Charmed mesons decays at BESIII

Bo Zheng
University of South China
(On behalf of BESIII Collaboration)

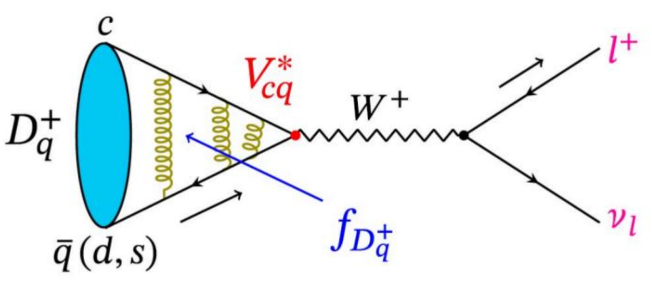
Outline

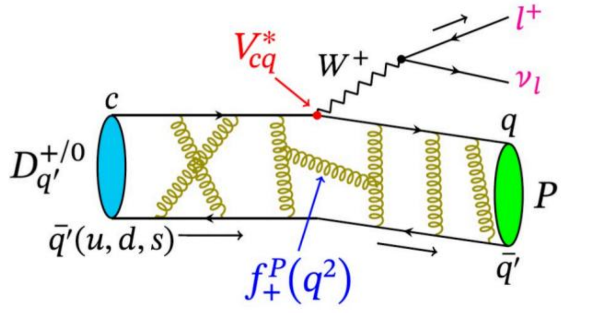
- Charm meson physics
- BEPCII and BESIII experiment
- Highlight charmed meson results at BESIII
  - Leptonic and semi-leptonic decays
  - Hadronic decays and other
- Conclusion and prospect

Charm meson physics

- Leptonic and semi-leptonic decay

Pure leptonic decay **Semi-leptonic decay**

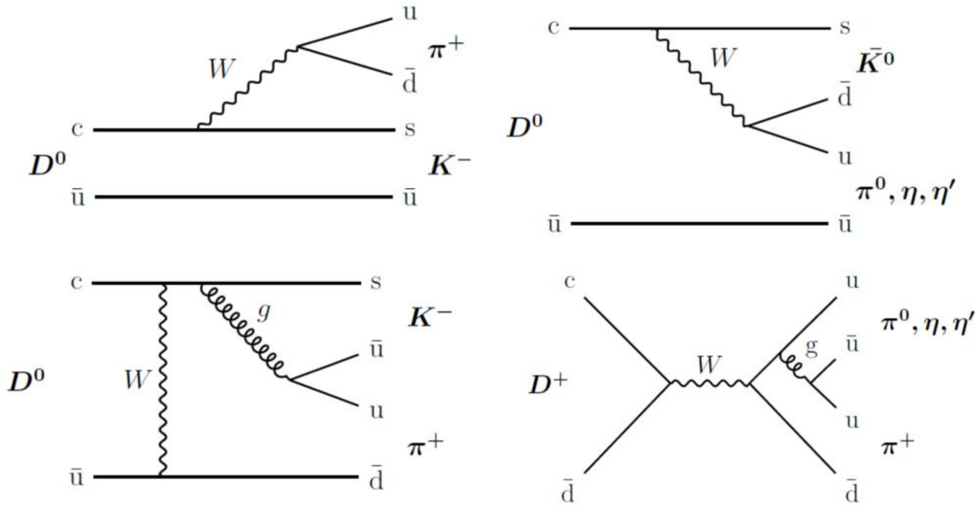




$\Gamma(D_{(s)}^+ \to l^+\nu_l) \propto |f_{D_s^+}|^2 \cdot |V_{cd(s)}|^2$

$\Gamma(D_{(s)} \to Pl^+\nu_l) \propto |f_+(q^2)|^2 \cdot |V_{cd(s)}|^2$

- Hadronic decay

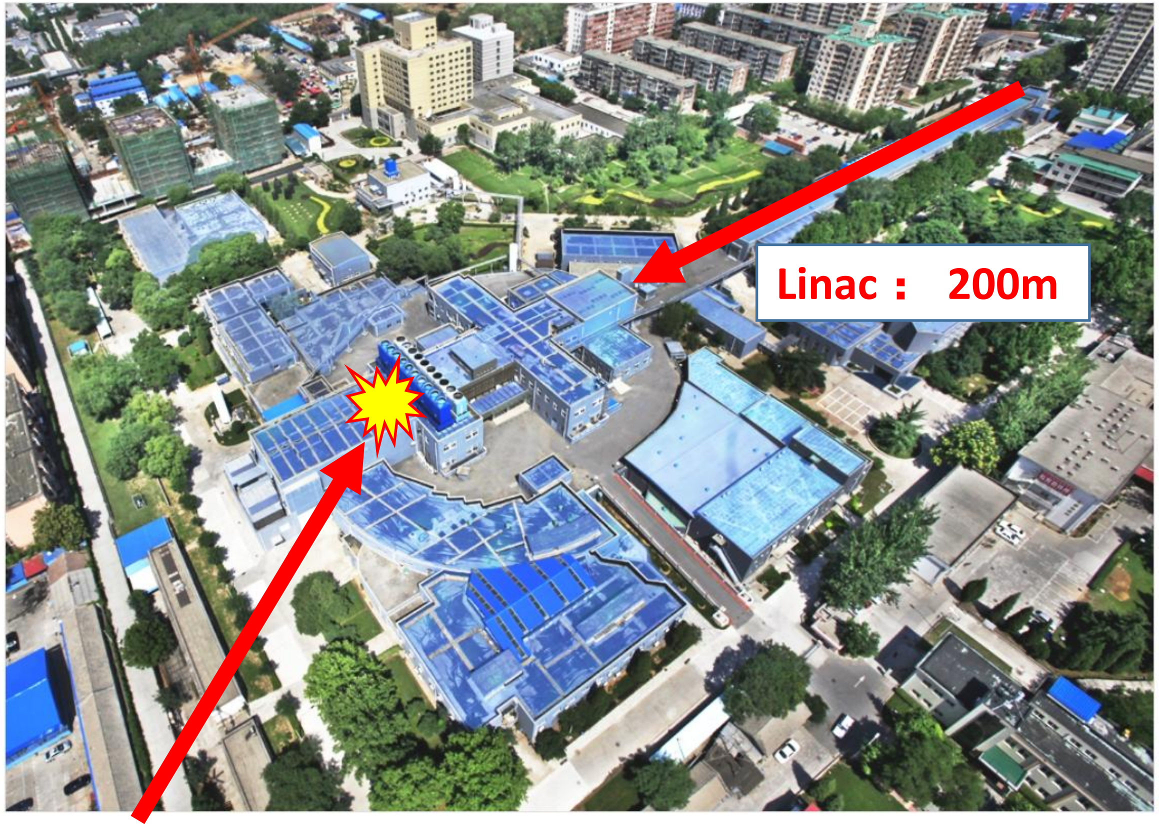


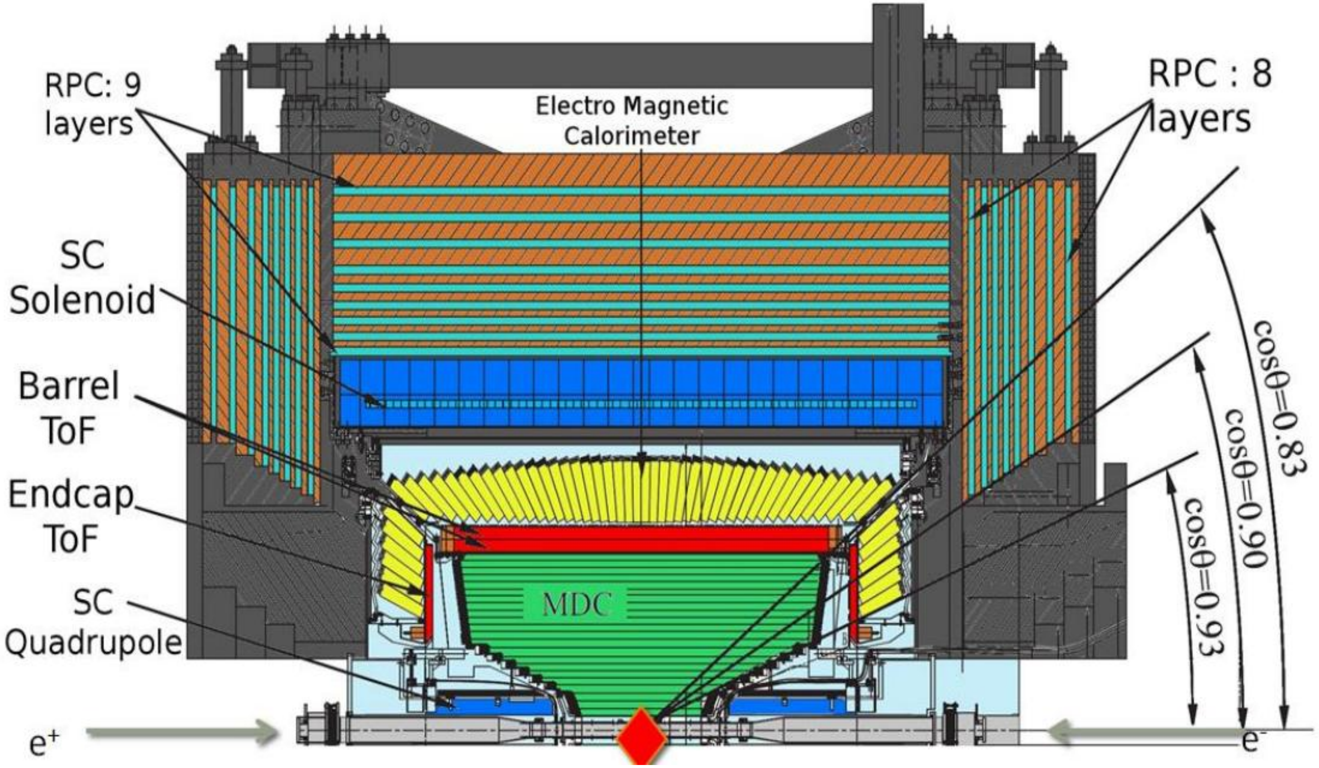
- Ideal bridge to access the strong and weak effects between quarks ;
- $|V_{cs}|$ and $|V_{cd}|$ →Test CKM matrix unitarity;
- Decay Constant $f_{D_{(s)}^+}$ and form factor f_+ → Calibrate LQCD;
- Branching fractions (BF) ratio →Test lepton flavor university.

- Amplitude analysis: Get information of $D \to VP,\ PP, \ldots$
- Absolute BFs measurements: Test theoretical calculations of these BFs and benefit the understanding of the quark SU(3) flavor symmetry and violation;
- Quantum correlated $D\bar{D}$, CP ratio measurements

BEPCII and BESIII experiment

➢ Bird View of BEPCII/BESIII





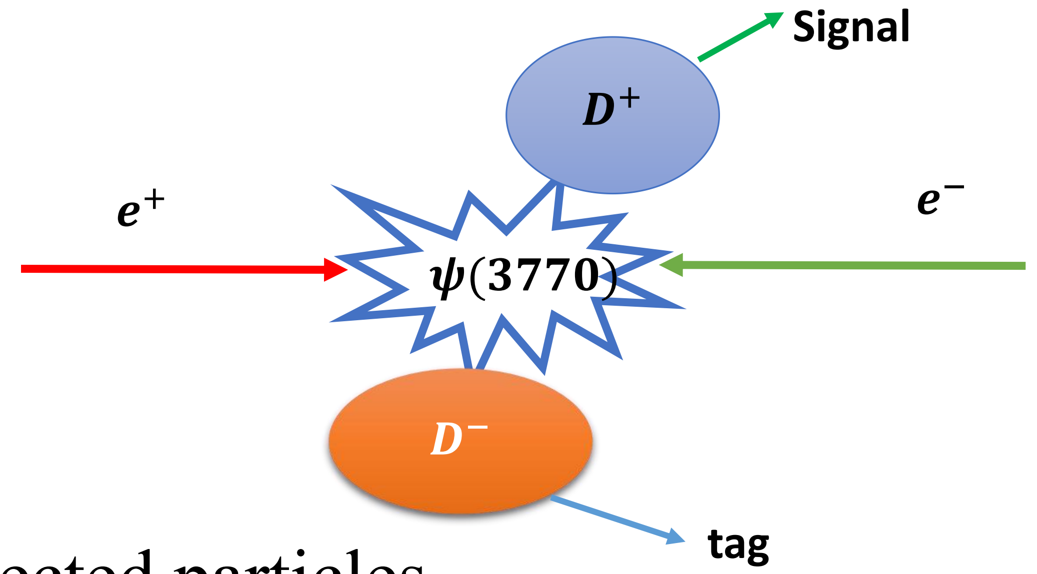
BESIII detector

- BEPC II: Large Crossing Angle, Double-ring
- CMS energy: 2 - 4.95 GeV
- Luminosity: $1 \times 10^{33}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$

- MDC: σ_p/p=0.5%@1 GeV, $\sigma_{dE/dx}$=6%;
- TOF: $\sigma_T = 68(110)$ ps for barrel(endcap); endcap TOF upgraded in 2015→ 60 ps;
- EMC: σ_E/E = 2.5% (5%) ps for barrel(endcap)

Data samples and Analysis method

- Data samples
  - 2.93 fb^{-1}data $e^+e^- \to \psi(3770)$ at $\sqrt{s} = 3.773$ GeV
  - 7.33 fb^{-1} $e^+e^- \to D_s^+ D_s^{*-}$ data collected at $\sqrt{s} = 4.128 \sim 4.226$ GeV
- Analysis method
  - Single tag(ST): reconstruct one $D_{(s)}$
    - Higher efficiency
    - Relatively high background
  - Double tag(DT): reconstruct both $D_{(s)}$
    - Clear background
    - Kinematic constraint on the undetected particles
    - Systematic uncertainties on the tag side mostly canceled.



