Flavor Physics Symposium Celebrating
BaBar's 30th Anniversary
March 7-8, 2024

CKM and Flavor Physics @ BESIII

Isabella Garzia, University of Ferrara and INFN
On behalf of the BESIII Collaboration

March 8, 2024

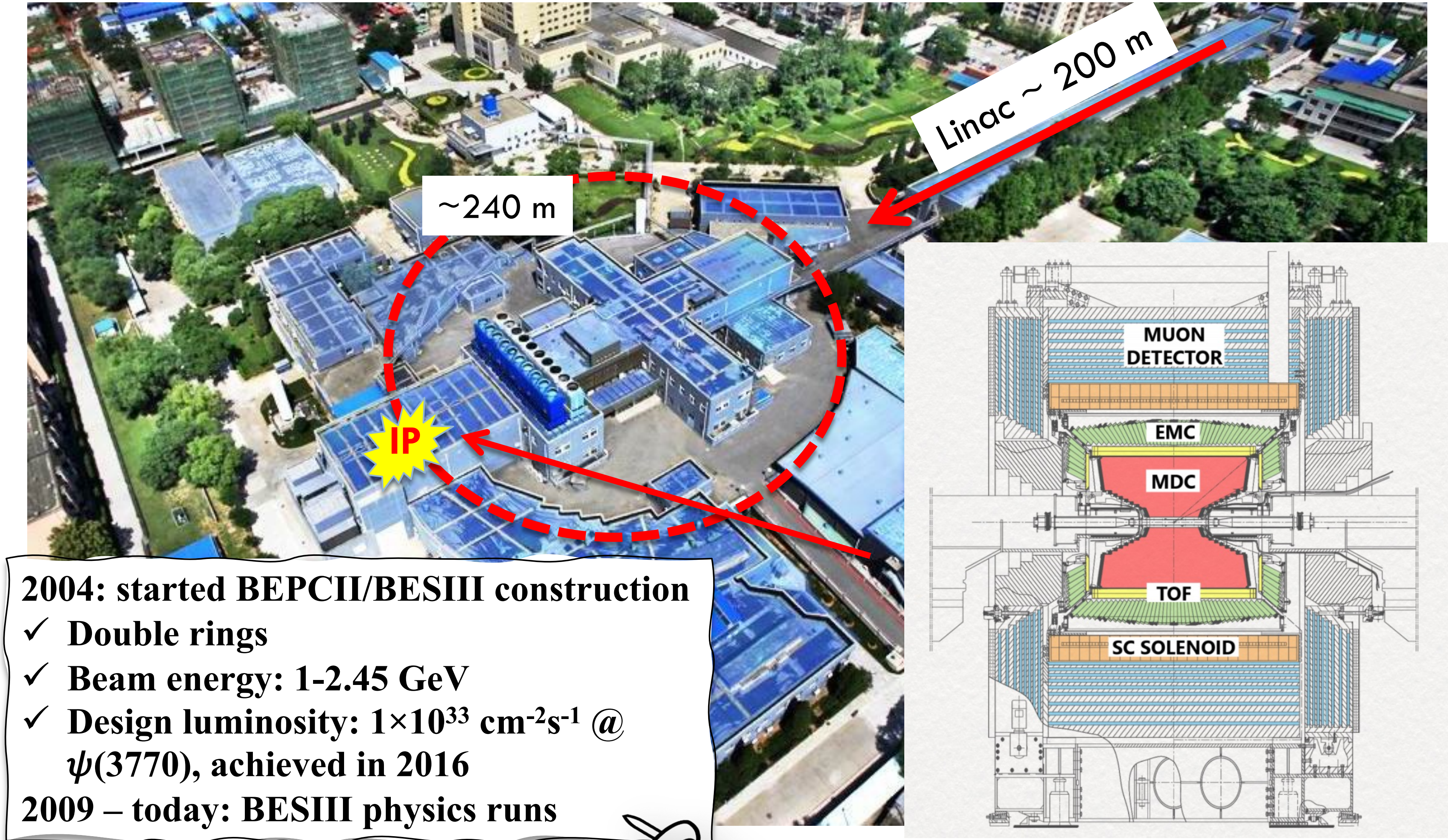
INFN
Istituto Nazionale di Fisica Nucleare

Università
degli Studi
di Ferrara

BESIII

BESIII - Beijing Spectrometer III

http://english.ihep.cas.cn



2004: started BEPCII/BESIII construction

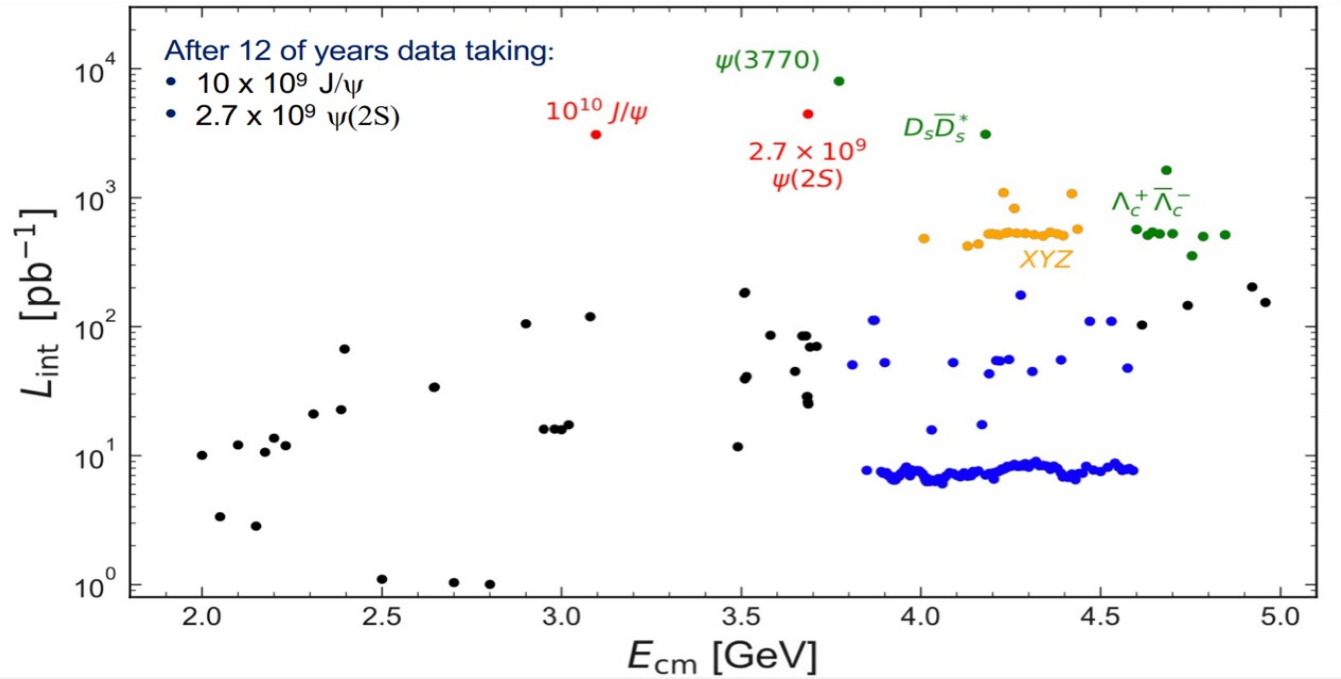
- ✓ **Double rings**
- ✓ **Beam energy: 1-2.45 GeV**
- ✓ **Design luminosity: 1×10^{33} cm^{-2}s^{-1} @ $\psi(3770)$, achieved in 2016**

2009 – today: BESIII physics runs

Nucl. Instr. Meth. A614, 345 (2010)

BESIII dataset and physics program

Optimised for flavour physics in the τ-charm region



- 130 points between 2 and 4.6 GeV (~715 pb^{-1} up to 3.08 GeV for ρ*, ω*, ϕ*,… studies)

- Light hadron spectroscopy
- η/η' decays
- Hyperon physics
- Charmonium transitions

- D^0D^0pairs
- $D_{(S)}$ meson decays
- $D^*_{(s)}$
- …

- XYZ decays and spectroscopy
- Open charm production
- Charmed baryons
- ...

Selected BESIII results

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

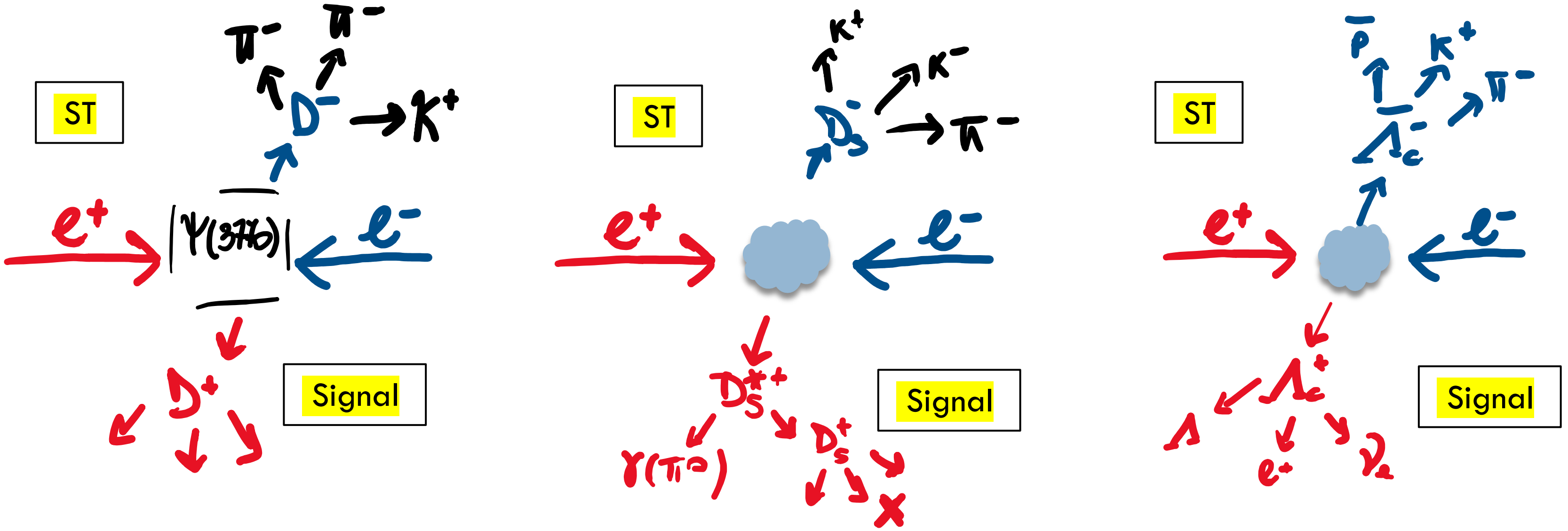
- Highlight results of charm baryon physics at BESIII
  - ΛC semi-leptonic decays
  - ΛC hadronic decays

- Summary and Outlook

General method

$$e^+e^- \to \psi(3770) \to D^{0(+)}\bar{D}^{0(-)} : 2.93\,\mathrm{fb}^{-1} @ E_{\mathrm{cm}} = 3.773\,\mathrm{GeV} \quad (2010, 2011)$$
$$e^+e^- \to D_s^{*\pm}D_s^{\mp} : 7.33\,\mathrm{fb}^{-1} @ E_{\mathrm{cm}} = 4.128 - 4.226\,\mathrm{GeV}$$
$$e^+e^- \to \Lambda_c^+\bar{\Lambda}_c^- : 6.4\,\mathrm{fb}^{-1} @ E_{\mathrm{cm}} = 4.60 - 4.95\,\mathrm{GeV}$$

Pair Production



Single Tag (ST): fully reconstruction of hadronic $D_{(s)}$/ mesons

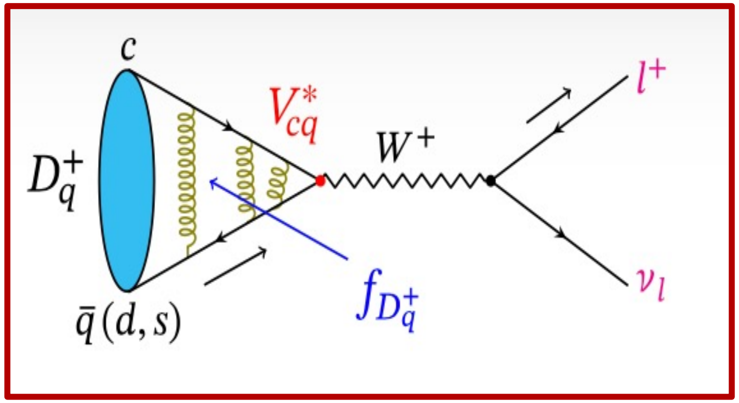
- Relative high background
- High efficiency and yields

Double tag (DT): in the recoiling ST we search for the signal (by looking at several variables)

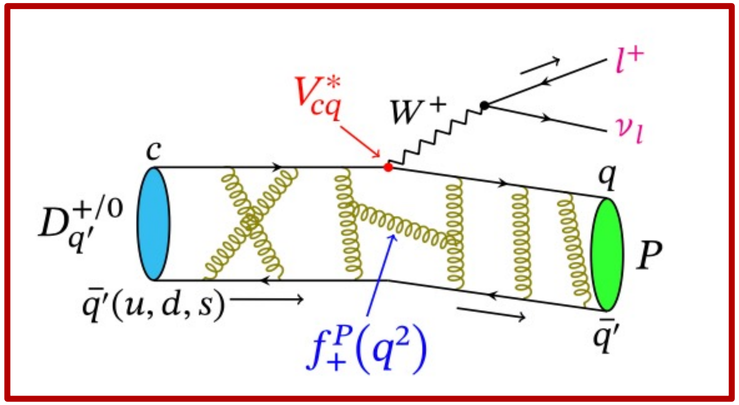
- Clean background
- Reduction of the systematic uncertainties
- Kinematic constraint on missing particle

(Semi) Leptonic Charm Decays

Pure leptonic decay



Semi-leptonic decay leptonic decay



decay rate

CKM matrix element

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

decay constant

CKM matrix element

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

partial decay rate

form factor

- Test CKM matrix unitarity
- Test of the Lepton Flavour Universality

Pure leptonic decay: $R = \left(1 - \frac{m_\mu^2}{M^2_{D^+_{(s)}}}\right)^2 m_\mu^2 \Big/ \left(1 - \frac{m_e^2}{M^2_{D^+_{(s)}}}\right)^2 m_e^2$; SM Ratio from SL decays require form factor dependent phase- space corrections

- Compare decay constants and form factors to theoretical predictions
- Semi-leptonic decays of charm meson is also helpful to study the meson spectrum

$D_s^{*+} \to e^+ \nu_e$

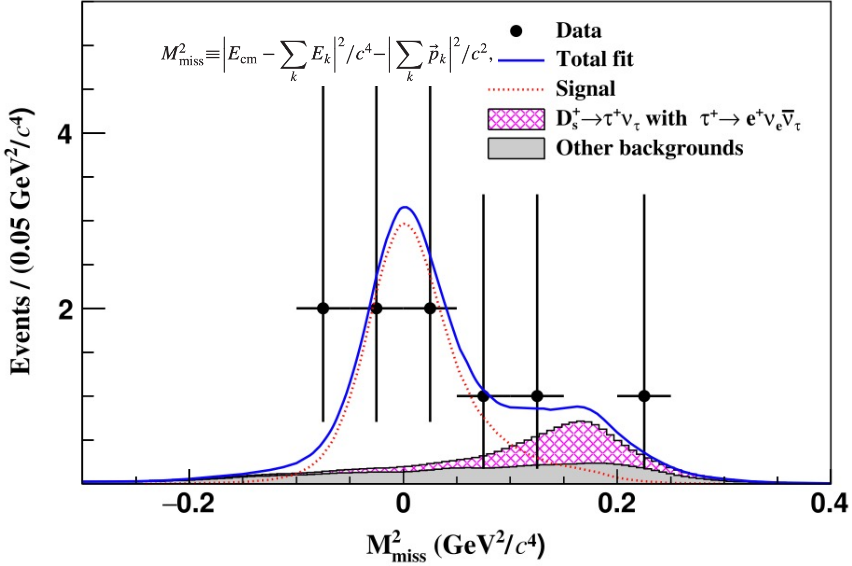
First experimental search

7.33 fb^{-1} of $e^+e^- \to D^{*\pm} D^{\mp}$ @ 4.128 – 4.226 GeV

- Understand the c → s quark transition
- Test lattice quantum chromodynamics (LQCD) calculations of $f_{D(*)+}$
- The most promising channel to observe the weak decay of a charmed vector meson

$$\Gamma(D_s^{*+} \to \ell^+ \nu_\ell) = \frac{G_F^2}{12\pi} |V_{cs}|^2 f_{D_s^{*+}}^2 m_{D_s^{*+}}^3 \left(1 - \frac{m_{\ell^+}^2}{m_{D_s^{*+}}^2}\right)^2 \left(1 + \frac{m_{\ell^+}^2}{2m_{D_s^{*+}}^2}\right)$$

