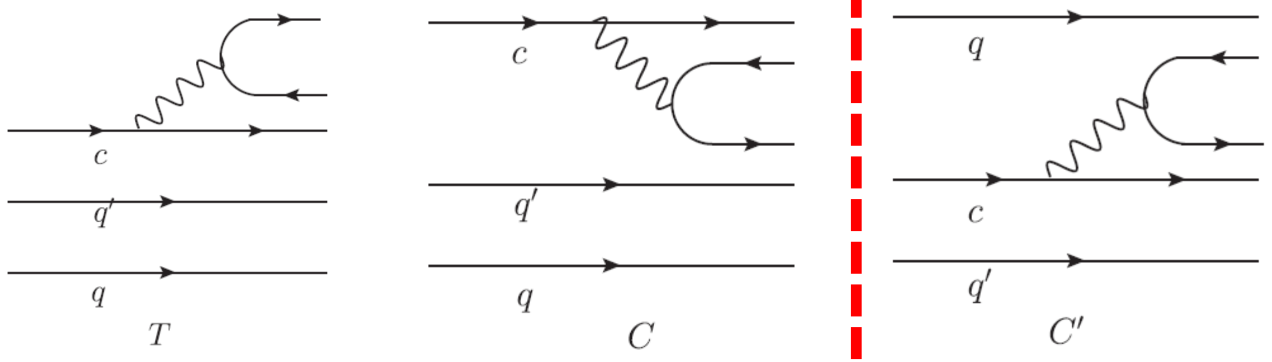
$$\mathcal{B}(D_s^+ \to a_0(980)^+\pi^0) = \mathcal{B}(D_s^+ \to a_0(980)^0\pi^+) = (1.46 \pm 0.15 \pm 0.23)\%$$

→ **Larger than pure W-annihilation decays $D_s^+ \to \omega\pi^+$, $D_s^+ \to \rho\pi^+$ by one order of magnitude**

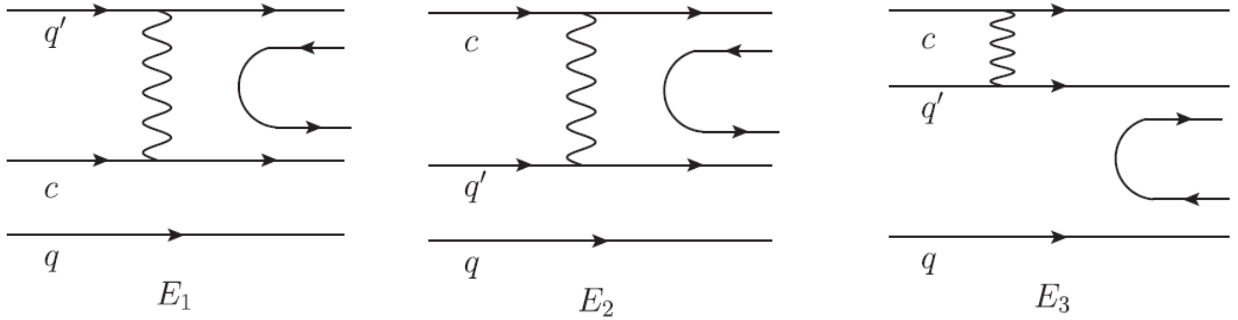
Charmed baryon decay

- Λ_c^+ may reveal more information of strong- and weak-interactions in charm region, complementary to D/D_s
  → Most charmed baryons eventually decay to Λ_c^+

Topological Diagrams for Λ_c^+ decays:



W-emission T **internal W-emission C** **inner W-emission C'**



W-exchange E_1, E_2, and E_3

H.-Y. Cheng, *et al.*, *Chinese Journal of Physics*, 78(2022) 324-362

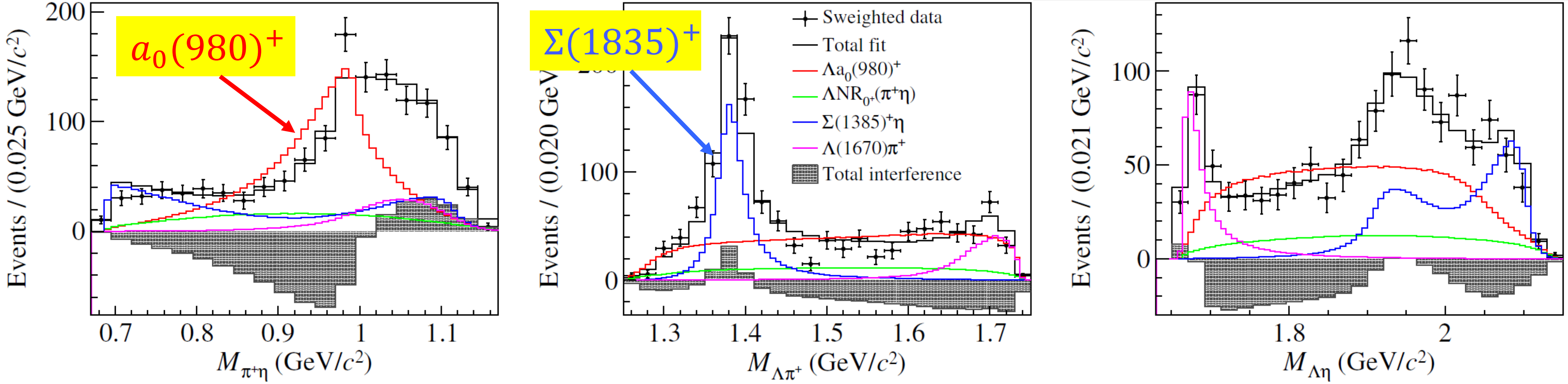
Non-factorization amplitude
→ Calculation is not reliable, need exp. input

Observation $a_0(980)^+$ in $\Lambda_c^+ \to \Lambda\pi^+\eta$

6.1 fb^{-1}@$E_{cm} = 4.600 - 4.843$GeV, arXiv:2407.12270

Observe $\Lambda_c^+ \to \Lambda a_0(980)^+$

1312 ± 45 signal events with 80% purity



$\mathcal{B}(\Lambda_c^+ \to \Lambda\pi^+\eta) =$
$(1.94 \pm 0.16_{\text{stat}} \pm 0.05_{\text{syst}})\%$

Process	FF (%)	significance	decay asymmetry α
$\Lambda a_0(980)^+$	$54.0 \pm 8.4 \pm 2.6$	13.1σ	$0.91^{+0.09}_{-0.18} \pm 0.08$
$\Sigma(1385)^+\eta$	$30.4 \pm 2.6 \pm 0.7$	22.5σ	$-0.61 \pm 0.15 \pm 0.04$
$\Lambda(1670)\pi^+$	$14.1 \pm 2.8 \pm 1.2$	11.7σ	$0.21 \pm 0.27 \pm 0.33$
ΛNR_{0^+}	15.4 ± 5.3	6.7σ	...

$\mathcal{B}(\Lambda_c^+ \to \Lambda a_0(980)^+, a_0(980)^+ \to \pi^+\eta) = (1.05 \pm 0.16_{\text{stat}} \pm 0.05_{\text{syst}} \pm 0.07_{\text{ext}})\%$

→ $\mathcal{B}(\Lambda_c^+ \to \Lambda a_0(980)^+) = (1.23 \pm 0.21)\%$ Larger than theoretical calculations by 1-2 orders.

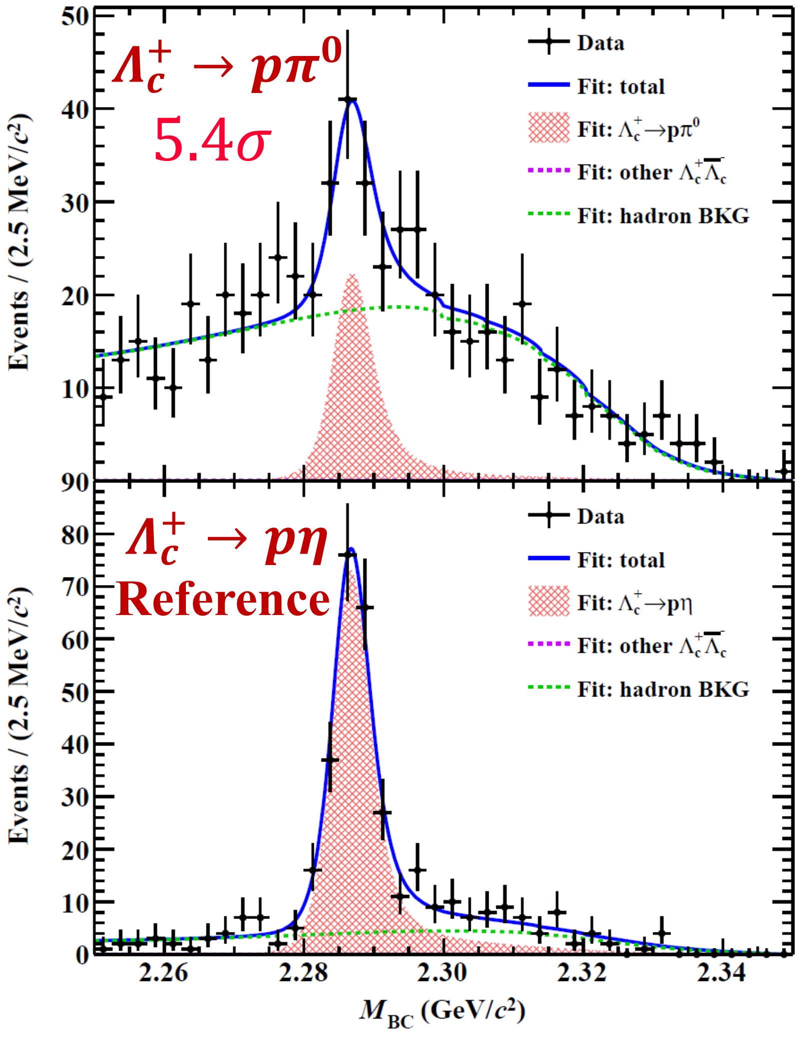
First Observation of $\Lambda_c^+ \to p\pi^0$

arXiv:2410.13368

BESIII

$4.5\ \mathrm{fb}^{-1}@E_{\mathrm{cm}} = 4.60 - 4.699\mathrm{GeV}$

- A deep learning approach is employed to distinguish the signal from backgrounds.