Highlight charmed meson results at BESIII

➢ Leptonic and semi-leptonic decay

- ✓ $D_s^{*+} \to e^+\nu_e$ PRL 131, 141802 (2023)
- ✓ $D_s^+ \to \mu^+\nu_\mu$ PRD 108, 112001 (2023)
- ✓ $D_s^+ \to \tau^+\nu_\tau,\ \tau^+ \to \mu^+\nu_\mu\bar{\nu}_\tau$ PRD 108, 092014 (2023)
- ✓ $D_s^+ \to \tau^+\nu_\tau,\ \tau^+ \to \pi^+\bar{\nu}_\tau$ JHEP09(2023)124
- ✓ $D_s^+ \to \pi^+\pi^-e^+\nu_e$ PRL 132, 141901 (2024)
- ✓ $D_s^+ \to K^+K^-\mu^+\nu_\mu$ JHEP12(2023)072
- ✓ $D_s^+ \to \eta^{(\prime)}e^+\nu_e$ and $D_s^+ \to \eta^{(\prime)}\mu^+\nu_\mu$
  Phys. Rev. D 108, 092003 (2023)
  Phys. Rev. Lett. 132, 091802 (2024)

➢ Hadronic decay and other

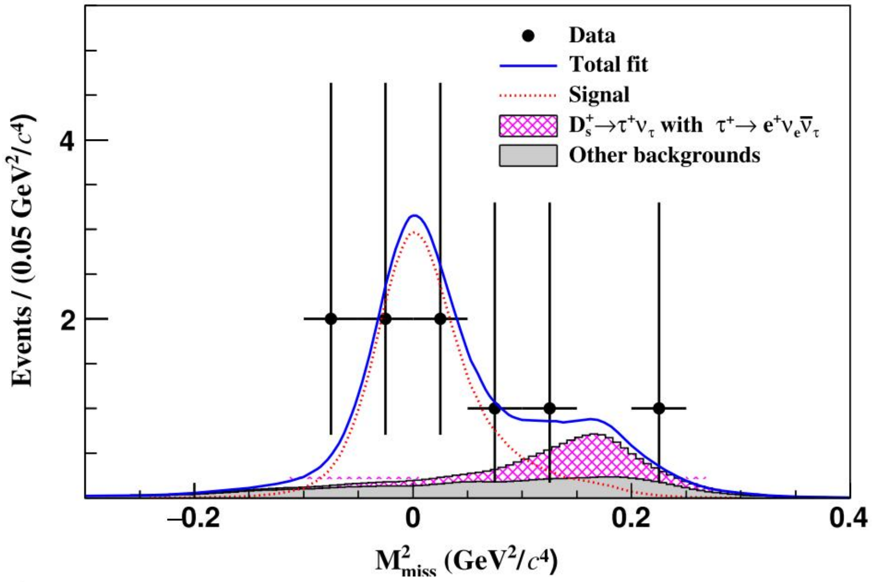
- ✓ $D_s^+ \to K_S^0K^+\pi^0$ PRL 129, 182001 (2022)
- ✓ $D^+ \to K_S^0\pi^+\pi^0\pi^0$ JHEP09(2023)077
- ✓ $D^{0(+)} \to K_S^0X$ PRD 107, 112005 (2023)
- ✓ $D_{(s)}^{0(+)} \to \pi^+\pi^+\pi^-X$ Phys. Rev. D 107, 032002 (2023) Phys. Rev. D 108, 032001 (2023)
- ✓ D_s^+ hadronic decays JHEP05(2024)335
- ✓ $D^0 \to K_S^0\pi^+\pi^-\pi^0$ PRD 108, 032003 (2023)
- ✓ $D^0 \to K^+K^-\pi^+\pi^-$ PRD 107, 032009 (2023)
- ✓ $D^+ \to K_S^0a_0(980)^+$ PRL 132, 131903 (2024)
- ✓ $D_s^+ \to h^+h^0e^+e^-$ arXiv:2404.05973

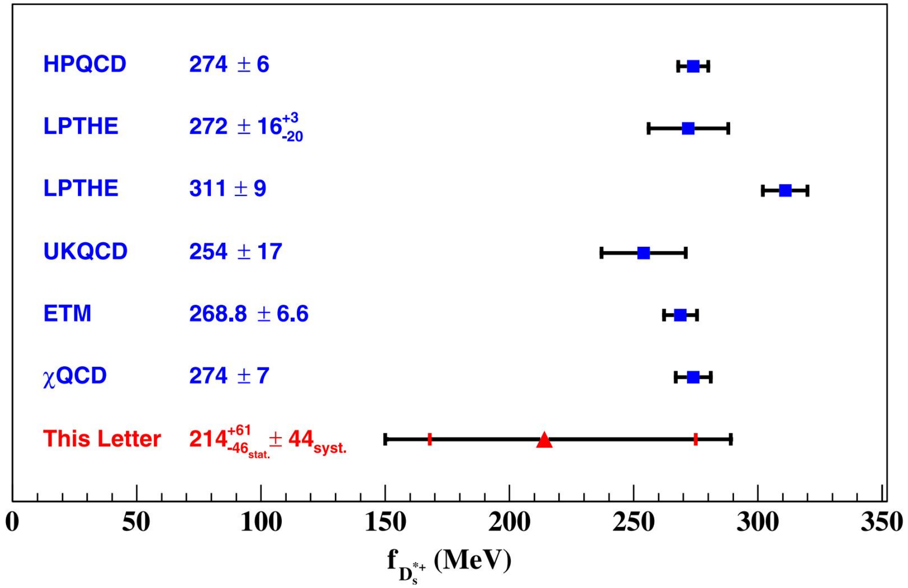
$D_s^{*+} \to e^+\nu_e$

$N_{D_s^{*+}\to e^+\nu_e} = 6.2^{+3.4}_{-2.7}$

PRL 131, 141802 (2023)

- Data sample: 7.33 fb^{-1} @4.128 – 4.226 GeV
- First measurement of BF and $f_{D_s^{*+}}$
  - ✓ $\mathcal{B}(D_s^{*+} \to e^+\nu_e) = \left(2.1^{+1.2}_{-0.9\,\text{stat}} \pm 0.2_{\text{syst}}\right) \times 10^{-5} (2.9\sigma)$
  - ✓ $f_{D_s^{*+}} = \left(214^{+61}_{-46\,\text{stat}} \pm 44_{\text{syst}}\right)$ MeV
- Combine $\frac{f_{D_s^{*+}}}{f_{D_s^+}} = 1.12 \pm 0.01$ from LQCD calculation:
  - $\Gamma^{\text{total}}_{D_s^{*+}} = \left(122^{+70}_{-52} \pm 12\right)$ eV
  - Agree with LQCD prediction (70 ± 28) eV within $\pm 1\sigma$
  - Indirectly constrains the upper limit on $\Gamma^{\text{total}}_{D_s^{*+}}$ from MeV to sub-keV level. (PDG2022:$\Gamma^{\text{total}}_{D_s^{*+}}$<1.09 MeV @90%C.L.)

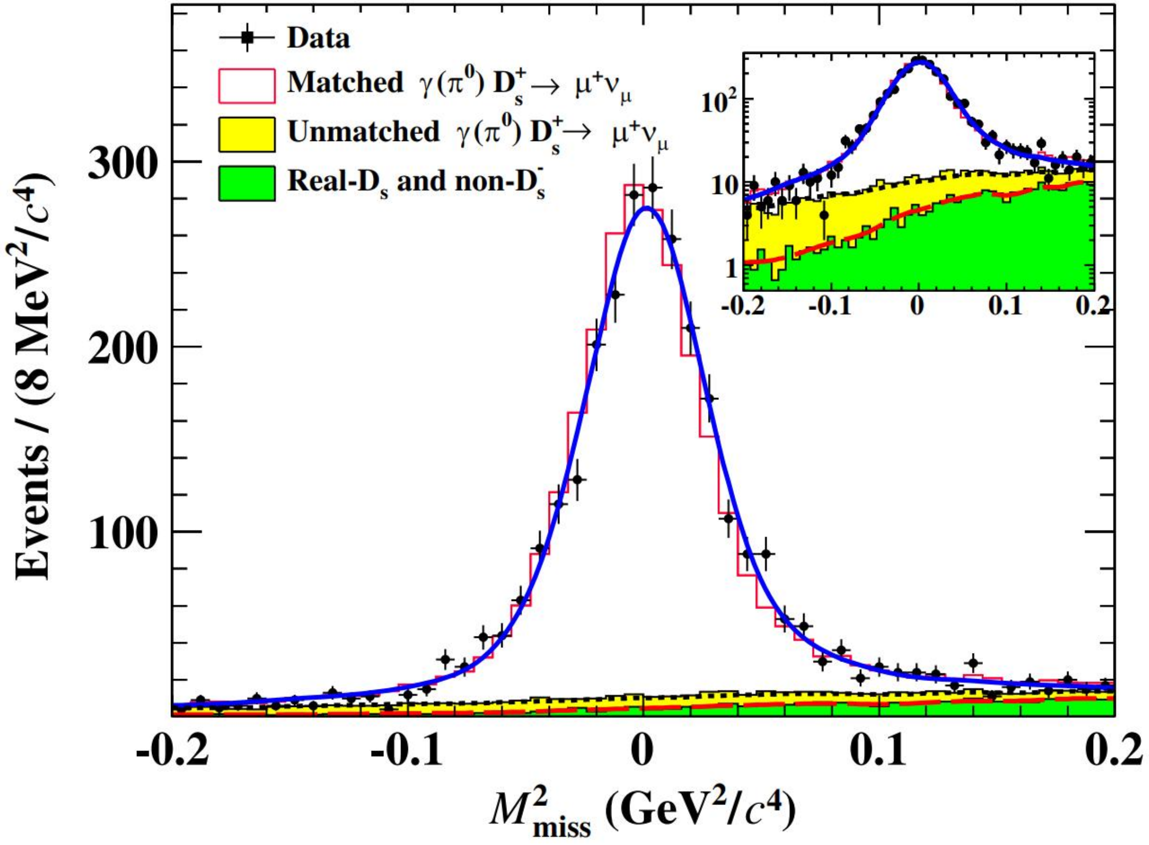




$D_s^+ \to \mu^+ \nu_\mu$

- Data sample: 7.33 fb^{-1} @4.128 – 4.226 GeV
- $e^+e^- \to D_s^+ D_s^{*-} \to \gamma(\pi^0) D_s^+ D_s^-$
- Analysis Method: DT method

PRD 108, 112001 (2023)