PRL**131**, 141802 (2023)



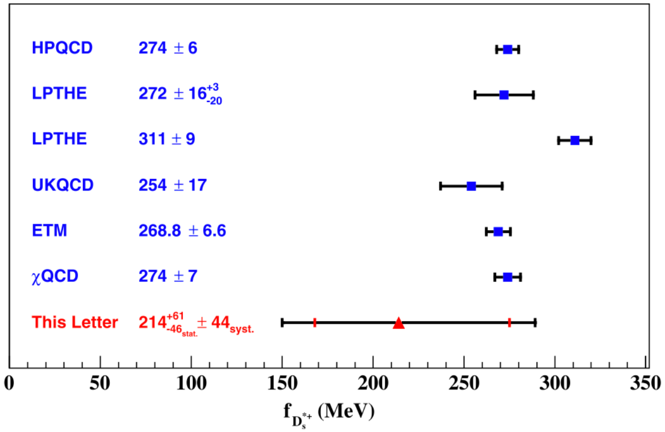
$$\boxed{\mathcal{B}(D_s^{*+} \to e^+ \nu_e) = (2.1^{+1.2}_{-0.9\,\text{stat.}} \pm 0.2_{\text{syst.}}) \times 10^{-5}\,(2.9\sigma)}$$

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

- By means of the world avare values (PDG):

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

Agree with (70±28) eV predicted by LQCD within ±1σ



$$f_{D_s^{*+}} = (214^{+61}_{-46} \pm 44)\ \text{MeV}$$

$$f_{D_s^{*+}} < 354\ \text{MeV} \quad @\ 90\%\ \text{CL}$$

With the input from LQCD ($\Gamma_{D_s^{*+}}$) and SM global fit $|V_{cs}|$

$D_s^+\to\tau^+\nu_\tau$ via $\tau^+\to\mu^+\nu_\mu\bar{\nu}_\tau$

JHEP**09** (2023) 124

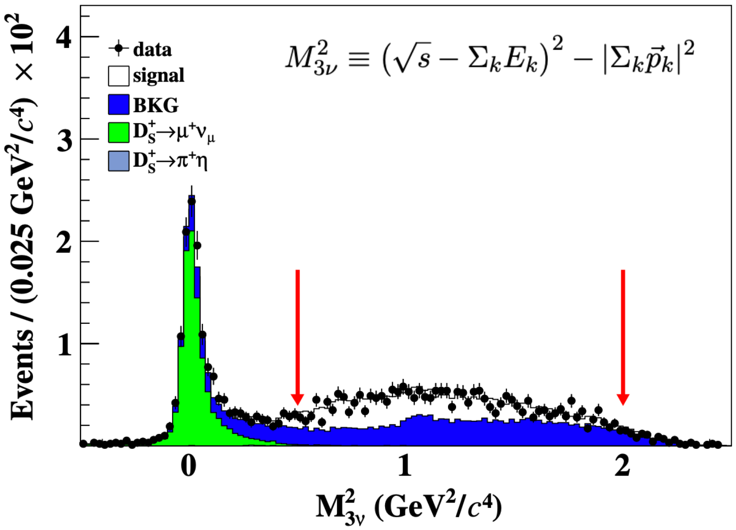
7.33 fb^{-1} of $e^+e^-\to D^{*\pm}D^{\mp}$ @ 4.128 – 4.226 GeV

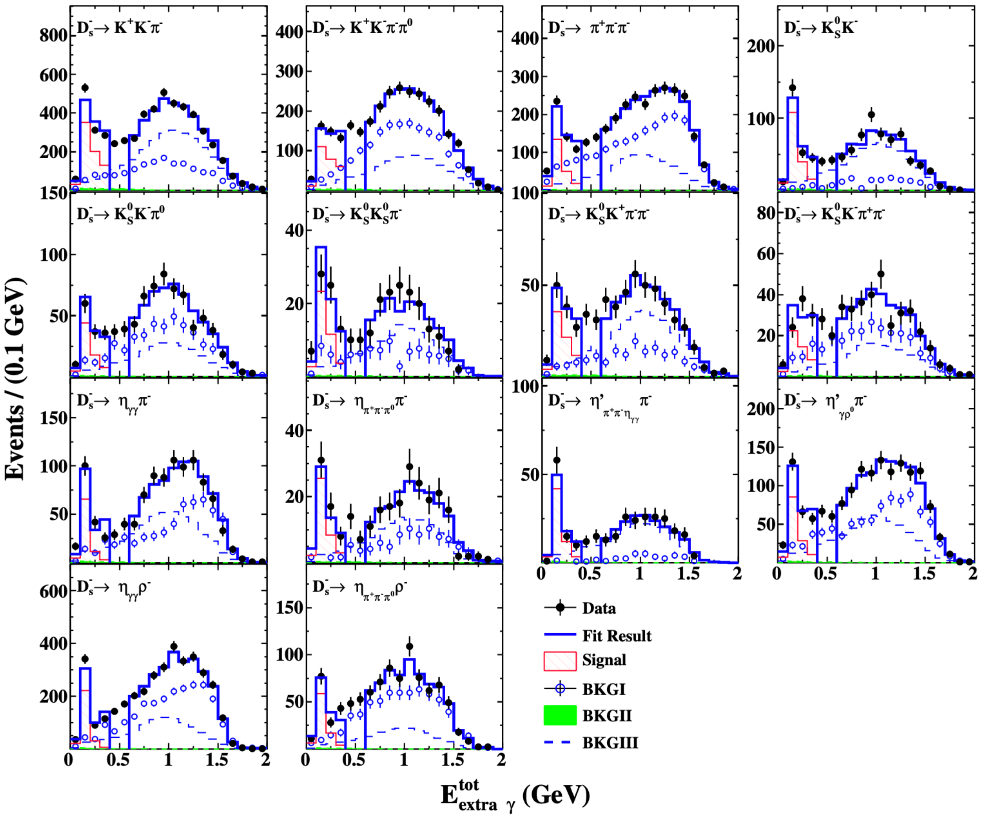
- ST: D_s^- candidates reconstructed in 14 different hadronic decay modes
- DT: Muon counter information used to separate muons from hadrons

$E^{tot}_{extra\ \gamma}$: total energy of good isolated EMC showers which have not been used in the tag selection

- ✓ N_{BKGIII}^{others} extrapolated from fit to bkg region $E^{tot}_{extra\ \gamma}$>0.6 GeV
- ✓ signal region: $E^{tot}_{extra\ \gamma}$<0.4 GeV

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





$D_s^+ \to \tau^+\nu_\tau$ via $\tau^+ \to \mu^+\nu_\mu\bar{\nu}_\tau$

JHEP**09** (2023) 124

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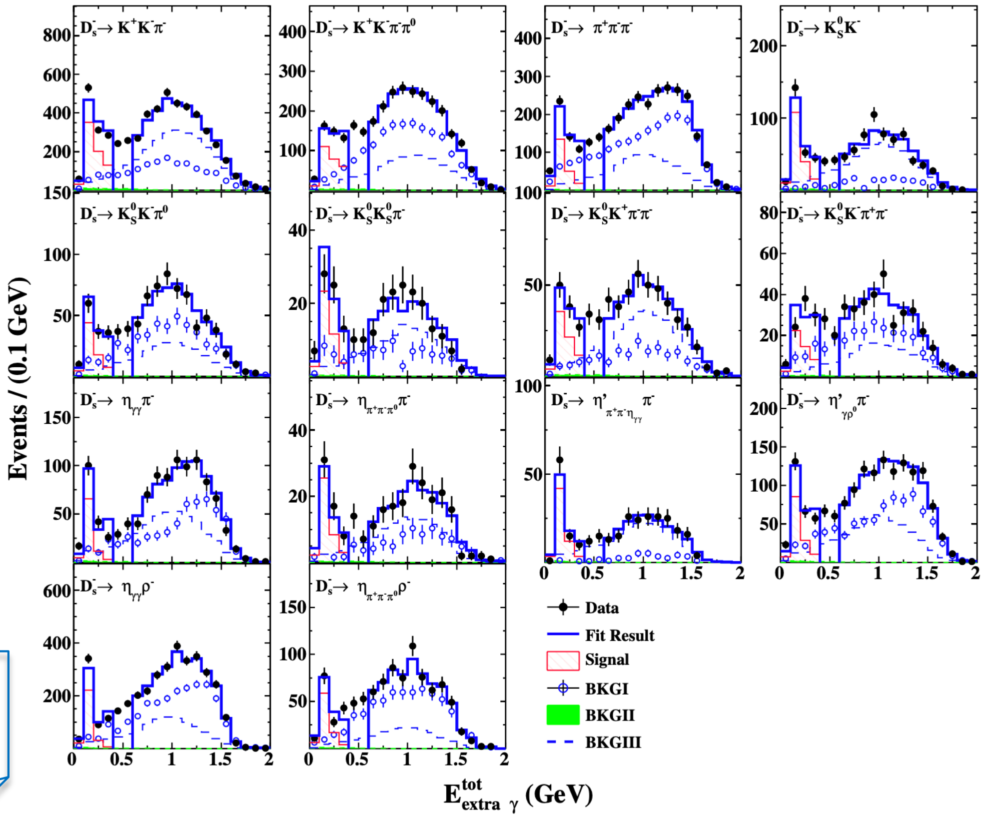
$$N_{\rm DT} = N_{\rm tot} - N_{\rm BKGI}^{{\rm non}-D_s} - N_{\rm BKGII}^{K_L^0\mu^+\nu_\mu} - N_{\rm BKGIII}^{\rm others}$$



$$\mathcal{B}_{D_s^+\to\tau^+\nu_\tau} = (5.37 \pm 0.17_{\rm stat} \pm 0.15_{\rm syst})\%$$

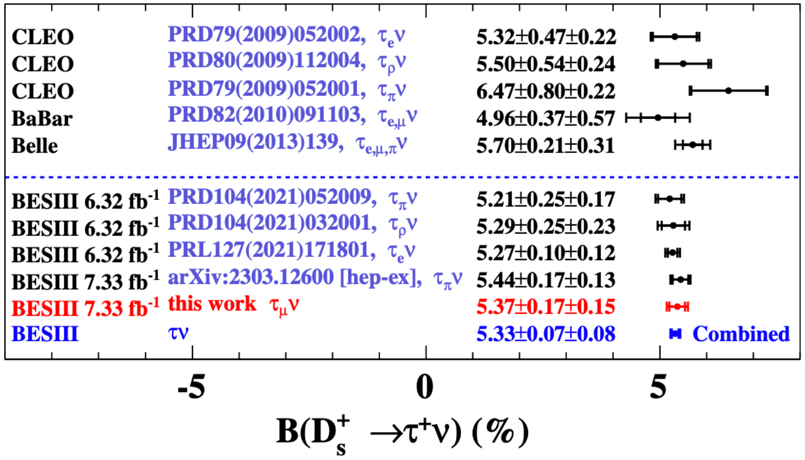
- Using this BF and the world average values (PDG):

$$f_{D_s^+}|V_{cs}| = (246.7 \pm 3.9_{\rm stat} \pm 3.6_{\rm syst})\ {\rm MeV}$$

|Vcs| from global fit: $f_{D_s^+} = (253.4 \pm 4.0_{\rm stat} \pm 3.7_{\rm syst})$ MeV

f_{D_s+} from LQCD: $|V_{cs}| = 0.987 \pm 0.016_{\rm stat} \pm 0.014_{\rm syst}$

$D_s^+\to\tau^+\nu_\tau$ via $\tau^+\to\mu^+\nu_\mu\bar{\nu}_\tau$



CLEO	PRD79(2009)052002, $\tau_e\nu$	5.32±0.47±0.22	
CLEO	PRD80(2009)112004, $\tau_\rho\nu$	5.50±0.54±0.24	
CLEO	PRD79(2009)052001, $\tau_\pi\nu$	6.47±0.80±0.22	
BaBar	PRD82(2010)091103, $\tau_{e,\mu}\nu$	4.96±0.37±0.57	
Belle	JHEP09(2013)139, $\tau_{e,\mu,\pi}\nu$	5.70±0.21±0.31	
BESIII 6.32 fb^{-1}	PRD104(2021)052009, $\tau_\pi\nu$	5.21±0.25±0.17	
BESIII 6.32 fb^{-1}	PRD104(2021)032001, $\tau_\rho\nu$	5.29±0.25±0.23	
BESIII 6.32 fb^{-1}	PRL127(2021)171801, $\tau_e\nu$	5.27±0.10±0.12	
BESIII 7.33 fb^{-1}	arXiv:2303.12600 [hep-ex], $\tau_\pi\nu$	5.44±0.17±0.13	
BESIII 7.33 fb^{-1}	this work $\tau_\mu\nu$	5.37±0.17±0.15	
BESIII	$\tau\nu$	5.33±0.07±0.08	Combined

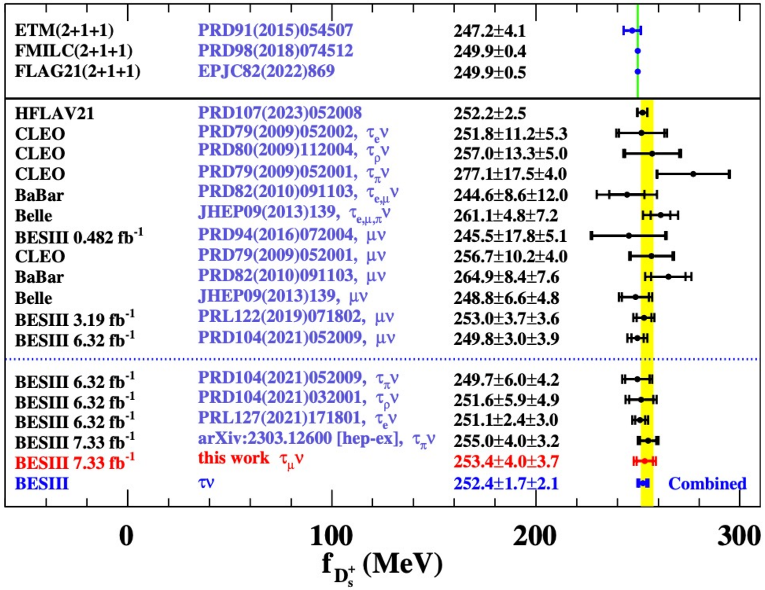
[JHEP09 (2023) 124](JHEP**09** (2023) 124)

$$\mathcal{R}_{\tau/\mu}=\frac{\mathcal{B}_{D_s^+\to\tau^+\nu_\tau}}{\mathcal{B}_{D_s^+\to\mu^+\nu_\mu}}=\frac{m_{\tau^+}^2\left(1-\frac{m_{\tau^+}^2}{m_{D_s^+}^2}\right)^2}{m_{\mu^+}^2\left(1-\frac{m_{\mu^+}^2}{m_{D_s^+}^2}\right)^2}=9.82\pm0.33$$

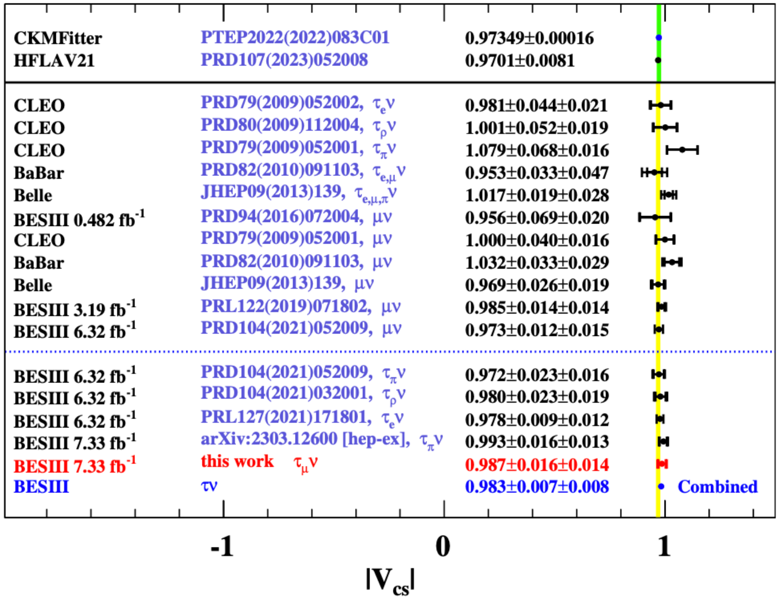
(exp. combined)

consistent with the expectation based on LFU (9.75 ±0.01)

BESIII is leading the measurement precision!