Single-tag method: reconstruct $\Lambda_c^+ \to p\pi^0$, measure relative BF:

$$\mathcal{B}(\Lambda_c^+ \to p\pi^0)/\mathcal{B}(\Lambda_c^+ \to p\eta) = (0.120 \pm 0.026_{\mathrm{stat.}} \pm 0.007_{\mathrm{syst.}})$$

$$\mathcal{B}(\Lambda_c^+ \to p\pi^0) = (1.79 \pm 0.39_{\mathrm{stat.}} \pm 0.11_{\mathrm{syst.}} \pm 0.08_{\mathrm{ref.}}) \times 10^{-4}$$

Using averaged BF for $\Lambda_c^+ \to p\eta$ from BESIII and Belle as reference

1. BESIII, JHEP 11, 137 (2023)
2. Belle, PRD 103, 072004 (2021)

BESIII PRD 109, L091101(2004)

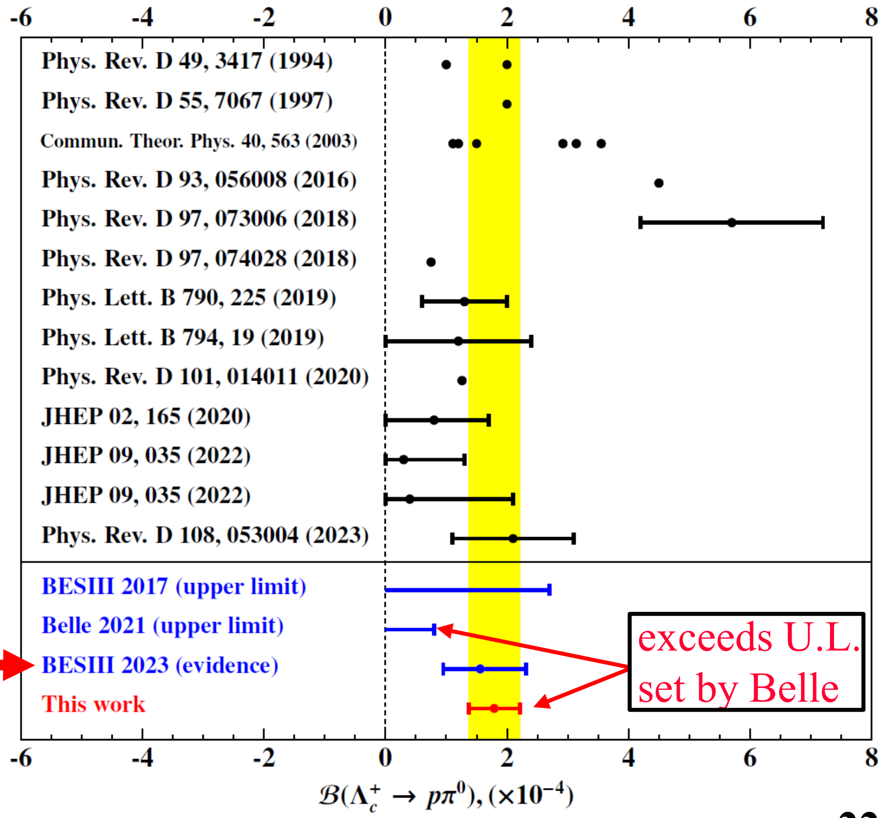
Double-tag method:

→ Reconstruct $\Lambda_c^+ \to p\pi^0$ with one of nine $\bar{\Lambda}_c^-$ tag modes. 3.7σ

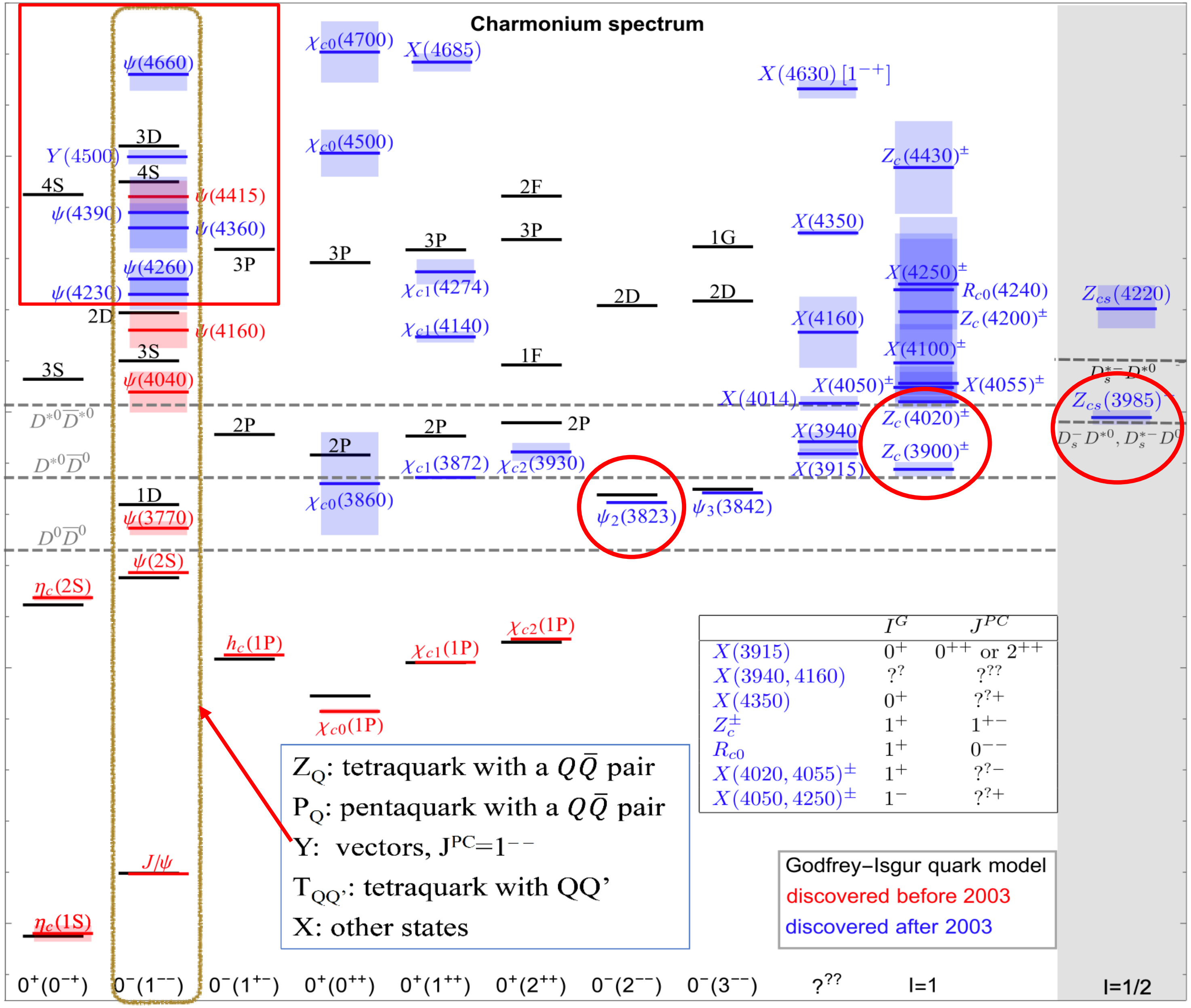
→ Measure absolute BF:

$$\mathcal{B}(\Lambda_c^+ \to p\pi^0) = (1.56^{+0.72}_{-0.58} \pm 0.20) \times 10^{-4}$$