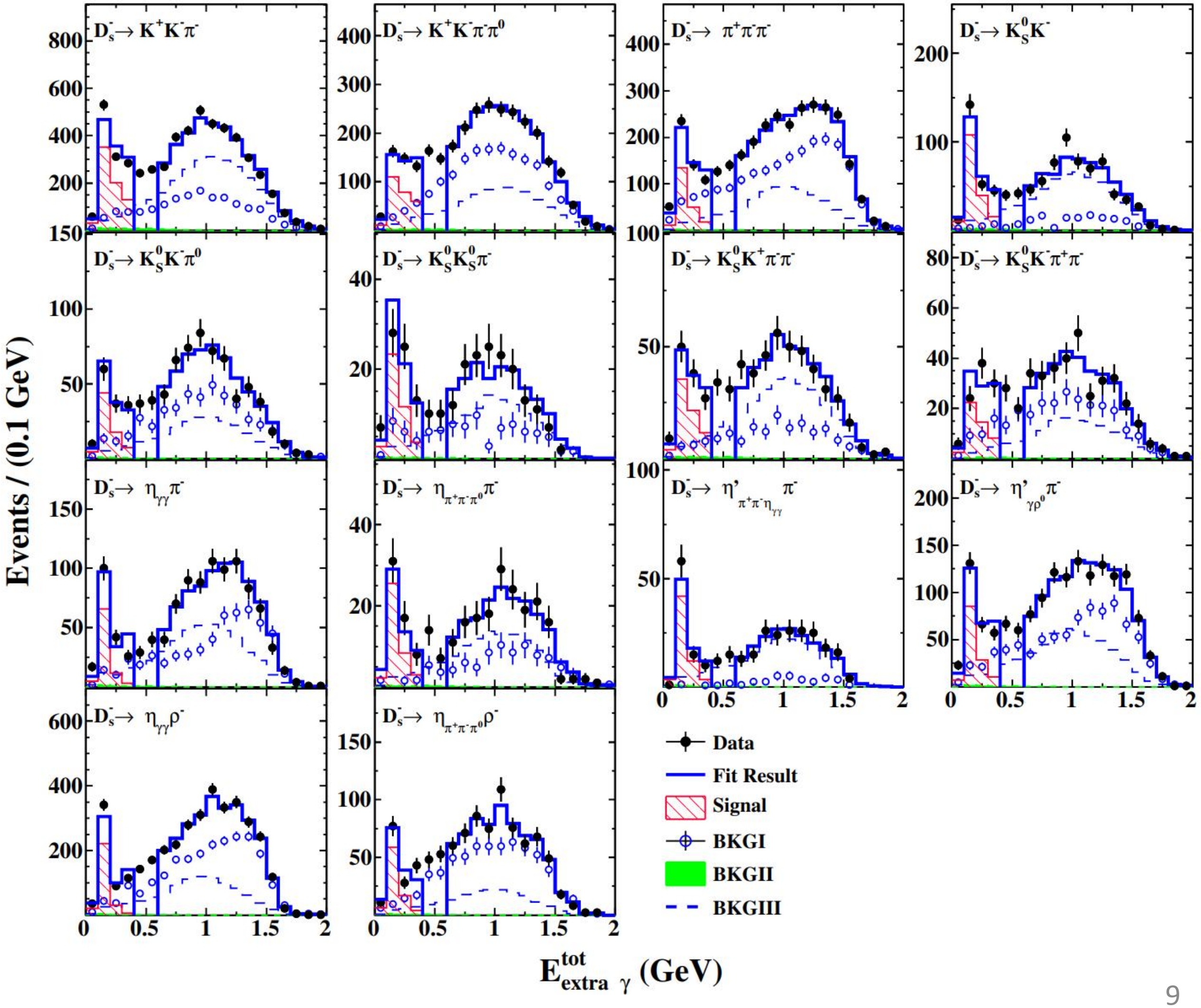


$N_{D_s^+ \to \mu^+\nu_\mu} = 2514.5 \pm 51.6$

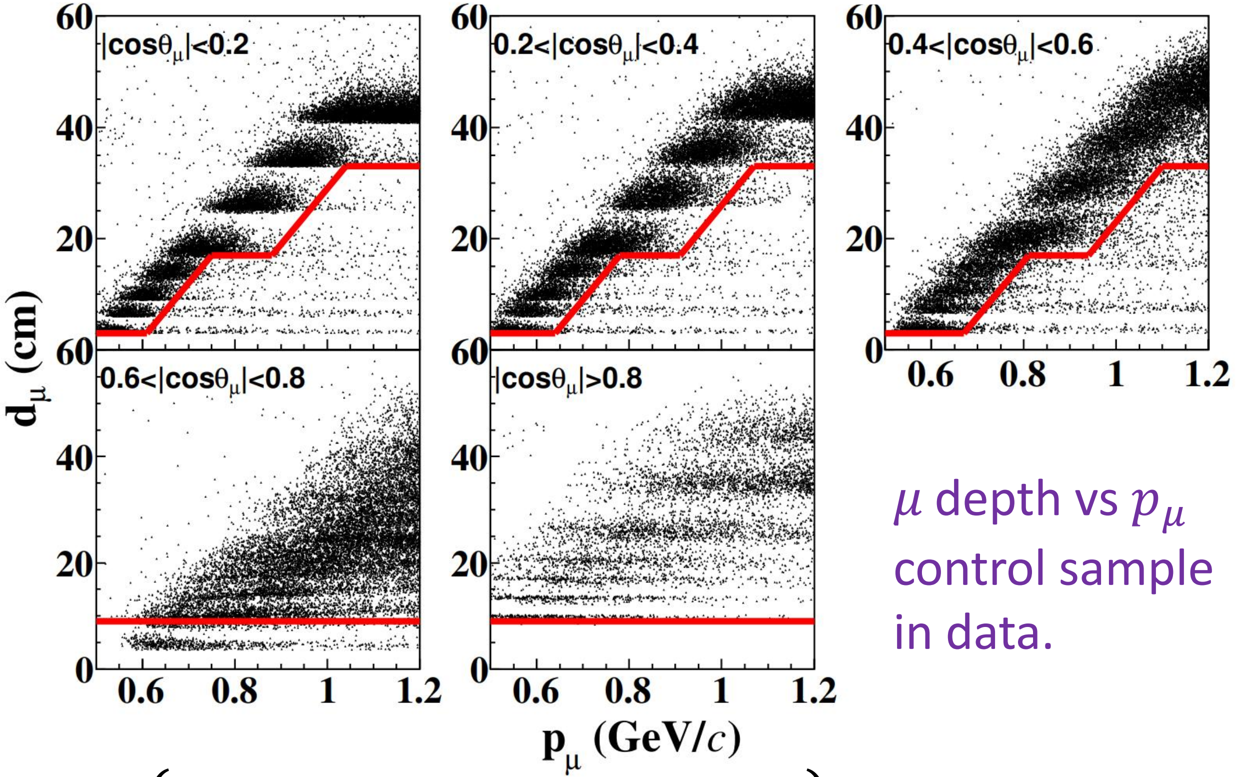
- $\mathcal{B} = (0.5294 \pm 0.0108_{\text{stat}} + 0.0085_{\text{syst}})\%$
- $f_{D_s^+}|V_{cs}| = (241.8 \pm 2.5_{\text{stat}} \pm 2.2_{\text{syst}})$ MeV
- $f_{D_s^+} = (248.4 \pm 2.5_{\text{stat}} \pm 2.2_{\text{syst}})$ MeV
- $|V_{cs}| = 0.968 \pm 0.010_{\text{stat}} \pm 0.009_{\text{syst}}$
- Precision of BF: 2.6%
- Highest precision of $|V_{cs}|$ to date: ~1.4%

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

- Data sample: 7.33 fb^{-1} @4.128 – 4.226 GeV
- Analysis Method: DT method



JHEP09(2023)124



μ depth vs p_μ control sample in data.

$$\mathcal{B} = (5.37 \pm 0.17_{\text{stat}} + 0.15_{\text{syst}})\%$$

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

$$f_{D_s^+} = (253.4 \pm 0.016_{stat} \pm 0.014_{syst})\ \text{MeV}$$

$$|V_{cs}| = 0.987 \pm 0.016_{stat} \pm 0.014_{syst}$$

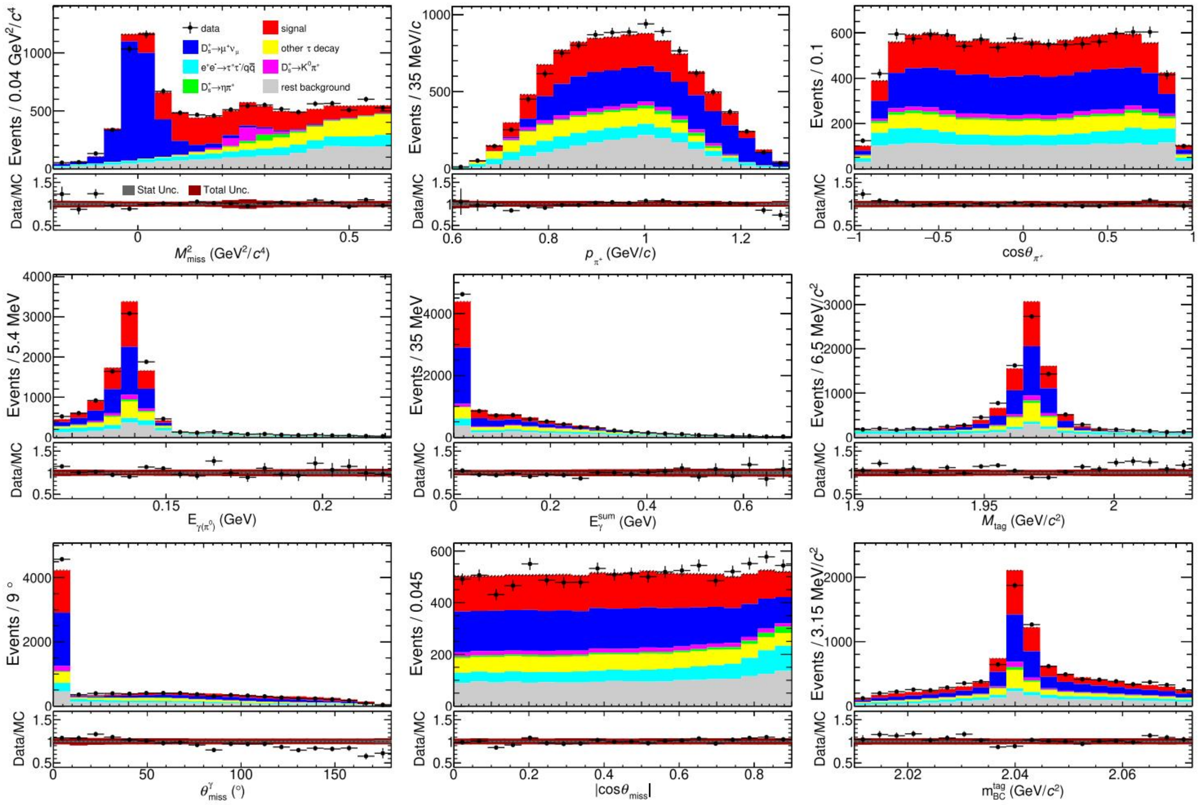
Precision of |Vcs|: ~1.9%

$D_s^+ \to \tau^+\nu_\tau,\ \tau^+ \to \pi^+\bar{\nu}_\tau$

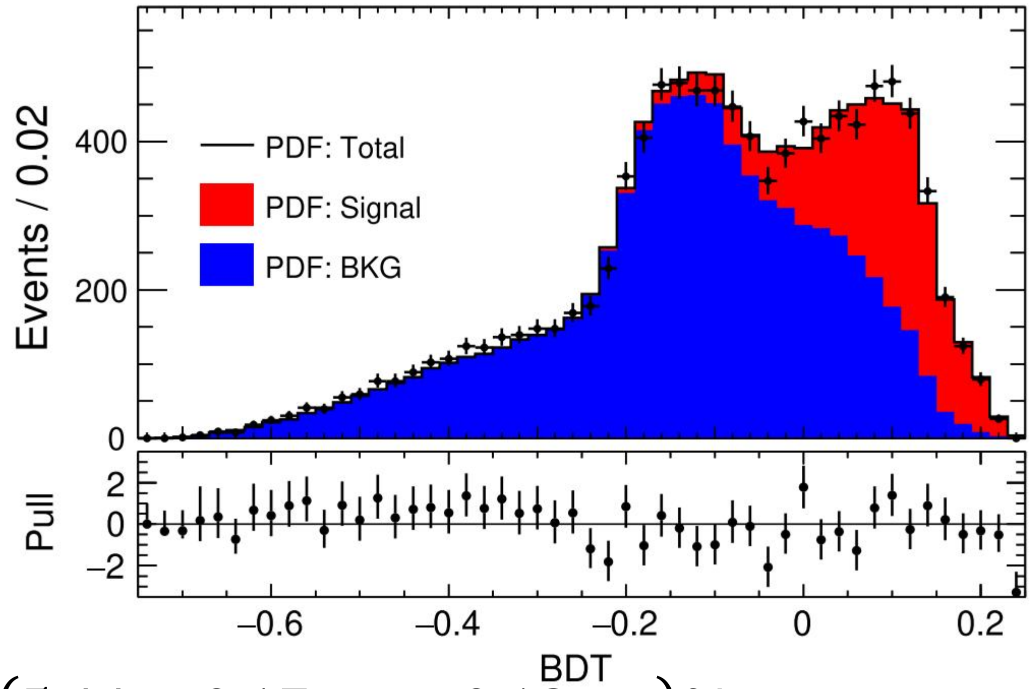
PRD 108, 092014 (2023)

- Data sample: 7.33 fb^{-1} @4.128 – 4.226 GeV
- Analysis Method: Boosted decision tree(BDT) method

$N_{D_s^+\to\tau^+\nu_\tau} = 2411 \pm 75$



Distributions of various input variables of the BDT



$\mathcal{B} = (5.44 \pm 0.17_{\rm stat} + 0.13_{\rm syst})\%$

$f_{D_s^+}|V_{cs}| = (248.3 \pm 3.9_{\rm stat} \pm 3.1_{\rm syst} \pm 1.0_{\rm input})$ MeV

$f_{D_s^+} = (253.4 \pm 0.016_{\rm stat} \pm 0.014_{\rm syst} \pm 1.0_{\rm input})$ MeV