ETM(2+1+1)	PRD91(2015)054507	247.2±4.1	
FMILC(2+1+1)	PRD98(2018)074512	249.9±0.4	
FLAG21(2+1+1)	EPJC82(2022)869	249.9±0.5	
HFLAV21	PRD107(2023)052008	252.2±2.5	
CLEO	PRD79(2009)052002, $\tau_e\nu$	251.8±11.2±5.3	
CLEO	PRD80(2009)112004, $\tau_\rho\nu$	257.0±13.3±5.0	
CLEO	PRD79(2009)052001, $\tau_\pi\nu$	277.1±17.5±4.0	
BaBar	PRD82(2010)091103, $\tau_{e,\mu}\nu$	244.6±8.6±12.0	
Belle	JHEP09(2013)139, $\tau_{e,\mu,\pi}\nu$	261.1±4.8±7.2	
BESIII 0.482 fb^{-1}	PRD94(2016)072004, $\mu\nu$	245.5±17.8±5.1	
CLEO	PRD79(2009)052001, $\mu\nu$	256.7±10.2±4.0	
BaBar	PRD82(2010)091103, $\mu\nu$	264.9±8.4±7.6	
Belle	JHEP09(2013)139, $\mu\nu$	248.8±6.6±4.8	
BESIII 3.19 fb^{-1}	PRL122(2019)071802, $\mu\nu$	253.0±3.7±3.6	
BESIII 6.32 fb^{-1}	PRD104(2021)052009, $\mu\nu$	249.8±3.0±3.9	
BESIII 6.32 fb^{-1}	PRD104(2021)052009, $\tau_\pi\nu$	249.7±6.0±4.2	
BESIII 6.32 fb^{-1}	PRD104(2021)032001, $\tau_\rho\nu$	251.6±5.9±4.9	
BESIII 6.32 fb^{-1}	PRL127(2021)171801, $\tau_e\nu$	251.1±2.4±3.0	
BESIII 7.33 fb^{-1}	arXiv:2303.12600 [hep-ex], $\tau_\pi\nu$	255.0±4.0±3.2	
BESIII 7.33 fb^{-1}	this work $\tau_\mu\nu$	253.4±4.0±3.7	
BESIII	$\tau\nu$	252.4±1.7±2.1	Combined



CKMFitter	PTEP2022(2022)083C01	0.97349±0.00016	
HFLAV21	PRD107(2023)052008	0.9701±0.0081	
CLEO	PRD79(2009)052002, $\tau_e\nu$	0.981±0.044±0.021	
CLEO	PRD80(2009)112004, $\tau_\rho\nu$	1.001±0.052±0.019	
CLEO	PRD79(2009)052001, $\tau_\pi\nu$	1.079±0.068±0.016	
BaBar	PRD82(2010)091103, $\tau_{e,\mu}\nu$	0.953±0.033±0.047	
Belle	JHEP09(2013)139, $\tau_{e,\mu,\pi}\nu$	1.017±0.019±0.028	
BESIII 0.482 fb^{-1}	PRD94(2016)072004, $\mu\nu$	0.956±0.069±0.020	
CLEO	PRD79(2009)052001, $\mu\nu$	1.000±0.040±0.016	
BaBar	PRD82(2010)091103, $\mu\nu$	1.032±0.033±0.029	
Belle	JHEP09(2013)139, $\mu\nu$	0.969±0.026±0.019	
BESIII 3.19 fb^{-1}	PRL122(2019)071802, $\mu\nu$	0.985±0.014±0.014	
BESIII 6.32 fb^{-1}	PRD104(2021)052009, $\mu\nu$	0.973±0.012±0.015	
BESIII 6.32 fb^{-1}	PRD104(2021)052009, $\tau_\pi\nu$	0.972±0.023±0.016	
BESIII 6.32 fb^{-1}	PRD104(2021)032001, $\tau_\rho\nu$	0.980±0.023±0.019	
BESIII 6.32 fb^{-1}	PRL127(2021)171801, $\tau_e\nu$	0.978±0.009±0.012	
BESIII 7.33 fb^{-1}	arXiv:2303.12600 [hep-ex], $\tau_\pi\nu$	0.993±0.016±0.013	
BESIII 7.33 fb^{-1}	this work $\tau_\mu\nu$	0.987±0.016±0.014	
BESIII	$\tau\nu$	0.983±0.007±0.008	Combined

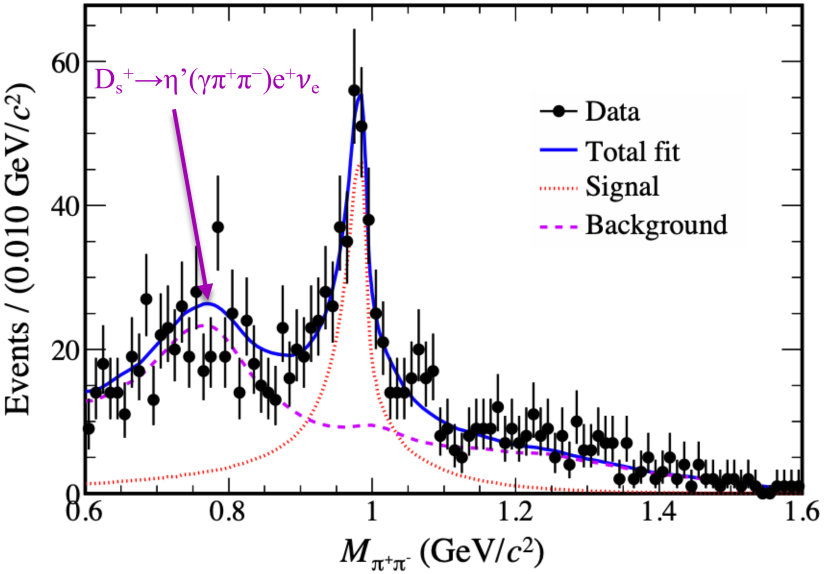
Study of $f_0(980)$ via $D_s^+ \to \pi^+\pi^- e^+\nu_e$

7.33 fb^{-1} of $e^+e^- \to D^{*\pm}D^{\mp}$ @ 4.128 – 4.226 GeV

arXiv:2303.12927
Submitted to PRL

Investigate the structure of the light scalar mesons

- Leptons and hadrons in the final state interact only weakly with each other → Semi-leptonic decays provide a unique way to probe the constituent qqbar component of light scalar states
- Study the dynamics by measuring the hadronic FF that describes the strong interaction between final-state quarks



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

2.6 times more accurate than PRD**92**,012009

- The dynamics of $D_s^+ \to f_0(980)e^+\nu_e$ decay is studied by dividing the signal candidate events in 4 intervals of q^2 (four-momentum transfer square of $e^+\nu_e$)

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

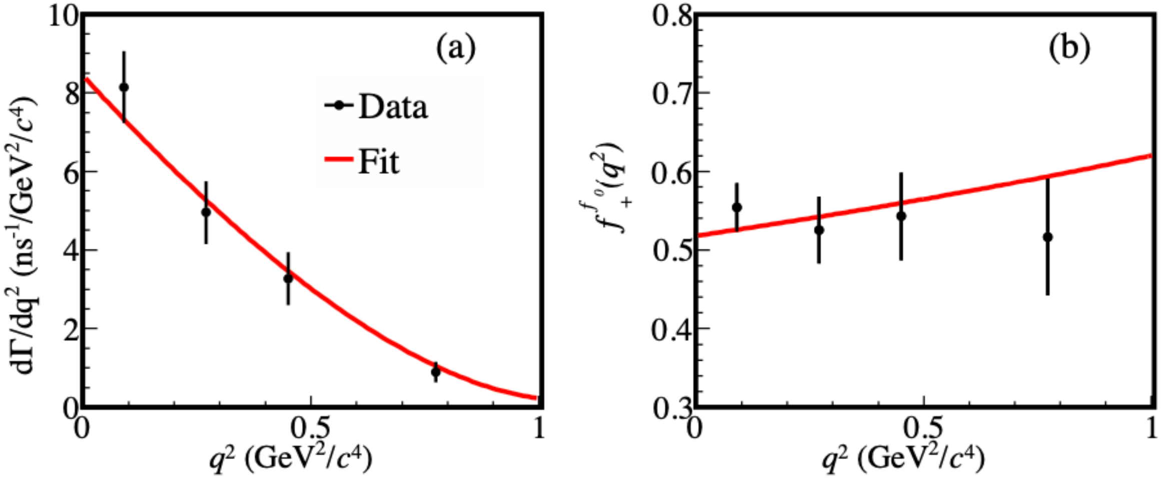
relativistic Flattè model

Simple pole parameterization

Study of $f_0(980)$ via $D_s^+ \to \pi^+\pi^- e^+\nu_e$

arXiv:2303.12927
Submitted to PRL

Fit to the differential decay rate and FF projection:



FIRST MEASUREMNT

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

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

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

The experimental measurements of the branching ratio and FF of this decay can provide a direct estimation of the mixing angle

$$|f_0(980)\rangle = \sin\phi\,|\frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d})\rangle + \cos\phi\,|s\bar{s}\rangle$$

- ➢ $s\bar{s}$ component is dominant

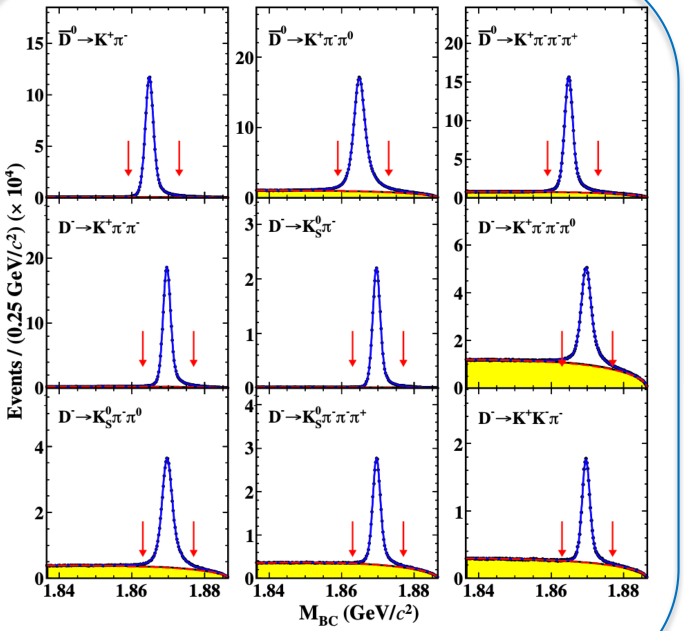
Disagree (based on CLEO measurement PRD**80**,052007)

	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°	$(8^{+21}_{-8})^\circ$	—	$(56 \pm 7)^\circ$	31°
		PRD**79**, 076004	PRD**79**, 076004	PLB**579**, 59-66	EPL**90**, 61001	PRD**81**, 074001	PRD**80**, 07430	PRD**102**, 016013

Search for $D^0\to K_S^0K^-e^+\nu_e$, $D^+\to K_S^0K_S^0e^+\nu_e$, $D^+\to K^+K^-e^+\nu_e$

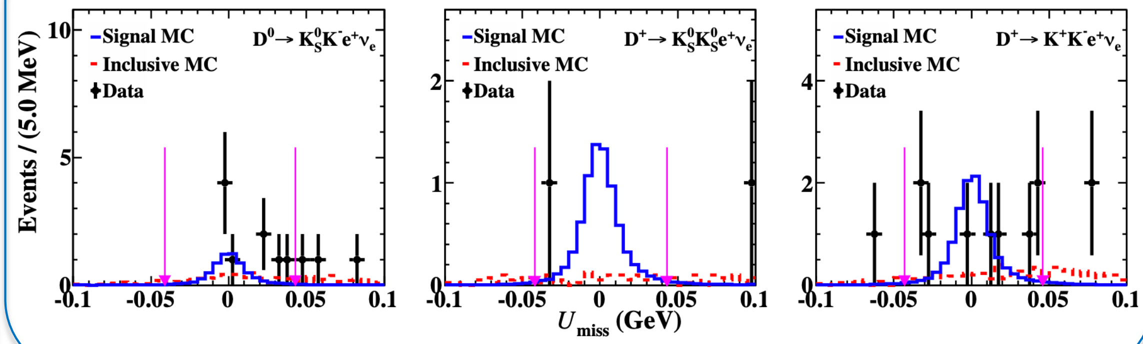
7.9 fb^{-1} of $e^+e^-\to D^{0\pm}D^{0\mp}$ @ $\psi(3.773)$ (2010, 2011, 2021)

arXiv:2312.07572



$\sqrt{E_{\rm beam}^2/c^4-|\vec{p}_{\bar{D}}|^2/c^2}$

$U_{\rm miss}\equiv E_{\rm miss}-|\vec{p}_{\rm miss}|c$



No significant signals are observed and the upper limit @ 90% C.L. are obtained to be

$$\mathcal{B}(D^0\to K_S^0K^-e^+\nu_e)=2.13\times10^{-5}$$

$$\mathcal{B}(D^+\to K_S^0K_S^0e^+\nu_e)=1.54\times10^{-5}$$

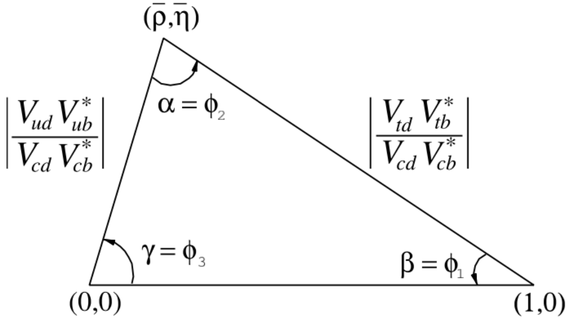
$$\mathcal{B}(D^+\to K^+K^-e^+\nu_e)=2.10\times10^{-5}$$

