

Studying $K_1(1270)$ in Semileptonic D decays

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Outline

- Motivation
- Experimental details on BESIII
- BESIII studies on
 - Observations of $D^+ \rightarrow K_1^- (\rightarrow K^- \pi^+ \pi^0) e^+ \nu_e K^-$ & $D^0 \rightarrow \bar{K}_1^0 (\rightarrow K^- \pi^+ \pi^-) e^+ \nu_e$
 - Decay dynamics in $D^{0,+} \rightarrow \bar{K}_1 (\rightarrow K^- \pi^+ \pi^{-,0}) e^+ \nu_e$
 - Observations of $D^{0,+} \rightarrow \bar{K}_1 (\rightarrow K_S^0 \pi^- \pi^{0,+}) e^+ \nu_e$
 - Observation of $D^{0,+} \rightarrow \bar{K}_1 (\rightarrow \bar{K} \omega) e^+ \nu_e$
- Prospects in BESIII & other experiments:
 - A_{UD} of $D^0 \rightarrow \bar{K}_1^0 (\rightarrow K^- \pi^+ \pi^-) \mu^+ \nu_\mu$ @ LHCb
 - A_{UD} of $D^0 \rightarrow \bar{K}_1^0 (\rightarrow K^- \pi^+ \pi^-) \mu^+ \nu_\mu$ @ STCF
 - Decay dynamics in $D^{0,+} \rightarrow \bar{K}_1 (\rightarrow K \pi \pi) e^+ \nu_e$: a novel method
- Summary & outlook

$K_1(1270)$

$$I(J^P) = \frac{1}{2}(1^+)$$

Mass $m = 1253 \pm 7$ MeV ($S = 2.2$)

Full width $\Gamma = 90 \pm 20$ MeV ^[1]

$K_1(1270)$ DECAY MODES	Fraction (Γ_i/Γ)	Scale factor	ρ (MeV/c)
$K \rho$	(38 \pm 13) %	2.2	†
$K_0^*(1430) \pi$	(28 \pm 4) %		†
$K^*(892) \pi$	(21 \pm 10) %	2.2	286
$K \omega$	(11.0 \pm 2.0) %		†
$K f_0(1370)$	(3.0 \pm 2.0) %		†
γK^0	seen		528

PRL 123 (2019) 231801

PRL 127(2021) 131801

PRL 135 (2025) 091801

JHEP 09 (2024) 089

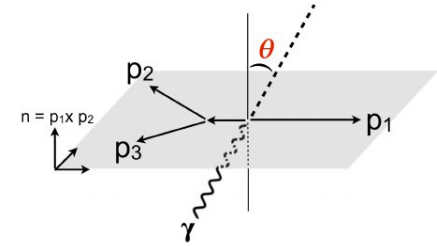
arXiv:2601.01817

PRD 104 (2021) 053003

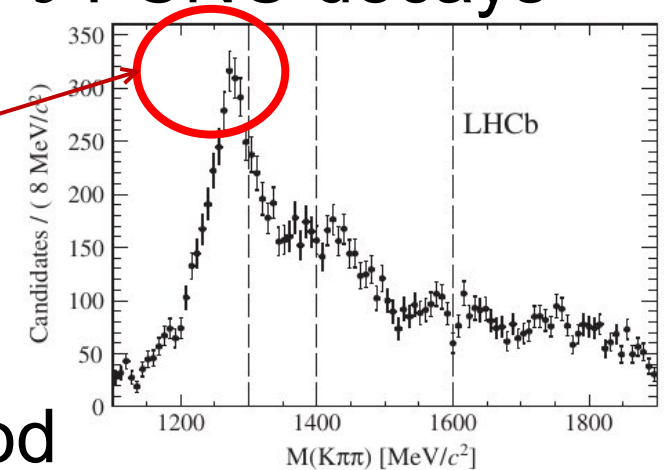
EPJC 81 (2021) 1068

arXiv:2604.00859

Why studying $K_1(1270)$



- Providing rich dynamics in search for NP in $b \rightarrow s$ FCNC decays such as $B \rightarrow K_1 \gamma$ and $B \rightarrow K_1 \ell^+ \ell^-$
 - Observation of up-down asymmetry A_{UD} in $K_1(1270)$ enhanced region in $B^+ \rightarrow K^+ \pi^- \pi^+ \gamma$ decay
[PRL 112 (2014) 161801]
- Inner structure of $K_1(1270)$ still poorly understood
 - Mixing with $K_1(1400)$
 - Double-pole structure from VP interactions?
- Decay modes of $K_1(1270)$ are also poorly known

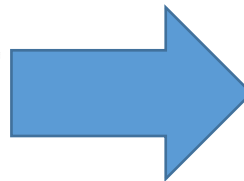


Details of $K_1(1270)$ decay modes

- Over the years, we are even less sure of the decay rates...

Belle2011 vs PDG08 [PRD 83, 032005 (2011)]

$K_1(1270)$ Decay mode	PDG	Branching fraction (%)	
		Fit 1	Fit 2
$K\rho$	42 ± 6	57.3 ± 3.5	58.4 ± 4.3
$K_0^*(1430)\pi$	28 ± 4	1.90 ± 0.66	2.01 ± 0.64
$K^*(892)\pi$	16 ± 5	26.0 ± 2.1	17.1 ± 2.3
$K\omega$	11 ± 2	14.8 ± 4.7	22.5 ± 5.2
$Kf_0(1370)$	3 ± 2	N/A	N/A



PDG2024

$K_1(1270)$ DECAY MODES

	Fraction (Γ_i/Γ)
$K\rho$	$(38 \pm 13) \%$
$K_0^*(1430)\pi$	$(28 \pm 4) \%$
$K^*(892)\pi$	$(21 \pm 10) \%$
$K\omega$	$(11.0 \pm 2.0) \%$
$Kf_0(1370)$	$(3.0 \pm 2.0) \%$
γK^0	seen

- Also inconsistencies between decades' old results from Kp reactions & newer results from collider-based experiments

Due to a recent BESIII measurement of $D_s^+ \rightarrow K^+ K^- \pi^+ \pi^0$

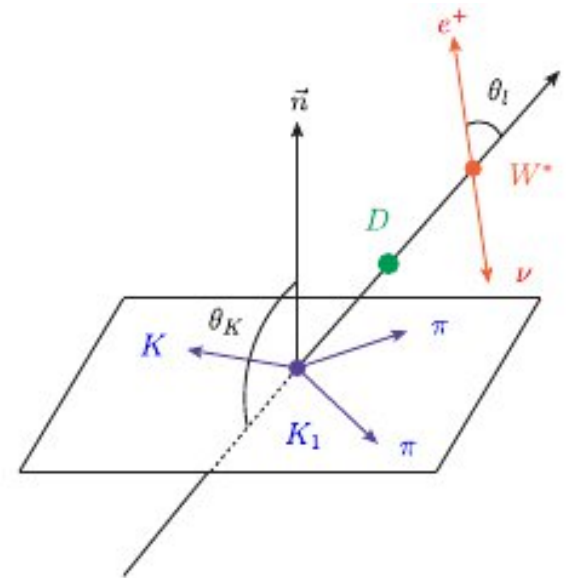
$\Gamma(K_1(1270) \rightarrow K^*(892)\pi) / \Gamma(K_1(1270) \rightarrow K\rho)$				Γ_3/Γ_1	-
VALUE	DOCUMENT ID	TECN	COMMENT		
0.56 ± 0.29	OUR FIT		Error includes scale factor of 2.2.		
$0.99 \pm 0.15 \pm 0.18$	ABLIKIM	2021U	BES3 $D_s^+ \rightarrow \bar{K}_1(1270)^0 K^+$		
References:					
ABLIKIM 2021U PR D104 032011 Amplitude analysis and branching fraction measurement of $D_s^+ \rightarrow K^- K^+ \pi^+ \pi^0$					

Why studying $K_1(1270)$ in SL D decays

- Free from interference from other non-K hadronic states, unlike in hadronic B/D decays & $B \rightarrow [c\bar{c}]K\pi\pi$ decays
- Almost free from contributions of non-resonant $K\pi\pi$ & $K_1(1400)$ in $D \rightarrow \bar{K}\pi\pi\ell^+\nu_\ell$ decays
- Extraction of $b \rightarrow s\gamma$ photon polarization in $B \rightarrow K_1\gamma$ in combination of $D \rightarrow \bar{K}_1e^+\nu_e$

[WW, FSY, ZXZ, PRL 125 (2020) 051802]

