BESIII Flavor Highlights and Prospects

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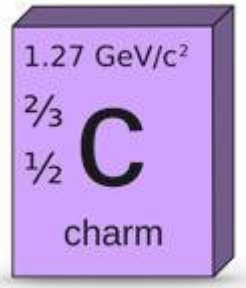
Wuhan University

On behalf of BESIII collaboration

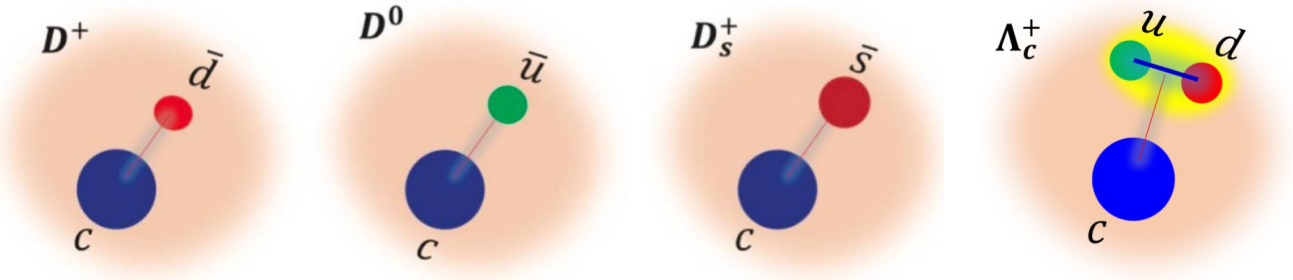
2026/10/24

CEPC Workshop 2026, Shanghai

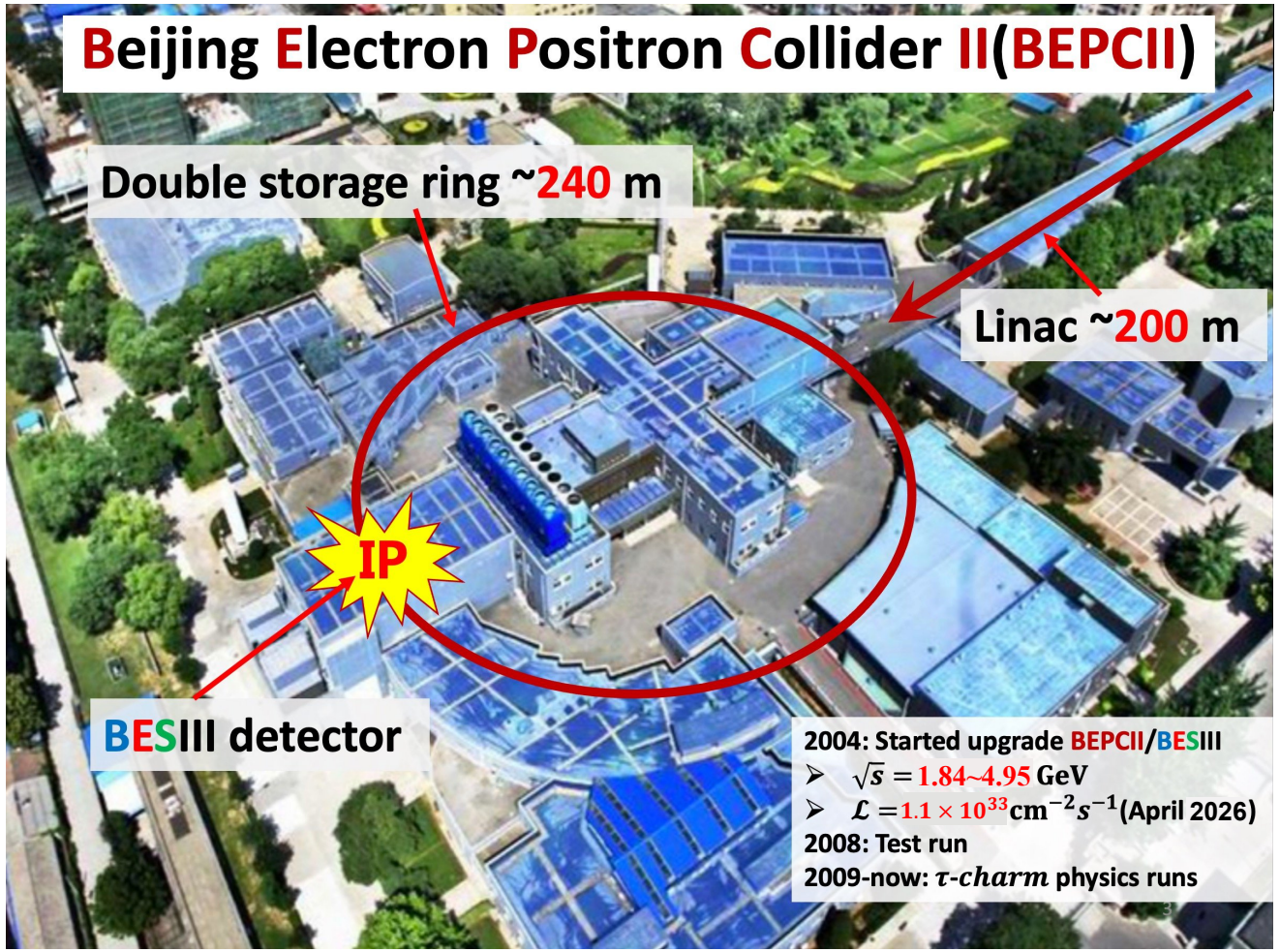
Outline



- BESIII experiment
- BESIII Datasets
- Highlight of recent results on charm physics (a personal selection!)
  - Strong phases in D decays
  - Semi-leptonic D decays
  - Hadronic D decays
  - Rare D decays
  - Physics on Λ_c^+
- Prospects and summary



BEPCII & BESIII



Electromagnetic CsI(Tl) Calorimeter (EMC)

σ_E/E < 2.5% @ 1 GeV (barrel)

σ_E/E < 5% @ 1 GeV (end-caps)

Time-of-Flight (TOF)

σ_t = 68 ps (barrel)

σ_t = 60 ps (end-caps)

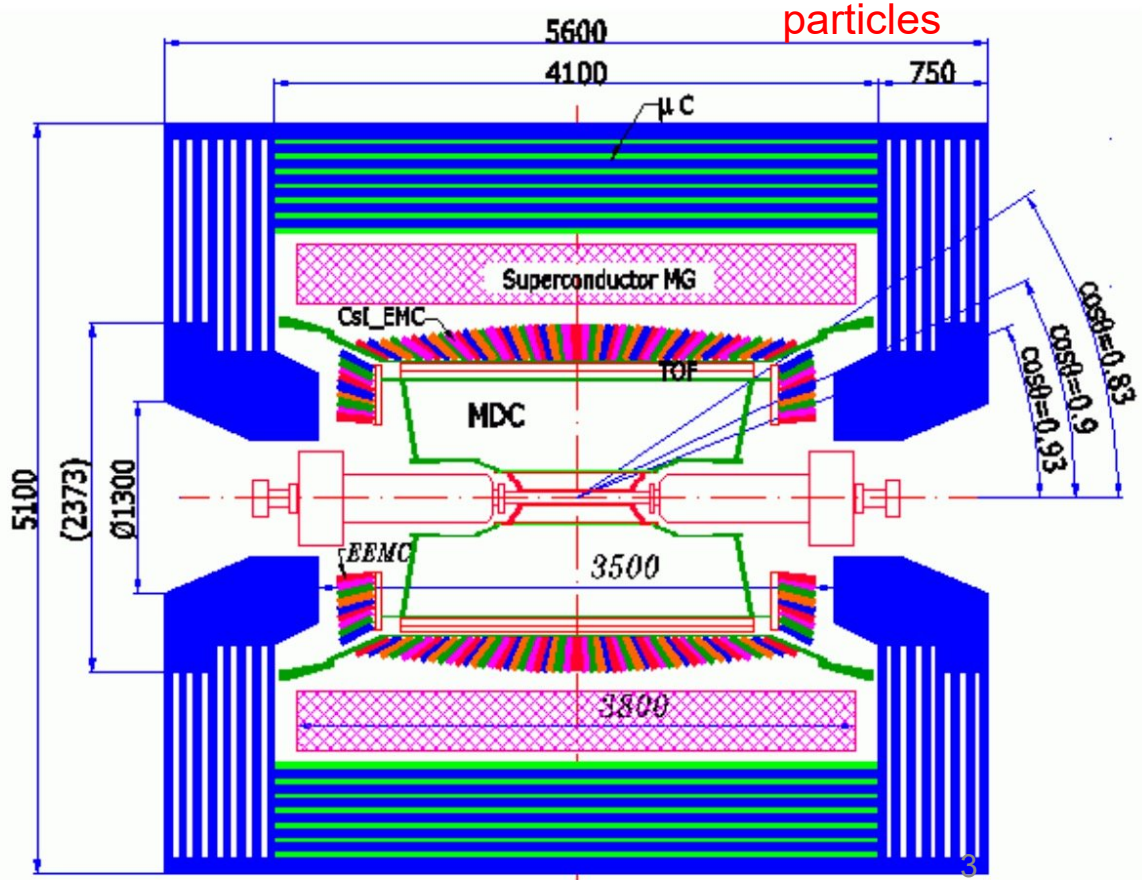
Main Drift Chamber (MDC)

$\sigma_{r\phi}$ = 130 μm (single wire)

σ_{p_t}/p_t = 0.5% @ 1 GeV/c

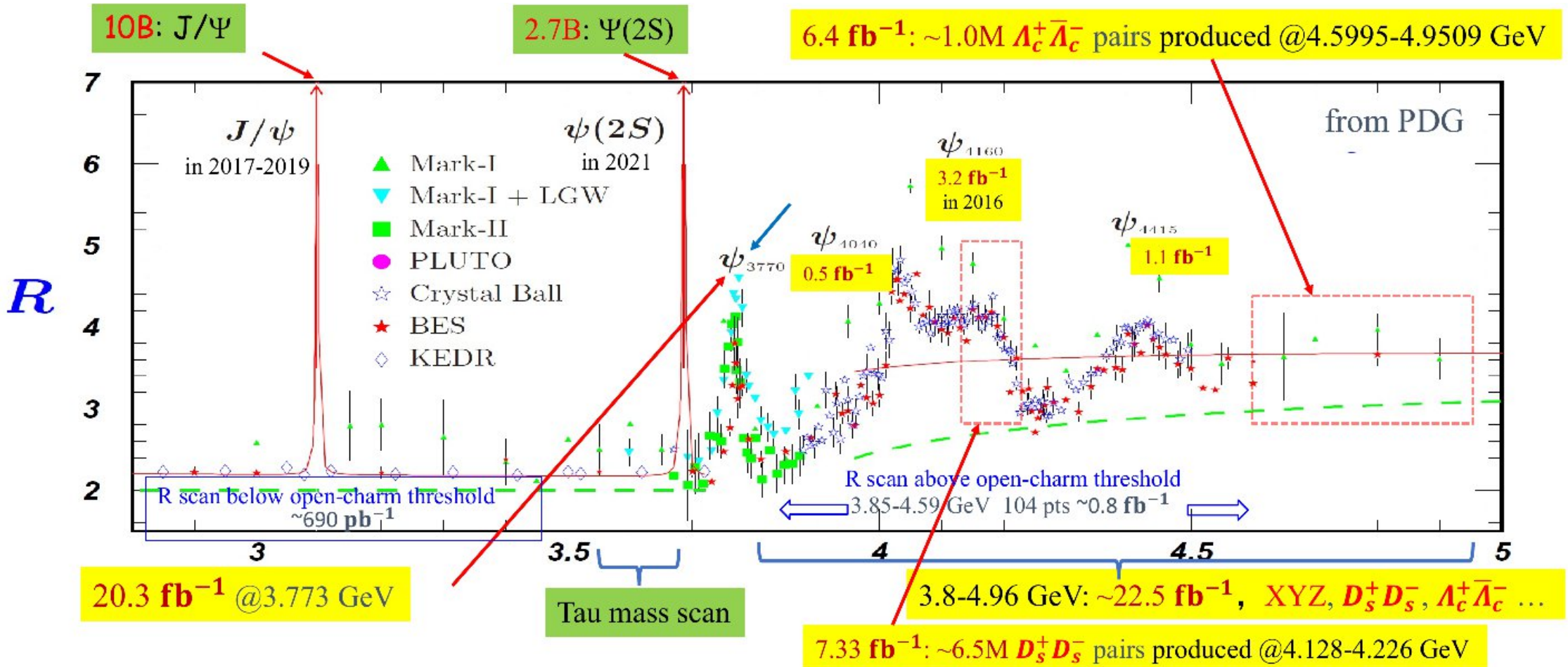
Superconducting solenoid (1 Tesla)