- In agreement with expectation
- A total of 20 fb^{-1} will be available soon

Hadronic $D_{(s)}$ Decays

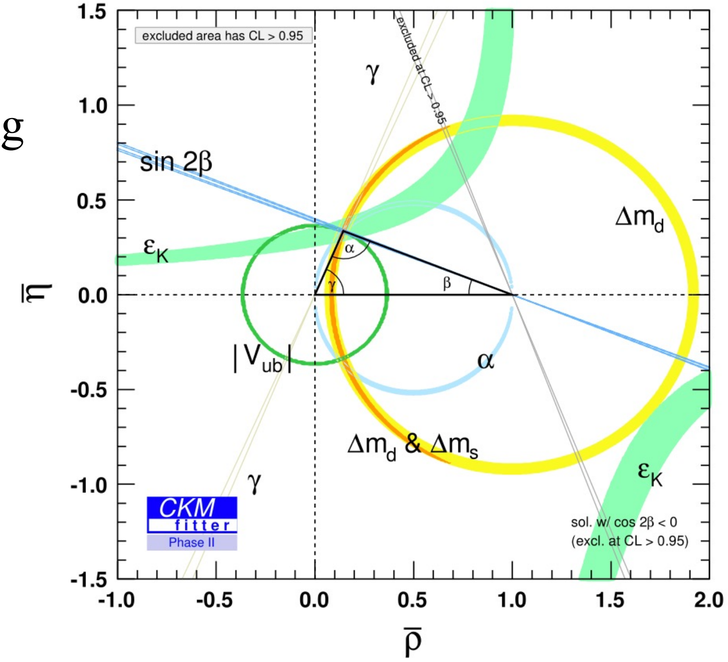
In B physics, precision measurements CKM UT angles are important for testing the CKM unitary and searching for CP violation beyond SM

- Extraction of γ: it is the only CP-violating observable that can be determined using tree-level decays ($B \to D^{(*)}K^{(*)}$)
- Limited knowledge of the strong phases of D decays will restrict the overall sensitivity



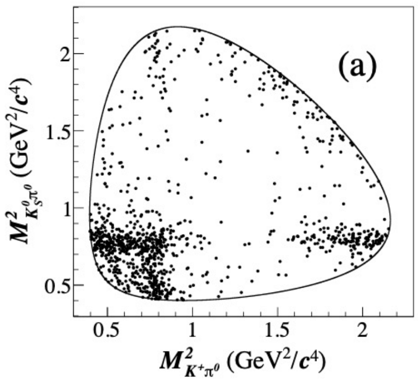
➢ Quantum-correlated $e^+e^- \to \psi(3770) \to D^0\bar{D}^0$ pairs at BESIII offer an ideal opportunity to extract the strong phase differences between D^0 and $\bar{D}^0$

- from CLEO: contribution of ~ 4° on the uncertainty to the γ measurement (PRD**82**,112006)
- from BESIII: contribution of ~1° on the uncertainty ($2.93\ \mathrm{fb}^{-1}$)
- A $20\ \mathrm{fb}^{-1}$ sample of $\psi(3770)$ data would lead to an uncertainty of ~ 0.4°



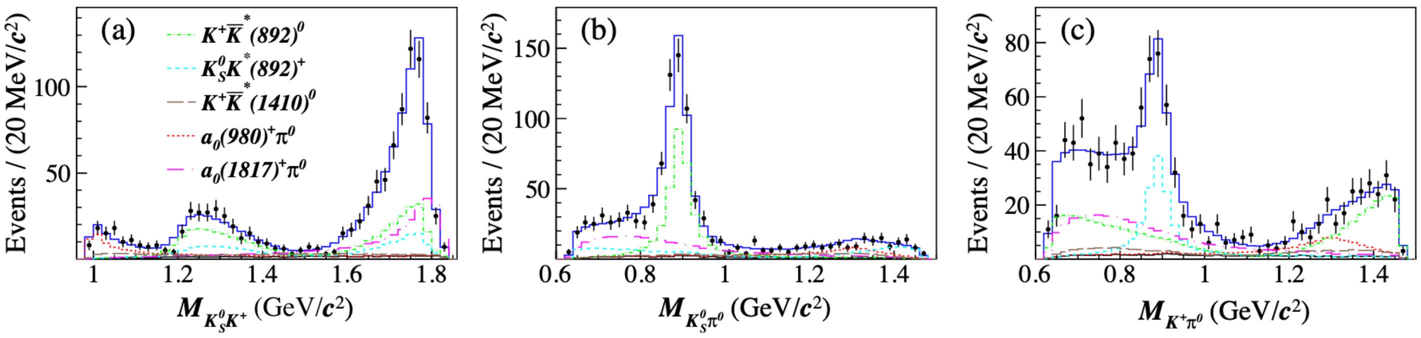
Amplitude Analysis of $D_s^+ \to K_S^0 K^+ \pi^0$

PRL129, 182001



6.32 fb^{-1} of $e^+e^- \to D_s^{*\pm} D_s^{\mp}$ @ 4.178 – 4.226 GeV

DT analysis; first Amplitude analysis; 1050 events, about 95% purity



$$M(a_0^+(1817)) = 1.817 \pm 0.008_{\text{stat.}} \pm 0.020_{\text{syst.}}\,\text{GeV}/c^2$$
$$\Gamma(a_0^+(1817)) = 0.097 \pm 0.022_{\text{stat.}} \pm 0.015_{\text{syst.}}\,\text{GeV}/c^2$$
$$\mathcal{B}(D_s^+ \to K_S^0 K^+ \pi^0) = (1.46 \pm 0.06_{\text{stat.}} \pm 0.05_{\text{syst.}})\%$$

Support the existence of a new a_0 triplet:

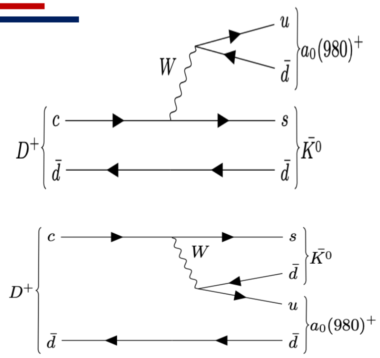
- BF consistent with the prediction by EPJC82, 225(2022) assuming it is the isospin-one partner of the $f_0(1710)$ meson;

Amplitude	Phase (rad)	FF (%)	BF (10^{-3})	σ
$D_s^+ \to \bar{K}^*(892)^0 K^+$	0.0(fixed)	$32.7 \pm 2.2 \pm 1.9$	$4.77 \pm 0.38 \pm 0.32$	> 10
$D_s^+ \to K^*(892)^+ K_S^0$	$-0.16 \pm 0.12 \pm 0.11$	$13.9 \pm 1.7 \pm 1.3$	$2.03 \pm 0.26 \pm 0.20$	> 10
$D_s^+ \to a_0(980)^+ \pi^0$	$-0.97 \pm 0.27 \pm 0.25$	$7.7 \pm 1.7 \pm 1.8$	$1.12 \pm 0.25 \pm 0.27$	6.7
$D_s^+ \to \bar{K}^*(1410)^0 K^+$	$0.17 \pm 0.15 \pm 0.08$	$6.0 \pm 1.4 \pm 1.3$	$0.88 \pm 0.21 \pm 0.19$	7.6
$D_s^+ \to a_0(1817)^+ \pi^0$	$-2.55 \pm 0.21 \pm 0.07$	$23.6 \pm 3.4 \pm 2.0$	$3.44 \pm 0.52 \pm 0.32$	> 10

- The mass is about 100 MeV/c^2 greater that predicted value: this may imply that it is the isospin-one partner of the X(1812) [PRD105,114014]

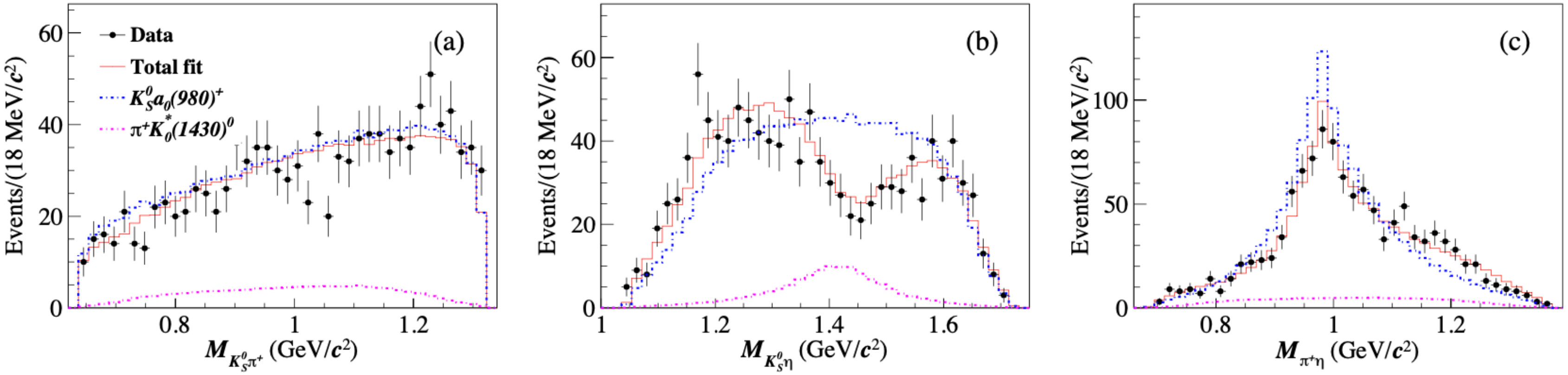
Amplitude Analysis of $D^+ \to K_S^0 \pi^+ \eta$

arXiv:2309.05760, submitted to PRL



Search for $D^+ \to K^0_S a_0(980)^+$ is the only decay free of weak annihilation contribution

- Test the validity of the diagrammatic approach
- It provides the most sensitive constraint to the contributions and phases of the external and internal W-emission amplitude involving the $a_0(980)$ in the diagrammatic approach



Amplitude	Phase ϕ_n (rad)	FF (%)	Significance
$D^+ \to K^0_S a_0(980)^+$	0.0(fixed)	$105.00 \pm 0.94 \pm 1.04$	$> 10\sigma$
$D^+ \to K_0^*(1430)^0 \pi^+$	$2.58 \pm 0.06 \pm 0.09$	$10.83 \pm 1.50 \pm 0.89$	$> 10\sigma$

$$\mathcal{B}(D^+ \to K^0_S a_0(980)^+,\ a_0(980)^+ \to \pi^+\eta) = (1.33 \pm 0.05 \pm 0.04)\%$$

$$\mathcal{B}(D^+ \to K_0^*(1430)^0 \pi^+,\ K_0^*(1430)^0 \to K^0_S \eta) = (0.14 \pm 0.02 \pm 0.02)\%$$

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

Consistent with previous measurement [PRL124,241803]

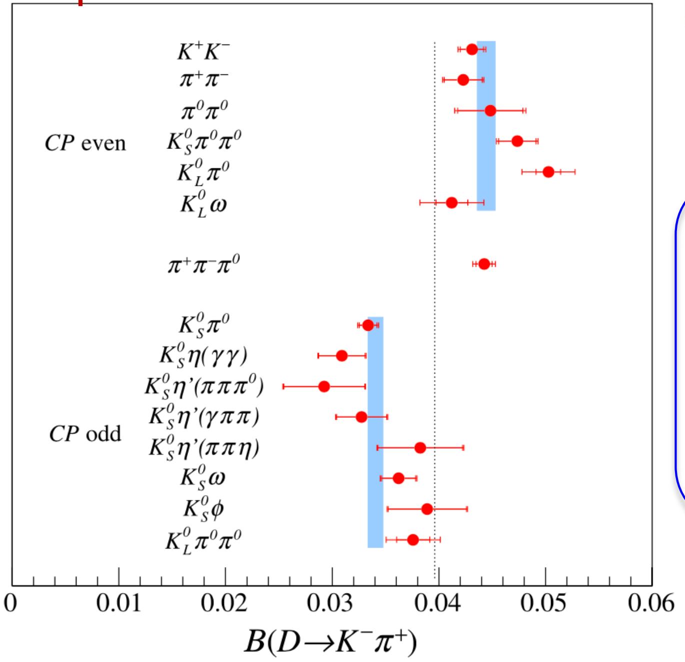
20 fb^{-1} more and precise investigation to the $a_0(980)$ and $f_0(980)$ production in D meson decays

Strong phase difference $\delta_D^{K\pi}$

EPJC82, 1009

2.93 fb^{-1} of $e^+e^- \to D^0D^0$ @ $\psi(3.773)$

Improved measurement



- BFs of three $D \to K^0_L X$ decays are determined
  - $\mathcal{B}(D^0 \to K^0_L\pi^0) = (0.97 \pm 0.03 \pm 0.02)\,\%$
  - $\mathcal{B}(D^0 \to K^0_L\omega) = (1.09 \pm 0.06 \pm 0.03)\,\%$
  - $\mathcal{B}(D^0 \to K^0_L\pi^0\pi^0) = (1.26 \pm 0.05 \pm 0.03)\,\%$

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

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

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

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

Using
$$r_D^{K\pi}\cos\delta_D^{K\pi} = -0.0562 \pm 0.0081 \pm 0.0050 \pm 0.0010$$
$$r_D^{K\pi}\sin\delta_D^{K\pi} = -0.011 \pm 0.012 \pm 0.007 \pm 0.003,$$

obtained from $D\to K^0_{SL}\pi^+\pi^-$ reconstructed as a tagging mode to $D \to K^-\pi^+$ and the measurements of $\mathcal{A}_{K\pi}$ and $\mathcal{A}_{K\pi}^{\pi\pi\pi 0}$

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

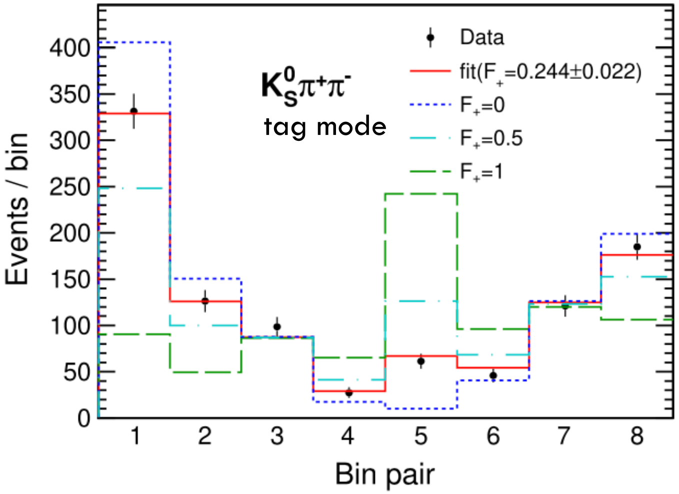
$$r_D^{K\pi}\exp(-i\delta_D^{K\pi}) = \frac{\langle K^+\pi^- | D^0\rangle}{\langle K^+\pi^- | \bar{D}^0\rangle}$$

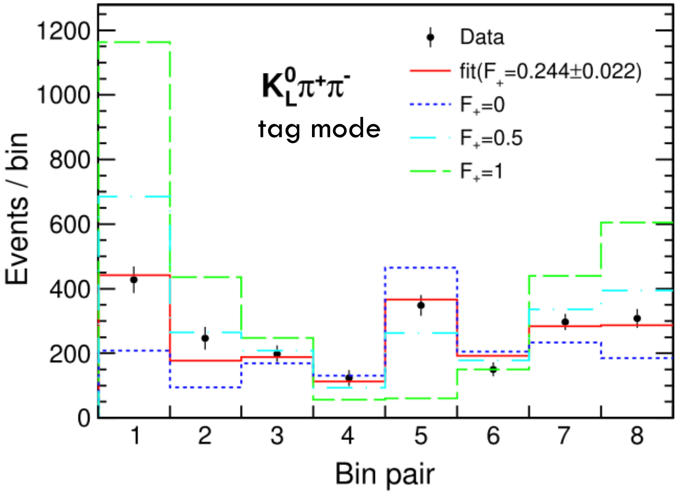
$r_D^{K\pi}$: ratio of amplitudes between DCS and CF decays

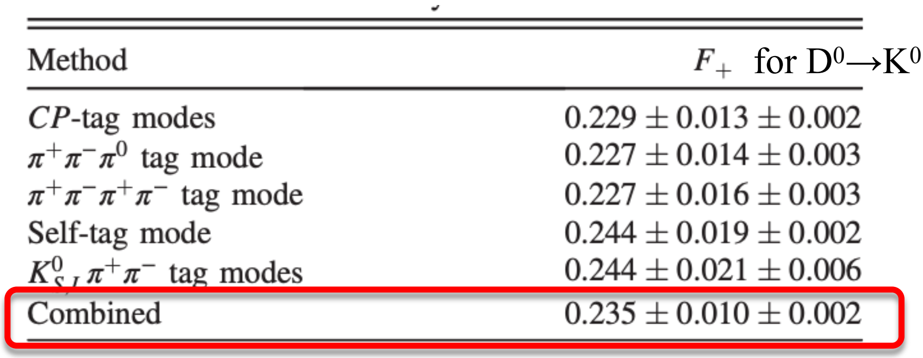
$\delta_D^{K\pi}$: phase difference between DCS and CF decays