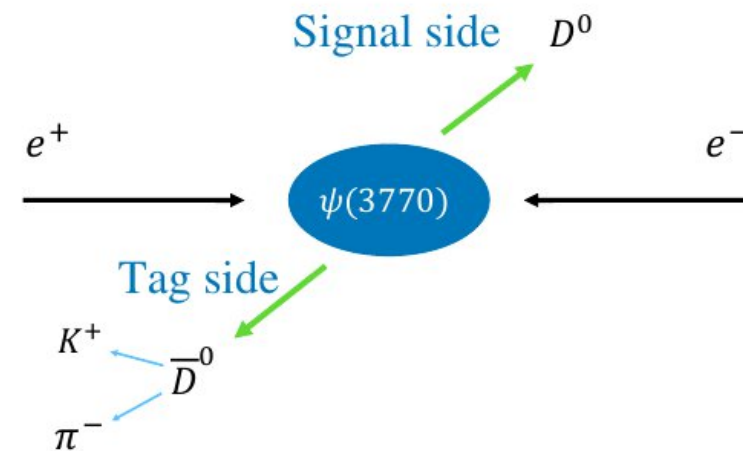
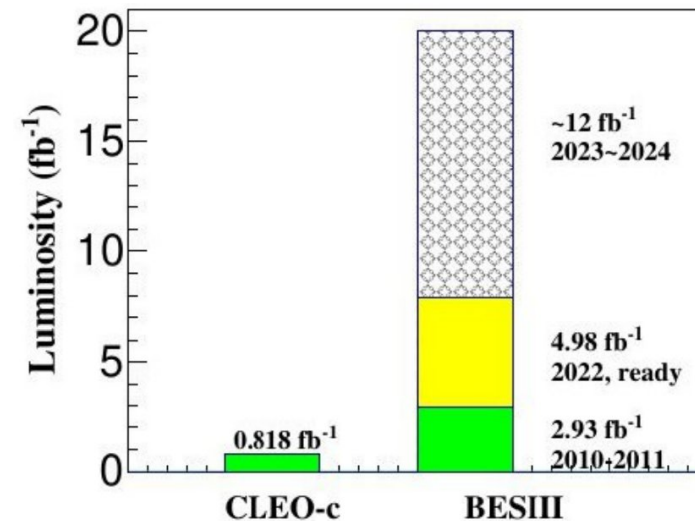
$$\mathcal{A}'_{\text{UD}} \equiv \frac{\Gamma_{K_1e\nu_e}[\cos\theta_K > 0] - \Gamma_{K_1e\nu_e}[\cos\theta_K < 0]}{\Gamma_{K_1e\nu_e}[\cos\theta_l > 0] - \Gamma_{K_1e\nu_e}[\cos\theta_l < 0]} \quad \lambda_\gamma = \frac{4}{3} \frac{\mathcal{A}_{\text{UD}}}{\mathcal{A}'_{\text{UD}}}$$



Why studying $K_1(1270)$ in BESIII?

- World's largest $\psi(3770) \rightarrow D\bar{D}$ sample
- Superb detector performance on charged electrons/pions/kaons, as well as π^0 s
- Double-tag method to infer kinematics of one single missing neutrino in the entire e^+e^- event
- Also measuring absolute BF using Double-tag method

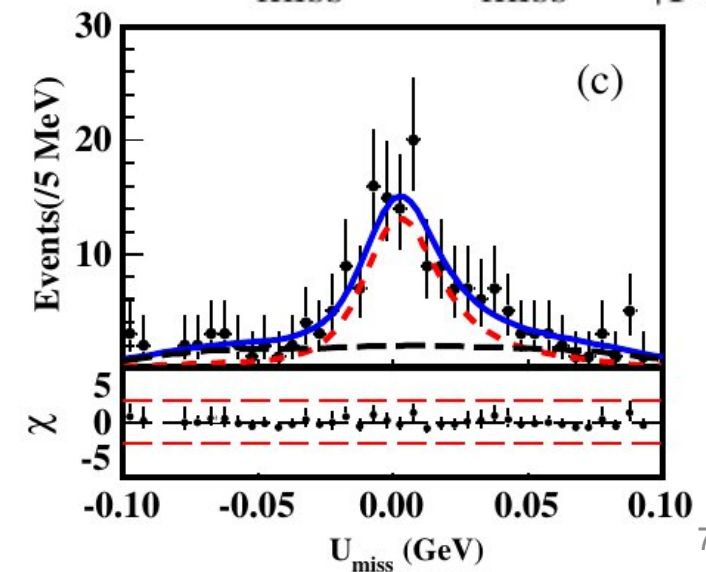
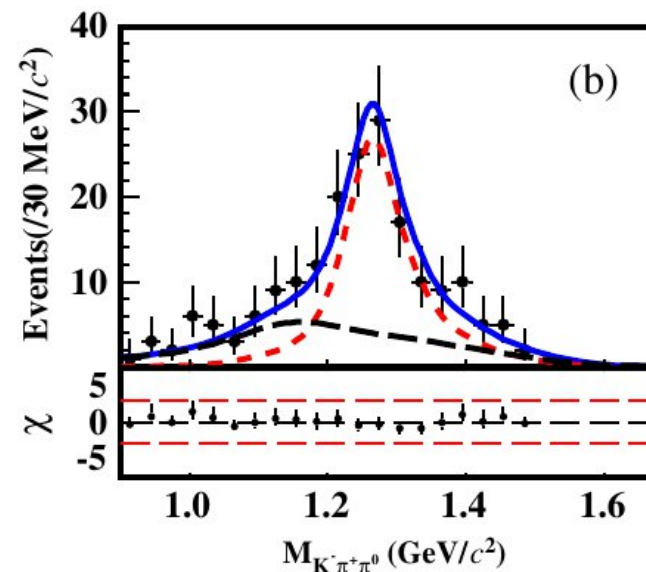
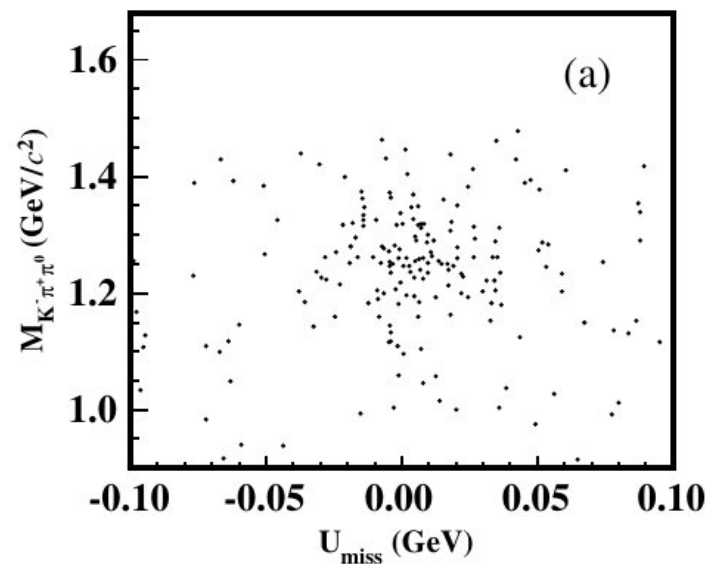
$$\mathcal{B}_{\text{sig}} = \frac{N_{\text{DT}}^{\text{sig}}}{N_{\text{ST}}^{\text{tot}} \bar{\epsilon}_{\text{sig}}}$$



The start: observation of $D^+ \rightarrow \bar{K}_1 \left(\rightarrow K^- \pi^+ \pi^0 \right) e^+ \nu_e K^-$