$$\mathcal{B}(\Lambda_c^+ \to p\eta) = (1.63 \pm 0.31 \pm 0.11) \times 10^{-3}$$

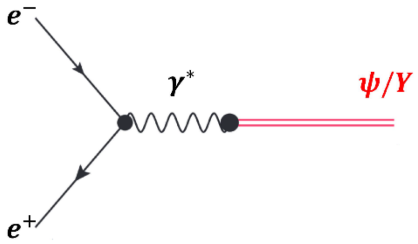


XYZ states



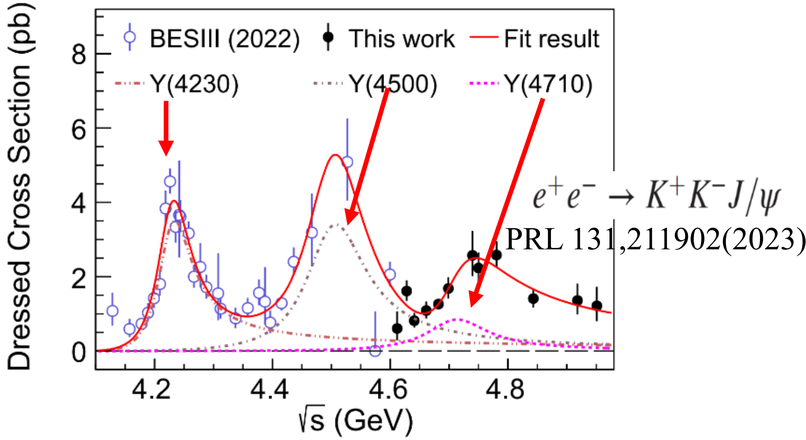
from F. K. Guo

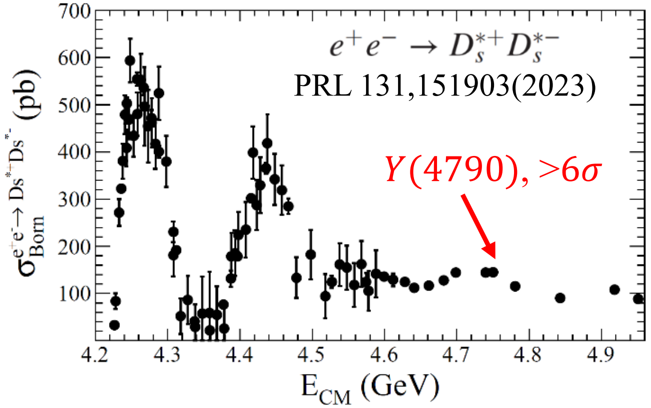
BESIII: a ψ/Y factory



→ Discovered $Y(4230)$ in >10 decay modes

→ Discovered $Y(4500)$, $Y(4710)/Y(4790)$



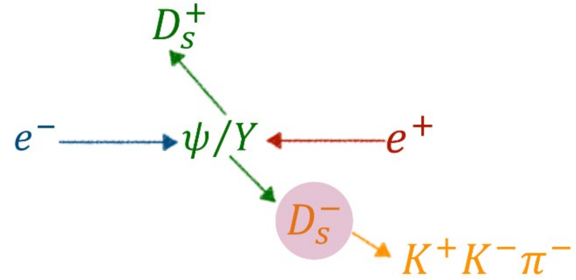


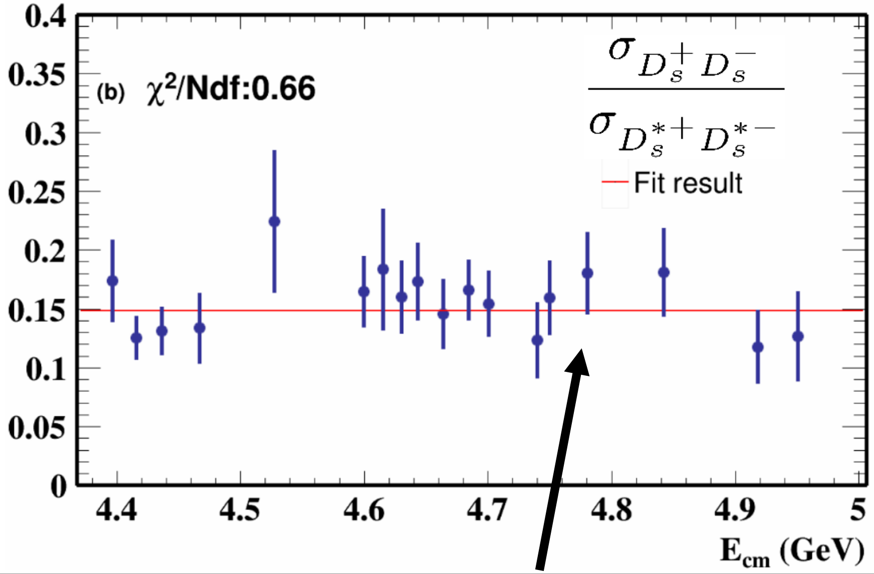
Precise Measurement of $\sigma[e^+e^- \to D_s^+ D_s^-]$

138 data samples with ~22.9 fb^{-1} at $\sqrt{s} = 3.94 - 4.95$ GeV

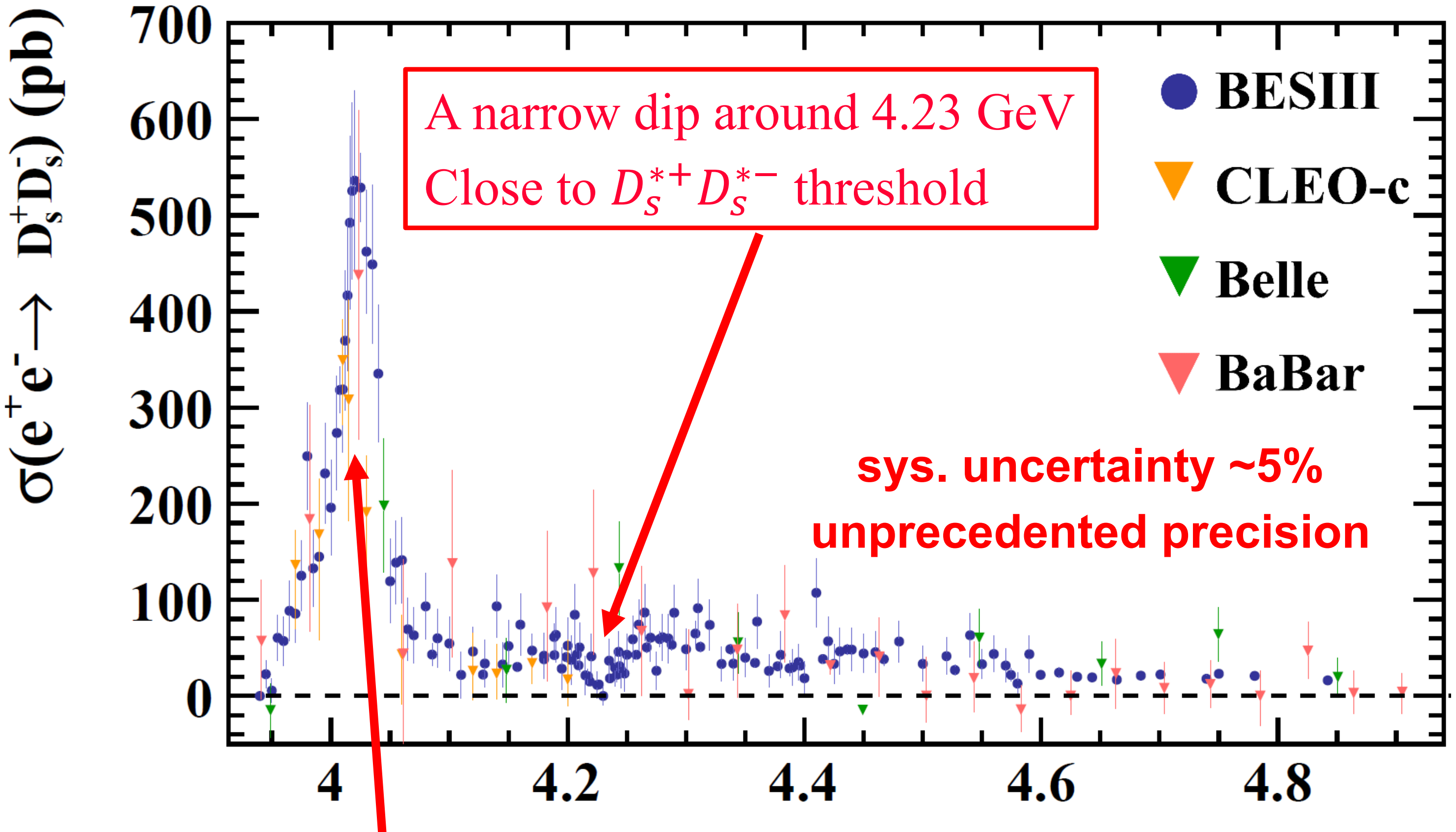
arXiv:2403.14998, submitted to PRL

Partial reconstruction





Constant ratio to $D_s^{*+}D_s^{*-}$, where a structure around 4.78 GeV is observed



Cross section peaks above the threshold,

→ presence of a strong coupled channel effect

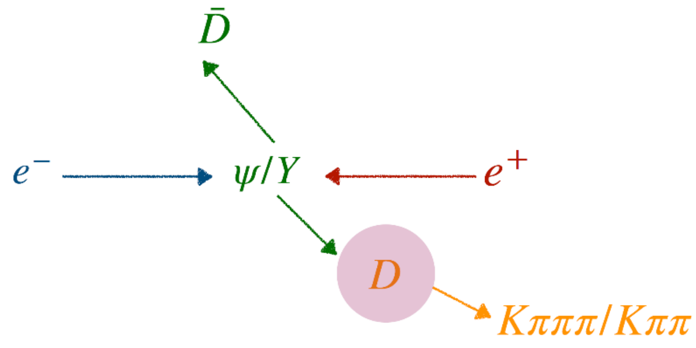
E. Eichten, et al., PRD 21, 203 (1980)