Other results …

[PRD108,032003(2023)](#)





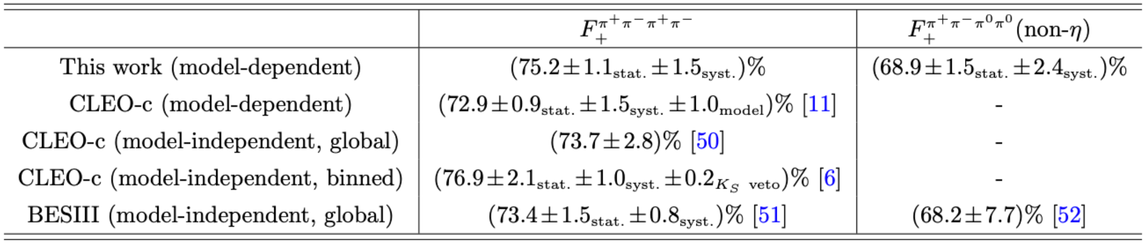


Method	F_+ for $D^0 \to K^0_S\pi^+\pi^-\pi^0$
CP-tag modes	$0.229 \pm 0.013 \pm 0.002$
$\pi^+\pi^-\pi^0$ tag mode	$0.227 \pm 0.014 \pm 0.003$
$\pi^+\pi^-\pi^+\pi^-$ tag mode	$0.227 \pm 0.016 \pm 0.003$
Self-tag mode	$0.244 \pm 0.019 \pm 0.002$
$K^0_{S,L}\pi^+\pi^-$ tag modes	$0.244 \pm 0.021 \pm 0.006$
Combined	$0.235 \pm 0.010 \pm 0.002$

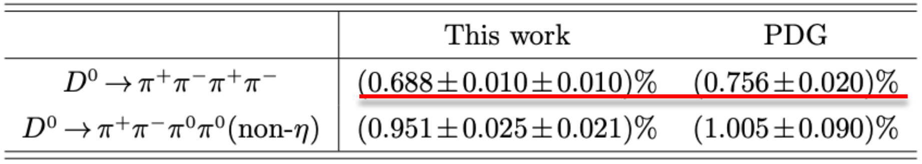
- Consistent with CLEO-c data (JHEP01,082)
- Measurement dominated by statistical uncertainty → improved precision by using larger data sample

[arXiv:2312.02524](#)

Joint amplitude analysis on
$D^0 \to \pi^+\pi^-\pi^+\pi^-$ and $D^0 \to \pi^+\pi^-\pi^0\pi^0$



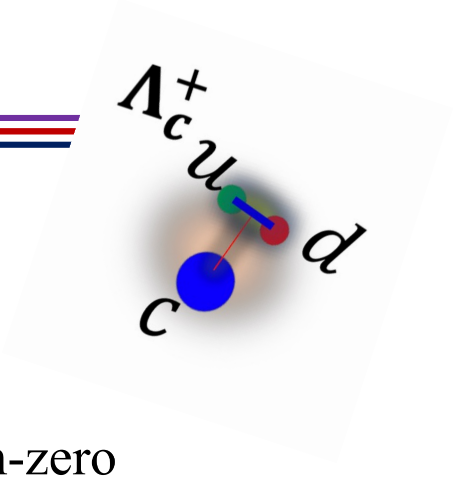
	$F_+^{\pi^+\pi^-\pi^+\pi^-}$	$F_+^{\pi^+\pi^-\pi^0\pi^0}$(non-$\eta$)
This work (model-dependent)	$(75.2\pm1.1_{\rm stat.}\pm1.5_{\rm syst.})\%$	$(68.9\pm1.5_{\rm stat.}\pm2.4_{\rm syst.})\%$
CLEO-c (model-dependent)	$(72.9\pm0.9_{\rm stat.}\pm1.5_{\rm syst.}\pm1.0_{\rm model})\%$ [11]	-
CLEO-c (model-independent, global)	$(73.7\pm2.8)\%$ [50]	-
CLEO-c (model-independent, binned)	$(76.9\pm2.1_{\rm stat.}\pm1.0_{\rm syst.}\pm0.2_{K_S\ \rm veto})\%$ [6]	-
BESIII (model-independent, global)	$(73.4\pm1.5_{\rm stat.}\pm0.8_{\rm syst.})\%$ [51]	$(68.2\pm7.7)\%$ [52]



	This work	PDG
$D^0 \to \pi^+\pi^-\pi^+\pi^-$	$(0.688\pm0.010\pm0.010)\%$	$(0.756\pm0.020)\%$
$D^0 \to \pi^+\pi^-\pi^0\pi^0$(non-$\eta$)	$(0.951\pm0.025\pm0.021)\%$	$(1.005\pm0.090)\%$

3σ difference (diff. in amplitude models which affect the $\varepsilon_{\rm rec}$)

Why Λ_c^+?



- The lightest charmed baryon
  - Important tagging for charmed and bottom baryons

- Naive quark model: a heavy quark (c) and an unexcited spin-zero diquark (u-d)
  - Excellent system to study the dynamics of light quarks in the environment of a heavy quark

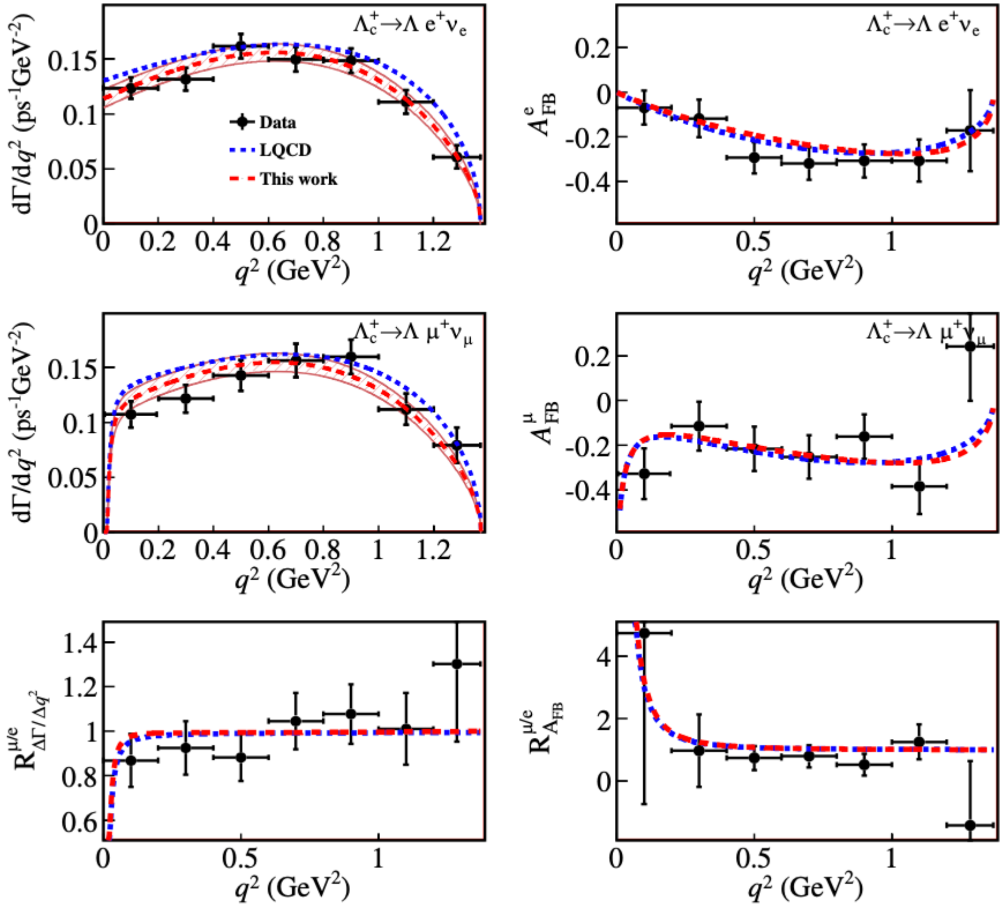
- Total measured BF is ~70%
  - Poorly understood compared to charm mesons

- Excellent platform for understanding non-perturbative QCD and weak decay mechanism
  - Test theoretical model, $SU(3)_F$ symmetry and LQCD calculations
- Semileptonic decays as test of LFU

$\Lambda_c^+ \to \Lambda l^+ \nu_l$

PRD108, L031105(2023)

- *4.5 fb^{-1} of $e^+e^- \to \Lambda_c^+\Lambda_c^-$* from 4.600 GeV to 4.699 GeV
- Improved measurement [PLB767,42 (2017)]

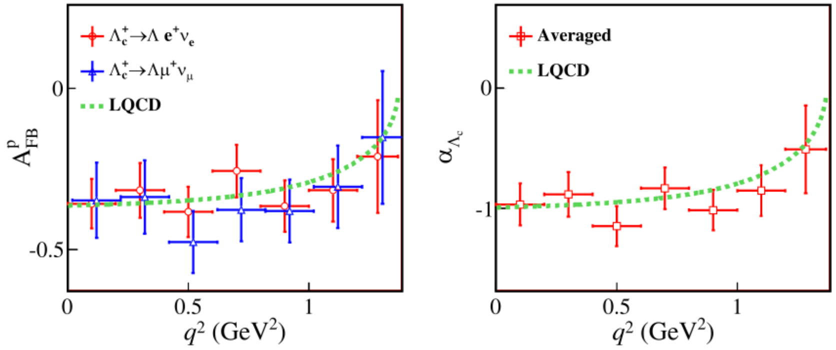


Improved by a factor 3

$$\mathcal{B}(\Lambda_c^+ \to \Lambda\mu^+\nu_\mu) = (3.48 \pm 0.14 \pm 0.10)\%$$

$$\frac{\mathcal{B}(\Lambda_c^+ \to \Lambda\mu^+\nu_\mu)}{\mathcal{B}(\Lambda_c^+ \to \Lambda e^+\nu_e)} = (0.98 \pm 0.05 \pm 0.03)\%$$

Consistent with LQCD [PRL118,082001(2017)]



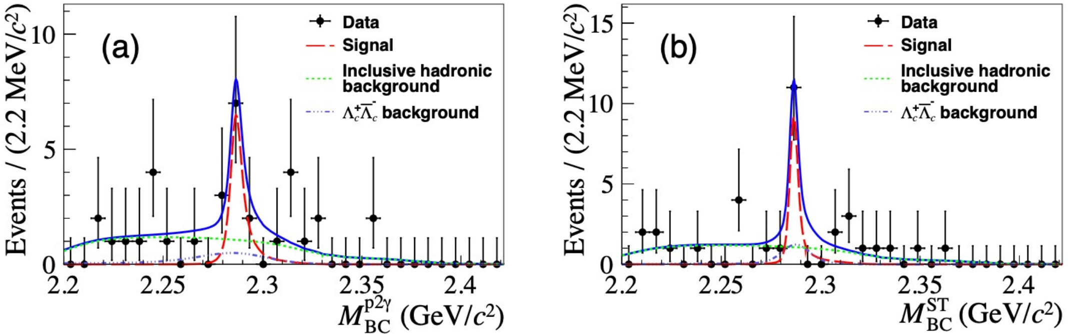
Good agreement with LQCD; Expected difference ~10^{-3} for e and μ modes not appreciable

$$\alpha_{\Lambda_c}(q^2) = \frac{2}{\alpha_\Lambda}[A^p_{FB}(q^2)],$$

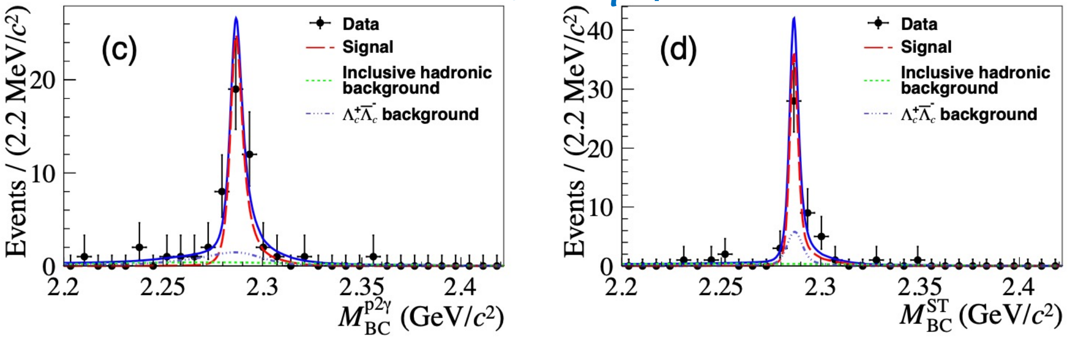
Λ→pπ decay asymmetry parameter

Singly CS $\Lambda_c^+ \to p\pi^0$ and $\Lambda_c^+ \to p\eta$ decays

$\Lambda_c^+ \to p\pi^0$



$\Lambda_c^+ \to p\eta$



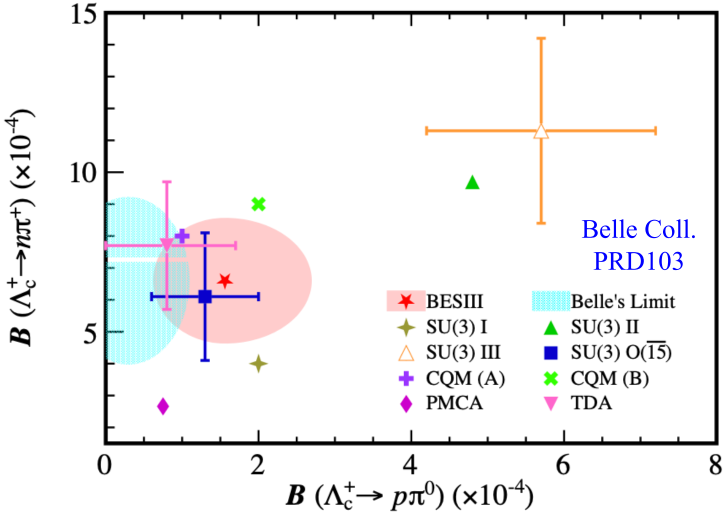
$$\mathcal{B}(\Lambda_c^+ \to p\pi^0) = (1.56^{+0.72}_{-0.58} \pm 0.20) \times 10^{-4} \quad 3.7\sigma$$

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

$\Lambda_c^+ \to n\pi^0$ and $\Lambda_c^+ \to p\pi^0$ agree with the calculation of $SU(3)_f$ symmetry including the contributions from both $\mathcal{O}(6)$ and $\mathcal{O}(15)$ [PLB790,225]

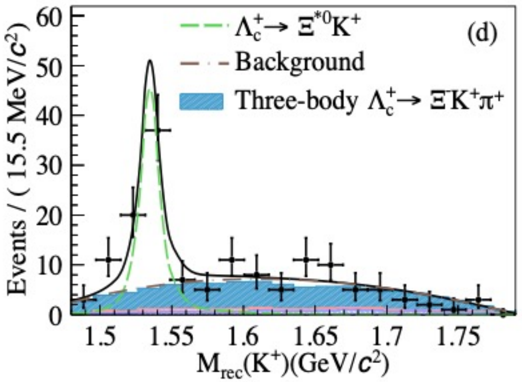
arXiv:2311.06883

- 6 fb^{-1} from 4.600 GeV to 4.843 GeV
- Decays of charmed baryons are helicity suppressed → W-boson exchange favored
- $\Lambda_c^+ \to p\pi^0$ and $\Lambda_c^+ \to p\eta$ proceed predominantly through internal W emission and W exchange ➔ BF information on the decay mechanism