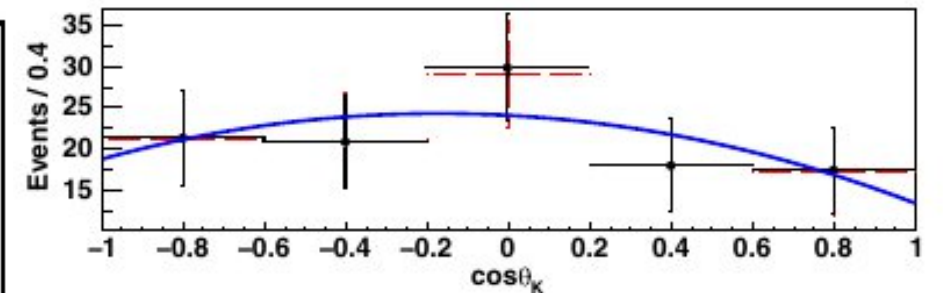
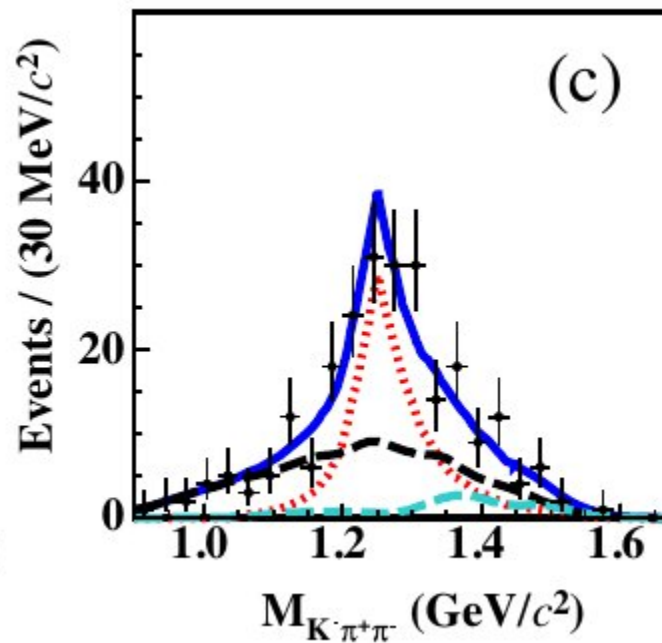
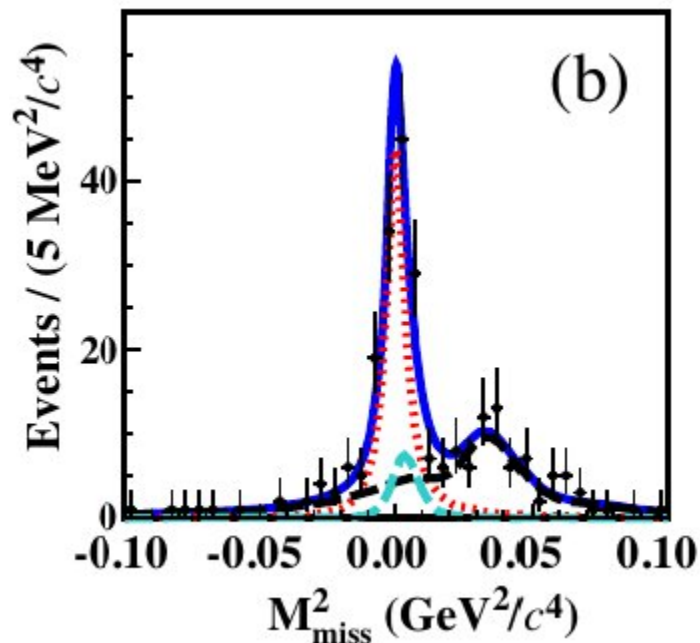
- Using $2.93 \text{ fb}^{-1} \psi(3770)$ data
- Double-tag method, six D^- tag modes
- First search, signal yield of 119.7 ± 13.3 with significance $>10\sigma$
- Branching fraction: $B(D^+ \rightarrow K_1^- e^+ \nu_e) = (2.30 \pm 0.26_{-0.21}^{+0.18} \pm 0.24) \times 10^{-3}$

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



Next: observation of $D^0 \rightarrow K_1^- (\rightarrow K^- \pi^+ \pi^-) e^+ \nu_e$ and more

- Using $2.93 \text{ fb}^{-1} \psi(3770)$ data
- Double-tag method, three \bar{D}^0 tag modes
- First observation, signal yield of 109.0 ± 12.5 with significance $>10\sigma$
- Branching fraction: $B(D^0 \rightarrow K_1^- e^+ \nu_e) = (1.09 \pm 0.26_{-0.21}^{+0.18} \pm 0.24) \times 10^{-3}$

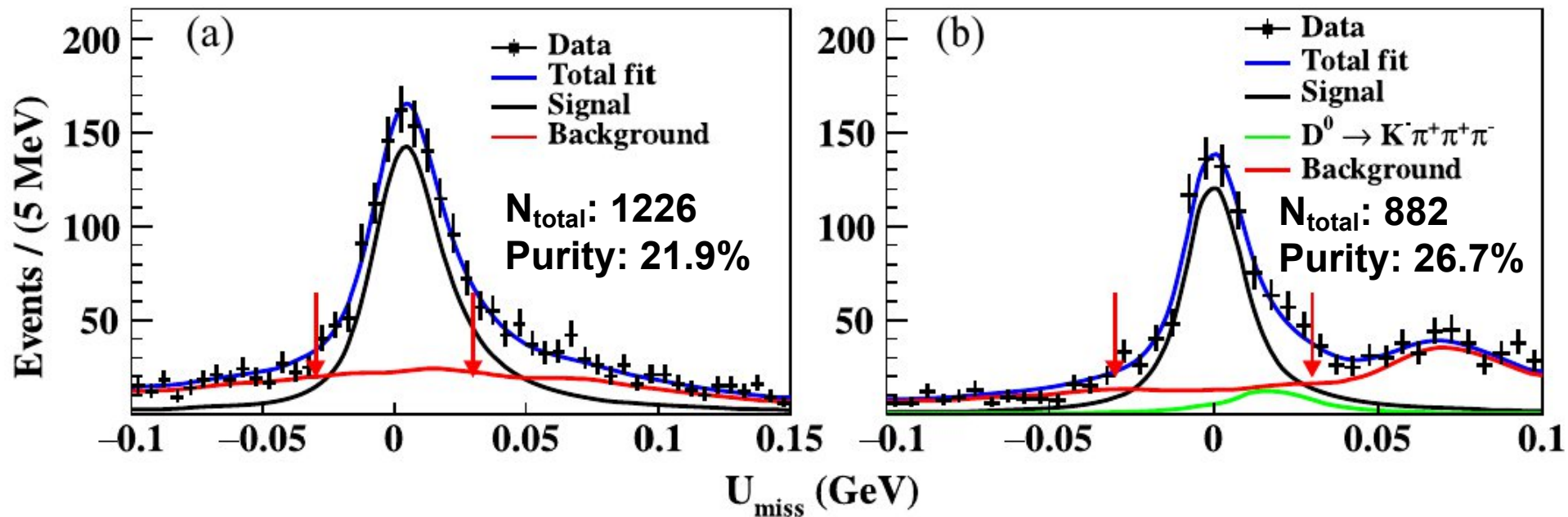


$$F_L = 0.50 \pm 0.17_{\text{stat}} \pm 0.08_{\text{syst}}$$

$$\frac{d\Gamma(D^0 \rightarrow K_1(1270)^- e^+ \nu_e)}{d \cos \theta_K} \propto 1 + k_1 \cos \theta_K + k_2 \cos^2 \theta_K,$$

Combined: decay dynamics in $D^{+,0} \rightarrow \bar{K}_1 \left(\rightarrow K^- \pi^+ \pi^{0,-} \right) e^+ \nu_e$

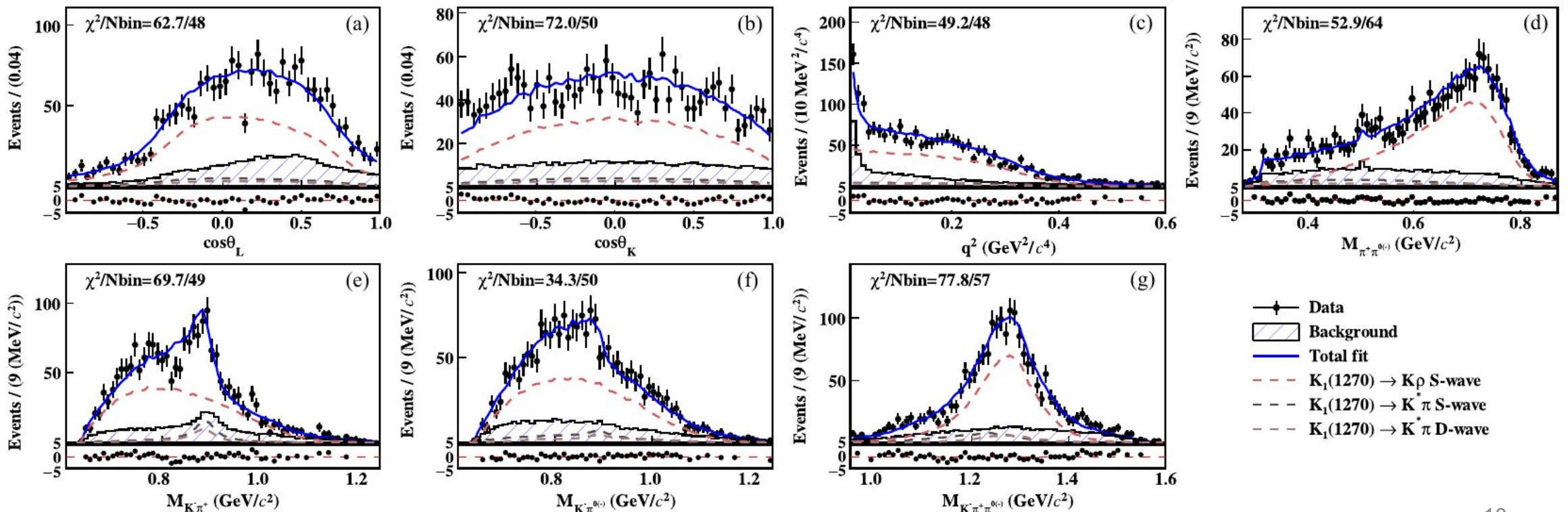
- Using 20.3 fb^{-1} $\psi(3770)$ data
- First amplitude analysis, within range $|\mathbf{U}_{\text{miss}}| < 0.03 \text{ GeV}$