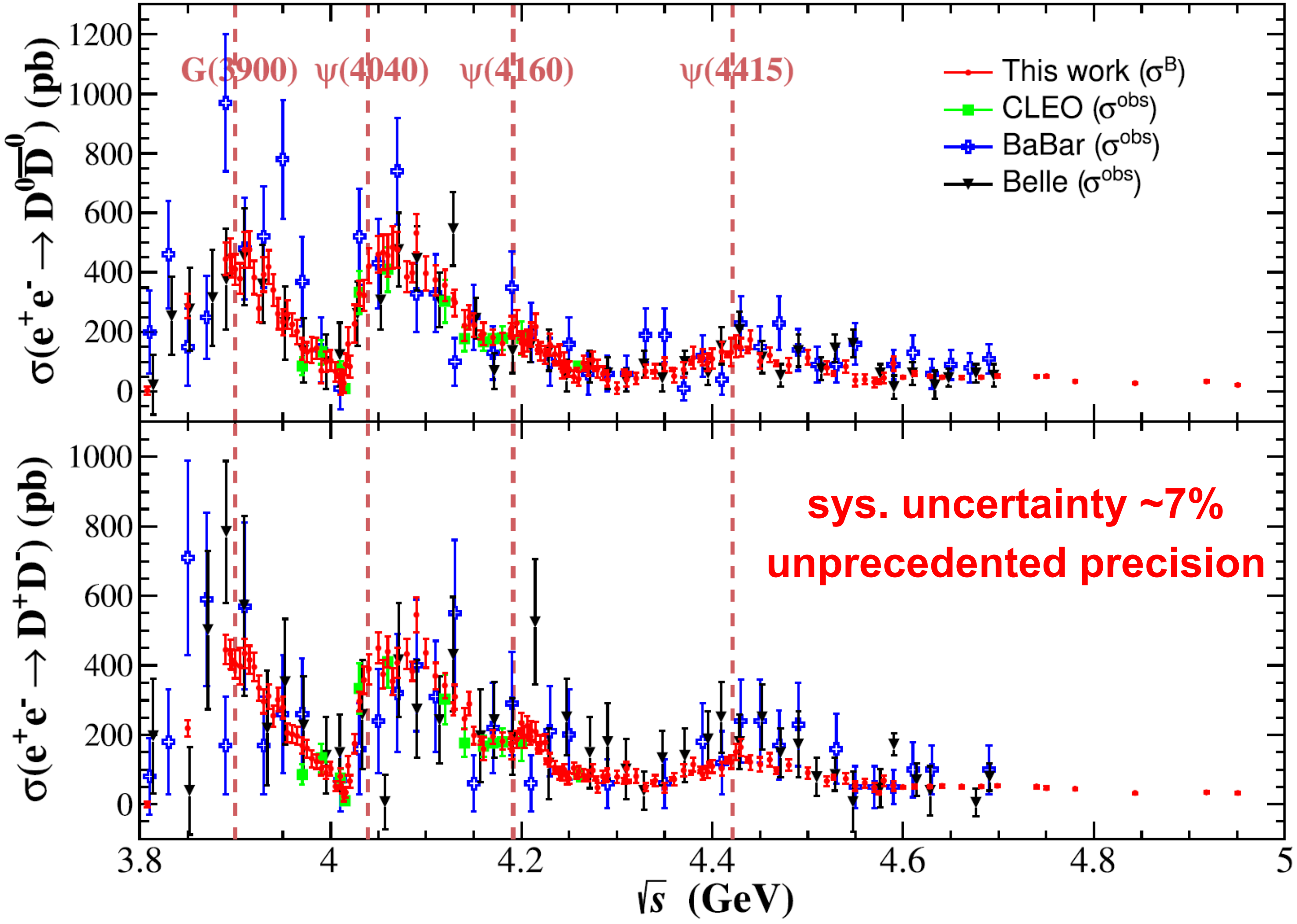
Precise Measurement of $\sigma[e^+e^- \to D\bar{D}]$

- 150 data samples with ~20 fb^{-1} at $\sqrt{s} = 3.8 - 4.95$ GeV

PRL 133, 081901 (2024)

Partial reconstruction





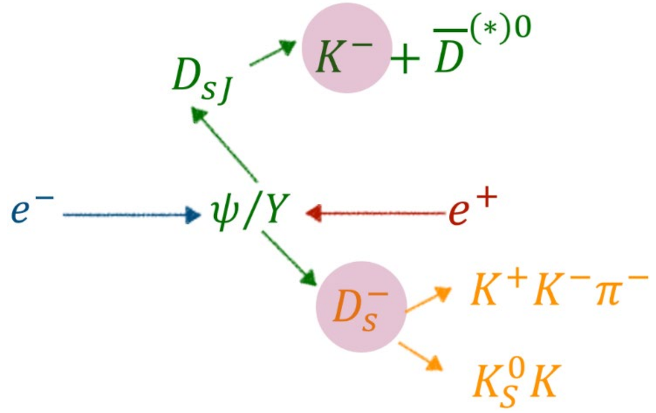
- Coupled channels analyses are desired to describe the cross–sections
- $e^+e^- \to DD^*, D_sD_s^*$ will be released soon

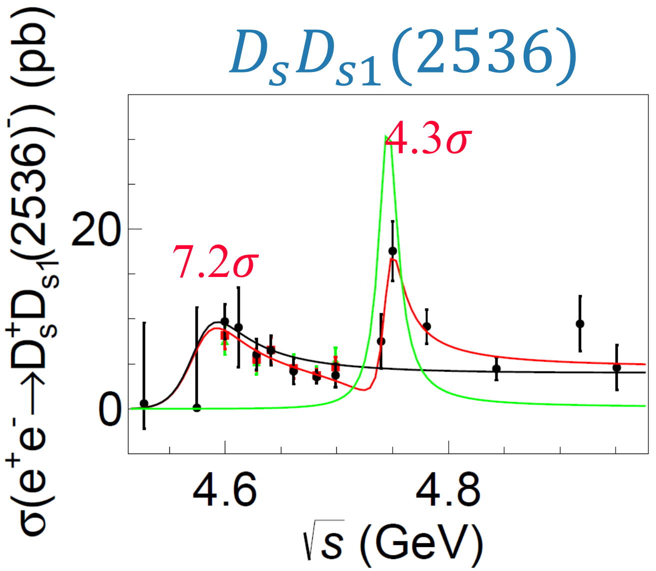
Production Properties of $D_{s1}(2536)$ and $D^*_{s2}(2573)$

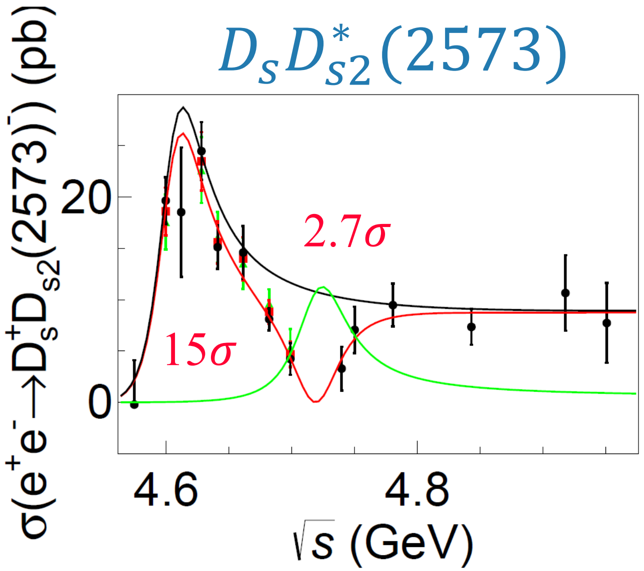
PRL 133, 171903 (2024)

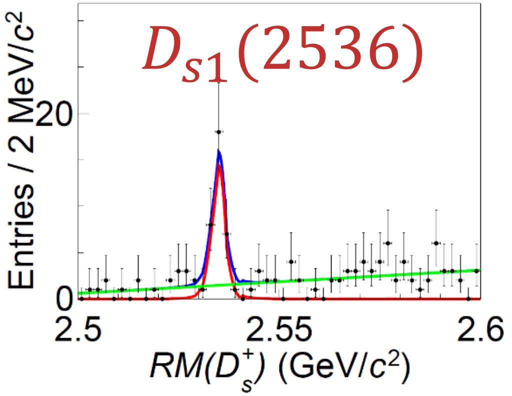
- 15 data samples with ~6.6 fb^{-1} at $\sqrt{s} = 4.53 - 4.95$ GeV

