Charmed Meson Hadronic decays at BESIII

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(On behalf of the BESIII collaboration)

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Outline

- Introduction
  - D^0, D^+,and D_s dataset
  - DTag and branching fraction
- Branching fraction measurement of D hadronic decays
- Amplitude analysis
  - $K^-\pi^+\pi^+\pi^-$, $K_S\pi^+\pi^+\pi^-$, $K^-\pi^+\pi^0\pi^0$, $\pi^+\pi^0\eta$ etc.
- Summary

BESIII Data Taken near DD^{bar} Threshold

- BEPCII collider: $e^+e^- \rightarrow \psi(3770) \rightarrow DD^{bar}$
- 2.9 fb^{-1} dataset at $\psi(3770)$ resonance (~3.6x larger than CLEO's)

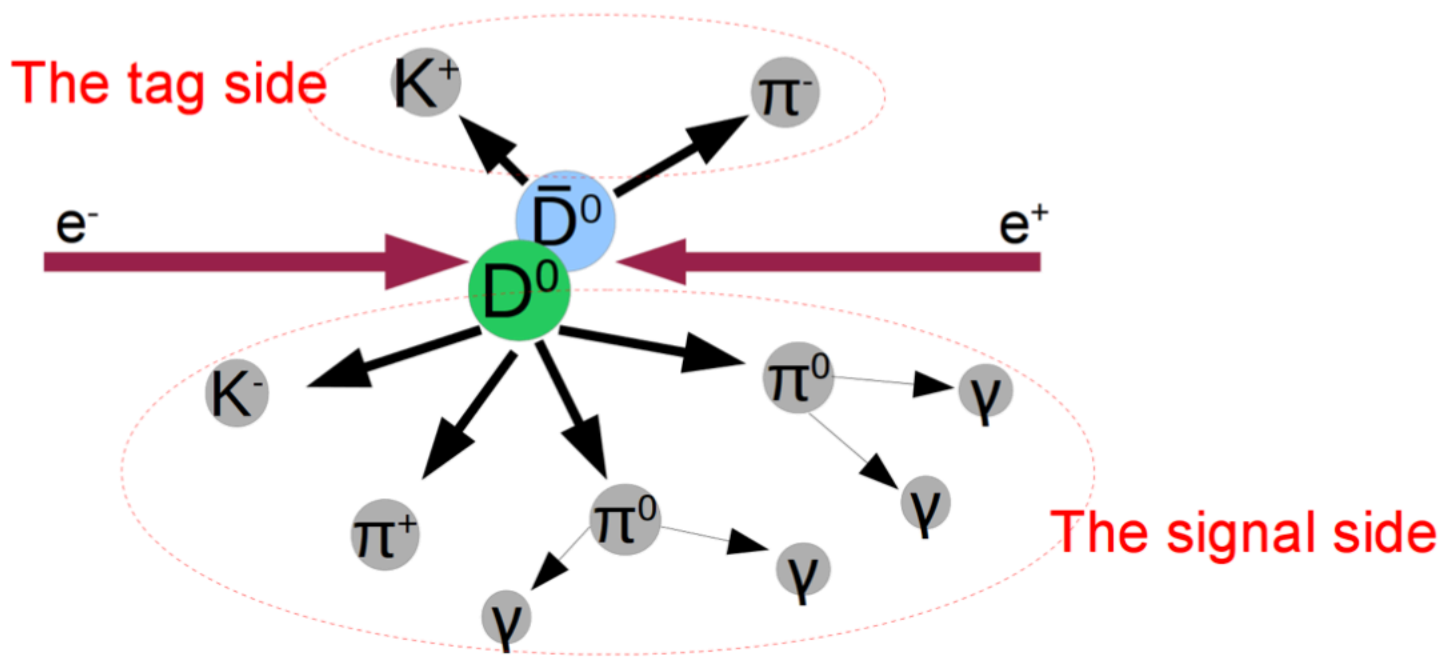
M_{D0}= 1864.84 MeV M_{D+}= 1869.62 MeV

$2M_{D0}$= 3729.68 MeV $2M_{D+}$= 3739.24 MeV

- 3.19 fb^{-1} dataset at E_{cm} 4.178GeV (~5.3x larger than CLEO's)
  - D_s are produced mostly via $e^+e^- \rightarrow D_sD_s^*$
  - more energy points are ready (4.190, 4.200, 4.210, 4.220.4.230 GeV. Total are about 0.8x of 4.178 data.)
- Advantages of DD^{bar} pair production near threshold
  - The DD^{bar} events are clean; not enough energy for even one additional pion
  - Tagging reduces background from light-quark "continuum" and other charm final states
  - Double tag technique can provide access to absolute BFs
  - Many systematic uncertainties cancel with tagging technique

DTag Technique

- There are two types of samples used in the Dtag technique: single tag (ST) and double tag (DT).
- Single tag: only one D meson is reconstructed through a chosen hadronic decay.
- Double tag: both D and $\bar{D}$ are reconstructed,
- the D reconstructed through the studied hadronic decay is called “the signal side”.
- the $\bar{D}$ reconstructed through well-known and clean hadronic decay modes is called “the tag side”.
- (Charge-conjugate states are implied throughout this talk.)



Observation of the Singly Cabibbo-Suppressed Decay $D^+ \to \omega\pi^+$ and Evidence for $D^0 \to \omega\pi^0$

Chose six (five) decay modes for $D^{+(0)}$.

In order to have a better solution for $D^{+(0)} \to \pi^+\pi^-\pi^0\pi^{+(0)}$ background, DT samples $D^{+(0)} \to \pi^+\pi^-\pi^0\pi^{+(0)}$ vs. tag modes are reconstructed first. Then fits to $\pi^+\pi^-\pi^0$ mass are performed.

Note that we are searching for $\omega \to \pi^+\pi^-\pi^0$.

$$\mathcal{B}_{\rm sig} = \frac{\sum_\alpha N_{\rm sig}^{{\rm obs},\alpha}}{\sum_\alpha N_{\rm tag}^{{\rm obs},\alpha} \epsilon_{\rm tag,sig}^{\alpha} / \epsilon_{\rm tag}^{\alpha}}$$