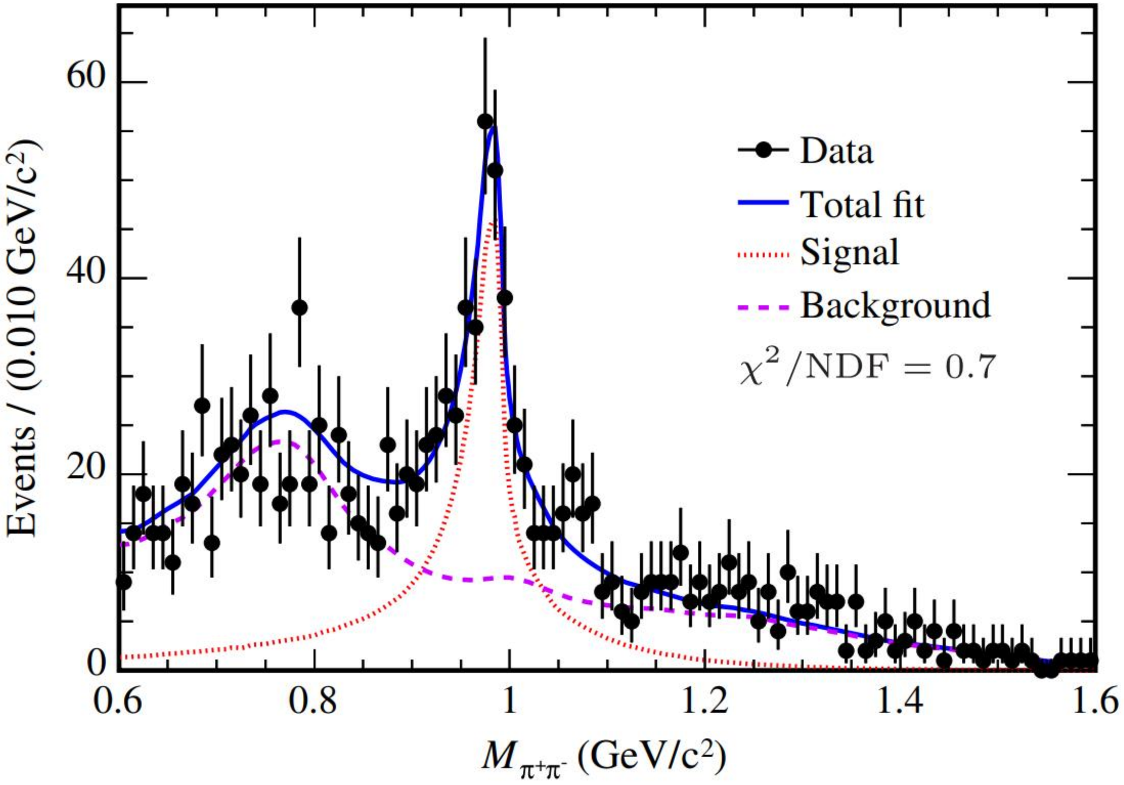
$|V_{cs}| = 0.993 \pm 0.015_{\rm stat} \pm 0.012_{\rm syst} \pm 0.004_{\rm input}$

Precision of |Vcs|: ~2.0%

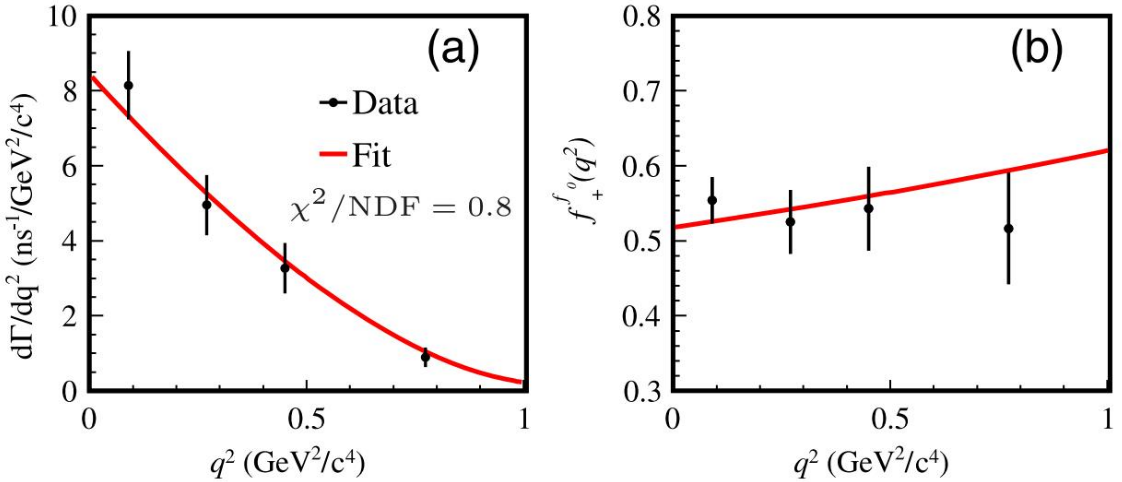
$D_s^+ \to \pi^+\pi^-e^+\nu_e$

PRL 132, 141901 (2024)

- Data sample: 7.33 fb^{-1} @4.128 – 4.226 GeV
- $\mathcal{B}(D_s^+ \to f_0(980)e^+\nu_e,\ f_0(980) \to \pi^+\pi^-) = (1.72 \pm 0.13 \pm 0.10) \times 10^{-3}$
- First form factor measurement with simple pole form and Flatte formula



$N_{sig} = 439 \pm 33$



- $f_+^{f^0}(0)|V_{cs}| = 0.504 \pm 0.017 \pm 0.035$
- $|V_{cs}| = 0.97349 \pm 0.0016$

  from SM global fit(PDG2022)

- $f_+^{f^0}(0) = 0.518 \pm 0.018 \pm 0.036$

$D_s^+ \to K^+K^-\mu^+\nu_\mu$

JHEP12(2023)072

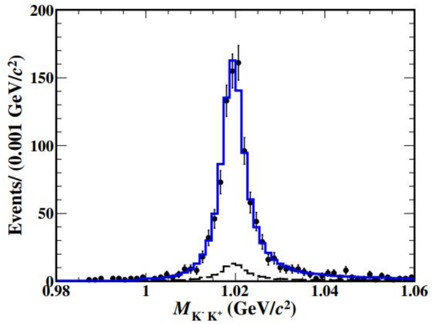
- Data sample: 7.33 fb^{-1} @4.128 – 4.226 GeV

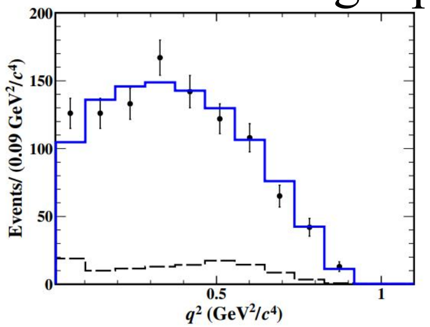
$\mathcal{B}(D_s^+ \to \phi\mu^+\nu_\mu) = (2.25 \pm 0.09 \pm 0.07) \times 10^{-2}$

$\mathcal{B}(D_s^+ \to \phi\mu^+\nu_\mu)/\mathcal{B}(D_s^+ \to \phi e^+\nu_e) = 0.94 \pm 0.08$ No LFU violation

$\mathcal{B}(D_s^+ \to f_0(980)\mu^+\nu_\mu) \cdot \mathcal{B}(f_0(980) \to K^+K^-)$
$< 5.45 \times 10^{-4}$@90%C.L. $\sim 2.2\sigma$

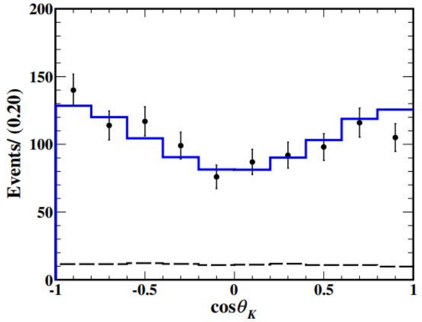
- First form factor measurement based on single pole parameterization.

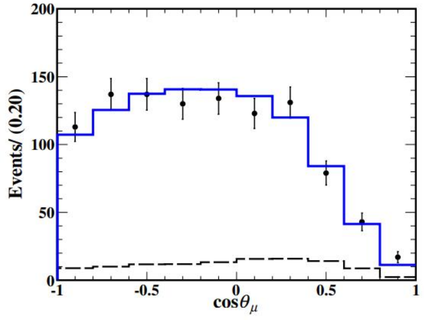


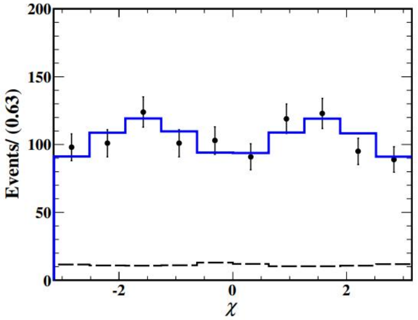


$|U_{miss}| < 0.02$ GeV

939 signal events with (9.8 ± 0.7)% Bkg

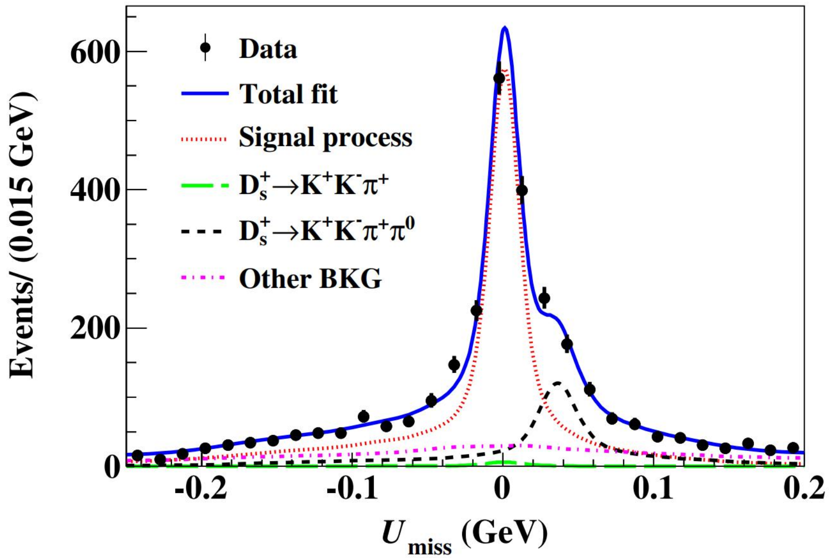






Projection of data and PWA fit results on kinematic variable

$N_{sig} = 1725 \pm 68$ for BF measurement

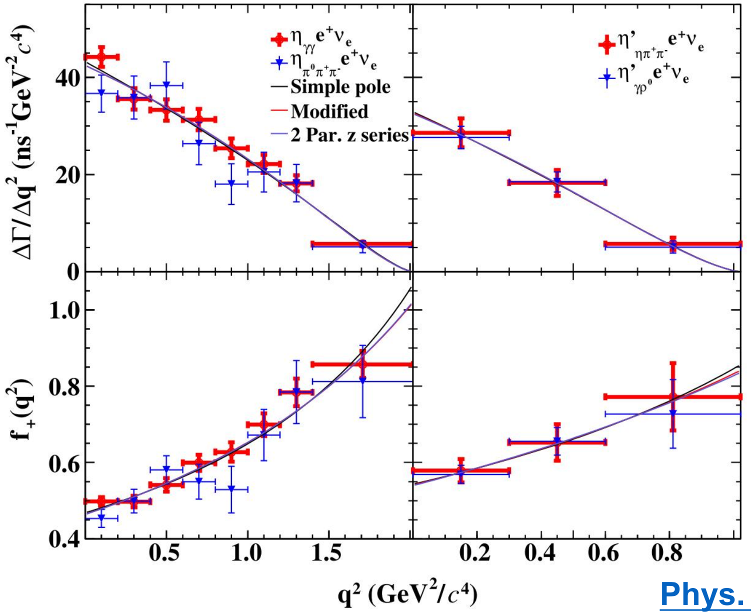


Measured FF ratios and comparison with previous measurements

Experiments	r_V	r_2
PDG [45]	1.80 ± 0.08	0.84 ± 0.11
This analysis	$1.58 \pm 0.17 \pm 0.02$	$0.71 \pm 0.14 \pm 0.02$
BABAR [26]	$1.807 \pm 0.046 \pm 0.065$	$0.816 \pm 0.036 \pm 0.030$
FOCUS [59]	$1.549 \pm 0.250 \pm 0.148$	$0.713 \pm 0.202 \pm 0.284$
Theory	r_V	r_2
CCQM [5]	1.34 ± 0.27	0.99 ± 0.20
CQM [6]	1.72	0.73
LFQM [7]	1.42	0.86
LQCD [3]	1.72 ± 0.21	0.74 ± 0.12
HMχT [8]	1.80	0.52

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

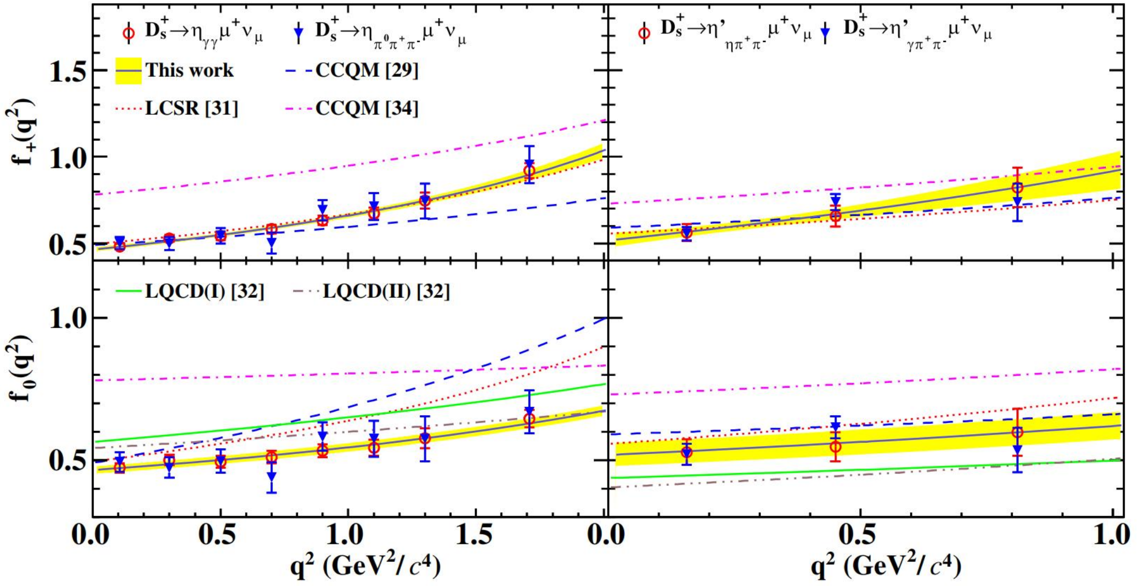
- Data sample: 7.33 fb^{-1} @4.128 – 4.226 GeV
- Improve the BFs
  - $\mathcal{B}(D_s^+ \to \eta e^+ \nu_e) = (2.255 \pm 0.039_{\text{stat}} + 0.051_{\text{syst}})\%$
  - $\mathcal{B}(D_s^+ \to \eta' e^+ \nu_e) = (0.810 \pm 0.038_{\text{stat}} \pm 0.024_{\text{syst}})\%$
- Form factor:
  - $f_+^{\eta}(0)|V_{cs}| = 0.4553 \pm 0.0071_{\text{stat.}} \pm 0.0061_{\text{syst.}}$
  - $f_+^{\eta'}(0)|V_{cs}| = 0.529 \pm 0.024_{\text{stat.}} \pm 0.008_{\text{syst.}}$
- $\eta - \eta'$ mixing angle:
  - $\cot^4 \phi_P \sim \frac{\Gamma(D_S^+ \to \eta' e^+ \nu_e)/\Gamma(D_S^+ \to \eta e^+ \nu_e)}{\Gamma(D^+ \to \eta' e^+ \nu_e)/\Gamma(D^+ \to \eta e^+ \nu_e)}$
  - $\mathcal{B}(D^+ \to \eta^{(\prime)} e^+ \nu_e)$ quoted from PDG.
  - $\phi_P = (40.0 \pm 2.0_{\text{stat}} \pm 0.6_{\text{syst}})^\circ$