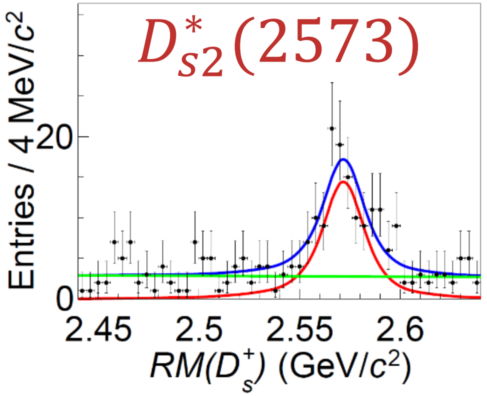
Partial reconstruction











$\sqrt{s} = 4.68$GeV

- Fit with $\sigma = |BW_0(\sqrt{s}) + BW_1(\sqrt{s})e^{i\phi_1}|^2$
- In both processes, the first resonance is ~4.6 GeV, width=50 MeV
  - → first observation, consistent with $Y(4626)/Y(4620)$

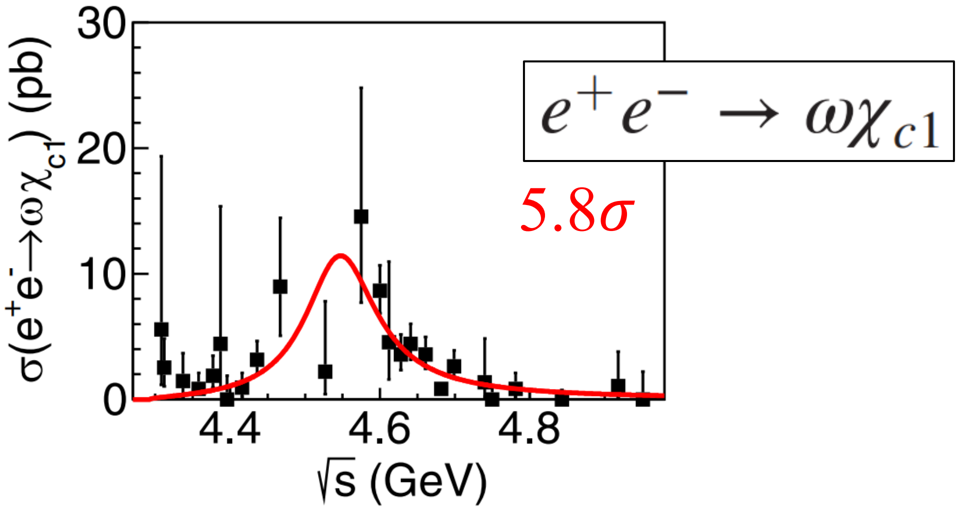
[Belle, PRD100, 111103(R) (2019), PRD101, 091101(R) (2020)]

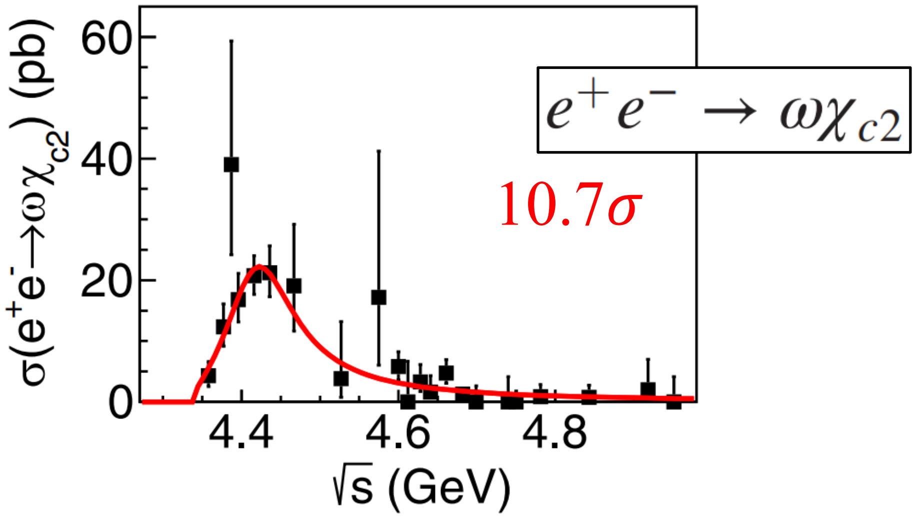
- Second structure is ~4.75 GeV, width=25 MeV in $D_s^+ D_{s1}(2536)^-$
  - ~4.72 GeV, width=50 MeV in $D_s^+ D^*_{s2}(2573)^-$
  - → first evidence, could be $Y(4710)/Y(4790)$

Measurement of $\sigma[e^+e^- \to \omega\chi_{c1,2}]$

PRL 132, 161901 (2024)

- 26 data samples with ~11 fb^{-1} at $\sqrt{s} = 4.3 - 4.95$ GeV





- Fit with a BW function: $\sigma(\sqrt{s}) = \frac{12\pi\Gamma_{ee}\mathcal{B}(\omega\chi_{cJ})\Gamma}{(s-M^2)^2+M^2\Gamma^2} \times \frac{\Phi(\sqrt{s})}{\Phi(M)}$

$M = 4544.2 \pm 18.7 \pm 1.7$ MeV/c^2

$\Gamma = 116.1 \pm 33.5 \pm 1.7$ MeV

Mass higher than structure seen in KKJ/ψ and $\pi D^* D^*$

$M = 4413.6 \pm 9.0 \pm 0.8$ MeV/c^2

$\Gamma = 110.5 \pm 15.0 \pm 2.9$ MeV

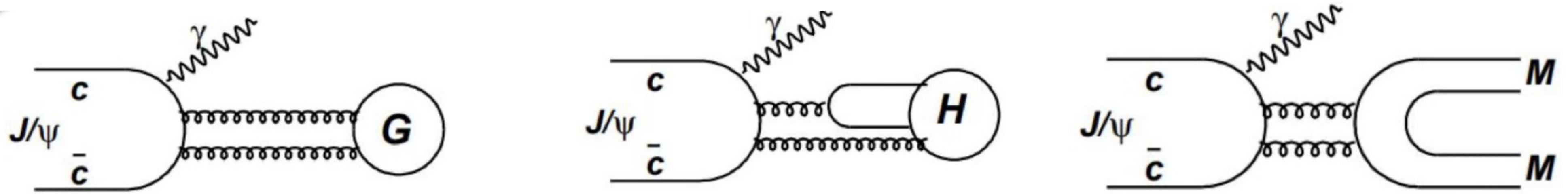
Parameters consistent with $\psi(4415)$

→ implying the existence of $\psi(4415) \to \omega\chi_{c2}$

Charmonium decays

- Charmonium radiative decays is the ideal lab for glueballs and hybrids hadron studies

  → clean environment, low background, high statistics and gluon-rich process



$\Gamma(J/\psi \to \gamma G) \sim O(\alpha\alpha_s^2)$ $\Gamma(J/\psi \to \gamma H) \sim O(\alpha\alpha_s^3)$ $\Gamma(J/\psi \to \gamma M) \sim O(\alpha\alpha_s^4)$

  → Glueballs and hybrids are expected to have a larger yield compared to mesons

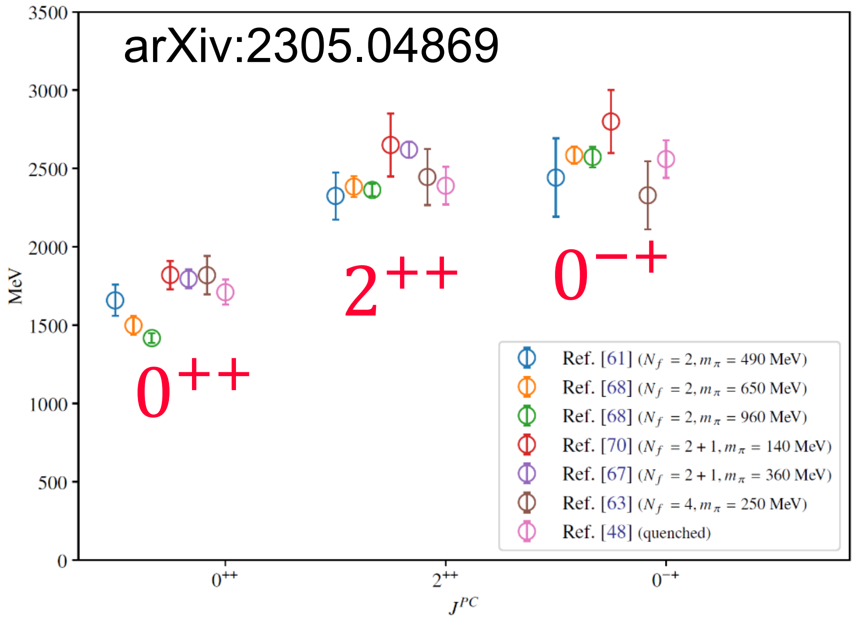
- Lattice QCD predictions on glueball masses:

  → 0^{++} ground state: 1.5 - 1.7 GeV/c^2

  → 2^{++} ground state: 2.3 - 2.4 GeV/c^2

  → 0^{-+} ground state: 2.3 - 2.6 GeV/c^2

- The mix of glueballs with ordinary $q\bar{q}$ mesons makes the situation more difficult.