93% coverage
Sensitive to missing particles



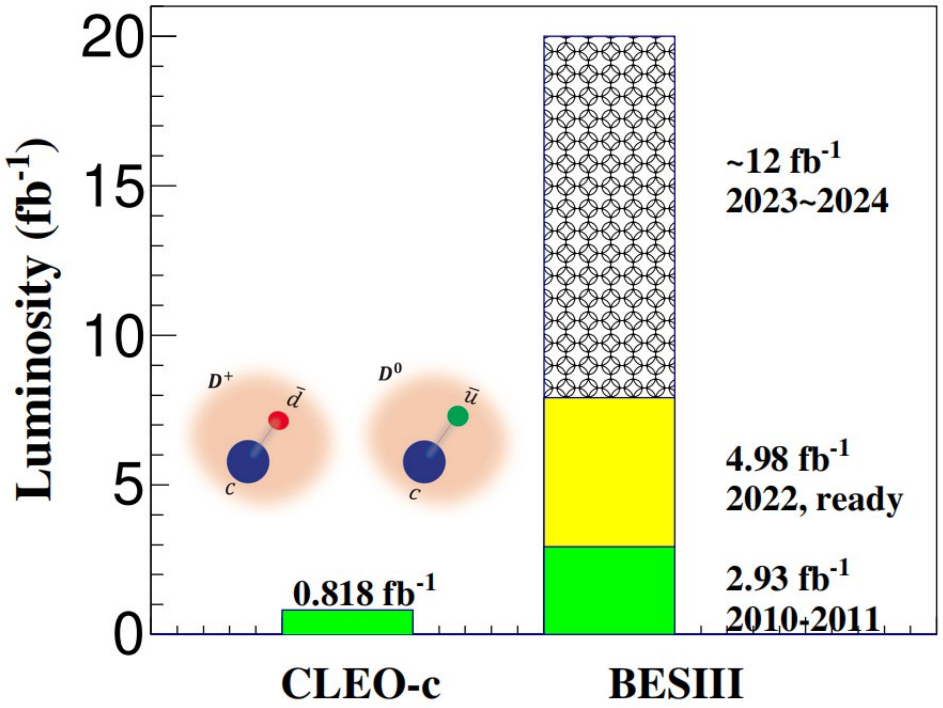
M. Ablikim *et al.* (BESIII Collaboration), Nucl. Instr. Meth. A614, 345 (2010)

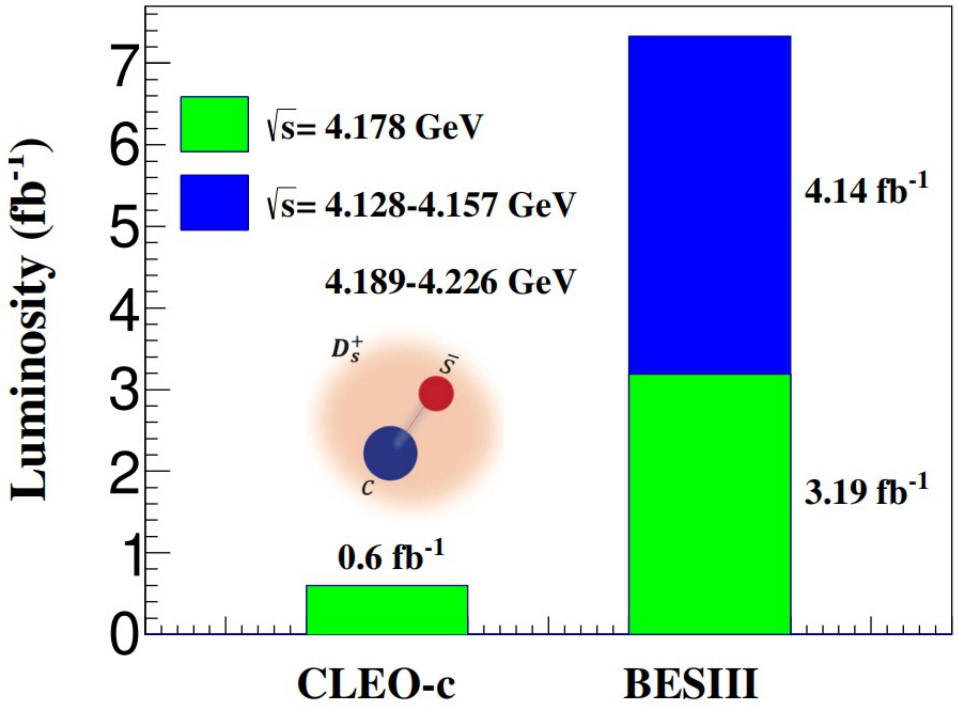
BESIII datasets



BESIII: ~55 fb^{-1} from 1.84 – 4.95 GeV

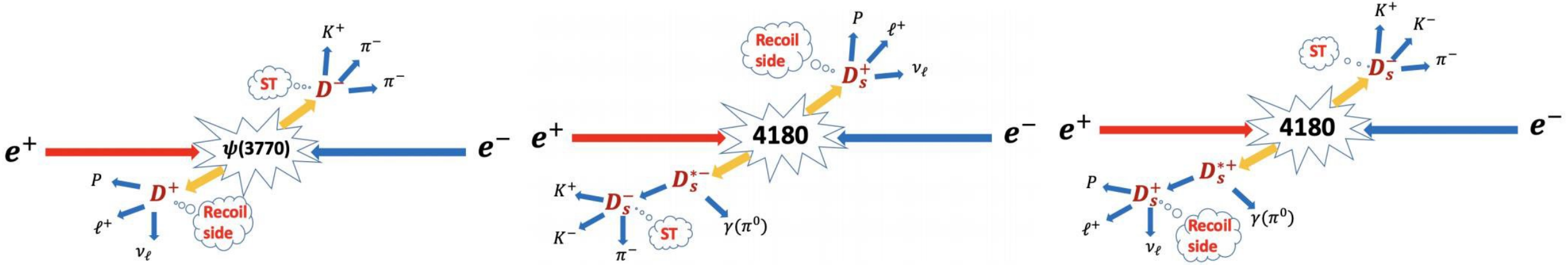
Near-threshold open charm datasets





- World's largest near-threshold charm-meson samples
  - Charm hadrons produced in pairs and quantum correlated

Double-tag method



- Hadronic tag modes:
  - $\overline{D}^0 \to K^-\pi^+(\pi)(\pi)$, ...
  - $D^- \to K_S^0\pi^-(\pi^0)$, $D^- \to K^+\pi^-\pi^-(\pi^0)$, ...
  - $D_s^- \to K_S^0K^-$, $D_s^- \to K^-K^+\pi^-(\pi^0)$, ...
- Absolute BF measurement:

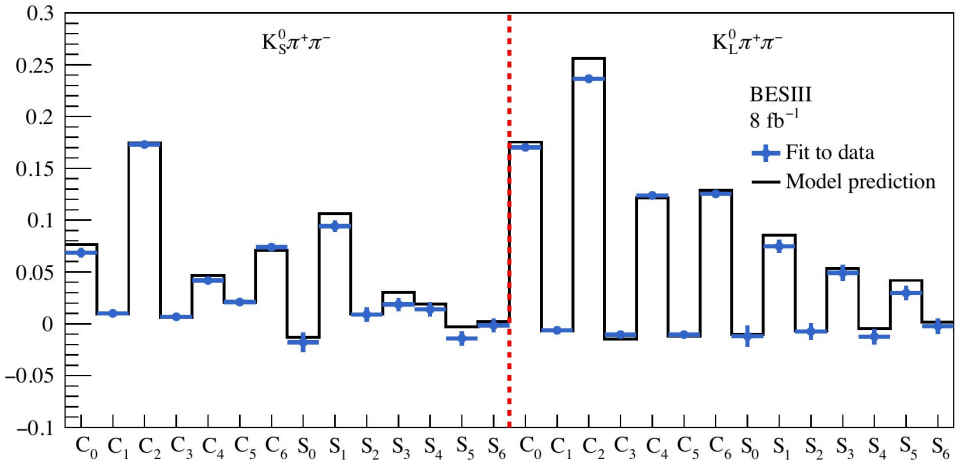
$$N_{\rm tag} = 2N_{D\bar{D}}\mathcal{B}_{\rm tag}\epsilon_{\rm tag}$$
$$N_{\rm DT} = 2N_{D\bar{D}}\mathcal{B}_{\rm tag}\mathcal{B}_{\rm sig}\epsilon_{\rm DT}$$
$$\mathcal{B}_{\rm sig} = \frac{N_{\rm DT}}{N_{\rm tag}\epsilon_{\rm DT}/\epsilon_{\rm tag}}$$

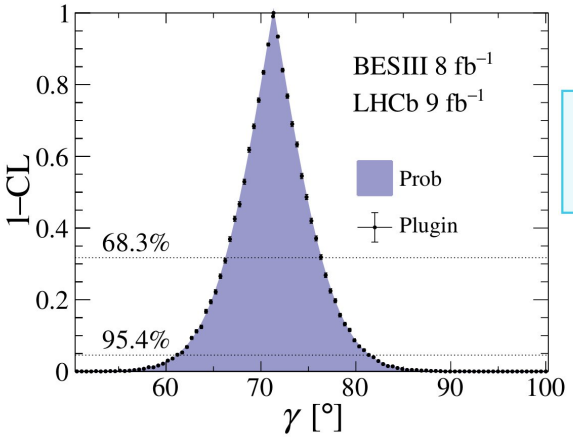
- Advantages:
  - Clean background; Access of QC in $D^0\overline{D}^0$ system; Able to infer info of missing particle (ν, K_L^0)

arXiv:2604.05712
arXiv:2604.05701

Determination on CKM angle γ

- A joint fit to LHCb 9 fb^{-1} & BESIII 8 fb^{-1} datasets to determine CPV observables & strong phase parameters simultaneously
- Novel approach: unbinned & model-independent => 5% gain in precision
- BESIII side: strong phase info from doubly tagged $D \to K^0_{S/L}\pi^+\pi^-$ and $D \to K^0_{S/L}K^+K^-$ decays
- Uncertainty on γ from BESIII charm strong-phase input is reduced to **0.6°**

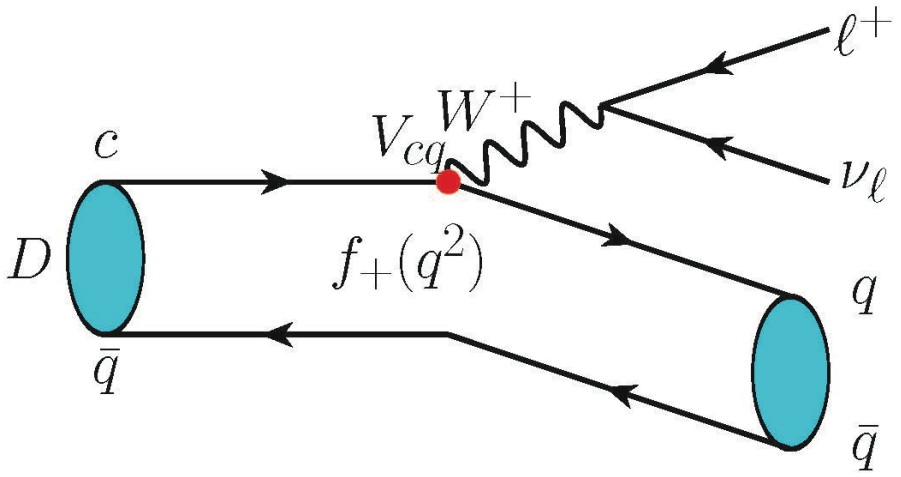




$\gamma = (71.3 \pm 5.0)°$

most precise single measurement to date

Semi-leptonic D decays



$$M = \frac{G_F}{\sqrt{2}} V_{cq} \times \langle P(S) | \bar{q} \gamma_\mu (1 - \gamma_5) c | D \rangle \times \bar{\nu}_\ell \gamma^\mu (1 - \gamma_5) \ell$$