Combined: decay dynamics in $D^{+,0} \rightarrow \bar{K}_1 \left(\rightarrow K^- \pi^+ \pi^{0,-} \right) e^+ \nu_e$

$$\ln \mathcal{L} = \sum_k^{N_{\text{data}}} \ln \left[(1 - \omega_{\text{bkg}}) \frac{|\mathcal{M}(p_j^k)|^2}{\int \epsilon(p_j) |\mathcal{M}(p_j)|^2 R_5(p_j) dp_j} + \omega_{\text{bkg}} \frac{B_\epsilon(p_j^k)}{\int \epsilon(p_j) B_\epsilon(p_j) R_5(p_j) dp_j} \right],$$

- Using $20.3 \text{ fb}^{-1} \psi(3770)$ data
- First amplitude analysis, within range $|\mathbf{U}_{\text{miss}}| < 0.03 \text{ GeV}$



Combined: decay dynamics in $D^{+,0} \rightarrow \bar{K}_1 \left(\rightarrow K^- \pi^+ \pi^{0,-} \right) e^+ \nu_e$

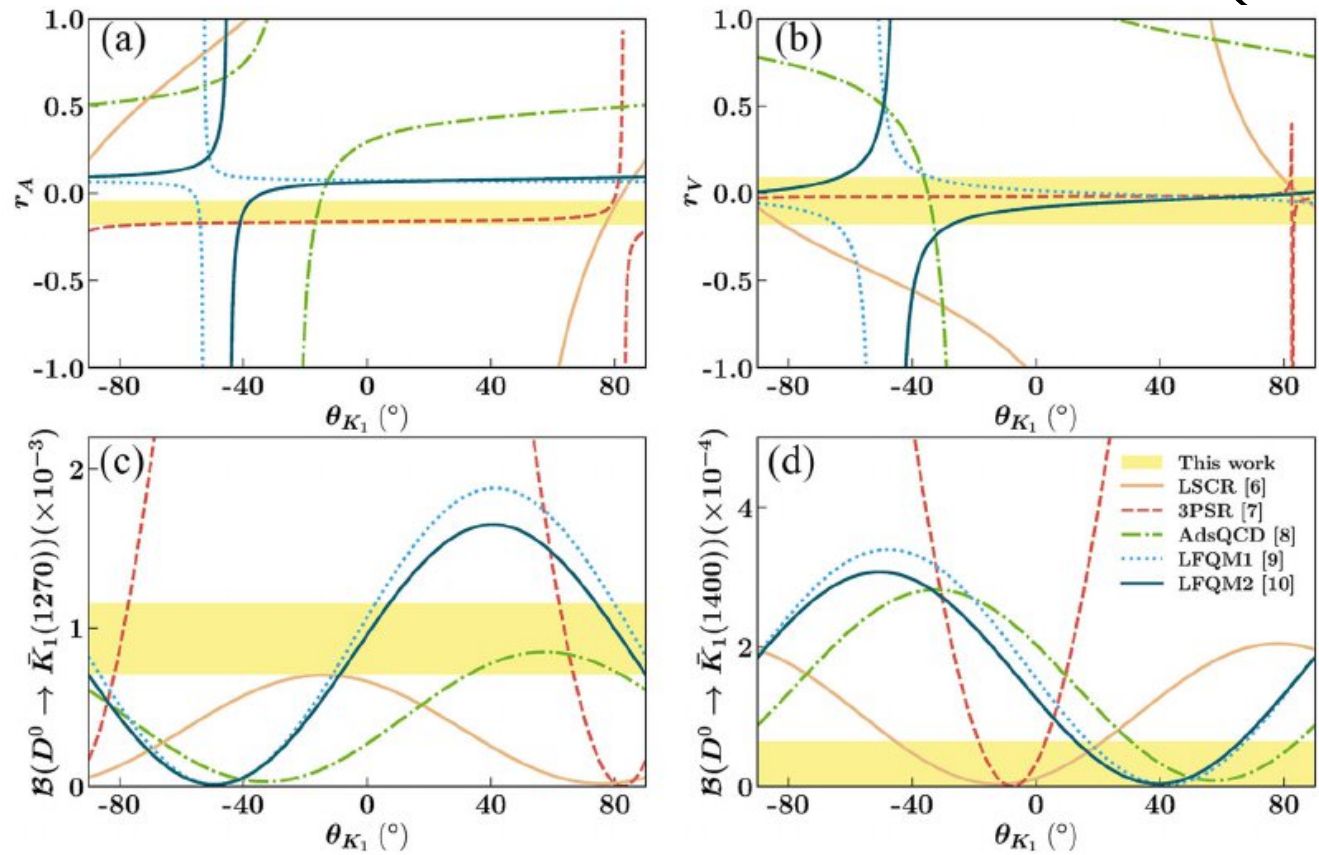
- Using $20.3 \text{ fb}^{-1} \psi(3770)$ data
- First amplitude analysis
- Extraction of (axial-)vector FFs
- $K_1 \rightarrow K\rho$ & $K_1 \rightarrow K^* \pi$ are found with $>5\sigma$ significance
- Other contributions below 3σ and neglected
- Upper limits on $D^{+(0)} \rightarrow \bar{K}_1(1400)e^+ \nu_e$ BFs are set: $< 1.4 (0.7) \times 10^{-4}$ @ 90% CL

$$r_A = A(0)/V_1(0)$$

$$r_V = V_2(0)/V_1(0)$$

Variable	Value
$r_A (\times 10^{-2})$	$-11.2 \pm 1.0 \pm 0.9$
$r_V (\times 10^{-2})$	$-4.3 \pm 1.0 \pm 2.5$
$f_{\rho K^-}^{D^+} (\%)$	$79.3 \pm 2.0 \pm 25.7$
$f_{\pi \bar{K}^*(892)}^{D^+} (\%)$	$10.9 \pm 1.2 \pm 3.0$
$f_{\bar{K}_1(1400)}^{D^+} (\%)$	< 5
$f_{\rho K^-}^{D^0} (\%)$	$71.8 \pm 2.3 \pm 23.9$
$f_{\pi \bar{K}^*(892)}^{D^0} (\%)$	$19.5 \pm 1.9 \pm 5.2$
$f_{\bar{K}_1(1400)}^{D^0} (\%)$	< 9
$m_{K_1(1270)} (\text{MeV}/c^2)$	$1271 \pm 3 \pm 7$
$\Gamma_{K_1(1270)} (\text{MeV})$	$168 \pm 10 \pm 20$