Phys. Rev. D 108, 092003 (2023)

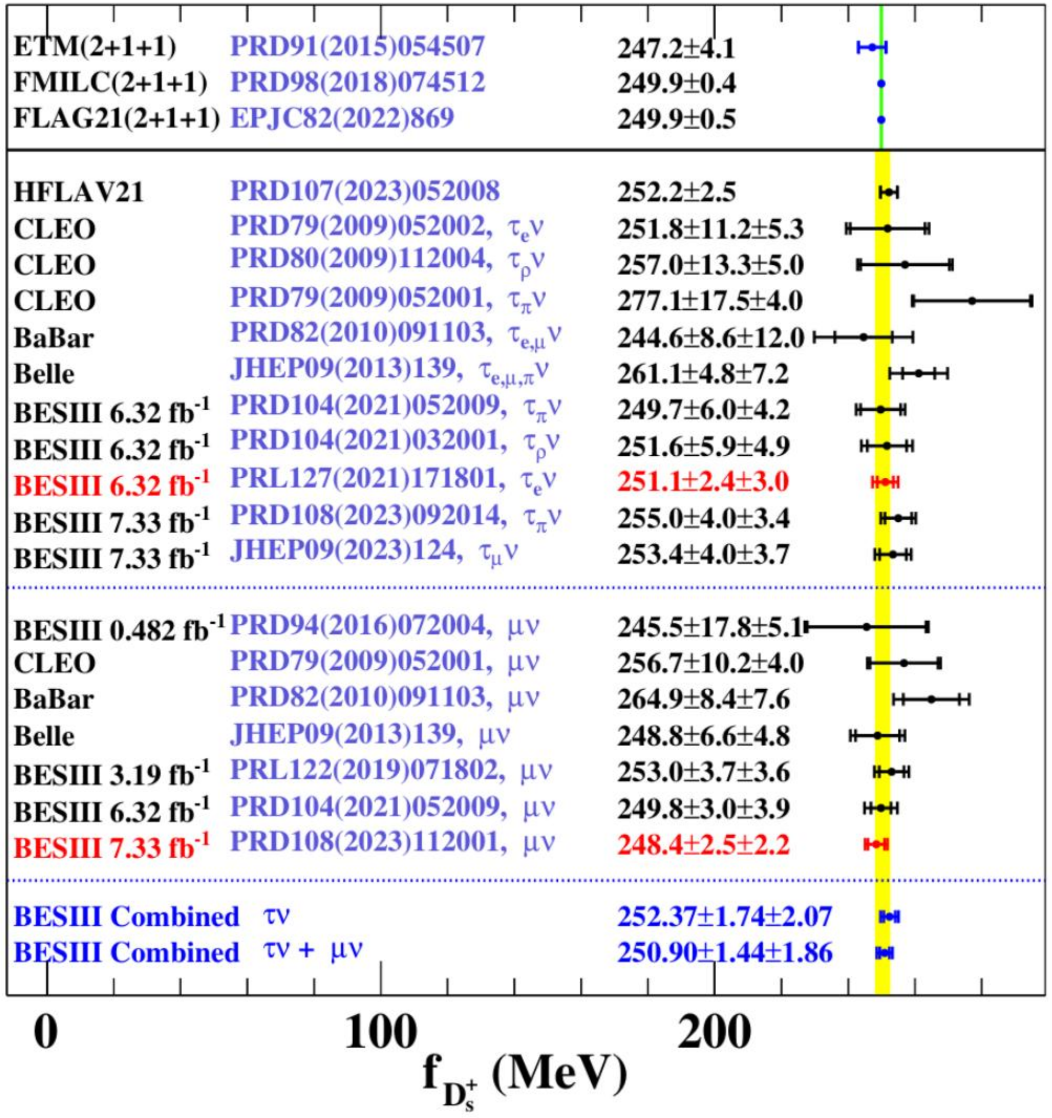
- Data sample: 7.33 fb^{-1} @4.128 – 4.226 GeV
- Improved BFs:
  - $\mathcal{B}(D_s^+ \to \eta \mu^+ \nu_\mu) = (2.235 \pm 0.051_{\text{stat}} + 0.052_{\text{syst}})\%$
  - $\mathcal{B}(D_s^+ \to \eta' \mu^+ \nu_\mu) = (0.801 \pm 0.055_{\text{stat}} \pm 0.028_{\text{syst}})\%$
- Form factors:
  - $f_+^{\eta}(0)|V_{cs}| = 0.452 \pm 0.010_{\text{stat.}} \pm 0.007_{\text{syst.}}$
  - $f_+^{\eta'}(0)|V_{cs}| = 0.504 \pm 0.037_{\text{stat.}} \pm 0.012_{\text{syst.}}$
- First extraction of the forward-backward asymmetry parameters of $D_S^+ \to \eta^{(\prime)} \mu^+ \nu_\mu$;
  - $\langle A_{\text{FB}}^{\eta} \rangle = -0.059 \pm 0.031_{\text{stat}} \pm 0.005_{\text{syst}}$
  - $\langle A_{\text{FB}}^{\eta'} \rangle = -0.064 \pm 0.079_{\text{stat}} \pm 0.006_{\text{syst}}$

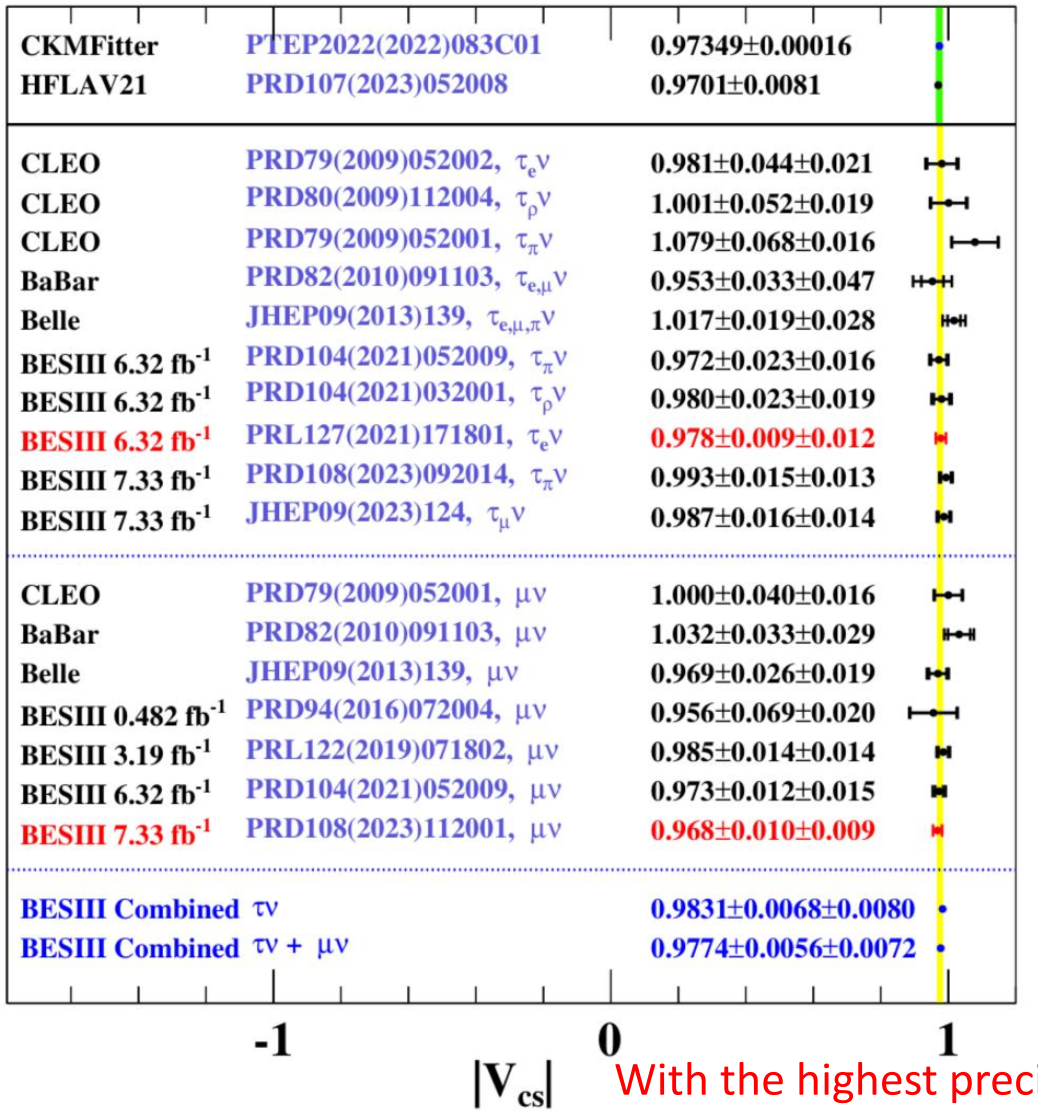
Phys. Rev. Lett. 132, 091802 (2024)



$|V_{cs}|$ & $|f_{D_s}|$

- The world average values of $|V_{cs}|$ and $|f_{D_s}|$ are currently dominated by the measurement results from the BESIII experiment.
- According to G_F, $m_{D_s^+}$, m_τ, m_μ from PDG2022, input $|V_{cs}|$, $|f_{D_s^+}|$.





With the highest precision: 0.9%

Amplitude analysis and BF measurement $D^+ \to K_S^0\pi^+\pi^0\pi^0$

JHEP09(2023)077

- Data sample: 2.93 fb^{-1} @3.773 GeV
- $\mathcal{B}\left(D^+ \to K_S^0 a_1(1260)^+(\to \rho^+\pi^0)\right) =$

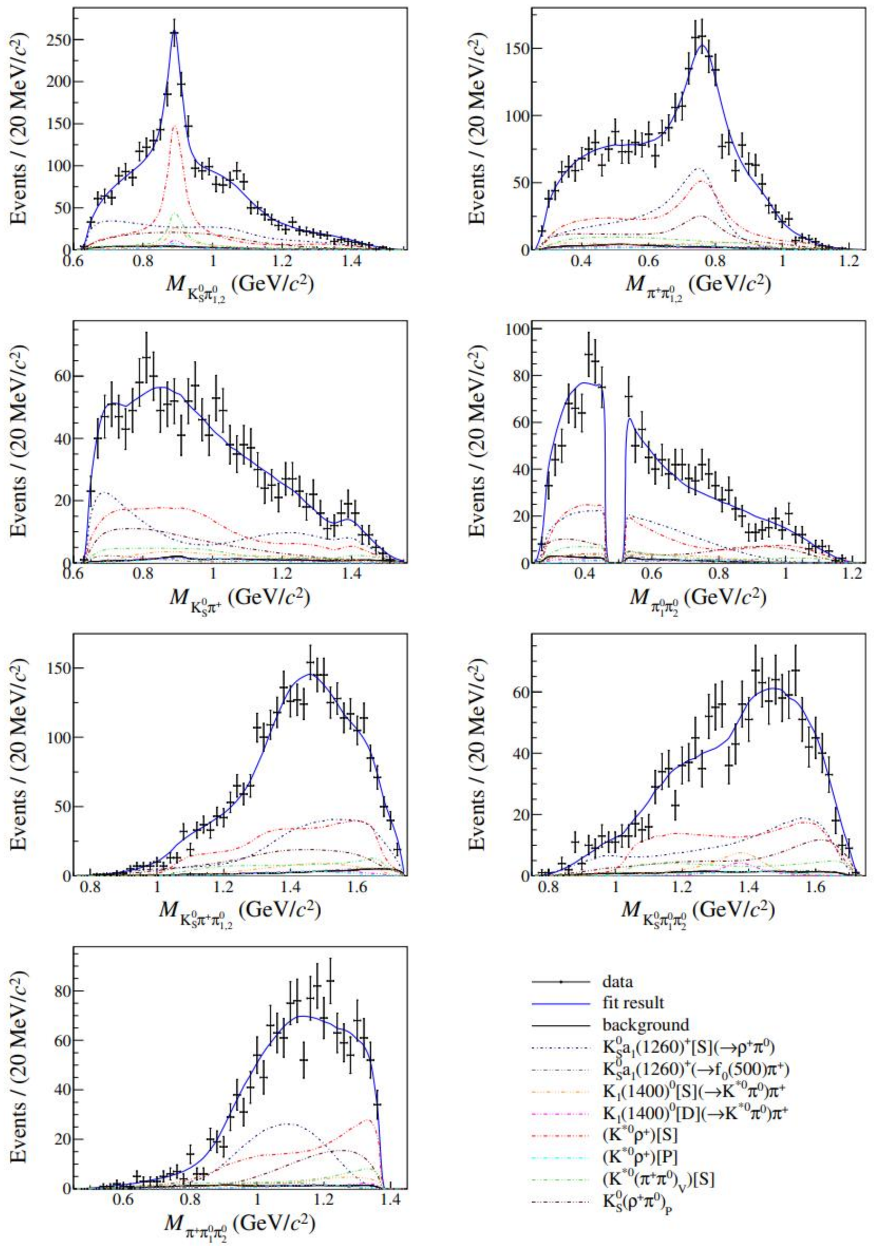
  $$\left(8.66 \pm 1.04_{\text{stat.}} \pm 1.39_{\text{syst.}}\right) \times 10^{-3}$$