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

$X = P, S, V, A, \ldots$

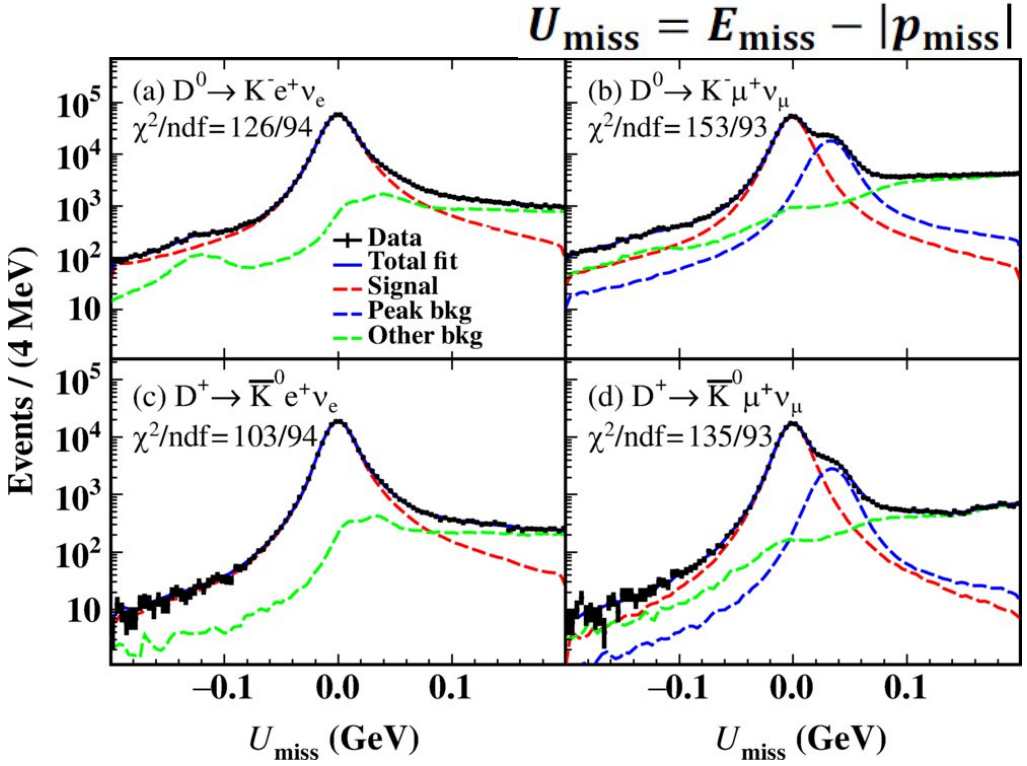
Physics objectives include:

- Determination of $|V_{cq}|$
- Extraction of form factors
- Lepton flavor universality tests, NP searches
- Study of ligh hadrons in a clean environment

PRL 137 (2026) 091803
PRD 114 (2026) 033008

$D^{0,+} \to \overline{K}\ell^+\nu_\ell$: combining four channels

- Using 20.3 fb^{-1} $\psi(3770)$ dataset
- Precise measurements on four BFs

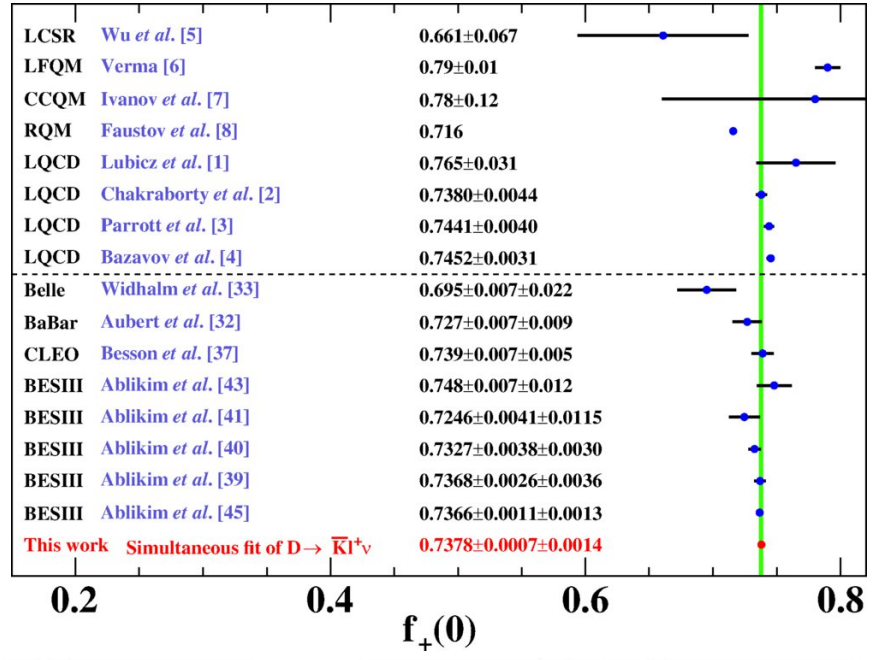


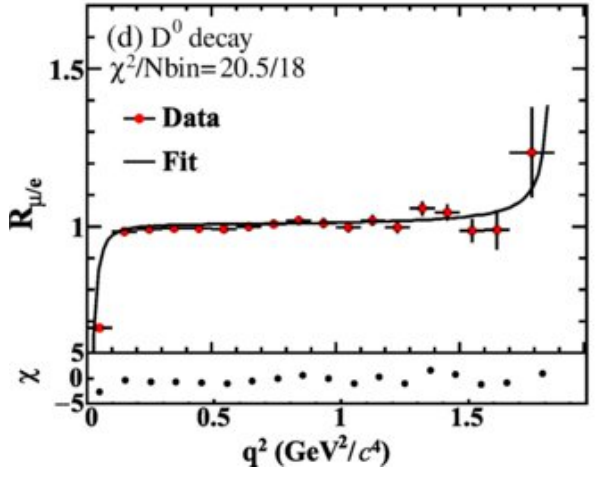
Channel	$N_{\rm DT}$ $(\times 10^3)$	$\bar{\epsilon}_{\rm sig}$ (%)	$\mathcal{B}_{\rm sig}$(%)
$D^0 \to K^-e^+\nu_e$	489.8 ± 0.8	68.25 ± 0.02	$3.548 \pm 0.006 \pm 0.017$
$D^0 \to K^-\mu^+\nu_\mu$	403.9 ± 0.8	57.96 ± 0.02	$3.445 \pm 0.007 \pm 0.017$
$D^+ \to \bar{K}^0e^+\nu_e$	149.3 ± 0.4	45.39 ± 0.02	$8.928 \pm 0.025 \pm 0.050$
$D^+ \to \bar{K}^0\mu^+\nu_\mu$	125.1 ± 0.4	38.74 ± 0.02	$8.770 \pm 0.029 \pm 0.053$

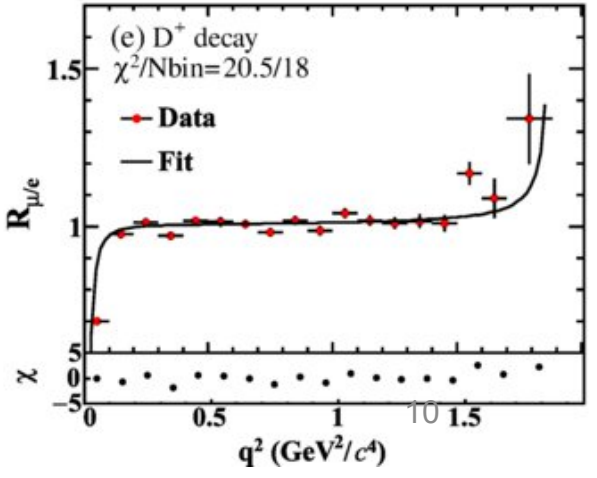
PRL 137 (2026) 091803
PRD 114 (2026) 033008

$D^{0,+} \to \overline{K}\ell^+\nu_\ell$: combining four channels

- Using 20.3 fb^{-1} $\psi(3770)$ dataset
- Precise measurements on four BFs
- Simultaneous fits in bins of q^2 lead to improved results on $f_+(0)|V_{cs}|$ & LFU







PRL 137 (2026) 091803
PRD 114 (2026) 033008

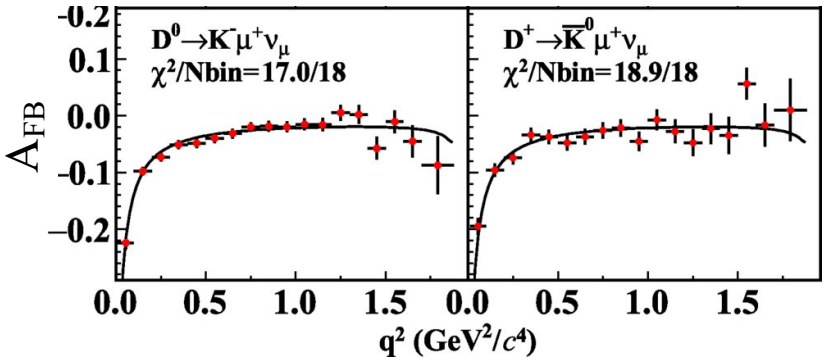
$D^{0,+} \to \overline{K}\ell^+\nu_\ell$: combining four channels

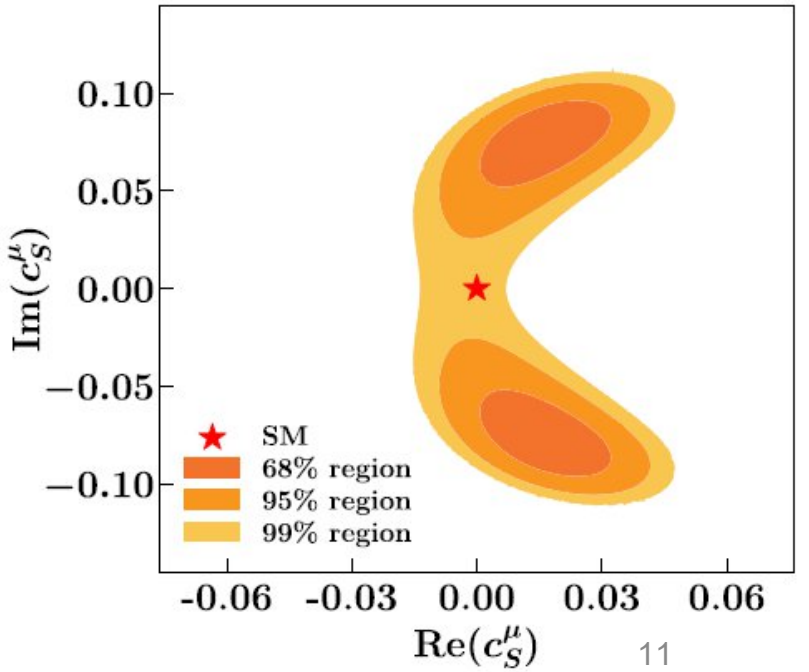
- Using 20.3 fb^{-1} $\psi(3770)$ dataset
- Precise measurements on four BFs
- Simultaneous fits in bins of q^2 lead to improved results on $f_+(0)|V_{cs}|$ & LFU
- Angular analysis yields first experimental constraint on scalar current:

$$\mathrm{Re}(c_S^\mu) = 0.017 \pm 0.008 \pm 0.006$$

$$\mathrm{Im}(c_S^\mu) = \pm(0.077 \pm 0.011 \pm 0.009)$$

Deviation from SM: 2.3σ

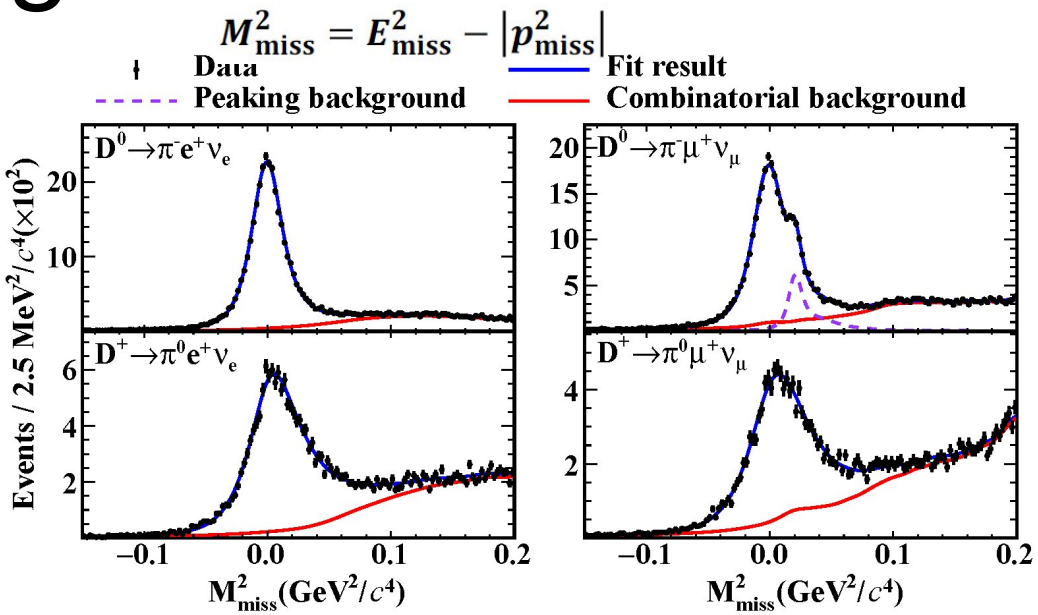


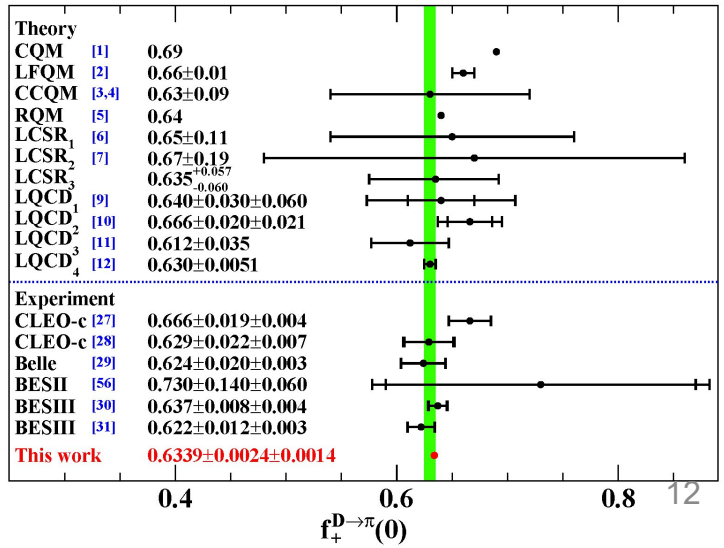


arXiv:2607.23949
arXiv:2607.23945

$D^{0,+} \to \pi^{-,0} \ell^+ \nu_\ell$: combining four channels

- Using 20.3 fb^{-1} $\psi(3770)$ dataset
- Precise BF measurements in four channels
- Simultaneous fits in bins of q^2 lead to much improved results on $f_+^{D\to\pi}(0)|V_{cd}|$ & LFU
- Scalar current contribution also measured for the first time