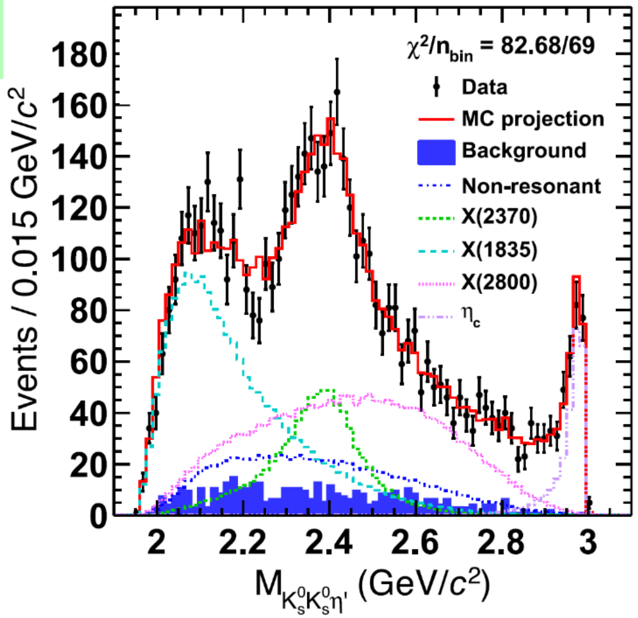


$X(2370)$: Glueball-like particle in $J/\psi \to \gamma K_S^0 K_S^0 \eta'$

- $f_0(980)$ selection with $M(K_S^0 K_S^0) < 1.1$ GeV

PRL 132, 181901 (2024)

state	J^{PC}	Decay mode	Mass (MeV/c^2)	Width (MeV/c^2)
X(2370)	0^{-+}	$f_0(980)\eta'$	2395^{+11}_{-11}	188^{+18}_{-17}
X(1835)	0^{-+}	$f_0(980)\eta'$	1844	192
X(2800)	0^{-+}	$f_0(980)\eta'$	2799^{+52}_{-48}	660^{+180}_{-116}
η_c	0^{-+}	$f_0(980)\eta'$	2983.9	32.0
PHSP	0^{-+}	$\eta'(K_S^0 K_S^0)_{S-wave}$	– – –	– – –
		$\eta'(K_S^0 K_S^0)_{D-wave}$	– – –	– – –



- $X(2370)$ measurements:

→ $J^{PC} = 0^{-+}$ with significance >9.8σ w.r.t. other J^{PC} assumptions

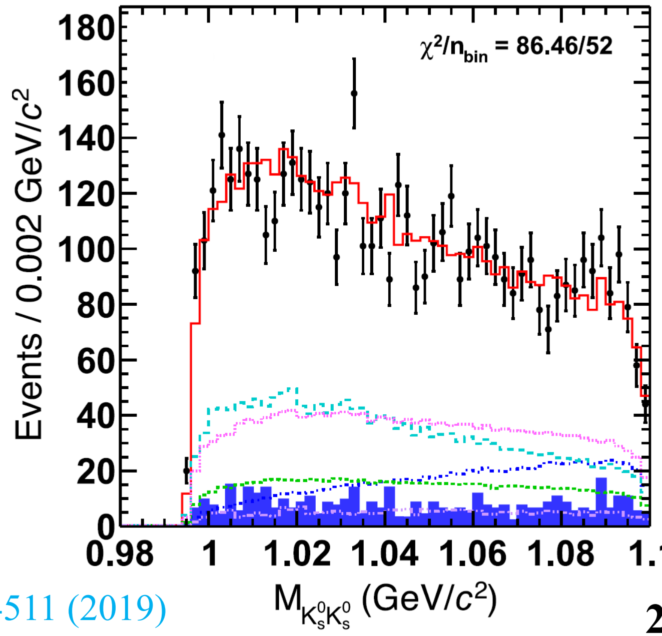
→ $\mathcal{B}[J/\psi \to \gamma X(2370)] \times \mathcal{B}[X(2370) \to f_0(980)\eta'] \times \mathcal{B}[f_0(980) \to K_S^0 K_S^0]$

$= (1.31 \pm 0.22(\text{stat})^{+2.85}_{-0.84}(\text{syst})) \times 10^{-5}$

$$M(X(2370)) = 2395 \pm 11^{+26}_{-94} \ \text{MeV/c}^2$$
$$\Gamma(X(2370)) = 118^{+18}_{-17}(\text{stat})^{+124}_{-33}(\text{sist}) \ \text{MeV}$$

Good agreement with LQCD prediction of lightest pseudoscalar glueball

L.~C. Gui, *et al.*, PRD 100, 054511 (2019)



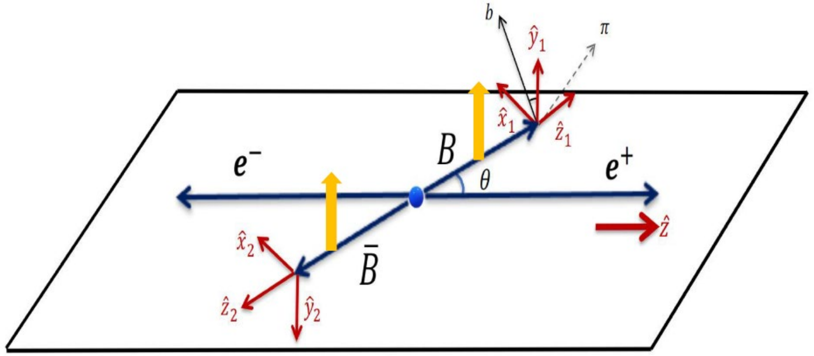
CP tests in hyperon decays

BESIII

- **Polarized** and **entangled** hyperon-antihyperon pairs enable *CP* tests in hyperon decays

BESIII: a hyperon factory

10 billion J/ψ	2.7 billion $\psi(2S)$
1.9×10^7 $\Lambda\bar{\Lambda}$	1.0×10^6 $\Lambda\bar{\Lambda}$
1.2×10^7 $\Sigma^0\bar{\Sigma}^0$	0.6×10^6 $\Sigma^0\bar{\Sigma}^0$
1.5×10^7 $\Sigma^+\bar{\Sigma}^-$	0.6×10^6 $\Sigma^+\bar{\Sigma}^-$
1.2×10^7 $\Xi^0\bar{\Xi}^0$	0.6×10^6 $\Xi^0\bar{\Xi}^0$
1.0×10^7 $\Xi^+\bar{\Xi}^-$	0.8×10^6 $\Xi^+\bar{\Xi}^-$
	1.5×10^5 $\Omega^+\bar{\Omega}^-$



Angular distribution: $\frac{d\Gamma}{d\Omega} \propto 1 + \alpha_\psi \cos^2\theta$

Transverse polarization:

Nature Phys. 15, 631 (2019)

$$P_y(\cos\theta) = \frac{\sqrt{1-\alpha_\psi^2}\sin(\Delta\Phi)\cos\theta\sin\theta}{1+\alpha_\psi\cos^2\theta}$$

Production parameters: $\alpha_\psi,\ \Delta\Phi$

- **Sequentially decaying** multi-strange and charm hyperons enable

→ Production and

→ decay parameters

Phys. Rev. 108, 1645 (1957)

$$\alpha = \frac{2Re(S*P)}{|S|^2+|P|^2},\ \beta = \frac{2Im(S*P)}{|S|^2+|P|^2} = \sqrt{1-\alpha^2}sin\phi$$

$$A_{CP} = \frac{\alpha_B+\alpha_{\bar{B}}}{\alpha_B-\alpha_{\bar{B}}},\ \phi_{CP} = \frac{\phi_B-\phi_{\bar{B}}}{2}$$

P and *S* are the *P* wave and *S* wave amplitudes in $\frac{1}{2}\to\frac{1}{2}+0$

Decay parameters: $\alpha,\ \phi$

CP observables: A_{CP}, ϕ_{CP}

- A **combination** of the two approaches enables

→ Separation of strong and weak decay phases → More sensitive *CP* tests!

$J/\psi \to \Xi^+\bar{\Xi}^- \to \Lambda(p\pi^-)\pi^-\bar{\Lambda}(\bar{n}\pi^0)\pi^+$ [PRL 132, 101801(2024)], $J/\psi \to \Sigma^+\bar{\Sigma}^-, \Sigma^+ \to \gamma p$ [PRL 130, 211901(2023)]