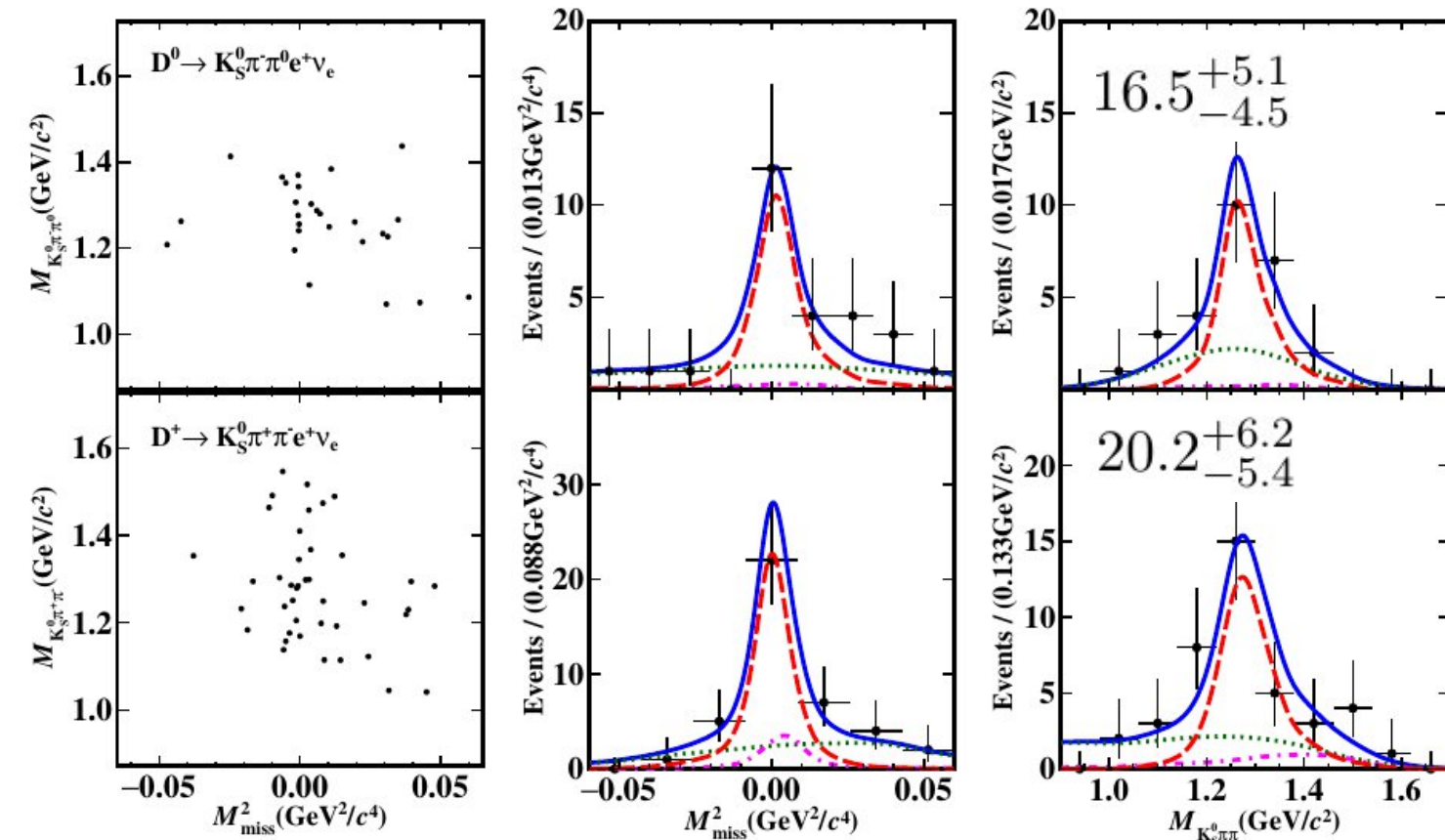
Combined: decay dynamics in $D^{+,0} \rightarrow \bar{K}_1 \left(\rightarrow K^- \pi^+ \pi^{0,-} \right) e^+ \nu_e$



- More universal theoretical calculations for all four observables: r_A , r_V , and BF's of $D \rightarrow \bar{K}_1(1270/1400) e^+ \nu_e$, are needed

More observations: $D^{+,0} \rightarrow \bar{K}_1 \left(\rightarrow K_S^0 \pi^- \pi^{+,0} \right) e^+ \nu_e$

- Using $2.93 \text{ fb}^{-1} \psi(3770)$ data



Decay mode	$\mathcal{B}_{\text{sig}} (\times 10^{-4})$
$D^0 \rightarrow K_S^0 \pi^- \pi^0 e^+ \nu_e$	$(1.69_{-0.46}^{+0.53} \pm 0.15)$
$D^+ \rightarrow K_S^0 \pi^+ \pi^- e^+ \nu_e$	$(1.47_{-0.40}^{+0.45} \pm 0.14)$
$D^0 \rightarrow K_1(1270)^- e^+ \nu_e$	$(10.6_{-2.8}^{+3.3} \pm 0.9 \pm 2.3)$
$D^+ \rightarrow \bar{K}_1(1270)^0 e^+ \nu_e$	$(12.9_{-3.5}^{+4.0} \pm 1.0 \pm 2.5)$

Large (~20%) uncertainties from $B^{PDG}(\bar{K}_1 \rightarrow K_S^0 \pi^- \pi^{+,0})$

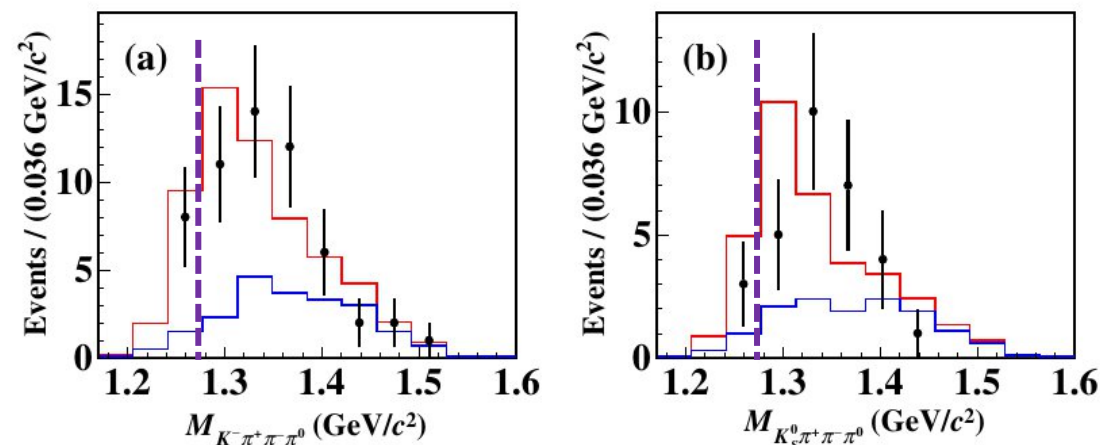
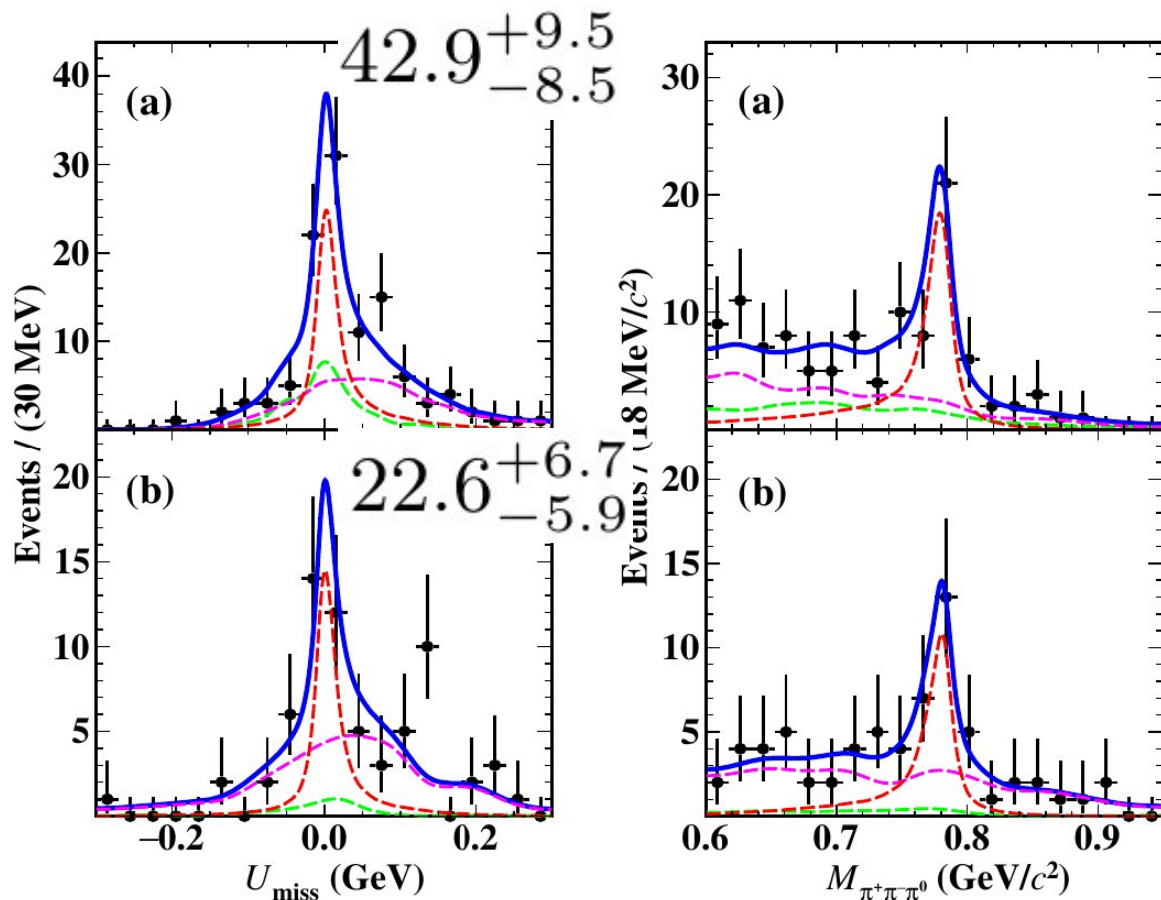
Observations of $D^{+,0} \rightarrow \bar{K}_1 (\rightarrow \bar{K}\omega) e^+ \nu_e$