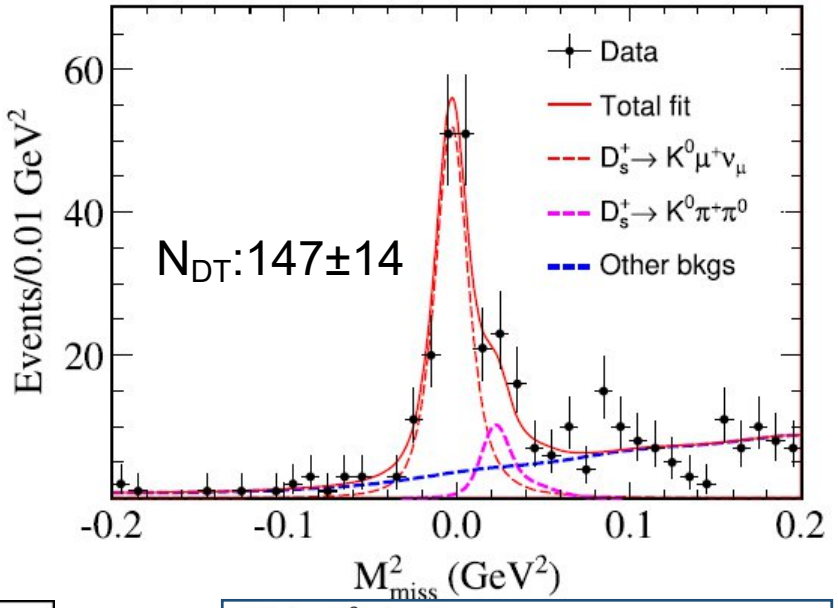


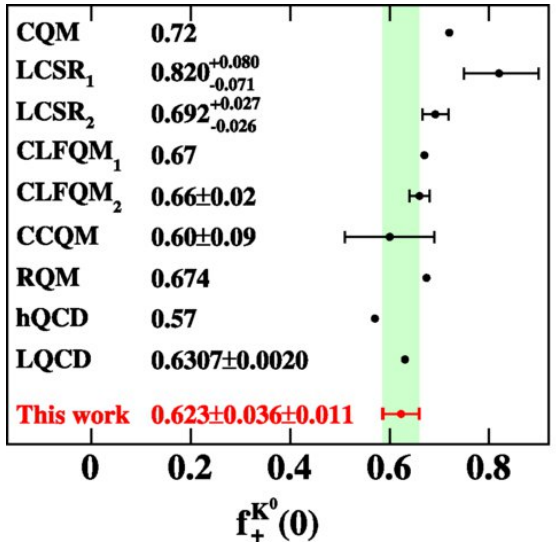


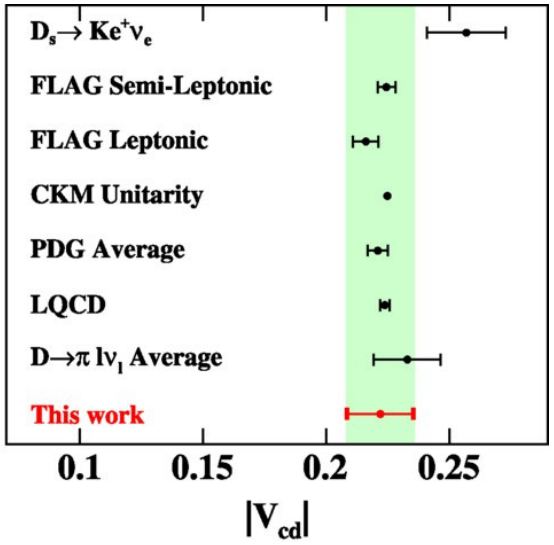
PRL 136 (2026) 161802

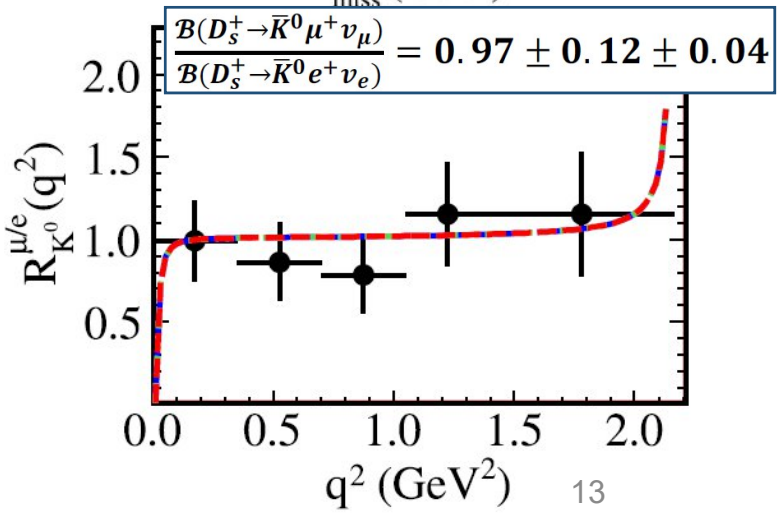
$D_s^+ \to K^0 \mu^+ \nu_\mu$: first measurement

- 7.33 fb^{-1} @ 4.128-4.226 GeV
- BF measured for the first time
- Simultaneous fits in bins of q^2 for both muon and electron channels lead to improved results on $f_+^{K^0}(0)$ & first LFU test







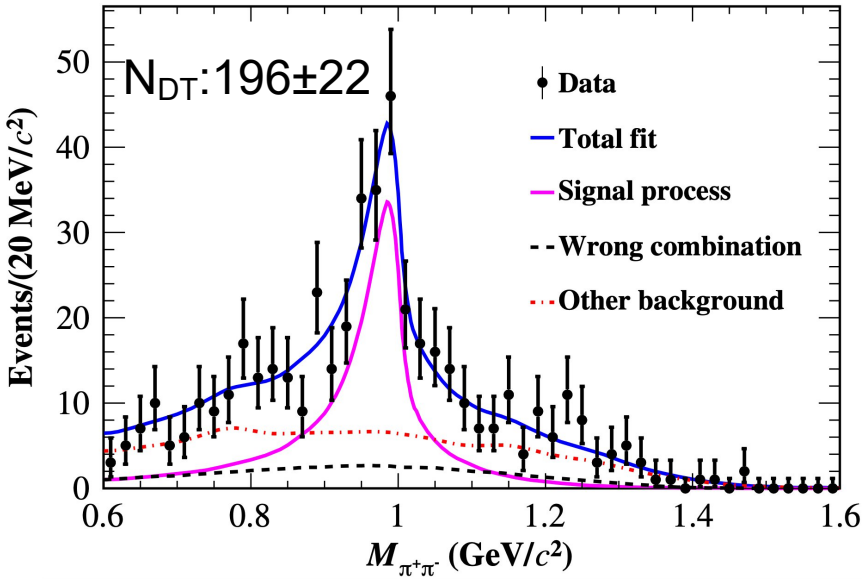


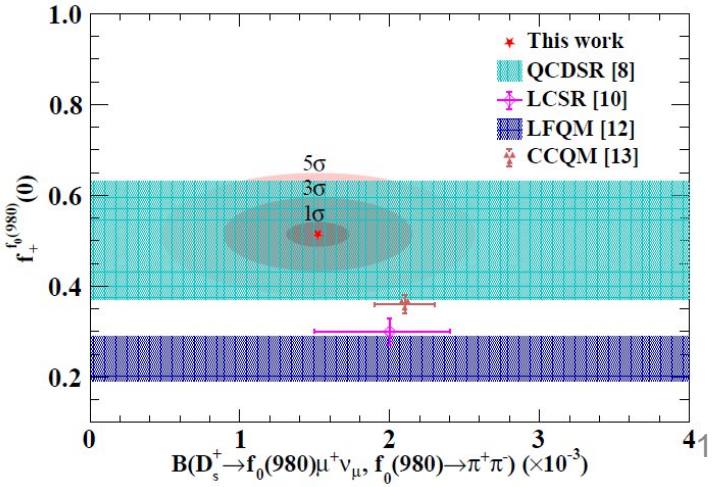
arXiv:2609.15655

$D_s^+ \to f_0(980)\,\mu^+\nu_\mu$: first measurement

- 7.33 fb^{-1} @ 4.128-4.226 GeV
- Requiring $f_0(980) \to \pi^+\pi^-$
- BF measured for the first time
- Simultaneous fits in bins of q^2 for both muon and electron channels lead to improved results on $f_+^{f_0(980)}(0)$ & first LFU test:

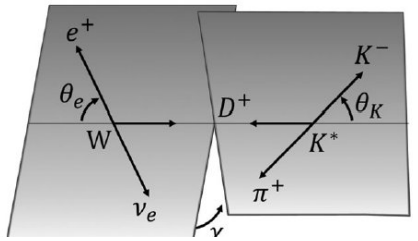
$$\frac{\mathcal{B}(D_s^+ \to f_0(980)\mu^+\nu_\mu)}{\mathcal{B}(D_s^+ \to f_0(980)e^+\nu_e)} = 0.92 \pm 0.13 \pm 0.08$$



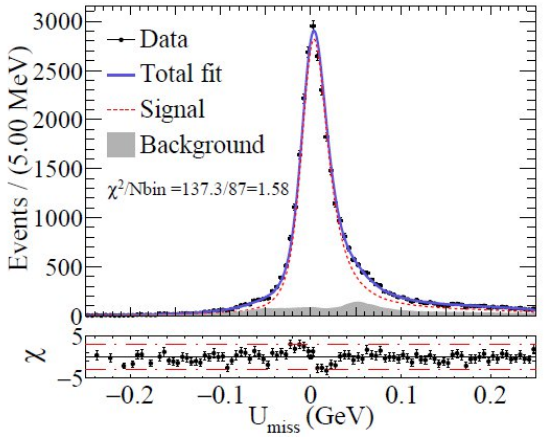


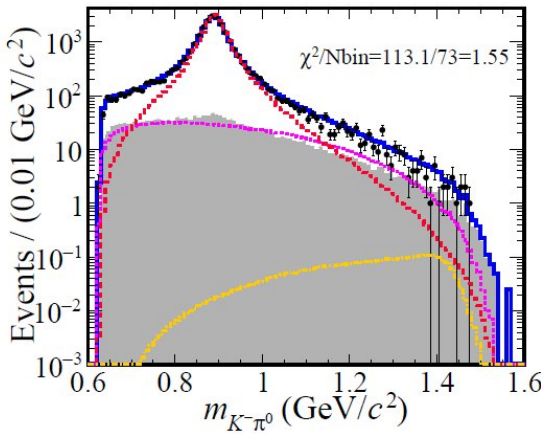
arXiv:2603.00743
arXiv:2603.04136

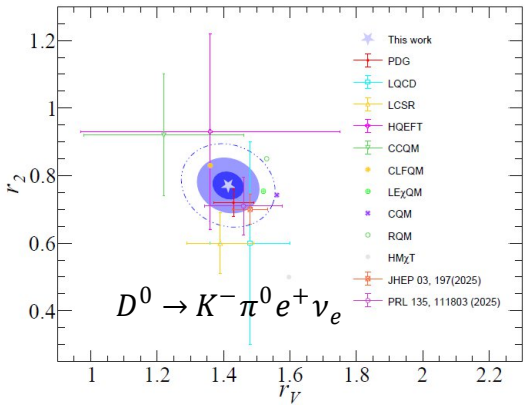
$D^0 \to K^-\pi^0 e^+\nu_e$ & $D^0 \to \overline{K}^0\pi^-\ell^+\nu_\ell$