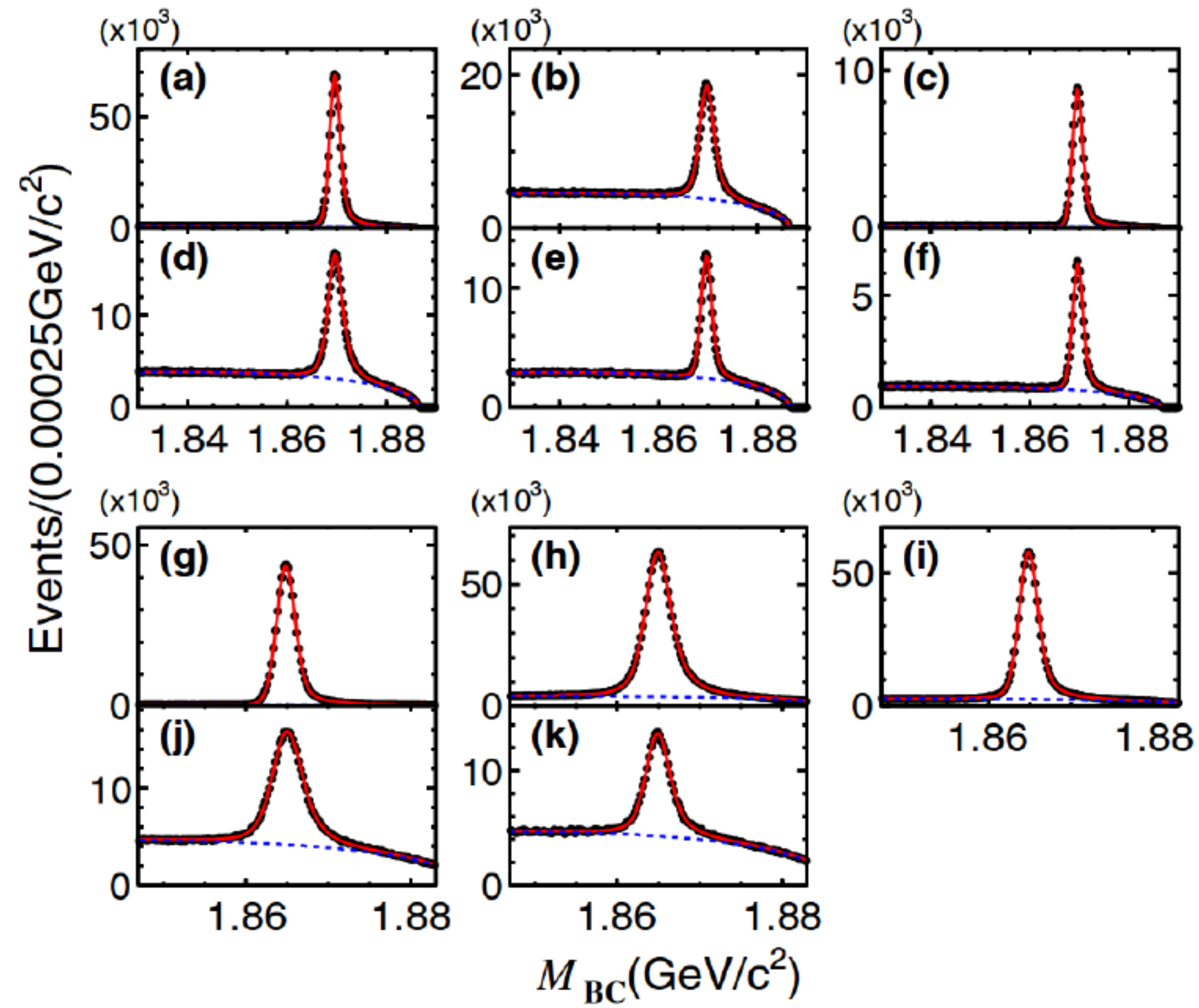


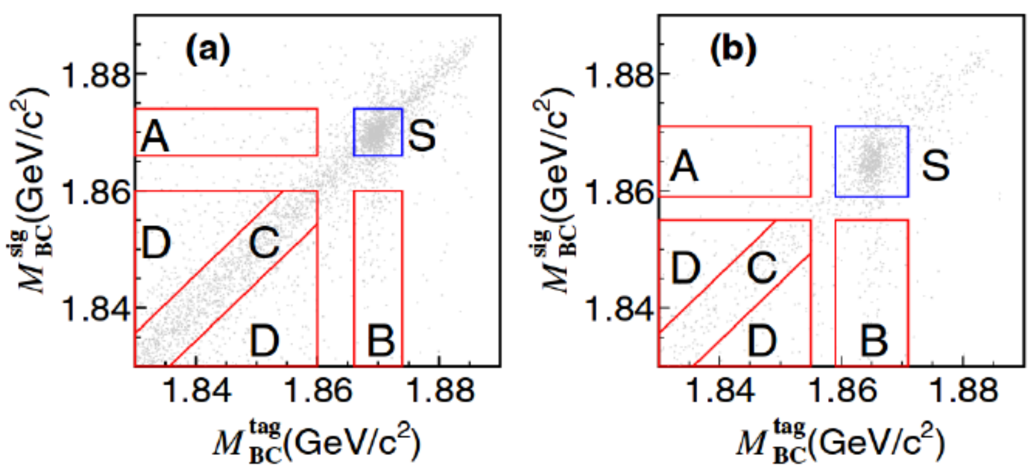
FIG. 1. $M_{\rm BC}$ distributions of ST samples for different tag modes. The first two rows show charged D decays: (a) $K^+\pi^-\pi^-$, (b) $K^+\pi^-\pi^-\pi^0$, (c) $K_S^0\pi^-$, (d) $K_S^0\pi^-\pi^0$, (e) $K_S^0\pi^+\pi^-\pi^-$, (f) $K^+K^-\pi^-$, the latter two rows show neutral D decays: (g) $K^+\pi^-$, (h) $K^+\pi^-\pi^0$, (i) $K^+\pi^-\pi^+\pi^-$, (j) $K^+\pi^-\pi^0\pi^0$, (k) $K^+\pi^-\pi^+\pi^-\pi^0$. Data are shown as points, the (red) solid lines are the total fits and the (blue) dashed lines are the background shapes. D and $\bar{D}$ candidates are combined.

DT $D^{+(0)} \to \pi^+\pi^-\pi^0\pi^{+(0)}$ vs. tag modes

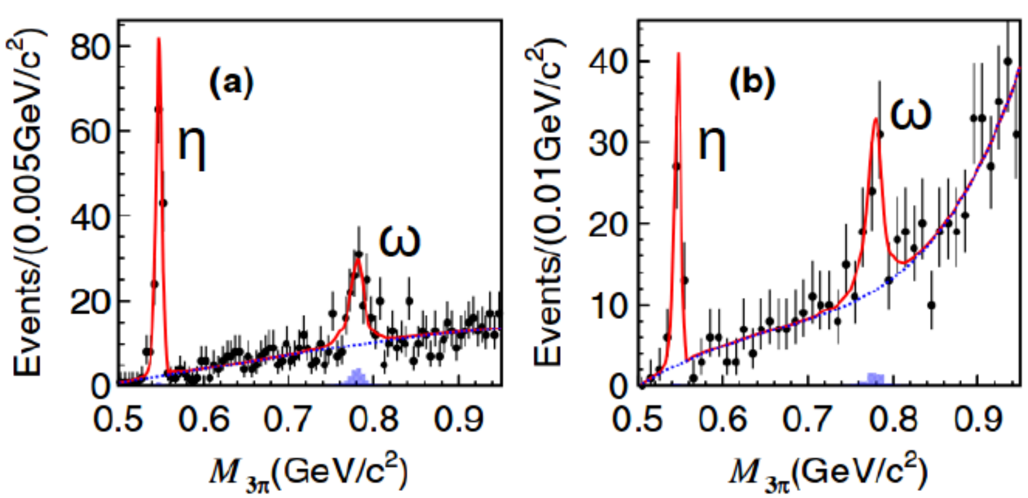
Fits to M3π distributions of signal and sideband regions to obtain the signal and peaking background yields, respectively.

Events counts in sidebands are projected into the signal region with scale factors.

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



ModeH	$N_{\omega(\eta)}$	$N^{bkg}_{\omega(\eta)}$	N^{obs}_{sig}
$D^+ \to \omega\pi^+$	100 ± 16	21 ± 4	79 ± 16
$D^0 \to \omega\pi^0$	50 ± 12	5 ± 5	45 ± 13
$D^+ \to \eta\pi^+$	264 ± 17	6 ± 2	258 ± 18
$D^0 \to \eta\pi^0$	78 ± 10	3 ± 2	75 ± 10



Mode	This work	Previous measurements
$D^+ \to \omega\pi^+$	$(2.79 \pm 0.57 \pm 0.16) \times 10^{-4}$	$< 3.4 \times 10^{-4}$ at 90% C.L.
$D^0 \to \omega\pi^0$	$(1.17 \pm 0.34 \pm 0.07) \times 10^{-4}$	$< 2.6 \times 10^{-4}$ at 90% C.L.
$D^+ \to \eta\pi^+$	$(3.07 \pm 0.22 \pm 0.13) \times 10^{-3}$	$(3.53 \pm 0.21) \times 10^{-3}$
$D^0 \to \eta\pi^0$	$(0.65 \pm 0.09 \pm 0.04) \times 10^{-3}$	$(0.68 \pm 0.07) \times 10^{-3}$