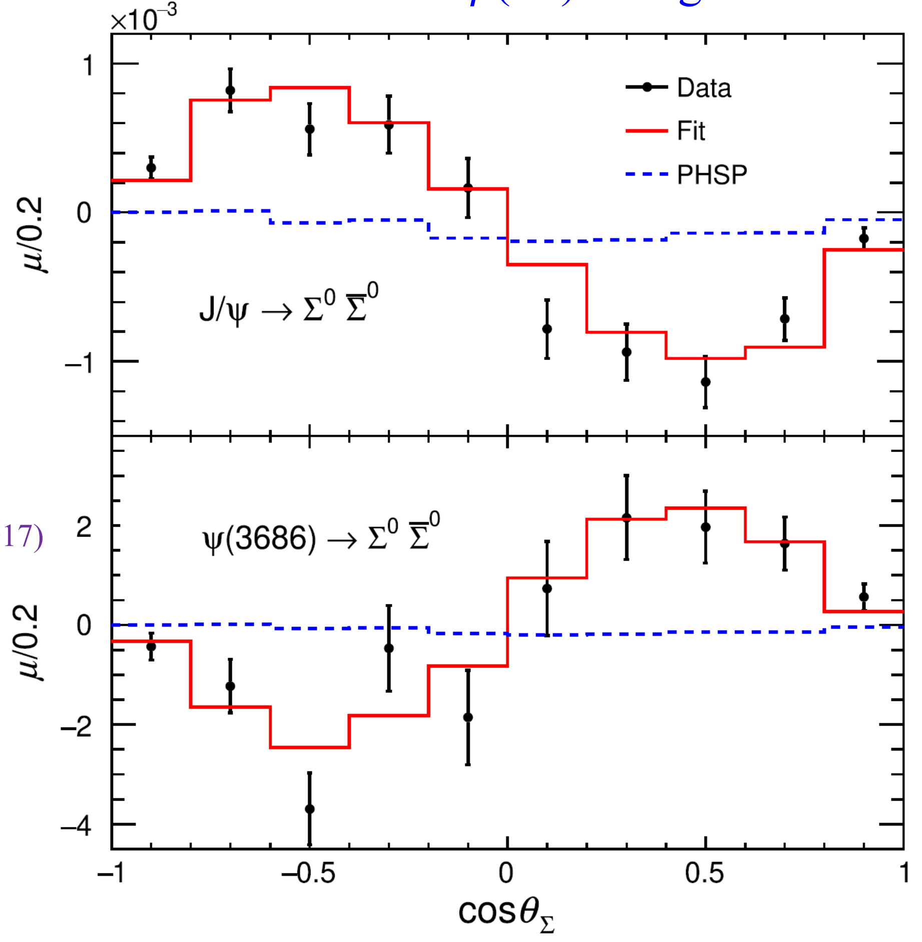
CP tests in $e^+e^- \to J/\psi, \psi(2S) \to \Sigma^0\bar{\Sigma}^0, \Sigma^0(\bar{\Sigma}^0) \to \Lambda\gamma(\bar{\Lambda}\gamma)$

PRL 133, 101902 (2024)

- First observation: transverse polarizations of Σ^0 hyperons in J/ψ and ψ(2S) decays are opposite
- First measurement: strong-CP symmetry is tested in hyperons decays by measuring Σ^0 decay parameters
- Weak-CP test is performed in subsequent decays of daughter particles Λ and $\bar{\Lambda}$

10B J/ψ: #Signal=1.1M
2.7B ψ(2S): #Signal=51.8K

Parameter	This Letter	Previous results
$\alpha_{J/\psi}$	$-0.4133 \pm 0.0035 \pm 0.0077$	-0.449 ± 0.022 (BESIII, PRD 95,052003 (2017))
$\Delta\Phi_{J/\psi}$ (rad)	$-0.0828 \pm 0.0068 \pm 0.0033$	...
$\alpha_{\psi(3686)}$	$0.814 \pm 0.028 \pm 0.028$	0.71 ± 0.12 (BESIII, PRD 95,052003 (2017))
$\Delta\Phi_{\psi(3686)}$ (rad)	$0.512 \pm 0.085 \pm 0.034$	...
α_{Σ^0}	$-0.0017 \pm 0.0021 \pm 0.0018$	...
$\bar{\alpha}_{\Sigma^0}$	$0.0021 \pm 0.0020 \pm 0.0022$	...
A_{CP}^{Σ}	$-(0.4 \pm 2.9 \pm 1.3) \times 10^{-3}$	...
α_{Λ}	$0.730 \pm 0.051 \pm 0.011$	0.748 ± 0.007 (PDG)
$\bar{\alpha}_{\Lambda}$	$-0.776 \pm 0.054 \pm 0.010$	-0.757 ± 0.004 (PDG)
A_{CP}^{Λ}	$(-3.0 \pm 6.9 \pm 1.5) \times 10^{-2}$	$(-2.5 \pm 4.8) \times 10^{-3}$ → BESIII, PRL 129,131801 (2022)



New Physics Search

BESIII

Symmetry violation

→ BNV/LNV: $D^0 \to pe^-/\bar{p}e^+$ [PRD 105, 032006(2022)], $D^+ \to ne$ [PRD 106, 112009(2022)],
$\Xi^0 \to Ke$ [PRD 108, 012006(2023)], $\Lambda - \bar{\Lambda}$ oscillation [PRL 131, 121801(2023)]

→ cLFV: $J/\psi \to e\mu$ [Sci. China-Phys. Mech. Astron. 66, 221011 (2023)], $J/\psi \to e\tau$ [PRD 103, 112007 (2021)]

Rare decays

→ Charmonium weak decays: $J/\psi \to e^+e^-e^+e^-, e^+e^-\mu^+\mu^-$[PRD 109, 052006 (2024)]

→ Charm FCNC: $D_s^+ \to h^+h^0e^+e^-$ [PRL 133, 121801(2024)]

Exotic particles

→ Invisible processes: $\Sigma^+ \to p$ +invisible [PLB 852 (2024) 138614]

→ Muonphilic vector/scalars: [PRD 109, L031102 (2024)]

→ Dark matter portals: Axion-like particles [PRD 110(2024) L031101], [PLB 828, 137698 (2023)]
Dark photon [PRD 106, 072008 (2022)], $D^0 \to \omega\gamma', D^0 \to \gamma\gamma'$[arXiv:2409.02578]

FCNC: Search for $D_s^+ \to h^+h^0e^+e^-$

$7.33\ \text{fb}^{-1}$ @4.178 – 4.226 GeV
PRL 133, 121801(2024)

BESIII

- Search for $D_s^+ \to \pi^+\pi^0 e^+e^-$,
  $D_s^+ \to K^+\pi^0 e^+e^-$, $D_s^+ \to K_S^0\pi^+ e^+e^-$
  Short-distance contribution via $c \to \mu l^+ l^-$
  flavor-changing neutral-current (FCNC) transition (10^{-9})

→ Observe long-distance interaction through presence of ϕ: $D_s^+ \to \pi^+\phi,\ \phi \to e^+e^-$

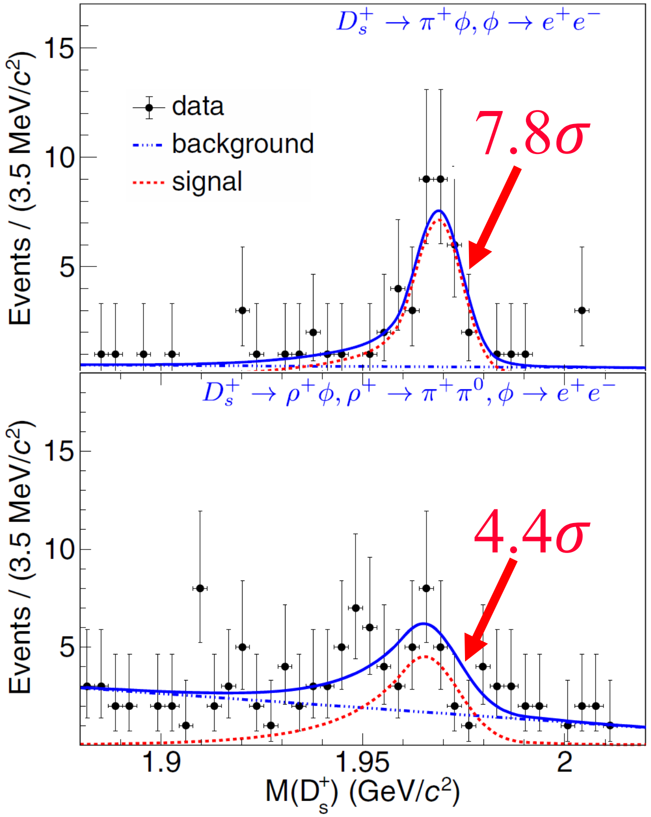
→ First evidence: $D_s^+ \to \rho^+\phi,\ \phi \to e^+e^-$