- Dominate intermediate processes:
  - $\mathcal{B}\left(D^+ \to K_S^0 a_1(1260)^+(\to \rho^+\pi^0)\right) =$

    $$\left(8.66 \pm 1.04_{\text{stat.}} \pm 1.39_{\text{syst.}}\right) \times 10^{-3}$$

  - $\mathcal{B}(D^+ \to \bar{K}^{*0}\rho^+) = \left(9.70 \pm 0.81_{\text{stat}} \pm 0.53_{\text{syst}}\right) \times 10^{-3}$

✓ Projections of the nominal ft onto invariant mass distributions. The labels $\pi^0_{1,2}$ mean that two distributions involving a single π^0 have been combined.

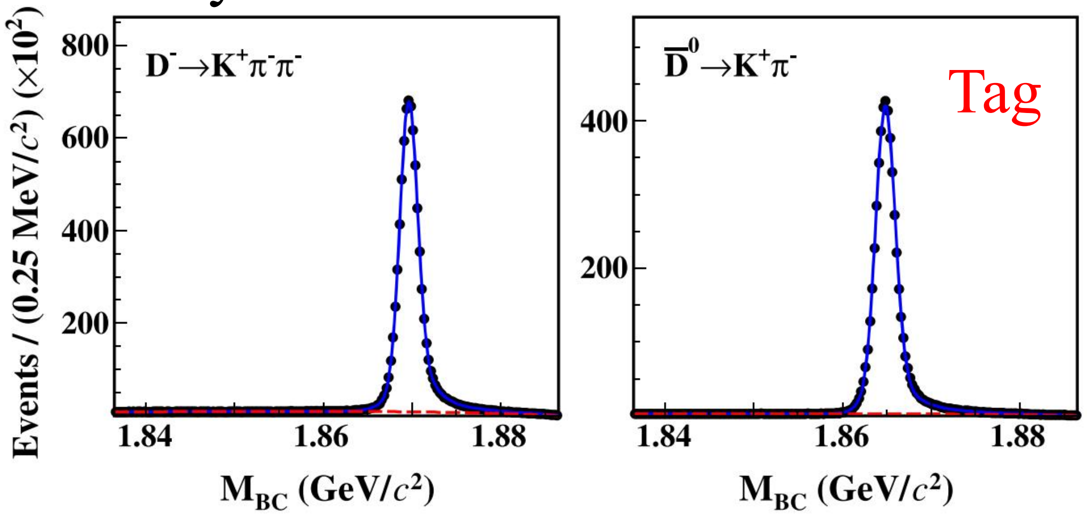


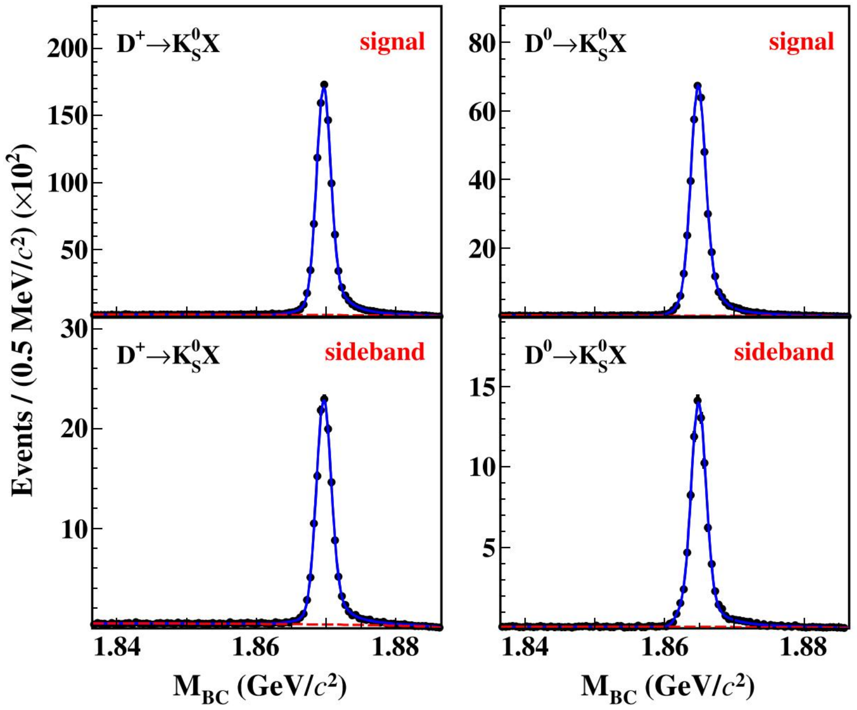
BFs measurement of $D^{0(+)} \to K_S^0 X$

- Data sample: 2.93 fb^{-1} @3.773 GeV
- Analysis method: DT method

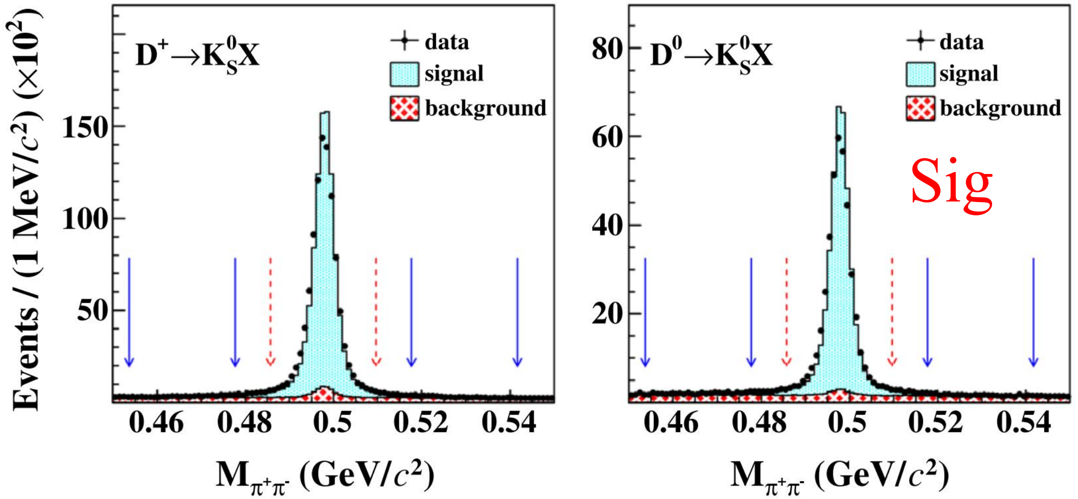
PRD 107, 112005 (2023)

Best fits to the M_{BC} distributions of the double-tag events in data.





The definitions of the K_S^0 signal and sideband regions.

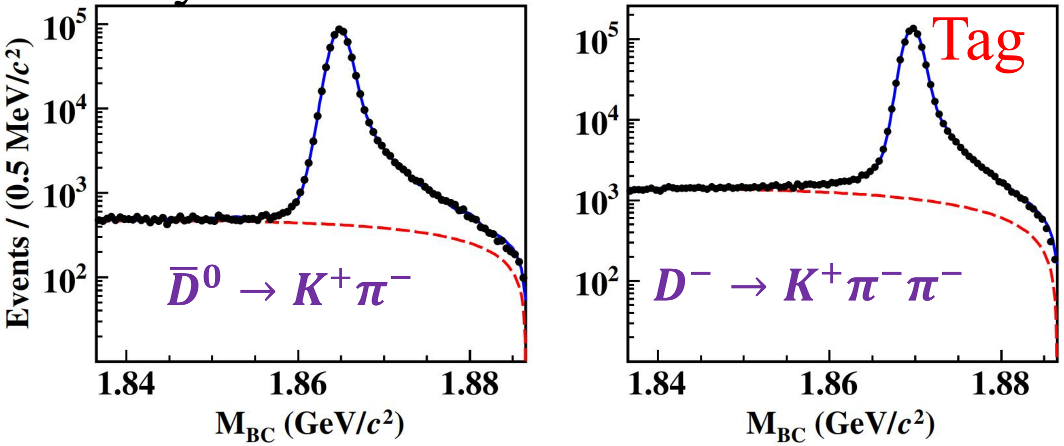


Decay mode	This work (%)	Exclusive decay(%)	Difference (%)
$D^+ \to K_S^0 X$	$33.11 \pm 0.13 \pm 0.36$	31.68 ± 0.32	1.43 ± 0.44
$D^0 \to K_S^0 X$	$20.75 \pm 0.12 \pm 0.20$	18.16 ± 0.72	2.59 ± 0.76

Some missing decay modes involving for K_S^0 both D^0 and D^+ yet to be observed.

BFs measurement of $D^{0(+)}_{(s)} \to \pi^+\pi^+\pi^- X$

- Data sample: 2.93 fb^{-1} @3.773 GeV
- Analysis method: DT method



$D^+ \to \pi^+\pi^+\pi^- X$ Phys. Rev. D 107, 032002 (2023)

i	N_{prod}	$d\mathcal{B}_{sig}$	$d\mathcal{B}^{corr}_{sig}$ (%)
1	1541.3 ± 89.9	0.28 ± 0.02	0.28 ± 0.02
2	9349.1 ± 206.0	1.71 ± 0.04	1.70 ± 0.04
3	14235.8 ± 271.8	2.60 ± 0.05	2.66 ± 0.05
4	22130.5 ± 295.0	4.04 ± 0.05	4.08 ± 0.05
5	24638.2 ± 264.9	4.50 ± 0.05	4.51 ± 0.05
6	16850.4 ± 207.4	3.07 ± 0.04	3.14 ± 0.04
7	4228.6 ± 127.5	0.77 ± 0.02	0.80 ± 0.02
8	1730.9 ± 113.7	0.32 ± 0.02	0.31 ± 0.02
9	676.1 ± 69.6	0.12 ± 0.01	0.11 ± 0.01
Total	95381.0 ± 598.9	...	17.60 ± 0.11

$D^0 \to \pi^+\pi^+\pi^- X$

i	N_{prod}	$d\mathcal{B}_{sig}$ (%)
1	1747.1 ± 111.1	0.22 ± 0.01
2	9683.3 ± 245.1	1.19 ± 0.03
3	17890.3 ± 349.6	2.20 ± 0.04
4	27671.6 ± 366.3	3.41 ± 0.05
5	33224.6 ± 340.2	4.09 ± 0.04
6	20383.9 ± 251.5	2.51 ± 0.03
7	5772.7 ± 155.4	0.71 ± 0.02
8	2661.8 ± 97.8	0.33 ± 0.01
9	2032.0 ± 81.1	0.25 ± 0.01
10	2803.0 ± 80.2	0.35 ± 0.01
Total	123870.2 ± 744.7	15.25 ± 0.09

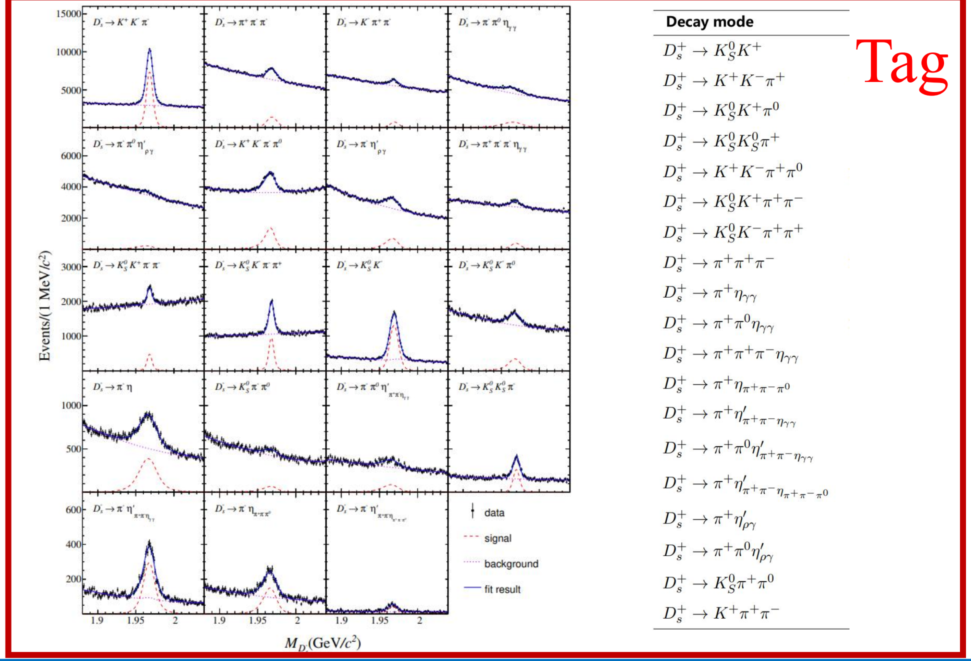
Decay mode	This work (%)	Exclusive decay (%)	Difference (%)
$D^+ \to \pi^+\pi^+\pi^- X$	$17.60 \pm 0.11 \pm 0.22$	16.05 ± 0.47	1.55
$D^0 \to \pi^+\pi^+\pi^- X$	$15.25 \pm 0.09 \pm 0.18$	14.74 ± 0.53	0.51
$D_s^+ \to \pi^+\pi^+\pi^- X$	$32.81 \pm 0.35_{stat} \pm 0.63_{syst}$	24.7 ± 1.5	8.11