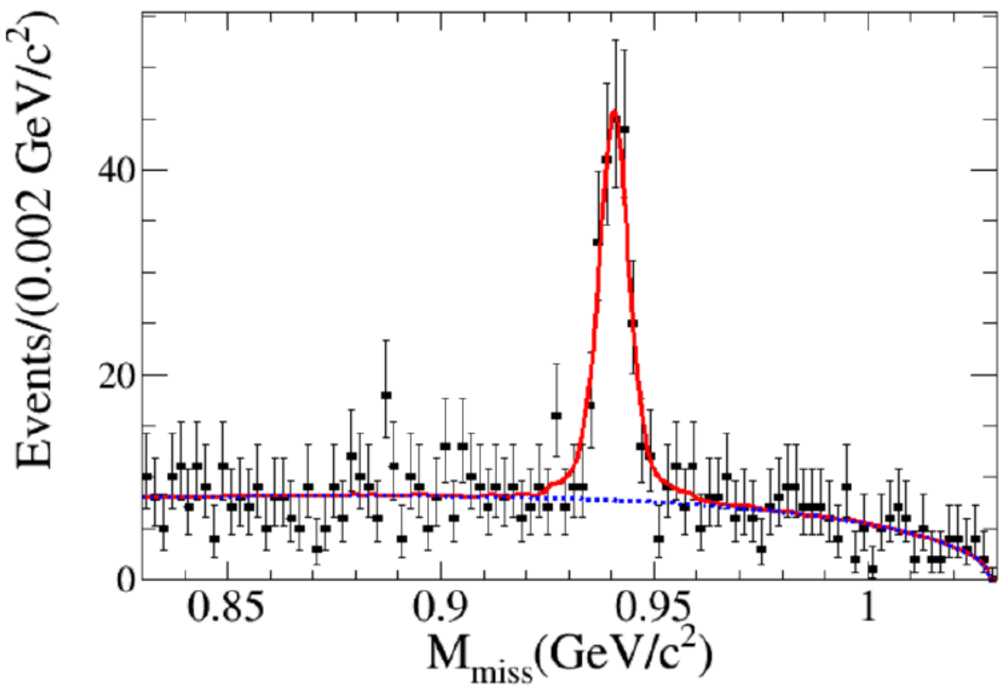
Red line: total fit

Blue line: background

Hatched histogram: peaking background From sidebands

PRL **116,** 082001 (2016)

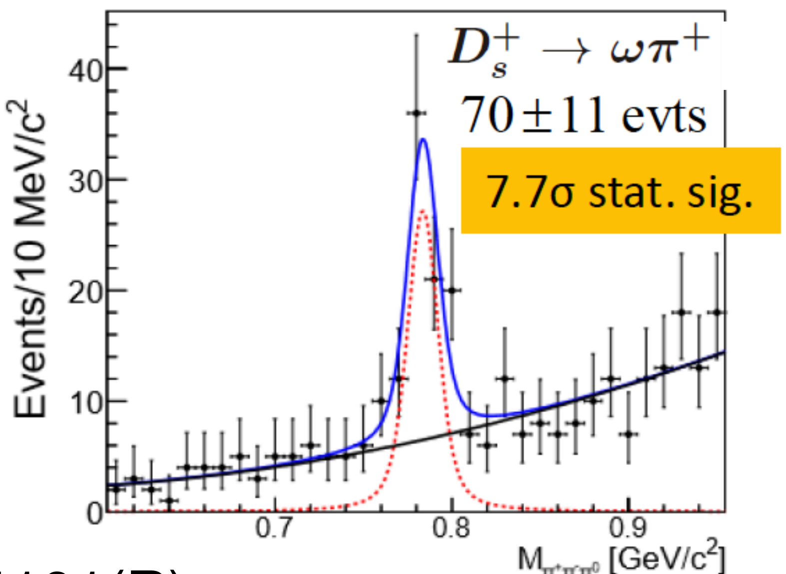
Measurements of pure W-annihilation decays in D_s^+

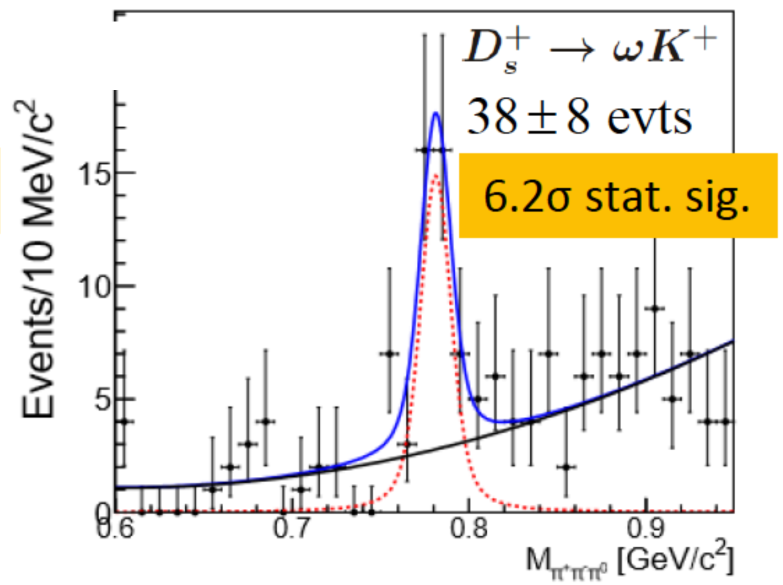


$$\boxed{\mathcal{B}_{D_s^+\to p\bar{n}} = (1.22 \pm 0.10) \times 10^{-3}}$$

Consistent with long-distance expectation

Phys. Rev. D **99**, 031101(R)





Phys. Rev. D **99**, 091101(R)

Consistent with CLEO's measurement, but more precise.

$$\mathcal{B}(D_s^+ \to \omega\pi^+) = (1.85 \pm 0.30_{stat.} \pm 0.19_{sys.}) \times 10^{-3}$$

$$\mathcal{B}(D_s^+ \to \omega K^+) = (1.13 \pm 0.24_{stat.} \pm 0.14_{sys.}) \times 10^{-3}$$

First observation !

This measurement of implies the ρ–ω mixing is negligible.

Amplitude Analysis of $D_{(s)}$ three- and four-body decays

The amplitude of the n^{th} intermediate state

$$A_n = P_n S_n F_n^r F_n^D$$

propagator

spin factor

Blatt-Weisskopf barrier factor

The total amplitude M

$$\sum c_n A_n$$

complex coefficient (we are going to fit)

The signal probability density function (PDF)

$$f_S(p_j) = \frac{\epsilon(p_j) \left|M(p_j)\right|^2 R_3(p_j)}{\int \epsilon(p_j) \left|M(p_j)\right|^2 R_3(p_j)\, dp_j}$$

Likelihood

$$\ln L = \sum_k^{N_{data}} \ln f_S(p_j^k),$$

The normalization is determined by MC integration

$$\int \epsilon(p_j) \left|M(p_j)\right|^2 R_3(p_j)\, dp_j \approx \frac{1}{N_{MC}} \sum_{k_{MC}}^{N_{MC}} \frac{\left|M(p_j^{k_{MC}})\right|^2}{\left|M^{gen}(p_j^{k_{MC}})\right|^2}$$

Propagator

K*(892), K*(1680): RBW $\quad P = \frac{1}{(m_0^2 - s_a) - i m_0 \Gamma(m)}$

Phys. Rev. D 95, no. 3, 032002 (2017)

a_0: two-channel-coupled Flatte formula $\quad 1/[(m_0^2 - s_a) - i(g_{\eta\pi}^2 \rho_{\eta\pi} + g_{K\bar{K}}^2 \rho_{K\bar{K}})]$

Amplitude Analysis of $K\pi\pi\pi$

- There are seven $D \to K\pi\pi\pi$ modes:

  $D^0 \to K^-\pi^+\pi^+\pi^-$ (published on PRD)

  $D^0 \to K^-\pi^+\pi^0\pi^0$ (published on PRD)

  $D^0 \to K_S\pi^0\pi^0\pi^0$

  $D^0 \to K_S\pi^+\pi^-\pi^0$ (on-going)

  $D^+ \to K^-\pi^+\pi^+\pi^0$ (on-going)

  $D^+ \to K_S\pi^+\pi^0\pi^0$ (on-going)

  $D^+ \to K_S\pi^+\pi^+\pi^-$ (published on PRD)
- Four-body decays are in five-dimensions
- We have
  - Partial Wave Analysis Tools based on CPU and GPU kernel
  - Great Electro-Magnetic Calorimeter (EMC) with CsI