Other Λ_c^+ Results

arXiv:2309.05484



- $\Lambda_c^+ \to \Sigma^- K^+\pi^+$ observed for the first time with 6.4σ
- Indication of the important role of non-factorizable components in three-body decays involving Σ^- baryon

$$\mathcal{B}(\Lambda_c^+ \to \Sigma^- K^+\pi^+) = (3.8 \pm 1.3 \pm 0.2) \times 10^{-4}$$

$$\mathcal{R}_{\Lambda K^+\pi^0} = \frac{\mathcal{B}(\Lambda_c^+ \to \Lambda K^+\pi^0)}{\mathcal{B}(\Lambda_c^+ \to \Lambda\pi^+\pi^0)} = (2.09 \pm 0.39) \times 10^{-2}$$

$$\mathcal{R}_{\Lambda K^+\pi^+\pi^-} = \frac{\mathcal{B}(\Lambda_c^+ \to \Lambda K^+\pi^+\pi^-)}{\mathcal{B}(\Lambda_c^+ \to \Lambda\pi^+\pi^+\pi^-)} = (1.13 \pm 0.41) \times 10^{-2},$$

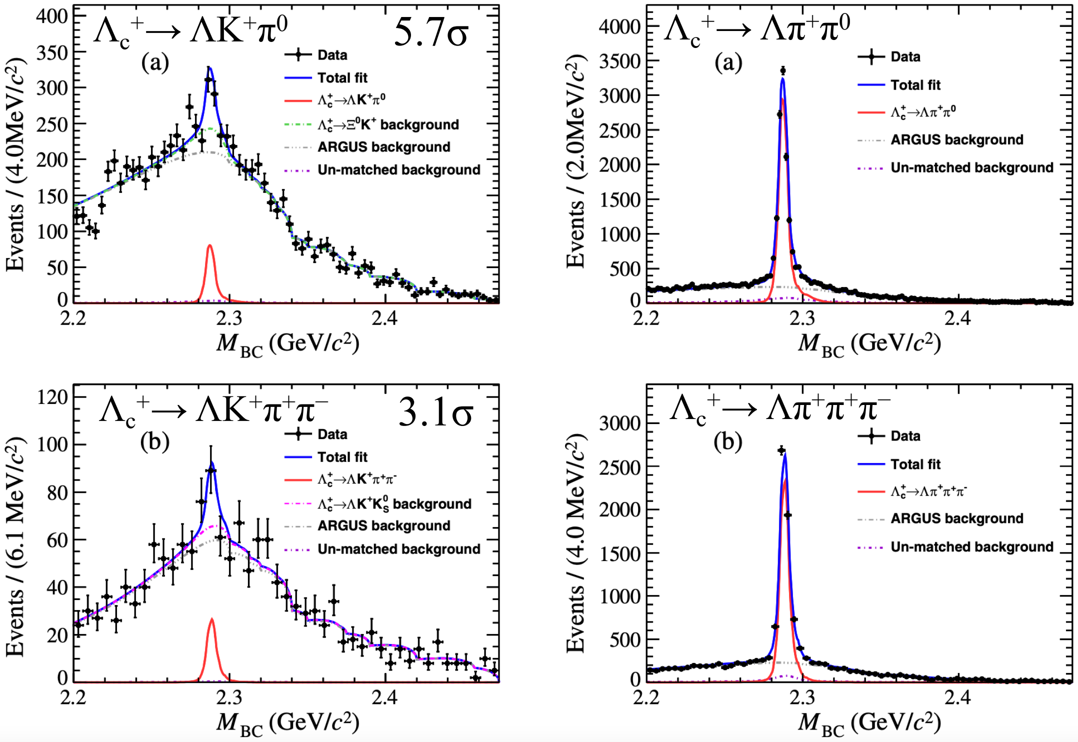
By combining these measurements with $\Lambda_c^+ \to \Lambda\pi^+\pi^0$ and $\Lambda_c^+ \to \Lambda\pi^+\pi^+\pi^-$ from PDG:

$$\mathcal{B}(\Lambda_c^+ \to \Lambda K^+\pi^0) = (1.49 \pm 0.27 \pm 0.05 \pm 0.08) \times 10^{-3}$$

$$\mathcal{B}(\Lambda_c^+ \to \Lambda K^+\pi^+\pi^-) = (4.13 \pm 1.48 \pm 0.20 \pm 0.33) \times 10^{-4}$$

These values deviate from prediction by 3.5σ and 3.0σ, respectively (PRD**99**,07300 and EPJC**79**,946)

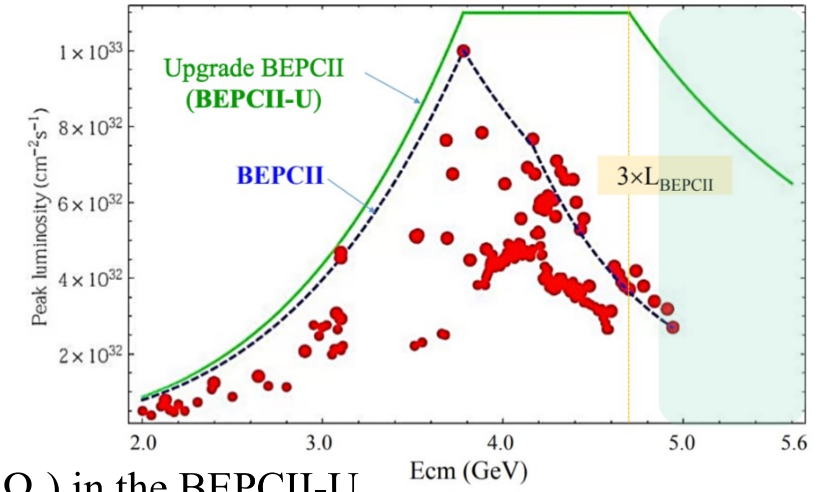
PRD109,032003(2024)



Summary and Outlook

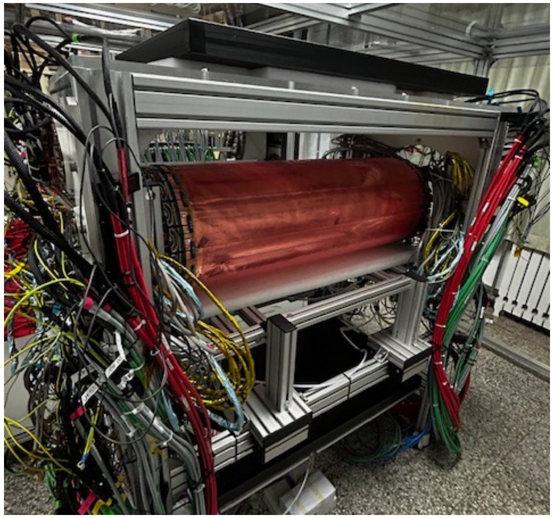
- Complementary information to B-factories and LHCb experiments
  - LFUV searches
  - Strong phases measurements
  - Amplitude analyses
  - Charmed baryons studies

- BESIII whitepaper Chinese Physics C 44, 040001 (2020) with outline of physics program for the next years
- Further upgrade in energy (5.6 GeV) and luminosity (BEPCII-U, 3x) planned for the next year



✓ Opportunities to study other charmed baryons (Σ_c, Ξ_c, Ω_c) in the BEPCII-U

- Inner MDC ➔ CGEM-IT



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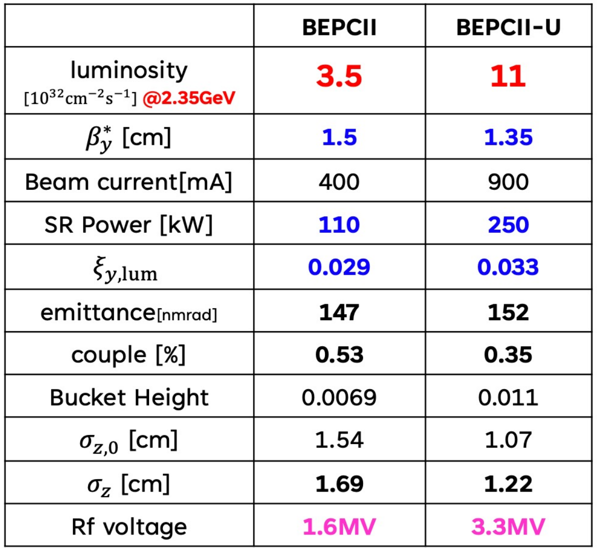


	BEPCII	BEPCII-U
luminosity $[10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$ @2.35GeV	3.5	11
β_y^* [cm]	1.5	1.35
Beam current[mA]	400	900
SR Power [kW]	110	250
$\xi_{y,\mathrm{lum}}$	0.029	0.033
emittance[nmrad]	147	152
couple [%]	0.53	0.35
Bucket Height	0.0069	0.011
$\sigma_{z,0}$ [cm]	1.54	1.07
σ_z [cm]	1.69	1.22
Rf voltage	1.6MV	3.3MV

Thanks for your attention

Back-up slides

Recent results since LP2022

- ➔ Semi-leptonic decays
  - ❖ $\Lambda_c^+ \to \Lambda\mu^+\nu_\mu$ [arXiv:2306.02624]
  - ❖ $\Lambda_c^+ \to \Lambda\pi^+\pi^-e^+\nu_e$ and $pK_S^0\pi^-e^+\nu_e$ [PLB 843, 137993 (2023)]
  - ❖ $\Lambda_c^+ \to Xe^+\nu_e$ [PRD 107, 052005 (2023)]
- ➔ Hadronic decays
  - ❖ $\Lambda_c^+ \to n\pi^+$ [PRL 128, 142001 (2022)]
  - ❖ $\Lambda_c^+ \to \Sigma^+h^+h^-(\pi^0)$ [arXiv:2304.09405]
  - ❖ $\Lambda_c^+ \to \bar{n}X$ [arXiv:2210.09561]
  - ❖ $\Lambda_c^+ \to n\pi^+\pi^0, n\pi^+\pi^-\pi^+$ and $nK^-\pi^+\pi^+$ [CPC 47, 023001 (2023)]
  - ❖ $\Lambda_c^+ \to \Lambda K^+$ [PRD 106, L111101 (2022)]
  - ❖ $\Lambda_c^+ \to p\eta'$ [PRD 106, 072002 (2022)]
- ➔ Rare decays
  - ❖ $\Lambda_c^+ \to \Sigma^+\gamma$ [PRD 107, 052002 (2023)]
  - ❖ $\Lambda_c^+ \to p\gamma'$ [PRD 106, 072008 (2022)]

Many exciting and interesting results!

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 ± 0.1 ± 2.2	4188.99 ± 0.06 ± 0.41
	2012	43.33 ± 0.03 ± 0.29	4188.59 ± 0.15 ± 0.68
4199	2017	526.0 ± 0.1 ± 2.1	4199.03 ± 0.05 ± 0.41
4209	2017	517.1 ± 0.1 ± 1.8	4209.25 ± 0.06 ± 0.42
	2012	54.95 ± 0.03 ± 0.36	4207.73 ± 0.14 ± 0.61
4219	2017	514.6 ± 0.1 ± 1.8	4218.84 ± 0.05 ± 0.40
	2012	54.60 ± 0.03 ± 0.36	4217.13 ± 0.14 ± 0.67
4226	2013	1047.34 ± 0.14 ± 10.16	4225.54 ± 0.05 ± 0.65
	2012	44.54 ± 0.03 ± 0.29	4226.26 ± 0.04 ± 0.65

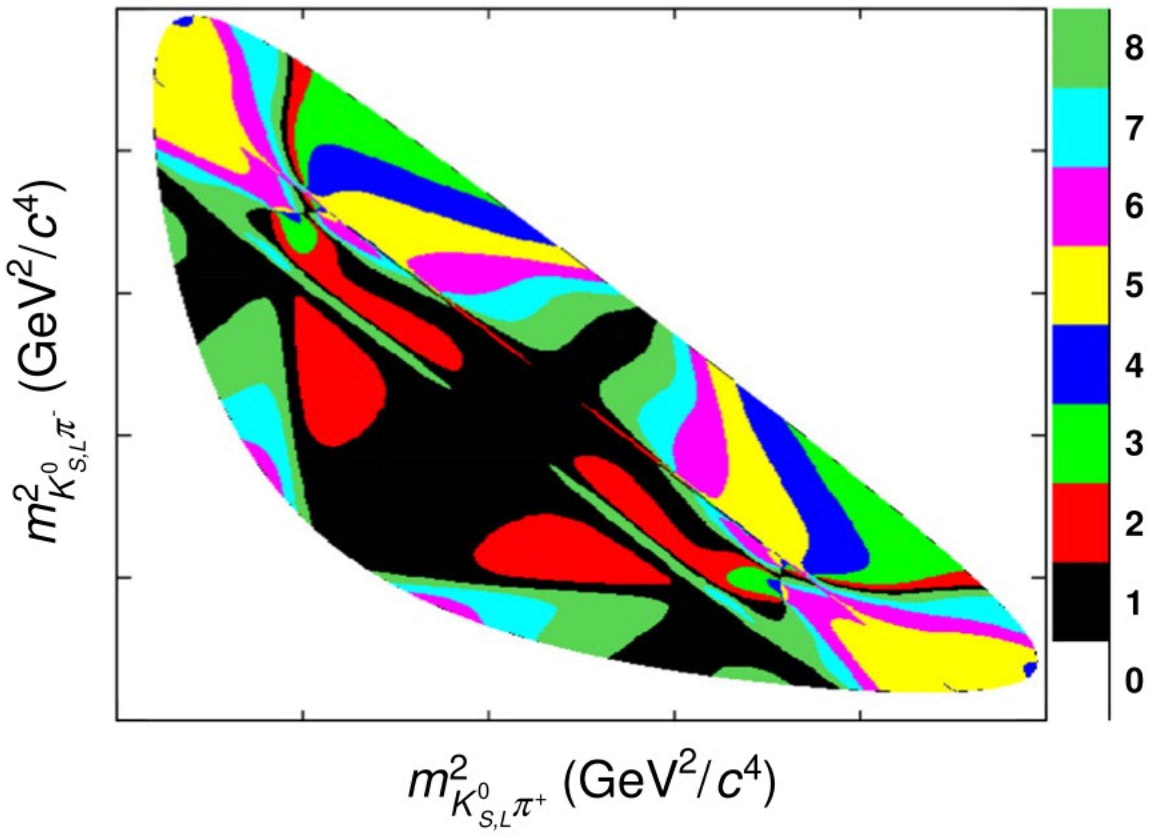
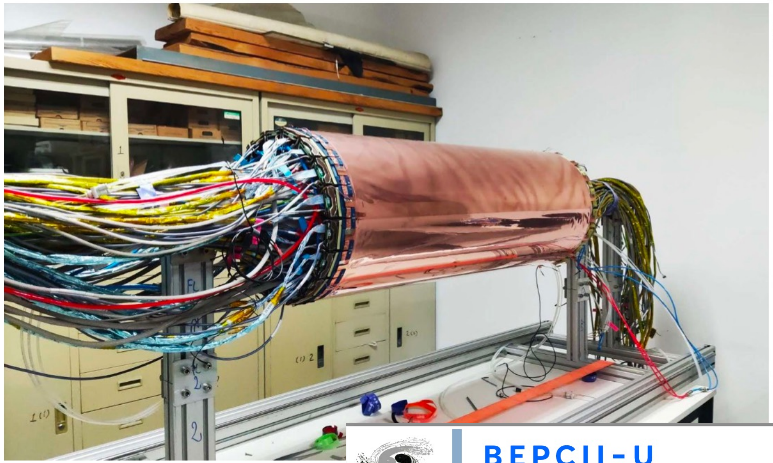


FIG. 1. The binning of the $D \to K^0_{S,L}\pi^+\pi^-$ Dalitz plot. The color scale represents the absolute value of the bin number $|i|$, where i is negative for the bin with $m_{K^0_{S,L}\pi^+} < m_{K^0_{S,L}\pi^-}$.