- Using $20.3 \text{ fb}^{-1} \psi(3770)$ data

- BFs observed:

$$\tilde{\mathcal{B}}(D^0 \rightarrow \bar{K}^- \omega e^+ \nu_e) = (9.3_{-1.9}^{+2.1} \pm 0.7) \times 10^{-5}$$

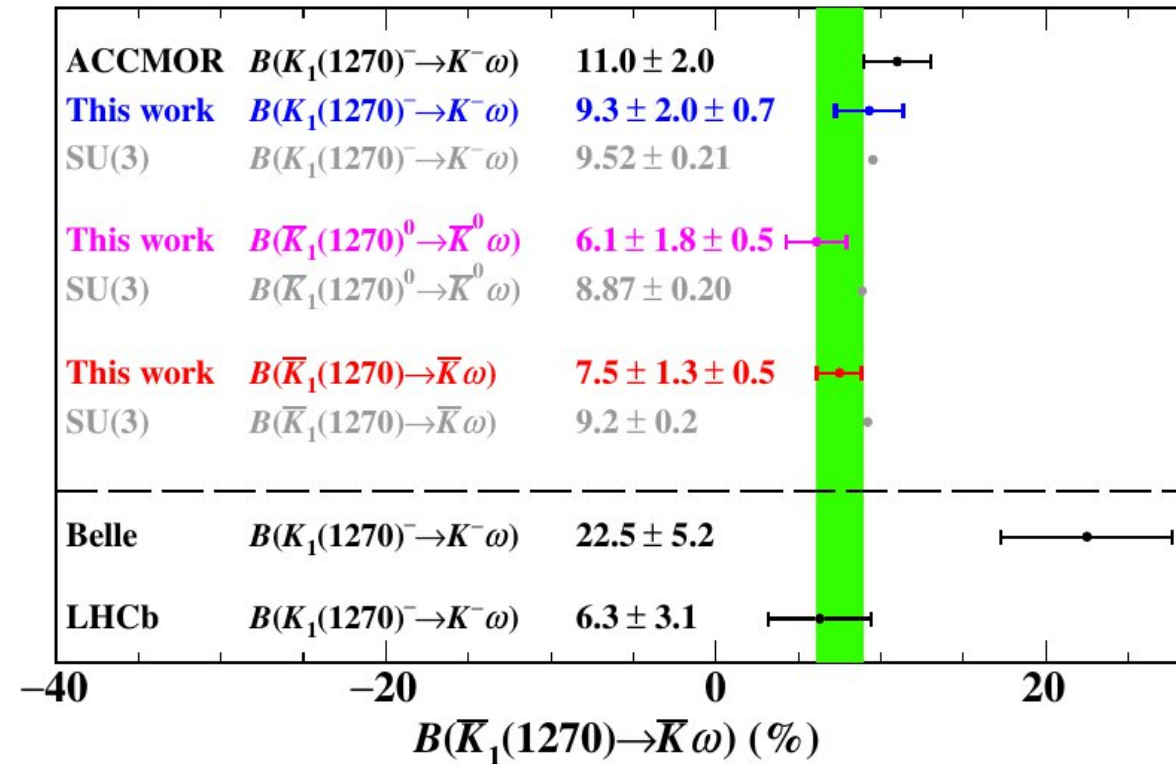
$$\mathcal{B}(D^+ \rightarrow K_S^0 \omega e^+ \nu_e) = (6.6_{-1.8}^{+2.0} \pm 0.6) \times 10^{-5}$$



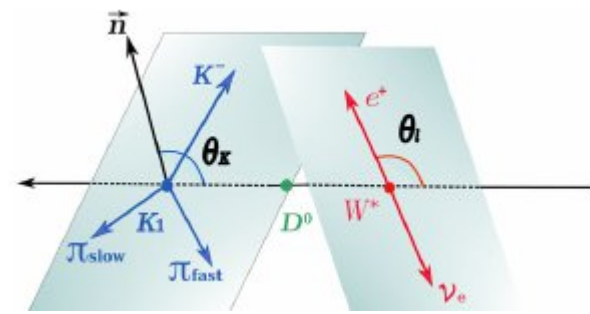
Significant mass shifts in both channels wrt
MC shape produced with $M = 1272 \text{ MeV}$!
 Possible hint of double-pole structure?

Observations of $D^{+,0} \rightarrow \bar{K}_1 (\rightarrow \bar{K}\omega) e^+ \nu_e$

- First observation of $K_1^0 \rightarrow K_S^0 \omega$
- First measurement of $\bar{K}_1 \rightarrow \bar{K}\omega$ BFs using dominant ω decay channel of $\pi\pi\pi^0$
- Important input to constrain $B(\bar{K}_1 \rightarrow \bar{K}\pi\pi)$ as $\Sigma [B(\bar{K}_1 \rightarrow \bar{K}\pi\pi)] \sim 1 - B(\bar{K}_1 \rightarrow \bar{K}\omega)$
- Opening up new opportunities of studying $K_1(1270)$
 - Almost free from interference from other VP channels, $K_1(1400)$, $K_2^*(1430)$, etc

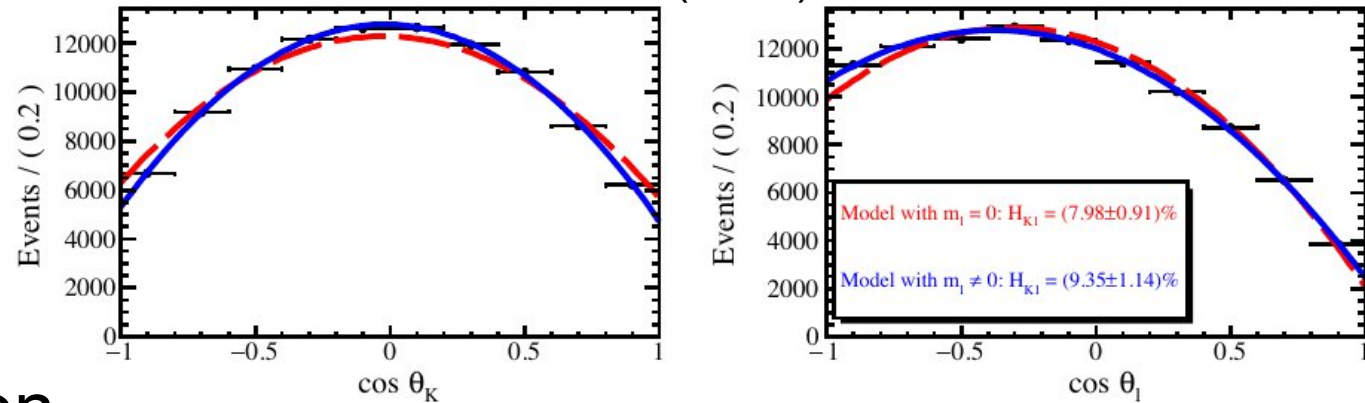


Prospects in other experiments

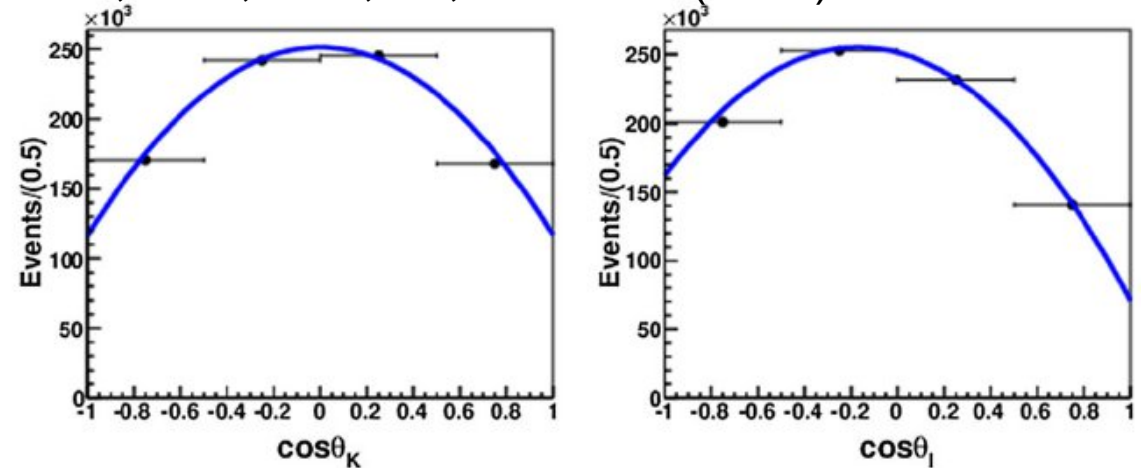


- **LHCb**: expecting $\sim 10^5$ $D^{*+} \rightarrow D^0 \pi^+$, $D^0 \rightarrow K^- \pi^+ \pi^- \mu^+ \nu_\mu$ events
- **STCF**: similar signal statistics of $D^0 \rightarrow K^- \pi^+ \pi^- e^+ \nu_e$ based on $1 \text{ ab}^{-1} \psi(3770)$ data
- Both will be able to achieve 1% sensitivity of A'_{UD} , which leads to precise determination of photon polarization in $b \rightarrow s \gamma$