    $\to$ superior resolution and efficiency of π^0
  - Largest dataset at $\psi(3770)$ resonance

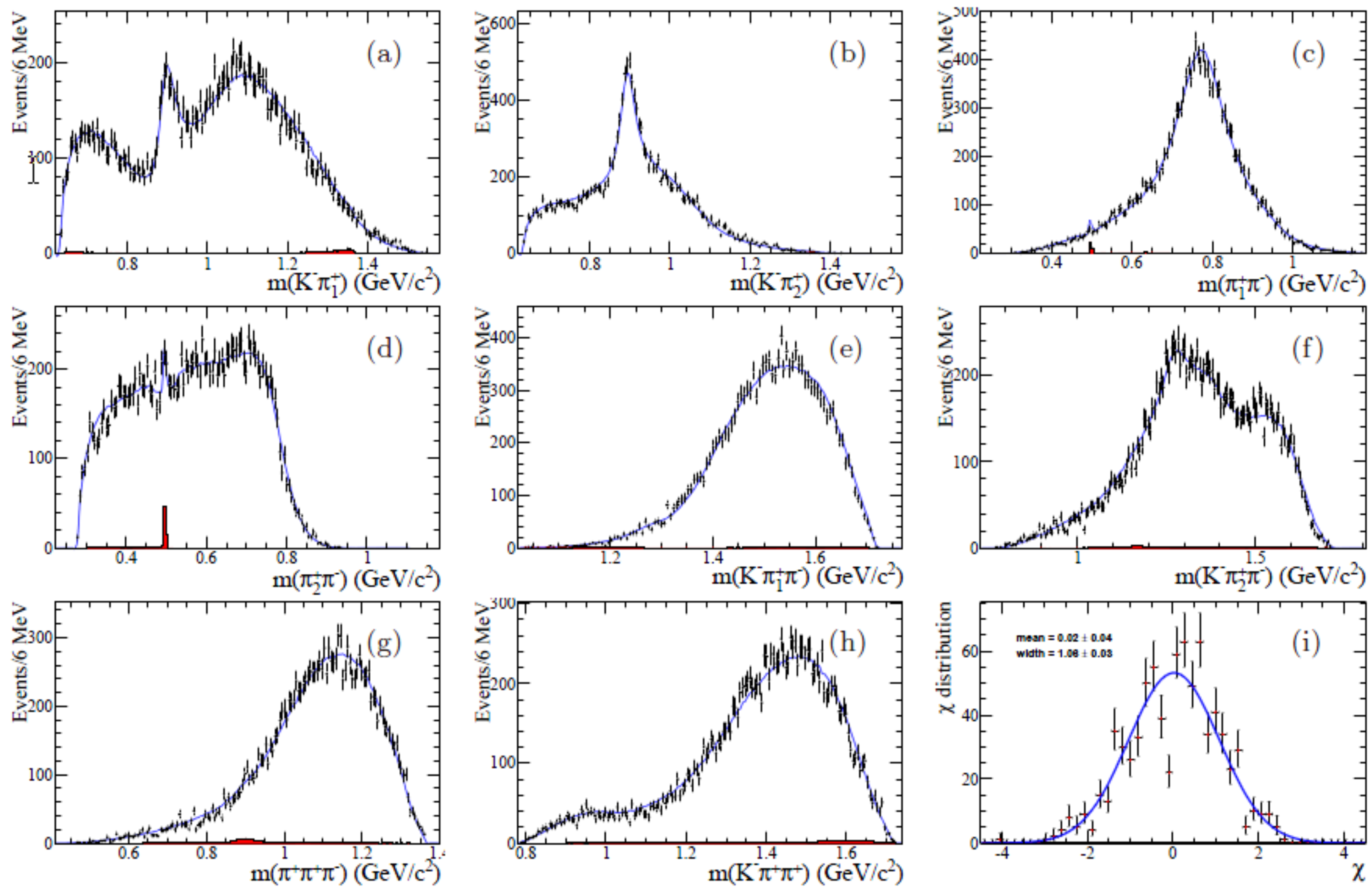
    $\to$ small statistical errors and clean background

Amplitude Analysis Results of $D^0 \rightarrow K^-\pi^+\pi^+\pi^-$

Double tag $D^0 \rightarrow K^-\pi^+\pi^+\pi^-$ vs. $D^0 \rightarrow K^+\pi^-$

Amplitude	ϕ_i	Fit fraction (%)
$D^0[S] \to \bar{K}^*\rho^0$	$2.35 \pm 0.06 \pm 0.18$	$6.5 \pm 0.5 \pm 0.8$
$D^0[P] \to \bar{K}^*\rho^0$	$-2.25 \pm 0.08 \pm 0.15$	$2.3 \pm 0.2 \pm 0.1$
$D^0[D] \to \bar{K}^*\rho^0$	$2.49 \pm 0.06 \pm 0.11$	$7.9 \pm 0.4 \pm 0.7$
$D^0 \to K^-a_1^+(1260),\ a_1^+(1260)[S] \to \rho^0\pi^+$	0(fixed)	$53.2 \pm 2.8 \pm 4.0$
$D^0 \to K^-a_1^+(1260),\ a_1^+(1260)[D] \to \rho^0\pi^+$	$-2.11 \pm 0.15 \pm 0.21$	$0.3 \pm 0.1 \pm 0.1$
$D^0 \to K_1^-(1270)\pi^+,\ K_1^-(1270)[S] \to \bar{K}^{*0}\pi^-$	$1.48 \pm 0.21 \pm 0.24$	$0.1 \pm 0.1 \pm 0.1$
$D^0 \to K_1^-(1270)\pi^+,\ K_1^-(1270)[D] \to \bar{K}^{*0}\pi^-$	$3.00 \pm 0.09 \pm 0.15$	$0.7 \pm 0.2 \pm 0.2$
$D^0 \to K_1^-(1270)\pi^+,\ K_1^-(1270) \to K^-\rho^0$	$-2.46 \pm 0.06 \pm 0.21$	$3.4 \pm 0.3 \pm 0.5$
$D^0 \to (\rho^0K^-)_{\mathrm{A}}\pi^+,\ (\rho^0K^-)_{\mathrm{A}}[D] \to K^-\rho^0$	$-0.43 \pm 0.09 \pm 0.12$	$1.1 \pm 0.2 \pm 0.3$
$D^0 \to (K^-\rho^0)_{\mathrm{P}}\pi^+$	$-0.14 \pm 0.11 \pm 0.10$	$7.4 \pm 1.6 \pm 5.7$
$D^0 \to (K^-\pi^+)_{\mathrm{S}}\rho^0$	$-2.45 \pm 0.19 \pm 0.47$	$2.0 \pm 0.7 \pm 1.9$
$D^0 \to (K^-\rho^0)_{\mathrm{V}}\pi^+$	$-1.34 \pm 0.12 \pm 0.09$	$0.4 \pm 0.1 \pm 0.1$
$D^0 \to (\bar{K}^{*0}\pi^-)_{\mathrm{P}}\pi^+$	$-2.09 \pm 0.12 \pm 0.22$	$2.4 \pm 0.5 \pm 0.5$
$D^0 \to \bar{K}^{*0}(\pi^+\pi^-)_{\mathrm{S}}$	$-0.17 \pm 0.11 \pm 0.12$	$2.6 \pm 0.6 \pm 0.6$
$D^0 \to (\bar{K}^{*0}\pi^-)_{\mathrm{V}}\pi^+$	$-2.13 \pm 0.10 \pm 0.11$	$0.8 \pm 0.1 \pm 0.1$
$D^0 \to ((K^-\pi^+)_{\mathrm{S}}\pi^-)_{\mathrm{A}}\pi^+$	$-1.36 \pm 0.08 \pm 0.37$	$5.6 \pm 0.9 \pm 2.7$
$D^0 \to K^-((\pi^+\pi^-)_{\mathrm{S}}\pi^+)_{\mathrm{A}}$	$-2.23 \pm 0.08 \pm 0.22$	$13.1 \pm 1.9 \pm 2.2$
$D^0 \to (K^-\pi^+)_{\mathrm{S}}(\pi^+\pi^-)_{\mathrm{S}}$	$-1.40 \pm 0.04 \pm 0.22$	$16.3 \pm 0.5 \pm 0.6$
$D^0[S] \to (K^-\pi^+)_{\mathrm{V}}(\pi^+\pi^-)_{\mathrm{V}}$	$1.59 \pm 0.13 \pm 0.41$	$5.4 \pm 1.2 \pm 1.9$
$D^0 \to (K^-\pi^+)_{\mathrm{S}}(\pi^+\pi^-)_{\mathrm{V}}$	$-0.16 \pm 0.17 \pm 0.43$	$1.9 \pm 0.6 \pm 1.2$
$D^0 \to (K^-\pi^+)_{\mathrm{V}}(\pi^+\pi^-)_{\mathrm{S}}$	$2.58 \pm 0.08 \pm 0.25$	$2.9 \pm 0.5 \pm 1.7$
$D^0 \to (K^-\pi^+)_{\mathrm{T}}(\pi^+\pi^-)_{\mathrm{S}}$	$-2.92 \pm 0.14 \pm 0.12$	$0.3 \pm 0.1 \pm 0.1$
$D^0 \to (K^-\pi^+)_{\mathrm{S}}(\pi^+\pi^-)_{\mathrm{T}}$	$2.45 \pm 0.12 \pm 0.37$	$0.5 \pm 0.1 \pm 0.1$