>2024 BESIII UPGRADE



BESIIICGEM FEST

RISE

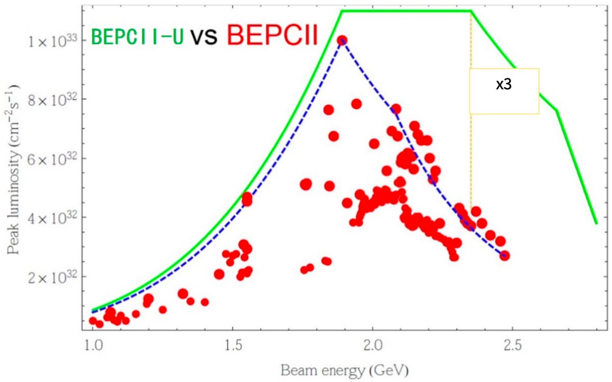
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

UPPSALA UNIVERSITET

中國科學院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

CG

BEPCII-U



- 2024 .7-12, Shut down for hardware dismantling and installation
- 2025-2028, Operation at 2.3~2.5 GeV, prepare for energy upgrade
- 2028.6-9, Energy upgrade to 2.8 GeV
- 2028.9~2030, Operation at 2.5~2.8 GeV

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	BEPCII	BEPCII-U
luminosity $[10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$ @2.35GeV	3.5	11
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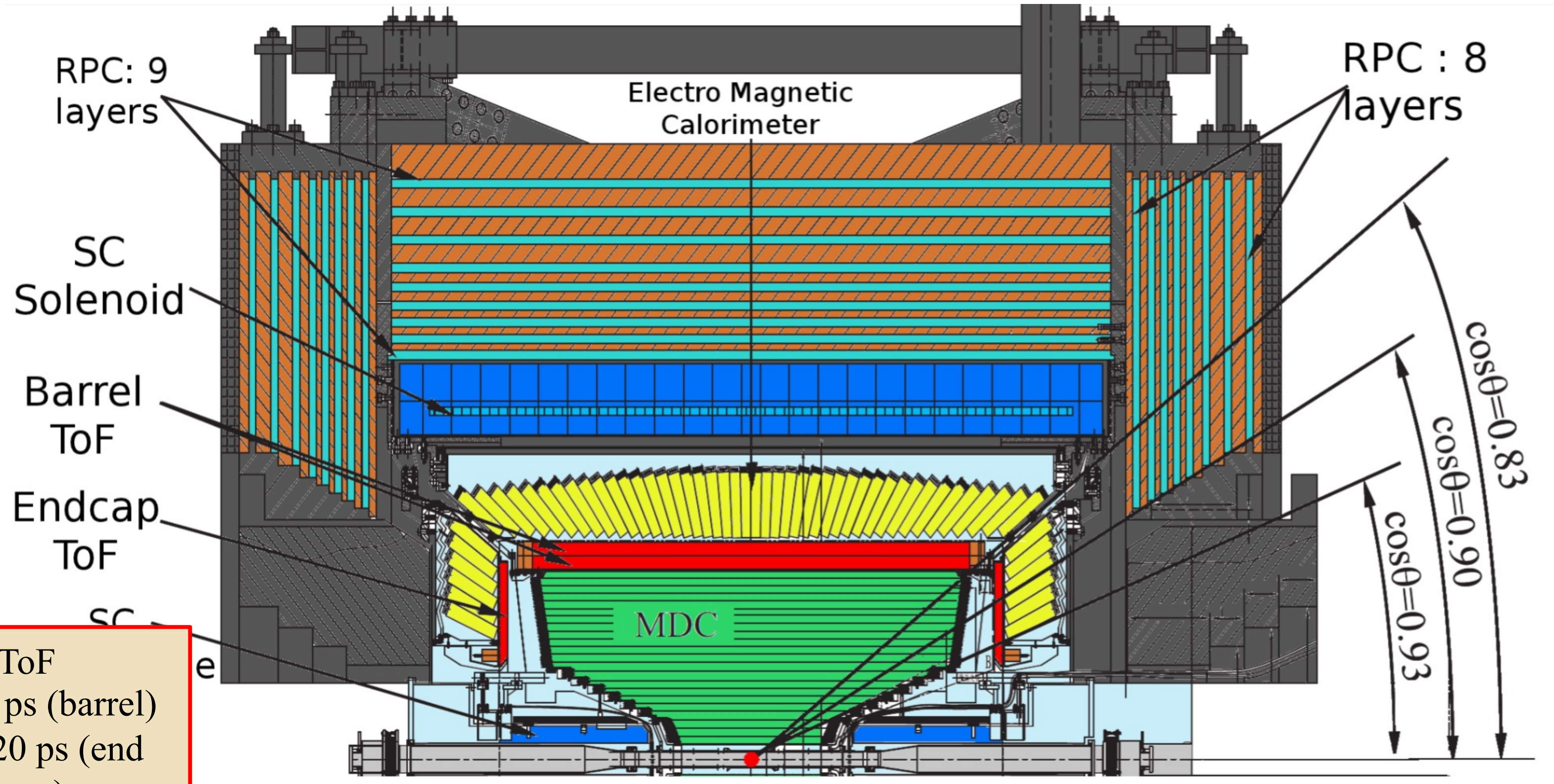
Beam current[mA]	400	900
SR Power [kW]	110	250
$\xi_{y,\mathrm{lum}}$	0.029	0.033
emittance[nmrad]	147	152
couple [%]	0.53	0.35
Bucket Height	0.0069	0.011
$\sigma_{z,0}$ [cm]	1.54	1.07
σ_z [cm]	1.69	1.22
Rf voltage	1.6MV	3.3MV

- ✓ **Phase I: @ 2.35GeV, Luminosity tripled to $11\mathrm{x}10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}$**
- ✓ **Phase II: Push higher energy, 2.47GeV>>2.80GeV**

The BESIII Detector

Nucl. Instr. Meth. A614, 345 (2010)



ToF
$\sigma_t \sim 90$ ps (barrel)
$\sigma_t \sim 120$ ps (end caps)

Drift Chamber
$\sigma_{r\phi} \sim 130\ \mu m$ (single wire)
$\sigma_{pt}/p_t \sim 0.5\ \%$ @ 1 GeV

Electromagnetic CsI(Tl) Calorimeter
$\sigma_E/E < 2.5\%$ @ 1 GeV (barrel)
$\sigma_E/E < 5\%$ @ 1 GeV (end caps)
$\sigma_{xy} \sim (6\ mm)/E^{1/2}$ @ 1 GeV

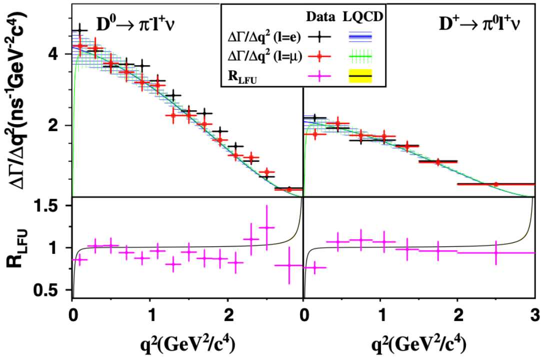
RPC Muon Detector
$\Delta\Omega/4\pi = 93\%$

Summary of LFU tests at BESIII

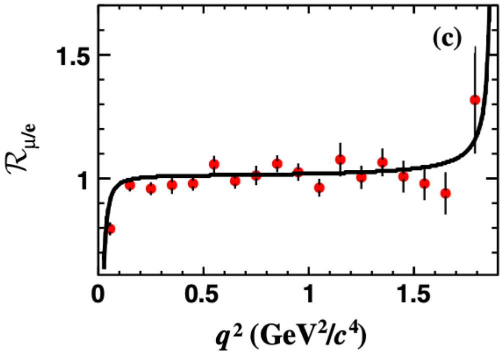
		References	**Measured B(l)/B(l')**	**SM prediction**
μ/e	$D^0\to K^-$	PRL**122**(2019)011804	0.974±0.014	~0.975
	$D^0\to\pi^-$	PRL**121**(2018)171803	0.922±0.038	~0.985
	$D^0\to\rho^-$	PRD**104**(2021)L091103	0.90±0.11	0.93-0.96
	$D^+\to\overline{K}^0$	EPJ C (2016) **76**:369	0.988±0.033	~0.970
	$D^+\to\pi^0$	PRL**121**(2018)171803	0.964±0.045	~0.985
	$D^+\to\omega$	PRD**101**(2020)072005	1.05±0.14	0.93–0.99
	$D^+\to\eta$	PRL**124**(2020)231801	0.91±0.13	0.97-1.00
	$D_s^+\to\eta$	PRD**97**(2018)012006	1.05±0.24	~1.0
	$D_s^+\to\eta'$		1.14±0.68	
	$D_s^+\to\varphi$		0.86±0.29	
	$\Lambda_c^+\to\Lambda$	PLB**676**(2017)42,47	0.96±0.16	~1.0
τ/μ	$D^+\to\tau^+\nu$	PRL**123**(2019)211802	3.21±0.77	2.66
	$D_s^+\to\tau^+\nu$	PRL**127**(2021)171801	9.72±0.37	9.75

Deviation from one due to the different PS available

PRL**121**(2018)171803



PRL**122**(2019)011804



Other results …

➔ Hadronic decays

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

➔ Semi-leptonic decays

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

➔ Rare decays

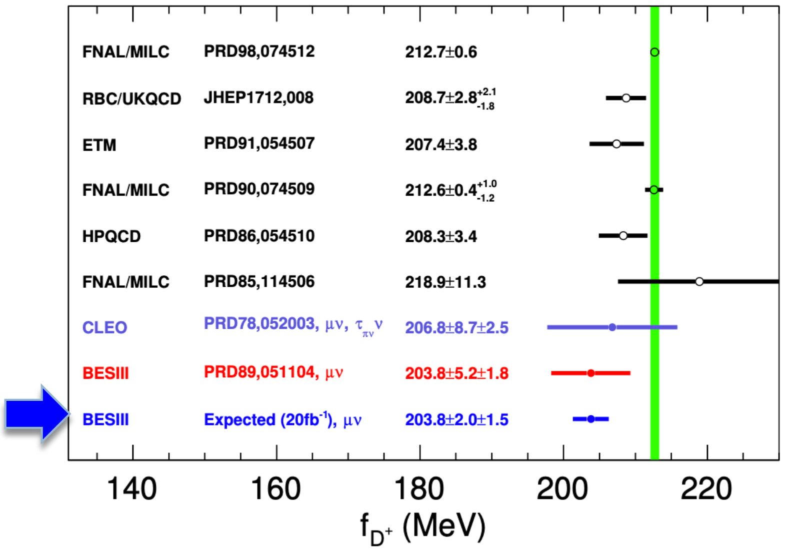
- $D^\pm \to n(\bar{n})e^\pm$ [PRD 106, 112009 (2022)]
- $D^0 \to \pi^0\nu\nu$ [PRD 105, L071102 (2022)]
- $D^0 \to \bar{p}e^+$ and pe^- [PRD 105, 032006 (2022)]

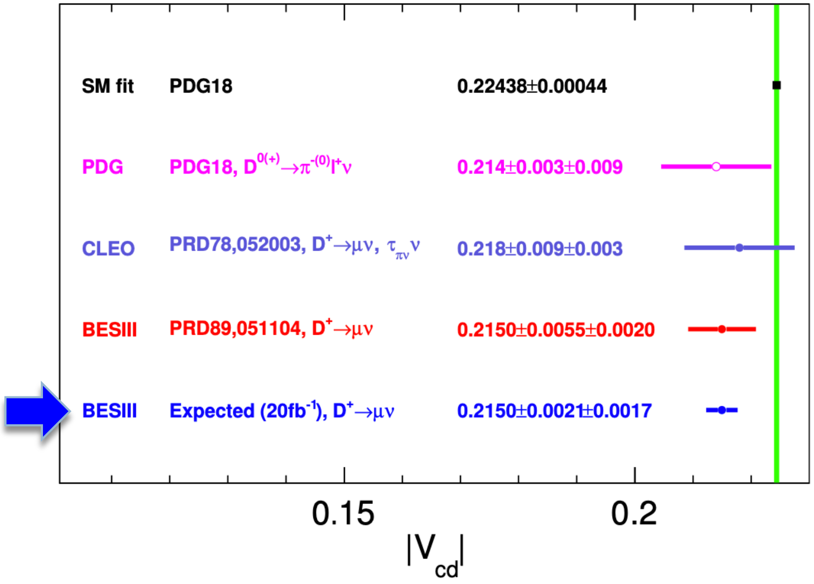
Plans: new data sets @ 3.770 GeV

Chinese Physics C 44, 040001 (2020)

$|V_{cd}|$ can be taken from the global fits of the other CKM matrix elements assuming unitary in SM, and f_{D+} can be determined

Alternatively, f_{D+} can be taken as input, and the leptonic BF measurements used to extract $|V_{cd}|$





○ LQCD calculations, ▮ LQCD uncertainty (PRD98, 074512(2018))

●— Best BESIII measurement

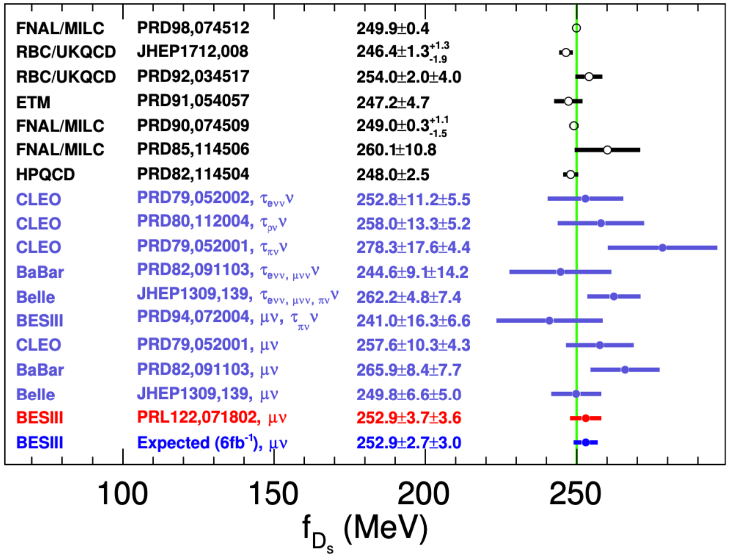
●— Expected precision with 20 fb^{-1} @ 3.773 GeV

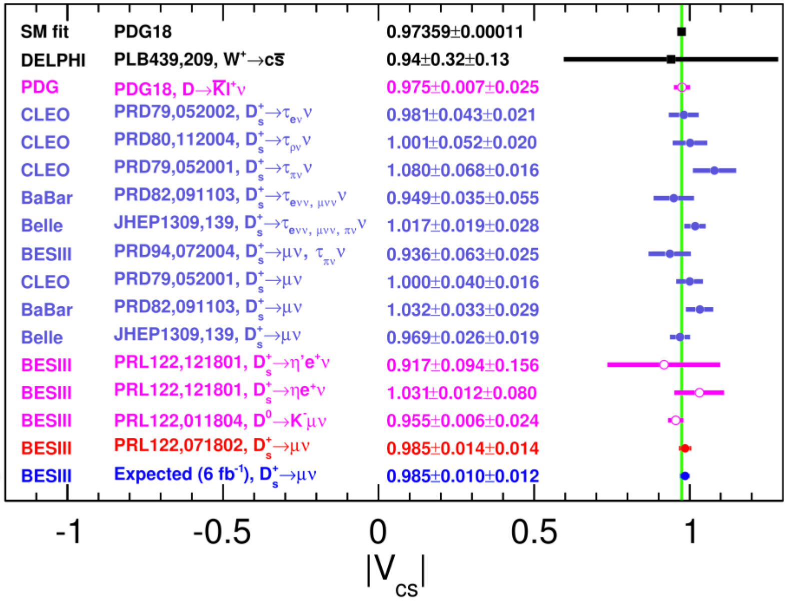
Plans: new data sets @ 4.178 GeV

Chinese Physics C 44, 040001 (2020)

$|V_{cs}|$ can be taken from the global fits of the other CKM matrix elements assuming unitary in SM, and f_{D_s} can be determined

Alternatively, f_{D_s} can be taken as input, and the leptonic BF measurements used to extract $|V_{cs}|$