LZB, LS, WW, PRD 104 (2021) 053003



YLF, XDS, XRZ, LS, EPJC 81 (2021) 1068



Extraction of $K_1(1270)$ decay dynamics using four $D \rightarrow \bar{K}\pi\pi e^+ \nu_e$ channels: an MI method

- The BFs of $K_1(1270) \rightarrow K\pi\pi$ are related to different decay modes:

$$\mathcal{B}_{K_1 \rightarrow KX^0(\pi^+\pi^-)} \equiv \mathcal{B}_{K_1 \rightarrow K^+\omega} \times \mathcal{B}_{\omega \rightarrow \pi^+\pi^-} + \mathcal{B}_{K_1 \rightarrow Kf_0(\pi^+\pi^-)}$$

$$\mathcal{B}_{K_1 \rightarrow K^+\pi^+\pi^-} = \frac{1}{3} \times \mathcal{B}_{K_1 \rightarrow K\rho} + \frac{4}{9} \times \mathcal{B}_{K_1 \rightarrow K^*(892)\pi} + \frac{4}{9} \times \mathcal{B}_{K_1 \rightarrow K_0^*(1430)\pi} + \mathcal{B}_{K_1 \rightarrow KX^0(\pi^+\pi^-)} \sim 0.36$$

$$\mathcal{B}_{K_1 \rightarrow K_S^0\pi^+\pi^0} = \mathcal{B}_{K_1 \rightarrow K^+\pi^-\pi^0} \times \frac{\mathcal{B}_{K_S^0 \rightarrow \pi^+\pi^-}}{2} \sim 0.16$$

$$\mathcal{B}_{K_1 \rightarrow K^+\pi^-\pi^0} = \frac{2}{3} \times \mathcal{B}_{K_1 \rightarrow K\rho} + \frac{4}{9} \times \mathcal{B}_{K_1 \rightarrow K^*(892)\pi} + \frac{4}{9} \times \mathcal{B}_{K_1 \rightarrow K_0^*(1430)\pi} \sim 0.47$$

$$\mathcal{B}_{K_1 \rightarrow K_S^0\pi^+\pi^-} = \mathcal{B}_{K_1 \rightarrow K^+\pi^+\pi^-} \times \frac{\mathcal{B}_{K_S^0 \rightarrow \pi^+\pi^-}}{2} \sim 0.11$$

$K_1(1270)$ DECAY MODES	Fraction (Γ_i/Γ)
$K\rho$	(38 ± 13) %
$K_0^*(1430)\pi$	(28 ± 4) %
$K^*(892)\pi$	(21 ± 10) %
$K\omega$	(11.0 ± 2.0) %
$Kf_0(1370)$	(3.0 ± 2.0) %
γK^0	seen

- Current BFs reported by PDG will lead to ~20% uncertainties on BFs of $K_1(1270) \rightarrow K\pi\pi$

A summary of current BESIII measurements



Decay mode	Signal yield	$\mathcal{B}(D \rightarrow \bar{K}\pi\pi e^+\nu) \times 10^{-4}$	$\mathcal{B}(D \rightarrow \bar{K}_1(1270)e^+\nu) \times 10^{-3}$	$\int \mathcal{L}dt$
$D^0 \rightarrow K^-\pi^+\pi^-e^+\nu_e$	109 ± 13	$(3.95 \pm 0.41^{+0.31}_{-0.52})$	$(1.09 \pm 0.13^{+0.09}_{-0.16} \pm 0.12)$	2.93 fb^{-1}
	731 ± 35	$(3.20 \pm 0.20 \pm 0.20)$	$(1.02 \pm 0.06 \pm 0.06 \pm 0.03)$	20.3 fb^{-1}
$D^+ \rightarrow K^-\pi^+\pi^0e^+\nu_e$	120 ± 13	$(10.6 \pm 1.2 \pm 0.8)$	$(2.30 \pm 0.26^{+0.18}_{-0.21} \pm 0.25)$	2.93 fb^{-1}
	1270 ± 56	$(12.70 \pm 0.60 \pm 0.40)$	$(2.27 \pm 0.11 \pm 0.07 \pm 0.07)$	20.3 fb^{-1}
$D^0 \rightarrow K_S^0\pi^-\pi^0e^+\nu_e$	17 ± 5	$(1.69^{+0.53}_{-0.46} \pm 0.15)$	$(1.05^{+0.33}_{-0.28} \pm 0.12 \pm 0.12)$	2.93 fb^{-1}
$D^+ \rightarrow K_S^0\pi^+\pi^-e^+\nu_e$	20 ± 6	$(1.47^{+0.45}_{-0.40} \pm 0.14)$	$(1.29^{+0.40}_{-0.35} \pm 0.18 \pm 0.15)$	2.93 fb^{-1}

All the four major $K_1(1270) \rightarrow K\pi\pi$ channels are established

The decay ratios

$$\mathcal{B}_{3\text{body}} \equiv \mathcal{B}_{K_1 \rightarrow K\rho} + \mathcal{B}_{K_1 \rightarrow K^*\pi} + \mathcal{B}_{K_1 \rightarrow KX^0(\pi^+\pi^-)} = 1 - \mathcal{B}_{K_1 \rightarrow K\omega} = (89 \pm 2)\%,$$

- We define $\beta^{-1} \equiv 1 - \frac{\mathcal{B}_{K_1 \rightarrow K^+\pi^-\pi^+}}{\mathcal{B}_{K_1 \rightarrow K^+\pi^-\pi^0}}$, $\alpha \equiv \frac{\mathcal{B}_{K_1 \rightarrow K^*\pi}}{\mathcal{B}_{K_1 \rightarrow K\rho}}$,
- By assuming $\mathcal{B}_{K_1 \rightarrow KX^0(\pi^+\pi^-)} \equiv \mathcal{B}_{K_1 \rightarrow K^+\omega} \times \mathcal{B}_{\omega \rightarrow \pi^+\pi^-} + \mathcal{B}_{K_1 \rightarrow Kf_0(\pi^+\pi^-)} \sim 0$, we have

$$\alpha = \frac{3}{4}(\beta - 2) \quad \mathcal{B}_{K_1 \rightarrow K^+\pi^+\pi^-} = \mathcal{B}_{3\text{body}} \cdot \frac{3 + 4\alpha}{9(1 + \alpha)}, \mathcal{B}_{K_1 \rightarrow K^+\pi^-\pi^0} = \mathcal{B}_{3\text{body}} \cdot \frac{6 + 4\alpha}{9(1 + \alpha)}$$

- In presence of non-zero $\mathcal{B}_{K_1 \rightarrow KX^0(\pi^+\pi^-)}$, we define $\delta_\alpha \equiv \frac{\mathcal{B}_{KX^0(\pi^+\pi^-)}}{\mathcal{B}_{K_1 \rightarrow K\rho}}$
- The formulae become:

$$\alpha = \frac{3}{4}[\beta(1 - 3\delta_\alpha) - 2]$$

$$\mathcal{B}_{K_1 \rightarrow K^+\pi^+\pi^-} = \frac{4}{3}\mathcal{B}_{3\text{body}} \cdot \frac{\beta - 3\delta_\alpha\beta + 3\delta_\alpha - 1}{(3\beta - 9\delta_\alpha\beta + 4\delta_\alpha - 2)},$$

$$\alpha^{\text{PDG}} = \frac{(28 \pm 4)\% + (21 \pm 10)\%}{(38 \pm 13)\%} = 1.29 \pm 0.52,$$

$$\delta_\alpha^{\text{PDG}} = \frac{(3 \pm 2)\%}{(38 \pm 13)\%} = 0.079 \pm 0.059.$$

$$\mathcal{B}_{K_1 \rightarrow K^+\pi^-\pi^0} = \frac{4}{3}\mathcal{B}_{3\text{body}} \cdot \frac{\beta - 3\delta_\alpha\beta}{(3\beta - 9\delta_\alpha\beta + 4\delta_\alpha - 2)}.$$