Amplitude Analysis Results of $D^0 \rightarrow K^-\pi^+\pi^+\pi^-$



Component	Fit fraction (%)
$D^0 \to \bar{K}^{*0}\rho^0$	$12.3 \pm 0.4 \pm 0.5$
$D^0 \to K^- a_1^+(1260)(\rho^0\pi^+)$	$54.6 \pm 2.8 \pm 3.7$
$D^0 \to K_1^-(1270)(\bar{K}^{*0}\pi^-)\pi^+$	$0.8 \pm 0.2 \pm 0.2$
$D^0 \to K_1^-(1270)(K^-\rho^0)\pi^+$	$3.4 \pm 0.3 \pm 0.2$
$D^0 \to K^-\pi^+\rho^0$	$8.4 \pm 1.1 \pm 2.2$
$D^0 \to \bar{K}^{*0}\pi^+\pi^-$	$7.0 \pm 0.4 \pm 0.3$
$D^0 \to K^-\pi^+\pi^+\pi^-$	$21.9 \pm 0.6 \pm 0.6$

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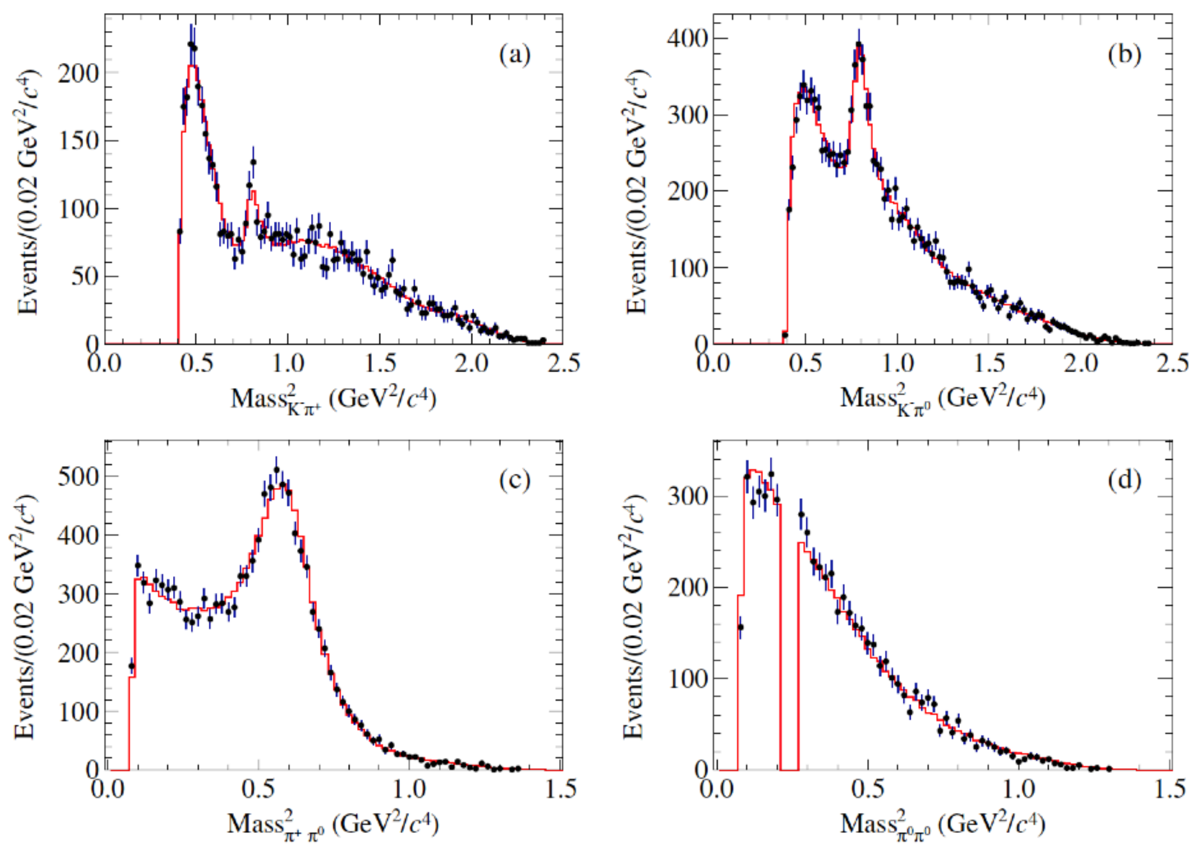
Amplitude Analysis Results of $D^0 \to K^-\pi^+\pi^0\pi^0$

Double tag: $D^0 \to K^-\pi^+\pi^0\pi^0$ (signal) vs. $\bar{D}^0 \to K^+\pi^-$ (tag)

The number of event selected is 5950 with a purity of ~99%

The data can be described with 26 amplitudes:

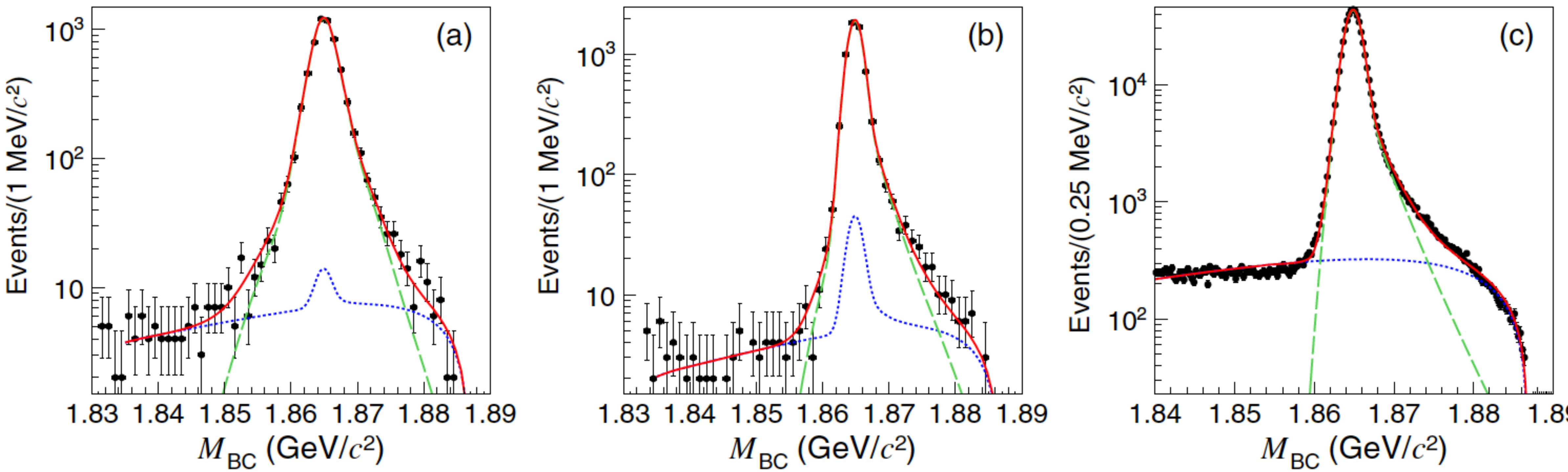
Amplitude mode	FF(%)	Phase (ϕ)
$D \to SS$		
$D \to (K^-\pi^+)_{S\text{-wave}}(\pi^0\pi^0)_S$	$6.92 \pm 1.44 \pm 2.86$	$-0.75 \pm 0.15 \pm 0.47$
$D \to (K^-\pi^0)_{S\text{-wave}}(\pi^+\pi^0)_S$	$4.18 \pm 1.02 \pm 1.77$	$-2.90 \pm 0.19 \pm 0.47$
$D \to AP, A \to VP$		
$D \to K^-a_1(1260)^+, \rho^+\pi^0[S]$	$28.36 \pm 2.50 \pm 3.53$	0 (fixed)
$D \to K^-a_1(1260)^+, \rho^+\pi^0[D]$	$0.68 \pm 0.29 \pm 0.30$	$-2.05 \pm 0.17 \pm 0.25$
$D \to K_1(1270)^-\pi^+, K^{*-}\pi^0[S]$	$0.15 \pm 0.09 \pm 0.18$	$1.84 \pm 0.34 \pm 0.43$
$D \to K_1(1270)^0\pi^0, K^{*0}\pi^0[S]$	$0.39 \pm 0.18 \pm 0.30$	$-1.55 \pm 0.20 \pm 0.26$
$D \to K_1(1270)^0\pi^0, K^{*0}\pi^0[D]$	$0.11 \pm 0.11 \pm 0.13$	$-1.35 \pm 0.43 \pm 0.48$
$D \to K_1(1270)^0\pi^0, K^-\rho^+[S]$	$2.71 \pm 0.38 \pm 0.29$	$-2.07 \pm 0.09 \pm 0.20$
$D \to (K^{*-}\pi^0)_A\pi^+, K^{*-}\pi^0[S]$	$1.85 \pm 0.62 \pm 1.11$	$1.93 \pm 0.10 \pm 0.15$
$D \to (K^{*0}\pi^0)_A\pi^0, K^{*0}\pi^0[S]$	$3.13 \pm 0.45 \pm 0.58$	$0.44 \pm 0.12 \pm 0.21$
$D \to (K^{*0}\pi^0)_A\pi^0, K^{*0}\pi^0[D]$	$0.46 \pm 0.17 \pm 0.29$	$-1.84 \pm 0.26 \pm 0.42$
$D \to (\rho^+K^-)_A\pi^0, K^-\rho^+[D]$	$0.75 \pm 0.40 \pm 0.60$	$0.64 \pm 0.36 \pm 0.53$
$D \to AP, A \to SP$		
$D \to ((K^-\pi^+)_{S\text{-wave}}\pi^0)_A\pi^0$	$1.99 \pm 1.08 \pm 1.55$	$-0.02 \pm 0.25 \pm 0.53$
$D \to VS$		
$D \to (K^-\pi^0)_{S\text{-wave}}\rho^+$	$14.63 \pm 1.70 \pm 2.41$	$-2.39 \pm 0.11 \pm 0.35$
$D \to K^{*-}(\pi^+\pi^0)_S$	$0.80 \pm 0.38 \pm 0.26$	$1.59 \pm 0.19 \pm 0.24$
$D \to K^{*0}(\pi^0\pi^0)_S$	$0.12 \pm 0.27 \pm 0.27$	$1.45 \pm 0.48 \pm 0.51$
$D \to VP, V \to VP$		
$D \to (K^{*-}\pi^+)_V\pi^0$	$2.25 \pm 0.43 \pm 0.45$	$0.52 \pm 0.12 \pm 0.17$
$D \to VV$		
$D[S] \to K^{*-}\rho^+$	$5.15 \pm 0.75 \pm 1.28$	$1.24 \pm 0.11 \pm 0.23$
$D[P] \to K^{*-}\rho^+$	$3.25 \pm 0.55 \pm 0.41$	$-2.89 \pm 0.10 \pm 0.18$
$D[D] \to K^{*-}\rho^+$	$10.90 \pm 1.53 \pm 2.36$	$2.41 \pm 0.08 \pm 0.16$
$D[P] \to (K^-\pi^0)_V\rho^+$	$0.36 \pm 0.19 \pm 0.27$	$-0.94 \pm 0.19 \pm 0.28$
$D[D] \to (K^-\pi^0)_V\rho^+$	$2.13 \pm 0.56 \pm 0.92$	$-1.93 \pm 0.22 \pm 0.25$
$D[D] \to K^{*-}(\pi^+\pi^0)_V$	$1.66 \pm 0.52 \pm 0.61$	$-1.17 \pm 0.20 \pm 0.39$
$D[S] \to (K^-\pi^0)_V(\pi^+\pi^0)_V$	$5.17 \pm 1.91 \pm 1.82$	$-1.74 \pm 0.20 \pm 0.31$
$D \to TS$		
$D \to (K^-\pi^+)_{S\text{-wave}}(\pi^0\pi^0)_T$	$0.30 \pm 0.21 \pm 0.32$	$-2.93 \pm 0.31 \pm 0.82$
$D \to (K^-\pi^0)_{S\text{-wave}}(\pi^+\pi^0)_T$	$0.14 \pm 0.12 \pm 0.10$	$2.23 \pm 0.38 \pm 0.65$



Branching Fraction Results of $D^0 \to K^-\pi^+\pi^0\pi^0$

Double tag(DT) $D^0 \to K^-\pi^+\pi^0\pi^0$ vs. $\bar{D}^0 \to K^+\pi^-$
Single tag(ST) $\bar{D}^0 \to K^+\pi^-$

$$\boxed{\mathcal{B}_{\rm sig} = \frac{N^{\rm DT}_{\rm tag,sig}}{N^{\rm ST}_{\rm tag}} \frac{\varepsilon_{\rm tag}}{\varepsilon_{\rm tag,sig}}}$$



The amplitude analysis result is used to determine the detection efficiency, where the DT efficiency is 8.39%

The branching fraction is determined to be

$$\boxed{(8.86 \pm 0.13(\text{stat}) \pm 0.19(\text{syst}))\%}$$

Phys. Rev. D 99, 092008 (2019)