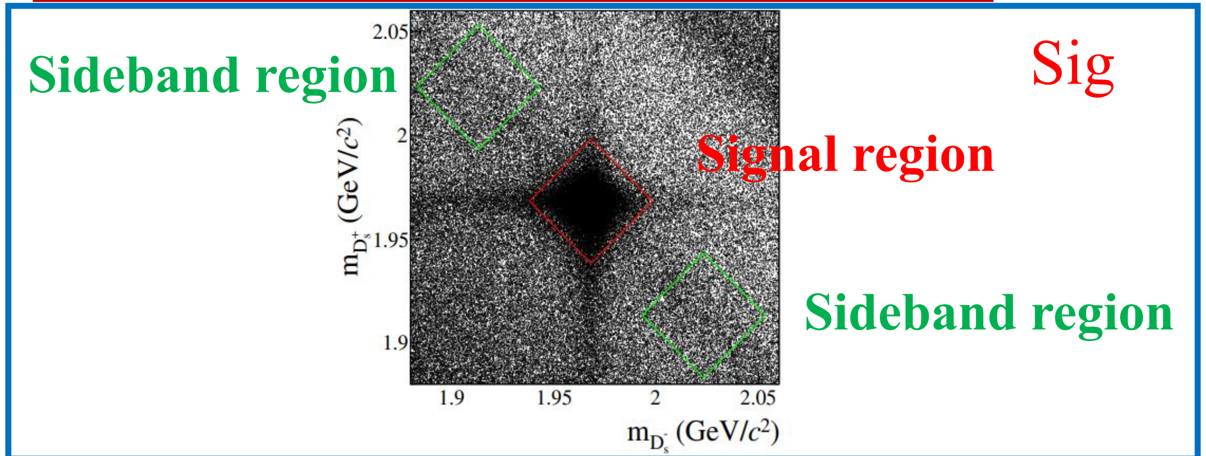
Phys. Rev. D 108, 032001 (2023)

The measured total and partial BFs of $D^{0(+)}_{(S)} \to \pi^+\pi^+\pi^- X$ offer important inputs to constrain the systematic uncertainties in future LHCb measurements on $R(D^*)$ with much larger data samples.

D_s^+ hadronic decays

- Data sample: 7.33 fb^{-1} @4.128 – 4.226 GeV
- Analysis method: DT method





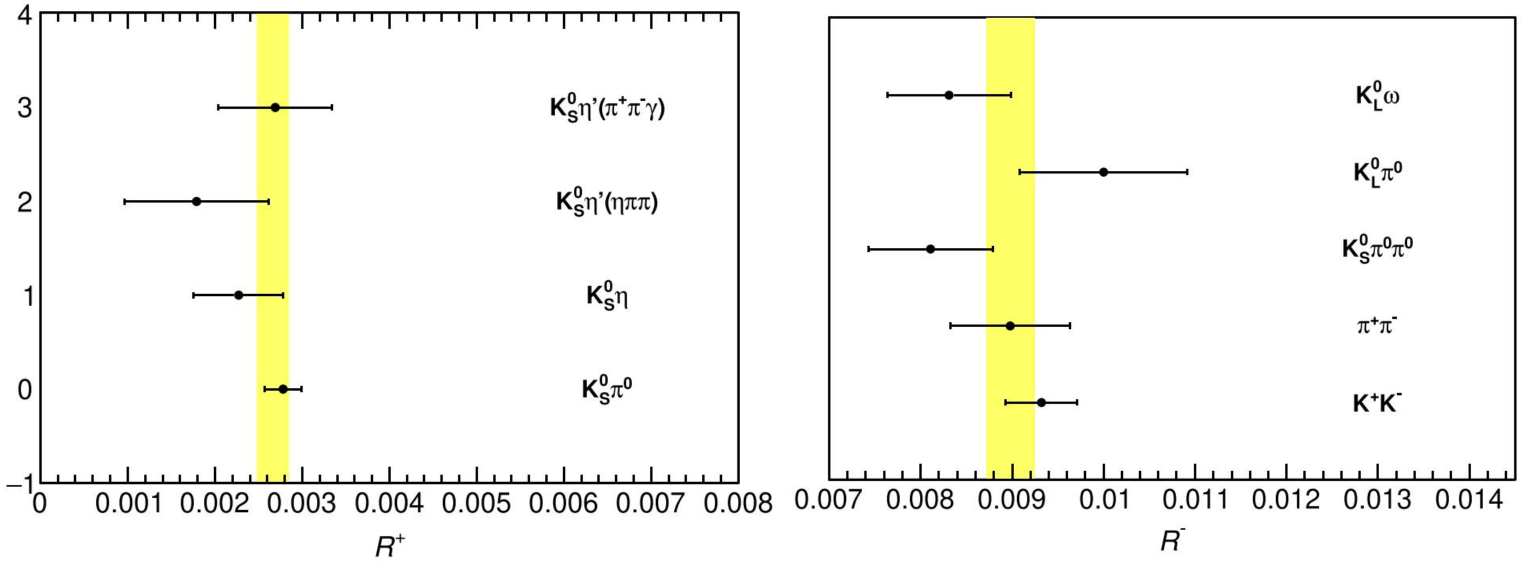
JHEP05(2024)335

Mode	$\mathcal{B}$ (%)	PDG $\mathcal{B}$ (%)
$D_s^+ \to K_S^0 K^+$	$1.502 \pm 0.012 \pm 0.009$	1.453 ± 0.035
$D_s^+ \to K^+K^-\pi^+$	$5.49 \pm 0.04 \pm 0.07$	5.37 ± 0.10
$D_s^+ \to K_S^0 K^+\pi^0$	$1.47 \pm 0.02 \pm 0.02$	1.47 ± 0.07
$D_s^+ \to K_S^0 K_S^0\pi^+$	$0.73 \pm 0.01 \pm 0.01$	0.71 ± 0.04
$D_s^+ \to K^+K^-\pi^+\pi^0$	$5.50 \pm 0.05 \pm 0.11$	5.50 ± 0.24
$D_s^+ \to K_S^0 K^+\pi^+\pi^-$	$0.93 \pm 0.02 \pm 0.01$	0.95 ± 0.08
$D_s^+ \to K_S^0 K^-\pi^+\pi^+$	$1.56 \pm 0.02 \pm 0.02$	1.53 ± 0.08
$D_s^+ \to \pi^+\pi^+\pi^-$	$1.09 \pm 0.01 \pm 0.01$	1.08 ± 0.04
$D_s^+ \to \pi^+\eta$	$1.69 \pm 0.02 \pm 0.02$	1.67 ± 0.09
$D_s^+ \to \pi^+\pi^0\eta$	$9.10 \pm 0.09 \pm 0.15$	9.5 ± 0.5
$D_s^+ \to \pi^+\pi^+\pi^-\eta$	$3.08 \pm 0.06 \pm 0.05$	3.12 ± 0.16
$D_s^+ \to \pi^+\eta'$	$3.95 \pm 0.04 \pm 0.07$	3.94 ± 0.25
$D_s^+ \to \pi^+\pi^0\eta'$	$6.17 \pm 0.12 \pm 0.14$	6.08 ± 0.29
$D_s^+ \to K_S^0\pi^+\pi^0$	$0.51 \pm 0.02 \pm 0.01$	0.54 ± 0.03
$D_s^+ \to K^+\pi^+\pi^-$	$0.620 \pm 0.009 \pm 0.006$	0.620 ± 0.019

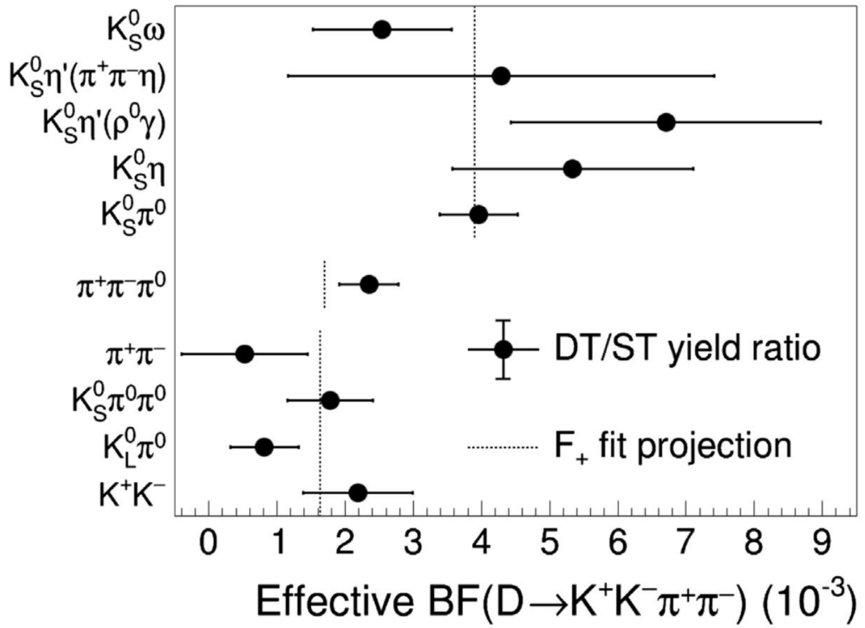
Agreement with the world-average values, but typically with much improved precision

CP-even fraction measurements

PRD 108, 032003 (2023)



PRD 107, 032009 (2023)



✓ The R^+ values (left) for the CP-odd tag modes and the R^- values (right) for the CP-even tag modes. The horizontal error bars show the total uncertainty for each measurement. The yellow bands show the fitted values with uncertainties.

- Data sample: 2.93 fb^{-1} @3.773 GeV
- $D^0 \to K^0_S\pi^+\pi^-\pi^0$
- $F_+ = 0.235 \pm 0.010 \pm 0.002$

✓ The effective branching fraction (BF) of $D \to K^+K^-\pi^+\pi^-$ measured against CP-odd (top), $D \to \pi^+\pi^-\pi^0$ and CP-even (bottom) tags. The black dotted lines indicate the values expected from the fit.

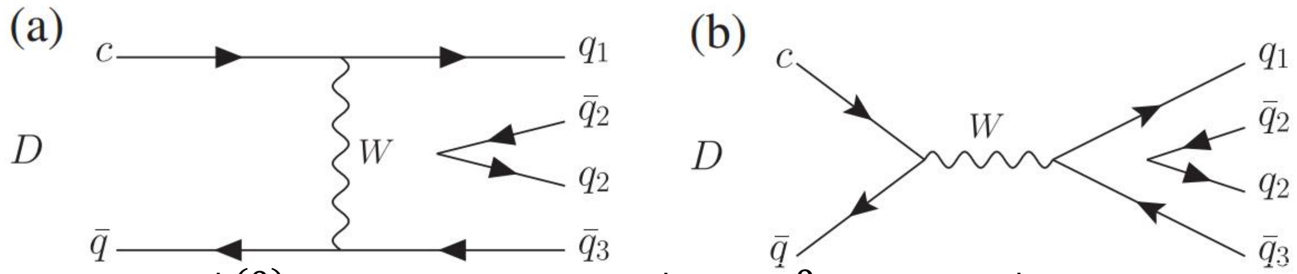
- Data sample: 2.93 fb^{-1} @3.773 GeV
- $D^0 \to K^+K^-\pi^+\pi^-$
- $F_+ = 0.730 \pm 0.037 \pm 0.021$
- First model-independent measurement

Observation of $D^+ \to K^0_S a_0(980)^+$

- Data sample: 2.93 fb^{-1} @3.773 GeV

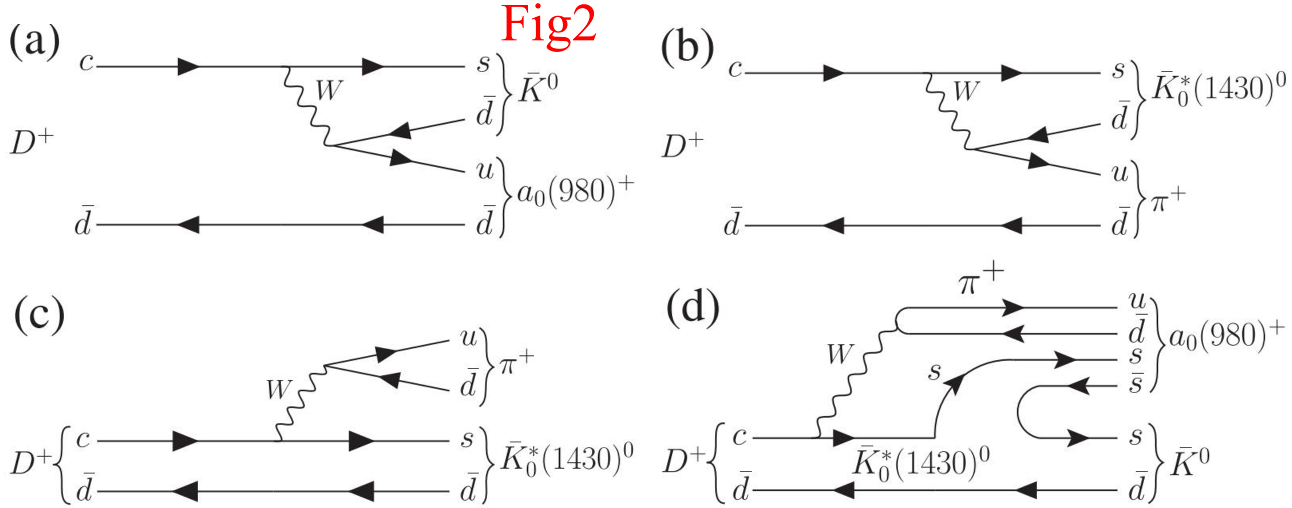
PRL 132, 131903 (2024)

Fig1



Among $D^{+(0)} \to a_0(980)P$, $D^+ \to K^0_S a_0(980)^+$ is the only decay free of weak-annihilation contributions, as depicted in Fig1, and mainly involves the internal W-emission in Fig2(a).