- The K_1 decay ratios such as α could be determined from the experimental observable of β

NB: Belle2011 differs significantly with PDG23 with $\alpha \sim 0.21$ and $\delta_\alpha \sim 0$, which are confirmed by BESIII2025

Simultaneous fit model

- The fit is performed across four modes (2 D^0 / 2 D^+) to extract signal yields:

$$R_{D^0} = \frac{\mathcal{N}_{K^-\pi^+\pi^-e^+\nu_e}}{\mathcal{N}_{K_S^0\pi^-\pi^0e^+\nu_e}},$$

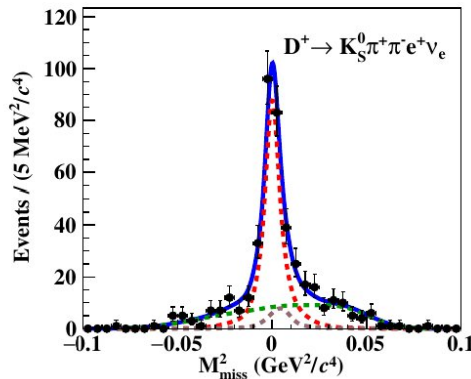
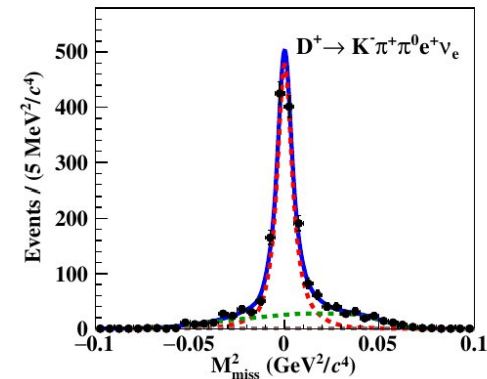
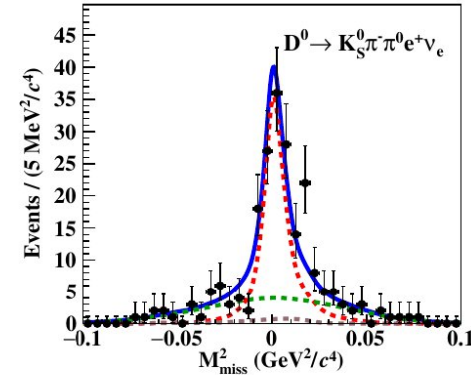
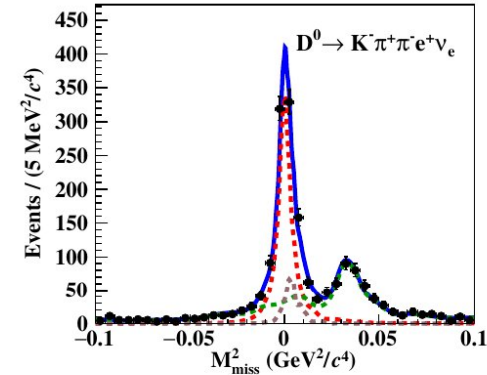
and

$$R_{D^+} = \frac{\mathcal{N}_{K_S^0\pi^+\pi^-e^+\nu_e}}{\mathcal{N}_{K^-\pi^+\pi^0e^+\nu_e}},$$

where $\mathcal{N}_i \equiv N_i/\epsilon_i$ (efficiency-corrected signal yield in mode i),

$$\beta_{D^0}^{-1} = \frac{\mathcal{B}_{K_S^0 \rightarrow \pi^+\pi^-}}{2} R_{D^0} - 1, \quad \beta_{D^+}^{-1} = \frac{2}{\mathcal{B}_{K_S^0 \rightarrow \pi^+\pi^-}} R_{D^+} - 1$$

- The β variable is shared across D^+ and D^0 modes
- The BFs of $D^+ \rightarrow \bar{K}_1^0 e^+ \nu_e$ and $D^0 \rightarrow K_1^- e^+ \nu_e$ will also be extracted at the same time



Fit to fake datasets with statistics matched to the $20.3 \text{ fb}^{-1} \psi(3770)$ dataset from BESIII

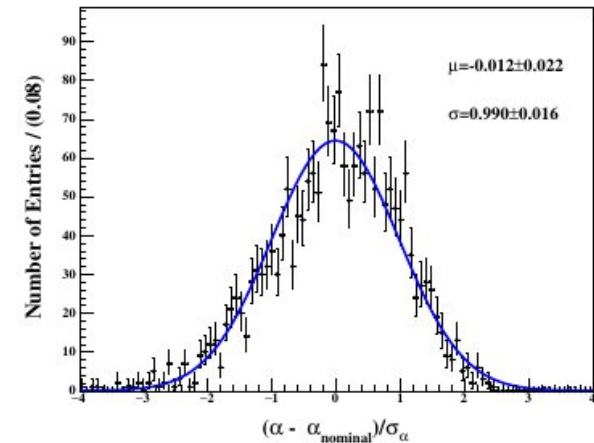
Expected sensitivities

- Expected statistical uncertainties larger than those of BESIII2025 due to less information used, however the systematic uncertainties are much improved
- This method will be more advantageous in future experiments such as STCF

Parameters	Input	Output	BESIII results
α [%]	20.3	$22.7 \pm 15.0 \pm 1.0 \pm 0.6$	$20.3 \pm 2.1 \pm 8.7$
$\mathcal{B}(\bar{K}_1(1270) \rightarrow \bar{K}^*(892)\pi)$ [%]	15.0	$16.5 \pm 9.0 \pm 0.7 \pm 3.5$	$19.5 \pm 1.9 \pm 5.2$ * $10.9 \pm 1.2 \pm 3.0$ †
$\mathcal{B}(\bar{K}_1(1270) \rightarrow \bar{K}\rho)$ [%]	74.0	$72.5 \pm 9.0 \pm 0.7 \pm 3.5$	$71.8 \pm 2.3 \pm 23.9$ * $79.3 \pm 2.0 \pm 25.7$ †
$\mathcal{B}(K_1^-(1270) \rightarrow K^-\pi^+\pi^-)$ [%]	31.3	$31.5 \pm 1.1 \pm 0.7 \pm 0.4$	31.3 ± 0.9
$\mathcal{B}(\bar{K}_1^0(1270) \rightarrow K^-\pi^-\pi^0)$ [%]	56.0	$55.7 \pm 2.1 \pm 1.3 \pm 0.8$	56.0 ± 2.7
$\mathcal{B}(D^0 \rightarrow K_1^-(1270)e^+\nu_e)$ [$\times 10^3$]	1.02	$1.01 \pm 0.05 \pm 0.02 \pm 0.01$	$1.02 \pm 0.06 \pm 0.06 \pm 0.03$
$\mathcal{B}(D^+ \rightarrow \bar{K}_1^0(1270)e^+\nu_e)$ [$\times 10^3$]	2.27	$2.29 \pm 0.10 \pm 0.05 \pm 0.01$	$2.27 \pm 0.11 \pm 0.07 \pm 0.07$

* From the channel of $D^0 \rightarrow K^-\pi^+\pi^-e^+\nu_e$;

† From the channel of $D^+ \rightarrow K^-\pi^+\pi^0e^+\nu_e$.



Unbiased measurement
from pseudo-experiments

What to expect with $20.3 \text{ fb}^{-1} \psi(3770)$ data

- Extraction of $K_1(1270)$ decay dynamics using four $D \rightarrow \bar{K}\pi\pi e^+ \nu_e$ channels
- Search for $D^{+,0} \rightarrow \bar{K}_1 (\rightarrow \bar{K}\pi^0\pi^0) e^+ \nu_e$
 - Free from dominating $\bar{K}\rho^0$ contribution
 - Expected to be dominated by $\bar{K}^{*0}\pi^0$
 - Sensitive to possible $\bar{K}f_0$ contributions
- A novel D tagging method to further boost sensitivity:
 - Generic tagging, adding all reconstructed tracks / neutrals
 - MVA tools to suppress background
 - Efficiency calibrated with control channels

Summary

- $K_1(1270)$ as important ingredient in $b \rightarrow s$ indirect NP searches
- Improved knowledge on $K_1(1270)$ structure could also lead to better understanding of nonperturbative QCD
- With world's largest $\psi(3770)$ data sample, BESIII has recently made significant progresses in studying $K_1(1270)$ via SL D decays, with major decay modes measured
- More to come, stay tuned!
 - More K_1 decay modes, new tagging method, muon channels, etc.
- Many thanks to collaborators from IHEP, SJTU, USTC, CCNU, ZZU, HTU, etc.