○ LQCD calculations, 🟩 LQCD uncertainty (PRD98, 074512(2018))

● Best BESIII measurement

● Expected precision with 6 fb^{-1} @ 4.178 GeV

Amplitude Analysis of $D_s^+ \to K^+\pi^+\pi^-$

DT analysis: 1356 events, about 95% purity

JHEP08(2022)196

$$\mathcal{B}(D_s^+ \to K^+\pi^+\pi^-) = (6.11 \pm 0.18_{\text{stat.}} \pm 0.11_{\text{syst.}}) \times 10^{-3}$$

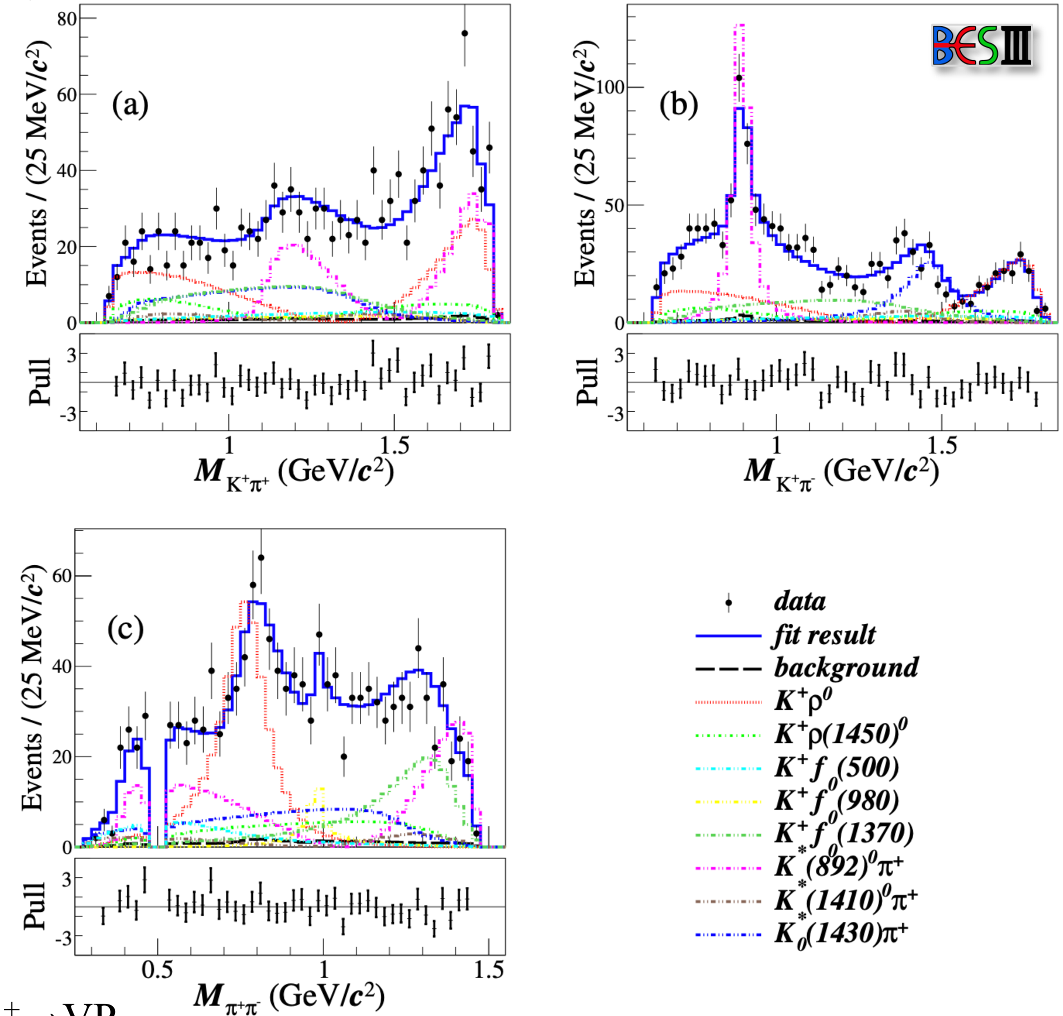
Improvement of a factor 2 w.r.t PDG

Intermediate process	BF(10^{-3})	PDG(10^{-3})
$D_s^+ \to K^+\rho^0$	$1.96 \pm 0.19 \pm 0.23$	2.5 ± 0.4
$D_s^+ \to K^+\rho(1450)^0$	$0.80 \pm 0.19 \pm 0.18$	0.69 ± 0.64
$D_s^+ \to K^*(892)^0\pi^+$	$1.85 \pm 0.12 \pm 0.13$	1.41 ± 0.24
$D_s^+ \to K^*(1410)^0\pi^+$	$0.27 \pm 0.13 \pm 0.15$	1.23 ± 0.28
$D_s^+ \to K_0^*(1430)^0\pi^+$	$1.13 \pm 0.16 \pm 0.16$	0.50 ± 0.35
* $D_s^+ \to K^+f_0(500)$	$0.44 \pm 0.13 \pm 0.27$	-
$D_s^+ \to K^+f_0(980)$	$0.27 \pm 0.08 \pm 0.07$	-
$D_s^+ \to K^+f_0(1370)$	$1.22 \pm 0.18 \pm 0.57$	-
$D_s^+ \to (K^+\pi^+\pi^-)_{NR}$	-	1.03 ± 0.34

*First measurements

$$A_{CP} = \frac{\mathcal{B}(D_s^+)-\mathcal{B}(D_s^-)}{\mathcal{B}(D_s^+)+\mathcal{B}(D_s^-)} = (3.3 \pm 3.0_{\text{stat.}} \pm 1.3_{\text{syst.}})\%$$

No significant CP violation

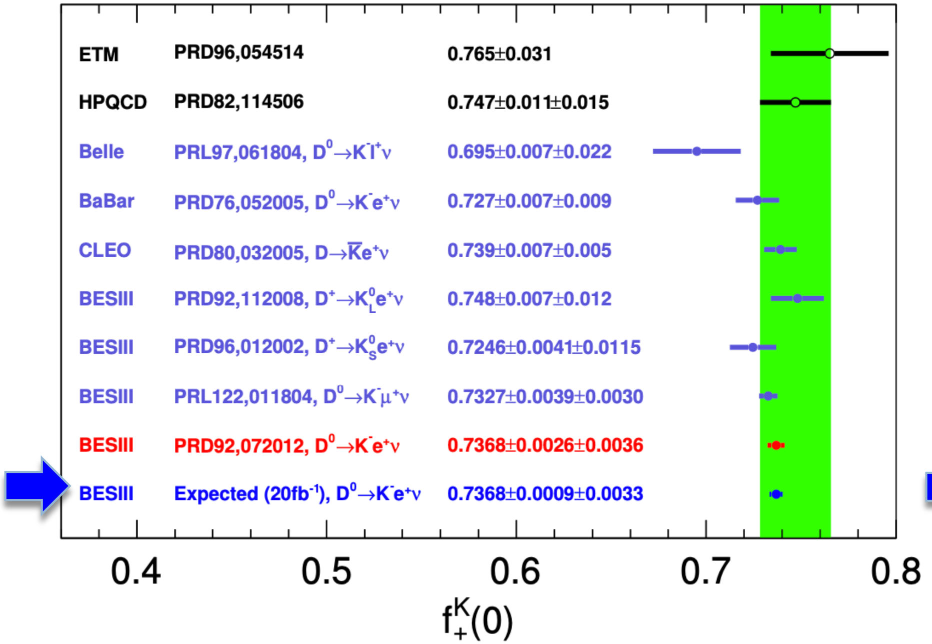


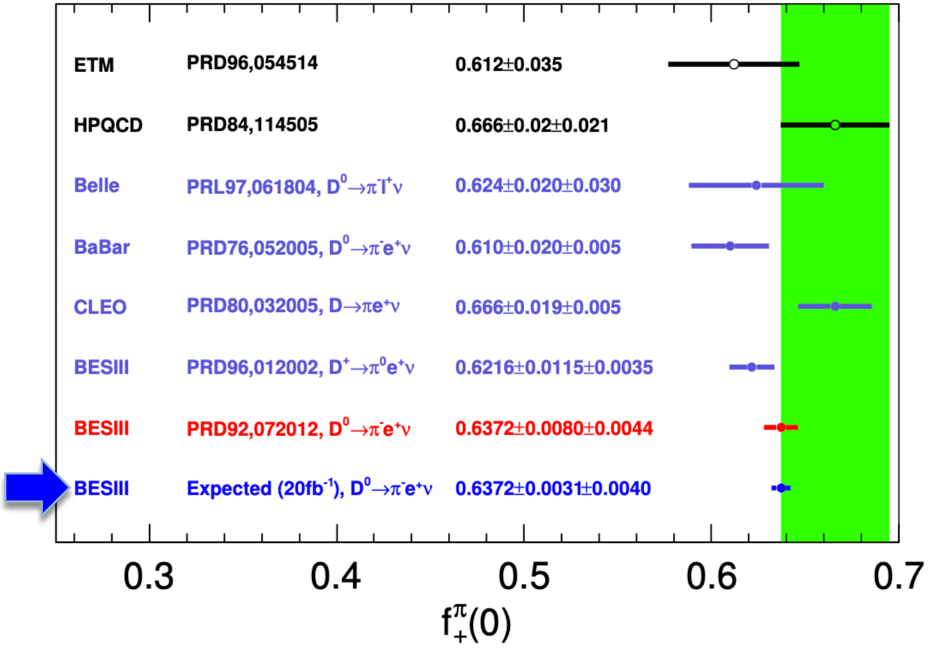
More precise theoretical predictions and measurements are needed to understand the $D_s^\pm \to VP$ processes and SU(3)$_F$ flavor symmetry breaking

Comparisons of $f_+^{\pi/K}(0)$

$|V_{cd(s)}|$ can be taken from the global fits of the other CKM matrix elements assuming unitary in SM, and $f_{D^+(s)}$ can be determined

Chinese Physics C 44, 040001 (2020)





○ LQCD calculations, 🟩 LQCD uncertainty (PRD82, 114506(2010); PRD 84, 114505(2011))

● Best BESIII measurement

● Expected precision with 20 fb^{-1} @ 3.773 GeV arXiv:2309.05760

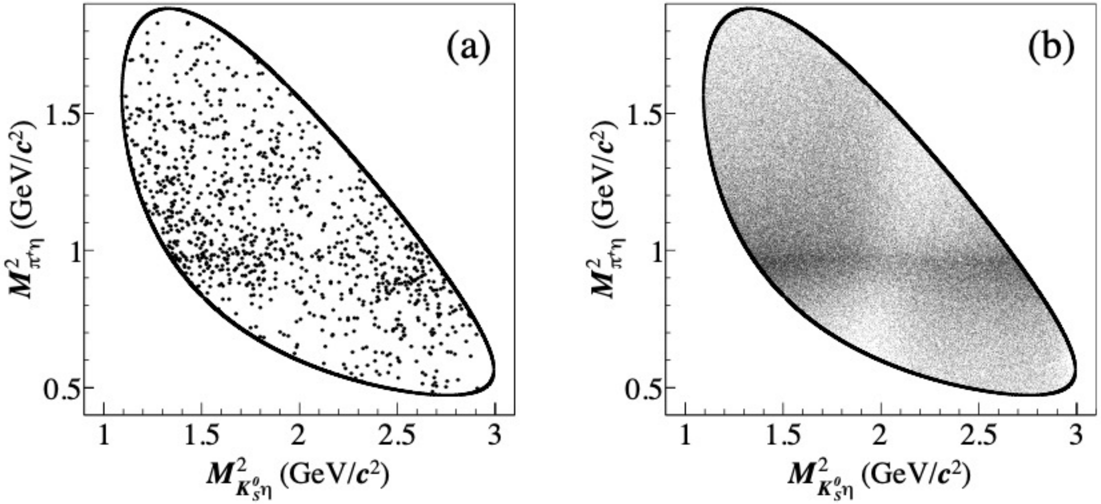
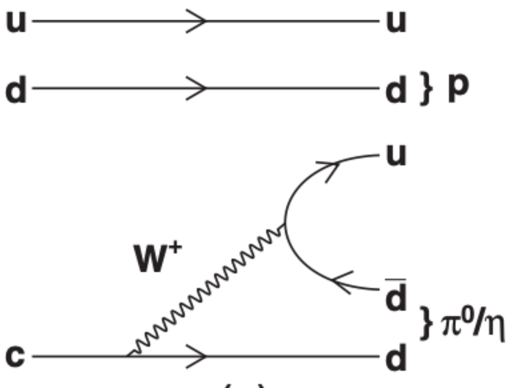


FIG. 3. The Dalitz plots of $M^2_{\pi^+\eta}$ versus $M^2_{K^0_S\eta}$ of the $D^+ \to K^0_S\pi^+\eta$ candidates in (a) the data sample and (b) the signal MC sample generated according to the amplitude analysis results.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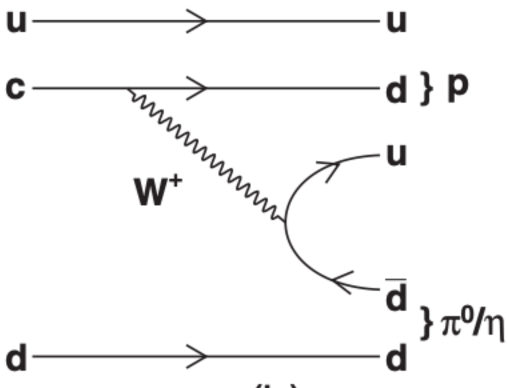
(a)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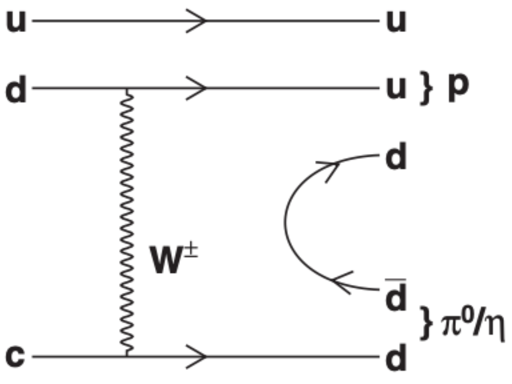
(b)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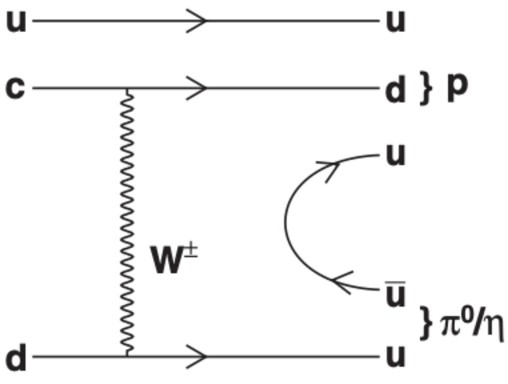
(c)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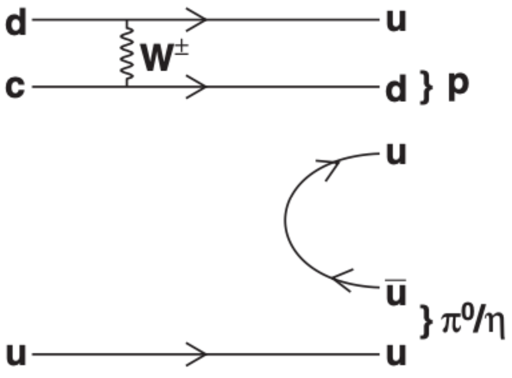
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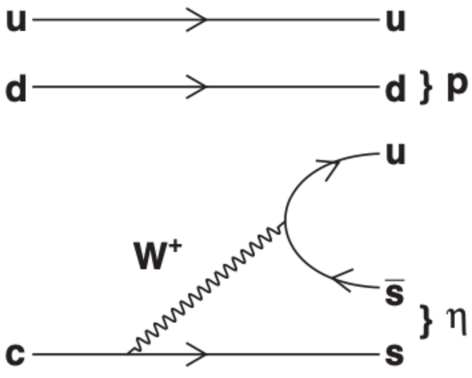
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