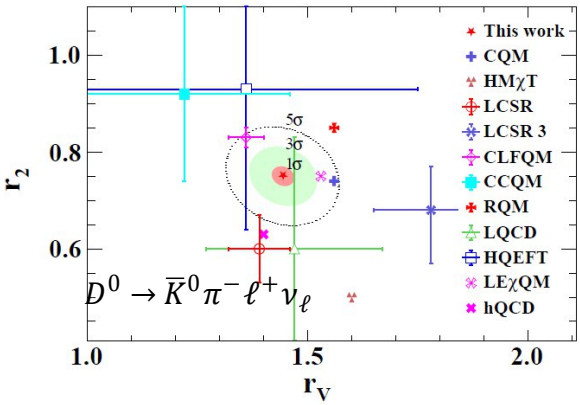


- Using 20.3 fb^{-1} $\psi(3770)$ dataset
- Amplitude analyses to decomposite $K\pi$ system
- D-wave $K_2^*(1430)^-$: first observations
- Form factors for dominant $K^*(892)^-$ contribution measured with improved precision
- Also improved knowledge of $K\pi$ S-wave using MI approach









PRL 136 (2026) 021801

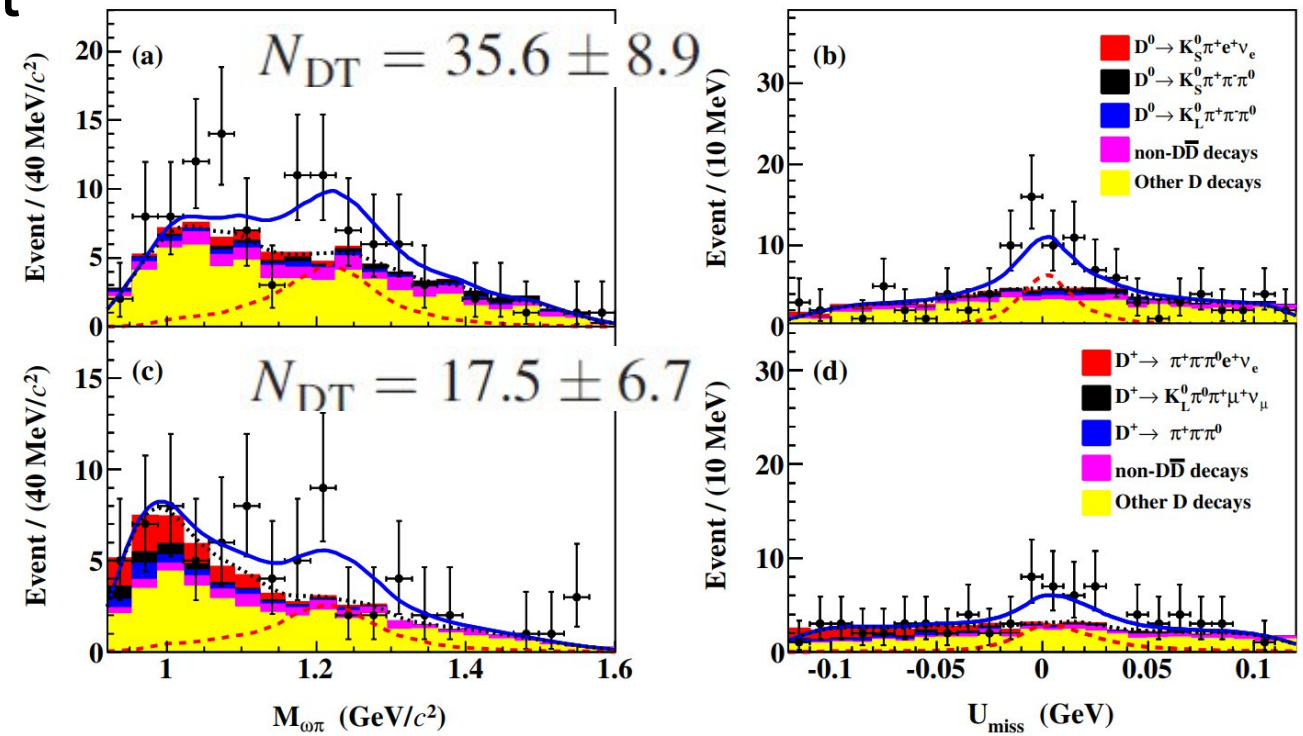
$D \to b_1(1235)\, e^+\nu_e$: first searches

- Using 7.9 fb^{-1} $\psi(3770)$ dataset
- First observation:

$$B\left(D^0 \to b_1^- e^+ \nu_e\right) \times B\left(b_1^- \to \omega\pi^-\right) = (0.72 \pm 0.18^{+0.06}_{-0.08}) \times 10^{-4}$$

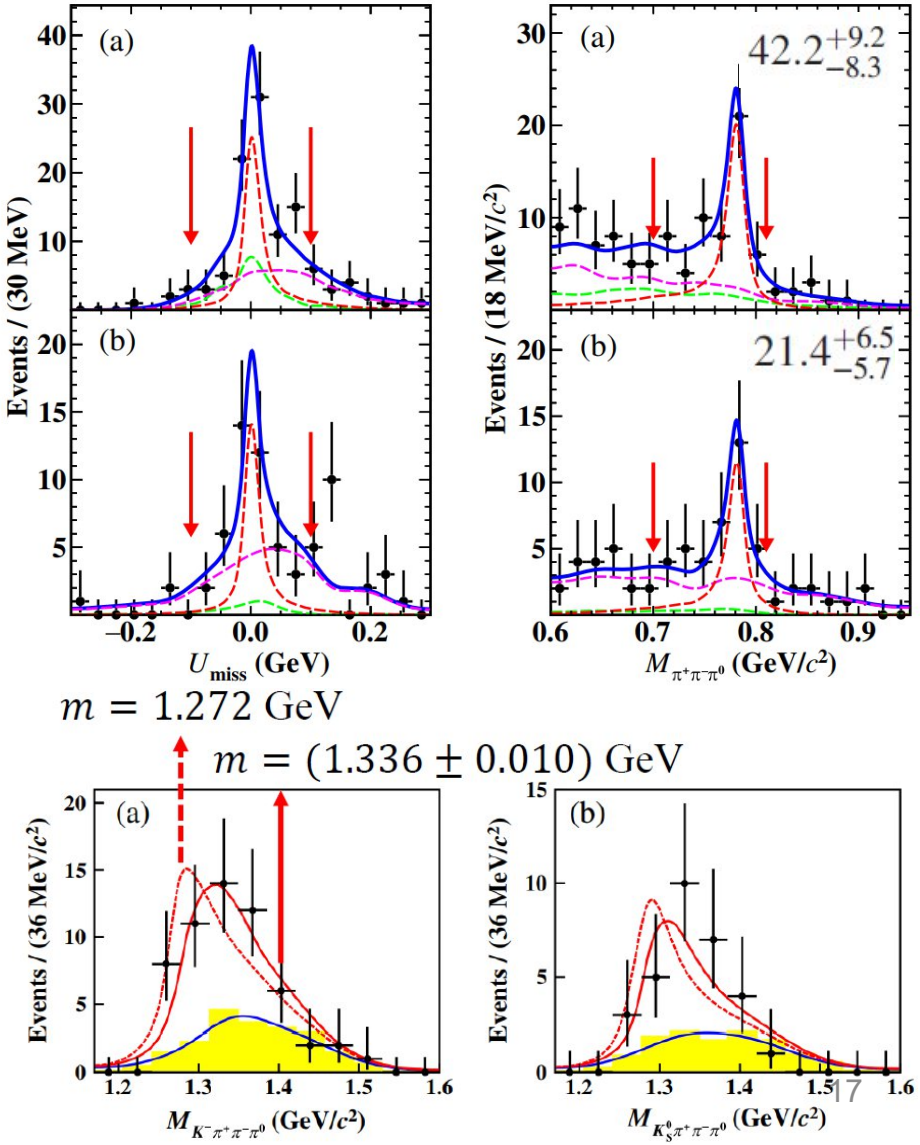
- First evidence:

$$B\left(D^+ \to b_1^0 e^+ \nu_e\right) \times B\left(b_1^0 \to \omega\pi^0\right) = (1.16 \pm 0.44 \pm 0.16) \times 10^{-4}$$



$D \to \overline{K}_1(1270)(\to \overline{K}\omega)e^+\nu_e$: first study

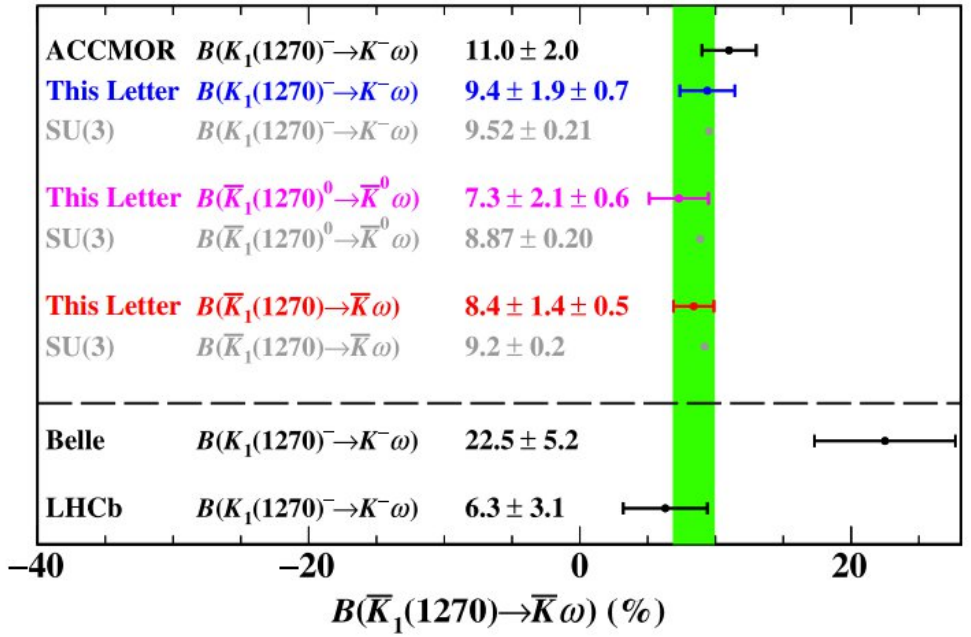
- Using 20.3 fb^{-1} $\psi(3770)$ dataset
- First study of $K_1(1270) \to K\omega$
- $K_1(1270)$ two-pole structure favored

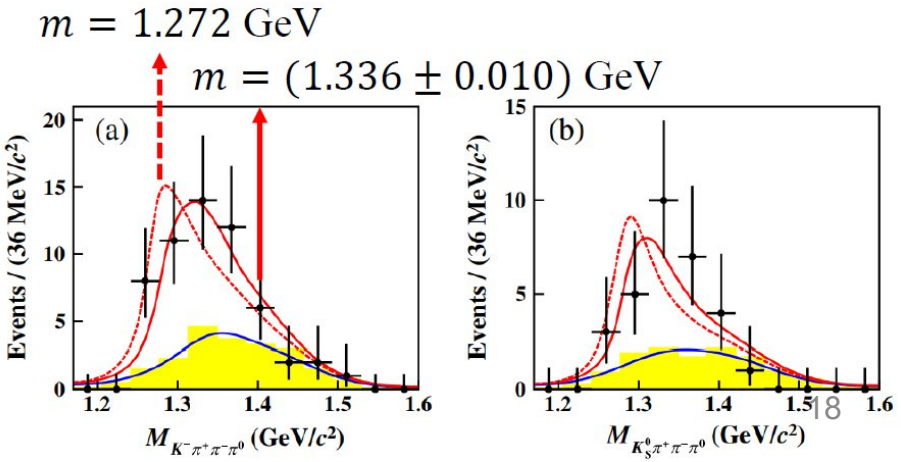


PRL 137 (2026) 091802

$D \to \overline{K}_1(1270)(\to \overline{K}\omega)e^+\nu_e$: first study

- Using 20.3 fb^{-1} $\psi(3770)$ dataset
- First study of $K_1(1270) \to K\omega$
- $K_1(1270)$ two-pole structure favored
- First direct measurement of $K_1(1270) \to K\omega$ BFs
  - Towards a complete & precise picture of $K_1(1270)$ decays