Fig2



(d)Assume $a_0(980)^+$ is a tetraquark state.

PRD 105, 033006(2022))

- Topological amplitudes of various $D \to SP$ decays

Decay	Amplitude
$D^+ \to f_0\pi^+$	$\frac{1}{\sqrt{2}}\alpha V^*_{cd}V_{ud}(T+C'+A+A') + \beta V^*_{cs}V_{us}C'$
$\to f_0K^+$	$V^*_{cd}V_{us}[\frac{1}{\sqrt{2}}\alpha(T+A') + \beta A]$
$\to a_0^+\bar{K}^0$	$V^*_{cs}V_{ud}(T'+C)$
$\to a_0^0\pi^+$	$\frac{1}{\sqrt{2}}V^*_{cd}V_{ud}(-T-C'-A+A')$
$\to \sigma\pi^+$	$\frac{1}{\sqrt{2}}\beta V^*_{cd}V_{ud}(T+C'+A+A') - \alpha V^*_{cs}V_{us}C'$
$\to \bar{\kappa}^0\pi^+$	$V^*_{cs}V_{ud}(T+C')$
$\to \bar{\kappa}^0K^+$	$V^*_{cs}V_{us}T + V^*_{cd}V_{ud}A$
$D^0 \to f_0\pi^0$	$\frac{1}{2}\alpha V^*_{cd}V_{ud}(-C+C'-E-E') + \frac{1}{\sqrt{2}}\beta V^*_{cs}V_{us}C'$
$\to f_0\bar{K}^0$	$V^*_{cs}V_{ud}[\frac{1}{\sqrt{2}}\alpha(C+E) + \beta E']$
$\to a_0^+\pi^-$	$V^*_{cd}V_{ud}(T'+E)$
$\to a_0^-\pi^+$	$V^*_{cd}V_{ud}(T+E')$
$\to a_0^+K^-$	$V^*_{cs}V_{ud}(T'+E)$
$\to a_0^0\bar{K}^0$	$V^*_{cs}V_{ud}(C-E)/\sqrt{2}$
$\to a_0^-K^+$	$V^*_{cd}V_{us}(T+E')$
$\to \sigma\pi^0$	$\frac{1}{2}V^*_{cd}V_{ud}\beta(-C+C'-E-E') - \frac{1}{\sqrt{2}}\alpha V^*_{cs}V_{us}C'$

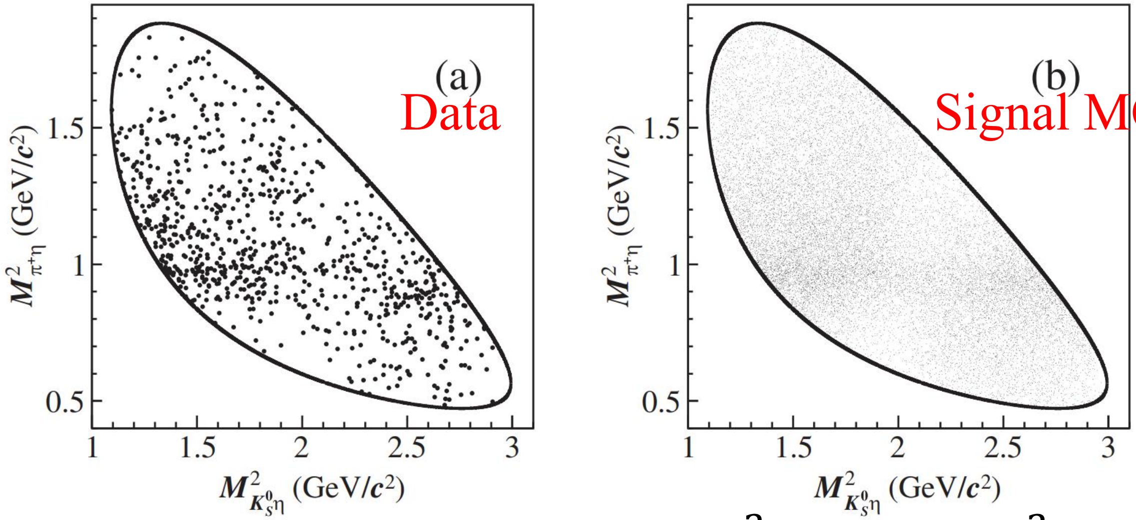
- Help to study the properties of the $a_0(980)$;
- Understand the inconsistency between the theory and experiment of the $D \to a_0(980)P$ process.

Observation of $D^+ \to K_S^0 a_0(980)^+$

- Data sample: 2.93 fb^{-1} @3.773 GeV

PRL 132, 131903 (2024)

The interferences between intermediate resonances are fully considered.



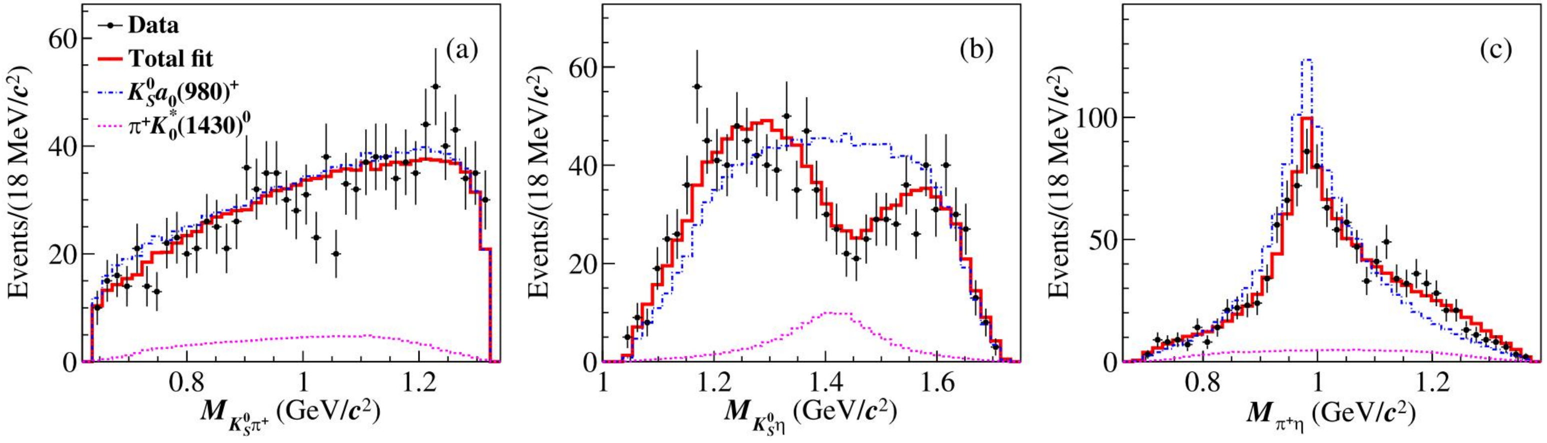
✓ The Dalitz plots of $M^2_{\pi^+\eta}$ versus $M^2_{K_S^0\eta}$

First observation

Phases, FFs, and statistical significances for different amplitudes.

Amplitude	Phase ϕ (rad)	FF (%)	Significance
$D^+ \to K_S^0 a_0(980)^+$	0.0 (fixed)	$105.00 \pm 0.94 \pm 1.04 \pm 0.07$	$>10\sigma$
$D^+ \to \bar{K}_0^*(1430)^0 \pi^+$	$2.58 \pm 0.06 \pm 0.09 \pm 0.01$	$10.83 \pm 1.50 \pm 1.27 \pm 0.08$	$>10\sigma$

A $(15.83 \pm 1.53_{stat} \pm 1.65_{syst})$ destructive interference is observed between the $D^+ \to K_S^0 a_0(980)^+$ and $D^+ \to \bar{K}_0^*(1430)^0 \pi^+$ amplitudes.



✓ Projections on the invariant masses.

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

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

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

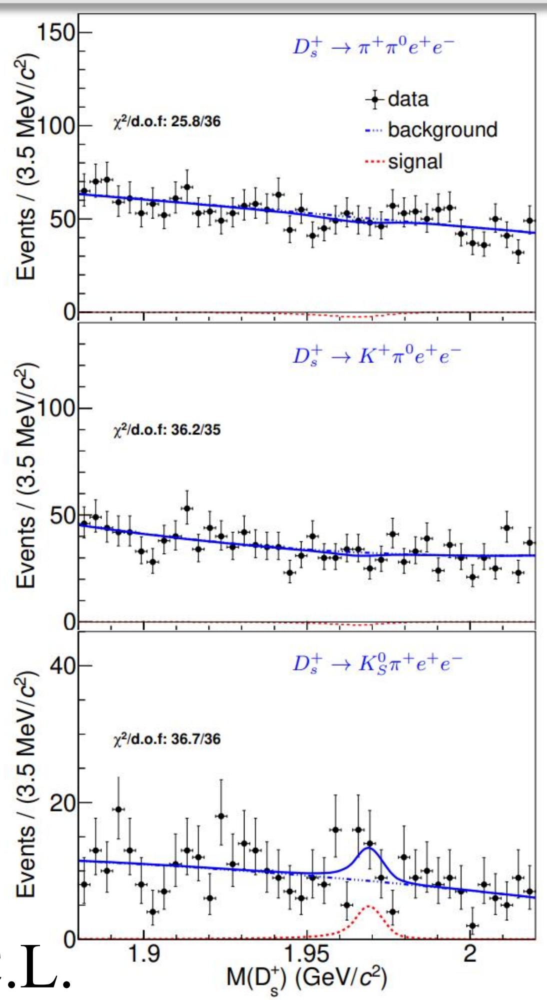
Search for the rare decays $D_s^+ \to h^+h^0e^+e^-$

- Data sample: 7.33 fb^{-1} @4.128-4.226 GeV
- Analysis method: ST method
- Reconstructed by:

  $D_s^+ \to \pi^+\pi^0e^+e^-$, $D_s^+ \to K^+\pi^0e^+e^-$,
  $D_s^+ \to K_S^0\pi^+e^+e^-$

Accepted by PRL

arXiv:2404.05973



Decay	N_{sig}	ϵ (%)	$\mathcal{B}$ ($\times 10^{-5}$)
$D_s^+ \to \pi^+\phi, \phi \to e^+e^-$	$38.2^{+7.8}_{-6.8}$	25.1	$1.17^{+0.23}_{-0.21} \pm 0.03$
$D_s^+ \to \rho^+\phi, \phi \to e^+e^-$	$37.8^{+10.3}_{-9.6}$	12.1	$2.44^{+0.67}_{-0.62} \pm 0.16$

7.8 σ for $D_s^+ \to \pi^+\phi,\ \phi \to e^+e^-$ improved by a factor of three;
4.4 σ for $D_s^+ \to \rho^+\phi,\ \phi \to e^+e^-$ First evidence.

- Upper limits @90%C.L.

Decay	N_{sig}	ϵ (%)	$\mathcal{B}$ ($\times 10^{-5}$)
$D_s^+ \to \pi^+\pi^0e^+e^-$	...	7.4	< 7.0
$D_s^+ \to K^+\pi^0e^+e^-$	...	5.3	< 7.1
$D_s^+ \to K_S^0\pi^+e^+e^-$	...	6.7	< 8.1

Conclusion and prospect

- Charm mesons are important for CKM matrix elements, calibrating LQCD, understanding non-perturbative QCD, and searching for new physics beyond the Standard Model …
- BESIII reports many important results on charm mesons decay:
  - ✓ Precise measurements of $D_s^+ \to \tau^+\nu_\tau$;
  - ✓ More inclusive decay results are published.

- Prospect:

  20 fb^{-1} data at $\sqrt{s}$=3.773 GeV has been collected at BESIII of 2024;

  New measurements with larger data samples are expected.


Thanks!