Amplitude Analysis of $D^+ \to K_S\pi^+\pi^+\pi^-$

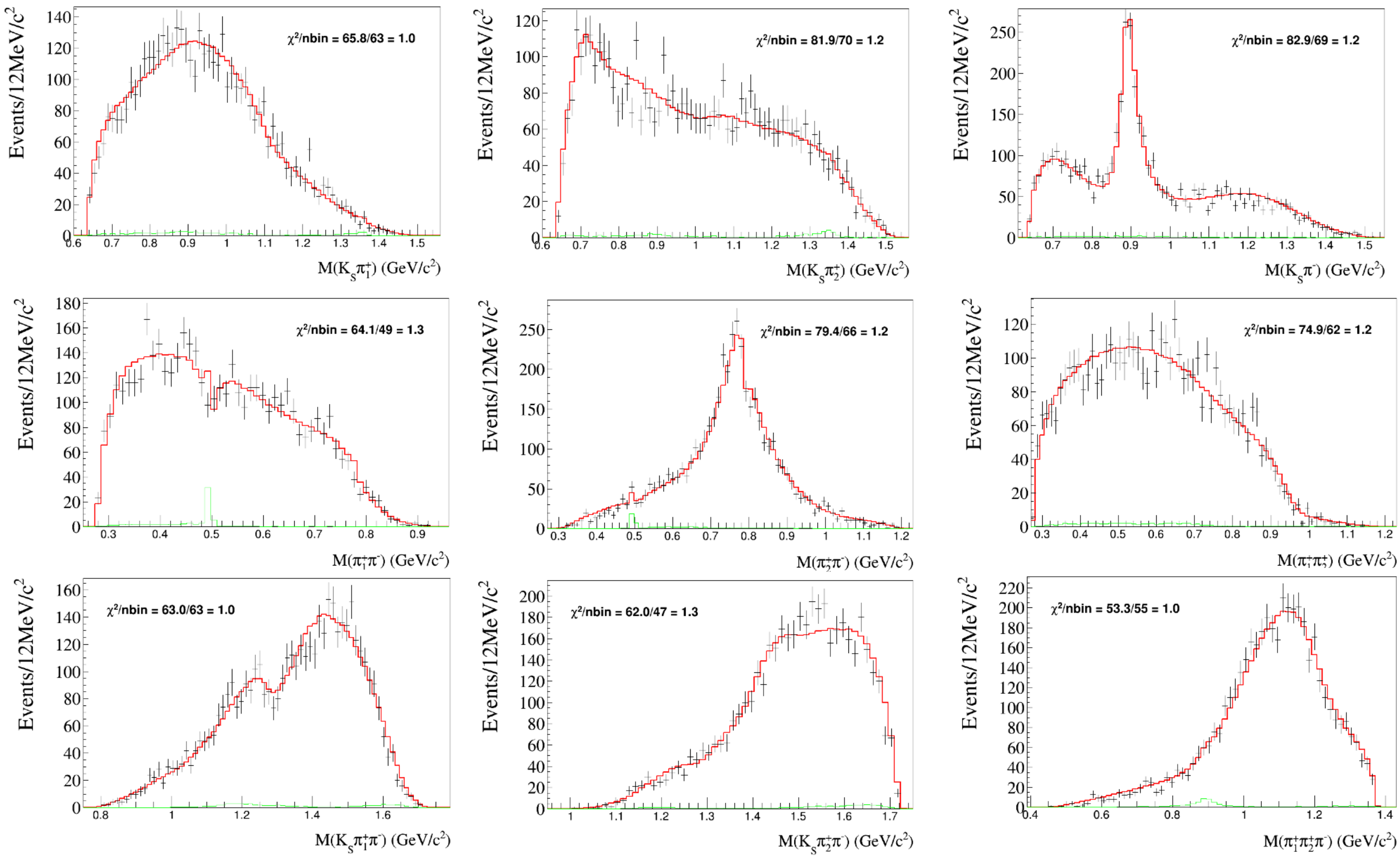
Double tag $D^+ \to K_S\pi^+\pi^+\pi^-$ vs. $D^- \to K^+\pi^-\pi^-$

The number of event selected is 4559 with a purity of ~99%

The data can be described with 12 amplitudes:

Amplitude	ϕ	fit fraction
$D^+ \to K_S^0 a_1(1260)^+, a_1(1260)^+ \to \rho^0\pi^+[S]$	0.000(fixed)	$0.567 \pm 0.020 \pm 0.044$
$D^+ \to K_S^0 a_1(1260)^+, a_1(1260)^+ \to f_0(500)\pi^+$	$-2.023 \pm 0.068 \pm 0.113$	$0.050 \pm 0.006 \pm 0.007$
$D^+ \to \bar{K}_1(1400)^0\pi^+, \bar{K}_1(1400)^0 \to K^{*-}\pi^+[S]$	$-2.714 \pm 0.038 \pm 0.051$	$0.380 \pm 0.013 \pm 0.014$
$D^+ \to \bar{K}_1(1400)^0\pi^+, \bar{K}_1(1400)^0 \to K^{*-}\pi^+[D]$	$3.431 \pm 0.137 \pm 0.117$	$0.015 \pm 0.004 \pm 0.005$
$D^+ \to \bar{K}_1(1270)^0\pi^+, \bar{K}_1(1270)^0 \to K_S^0\rho^0[S]$	$-0.418 \pm 0.070 \pm 0.087$	$0.036 \pm 0.004 \pm 0.002$
$D^+ \to \bar{K}(1460)^0\pi^+, \bar{K}(1460)^0 \to K_S^0\rho^0$	$-1.850 \pm 0.120 \pm 0.223$	$0.014 \pm 0.004 \pm 0.003$
$D^+ \to (K_S^0\rho^0)_A[D]\pi^+$	$2.328 \pm 0.097 \pm 0.068$	$0.011 \pm 0.003 \pm 0.002$
$D^+ \to K_S^0(\rho^0\pi^+)_P$	$1.656 \pm 0.083 \pm 0.056$	$0.031 \pm 0.004 \pm 0.010$
$D^+ \to (K^{*-}\pi^+)_A[S]\pi^+$	$-4.321 \pm 0.047 \pm 0.073$	$0.132 \pm 0.011 \pm 0.011$
$D^+ \to (K^{*-}\pi^+)_A[D]\pi^+$	$0.989 \pm 0.158 \pm 0.229$	$0.013 \pm 0.004 \pm 0.004$
$D^+ \to (K_S^0(\pi^+\pi^-)_S)_A\pi^+$	$-2.935 \pm 0.060 \pm 0.125$	$0.051 \pm 0.004 \pm 0.003$
$D^+ \to ((K_S^0\pi^-)_S\pi^+)_P\pi^+$	$1.864 \pm 0.069 \pm 0.288$	$0.022 \pm 0.003 \pm 0.003$

Amplitude Analysis of $D^+ \to K_S\pi^+\pi^+\pi^-$



Amplitude Analysis of $D^+ \to K_S\pi^+\pi^+\pi^-$

The preliminary results of branching fractions for different components：

Component	Branching fraction (%)
$D^+ \to K^0_S a_1(1260)^+(\rho^0\pi^+)$	$1.684 \pm 0.059 \pm 0.131 \pm 0.062$
$D^+ \to K^0_S a_1(1260)^+(f_0(500)\pi^+)$	$0.149 \pm 0.018 \pm 0.021 \pm 0.006$
$D^+ \to \bar{K}_1(1400)^0(K^{*-}\pi^+)\pi^+$	$1.105 \pm 0.045 \pm 0.048 \pm 0.041$
$D^+ \to \bar{K}_1(1270)^0(K^0_S\rho^0)\pi^+$	$0.107 \pm 0.012 \pm 0.006 \pm 0.004$
$D^+ \to \bar{K}(1460)^0(K^0_S\rho^0)\pi^+$	$0.042 \pm 0.012 \pm 0.009 \pm 0.002$
$D^+ \to K^0_S\pi^+\rho^0$	$0.131 \pm 0.015 \pm 0.015 \pm 0.005$
$D^+ \to K^{*-}\pi^+\pi^+$	$0.413 \pm 0.036 \pm 0.059 \pm 0.015$
$D^+ \to K^0_S\pi^+\pi^+\pi^-$	$0.220 \pm 0.015 \pm 0.024 \pm 0.008$

stat. uncertainty from FF

sys. uncertainty from FF

uncertainties related to BF($D^+ \to K^0_S\pi^+\pi^+\pi^-$) in PDG

The measurements of the decays with $K1(1270)$and $K1(1400)$involved provide some experimental information in understanding the mixture of the two excited Kaons.