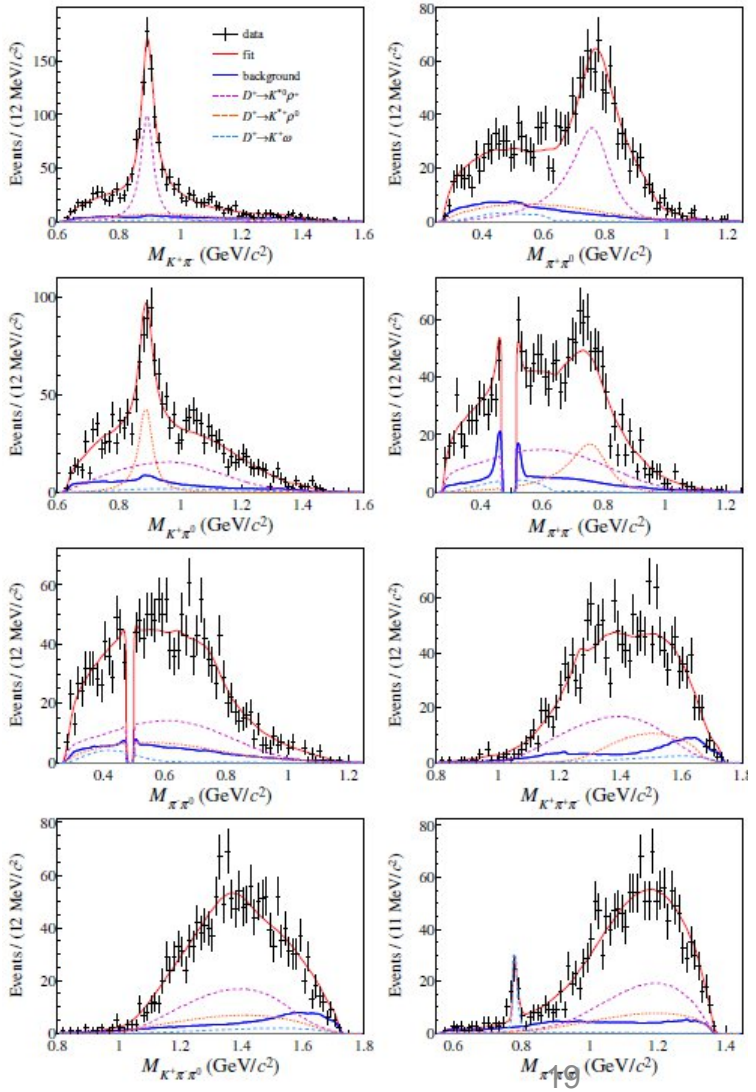
arXiv:2610.05261

$D^+ \to K^+\pi^+\pi^-\pi^0$: first amplitude analysis

- Using 20.3 fb^{-1} $\psi(3770)$ dataset
- DCS decay, sensitive to SU(3) symmetry breaking effects
- 1739 DT events with purity ~86% selected
- Large transverse polarizations in $D \to VV$ decays:

$$F_L\left(D^+ \to K^{*0}\rho^+\right) = 0.111 \pm 0.024 \pm 0.008$$

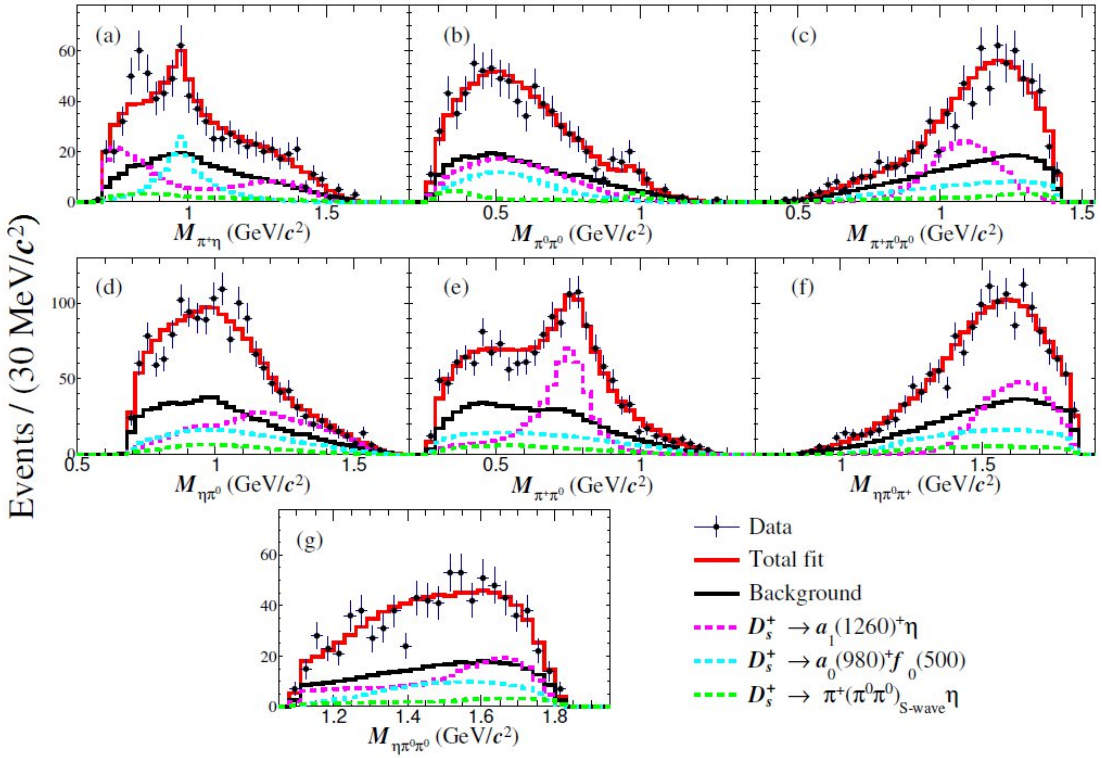
$$F_L\left(D^+ \to K^{*+}\rho^0\right) = 0.263 \pm 0.049 \pm 0.015$$



arXiv:2603.18521

$D_s^+ \to \pi^+\pi^0\pi^0\eta$: observation of $D \to SS$

- 7.33 fb^{-1} @ 4.128-4.226 GeV
- 821 DT events with purity ~58% selected
- First amplitude analysis yield unexpected large contribution of $a_0(980)^+ f_0(500)$
- Important input to understand nature of $a_0(980)^+$

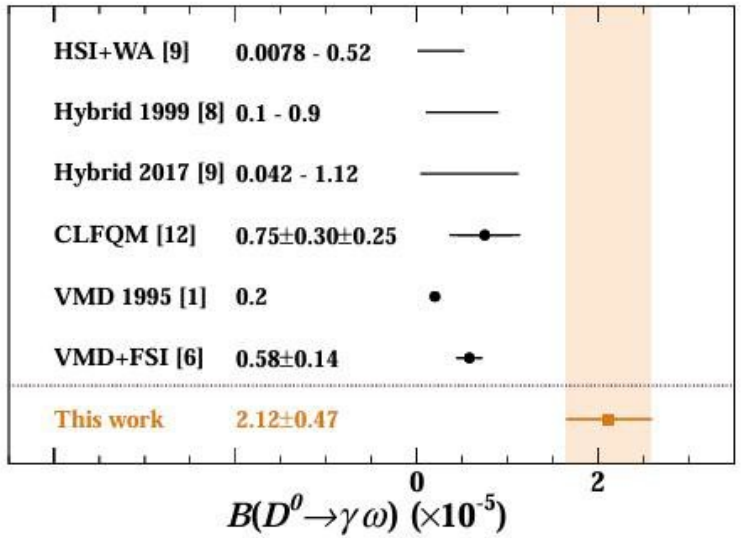


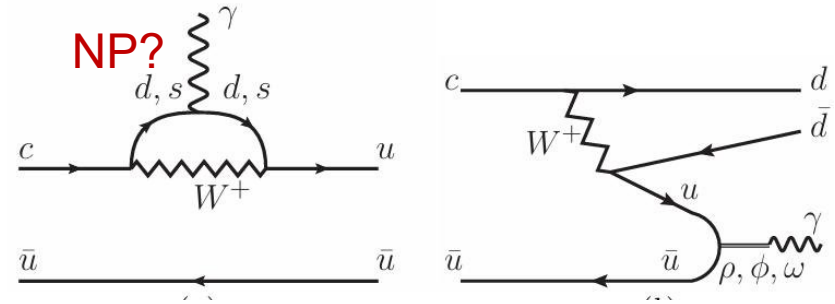
Amplitude	Phase (rad)	FF (%)	BF (%)	Significance
$D_s^+ \to a_1(1260)^+\eta, a_1(1260)^+ \to \rho(770)^+\pi^0$	0.0 (fixed)	$59.7 \pm 5.2 \pm 2.9$	$1.77 \pm 0.21 \pm 0.12$	$> 10\sigma$
$D_s^+ \to a_0(980)^+ f_0(500)$	$2.8 \pm 0.2 \pm 0.3$	$33.1 \pm 4.9 \pm 6.8$	$0.98 \pm 0.16 \pm 0.22$	$> 10\sigma$
$D_s^+ \to \pi^+(\pi^0\pi^0)_{\mathcal{S}-\text{wave}}\eta$	$-0.8 \pm 0.2 \pm 0.3$	$9.4 \pm 1.9 \pm 4.1$	$0.28 \pm 0.06 \pm 0.13$	4.5σ

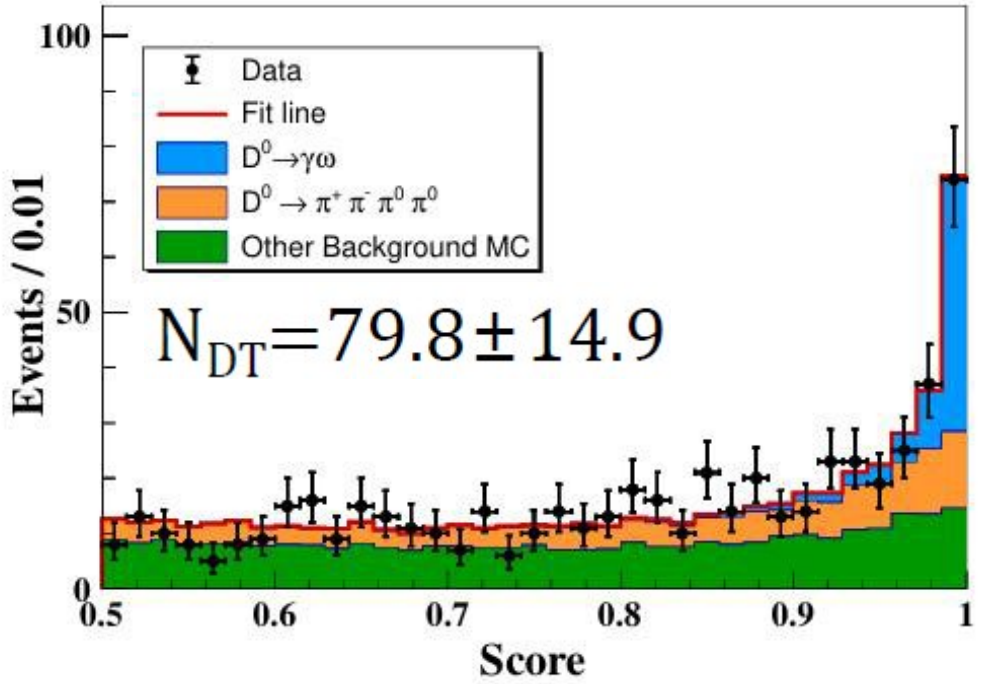
arXiv:2610.21982

Observation of $D^0 \to \omega\gamma$

- Using 20.3 fb^{-1} $\psi(3770)$ dataset
- 1D fit to DNN score distribution for signal extraction
- First observation with 6.0σ significance
- Measured BF compared to predictions:



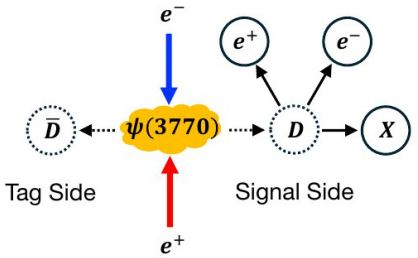


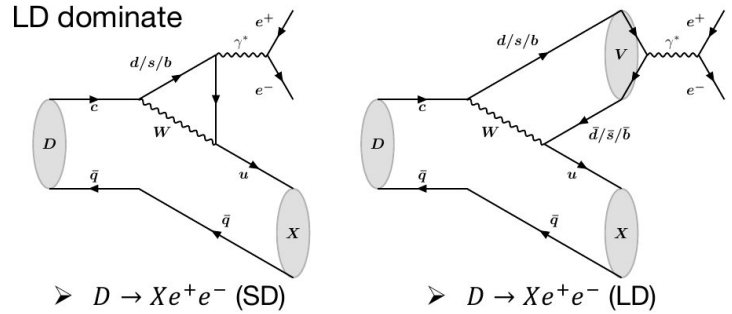


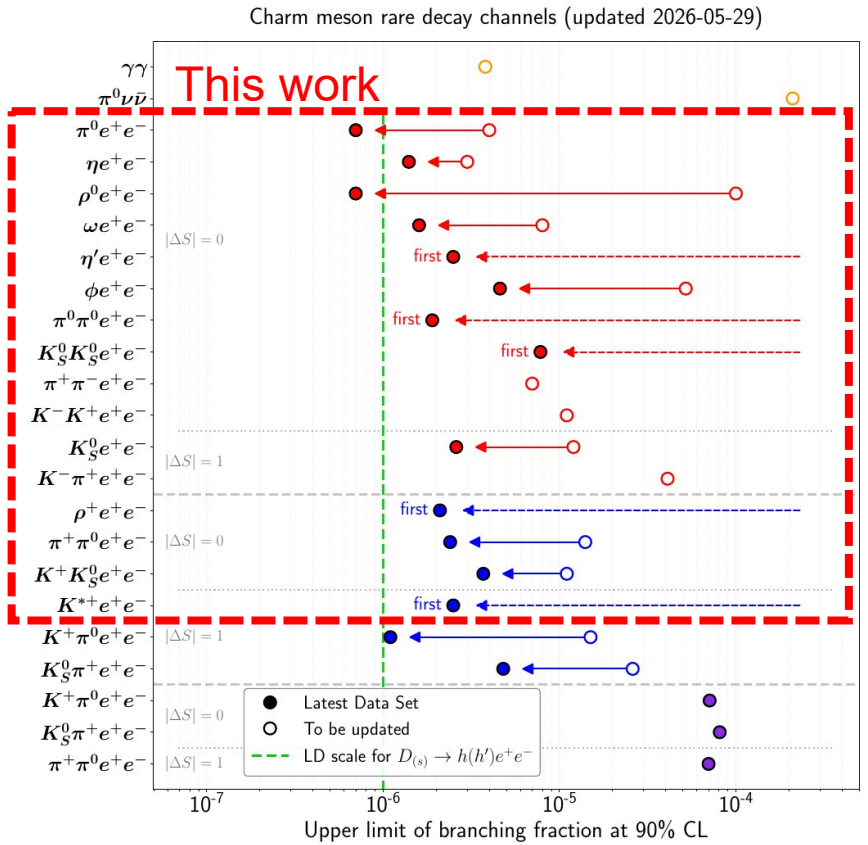
PRD 113 (2026) 092010

Search for $D \to h(h^{(\prime)})e^+e^-$

- FCNC $c \to ue^+e^-$ process highly suppressed in SM
- Dominated by LD effects (VMD)
- Using 20.3 fb^{-1} $\psi(3770)$ dataset
- DT method
  - $\overline{D}^0$: ~16 M tagged in 3 modes
  - D^-:~11 M tagged in 6 modes
- Upper limits at 10^{-6}-10^{-7} level are set for 16 rare decays, with many being the first





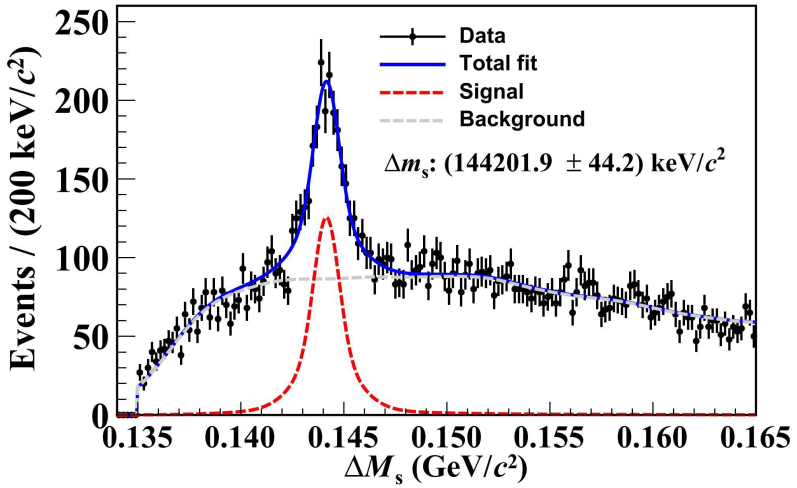


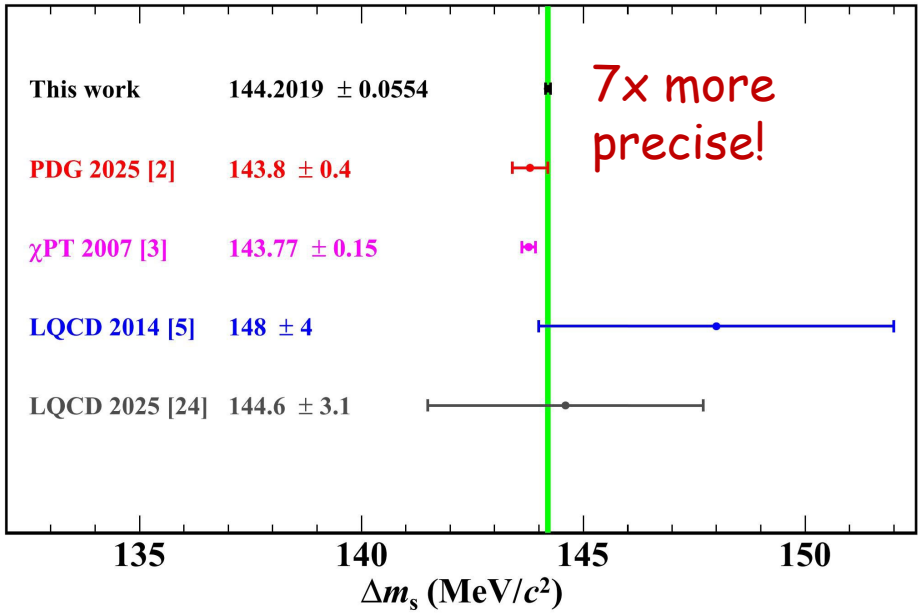
Sci. Bul. 71 (2026) 2675

Precise D_s^{*+} mass measurement

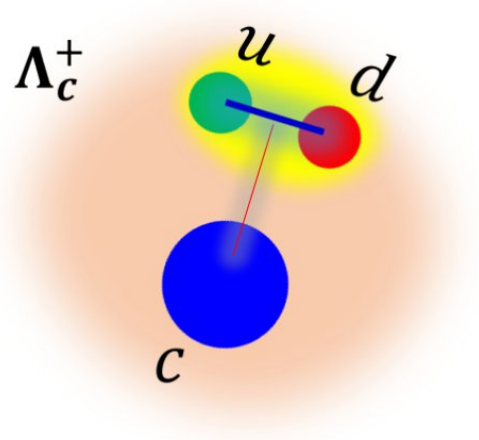
- 3.19 fb^{-1} @ 4.178 GeV
- Measuring $D_s^{*+} - D_s^+$ mass split using decay $D_s^{*+} \to D_s^+(\to K^+K^+\pi^-)\pi^0$
- Momentum of π^0 calibrated using $D^{*+} \to D^+(\to K^-\pi^+\pi^+)\pi^0$ and validated with $D^{*+} \to D^+(\to K^+K^+\pi^-)\pi^0$
- The π^0 calibration method could lead to vastly improved mass measurements for $D_{s0}^+(2317), D_{s1}^+(2460), \Xi^0$,...

Great potentials for precise (sub-100 keV) mass measurements @ BESIII!

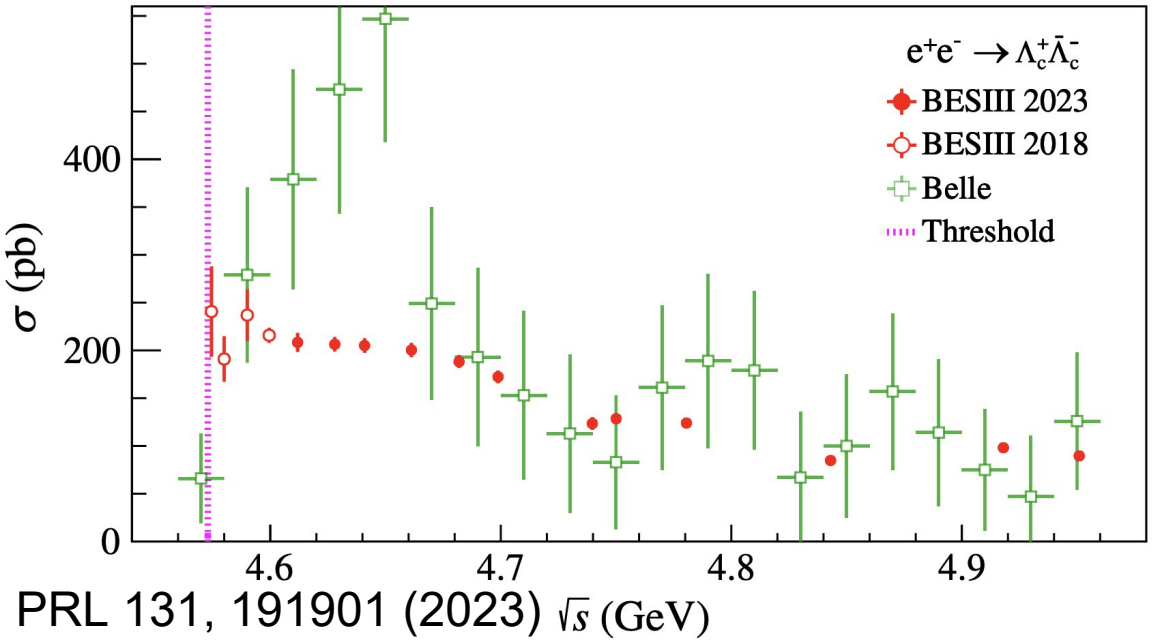




Physics on Λ_c^+



- Dedicated $\Lambda_c^+\bar{\Lambda}_c^-$ samples
  - Total 6.4 fb^{-1} @ 4.6-4.95 GeV
  - About 1M pairs



PRL 131, 191901 (2023)

Sample	$E_{\rm cms}$/MeV	$\mathscr{L}_{\rm Bhabha}$/pb^{-1}
4610	4611.86±0.12±0.30	103.65±0.05±0.55
4620	4628.00±0.06±0.32	521.53±0.11±2.76
4640	4640.91±0.06±0.38	551.65±0.12±2.92
4660	4661.24±0.06±0.29	529.43±0.12±2.81
4680	4681.92±0.08±0.29	1667.39±0.21±8.84
4700	4698.82±0.10±0.36	535.54±0.12±2.84
4740	4739.70±0.20±0.30	163.87±0.07±0.87
4750	4750.05±0.12±0.29	366.55±0.10±1.94
4780	4780.54±0.12±0.30	511.47±0.12±2.71
4840	4843.07±0.20±0.31	525.16±0.12±2.78
4920	4918.02±0.34±0.34	207.82±0.08±1.10
4950	4950.93±0.36±0.38	159.28±0.07±0.84

CPC 46, 113003 (2022)

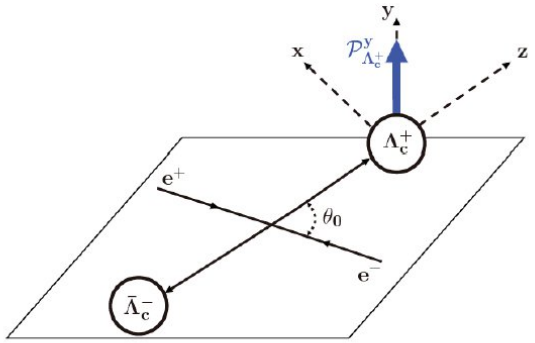
Λ_c^+ transverse polarization in $e^+e^- \to \Lambda_c^+\bar{\Lambda}_c^-$