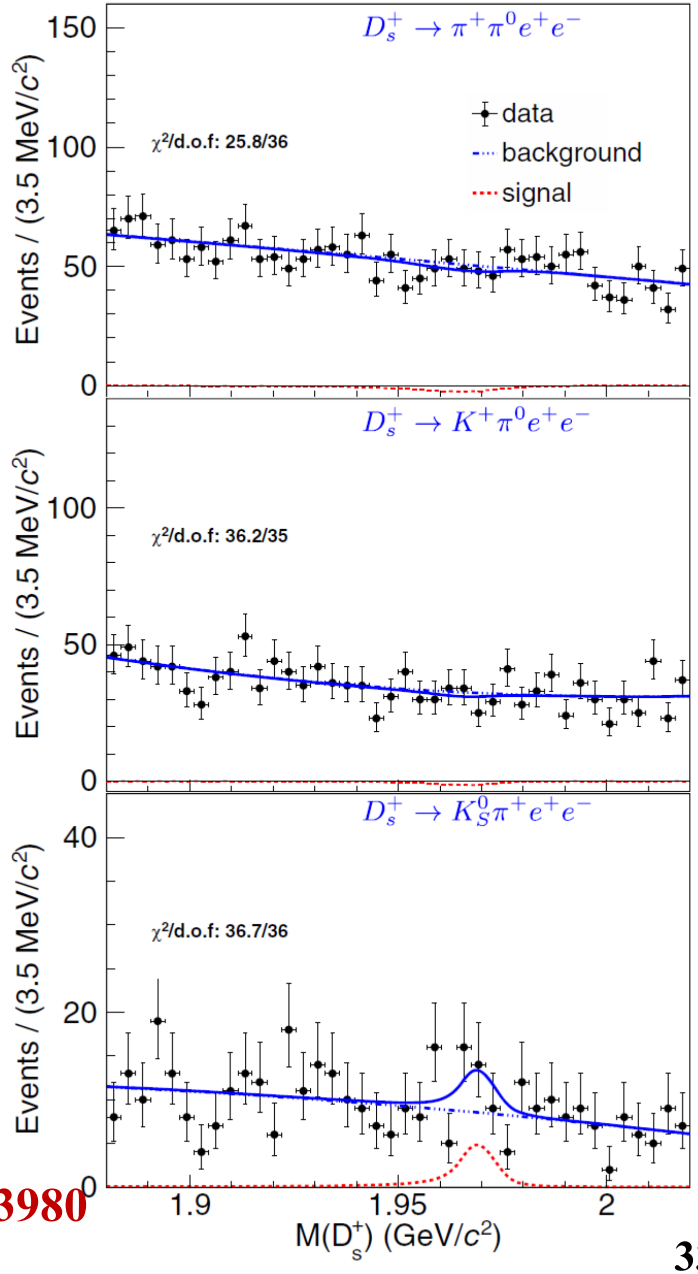
Decay	$N_{\rm sig}$	$\mathcal{B}(\times10^{-5})$
$D_s^+ \to \pi^+\phi,\ \phi \to e^+e^-$	$38.2^{+7.8}_{-6.8}$	$1.17^{+0.23}_{-0.21} \pm 0.03$
$D_s^+ \to \rho^+\phi,\ \phi \to e^+e^-$	$37.8^{+10.3}_{-9.6}$	$2.44^{+0.67}_{-0.62} \pm 0.16$

Improved by a factor of three

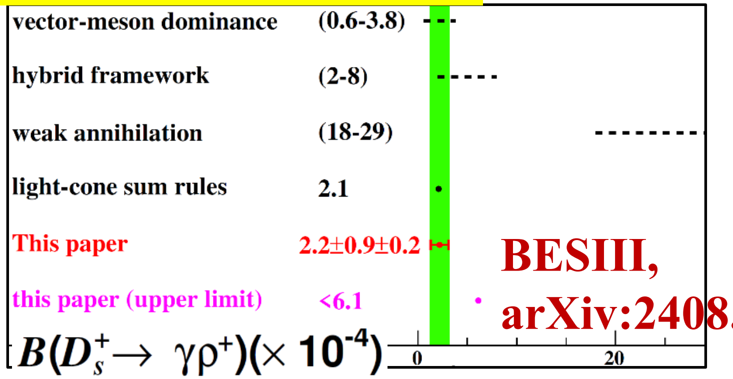
→ First upper limits: @90% C.L.

Decay	$N_{\rm sig}$	$\mathcal{B}(\times10^{-5})$
$D_s^+ \to \pi^+\pi^0 e^+e^-$	···	<7.0
$D_s^+ \to K^+\pi^0 e^+e^-$	···	<7.1
$D_s^+ \to K_S^0\pi^+ e^+e^-$	···	<8.1





Enlighten $D_s^+ \to \gamma V$



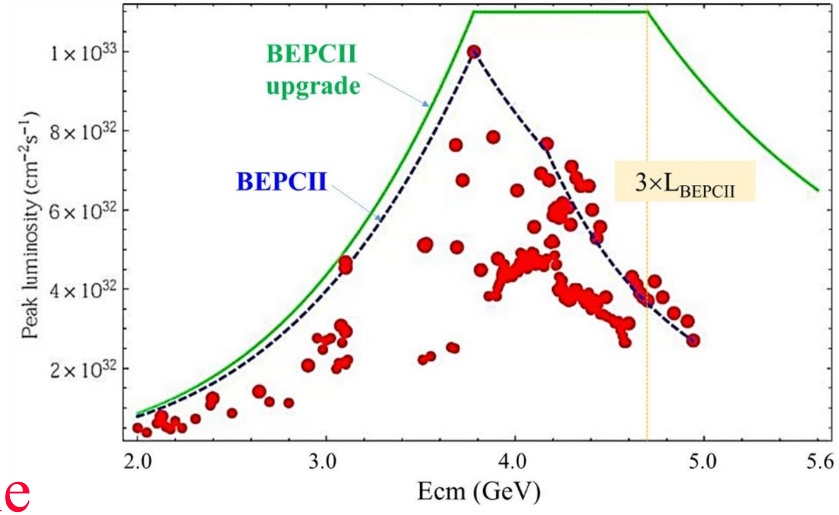
BESIII, arXiv:2408.03980

BEPCII upgrade → BEPCII-U

BEPCII-U (2024-2028)

→ Increase luminosity by a factor of 3 @E_{cm}= 4.7 GeV

→ Increase beam energy to 2.8GeV (E_{cm}= 5.6 GeV)



Schedule

→ Jul.-Dec. 2024, Shutdown for Hardware Installation

→ Jan. 2025, **Restart**

→ Jan.2025 - Jul.2025, $\psi(3686)$

→ Oct.2025 - Sep.2028, 4.0-5.0 GeV

→ Sep.2028 - Jul.2030, **5.0-5.6** GeV

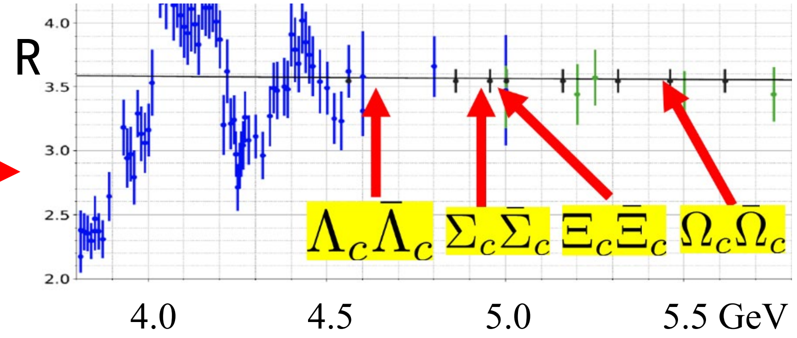
Future Physics Programme of BESIII

Chin. Phys. C 44, 040001 (2020)

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

The proposed remainder samples of BESIII

Opportunities to study Σ_c, Ξ_c, Ω_c in the BEPCII-U



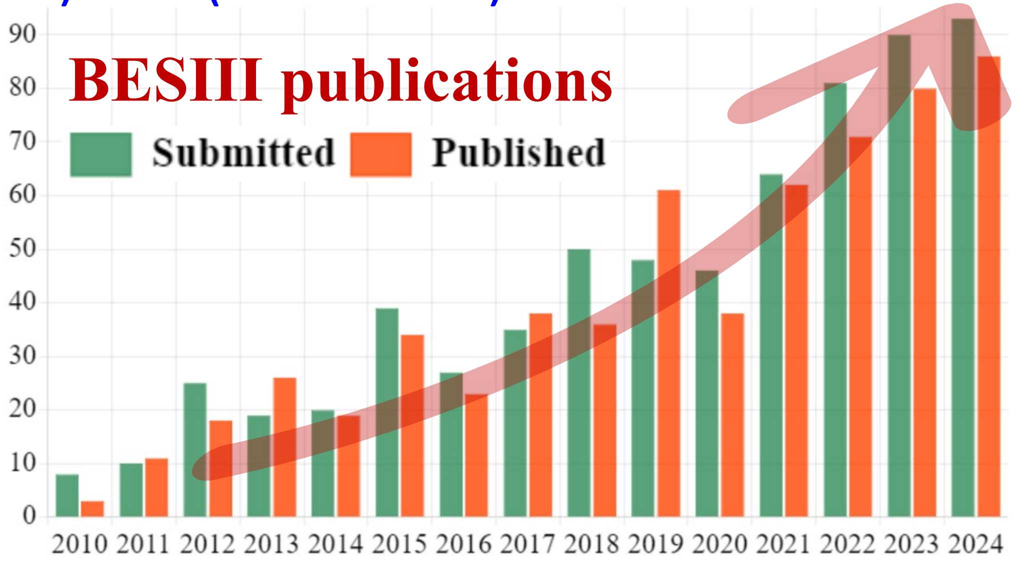
Conclusions and Outlook

- BESIII made **significant contributions** to charmed flavor physics and hadron physics.
- BESIII is becoming increasingly active and productive.

  Publications as of Oct.25 2024: 606 + 8(accepted) + 41(submitted)

  In 2024, 86 published and 8 accepted,

  (**20** in PRL/Nature Commun.).



- BESIII is in very good status.

  → CGEM successfully installed.

- BESIII's Future prospects

  → More interesting results are coming using full collected statistics.

  → BEPCII-U will extend the lifetime of BESIII (**will continue to run till ~2030**).

  3× luminosity above 4 GeV & max energy to 5.6 GeV

Exciting times are coming!

谢谢！