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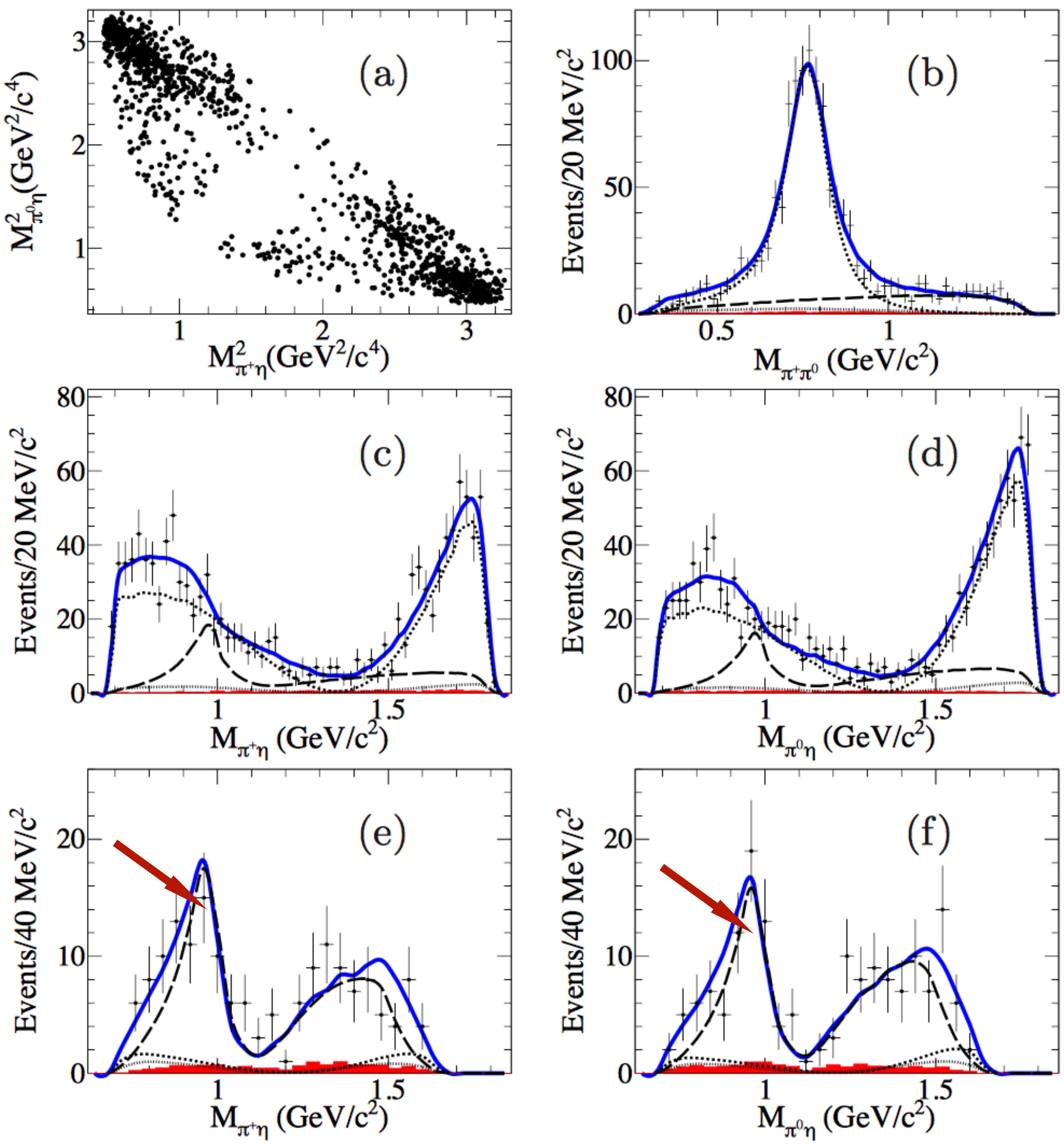
Amplitude Analysis of $D_S^+ \to \pi^+\pi^0\eta$

Observation of $D_S^+ \to a^0(980)^+\pi^0$

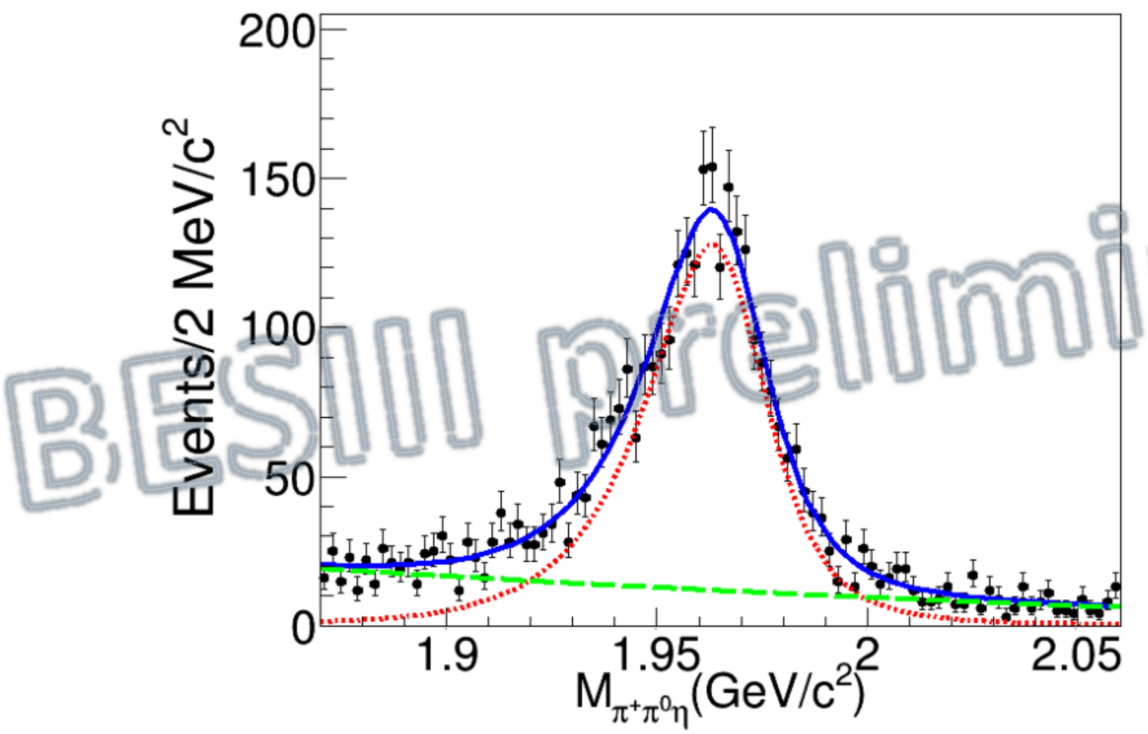


Dots with error bar: data
Solid line: total fit
Dashed line: rho+ eta
Lond-dashed line: a0(980)π

The phase difference between $a_0(980)^0\pi^+$ and $a_0(980)^+\pi^0$ is found to agree with 180°

Amplitude Analysis of $D_s^+ \to \pi^+\pi^0\eta$

Fit to signal mode



Total Tag yield: 255895 ± 1358.

DT yield: 2626 ± 77.

Efficiency is determined with the amplitude analysis result.

- Dots with error bars: data.
- Total fit.
- Signal: MC shape convoluted with a Gaussian.
- Background: second-order Chebychev.

$$BF(D_s^+ \to \pi^+\pi^0\eta) = (9.50 \pm 0.28_{stat.} \pm 0.41_{sys.})\%$$

Branching fraction (%)
$\mathcal{B}(D_s^+ \to \rho^+\eta) = 7.44 \pm 0.48_{stat.} \pm 0.44_{sys.}$
$\mathcal{B}(D_s^+ \to a_0(980)\pi)^* = 2.20 \pm 0.22_{stat.} \pm 0.34_{sys.}$
$\mathcal{B}(D_s^+ \to a_0(980)^+\pi^0)^* = 1.46 \pm 0.15_{stat.} \pm 0.22_{sys.}$
$\mathcal{B}(D_s^+ \to a_0(980)^0\pi^+)^* = 1.46 \pm 0.15_{stat.} \pm 0.22_{sys.}$

BF(sub-mode n) = $\mathcal{B}(D_s^+ \to \pi^+\pi^0\eta)FF(n)$

First observation

The measured $\mathcal{B}(D_s^+ \to a^0(980)^+\pi^0)$ is larger than other measured pure *W*-annihilation decays ($D_s^+ \to pn$, $D_s^+ \to w\pi^+$) by one order.

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Summary

- DTag and DD^{bar} threshold data allows us to perform inclusive and exclusive branching fraction measurement
- Double tag provides clean samples for amplitude analysis
- Many D^0 and D^+ studies have been published, including strong phase and y_{cp} measurements, and more related measurements are on-going
- Excellent D_s studies are published based on our 3.19 fb^{-1} data at E_{cm} = 4.178 GeV (and at 4.190-4.230 GeV)
  - “Many" D_s amplitude analyses of three- and four-body decays are expected to be published in the next year.