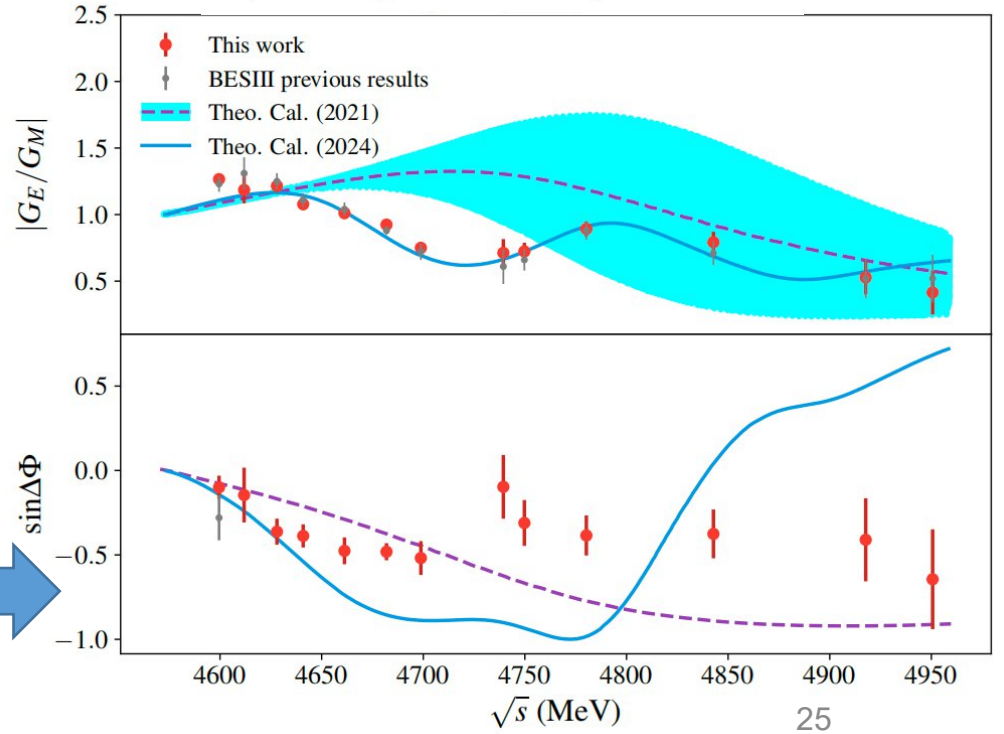
- $e^+e^- \to \Lambda_c^+\bar{\Lambda}_c^-$ process dominated by single photon exchange
- Λ_c^+ transverse polarization depending on nonzero EMFFs difference:

$$\mathcal{P}^{y}_{\Lambda_c^+}(\cos\theta_0) = \frac{3}{2(3+\alpha_0)}\sqrt{1-\alpha_0^2}\sin\theta_0\cos\theta_0\sin\Delta\Phi,$$

α_0 depends on $|G_E/G_M|$ $\quad$ $\Delta\Phi = \arg(G_M) - \arg(G_E)$

- First observation of Λ_c^+ transverse polarization
- Deviation of $\Delta\Phi$ from theoretical prediction
  - Improved understanding of EMFFs needed





$\Lambda_c^+ \to \Lambda X$: BF measurement & CPV search

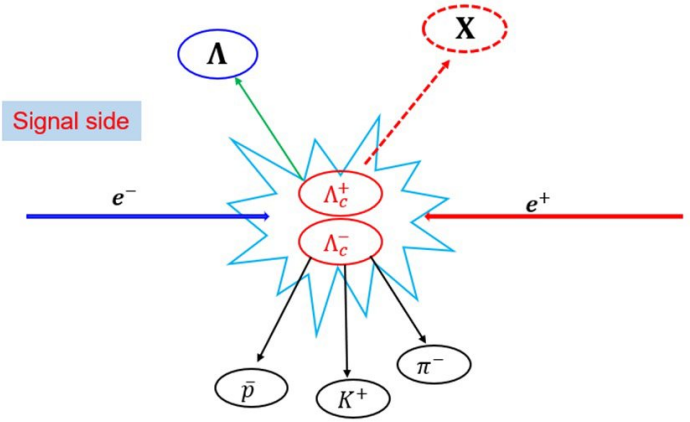
- BF measured with 4x precision improvement:

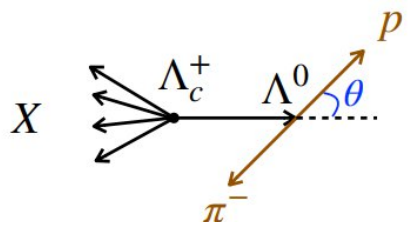
$$\mathcal{B}(\Lambda_c^+ \to \Lambda X) = (38.07 \pm 0.38 \pm 0.49)\%$$

  - About (6.71±1.25)% exclusive decays unaccounted for
- First measurement of Λ longitudinal polarization in inclusive Λ_c^+ decay:

$$\mathcal{A}_{\rm CP}^{\rm pol} \equiv (\mathcal{P}_\Lambda \alpha_- - \mathcal{P}_{\bar{\Lambda}} \alpha_+)/(\mathcal{P}_\Lambda \alpha_- + \mathcal{P}_{\bar{\Lambda}} \alpha_+)$$

  - No CPV found for A_{CP}^{dir} or A_{CP}^{pol}

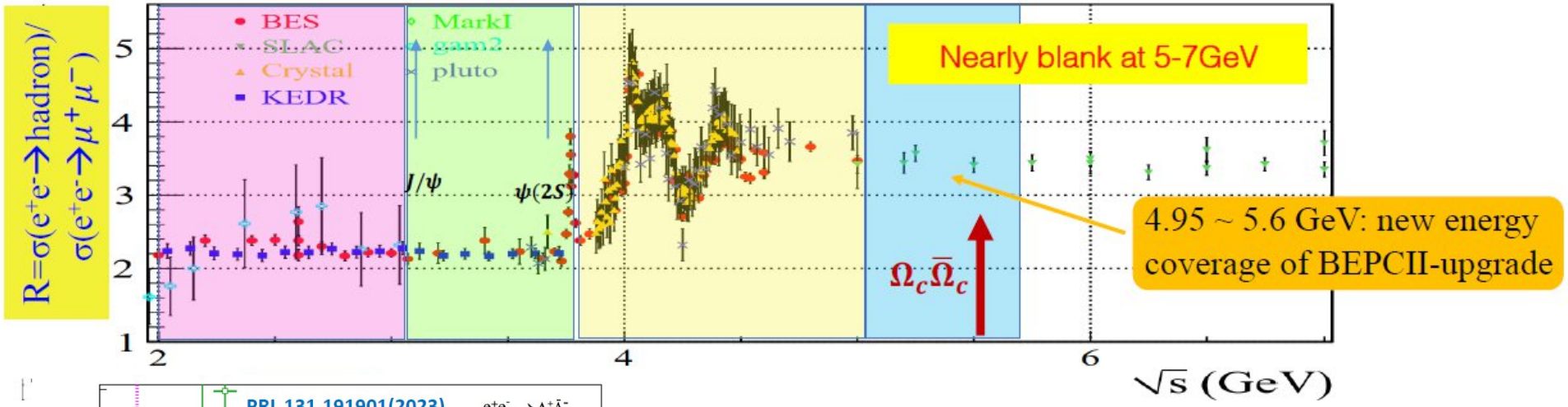


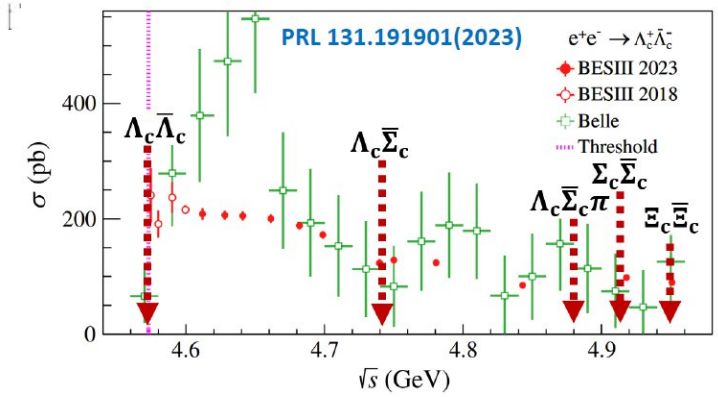


	Results
A_{CP}^{dir}	$(1.5 \pm 1.0 \pm 1.0)\%$
$\mathcal{P}$	$-0.393 \pm 0.055 \pm 0.020$
$\bar{\mathcal{P}}$	$0.288 \pm 0.056 \pm 0017$
A_{CP}^{pol}	$0.15 \pm 0.12 \pm 0.03$

The BEPCII upgrade

- Optimized E_{cm} at 4.7 GeV with luminosity 3 times higher than the current BEPCII





- A new round of Λ_c^+ data-taking @ 4.68 GeV in 2026
- Opportunities for heavier charm baryons lie ahead

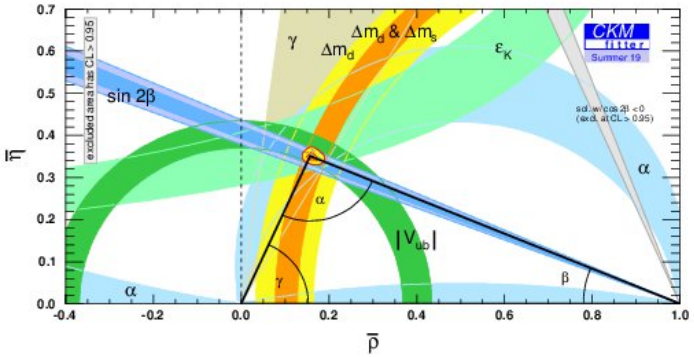
Summary

- BESIII has world's largest near-threshold charm hadron samples
- Playing dominating roles in various aspects of charm physics
  - Strong phases, (semi)leptonic decays, inclusive decays, ...
- BESIII is entering precision era:
  - CKM matrix elements (γ, $\mathrm{V}_{cs(d)}$), FFs, $R_{\mu/e}$, angular asymmetries, masses, ...
- New technologies: machine learning, generic D tag method, ...
- Not covered today: studies on light hadrons with $\mathrm{c\bar{c}}$ datasets
- New data on the way: higher energies, more statistics

Backup Slides

LHCb-PUB-2016-025
October 11, 2016

$$V_{\mathrm{CKM}} \propto \begin{pmatrix} |V_{ud}| & |V_{us}| & |V_{ub}|\, e^{-i\gamma} \\ -|V_{cd}| & |V_{cs}| & |V_{cb}| \\ |V_{td}|\, e^{-i\beta} & -|V_{ts}|\, e^{-i\beta_s} & |V_{tb}| \end{pmatrix}$$



Synergy of BESIII and LHCb physics programmes

LHCb Collaboration

Abstract

There is potential for BESIII open-charm measurements to have a significant impact on the LHCb physics programme. Despite the general purpose design of the LHCb detector there are certain inputs that can be better determined in other environments or in production mechanisms not accessible at the LHC. With the unprecedented amount of LHCb data that will become available over the one-to-two decades it is necessary to consider where additional inputs are essential, to avoid the situation where the uncertainty on a measurement is dominated by the lack of knowledge of an external input. This document considers the capabilities of the BESIII experiment to provide vital inputs into key LHCb measurements. A number of different potential measurements that could be pursued are discussed.

LHCb-PUB-2016-025
11/10/2016

b physics programmes that are most
ted at BESIII. The first is composed
) mesons, whose knowledge is vital
for a high precision measurement of the CKM angle γ. The use of existing CLEO-c measurements has allowed LHCb to include a wide range of D modes in its determination of the CKM angle γ using $B \to DK$ decays, which together have made possible the currently achieved precision on this fundamental parameter of 8° [1]. These CLEO-c measurements themselves contribute an uncertainty of approximately 2° which, while small compared to the current statistical uncertainties, will soon become dominant as the LHCb rate of data collection increases.

The $\Psi(3770)$ data already accumulated by the BESIII experiment are sufficient to bring the contribution from strong-phase uncertainties to approximately 1°. The goal of the LHCb phase-1 upgrade, due to start collecting data in 2021, is to measure γ with a precision of 1°, which will approximately match the uncertainty on this parameter from indirect constraints from other measurements. Therefore it would be most desirable to have strong-phase measurements from an even larger dataset so that the uncertainty from external inputs does not become dominant. For this reason the existing plan to take another 15-20 fb^{-1} at this resonance would be very important and is highly encouraged. With this amount of data, the strong-phase contribution to the uncertainty on γ will remain sub-dominant throughout the physics programme of the approved LHCb phase-1 upgrade. Plans are also being formulated for a second, phase-2 upgrade, which would accumulate a much larger data set. In this case the input from a 15-20 fb^{-1} $\Psi(3770)$ sample would be essential.

Input from 20.3 fb^{-1} ψ(3770) BESIII data essential to match with new LHCb data for improved CKM γ measurements